J. Basic. Appl. Sci. Res., 4(6)200-214, 2014
© 2014, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied
Scientific Research
www.textroad.com

Collaborative Systems for Video Streaming in Heterogeneous Wireless Networks with Mobile Peers

Samana Zehra[1] and Adeel Akram[2]

[1] Computer Engineering Department, University of Engineering and Technology, Taxila, Pakistan
[2] Telecommunication Engineering Department, University of Engineering and Technology, Taxila, Pakistan.

Received: April 19, 2014
Accepted: May 25, 2014

ABSTRACT

Video streaming is a popular and rapidly growing application over the Internet. Users produce, share and view video content on fixed as well as mobile devices. Mobile Peer-to-peer (P2P) based video streaming is an emerging area for video delivery over the wireless medium. Although well established for wired networks, video streaming faces numerous challenges over the wireless medium. This paper discusses the significance of wireless video streaming, wireless video streaming architectures, and existing P2P wireless video streaming systems with mobile peers. It also proposes an optimized framework which incorporates hybrid wireless networking techniques and collaboration among wireless devices for ensuring continuous video delivery.

KEYWORDS: Ubiquitous, Video on-demand, Wi-Fi Direct, Mobility, Peer-to-peer, Hybrid.

1. INTRODUCTION

The evolution of wireless devices and communication networks has made ubiquitous connectivity a reality. Throughout the world, users now have the liberty to move around and stay connected to data, audio and video services using wireless communication networks. More and more users are choosing mobile devices for viewing, producing and sharing video contents with others. The ease of use and improvements in design and specifications of mobile devices such as Smart phones, Tablets, Laptops, etc., have given a boost to this trend. With media rich applications, these portable devices are commonly used for business meetings, video conferencing, Internet TV, gaming and social networking. The mobile data traffic is growing exponentially and video applications & mobile web are the major contributors to the overall increase in numbers [1]. Video applications are generally categorized into video conferencing, live streaming video and video on-demand (VoD). Be it communication, healthcare, entertainment or surveillance, video over wireless has its applications in all walks of lives and will continue to grow further [2].

Delivering video over wireless medium presents many more challenges as compared to conventional wired networks. The reasons include variable channel conditions, signal interferences and wireless devices' limitations (battery capacity, processing power, limited memory, screen size, fewer supported video formats, etc.). User mobility adds up further complexity making wireless video streaming with user mobility an interesting area of research.

This paper discusses video delivery over wireless networks with a special focus on P2P systems with mobile peers and proposes a framework overcoming the issues related to mobile P2P video streaming. From the literature survey it was concluded that existing research work in this domain covers identification of mobility related issues such as handoffs & addressing [3], maintaining Quality of Service (QoS) of streamed multimedia content for moving peers [4], dealing with heterogeneity of video receiving devices [5, 6, 7], managing multimedia streaming cost & bandwidth consumption [8, 9, 10, 11], improving system performance & reducing video startup delays [12, 13], techniques for chunk distribution among peers [7, 14], cross-layer designs [15] and video transport schemes [16] for video streaming optimization. Patch Peer [17] may be one of the few P2P based VoD streaming systems which discusses peer mobility, handover, admission control and recovery procedures under peer mobility. It appears that much of the publications cater for only specific problem scenarios and do not cover the P2P wireless video streaming issues in entirety. Therefore, a comprehensive study was carried out for research trends over the last decade in wireless video streaming systems with mobile peers. This paper consolidates various research aspects. This work will be useful for researchers interested in investigating similar problem domain. Moreover, we also propose a framework for wireless video streaming which will serve as a reference for practical implementation of video streaming solutions where end users are mobile.

The rest of the paper is organized as follows. Section 2 describes various architectures used for wireless video streaming. Section 3 discusses the existing P2P wireless video streaming systems, their limitations and possible improvements. The proposal of an efficient framework for wireless video streaming with mobile peers is presented in Section 4. The paper is concluded by discussing future direction of research.

Corresponding Author: Samana Zehra, Computer Engineering Department, University of Engineering and Technology Taxila, Post Code 47050, Pakistan. Email: samana.zehra@uettaxila.edu.pk

2. WIRELESS VIDEO STREAMING ARCHITECTURES

The choice of network architecture used affects the performance of the video streaming application. The same architecture may not be suitable for every video streaming solution. This section briefly describes wireless video streaming architectures and their examples.

2.1 Client Server Model

This is the simplest video sharing model. In a typical wireless client-server setup, the server responds to the client by streaming the requested video to it directly through a wireless router. Sometimes a proxy server may also be involved between the actual server and the client. World Wide Web (WWW) is one of its classic examples. Figure 1 shows a typical client-server interaction in a wireless environment.

In spite of its advantages, the client server model has limitations such as system scalability and the server being the single point of failure. The performance analysis of client-server application in [3] shows its unsuitability for mobile environment.

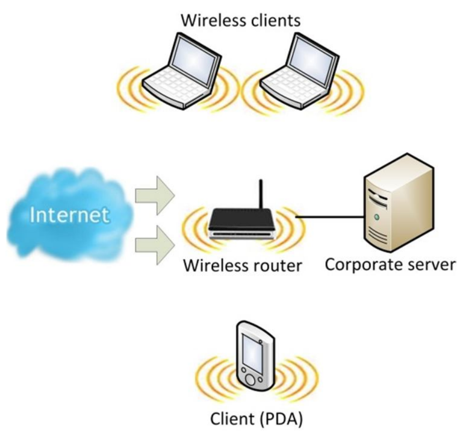

Figure 1. Typical wireless client-server interaction [18]

2.2 Content Delivery Network

A Content Delivery Network (CDN) is a variation of client-server model [19]. In a CDN, the video origin server distributes content to a set of strategically placed content delivery (edge) servers. A client is normally served by its nearest edge server thus relieving load of origin server. CDN reduces the startup delays, network traffic and serves greater number of users.

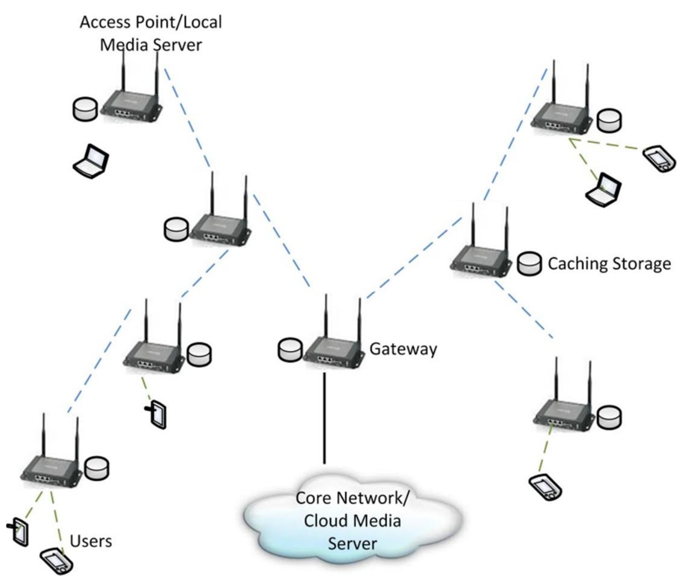

Figure 2. Wireless CDN based on mesh Wi-Fi [20]

The research work in [20] presents a special class of video CDN, namely pervasive wireless CDN based on Mesh Wi-Fi as shown in Figure 2. The basic concept of this wireless CDN is to offer node caching to help distribute traffic among network elements with low latency and high user experience.

