Performance Evaluation Of Wimax Network

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Abstract: **WiMAX networks, built on all-IP network architecture for plug and play network deployments, can support a mix of different usage and service models. While some consider mobile WiMAX as a candidate for the fourth generation of mobile networks, others view it as the first generation of mobile Internet technologies emerging from a wider ecosystem targeting to extend the success of WiFi over wide area networks supporting mobility.** ***WiMAX is one of the important broadband wireless technologies .Being an emerging technology, WiMAX supports multimedia applications such as voice over IP (VoIP), voice conference and online gaming The use of different modulation schemes like QPSK, QAM gives better flexibility for WiMAX network. In this paper, we analysed and simulated the different modulation schemes for WiMAX.***

Keywords: OFDMA,SOFDMA,QPSK.QAM,WiMAX

I. INTRODUCTION

Mobile WiMAX refers to a rapidly growing broadband wireless access solution built upon the IEEE 802.16e-2005 air interface standard. Contrary to its name, Mobile WiMAX is equally applicable to fixed, portable and mobile applications. Mobile WiMAX technology supports optimized handover schemes with latencies less than 50 ms to help ensure real-time applications such as Voice over Internet Protocol (VoIP) are efficiently supported without service degradation. Flexible key management schemes help assure security is maintained during handover. IEEE 802.16e or Mobile WiMAX improves on the modulation schemes used in the Original (Fixed) WiMAX standard by introducing scalable orthogonal frequency division multiple access (SOFDMA). The system profile in IEEE 802.16e-2005 is not backward compatible with the Fixed WiMAX system profile. The Mobile WiMAX (Worldwide Interoperability for Microwave Access.) standard of 802.16e is divergent from Fixed WiMAX. It attracted a significant number of Forum members towards an opportunity to substantively challenge existing 3G technology purveyors. While clearly based on the same OFDM base technology adopted in 802.16-2004, the 802.16e version is designed to deliver service across many more sub-channels The 802.16e standard adds OFDMA 2K-FFT, 512-FFT and 128-FFT capability. Sub-channelization facilitates access at varying distance by providing operators the capability to dynamically reduce the number of channels while increasing the gain of signal to each channel in order to reach customers farther away. The reverse is also possible. For example, when a user gets closer to a cell site, the number of channels will increase and the modulation can also change to increase bandwidth. At longer ranges, modulations like QPSK (which offer robust links but lower bandwidth) can give way at shorter ranges to 64 QAM (which are more sensitive links, but offer much higher bandwidth). Each subscriber is linked to a number of sub channels that obviate multi-path interference. The upshot is that cells should be much less sensitive to overload and cell size shrinkage during the load than before. WiMAX systems are based on the IEEE 802.16-2004 and IEEE 802.16e-2005 standards which define a physical (PHY) layer and the medium access control (MAC) layer for broadband wireless access systems operating at frequencies below 11 GHz. The first of these standards, published in 2004, addresses fixed services, and the second, published in 2005, is intended for mobile services. In this report, we focus on mobile WiMAX systems based on the IEEE 802.16e-2005 standard [1-5]. The IEEE 802.16e-2005 specifications actually define three different PHY layers: Single-carrier transmission, orthogonal frequency-division multiplexing (OFDM), and orthogonal frequency-division multiple access (OFDMA). The multiple access technique used in the first two of these PHY specifications is pure TDMA, but the third mode uses both the time and frequency dimensions for resource allocation. From these 3 PHY technologies, OFDMA has been selected by the WiMAX Forum as the basic technology for portable and mobile services. Compared to TDMA-based systems, it is known that OFDMA leads to a significant cell range extension on the uplink (from mobile stations to base station). This is due to the fact that the transmit power of the mobile station is concentrated in a small portion of the channel bandwidth and the signal-to-noise ratio (SNR) at the receiver input is increased. Cell range extension is also achievable on the downlink (from base station to mobile stations) by allocating more power to carrier groups assigned to distant users. Another interesting feature of OFDMA is that it eases the deployment of networks with a frequency reuse factor of 1, thus eliminating the need for frequency planning.

