Analysis of Mobile WiMAX 802.16e Physical Layer Performance for Multimedia Communication

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ABSTRACT
WiMAX technology enables ubiquitous delivery of wireless broadband service for fixed and mobile users, the scalable architecture, high data throughput and low cost deployment make Mobile WiMAX a leading solution for wireless broadband services. The Mobile WiMAX Air Interface adopts Orthogonal Frequency Division Multiple Access (OFDMA) for improved multi-path performance in non-line-of-sight environments In this paper we are evaluating the performance of mobile WiMAX 802.16e physical layer for different data types like,,Image,Speech,Text,Random data using different modulation schemes like BPSK,QPSK,16-QAM,64-QAM with varying data rates and SNR.

Keywords
Mobile WiMAX, RS Encoder, Interleaver, OFDM, BPSK, QPSK,AWGN Channel,64-QAM,Datarate, SNR,Randomizer.

1. INTRODUCTION
Many older cable networks do not have return channel which will prevent to offer internet access and many commercial areas are often not covered by cable network. But with BWA (Broadband Wireless Access),this difficulties can be overcome. IEEE. 802.16 is a standard for BWA and its associated industry consortium[1], Worldwide Interoperability for Microwave Access (WiMAX) forum promise to offer high data rate over large areas to a large number of users where broadband is unavailable. The WiMAX technology based on the IEEE 802.16-2004 Air Interface Standard is rapidly proving itself as a technology that will play a key role in fixed broadband wireless metropolitan area networks. The first version of the IEEE 802.16 standard operates in the 10–66GHz frequency band and requires line of sight (LOS) towers. Later the standard extended its operation through different PHY specification to 2-11 GHz frequency band enabling non line of sight (NLOS) connections, which require techniques that efficiently mitigate the impairment of fading and multipath.. Because of its wireless nature, it can be faster to deploy, easier to scale and more flexible, thereby giving it the potential to serve customers not served or not satisfied by their wired broadband alternatives. Some of the examples of BWA are WiMAX, Wi-Fi, etc.Wi-Fi is a local area network technology that was originally thought to replace the thousands of miles of LAN cables. WiFi has been viewed as complementary to 3G and other mobile standards as it has worked to enhance mobile services offered by operators. Its coverage is not as great as that of 3G, but it gives a much higher transmission rate than mobile technology. Mobile WiMAX as IEEE 802.16e supports mobility, so the mobile user in the business areas can access high speed services through their IEEE 802.16/WiMAX enabled handheld devices like PDA, Pocket PC and smart phone. WiMAX can use base stations to provide high speed data connections that can be used for voice, data and video services to distances of over 30 km.The IEEE 802.16e version of the standard has been optimized for mobile radio channels. This uses Scalable OFDM Access and provides support for handoffs and roaming. IEEE 802.16e based network is also capable to provide fixed access. The Mobile WiMAX profiles will cover 5, 7, 8.75, and 10 MHz channel bandwidths for licensed worldwide spectrum allocations in the 2.3 GHz, 2.5 GHz, 3.3 GHz and 3.5 GHz frequency bands. Characteristics of IEEE 802.16e are Advanced antenna diversity schemes, hybrid automatic repeat-request (HARQ),Adaptive Antenna Systems (AAS), MIMO technology, denser sub-channelization, thereby improving indoor penetration, introducing Turbo Coding and Low-Density Parity Check (LDPC),introducing downlink sub-channelization, allowing administrators to trade coverage for capacity or vice versa ,adding an extra QoS class for VoIP applications.

