The impact of the PiP EPG method for the processing time of IPTV channel change requests and QoE

R. Bruzgiene, L. Narbutaite and T. Adomkus

***Abstract*—**The broadcast of the digital Internet Protocol Television channels is an exclusive due to the each user behaviour in the search of the desired television program. The different methods for the channel searching and selection affect the channel change process and its duration, called the channel zapping time. This impact depends on the quantity of requests for the channel change and its processing time in the network. So, the authors proposed a method that modifies the process of the channel change in order to reduce the processing time of the requests and increase the user's perceived quality assessment for Internet Protocol Television service.

***Keywords*—**Channel change, EPG, IPTV, Picture in Picture.

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. All these needs influence the attractiveness of IPTV service in respect of QoS (Quality of Service) and QoE (Quality of Experience) parameters. TV channel zapping time is the most important criteria influencing the subjective IPTV QoE evaluation [1], 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 [2]. 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 [3]. 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.

IPTV channel zapping time affects the relationship between IPTV service quality and service quality perception level (Fig. 1).

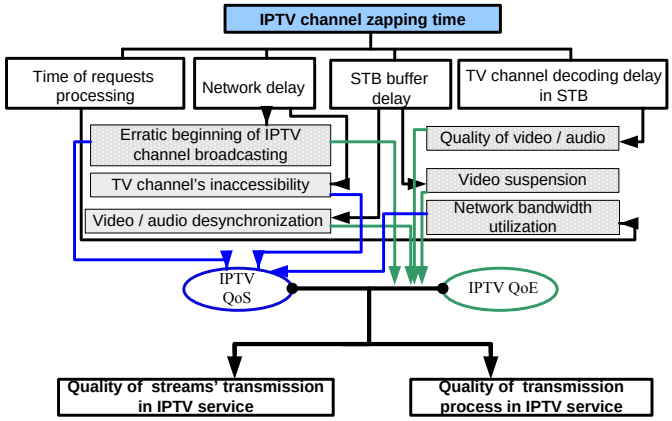

Fig. 1. Influence of channel zapping time on IPTV QoS and QoE

The impact of the channel zapping time on IPTV service QoS and QoE relationship (Fig. 1) is directly dependent on main components of IPTV channel change process: time of requests for TV channel change processing, network delay, Set Top Box (STB) buffer delay and TV channel data stream decoding delay in STB.

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 [4]-[9].

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 [10]. However, in addition to main components, IPTV channel change process and its zapping time is also affected by factors of user's

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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 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.

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. 2 and Fig. 3.

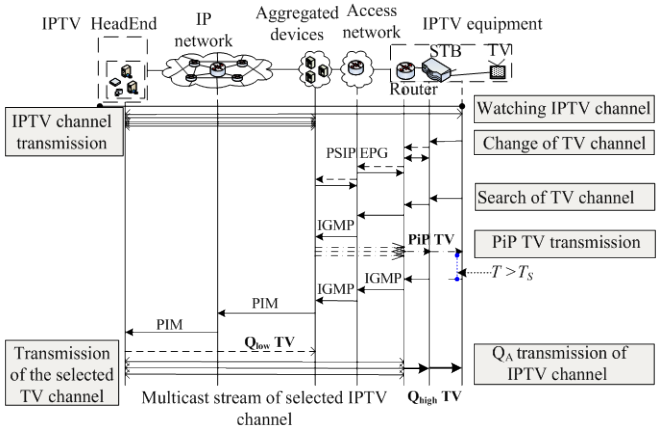

Fig. 2. The proposed method of IPTV channel change flow transmission during the channel change process

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

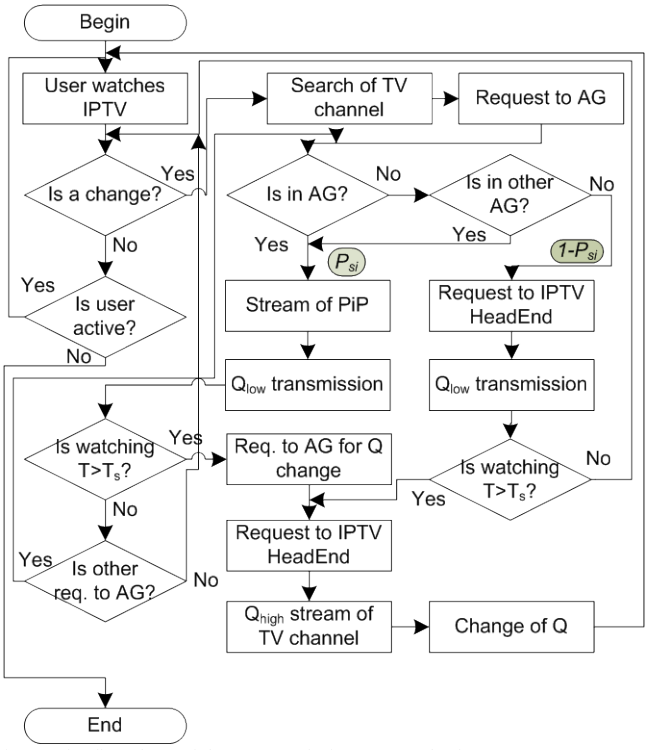

Fig. 3. The flowchart of the proposed PiP EPG method

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 (Q_{high}). The marking P_{si} is the probability, that the selected IPTV channel will be transmitted from the aggregated device in Fig. 3.

