DYNAMIC MOBILE SERVER FOR LIVE CASTING APPLICATIONS

MUHAMMAD SAZALI BIN HISHAM

UNIVERSITI TEKNOLOGI MALAYSIA

DYNAMIC MOBILE SERVER FOR LIVE CASTING APPLICATIONS

MUHAMMAD SAZALI BIN HISHAM

A thesis submitted in the fulfilment of the
requirements for the award of the degree of
Master of Engineering (Electrical)

Faculty of Electrical Engineering
Universiti Teknologi Malaysia

MARCH 2014

To my beloved mother and father

ACKNOWLEDGEMENT

As a muslim, I am very grateful to Allah for his kindness of giving me physical and mental strength to complete this thesis on time. As a child, I would like to thank my mother and father for their unconditional support and encouragement to pursue my interest besides giving financial support. I also would like to thank my siblings for their support since I am a kid.

Academically, I would like to thank my main supervisor, Assoc. Prof. Dr. Sharifah Hafizah Syed Ariffin for her willingness to guide me on my research and bears with my weaknesses. I am very thankful for her motherly kindness from the start of my research until the completion of this thesis. I also would like to thank my co-supervisor, Dr. Choong Khong Neng who always supporting and advising me on the proper way of doing a research and emphasizing me of the importance of having a vision.

I am very grateful to be a part of Telematic Research Group (TRG) of UTM. Besides that I would like to thanks MIMOS Berhad, especially the head of Wireless Communication Cluster, Dr. Mazlan Abbas for giving me the opportunity to work in MIMOS. I have been exposed to creative thinking and industrial research while working in MIMOS. Other than that, I would like to thank Ministry of Science, Technology and Innovation (MOSTI) for funding my research work.

Last but not least, I would like to thank my fellow teammates in Dynamic Mobile Cloud department, fellow research assistants and also all the staff researchers in Wireless Communication Cluster for the advices, supports, and beautiful friendship.

ABSTRACT

Live casting applications have become a popular trend in the evolution of the Internet. The increasing number of clients worldwide has made the conventional point-to-point client-server delivery method obsolete in supporting these applications. Point-to-point delivery uses unicast transmission which consumes high bandwidth as multiple duplicated streams are transmitted to clients who request for the same content. An increasing number of clients are translated directly into an increase of server workload and server network traffic. Because of that, end users suffered from bad quality of experience. In this research, Dynamic Mobile Server (DMS), a generic end-user platform of delivery mechanism has been developed to address these problems. This platform is designed to support multiple live casting applications compared to current infrastructure Content Delivery Network (CDN) and Peer to Peer (P2P) which only support live video streaming application. This mechanism consists of a web application system (application layer approach) which also involves server mobility and traffic redirection concept. Duplicated connections are minimized by confining the traffic in Local Area Network (LAN). In order to guarantee the scalability of the system, DMS uses IP multicast to stream the video in LAN. Compared to the conventional point-to-point delivery, proof-of-concept implementation (prototype) experiment results show that DMS double the bandwidth availability, and maintains excellent video quality with Peak Signal to Noise Ratio (PSNR) more than 80. Despite of the congested traffic in the network, DMS had proofed to maintain the average start-up latency to only one second.

