A Comparative Study of Tree-based and Mesh-based Overlay P2P Media Streaming

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Abstract. Streaming media technology has seen tremendous growth and is currently a popular research area. While most of the work on streaming media technology is on ensuring the quality of the video playback and the scalability of the overall media streaming solution, there are few researches that are being conducted to address the limitations of the network, computer hardware nor the streaming media characteristics. These are the other factors that causes network capacity bottleneck. It is generally accepted that a Peer-to-Peer network is suitable for streaming media network and these can be classified into two main network architectures; a tree-based architecture and a mesh-based architecture. In this paper, we investigate and evaluate the network limitations between a Peer-to-Peer tree-based architecture and the more popular mesh-based architecture for media streaming performance. The simulations were conducted under various real-world scenarios and evaluated using different critical performance metrics that affects the reliability of the streaming quality and performance.

Keywords: Peer-to-Peer, media streaming, mesh-based, tree-based.

1 Introduction

In recent years, with the proliferation of high speed networks, there is an explosive growth in Internet data traffic especially video related traffic. Cisco forecasted by 2015, there will be more than 15 billion devices connected to the global Internet [1]. Peer-to-Peer (P2P) is a viable streaming model that is able to overcome the setback and bottleneck of centralized streaming server due to its distributed design and architecture. A P2P overlay network (Figure 1) is a type of overlay network that is a distributed system in nature without any hierarchical organization or centralized control.

In terms of distributing large amount of data over the Internet, BitTorrent [2] (a P2P file sharing protocol) has shown tremendous success and managed to inspire the usage of similar file sharing model for P2P media streaming [3][4][5][6].

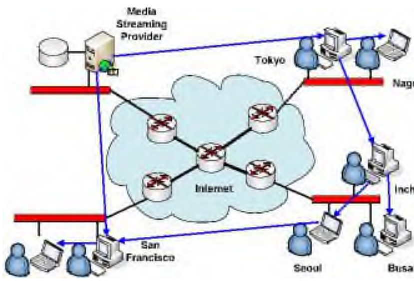

Figure 1: P2P Overlay Network

Generally, P2P media streaming architectures are classified into two main categories: (1) Tree-based topology and (2) Mesh-based topology. Tree-based P2P streaming is an extension of tree-based multicast system. In this system, a peer is either an interior node or a leaf node.

In this paper, we attempt to investigate and evaluate the performance P2P media streaming for both tree-based and mesh-based architectures. The rest of this paper is organized as follows; In Section II, we summarized the works that have been done by previous researchers. Then in section III, we describe the model, simulation setup and implementation, followed by the results and discussions in section IV. Finally, we conclude our findings in section V.

2 Related Works

In most cases, a P2P network can be classified based on organization of connected peers. A tree-based architecture is structured network whilst a mesh-based architecture is unstructured network.

Figure 2 illustrates a common tree-based topology, where there is only a single delivery path from the streaming media source to any other connected peers. Figure 3 shows a mesh-based topology where each peer in the network is connected to other peers in the network.

A. Tree-based Architectures

Tree-based P2P media streaming topology is an extension of single-tree multicast routing in which one overlay routing tree rooted at the server is constructed and maintained on the top of all the nodes in a system. [7] A node that forwards data is called a parent node, and a node that receives it, is a child node.

Due to the nature of tree-based which is structured network, the impact of high churn rate will drastically affects the performance of the P2P media streaming system. Multiple tree-based [7] overlay architectures are proposed to resolve the strong dependency of a peer on all its parent peers in architectures based on a single tree.

B. Mesh-based Architectures

The mesh-based overlay media streaming architecture is an unstructured approach where network is not constructed or maintained any explicit structure data delivery.

[8][9]In contrast to structured network, which constantly repairs its structure in a highly dynamic P2P environment, the data availability among peers guides the peer relationships for mesh-based streaming model. The mesh-based architectures also sometimes referred as the data-driven approach. [4]

Since a mesh overlay does not maintain a parent-child relationship during routing of the data blocks, mesh-based architectures have various disadvantages for whenever data blocks needed to be pulled from neighbors. Lastly, mesh-based topology requires large buffers to support the chunk pull from neighbor peers.

