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Comparative Study of WiMAX and LTE

Sapinder Kaur
M.Tech Student, Computer Science and Engineering
Kurukashetra University Kurukashetra, India

Abstract:
The Worldwide interoperability for microwave access (WiMAX) based on IEEE 802.16 and Long Term Evolution (LTE),are the most emerging broadband wireless technologies and is viable alternative to traditional wired broadband techniques due to its high resource utilization, easy implementation and low cost. A simulator for the WiMAX and LTE physical layer is presented in this paper. The main objective of this paper is to analyze and compare the performance of WiMAX and LTE physical layer under different modulation schemes based on SNR and BER results are presented with different digital modulation schemes in AWGN channel.

Keywords*: WiMAX, IEEE, LTE, 3GPP, Physical layer, BER*

1. Introduction

WiMAX (also known as IEEE 802.16) is a wireless digital communications system that is intended for wireless "metropolitan area networks" (WMAN). It can provide broadband wireless access (BWA) up to 30 miles (50 km) for fixed stations, and 3 - 10 miles (5 - 15 km) for mobile stations. In contrast, the WiFi/802.11 wireless local area network standard is limited in most cases to only 100 - 300 feet (30 - 100m). WiMAX can be used for wireless networking in much the same way as the Wi-Fi protocol. WiMAX is a second-generation protocol that allows for more efficient bandwidth use, interference avoidance, and is intended to allow higher data rates over longer distances. The IEEE 802.16 group was formed in 1998 to develop an air-interface standard for wireless broadband. The group's initial focus was the development of a LOS-based point-to-multipoint wireless broadband system for operation in the 10GHz–66GHz millimeter wave band. The resulting standard—the original 802.16 standard, completed in December 2001—was based on a single-carrier physical (PHY) layer with a burst time division multiplexed (TDM) MAC layer.

The IEEE 802.16 group subsequently produced 802.16a, an amendment to the standard, to include NLOS applications in the 2GHz–11GHz band, using an orthogonal frequency division multiplexing (OFDM)-based physical layer [1]. LTE is Wireless data communication standard was developed by 3GPP and was first commercialized by Telia Sonera in 2009 named as 4G LTE. LTE is the evolution of the GSM/UMTS standards. Goals of LTE was to increase the capacity, speed of wireless data networks using DSP technique, redesign and simplification of the network architecture, provide improved data rate, cell edge throughput, power consumption, latency, etc. The LTE wireless interface is incompatible with 2G and 3G networks; a separate wireless spectrum is required to implement LTE.

Rest of this paper is organized as follows: Section II gives a brief overview about different WiMAX and LTE standards. WiMAX and LTE features are discussed in Section III. In Section IV detailed study about the WiMAX and LTE physical layer is presented. Section V shows our simulation results. Finally conclusion and future work are presented in section VI.

2. WiMAX and LTE Features

WiMAX is a revolutionary wireless technology that has a rich set of technological improvements compared to the other broadband access technology.

The set of features of WiMAX is listed below:

OFDM based physical layer: WiMAX is based on orthogonal frequency division multiplexing that offers multipath resistance and allow NLOS communication.

High data rate: WiMAX can support very high peak data rate which is as high as 74 mbps.

Quality of service: WiMAX MAC layer is responsible for QoS. WiMAX MAC layer support real-time, non real time and best effort data traffic and its high data rate, sub channelization, and flexible scheduling improve the QoS.

Flexible architecture: WiMAX architecture is very flexible. It can support point to point and point to multipoint connection according to its requirements. It also supports IP-based architecture that is easily converge with other networks and takes advantage of application development from the existing IP based application.

TDD and FDD support: WiMAX support both time division duplex and frequency division duplex which helps in spectrum management, transceiver design and low cost system development.

Adaptive modulation and coding: Adaptive modulation and coding scheme can connect more users. It is a technique to maximize throughput and able to setup connection in a low signal strength and noisy environment.

