A Review on Modulation and channel encoding schemes over IEEE 802.16 Based Networks

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Abstract

The wireless medium has limited bandwidth, higher packet error rate, and higher packet overheads that altogether limit the capacity of the network to offer guaranteed QoS. OFDM systems, also referred as Multi-carrier Systems, are known to be the basis of 3G and 4G technology, for example in LTE (Long Term Evolution) 4G cellular standards, WiMAX Standards, IEEE 802.11 a/g/n Microwave standards, etc. Thus OFDM is a key wireless broadband technology which supports high data rates. Despite of several advantages of this technique, OFDM suffers from a high PAPR which degrades BER performance and results in loss of orthogonality. In this paper, we provide a simulation based evaluation of the cyclic prefixes (Conventional/ Turbo) against various service classes and adaptive QoS modulation schemes that are the key functions in the MAC common part sub layer.

Keywords— *IEEE, OFDM, PAPR, WIMAX, QoS.*

I. INTRODUCTION

Broadband wireless access (BWA) represents a cost-effective solution to provide last-mile access, and in some cases it may represent the only viable solution to the digital divide. As a consequence of the wide interest in wireless broadband access, in 1999 the IEEE Standards Board activated the 802.16 Working Group on BWA standardswith the aimof developing standards and recommended practices to support the development and deployment of broadband wireless metropolitan area networks. WiMAX is essentially a

next-generation wireless technology that enhances broadband wireless access. WiMAX, like Wi-Fi, uses unregulated radio frequency spectrum, but unlike Wi--Fi, it does not require line of sight and is not limited to a dozen or so clients per access point. WiMAX can deliver ultra-fast Internet access over many miles. WiMAX is primarily built around broadband data, rather than voice, whereas 3G is primarily built around voice, with support for data services. WiMAX could prove disruptive to wireless carriers. Existing mobile operators who want to provide broadband data and voice services could also utilize the technology.

WiMAX is also expected to solve the problems of rural connectivity, as it is suited for remote places that don't have an established infrastructure of power lines or telephone poles. WiMAX offers both increased range and download speeds. It is a telecommun-ications protocol that provides fixed and mobile Internet access. Although initial WiMAX deployments are likely to be for fixed applications, the full potential of WiMAX will be realized only when used for innovative nomadic and mobile broadband applications.

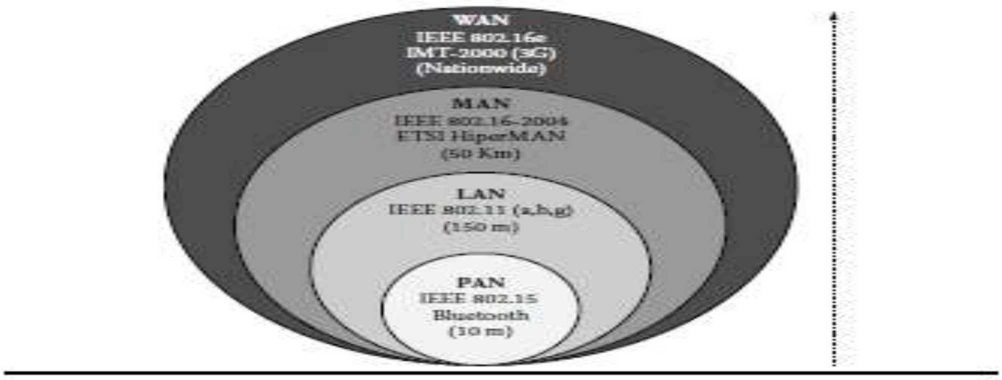

Figure 1 :Illustration of network types

WiMAX comes in two varieties, fixed wireless and mobile. The fixed version, known as IEEE 802.16d (2004), was designed to be a replacement or supplement for broadband cable access or DSL.

