Performance and Efficiency of WiMAX-MAC-Layer: IEEE-802-16e

M.A. Mohamed[1], M.S Abou-El-Soud[2], and H.M. Abdel-Atty[2]
[1]*Electronics and Communications Engineering Department, Mansoura University*
[2]*Electrical Engineering Department, port-said University*

Summery
The IEEE 802.16 standard which has emerged as a broadband wireless access technology is capable of delivering very high data rates. However, providing performance guarantees to delay sensitive applications like streaming media is still a challenge. In this paper, the media access control (MAC) layer of WiMAX has been discussed and simulated; exploiting its flexible features to dynamically construct the MAC-packet data units (MPDU). The overhead caused by the MAC-layer of the network is an important performance indicator, because it significantly influences the throughput. It is interesting to know how the MAC-efficiency is dependent on the physical-layer. The MAC-efficiency for point-to-multipoint point topology is simulated based on IEEE-802.16 standard under the influence of several overhead parameters: the number of subscriber stations; modulation techniques; error control coding techniques, and length of MAC-message's PDU. As well as the performance of all over system is simulated. The results show these parameters have significant impact on the efficiency of MAC-layer. As well as the MAC overhead of the IEEE 802.16 system can reduces the throughput by approximately 10%. The performance analysis has shown that the IEEE 802.16 standard provides several means to adapt the MAC- and PHY-layer configuration to the system environment and user demands. Using the features efficiently, the system performance can be optimized by maintaining the robustness and operability of the system. Finally, some recommendations to reduce the overhead are put forward.

Keywords: WiMAX-IEEE802.16, Medium Access Control efficiency, and overhead; physical layer, and MAC-layer.

1. Introduction

New and emerging services such as Video on Demand (VoD), Internet Protocol Television (IPTV), and triple play bring multimedia content to end users whenever they want. The next step is to deliver these contents wherever the users are. Traditional wire-based access networks can deliver the contents only to the fixed points. Hence, a new technology that can deliver the contents to mobile users is needed. Worldwide Interoperability for Microwave Access (WiMAX) technology is based on IEEE-802.16–2004 and 802.16e−2005 standards for fixed and mobile wireless access in metropolitan area networks (MAN). It can deliver data rates of 70Mbps, cover ranges in excess of 30km, and it can provide secure delivery of content and support mobile users at vehicular speeds [1, 2]. WiMAX physical (PHY)-layer uses adaptive modulation based on Orthogonal Frequency division multiplexing (OFDM) and orthogonal frequency division multiple access (OFDMA). Adaptive modulation is used to achieve the highest possible data rate for a given link quality. Modulation can be adjusted at very short time intervals, to provide robust transmission links and high system capacity. The higher modulation constellations offer a larger throughput per frequency-time slot but not all users receive adequate signal levels to reliably decode all modulation types. Users that are close to the base station that exhibit good propagation and interference characteristics are assigned with higher modulation constellations to minimize the use of system resources. While users that are in less favorable areas use the lower order modulations for communications to ensure data is received and decoded correctly at the expense of additional frequency/time slots for the same amount of throughput [3].
Assigning modulations based on the link conditions increases the overall capacity of the system. WiMAX-MAC-layer supports real time poling services (rtPS) that ensures required bandwidth and minimum latencies for video services through quality of service (QoS). PHY-layer is resilient to multipath fading channels. Moreover, it uses forward error correction (FEC) to increase service quality. Since WiMAX-PHY supports varying frame sizes and scalable bandwidth, WiMAX is an ideal choice for new services. WiMAX is considered as an all IP access network offering transparency for packet based core networks. Additionally, WiMAX radios are designed not to add any impairment to the content delivery. Hence, WiMAX base stations (BSs), subscriber and mobile stations (SSs/MSs) are ideally suited for the delivery of IP based services; (triple play) VoIP, IPTV, internet multimedia over wireless MAN. This makes WiMAX a superior choice over conventional cable, DSL, and satellite solutions. WiMAX access networks will offer the much desired ubiquity for the contents. Eventually, WiMAX deployments will deliver IPTV to rural and underserved regions with high degree of video and audio quality at affordable prices. WiMAX Support two type of network topologies: point-to-multipoint and mesh. In point-to-multipoint, the link connection is only between BS and SS; a connection, used for the purpose of transporting MAC management messages, required by the MAC-layer. The overhead caused by the MAC-layer of the network is an

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important performance indicator, because it significantly influences the throughput [4-6].
This paper aims to discuss the performance and efficiency of WiMAX MAC-layer for point-to-multipoint topology. The influence of several parameters is examined. The remainder of this paper is organized as follow in Section-2 overview of WiMAX is introduced. IEEE 802.16 medium access control layer is presented in Section-3. Common part sublayer features are described in section-4. Section-5 introduces IEEE 802.16 PHY-layer. Simulation results are given in Section-6. Finally the paper is concluded in Section-7.

