Development of an Effective Zapping Delay Framework for Internet Protocol Television over a Converged Network

By

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Submitted in fulfilment of the requirements of the

DOCTOR OF PHILOSOPHY IN INFORMATION AND COMMUNICATION TECHNOLOGY

In the

DEPARTMENT OF INFORMATION TECHNOLOGY

In the

FACULTY OF ACCOUNTING AND INFORMATICS

At

DURBAN UNIVERSITY OF TECHNOLOGY

May 2018

DECLARATION

I, Adeliyi, Timothy Temitope hereby declares that this dissertation is my own work and has not been previously submitted in any form to any other university or institution of higher learning by other persons or myself. I further declare that all the sources of information used in this dissertation have been acknowledged.

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PhD (Computer Science)

DEDICATION

This dissertation is dedicated to Almighty God for his grace and mercy towards the completion of this work and to my family for their support, encouragement and motivation throughout the period of this study.

ACKNOWLEDGMENT

My profound gratitude goes to Almighty God for his grace, wisdom and strength throughout the period of this study. I am very grateful to my supervisor Prof. Oludayo Olugbara for his assistance, support, and mentorship which helped me through this work; without his constructive advice and continuous motivation, it would not have been possible to complete this work. Special thanks are due to my fellow research colleagues, for their constant encouragement and all the good times we had over the years. My never-ending love goes to my fiancé, TJ, parent and siblings for their love, unwavering support and giving me the opportunity to be part of this great high institution of learning.

LIST OF ABBREVIATIONS AND ACRONYMS

ADSL	Asymmetric Digital Subscriber Line
DiffServ	Differentiated Services
DSLAM	Digital Subscriber Line Access Multiplexer
EPG	Electronic Program Guide
GOP	Group of Picture
HDTV	High Definition Television
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPTV	Internet Protocol Television
ITU	International Telecommunications Union
MOS	Mean Opinion Score
OPNET	Optimized Network Engineering Tool
PIM	Protocol Independent Multicast
QOE	Quality of Experience
QOS	Quality of Service
RFC	Request for Comment
RSS	Really Simple Syndication
SDTV	Standard Definition Television
STB	Set-Top-Box
TV	Television
VOIP	Voice over Internet Protocol

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Adeliyi, T., Olugbara O. 2018. Fast Channel Navigation of Internet Protocol Television Using Adaptive Hybrid Delivery Method. *Journal of Computer Networks and Communications.* (Hindawi – Published).

Adeliyi, T., Olugbara O. 2018. Designing Effective Two-list Group Program Driven Algorithm for Channel Navigation in Internet Protocol Television. *International Journal of Advanced Media and Communication (IJAMC)* – (Inderscience- Published)

Adeliyi, T., Olugbara O. 2018. Detection of Salient Objects in Non-Stationary Video Sequence Images for Analysing User Perceptions in Internet Protocol Television. *Multimedia Tools and Applications.* (Springer - Under review).

ABSTRACT

Internet Protocol Television is a system that has revolutionized the media and telecommunication industries. It provides the platform for transmitting digitised television services across the Internet Protocol infrastructure. Internet Protocol Television took advantage of the Internet service convergence by providing seamless interactivity, time shifting, video on demand and pay per view to subscribers. However, zapping delay is a critical problem that deters the switching intention of terrestrial subscribers and the widespread of Internet Protocol Television services. Subscribers often experience this zapping delay problem in Internet Protocol Television when switching channels, which makes subscribers, wait for several seconds before the desired channel is found and made available. The zapping delay problem is intrinsically caused by video stream end-to-end delay, buffering delay, network jitter and traffic load. In the last few decades, a lot of frameworks, for instance, those based on multiple channels, have been proposed to reduce zapping delay in Internet Protocol Television. Such frameworks are implemented at the subscriber level, network level or video level. However, high bandwidth is still required to make the existing frameworks work effectively, which is an intrinsic limitation because not all subscribers can afford the cost of high bandwidth.

This research develops a unified framework that takes the advantages provided at the subscriber level and network level to solve the zapping delay problem in Internet Protocol Television. It is possible to reduce zapping delay in Internet Protocol Television using an effective framework to aid faster channel switching and increase the quality of experience. The framework being proposed in this research is faster than a regular stream and it reduces the zapping delay to the bare minimum. The framework has been validated at both subscriber and network levels, which indicates that as traffic load increases at a set bandwidth within the converged network, packet end to end delay and network jitter should be reduced in order to eliminate zapping delay. Furthermore, the encoded and decoded video sequence available to the subscriber is evaluated using popular quantitative metrics and mean opinion score to determine subscriber perceptions of video quality through the salient object that will interest the subscriber in the video sequence displayed in order to aid a high satisfaction level video quality of experience. A large-scale implementation of the proposed framework by a telecommunication firm promises to generate revenue for the firm. In addition, the implementation and practical deployment of the proposed framework would also benefit subscribers to enjoy unlimited Internet Protocol Television services at reduced cost.

CHAPTER ONE

INTRODUCTION

Television is one of the prevailing media infrastructures in existence today. According to the Broadcast Research Council of South Africa in 2017, over 44 million viewers were recorded, showing how this service has grown in recent years. With the recent advancement of digital technology, television signal distribution is also going through rapid changes. The days where the television signal was delivered through radio frequency that is an analogue signal and terrestrial broadcasting are winding up.

In accordance with the International Telecommunications Union (ITU) recommendation, that countries in various continents should migrate from the conventional analogue signal to digital signal for broadcast transmission (South Africa Department of Communication, 2015). The implementation of IPTV services over a converged network will fast-track the actualization of the Gazette of Broadcasting Digital Migration Policy in South Africa. This migration comes at the expense of assuring reliability and service assurance to convince subscribers to upgrade from current cable or satellite TV models to IPTV.

The demand for a higher bandwidth has been overwhelming in recent years because of the deployment of a broadband converged network and delivering service paradigm. This service paradigm is rapidly evolving and expanding to a true triple-play service represented by voice, the Internet, and IPTV (Choi *et al.,* 2012). The International Telecommunication Union (ITU-T), then defined IPTV as "multimedia services such as television, video, audio, text, graphics, data delivered over IP-based networks managed to provide the required level of QoS/QoE, security, interactivity, and reliability".

Internet Protocol Television is seen as the future of television broadcasting because it offers a real-time video service by transmitting varieties of video contents over an IP infrastructure. Zeadally *et al.,* (2011) also described IPTV as a system that uses Internet Protocol (IP) infrastructure to deliver the television service broadcast. Shi *et al.,* (2008) further explain that the IPTV system conforms to the trend of triple play service, which is used as a medium to provide subscribers with digital media services such as video, voice, and data. Consequently, IPTV subscribers get IPTV services through a set-top-box (STB), which distinguishes it from Internet TV. This STB, through an operating software installed on it, makes a non-smart TV becomes a smart TV due to the interactive features it offers such as short message service (SMS) caller ID, e-mail and instant messaging (Held 2006). Furthermore, IPTV offers thousands of TV channels, time shifting, video-on-demand (VoD) and pay per view (PPV) to subscribers.

The emergence of IPTV, a key broadcasting service on a converged network, brought immense potential, giving network providers the capacity to expand their market value and revenue generated by increasing the number of subscribers (Horwitt, 2005; Joo *et al*., 2012). Internet Protocol Television in a converged network is a technique that aggregates data, voice, and digital television on a single network infrastructure line giving subscribers a packed broadband service experience and helping with the utilization of broadband service (Mark and Miller, 2005).

"Convergence is the capability of the Internet to act as a foundational base for various functions that conventionally had their own platforms" (Jo *et al* 2014). Therefore, Ethernet is seen as the foundation for converged networks due to the ubiquity of its presence for connecting data traffic between computers (Tim, 2012). A converged network, hence integrates Ethernet and fibre channel traffic over a common infrastructure for diminution of cost and simplified management. The need for an efficient and professionally designed framework cannot be overemphasized; to this end, a great level of reliability is required for IPTV in a converged network.

Television subscribers are accustomed to changing television channels without any form of delay while watching TV, although traditional TV broadcast does not have as many channels IPTV offers. However, the best effort model has been the default way of providing data services across IP networks. This model, which guarantees zero to minimum service level agreement where streams of packets are treated alike without any form of priority accorded to any stream of packets (Ghaffarian *et al.*, 2008). Therefore, IPTV cannot afford the luxury of delivering IPTV services using best effort. IPTV is based on a multicast system for transmitting video across the Internet Protocol (IP) infrastructure because not all channels can be sent to the subscriber home gateway as a result of the limited network bandwidth (Dekeris and Narbutaite, 2010; Chase, 2016). However, IPTV has caused the available bandwidth per subscriber to increase while an emerging group of services will demand higher bandwidth (Vedantham *et al*., 2006).

The Digital Subscriber Line (DSL) is the dominant network infrastructure for delivering IPTV service in a broadband converged network (Cruz *et al*., 2011). This DSL access line employs a twisted copper cable in the last mile of the network connection at the network subscriber's premise. While interlinked to the digital subscriber line access multiplexer (DSLAM) which act as the network line exchange linked to the Internet service provider trunk office. Asymmetric digital subscriber line (ADSL) is a type of DSL that has a maximum bitrate of 8mb/s and can only support one HDTV channel at a time, while ADSL2 and Very-high-bit-rate Digital Subscriber Line (VDSL) support up to 24mb/s and 50mb/s respectively (Artundo *et al.,* 2010). IPTV stream requires about 2-4mb/s sustained bandwidth per standard definition (SD) stream, using MPEG4 compression standard, with high definition increasing the bandwidth demand to 6-12mb/s per stream (Asghar *et al.*, 2009; Oh *et al*., 2017).

The Quality of Service (QoS), which is an important metric frequently used to measure network performance is required in order to guarantee end-to-end IPTV deployment over a converged network and to provide Quality of Experience (QoE) assurance to subscribers. QoS is essential for providing a seamless IPTV service that aids QoE for subscribers. To this end, a satisfactory level of the service provided by a network provider is determined by the QoE perceived by subscribers (Lai and Wolfiger, 2012). The lower the QoE, the higher the level of dissatisfaction and the chances of subscribers abandoning such a service. QoE is composed of a variety of metrics frequently used to measure satisfaction by subscribers. The metrics include, network performance parameters such as the end-to-end delay and jitter as well as the service quality parameters such as cost, reliability, availability and usability (Kim and Choi, 2010). IPTV is considered as a real-time broadcast service over the IP infrastructure.

In view of this advantage, zapping delay is a major concern for IPTV widespread deployment, which affects the attractiveness to IPTV and significantly deters the switching intention of current terrestrial subscribers (Ramos *et al.,* 2011). Quintero *et al*., (2015) explain the zapping delay as a problem that is often experienced by users when switching channels, which makes subscribers wait for several seconds before the channel is made available. This is an impairment that occurs in subscribers’ set-top boxes or other end-user equipment. Zapping delay problem sets in when a change of channel takes 0.43 seconds or more (Kooij *et al.*, 2006; Ferro *et al.*, 2016; Manikandan *et al*., 2016; Shin *et al*., 2016) that affects the QoE perceived by subscribers. This zapping delay problem is heightened when network delay and jitter occur such that the channel selected by a subscriber experiences more than 2 second delay when compared to the same channel aired on the traditional broadcasting service. The motive behind this thesis is to develop an effective zapping delay framework for Internet Protocol Television over a converged network by investigating the causes of zapping delay faced by IPTV subscribers and the use of the proposed framework to analyse and evaluate the problem faced by IPTV subscribers in a converged network.

1.1 Motivation

The motivation for doing this research on IPTV is based on the fact that there is currently no IPTV service running in Africa and I see it as an area yet to be tapped into which promises great gain to end-users and service providers with the advent of increasing usage of the Internet. Until now, end users have been subscribing to terrestrial broadcasting through traditional TV networks that use analogue signals to broadcast few free-to-air channels to end users while end users receive Ultra High Frequency (UHF) and Very High Frequency (VHF) signals with the use of TV antennas. Some years back, digital television services were introduced in Africa, a broadcasting medium that solved the challenges facing the traditional analogue television through the use of satellite due to the increase in digital TV channels.

IPTV services today have reinvented television broadcast blending digital media with Internet (Thompson and Chen 2009). Prior to the Internet age, television service was provided through a mono directional broadcast medium without the bidirectional communication needed, which fully empowers viewer's interaction and engagement to the provided service, consequently increasing the subscribers perceived quality of the experience. IPTV is hence seen as the future of television providing live television, VoD (Davidovic, 2014), interactive television services (Oliveira *et al*., 2017) among other applications that make IPTV a 'killer' application over the IP platform. As opposed to PC-based viewing, or Internet TV as many people know it to be, a managed IPTV service provided by telecommunication companies emulates a TV viewing setting incorporated alongside the set-top boxes (STBs), which provides a par cable TV like experience because of the quality of service provided.

With the upward emergence of broadcasting establishments such as the British Broadcasting Corporation (BBC) and France TV (FTV) to mention a few, as well as independent media content providers, who provide direct access to digital television contents using the broadband internet access, and a bi-directional interactivity approach. Enli (2008) describes the BBC as the bastion in Europe, serving as a forerunner and a pacesetter blending new and old media transmission approaches together, which offers a variety of dynamic new services and application such as the BBC iPlayer that has revolutionized the digital media broadcasting and has impacted subscriber lives increasing the level of quality of experience. This emerging approach is often referred to as over-the-top (OTT) video broadcast since it essentially uses the Internet as a carrier in delivering the digital content. However, Internet providers are not responsible for the content itself, but only for its communication without guaranteeing the quality of service a limitation experienced by subscribers resulting in a low perceived quality of experience (Dong *et al.*, 2012).

Due to the limitations experienced in OTT media broadcast, there has been a rapid rollout of managed IPTV in recent years across the world by Internet service providers (ISPs) in developed countries which include PCCW global based in Hong Kong, Telefonica based in Spain, France Telecom based in France, AT&T and Verizon based on United State of America, China Telecom based in China, and Korea Telecom based in South Korea. These service providers are world leading managed IPTV providers who have implemented a well provisioned, managed IPTV framework in their national core network backbones with an efficient IP service delivery for IPTV service transmission through the network subscriber line and set-top boxes (STBs) at the subscriber premise, providing a cable television experience (Cha *et al*., 2008a). With the annual increase in deployments and addition of potential subscribers to the IPTV network, it became incumbent on ISPs and content providers to improve network architecture for IPTV delivery, QoS mechanisms and subscriber device interface, as well as to enable a simplified usage of enhanced services. Regardless, zapping delay has been a deterrent to the widespread use of the IPTV service, especially in Africa.

1.2 Problem Statement

The International Telecommunications Union resolution that all broadcasting media services should migrate from analogue signal to digital signal means that IPTV is seen as the future of digital broadcasting service in actualizing this commitment due to the ubiquity of IP infrastructure provided by telecommunication firms (Montpetit *et al*., 2010). However, the zapping delay problem in IPTV deters the large-scale implementation of IPTV service by telecommunication firms. Video encoding and decoding time, bandwidth, traffic load, network jitter and network delay intrinsically cause this zapping delay problem.

IPTV content distribution is very intensive. Gone are the days where high definition (HD) video quality was the ultimate expectation of the viewer. Nowadays ultra-high definition (UHD) and 4k videos are in vogue, mounting pressure on the video quality IPTV provides, especially with limited bandwidth available. Over the years, the current IPTV multicast service used in delivering IPTV contents seems adequate, despite some snags and inefficiencies, with the current video quality available. An IPTV service distribution framework must be looked into in order for the service to remain competitive when compared to other terrestrial TV services and to allay the fear of subscribers in providing a high level of experience.

In spite of the amount of literature addressing the zapping delay problem in recent years, there seems to be no effective solution to resolving this problem. In response to the zapping delay problem, this thesis will address the overall problem of zapping delay by developing an effective zapping delay framework of the network, video and subscriber level to reduce the zapping delay to the bare minimum in order to improve the QoE perceived by subscribers.

1.3 Aim

The overarching aim of this study is to reduce the zapping delay problem in IPTV within a converged network by developing an effective framework to solve the zapping delay in IPTV.

1.4 Objectives

To achieve the aim of this study, the following objectives are defined.

1. To comprehensively review relevant publications based on zapping delay in IPTV over a converged network.

2. To implement an adaptive hybrid service delivery method flow for video requests at the network level in order to aid fast channel delivery.
3. To develop an effective zapping delay framework at the subscriber level in order to aid fast channel navigation.
4. To validate the proposed framework, using Linux operating system on raspberry pi hardware to build an IPTV set-top-box that shows how zapping delay will be reduced to the bare minimum.
5. To use image segmentation approach in analysing the subscriber perceptions of IPTV video quality.

1.5 Summary of Research Contributions

In this thesis, the zapping delay framework at the subscriber level and network level were analysed to assist IPTV providers with the deployment and delivery of IPTV services. The proposed framework highlighted the channel switching challenges discussed earlier. The main contributions of the proposed zapping delay framework reported in this thesis are as follows:

a. Currently, TV channels for IPTV subscribers are being delivered using a multicast service by the IPTV service provider, which implies that despite the fact that all channels cannot be broadcast to the subscribers at once, channels are distributed continuously over the network, which makes channels available at subscribers' request. The first contribution of this thesis was to propose a method for fast channel navigation using an adaptive hybrid service delivery method at the network level, which was demonstrated by using OPNET Modeller. This method will deliver IPTV channels to subscribers using a unicast stream with a DiffServ QoS from a multicast tree service when zapping delay sets in above 0.43ms that are the time it takes for the image of the requested TV channel to be made available to the subscriber. The research work concluded, that the first modular approach based on the adaptive hybrid service delivery method, reduced to the bare minimum queuing delay, end-to-end packet delay, packet variation and throughput when compared with the state-of-the-art methods hence, reducing zapping delay.

b. The second contribution of this thesis is the intrinsic analyses aimed at reducing total channel seek distance and total channel seek time during subscribers' channel navigation, using a two-list group program driven method (TGPD). This method, at the subscriber level, gives the subscribers the choice to select channels to watch from a genre of programs into the hot-list or cold-list that is the two-list method group program driven method based on preference in order to determine channel popularity based on the rate of watching a channel over a period of time. By performing a trace-driven analysis, this research work concluded that the modular approach would reduce zapping delay as the result was benchmarked with state-of-the-art approaches.

c. The third contribution merged a framework at the subscriber and network level, an approach that uses a group program driven two-list method with a personalized electronic program guide. This approach saves subscribers a painstaking amount of time in searching for the desired channel to watch and gives subscribers a program description using Explicit Semantic Analysis Bag-of-Words (ESA-BOW) approach to aid them to choose TV channels in the hot-list. This reduces zapping delay when compared with several state-of-the-art approaches.

d. Furthermore, this research work demonstrated a means of analysing the perception of subscribers on video quality in aiding high satisfactory level of video quality of experience in accomplishing the fourth contribution. A segmentation algorithm was adopted that can segment salient objects in an encoded and decoded video sequence image in order to obtain the salient object in a video sequence image that will interest the IPTV subscriber. The adopted object detection algorithm was benchmarked with seven different state-of-the-art saliency object detection algorithms. Furthermore, detailed evaluation performances against the saliency images obtained from the object detection algorithms with the non-saliency ground truth images to demonstrate the performance and effectiveness of the adopted object detection algorithm. This research work further evaluated the object detection algorithms both qualitatively and quantitatively on different challenging video sequence images of humans, objects and animals acquired from two publicly available benchmark datasets using eight standard statistical evaluation metrics in terms of Specificity, Sensitivity, Error, Jaccard, Area Under The Curve (AUC), Hammoude distance and Dice.

1.6 Thesis Structure

This thesis is organized into eight chapters. A brief summary of information on all the eight chapters is given here; the first two chapters of this thesis, presents the introduction, background studies and literature review, while the preceding five chapters give a detailed description of the thesis. The last chapter gives a summary of the thesis. The thesis chapters are organized as follows.

Chapter one, Introduction - the first chapter presents the background study of IPTV in a converged network by giving a highlight of what the thesis entails and succinct description of key subheadings of the thesis topic such as, zapping delay, problem statement, aim, objectives, the significance of the study and the structure of the thesis.

Chapter two, Literature review- presents a detailed, cogent information and a critical assessment about the related literature of zapping delay framework used earlier, and evaluation measures of IPTV over a converged network while explaining elaborately the underlying features of IPTV over a converged network using academic resources to justify claims.

Chapter three, Methodology- presents the zapping delay framework of this research study. In this chapter, the zapping delay framework was broken down into four modular approaches. Highlights of the four modular approaches in order to achieve the set research aim and objectives were explained. The four proceeding chapters explain in details each of the modular approaches that formulate the core zapping delay framework proposed in this thesis in order to reduce the zapping delay problem to the bare minimum.

Chapter four introduces the first modular frameworks of the zapping delay framework. This approach uses a fast channel navigation method using an adaptive hybrid service delivery method at the network level to reduce zapping delay in IPTV. This method uses unicast channel stream to respond to a channel request from a multicast tree network when zapping delay sets in. This research work simulated and analysed the method using OPNET 14.5 modeller.

Chapter five introduces the second modular approach, where the framework at the subscriber level uses a two-list group program driven method to reduce the total channel seek distance and the total channel seek time to aid fast channel navigation in IPTV systems.

Chapter six further presents the third modular approach, that unifies the approaches of the subscriber level and network level, an approach that uses a two-list group program driven method with the personalized electronic program guide to aid fast channel switching and navigation. Furthermore, a real-life implementation was made to test the framework by using raspberry pi3 hardware, and the Linux operating system. The implementation and the analysis are evaluated and compared with state-of-the-art approaches like YouTube and other OTT services.

Chapter seven, the research work further analysed the perception of subscribers on video quality by using a segmentation algorithm that detects salient objects that will interest IPTV subscribers in the encoded and decoded video sequence images. The fourth modular approach was used to evaluate the video image displayed from the first three modules of the proposed zapping delay framework to test the effectiveness and the performance of the proposed zapping delay framework. Complex and challenging public datasets available online were used to benchmark the segmentation algorithm with seven different state-of-art segmentation algorithms. The performance of the algorithms was further evaluated using eight popular metrics.

Chapter eight, Conclusion- the summary of the thesis is made, restating its contribution to research. Future work suggestions are made on how to build on the proposed framework.

CHAPTER TWO

LITERATURE REVIEW

2. Introduction

This chapter gives a broad review of related findings that have influenced literature in recent studies on IPTV and the confronted zapping delay problem. For clearness, this chapter is subdivided into ten main sections. The first section presents the Internet Protocol Television, with its characteristics and network infrastructure. The second and third section presents the form of transmission and its protocols. The fourth and fifth section presents the IPTV architecture and requirements buttressing on the genesis of zapping delay and techniques in the literature that have been proposed beforehand. The sixth and seventh section presents the IPTV standards and the video coding structure. Furthermore, the eighth section presents the converged network for the triple-play services (voice, video and data). Finally, the ninth and tenth section present the quality of service approaches used by service providers to enhance the quality of experience.

Media broadcasting through television is the leading approach of broadcasting, where video content is distributed to a dispersed audience (Evens and Donders, 2016). Television was introduced in the early 90s, since then it has become a pervasive and dominant mass medium (Sudo and Ito, 2017). Television presenter work from the studios while the program contents are aired to viewers from the broadcasting facility. However, in recent years the number of TV channels has skyrocketed from a few traditional free-to-air analog broadcast platform for several hundred terrestrial, cable and satellite digital broadcast and most recently to the Internet protocol Internet TV and IPTV networks that transmit more channels to designated subscribers (Pierson and Bauwens, 2015; Corcoran *et al*., 2015). With the continuous improvement of media technology, gone are the days where television, video signal are transmitted and received in black and white or analogue colour signals, video signals now range from the high-definition digital stream to 4k video digital stream (Cha *et al.*, 2008a; Misu *et al*., 2015).

Whilst television broadcasting continues to be a dominant factor in digital multimedia, today it has intrinsically added new trends to how TV channels are being aired. The migration of television broadcasting from analogue to digital is in progress, especially in developing and third world countries, generating new business prospects for manufacturers of media equipment, and television content providers. With the advent of rapidly evolving and innovative deployment approaches in transmitting video contents and live TV broadcast such as the Internet protocol television, which creates avenues for content providers and network provider to expand, reaching out to new subscribers due to services provided. This rapid trend that adopts the new innovative approach for video transmission of digital media is mostly accepted in the younger age groups and has become part and evident in their daily lives (Al-Mohammed and Linge, 2016).

2.1 Internet Protocol Television

The digital media industry is moving into a new era in delivering improved services to subscribers. With the advent of a bidirectional interactive characteristic in digital media platform, which has revolutionized and opened up an innovative paradigm in media transmission. The two distinct platforms that run in the parallel world that is the media platform (television) and the Internet are being conjoined into a completely new entity, to provide a bidirectional interactive function in televisions.

"IPTV is a set of multimedia services that are distributed throughout an IP network, where the end user receives video streams through a set-top-box (STB) connected to a broadband connection" (Hamodi and Thool, 2013). The emergence of IPTV has brought with it the potential to revolutionize personal entertainment and the way television programs are being aired. The IPTV platform often offers services that include interactive TV, live TV, and Video on Demand (Minoli, 2012) through the network and content providers. Chauhan and Yadav (2015) further explained that IPTV has a large number of characteristics such as support for interactive TV, where interactive means a bidirectional ability of the IPTV platform, which permit network and content providers to transmit different digital applications that support TV interactive function. IPTV characteristics include the following:

a. Interactive Television Support: IPTV platforms have channels that let the service provider support bidirectional interactive applications, live television, high definition TV (HDTV), 3DTV, UHDTV, interactive games, and ability to surf the internet, among many others.
b. Time Shifting: this service can be used to record TV so that users can view the recorded contents later. VoD services, contents are not live but pre-encoded contents available at any time from servers (Hamodi and Thool, 2013).
c. Personalized content: IPTV has a bidirectional communication channel which accords subscribers the choice of deciding what to watch amongst ranges of channels available.
d. Requires low bandwidth: IPTV does not transmit all the channels to subscribers instead, it only allows transmission of channels as requested by the subscriber. However, it makes use of multicast service delivery to transmit

channels as requested by the subscriber; hence saving bandwidth (Kanellopoulos, 2013).

From the standpoint of Internet service providers, IPTV services are transmitted to subscribers through the acquisition of TV content from a broadcasting station, processing and coding, and secure distribution of TV content on the IP network infrastructure. According to ITU (2008), the IPTV services provided by the ISPs must possess a "satisfactory level of quality of service, security, interactivity, and reliability". IPTV is rapidly revolutionizing to a full-blown digital media platform enabling service providers to include IPTV as a triple-play product bundle, with the benefit of cost reduction in delivering digital television, voice and data packages through Internet Protocol to subscribers. This insinuates bits of video sequence streams are sent across the Internet in a packetized data user datagram protocol (UDP) for fast delivery.

IPTV is the only platform that offers total digital television because it has a different service delivery model when compared with other traditional terrestrial TV services, increasing its popularity (Jimenez *et al.*, 2015). Although IPTV differs from Internet TV and P2P, (peer-to-peer) TV in terms of the service model delivery to the subscribers, service-publishing technical and hardware infrastructure, however, many people contextualize and interchange them with each other.

Internet TV also referred to as OTT, is a media service that delivers TV content through the Internet, usually to personal computers via streaming or through video on demand services, which are downloadable by using a web browser (Ahmad and Begen, 2009). The content aired on Internet TV is either user-generated such as YouTube (Xiao and Ye, 2008) or provided by some content providers (such as al Jazeera, France 24, BBC among many others). While point-to-point (P2P-TV) transmits live TV contents by arranging and exchanging the packetized video stream in chunk bits, among peers within the P2P network (da Silva *et al.,* 2008). However, IPTV services are delivered over a managed IP network, which is provided by a network and content providers with a guaranteed QoS, which aid a high level of quality of experience.

IPTV services can be transmitted using managed or unmanaged approaches. According to Begen (2011), most digital multimedia services today, like video-on-demand, live TV broadcast, and interactive TV originates from video or content service providers. Cha *et al.,* (2008b), explain that service providers, managed network where transmission of video contents, storage management, and bandwidth provisioning are guaranteed and have fewer bandwidth limitations and end-to-end connectivity difficulties when compared to the challenges faced by other P2P-TV applications that are deployed over the unmanaged service without any form of service delivery guarantee.

2.1.1 Managed Network

In a managed IPTV network infrastructure, service/network providers guarantee a controlled network bandwidth, from the distribution of TV content, storage management to the use of traffic prioritization and bandwidth reservation techniques in providing a seamless quality of experience (QoE) to subscribers, hence, reducing bandwidth limitations and end-to-end network connectivity difficulties confronted by P2P and other OTT application services (Begen *et al.,* 2010; Cha *et al.,* 2008b).

Friedrich *et al.* (2010) also state that a managed IPTV service enables video content to be offered by a single network operator who operates IPTV businesses or has agreements with video content providers where the quality of service is guaranteed, increasing a subscriber perception of the quality of experience. Moustafa (2012), further explained managed service to be a service provided by service providers through the set-top box (STB) provisioning a reserved or guaranteed bandwidth in optimizing IPTV services delivered to subscribers.

IPTV uses IP multicast for efficient distribution, which is defined in RFC 1112 specifying that a datagram sent to an IP multicast address range (224.0.0.0 through 239.255.255.255). The multicast delivery approach supports both one-to-many and many-to-many group communication. IPTV subscriber's STB joins the multicast session to receive TV content only for the intended channel in which the subscriber is interested via the STB remote control. IPTV specifically operates using the source-specific multicast for delivering live TV contents to subscribers. (Cain, 2006; Bhattacharyya, 2003).

2.1.2 Unmanaged Network

The unmanaged network uses hypertext transfer protocol (HTTP) for web TV or Internet TV and transmission control protocol (TCP) as a reliable means to transmit over-the-top of a best-effort open Internet giving no guarantee for the quality of service due to the unpredictable availability of bandwidth per time. In this service content owner, resellers, and distributors use consumers' broadband connections to deliver content on demand. This content may be sourced from one or more servers, as part of a content delivery network, or from other consumers via peer-to-peer connections. YouTube is one famous representative of this model, as the customers themselves generate video content rather than content providers (Begen *et al.*, 2010; Moustafa and Zeadally, 2012).

Many of the unmanaged network video streaming applications use HTTP to transport video content, allowing the content to be easily watched via a web browser. However, abnormalities experienced in the subscriber's connection reveal that without any preferential treatment from the Internet service provider (ISPs) metrics such as packet loss, delay and jitter, aid the reduction of the subscribers' satisfactory quality of experience level. The only advantage of an unmanaged network is that it does not require additional infrastructure dedicated for video distribution. In an unmanaged IPTV deployment, a third party via the Internet service provider (ISP) or a phone company without a guarantee of QoS and QoE offers video content. Friedrich *et al.,* (2010) further explain unmanaged service as IPTV services that are delivered through a service called Over the Top (OTT) that is, delivery of a multimedia service without any multi-system operator. However, managed IPTV deployment is seen as the best when compared with unmanaged deployment as it guarantees constant bandwidth and QoE to some extent.

2.2 Unicast, Multicast, and Broadcast in IPTV

The form of transmission of data streams from a source address to a destination address within a network for service delivery, such as voice, data and video can be unicast, multicast or broadcast.

2.2.1 Unicast

Unicast services were primarily used in computer networks for delivery of services and applications such as HTTP, FTP, email etc. Prior to the emergence of converged networks. Regardless, unicast service has a vital role to play in most of the on-demand traffic on the Internet. A unicast service in IPTV is a one-to-one model were setting up a unicast flow sends the contents of a specific program to a single subscriber on request from a video-on-demand server to the subscriber's STB. The unicast service is a one-to-one connection method that conventionally uses the Real Time Streaming Protocol (RTSP) and Real-Time Protocol (RTP) to recover lost packets. It accelerates a channel change by delivering IPTV contents at a higher rate than the streaming rate of video (Begen *et al.*, 2009; Jana *et al.*, 2016). A unicast service requires a dedicated zapping server to transmit a unicast burst when a subscriber initiates a channel change request. This stream is sent at a higher bit rate than the usual bit rate that allows the playout buffer to be quickly filled, making a channel readily available to a subscriber (Ramos *et al.*, 2011).

When a channel is requested using the unicast stream, the new channel's data are sent at a higher bit rate. This higher bit rate allows the playout buffer to be filled quicker than the nominal rate at which the multicast stream is transmitted making channels available to the subscriber (Banodkar *et al.*, 2008). The downside of a unicast stream is that there is a burst load on the bandwidth imposing a significant input and output demands on the video servers. This is heightened because of the huge requests from subscribers coupled with the variation of the unicast packet rate of transmission and ability to the recover lost packet. Hence, the unicast stream does not scale well. Chase (2016), summarizes that IP multicast is used as a countermeasure because it provides huge bandwidth efficiency over the unicast delivery.

2.2.2 Multicast

IP multicast is a one-to-many method for simultaneously delivering content to a group of nodes instead of one. IP multicast is required to provide IPTV services by joining the multicast group through a channel request initiated from the remote control of the subscriber's set-up box. This multicast service saves bandwidth at both the core and access networks because there is a high probability that multiple subscribers would likely watch the same program at the same time (Xiao *et al.,* 2007 and Banodkar *et al.,* 2008). The IGMP is used for management purposes, allowing IPTV subscribers to report group memberships to any neighbouring routers that are multicast enabled to manage multicast video streams at the service provider zone (Collet *et al.,* 2011). The STB performs the process of sending IGMP multicasting tree when an IPTV subscriber switches between channels using a remote control. The leaving group sends a leave message to the edge router at the service provider zone on receiving the IGMP leave message. The edge router will react by sending a specific multicast video stream and terminate the specific multicast channel while the join group message is used to obtain a new channel. After waiting for the IPTV content of the requested channel to be delivered, the STB wait for a decodable frame, called an Intra-coded frame (I-frame). The requested channel is ready to be displayed on the TV set once the requested channel is delivered to the STB of the subscriber (Lee *et al.,* 2010; Lee *et al.,* 2011). Unfortunately, there is a channel zapping delay due to the time it takes to join the multicast group, which can last for several seconds, invariably causing an unacceptable quality of experience to the IPTV subscriber.

2.2.3 Broadcast

In broadcast service, packets are being flooded to all the nodes in that network. The traditional over-the-air broadcasting (analogue signal) and the digital broadcasting service provide linear programming TV services using the broadcast service through several broadcast networks such as terrestrial, cable, satellite, etc. Such that all channels get to the customer premises at once, hence channel change time in this instance is instantaneous while delay, if at all, is minimal (Somu and Rengarajan, 2012).

On the other hand, the IPTV service utilizes a packetized video distribution; the set-top-box receives channels based on the subscriber's request. Owing to bandwidth constraints, all the channels cannot be sent simultaneously in order to avoid buffer overflow, which may cause play-out glitches and degrade the quality of viewing experience by subscribers. Furthermore, broadcast service can cause burst conflicts, which occur when two or more bursts intersect with each other, which directly cause zapping delay and may affect subscribers in opting for such services (Hefeeda and Hsu, 2010). Based on the downsides unicast and broadcast service possess, multicast service is seen as the best means for IPTV service delivery (Koch *et al.,* 2017).

2.3 IPTV Protocols

The technological infrastructure behind IPTV combines digital media from the content providers and IP protocols. The original video content is too heavy to be transmitted over the IP network, hence it is compressed with the use of encoders to make the original video stream manageable for transmission over the IP network. In traversing this managed digital video over the IP network infrastructure Yu *et al.,* (2009) and Ko *et al.,* (2010) describe the underlying primary protocols used for IPTV. These include the Internet group management protocol (IGMP), the real-time transport protocol (RTP) or real-time streaming protocol (RTSP) and Protocol Independent Multicast (PIM).

a. IGMP is a standard protocol used to manage memberships of multicast groups of subscribers connected to the multicast router over the network. According to Rattanawadee *et al.,* (2015) IGMP comprises three messages: IGMP query message is used to announce IPTV server services by learning which groups have members on the attached network and for checking subscriber's membership status periodically. When subscribers receive the query message they use the join message to request a service from the router while subscribers notify the IPTV server about leaving the group using the leave group message. Through multicast technology, content providers can send the same video content to millions of subscribers at the same time saving a large amount of network bandwidth compared to unicast requests (Yu *et al*., 2009).

b. Protocol Independent Multicast (PIM) provides support for routing multicast traffic between routers within an autonomous system on the basis of routing information obtained from a unicast routing protocol (such as RIP, OSPF). This is sub-divided into two modes, sparse mode (PIM-SM) and dense mode (PIM-DM) (Jackson *et al.,* 2014; Lencse and Derka, 2012). PIM-SM is a protocol for efficiently routing IP packets to multicast groups that may span a wide area of the network explicitly constructing a tree from each sender to the hosts in the multicast group.

PIM-SM has two types of distribution trees: a source tree and a shared tree. The source tree is a method of transmitting the data packets from the source to hosts by using the Shortest Path Tree. The shared tree transmits data packets over a Rendezvous Point (RP), which acts as the meeting place for sources and hosts of multicast data. (Ko *et al.,* 2010). PIM-DM enabled routers to operate by building a multicast tree and then flooding packets to all destinations from a source within the network. 'Prune' packets from the traffic distribution tree are sent to indicate that there are no members accessing that multicast stream (Mir *et al.*, 2014; Lencse and Derka, 2013).

2.4 Internet Protocol Television Architecture

IPTV in a converged network is a service that uses the IP protocol to deliver multicasting contents to subscribers via a broadband connection. The IPTV architecture spans across four zones as shown in Figure 2.1. The customer premise where we find devices such as TV, STB, PC, IP Phone and ADSL router presents IPTV contents to a subscriber for display. The network provider zone allows a connection between the consumer premise and service provider zone. The service provider zone is responsible for providing services to the subscribers. The content provider zone owns or is licensed to air contents and encoded video (Zeadally *et al.*, 2011).

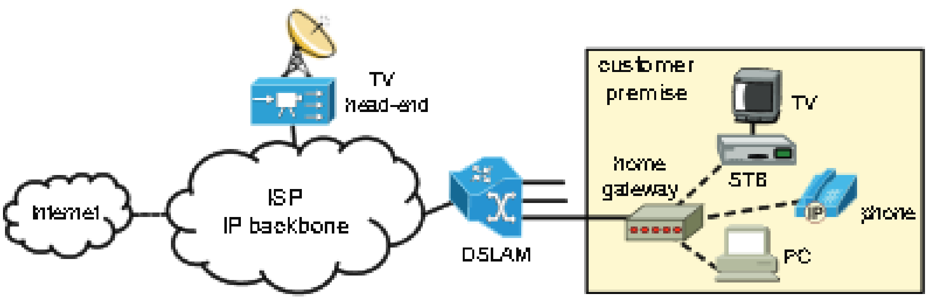


Figure 2.1: IPTV architecture over a converged network (Cha et al, 2008a)

Figure 2.1 illustrates a typical IPTV architecture over a converged network. The IPTV head-end of the content provider zone where TV channels are being distributed injects live TV streams encoded as IP packets to the network core at the service provider zone using a multicast service. These IP packets travel through the network to routers that are connected to the Digital Subscriber Line Access Multiplexers (DSLAMs) at the network provider zone, which then distributes traffic to several subscribers and connects them to the high-speed backbone through the gateway at the customer premises.

The series of communication between the subscribers STB and the IPTV headend is based on the channel switching signals. The STB translates a channel-switching event from the subscriber's remote control into a pair of Internet Group Management Protocol (IGMP) messages. The first message is to inform of the subscriber's departure from the multicast group of a TV channel, and the second message is to join another multicast group on the requested new channel. According to Degrande *et al.,* (2008) and Chen *et al.,* (2009), the IPTV architecture consists of three basic components as shown in Figure 2.2:

a. Super Head End (SHE): re-encodes and packetizes each video broadcast channel, live video feeds and VoD content it receives from various nationwide content providers into an IP flow, which is transported over a core network.
b. Video Hub Office (VHO) often referred to as "local office" also can re-encode and packetize local broadcast TV channels. A VHO delivers both the nationwide and local IP flows, over a metropolitan area network. It contains a mix of devices including, streaming servers or proxies, VOD servers, access switches, network routers that connect to the national SHE and encoders for local TV stations.
c. Video Serving Office (VSO) is used to distribute the TV content over an access network through the home network to the subscribers STB.

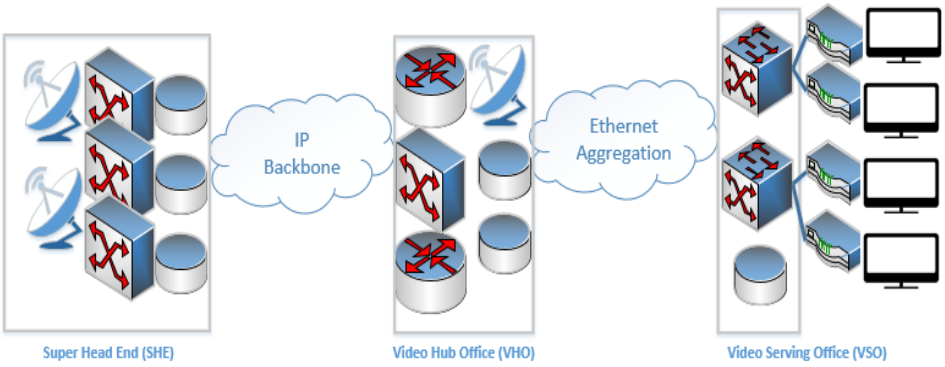


Figure 2.2: IPTV architecture components (Uzunalioglu, 2009)

2.5 IPTV Requirement

Delivering IPTV services over a converged network places an extra demand on the network beyond the best effort traditional demand required of the Internet. IPTV is a real-time application, which makes it incumbent that it provides a high quality of experience. Subscribers' expectations are high in expecting high definition (HD) video quality in addition to a service that is instantaneous and readily available at the switch on the remote control. This means a higher bandwidth, coupled with the quality of service, is required in order to provide this high-end expectation providing an IPTV service better than what the terrestrial network, satellite and cable operator (Vanhastel and Hernandez, 2008). The successful provision of this subscriber's requirement of a high quality of experience will lead to a rapid increase in the number of subscribers, generating more revenue for the service provider.

2.5.1 Channel Change Operation in IPTV

When an IPTV subscriber initiates a channel change request via the IPTV STB remote control as shown in Figure 2.3, the STB stops the packet stream belonging to the current TV channel, checks if the requested TV channel is readily available. If the channel is available it is displayed. This immediate checking of TV channel is available only if multiple channels are sent to the subscriber's STB. However, if the TV channel is not readily available at the STB, an Internet Group Management Protocol leave message is generated by the STB for the currently viewed channel and IGMP join message is generated for the requested TV channel.

The join message is forwarded through the subscriber's gateway towards the aggregation network to an IGMP proxy server that has the requested channel is reached. The requested channel is thereby forwarded to the subscriber's STB and ready to be displayed on the TV set. This channel request change causes the zapping delay problem in IPTV because it is based on channel seek distance and channel seek time. Since a large range of channels is available to subscribers, selecting the desired channel to watch becomes a big challenge that aids the zapping delay (Manikandan *et al.*, 2014).

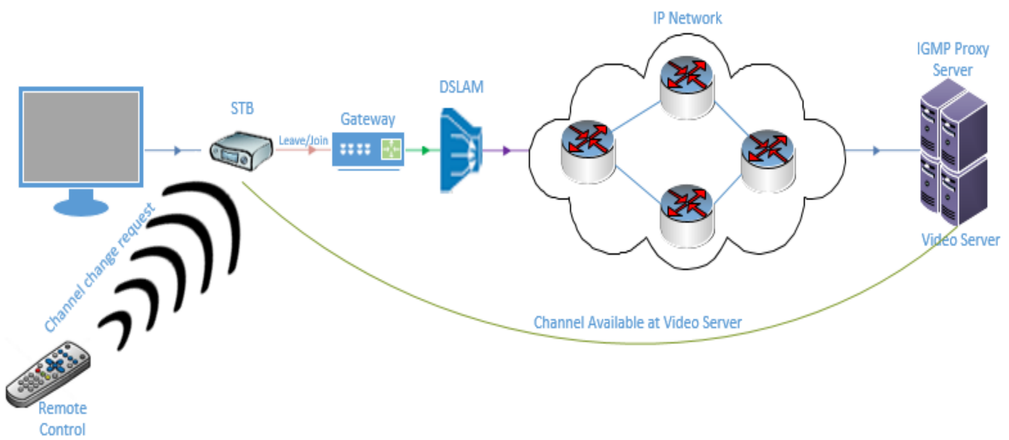


Figure 2.3: Channel change request

2.5.2 Zapping Delay

Zapping delay time, also called channel change delay time (Siebert *et al.* 2009) has a significant impact on the subscriber's quality of experience. Fuchs and Farber (2008) explain that user acceptance of IPTV services drops significantly if the channel change time is too high, a situation where subscribers experience a channel change delay of more than two seconds. Gómez-Barquero *et al*., (2009) further explain the zapping delay as a delay time, which is perceived by subscribers using IPTV, a delay suffered while changing the channel that makes subscribers wait for several seconds in order to start watching a chosen channel which is intrinsically caused by a transmission error and network delay.