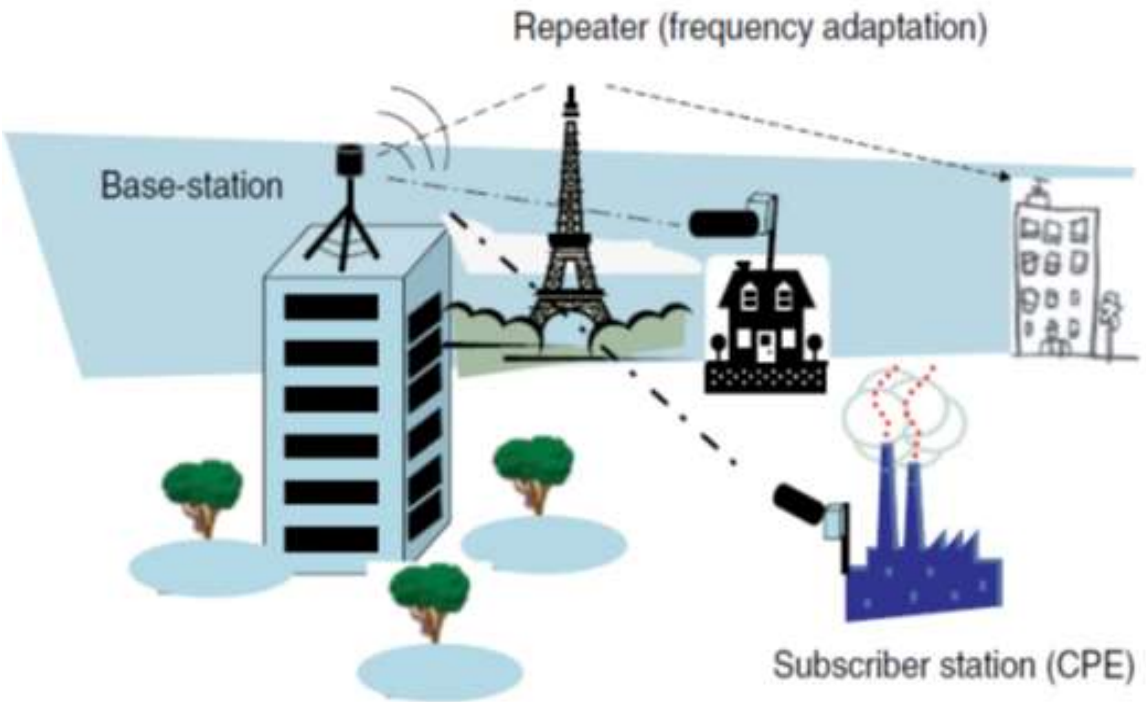

Figure 2: WiMAX- fixed deployment scenario.

A recently ratified version, IEEE 802.16e (2005), also can support fixed wireless applications, but it allows for roaming among base stations as well.

Thus, the two standards are generally knownas *fixed* WiMAX and *mobile* WiMAX. WiMAX is designed to run in licensedbands of spectrum. Some of the more salient features that deserve highlighting are as follows:

