Resource management In P2P and MANETs using layered coding techniques

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Abstract

The thesis addresses the resource utilization problem to provide smooth video delivery over P2P wired or Mobile Ad hoc networks by exploiting the properties of layer coding techniques. Given a request for a video, the aim is to stream the video to all destinations with the maximum achievable quality. This problem is known as the resource utilization problem and it has been studied extensively over wired and wireless networks, and it is known to be NP hard. However, due to the high dynamicity of peers and current network conditions, the resource allocation problem is still open. Most of the carried research considers streaming the videos to the destination node using a single source and without implementing any coding techniques which introduces huge playback issue. Moreover, in the context of MANETs, the resource utilization adds further challenges as nodes are considered to have limited energy with a highly dynamic topology. Recently, there has been much research carried out towards providing different routing protocols or streaming techniques to efficiently handle the resource. However, most of the work considers either energy or link bandwidths as a constraint to handle the resources of nodes.

This thesis, investigates the resource utilization problem over P2P and MANETs using layer coding to efficiently utilize the available resources in the network. Hence, the thesis proposes approximation algorithms to this purpose. The main contributions of the thesis are summarized below;

The thesis proposes an algorithm that *exploits the properties of Scalable Video Coding (SVC) in order to minimize the upload bandwidth at each peer. More specifically, the concept of streaming different layers of the same video from different peers has been proposed.* Further, an optimization problem is defined to handle the upload bandwidths at peers. However, the solution to the proposed problem is NP complete. Therefore, an approximation algorithm is proposed to solve this problem. *In addition, seed servers are introduced in order to deal with extra load in the network.* The proposed method provides better performance as compared to the current approaches that use single layer video in combination with SVC. The simulation results are compared against the model proposed in the literature.

According to the results, the proposed model improves diversity, increases average video quality, reduces the effect of churn and manages flash crowds.

Apart from basic P2P network, the thesis also *investigates the resource allocation problem for distributing the video in a P2P mobile ad hoc network (MANET) to provide users' with a better quality of experience (QOE*). Therefore, a linear optimization problem to efficiently utilize the upload bandwidth at each mobile node is defined. Scalable video coding (SVC) i*s used to help maximize the Quality of experience (QOE) by distributing the load across the nodes to minimize the power consumed and the upload bandwidth at each peer.* However, the solution to the proposed problem is NP complete. Therefore, a QOE based Energy Efficient model (QEE) is proposed that provides an approximation algorithm and compares the performance of the proposed model with the existing models as explained in the literature. The simulations results show that QEE provides better QOE, consumes less power and minimize the upload capacity at each peer as compared to the existing models. Furthermore, QEE model also helps to manage the flash crowd and effect of churn in the network.

The thesis also addresses *the data collection and routing problem for streaming video over a decentralized MANET to improve the average video quality received. The solution to such a problem is known to be NP complete.* Hence, *a novel Energy-Efficient Video Streaming method, called EEVS, is proposed that provides an adaptive data collection technique and a routing protocol to share the video across the network*. In adaptive data collection technique, the nodes share their available information across every node they meet. However, the routing protocol helps to identify the sources and stream the video through multiple sources towards a given destination to reduce the overall load at each node. Furthermore, in order to handle the heterogeneous peers in MANETs, Multiple Descriptive Coding (MDC) is used which provides the video at different quality levels. The performance of EEVS is compared other well-known protocols in two experiments. In the first experiment, the data collection phase of EEVS is compared against MVSS and HAS-A-GEM. In this experiment, the information available across the nodes is shared across every other node they meet. In second experiment, the routing phase of EEVS is compared against EDSR and MP2P+MDC. The simulation results show that EEVS has 120%

less overhead than HAS-A-GEM and approximately 170% less overhead than MVSS. Furthermore, the results show that the EEVS outperforms MP2P+MDC and EDSR by efficiently managing the energy across the nodes and distributing the load across the network using multiple sources. Hence, this increases the network lifetime. Moreover, the results also show that in EEVS the average video quality received is 30% more than MP2P+MDC and approximately 50% more than EDSR. The results also show that EEVS reduces the streaming delay up to 165% as compared to MP2P+MDC and approximately up to 300% as compared to EDSR.

Statement of Originality

This is to certify that the work described in the thesis is entirely my own, except where due reference is made in the text.

No work of the thesis has been submitted for a degree to any other university or institution.

Signed

Muhammad Salman Raheel
31st August, 2015

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1 INTRODUCTION

1.1 Motivation

Multimedia streaming over the internet has gained huge popularity due to high data rates provided by ISP’s and with the wide deployment of broadband networks. According to [1], a US company, Cisco Systems estimated that the internet traffic is increased fourfold by 2015. This happened due to the rapid increase in the video traffic generated by the users, including mobile phones, TVs, Video on demands, Internet Videos and P2P Videos. Similarly, in [2], the authors discovered that Skype (a popular net calling service) controls more than 13% of the international communications supporting 663 million users.

According to an industrial research [3] report, more than 60 million people are using streaming media each month, 58 US TV stations are providing live web casting, 34 stations are showing on demand streaming programs, and 69 stations offer international web casting. The research also concludes that more than 6000 hours of streaming content is uploaded over the Big Brother UK server every week. Moreover in [4] Huang et.al showed that the average bit rate for the videos offered by MSN network has increased by 50 % over a nine month duration, and it is most likely to increase much further in the future.

1.1.1 Conventional Streaming Architecture

In conventional streaming architectures, the Client Server architecture [5] is one model being used for many years. In this architecture, the client communicates with the server to access the data required for streaming and the server responds to the client’s request. However, the major disadvantage of this approach is that large number of users cannot be accommodated due to the bandwidth bottleneck at the

server. To overcome the bandwidth issue, Content Distribution Networks (CDN) [6] was proposed that introduced the concept of using dedicated servers at different geographical locations that collaboratively overcomes the bandwidth limitations. However, the disadvantage of this approach is a huge deployment cost and a backbone connection is required between servers to serve clients request.

Hence, in order to overcome the disadvantages of CDN networks, a more distributed architecture is required, that relies on the network users themselves for resources. These have become popularly known as peer to peer (P2P) networks. This architecture has largely solved many of the existing streaming problems and provides scalability.

1.1.2 P2P Networks

In a Peer to Peer network, each peer shares its own resources with other peers and acts as both client and server. At the same time, peers not only download the data but also upload the downloaded data for other users. These capabilities in peers help to reduce overall load on the server. Unlike conventional approaches; maintenance and monitoring in p2p networks are distributed among peers. In recent years, video P2P has attracted numerous users, especially for streaming applications such as UUSee [7], CoolStreaming [8], PPLive [9] and SopCast [10]. As, more users join to see the multimedia content, the requirement to provide better video quality as compared to what is available at many systems increases.

1.1.3 MANETS

Mobile ad hoc network (MANET) is an assembly of wireless mobile nodes arranged to communicate with each other without the support of any fixed infrastructure. They are similar to P2P networks, and are considered to be self-configurable, self-adaptive and self-manageable. These networks can be a mobile phone, tablet, PDA or any personal device with a wireless interface and has a tendency to join a wireless

network. According to [11], MANETs are comprised of several wireless technologies such as Bluetooth, 802.11 WLAN, 3G and 4G, etc.

Each node communicates with any other node using different wireless links and with the help of the intermediate nodes the information can be forwarded beyond a nodes coverage area. However, the topology of MANETs is fully dynamic; this is because the nodes continuously change their positions in the network. Hence, at any time a node can join or leave a particular network.

MANETs are widely used in situations where it is difficult to provide any fixed infrastructure. In [12], the authors have identified a number of applications where MANETs are a valuable solution such as; emergency situations, unplanned crowd, disaster recoveries and over the military applications. However, apart from its wide applications, one of the major disadvantages in MANETs is the limited battery life at the mobile nodes. Hence, it is a major requirement of any protocol designed to consider the energy efficiency as a primary objective. It is even more important to look at energy when video distribution or streaming over MANETs.

1.1.4 Video Coding Techniques

In addition to recent development in P2P and MANETs, different video coding standards have become known to handle video delivery over the internet with high QOS such as MPEG-2, H.264 AVC, SVC and MDC as explained in [13]. Among those, SVC [14] and MDC [15] are considered to be the most promising approaches.

In SVC, video is coded into layers including a base layer and several enhancement layers. The base layer carries the most important and the basic information of the video whereas the enhancement layers can further improve the quality of the base layer stream. However in MDC, the video is coded into multiple descriptors and each descriptor can be decoded independently. The quality of video depends on the number of descriptors received.

The most recent state of the art has combined these techniques and has carried out towards deploying P2P or MANETs using video coding techniques such as SVC or MDC [99-127] and [156-171] to combine the advantages of these techniques. However, there is still lack of comprehensive study to effectively utilize the resources such as energy, upload capacities of the nodes and provide a system with better QOS among the users. This is a major motivation of this thesis to provide a resource allocation algorithm for P2P networks and MANETs by utilizing the properties of video coding techniques to provide a smooth video streaming system. The following section covers the research problems and contributions of this thesis.

1.2 Research Problems

There is a lot of research carried out towards streaming video over P2P or MANETs. But, due to heterogeneous nature of nodes in the network, it becomes challenging to stream the video using the single layer coding. Hence, different video coding techniques are introduced such as SVC or MDC; to provide a way to quickly adapt the quality of the video based on the current network conditions. However, it is not so easy to achieve an acceptable QOS/QOE due to frequent nodes joining and leaving the network. Here we list a number of research questions to be answered by this thesis.

– Upload Bandwidth

In order to provide continuous and reliable video streaming, it is necessary to design a system that has an average upload bandwidth of peers greater than the rate at which video is streamed from the server node. A number of studies [16] [22] have been carried out in developing such a kind of a system. But, in today's internet due to heterogeneous peers, each peer shares different upload bandwidth in the network.

Hence, the first research question is to design an algorithm that minimises the upload bandwidth from peers using scalable video coding. The question can be put in another way: given n nodes that contain a particular video that has been encoded in a scalable way, which nodes need to transmit and at what rate and over which

paths that it results in a maximum data rate at the receiver (highest QOS) and minimises the upload bandwidth from each node.

– Peer Churn

The heterogeneous nature of peers affects video streaming in a way that whenever a peer joins or leaves the network, it takes some time to find its neighbours or an alternate route for streaming the media. Recent studies show that in [16] [17] and [18] different scheduling techniques have been proposed in P2P networks to provide video streaming under churn.

Hence, the second research question is to reduce the effect of a peer churn in the network through the use of multiple sources or mixed topology architecture. This helps to maintain a better quality even if a source node leaves the network.

– Quality of Service (QOS)

QOS usually depends on the type of streaming. A non-interactive system may tolerate longer delays as compared to live and interactive systems. To accommodate a large number of users, P2P systems are usually built over application level overlay networks. However, heterogeneous bandwidth of peers and a large distance from source to destination increases the end to end delay. Hence, it becomes a problem to provide a system that requires less playback delay with maximum playback continuity so that the user can smoothly watch the video. Researchers have carried out work in [16] [19] [20] and [21] to provide better QOS among users in a P2P network.

Therefore, a third research question that arises is to minimise the playback delay by providing an efficient streaming mechanism such as streaming the video through the sources that are closer to the requesting nodes.

– Flash Crowd

A flash crowd is a crowd that suddenly joins the network for a short duration of time and starts streaming the content without sharing their resources with the network. Hence, they impose a large load on the network. In order to overcome such crowds, research appeared in [22] that describe a system that can continuously monitor the activity of each node in the network. Depending upon the available bandwidth within a network system, p2p overlay either allows or does not allow these nodes to extract the media content from their neighbouring peers.

Hence, the fourth research question is to provide a technique that can effectively handle the flash crowd in the network.

The first four research questions are similar for streaming video over P2P and MANETs but in order to provide video streaming over a decentralized MANETs. There are some more additional challenges for the network to deal with as discussed below.

– Signalling Overhead

Due to dynamic network topology and heterogeneous nature of nodes, the routing and data information over the nodes may change over time. Hence, the nodes are required to update the information after different intervals of time which produces high signalling overhead.

Hence, the research problem is how the nodes can effectively communicate with every other in a MANET to share the available information such that the signalling overhead can be minimized.

– Streaming Delay

The streaming delay is considered as another problem as discussed in [168-170] [172-175] [180-183]. In a highly dynamic network, the contact duration between the nodes

becomes short and the video cannot be streamed until some other source node streams the remaining video, this produces an excessive delay. The streaming delay is bearable in on demand streaming in which the receiver nodes are happy to wait for some seconds before the video can actually be played. However, in the case of live streaming, streaming delay produces skipping issue.

Hence the research question becomes what kind of node selection criteria is used to select the nodes that can efficiently stream the video across the requesting nodes with the minimum overall streaming delay. It is not ideal to stream the video through nodes that communicates with the network for a shorter period of time.

– Energy Utilization

The efficient utilization of nodes energy as discussed in [178] [180-181] [185-188] plays an important role for streaming video across MANETs. In MANETs, if a node’s energy is fully utilized, the network may miss that node and results in a network with a number of missed nodes which eventually degrades the quality of the video. If the nodes with a high transmission speeds are used to transmit layers, the layers deliver to the requesting node with a minimum streaming delay. However the nodes will consume most of their energy and run out of battery quickly and ends up with a network of missed nodes. Moreover, the energy consumption also depends on the distance between the sender and a receiver node. If the distance between the nodes increases, more power is consumed. Therefore, it is necessary to provide an energy efficient routing protocol that provides the trade-off between node's energy and streaming delay together.

Hence the research question becomes how optimally the available energy and transmission speed across each node is utilized such that the load congestion can be minimized. The congestion deteriorates the network service quality, resulting in queuing delay, packet loss and blockage of the new requests.

– Load Distribution

The available transmission speeds at the nodes should be utilized effectively as discussed in [166] [170] [178] and [185-188]. If a node with high transmission speed is always used to handle the new requests, the network will soon encounter congestion. Congestion occurs when the demand for the capacity exceeds the available transmission speed which eventually degrades the quality of service and introduces packet loss and blocks further requests.

What is an effective way to distribute the layered coded video across MANET in order to share the load across different source nodes such that the nodes' resources can be efficiently utilized? The load balancing helps to increase video dissemination rate.

– P2P Streaming

Streaming video through multiple sources encounter problems such as interference, congestion and link failures specifically in MANETs; where the upload capacity across the nodes is quiet limited. Hence, the research questions can be summarized as;

What is an effective way to download a video comprising of different layers using multiple sources such that a better quality of the video can be received at the end users'.

1.3 Contributions

This thesis aims to study the resource utilization and allocation problems under P2P networks, centralized control MANETs and a decentralized control MANETs. Specifically, it designs and evaluates different approximation algorithms to provide streaming video using layer coding (SVC or MDC) to improve the average quality received.

1. The thesis presents an approximation algorithm that utilizes the properties of Scalable Video Coding (SVC) to solve a linear optimization problem to minimize the upload capacity utilization at each peer. More specifically, the thesis proposes streaming of different layers of a video from multiple peers. These layers are then combined at the destination. In addition to peers, seed servers are also deployed in the network to handle extra load in the network. The propose algorithm provides better performance as compared to the recent approaches that use different coding techniques such as in [115]. Extensive simulations have been performed to show that the proposed algorithm introduces network diversity; increase average video quality received, reduces the churn effect and effectively handles the flash crowds.

2. The thesis studies a resource allocation problem to distribute a SVC coded video across MANETs using P2P to provide better quality of experience (QOE) among users. The solution to such a problem is known to be NP complete. Hence, a QOE based energy efficient model (QEE) is proposed that provides an approximation algorithm to solve this problem. SVC helps in maximizing the QOE by distributing the load across multiple sources in order to minimize the energy and upload capacity utilization at each mobile node. It is assumed that the MANET is centralized control with the help of a controller that helps every other node to share available information and resources across the network. QEE is then compared with the recent existing models as given in [164] and [165]. Extensive simulations results show that QEE provides better QOE, consumes less power and minimize the upload capacity at each peer as compared to the existing models. Furthermore, QEE model also helps to manage the flash crowd and effect of churn in the network.

3. The thesis addresses the data collection and routing problem for streaming video over a decentralized MANETs to improve the average video quality received. The solution to such a problem is known to be NP complete. Hence, a novel Energy-Efficient Video Streaming method, called EEVS, is proposed that provides an adaptive data collection technique and a routing protocol to

share the video across the network. In the adaptive data collection technique, the nodes share their available information across other nodes upon contact. However, the routing protocol helps to identify the sources and stream the video through multiple sources towards a given destination to reduce the overall load at each peer. Furthermore, in order to handle the heterogeneous peers in MANETs, MDC is used which provides the video at different quality levels. The performance of EEVS is compared with other well-known protocols in two experiments. In the first experiment, the data collection phase of EEVS is compared against MVSS and HAS-A-GEM. This way, all nodes will receive the video summary table of each other. In the second experiment, the routing phase of EEVS is compared against EDSR and MP2P+MDC. The simulation results show that EEVS has 120% less overhead than HAS-A-GEM and approximately 170% less overhead than MVSS. Furthermore, the results show that the EEVS outperforms MP2P+MDC and EDSR by efficiently managing the energy across the nodes and distributing the load across the network using multiple sources. Hence, this increases the network lifetime. Moreover, the results also show that in EEVS the average video quality received is 30% more than MP2P+MDC and approximately 50% more than EDSR. The results also show that EEVS reduces the streaming delay up to 165% as compared to MP2P+MDC and approximately up to 300% as compared to EDSR.

1.4 Publications

The thesis has resulted is the publication or submission of the following papers:

- M.S. Raheel, R. Raad and C Ritz *Efficient utilization of peer's upload capacity in P2P networks using SVC,* IEEE ISCIT 2014,Inch-eon, South Korea, September, 2014

- M.S. Raheel, R. Raad and C Ritz *Achieving maximum utilization of peer's upload capacity in P2P networks using SVC*, Springer Peer-to-Peer Networking and Applications Journal, Pages 1-21, August, 2015

- M.S. Raheel, R. Raad and C Ritz *QOE based P2P Scalable Video Streaming Over Mobile Adhoc Networks*, IEEE NGMAST 2015, Cambridge, United Kingdom, September, 2015 (Accepted)

- M.S. Raheel, R. Raad and C Ritz *Energy Efficient Scalable Streaming in Mobile Ad hoc Networks to maximize QOE*, Submitted to EURASIP Wireless Communications and Networking.

- M.S. Raheel, S. Iranmanesh, R. Raad and C Ritz *A novel energy efficient video streaming method for decentralized Mobile ad hoc Networks*, Submitted to Wiley International Journal of Ad Hoc and Ubiquitous Computing.

1.5 Thesis Structure

1. Chapter 2. This chapter provides the background of P2P and Wireless ad hoc networks more specifically in MANETs including its types, advantages and development challenges. Furthermore, this chapter also covers the existing video coding techniques such as SVC and MDC including its types and applications.

2. Chapter 3. This chapter includes a literature review of the existing approaches on streaming video in P2P and MANETs. The literature is divided into two parts; the first section covers the existing works related to video streaming in P2P with and without the use of coding techniques. Whereas the second section talks about the recent works related to video streaming in MANETs with and without using the video coding techniques. The section also covers the energy efficient routing protocols for streaming video.

3. Chapter 4. This chapter proposes an approximation algorithm that utilizes the properties of Scalable Video Coding (SVC) to solve a linear optimization problem to minimize the upload capacity utilization at each peer.

4. Chapter 5. This chapter designs a centralized model, called QEE, over MANETs to study the resource allocation problem using SVC.

5. Chapter 6. This chapter outlines a decentralized model, called EEVs, over MANETs to study the data collection and resource allocation problem using MDC.

6. Chapter 7. This chapter provides the conclusion of the contributions made in the thesis, and provides a summary of different outcomes by this research. Moreover, future research directions are discussed.

2 BACKGROUND

2.1 P2P Networks

A P2P network is a kind of virtual network that is built over the physical network. It is made up of various heterogeneous peers connected with each other that have different upload and download capacities, storage, processing powers as shown in Figure 2.1. P2P networks have the following features as discussed below, its main feature is that the peers can communicate to any other peer without necessarily a server being present;

- As compared to Client Server [5] and CDN [6], P2P networks don't rely on any centralized entity. The maintenance and monitoring across the network is distributed among the peers.

- P2P is considered to be a promising approach to provide resource sharing services in a network such as Bittorrent [23], SOPCAST [10] and NAPSTER [24].

- Nodes in the p2p network organize themselves using a discovery process. Hence, no particular indexing is required.

- Each peer in the network behaves as a client or a server. So, at any time, peers can not only download data but it can upload the downloaded data for other users which helps to reduce the overall load at the server.

- P2P networks are considered to be robust as each peer shares its resources among other peers; hence a single point of failure doesn't affect the system performance.

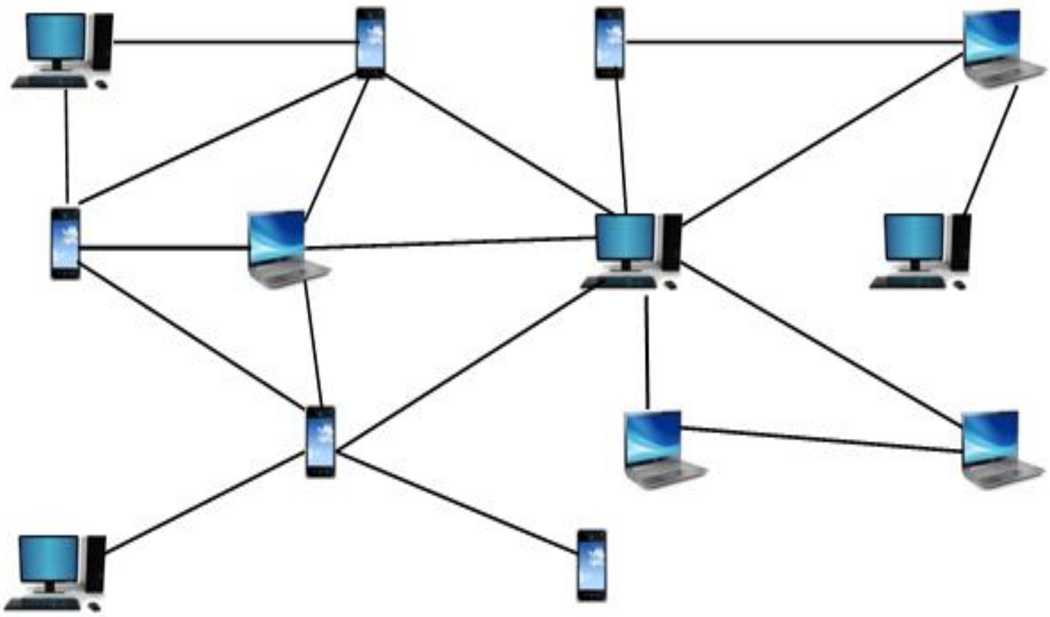


Figure 2.1 P2P Networks Architecture

2.1.1 Applications of P2P Networks

P2P networks are used in number of applications due to their well-known features as discussed in previous section. These applications are mostly divided into two different categories: resource sharing and data sharing applications. In the resource sharing applications, the P2P networks help to perform the tasks by utilizing the resources of different peers over the network instead of deploying a super computer which increases the cost. On the other hand, in data sharing applications, P2P networks share the data across different nodes using different techniques. The detail description of different applications of P2P networks are discussed below;

- **Content Sharing.** Due to the property of P2P networks to work both as a source and a client at the same time, it is considered to be the promising application to share the content. Each peer forwards the request for the requested content which travels through different peers to reach the source which then forwards the content. Examples of such networks include; Freenet [25], Haven [26], Gnutella [27] or Publis [28].

- **Extensive Computation.** P2P network reduces the need of super computers for distributing the computation load to solve complex problems. This reduces the system cost and makes an effective use of idle computers.

- **Entertainment.** P2P network is considered to be a promising application that provides an interactive gaming over the internet.

- **Instant Messages.** People use instant messaging to communicate and share the information over the internet. It is a type of application that uses P2P technology to identify the route and provides information of the peer's availability. Skype [29] is an example of such applications that not only provide a platform to share written messages but also video and voice messages can be sent.

- **Global Work Environment.** P2P networks allow users to work and cooperate with each other that are located at different geographical locations. Magi [30] are one of the examples that provide this collaboration.

- **Collaborative Caching.** P2P networks help the enterprise to share the most common content among users using their local caches [31]. Similarly, P2PTV is considered to be one of the applications that use the collaborative cache concept. Such applications help to download the content through different peers that has the video segments cached. This reduces the overall system cost.

- **Data Sharing.** P2P manages to share the local databases available at each peer to be shared with the centralized servers. This provides a number of advantages such as in health care, the basic information of the patients is stored at the server whereas the detail information of each patient is stored at the specialist computer. In case, if another doctor wants to see the patient history it can ask the server which then forwards the information available at the specialist computer to him. This helps to reduce the cost of sharing the information.

2.1.2 Challenges in P2P Networks

Based on the applications of P2P networks as discussed above, it is considered to be an appropriate solution for resource and data sharing. However, on the other hand there are certain problems that still exist in P2P networks as discussed below.

- **Heterogeneous Peers.** Peers with diverse characteristics such as variable upload/download capacities, transmission powers or energies join the network to form an overlay architecture. Therefore, an incentive or credit based techniques are required that helps to handle the heterogeneous network.

- **Peers Availability.** In P2P, peers join or leave the network randomly which makes the network unpredictable. Due to this, data or information may not be available for all times and the request for such data is not completed. In order to overcome, such issue a replication strategy can be used that can duplicate the data available at different peers.

- **Network Performance.** The performance of the network largely depends on the peers' connectivity and the network topology at the time a request is made. Because, if a same request is made at different intervals of time, it may have a different impact over the network performance. Hence, content replication and caching techniques can be used to improve the overall network performance. Moreover, load balancing techniques can also be applied so that peers with more resources can be placed closer to the sources.

- **Reliability**. In order to improve the network performance and handle heterogeneous peers, replication strategies are used. However, it becomes hard to maintain the reliability of the content as it gets outdated after a certain time. Hence, different approaches are required that may validate the copies because the data can be modified by anyone.

- **Resource Discovery.** The most important requirement of a P2P network is to discover the resources (i.e. videos). There are flooding based approaches that are available that can be used to broadcast the request of the requesting peer

until the source is identified such as in Gnutella [27]. However, this is not considered to be an appropriate approach for resources discovery as it introduces huge traffic in the network. Hence, the challenge is to find the exact data that can help to search efficiently. Whereas it is a challenging task to maintain such data because of frequent joining and leaving of peers.

- **Handling Requests.** In order to handle a simple data request, the easiest solution is to perform a quick keyword search to identify the location of the data. However, in order to handle the complex requests, an advanced technique is required.

- **Security Threats**. P2P networks encounter several security threats such as; by allowing other nodes to access the content of a node, the node is more susceptible to attack where it acts only as a client. Moreover, if number of nodes tries to communicate at a single time, the network may expose to denial of service attacks. Furthermore, in a decentralized P2P, malicious peers can easily travel in the network.

- **Incentives and fairness.** It is very crucial to provide incentives to the peers in the network that are contributing a lot to the community. It can be a case that a peer finds it overloaded with so many requests whereas the network doesn't provide any incentives. Hence, the peer can decide to leave. Moreover, there is a case in which few peers in the network do not contribute anything towards the network and utilize system resources. Therefore, there must be some mechanisms that should provide fairness.

2.1.3 Types of P2P Networks

In order to provide reliable data delivery, the P2P networks are classified into three different network types; a centralized P2P networks, a decentralized P2P structured networks and a decentralized P2P unstructured networks as discussed in [32].

2.1.3.1 Centralized P2P Networks

In a centralized P2P network, a centralize peer or a server is available that maintains the information about the content available across nodes in the network using a global indexing approach. Whenever a peer joins the network, it identifies the centralized peer about the content it has to share with other peers in the network. Figure 2.2 shows an example of a centralized network in which a node requests a query for a video A to the server. The Server checks which peer has this video; it identifies the requesting peer by sending a response message that this particular peer has video A. The peer can then directly download the video through that peer. These networks are easy to build and consume less bandwidth while discovering the content. NAPSTER [24] is one such network type that shares files among peers.

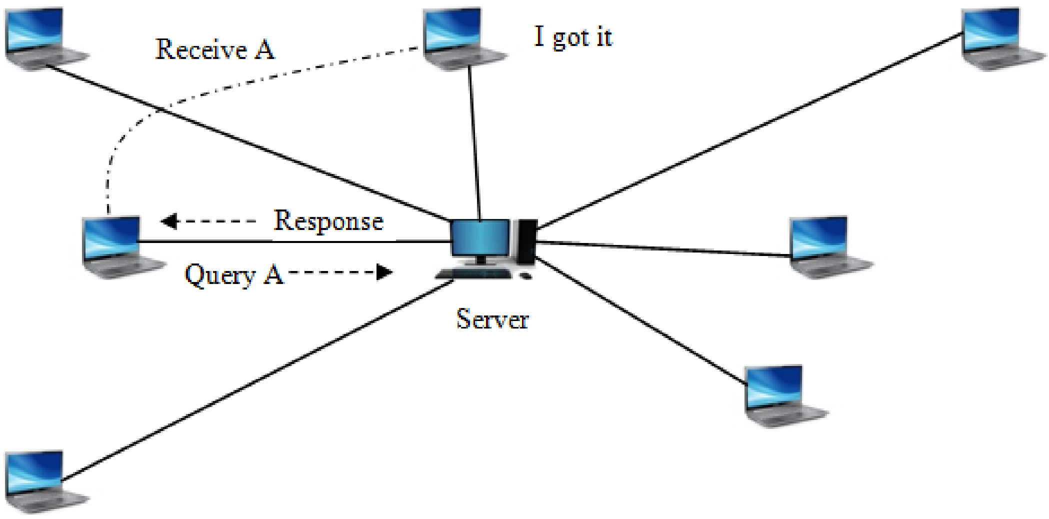


Figure 2.2 Centralized P2P Network

2.1.3.2 Decentralized Structure P2P Network

In a structured P2P network, the peers are organized into a specific topology and the content location is determined using the deployed P2P protocol. Distributed Hash Table (DHT) is used as a support to provide lookup service in the network. DHT stores the key value pairs such that any participating peer can able to retrieve the value associated to a particular key. These keys are then mapped over different peers in the network in order to provide an efficient way of content discovery as shown in

Figure 2.3. The examples of decentralized P2P networks include CAN [33], Tapestry [34] and Chord [35].

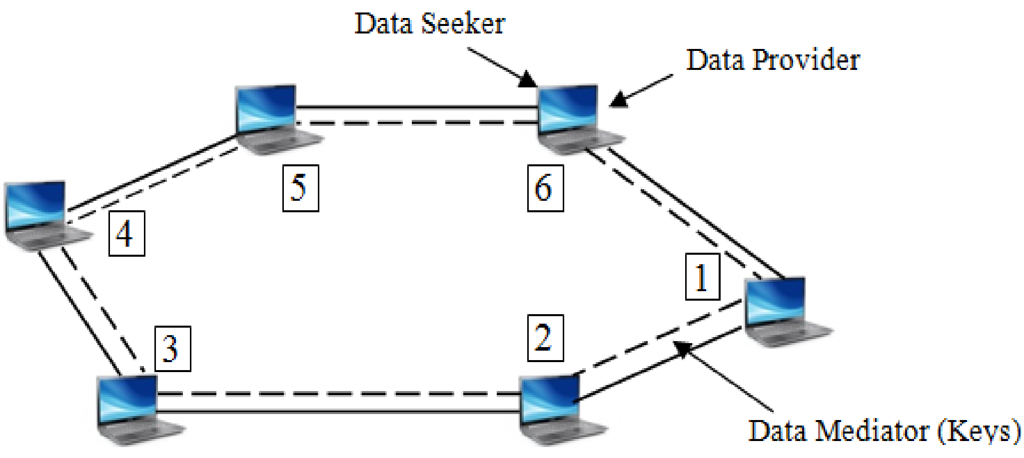


Figure 2.3 Decentralized Structured P2P Network

2.1.3.3 Decentralized unstructured P2P overlays

In a decentralized unstructured overlay, whenever a peer joins the network and makes a request, it doesn't have any information about the network topology as shown in Figure **2.4**. Hence, the flooding based approach is used to discover the content. However, this approach is not an appropriate solution specially for identifying rare content as this burden the network with an additional load of requests such as Gnutella [36].

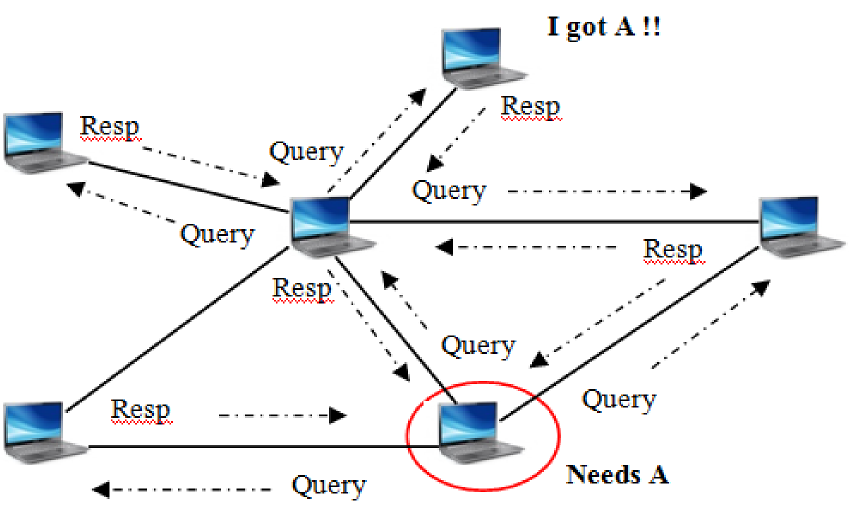


Figure 2.4 Decentralize unstructured P2P Network

2.1.4 P2P Overlay Architectures

Overlay architecture runs at the top of the internet and acts as a substrate to provide efficient media delivery. It is made up of different nodes that are connected with each other using some logical links such that each link defines the path between the nodes. The overlay architecture is usually classified into three different types; tree based, mesh based and hybrid overlays as given in Figure 2.5.

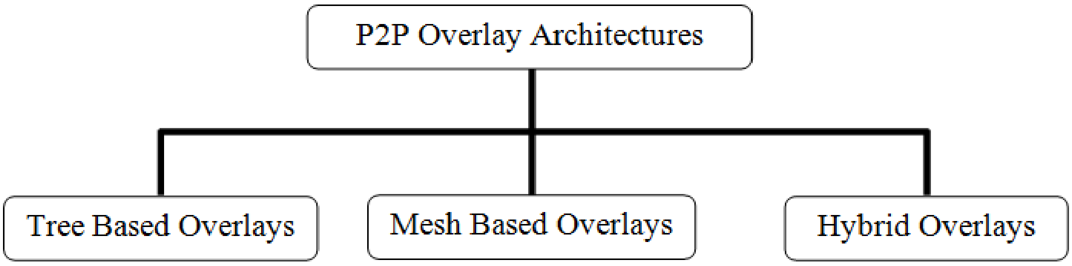


Figure 2.5 Types of P2P Overlay Architectures

2.1.4.1 Tree Based Overlays

In a tree based overlay, peers organize themselves in the form of a tree, making a parent child relationship among each other. These overlays use a push based data delivery scheme, in which the parent node pushes the available data towards its children as received. For example in Cooperative Networking (Coop Net) [37], Overcast [38] and ESM [39]. The tree based approach is classified into single and multi-tree based overlay architectures. In a single tree based approach, each parent node forwards the video to its child node which then forwards it to it child. The advantage of this technique is that it reduces the load experienced by the server node. This architecture is well illustrated in Figure 2.6 in which node S acts as a parent node to transfer media to its child peers; peer 0 and peer 1 which then becomes parents for the peers underneath.

However, a single tree based overlay faces number of challenges such as; Firstly, only the parent nodes participate in the streaming process to forward the content while rest of the peers act as leaf nodes and do not contribute to the network.

Secondly, if a higher level peer departs from the network then the video delivery stops for all of its children. Finally, the larger trees usually have more playback lag as compared to the one closer to the source.

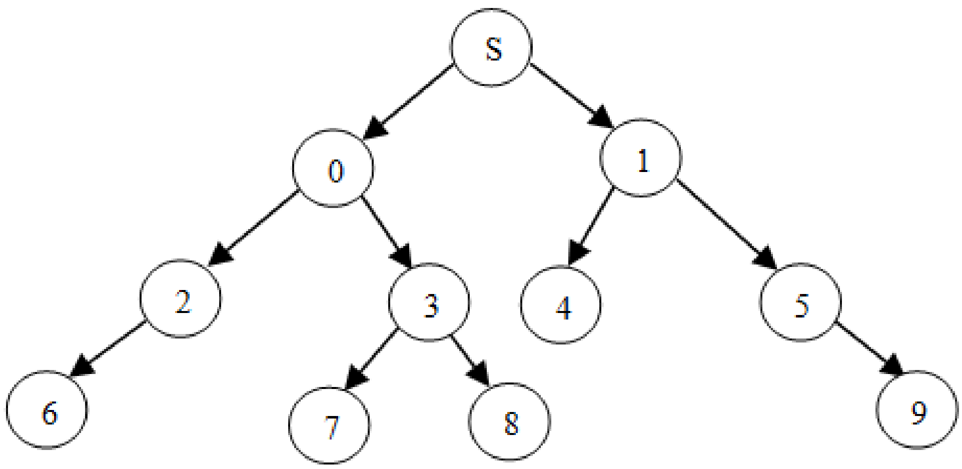


Figure 2.6 Single Tree Based Overlay

In order to overcome the issues of the single tree based architectures, a multi tree overlay architecture is designed that helps to reduce the effect of churn and effectively utilizes the available resources. Each peer determines the number of trees to join based on the access link bandwidth. In multi tree, each peer behaves as an internal node in one tree and leaf node in any other participating tree as in [6]. The basic architecture of multi tree based overlay is shown in Figure 2.7. Whenever a new peer joins the network it contacts the bootstrapping server in order to find the parent node in the trees. Peers behave as a parent in one tree to forward the sub stream whereas a child in other tree to download the sub streams.

However, in order to overcome the sudden departure of peers from the overlay, it is important to reassign the affected peers to the source or to the other available peers in the neighbours. This can be done either by using a centralized or a distributed approach. In a centralized approach, whenever a peer joins the network it contacts the centralized server, the server then decides the position and parent it needs to connect with. Similarly, when a peer leaves the network, centralized server recalculates the topology for the remaining peers and forms a new topology. The

disadvantage of centralized server is that it can become a performance bottleneck because of a single point of failure. In order to overcome this issue, a number of distributed algorithms have been proposed such as ZIGZAG [40]. ZIGZAG tries to maintain the streaming tree in a distributed manner to provide low end to end delay, low control overhead, low maintenance and efficient management of leaving and joining of peers by designing a hierarchy of bounded cluster size. However, the high churn cannot be accommodated in tree based architecture.

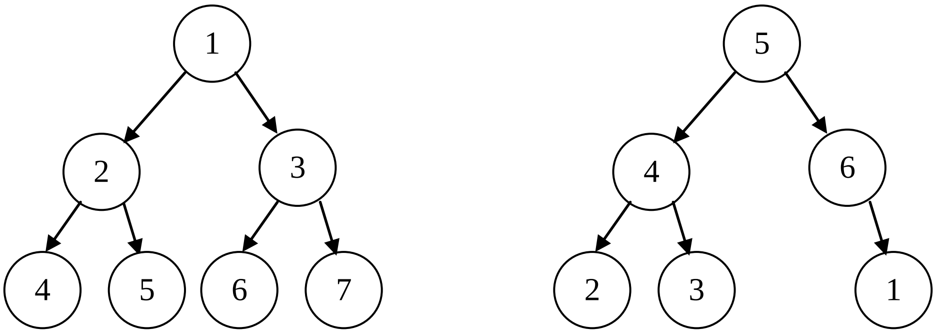


Figure 2.7 Multi tree based overlay

2.1.4.2 Mesh Based Overlays

Unlike tree based overlays in which peers have only one parent to download its content from and if that particular parent leaves the overlay then the corresponding child stops receiving media until the overlay topology is revised which causes huge delay and playback issues. To counter this issue, a mesh based overlay architectures are introduced like PPLive [41] and Cool Streaming [8].

In a mesh based overlay, the peers randomly connect with multiple neighbours at the same time in order to form a mesh. Each peer exchanges the media with different neighbours such that if a neighbouring peer leaves the network, the peer can still be able to download through other neighbouring peers. Therefore, the mesh based overlays are considered to be more robust as it can efficiently handle the dynamic behaviour of peers. In mesh architecture, the source peer divides the media into small chunks such that each chunk is assigned a unique id and then the chunks are

distributed across different peers. This concept is well illustrated using Figure 2.8 in which peers receive the chunks through different paths.

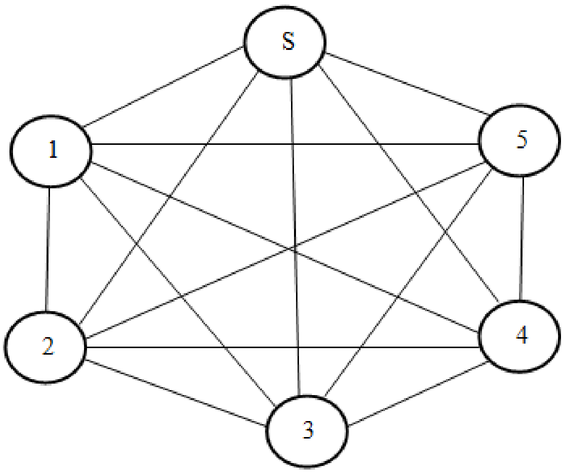


Figure 2.8 Mesh based Overlay

A mesh based scheme is further categorized as either a push based and pull based scheme. These schemes help peers to make a decision for which packet to receive and which packets to send. A push based approach works well under uplink constrained peers, as it avoids multiple requests of packets. Similarly, a pull based scheme works exceptionally well within a downlink constrained peers as peer can handle incoming rate of packets from neighbours.

The major concern of a P2P network is to have a network with less overhead and low start up delay. In a push based scheme, low delay can be achieved by immediately forwarding data as received to its neighbours. But this solution results in large overhead, as a peer receives multiple copies of the same video from its neighbours. Hence, a pull based scheme is introduced, in which instead of forwarding the whole data to peers, the missing blocks can be requested explicitly. Whereas, this system encounters intolerable delays as data is acknowledged to be sent and received. Therefore, a trade-off exists between the overhead and efficiency of the network. To handle this trade-off, hybrid models are designed as discussed in the next section which considers the advantages of both push and pull based systems.

2.1.4.3 Hybrid Overlays

A hybrid overlay is a combination of the advantages of both mesh and tree based overlays. A Tree based overlay results in less end to end delay due to single direction data delivery whereas it has a drawback of single point of failure and churn in the network. On the contrary, a mesh based overlay provides high resilience to churn but excessive exchange of information between peers produce high end to end delay and large overhead. Hence, in a hybrid overlay, data is first pushed through the server using a tree based approach then mesh based approach pulls the data in order to efficiently utilizing the upload bandwidth of peers. Figure 2.9 gives an overview of the hybrid overlay architecture in which a tree is formed over a mesh.

An example of hybrid based overlay is designed in [42] named as AnySee2. It forwards the data and control messages through different overlays. The control message that carries the information about the peer selection and time synchronization are sent using the tree overlay whereas the data information is sent through the mesh overlay. It also maintains the buffer information for transferring data packets towards the peers.

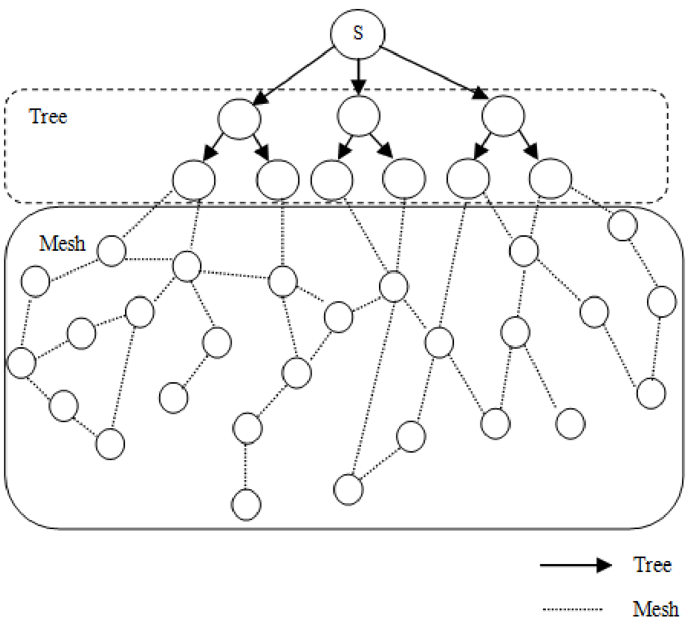


Figure 2.9 Hybrid Overlays

Similarly, in [37] a scalable and distribution algorithm (Bullet) is designed that uses both tree and mesh systems for delivering live video packets. It forms a mesh topology at top of overlay tree in order to provide a high bandwidth throughput as compared to the traditional tree based or mesh based streaming systems.

2.2 Wireless Ad Hoc Networks

Wireless ad hoc networks consist of wireless nodes that are connected with each other to share or forward the data among the nodes without the support of any infrastructure. The word ad hoc is derived from a Latin word which means ' for this only'. The best way to understand ad hoc network is to compare them with cellular and WLAN as they support infrastructure based communication. It means that whenever a node wants to share content with any other node in the network, it has to communicate to the base station in GSM that behaves as an access point between them. However, the disadvantage of the infrastructure based communication is that if an access point becomes faulty, nodes cannot able to communicate with each other. Therefore, wireless ad hoc networks are considered to be an appropriate approach that overcomes these issues.

