BER Performance & Spectral Efficiency of Various Channels in BWA

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Abstract:

This paper is the implementation and comparison of the IEEE 802.16e OFDM Physical layer using MATLAB in order to evaluate the BER and S/N performance under Different channels model. To keep matters simple we avoided doing oversampling of the data samples before using the channel model. On the receiver side, we have assumed perfect channel estimation to avoid the effect of any particular estimation method on the simulation results, though insertion of pilot subcarriers in the OFDM symbols makes use of any comb type estimator possible. The developed simulator can be easily modified to implement new features in order to enhance the PHY layer performance. The performance evaluation method was mainly concentrated on the effect of channel coding on the Physical layer. The overall system performance was also evaluated under different channel conditions. A key performance measure of a wireless communication system is the BER and S/N.

INTRODUCTION

Before some time, we were purely dependent on analog system. Both the sources and transmission system were on analog format but the advancement of technology made it possible to transmit data in digital form. Along with those, the computer was getting faster to the fastest, the data payload capacity and transmission rate increased from kilobit to megabit and megabit to gigabit. From wire to wireless concept emerged and after researching and investing so much money, engineers became successful to invent wireless transmitter to transmit data. Applications like voice, Internet access, instant messaging, SMS, paging, file transferring, video conferencing, gaming and entertainment etc became a part of life. Cellular phone systems, WLAN, wide-area wireless data systems, ad-hoc wireless networks and satellite systems etc are wireless communication. All emerged based on wirelesstechnology to provide higher throughput, immense mobility, longer range, robust backbone to thereat. The vision extended a bit more by the engineers to provide smooth transmission of multimedia anywhere on the globe through variety of applications and devices leading a new concept of wireless communication which is cheap and flexible to implement even in odd environment.

This is a fact that, Wireless Broadband Access (BWA) via DSL, T1-line or cable infrastructure is not available especially in rural areas. The DSL can covers only up to near about 18,000 feet (3 miles), this means that many urban, suburban, and rural areas may not served. The Wi-Fi standard broadband connection may solve this problem a bit but not possible in everywhere due to coverage limitations. But The Metropolitan-Area Wireless standard which is called WiMAX can solve these limitations. The wireless broadband connection is much easier to deploy, have long range of coverage, easier to access and more flexible. This connectivity is really important for developing countries and IEEE 802.16 family helps to solve the last mile connectivity problems with BWA connectivity. The structure of the baseband part of the implemented transmitter and receiver is shown in Figure 1. 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 Reed Solomon (RS) and inner Convolution Code (CC). The complementary operations are applied in the reverse order at channel decoding in the receiver end. The complete channel encoding setup is shown in Figure 2 while corresponding decoding setup is shown in Figure 3.

