A Comparison of Channel Switching Schemes for IPTV Systems

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Abstract—One of the main challenges in IPTV systems is the reduction of startup delays, especially in channel switchings. While this problem does not exist in traditional television, in IPTV systems it is relevant, due to bandwidth limitation as well as to buffering. This paper proposes three novel schemes for fast channel switching that reduce the occurrences of latencies caused by buffering and overlay structures.

I. INTRODUCTION

IPTV architectures can be either private or public. In private architectures, also known as commercial IPTV and owned by telecommunication providers, the size of the network limits the population served. In public architectures, also known as cooperative IPTV, the Internet provides the infrastructure, enabling a global population to have access to services. Cooperative IPTV typically employs P2P networks for the distribution of video streams, given the scalability of these networks [1].

In spite of the increasing deployment of IPTV services, there are still challenges to be overcome [1], [2]. One of the main problems is the reduction of startup delays, especially in channel switchings. This problem does not exist in traditional television because channel switching is performed by changing the frequency to access the desired content. In IPTV systems, due to bandwidth limitation, only a portion of the broadcast content is transmitted to the users. Moreover, buffers and overlay structures are employed to ameliorate the problems arising from network bandwidth fluctuations and connection failure. These techniques enlarge playback latencies, especially when there are multiple channels and fast navigation is desirable [3]. Since users of traditional television appreciate the possibility of switching channels quickly, IPTV services require the reduction of startup delays from tens to just a few seconds [2].

This paper proposes three novel schemes for fast channel switching in IPTV systems that reduce the occurrences of latencies caused by buffering and overlay structures. Multiple description coding (MDC) [4] is used to generate sub-streams with minimum quality for each channel, which are transmitted using multiple distribution trees. By combining a set of sub-streams, it is possible to provide users with either one channel in full quality or multiple channels with minimum quality, which is sufficient to check the program being broadcasted. In a previous work [3], we demonstrated the benefits of this approach by evaluating a single channel switching scheme and comparing it to a system which does not employ any scheme.

In the present paper, the new proposed schemes are compared to the previous one as well as to a system with no scheme employed. Although other proposals adopt the transmission of redundant streams with minimum quality [5], it is the authors’ best knowledge that the work presented in [3] is the first to employ multiple description coding and multiple distribution trees.

The remainder of this paper is organized as follows. In Section II, the proposed schemes are introduced. In Section III, simulation experiments are described. In Section IV, the schemes are evaluated and conclusions are drawn in Section V.

II. PROPOSED CHANNEL SWITCHING SCHEMES

This section introduces the proposed schemes.

A. Background

The idea behind the proposed schemes is that users do not need to receive streams with maximum quality to check the content broadcasted on the channels. In IPTV systems, it is sufficient for the identification of the content broadcasted to display streams with minimum quality [3]. As these streams have low bandwidth demand, it is possible to transmit multiple channels simultaneously. Media players can keep multiple buffers continuously filled for immediate playback of those channels. In this way, it is possible to provide instantaneous channel switching to the content stored in the buffers [3].

The proposed schemes count only on two components: multiple distribution trees and multiple description coding. The employment of multiple distribution trees in IPTV systems is common and preferable to mesh topologies [1], [3]. Multiple description coding has already been employed for video transmission to achieve data and network path redundancy [6], bandwidth heterogeneity adaptation [7], [8] and incentive mechanisms for cooperation [8]. In the present work, a channel is divided into multiple sub-streams (or descriptions), which have minimum quality, and transmitted via multiple distribution trees. By doing that, the proposed schemes can be easily adopted in both cooperative and commercial IPTV.

To employ the proposed schemes in cooperative IPTV, it is sufficient to provide streams with minimum quality to the connected users. This means that a user must be able to be admitted into at least one distribution tree for each channel and into all distribution trees for the selected channel, when she/he is not surfing [1]. In commercial IPTV, channel streams should be encoded with multiple description coding and each
multicast group should be subdivided into multiple distribution trees, one for the transmission of each description. Since in these commercial IPTV systems IP multicast is usually employed [9], the management overhead of multiple trees is distributed among the various existing routers [3]. Therefore, users have access to all the descriptions of all channels, in spite of receiving only a subset of them at a time.

