Intelligent Pre-fetching to Reduce Channel Switching Delay in IPTV Systems

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***Abstract*—IPTV is the future of television. With the tremendous potential for interactivity and highly promising feature set IPTV is almost set to rule the entertainment market. One of the biggest challenges faced by the IPTV technology is the Channel Switching Delay due to low bandwidth in the end links. In this paper a novel technique has been proposed to minimize delay in Channel Switching by intelligently prefetching contents based on user behavior.**

I. Introduction

Since the conception of internet, its demand in every application is growing day by day. No wonder, like every other services Television is also getting attention. IPTV is not a new concept as such. Early days of internet did not have enough bandwidth to support entertainment quality media delivery. Hence Broadcast over IP network did not become popular. The recent advancement in communication network and in media compression techniques have now enabled network delivery of high quality content.

A. What is IPTV

Internet Protocol TeleVision is a new form of television technology that uses the existing IP network to deliver entertainment grade audio-video content to consumers. [1] It uses video compression techniques to reduce the data to be transported to the end user. And then the compressed digital media is then transported to end users over a standard IP network which is already in place for data services. This is called in industry terms, Triple Play. Data, Voice and Video these three are the components of the service. IPTV falls into the category of Video. The other component being Video on Demand service over the network.

The Key promises of IPTV System are,

- Integrated Service: Consumers prefer a reliable one-stop service from a trusted provider.
- Flexibility: Since the underlying infrasturcture is general network the upper layer is possible to be modified and altered without fiddling with the base.
- Low Cost: IPTV Service being built on top of the existing data network infrastructure the deployment cost is low.
- Feature Set: Being based on a data network, essentially IPTV provides better interactivity and feature set available to regular TV through the Set Top Box.

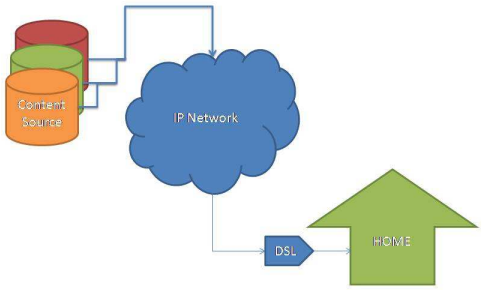

Fig. 1. Overview of IPTV System

Witch such huge expectations IPTV is goint to pose a number of challenges to the industry to meet user expectations.

II. IPTV Architecture

Figure 1 shows an overview of a typical IPTV system architecture. The IPTV System consists of the following components, [8]

1) *Content Source:* Consists of Broadcasting agencies and Video on Demand Servers
2) *Service Nodes:* The entry point for the media content from the different sources to be multiplexed into the data network.
3) *Wide Area Distribution Network:* This is the main data network backbone used for the media transport.
4) *Customer Access Links:* Access lines from the data network to the Customer Premises.
5) *Customer Premises Equipment:* The termination point for the broadband access link at the customer premises.
6) *IPTV Client:* The end equipment that actually terminates the IPTV traffic and presents the media to the user.

Though there are a variety of proposed architectural details for IPTV deployment available, more or less this is the core structure. We will describe each component here in detail.

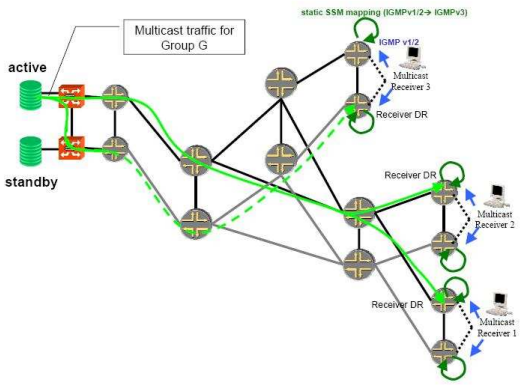

Fig. 2. A Backbone Network with PIM-SSM

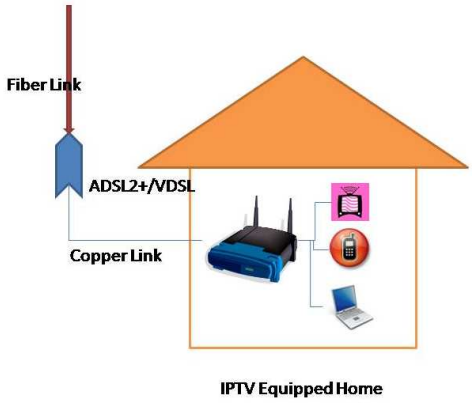

Fig. 3. Typical Home with IPTV System

A. Content Source

Content Source genrally refers to the different sources of media content in the IPTV system. The trivial content sources are,

- Broadcasters, the biggest segment among the content providers. They are responsible for all the live media content on the television channels.
- Video on Demand Services, these are stored media sources. Provides recorded media to the customers.

