An analysis for the paper

Video Steaming with Network Coding [1]

Richard A. Kramer, Oregon State University, Member IEEE

Abstract

This paper provides an analysis of the paper "Video Streaming with Network Coding" [1] and the related subject matter. "Video Streaming with Network Coding" teaches that there are two (2) primary video streaming network solutions that exist:

1. **Content Delivery Networks (CDNs):** A Content Delivery Networks offer a network topology/solution which typically pushes multiple copies of the same content to servers at the edge of the Internet. Thus client receivers are able to receive the content quickly (e.g., low latency) from near-by edge servers.

2. **Peer to Peer (P2P) Networks:** P2P Networks typically propagate multiple copies of the same content though interconnecting peer servers, whereas a peer server or combination of peer servers then connect to a receiver.

Applied to the abovementioned CDN and P2P Networks, *multi-sender streaming solutions* have been proposed, but the multi-sender streaming solutions introduce additional problems (see Section below: "The Problems to be Solved"). The paper "Video Streaming with Network Coding" proposes a multi-sender streaming network framework with the following improvements over existing systems:

1. **Reduction of Redundant Storage:** "Video Streaming with Network Coding" provides a network coding technique that reduces overall storage.

2. **Reduction of Complex Sender Synchronization:** "Video Streaming with Network Coding" offers a network coding technique that reduces the complexity of sender synchronization.

3. **Allowance for the Use of Network Friendly Protocols:** "Video Streaming with Network Coding" offers a network and firewall friendly solution that enables TCP streaming as opposed to UDP.

To accommodate the abovementioned improvements, "Video Streaming with Network Coding" proposes Hierarchical Network Coding ("HNC") to provide a "scalable video bit stream to combat bandwidth fluctuation on the Internet" (*see* "Video Streaming with Network Coding" at Abstract). This paper provides a detailed analysis of the paper "Video Streaming with Network Coding" organized into the following sections:

1. **The Problems to be Solved**
2. **The Proposed Solutions**
3. **Strengths of the Proposed Solutions / Effectiveness**
4. **Weaknesses of the Proposed Solutions / Additional Considerations**
5. **Conclusion**

Indeed, as demonstrated by the "up to 60% [improvement in bandwidth savings] over the traditional schemes" (*id.* at Abstract) the paper "Video Streaming with Network Coding" provides a network coding technique that reduces storage of servers as compared to CDNs, eliminates the need for tight synchronization between senders, and integrates easily with TCP.

> *"Video Streaming with Network Coding" proposes solutions to provide the smooth playback of data packets with minimal storage as compared to CDNs (Content Delivery Networks) and with maximum bandwidth efficiency as compared to P2P (Peer to Peer) Networks (see "Video Streaming with Network Coding" at pg. 9).*

1. The Problems to be Solved

To expand, the paper "Video Streaming with Network Coding" teaches that multi-sender solutions provide agility for a client to receive content from multiple sources to overcome the limitations of congested and unreliable networks. In a multi-sender environment, video content is separated into multiple parts, whereas each part is then ideally streamed by separate servers via separate paths. By doing so, multi-sender solutions provide diversity of both the sending server and the network path, and can further adapt and redistribute the sending servers and network path in the presences of congestion. *Nonetheless, CDN and P2P Networks that employ multi-sender streaming techniques suffer from the following issues:*

A. Redundant Storage: Typically, by the very nature of CDN, redundant storage occurs throughout the network in order to push duplicate copies to each of the edge servers. Further, P2P networks send uncoordinated copies of content to peer servers (e.g. KaZaa [2], a now inactive P2P file sharing application for songs), likewise resulting in redundant storage.

B. Inefficient Synchronization of Servers: Efficient multi-sender solutions *cannot* be realized unless for following is true: different video content partitions must be sent to different servers. This problem is compounded in the presence of unbalanced network throughput to a client receiver from multiple-sender servers, whereas in any given period of time the client receiver may receive a significant imbalance of partitions from one sending server as compared to another sending server. Further, in pull based P2P Networks, multiple peers may unknowingly request the same content partitions.

C. Network Protocols: Many video streaming applications utilize UDP because by UDP's very nature, UDP allows the sender to control the delivery rate and therefore presentation rate of the video in real-time. Unfortunately, UDP is often blocked by firewalls because hackers use the flexibility of UDP to create attacks on servers and networks.

All of the above are important problems to be solved because the need to provide robust and efficient video streaming network coding requires the efficient storage of video content, the efficient distribution of video content between servers, and the efficient protocol transport of streaming video content over the network connections. The failure to provide efficiencies in each of these areas predictably results in wasted cost in storage, inefficient and therefore high cost for server resources, higher network costs, poor performance to receive the video content at the client receiver (e.g., lost packets, higher latency, etc.).

2. The Proposed Solutions

As noted above, the objective of "Video Streaming with Network Coding" is to provide: (1) a reduction of redundant storage, (2) a reduction in complex sender synchronization, and (3) allow for the use of network friendly protocols. To this end, *"Video Streaming with Network Coding" proposes solutions to provide the smooth playback of data packets with minimal storage as compared to CDNs and with maximum bandwidth efficiency as compared to P2P Networks (id. at pg. 9).*

A. Hierarchical Network Coding (HNC) data redundancy: "Video Streaming with Network Coding" proposes the use of HNC as an improvement over Random Network Coding (RNC; for more information see the callout box below). The proposed HNC technique uniquely codes information into layers based on the importance of each layer's data as it relates to the impact on the viewing of the video streaming data. Thus the streamed video data is organized in the hierarchical layers, starting with a "base" layer as being the most important information, and then subsequent "enhancement" layers for