In the traditional terrestrial TV broadcasts, all channels are being broadcasted once to a viewer, making channel changes almost immediately. This instantaneous change of channel involves the TV receiver tuning to a specific carrier frequency, demodulating the content and displaying it on the TV screen (Kim *et al.,* 2016; Nikoukar *et al.,* 2016). Terrestrial viewers through their experiences expect channel requests to be instantaneous because zapping delay in this system is less than 0.20s. However, zapping delay occurs in IPTV when the channel change time is above 0.43s because one requested channel is sent to a subscriber at a time due to high bandwidth consumption that deters the widespread use of IPTV service (Ramos, 2013). In addition, the problem occurs when an IPTV subscriber desires to change a channel but needs to wait until the target channel is available (Ryu *et al.*, 2014). The zapping delay is considered one of the most important parameters of QoE that defines the acceptability of how subscribers would perceive IPTV contents and services. This is intrinsically caused by command processing time (T_c), network delay (T_n), STB jitter buffer delay (T_b), and video decoding delay (T_v) (Dekeris and Narbutaite, 2015) as shown in Figure 2.4. The zapping delay factors (T_Z) is expressed as follows:

$$T_z = T_c + T_n + T_b + T_v \tag{2.1}$$

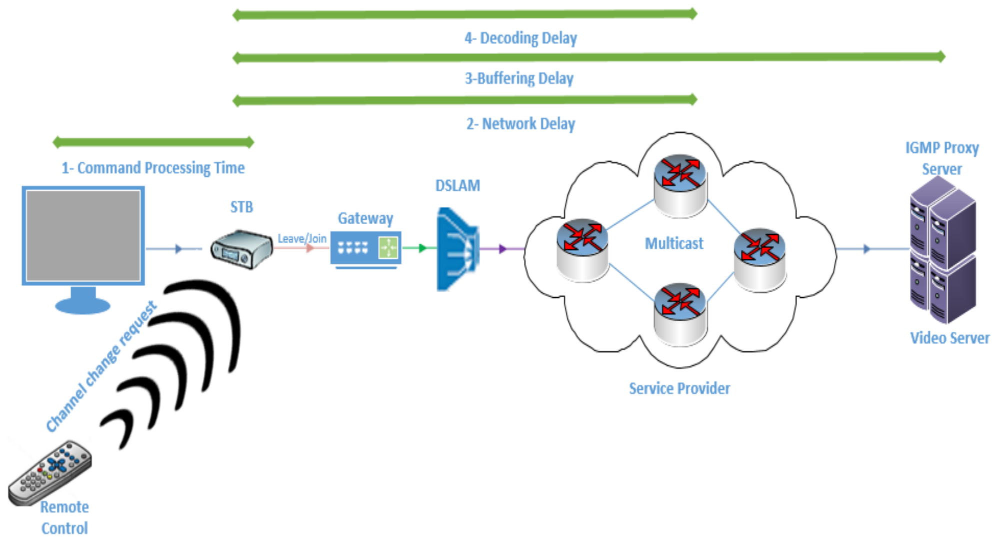


Figure 2.4: Factors of zapping delay in a converged network

The first factor that causes zapping delay in IPTV is the command processing time, which is the time required to examine the header of a frame in order to determine where to direct the frame (Li *et al.*, 2017). The command processing time causes a delay that ensues at the instance a subscriber initiates a channel change request. That is, the time it takes the IGMP leave group message to leave the current channel while the IGMP joint group message is initiated through the multicast network service at the service provider zone to request for the desired channel.

Thereafter is the network delay, which is the time it takes for the requested channel to arrive after the initiation of the IGMP join group message. The buffering delay arises from buffering video frames after the arrival of the first I-frame. It is the time it takes to repair and retransmit content in order to provide reliability when packets are lost. This buffering is designed to help overcome the intrinsic problems caused by reordering and fluctuations of packets by the unavailability of content resulting from packet loss ratio (PLR), end-to-end delay, network jitter and throughput rate (Manzato and da Fonseca, 2013; Kim *et al.*, 2015). Packet loss is bound to occur if the network parameter for receiving IPTV traffic is not appropriately coupled with the different transmission rate. Consequently, PLR is the corrupted, lost or excessively delayed packets divided by the total number of packets expected at the STB of a subscriber as follows (Hamodi *et al.*, 2013 and Kim *et al.*, 2013):

$$PLR = \left(\frac{lost_{packet}}{lost_{packet} - received_{packet}} \right) \tag{2.2}$$

The end-to-end delay is the time taken for a packet to be transmitted across a network from the IPTV headend to the STB. It is computed as follows (Manzato and da Fonseca, 2013):

$$D_{E-E} = N\left(d_{proc} + d_{queue} + d_{tran} + d_{prop}\right) \tag{2.3}$$

Where N is the network parameters between the IPTV headend and subscribers' customer premise zone, D_{proc} is the processing delay, D_{queue} is the queuing delay, D_{tran} is the transmission delay and D_{prop} is the propagation delay.

The network jitter in IPTV is defined as a variation in the end-to-end delay of receiving the video stream. At the IPTV headend, video streams are sent in a continuous stream with the packets spaced evenly apart. It is numerically determined as follows (Kim *et al*., 2015):

$$D_{jitter} = t_{actual} - t_{\text{expected}} \tag{2.4}$$

Where t_{actual} is the actual time it takes for the IPTV packet to be received by a subscriber and $t_{expected}$ is the expected time it takes for the IPTV packet to get to the subscriber.

The throughput (B_w) is the ratio of network capacity (N_c) that is, the network bandwidth over the cumulated load (W) of the average amount of IPTV traffic that passes through to the STB. It is determined numerically as follows (Manzato and da Fonseca, 2013):

$$B_w = \left(\frac{N_c}{W} \right) \tag{2.5}$$

Finally, a video decoding delay is the time it takes for a compressed video to be decoded, which is achieved by using I-frames. It is related to the encoding structure and the maximum video decoding delay is the length of a Group of picture (Tian *et al.,* 2013). IPTV contents are compressed by encoding multicast video stream over IP network where the video streams are divided into groups of pictures (Joo *et al.,* 2008).

2.5.2.1 Techniques to reduce IPTV Zapping Delay

In spite of the amount of literature addressing the zapping delay problem in recent years, there seems to be no effective solution in resolving this problem; a critical problem that has deterred the widespread deployment of IPTV. Over the years, various approaches have been developed for improving zapping delay in IPTV, a delay caused by command processing time, network delay, STB jitter buffer delay, multicast leave and join times, processing time in the display device, size of video buffer in the encoder and video decoding delay (Joo *et al.,* 2008; Siebert *et al.,* 2009).

Some literature proposed approaches that substitute a multicast-based IPTV service with a unicast-based IPTV service (Uilecan *et al*., 2007; Krogfoss *et al*., 2008). According to Škrbić *et al.,* (2010) multicast-based IPTV service has some shortfalls in that all network devices deployed within the network must support the Internet Group Management Protocol (IGMP) hence increasing the cost of implementation. They also add that troubleshooting multicast service is complex. Contrary to this Jackson *et al.,* (2014) explain that the substitution of multicast service with unicast service is not viable because as the number of subscribers increases, the required bandwidth to service the subscribers also increases, hence it becomes more expensive to maintain a standard quality of experience required by the subscriber. This can be likened to a mail delivery man that needs to deliver ten letters to different houses on a particular street, and instead of picking all the mail at a time he goes back to the post-office after each delivery to get the other mail for delivery. The cost and energy expended in such practice, heightened when compared to the delivery of all the mail at once.

Cho *et al.,* (2004) propose an approach that sends an adjacent channel alongside the channel requested by the subscriber. Their proposal was based on the fact that subscribers are likely to watch the adjacent channel of the desired channel requested. However, this approach did not solve the zapping delay problem because if the subscriber does not switch to the adjacent channel it forfeits the purpose. Hereafter Lee *et al.,* (2011) improved on this approach by adding channel popularity with adjacent-based prefetching. This approach is used in prefetching contents of the adjacent channels before they are requested; differentiating the channels prefetched among up and down direction buttons on the STB remote control based on channel popularity. However, the disadvantage of this approach is that the bandwidth load becomes high, causing overload and it ends up not reflecting the desired channel subscribers want to watch.

A new approach that predicts the desired channel subscribers might likely watch was proposed solving the downside of (Cho *et al.,* 2004 and Lee *et al.,* 2011). This approach provides Intelligent Fast Channel Switching (IFCS) based on subscribers' behaviour, predicting channel traffic in advance for the subscriber who desires to view a channel within a timeframe. It analyses subscribers' behaviours and obtains their preferences for viewing channel based on history, which consequently reduces the waiting time of subscribers as channels based on subscribers' interest are delivered before such channel is requested (Beyragh and Rahbar 2014). Furthermore, a new technique based on deploying the awareness of demand (Alasaad et al., 2015) was used in predicting the imminent demand of media content in a community network using a delicate hybrid media streaming system that involves the edge-server, peers, and helpers. However, it does not cogitate the problem of streaming live media content.

According to Lee *et al.,* (2014), their approach is based on the video level. It was stated that in order to address the zapping delay problem in IPTV, the 'hot' list of channels was identified. That is, those channels likely to be watched by an IPTV subscriber in the near future. Their method was to actively maintain a list of hot channels, and the second list of cold channels, those likely not to be watched. The segregation of these channels into the hot or cold lists is based on their recent popularity across all IPTV subscribers and the viewing history of the subscribers. They concluded their theory by suggesting that channels in the 'hot' list should be viewed in low resolution when subscribers make channel changes.

Furthermore, Ramos *et al.,* (2010) propose an approach called channel smurfing, based at the network level, which sends the neighbouring channels that is, channels adjacent to the requested one to the set-top box. According to their proposition, these neighbouring channels are sent concurrently to the requested channel as if they were merged. Hence, if the subscriber decides to switch to any of these neighbouring channels, the switching delay is almost zero, while subscriber experience is not affected.

Lee *et al.,* (2010) improved on Ramos's approach above by adding a predictive tuning method based on the user's channel selection behaviours compared to what was earlier proposed. They consider that IPTV subscribers tend to keep pushing the remote control button to change channels and the STB can match a channel number, called an 'expected channel,' with any pushed button. There is also a method of pre-joining channels that have been recently watched and are numerically adjacent to the current channel and they described subscriber's behaviour model in two forms. The first is the channel switching behaviour and the second the channel surfing behaviour, which they used in predicting which channel the subscriber, might request for.

Merani *et al.,* (2016) propose a subscriber behaviour, learning approach that learns and monitors subscribers' channel interests and behaviours of their recent TV request. Their method adopts the peer-to-peer approach, where clusters of subscribers with different TV channel request behaviours are used in generating a scheduling algorithm to serve frequent viewers. However, those that do not watch regularly are not catered for and Ghaderzadeh *et al.,* 2017 claim their approach causes network overload. Hence, they propose an approach that uses distributed intelligence substituting agents with bootstrapping peers in the channels to model user behaviours and to share the aggregated knowledge among the agents to disseminate the learned models

In addition to the aforementioned solution presented above, Oh *et al.,* (2010) propose a hybrid method for solving the problem of zapping delay in IPTV, an approach that combines channel prefetching and reordering methods. Specifically, adjacency and popularity based prefetching methods are combined with popular channel reordering methods. Ghahfarokhi *et al.,* (2017) propose a recent approach to solve zapping delay. They introduced a new channel zapping protocol that aims to remove the synchronization and buffering delays while maintaining the bandwidth utilization and the received video quality using the in-network caching feature of the Information-Centric Networking paradigm.

Table 2.1: Channel Switching Approaches

Authors	Delay component	IPTV architecture	Video Coding	First switching	Stream with min quality	Multiple view state	Next channel prediction
Chen *et al.*, 2012	Network	P2P	MPEG/H.264	Yes	No	No	Same watched genre
Ferro *et al*., 2015	Network	Managed	MPEG/H.264	Yes	No	No	—
Sarni *et al.*, 2009	Network	Managed	MPEG/H.264	Yes	No	No	—
Boyce and Tourapis, 2005	Synchronization	Managed +P2P	MPEG/H.264	Yes	Yes	No	—
Banodkar *et al*., 2008	Synchronization + buffering	Managed	MPEG/H.264	Yes	Yes	No	—
Mandal and Mburu, 2008	Synchronization + buffering	Managed	MPEG/H.264	Yes	Yes	No	Set-top-box statistics / user locality/most previewed
Nikoukar *et al*., 2016	Synchronization + buffering	Managed	MPEG/H.265	Yes	No	No	Adjacent
Cho *et al*., 2004	All	Managed	MPEG/H.264	Yes	No	No	Adjacent
Lee *et al*., 2007	All	Managed	MPEG/H.264	Yes	No	No	Adjacent/expected list
Kim *et al.*, 2008	All	Managed	MPEG/H.264	Yes	No	No	Surfing patterns/channel preferences
Ramos *et al*., 2010	All	Managed	MPEG/H.264	No	No	Yes	Adjacent
Ramos *et al*., 2011	All	Managed	MPEG/H.264	No	No	Yes	Adjacent/popular/user behaviour
Lee *et al*., 2008	All	Managed	SVC (H.264/AVC)	No	Yes	Yes	Adjacent/recently watched
Lee *et al*., 2010	All	Managed	SVC (H.264/AVC)	Yes	Yes	Yes	Surfing patterns / channel preferences
Manzato and da Fonseca, 2013	All	P2P	MDC	Yes	Yes	Yes	Adjacent/popular/old channel
Khosroshahi *et al*., 2016	All	WiMAX	MPEG/H.264	Yes	No	No	Popular/user behaviour

2.6 Internet Protocol Television Standardizations

According to the ITU-T, IPTV services provided over a managed network have a different technical specification. To this end, IPTV standardization is an ongoing process in the telecommunication world today in order to make IPTV services popular. In this section, we will highlight six major IPTV standards.

2.6.1 Digital Video Broadcasting over IP Networks

According to European Telecommunications Standards Institute - Technical Specification - ETSI TS, digital video broadcasting (DVB) provides a set of technical specifications that help transport MPEG-2 based DVB services and Service Discovery and Selection (SDS) mechanisms for DVB based audio/video over bi-directional IP-based networks (Kornfeld and May, 2007). DVB supports remote management, retransmission mechanism firmware update services, and regionalization meta-data for managed and unmanaged network services. Differentiated service (DiffServ) Quality of Service is implemented when using this standard.

2.6.2 ITU-T FG Internet Protocol Television

The International Telecommunications Union - Telecommunication Focus Group for IPTV was established in April 2006, and their mission was to coordinate and promote the development of a high-level requirement framework and global IPTV standards. Various standards and issues were evaluated which include:

a. Architecture and Requirements
b. QoS and Performance Aspects
c. Service Security and Content Protection
d. IPTV Network Control
e. End Systems and Interoperability Aspects

f. Toolbox for Content Coding
g. IPTV Middleware
h. Service Navigation System
i. Middleware, Application and Content Platforms

2.6.3 ETSI TISPAN

ETSI TISPAN (Telecommunications and Internet converged Services and Protocols for Advanced Networking) is the key standardization body for establishing Next Generation Networks (NGN) specifications. According to ETSI NGN release 1 on TISPAN in December 2005, this specification provides a robust and open standard requirement for development, testing, and implementation of first generation NGN systems in Industries (Rothenberg and Roos, 2008). NGN release 2 finalized in 2008, was the second-generation NGN system, adding key elements such as IP Multimedia System (IMS) and non-IMS-based IPTV, integrating live TV broadcast with other telecommunication services such as voice and data. This version answers the emerging market need for triple-play services (Rings *et al*., 2009)

2.6.4 ATIS IIF

The Alliance for Telecommunications Industry Solutions (ATIS) IPTV Interoperability Forum (IIF) established in July 2005 is recognized as a leading standard that develops interoperability, interconnection, and specification of IPTV systems and services, including live broadcast video content, video on demand, interactive TV (ITV) services and pay per view (PPV). The ATIS IIF developed standards related to IPTV functions and the following are the key activities and deliverables (Mikoczy *et al*., 2008; Takahashi *et al*., 2009):

a. IPTV Architecture Roadmap and Requirements
b. IPTV High-Level Architecture

c. IPTV Packet Loss Issue

d. Remote Management of Devices

e. Media Formats and Protocols for IPTV Services

f. Emergency Alert Service Provisioning Specification for IPT

g. IPTV Content on Demand Service

ATIS offers a unique and pragmatic industry standard development, for content delivery with the quality of experience; digital rights management (DRM) interoperability requirements, packet reliability, and robustness of system service components (Mikoczy *et al.*, 2008). According to Wey *et al*., (2009), the ATIS IIF specification applies only to the managed network devices at the customer premises. ATIS IIF adopted the technical report protocol (TR-069), a method for provisioning and configuring both IPTV terminal function (ITF) and delivery network gateway (DNG) devices, providing also additional security mechanisms to guarantee authentication of the content program before executing it by employing a layered principle at the customer premises to monitor information at the STB, IP transport, and the service layers.

2.6.5 3GPP MBMS

Traditionally, mobile networks support unicast stream for service delivery, which unfortunately does not effectively utilize the network resources considering that many mobile subscribers at times are interested in the same content. In order to resolve this problem of underutilization of services in the mobile network, service extensions supporting multicast and broadcast were proposed for mobile networks. Third Generation Partnership Project (3GPP) specifies the integration of multimedia multicast and broadcast services, called Multimedia Broadcast Multicast Service (MBMS) specifications, which are a point-tomultipoint service where the same data traffic is transmitted from a single source to multiple recipients which allow network resources to be shared, enabling efficient group related one-to-many data distribution services of mobile networks (Zhu *et al.*, 2010; Hartung *et al.*, 2007).

3GPP makes use of MBMS to efficiently deliver services over a 3G network in two modes, which are broadcast, and a multicast mode. MBMS is at this point limited to, mobile TV channel bandwidth, which supports TV services (live TV broadcast, video on demand, and over the top (OTT) content). Hefeeda and Hsu, (2010) further state that the dedicated IP broadcast service in 3GPP is only employed in mobile networks to enable user interaction with some TV programs, but not to transmit video content.

2.7 Video Coding

Videos are made up of a sequence of pictures over a period of time denoted as frames, but without video coding, it seems impossible to efficiently transverse the video data rate in its original format over the IP network. For instance, the uncompressed data rate for HDTV and SDTV is 2.78Gbit/s and 270Mbit/s respectively, which are too high for transportation over the IP network infrastructure, hence, video coding is non-negotiable in order to reduce video data rate.

The video-coding mode uses three different types of frames, which compose the group of picture (GOP) layer: Intra-code (I), Predictive (P) and Bidirectional-Predictive (B). The intra coded frames (I) are coded without reference to the previous frames, using only transform coding by providing a point of access to the compressed video data, while the predictive-coded frames (P) are produced by making reference to the previous I-frame or P-frame because P-frames use information already transmitted in previous I or P frames. Bidirectionally coded frames (B) provide the highest degree of compression (the smallest average size) using as a reference the previous and next I or P frame because B frames are coded in part based on future frames (Doulamis *et al*., 1997; Frey and Nguyen-Quang, 2000).

The three types of video coding mode are organized as a group as shown in Figure 2.5, for example, with an MPEG codec, the generic GOP is I B1 B2 P1 B3 B4 P2 B5 B6 P3 B7 B8 I… with the first frame in each GOP an I-frame, an intra-coded frame without reference to any other frames by the distance N between I-frames and the distance M between P-frames with (N, M) = (12, 3) followed by B frames that are being intra-coded and inter-coded, and they use both the previous and following P or I-frames as references (Cai *et al*., 2009). The additional redundancy the I-frame carries is only needed when the subscriber has no information about the prior frame; that is, the client is starting the decoding process of the selected channel which only occurs when the subscriber is changing the channel (Jennehag and Zhang, 2004).

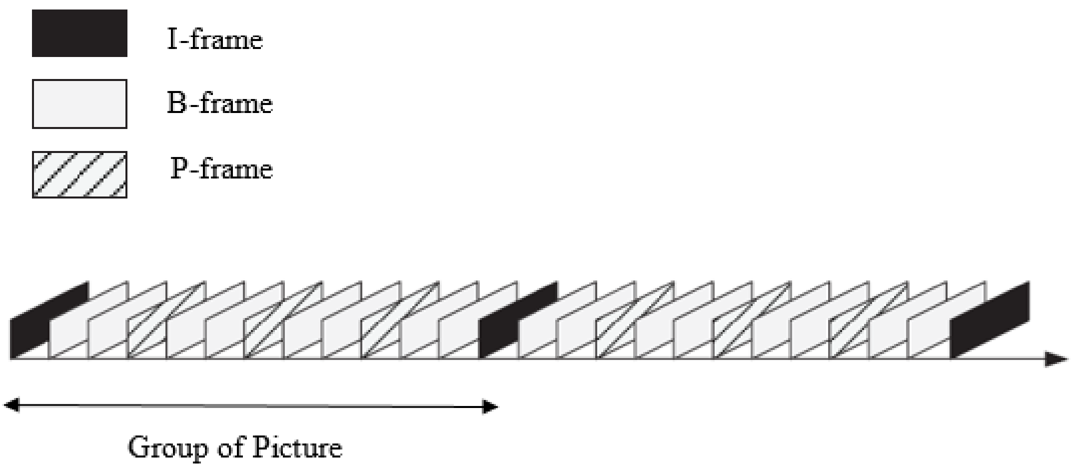


Figure 2.5: Video Coding Frame Structure

The video coding frame structure in Figure 2.5 depicts the three types of frames. The B and P-frames in between keyframes are called the GOP while the distance between the keyframes is known as the GOP size. A point to note is that all B and P-frames cannot be decoded independently without referencing an already decoded I frame, which means an I-frame can be decoded independently, which makes it the keyframe. The B and P-frame according to Bhaumik *et al.,* (2015) help provide video compression hence lowering the bit rate for video data rate across the IP network infrastructure.

2.7.1 IPTV Coding

Video codecs enable compression or decompression of digital video. The main advantage of video codecs is that it helps to reduce frame content hence reducing required bandwidth. The digital codification of a high-resolution TV program can generate a 20 Mb/s stream while standard resolution generates about 6Mb/s. This can be reduced significantly using video codecs that help with video compressing. Vanhastel and Hernandez (2008) state that IPTV requires about 3 Mb/s sustained bandwidth per standard definition stream, with high definition increasing the demand to 8 Mb/s per stream. According to Ahmad *et al.,* (2009), a widely accepted IPTV standard is not available yet, but the current popular coding methods for IPTV include H.264 advanced video coding (AVC), H.264 medium grained scalability coding (MGS), and H.264 scalable video coding (SVC) (Guo *et al.*, 2011)

2.7.1.1 H.264 Advanced Video Coding (AVC)

The digitization, encoding, and compression of video images have been extensively studied and standardized over the past years. The H.264 video coding standard represents the state of the art in video compression. The standard was developed recently through the joint work of the International Organization for Standardization's MPEG group (ISO/IEC/SG29/WG11) and the International Telecommunication Union's video coding expert group (VCEG, ITU-T/SG16/Q.6) (Marpe *et al.,* 2006). This collaboration resolved on defining what is today known as the H.264 Advanced Video Coding (AVC) standard (Ahmad and Begen, 2009)

The H.264 is a general-purpose codec intended for applications ranging from low-bitrate mobile video applications for high-definition TV. The broad range of applications as well as a significant improvement in compression efficiency has resulted in a strong interest from the industry with significant improvements in the coding algorithm. These advances have made it possible to develop H.264 as a computationally complex, but highly efficient, video coding standard (Kalva, 2006). The compression efficiency of the H.264 makes the video coding standard, most suitable for video services over IP infrastructure.

The low bitrate attributes of H.264 also enables video download services where the video is distributed to video subscribers using simple byte serving, instead of expensive video servers, and the video can be played back later over standard equipment. Kerpez *et al.,* (2006) further explain that video content in IPTV requires roughly 2 Mb/s for each standard definition TV (SDTV) channel and 8 Mb/s for each HDTV channel using advanced video compression.

2.7.1.2 Scalable Video Coding

The scalable video coding (SVC) technology lets the system, consider the network's available bandwidth and how it is being terminal. Despite SVC having the capability to enable scalable representation of video content with high coding efficiency, it is difficult to perform real-time encoding because of the SVC encoder's complexity (Park and Jeong, 2008). According to Mrak *et al.*, (2008) scalable video coding targets coherent delivery of digital content, enabling maximal user-centred, multichannel and cross-platform media services for global video delivery to a wide range of applications.

The recent convergence of multimedia services gave rise to the need for improvement in modalities in the delivery of digital content. SVC is attractive due to the ability to encode a high-resolution video signal and enables decoding of partial bitstream based on the resolution specified by a certain application (Ohm, 2005). SVC standard extension of H.264 MPEG4-AVC offers an outstanding bit rate and format adaptation (Wiegand *et al*., 2009). This extension provides support for multiple display resolutions within a single compressed bitstream, which is referred to here as spatial scalability (Segall *et al.*, 2007).

2.8 Converged Network

Innovations in Information Communication Technology (ICT) have transformed almost every domain of the ICT industry and society and have steered in an innovative era of convergence; this apparent inclination regarding convergence is as a result of the diversification of digital technology and the development and implementation of digital infrastructure (Kim *et al.*, 2010). In order to achieve network internetworking and service ubiquity, IP arises as a key element for the realization of a unified environment, which enables convergence between traditional and emerging technologies (Gardikis *et al.*, 2010). The conception of converged network came into existence as the emergence of new Internet technology increased.

VoIP a major contributor in the triple-play services offered over a converged network is seen as the future of communication, which allows the traversing of voice packets over the IP network infrastructure. Because of this feature it entails, such as cost saving ability a more cost-effective platform when compared with the traditional PSTN. A converged network demands a broad range of requirements of the fundamental network depending on the services. IPTV places a stringent requirement on packet loss, packet end-to-end delay, jitter, and throughput (Hamodi and Thool, 2013). This requirement shown in Figure 2.6 drives the need for a robust, scalable and easy to use network management platform, which enables the service provider to monitor and manage their networks to provide the necessary quality, availability, and security for IPTV service within a converged network.

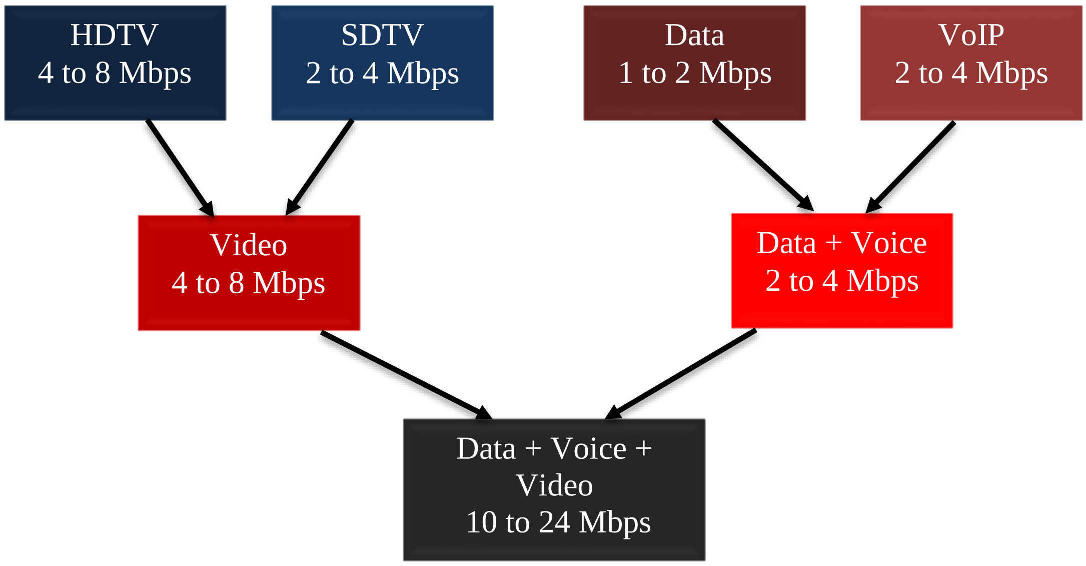


Figure 2.6: Bandwidth Requirements for Services over a Converged Network

In Figure 2.6, the video format quality in IPTV SDTV requires up to 4Mbps while HDTV requires up to 8Mbps (Zaki *et al.*, 2016; Vanhastel and Hernandez, 2008). Furthermore, the data applications such as Internet access and Web browsing can operate over a range of data rates up to 2Mbps while VoIP requires up to 4Mbps. Hence, for a converged network using the ADSL infrastructure, the bandwidth requirement needed is between 10 to 24Mbps (Tzannes, 2016).

2.9 Quality of Service

The Internet is designed to be the best effort network, giving no guarantees in satisfactory levels to subscribers. Regardless, Quality of Service (QoS) is a critical factor in a subscriber satisfaction and is an additional mechanism used for real-time services such as voice and video packet to guarantee subscriber satisfaction. Kim *et al.*, (2010) describe the quality of service (QoS) as the parameter of the performance of a network service, which provides the type of usage, attributes, and level of requirement per user request. QoS allows the network providers to measure bandwidth, detect network fluctuations (such as network and packet delay, jitter, packet loss ratio and availability of bandwidth) and prioritize or throttle traffic in a manner to enhance the level of subscriber experience of the service provided (Peart and Good, 2012; Liem *et al.,* 2016).

The quality of service is a technology that provides different classes of traffic with different levels of quality in order to reduce the cost of operation, manage expensive WAN bandwidth, or deploy applications such as IPTV to the subscribers to enhance QoE. The QoS on a converged network is vital, as its goal is to provide better and more predictable network service by providing dedicated bandwidth, controlled jitter, latency, and improved loss of packets. Video frames are bound to get lost within a network if the quality of service is not implemented, hence, Vedantham *et al.,* (2006) recommend that service providers should guarantee bandwidth for IPTV video packets and QoS differentiation of the supported classes of traffic.

The IPTV application is a real-time application that involves constant communication between subscribers and the IPTV headend; therefore delay must be reduced to the bare minimum of about 430 milliseconds in order to achieve an acceptable quality of experience level perceived by the subscribers. Due to many services such as data and voice alongside with video packets running over the converged network and each service demanding a level of high bandwidth it is imperative that a good QoS technique is imbibed to guarantee a high service level for traffic generated by these multimedia services that run over the converged network.

For there to be a high quality of IPTV services in a converged network, the super headend and subscribers must be able to send and receive quality video service effortlessly. Therefore, the supporting key QoS factors in reducing the zapping delay problem in IPTV issues such as loss of packets, video encoding and decoding time, network delay, and jitter must be addressed through careful system design such as overprovisioning, careful traffic control in the network (such as traffic engineering and service differentiation), and optimized buffering and error-correction at the network level to ensure high QoE by subscribers. The following are the service level agreement (SLA) requirements that QoS must take care of in improving zapping delay in IPTV.

a. Packet Loss – Loss of packets is the inability of one or many streams of data travelling across the network to reach their destination (Radmand and Talevski 2010). A packet drop that occurs before getting to its destination within a specific period is also considered as packet loss where the demand for a resource (such as bandwidth or buffer) may exceed the available capacity (Sanneck *et al.,* 2000). The effect of any degrading multi-media coding scheme introduced in IPTV for more efficient transmission within the network also leads to loss of packets. Furthermore, Greengrass *et al.,* (2009) explain that there are three primary causes of packet loss:

    1. Congestion- Packet losses are triggered by congestion on an interface within the network. Congestion can be explained to be a user-visible degradation of network performance caused by the full capacity of the buffer, leading to queue buildups. The more the congestion period persists; loss of packet becomes significant, reducing user's quality of experience (Fowler and Leland, 1991).

    2. Lower-layer error - high dependence on the lower layer of the Open Systems Interconnection (OSI) model to carry the packets, especially at the physical layer where bit errors may occur due to transmission medium has been prone to noise, interference, and attenuation, which can lead to loss of packets. Although fibre optic links might support bit-error rates as low as 1 error bit in 10^{13} transmitted bits ($1e^{-13}$), asynchronous digital subscriber line

(ADSL) services might have bit-error rates as high as $1e^{-3}$ (Greengrass *et al.,* 2009).

3. Network element failures - Although the Internet offers best effort quality of service, there still exists a level of resiliency in the services provided - that is the ability for the network to stay operational. Nevertheless, network element failure, such as link and network devices (router, switch, servers, etc.) failure can lead to the unavailability of service that results in loss of packet pending the network recovering the connections affected by the failed network element.

b. Network delay – this represents the time difference for an IP packet at the source node to reach its destination node (Ghiata *et al.*, 2011), that is how long it takes a packet to traverse the network from the source to its destination. Cho *et al.,* (2004) further explain network delay in IPTV as the time interval between the transmission of the join message and the reception of the first multicast packet of the requested channel to the STB. The network delay also aids IP packets to arrive out of order leading to a low-quality level of service being delivered to subscribers.

c. Jitter - The variation or increase in the delay between consecutive packets over a transmission medium in a single flow. The network jitter plays an important role in determining the size of queues required within the packet-switched IP routers, and the size of the playback queues at the destination. It also has a severe impact on subscribers' perceived quality of experience due to the degradation of service provided (Szymanski and Gilbert, 2009). Although, multimedia services are highly intolerant of network jitter, some measures are used to significantly reduce and minimize network jitter by reducing the number of packets or cells queued within the IP routers and the playback queues and variation by the means of buffering, effectively eliminating delay variation as perceived at the user level (Kim and Cho, 2010).

$$J(d) = \sum_{i=1}^{N} (d_i^{AF} - d_{avg})^2 / N \quad (2.6)$$

Jitter J(d) is calculated in equation 2.6, where d_i^{AF} is the delay time of the IPTV live-streaming packet i, and d_{avg} is the average delay time of IPTV traffic flow, and N is the total number of received IPTV packets (Liem *et al*., 2016).

d. Bandwidth - Bandwidth can be defined as the number of bits a network link can transport within a given time interval. The effective bandwidth of an IPTV flow is the minimum amount of bandwidth required to satisfy its QoS, which depends on the characteristics of the source traffic in conjunction with the QoS constraints (Chang and Thomas, 1995). The available bandwidth of a network path P is the maximum throughput that the path can provide to a packet, without reducing the throughput rate of the traffic flow that is without congestion (Jain and Dovrolis, 2002). The term u_i is the utilization of link i during a time interval T, with $0 \leq u_i \leq 1$. Therefore, the available bandwidth Ai of link i in time T can be defined as the portion of the full link's capacity that has not been utilized during that interval and its defined in equation 2.7:

$$A_i = C_i\,(1 - u_i) \quad (2.7)$$

Best-effort service is a model where data are being sent without informing the destination. This type of service makes video traffic deteriorate within a network, particularly when there is congestion. Due to the best-effort service offered by the Internet and high multimedia services such as voice and video on the converged network, the network communication medium encounters several challenges due to several QoS requirements imposed on these multimedia services. There is another quality of service model aside from best effort that is used to support QoS over the Internet. The most established ones that were defined by international organizations include - Integrated service (Intserv) (Harju and Kivimaki, 2000), and Resource Reservation Protocol (RSVP) (Black, U., 2000) and Differentiated Service (Diffserv) (Fgee *et al*., 2005).

Integrated Service (Intserv) – is a multiple service model that provides means for providing end-to-end quality of service within the network. According to Harju and Kivimaki (2000), IntServ is a kind of service where application requests from the network are made before data has been forwarded, and a signalling protocol is required to tell the routers which flow of packets requires special QoS treatment. This request includes bandwidth, delay requirement, etc., and Resource Reservation Protocol (RSVP) is used in carrying out this signalling process. Admission control of quality of service is carried out based on the information gathered and available network resources. Therefore, Black, (2000) concludes that this model guarantees each flow quality of service requirement through the network path, from the sender to the receiver.

The intrinsic problem with the Intserv model is scalability. Hence, in order to overcome this problem, differentiated services (DiffServ) were proposed. According to Fgee *et al.,* (2005), Diffserv is more scalable, manageable and easy deployable for service differentiation in IP networks. In Diffserv model, the complexity is pushed out to the edge routers and the core routers are maintained as simple as possible. This model is set up to serve multiple class of service and it is accomplished by mapping, multiple flows into the class appropriate quality of service are being applied to each class relative to the traffic flow. Therefore, Diffserv will be used in the course of this project, because it supports high-speed transit network and its usage in large networks, which has proven effective over Intserv.

2.10 Quality of Experience

IPTV subscribers want channel changes to be instant without any form of delay. The quality of experience is the most important factor in satisfying IPTV subscribers in order to aid their loyalty and acceptance of the service. The quality of experience, according to the International Telecommunication Union Focus Group on IPTV (2006) was defined as the overall acceptability and the degree of satisfaction of an application or service as perceived subjectively by the subscribers. The ability to measure the quality of experience in multimedia services provided by IPTV application is important to service providers and network operators in ensuring that content is prepared, transmitted, and received according to an appropriate standard of quality (Takahashi *et al.,* 2008).

For IPTV services, it is necessary to assure a high-quality level of experience using QoS to identify and resolve problems before they have a negative impact on the subscribers' experience at the access level. In order to support subscribers perceived level of QoE, it is imperative for IPTV service providers deliver a resource-aware IPTV service. The subscriber will not condone service interruptions, image degradations or long zapping delay time because of network throttling (Park and Jeong, 2008; Lloret *et al.,* 2011).

The high-quality level of multimedia services is an indicator of how satisfying the multimedia quality meets the subscriber's perception and it is quantified in terms of Mean Opinion Scores (MOS). The International Telecommunication Union defines the MOS as the "value on a predefined scale that a subject assigns to his opinion of the performance of a system". For service providers being able to deliver the high-quality level of video acceptable to subscribers, service providers need to accurately measure the quality of the videos delivered over their networks. Without accurate QoE measurement, it becomes difficult to predict subscribers' satisfaction, which prevents service providers from being aware of any video lags and viewing problems until been reported by the subscribers (Spachos *et al*., 2017).

The end-to-end QoS must be continuously monitored to trigger adaptations when it drops below acceptable values. This is very important to service providers because it allows them to keep their customers happy, make them loyal and attracting new ones. MOS is now the “de-facto” metric, which gives a synopsis of the state of the art objective used to quantify perceived media quality (Streijl *et al*., 2016). The 5-point range MOS scale (excellent, good, fair, poor, and bad) as defined by the ITU recommendation BT 500 is extremely popular and it is shown in table 2.2.

Table 2.2. MOS Scale, Quality and Impairment

Scale	Quality	Impairment
5	Excellent	Imperceptible
4	Good	Perceptible
3	Fair	Slightly
2	Poor	Annoying
1	Bad	Worst possible

For quality criteria that can be measured, we have used QoS as a technical concept in order to understand the correspondence between QoS and QoE in dividing QoE into two major parts from the viewpoint of network provider (QoE_N) and the subscribers (QOE_S) making use of the service. The QoE_N focuses on network related effects such as network delay (N_d) and network jitter N_j when these two effects are high that is, N_d and N_j the QoE_N value will be low leading to packet loss (pl) which invariably affects the overall QoE perceived by the subscribers.

$$QoE = QoE_N + QoE_S \qquad (2.8)$$

According to Mansouri *et al.,* (2016) QoE_S with regard to subscribers is full of sensations, perceptions, and opinions of how the subscribers interact with the system. This may lead to positive, pleasant and entertaining feelings or a negative displeasing and frustrating feeling. That leads to a subjective measure from the subscriber's perspective of the overall value of the service provided ranging from the video quality to the audio quality. This characteristic eschewed by the subscribers made it a compulsion on service providers to lay more emphasis on the quality level of experience being provided. Streijl *et al.,* (2016) in this study examines the parameters involved in how to measure QoE_S. This concept shows that the video quality (VQ), synchronization time and zapping delay time play a major role in the satisfaction level of subscribers.

From this vantage point Alben (1996), explains that in order to meet subscribers' satisfactory level of experience, we must take credence to how subscribers feel, how the service provided gives an aesthetical and sensual experience, whether it satisfies their desired needs, and if it is user-friendly. Meeting all these criteria can lead to unforeseen opportunities that will aid the level of acceptability of IPTV application and its services. Therefore, in order to measure the quality of the video, comparison of the video broadcasted from the video network header with the video received by the subscriber is related to the VQ. The MOS scale range of 1 to 5 that is, bad to excellent, will be used to certify the video quality, for instance, if the MOS is 2 it shows from table 1 that the video quality is poor.

$$QoE = \frac{k_1}{(N_d + k_3 * N_j) * e^{pl}} + \frac{k_2 * \log_{10}(VQ)}{Z_t + k_4 * sync} \tag{2.9}$$

In equation 2.9, k_1 and k_2 units are milliseconds. Regulating the QoE_N and QoE_S weight in the formula and k_3 gives higher importance to the network jitter parameter in comparison to the network delay, k_1, k_2 and k_3 $\geq 0 \leq 1$. k_4 is a constant that gives more or less importance to the sync vs the zapping delay time (Z_t). Based on the original video quality, which is considered distortion free and can be used as a reference in evaluating the distorted level of video quality, quality of experience is further measured using three main models and they are Full-Reference (FR), Reduced-Reference (RR) and No-Reference (NR) model.

a. Full-Reference (FR) – this model requires the processed signal and the complete reference signal comparing it with the received stream in order to calculate the corresponding QoE value and thus provide the most accurate predictions (Bhat *et al*., 2012; Chen *et al.*, 2015). Typical metrics of a full-reference model are PSNR (peak signal to noise ratio), SSIM (structural similarity) and VQM (video quality monitor). These full-reference metrics are efficient for forecasting subjective satisfactoriness of video signals to some level. Hence, their prediction performance can be considerably improved by considering the effects of video resolution, frame rate, display characteristics, and content features (De Vriendt *et al.*, 2013; Song and Tjondronegoro, 2014).
b. Reduced-Reference (RR) – this model requires the processed signal and only part of the reference signal to calculate the QoE. The RR model extracts specific video information from the reference image and could achieve medium accuracy that is believed to be the most practical since original sequences of FR methods are usually inaccessible and the performance of NR methods is limited to specific application scenes (Li *et al.*, 2015). This extracted information is subsequently used with the distorted image to estimate the quality. The RR model is beneficial in a vast number of applications, particularly in real-time visual broadcasting systems, where they can be utilized in tracking image quality degradations and control the streaming resources (Wang and Simoncelli, 2005).

c. No-Reference (NR) – this model requires only the processed signal in determining the QoE value because no access is provided to the original video stream, making it easier to implement, as the original video sequence is not accessible to the end-user devices where the quality is measured (Van Wallendael *et al*., 2012). Unfortunately, this model is only useful if knowledge about the types of distortion used between the reference and distorted images are fixed or known (e.g. Gaussian blur). This model becomes useless when there is no information about the distortions as the knowledge about this distortion information is not easy to obtain in the case where network impairments sets in, such as packet loss, encoding and decoding time (Mocanu *et al*., 2015).

2.11 Chapter Summary

This chapter presents a comprehensive background, which lays out on how IPTV works while relevant publications were presented and reviewed based on the channel switching delay that is, zapping delay. Furthermore, the converged network component was highlighted while emphasis was made on how QOS and QOE are key in IPTV service delivery. As highlighted earlier, it can be seen that despite different methods and approaches that have been proposed over the years to tackle the zapping delay problem. The problem still exists and it is a challenging factor that deters widespread acceptance of IPTV. This gap serves as a motivation to develop a framework to resolve the zapping delay. The next chapter explained the zapping delay framework proposed in achieving the set aim and objectives of this study.

CHAPTER THREE

RESEARCH METHODOLOGY

3. Introduction

This chapter introduces the methodological steps of the proposed framework as shown in Figure 3.1 in order to accomplish the aforementioned aim and objectives. The proposed zapping delay framework used a modular approach, taking advantages proposed at the subscriber level and network level and consequently, unifying the modular approaches. The modular approach was adopted because each module of the framework is dedicated to a specific function. Furthermore, it gives the ability to add or remove features without complexities which help aid scalability of the service (Gardikis *et al*., 2012; Rodrigues *et al*., 2011a; Rodrigues *et al*., 2011b). The proposed framework was segmented into four major modules. Firstly an approach at the network level.

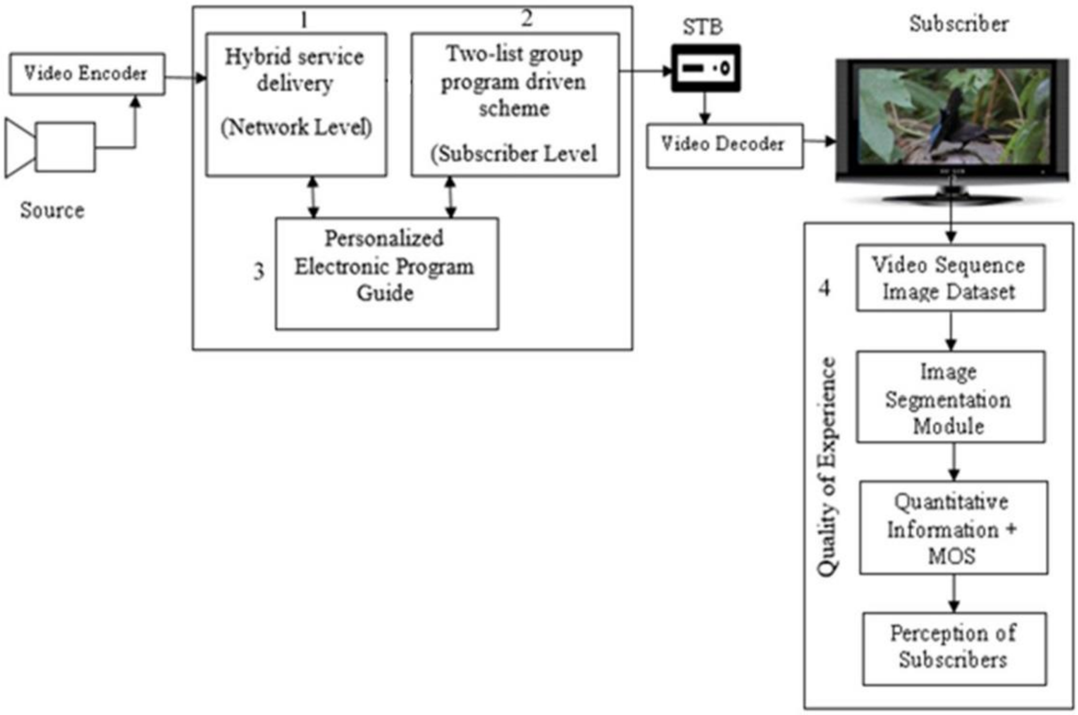


Figure 3.1: Proposed Zapping Delay Framework

Secondly an approach at the subscriber level, thirdly an approach that combines the subscriber and network levels. Finally, an approach that takes the perception of subscribers on video quality in aiding satisfactory level of subscribers' quality of experience.

