A Cloud-based Platform for Watching Same Content on Three-Screen TV Continuously in Smart Home

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***Abstract*—Watching Same Content on Three-Screen TV Continuously (WSC3STVC) has been considered as one of the representative services in smart homes recently. This service offers content mobility among multiple kinds of screens based on user position in home. Quality of Experience (QoE) and service implementation cost are two important challenges for supporting WSC3STVC service. To the best of our knowledge, there is no visible attempt to design a comprehensive platform for supporting this service in smart homes. Benefiting from cloud computing, peer-to-peer (P2P) network, clustering and H.264 SVC transcoding, this paper proposes a QoE-aware and cost-effective platform for supporting WSC3STVC service in smart home. The strong points of the proposed platform are transcoding in cloud instead of Home GateWay (HGW) for decreasing HGW cost, content switching inside HGW for reducing service delay, using a cloud-managed P2P network for improving bandwidth between cloud and homes and also clustering homes for reducing transfer delay between homes.**

Keywords-cloud-based; smart home; three screen TV

I. INTRODUCTION

All Consumers desire to access rich multimedia resources via cell phone, television, and computer anytime and anywhere.

Three-screen services provide the right solution for this imminent need, and they lure enormous attention and investment from the major telecommunication, media, and entertainment companies. Enabling technologies and standards for such services include advanced video coding methods, video streaming and distribution mechanisms, multi-modal user interfaces designed for different devices, video content analysis and management, IPTV technologies, the IP Multimedia Subsystem framework, broadband wired and wireless access, modern cell phones with powerful multimedia rendering capabilities, touch screen input, high speed data connections, etc. In fact, the wide range of available devices beyond the familiar TV, handset and laptop/PC has led to the use of the term “any screen services” [1].

Smart home is a concept of the pervasive computing. It gradually becomes significant in the high technology area. Several services have been proposed for supporting user requirements in smart homes. Watching same content on three screen TV continuously (WSC3STVC) has been considered as one of the representative services in smart homes recently.

For example, a user (i.e. Allice) is watching a content in the living room by her TV at time T0, then and time T1 she leaves living room and goes to kitchen and wants to continue watching that content by her mobile. After that at Time T2 she goes to bedroom and is interested in watching remaining of that content by her notebook. WSC3STVC service is consuming same contents on several devices continuously. It is considered as one of the representative services supporting service mobility among multiple kinds of screens [2].

One important factor for implementation of the WSC3STVC service is content transcoding. As a solution, content transcoding can be done in Home GateWay (HGW) for supporting WSC3STVC service. However, the computational complexity needed to transcode a content which has a certain bit rate to another is too severe and also preparing this type of advanced HGW is expensive for users compared with the benefits of using the service. Another way is relying on content providers for transcoding. But procedure of transcoding by content providers is rather time consuming and it cannot be an appropriate method for serving WSC3STVC service that usually has high number of content switching between screens inside home.

Although there are some studies that are related to WSC3STVC service indirectly such as designing cloud-based transcoders or using transcoding inside HGW (some of them will be introduced in Related Work) but we could not find a visible attempt to design a comprehensive and complete platform specialized for supporting WSC3STVC service in smart homes. For this reason, we think designing a cost-effective platform that reduces content switching delay between in home screens for supporting WSC3STVC service is specially necessary.

This paper proposes a Quality of Experience (QoE)-aware and cost-effective platform for supporting WSC3STVC service in smart homes. For having more cheaper and simpler HGW, content transcoding function is moved to cloud and only content switching is done inside HGW. Remaining content switching in HGW can guarantee content switching delay. Also for improving delay and bandwidth we categorize homes into some clusters (based on their location) and homes (HGWs) of each cluster are connected together by a P2P network. For transcoding part of our platform we select Scalable Video Coding (SVC) that

978-1-4799-5245-8/14 $31.00 © 2014 IEEE
DOI 10.1109/ISCC-C.2013.9

is extension of the H.264/ AVC standard [3]. SVC provides functionalities such as graceful degradation in lossy transmission environments as well as bit rate, format, and power adaptation. As we mentioned, cloud computing and P2P network play important roles in our platform. Cloud computing is the emerging buzzword in Information Technology. It is growing day by day due to its rich features of services. It is a virtual pool of resources which are provided to the users through Internet [4]. It is an information-processing model in which centrally administered computing capabilities are delivered as services, on an as-needed basis, across the network to a variety of user-facing devices [5].