ABSTRAK

Aplikasi aliran secara langsung di dalam internet telah menjadi popular sejak perkembangan yang berlaku terhadap internet. Peningkatan jumlah pengguna aplikasi ini seluruh dunia telah menyebabkan teknik penghantaran titik ke titik pelayan-klien tidak sesuai lagi. Penghantaran titik ke titik menggunakan teknik penghantaran unikas. Jadi ia menggunakan jumlah jalur lebar yang tinggi kerana banyak penghantaran diduplikasikan untuk melayan semua pengguna yang meminta kandungan yang sama. Di tahap jumlah pengguna yang terlalu tinggi, beban kerja bagi pelayan menjadi sangat tinggi di samping boleh menyebabkan kesesakan di dalam rangkaian pelayan. Oleh kerana itu, pengguna menanggung akibat kualiti penghantaran yang buruk. Di dalam penyelidikan ini, Pelayan Bergerak Dinamik (DMS), satu landasan penghantaran yang generik telah dibangunkan untuk mengatasi masalah-masalah ini. Secara ideal, landasan ini mampu menyokong pelbagai applikasi aliran secara langsung jika dibandingkan dengan infrastruktur yang ada sekarang seperti Rangkaian Penghantaran Kandungan (CDN) dan penghantaran Rakan kepada Rakan (P2P) yang hanya menyokong aplikasi aliran video secara langsung sahaja. Mekanisma penghantaran ini terdiri daripada sistem aplikasi web yang juga menggunakan konsep pelayan mampu bergerak and juga konsep penukaran arah trafik. Sambungan yang diduplikasikan telah dikurangkan dengan menumpukan trafik di dalam Rangkaian Kawasan Setempat (LAN). Multikas di dalam LAN telah digunakan untuk menjamin kebolehan untuk diskalakan bagi sistem ini. Jika dibandingkan dengan teknik penghantaran titik ke titik, prototaip menunjukkan prestasi DMS adalah dua kali lebih baik dari segi kadar penggunaan jalur lebar dan mengekalkan kualiti video yang sangat baik dengan nilai Isyarat Puncak kepada Nisbah Bunyi (PSNR) lebih 80. Walaupun dalam keadaan rangkaian yang sesak, DMS telah membuktikan bahawa kadar purata kelewatan permulaan dikekalkan pada satu saat sahaja.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS

AP	-	Access Point
API	-	Application Programming Interface
APIaaS	-	API as a Service
CC	-	CSRC count
CDN	-	Content Delivery Network
CSRC	-	Contributing Source
DaaS	-	Data as a Service
DMS	-	Dynamic Mobile Server
GUI	-	Graphical User Interface
HTTP	-	Hypertext Transport Protocol
IaaS	-	Infrastructure as a Service
IGMP	-	Internet Group Management Protocol
IP	-	Internet Protocol
IPTV	-	Internet Protocol Television
ISP	-	Internet Service Provider
LAN	-	Local Area Network
LP	-	Loss Percentage
M	-	Marker
MOS	-	Mean Opinion Score
MSC	-	Mobile Server Container
PSNR	-	Peak Signal to Noise Ratio
N	-	Number of Client that requesting the same content
NKEA	-	National Key Economic Area
OS	-	Operating System
P	-	Padding
PT	-	Payload Type

P2P	-	Peer to Peer
PaaS	-	Platform as a Service
PNC	-	Proxy Network Coordinator
QoE	-	Quality of Experience
QoS	-	Quality of Service
RTCP	-	Real-Time Control Protocol
RTP	-	Real-Time Transport Protocol
RTSP	-	Real-Time Streaming Protocol
RTT	-	Round Trip Time
SaaS	-	Service as a Service
SDP	-	Session Description Protocol
SECaaS	-	Security as a Service
SN	-	Sequence Number
SSM	-	Source Specific Multicast
SSRC	-	Synchronization Source
STaaS	-	Storage as a Service
TCP	-	Transmission Control Protocol
TD	-	Trigger to Download
TEaaS	-	Test Environment as a Service
TL	-	Trigger to Load
TSP	-	Telecommunication Service Provider
UDP	-	User Datagram Protocol
URL	-	Uniform Resource Locator
VoD	-	Video on Demand
VoIP	-	Voice over IP
WAN	-	Wide Area Network
X	-	Extension

LIST OF APPENDICES

CHAPTER 1

INTRODUCTION

1.1 Background

Web application development has moved towards developing rich web application which consists of a mixture of dynamic and static content [1]. Dynamic content such as live casting applications have become more popular among the Internet users. Live casting application however is not limited to just live video streaming of an event such as a live concerts or football matches. It could further include video conferencing, Voice over IP (VoIP) or even a stock trading application. Although these contents are making the Internet world more attractive, these real-time contents consume high network bandwidth which may cause network bottleneck in certain part of the network. As a result, the end user experience cannot be maintained at a certain performance threshold.

This situation is worsened by the emerging trend of mobile Internet. Surprisingly, mobile Internet is ramping faster than desktop Internet. This is due to smartphone usage that has increased rapidly. Based on data collected by Nielsen Malaysia, it is predicted that the growth of tablets and smartphones market in Malaysia had reached up to 75% and 89% respectively in 2012 [2]. This trend can be a burden in terms of network bandwidth consumption according to Joel Brand, Vice President of Product Management of Bytemobile. Bytemobile research shows that 5% of mobile data users generate approximately 75% of the data traffic [3].