In Figure 3.1, the proposed zapping delay framework unifies the advantages at both network level and subscriber level. From the IPTV source, raw uncompressed video live streaming is forwarded to the video encoder to encode the raw video to a format compatible with the IP infrastructure. The adaptive hybrid service delivery used at the network level agglutinates multicast service and unicast service delivery to combat zapping delay. It is considered a better option for IPTV service delivery as opposed to the traditional multicast and unicast service delivery because of the shortfalls that exist (Škrbić *et al.,* 2010; Chase, 2016). The two-list group program driven at the subscriber level categorizes TV channels manually based on genre and prefetch them into the hot channel list or cold channel list in order to aid fast channel switching. To enhance fast channel switching a personalized electronic program guide (EPG) and really simple syndication (RSS) feed was used combining potentials at the network level and subscriber level.

The encoded video is thereafter forwarded to the set-top-box where the IPTV subscriber through a video decoder decodes it to a format viewable. The perception of subscribers on video quality is determined through quantitative information extracted from a salient object in a video sequence image while mean opinion score (MOS) is used to analyse the subscriber's perception on video quality which will aid satisfactory video quality of experience, hence, aid IPTV channel popularity.

3.1 Adaptive Hybrid Service Delivery

The first modular approach was at the network level, presenting an adaptive hybrid service delivery method, that combines advantages of multicast and unicast service delivery to reduce zapping delay as shown in Figure 3.2; where IPTV content is delivered to subscribers from a multicast core network at the network provider's zone; when zapping delay sets in a delay greater than 0.43s a unicast service delivery will be used to deliver IPTV content from the multicast core network to subscribers taking the advantage of higher rate streaming unicast stream provides (Banodkar *et al.*, 2008). In addition to the unicast service delivery a differentiated service (DiffServ) quality of service is also implemented which helps provide quality guarantee by addressing the requirements of delay, jitter and real-time sensitive traffic during short-term periods of congestion with over-provisioning of bandwidth to minimize the long-term average level of congestion within the converged network for all the subscribers requesting IPTV channel (Maraj and Shehu, 2012; de la Fuente *et al*., 2014).

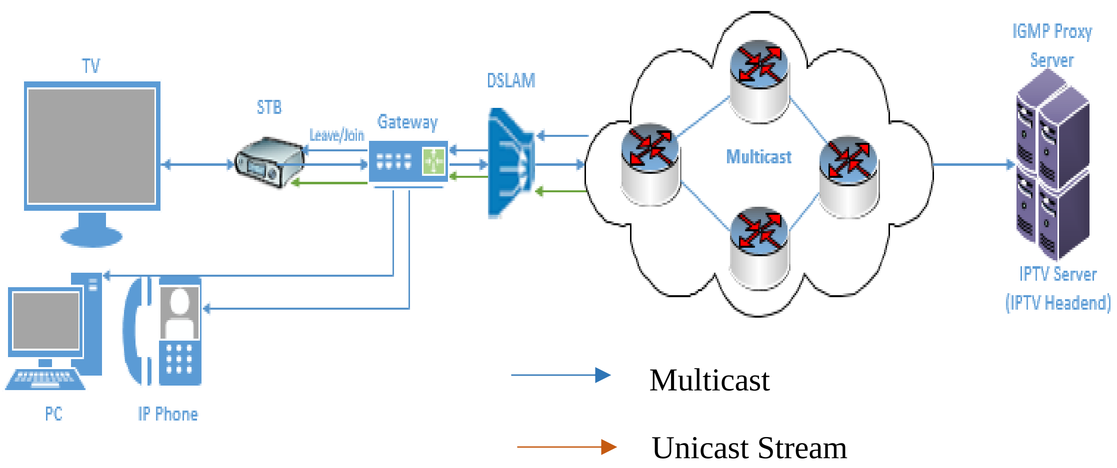


Figure 3.2: Adaptive Hybrid Service Delivery over a Converged Network

In Figure 3.2, it depicts the combination of multicast and unicast service where the red arrow line shows the unicast burst stream when zapping delay sets in coupled with DiffServ quality of service to guarantee bit rate transmitted. When the zapping delay subsides the stream switches back to the multicast service. The switch between the multicast and unicast service delivery is represented in Figure 4.1, whereby, when zapping delay sets in, a delay greater than 0.43 (Sue et al., 2016) a unicast stream coupled with the DiffServ QoS will be used in delivering IPTV service to subscribers from a multicast IP core at the service provider level and once the zapping delay is normalized the multicast stream will be used for service delivery to the IPTV subscriber.

This research work used a simulation software OPNET (Optimized Network Engineering Tool) in simulating the adaptive hybrid service delivery over a converged network as shown in Figure 4.2 using seven major components which include: IP backbone, link model, server model, servers, computers, routers, and switches. Link bandwidth was configured and traffic type of service (video, voice, and data) was also configured. This research furthered the work of building an IPTV set-top-box using the raspberry pi3 in comparing the video playback end-to-end delay and buffering delay for the adaptive hybrid service delivery with other internet TV applications approaches such as YouTube, Stream2Watch etc.

3.2 Two-list Group Program Driven Method

The second modular approach was at the subscriber level, presenting an effective two-list group program driven (TGPD) method to reduce zapping delay in IPTV by minimizing channel seek distance and channel seek time of the IPTV channels during channel navigation. This method considered the challenge subscriber face during channel navigation in selecting the desired TV channel that leads to zapping delay due to hundreds to thousands of TV channels available to IPTV subscribers (Hei et al., 2008; Liu et al., 2014).

The TGPD method manually groups similar genre of channels into similar categories, elating the burden on subscribers from surfing through channels that do not interest them. This method eliminates channel prediction which is not promising and does not solve the subscriber's channel navigation challenge which gets heightened with the increase of network bandwidth demand. (Pavlić and Bratković, 2015). Channels using the TGPD method are managed using the hot channel list, set of channels that are popular based on the rate at which such channel is viewed over a period of time and the cold channel list, set of channels that lack popularity that is channels not frequently watched by subscribers.

The TGPD method enables the subscriber to choose channels into the hot list at the setup of the set-top-box based on preference as shown in Figure 3.3, while other channels remain on the cold list. However, a flowchart was represented in chapter four that helps maintain the hot channel and cold channel list. The proposed TGPD method was benchmarked with state-of-the-art approaches such as numerical ordering, frequency circular ordering and frequency interleaved ordering. Based on the experiment carried out at chapter four using synthetically generated traces, the research work concluded that the proposed TGPD method outclassed other state-of-the-art approaches reducing the total seek distance and the total seek time during channel navigation hence, aiding the reduction of zapping delay

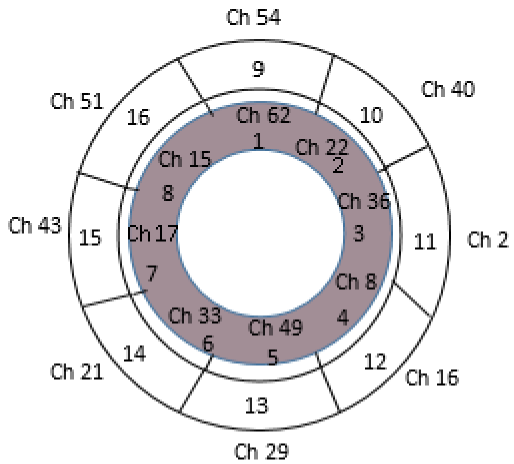


Figure 3.3 Channels selected into a hot channel list using the two-list group program driven method

In Figure 3.3 the inner highlighted circle depicts the popular channels that are, the hot channels that the subscriber is interested in based on preference. These channels are selected from the genre categories of channels, while the outside circle depicts the cold channel list, invariably the unpopular channels

3.3 Fast Channel Switching Using Personalized Electronic Program Guide

The third modular approach unifies advantages at the network level and subscriber level in order to reduce zapping delay taking into consideration the time taken for channel switching. At this section a personalized electronic program guide (EPG) and really simple syndication (RSS) feed was used to aid channel selection into the hot channel list using the TGPD method and fast channel navigation to further aid subscribers dependency, eliminating channel prediction based on behaviour analysis which based on literature infringe on subscribers privacy (Touceda et al., 2015; Khayati et al., 2016).

The personalized EPG uses the Explicit Semantic Analysis Bag-of-Words (ESA-BOW) model to enrich program descriptions with new information of programs aired by TV channels. The ESA-BOW enhances subscriber selection of channel into the hot channel list using the TGPD method consequently, ESA-BOW gives an electronic description of programs aired by channels through a large corpus such as Wikipedia, a corpus adopted due to the timely update of information and vast open source of knowledge available across different spectrum and disciplines.

The ESA-BOW represent textual data with text categorization, semantic relatedness, and information retrieval an advantage that helps streamline the description of a keyword from varieties of related keywords that may be available. The ESA-BOW retrieval process consists of four major steps and they include:

i. Semantic interpreter - is a relationship between term (t_i) and concept (c_i) matrix, where each column corresponds to a concept and each row denotes a term that occurs in a large corpus repository. Each element of a row in the matrix corresponds to the value of term frequency-inverse document frequency (TF-IDF). The term is matched with the concept and the highest TF-IDF will be displayed. Figure 5.4 depicts how TF-IDF is used to interpret and select the appropriate result for a description

ii. Program indexing – ESA-BOW adopted an indexing method for titles and descriptions of TV programs aired by IPTV channels. The original program descriptions is extended with keywords belonging to the semantic interpretation concept vector of the most representative corpus repository they are associated with; once the concept vector for all the programs are generated by a mapping that links each concept to its original document is created (Narducci et al., 2017; Liu et al., 2017).

iii. Program query - is used to find the items that contain a much possible description of the TV program by multiplying the subscriber's query through keywords with the semantic interpreter.

iv. TV program retrieval- the relevant program is fetched from the program indexing using the selected program query concepts; the computing semantic relatedness between the query (the short term subscriber needs using keywords) and the program is reduced to calculating the cosine similarity between their concept vectors. Consequently, the TV programs with the highest similarity score are returned as the result

In addition to the ESA-BOW, a really simple syndication (RSS) feed a web 2.0 based service is used to notify subscribers of news update and subsequent changes to the hardware firmware and operating system. However, the RSS feed is optional and can be activated at subscribers will consequently the RSS feed does not interfere with the channel program a subscriber is watching and the feed can only be viewed during channel change or when the set-top-box is switched on.

3.4 Subscribers Perception of Video Sequence Images

The fourth modular approach in the zapping delay framework was implemented to enhance the high satisfactory level of quality of experience through the analysis of subscribers' perception on video quality viewed. Predicting subscribers' eyes fixation on video sequence images in order to identify a region containing the salient object that is, the region that will interest the subscriber from the original video sequence image varies due to the complex nature of human vision system in detecting the salient object. However, the salient object that will interest the subscriber was extracted from an original video sequence image through the use of image segmentation algorithm in separating the foreground image from the background image; highlighting the salient object that will interest the subscribers in a multi background video sequence images.

This research work used two video sequence image datasets: SegTrackv2 and VidSal dataset available on the public domain to perform the analysis of subscribers' perception in determining subscribers' satisfactory level on video quality. A saliency-based skin lesion segmentation (SSLS) algorithm was used as a tool for detecting the salient object taking the advantage of the multi-background segmentation potential of the algorithm. Consequently, the SSLS algorithm was compared with seven other state-of-the-art salient object detection segmentation algorithms.

After the salient object has been extracted, eight popular metrics (specificity, sensitivity, error rate, accuracy, dice, AUC, Jaccard and Hammoude distance was used to extract the quantitative information by comparing the SSLS algorithm video sequence segmented image with the ground truth. Furthermore, the mean of score scale as defined by the ITU recommendation BT 500 using a five opinion (excellent, good, fair, poor, and bad) was used to analyse perception of subscribers based on the extracted quantitative information which can determine if a subscriber will continue watching a TV channel or not and whether a channel will be added to the hot channel list.

3.5 Conclusion

This chapter presented the zapping delay framework methodological steps taken to achieve the aim and objectives set in this research study in order to reduce zapping delay to the bare minimum. The chapter discusses in detail the four modular approaches that serve as the foundation of the zapping delay framework combining advantages that the subscriber and network level provide.

The first approach highlighted the use of an adaptive hybrid service delivery method to reduce end-to-end delay and buffering delay one of the major components that aid zapping delay by combining the multicast and unicast service stream. The second approach at the subscriber level proposed a two-list group program driven method that helps reduce total seek time and total seek time during channel navigation; the TGPD method categorize channels based on their genre and give subscribers the choice to choose channel into the hot channel list based on their preference while the channels are being maintained using an algorithm based on channel popularity.

The third modular approach used the personalized electronic program guide to aid channel selection into the hot channel list or left in the cold channel list by giving program description using the ESA-BOW and it also helps to reduce channel navigation. While the RSS feed was used to intimate subscribers of update and news flash. The fourth modular approach obtained two video sequence image datasets available in the public domain in determining the perception of subscribers on video quality using the SSLS algorithm; the algorithm was further compared with eight state-of-the-art algorithms to validate the effectiveness in detecting the salient object from the original video sequence images. Furthermore, MOS scale was used to in analysing the perception of subscribers using alongside the extracted quantitative information through eight popular metrics. The next four chapters provide the explicit breakdown of the four modular approaches, evaluation experiments, and analysis results.

CHAPTER FOUR

Fast Channel Delivery Using Adaptive Hybrid Service Delivery Method

4. Introduction

This chapter presents the first modular approach of the zapping delay framework to accomplish the second objective of this research in order to reduce zapping delay in internet protocol television (IPTV) to the bare minimum. This approach used the adaptive hybrid service delivery at the network level to aid fast channel delivery to an IPTV subscriber.

4.1 Background

IPTV over a converged network brought seamless potential that has revolutionized the media and telecommunication industries by providing a platform for transmitting digitised television services. The IPTV system provides TV services over the Internet, similar to that of traditional cable TV and satellite TV services, however, it presents many benefits in supporting bidirectional capability. However, when compared to the traditional cable and terrestrial broadcasting services, zapping delay becomes the deterrent to the widespread use of IPTV. Zapping delay is a critical factor that affects the quality of experience in the internet protocol television. This problem is intrinsically caused by command processing time, network delay, jitter, buffer delay and video decoding delay. Zare *et al.*, (2018) explain the zapping delay as a problem that occurs when subscribers want to change IPTV channels, but have to wait for several seconds for the desired channel to be made available.

In view of this, we propose the use of an adaptive hybrid delivery method that agglutinates multicast and unicast methods to address the zapping delay problem in the IPTV over a converged network. In literature, many adaptive network methods have been proposed to address the zapping delay problem over a converged network. The methods include the Data-Centric Network Architecture (DCNA) that supports both data-centric and host-centric applications in order to address the Internet challenges. The DCNA approach is based on the inclusion of a shim layer between the application layer and the transport layer with appropriate interfaces to efficiently connect these layers (Luo *et al*., 2014). Furthermore, a collaborative Internet architecture using the Smart Identifier NETworking (SINET) was proposed to completely eliminate resource location, data content and user network restrictions. Consequently, the SINET method was designed to absorb all kinds of traffic dominance while compliantly meeting the various future IPTV requirements such as the vehicular network that provides inordinate prospects to address many of the challenging issues facing the current Internet architecture (Quan *et al*., 2017; Zhang *et al*., 2016).

The adaptive hybrid delivery method presented in this chapter deals with fast channel delivery at the network level. It is a method that agglutinates multicast and unicast enabled services when zapping delay is greater than 0.43s. When the zapping delay occurs, a unicast stream will request the IPTV channel from a multicast IP core network. This request takes the stream burst advantage of the unicast stream to provide fast channel delivery. Furthermore, a DiffServ quality of service is implemented along with the unicast service delivery method to guarantee the service delivery of the video stream for the IPTV channel.

This method aids a faster transmission by sending a join message to the multicast stream at the service provider zone to acquire the requested channel. The adaptive hybrid method reported in this chapter was benchmarked with the state-of-the-art multicast stream and unicast stream methods. Results show that the hybrid method has an excellent performance by lowering point-to-point queuing delay, end-to-end packet delay, packet variation and increasing throughput rate.

4.2 Approaches to Reduce IPTV Channel Change Delay

There are various methods developed over the years for improving zapping delay in IPTV. Zapping delay is usually caused by command processing time, network delay, buffer delay, multicast leave and join times, processing time in the display device, size of video buffer in encoder and video decoding delay (Joo *et al.*, 2008; Siebert *et al.*, 2009; Khosroshashi *et al.*, 2016). In this section, we discuss some of these methods such as the substituting multicast-based IPTV service with the unicast-based IPTV service. A multicast-based IPTV service comes with some intrinsic downfalls in that all network devices deployed within the network must support the Internet Group Management Protocol (IGMP) (Škrbić *et al.*, 2010). However, troubleshooting multicast service is complex, which further heightens the incurred cost of implementation.

In 2003, Microsoft proposed a channel change acceleration mechanism to reduce channel change delay by delivering IPTV via the windows media platform. This Microsoft instant channel change relies on channel change acceleration servers at the IP backbone in providing video stream during channel change, starting with an I-frame deploying a unicast flow at a faster rate as opposed to the regular stream rate. However, the proposed Microsoft method indeed accelerates the channel change, but it thus requires an extra bandwidth to handle bursty unicast stream channel. The channel switching delay gets heightened during commercial break increasing the network bandwidth demand however, Smith, (2007) present a mathematical model to determine the network bandwidth demand of multicast and surfing during commercial breaks that helps steady the bandwidth demand.

Cho *et al.*, (2004) propose a method that sends adjacent channels alongside the channel requested by the subscriber, their assumption is based on the fact that subscribers are likely to watch the adjacent channel of the desired channel requested. However, this method did not solve the zapping delay problem because if the subscriber does not switch to the adjacent channel it forfeits the purpose. Hereafter Lee *et al.*, (2011) improved on this method by adding channel popularity with adjacent-based prefetching, this method is used in prefetching contents of the adjacent channels before they are requested differentiating the channels prefetched among up and down direction button on the STB remote control based on channel popularity. However, the disadvantage of this method is that the bandwidth load becomes high causing overload and it ends up not reflecting the desired channel subscribers want to watch.

A new method that predicts the desired channel that a subscriber might likely watch was proposed to address the downside of the channel popularity with adjacent-based prefetching method (Cho *et al.*, 2004; Lee *et al.*, 2011). This method provides Intelligent Fast Channel Switching (IFCS) based on the behaviour of a subscriber. It predicts channel traffic in advance for the subscriber who wishes to watch the channel in the next few moments. Moreover, it analyses the behaviours of subscribers and obtains their preferences of watching channels to reduce the waiting time of the subscribers (Beyragh and Rahbar 2014).

Despite all efforts in reducing zapping delay, there has not been any long-lasting solution. Chen and Liao (2016) proposed a method to be deployed based on peer-to-peer (P2P) structure for saving the cost of network hardware equipment and bandwidth requirements. Since peers may join and leave the P2P system arbitrarily, it may cause the service quality to be unstable. They compared IP addresses to find partner peers in proximity, and used specific packet pairs to probe partner peers that had a larger bandwidth, to reduce the switching delay through pushing the video chunks proactively, while also using two buffers that stored data of both current and newly selected channels to improve the stability of media playback.

In spite the number of literature addressing the zapping delay problem in recent years, there seems to be no sufficient literature covering IPTV zapping delay in a converged network. This gap intrinsically served a strong motivation for this study. In response to this gap, our proposed method addresses the overall problem of zapping delay by using an adaptive hybrid delivery for fast channel navigation.

4.3 Methodology for Fast Channel Delivery

The adaptive hybrid delivery method for minimizing zapping delay in a converged network at the network level was achieved by agglutinating multicast and unicast services to deliver IPTV content. The essential steps of our adaptive hybrid delivery method that agglutinates the methods of multicast and unicast to minimize zapping delay in a converged network are shown in Figure 4.1. Once zapping delay occurs, a unicast method with Differentiated Service (DiffServ) QoS will be used to deliver IPTV contents from a multicast group to subscribers. This content is sent at a higher rate by using the unicast stream which allows the playout buffer to be filled faster (Banodkar *et al.,* 2008). This method addresses the requirements of delay, jitter and real-time sensitive traffic during short periods of congestion. The over-provisioning of bandwidth will help to minimize the long-term average level of congestion within the converged network (Maraj and Shehu, 2012). It is imperative to use DiffServ QoS to fairly prioritize bandwidth from the unicast stream when zapping delay set in, because different services run on a converged network. DiffServ admission control solves the scalability issues and provides IPTV subscribers with a consistently high-quality video with a responsively reduced channel zapping delay time. In addition it reduces bandwidth consumption by policing IPTV traffic to ensure that it conforms to the service level agreement (Xiao *et al.,* 2007; Bahnasse *et al*., 2018).

As shown in Figure 4.1, a decision is needed as to when to provide a hybrid stream and a multicast stream for a channel request. This is accomplished when the channel request is received and zapping delay is greater than 0.43s. In order to implement the adaptive hybrid delivery method, all network equipment must be multicast enabled. The hybrid stream is used for content delivery while a dedicated bandwidth is allocated using the DiffServ for an IPTV content in order to avoid delay and jitter. However, if zapping delay is less than 0.43s, the channel content stream will be delivered with a multicast stream. The adaptive hybrid delivery method for channel navigation can reduce the problem of zapping delay during IPTV content delivery. Moreover, it can optimize the usage of network bandwidth while providing a resilient quality of service to subscribers aiding QoE. In addition, it can aid bandwidth saving and reduce zapping delay as channel request over the converged network must provide a real-time service.

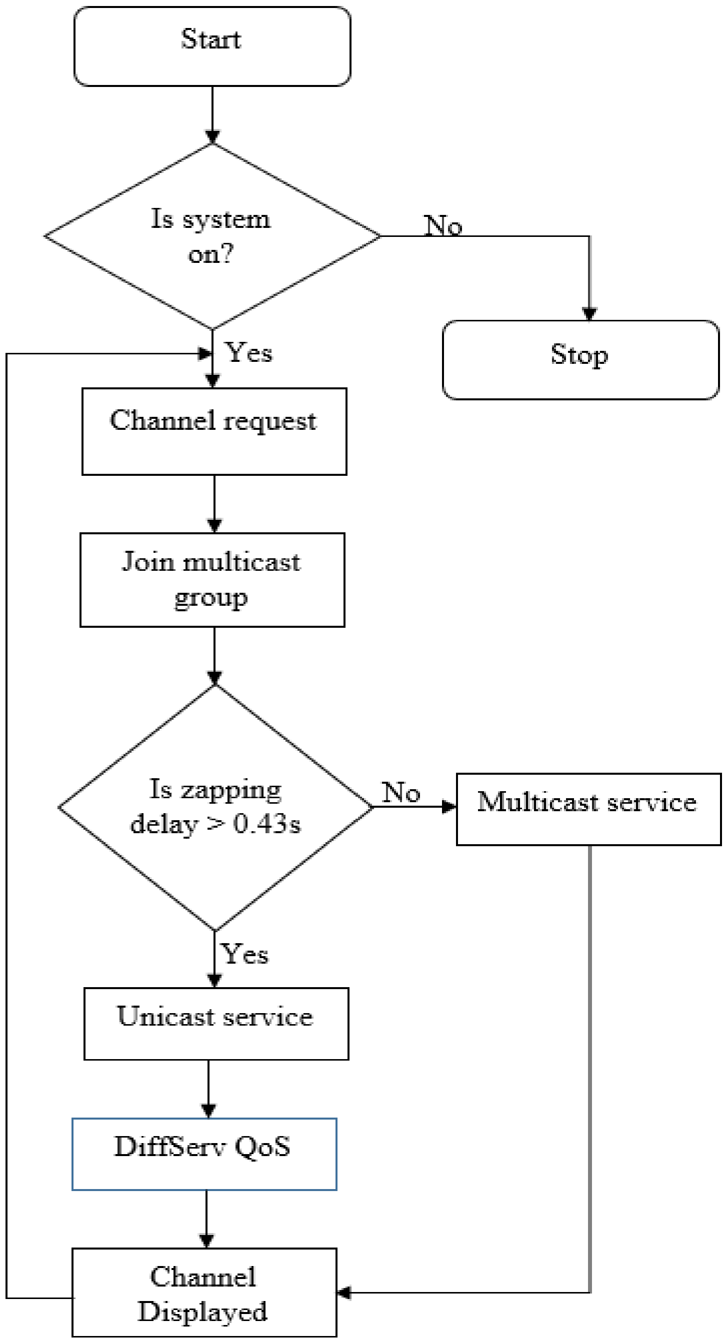


Figure 4.1: The adaptive hybrid delivery of IPTV channels

4.4 Simulation Experiment

To simulate a realistic adaptive hybrid delivery method that will produce an accurate result within an acceptable timeframe, we have used the Optimized Network Engineering Tool

(OPNET) Modeler 14.5 for simulation. The performance of the adaptive hybrid method has been compared with the performances of the state of the art multicast and unicast methods using the OPNET integrated development environment. Lucio *et al.*, (2003) explain that the OPNET modeler provides different levels of modeling, depending on the requirements of the simulation. The graphic user interface of OPNET modeler establishes an overall environment called a project. The operator can develop several network scenarios from a project in order to evaluate and analyze the performance of that network in different "what-if" scenarios. The modeler has to be configured as shown in Figure 4.2 in order to obtain the desirable results. For the simulation experiment we created a converged network with two routers, which are: first hop router and last hop router connected to the cloud with a digital signal level 3 T-carrier link of 44.736Mbit/s data circuit. The first hop router is connected to the converged network service with the IPTV headend, VoIP server and data server (HTTP, database, and FTP) servers.

4.4.1 OPNET

The OPNET is an application software that provides a comprehensive integrated development environment (IDE) for the specification, simulation, performance analysis and evaluation of communication networks (Qaddour and Polishetty, 2016). It makes the simulation of real-life network environment close to reality (Salah and Alkhoraidly, 2010). Other features of OPNET include graphic user interface, a comprehensive library of network protocols and models, the source code for all models, graphical results and statistics. OPNET Modeler was used as a simulation tool for network modelling, evaluation and comparison purposes.

The simulation of the adaptive hybrid service delivery method took four steps and they are: (i) The design of network topology for simulation. (ii) Designing of the routing protocol method in the network domain. (iii) Assigning Traffic (data, voice, and video). (iv) Selection of parameters for simulation. In order to investigate the network performance, running different protocols on the network and then analysing data performance within a converged network used the simulation-based analysis. A medium sized network topology was designed to achieve all the objectives. Different scenarios were designed in representing different method. The network topology used in the simulation is shown in Figure 4.2:

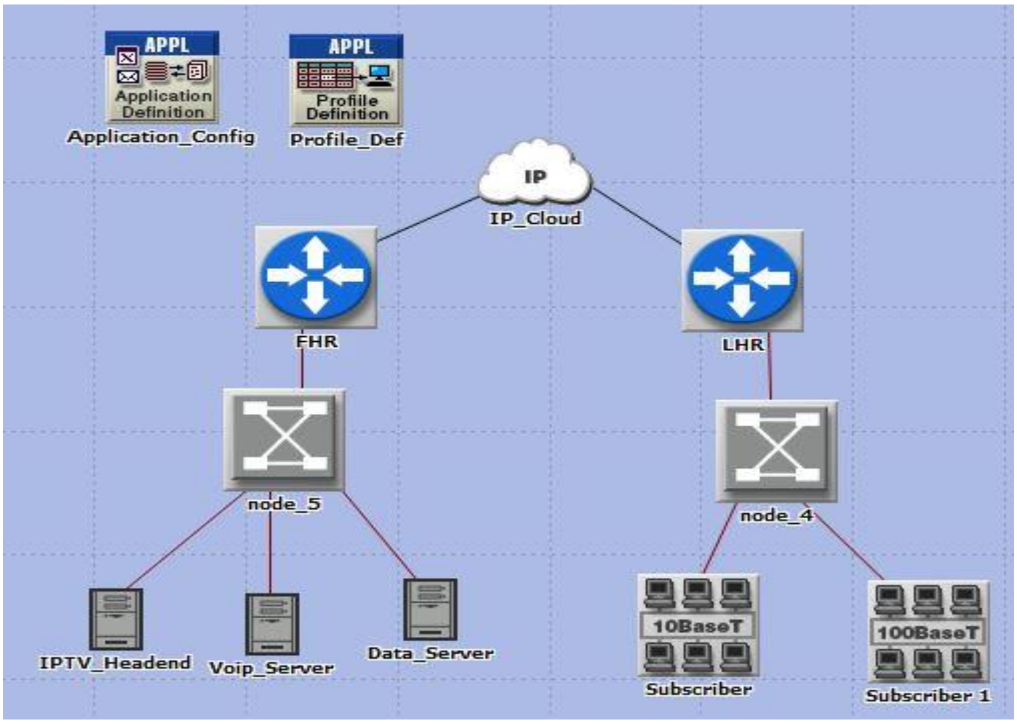


Figure 4.2 The OPNET simulation model of a converged network

Table 4.1 shows the network parameters used to configure the converged network topology in Figure 4.2. This topology has servers equipped for transmitting video, voice and data services to the subscribers. The Protocol Independent Multicast Dense Mode (PIM_DM) was added to the network node models for simulation of the multicast stream. This has helped to efficiently generate, process and deliver multicast packet within the converged network (Golechha *et al.,* 2016). Furthermore, multicast services were enabled on all nodes in order to support efficient multicast stream delivery. The application model of the OPNET was configured to generate and process unicast stream for the simulation of the unicast steam. The OPNET configuration for the simulation of a converged network runs for the duration of 15 minutes in order to improve the processing speed.

Table 4.1 Parameters for simulating Converged Network

Network	Converged Network
IP Backbone	IP Cloud
Link Model	PPP DS3
Server Model	Ethernet Server
No of Server	3
No of Subscriber	20
Link Bandwidth (Core)	44.736Mbps
Link Bandwidth (Access)	100Mbps
Traffic Type of Service	IPTV – (Streaming Video) VoIP, HTTP, FTP, Database

In simulating the adaptive hybrid service delivery over a converged network as shown in Figure 4.2, OPNET has three application modeling techniques in which a simulation will be carried out and they include: (i) Explicit- simulate all packets in detail with very high fidelity results while it potentially run for longer time and takes a lot of internal memory. (ii) Analytical- simulate majority of the traffic using a mathematical representation with a faster simulation run times than explicit technique. (iii) Hybrid combines both explicit and analytical modelling techniques to provide accurate and detailed results for targeted flows while it gives a faster simulation run time. However, for the purpose of this project, this research work used the hybrid modelling technique in providing an accurate and detailed result. To implement and simulate the converged network above, it is useful to know that OPNET has three major workflows, which are model, simulates and analysis.

4.5 Simulation Results and Analysis

In this section, the analysed graphed results in bytes per seconds against the number of minutes used in running the simulation for the state-of-the-art multicast and unicast method was compared with the adaptive hybrid service delivery method based on the same converged network topology. Figure 4.3 shows the IPTV traffic received from the headend and traffic sent to 12 subscribers. Specifically, Figure 4.3a shows the IPTV traffic received by the headend from the subscribers for multicast, unicast and our adaptive hybrid methods. All these methods received the same amount of traffic over a period of time. At the same time the traffic sent by the IPTV headend to the subscribers as shown in Figure 4.3b has the same traffic value for all methods. This provides a fair comparison of the simulated methods.

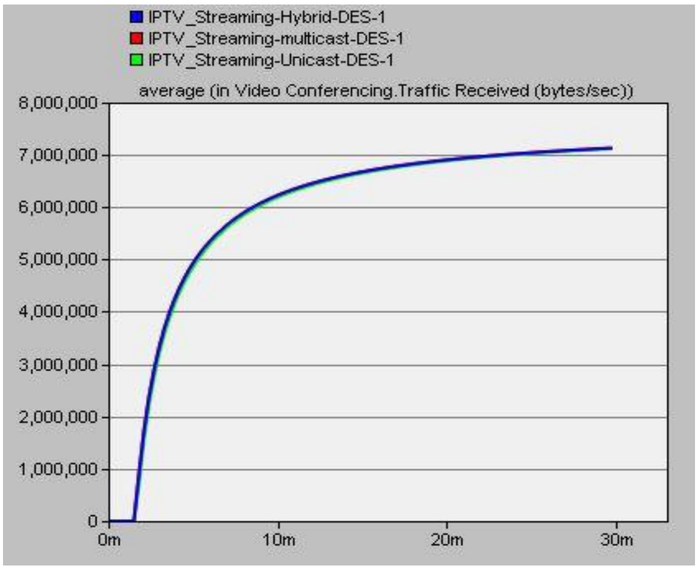


Figure 4.3a. IPTV traffic received

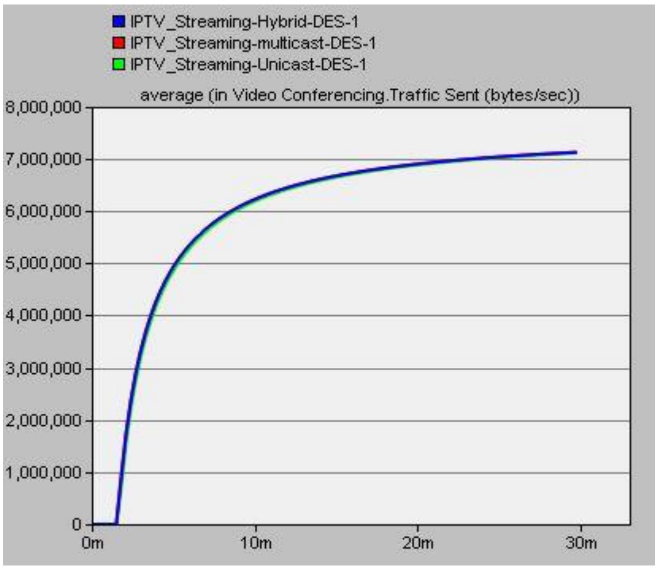


Figure 4.3b. IPTV traffic sent

Figures. 4.4a and 4.4b depict the IPTV traffic load from the headend versus the throughput rate for the traffic delivered to subscribers for the unicast and multicast methods respectively. Although the throughput of the unicast method was higher than that of multicast, the downside effect is that it consumes excessive network resources while multicast has resource allocation challenge (Almowuena *et al*., 2016; Condoluci *et al*., 2016).

However, Figure 4.4c illustrates the throughput rate of our adaptive hybrid method for the traffic delivered to subscribers, which is higher than the load. This result indicates that the adaptive hybrid method outclassed the state of the art methods, which is possible by concomitantly taking the advantages of both unicast and multicast methods.

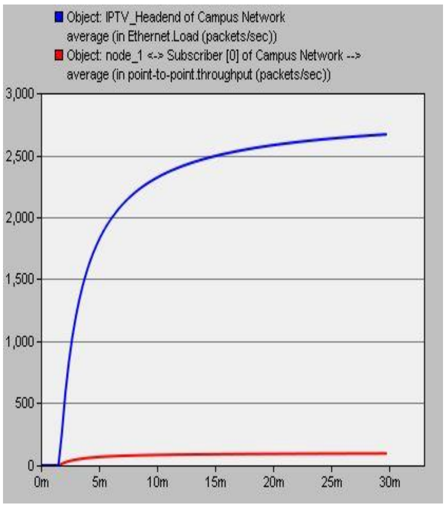


Figure 4.4a. Unicast (load vs throughput)

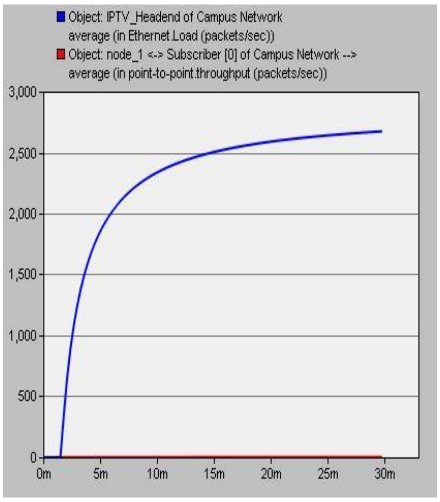


Figure 4.4b. Multicast (load vs throughput)

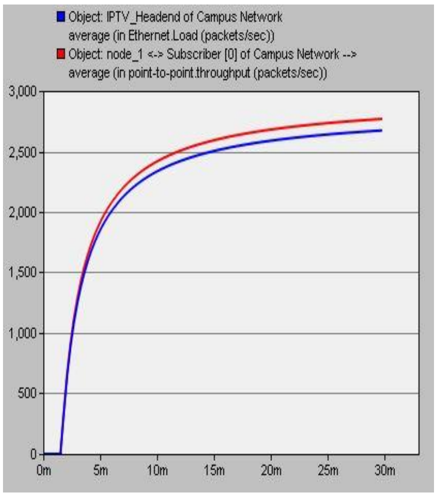


Figure 4.4c. Adaptive hybrid (load vs throughput)

Figure 4.5a shows the performance result of the IPTV headend processing time in responding to requests from subscribers. The comparative result shows that our proposed adaptive hybrid method, when compared with the unicast and multicast methods has the lowest processing time, despite having a higher traffic request per second as shown in Figure 4.5b. Consequently, our adaptive hybrid method efficiently shares network resources evenly without affecting the network performance.

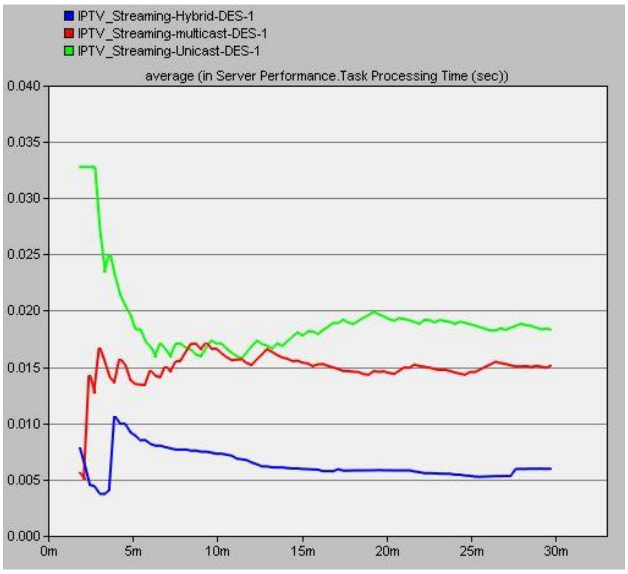


Figure 4.5a. Processing time

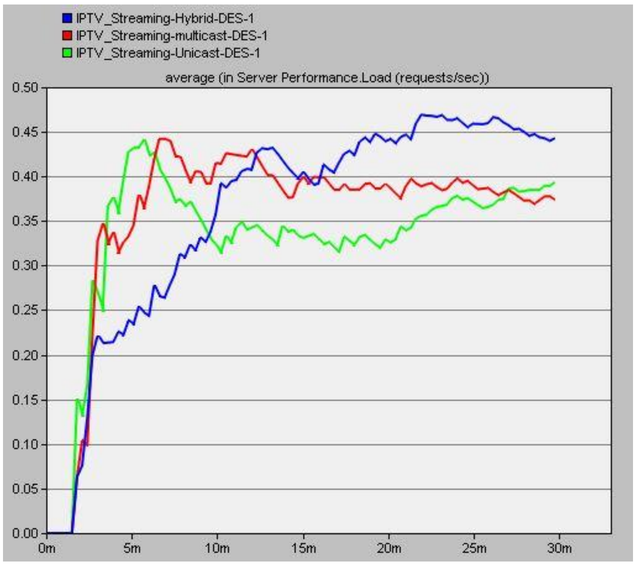


Figure 4.5b. Traffic request

Figure 4.6 illustrates the end-to-end delay of all packets received at the IPTV headend. The result shows that although our adaptive hybrid method has the highest traffic request, the end-to-end delay is low when compared with the results of the unicast and multicast state of the art methods.

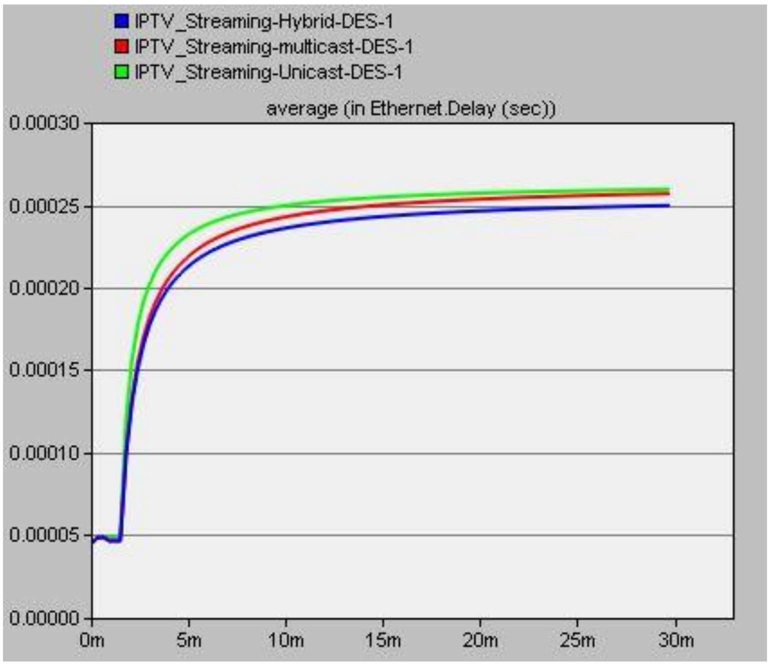


Figure 4.6 End-to-End Delay

In Figure 4.7, the packet delay variation (jitter) of our adaptive hybrid method is significantly less when compared to the unicast and multicast methods. This would help to reduce the zapping delay problem in IPTV.

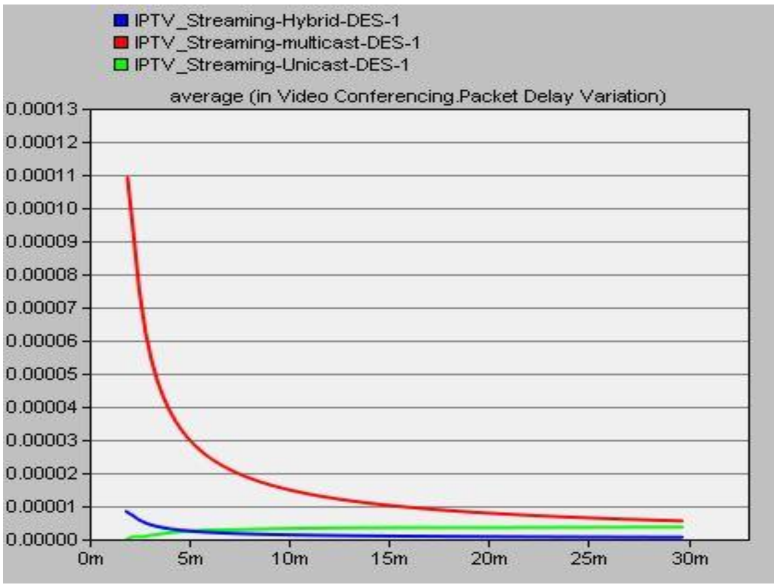


Figure 4.7 Network Jitter

The queuing delay in Figure 4.8 is the time it takes the IPTV packet to wait in a queue until it is forwarded to the IPTV subscriber. The adaptive hybrid method has the least waiting time when it comes to delivering packets. This can reduce the network delay time and zapping delay in order to increase the perceived quality of experience by a subscriber.

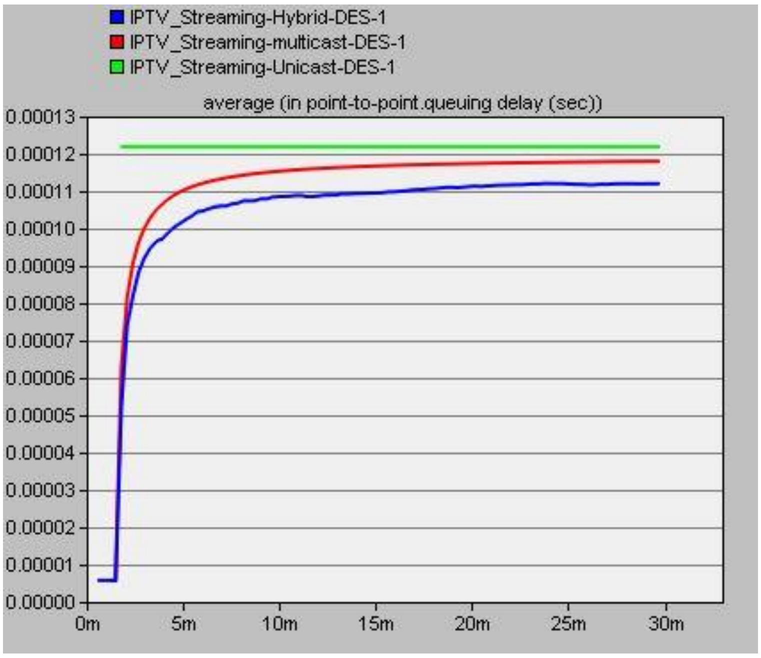


Figure 4.8. Queuing delay

4.6 Analysis of Adaptive hybrid Service Delivery Implementation

The proposed Adaptive hybrid delivery method was implemented on a raspberry pi 3B with a Linux operating system over a converged network using Durban University of Technology's campus network composed of a multicast router, switch and servers (such as IPTV TV headend, VoIP, file, database etc.) It is worth to note that data gathered for analysis in this section is from the implementation. Figure 4.9 depicts a comparison of video playback (i.e. decoded video made available to the subscriber on request) end-to-end delay in seconds for the proposed method with various other OTT services for a period of one month.