Peer-to-Peer (P2P) is a mature technology, which can enable cloud to achieve more special functionality for smart home. Meanwhile, the concept of data dissemination based on P2P communication principles has become very popular. The characteristic property of the concept is that the data is downloaded not only from a fixed set of servers but those users who have already downloaded parts of a file start to upload them to other interested users. Proceeding in this way prevents servers' uplinks from becoming capacity bottlenecks of the dissemination process, thus allowing for faster downloads, while at the same time decreasing costs for content providers since they do not have to pay for expensive uplinks. Despite of its importance, the problem of efficient data transport in a P2P network is still an open issue, mainly due to its complex combinatorial structure [6].

The rest of the paper is organized as follows. In Section II, we overview related work. Section III presents the main contribution of this paper which is basically describing our proposed platform. The assessment of the proposed method is covered in Section IV, and finally, Section V concludes the paper.

II. RELATED WORK

Most important part of our platform is content transcoding module and its location in the platform. Place of transcoder has a direct and visible effect on performance of our proposed platform. A traditional solution for source coding was to prepare separate pre-encoded video streams according to the capability of each targeted device: such as screen size, computational power, and available bandwidth. However, this approach results in relatively large storage requirements at the server as well as a significant bandwidth adaptation problem in the wireless network because the 3STV service considers the variable channel conditions such as bandwidth while mobile TV moves around the home.

Another, more advanced solution is transcoding technology with down sampling. By transcoding one high resolution and high bit rate video sequence for targeted screen sizes and bit rates of TV clients, a video service provider is able to reduce storage requirements and adapt to bandwidth fluctuations. But this technology has a computational complexity problem when it has to support multiple TVs which have variable screen sizes and are hard to apply in a real-time system [7].

Eun Seok Ryu et al in [7] and [8] proposed an elasticvideo streaming solution for 3STV which is light-weight as well as error robust. In their method, the HGW distributes the video information from the video provider server to multiple TV clients over a variable-bandwidth erroneous in-home wireless links.

In [9] Jae-Won Kim et al proposed an efficient video transcoding technique as the key component of the HGW architecture. Zixia Huang et al [10] proposed a cloud-based video proxy that can deliver high-quality streaming videos by transcoding the original video in real time to a scalable codec which allows streaming adaptation to network dynamics. In [11] Zhenhua Li et al proposed and implemented a cloud-based transcoder which utilizes an intermediate cloud platform to bridge the format and resolution "gap" between Internet videos and mobile devices by performing video transcoding in the cloud.

III. PROPOSED PLATFORM

A. General Architecture

In our proposed platform (Fig.1), the content provider sends original content to the cloud, then our cloud-based SVC transcoder transcodes the content into different layers and then whole layers of SVC video sequence are sent to individual homes that asked the content inside a cluster through a P2P network.

After receiving content, HGW starts to do WSC3STVC service and the content switching is performed in the HGW as it responds to feedback of user position, device available and link quality. Core of the platform are two decision makers.

One located inside cloud and another(s) located in HGW(s).

These two types of decision makers cooperate together to do WSC3STVC service to the users. Cloud computing can help to migrate transcoding function from HGW to cloud and reduce HGW cost.

In the proposed platform, for effective transferring content from cloud to homes, a P2P network of HGWs is considered.

The chunk-based mesh design is the most popular and successful design in P2P live streaming today, due to its robustness to peer dynamics, high network scalability, and simplicity. Most of the existing P2P live streaming systems adopt this design.

In a chunk-based mesh-pull delivery architecture for live video streaming the source divides the encoded bit stream into video chunks and then disseminates the video chunks to a set of randomly selected peers [12].

In traditional P2P network, each peer should know situation and requests of other peers and also should inform its situation and request to the others (for example, see PPSP protocol [13]). This distributed management of traditional P2P networks causes a high traffic load between peers. In our proposed platform, all HGWs are managed by cloud and there is no need to exchange messages between HGWs.