Given the availability of the descriptions of all channels, it is possible to select and transmit a subset of them. Depending on whether the user is surfing or not, the selection can vary. The proposed schemes define two viewing states: “watching mode” and “browsing mode”. In the first state, the user’s bandwidth is employed primarily for the reception of the descriptions of the selected channel, while in the second state the bandwidth is used primarily for the reception of descriptions of different channels, i.e., streams with minimum quality of other channels. In order to decrease the probability of having startup delay at the beginning of a channel switching operation, in the state “watching mode” part of the user’s bandwidth is reserved for the reception of a reduced selection of streams with minimum quality. There is a clear trade-off between providing better quality of reception for the selected channel and providing more channels to increase the probability of having an instantaneous channel switching. In the state “browsing mode”, part of the bandwidth is reserved for keeping partially the reception of the old channel. If the user returns to the old channel at the end of a channel switching operation, this channel will be available and it will have intermediate quality, which is higher than that of navigation and lower than that obtained in the state “watching mode”. According to [9], the probability of a user returning to the old channel after a channel switching operation ends is about 17%.

It is also known that 56–60% of the channel switchings involve sequential channels (linear), being 69–72% of them upward and 28–31% of them downward [9], [10]. This information suggests that part of the bandwidth reserved for navigation (in both states) should be used for channels which are adjacent to the selected one. Switchings to non-sequential channels (non-linear) correspond to 40–44%, and this suggests that part of the bandwidth reserved for navigation should be used for popular channels, which have high probability of being selected. Considering these patterns, three different strategies for selecting the navigation descriptions are proposed: old channel, popular channels and adjacent channels.

Whenever a new channel is requested, if at least one description of this channel is available in the buffers of the media player, the change is immediate, since the content is already ready to be played. On the contrary, if no description of the selected channel is available, latency is introduced due to the time required for admission into the new distribution tree as well as to the time used for buffering video frames. Since the probability of channel switching is higher in the state “browsing mode”, channel diversity is privileged in this state by the transmission of single descriptions of multiple channels, whereas in the state “watching mode”, the quality of reception is privileged by the transmission of multiple descriptions of the same channel. The proposed schemes aim at addressing not only the usability, but also the quality of service of the system. Next, the new schemes are introduced.

B. Linear Scheme

When a user is in the state “watching mode” and she/he starts a channel switching operation, most of the incoming bandwidth is released by dismissing a subset of the descriptions of the watched channel. The bandwidth released is used to receive more navigation descriptions of other channels, and the state is changed to “browsing mode”. Every time a user enters the state “browsing mode” or requests a new channel change, an individual timer is started, which counts the time elapsed since the last channel change occurred. During an initial period, i.e., the timer value is in the time interval [0:TransitionStartTime] seconds, no change is made to the descriptions of the user. During the following period, i.e., while the timer value is in the time interval [TransitionStartTime:TransitionFinishTime], a gradual transition back to the state “watching mode” takes place. If the timer reaches the value of TransitionFinishTime seconds, the state is changed back to “watching mode”; on the contrary, the user remains in the state “browsing mode”. Both parameters TransitionStartTime and TransitionFinishTime can be configured.

In the Linear scheme [3], the gradual state transition consists in increasing linearly the number of descriptions received for the selected channel, until the quality of reception reaches its maximum value (which is that of the state “watching mode”). For that, update events happen at each TransitionUpdatePeriodicity seconds, during the time interval [TransitionStartTime:TransitionFinishTime]. The parameter TransitionUpdatePeriodicity can also be configured. Let T be the number of update events in the time interval (T = (TransitionFinishTime − TransitionStartTime)/TransitionUpdatePeriodicity), t be the discrete number of the current update event (0 <= t <= T), and M the maximum number of descriptions in the state “watching mode”. The number of descriptions received, n, for the selected channel at the current discrete time, t, is given by:

\[ n(t) = 1 + \lfloor (t/T) \times (M - 1) \rfloor \] (1)

The number of descriptions varies in the set [1..M], since at least one description of the current channel must be provided to the user at any time. To avoid the aggregate bandwidth to exceed the user’s incoming bandwidth, the Linear scheme releases gradually the descriptions of the non-selected channels. If, during the state transition, the user requests another channel, then the additional descriptions of the current channel are released and new navigation descriptions are requested. At the end of the state transition, the user is already receiving all the descriptions of the selected channel, its state is changed back to the “watching mode” and all the descriptions of the old channel have already been released.