Mobility support: WiMAX offer optimized handover which support full mobility application such as voice over internet protocol (VOIP). It has also the power saving mechanism which increases the battery life of handheld devices.

Scalability: WiMAX offer scalable network architecture that support user roaming in different networks. It also enhances the broadband access capability.

Strong Security: WiMAX support extensible security feature for reliable data exchange. It uses Advanced Encryption Standard (AES) encryption for secure transmission and for data integrity, it use data authentication mechanism.

LTE is advanced and latest technology adopted by most of the service providers worldwide.

The set of features of WiMAX are listed below:

Download and Upload rates: Depending upon the user equipment category of 4x4 antennas of 20 MHz spectrum, Download rates and upload rates up to 299.6 Mbits/s and 75.4 Mbits/s respectively. Terminals are able to process 20 MHz bandwidth with five terminal classes from voice centric class to high end terminal which supports peak data rates.

*Data transfer latencies:*LTE provide lower data transfer latencies e.g. in optimal conditions with small IP packetslatency is sub-5 ms, LTE have lower latencies for handover and connection setup time then earlier radio access technologies.

Mobility Support: It has improved the mobility support for terminals with moving speed up to 350 km/h or 500 km/h depending upon frequency band.

Downlinks/Uplinks: To save power it uses OFDMA for downlinks and SC-FDMA for uplinks.

FDD and TDD support: LTE supports FDD, TDD, and half-duplex FDD with same radio technology.

Supporting frequency bands: LTE currently used by IMT systems by ITU-R, but it can support all frequency bands.

Spectrum flexibility: LTE increased standardized spectrum flexibility: 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz wide cells.

Cell radius coverage support: LTE supports cell radius size from 10 ms up to 100 kms. For large distant rural areas with lower frequency bands, 5km is optimal cell size; 30 km is reasonable performance, and 30 - 100 km cell size support acceptable performance. Higher frequency bands (e.g. 2.6 BHz) are supported into urban areas for high speed mobile broadband, but cell radius is limited to 1 km or less in this cases.Higher performance can be delivered with lower coverage area, but lower frequencies increase the coverage area and reduce the bandwidth.

Active users support: On every 5 MHz cell it supports at least 200 active users.

Architecture simplification: Architecture is simplified where E-UTRAN is composed only eNode base station.

Support for inter-operation and co-existence: It provides support for inter-operation and co-existence with legacy standards (e.g. GSM/EDGE, UMTS and CDMA2000). Compatibility of LTE user with existing networks provides flexibility to users to make calls or access data even if coverage of LTE is not available.

Packet switched radio interface: The route towards fast packet scheduling over the radio interface was already opened by HSDPA, which allowed the transmission of short packets having duration of the same order of magnitude as the coherence time of the fast fading channel.

Support for MBSFN: Support for MBSFN (Multicast-Broadcast Single Frequency Network) using which can provide services like Mobile TV using the LTE infrastructure.

3. WiMAX and LTE Physical Layer

Physical layer is the most important layer. The role of the physical layer is to encode the binary digits that represent MAC frames into signal and transmit and receive these signals across the communication media. The WiMAX and LTE physical layer is based on OFDM which is used to enable high speed data, video and multimedia used by a variety of commercial application.

3.1. WiMAX Physical Layer

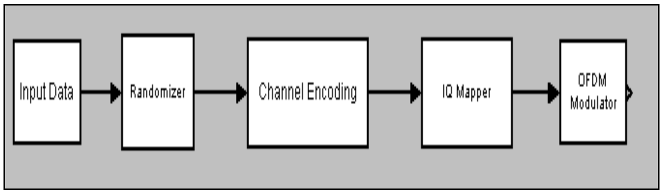

Figure 1: WiMAX Physical Layer (Transmitter Side)

3.1.1. Randomizer

Randomization is the first process carried out in the physical layer after the data packet is received from the higher layers. The randomization process is used to minimize the possibility of transmissions of non-modulated subcarriers. The process of randomization is performed on each burst of data on the downlink and uplink, and on each allocation of a data block. The stream of packets is randomized using a pseudo-random binary sequence (PRBS) generator. The randomized bits are the modulo-2 summation of the data with the PRBS output.