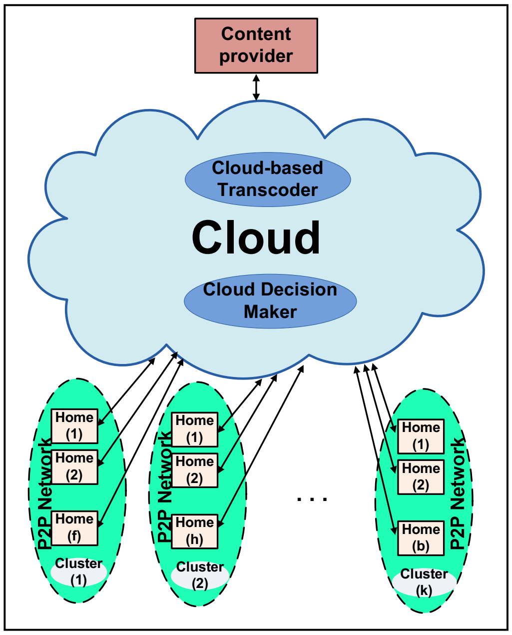

Figure 1. General Architecture

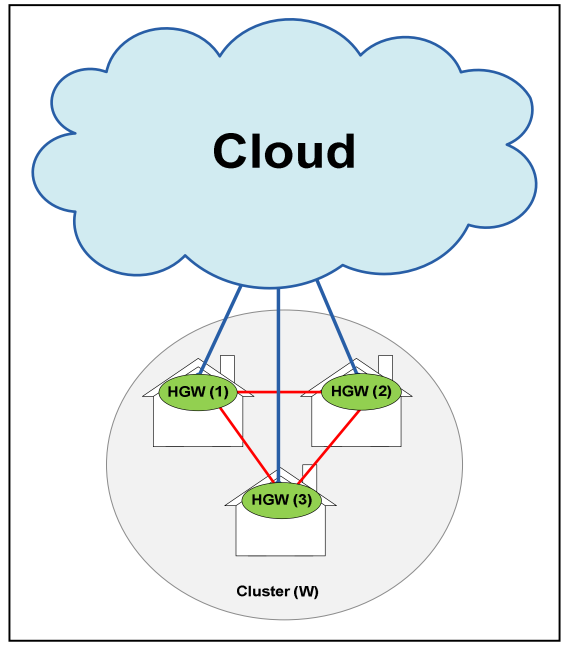

Figure 2. Cluster Architecture

We use SVC coding for our platform. SVC coding has several advantages. First, it enables service providers to reduce total bandwidth, storage, and computational complexity for transcoding by supporting many clients with a single video content file. Second, it is applicable to many unequal error protection (UEP) methods using priorities of each layer. For example, the base layer can be provided a higher level of error protection than the other enhancement layers because the decoder cannot reconstruct video sequence without base layer [14] [15], suggesting higher priority for it. Third, the SVC approach is inherently more because of its error resilient tools [7]. Following we describe different parts of our proposed platform in more detail.

B. *Cluster Arhitecture*

Our platform is based on clustering. We think HGWs that are very far from each other, because of delay and other network limitations, cannot cooperate together very well. Therefore we propose a cluster-based platform. In this platform each HGW is connected to the cloud directly. Also HGWs that physically are located near each other establish a cluster. These clusters are created and managed by cloud Decision Maker. HGWs that are in same cluster establish a P2P network, see Fig.2.

As we mentioned, our platform uses layered video on chunk-based mesh P2P streaming systems. The video transcoder encodes a video into layers and each layer is sliced into packets, called Layer Chunks (LCs). Cloud Decision Maker distributes these LCs over a P2P cluster, as we describe subsequently. When a HGW requests content, the Cloud Decision Maker forms neighbor relationships with it. Then HGW obtains a Neighbor List from cloud Decision Maker.

Each HGW maintains buffers, one for each layer, with each buffer caching the LCs for its layer. A HGW buffer map is a data structure that indicates which LCs are currently inside HGW.

After receiving and buffering each LC, HGW will broadcast it to HGWs that are in its Neighbor List. Cloud Decision Maker updates and sends Neighbor List periodically.

C. *Home Architecture*

Part of proposed platform includes home architecture. Fig.3 shows a general view of our home architecture.

