Chapter: Conclusion

In this chapter, the different sections of the research are gathered to produce conclusions. The scope includes the research definition, and the study Objectives. The chapter presents the study methodology and summarisation of the findings. The chapters mainly borrow form the earlier chapters to provide an overview of the case. The conclusion has been written based on in-depth analysis of the earlier chapters and only summarises main points.

The Study Problem

This paper discusses the HTTP adaptive streaming technology with references to implementations aimed at promoting streaming experience. The HTTP adaptive streaming technology is majorly adopted by different video producers and content delivery platforms that utilize it to adapt videos transmitted to certain conditions prevailing on the network, which enhances Quality of Experience (QoE) and improve stream quality. Irrespective of the wide adoption of HTTP adaptive streaming (H.A.S) technology, HTTP Live Streaming bitrate adaptation methods with multi-tier caching servers still faces certain challenges because of the heterogeneous nature of networks, which poses a high demand among users as well as the dominance of high-quality live streams. The challenges comprise multi-client rivalry that results in stability lapses, QoE measurements, steady live streams quality, and optimization as well as inter-destination synchronization of content.

The significance of the study cannot be downplayed considering the fast acceptance and demand of HTTP Live Streaming across the world. In the recent years, HAS solution has expanded to the most famous streaming technology since it has adapted well among various users in the internet video arena. The technology enables service providers to consume from mobile-edge caches as well as traditional-stateless web servers to stream videos. In addition, it enables its consumers to access various media content through Network Address Translations (NATs) as well as behind different Firewalls. Despite the importance of the HTTP technology, studies have been completed in this area to determine its efficiency. The technology is also consistently evolving. Therefore, it was imperative to analyse the quality of HTTP Live Streaming bitrate adaptation methods with multi-tier caching servers.

For analysing the quality of HTTP Live Streaming bitrate adaptation methods with multi-tier caching servers aim, the thesis used four approaches. Firstly, the study carried out the performance comparison of HLS & DASH packaging and delivery tests. Secondly, the study conducted a performance analysis of utilizing centralized storage with RAM, in comparison to the

traditional hard-disk based storage. Thirdly, the researcher compared the utilization of non-variable bit rate streams with the variable multi bit-rate streams for HLS and DASH packaging outcomes as well as collected analytics as shown. Finally, the researcher analysed the performance benefit of the application of cache re-packagers as well as IP-based load balancing functionality for the region-based deployment of the cache server.

A comparison test was undertaken for different variables to determine the most effective. The research variables were: HLS & DASH video packaging & delivery centralized Storage with HDD & RAM-Disk infrastructure; Variable Bitrate Configuration for adaptive bitrate response; Non-variable Bitrate Configuration; Separate HLS & DASH video repackaging using cache modules; and IP Based load balancing implementation. For the HLS & DASH video packaging & delivery implementation, the servers were deployed by a virtualized backbone. Its powerful Http serving capabilities and the high usage and adaptation was handled by Linux based NGINX services. However, since NGINX service does not support Video-On-Demand packaging, Nginx-Vod-Module was combined with NGINX dependencies. As a result, the internet access was made possible and easy. As an essential part of the research, HTTP based HLS and DASH protocols were considered for the streaming delivery and experience. Separate storage systems were set by the centralized storage HDD and RAM-Disk infrastructure. In the research, a Linux server with Linux distro was considered effective because of its downtime critical application and reduced headroom. Samba software was used to create a shared HDD and a RAM-disk based storage.

Chapter Summary

In chapter 1, the study focused on the definition of the problem, motivation behind the research, and definition of research objectives. Further, various chapters of the study have been presented. The chapter provides the foundation of the problem or background of the study. It presents the basic idea of HTTP Adaptive Streaming (HAS), specifically providing some of the issues involved in this technology. Specifically, it introduces quality issues of HTTP live streaming bitrate adaptation methods. In chapter 2, the researcher conducted a review of literature on similar studies previously completed on the quality of HTTP live streaming bitrate adaptation methods. It reviewed past studies on cache replacement modules, using multi-tier fog architecture, and the application of three-tier fragmentation systems. Common issues observed during HTTP adaptive streaming, bit-rate adaptation, cache partitioning, the results in bit-rate adaptation, replacing cache based on distance, and use of HTTP adaptive streaming were also reviewed. The review of a study by Fisher (2015) revealed that broadcast television is becoming obsolete for online media services because of the advancement of streaming solutions which leverage the robust internet

networks. Further, the review established that content distribution networks (C.D.N) which entail performance, as well as video cache optimization, is crucial to the evaluation process. The review of work completed by Osuga, Asakura, and Taniguchi (2013, p. 1151) acknowledge that live streaming have gained popularity in recent times. The review identified a research gap that would need to be addressed, that is, the issue of commonplace evidenced in high-traffic usage. It emphasized the effective address for high-performance cache servers since ejection content appears to exhibit a higher probability of working status, especially in high traffic events.

