ADAPTABLE TOPOLOGY FOR PEER-TO-PEER LIVE VIDEO STREAMING

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ADAPTABLE TOPOLOGY FOR PEER-TO-PEER LIVE VIDEO STREAMING

By

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DEDICATION

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ABSTRAK

Aliran video menjadi satu aplikasi yang penting yang digunakan melalui internet. Penggunaan video yang semakin meningkat dengan pesat dalam pelbagai jenis rangkaian membawa kepada pencarian lebih banyak teknik untuk mengatasi isu berskala. Sistem rakan ke rakan dianggap sebagai murah dan merupakan teknik yang berkesan untuk mengatasi isu berskala dan juga menggantikan sistem tradisional server/pelanggan. Topologi rakan ke rakan mempunyai impak yang tinggi di antara semua bahagian komponen sistem rakan ke rakan seperti penjadualan, ukuran, pengedaran kandungan dan lain – lain; topologi rakan ke rakan menunjukkan sambungan maya antara rakan melalui rangkaian fizikal, oleh itu, topologi rakan ke rakan mempunyai impak yang besar ke atas aliran video dan kelewatan menerima video. Topologi yang dicadangkan dalam kajian ini ialah topologi penyesuaian yang dipengaruhi oleh dua faktor; kadar-bit video dan memuat naik jalur lebar bagi setiap satu rakan dalam rangkaian; di mana sambungan antara rakan akan bertukar berdasarkan pada perubahan pada setiap satu atau dua faktor tersebut. Bentuk topologi akhir yang dicadangkan merupakan hybrid di antara dua topologi sedia ada iaitu topologi jaringan dan topologi pepohon. Topologi pepohon terdiri daripada rakan dengan muat naik jalur lebar yang tinggi, sementara dalam topologi pepohon terdapat pepohon yang bertindak sebagai server untuk pengagihan sumber video di mana rakan ini akan menjadi asas kepada pepohon tersebut. Sementara itu, topologi rangkaian terdiri daripada rakan dengan muat naik jalur lebar yang rendah. Topologi terakhir tidak mempunyai rakan pasif, semua rakan mengambil bahagian dalam muat

turun dan muat naik aliran video dengan penggunaan maksimum sumber rakan. Penghantaran data telah dikemukakan juga, di mana penghantaran data penyesuaian kepada topologi yang dicadangkan pada masa yang sama topologi cadangan member kesan positif terhadap penyampaian teknik data dan lebih mudah untuk dilaksanakan. Penilaian menunjukkan topologi penyesuaian mempunyai 23 dan 66 peratus ke atas semua prestasi berbanding topologi rangkaian dan “tree” biasa dan 37 dan 57 peratus pengunaan yang lebih baik bagi rakan muat naik jalur lebar.

ADAPTABLE TOPOLOGY FOR PEER-TO-PEER LIVE VIDEO STREAMING

Abstract

Video streaming is one of the most important applications used over the internet. The rapidly increasing video usage in all types of the networks led to the need for more techniques to overcome the scalability issue. Peer-to-peer systems are considered as a cheap and effective technique to solve the scalability issue for replace traditional server-client systems. Peer-to-peer topologies show the virtual connection between peers over the physical network, as a result, peer-to-peer topologies have significant effect on video streaming flowing and video receiving delay. The proposed topology presented in this study is an adaptable topology constructed based on video bitrate and upload bandwidth for each peer in the network. The final shape of the proposed topology will be a hybrid between two well known existing topologies, mesh topology and tree topology. A tree topology consists of peers with high upload bandwidth. In tree topology there is a peer who acts as server to distribute the video source, this peer will be the root of the tree, while mesh topology consists of peers with low upload bandwidth. All peers in the final topology participate in downloading and uploading the video stream with maximum usage of peer resources. A data delivery mechanism has been proposed, which is adaptive to the proposed topology. At the same time the proposed topology positively affects data delivery mechanism and makes it very easy to implement. The evaluation shows that the proposed adaptive topology has 23% and 66% overall better performance comparing to regular tree and mesh topologies respectively in terms of video chunk delay, and 37% and 57% overall better usage of peer upload bandwidth.

CHAPTER ONE

INTRODUCTION

1.1 Background

The number of Internet users has continued to increase rapidly as a normal result of our daily use of the Internet. Currently, a large number of Internet application types are available for users, and these may be characterized by variety of qualities. The most extensive Internet application is the multimedia, of which, videos are the most popular type. YouTube and its TV channel is a good example of video use in the Internet (Youtube, 2013).

The traditional method of providing video streaming service to users through the Internet is known as a server-based (server/client) system. A server-based system is one that divides network processing among two or more machines. The database in a server-based application stores, handles, and retrieves data through the server, whereas data processing, data manipulation, and data presentation are usually handled by clients. In other words, in a server-based system, the server acts as the data storage, and clients create or obtain these data. The idea behind the server-based system is to provide more than one user with access to the same data (George, 2000). Figure 1.1 shows a server based system.

