Signal Processing: *Image Communication* 27 (2012) 312–328

Contents lists available at SciVerse ScienceDirect

Signal Processing: *Image Communication*

journal homepage: www.elsevier.com/locate/image

Using bandwidth aggregation to improve the performance of quality-adaptive streaming

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ARTICLE INFO

Available online 7 November 2011

Keywords:
Multihoming
Bandwidth aggregation
Video streaming
HTTP
Quality adaptive streaming

ABSTRACT

Devices capable of connecting to multiple, overlapping networks simultaneously is becoming increasingly common. For example, most laptops are equipped with LAN- and WLAN-interface, and smart phones can typically connect to both WLANs and 3G mobile networks. At the same time, streaming high-quality video is becoming increasingly popular. However, due to bandwidth limitations or the unreliable and unpredictable nature of some types of networks, streaming video can be subject to frequent periods of rebuffering and characterized by a low picture quality.

In this paper, we present a multilink extension to the data retrieval part of the DAVVI adaptive, segmented video streaming system. DAVVI implements the same core functionality as the MPEG DASH standard. It uses HTTP to retrieve data, segments video, provides clients with a description of the content, and allows clients to switch quality during playback. Any DAVVI-data retrieval extensions can also be implemented in a DASH-solution.

The multilink-enabled DAVVI client divides video segments into smaller subsegments, which are requested over multiple interfaces simultaneously. The size of each subsegment is dynamic and calculated on the fly, based on the throughput of the different links. This is an improvement over our earlier subsegment approach, which divided segments into fixed size subsegments. The quality of the video is adapted based on the measured, aggregated throughput. Both the static and the dynamic subsegment approaches were evaluated with on-demand streaming and quasi-live streaming. The new subsegment approach reduces the number of playback interruptions and improves video quality significantly for all cases where the earlier approach struggled. Otherwise, they show similar performance.

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1. Introduction

Streaming high-quality video is rapidly increasing in popularity. Video aggregation sites, like YouTube and Vimeo, serve millions of videos every day, various events are broadcasted live over the Internet and large investments are made in video-on-demand services. One example is Hulu,[1] which is backed by over 225 content companies and allow users to legally stream popular TV-shows like Lost, Glee, and America's Got Talent. This paper is an extended version of our MMSYS 2011-paper "Improving the Performance of Quality-Adaptive Video Streaming over Multiple Heterogeneous Access Networks".

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[1] http://www.hulu.com/about

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doi:10.1016/j.image.2011.10.007

However, high-quality video has a high bandwidth requirement. For example, the bitrate of HD-video when streaming is several MB/s. This might not be a problem in areas with a highly developed broadband infrastructure, but a single average home connection to the Internet might not be able to support this quality. For example, the average broadband connection in the United States is about 4 MB/s [1]. Due to bandwidth limitations or the unreliable and unpredictable nature of some types of networks, for example WLAN and 3G (HSDPA), streaming video can be subject to frequent periods of rebuffering, characterized by a low picture quality and playback interruptions.

Today, devices capable of connecting to multiple, overlapping networks simultaneously are common. For example, most laptops are equipped with LAN- and WLAN-interface, and smart phones can often connect to both WLANs and 3G-networks. One way to alleviate the bandwidth problem is to increase the available bandwidth by aggregating multiple physical links into one logical link. Adaptive, segmented streaming solutions, like DASH, divide videos into segments, and these can be requested and sent over independent links simultaneously, achieving bandwidth aggregation. Also, the same segment is encoded at multiple quality levels (bitrates). This allows clients to adapt the requested video quality according to the available resources, for example to ensure a smooth playback.

We have previously developed and presented a client-side request scheduler that retrieves video segments in several encodings over multiple heterogeneous network interfaces simultaneously [2]. To improve performance even further, the segments are divided into smaller logical subsegments, and the request scheduler performed well in our experiments. It reduced the number of playback interruptions and increased the average video quality significantly. However, this subsegment approach has a weakness—segments are divided into fixed-sized subsegments which, in combination with limited receive buffers, have a significant effect on multilink-performance. Unless the buffer is large enough to compensate for the link heterogeneity, this static approach is unable to reach maximum performance. Increasing the size of the receive buffer alleviates the problem. However, it might not be acceptable, desirable or even possible with a larger buffer, as it adds delay and requires more memory.

In this paper, we present an improved subsegment approach. Subsegment sizes are dynamic and calculated on the fly, based on the links' performance. By doing this, the request scheduler avoids idle periods by allocating the ideal amount of data (at that time) to each link. The request scheduler and both subsegment approaches were implemented as extensions to the DAVVI [3] streaming platform, which offers the same core functionality as DASH [4,5]. Both DAVVI and DASH-based solutions encode the same segments at multiple bitrates, provide the client with a description of the content and allow clients to switch quality during playback. Even though DAVVI's equivalent of DASH's Media Presentation Description (MPD) is structured differently, they both contain enough information to support the same quality adaptation and data retrieval techniques. A client will first select the appropriate quality, based on for example the measured throughput and the amount of buffered data, and then request the selected segment using HTTP. In other words, any modifications to the data retrieval part of DAVVI can also be applied to DASH.

The two subsegment approaches were evaluated with on-demand streaming and live streaming with and without buffering, in a controlled network environment and with real world wireless links. In the context of this paper, live/liveness is defined as how much the stream lags behind the no-delay broadcast. The dynamic subsegment approach significantly reduces the number of playback interruptions, and improves the video quality when multiple links are used. When the buffer is large enough to compensate for the link heterogeneity, both the old and the new subsegment approaches show similar performance. When buffers are small, our new solution achieves a higher video quality.

The rest of the paper is organized as follows. Section 2 contains a presentation of related work, while Section 3 describes DAVVI, more on how it compares to DASH and our multilink modifications. Our testbed setup is introduced in Section 4, and the results from our experiments are discussed in Section 5. Finally, we give the conclusion and prospects for future work in Section 6.

2. Related work

HTTP is currently one of the, if not the, most common protocol used to stream video through the Internet, and multi-quality encoding and file segmentation is a popular way to allow quality adaptation and increase performance. By picking the quality most suited to the current link performance, a smoother playback can be achieved. Also, file segmentation allows content providers to build more scalable services that offer a better user experience due to increased capacity. Commercial examples of HTTP-based streaming solutions built upon segmentation of the original content, include Move Networks [6], Apple's QuickTime Streaming Server [7] and Microsoft's Smooth Streaming [8]. The goal of MPEG DASH is to provide a standardized alternative to these proprietary solutions.

Picking the most appropriate server is a non-trivial problem that has been studied extensively. Parallel access schemes, like those presented in [9] and [10], try to reduce the load on congested servers by automatically switching to other servers for further segment requests. These parallel access schemes assume that excessive server load or network congestion create the throughput bottleneck. We assume that the bottleneck lies somewhere in the access network. However, the scheduling problem is similar—either the client or server has more available bandwidth than the other party can utilize.

Parallel access schemes are not suitable for achieving live or quasi-live streaming (sometimes referred to as "progressive download"), as they have no notion of deadlines. Also, the additional complexity introduced by automatically adapting the video quality is not solved by these parallel access schemes. Still, with some modifications, the techniques developed within the field of parallel

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