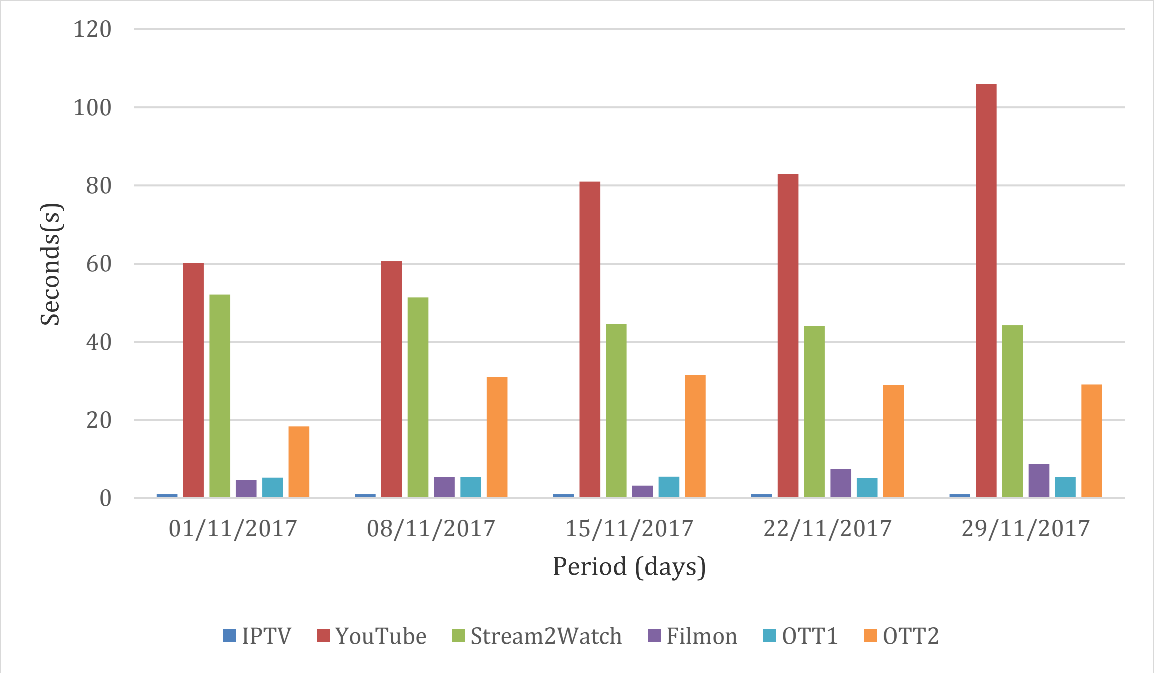


Figure 4.9 Average Video playbacks End-to-End Delay

In Figure 4.9 it can be noticed that the proposed method of end-to-end video playback delay gives a result of 1s, which is the least when compared with other systems. It can also be observed that YouTube has the highest video end-to-end playback delay ranging from 61.01s to 106s. Stream2Watch, an internet TV service that provides live TV, has the second highest video playback end-to-end delay with the lowest value of 44s and the highest of 52.1s, OTT2 (Livenewson) also a live TV internet service, has the third highest value for video playback end-to-end delay. Furthermore, OTT1 (Put Channel) and Film on a live Internet TV service have the lowest values of 5.2 and 3.0 respectively while the highest recorded values are 5.5 and 8.7 respectively. Based on the output and analysis made, it can be concluded that the proposed adaptive hybrid delivery for fast channel navigation is effective when compared with the other OTT services that make use of multicast and unicast service delivery.

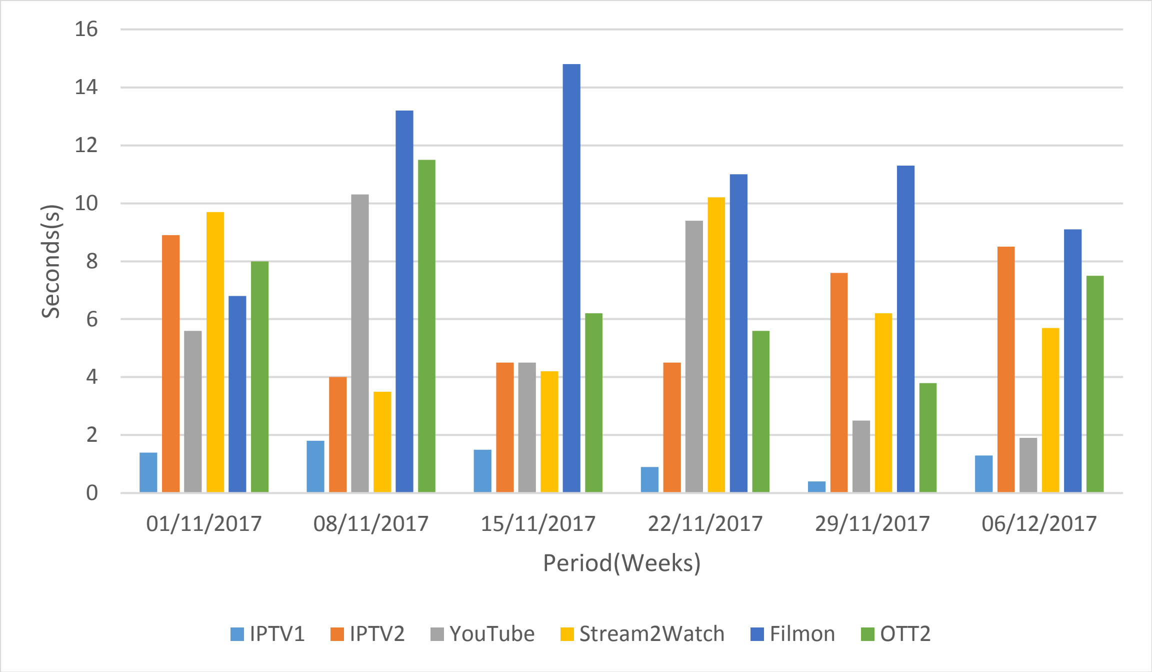


Figure 4.10 Average Buffering Delay

In Figure 4.10 the measured buffering delay was presented the time needed to buffer a requested content before it is displayed on the subscriber's TV. The measurement was taken over a period of five weeks. It can be noticed that IPTV1 a local IPTV setup using a TV headend server at the ICT advanced research lab, Durban University of Technology recorded the lowest buffering delay ranging between 0.4s and 1.8s. IPTV2 a third party IPTV server connected using the DUT network recorded a higher buffering delay when compared to the proposed method (IPTV1), the results recorded range from 4s to 8.9s. The third system used for comparison was the YouTube system. It recorded a low buffering delay of 1.9s and a high buffering delay of 10.3. However, the high buffering delay was due to the 5s delay for an advertisement before hitting the skip button and it was noticed during the experiment that YouTube displays a low resolution of 480p. The fourth system is the Stream2watch OTT service. It can be observed that it gave a result ranging from 3.5s to 10.2s. However, it was noticed that in this method, audio of the requested channel was heard before the actual display of the visual at times. Furthermore, the fifth system, Filmon gave a result that ranged from 9.1s to 14.8. The sixth system was the OTT2 that gave an average result ranging from 3.8 to 11.5 seconds. From the analysis made based on buffering delay, it can be concluded that the Adaptive hybrid delivery for fast channel navigation reduced buffering delay to less than 1s and hence helped reduce zapping delay

4.7 Conclusion

In this chapter, we have developed and evaluated an adaptive hybrid delivery method that agglutinates the state of the art multicast and unicast methods for fast channel navigation in Internet protocol Television over a converged network. The simulation results show that the adaptive hybrid delivery method has a better performance by lowering point-to-point queuing delay, end-to-end packet delay, jitter and network throughput. The use of the adaptive hybrid delivery method reported in this thesis can provide efficient, resilient and reliable IPTV video distribution to subscribers. Moreover, it provides a mechanism for reducing the zapping delay often experienced by IPTV subscribers during channel navigation.

CHAPTER FIVE

Fast Channel Navigation Using Two-list Group Program Driven Method

5 Introduction

In this chapter, the second modular approach of the zapping delay framework was discussed to accomplish the third objective of this research. The purpose of this method is to aid fast channel navigation in IPTV over a converged network in order to reduce zapping delay to the bare minimum. This method used the proposed two-list group program driven method at the subscriber level, a method that gives subscribers choice to choose channels based on preference from a cold channel list into a hot channel list from a group genre of programs to aid fast channel navigation. In addition, a flowchart at the subscriber level is also used to maintain the hot and cold channel list.

The internet protocol television took the advantage of the convergence of internet services to provide seamless interactivity, time shifting, video on demand and pay per view services. However, zapping delay is a critical problem that deters the switching intention of terrestrial subscribers and widespread of internet protocol television services. Subscribers often experience this zapping delay problem in IPTV when switching channels, a difficulty faced in choosing a desired channel to watch among hundreds to thousands of channels available at a subscriber's disposal. This chapter presents the design of an effective two-list group program driven algorithm that minimizes the channel seek distance and channel seek time in order to reduce zapping delay in internet protocol television. The algorithm groups similar channel programs in related service categories such as news, movies, sports, music and documentary to make it easier for channels with similarly aired programs to be identified rapidly among several channels that an internet protocol television offers. The simulated results of the proposed method show that the average seek distance is significantly reduced by 58 per cent when benchmarked with the state of the art numerical ordering, frequency circular ordering and frequency interleaved ordering, thus reducing the zapping delay problem based on channel navigation.

5.1 Background

Television signal transmission is going through rapid changes with the recent advancement of digital technology. The days where a television signal is delivered through a fixed radio frequency spectrum and terrestrial broadcasting is coming to an end, to pave the way for Internet Protocol Television (IPTV). This emerging model of television uses the internet technology to deliver TV programs on demand and it is the future of television broadcasting. (Zare et al., 2018). The IPTV provides multimedia services such as VoD, pause live TV (PLTV), audio, text, graphics, and data delivered over the Internet Protocol (IP) based networks. The networks are managed to provide the required level of quality of service, quality of experience, security, interactivity and reliability (Beyragh and Rahbar 2016; Lee *et al.,* 2015).

The IPTV should offer an improved QoE than the terrestrial models, regardless of the intrinsic advantages that come with it. In view of this, it is practically essential to address the zapping delay problem often experienced in the IPTV. Zapping delay is a problem inherently caused by decoding and encoding time, STB processing delay, jitter and channel changing time (Zare et al., 2016; Nikoukar *et al.,* 2016). The problem is often heightened by constant channel navigation in initiating a change to watch a desired channel among several available channels. The zapping delay is a major impediment to seamless deployment that affects the attractiveness of IPTV and significantly deters the switching intention of current terrestrial subscribers (Ramos *et al.,* 2011; Quintero *et al.,* 2015).

Channel navigation is a critical enhancer for determining subscribers' perception of quality of experience in ensuring IP-based video delivery systems at the subscriber level. This chapter introduces a new method that eliminates channel prediction and channel driven method (Bikfalvi *et al.,* 2011; Das *et al.,* 2015) in order to address the zapping delay problem effectively (Ryu et al., 2014). This new method proposes a two-list group program driven algorithm that enables the subscribers to select the desired channel from a group of channels according to the personalized popularity of the channel. In addition, subscribers can personalize channels in regards to the order of preferences through two separate lists of hot and cold channels. The lists of hot and cold channels are subsequently updated based on how frequent a channel is watched in relation to the time spent watching the channel. This method can be implemented in both the managed and unmanaged IPTV through a set-top-box strategy.

5.2 Approaches to Reduce IPTV Channel Navigation

In recent years, a number of methods have been proposed to reduce the effects of zapping delay problem in IPTV caused by channel navigation at the subscriber level. For instance, Lee *et al.,* (2014) proposed a two-list method that identifies a hot and cold channel list. This method actively maintains a list of the hottest channels to watch in the near future by a subscriber and a list of cold channels that a subscriber is not likely to watch. The segregation of channels into hot and cold lists is based on how frequently and recently a channel has been viewed by a subscriber. Their scheme fetches the channels in the 'hot' list, previewed in a low resolution when a subscriber changes a channel. However, the channels in the hot and cold lists are arranged in reference to the Frequency Channel Ordering (FCO). This mechanism gives a longer channel seek distance when compared to the Frequency Interleaved Ordering (FIO) that places hot channels in the centre of a circular list according to their popularity (Lee *et al.,* 2009). According to Mazanto and Fonseca (2010), 56 to 60 per cent of channel switching is linear, where 69 to 72 per cent of those switches are upward and 28 to 31 per cent of them are downward. Based on their findings they suggested that channel navigation should be adjacent to the selected one in the upward and downward proportion in order to save bandwidth. However, these method increases channels seek distance and hence, causes zapping delay.

A channel reordering method called the Frequency Interleaved Ordering (FIO) was proposed to minimize zapping delay for subscribers to view the preferred channels with no delay (Shakin et al., 2014). FIO reorders "n" total number of channels based on ranking from 1 to n, placing the most popular channels in the centre of a circular list. The channels with odd ranks are placed on the left of the list whilst channels with even ranks are placed on the right of the list (Chen and Chiu, 2012). Regardless of how effective this method is, popular channels are still adjacent to the less popular channels. Moreover, there is no assurance that subscribers are going to switch between the proposed popular channels.

Lee *et al*., (2006) propose two dynamic recommendation methods that use most recent selected (MRS), a channel reordering method by using subscriber's most recently watching history, and most frequently selected (MFS), thus it is based on the most frequently watched channel by the subscriber. However, subscribers' preferences differ and in a family of five they will definitely have different preferences and this can increase the seek distance and hence it does not solve the zapping delay problem.

Ramos *et al.* (2010) proposed a method called channel smurfing that concurrently sends the neighbouring channels with the requested channel to the STB. Hence, if a subscriber decides to switch to any of these neighbouring channels, the switching delay is virtually zero and quality of experience is less affected. However, the challenge is that if a subscriber does not switch to a neighbouring channel, zapping delay problem absolutely remains. Lee *et al.,* (2010) improved the channel smurfing scheme by adding a predictive tuning algorithm based on the preferred channel selection behaviour of a subscriber. The improved scheme predicts a channel that a subscriber is likely to watch rather than the adjacent channel. This intrinsically eliminates the uncertainty of sending a channel that a subscriber won't be likely watching. The authors assumed that IPTV subscribers tend to keep changing channels via the remote controller, which informs the use of STB for channel prediction. The behavioural model of subscribers occurs in two forms. The first form is the channel switching behaviour and the second is the surfing behaviour that they used to predict the channel that a subscriber might request.

Oh *et al.,* (2010) proposed a hybrid scheme that agglutinates channel prefetching and reordering schemes to address the zapping delay problem in the IPTV. Specifically, the adjacency and popularity based prefetching schemes were amalgamated with a popular channel reordering scheme to address the zapping delay problem. In spite of the amount of literature addressing zapping delay in recent years, there seems to be no lasting solution based on channel navigation, a gap that inherently serves as a strong inspiration for this study. In response to this gap, our proposed algorithm addresses the overall problem of zapping delay by developing an effective two-list group program driven algorithm to effectively reduce the channel seek distance and channel seek time.

5.3 Fast Channel Navigation Methods

The IPTV offers several channels, but selecting the desired one in regards to the desired program is a hard problem. This is intrinsically becoming a factor that causes zapping delay in the IPTV. (Cha *et al*., 2008b). In this section, we present in Figure 5.1 (a-d) a discussion of popular channel navigation method for reducing channel seek time and seek distance.

In Figure 5.1a, the conventional numerical ordering (NO) is a method where channel popularity is likely scattered and not aligned with subscribers' preferences. This makes the total seek distance before a subscriber finds a preferred channel in most cases longer (Lee and Choi, 2011). Figure 5.1b in which channels are arranged in a circular form shows the Frequency Circular Ordering (FCO) scheme that improves the NO by aligning channels based on popular preferences of subscribers (Zare and Rahba, 2016).

However, Manjunath *et al*., (2013) criticized this method because of the innate weakness that it possesses in that the least cold channel is adjacent to the most popular hot channel when navigating in a circular form. They concluded that although the chances of it happening are low, it is in contradiction to the main goal of reducing total seek distance. Figure 5.1c, Frequency Interleaved Ordering (FIO) addresses the weakness of the scheme in Figure 2b, by placing the most popular hot channel at the centre of the circular list and channels with even and odd ranks on the right and left sides respectively. (Lee and Choi, 2011; Azgin and Altunbasak, 2013). This method makes the use of up and down buttons on the remote control to quickly search for the preferred channels, hence reducing the channel seek time. Figure 5.1d shows the two-list scheme to discuss further because it provides a theoretical foundation for the two-list group program driven algorithm of this chapter.

The two-list scheme (TLS) Lee *et al.* (2014) identifies hot and cold channel lists where channel preferences are determined from the previous channels watched by a subscriber. In this study, we have built on the TLS by arranging channels based on their popularity, placing the most popular hot channels in a separate list in the inner circle. The channels with even and odd ranks are respectively placed on the right and left sides based on the preferences of subscribers. In addition, cold channels are placed on a separate list in the outer circle whilst hot channels are placed in the inner circle as shown in Figure 5.1d. This configuration eliminates the possibility of cold channels to be adjacent to the hot channels.

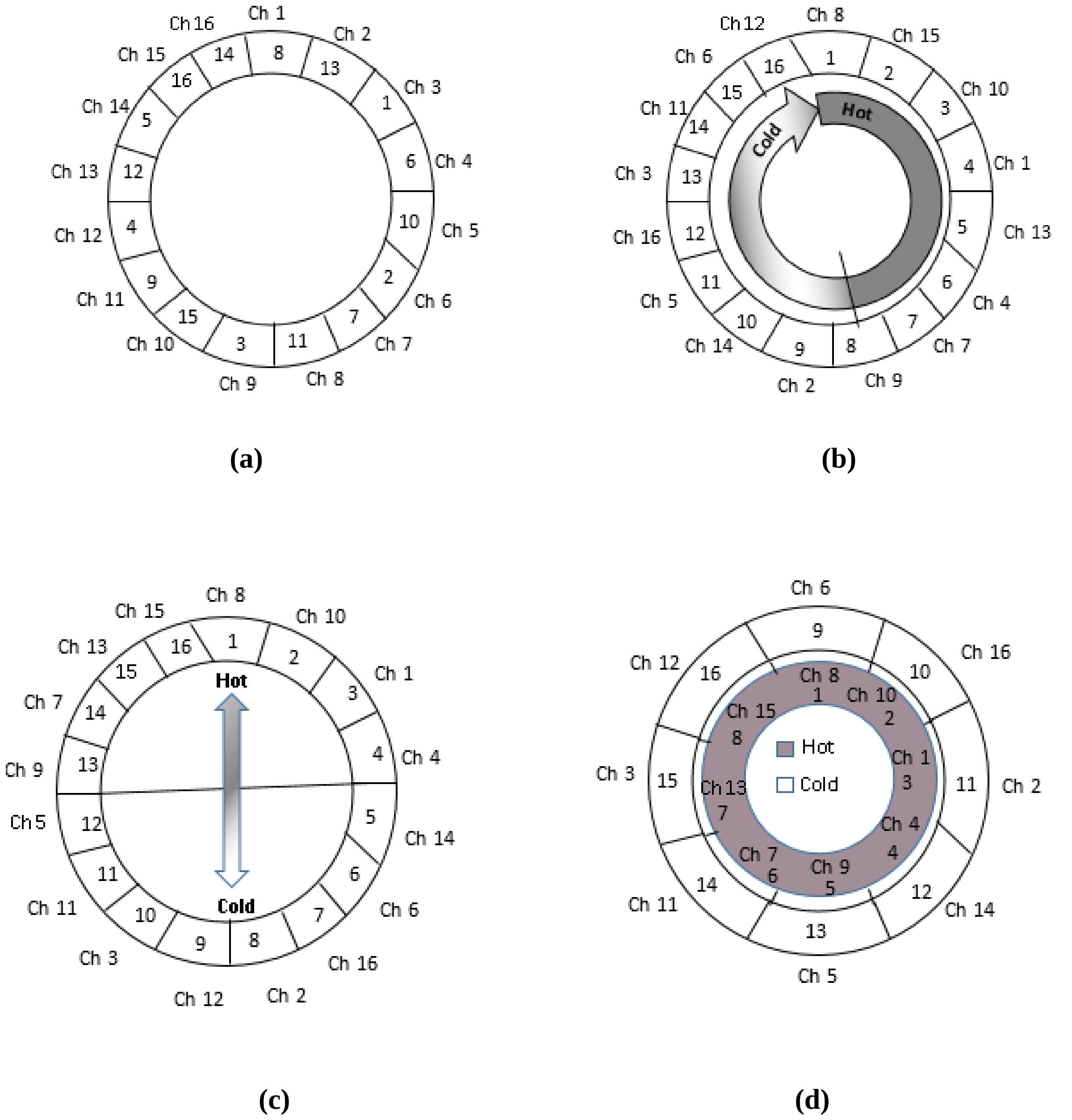


Figure 5.1 Popular channel navigation approaches for reducing channel seek distance and channel seek time

5.4 Proposed Two-list Group Program Driven Method

The conventional channel-driven algorithms such as the numerical ordering, frequency circular ordering and frequency interleaved ordering for channel navigation still present zapping delay that limits the subscribers to view the desired channel effectively because of the high channel switching rate (Zare and Rahbar, 2016). The Two-list Group Program Driven (TGPD) algorithm reported in this section reduces zapping delay by minimizing the total seek distance and total seek time. The algorithm groups similar channel programs in related service categories such as news, movies, sports, music and documentary. This strategy makes it easier for channels with similarly aired programs to be identified rapidly among several channels that an IPTV offers.

Channels are arranged based on popularity by placing the most popular hot channel in a separate list in the inner circle. Channels with even rankings and odd rankings are placed on the right and left side respectively, based on subscribers' preference. The cold channel list is also placed on a separate list in the outer circle with even rankings and odd rankings placed on the right and left side respectively. This eliminates the possibility of unpopular channels being adjacent to the most popular channels.

Furthermore, the two-list group program driven method presents in Figure 5.2 a flowchart that allows the subscribers to personalize channels into hot (channels often viewed by the subscriber) and cold (channels not often viewed by the subscriber) lists according to their preference ordering (Al-Hezmi et al, 2006; Yang et al., 2015). This strategy eliminates the previous method of predicting the channel that a subscriber would likely prefer to watch (Oh et al., 2010).

A subscriber selects a channel to view over a period of time. A subscriber selects a channel to view over a period of time. The channel popularity P is determined based on the viewing rate R of a channel across all subscribers and $H(x)$ is the time-weighted frequency of watching the channel by the subscriber. The function $H(x)$ is determined by the contribution of each past view of a channel, while x is the elapsed time for viewing the channel (Lee *et al.*, 2014). The channel popularity determines if a channel is to be placed in a hot or cold channel list and is expressed as follows:

$$P = RH(x) \tag{5.1}$$

The popularity of a channel decreases if the channel is not regularly viewed over a period of time and it increases otherwise. Decreasing in the popularity of a channel means that the popularity value is less than a given maximum threshold (Thr_Max). The threshold value is usually set by the IPTV provider whilst channel popularity increases if its value is greater or equal to Thr_Max. If the popularity of a channel in the hot list is less than Thr_Max, the channel will be moved to the cold list. Similarly, if the popularity of a channel in the cold list is greater or equal to Thr_Max, the channel will be moved to the hot list. This process is iterated in order to update hot and cold channel lists based on the predefined maximum threshold.

The channel popularity was modelled by the Zipf distribution, which has the ability to represent the skewness of channel popularity (Oh et al, 2010). The probability P_i of the i^{th} popular channel that will be viewed by a subscriber is determined by the following Zipf distribution function (Zipf, 2016).

$$P_i = \frac{(1/i)^\theta}{\sum_{k=1}^{n}(1/k)^\theta} \tag{5.2}$$

Where n is the total number of channels and θ ($0 \le \theta \le 1$) is the Zipf parameter that determines the degree of the skewness of channel popularity. All channels are equally popular whenever θ is zero, but the popularity of a channel is increasingly skewed as the value of θ increases. Finally, the popularity is mostly skewed whenever it becomes one.

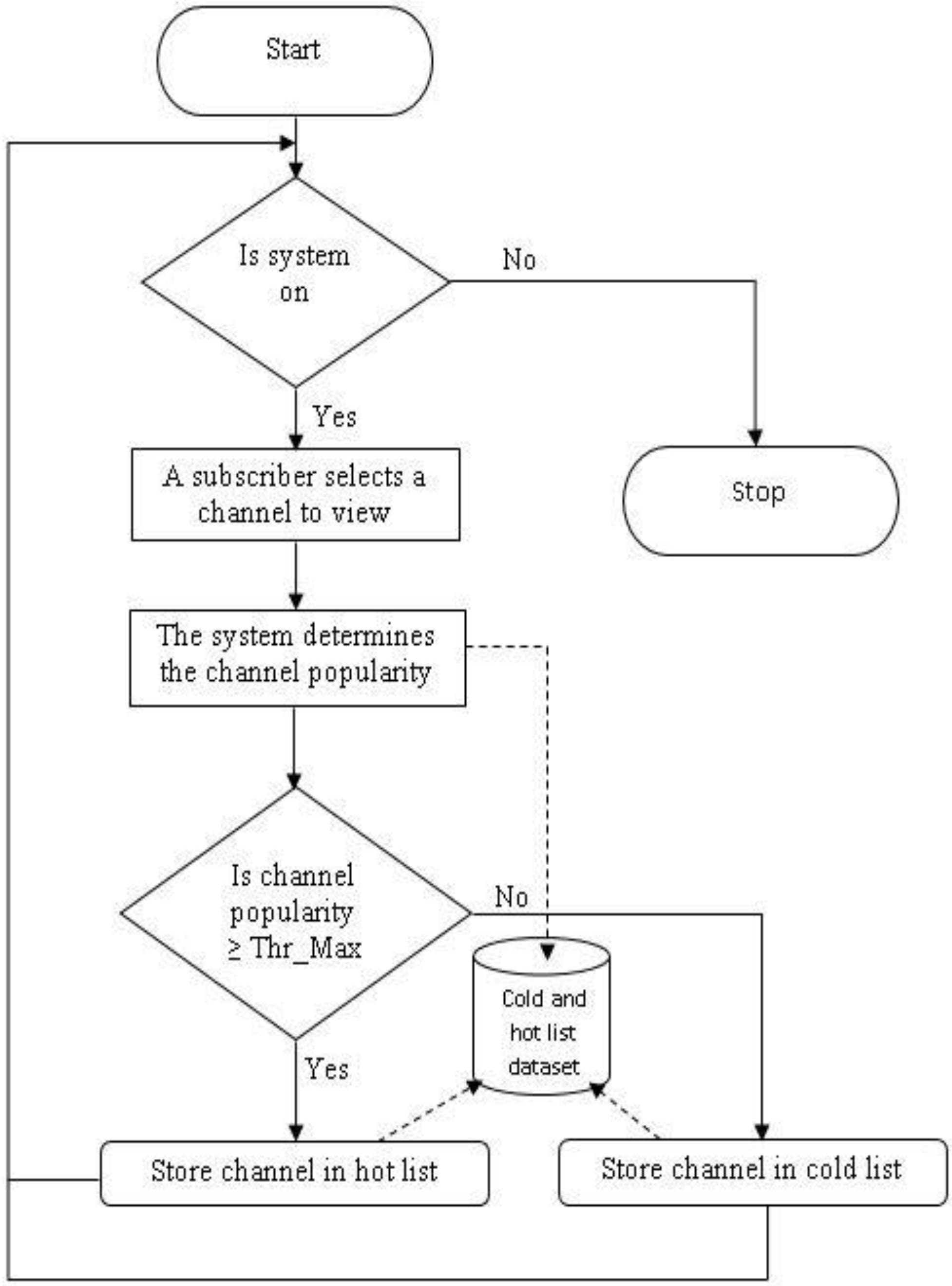


Figure 5.2: The flowchart to maintain or update channels in hot and cold lists

The group program driven two-list method keeps a channel in the hot-list channels with reference to channel popularity. Based on this popularity hot-list channels are put adjacently. Therefore, to measure the seek cost of the proposed method the expected seek distance (ESD) is defined as follows (Lee *et al*., 2009):

$$ESD_i = \sum_{i=1}^{n} p_i d_i \tag{5.3}$$

The expected seek distance in equation 5.3 is measured by the popularity p_i the rate of watching a channel i over a period of time by the distance d_i to switch from one channel to another and n is the total number of channels. The proposed method promotes faster channel switching when benchmarked with other conventional popular methods like numerical ordering, frequency circular ordering, and frequency interleaved ordering. Selecting channels for the desired program in IPTV can be difficult among hundreds to thousands of channels, thereby increasing the channel-switching rate. To buttress the high channel switching rate in IPTV Zare and Rahbar (2016) state that other methods like a channel-driven approach would also make subscribers not to be able to view the desired channel because of the high channel-switching rate.

The setup phase of the TGPD algorithm allows a subscriber to choose a channel from a hot list or cold list. The flowchart shown in Figure 5.3 maintains the channels in the hot and cold lists based on the viewing rate and time spent by a subscriber during the watching of a program. The TGPD algorithm makes it possible that when a subscriber chooses a channel from a program category, the channels with similar programs will be available in the group. This strategy reduces channel navigation and streamlines the channels based on the desired channel that a subscriber has requested.

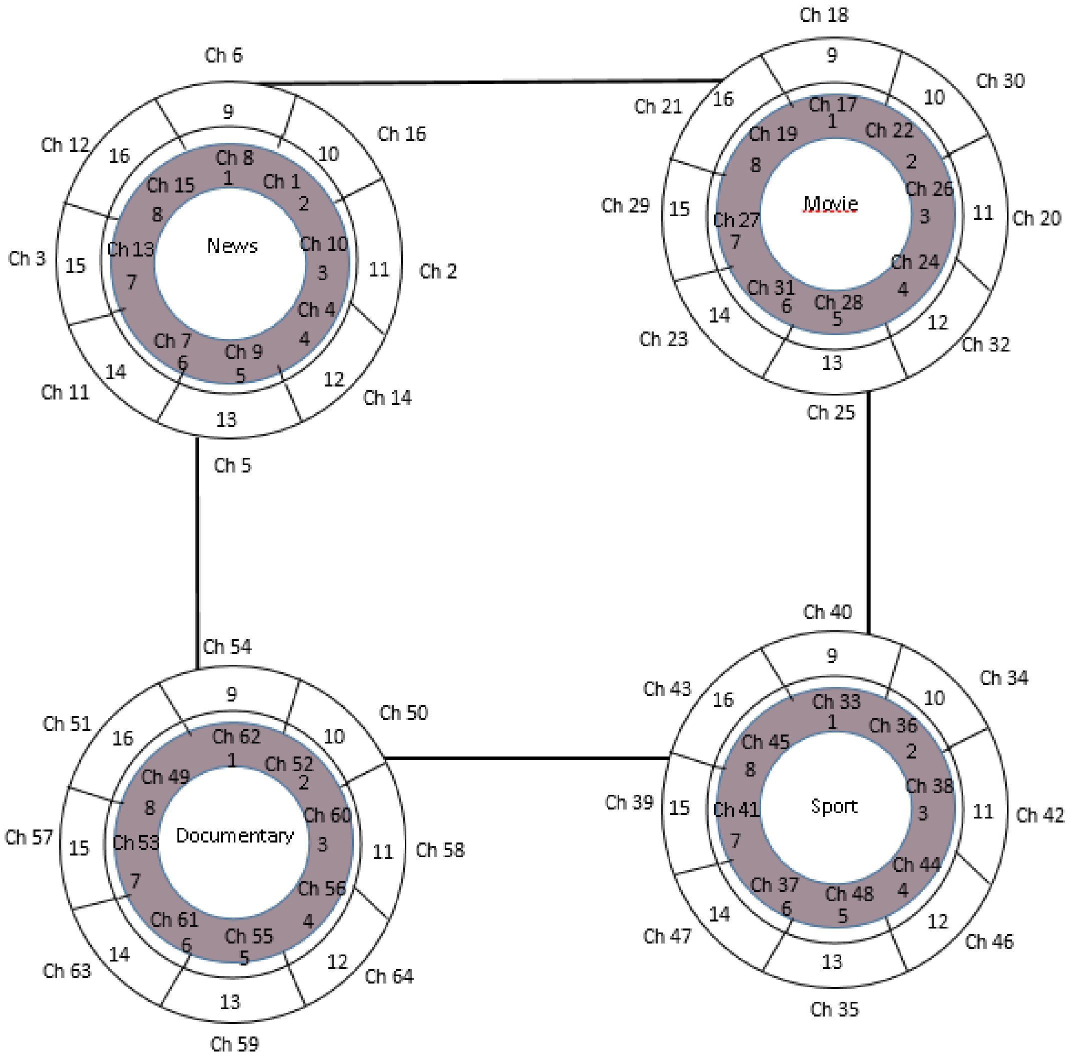


Figure 5.3 Prefetching processes of TGPD when a subscriber chooses a channel

The TGPD algorithm selects the pre-joined channels based on their popularity. In Figure 5.3, a random channel switching sequence for four program channel groups is used to calculate the number of channel switches and average total seek distance in comparison with other conventional schemes. The groups are ordered using the two-list scheme and we have assumed that subscribers of popular groups may want to watch news, movies, sport and documentary. The seek distance in moving from one group to another is one and the seek distance in moving from hot channel list to the cold channel list is also one. Figure 5.4 shows the prefetched popular channels that interest a subscriber among the four groups of program channels.

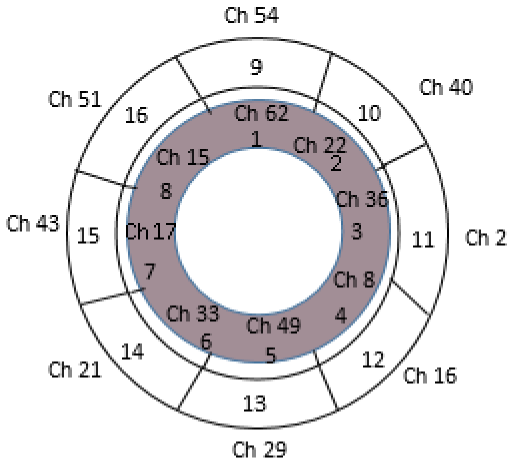


Figure 5.4: Prefetched channels into hot and cold lists from the four different program groups

5.5 Experimental Result Analysis

The simulation experiment of this study was performed by using a pseudo-randomized grouping (Manikandan *et al*., 2014; Lee *et al*., 2014; Zare *et al*., 2016) to validate the performance of the TGPD algorithm. We have assumed in this study that channel popularity is based on how frequent a channel is being viewed and bandwidth is steady and sufficient. Moreover, we have categorized TV channels into four groups, which are news, movies, sports and documentary based on the similar programs the channels offer. The network parameters like end-to-end delay and jitter were not considered during the experimentation to avoid their negative effects.

To determine how channels will be maintained in the hot and cold lists, the viewing rate of a particular channel is multiplied by the total number of traces. If the viewing rate of watching a channel is 0.58, the number of times the subscriber has viewed that particular channel will be 870 out of 1500 traces. Such a channel with a threshold higher than 500 will be maintained in a hot list. Similarly, if the viewing rate is 0.16, the number of times a subscriber has viewed a particular channel is 240 out of 1500 traces and such a channel will remain in the cold list. Figure 5.5 shows the comparison of the TGPD algorithm with the state of the art, Number Ordering (NO), Frequency Circular Ordering (FCO) and Frequency Interleaved Ordering (FIO) for channel switches when TV channel is 20. This result indicates that the TGPD algorithm gives a significant channel switching reduction when the number of TV channels is set at 20.

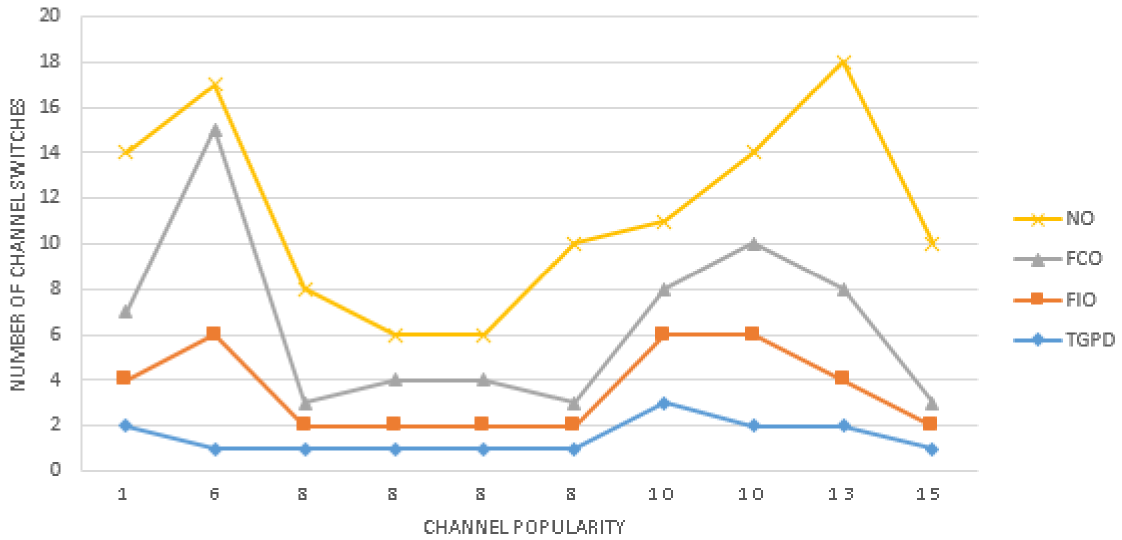


Figure 5.5: The number of channel switches when the number of TV channels is 20

Figure 5.6 shows the comparison of the TGPD algorithm with the conventional schemes when TV channels are 64. This result indicates that the TGPD algorithm consistently gives a significant channel switching reduction with increasing number of TV channels.

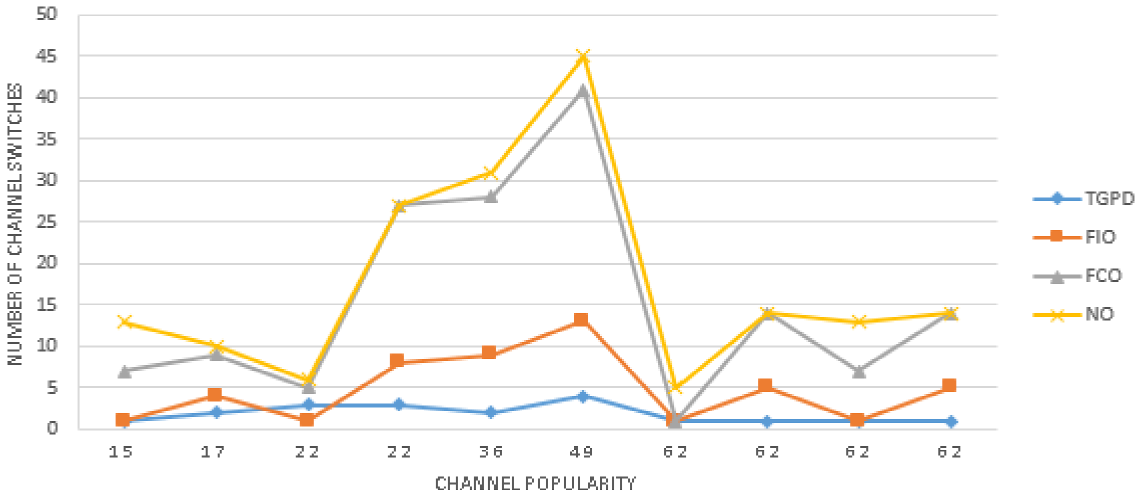


Figure 5.6: The number of channel switches when the number TV channel is 64

The simulation experiment was performed to validate how channels are prefetched from the hot and cold lists with synthetically generated traces. The number of channels requested in the trace is 1500 and the number of distinct channels ranges from 10 to 150. Figure 5.7 shows the percentage of the average seek distance reduction of the TGPD algorithm when compared with other conventional schemes as the channel popularity varies by the Zipf parameter. When the Zipf parameter θ is 0, all the schemes merge to a point, which means that all channels have an equal average seek distance. Moreover, when the Zipf parameter reaches 1, the TGPD algorithm reduces the average seek distance by 58 per cent in comparison to the other schemes.

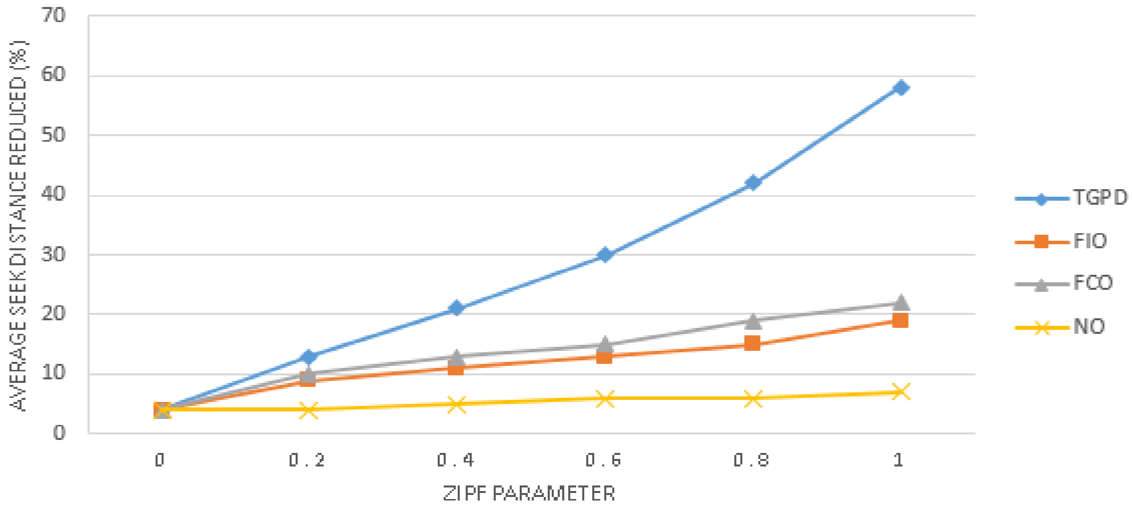


Figure 5.7: Number of channel switches when the number of popular TV channels is 64

The experimental results of this study generally imply that the TGPD algorithm is suitable for addressing zapping delay. The proposed algorithm recorded impressive results when compared to the other schemes investigated in this study because of its ability to prefetch channels from the group of programs. The algorithm will enable subscribers to surf for their desired channel within a limited time.

5.6 Conclusion

This chapter presented the second modular approach of the proposed zapping delay framework for channel navigation in IPTV using an effective two-list group program driven algorithm to address the zapping delay problem in IPTV. The algorithm has been validated through a trace-driven simulation by identifying hot and cold channel lists through different categories of TV programs put together as a group. The channels are being prefetched from a group and stored in a hot or cold channel list based on their popularity. The simulation results of this study show that the performance of the algorithm reported is impressive when compared to other conventional schemes. It can serve as an important tool for reducing the zapping delay time it takes a subscriber to choose the desired channel in the IPTV.

CHAPTER SIX

Fast Channel Switching Using a Personalized Electronic Program Guide

6 Introduction

In this chapter, the third modular approach of the zapping delay framework was discussed to accomplish the fourth objective of this research. The proposed channel delivery and navigation approach in chapter four and five were combined with an extension of the channel navigation approach in chapter five using a personalized electronic program guide with really simple syndication feed. A proposed solution at the subscriber and network level in achieving a drastic zapping delay reduction during channel switching. The adoption of the change from mono-directional push-based traditional media broadcasting to a bidirectional interactive pull based Internet Protocol Television service has observed momentous advancement in recent years due to the vast number of TV channels and applications it provides.

Despite the increase in the deployment of the IPTV systems around the world, channel switching a major functionality in every TV system needs further improvement. Zapping delay in IPTV, a delay that occurs during channel switching brings a major setback to the IPTV system, especially when compared with the traditional television services. In order for subscribers to benefit from the vast number of IPTV channels and video contents, it is imperative for subscribers to instantly and effortlessly surf live TV channels and video content that interest them. This zapping delay problem calls for improvement in order to reduce this painstaking effect on subscribers when choosing their desired channel of interest.

Instead of analysing the behaviour of channels, switching and predicting channels based on behaviour analysis, the proposed approach will enable subscribers to choose their favourite channels from a different genre, into the hot and cold channel list. Where hot channels are channels regularly viewed by the subscriber and cold channels are channels not viewed by subscribers. This approach saves subscribers a painstaking amount of time in searching for the desired channel to watch. This will be effective in reducing zapping delay when compared with several state-of-the-art approaches.

6.1 Background

The rapid spread of IPTV, an evolution of digital broadcasting service, has become a force to reckon with, emerging as an alternative to traditional TV broadcasting delivery systems (Manzato, and da Fonseca, 2013). IPTV offers an attractive package for a diverse range of applications to subscribers, providing tremendous flexibility to network and content providers, opening an avenue for expansion and serving as a great source of income. The services provided by IPTV can be subdivided into two main categories: live video stream and video-on-demand (VoD). Due to bandwidth, limitations, live TV is transmitted over a multicast network after the live raw video has been encoded and forwarded to subscribers at the request of the subscriber, while VoD is stored media content delivered to subscribers anytime when it is requested. Despite the advantages posed by IPTV in offering a vast range of live TV channels and videos across different categories of digital multimedia in different countries, subscribers still find difficulties in choosing desired channels to watch, which then get heightened by zapping delay. It is imperative that IPTV network providers guarantee a higher level of quality of experience than that offered by conventional traditional broadcast TV services.

Subscribers tend to switch between TV channels in no longer than 13 minutes in an IPTV multi-channel system due to the diversity of channel content being aired, or through the natural curiosity of the subscribers, or through the subscribers' inclination to skip commercial breaks (Yang and Liu, 2015). According to Abreu *et al.*, (2013) subscribers preferred ways to switch between TV channels include pushing the TV channel number on the TV remote control or pushing the remote control button in a sequential way or using the up and down remote buttons both with a preference of 57 per cent. Other ways of switching channels are the use of an electronic program guide, or navigation between channels in the same category. These are the least preferred ways, both with 14 per cent preferences.

