A Better Dynamic Broadcasting Protocol for Video-on-Demand

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Abstract

1. Introduction

Video-on-demand (VOD) will one day allow customers to select any given video from a large on-line video library and watch it on their televisions without any further delay.. Despite all the attractiveness of the concept, VOD has yet to succeed on the marketplace. The reason for this situation is simple: VOD services still remain much more expensive than videocassette rental or pay-per-view.

This situation has resulted in many proposals aimed at reducing the bandwidth requirements of video-on-demand services. Despite all their differences, all these proposals are based on the same idea, namely, sharing as many data as possible among overlapping requests for the same video. Hence, most of these proposals assume that customers receive their videos through a set-top box (STB) capable of (a) simultaneously receiving data from several video channels and (b) storing in a local buffer the video data it receives out of sequence.

Unfortunately this approach does not work well for the first few minutes of each video because the customer STB has very little or no time to collect the required data. As result, distributing the fist few minutes of a video takes a very large fraction of the total bandwidth required to distribute the video. Consider, for instance, the case of a video distributed through Juhn and Tseng's *fast broadcasting* protocol [Juh98]. The fast broadcasting protocol requires a bandwidth equal to seven times the video consumption rate to guarantee a maximum waiting time of 57 seconds for a two-hour video. Fifty-seven percent of this bandwidth is used to distribute the first 14 minutes of the video, that is less than 12 percent of the duration of the video.

Consider now a video-on-demand service offering to its customers

2. RELEVANT WORK

Most of the proposals aimed at reducing the bandwidth requirements of video-on-demand services fit into one of two groups. A first group of proposals follows a *reactive* approach. These proposals assume that the video server will merely answer individual customer requests without trying to anticipate them. Whenever several user requests for the same video arrive in close succession, the server will try to transmit only once all the data that can be shared by two or more requests. The best known reactive protocols include *piggybacking* [Gol94], *channel tapping* [Car97]–also known as *patching* [Hua98]–and *dynamic skyscrape*r [Eag98].

Proposals in the second group take a different approach: they anticipate customer demand and distribute the various segments of each video according to a deterministic schedule. These distribution protocols are said to be *proactive* and are grouped under the common name of *broadcasting protocols*. Some of the best-known broadcasting protocols are *staggered broadcasting* [Won88], *pyramid broadcasting* [Vis96], *skyscraper broadcasting* [Hua97], *harmonic broadcasting* [Juh97] and *fast broadcasting* [Juh98].

First Channel	S_1	S_1	S_1	S_1
Second Channel	S_2	S_3	S_2	S_3
Third Channel	S_4	S_5	S_6	S_7

Figure 1. Fast broadcasting with three channels.

The simplest broadcasting protocol is Juhn and Tseng's *fast broadcasting* (FB) protocol [Juh98]. FB allocates to each video k channels whose bandwidths are all equal to the video consumption rate b. It then partitions the video to be broadcast into 2^{k-1} segments S_1 to $S_{2^{k-1}}$ of equal duration d. As Figure 1 indicates, the first channel continuously rebroadcasts segment S_1, the second channel transmits segments S_2 and S_3, and the third channel transmits segments S_4 to S_7. More generally, channel j with $1 \le j \le k$ transmits segments $S_{2^{j-1}}$ to S_{2^j-1}. Hence the maximum waiting time for a video of duration D broadcast over k channels is given by $D/(2^k - 1)$.

Pagoda Broadcasting [Pâr99a] improves upon fast broadcasting by using a more complex segment-to-channel mapping. Segments are now allocated to pairs of consecutive channels, which allows packing more segments into the same number of channels. For example, a segment mapping using three channels would be:

First Channel	S_1	S_1	S_1	S_1	S_1	S_1
Second Channel	S_2	S_4	S_2	S_5	S_2	S_4
Third Channel	S_3	S_6	S_8	S_3	S_7	S_9

Figure 2. Pagoda broadcasting with three channels.

Pagoda broadcasting can pack 9 segments into 3 channels, that is 2 segments more than fast broadcasting. Hence the maximum waiting time for a video of duration D is $D/9$ instead of $D/7$. More generally, the maximum waiting time for a video of duration D broadcast over n channels is given by $d = D / [2 \times 5^{((n-1)/2)}]$ for n odd, and $d = D / [4 \times 5^{((n-2)/2)}]$ for n even.

Selective catching [Gao99] combines both reactive and proactive approaches. It dedicates a certain number of channels for periodic broadcasts of videos while using the other channels to allow incoming requests to catch up with the current broadcast cycle. As a result, its bandwidth requirements are $O(\log(\lambda_\iota L_i)$ where λ_ι is the request arrival rate and L_ι the duration of the video.

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