When releasing the descriptions of the non-selected channels, n − 1 descriptions of the old channel are first gradually...
dismissed, so that there is at least one description to ensure immediate switching in case the user returns to that channel again. After that, the scheme dismisses the navigation descriptions with low probability of being selected, provided that the number of navigation descriptions is not less than that when in the state “watching mode”. Finally, the last description of the old channel is dismissed, completing the transition.

C. Fast Scheme

In the Fast scheme, the transition from the state “watching mode” to the state “browsing mode” occurs in the same way as in the Linear scheme, with the user starting a channel switching operation. Another similarity to the Linear scheme is that the transition from the state “browsing mode” to the state “watching mode” takes place gradually and in the same time interval \([\text{TransitionStartTime:TransitionFinishTime}]\) seconds. However, in the Fast scheme, the number of descriptions of the selected channel is increased during the gradual transition at a Lognormal rate. Let \(C\) be a factor defining the steepness of the Lognormal rate; the number of descriptions received, \(n\), for the selected channel at the current discrete time, \(t\), is given by:

\[
n(t) = 1 + \left(\frac{\ln(C + \frac{t}{T} + 1)}{\ln(C + T + 1)}\right) \times (M - 1)
\]  

(2)

As in the Linear scheme, the descriptions of the non-selected channels are released gradually, following the same order described previously. The value of \(C\) varies between 0.5 and 2000. In the Fast 1 scheme, the value of \(C\) was defined so that an increase of 80% of the descriptions completes in the first half of the time interval. In the Fast 2 scheme, the value of \(C\) was defined so that an increase of 20% of the descriptions completes in the first 10% of the time interval.

Both schemes aim at improving the stream quality in the state “browsing mode”, as well as keeping as much as possible the number of delayed channel switching events, when compared to the Linear scheme. To accomplish that, these two schemes bring forward the release of the navigation descriptions during the gradual state transition, so that there is more room to accommodate additional descriptions of the selected channel.

D. Slow Scheme

In the Slow scheme, the transition from the state “watching mode” to the state “browsing mode” occurs similarly to the Linear scheme; moreover, the transition from the state “browsing mode” to the state “watching mode” takes place gradually and in the same time interval \([\text{TransitionStartTime:TransitionFinishTime}]\) seconds. Nevertheless, in the Slow scheme, the number of descriptions of the selected channel is increased during the gradual transition at a rate which is the inverse of the Lognormal function adopted in the Fast scheme. The number of descriptions received, \(n\), for the selected channel at the current discrete time, \(t\), is given by:

\[
n(t) = 1 + \left(1 - \left(\frac{\ln(C + (T - t) + 1)}{\ln(C + T + 1)}\right)\right) \times (M - 1)
\]  

(3)

The descriptions of the non-selected channels are also released gradually, following the same order of the Linear scheme. The value of \(C\) also varies between 0.5 and 2000. In the Slow 1 scheme, the value of \(C\) was defined so that an increase of 20% of the descriptions completes in the first half of the time interval. In the Slow 2 scheme, the value of \(C\) was defined so that an increase of 20% of the descriptions completes in the first 90% of the time interval.

Both schemes aim at further reducing the number of delayed channel switching events, as well as keeping as much as possible the stream quality in the state “browsing mode”, when compared to the Linear scheme. To accomplish that, these schemes postpone the release of the navigation descriptions during the gradual state transition, so that there is a higher chance of at least one description of the selected channel be available when a channel switching occurs.

E. Immediate Scheme

In the Immediate scheme, there is no gradual transition. When the user is in the state “browsing mode” and the initial time interval \([0:\text{TransitionStartTime}]\) seconds has elapsed, during which no change was made to the descriptions received, the additional navigation descriptions are released at once, including the descriptions of the old channel. Moreover, the additional descriptions for the selected channel are requested altogether. Finally, the state is immediately changed back to the “watching mode”. The transition from the state “watching mode” to the state “browsing mode” occurs in the same way as in the previous schemes. In this scheme, the parameters \(\text{TransitionFinishTime}\) and \(\text{TransitionUpdatePeriodicity}\) are not used.

The number of descriptions requested, \(n\), for the selected channel at the time \(t = \text{TransitionStartTime}\), is given by:

\[
n(t) = M
\]  

(4)

The \(\text{TransitionStartTime}\) parameter varies in the set: \([5, 30, 60]\) seconds. In the Immediate 1 scheme, the immediate transition occurs at the same time the gradual transition starts in the other schemes. In the Immediate 2 scheme, the immediate transition occurs at a time corresponding to the middle of the gradual transition in the other schemes. In the Immediate 3 scheme, the immediate transition occurs at the same time the gradual transition ends in the other schemes.

