# INCREASING BANDWIDTH UTILIZATION IN NEXT GENERATION IPTV NETWORKS

*Ulf Jennehag and Tingting Zhang*

Teleinformatics Research Group (ITM/IKS), Mid-Sweden University, SE-851 70 Sundsvall, Sweden
Ulf.Jennehag@mh.se Tingting.Zhang@mh.se

## ABSTRACT

In this paper we present a novel idea regarding transmission of next generation IPTV content. Today IPTV systems utilize a GOP structure to provide stream synchronization points for the clients, these are used when a channel switch occur. Since channel switches made by TV audiences are quite rare it is redundant to send synchronization opportunities in a GOP manner. The proposed design, synchronization frames for channel switching (SFCS), only requests synchronization frames when needed. We present a network traffic analysis model and compare it with simulations. SFCS increases bandwidth utilization compared to traditional GOP system under the presented transmission environment.

## 1. INTRODUCTION

In recent years the development of high-speed metropolitan networks has exploded, more and more households have access to such a network. The increasing number of actors (i.e. ISP and net owners) providing this service lowers the cost, this pressure these actors to introduce new services to increase revenue. Examples of such services are IP-telephony, IPTV and VoD.

In the case of IPTV there exists a need for an efficient way of transporting digital video over an Internet like network in a broadcast fashion. IP-Multicast is a proven way to efficiently transmit multimedia content to a selected set of receivers. The issue of transmitting multimedia via IP-Multicast and related questions has been under research for several years [1]. An IPTV stream (channel) consists of video, audio (could be several streams), and additional information. However, the video part of the stream is dominating.

For an IPTV transmission system to be economically feasible in an Internet-like environment a reasonably large number of clients must be connected; in addition to this there must be a sufficient number of channels available.

A widely spread solution to this problem is to use broadcast material in a Multicast environment using an existing video coding standard [2] over a well established transport system [3]. Such systems are in use all over the world today.

In such a system it is necessary to provide a system for a new client to synchronize to a stream. In most cases this is done by utilizing a video coding scheme with a group of pictures (GOP) structure. The GOP structure provides a reoccurring event of resynchronization points called Intra coded frames (I-frames). I-frames can be decoded without knowledge about the previous frames. To increase coding efficiency modern video coding schemes also use motion compensated predictive coded frames (P-frames). The additional redundancy the I-frame is carrying is only needed when the client have no information about the prior frame at all, i.e. the client is starting the decoding process of the selected stream. This occurs typically then the client is changing stream (i.e. channel). A study [4] of the channel changing behavior of a typical TV audience reports that the average number of changes in one hour of TV watching is quite small, about five times. Thus, transmitting I-frames to all users because one client is changing channel is a waste of bandwidth.

In this paper we propose a novel idea for the next generation IPTV networks. We propose a design that provides one multicast stream consisting of P-frames only, accompanied by a stream of synchronization frames. When a synchronization frame is needed it is transmitted on a separate multicast address and received only by the users who actually request it. In this paper we only focus on the video part of the IPTV data. All data received by a client is considered to be rendered immediately.

The paper is organized like follows; in section 2 and 3 we propose a novel idea regarding the transmission of digital video content for a broadcast environment like an IPTV service, in section 4 we present simulation results and finally in section 5 we present conclusions and future work.

## 2. SYNCHRONIZATION FRAME FOR CHANNEL SWITCHING

Our proposed design, Synchronization Frame for Channel Switching (SFCS) is based on the idea that it is redundant to send intra coded frames at a fixed frequency to provide stream resynchronization points. With SFCS a stream consisting of resynchronization points (S-frames) is separated from the main stream (P-frames only). Clients (receivers) who want to decode the video stream (in this case a TV-channel) must receive the both the main stream and the synchronization stream. However, the synchronization stream is only received at the actual synchronization point and is later left. The streams are spliced and sent to the decoder. The decoded frames at a synchronization point must produce the same result in order to not produce mismatch and drift. One technique capable of this is switching pictures (SP/SI-frames) [5]. Although the concept SP-frames have been researched before [6], and is part of a standard [7], it has been very little or no work done on the technique applied to an IPTV environment.