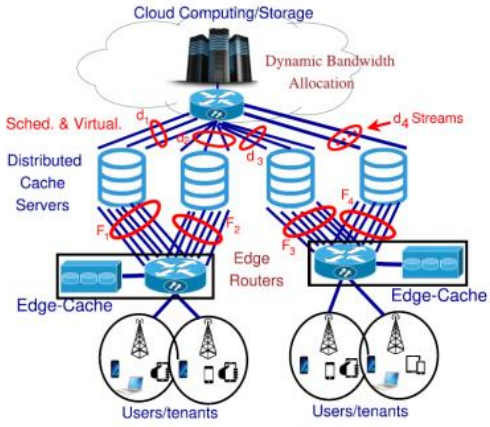
The third chapter covered the methodology used to analyse the quality of HTTP Live Streaming bitrate adaptation methods with multi-tier caching servers. The chapter outlined the implementation method of various subsidiaries, including HLS & DASH video packaging and delivery, centralized storage with HDD and RAM-Disk infrastructure, and variable bitrate configuration for adaptive bitrate response. It also covered the subsidiaries of non-variable bitrate configuration, separate HLS and DASH video re-packaging using cache modules, and IP based load balancing implementation. The chapter also presented the adopted testing methods and the study research limitation. The adopted testing methods for this study comprised the comparison of HLS and DASH performance, HDD based storage compared with Cache based storage, adaptive bitrate versus single bitrate comparison, single node versus dispersed caching nodes, and load-balanced set-up versus point to point.

During the implementation, Variable Bitrate Configuration was done for adaptive bitrate response. The files used were transformed into three distinct birates: HD - 7 Mbit/s, SD - 3.5 Mbit/s and SD - 1.5 Mbit/s. With these, the streaming could achieve the SD resolutions and even HD resolution. It's transcodes where conducted in H.264 encoding. For non-variables; however, the test for the implementation was conducted by 20Mbit/s video files which was transcoded in the three different variants with a packager that reduced the lower bit rate of the video files. This was necessary for birate adaptation and scaling. Consequently, to achieve HLS & DASH video repackaging implementation; four identical Linux virtual machines that were connected to Nginx server features were deployed. Also, a new packager with the network infrastructure was deployed to pass the streams over the servers. Load balancing was another critical implementation that allowed viewers to have a specific caching server. It was determined that it is essential for interfacing over added caching servers under IP address or one domain name. It was set on a separate Linux based virtual machine running a standard NGINX server. The key implementation testing included following subsidiaries: HLS vs DASH performance comparison, HDD based Storage vs Cache based storage, Adaptive Bitrate vs Single Bitrate comparison, Single

Node vs Dispersed Caching Nodes, and Load Balanced Setup vs Point to Point. The concern on the viewer's quality of the experience was also addressed.

The Study Finding

Every video viewer struggles to have the Quality of Experience (QoE); however, many factors come into play before this is fully realized. Factors that promote QoE experience include the content, which includes the live-streaming resolution and quality and the encodings, and the content distribution networks (C.D.N.), which is concerned with video cache performance and optimization. C.N.D involves many aspects of the quality necessary for QoE. C.D.A can be made up of video distribution composed of a single Datacenter, four caching servers, and two edge routers as shown in the figure below.



Worth noting is that the quality of streaming is directly affected by the devices used and their applications. Besides, the level of interaction with the device affects users' behavior and the level of satisfaction. Therefore, in the end to end watching the users should be able to handle the devices with ease. To determine the users QoE, the focus is set on the time the user starts viewing the content; when it starts streaming; the rebuffed rate during the live event; and the average bit rate. Several implementations have been made to ensure QoE. Among these is the deployment of Efficiencies such as Least Recently Used (L.R.U.) and Least Frequently Used (L.F.U.) in caching. Because of increased live streaming, service providers have opted for faster and realistic implementations, such as the use of fast solid-state drives and RAM sticks. Despite these, caches continue to present challenges, such as low access frequencies and inability to remove or replace videos.