Diverse approaches have been suggested to guide subscribers in finding the desired channel of interest quickly, an approach implemented to lure traditional TV users to adopt the IPTV service. Such approaches include a recommendation system, EPG and a search engine (Zhang *et al.,* 2016; Yu *et al.,* 2017). The recommendation system enables users to filter preferences and use that information as a point of reference when selecting channels by making a good recommendation to meet subscriber needs of choosing the desired channel. Using either explicit or implicit methodology to capture subscriber preferences and to create subscriber suiting profiles based on channel viewed history, channel switching behaviour, VOD purchased transactions and demographic information (Elmisery *et al.,* 2016).

The recommendation system adopts many technologies such as advanced natural language processing, advanced machine learning techniques, collaborative filtering, data mining, information retrieval and multimedia content analytics. These methods have been developed to automatically generate recommendations for subscribers by suggesting channels that might interest them. Currently, Amazon, MovieLens, Netflix, and Spotify are companies that have deployed the recommendation system to enhance subscribers' quality of experience (Chang *et al.,* 2014). Since recommendation systems rely solely on information obtained from subscribers such as history logs, Unger *et al.,* (2016) claim that the recommendation system may raise privacy issues since network providers are aware of the subscribers' content and such content can be extracted. Furthermore, the service provider can obtain latent content automatically by applying unsupervised learning techniques, although obtaining such content may lead to zapping delay by interfering with subscribers' activities due to a resource demanding task at the back-end.

In some cases, to avoid lawsuits from subscribers due to information extraction, service providers came up with another technique by motivating their subscribers to provide explicit feedbacks based on their preferences. Such techniques include star ratings of the content viewed by the subscriber on a scale of one to five. However, Zhang *et al.,* (2016) queried this star rating technique because such explicit information is not always available due to subscriber's poor participation in rating, and the central characteristics it possesses give a scalability problem, making IPTV channel recommendation sometimes unrealistic and undependable.

In order for subscribers to query search engines are used to match content searched for, in order to locate TV channels and other IPTV content they cannot recommend or predict to subscribers the preferred choice of channel and content to watch. Furthermore, the EPG is also used to guide subscribers' channel switching. It is a program schedule organized in a multi-layer menu that contains the programs' information such as titles, names, specific start and end times, and their playing periods which acts as a guide in an IPTV multi-channel environment stored on the IPTV set-top-box. The importance of this service is increasing due to the ability to obtain scheduling information for both current and future events of TV channels (Beyragh and Rahbar, 2014; Manikandan *et al.,* 2016; Park and Lee, 2016).

6.2 Approaches to Reduce IPTV Channel Switching

Traditional broadcast television service, a study of subscribers' channel switching was not necessary because it was not a challenge. All TV channels are sent to the subscriber at once and the channel change time is less than half a second, making it acceptable to subscribers. With the introduction of IPTV, where a vast number of TV channels are made available to subscribers, network bandwidth became a limitation invariably affecting channel switching and hence, causing zapping delay. Various techniques and approaches have been adopted to reduce zapping delay in IPTV.

One of the prominent approaches was the context-aware recommender systems which deal with modeling and conjecturing subscriber perceptions and preferences incorporate existing contextual information into the recommendation procedure adding explicit categories of data such as time and place in contrast to the traditional recommender system that only deals with two types of entities, the users and items, and does not include these entities when making a recommendation (Adomavicius and Tuzhilin 2011; Steeg, 2015). Furthermore, context-aware recommender system takes the advantage of the neural network system (Krstić and Bjelica, 2012) for live channels to aid subscribers to find channels that would interest them. This system is expended as a classifier tool guesstimating whether a subscriber is enthusiastic about a particular channel program viewed; this system makes use of both program genre and the temporal context data with relation subscriber's viewing habits.

Later Chang *et al.*, (2014) propose a cloud-assisted channel-recommendation system under a cloud computing environment, to speed up the performance of channel switching, in order to help subscribers find their favourite channels in less time. The latent Dirichlet allocation (LDA) based model (Zhang *et al.*, 2016) is another improved recommendation system which considers subscribers playing behaviour as well as the cogent feedback of surfing and history, capturing intrinsic viewing preference of individual subscribers'. The cogent feedback of the LDA is integrated via TV program characteristics. Furthermore, a mutual secrecy approach for curtailing privacy jeopardies in services provided by the IPTV recommendation system (Elmisery *et al.*, 2016) was included, running a middleware on the subscribers' side in order to conceal subscribers information. However if need be to act otherwise such data when unconcealed are used for recommendation purposes. Consequently, for security reasons over subscriber information, a distributed data collection protocol along with a two-phase concealment approach was hard-coded on the middleware in order to give subscribers absolute control of their privacy.

A TV channel prefetching method based on channel popularity (Oh *et al.,* 2010; Lee *et al.,* 2014) was introduced in order to reduce zapping delay in IPTV with hopes of improving subscribers’ quality of experience. Bahn (2016) further presented hybrid methods that combine channel prefetching and reordering methods to reduce zapping delay in IPTV, while personalized channel lists (Kim *et al.,* 2016) for individual subscriber was proposed to also reduce zapping delay. The motivation behind fully intelligent personalised EPG (Kwon and Hong, 2011; Narducci *et al.,* 2017) is that it is supposed to analyse subscribers’ behaviour, such as the viewed history which is included in the subscribers individual information and is exploited to recommend the interested channel programs as at when due in order to help subscriber select a channel of interest.

In recent times much media research has been adopting EPG personalization by using context-aware recommender systems to deliver recommended TV programs to subscribers in order to meet their program needs and to increase their media experience. However, Sailaja *et al*., (2017) explore subscriber stance regarding a personalized electronic program guide that makes use of recommendation system, which accepts subscribers' personal information as input. According to their findings, subscribers rate highly the accrued capabilities provided by the personalization of digital broadcast but were angst-ridden about the implications of retrieved private information about them, particularly with regards to their physical location. This claim served as a motivation for us in this chapter by giving subscribers the autonomy to personalize their EPG with a reminder, without prying into their personal information, an approach that has long been called for by IPTV subscribers, to enjoy the benefits of a personalized EPG while their personal information remains unexploited, in order to increase the level of media experience.

A channel change acceleration method delivery (Cha *et al.,* 2008c) was proposed, which consists of deploying one Fast Channel Change Server (FCC) in the IP backbone in order to send the unicast stream to the STB before sending the normal multicast stream after each channel change. However, deploying such a solution would cause high bandwidth usage in the network because of the huge unicast traffic sent by the FCC server to the STBs (Uzunalioglu, 2009). However, Khabbiza *et al.,* (2017) improved on it by proposing a new solution to reduce zapping delay by using a peer-to-peer approach that reduces bandwidth occupancy of the unicast traffic. Instead of deploying a fast channel change server at the IP backbone they proposed a deployment of the FCC server at the subscriber level that is, on the STB of the subscriber, which implies that the STB will receive the unicast traffic from another STB instead of the central server. However, this approach will cause buffer overload on the subscriber's STB which aids zapping delay

6.3 Proposed TGPD with Personalized Electronic Program Guide

In Figure 6.1 a novel channel switching framework technique was described, based on keywords using the Explicit Semantic Analysis Bag-of-Words (ESA-BOW) model. This model enhances channel program descriptions with updated information of channels in a hot channel list while the RSS feed is used to notify subscribers of an update in the IPTV system. This framework aims to reduce channel switching delay and increase subscribers QoE by giving them autonomy based on their preference using personalized EPG.

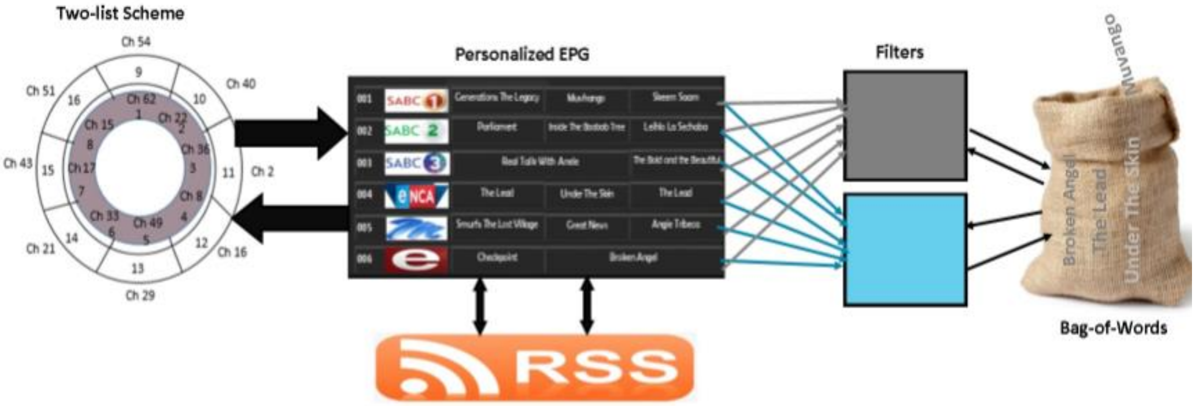


Figure 6.1 TGPD with Personalized Electronic Program Guide

6.3.1 Two-list Group Program Driven Method

The two-list group program driven method is a group program driven algorithm discussed earlier in chapter five, which reduces zapping delay by minimizing total seek distance and total seek time that is, an algorithm that promotes faster channel switching. Selecting the desired program in IPTV can be difficult among hundreds-thousands of channels available, thereby increasing the channel switching rate. This method groups similar programs of channels into similar categories, such as news, movies, sports, music, documentary, etc. as shown in Figure 6.2, making it easier for channels with similarly aired programs to be identified by the subscriber out of the enormous number of channels IPTV offers. These channels are requested using a group two-list method, which is being used in managing two separate lists for the hot and cold channels.

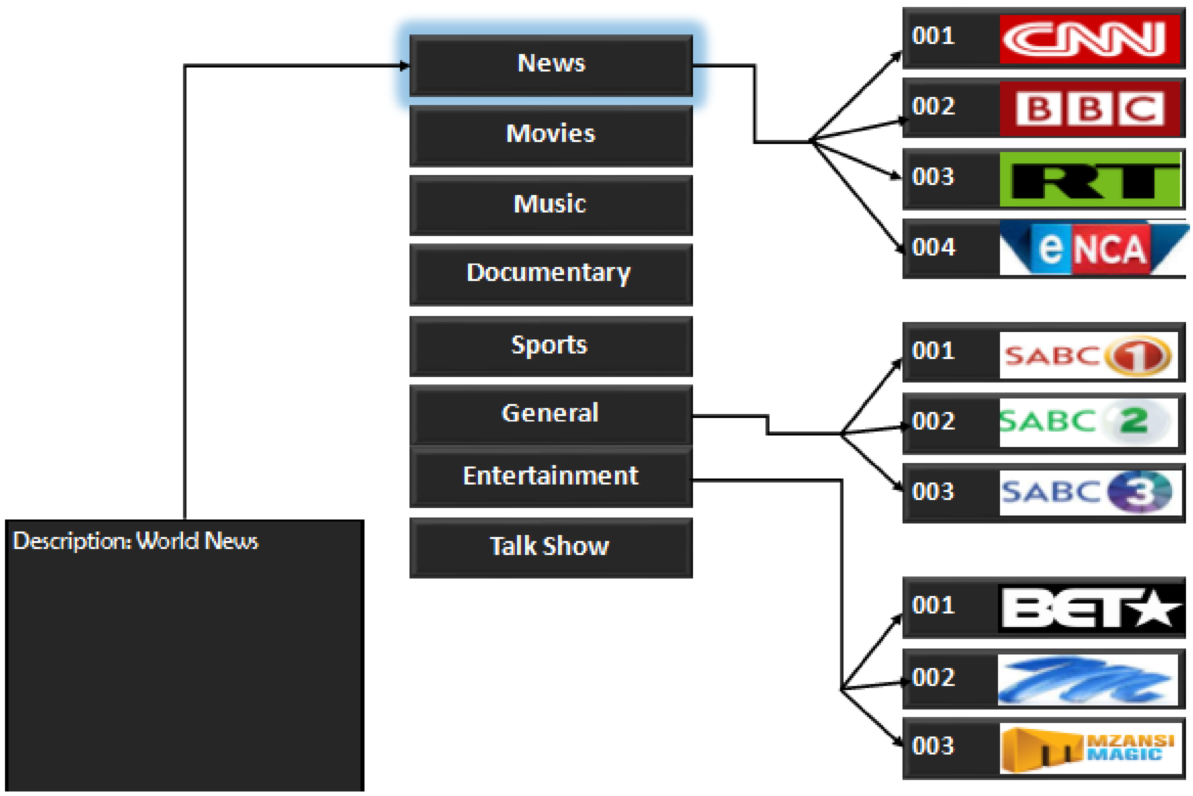


Figure 6.2: Channel Categories

Figure 6.2 depicts channel categories across different genres where subscribers will be able to select their preferences at setup. All channels in different categories are placed in the cold channel list. At setup stage, subscribers can then choose channels based on preference, with the help of genre description and channel description to suit their channel preferences. The channels selected based on preference will be placed into the hot channel list, such channels will remain in the hot channel list as long as subscribers keep viewing the channel, otherwise the channel will be removed from the hot channel list to the cold channel list. The advantage the two-list method provides is that channel preferences can be updated at subscribers' will.

The algorithm which recommends that programs of TV channels are scheduled on EPG is based on the most popular channels, where channel popularity is computed on a per-subscriber basis on channels in the hot channel-list. The popularity of a channel is defined in terms of the rate (R) of watching a channel over a period of time (T). This popularity of channels (P_i) in the hot channel list is therefore defined as:

$$P_i = R_i T_i \qquad (6.1)$$

6.3.2 Proposed Personalized Electronic Program Guide

The advent of digital television and IPTV coupled with the unprecedented volume of live TV channels and video content available for subscribers to choose from has caused a new level of information overload leading to channel switching delay time. The electronic program guide (EPG) which provides IPTV subscribers with continuous updated scheduled program details for current and upcoming channel program events is seen as a partial solution to reduce the channel switching time (Narducci *et al*., 2017). Presently, the traditional EPG as shown in Figure 6.3, gives an electronic equivalent of a printed channel program guide to the traditional broadcasting service which only itemizes the programs broadcasted by the content providers with no procedure for personalization or recommendation to match subscribers' program needs and preferences. The proposed personalized EPG eliminates the traditional mono directional channel limitations, offering subscribers with bidirectional personalized channels, which include only programs that interest subscribers' such channels are hereby selected in the hot channel list.

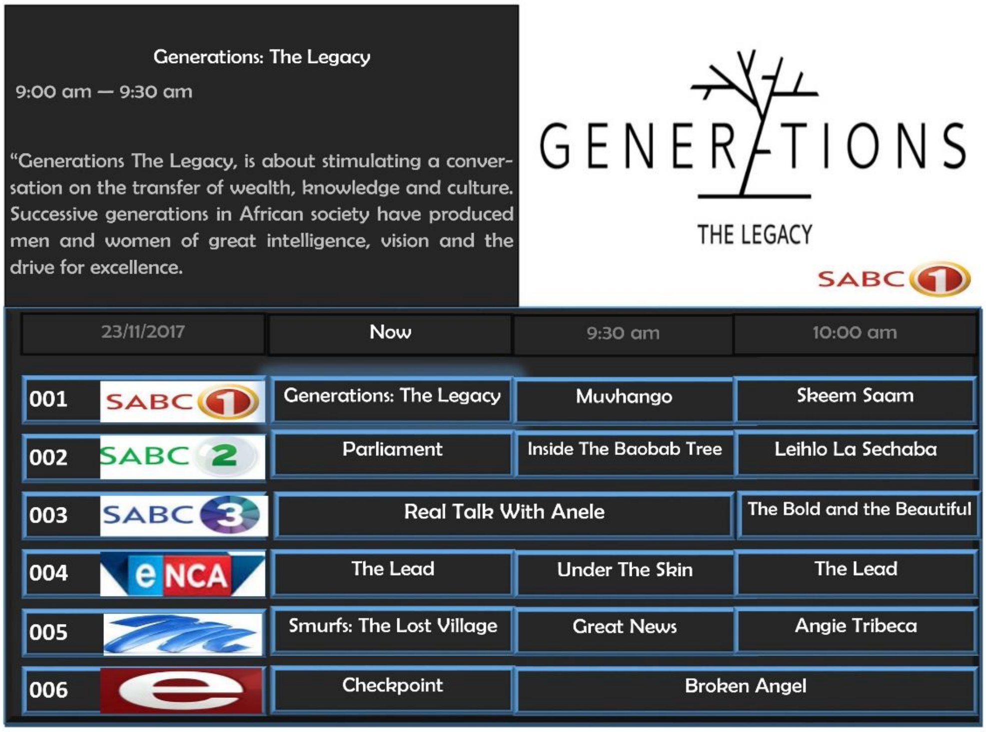


Figure 6.3: Electronic Program Guides

Typically, recommendation technologies are seen as a way of making traditional EPG intelligent; the ability to personalize EPG gives subscribers a level of support to find and watch programs that interest them. Therefore, this research work exploited the use of reminders giving subscribers the ability to set what program they are interested in based on the explicit preference of channels in the hot channel list, thus giving them the ability to personalize their EPG. Figure 6.4 depicts a subscriber setting a reminder for an upcoming program. However, the set reminder on the EPG only allows delivering of the subscriber's targeted program on the hot channel list as long as the channel remains on the hot channel list.

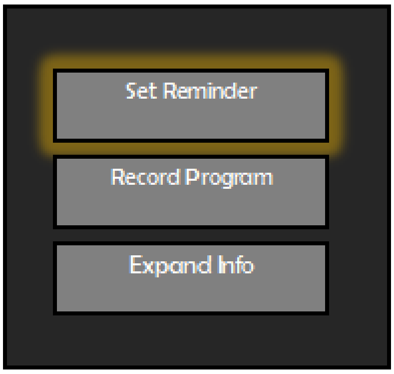


Figure 6.4: Electronic Program Guide with Reminder

6.3.3 Techniques for Program Representation

In this section, two major techniques for program representation was highlighted and they include a bag of words (BOW) and an explicit semantic Analysis bag of words (ESA-BOW) which are used for the textual description of TV programs.

6.3.3.1 Bag of Words

The successful implementation of text categorization (Joachims, 1998), a technique used to classify news reports, in order to discover fascinating information on the world wide web, and to pilot user's exploration via hypertext, led to the introduction of bag-of-words (BOW). A widespread approach for representing not only text but also image content inclusive, which has led to successful implementation to image classification, natural language processing and information retrieval (Zhang et al., 2010).

According to Wu *et al.*, (2016), the BOW model was initially used for text retrieval at inception, and then subsequently transferred to the other fields such as image retrieval and image classification. This model presents an efficient approach used in quest of images with visual expressions as it works satisfactorily despite the enormous amount of data at disposal.

The BOW model offers an effective, easy to medium difficulty text categorization tasks where the categorization of a sentence or document can be identified by several easily distinguishable keywords. In BOW, keywords used within sentences or a document are represented as a multi-set of the word without considering grammatical errors or word order but are kept as a large set. Pruning of this keyword multi-set is vital because of grammatical errors that might exist in either a sentence or a document. In order to solve this challenge in BOW, stop word removal and stemming are applied, which will have no negative impact on the keyword of the sentence or document (Marinai *et al.,* 2011; Kren *et al.,* 2017).

The Bag-of-Words model is one of the easiest ways to characterize textual data as BOW representation has recently been improved and has been used in medical sciences for classification of health-related text while adapting the machine learning algorithm in Natural Language Processing (NLP) techniques (Hughes *et al.,* 2017). However, due to the BOW simplicity in representing textual data, Narducci *et al.,* (2017) suggest the BOW model can be used for EPG channels, that is, the description of channel program in digital television. The core inkling behind this model is to describe each item through listing the keywords that are seen within the text. Given an item i, described by characteristics (c_1... c_n), the BOW representation of the item i is therefore represented in equation 6.2:

$$bow_i = \{(c_1, w_1), (c_2, w_2), ..., (c_n, w_n)\} \qquad (6.2)$$

Given that w is the weight of the word (characteristic) c. The weight can be calculated by diverse weighting approaches, which varies from the simple Boolean approach, centred on the simple counting of the occurrences (even normalized) of features in the documents, to the more complex term frequency-inverse document frequency a statistic that reflects the importance of a collection of words in a document.

6.3.3.2 Explicit Semantic Analysis BOW

Explicit Semantic Analysis (ESA) Bag-of-Word model (Gabrilovich and Markovitch, 2006), is a method for explicit semantic representation, a feature generation process for general domain natural language texts. Explicit Semantic Analysis Bag-of-Word (E-BOW) is a model that is associated with text categorization, semantic relatedness and information retrieval (Egozi *et al.,* 2008) where a program description set of related concepts is automatically derived from large-scale repositories such as Wikipedia. However, because Wikipedia has a large volume of concepts and articles that are expressed efficiently and accurately, it is therefore seen as a large corpus of documents $D = \{d_1, d_2... d_m\}$, which defines a set of concepts $C = \{c_1, c_2... c_n\}$, each one identified by the title of the corresponding article (Son *et al.,* 2013).

How related is “Muvhango” and “Generations: The Legacy”? Soap operas aired on South Africa TV stations and what about “eNCA” and “SABC1”, TV stations also in South Africa. The relationship and description between the soap operas and the TV channels that air them is a significant and widely studied question in Natural Language Processing in building the relevance between the program and the TV Channels that air such program. There are various techniques for representing textual documents which include BOW in vector space (Baeza-Yates and Ribeiro-Neto, 1999), using lexical resources, and using latent semantic analysis (Wang *et al*., 2008). In the proposed approach, a basic semantic relatedness of text documents represented using the BOW for the personalized EPG were used for the purpose of the research work.

The advantage of using Wikipedia is that it exploits the open source knowledge in which information is promptly updated. To this end, this research work adopted Wikipedia for the ESA-BOW approach for text classification where the relationship between the Wikipedia corpus documents D is represented by an ESA matrix T in which each concept c corresponds to the column while the row corresponds to the keyword in the document D. The cell T (i, j) holds the TF-IDF (term frequency–inverse document frequency) a statistical value that is projected to reveal how significant a word is to a document d_j of term t_i in a corpus (Musto *et al.*, 2012; Leskovec *et al.*, 2014) which is represented by the association between term t_i and concept c_j as shown in Figure 6.5. It is worth to note that TV programs have dedicated pages on Wikipedia, which makes the ESA-BOW work easier during classification.

		Wikipedia articles				
	ESA	C_1	C_2	C_3	…	C_n
Terms occurring in at least 5 Wikipedia articles	T_1	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**
	T_2	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**
	T_3	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**
	…	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**
	T_k	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**	**TF-IDF**

Figure 6.5: Explicit Semantic Analysis (ESA) Matrix

ESA-BOW possesses an advantage that helps streamline the description of a keyword from varieties of related keywords that may be available. For example, the description of the soap opera Generations: The Legacy may have several descriptions in the Wikipedia corpus. However, ESA-BOW will streamline the keyword that is, the soap opera title to the TV channel station airing it. In achieving this it uses an NLP operation such as a stop word removal and stemming in order to get the corresponding description to the keyword issued. It is worth to note that the highest TF-IDF will be displayed when the term is matched with the content as shown in Figure 6.5.

6.3.4 Really Simple Syndication (RSS) Feed

Really Simple Syndication, a feed system propagating eXtensible Markup Language (XML) documents containing short descriptions of web updates which enable IPTV subscribers to subscribe to a feed that they are interested in of channels in the hot channel list, a feed they receive periodically in order to get the channel and program updates (Wusteman, 2004; Liu *et al.*, 2005; Kim and Lee 2008). Any new update in the IPTV system will be published by putting it into the RSS feed. Thereafter, the RSS reader or aggregator will poll the feed periodically and display the updates to the subscriber. There has been some uproar in literature debating if RSS feed will add to IPTV zapping delay by using up the network bandwidth.

However, according to research carried out by Liu *et al.*, (2005), an RSS feed is relatively small and it is less than 10KB, while the minimum RSS feed size is 356 bytes, and 99.9 per cent of the feeds are smaller than 100KB. The system architecture of RSS as shown in Figure 6.6 consists of four major components:

- RSS Provider - the originator of the published feed
- RSS Collector - it intermittently collects latest feed contents for digital channel information and contents from RSS provider
- RSS Manager - permits the RSS Manager to configure a bi-directional metadata server for data collection, which also assumes the role of an integrated manager for live TV metadata contents stored on the metadata database.
- Subscriber Terminal- It gives access to periodically updated news to IPTV subscribers that subscribe to the RSS feed

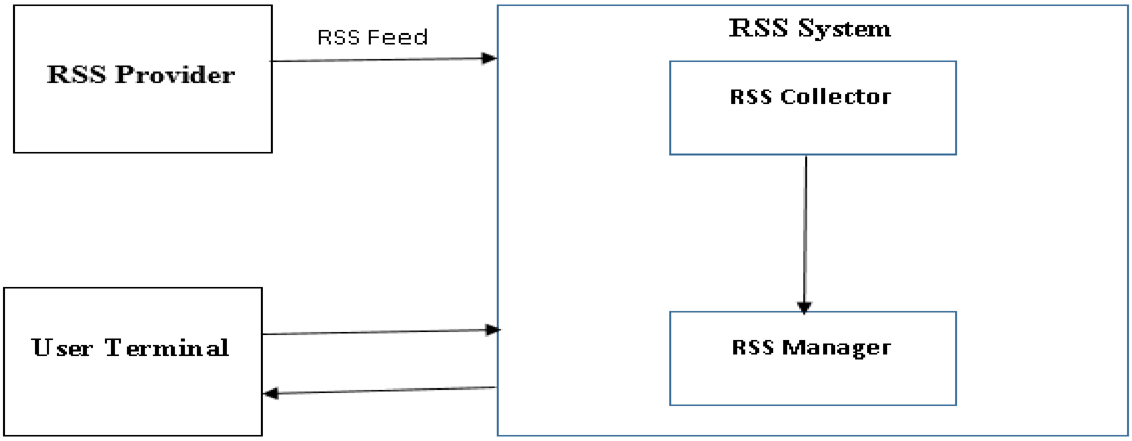


Figure 6.6: RSS Architecture

The architecture of RSS is quite simple. In Figure 6.6, the service provider is the originator of the RSS feed, while the RSS collector collects and extracts multimedia content and data for an RSS feed, the RSS manager allows the system to set some factors such as genre, and keywords with which the RSS Collector would retrieve updated information, content and at the subscriber terminal, the subscribers using a user interface subscribes to a feed that they are interested in and pulls the feed periodically to receive updates.

The proposed Personalized EPG service can be expanded in IPTV by using it with RSS. The RSS version ranges from version 0.90 to the latest version 2.0.1. It is a system that enhanced IPTV subscribers' QoE. Figure 6.7 depicts a sample of an RSS XML file. Expedient RSS data for information update services are elements for each news item, that is, title, link, description, pubDate, and author (Lee *et al.*, 2007).

```
<?xml version="1.0" encoding="UTF-8" ?>
<rss version="2.0">
 <channel>
<title>eNCA News</title>
<link>http://enca.co.za/</link>
<description>Breaking News.
</description>
 <language>en-us</language>
<pubDate>Tue, 21 Nov 2017 15:00:00 GMT
</pubDate>
 <lastBuildDate>Tue, 21 Nov 2017 17:20:01 GMT
</lastBuildDate>
<docs>http://blogs.enca.co.za/tech/rss
</docs>
</channel>
</rss>
```


Figure 6.7: RSS XML File

6.4 Proposed TGPD with Personalized Electronic Program Guide Dataset

We used user behaviour-based synthesis dataset (Abdollahpouri *et al.,* 2017) for modelling IPTV subscriber's preference. This dataset was created from MovieLens dataset which was collected by the GroupLens Research Project at the University of Minnesota. The dataset was acquired from the MovieLens website (movielens.umn.edu) from September 1997 through August 2017. The information about the dataset was streamlined in order to create a subscriber's preference trace file an artificial dataset based on subscriber's preference of channels available on the hot channel list (http://eng.uok.ac.ir/abdollahpouri/UBSDI/UBSDI per cent28Preferences per cent29.txt).

This dataset was adapted because regular IPTV datasets are not available in the public domain, hence, the adapted dataset consists of a trace file captured for a period of two months for 6040 subscribers. The data in the dataset were assigned to 50 channels and they are composed of 588,698 TV shows. In Figure 6.8 the descriptions of program distribution on the 17 different genres and the number of TV shows per genre were illustrated. The following are the genres captions: Action, Adventure, Animation, Children, Comedy, Crime, Documentary, Drama, Fantasy, Horror, Musical, Mystery, Romance, Sci-Fi, Thriller, War, and Western (Shambour and Lu, 2011).

In Table 6.1 the 50 IPTV channels are grouped with several genres from the dataset represented in Figure 6.8 such as Channel1 (Action), channel11 (Drama), Channel 24 (Thriller and Documentary). As it can be seen in Figure 6.8 it depicts a descriptive analysis of the dataset, however, the dataset is quite unbalanced towards some genres (i.e. Program types) such as Comedy, Drama, Action, and Thriller unlike other types of the genre with small numbers such as Fantasy and War.

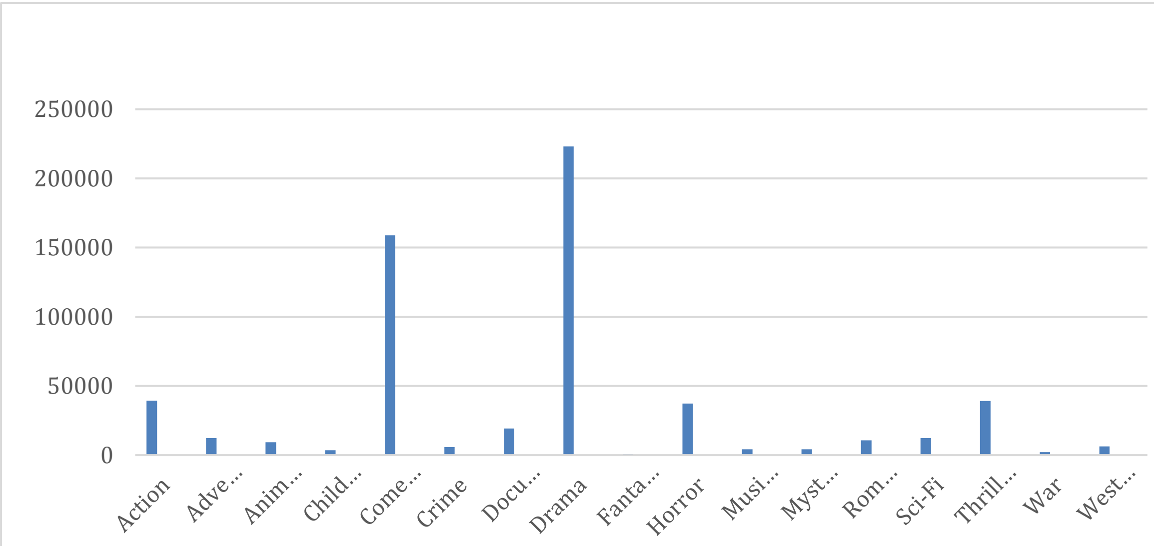


Figure 6.8: Distribution of TV shows among 17 different genres

After the genre distribution into the 50 channel list, Table 6.2 depicts an instance of the dataset; the first 100 IPTV subscribers with their subscriber identity along with the number of switches that occurred in peak period over a period of a week. It also depicts the number of channels in the hot-list based on subscribers' preferences across the number of genres the channels are being selected from. The minimum and maximum duration before the channel change was also represented and finally the most popular channel based on the rate of watching a channel over a period of time. It can be seen that channel 14 from the drama genre was the most watched channel.

Table 6.1: IPTV Channels and Their Genre Category for 50 Channels

Channel	Genre
Channel1	Action
Channel2	Adventure
Channel3	Animation
Channel4	Children
Channel5	Comedy
Channel6	Comedy
Channel7	Comedy
Channel8	Crime
Channel9	Documentary
Channel10	Documentary
Channel11	Drama
Channel12	Drama
Channel13	Drama
Channel14	Drama
Channel15	Drama
Channel16	Fantasy
Channel17	Horror
Channel18	Horror

Channel19	Musical
Channel20	Mystery
Channel21	Romance
Channel22	Sci-Fi
Channel23	Documentary, Thriller
Channel24	War
Channel25	Western
Channel26	Action
Channel27	Action
Channel28	Action
Channel29	Action
Channel30	Action
Channel31	Adventure
Channel32	Animation
Channel33	Children
Channel34	Comedy
Channel35	Comedy
Channel36	Comedy
Channel37	Comedy
Channel38	Comedy
Channel39	Comedy
Channel40	Crime
Channel41	Drama
Channel42	-
Channel43	Drama
Channel44	Drama
Channel45	Drama
Channel46	Drama
Channel47	Horror
Channel48	Horror
Channel49	Mystery
Channel50	Sci-Fi

Table 6.2: Number of Channel Switches for 100 IPTV Subscribers

No/ Sub_ ID	Number of switches	Number of channels	genre	Min duration before switch	Max duration before switch	popularity
1 (2)	84	22	10	2s	3770s	14
2 (3)	56	17	10	2s	2178s	14
3 (4)	66	23	14	2s	2940s	14
4 (6)	113	21	10	2s	2687s	14
5 (7)	121	20	11	2s	3775s	14
6 (8)	44	14	11	2s	2819s	14
7 (9)	77	17	11	2s	2835s	14
8 (10)	70	20	13	2s	1098s	14
9 (12)	174	25	13	2s	4154s	14
10 (13)	31	12	7	2s	1509s	14
11 (15)	89	20	11	2s	3128s	14
12 (17)	84	23	10	2s	2234s	14
13 (18)	98	22	13	3s	2722s	14
14 (19)	77	21	14	2s	1611s	14
15 (21)	127	22	13	2s	3092s	14
16 (22)	18	8	4	2s	5416s	11
17 (23)	138	27	14	2s	3020s	14
18 (24)	114	22	12	2s	2804s	14
19 (26)	29	12	9	2s	3262s	14
20 (27)	167	31	14	2s	4383s	14
21 (29)	34	17	10	3s	2599s	14
22 (30)	147	26	13	2s	4481s	14
23 (31)	33	11	7	2s	2376s	14
24 (32)	50	19	12	2s	3097s	14
25 (33)	27	12	8	3s	4179s	14
26 (35)	450	26	16	2s	4362s	14
27 (36)	107	23	12	2s	2334s	14
28 (37)	163	21	12	2s	4232s	14
29 (40)	22	10	7	3s	2979	6
30 (41)	97	25	13	2s	2585	14
31 (42)	73	23	12	2s	3092s	14
32 (43)	147	26	12	2s	3181s	6
33 (44)	293	31	15	2s	3985s	14
34 (46)	64	19	11	2s	2781s	14
35 (47)	103	21	11	2s	2880s	14
36 (48)	194	26	13	2s	3997s	14
37 (51)	31	15	9	2s	4419s	14
38 (54)	28	15	10	2s	2816	14
39 (56)	8	6	5	6s	1685s	18
40 (57)	597	36	16	2s	6393s	14
41 (58)	90	23	14	3s	2999s	14
42 (59)	45	18	12	2s	2651s	7
43 (60)	34	14	9	2s	1969s	14

44 (61)	42	16	11	2s	1041s	7
45 (64)	170	29	15	2s	4918s	14
46 (65)	19	8	6	2s	3254s	7
47 (66)	57	16	10	2s	3867s	14
48 (67)	84	21	12	2s	2169s	14
49 (68)	125	22	11	2s	4285s	14
50 (71)	39	18	10	3s	2516s	14
51 (72)	203	28	15	2s	2292s	14
52 (73)	63	18	12	2s	2385s	14
53 (74)	141	25	11	2s	4405s	14
54 (75)	214	27	15	2s	4637s	14
55 (76)	5	4	2	4s	2075s	7
56 (77)	174	31	12	2s	4632	14
57 (78)	38	14	8	2s	2830s	7
58 (79)	37	21	11	2s	3859s	6
59 (80)	187	28	15	2s	2976s	14
60 (81)	121	20	13	2s	2931s	14
61 (83)	122	22	11	2s	3169s	14
62 (85)	82	22	11	2s	3158s	14
63 (87)	79	23	13	2s	8013s	14
64 (88)	31	15	11	3s	3573s	7
65 (89)	293	31	17	2s	5486s	14
66 (90)	124	25	14	2s	4652s	11
67 (91)	172	29	16	2s	3205s	14
68 (92)	252	28	15	2s	4539s	14
69 (94)	66	20	12	2s	3079s	7
70 (95)	32	13	7	2s	1630s	14
71 (96)	104	20	12	2s	3010s	14
72 (97)	35	15	11	2s	5036s	1
73 (98)	323	30	15	2s	3781s	14
74 (99)	34	15	10	2s	2781s	11
75 (100)	157	23	13	2s	5252s	14
76 (101)	230	33	14	2s	3021s	14
77 (102)	160	26	13	2s	3385s	14
78 (103)	65	16	12	2s	2781	14
79 (104)	48	20	11	3s	2836	14
80 (105)	50	18	10	2s	4254s	14
81 (106)	176	24	12	2s	5934s	14
82 (107)	91	21	14	2s	2593s	14
83 (108)	176	22	13	2s	2684s	14
84 (109)	15	8	7	3s	2698s	14
85 (110)	135	27	15	2s	3754s	14
86 (114)	23	11	8	3s	1729s	14
87 (115)	62	16	11	2s	1274s	7
88 (116)	118	25	13	2s	2621s	14
89 (117)	63	13	6	3s	3921s	24
90 (118)	126	23	13	2s	3351s	14
91 (119)	32	13	7	3s	6984s	13

92 (122)	285	28	15	2s	3033s	14
93 (123)	55	20	10	3s	3919s	14
94 (124)	25	11	6	4s	3614s	14
95 (126)	90	20	12	2s	6040s	14
96 (128)	79	18	10	2s	3140s	6
97 (129)	82	19	12	2s	3992s	24
98 (130)	65	20	10	2s	3902s	14
99 (131)	114	24	11	2s	2875s	6
100(132)	141	23	12	2s	6619s	14

6.5 Implementation of TGPD with Personalized Electronic Program Guide

This research work implemented the two-list method with personalized EPG on a raspberry pi 3 B model using free IPTV channels. It is worth noting that these IPTV channels were only used for educational purposes and for the purpose of this research with no intention of commercializing. The result achieved was analysed and compared with various OTT services and YouTube.

45 channels were selected in the hot channel list from over 500 working channels available across different genres, which can be accessed on https://pastebin.com/9rnRHnhx. This implementation setup was configured over a Durban University of Technology network that entails a converged network. Figure 6.9 shows the average time it takes for channel switching across five different platforms compared with the proposed approach over a period of a month. It can be seen that the proposed approach has the lowest channel switching time when compared to YouTube that makes use of the recommendation system and other approaches that make use of the search engine approach. Based on this experiment, it can be seen that the proposed approach gives subscribers the ability to dictate their priority based on preference per subscribers and not based on popularity and recommendation approach.

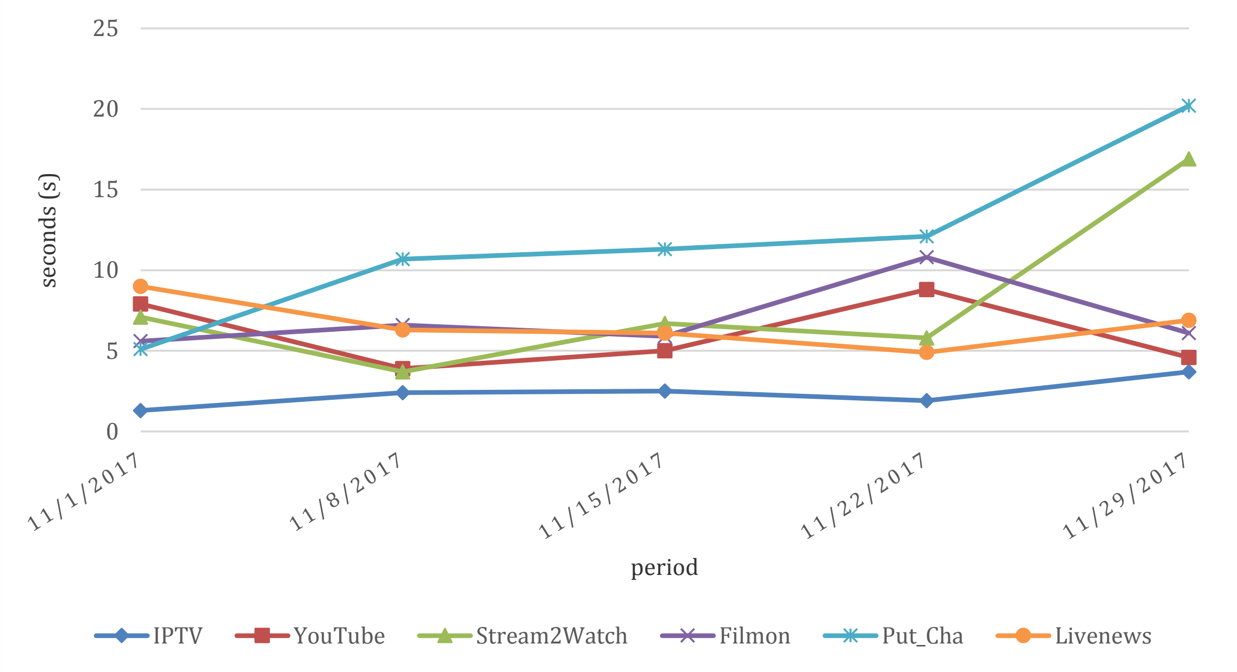


Figure 6.9: Time Taken for Channel Switching

6.6 Conclusion

In this chapter, this research work developed a fast channel navigation using a group program driven two-list method with personalized EPG and RSS feed. A description of the program using the personalized EPG through text classification with the help of ESA-BOW techniques, which help aid subscribers in choosing the desired channel into the hot-list of the two-list method, was highlighted. Furthermore, an RSS feed that notifies the subscriber of an update and changes was also used to aid subscribers in choosing a channel. Although IPTV dataset is not made public for security reasons this research work adopted a dataset crafted from the Movielens dataset to explain channel switching in the hot-list based on the subscriber's preference. Finally, the framework was implemented on the raspberry pi 3B and compared with five other OTT service applications as observed it can be concluded that the proposed approach outclassed other approaches with regard to performance during channel switching.

CHAPTER SEVEN

Subscribers Perceptions on Video Sequence Images

7 Introduction

This chapter presents the fourth modular approach of the zapping delay framework was discussed to accomplish the fifth objective of this research. The purpose of this chapter is to analyse subscribers' perception of video sequence images and to evaluate the video displayed from the first three modules of the proposed zapping delay framework using the saliency detection algorithm to validate the quality of experience (QoE). Salient object detection is a visually important region in a video sequence image that captivates the attention of subscribers. The validation of the quality of experience in this chapter is important as it is used as a criterion to analyse how subscribers perceive the video sequence images viewed through the Internet Protocol Television (IPTV) set-top-box.

The ubiquitous utilization of video application such as IPTV in recent years has made research on the video quality of experience paramount. Raw video contents cannot be transmitted to subscribers due to lack of bandwidth which gave rise to encoders which are being used in compressing video contents for easy transmission over the Internet Protocol infrastructure.

The perception of subscribers' on quality of encoded and decoded non-stationary video received from digital video application varies because of the complex nature of human vision system. Consequently, the automatic detection of the salient object is useful in determining subscribers' perception of video quality. Researches in this area have been subjective in nature and cannot be relied on in giving a concrete result about the perception of subscribers'. To address this limitation this research work used SSLS detection algorithm as a tool for detecting the salient object taking the advantage of multi background detection potential of the algorithm.

The SSLS detection algorithm was applied to 140 video sequence images across two datasets and evaluated with eight different popular quantitative metrics. Experimental outcome illustrates that the SSLS outperformed other benchmarked saliency detection algorithms more effectively for difficult video sequence cases highlighting salient objects uniformly suitable for analysing the perception of subscribers' on video sequence images.

7.1 Background

Multimedia services such as digital video-based applications (IPTV) are transmitted through the IP network infrastructure, unlike other terrestrial broadcasting services that broadcast all video channels and services to the subscriber. IPTV has a bandwidth limitation hence, TV channels and services are forwarded to subscribers on request. The lack of bandwidth availability in IP networks gave rise to the use of different video coding standards. The high-efficiency video coding (HEVC) standard is a hybrid coding method that introduces robust and powerful coding tools in acquiring compression efficiency when compared to its predecessors H.264/AVC (Corrêa *et al.,* 2012; Podder *et al.,* 2016).

The H.264/AVC allows encoding at a significantly lower bit rate that may impair the quality of video through bit errors and loss of the video packet although HEVC improved on the coding standard, but higher coding adeptness is unfortunately attained at the expense of substantial surge in computational intricacies, mainly resulting from much more demanding processing requirements aiding video zapping delay (Engelke *et al.,* 2010; Li *et al.,* 2012). This limitation caused by different coding standards for compressed video sequence images over the IP infrastructure gave rise to the study of video QoE in order to offer subscribers' a high-level quality of experience.

Human vision has a cognitive mechanism that can concentrate on salient objects quickly in a crowded visual scene with multifaceted backgrounds without training because of the existence of the human visual attention. The part of a video that captures human attention is said to be the salient part of the video image where people focus when looking at any video scene. Therefore, humans can deal effortlessly with broad object detection well (Lou *et al*., 2016). The outcome of salient object detection is generally a saliency map where the intensity of each pixel denotes the possibility of that pixel belonging to the salient object (Guo and Zhang, 2010; Wang *et al.,* 2015; Souly and Shah, 2016).

