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Analysis and performance evaluation of the OFDM-based metropolitan area network IEEE 802.16

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Abstract

Wireless last mile technology is becoming a challenging competitor to conventional wired last mile access systems like DSL and cable modems or even fiber-optic cables. The Institute of Electrical and Electronics Engineers has developed a standard for fixed broadband wireless access systems namely IEEE 802.16. Its OFDM mode targets frequency bands below 11 GHz.

This paper gives an overview of the OFDM-based transmission mode of the IEEE 802.16 standard. The medium access control (MAC) and the physical layer are described in detail. Especially the MAC frame structure is elaborated. An analytical performance evaluation of an example scenario is performed which results in overall system performance measures. Especially the interaction of fragmentation and padding of OFDM symbols and its effect on the system capacity is evaluated. Furthermore, different MAC layer configurations with different levels of robustness are analyzed. Optional features to resist challenging channel conditions are outlined. Their trade off, i.e., a reduced MAC layer capacity is pointed out. It is shown that the system can be optimized while maintaining the necessary robustness against environmental challenges. A prototypical IEEE 802.16 protocol stack including a sophisticated channel model has been implemented. By means of this stochastic event-driven computer simulator, downlink and uplink delay as well as throughput evaluation is performed. Thus, performance results based on meaningful MAC configuration examples are provided. Simulative and analytical results are compared.

Keywords: IEEE 802.16; WiMAX; MAC; PHY; OFDM; Performance evaluation; Analysis; Simulation

1. Introduction

The wireless metropolitan area networks (MAN) IEEE 802.16-2001 and its amendment for frequencies between 2 and 11 GHz IEEE 802.16a-2003 have been standardized in 2003

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[1,2]. They specify four different physical (PHY) layers, whereof only the orthogonal frequency division multiplex (OFDM) layer is considered in the paper. The revision of the standard, including the MAN base document, the amendment for lower frequencies, i.e., below 11 GHz, and the amendment for detailed system profiles was published in October 2004 as IEEE 802.16-2004 [3]. From the date of publication the previous volumes are superseded by the new one.

The OFDM-based transmission mode of the IEEE 802.16 standard has been standardized in close cooperation with the European Telecommunications Standards Institute (ETSI) whose standard is named High PERformance Metropolitan Area Network (HiperMAN) [4,5]. Thus, the HiperMAN standard and the OFDM-based transmission mode of IEEE 802.16 are nearly identical. Both OFDM-based physical layers shall comply with each other and a global OFDM system should emerge [6]. Both standards form a basis for WiMAX certified technology. The WiMAX Forum (Worldwide Interoperability for Microwave Access) is an industry-led, non-profit corporation formed to promote and certify compatibility and interoperability of broadband wireless products such as IEEE 802.16 and HiperMAN [7].

The main advantage of fixed broadband wireless access (FBWA) technologies over wired systems like DSL and cable modems results mainly from the high costs of the labor-intensive deployment of cables. "A 200-square-kilometer service area costs a DSL provider over $11 million. The same area can be served wirelessly for about $450,000" [8].

Apart from being wireless the above-mentioned FBWA systems IEEE 802.16 and HiperMAN have been designed to meet today's most promising challenges: Non-line-of-sight operation capability cuts the deployment costs. Large cells radii allow for rapidly deployable infrastructure networks. This will decrease time to market for new broadband services which will be crucial for the success of new operators. Networks become even more scalable by utilizing the optional Mesh deployment. The system performance enables operators to offer services requiring high peak bit rates. Quality of service (QoS) support for packet-based services is provided by the system.

Following this introduction the OFDM-based transmission mode of the IEEE 802.16-2004 MAC protocol is described in detail in Section 2. Section 3 outlines the OFDM-based PHY layer with its main transceiver modules. A multi-user multi-mode scenario based on a realistic PHY mode distribution is derived in Section 4. A system performance evaluation by means of a mathematical system model follows in Section 5. The PHY and MAC layer capacity of the example scenario is calculated. Moreover, the interaction of fragmentation and padding is evaluated. MAC layer configurations with different levels of robustness are compared. In Section 6 a prototypical implementation of the IEEE 802.16 protocol stack is introduced. By means of the stochastic event-driven computer simulation, packet delay as well as throughput evaluation is performed. The simulation results are compared with analytical results.

2. IEEE 802.16 medium access control protocol

The scope of the IEEE 802.16 standard comprises the MAC and the PHY layer as illustrated in Fig. 1. The MAC includes a service-specific convergence sublayer that interfaces higher layers. The MAC common part sublayer carries the key functions and below resides the security sublayer.

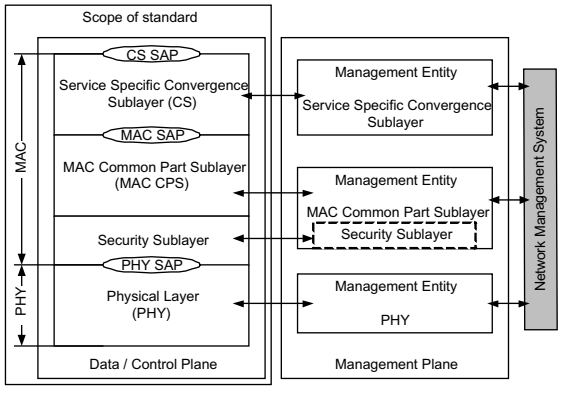

Fig. 1. IEEE 802.16 protocol layering [3].