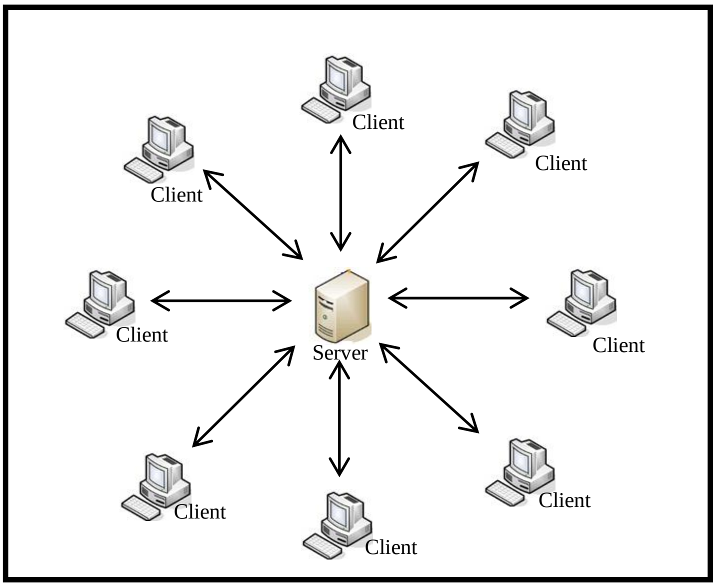

Figure 1.1. Server Based System

The server based system has limitations that draw borders for this system. Passing these borders causes network problems. Bandwidth limit is the most common issue in a server-based system, as the maximum server utilization of clients depends on the maximum server upload bandwidth. Thus, if the clients request for data in a server larger than the server is upload bandwidth, a congestion problem, referred to as a bottleneck, will occur. Bottlenecks are congestion points in the system that slow down the entire network operations (Beygelzimer, Kephart, & Rish, 2007; Wang, Zhao, & Zheng, 2005).

This problem can be solved in a couple of ways. The first solution is to use more than one server; however, this solution involves high financial costs (Nygren, Sitaraman, & Sun, 2010). The second solution is to increase the server upload bandwidth. However, this solution still has some limitations. For instance, a server with 50 Mbps of upload bandwidth performs video multicasting with each client using 100 kbps. The maximum number of clients that can be served is therefore 500. If the server upload bandwidth is increased by doubling it, the maximum number of clients would be 1000. But what if there are thousands, a hundred thousand, or even millions of clients? How would this be addressed?

To solve the issue of serving huge numbers of clients, new system architecture was invented. The system, known as peer-to-peer network, is a virtual network over the physical (underlay) network. Each peer (node) downloads data from peers and uploads it to other peers. Therefore, each peer participates in the distribution of data in the network, thereby avoiding network congestion or bottleneck problems (V. Padmanabhan & Sripanidkulchai, 2002; Schollmeier, 2001).

1.2 Peer-to-peer Network Topology

A peer-to-peer network is a network built over the physical network. Hence, the peer-to-peer network uses physical network routing and forwarding functions. In a peer-to-peer network, peers cooperate to provide services to each other; thus, peers are simultaneously clients and servers. This is the main difference of this system from a server-based system, wherein centralized servers provide services to clients (Dong, Chunming, Wei, & Ming, 2009).

Peer-to-peer networks are usually built in the application layer. Peers in the peer-to-peer network are connected via logical links, and the link between two peers may take several hops in the physical network. These links between peers construct the path of the payload direction in the peer-to-peer network called the peer-to-peer network topology (Yunhao, Xiaomei, Li, Ni, & Xiaodong, 2004).

A peer-to-peer network is formed by choosing a subset of physical network nodes. The connection between these subset nodes are peer links. The links between peers have different methods and procedures of selection. This has an impact on peer-to-peer network quality and performance. These links comprise the so-called peer-to-peer network topology (Z. Li & Mohapaira, 2004).

Choosing a connection link between peers in the peer-to-peer network is usually done using information obtained from the physical network. This is then used to construct the peer-to-peer network topology. Peer-to-peer network topology can be divided into two main types: unstructured and structured topologies.

1.2.1 Unstructured Peer-To-Peer Network Topology

Of the two main types of peer-to-peer network topology, the unstructured peer-to-peer network is more widely used than the structured one. In this type of topology, peers can join and leave with usually some determinants such as sending request to joining and leaving and selecting its neighbors, as an unstructured peer-to-peer network does not require information on the physical network (Hyojin, Jinhong, Juyoung, Shin Gak, & Jun Kyun, 2008). An unstructured peer-to-peer network is based on a random graph to choose the connection for each peer; the most common topology in unstructured peer-to-peer network is the mesh topology (Doval & O'Mahony, 2003).

1.2.2 Structured Peer-To-Peer Network Topology

This type of peer-to-peer network is tightly controlled, and there is no randomization in peers' arrangement. Each peer is organized into a structured graph and each peer registers with serves, providing information that is required by the server (Eng Keong, Crowcroft, Pias, Sharma, & Lim, 2005).

The most important feature in a structured peer-to-peer network is the distributing hash table (DHT), which defines the structure of the peer-to-peer network. The task also, maintains peers data in this structure, and routes data between peers (Gai & Viennot, 2004).

1.3 Peer-to-Peer Network Data Delivery

Any topology in peer-to-peer network needs to method to deliver data over the network, this method used to manage the resources and tasks of peers, this managing almost done by evaluate peers resources such as processor, memory, disk storage, and network bandwidth, and assigns tasks to suitable resources to improve utilization based on the resource information of peers (Norihiro, Hidemoto, & Satoshi, 2007).

The main objectives of any peer-to-peer network data delivery represented by reducing data transfer time to a minimum, being adaptive to peer-to-peer network topology (Reza & Antonio, 2003), and increasing the throughput (using maximum available bandwidth) (Xinyan, Jiangchuan, Bo, & Yum, 2005).