3 P2P Streaming Models

In order to investigate and evaluate the performance for both tree-based P2P streaming model and mesh-based P2P streaming model, we construct both topologies using discrete event network simulator, OMNET++ [10].

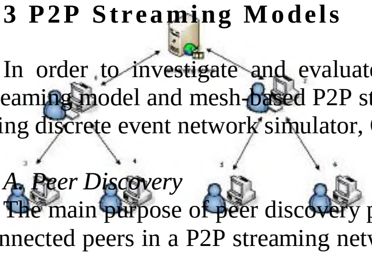

Figure 2: Single Tree-based Topology

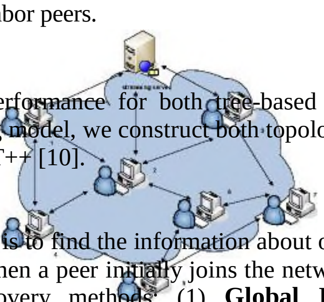

Figure 3: Mesh-based Topology

A. Peer Discovery

The main purpose of peer discovery protocol is to find the information about other connected peers in a P2P streaming network, when a peer initially joins the network. Generally, there are two general peer-discovery methods: (1) **Global Peer Information**: maintains the global peer information and keep only the information about a small list of peers. (2) **Peer Discovery Method**: which maintains the information for only a small list of peers can be further classified into categories: flooding-like method and gossip-based method. [11]

B. Peer Selection

Peer selection protocol is basic for a P2P streaming network where it directly determines the performance of individual peer and the overall network. In order to achieve a reliable media streaming, peers are usually selected to achieve the followings: 1) to be more resilient to peer churn and network dynamics, 2) to minimize packet delay and 3) to achieve a minimum of total streaming rate required at a peer.

C. Peer Replacement

If a peer leaves the system without notification, the streaming of the media will be disrupted at the descendant peers of the missing peer and the routing structure of the network is weakened, especially in tree-based networks. There are two approaches are available to replace a peer: 1) **Reactive**: when a peer leaves the network, or a peer failure has occurred, the connectivity of the network is retained by assigning a new parent peer to each child of the missing peer. 2) **Proactive**: the restoration plan for the descendant peers of the missing peer is carried out before the peer leaves the network.

4 Result and Discussions

In order to investigate and evaluate the media streaming performance for both tree-based P2P media streaming model and mesh-based P2P media streaming model, we conducted the simulations under various scenarios using discrete event network simulator, OMNET++.

A. Simulation Configurations

Simulations were configured with different network sizes, peer churn and number of neighbors. For simulating valid video stream, we used Star Wars IV trace file which can be obtained from Video Trace Library [12]. By varying different simulation configurations, we conducted simulations which were repeated for 5 times. We tabulate the results and calculate the average all the peer's output for each scenario. Table I shows the simulation parameters used for both mesh-based and tree-based media streaming simulations.

Maximum packet size	1 Kbytes
Peer side buffer	40 seconds
Buffer map exchange period	5 seconds
Video codec	MPEG4 Part I
Video FPS	30
Number of frames in GOP	12 frames
Selected trace file	Star Wars IV
Average video bitrate	512 Kbps
Start-up Buffering	8 seconds
Source Bandwidth	6Mbps
Number of neighbours	(2 , 4)
Simulation duration	250 seconds

TABLE I. Simulation Parameters

B. Performance Metrics

The following performance metrics were measured for both tree-based streaming model and mesh-based models:

1. **End-to-end delay**: the time between the video message created at the source and time for the video frame reaches the client node.
2. **Frame Loss ratio**: the ratio of the dropped over the video frame transmission.
3. **Playback delay**: defined as the time elapsed from the instant in which the source provides the content to the instant in which a client reads it from the peer's playout buffer.

