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Performance evaluation of sender-assisted HTTP-based video streaming in wireless ad hoc networks

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ABSTRACT

HTTP Adaptive Streaming (HAS) delivers video streaming services according to a client–server architecture where the client originates consecutive HTTP requests to download chunks of encoded video. In state-of-the-art systems, the client selects the chunk out of a finite set of differently encoded versions of the same video made available at the server site; the selection is driven by a client-centered buffer management procedure. Still, dynamic bitstream switching may have drawbacks in terms of undesirable visual quality fluctuations artifacts at the final user; besides, it may result in oscillatory behavior of the overall traffic in case of multiple users. Therefore, this paper proposes a sender-assisted procedure for HTTP Adaptive Streaming (HAS) services with improved user Quality of Experience (QoE) that proactively avoids buffer underflow events at the receiver side, thus reducing the need for dynamic bitstream switching. In the proposed sender-assisted approach, HAS leverages information on the encoded video available at the server side to assist the client in originating the data requests. Specifically, the sender-assisted HAS procedure exploits information on the encoded video content available at the sender side to regulate the interval between consecutive client-originated download requests. Significant QoE improvements brought by the proposed sender-assisted video streaming procedure are demonstrated in challenging fluctuating throughput conditions encountered in wireless ad hoc networks.

1. Introduction

The demand of video streaming services is rapidly increasing and is expected to unrelentingly grow in the next few years [1]. Mobile and wired network traffic is composed of an ever increasing percentage of video streaming traffic and the efficiency of streaming services will certainly impact the resulting network load. The most popular streaming architecture, known as HTTP Adaptive Streaming (HAS), underlies several commercial streaming video services in current video networking systems. HAS is used in world-wide adopted streaming platforms such as Microsoft's Smooth Streaming, Adobe's HTTP Dynamic Streaming, or Apple's HTTP Live Streaming [2].

HTTP-based systems benefit from full compliance with network devices and middleboxes (e.g., firewalls, NATs) currently used in the Internet. Adaptivity allows the client to select video chunks out of a set of bitstreams encoded at different quality levels and representing the same video and made available for bitstream switching purposes at the server side. In this way, the download rate of the chunks can be adapted to the current network conditions (i.e., available bandwidth). Therefore, the effective video streaming rate depends on both the encoding settings

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and on the end-to-end channel throughput experienced between the sender and the client [3]. Being based on the underlying reliable TCP network protocol, HAS prevents packet error and losses at the price of introducing random end-to-end packet transmission delays, which in turn may result in underflow events at the client buffer. A standard framework for HAS, known as Dynamic Adaptive Streaming using HTTP (DASH) [4], has also been defined within MPEG and 3GPP standardization activities.

When an underflow event occurs, video playout is interrupted and the client enters a rebuffering phase until the buffer is loaded to a preset threshold prior; then, playout restarts. Underflow events and rebuffering delays affect the quality perceived by the user, especially on wireless IP networks with large TCP throughput variations [5]. Even in stable end-to-end bandwidth conditions, random delay is introduced because of the random size of the encoded video chunk [6]. Therefore, a significant margin between the current throughput and the average encoding rate is required to avoid non-negligible QoE degradation due to fluctuations of the encoding rate. Furthermore, experimental evaluations of different commercial HAS systems [2,7] show that even the visual quality fluctuations caused by the client-based rate adaptation strategies result in fluctuations of the Quality of Experience (QoE) at the client side.

In this paper, we propose a sender-assisted HTTP streaming strategy that avoids unnecessary dynamic rate adaptation using an efficient scheduling of the HTTP-GET request underlying the streaming session. Specifically, the sender (i) proactively foresees upcoming underflow events using information on the encoded video content available at the sender side, and (ii) it uses this information to adaptively control the duration of the intervals between consecutive video segment requests performed by the client. The proposed strategy enables efficient and flexible management of the rapidly varying random fluctuations of the packet delays that are caused by the interplay of the characteristics of the encoded content and of the network conditions. This approach is especially beneficial in wireless ad hoc networks where challenging network conditions are typically encountered as a consequence of the variability of network accesses and of the wireless channel and interference dynamics.

The remainder of this paper is organized as follows. Section 2 discusses related work. Section 3 introduces the architecture of the discussed sender-assisted video streaming procedure, while Section 4 proposes a model of its performance. Section 5 discusses the proposed buffer management algorithm. Section 6 discusses performance evaluation results, and Section 7 concludes the paper.

2. Related work

Video streaming in wireless systems has been addressed in several papers, e.g., [8–11]. A cross-layer selection of the optimal parameter values that maximize the expected user-perceived video quality is proposed in [8]. This requires computing, for each user and each parameter set, the expected video reconstruction quality at the receiver application layer. The proposed approach is shown to lead to good performance even if the computational cost is high and dramatically increasing with the number of users. In [9], the authors analyze the video bitstream across a multi-hop IEEE 802.11a/e wireless network by investigating (i) the video quality improvement that can be obtained with an integrated cross-layer optimization involving all layers of the protocol stack and (ii) the impact on performance and complexity if the optimized streaming solution is performed using only limited, localized state information. However, the authors consider the case of a general video encoded reproducing the MPEG behavior.

In [10], the authors present a buffer and rate optimization algorithm aimed at reducing frame loss, buffer underflow events, and buffer delay in wireless networks, so as to improve the users' QoE. This algorithm applies a low-cost bandwidth estimation approach at the application layer to provide information on the effective capacity, available bandwidth, and variance in bandwidth for the bottleneck wireless link. Different from our approach, the authors propose to employ, before starting video streaming, a mechanism to capture the time-varying nature of the current wireless conditions within a cumulative density function (CDF) estimate. Conversely, we rely only on an approximation of the buffer occupancy obtained by measuring the current wireless access behavior (in terms of MAC collisions) and size of video chunks sent to the client.

Another class of papers deals with mobile video adaptation. As an example, in [12] challenges related to the variability of TCP throughput in wireless networks as well as to the management of client-side video playback buffer and to variations of the battery level of the mobile terminals are faced. The authors propose an adaptation algorithm consisting of one module that derives the rate for chunk downloading based on the current buffered video time, recent TCP throughput history, and video rates for the previous chunks and one module to generate bundled chunk download schedule to increase the energy efficiency of 3G radios. Similar to this approach, we propose a server-side adaptation algorithm suitable for ad hoc networks where different competing communications share the channel. In our case, the target performance metrics are related to the buffer freezes and we define a content-aware approach for mobile HAS that regulates client HTTP requests.

We propose a short-term rate adaptation scheme based on a look-ahead mechanism operated at the sender side. We expect the proposed scheme to be able to reduce playout buffer underflows and oscillations that characterize the system in Fig. 1. Within this context, the objective of this work is to propose enhancements to state-of-the-art HTTP-based video streaming protocols specialized for ad hoc networks, where mobile devices may experience large bandwidth fluctuations due to either physical layer fluctuations of the wireless channel or to random MAC delays due to coexistence of multiple users. The proposed HAS architecture provides an effective basis to develop a new generation of flexible HTTP video streaming strategies that can match these specific challenges of ad hoc networks.

3. Sender-assisted HAS architecture

Typical HAS systems, e.g., Dynamic Adaptive Streaming based on HTTP (DASH) systems [4], are characterized by the consecutive stages described in the following. First,