While the aim of the Immediate 1 scheme is similar to that of the Fast schemes, the aim of the Immediate 3 is similar to that of the Slow schemes. Moreover, they balance the benefits of having or not a gradual state transition. They also establish upper bounds to bring forward and to postpone the release of the navigation descriptions, respectively. The Immediate 2 scheme represents an intermediate trade-off between them.

III. SIMULATION EXPERIMENTS

A simulator for IPTV systems was developed to assess the effectiveness of the proposed schemes. To the authors’ best knowledge, none of the existing simulators which implement the fundamental operations of IPTV services is publicly
available. The tool developed in [10] for generating synthetic traffic, which was constructed from statistical models derived from real traces, was not available for use at the time of the development of this work. This led to the development of a simulator that includes the fundamental operations of IPTV services from the statistical models introduced in [9], [10].

A non-stationary process consisting of sequences of piecewise-stationary Poisson arrival processes, each lasting 15 minutes [11], was used to model the arrival of new peers. The rates of such sequences varied between 5 and 2000 arrivals per minute and were defined to reflect the total number of users of a real system per period [9]. As a result, daily patterns of real systems were reproduced, having two main peaks around 3PM and 10PM and a smaller peak around 8AM [9]. Session duration follows a lognormal distribution with parameters \( \mu = 6.351 \) and \( \sigma = 2.01 \) [11], averaging 4320 seconds (1.2 hours) [9]. To model channel holding times, it was used a histogram built from a trace collected in an operational IPTV system [9]. The mean and median of these values are, respectively, 14.8 minutes and 8 seconds. The total period simulated involves 7 days, generating more than 62 million channel switching events.

The number of channels used was 105 [9]. Channel popularities and transition probabilities were derived from information and data obtained from [9], [10]. The viewing time threshold was set to 60 seconds [9]. To simulate heterogeneous access profiles, connection classes were defined according to the statistics of Brazilian Internet access pattern [12]. The classes are: ADSL 1 Mbps, ADSL 2 Mbps, ADSL 4 Mbps, ADSL 8 Mbps, HFC 500 Kbps, HFC 3 Mbps, HFC 6 Mbps, HFC 12 Mbps. Stream bandwidth values varied in the set: 300 Kbps, 1024 Kbps, 2048 Kbps [2]. The number of distribution trees varied in the set: 16, 32 [6], [7]. Startup delays, composed by the period of time necessary for admission in the trees and the period of time used for buffering video frames, were modeled by a uniform distribution in the interval \([5 - 20]\) seconds [2], [13].

Since most of the channel switching events occur around 4 seconds after the last change [9], the default value of TrASN. was set to 5 seconds. Following the viewing time threshold adopted in [9], the value of TFIN. was set to 60 seconds. The value of TUP. was set to 1 second. In the state “watching mode”, the fraction of the user’s bandwidth reserved for navigation was set to 50%. In the state “browsing mode”, the fraction of the user’s bandwidth reserved for receiving the descriptions of the old channel was set to 50%. In both states, the fraction of the navigation bandwidth used for adjacent channels was set to 56%; the remaining bandwidth was employed for popular channels. It was defined that 70% of the bandwidth used for adjacent channels is for upward channels and 30% for downward channels [9], [10].

The following metrics were collected: (i) Delayed channel switching events, which is the percentage of channel switching events with latency; and (ii) Stream quality, which is the mean number of descriptions received by the peers.

### IV. Evaluation of the Schemes

In this section, the proposed channel switching schemes are evaluated. A comparative analysis to a system which does not employ any scheme and to a system which employs the Linear scheme was conducted. Since the aim is to investigate the performance of the schemes in different situations of bandwidth contention, the stream bandwidth of existing channels and the number of distribution trees was varied. Table I illustrates the configurations of different scenarios considered as well as the variations of the schemes evaluated in each scenario. We define the scenario S1024T16 as an average case reference.