From the Internet Service Provider (ISP) point of view, this kind of Internet behaviour is very costly due to high amount of traffic going through the international gateways[1]. Nowadays web hosting has moved towards cloud infrastructure[2] [4], where the distance between client and server is increased since most cloud infrastructure is located overseas. Thus this requires higher cost as the traffic pass through more international gateways. This scenario is proven as reported in Malaysia National Key Economic Area (NKEA) which stated that 80% to 90% contents accessed on the Internet in Malaysia are originating from the a remote server cloud overseas over a long distance network [5].

1.2 Problem Statement

Live casting events usually attract people around the world. Moreover, the Internet has become one of the medium to view such live events. Traditionally, this live casting application on the Internet is delivered using conventional point-to-point method as shown in Figure 1.1.

[1] International gateways in this thesis is referring to the network interconnection points beyond the local Internet Service Provider (ISP) backbone
[2] Cloud infrastructure is referring to the remote servers that are provided as a service

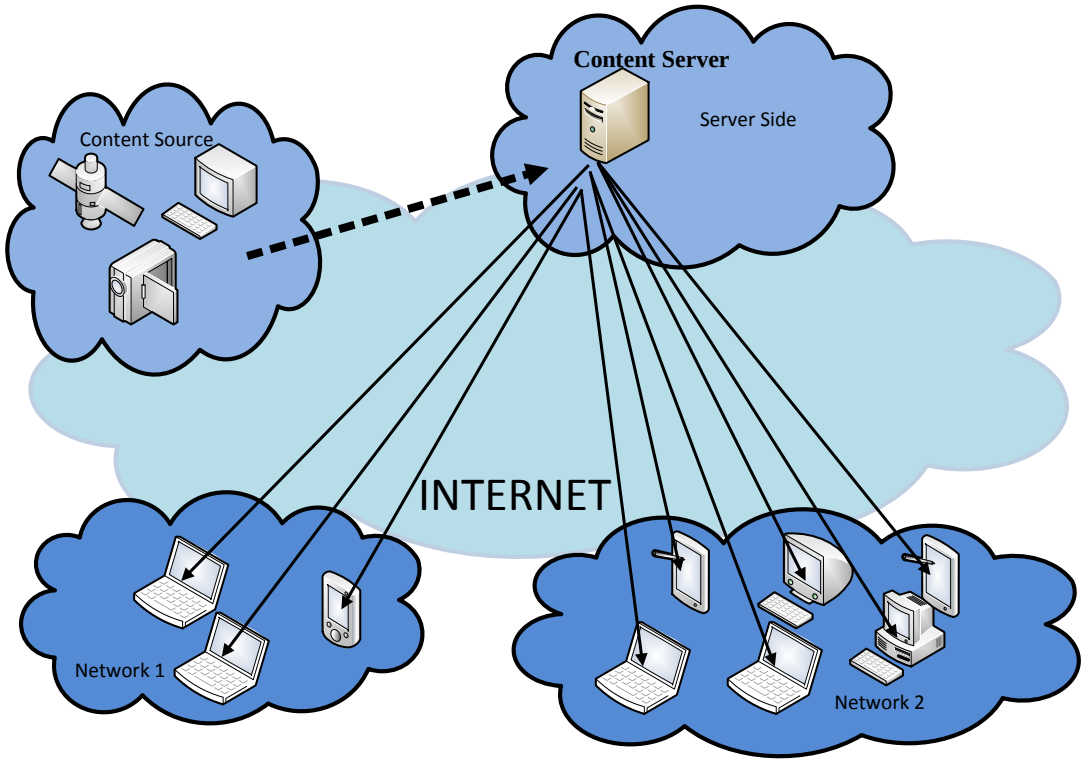

Figure 1.1: Conventional Point-to-Point Delivery Method

Given the usage of live casting application on the Internet has increased rapidly, conventional point-to-point delivery method which used unicast transmission has incurred some problems. These problems need to be addressed in order to enable the application to sustain the growth of the Internet users. The identified problems are given as follows:

- The number of streams of the same content[3] delivered by the same source through the Internet is equal to the numbers of users that are accessing that content. Since those streams are the same type of content, unnecessary duplicated connections are established to deliver the content.
- This duplicated connections obviously wasting the bandwidth available on the Internet. Higher numbers of Internet users along with other network activities will cause bottlenecks on the server and client network. This may cause the quality experience of the users degraded significantly.

