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ECVBA traffic-smoothing scheme for VBR media streams

By Han-Chieh Chao* C. L. Hung and T. G. Tsuei

We propose an effective and efficient traffic-smoothing called the efficient changes and variability bandwidth allocation (ECVBA) scheme. This algorithm not only minimizes the peak rate of a stream but also increases the likelihood of successful VBR stream transmission. The main benefit is that it can immediately release bandwidth to other sites in the network. Copyright © 2002 John Wiley & Sons, Ltd.

Introduction

Data transmission on the Internet is not limited to text. Many multimedia applications such as VoD, distance learning and the digital library have been adapted to Internet technology.[1] Although the network bandwidth has continuously increased, problems exist that cannot be solved by increased bandwidth alone.[2] An Internet video transmission requires many more bytes than a comparable text transmission.[3,4] Because of the great number of video bytes, 'bursts' are generated on the network which can lead to network congestion. To decrease the number of required bytes in a video, many encoders compress the video streams. A constant-bit-rate (CBR) encoder decreases the data by requiring a fixed number of bits.[5] CBR can result in compressed video quality and often, the viewer can sense the low quality. To solve this problem, the variable-bit-rate (VBR) encoder utilizes a variable number of bits to produce a constant compressed quality.[6,7,8] Because each frame is encoded based on the previous frame, more bits are needed to encode the media when there is an acute variation between the present and prior frames. This can result in a burst. However, if the video is compressed using a CBR or VBR encoder, the bytes in the compressed stream will be so large that the network will suffer congestion.[9] A receiver should have a sufficient buffer to receive media streams sent from the server. To ensure that the client can receive continuous playback on-line, the system should provide QoS for the server. The system should reserve the bandwidth required by the server. VBR is naturally bursty and the buffer provided by the client is not infinite, with the result that media streams will underflow or overflow.[10,11,12,13] To smooth these bursts, smoothing algorithms have been developed for implementation in limited client buffers.[14] In addition, the variability in smoothing algorithms presents different properties. The minimum change bandwidth allocation (MCBA) algorithm can minimize the number of rate changes, but it requires more time to calculate a smoothing scheme. To avoid systems without enough bandwidth, the minimum variability bandwidth allocation (MVBA) algorithm minimizes the variability in the bandwidth requirement, but produces a greater number of rate changes. The PCRTT algorithm changes the transmission rates at periodic intervals. Other algorithms focus on minimizing the client buffer, etc. This paper will propose an algorithm that immediately releases

Han-Chieh Chao and C. L. Hung, serve in the Department of Electrical Engineering, National Dong Hwa University, Hualien, Taiwan, ROC.

T. G. Tsuei teaches in the Department of Electronics, Ta Hwa Institute of Technology, Hsinchu, Taiwan, ROC.

**Correspondence to: Han-C. Chao, Department of Electrical Engineering, National Dong Hwa University, No. 1 University Road, Sec. 2, Jyh-Shyuetsuen, Show-Feng Shiang, Hualien, Taiwan, R.O.C.
E-mail: hcc@mail.ndhu.edu.tw*

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the bandwidth upon a rate decrease. Moreover, it focuses on increasing network utilization.

The next section introduces the basic smoothing plans. The third section explains the algorithm. The experimental results are discussed in the fourth section and the final section presents our conclusions.

Basis Smoothing Bounds

Many smoothing algorithms have been proposed with the following rules. The rule is two lines: L_{under} and L_{over}. Figure 1 illustrates the basic bandwidth-smoothing plan. We define that

$$L_{under} = \sum_i f_i$$

$$L_{over} = \sum_i f_i + b$$

where i expresses the ith frame, and f_i expresses the number of bytes in ith frame. b is the buffer given by the client. L_{under} indicates that the video was played back by the client. The server should therefore transmit enough streams to avoid non-continuous playback on the client site. The client can provide a buffer to receive streams that are not yet needed for playback. Hence, L_{over} indicates that the server should not transmit more than the necessary lines to avoid overflow. If overflow occurs, the client site can produce two results. The first is that the client loses streams and the playback becomes non-continuous video. The second is that the client can delay receiving the streams and the playback becomes a slow-motion stream. The smoothing algorithm must create a bandwidth scheme that must satisfy the function

$$L_{under} \leq S \leq L_{over}$$

to avoid both underflow and overflow and ensure that the video playback is continuous. S indicates the bandwidth smoothing schemes and is defined as follows:

$$S = \sum_{i,j} r_{i,j}$$

where i expresses the ith rate requirement during a period of time j.

