Introduction to the Special Issue on Streaming Video

Due to the explosive growth and great success of the Internet, as well as increasing demand for multimedia services, streaming media over the Internet have drawn tremendous attention by both academia and industry. With the rapid increase of bandwidth and computing power, streaming video over the Internet—since its introduction in early 1990s—has been experiencing dramatic growth and a transition from novelty to mainstream media communications. As the most successful video application on the Internet to date among all the video applications, streaming video has pervaded into both people's daily lives and business. Besides reading e-mail and surfing the Web, more and more people become consumers on the Web for video content.

From the compression side, there is much activity in both the standards arena and development of proprietary solutions. The MPEG-4 and H.26x standards have been standardizing various technologies for applications related to streaming media.

On the client side, the three most commonly used players today for streaming media are Apple's QuickTime™, Microsoft's Windows Media Player™, and RealNetwork's RealPlayer™. They use many different media codecs with proprietary or H.26x or MPEG-4 techniques.

From the distribution side, a majority of the streaming video applications today use unicast, in which a point-to-point connection is set up between a server and a client. There is an increasing push to move towards multicast applications and bring the broadcasting flavor to the streaming world. Mbone has been an initial experimental application that uses multicasting.

However, both unicast- and multicast-based streaming video technologies and applications are in their infancy. Many interesting barriers—ranging from a lack of QoS to unpredictable behavior of the Internet Channel, a wide range of devices with a wide range of processing powers, and building of new networking infrastructure and new business models—need to be overcome in the near future. Needless to say, streaming video over the Internet faces many technical as well as business challenges, and new codecs, protocols, players, and systems need to be developed to address them. The purpose of this Special Issue is to provide an overview of the state-of-art streaming video technologies and trends in research directed towards overcoming some of those challenges.

This Special Issue is organized in three parts. The first part consists of an Invited Paper from RealNetworks. We also invited a paper from Microsoft's Windows Media Player™ Team and the invitation was accepted; unfortunately, they could not submit a paper due to the time constraint. Our invitation to Apple's QuickTime™ team was not answered. The second part contains two excellent overview papers. One is on approaches and directions taken towards distribution of video over the Internet, and the other is on one of the profiles, fine granularity scalability (FGS) profile, of the MPEG-4 standard that can be helpful in streaming video over the Internet. The third part contains technical papers on source coding, coding for storage, error-control coding, transcoding, streaming systems, and system-related techniques.

The Special Issue opens with the Invited Paper from RealNetworks, "Video Coding for Streaming Media Delivery on the Internet." It provides an overview of the RealPlayer™ architecture, the Internet streaming media delivery network named RealSystem™ 8 and RealVideo™ 8. It also describes various problems that such a system faces with regard to video coding. Specifically, it explains how some of these problems can be addressed using a conventional framework of motion-compensated, transform-based video compression algorithms, supported by appropriate channel-adaptation mechanisms in client and server components of a streaming media system.

The second part consists of two overview papers. The first paper, entitled "Streaming Video over the Internet: Approaches and Directions" by D. Wu *et al.*, addresses six key areas of streaming video, from compression to system: video compression, application-level QoS control, continuous media-distribution services, streaming servers, media synchronization, and protocols for streaming media. In each area, the major approaches and mechanisms, as well as tradeoffs of the approaches, are discussed. Moreover, some future directions are pointed out.

Responding to the growing demand on a video-coding standard for streaming video over the Internet, MPEG-4 has been actively defining profiles for this application. Two of those profiles are advanced simple profile (ASP) and fine granularity scalability (FGS) profile, defined in an Amendment of MPEG-4. The second overview paper, entitled "Overview of Fine Granularity Scalability in MPEG-4 Video Standard" by W. Li, reviews the FGS video-coding technique in MPEG-4 standard. FGS provides capability to distribute multiple-layer frame-based video with a wide range of bit rates, which can adapt to the varying network bandwidth.

The third part of this Special Issue is composed of ten papers that cover some of very important issues in streaming video.