[3] Content: Live casting content can be either video, audio or data

- In the view of Internet Service Provider (ISP), these duplicated connections contribute to high amount of traffic passing through the international gateways. Assuming that the content server[4] has been deployed in the cloud infrastructure overseas, the distance between the users and the content server increased. Thus more international gateways are involved. The cost to sustain these traffics will increase.
- High numbers of users mean higher workload on the content server. Hence, more servers have to be deployed in order to support the increasing numbers of users with acceptable performance.

1.3 Objectives

The objectives of this research are:

- To develop a delivery platform of real time application for enterprise usage at the application layer - without interrupting current network infrastructure on the internet.
- To develop an agent that is able to manage the users and confines the traffic locally in orders to shorten connection distance and reduce duplicated connections through the internet.
- To implement a prototype as proof of concept using live video streaming scenario with performance evaluation.

1.4 Scope

The scope of this research is within a web-based live casting application platform or framework that uses live video streaming as the selected application or scenario. The delivery mechanism of the system combines IP unicast and IP multicast.

[4] Content Server: Server which streams out the content in real-time

It also makes use of traffic redirection concept and server virtualization concept at the application level. The system is able to work in both wired and wireless environments at the client-side over a wireless access point. A prototype has been developed and evaluated in a laboratory environment.

1.4 Research Contributions

This research has been conducted to provide a platform for live casting applications where its delivery is more reliable compared to the conventional point-to-point delivery. It is also proven that the problems mentioned in Section 1.2 can be addressed by using a locally centralized solution, compared to existing decentralized peer- to-peer approach. More details of the contributions are mentioned as follows:

- Duplicated connections and bandwidth consumption of the link between the client and the server have successfully been reduced compared to the conventional point-to-point delivery method. Thus, it has the potential to be practically applied with the aim of reducing the traffic cost passing through the international gateways.
- User friendly application has been successfully developed using the server virtualization concept. This is because the system become generic thus various kinds of real-time application can be deployed into the system without requiring additional hardware and maintenance.
- Seamless switching between two different video sources at application level has been successfully deployed. Thus, the switching does not affecting the user experience.
- Proof of concept testbed for delivering live video casting has been successfully developed where the experimental results show that the user experience has been improved in a congested network compared to conventional point-to-point delivery method.

1.5 Thesis Organization

This thesis is organized as follows;

Chapter 2 discusses on literature review of the research. This includes the fundamental information related to live casting application such as real time IP protocol, cloud computing and data transmission method, and also the basic concepts of the approaches that have been opted in this research such as server mobility and server virtualization. Other than that, this chapter discusses on the closest related works that have been done previously which is more on the existing infrastructures.

Chapter 3 explains on the methodology of the research. First it explains on the first phase of the research which is designing the proposed solution which includes the architecture, the approaches that has been used to develop the system and the workflows of the system. Then, this chapter focuses on the second phases where the designs are then translated into a prototype as the implementation.

Chapter 4 discusses on the results of the experiments that have been conducted. The experiments are divided into two parts. The first part is the validation experiments while the second part is the performance benchmarking experiment.

The conclusion of the research with some recommendations and future works has been discussed in Chapter 5.

REFERENCES

1. Jeon, J. Seunghwa, L. Position Paper: Toward a Mobile Rich Web Application – Mobile AJAX and Mobile Web Application. 2008
2. Malaysia Tablet and Smartphone Ownership Rising Sharply (2011, October 25). *Bintulu Weekly*. Retrieved March 10, 2012, from http://www.bintulu.org/news/2011/10/25/malaysia-tablet-smartphone-ownership-rising-sharply.php
3. Bytemobile's Mobile Internet Gateway Provides Carrier Options for Tiered Pricing (February 16, 2010). TMCnews. Retrieved March 10,2012, from http://www.bytemobile.com/newsevents/2010/archive_160210.html
4. Prodan, R. Ostermann, S. A survey and taxonomy of infrastructure as a service and web hosting cloud providers. *Grid Computing, 2009 10th IEEE/ACM International Conference on* , vol., no., pp.17-25, 13-15 Oct. 2009
5. Communications Content and Infrastructure. *National Key Economic Area (NKEA)*. Chapter 13. 2011, from http://www.kpkk.gov.my/pdf/tahukah_anda/ETP_bi/chapter12.pdf
6. Alstrup, S. Rauhe, T. and Brown, S. Video consumption dramatically outpaces Internet capacity: exploration, challenges and solutions. *EBU Technical Review* (2011).
7. Gongcai Wu and Gongxin Wu. Research on P2P live streaming system. *Electronics, Communications and Control (ICECC), 2011 International Conference on*. IEEE, 2011.
8. Monaco, A. (June 7,2012). A View Inside the Cloud. *theinstitute.ieee.org (IEEE)*. Retrieved August 21, 2012.
9. Lee, Y. Min, O. and Kim, H. Performance evaluation technique of the RTSP based streaming server. *Computer and Information Science, 2005. Fourth Annual ACIS International Conference on*. IEEE, 2005