Saliency detection is widely used to extract and focus on a salient object automatically, which will captivate the human eye's attention in the images (Kuen *et al*., 2016). Capturing the region of interest is the key step in object detection for various image processing applications which include: object detection and recognition (Girshick *et al.,* 2014; Dollar et al., 2014), video compression (Itti, L. 2004; Hadizadeh and Bajic, 2014) video summarization (Potapov *et al.,* 2014; Gong *et al.,* 2014), and video QoE assessment (Luo et al., 2014) to name a few. Recently, numerous salient object detection models have been recommended for the compressed video domain. However, videos over the public domain, such as the Internet is always collected in a compressed format, such as MPEG4 Visual, H.264, MPEG2, and of recent the HEVC (Guo and Zhang, 2010; Fang *et al.*, 2014).

A key issue in video saliency detection is how to effectively capture the moving object and intrinsic properties of the video sequence as well as their associated contextual structure (GOP) (Chen *et al.,* 2017; Wei *et al.,* 2017). Saliency detection can be used to assess the video quality of experience by identifying the important parts of a video, predicting the human gaze in extracting the region of interest and perception of subscribers on video quality. The perceptual characteristics of the video sequence images are also obtained to measure the importance of each pixel and then combined to detect the salient object, which results in computing the saliency map. Such that when high pixel intensity is obtained it indicates the detection of the vital pixel of the image; thus saving limited system resources in image processing and computer vision applications (Lee *et al.,* 2016).

Object detection in video images is a binary classification problem aiming to separate foreground pixels from the background pixels of a video sequence image (Perazzi *et al.,* 2016; Zhang *et al*., 2017) which has led to the development of countless video object detection algorithms to address the problem. Khoreva *et al.*, (2016) and Shen *et al*., (2014) explain that video object detection algorithms rely mostly on superpixels at the starting point which directly impacts the final segmentation quality. However, there is a gap in analysing subscribers perception of a viewed video quality for video sequence images in order to aid a high-level QoE perceived by the subscribers. To this end, the SSLS object detection algorithm was used to separate the foreground pixels from the background pixels so as to extract the salient object from the video sequence images. To measure the performance of the SSLS algorithm, eight popular quantitative metrics were used to measure the effective response towards video sequence images based on subscribers perception.

Interpreting subscribers' perception is very challenging as different subscribers have a different opinion about a video sequence image viewed. To this end, the five-point range mean opinion score (MOS) scale excellent, good, fair, poor, and bad as defined by the ITU recommendation BT 500 was adopted in this research work to measure subscribers perception of video quality via detection of a salient object in a video sequence image (Segura-Garcia et al., 2018). Figure 7.1 shows the relationship between subscribers' semantic knowledge of video quality (qualitative) and the observation, analysis of the video quality (quantitative).

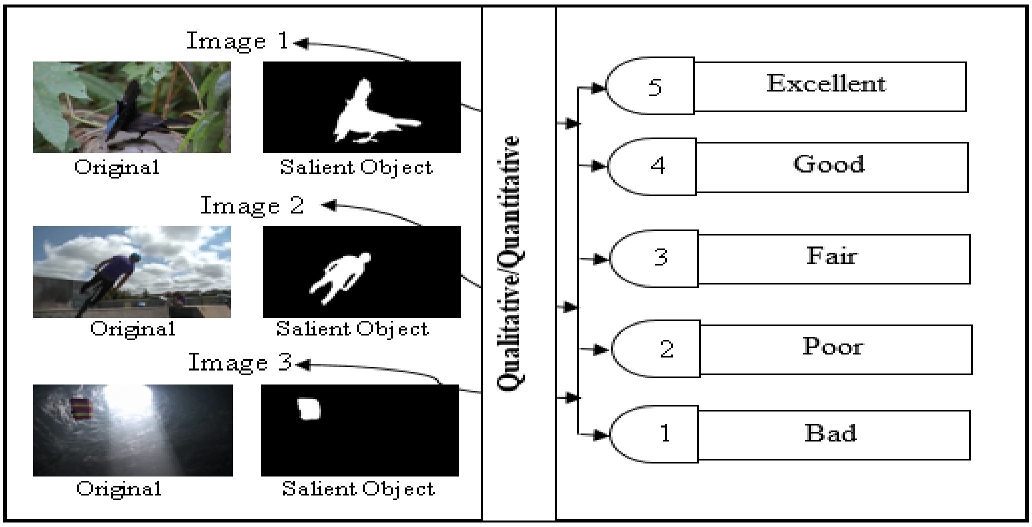


Figure 7.1: Relationship between Subscribers' Semantic Knowledge and Observation Analysis of the Video Quality

7.2 Salient Object Detection

The subjective perception of subscribers on video quality can be subtle in detecting a probable salient object in a video image sequence in order to aid quality of experience. This gap leads to this research work in adopting an object detection algorithm that will detect the absolute salient object within difficult video sequence images while popular quantitative metrics is implemented to help analyse the perception of subscribers on the video quality of the image viewed.

Previous work that simulates saliency detection includes Jiang *et al.*, (2013) who proposed the Markov Chain (MC) saliency detection algorithm where it absorbs the Markov chain on the image pixel graph. A virtual boundary point on the image is chosen as the absorbing point in a Markov chain and then the absorbed time for each transient point to boundary absorbing point is computed. The salient object that is the foreground pixel of the image can be consistently separated from the background pixel when the absorbed time is used as a metric. The absorbed time of transient point calculates its global similarity with all-absorbing points.

Margolin *et al.,* 2013 further proposes a widespread and proficient algorithm called the Principal Component Analysis (PCA), which divulges the internal structure of an image that could help solve missing homogeneous regions of the salient object and detect patterns that are distinct, such as the boundaries between a foreground pixel and the background pixel. It further detects the components that best elucidate the inconsistencies in the pixels to characterize the set of patches of an image and use this depiction to establish distinctness without considering the non-salient statistics of all the other image patches.

The Context-Aware (CA) algorithm, Goferman *et al.,* (2012) an object saliency detection algorithm which identifies the pixels that correspond to the bottom row that is the title that depicts the image. According to their method, the salient region of an image should not only include the conspicuous foreground pixels, but also include parts of the background pixels. Which depicts that the prioritized salient region close to the area of interest in the original image should maintain some element of the background texture in order to give the salient object meaning.

The Model-Guided (MG) visual co-saliency, Li *et al.*, (2015) entails of three key stages which are: single image saliency map, guided co-saliency detection and fusion. These stages take an image under a graph structure using the four vital points at the four cardinal border of the image. Thereafter a geodesic saliency measure is expended to attain four saliency maps, which are all coalesced to generate a single image saliency map. Furthermore, at the second stage, a guided detection pipeline led by probes is used to achieve the guided saliency maps of the image set via a grading pattern. Then at the final stage, the guided saliency maps generated by different probes are bonded taking the advantage of both averaging and multiplication.

In addition, Achanta and Süsstrunk (2010) proposed the MSSS saliency detection algorithm which preserves the boundaries of the saliency map by retaining the substantial content of the original image. However, if the region of interest contains a larger per cent pixel of the original image, which depicts a complex background, consequently, the background is highlighted in place of the detected salient object. This method exploits features of colour and luminance. A border is selected on the image by making the surround symmetric around the image centroid in connection to the image borders exploiting the local surround region. Thereafter, each pixel at the centre is treated to be its own sub-image in generating the saliency map.

Furthermore, a cluster based co-saliency detection algorithm (Fu *et al*., 2013) using three visual saliency keys: contrasts, spatial, and corresponding, which are concocted to efficiently, quantify the cluster saliency. Consequently, merging the single image saliency and multi-image saliency to generate the final co-saliency maps. According to them, this algorithm is advantageous because of its bottom-up learning approach as it eliminates hefty learning, hence, it gives simple, proficient, and fast characteristics when generating the saliency map. However, the challenge with this approach is caused by varying illumination conditions, diverse backgrounds, changing viewpoints and large appearance of salient objects (Han *et al*., 2017).

The Hypercomplex Fourier Transform (Li *et al.*, 2013), a bottom-up algorithm for highlighting visual areas of interest, by using a scale space exploration for natural images with an amplitude spectrum of the images. This depicts that the complexity of the image amplitude spectrum with a low-pass Gaussian kernel of a suitable scale is corresponding to the detected salient object. The final saliency map S is derived using the saliency approach based on the Hypercomplex Fourier Transform which is acquired by restructuring the 2-D signal of the original image and the amplitude spectrum, which is further filtered at a selected scale through saliency map entropy minimization.

7.3 Subscriber Interpretation of Salient Object Detection

The conventional salient object detection algorithms have difficulties when the object foreground is not at the centre of the image and when the contrast between the foreground colour and the background colour is similar. Furthermore, the conventional algorithms also perform poorly when the background is heterogeneous or when the foreground object touches the image boundaries; these difficulties observed in conventional algorithms result in over-segmentation or under-segmentation of the video sequence images. However, the advantage SSLS algorithm has over other conventional saliency detection algorithm is that it does not assume that the salient object is at the epicentre of the image (Lei *et al*., 2016). Instead, it measures the connectivity boundary of each video sequence image segment to detect the salient object by creating a background template.

The cogent purpose of this chapter is to focus on subscriber perceptions on video quality in determining the video quality of experience. The analysis of user's perception is in four steps as shown in Figure 7.2: (i) obtain the video sequence image dataset from a public domain (ii) obtain a salient object from an original video sequence image using the SSLS algorithm (iii) extract quantitative information from the salient object using popular metrics (iv) analyse users' perception of video quality using MOS scale based on the quantitative information extracted. Quality of experience in the framework helps to determine if the user receiving the video stream has a maximum degree of satisfaction with the video quality viewed (Jiménez *et al.*, 2015).

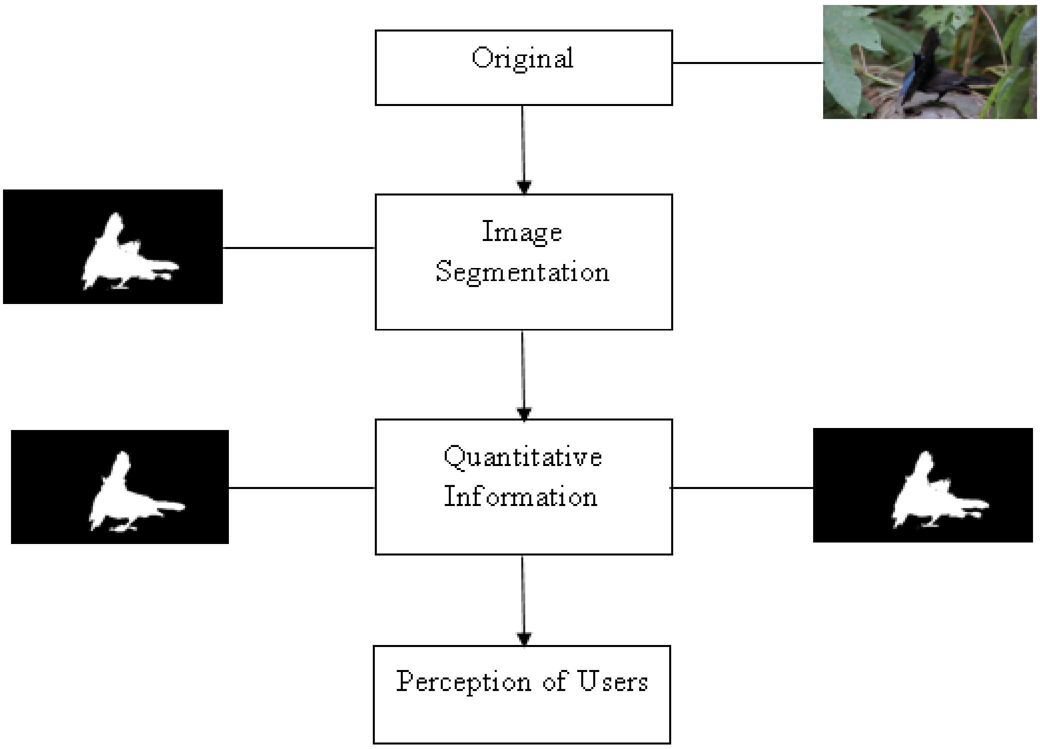


Figure 7.2: Methodological Workflow for Analysing Perception of Subscribers

An overview of the methodological workflow in analysing perceptions of the subscriber as shown in Figure 7.2 takes the compressed video sequence images as the original image, then implement the adopted SSLS algorithm tool in obtaining the salient object from the original image using five steps as shown in Figure 7.3:

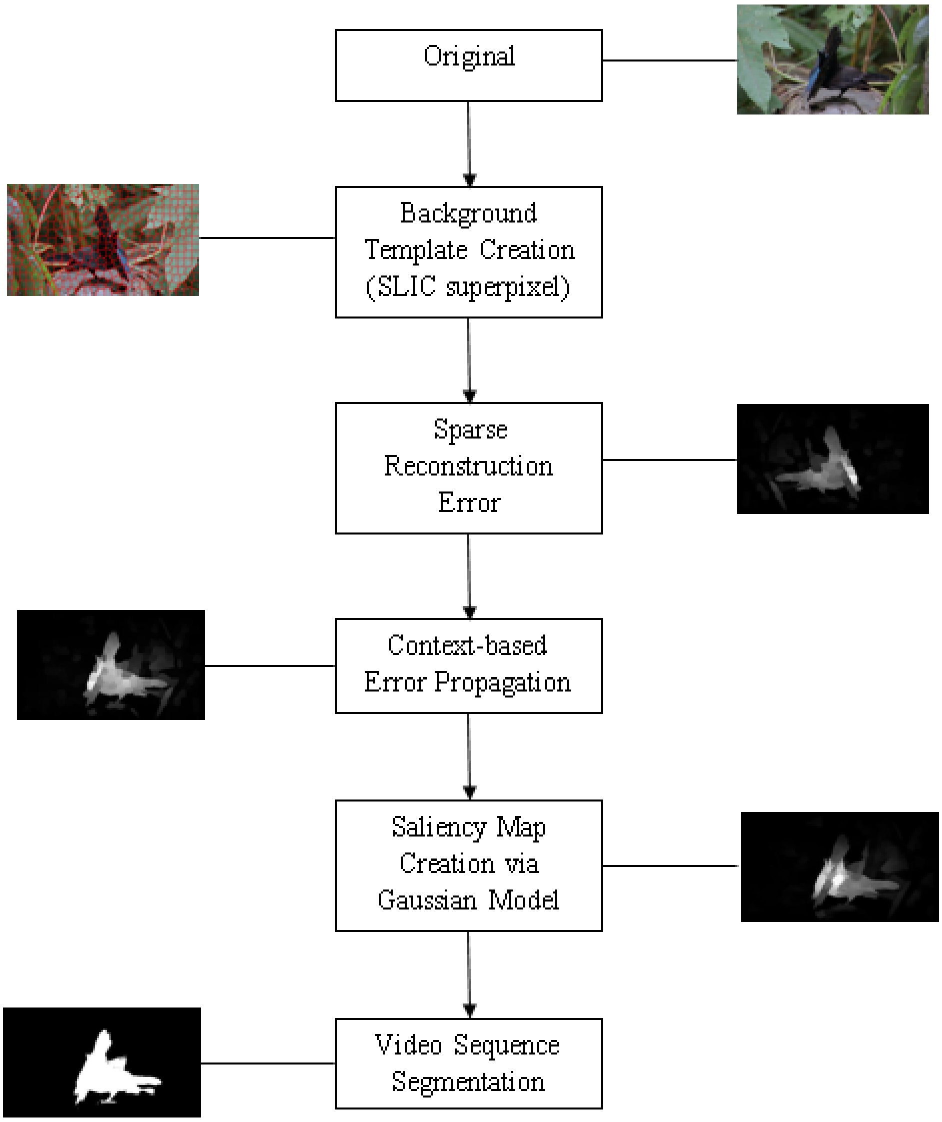


Figure 7.3: Salient Object Detection in Video

(i) Background template creation using a SLIC superpixel algorithm (Achanta *et al.*, 2010; Ren and Reid, 2011; Achanta *et al.*, 2012). (ii) The sparse reconstruction error measures the saliency of each captured video sequence image region in order to obtain the likelihood of where the salient object belongs (Wright *et al.*, 2009; Lu *et* *al.,* 2016). (iii) The content-based error propagation is used to smoothen image output at the sparse reconstruction phase, allowing the salient object in the video sequence image to be evenly highlighted (Ahn et al., 2017). (iv) The saliency map was generated by applying multi-scale reconstruction error and later redefined using a lesion-based Gaussian model. (v) The video sequence image binarization was generated via the saliency map using fuzzy thresholding (Huang *et al*., 1995).

After generating the image segmentation, popular metrics such as specificity, sensitivity, accuracy, AUC, dice, and Jaccard was used to obtain quantitative information by comparing the salient object obtained from the segmentation algorithm for the non-saliency ground truth image of the original image. Thereafter, the MOS value was obtained by analysing the perception of subscribers on video quality.

7.3.1 Background Template – SLIC Superpixel

The Simple Linear Iterative Clustering (SLIC) algorithm for superpixel segmentation (Achanta *et al.,* 2010) was used in capturing structural information; by segmenting the video sequence images into N segment as shown in Figure 7.4. SLIC superpixel algorithm groups pixels in a combined five-dimensional colour and image plane space to efficiently produce almost uniform and compact superpixels to detect salient regions or the focus of attention in the video sequence images measuring subscribers' perception of digital video quality. With SLIC Superpixel method, a 5-D spectral clustering and boundary-focused region merging; is used for clustering the video sequence images in creating a background template.

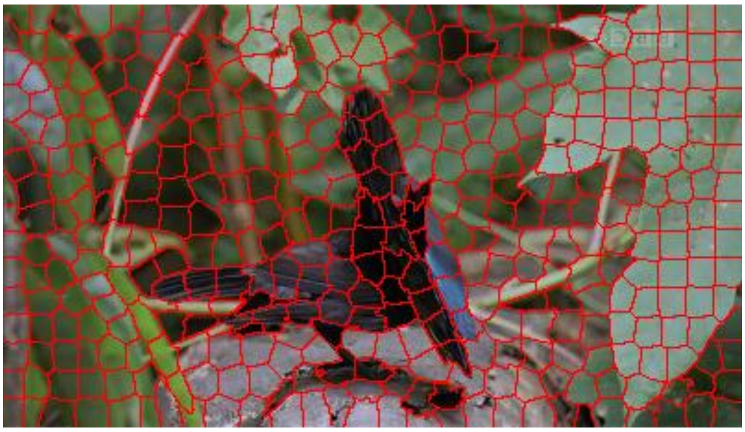


Figure 7.4: Example Result of SLIC Superpixel Segmentation

For color images in the CIE L*A*B color model, the clustering process starts with an initialization step where k circular seeds in a lattice formation and the distance between lattice neighbors of initial cluster centers C_i= [L*a*b*R*G*B*x*y] is tested on a regular grid spaced S pixels apart in order to produce almost the equal superpixel size, which represents the saliency detection performance of each segment represented. The space grid S =$\sqrt{N/k}$. Where N is the nth number of the pixels in the image so as to ensure even distribution of the superpixel of the video sequence image (Ren and Reid, 2011; Achanta *et al.,* 2012; Shen *et al.,* 2014; Ahn *et al.,* 2015).

7.3.2 Sparse Reconstruction Error

A sparse reconstruction error was used to measure the saliency of each captured video sequence image region. The appearance of the sparse reconstruction error produces specific and unique representations of the salient object, particularly, for homogeneous background images with complex scenes. Sparse representations (Han *et al.,* 2014) of these data can be addressed by solving the minimization problem in equation 7.1:

$$\min_{B,\alpha} \| X_i - Bx \|_2^2 + \eta \| \alpha_i \|_1 \quad (7.1)$$

To segment the testing data X_i, this research work sparsely coded it by Wright *et al.,* (2009) and based on the assumption, Lu *et al.,* (2016) that the background can be better represented than the foreground by a linear combination of the background templates B= (b_1, b_2,….,b_M), set of background templates B was used as the bases for sparse representation, and encoded the video sequence image segment i by equation 7.2

$$\alpha_i = \arg\min_{\alpha_i} \| X_i - B\alpha_i \|_2^2 + \eta \|\alpha_i\|_1 \quad (7.2)$$

The sparse reconstruction error was used to calculate the probability of where the salient object is in the background. The sparse reconstruction error ε_i is defined by equation 7.3:

$$\varepsilon_i = \|X_i - B\alpha_i\|_2^2 \quad (7.3)$$

7.3.3 Content-Based Error Propagation

As shown in Figure 6.3, content-based error propagation is used to smoothen image output at the sparse reconstruction phase, allowing the salient object in the video sequence image to be evenly highlighted. The new smooth reconstruction error $\acute{\varepsilon}_i$ derived by coalescing the weighted median error of another segment in the same cluster with the sparse reconstruction error ε (Ahn et al., 2017) is defined in equation 7.4:

$$\varepsilon = \tau \sum_{j=1}^{N_c} w_{ik_j} \varepsilon_{k_j} + (1-\tau)\varepsilon_i \quad (7.4)$$

Where k is the number of cluster subset of [k_1, k_2, k_3,….,k_{Nc}] and τ is a weight parameter and N_c is the number of superpixels. While the weight of each superpixel I was derived from the normalized similarity defined by (Ahn et al., 2015) in equation 7.5:

$$w_{ik_j} = \frac{\exp\left(-\frac{\|x_i - x_{k_j}\|^2}{2\sigma x^2}\right)(1-\delta(k_j - i))}{\sum_{j=1}^{N_c} \exp\left(-\frac{\|x_i - x_{k_j}\|^2}{2\sigma x^2}\right)} \tag{7.5}$$

Where $2\sigma x^2$ represents the sum of the variance in each original background X_i while $\delta(k_j - i)$ is the indicator function.

7.3.4 Saliency Map Creation

Two major processes were applied before the creation of saliency map, the first is the integration of pixel level multi-scale reconstruction error which increases the boundary region since the boundary cluster of the segmented region will be eliminated. The pixel level multi-scale E(m) reconstruction error is defined in equation 7.6 and 7.7:

$$E(m) = \frac{\sum_{s=1}^{N_s} \omega_{mn^{(s)}} \varepsilon_{n^{(s)}}}{\sum_{s=1}^{N_s} \omega_{mn^{(s)}}} \tag{7.6}$$

$$\omega_{mn^{(s)}} = \frac{1}{\| f_m - X_{n^{(s)}} \|_2} \tag{7.7}$$

Where $n^{(s)}$ is the cluster of the region containing pixel m of graph-scale s and f_m is the pixel m feature. The second process before saliency map creation is the use of the Gaussian refinement model, a method adopted because based on a literature salient object in a video sequence image is majorly situated at the centre (Borji *et al.*, 2015;

Lu *et al.*, 2016). The Gaussian refinement model is, therefore, defined in equations 7.8 and 7.9:

$$G(m) = \exp\left[-\left(\frac{(x_m - x_c)^2}{2\sigma_{x^2}} + \frac{(y_m - y_c)^2}{2\sigma_{y^2}}\right)\right] \tag{7.8}$$

$$x_c = \sum_i \frac{E(i)}{\sum_j E(j)} x_i, \qquad y_c = \sum_i \frac{E(i)}{\sum_j E(j)} y_i \tag{7.9}$$

Where x_c and y_c represent the image centre coordinates from the pixel error. Therefore, the saliency map creation is finally defined in equation 7.10:

$$S(m) = G(m) * E(m) \tag{7.10}$$

7.3.5 Detection of Video Sequence Images

The video sequence image detection was generated via the saliency map into a binary image using fuzzy thresholding (Huang *et al.*, 1995). The fuzzy thresholding tool used in generating the video sequence image segmentation is available on a public domain and can be accessed on https://imagej.net/Auto_Threshold#Huang. The fuzzy thresholding helps to effectively locate the salient object from the multi-background video sequence images minimizing the fuzziness of an image. The fuzziness of each salient object pixel can be measured by using Shannon's entropy or the Yager's measure, however, in this research work Shannon's entropy was used in the experiment because it is best in measuring the fuzziness (Fei *et al.*, 2015) and it is defined by Bhandari *et al.*, (2015) in equation 7.11

$$S(p) = -\sum_{i=1}^{n} p_i \ln(p_i)$$

(7.11)

Where n is the number of possible outcomes with probabilities $p_1,....,p_n$

7.4 Experimental Results

Due to different encoders and decoders adapted for IPTV service transmission over the IP network infrastructure which may impede video quality consequently, reducing the quality of experience perceived by subscribers. In this chapter, a real-time video sequence images was used through capturing salient objects using SSLS algorithm while obtaining the quantitative information of the generated binary image segmentation comparing it with the ground truth to analyse the perception of subscribers on video quality viewed.

For the experiments, it is believed a good saliency detection algorithm should give a good result and deliver a high performance across many datasets. However, many of the object detection algorithms are image dependent (Fu *et al*., 2015; Maggiori *et al*., 2017). Therefore, two public benchmark datasets were used for video sequence image salient detection in measuring subscriber's salient object. In the SegTrackv2 (Tsai *et al.*, 2010; Li *et al.*, 2013) as shown in Figure 7.5 there are 14 videos categories and 1498 video sequences in this dataset of humans and animals designed to be challenging with respect to background and foreground colour similarity, fast motion, multiple adjacent objects and complex shape deformation.

In Figure 7.6 the Vidsal dataset was represented, containing seventeen video categories, complex colour distributions and 963 video sequence frames (Wang *et al.*, 2015). Also, a non-saliency ground truth image for each video sequence images are available. However, this research work only made use of seven categories each from the two datasets surpassing Perazzi et al., (2017) that made use of two categories and Li et al., (2018) that made use of six categories.

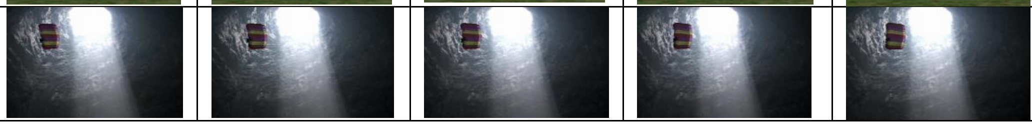
SegTrackV2	Video Sequence 1	Video Sequence 2	Video Sequence 3	Video Sequence 4	Video Sequence 5
Monkey					
Soldier					
Bmx					
Drift					
Bird of Paradise					
Girl					
Parachute					

Figure 7.5: SegTrackv2 Video Sequence Dataset

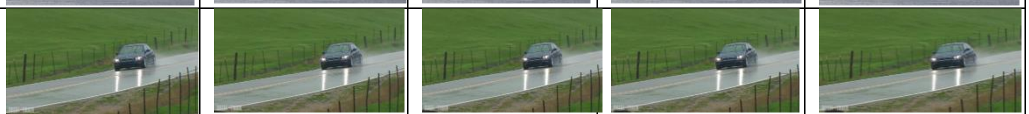
VidSal	Video Sequence 1	Video Sequence 2	Video Sequence 3	Video Sequence 4	Video Sequence 5
Aeroplane					
Boat 2					
Car					
Cat					
Panda					
Rider					
Lion					

Figure 7.6: VidSal Video Sequence Dataset

The video sequence images across the two datasets used in this chapter were free of noise that is, the segmented results attained for all the algorithms employed to provide a satisfactory segmentation result. Sadri *et al.*, (2013) explain three major filters at the pre-processing stage used in removing noise: median filter, morphological filter, and dull-razor filter, but due to the quality of video sequence images employed, the noise has been eliminated for each image.

The image detection algorithm performance is measured according to the dissimilarities between the segmented image and the ground truth image. In order to validate the efficiency of the SSLS algorithm, this research work compared the SSLS algorithm with seven other benchmark saliency detection algorithms: MC (Jiang et al., 2013), CA (Goferman *et al.,* 2012), MG (Li *et al.,* 2015), PCA (Margolin *et al.,* 2013), MSSS (Achanta and Süsstrunk, 2010), CC (Fu *et al.,* 2013), HFT (Li *et al.,* 2013). Despite different motion patterns and the complexity of the video sequence frames across the two datasets used, thus the SSLS algorithm adapted well in producing reliable saliency maps.

7.5 Evaluation Metrics

The purpose of evaluation metrics in this chapter is to examine the performance of the SSLS algorithm through a comprehensive quantitative comparison between the binary segmentation result with the seven other benchmark saliency detection algorithms and the ground truth image on video sequence images acquired from the SegTrackv2 and VidSal corpora.

In order to more holistically evaluate the performance of the saliency detection algorithms for video sequence images and validate that one algorithm is superior to the other, eight popular evaluation metrics which are widely used in literatures including specificity, sensitivity, error rate, accuracy, AUC (Area under ROC curve) score, dice, Jaccard coefficient and Hammoud distance (Sajid, and Cheung, 2017; Zhang *et al*., 2017) were employed in evaluating the saliency detection of video sequence images across two datasets. The evaluation result between the binary saliency detection algorithms and the non-saliency ground truth images with a satisfactory performance should record a high sensitivity, specificity, accuracy, AUC, dice, Jaccard value and a low value for error rate, and hammonde distance (Pont-Tuset *et al*., 2017).

The evaluation metrics employed in this chapter were computed based on the following parameters: True Positive (TP) the amount of true positive pixels, foreground pixels that are accurately identified as salient object; False Positive (FP) the amount of false positive pixels, background pixels that are wrongly identified as foreground; True Negative (TN) the amount of true negative pixels, background pixels that are accurately identified as a background region and False Negative (FN) the amount of false negative background detected (Yang and Zou, 2015).

7.5.1 Specificity

Specificity is also known as a true negative rate (TNR). It measures for each negative image background and compares it with the ground truth in order to identify the negative value by the evaluated segmentation (Shattuck *et al.*, 2009; Taha and Hanbury, 2015). It is mathematically defined as:

$$Specificity = \frac{TN}{TN + FP} \tag{7.4}$$

7.5.2 Sensitivity

The recall value, also known as a true positive rate (TPR), is expressed as the percentage of salient pixels detected with respect to the non-saliency ground truth images (Han *et al.*, 2014; Zhang *et al.*, 2017). It is mathematically defined as:

$$Sensitivity = \frac{TP}{TP + FN} \tag{7.5}$$

7.5.3 Error Rate

The error rate measures the difference between the segmented areas of the image and the ground truth in order to measure the accuracy of the segmented result that is, the lower the value of error indicates a better segmentation result (Guo *et al.*, 2017).

$$Error = \frac{FP + FN}{TP + FP + TN + FN} \tag{7.6}$$

7.5.4 Accuracy

Accuracy is a measurement which denotes the degree to which the segmentation agrees with the ground truth (Udupa *et al.*, 2006; Popovic *et al.*, 2007)

$$Accuracy = \frac{TN + TP}{TP + FN + TN + FP} \tag{7.7}$$

7.5.5 Dice

The Dice coefficient measures the degree of overlap between the ground truth image and the algorithmic binary segmented result. In this case, a value of 0 means the segmented result does not match the ground truth while a value close to 1 indicates good segmentation (Scharr *et al.*, 2016).

$$Dice = \frac{2TP}{2TP + FP + FN} \tag{7.8}$$

7.5.6 AUC (Area under ROC curve) score

Plotting the true positive rate against a false positive rate produces area under the ROC curve. The benefit of this metric is that it depends absolutely on the order of pixels rather than their outright derived saliency values (Tasse *et al.,* 2016; Zhang and Sclaroff, 2016; Qi *et al*., 2017).

$$AUC = \frac{TPR + TNR}{2} \tag{7.9}$$

7.5.7 Jaccard

Object similarity can be checked using various existing similarity metrics. One of the most common similarity metrics is the Jaccard Coefficient (JC) defined as the connection over the union of the probable segmentation and the ground truth image used in measuring the similarity between objects. (Kou *et al*., 2014; Olugbara *et al.*, 2015; Samanthula and Jiang, 2016) it provides intuitive, scale-invariant information on the number of mislabeled pixels giving a more accurate result than F-measure (Perazzi *et al.,* 2016; Pont-Tuset and Marques, 2017).

$$Jaccard = \frac{TP}{TP + FN + FP} \tag{7.10}$$

7.5.8 Hammoude distance

The Hammoude distance is established on a pixel by pixel evaluation of pixels encircled by the two boundaries (El Abbadi and Miry, 2014; Al-azawi *et al.*, 2017).

$$Hammoudedis\tan ce = \frac{FP + FN}{TN} \tag{7.11}$$

7.6 Results and Discussion

In this section, the qualitative analysis of the saliency map generated in Figure 7.7 using the SSLS algorithm and other seven benchmarked saliency detection algorithms from the video sequence images selected from the SegTrackv2 and VidSal datasets in Figure 7.5 and Figure 7.6 respectively.

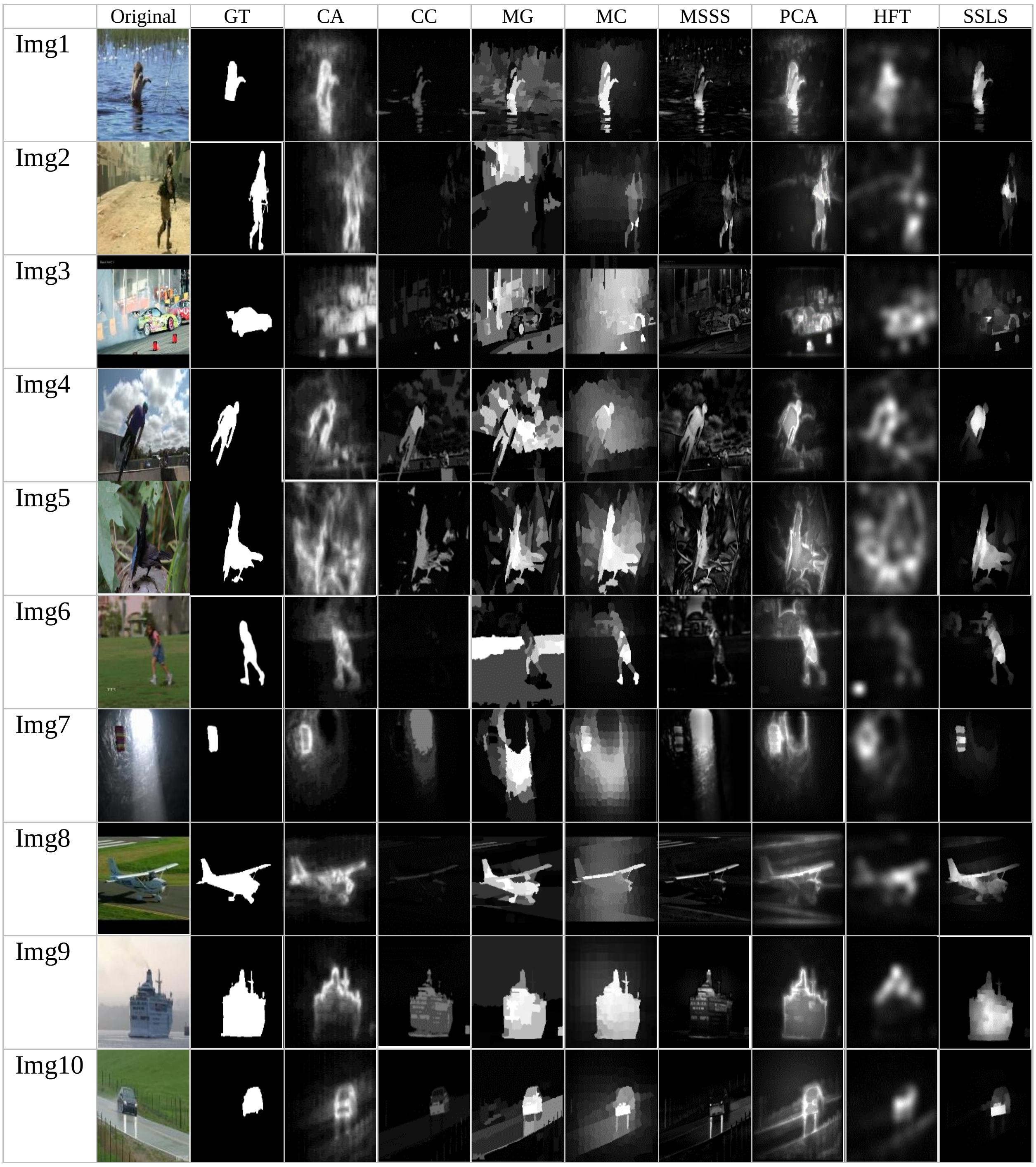


Figure 7.7: Qualitative illustration of Saliency Map results obtained using seven benchmark saliency detection algorithms and the SSLS Detection algorithm on video sequence images from the SegTrackV2 and VidSal dataset.

It can be noticed from Figure 7.7 that the saliency map generated by the SSLS detection algorithm produced a higher pixel resolution and maintained good performance across both datasets despite background difficult images and heterogeneous foreground the images possess.

The first two images of the dataset that is img1 and img2 in Figure 7.7 depict when there is a high and low contrast amongst the salient object and background with a comparison to the ground truth (He *et al*., 2015). It can be seen with reference to the qualitative analysis of saliency results that CA, MG, and HFT algorithm maintains poor performance saliency maps with low resolution, blurry (Zhang and Sclaroff, 2013) and poorly defined borders, carrying less or no information across both datasets while CC and MSS algorithm salient object show a low contrast and resolution result. It is also noticeable that the PCA, MC and the SSLS algorithm produced credible saliency maps for images in img1 and img2.

Img3 across all detection algorithms showed a low contrast and resolution salient object while HFT and CA remain blurry. However, img4 and img5 show that the SSLS algorithm produced a satisfactory result highlighting the salient object more accurately and it does not lose the real image information when compared with the ground truth, unlike the blurry images are seen in HFT and CA, while CC generated a saliency map with low contrast and resolution. Although MC, PCA, and MG produced a salient object closely related to the ground truth heterogeneous background can be seen around the salient object (Shen and Wu, 2012).

It can be observed that saliency map CC algorithm produced failed for img6 while the HFT segmentation algorithm salient object result remains blurry along with earlier images discussed. However, CA, MG, MC and PCA algorithm results show the salient object but some part of the background is being highlighted while the MSSS algorithm result shows a low contrast and resolution image of the salient object. In sharp contrast to earlier algorithms discussed, the SSLS algorithm showed a high resolution and precise salient object.

The CA, MG, MC, MSSS and PCA algorithms result in img7 showing the salient object but some part of the light reflection in the background is being highlighted. The HFT algorithm shows a blurry saliency object output and the CC algorithm result failed by not highlighting the salient object. However, the SSLS algorithm gave a precise result eliminating the light reflection shadow of the original image. In img8 it can be seen that CA and HFT algorithms gave an imprecise and blurry image when compared to the ground truth, while CC and MSSS algorithms gave a low contrast and resolution result, although MC and PCA captured the salient object. However, there remains a great extent of the heterogeneous background in the result provided while MG and SSLS algorithms gave a precise and high-resolution result.

For img9 the HFT and CA algorithms results remain blurry while CC and MSS highlighted the salient object with a low contrast and resolution output. Although MG and MC algorithms produced a precise high-resolution salient object as output there was a trace of background images. It can be seen that the SSLS and PCA algorithms produced a high-quality result, however, SSLS has a higher resolution than PCA. In img10 CC and MSS highlighted the salient object but the output gives a low contrast and resolution result while HFT and CA algorithms results remain blurry. MG, MC, PCA and SSLS segmentation algorithms highlighted the salient object but only SSLS was able to eliminate the background image.

In img10 CA and HFT algorithms produced a blurry result while CC algorithm produced a low contrast and resolution result. MG, MC, MSS, and PCA highlighted the salient object but SSLS gave the most accurate result eliminating image background. For img12 and img13 CA and HFT algorithms remain blurry, the CC and MSSS algorithms produced a low contrast and resolution result. A precise salient object was captured for MG, MC and SSLS but SSLS eliminated the heterogeneous background.

In img14 it can be seen that CA, MSSS, and HFT algorithms failed at highlighting the salient object. In addition, CC algorithm failed while the PCA algorithm produced a blurry result. MG, MC and SSLS highlighted the salient object but SSLS algorithm eliminated the image background. As shown in Figure 7.7, the SSLS algorithm effortlessly produced saliency maps highlighting both salient objects across the datasets and producing a high resolution while clearly defining the image borders.

7.6.1 Evaluation of Result

The goal of this section is to quantitatively evaluate the performance of the SSLS algorithm with seven benchmark algorithms across the SegTrackv2 and VidSal video sequence dataset. For the experimental evaluation, this research work used a PC with Intel i7 CPU (2.93 GHz) and 4 GB RAM with MATLAB 2017a. In order to conduct a quantitative evaluation performance between the binary segmentation result and the ground truth image of the SSLS algorithm and other benchmarked saliency detection algorithms in detecting the salient object from the video sequence images that will determine subscribers perception of video quality.

The quantitative evaluation of the object detection algorithms using popular metrics to analyse the performance of these algorithms eliminates the use of IPTV subscribers in giving feedback based on the quality of video viewed. It has been stated in the literature that the network and content providers sometimes cannot fully measure the performance of services provided based of low feedback, participation from subscribers while some have to go extra mile compelling subscribers to give feedbacks based on incentives (Chen *et al*., 2015; Yu *et al*., 2016).

Furthermore, the adoption of object detection algorithm eliminates the limitation of the human cognitive vision system (Cheng *et al*., 2015; Cohen *et al*., 2016). Over the years the evaluation of QoE for video quality has been subjective and does not give an accurate result. For instance, if ten subscribers are put under the same condition to analyse the video quality experience they will have a different perceived opinion based on this limitation. Hence, the use of this algorithm gives a uniform analysis of video quality viewed in order to measure the quality of experience perceived by subscribers.

The binary salient maps are conventionally generated based on thresholding algorithms. Therefore, all seven state-of-the-art detection algorithms, including the SSLS algorithm were segmented using the fuzzy thresholding (Huang, 1995) to convert the saliency map to the binary image. In order to perform a quantitative comparison to obtain the salient object IPTV subscribers concentrated on, a video of sequence images, an evaluation method was carried out by comparing the saliency map with the ready availability of the manual segmented ground truth image made available in the two datasets used in this research work. Eight widely used evaluation metrics were adopted for accurate evaluation results.

In table 7.1 presents, the overall median value was presented for all the video sequence images selected from the Segtrackv2 dataset, experimental results of the SSLS algorithm with seven other state-of-the-art algorithms were compared. The specificity value of the SSLS algorithm of the SegTrackv2 dataset as shown in Table 7.1 was lower than that of MC, PCA, CA, and HFT, which was due to an over-segmentation of these algorithms (Rabbani *et al*., 2006) but higher than MG, MSSS, and CC. However, it can be observed that the sensitivity value of the SSLS algorithm (98.43 per cent) is higher than the seven other state-of-art algorithms. For the SegTrackv2 dataset, it can be observed that the sensitivity value for MG is the lowest (5.57 per cent) due to the complex video sequence image of the dataset.

Table 7.1: Median Value of Video Sequence Image Segmentation on SegTrackv2 dataset

Method	Specificity	Sensitivity	Error	Accuracy	AUC	Dice	Jaccard	Hammonde
MC	99.92	32.08	9.82	88.06	65.92	48.24	38.92	15.04
PCA	99.77	58.18	3.74	96.72	78.17	70.80	56.77	3.61
CA	99.91	29.77	6.85	93.40	64.80	44.82	21.57	6.35
MG	98.30	5.57	14.34	85.66	51.91	10.25	5.40	16.90
MSSS	98.80	44.36	6.37	93.63	71.49	47.37	29.30	6.88
CC	98.37	50.50	3.43	96.57	74.49	44.13	28.31	3.60
HFT	99.88	42.27	5.56	94.44	71.05	58.42	41.26	6.09
SSLS	99.26	98.43	1.18	99.26	98.09	80.10	66.80	1.24

It can also, be observed from Table 7.1, that MG algorithm has the highest error rate (14.34 per cent) from the SegTrackv2 dataset while the SSLS algorithm recorded the lowest rate (1.18 per cent) depicting that SSLS produced a better segmentation result. While computing the accuracy metrics SSLS outclassed other seven segmentation algorithms with a value of 99.26 per cent and MG recorded the lowest value of 85.66 per cent denoting the degree that SSLS produced segmentation result agrees to the ground truth (Ahn *et al.*, 2015). Furthermore, SSLS maintained a better performance when compared with the AUC, dice and Jaccard metrics giving a value of 98.09 per cent, 80.10 per cent, and 66.80 per cent respectively, while, MG gave the lowest AUC, dice and Jaccard metric value of 51.91 per cent, 10.25 per cent, and 5.40 per cent. The lower the value for Hammoude the better the result (Masood *et al.*, 2013; El Abbadi and Miry, 2014); it can be observed that the SSLS algorithm gave the lowest value of 1.24 per cent while MG gave the highest Hammoude value of 16.90 per cent.

The quantitative analysis of the eight metrics median value for the VidSal dataset is presented in Table 7.2.