On the other hand, the wireless ad hoc networks encounter certain challenges which needs to be considered while sharing the data across the nodes. The first encountered challenge is an unpredictable network topology. This states that the nodes communicate with each other without the support of any infrastructure and are free to join any node across the network which makes the topology unpredictable and increases delay and network complexity. The second encountered challenge is the transmission range among the nodes which affects the network topology and energy consumption significantly. Higher transmission range increases forwarding of the data packets whereas the energy consumption across each node starts increasing. On the other hand, lower transmission range consumes less energy to forward data packets to the next hop however the network topology becomes complex. Moreover, the wireless ad hoc network is influenced by physical obstruction, climate conditions and interference from other nodes.

2.2.1 Applications of Ad hoc Networks

Ad hoc network are used in a number of applications where it becomes really hard to deploy any infrastructure. Hence, the applications are classified as:

2.2.1.1 Military Services

Ad hoc networks are widely used to support military services [12]. Soldiers communicate with each other using a small transmitter that has a certain small range in which it can interact with other soldiers. Hence, soldiers make an ad hoc network on which they forwards the message over a single or multiple hops.

2.2.1.2 Emergency and Rescue Services

In case of any emergency such as earth quake or tsunami when the communication infrastructure is completed destroyed, ad hoc networks are quickly deployed to support the rescue services. Ad hoc networks adapt dynamic topology such that number of participants can be added or removed.

2.2.1.3 Personal Area Networks (PANs)

Ad hoc networks can be used to build a small localized network in which numbers of nodes are connected to a single node [43]. Piconet is an example of such type of ad hoc network that consist of one master node and several slave nodes connected to it. Figure 2.10 shows how the architecture of Piconet.

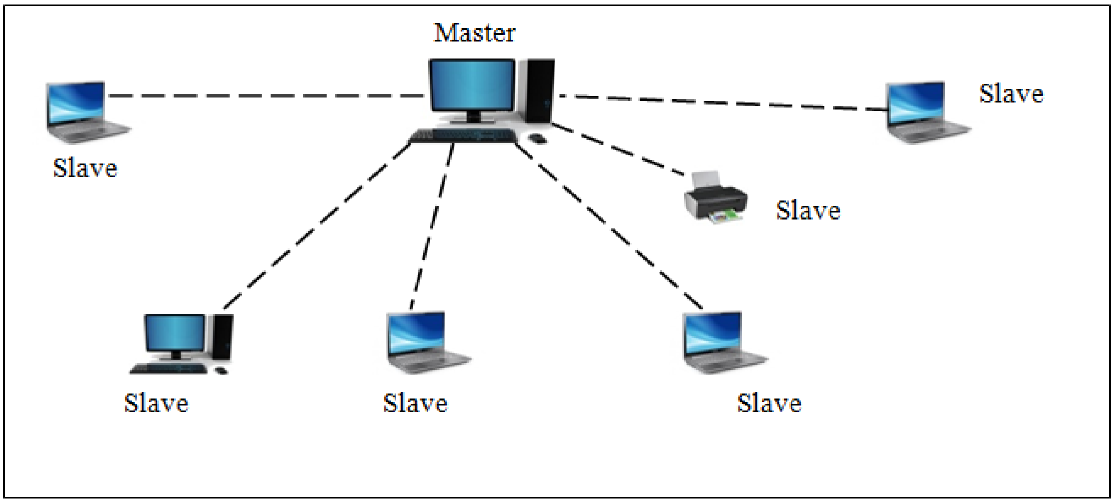


Figure 2.10 Piconet Architecture (1 Master, 6 Slaves)

2.2.1.4 Wireless Sensor Networks (WSNs)

Ad hoc networks are used to build WSNs comprising of various sensor nodes, such that each sensor can transmit and receive data to the gateway node it is connected with as shown in Figure 2.11. The gateways are then connected with each other to share the information across other nodes. Sensor nodes are used to measure or sense an activity whereas the network is used to forward the collected information among other nodes. The applications of WSNs are monitoring forests, animal or any dangerous areas.

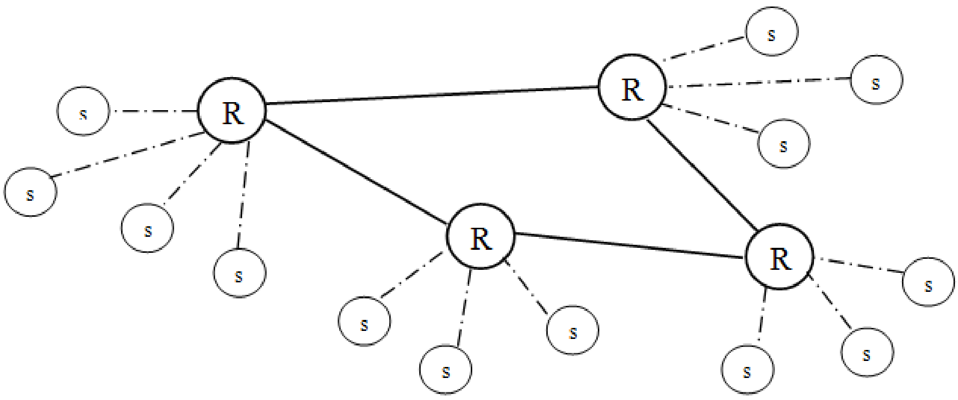


Figure 2.11 Wireless Sensor Networks

2.2.1.5 Wireless Mesh Networks (WMNs)

Wireless mesh networks consist of mesh clients and mesh routers [12]. The mesh clients are often cell phones, laptops or any other wireless device whereas mesh routers are used to route the packets from one client to another. In WMNs, whenever a mesh client wants to communicate with any other mesh client in the network, the communication takes place through the mesh router which acts as an access point between them. The applications of WMNs include (Local area Networks) LANs or (Metropolitan Area Networks) MANs. Figure 2.12 shows the basic architecture of wireless mesh network.

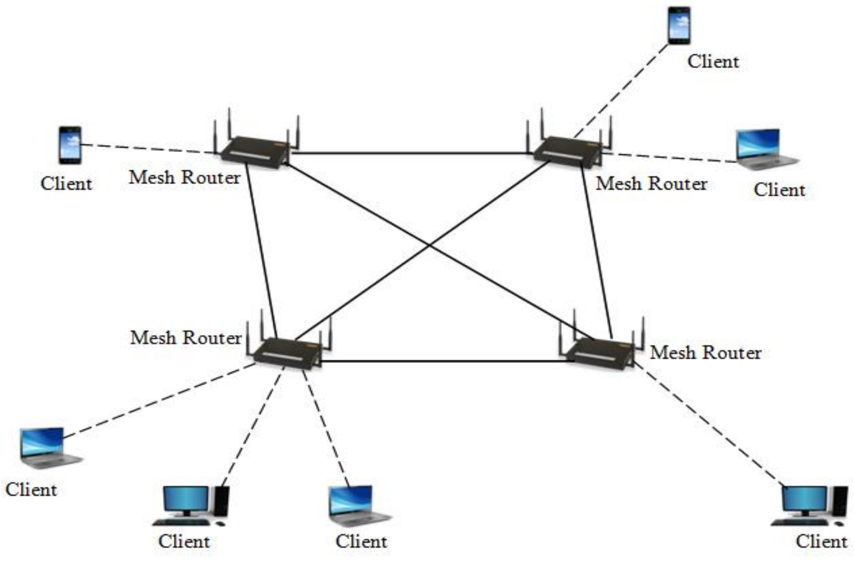


Figure 2.12 Wireless Mesh Network (WMNs)

2.2.1.6 Vehicular Ad Hoc Networks (VANETs)

Vehicle ad hoc networks are used to deliver spontaneous data among vehicles in order to provide intelligent services and assistance to the driver. The applications include electronic breaking lights and traffic information systems. Figure 2.13 shows the basic structure of how VANETs work in case of any emergency situation or accident on the roads. Each car communicates with each other using inter vehicular communication and send the updates to the nearest Road Side Unit (RSU). RSU then forwards the information among other RSU such that the information regarding accident or lane change is available to the cars which are away from the accident area.

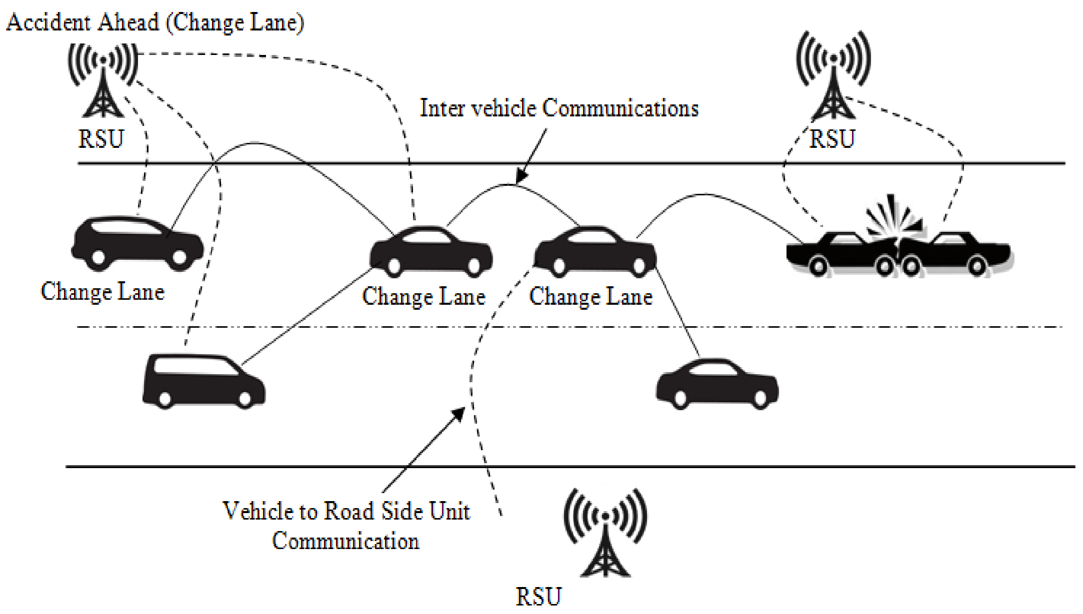


Figure 2.13 Vehicular Ad hoc Networks (VANETs)

2.2.1.7 Mobile Ad Hoc Networks (MANETs)

MANETs is a kind of ad hoc network in which the mobile nodes can freely share or forwards the data among each other without use of any centralized control as shown in Figure 2.14. Due to its feasibility, the node's mobility and dynamic joining and leaving of the nodes makes the topology in MANETs highly dynamic. Hence, the traditional routing techniques cannot be used to generate the routing tables as rapid response is required to change of the topology [44]. Whereas to deal with the performance of MANETs many routing protocols have been proposed, this will be discussed in the literature review.

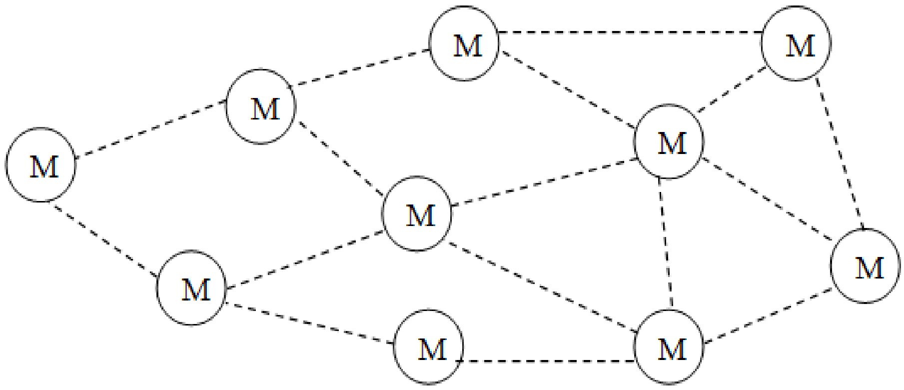


Figure 2.14 Vehicular Ad hoc Networks (VANETs)

2.2.2 Routing Techniques for Mobile Ad hoc Networks

Routing protocols are used to establish and maintain the route between the nodes in an ad hoc network. There are a number of routing protocols that have been proposed for wireless networks which are based on following criteria's: What type of routing information needs to be exchanged, how and when is it required to share the routing information, which ways the routes are calculated etc. [45].

2.2.2.1 Proactive Routing Protocols

This type of routing protocol is also called as table driven routing protocol which maintains the routing tables for all the nodes in the network. Each node periodically shares the routing information in order to keep the updated information of the network topology. The main advantage of proactive routing protocol is that the route is always available between the source and destination node. Hence, the lookup time is minimum that makes it a best protocol to be used within the fixed networks. DSDV [46] is an example of such routing protocols. However, sharing the routing information throughout the network consumes a lot of network resources, which is a challenge for MANETs where nodes have less computing memory and power. Similarly, sharing the information for unused routes makes the protocol less efficient.

2.2.2.2 Reactive Routing Protocols

Reactive routing protocols are also known as on demand routing protocols which only creates the routes when required by the source node. These protocols comprise of a route discovery and a route maintenance process. In a route discovery process, whenever a source node wants to send the data to the destination it floods the route request messages into the network until the route is found. The destination in returns forwards a route reply message to the source node. When the route is established, it is managed using a route maintenance process that helps to adapt the changes in the topology.

Hence in reactive routing protocols, the routes are only available between nodes when requested so it does not keep any unused routing information that's why these protocols are widely used in MANET's. There are a number of protocols that are proposed for on demand routing such as AODV [47], DSR [48] and TORA [49]. However, reactive routing protocols also have some disadvantages as the route discovery process requires processing and delay. Furthermore, in order to identify the nodes, request messages are flooded which can produce a broadcast storm issue as explained in [50]. The Table 2.1 below provides the comparison between the proactive and the reactive routing protocols.

Table 2.1 Comparison between proactive and reactive routing protocols

Parameters	Proactive	Reactive
Routing Information	Always available	Obtain when needed
Route Updates	Required	Not required
Mobility of nodes	Fixed	Mobile
Delay	Less as routes are known	More as route is requested
Power consumption	High as unused route information is available.	Less as there is no unused route.

2.2.2.3 Single and Multipath Routing

These types of routing protocols are designed to provide single or multipath routing across the nodes. In a single path routing, the best possible path or the shortest path is

used between a source and destination node to share the resources. However, the disadvantage of single routing path is that a single point of failure. In order to overcome this issue, multiple routing paths are used that identifies all the possible paths between a source and a destination node. Multiple path routing is used to provide redundant route in case of failure as it provide better throughput but on the other side it produces overhead to discover the routes as compared to single path routing.

2.2.2.4 Table Driven or On Demand Routing

In a table driven routing, each node shares the information across every other node in the network after a regular intervals of time. Similarly, whenever a network topology changes, nodes share the information. However, in on demand routing, nodes do not share any routing information, the routing information.

2.2.3 Traditional Issues and Challenges in MANETs

A Mobile Ad hoc network is considered to be a promising approach to deliver data across nodes without the use of any centralized architecture. However, there are still some issues and challenges that exist for reliable data deliveries in MANETs as mentioned in [51] are discussed below;

2.2.3.1 Providing Scalability

Scalability is one of the most important research topics that need to be considered during the designing of various solutions for Ad hoc networks. Ad hoc networks are usually suffered from scalability issues in capacity. To understand the scalability issue, consider a simple example of a non-cooperative network that uses Omni-directional antennas. If the designer has fixed the link capacity and radiation pattern of the antenna to a certain limit then a new protocol is required to handle such situation. Hence, scalability should be considered such that small changes can be handled by the protocols.

2.2.3.2 Routing Issue

The heterogeneous nature of the nodes in MANETs makes the network topology highly dynamic. Each node comes in the network for a short period of time to exchange data. As nodes are mobile, so during data dissemination, they continuously change their positions. Therefore, a routing technique or protocol is required that can quickly able to adapts to the current network topology and establish new routes among the nodes.

2.2.3.3 Quality of Service (QOS)

It is one of the challenging issues to provide QOS across MANETs due to heterogeneous nature of nodes. The network has to guarantee a certain level of QOS while receiving or transmitting the data. QOS parameters include delay, jitter, and packet loss or bandwidth utilization. QOS issues in MANETs are still considered as open research which includes in providing routing protocols, algorithm and protocols.

2.2.3.4 Addressing Issues

In MANETs, the locations of the nodes are mostly unknown due to infrastructure less nature of network. Hence an addressing approach is required that is responsible for supporting various network services.

2.2.3.5 Security Issues

As known in MANETs, each node shares the information across every other node in the network without the support of any fixed or centralized infrastructure. Hence the network becomes more vulnerable to interference and security threats such as malicious nodes can cause interference in sharing messages, denial of service attacks, spoofing and eavesdropping the other nodes.

2.2.3.6 Node Coordination Issues

The node coordination issue is quiet similar to security issue in which the nodes communicate with each other to relay the data packets. However, if the coordination among the nodes is not appropriate, it can waste the resources available across other

nodes to share unnecessary information. For example, if a node that handles very crucial tasks such as notification of fire alarms across the building wastes it's battery by relaying some gaming information for other nodes.

2.2.3.7 Energy Issues

The most crucial issue in MANETs is the fast consumption of available energy across the nodes. Therefore, the current studies as discussed in [51] are working on improving or maximizing the network lifetime by reducing the energy consumption. In order to resolve the energy issue, one solution is to provide better batteries which is not an effective solution and introduces cost. However, energy consumption at the network layer can be reduced by providing some efficient routing and load balancing techniques.

2.2.4 Deployment Challenges in MANETs

There are certain issues that need to be considered during the deployment of MANETs as explain below:

2.2.4.1 Environmental Issues

According to the environment, ad hoc network behaves differently such as if the nodes are located in a high distortion area like mountains or forests, the communication range is different from if it is located at some low distortion area. In some circumstances, nodes also sometimes damage or fail due to the environmental conditions.

2.2.4.2 Wireless Medium

Due to variable nodes behaviour under different environmental conditions such as high level of EM waves or inclement weather, it is not possible to determine the exact quality level of a wireless link.

2.2.4.3 Resource Constrained Nodes

In MANETs, nodes are usually low powered with limited processing capabilities and storage. Hence, different energy efficient methods are used to limit the energy and

processing speed at nodes. But in this case, the available bandwidth of wireless medium also reduces as nodes do not share their resources properly.

2.2.4.4 Topology Constraints

Due to mobility nature of the nodes, the topology of MANETs changes quiet frequently. Therefore, it is required to consider the topology constraints while deploying MANETs.

2.3 Video Coding Techniques

In the previous section, it has been discussed that P2P or MANETs comprises of different heterogeneous nodes connected with each other that makes video streaming a challenging as it becomes hard for such peers to meet the stringent bandwidth requirements of a particular video request. Hence, one way to solve such issues is to stream an appropriate codec that can stream the video at different rates. Hence, when the channel condition changes, video can be sent at higher or lower rates based on the link bandwidths. There are number of different audio/video coding standards that are available which are used for efficient video delivery over the IP. ITU-T and ISO/IEC are the two most known organizations that provide different coding standards. ITU-T coding standards are denoted by H.26X (such as H.263 or H.264). On the other had ISO/IEC video coding standards are denoted by MPEG-x (e.g. MPEG-1, MPEG-2 etc.).

The ITU-T coding standards are particularly designed for real time application e.g. video conferencing whereas, the ISO/IEC standards are particularly designed to handle storage videos, video broadcast and streaming applications [52][53]. In most of the cases, both organizations have worked independently to provide different standards of videos but in some cases they produced joint video coding standards from which the most known is H.264 (also known as MPEG-4 AVC) [54][55] was developed in 2003 with the further extension to this in 2007 and produced H.264/SVC.

In the next section, the most widely known video coding techniques for streaming multimedia over the networks has been discussed. These are categorized as: Scalable video coding (SVC) [14] and multiple descriptive coding (MDC) [15]. The detailed discussion of these coding techniques has been given below.

2.3.1 Scalable Video Coding (SVC)

SVC is well known type of layer coding technique, which is an extension of H.264 standard that is known to be the most promising approach for streaming media over heterogeneous nodes as in [14] and [54]. In SVC, each video stream is coded into multiple layers comprising of a base layer and several enhancement layers. The base layer carries the basic information of the video whereas the enhancement layers can further improve the quality of the base layer. Hence, it is important to receive the base layer, if a base layer gets corrupted or not received then it is useless to transmit an enhancement layer.

2.3.1.1 Advantages of Scalable Video Coding (SVC)

SVC is capable of providing a number of advantages as discussed in [56]. This section discusses few of the widely used applications in SVC.

- **Single Time Encoding.** In SVC, multiple bit streams of the same content with variable resolution, frame rate or bit rate are provided simultaneously. The source encodes the content once and then the receiver can decode the required sub stream based on its resource capabilities and discard the remaining streams.

- **Handle Restricted Resources**. Clients with limited resources such as energy, resolutions or capacities can decode only the required part of the coded video.

- **Handle Multicast.** In a multicast scenario, in which node is sending a same video to number of clients with different capabilities, SVC is an appropriate solution.

- **Unequal Error Protection.** Another advantage of SVC is that it provides unequal error protection to the content which is quiet helpful as each bit stream contain some

part that is the most important to stream content. By applying a stronger protection, error resilience can be achieved.

- I**n Surveillance Applications.** SVC is considered to be a valid approach to be used for surveillance applications, in which video is not just played at receivers with different capabilities such as TV, Laptop or PDAs but the video needs to be stored and looked back in the future. Hence, it is also considered to be used in home applications.

2.3.1.2 Types of SVC Coding

SVC is performed on a video stream to provide sub streams based on three different categories: Temporal, Spatial and Quality scalabilities [57]. The temporal and spatial scalabilities are used to encode the video into various bit stream of reduced frame rate or reduced picture size. While on the other hand, in quality scalability, sub streams are considered to have the same spatial and temporal resolution for the whole bit stream, but with different fidelity levels. The fidelity levels are known as different signal to noise ratio (SNR) values. Hence, it is sometimes also known as SNR scalability.

Moreover, there are also some rarely used scalabilities that consider region of interest or object based scalability. In such type of scalabilities, different sub streams are combined together to represent the continuous regions of an actual image. Furthermore, various type of scalabilities are also combined to provide sub streams with different spatial and temporal values. In this section, the three basic types of scalabilities provided by SVC are discussed.

2.3.1.2.1 Temporal Scalability

Temporal scalability is used when the video is partitioned into a temporal base layer and one or more temporal enhancement layers. The term temporal represents the ability to represent the video with different frame rates. It is well illustrated in Figure 2.15. Each encoded video is composed of three kinds of frames; I (intra), P (predictive) and B (bi-predictive). In the past video coding standards such as MPEG-

2 or H.263, the temporal scalability is performed by encoding the video into different layers based on different frame rates. For example, if a video is comprised of I, B and P frames, then I frames can represent the base layer whereas P and B frames can be decoded as Enhancement layers. However, in H.264/SVC the temporal scalability is performed on the structure of group of pictures (GOPs). Hence, each frame is divided into different layers with I, P and B frames in each layer. It is important to remember that it is not necessary that the base layer is only encoded using I frames, however the first frame should be coded into as I frame.

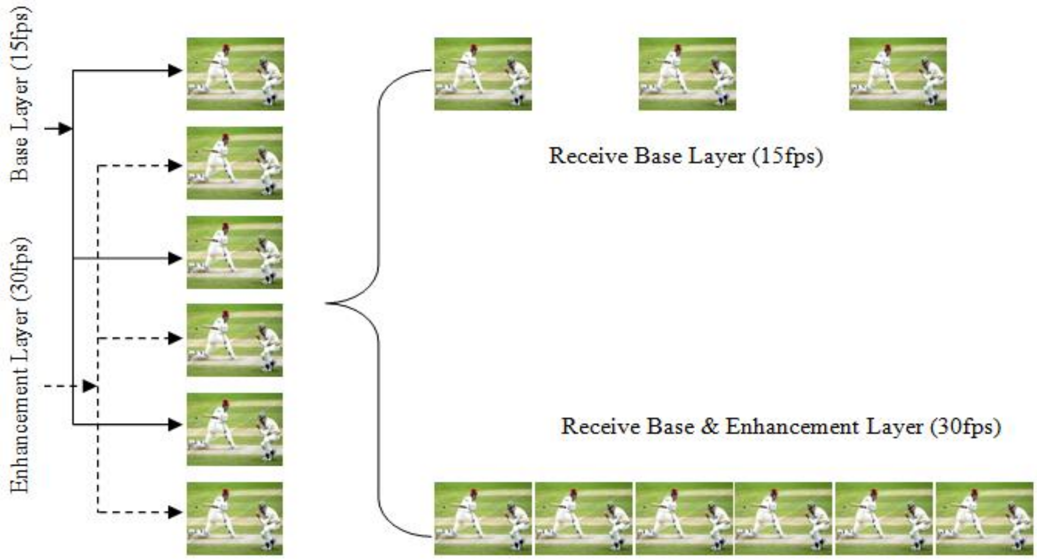


Figure 2.15 Temporal Scalability

2.3.1.2.2 Spatial Scalability

The spatial scalability is performed to encode the video into different resolutions i.e. each higher layer improves the resolution of the lower layer in order to provide better quality of the video as shown in Figure 2.16.

Figure 2.16 Spatial Scalability

In order to improve the image quality received, H.264 encoder uses ILP (Inter layer prediction) module. The main idea to use this module is to increase the prediction of reused data from the previous layers. Until now, ILP is used to provide three different types of motion predictions.

-Inter Layer Motion Prediction. In this type, the motion vectors used in lower layers are used in higher layer.

- **Inter Layer Intra Texture Prediction.** SVC can support the texture prediction for the same reference layer in internal blocks. This block prediction can be used by higher layers for prediction of other blocks. So, the advantage of this module is that it improves the resolution of the lower layers by calculating the different among them.

- **Inter Layer Residual Prediction.** It has been investigated that if two consecutive layers have the same motion information then the inter layer register highly correlates with each other. Therefore, in SVC this inter layer residual prediction is used just after the motion compensation in order to check the redundancies.

2.3.1.2.3 SNR Scalability

SNR scalability is used to provide video with different quality levels. In this type of each layer is assigned a different quantization parameter. According to research,

there are three different types of SNR scalabilities are available. Coarse Grain Scalability, Medium Grain Scalability and Fine Grain Scalability.

- **Coarse Grain Scalability.** In this scalability, each layer has a different prediction procedure whereas the references have the same quality level as for the SNR scalability in MPEG 2 standard. It is also considered to be a special case of SNR scalability in which the consecutive layers have the same resolution. This scalar granularity mode is explained in Figure 2.17 (a).

- **Medium Grain Scalability.** This type of scalability uses the base layer and enhancement layers as a reference for the prediction module to improve the efficiency. But, the disadvantage of this approach is that in the case where only the base layer is received, it introduces drift effect which affects the synchronization between the encoder and the decoder. However, this issue is resolved with the help of using the periodic key pictures, which helps the prediction module to quickly resynchronize. The concept of MGS is explained in Figure 2.17 (b).

- **Fine Grain Scalability.** This type of scalability is the most commonly used nowadays. In FGS, the output bit rate of the video is continuously adapted by comparing it to the bandwidth available in real time. FGS uses advanced bit plane techniques in which different layers transport distinct bits for each set of information. This scheme provides data truncation to support improvement in the values of transform coefficients. The concept of FGS is explained in Figure 2.17 (c).

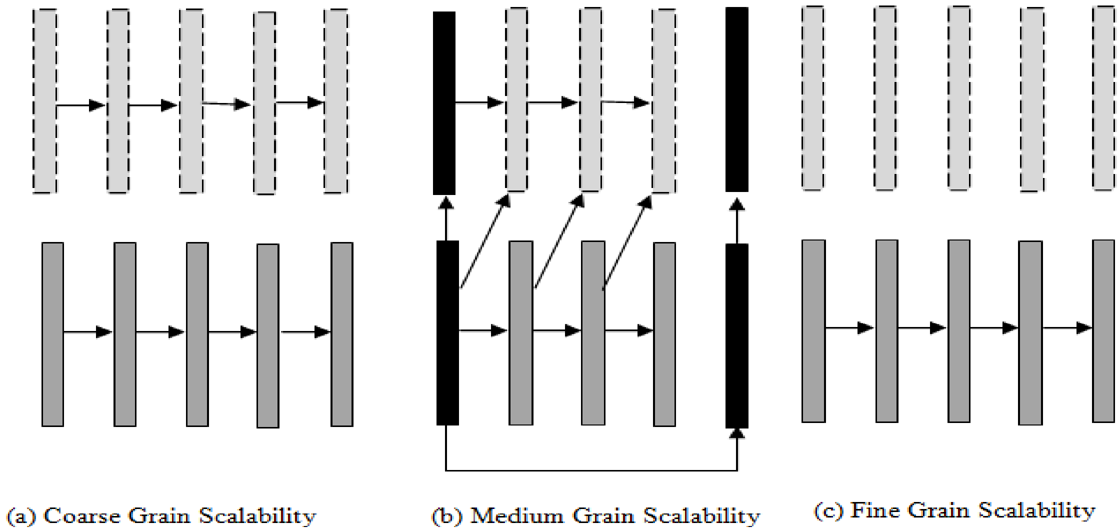


Figure 2.17 SNR Scalability over two layers

2.3.2 Multiple Descriptive Coding (MDC)

Multiple descriptive coding (MDC) is a type of layered coding that generates multiple independent bit streams or descriptors of a single video stream. The advantage of MDC is that it provides high resilience to packet loss. The quality of the video depends on the number of descriptors received. The basic concept of MDC is well illustrated using Figure 2.18 in which a media server generates a video with 4 different descriptors and transmits it over the network. At the receiver end, the video is decoded by the receivers with different capabilities such as PDA phones or tablets usually have low bandwidths provided by ISP's and processing power so they download only a single descriptor of the video. On the other hand, the devices with larger screens and higher bandwidths download more descriptors. Hence, they have better download rates and the video can be decoded with more number of descriptors.

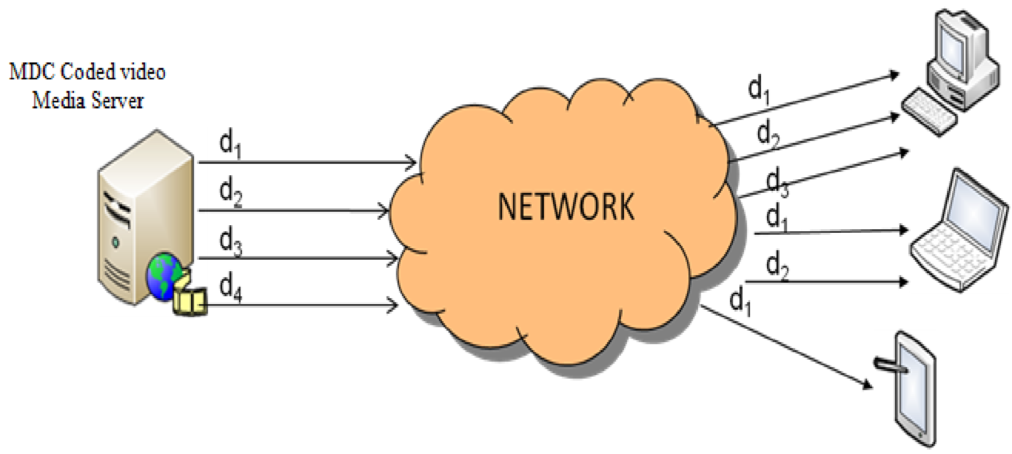


Figure 2.18 Multiple Descriptive Coding

2.3.2.1 Advantages of Multiple Descriptive Coding (MDC)

Multiple descriptive coding is considered to be a reliable approach to encode the video into different small descriptors and download them independently. Hence, the following advantages of MDC are discussed below;

- **Support Heterogeneity.** In MDC, video is encoded into different descriptors that can be decoded independently. Hence, MDC is capable to support a network with heterogeneous nodes (different upload capacities and processing power).

- **No Layer Dependency.** An important advantage of MDC is that the layers can be decoded independently without any relation with the former layers. However in SVC, the enhancement layers are dependent on the base layer. If the base layer is missed, the media stream gets interrupted.

- **Provide Error Resilience.** As compared to SVC, the bit streams can be decoded independently with no relation among each other's. Due to this advantage, it is being widely deployed in wireless networks specifically in MANETs.

- **Rate Adaption.** MDC allows rate adaptive streaming. The source nodes can forward the video with all descriptors to the network without looking at the

download limits of the receivers. Whereas, the receivers receives the descriptors based on their available bandwidths.

- **In Wireless Applications.** MDC is considered to be a best approach to use in wireless communication as each layer can be decoded independently. Furthermore, MDC uses forward error connection (FEC) so it is capable to receive the missing information from one layer using the information available in different stream. All of these features make it an excellent approach to be used for multimedia communication in wireless networks where links are considered to be unstable and it is hard to maintain reliable paths due to dynamic network topology.

2.3.3 Comparison between SVC and MDC

The main difference between SVC and MDC techniques is that, in MDC, the quality of video depends on the number of descriptors receive in parallel. Whereas in SVC, the video is coded into a base layer and several enhancement layers. The base layer carries the basic information of the video whereas the enhancement layers are used to further improve the quality of the video. Moreover in SVC, the higher layers strongly depend on lower layers. Therefore, it is crucial to provide a reliable transmission of lower layers in order to receive higher layers of the video. Whereas MDC doesn't require any priorities or retransmissions of the descriptors. Further it is considered to be more robust as it hardly happens that all the descriptor of the video gets corrupted. Therefore, MDC is widely used in the case where the network is exposed to more churn as it provides error resilience which helps the video to still survive at better quality. However, SVC is still preferred in the networks in which a network is static or centralised control and there is a less chance of churn to enter the network because of its high coding efficiency that still helps to provide the video at better quality. On the other hand, the main disadvantage of MDC is that it is not standardized which means that there is no specific codec is available that can able to generate different unified descriptors as in SVC where an encoder link JSVM is used to encode different layers as standardized by MPEG and IUT.

The next chapter discusses about the different state of the arts proposed for video streaming using P2P over wired or wireless (MANETs) using SVC and MDCas introduce in this chapter.

3 Literature Review

This chapter investigates that P2P network is the best possible approach to date for streaming video over the internet. However, there are number of challenges still exist which include; Overlay topology construction, sender or receiver end scheduling, resource discovery, handling heterogeneous nodes and resource allocation across peers. Moreover, the recent developments in mobile devices and wireless technologies extend video streaming applications over mobile users such as MANETs. However, as stated in the background, MANET faces a number of challenges for reliable video streaming which includes: Scalability, routing, QOS, security and stability across wireless medium. Furthermore, different coding techniques such as SVC [14] and MDC [15] are also discussed in Chapter 2. These techniques help to encode the video into layers or descriptors to match the receiving peers' capabilities and further improve the playback.

This chapter summarizes the literature related to the existing works on video streaming across P2P networks that are implemented over a wired or a wireless network (MANETs). The literature is divided into two sections. The first section covers the literature review over video streaming in P2P networks and more specifically over the wired network based on Single layer coding, SVC and MDC. The second section discusses the works related to the study of video streaming in MANETs based on the coding techniques to handle the stringent requirements of streaming video over the wired or a wireless network. This section also covers the existing file sharing methods in MANETs. In the end of each section, a discussion section is provided that talks about the current issues in the existing techniques along with the table that summarizes the advantages and disadvantages of the existing video streaming techniques.

3.1 Video Streaming over P2P Networks

During the last decade, there have been a lot of studies to improve video streaming across P2P networks. In P2P networks, peers join the network and arrange themselves in a form of an overlay. The overlay architectures are categorized as tree based, multi-tree based, mesh based or hybrid overlays [58].

In a tree based overlay [59, 60], peers organize themselves in a tree shape architecture and forms a parent child relationship with each other. The media server is located at the root of the tree whereas the peers are located at different locations across the tree. Media content is rooted from the tree root towards the leaf nodes. However, the disadvantage of this approach is that this architecture lacks robustness under peer churn and the leaf nodes do not contribute their upload capacities to the network.

In order to overcome these issues, multi-tree based overlay architectures are proposed as discussed in [61, 62, 63] that divides the video into various sub-streams where each sub-stream is forwarded over one of a sub-tree. The advantage of this approach is that the upload capacity of the leaf nodes can also be utilized by other peers in the network. However, the churn effect is still a problem.

To overcome this issue, a mesh based overlay architecture is used as discussed in [8, 64] that efficiently utilize the peer’s bandwidth and improves the overall system performance. In a mesh based approach, whenever a new peer wants to join the network, it makes a request to receive the information about the existing peers in the network. Then based on the information received, peer form a neighbouring relation with a certain group of peers that shares a common interest. The advantage of mesh based scheme is that it is highly resilient to churn and provide efficient bandwidth utilization as compared to tree based approach. Therefore, it is being widely used in most of the commercial architectures [7, 9, 65]. However, the disadvantage of mesh based systems is that whenever a peer joins the network it has to forward a number of messages to find its neighbours which produces high overhead complexity.

In order to overcome some existing issues in tree and mesh based overlays, hybrid overlay architecture is proposed. The hybrid overlay combines the advantages of both mesh and tree based overlays. There are a number of hybrid overlay architectures that are available such as in [66], a hybrid mesh tree overlay structure is implemented that employs the concept of layered streaming to overcome latency and provide resilience in the network. In this overlay design, each peer forms a mesh based overlay at the start but after some time tree overlay is formed by the stable peers. Whenever a node is willing to join a mesh based overlay network, a message is sent to the tracker that searches for the peers with available bandwidth and sends a response message in return to requested peer who then establish connection with nodes and start receiving chunks. After a threshold time, newly joined peers can be considered as a stable peer and it can join a tree based overlay by sending a message to tracker which finds an appropriate parent for it. Authors proposed two phases of data delivery in this protocol. In the first phase, the base layer and enhancement layer are both transferred using a mesh based scheme and each peer requests chunks of the video from nearby neighbours where as in second phase after peer becomes stable, base layer is transferred using a tree to reduce delay as it contains the most crucial video content. Whereas, the enhancement layers are requested using mesh based overlay. Table 3.1summarizes the advantages and disadvantages of different overlay architectures based on bandwidth utilization, churn, playback and overhead complexity.

Table 3.1 Overview of Overlay Architectures

Overlay Architectures	Bandwidth Utilization	Handling Churn	Playback Latency	Overhead Complexity
Tree Based	Worst	No	Low	Low
Multi Tree Based	Good	No	Low	Low
Mesh Based	Best	Yes	High	High
Hybrid Based	Best	Yes	High	Medium

In order to overcome the existing issues among different overlay topologies, a number of studies have appeared in the literature. For example, in order to provide tree resilience towards churn in the network, the concept of backup parents is considered as discussed in [67, 68, 69]. The backup parents help to manage better

video quality during the node's failure. However, the disadvantage of such an approach is that a single parent is used for the backup which is insufficient to handle high churn. Similarly in [70], the authors propose the concept of using backup parents' pool in order to provide more resilience.

Authors in [71] proposed a tree based P2P video streaming method for live video. The proposed method constructs the multicast trees on top of clustered peers. Whenever a peer wants to join the network, it sends a request to the bootstrap server that carries the information of the topology. However, the disadvantage of such an approach is that it can encounter a single point of failure. Similarly in [72], the authors consider joining of nodes to the multicast trees based on the round trip time (RTT). The RTT is calculated across root and the joined node. The nodes that have a similar value of RTT are usually placed closer to each other.

In [19] the authors introduce a multicast streaming system, Chainsaw. This system eliminates the trees concept. In this system, neighbours identify each peer by sending a NOTIFY message related to the new available packets which a peer can request from its neighbours. This overcomes the duplication of data packets which helps to reduce the upload bandwidth consumed in uploading the packets that are available at the neighbouring peers. The experimental results show that the proposed method provides resilience to packet loss and maintains a good QOS with less start-up delay.

In [8] the authors proposed an optimization scheduling method to improve the real time streaming experience based on the concept of Cool Streaming. The authors have used a bandwidth estimation algorithm that monitors the behaviour of dynamic network and estimates the capability of the peer to transfer data based on each data distribution. Furthermore, a zonal request buffer scheme has been introduced that categorizes the buffer into three different zones; urgent zone, common zone and ease zone in order to provide efficient video streaming. The authors found that using a tree based method for sending the control message, reduces the overall overhead by 0.7% as compared to Cool Streaming. Similarly using an optimized scheduling method assures good quality of service by increasing the buffer by 21%.

Furthermore, there are number of studies [71] [73-75] are carried out towards providing decentralized methods for streaming the video in tree based overlays. In such methods, peers are organized in the form of clusters and each peer receives the video through the leaders in the cluster known as cluster leaders. The link between a cluster leader and the peers comprise of different multicast trees. However, the disadvantage of such approaches is that the capacity across the leaders is not taken into consideration. However, in [69] the authors show that if the capacity of the cluster leaders is taken into consideration, the QOE across the users is largely improved.

As discussed in [76], an incentive based approach is used to provide better quality of service across P2P network. These approaches are widely used to overcome free riders (nodes that do not contribute), churn (nodes that may leave and join) and attacks (malicious nodes) in the network. There are number of incentive based mechanism are available such as in [77] the authors introduce a reciprocal mechanism that records the history of each node encounters and based on that history, nodes are rewarded.

Similarly in [78] the authors have designed a reputation based method that considers a global rank among the peers to provide priorities among peers to receive the requested media segments. The authors in [79] study a taxation based approach in which peers are given motivation to contribute more towards the system in order to improve the perceived quality received by peers. Furthermore in [80] the authors explain a pricing based mechanism to help manage maximizing the social benefits or incentives for optimal resource allocation across the network.

In [81] the authors have studied a well-known tit for tat algorithm implemented over Bit Torrent. The proposed method helps to overcome the free riders [82, 83] across the networks. The free riders are considered to be those peers in the network that do not contribute any resources towards the network. According to the proposed method, the node that contributes more towards the network by sharing its resources, receives better quality of the video upon request.

Similarly in [69], the authors have introduced a score based approach in which a score is assigned to each peer based on the provided contribution to the network by consuming their resources. The node with the highest score usually made more contribution towards the network and receive more content on request. In order to efficiently utilize the bandwidth across the peers in a tree based architecture, authors in [8, 84] use the concept of incentive based mechanism in which the nodes with higher upload capacities or resources are usually placed closer to root nodes or as a root node. The disadvantage of this mechanism is that the effect of churn across the network is not considered.

In [8] the authors propose a data driven overlay network (DONET) for streaming the live media content. In this architecture, each node exchanges information of available data with its nearby neighbours and fetches the required data from them or supplies the available data to other neighbouring peers. Authors focus on three features of DONET design such as: Easy to design as it should not have a complex architecture, efficient in data delivery and robust as available data information is switched swiftly among multiple suppliers. Furthermore, authors discuss about how a neighbouring relation is formed, how information for data delivery is exchanged and how video data is retrieved and distributed among peers. To provide seamless streaming of media content with low overhead, they proposed a scalable membership management protocol based on gossiping protocol in which a node keeps on sending newly generated messages to random nodes; these nodes then spread the messages in a similar way to other nodes until all nodes retrieve them. The data delivery concept is partially motivated from gossip but it was not fully utilized as using gossip for streaming can cause redundancy issues due to random pushes. Hence, authors also design a partner selection algorithm with a low overhead scheduling algorithm that can pull data from the nodes. They also encounter the peers having heterogeneous nature. Each node has a unique identifier e.g. IP address and the node maintains a small list comprises of active nodes in DONET. In a node joining algorithm, each newly joined node contacts the server node, which then select a deputy node from its membership cache and forward the new node towards it to make partners. Moreover, each video stream is divided into small segments of uniform length and buffer map represents the availability of the segments in a buffer. Each node exchanges buffer

map with its partners to fetch the video segments. In order to fetch the available segments from the partners, a scheduling algorithm is proposed that calculates the supplier for each segment. The algorithm monitors the supplier of each segment starting from one potential supplier to many. The scheduler then selects one of the suppliers that have high bandwidth and enough available time. Authors also investigated that a departing node leaves a message having the same format of membership message to inform the partner node about leaving the network. The partner then detects the node failure. Each node that receives the message flushes the departing node from its mCache. Finally, a new partnership relation is formed. The performance results show that DONET has comparatively very less overhead which does not grow with the size of overlay. Furthermore, it is investigated that under high dynamic environment, it has high playback continuity and has less end to end delay.

The bandwidth fluctuation leads towards degradation of playback continuity in a way that video freezes or portion of video starts skipping. This fluctuation is very severe in delivering the content over live streaming network. In order to handle content bottleneck, one way is to degrade the quality of the video or skip some parts of the video using different coding techniques as discussed in Section 3.1.2. This means that to transfer only a certain amount of information that helps to recover the lowest quality of the video. However, another solution to such approach is to use proper efficient scheduling techniques.

In [85] the authors present Grid Media to study the performance of a live video streaming system based on user's population, quality, connection heterogeneity and online duration of certain peers in a network. Authors defined a rendezvous point (RP) consisting of content information, IP address and port number of the streaming server. RP helps peers to join overlay, maintain random part of active participants and acts as a network administrator. When a new node joins, RP returns peer with the list of peers' already in overlay with their IP addresses and port numbers. Afterwards, peer calculates the round trip time of each peer in the list and selects peers as its neighbours with minimum trip time as half of its neighbours. However, the other half neighbours are randomly chosen to overcome the overlay division. Each peer in overlay is provided with membership list and neighbours list that keep

on updating with time. To provide active nodes with in an overlay, a term life time is used that keeps track of the information of message received from a certain peer. If the value of life time increases over the threshold value then that peer is discarded from the overlay. The update membership information is exchanged between neighbours for updating their membership lists. Membership list actually provides information that each peer is sharing the same amount of burden, it shares overlay information and video segments with in neighbours. In Grid Media authors proposed a streaming scheduler that takes the responsibility of distributing media segments within the neighbours. Each peer periodically shares buffer maps of video segments and gets the required segments from other peers. In the start authors deployed data driven pull approach to request packets from neighbours. But, this method causes huge latency. On the other hand push mechanism, directly gets the segments without any request which decreases transmission delay but suffers from the link failure. Grid media used the advantages of both pull and push based schemes. For live streaming, buffer map is replaced by a scheduler with push pull mechanism at neighbours.

