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A multimedia traffic modeling framework for simulation-based performance evaluation studies ☆

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Abstract

The emergence of high-speed communication systems has enabled the support of complex multimedia applications. The traffic patterns generated by such applications are likely to be more complicated than those of simple voice and data traffic sources. Source traffic models are very important in the performance evaluation of traffic control algorithms in communications networks. In this paper, a multimedia traffic modeling framework is presented. The framework dissociates the traffic generated by a multimedia application into a number of basic components and derives a traffic model for each component. These components are then integrated into a multimedia traffic source model. A Graphical User Interface (GUI) is presented to facilitate the traffic modeling process. These multimedia traffic models can be easily integrated into simulation studies. In order to illustrate the usefulness of the framework, a performance evaluation study of scheduling algorithms for the High Speed Downlink Packet Access (HSDPA) feature of UMTS (Universal Mobile Telecommunications System) is presented. It was found that a Cost Function-based scheduling algorithm that takes into account the head-of-line packet delays of all components of the multimedia application achieved a higher average user throughput.

Keywords: Multimedia; Traffic modeling; Simulation; HSDPA; Packet scheduling

1. Introduction

Computer simulation forms an integral part in the performance evaluation of computer and communications networks. Simulation studies assist tele-traffic engineers in designing traffic control algorithms that enforce Quality of Service (QoS) objectives and also improve the cost/performance trade-off of the network [1]. In developing a simulation program for a communications network, there is a need to model the random user demands for network resources, characterize network resources required to meet those demands and estimate the performance, based on output data generated by the simulation [2]. The user demand characterization is straight forward in a telephone network which uses a circuit-switched paradigm. The traffic modeling process is usually considered at the aggregate level with the user arrival process being Poisson distributed and the call duration being exponentially distributed, for instance. Such assumptions are plausible for circuit-switched networks and the

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performance of these systems can be derived analytically using queuing theory techniques [3]. Computer networks and high-speed communications networks, on the other hand, use a packet-switched paradigm. Network resources are allocated on a packet-by-packet basis. The main reason for using this packet-switched configuration is to reap the statistical multiplexing gain that can be obtained when many users are contending for resources. This gain occurs because of the randomness in the packet generation process of contending users and hence the randomness in user demands for network resources. Traffic modeling deals with the issue of characterizing the randomness in the traffic generated by users. Understanding the nature of traffic in a system and selecting an appropriate traffic model are crucial to the success of the whole simulation study.

A lot of research has been carried out in the modeling of data traffic in communications networks. One important aspect of traffic modeling is capturing the autocorrelation in the traffic trace [2]. Markov-based traffic models and autoregressive traffic models generate traffic that has an exponentially decaying autocorrelation function [4]. Such techniques have been used to model data traffic and variable bit rate video traffic [5]. Recent studies have revealed that both network traffic and video traffic exhibit a phenomenon known as self-similarity [6,7]. This implies that traffic remains bursty irrespective of the level of aggregation considered. As a result, such traffic exhibits long-range dependence, i.e., the autocorrelation function decays much less rapidly than the exponential function. One parameter that can conveniently capture the self-similarity effect is the Hurst parameter [6]. Using this parameter, self-similar traffic models like the Fractional Gaussian Noise [8] and Fractional ARIMA [9] can be used to capture the long-range dependence in data traffic. One major drawback with these models is that they require a large amount of computing power, which can slow down a simulation considerably. To overcome this problem, Sheng Ma [10] has proposed the wavelet model for modeling self-similar traffic. Although initially created to model self-similar video traffic, this technique has been extended to model network traffic [11] also. Excellent surveys of traffic modeling for telecommunications networks are provided in [2,4]. In [5], a survey of statistical source models for variable-bit-rate compressed video is provided.

In this paper, the focus is on modeling the traffic generated by multimedia traffic sources. A multimedia application will consist of traffic generated by different media types. The main difference from earlier work is that the authors consider an approach to mimic such behavior instead of focusing on the creation of traffic models for single media types. Thus, the work presented here builds on previous work carried out in traffic modeling for single media types. Instead of deriving a model for a particular application, it was considered more useful to design a generalized framework that can be used to model a large number of multimedia applications that exist or will emerge in the future. In order to achieve this aim, multimedia traffic was categorized into a number of distinct components as described in Section 2. In Section 3, the approach taken to model each component of the multimedia application is provided. A GUI was developed to facilitate the traffic modeling process and this is also described in Section 3. In Section 4, the technique used to integrate the various components into a multimedia presentation is described. A simulation study was carried out to illustrate the use of the traffic modeling framework. This study investigates the performance of scheduling algorithms used for the HSDPA feature of UMTS. The packet scheduling algorithms, performance measures and multimedia traffic model used in the study are described in Section 5. In Section 6, performance results are provided for the simulation study considered. Finally, the paper concludes in Section 7, with scope for future work identified.

2. Basic components of multimedia applications

A multimedia application consists of an integration of two or more media types into a multimedia presentation. For example, a classroom lecture-based application might generate audio traffic, video traffic and data traffic (in the form of text or data files). It is evident that the components of a multimedia application will vary from one application to the next. Moreover, even if two applications have the same media types, the amount of data generated and the statistics of the data generation process might be different. Consequently, instead of deriving a traffic model for each application it is more valuable to identify traffic patterns (skeletons) common to a large number of multimedia applications. A source model for a particular multimedia application can then be built using these basic traffic patterns which can be adapted for the application at hand. Thus, the first step in creating the proposed