10. Andrew Tanenbaum (2003). *Computer Networks*. Englewood Cliffs, N. J.: Prentice Hall.
11. Alay, O. et al. An experimental study of packet loss and forward error correction in video multicast over IEEE 802.11 b network. *Consumer Communications and Networking Conference, 2009. CCNC 2009. 6th IEEE*. IEEE, 2009.
12. B, Cain. et al. Internet Group Management Protocol, Version 3. RFC 3376, October 2002.
13. Bhattacharyya, S. and Ed, S. *An Overview of Source-Specific Multicast (SSM)*. RFC 3569, July 2003.
14. Schulzrinne, H. Casner, S. Frederick, R. and Jacobson, V. *RTP: A Transport Protocol for Real-Time Applications*. RFC 3550, July 2003.
15. Schulzrinne, H. and Casner, S. *RTP Profile for Audio and Video Conferences with Minimal Control*. RFC 3551, July 2003.
16. Schulzrinne, H. Rao, A. Lanphier, R. *Real Time Streaming Protocol (RTSP).* RFC 2326, April 1998.
17. Casner, S. *Session Description Protocol (SDP) Bandwidth Modifiers for RTP Control Protocol (RTCP) Bandwidth*. RFC 3556, July 2003.
18. Ma, K. J. Bartoš, R. and Bhatia, S. A survey of schemes for Internet-based video delivery. *Journal of Network and Computer Applications*34.5 (2011): 1572-1586.
19. Liu, J. and Jianliang, X. A survey of streaming media caching. *available at:\ n\ w. comp. hhbu. edu. hkujllstreamCaching. pdf* (2003).
20. Chen, S. et al. SProxy: A caching infrastructure to support internet streaming. *Multimedia, IEEE Transactions on* 9.5 (2007): 1062-1072.
21. Bolic, M. Begic, Z. and Secerbegovic, E. Virtual active network for live streaming media delivery. *MELECON 2010-2010 15th IEEE Mediterranean Electrotechnical Conference*. IEEE, 2010.
22. Vakali, A. and George P. Content delivery networks: Status and trends. *Internet Computing, IEEE* 7.6 (2003): 68-74.
23. Mulerikkal, J. P. and Ibrahim, K. An architecture for distributed Content Delivery Network. *Networks, 2007. ICON 2007. 15th IEEE International Conference on*. IEEE, 2007.
24. Muhammad, B. T. Ravi, J. and Kawahara, T. Mobility aware server selection for mobile streaming multimedia content distribution networks. *Web content caching and distribution* (2004): 1-18.