2. Overview of Wimax

In 1998, IEEE formed a group called 802.16 to develop standards for what was called a WMAN. The purpose of developing 802.16 standards is to help industry to provide compatible and interoperable solutions across multiple broadband segments and facilitate the commercialization of WiMAX products. Currently, WiMAX has two main variations: one is for fixed wireless applications (covered by IEEE-802.16-2004 standard) and another is for mobile wireless services (covered by IEEE-802.16e standard). Both of them are evolved from IEEE-802.16 and IEEE-802.16a, the earlier versions of WMAN standards [7, 8]. The 802.16 standards only specify the PHY-layer and MAC-layer of air interface while the upper layers are not considered. IEEE-802.16 suite of standards (IEEE-802.16-2004/IEEE-802-16e-2005) defines within its scope four PHY-layers, any of which can be used with the MAC-layer to develop a broadband wireless system. The PHY-layers are defined in IEEE-802.16 are: (i) WMAN-SC: a single carrier PHY-layer intended for frequencies beyond 11GHz requiring a LoS condition; (ii) WMAN-SCa: a single carrier PHY-layer for frequencies between 2GHz and 11GHz for point–to–multipoint operations; (iii) WMAN-OFDM: a 256–point FFT–based OFDM-PHY-layer for point–to–multipoint operations in NLoS conditions at frequencies between 2GHz and 11GHz; (iv) WMAN-OFDMA: a 2^{11}-point FFT–based OFDMA-PHY-layer for point–to–multipoint operations in NLoS conditions at frequencies between 2GHz and 11GHz. In the IEEE-802.16e–2005, this layer has been modified to scalable OFDMA, where the FFT size is variable and can take any one of the following values: 2^7, 2^9, 2^{10}, and 2^{11} [6, 7]. The variable FFT size allows for optimum operation/ implementation of the system over a wide range of channel bandwidths and radio conditions; this PHY-layer has been accepted by WiMAX for mobile and portable operations and is also referred to as *mobile* WiMAX [7]. Provisions have been made to include advanced antenna systems in the WiMAX standard to improve throughput and link reliability.

IEEE 802.16 allows for several antennas to be used at the transmitter and the receiver to create a Multiple-Input Multiple-Output (MIMO) system. Techniques such as space-time coding can be used to reduce the occurrence of deep fades in the signal level across the transmission band. An increase in throughput can be achieved by spatially multiplexing different data streams on each of the transmit antenna elements at the same time on the same frequency [8]. The WiMAX MAC layer supports point-to-multipoint (PMP) and mesh topologies, both of which rely upon a shared access medium. In PMP topology, a WiMAX network is divided into cells and sectors consisting of one base station (BS) and many subscriber stations (SS), similar to a cellular telephone network.
This architecture naturally lends itself to PMP operation in the downlink direction, from BS to SS, where time-division duplex (TDD) or frequency-division duplex (FDD) is used. In practice, TDD is typically used, where BS dynamically adjusts the duration of the downlink and uplink portions of the data frame, depending on the requirements. Uplink access is usually TDMA, with scheduling fully controlled by the BS. The MAC layer is connection-oriented and unidirectional. All service flows are mapped to connections between BS and SS [9].

3. IEEE-802.16 MAC-Layer

The primary task of the WiMAX MAC-layer is to provide an interface between the higher transport layers and the PHY-layer. The MAC-layer takes packets from the upper layer- these packets are called *MAC service data units* (SDUs) - and organizes them into *MAC protocol data units* (PDUs) for transmission over the air. For received transmissions, the MAC-layer does the reverse. The IEEE-802.16-2004 and IEEE 802.16e-2005 MAC design includes three sublayers which interact with each other through the service access points (SAPs) as shown in Fig.1. The service specific convergence sublayer (CS) provides any transformation or mapping of external network data, received through the CS service access point (SAP). This includes classifying external network service data units (SDU) and associating them with the proper service flow identified by the connection identifier (CID). A service flow is a unidirectional flow of packets that is provided with a particular QoS. The MAC common part sublayer is the core functional layer which provides system access, bandwidth allocation, connection establishment, and connection maintenance. It receives data from various CSs classified to particular connection identifier CIDs. QoS is applied to transmission and scheduling of data over the PHY layer. Privacy sublayer provides authentication, secure key exchange and encryption on the MAC PDUs formed from the MAC SDUs and passes them over to the physical layer [4, 7].

