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HTTP adaptive streaming scheme for improving the quality of experience in multi-server environments☆

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ABSTRACT

Many studies have been conducted on multi-server HTTP Adaptive Streaming (HAS). The existing schemes can highly utilize the available bandwidth by aggregating the multipath bandwidth and improve the video quality by switching servers when network congestion occurs. However, these existing schemes have problems that adversely affect the Quality of Experience (QoE) in a multi-server environment. To cope with these problems, we analyze the existing HAS schemes in multi-server environments. Through simulation-based performance analysis, we prove that these existing schemes lead to playback stalling and frequent quality changes. Based on the analysis, we propose a new HAS scheme for multi-server environments. The proposed scheme improves the QoE by alleviating the problems of the existing schemes. Through the simulation results, we prove that the proposed scheme alleviates the shortcomings of the existing schemes and improves QoE metrics compared with the existing multi-server schemes.

1. Introduction

HTTP Adaptive Streaming (HAS), which can adapt to various environments, has attracted attention with the spread of high-performance mobile devices and the development of network technologies [1–3]. In the HAS approach, video content is encoded at multiple bitrates, and the encoded video content is segmented into small parts of fixed durations. Recently, commercial streaming services, such as Netflix and YouTube, have begun employing HAS as their default delivery method. Also, these commercial services usually operate in multi-server environments because of the merits of multi-server HAS, which are expanded bandwidth, link diversity, and reliability.

Many studies have been carried out on applying multi-HAS. The work in [4] is among the first to study HAS for multi-server environments. This method is an extension of the rate adaption for the single-server. In [5], the authors propose QoE-driven Adaptive Server selection (QAS), which dynamically selects servers according to users' QoE feedback for VoD systems in the cloud. In [6], the authors propose a Control-Theoretic approach to Rate Adaptation (CTRA), which utilizes network and application conditions to provide smooth video playback for multi-server environments.

Many HAS schemes have been proposed for multi-server environments. However, the existing schemes have problems that include bottleneck creation, bandwidth fluctuation issues, and out-of-order segment issues. These issues adversely affect the QoE. To figure out the reason for QoE degradation, we analyze the behavior of the previous schemes. There are three main causes for degradation, as follows: (1) the bottleneck link creation problem when multiple clients compete, (2) bandwidth fluctuation issues because of bandwidth aggregation, and (3) out-of-order issues due to the diversity of bandwidth of the links between the client and servers.

To cope with these problems, we propose a novel HAS scheme for multi-server environments. The proposed scheme selects the source server based on network status, which is measured by segment information or probing packets. Also, to meet the playback deadline, it schedules media segments according to the measured network status. Finally, to prevent concentration of request messages when multiple clients compete, the proposed scheme switches source servers and adapts the video quality based on the network status. We evaluate the proposed scheme in various network statuses using the NS-3. The results show that the proposed scheme improves the QoE compared to the existing scheme by reducing unnecessary quality changes, improving the video quality and supporting seamless playback. By alleviating the problems of existing schemes, the proposed scheme can significantly improve the QoE.

The rest of this paper is organized as follows. Section 2 provides the

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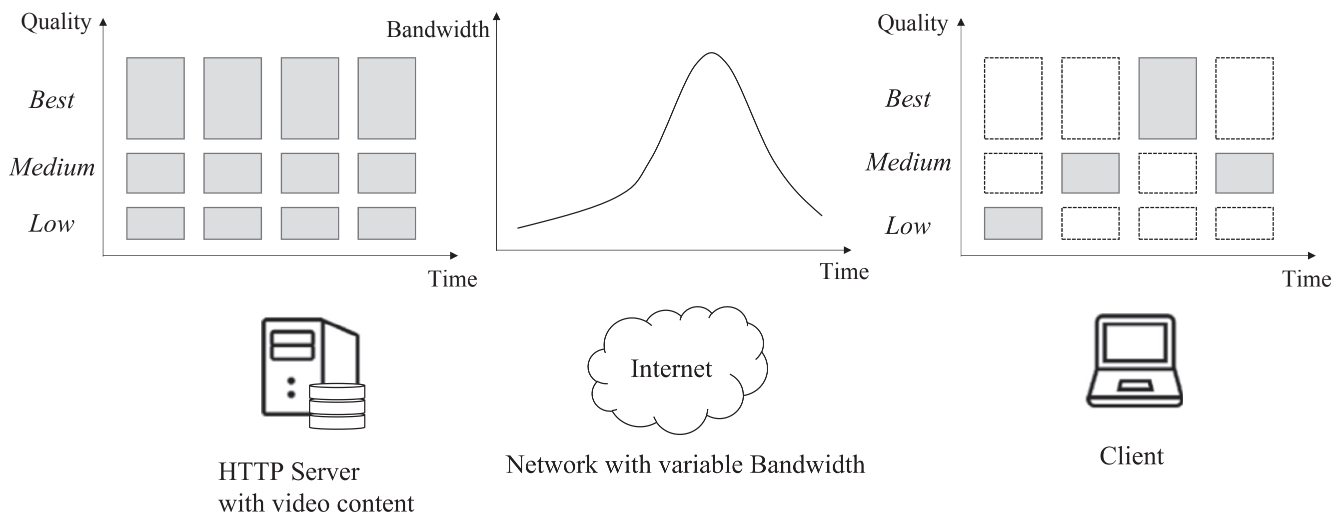