The better quality of the content is received if the available streaming rate is high. Furthermore, the higher stream rate also helps to absorb the bandwidth variations caused by churn and the congestion across the network. In [86] the authors present an adaptive queue based scheduling algorithm that can achieve an optimal upload bandwidth rate of peers. In the proposed system, peer side scheduling is performed in a way that each peer maintains a streaming content from source and other peers in a playback buffer in an order it needs to be played. Each peer also maintains a forwarding queue which stores the content that needs to be forwarded to other peers. To fully utilize the peer upload bandwidth, it is required that the forwarding queue should always fetch the data. Whenever the forwarding queue becomes empty, a pull signal is sent from the server to request more content. On the server side, it maintains the content and signalling queue. Content queue contains two different dispatchers; F (forward) marked and NF (non-forward) marked dispatcher. If there is a pull signal in a signalling queue, it forwards a chunk of content from content buffer to peer from where a pull signal is originated using F marked dispatcher. If the signalling queue is empty, server forwards a chunk of content from buffer to peers by marking them as NF (Non-forwarding). Authors investigated the algorithm while considering

parameters including peer churns, peer bandwidth variations and network congestion to provide an optimal system for real time content streaming.

Similarly, in [87] a request peer selection algorithm to maximize the uplink bandwidth utilization across the peers is proposed. Each peer in the network monitors the network service response time (SRT) between a neighbor and itself. SRT is measured with respect to the time a data packet request is sent until the requested data packet arrives. The algorithm works as; whenever a peer makes a request for a packet, the neighbor with the smallest value of SRT and with few data packets will be favored against the potential providers. This happens because smaller SRT involves excessive available capacity and far fewer data packets means less packet requests are received. The authors showed that the proposed peer selection algorithm balance the load across the network as the data packets uploaded by each peer is normalized and the number of repeat requests generated by peers (due to failure) are reduced. They also showed that this algorithm reduces the overall load across the server and improves the quality of service and reduce the startup delay.

In [88], the authors have deployed a primal dual algorithm in an undirected graph to measure the streaming capacity of a P2P network. However, the disadvantage of such approach is that the degree bounds (number of peers that can be served at a single time) at each node is not introduced. Later in [89] and [90], the authors introduced the concept of helper nodes that act as a source of transmission and leads to the deployment of greedy and proximal algorithms for managing the capacity of the P2P networks. However, the proposed algorithms have high overhead complexity which causes huge playback delay, which is not manageable for real-time video distribution.

In [91] authors propose an algorithm that determines the maximum streaming capacity that can be achieved in a P2P streaming system. However, the proposed approach considers the nodes to have an equal bit rates. In [92], the authors have used the taxonomy of sixteen different formulations depending on various network scenarios. In each formulation, authors computed an optimal set of multicast trees to find the optimal P2P streaming capacity. The authors produced a combinatorial

optimization approach to solve the streaming capacity problem. The combinatorial problem is converted into a linear optimization problem with exponential variables, which is then solved using a primal dual approach. The authors developed algorithms for single and multiple streaming sessions and found that with the help of smallest price tree construction, each receiving peer is able to achieve a maximum streaming rate.

In [93] the authors design a network comprising on super peer. According to the authors, super peer is a node that works as a server to a certain set of clients. Super peers help to provide the incentives of the centralized approach, load balancing and handles the attacks which affects the distributed network. Furthermore authors have studied potential drawback of using seed servers such as cost and complexity of a network.

Labib et.al [94] propose an enhanced media streaming system that organize the network entities in a structured P2P network to provide big media storage and to dynamically participate in delivering media. Furthermore, multiple sources are used which improves the network resources and reduce the consumption of network bandwidth. Authors propose an algorithm that helps to significantly reduce the load across the original server.

Similarly, in [95] authors have introduced the concept of using seed servers in the network. The seed servers are the dedicated servers that handle the requests if the available peers upload capacity is fully utilized. Authors have deployed seed servers in a P2P streaming network for non SVC streams and investigate the optimal utilization of seed servers by evaluating when the servers can be switched on or off.

Similarly, in [96] the authors design a cloud assistive P2P live streaming system that maintains a predefined quality level by renting the helper peers from cloud architecture. The problem is modeled as an optimization problem with an objective to minimize the total cost incurred in renting the cloud resources in order to maintain a desired QOS level. The authors have provided an online heuristic approximate solution that adapts the network dynamics. Authors have used a gossip based

aggregation protocol to estimate the upload capacity available in the P2P system and provide provision to get resources from the cloud in order to maintain the QOS at low cost. The simulation results show that their proposed method provides high playback latency with a short playback delay. However, the proposed suffers from the cost of renting the resources from the cloud.

In [97] the authors have used the concept of dynamic renting the virtual machines from the cloud servers. Authors have introduced a centralized based method that performs the estimation of the total number of virtual machines required to provide the requested QOS. The experiment results show that the proposed method efficiently distribute the resources across peers and improves the overall system bandwidth.

Dongni et.al [98] study a mesh based protocol, Fast Mesh, which reduces the source to peer delay while considering the requirement of streaming bandwidth. The proposed protocol supports the network comprises of super nodes, proxies or content distribution networks. Authors study a minimal delay multipath tree problem and proposed a centralized heuristic that can be used over a small network. Furthermore, authors propose a distributed algorithm in which peers select parents based on power factor that is obtained through the ratio of throughput and delay. The simulation results show that the proposed method reduce delay and load across the servers.

3.1.1 Video Streaming over P2P Networks Using SVC

As discussed, SVC is a type of layer coding that divides a single video stream into different sub streams or layers based on the resolution, frame rate or fidelity level of the video. The sub streams are divided into one base layer and several enhancement layers. The base layer carries the basic quality of the video whereas enhancement layers further improve the quality of the base layer stream.

A good p2p streaming should provide right balance between efficiency, fairness and incentives. In [99], the authors presented a streaming design to provide efficiency, fairness and incentives with in a layer p2p streaming system. In this design, the video

Table 3.2 Qualitative Comparison for Existing P2P Streaming Techniques

Approach	Cod. Tech.	Objectives	Advantages	Disadvantages	Multi. Sender Sources
[59, 60] tree based architecture	S.L	Media streaming	Imp. scalability	Churn cannot be handled	No
[61, 62, 63] multi-tree architecture	S.L	Handle leaf nodes capacities	Upload cap. Of leaf nodes is utilized	churn effect	No
[8,64] mesh based architecture	S.L	Utilize the peer's b/width to imp. Sys. Perform.	Resilient to churn and prov. b/width utilization	High overhead complexity	No
[66] hybrid based architecture	S.L	Mange the adv. Of both tree & mesh	Improve sys. Performance. Imp. Latency & provide resilience	High overhead complexity	No
[70] concept of backup parents' pool	S.L	In order to provide more resilience	Reduce quality degradation	Single node failure	No
[71] multi cast tree over clustered peers	S.L	Construct multi cast tree over clustered peer	Maintain quality	Single node failure	No
[72] RTT over multi cast trees	S.L	Build the overlay	Eff. Management of resources	Not appropriate solution	No
[19] rand. Pickingstrategy & override algo.	S.L	Introduce a multicast streaming	Reduce cons. of upload b/width; provide resilience to packet loss & main. QOS	Upload b/width is not eff. utilized	No
[8] Optimization scheduling method, b/width estim. algo	S.L	Imp. real time streaming exp.	Red. overhead, assures good QOS	Flash crowd effects are not studied	No
[71] [73-75] cluster based tree overlays	S.L	Improve QOE	Better Quality is rec. across peers	Cluster leaders capacity is not cons.	No
[69] Cluster based tree overlays	S.L	Improve QOE	QOE improved. Cap. Across leaders are cons.	Churn is not studied	No
[76] incentive based approach	S.L	Provide better QOS across network	Overcome free riders and handle churn	Low capabilities nodes have to cont. more to rec. more	No
[77], reciprocal mechanism	S.L	Monitors history	Improve QOS	No app. sol. History changes freq.	No
[78] Reputation based approach	S.L	Priorities across peers to rec. data	Nodes with more rep. rec. data first	Less prior. Nodes are not cons.	No
[79] study a taxation based approach	S.L	To imp. received quality	Quality across peers is imp.	Flash crowd is not cons.	No
[80] pricing based mechanism	S.L	Optimal resource allocation	Resource alloc. Improved	Churn is not studied	No

[81] tit for tat algorithm	S.L	Over. free riders	Rec better quality on request	Churn is not studied	No
[69] score based app.	S.L	Share content based on connections.	High score rec. more content.	Res. Are not eff. Utilized.	No
[8,84] concept of incentive based mechanism	S.L	Higher upload cap. nodes are placed closer to root	Eff. B/width utilization in tree based network	Churn is not studied	No
[8] Membership man. Protocol & partner sel.& scheduling algo.	S.L	Data exchange across nodes	Less over. , high playback cont. & low delay	B/width fluctuation reduce quality	No
[85] data driven pull approach	S.L	Req. packets from neighbours	Better quality rec. Red. churn & congestion	Latency issues	No
[86] Adaptive queue based scheduling algo.	S.L	Achieve optimal upload bandwidth of peers	Provide better streaming rate	Free riders are not studied.	No
[87], a request peer selection algorithm	S.L	Max. uplink b/width util. across peers	Load bal. red. & imp. quality of video	No content adaption	No
[88], a primal dual algorithm in an undirected graph	S.L	Meas. the stream. capacity of a tree based network	Max. the throughput	The degree bounds at each node is not introduced	No
[89] and [90] deployed greedy and proximal algorithms	S.L	Managing the capacity of the p2p networks	Improves capacity received	Overhead complexity which causes huge playback delay	Helper Nodes
[91], algorithm to provision resources for streaming	S.L	Monitor network performance	Offer high video quality & red. the effect of churn	Nodes with equal bitrates	Helper Nodes
In [92] the taxonomy of sixteen diff. problems	S.L	Opt. set of multicast trees to find the p2p stream. capacity	Rec. peer is able to achieve max. stream rate	Eff. util. of upload cap. at each peer is not considered	Helper Nodes
[93] Design a net. Comp.on super peer	S.L	To provide load bal. & handling attacks	Load is balanced	Cost & complexity	Super Peers
[94] enhanced media streaming system	S.L	Provide big media storage	Imp. Net. res. & red. consumption of b/width	Cost	No
[95], deployed seed servers in a p2p network	S.L	Opt. util. of seed servers by det. switched on/off	Imp. Capacity & red. impact of peers failure	Intro. delay and suffer from low quality	Seed Servers
[96], a cloud assistive opt. prob. to maintain a predefined quality	S.L	Min the total cost incurred in renting the cloud resources	Provide high playback lat. with short playback delay	Suffers from cost of renting cloud res.	Cloud Servers
[97] introduced a centralized based method	S.L	No. of virtual machines req. to provide QOS	Imp. Overall sys b/width	Cost & complexity	Virtual Machines
Dongni et.al [98] min. delay multipath tree & distributed algo.	S.L	Supports net. comp. of super nodes, proxies or CDN.	Red. delay & load across servers	Small network	Proxy, CDN

content is distributed over mesh and a tracker acts as a bootstrapping node for the system. The design parameters for layered p2p streaming are layer subscription, chunk scheduling and topology adoption. To determine number of layers required by a peer, layer subscription algorithm with adaptive increase adaptive decrease and exponential back off is proposed. Whenever a peer joins a streaming session, it sets initial layer subscription. If all the layers are received by time and one of neighbouring peer carries more layers, it increases its subscribed layers. However, if the top subscription layer becomes non-decode able, it reduces the assigned layers. Furthermore, each peer shares their buffer maps with the neighbouring peers to monitor the chunk availability.

The author also presented a chunk scheduling algorithm that decides how to issue and request the chunks to neighbouring peers. During chunk request, chunks with more importance are requested first. Whereas in chunk serving, each peer maintains two FIFO queues named as entitled and excess queues for each neighbour. Entitled queue are retrieved firstly and excess queues are served if peer has excess bandwidth. In this system, author presented a mesh topology in which peers periodically contact the tracker to retrieve neighbour list. Every peer maintains a present peer out degree. If number of neighbour increases the present out degree, peer cancels its connections with some of its neighbours whereas if it’s lower than present out degree, it makes connection with more neighbours. Finally, to provide a balance between social welfare and individual peer welfare, a taxation based peering strategy is used.

In [100] the authors consider the behavior of live P2P multicast session over a large network. According to the authors, in order to efficiently distribute the video across the requesting nodes, it is necessary to encounter high bandwidth, high peer churn and the low peer persistence. Moreover, the authors monitor the quality of service (QOS) of the most popular content and correlate the monitored quality against the peer behaviors so that the better performance strategies can be provided.

In [101] the authors propose a system that monitors the available bandwidth among the nodes and consider multicast trees scenario to disseminate the content across nodes. Furthermore, SVC is used to maximize the video quality received with

minimum possible delay while keeping the upload bandwidth of peers into consideration. Authors consider that if the peers with better available bandwidth are placed closer to the source or root node of the tree the overall performance of the system improves.

In [102], the authors study a p2p streaming network using SVC in order to provide an efficient video streaming and video sharing system. They extended the famous bit-torrent protocol by combining it with SVC to support live content delivery with different quality levels. In order to achieve a better QOS, they organized the overlay based on grouping the peers with the same capacity together. Furthermore the high capacity peers are placed closer to the source node. The authors showed that the proposed system has better QOS received and performs better than the existing single layer techniques.

In p2p live streaming system, the overall bandwidth across the network automatically scales up based on bandwidth contribution of the peers in a system. For efficiently video streaming, each peer is required to download the video within a certain playback interval. Hence, it is important to manage a right balance between the bandwidth supplied and bandwidth demanded. In [103] the authors address this issue by proposing a system that automatically adapts the network towards full bandwidth utilization. A link level homogeneous network is designed that have identical bandwidth value. The advantage of identical bandwidth is that video flowing through overlay will not encounter any issues, and guaranteed downloading rates can be achieved. Moreover, depending upon the peer downloading rate, the server adjusts video playback rate to provide quality video by fully utilizing the network bandwidth. In the proposed system, raw video is generated at the source which is then forwarded to the media server. The media server encodes the video using SVC. The compression rate of the video is estimated based by monitoring the downloading rate of peers which then helps to select an appropriate playback rate. After the video compression, a channel coding scheme is applied before it is broadcasted to P2P network. On the other hand, at the receiver, a reverse operation is performed in order to decode the video to be played at the given playback rate.

Yi Cui et.al [104] propose an algorithm for online selection of peers in order to provide throughput maximization under peer churn. The algorithm can be upgraded to multi parent streaming from a single peer streaming. Authors have also implemented an admission control mechanism by which the peers are rejected if the desired throughput is not achieved.

In [22] Lie et.al propose a LayerP2P system that combines layer coding with mesh overlay. Authors then provide a tit for tat strategy in which more incentives are given to those peers which contributes more towards the network. The video source encodes a video into different layers which is further broken down into small chunks known as layered chunks. The layer chunks are then distributed using a mesh based overlay. Whenever a peer joins the network, it obtains a complete list of its neighbouring peers similar to single layer streaming. Afterwards, the tit for tat strategy is used by which peers allocate more bandwidth to those peers that have high contribution of the upload bandwidth. Furthermore, the proposed system provide a viewable quality to peers if the sender peers bandwidth falls below the total supply bandwidth.

In [22] the authors have also considered an incentive based approach using SVC. In the proposed approach, peer requests the base layer chunks firstly based on their upload capacities. Similarly in [105], authors have introduced a probability based resource sharing. The probability is proportional to the upload capacity of the node.

Similarly in [106], a data scheduling approach is designed to achieve high throughput and low packet delay, high layer delivery ratio, low useless packets ratio and low subscription jitter. Furthermore, authors study a three stage mechanism for requesting the missing blocks: free, decision and remedy stage to provide a system that can handle the live streaming content. During a free stage, the network is modelled as a minimum cost network flow model in order to schedule the data for achieving high throughput. The decision stage considers the total number of layers subscribed to a specific window in order to achieve high delivery ratio, less jitter and less useless packet ratio. Finally, the remedy stage carries the blocks with the most

urgent playback time; the missed blocks are then requested through peers using multiple users.

In [18], the authors have introduced a new video streaming protocol, LayeredCast. The proposed protocol uses the incentives of both mesh and tree based approaches and provide a multi service network core to clients. The experimental results show that the proposed method provides better QOS. The tree based approach is used to push the base layer across all the requesting nodes whereas the enhancement layers are pulled using the mesh based approach.

In [107] the authors study a new approach for dynamic construction and maintenance of a tree based method for streaming live video in P2P networks. In this approach, peer continuously change their positions reduce the effect of churn on the quality of the video by utilizing SVC and backup parents. Authors divide the overlay multicast tree into hierarchical clusters so that it becomes easy to change the position of peers located under small trees. The joining of node comprises of two phases; firstly node joins the cluster and then afterwards it joins the tree within the particular cluster based on the node's upload capacity. This joining of nodes reduces the message complexity because of its simplicity. Furthermore, authors have considered different factors while the construction of multicast tree such as dynamics, capacity awareness, incentive mechanism and scalable utilization. Authors have also introduced the concept of streaming leaders list, in this case if a leader fails or leave the network, an alternate leader is available. Each streaming leader is responsible to provide management to the part of the tree within their clusters. Moreover a data dissemination algorithm is provided that maintains the backup parents list to provide tree resilience and maintains better quality. The experiment results show that the proposed method provides high QOE among peers, improve playback latency and reduce the duration of video pauses.

In [108], a taxation based scheme is deployed that provides fairness among peers requesting scalable video streams and have variable upload and download bandwidths. Similarly, in [109] authors have considered a rate distortion model for SVC video using a fine grained scalable method in order to maximize the perceived

video quality. The proposed model is more suitable as compared to the assumption that all layers have equal bit rates. However, in both models, different SVC coded packets of a video are streamed from each peer that carries data for multiple layers. If one of a peer fails or leaves the network, the video cannot be streamed and peers start starving until a new peer is available, which produces an excessive delay.

The authors in [110] proposed a quality adaption mechanism over the p2p network with the help of SVC. The quality adaption mechanism works in two different phases. In a first phase, a layer level initialization (LLI) strategy is used. In this, the initial quality of the video is selected based on the peer's static resources such as power, screen resolution and the available bandwidth. When the streaming starts, the second phase is initiated in which layer level adjustment (LLA) algorithm is performed. This adapts the quality of video to various dynamic parameters such as memory, energy consumption, block availability and throughput.

In [111] the authors address the problem of the quality bottleneck in adaptive SVC streaming. The authors investigated the problem as a joint optimization problem of overlay formation, data distribution and content adaption in order to maximize the quality of experience whereas avoiding the quality bottleneck. In the scheduling strategy, the authors aimed to consider the effect of neighbor's departure on the received video quality. According to them, the data requests are forwarded to peers based on what they can handle with the available upload capacity. Furthermore, in order to avoid the quality bottleneck problem, the authors form an overlay with more stable neighbors based on their lifetime duration. However, it is suggested that even with proper scheduling and an overlay design, the network can still be affected with different network conditions such as bandwidth fluctuation. Therefore, the authors have considered using a soothing function to overcome bandwidth fluctuations and provide better quality of experience. The experimental results showed that the proposed method reduces the quality bottlenecks, increase the churn tolerance and efficiently utilizes the bandwidth.

The investigators in [112] have considered an efficient bandwidth allocation technique to allocate the sender peers upload bandwidth to the receiver peers. In the

proposed method, the peer's upload bandwidth is allocated based on the quality level requested by the requesting peer. The authors have used an auction based game that distributes the bandwidth across the requesting peers, where the sender peers sell their upload bandwidth based on the bids from the requesting peers. The overall goal of their proposed work is to provide benefit to high priority peers whereas ensure the minimum quality for all the peers. The authors have combined the bandwidth allocation technique with an efficient scheduling mechanism that takes the advantage of allocated bandwidth with respect to the layer dependency and the playback deadline of the data packets. The simulation results showed that the proposed technique improves quality of the video, bandwidth utilization under heterogeneous peers.

In [113], the authors presented a data driven overlay network for streaming live media content using SVC. Peers forward data according to their upload bandwidths. A centralized server is used with an efficient scheduler that handles the requests from peers and serves them according to their capacities. However, the disadvantage of this approach is that it can only be used over the small p2p networks.

In [95] and [114], the authors have studied the resource allocation problem in p2p streaming using SVC and the seed servers. In [95], the authors proposed an algorithm that runs on each peer separately in order to request SVC layers from a given set of heterogeneous senders (each sender has a different outbound capacity), however it is assumed that all the layers have equal bit rates and offer equal video quality. Moreover, each peer sends SVC layers depending upon its outbound capacity and the receiver receives layers according to its inbound capacity. If all the peers are not able to overcome the requirement of layers of receiving peers then the remaining layers are served using seed servers.

Similarly in [114], the receiver continuously sends periodic messages for requesting the packets from each sender. The receiver determines a set of senders that can increase the system throughput and then finds the maximum number of layers that can be sent. The authors have implemented a congestion control mechanism in which each sender sends the packets to receivers upon request.

In [115] Shabnam *et.al* proposed a p2p system that uses SVC and network coding (NC). SVC helps to support heterogeneous peers in the network whereas NC handles the peer dynamics and maximizes the network throughput. NC enables to perform single operations on the video packets before they are forwarded. The forwarding of packets allows peers to share partial information with the destination node. The receiver can receive the whole video after receiving all the necessary partial information from the peers. The proposed model uses three different entities; trackers, sources and peers. Trackers identify the peers who are watching the same video in the network. Source nodes initialize the video stream in the network and provide extra capacity in the network if the available upload capacity at the peers is fully utilized. Source nodes perform NC on video data before forwarding them to distribute in the network. The results show that the proposed system improves average video quality, average streaming rates reduces the effects of churn and manages flash crowd.

In [116], the authors propose an efficient scheme to manage seed server resources in a p2p network. The scheme uses an adaptive layer streaming and monitors the peers' contribution according to their upload bandwidths. Furthermore, the authors consider the problem of capacity management across seed servers and provide a capacity allocation algorithm. The algorithm helps to deliver seed server resources in order to maximize a system wide utility function i.e. overall video quality received by the peers. The results show that when seed servers are introduced in the network, the overall quality of the video is improved. However, the drawback of this approach is that it introduces a certain cost at the seed servers.

In [96] the authors suggest a cloud based p2p live video streaming platform (CloudPP) that uses cloud servers as peers to develop a p2p streaming network using SVC. The authors have designed a tree based network using SVC so that all the requests are served using the minimum number of cloud servers. The working of the proposed method is like whenever a new client joins the system, it searches for a cloud server using a breadth first search method starting from the SVC base layer tree. If the cloud server has enough available bandwidth to maintain the streaming

quality requested by the new client, the client is added as its child. However, if an existing cloud server is unable to provide the required streaming quality to the client, the system boots a new cloud server and the existing client redirects its entire client to the new cloud server and makes it free to serve more clients. Similarly, when a peer leaves a network, the parent cloud server shuts down if no other children are connected to it that reduces the overall cost.

3.1.2 Video Streaming over P2P Networks Using MDC

The MDC proposal was explained thoroughly in the early 1980s by researchers in [117], [118] and [119] and [120]. By the mid of 1990s, MDC has become the most important tool to reduce the propagation errors in video delivery over the networks. As discussed, MDC is a type of layer coding technique that generates multiple layers or descriptors of a single video stream. The advantage of MDC is that the video can be decoded at the receiver at different qualities and it provides high resilience to packet loss.

In [121] the authors propose an algorithm to provide better QOS across peers using MDC. The proposed algorithm distributes the data by quickly adapting the variable bandwidth across peers. However, the disadvantage of this method is that the transmission loss occurs due to unavailability of signals at the decoder. In [122] the authors propose SEACAST, a P2P streaming protocol for streaming live media content. The proposed protocol provides flow control and application-layer error control using MDC techniques as discussed in [123]. The flow control states that the network assures a constant flow of data through the overlay with low start-up latency and with a considerable packet loss. The advantage of SEACAST is that it started using new techniques like RTP, UDP, and RTSP/SDP to establish sessions and provide flow control across them. On the other hand, the error control technique helps to reduce the error within the prediction loop.

In [124] authors use MDC to provide error resilience in order to handle the lost frames at the receiver end. Authors propose an algorithm that uses spatial temporal correlation to reconstructs the video signal from lost descriptors. In the algorithm, if both the descriptions are received, the decoder will efficiently reconstruct the signal.

However, if any one of the descriptions is received, then the decoder reconstructs the signal using spatial-temporal smoothness measure in the received description.

In [125] the authors introduce CoopNet that uses the concept of cooperative networking to allocate the streaming content. It comprises of a central tree management protocol that helps to provide redundancy in both network path using multiple trees and for the diverse distribution of data using MDC. The protocol helps to reduce the effect of churn in the network. Furthermore, scalable feedback method is used that manage the effectiveness of trees by monitoring the physical and logical topology. Similarly in [126, 127], the authors used multicast tree to stream the MDC video comprises of different descriptors. In the propose methods, different descriptors of the video are forwarded using different trees.

Table 3.2 and Table 3.3show the qualitative analysis of the existing video streaming techniques that uses S.L, SVC and MDC to improve the video quality received across the peers. The analysis shows that in a p2p network with heterogeneous peers, S.L coding has usually achieves low video quality whereas SVC and MDC maintains better video quality due to their quality adaption property. Furthermore, the techniques are differentiated based on the available source such as peers, helper nodes, multiple senders, seed servers and cloud severs. These video streaming sources help to increase the overall network capacity and maintain the better video in a highly dynamic network such as network with churn or flash crowds.

3.1.3 Discussion

The Section 3.1.1 covers different video streaming techniques [99-127] to stream video over P2P networks in order to provide better QOS among peers while reducing the encountered delay. Furthermore, the studies also show different approaches to handle churn in the network. Moreover, the authors showed that by using different incentive based mechanisms, the free riders in the network can also be reduced.

However, the disadvantage of these techniques is that they do not provide any adaptive solution to stream the video that is considered to be most crucial nowadays

Table 3.3 Qualitative Comparison for Existing P2P Video Streaming Techniques

Approach	Cod. Tech.	Objectives	Advantages	Disadvantages	Multi. Sender Sources
[99] Layer subs., chunk scheduling & topology adoption algo.	SVC	To provide eff. fairness and incentives	Improve QOS, Red. Effect of free rider	B/width is not efficiently utilized	No
[101] multi-cast tree to disseminate content	SVC	To max. video quality received with min. delay	Overall system performance is improved.	Do not support heterogeneous peers	No
Abdelhalim [102]	SVC	Live video at diff. qualities	Achieves better QOS	Priority to nodes with more capacity	No
[103] Stream. system	SVC	Full b/width utilization of the network	Guarantee downloads rates.	Receiver Sync. problem	No
[104] an admission control mechanism	SVC	To provide throughput maximization.	Impr. Throughput of net. Reduce churn	Poor Utilization of b/width at peer	No
[22], LayerP2P	SVC	To provide more incentive to peers that cont. more	Improve video quality	Flash crowd is not studied	No
[22], an incentive based approach	SVC	Reduce skipping of content	Reduce latency	More overhead complexity	No
[106] mechanism to request missing blocks	SVC	To achieve high throughput & low delay	Provide high quality with min. delay	High overhead complexity	No
[18], introduced Layered Cast protocol	SVC	Incentives of both mesh and tree based approaches	Provides better QOS.	Increase complexity	No
[107] Data dissemination algo. with stream. leaders list	SVC	To construct & maintain	Red. message compl. and churn. Provide high QOE,	B/width is not eff. utilized.	No
Hao[108], taxation based scheme	SVC	Provide fairness among peers	Balance b/w efficiency & fairness	Utilizes most of the capacities of peers	No
Mohamed [109], rate distortion scheme	SVC	Max. perceived video quality	Improves quality of video	Handle heterogeneous network	Multi. Senders
Lahbabi[110], link layer initialization &adaption mech.	SVC	Adapts quality of video over various dynamic parameters	Devices retrieve qualities based on resources	Effect of different network conditions flash crowd &churn	No
Medjiah[111],opt. prob. of overlay form., data distr. & adaption	SVC	Max. QOE while avoid quality bottleneck	Red. Quality bottleneck, incr. churn tol. & utilize b/width	Overhead complexity &Effect of flash crowd	No
[112], auction based game to distribute bandwidth	SVC	Incentives to priority peers & ensure min. quality for all peers	Improves quality, bandwidth util. across network	Upload capacity of peers is not efficiently utilized	No

[113], data driven overlay network for stream. live media	SVC	Node handles req. according to their capacities	Adapts quickly to heterogeneous nature of peers	Only for small P2P networks	No
[95],algo.runs at each peer sep. to req. layers from sender peers &intro. seed servers	SVC	Peers send layers dep. on outbound cap. and receives based on inbound capacity	Max. deliver quality while min. server & network load	Dynamics of b/width variation is not discussed.	Seed Servers
[114], congestion control mech. to send packets to receivers upon req.	SVC	Det. set of senders that incr. throughput &finds senders that max. no. of layers rec.	Improves system throughput and the video quality rec.	Doesn't support variable bit rate and peer's dynamics	Multi. Senders
Shabnam [115] proposed a p2p system	SVC-NC	Support hetero. Peers & hand. peer dynamic	Imp. Video quality, avg. rate, red. churn eff. & manage crowd	Upload b/width across peer is not utilized	Seed Servers
[116], adaptive layer streaming scheme	SVC	Use seed server res. to max. system utility	Reduce cost of stream. seed server resources	Upload capacity at peers is not utilized	Seed Servers
[96] cloud network that uses breadth first search method to handle req.	SVC	Tree based approach to serve the req. using min. cloud servers	Reduces the overall cost of the network	Resources across the peers are not utilized	Cloud Servers
[121] Algorithm that distrib. data by adapt. Var. b/width at peers	MDC	To provide better streaming quality	Provide better QOS	transmission loss occurs due to unavailability of signals	No
[122] [123] SEACAST protocol	MDC	To provide flow control & app. layer error control	Flow & error control. Low latency	Churn & Flash crowd is not studied.	No
[124] propose an algo. that uses spatial temporal correlation	MDC	To reconstructs video signal from lost descriptors	Pro. error resilience to handle lost frame at rec. end	Bandwidth is not efficiently utilized	No
[125] CoopNet that uses cooperative networking	MDC	Allocate streaming content	Reduces effect of churn	Handling flash crowd	No
[126,127] multicast tree	MDC	Stream MDC coded video over diff. paths	Provide error resilience	Flash crowd are not considered	No

because of the heterogeneous nodes in the network. Hence, the propose approaches introduce playback delay and skipping of the video content which cannot be a part of real time video distribution.

To overcome such issues, different video coding techniques have been discussed in Section 3.1.2 related to P2P video streaming using SVC [14] and Section 3.1.3 covers different approaches for P2P video streaming using MDC [15]. Theses coding techniques help to improve the average video quality received at the receivers. Furthermore, the most important advantage of using video coding techniques in P2P networks is that it can quickly adapt the video quality based on receiver capabilities and heterogeneous network.

However, there are certain limitations to each approach as in SVC; the video segment is encoded into different layers such as one base layer and several enhancement layers. Each layer is decoded one after another starting from the lower layer such that higher layers depend on lower layers. Hence, it is required to provide reliable transmission of a base layer so that video can be played at the receiver. In case, the base layer is not received there is no use of receiving the higher quality layers.

However, in case of MDC allows a bit more scalability while encoding the video into different layer or descriptors. This is because MDC does not require any priorities or retransmissions. Further it is considered to be robust as it hardly happens that all the descriptor of the video gets corrupted. Therefore, MDC is widely used in the case where the network is exposed to more churn as it provides error resilience which helps the video to still survive at better quality. However, SVC is still preferred in the networks in which a network is static or centralized control and there is a less chance of churn to enter the network because of its high coding efficiency that still helps to provide the video at better quality.

As discussed in MDC, the data packets are sent through same or separate physical channels which helps to overcome packet loss and an acceptable quality of the video can be obtained. Henceforth, MDC is considered to be a possible solution to stream the video across a decentralized network where the topology of the network is not known. Therefore, MDC coding is widely used in wireless network more specifically in MANETs as discussed in Section 3.2.3.

3.2 Video Streaming in MANETs

Streaming video over MANETs is among one of the most challenging issues [128]. It is usually affected by heterogeneous uplink bandwidth of nodes, playback latency, transmission power for the nodes, node mobility, collision, interference, multipath fading and dynamic change in topology etc. Hence, the overall challenge becomes to improve the QOE among users throughout the multimedia session. This can be achieved if the network has enough bandwidth available and can able to maintain latency.

There are number of solutions have been proposed to solve the issues as discussed above. Examples of improvement methods are:

- Provide efficient video coding technique so that the bit rate matches the network and the video decoded at the receiver matches the receiver capabilities.

- Provide optimized routes to transfer video at the higher quality. Usually, multiple routes are used to stream layer coded videos.

- In order to meet end to end delay, provide packet prioritization of the video content at the MAC layer.

3.2.1 Issues for Streaming Video in MANETs

MANETs rely on the participating nodes in the network to share the resources among each other. This adds further challenge to the network to maintain and discover the optimal routes because of the mobility nature of the nodes. Hence, in order to solve this issue a wide range of routing techniques has been proposed as discussed in [170-193]. Whereas in order to perform video streaming over MANETs add further challenge to the network due to its stringent bandwidth and delay requirements. The detailed description of the possible issues in MANETs for streaming the video is discussed below;

3.2.1.1 Wireless Transmission

There are number of errors induced in wireless transmission such as collision, multiple path fading or interference which makes streaming in MANETs a challenging task. In order to recover from such errors, retransmission is required that introduces delay and badly affects the quality of the video. Furthermore, each node in the network has limited transmission range which effectively depends on the transmission protocol, size of the antenna, energy usage, interference through obstacles and the current weather condition. If the range is limited, data has to travel through multiple hops to reach towards the destination which introduces delay [129].

3.2.1.2 Dynamic Topology

Due to the mobility nature of nodes, the topology of the network is highly dynamic which means that the nodes change their positions in the network at random intervals of time. Whenever a node leaves the network and the route breaks, the route discovery is initiated to find an alternate route which produces an excessive delay and affects the video quality. Moreover, topology changes may reduce the available network bandwidth or makes a network with the missed nodes. If the source or destination leaves the network, the streaming stops [51,128]. In [130] the authors investigated that mobility nature of nodes introduces route stability that cause jitter and increases the packet drop ratio.

3.2.1.3 Multiple hop transmission

In MANETs, nodes can be connected via multiple hops to a destination node which introduces a number of challenges. The most crucial challenge that rises up with multiple hops is the half duplex channel and the capacity declined per hop. Furthermore, the end to end delay significantly increases with the number of hops. Such as in [131] the authors introduce upper bound on number of hops to provide live streaming in the network. Similarly in [51], the authors investigates that using 3 hops introduce the playback delay of 250ms that badly affects the streaming. Moreover in multiple hops, packets have to travel over long distances which increase a high risk of packet loss. Furthermore in [132], the authors study that in multiple

hops the nearby links also introduce interference. This happens when the departure time of a packet is less than the actual end to end delay over the path.

3.2.1.4 Limited Resources

Mostly in MANETs, the devices that take part have limited processing power, memory and the storage capacity [128]. Furthermore, the devices are usually battery powered therefore the energy consumption should be kept at minimum. However, an increase in the overall network traffic causes an extra load over the network which consumes most of the energy.

3.2.1.5 Lack of Infrastructure

In MANETs, the nodes are responsible to behave as a source, a destination or a relay node to route the data packets as discussed in [128]. Hence, a lot of responsibilities are imposed on nodes with limited resources.

3.2.2 File Sharing Systems in MANETs

The existing file sharing systems in MANETs are divided into four different categories: flooding based, advertisement based, cache replication based and social content based approaches. The first three methods are mostly used for the centralized MANETs whereas the social content based approach is more specifically used for decentralized MANETs. The detail description of existing file sharing systems is discussed below.

3.2.2.1 Flooding based approach

Papadopouli et al [133] propose a first method to use P2P technology over MANETs that considers the mobility pattern of node into consideration while forwarding the data across the neighbouring nodes. Klemm et al [134] design an application layer special purpose on demand algorithm for sharing and transferring files. The advantage of the propose method is that it aggregates the results of the queries from other neighbouring peers to reduce the redundant paths to a particular node. In [135] the authors propose a distributed algorithm that uses local broadcasting to search the content and put the content index over the nodes along a route reply to help improve

searching. Similarly in [136] a keyword approach is used to identify the interest of users. However, the overall disadvantage of these techniques is that it produces a high overhead due to flooding.

3.2.2.2 Advertisement based approach

Vadiya et.al [137] design a Geography based content location protocol (GCLP) for content discovery in location aware MANETs. The proposed protocol takes the physical location information into account in order to achieve scalability and cost effectiveness based on the distance between the clients and the discovered servers. In [138] the authors suggest a system in which nodes use a Bloom filter to make a synopsis of the data and then distribute it among the nodes to handle requests. Similarly in [139] Hoh et al. propose a p2p swarm intelligence based file sharing system over MANET that combines both the advertisement and discovery based methods together. In the propose method, the files are considered as a source of food for the nodes whereas the routing table is a pheromone. Each source node that has a file identifies the surrounding nodes about the available files by broadcasting an advertisement message. Similarly, discovery process discovers the requested file and leaves a pheromone for other nodes to easily locate the request in future. However the advertisement based approaches still do not overcome the overhead through advertisement and hence to distribute the file using these approaches is not a huge success due to nodes mobility.

In [140] the authors propose an ant inspired mini community based video sharing solution for on demand streaming services (AMCV). AMCV relies on two layer architecture and on an algorithm inspired by the indirect communications between ants via pheromone trails which enable them to identify the shortest paths. ACMV organizes the media server and multiple nodes in a structure with two layers, a mini community network layer and a community member layer. The community structure and the logical links are designed in mini community network layer, this helps to achieve fast resource search and low cost link maintenance. However, the role and tasks of the community members are assigned in community member layer.

3.2.2.3 Cache Replication Based Approaches

Gao et al [141] propose a cooperative caching technique for disruption tolerant networks that makes a duplicate of each file to a central location that most of the nodes frequently visits such that data can be accessed quickly. In [142] a podcasting approach is used across wireless ad hoc networks in which each node saves the content of its neighbours in which they are interested or the nodes which are encountered before. Similarly in [143] the authors use a file caching approach to provide an efficient content distribution across opportunistic networks. The propose approach also considers the user's impatience towards a video apart from file popularity and nodes mobility while creating the file replicas.

In [144] Chen et al. suggest an optimal file replication approach for MANETs that also consider nodes ability to encounter replica of resources with a high availability. However, all of these approaches improves the availability of files across the nodes whereas on the other end nodes have to wait for the interested content apart from searching it which eventually introduces more delay.

In [192] authors study the techniques to improve the search efficiencies by content popularity ranking. They investigated that the existing techniques does not provide proper ways to estimate the popularity, therefore it induces high cost and overhead. Hence, authors propose a gossip based approach hybrid adaptive search method to share file index table among the nodes. The proposed method considers topology and interest aware links instead of DHT. The simulation result shows that HAS-A-GEM performs better over the large network by informing about the popular content.

3.2.2.4 Social Network Based Approaches

In [145] the authors study the relation across the nodes to provide a content based service. In the proposed system, the frequently contact nodes are combined in a group and identifies the node in a group that frequently contact other groups in the network and named it as a broker. The broker is then responsible for inter communities communication. In case, nodes make request for the content and it is

not available in a specific group it asks the broker to check identifies other communities to see if the content is available or not.

In [146] Costa et al. introduces Social Cast that determines the nodes utility based on the nodes mobility and position of the nodes based on interest. The propose method forwards the content among the nodes with high utility of interest. In [147] authors suggest the social relationship based communities and caching policies. In this technique, each node determines the utility of the published data it come across based on the location of data and the connected communities. Finally, the data which has the highest utility is placed on the top.

In [148] a similar approach is used as discussed in [145], the centrality nodes are selected as brokers. The brokers use unicast or direct protocol to communicate. The node publications are first forwarded to the broker node of the nodes community and then towards all other brokers to determine the matched subscribers. In [149] authors propose a p2p content based file sharing system, SPOON for disconnected MANETs. The proposed method uses an interest extraction algorithm to obtain the node interests based on the available files. The algorithm groups the nodes that has a common interest and frequently meet each other as communities. Furthermore, the stable nodes with high mobility and frequent contacts across the community member are considered as community coordinators for intra community searching. Similarly, the highly mobile nodes that often visit other communities are considered to be the community ambassadors for intercommunity searching. The propose method significantly lowers the transmission cost and improves the file searching efficiency.

3.2.3 Video Streaming Techniques in MANETs

As explained in the previous section, that streaming over MANETs faces a number of challenges because of limited resources, mobility, multi hops and wireless links. This section discusses about the existing work to provide video streaming services over MANETs using different streaming techniques. These streaming techniques are classified as; Cross layer techniques, video coding techniques and routing techniques.

3.2.3.1 Cross Layer Techniques

In a cross layer technique, the information is exchange across different OSI layers in order to obtain better performance and adaption. Xiao et. al[150-151] study a two level mechanism to provide video and voice traffic. The advantage of propose method is to minimize the number of collisions without focusing on the total active stations to disseminate the data. Furthermore, the traffic is controlled dynamically based on the load. Authors have introduced various rules such as fast back off, dynamic adjust of parameters when fail or dynamic adjustment of parameters while consecutive successes. The fast back off rule achieves large window size quickly and works faster when back off stage becomes greater as compared to the exponential back off. In dynamic adjustment of parameters while failure rules: if a frame keeps on dropping until it reaches the retry limit, the parameters are adjusted. Whereas in the rule of dynamic adjustment of parameters when a consecutive success, if a frame receives a certain successful frames, the parameters are adjusted to reach the lowest limit.

In [152] Wang et.al propose a cross layer approach that jointly consider video coding and transmission across WMNs. Authors have used the concept of dynamic programming to solve the distortion minimizing problem. Furthermore in [153], the authors investigate that the node awareness about the links is restricted to a certain number of hops. Based on the information and the information about the number of path values help to determine a pre-established path for rest of the mesh network. Moreover, the authors provide packet scheduling over each hop to reduce distortion and delay deadlines. However, this approach consider that the routes are already established using a centralized coordinator.

Similarly, [154,155] also consider the use of multiple users for optimization. These methods are more specifically deployed in enterprises where users are willing to share their applications. In [154] the authors perform a cross layer optimization at each peer to exchange the network resources. Based on resource sharing, authors use the distributed algorithms to perform admission control, path provision and time reservations. The propose solution is used over AOMDV routing protocol. However, in the case of [155] paths are also established dynamically using the self-learning

approach. In this approach, each intermediate node among a source and a destination node determine the next hop based on the estimated delay to the destination under current conditions. The delay estimation is received through the downstream hops. Moreover, the authors perform prioritized packet scheduling at each hop based on the packets deadline and distortion reduction. The prioritization is also extended towards saving the network resources from forwarding the packets that has a high risk of getting drop lately over the path.

As discussed in this section, that cross layer approach interact with different layers to provide better network performance or maintain better quality. Furthermore, it also helps to provide adaptability at each layer for sharing the information. However, these techniques significantly increase the network complexity when designing the model. Another disadvantage of this approach is that each layer is dependent on other layer, if a change occurs at one layer, it may affect others. Therefore, a lot of research has focused towards using video coding techniques or routing techniques as discussed in the next section.

3.2.3.2 Video Coding Techniques

Video coding techniques helps to quickly adapt the quality of a video to the current network conditions. Moreover, coding further handles heterogeneous nodes with variable upload and download bandwidths and provides error resilience towards the packet losses. Table 4 shows the taxonomy of all reviewed video coding techniques. Current research in different video coding techniques such as Scalable Video Coding (SVC) or layered coding [22] and Multiple Descriptive Coding (MDC) [121] introduces novel methods for distributing the video in MANETs.

In [156] author proposes an approach for distributing the video using uncoordinated P2P relay nodes in an overlay network at the top of MANET. This approach helps to provide an optimized rate allowance to transmit SVC stream through the relay nodes. The method use path or source diversity in order to provide stable connectivity to relay nodes that improves the network throughput.In [157][158] the authors study the optimization of video in wireless network using a simple QOE model, however the network resources such as available energy and the upload bandwidth across the nodes are not considered. In [159] the authors use a QOE based approach to measure

the streaming performance across P2P MANETs. Authors show that the performance of video streaming strongly depends on the chunk size of the video. If the chunk size of the video is considered to be small, then network has better values of QOE and QOS whereas encounters more overhead. On the other side, if the size of a chunk is increased the streaming performance is badly degraded. Hence, authors suggested that a proper value of a chunk size is required to obtain the desired QOE.

Singhal et.al [160] suggests a cross layer optimization framework in order to improve the QOE and energy among heterogeneous wireless receivers. Authors study that by grouping the user based on different device capabilities and channel conditions and adaptively forwarding the content using SVC. The results show that the propose method improve QOE among all users, increase energy savings across the nodes.

Similarly in [161], the authors consider an adaptive streaming over wireless networks to jointly design an optimal transmission scheduling and an admission control policy. The authors formulate a dynamic network utility maximization problem and break the propose problem into sub-problems. The admission control policy helps the user to choose the possible quality of a video chunk to download based on the network congestion in the neighborhood. The propose admission control policy is compatible with the existing video streaming based on the DASH protocol over TCP connections. Furthermore, the queuing delay is reduced by dropping the bits from the transmission queues. This helps to pre-fetch the number of chunks for smooth playback with the minimum possible interruptions.

Similarly in [162] authors have used MDC for streaming in MANETs, the model is based on the motion compensation such that for each frame, it generates two different predictions: central prediction is the one that uses the linear superposition of previous frames n-1 and n-2 whereas side prediction only uses n-2 frame. It produces two different descriptors with even and odd frames. However, these models used single path routing in MANET's that is not considered to be a reliable solution to handle the dynamic nature of the network.

Therefore, multipath routing is considered a better solution for video streaming in MANETs. It can improve QOS because; the capacity is broken into different routes

and the delay and bandwidth of each route will be less used. Similarly, the load is balanced for the nodes with high traffic load. Paths are considered disjoint so that the system can be fault tolerant. In [163] authors have designed a multi path streaming system to find the optimal routes for MPEG 2 video. The authors investigate that the optimal routes are three, in which I, P and B frames can be sent independently to the destination nodes.