1.4 Motivation and Justification

The need compatible topology and data delivery in peer-to-peer system specializing in video live streaming is the main motivation for this thesis. This topology and data delivery takes into account videos types or bitrates, the physical network, and bandwidth of peers; the system consists of two divisions: topology and data delivery. Constructing adaptable topology and data delivery reduce video delivery delay to a minimum using the maximum resources of the peers in the same time.

A system that has been characterized previously can work with different types of video and different types of peers belong to heterogeneous networks. In this system, every peer is assigned to a job suitable to its resources. The system should be fully structured and centralized with no place for randomization.

1.5 Research Problem

Although peer-to-peer networks have numerous types of topology in live video streaming, improving such types of topology to reduce video delivery time delay and to maintain the continuity of video streaming compared with video time play remains a challenge for researchers.

Smooth video playing without breaks or skipping is a desirable outcome. Thus, the need to identify a topology for peer-to-peer live video streaming networks that has low delay time and is capable of providing continuity in video streaming has been made more challenging by the different types of video quality specially the high-definition or high-quality videos that are currently available worldwide.

An adaptive topology requires that a connection path be efficiently established between peers that can gain the maximum benefit from peer resources, such as bandwidth while the topology executes continuous video streaming for long periods.

Topologies in peer-to-peer networks refer to the paths among nodes that serve as a road for video streaming in the network. Each type of topology has a process by which to distribute the streamed video efficiently. This process is referred to as data delivery. Each type of topology employs a certain type of video data delivery, such as push down video data delivery for tree topology, swarming data delivery for mesh topology, and so on. Using existing standard data delivery methods would certainly degrade the overall performance of the peer-to-peer system because such approaches do not consider additional components that have been added on standard topology which is usually are artificial intelligence tools. Thus, designing innovative data delivery approach is highly recommended. Moreover, an adaptive data delivery algorithm that can accommodate innovative topology and distribute a video stream to peers is also a necessity.

1.6 Objectives

The current types of topology of video live streaming in peer-to-peer networks do not consider video characteristics. Thus, the same topology is used for any size or type of video bitrate. Moreover, no relation has been established between video characteristics and peer bandwidth. Therefore, the objectives of this thesis are as follows:

- To design and implement a topology for peer-to-peer networks that is built for broadcasting live video streaming based on the relationship between video bitrate and peers' bandwidth in constructing this topology.

- To design and implement data delivery mechanism of live video streaming that is adaptive to the proposed topology based on the information obtained from peers during topology construction. Such data delivery would be based on the relationship among video bitrate, peer bandwidth, and the location of each peer in the network.

1.7 Scope and Limitation

This thesis focuses on peer-to-peer networks, and the concerns are on building a topology for this type of network for use in video live streaming. The proposed topology will be built based on the bandwidth of the peers and video bitrate. The position and neighbors of the peers will be based on the bandwidth.

This thesis also focuses on data delivery, which has been used to determine the distribution method of the video chunk to peers in the peer-to-peer network. This data delivery will be adaptable to the proposed peer-to-peer network topology and will be based on video bitrate and the bandwidth and position of the peers, whereas the method of distributing video chunks and the size of the chunks itself will be determined according to video bitrate.

1.8 Contributions

The first contribution of this thesis is the invention of topology for peer-to-peer video live streaming network. This topology is fully structured based on the relation between two factors: the bandwidth and video bitrate. During construction, the bandwidth between two peers will undergo evaluation. This evaluation will occur through the use of a well-known method called round time trip (RTT). The proposed topology has no randomization in the relationship of peers, and uses the maximum bandwidth of each peer (best throughput).

The second contribution is the invention of data delivery method adapted to the designed topology that can distribute video chunks for both types of the topology's peers. This data delivery method is based on video bitrate as a size of the chunks among peers in the tree topology section. By splitting these chunks into suitable sizes, they can be distributed among peers in the mesh topology to achieve a minimum video delay in peers with minimum network overhead at the same time.

The final figure of the designed topology will be a hybrid of tree and mesh topologies. Peers with bandwidths greater than that of the double video bitrate will be a part of the tree topology section; otherwise, they will be part of the mesh topology.

1.9 Thesis Organization

This thesis contains six chapters as shown in following.

Chapter 2 provides the literature review of peer-to-peer live video streaming topology and discusses the main types of topologies as well as the hybrid and modified peer-to-peer network topologies. This chapter also evaluates data delivery and its usages after topology construction and provides analysis on the exited peer-to-peer live video streaming systems.

Chapter 3 presents the framework of topology construction for peer-to-peer live video streaming and the joining and leaving peer issues. The chapter also shows adaptable data delivery for the proposed topology.

Chapter 4 exhibits the various ways of implementing the server and peer exhibits the various ways of implementing network and the pseudo code for network construction and network data delivery.

Chapter 5 shows the performance of the adaptable topology and its data delivery the results analyzed, compared, and discussed.

Chapter 6 concludes the thesis and provides recommendations for future work.

1.10 Research Methodology

Figure 1.2 shows the complete research steps of this thesis.