2.3 Peer-to-Peer Network

Peer-to-Peer (P2P) technology is an efficient and cost effective alternative to the client-server paradigm. Each member called peer behaves as client and server at the same time. A peer contributes to the network by sharing its downloaded data with other peers. P2P technology has become an accepted solution for video services [3].

Many Internet-based P2P systems have been deployed for video on-demand and live streaming [21-26]. Based on the overlay structure, the P2P systems are differentiated into two basic topologies; tree-based and mesh-based [3, 18, 27, 28]. Researchers have proposed hybrid of tree and mesh topology to gain benefits of both structures [29-32]. Figure 3 shows various possible P2P architectures with mobile peers.

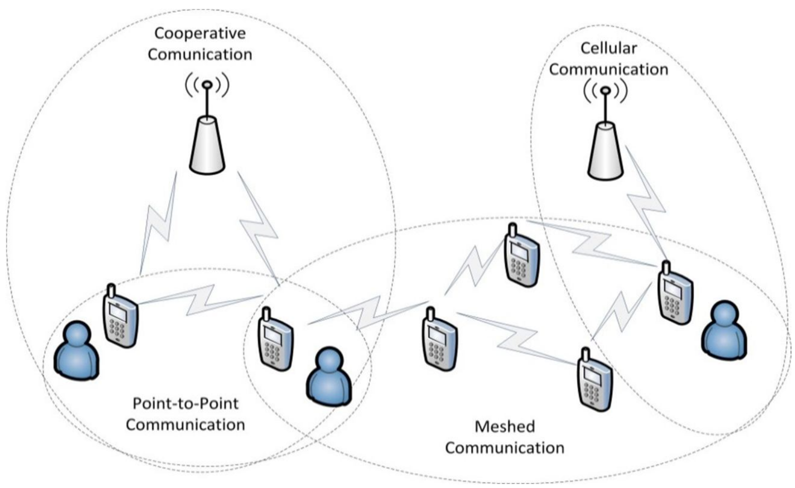

Figure 3. Mobile P2P – overall architecture [33]

2.4 CDN-P2P Hybrid Network

CDNs and P2P Networks were developed to counter the scalability and robustness issues of the traditional systems. But, both have their own limitations. CDN has replica placement, maintenance, and deployment cost issues, whereas P2P systems have issues such as initial playback delays, ISP (Internet Service Provider)-unfriendly policies and sometimes inefficient usage of network resources due to scheduling and peering schemes used. Researchers found that the integration of these two technologies provides gains of both the worlds while overcoming the limitations. There are numerous academic efforts for CDN-P2P hybrid system [34-37] based on wired networks. Some CDN-P2P hybrid systems for wireless video streaming also exist [7, 13].

Figure 4 shows network model for Sangam - a Cellular-Wi-Fi based CDN-P2P Framework for video sharing among peers with dual network interfaces.

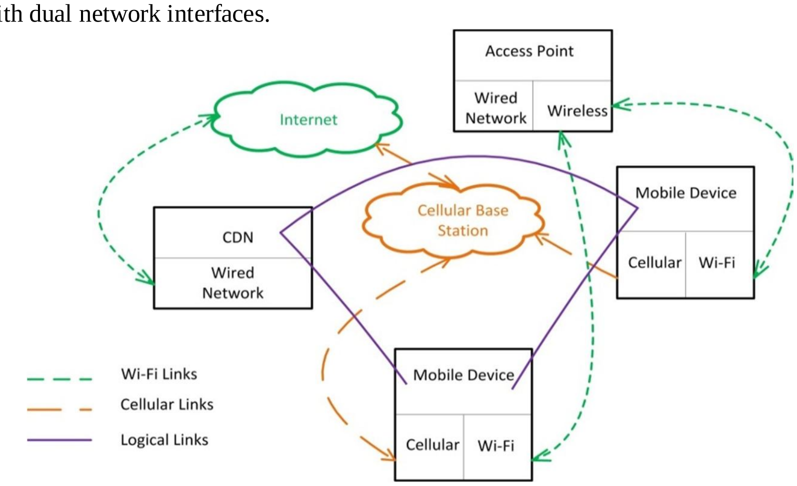

Figure 4. Sangam network model [7]

2.5 Hybrid Wireless Architectures

Besides the above mentioned architectures, many hybrid wireless network architectures also exist such as Infrastructure LAN + Ad hoc wireless [16], Cellular + Wi-Fi [7, 8, 9], Cellular + Ad hoc[11, 14, 17], etc.

Table 1 provides a comparison of the architectures discussed above with respect to their salient features.

Table 1. Comparison of wireless streaming architectures w.r.t. features

Features	Client-Server	CDN	P2P	CDN-P2P	Other Hybrid
Streaming Delays	Low	Low	Medium	Low	Variable*
Control	High	High	Low	Medium	Medium
Security	High	High	Low	Medium	Medium
Scalability	Low	High	High	High	High
Reliability	Medium	High	High	High	High
Management cost	Medium	High	Low	Medium	Medium
Deployment cost	High	High	Low	Medium	Medium

*depends on type of implementation

3. WIRELESS VIDEO STREAMING SYSTEMS

This section discusses existing research efforts and proposed solutions on different network layers to provide reliable wireless video streaming with a special focus on P2P systems with mobile users. Limitations of some of these systems are identified and improvements are suggested where possible.

3.1 Physical Layer Solutions

A reliable physical link leads to smooth network operation, lesser retransmissions and better data rates. Since physical layer deals with actual signal transmission, so manipulating factors such as bit-rate, frequency/ modulation scheme and antenna design can enhance the physical layer for wireless video streaming. IEEE standards for wireless networks, for example, Wireless Local Area Network (WLAN) - IEEE 802.11 a/b/g/n, Wireless Metropolitan Area Network (WMAN) - IEEE 802.16 and Wireless Wide Area Network (WWAN) - IEEE 802.20 provide a variety of data rates and modulation schemes. The consumers can follow these IEEE standards according to their requirements. Various antenna schemes have also been proposed. Multiple-Input multiple-Output (MIMO) antenna technology is one such example which is used in IEEE 802.11n. MIMO provides better levels of Signal-to-Noise Ratio (SNR) for IEEE 802.11n as compared to other versions of 802.11 and hence more throughput. The recently approved wireless standard IEEE 802.11ac [38] is expected to enhance throughput of networks even further with more channel bonding, denser modulation and multiuser MIMO.

Wang et al. [39] presents the design of a cross-layer model for transmitting video reliably over wireless networks. It involves adaptive modulation and coding at physical layer as discussed further in Section 3.5.

3.2 MAC Layer Solutions

The optimizations at MAC layer level can be related to scheduling schemes, addressing and channel access mechanisms.

The IEEE 802.11e standard has introduced QoS enhancements at the MAC layer, known as Wi-Fi-Multimedia (WMM) Extensions or WME. WMM defines four priority queues for network traffic: voice, video, background and best-effort (BE). Based on WMM, video application traffic can get priority over the BE traffic.