4. Common Part Sublayer Features

We focus on the common part sublayer to explore its rich set of features. This sublayer controls the on-air timing based on consecutive frames that are divided into time slots. The size of these frames and the size of the individual slots within these frames can be varied on a frame-by- frame basis. This allows effective allocation of on-air resources [10].

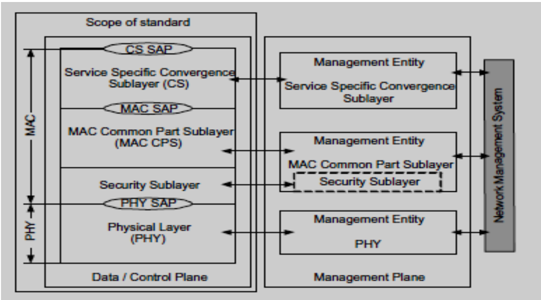

Figure 1. IEEE 802.16 protocol layering [4]

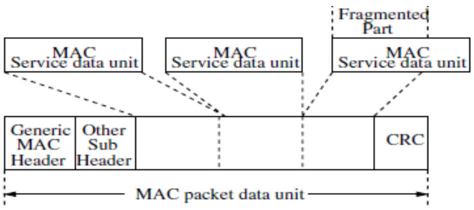

Figure.2 Packing [9]

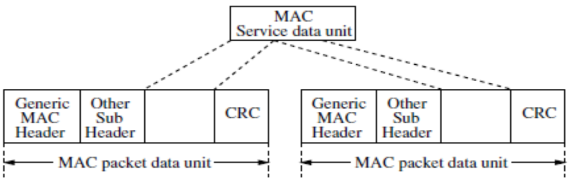

Figure.3 Fragmentation [9]

A. Packing and Fragmentation

The common part sublayer is capable of packing more than one complete or partial MAC SDUs into single MAC-PDU. In Fig.2, it can be seen that the payload of the MAC-PDU can accommodate more than two complete MAC-SDUs, but not three. Therefore, a part of the third MAC-SDU is packed with the previous two MAC-SDUs to fill up the remaining payload field preventing wastage of resources. The payload size is determined by on-air timing slots and feedback received from subscriber station. The common part sublayer can also fragment a MAC-SDU into multiple MAC-PDUs as shown in Fig.3 [10].

B. MAC-PDU Formats

MAC PDUs consist of a fixed-length MAC-header, a variable-length payload and an optional 32-bit cyclic redundancy check (CRC). Since the size of the payload is variable, this allows the MAC to tunnel various higher layer traffic types without knowledge of the formats of those messages. The MAC header might be directly followed by one or more subheaders. There are several different subheaders carrying information for various purposes such as Mesh, automatic repeat request (ARQ), packing or fragmentation and grant management. Each MAC-PDU consists of a header. Two MAC-header formats are defined: (i) the *generic* MAC PDU generally used for carrying data and MAC-layer signaling messages. A generic MAC-PDU starts with a generic header whose structure is shown in Fig.4 as followed by a payload and a CRC. The various information elements in the header of a generic MAC-PDU are shown in Table.1 and (ii) the *bandwidth* request PDU is used by the MS to indicate to the BS that more bandwidth is required in the UL, due to pending data transmission. A bandwidth request PDU consists only of a bandwidth-request header, with no payload or CRC [7].

C. Quality of Service

One of the key functions of the WiMAX MAC-layer is to ensure that QoS requirements for MAC-PDUs belonging to different service flows are met as reliably as possible given the loading conditions of the system. The WiMAX MAC-layer uses a *scheduling service* to deliver and handle SDUs and MAC PDUs with different QoS requirements. WiMAX defines five scheduling services such as: (i) unsolicited grant service (UGS); (ii) real-time Polling Service (rtPS); (iii) Non-real-time Polling Service (nrtPS); (iv) Best Effort (BE), and (v) Extended real-time Polling service (ertPS) [4].