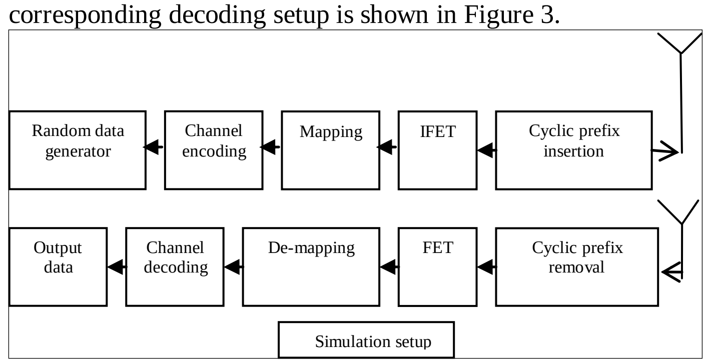

FIG. 1

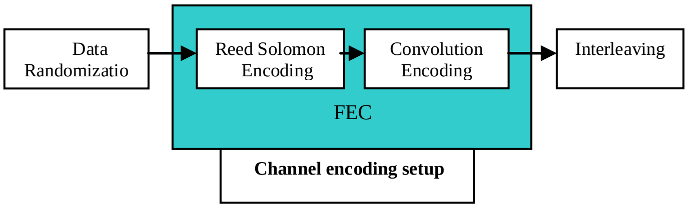

FIG. 2

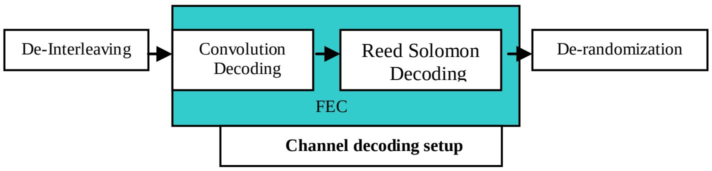

FIG. 3

OFDM SYSTEM IMPLEMENTATION

The digital implementation of OFDM system is achieved through the mathematical operations called Discrete Fourier Transform (DFT) and its counterpart Inverse Discrete Fourier Transform (IDFT). These two operations are extensively used for transforming data between the time domain and frequency domain. In case of OFDM, these transforms can be seen as mapping data onto orthogonal sub carriers.

In order to perform frequency domain data into time domain data, IDFT correlates the frequency domain input data with its orthogonal basis functions, which are sinusoids at certain frequencies. In other ways, this correlation is equivalent to mapping the input data onto the sinusoidal basis functions. In practice, OFDM systems employ combination of fast Fourier transform (FFT) and Inverse fast fourier transform (IFFT) blocks which are mathematical equivalent version of the DFT and IDFT.

At the transmitter side, an OFDM system treats the source symbols as though they are in the frequency domain. These symbols are feed to an IFFT block which brings the signal into the time domain. If the N numbers of sub carriers are chosen for the system, the basis functions for the IFFT are N orthogonal sinusoids of distinct frequency and IFFT receive N symbols at a time. Each of N complex valued input symbols determines both the amplitude and phase of the sinusoid for that sub carrier. The output of the IFFT is the summation of all N sinusoids and makes up a single OFDM symbol. The length of the OFDM symbol is NT where T is the IFFT input symbol period. In this way, IFFT block provides a simple way to modulate data onto N orthogonal sub carriers.

Cyclic Prefix Addition

The sub carrier orthogonally of an OFDM system can be jeopardized when passes through a multipath channel. CP is used to combat ISI and ICI introduced by the multipath channel. CP is a copy of the last part of OFDM symbol which is appended to the front of transmitted OFDM symbol. The length of the CP (*Tg*) must be chosen as longer than the maximum delay spread of the target multipath environment. Fig 3.6 depicts the benefits arise from CP addition, certain position within the cyclic prefix is chosen as the sampling starting point at the receiver, which satisfies the criteria

$$\tau_{max} \le T_x \le T_g$$

Where τ_{max} is the maximum multipath spread. Once the above condition is satisfied, there is no ISI since the previous symbol will only have effect over samples within [0, τ_{max} And it is also clear from the figure that sampling period starting from *Tx* will encompass the contribution from all the multipath components so that all the samples experience the same channel and there is no ICI.

System Design Parameters

The design parameters are derived according to the system requirements. The design parameters for an OFDM system are as follows

- Number of sub carriers: We stated earlier that the selection of large number of sub carriers will help to combat multipath effects. But, at the same time, this will increase the synchronization complexity at the receiver side.
- Symbol duration and CP length: A perfect choice of ratio between the CP length and symbol duration should be selected, so that multipath effects are combated and not significant amount bandwidth is lost due to CP.
- Sub carrier spacing: Sub carrier spacing will be depending on available bandwidth and number of sub carriers used. But, this must be chosen at a level so that synchronization is achievable.
- Modulation type per sub carrier: The performance requirement will decide the selection of modulation scheme. Adaptive modulation can be used to support the performance requirements in changing environment.
- FEC coding: A suitable selection of FEC coding will make sure the robustness of the channel to the random errors.

CHANNEL MODEL

In order to evaluate the performance of the developed communication system, an accurate description of the wireless channel is required to address its propagation environment. The radio architecture of a communication system plays very significant role in the modeling of a channel. The wireless channel is characterized by:

- Path loss (including shadowing)
- Multipath delay spread
- Fading characteristics

- Doppler spread
- Co channel and adjacent channel interference

All the model parameters are random in nature and only a statistical characterization of them is possible, i.e. in terms of the mean and variance value. They are dependent upon terrain, tree density, antenna height and beam width, wind speed and time of the year.