Yoon et al. [12] build-on their prior work - Mobile Opportunistic Video-on-demand (MOVi). MOVi is a Wi-Fi based P2P VoD streaming system and uses Inter-BSS Direct Link Setup (iDLS) protocol for direct connectivity among mobile clients (MC). The MOVi system has centralized control, tracking and scheduling (at the Server). This paper proposes an improved MOVi scheduling algorithm. Previous MOVi design is enhanced for discovery and management of interference sources and maximizing wireless channel resource utilization by opportunistic download skipping. This system works efficiently under the assumption that all MCs in the MOVi domain are interested in the same video content. When the situation is not so, MOVi would lose its gains and behave like an ordinary VoD system. In practical world, there are situations when different users are interested in different videos at a time. One possibility is to do the following:

- MOVi has a central repository of content at MOVi Server (MS). If local caching of content at some replica or proxy servers in the local network is done, then this content can be used when most of the MCs are not viewing the same content. A P2P relationship can also be established among the replica or proxy servers.

3G-MOVi [11] enhances the previously proposed MOVi framework. The proposed system is a combination of 3G and ad hoc Wi-Fi (instead of infrastructure Wi-Fi). It aims to minimize 3G bandwidth use and cost by using ad hoc Wi-Fi P2P. A trust mechanism is also proposed for trusted ad hoc connections. The mobile devices download content from a centralized server which manages device connectivity information, content availability information, content scheduling and trust level information. The 3G network carries out initial streaming and then the P2P sharing is enabled over ad hoc links.

- Most of the functionality in 3G-MOVi is concentrated on the server side which can be a single point of failure. Distributing this functionality may make the system more robust to failures.

Sheu et al. [13] propose a CDN-P2P based media streaming system in mobile environment. The proposed system uses a peer schedule algorithm which lowers startup latency as well as playback timeout rate. According to the algorithm, a mobile peer contacts its nearest CDN replica for a list of CDN replicas having its required media. The mobile peer then selects one of the candidate CDN replicas based on Round-trip-time (RTT). If the required segment is not received within a defined timeout, the mobile peer does not wait and requests another CDN replica. The mobile peers have been depicted as receive-only devices with limited capabilities and they have no contribution to other peers. The following improvement is suggested for improving this system:

- As mobile devices are evolving and becoming more capable, they should contribute to the system instead of being free-riders.

3.3 Network Layer Solutions

As network layer mainly deals with routing and addressing issues, so efficiency in location management, routing, forwarding and handoffs can lead to better video transmission in wireless networks with mobile users. A considerable amount of research has been done in this context.

The researchers in [3] examine the performance of some P2P applications for video streaming with user mobility in Wireless Mesh Network (WMN). The P2P applications under analysis include PPLive [22], SopCast [23], TVAnts [24] and PPStream [25]. Some practical problems identified relate to handoff between routers, interferences and protocol reconfiguration. The hand off duration causes service interruptions and this duration depends on addressing and forwarding strategies used by WMN. Addressing issues exist because of users behind Network Address Translator (NAT) devices. Forwarding issues arise due to either dynamic IP address of mobile devices or tunneling time for fixed IP address devices. It was also indicated that UDP based P2P applications show better adaptation to WMN environment. On the other hand, TCP based applications can be viable if many short-term connections are used. The short-term connections occur when peers enter and leave the network in P2P video sessions. Hence, P2P can be used for video streaming independent of the transport protocol.

The users' demand for ubiquitous network access has led to integration of different networking technologies. As mentioned earlier in Section 2.4, Sangam [7] is an interesting example of Cellular and Wi-Fi technology integration. It has a hybrid CDN-P2P framework for video file sharing among co-located user groups. It considers heterogeneity among phones in terms of sizes, CPU & power levels, size and number of chunks to be distributed within P2P, and hybrid scheduling policies for chunk distribution. A group of peers with multi-radio interfaces communicate with each other via Wi-Fi Access Point. The cellular network is used for CDN connections between the group of peers and the server. It is assumed that the group of peers is interested in a common file. The cellular-CDN is used for file chunks assignment to the group of peers. The missing chunks are then exchanged among peers via Wi-Fi-P2P network.

- Although the paper covers cellular-Wi-Fi but an assumption in the "Mobility and Access Model" states that the peers are static or very slow moving. Whereas in the implementation, it is assumed that there is no mobility at all.

Another 3G cellular and Wi-Fi integration is presented in [8]. Mobile devices having dual interfaces can simultaneously connect to cellular and Wi-Fi networks. But the mobile user has to pay to the cellular service provider for pulling video streams from the network server. To counter the high streaming cost and scalability issues, a cost-effective and scalable protocol is proposed in [8] for multimedia distribution to mobile nodes in a P2P manner. In the protocol "Collaborative Streaming among Mobiles" (COSMOS), the few peers who pull video streams from base stations share them with nearby neighbours using Wi-Fi or Bluetooth. In COSMOS system, some mobile peers are "pullers" and others are "receivers". Several peers take role of the puller one after the other to achieve fairness. The broadcasting is limited to one to two hops to achieve good performance and low delays. A broadcast algorithm has also been proposed. According to the algorithm, a node collects information locally based on which it does not re-broadcast a video packet if many of its neighbouring nodes have already received that description. Thus, it avoids bandwidth waste. The authors have compared COSMOS against CHUM (Cooperating ad-hoc networking to support messaging) [9, 10]. CHUM uses a tree overlay and point-to-point communication, while COSMOS is mesh-based and uses broadcasts. Simulation results show COSMOS to be better than CHUM in terms of resilience to peer failures, video bit-rate achieved, stable stream and fairness in cost sharing.

- The limitation of this system is that it is effective only when enough number of peers is viewing the same video content.
- The peers need to be close in vicinity as the performance stays good up to only two hops. This brings doubts on its scalability.
- Incentive schemes for peers to become pullers and share video with others are yet to be explored.

PatchPeer [17] presents a hybrid wireless architecture (cellular+ad hoc) for VoD streaming. The proposed solution scales the VoD system beyond the actual server capacity by incorporating P2P relationship among the mobile clients/nodes. The nodes join a video multicast from content server via base station and obtain the missing portion from other peers as a patching stream. The paper discusses the admission control in shared wireless environment, node mobility and recovery procedures needed when sessions disconnect due to mobility or node departure. As part of recovery procedure, the system monitors transmission rate of patching stream for out-of-range detection and consequently searches for a new patch provider. But practically, the change in distance may not be the only reason to affect transmission rate.

- It is suggested the factors such as Received Signal Strength (RSS) and threshold values should be considered to determine out-of-range scenario.
- PatchPeer assumes that all requesting peers are interested in the same video but in VoD systems, peers requests can be for different content. Placing popular content at Proxy Servers may be helpful.
- If the video of interest is not available among neighboring peers, then individual unicast sessions will have to be arranged. Alternatively, having content on replica/edge servers at the base station can reduce origin content servers' load and transmission time at the same time.

3.4 Application Layer Solutions

Various functionalities can be handled at the application layer of a video streaming system. These include application layer buffer management, traffic management, video source coding and processing.