These service providers are mainly the client base for the IPTV platform providers.

B. Service Nodes

Service Nodes, also known as Aggregation nodes, provides the entry point for the media to the underlying data network. The 'Service Node' is defined as a functionality which receives video streams in different formats. These video streams in different formats then reformat and encapsulate it for transmission with appropriate quality of service indications to the wide-area network. This makes it ready for delivery to customers. In regards to service management, the Service Nodes communicate with the customer premises equipment (CPE); for the subscriber, session and digital rights management, service nodes communicate with the IPTV service.

C. Wide Area Distribution Network

This network provides support for Multicasting and similar optimizations to reduce redundant data transport. Typical configurations are PIM-SSM, PIM-LSP, PIM-SM etc. PIM-SM is only efficient when the multicast group addresses are quitelarge, source addresses are not known apriori or multicast source addresses change often. [4]

This is not quite the case for IPTV services. The service providers are limited and are more or less stable and fixed. For this reason PIM-SSM/PIM-LSP is recommended for IPTV backbones. Figure 2 illustrates a backbone network with PIM-SSM.

This also covers the Core optical distribution network and the edge Digital Subscribers Line Access Multiplexers (DSLAMs). Generally these are located at the end points of teh core network, eg. Sites of local distribution points.

D. Customer Access Links

Customer Access Links refer to the end links used by the subscribers to connect to the network. The availability of high speed broadband links such as ADSL2+ and VDSL are the main influencing factor behind the whole IPTV initiative. With the help of these advanced technologies the data can be delivered to the customer using the existing loop lines and /or phone lines to their homes.

A few other alternatives are now a days being considered by providers to increase the available bandwidth and capacity such as Fibre To The Home (FTTH) [9] etc. Of course such connectivity has to be complemented by the IPTV Middleware which controls the availale feature set in the system.

E. Customer Premises Equipment

Customer Premises Equipment, also known as Home Gateway, serves as the broadband network termination point at homes. Its main functionality is to receive the broadband signal and present it to the IPTV equipment and other devices that are serviced by the same connection. Such as, VOIP Telephone, Internet Connectivity for Computers etc. Figure 3 illustrates the typical scenario at homes using Triple Play services.

F. IPTV Client

IPTV Client is the Unit that terminates the IPTV traffic at the customer premises. It is essentially a device that can do the functional processing required by the IPTV system. The functions of such an equipment includes setting up the connection, provide authentication to the service provider, assembly of the incoming traffic, decoding the media content, channelize the content to proper output devices, provide user access to the system in an interactive way such as functions to change channel, program recording, set up access control mechanisms etc. As evident from the purpose this unit has to be most userfriendly yet attractive to gain consumer attention. Figure 4 shows an Example channel guide. [2].

Fig. 4. Example TV Guide

III. QoS/QoE

The most important QoS metric that needs to be addressed in an IPTV application are Delay and Packet Loss. For a pleasurable user experience the requirements are quite stringent in this case. The metrics are more appropriately termed as Quality of Experience (QoE). The main QoE parameters for any IPTV platform can be classified into following categories,

- *Channel Switching:* a. k. a. Channel ”Zapping” refers to the delay between a new channel request and its display on the monitor. Study shows the acceptable delay between a channel request by the user and the appearance of the frame on the screen is 200 ms [6]. This will be discussed in more detail in the following section.
- *Media Quality:* The Quality of the media delivered, i.e. Sound and Video is of utmost importance. Especially in a market where already conventional digital cable offers High Definition(HD) content. For a standard entertainment quality experience one can have no more than a single visual degradation over a period of 2 Hour. Which translates to the QoS requirement of no more than single packet loss per million packets.
- *Stability:* The stability of the service is also very important. Television being one of the most common form of near real time applications.[7]
- *Security:* Suitable access control and piracy prevention.[7]

IV. Channel Switching

Channel switching delay is one of the key factors that has been bothering service providers from the beginning of IPTV concept. It is still hindering the process of large scale commercial deployment. In this section we will describe the process of changing channel in a typical IPTV installation. Then we will discuss the weak links in the process that is the source of the delays. In telephone service, the call setup time has always been there. But TV has always presented the users with the ability to switch channel instanteneously. Having that scenario, IPTV can not have an annoying blank in between channels.