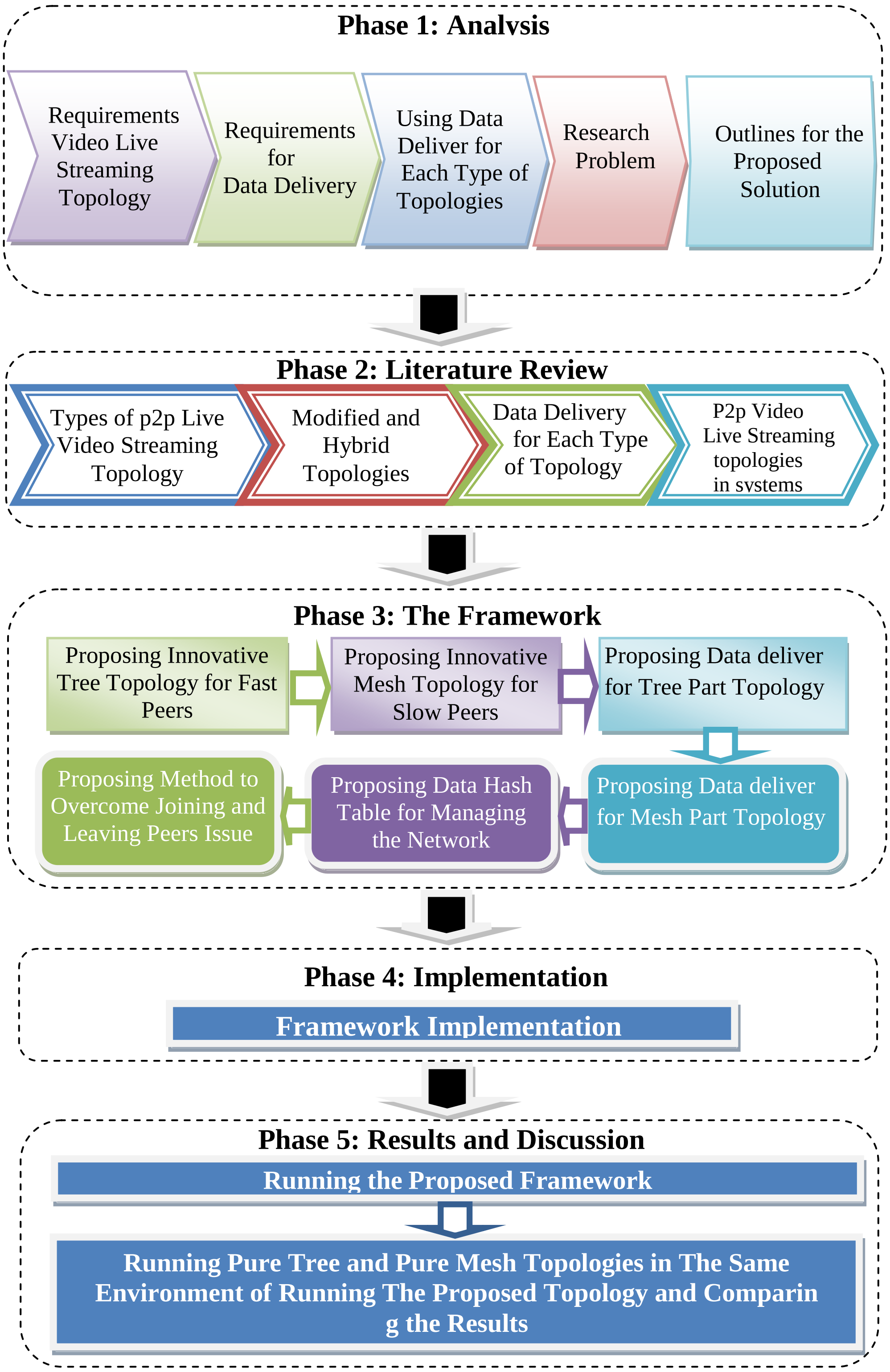

Figure 1.2. Research methodology

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on peer-to-peer topology and data delivery in live video streaming discussed by previous studies. This chapter serves as a reference to support the present thesis and to formulate a new peer-to-peer topology and data delivery method. This chapter is divided into the following sections. Section 2.2 provides background and definitions for terms used in this thesis. Section 2.3 presents studies on the main types of peer-to-peer topology for live video streaming. Section 2.4 analyzes the data delivery mechanisms in peer-to-peer live video streaming, including the types, issues, and specifications of these delivery mechanisms. Section 2.5 provides specific details of commercial peer-to-peer live video streaming systems widely available over the Internet nowadays. Section 2.6 summarizes and concludes the previous studies. Figure 2.1 shows the structure of Chapter two.

Although peer-to-peer systems, such as Gnutella, BitTorrent, and Freenet, are initially used for sharing files, many peer-to-peer systems now used for live video streaming. File sharing and live video streaming share a common concept on how each peer works as a client and as a server simultaneously. However, live video streaming requires special requirements to reduce the delay in the delivery of video chunks.