Since the next generation IPTV technology probably will be based on modern compression scheme where SP/SI-frames, or similar, are included. In such system it should be possible to implement SCFS with success.

In this paper we focus on two types of frame coding, synchronization frame (S-frame) and predictive frame (P-frame). An S-frame at time *t* produces the same decoded content as the P-frame at time *t*.

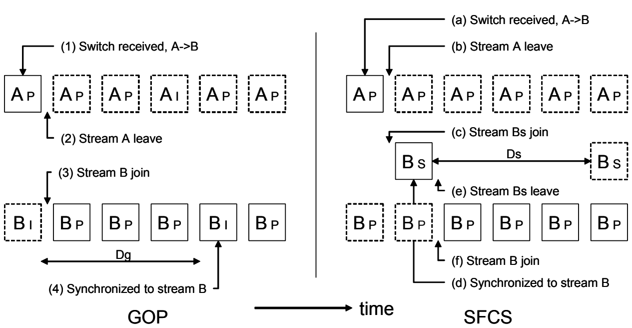

Figure 1: Channel switch with both GOP and SFCS

The following example (Figure 1) illustrates a client performing a typical switch from the present channel to another (i.e. A->B); in order to compare performance the same switch is also made in a GOP system.

In the GOP system the client requests a switch at (1). The client leaves the A stream (2) and joins the B stream (3). The decoder waits for the next I-frame in order to synchronize with the stream. The distance between these synchronization points (I-frames) equals Dg.

For the SCFS system the client requests the switch at (a), the A-stream is left at (b) and the synchronization stream (S-frames) for B (Bs stream) is joined (c). The client is now synchronized to steam B (d). The distance between two S-frames is Ds. The client leaves the Bs stream (e) and joins the main B stream (P-frames) (f).

The main feature of SFCS is that the link bandwidth for a specified channel is reduced due to the low number of synchronization frames needed compared to the amount sent when utilizing a GOP scheme.

Factors that govern the efficiency of SFCS are; number of receivers, number of selectable channels, channel popularity, frequency of synchronization frame offers, and the duration between channel switches.

## 3. NETWORK TRAFFIC

In this section, we compare the bandwidth requirements of SFCS and the traditional method (GOP). We consider a network as a set of links connected at nodes. A link can either be router-to-router link (RRL) or a router-to-client link (RCL).

The RRL carries the video streams between routers (or between the video server and the first router) and the RCL delivers the selected streams to a single client. Routers are considered to be Multicast enabled.

For the reader's convenience, we provide a list of all the variables used:

| | |
|---|---|
| $fps$ | number of frames per second |
| $d$ | average duration in seconds between channel changes for a client |
| $\alpha$ | Zipf distribution parameter (0-1) |
| $R_S$ | number of resynchronization points for SFCS during a second |
| $R_G$ | number of resynchronization points for GOP during a second |
| $P$ | average P-frame size in bits |
| $S$ | average S-frame size in bits |
| $r_{SP}$ | size ratio, S-frame size/P-frame size |
| $M$ | number of available channels |
| $N$ | number of receivers |

### 3.1 Bandwidth requirement for the RCL

The average bandwidth requirement for the SFCS approach is

$$B_{SC} = \left( fps + \left( \frac{r_{SP}}{d} \right) \right) P \qquad (1)$$

And for a traditional GOP approach it is:

$$B_{GC} = \left(fps - R_G + R_G \cdot r_{SP}\right)P \tag{2}$$

### 3.2 Bandwidth requirement for the RRL

Let the probability of change to channel $q$ is $p_q$. The process of channel change is considered to be Poisson distribution distributed. The possibility of one receiver changing to channel $q$ between two resynchronization points is $\frac{p_q}{R_S \cdot d}$. The average number of receivers changing to channel $q$ between two resynchronization points is $\frac{N \cdot p_q}{R_S \cdot d}$.