- **OFDM-based physical layer:** The WiMax physical layer (PHY) is based on orthogonal frequency division multiplexing, a scheme that offers good resistance to multipath, and allows WiMax to operate in NLOS conditions.
- **Scalable bandwidth and data rate support:** WiMax has a scalable physical-layer architecture that allows for the data rate to scale easily with available channel bandwidth. This scalability is suppo rted in the OFDMA mode, where the FFT (Fast Fourier transform) size may be scaled based on the available channel bandwidth.
- **Adaptive modulation and coding (AMC):** WiMax supports a number of modulation and forward error correction (FEC) coding schemes and allows the scheme to be changed on a per user and per frame basis, based on channel conditions. AMC is an effective mechanism to maximize throughput in a time-varying channel.
- **Robust security:** WiMax supports strong encryption, using Advanced Encryption Standard (AES), and has a robust privacy and key-management protocol. The system also offers a very flexible authentication architecture based on Extensible Authentication Protocol (EAP), which allows for a variety of user credentials, including username/password, digital certificates, and smart cards.
- **Quality-of-service support:** The WiMax MAC layer has a connection-oriented architecture that is designed to support a variety of applications, including voice and multimedia services. The system offers support fo r constant bit rate, variable bit rate, real-time, and non-real-time traffic flows, in addition to best-effort data traffic. WiMax MAC is designed to support a large number of users, with multiple connections per terminal, each with its own QoS requirement.
- **Link-layer retransmissions**: For connections that require enhanced reliability, WiMax supports automatic retransmission requests (ARQ) at the link layer. ARQ-enabled connections require each transmitted packet to be acknowledged by the receiver; unacknowledged packets are assumed to be lost and are retransmitted. WiMax also optionally supports hybrid-ARQ, which is an effective hybrid between FEC and ARQ.
- **Support for TDD and FDD:** IEEE 802.16-2004 and IEEE 802.16e-2005 supports both time division duplexing and frequency division duplexing, as well as a half-duplex FDD, which allows for a low-cost system implementation.
- **Support for mobility**: The mobile WiMax variant of the system has mechanisms to support secure seamless handovers for delay-tolerant full-mobility applications, such as VoIP. The system also has built-in support for power-saving mechanisms that extend the battery life of handheld subscriber devices.

II ARCHITECTURE OF IEEE 802.16 BASED NETWORKS

The WiMax Forum's Network Working Group [3], is responsible for developing the end-to-end network requirements, architecture, and protocols for WiMax, using IEEE 802.16e-2005 as the air interface. The network reference model envisions unified network architecture for supporting fixed, nomadic, and mobile deployments and is based on an IP service model. Figure 1.8 shows a simplified illustration of IP-based WiMax network architecture. [2] The overall network may be logically divided into three parts:

Mobile Station (MS): It is for the end user to access the mobile network. It is a portable station able to move to wide areas and perform data and voice communication. It has all the necessary user equipments such as an antenna, amplifier, transmitter, receiver and software needed to perform the wireless communication. GSM, FDMA, TDMA, CDMA and W-CDMA devices etc are the examples of Mobile station. Mobile stations used by the end user to access the network.

Access Service Network (ASN): It is owned by NAP, formed with one or several base stations and ASN gateways (ASN-GW) which creates radio access network. It provides all the access services with full mobility and efficient scalability. Its ASN-GW controls the access in the network and coordinates between data and networking elements. ASN comprises one or more base stations and one or more ASN gateways that form the radio access network at the edge.

Connectivity Service Network (CSN): Provides IP connectivity to the Internet or other public or corporate networks. It also applies per user policy management, address management, location management between ASN, ensures QoS, roaming and security. CSN provides IP connectivity and all the IP core network functions.

The architecture allows for three separate business entities:

i. Network access provider (NAP), which owns and operates the ASN;

ii. Network services provider (NSP), which provides IP connectivity and WiMax services to subscribers using the ASN infrastructure provided by one or more NAPs;

iii. Application service provider (ASP), which can provide value-added services such as multimedia applications using IMS (IP multimedia subsystem) and corporate (virtual private networks) that run on top of IP.