D. ARQ Mechanism

The IEEE 802.16 ARQ mechanism is an optional part of the MAC layer and can be enabled on a per-connection basis during connection establishment. It is a bitmap-based ARQ mechanism based on the fragment sequence number of the fragmentation or packing subheader. The mechanism can either work as a cumulative, a selective acknowledge or a combined ARQ mechanism [8].

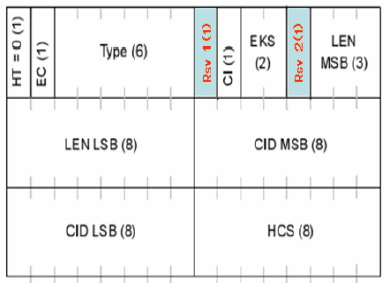

Figure 4. Generic MAC PDU header [7]

Table.1 Generic MAC Header Fields

Field	Length (bits)	Description
HT	1	Header type (set to 0 for such header)
EC	1	Encryption control (0 = payload not encrypted; 1 = payload encrypted)
Type	6	Type
ESF	1	Extended subheader field (1 = ES present; 0 = ES not present)
CI	1	CRC indicator (1 = CRC included; 0 = CRC not included)
EKS	2	Encryption key sequence (index of the traffic encryption key and the initialization vector used to encrypt the payload)
Rsv	1	Reserved
LEN	11	Length of MAC PDU in bytes, including the header
CID	16	Connection identifier on which the payload is to be sent
HCS	8	Header check sequence; generating polynomial $D^8 + D^2 + D + 1$

E. MAC Support of PYH-Layer

The system supports a frame-based transmission, in which the frame can adopt variable lengths. The frame structure of OFDM-PHY-layer operating in time division duplex (TDD) mode is illustrated in Fig.5. Each frame consists of a downlink (DL) subframe and an uplink (UL) subframe, with the DL subframe always preceding the UL subframe. The following frame control header (FCH) contains the DL frame prefix (DLFP) and occupies one OFDM symbol. The DLFP specifies the location as well as the modulation and coding scheme (PHY-mode) of up to four DL bursts following the FCH. The mandatory modulation used for the FCH is BPSK with code rate 1/2. The FCH is followed by one or multiple DL bursts, which are ordered by their PHY-mode. While the burst with the most robust PHY mode, e.g., BPSK 1/2 is transmitted first, the last burst is modulated and coded using the highest PHY-mode, i.e., 64-QAM 3/4. Each DL burst is made up of MAC packet data units scheduled for DL transmission. UL subframe consists of contention intervals scheduled for initial ranging and bandwidth request purposes and one or multiple UL PHY transmission bursts, each transmitted from a different SS. The initial ranging slots allow a SS to enter the system by requesting the basic management CIDs, by adjusting its power level and frequency offsets and by correcting its timing offset. The bandwidth request slots are used by SSs to transmit the bandwidth request header [1, 5].

F. MAC Management Messages

n the following the broadcast MAC-management messages are described. Fig.6 shows the basic MAC management messages used to specify the internal structure of the MAC frame. The time references of the messages to the corresponding elements of the MAC frame are indicated by arrows. The DLFP contains up to four information elements (IEs). Each IE specifies a DL burst. Thus, the DLFP can specify up to four DL bursts. If the DL subframe is made up of more than four bursts, an additional DL-MAP specifies the remaining ones. If there are less than four bursts present, the DLFP is sufficient and no DL-MAP has to be transmitted.

The DLFP IE contains the length and the PHY mode of the corresponding DL burst. DL burst 1 contains the broadcast MAC control messages, i.e., DL and UL channel descriptor (DCD, UCD) as well as the UL- and DL-MAP. DCD and UCD define the characteristic of the physical channels. The DL-MAP defines access to the DL channel and the UL-MAP allocates access to the UL channel. Thus, the whole MAC frame is specified by the MAC messages included in the FCH and the DL burst [1, 5].

5. IEEE-802.16 OFDM Physical layer

The role of the PHY-layer is to encode the binary digits that represent MAC frames into signals and to transmit and receive these signals across the communication media. The WiMAX-PHY-layer is based on OFDM; which is used to enable high-speed data, video, and multimedia communications and is used by a variety of commercial broadband systems.