The limited battery life across the mobile nodes makes the transmission of multimedia content over the wireless adhoc network more challenging. In [164] authors design a protocol that efficiently optimizes the energy consumption while transmitting the video streams. Authors take advantage of SVC coding to dynamically adjust the video quality based on the node's characteristics. The quality of the video is monitored based on the number of transmitted and received enhancement layers. Furthermore, authors consider the routing aspects to guarantee a satisfied QOS to the destination nodes. Authors show that the propose method increases the network lifetime by reducing the overall energy consumed across the nodes whereas the better video quality is perceived.

However, the decisions to select the number of layers need improvement. Therefore in [165] authors present different strategies based on distributed admission control to improve the overall performance of video transmission over MANETs. Furthermore, authors investigate the combination of the best possible strategy under given network resources to determine the number of layers to transmit in order to provide better QOS to the end user. The results shows that propose method has better fairness and delay as compared to the existing models.

Mao *et al*. [166] proposed a method to combine multi-stream coding with multi-path transport. The proposed technique overcomes the transmission error using multiple paths and introduces path diversity. They examined the performance of the proposed method over two different coding techniques namely Scalable Video Coding (SVC) and Multiple Descriptive Coding (MDC). In SVC, video is encoded at different frame rates, resolutions or signal to noise ratio (SNR) levels, which produces different sub streams called layers. The layers are categorized as a base layer and several enhancement layers. In the proposed method when SVC is used; base layer has given more importance and transmitted over a stable path (less probability of

packet loss) and enhancement layers over the other. As base layer has the basic information to construct a minimum quality video, receiver updates the sender periodically to report a packet loss at the base layer. If a packet loss occurs at the base layer, sender forwards base layer packets over enhancement layers path which reduces the transmission rate or drops an enhancement layer. Similarly, if MDC is used with the proposed method, video is coded into several sub streams or descriptors such that each descriptor can be decoded independently. The quality of video depends on number of descriptors received. The proposed scheme uses motion compensation in MDC such that for each *n* frame two predictions are available. The first prediction is a linear superposition of the last two frames *n-1* and *n-2* and the second prediction is from *n-2* frame. The residuals are combined from the predictions to form two different descriptors from even and odd frames. If both descriptors are decoded, highest possible video quality can be constructed otherwise the video can still be decoded at lower quality. However, the disadvantage of the proposed method using SVC is that the base layer has given more importance by sending updates at sender whereas enhancement layers are not given any importance and can be dropped if required. Furthermore, receiver sends a periodic update of the received packets to the sender, this produces large overhead and propagation delay which makes hard to stream live or delay sensitive video.

Similar to [166], Qin *et al*. [167] design a dynamic service replication technique to provide guaranteed streaming among all nodes in MANETs. In the proposed technique, a link availability prediction approach is used with SVC such that if the link availability between a source and destination drops down to a certain threshold, service replication is implemented. In service replication, if a node detects less coverage from the source, node asks the server to replicate the streaming service. The advantage of this technique is to provide alternate path for guaranteed streaming of base layer and enhancement layers. This helps to manage link failures and network congestion. However, the disadvantage of this technique is that, it uses SVC to stream the video among nodes, this requires strong dependency over the order of the layers received or synchronization among the number of layers received which makes difficult for SVC to maintain the better quality of a video.

To address this issue, in [168], Kim *et al.* describes a channel adaptive MDC technique for robust video delivery in wireless ad hoc networks. A multi-stream rate allocation algorithm is designed that generates two correlated descriptors by controlling the source coding rate for each descriptor and the redundancy in MDC under time varying network. The source coding rate for each descriptor can be obtained such that the expected end to end distortion is minimized while keeping the packet loss rate and channel capacity at each link into consideration. The multiple descriptive (MD) codec generates two descriptors from a single layer video coder by splitting the transform coefficients into important and less important transform coefficients. These transform coefficients are separated depending on the amount of redundancy required. The transform coefficients are transmitted through different paths; the important coefficients are replicated across both descriptors whereas the less important coefficients are sent between any of the two descriptors. The proposed coding technique is error resilient, adapts network conditions and provides constant video quality under time varying network.

The aforementioned video streaming techniques focus on MDC and SVC coding techniques separately. As a combination of MDC and SVC, Kim *et al*. [169] propose a video transmission system that uses layered MDC technique and multi-path transport for reliable video transmission in wireless ad-hoc networks. The MDC extends the quality SVC algorithm to generate two descriptors. These descriptions are transmitted over the separate paths to receiver in order to minimize the effect of unstable channel conditions of wireless ad-hoc network. If both the descriptors are received, highest quality of the video can be constructed. However, if one of the descriptor is lost, video can still be decoded at lower quality and the received descriptor can help to identify the lost information of corrupted descriptor. The simulation results show that the proposed method reduces the packet loss.

In a different video streaming technique, Apostolopoulos *et al*. [170] propose a multiple state video coding called MSVC that divides the video stream into different independently decoded descriptors, with different prediction process and state information. The advantage of the multi-state coding is that if one state gets corrupted other can still be decoded to produce a usable video and can be used to recover the lost state. For example, if an odd frames bit stream is lost, even frames

Table 3.4 A taxonomy of different video coding techniques in MANETs

Approach	Info. Used	Cod. Tech.	Obj.	Adv.	Disadvantage	Over. Comp	Delay	Multi Path
[156] proposed an approach for video distribution	Video	SVC	Prov. opt. rate allow.using relay nodes	Improve net. throughput	Dep. On lower layer	High	Less	Yes
[157], [158] QOE model	Video	SVC	Provide QOE at users	Imp. QOE by send. layers	Energy & upload b/width is not cons.	Low	Less	Yes
[159] QOE based approach to measure stream. perf.	Video	SVC	Obtain value of chunk size forQOE	Net. has better values of QOE&QOS	If chunk size increase stream.perfor. degrades	High	High	Yes
Singhal et.al [160] suggests a cross layer optimization	Video	SVC	Improve QOE&energy at hetero. receivers	Imp. QOEamong users, incr. energy savings	Upload b/width at each peer is not utilized.	High	Less	No
[161] adaptive stream. tech. for dynamic net. utility max. prob.	Video	SVC	Quality of video chunk based on net. Cong.	Smooth playback with min. Interrupts.	Dependence on lower layers	High	Less	No
[162] single path routing	Video	MDC	Prediction of prev. frames	Provide error resilience.	Single point of failure	High	High	No
[163] a multi path stream. system	Video	MDC	Find opti. routes for video del.	Imp. QOS, load bal. at nodes.	Limited battery is not considered	High	Less	Yes
[164] design a protocol	Video	SVC	Optimize resource consum.	Incr. QOE & net. lifetime	Layer dependency issue	High	Less	No
[165] present different strategies based on distri. admiss. control	Video	SVC	To imp. perf. of video trans.	Better fairness and playback latency.	Depend. On lower layers	High	Less	No
Mao[166] multi stream cod. multipath trans.	Video	SVC MDC	Overcome trans. error	Intro. path diversity	Base layer has more imp.	High	High	Yes
Qin [167], serv. repl. tech. & link avail. prediction	Video	SVC	Provide guarantee streaming	Diff. path of base & en. Man. link fail. Net. cong.	Strong dep. to order of layers rec. or sync. among layers rec.	High	Less	Yes
Kim [168] chan. adaptive tech. & multi-stream rate allocation alg.	Video	MDC	Robust video delivery	Exp. end to end dist. is min. & adapts net. cond.	Necessary to have disjoint &uncorrelated paths	Low	Less	Yes
Kim et al. [169], MDC extends quality	Video	SVC MDC	Min. eff. of unstable chan. cond.	Red. packet loss	Layers dep.	Slight High	Less	Yes

SVC algorithm								
Apostolopoulos [170], multi. state video cod.	Video	MSVC	Over. error prop. at decoder	Video decode at low qual. Recover loss state.	Multi. frames get corrupt. Video freezes or distorted	High	Less	No
Radulovic[171] multi. state video cod. with red. pictures	Video	MSVC -RP	Error drift during loss	Red. error drift& imp. qual. at receiver	Multi. frames get corrupt. video degrades	High	High	No

can still be decoded and the video can be displayed at half rate. In the proposed technique, they suggest to recover the lost frames by using the temporally adjacent frames in other descriptors and use these recovered for future predictions. The disadvantage of this technique is that if there are multiple frames corrupted then both the streams are affected and results in either freeze or leads to significant distortion.

In [171], Radulovic *et al.* propose an error resilient tool that uses redundant pictures with MVSC in order to overcome the error drift during loss. The redundancy is based on the expected loss rate and controlled by quantization parameters that code the redundant pictures. The addition of redundant pictures reduces the error drift, increase error resilience and quality at receiver. The propose method shows significant improvement in case of PSNR, temporal fluctuation of the video quality and show robustness against different network conditions.

The section is then followed by considering different routing schemes related to video streaming in MANETs. Routing schemes helps to route the video packets from source to destination nodes. Table II gives a comparison of different routing techniques.

3.2.3.3 Energy Efficient Routing for Streaming Video in MANETs

In [172] author propose a cross layer quality of service (QOS) provisioning algorithm that considers the information collected at different layer of the network stack. Furthermore, multiple path routing technique is considered that uses dynamic source routing (DSR) to provide paths from multiple sources to the destination. The optimal routing paths are considered to be three as the video is coded into I, P and B frames accordingly. The proposed scheme shows that video streaming performance

is improved over ad-hoc networks. Similarly in [173] authors consider another cross layered approach for real time video streaming in multi hop wireless network. They proposed an efficient routing approach to obtain an optimal routing path that minimize end to end delay within the packet delay deadline. The approach uses video source coding with path routing to efficiently utilize the network resources and maximizes the user perceived video quality under a given playback time.

In [174] authors use SVC over MANET using multiple path optimized link state routing with unequal error protection in order to improve the QOE among users. The metric used to measure the quality is peak signal to noise ratio (PSNR) and is usually measured in dB. The advantage of using SVC in a proposed method is that it gives high priority to the base layer data which helps to protect loss.

In [175] authors proposed multi path routing over the dynamic source routing technique. In this model, initially a source node sends a message to destination node using any available path. This triggers a time out of the message received at the destination. If the packet receives after the time out is discarded. After the time out a reply message is originated from the destination node towards the source node that carries the sampled values of QOS parameters. This information at path is used to discover the best, medium and worst paths. Afterwards the packets are sent according to the priority levels, the best path is used to send higher priority packets and vice versa.

In [176] authors have used ad hoc on demand distance vector (AODV) routing protocol to forward the video content using multiple paths. In AODV, on demand routing approach is used for finding routes, which means that a route is established when it is required by a source node to transmit packets. Authors have used three different qualification to transfer content over multiple paths; primary path, node disjoint path and fail safe paths. Base layer is forwarded using the primary path and the enhancement layers are forwarded using the lower quality paths.

In [177] Chaparro *et al.* use a distributed admission control policy DACMESV (Distributed Admission Control for MANETs - Scalable Video) to provide QOS in video streaming using a coding technique called SVC for MANETs. The admission

control policy depends on a periodic update of messages that measures the bandwidth available and delay across the path. In order to avoid the network congestion, the proposed model determines the optimal number of layers to transmit at a certain time.

In another work, Mads *et al*. [178] propose an energy efficient routing mechanism for MANETs that uses the combination of span and AFECA. Span [179] uses a power saving approach based on the concept of Connected Dominating Sets (CDS). CDS is a connected set of nodes (coordinators) accessible by other nodes in the network and acts as routers for the whole network. SPAN runs a distributed coordinator selection withdrawal algorithm to select a CDS of coordinators. The coordinators are selected based on utility and the remaining battery of a node. When a CDS is formed Adaptive fidelity energy conserving algorithm (AFECA) is used with Span so that non coordinators can participate in power saving method. In AFECA, nodes switch to sleep, listen and active states within the fixed interval. In order to ensure successful forwarding, active nodes have to retransmit several times before receiver node is listening or in active state.

However, Span - AFECA is a only a power saving algorithm so it has to be combined with AODV a reactive protocol for MANETs. AODV helps to keep the nodes alive at low traffic conditions by sending the periodic control messages. The simulation results show that the proposed power saving method use 80% of energy reserves as compared to pure AODV. However, the disadvantage of this technique is the packet loss occur quiet frequently. There are two reasons of packet loss; the receiving node is sleeping as the packet arrives and the collision occurs because of extra packets are sent. High flow of traffic and repeated packets consume more energy and hence the algorithm performance decreases.

Yumei*et al.* [180] design a multipath routing protocol called maximal minimal nodal residual energy adhoc on demand multipath distance vector routing protocol (MMRE-AOMDV) to encounter limited battery and highly dynamic nature of nodes. The main idea of their work is to balance nodal energy consumption among nodes to avoid low battery nodes. The protocol has two main components; finding minimal nodal residual energy of each route using route discovery process and arranging them

in descending order to use route with maximum available residual energy to forward packets. The proposed model performs better than AOMDV protocol in packet delivery ratio because the energy is balanced among nodes. Furthermore, the lifetime of nodes is nearly 20% more than AOMDV.

Florina*et al.* [181] propose a multipath energy aware dynamic source routing protocol (MEA-DSR) to extend DSR. In order to have the update information in a routing cache, a cache update mechanism is implemented using probe packets. Furthermore, a round robin data scheduling is implemented among multiple paths to balance load and energy consumption. Among all possible paths from source to destination, node disjoint paths are considered. The paths are arranged according to energetic metric. This energetic metric is the cost function of entire path and it is considered when RREP travels through source to destination. The metric value is updated using cache mechanism for all the stored paths at the source. It is investigated that MEA-DSR consumes less energy as compared to DSR and the data packet delivery ratio is 10% more than DSR. However, the disadvantage of this protocol is a large overhead which consumes most of the residual energy especially at source nodes.

Sahar*et al*. [182] propose score based clustering algorithm (SBCA) to efficiently utilize the energy of nodes. The score values are based on remaining battery, neighbours, members and stability. This protocol finds the cluster heads depending on the neighbour nodes information. SBCA outperforms other methods if the node mobility and density is high because the cluster size doesn't vary a lot. Therefore, the energy consumption is less as compared to others. However, the disadvantage of SBCA is that due to dynamic nature of nodes, the network has different topologies at every instant. Therefore, the links and clusters break and re-establish quiet frequently which causes overhead and change in cluster head which degrades the overall performance of the system.

In [183] Subha*et al*. design a modified version of hybrid adaptive routing protocol for MANET (MHARP). The protocol uses local and global routing as modules to route the packets. The largest traffic is directed to nearby nodes using reactive routing protocols which achieves local routing; AODV, DSR etc. For global routing,

modified distance routing effect algorithm for mobility (MDREAM) is considered. In MDREAM, the sender forwards the packet to all one hop neighbours within a certain distance. Nodes calculate the region to determine the approximate location of destination to avoid redundant forwarding of packets. Local routing helps to increase packet delivery ratio by avoiding redundant flow. The end to end delay limits the coverage of reactive routing under large routes. However, the drawback of this technique is to have a constant uniform zone radius for all nodes. Therefore, it is needed to have a protocol that can dynamically optimize the zone radius.

In [184] Florina*et al.* propose an energy efficient optimized link state routing (EE-OLSR) mechanism in order to increase the life of the network. The key concept used in OLSR is the multipoint relay nodes (MPRs) who forward the broadcast messages during the process of flooding. MPRs are also used to generate the link state information. EE-OLSR uses three different methods to obtain energy efficiency: Energy Aware (EA) willingness setting, overhearing exclusion and energy aware packets forwarding. EA willingness considers energetic status of nodes into consideration. Each node calculates the energetic status and declares its willingness. Willingness is dependent on battery and the energy drain rate of a node. A heuristic is used to select an MPR depending on its willingness. As the MPR is selected, the next hop for data forwarding is considered using the metric of minimum drain rate. Overhearing exclusion turns off the device if a uni-cast message exchange happens in the neighbourhood as it saves a lot of energy. The advantage of this protocol is that it extends the lifetime of a network and the energy is consumed at lower rate. However, high bandwidth requirements and overhead due to route updates make the protocol less efficient as compared to other reactive protocols.

In [185] Lamia*et al.* present a rate based model that calculates the energy consumption rate in order to maximizes the network lifetime and improve the performance obtained through AODV routing algorithm. The model considers routing of packets through nodes with better residual lifetime. Lamia proposes an energy efficient metric that considers traffic at each node and its contribution in the network for forwarding data packets. However, the proposed mechanism increases network complexity due to source and network assistance which makes it expensive and inefficient.

La *et al.*[186] design an energy level based routing protocol (ELBRP) that considers the request delay framework and the remaining energy available at nodes. The idea of this protocol is that during routing process, nodes make the decision of forwarding packets depending on their energies. The delay request mechanism is to consider a node that is not a destination or has a path to destination in its routing table. The node holds a packet for a certain waiting period before it forwards it towards the neighbours in order to discards duplicate requests. The nodes with higher energy levels forward the packets earlier than nodes with lower energy levels. The route discovery mechanism is continued until a path from source to destination is discovered with high energy level nodes.

In [187] Usaha *et al.* propose an energy efficient path selection algorithm that aims to maximize the network lifetime and the minimizing the energy consumption of nodes in MANETs. The information about the remaining battery and energy consumption to forward packets is considered as state. Base on it, path is selected for the best performance. In [188] Kwang*et al.* describe an energy aware routing protocol named minimizing the maximum used power routing method (MMPR). The method optimizes two objectives; minimize the overall energy consumption and fair usage of energy among nodes. Authors consider the used energy a metric. If a node has multiple paths available towards destination a route cost is considered. A path with minimum route cost is considered to transmit packets. The proposed method optimizes the route by minimizing the maximum used energy which avoids the node that is over exhausted. Furthermore, the fair distribution mechanism optimizes the energy usage at each node; MMPR updates the route cost after each packet transmission and update the energy information received in route request. The procedure of route requests takes place at the source node, therefore the intermediate and destination nodes do not overload. However, the proposed technique used dynamic source routing (DSR) which makes the performance of the network less effective as duplicate route will be available to route packets.

In [189] the authors provide an energy efficient routing method comprises of QOS monitoring agents. These agents collect and measure that how reliable the link is based on link expiry time, probability based on how much a link is reliable, packet error rate over the link and the signal strength over the link. Furthermore, residual

battery power is implemented in order to maintain efficient energy network. Moreover, the route selection probability is measured based on the concept of fuzzy logic. The results show that the proposed method reduces energy consumption and improve packets delivery ratio.

In [190] authors propose a node disjoint on demand multi path routing protocol MMQARP. In the propose protocol, the routing decisions are made based on three different constraints: Delay, route life time and the energy. These constraints are used together to identify multiple paths that satisfy the requirements and only these paths become part of the routing table. The simulations results show that the proposed routing protocol improves the route life time, limits the energy consumed and reduce the jitter and delay as compared to AOMDV protocol.

In [191] authors propose an enhanced version of dynamic source routing protocol (DSR) based on Ant Colony optimization algorithm. The propose algorithm provides high data packet delivery ratio, low end to end delay with low routing overhead and low energy consumption. In the propose method, when a node wants to forward a packet to another node, like DSR, it checks the cache to look up for any existing routes. If there is no route, sender broadcasts the Route Request control packets (Req.Ant packets) to find the routes. This concept is pretty much similar to ants spread in different directions from their colony in search of food. When ants identify the food source, they return to the colony and leave a pheromone on their way so that other ants get informed about the paths. Similarly, in our routing scheme, Req.Ant packets propagate through the network based on route discovery scheme and gather the information of the route such as total length of route, congestion across the route and end to end path reliability, until it reaches to the destination. When destination node receives the Req.Ant packet, it sends back a Rep.Ant (Route Reply control packet) which carries the route information of Req.Ant to the source node through the same route. When source node receives such Req.Ant packets through different routes, it identifies the possible routes. Based on ant colony framework, the best route is selected using the pheromone level of the route. Similarly, authors calculate the pheromone level based on number of hops, congestion across the route and end to

end path reliability of the route. The route that has highest pheromone level is considered for data packet delivery.

3.2.3.4 Video Streaming Using Multiple Sources in MANETs

Authors in [193] presented two scheduling algorithms (serial and parallel) for multiple source video streaming in a mobile P2P architecture. In a serial scheduling, the server peer transmits the streamed data at the same time. However, in this case if the QOS receive at the receiver decreases, then the video source is changed with a new source and then the streaming sequence is synchronized with the time model. Whereas in parallel scheduling, multiple sources simultaneously handle a request of a receiving peer. Each node is assigned a transmission task based on block level bit assignment strategy. In this strategy, video sequence is first divided into series of different small blocks while the number of frames are fixed, then bits are assigned at block level such that relation between frames is considered. Both the scheduling techniques are called based on current situation of the network. The experiment results show that the propose method provides better video quality and reduces delay.

In [194] Utsu et al. combined MDC with multiple source transport to achieve smooth streaming of video over wireless ad hoc networks. In the propose method, MDC helps to stream the video over the disjoint paths to improve the quality of video at the receiving node. The experiment result shows that the propose method improves throughput and packet delivery reach ability. However, in this approach authors consider to provide a better effort service for video delivery therefore video synchronization and delays are not considered.

In [195] Qadri et al. propose a mesh based p2p streaming using MDC over MANETs for delivery of real time video. Authors encode the MDC video into two different descriptors comprising of odd and even frames which are sent over different paths. The descriptors are then decoded at the receiver using intra coded instantaneous decoder refresh frames. Authors also consider that each source node has an independent video description. The result shows that when a mesh based P2P is combined with MDC, the video quality improves and makes acceptable for ad hoc networks.

Table 3.5 Comparison of different routing techniques

Approach	Info. Used	Obj.	Adv.	Disadv.	Over. Comp.	Delay	Multi Path
Frias [172], cross layer prov. alg. (DSR)	Video	QOS among users	Streaming perform. is improved	Video freeze due to loss	High	Less	Yes
Wu [173], application centric routing	Video	Optimal routing path	Eff. util. of res.& main. playback	Video effected due to loss	Less	Less	Yes
Yi [174], link state rout. alg. with SVC	Video	Improve QOE	Reduce packet loss	B.L protected only	Slight High	Less	Yes
Monica [175], multipath DSR(MMDSR)	Video	Disc. diff. paths	Priority packets are given imp.	No strategy to handle packet loss.	High	Less	Yes
Vadiya [176], AODV with multiple alter. path routing protocol	Video	Establishment of multi. paths	Accept. quality is received	B.L has given more importance.	High	Less	Yes
Chapparo [177], DACMESV	Video	Provide QOSin MANET	Reduce network congestion	Video qual. deg. if net.is congested.	Slight High	Less	No
Mads [178], energy efficient routing (SPAN AFECA AODV)	Data	Energy efficient routing	Red energy cons. as compared to AODV	Packet loss occurs frequently	Less	Less	No
Yumei[180],multipath routing protocol (MMRE-AOMDV)	Data	Enc. limited battery & dynamic nat. of nodes	High packet del. ratio. More life time of nodes	Nodes with more energy consumed can leave net. at any time.	Less	Less	Yes
Florina [181] energy aware routing &round robin sched.	Data	Multi. path EDSR among nodes	Cons. less energy.	Large Over. that cons. most of node energy	High	Very Less	Yes
Sahar[182], score based clustering algo.(SBCA)	Data	Eff.energy util. of nodes	Less energy cons.	Sys. performance degrades	High	Less	No
Subha [183] modified hybrid adapt. routing protocol (MEHRP)	Data	Local &global rout. to route packet	Less packet del. ratio	Const. uniform zone radius of nodes.	Less	Very Less	No
Florina[184], energy eff. LSR (EE-OLSR)	Data	Incr. life of the network	Energy cons. at low rate	High b/width req. &over.	High	High	No
Lamia[185], rate based model (E-AODV)	Data	Imp. performance	Max. network life time	Incr. net. complexity	Very Less	Very Less	No
La [186], energy aware routing (ELBRP)	Data	Nodes for. req. based on energy	High energy level nodes trans. data	Video quality degrades rapidly.	Less	Less	No
Usaha [187] energy eff. path selection algo.	Data	To max. Net. lifetime &min. energy consumption	Nodes stay for longer	B/width at each node is not considered	Less	Less	No
Kwang [188] energy aware rout. protocol (MMPR)	Data	Min. energy cons.	Min. max. Use of energy to over.	Net. Perf. is deg. as dupl. route is available	Less	Less	No

			exhaustion				
[189] energy efficient routing method comprises of QOSmonitoring agents	Video	To measure link reliability	Red. Energy cons. & imp. packet del. ratio.	Upload B/width at peers is not considered	High	Less	Yes
[190] node disjoint multi path routing protocol MMQARP	Video	Routing dec.on delay, route life time & energy	Imp. route lifetime, limit energy & delay	High Overhead complexity	High	Less	Yes
[191] enhanced DSR based on Ant Colony opt	Data	Route discovery based on ACO	High del. ratio, low delay, energy cons. & over.	Multiple source trans. is not considered.	Less	Less	Yes
Authors [193] scheduling algo. (serial and parallel) using MDC	Video	To achieve better quality.	Prov. better quality & red. delay.	Energy at nodes is not considered.	High	Less	Yes
Utsu et al. [194] combined MDC with multiple source transport	Video	To achieve smooth stream.	Imp. throughput & packet delivery	Sync and delay are not considered	High	High	Yes
Qadri et al. [195] proposed a mesh based p2p stream. using MDC	Video	Del. of real time video	Video quality improves.	Energy at nodes is not considered	Less	Less	Yes

3.2.4 Discussion

The previous section reviewed different video coding and routing techniques to provide efficient streaming of the video over MANETs. In coding techniques, SVC and MDC coding are majorly considered to encode the video. The advantage of SVC is that it has less overhead complexity as compared to MDC. However, SVC is not preferable considered in MANETs as nodes change their positions randomly at each time interval that can cause change in the location of source nodes which eventually degrades the quality of a video if a transmission range of a source node increases.

Furthermore, in SVC, higher layers are strongly dependent on lower layers. Hence, if any of the lower layers is lost, the upper layers become useless until the lost layer is recovered and this effects on the quality of the video. On the other hand, MDC is considered to be a promising approach for streaming in MANET, because the sub-streams are not dependent on each other and can be decoded independently. This helps to maintain a better quality of a video over the random mobility pattern of nodes. Henceforth, a similar technique as MDC is considered in Chapter 5 while

studying video streaming across MANETs in which the video is coded at different layers such that each layer can at least able to maintain a lowest possible frame rate.

4 P2P STREAMING USING SVC

As discussed in Chapter 3, a p2p network is considered to be a promising approach to deliver live or on demand video among peers such as PPLive [9] and Cool Streaming [8] systems. It was also stated that in order to serve heterogeneous peers (variable bandwidth), a number of different coding schemes exist such as multiple descriptive coding (MDC) [15] or scalable video coding (SVC) [14]. However, there are still certain research questions that are open: What is an optimal streaming capacity of a p2p network; what type of configuration or topology is required to efficiently utilize the upload capacities of the network peers. The solution to the proposed questions is considered to be NP complete as discussed in [115].

Henceforth, this chapter considers an algorithm that exploits the properties of Scalable Video Coding (SVC) in order to minimize the upload bandwidth at each peer. *More specifically, streaming different layers of the same video from different peers is proposed*. The chapter defines an optimization problem to handle the upload bandwidth at each peer. Therefore, an approximation algorithm is proposed to solve bandwidth utilization problem. In addition, seed servers are introduced in order to deal with extra load in the network. The proposed model provides better performance as compared to the current approaches that use single layer video in combination with SVC. The simulation results of the proposed model are compared with the existing model in [115]. The results show that the proposed model improves diversity, increases average video quality, reduces the effect of churn and manages flash crowds.

The majority of this work has already been published in Springer Peer-to-Peer networking and Applications Journal.

4.1 Problem Formulation

To date, most research in this area has addressed single layer video streaming with limited research on multi-layered video. This chapter aims to minimize the upload stream from each peer and hence streaming of the video layers through multiple peers is considered. This introduces a variety of problems, the most complex of which is synchronization. This problem is not considered in this chapter and it is aimed to be addressed in the future work while this chapter mainly focuses on the capacity management across peers.

The major contribution of this work is to share the load among peers using SVC in order to minimize the upload bandwidth shared by each peer. Furthermore, seed servers are used in the network to handle the requests that peers cannot handle. A similar scenario as discussed in [116] has been considered to handle the video request. However, the authors focused towards the problem of managing the capacity of seed servers and shows that the solution to this problem is NP complete. Therefore, an approximation algorithm is proposed to solve the capacity management problem.

Table 4.1 summarizes the differences between the proposed approach to the idea proposed in [116] with the description is given as follows;

Table 4.1 Comparison between Proposed and the Existing Technique [116]

Existing Technique [116]	**Proposed Approach**
Seed servers capacity allocation problem is studied	Peers and seed servers capacity allocation problem is studied
Maximize the no. of requests served by the seed servers	Max the no. of requests served & Min upload capacity at each peer
Single source streaming using SVC	Multiple source streaming using SVC
Churn effect is not considered	Reduces the churn effect
Video quality of the existing peer is compromised to handle flash crowd	Video quality of existing peers is not compromised during the flash crowd
Load is not shared across the nodes	Multiple sources share the load and introduces diversity
Video's playback is not considered	Playback is considered as an important metric

- A linear optimization problem is proposed to efficiently manage the upload capacity at each peer.
- An algorithm is proposed to solve the problem that minimizes the available upload capacity at each peer by using SVC technique to stream layers through multiple peers. Furthermore, if the peers are not able to handle the requests, the seed servers are used to handle the request.
- It has been shown that the propose algorithm helps to reduce the effect of churn and improves playback continuity. If a sending peer leaves the network, the requesting peer still receives the video at a lower rate without any playback delay.
- Furthermore, it has been observed that the proposed method efficiently manages the peer's upload capacity, if a flash crowd enters the network.

4.2 System Design and Mathematical Model

In this section, the system design of the proposed p2p network is discussed along with a mathematical model is presented to formulate the capacity allocation problem.

4.2.1 System Design

The proposed p2p streaming network is shown in Figure 4.1. The network consists of seed servers, peers and trackers.

Seed Servers are the dedicated servers that handle the requests coming from the newly joined peers if the available upload capacity at peers is fully utilized. Peers join the network in order to form overlay architecture. Each peer maintains a neighboring relationship among other peers and shares a periodic update of the data available at peers.

Trackers are located at different locations and are used to handle the requests made by the peers within the network. Whenever a new peer joins the network, it contacts one of the trackers to which it sends the requests for the required video. Furthermore, the trackers queue the requests received from the requesting peers and assign these

requests to sending peers in a manner that the upload bandwidth can be efficiently managed. If the peers do not have the available capacity to serve more requests, then the requests are handled by the seed servers.

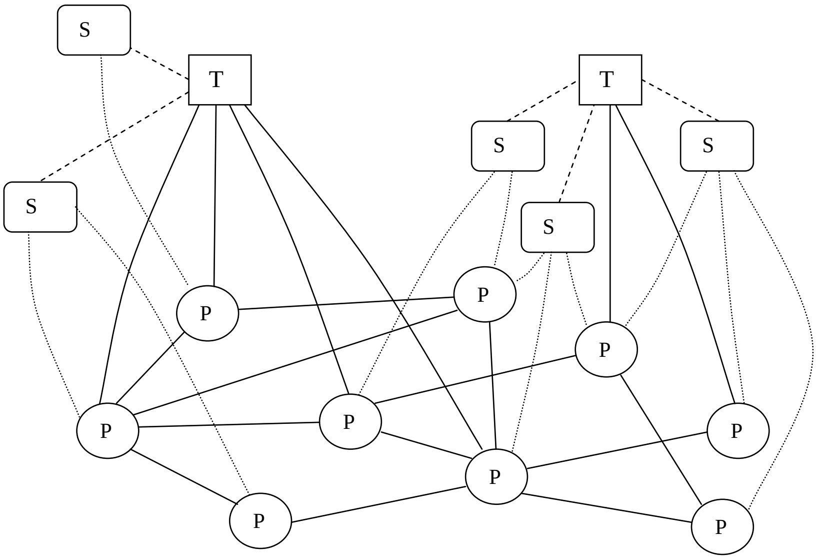


Figure 4.1 Proposed P2P network model

Table 4.2 List of Notations

Variables	Descriptions
V	A video *V* for streaming within p2p network
V	Small video segments of a single video *V such that v Ɛ V*
K	Total number of requests made by newly joined peers
req_k.,$req_{k,j}$	k^{th} request in queue, sub-request for requested layer *j*
n_k	Number of layers in a particular video segment
r_{v_l}	Bit rate of l^{th} layer of video *v*
u_p	Upload capacity of peer p
$b_{k,j}$	Utility benefit gained by serving layers in the network
$c_{k,j}$	Cost of the seed server to serve peer's request *k*
C	Seeding Capacity of the seed server
x_k	*k* requests to be served out of total sub requests to maximize utility
P	Set of peers who have a complete video available to share
L	Set of layers available for a particular video
n_{p_i}	Number of layers peer *i* can share
T	Sum of the total upload capacity shared by each peer
$a_{i'}$	Set of peers with the available upload capacity to share
$a_{i''}$	Set of peers with no available upload capacity to share

4.2.2 Problem Description

Let V represent a video that exists on a p2p network. A video is further sub-divided into small video segments v such as ($v \in V$). It is assumed that number of layers during a particular segment is constant however it may vary within different segments. For example, segment 1, may have 2 layers while segment 2 may have 5 layers. Furthermore, it is assumed that each peer has a constant number of layers for a particular segment. Hence peers i and j will have the same number of layers for a particular video segment v. This assumption is made to simplify the problem as it is not the main objective of this research. The main objective is to distribute the load among different peers in the network. It is assumed that there are K requests being made by the peers. Each request req_k is in the form $\{req_k.p,\ req_k.v,\ req_k.t,\ req_k.l_1,\ req_k.l_n\}$, which states that the newly joined peer p is making a request $req_k.p$ to receive layers $req_k.l_1$to $req_k.l_n$of a video segment v such that $req_k.v$, during the time t of segment $req_k.t$. However, it is possible that all layer requests are not served by the peers and hence these requests are forwarded to the seed servers.

Each request from a peer $req_k.p$ looks for $n_k = req_k.l_n - req_k.l_1 + 1$ number of layers from the set of peers or seed servers that already have the video. The request is further subdivided into n_k sub-requests, denoted by $req_{k,j} (1 \leq j \leq n_k)$. Each sub-request represents a request for a particular layer from a peer, i.e. $req_{k,1}$ is a request for a base layer. So, $req_{k,j}$ represents the requests for all possible layers $req_k.l_1$through $req_k.l_1 + j - 1$. The breakage of the video requests into further sub-requests helps to manage the upload capacity at each peer.

In the network, the requests are at first handled by the peers until there is enough available upload capacity. However, if the available capacity at peers is fully utilized, seed servers handle the new requests. If a request is handled using a seed server, a certain cost $c_{k,j}$ is introduced that is equal to the sum of total bit rates of the j requested layers. The total cost of req_k's sub requests for the requested video segment v in req_k can be represented as follows:

$$c_{k,j} = \sum_{l=req_k.l_1}^{req_k.l_1+j-1} r_{v_l} (1 \leq k \leq K,\ 1 \leq j \leq n_k) \tag{4.1}$$

where equation (4.1) shows that serving a particular request for a video using a seed server incurs a cost. Using the concept of $req_{k,j}$, a utility benefit is gained that is represented by $b_{k,j}$. The utility benefit attained consists of serving the required layers to the requesting peers. It can be represented as $\sum_{l=req_k.l_1}^{req_k.l_1+j-1} b_{k,j}(req_k.p, l)$.

4.2.3 Mathematical model for Capacity allocation & Peer's Upload Capacity Management

Assume a total number of *k* requests, req_1,... req_k, are queued at the tracker. In order to serve each request, the peers or seed server has a certain cost $c_{k,j}$ in bits per second (bps), utility $b_{k,j}(1 \leq k \leq K, 1 \leq j \leq n_k)$, and a seeding capacity C bps, find x_k ($0 \leq x_k \leq n_k$), which indicates that the following sub-requests $req_{k,1}$, ... req_{k,x_k} are to be served out of total request req_k to maximize the system wide utility. Furthermore, the upload capacity of each peer is considerably smaller than the download capacity. In order to efficiently utilize the upload capacity u_p available at each peer *p*, the goal of minimizing the upload capacity u_p served by each peer to handle a particular request for the video segment *v* is considered.

It is assumed that when a request for a video is made, tracker identifies the network with a set of all possible peers *P* where *P* = $\{p_1, p_2 \ldots p_m\}$ that has a particular video available. Each peer in a set *P* has a certain upload rate $u_p = \{u_{p_1}, u_{p_2}, \ldots\ldots u_{p_m}\}$ and can transmit different layers L=$\{l_1, l_2 \ldots l_n\}$ at a streaming rate of $r_{v_l} = \{r_{v_{l_1}}, r_{v_{l_2}}, \ldots..\ r_{v_{l_n}}\}$.The mathematical problem can be formulated as:

$$\text{Max} \quad \sum_{k=1}^{K} b_{k,x_k} \tag{4.2a}$$

$$\text{s.t} \quad \sum_{k=1}^{K} c_{k,x_k} \leq C \tag{4.2b}$$

$$\text{Min} \quad u_{p_i} \tag{4.2c}$$

$$\text{s.t.} \quad u_{p_i} \geq r_{v_{l_j}} \tag{4.2d}$$

$$x_k \in \{0,1,\dots,n_k\}, (1\leq k \leq K), u_{p_i}(1\leq i \leq \mathrm{m}), \quad r_{v_{l_j}}(1\leq j \leq n) \quad (4.2e)$$

Where equation (4.2a) indicates that x_k sub-requests are served out of a total available requests for the different layers by the seed server in order to maximize system wide utility. Similarly, equation (4.2b) applies the condition that the total cost of serving particular sub-requests should be less than the total upload capacity of that particular seed server. Equation (4.2c) indicates contribution towards maintaining the peer's upload capacity by minimizing the upload capacity shared at each peer. However, a condition is applied (as shown in equation (4.2d)) that the upload capacity available at each peer should be greater than or equal to the rate at which the layer is streamed.

4.3 Proposed Solution

An approximation algorithm to solve the optimization problem as discussed in the previous section is proposed. The objective of the proposed algorithm is to maximize the number of requests served by the peers or seed servers while efficiently utilize the available upload bandwidth at each peer. However, if the peers' capacity is already utilized, seed servers handle the requests. In order to distribute the load, video streaming using multiple peers is considered such that the playback latency of the requesting peers is maintained.

The proposed algorithm handles the video requests made by the newly joined peers and distributes the load across multiple peers using the equation (4.2c) such that the uplink capacity served by each sender peer is minimized. The constraint of (4.2c) is that only those peers can participate in the streaming session to serve the requests whose uplink capacity is greater than the rate at which a particular layer is streamed. In order to estimate the number of layers shared by each sender peer in a set *P*, it is first necessary to find how many layers each peer has a tendency to share based on its available upload capacity. Let $n_{p,i}$ represent the number of layers that a peer *i* can share, i.e. $n_{p,1}$=3 means that there are three layers that peer 1 can share of a particular video segment among other peers. The video is SVC coded into different layers where each layer adds a certain quality to the video. Further, it is assumed that the rate at which a layer is streamed from a peer is constant i.e. the rate for a base layer or an enhancement layer is equal.

$$n_{p_i} = \frac{u_{p_i}}{r_{v_{l_j}}} \qquad (\text{j=1}) \qquad (4.3)$$

Equation (4.3) explains that the number of layers each sender peer in a set P can share to the newly joined peers in the network. Consider a simple example comprises of three sender peers with the same video as represented in set $P = \{p_1, p_2, p_3\}$. Each sender peer has an upload rate at which it can upload the video V such as $u_p = \{128kbps, 256kbps, 512kbps\}$.The video is SVC coded into four different layers such as L=$\{l_1, l_2, l_3, l_4\}$ whereas each layer is considered to have a same rate as given in $r_{v_l} = \{64kbps,\ 64kbps,\ 64kbps,\ 64kbps\}$. Hence, the total number of layers shared by each sender peer is calculated using equation (4.3) is given as in $n_{p_i} = \{2,4,6\}$.

According to the proposed algorithm, the aim is to minimize the upload capacity shared by each peer in the network. In order to achieve this, the algorithm is categorized into two different cases to stream the video. The first case represents that the number of the peers with the video are more than the total number of layers of the video. Whereas the second case represents that number of peers with the video is less than the actual number of layers for a particular video. The detail explanation is given below.

4.3.1 Case 1 (Number of peers ≥ Number of Layers)

In the first case, it is assumed that the total numbers of layers of a particular video segment are less than the total number of peers available in a set P. In this case, the upload capacity can be minimized at each peer by distributing the load and transmitting one layer from each peer. However, the condition in equation (4.2d) that explains that only those peers can participate in the overlay whose uplink capacity is greater than the layer stream rate needs to be fulfilled. The distribution of the video layer's is based on the equations discussed as follows:

For $n_{p_i} = 1$

$$u_{p_i} = r_{v_{l_j}} \tag{4.4a}$$

For $n_{p_i} > 1$

$$u_{p_i} = \{u_{p_i} - \sum_{j=1}^{n_k - 1} r_{v_{l_j}}\} \tag{4.4b}$$

These equations are used in the proposed algorithm (as given in Fig 3 for case 1 with different values ofn_{p_i}). Firstly, equation (4.4a) checks that if the value of n_{p_i} for a selected peer is equal to one, the particular peer transmits only one layer. Secondly, if the value of $n_{p_i}$is greater than one, this means that a selected peer has a tendency to transmit more than one layer. In this case, equation (4.4b) applies over the selected peer such that only one layer is transmitted using that peer. Furthermore, the available upload capacity of the selected peer is subtracted by the layered stream rate. This identifies that the selected peer still has the remaining upload capacity to handle more requests.

The total upload capacity required to share for a particular video segment is measured by summing all the upload capacities shared by different peers in a set P as indicated in equation (4.4c).

$$T = \sum_{i=1}^{m} u_{p_i} \tag{4.4c}$$

4.3.2 Case 2 (Number of peers < Number of layers)

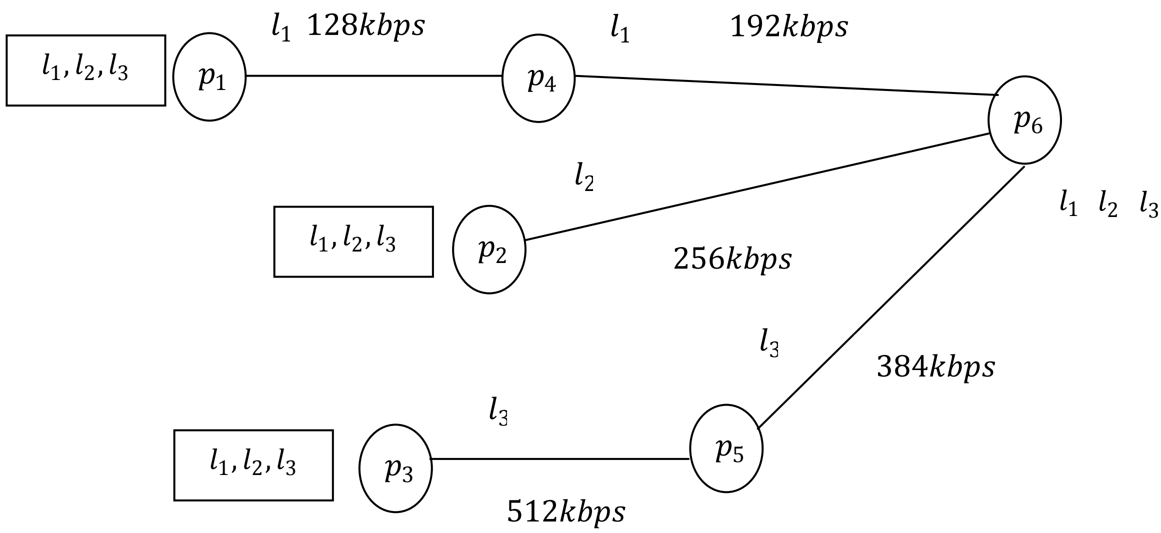
In this case, it is considered that the number of layers for a requested video segment is greater than the number of peers in a set *P*. Each peer in a set *P* has a tendency to share their resources upon request from the newly joined peers. In order to maximize the average video quality at the requesting peer, it is necessary to receive as many layers as possible. However in this case, there are less peers available that have the content in set *P*, therefore it is required that some of the peers have to share more than one layer in order to achieve the desired quality level. The algorithm for the second case uses similar equations (4.4a) and (4.4b) and the working of the algorithm is

shown in Figure 4.3. The difference in this case is a subtraction of the number of layers available at each peer by one, when all the peers in a set P transmit the first layer. In the algorithm, it is further checked which peers are in a set P still has the capacity to share layers. The total upload rate of a video can be measured by summing up the upload rates from each peer as in equation (4.4c).