Overview of the Standard 802.16-The IEEE Standards Board established the IEEE 802.16 working group in 1999 to prepare formal specifications for global deployment of broadband wireless metropolitan area networks, which is officially called Wireless MAN. The IEEE 802.16 working group, which is a unit of the IEEE 802 LAN/MAN Standards Committee, is responsible for framing specifications of the IEEE 802.16 family standard,[11] but not testing them. Thus, another industrial group was established in April 2001 called the WiMAX Forum. WiMAX Forum is on a mission to advance and certify compatibility and interoperability of broadband wireless products based on IEEE 802.16 family standards. The IEEE 802.16 standard (also known as the air interface for fixed broadband wireless access (FBWA) systems or IEEE WMAN air interface) is the first version of 802.16 family standards (published in April 2002). It specifies fixed broadband wireless systems operating in the 10–66 GHz licensed spectrum, which is expensive but there is less interference at the high-frequency band and more bandwidth is available. Because radio waves in this band are too short to penetrate buildings, the 802.16 standard is only used for line-of-sight (LOS) connections. Compared to non line-of-sight (NLOS) connections, LOS links are not so flexible but are stronger and more stable against transmission errors. IEEE 802.16 is interoperable with other wireless networks, such as cellular systems and wireless local area networks (WLANs). However, the IEEE 802.16-2001 standard was not an adequate air interface standard for broadband wireless access. It addressed frequencies in a licensed spectrum that introduces significant challenges to the short wavelength and is limited to line-of-sight (LOS) propagation. Thus, the initial 802.16-2001 standard was followed by several amendments. The first one was IEEE 802.16c (LAN/MAN committee, 2002). The main objective of this amendment was to ensure interoperability among the existing local multipoint distribution service (LMDS) LOS solutions working in the 10–66GHz range. Naturally, since the 802.16c is defined over a wide range of frequency it provides more bandwidth. However, and for the same reason, the maximum coverage of 802.16c does not exceed 5 km. In addition to 802.16c's main objective, it addressed other issues such as testing, performance evaluation, and system profiling. System profiling is a vital requirement for interoperability. 802.16c provides guidelines for vendors through mandatory and optional elements of system profiling to ensure interoperability. As for mandatory elements of 802.16c profiling, vendors should support provisioned connections, provide IPv4 support on transport connection, and support fragmentation. As for optional elements, 802.16c allows for different levels of security protocols that allow vendors to provide different functionalities that differentiate their products. As a final remark on 802.16, it is specified to be network technology independent. Thus it can run under asynchronous transfer mode (ATM), internet protocol (IP), or frame relay. The second amendment was the IEEE 802.16b, also called Wireless HUMAN (Wireless high-speed unlicensed metropolitan area network). This amendment mainly provided for quality of service (QoS) features to ensure differentiated service levels for different traffic types. It extended 802.16-2001 to operate under license-exempt regulation in the 5–6GHz range. However, 802.16b does not exist anymore. In April 2003, 802.16a, the most eminent among amendments, was published to standardize the lower-frequency multi channel multipoint distribution service (MMDS) solutions in the licensed and unlicensed range of 2–11 GHz. Working at a lower-frequency range than 802.16-2001, 802.16a (LAN/MAN committee, 2003) has the advantage of being able to offer non line-of-sight (NLOS) communication and a cell coverage up to 50km with a bit rate up to 75 Mbps. An additional feature of 802.16a is that it provides for mesh mode operation, which facilitates subscriber-to-subscriber communications. IEEE 802.16d project was launched to produce interoperability specification and to provide for some fixes for 802.16a. However, the project was transitioned into a revision project for 802.16-2001 and all its amendments. The revision project result is no longer called 802.16d, but it is formally called 802.16-2004 (LAN/MAN committee, 2004). Yet, this active standard was followed by different working groups to address different issues as follows[6-9]:

1. Active standards

a. IEEE 802.16e-2005 (formerly known as IEEE 802.16e)—addressing mobility, concluded in 2005)

b. 802.16f—Management Information Base

2. Drafts under development

a. 802.16g—Management Plane Procedures and Services

b. 802.16k—Bridging

c. 802.16h—Improved Coexistence Mechanisms for License-Exempt Operation

3. Projects in pre draft stage

a. 802.16i—Mobile Management Information Base

b. 802.16j—Mobile Multihop Relay

III.MODULATION TECHNIQUE USED IN 802.16

Scalable Orthogonal Frequency Division Multiple Access

(SOFDMA) is the air interface defined for portable/mobile Wi-MAX systems by IEEE in IEEE 802.16e (2005) standard. SOFDMA (Scalable Orthogonal Frequency Division Multiple Access) [7] is a multiple access method based on OFDM signaling that allows simultaneous transmissions to and from several users along with the other advantages of OFDM. While OFDM-256 is used in fixed WiMAX (based on IEEE 802.16-2004, [8]), SOFDMA mode has many advantages to be considered for nomadic/mobile usage and is used in IEEE 802.16. In OFDMA, sub-carriers are assigned to sub-channels that in turn can be allocated to different users. This provides high-granularity bandwidth allocation as illustrated in Figure 1