Evidently, several methods have been tried to boost cache performance. Among these is the use of multi-tier fog architecture. Apart from improving live streaming experiences, Using

multi-tier fog architecture also boost streaming from the cloud. The boosting methods include the implementation of the three-tier fragmentation system, bit-rate adaptation, HTTP adaptive caching, and separating cache content based on distance. All these strategies have led to improved live streaming and QoE among many users. The main tests include HLS & DASH packaging and delivery performance comparison, the performance of RAM versus the traditional hard disk, and the application of non-variable bit rate streams compared to variable multi bit-rate streams. Additionally, several analyses were undertaken, among them was the performance benefit on the use of cache repackaging and IP based load balancing on region-based cache server deployment. New insights were gained from each of the tests that were conducted. The results can be applied in enhancing live streaming and its experience among users.

The test showed that HLS and DASH packaging are substantially similar but their performances differ. One difference is that HLS doubles the bandwidth use compared to DASH. DASH packaging sends smaller bandwidth at a higher frequency compared to HLS that send fewer but larger files. Analysis of the server performance ratio to the client performance ratio showed that HLS demanded 16% to 19% lesser power as compared to DASH. Other disparities included tune-in speed and latency even tho the two technologies were almost similar in quality. When Adaptive Bit-rate and Single Bit-rate comparison was undertaken, both HLS and DASH delivery was similar. However, DASH recorded a reduced transfer rate as compared to HLS. The test revealed a similarity between server-side performance and that of the client's side as well as tune-in speed. However, bit rates and even tune-in rates yielded different results based on the condition of operation. There was a minimum increase in responsiveness and latency reduction between HDD based Storage as compared Cache based storage. VOD packager was faster in HDD than Cache storages. The result also determined that the Dispersed Caching Modules were significantly efficient than the Single Node. Finally, there was negligible added latency and tune-in speed and effect on dropped frames and buffering between Load Balanced Setup and Point to Point. The Point to Point; however, reduced the number of clients it can handle as compared to load balance. Based on the test, Load Balancing could handle more clients as compared to Point-to-Point. The test effectively covered the important HLS and DASH critical areas.

Based on the quantitative data collected through a multitude of performance as well as qualitative tests conducted on the Video-On-Demand platform utilizing JMeter for reliable as well as accurate results, the findings obtained were contrasted with the previous studies reviewed in the second chapter of this study. The comparison was done to ascertain areas of similarities or differing opinions. On the observation of the quality of the live stream, the findings established that a non-adaptive stream quality is achieved from the stream's capability of not dropping the

frames because both streams are HTTP-based, have similar technologies, and possess similar quality. Nonetheless, the study observed an 8 percent increment in HLS dropped frames. The study recommended the development of adaptive bit-rate streams to improve the viewer experience and minimize the chance of dropped frames and buffering.

On tests done on adaptive bit-rate versus single bit-rate comparison, the findings of the study proved that both DASH and HLS are similar. However, both exhibited more critical performance results in different instances. The study established that the DASH variable bit-rate potentially swap between various bit-rate more coherently and tune-in faster as well as consistently compared with HLS. On HDD based storage versus cache based storage, the study found that despite RAM-based disks being faster compared to traditional drives when simultaneously accessing small volume of content, that is, 2 –second video segments, the RAM storage suffer the limitation of the process to obtain the location of the video data as well as metadata. The findings obtained from the comparison of single node versus dispersed caching modules, the test results showed a substantial decrease of dropped frames as well as buffering time. The outcome of this observation demonstrates the fact that 100 clients differed between four dissimilar cache servers, as well as the additional transmission between the cache server and VOD server has substantially decreased.

Combing all the results together it is evident that for an efficiently scalable and better streaming experience, DASH would be the technology to choose however HLS is still preferred for running on low-power devices and still imposes the limitation of running natively on Apple compatible devices which is substantially a large device compatibility share, having said that, DASH is meant to be widely adopted across the board with new web browser language HTML 5.

Limitations & Future Work

Limitations experienced in this research paper included the limitation of using a single example of delivery systems, the comparison of other HTTP services would show the affect of optimisations and system deliverables.

Use of UHD or 4k video content was excluded due to media player limitations, such future work would enhance the outcome of the paper for additional results with higher bandwidth demand for both the server and client.

Network throughput was capped at 1 Gigabit per second due to equipment restrictions and limited testing support, an increased network throughput would enable for continued scalability testing.

On demand transcoding was not included in this research paper due to hardware and software limitations but is considered as an additional process which allows for an enhanced method to efficiently use VOD storage and supply users with varied bit-rates but storing a single version in the centralised storage.

Increased user concurrent streams where capped to 100 users for most tests because of Jmeter result logging limitations, this limitation would be ideal to be revised in future work to gather additional results. Additional to this, other HTTP streaming testing applications should be considered for result comparisons as this was not sought through due to finance limitations and deadline restrictions.