The PHY-layer of WiMAX includes various functional stages: (i) FEC: including; randomizing, channel encoding, rate matching, interleaving, and symbol mapping; (ii) OFDM symbol in frequency domain, and (iii) conversion of the OFDM symbol from the frequency domain to the time domain [9]. In the following, the basic modules of IEEE 802.16 transmitter respectively receiver are outlined [10]. A randomizer adds a pseudo-random binary sequence to the DL and UL bit stream to avoid long rows of zeros or ones for better coding performance. The forward error correction (FEC) scheme consists of the concatenation of a Reed–Solomon (RS) outer code and a convolutional inner code (CC). The RS coder corrects burst errors at the byte level. After the RS encoding process, data bits are further encoded by a binary CC, which has a native rate of 1/2 and a constraint length of 7.

The CC corrects independent bit errors. Puncturing is the process of systematically deleting bits from the output stream of a low-rate encoder in order to reduce the amount of data to be transmitted, thus forming a high-rate code. The process of puncturing is used to create the variable coding rates needed to provide various error protection levels to the users of the system. The interleaver is defined by a two-step permutation. First ensures that adjacent coded bits are mapped onto nonadjacent subcarriers to overcome burst errors. The second permutation insures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of lowly reliable bits [8]. BPSK, QPSK, 16-QAM and 64-QAM are the modulation schemes to modulate bits to the complex constellation points.

The FEC options are paired with the modulation schemes to form burst profiles. OFDM is a multicarrier modulation technique, which provides high bandwidth efficiency because the carriers are orthogonal to each other and multiple carriers share the data among themselves. The main advantage of this transmission technique is their robustness to channel fading [11]. At the receiving side, a reverse process (including deinterleaving and decoding) is executed to obtain the original data bits. As the deinterleaving process only changes the order of received data, the error probability is intact. When passing through the CC decoder and the RS-decoder, some errors may be corrected, which results in lower error rate.

6. Simulation Results

In this work the performance of IEEE 802.16 MAC- frame structure and WMAN-OFDM PHY-layer characteristics have been modeled and simulated using MATLB-2009b installed on a personal computer of core2due of 2.93 GHz and 2MB cache RAM.

A. Parameters of Simulation

- *OFDM Parameters:* The standard defines two types of parameters, the primitive parameters, that will be specified by users or system requirements and the derived parameters, defined in terms of the primitive ones. OFDM parameters are given in Table.2.

Table.2 OFDM Simulation Parameters

Type	Parameters	Value
Primitive	Channel Bandwidth, BW	20MHz
	Number of data subcarriers, N_{data}	192
	Number of pilot subcarriers N_{pilot}	8
	Sampling Factor n_f	144/125
	Guard time/useful symbol time, G	1/4 ,1/8, 1/16, 1/32
Derived	NFFT	255
	Number of Used subcarriers N_{used}	200
	Sampling Frequency,	800×floor(n_f.BW/8000)
	Subcarrier Spacing,Δf	$\Delta f = f_s/N_{FFT}$
	Useful Symbol Time T_b	$T_b = 1/\Delta f$
	CP Time T_g	GT_b

- *IEEE802.16-OFDM-PHY Layer Parameters:* The system supports four modulation schemes and two channel models: additive white Gaussian noise (AWGN) and Rayleigh fading. The channel coding part is composed of three steps: randomization; FEC, and interleaving. The simulated coding, modulation schemes (PHY-mode) and also noisy channels used in the present study is shown in Table.3. Numerical values of OFDM parameters, which are used to obtain the resulting efficiencies and throughput, haven't been presented before, are T_{frame} and T_{symbol}. T_{frame} defined by the standard IEEE802.16e2005 [2]. T_{frame} could has values from 2.5ms to 20ms. The third highest value, T_{frame}=10ms, is chosen for the calculation. T_{symbol} can be calculated using Eq.1, with substituting the following: G=1/4, BW=20MHz and n=144/125. These values are allowed by the standard for license-exempt bands. Bandwidth of 20 MHz and the ratio of the cyclic prefix to the useful symbol time are both the largest allowed. The final symbol duration is then 13.89µs.

