Development of a Distributed Video Streaming System using Application Layer Multicasting

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Abstract—Video streaming over Ethernet-based networks are becoming very popular - with implementations such as YouTube providing high quality streaming video over the internet. These streaming systems traditionally use a Content Delivery Network (CDN) consisting of a large number of servers with very high network bandwidth to meet the requirements of network-based video streaming. Alternatively, by distributing the server bandwidth requirement over a number of nodes, an Application Layer Multicasting (ALM) system can provide high quality video from a streaming video source to a large number of receivers with low latencies and minimal additional overhead. In this paper the development of a score-based Minimum Spanning Tree (MST) system for the distribution of real-time streaming video is presented.

Index Terms—Streaming Media, Video Streaming, Distributed Networking, Application Layer Multicasting (ALM)

I. INTRODUCTION

Today, real-time video streaming is becoming more and more popular as a communicative and teaching tool. According to a recent estimate by comScore, almost 80% of internet users worldwide watch online video, with viewing numbers in the U.S. reaching 33 billion in December 2010 alone [1].

Media distribution, and streaming in particular, can be done using a number of techniques including unicasting, multicasting and Application Layer Multicasting (ALM). Unicasting refers to the use of numerous channels, one for each receiver, directly connected to the sender, so each receiver gets a copy of the original stream. Multicasting is implemented in the network layer and relies on router-based multicast addressing to allow one stream to be forwarded by the routers to each receiver. ALM on the other hand, is implemented in the application layer, and relies on receivers forwarding their copy of the stream to other receivers using idle bandwidth.

Historically, Content Delivery Networks (CDN) were used to distribute the video streams, but since they rely on a unicasting-based architecture, they now require large amounts of available bandwidth to keep up with the growing demand. To combat the ever increasing cost of servers capable of coping with these loads, an alternative was developed in the form of distributed or peer-to-peer (P2P) streaming networks. These networks typically use ALM or Gnutella-based approaches to distribute the video stream by forwarding the stream from receiver to receiver [8].

A number of real-time video streaming applications exist, including CoolStreaming [6] and End System Multicast (ESM) [7]. However, none cater for very high quality video (>1Mbit/s) over higher bandwidth networks and most suffer from highly complex implementations or fragile tree networks [8]. In this paper a high quality implementation of ALM using a score-based MST will be presented.

II. BACKGROUND

A. Application Layer Multicasting (ALM)

While very similar to normal multicasting in that the server sends a much smaller number of copies of the video stream than the number of receivers, ALM is implemented in the application layer, providing better scalability through heterogeneous networks and networks where the sender does not have administrative access to intermediary routers such as the Internet. This technique can be implemented in a number of ways and has been the focus of many studies [2] - [4].

A very popular implementation method is the use a tree-based system where the video stream propagates down the tree between receivers. The problem with this approach is the tree is inherently fragile, with disconnecting receivers possibly creating a number of partitioned sub-trees with no connection to the server as seen below in figure 1 [2].

![Fig. 1. Tree partitioning as a result of disconnecting clients][1]

B. Minimum Spanning Tree (MST)

The Minimum Spanning Tree method involves minimizing the relevant cost of connecting a number of vertices in a graph together in a tree. In the network environment, it is used to determine the best configuration of connecting a number of nodes together, optimizing for either latency, throughput or cost of cabling.

This property is used to minimize the cost of routing the

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[1]: https://example.com

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[8]: https://example.com
video stream between receivers and ensures an optimal network structure using the least amount of connections.

III. PROPOSED DISTRIBUTED VIDEO STREAMING ARCHITECTURE

A. Score-based Spanning Tree Architecture

By developing a server and client application to implement ALM through a score-based MST topology, the relevant parameters of the system, including network utilization, edge receiver latencies and robustness can be optimized.

Each client connects to a single video stream source (be it the server or another client) and can serve up to \( k \) clients. An example MST is shown below in figure 2 for 6 clients with \( k = 2 \).

![Figure 2: Hierarchical implementation of a score-based MST with \( k = 2 \)](attachment:image)

A periodically updated, normalized score is allocated to each client (receiver), which incorporates the current server-client connection latency, the number of hops between the client and the server, the number of clients connected to it and the current stream throughput. This allows the server to create an MST for the current system environment when a new client requests a connection.

Since the scores are updated periodically, a dynamic environment is produced. Conversely, the system only reconfigures itself when new clients connect to avoid unnecessary disruption of existing connections.

In the event that a client disconnects, the top-tiered clients of the partitioned trees request a new connection from the server - which provides a suitable candidate to restore the spanning tree.

IV. PRELIMINARY RESULTS

The test setup consisted of a host acting as server and 2 hosts running 20 clients each; all connected through a single switch in a LAN environment. A DivX encoded video with an average bit rate of 1048kbps was streamed to all clients.

Initial results suggest low overhead figures of 0.8%, with 11 bytes overhead for each video stream packet of 1329 bytes. Control stream overhead is negligible, with an average throughput of 10B/s per receiver.

Purposely disconnecting an intermediary client and measuring the reconnection latency - the time elapsed from when the loss of the stream is perceived to when data reception is restored - resulted in an average of 16.3ms, excluding switching and propagation delays. Thus, streaming a 4Mbit/s video stream would incur a minimum average loss of 6.52 packets upon source disconnection.

Subjective video quality analysis of the test configuration provided very good results, with momentary video deterioration during the disruption of the network and imperceptively low latencies between node hops.

V. FURTHER RESEARCH

Further research includes the optimization of the score based algorithm and the inclusion of multiple sources for each receiver, effectively creating a multi-layered MST of interconnecting receivers similar to the Sunflower approach used by Z. Liu and G. He [5]. This should provide added redundancy and lower overall packet loss due to tree partitioning.

Stream segmentation and reassembly will be implemented accordingly to allow for sub-stream division. Promising techniques include alternating sequencing and dynamic throughput adjustment. The optimal segmentation method will be determined through research and experimentation of a dynamic connecting network.

VI. CONCLUSION

Preliminary results are very promising, with very low overheads incurred in the tree management and low reconnection latencies. The overall network utilization for the ALM system is also much lower at the server interface, with only 3 copies of the stream serving a tree of 40 receivers.

Low latencies per hop also indicates that real-time video streaming to a large number of receivers is possible.

VII. ACKNOWLEDGEMENTS

This work was completed with funding from the Telkom Centre of Excellence at the NWU, Potchefstroom Campus.

VIII. REFERENCES


Samuel van Loggerenberg received his B.Sc degree in Business Mathematics and Informatics in 2009 from the North-West University, Potchefstroom campus. He is currently studying towards his B.Eng degree in Computer and Electronic Engineering at the same institution. His research interests include network coding, data distribution and streaming media.