3.1.2. Channel Encoding

The encoding process consists of a concatenation of an outer Reed-Solomon (RS) code and an inner convolutional code (CC) as a FEC scheme. That means that first data passes in block format through the RS encoder, and then, it goes across the convolutional encoder. The last part of the encoder is a process of interleaving to avoid long error bursts. Now we consider various blocks of channel encoder in detail.

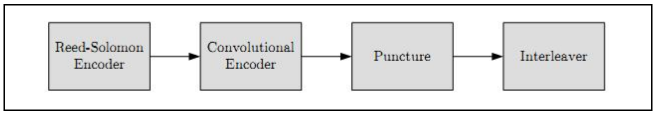

Figure 2 Encoding Process in WiMAX

3.1.2.1. RS Encoder

A Reed-Solomon code is specified as RS (n, k,t) with l-bit symbols. This means that the encoder takes k data symbols of l bits each and adds 2t parity symbols to construct an n-symbol codeword. Thus, n, k and t can be defined as:

- n: number of bytes after encoding,
- k: number of data bytes before encoding,
- t: number of data bytes that can be corrected.

The error correction ability of any RS code is determined by (n − k), the measure of redundancy in the block. If the location of the erroneous symbols is not known in advance, then a Reed-Solomon code can correct up to t symbols, where t can be expressed as $t = (n - k)/2$.

3.1.2.2. Convolutional encoder

After the RS encoding process, the data bits are further encoded by a binary convolutional encoder, which has a native rate of 1/2andaconstraintlengthof7.A convolutional code is a type of FEC code that is specified by CC (m, n, k), in which each m-bit information symbol to be encoded is transformed into an n-bit symbol, where m/n is the code rate (n> m) and the transformation is a function of the last k information symbols, where k is the constraint length of the code [5].

3.1.2.3. Puncturing process

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.

3.1.2.4. Interleaver

Interleaving does not change the state of the bits but it works on the position of bits. Interleaving is done by spreading the coded symbols in time before transmission. The incoming data into the inter-leaver is randomized in two permutations. First permutation ensures that adjacent bits are mapped onto non-adjacent subcarriers. The second permutation maps the adjacent coded bits onto less or more significant bits of constellation thus avoiding long runs of less reliable bits. The block inter-leaverinter leaves all encoded data bits with a block size corresponding to the number of coded bits per OFDM symbol.

3.1.3. IQ Mapper

Once the signal has be encoded, it enters the modulation block. All wireless communication systems use a modulation scheme to map coded bits to a form that can be electively transmitted over the communication channel. Thus, the bits are mapped to a subcarrier amplitude and phase, which is represented by a complex in-phase and quadrature-phase (IQ) vector. The IQ plot for a modulationschemeshowsthetransmittedvectorforalldatawordcombinations. QPSK, 16QAM and 64QAM modulations are supported by the system.

- QPSK This is also known as four-level PSK where each element represents more than one bit. Each symbol contains two bits and it uses the phase shift of π/2, means 90º instead of shifting the phase 180º.
- 16-QAM This is called 16-states Quadrature Amplitude Modulation which means four different amplitude levels would be used and the combined stream would be one of 16 = 4 * 4 states. In this mechanism, each symbol represents 4 bits [6].
- 64-QAM This is same as 16 QAM except it has 64-states where each symbol represents six bits (2^6=64). It is a complex modulation techniques but with greater efficiency [6]. The total bandwidth increases according to the increasing number of states for each symbol. Mobile WiMAX uses this higher modulation technique when the link condition is high.

The use of variable or adaptive modulations to increase capacity is a trend also observed in other recently developed mobile phone and data standards like WCDMA [7], [8]. The constellation mapped data are assigned to all allocated data subcarriers of the OFDM symbolinorder of increasing frequency offset index.

