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A smooth broadcasting scheme for VBR-encoded hot videos

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Abstract

One way of broadcasting a popular video is partitioning the video into segments, each being broadcasted on several streams periodically. The approach alleviates the bandwidth thirsty in real-time video broadcasting without sacrificing viewers' waiting time by allowing multiple users to share the same video segments. One representative scheme of the category is the recursive frequency-splitting (RFS) broadcasting scheme, which yields approximate minimum waiting time. In this paper, a novel approach is introduced to enhance RFS, called Smooth RFS (SRFS), in which the approaches of segment patching and asynchronous downloading–playing are proposed for achieving a smooth broadcast of variable-bit-rate (VBR) -encoded videos. The design of SRFS aims to reduce the peak bandwidth consumption and variance during the distribution of VBR videos in order to achieve better upper bounds on the bandwidth peak and the variance. Extensive simulation has been conducted on the proposed scheme by comparing a number of past reported counterparts, including the trace-adaptive fragmentation (TAF) scheme and the smooth fast broadcasting (SFB) scheme. The results indicate that the proposed scheme yields lower bandwidth peak and variance. Besides, given a fixed bandwidth that is smaller than the peak, SRFS obtains a much smaller blocking rate than that of the other schemes.

Keywords: Hot-video broadcasting; Video-on-demand (VOD); Variable-bit-rate (VBR)

1. Introduction

With the advances in the broadband networking technology as well as the growth of processor speed and disk capacity, video-on-demand (VOD) services have become possible [14,18]. A VOD system is typically implemented under a client–server architecture, and may easily run out of bandwidth because the growth in bandwidth can never keep up with the growth in the number of clients. This results in a tremendous demand for computing power and communication bandwidth on the system.

To alleviate the stress on bandwidth and I/O demands, many alternatives have been proposed by sacrificing some videocassette recorder (VCR) functions, or known as near-VOD services, which, nonetheless, may bring some side effects on the subsequent operation. According to [7], 80% of demands are on a few (10 or 20) very popular videos, which dominate the bandwidth consumption. To improve the bandwidth efficiency, broadcasting is an effective approach in dealing with the popular video delivery that may interest many viewers at a certain period of time by recognizing the fact that the server's broadcasting activity is independent of the arrivals of requests from the users. One way to broadcast a popular video is to partition the video into segments, each being broadcasted on several streams periodically. The class of schemes shares a similar arrangement by dividing a video file into segments at the server that can be simultaneously broadcasted on different data streams. One of these streams transmits the first segment in real-time, while the other streams carry the

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remaining segments according to a pre-defined schedule. When a client issues a request for watching a video, the client waits for the arrival of the first segment in the first stream. Thus, the resultant maximum user waiting time is simply determined by the time duration before the arrival of the first segment. While the client starts watching the video, the set-top boxes (STB) or computers continue downloading the following segments from the other streams at the same time such that the video can be played continuously in a right order at the client's side.

Based on the above mentioned approach, a simple scheme is the staggered broadcasting [1], in which the server allocates k streams to carry a video with the maximum waiting time being L/k, where L is the video duration. To reduce the waiting time, the pyramid broadcasting [25] scheme partitions a video into segments with an increasing size and transmits them on multiple streams of the same bandwidth. The fast broadcasting (FB) scheme [12] can further reduce the waiting time in the previous schemes by dividing a video into a geometrical series of $1, 2, 4, \ldots, 2^{k-1}$ with the maximum waiting time $L/(2^k - 1)$, where the improvement is mainly due to the simple implementation on conventional IP networks [28]. Based on the pagoda broadcasting scheme [20], a newly modified pagoda broadcasting (NPB) scheme [21] is devised such that the video is partitioned into fixed-sized segments, which are mapped into data streams of equal bandwidth at the proper decreasing frequencies. Accordingly, NPB achieves shorter waiting time than that by FB. The recursive frequency-splitting (RFS) scheme [24] further reduces the waiting time in the NPB scheme to the extent very close to the optimal case. With almost the same performance as that in RFS, Bar-Noy and Ladner [2] proposed a greedy broadcasting scheme by formulating the segment-to-stream mapping effort into a window-scheduling problem.