Table 7.2: Median Value of Video Sequence Image Segmentation on Vidsal

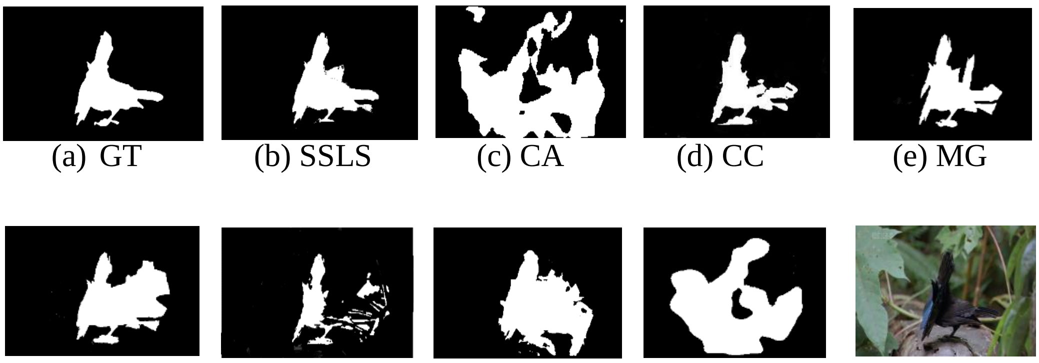
Method	Specificity	Sensitivity	Error	Accuracy	AUC	Dice	Jaccard	Hammonde
MC	99.79	47.41	9.83	90.17	73.25	59.71	42.56	11.33
PCA	99.69	41.88	7.18	92.47	68.73	49.91	53.44	8.47
CA	98.38	53.11	12.35	87.99	76.56	51.53	33.80	14.68
MG	98.62	81.75	3.29	96.30	89.88	81.34	68.55	4.13
MSSS	96.58	63.90	7.10	92.90	77.69	50.24	33.54	7.70
CC	97.64	89.93	3.12	96.19	93.80	70.04	53.89	4.16
HFT	97.40	65.56	5.20	94.80	82.75	68.30	51.86	5.83
SSLS	98.19	94.06	2.17	97.86	96.09	82.35	67.05	3.51

The SSLS segmentation algorithm for specificity metrics outperformed HFT, MSSS, and CC but has a lower value when compared with MC, PCA, CA and MG segmentation algorithms. Despite the low sensitivity value of other algorithms, the SSLS algorithm proved otherwise with an overall median sensitivity value of 94.06 per cent, while PCA had the lowest specificity value of 41.88 per cent. The SSLS algorithm displayed consistency in performance has the error rate recorded the lowest of 2.17 per cent, while CA algorithm gave the highest error rate value of 12.35 per cent. For the accuracy and AUC metrics, the SSLS algorithm outperformed other seven segmentation algorithms with a result of 97.869 per cent and 96.09 per cent respectively while CA segmentation algorithm has the lowest value of accuracy metrics with a value of 87.99 per cent and PCA has the lowest AUC metric with a value of 68.73 per cent.

Furthermore, the SSLS algorithm remains consistent in displaying a high median dice metrics value of 82.35 per cent while PCA segmentation algorithm has the lowest value of 49.91 per cent. The MG algorithm (68.55 per cent) was slightly higher than the SSLS algorithm (67.05 per cent) for the Jaccard metrics while MSSS algorithm gave the lowest median dice metrics. The SSLS algorithm further displays consistency in giving a median value of 3.51 per cent for Hammoude metrics while CA gave a result of 14.68 per cent. To know how good a segmentation algorithm is, it must be able to give good result across diverse multi background video sequence images; however, the SSLS segmentation algorithm proved successful in getting a good salient object from non-stationary multi background video sequence images.

7.7 Interpretation of Subscriber Perceptions

The video sequence segmented images with the ground truth and original video sequence image is shown in Figure 7.8. Bare looking at the video sequence segmentation output from the SSLS algorithm and other state-of-the-art segmentation algorithms, subscribers will have a different perception of the salient object generated as shown in Figure 7.8 (a-j).



(a) GT (b) SSLS (c) CA (d) CC (e) MG

(f) MC (g) MSSS (h) PCA (i) HFT (j) original

Figure 7.8: Segmentation result from eight segmentation algorithms (a) GT (b) SSLS (c) CA (d) CC (e) MG (f) MC (g) MSSS (h) PCA (i) HFT (j) Original

If the qualitative analysis was to be carried out based on subscribers perception, it will be observed that different subscribers will have a dis-similar opinion with regards to choosing the best salient object in Figure 7.8. The quantitative information q(m) of the given metrics is multiplied by the MOS value to get the quantitative analysis of subscriber perception is represented in equation 7.12:

$$S(i) = q(m) * MOS \tag{7.12}$$

Figure 7.9 shows the quantitative analysis of subscribers' perception S(i) across six popular metrics (specificity, sensitivity, accuracy, AUC, dice and Jaccard) for the SegTrackv2 dataset.

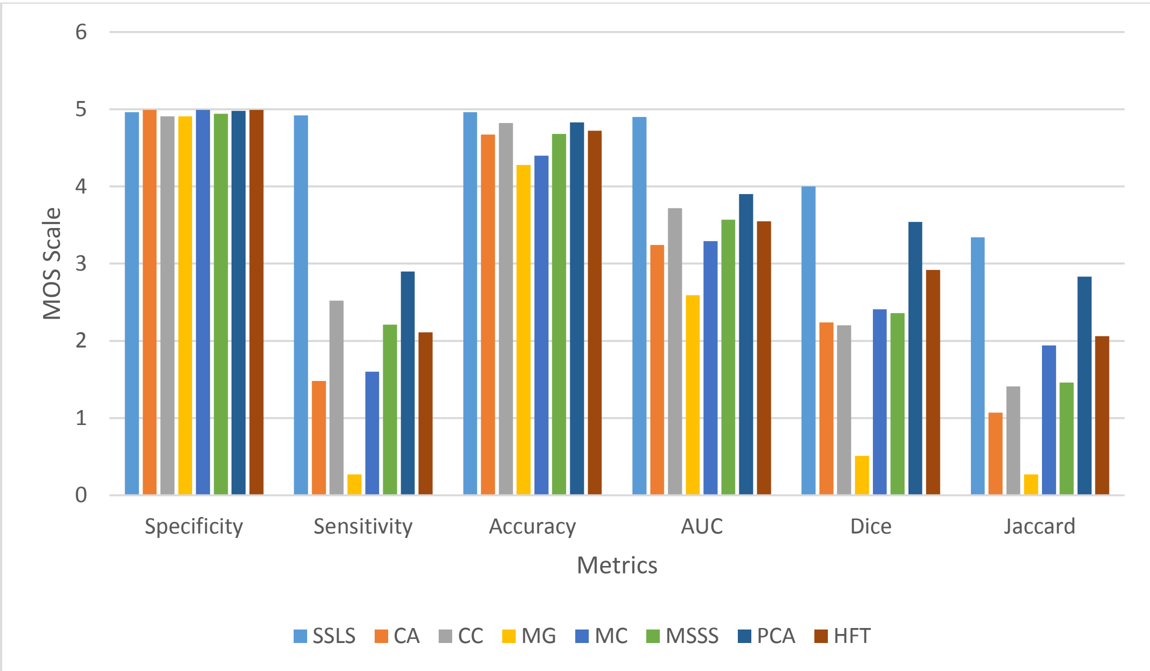


Figure 7.9: MOS Scale vs. Metrics for SegTrackv2 Dataset

It can be seen in Figure 7.9, that the SSLS algorithm MOS value for specificity is 4.96, lower than that of CA, MC, PCA and HFT algorithms which are 4.99, 4.99, 4.98 and 4.99 respectively. However, the MOS value for all the saliency detection algorithms depicts that the video quality is good. The SSLS algorithm MOS value of sensitivity depicts the video quality as being good while that of CA, CC, MG, MC, MSSS, PCA, and HFT depict the video quality to be either bad or poor. The

MOS value of accuracy across all datasets is interpreted to be of good video quality while the SSLS algorithm MOS value for AUC is good and other algorithms are interpreted to be fair. It can also be noticed that the SSLS algorithm MOS value for Dice depicts the video quality to be good while other algorithms are either fair or bad. Furthermore, the SSLS algorithm MOS value also outclassed other algorithms by interpreting the video quality to be fair while other algorithms video quality is either bad or poor. It can then be concluded based on the qualitative metrics adopted in interpreting subscribers' perception that the SSLS algorithm on the median value outclassed other benchmarked algorithms interpreting the video quality has to be good. Furthermore, in Figure 7.10, depicts the quantitative analysis of subscribers' perception S(i) calculated for the VidSal dataset across six metrics (specificity, sensitivity, accuracy, AUC, dice and Jaccard).

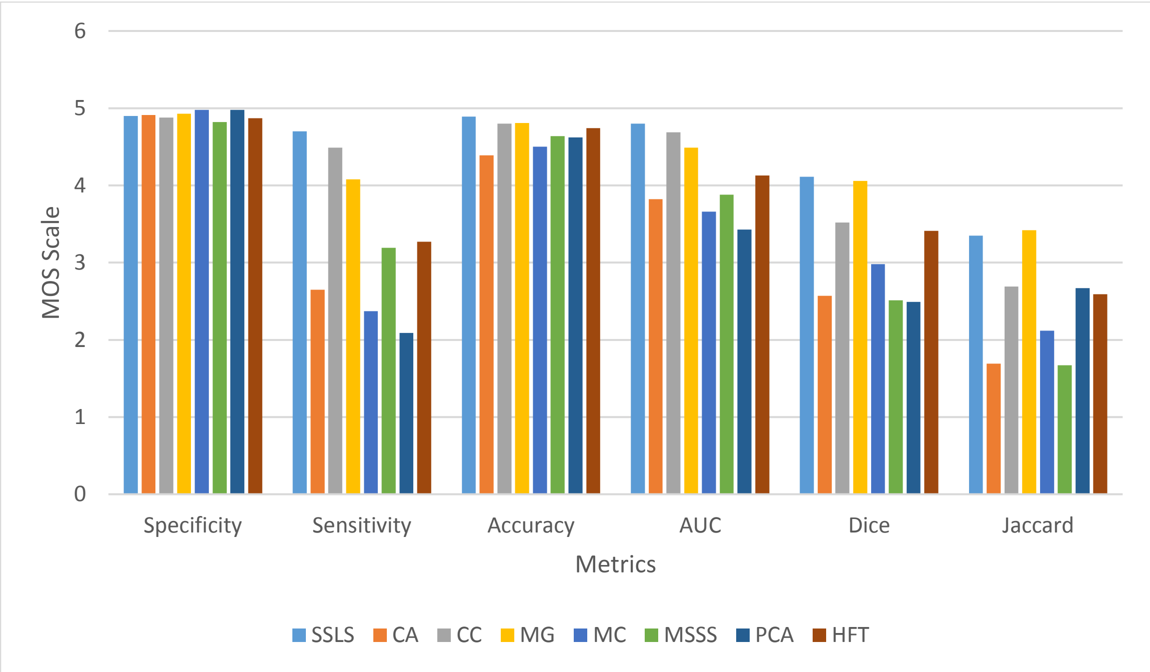


Figure 7.10: MOS Scale vs. Metrics for VidSal Dataset

In Figure 7.10, the SSLS algorithm MOS value for specificity is 4.90 but it can be observed that MOS value for HFT was higher in the SegTrackv2 dataset, but it is lower at the VidSal dataset with a MOS value of 4.87, however the MOS value for MG performed better at the VidSal dataset with a MOS value of 4.93 but was lower at the SegTrackv2 dataset. The CA, MC, and PCA MOS value remain higher by giving a value of 4.91, 4.98 and 4.98 respectively, however, the MOS value interpretation across all benchmarked algorithm interprets the video quality as being good. The SSLS and MG algorithm MOS value for sensitivity depicts that the video quality is good while other six segmentation algorithms interpret the MOS value for sensitivity to either be poor or fair. Furthermore, the MOS value of accuracy across all segmentation algorithms depicts the video quality to be good, while SSLS and MG, MOS value for Dice maintains a good video quality and other six benchmarked algorithms are either poor or fair. For SSLS, CC, MG, and HFT MOS value depict that the video quality is good while CA, MC, and MSSS MOS value interprets the video quality to be fair. The SSLS and MG MOS value for Jaccard maintains a fair video quality while other six algorithms video quality is either bad or poor. Based on the analysis of subscriber perception, it can also be concluded that across all the segmentation algorithm the SSLS algorithm outclassed other algorithms by analysing subscribers' perception of video quality to be good.

7.8 Conclusion

On the basis of human visual characteristics, subscribers pay more attention to the salient objects in the video. In this chapter, this research work introduced the use of the salient object in analysing the perception of subscribers on the video quality of video sequences via the MOS score. First, the SSLS algorithm was used as a tool to obtain the salient object for complex video sequence images with dramatic foreground and background appearances with different motion pattern variations across two datasets. The validation of the SSLS algorithm was compared with seven others state-of-the-art algorithms. The quantitative evaluation carried out between the binary-segmented image and the ground truth across the two public datasets showed that the performance of the SSLS algorithm across eight metrics recorded a high overall median score. Based on the quantitative information extracted from the salient objects across the two datasets, the conclusion was made that when subscribers' perception is low, that is, between 1 and 2 of the MOS value. There is a high tendency for subscribers to be disgruntled about the image viewed than when subscribers perception is high, that is, a MOS value between 3 and 5 a high perception will interest the subscriber in viewing the video sequence hence aiding high satisfactory level of the video quality of experience.

CHAPTER EIGHT

SUMMARY AND FUTURE WORK

In closing this thesis, this chapter summarizes the work done, based on original contributions and presented possible research recommendations for further improvement on the proposed approach.

8.1 Summary of Contributions

In this study, a new approach was proposed different from the norm in tackling the problem of zapping delay over a converged network. The overarching aim of this study was to scrutinize zapping delay problems in IPTV within a converged network towards developing an effective framework that would reduce zapping delay in IPTV. The five objectives set at the beginning have been met in order to achieve the goal of this study. Hence, these objectives are summarized in detail for clarity sake and they are as follows:

1. To comprehensively, review relevant publications based on zapping delay in IPTV over a converged network.

To achieve the first objective this research work started by laying the background of television and the transition from analog signal to digital signal with reference to the International Telecommunications Union (ITU) resolution that countries in region 1 (including Europe, Russia, Africa and the Middle East) should migrate their broadcasting services from analog to digital signal. This thesis further explained how IPTV was adopted due to the widespread advancement of the Internet and was seen as a killer application in actualizing the ITU resolution. This research work also looked at forms of delivery and how they differ from the terrestrial broadcasting service. Protocols, and architecture of IPTV were examined. This research work further explained how channel changes occur and how it leads to zapping delay, the major problem that this thesis focused on and how zapping delay still exists in both managed and unmanaged networks. A comprehensive survey of techniques based on literature was presented on how to reduce zapping delay which to date still exists.

The intrinsic element of IPTV was further explained, stating different standards that exist and its video coding, also describing the component that makes up a converged network such as IPTV (video), VoIP (voice), and data. Finally, the thesis talked about QoS and how it aids subscribers' experience using the MOS scale of impairment where the quality of service ranges from bad (1) to Excellent (5) and the service impairment based on subscriber perspectives ranges from the worst possible to imperceptible. All the subsections reviewed to highlight the importance of the effect zapping delay problems causes IPTV subscribers, deterring the widespread of this service.

2. To develop an effective zapping delay framework at the subscriber level in order to aid fast channel switching

In order to develop an effective zapping delay framework in a converged network, this research work first developed an individual approach at two levels (subscriber and network level), which was discussed separately in chapter three and four. At chapter five, adaptive hybrid service delivery with the two-list group program driven method was combined in order to aid fast channel switching and navigation. In chapter three of this thesis a zapping delay framework was presented, that will aid fast channel switching in order to reduce zapping delay. A new proposed framework called the group program driven two-list method, which categorizes TV programs into genres or program categories such as news, music, sport and so on. This research work, further used a two-list method that gives subscribers the freedom to choose channels based on preference from different program categories into a hot-list. A channel not added into the hot-list remains a cold-list channel. Consequently, I illustrated an algorithm at the two-list method that maintains the channel in both hot-list and cold-list. Any channel that is not watched over a period of time becomes a cold channel in order to reduce the total seek distance and the total seek time when changing channels. However, channels in the cold-list can be added to hot-list at any time. The TGPD approach was compared with three other popular methods and the proposed framework outclassed other approaches, reducing the total seek distance and total seek time, hence reducing zapping delay.

3. To implement an optimal multicast server-based and unicast flow of video request technique at the network level

For us to implement an optimal multicast server-based network OPNET modeller 14.5 was used to build an adaptive hybrid service delivery approach over a converged network, and a multicast server-based network was also configured. An adaptive hybrid delivery for fast channel navigation using a unicast service with DiffServ QoS to get channels from a multicast-based server was also configured. This research work also showed that, during evaluation, the adaptive hybrid method, when compared to the unicast and multicast methods, has a better performance. Lowering point-to-point queuing delay, end-to-end packet delay, packet variation, and network throughput which gave us the conclusion that the approach implemented at the network level helps in reducing zapping delay.

This thesis further implemented the approach on a raspberry pi 3B using DUT network and a TV headend at the ICTAS advanced lab by using a multicast server-based network while during zapping delay occurrence a unicast approach was used to get a requested channel. This research was able to ascertain that using the proposed approach; the average video playback end-to-end delay was lower than with other famous IPTV and OTT service providers. The proposed approach also lowered the buffering delay at the network level, which helps us conclude that fast channel navigation in a converged network using an adaptive hybrid delivery helps actualize lowering of the zapping delay to the bare minimum.

4. To validate the proposed framework, raspberry pi hardware, and Linux operating system will be used to build an IPTV set-top-box to show how the problem of zapping delay will be reduced to the bare minimum.

In order to validate the proposed framework by infusing approaches at the subscriber level and network level, a fast channel-switching framework was implemented using a group program driven two-list method with the personalized electronic program guide and RSS feed. This framework was implemented on a raspberry pi 3B box with a Linux server used as a backend operating system. During configuration of this box, subscribers were given the autonomy at setup to choose, based on preference, TV channels from a different genre. The channels are selected one after the other from the cold-list into the hot-list, which implies that all channels before setup are placed on the cold channel list. Furthermore, a personalized EPG with TV guide using ESA-BOW was adopted. It enables the program description from a bag-of-words using Wikipedia, a large corpus because of his vast and prompt information update. This makes channel selection decisions easy and convenient while the RSS feed was to give subscribers update about channels. This approach saves subscribers a painstaking amount of time in searching for the desired channel to watch, hence, reducing zapping delay

5. To analyse the quality of experience based on salient object IPTV subscriber will be interested in for video sequence images viewed by subscribers using a saliency detection algorithm, comparing the performance of the SSLS algorithm with state-of-art saliency detection algorithms using well-known evaluation metrics.

The SSLS algorithm was used for video sequence images to detect salient objects that IPTV subscribers will be interested in, in an encoded and decoded video being displayed on the TV. A simple linear iterative was used to cluster superpixel salient algorithm that cluster pixels in a combined five-dimensional colour and image plane space to efficiently generate compact, and nearly uniform superpixels to create a background template. Consequently, the sparse reconstruction error segmented the image and finally, a saliency map was created to determine the salient object. The saliency map output of the SSLS algorithm was compared for performance with seven other state-of-the-art algorithms. Two public video sequence datasets were adopted and both qualitative and quantitative evaluation methods were explored for performance evaluation. The qualitative evaluation was carried out using the effectiveness of the generated saliency map compared with other state-of-the-art algorithms. The quantitative evaluation performance was carried out using eight well-known metrics.

8. 2 Future Works

In this thesis, significant progress was made in addressing challenges that face widespread use of IPTV, such as zapping delay. The framework proposed, evaluated and analysed in this thesis helped reduce zapping delay. However, several challenges to IPTV persist and to this end, this thesis suggested the following possible directions in making this research go further.

1. Further research should be made at the video level, especially in relation to IPTV video coding. A zapping delay framework can then be implemented that infuses the subscriber, network and video level in developing a framework that meets challenges faced by subscribers at all levels.
2. Classification of TV programs into different genre must be done using clustering algorithms.
3. New approaches can also be researched and developed in reducing total seek time and total seek distance other than the use of the up/down remote approach and some OTT approaches that make use of the mouse selection.
4. The proposed algorithm can be practically implemented in a real-world managed converged network via service providers. The performance of the algorithm can be tested on different broadband line, speeds to ascertain optimal performance.
5. Further research should be carried out at the network level in order to eliminate the zapping delay problem. So as to resolve network parameters such as end-to-end delay, jitter and throughput rate. This will empower wide IPTV service deployment when benchmarked with different terrestrial broadcasting services.

8.3 Conclusion

This thesis investigated the problem of zapping delay in a converged network, in order to improve the quality of service caused by zapping delay and aid a high satisfactory quality of experience for IPTV subscribers. A comprehensive review of research work was presented. However, it is quite unfortunate that despite the vast amount of literature and research into combating the problem of zapping delay. Various approaches, methods, and frameworks all seem abortive and non-effective, which has deterred the widespread adoption of IPTV when compared to the terrestrial broadcasting services.

The work presented in this thesis investigated the proposed zapping delay framework and it was benchmarked with different other approaches to measure total seek time, total seek distance, point-to-point queuing delay, end-to-end packet delay, packet variation, network throughput and buffering delay. The analysis shows that the proposed zapping delay framework helps to reduce zapping delay with the aforementioned metrics. Furthermore, subscriber perceptions were analysed for the highly satisfactory level of quality of experience using a segmentation algorithm for video sequence images to capture salient objects that will interest the subscribers. The SSLS algorithm was compared with seven other popular algorithms and evaluated while eight popular metrics were used to extract the quantitative information by comparing the segmented video sequence image with the ground truth. MOS value was further used to analyse subscriber perception based on the extracted quantitative information. The application of the proposed zapping delay framework has proved that it is indeed possible to reduce zapping delay in IPTV over a converged network to the bare minimum.

REFERENCES

Abdollahpouri, A., Qavami, R. and Moradi, P., 2017. On the synthetic dataset generation for IPTV services based on user behaviour. *Multimedia Tools and Applications*, 77:8475–8493.

Abreu, J., Almeida, P., Teles, B. and Reis, M. 2013. Viewer behaviours and practices in the (new) television environment. In: Proceedings of *Proceedings of the 11th european conference on Interactive TV and video*, 5-12.

Achanta, R., Shaji, A., Smith, K., Lucchi, A., Fua, P. and Süsstrunk, S. 2010. Slic superpixels. *EPFL-report-149300*, 1-15.

Achanta, R., Shaji, A., Smith, K., Lucchi, A., Fua, P. and Süsstrunk, S. 2012. SLIC superpixels compared to state-of-the-art superpixel methods. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 34 (11): 2274-2282.

Achanta, R. and Süsstrunk, S. 2010. Saliency detection using maximum symmetric surround. In: Proceedings of *Image processing (ICIP), 2010 17th IEEE international conference*, 2653-2656.

Adomavicius, G. and Tuzhilin, A. 2011. Context-aware recommender systems. In: *Recommender systems handbook*, 217-253.

Ahmad, K. and Begen, A. C. 2009. IPTV and video networks in the 2015 timeframe: The evolution to medianets. *IEEE Communications Magazine*, 47 (12): 68-74.

Ahn, E., Bi, L., Jung, Y. H., Kim, J., Li, C., Fulham, M. and Feng, D. D. 2015. Automated saliency-based lesion segmentation in dermoscopic images. In: Proceedings of *Engineering in Medicine and Biology Society (EMBC), 2015 37th Annual International Conference of the IEEE*, 3009-3012.

Ahn, E., Kim, J., Bi, L., Kumar, A., Li, C., Fulham, M. and Feng, D.D., 2017. Saliency-based lesion segmentation via background detection in dermoscopic images.

IEEE journal of biomedical and health informatics, 21(6): 1685-1693.

Alasaad, A., Gopalakrishnan, S. and Leung, V. C. 2015. A hybrid approach for cost-effective media streaming based on prediction of demand in community networks. *Telecommunication Systems*, 59 (3): 329-343.

Al-azawi, R. J., Abdulhameed, A. A. and Ahmed, H. M. 2017. A Robustness Segmentation Approach for Skin Cancer Image Detection Based on an Adaptive Automatic Thresholding Technique. *American Journal of Intelligent Systems*, 7 (4): 107-112.

Alben, L. 1996. Defining the criteria for effective interaction design. *interactions*, 3 (3): 11-15.

Al-Hezmi, A., Rebahi, Y., Magedanz, T. and Arbanowski, S. 2006. Towards an interactive IPTV for mobile subscribers. In: Proceedings of *International Conference on Digital Telecommunications (ICDT'06)*, 45-45.

Al-Mohammed, E. and Linge, N. 2016. A generic, personalized electronic program guide system for accessing multiple online TV providers. In: Proceedings of *Internet Technology and Secured Transactions (ICITST), 2016 11th International Conference*, 291-296.

Almowuena, S., Rahman, M.M., Hsu, C.H., Hassan, A.A. and Hefeeda, M., 2016. Energy-aware and bandwidth-efficient hybrid video streaming over mobile networks. *IEEE Transactions on Multimedia*, 18(1):102-115.

Arberg, P., Cagenius, T., Tidblad, O. V., Ullerstig, M. and Winterbottom, P. 2007. Network infrastructure for IPTV. *Ericsson Review*, 84(3): 79-83.

Artundo, I., García-Roger, D., Ortega, B. and Capmany, J., 2010, July. Converged optical networks for video and data distribution in hospitality environments. In *Optical Communication Systems (OPTICS), Proceedings of the 2010 International Conference*, 1-7.

Asghar, J., Hood, I. and Le Faucheur, F. 2009. Preserving video quality in IPTV networks. *IEEE Transactions on Broadcasting*, 55 (2): 386-395.

Azgin, A. and Altunbasak, Y. 2013. Dynamic channel reordering to reduce latency during surfing periods in IPTV networks. *IEEE Transactions on Broadcasting*, 59 (3): 471-483.

Baeza-Yates, R. and Ribeiro-Neto, B. 1999. Modern information retrieval. *ACM press New York*. 463: 1-103

Bahn, H. 2016. Channel Reordering and Prefetching Techniques for Efficient Channel Navigation in IPTVs. *The Journal of the Institute of Internet, Broadcasting and Communication*, 16 (3): 1-6.

Bahnasse, A., Louhab, F.E., Oulahyane, H.A., Talea, M. and Bakali, A., 2018. Novel SDN architecture for smart MPLS Traffic Engineering-DiffServ Aware management. *Future Generation Computer Systems*, 87: 115–126.

Banodkar, D., Ramakrishnan, K., Kalyanaraman, S., Gerber, A. and Spatscheck, O. 2008. Multicast instant channel change in IPTV systems. In: Proceedings of *Communication Systems Software and Middleware and Workshops, 2008. COMSWARE 2008. 3rd International Conference on*, 370-379.

Begen, A., Akgul, T. and Baugher, M. 2011. Watching video over the web: Part 1: Streaming protocols. *IEEE Internet Computing*, 15 (2): 54-63.

Begen, A. C., Perkins, C. and Ott, J. 2010. On the use of RTP for monitoring and fault isolation in IPTV. *IEEE Network*, 24 (2): 14-19.

Beyragh, A. A. and Rahbar, A. G. 2014. IFCS: an intelligent fast channel switching in IPTV over PON based on human behaviour prediction. *Multimedia Tools and Applications*, 72 (2): 1049-1071.

Beyragh, A. A. and Rahbar, A. G. 2016. A novel idea on supporting mobile IPTV services over mixed DVB-H and 3G networks. *Multimedia Tools and Applications*, 75 (4): 2091-2110.

Bhandari, A. K., Kumar, A. and Singh, G. K. 2015. Tsallis entropy based multilevel thresholding for colored satellite image segmentation using evolutionary algorithms. *Expert Systems with Applications*, 42 (22): 8707-8730.

Bhat, A., Kannangara, S., Zhao, Y. and Richardson, I. 2012. A full reference quality metric for compressed video based on mean squared error and video content. *IEEE Transactions on Circuits and Systems for Video Technology*, 22 (2): 165-173.

Bhattacharyya, S. 2003. An overview of source-specific multicast (SSM*). IETF: Network Working Group*, 1-14.

Bhaumik, P., Reaz, A. S., Murayama, D., Suzuki, K.-I., Yoshimoto, N., Kramer, G. and Mukherjee, B. 2015. IPTV over EPON: synthetic traffic generation and performance evaluation. *Optical Switching and Networking*, 18: 180-190.

Bikfalvi, A., García-Reinoso, J., Vidal, I., Valera, F. and Azcorra, A. 2011. P2P vs. IP multicast: Comparing approaches to IPTV streaming based on TV channel popularity. *Computer Networks*, 55 (6): 1310-1325.

Black, U. D. 2000. QoS in wide area networks. *Prentice Hall PTR*, 1-343

Boyce, J. M. and Tourapis, A. M. 2005. Fast efficient channel change [set-top box applications]. In: Proceedings of *Consumer Electronics, 2005. ICCE. 2005 Digest of Technical Papers. International Conference*, 1-2.

Brennan, M. and Syn, M. 2001. Television viewing behaviour during commercial breaks. In: Proceedings of *2001 Australian & New Zealand Marketing Academy Conference*, 1-5

Cai, L. X., Cai, L., Shen, X. S. and Mark, J. W. 2009. Resource management and QoS provisioning for IPTV over mmWave-based WPANs with directional antenna. *Mobile Networks and Applications*, 14 (2): 210-219.

Cain, B. 2006. Source-specific multicast for IP. *IETF: Network Working Group*, 1-19.

Caja, J. 2006. Optimization of IPTV multicast traffic transport over next generation metro networks. In: Proceedings of *Telecommunications Network Strategy and Planning Symposium, 2006. NETWORKS 2006. 12th International*, 1-6.

Cha, M., Gummadi, K. and Rodriguez, P. 2008c. Channel selection problem in live IPTV systems. *Proc. of ACM SIGCOMM Poster*, 495-496.

Cha, M., Rodriguez, P., Crowcroft, J., Moon, S. and Amatriain, X. 2008a. Watching television over an IP network. In: Proceedings of *Proceedings of the 8th ACM SIGCOMM conference on Internet measurement*, 71-84.

Cha, M., Rodriguez, P., Moon, S.B. and Crowcroft, J., 2008b. On next-generation telco-managed P2P TV architectures. In *IPTPS*, 1-6.

Chang, C.-S. and Thomas, J. A. 1995. Effective bandwidth in high-speed digital networks. *IEEE Journal on Selected Areas in Communications*, 13 (6): 1091-1100.

Chang, H.-Y., Huang, S.-C. and Lai, C.-C. 2014. A personalized IPTV channel-recommendation mechanism based on the MapReduce framework. *The Journal of Supercomputing*, 69 (1): 225-247.

Chase, C. J. 2016. *Broadcast interactive television system*: Google Patents.

Chauhan, P. and Yadav, I. 2015. Performance Analysis of IPTV over WiMAX using QAM and QPSK Modulation. *International Journal of Science, Engineering and Technology Research (IJSETR)*, 4 (6): 1834-1838

Chen, C., Li, S., Wang, Y., Qin, H. and Hao, A. 2017. Video Saliency Detection via Spatial-Temporal Fusion and Low-Rank Coherency Diffusion. *IEEE Transactions on Image Processing,* 26 (7): 3156-3170.

Chen, C. W., Chatzimisios, P., Dagiuklas, T. and Atzori, L. 2015. *Multimedia Quality of Experience (QoE): Current Status and Future Requirements*. John Wiley & Sons, 1-173

Chen, Y., Le Merrer, E., Li, Z., Liu, Y. and Simon, G. 2012. OAZE: A network-friendly distributed zapping system for peer-to-peer IPTV. *Computer Networks,* 56 (1): 365-377.

Chen, Y.-C. and Liao, C.-Y. 2016. Improving quality of experience in P2P IPTV. In: Proceedings of *Network Operations and Management Symposium (APNOMS), 2016 18th Asia-Pacific*, 1-4.

Chen, Y.-F., Huang, Y., Jana, R., Jiang, H., Rabinovich, M., Rahe, J., Wei, B. and Xiao, Z. 2009. Towards capacity and profit optimization of video-on-demand services in a peer-assisted IPTV platform. *Multimedia Systems*, 15 (1): 19-32.

Chen, Y.-W. and Chiu, T.-T. 2012. Minimizing Zapping Time in IPTV Based on User's Interest. *International Journal of Computer and Communication Engineering*, 1 (2): 77.

Chen, Y., Jermias, J. and Lee, G., 2015. The Impact of Goal Achievability in Incentive Contracts and Feedback on Effort and Performance. In *Academy of Management Proceedings,* 2015(1): 16959).

Cheng, M.M., Mitra, N.J., Huang, X., Torr, P.H. and Hu, S.M., 2015. Global contrast based salient region detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence, 37*(3): 569-582.

Cho, C., Han, I., Jun, Y. and Lee, H. 2004. Improvement of channel zapping time in IPTV services using the adjacent groups join-leave method. In: Proceedings of *Advanced Communication Technology, 2004. The 6th International Conference*, 971-975.

Choi, J., Reaz, A. S. and Mukherjee, B. 2012. A survey of user behaviour in VoD service and bandwidth-saving multicast streaming schemes. *IEEE Communications Surveys and Tutorials*, 14 (1): 156-169.

Cohen, M.A., Dennett, D.C. and Kanwisher, N., 2016. What is the bandwidth of perceptual experience? *Trends in cognitive sciences*, *20*(5): 324-335.

Collet, J.-L., Drouet, F.-X., Lebrun, S. C. M. M. and Marmigere, G. 2011. *Method and apparatus for workload management of a content on demand service*: Google Patents.

Condoluci, M., Araniti, G., Molinaro, A. and Iera, A., 2016. Multicast resource allocation enhanced by channel state feedbacks for multiple scalable video coding streams in LTE networks. *IEEE Transactions on Vehicular Tech*nology, 65(5): 2907-2921.

Corcoran, P., Dukes, S. and Reimers, U.H., 2015. Champions in our midst: the father of digital video broadcasting. *IEEE Consumer Electronics Magazine*, *4*(2): 71-78.

Correa, G., Assuncao, P., Agostini, L. and da Silva Cruz, L. A. 2012. Performance and computational complexity assessment of high-efficiency video encoders. *IEEE Transactions on Circuits and Systems for Video Technology*, 22 (12): 1899-1909.

Cruz, R.A.S., Nunes, M.S., Menezes, L. and Domingues, J., 2011. IPTV architecture for an IMS environment with dynamic QoS adaptation. *Multimedia Tools and Applications*, *53*(3): 557-589.

da Silva, A. P. C., Leonardi, E., Mellia, M. and Meo, M. 2008. A bandwidth-aware scheduling strategy for P2P-TV systems. In: Proceedings of *Peer-to-Peer Computing, 2008. P2P'08. Eighth International Conference*, 279-288.

Das, S. K., Naor, Z. and Raj, M. 2015. Popularity-based caching for IPTV services over P2P networks. *Peer-to-Peer Networking and Applications*, *10*(1): 156-169.

Davidovic, N. 2014. Program Popularity and Viewer Behaviour in a Large TV-on-Demand System. *Seminar: Internet Measurements*, 1-11

de la Fuente, A., Armada, A. G. and Leal, R. P. 2014. Joint multicast/unicast scheduling with dynamic optimization for LTE multicast service. In: Proceedings of *European Wireless 2014; 20th European Wireless Conference; Proceedings of*. VDE, 1-6.

De Vriendt, J., De Vleeschauwer, D. and Robinson, D. 2013. Model for estimating QoE of video delivered using HTTP adaptive streaming. In: Proceedings of *Integrated Network Management (IM 2013), 2013 IFIP/IEEE International Symposium*, 1288-1293.

Degrande, N., Laevens, K., De Vleeschauwer, D. and Sharpe, R. 2008. Increasing the user perceived quality for IPTV services. *IEEE Communications Magazine*, 46 (2): 94-100.

Dekeris, B. and Narbutaite, L. 2015. IPTV channel zap time analysis. *Elektronika ir Elektrotechnika*, 106 (10): 117-120.

Dollár, P., Appel, R., Belongie, S. and Perona, P. 2014. Fast feature pyramids for object detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 36 (8): 1532-1545.

Dong, W., Wilkinson, R. T. and Robinson, P. A. 2012. *Monitoring Over-the-Top Adaptive Video Streaming*: Google Patents.

Doulamis, N. D., Doulamis, A. D., Konstantoulakis, G. E. and Stassinopoulos, G. I. 1997. Performance models for multiplexed VBR MPEG video sources. In: Proceedings of *Communications, 1997. ICC'97 Montreal, Towards the Knowledge Millennium. 1997 IEEE International Conference*, 856-861.

Egozi, O., Gabrilovich, E. and Markovitch, S. 2008. Concept-Based Feature Generation and Selection for Information Retrieval. In: Proceedings of *AAAI*, 1132-1137.

El Abbadi, N. K. and Miry, A. H. 2014. Automatic segmentation of skin lesions using histogram thresholding. *Journal of Computer Science*, 10 (4): 632-639.

Elmisery, A. M., Rho, S. and Botvich, D. 2016. Collaborative privacy framework for minimizing privacy risks in an IPTV social recommender service. *Multimedia Tools and Applications*, 75 (22): 14927-14957.

Engelke, U., Barkowsky, M., Le Callet, P. and Zepernick, H.-J. 2010. Modelling saliency awareness for objective video quality assessment. In: Proceedings of *Quality of Multimedia Experience (QoMEX), 2010 Second International Workshop*, 212-217.

Enli, G. S. 2008. Redefining public service broadcasting: Multi-platform participation. *Convergence*, 14 (1): 105-120.

Evens, T. and Donders, K., 2016. Mergers and acquisitions in TV broadcasting and distribution: Challenges for competition, industrial and media policy. *Telematics and Informatics*, *33*(2): 674-682.

Fang, Y., Lin, W., Chen, Z., Tsai, C.-M. and Lin, C.-W. 2014. A video saliency detection model in compressed domain. *IEEE Transactions on Circuits and Systems for Video Technology*, 24 (1): 27-38.

Fei, L., Deng, Y. and Mahadevan, S. 2015. *Which is the best belief entropy*. *Journal of Latex Class Files*, 13(9): 1-4

Ferro, R., Hernández, C. and Puerta, G., 2016. Rating prediction in a platform IPTV through an ARIMA Model. International Journal of Engineering and Technology, 7(6): 2018-2029.

Ferro, R., Rodríguez, J. and Hernández, C. 2015. Modelo en Series de Tiempo del Retardo del Cambio de Canal en una Transmisión IPTV. *Información tecnológica*, 26 (6): 155-168.

Fgee, E.-B., Kenney, J. D., Phillips, W. J., Robertson, W. and Sivakumar, S. 2005. Comparison of QoS performance between IPv6 QoS management model and IntServ and DiffServ QoS models. In: Proceedings of *3rd Annual Communication Networks and Services Research Conference (CNSR'05)*, 287-292.

Fowler, H. J. and Leland, W. E. 1991. Local area network characteristics, with implications for broadband network congestion management. *IEEE Journal on Selected Areas in Communications*, 9 (7): 1139-1149.

Frey, M. and Nguyen-Quang, S. 2000. A gamma-based framework for modeling variable-rate MPEG video sources: the GOP GBAR model. *IEEE/ACM transactions on networking*, 8 (6): 710-719.

Friedrich, O., Thatmann, D. and Arbanowski, S. 2010. An IPTV Service State API for converging managed and unmanaged IPTV infrastructures. In: Proceedings of *Multimedia and Expo (ICME), 2010 IEEE International Conference*, 1493-1498.

Fu, H., Cao, X. and Tu, Z. 2013. Cluster-based co-saliency detection. *IEEE Transactions on Image Processing,* 22 (10): 3766-3778.

Fu, X., Wang, C.-Y., Chen, C., Wang, C. and Jay Kuo, C.-C. 2015. Robust image segmentation using contour-guided color palettes. In: Proceedings of *Proceedings of the IEEE International Conference on Computer Vision*, 1618-1625.

Fuchs, H. and Farber, N. 2008. Optimizing channel change time in IPTV applications. In: Proceedings of *2008 IEEE International Symposium on Broadband Multimedia Systems and Broadcasting*, 1-8.

Gabrilovich, E. and Markovitch, S. 2006. Overcoming the brittleness bottleneck using Wikipedia: Enhancing text categorization with encyclopedic knowledge. In: Proceedings of *AAAI*, 1301-1306.

Gardikis, G., Boula, L., Xilouris, G., Kourtis, A., Pallis, E., Sidibé, M. and Negru, D., 2012. Cross-layer monitoring in IPTV networks. IEEE Communications Magazine, 50(7), pp.76-84.

Gardikis, G., Xilouris, G., Montpetit, M.-J., Vanelli-Coralli, A. and Negru, D. 2010. IP and Broadcasting Systems Convergence. *International Journal of Digital Multimedia Broadcasting*, 1-2.

Ghaderzadeh, A., Kargahi, M. and Reshadi, M. 2017. ReDePoly: reducing delays in multi-channel P2P live streaming systems using distributed intelligence. *Telecommunication Systems*, 1-16.

Ghaffarian, H., Fathy, M. and Soryani, M. 2008. Channel access delay analysis of IEEE 802-16 Best Effort services. In: Proceedings of *INFOCOM Workshops 2008*, 1-5.

Ghahfarokhi, B. S., Moghim, N. and Eftekhari, S. 2017. Reducing channel zapping time in live TV broadcasting over content centric networks. *Multimedia Tools and Applications*, 76 (22): 23239-23271.

Ghiata, N. and Marcu, M. 2011. Measurement methods for QoS in VoIP review. In: Proceedings of *Ultra Modern Telecommunications and Control Systems and Workshops (ICUMT), 2011 3rd International Congress*, 1-6.

Girshick, R., Donahue, J., Darrell, T. and Malik, J. 2014. Rich feature hierarchies for accurate object detection and semantic segmentation. In: Proceedings of *Proceedings of the IEEE conference on computer vision and pattern recognition*, 580-587.

Goferman, S., Zelnik-Manor, L. and Tal, A. 2012. Context-aware saliency detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 34 (10): 1915-1926.

Golechha, A., Karanje, S. and Abraham, J., 2016. Comparative study of multicasting protocols based on average end-to-end delay. *Computing, Analytics and Security Trends (CAST),* 58-61.

Gomez-Barquero, D., Gozálvez, D. and Cardona, N. 2009. Application layer FEC for mobile TV delivery in IP datacast over DVB-H systems. *IEEE Transactions on Broadcasting*, 55 (2): 396-406.

Gong, B., Chao, W.-L., Grauman, K. and Sha, F. 2014. Diverse sequential subset selection for supervised video summarization. In: Proceedings of *Advances in Neural Information Processing Systems,* 2069-2077.

Greengrass, J., Evans, J. and Begen, A. C. 2009. Not all packets are equal, part i: Streaming video coding and sla requirements. *IEEE Internet Computing*, 13 (1): 70-75.

Guo, C. and Zhang, L. 2010. A novel multiresolution spatiotemporal saliency detection model and its applications in image and video compression. *IEEE Transactions on Image Processing,* 19 (1): 185-198.

Guo, L., Cheng, T., Huang, Y., Zhao, J. and Zhang, R. 2017. Unsupervised video object segmentation by spatiotemporal graphical model. *Multimedia Tools and Applications*, 76 (1): 1037-1053.

Guo, T., Foh, C. H., Cai, J., Niyato, D. and Wong, E. W. 2011. Performance evaluation of IPTV over wireless home networks. *IEEE transactions on multimedia*, 13 (5): 1116-1126.

Hadizadeh, H. and Bajic, I. V. 2014. Saliency-aware video compression. *IEEE Transactions on Image Processing*, 23 (1): 19-33.

Hamodi, J. M. and Thool, R. C. 2013. Investigate the performance evaluation of IPTV over WiMAX networks. 5(1): 81-95

Han, J., Cheng, G., Li, Z. and Zhang, D. 2017. A Unified Metric Learning-Based Framework for Co-saliency Detection. *IEEE Transactions on Circuits and Systems for Video Technology*, 1-11.

Han, J., Zhou, P., Zhang, D., Cheng, G., Guo, L., Liu, Z., Bu, S. and Wu, J. 2014. Efficient, simultaneous detection of multi-class geospatial targets based on visual saliency modeling and discriminative learning of sparse coding. *ISPRS Journal of Photogrammetry and Remote Sensing*, 89: 37-48.

Harju, J. and Kivimaki, P. 2000. Co-operation and comparison of DiffServ and IntServ: performance measurements. In: Proceedings of *Local Computer Networks, 2000. LCN 2000. Proceedings. 25th Annual IEEE Conference*, 177-186.

Hartung, F., Horn, U., Huschke, J., Kampmann, M., Lohmar, T. and Lundevall, M. 2007. Delivery of broadcast services in 3G networks. *IEEE Transactions on Broadcasting*, 53 (1): 188-199.

He, S., Lau, R.W., Liu, W., Huang, Z. and Yang, Q., 2015. Supercnn: A superpixelwise convolutional neural network for salient object detection. *International journal of computer vision*, *115*(3): 330-344.

Hefeeda, M. and Hsu, C.-H. 2010. On burst transmission scheduling in mobile TV broadcast networks. *IEEE/ACM Transactions on Networking (TON)*, 18 (2): 610-623.

Hei, X., Liu, Y. and Ross, K. W. 2008. IPTV over P2P streaming networks: the mesh-pull approach. *IEEE Communications Magazine*, 46 (2): 86-92.

Held, G. 2006. *Understanding Iptv*. CRC Press, 177-184.

Hiçsönmez, S., Sencar, H. T. and Avcibas, I. 2011. Audio codec identification through payload sampling. In: Proceedings of *Information Forensics and Security (WIFS), 2011 IEEE International Workshop*, 1-6.

Horwitt, E., 2005. Dawning of the converged IP Network.*Broadcom White Paper*.

Huang, L.-K. and Wang, M.-J. J. 1995. Image thresholding by minimizing the measures of fuzziness. *Pattern recognition*, 28 (1): 41-51.

Hughes, M., Li, I., Kotoulas, S. and Suzumura, T. 2017. Medical Text Classification using Convolutional Neural Networks. S*tud Health Technol Inform, 235: 246-296*

International Telecommunication Union. 2008. *IPTV Focus Group*. Available: http://www.itu.int/en/ITU-T/focusgroups/iptv/Pages/default.aspx (Accessed 16 July 2016).

IPTV Forum Japan. 2015. *Integrated Broadcast-Broadband System Specification*. Available: http://www.iptvforum.jp/en/info/2014/02061800.html (Accessed 6 August 2016).

Itti, L. 2004. Automatic foveation for video compression using a neurobiological model of visual attention. *IEEE Transactions on Image Processing*, 13 (10): 1304-1318.

ITU-T. 2006. *ITU-T Focus Group on Internet Protocol Television* Available: http://www.itu.int/en/ITU-T/focusgroups/iptv/Pages/default.aspx (Accessed 12 August 2016).

ITU-TRec.P.10. 2006. Vocabulary for performance and quality of service.

Jackson, D. L., Hansen, R. A. and Smith, A. H. 2014. Multicast Delivery of IPTV over the Internet. *GSTF Journal on Computing (JoC),* 1 (1): 164-169.