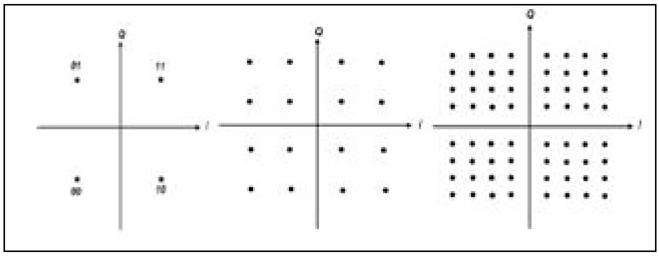

Figure 3: Constellation of QPSK, 16-QAM and 64-QAM

3.1.4. OFDM Modulator

In this section firstly inverse fast fourier transform is used to produce a time domain signal and then cyclic prefix is added to reduce the effect of multipath.

- **Channel:** The channel that we used is pure AWGN. This is a noise channel. This channel effects on the transmitted signals when signals passes through the channel. It adds white Gaussian noise to the input signal. After adding Gaussian noise data is then passed to the receiver.

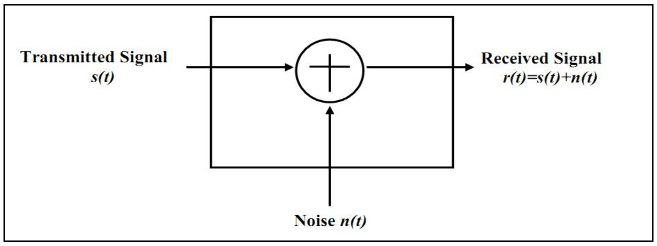

Figure 4: AWGN Channel

- **Receiver:** The complementary blocks are implemented in the receiver: the CP is removed, sub-carriers are demodulated via the FFT transform, and then sub-carrier de-mapping is performed. After that Channel decoding process is performed with the help of de-interleaver, convolution decoder and RS decoder. Data is then de randomized and in last we get final data.

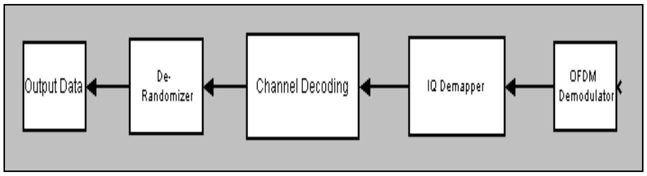

Figure 5(a): Physical Layer (Receiving side)

3.2. LTE Physical Layer

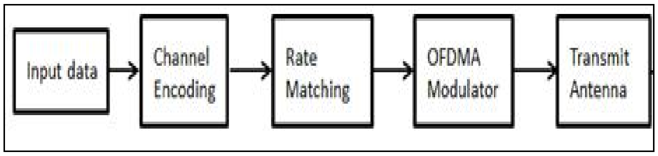

Figure 5(b): LTE Physical Layer (Transmitter Side)

3.2.1. Channel Encoding

3.2.1.1. CRC (Cyclic Redundancy Check)

CRC is utilized at beginning of channel encoding. Cyclic redundancy check is an error detection technique which can occur accidently. A certain number of check bits appended on each input block. Receiver can determine if incoming data is agreeing with check bits or not. In this simulation model two CRC schemes are used as shown in Fig. 6. Both schemes use 24 parity bits length, one 24 parity bits applied on transport block and another 24 parity bits applied on code block.

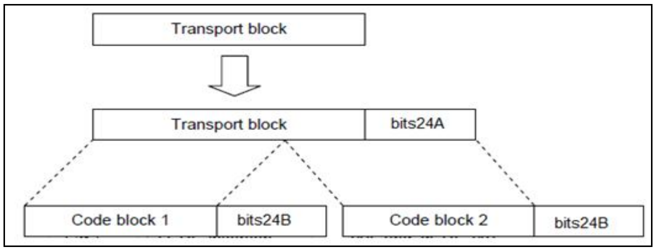

Figure 6: CRC

3.2.1.2. Turbo Encoder

In this simulation turbo coding as shown in Figure 4.10 is used to enhance the performance of system. Turbo encoder block encode the binary input using parallel coding scheme. Turbo codes are high performance error correction codes (Forward Error Correction). Using turbo encoding with AWGN channel, deliver the performance close to theoretical capacity limits.