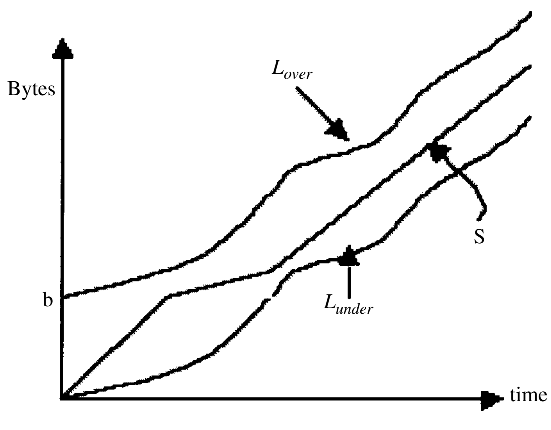

Figure 1. Basis of the smoothing plan

Scheme

This paper proposes a smoothing algorithm that based on the MVBA and MCBA smoothing algorithms called ECVBA. This increases network resource utilization. As Figure 2 shows, the scheme starts a rate increasing at the leftmost point on the frontier, where the trajectory for run r_i meets the L_{under} curve. To decrease the rate, the algorithm performs a search along the frontier to locate the starting point that allows the next trajectory to extend as far as possible.

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Figure 2. Plan rules

a rate increase. It can increase the likelihood of success for rate requirement operations and avoid non-continuous transmission to the client site. This scheme can immediately release un-needed bandwidth and lessen the number of rate changes. This method can provide extra bandwidth to other sites and help the system to ensure the QoS of those sites.

Simulation Results

—Simulation Environment—

This smoothing program runs on 64 M RAM, CELERON™-MMX CPU at 450 MHZ. The client buffer size is 128 kbytes. The smoothing plan samples are shown in Figure 3.

As Table 1 shows, the MVBA only needs 13 minutes to complete a smoothing plan. The MCBA needs more than 6 hours. The MVBA always starts a rate at the leftmost point during a rate increase or decrease and results in a worst-case complexity of $O(n^2)$. The MCBA performs a search operation on the frontier of each rate change for a starting point, which results in the next run having a worst-case complexity of $O(n \log n)$. ECVBA combines the above algorithms and takes about 3 hours, about half of the time required for the MCBA.

The minimum elapsed time scheme (MVBA) still needs 13 minutes to process before transmitting multimedia streams. This delay is too slow for real-time services. To solve this problem, several smoothing plans are performed in advance using various buffer sizes. The client sites can utilize the buffer size value acceptable for the video streams in the window field of the TCP packet during the connection setting to the server. After the server receives the client buffer size, it can choose the appropriate plan that is most suited for its client buffer.

Algorithms	MVBA	MCBA	ECVBA
Elapsed Times (min)	13	399	201

Table 1. Elapsed times for various algorithms

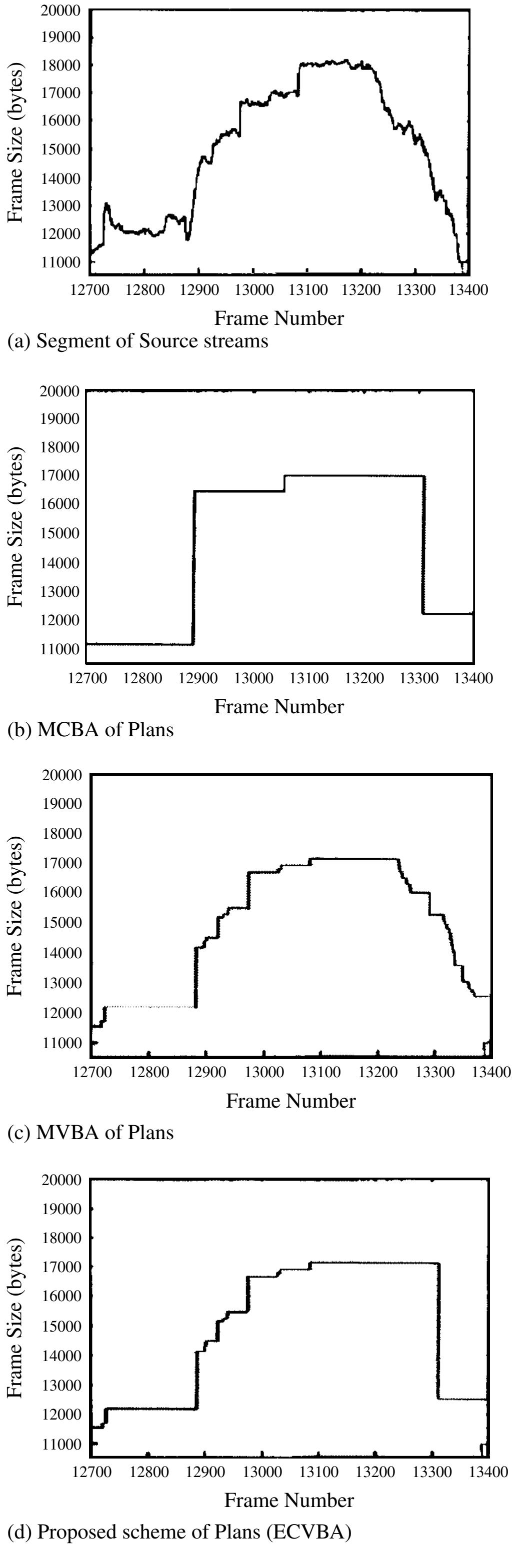

Figure 3. Various smoothing plans