Jain, M. and Dovrolis, C. 2002. Pathload: A measurement tool for end-to-end available bandwidth. In: Proceedings of *In Proceedings of Passive and Active Measurements (PAM) Workshop*, 1-12.

Jana, R., Aggarwal, V., Chen, X., Gopalakrishnan, V., Ramakrishnan, K. and Vaishampayan, V. 2016. *System for consolidating heterogeneous data centers through virtualization of services*: Google Patents.

Jennehag, U. and Zhang, T. 2004. Increasing bandwidth utilization in next generation IPTV networks. In: Proceedings of *Image Processing, 2004. ICIP'04. 2004 International Conference on*, 2075-2078.

Jiang, B., Zhang, L., Lu, H., Yang, C. and Yang, M.-H. 2013. Saliency detection via absorbing markov chain. In: Proceedings of *Proceedings of the IEEE International Conference on Computer Vision*, 1665-1672.

Jiménez, J. M., Canovas, A., López, A. and Lloret, J. 2015. A new algorithm to improve the QoE of IPTV service customers. In: Proceedings of *Communications (ICC), 2015 IEEE International Conference*, 6990-6995.

Joachims, T. 1998. Text categorization with support vector machines: Learning with many relevant features. *Machine learning: ECML-98*: 137-142.

Jo, M., Maksymyuk, T., Batista, R.L., Maciel, T.F., De Almeida, A.L. and Klymash, M., 2014. A survey of converging solutions for heterogeneous mobile networks. *IEEE Wireless Communications*, 21(6): 54-62.

Joo, H., Song, H., Lee, D.-B. and Lee, I. 2008. An effective IPTV channel control algorithm considering channel zapping time and network utilization. *IEEE Transactions on Broadcasting*, 54 (2): 208-216.

Joo, H., Yoon, C., Um, T.-W. and Song, H. 2012. A novel fountain code-based mobile IPTV multicast system architecture over WiMAX network. *Journal of Visual Communication and Image Representation*, 23 (1): 161-172.

Kalva, H. 2006. The H. 264 video coding standard. *IEEE multimedia*, 13 (4): 86-90.

Kanellopoulos, D. 2013. *Intelligent Multimedia Technologies for Networking Applications: Techniques and Tools: Techniques and Tools*. IGI Global, 248-269

Kao, K.-L., Ke, C.-H. and Shieh, C.-K. 2006. An advanced simulation tool-set for video transmission performance evaluation. In: Proceedings of *Proceeding from the 2006 workshop on ns-2: the IP network simulator*, 1-8.

Ke, C.-H., Lin, C.-H., Shieh, C.-K. and Hwang, W.-S. 2006. A novel realistic simulation tool for video transmission over wireless network. In: Proceedings of *IEEE International Conference on Sensor Networks, Ubiquitous, and Trustworthy Computing (SUTC'06)*, 1: 1-7.

Ke, C.-H., Shieh, C.-K., Hwang, W.-S. and Ziviani, A. 2008. An Evaluation Framework for More Realistic Simulations of MPEG Video Transmission. *J. Inf. Sci. Eng.*, 24 (2): 425-440.

Kerpez, K., Waring, D., Lapiotis, G., Lyles, J. B. and Vaidyanathan, R. 2006. IPTV service assurance. *IEEE Communications Magazine*, 44 (9): 166-172.

Khabbiza, E.H., El Alami, R. and Qjidaa, H., 2017. A Novel Approach to Reduce the Unicast Bandwidth of an IPTV System in a High-Speed Access Network. *International Journal of Digital Multimedia Broadcasting*, 1-10.

Khayati, L. J., Orencik, C., Savas, E. and Ustaoglu, B. 2016. A practical privacy-preserving targeted advertising scheme for IPTV users. *International Journal of Information Security*, 15 (4): 335-360.

Khoreva, A., Benenson, R., Galasso, F., Hein, M. and Schiele, B. 2016. Improved image boundaries for better video segmentation. In: Proceedings of *Computer Vision–ECCV 2016 Workshops*, 773-788.

Khosroshahi, A.A., Yousefi, S. and Rahbar, A.G., 2016. IPTV channel switching delay reduction through predicting subscribers' behaviours and preferences. *Multimedia Tools and Applications,* 75(11): 6283-6302.

Kim, D. H., Huh, J. H. and Kim, J. D. 2015. Analysis of broadcast packet loss for unequal loss protection in Wi-Fi broadcasting system. In: Proceedings of *IT Convergence and Security (ICITCS), 2015 5th International Conference*, 1-4.

Kim, H. J. and Choi, S. G. 2010. A study on a QoS/QoE correlation model for QoE evaluation on IPTV service. In: Proceedings of *Advanced Communication Technology (ICACT), 2010 The 12th International Conference*, 1377-1382.

Kim, H.-S., Kim, I., Han, K., Kim, D., Seo, J.-S. and Kang, M. 2016. An Adaptive Buffering Method for Practical HTTP Live Streaming on Smart OTT STBs. *KSII Transactions on Internet and Information Systems (TIIS)*, 10 (3): 1416-1428.

Kim, J., Lee, I. and Noh, S. 2010. VoIP QoS (Quality of Service) Design of Measurement Management Process Model. In: Proceedings of *2010 International Conference on Information Science and Applications,* 1-6.

Kim, S., Lee, H. and Lee, M. H. 2010. Research in Convergence: A literature analysis. *Journal of Research and Practice in Information Technology,* 42 (3): 191-205.

Kim, S. and Lee, S. 2008. Web technology and standardization for web 2.0 based IPTV service. In: Proceedings of *Advanced Communication Technology, 2008. ICACT 2008. 10th International Conference*, 1751-1754.

Kim, T., Choi, S. and Bahn, H. 2016. A personalized interface for supporting multi-users in smart TVs. *IEEE Transactions on Consumer Electronics,* 62 (3): 310-315.

Kim, Y., Park, J. K., Choi, H. J., Lee, S., Park, H., Kim, J., Lee, Z. and Ko, K. 2008. Reducing IPTV channel zapping time based on viewer's surfing behaviour and preference. In: Proceedings of *Broadband Multimedia Systems and Broadcasting, 2008 IEEE International Symposium*, 1-6.

Klaue, J., Rathke, B. and Wolisz, A. 2003. Evalvid–A framework for video transmission and quality evaluation. In: Proceedings of *International Conference on Modelling Techniques and Tools for Computer Performance Evaluation*, 255-272.

Ko, J., Park, S. and Lee, E. 2010. An extended PIM-SM for efficient data transmission in IPTV services. In: Proceedings of *Network Infrastructure and Digital Content, 2010 2nd IEEE International Conference*, 115-119.

Koch, C., Hacker, S. and Hausheer, D. 2017. VoDCast: Efficient SDN-based multicast for video on demand. In: Proceedings of *A World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2017 IEEE 18th International Symposium*, 1-6.

Kooij, R. E., Kamal, A. and Brunnström, K. 2006. Perceived quality of channel zapping. In: Proceedings of *Communication Systems and Networks*, 156-159.

Kornfeld, M. and May, G., 2007. DVB-H and IP datacast—broadcast to handheld devices. IEEE Transactions on Broadcasting, 53(1): 161-170.

Kou, G., Peng, Y. and Wang, G. 2014. Evaluation of clustering algorithms for financial risk analysis using MCDM methods. *Information Sciences*, 275: 1-12.

Koumaras, H., Skianis, C., Gardikis, G. and Kourtis, A. 2005. Analysis of H. 264 video encoded traffic. In: Proceedings of *Proceedings of the 5th International Network Conference (INC2005)*, 441-448.

Kren, M., Kos, A., Zhang, Y., Kos, A. and Sedlar, U. 2017. Public Interest Analysis Based on Implicit Feedback of IPTV Users. *IEEE Transactions on Industrial Informatics*, *13*(4): 2077-2086.

Krogfoss, B., Sofman, L. and Agrawal, A. 2008. Caching architectures and optimization strategies for IPTV networks. *Bell Labs Technical Journal,* 13 (3): 13-28.

Krstic, M. and Bjelica, M. 2012. Context-aware personalized program guide based on neural network. *IEEE Transactions on Consumer Electronics*, 58 (4): 1301-1306

Kuen, J., Wang, Z. and Wang, G. 2016. Recurrent attentional networks for saliency detection. In: Proceedings of *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 3668-3677.

Kwon, H.-J. and Hong, K.-S. 2011. Personalized electronic program guide for IPTV based on collaborative filtering with novel similarity method. In: Proceedings of *Consumer Electronics (ICCE), 2011 IEEE International Conference on*. IEEE, 467-468.

Lai, J., Li, J. C., Abdollahpouri, A., Zhang, J. and Lei, M. 2014. A fairness-based access control scheme to optimize IPTV fast channel changing. *Mathematical Problems in Engineering,* 1-12.

Lai, J. and Wolfinger, B. E. 2012. A method to improve the channel availability of IPTV systems with users zapping channels sequentially. In: Proceedings of *International Conference on Wired/Wireless Internet Communications,* 76-89.

Lee, C.-S. 2007. IPTV over next generation networks in ITU-T. In: Proceedings of *Broadband Convergence Networks, 2007. BcN'07. 2nd IEEE/IFIP International Workshop on*, 1-18.

Lee, C. Y., Hong, C. K. and Lee, K. Y. 2010. Reducing channel zapping time in IPTV based on user's channel selection behaviours. *IEEE Transactions on Broadcasting*, 56 (3): 321-330.

Lee, E., Ku, J. Y. and Bahn, H. 2014. An efficient hot channel identification scheme for IPTV channel navigation. *IEEE Transactions on Consumer Electronics*, 60 (1): 124-129.

Lee, E. W., Jiyoung; Oh, Uran; Koh, Kern; Bahn, Hyokyung. 2009. Popular channel concentration schemes for efficient channel navigation in internet protocol televisions. *IEEE Transactions on Consumer Electronics*, 55 (4): 1945 - 1949.

Lee, H., Kim, H. Y. and Lee, H.-K. 2007. News package service based on TV-Anytime metadata gathered from RSS. In: Proceedings of *Consumer Electronics, 2007. ISCE 2007. IEEE International Symposium*, 1-6.

Lee, H., Lee, S., Kim, H. and Bahn, H. 2006. Personalized recommendation schemes for DTV channel selectors. *IEEE Transactions on Consumer Electronics*, 52 (3): 1064-1068.

Lee, J., Lee, G., Seok, S. and Chung, B. 2007. Advanced scheme to reduce IPTV channel zapping time. *Managing Next Generation Networks and Services*, 235-243.

Lee, S., Moon, H., Bahn, H., Kim, T. and Kim, I.-S. 2011. Popularity and adjacency based prefetching for efficient IPTV channel navigation. *IEEE Transactions on Consumer Electronics*, 57 (3): 1135-1140

Lee, S., Park, E.-A., Lee, S. and Brown, J. 2015. Determinants of IPTV diffusion. *Telematics and Informatics*, 32 (3): 439-446.

Lee, S.-G. and Choi, J.-H. 2011. Dynamic Popular Channel Surfing Scheme for Reducing the Channel Seek Distance in DTV. *Journal of the Korea Society of Computer and Information*, 16 (2): 207-215.

Lee, S.-H., Kang, J.-W. and Kim, C.-S. 2016. Compressed domain video saliency detection using global and local spatiotemporal features. *Journal of Visual Communication and Image Representation*, 35: 169-183.

Lee, Y., Lee, J., Kim, I. and Shin, H. 2008. Reducing IPTV channel switching time using H. 264 scalable video coding. *IEEE Transactions on Consumer Electronics*, 54 (2): 912-919.

Lei, J., Wang, B., Fang, Y., Lin, W., Le Callet, P., Ling, N. and Hou, C., 2016. A universal framework for salient object detection. *IEEE Transactions on Multimedia*, *18*(9): 1783-1795.

Lencse, G. and Derka, I. 2013. Investigation of the fault tolerance of the PIM-SM IP multicast routing protocol for IPTV purposes. *Infocommunications Journal*, 5 (1): 21-28.

Leskovec, J., Rajaraman, A. and Ullman, J. D. 2014. *Mining of massive datasets*. Cambridge university press, 1-16

Li, B., Sullivan, G. J. and Xu, J. 2012. Comparison of compression performance of HEVC working draft 5 with AVC high profile. *document JCTVC-H0360*, 886-889.

Li, F., Kim, T., Humayun, A., Tsai, D. and Rehg, J. M. 2013. Video segmentation by tracking many figure-ground segments. In: Proceedings of *Proceedings of the IEEE International Conference on Computer Vision*, 2192-2199.

Li, J., Levine, M. D., An, X., Xu, X. and He, H. 2013. Visual saliency based on scale-space analysis in the frequency domain. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 35 (4): 996-1010.

Li, J., Xia, C. and Chen, X. 2018. A Benchmark Dataset and Saliency-Guided Stacked Autoencoders for Video-Based Salient Object Detection. *IEEE Transactions on Image Processing*, 27 (1): 349-364.

Li, R., Li, M., Liao, H. and Huang, N. 2017. An efficient method for evaluating the end-to-end transmission time reliability of a switched Ethernet. *Journal of Network and Computer Applications*, *88*: 124-133.

Li, W., Luo, Q., Yu, P. and Qiu, X. 2015. Reduced-reference video QoE assessment method based on image feature information. In: Proceedings of *Network Operations and Management Symposium (APNOMS), 2015 17th Asia-Pacific*, 519-522.

Li, Y., Fu, K., Liu, Z. and Yang, J. 2015. Efficient saliency-model-guided visual co-saliency detection. *IEEE Signal Processing Letters*, 22 (5): 588-592.

Liem, A. T., Hwang, I.-S., Nikoukar, A., Yang, C.-Z., Ab-Rahman, M. S. and Lu, C.-H. 2016. P2P live-streaming application-aware architecture for QoS enhancement in the EPON. *IEEE Systems Journal*, *12*(1): 648-658.

Liu, H., Liu, Y.-S., Pauwels, P., Guo, H. and Gu, M. 2017. Enhanced Explicit Semantic Analysis for Product Model Retrieval in Construction Industry. *IEEE Transactions on Industrial Informatics*, *13*(6): 3361-3369.

Liu, H., Ramasubramanian, V. and Sirer, E. G. 2005. Client behaviour and feed characteristics of RSS, a publish-subscribe system for web micronews. In: Proceedings of *Proceedings of the 5th ACM SIGCOMM conference on Internet Measurement*, 1-3.

Liu, N., Cui, H., Chan, S.-H. G., Chen, Z. and Zhuang, Y. 2014. Dissecting user behaviours for a simultaneous live and VoD IPTV system. *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMM)*, 10 (3): 1-16.

Lloret, J., Garcia, M., Atenas, M. and Canovas, A. 2011. A QoE management system to improve the IPTV network. *International Journal of Communication Systems*, 24 (1): 118-138.

Lou, J., Zhu, W., Wang, H. and Ren, M. 2016. Small target detection combining regional stability and saliency in a color image. *Multimedia Tools and Applications*, 1-18.

Lu, H., Li, X., Zhang, L., Ruan, X. and Yang, M.-H. 2016. Dense and sparse reconstruction error based saliency descriptor. *IEEE Transactions on Image Processing*, 25 (4): 1592-1603.

Lucio, G. F., Paredes-Farrera, M., Jammeh, E., Fleury, M. and Reed, M. J. 2003. Opnet modeler and ns-2: Comparing the accuracy of network simulators for packet-level analysis using a network testbed. *wseas transactions on computers*, 2 (3): 700-707.

Luo, H., Zhang, H., Zukerman, M. and Qiao, C., 2014. An incrementally deployable network architecture to support both data-centric and host-centric services. *IEEE Network*, 28(4): 58-65.

Luo, Q., Geng, Y., Liu, J. and Li, W. 2014. Saliency and texture information based full-reference quality metrics for video QoE assessment. In: Proceedings of *Network Operations and Management Symposium (NOMS)*, 1-6.

Maggiori, E., Charpiat, G., Tarabalka, Y. and Alliez, P. 2017. Recurrent Neural Networks to Correct Satellite Image Classification Maps. *IEEE Transactions on Geoscience and Remote Sensing*, *55*(9): 4962-4971.

Malkoş, S., Uccedil, E. and Akdeniz, R. 2012. Improving QoE in multicast IPTV systems: Channel zapping times. *Scientific Research and Essays*, 7 (35): 3107-3113.

Mandal, S. K. and MBuru, M. 2008. Intelligent pre-fetching to reduce channel switching delay in IPTV systems. *Texas A & M*, 1-6.

Manikandan, M., Saurigresan, P. and Ramkumar, R. 2016. Grouped frequency interleaved ordering with pre-fetching for efficient channel navigation in internet protocol television. *Multimedia Tools and Applications*, 75 (2): 887-902.

Manikandan, M. S. K., Saurigresan, P. and Ramkumar, R. 2014. Grouped frequency interleaved ordering with pre-fetching for efficient channel navigation in internet protocol television. *Multimedia Tools and Applications*, 75 (2): 887-902.

Manjunath, L. and Mastani, S. A. 2013. A novel approach for increasing channel navigation in IPTV based on user's channel selection interests. *Int J Eng Res Appl (IJERA)*, 3 (3): 1331-1336.

Mansour, H., Fallah, Y. P., Nasiopoulos, P. and Krishnamurthy, V. 2009. Dynamic resource allocation for MGS H. 264/AVC video transmission over link-adaptive networks. *IEEE transactions on multimedia*, 11 (8): 1478-1491.

Mansouri, T., Nabavi, A., Ravasan, A. Z. and Ahangarbahan, H. 2016. A practical model for ensemble estimation of QoS and QoE in VoIP services via fuzzy inference systems and fuzzy evidence theory. *Telecommunication Systems*, 61 (4): 861-873.

Manzato, D. A. and da Fonseca, N. L. 2010. A channel switching scheme for IPTV systems. In: Proceedings of *Global Telecommunications Conference (GLOBECOM 2010)*, 1-6.

Manzato, D. A. and da Fonseca, N. L. 2013. A survey of channel switching schemes for IPTV. *IEEE Communications Magazine*, 51 (8): 120-127.

Maraj, A. and Shehu, A. 2012. Analysis of different parameters that affect QoS/QoE for offering multi-IPTV video simultaneously in TK. *JOURNAL of Communication and Computer*, 9: 1412-1423.

Margolin, R., Tal, A. and Zelnik-Manor, L. 2013. What makes a patch distinct? In: Proceedings of *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 1139-1146.

Marinai, S., Miotti, B. and Soda, G. 2011. Digital libraries and document image retrieval techniques: A survey. In: *Learning structure and schemas from documents*, 181-204.

Mark, A. and Miller, P. E. 2005. Introduction to Converged Networking. *A technical briefing series on VoIP and converged networks*, 1: 1-8.

Marpe, D., Wiegand, T. and Sullivan, G. J. 2006. The H. 264/MPEG4 advanced video coding standard and its applications. *IEEE Communications Magazine*, 44 (8): 134-143.

Masood, A., Al-Jumaily, A. A. and Maali, Y. 2013. Level Set Initialization Based on Modified Fuzzy C Means Thresholding for Automated Segmentation of Skin Lesions. In: Proceedings of *International Conference on Neural Information Processing*, 341-351.

Merani, M. L., Natali, L. and Barcellona, C. 2016. An IP-TV P2P streaming system that improves the viewing quality and confines the startup delay of regular audience. *Peer-to-Peer Networking and Applications*, 9 (1): 209-222.

Mikoczy, E., Sivchenko, D., Xu, B. and Rakocevic, V. 2007. IMS based IPTV services: architecture and implementation. In: Proceedings of *Proceedings of the 3rd international conference on Mobile multimedia communications*. ICST (Institute for Computer Sciences, Social-Informatics and Telecommunications Engineering), 15: 1-7.

Mikoczy, E., Telekom, S., Sivchenko, D., Xu, B. and Moreno, J. I. 2008. IPTV Systems, Standards and Architectures: Part II-IPTV Services over IMS: Architecture and Standardization. *IEEE Communications Magazine*, 46 (5): 128-135.

Minoli, D, 2012. IPTV Systems and Technologies. *Linear and Nonlinear Video and TV Applications: Using IPv6 and IPv6 Multicast*, pp.147-239.

Misu, T., Matsuo, Y., Iwamura, S. and Sakaida, S., 2015, January. Real-time video coding system for up to 4K 120P videos with spatio-temporal format conversion. In *Consumer Electronics (ICCE), 2015 IEEE International Conference*, 52-55.

Mocanu, D. C., Exarchakos, G., Ammar, H. B. and Liotta, A. 2015. Reduced reference image quality assessment via boltzmann machines. In: Proceedings of *Integrated Network Management (IM), 2015 IFIP/IEEE International Symposium*, 1278-1281.

Montpetit, M.-J., Klym, N. and Blain, E. 2010. The future of mobile TV: when mobile TV meets the internet and social networking. In: *Mobile TV: Customizing content and experience*, 305-326.

Moughit, M., Badri, A. and Sahel, A. 2013. A Multicast IPTV Bandwidth Saving Method. *International Journal of Computer Applications*, 64 (14): 22-26

Moustafa, H. and Zeadally, S. 2012. *Media Networks: Architectures, Applications, and Standards*. CRC Press. 1-555.

Mrak, M. and Izquierdo, E. 2008. Scalable Video Coding Fundamentals. In: *Encyclopedia of Multimedia*, 771-775.

Musto, C., Narducci, F., Lops, P., Semeraro, G., De Gemmis, M., Barbieri, M., Korst, J. H., Pronk, V. and Clout, R. 2012. Enhanced Semantic TV-Show Representation for Personalized Electronic Program Guides. In: Proceedings of *UMAP*, 188-199.

Narducci, F., Musto, C., de Gemmis, M., Lops, P. and Semeraro, G. 2017. TV-Program Retrieval and Classification: A Comparison of Approaches based on Machine Learning. *Information Systems Frontiers*, 1-15.

Nikoukar, A., Hwang, I.-S., Liem, A. T. and Lee, J.-Y. 2016. Mitigating the IPTV Zap time in enhanced EPON systems. *Journal of Optical Communications and Networking*, 8 (6): 451-461.

Nlend, S., Swart, T. G. and Clarke, W. A. 2011. Optimization of resources for H. 323 endpoints and terminals over VoIP networks. In: Proceedings of *AFRICON, 2011*, 1-5.

Oh, U., Lim, S. and Bahn, H. 2010. Channel reordering and prefetching schemes for efficient IPTV channel navigation. *IEEE Transactions on Consumer Electronics*, 56 (2): 483-487.

Oh, J.G., Won, Y.J., Lee, J.S.S. and Kim, J.T., 2017. A convergence broadcasting transmission of fixed 4K UHD and mobile HD services through a single terrestrial channel by employing FEF multiplexing technique in DVB-T2. Electrical Engineering, 99(3): 1021-1042.

Ohm, J.-R. 2005. Advances in scalable video coding. *Proceedings of the IEEE*, 93 (1): 42-56.

Oliveira, R., de Abreu, J. F. and Almeida, A. M. 2017. Promoting Interactive Television (iTV) Accessibility: an adapted service for users with visual impairments. *Universal Access in the Information Society*, 16 (3): 533-544.

Olugbara, O. O., Adetiba, E. and Oyewole, S. A. 2015. Pixel intensity clustering algorithm for multilevel image segmentation. *Mathematical Problems in Engineering*, 1-20.

Otsu, N. 1979. A threshold selection method from gray-level histograms. *IEEE transactions on systems, man, and cybernetics*, 9 (1): 62-66.

Park, D.-J. and Lee, J.-D. 2016. Implementation of Personalized EPG Service based on Tru2Way. *Journal of the Korea Industrial Information Systems Research*, 21 (1): 51-59.

Park, S., Jeong, S.-H. and Hwang, C. 2008. Mobile IPTV expanding the value of IPTV. In: Proceedings of *Networking, 2008. ICN 2008. Seventh International Conference*, 296-301.

Pavlić, M. and Bratković, D. 2015. Comparison of different NGN aggregation networks scenarios. In: Proceedings of *ELMAR (ELMAR), 2015 57th International Symposium*, 81-84.

Peart, A. and Good, A. 2012. Wireless bandwidth authentication improving quality of service. *Academic Journal of Manufacturing Engineering*, 10 (3): 1-11.

Perazzi, F., Khoreva, A., Benenson, R., Schiele, B. and Sorkine-Hornung, A. 2017. Learning video object segmentation from static images. In: Proceedings of CVPR, 2663-2672.

Perazzi, F., Pont-Tuset, J., McWilliams, B., Van Gool, L., Gross, M. and Sorkine-Hornung, A. 2016. A benchmark dataset and evaluation methodology for video object segmentation. In: Proceedings of *Proceedings of the IEEE Conference on Computer Vision and Pattern Recognition*, 724-732.

Pierson, J. and Bauwens, J., 2015. *Digital Broadcasting: An Introduction to New Media*. Bloomsbury Publishing, 803-805

Podder, P. K., Paul, M. and Murshed, M. 2016. Fast mode decision in the HEVC video coding standard by exploiting region with dominated motion and saliency features. *PloS one*, 11 (3): 1-22.

Pont-Tuset, J., Arbelaez, P., Barron, J.T., Marques, F. and Malik, J., 2017. Multiscale combinatorial grouping for image segmentation and object proposal generation. *IEEE transactions on pattern analysis and machine intelligence, 39*(1): 128-140.

Pont-Tuset, J. and Marques, F. 2016. Supervised evaluation of image segmentation and object proposal techniques. *IEEE Transactions on Pattern Analysis and Machine Intelligence,* 38 (7): 1465-1478.

Popovic, A., De la Fuente, M., Engelhardt, M. and Radermacher, K. 2007. Statistical validation metric for accuracy assessment in medical image segmentation. *International Journal of Computer Assisted Radiology and Surgery*, 2 (3): 169-181.

Potapov, D., Douze, M., Harchaoui, Z. and Schmid, C. 2014. Category-specific video summarization. In: Proceedings of *European conference on computer vision*, 540-555.

Qaddour, J. and Polishetty, Y., 2016. Modeling and Performance Analysis of a Converged Network. *International Conference on Wireless and Mobile Communications (ICWMC),* 23-27.

Qi, J., Dong, S., Huang, F. and Lu, H. 2017. Saliency detection via joint modeling global shape and local consistency. *Neurocomputing*, 222: 81-90.

Quan, W., Liu, Y., Zhang, H. and Yu, S., 2017. Enhancing Crowd Collaborations for Software Defined Vehicular Networks. *IEEE Communications Magazine*, 55(8): 80-86.

Quintero, M. A. R., Zachey, B. and Raake, A. 2015. Annoyance and acceptability of video service responsiveness. In: Proceedings of *Quality of Multimedia Experience (QoMEX), 2015 Seventh International Workshop*, 1-6.

Rabbani, T., Van Den Heuvel, F. and Vosselmann, G. 2006. Segmentation of point clouds using smoothness constraint. *International archives of photogrammetry, remote sensing and spatial information sciences,* 36 (5): 248-253.

Radmand, P. and Talevski, A. 2010. Impact of encryption on QoS in VoIP. In: Proceedings of *Social Computing (SocialCom), 2010 IEEE Second International Conference*, 721-726.

Ramos, F., Song, F., Rodriguez, P., Gibbens, R., Crowcroft, J. and White, I. H. 2009. Constructing an IPTV workload model. *SIGCOMM Poster Session*, 1-2.

Ramos, F. M. 2013. Mitigating IPTV zapping delay. *IEEE Communications Magazine*, 51 (8): 128-133.

Ramos, F. M., Crowcroft, J., Gibbens, R. J., Rodriguez, P. and White, I. H. 2010. Channel smurfing: Minimising channel switching delay in IPTV distribution networks. In: Proceedings of *Multimedia and Expo (ICME), 2010 IEEE International Conference*, 1327-1332.

Ramos, F. M., Crowcroft, J., Gibbens, R. J., Rodriguez, P. and White, I. H. 2011. Reducing channel change delay in IPTV by predictive pre-joining of TV channels. *Signal Processing: Image Communication*, 26 (7): 400-412.

Rattanawadee, P., Ruengsakulrach, N. and Saivichit, C. 2015. The transmission time analysis of IPTV multicast service in SDN/OpenFlow environments. In: Proceedings of *Electrical Engineering/Electronics, Computer, Telecommunications and Information Technology (ECTI-CON), 2015 12th International Conference on*, 1-5.

Ren, C. Y. and Reid, I. 2011. gSLIC: a real-time implementation of SLIC superpixel segmentation. *University of Oxford, Department of Engineering, Technical Report*, 1-6.

Rings, T., Caryer, G., Gallop, J., Grabowski, J., Kovacikova, T., Schulz, S. and Stokes-Rees, I., 2009. Grid and cloud computing: opportunities for integration with the next generation network. *Journal of Grid Computing*, 7(3): 375-393.

Riverbed Modeler. *For defense organizations, network equipment manufacturers, and research organizations*. Available: https://www.riverbed.com/document/fpo/9306_Riverbed_Modeler_DS_101314KC-2.pdf (Accessed 10 September 2016).

Rodrigues, J., Salvador, P. and Nogueira, A., 2011, April. Multimedia content aggregator applied to an IPTV content-zapping service. In EUROCON-International Conference on Computer as a Tool (EUROCON), 2011 IEEE (pp. 1-4). IEEE.

Rodrigues, J., Nogueira, A., Salvador, P. and Rodrigues, J.J., 2011. IPTV service based on a content-zapping paradigm. Multimedia systems, 17(4), pp.351-364.

Rothenberg, C.E. and Roos, A., 2008. A review of policy-based resource and admission control functions in evolving access and next generation networks. *Journal of Network and Systems Management,* 16(1): 14-45.

Ryoo, J.-K. 2000. *Transmission power control method in asymmetric digital subscriber line system*: Google Patents.

Ryu, J.-h., Lee, B., Kim, K. T. and Youn, H. Y. 2014. Reduction of IPTV channel zapping time by utilizing the key input latency. In: Proceedings of *Consumer Communications and Networking Conference (CCNC), 2014 IEEE 11th*, 263-268.

Sailaja, N., Crabtree, A. and Stenton, P. 2017. Challenges of using personal data to drive personalised electronic programme guides. In: Proceedings of *Proceedings of the 2017 CHI Conference on Human Factors in Computing Systems*, 5226-5231.

Sajid, H. and Cheung, S.C.S., 2017. Universal multimode background subtraction. *IEEE Transactions on Image Processing*, *26*(7): 3249-3260.

Salah, K. and Alkhoraidly, A. 2006. An OPNET-based simulation approach for deploying VoIP. *International Journal of Network Management*, 16 (3): 159-183.

Samanthula, B. K. and Jiang, W. 2016. Secure multiset intersection cardinality and its application to jaccard coefficient. *IEEE Transactions on Dependable and Secure Computing*, 13 (5): 591-604.

Sanneck, H., Carle, G. and Koodli, R. 2000. Framework model for packet loss metrics based on loss runlengths. In: Proceedings of *PROC SPIE INT SOC OPT ENG*, 177-187.

Sarni, M., Hilt, B. and Lorenz, P. 2009. A novel channel switching scenario in multicast IPTV networks. In: Proceedings of *Networking and Services, 2009. ICNS'09. Fifth International Conference on,* 396-401.

Scharr, H., Minervini, M., French, A. P., Klukas, C., Kramer, D. M., Liu, X., Luengo, I., Pape, J.-M., Polder, G. and Vukadinovic, D. 2016. Leaf segmentation in plant phenotyping: a collation study. *Machine vision and applications*, 27 (4): 585-606.

Segall, C. A. and Sullivan, G. J. 2007. Spatial scalability within the H. 264/AVC scalable video coding extension. *IEEE Transactions on Circuits and Systems for Video Technology*, 17 (9): 1121-1135.

Segura-Garcia, J., Felici-Castell, S. and Garcia-Pineda, M., 2018. Performance evaluation of different techniques to estimate subjective quality in live video streaming applications over LTE-Advance mobile networks. *Journal of Network and Computer Applications*, *107*: 22-37.

Shakin Banu, A., Ayswarya, K., Jenifer Esther Gethsee, T. and Arockia Julie, T. 2014. Reconfigurable Channel Reordering To Reduce Latency In IPTV Networks. *International Journal of Innovative Research in Science, Engineering and Technology (IJIRSET*), 3(3): 1655-1661.

Shambour, Q. and Lu, J., 2011, August. A hybrid multi-criteria semantic-enhanced collaborative filtering approach for personalized recommendations. In *Proceedings of the 2011 IEEE/WIC/ACM International Conferences on Web Intelligence and Intelligent Agent Technology*, *1*: 71-78.

Shattuck, D. W., Prasad, G., Mirza, M., Narr, K. L. and Toga, A. W. 2009. Online resource for validation of brain segmentation methods. *NeuroImage*, 45 (2): 431-439.

She, J., Hou, F., Ho, P.-H. and Xie, L.-L. 2007. IPTV over WiMAX: Key success factors, challenges, and solutions [advances in mobile multimedia]. *IEEE Communications Magazine*, 45 (8): 87-93.

Shen, J., Du, Y., Wang, W. and Li, X. 2014. Lazy random walks for superpixel segmentation. *IEEE Transactions on Image Processing*, 23 (4): 1451-1462.

Shen, X. and Wu, Y. 2012. A unified approach to salient object detection via low rank matrix recovery. In: Proceedings of *Computer Vision and Pattern Recognition (CVPR), 2012 IEEE Conference*, 853-860.

Shi, L., Liu, C. and Liu, B. 2008. Network utility maximization for triple-play services. *Computer communications*, 31 (10): 2257-2269.

Shin, Y., Seol, S. and Lee, K., 2016, July. A study on quality of experience of controlling a device remotely in an IoT environment. *In Ubiquitous and Future Networks (ICUFN)*, 699-702.

Siebert, P., Van Caenegem, T. N. and Wagner, M. 2009. Analysis and improvements of zapping times in IPTV systems. *IEEE Transactions on Broadcasting*, 55 (2): 407-418.

Škrbic, M., Šecic, N. and Varatanovic, M., 2010, August. A unicast-based IPTV service control. In *Systems and Networks Communications (ICSNC), 2010 Fifth International Conference,* 278-282.

Smith, D. E. 2007. IP TV bandwidth demand: Multicast and channel surfing. In: Proceedings of *INFOCOM 2007. 26th IEEE International Conference on Computer Communications*, 2546-2550.

Son, J.-W., Kim, A. and Park, S.-B. 2013. A location-based news article recommendation with explicit localized semantic analysis. In: Proceedings of

Proceedings of the 36th international ACM SIGIR conference on Research and development in information retrieval, 293-302.

Song, W. and Tjondronegoro, D. W. 2014. Acceptability-based QoE models for mobile video. *IEEE transactions on multimedia*, 16 (3): 738-750.

Souly, N. and Shah, M. 2016. Visual saliency detection using group lasso regularization in videos of natural scenes. *International Journal of Computer Vision*, 117 (1): 93-110.

South Africa Department of Communication. 2015. *Broadcasting digital migration*. Available: http://www.gov.za/about-government/government-programmes/digital-migration (Accessed 10 July 2016).

Spachos, P., Lin, T., Li, W., Chignell, M., Leon-Garcia, A., Jiang, J. and Zucherman, L. 2017. Subjective QoE assessment on video service: Laboratory controllable approach. In: Proceedings of *A World of Wireless, Mobile and Multimedia Networks (WoWMoM), 2017 IEEE 18th International Symposium*, 1-9.

Steeg, F. v. 2015. Context-aware recommender systems. *Department of Information and Computing Sciences*, 1-80.

Streijl, R. C., Winkler, S. and Hands, D. S. 2016. Mean opinion score (MOS) revisited: methods and applications, limitations and alternatives. *Multimedia Systems*, 22 (2): 213-227.

Sudo, S. and Ito, Y., 2017, July. An Analysis of the Service Ecosystem of the Japanese Pay-Television Industry from the Perspective of Service Dominant Logic. In *Management of Engineering and Technology (PICMET), 2017 Portland International Conference*, 1-10.

Sue, C.-C., Hsu, C.-Y. and Su, Y.-H. Reducing Iptv Channel Change Time By Estimating User Behaviour with Recent-First-Estimator Variation. *International Journal of Advanced Computer Technology (IJACT)*, 5(2): 12-20.

Szymanski, T. H. and Gilbert, D. 2009. Internet multicasting of IPTV with essentially-zero delay jitter. *IEEE Transactions on Broadcasting*, 55 (1): 20-30.

Taha, A. A. and Hanbury, A. 2015. Metrics for evaluating 3D medical image segmentation: analysis, selection, and tool. *BMC medical imaging*, 15 (1): 29.

Takahashi, A., Hands, D. and Barriac, V., 2008. Standardization activities in the ITU for a QoE assessment of IPTV. *IEEE Communications Magazine*, 46(2): 78-84.

Tasse, F. P., Kosinka, J. and Dodgson, N. A. 2016. Quantitative analysis of saliency models. In: Proceedings of *SIGGRAPH ASIA 2016 Technical Briefs*, 1-9.

Thompson, G. and Chen, Y.-F. R. 2009. IPTV: Reinventing television in the Internet age. *IEEE Internet Computing*, 13 (3): 11-14.

Tian, X., Cheng, Y. and Shen, X. 2013. Fast channel zapping with destination-oriented multicast for IP video delivery. *IEEE Transactions on Parallel and Distributed Systems*, 24 (2): 327-341.

Tim, L. 2012. *Network convergence: Challenges and solutions* Available: http://www.datacenterknowledge.com/archives/2012/03/21 /network-convergence-challenges-and-solutions (Accessed 18 August 2016).

Tipton, H. F. and Krause, M. 2003. *Information security management handbook*. CRC Press. 117-120.

Touceda, D. S., Cámara, J. M. S. and Isaac, J. T. 2015. Privacy in Peer-to-Peer Networks. In: *Privacy in a Digital, Networked World*, 111-139.

Tsai, D., Flagg, M. and Rehg, J. 2010. Motion coherent tracking with multi-label mrf optimization, algorithms. Int J Comput Vis (2012) 100:190–202.

Tzannes, M. 2016. *Method and multi-carrier transceiver with stored application profiles for supporting multiple applications*: Google Patents.

Udupa, J. K., LeBlanc, V. R., Zhuge, Y., Imielinska, C., Schmidt, H., Currie, L. M., Hirsch, B. E. and Woodburn, J. 2006. A framework for evaluating image segmentation algorithms. *Computerized Medical Imaging and Graphics*, 30 (2): 75-87.

Uilecan, I. V., Zhou, C. and Atkin, G. E. 2007. Framework for delivering IPTV services over WiMAX wireless networks. In: Proceedings of *Electro/Information Technology, 2007 IEEE International Conference*, 470-475.

Unger, M., Bar, A., Shapira, B. and Rokach, L. 2016. Towards latent context-aware recommendation systems. *Knowledge-Based Systems*, 104: 165-178.

Uzunalioglu, H. 2009. Channel change delay in IPTV systems. In: Proceedings of *Consumer Communications and Networking Conference, (CCNC)*, 1-6.

Van Wallendael, G., Staelens, N., Janowski, L., De Cock, J., Demeester, P. and Van de Walle, R. 2012. No-reference bitstream-based impairment detection for high efficiency video coding. In: Proceedings of *Quality of Multimedia Experience (QoMEX), 2012 Fourth International Workshop*, 7-12.

Vanhastel, S. and Hernandez, R. 2008. Enabling IPTV: what's needed in the access network. *IEEE Communications Magazine*, 46 (8): 90-95.

Vedantham, S., Kim, S.-H. and Kataria, D. 2006. Carrier-grade ethernet challenges for IPTV deployment. *IEEE Communications Magazine*, 44 (4): 24-31.

Wang, W., Chen, P. and Liu, B. 2008. A self-adaptive explicit semantic analysis method for computing semantic relatedness using Wikipedia. In: Proceedings of *Future Information Technology and Management Engineering, 2008. FITME'08. International Seminar*, 3-6.

Wang, W., Shen, J. and Shao, L. 2015. Consistent video saliency using local gradient flow optimization and global refinement. *IEEE Transactions on Image Processing*, 24 (11): 4185-4196.

Wang, Z. and Simoncelli, E. P. 2005. Reduced-reference image quality assessment using a wavelet-domain natural image statistic model. In: Proceedings of *Human Vision and Electronic Imaging*, 149-159.

Wei, L., Wang, F., Li, X., Wu, F. and Xiao, J., 2017. Graph-Theoretic Spatiotemporal Context Modeling for Video Saliency Detection. *arXiv preprint arXiv:1707.07815,* 1-5.

Wey, J. S., Lüken, J. and Heiles, J. 2009. Standardization activities for IPTV set-top box remote management. *IEEE Internet Computing*, 13 (3):32-39.

Wiegand, T., Noblet, L. and Rovati, F. 2009. Scalable video coding for IPTV services. *IEEE Transactions on Broadcasting*, 55 (2): 527-538.

Wright, J., Yang, A. Y., Ganesh, A., Sastry, S. S. and Ma, Y. 2009. Robust face recognition via sparse representation. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 31 (2): 210-227.

Wu, J., Wan, Y., Qu, W., Ji, C., Li, Y., Xiao, P. and Sun, J. 2016. A Novel Image Retrieval Approach with Bag-of-Word Model and Gabor Feature. In: Proceedings of *Trustcom/BigDataSE/I SPA*, 1706-1711.

Wusteman, J. 2004. RSS: the latest feed. *Library hi tech*, 22 (4): 404-413.

Xiao, Y., Du, X., Zhang, J., Hu, F. and Guizani, S. 2007. Internet protocol television (IPTV): the killer application for the next-generation internet. *IEEE Communications Magazine*, 45 (11): 126-134.

Xiao, Z. and Ye, F. 2008. New insights on internet streaming and IPTV. In: Proceedings of *Proceedings of the 2008 international conference on Content-based image and video retrieval*, 645-654.

Yang, C. and Liu, Y. 2015. On achieving short channel switching delay and playback lag in IP-based TV systems. *IEEE transactions on multimedia*, 17 (7): 1096-1106.

Yang, J., Park, H., Lee, G. M. and Choi, J. K. 2015. A web-based IPTV content syndication system for personalized content guide. *Journal of Communications and Networks*, 17 (1): 67-74.

Yang, B. and Zou, L., 2015. Robust foreground detection using block-based RPCA. *Optik-International Journal for Light and Electron Optics, 126*(23): 4586-4590.

Yeh, C.-Y. and Zhuo, C.-Z. 2012. An efficient complexity reduction algorithm for G. 729 speech codec. *Computers & Mathematics with Applications*, 64 (5): 887-896.

Yu, C., Ding, H., Cao, H., Liu, Y. and Yang, C. 2017. Follow Me: Personalized IPTV Channel Switching Guide. In: Proceedings of *Proceedings of the 8th ACM on Multimedia Systems Conference*, 147-157.

Yu, E., Hong, A. and Hwang, J., 2016. A socio-technical analysis of factors affecting the adoption of smart TV in Korea.*Computers in Human Behaviour, 61:* 89-102.

Yu, G., Westholm, T., Kihl, M., Sedano, I., Aurelius, A., Lagerstedt, C. and Odling, P. 2009. Analysis and characterization of IPTV user behaviour. In: Proceedings of *Broadband Multimedia Systems and Broadcasting, 2009. BMSB'09. IEEE International Symposium*, 1-6.

Zaki, M., Astuti, R. P. and Kurniawan, A. 2016. Scaling technique of triple play services in passive optical network using subcarrier allocation algorithm. In: Proceedings of *Control, Electronics, Renewable Energy and Communications (ICCEREC), 2016 International Conference*, 81-85.

Zare, S., Mohammad Hosseini Verki, S. and Ghaffarpour Rahbar, A., 2018. Channel-Zapping Time in IPTV: Challenges and Solutions. *IPTV Delivery Networks: Next Generation Architectures for Live and Video‐on‐Demand Services*, 151-183.

Zare, S. and Rahbar, A. G. 2016. Program-driven approach to reduce latency during surfing periods in IPTV networks. *Multimedia Tools and Applications*, 75 (23): 16059-16071.

Zeadally, S., Moustafa, H. and Siddiqui, F. 2011. Internet protocol television (IPTV): architecture, trends, and challenges. *IEEE Systems Journal*, 5 (4): 518-527.

Zhang, D., Han, J., Jiang, L., Ye, S. and Chang, X., 2017. Revealing event saliency in unconstrained video collection. *IEEE Transactions on Image Processing*, *26*(4): 1746-1758.

Zhang, D., Meng, D. and Han, J. 2017. Co-saliency detection via a self-paced multiple-instance learning framework. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 39 (5): 865-878.

Zhang, H., Quan, W., Chao, H.C. and Qiao, C., 2016. Smart identifier network: A collaborative architecture for the future internet. IEEE network, 30(3): 46-51.

Zhang, J., Li, Y., Chen, M. and You, L. 2016. An implicit feedback integrated LDA-based topic model for IPTV program recommendation. In: Proceedings of *Communications and Information Technologies (ISCIT), 2016 16th International Symposium*, 216-220.

Zhang, J. and Sclaroff, S. 2013. Saliency detection: A boolean map approach. In: Proceedings of *Proceedings of the IEEE international conference on computer vision*, 153-160.

Zhang, J. and Sclaroff, S. 2016. Exploiting surroundedness for saliency detection: a Boolean map approach. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 38 (5): 889-902.

Zhang, L., Yang, C., Lu, H., Ruan, X. and Yang, M.-H. 2017. Ranking saliency. *IEEE Transactions on Pattern Analysis and Machine Intelligence*, 39 (9): 1892-1904.

Zhang, Y., Jin, R. and Zhou, Z.-H. 2010. Understanding bag-of-words model: a statistical framework. *International Journal of Machine Learning and Cybernetics*, 1 (1-4): 43-52.

Zhu, H.B., Yang, L.X. and Yu, Q., 2010. Investigation of technical thought and application strategy for the internet of things. Journal on Communications, 31(11): 2-9.

Zipf, G.K., 2016. *Human behaviour and the principle of least effort: An introduction to human ecology*. Ravenio Books, 1-573.