Table.3 Simulated coding, modulation schemes and noisy channels

Modulation	RS code	CC code	Noise Channels
BPSK QPSK 16-QAM 64-QAM	(255, 239, 8)	(1/2) (1/2, 3/4) (1/2, 3/4) (1/2, 3/4)	AWGN Channel
BPSK QPSK 16-QAM 64-QAM	(255,239,8)	(1/2) (1/2, 3/4) (1/2, 3/4) (1/2, 3/4)	AWGN+ Rayleigh Channel

$$T_s = T_b + T_g = \left(\frac{1}{\Delta f}\right) + G.T_b = \left(\frac{1}{\Delta f}\right)(1+G) = \left(\frac{N_{FFT}}{f_s}\right).(1+G) = \left[\frac{N_{FFT}}{\left(\left\lfloor n_f \frac{BW}{8000} \right\rfloor 8000\right)}\right].(1+G) \quad (1)$$

- *IEEE802.16-MAC Layer Parameters:* The model of 16 MAC-frame structures takes all the above introduced features into account (MAC-header, CRC, broadcast MAC-management messages. The scheduling is based on a fair queuing algorithm where all SSs are treated equally; ARQ also disabled. Besides the main parameter, the number of N_{ss}, length of data MAC-PDUs, modulation/coding used, and number of burst profiles are chosen for the evaluated efficiency of MAC-layer. As well as point to multipoint mode is well suited. MAC efficiency can be defined as the ratio of the net throughput of MAC-layer and throughput per OFDM symbol [12, 13].

$$\eta = \frac{\Theta_{MAC\,net}}{\Theta_{OFDM\,symbol}} \quad (2)$$

The net throughput of MAC-layer is defined by Eq.3. It is the ratio of the total number of payload bits, i.e. without all MAC-overhead in a frame to the frame duration $T_{frame.}$

$$\Theta_{MAC\,net} = \frac{\sum payload\ bits}{T_{frame}} \quad (3)$$

To evaluate the MAC-layer efficiency as the ratio of OFDM symbols used for payload transmission in a frame to the total number of OFDM symbols in a frame. Letter L in the following equation always means length expressed as a number of OFDM symbols [12, 14].

$$\eta = \frac{L_{net\,payload}}{L_{frame}} \quad (4)$$

The number of symbols in a frame does not depend on the modulation or coding, as defined by Eq.5:

$$L_{frame} = \left\lfloor \frac{T_{frame}}{T_{symbol}} \right\rfloor \quad (5)$$

B. Simulation Results

▪ *MAC-layer throughput:* the maximum throughput values are obtained for all modulation and coding schemes are presented in Table.4. The theoretical throughput values have not been exactly matched with the simulated values due to overhead introduced by MAC-PDU-header, CRC, MAC management messages and the channel introduces transmission errors further reduces the capacity slightly. Fig.7 plots the MAC throughput of 802.16 systems using different cyclic prefixes and 64 QAM 3/4 is assumed in the simulation. It can be seen that the throughput highly depends on the length of the CP. Thus, the CP should not be made longer than strictly necessary.

▪ *The efficiency on MAC-Layer*: the efficiency of MAC layer can be calculated for various parameters will be presented:

▪ *MAC PDU length*: the length of data MAC-PDUs plays an important role for efficiency value. The shorter PDU is used, the bigger part of it is occupied by the generic MAC header and CRC bytes, which for lower lengths significantly decrease the efficiency. The modulation QPSK 1/2 is assumed in the simulation. 1 DL burst profile and 1 UL burst profile is also considered. In Fig.8, the results for different number of N_{ss} are shown. It can be seen that efficiency rises rapidly for smaller K values (up to 100 bytes). After this point, the efficiency increase only gradually and for K values of 1000 bytes and more it is almost constant. At the same time it can seen that for a certain MAC PDU length the largest number of subscriber station has the lowest efficiency.

▪ *Various modulation and coding schemes*: the influence of modulation and coding is presented when using 1 DL burst profile, 1UL burst profile and fixing the MAC PDU length to 2^{10} bytes. When assuming this length or higher, the influence of the number of subscriber stations is much more noticeable than the influence of the PDU length. Based on Table.1, the efficiencies are calculated for seven most common PHY-modes. Fig.9 shows that higher modulations usages mean lower MAC overhead. When a PHY-mode with a higher number of bytes per symbol is used the messages occupy a smaller portion of the PMP-frame. For a higher number of subscribers station the difference in efficiency for different modulation increases.

▪ *Various number of burst profiles*: MAC-PDU length of 1024 bytes was assumed, and more uplink and downlink burst profiles are specified (1 BP: 6 BPs). Fig.10 shows that the lower number of burst profile gives the lowest efficiency when N_{ss} is higher.