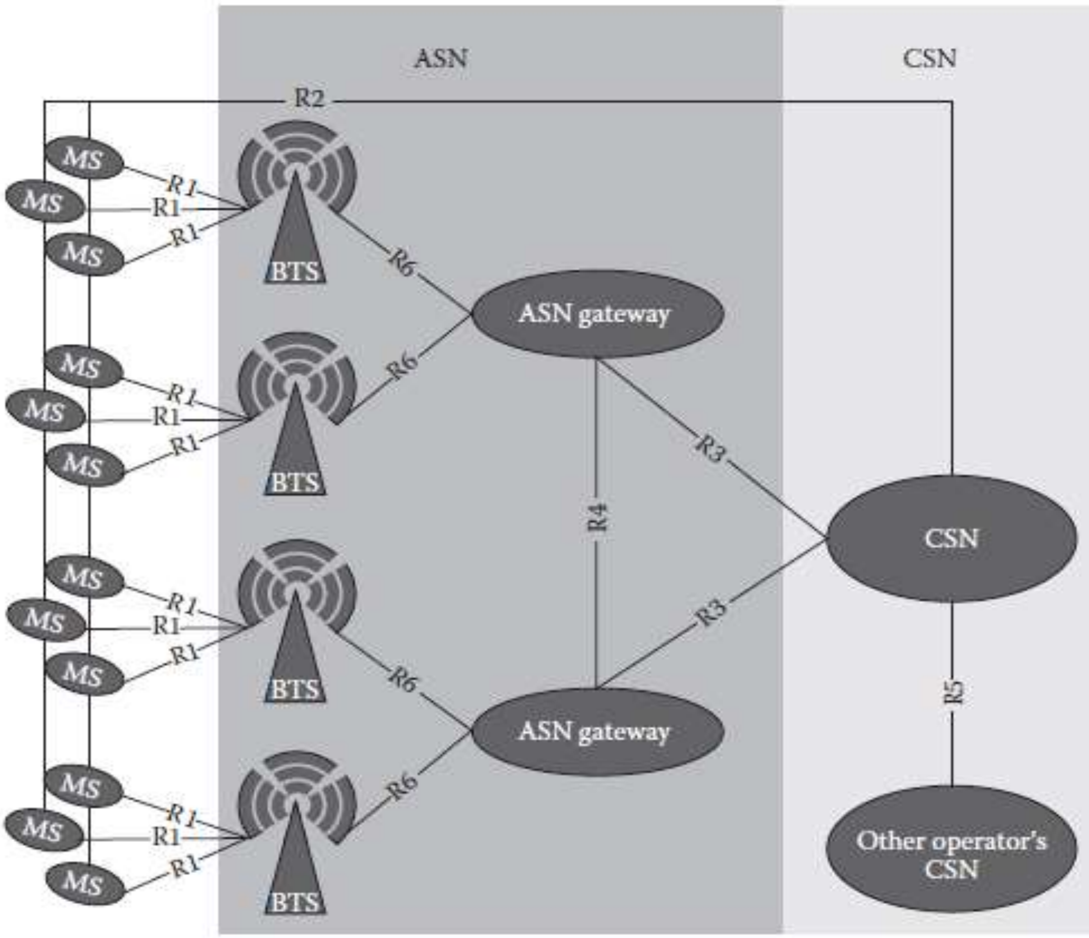

Figure 3: WiMAX-network architecture.

III. OFDM

The IEEE 802.16 standard supports multiple physical specifications due to its modular nature. The 802.16e OFDMA PHY is based on OFDMA modulation, which includes OFDM modulation and subcarriers allocation [3]. OFDM belongs to a family of transmission schemes called multicarrier modulation, which is based on the idea of dividing a given high-bit-rate data stream into several parallel lower bit-rate streams and modulating each stream on separate carriers, called subcarriers, or tones. OFDM realize data transmission by using a radiofrequency range of 2-11 GHz and 10-66 GHz. WiMAX system is a telecommunications technology which enables wireless transmission of voice and data and provide wireless access [13]. In an OFDM system, a high-data-rate sequence of symbols is split into multiple parallel low-data rate-sequences, each of which is used to modulate an orthogonal tone, or subcarrier. The transmitted baseband signal, which is an ensemble of the signals in all the subcarriers, can be represented as

$$x(t) = \sum_{i=0}^{L-1} s[i] e^{-2\pi j(\Delta f + iB_c)t} \quad 0 \leq t \leq T$$

where $s[i]$ is the symbol carried on the ith subcarrier; B_c is the subcarrier bandwidth, frequency separation between two adjacent subcarriers; Δf is the frequency of the subcarrier;

T' is the total useful symbol duration (without the cyclic prefix).