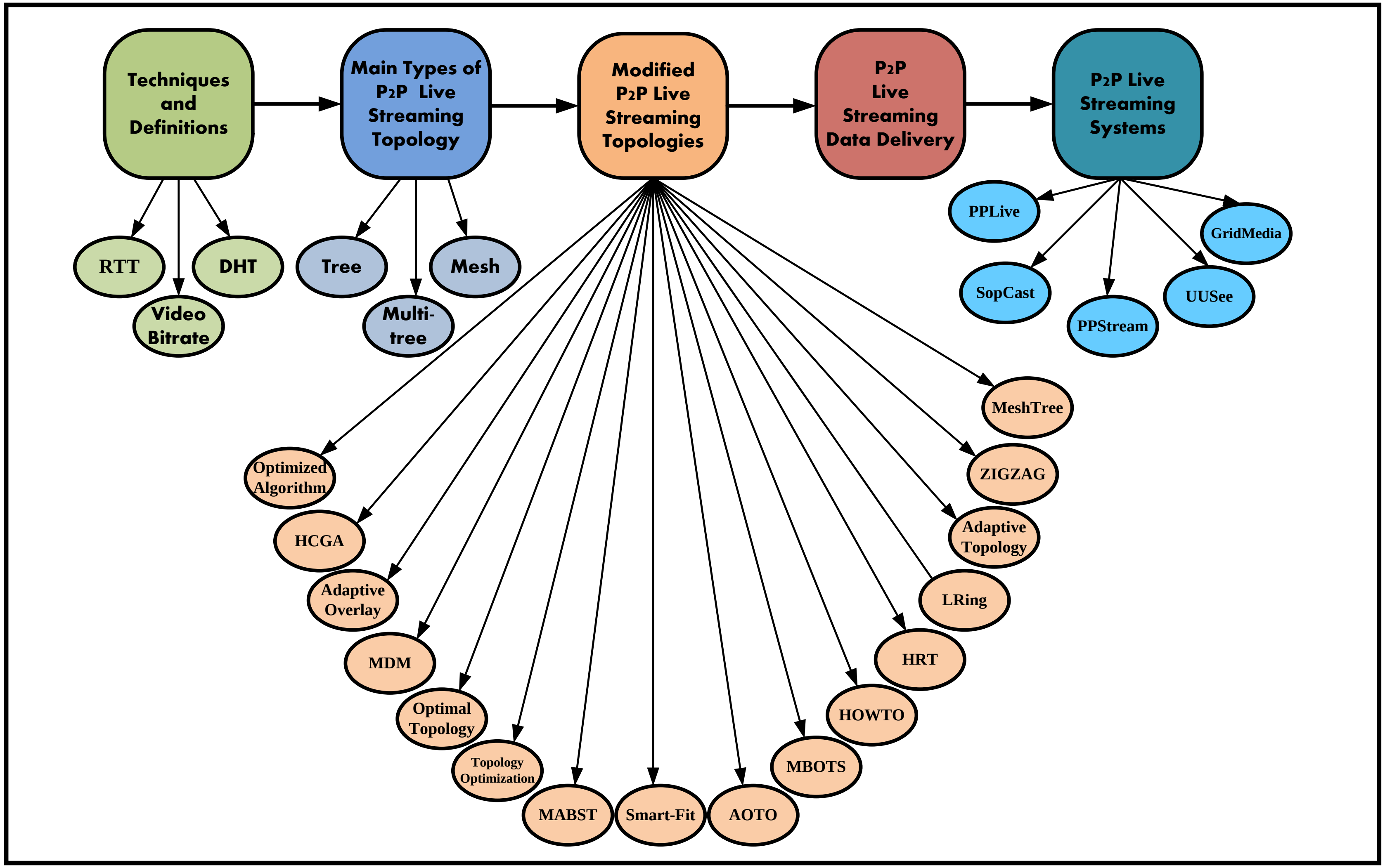

Figure 2.1. Structure of Chapter two

2.2 Background

This section explains three terms in reference to the three techniques that will be used in this thesis.

2.2.1 Round Trip Time

Round-trip time (RTT) is the time needed to send packets plus the length of time to receive an acknowledgment of that packet. Therefore, RTT is the time spent on the delay of packet transmission between two nodes (Comer, 2006).

RTT can also be used to calculate the throughput between two nodes in the TCP connection by using the following formula:

$$Throughput(bit\ per\ second) = \frac{TCPwindow\ size(bits)}{RTT\ (second)} \quad \ldots\ldots\ldots\ (2.1)$$

For example, the throughput of connection with 30 ms and 64 KB TCP windows size is

$$Throughput(bit\ per\ second) = \frac{65536 * 8}{0.03} = 17.4\ Mbps$$

The 17.4 Mbps here represent the maximum throughput between the two nodes (Hedlund, 2008). The default and maximum TCP window size in most operating systems nowadays is 64 KB. Given that the TCP window size is maintained, the RTT is the only factor affecting the measurement of the maximum throughput (cisco, 2009). Throughput can be defined as the average bitrate of a successful packet delivery over a communication channel between two nodes (Forouzan, Coombs, & Fegan, 2001).

2.2.2 Video Bitrate

Video bitrate is the number of bits processed per unit of time and is usually expressed in seconds. The video bitrate is always in kilobits per second (Gupta, 2006).

Different video bitrates depend on the usage of the video or the technology used. High-bitrate videos have better quality and larger size than low-bitrate videos do. The video bitrate used for live video streaming over the Internet nowadays range from 150 Kbps to 400 Kbps. With less number of video using 800 Kbps video bitrate type (X. Hei, Liang, Liang, Liu, & Ross, 2007; Hisamatsu & Asaeda, 2010).