Some research has been conducted to investigate the theoretical boundaries on the end-user waiting time and bandwidth consumption. The harmonic broadcasting (HB) scheme [10] first divides a video into several segments equally, where each segment is further divided into sub-segments according to the harmonic series. The sub-segments of a segment are then distributed to the same stream in turn. Yang et al. [27] proved that given a fixed bandwidth demand, the HB scheme obtains the minimum waiting time. The greedy equal bandwidth broadcasting (GEBB) scheme [9] requires the clients to wait for a fixed amount of time, where the video data is carried by multiple equal bandwidth streams with the increasing size of successive segments instead of simply decreasing the stream bandwidth.

The above schemes assume that the videos are encoded in a constant-bit-rate (CBR) fashion where variable-bit-rate (VBR) videos cannot be supported well. It is clear that the following two issues must be addressed in distributing VBR videos: (1) to achieve continuous playing on the client side, and (2) to assure smooth bandwidth consumption on the server side. To address the two issues, some schemes have been proposed. The harmonic series schemes with VBR support were studied in [22,26,29], where the variable bandwidth harmonic broadcasting (VBHB) scheme [22] divides a VBR video into fixed size segments such that the first and second segments are broadcasted at a transmission rate that can guarantee an on-time delivery of all frames, while the remaining segments are divided into equal-size sub-segments and are distributed in the same way as that in the cautious harmonic broadcasting (CHB) scheme [19]. Yu et al. [29] proposed a simple VBR staircase broadcasting (SVSB) scheme, which enables the staircase broadcasting scheme [11] to support VBR-encoded videos with smaller client buffers. The live harmonic broadcasting (LHB) scheme [26] was proposed to support live VBR video. Based on the GEBB scheme, Nikolaidis et al. [17] proposed a lossless and bandwidth-efficient (LLBE) scheme, which can broadcast VBR videos in an optimal manner. With these schemes, the bandwidth consumption is constant when the VBR videos are broadcasted at the expense of higher complexity and less practicality due to the multitude of the allocated streams [21]. This can be easily observed in the case with a video of 100 min long under the constraint on waiting time of 1 min, where the VBHB scheme requires a video server to broadcast data on 100 streams simultaneously.

The non-harmonic schemes with a VBR support have been extensively reported [16,23,30]. The periodic broadcasting with a VBR-encoded video (VBR-B) [23] delivers VBR videos by integrating the pyramid broadcasting scheme with the techniques of the smoothing on group of pictures (GoP), server buffering, and client prefetching. Based on the VBR-B scheme, the trace-adaptive fragmentation (TAF) scheme [16] was developed by taking the trace of each video into account to predict the bandwidth requirements, where the client-centric approach (CCA) [4] was adopted to select the best segmentation for minimizing the loss by enumerating all the possible segmentations. Based on FB, Yu et al. [30] proposed a simpler and more effective scheme, called smooth fast broadcasting (SFB), which can reduce the variance of the required bandwidth. The video server divides a VBR video into multiple equal-duration segments, and then transmits each segment at constant bit rate. The order of the segments on each stream is further elaborated to smooth the total required bandwidth. Although the bandwidth requirements are not constant, the non-harmonic schemes with a VBR support are more feasible than the other counterparts by having a much smaller number of allocated streams. For example, given a video of 100 min and a waiting time of 10 s, the VBHB scheme requires a video server to broadcast data on 600 streams simultaneously while the SFB scheme only allocates 10 streams.

In this paper, a novel non-harmonic scheme with a VBR support called smooth RFS (SRFS) is introduced, where the approaches of segment patching and asynchronous downloading–playing are proposed and employed to