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Resource management policies in GPRS systems☆

Michela Meo*, Marco Ajmone Marsan
Dipartimento di Elettronica, Politecnico di Torino, Corso Duca degli Abruzzi 24, 10129 Turin, Italy

Abstract

In this paper we consider the problem of resource management in GSM/GPRS cellular networks offering not only mobile telephony services, but also data services for the wireless access to the Internet. In particular, we investigate channel allocation policies that can provide a good tradeoff between the QoS guaranteed to voice and data services end users, considering three different alternatives, and developing analytical techniques for the assessment of their relative merits. The first channel allocation policy, voice priority, gives priority to voice in the access to radio channels; we show that this policy cannot provide acceptable performance to data services, since when all the channels are busy with voice connections, data services perceive long intervals of service interruption. The second channel allocation policy is called *R-reservation*; it statically reserves a fixed number of channels to data services, thus drastically improving their performance, but subtracting resources from voice users, even when these are not needed for data, thus inducing an unnecessary performance degradation for voice services. The third channel allocation policy is called dynamic reservation; as the name implies, it dynamically allocates channels to data when necessary, using the information about the queue length of GPRS data units within the base station. A threshold on the queue length is used in order to decide when channels must be allocated to data. Numerical results show that the dynamic reservation channel allocation policy can provide effective performance tradeoffs for data and voice services, with the additional advantage of being easily managed through the setting of the threshold value.

Keywords: GPRS system; Markovian model; Channel allocation

1. Introduction

The successes of mobile telephony on one side, and Internet services on the other, are producing very high expectations for the commercial success of wireless Internet access services.

Mobile telephony companies in Europe have made huge investments in this sector to acquire UMTS (Universal Mobile Telecommunications System) licenses, and are already offering data services over their existing GSM (Global System for Mobile Communications) networks, so as to start building the market, which will hopefully expand with the advent of UMTS and the proliferation of IEEE 802.11 Wireless LAN islands.

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* Corresponding author. Tel.: +39-011-5644167; fax: +39-011-5644099.
E-mail addresses: michela@polito.it (M. Meo), ajmone@polito.it (M. Ajmone Marsan).

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The technology that is now becoming available to integrate packet data services into GSM networks is GPRS (Generalized Packet Radio Service). The fact that GPRS exploits the same resources used by mobile telephony raises a number of questions concerning the dimensioning and the management of the GSM/GPRS radio interface. In this paper we tackle this issue, and discuss three possible approaches to manage the radio interface in a GSM/GPRS cell, providing analytical models for their performance analysis, as well as numerical performance results that provide insight into the relative merits of the alternate approaches.

The paper is organized as follows. In Section 2 we describe the characteristics of the GSM/GPRS cellular mobile communication network that we consider, together with the probabilistic assumptions that are needed to describe the system dynamics with Markovian models. In the same section we also describe the three channel allocation policies which will be analyzed and compared in the following sections. After a short discussion on related work in Section 3 we present the analytical models and their solutions in Section 4. Some numerical results are shown and discussed in Section 5. Section 6 concludes the paper.

2. System and modeling assumptions

Dual-band GSM/GPRS networks exploit two separate frequency bands around 900 MHz and 1.8 GHz. Cells served by frequencies in the 900 MHz band are rather large (up to 35 km around the base station) and are normally called “macrocells,” whereas cells served by frequencies in the 1.8 GHz band are much smaller (typically with a diameter of less than 1 km), due to the much worse propagation characteristics of microwaves in the latter frequency range through the atmosphere. These cells are often called “microcells,” or simply cells. Radio coverage is thus obtained by a two-level hierarchical cellular structure. We focus on a particular area, covered by one macrocell and m cells, where the macrocells are essentially disjoint, and the macrocell overlaps with all cells. This structure is called a *cell cluster*.

Within each cell or macrocell, one or more carrier frequencies are activated, and over each carrier a TDMA *frame* of $T_{\mathrm{f}} = 60/13$ ms is defined, comprising eight *slots* of 15/26 ms each. A circuit (or channel) is defined by a slot position in the TDMA frame, and by a carrier frequency. Since some channels must be allocated for signaling, each carrier frequency can devote to the transmission of end user information from 6 to 8 channels, depending on the cell configuration; we will assume that the TDMA frame allocates seven slots to end users and one slot to signaling. In the model development, we assume that in the considered cell cluster the macrocell is equipped with $N^{(\mathrm{M})}$ user traffic channels, while each cell is equipped with N user traffic channels.

We consider two services: telephony and data transfer. Telephony provisioning relies on the usual circuit-based GSM service; data packets are instead transferred according to the GPRS standard, using the same resources deployed for telephony. Based on the provider strategic decisions, different channel allocation policies can be adopted for the simultaneous delivery of telephony and data transfer services. In this paper we consider three different strategies, and we compare their performance. We focus on the telephone call blocking probability (where call blocking may result from the lack of channels to allocate either a new call request or a handover request) as the main QoS parameter for the telephony service. The main QoS parameters for the data transfer service are the data packet loss probability and average data packet transfer delay.

The first channel allocation policy is the result of strategic decisions that acknowledge the primary role of the telephony service (telecommunications network operators today still generate most of their