In "Video Streaming with Network Coding", ***Hierarchical Network Coding (HNC) is contrasted to Random Network Coding (RNC) [3][4]:*** *RNC obtains the maximum network capacity by randomizing the data using random linear network coding as compared to routing. The advantages of RNC are further explained in the paper "A Random Linear Network Coding Approach to Multicast" at pg. 1 [3]. RNC requires less storage as compared to CDN because with RNC "each assisted server keeps a fraction of the coded packets which are pushed to the receiver randomly" (id. at pg. 18).*

decreasingly less important information. For HNC, because the base layer information is most important, a server source sends "more duplicates of the important data" within the HNC coding scheme. This is done by giving packets that contain the base layer information a higher probabilistic weight for transmission and the base layer information is further included along with the enhancement layer information (*id.* at Table 1 and pgs. 12-13, 18-22).

B. Network Friendly "End of Chunk", allowing for the use of TCP: To allow for the use of network friendly protocols such as TCP, "Video Streaming with Network Coding" proposes an "end of chuck" message to be sent by the client receiver to notify the source senders to move to the next chuck of data, thus providing deterministic feedback to harness the near collective network throughput of "the total throughputs from all senders" (*id.* at pg. 16).

3. Strengths of the Proposed Solutions / Effectiveness

In my opinion, "Video Streaming with Network Coding" provides a number of strengths as further shown by the simulated results. The areas that I found that "Video Steaming with Network Coding" proves effective include:

A. HNC Provides Improved Performance in Environments where Data Redundancy is Less than Zero; likewise offering Improved Storage and Server Synchronization: *For data redundancy levels less than zero within a system*, HNC provides superior data recovery as compared to WLCN, RS, RNC and un-coded schemes. This is further shown in Figs. 4-6 of "Video Streaming with Network Coding" paper (*id.* at pgs. 19-20). Inherently because redundancy levels are less than zero, this improvement provides improved storage because redundancy within the network is avoided (e.g. storing multiple copies of the video content as is the case with CDN is not done). Likewise because HNC includes the base information within each partition of data, the need to coordinate, transmit, and retransmit lost packets within a P2P Networks is improved upon.

B. HNC Provides Improved Latency: Because HNC provides the base layer information in each partition of data, HNC inherently provides superior (less) latency as compared to RNC, whereas RNC requires the reassembly of the partitioned data received from each of the disparate servers prior to decoding. This is further shown in Fig. 7 (*id.* at pg. 21).

I find that each of the above areas are important improvements to obtain to overall objectives for the reasons stated above.

4. Weaknesses of the Proposed Solutions / Additional Considerations

While I found "Video Steaming with Network Coding" to be highly effective in providing the stated goals of: (1) a reduction of redundant storage, (2) a reduction in complex sender synchronization, and (3) allowance for the use of network friendly protocols, I do foresee a number of areas for further study and extension, including:

A HNC Hybrid Coding Technique in Systems with Greater than Zero Redundancy: The paper "Video Streaming with Network Coding" provides definitive trade-offs between RNC and HNC performance. *Based on the well documented performance for both HNC and RNC, one possible area of research would entail developing a coding technique that combines the advantages of both RNC and HNC.* For instance, a coding scheme could be developed that would sense the system data redundancy and for Redundancy < zero (0), the coding scheme would employ HNC, and as the Redundancy level approaches zero, RNC or a hybrid of HNC and RNC could be used. *Thus based on Figs. 4-7 of the paper "Video Streaming with Network Coding", the performance of the HNC + RNC hybrid coding scheme would be the composite "best case" performance of the HNC and RNC performance plots combined.*

Conclusion

In all, I found "Video Streaming with Network Coding's" HNC to provide unique improvement over RNC and the other abovementioned network coding schemes for multi-sender CDN and P2P Networks as measured by the foregoing three objectives: (1) a reduction of redundant storage, (2) a reduction in complex sender synchronization, and (3) allowance for the use of network friendly protocols. The paper shows that HNC accomplishes each of these objectives in systems that offer less than zero redundancy. *Further, the paper invites additional advancements in systems employing either less than or greater than zero redundancy*. Subsequently, I found that "Video Streaming with Network Coding" and specifically HNC had many strengths as shown by the demonstrable performance of the system.

References

[1] Kien Nguyen, Thinh Nguyen, and Sen-Ching Cheung, "Video Steaming with Network Coding, Hedera: Dynamic Flow Scheduling for Data Center Networks", undated.

[2] https://en.wikipedia.org/wiki/Kazaa, last viewed on Oct 3, 2015. As of August, 2012 www.kazaa.com became a non-working web-site.

[3] T. Ho, R. Koetter, M. Mdard, M. Effors, J. Shi, and D. Karger, "A Random Linear Network Coding Approach to Multicast," IEEE/ACM Transactions on Information Theory, Vol. 52, No. 10, Oct 2006.

[4] T. Ho, R. Koetter, M. Mdard, D. R. Karger, and M. Effros, "The Benefits of Coding over Routing in a Randomized Setting", International Symposium on Information Theory, 2003.

[5] Irving S. Reed, Irving S.; Gustave, "Polynomial Codes over Certain Finite Fields", Journal of the Society for Industrial and Applied Mathematics, 1960.

Glossary of Acronyms and Terms Used

RNC: Random Network Coding; see [3], [4]

RS: Reed Solomon – A well known forward error correction (FEC) method. [5]

WNLC: Within Layer Network Coding; *see* "Video Streaming with Network Coding", pgs. 13, 18. [1]

HNC: Hierarchical Network Coding; *see* "Video Streaming with Network Coding", pgs. 12, 18. [1]