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# Flexible adjustment of the short-term correlation of LRD M/G/ $\infty$ -based processes

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## Abstract

Video represents a larger and larger portion of the traffic in Internet. This traffic is characterized by a high burstiness and a strong short- and long-range correlation, that is very important from the performance point of view. Particularly, the efficient generation of synthetic sample paths is fundamental because real traces are usually of limited length and lack the necessary diversity required to perform such analysis. In this paper, we focus on the M/G/ $\infty$  process due to its theoretical simplicity, its flexibility to exhibit both Short- and Long-Range Dependence and its advantages for simulation studies when compared to other types of processes, and we improve the adjustment of the short-term correlation of LRD M/G/ $\infty$ -based processes adding autoregressive filters.

**Keywords:** Video traffic modeling; M/G/ $\infty$  process; Correlation; Synthetic efficient on-line generation

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## 1 Introduction

With the increasing popularity of multimedia applications, video data represents a larger and larger portion of the traffic in Internet. Consequently, adequate models of video traffic, characterized by a high burstiness and a strong positive correlation, are very important for the performance evaluation of network architectures and protocols.

In the last decade several traffic studies have convincingly shown the existence of persistent correlations in several kinds of traffic as VBR video [14,3,23,4,7,32]. These experimental findings stimulated the opening of a new branch in the stochastic modeling of traffic, since the impact of the correlation on the performance metrics may be drastic [17,15,22,16,8]. So, working with classes of stochastic processes that

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can display diverse forms of correlation by making use of few parameters (parsimonious modeling) is essential for traffic modeling purposes. Some of these processes are Fractional Gaussian Noise (FGN), Fractional AutoRegressive Integrated Moving Average (F-ARIMA) and  $M/G/\infty$ .

The use of these processes in performance evaluation has opened new problems and research issues in simulation studies, where the efficient generation of synthetic sample paths is fundamental because real traces are usually of limited length and lack the necessary diversity required to perform such analysis.

Several works have been conducted in modeling VBR video traffic, based on different stochastic methods [10,13,18,20,21,9,25]. We focus on the  $M/G/\infty$  process [5], due to its theoretical simplicity, its flexibility to exhibit both Short-Range Dependence (SRD) and Long-Range Dependence (LRD) in a parsimonious way and its advantages for simulation studies [13,24], such as the possibility of on-line generation (the main drawback of FGN and F-ARIMA processes is that only off-line methods for trace generation are efficient enough to be of practical use [19]) and the lower computational cost [27].

In this paper, we improve the adjustment of the short-term correlation of LRD  $M/G/\infty$ -based processes adding autoregressive filters.

In order to apply a model to the synthetic generation of traces with a correlation structure similar to that of real sequences, a fundamental problem is the estimation of the parameters of the model. Among the methods proposed in the literature [31,1,30], those based on the Whittle estimator are especially interesting because they permit both fitting the whole spectral density and obtaining confidence intervals of the estimated parameters. Moreover, in [26] we have presented a method based on the prediction error of the Whittle estimator to choose, among several models for compressed VBR video traffic based on the  $M/G/\infty$  process, the one that gives rise to a better adjustment of the spectral density, and therefore of the correlation structure, of the traffic to model. In this paper we extend this method in order to deal with the new models. Moreover, we check if the numerically better adjustment is significant or not.

The remainder of the paper is organized as follows. We begin reviewing the main concepts related to the  $M/G/\infty$  process in Section 2 and those related to the Whittle estimator in Section 3. In Section 4 we explain the models for VBR video traffic that we propose and compare in this work. In Section 5 we explain how to use the Whittle estimator to check that the new models are more flexible in order to fit the autocorrelation function measured from empirical VBR traces. Finally, concluding remarks and guidelines for further work are given in Section 6.

## 2 $M/G/\infty$ process

The  $M/G/\infty$  process [5],  $X$ , is a stationary version of the occupancy process of an  $M/G/\infty$  queueing system. Let  $\lambda$  be the arrival rate to the system, and denote by  $S$  the service time distribution, with finite mean value  $E[S]$ .

Considering a discrete time analysis [29], if the initial number of users is a

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