#### A. Delayed Channel Switching Events

Figure 1 illustrates the percentages of channel switching events with latency, for each scenario and scheme considered. When no channel switching scheme is employed, no reduction of the number of delayed events is achieved. When any of the proposed schemes is employed, it can be noticed that the smaller the stream bandwidth and the higher the number of distribution trees, the greater is the reduction of the number of delayed events. This happens because in all the schemes the number of navigation channels that each user can receive is determined by the bandwidth of each description, which is proportional to the stream bandwidth and inversely proportional to the number of trees used; the more navigation descriptions used, the higher is the probability of a channel selected being already available for playback. Regarding the effectiveness of the schemes separated by each strategy employed (old channel, popular channels and adjacent channels), all the new schemes presented the same distribution of hits of the Linear scheme, which was discussed in [3]. Due to space constraints, we omit such discussion here and focus on the overall differences between the Linear scheme and the new proposed schemes.

It can be seen that, except for the Immediate 1 scheme, all the new proposed schemes present similar results to those of the Linear scheme in all scenarios, considering the reduction of the number of delayed events. Comparing to the case in which no scheme is employed, a reduction of around 68% is achieved in the average case (scenario S1024T16, stream bandwidth of 1024 Kbps and 16 distribution trees). In the best case (scenario S300T32, stream bandwidth of 300 Kbps and 32 distribution trees), a reduction of around 90% is observed.

#### Table I: Scenarios considered, varying stream bandwidth (Str.) and number of trees (Trs.); and schemes evaluated, varying lognormal factor (C) and time out for state transition (t).

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Str.</th>
<th>Trs.</th>
<th>Scheme</th>
<th>Variation</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Scheme</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
<td>N/A</td>
</tr>
<tr>
<td>Linear</td>
<td>N/A</td>
<td>N/A</td>
<td>Fast 1</td>
<td>C = 0.5</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Slow 1</td>
<td>C = 0.5</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Immediate 1</td>
<td>t = 5s</td>
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<tr>
<td></td>
<td></td>
<td></td>
<td>Immediate 2</td>
<td>t = 10s</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Immediate 3</td>
<td>t = 60s</td>
</tr>
</tbody>
</table>

(a) Scenarios considered.

(b) Schemes evaluated.
navigation descriptions. Thus, this metric points out the cost of using the proposed schemes, which varies according to the bandwidth contention: the higher the contention, the greater is the reduction of the stream quality. For the Linear scheme, the cost gives an average reduction of 20.08% in the average case (scenarios with stream bandwidth of 1024 Kbps). In the best case (scenarios with stream bandwidth of 300 Kbps), there is an average reduction of 4.49%. In the worst case (scenarios with stream bandwidth of 2048 Kbps), there is an average reduction of 34.86%.

When analyzing the new proposed schemes, it can be seen in Figures 2a and 2b that the Immediate schemes produced the worst stream qualities among all the schemes evaluated. To illustrate that, in the scenario S1024T16 and in the state "browsing mode", the Immediate 1, Immediate 2 and Immediate 3 schemes had stream quality of 76.05%, 56.89% and 51.5% lower than that of the Linear scheme, respectively. The only reason why the Immediate 2 and Immediate 3 schemes had a slight better stream quality than the Immediate 1 scheme is due to the postponed state transition to the "watching mode", which enabled the old channel strategy to act more often, when the peer was still in the state "browsing mode". Nevertheless, since these three schemes had the worst stream qualities and did not diminish the number of delayed channel switching events in comparison to the Linear scheme, they bring no benefit over the Linear scheme. In fact, they justify the gradual state transition employed by the other schemes, which, according to the results obtained, helps to reduce the occurrences of changes with latency, as well as to improve the stream quality received.

The second worst group of schemes presenting poor stream qualities is composed by the Slow 1 and Slow 2 schemes. To illustrate that, in the scenario S1024T16 and in the state "browsing mode", they produced a stream quality 31.14% and 45.81% lower than that of the Linear scheme, respectively. Following the previous rationality, given that these two schemes had low stream qualities and did not diminish the number of delayed channel switching events in comparison to the Linear scheme, they bring no benefit over the Linear scheme.