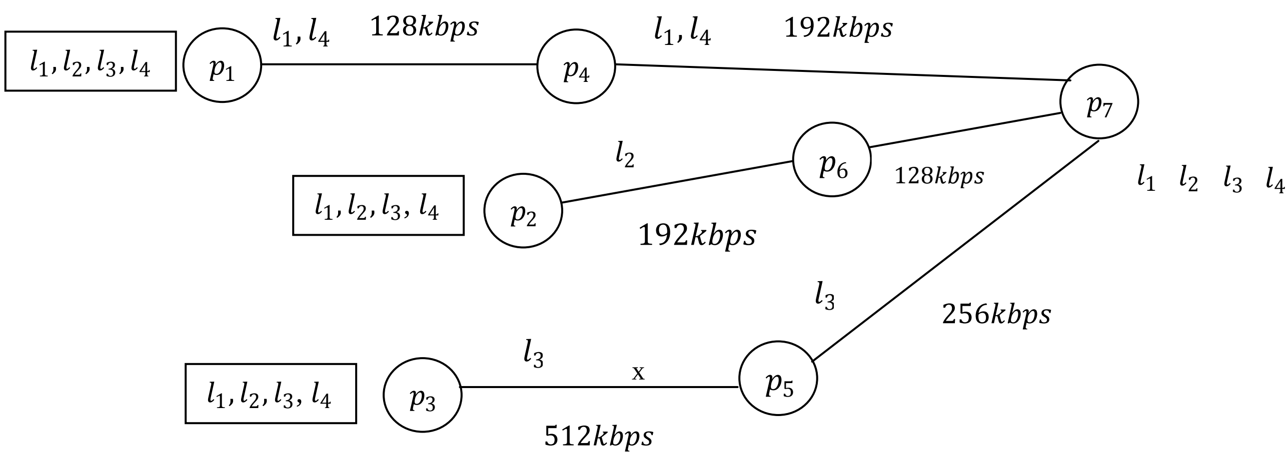
Consider a simple example as given in Figure 4.2 to understand that how the uplink capacity across each sender peer is minimized whereas the average video quality received at the receiver is maximized. It is assumed that the network comprises of five different peers connected with each other to form an overlay. Let suppose that p_6 joins the network and makes a request for a video v_1 comprising of 3 layers $L = \{l_1, l_2, l_3\}$ whereas each layer is considered to have a same layer rate as r_{v_l} = $\{64kbps$,$64kbps$,$64kbps\}$ as in Figure 2(a) for case 1. The request is forwarded to the tracker T that identifies that there are three sender peers P = $\{p_1, p_2, p_3\}$ that have v_1 and maintains the playback withp_6. Each sender peer has an upload capacity that is given by u_p= $\{128kbps, 256kbps, 512kbps\}$.Hence, the total number of layers can be shared by each sender peer are n_{p_i} = {2,4,6}. For case 1, the numbers of sender peers should be greater than or equal to the number of layers need to be streamed. The example show that there are 3 peers with the video that maintains the playback and the video comprises of 3 different layers. So for this case the algorithm works to disseminate at least one layer from each sender peer using multiple paths. In this way, the upload capacity across each peer is minimized and p_6 receives v_1 with all 3 layers.

Similarly in Case 2, the number of peers with the video is less than the total number of layers to share. Consider an example as shown in Figure 2(b), p_7 joins the network and requests for video v_2 comprising of four layers L=$\{l_1, l_2, l_3, l_4\}$ whereas each layer is considered to have a same layer rate as r_{v_l} = $\{64kbps$, $64kbps$, $64kbps$, $64kbps\}$. Tracker T identifies that there are three sender peers P = $\{p_1, p_2, p_3\}$ that have v_2 and maintains the playback with p_7. Each sender peer has an upload capacity that is given by u_p= $\{128kbps, 192kbps, 512kbps\}$.Hence, the total number of layers can be shared by each sender peer are n_{p_i} = {2,3,6}. So, the network has 3 sender peers that needs to share video v_2 made up of 4 different layers. In this case,

the algorithm works to disseminate one layer from each peer but as the number of layers are more than number of sender peers so p_1 shares two layers however the uplink capacity across each peer is still minimized and p_7 receives all four layers.



a. Case 1 (No. of peers ≥ No. of layers)



b. Case 2 (No. of peers < No of layers)

Figure 4.2 Working of the algorithm, **a.** Case 1, **b.** Case 2

// **Input:**
//*K*: number of requests, *L*: no of layers for video *V*, *P*: set of peers with video *V*
// n_{p_i}: number of layers at p_i, u_{p_i}: upload capacity at p_i, r_{v_l}: rate at which a layer *l* stream
// **Output:**
// x_k**:** number of sub requests (layers) served for request # *k*
1. **First Case if** (P ≥ L) **then**
2. $n_{p_i}, a_{i'}, a_{i''}$ // Defining arrays
3. **While** ($n_{p_i} \neq 0$) **do**
4. **If** (n_{p_i} = 1) **then**
5. $u_{p_i} = r_{v_l}$ // a layer *l* is transmitted at the rate of r_{v_l}
6. $x_k = x_k + 1$ // the sub request is served
7. **else if** (n_{p_i}> 1)
8. u_{p_i} = [$u_{p_i} - \sum_{l=1}^{n_k} r_{v_l}$] // u_{p_i} is updated by subtracting r_{v_l} from actual u_{p_i}
9. $u_{p_i} = r_{v_l}$
10. $x_k = x_k + 1$ // the sub request is served
11. $a_{i'} = n_{p_i}[1: length(l)]$ - 1 // subtracting layers from peers in a set *P* who share the video
12. $a_{i''}$ = n_{p_i}(*length*(*l*)+*1: length*(*P*)) // Peers who do not contribute from set *P*
13. n_{p_i}[ ] = [$a_{i''}$ $a_{i'}$] // combine both arrays to generate new updated array of n_{p_i}
14. **Second Case if** (P < L) **then**
15. $n_{p_i}, a_{i'}, a_{i''}$ // Defining arrays
16. y = L // defining a variable y equals to number of layers of *V*
17. **While** ($n_{p_i} \neq 0$) **do**
18. a: **If** (n_{p_i} = 1) **then**
19. $u_{p_i} = r_{v_l}$ // Same as 5
20. $x_k = x_k + 1$ // the sub request is served
21. y=y-1; // Subtract by 1 represents that a layer is transmitted
22. **else if** (n_{p_i}> 1)
23. u_{p_i} = [$u_{p_i} - \sum_{l=1}^{n_k} r_{v_l}$] // same as 8
24. $u_{p_i} = r_{v_l}$
25. $x_k = x_k + 1$ // the sub request is served
26. y=y-1;
27. $a_{i'} = n_{p_i}[1: length(P)]$ - 1 // subtracting layers from peers who shared
28. **If** (y>=1)
29. **go to** a
30. **else** Generate a new array for n_{p_i}
31. **return**x_k[] // the total number of sub requests served for request *k*

Figure 4.3 Proposed Algorithm

4.3.3 Complexity Analysis

The complexity analysis of the proposed upload capacity management algorithm is discussed in this section. The algorithm receives K requests for a video playback, it in turn breaks these K requests into smaller sub-requests which consist of L layers, and here L is the average number of layers per video. There is a one off cost in determining the set P – the number of source peers, which is assumed that they are already available to the algorithm. The algorithm executes L iterations per request, which gives a complexity of $O\ (KL)$ iterations. Hence, the performance of the algorithm is proportional to load (K requests) and the number of layers (L) for each video.

4.4 Parameters to Design the P2P Network

In order to design an efficient p2p streaming system, there are some important parameters that need to be considered. In the proposed model, the playback latency of a video, flash crowd and the average video quality are considered as important parameters to stream video content through multiple peers. The description of these parameters is stated as follows.

4.4.1 Playback Latency

In order to maintain the playback latency, it is necessary to maintain a certain playback delay constraint. The playback delay constraint is equal to the sum of the propagation delay across each hop count and the total transmission delay from a sender peer to the receiving peer. This chapter focuses on minimizing the upload capacity shared by each sender peer in the network. However the sender peers are located at different geographical locations, therefore it might be possible that the requesting peer picks up a sender peer that is available quiet far away from it. The

disadvantage of streaming the video using that particular sender peer is that it produces an excessive delay and causes latency issues.

In order to resolve this issue, the possible solution is to stream the content using the sender peers that maintains the playback latency with respect to the requesting peer. Therefore, the proposed model consider streaming the video from only those sender peers from a set P (sources with similar videos) whose streaming delay is less than the playback latency set for a particular video segment at the receiver node. There are number of different scheduling techniques are available which can be used to maintain the playback latency in the network. However, the focus of this chapter is towards the upload capacity utilization and the scheduling technique is not considered.

In order to consider a sender peer to stream a video segment, the total streaming delay is measured and compared against the playback latency set for the receiver. The streaming delay is the sum of the total transmission delay as in equation (4.5) plus the propagation delay. The transmit delay required for a video packet to be forwarded to the next hop neighbor is given as in equation (4.5);

$$TD_{N_i N_{i+1}} = \frac{Segment\ \ Size}{u_{p_i}} \tag{4.5}$$

Equation (4.5) determines the transmission delay to transmit a video segment from a sender peer i to its neighboring peer i+1. However, the total delay for a video to stream is measured using equation (4.6) which is equals to the sum of total transmission delay $TD_{N_i N_{i+1}}$ and the propagation delay TP_i between the numbers of hops encountered in between source to destination peer. It is known that the transmission delay is significantly larger than a propagation delay and has more effect over the playback latency. Therefore, the effect of the propagation over the network is neglected.

$$D = \sum_{i=1}^{N-1} (TD_{N_i N_{i+1}} + TP_i) \tag{4.6}$$

In order to have a smooth video playback, it is necessary that each peer should meet the playback condition as in equation (4.7). If the condition is not met, peers are not considered for streaming the content.

$$D < Playback\ Latency \tag{4.7}$$

4.4.2 Average Video Quality

In order to measure the average video quality received by peers, it is necessary to measure the rate received by the requesting peers. If the peers received the video at higher rates, the average video quality received will be high. As, SVC is used to encode the video into different layers, hence the average video quality depends on the number of layers received. In order to estimate the average video quality, the peak signal to noise ratio (PSNR) is calculated as follows;

$$PSNR = 10\ log_{10} \frac{(MAX)^2}{\text{MSE}} \tag{4.8}$$

$$where\ MSE = \frac{1}{L}(MAX(L_a) - MAX(L_b))^2 \tag{4.9}$$

In equation (4.8), the value of MAX represents the maximum quality at which the video can be received and MSE represents the mean square error between the maximum and the received video quality as calculated using equation (4.9). It is further divided by L in equation (4.9) in order to find the actual video quality based on each layer.

4.4.3 Flash Crowd

In a flash crowd, a large number of peers enter the network at the same time creating an excessive demand on the playback. In order to handle the flash crowd, the upper bound on the maximum number of peers that can encounter is calculated. Therefore, two different approaches are considered to accommodate the flash crowd: (i). Serve

the existing peer's with the same video quality as before and accommodate the crowd using the remaining upload capacity at the sender peers; and (ii). Reduce the average video quality receives at the existing peers such that more number of peers can be accommodated during flash crowd. However, the second method is not much considerable because it depreciates the quality of the video received at the existing peers.

In order to measure the number of peers that can be accommodated during a flash crowd, n_{p_i} is calculatedthat represents the total number of layers a peer i can share within a p2p network;

$$N_{PFC} = \sum_{y=1}^{size\,(P)} n_{p_i}[y] - \sum_{y=1}^{size\,(P)} n'_{p_i}[y] \quad (4.10)$$

In equation (4.10), the first term represents the tendency of each sender peer to serve the number of layers based on the available upload capacity whereas the second term represents the number of layers that were already shared by the sender peers before the flash crowd enters the network. The subtraction of these two terms measures the upper bound on the number of peers which can be served during a flash crowd.

4.5 Numerical Evaluation and Results

In order to study the advantages of the proposed p2p streaming model, the model is numerically evaluated and a number of simulations are run using MATLAB. The numerical evaluation and results validate that the propose model improves the average video quality by distributing the load among peers which introduces diversity within the network. Furthermore, the model is compared against the existing SVC-NC, SVC and SL p2p streaming systems as discussed in [115]. The simulation results show that the propose algorithm achieves better average video quality, reduces the churn effect and facilitates dealing with a flash crowd.

4.5.1 Numerical Evaluation

In this section,, the performance of the proposed model is evaluated for the different cases of the algorithm discussed in Section 4.3.2. The first case describes the number of peers that can handle a request are greater than or equal to the total number of requested SVC layers. For example, if a network has 10 or more peers that have the available upload capacity and maintain the playback latency for the requesting peer, then, the best possible solution is that each peer shares at least one layer in order to minimize the upload bandwidth. Whereas in the second case, the number of available peers to stream the video to the requesting peer are less than the total number of SVC coded layers. For example, if a request is made to stream a video that comprises of 10 SVC layers and there are only 5 peer that has the available content and maintains the playback latency. In order to distribute the load, the best possible solution is to stream at least two layers from each peer. The performance is compared against the existing SVC-NC, SVC and SL model as discussed in [115].

To investigate the models, a network of 100 mesh nodes connected with each other to form an overlay network is considered. It is assumed that among these nodes, 10% of the nodes have the requested video. Each peer is considered to have a heterogeneous upload bandwidth available. The upload bandwidth varies within the range of 200kbps to 300kbps and it is randomly distributed among the peers in the network. A 10 minutes video is requested by the newly joined peers from the peers available in a set P with the requested video. It is assumed that the video is further broken into 10 different 1 minute segments. Each segment is scalably coded into L=10 different layers, where each layer is assumed to be 64kbps. So, the total upload bandwidth required to stream the video at the highest quality will be 640kbps.

The algorithm is shown in Figure 4.3 that is used to determine the working of both the cases as discussed below. In order to better understand the performance of the proposed algorithm, only those peers are considered which actually participate in streaming the video to the requesting peers.

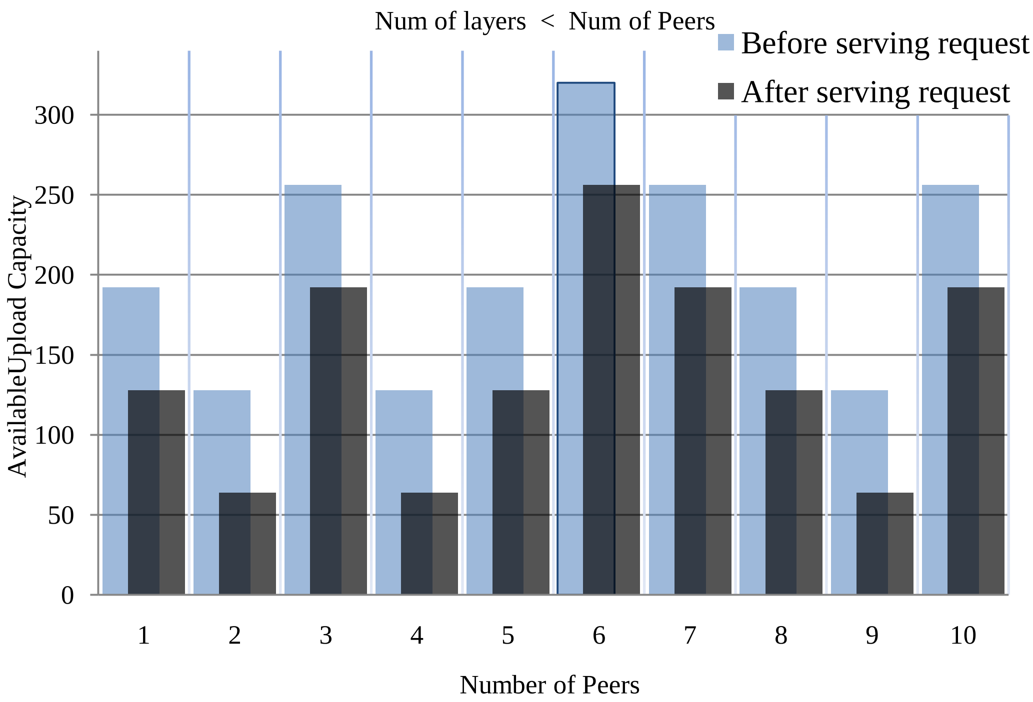


Figure 4.4 Case I (number of peers are greater than number of layers)

Figure 4.4 shows the result for case 1 in which the number of peers are greater than number of SVC layers for the video. It is assumed that the network has more than 10 uploading peers available in a set *P* which maintain the playback time to stream a video comprises of 10 SVC layers. The first set of bars represent the total upload capacity available at each peer in a set *P* before a new peer's makes a request for the video. Whereas, the second set of bars represent the remaining upload capacity after a request is served by the peers. As shown in the figure, each peer has a tendency to share different layers of the video where the aim is to distribute the load across the peers in order to minimize the upload bandwidth shared by each peer. Hence, each peer is considered to share one layer of the video.

In a similar way, Figure 4.5 represents the graph for the second case of the proposed algorithm. In this case, a video comprises of 10 SVC layers is streamed using 7 different peers available in a set *P*. The left bars represent the total number of layers each peer can share before a new request is served. Whereas, the right bars represent the remaining available layers in a set *P* after the newly joined peer is served. As shown in the figure, the number of peers are less than the number of layers, therefore,

each peer has to share more than one layer in order to minimize the upload bandwidth shared by each peer.

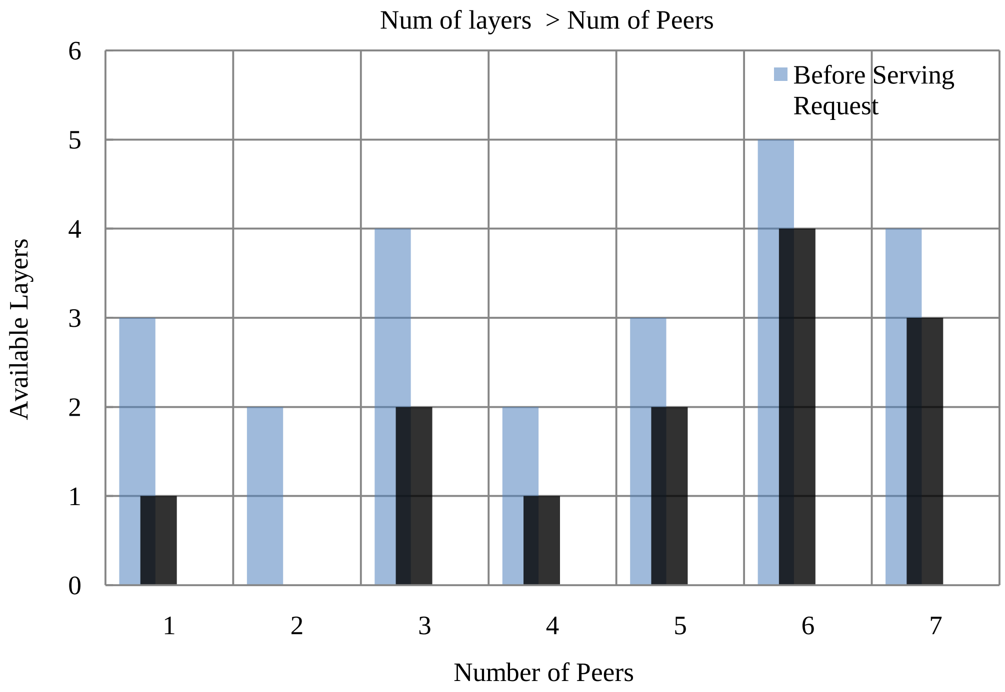


Figure 4.5 Case II (number of peers are smaller than number of layers)

Figure 4.6 shows that how a request for a video with 10 layers is handled by the peers available in a set *P* using [115] for the case of SVC-NC and SVC. The left bar represents the number of layers peers can share before a request arrive and the right bar represents the number of remaining layers peers can share after a request for a video is served. The figure shows that the first three available peers in the set *P* will totally utilize their upload capacities to serve the request layers because there is no capacity management or load management mechanism is involved in it.

The advantage of the proposed algorithm is that if the seed peers leave the network, the remaining seed peers can still stream the requesting peer at the same or lower rate. However, in case of S.L system if a peer drops out then the video gets delayed until a new streaming peer is available to stream. Similarly, the number of layers received by each peer also depends on the available upload capacity of the peers. If the peers are not able to send the video to the requesting peer at the required rate as illustrated in Figure 4.7 then the remaining layers are served using seed servers that help to achieve

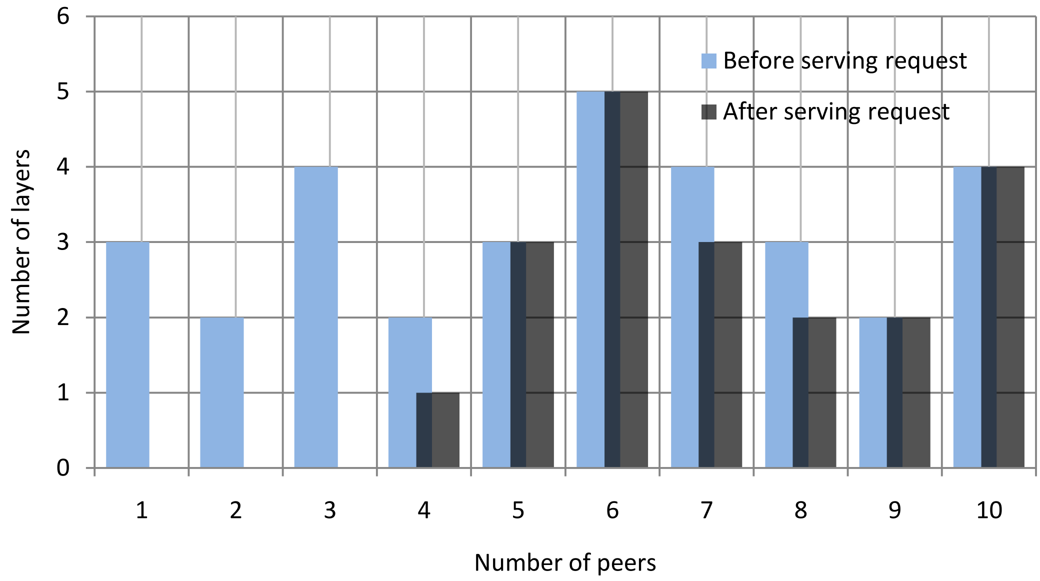


Figure 4.6 Serving a video request using SVC-NC and SVC [115]

required rate and increase overall system capacity. Figure 4.7 represents two lines; the dotted line represents how many layers each peer can receive using the total available upload capacity across the sender peers in the set *P*. For example, it is considered a network in which 36 peers are making a request to receive a same video *V* and the total upload capacity available at the sender peers in a set *P* is varied from 0-24kbps. The figure shows that at an upload capacity of approx. 24kbps, 36 peers can receive the complete video with all 10 layers such that the each layer has a rate of 64kbps. However, if the total available upload capacity among the peers is halved at around 12kbps then each peer can receive only the first four layers.

On the other hand, the solid line represents how many peers are able to receive the video with all 10 layers at a rate of 640kbps. In order to understand that the number of layers are fixed to 10 and varied the upload capacity among sender peers from 0-24kbps. The figure shows that if the total available capacity is 24kbps, all the 36 peers who make the requests are served at full rate with all the 10 layers. However, if thesum of the total available upload capacity among sender peers is decreased to 10.6 kbps then only 16 peers are able to receive the video at the full rate. While the remaining peers starve for the video.

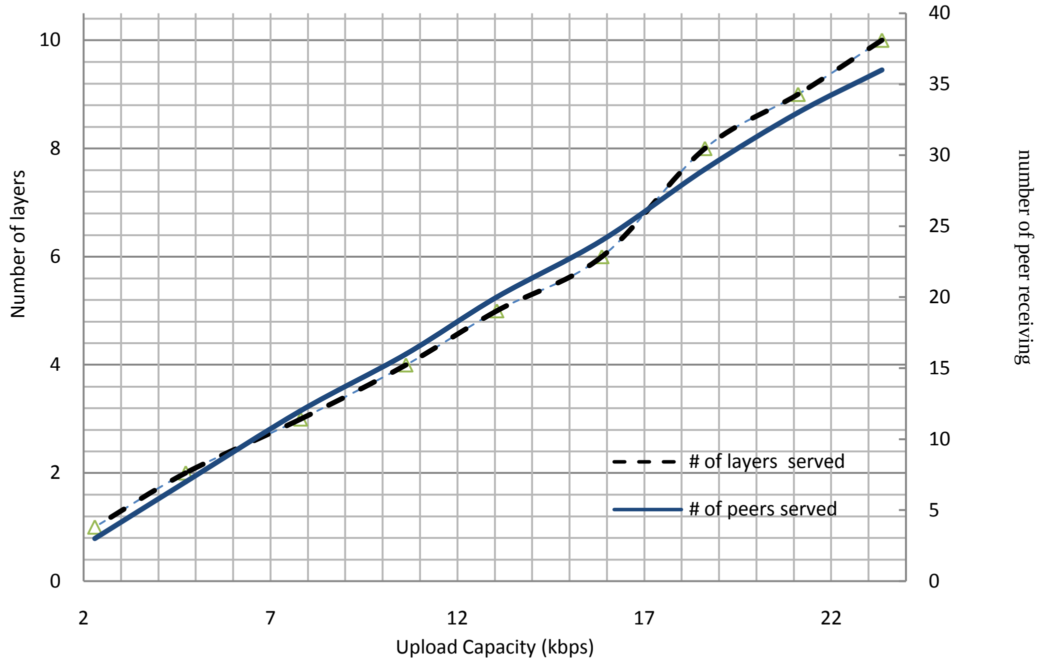


Figure 4.7 Upload capacity vs. number of peers / layers

The advantage of the proposed model is that the load is distributed and each peer can still receive the video even at the lower rate. This helps to introduce diversity in the network. In order to study the problem, only one condition of admission control is considered to share the available capacity among each peer. However, there can be different admission control policies can be used such as bandwidth is shared among a few peers and the rest are blocked from streaming. Another policy will be to share a certain level of layers among each peer and later on increase it, depending upon the available upload capacity at network traffic.

4.5.2 Results

In order to validate the results, a network comprising of 1000 nodes with the heterogeneous upload bandwidths located at different geographical locations is created. The contributed upload capacity of each peer is considered to be in between the range of 150kbps to 1000kbps using the distribution given in [22].For the performance study of the model, against churn and flash crowd it is assumed that peers can randomly join or leave the system at any time based on different

probability distributions. Each section has different setting for the peer distribution with the detail description.

A 10 minute video is SVC coded into 5 different layers with a frame rate of 30fps. The resolution of the video is CIF (352x288) and each group of pictures is made of 16 different frames. The proposed model is compared against the existing SVC-NC, SVC and SL model as discussed in [115].The results are obtained in order to measure the impact of different system parameters on average video quality received as measured using the peak signal to noise ratio (PSNR). Hence, the proposed model is tested during churn, without churn or flash crowd and under flash crowd.

4.5.2.1 Churn Effect

The churn rate is stated as the rate at which a certain amount of peers enter or leave the network. It is an important metric to consider the behavior of the p2p streaming system. So, at different time intervals, the peers leave or join the network that eventually degrades the average video quality. In order to test the proposed model against the effect of churn, the model is compared against the model proposed in [115] that uses SVC-NC, SVC and SL streaming models.

In a dynamic network of heterogeneous peers, a large number of peers join or leave the network at the same time. Therefore, the available upload capacity at peers varies at all times within the network. Whenever a peer joins the network, it shares it resources with other peers in the network whereas at the same time another peer may depart the network which results in reducing the average streaming quality. One method to study the effect of churn is to estimate the online and offline time of peers in the network. If a peer has more online time, then it can be available in the network for most of the time which means that it has less effect of churn whereas if it stays offline for a longer time, the churn rate is higher. Another method to study the churn effect in the network is by estimating p number of peers that leave or join the network during a certain time.

This chapter considers the second method to study churn effect and compared the results in Figure 4.8 with SVC-NC, SVC and SL streaming systems. Similar to [115], it is considered that all the arrivals and departures are distributed according to a Poisson distribution. The ratio of the number of arriving peers to the number of peers departing during the time of simulation is considered as the churn rate. The churn rate in between the values from 1 to 8 such that a churn rate of 2 means that if x number of peers leave the network then 2x peers join the network at the certain time.

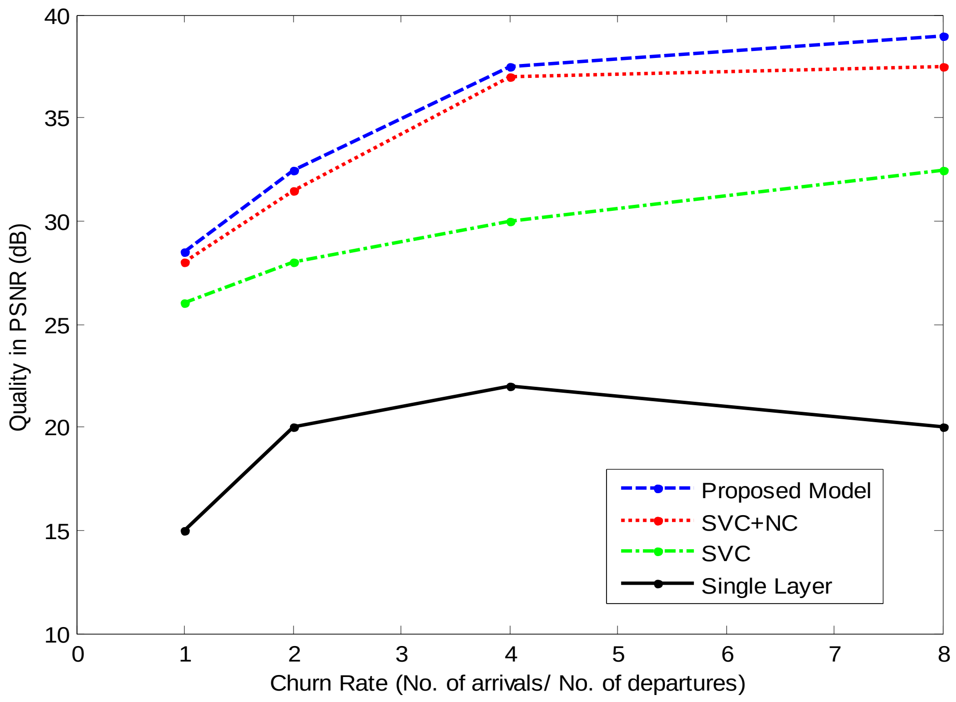


Figure 4.8 Churn Effect on p2p network

Figure 4.8 shows that the proposed solution performs better than the other presented solutions because in our case the load is distributed among sender peers. This helps to reduce the degradation on the average video quality and the newly joined peers only have to transmit the lost layers. The actual quality of the video is better than existing models because the video is streamed from the peers, who are closer to the requesting nodes and maintains the playback constraint. The playback constraint helps to reduce the number of layers or requests exceeding the deadline which is not considered among other models. However, the results obtained using SVC-NC are quiet close to our proposed method because in this technique, video is SVC coded into different

layers and then each layer is NC coded into different encoding blocks. Video is then forwarded among different peers and the missing block for each layer can be requested through other streaming peers which help it to maintain a better average video quality.

4.5.2.2 Average Video Quality

In this section, the average video quality received by each active peer in the network is investigated. The average video quality received depends on the number of layers received by the requesting peers in the network. PSNR is considered as a quality metric to measure the average quality. The video quality is measured as the number of layers received on time to the actual number of layers and then averaged over all active peers.

Figure 4.9 estimates the average quality received using PSNR as a quality metric based on the maximum video rate received by the requesting peer. In this figure, it is considered that a video is SVC coded into 10 different layers such that each layer is of 64kbps. Each requesting peer receives the video based on the available upload capacity among the peers in a set *P*. If a requesting peer receives the video at the rate of 640kbps, the PSNR received will be approximately 40dB. However, if a peer receives a video at 64kbps then the average PSNR will be only 11dB. The advantage of the proposed solution is that the video is streamed through multiple peers, so in the case of some peers departing from the network during streaming, it is possible to receive the video at lower PSNR. However, in other streaming techniques such as SVC or SL, if a sender peer leaves the network, the average video quality drops out until a new peer is available to stream the missing layers.

Figure 4.10 represents the average quality of video received under normal conditions (no churn or flash crowd) using different streaming solutions. In order to measure the average video quality received, a network comprising of 1000 nodes with heterogeneous upload bandwidths is considered. The nodes are located at different geographical locations. Furthermore, it is assumed that under normal conditions, 10%

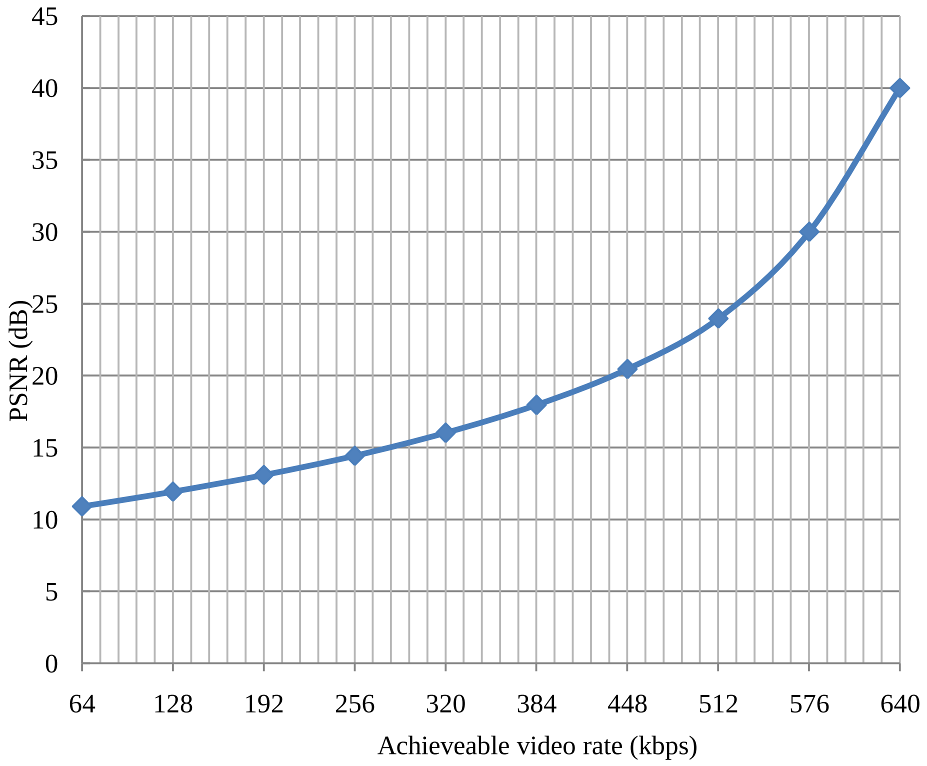


Figure 4.9 Average video quality

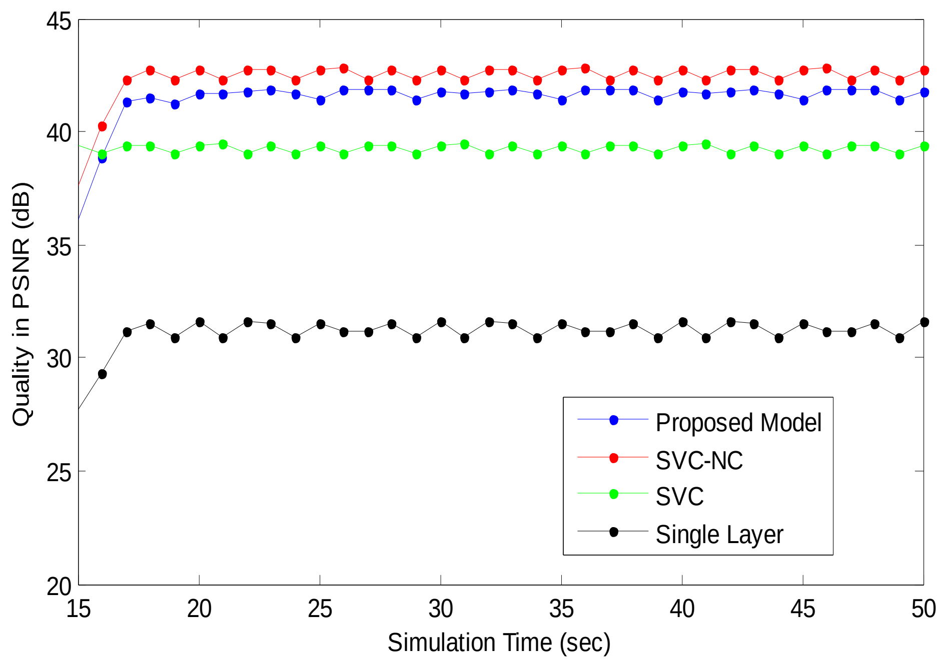


Figure 4.10 Comparison of average video quality received

of the peers leave or join the network at random times. The figure shows that the proposed the proposed model can effectively utilize the upload bandwidth available

at each peer as compared to SVC and SL models. The proposed model yields up to 2 dB improvement in quality as compared to SVC and approximately 7 dB improvement as compared to SL model. However, the SVC-NC model has slightly better video quality up to 1dB more than our proposed model under normal conditions. This is because in SVC-NC, SVC coded video is further encoded using NC into different small blocks. Each missing block can be received from the neighbouring peer requests for a similar video. The use of network coding provides more error protection to the network but receiving the missing block from each peer makes a network a bit more complex. It is shown that by distributing the load among different peers, the video can still be available at the rate approx. equal to SVC-NC model.

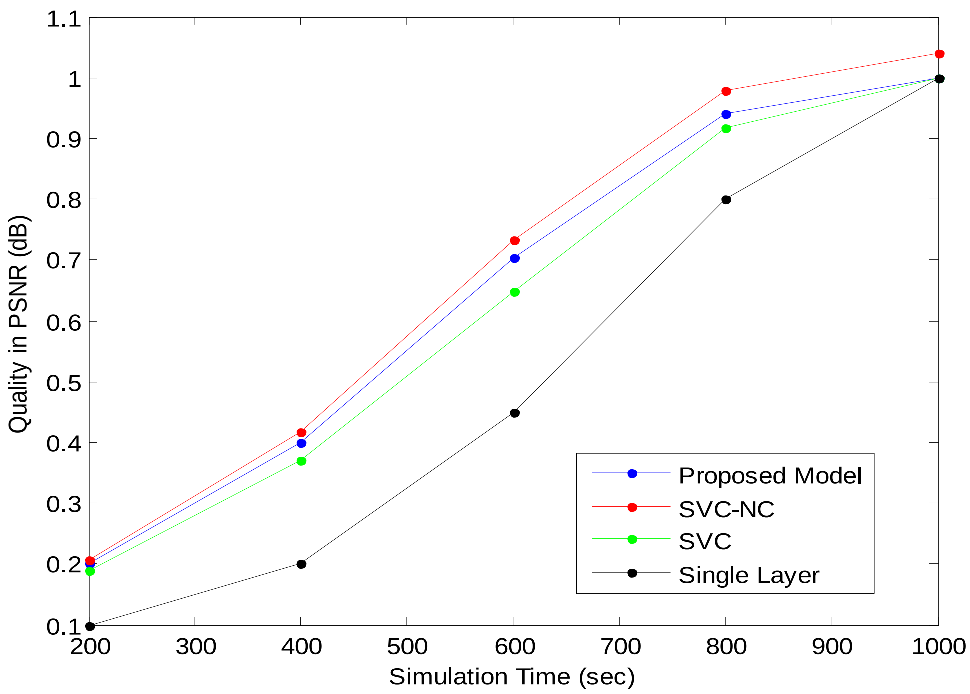


Figure 4.11 Average streaming rate using different models

In addition to the average streaming quality, the average streaming rate of the video is also calculated. The average streaming rate is the amount of data received per second. Figure 4.11show that the proposed model outperforms the existing SVC model and SL systems. It can be seen from the figure that approx. 20% of peers receive a rate around 200kbps or less in our proposed algorithm which is roughly 40% higher than in single layer. Similarly, more than 50% of peers receive the video at a rate of

600kbps or more whereas in SVC it is 10% less and in SL it is more than 20% less peers as compared to the proposed algorithm. Furthermore, the figure shows that the SVC-NC model has slightly better streaming rate than our proposed method because in SVC-NC, video is further encoded into different small blocks and these blocks can be stream through different peers using the remaining upload bandwidth available on them.

4.5.2.3 Flash Crowd

In a flash crowd peers enter the network for a short period of time and the demand of video becomes more than the available resources. Flash crowds affect the average streaming quality received by peers; therefore, it is crucial to see the behavior of the p2p network under crowd. There are two different cases to study flash crowd are considered: (i) serve the existing peer's with the same video quality and accommodate flash crowd using the remaining upload capacity; and (ii) reduce the average video quality receives at the existing peers such that more number of peers can be accommodated during flash crowd.

In order to study the first case, a network of 100 peers is considered. It is assumed that out of which 10% peers have the available video and considered as sender peers. The available upload capacity of the sender peers varies in between 64kbps to 256kbps. The total available capacity among the sender peers is approximately 24kbps. A 10 minutes video is SVC coded into 10 different layers such that each layer is of 64kbps. Figure 4.12shows the behaviour of the proposed method during flash crowd. It can be seen from the figure that up to 11 kbps of the total available upload capacity among peers, the crowd size remains below 15.This means that the sender peers have enough upload capacity to serve complete videos comprising of 10 layers, each of 64 kbps to 15 requesting peers. But after 11 kbps, a flash crowd is introduced in the network and the crowd size suddenly jumps from 15 to 200 peers. In order to serve the crowd, the base layer is served to the newly joined peers and the existing peers still receive the video at better quality. Furthermore, with the help of

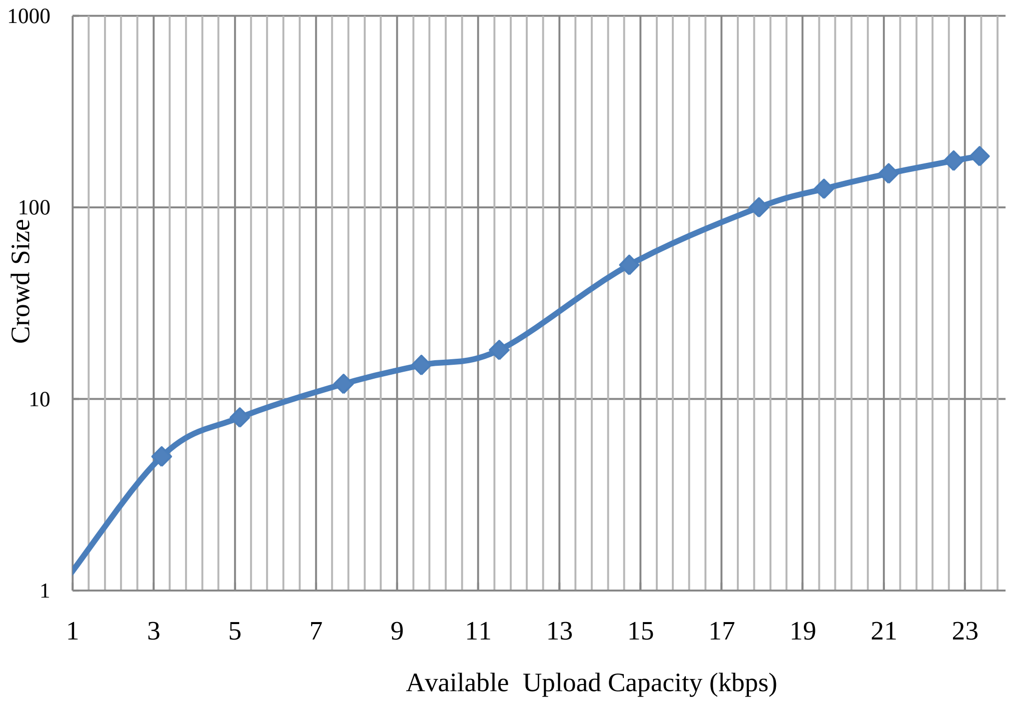


Figure 4.12 Flash crowd Vs. upload capacity of peers

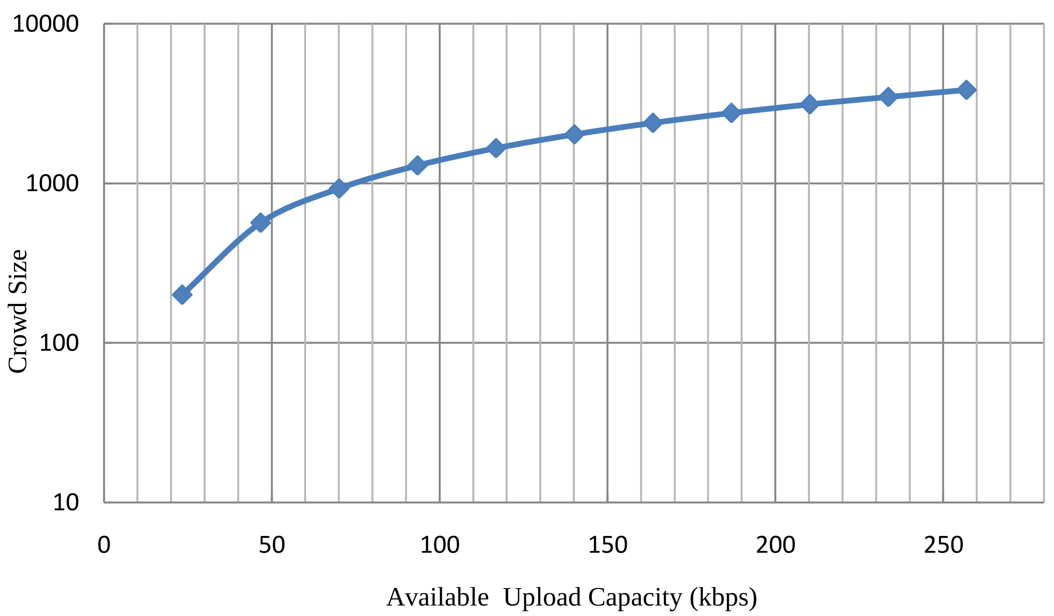


Figure 4.13 Flash crowd Vs. upload capacity of seed servers

seed servers, more upload capacity is available that helps to accommodate more peers or helps to improve the average video quality received as shown in Figure 4.13.

In the second case, the video quality received at each peer is degraded to accommodate more number of peers during the flash crowd. A network where on an average of 15 to 50 peers arrive per minute with steps of 5 is considered. Peers arrive in the network at random locations during the simulation time. The average quality of the video is measured against different systems for different numbers of peers arriving.