The possibility of there is no receiver changing to channel $q$ between two resynchronization points is $e^{-\frac{N \cdot p_q}{R_I \cdot d}}$. The average number synchronization frames per second is $R_S \cdot \sum_{s=1}^{M}\left(1 - e^{-\frac{N \cdot p_q}{R_S \cdot d}}\right)$. So the average Bandwidth requirement of RRL is:

$$B_{SR} = \left(fps \cdot M + r_{SP} \cdot R_S \sum_{s=1}^{M}\left(1 - e^{-\frac{N \cdot p_q}{R_S \cdot d}}\right)\right)P \tag{3}$$

In our simulation results (section 4) and in the network analysis calculations we use Zipf's distribution [8] with parameter 0 ($\alpha$=0) and uniformly distributed channel popularity. The true channel popularity distribution is argued to be somewhere in between these.

In the case of channel popularity being uniformly distributed, we have

$$p_q = \frac{1}{M} \tag{4}$$

The average bandwidth for the SFCS approach is

$$B_{SRU} = \left(fps \cdot M + r_{SP} \cdot R_S \cdot M \cdot \left(1 - e^{-\frac{N}{R_S \cdot d \cdot M}}\right)\right)P \tag{5}$$

When channel popularity is Zipf distributed, we have

$$p_q = \frac{1}{q^{1-\alpha} \cdot C} \quad for\ all\ q = 1, \ldots, M \tag{6}$$

where,

$$C = \sum_{j=1}^{M} \frac{1}{j^{1-\alpha}} \quad for\ all\ j = 1, \ldots, M \tag{7}$$

From equation (6), (7) and (3), we get the following traffic bandwidth expression:

$$B_{SRZ} = \left(fps \cdot M + r_{SP} \cdot R_S \sum_{q=1}^{M}\left(1 - e^{-\frac{N}{R_q \cdot d \cdot q \cdot C}}\right)\right)P \tag{8}$$

For the traditional GOP approach, we get the following bandwidth expression:

$$B_{GR} = M\left(fps - R_G + R_G \cdot r_{SP}\right)P \tag{9}$$

## 4. SIMUALTION RESULT

A simulation environment was created to compare with the theoretical results. The environment consists of a program simulating traffic flow in a predefined fictive multicast broadband network. The used network layout is described in Figure 2. Each client is connected to a router and is tuned to one channel (video stream) at a time. The popularity of the channels is either uniform or Zipf distributed with parameter 0. Group management messages (IGMP) and related traffic are considered to propagate and take effect immediately. In all the simulation and theoretical results the value of 3 is used for $r_{SP}$.

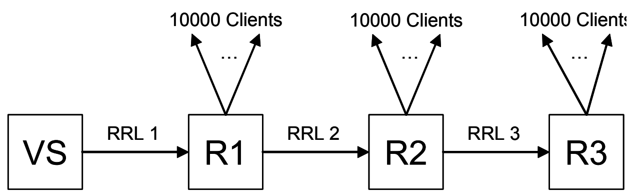


Figure 2: Simulated network

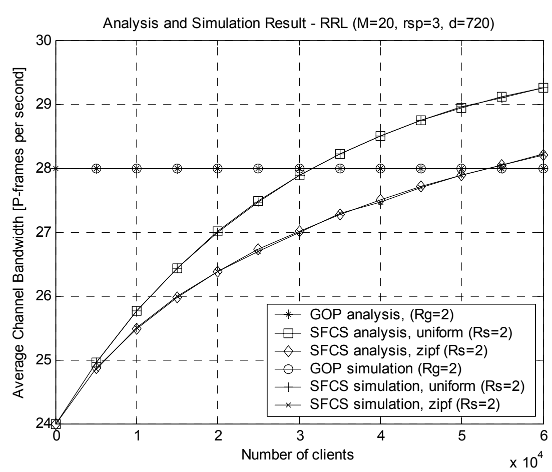


Figure 3: Analysis and simulation results.

