



Chapter X

VBR Traffic Shaping for Streaming of Multimedia Transmission

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INTRODUCTION

In multimedia applications, media data such as audio and video are transmitted from server to clients via network according to some transmission schedules. Different from the conventional data streams, end-to-end quality-of-service (QoS) is necessary for media transmission to provide jitter-free playback. Therefore, each data packet has been assigned with related timing constraints for transmission. As network resources are allocated exclusively in fixed-size chunks to serve different data streams, it is simple to support constant-bit-rate (CBR) transmission. Grossglauser and Keshav (1996) have investigated the performance of CBR traffic in a large-scale network with many connections and switches. They concluded that the network queuing delay for CBR transmission is less than one cell time per switch even under heavy loading. Besides, resource allocation and admission control are simple as there are no variations in resource requirements. However, media streams are notably variable-bit-rate (VBR) in nature due to the coding and compression technologies applied (Garrett and Willinger, 1994). The average data rate of an MPEG-1 movie is usually less than 25% of its peak data rate. It is inherently at odds with the goals of designing efficient real-time network transmission and admission control mechanisms capable of achieving high resource utilization (Sen et al., 1997). The conventional CBR service model that allocates the peak data rate to transmit the VBR stream would be a waste of bandwidth. Furthermore, it requires a large size of client buffer. To ameliorate this problem, we need a good traffic shaping algorithm to transmit VBR video in a less bursty (i.e., smoother) manner by exploiting different performance measurements. In a multimedia system, we usually measure the performance of a transmission schedule by the following four indices: peak bandwidth, network utilization, initial delay and client buffer.

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- *Peak bandwidth* is the maximum network bandwidth allocated for media transmission. A user request is admitted if the peak bandwidth required is smaller than the available bandwidth of the current network.
- *Network utilization* is the ratio of the total bandwidth consumed to the total bandwidth allocated. Maximizing the network utilization is beneficial for the server and the network, as well as for a client who pays on a per-unit time basis. Generally, the higher the network utilization means more users can be served at the same time.
- *Initial delay* is the length of time interval from the time that the client sends the media request to the time that the client starts playing the received data. It is an important QoS indicator for users.
- *Client buffer* acts as a reservoir to regulate the difference between the transmission rate and the playback rate. It is an important resource for users to prevent playback jitters, i.e. buffer overflow and underflow.

While serving a VBR media stream, a good transmission schedule is designed to minimize the peak bandwidth, initial delay and buffer size required to keep the network utilization as large as possible. Then, the variance of transmission rates is minimized (smoothed) to reduce the traffic burst. Moreover, end-to-end QoS of media transmission needs to be guaranteed for supporting jitter-free playback (Lam et al., 1994; Ott et al., 1992).

In past years, different approaches are proposed to shape the traffic burst for high network utilization, smaller buffer size and short initial delay. In McManus and Ross (1996) the CRTT (constant-rate transmission and transport) method was presented to transmit VBR media data by a constant bandwidth. By giving the available transmission bandwidth and initial delay, CRTT minimized the required buffer size by the dynamic programming technique. It takes $O(n^2 \log n)$ computation complexity where n is the number of data frames of the media stream. In Sen et al. (1997) a speedup algorithm that takes $O(n \log n)$ computation complexity is proposed. It examines the tradeoffs between the transmission rate, the client buffer size, the network utilization and the initial delay. Although the CRTT transmission approach was simple in admission control and transmission schedule, it had the drawback of requiring large buffer and delay. To reduce the required buffer, a piecewise CRTT (PCRTT) method was introduced to evenly divide the media stream into sub-streams and applied CRTT to each sub-stream. Based on the similar idea, the RCBR (renegotiated CBR) method (Grossglauser et al., 1995) was proposed to use the average data rates in different sub-streams. Given initial delay and client buffer, the MCBA (minimum changes bandwidth allocation) (Feng et al., 1996) and CBA (critical bandwidth allocation) (Feng and Sechrest, 1995) methods were proposed to minimize the number of bandwidth changes and the peak bandwidth required, respectively. In Salehi et al. (1996) the MVBA (minimum variability bandwidth allocation) method was proposed to minimize the bandwidth variation for media transmission by the shortest-path algorithm (Reibman and Berger, 1995).

Although the conventional traffic shaping methods had reduced some problem parameters in media transmission, they did not achieve the optimize schedule results that minimize the initial delay, the client buffer and the bandwidth utilization at the same time. For example, in MVBA, the allocated initial delay and the bandwidth utilization were not optimized as discussed in Zhang and Hui (1997). In this chapter, a novel traffic shaping approach is presented to optimize both the resource allocation and utilization for VBR media transmission. Then, we extend this idea to online transmission problems. More issues about the admission control can be found in Chang et al. (1998). It takes $O(n \log n)$ computation complexity to examine the tradeoffs between the transmission rate, the client buffer size, the network utilization and the initial delay. (Different from the CBR transmission schedule

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