25. Bakiras, Spiridon. Approximate server selection algorithms in content distribution networks. *Communications, 2005. ICC 2005. 2005 IEEE International Conference on*. Vol. 3. IEEE, 2005.
26. Mao, Shiwen. et al. On joint routing and server selection for MD video streaming in ad hoc networks. *Wireless Communications, IEEE Transactions on* 6.1 (2007): 338-347.
27. Wan, Jianxiong. et al. On the Optimal Request Routing Strategy in CDN Live Streaming Application. *Communications (ICC), 2011 IEEE International Conference on*. IEEE, 2011.
28. Rayburn, D. Updated List of Vendors In The Content Delivery Ecosystem. *StreamingMedia. com, July* (2011).
29. De Cicco, L. Saverio, M. and Vittorio P. Feedback control for adaptive live video streaming. *Proc. of MMSys* (2011).
30. Zhuang, Z. and Chun, G. Optimizing CDN Infrastructure for Live Streaming with Constrained Server Chaining. *Parallel and Distributed Processing with Applications (ISPA), 2011 IEEE 9th International Symposium on*. IEEE, 2011.
31. Sung, M. and Chi-Moon, H. A study on architecture of CDN (Content Delivering Network) with content re-distribution function. *Advanced Communication Technology, 2009. ICACT 2009. 11th International Conference on*. Vol. 1. IEEE, 2009.
32. Magharei, N. Reza R. and Yang, G. Mesh or multiple-tree: A comparative study of live P2P streaming approaches. *INFOCOM 2007. 26th IEEE International Conference on Computer Communications. IEEE*. IEEE, 2007.
33. Liu, Y. Yang, G. and Chao, L. A survey on peer-to-peer video streaming systems. *Peer-to-peer Networking and Applications* 1.1 (2008): 18-28.
34. Karagiannis, T. Rodriguez, P. and Konstantina, P. Should internet service providers fear peer-assisted content distribution?. *Proceedings of the 5th ACM SIGCOMM conference on Internet Measurement*. USENIX Association, 2005.
35. Alhaisoni, M. Mohammed, G. and Liotta, A. Localized multistreams for p2p streaming. *International Journal of Digital Multimedia Broadcasting* 2010 (2010).
36. Shen, Zhijie. and Zimmermann, R. LAN-awareness: improved P2P live streaming. *Proceedings of the 21st international workshop on Network and operating systems support for digital audio and video, ACM*. 2011.

37. Yin, Hao. et al. LiveSky: enhancing CDN with P2P. *ACM Transactions on Multimedia Computing, Communications, and Applications (TOMCCAP)* 6.3 (2010): 16.
38. Cho, S. Joonho, C. and Shin, S. Playback Latency Reduction for Internet Live Video Services in CDN-P2P Hybrid Architecture. *Communications (ICC), 2010 IEEE International Conference on*. IEEE, 2010.
39. Lu, Z. et al. Scalable and reliable live streaming service through coordinating CDN and P2P. *Parallel and Distributed Systems (ICPADS), 2011 IEEE 17th International Conference on*. IEEE, 2011.
40. Armbrust, M. et al. A view of cloud computing. *Communications of the ACM* 53.4 (2010): 50-58.
41. Habib, I. Virtualization with kvm. *Linux Journal* 2008.166 (2008): 8.
42. Hacking, S. and Benoît, H. Improving the live migration process of large enterprise applications. *Proceedings of the 3rd international workshop on Virtualization technologies in distributed computing*. ACM, 2009.
43. Bradford, Robert. et al. Live wide-area migration of virtual machines including local persistent state. *Proceedings of the 3rd international conference on Virtual execution environments*. ACM, 2007.
44. Svard, Petter. et al. High performance live migration through dynamic page transfer reordering and compression. *Cloud Computing Technology and Science (CloudCom), 2011 IEEE Third International Conference on*. IEEE, 2011.
45. Kamada, Keisuke, et al. "Design and Evaluation of Global Live Migration with Mobility Support for IP Multicast." *Applications and the Internet (SAINT), 2012 IEEE/IPSJ 12th International Symposium on*. IEEE, 2012.
46. Lin, C. et al. The packet loss effect on MPEG video transmission in wireless networks. *Advanced Information Networking and Applications, 2006. AINA 2006. 20th International Conference on*. Vol. 1. IEEE, 2006.
47. Cisco System. Cisco IP Solution Center Quality of Service User Guide, 2006. Available at: http://www.cisco.com/en/US/docs/net_mgmt/ip_solution_center/3.0/qos/user/guide/concepts.html
48. Cacheda, R. et al. QoS Requirements for Multimedia Services. *Resource Management in Satellite Networks* (2007): 67-94.

49. Shillingford, N. and Christian P. A framework for route configurability in power-constrained wireless mesh networks. *Ad Hoc Networks*8.8 (2010): 857-871.
50. Luby, M. G. and Jerry W. M. The impact of packet loss on an IPTV network. *Online at http://www. digitalfountain. com* (2007).
51. Klaue, J. Berthold, R. and Adam, W. Evalvid–A framework for video transmission and quality evaluation. *Computer Performance Evaluation. Modelling Techniques and Tools* (2003): 255-272.
52. Dai, Q. and Ralf L. Impact of packet loss on the perceived video quality. *Evolving Internet (INTERNET), 2010 Second International Conference on*. IEEE, 2010.