3.2.2. Rate Matching

Main task of Rate Matching is to extract the exact set of bits to be transmitted. Below will discuss the blocks of rate matching in details.

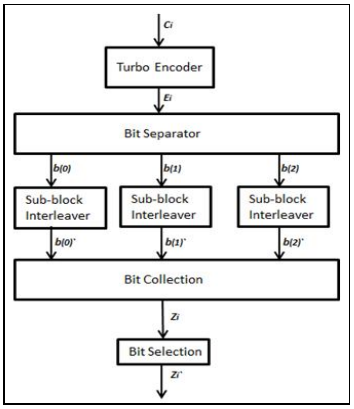

Figure 7: Rate Matching

3.2.2.1. Sub-block interleaver

Turbo encoder output blocks b (0), b (1) and b (2) corresponding to the 1st, 2nd and 3rd parity streams as shown in Fig. 7 are interleaved separately using sub block interleaver.

3.2.2.2. Bit Collection

In the LTE simulator, the bit collection is mainly achieved by an Interleaver Block and a Matrix Concatenate Block. The Interleaver Block primarily puts the parity bit stream and the interleaved parity bit stream together as a new bit stream. Meanwhile it arranges the bits from the former stream at the odd sequence and the bits from the latter stream at the even sequence. Afterwards the Matrix Concatenate Block concatenates the new bit stream and the former systematic bit stream together to create the input for the following circular buffer block.

3.2.2.3. Bit Selection

The bit selection extracts consecutive bits from the circular buffer to the extent that fits into the assigned physical re-source [15]. Combined with the Turbo coding, the circular buffer can puncture or repeat the collected coded bits to achieve an alterable channel coding rate under different scenarios.

3.2.3. OFDM Modulator

In this section processed signal further be modulated with Orthogonal Frequency Division Multiplexing.

3.2.3.1. Transmit Antenna

Antenna mapping consist of Layer mapping and Pre-coding.

3.2.3.1.1. Layer Mapping

In layer mapping, modulated symbols for one or more code words will be mapped on one or more layers. In our simulation mapping single antenna is used for transmission. Two types of layer mapping are used, spatial multiplexing and transmit diversity.

3.2.3.1.2. Pre-coding

The layers in transmit diversity are used to conveniently carry out the following pre-coding by some pre-defined matrices. Transmit diversity for two antenna ports is based on Space Frequency Block Coding (SFBC), and transmit diversity for four antenna ports is based on a combination of SFBC and Frequency Shift Transmit Diversity (FSTD). According to the specifications, transmit diversity is implemented by a predefined matrix.

3.2.3.2. Receiver

In LTE downlink, the receiver simulates the operation of one user equipment that processes the received signals and interacts with the eNodeB. Figure 8 shows the basic flow. After the steps of inverse-OFDM and inverse re-source mapping, the receiver has to do the channel estimation to provide the necessary channel information to the following blocks of equalizer and PMI calculation.

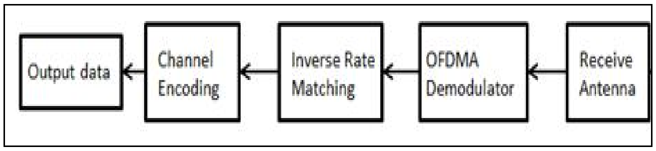

Figure 8: LTE Physical Layer (Receiver Side)

The following blocks of demodulation, inverse rate-matching, channel decoding, and HARQ will detect each transmitted bits and ask for a retransmission if any errors remain after the Turbo decoding.