2. WiMAX PHYSICAL LAYER DESCRIPTION.
WiMAX system relies on a physical (PHY) layer and appropriate MAC (Media Acess Controller) layer to support all demands driven by the target applications. The IEEE 802.16 standard supports multiple physical specifications due to its modular nature. The first version of the standard supported only single carrier modulation. Since that time, OFDM and scalable OFDMA have been included to operate in NLOS environment and to provide mobility. OFDMA employed in mobile WiMAX is scalable in the sense that by flexibly adjusting FFT sizes and channel bandwidths with fixed symbol duration and subcarrier spacing, it can address various spectrum needs in different regional regulations in a cost-competitive manner. The standard has also been extended for use in below 11 GHz frequency bands along with initially supported 10-66 GHz bands. Frequency band 2-11 GHz are licensed and non licensed exempted, additional physical functionality supports have been introduced to operate in Near LOS and NLOS environment and to mitigate the effect of multipath propagation. In 10-66 GHz frequency band due to shorter wave length, line of sight operation is required and as a result the effect of multipath propagation is neglected. The standard promises to provide data rates up to 120 Mb/s[2]. The abundant availability of bandwidth is also another reason to operate in this frequency range. The simple transceiver structure of OFDMA also enables feasible implementation of advanced antenna techniques such as MIMO with reasonable complexity.

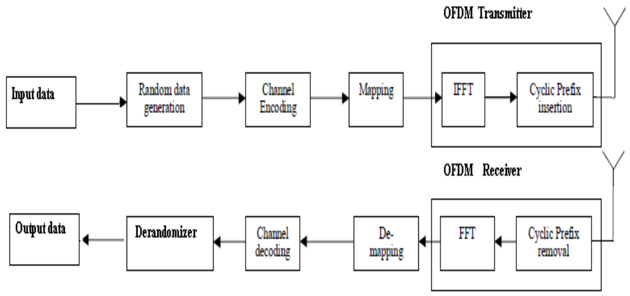

Figure 1: Physical layer setup of mobile WiMAX IEEE 802.16e transmission and reception

2.1 Physical Layer Set Up

Figure 1, depicts the structure of the baseband part of the implemented transmitter and receiver[11]. This structure corresponds to the physical layer of the IEEE 802.16e Mobile WiMAX. In this setup, we have just implemented the mandatory features of the specification, while leaving the implementation of optional features for future work. Channel coding part is composed of three steps randomization, Forward Error Correction (FEC) and interleaving. FEC is done in two phases through the outer ReedSolomon (RS) and inner Convolutional Code (CC). The complementary operations are applied in the reverse order at channel decoding in the receiver end.

2.1.1 Transmitter

We have different input data forms like text, image, and speech which are converted from their actual form of representation in to their binary values for example, text data represented in terms of ASCII values are converted in to corresponding binary values, image data represented in gray scale values are converted in to their binary values, for speech data the audio files (like .wav), are converted in to their corresponding binary values. Followed by the input data we have randomizer which performs randomization of input data on each burst on each allocation to avoid long sequence of continuous ones and zeros. This is implemented with a Pseudo Random Binary Sequence (PRBS) generator which uses a 15 stage shift register with a generator polynomial of $1+x^{14}+x^{15}$ with XOR gates in feedback configuration (figure 2).

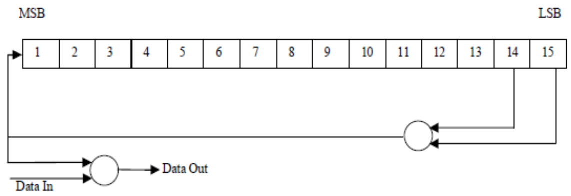

Figure 2. PRBS generator

2.1.2 Channel Encoding

Channel encoder comprises of RS Encoder and Convolution Encoder followed by Interleaver (figure 3). The implemented RS encoder is derived from a systematic RS (N=255, K=239, T=8) code using GF (2^8). The following polynomials are used for code generator and field generator:

$$G(x) = (x+\lambda^0)(x+\lambda^0)\ldots(x+\lambda^{2T1}), \quad \lambda = 02\text{hex} \qquad (1)$$

$$p(x) = x^8 + x^4 + x^3 + x^2 + 1 \qquad (2)$$

The encoder support shortened and punctured code to facilitate variable block sizes and variable error correction capability. A shortened block of k´ bytes is obtained through adding 239k ´ zero bytes before the data block and after encoding, these 239k ´ zero bytes are discarded. To obtain the punctured pattern to permit T´ bytes to be corrected, the first 2T´ of the 16 parity bytes has been retained[5].