An Interleaved Distributed Transcoding (IDT) encoding scheme is proposed in [5, 6] for streaming video to mobile peers which have limited capabilities (downlink bandwidth, media decoding) and also differ in their capabilities. The system comprises of both fixed and mobile peers. The fixed peers are computationally powerful computers with wired connection to the network. The mobile peers due to their limited resources, act as leeches. The IDT scheme is based on H.264/AVC baseline profile. Each fixed node transcodes the original video stream into a sub-stream. The mobile device can receive different sub-streams from multiple fixed nodes (parents). The single stream formed after assembling them is decodable by any decoder compliant with H.264/AVC baseline profile. The results demonstrate that the proposed IDT scheme provides robustness against peer churns and adverse wireless channel conditions. The paper also discusses performance comparison of IDT and Multiple Description Coding (MDC). Simulation work shows IDT performs better than MDC by 1 to 1.5 dB. The authors have verified their analysis and simulation by implementing a real-time IDT encoder. A limitation of this system include the inability of mobile peers to contribute to the P2P system. The authors state that as each of them receives customized video, it will not be useful for any other mobile peer.

- It is suggested that if any peer with similar features exist, then sharing should be allowed between them.
- The IDT scheme conforms to H.264/AVC baseline profile so only those mobile peers with decoders compliant to this profile can benefit from this scheme.

A P2P approach is presented in [14] where a number of peers collaborate to obtain different chunks of a live video and then share the chunks among themselves. The authors discuss the scenario of a high speed train in which user devices have two communication links; a wireless internet access link (e.g., UMTS, HSDPA or GPRS) and a local sharing link (e.g., WLAN in ad hoc mode). The P2P group has a centralized control for chunk retrieval. The scheduling of chunks over the links is determined by chunk schedulers. The paper defines three schedulers and evaluates them through simulation work. Note that the peers themselves are not mobile and actually within a train moving at high speed.

With advancement in codecs, Scalable Video Coding (SVC) [40] was introduced as an extension of H.264/AVC [41]. SVC allows spatial, temporal and quality scalability of video streams. This scalability allows media rate adaptation and device capability adaptation without the need of transcoding and transrating. SVC performs layered video coding (a base layer and several enhancement layers). Although earlier codecs like H.262, H.263, MPEG-2, and MPEG-4 supported layered coding but had inferior coding efficiency as compared to SVC [42]. The paper [43] explains the potential use of SVC for transmitting video in mobile networks.

The proposed system in [16] uses a combination of infrastructure and ad hoc wireless network. The users form a P2P style ad hoc network and access the layer-encoded videos stored on the server. Upon a video request, the base layer is sent directly from the server to the requesting peer via the access-point (AP) of WLAN. The enhancement layers get transported over multiple paths of ad hoc network. Any peer in the network having requested video content is called super-peer. The server directs the super-peer to deliver the cached enhancement layers to the requesting peer via multiple ad hoc paths. The system has centralized control of content distribution by sending base layer through AP. The AP can detect the churn of a super-peer during streaming and arranges an alternate. Simulation work demonstrates the efficiency of the proposed system in comparison to simple WLAN.

H.264/SVC is most suitable for video transmissions in variable network conditions of wireless networks and users with heterogeneous devices [43, 44]. But, the authors in [6] state that there were no SVC decoders available for mobile devices at the time when this paper was being written (2012). The support for SVC based video streaming has started emerging recently. A few examples are Microsoft Lync - a unified communication platform that enables HD quality video conferencing among a variety of devices [45], Vidyo's video conferencing products based on H.264/SVC [46] and products by Radvision [47]. Another on-going research project cool SVC [48] is an effort to build a framework to offer best decoded video quality (in perceptual sense) under rate and device power constraints on mobile platforms. These developments assure that SVC decoders for mobile devices will become commonly available soon.

3.5 Cross Layer Video Streaming Solutions

Most of the existing work discussed so far for wireless video streaming is based on single layer optimization. Recent research has brought focus to cross-layer designs to improve the transmission of video over wireless networks. Cross-layer designs usually involve optimizations at two or more layers to achieve optimum performance.

As mentioned in Section 3.1, [39] elaborates a cross-layer model for transmitting video reliably over the wireless networks. The physical layer design involves optimization of Adaptive Modulation and Coding (AMC) parameters. AMC is considered an effective way of dealing with varying wireless channel conditions. The paper presents joint optimization of ARQ and application layer Forward Error Correction (A-FEC) parameters at data-link layer and application layer respectively. This maximizes the number of frames that can be correctly decoded for a video.

A cross-layer based mobile P2P framework has been proposed in [15] for VoD over mobile networks. The framework has Mobile Peer-to-Peer (MP2P) overlay at application layer and Stream Control Protocol (SCTP) at the transport layer. SCTP can provide seamless support to sessions over multiple heterogeneous networks. The system has a hybrid structure; structured tree and unstructured distribution network. In the latter, peers form random peer relationships based on buffer overlapping and gossip protocol. On joining the system, a node downloads some video segments from source server according to a prefetching algorithm. Normally a node gets streaming from gossip partners/nodes. When VCR-like operations occur, the original partner cannot provide the streaming for the changed playback position. The structured tree searches for a new target node corresponding to the target playback position and helps in continuous smooth playback. The authors also claim to optimize SCTP congestion control and path management mechanisms for better streaming performance and mobile handover.

Table 2 summarizes various features of some P2P video streaming work discussed above.

Table 2. Summary of Various P2P Video Streaming Systems

Features / Title	Architecture	Wireless Technology	Distribution Scheme	Video Codec	Evaluation Basis
Streaming to Mobile Users [5] & Robust mobile Video Streaming in P2P [6]	Tree-like P2P	Wired + Wireless	P2P transcoding	H.264/AVC	Simulation + Implementation
Sangam [7]	Hybrid CDN-P2P	Cellular + Wi-Fi	Pull	-	Implementation
COSMOS [8]	Mesh-based P2P	Cellular + Wi-Fi/ Bluetooth	Pull + broadcast	MDC	Simulation
CHUM [9, 10]	Tree-like P2P	3G/Cellular+ Ad hoc Wi-Fi/ Bluetooth	Broadcast	-	Implementation
3GMOVi [11]	Ad hoc style P2P	Cellular + Ad hoc Wi-Fi	Pull	-	Implementation
MOVi [12]	Ad hoc style P2P	Wi-Fi	Pull	(unknown)	Implementation
Mixed CDN-P2P [13]	CDN-P2P	Wired +Wi-Fi	Pull		Simulation
System for Resource Constrained Mobile Environments [14]	Mesh-based P2P	Cellular + Adhoc Wi-Fi	Pull	-	Simulation
Cross-Layer Design MP2P [15]	Hybrid (structured + unstructured)	Wired + Wi-Fi	Push + Pull	-	Simulation
Centralized P2P Video Streaming over Hybrid Wireless [16]	Ad hoc style P2P	WLAN + Ad hoc wireless	Wi-Fi + AODV	MPEG / PFGS	Simulation
Patch Peer [17]	Ad hoc style P2P	Cellular + Adhoc Wi Fi	Pull	-	Simulation

4. PROPOSED FRAMEWORK

This section provides an overview of our proposed framework for ubiquitous on-demand video streaming which supports user mobility. Shah and Nawaz [49] suggest that the mobile user expectations can be met by using wireless multi-technology networks which are modern as well as affordable. Hence, we propose a cost effective system which incorporates hybrid wireless networking technologies and collaboration among mobile user devices for sharing available content. Figure 5 shows the overall system's architecture where mobile devices support connections to WWAN (cellular network), WLAN (infrastructure mode Wi-Fi) and peer devices (Wi-Fi Direct). These mobile devices can be Smart Phones, Laptops, Tablets, etc. A hybrid approach was chosen based on the comparison of various architectures discussed in section 2. In the proposed architecture, although laptops do not support a cellular connection directly, but they can utilize Wi-Fi Direct capability of their operating system (e.g., Windows 8.1) to gain Internet access via cellular network of a Smart Phone acting as Group Owner in a WiFi Direct P2P group. Nowadays, Wi-Fi Direct is commonly available on mobile devices, e.g. Android based devices such as Samsung Note 10.1, Samsung Galaxy S3, Google Nexus 7 and Apple's proprietary systems such as iPad and iPhone with iOS7 feature AirDrop.