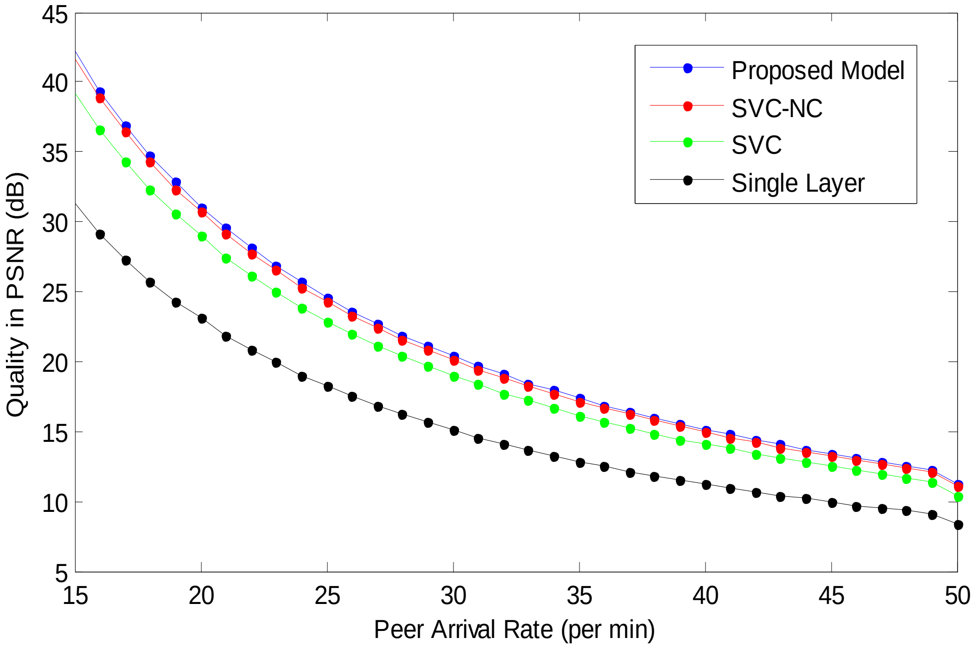


Figure 4.14 Impact of flash crowd on video streaming quality

Figure 4.14 shows the performance of the proposed algorithm during a flash crowd. It can be seen from the figure that at high peer arrival rate the average video quality of all the systems decreases. However, the proposed model still perform better during flash crowd as the quality received even at high arrival rate is at least 2dB more than SVC model and 3 dB more than SL model. Furthermore, the SVC-NC model performs quiet similar to our proposed model because in their model, blocks of the video can still be recovered from the sender peers with a very few upload capacity left.

4.6 Conclusion

In this chapter, p2p streaming with SVC is considered to efficiently utilizing the upload bandwidth across the peers. It is known that the problem to efficiently allocate the resources is NP complete. Therefore, an efficient approximation algorithm is proposed to solve the resource utilization problem. Using the algorithm, the upload capacity at each peer can be reduced. Furthermore, seed servers are deployed to overcome the limited capacity available at peers. The proposed model is validated numerically and it confirms that efficient management of capacity at peer level helps the p2p system to perform well under churn and manages a flash crowd. Furthermore, a number of simulations are performed to show that the proposed model introduces fairness and diversity in the network. Moreover, it is investigated that the proposed model maintains high average video quality during churn. The work is further extended to see the behavior of peers during the 'flash crowd', where a number of peers enter the system and the link capacity is not able to handle all peers at a certain time. The results are compared with SVC-NC, SVC and SL systems as discussed in [115] and the results show that the proposed reduces the effect of churn and can efficiently manage the flash crowds and with the help of seed servers a large number of peers can be accommodated.

The next chapters discuss about the video streaming problem over MANETs.

5 VIDEO STREAMING ACROSS MANETS: A CENTRALIZED APPROACH

In the previous chapter, p2p streaming across the wired network was studied to efficiently utilize the upload capacity at each peer. Furthermore seed servers were deployed to overcome the bandwidth limitations across the peers. However, streaming across wired networks is always considered to have less constraint as nodes are always stationary. On the other hand, the streaming of live or on demand video in MANETs makes it more challenging due to number of constraints such as heterogeneous uplink bandwidth of nodes, transmission power for nodes based on the distance between two mobile nodes (number of hop counts) and the playback latency of the receiver. Hence, the following research question remains open: what is an effective way to provide users with a satisfactory quality of the video over the MANETs, i.e. the users have better quality of experience (QOE) for the requested video throughout the session.

This chapter studies the resource allocation problem for distributing video across MANETs using P2P to provide better QOE among the users. A linear optimization problem has been proposed to efficiently utilize the upload bandwidth at each mobile node. Furthermore, SVC is used to help streaming the video using multiple nodes such that the load across the nodes is distributed. However, the solution to the proposed optimization problem is known to be NP complete. Therefore, a QOE based energy efficient (QEE) model has been proposed that provides an approximation algorithm to maximize the QOE among users while effectively utilizing the upload capacity and the energy at each sender node. The proposed QEE model is compared with the models proposed in [164] and [165] referred as EVAN and WCNC.

EVAN is an energy aware routing protocol for streaming video across MANETs that uses SVC. Similar in WCNC , different admission control strategies are designed to

improve the overall performance of streaming video across MANETs. Furthermore, the QEE model is compared against NQNE and QNE models built during the construction of QEE model. NQNE model is a non QOE based non energy efficient model that does not take into node's power and upload capacity while streaming the video whereas QNE model maintains quality of experience but doesn't take into account the nodes' power. The results show that the propose model outperforms other existing models as it delivers the receiver nodes with a better quality of video with a limited number of resources utilization and maintains a smooth playback.

The part of this work has already been accepted in IEEE NGMAST 2015.

5.1 Contributions

This chapter aims to efficiently utilize the network resources using SVC to improve the QOE across users in a mobile ad hoc network. Multiple sources are used to stream the layered coded video. However, this introduces synchronization issues which are not addressed and it is left as a future work.

The main contributions of the proposed system are as follows:

- A NP complete linear optimization problem is proposed to provide users a better quality of experience while efficiently managing the available network resources.

- In order to solve the linear optimization problem, a QEE model has been proposed that provides an approximation algorithm to efficiently utilize the resources.

- The result shows that the propose QEE model reduces the energy consumption across each node and provide users with a better QOE.

- Furthermore, QEE model ensures that streaming the video through multiple sources using SVC effectively reduces the effects of churn and helps to efficiently manage the flash crowd.

5.2 System Design

The propose p2p MANET is shown in Figure 5.1. The network comprises of different set of nodes connected with each other to form p2p overlay architecture. The node can be a source, a destination and a relay or helper node. Each node is assigned with a defined transmission range in which they can interact with each other. In order to keep the network as a resource utilization problem, it is assumed that the network is centralized. This states that a centralized node exists in the network that performs certain operations to keep the network information and is always connected to a power source.

The centralized node is consider being responsible for allocating the available upload bandwidth and energy at each node, manages the link capacities, identifies the sources upon requests, notifies the churn (nodes departure or arrival) and the flash crowd in the network. The centralized node keeps updating the all the network information after every *t* time units such that the current status of the network is known. Moreover, it identifies the mobility nature of nodes as the network topology is not always be the same.

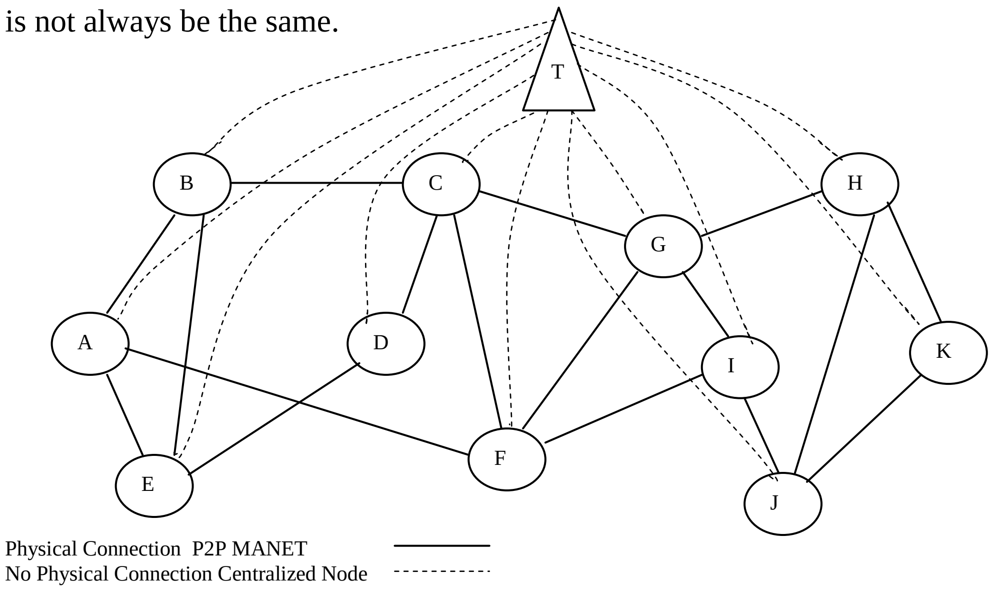


Figure 5.1 P2P Streaming Using MANET

5.3 Problem Description

Let *V* denotes a video that is being scalable coded into n number of different layers such that L={l_1, l_2 ... l_n} where l_1 represents the base layer and l_2 ... l_n represent the enhancement layers. The rate at which each layer is streamed is represented using a stream rate vector such thatr_{v_l}={$r_{v_{l_1}}$, $r_{v_{l_2}}$ ..... $r_{v_{l_n}}$}. $S_{r_{v_L}}$represents the total source rate in bps at which the video is streamed from the source. The study is focused towards maximizing the QOE among users whereas the energy and the bandwidth across the nodes are minimized.

In the proposed system, whenever anode joins the network and makes a request for a video, the request is forwarded to the centralized node which then identifies the video sources. Consider that there are a total of k nodes in the network as represented in a set *N* such that $N = \{p_1, p_2 \text{ ... } p_k\}$. It is assumed that out of the total k nodes there are m such nodes that are identified as source nodes for a particular video *V* by the centralized node as represented in a set Q such that Q={q_1, q ... q_m}.In order to receive the video at the best possible quality, a total of n number of layers should be received. If a requesting node receives the video at the rate equal to $S_{r_{v_l}}$, then the p2p system is considered to be receiving the video with the best possible quality. Otherwise, nodes can still download the video at the lower quality.

5.4 Problem Formulation

Consider a directed graph *G*= (*N*, *M*) where *N* is a set of mobile nodes that forms a MANET and the paths between nodes is represented by a matrix *M* whereas the elements of the matrix are given as $m_{i,j}$.If $m_{i,j} = 1$, it means that there exists a physical connection between node *i* and the node *j*. Let $u_{i,j}(t)$represents the allocated uploadrate across a link $m_{i,j}(t)$ at time t. The upload capacity and the link are considered as a function of time *t* because the nodes are highly dynamic. Equation 5.1 explains that the upload rate of each sender node is constrained by the maximum

transmission capacity $C_{i,j}(t)$available across a particular link at time *t*. SVC is used that helps to reduce the upload rate across each sender node by sending the layers using multiple sources. This helps to reduce the network traffic across each node.

$$u_{i,j}(t) \leq C_{i,j}(t) \tag{5.1}$$

When a node i makes a request for a particular video *V*, the centralized node forwards the request to the source nodes present in a set Q that has a requested video. However, it is not necessary that all the sources are selected to forward the requested video. The sources are selected based on the available upload capacities, energy levels and the playback deadline for a video at the receiver. The playback deadline represents the time at which the video is available at the destination node ready to be played.

If an intermediate node or a destination node *k* is receiving the video from the source nodes present in a set *Q*, the receiving rate for node *k* will be given as;

$$R_k(t) = \sum_{j \in Q} m_{jk}(t)\, u_{jk}(t) \qquad \forall j \in Q \tag{5.2}$$

Similarly, if a node k is a helper or a relay node that forwards the video to another network node until it reaches the destination node. The total sending rate for node *k* is calculated using Equation 5.3.

$$S_k(t) = \sum_{j \in N} m_{kj}(t) u_{kj}(t) \qquad \forall i \in N\text{-}\ Q \tag{5.3}$$

Equation 5.2 shows the rate at which the requesting or intermediate node receives the content through multiple sources in the network. Similarly, Equation 5.3 describes the rate at which the same requesting or intermediate nodes ends the received content to other nodes in the network. Both Equation 5.2 and Equation 5.3 are considered as function of time because the links and the upload capacity across each node changes with time which affects the stream rate of the video. In order to introduce the network diversity, it is considered to stream the video through multiple sources.

However, in order to propose a method that can reduce the resource utilization across each node in MANET, there are few constraints that need to be addressed.

5.4.1 Power Constraint

In MANET, the most important constraint that needs to be addressed is a power constraint because of the limited available energy across each node. Power is defined as the amount of energy consumed per unit time. The transmitted power of a node has an inverse relation with the total distance to stream video to the next hop neighbour as explained in [158] using the Friis transmission equation. So, if a sender node is located away from the receiver node, it requires more power to transmit the content. Hence, more energy of a source node is consumed. Therefore, the power constraint can be given as in Equation 5.4.

$$0 \leq p_l \leq p_{l,max} \tag{5.4}$$

The power constraint explains that the total power required to forward the video content should be less than or equal to the total tendency of a power consumption based on the available energy across the node.

5.4.2 Upload Capacity Constraint

Another important constraint is the available upload capacity across each node that changes with respect to time. Each node in the network has a certain upload rate at which it can upload the content. Consider that the upload rate is represented by U_i.

$$\sum_{j \in N} m_{ij}(t)\,(u_{ij}(t) + F_{ij}(t)) \leq U_i(t) \qquad \forall i \in Q \tag{5.5}$$

Equation 5.5 shows that nodes in a set Q follow the upload rate constraint to stream to the requesting nodes. The upload rate constraint states that the sum of all the allocated upload rates to handle requests should be less than or equal to the maximum upload rate for a particular node. Here, $F_{ij}(t)$ represents the total traffic flow from node *i* to *j* at time *t*.

5.4.3 Forwarding Constraint

The forwarding constraint is another constraint that needs to be considering for streaming video in MANETs. The constraints state that each outgoing link from a node should not carry a rate larger than the total rate incoming to the node. Similarly, if the node is a source then each outgoing link from the source node should not carry a rate larger than the actual source rate at which the video is SVC coded. So, the link forwarding constraint can be written as;

$$u_{ij}(t) - R_i(t) \leq \sigma_{ij}(t),$$

$$i.e. u_{ij}(t) - \sum_{j \in N} m_{ji}(t) u_{ji}(t) \leq \sigma_{ij}(t), \ \forall l_{ij}(t) \in L \tag{5.6}$$

where $\sigma_{ij}(t)$ is the link forwarding compensation vector and can be considered as follows;

$$\sigma_{ij}(t) = \begin{cases} S_{r_{v_l}} & \text{if } i = 0, m_{ij}(\mathrm{t}) \text{ is a direct downlink of source node} \\ 0 & \text{otherwise} \end{cases} \tag{5.7}$$

5.4.4 Playback Latency

In order to provide a smooth playback, the centralized node will select only those sources to stream the video which are able to maintain the playback latency of a requesting node. In order to estimate the playback latency, the transmission delay is calculated first. The transmission delay is based on the time required to transmit a video segment using a source node with a certain upload rate as given in Equation 5.8.

$$T_d = \frac{Segment\ \ Size}{u_{p_i}(t)} \tag{5.8}$$

However, the total delay to stream the content from the source to the requesting node is dependent on the sum of transmission delay and the propagation delay across each hop node in the network as given in Equation 5.10. The propagation delay is defined as the time required transmitting a video segment from a source to the next hop neighbor as given in Equation 5.9. Equation 5.9 shows that the propagation delay for a node i equals to the distance between two nodes to the propagation speed which is assumed to be equals to the speed of light in wireless communication. The total propagation delay from a source to a receiver is equals to the sum of all the propagation delay as given in Equation 5.10 where h represents the total number of hop counts.

$$T_{p_i} = \frac{Distance}{Speed} \tag{5.9}$$

$$D = T_d + \sum_{i=1}^{h} T_{p_i} \tag{5.10}$$

In order to have a smooth playback, it is considered that the total delay should be less than the actual playback latency of the requesting node to play the video as shown using Equation 5.11. However, if the playback latency constraint doesn't meet, the video starts freezing.

$$D < Playback \tag{5.11}$$

5.5 Mathematical Model

In this section, a mathematical model is proposed to study the resource allocation problem in order to efficiently allocate the resources among MANET nodes such that the maximum QOE among the nodes is achieved. The solution to this problem is known to be NP complete. Hence, a linear optimization problem is proposed to study this resource allocation problem is proposed as given in Equation 5.12.

$$Max \quad \sum_{k=1}^{n} MOS_k R_k \tag{5.12a}$$
$$\text{subject to} \quad u_{i,j}(t) \leq C_{i,j}(t) \tag{5.12b}$$
$$\sum_{j \in N} m_{ij}(t)\,(u_{ij}(t) + F_{ij}(t)) \leq U_i(t) \quad \forall i \in Q \tag{5.12c}$$
$$Min \quad u_{p_i} \tag{5.12d}$$
$$\text{subject to} \ \ u_{p_i}(t) \geq r_{v_{l_j}} \tag{5.12e}$$
$$u_{ij}(t) - \sum_{j \in N} m_{ji}(t) x_{ji}(t) \leq \sigma_{ij}(t) \ \ \forall\, m_{ij}(t) \in M \tag{5.12f}$$
$$0 \leq p_l \leq p_{l,max} \tag{5.12g}$$
$$u_{ij}(t) \geq 0,\ u_{p_i}(1 \leq i \leq m),\ r_{v_{l_j}}(1 \leq j \leq n)$$

Equation (5.12a) indicates that the aim to maximize the QOE among users by predicting the mean opinion score (MOS). MOS is a test that measures the perceived user quality based on a numerical value. The lower value of MOS indicates that users experience the poor quality. However, Equation (5.12b) states the total available capacity over the link should be less than the total upload capacity at which a source node streams the video. Moreover, Equation (5.12c) explains that the total available upload capacity across a node should be enough to handle the sum of the upload capacities from various requests.

The works also aims to minimize the upload capacity shared by each node as given equation (5.12d) in order to stream video through multiple sources. However, a condition is applied (as shown in equation (5.12e)) that the upload capacity available at each sender node should be greater than or equal to the minimum rate $r_{v_{l_j}}$ at which one of the SVC layer can stream. Similarly, equation (5.12f) and (5.12g) considers the forwarding constraint and the power constraint to stream the video to the requesting nodes.

5.6 Proposed Solution

In the previous section, we propose a mathematical model as a linear optimization problem to solve the resource allocation issue in MANETs. The solution to the propose optimization problem is known to be NP complete. It means that there is no direct solution available to solve the problem. Therefore, a novel QOE based energy efficient model called (QEE) has been proposed that considers node's upload capacity, energy and the node's playback time as constraints to provide better QOE among

users. Moreover, the load is distributed across multiple sources to minimize the upload capacity requirement at each node and reduces the effect of churn and flash crowd in the network.

In QEE, an approximation algorithm as shown in

Figure **5.2** is proposed to solve the resource allocation problem in MANETs. The working of the resource allocation problem is as follows;

5.6.1 Initializing the Parameters

i. *Define the input parameters such that the network has N number of nodes and V set of videos that need to be shared upon requests.*

ii. *Define the output parameters; the average power consumed by the network i.e. Avg_Power and the average video quality perceived by the users in terms of MOS i.e. Avg_MOS.*

iii. *Initializing the basic parameters required such that the available upload capacity across nodes U_p, initial set of up-loader nodes Q, energy across each node T_{power} and the play-out time for the nodes T_{pout}.*

5.6.2 Network Characteristics

This section defines the different constants required to design the MANET model. These constraints are given below;

i. *Whenever a video is requested the request is forwarded to a centralized node that has complete network information. The centralized node then identifies the nodes with the requested video and save the available source nodes in set Q.*

ii. *The centralized node also identifies the node whose upload bandwidth is greater than the total link capacity among two neighboring nodes. The node whose link capacity is less than the upload capacity of a node doesn't take part in streaming the video.*

QOE and Energy Efficient Algorithm

Input : *N, V // N:* no. of mobile nodes, *V*: SVC coded video
Output: Avg_Psnr, Avg_MoS, Avg_Power

Initializing Parameters: U_p, Q, Tx_{power}, T_{pout}
// U_p: Upload capacity, *Q:* initial up-loaders for set *Q*, T_{power}*:* Transmission power of each node, T_{pout}*:* Play-out time for node //

// Model Constants //

1. *init_P( );*
2. **for** $i \leftarrow 1$ *to N* **do**
3. **if** $(u_{i,j} \le C_{i,j})$ **then**
4. *Nodes can upload*
5. *set_*Tx_{power}*( )*; // Total transmission power of each node
6. *set_*T_{pout}*( );* // Set the play-out time for each node
7. *set_* U_p*( );* //Set the initial upload capacity
8. **for** $j \leftarrow$ *1:Sim_Time* **do**
9. *net_topo ( )*; // Create the network topology
10. *cal_txpower_layer_distance( );* // Function to cal. the power require to transmit layer
11. *set_Upload_maxUploadRate( );*// Set max upload capacity for each node
12. *set_*$P_{threshold}$ *( );* // min threshold on power at each node
13. *set_*R_t*( );* // transmit range for each node to communicate

// Main Function ( )

14. **for***(k ←1 to N)* **do**
15. **nested for** (l←1: *Simulation time)* **do**
16. *tx_power_array( );* // calculate transmit distance from source to receiver node
17. **if** *cal_direct_distance( ) <*R_t **then** // Shortest path is considered for transmission
18. **if***Upload_maxUploadRate( ) > deltarate_layer;***then** // Check if node has enough upload capacity
19. **if** *node_totalpower >*Tx_{power}+ $P_{threshold}$*;* **then**
20. $U_{p\ left}$ = available U_p - R_l ; // Update the upload of node transmitted
21. $Total_{power}$ = $Total_{power}$ - Tx_{power};// Update the nodes transmit power
22. **if** *m =1* **then** // Base Layer is transmitted
23. **else if** *m =2* **then //** EL1 is transmitted
24. **else if** *m=3* **then //** EL2 is transmitted
25. *Discard the layers not received within deadline*
26. **return**

Figure 5.2 Proposed Algorithm

iii. *Set the total transmission power for each node based the power curve given for 802.11n as in [196].*

iv. *Adjust the play-out time for each node. The play-out time defines the time at which the receiver node will start playing the video.*

v. *Create the topology of the network based on a map based mobility pattern. It is considered that the topology of the network changes after every t time units in order to study the dynamic nature of nodes. Furthermore, the node speed is varied to see the behavior of the network under fast and slow moving nodes.*

vi. *Calculate the transmission power required to transmit the video among two nodes based on the distance and data rate.*

vii. *Adjust the available upload capacity as the maximum capacity available across each node. When a node serves a request, the maximum upload capacity is changed to a new upload capacity.*

viii. *Set the minimum threshold on the energy across each node. If the total transmit power to handle a request drops toa certain threshold, the source is not considered to stream the content. This helps to reduce the nodes miss out from the network.*

ix. *The transmission range for each node is monitored. If a node is located closer to the sender node, video is forwarded at higher data rate. However, if the distance between a sender and a receiver increases the video is streamed at low rate. However, if the node goes out of the communication range, the video cannot be forwarded.*

5.6.3 Working of the algorithm

This section explains the working of the propose algorithm as follows.

i. *Calculate the transmit distance from the sender to receiver node using the transmit power array defined in the previous section.*

ii. *If a sender node is within the communication range of the receiver node as calculated using the dijkstra algorithm, the sender node is selected to stream the video.*

iii. *Check if the selected sender node in the previous section has enough upload capacity available to share.*

iv. *If both the previous steps are satisfied, the node is checked if it has enough energy to be consumed as power. If the node has energy that is greater than the total power required by the source to transmit video to the receiver node; then the node is considered for streaming the video.*

v. *If a source node satisfies all the constraints discussed in the last three steps, the node transmits the layer to the receiver and update it's the upload capacity and energy.*

vi. *If the transmitted layer is a base layer, it notifies the centralized node that the base layer is transmitted. In a similar manner, enhancement layers are transmitted.*

vii. *The receiver node has a certain playback deadline, if the layer is received after the playback, the layers is of no use and get discarded.*

viii. *The algorithm runs until all the requesting nodes are served with the layers of the video and the simulation time finishes.*

5.7 Results

In order to validate the results, a number of simulations are run using MATLAB software to study the behaviour of MANET towards the propose QEE model. The metrics use to measure the performance of the proposed model are average MOS received of all the received layers and the CDF for power consumed across the nodes in the network. The model is tested with a network comprises of 100 nodes which are placed at random geographical locations. The network is considered to be highly dynamic which means that the nodes change their positions quiet frequently. The nodes are considered to be moving with different velocities such as 1m/sec for pedestrians, 5m/sec for slow moving cars and 20m/sec for fast moving cars. The upload capacity is considered to be within the range of 400 to 600 kbps for each network node. The link capacity varies in between 1Mbps to 5Mbps based on the transmission range across a sender and a receiver as in [196]. The maximum transmission range for each node to stream the video is set to 40m. This means that if

the transmission range is more than 40m that node cannot be considered to stream the video. However, if the transmission range is less than 40m, the node adjusts the link capacity within the range of 1 to 5Mbps. The algorithm is simulated with 10% and 50% up-loader nodes with the video whereas the remaining mobile nodes request videos from these up-loaders.

A 5 sec video is encoded using Scalable Video Coding (SVC) into 5 different segments such that the length of each segment is 1sec.To encode the video into different layers, the JSVM software is used that generates 3 different layers (base layer, enhancement layer 1 and enhancement layer 2) for the video and the stored video parameters are received in a text file. The text file represents the PSNR, Data Rate (kbps) and the Frame Rate (fps) of all the layers. Each simulation is run multiple times over the MATLAB in order to estimate the mean value for the results obtained. This average value helps to mitigate the abrupt behavior of the network that can obtain with a single simulation run. The Spatio-Temporal Video Quality Metric (STVQM) is used as a parameter to evaluate the quality perceived by users as discussed in [197]. The advantage of using STVQM is that it takes into account PSNR, frame rate and spatial and temporal video parameters of a video at the same time. The STVQM is evaluated over the range from 0 to 100, where STVQM=0 represents an extremely poor quality and STVQM=100 represents a very high quality. The estimated Mean Opinion Score (MOS) for the video quality perceived can be estimated from STVQM using [157]. It is mapped over the scale of 1 to 4.5. If the value of MOS is 4.5, this means that the best possible quality of a video is received whereas if the value of MOS=1, it means that a very low quality of video is received. The nodes are considered to be moving with variable speeds and have different upload capacities.

In the following sub sections, the propose model is compared against QNE, NQNE, (EVAN) [164] and (WCNC) [165] network models to monitor the MOS received and the total power consumed by the users. EVAN is an energy aware routing protocol for streaming video across MANETs that uses SVC. Similar in WCNC , different admission control strategies are designed to improve the overall performance of streaming video across MANETs. Moreover, the behavior of the propose model is tested against the churn and the flash crowd in the network.

5.7.1 Average MOS Received

In this section, the model is compared against other existing models in order to investigate the average MOS received by receiving the video comprising on layers. The higher value of MOS represents that the user's experience a better average quality. The model is compared against the already existing models. The first test is conducted to measure the average MOS received as the number of up-loaders (source nodes) are varied from 10% and 50% nodes in the network. In order to encounter the dynamic behavior of network, nodes are considered moving. The nodes velocities are considered to be 1m/sec, 5m/s and 20m/sec at random locations.

5.7.1.1 Average MOS Received with 10% Up-Loaders

The average MOS received for video with 10% up-loaders in the network is estimated. In each figure, the nodes are considered to have different velocities i.e. 1m/sec, 5m/sec, and 20m/sec. Figure 5.3 shows the average MOS received when the nodes velocity is considered to be 1m/sec (pedestrians). The higher value of MOS means that users have better QOE. The proposed model is compared against different existing models and the behavior of the proposed model is considered to be same as others. The average MOS received by propose model, EVAN and QNE model is roughly the same. However, the propose model dominates WCNC and the NQNE model.

Figure 5.4 and Figure 5.5 represent the average MOS received when the nodes velocity changes to 5m/sec and 20m/sec whereas the numbers of up-loaders are still the same. Figure 5.4 shows that the propose model stills performs better than the existing models when the nodes velocity is increased to 5m/sec (slow moving cars). The QNE and EVAN behave nearly closest to the propose model. The QNE model is a part of the model discussed in this chapter without the power constraint. On the other hand, EVAN considers the power constraint and has nearly the same behavior during the start of the simulation but eventually starts decreasing because the playback latency is not considered as part of the routing technique used.

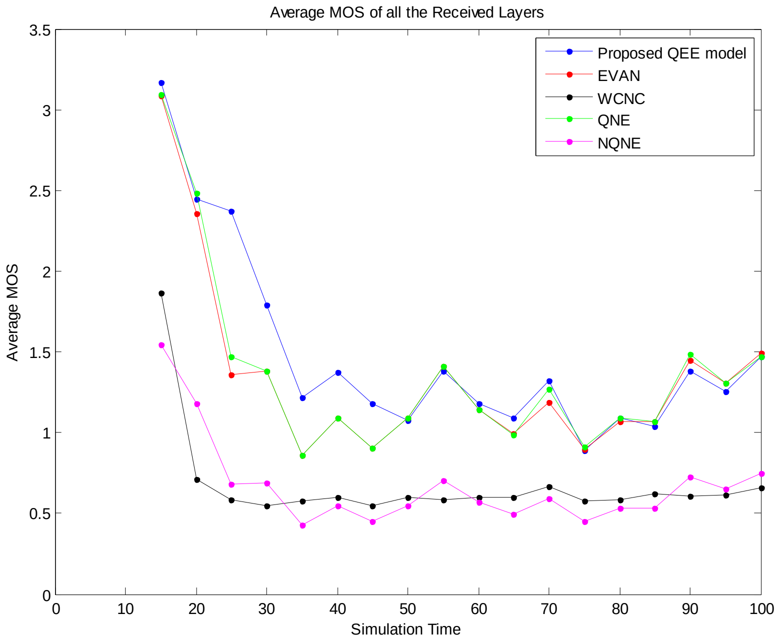


Figure 5.3 MOS received 10% up-loaders and nodes velocity 1m/sec

Figure 5.5 also represent the similar behavior to Figure 5.4 and the propose model still perform better under the fast moving nodes. The WCNC and NQNE models have very low MOS received because in WCNC, an extra bandwidth is reserved across the nodes to encounter the link capacity fluctuation. This helps to maintain the better delay across the network however the quality experience by the users' decreases as more of the bandwidth is wasted.

5.7.1.2 Average MOS Received with 50% Up-Loaders

In this scenario, the average MOS received for video with 50% up-loaders in the network is estimated. In each simulation, the nodes are tested against different velocities i.e. 1m/sec, 5m/sec, and 20m/sec. Figure 5.6 represent the average MOS when the nodes are moving at the speed of 1m/sec. The behavior of the network is the same as discussed in Figure 5.3, however the MOS received at all the models is more higher because of more number of up-loaders are available in the network to upload the video. The propose model dominates the WCNC model because of its bandwidth reservation to encounter the sudden fluctuation in the network.

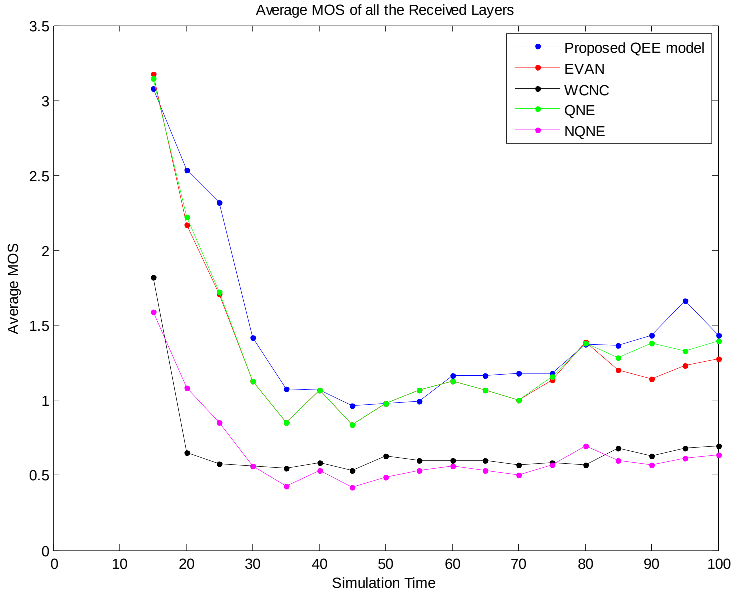


Figure 5.4 MOS received 10% up-loaders and nodes velocity 5m/sec

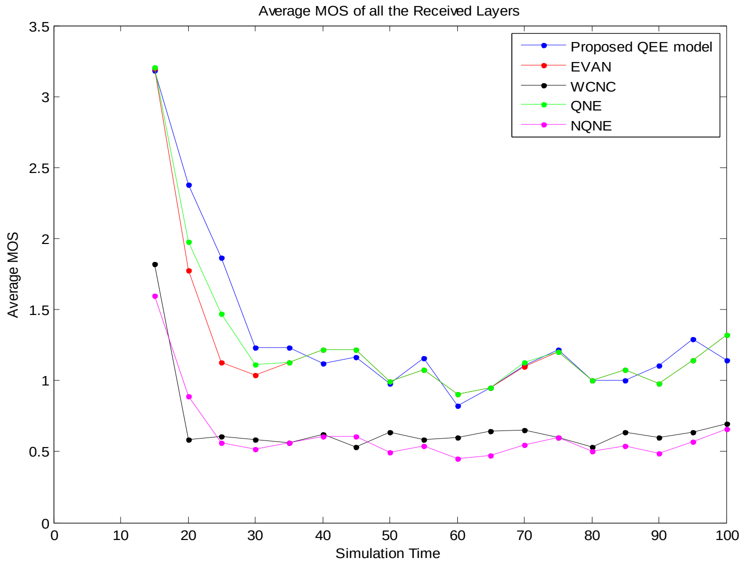


Figure 5.5 MOS receive 10% up-loaders and node velocity 20m/sec

Figure 5.7 and Figure 5.8represent the MOS received when the node starts moving at higher speeds of 5m/sec and 20m/sec. The propose model performs better than the existing models. The MOS received by EVAN starts decreasing a bit as the model

doesn't consider the playback latency that eventually drops the layers and leave the users with low quality received.

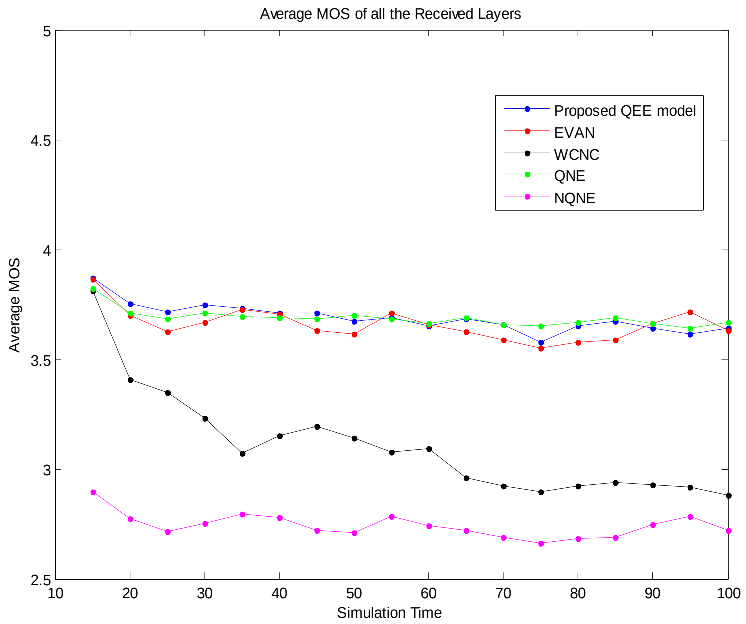


Figure 5.6 MOS received 50% up-loaders and nodes velocity 1m/sec

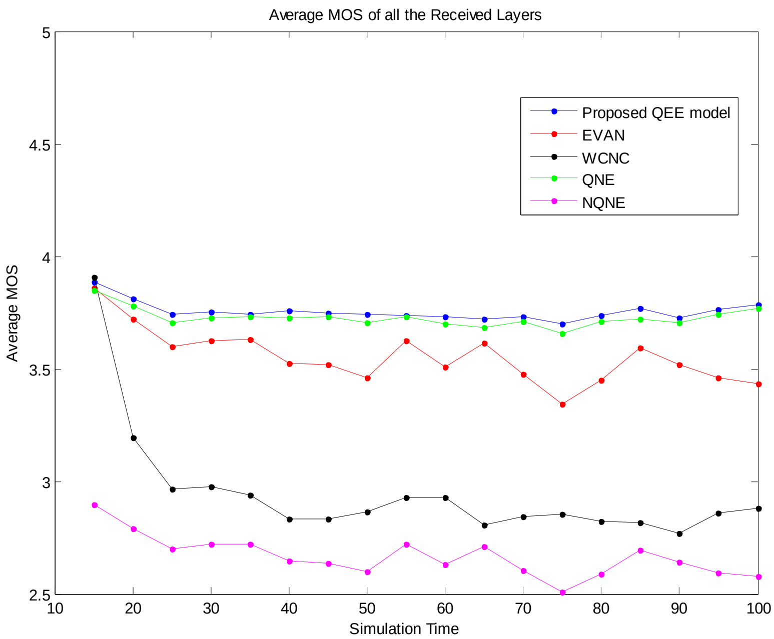


Figure 5.7 MOS received 50% up-loaders and nodes velocity 5m/sec

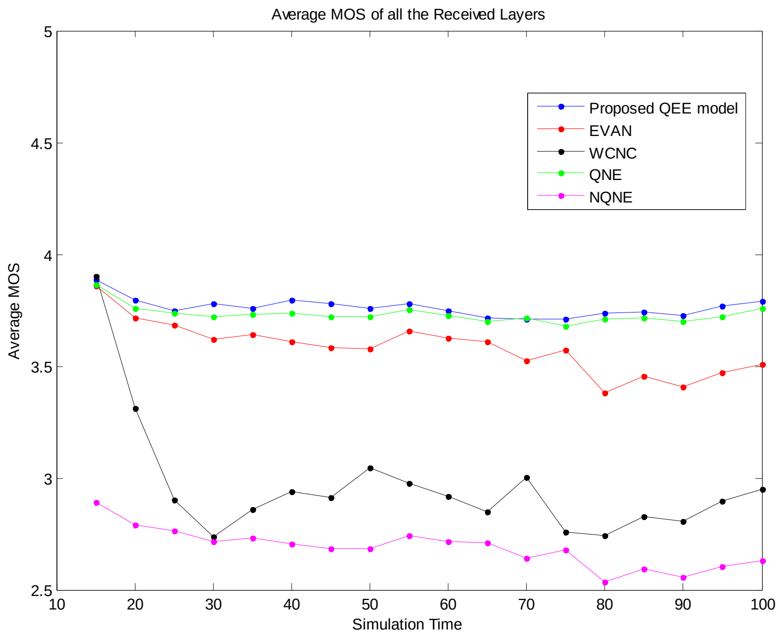


Figure 5.8 MOS receive 50% up-loaders and node velocity 20m/sec

5.7.2 Power Consumed

The power consumption is monitored as a cumulative distribution function (CDF), when the requested video layer is shared by the sources across the network. The proposed model is compared against the already existing models while considering two different scenarios. In the first scenario, the number of up-loaders that has the video is considered to be 10% of the total nodes in the network whereas in the second scenario almost 50% of the total nodes in the network are the up-loaders. Furthermore for each scenario, nodes are considered to be moving at different speeds such as 1m/sec, 5m/s and 20m/sec at random locations.

5.7.2.1 Power Consumed with 10% Up-loaders

The power consumed to distribute the video with 10% up-loaders in the network is estimated. Nodes are tested for variable speeds i.e. 1m/sec, 5m/sec, and 20m/sec.

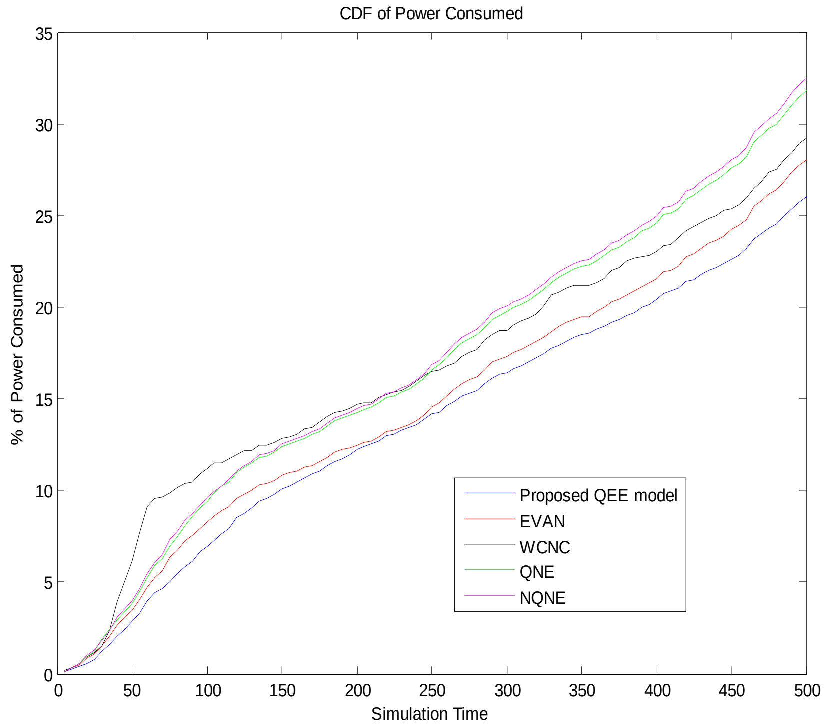


Figure 5.9 Power Consumed with 10% up-loaders at node speed of 1m/sec

Figure 5.9 shows the CDF for power consumed when the nodes speed is considered to be moving at the speed of 1m/sec (pedestrians). The power consumption is measured based on the number of layer received or discarded during a simulation time. The result shows that the proposed model consumes slightly less power as compared to the already existing models as the load is distributed across multiple sources. On the other hand, the power consumption across EVAN and WCNC is slightly more as EVAN considers receiving the video layers from any source that maintains a defined threshold levels without focusing on the playback latency of the requesting node. Similarly, WCNC reserves an extra bandwidth to encounter the fluctuation over the link capacities which eventually increases the power consumption.

Similarly,

Figure **5.10** and Figure 5.11 represent the CDF for power consumed when the nodes are moving with the speed of 5m/sec and 20m/sec. The result shows that even with the node's mobility, the proposed model consumes less power as compared to the

other existing models. However, due to the mobility nature of nodes, the source node doesn't forward many layers and hence, the video is received at lower quality as discussed while studying MOS received in the previous section. However, the power consumption across EVAN and WCNC is slightly a little more as EVAN considers receiving the layers from any source that maintains the defined threshold levels and WCNC reserves an extra bandwidth to encounter the fluctuation in the link capacities.

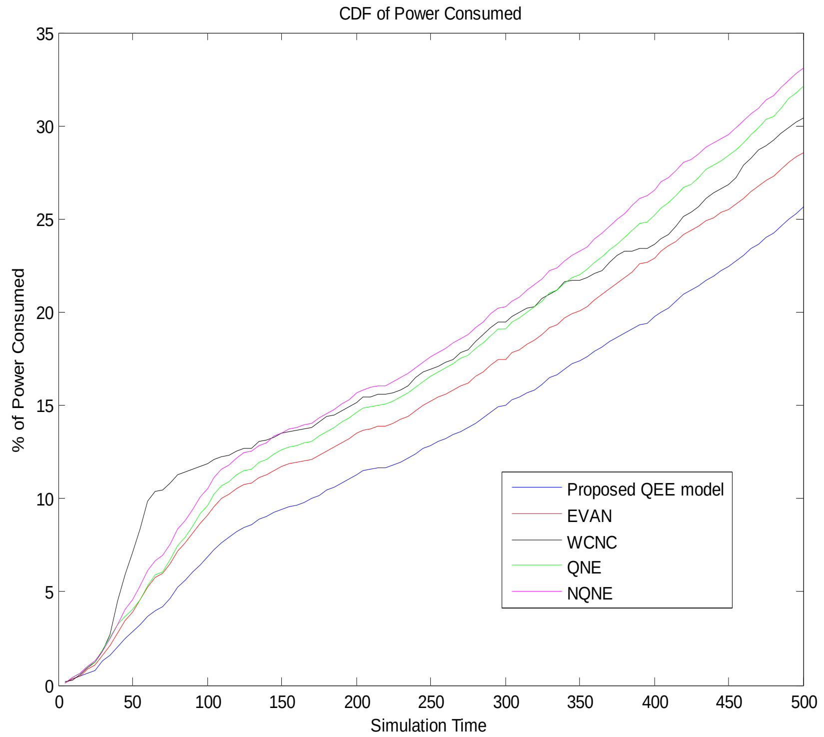


Figure 5.10 Power Consumed with 10% up-loaders at node speed of 5m/sec

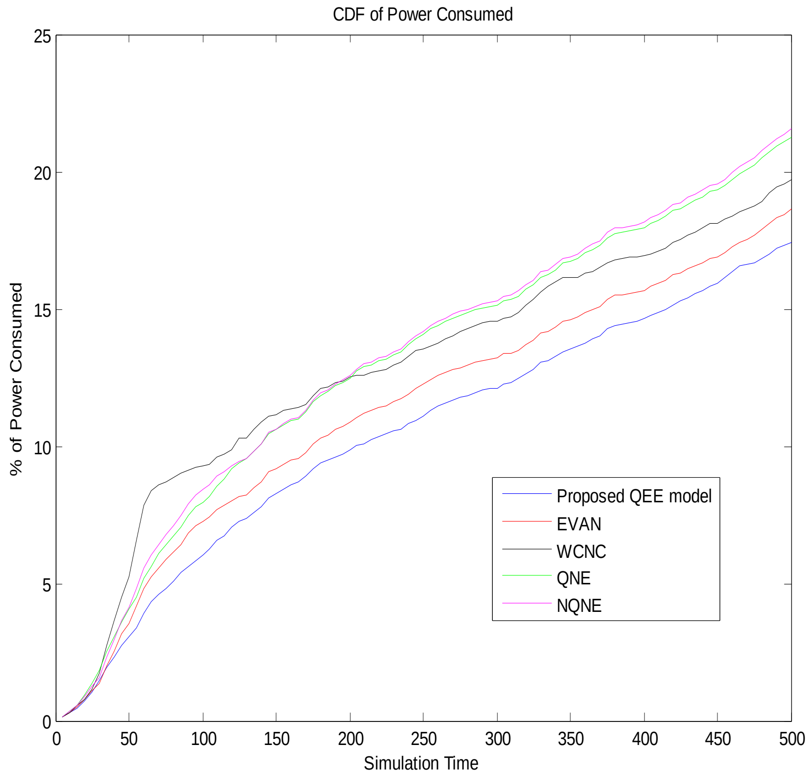


Figure 5.11 Power Consumed with 10% up-loaders at node speed of 20m/sec

5.7.2.2 Power Consumed with 50% Up-Loaders

In this scenario, the CDF for power consumed with 50% up-loaders is estimated when the nodes are moving with the variable speeds i.e. 1m/sec, 5m/sec, and 20m/sec. The overall network consumes more power than the network with 10% up-loaders as discussed above because there are more up-loader nodes in the network to share the resources within the simulation time. Figure 5.12 represents the power consumed when the nodes are moving at the speed of 1m/sec. The propose model consumes less amount of power as compared to other existing models because the network consider streaming the video through multiple sources at the same time that eventually helps to reduce the power consumption across each node.