The outer RS encoded block is fed to inner binary convolutional encoder symbol[11]. In IEEE 802.16, the interleaver is defined by two step permutation. The first ensures that adjacent coded bits are mapped onto nonadjacent subcarriers. The second permutation ensures that adjacent coded bits are mapped alternately onto less or more significant bits of the constellation, thus avoiding long runs of unreliable bits. At the receiver (figure 1) the channel decoder performs the reverse operation of that of channel encoder (figure 3).

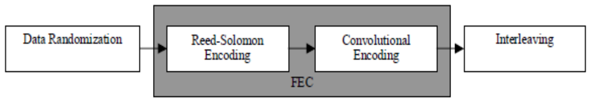

Figure 3. Channel encoder

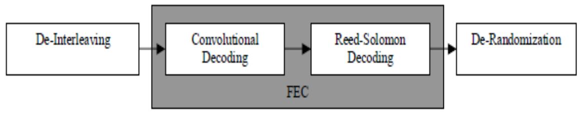

Figure 4. Channel decoder

2.2 OFDM

OFDM is a digital modulation scheme that is used in both wireline and wireless systems to transmit numerous modulated carriers that are mathematically orthogonal to each other[10]. In other words, the subcarriers ideally exhibit zero mutual inference.OFDM is similar to frequency division multiplexing (FDM) in that it multiplexes carriers across frequency, but with two important differences. First, FDM is the traditional method to separate signals intended for different radios. When it is used to allow multiple users to share the same channel it is called frequency-division multiple access (FDMA). OFDM is often used for multiple access as well, but the primary motivation for using OFDM is to increase performance over using a single carrier modulation. Secondly, OFDM differs from traditional FDM in its subcarrier spacing. In OFDM, the carriers overlap to a great degree, each carrier is ideally represented mathematically by a sin(x)/x pulse, which have nulls at a spacing of 1/Ts where Ts is the symbol time of each subcarrier. In OFDM, the carrier spacing is 1/Ts, which is precisely the location of nulls in a sin(x)/x pulse and thus, ideally, there is zero inter-carrier interference (ICI). This is a secondary advantage of OFDM, in that it is more spectrally efficient than standard FDM. ISI and frequency-selective fading are the crucial bottlenecks for very high data rate systems using single carrier modulation. It can be compensated for using complex adaptive multi-tap equalizers and error control coding, but there comes a certain point at which the cost of combating ISI and frequency-selective fading outweigh the benefits of using a single-carrier modulation technique. An OFDM system can alleviate the ISI and frequency selective fading problem without the need for complex equalization. The primary advantage of OFDM is that by using multiple distinct subcarriers, a frequency selective fading channel can be transformed into multiple approximately flat-fading channels.

At baseband, an OFDM signal can be represented by a sum of modulated complex exponentials,

$S(t)=\sum_{k=0}^{N-1} X(k)e^{j2\pi k\Delta ft}$ (3)

Where, X(k) is a complex number representing a BPSK, QPSK, or QAM baseband symbol modulating the kth subcarrier and ,Δf is the subcarrier spacing.
If this signal is sampled

$S(nTs)=\sum_{k=0}^{N-1} X(k)e^{j2\pi k\Delta fnTs}$ (4)

then the sampled signal is exactly equivalent to an inverse N-point discrete Fourier transform (DFT),

$X(l) =\sum_{l=0}^{N-1} x(n)e^{(-\frac{j2\pi nl}{N})}$ l=0…..N-1 (5)

$x(n)=1/N \sum_{n=0}^{N-1} X(l)e^{(\frac{j2\pi nl}{N})}$ n=0…..N-1 (6)

The Fast Fourier Transform (FFT) is simply a computationally efficient implementation of the DFT. The IFFT and FFT are the core modulation and demodulation operations used in OFDM. Furthermore, the introduction of the cyclic prefix (CP) can completely eliminate Inter-Symbol Interference (ISI) as long as the CP duration is longer than the channel delay spread. The CP is typically a repetition of the last samples of data portion of the block that is appended to the beginning of the data payload. The CP prevents inter-block interference and makes the channel appear circular and permits low-complexity frequency domain equalization. A perceived drawback of CP is that it introduces overhead, which effectively reduces bandwidth efficiency. While the CP does reduce bandwidth efficiency somewhat, the impact of the CP is similar to the "roll-off factor" in raised-cosine filtered single-carrier systems. Since OFDM has a very sharp, almost "brick-wall" spectrum, a large fraction of the allocated channel bandwidth can be utilized for data transmission, which helps to moderate the loss in efficiency due to the cyclic prefix. In this paper we consider the channel to be AWGN (additive gaussian noise channel) whose power spectral density is constant for infinite bandwidth.