A device will either use cellular or Wi-Fi to serve a user's video request. The proposed approach prefers Wi-Fi over cellular. Although cellular network has more geographical coverage area as compared to Wi-Fi network but a user has to pay per content download for using the cellular bandwidth. In contrast, the Wi-Fi has better data rates and no cost involved per download other than the standard fee to service provider. A device in Wi-Fi Direct P2P connection with another device may simultaneously be connected to cellular or Wi-Fi network. It can also set up multiple Wi-Fi Direct P2P connections over the same wireless interface. Wi-Fi Direct technology allows secure connections between devices anywhere, anytime without the need of AP or Internet connection [50].

The proposed system arranges for ubiquitous video service to user devices as upon request they can obtain video from:

- original content servers through infrastructure WiFi - Access Points (AP) or
- neighbouring peers through Wi-Fi Direct who have already obtained the video of interest or
- proxy servers (associated with WLAN or ISP Intranet) which cache the traversed content or
- proxy servers (associated with cellular network or ISP Intranet) which cache traversed content or
- original content servers through cellular network - Base Station (BS)

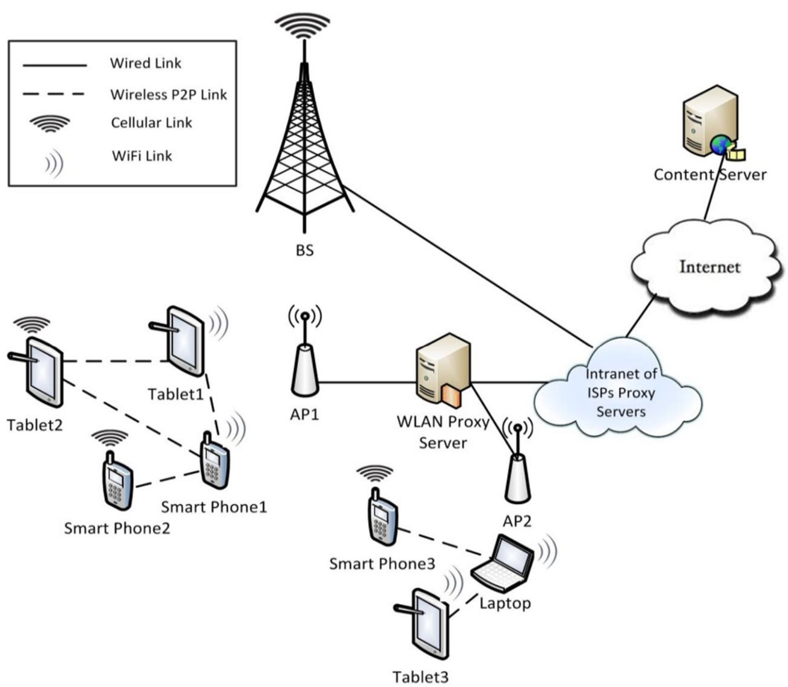

Figure 5. Proposed system architecture

Figure 5 shows Smart phone1 and Tablet1 to be connected with AP1. The Smart Phone2 is out of AP1 wireless range so it can use cellular network for Internet access. Smart Phone1, Smart Phone2, Tablet1 and Tablet2 have P2P Wi-Fi Direct connections. The AP1 is connected to its local Proxy Server which is further connected to the Internet through its Internet Service Provider's (ISP) Proxy Server. It is assumed that all ISPs maintain Proxy Servers which form an Intranet. These Proxies implement the local caching mechanism to avoid unnecessary hits on the original content server. The AP2 has Tablet3 and Laptop in its Wi-Fi network and Smart Phone 3, being out of its range, is connected to cellular BS. BS can access Internet via its ISP Proxy Server. The Proxy Servers in the network implement local caching mechanism and avoid unnecessary hits to original content server.

Upon joining an access network, the device's capabilities get registered with the proxy servers; WLAN proxy for Wi-Fi network and Cellular ISP proxy server for cellular network. The capabilities information includes its supported video formats, buffer size, screen resolution, remaining battery time and cached video content. A software called Proxy Agent resides on the proxy server. It comprises of a Tracker module (which registers capabilities), Content Adaptation module and a Local Cache. The Proxy Agent's Content Adaptation module interacts with the Tracker module for obtaining this information for adapting content for a requesting device. The user desired video content is either available in Proxy Server's Local Cache or is obtained from ISPs Proxy Servers Intranet or from the original content server on the Internet. Irrespective of from where video is obtained, the Proxy Agent's Content Adaptation module performs transcoding, if required, to convert it into the video format/codec supported by user device. At other times it may perform steps to change video's spatial resolution and/or temporal resolution (frame rate) before delivering it to user device. Proxy side content adaptation is considered to be the best location for a particular media type and energy awareness for mobile devices among client side, server side and distributed content adaptation locations [51]. The Proxy Agent interacts with the client-side software called User Agent, for delivering the video to user device as depicted in Figure 6.

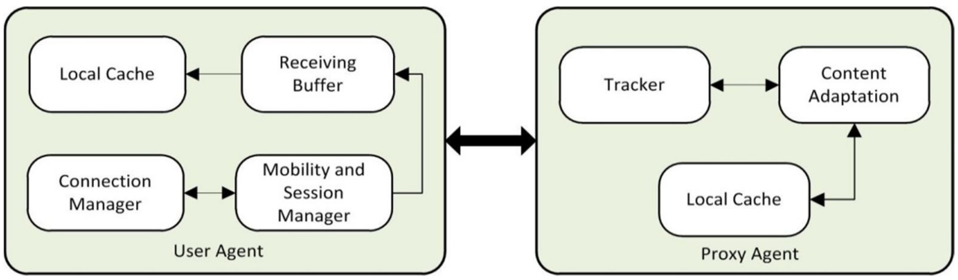

Figure 6. Interaction of software modules

The User Agent has two modules; Connection Manager and Mobility & Session Manager. The Connection Manager module within User Agent determines the device connection with other network components which include cellular BS, AP or peer devices. The Mobility & Session Manager module keeps monitoring the available signal strength for a certain network connection. If it falls below the predefined threshold then it starts preparing for handover and indicates to the connection manager to start scanning for a new connection before losing the existing one. Session information such as video ID, length of video downloaded, video source, etc. are then transferred to the new connection. Figure 7 shows the user device model. It is assumed that user requests a video through the device's Media Player. The Media Player sends request to User Agent. The Connection Manager of User Agent establishes the connection (procedure discussed later). On receiving video chunks, the Receiving Buffer sends them to the Local Cache of the User Agent for consolidating/combining the chunks into a continuous stream for feeding them to Media Player's Playback Buffer for playing. The content in Local Cache is stored for a defined time period for subsequent feeding if same video is played again by the User. The Mobility and Session Manager keeps track of the number of video chunks received from the time a session started till a handoff occurs or video transfer is completed.