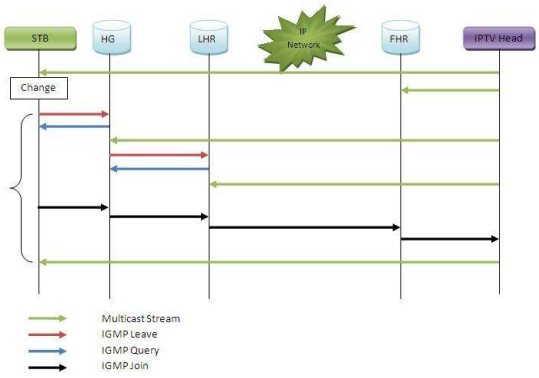

Fig. 5. Channel Changing Process

A. Typical Chennel Switching Protocol

There are a number of sequential steps involved in the process of switching channel while watching television. [3]

- User initiates a request. (usually in the form of a button press on the remote)
- If the channel is NOT already being transmitted to the STB(Set Top Box), it translates the request into a IGMP Leave request and send to the network.
- The End router responds with a IGMP Query or forwards the Leave message to upper level routers. This continues till the server end is reached.
- Next, the STB sends a IGMP Join request. It also propagates in the same fashion.
- Server node prepares a new stream for the requested channel. And begins transmission of the stream.
- STB starts receiving the stream from the network, does buffering and begins decoding and sending the picture to the television.

Figure. 5 will give a clear view of the process that is involved in the task of channel switching.

B. Bottlenecks

On careful observation of the steps involved in the channel switching procedure, one can find a number of places where it can go slow and make the channel change experience miserable. Lets term these section of the IPTV system as point of delay. There are several point of delay possible in the current IPTV setup.

1) *Access Link Delay:* This is the delay experienced by the incoming stream in reaching the customer premises. This represents the time it takes from the first byte of the expected stream to reach the home device after it has been transmitted by the local distribution point via the access links. This is absolutely dependent on the communication technology that is being used. Newer technologies like VDSL etc has less delay compared to older ones. Fiber lines to the home further reduces this delay. But this is inherent in the architecture and hence can not be eliminated.

2) *End Bandwidth:* The available bandwidth at the user end highly affects the quality of IPTV service. This limits the number of streams that can be sent to the customer premises simultaneously. Assuming MPEG-4 streams of HD quality puts a limit of 2 streams on the ADSL access links.
3) *STB Processing Delay:* This refers to the delay induced by the Set Top Box after the user initiates a request by pressing a button. This may be caused by a variety of factors like,
   - Processing Power of the STB
   - The Underlying Network Protocol being used
4) *Access Mechanism:* This refers to the mechanism used by the system to send a request to the service nodes and then retrieving responses. Inherent serialization of the control can delay the processing of the incoming media stream even though its ready.
5) *Content Preparation Time:* This is the time needed by the local redistribution points to set up an incoming stream for delivery via access links if it already exists or first retrieving the stream from the deeper level network and then preparing it for delivery. This is a significant overhead which we will address using our prefetching techniques.

V. Existing Approaches

There has been different approaches to reduce the delay associated with each component. In this section we will discuss the existing approaches towards reduction of Channel Switching Time.

A. Multiple Streams

This is the most fundamental approach towards minimization of Channel Switching Delay. The basic idea is to pipe in as many channels as possible to the customer premises. This helps in a way that when the user switches channels within the channels being streamed to his home does not experience much delay apart from the STB processing time. This is inspired by the fact that in traditional television, all the channels are always available to the end user. Which is the best possible case giving the user a no delay experience.

The success of this approach is limited by the bandwidth availabe in the access links. Which is in tern limited by the technology being used. Still this techniqe serves as the foundation of many other technique that attempt to improve the channel swithing time.

B. Adjacent Multicast Join

This approach [3] is based on the same idea as the previous one. This utilizes the expectation that adjacent channels are going to be watched more frequently by viwers. The scheme is as follows,

Whenever a channel is requested, the adjacent channels in the multicast group along with the channel being requested are also subscribed for till the limit is reached. This is based on the localized channel surfing behaviour. This method maintains a table along with the group membership tables and keeps track of adjacent channel requests. It adds non existent adjacent channels to the table and joins them while a join is in progress. Does the reverse while processing a leave.

C. Statistical Selection of Simultaneous Streams

This scheme [5]further improves the previous scheme by adding statistical selection of channel to join instead of choosing based on adjacency in goup membership. The approach maintains a local favourite list at each level of the network and keeps those streams alive. Exploiting the property that tha viwer choices dont vary rapidly in a locality. Thus giving a higher hit rate amongst already subscribed channels.