2.3 AWGN CHANNEL

Additive white Gaussian noise (AWGN) is a channel model in which the only impairment to communication is a linear addition of wideband or white noise with a constant spectral density (expressed as watts per hertz of bandwidth) and a Gaussian distribution of amplitude[7]. The model does not account for fading, frequency selectivity, interference, nonlinearity or dispersion.However, it produces simple and tractable mathematical models which are useful forgaining insight into the underlying behavior of a system before these other phenomena are considered.Wideband Gaussian noise comes from many natural sources, such as the thermal vibrations of atoms in conductors, shot noise, black body radiation from the earth and other warm objects, and from celestial sources such as the Sun.The AWGN channel is a good model for many satellite and deep space communication links. It is not a good model for most terrestrial links because of multipath, terrain blocking, interference, etc.

3.SIMULATION RESULTS

In this section we will compare and analyse the performance of different data forms like Random data,Text data,Image data,Speech data,with various modulation schemes ,data rates and SNR .

As seen from figure 6 and 7, when we transmit an image at 30 db ,approximately same image is received,when the transmitting SNR is 10db much of distortions are seen .So transmitting at higher SNRs will give better performance.

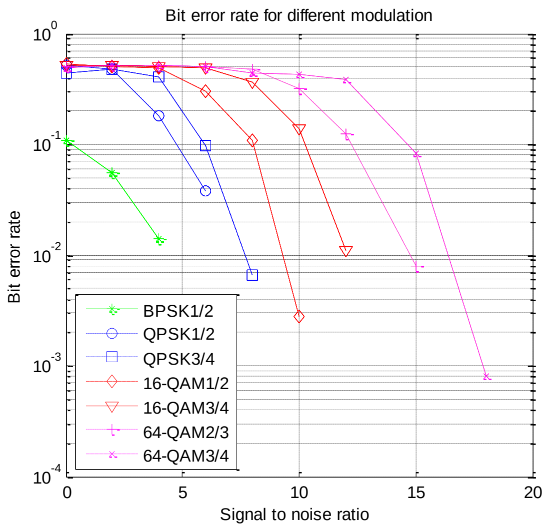

Figure 5 :Bit Error Rate plot for different modulation technique at various data rates.

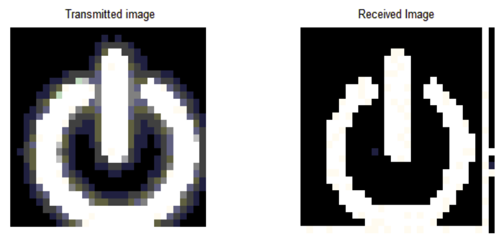

Figure 6: Simulation run for Image data recovery for SNR 30 db.

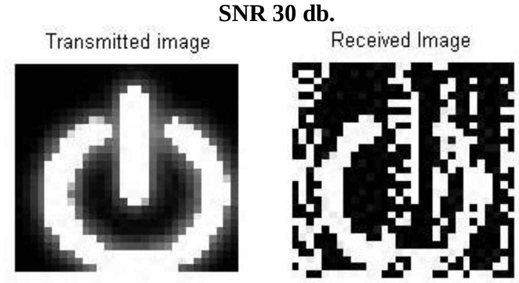

Figure7:Simulation run for Image recovery for SNR 10db.