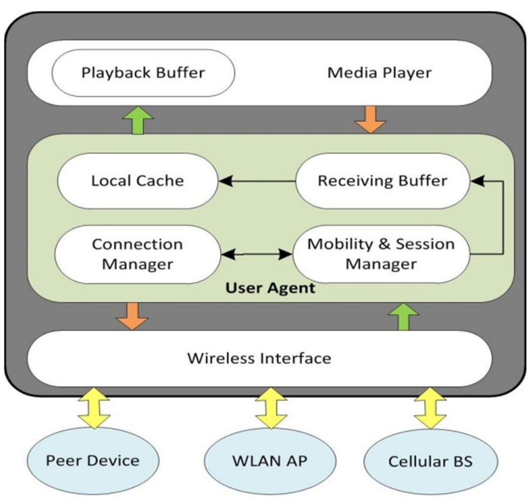

Figure 7. User device model

When Wi-Fi network is available with reasonable threshold signal strength ($RSS_{WiFi} > RSS_{WiFiTH}$), the Connection Manager routes the user video requests through the Wi-Fi network. Wi-Fi is preferred over cellular connection mode as the later involves higher cost and lower data rates as compared to Wi-Fi. But if Wi-Fi signal strength (RSS_{WiFi}) is less than a predefined threshold (RSS_{WiFiTH}), then cellular connection mode has to be used.

While using the cellular connection, it is possible that more than one users request for the same video. When a number of mobile devices are interested in the same video, the ISP Proxy behind the BS can carry out a multicast. A device which requests for the same video a little later can join the multicast in progress and obtain missing content as patch stream from neighbouring peers similar to the PatchPeer [17] approach. But unlike PatchPeer's ad hoc P2P links, the proposed scheme uses Wi-Fi Direct for P2P communication. In case of a unicast in progress, the requesting peer can connect directly to the peer having unicast. When there is neither a multicast or unicast in progress, the system checks for video availability at its ISP proxy server local cache within the ISP Intranet. Locally cached content at the proxy servers reduces load on original content servers. The content can be further searched within the caching facilities in the ISPs Intranet. If a cached copy is found it is streamed to the user device otherwise the request gets routed to the original content server.

When Wi-Fi connection is used, the User Agent requests Proxy Agent (of WLAN Proxy Server) to first check if the requested video is available with any peer(s) in the neighbourhood. If available, a list of candidate peers which match the requesting device capabilities, is given to it. Candidate peers having complete video (seeds) and the ones having partial video (chunks) are enlisted separately. The requesting device prefers obtaining video from seed peers. So, it selects a candidate seed peer based on selection criteria (elaborated in Algorithm 2) to connect in a P2P arrangement using Wi-Fi Direct technology. During streaming if seed peers becomes unavailable then the next one in the list is selected for remaining video. When no more seed peers are available, then the requesting device connects to peers having chunks of video. If some chunks are still missing then the WLAN proxy server provides locally cached content to the requesting device. When the video is not available at WLAN proxy cache, then the video is searched in the ISP proxy server. This enhances the possibility of fetching of contents from closest possible source and reduces the latency. If content is not available in any of these caching facilities then the request is finally routed to the original content server. If the list of seed peers is null then the requesting device uses list of peers having different video chunks. It forms Wi-Fi Direct P2P connections with them to obtain video chunks. For any missing chunks, the request goes to WLAN proxy server cache or ISP Proxy Servers caches and in the worst case to the original content server.

The algorithm 1 shows the User Agent routine, as discussed above, for choosing a connection mode to connect to a communication network for acquiring a video of interest.

Algorithm 1 –User Agent Routine for Connection Management and Video Acquisition

---

r_VID: requested video ID
conn_mode: connection mode for routing video request
node: a user device within a WLAN
seed_candidate_list: list of nodes that have full requested video
chunk_candidate_list: list of nodes that have portions of requested video
UA: User Agent
PA: Proxy Agent
RSS_{WiFiTH}: Threshold value for Wi-Fi signal strength

UA decides connection mode to be used when user initiates a video request
if $RSS_{WiFi} > RSS_{WiFiTH}$ **then**
    conn_mode = WiFi
    UA requests *PA* at WLAN proxy server to find video among local nodes
    PA's Tracker module checks its content maps. It performs following checks for all nodes
        if node has full *r_VID* and node is alive **then**
            add nodeID to *seed_candidate_list*
        else
            if node has portion of *r_VID* and node is alive **then**
                add nodeID to *chunk_candidate_list*
            end if
        end if
    PA returns *seed_candidate_list* or *chunk_candidate_list* to *UA*. *UA* does these steps
    if *seed_candidate_list* is not null **then**
        select a candidate node from the list according to Algorithm 2
    else
        if *chunk_candidate_list* is not null **then**
            conn_mode = Wi-Fi Direct

```
            get chunks from candidates using P2P connection
            if any chunks are missing then
              conn_mode = WiFi
              send request to PA which checks local cache or caches of ISP Proxy Servers within ISP Proxy
              Intranet, for missing chunks
              if cached copy found then
                 Stream to requesting node
              else
                 send request to original content server
              end if
           end if
         end if
    end if
    if seed_candidate_list is null and chunk_candidate_list is null then
         send request to PA which checks local cache or caches of ISP Proxy Servers within ISP Proxy Intranet

         if cached copy found then
            Stream to requesting node
         else
            send request to original content server
         end if
    end if
else
    RSS_WiFi == null or RSS_WiFi < RSS_WiFiTH then
    conn_mode =Cellular
    Check BS ISP Proxy Server for a multicast or unicast in progress for r_VID
    if multicast is in progress then
         request to be added to batch of nodes receiving multicast and get node IDs to receive
         missing content patches
    else
         if  unicast is in progress then
            set up WiFi Direct connection with the node having unicast
         else
            Check BS ISP Proxy Server local cache for r_VID
            if cached copy found then
               Stream to requesting node
            else
               Send request to original content server
            end if
         end if
    end if
end if
```

Algorithm 2 – User Agent Routine for selecting candidate peers for P2P communication

t: time interval after which it is checked if node is alive/available
seed_candidate_list: List of nodes which can serve complete requested video
conn_mode: connection mode
PA: Proxy Agent

```
         if seed_candidate_list > 1 then
              conn_mode = WiFi Direct
              select node with max. battery time and set Wi-Fi Direct P2P connection for content
              check if node is available after every t seconds
              if node not available then
Seed_Update:        remove node from seed_candidate_list
                    if seed_candidate_list is not null then
                         select next node with max. battery time and set Wi-Fi Direct P2P connection for
                         remaining content
                         check if node is available after every t seconds
                         if node not available then
```

```
                    goto Update_Seed
                else
                    if chunk_candidate_list is not null then
                        get missing chunks from candidates using P2P connection
                        if any chunks are still missing then
                            conn_mode = WiFi
                            for remaining chunks send request to PA which checks local cache or caches
                            of ISP Proxy Servers within ISP Proxy Intranet
                            if cached copy found then
                                Stream to requesting node
                            else
                                send request to original content server
                            end if
                        end if
                    end if
                end if
            end if
    end if
else
    select the only node available for Wi-Fi Direct P2P connection
    check if node is available after every t seconds
                if node not available then
                    conn_mode = WiFi
                    for remaining chunks send request to PA which checks local cache or caches of ISP
                    Proxy Servers within ISP Proxy Intranet
                    if cached copy found then
                        Stream to requesting node
                    else
                        send request to original content server
                    end if
                end if
end if
```

At any point in time, if the local (WLAN) Proxy Server goes down while it is required, the Connection Manager module will switch the connection to cellular mode to keep the service going for the P2P Group Owner (GO) and its group members.

