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Performance analysis for voice/data integration on a CDMA-based wireless system

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Abstract

In this paper, two analytical methods are proposed for the evaluation of system performance of the double movable boundary strategy in a CDMA-based voice/data integration system. One is the traditional Markov analysis (TMA), which is used to calculate the voice call blocking probability, and the other is the Transient Fluid analysis (TFA), which is adopted to evaluate the data delay. Computer simulations validate the mathematical models. The double dynamic boundaries help to alleviate the traffic congestion problem, and suggestions of how to adjust these boundaries and parameters are also given. © 2002 Elsevier Science B.V. All rights reserved.

Keywords: Code-division multiple access; Media access control; Movable boundary; Traditional Markov analysis; Transient fluid analysis

1. Introduction

Future wireless cellular systems will be required to accommodate various service applications, such as voice, interactive data, file transfer, internet access, images, and facsimiles. The growing user population of wireless applications demands efficient and dynamic allocation of the bandwidth to satisfy different services demands.

Various media access control (MAC) schemes have been proposed in the literature for voice and data integration in wireless networks [1–10]. These schemes are broadly classified into two categories based on whether they employ speech activity detectors (SADs) or not. Firstly, with SADs, packet reservation multiple access (PRMA) and its variants [1–4], have been studied. Secondly, without any SADs, wireless integrated multiple access (WIMA) and its modifications [5–10] have been proposed.

PRMA [1], a kind of reservation ALOHA (R-ALOHA), takes advantage of silence gaps by considering each talk spurt as an independent periodic communication for data transmission. A modified PRMA (MPRMA) [2] is proposed which efficiently supports voice and data traffics in low earth orbit (LEO) mobile satellite systems. Two different data traffic management policies, the gated discipline and the exhaustive scheme, are considered. Another modified PRMA, called PRMA with hindering states (PRMA-HS) [3], for voice and data integration in mobile cellular systems with high propagation delays is proposed. Voice terminals with slow SADs are modeled as on/off sources. Moreover, two types of data terminals, viz. a classical Poisson source and a bursty source, are envisaged. Recently, a new multiple access protocol termed collision resolution and dynamic allocation (CRDA) [4] overcomes the main shortcoming of the previous PRMA schemes, i.e. the contention, through the integration in the MAC protocol of a CDMA transmission mode to access the reservation slots. This prevents collisions during the reservation phase and enhances channel throughput, notably in the case of mixed voice/data traffic.

WIMA [5] has been proposed by incorporating a movable boundary mechanism to share the channel between voice and data. Under this scheme, TDM frame is divided into two compartments, voice and data. The slots that are not used by voice are used for data traffic. Joint CDMA/TDMA movable boundary protocol [6] is a two-dimensional channel assignment rather than one-dimensional case like WIMA. In the time domain, the frame is slotted and is also divided into two compartments. In the code domain, a certain number of codes can be assigned for voice and data, respectively, according to their bit error rate (BER) requirements. Data is permitted to use any idle channel of the voice compartment, but the voice traffic is not allowed to use the unused data channels. Its complete analytical model is developed in Ref. [6]. We call this scheme as

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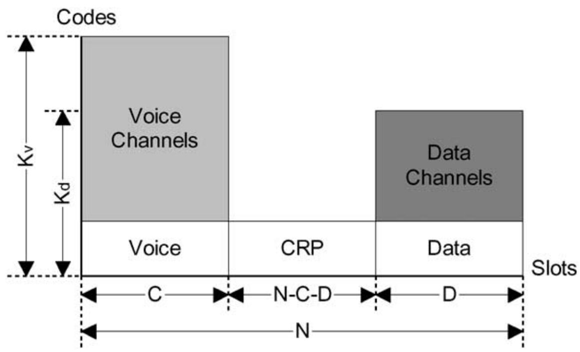

Fig. 1. DMBS frame structure.

