Video Streaming Over the Internet

1. Research Team

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2. Statement of Project Goals

Quality of service (QoS) in streaming of continuous media over the Internet is still poor and inconsistent. The degradation in quality of continuous media applications, involving delivery of video and audio, is partly due to variations in delays as well as losses experienced by packets sent through wide-area networks. Although many such applications can tolerate some degree of missing information, significant losses degrade an application's quality of service.

The long-term goal of this project is to provide significant improvements in the QoS experienced by viewers of continuous media (e.g., video) over the Internet. We aim to accomplish this by (a) finding under-utilized resources on the Internet, (b) using them to provide better quality of service in continuous media streaming over the Internet, and (c) accomplishing this through application-level adaptation and control mechanisms in delivery of continuous media over best-effort networks.

3. Project Role in Support of IMSC Strategic Plan

Delivery of immersive media streams over the Internet, under stringent bandwidth and loss constraints, is a challenging problem. The development of our multi-path streaming technology will result in significantly lower losses in stream data as well as significantly higher bandwidth availability, thus facilitating delivery of high quality immersive media streams and contributing significantly to the quality of the overall immersive experience.

Moreover, our multi-path streaming efforts are synergistic with the current YIMA server technology efforts. That is, integration of multi-path streaming technology with the YIMA server will also lead to significantly higher quality immersive experience.

Lastly, multi-path streaming also supports two of the main thrust applications in IMSC, namely entertainment and education thrusts, as applications in both thrusts require delivery of high quality continuous media, with stringent loss and bandwidth requirements.

4. Discussion of Methodology Used

In this project, we propose to mitigate the problem of improving QoS of streaming over the Internet through the exploitation (at the application layer) of multiple paths existing in the network between a sender and a receiver of continuous media. One advantage of this approach is that the complexity of QoS provision can be pushed to the network edge (an original design

principle of the Internet) and hence improve the scalability and deployment characteristics while at the same time provide a certain level of QoS guarantees.

Exploitation of multiple paths (with disjoint points of congestion) includes the following potential benefits: (a) reduction in correlation between consecutive losses, (b) increased throughput, and (c) ability to adjust to variations in congestion patterns on different parts of the network. Thus, multi-path streaming provides a mechanism for us to find under-utilized resources in the network and use them to improve a streaming application's perceptual quality.

In this project, we study and evaluate the fundamental benefits and costs of multi-path stream through analytical models, simulation studies, measurements over domestic and international links (in cooperation with our national and international collaborators), as well as a prototype implementation.

5. Short Description of Achievements in Previous Years

This is a new report as the project leader joined IMSC in the middle of last year.

5a. Detail of Accomplishments During the Past Year

The contributions of this work thus far are as follows. We give an analytical characterization of when a multi-path approach is beneficial, as compared to a single path approach, using the following metrics (a) packet loss rate, (b) lag-1 autocorrelation of packet losses, and (c) burst length distribution of losses. We also extend this analysis to information loss rate, i.e., we consider the resulting losses after an application of an erasure code. Secondly, we extend the evaluation of the multi-path approach benefits using simulations of the analytical model. These are also performed with and without the use of an erasure code.

Our results thus far indicate that: (1) in general, multi-path streaming exhibits better loss characteristics than single-path streaming, (2) use of an erasure code may not necessarily improve data loss characteristics in the case of single-path streaming, while multi-path streaming (with or without use of an erasure code) can improve data loss characteristics, and (3) lag-1 autocorrelation of multi-path streaming is usually closer to zero than that of single path streaming, and we believe that this will also result in a higher viewing quality of the received continuous media stream.

Details of our results can be found in [4,12].

6. Other Relevant Work Being Conducted and How this Project is Different

Unique aspects of our work include a fundamental theoretical characterization of multi-path streaming benefits; we strive to provide such characterization under a variety of metrics, including loss rates, burst-length distributions, auto-correlations, and so on. Another important aspect is that our approach is an application level solution, which means that we require no explicit knowledge of network state or topology, and moreover we require no changes to or support from network or transport level protocols. Hence, our solution can be deployed today,

over the current Internet. A brief survey of other relevant work being conducted, including how our project is different, is given below.

Earlier efforts on dealing with losses through the use of multiple independent paths (although at lower layers of the network) include disparity routing, as proposed by Maxemchuk [7-9], which focused on reducing delay. In contrast, we focus on streaming applications where the data transmission rate is determined by the application's needs rather than on delivering the data to its destination as fast as possible.