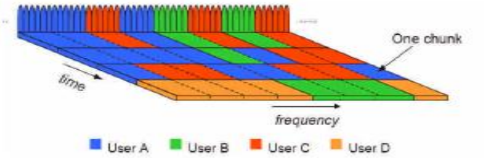

Figure 1: Two-dimensional scheduling in OFDMA

OFDMA (Orthogonal Frequency Division Multiple Access)

OFDMA employs multiple closely spaced sub-carriers. The sub-carriers are divided into groups of sub-carriers. Each group is named a sub-channel. The sub-carriers that form a sub-channel need not be adjacent. [9] OFDMA provides multiplexing operation of data streams from multiple users onto the downlink sub-channels and uplink multiple access by means of uplink sub-channels. The multiple access is achieved by assigning different OFDM sub - channels to different users. In the downlink, a sub-channel may be intended for different receivers. In the uplink, a transmitter may be assigned one or more sub-channels.

The Cyclic Prefix

The increased symbol duration in OFDMA improves the delay spread while the Inter Symbol Interference (ISI) is completely eliminated by introduction of a Cyclic Prefix (some data). CP is a repetition of the last samples of the data portion that is appended at the beginning of the data payload. The ISI is completely eliminated as long as the CP duration is longer than the channel delay spread [9]. A drawback of the CP is that it introduces overhead, which effectively reduces bandwidth efficiency. Since OFDM signal power spectrum has a sharp fall off at the edge of channel, a larger fraction of the allocated channel bandwidth can be utilized for data transmission which compensates the loss in efficiency due to the cyclic prefix.

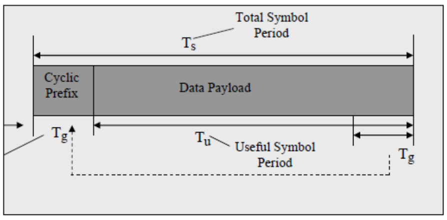

Figure 3: Cyclic Prefix

OFDMA symbol Structure and sub channelization.

Both OFDM and OFDMA symbols [10]are structured in similar way. In OFDMA each symbol consists of sub-channels that carry data sub-carriers carrying information, pilot sub-carriers as reference frequencies and for various estimation purposes, DC sub-carrier as the center frequency, and guard sub-carriers or guard bands for keeping the space between OFDMA signals as shown in figure 2

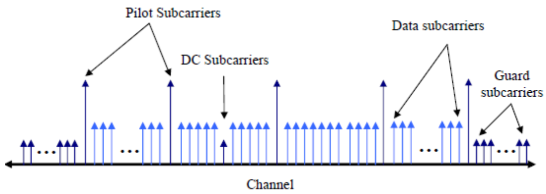

Figure 2: Structure of sub-carriers in OFDMA[10]

Sub-channelization

Active (data and pilot) sub-carriers are grouped into subsets of sub-carriers called sub-channels Sub-channelization defines sub-channels that can be allocated to subscriber stations (SSs) depending on their channel conditions and data requirements. Using sub-channelization, within the same time slot, a BS can allocate more transmit power to SSs with lower SNR and less power to user devices with higher SNR. Sub-channelization also enables the BS to allocate higher power to sub-channels assigned to indoor SSs resulting in better in-building coverage. Sub-channelization in the uplink can save a user device transmit power because it can concentrate power only on certain sub-channel(s) allocated to it. This power-saving feature is particularly useful for battery-powered user devices. The concept of sub-channelization is explained in figure 4

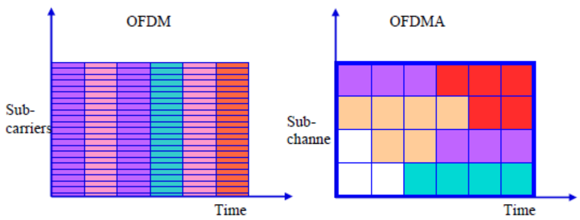

Figure 4: Sub-Channelization in OFDM and OFDMA[10]

Scalability is supported by adjusting the size of FFT size while fixing the sub-carrier frequency spacing in 10.94 kHz. It supports channel bandwidths ranging from 1.25 MHz to 20 MHz. SOFDMA adds scalability to OFDMA. With bandwidth scalability, Mobile Wi-MAX

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technology can comply with various frequency regulations worldwide.