2.2.3 Distributed Hash Table (DHT)

The DHT is the main difference between structured and unstructured topologies in the peer-to-peer system (Waldvogel & Rinaldi, 2003), which has been invented to eliminate flooding messages in large-scale file-sharing peer-to-peer systems such as Chord (Stoica, Morris, Karger, Kaashoek, & Balakrishnan, 2001), Tapestry (Zhao, Kubiatowicz, & Joseph, 2001), Pastry (Rowstron & Druschel, 2001), and CAN (Ratnasamy, Francis, Handley, Karp, & Shenker, 2001). These flooding messages consume high bandwidth and processing of networks (Doval & O'Mahony, 2003). The main service of DHT is the lookup operation, a hash function search used in the lookup operation. This operation is based on the value associated with any given key. The hash function reduces searching time (Ghodsi, 2006).

The DHT is used to manage the distribution of data among peers in structured peer-to-peer systems. The DHT also saves an updating list of the current peers by adding and removing the peers' IDs from the list, which is based on the joining and living of peers with their resources and assigning a suitable task for each peer (Gai & Viennot, 2004). The use of DHT in live video peer-to-peer systems has become popular because of the advantage of the use of the list of peers and its resources in broadcasting videos as efficiently as possible (J. Li, Sollins, & Lim, 2005).

2.3 Peer-to-Peer Video Live Streaming Topology

In this section we will discuss studies of peer-to-peer video live streaming topology, there are three main topologies. In section 2.2.1 discussed these three types; while in section 2.2.2 discussed the researches which try doing some modification or hybrid between two of them, some of these researches try using some artificial intelligence.

2.3.1 Main Types of Peer-to-peer Topology

There are three main types of peer-to-peer topology, these types are: single tree, multi tree, and mesh topology; almost one or more of these topologies are used in any peer-to-peer system even is there some modification or enhancement on them, to know the principles of these topologies we will discuss each one of them (Yue, et al., 2011)

2.3.1.1 Single-Tree Topology

Single tree topology is a structured topology wherein peers participating in live video streaming session form a tree structure at the application layer, with the video source server acting as the root of this tree. Every peer in this tree becomes a part of a certain level. In tree topology, each peer receives the video from its parent peer at one level above and forwards the received video to its children peers at one level below; Figure 2.2 shows the tree topology (Hudzia, Kechadi, & Ottewill, 2005).

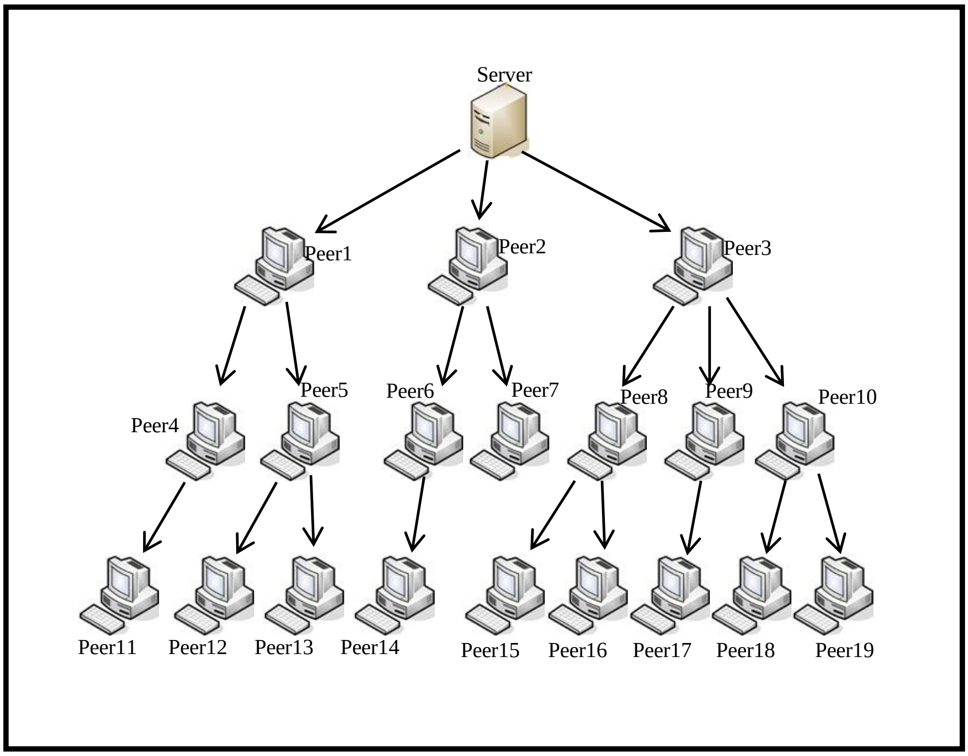

Figure 2.2. Tree topology for pee-to-peer video live streaming

The aims of any constructing algorithms of tree topology are putting every peer in the suitable level, and choosing the parent and children. All these algorithms attempt to decrease the levels of the tree by increasing the number of peers per each level (LianQing & Jun, 2009). Some researches suggest reducing the tree level by adding joining peer to any peer while have space in its upload bandwidth (Pourebrahimi, Bertels, & Vassiliadis, 2005), discovering this space can be successful in local networks. The reason behind the reduction of the tree levels is to reduce the number of hops taken by the chunks, and thus reduce video delay, especially at lower levels (Amad, Meddahi, AÃ¯ssani, & Vanwormhoudt, 2008). Tree topology is efficient in distributing packets, tree topology excellent performance with peers with high upload bandwidth, and one video source (Tu, 2007).