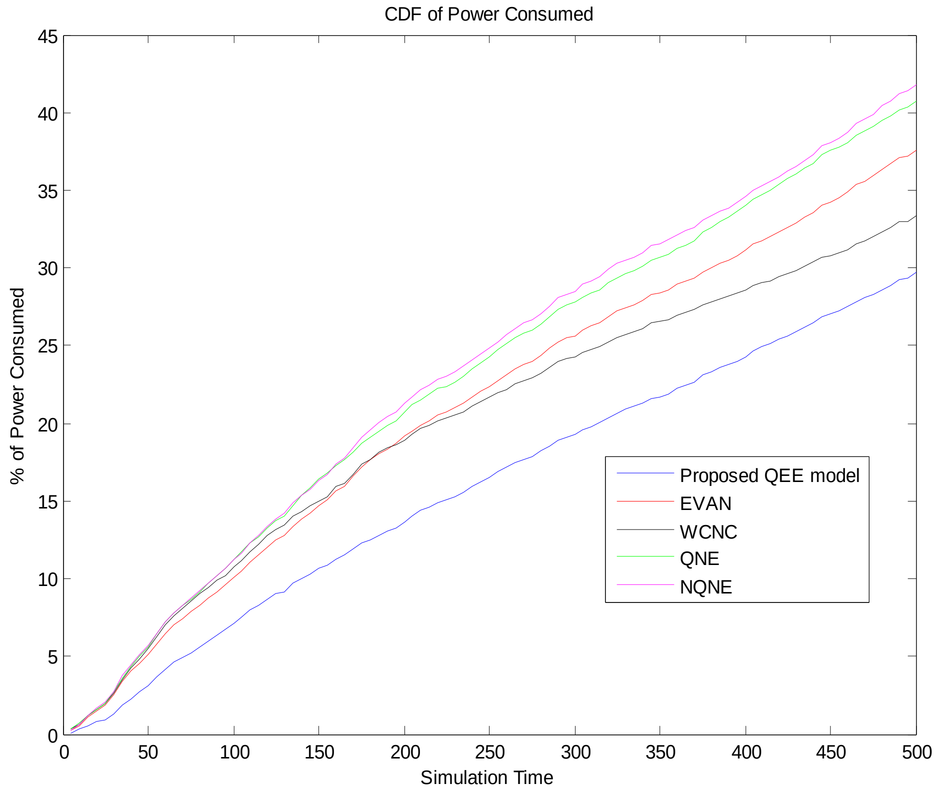


Figure 5.12 Power Consumed with 50% up-loaders at node speed of 1m/sec

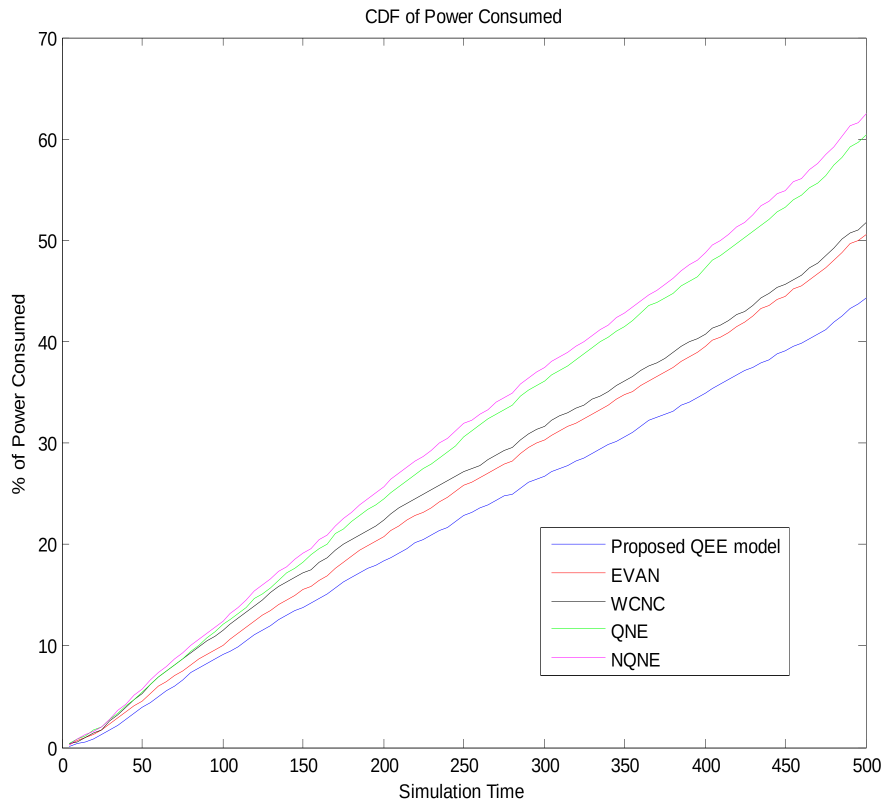


Figure 5.13 Power Consumed with 50% up-loaders at node speed of 5m/sec

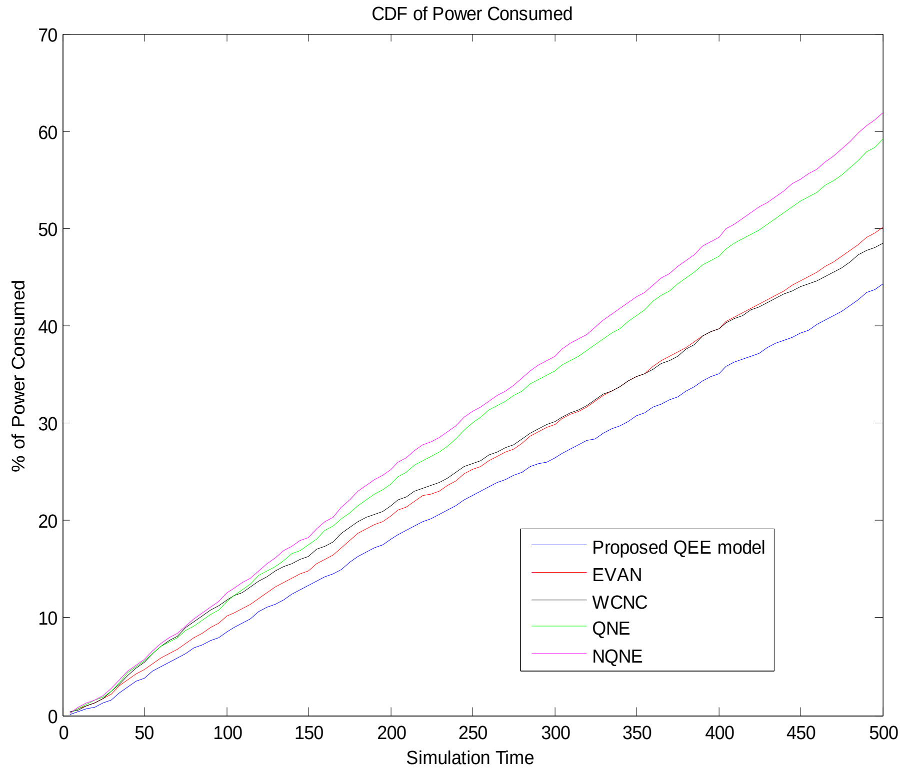


Figure 5.14 Power Consumed with 50% up-loader at node speed of 20m/sec

Similarly, Figure 5.13 and Figure 5.14 shows the CDF of the power consumed when the node speeds are increased to 5m/sec and 20m/sec. Figure 5.13 shows that the power consume across the propose model is less than the existing models. On average, the power consumption across the propose model is slightly increases as compared to Figure 5.12 because the nodes are moving at faster speed in the network. This reduces the chance of source nodes connected to the receiver nodes for a longer time. However, the propose model still consumes less energy as compared to all the existing models. Figure 5.14 represents the similar behavior of the network against the power consumed. However, the power consumption across the propose model increases whereas the power consumption across WCNC model decreases as it reserves the bandwidth for the peers which helps them to have less power consumption while nodes move at higher speed.

5.7.3 Churn Effect

In order to study the effects of churn over the network, the propose model is tested against three different scenarios such as 100%, 80% and 50% of the nodes are considered to be active and inactive. Figure 5.15 shows the average PSNR received in the proposed model by varying the active inactive nodes in the network. Moreover, Figure 5.16 represents the average MOS received by the proposed model. The results show that the proposed model maintains better QOE among users even when there are 50% of nodes leave and join the network. However, in general the MOS received decreases when more amount of churn enters the network. Similarly, Figure 5.17 shows the comparison of the proposed model with the existing models as in [164] [165]. The results show that the proposed model achieves a higher MOS as compared to other models when 50% of the nodes leave and join the network. Because, the load is distributed across difference sources and this helps the requesting nodes to receive the video at lower quality.

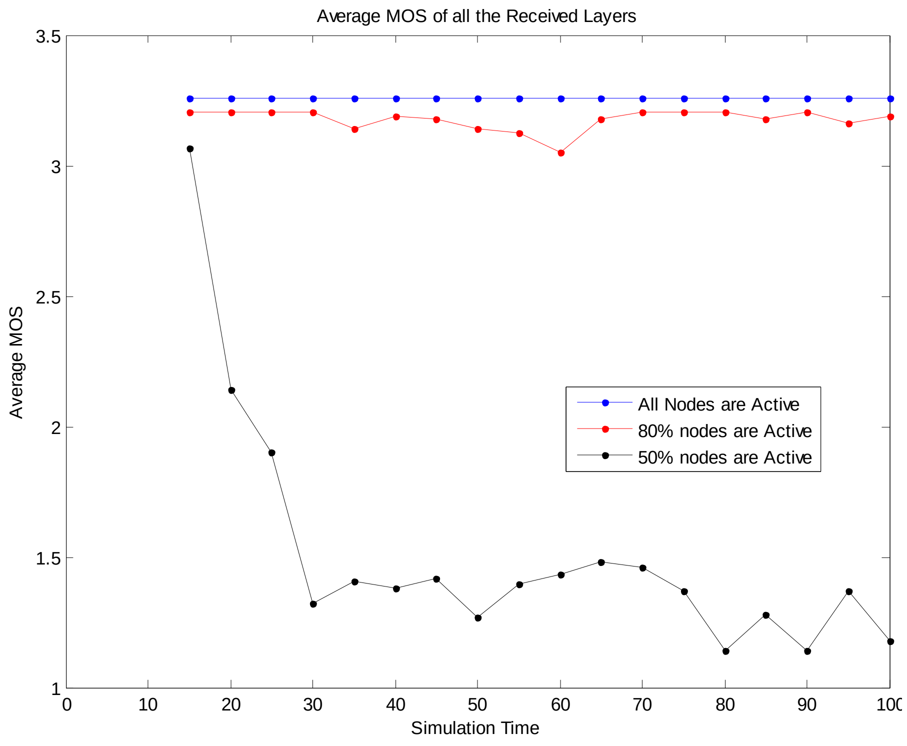


Figure 5.15 Average MOS received under Network Churn

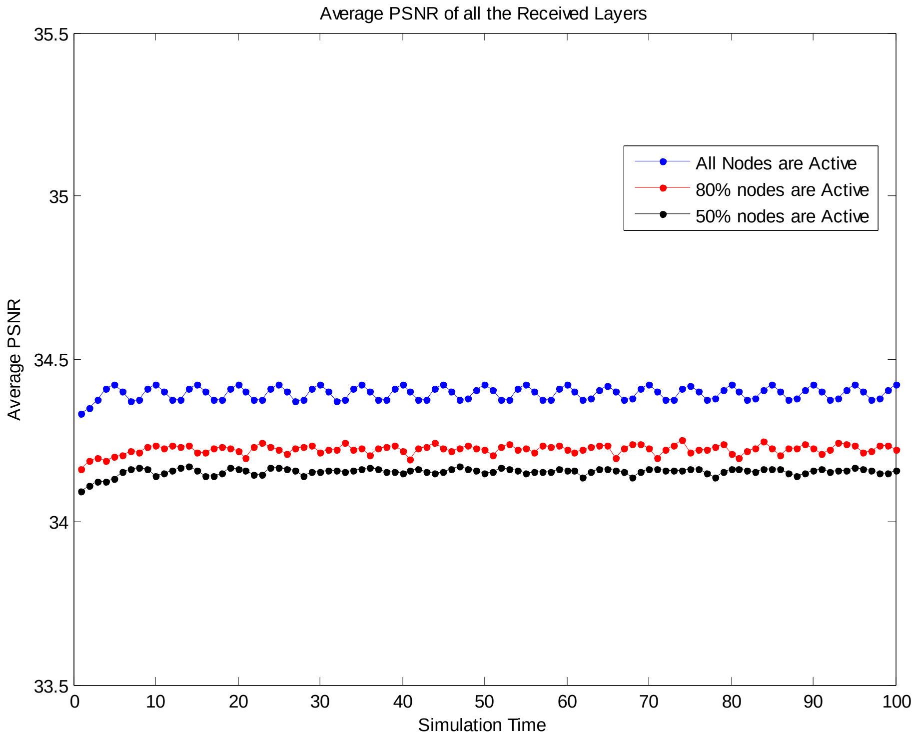


Figure 5.16 Average PSNR received under Network Churn

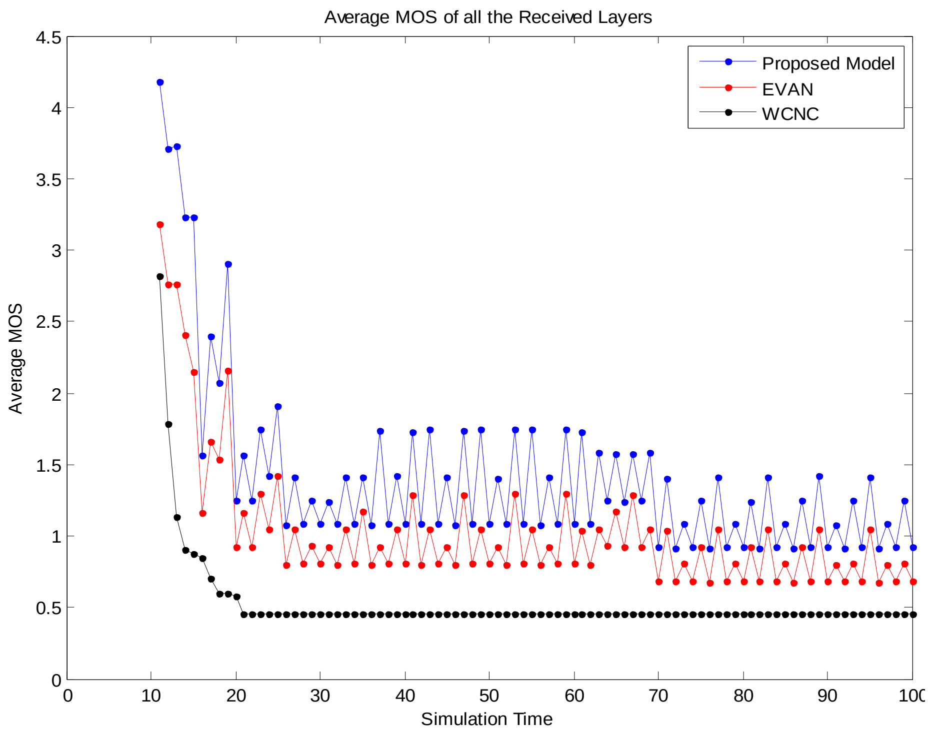


Figure 5.17 Comparison of Average MOS Received during Churn

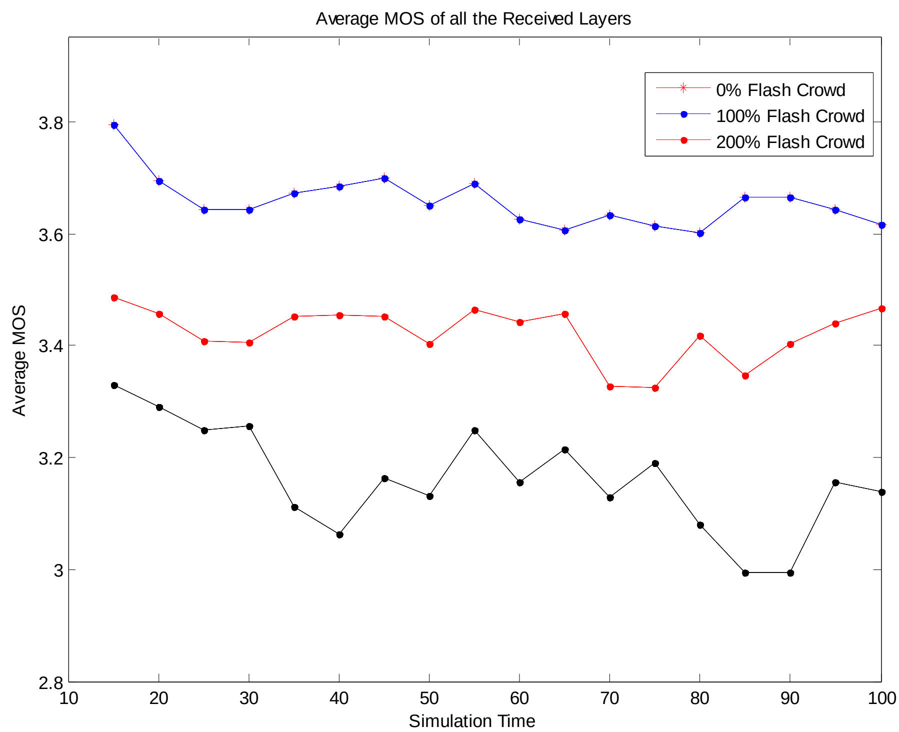


Figure 5.18 Average MOS received under Flash Crowd

5.7.4 Flash Crowd

In order to estimate the effect of flash crowd in the network. The propose model is tested against the average MOS received against the network with 100% and 200% crowd enters the network as shown in Figure 5.18. The results show that during the flash crowd with 200% nodes enters the network, the proposed model still maintains better average video quality at the requesting nodes.

5.8 Conclusion

In this chapter, a centralized approach was considered to efficiently allocate the network resources in order to make p2p streaming possible in MANET using SVC. The resource allocation problem is known to be NP complete. Hence, a liner optimization problem is considered that helps to solve the resource allocation problem. In order to solve this optimization problem, an approximation algorithm is

proposed in this chapter. The simulation results show that the proposed model improves the QOE received among the users by efficiently utilizing the upload capacity and energy at each node. The model is compared with the existing models as in [164] and [165]. Furthermore, the model is tested against QNE and NQNE models which were designed during the designing of the propose model. The propose model provides better QOE among users, maintains better average PSNR received and consume less amount of energy. The proposed model is further tested against churn and flash crowd in the network. The results shows that propose model still maintains better PSNR and QOE during such conditions.

6 VIDEO STREAMING ACROSS MANETS: DECENTRALIZED APPROACH

The previous chapter proposed a centralized approach to efficiently distribute the available resources across the nodes to stream the video in MANETs. However, this introduces cost because a centralized node or server is needed in order to keep the track of the available resources, transmission speed and the routing information for each node in the network. This method performs well for a wired or a wireless mesh network as the nodes are always connected to a power source and their positions do not change. However, in the case when nodes are highly mobile, the routing information is frequently changed over the time. Hence, collecting all the routing information produces high signalling overhead. Similarly, due to the limited energy available across the nodes, they may run out of battery quickly.

This chapter covers a decentralized approach to stream video across MANETs in order to provide users a better quality of service by efficiently utilizing the available resources across the nodes. Henceforth, the following research question remains open; how to collect the information about the data available across the node in the network such that the sources can be identified. Moreover, how efficiently the resources available at the sources to stream the video are utilized. In order to solve the problem, a novel Energy-Efficient Video Streaming System (EEVS) is proposed that categorized the system into different techniques; an adaptive data collection technique and a routing technique. The adaptive data collection technique is used to share the information available across the nodes. However, in the routing technique, the sources with the video are identified first and then video is streamed using the source to the destination node. Layer coding is used to provide the nodes with different video quality levels based on their available resources. Furthermore, the concept of multiple sources is used in order to distribute the load across each node in

the network. The simulation results show that EEVS has 120% less overhead than HAS-A-GEM and approximately 170% less overhead than MVSS. Furthermore, the results show that the EEVS outperforms MP2P+MDC and EDSR by efficiently managing the energy across the nodes and distributing the load across the network using multiple sources. Hence, this increases the network lifetime. Moreover, the results also show that in EEVS the average video quality received is 30% more than MP2P+MDC and approximately 50% more than EDSR. The results also show that EEVS reduces the streaming delay up to 165% as compared to MP2P+MDC and approximately up to 300% as compared to EDSR.

6.1 System Description

Consider a mobile ad-hoc networks (MANET) with *v* mobile nodes represented by the set $\boldsymbol{N}$={n_1,n_2 …, n_v}. A node can be a source, destination or a relay. A source node is the one that carries the requested video. A destination node is the one that makes a request for a particular video. Suppose that at any time instant *t*, nodes are connected with each other such that there is at least a path from any source to any destination. In order to forward a given video to the destination, if there does not exist any direct link between the source and destination, a number of nodes are involved as relayed nodes to deliver the video. Note, there are multiple sources and destinations in the network, meaning a given video may be streamed to a destination from various sources. In this model, we assume that the network is decentralized. This means that in real-time, a node cannot collect any information exists at other nodes. This issue is going to be challenging when the update rate of videos is high. In terms of nodes' mobility pattern, we assume that the nodes are mobile and the network topology is dynamic. The routes can be discovered based on any existing routing protocol i.e., Dynamic Source Routing (DSR) [198]. DSR is a simple routing protocol that is used for multi hop ad hoc networks. It should be noted that we focus on how to disseminate frames rather than discovering paths.

Every node i in the network has a degree $\mathcal{E}_i$, that indicates the number of node i's neighbours at a certain time *t*. Each node *i* has energy $E_i(t)$in order to move, store,

transmit and receive messages that is consumed based on the node's power P_i at time t. Once a node runs out of energy, the node cannot behave as a relay node and the network misses one of its nodes. In this chapter, it is assumed that each node i has limited energy E_i that is consumed based on the node's mobility, radio range, and the transmission rate. The energy across each node is maintained in the video summary table which gets updated in regular intervals of time as discussed in Section IV. Hence, based on the history of each node, the remaining energy can be predicted by subtracting the actual energy before time t from the energy consumed at any given time. Similarly, $TR_{ij}(t)$ represents the transmission speed of a link between node i and j at time t. This implies that how quick a video can be transmitted from node i to j or vice versa. Note, the link capacity changes with respect to nodes mobility pattern, traffic conditions and wireless channel conditions because at any time t the distance between node i to node j changes. For example, if two mobile nodes equipped with 802.11n meet each other at a distance of 40 meters the average transmission speed would be 35Mbps. Whereas, if the distance increases to 120 meters the transmission speed drops down to 12.7Mbps [196].

6.2 Data Structure

A video structure is defined as a sequence of pictures which come after each other within a second. Accordingly, when the number of pictures within a second increases, the human eye cannot detect the gap between the pictures. This represents the quality of video that is indicated by "*frames per second"* (fps). Furthermore, a frame is composed of a number of pixels that represents the resolution. From said definition, the size of a video of second *t*, *VS(t)* is calculated as follows,

$$VS(t) = P * C * F \qquad (6.1)$$

where P represents the number of pixels and C is the number of bits which are required to illuminate the main colours, namely red, blue and green in order to generate any visible spectrum. Lastly, F indicates the number of frames of second t. As an example, a video has 1 minute length that is recorded with a resolution of 640×480 pixels and with the quality of 100 fps. Currently, most of the typical video adapters uses 24 bits of information to represent each pixel where each red, blue or

green comprises of 8 bits. Hence, this approach helps to generate 2^{24} different combinations of the spectrums using R, G and B. In order to measure Equation 6.2 is used to measure the size of every second *t* of the video is;

$$VS(t) = 307200 * 24 * 100 = 90000KB \qquad (6.2)$$

Now, consider that every second *t* of a given video is compressed into *m* layers based on the number of frames. For example, a video with 100fps can be compressed into four layers with 25 frames each. In order to keep each layer at least within a basic quality level, a minimum number of frames to each layer are allocated. The number of layers is dependent on the number of frames per second and the number of frames in each layer. For example, if a video has 1000 fps and each layer includes 25 frames, there will be 40 layers per second. Let $L_t = \{\ell_{1,t}, \ell_{2,t} \dots \ell_{m,t}\}$ be the set of *m* layers for every second *t* of the video. Note that, each layer has its importance with no priority over other layer. This implies that the quality of a video increases if more layers is received by a receiver node.

Figure 6.1 shows an example of MANET with six nodes $N = \{n_1, \dots, n_6\}$ where n_1, n_2 and n_3 are the source nodes, n_4 and n_5 are the relay nodes and n_6 is the destination node. The source nodes have a complete video of 5 seconds in length with a size of approx 3600*Mb* (see equation 2). Every second of the video is compressed into 4 different layers at the frame rate of 25 frames with a size of approximately *180Mb*. Each source node is ready to stream the video towards the destination node through any of the three available paths or using the combination of paths. The download time for each node to receive a video is obtained by calculating the time required to forward whole video layers.

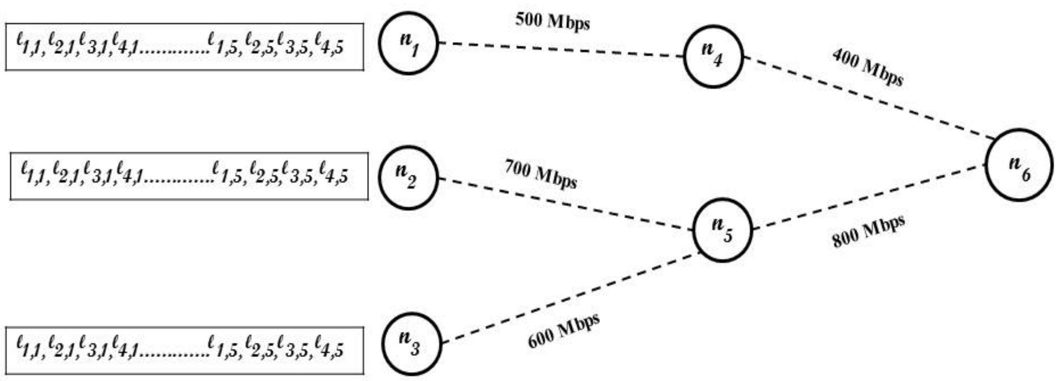


Figure 6.1 An example of video distribution over MANETs

As an example, consider a path in which a destination n_6 can download the video from source n_2 using an intermediate node n_5. Source n_2 forwards each layer of a video to n_5 at 0.25sec where the transmission speed is TR_{25}= 700Mbps and the time required by n_5 to forward the received layer to destination n_6 at 0.22sec where the transmission speed is TR_{56}= 800Mbps. The total time required for source n_2 to forward a layer to n_6 will be 0.25+0.22=0.47sec. Similarly, n_2 forwards the second layer to n_5 at 0.25sec and takes another 0.25sec to be available at n_5 using parallel processing. Noden_5 forwards the second layer at 0.50sec to n_6 and take another 0.22sec such that 0.50+0.22=0.77sec and vice versa. So, the total length of a video is 5sec and each second have 4 layers so the whole video can be downloaded by n_6 within 5.22 seconds. In another example, if two layers of every second of the video is downloaded from n_2 and one layer from n_1 and one layer from n_3, the total download time require is 4.05 seconds.

In order to disseminate the data information across the network, it is assumed that each node *i* maintains a video summary table $\mho_i$ and a node information table $\aleph_i$. In case of video summary table, if a node identifies a change, it shares the updated portion of the summary table with the encountered nodes. Hence, there is no fixed time unit for the update to occur. On the other hand, the node information table is updated after a certain time interval T_{update} and shared across the nodes in the network. The video summary table for node *i* categorized into two different sets of information such as video data parameters and the number of viewers. The video data parameters carries the information about the detail specifications of the available

videos such as the name of the videos, size of the videos and the total number of layers belong to each video. On the other hand, the number of viewers has the information of the actual viewers watching the videos. Similarly, the node information table keeps the information about node's degree information $\mathcal{E}_i$, node's energy$E_i(t)$ and the transmission speed $TR_{ij}(t)$ across the link between node *i* and *j* at time *t*.

Let us consider an example that explains the basic understanding of the video summary table and the node information table available across each node as shown in Figure 6.2. A network comprises of seven nodes such as $N = \{n_1, \dots, n_7\}$, each node shares a video summary table among other nodes. For node n_1, video summary table comprises of the video data parameters such that a video V_{abc} of size 90MB comprises of 40 different layers being watched by 20 different viewers. The node's information table has the information about the nodes' degree for $n_1$which is $\mathcal{E}_1$ =2 because n_1 is connected with nodes n_2 and n_5 at the same time instant *t*. The available energy at n_1 is $E_1(t) = 70\%$ and the transmission speeds from $n_1$to n_2 and$n_1$to n_5 are TR_{12} and TR_{15} equal to 400 and 600 Mbps. Similarly, n_2 has a video V_{def} of size 40MB comprises of 40 layers being watched by 100 different viewers. Node n_2 has a degree $\mathcal{E}_2$ =2 as it is connected with node n_1 and n_3 at a time*t*. The available energy at$n_2$is$E_2(t) = 80\%$with the transmission speeds TR_{21} and TR_{23} equal to 400 and 800 Mbps. Similarly, n_3 carries the same video V_{abc} available at n_1, however, n_3 has a node degree $\mathcal{E}_3$ =3 as it is connected withn_2, n_4 and n_6. The available energy at $n_3$is$E_3(t) = 80\%$and the transmission speeds TR_{32}, TR_{34} and TR_{36} are given as 800, 500 and 500 Mbps. Each node shares the video summary table and the node information table among other nodes during its contact. The detail description of the information sharing is given in Section VI below.

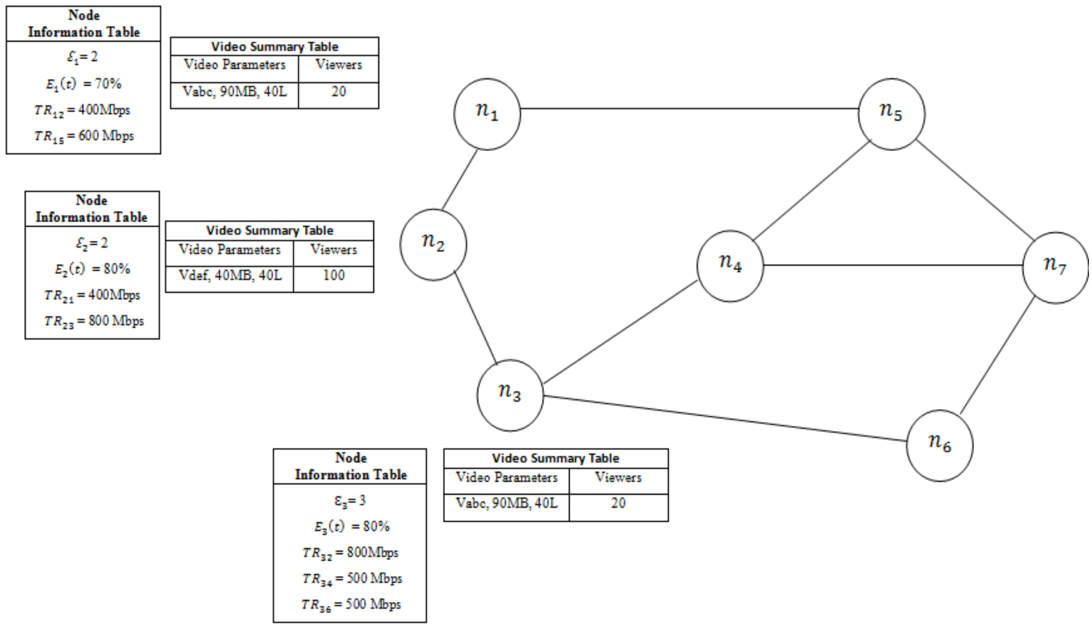


Figure 6.2 Information across the nodes in MANET

Table 6.1 List of Notations

Variables	Descriptions
V	Total number of mobile nodes in the network
N	Set of v mobile nodes in the network $\boldsymbol{N}=\{n_1,n_2\ \ldots,n_v\}$
$\mathcal{E}_i$	Degree of node i at time t
$E_i(t)$	Energy of the node i at time t
P_i	Nodes power at time t
$TR_{ij}(t)$	Transmission speed of a link between node i and j at time t
$VS(t)$	Size of a video of second t
P	The number of pixels of video at time t
C	The number of bits required to illuminate main colors *(R,G,B)*
F	The number of frames of second t
m	Total number of layers at which video is coded at time t
L_t	Set of m layers of the video at time t ($L_t = \{\ell_{1,t}, \ell_{2,t} \ldots \ell_{m,t}\}$)
$\mathcal{U}_i$	Video summary table for node i
$\mathcal{N}_i$	Node information table for node i
$P_{i,j}$	Percentage of node i video summary table shared with node j
U_i	Utility of path i
$d_{i,j}$	Time required to receive packet from node i to j
$D_{j,v,s}$	Node j shared proportion of video layers for second t

6.3 Problem Description

In past works such as [199-204], the authors assume that the network is centralized which means a centralized node is available that keeps the track of the available resources, available transmission speed and the routing information for each node. This method performs well for the wired or wireless mesh network as the nodes position do not change and they are always connected to the power. However, when nodes are highly mobile, routing information may change over time. Hence, collecting routing information is not efficient due to the high signalling overhead. In addition, due to limited energy available at the node [166-171], nodes may run out of battery quickly. Recall that MANET possesses limited energy at nodes which consume with the distribution of data. As an example, consider the model as shown in Figure 6.1. Let node n_7 wants to download the content from the network with 7 nodes and 9 links, it communicates with every other node n_1 to n_6 in the network to identify the nodes that have the required video. This process requires at least 9 signals to be sent by the requesting node to locate the nodes with video. So, the encountered problem is a large signalling overhead if more number of nodes join and request for the content in a decentralized network.

The streaming delay is considered as another problem as discussed in [168-170] [172-175] [180-183]. In a highly dynamic network, the contact duration between the nodes become short and the data cannot be transferred until some other source node forwards the remaining data, this produces an excessive delay. Let us consider an example shown in Figure 6.2 where node n_1 wants to transmit a layered video V to destination node n_6 using a relay node n_4. Node $n_1$sends video to $n_4$with a transmission speed of TR_{14}= 500Mbps and n_4 forwards it to $n_6$with a transmission speed of TR_{46}= 400Mbps. Therefore, the total time required to download a 5sec video with all the layers is 9.36 sec. However, if the contact duration between node $n_1$and n_4 is 6sec, then first 3sec of a 5sec video is downloaded and then node n_6 finds an alternate source to transfer the remaining 2sec video that causes an excessive delay. The streaming delay is bearable in on demand streaming where the video is downloaded from the server with no time constraint but in live streaming network, delay cannot be justified.

The efficient utilization of nodes energy as discussed in [178] [180-181] [185-188]plays an important role for streaming video across MANETs. In MANETs, if a node's energy is fully utilized, the network may miss that node and results in a network with a number of missed nodes which eventually degrades the quality of the video. If the nodes with a high transmission speeds are used to transmit layers, the layers deliver to the requesting node with a minimum streaming delay. However the nodes will consume most of their energies and run out of battery quickly and ends up with a network of missed nodes. Moreover, the energy consumption also depends on the distance between the sender and a receiver node. If the distance between the nodes increases, more power is consumed. Therefore, it is necessary to provide an energy efficient routing protocol that provides the trade-off between node's energy and streaming delay together.

The available transmission speeds at the nodes should be utilized effectively as discussed in [166] [170] [178] and [185-188]. If a node with high transmission speed is always used to handle the new requests, the network will soon encountered congestion. Congestion occurs when the demand for the capacity exceeds more than the available transmission speed which eventually degrades the quality of service and introduces packet loss and blocks further requests. Let us consider Figure 6.2 as an example, consider n_6 downloads the video with 4 layers from source n_2 using an intermediate node n_5 with the transmission speed of 700Mbps. The total time required for source n_2 to forward the video will be 5.22 seconds. However, the transmission speed across n_2 is fully utilized to handle a single request, if n_2 want to handle any other request, it has to wait until the first request is served, which produces network congestion.

Given the above challenging issues, this chapter investigates the following research questions:

- How effectively destination nodes communicate with every other node in MANET to discover the source nodes with a requested video such that the signalling overhead can be minimized.

- What kind of node selection criteria is used to select the nodes that can efficiently stream the video across the requesting nodes with the minimum overall streaming delay. It is not ideal to stream the video through nodes that communicates with the network for a shorter period of time. Furthermore, how optimally the available energy and transmission speed across each node is utilized such that the load congestion can be minimized. The congestion deteriorates the network service quality, resulting in queuing delay, packet loss and blockage of the new requests.

- What is an effective way to distribute the layered coded video across MANET in order to share the load across different source nodes such that the nodes' resources can be efficiently utilized. The load balancing helps to increase video dissemination rate.

In this section, the existing problems for streaming the video over MANET have been discussed. In the following section, a video steaming technique system is designed that addresses the aforementioned problems in order to provide a better quality of service.

6.4 The Proposed Method

This section propose a novel Energy-Efficient Video Streaming method called EEVS that considers nodes' degree and the network capacity as important metrics to reduce signalling overhead and minimizes the delay. EEVS considers an adaptive data collection technique to share video summary table and the node information table upon contacts. In EEVS, whenever two nodes contact each other, each node shares a portion of their video summary tables along with the node information table. The portion of video summary table is shared based on the nodes' degree and the videos' popularity. Hence, the first phase of EEVS is data collection which includes video summary table and the node information table. The second phase of EEVS is related to the routing algorithm which considers the parameters such as node's degree,

remaining energy and transmission speed in order to discover stable and quick paths for streaming the video.

In the following sections, an adaptive data collection technique is proposed which consider sharing the information available across the tables. Then, a routing algorithm is proposed to discover low delay and resource friendly paths for streaming the video.

6.4.1 Adaptive Data Collection

To collect the video and nodes' information table, the initial approach is to flood nodes' video summary table and nodes' information table upon contacts. However, this results in protocol with a large signalling overhead. In this section, an adaptive data collection technique is proposed which reduces the signalling overhead of the system by prioritizing the nodes using their video summary tables. This means that upon contacts, nodes may flood the whole or just a small portion of a video summary table along with the nodes' information table to the next hop neighbour in the network.

First, consider the overhead of the system when the network is fully connected. In this case, assuming the links are bidirectional and flooding technique is used, the total number of links required to communicate is equal to $\frac{n(n-1)}{2}$, where n is the number of nodes. Moreover, the numbers of tables sent over each link are *2n(n-1)*. Therefore, the complexity is $O(2n^2)$. As an example, in a network with five nodes, assuming all nodes have video summary table and the node's information table, 2x20=40 tables are forwarded. Now suppose that the network is not fully connected. In this case, the total number of links equal to nodes degree (number of nodes' neighbours). Specifically,

$$M = \frac{\sum_{i=1}^{n} \varepsilon_i}{2} \qquad (6.3)$$

Where $\mathcal{E}_i$ is the degree of node i and n is the number of nodes. Based on equation (6.3), the number of tables transferred $4M$ because each node has two tables to share, where compared to fully connected network $4M \leq 2n(n-1)$.

This chapter considers an adaptive data collection technique to share video summary tables and the node's information table across the network. In this technique, the videos of each video summary table are sorted based on the number of viewers so thus; this implies that how much a video is popular. This observation is then used to prioritize the videos' summary in exchanging upon contacts. Another parameter is also considered, called node's degree, which represents that how many nodes a node is attached with at a particular time interval. When two nodes meet each other, they evaluate their node's degree. Note that if a node is located in a high density area, the node will have a higher value of the degree. The advantage of this observation is taken in order to send more content of video summary tables to such nodes. This is because these nodes are more visible compared to other nodes and sending video summary tables to these nodes causes that the video information becomes available amongst a large number of nodes. As an example, a study in [205] investigates that YouTube has approximately more than one billion active users each month. This implies that YouTube has a very high nodes' degree. On the other hand, ordinary servers i.e., cell phones, have usually low degree with only few nodes connected to it.

Every node *i* under EEVS has a degree ε_i, when nodes *i* meets node *j* and wants to send its video summary table along with node's information table, node *i* evaluates the ratio of the degree with respect to node *j*'s degree. Based on this, a proportion of the video summary table is forwarded along with the node's information table.

Specifically,

$$P_{i,j} = \frac{\mathcal{E}_j}{\mathcal{E}_j + \mathcal{E}_i} \times 100 \qquad (6.4)$$

where node *i* will send $P_{i,j}$% of its video summary table to node *j*. In words, equation (6.4) states that node *i* shares a percentage of its video summary table to node *j* based on its degree and node *j*'s degree.

Therefore, in this technique, each node shares a portion of its video summary table with every met node based on equation (6.4). However, if a node also have the video summary table of other nodes that it met before and wants to send them to a newly met node, then the equation (6.4) is applied to all the tables in order to share the portion of these tables based on the degree of a new node. If the two already contacted nodes contact each other again, the nodes update the video summary tables by only sharing their new data vectors or update the nodes' information table. For example, if a new video is added as a data vector in the video summary table of node n_1 which is shared with n_2. Then, n_2 will update only the new data vector of $n_1$instead of sharing the whole table again.

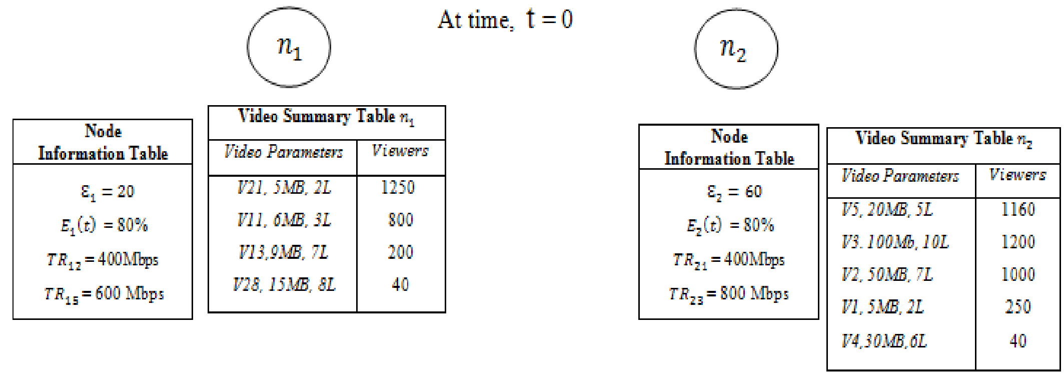
Consider a simple example as shown in Figure 6.3 to understand the basic concept of the proposed data collection method. A snapshot of a small portion of a network is taken in which any two of the three different nodes n_1, n_2 and n_3 meet each other at different time intervals t_1, t_2 and t_3 to share their video summary tables and nodes' information table among themselves.

Figure6.3(a) shows the video summary table and node's information table available across n_1 and $n_2$to share before they contact each other at time t_0. Figure6.3(b) shows the case at whichn_1 with $\mathcal{E}_1 = 20$ contacts n_2 with $\mathcal{E}_2 = 60$ at t_1. During the contact, n_1 shares $\frac{60}{60+20} x100 = 75\%$ of its video summary table with n_2.

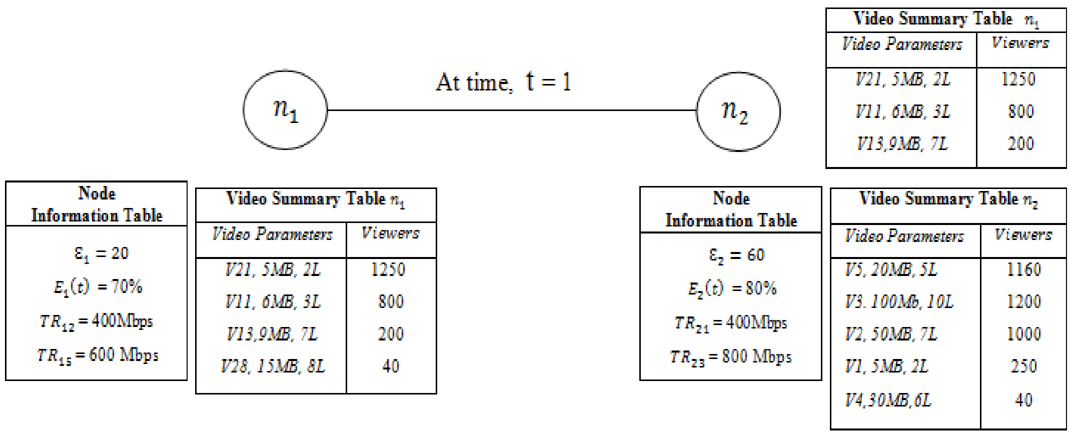
Figure 6.3(c) indicates the case at time t_2, n_2 with $\mathcal{E}_2 = 60$ meets $n_3$with $\mathcal{E}_3 = 100$, n_2 will share $\frac{100}{100+60} x\ 100 = 62.5\%$ of its video summary table with n_3. Whereas, n_2 already contacted n_1 at t_1, therefore it also carries a portion of the video summary table for n_1.Hence, it will also share 62.5% of the video summary table of $n_1$with n_3.