IV PERFORMANCE ANALYSIS OF MOBILE WIMAX[12]

WiMAX throughput depends mostly on the following factors [11]:

- Channel spacing,
- Number of sub-carriers inside a channel,
- Sub-carriers used as pilot carriers,
- Sub-carriers used as guard carriers,
- Symbol duration,
- Modulation Rates,
- Effective Code Rates.

It is possible to estimate throughput knowing the number of bits per OFDM symbol, and the duration of the symbol. The latter can be calculated by:

$$T_{S[\mu s]} = [N_{TSC} / n.\Delta f_c].(1+\Delta t_G) \text{ T}_{\text{s [us]}}$$

where:

- N_{TSC} : number of total sub-carriers,
- n : sampling factor depending on the channel bandwidth,
- Δf_c : channel bandwidth,
- Δt_G : guard time factor.

The possible values for n are: 8/7, 86/75, 144/125, 316/275 and 57/50. The possible values for Δt_G are: 1/32, 1/16, 1/8 and 1/4. The number of information bits per OFDM symbol is given by:

$$N_b = N_{DSC}.M_R.\beta$$

where:

- N_{DSC} : number of sub-carriers that carry data,
- M_R : modulation rate,
- β : effective code rate.

The modulation rate is related to the number of bits that are carried in a symbol using a certain modulation scheme. The four modulations supported by WiMAX are: BPSK, QPSK, 16QAM and 64QAM. Throughput is obtained dividing (1) by (2), resulting:.

$$\rho\ (bps) = \frac{N_{DSC}.M_R.\beta}{[N_{TSC} / n.\Delta f_c].(1+\Delta t_G)}$$

The possibility of using several modulations has the advantage of link adaptation, i.e., adapting modulation according to radio channel conditions. A high-level modulation is used for a good radio link, while a low-level modulation is the most suited for bad radio link conditions.Mobility is based mostly on handover, which is an essential operation in every cellular network. For Mobile WiMAX, the types of handover are HHO and SHO, but only HHO is mandatory. Handover requirements are basically regarding security and time. The latter is due to the fact that handover must be fast enough, in the order of 50 or 150 ms. The procedure for handover in Mobile WiMAX is basically the same as the one used for UMTS/HSDPA, where there is a cell reselection by scanning neighbouring BSs, after which there is the process of synchronization with the selected BS and consequent cell ranging. Handover may also be accomplished according to radio channel conditions or cell capacity considerations. In the WiMAX architecture, the components responsible for handling handover functionality are located in the ASN. Power management is supported by Mobile WiMAX, two modes being available: Sleep and Idle. Sleep Mode is when the MT establishes periods of absence with the BS, in which the MT is unavailable for UL or DL traffic, allowing a better resource management for the BS, and decreasing the power usage by the MT. The Idle Mode is when the MT becomes periodically available for DL traffic without prior registration to a serving BS, occurring when the MT crosses an area populated by numerous BSs; it is beneficial as handover requirements are no longer needed, whether for MT or BS. Mobile WiMAX air interface adopts SOFDMA to improve multi-path performance in NLoS scenarios. The use of SOFDMA enables the change of the number of used sub-carriers, therefore, providing adaptation to the occupied frequency bandwidth and consequently adapting data rate. SOFDMA supports a range of bandwidths from 5 to 10 MHz, to flexibly adjust the need for spectrum allocation. Supported sub-carriers numbers are 128, 512, 1024 and 2048. Only 512 and 1024 are mandatory for Mobile WiMAX.