During a P2P video streaming session, the sender or receiver peer may move around. To ensure quality and continuity in video, receiver peer can change sender/source peer by selecting a different peer from the candidate list as soon as QoS from existing source drops beyond a defined QoS level. When a suitable source peer is not available or receiving peer gets out of sender peers' range, it can connect with WLAN proxy server (in infrastructure mode) for the video content. If content is not available at proxy server than it can change connection to cellular mode. When a mobile peer is about to move out of the coverage area of the AP or BS, then a handoff must take place from:

- one AP to another AP
- one BS to another BS
- AP to BS (if no other AP is available)
- BS to AP (if no other BS is available)

All metadata for an on-going streaming session is exchanged during switching between these entities for seamless and continuous video service to the mobile device. Session handover details are not included in this paper.

Hence, the proposed system manages continuous video delivery to mobile peers. It has built-in secure and protected P2P connections due to Wi-Fi Direct technology features. The proposed design avoids a single point of failure as video service delivery is not dependent on a single entity. It offers more options for ubiquitous connectivity other than cellular link during video streaming session which makes is cost effective. It is better than the CDN-P2P hybrid systems as it does not have the CDN edge/replica placement and maintenance issues and the P2P streaming is limited within the local area network without overloading ISPs with unwanted traffic. It makes use of local caching facilities and avoids overloading the original content server as much as possible.

5. CONCLUSION

The progression in computer networks and device technology has revolutionized the face of communication. Users can now enjoy continuous video streaming on their portable wireless devices. However, the changing network conditions and user mobility present challenges to video streaming over wireless networks.

P2P based video streaming over wireless networks has been adopted and optimized for saving bandwidth and costs. Research work in this domain was investigated to find various areas which have received researchers' attention. Limitations of some of their work were identified and improvements were suggested where possible. An optimized framework was also proposed for on-demand video streaming which makes use of hybrid wireless networking technologies and P2P techniques for continued video service under peer mobility. Future research in this area may address the following:

- *Use of efficient video codecs*
  H.264/SVC is a promising video codec which can deal with various issues of wireless video systems such as variable channel conditions, device heterogeneity and quality requirements. Its use has been proposed for video transmission in many wireless networks [43, 52, 53]. The use of H.264/SVC codec in wireless P2P systems can be explored under user mobility and compared with other layered video codecs.
- *Video content adaptation to heterogeneous mobile devices*
  The mobile devices available today differ in their capabilities (battery time, display properties, memory, codec support, etc.). Some published work suggests use of transcoding to deal with this heterogeneity [5, 6, 54]. Transcoding is computationally extensive and requires powerful systems with dedicated power supply which are mostly non-mobile/fixed systems. This paper also proposes proxy side content adaptation. In future work, layered video coding approach may be explored.
- *Levels of mobility*
  Many existing solutions for video streaming to wireless devices/peers have either ignored explaining mobility level [5, 6, 9, 13] or assumed low mobility (walking) [3] or no mobility at all [7]. In future, various levels of user mobility need to be assessed for viable solutions.

ACKNOWLEDGEMENT

We would like to thank Dr. Ghalib A. Shah for his valuable suggestions and ideas in carrying out this research work. Dr. Shah is presently an Associate Professor in University of Engineering and Technology Lahore Pakistan. He has extensive research experience. His research interests are ad hoc mobile networks, wireless sensor networks, cognitive radio networks, and multimedia networking.

REFERENCES

[1] Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update 2012-2017 [Online] http://www.cisco.com/en/US/solutions/collateral/ns341/ns525/ns537/ns705/ns827/white_paper_c11-520862.html

[2] Akyildiz, I.F., M. Tommaso and K. R. Chowdhury, 2007. A survey on wireless multimedia sensor networks: Comput. Netw., 51(4): 921-960.

[3] Moraes, I.M., M. E. M. Campista, L. H. M. K. Costa, O. C. M. B. Duarte, J. L. Duarte, D. G. Passos and M. G. Rubinstein, 2008. On the impact of user mobility on peer-to-peer video streaming: IEEE Wirel. Commun., 15(6): 54-62.

[4] Nemati, A.G., T. Enokido and M. Takizawa, 2008. A Multi-Source Streaming Model for Mobile Peer-to-Peer (P2P) Overlay Networks. In the Proceedings of the International Conference on Distributed Computing Systems Workshop, pp: 18-23.

[5] Noh, J. , M. Makar and B. Girod, 2009. Streaming to mobile users in a peer-to-peer network, In the Proceedings of 5th International ICST Mobile Multimedia Communications Conference, pp: 24:1-24:7

[6] Noh, J. and B. Girod, 2012. Robust mobile video streaming in a peer-to-peer system: Signal Process-Image, 27(5): 532-544

[7] Sridhar, A., K. Nahrstedt and L. Vu, 2013. Sangam - Efficient cellular-wifi group framework for file sharing service, In the Proceedings of Military Communications Conference, pp: 1-6

[8] Leung, M. and S.-H. G. Chan, 2007. Broadcast-based peer-to-peer collaborative video streaming among mobiles: IEEE T. Broadcast., 53(1): 50-61.

[9] Kang, S. and M. W. Mutka, 2003. Mobile peer membership management to support multimedia streaming. In the Proceedings of ICDCS Workshop on Mobile and Wireless Networks, pp: 770–775.

[10] Kang, S. and M. W. Mutka, 2005. A mobile peer-to-peer approach for multimedia content sharing using 3G/WLAN dual mode channels: Wirel Commun & Mob Com, 5(6): 633-645.

[11] Iyer, T., R. Hsieh, N. B. Rizvandi, B. Varghese, & R. Boreli, Mobile P2P Trusted On-Demand Video Streaming. arXiv preprint arXiv:1204.0094.2012, unpublished.

[12] Yoon, H., J. W. Kim, R. Hsieh, 2014. Peer-assisted video on-demand streaming system in practical WiFi-based mobile opportunistic networks: J. Netw. Comput. Appl., 37: 33-44

[13] Sheu, S. and C. Huang, 2011. Mixed P2P-CDN system for media streaming in mobile environment, In the Proceedings of the 7th International Wireless Communications and Mobile Computing Conference (IWCMC), pp: 657 – 660

[14] Stiemerling, M., S. Kiesel, 2009. A System for Peer to Peer Video Streaming in Resource Constrained Mobile Environments. In the Proceedings of 1st ACM workshop on User-provided networking: challenges and opportunities, pp: 25-30.

[15] Xu, C., L. Zhong, J. Guan, H. Zhang, 2010. A cross-layer design or mobile peer-to-peer video on demand services. In the Proceedings of International Conference on Advanced Intelligence and Awareness Internet, pp: 166-169.

[16] He, Y., I. Lee, X. Gu, L. Guan, 2005. Centralized peer-to-peer video streaming over hybrid wireless network. In the Proceedings of International Conference on Multimedia and Expo, pp: 550–553.