Fig. 1. Concept of the HTTP adaptive streaming.

background and related works. Section 3 analyzes how the existing HAS scheme works in multi-server environments. Section 4 describes the proposed HAS scheme. Section 5 provides implementation results, and Section 6 concludes the paper.

2. Background and related works

This section provides an overview of HAS and reviews the existing HAS schemes for multi-server environments.

2.1. HTTP adaptive streaming

Fig. 1 illustrates the concept of HTTP adaptive streaming [7] in which the server holds multiple profiles of the same video, encoded at different bitrates and quality levels. In addition, the video object is partitioned into segments, typically a few seconds long. A client can then adapt to the underlying dynamic network conditions, such as available-bandwidth fluctuations or delay jitter, by requesting different segments at different encoding bitrates. The adaptation logic to determine the bitrate for each segment request is built into the client rather than the server. This improves the server-side scalability and the system performance. Another benefit of this approach is that it provides the ability to dynamically adjust the rate at which new segments are requested, allowing the client to control the playback buffer size.

In communication networks, the Quality of Service (QoS) is objectively expressed by network parameters like packet loss, delay, or jitter. However, a good QoS does not guarantee that all customers experience good streaming service. Thus, Quality of Experience (QoE) was introduced, which is a concept of subjectively perceived quality. It takes into account how customers perceive the overall value of a service and thus relies on subjective criteria [8]. Therefore, QoE in HAS streaming is an important value. The 3rd-Generation Partnership Project (3GPP) and Moving Picture Experts Group (MPEG), which standardize the Dynamic Adaptive Streaming over HTTP (DASH), provides the QoE metrics of HAS, shown in Table 1 [9–11].

For HTTP video streaming, [12,13] show in their results that stalling frequency, switching frequency and time on each layer are the key influence factors of QoE.

To improve the QoE, many studies have been conducted in single-server HAS environments. To prevent buffer underflow and reduce changes in video quality, Liu et al. proposed the Rate Adaptation for adaptive HTTP Streaming (RAHS) scheme [14]. The RAHS scheme determines the network status based on the segment fetch time. Thang et al. proposed the Adaptive Streaming of Audiovisual Content (ASAC) scheme, to reduce unnecessary changes in video quality, by adapting the video quality based on the estimated segment throughput [15]. Mok et al. proposed the QoE-aware DASH system to improve the QoE, by using a stepwise decrease in video quality [16]. However, these studies do not consider multi-server environments.

Table 1
QoE metrics of HAS.

User-perceived factor	QoE metrics
Waiting times	Initial delay Stalling frequency Stalling duration
Video adaptation	Switching frequency Amplitude Time on each layer
Video quality	Spatial resolution Temporal scalability Image quality

2.2. HAS scheme for multi-server environments

While most HAS-based streaming services employ multiple servers hosting the same set of video content, each client is only assigned to one server [17]. It is obviously more advantageous if an HAS client is allowed to dynamically switch from one server to another, or even better, simultaneously download from multiple servers. The primary advantage of multi-server HAS is to rescue multimedia streaming when the link is congested or broken, by resorting to alternative links. Basically, multi-server HAS schemes are categorized into server selection schemes and concurrent download schemes. The server selection scheme dynamically switches the source from one server to another, while the concurrent download scheme receives the content from multiple servers at the same time, as shown in Fig. 2.

Much research has been carried out to study the HAS scheme for multi-server environments. The work in [4] is among the first to study the HAS scheme for multi-server environments. It considers two cases; in the first case, given n servers, a client always connects to the server that can provide the highest video download rate; in the second case, a client simultaneously connects to s out of n servers, downloads different segments from different servers, and then combines them in the order of the video sequence. This method is an extension of the rate adaption for single-server environments.

The QAS scheme, which is a server-selection scheme, selects the server according to the client's QoE information [5]. In [18], the