Finally, the PMI will be fed back to the eNodeB, and the de-coded bits are transferred to the output calculation block to evaluate the simulator performance.

4. Simulation and Results

The Model for the WiMAX and LTE is built from the standard documents [9, 10]. The performance of the WiMAX and LTE -PHY layer was tested and evaluated at different noise levels. We performed our simulation in Matlab Simulink version r2014a. We have preferred the Matlab because it is adequate for the simulation of different signal processing methods used in wireless networks.

After running our simulation model at different values of signal to noise ratio we got different values of bit error rate. Fig. 9 to Fig. 14 shows the BER Vs SNR plots for QPSK, 16-QAM and 64-QAM. From figures it is clear that increasing the value of Signal to Noise Ratio (SNR) decreases the value of Bit Error Rate (BER). From figures it is clear that increasing the value of Signal to Noise Ratio (SNR) decreases the value of Bit Error Rate (BER). If you see the result of WiMAX, it is performing well when QPSK is used, almost equal when 16QAM is used and LTE is performing slightly well when 64QAM is used. Turbo decoder also significantly improved the performance; we have applied turbo decoder in LTE model. Five turbo decoders are applied and it reduced the BER impressively. Turbo decoders increase the complexity of system but provide better performance. Increase in number of turbo decoders decrease the BER and decrease in number of turbo decoders increase the BER up to ideal channel BER.

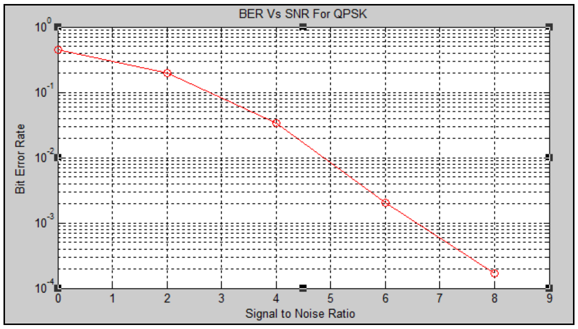

Figure 9: BER vs. SNR plot for QPSK (WiMAX)

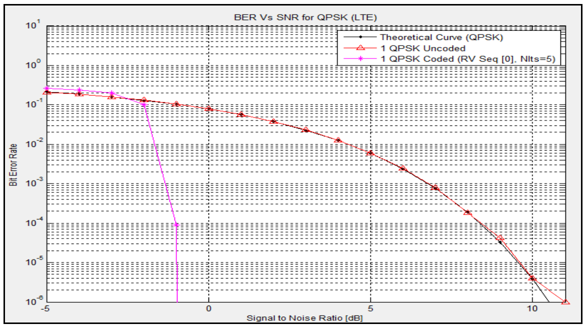

Figure 10: BER vs. SNR plot for QPSK (LTE)

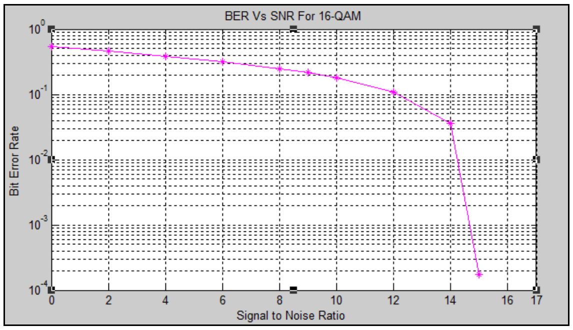

Figure 11: BER vs. SNR plot for 16-QAM (WiMAX)

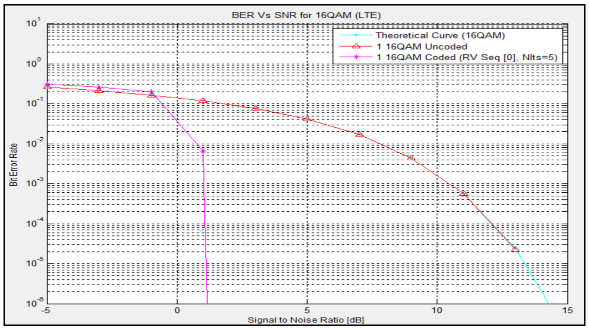

Figure 12: BER vs. SNR plot for 16-QAM (LTE)