[17] T. Do, T., K. A. Hua, N. Jiang, F. Liu, 2009. PatchPeer: A scalable video-on-demand streaming system in hybrid wireless mobile peer-to-peer networks: Peer-to-Peer Netw.Appl. Springer, 2(3): 182-201.

[18] Client-Server Model of Computing [Online] - http://www.hp.com

[19] Liu, Y., Y. Guo, C. Liang, 2008. A survey on peer-to-peer video streaming systems: Peer-to-Peer Netw. Appl., 1(1): 18-28.

[20] Bosovic, D., F. Vakil, S. Dautovic, M. Tosic, 2011. Pervasive wireless CDN for greening video streaming to mobile devices. In the Proceedings of the 34th International Convention MIPRO, pp: 629-636.

[21] Ouyang, Z., 2012. On heterogeneous user demands in peer-to-peer video streaming systems, PhD thesis, University of Nebraska, Lincoln.

[22] PPLive [Online] - http://www.pplive.com

[23] SopCast [Online] -http://www.sopcast.com

[24] TVAnts [Online] - http://tvants.en.softonic.com

[25] PPStream [Online] - http://www.ppstream.com

[26] Zhang, X., J. Liu, B. Li, T. P. Yum, 2005. CoolStreaming/DONet: a data-driven overlay network for peer-to-peer live media streaming. In the Proceedings of 24th Annual Joint Conference of the IEEE Computer and Communication Societies INFOCOM, pp: 2102-2111.

[27] Mavlankar, A., P. Baccichet, B. Girod, S. Agarwal, J. Singh, 2008. Video quality assessment & comparative evaluation of peer-to-peer video streaming systems. In the Proceedings of IEEE International Conference on Multimedia and Expo, pp: 645- 648.

[28] Magharei, N., R. Rejaie, and Y. Guo, 2007. Mesh or multiple-tree: A comparative study of live p2p streaming approaches. In the Proceeding of 26th IEEE International Coference on Computer Communications, INFOCOM, pp: 1424-1432.

[29] Byun, H. and M. Lee, 2009. HypPO: A peer-to-peer based hybrid overlay structure. In the Proceedings of 11th International Conference on Advanced Communication Technology ICACT, pp: 840-844.

[30] Lu, Z., Y. Li, J. Wu, S. Zhang and Y. Zhong, 2008. MultiPeerCast: A tree-mesh-hybrid P2P live streaming scheme design and implementation based on peercast. In the Proceedings of 10th IEEE International Conference on High Performance Computing and Communications, pp: 714-719.

[31] Huang, Q., H. Jin and X. Liao, 2007. P2P live streaming with tree-mesh based hybrid overlay. In the Proceedings of International Conference on Parallel Processing Workshops, pp: 55.

[32] Yang, M. and Y. Yang, 2010. An efficient hybrid peer-to-peer system for distributed data: IEEE Trans. Comput., 59(9), 1-10.

[33] P. Ftzek, H. and H. Charaf, 2009. Mobile peer to peer (P2P) – A Tutorial Guide, John Wiley & Sons, Ltd. pp: 6.

[34] Wu, J., Z. Huilu, B. Liu and S. Zhang, 2008. PeerCDN: a novel P2P network assisted streaming content delivery network scheme. In the Proceedings of 8th IEEE International Conference on Computer and Information Technology, pp: 601-606.

[35] Jiang, H. , J. Li, Z. Li, et al, 2009. Efficient large scale content distribution with combination of CDN and P2P networks: International Journal of Hybrid Information Technology, 2(2), 13-24.

[36] Xu, D., S. S. Kulkarni, C. Rosenberg and H. Chai, 2006. Analysis of a CDN–P2P hybrid architecture for cost-effective streaming media distribution, Multimedia Systems: 11(4), 383–399.

[37] Huang, Y., T. Z. J. Fu and D. Chiu, 2008. Challenges, Design and analysis of a large-scale P2P-VoD system, In the Proceedings of ACM SIGCOMM, pp: 375-388.

[38] Cisco White Paper [Online]- http://www.cisco.com/en/US/prod/collateral/wireless/ps5678/ps11983/white_paper_c11-713103.html

[39] Wang, Z., H. Chen, L. Xie, K. Wang, 2010. Cross-layer design for wireless video stream transmission. In the Proceedings of IEEE Wireless Communications and Networking Conference (WCNC), pp 1-6.

[40] Advanced Video Coding for Generic Audiovisual Services, ITU-T Rec.H.264 & ISO/IEC 14496-10 AVC, v3: 2005, Amendment 3: Scalable Video Coding.

[41] Advanced Video Coding for Generic Audiovisual Services, ITU-T Recommendation H.264 & ISO/IEC 14496-10 AVC, v3: 2005.

[42] Schierl, T., T. Stockhammer and T. Wiegand, 2007.Mobile video transmission using scalable video coding: IEEE T. Circ. Syst. Vid., 17(9): 1204-1217.

[43] Yang, S., Z. Wei and L. Ling, 2011. Multimedia communication and scalable video coding. In the Proceedings of International Conference on Intelligent Computation Technology and Automation, pp: 28-29.

[44] Abdelhalim, A., T. Ahmed, H. Walid-Khaled and S. Matsuoka, 2012. Using Bittorrent and SVC for efficient video sharing and streaming. In IEEE Symposium on Computers and Communication (ISCC), pp: 000537-000543.

[45] Lync [Online] - http://lync.microsoft.com/en-us/Pages/Lync-2013-Preview.aspx

[46] Vidyo [Online] - http://fr.vidyo.com/2012/03/vidyo-ready-to-test-h-264-svc-interoperability-at-imtc-superop

[47] Radvision [Online] - http://www.radvision.com/NR/rdonlyres/FEF8D1A4-3912-4531-9F8A-AC985FC6BC02/0/Product_Catalogue_MKT1018CEN_Screen.pdf

[48] CoolSVC [Online] - http://vision.poly.edu/~coolsvc/

[49] M. A. Shah, A., T. Nawaz, 2014. StreaMER: Streaming Media Edge Router, A centrailzed multimedia transcoding gateway for multi-bit-rate networks, J. Basic. Appl. Sci. Res, 4(2) 2014, pp. 126 - 134

[50] Wi-Fi Direct - http://www.wi-fi.org/

[51] N. Ismail, M., R. Ibrahim and M. F. M. Fudzee, 2013. A Survey on Content Adaptation Systems towards Energy Consumption Awareness: Advances in Multimedia, 2013.

[52] Casasempere, J., P. Sanchez, T. Villameriel and J. D. Ser, 2009. Performance evaluation of H.264/MPEG-4 scalable video coding over IEEE 802.16e networks. In IEEE International Symposium on Broadband Multimedia systems and Broadcasting, pp: 1-6.

[53] Gallucci, D., A. Fiandrotti, E. Masala and J. Martin, 2009. Content-adaptive robust H.264/SVC Video communications over 802.11e networks. In the Proceedings of IEEE International Conference on Advanced Information Networking and Application, pp: 189-196.

[54] Tamai, M., et al, Transcasting, 2008. Cost-efficient video multicast for heterogeneous mobile terminals. In the Proceedings of 16th International Workshop on Quality of Service, pp: 171-180.