Finally, Figure 6.3(d) discusses another case that considers $n_1$with $\mathcal{E}_1 = 20$ meets n_3 with $\mathcal{E}_3 = 100$ at t_3 in order sharing$\frac{100}{100+20} x\ 100 = 84\%$ of the available video

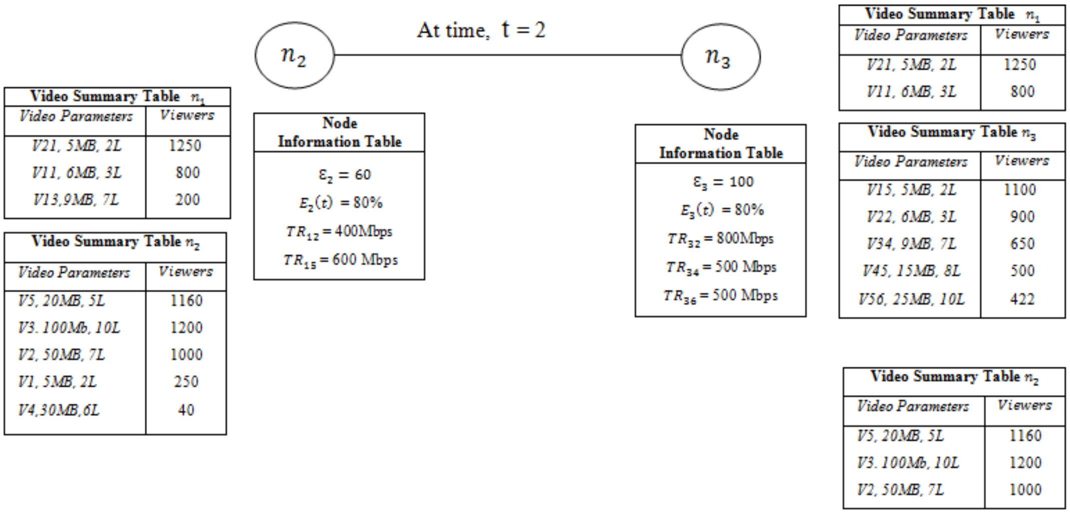
summary tables. However, in this case node n_1 and n_3 already have the video summary tables for n_1 and n_2 therefore instead of sharing the whole table again, n_1 update the tables at n_3 with some new vectors such as *V9* is the new video added up at n_2 and becomes the most popular with most number of viewers. Similarly, *V3* becomes less popular and *V2* gets more priority. However, the remaining videos priorities and viewers remain the same.



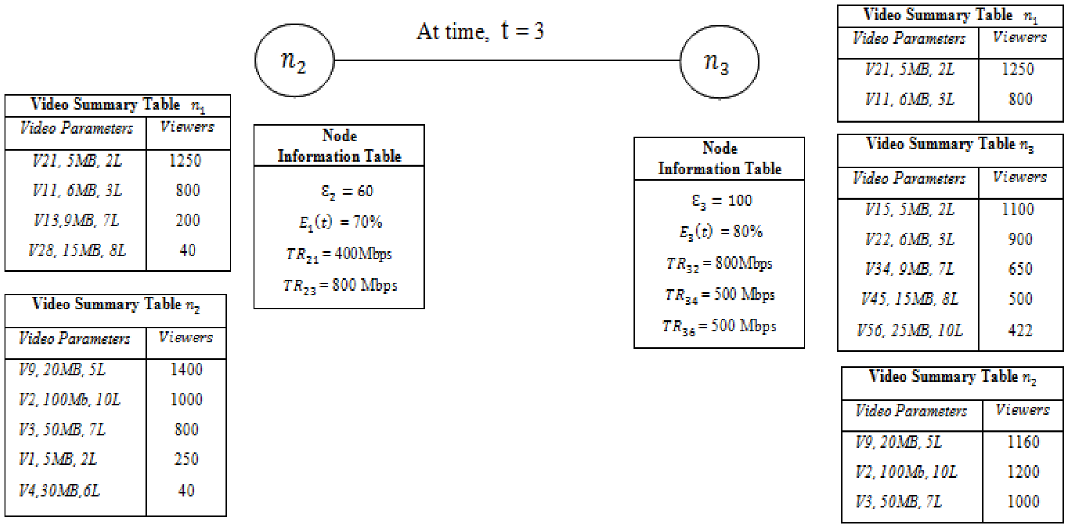
(a) Nodes' information before contact



(b) Node's updated information after their first contact



(c) Node's updated information after second contact



(d) Node's with the similar or updated information contacts

Figure 6.3(a) Nodes' information before contact, **(b)** Node's updated information after first contact, **(c)** Node's updated information after second contact, **(d)** Node's with the similar or updated information contacts

The proposed data collection technique is an efficient method to share the video summary table and the node information table across every node in the network such that the overall signalling overhead is reduced. Furthermore, in the proposed method, high priority is given to the nodes with more popular videos at a certain time interval based on the number of viewers.

This section has covered an adaptive data collection technique to share the video summary table and node information table available across each node. In the

following section, a routing protocol is proposed that helps to stream the requested video towards the destination nodes with a minimum utilization of resources.

6.4.2 Routing Algorithm

This section proposes a routing protocol that stream videos towards a given destination such that minimum delay achieves and energy consumption is balanced amongst nodes. This means that if a link has a high transmission speed, all data will not be sent over that link necessarily. As a result, the network does not miss the nodes quickly due to the lack of battery. In addition, as the video's segments are streamed over different paths, congestion will not happen over high speed links. For this reason, for each discovered path, a utility is calculated comprising of remaining energy and expected delay. This utility implies that if a data is forwarded over a path, (i) how stable is the path such that no node is missed? and, (ii) how fast the data is delivered over the path? Based on each route utility, a number of layers are forwarded. In the following section, the algorithm is discussed that disseminates the video layers from different sources towards a given destination.

When a node requests a video, the first step is to discover the source nodes. For this reason, the destination node floods the request throughout the network. Once a source node receives the request, the source node calculates the time that the request has arrived at other sources. It is highly dependent on how visible this node is. Recall that, nodes may use a simple route discovery technique i.e., DSR, in order to discover all the possible paths from any source to any destination. In addition, based on the data collection technique described, nodes' information is known to all nodes and a source node may know that what other sources have a given video. Accordingly, each source node can estimate the number of layers which has been forwarded earlier and based on that, the rest of layers is forwarded. Specifically, the utility of every path *i* is calculated as follows.

$$U_i = \frac{E}{E_{max}} \times \frac{TR}{TR_{max}} \qquad (6.5)$$

Where E is average energy of nodes involved in path i and TR is the average transmission speed of links in path *i*. Also, E_{max} and TR_{max} represent the maximum possible value of energy and transmission speed respectively. In this work, it is assumed that maximum energy is 100 and the maximum link transmission speed based on the *IEEE 802.11ad* technology is equal to 6.75 GB/s. In words, Eq.(6.5) normalizes the remaining energy of nodes and the link transmission speed of them in a path and combine them as a utility in order to estimate how busy are links and how much is the remaining energy of nodes.

Every source node j that receives a request, it needs to know which layers of the video are already forwarded by other source nodes. This requires node *j* to calculate the utility of paths from other source nodes *i* which node *j* has already received the video summary table of them. Remind that source node *j* knows other source nodes only if it receives their video summary table. Also, in order to know which source nodes have received the request earlier than node *j*, it needs to calculate the delay based on the route's speed which is obtained from the link capacity. This information is used to calculate how many layers are already forwarded from the sources which have received the request earlier than node *j*. Then, node *j* can forward a proportional number of remaining layers based on the utility of it paths. In this method, for a given video *v*, every source node *j* forwards a proportional number of layers of second*s* along a path *i* based on the utility U_i.

Specifically,

$$D_{j,v,s} = \lfloor U_i \times L_t \rfloor \tag{6.6}$$

Eq.(6.6) determines the number of layers that can be forwarded by each node based on the path utility. It should be noted that for each second of a video, each source node only one time forward the corresponding layers. In other words, for each second of a video, when a source node allocates different number of layers to each discovered path, it will not forward the remaining layers of that second anymore. This is because; it is the responsibility of other source nodes to forward the rest of layers for that second. However, in order to provide parallel distribution of video layers, the current source node starts to disseminate the layers of next second of the

video. This way, every source node can estimate that which layers of the video is being forwarded by other source nodes. Accordingly, current source node can start to forward the rest of layers. This estimation is based on the time that a source node receives the request.

Now consider the case where during streaming, a source node, for some reasons (such as: lack of battery, mobility) is missed and is not able to stream its video for a while. Hence, the layers which were supposed to be streamed by the missed node will not be delivered. In this case, as nodes are always aware of the network topology, the source nodes which have recorded the video summary table of the missed node will make a decision to forward the layers which were supposed to be forwarded by the missed source node. It should be noted that this recovery has to be done over the quickest possible path from current source nodes. This is because those lost layers of the video may belong to earlier seconds of the video.

In the case of live videos streaming, a loading time LT is assumed that represent the time that a receiver has to wait since the first layer of a video is received. This improves the quality of videos as more layers will have been received before the time of watching. This implies that if loading time decreases, the downloaded video will have less gap with respect to the live. However, this may reduce the quality of video. In the worst case, for any reason if a receiver does not receive any layer of a segment (every second of video), there receiver has not to wait to receive the layers. Hence, due to not miss the live videos, a waiting time WT is defined that determines how long a receiver has to wait to receive the current layers of the video.

Figure 6.4 studies a simple example to show how a video is stream across a decentralized network. It is considered that n_6 makes a request for a video V recorded at a resolution of 640 x 480 at the frame rate of 100 fps with a total video length of 3 seconds, hence the total size of the video for each second is $VS(1) = (640 * 480) * 24 * 100 = 740Mb$. Further, it is assumed that the video V is coded into four different layers such that each layer carries 25fps. Therefore, the size of each layer of the video per second is 185 *Mb*. Based on the data collection technique, the network identifies that the sources n_1, n_2 and n_3 have the video *V*. Each source n_1,

n_2 and n_3 calculates the time at which the request is received to other sources. Let's assume that the size of each request made by n_6 over different paths is same such as 10 Kb. Hence, the time n_1, n_2 and n_3 receives the request is calculated as;

$$d_{61} = d_{64} + d_{41} = \frac{10 * 10^3}{300 * 10^6} + \frac{10 * 10^3}{500 * 10^6} = 53.33\ \mu s$$

$$d_{62} = \frac{10 * 10^3}{600 * 10^6} = 16.66\ \mu s$$

$$d_{63} = d_{65} + d_{53} = \frac{10 * 10^3}{750 * 10^6} + \frac{10 * 10^3}{850 * 10^6} = 25.065\ \mu s$$

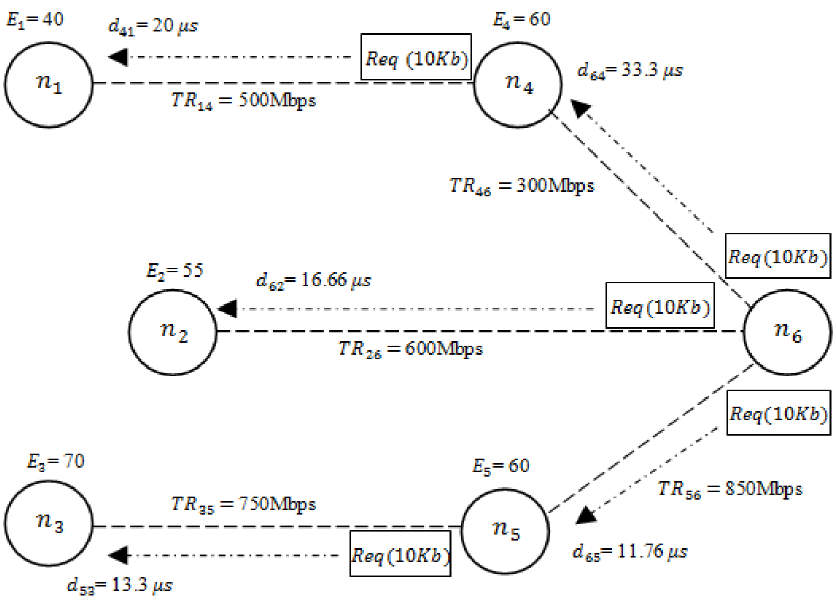


Figure 6.4 Proposed video streaming method in a decentralized MANET

In order to find the number of layers forwarded by n_1, n_2 and n_3, the path utility is calculated based on the average transmission speeds and energies over the paths. The average transmission speed is given as the minimum speed over the links in a path that will be TR_{16}, TR_{26} and TR_{36} equals to 300Mbps, 600Mbps and 750Mbps. Furthermore, the average energy over the paths is given as E_{16}, E_{26} and E_{36} equals to 40, 55 and 60. Hence, the utility for each path is calculated using Eq.(6.5) as,

$$U_1 = \frac{40}{100} \times \frac{300Mbps}{500Mbps} = 0.24$$

$$U_2 = \frac{55}{100} \times \frac{600Mbps}{600Mbps} = 0.55$$

$$U_3 = \frac{60}{100} \times \frac{750Mbps}{850Mbps} = 0.52$$

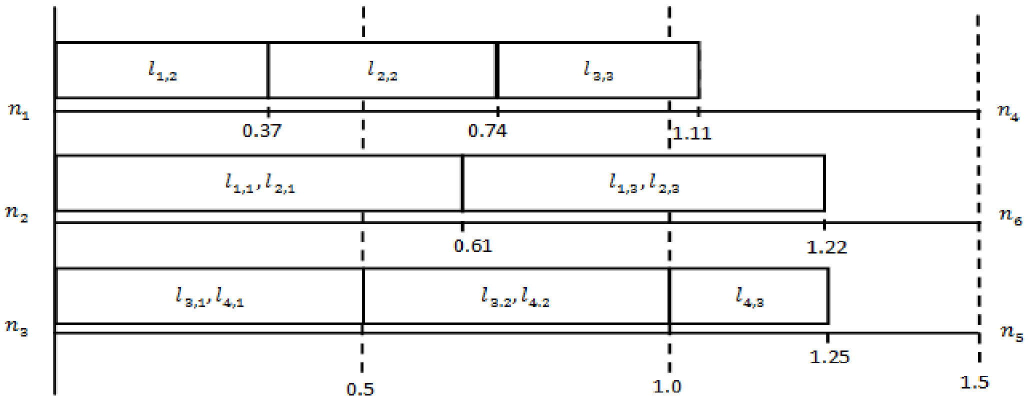
Based on the calculated utilities of each path, the number of layers are forwarded over each path is calculated using Eq. (6.6) where, L_t = 4;

$$D_{1,v,s} = U_1 \times L_t = 0.24 * 4 = 0.96 = 1\ approx$$

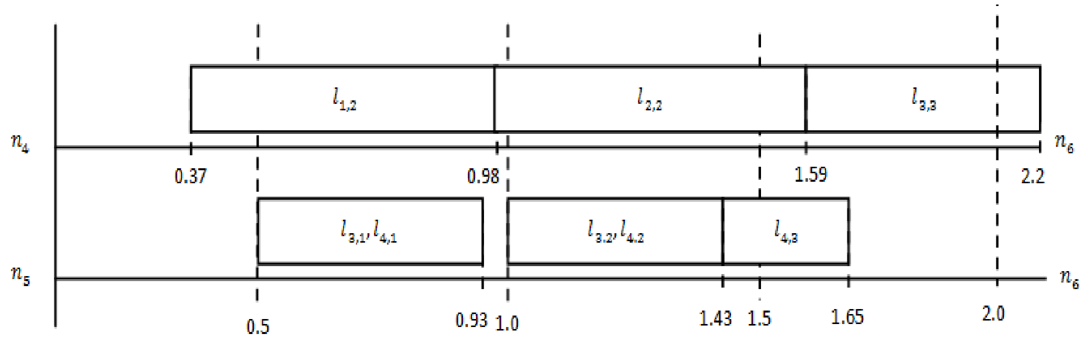
$$D_{2,v,s} = U_2 \times L_t = 0.55 * 4 = 2.2 = 2\ approx$$

$$D_{3,v,s} = U_3 \times L_t = 0.52 * 4 = 2.08 = 2\ approx$$

Figure 6.5 shows that based on the path utility, the proportional number of frames forwarded by each source node using the concept of parallel processing. Figure 6.5(a) represents the time taken by the sources to forward the content to the next hop neighbour. Whereas Figure 6.5(b) shows that the source n_4 and n_5 are the helper nodes that forwards the content from n_1 and $n_3$to n_6.



(a) Source forwarding layers to the next hop helper nodes



(b) Helper nodes forwards the layers to the destination node

Figure 6.5 **(a)** Source forwarding layers to the next hop helper nodes, **(b)** Helper nodes forwards the layers to the destination node

6.4.3 Algorithm

Figure 6.6 shows the pseudo code of the algorithm that uses multiple sources to stream the proportional number of layers of each video towards the destination nodes. As the input of the algorithm, every node discovers all the possible paths towards any node via an algorithm such as DSR. Firstly, an adaptive data collection part is considered (lines 2-7). In this part, whenever a node *i* meets another node *j* (line 2), a proportion of video summary table is shared by each node *i* to node *j* based on the degree of node *j* (line 3-4). Secondly, the routing part of the algorithm is considered (lines 6-18). In this part, whenever a node *i* makes a request for a video *v* (line 6), the destination *d* floods the request for video *v* until a source node *j* receives the request (line 8). Then for every source node *j*, the time a request is received from the destination node *i* is calculated (line 10). This information helps to calculate the number of layers forwarded by each source earlier than node *j*. Finally, each node *j* then estimates the proportional number of layers to be forwarded based on calculating the path utility (line 14).

Algorithm: Energy Efficient Video Streaming System (EEVS)

Input 1: paths $\{P_1, \ldots, P_i\}$
Input 2: collected video summary tables Ʋ ∈ {Ʋ$_1$, …. , Ʋv}
Input 3: collected node information table Ɲ ∈ {Ɲ$_1$, … , Ɲ$_v$}
Output: Proportion of layers forwarded by each Source

Begin
FOR *every node* n_i *that meet node* n_j **DO**
$P_{send} \leftarrow \frac{\varepsilon_j}{\varepsilon_j+\varepsilon_i} \times 100$
sendP_{send} *% of* Ʋ$_i$ *to node* n_j
ENDFOR
FOR *every request made by* n_i *for a video v* **DO**
$d \leftarrow FloodRequest(v)$ // Destination floods the request for a video *v*
$n_j \leftarrow ReceiveRequst(v)$ // Source *j* receives the request for video *v*
FOR *every source node*n_j **DO**
$d_{ji} \leftarrow CalculateDelay(P_i, n_j, d)$
$l_t \leftarrow L_t.numOfLayers$
$d \leftarrow L_t.destination$
$U_i = \frac{avg\,(E)}{E_{max}} \times \frac{avg\,(TR)}{TR_{max}}$
$D_{j,v,s} = \lfloor U_i \times L_t \rfloor$
$l_{send} \leftarrow D_{j,v,s}$
sendl_{send} *proportional of* L_t *to destination d*
END FOR
END FOR
END

Figure 6.6 Proposed Algorithm for EEVS

6.5 Experiments and Results

The Opportunistic Network Environment (ONE) [206] is a Java-based simulator that is designed to simulate delay tolerant networks. However, this simulator is able to generate node movement using different mobility models and import real-world traces or maps. Hence, the simulator is modified such that the network is always connected while nodes are mobile. Using ONE, the performance of EEVS is evaluated under map based mobility model [206]. In map based model, nodes have predefined movement in an area of approximately 5×3 km^2 of downtown Helsinki, Finland. It is assumed that a majority of these nodes are pedestrian. Specifically, it is

assumed that there are 150 mobile nodes in the network where 64% of nodes model pedestrians with speed between 0.5 and 1.5 m/s. Another 32% of nodes are vehicles with speed ranging from 2.7 and 13.9 m/s. The remaining nodes are configured to follow pre-defined routes (like tram lines) with speed between 7 and 10 m/s. All nodes have a transmission range of approximately 80m for the pedestrians and vehicles except trams that have longer radio range connected with MIMO antennas to cover up to 500m using IEEE 802.11n technology.

The offered load by adjusting the number of requested videos from 100 video requests (high load), to 50 video requests (medium load), to 10 video requests (light load). In all simulations, videos are randomly distributed between all nodes as source nodes. Note, each video may be distributed at different nodes as source nodes. Note, each video is recorded at the resolution of 720p with a frame rate of 100 fps. Also, assume that each video is coded into 10different layers such that the video can be decoded at 10fps, up to 100fps with the increment of 10. The supported data rates for layer encoded video with a resolution of 720p are 7800, 4800, 2750, 1500kbps according to [207]. In terms of bandwidth, pedestrians, vehicles are assumed to have a transmission speed of 250 kBps whereas the trams are considered to have a transmission speed of around 10MBps. Each simulation lasts for 12 simulated hours and each data point is an average of 10 simulation runs.

EEVS is compared against other well-known protocols in two experiments. In first experiment, the data collection phase of EEVS is compared against a flooding-based called MVSS and encounter-based techniques called Hybrid Adaptive Search According to Gossip Exchange Method (HAS-A-GEM). Briefly, they operate as follows. In MVSS, each node broadcast its video summary table and others recorded to the neighbours. This way, all nodes will receive the video summary table of each other. In, HAS-A-GEM nodes with a high encounters rate will receive video summary tables.

Table 6.2 Parameters for Experiment Setup

Parameters	**Values**
Wireless Technology	802.11n
Routing Protocol	DSR
Simulation Software	ONE
Mobility Patterns	Map-based model
Roaming Area	5×3 km^2
No. of mobile nodes	150
Speed of Mobile nodes	64% pedestrians (0.5-1.5 m/s) 32% vehicles (2.7-13.9 m/s) 6% tram lines (7-10 m/s)
Transmission Range	80m Pedestrians& Cars 500m Tram lines using MIMO antenna
Number of videos	1000
Offered Load	100 videos (high load) 50 videos (medium load) 10 videos (light load)
Video Parameters	Video Size 26Mb Resolution 720p Frame rate 100 fps Layers 10, 10fps each
Average Transmission Speed	250 kBps Pedestrians & Cars 10MBpsTram lines using MIMO antenna
Simulation Time	12 hours

In second experiment, the routing phase of EEVS is compared against EDSR and MP2P+MDC that are briefly explained as follows. In EDSR, an ant colony optimization is used, when the request packets are forwarded over the link to discover destination. When the destination node receives the message it sends a route reply packet. Source node then identifies the possible paths to send the packets. As ant colony framework is used hence the best route is selected based on the pheromone level of the route. Similarly in MP2P+MDC, video is coded into two layers such that each layer is forwarded to the receiver using multiple paths.

The routing protocols are evaluated using three performance metrics, namely 1) *average number of received layers*, 2) *signalling overhead*, and 3) *average delay*.

Briefly, *average number of received layers* is to determine the quality of downloaded video based on the number of received layers for each second of video. Hence, if more layers are received, the quality of video will be higher. The metric *signalling overhead* is the amount of data transferred in exchanging video summary tables. Finally, *average delay* is the average time until a video is downloaded.

6.5.1 Signalling Overhead

Figure 6.7 represents the total signalling overhead encountered to share information tables across the network when the numbers of nodes are varied from 50 to 200. The result shows that EEVS performs up to 120% better than HAS-A-GEM and up to 170% better than MVSS. This is because, EEVS only forwards the percentage of video summary tables based on the degree of the met. Furthermore, the priority is given to the popular videos based on number of viewers. This effectively helps to reduce sharing the whole summary tables at each node. However, in case of HAS-A-GEM consider popularity based flooding in which only the popular nodes shares the video summary tables with other nodes. Similarly in case of MVSS, the whole video summary tales are forwarded across all nodes.

6.5.2 Energy Utilization

Figure 6.8 shows that percentage of remaining energy across the nodes after a simulation run. The result shows that EEVS better utilizes the energy by keeping the nodes energies within the range of 30% to 70% as compared to MP2P+MDC that has a range of energies from 15% to 65% and EDSR that has a range of energies from

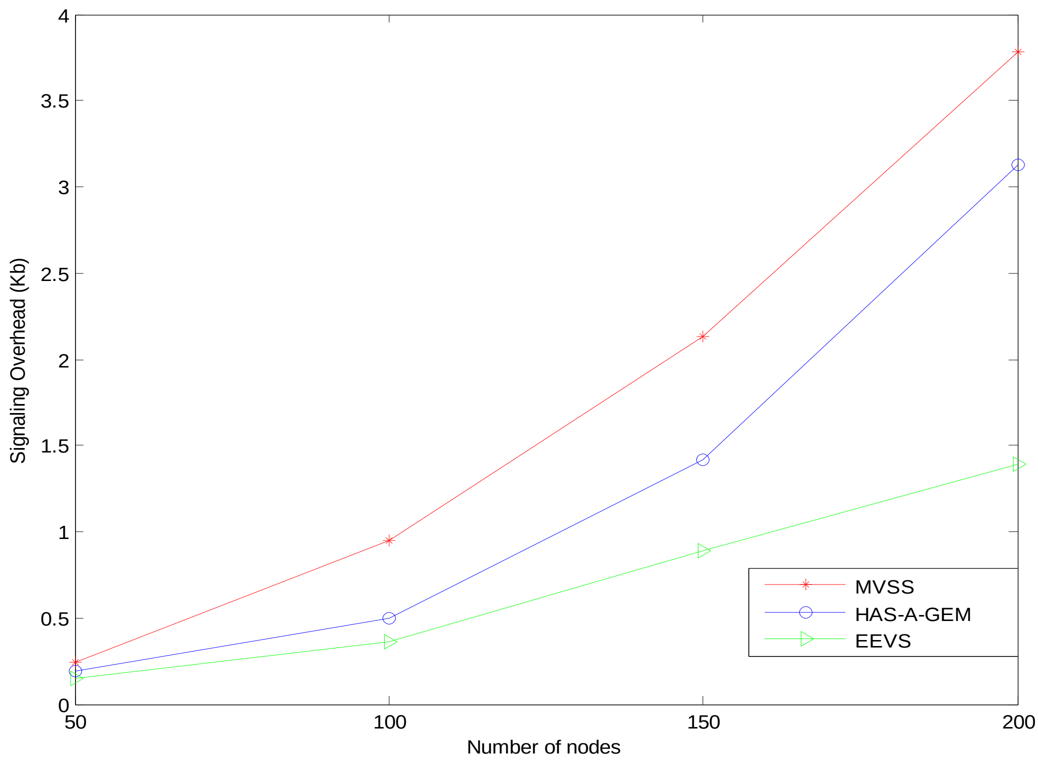


Figure 6.7 Signalling Overhead when number of nodes vary from 50 to 200

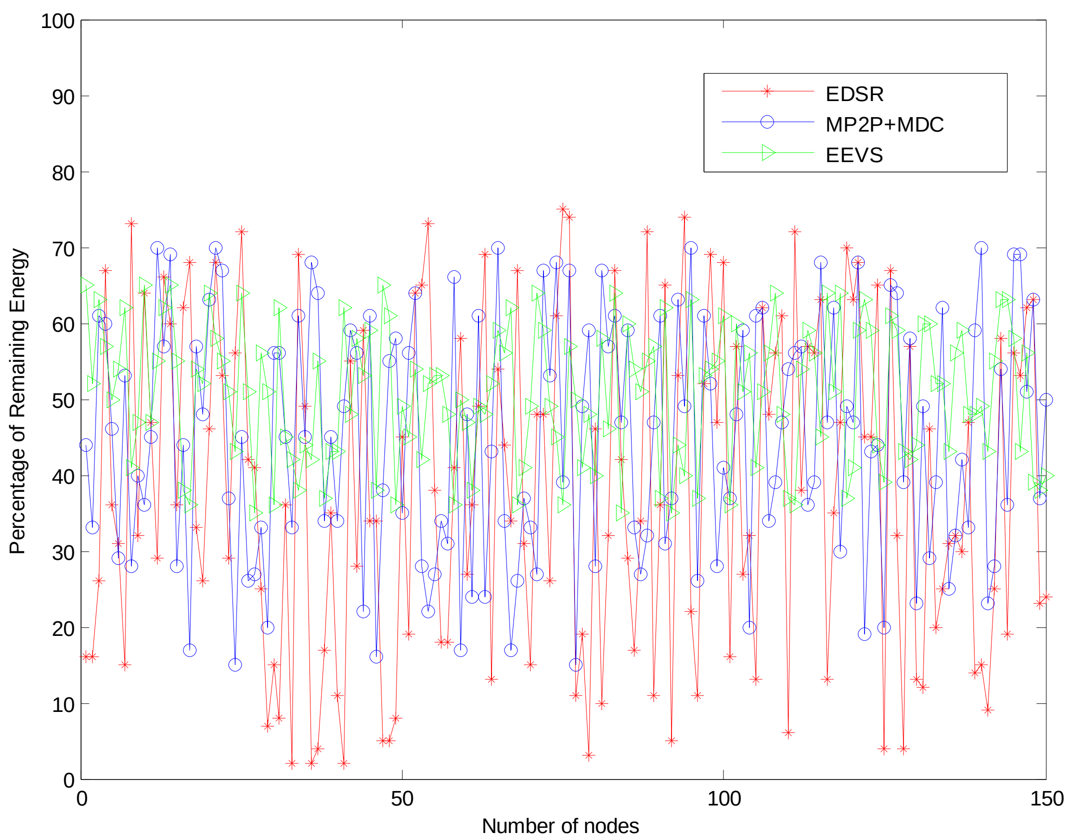


Figure 6.8 Energy Utilization when the numbers of nodes are fixed at 150

2 % to 75%. This is because in EEVS, the load is shared across multiple sources and the video is received using multiple paths. Therefore, it obtains better path diversity. Furthermore, as the video is coded into 10 different layers. This helps EEVS to obtain path utility and improves network life time. Whereas, in the case of MP2P+MDC, the load is still utilize better than EDSR, this is because in MP2P+MDC, the load is still divided over two different paths and by using MDC coding technique, each layer is forwarded over a different path. Whereas in case of EDSR, each node randomly choose the path based on the ant movement which quickly drains out the batteries of the nodes over the path.

6.5.3 Average number of Received layers

The quality of the video depends upon the number of layers received at the requesting nodes. Figure 6.9 shows the case in which three different levels of loads such as light load (10 videos requests), medium load (30 videos request) and high load (100 video requests) is applied over the network to measure the effect of load over the quality of the video. The result shows that under light load, the average number of layers received is more as compared to medium and heavy nodes. This is because in case of light load, only 10 requests come to the network which can easily be handling by the network of 100 nodes. In case of waiting time of the receiver is set at 3 seconds, all layers at received in a case of light load. However, in the case of medium load approximately 9 layers are received by each peer whereas under heavy load peer receives approximately 6 layers. This happens as the network has to entertain more number of video requests. Furthermore, at lower waiting time, the video quality is compensated if the numbers of requests are increased.

Similarly, Figure 6.10 shows the case when the waiting time is considered to be fixed at 1 second and the load is medium. The result shows that with the increase in number of nodes, more nodes are able to handle the requests hence the video quality increases for all models. However the number of layers received by EEVS is 30% more as compared to MP2P+MDC and approximately 50% more than EDSR. This is

because EEVS stream the video layers from multiple path and multiple sources that helps to retrieve more number of layers from the network. MP2P+MDC still perform

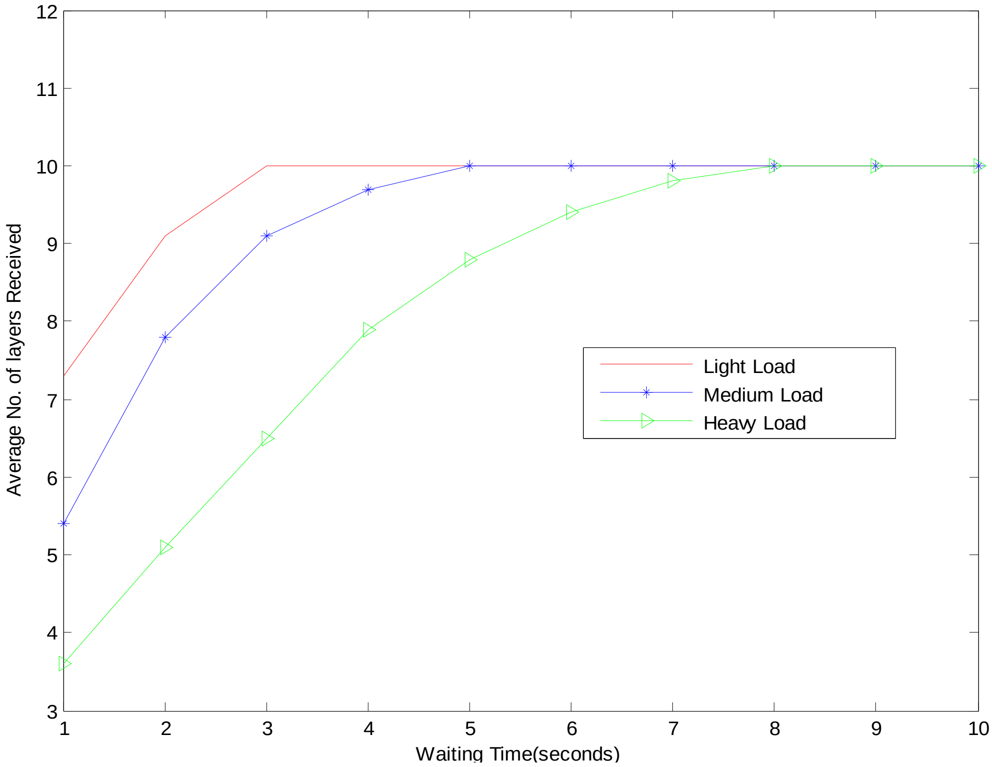


Figure 6.9 Average no. of layers received with waiting time (1-10)

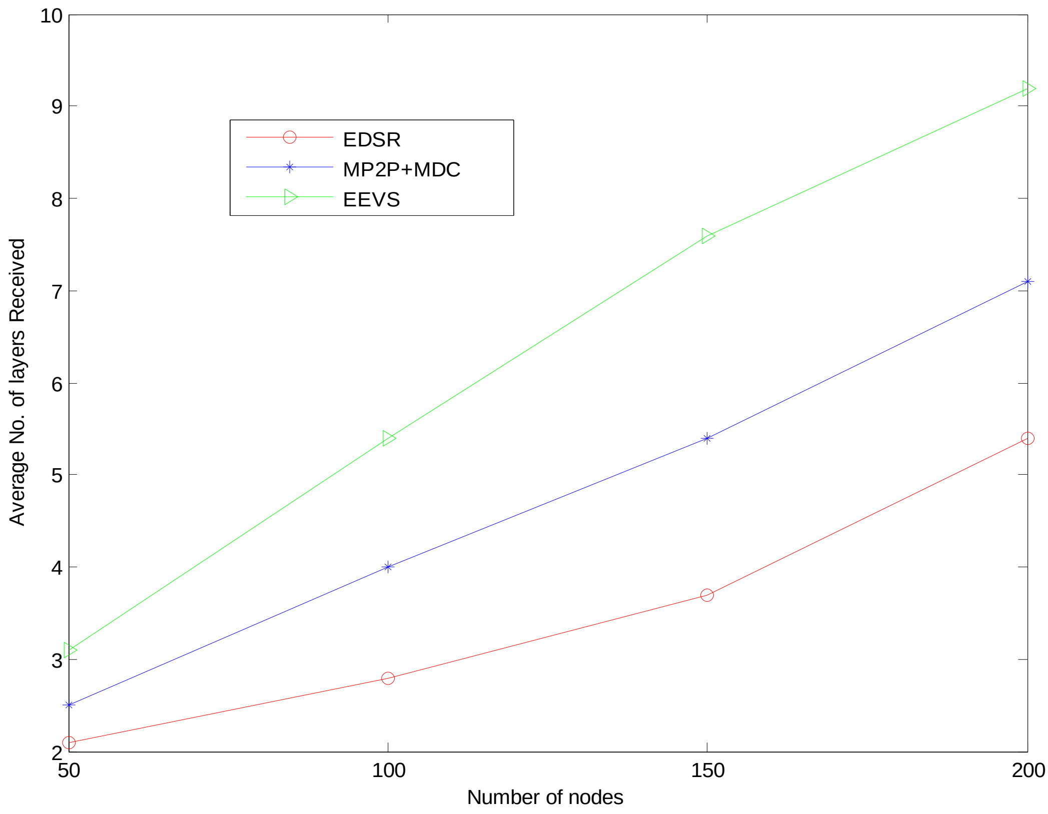


Figure 6.10 Average number of layers received when nodes (0-200)

better than EDSR as because it still route the video layers using two different paths. However, in case of EDSR as path are identified based on ant colonies concept so at most these links are busy to serve other requests as well which eventually reduces the average number of layers received.

6.5.4 Average Delay

Figure 6.11 estimates the average delay in seconds and the waiting time is set to 0 for the case of live streaming. This means that the video is played as it receives and the high load is applied on the network. The results show that when the average number of participating nodes increases, the average delay for all the models decreases. This is because there are more number of nodes are available that can handle the requests.

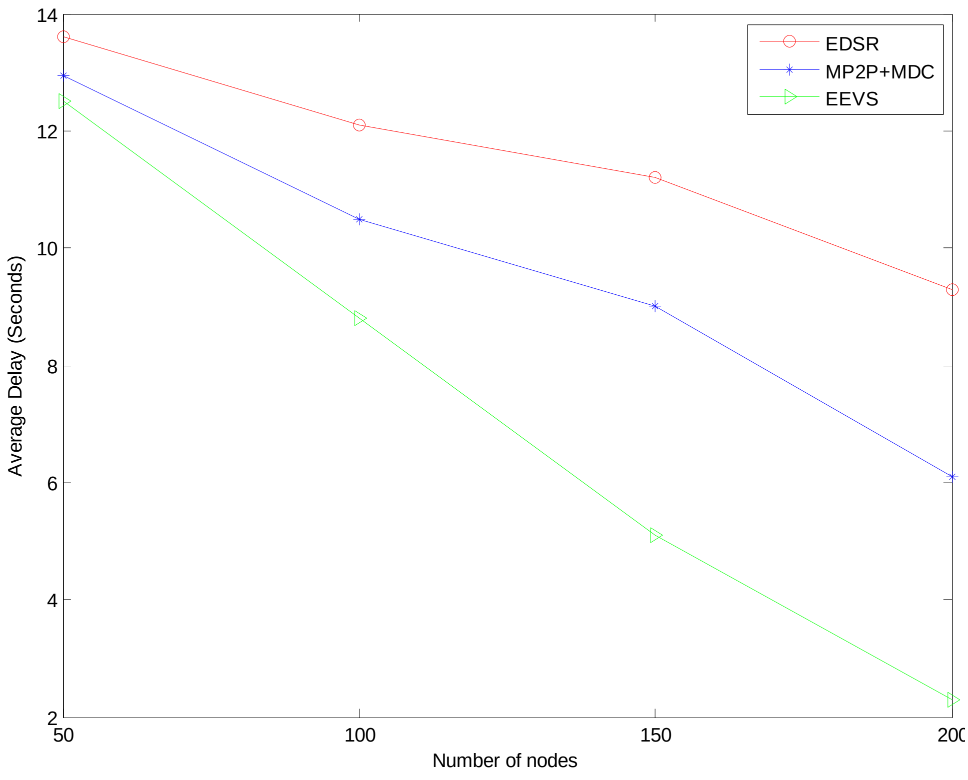


Figure 6.11 Average Delay when numbers of nodes are varied from 50 to 200

The figure also shows that the performance of EEVS increases quiet rapidly such that in the case with 150 nodes in the network, EEVS delivers the video 76% quicker than using MP2P+MDC and approximately 119% quicker than using EDSR. This improves more when the numbers of nodes are increased to 200. EEVS delivers 165% quicker than MP2P+MDC and 300% quicker than EDSR. This is because EEVS consider multiple sources to stream the video using multiple paths which helps it to deliver the video with less average delay.

6.6 Conclusion

This chapter addresses the data collection and routing problem for streaming video over a decentralized MANETs. The solution to such a problem is known to be NP complete. Hence, a novel Energy-Efficient Video Streaming method, called EEVS, is proposed that provides an adaptive data collection technique and a routing protocol to share the video across the network. In adaptive data collection technique, the

nodes share their available information across other nodes upon contact. However, the routing protocol helps to identify the sources and stream the video through multiple sources towards a given destination to reduce the overall load at each peer. Furthermore, in order to handle the heterogeneous peers in MANETs, MDC is used which provides the video at different quality levels.

The simulation results show that EEVS has 120% less overhead than HAS-A-GEM and approximately 170% less overhead than MVSS. Furthermore, the results show that the EEVS outperforms MP2P+MDC and EDSR by efficiently managing the energy across the nodes and distributing the load across the network using multiple sources. Hence, this increases the network lifetime. Moreover, the results also show that in EEVS the average video quality received is 30% more than MP2P+MDC and approximately 50% more than EDSR. The results also show that EEVS reduces the streaming delay up to 165% as compared to MP2P+MDC and approximately up to 300% as compared to EDSR.

7 CONCLUSIONS

This thesis has studied the resource utilization and allocation problems for streaming video under P2P networks, centralized control MANETs and a decentralized MANETs. As explained in Chapter 1, due to high dynamicity of peers, video coding techniques are used to provide a quick quality adaption for the video based on the available resources and current network conditions. Moreover, in the context of MANETs, nodes are considered to be mobile with dynamic topology and have limited energy and hence, it becomes challenging to achieve an acceptable QOS due to sudden joining and leaving of nodes. Until this point, the thesis provided the background of the techniques discussed for streaming video in Chapter 2 and then in Chapter 3 different state of the arts were discussed that address the resource allocation for these networks.

Chapter 4 proposed an algorithm that exploits the properties of Scalable Video Coding (SVC) in order to minimize the upload bandwidth at each peer. More specifically, this chapter proposed streaming different layers of the same video from different peers. The chapter defined an optimization problem to handle the upload bandwidth at each peer. However, the solution to the proposed problem is NP complete. Therefore, an approximation algorithm was proposed to solve this problem. In addition, seed servers are introduced in order to deal with extra load in the network. The proposed method provided better performance as compared to the current approaches that use single layer video in combination with SVC. The simulation results were compared against the model proposed in [115]. According to the results, the proposed model improved diversity, increases average video quality, reduces the effect of churn and manages flash crowds.

Chapter 5 studied a resource allocation problem for distributing the video in a P2P mobile ad hoc network (MANET) to provide users' with a better quality of experience (QOE). The chapter defined a linear optimization problem to efficiently

utilize the upload bandwidth at each mobile node. Scalable video coding (SVC) was used to help maximize the QOE by distributing the load across the nodes to minimize the power consumed and the upload bandwidth at each peer. However, the solution to the proposed problem is NP complete. Therefore, this chapter proposed a QOE based Energy Efficient model (QEE) that provides an approximation algorithm and compare the performance of the propose model with the existing models as explained in [164] and [165]. Furthermore, the performance of the model was compared against a non-quality of experience plus non-energy efficient (NQNE) and a quality of experience plus non-energy efficient (QNE) models. The simulation results showed that the proposed model provides better quality of experience consumes less power and minimizes the upload across each node. Furthermore, the propose algorithm reduced the effects of churn and handles the flash crowd in the network.

Chapter 6 addressed the data collection and routing problem for streaming video over a decentralized MANETs to improve the average video quality received. The solution to such a problem is known to be NP complete. Hence, a novel Energy-Efficient Video Streaming method, called EEVS, is proposed that provides an adaptive data collection technique and a routing protocol to share the video across the network. In adaptive data collection technique, the nodes share their available information across other nodes upon contact. However, the routing protocol helps to identify the sources and stream the video through multiple sources towards a given destination to reduce the overall load at each peer. Furthermore, in order to handle the heterogeneous peers in MANETs, MDC is used which provides the video at different quality levels. The performance of EEVS is compared other well-known protocols in two experiments. In the first experiment, the data collection phase of EEVS is compared against MVSS and HAS-A-GEM. This way, all nodes will receive the video summary table of each other. In second experiment, the routing phase of EEVS is compared against EDSR and MP2P+MDC. The simulation results show that EEVS has 120% less overhead than HAS-A-GEM and approximately 170% less overhead than MVSS. Furthermore, the results show that the EEVS outperforms MP2P+MDC and EDSR by efficiently managing the energy across the nodes and distributing the load across the network using multiple sources. Hence, this increases the network lifetime. Moreover, the results also show that in EEVS the

average video quality received is 30% more than MP2P+MDC and approximately 50% more than EDSR. The results also show that EEVS reduces the streaming delay up to 165% as compared to MP2P+MDC and approximately up to 300% as compared to EDSR.

A key future research direction is to implement the proposed methods in a more realistic network model, where a delay encountered in sending and receiving requests can be thoroughly investigated. Although the video streaming through multiple sources improves the average video quality received and reduces the playback. But in some circumstances, it may not be ideal to stream the video layers from multiple sources as it introduces complexity, playback delays and synchronization issues which are not considered as part of this research. Further work is also required to efficiently distribute the layers of the video in the first place and further work is required into the layer discovery algorithms to bring the video together at the receiver.

The proposed methods are implemented using MATLAB and ONE simulator as the aim of this research is to provide an approach to stream a layered video using multiple sources such that load at each node can be distributed. However, in order to see the behaviour of the propose methods in real world, these can be implemented over PLANET LAB or any other software that carries more than 10,000 nodes at a single time.

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