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Greedy scheduling algorithm (GSA) – Design and evaluation of an efficient and flexible WiMAX OFDMA scheduling solution

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ABSTRACT

WiMAX is one of the most promising technologies to provide broadband wireless access in the near future. In this paper we focus on the study of the combined performance of a WiMAX Base Station MAC downlink scheduler and OFDMA packing algorithm which mainly determine the usage efficiency of the available radio resources. We design and analyze an efficient and flexible solution, greedy scheduling algorithm (GSA), and evaluate its performance as compared to several relevant alternative solutions. Specifically, we analyze performance differences with respect to efficiency, flexibility to provide per subscriber station burst shape preferences, interference mitigation and computational load. Our results show that GSA achieves a performance similar to the one of the competing approaches considered in terms of efficiency, even better in some cases, and significantly outperforms them in flexibility to provide per subscriber station burst shape preferences, interference mitigation and computational load. As a conclusion, the proposed GSA solution is a promising candidate to maximize the utilization of the available WiMAX radio resources at a low computational cost while at the same time being able to fulfill a wide range of requirements based on operators' preferences and/or network environment specifics.

1. Introduction

The essential role played nowadays by the Internet has set the competition among operators off in order to deliver the desired always-connected mobile support with the largest bandwidth at the lowest possible cost. In this arena, a plethora of wireless access technologies have been developed being WiMAX one of the latest and most promising ones. Indeed, the IEEE 802.16 family of standards, which started with 802.16-2004 [1] followed by 802.16e-2005 [2] and recently by 802.16-2009 [3], has been developed in order to provide improved throughput rates and coverage with respect to the current performance offered by well-established technologies such as High Speed x Packet Access and Wireless LAN. An international organization, namely the WiMAX Forum [4], guarantees the interoperability between products of different vendors by defining certification programs.

The main features advocating in favor of the adoption of WiMAX are mainly coming from the advanced PHY layer technology it builds upon. Scalable OFDMA and Advanced Antenna System techniques such as MIMO or Beamforming ensure a higher degree of flexibility and allow at the same time to fully exploit the characteristics of the wireless channel.

OFDMA is a multiple access scheme stemming from Orthogonal Frequency Division Multiplexing (OFDM), which allows assigning different subcarriers to different users in order to implement advanced radio resource management algorithms. In WiMAX though subcarriers are not directly assigned to individual users but are first

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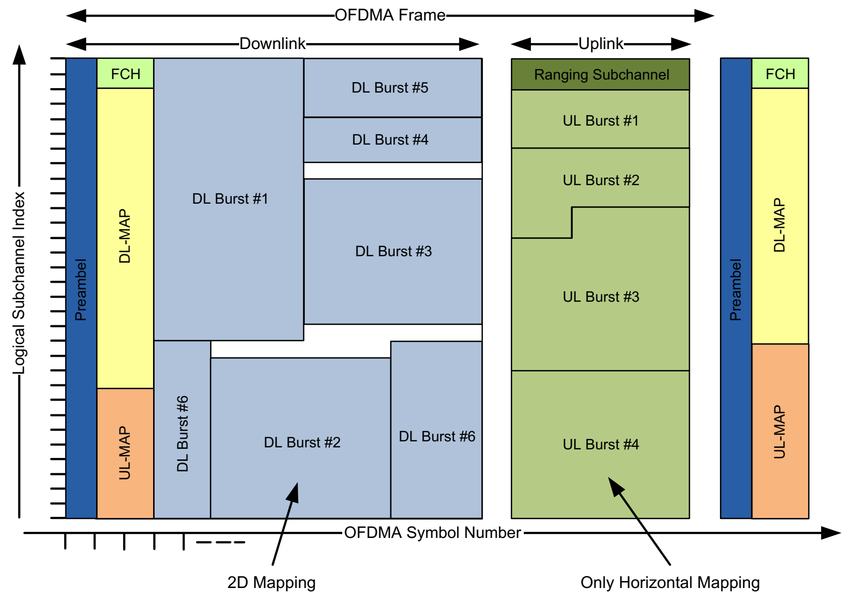

Fig. 1. WiMAX OFDMA frame.

grouped into basic radio resource units called subchannels, which are then scheduled among the different users by the Base Station (BS). The *permutation scheme* is the algorithm that defines how the physical subcarriers are mapped to the logical subchannels. Two basic types of permutation schemes have been defined in WiMAX that are suited for different types of environments. *Distributed* permutation schemes, like Partially Used Sub-Carrier (PUSC) or (Fully Used Sub-Carrier) FUSC [3], spread the subcarriers contained in a logical subchannel across the available spectrum, hence reducing fading effects by exploiting frequency diversity. Distributed permutation schemes are suited for mobile environments. Instead, *adjacent* permutation schemes, like Band Adaptive Modulation and Coding [3], map physically adjacent subcarriers into the same subchannels, allowing to efficiently exploiting multiuser diversity at the cost of an increased feedback from the stations. Adjacent permutation schemes are suited for environments with low mobility.

Additionally, a key element that further enables differentiation among vendors when competing for their share of the WiMAX market is their ability to handle Quality of Service (QoS). In WiMAX, as illustrated in Fig. 1, uplink and downlink transmissions can be multiplexed in a Time-Division Duplex (TDD) manner. Thus, the problem of assigning resources between different connections in order to provide QoS guarantees should be seen as a two dimensional problem, because both frequency and time are resources that can be allocated. The QoS and radio management algorithms implemented in WiMAX BS will determine up to what extent the agreed QoS is honored and the underpinning radio resources are efficiently used.

Our work in this paper focuses on the intricacies related with the design and the analysis of an efficient and flexible WiMAX OFDMA downlink scheduler algorithm, hereafter referred to as Greedy Scheduling Algorithm (GSA). A unique characteristic of GSA in front of other solutions in the state of the art is that GSA has been designed with the aim of simultaneously addressing a wide range of performance aspects like efficiency, flexibility to provide per Subscriber Stations (SS) burst shape preferences, interference mitigation and reduced computational load. Instead, previous work in the state of the art designed OFDMA downlink scheduling algorithms tailored to solve a particular performance aspect. For instance, [5,6] presented downlink scheduling algorithms designed to maximize efficiency, however a price was paid in terms of other performance aspects like flexible burst orientations or reduced computational complexity. Desset et al. proposed an OFDMA downlink scheduling algorithm aiming specifically at reducing the power consumption of the associated SSs [7]. In our own previous work [8] we proposed an OFDMA downlink scheduler that balanced efficiency with execution time. The work presented in this paper goes one step further and proposes an OFDMA scheduling solution which is able to efficiently consider multiple requirements at the same time. To the best of the authors' knowledge there is no solution in the state of the art able to simultaneously address as many performance aspects as our proposal, GSA, does.

The rest of the paper is structured as follows. In Section 2 the major challenges to face when designing a WiMAX OFDMA downlink scheduling algorithm are introduced. Our GSA scheduling algorithm is then presented and analyzed in Section 3. In Section 4 the main algorithms against which GSA is compared are described and a thorough performance evaluation is carried out. The main results of our comparison are then summarized in Section 5 that concludes the paper.