C. WiMAX Based on IEEE 802.16 Simulations

The overall performance of the WiMAX-PHY and MAC-layers were tested and simulated at different noise levels. Various BER vs. SNR plots are presented for all the essential modulation and coding profiles in the standard on different channel models. Fig.11 and 12 display the performance on AWGN and Rayleigh channel models respectively. It can be noticed that the lower modulation and coding scheme provides better performance with less SNR. Furthermore, the selection of the PHY modes is made in such a way that it guarantees a BER below a given target BER. SNR required to attain BER level at 10^{-3} are tabulated in Table.5; it can be demonstrated that, as the channel SNR is higher, higher PHY-modes are used to give us the best spectral efficiency while providing the desired BER performance.

Table. 4 PHY mode and corresponding throughput

Modulation	Code rate	PHY throughput[Mbps]		MAC throughput[Mbps]	
		Simulated	Theoretical	Simulated	Theoretical
BPSK	1/2	6.01	6.91	5.8	6.09
QPSK	1/2	12.38	13.82	11.2	12.19
QPSK	3/4	19.36	20.74	17.32	18.59
16 QAM	1/2	26.1	27.65	23.21	24.69
16 QAM	3/4	38.72	41.47	35.2	37.19
64 QAM	2/3	51.58	55.3	46.9	49.68
64 QAM	3/4	56.87	62.21	51.2	55.78

Table.5 AMC Scheme to SNR Range

AMC	AWGN channel	Rayleigh channel
BPSK	7 dB<SNR<11 dB	4 dB<SNR<9 dB
QPSK, CC=1/2	11 dB<SNR<17 dB	9dB<SNR<15 dB
QPSK, CC=3/4	17dB<SNR<19 dB	15dB<SNR<18dB
16QAM,CC=1/2	19 dB<SNR<22 dB	18dB<SNR<23 dB
16QAM,CC=3/4	22 dB<SNR<25 dB	23dB<SNR<28dB
64QAM,CC=1/2	25 dB<SNR<29 dB	28dB<SNR<40dB
64QAM,CC=3/4	SNR>29 dB	SNR>40 dB

Conclusions

A detailed introduction to the IEEE 802.16 MAC and PHY-layer protocol is presented. The MAC-frame structure is illustrated and the basic control elements are described. The basic PHY-layer chain modules of the IEEE 802.16 transmitter and receiver are outlined as well. Based on the PHY-layer the MAC-layer capacity is calculated. The MAC-layer configuration is analyzed in the context of throughput and overhead. Performance on the MAC-layer of the IEEE 802.16 WMAN standard has been simulated. The point to multipoint mode is well suited for higher number of subscriber stations. MAC PDU length of 1024 bytes, the efficiency of the MAC-layer is for 100 subscriber station around 75%. The data MAC PDU length is the parameter that highly influences on the MAC-layer performance. Obviously longer PDUs mean less MAC overhead. Another way of reducing the MAC-overhead is usage of a higher modulation/coding. Especially for the PMP mode, transmitting the broadcast message with higher number of bytes per symbols gives more space to the data MAC PDUs transmission. Introducing some changes to the IEEE 802.16 standard, for example defining more space saving (type/

length/value) TLV tuples for some of the management MAC-messages could also bring some minor saving.

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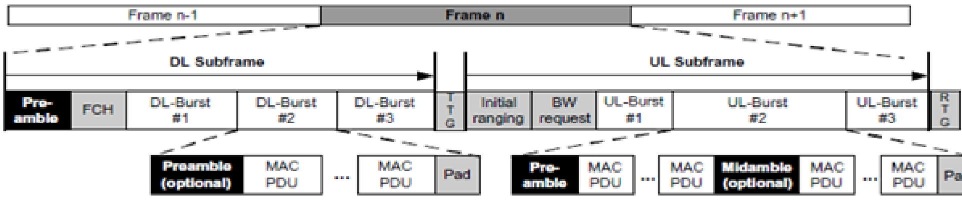

