Modeling and Simulation of Self-Similar Traffic in Wireless IP Networks

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ABSTRACT

The article examines self-similar properties of real telecommunications network traffic data over a wide range of time scales. These self-similar properties are very different from the properties of traditional models based on Poisson and Markov-modulated Poisson processes. Simulation with stochastic and long range dependent traffic source models is performed, and the algorithms for buffer overflow simulation for finite buffer single server model under self-similar traffic load SSM/M/1/B are explained. The algorithms for modeling fixed-length sequence generators that are used to simulate self-similar behavior of wireless IP network traffic are developed and applied. Numerical examples are provided, and simulation results are analyzed.

Keywords: Internet, Modeling and Simulation, Queuing Systems, Self-Similar Traffic, Stochastic Processes, Wireless Communication Networks

INTRODUCTION

The growth of broadband networks and the Internet has been exponential in terms of users and user-end systems as well as in traffic in recent years. High-speed communications networks are able to support a wide range of multimedia applications, such as audio, video and computer data that differ significantly in their traffic characteristics and performance requirements (Hayes & Ganesh Babu, 2004).

One possible goal for developers is to build a unified high-speed communication network platform capable of carrying diverse traffic and supporting diverse levels of Quality of Service (QoS). Recent studies of real telecommunications network traffic data have shown that teletraffic exhibits self-similar (or fractal) properties over a wide range of time scales (Boxma & Cohen, 2000; Marie, Blackledge, & Bez, 2007).

The properties of self-similar telecommunications network traffic are very different from properties of traditional models based on Poisson, Markov-modulated Poisson, and...
related processes (Giambene, 2005). The use of traditional models in networks characterized by self-similar processes can lead to incorrect conclusions about the performance of analyzed networks (Jeong, 2002). Traditional models can lead to over-estimation of the network performance (Faraj, 2000), insufficient allocation of communication and data processing resources, and hence difficulties in ensuring the QoS. Then, full understanding is that the self-similar nature in teletrafic is an important issue.

Self-similar teletraffic is observed in LAN and WAN, where superposition of strictly independent alternating ON/OFF traffic models whose ON- or OFF-periods have heavy-tailed distributions with infinite variance can be used to model aggregate network traffic that exhibits self-similar (or long-range dependent) behavior typical for measured Ethernet LAN traffic over a wide range of time scales (Kushner, 2001).

In ATM network traffic self-similar traffic arriving at an ATM buffer results in a heavy-tailed buffer occupancy distribution, and buffer cell loss probability decreases with the buffer size, not exponentially as in traditional Markovian models, but hyperbolically.

Another implementation of traffic self-similarity is in Internet traffic, where many characteristics of WWW can be modeled using heavy-tailed distributions, including the distribution of traffic times, the distribution of user requests for documents and the distribution of WWW document sizes (Jeong, 2002).

In TCP/IP network traffic the transfer of files or messages shows that the reliable transmission and flow control mechanisms of TCP serve to maintain long range dependent structure included by heavy-tailed file size distributions (Bobbio, Horváth, Scarpa, & Telek, 2003). The relationship between self-similar traffic and network performance is defined in (Ilnickis, 2004) as captured by performance measures such as packet loss rate, retransmission rate and queuing delay, where increased self-similarity results in degradation of performance, and queuing delay exhibits a dramatic increase as self-similarity increases.

The self-similarity observed in video traffic provides possibility for developing models for Variable Bit Rate (VBR) video traffic using heavy-tailed distributions (Radev, 2005). The autocorrelation of the VBR video sequence decay hyperbolically and can be modeled using Fractional Autoregressive Integrated Moving-Average (F-ARIMA) and Fractional Gaussian Noise (FGN) self-similar processes (Radev, Rashkova, & Stankovski, 2007; Radev & Lokshina, 2009).

The impact of self-similar models on queuing performance is significant and the main trends in such findings are connected with (a) permission traffic modeling for high-speed networks, (b) efficient simulation of actual network traffic and (c) analyzing queuing models and protocols under realistic traffic scenarios (Mehdi, 2003). The traditional models of teletraffic that assume independent arrivals, based on Poisson processes, Markov-modulated Poisson processes and other related processes are not able to capture the self-similar nature of teletraffic (Hayes & Ganesh Babu, 2004).

The time series of self-similar processes exhibit burstiness over a wide range of time scales. Self-similarity can statistically describe wireless IP network traffic that is bursty on many time scales. Modeling and simulation of self-similar telecommunications network traffic can be performed with the generators of synthetic self-similar sequences (Horn, Kvalbein, Blom-skøld, & Nilsen, 2007), which are divided into two practical classes: the sequential generators and the fixed-length sequence generators. The fixed-length sequence generators for simulation of self-similar wireless IP network traffic are considered in this article.

**PROPERTIES OF LONG-RANGE DEPENDENT SELF-SIMILAR PROCESSES**

Self-similarity can be classified into two types: deterministic and stochastic (Stathis & Maglaris, 2000). One can distinguish two types of stochas-
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