Although the tree topology is a good structure for video live streaming, it still has two drawbacks. The first is when a peer gets off the video streaming, its children and descendant peers will also be taken off. The server can detect the peer getting off either through sign-off signal or using time-out inference. The second drawback is the occurrence of tree leafs. Leafs contribute only in downloading, and are passive in uploading. At the same time, the tree topology is simple to construct, and usually involves only two factors, namely, parent selection and loop detection and avoidance (Chu, Rao, Seshan, & Zhang, 2002; Jannotti, Gifford, Johnson, & Kaashoek, 2000).

Tree topology is usually used for scientific applications or for small number of peers in limited geographical area when peers resources and assigning jobs to peers can be easy to estimated, otherwise, using tree topology in large scale of peers or with wide geographical area make discovering peers' resources and dealing with peers joining and leaving issues unmanageable (Castellà, Blanco, Giné, & Solsona, 2011). Therefore, some studies used fixed number of children peers for each parent peer in the network (Tran, Hua, & Do, 2003).

There few techniques have been proposed to solve peer joining and leaving issue. In peer joining there are the following techniques:

- All peers in the network have constant maximum number of children; every joining peer try to connect to peer has children less than the maximum number of children.
- Using round robin method to add joining peer to the peers in the network; the server applying these method to all peers in the network one by one.
- The joining peer try to connect with peer has the most similar bandwidth.

For leaving peer there are few techniques too:

- The grandparent peer will be the responsible for providing children peers of the leaved peer.
- One of the children peers of the leaved peer will take the parent peer place and one of its children will be in its old place and so on until the end of the tree.
- All peers of the branch from leaved peer to the end will connect directly to the server (Deshpande, Bawa, & Garcia-Molina, 2001).

2.3.1.2 Multi-Tree Topology

Multi-tree topology is an unstructured topology, in which there are more than one sub-tree instead of one streaming tree. The video streaming is divided by the server to multiple sub-streams and each sub-stream provides one of the sub-trees.

Although we call them sub-trees, each sub-tree has all the peers but in different order and every peer has different positions in different sub-trees. Each sub-stream flows in its own sub-tree form server to leafs. The purpose of multi-tree topology is to fix the passive leafs' problem in single tree topology because the leaf in some sub-tree is middle peer in another sub-tree. Another problem in which a sub-tree is solved is when peer becomes off, because the children peers can receive video streaming from another sub-tree. Figure 2.3 shows Multi-tree topology (Hefeeda, Habib, Xu, Bhargava, & Botev, 2005; Venkataraman, Francis, & Calandrino, 2006).

The number of levels of Multi-tree topology like single tree topology many studies tries to reduce the levels of each tree to the minimum (Liang, Liu, & Ross, 2009). We can consider multi-tree topology as a combination between the simplicity of tree topology and unstructured topologies. This topology has two drawbacks: The first is increasing the overhead of the streaming compared to tree topology. The second occurs when a peer becomes a leaf in all sub-trees and contributes only in downloading without uploading (Castro et al., 2003); to solve last drawback, an algorithm has been suggested for joining peers in multi tree become middle peer in only one sub-tree and leaf for other sub-trees (Noh, Mavlankar, Baccichet, & Girod, 2008).

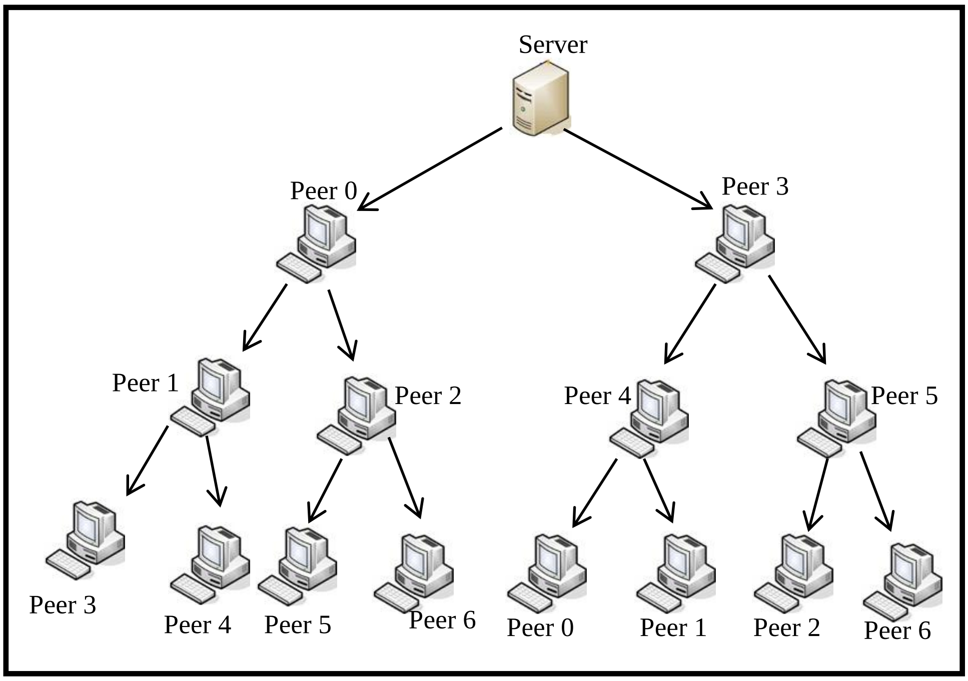

Figure 2.3. Multi-tree topology for pee-to-peer video live streaming

2.3.1.3 Mesh Topology

Mesh topology is one of the unstructured topologies where peers can join and leave dynamically by establishing connection with the neighbors and disconnecting it at any given time. In mesh topology, peers download video streaming from multiple neighbors' peers and upload video streaming to multiple neighbors at the same time. If one of the peer's neighbors leaves and stops the connection with the peer, the peer can still download and upload video streaming from/to other neighbors. Mesh topology has high flexibility against the peers who have sequences of on and off state, or what we call the churn problem (Y. Liu, et al., 2008).