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.

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III. The Analytical Model for the Evaluation of the Processing Time of IPTV Channel Change Requests

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.

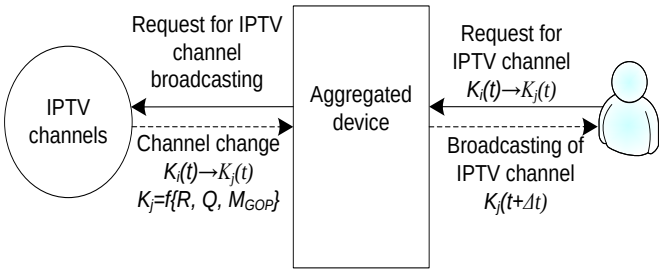

Fig. 4. IPTV channel change process using the sequential TV channel's selection

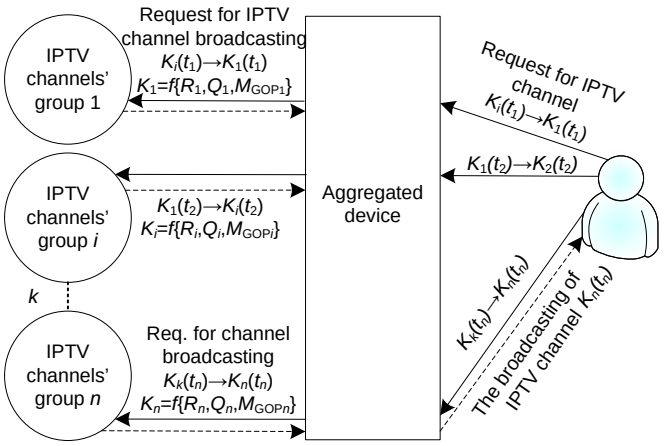

Fig. 5. IPTV channel change process using the random TV channel's selection

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 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).

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.

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

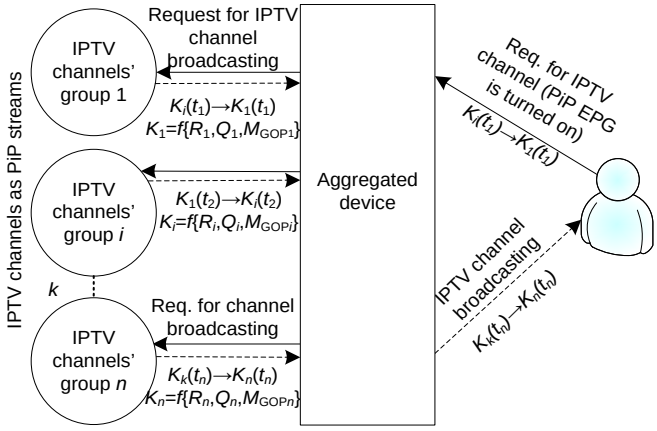

Fig. 6. IPTV channel change process using the proposed PiP EPG method

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.

IV. 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 $\mu = 90$ reqps. The results are presented in Fig. 7 and Fig. 8.

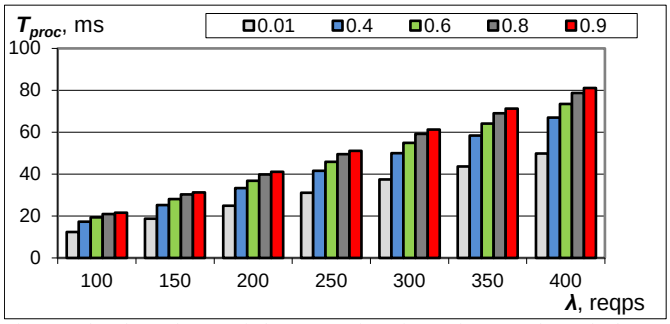

Fig. 7. The dependence of the processing time of IPTV channel change requests on the intensity of the requests, when TV channel is selected randomly

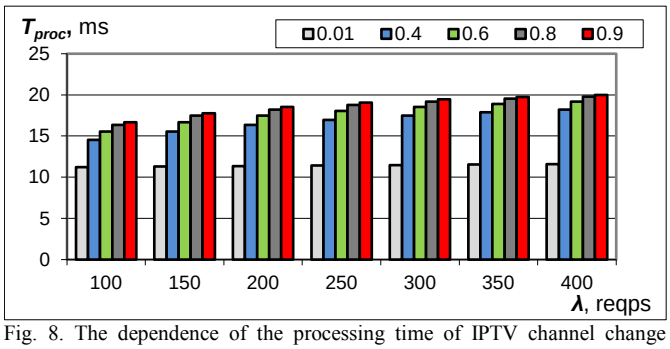

Fig. 8. The dependence of the processing time of IPTV channel change requests on the intensity of the requests, when TV channel is selected using the proposed PiP EPG

According to the results in Fig. 7 and Fig. 8, 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 $\lambda = 400$ reqps and $P_{i,j}$=0.9.

