

# VIDEO TRAFFIC MODELING OF FULL-LENGTH VBR VIDEO FOR EFFICIENT BROADBAND NETWORK SIMULATION

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## KEYWORDS

Multimedia, Broadband, Traffic modeling, Video-streaming.

## ABSTRACT

This paper describes a general methodology for constructing probabilistic source models of long sequences (full length movies) of full-motion compressed VBR (variable bit rate) video. This methodology is illustrated with empirical data and applied to a series of simulation studies. The empirical data used in the modeling process as well as in the simulation studies was obtained by encoding a set of four full length movies with two different implementations of the MPEG-4 standard. The target bit rates selected were 100, 200, and 300 Kbps with a frame rate of 30 fps. These encoding programs incorporate adaptive rate algorithms, which try to preserve the quality as much as possible, while at the same time trying to maintain the set target rate. This process generates a video compressed signal with a relatively low varying rate, which in turn allows for a more efficient bandwidth allocation and multiplexing process.

The procedure for the creation of the probabilistic traffic models includes: data acquisition of frame size and scene duration; data modeling using histogram representation; and modeling with standard probability density functions.

These models can be used to perform efficient and accurate simulations of broadband telecommunications networks in the transmission of medium-high quality

compressed video. These encoding algorithms have been selected as the object of study in this paper due to their extended use around the world (over 70 million users) and their impact on video transmission on the Internet.

## INTRODUCTION

Activity in the area of broadband integrated networking has been expanding at a rapid rate. Future BISDN (broadband integrated services digital networks) networks promise to provide the means to transport diverse traffic streams. These streams vary in their traffic characteristics and performance requirements. It is expected that video traffic will constitute a significant portion of the load in future, especially with ATM (asynchronous transfer mode) transport in what are labeled broadband networks.

The purpose of this work is to create accurate source (traffic) models of video workload in terms of VBR (variable bit rate) compressed video. The term VBR refers to the fact that the bit rate (frame sizes) of compressed (coded) video is not constant, but rather a random process. The size of broadband networks, combined with the complexity and diversity of their heterogeneous traffic of voice, video, and data have changed the traditional techniques used in network design and network performance evaluation.

A careful performance analysis effort is

required for accurate modeling of broadband networks, mainly via simulation experiments. These simulations must rely on high-fidelity traffic modeling in order to provide accurate and useful conclusions.

Several traffic models have been proposed to characterize compressed video streams (Bragg and Chou 1994), (Chan and Garcia 1994), (Grunenfelder et al. 1991), (Heyman et al 1992), (Lazar et al 1993), (Maglaris et al. 1988), (Marafih 1994), (Melamed 1991), (Sen et al. 1989), (Skelly et al. 1993), (Yegenoglu 1993). The parameters of these models were obtained by matching specific statistical characteristics of actual video sequences and the models under consideration. Additional video source modeling has been performed on short sequences of empirical records consisting of one or few scenes (Melamed and Sengupta 1992), (Yasuda 1989), (Yegenoglu et al. 1993), or to conference video (Heyman et al. 1992), (Heyman et al. 1994), (Ramamurthy and Sengupta 1992), (Verbiest and Pinoo 1988), but recently, the increased availability of relatively long full-motion VBR video records rendered their modeling an active field of research.

Long-range dependence in video records and the study of the statistical multiplexing that can be achieved in the presence of long-range dependence are discussed in (Garret 1993), (Beran et al. 1995), and (Garret and Willinger 1994). A comprehensive study of eleven full-motion video and one teleconference video appeared in Heyman and Lakshman (Heyman and Lakshman 1994). The differences between full-motion and teleconference video were noticed earlier in (Verbiest and Pinoo 1989).

The empirical coded VBR video data, used in this study was the smoothed bit rate record obtained from compressing the set of four full length movies (Star Wars, Jurassic Park, Good Morning Vietnam, and Barry Lyndon) with two MPEG-4 implementations. The movies were selected for being good representatives of full-

motion video, containing a diverse collection of video sequences with a wide range of visual complexity and motion content. Each data record consisted of the equivalent of about two hours of video elapsed time at the target rate of 30 frames a second.

The simplified variant coded only the luminance component resulting in monochrome video. The digitized frame size is 320x240 pixels. The frame is partitioned into blocks of 8 x 8 pixels, on which a discrete cosine transform (DCT) is performed. The DCT coefficients are uniformly quantized into 8 bits and then entropy coded.

## STATISTICAL CHARACTERISTICS OF COMPRESSED VIDEO

The first parameter recorded was the frame size. Published studies in the area of video traffic modeling report analysis of relatively short periods of time, ranging from a few seconds to several minutes. The study presented in this paper includes an analysis of a video sequences of over two hours. This characteristic will have important implications in the statistical value of the obtained results.

The second parameter recorded was the scene length distribution. To model the length of a scene, we measured the length of the scenes in seconds by visual inspection. Some heuristic approaches to determine the length of scenes can also be used instead of the visually measured values. The heuristic methods proved to be quite accurate (Krunz and Huges 1995). They are based on the fact that sufficient change in the size of consecutive I frames is a strong indication of the start of a new scene.

From the frame time and file size obtained and recorded, a model of the video traffic could be determined. Using a simple custom program, the recorded frames are expanded

to a set of frames with a rate of 30 per second. This is done by repeating the current frame for the time duration between the present scene and the next scene.

## **DATA MODELING**

Once the process of obtaining the set of frame sequences is completed, a histogram representing the frame size based on the state probabilities of the complete VBR stream is obtained. This histogram is used to determine the probability distribution of the video traffic model.

In order to determine a suitable model for the video traffic source, the data histogram is compared with candidate histograms obtained from selected probability distributions. This modeling involves a parametrization process. It uses statistics obtained from the raw data and directly or through numerical methods determines the parameters of the candidate probability distribution functions.

Several probability density functions (pdf's) are examined to determine the best fit to the experimental histograms. The maximum likelihood estimators (MLEs) for the parameters of these functions are used to obtain the fitted distributions. The amplitudes in each histogram are normalized so that the total area under the histogram is one.

## **SIMULATION AND RESULTS**

A set of simulation experiments were conducted in order to study the performance of an ATM multiplexer for compressed video traffic streams (Olabe 1996). The simulation experiments are based on combinations of the proposed traffic models. The video source consists of a large number of frames arranged according to the compression pattern obtained in the modeling process. Bits in each frame are

packetized into ATM cells (with a 5-byte header added to each cell).

The simulations are performed for different levels of traffic multiplexing to evaluate the network performance under different conditions of video traffic multiplexing. The objective of the simulation is to determine the maximum number of channels that the network could effectively multiplex without causing gridlock or excessive loss of cells when compressed video is transmitted. In addition, the throughput and utilization of the network will be analyzed as function of the number of multiplexed channels.

From the data models obtained, the compressed video traffic is modeled in COMNET III. To simulate five different levels of multiplexing, the interarrival rate of frames is varied according to the number of simultaneous channels being transmitted over the same link. The transmission link has a capacity of 30 Mbps.

The simulated network includes source and destination nodes connected via a transmission link. A traffic block connected to the source node generates the information required in the creation of the video frames of each multiplexed channel. In addition, each frame in turn generates a number of cells according to the compression ratio achieved for each image. These compression ratios, and therefore, the number of cells needed to transmit each image are random, and correspond to selected distributions.

The duration of the network simulations is controlled in order to collect data representative of the network. The selected threshold is 30000 transmitted cells. The five different levels of multiplexing are 100, 150, 200, 250 and 300 channels respectively.

The buffer size was defined with no limit. This allows for a subsequent analysis of the network for different QoS goals.

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