Although most peers-to-peers systems which using mesh topology based on random choosing for the neighborhoods and represent it in random graph, other systems tries to make some determinants in selecting peers in these neighborhoods and to do connection between each pair peers according to these determinants or agreement (Fuhrmann, 2003).

Different topologies comprise different policies of the connection such as how many peers to make a connection and which peers should they connect to, etc. The peering decisions are usually based on the peer's functions and resource availability on both peers, such as the number of connections of peers, bandwidth, CPU and memory usage. Peers in mesh topology not only make a connection as a reaction to neighbor peers leaves, but also change neighbors optionally to reach better performance. Figure 2.4 shows mesh topology (Ghoshal, Xu, Ramamurthy, & Wang, 2007).

Choosing better neighbors for each peer in mesh topology improve the video chunk exchange between neighbors. The decision of choosing neighbor relationship is mostly based on the following:

- The available resources in the neighborhood peers, such as the number of peers connected with the two peers upload and download bandwidth, CPU and memory usage, etc.
- The link quality between every two peers which can be characterized by transmission delay and packet loss rate.

- The video parts are complementary, which means that each peer in the neighborhood has video chunks needs than other neighbor peers and vice versa (J. Liu, Rao, Li, & Zhang, 2008).

Previous studies proofed that best number of peers in each neighborhood to get best performance is eight; this meaning each peer has seven peers' neighbors exchanging video chunks between them (Cheng, Stein, Jin, Liao, & Zhang, 2008; Sentinelli, Marfia, Gerla, Kleinrock, & Tewari, 2007).

Mesh topology suffering from two drawback, which they are; the high delay in chunk delivery and increasing number of connections between peers cause bandwidth overhead by dividing upload bandwidth into the number of neighbors (Goh et al., 2013; Lei, Dengyi, & Hongyun, 2013).

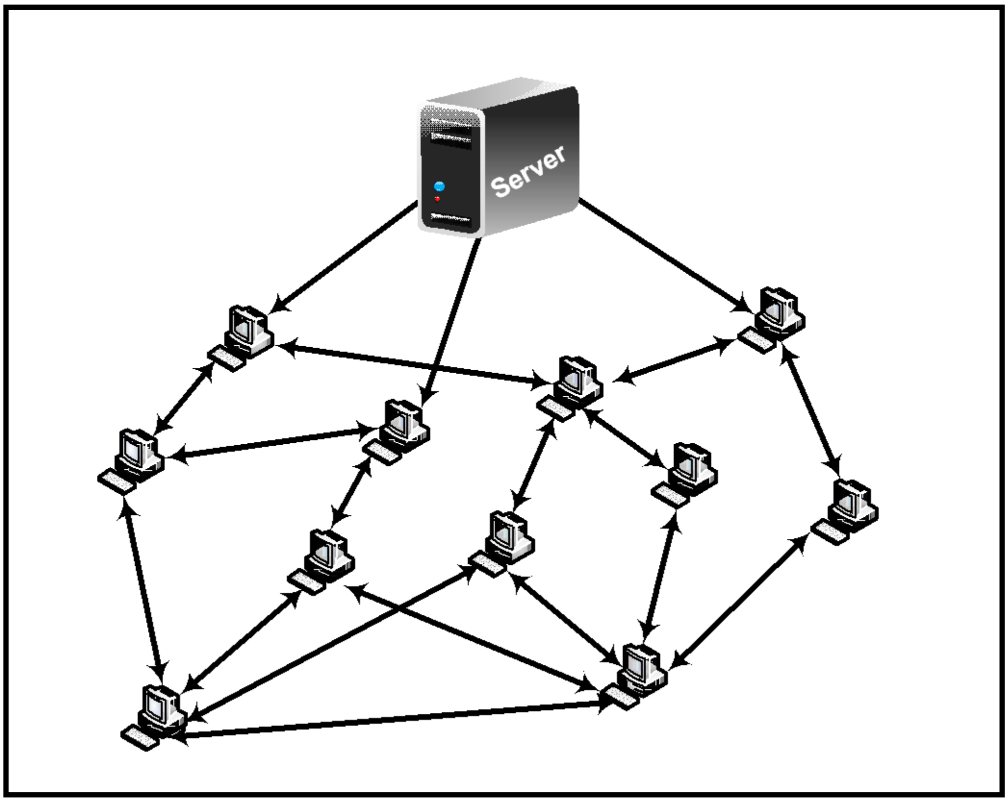

Figure 2.4. Mesh topology for pee-to-peer video live streaming

2.3.2 Modified Topologies

Numerous studies have attempted to apply several modifications on the three main topologies to obtain a more efficient topology or to cover the drawbacks of one of these topologies by applying a particular method, algorithm, or a hybrid between two topologies. These studies are shown below.

2.3.2.1 Topology Optimized Algorithm

In this topology, a new structured algorithm was proposed to construct a peer-to-peer live video-streaming topology. The algorithm is an optimization algorithm based on the minimum-maximum k-means clustering. The algorithm takes information used in the clustering from the peers' communication history, and then