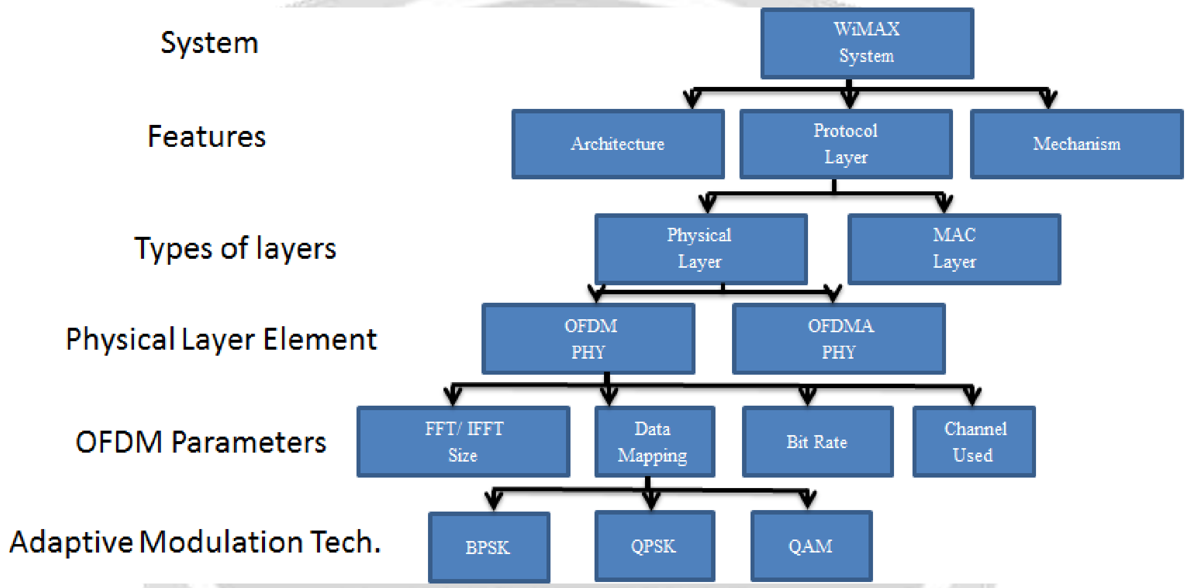

Figure 4 Functional stages of a WiMAX PHY layer [11].

IV. ADAPTIVE MODULATIONS, AND CODING RATE CONTROL

IEEE 802.16 supports fixed-length frame, with flexible (adaptive) DL/UL resource usage ratios. The BS adaptively adjusts DL and UL subframe lengths on a frame-by-frame basis depending on the DL/UL traffics and channel conditions. Typically, the DL:UL resources can be varied from 3:1 to 1:1 in a PMP WiMAX network. Figure 5, illustrates the fixed-length frame in the PMP WiMAX network, and the flexible DL/UL subframes. The figure also depicts the network entry process for subscriber stations (SS) and the scheduling periods for assigning transmission opportunities to SS already initiated into the network. power, etc.) in the DL/UL MAPS of the next frame, and the SS gets initiated into the network. For the mesh mode, new SS waits for network entry signal broadcast at the beginning of a frame, to which they can respond within a specified period. Scheduling process is used for initiating new SS into the network. SS transmits on the scheduled slots.

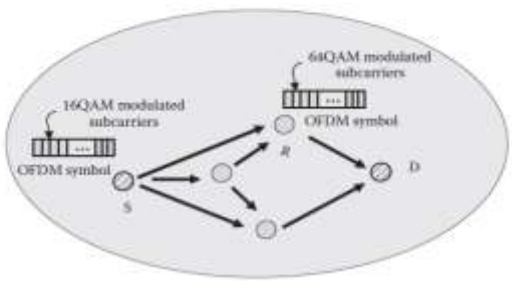

Figure 5: Adaptive DL/UL subframes in WiMAX standard.