The use of multiple paths in routing data has of course been considered at the network layer, although not widely done in the current Internet. Hence, higher layer mechanisms should be considered. Another set of works on the topic considers higher level mechanisms, but requires some assistance from the lower layers and/or assumes significant knowledge of network topology and/or link capacities and delays (on all links used for data delivery), e.g., as in [2,3]. In contrast, our approach does not rely on specific knowledge of topologies, capacities, delays, etc., and only considers whether a set of paths do or do not share joint points of congestion, as can be detected at the end-hosts.

Related recent literature also includes voice-over-IP type applications, e.g., [5,6] which uses multiple description coding (MDC) for multi-path delivery and FEC for single-path delivery. In contrast, we believe that it is important to understand the effects of multi-path delivery on loss characteristics, even without the use of coding techniques.

In [1], MDC is used to explicitly transmit differently encoded packet streams over different paths; here, we consider traffic splitting issue independently of the encoding scheme used. The work in [10,11] considers a similar environment to ours, however, it focuses on a transport protocol as well as on irrecoverable errors only. Due to the nature of the application, we believe that it is important to consider loss characteristics even when the losses cannot be fully recovered. That is, since we are considering delivery of video (which can be displayed even under some losses) in contrast to file transfer, it is important to consider other metrics (as those mentioned above).

7. Plan for the Next Year

Currently we are designing and developing a prototype of a multi-path streaming system using peer-to-peer type architecture. Our goal for next year is to finish developing the prototype and use it in large-scale experimentation over wide-area networks, including long-haul highly lossy international links. We will perform these experiments with our international and national collaborators, e.g., such as our collaborators in Hong Kong, Italy, and Brazil.

We also plan to extend our multi-path streaming technology to be able to adapt to changes in network conditions during the delivery of continuous media, as many applications of interest correspond to fairly long delivery times and require adaptation as network conditions change.

Another part of our plan is to experiment with multi-path streaming in the context of immersive technologies. This will be accomplished by exploring integration of our multi-path streaming technology with the YIMA server technology.

8. Expected Milestones and Deliverables

Our expected milestones and deliverables are:

- a peer-to-peer based prototype of a multi-path streaming system
- wide-area measurement experiments over national and international links, including long-haul highly lossy links
- a detailed performance study of the measurement experiments
- revision of multi-path techniques based on the results of the experiments
- novel adaptation algorithms, based on changes in network conditions, intended for applications running over longer time scales

9. Member Company Benefits

This is a new project, which currently does not have member companies.

10. References

[1] J. Apostolopoulos. Reliable video communication over lossy packet networks using multiple state encoding and path diversity. In the Visual Communications and Image Processing, San Jose, California, January 2001.
[2] J.-C. Chen and S.-H. Chan. Multipath routing for video unicast over bandwidth-limited networks. In the IEEE Globecom, San Antonio, Texas, November 2001.
[3] H. Chu and K. Nahrstedt. Dynamic multi-path communication for video traffic. In the Hawaiian International Conference on System Science, Hawaii, January, 1997.
[4] L. Golubchik, J. C.S. Lui, T. F. Tung, A. L.H. Chow, W.-J. Lee, G. Franceschinis, and C. Anglano. Multi-path Continuous Media Streaming: What are the Benefits? Performance Evaluation, 49:429--449, September 2002.
[5] Y. J. Liang, E. G. Steinbach, and B. Girod. Multi-stream voice over ip using packet path diversity. In the IEEE Fourth Workshop on Multimedia Signal Processing, Cannes, France, October 2001.
[6] Y. J. Liang, E. G. Steinbach, and B. Girod. Real-time voice communication over the Internet using packet path diversity. In the ACM Multimedia Conference, Ottawa, Canada, September/October 2001.
[7] N. F. Maxemchuk. Dispersity routing. In the IEEE International Conference on Communications, San Francisco, California, June 1975.
[8] N. F. Maxemchuk. Dispersity routing in high-speed networks. In the Workshop on Very High Speed Networks, Greenbelt, Maryland, March 1991.
[9] N. F. Maxemchuk. Dispersity routing in an atm network. In the IEEE INFOCOM, San Francisco, California, March/April 1993.
[10] T. Nguyen and A. Zakhor. Distributed video streaming with forward error correction. In the International Packetvideo Workshop, Pittsburg, Pennsylvania, April 2002.

[11] T. Nguyen and A. Zakhor. Distributed video streaming over Internet. In the SPIE Conference on Multimedia Computing and Networking, San Jose, California, January 2002.
[12] L. Golubchik and J.C.S. Lui. Multi-path Streaming: Is It Worth the Trouble? In the 4th Workshop on Mathematical (performance) Modeling and Analysis (MAMA), held in conjunction with ACM SIGMETRICS 2002, Los Angeles, CA, June 2002. Appears as part of the MAMA 2002 Workshop in the ACM SIGMETRICS Performance Evaluation Review, Volume 30, Number 3, December 2002.