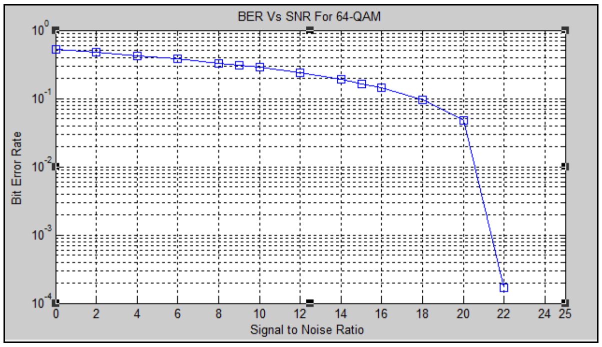

Figure 13: BER vs. SNR plot for 64-QAM (WiMAX)

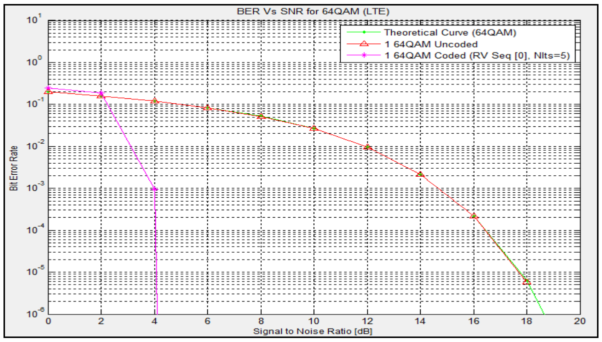

Figure 14: BER vs. SNR plot for 64-QAM (LTE)

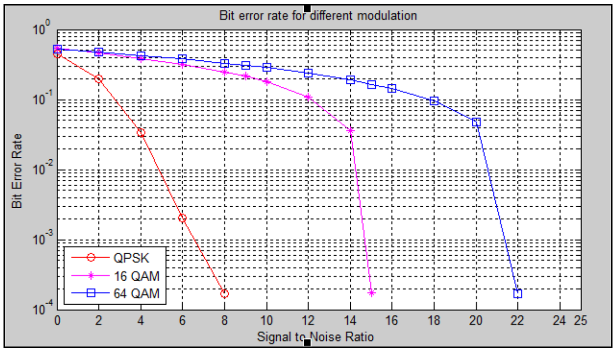

Figure 15: Comparison between modulations schemes (WiMAX)

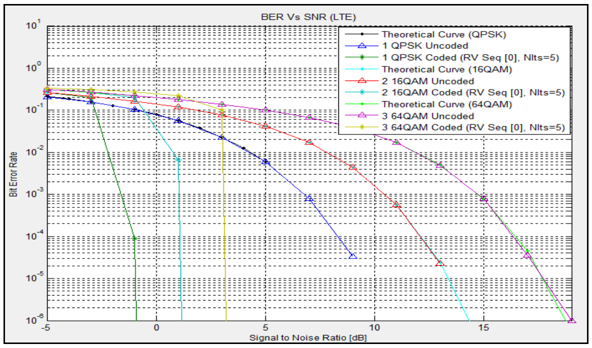

Figure 16: Comparison between modulations schemes (LTE)

5. Conclusion

The wireless communications industry is gaining momentum in both fixed and mobile applications. The continued increase in demand for all types of wireless services (voice, data, and multimedia) is fuelling the need for higher capacity and data rates not only in fixed but also in mobile applications. WLANs and 3G cellular networks are experiencing several difficulties for reaching a complete mobile broadband access, bounded by factors such as bandwidth, coverage area, or infrastructure costs. In this context, Wi-MAX and LTE appears to fulfill these requirements, providing vehicular mobility and high service areas and data rates. Defined to provide broadband wireless access, it is increasingly gaining interest as an alternative last mile technology to DSL lines and cable modems, and a complementary technology where wireless networks are not sufficiently developed. This thesis is devoted to the study of the Wi-MAX and LTE system. More specifically, it examines the comparative implementation of a Wi-MAX and LTE physical layer simulator over BER v/a SNR, built with Matlab Simulink.