The simulation program simulates the traffic load in the RRL (i.e. RRL 1-3) between the server and the connected routers. Figure 3 show the correlation between our theoretical model and the simulation results with only one RRL. Since the results are nearly identical, we only present theoretical results in our following figures. Figure 4 and 5 show that the performance for the proposed scheme is better than traditional GOP, even for a relatively low number of selectable channels. If the number of selectable channels is low or if the number of users is high, the number of resynchronization requests per channel and per second increases and approaches Rs. In this case SFCS can consume more bandwidth than GOP.

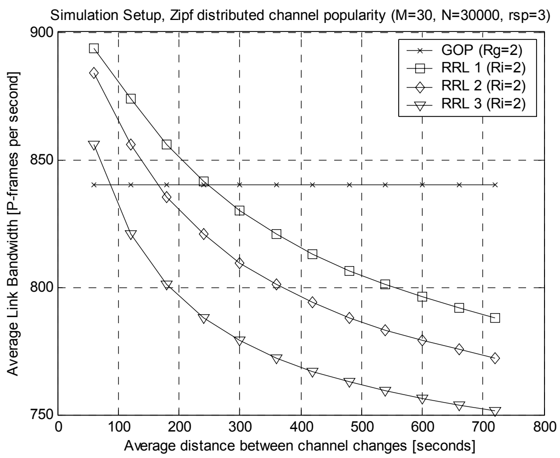


Figure 4: P-frames per second for RRL in the simulation setup (Figure 2) with varying average channel change duration, the number of selectable channels is 30.

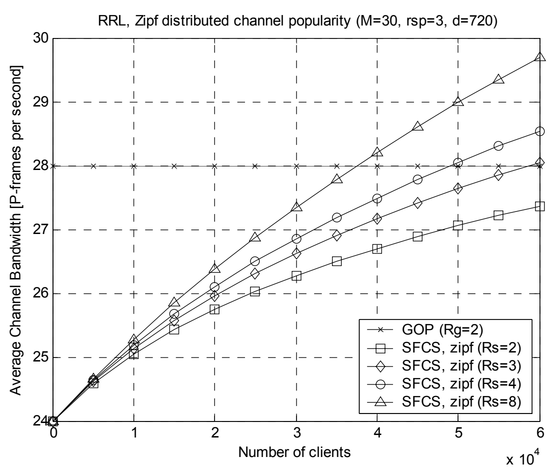


Figure 5: RLL client sweep with different Rs settings.

By changing the number of available resynchronization points per second (i.e. Rs), the time between the actual switch and until the receiver is synchronized to the stream (Ds in Figure 1). However, as mentioned before, and as illustrated in Figure 5 this influences the performance of the system.

## 5. CONCLUSIONS

In this paper we presented a novel idea using synchronization frames for channel switching (SFCS). SFCS is proved to significantly increase bandwidth utilization, in terms of average channel bandwidth, on RRL's even for a large number of users and a relatively small set of selectable channels when compared to a traditional GOP based IPTV system. SFCS can also decrease the waiting time between channel switches by increasing the frequency of S-frames per second. Since splicing of the streams can be conducted in a pre-decoder manner the actual implementation of the decoder is not an issue, as long as the requirements for SFCS are met.

Efficiency of SFCS is dictated by; number of receivers, number of selectable channels, channel popularity, frequency of synchronization frame offers, and the duration between channel switches.

### 5.1 Future Work

The following topics are of interest for future work:

- Error concealment, SFCS provides means for stream resynchronization when packet loss is detected.
- SFCS is inefficient for popular channels or when switching occurs to often, a hybrid scheme with GOP and SFCS is of interest.

## 6. REFERENCES


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