The results (in Figure 9) 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. 9), 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 $\lambda = 400$ reqps and $P_{i,j}$=0.7.

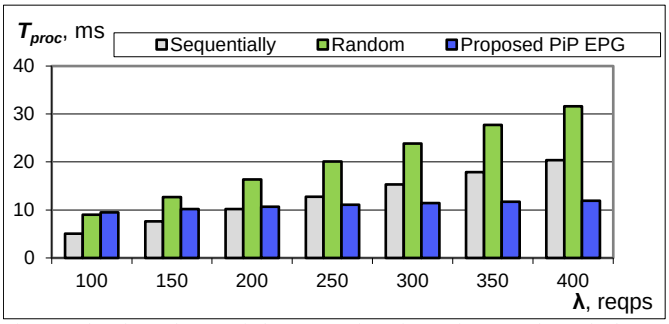

Fig. 9. The dependence of the processing time of IPTV channel change requests on the intensity of requests

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. 10.

The results in Fig. 10 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

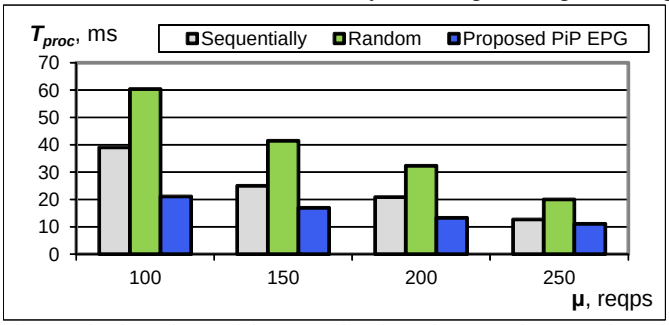

Fig. 10. The dependency of the processing time of requests for IPTV channel change on the request processing intensity

is $\mu = 250$ 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.

V. 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

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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 [11]. 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. 11).

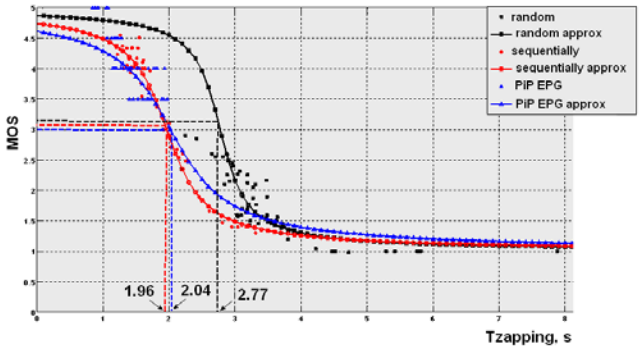

Fig. 11. The relationship between the user perceived quality of service (MOS) and TV channels zapping times using the different methods for IPTV channel search

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]. This expression is presented in (1).

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

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].

$$MOSo = \begin{cases} 5, & if \quad T_{zapping} \le 1.4 \\ MOS1, & if \quad 1.4 < T_{zapping} \le 2.5 \\ MOS2, & if \quad 2.5 < T_{zapping} \le 3.6 \\ 1, & if \quad T_{zapping} > 3.6 \end{cases}, \quad (6)$$

where $MOS1$ is the expression presented in (7) and $MOS2$ is the expression presented in (8). These expressions were carried out during the determination of the regression analysis by third and fifth degree polynomials [11].

$$MOS1 = -0.032 \cdot (T_{zapping})^3 + 0.627 \cdot (T_{zapping})^2 - 4.020 \cdot T_{zapping} + 9.372 \quad ; \quad (7)$$

$$MOS2 = -0.072 \cdot (T_{zapping})^5 + 0.273 \cdot (T_{zapping})^4 + 2.014 \cdot (T_{zapping})^3 - 12.752 \cdot (T_{zapping})^2 + 21.276 \cdot T_{zapping} - 6.756 \quad . \quad (8)$$

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. 12.

The results shows, that proposed PiP EPG method allows to

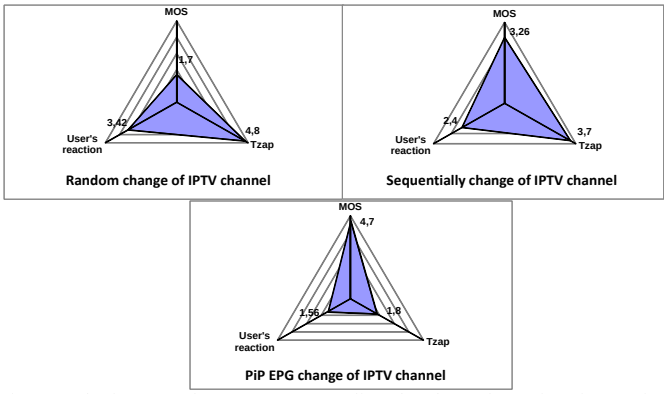

Fig. 12. The integrated IPTV QoE according the channel zapping time, using the different methods for channel search

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.

VI. CONCLUSIONS

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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