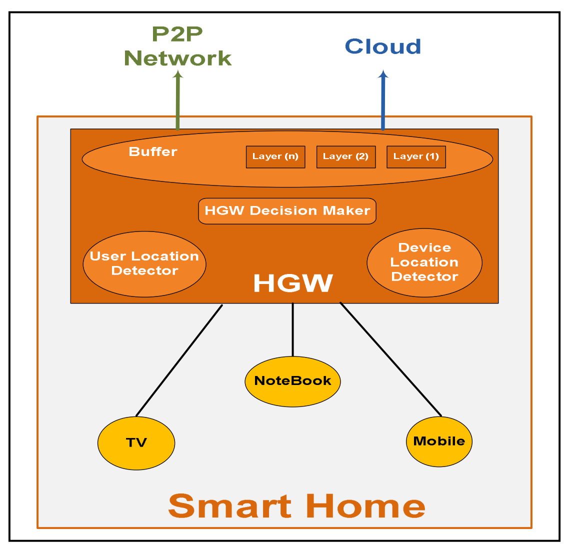

Figure 3. Smart Home Architecture

HGW is important part of home architecture. It is not only heart of home network, which whole home network equipments interconnect via it, but also a bridge between home network and public network, which home network equipments may visit outside network and outside network may provide services for home network by HGW [16]. In our proposed home architecture, each HGW has two types of connections for connecting outside home. First type is for connecting to cloud directly. Second type is for connecting to HGWs that physically are located in its cluster. Also all devices (screens) inside home are connected to HGW for getting service. Each HGW maintains buffers, one for each layer, with each buffer caching the LCs for its layer.

Most important part of our HGW is a HGW Decision Maker. The HGW Decision Maker has a close relation with Cloud Decision Maker. It is responsible for sending user requests to cloud, receiving content (LCs) from cloud and neighbors, sending content to its neighbors. It also has cooperation with User Location Detector and Device Location Detector modules to find best appropriate device and also best fit content for that device based on current position of user.

D. Scenario

We present our scenario with an example. We assume homes (1), (2) and (3) that are located in same cluster (i.e. Cluster W in Fig.(2)). Three users that are inside these homes want to watch same content. Fig.(4) shows our scenario for three homes and Fig.(5) shows position of each user at each time.

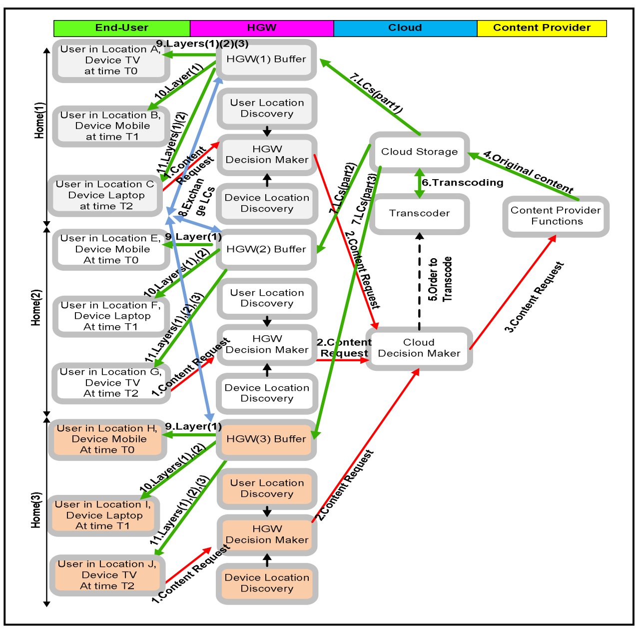

Figure 4. Scenario Description Diagram

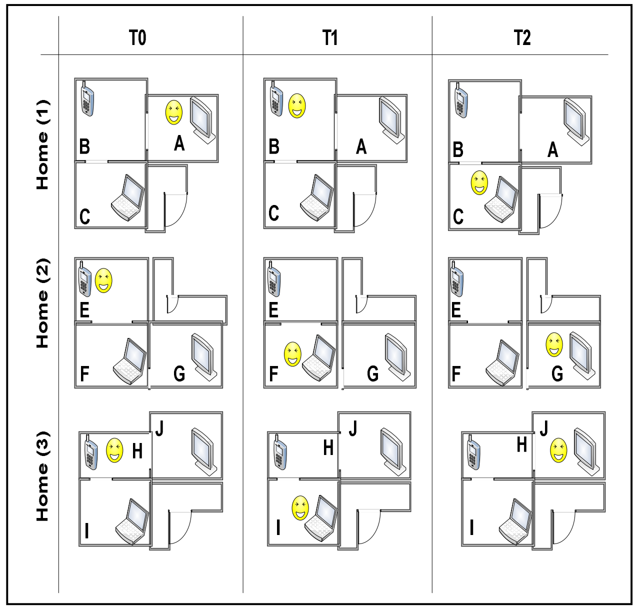

Figure 5. Scenario Environment

However, our scenario can support more than three homes and just for simplicity we consider three homes.

1. User–> HGW Decision Maker: User in home(1) sends its content request to HGW (1). If HGW Decision Maker can find the content in the HGW buffer, we can jump to step (9), (10) or (11); based on device capability. This step is same for users located in homes (2) and (3).