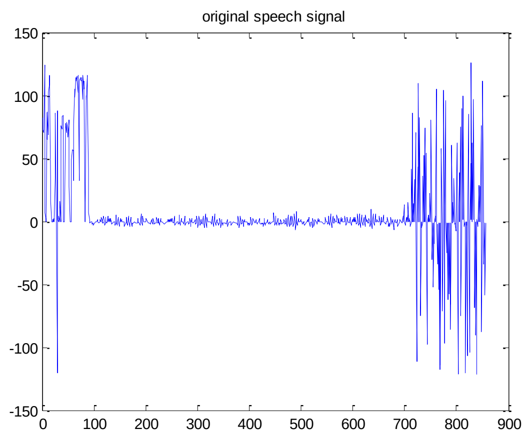

Figure 8: Simulation run for speech data recovery for SNR 30db

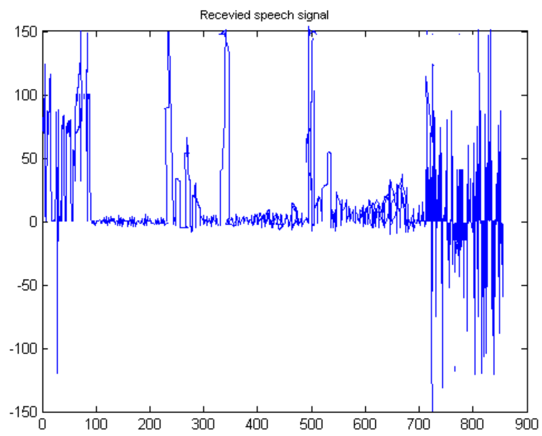

Figure 9: Simulation run for speech data recovery for SNR 15 db

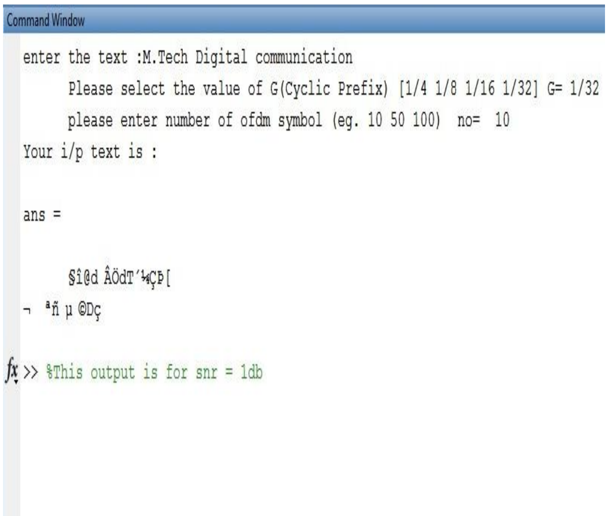

Figure 10:Simulation result for text data recovery for SNR=3db

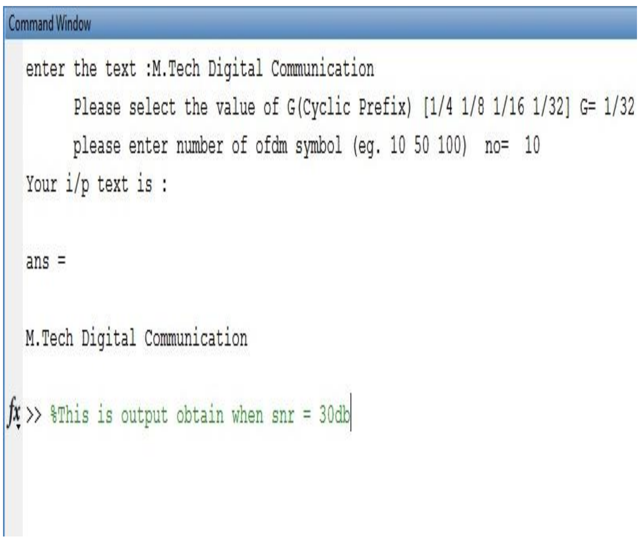

Figure 11:Simulation result for text data recovery for SNR=15db

4. CONCLUSION AND FUTURE SCOPE

The attributes and performance capability of Mobile WiMAX makes it a compelling solution for high performance, low cost broadband wireless services. Mobile WiMAX is on a path to address a global market through a common wide area broadband radio access technology and flexible network architecture. From the simulation result we conclude that as the SNR increases the performance of the system. whereas in the speech signal we can notice that the received signal is not the exact replica of the transmitted signal which is due to the limitation of bandwidth in the simulation software.In this paper we have used singal transmitting and receiving antenna whereas in future we can extend the work by incorporating various diversity techniques like SIMO, MISO,MIMO and improve the performance.

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