C. Simulation Results

Figure 4 shows the average end-to-end delays among all peers. Overall, tree-based approach has lower end-to-end delay compared to mesh-based approach. In tree-based approach, the parent nodes keep pushing the video data down to their child nodes and this pushing method considerably speeds up the video delivery rate. For mesh-based approach, pull strategy is used where each node needs to send the request to their neighbor nodes in order to receive the requested frames from neighbor nodes.

We also evaluated the effects of dynamics of peer churn towards the content delivery. Based on our simulation results (Fig. 4, 5 and 6), peer churn adversely affect the larger peer group size. It is noted that the dynamics churn shows higher delay rate than the static churn in between 200 nodes larger network. While in tree-based approach, a child node is able to find a new parent node easily in a smaller peer group size after its former parent node leaves

Figure 5 depicts the frame loss ratio for both models with the increase of network sizes. The tree-based model has lower frame loss compared with the mesh-based model. In tree-based approach, all the nodes are constructed via parent-child relationship. Thus, nodes have stable frame source and the push mechanism guarantee the data is transferred from the parent to their own child node. However, in dynamic peer churn environment, mesh-based architecture has lower frame loss ratio than the tree-based. Every node in mesh-based topology is able to request the frames from more neighbors when the network size increases. With more frame suppliers, there will be less frame loss and this guarantees the smoothness of video delivery.

Figure 6 shows the playback delay experienced by both topologies under static churn and dynamic churn. The tree-based approach exhibits lower playback delay across all peer group sizes. Push mechanism in the tree-based architecture is more effective to reduce the playback delay compared to the pull mechanism in mesh-based architecture. In mesh-based approach, the playback delay increases with the network sizes. When there are more peers in the network, the longer path which the frames need to transfer from the streaming source to the playout buffer of the destination node.

For both topologies with dynamic churn environment, mesh-based architecture has lower playback delay as the network size increases. Overall, node has smoother playback continuity due to the increase of frame suppliers' increase. Nodes in mesh-based network can make new connection much easier to neighbor nodes whenever neighbor nodes leave the network. In tree-based approach, leaving nodes causes increase playback delay as the remaining child node needs to find a replacement parent node or new path for the video delivery.

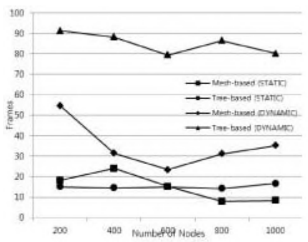

Figure 4: End-to-end delays for both Static and Dynamic Mesh-based & Tree-based Topologies

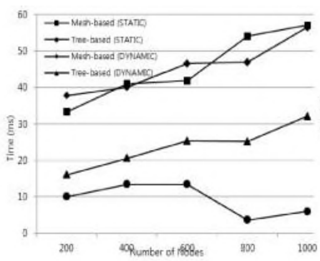

Figure 5: Frame loss ratio for both Static and Dynamic Mesh-based & Tree-based Topologies

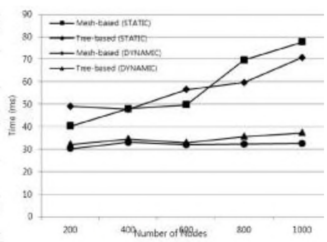

Figure 6: Playback Delay for both Static and for both Static and Dynamic Mesh-based & Tree-based Topologies

5 Conclusion

In this paper, we investigate and evaluated the performance for both tree-based and mesh-based streaming architectures. Simulations were conducted for both architectures under static and dynamic of peer churn scenarios. Both streaming architectures were evaluated using performance metrics: end-to-end delay, frame loss ratio and playback delay. Simulation results show that both streaming models demonstrate their strengths and weaknesses under various scenarios. Tree-based model has more stable video delivery quality, low playback delay and end-to-end delay. However, under dynamic peer churn, the peer replacement and recovery mechanism require time consume for peer replacement. In contrast, mesh-based approach is more resilient toward dynamic peer churn environment, and peers have more resources to choose frame suppliers with increase in the size of network increases.

Acknowledgement

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