2. HGW Decision Maker–>Cloud Decision Maker: HGW Decision Maker of home(1) resends the request to Cloud Decision Maker. This procedure is same for users located in home 2 and 3. If Cloud Decision Maker can find the content in cloud cache we can jump to step 5.

3. Cloud Decision Maker–>Content provider: Cloud Decision Maker receives all requests from homes and sends a content request to the content provider.

4. Content provider–>Cloud storage: In this stage, content provider transfers the requested content to the storage part of cloud.

5. Cloud Decision Maker–>Transcoder: After receiving the original version of the content, Cloud Decision Maker asks cloud transcoder to transcode the content into different layers.

6. Cloud Transcoder–>Cloud storage: Transcoder transcodes the original content and sends it back to the storage.

7. Cloud–>HGWs: Each part of content transferred to one home (i.e. HGW (1), (2) and (3)) based on policy of the Cloud Decision Maker.

8. Exchanging LCs: After receiving a LC, each HGW looks at its Neighbor List and re-broadcast the LC to member of its Neighbor List.

9. Content–>Device (time T0): Now content is in HGW buffer. User Location Discovery, Device Location Discovery and HGW Decision Maker of each home cooperate together to find position of user, best available device and best fit

content for servicing the user at time T0. For example, in Fig.5, user in home (1) is in position A and near TV, user in home (2) location E and mobile and user in home (3) location H and mobile. Therefore, home (1) sends all layers (i.e. 3 layers) for TV, home (2) and (3) send just layer (1) for mobiles.

10. Content–>Device(time T1): Same as step (9), user Location Discovery, Device Location Discovery and Decision Maker of each home cooperate together to find position of user, best available device and best fit content for servicing the user at time T1. For example user in home (1) changes its position from location A to location B and its device should change from TV to mobile. Therefore, content resolution should be changed for mobile. User in home (2) changes it position from E to F and mobile to laptop. User in home (3) goes from H to I and mobile to laptop.

11. Content–>Device: Same as steps (9), each HGW detects position of user and prepares best type of content based on available device.

Notice: For simplicity we assumed all three users in three homes change their location in same time. But there is no limitation and each HGW acts independently to give service to its user.

IV. PERFORMANCE EVALUATION

For both analysis and simulation we consider two scenarios: in scenario I although all HGWs are connected to cloud but there is no direct relation between them. Scenario II is our proposed architecture that all HGWs inside a cluster are connected to cloud and also initiate a P2P network together.

A. Analysis

Here a simple but effective analysis for evaluating performance of the proposed method is done. Assume K peers (HGWs) located in same cluster request same content with size of N chunks. Also we assume time that takes until a chunk reaches from cloud to a HGW is T1 and from one HGW to its neighbors is T2 which T1 is bigger than T2 (i.e. T1=R.T2). T1 can be computed based on Equation (1).

$$\alpha + \beta = T1. \quad (1)$$

Where represents intra-cloud latency and is network or Internet latency. We can estimate average time for delivering content with size of N chunks based on Equation (2).

$$N * T1 = \delta 1. \quad (2)$$

It means after units of time, all HGWs will receive the content completely. In Scenario I, number of HGWs that request a same content is not effective in improving transfer time. Equation.(3) computes service time for scenario II.

$$T1 * [N/K] + T2 = \delta 2. \quad (3)$$

As you can see, unlike scenario I, with increasing of number of HGWs (K) that request same content, will be decreased. Equation (4) shows difference between Scenario I and II.

$$\delta 1 / \delta 2 = \omega. \quad (4)$$

If we assume R=1 (T1= T2), we will get Equation (5).

$$(N * K) / (N + K) = \omega. \quad (5)$$

We also know N>>K. Therefore, we can say speed of transferring a same content in our proposed method(Scenario II) is about K times faster than Scenario I.

B. Simulation

For simulation, we use the Glomosim simulator developed by UCLA [17]. In our simulation model we consider K=10 peers (HGWs) located in same cluster and request same content with size of 10000 chunks. Each chunk has size of 2048 bit. Cloud storage is located about 20 Km far from cluster and HGWs are at most about 200 m far from each other.

We consider a bandwidth equal to 256 KByte per second for each HGW to cloud and 512 KByte per second for HGWs connection togethers. Also propagation delay from cloud to each HGW consider 100000 ns and from each HGW to other about 1000 ns.

Simulation results show for scenario I it takes 999908.50825 ms to transfer the content to each home.

For Scenario II it takes 99912.399875 ms for transferring the content to each home. As we predicted and Analysis section showed Scenario II could improve content transmission time about k=10 times in comparison with Scenario I.