conventional movable boundary scheme (MBS). Recently, a double movable boundary scheme (DBMS) is proposed in Ref. [7] for satellite networks. It divides TDM frame into three compartments instead of two, where the extra compartment provides common channels. Under certain pre-defined resource sharing rules, voice and data is allowed to use these common channels. The results of its study are obtained from discrete-time simulations without a complete mathematical analysis. Another movable boundary scheme considering the effect of handoff with a finite data buffer is proposed in Ref. [8]. Designated voice and data channels are dedicated for voice and data traffic transmissions, respectively. Either type of traffic can use the shared channels. Since the existing approaches usually only consider the resource sharing between data and voice, Wu [9] proposed an efficient bandwidth-sharing scheme for voice and video calls based on TDMA structure. Voice calls can borrow channels from those pre-allocated to video calls temporarily when all voice channels are busy. A threshold type decision policy is designed such that the channel borrowing will be granted only if the quality of service (QoS) requirement on video call blocking will not be violated during the duration of channel lending. As an improvement for the conventional MBS [6], a double movable boundary (DMBS) protocol for CDMA-based systems is proposed in [10] based on the satellite networks channel assignment given in Ref. [7]. It divides each frame into three compartments instead of two, namely, voice, data and common resource pool (CRP). Voice is allocated resources from the voice compartment first, till it is fully used, then resources from CRP compartment can be allocated to voice subject to data queue length. After allocating resources to all voice traffic, data can then be allocated to all the remaining slots on the frame within its three different compartments. In Ref. [10], simulation method is implemented to evaluate the system performance, but analytical models are not developed.

The purpose of this paper is to propose two mathematical methods to study the performance of the DMBS protocol [10]. One is the traditional Markov analysis (TMA), which can provide accurate results, but it is only applied when the system states are small due to the computational complexity and computer accuracy problems. The other is the transient fluid analysis (TFA), which is very fast and requires much less computer accuracy and memory. However, it is difficult for TFA to calculate voice call blocking probability, which requires system state probability information. Therefore, in this paper, TFA is adopted to evaluate the data delay, while TMA is used to evaluate the voice call blocking probability.

This paper is organized as follows. In Section 2 the system model is established. In Section 3, TMA is presented to evaluate voice performance and TFA is constructed to calculate data delay performance. The accuracy of analytical results is confirmed by simulation results in Section 4. Finally, Section 5 concludes the paper.

2. System model

DMBS scheme can be described with a two-dimensional channel resource. Its frame structure is shown in Fig. 1. In code domain, K_v (and K_d) is the maximum number of codes that can be assigned to voice calls (and data packets) transmitted in a slot so that the expected QoS remains below a specified value. In time domain, a frame consists of N information slots, which is divided into three parts. The C slots are reserved for voice, D slots for data, while the third part constitutes a common resource pool ($\text{CRP} = N - C - D$). Its resource allocation scheme is shown in Fig. 2, which is modeled by a continuous-time model with heterogeneous arrivals (voice and data) and multiple designated channels (voice, data and CRP). Voice traffic is blocked and dropped immediately if legitimate channels are all in use upon its arrival. On the contrary, data traffic would be queued in a buffer should legitimate channels be busy. Data can use both

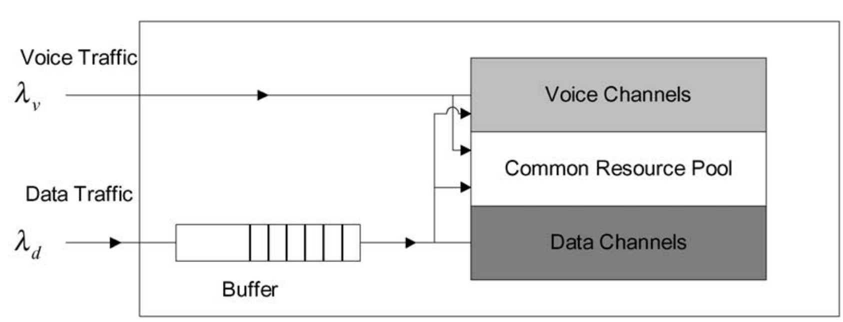

Fig. 2. DMBS resource allocation scheme.