M. van der Schaar and H. Radha present a scalable video-coding approach in "A Hybrid Temporal-SNR Fine-Granular Scalability for Internet Video," which provides SNR, temporal, and hybrid temporal-SNR FGSs for a streaming video system building upon the FGS approach. It provides a new level of

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abstraction between the encoding and transmission process by supporting both SNR and temporal scalabilities through a single enhancement layer.

In the paper "A Framework for Efficient Progressive Fine Granularity Scalable Video Coding," F. Wu *et al.*describe an efficient and progressive FGS (PFGS) coding approach, which uses multiple layers of references with increasing quality for motion prediction. It provides high coding efficiency and limits drifting, yet still keeps all the FGS properties.

A two-pass variable bit-rate (VBR) coding algorithm for fixed-size storage applications, such as streaming video, digital versatile disk (DVD), digital library, and video on demand (VOD), is described in "A Novel Two-Pass VBR Coding Algorithm for Fixed Size Storage Applications" by Y.Yu *et al.* The scheme provides more consistent video quality and an improved coding efficiency.

The paper "Rate-Distortion Optimized Layered Coding with Unequal Error Protection for Robust Internet Video" by M. Gallant and F. Kossentini describes an error-control approach to increasing the error-resilience of low bit-rate video communication over error-prone packet-switched networks. It considers rate-distortion optimized mode selection, channel conditions, error recovery and concealment by joint source coding and channel coding.

W.-T. Tan and A. Zakhor present the use of layered forward error correction (FEC) in "Video Multicast Using Layered FEC and Scalable Compression" as an error-control mechanism in a layered multicasting. In this technique, each receiver obtains a different level of protection commensurate with its channel condition.

A. Vetro *et al.* present an object-based transcoding approach for video content delivery in "Object-Based Transcoding for Adaptable Video Content Delivery." This object-based transcoder provides flexibility in adapting the contents in manipulations of object-based video contents.

In the paper "The Importance of the Bi-directionally Predicted Pictures in Video Streaming," T. Shanableh and M. Ghanbari, highlight the vitality of the bi-directionally predicted pictures in MPEG-coded bitstreams to applications of video streaming. This technique can be exploited for efficient video transcoding into lower resolution and different encoding formats for pre-encoded video streams.

The paper "MPEG Video Streaming with VCR Functionality" by C.-W. Lin *et al.* describes a least-cost scheme for the efficient implementation of MPEG streaming video system with full VCR functionality over an IP network with minimum requirement on the network bandwidth and the video decoder complexity. It also discusses their implementation of an IP-based MPEG-4 video streaming platform that provides full VCR functionality.

K. C. Almeroth presents an adaptive and workload-dependent scheduling for large-scale content delivery systems in "Adaptive, Workload-Dependent Scheduling for Large-Scale Content Delivery Systems." This paper develops a set of workloads with variable request rates, presents a set of rate-based allocation algorithms, quantifies the drawbacks of traditional greedy channel-allocation algorithms, and generalizes the content-delivery model.

Finally, the paper "Multicast with Cache (Mcache): An Adaptive Zero-Delay Video-on-Demand Service" by S. Ramesh *et al.* describes a closed-loop (demand-driven) approach towards video-on-demand service. It provides a truly adaptive video-on-demand service with minimum bandwidth usage, and removes the need for *a priori* knowledge of client disk storage requirements.

We, the Guest Editors of this Special Issue, would like to thank the RealNetworks and Microsoft teams who accepted the invitations, and especially the RealNetworks team who put together the overview paper on streaming video coding and delivery networks. This gave us the opportunity to get a view of what is inside one of the most popular streaming video systems.

We would also like to thank all the authors for their excellent contributions, efforts, and insights in streaming video.

We are deeply indebted to the many reviewers for their kind help and effort in providing expert reviews on the submitted manuscripts. This significantly helped us, as well as the authors, to improve the quality of the papers in this Special Issue.

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