For access (PMP) mode, new SS detects preamble and frame control header (FCH), and identifies the number of DL burst transmissions from the DL MAP in the FCH. At the end of the last DL burst (Figure 4), new SS uses a contention period to exchange network entry request signal with the BS. If successful, the BS process the request and sends entry instruction (assigned DL/UL transmission opportunities, In the WiMAX standard (802.16e), UL and DL assignments are based on time division multiple access (TDMA). In each frame, the BS scheduler assigns UL and DL transmission opportunities to SS until their negotiated data periods expire. The resources given to an SS for its data transmission are both in the frequency and time domain. WiMAX MAC thus supports frequency-time resource allocation in both DL and UL on a per-frame basis. The resource allocation is delivered in media access protocol (MAP) messages at the beginning of each frame. Therefore, the resource allocation can be dynamically changed frame-by-frame in response to traffic and channel conditions. Additionally, the amount of resource in each allocation can range from one slot to the entire frame in the time domain, and from one sub -channel to the entire sub-channels in an OFDM symbol, in frequency domain. Also WiMAX employs fast scheduling both in the DL and UL to respond to fast variations in channel conditions. This fast and fine granular resource allocation allows superior QoS for data traffic in a bursty traffic and rapidly changing channel condition. The fundamental premise of the IEEE 802.16 MAC architecture is QoS. It defines services flows which can map to Diffserve code points orMPLS flow labels that enable end-to-end IP-based QoS. Additionally, subchannelization and MAP-based signaling schemes provide a flexible mechanism for optimal scheduling of space, frequency, and time resources over the air interface on a frame-by-frame basis. This flexible scheduling allows QoS to be better enforced and enable support for guaranteed service levels including committed and peak information rates, latency, and jitter for various types of traffic on a customer-by-customer basis.

A. *Digital Modulation*

A digital modulation is to modulate an analogue signal with a digital sequence in order to transport this digital sequence over a given medium: fibre, radio link, etc. Many digital modulations can be used in a telecommunication system. The variants are obtained by adjusting the physical characteristics of a sinusoidal carrier, either the frequency, phase or amplitude, or a combination of some of these. Different modulations are supported by the IEEE 802.16 standard BPSK, QPSK, QAM.

Table I, shows various modulation Schemes along with their standard coding rates and signal to noise ratio.

Table I : Comparsion of various digital modulations

Modulation	Defination	Coding Rate	SNR (Min. Range)
BPSK	**Binary Phase Shift Key digital modulation** : One modulation symbol is one bit. This gives high immunity against noise and interference and a very robust modulation.	1 / 2	5
QPSK	**Quadrature Phase Shift Keying :** QPSK considers two-bit modulation symbols, less noise resistant than BPSK as it has a smaller immunity against interference.	1 / 2	5
		3 / 4	8
QAM	**Quadrature Amplitude Modulation :** changes the amplitudes of two sinusoidal carriers depending on the digital sequence that must be transmitted; the two carriers being out of phase of +π/2, this amplitude modulation is called quadrature. **Available Variants :** 16-QAM, 64- QAM	1 / 2	10.5
		2 / 3	14
		3/ 4	16

V CONCLUSION

WiMAX networks promise to offer an easy deployable and relatively low cost solution for the wireless broadband access. In usual operating conditions, WiMAX will likely support traffic belonging to a wide range of broadband applications, and it is claimed to provide differentiation among heterogeneous demanding flows. In this paper, we describe the main technical characteristics of the Mobile WiMAX or IEEE 802.16 e standard along with their different layers and their architecture, but at the beginning we explain the main benefits of the standard and some political issues behind it such as adaptive modulation and encoding schemes. Channel encoding and QoS Modulation schemes are the key components to provide QoS capability and proportional fairness in the bandwidth sharing over a changing radio environment.

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