The Fast 1 and Fast 2 schemes produced, in the state "watching mode", the same stream qualities as those of the Linear scheme. However, in the state "browsing mode", they achieved a considerably higher stream quality than the Linear scheme. To illustrate that, in the scenario S1024T16, the Fast 1 and Fast 2 schemes presented a stream quality of 42.81% and 78.74% higher than that of the Linear scheme, respectively. Since the aim of both the Fast 1 and Fast 2 schemes was to improve the stream quality in the state "browsing mode", in comparison to the Linear scheme, as well as to keep as much as possible the reduction of the number of delayed channel switching events, they successfully accomplished their target. Moreover, the Fast 2 scheme overcame the Fast 1 scheme in all scenarios, being the best scheme evaluated. The mentioned gain of 78.74% in comparison to the Linear scheme is for the average case (scenario S1024T16, stream bandwidth of 2048 Kbps), a reduction of around 48% is obtained.

The Immediate 1 scheme presents a reduction 7% smaller than that of the other schemes. The reason is that, in a short period of time (5 seconds after the last channel change), it dismisses most of the navigation descriptions at once, not taking full advantage of the state "browsing mode". Although most channel changes occur in the first 5 seconds after the last change, there is still a smaller portion of them taking place after this period has elapsed. This is why the Immediate 2 and Immediate 3 schemes have better performance than the Immediate 1 for this metric. Even not employing the gradual state transition, the Immediate 2 and Immediate 3 schemes only release the navigation descriptions after 30 and 60 seconds of the last channel change, respectively.

Since the main purpose of the Slow 1, Slow 2, Immediate 3, and (partially) the Immediate 2 schemes was to further reduce the number of delayed events in comparison to the Linear scheme, they all failed in accomplishing their aim. In fact, only a reduction of around 0.04% was achieved, which is not relevant. Given that postponing the release of the navigation descriptions impacts on the stream quality, these schemes are not likely to overcome the Linear scheme.

**B. Stream Quality**

Figure 2 describes the mean numbers of descriptions received by the peers, for each scenario and scheme considered. Figures 2a and 2b show this metric for the states “browsing mode” and “watching mode”, respectively, while Figure 2c provides the overall results. In Figure 2c, it can be seen that the number of descriptions received when no channel switching scheme is employed is higher than those when a scheme is employed; it varies as a function of the bandwidth contention (when the bandwidth contention increases, there are more users who do not manage to receive all the descriptions for the channels). When any of the proposed schemes is employed, there is a slight decrease of the number of descriptions received. The reason is that, in all schemes, part of the user’s bandwidth is employed for the reception of
In this paper, three novel schemes for fast channel switching in IPTV systems were proposed, aiming at reducing the occurrences of latencies, as well as keeping as much as possible the stream quality received. The new schemes were compared to a system with no scheme employed and also to the Linear scheme, which was proposed in a previous work [3].

According to simulation results, all the new proposed schemes but the Immediate 1 produced a similar reduction of the number of delayed events, in comparison to the Linear scheme. Regarding the stream quality, only the Fast 1 and Fast 2 schemes achieved an increase of it, in comparison to the Linear scheme.

Among all the proposed schemes, only the Fast 1 and Fast 2 accomplished their target of overcoming the Linear scheme. Moreover, the Fast 2 scheme overcame the Fast 1 in all scenarios, being the best scheme evaluated. In comparison to the Linear scheme, the Fast 2 was able to maintain the same reduction of the number of delayed channel switching events (68%, on average), as well as to improve by 78.74% (on average) the stream quality during the channel switching operations (in the state “browsing mode”).

Since the probability of a peer being in the state “browsing mode” is considerably lower than being in the state “watching mode”, the high variations observed in Figure 2a are smoothened by the rare variations seen in Figure 2b, resulting in the overall metric given by Figure 2c. Although this work focused on improving the stream quality in the channel switching operations, it is important to consider the overall metric when evaluating the cost of employing the channel switching schemes. Following this rationality, the Fast 2 scheme results on an average reduction of 18.85% in the average case (scenarios with stream bandwidth of 1024 Kbps). In the best case (scenarios with stream bandwidth of 300 Kbps), the average reduction is of 3%. In the worst case (scenarios with stream bandwidth of 2048 Kbps), the average reduction is of 33.9%. Thus, considering that these costs are lower than those of the Linear scheme, it can be said that the Fast 2 scheme is an interesting option to be adopted for channel switching in IPTV systems.

V. CONCLUSION

In this paper, three novel schemes for fast channel switching in IPTV systems were proposed, aiming at reducing the occurrences of latencies, as well as keeping as much as possible the stream quality received. The new schemes were compared to a system with no scheme employed and also to the Linear scheme, which was proposed in a previous work [3].

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