We studied Wi-MAX and LTE standards, its architecture, OFDM physical layer, different modulation schemes and features with the help of necessary figures and tables. We also discussed our simulation model in detail.

We have used three modulation schemes QPSK, 16-QAM and 64-QAM and compared them on the basis of their constellation, OFDM spectrum and Bit Error Rate (BER). Result shows that at very low signal to noise ratio symbols are very difficult to recognize and also spectrum is worse. By increasing the value of signal to noise ratio spread reduction takes place and also spectrum is clearer. From bit error rate and signal to noise graphs it is clear that QPSK has lowest bit error rate and WiMAX has lower bit error rate the LTE and 64-QAM has highest bit error rate and in this case LTE has advantage over WiMAX with lower bit error rate then WiMAX. Bit Error Rate of 16-QAM lies between these two modulation techniques WiMAX and LTE has almost equal bit error rate.

6. References

1. WiMAX Forum, “Mobile WiMAX – Part 1: A Technical Overview and Performance Evaluation”, August 2006
2. IEEE 802.16 2004,” IEEE Standard for Local and Metropolitan Area Networks Part16: Air Interface for Fixed Broadband Wireless Access Systems”, 1 October, 2004
3. IEEE. Standard 802.16e-2005.“Part16: Air interface for fixed and mobile broadband wireless access systems—Amendment for physical and medium access control layers for combined fixed and mobile operation in licensed band.” December 2005.
4. C. Eklund, “IEEE Standard 802.16: A Technical Overview of the Wireless MAN Air Interface for Broadband Wireless Access,” IEEE Commun. Mag.,pp. 98107,June 2006
5. NuaymiLoutfi, 2007, “WiMAX Technology for Broadband Wireless Access”, Wiley, London
6. William Stallings, “Wireless: Communications and Networks”, Page 139-146, Pearson Education, 2002.
7. Y.Xiao, “WiMAX-MobileFi: Advanced research and technology," Auerbach publications, 2008.
8. R.B. Marks, K. Stanwood, D.Chang, et al., “IEEE Standard for Local and Metropolitan Area Networks, Part 16: Air Interface for Fixed Broadband Wireless Access Systems,” October, 2004.

9. ETSI TS 102177 Version 1.3. 1, February 2006,"Broadband Radio Access Networks (BRAN); HiperMAN;Physical (PHY) Layer"
10. IEEE 802.16-2006:"IEEE Standard for Local and Metropolitan Area Networks-Part 16: Air Interface for Fixed Broadband Wireless Access Systems"
11. J. C. Ikuno, M. Wrulich, M. Rupp, System level simulation of LTE networks, 2010 IEEE First Vehicular Technology Conference: VTCS2010, Taipei, Taiwan, 16-19May, 2010.
12. Agilent Technologies, John Wiley & Sons, LTE and the Evolution to 4G Wireless: Design and Measurement Challenges, 2nd ed., John Wiley & Sons, 2009.
13. FahimehRezaei, Michael Hempel, Hamid Sharif "A Comprehensive Performance Analysis of LTE and Mobile WiMAX" IEEE publications, Nov. 2012
14. ZakariaHanzaz, Hans Dieter Schotten "Analysis of Effective SINR Mapping Models for MIMO OFDM in LTE System" IEEE publications, July 2013
15. "Fact sheet 3GPP LTE", Federal Office of Communications OFCOM, January 2011.
16. XuanGuo&PengtaoSong "Simulink Based LTE System Simulator"Chalmers University of Technology, 2010