Path loss:

Path loss is affected by several factors such as terrain contours, different environments (urban or rural, vegetation and foliage), propagation medium (dry or moist air), the distance between the transmitter and the receiver, the height and location of their antennas, etc. It has only impact on the link budget [11], that is why we will not consider it in our channel modeling.

Multipath Delay Spread:

Due to the non line of sight (NLOS) propagation nature of the Wireless MAN OFDM, we have to address multipath delay spread in our channel model. It results due to the scattering nature of the environment. Delay spread is a parameter used to signify the effect of multipath propagation. It depends on the terrain, distance, antenna directivity and other factors. The rms delay spread value can span from tens of nano seconds to microseconds.

Fading characteristics:

In a multipath propagation environment, the received signal experiences fluctuation in its amplitude, phase and angle of arrival. The effect is described by the term multipath fading. Due to fixed deployment of transmit and receive antenna, we just have to address the small-scale fading in our channel model. Small-scale fading refers to the dramatic changes in signal amplitude and phase that can be experienced as a result of small changes (as small as a half wavelength) in the spatial positioning between a receiver and
a transmitter.

Small-scale fading is called Rayleigh fading if there are multiple reflective paths that are large in number and there is no lineofsight signal component; the envelope of such a received signal is statistically described by a Rayleigh pdf. When a dominant non fading signal component is present, such as a lineofsight propagation path, the small-scale fading envelope is described by a Rician pdf [14]. In other words, the small-scale fading statistics are said to be Rayleigh whenever the lineofsight path is blocked, and Rician otherwise. In our channel model we will consider Rician fading distribution. The key parameter of this distribution is the K factor, defined as the ratio of the direct component power and
the scatter component power.

Doppler Spread

In fixed wireless access, a Doppler frequency shift is induced on the signal due to movement of the objects in the environment. Doppler spectrum of fixed wireless channel differs from that of mobile channel [12]. It is found that the doppler is in the 0.12Hz frequency range for fixed wireless channel. The shape of the spectrum is also different than the classical Jake's spectrum for mobile channel. Along with the above channel parameters, coherence distance, co channel interference, antenna gain reduction factor should be addressed for channel modeling. Having the primary requirements for our channel model, we have two options to go with. Either we can use mathematical model for each of them or we can choose an empirical model that care of the above requirements. We chose the AWGN, Rayleigh and Nakagami channel models for our simulation.

CHANNEL MODULE

In this section we are presenting the wireless channels.

- **Additive White Gaussian Noise (AWGN)**
- **Rayleigh Fading Channel**
- **Nakagami fading channel**

In wireless communication, the data are transmitting through the wireless channel with respective bandwidth to achieve higher data rate and maintain quality of service. The transmitting data has to take environmental challenges when it is on air with against unexpected noise. That’s why data has to encounter various effects like multipath delay spread, fading, path loss, Doppler spread and co-channel interference. These environmental effects play the significant role in WiMAX Technology. To implement an efficient wireless channel have to keep in mind the above fact.

Additive White Gaussian Noise (AWGN)

This is a noise channel. This channel effects on the transmitted signals when signals passes through the channel. This noise channel model is good for satellite and deep space communication but not in terrestrial communication because of multipath, terrain blocking and interference. AWGN is used to simulate background noise of channel. The mathematical expression as in received signal $r(t) = s(t) + n(t)$ is shown in figure 5.1 which passed through the AWGN channel where $s(t)$ is transmitted signal and $n(t)$ is background noise.

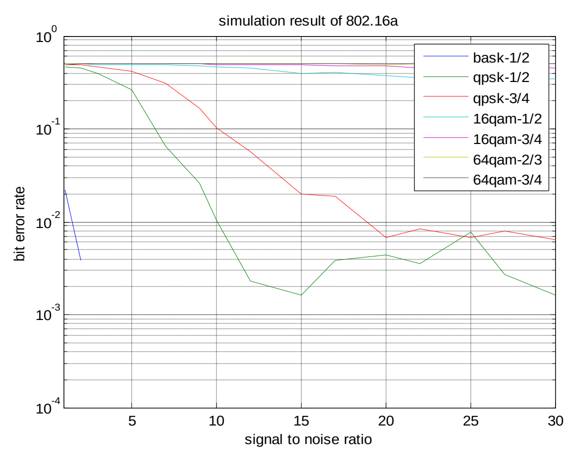

FIG.4 AWGN CHANNEL (G=1/8, OFDM SYMBOL=50)