V. CONCLUSIONS

WSC3STVC has been considered as one of the representative services in smart homes. This service exchanges content among multiple kinds of screens based on user position in smart home. QoE and service implementation cost are two important challenges for supporting WSC3STVC service in smart homes. Considering these two challenges, this paper proposed a comprehensive platform for supporting this service in smart homes. The strong points of the proposed platform are: transcoding in cloud instead of HGW for decreasing HGW cost, content switching inside HGW for reducing service delay, using a type of P2P network for improving bandwidth between cloud and homes and clustering homes by cloud for reducing transfer delay between homes. Finally, simulation results showed our proposed platform can improve content transmission time significantly in comparison with traditional platform.

Acknowledgment

This work was supported by the EU ITEA 2 Project: 11012 "ICARE: Innovative Cloud Architecture for Real Entertainment".

References

[1] Zhu Liu, David C. Gibbon, Harris Drucker, Andrea Basso, "Content Personalization and Adaptation for Three-Screen Services" CIVR, Niagara Falls, Canada, July 7-9, 2008.

[2] Changwoo Y oon, Taiwon Urn, Hyunwoo Lee, "Classification of NScreen Services and its Standardization", ICACT, Korea, Feb 19-22, 2012.

[3] Heiko Schwarz, Detlev Marpe and Thomas Wiegand, "Overview of the Scalable Video Coding Extension of the H.264/AVC Standard", IEEE Transactions on Circuits and Systems for Video Technology, Vol. 17, No. 9, Sep 2007.

[4] Brian J.S. Chee and Curtis Franklin, Jr, "Cloud Computing Technologies and Strategies of the Ubiquitous Data Center", CRC Press, 2010.

[5] Sameer Rajan, Apurva Jairath,"Cloud Computing: The Fifth generation of Computing", International Conference on Communication Systems and Network Technologies, 2011.

[6] Konstantin Miller, Adam Wolisz, "Transport Optimization in Peer-to-Peer Networks" 19th International Euromicro Conference on Parallel, Distributed and Network-Based Processing, Cyprus, 2011.

[7] Eun-Seok Ryu and Nikil Jayant, "Home Gateway for Three-Screen TV Using H.264 SVC and Raptor FEC", IEEE Transactions on Consumer Electronics, Vol. 57, No. 4, November 2011.

[8] Eun Seok Ryu and Nikil Jayant, "Architecture of a Home Gateway for Three-Screen TV", IEEE International Conference on Consumer Electronics (ICCE),2011.

[9] Jae-Won Kim et al, "Efficient Video Transcoding Technique for QoSBased Home Gateway Service", IEEE Transactions on Consumer Electronics, Vol. 52, No. 1, Feb, 2006.

[10] Z. Huang, C. Mei, L. Li, and T. Woo, "CloudStream: Delivering highquality streaming videos through a cloud-based SVC proxy", IEEE INFOCOM, Changhai, China, April 10-15, 2011.

[11] Zhenhua Li, Yan Huang and Gang Liu, "Cloud Transcoder: Bridging the Format and Resolution Gap between Internet Videos and Mobile Devices", NOSSDAV12, Toronto, Canada, June 78, 2012.

[12] Zhengye Liu, Yanming Shen, Keith W. Ross, Shivendra S. Panwar, and Yao Wang, "LayerP2P: Using Layered Video Chunks in P2P Live Streaming", IEEE Transactions On Multimedia, Vol. 11, NO. 7, Nov 2009.

[13] A. Bakker , R. Petrocco , V. Grishchenko, "Peer-to-Peer Streaming Peer Protocol (PPSPP)", Internet-Draft, 2013.

[14] C. Hellge, T. Schierl, and T. Wiegand, "Receiver driven layered multicast with layer-aware forward error correction", 15th IEEE Internationa Conference Image Processing (ICIP 2008), pp. 2304-2307, California, USA, 2008.

[15] T. Schierl, H. Schwarz, D. Marpe, and T. Wiegand, "Wireless broadcasting using the scalable extension of H.264/AVC", IEEE International Conference Multimedia and Expo (ICME 2005), pp. 884-887, 2005.

[16] Dongyao Zou, Meina Song, Junde Song, "Research of Universal Home Gateway Architecture and its Functions" Wireless, Mobile and Multimedia Networks (ICWMMN), hangzhou, China , 2006.

[17] Glomosim Simulator: http://pcl.cs.ucla.edu/projects/glomosim.