Figure.5. IEEE 802.16 MAC frame in TDD mode

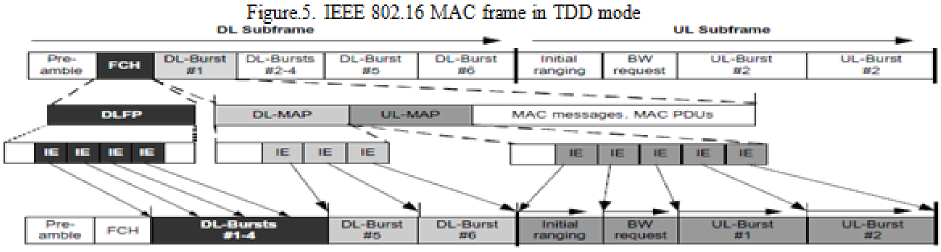

Figure.6. IEEE 802.16 references of MAC management messages

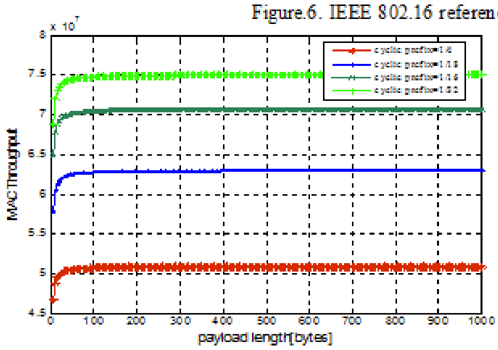

Figure.7 MAC throughput with different cyclic prefix

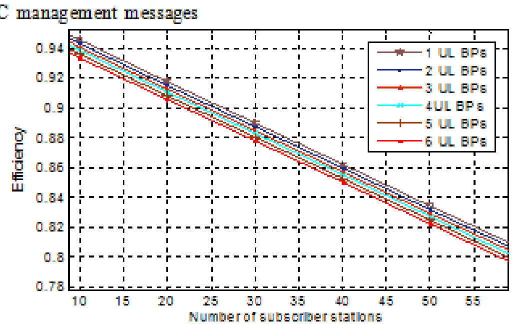

Figure.10 PMP efficiency for different Nss with Various number of burst profiles (BP)

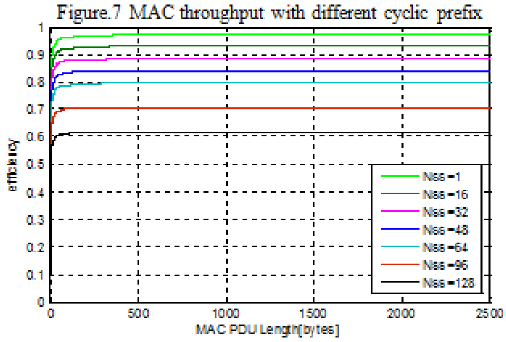

Figure. 8 PMP efficiency with variable PDU at different Nss

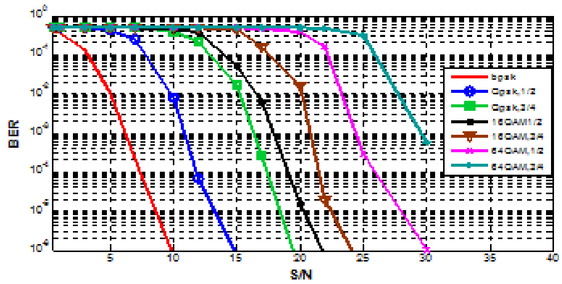

Figure .11 Performances at different modulation schemes for 1/2&3/4 code rates in AWGN channel.

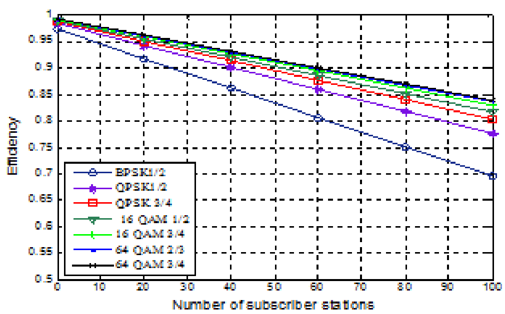

Figure. 9 PMP efficiency for different Nss with Various modulation and coding schemes

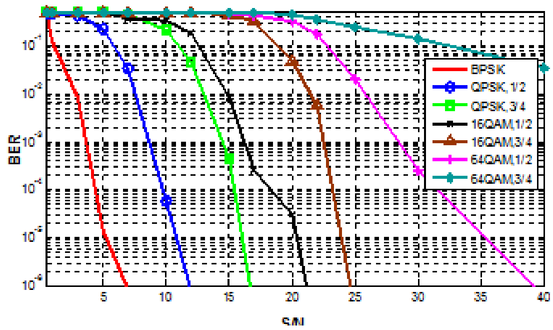

Figure .12 Performances at different modulation schemes for 1/2&3/4 code rates in Rayleigh channel.