Video Streaming Over the Internet

1. Research Team

Project Leader: Prof. Leana Golubchik, *Computer Science Department*

Graduate Students: Bassem Abdouni, Alix Chow, Zhihui Chen

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

The contributions of this work in the past are as follows. We gave an analytical characterization of when a multi-path approach is beneficial, as compared to a single path approach. Secondly, we extended the evaluation of the multi-path approach benefits using simulations of the analytical model. These results indicated that multi-path streaming exhibits better loss characteristics than single-path streaming which we believe will result in a higher viewing quality of the received continuous media stream. Hence, multi-path streaming is a promising approach. Details of these results can be found in [4.12].

5a. Detail of Accomplishments During the Past Year

We have designed and developed a prototype of a multi-path streaming system using peer-to-peer type architecture. We have been using this prototype in experimentations over wide-area networks. Real experiments over the Internet are quite difficult and time consuming. Thus far we have performed experiments between USC and the east coast (University of Maryland). In addition, we have also performed experiments between USC and our partner university in Hong Kong (the Chinese University of Hong Kong). We are in the process of setting up additional experiments with other national and international partner universities (including a university in Brazil (UFRJ). All these experiments will provide us with (a) detailed measurements which will help us validate our theoretical work on this topic as well as (b) detailed evaluation of the resulting quality of service due to the multi-path approach. Hence, it is important to continue with these experiments and obtain data over a variety of networking environments.

On the more theoretical side of the project, we extended our multi-path streaming technology by providing a methodology for optimally splitting the continuous media traffic between the multiple available paths, with the goal of optimizing the resulting quality of the streamed media. This is an important step in the direction of adaptation to network conditions during the delivery of continuous media. Adaptation to network conditions is an important goal of this project as many applications of interest correspond to fairly long delivery times, and hence adaptation of the optimal traffic split is desirable when network conditions change. The measurement studied described above is an important factor in facilitating advances in our theoretical work as well.

We have also been exploring integration of our multi-path streaming technology with the YIMA server technology. Currently, students from each project are working on an integration plan.

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 dispersity routing, as proposed by Maxemchuk [7.8.9], 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 used in our work).

7. Plan for the Next Year

We plan to continue our experiments over wide area networks, with our national and international partner universities to obtain a greater number of measurements over a variety of networking environments. These are needed to both, validate our existing multi-path streaming methodologies as well as improve them.

We also plan to utilize our optimization work, developed this year, in developing adaptation algorithms, which are needed in long-lasting streaming applications for adjusting to changes in networking conditions, which occur during the streaming process.

In addition, we plan to integrate our multi-path streaming technology with the YIMA server technology. Two students, one from each project, have begun the integration efforts, and we plan to have an initial prototype, which can be used to experiment with this integrated technology over real networks.

8. Expected Milestones and Deliverables

Our expected milestones and deliverables are:

- extending wide-area measurement experiments to a greater variety of national and international links
- a detailed performance study of these measurement experiments
- further revisions of multi-path methodologies based on the results of the experiments
- novel adaptation algorithms, based on changes in network conditions, intended for applications running over longer time scales, using the optimization methodology developed this year
- an initial integration of our multi-path approach into the YIMA prototype

9. Member Company Benefits

This project currently does not have member companies. However, BTG has expressed significant interest in this work recently.

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.