D. Instant Channel Change

This approach is used and being marketed by Microsoft TV.[2] They use a buffering technique. This method creates multiple unicast streams that are sent to the customer along with the broadcast multicast and it gets buffered for the amount of time that is the anticipated multicast establishment time. So when the user requests a channel swap it immediately switches to the buffered content as it proceeds with the new multicast request. By the time buffer runs out its expected that the multicast establishment will be complete and the display can resume the multicast. This creates an illusion of Instant Channel Switching by creating an artificial delay in the presentation framework.

This scheme is demonstrated by Microsoft in their setup. But it has serious scalability issue. Since it uses unicast for stream buffering as the number of subscriber grows the number of stream will increase. And will consume more BW in the core network. It prevents the user from getting a real time broadcast experience.

All of these approaches do address the issue of Channel Switching Delay but fail to perform in a scalable and reliable manner without disrupting viewer's concern in any respect.

VI. Proposed Approach

In this section we propose a new technique for minimizing channel switching delay in IPTV systems exploiting both spatial and temporal channel surfing behavior of the customers.

A. Motivation

The factors leading to the proposed scheme are as follows,

- Most customer have a few favoutire channels that he/she watches often and cycles through.
- Customers belonging to a locality are likely to have a common subset of preferred channels.
- If available viewers would like to se a preview, before actually switching the channel.
- Following from the second and third point, there will be a common subset of channels that are likely to be previewed more
- A considerable amount of time is spent to do the preprocessing of incoming stream before it is actually fed into the access links.

- Significant portion of the delay is the wait time for the key frames (I,P) to arrive.

We will make use of these characteristics in our scheme.

B. Scheme

The scheme is based on a feedback mechanism. The basic working is going to be as follows.

- Along with the channel stream that is being watched, a series of multicast containing a window of channels will be streamed at a smaller resolution and bandwidth.
- The STB will use these streams to show preview for the channel. This window will be updated at the service ends dependent on usage pattern, subscription statistics etc. This will keep the window size controllable.
- The STB will also keep track of a smaller window of channel that the user has previewed most recently for a time more than a set threshold. The idea being that, a user is likely to request a channel if he is previewing it for a longer time.
- The STB will keep sending this information periodically to the local service end.
- At the service end, the server upon receiving the preview information will do prefetching of the channels and prepare the streams for transmission.
- The service end also buffers the key frames for those channels so that they can be sent immediately upon receipt of a request.
- Upon receiving an actual channel change even, STB will generate a network request. But this time it will be processed much faster because the server end processing is already done in most cases.

C. Benefits

Clearly specified by the objective of the scheme, it is expected to improves the delay of channel switching. To be specific the benefits are manyfolds.

1) Effective: Since it is based on viewer surfing behavior its effective.
2) Scalable: Since it uses a fixed number of streams aleays it is more scalable.
3) Adaptive: Since it this scheme reports usage pattern more frequently it is more adaptive to changing preference of viewers.
4) Content Friendly: Unlike Instant Channel Change of Microsoft it does not defer the delivery of normal stream to compensate for the delay in processing the new one.

D. Limitation

The proposed solution is still limited by a number of factors. They can be illustrated as follows.

- *Limited End User Bandwidth:* The huge number of IPTV channels and limited bandwidth available at the user end still limits the effectiveness of the method. Though this can minimize the delay between channels on average it can not eliminate the delay. Because, at any given time there will be some channels which are not being transmitted to the home gateway. And to switch to those channel the whole process illustrated in Figure 5 has be repeated.
- *Extra Processing:* This scheme requires some extra processing at the service ends because, not all the channels previewed by the user are actually requested. But this scheme processes those channels as well to some extent. Although the same thing happens with other schemes when they send multiple channel simultaneously. This scheme does not improve on that.

E. Validation

We still lack proper methodologies to validate such distributed schemes on a network. Simulation could be one solution though the accuracy in terms of its ability to reproduce real scenario is another topic of research itself.

VII. Future Directions

We are yet to validate the schemes in real scenarios. The behaviour can be very different when tested in a platform of thousands may be millions of users. The load on the system and how it reacts to the increase in the number of requests. There are lots of other issues involved in the performance of IPTV system. Such as,

- Admission Control: how to select which users to allow access and which to not when the resources are limited.
- Reliability: how to ensure quality of service in case of a failure, how this scheme reacts to such a situation.
- Secutiry: how to maintain the privacy and security of viewers subcriptions while still exploiting the common interest nature.

VIII. Conclusion

IPTV being more of a consumer technology is much more sensitive to perception than measurements. Channel switching being instantenious for years since the advent of cable television, is one of the most sensitive aspects. Our technique can prove to be essential even when the network availibility and the bandwidth increases. With efficient and controlled application of our method IPTV experience can be richer and more realistic. This if succesfully implemented will smash the barrier between todays television and the next generation television IPTV.

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