Rayleigh Fading Channel

Rayleigh Fading is one kind of statistical model which propagates the environment of radio signal. According to Rayleigh distribution magnitude of a signal which has passed though the communication channel and varies randomly. Rayleigh Fading works as a reasonable model when many objects in environment which scatter radio signal before arriving of receiver. When there is no propagation dominant during line of sight between transmitter and receiver on that time Rayleigh Fading is most applicable. On the other hand Rician Fading is more applicable than Rayleigh Fading when there is dominant line of sight. During our simulation we used Rayleigh Fading when we simulate the performance of Bit Error Rate Vs Signal to Noise Ratio.

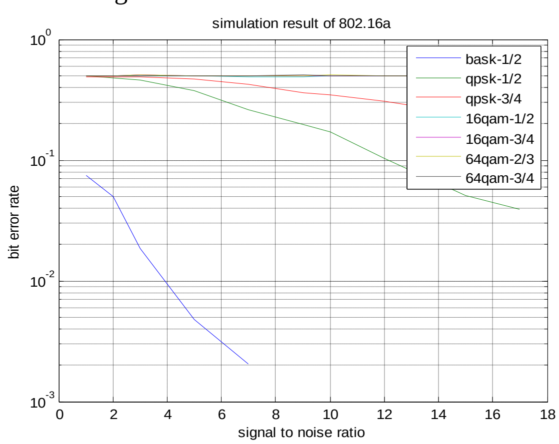

FIG.5 RAYLEIGH FADING CHANNEL (G=1/8, OFDM SYMBOL=50)

Nakagami Fading Channel

The capacity of Nakagami multipath fading (NMF) channels with an average power constraint for three power and rate adaptation policies. We obtain closed-form solutions for NMF channel capacity for each power and rate adaptation strategy. Results show that rate adaptation is the key to increasing link spectral efficiency. We then analyze the performance of practical constant-power variable-rate M-QAM schemes over NMF channels. We obtain closed-form expressions for the outage probability, spectral efficiency and average bit-error-rate (BER) assuming perfect channel estimation and negligible time delay between channel estimation and signal set adaptation. We also analyze the impact of time delay on the BER of adaptive M-QAM.

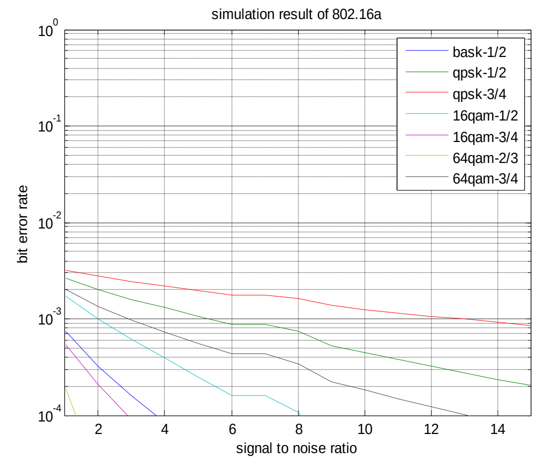

FIG.6

NAKAGAMI CHANNEL (G=1/8, OFDM SYMBOL=50)

Conclusion:

We put some values of cyclic prefix (G) and OFDM Symbol in our simulation to find out Bit Error Rate against Signal-to-Noise Ratio for all modulation techniques using AWGN, Rayleigh Fading and Nakagami channel respectively. The results are shown in figures above. An interesting simulation of FEC is that without the Reed Solomon encoder, how much performance degradation will appear in this design. The performance improvement due to RS codec on different modulation and coding profiles has been observed on channel model.

We conclude that for nakagami channel as the SNR increase, the BER is more decreased than other channels means if we increase the SNR for different modulation techniques we received the less noise free signal as compared to other channel for these G and OFDM Symbol values.

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