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Performance analysis of the general packet radio service

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Abstract

This paper presents an efficient and accurate analytical model for the radio interface of the general packet radio service (GPRS) in a GSM network. The model is utilized for investigating how many packet data channels should be allocated for GPRS under a given amount of traffic in order to guarantee appropriate quality of service. The presented model constitutes a continuous-time Markov chain. The Markov model represents the sharing of radio channels by circuit switched GSM connections and packet switched GPRS sessions under a dynamic channel allocation scheme. In contrast to previous work, the Markov model explicitly represents the mobility of users by taking into account arrivals of new GSM and GPRS users as well as handovers from neighboring cells. Furthermore, we take into account TCP flow control for the GPRS data packets. To validate the simplifications necessary for making the Markov model amenable to numerical solution, we provide a comparison of the results of the Markov model with a detailed simulator on the network level.

Keywords: Mobile Internet services; Packet switched data transmission for mobile communication; Continuous-time Markov chains; Discrete-event simulation

1. Introduction

The general packet radio service (GPRS) is a standard from the European Telecommunications Standards Institute (ETSI) on packet data in GSM systems [10]. By adding GPRS functionality to the existing GSM network, operators can give their subscribers resource-efficient wireless access to external Internet protocol-based networks, such as the Internet and corporate Intranets. The basic idea of GPRS is to provide a packet-switched bearer service in a GSM network. As impressively demonstrated by the Internet, packet-switched networks make more efficient use of the resources for bursty data applications and provide more flexibility in general.

To evaluate the performance of GPRS, several simulation studies were conducted. Early simulation studies for GPRS have been reported in [6,7]. Meyer evaluated the performance of TCP over GPRS under several carrier to interference conditions and data coding schemes [13,17]. Malomsoky et al. developed a simulator for dimensioning GSM networks with GPRS [15]. Stuckmann and Müller developed a system simulator for GPRS

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and studied the correlation of GSM and GPRS users for fixed and on-demand channel allocation techniques [18].

In previous work, several analytical models based on continuous-time Markov chains have been introduced for studying performance issues in GSM networks. Marsan et al. evaluated the impact of reserving channels for data and multimedia services on the performance in a circuit switched GSM network [1]. Marsan et al. developed an approximate analytical model for evaluating the performance of dual-band GSM networks [3]. Boucherie and Litjens developed a Markov model for analyzing the performance of GPRS under a given GSM call characteristic [5]. Markoulidakis et al. developed a Markov model for third generation mobile telecommunication systems [16]. They employed the Markov model for estimating the cell border crossing rate and the time it takes a busy mobile user to leave a cell area. Recently, Ermel et al. developed a Markov model for deriving blocking probabilities and average data rates for GPRS in GSM networks [9]. In none of these previous work, the question how many packet data channels (PDCH) should be allocated for GPRS for a given amount of traffic in order to guarantee appropriate quality of service (QoS) has been investigated.

This paper presents an efficient and accurate analytical performance model for the radio interface of the GPRS in a GSM network. The presented model constitutes a continuous-time Markov chain. The Markov model introduced in this paper represents the sharing of radio channels by circuit switched GSM connections and packet switched GPRS sessions under a dynamic channel allocation scheme. We assume a fixed number of physical channels permanently reserved for GPRS sessions and the remaining channels to be shared by GSM and GPRS connections. The model is utilized for investigating how many PDCH should be allocated for GPRS for a given amount of traffic in order to guarantee appropriate QoS. We present performance curves for average carried data traffic, packet loss probability, throughput per user, and queueing delay for different network configurations and traffic parameters.

In contrast to previous work, the Markov model explicitly represents the mobility of users by taking into account arrivals of new GSM and GPRS users as well as handovers from neighboring cells. Furthermore, we employ the traffic model defined by the 3rd Generation Partnership Project (3GPP) in [11] that can be effectively represented by an interrupted Poisson process (IPP), i.e., an on–off source. We consider a cluster comprising of seven hexagonal cells in an integrated GSM/GPRS network, serving circuit-switched voice and packet-switched data sessions. To allow the effective employment of numerical solution methods, the Markov model represents just one cell (i.e., the mid-cell) and employs the procedure for balancing incoming and outgoing handover rates introduced in [2]. To validate this simplification, we provide a comparison of the results of the Markov model with a detailed simulator implemented using the simulation library CSIM [8]. The simulator represents the entire cell cluster on the network level. Furthermore, an accurate implementation of the TCP flow control mechanism is included in the simulator. This validation shows that almost all performance curves derived from the Markov model lie in the confidence intervals of the corresponding curve of the simulator. Because of the employment of a numerical method for steady-state analysis, we can efficiently and accurately compute sensitive performance measures such as loss probabilities. In fact, using the presented Markov model sensitive performance measures can be computed on a modern PC within few minutes of CPU solution time. Note, that even with simulation runs in the order of hours proper estimates for such measures cannot be derived using discrete-event simulation because the large width of confidence intervals makes the results meaningless.

The remainder of the paper is organized as follows. Section 2 describes the basic GPRS network architecture and the radio interface which provide the technical background of the simulator and the analytical model. In Section 3, we describe the model and introduce its parameters. Section 4 derives the state space and driving processes for the analysis of the Markov model. Comprehensive performance studies for GPRS are presented in