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Towards an optimal transmission of SDUs in IEEE 802.16e WiMAX systems

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A B S T R A C T

In this paper we address the mutual influence between the PHY layer budding blocks (FEC blocks) and the MAC level allocations in the Uplink and Downlink of IEEE 802.16e systems, and address methods to increase the overall PHY and MAC combined efficiency. We evaluate the efficiency of several schemes for the transmission of Service Data Unit (SDU) packets through Protocol Data Units (PDUs) in physical Bursts. The optimality criterion is the Goodput. When using the Convolutional Turbo Code, Bursts are composed of FEC blocks that have a direct influence on the probability of bits being received successfully, and thus on the Goodput. In the first scheme, every SDU is transmitted as a stand-alone PDU. In the second scheme, the Burst is first divided into PDUs in a way that maximizes the Goodput, assuming the transmission of a bit stream (and not SDUs). Then the SDUs are mapped into the PDUs with possible Fragmentation/Packing. The optimal size of the PDUs is computed by an $O(1)$ running time algorithm, an important feature because this algorithm is a part of the scheduler in the BS. The results show that when the estimation of the FEC success probability is accurate, SDUs should be mapped into optimal size PDUs in reliable channels. For unreliable channels it is better to transmit each SDU as a separate PDU. When the estimation of the FEC success probability is not accurate, it is always better to transmit SDUs as separate PDUs.

1. Introduction

Broadband Wireless Access (BWA) networks constitute one of the greatest challenges for the telecommunication industry in the near future. These networks fulfill the need for range, capacity, mobility and QoS support from wireless networks. IEEE 802.16e [1], also known as WiMAX (Worldwide Interoperability for Microwave Access) is the industry name for the standards being developed for broadband access.

IEEE 802.16e is a cell based, Point-to-MultiPoint (PMP) technology, providing high throughput in Wireless Metropolitan Area networks (WMANs). The IEEE 802.16e standard reference model includes the Physical and Medium Access Control (MAC) layers of the ISO protocol stack. Multiple physical layers are supported, operating in the 2–66 GHz frequency spectrum and supporting single and multi-carrier air interfaces, each suited to a particular environment. For IEEE 802.16e to be able to fulfill the promise for high speed service, it must efficiently support advanced Modulation and Coding schemes (MCSs) and progressive scheduling and allocation techniques.

In this study, we focus on the influence between the PHY layer budding blocks (FEC blocks) and the MAC layer allocations in the Uplink and Downlink of IEEE 802.16e systems, and methods to increase the overall PHY and MAC layers' combined efficiency.

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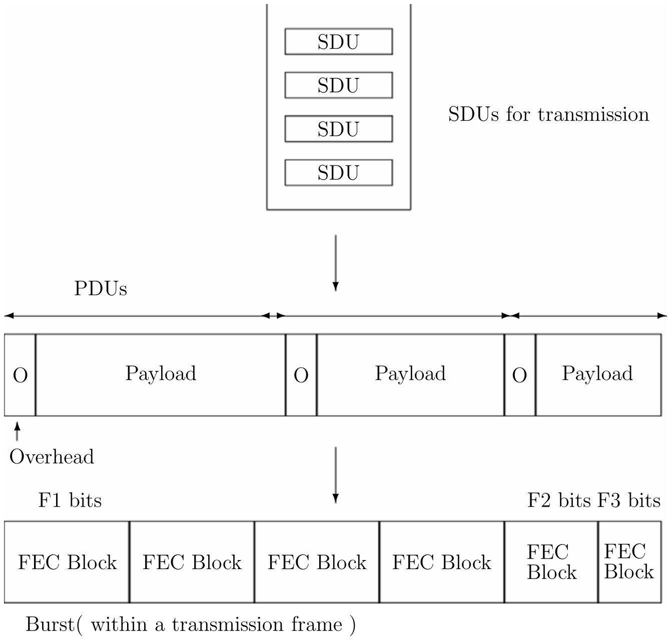

Fig. 1. Transmission of SDUs within PDUs within a PHY Burst.

Many papers have been published on the transmission efficiency of IEEE 802.16e systems. Most of these studies deal with scheduling methods, an issue that is not defined in the IEEE 802.16e standard and is left to the vendors' discretion. Moreover, some papers deal with the performance of transport layer protocols, such as TCP and UDP, over IEEE 802.16e systems. All the studies assume the assignment of transmission time to the stations, but they do not deal with the issue of how these transmission times can be used efficiently by the stations. This is precisely the subject of this paper. In order to understand how transmission times can be used efficiently we first need to describe how stations transmit in IEEE 802.16e systems, and how we define efficiency.

1.1. The IEEE 802.16e/WiMAX network structure

IEEE 802.16e/WiMAX is a standard for a Broadband Wireless Access (BWA) network [1] which enables home and business subscribers high speed wireless access to the Internet and to Public Switched Telephone Networks (PSTNs). The system is composed of a Base Station (BS) and subscribers in a cellular architecture. The transmissions in a cell are usually Point-to-Multipoint, where the BS transmits to the subscribers on a Downlink channel and the subscribers transmit to the BS on an Uplink channel.

A common PHY layer used in IEEE 802.16e is Orthogonal Frequency Division Multiple Access (OFDMA) in which transmissions are carried in *transmission frames* [1]. Every frame is a matrix in which one dimension is a sub-channel (band of frequencies) and the other dimension is time. A cell in the matrix is denoted as a *slot*. The number of data bits that can be transmitted in a slot is a function of the Modulation and Coding scheme (MCS) that is used in the slot.

A Burst in a frame is a subset of consecutive slots sharing the same MCS. On the Uplink, a Burst is designated to a subset of MSs for their transmissions. In the most common case a Burst is designated to a single MS, and this is the case that we consider in this paper. On the Downlink, only the BS transmits in Bursts to MCSs. In this paper we assume that the Convolutional Turbo Code (CTC) is used as the coding scheme, and in this case a Burst also maps *Forward Error Correction (FEC) blocks* to the slots. In telecommunication and information theory, FEC is an error control system for data transmission, whereby the sender adds redundant data to its messages, also known as an error-correction code, using a predetermined algorithm. This allows the receiver to detect and correct errors (within some bounds) without needing to ask the sender for additional data. The advantage of FEC is that a back-channel is not required, or that retransmission of data can often be avoided, at the cost of higher bandwidth requirements on average. In this paper knowing the details behind the FEC technology is unnecessary so we will not elaborate on this subject. The interested reader can consult [2] which is a good reference on the subject. The only property needed is that all the data bits in a FEC block have some probability p to arrive successfully at the receiver. We elaborate on this probability later on. According to the IEEE 802.16e standard, a Burst can contain up to 3 different sized FEC blocks [1]. See the bottom part of Fig. 1.

1.2. Transmissions in IEEE 802.16e systems

The BS and the MSs transmit *Protocol Data Units* (PDU) within Bursts. The MAC layer of IEEE 802.16e is connection oriented and PDUs, which are the MAC level frames, thus belong to MAC connections [1]. Within PDUs the BS and the MSs transmit