Overall Delay in IEEE 802.16 with Contention-Based Random Access

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Abstract. In this paper we address the overall message delay analysis of IEEE 802.16 wireless metropolitan area network with contention-based multiple access of bandwidth requests. The overall delay consists of the reservation and scheduling components. Broadcast polling is used for bandwidth reservation with binary exponential backoff (BEB) collision resolution protocol and a simple scheduling is applied at the base station. An analytical model is developed with Poisson arrival flow for the Non Real-Time Polling Service (nrtPS) class. The model enables asymmetric traffic flows, different message sizes at the subscriber stations and also allows for Best Effort (BE) service class. An approximation of the mean overall delay is established for the nrtPS service class. The analytical model is verified by means of simulation.

Keywords: IEEE 802.16, WMAN, performance evaluation, bandwidth reservation, contention-based multiple access, BEB, queueing model.

1 Introduction

IEEE 802.16 is a notorious specification, which is recommended for Wireless Metropolitan Area Networks (WMANs). The standard specifies an air interface for Broadband Wireless Access (BWA) \[1\]. It proposes a high-speed access system supporting multimedia services and an extensive quality-of-service (QoS) guarantee. In IEEE 802.16 protocol stack the Medium Access Control (MAC) layer supports multiple Physical (PHY) layer specifications, each of them covering different operational environments.

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Many authors studied the performance of the various IEEE 802.16 features. In particular, the bandwidth requests mechanism to reserve a portion of the channel resources is frequently addressed. A detailed description of the reservation techniques and a general queueing model are given in the fundamental works [2] and [3]. The standard allows a random multiple access (RMA) reservation scheme and implements the truncated binary exponential backoff (BEB) protocol for the purposes of the collision resolution.

The asymptotic behavior of the BEB protocol was substantially addressed in the literature. In [4] it was shown that the BEB protocol is unstable in the infinitely-many users case. By contrast, [5] shows that the BEB is stable for any finite number of users, even if it is extremely large, and sufficiently low input rate. An exhaustive description of various analytical RMA models may be found in [6] and [7]. The performance of the BEB algorithm in the framework of the reference RMA model ([8], [9]) is addressed in [10], which allowed a deeper insight into its operation. In the fundamental analysis of [11] an extremely useful Markovian model to analyze the performance of the BEB algorithm was first introduced.

Together with the analysis of the BEB itself, much attention is paid to its proper usage in IEEE 802.16 standard. It is known that the BEB algorithm may be adopted for both broadcast and multicast user polling. The efficiency of broadcast and multicast polling was extensively studied in [12] and [13]. Some practical aspects of the BEB application for the delay-sensitive traffic were considered in [14].

Considerable research effort is done also on overall performance aspects of the IEEE 802.16 system. For example in [15], [16] and [17] various frameworks are built and analyzed to guarantee a specified level of QoS. Furthermore, in [18] and [17] the overall system delay is estimated and verified. However none of these methods are dealing with overall delay in the context of contention-based random access.

In this paper we develop a first analytic approximation for the overall delay in the IEEE 802.16 system with broadcast polling.

The rest of the paper is structured as follows. Section II gives a brief overview of IEEE 802.16 MAC layer. In Section III we provide the description of the model and the notations. We conduct the overall delay analysis in Section IV. In Section V we verify the analytical results by means of simulation. Finally, we give our conclusion in Section VI.

2 Brief Overview of IEEE 802.16 MAC

IEEE 802.16 standard supports two operational modes: the mandatory Point-to-MultiPoint (PMP) and the optional mesh mode. In the centralized PMP architecture the Base Station (BS) is the main node. It is responsible for coordinating the communication process among the other nodes – Subscriber Stations (SSs). All communication among the SSs is directed through the BS and takes place on independent transmission channels of two types. In the Downlink Channel (DL) only the BS transmits data to the SSs, while in the Uplink Channel (UL) the