TABLE 1: SOFDMA PARAMETERS FOR MOBILE WIMAX

Parameters	Values			
	DL	UL	DL	UL
System Channel Bandwidth [MHz]	5		10	
Number of Sub-Carriers	512		1024	
Sub-Carrier Frequency Spacing [kHz]	10.94			
Null Sub-Carriers	92	104	184	184
Pilot Sub-Carriers	60	136	120	280
Data Sub-Carriers	360	272	720	560
Sub-Channels	15	17	30	35
OFDM Symbol Duration [μs]	102.9			
Frame Duration [ms]	5			
Number of OFDM Symbols (per 5 ms frame)	48			
Number of Data OFDM Symbols	44			

A sub-channel is an entity defined in the frequency domain, therefore, it is a group of sub-carriers. For each sub-channel, there are 24 data sub-carriers, along with pilot sub-carriers. This is used with the Partially Used Sub-Carrier (PUSC) technique, which is mandatory for Mobile WiMAX. According to the used channel bandwidth, there are 15 sub-channels for DL and 17 for UL in the 5 MHz channel, and 30 sub-channels for DL and 35 for UL in the 10 MHz one. This allows serving 15 users for 5 MHz channels, or 30 users for 10 MHz ones, in the same period of time. It is also possible to dynamically allocate the number of sub-channels for a single user concerning the throughput requested by the user. All sub-channels can be addressed to one single user in the limit situation.

Data rate values for the Physical Layer (PHY) are obtained by

$$\frac{N_{DSC}.M_R.\beta.N_{DS}}{T_s}$$

- ρ : physical layer throughput
- N_{DS} : number of data symbols
- F_T : frame duration

These results were obtained and published by the WiMAX Forum, so they may be optimistic. WiMAX can achieve physical data rates up to 15 Mbps using 5 MHz channel spacing and a range of almost 5 km. It is also possible to have NLoS transmission.

V RESULTS AND DISCUSSION

In our system we investigated the behaviour of adaptive modulation technique of WiMAX network. The adaptive modulation used Quadrature Phase Shift Keying (QPSK), 16-Quadrature Amplitude Modulation (16- QAM), for modulating the signal. Based on these modulation techniques the Bit Error Rate (BER) and data rate were investigated.The table 2 shows the system parameters used for simulation.

TABLE 2:SIMULATION PARAMETERS

Parameters	Value
Channel Bandwidth	10MHz
FFT Size (FFT)	1048
Cyclic prefix or guard time	1/16,1/32

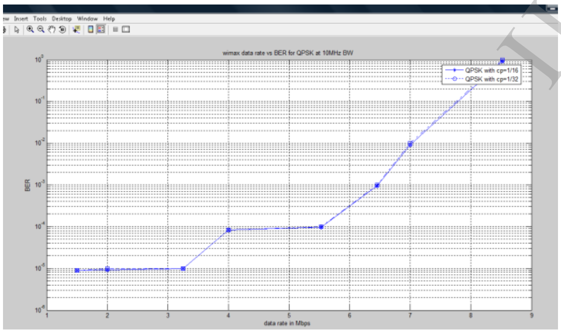

Figure 5:Data rate vs Bit error rate for QPSK for different cylic prefix at 10MHz BW.

Figure 5 shows Data rate vs Bit error rate for QPSK for different cylic prefix(CP=1/16 and 1/32) at 10MHz Bandwidth.

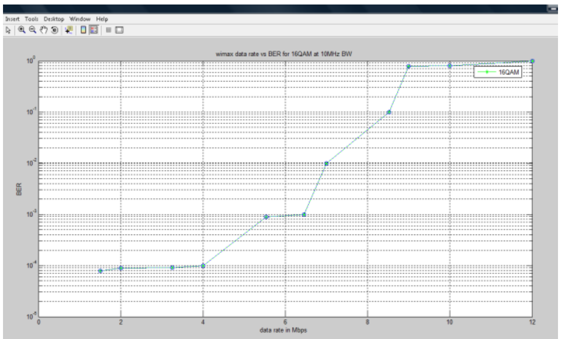

Figure 6: Data rate vs Bit error rate for 16QAM at 10MHz BW.

Figure 6 shows Data rate vs Bit error rate for 16QAM at 10MHz Bandwidth. QPSK modulation techniques are used for the simulation.. But QPSK is a little bit more reliable than others like 16-QAM.

VI CONCLUSION

QPSK modulation technique under different cyclic prefix provides satisfactory performance among the QAM modulation Scheme.

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