Performance Evaluation of LTE System in Different Channels with Different Retransmissions

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Abstract - *Long Term Evolution (LTE) is the latest step in moving forward from the cellular Third Generation (3G) services. LTE is a standard for wireless communication which provides high-speed data. The present day's wireless communication is more data-centric than in the past. The objective of this paper is to evaluate the performance of different LTE channels with different retransmissions by using "Vienna LTE Link Level Simulator". In this work, we measured the BLER vs. SNR and throughput vs. SNR for different LTE channels. Among different modulation techniques, we observed the performance of the 16QAM modulation technique. The performance of an LTE transmission can be simulated with an uncorrelated PedB, VehB, TU, and AWGN channels for several transmission such as Single-Input Single-Output (SISO), Transmission Diversity (TxD), and Open Loop Spatial Multiplexing (OLSM) modes. The channel performance is measured in accordance with the parameters SISO, TxD 2x1, TxD 4x2, and OLSM 4x2. The channels are highly related to the noise where the performance of the communication channel is degraded with increasing noise. The performance and evaluation can be done of the LTE system in the multi-path channels.*

Key Words: *AWGN, BLER, LTE, PedB, SISO, SNR, Throughput and VehB.*

1. INTRODUCTION

Wireless communications methods and services have been enthusiastically adopted by people throughout the world within a short time. The demand to communicate with each other whatever places the receiver may be, wireless technology started to emerge. Fading and interference is a major phenomenon in communication [1]. The design of wireless systems has focused on increasing reliability of the air interface but the recent focus on increasing spectral efficiency. In communication systems to observe a clear video transmission, live conversation reliably, high speeds multimedia internet access, and without delay transmission is a very common demand for humans. Efficient technology is required to mitigate this demand. Therefore, scientists, researchers, and technologists are trying to discover new technologies and also reduce the limitation of different wireless systems. LTE is a promising technique for achieving higher spectral efficiency, capacity, and data rates that ensure reliable wireless communication [2]. Worldwide acceptable technology LTE perspective for 2G, 2.5G, and 3G and so on networks based on WCDMA/HSPA, GSM/EDGE, TD-SCDMA, and CDMA technologies. The motivation for LTE is:

- User demand for higher data rates and quality of service
- Packet Switch optimized system
- Continued demand for cost reduction
- Low complexity
- Avoid unnecessary fragmentation of technologies for paired and unpaired band operation

Table-1: Different standard uses in different generations for mobile technology.

1G	2G	3G	4G
1.Paging Systems 2.Cordless Telephony 3.Private Mobile Radio 4.Cellular systems (NMT, AMPS etc.) 5.Mobile Satellite systems (INMARSAT)	1.Paging Systems 2.Cordless Telephone 3.Private mobile radio 4.WLL Cellular systems (GSM, D-AMPS, PDC) 5.Mobile Satellite systems	1.Single standard under IMT-2000, UMTS, MC-CDMA and TD-SCDMA	1.LTE-A 2.IEEE 802.16m 3.3GPP LTE 4.Mobile WiMAX (IEEE 802.16e)

1.1 PERFORMACE ANALYSIS AND ENHANCEMENT

A system can be the judge to analyze the system performance. Several parameters can be used to measure the system such as Bit Error Rate (BER), Block Error Rate (BLER), Signal to Noise Ratio (SNR), Throughputs, Quality of Service (QOS) and transmission rate, etc. The higher throughputs, SNR, and

lower BLER are better for a system [3]. Diversity and Equalization, Coding, Modulation, etc. are common techniques for enhancing system performance. The performance evolution is based on the signal transmission through its modulation and demodulation sections.

1.2 RESEARCH OBJECTIVES

The aim of this paper is to compare different LTE channels and measured retransmission performance. To find a better channel model among different channels, we used the performance parameters BLER, SNR, and throughput. The research objectives are to find a better channel model which provides lower BLER and higher throughput with respect to SNR and also consider the retransmission.

2. LONG TERM EVOLUTION (LTE)

LTE is a standard that provides of high-speed data for mobile phones and data terminals. It is based on GSM/EDGE and UMTS/HSAP network technology. Everything goes much faster in LTE systems. In December 2009, the first commercial LTE network in Sweden has put the operation. Figure-1 shows the GSM Family Technology Evolution.
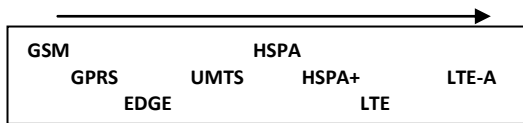
Figure-1: Evolution of LTE Technology

2.1 LTE NETWORK ARCHITECTURE

LTE network expended rapidly due to their additional efficiency, lower latency, and the ability to handle increasing data traffic. This network is shown the evolution from GSM to LTE technology.
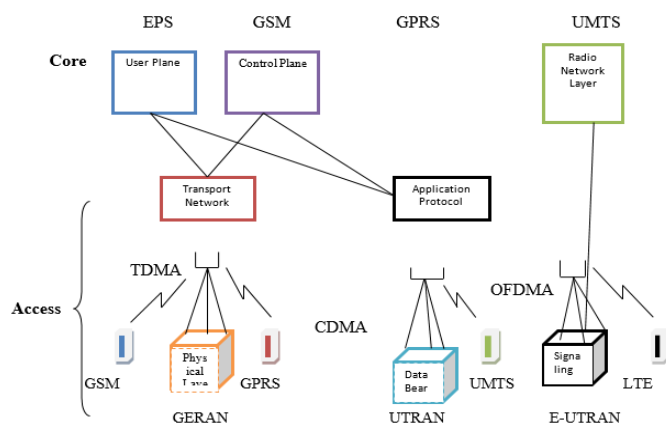


Figure-2: LTE Network Architecture

The core technology moves from the circuit-switched to the packet-switched. The access has moved from TDMA to OFDMA as the need for higher data and other flexibility. The LTE network architecture is divided into two parts such as core and access is shown in the figure-2. The core network also called EPC is responsible for overall control of the UE. The access network of LTE, E-UTRAN, simply consists of a network of eNB. The eNB are normally interconnected with each other employing an interface. The protocols that run between the eNB and the UE are known as the AS protocols. The major components of LTE technology are OFDM, OFDMA, SC-FDMA, TDD, FDD, Spectrum Flexibility, MIMO, Link Adaption, Turbo codes, cyclic prefix, etc. which is used for operation based on the access criteria [3-5]. OFDMA can be used to overcome multipath fading effects from the base station to the terminal to transmit data over many narrow band careers. MIMO is a major integral part of LTE that improves the system performance which includes the number of the antenna with the system to provide higher data rates with spectrum efficiency. Turbo code is also a very powerful code that can come within a fraction of a dB of the Shannon capacity limit on AWGN channels [2]. Turbo codes had the error-correction capability and they were endowed with a structure that permitted relatively easy to moderately complex decoding.

2.2 LTE SYSTEM ARCHITECTURE

LTE System Architecture Evolution (SAE) follows the WCDMA/HSPA system by splitting the architecture between the RAN and CN. The architecture has been developed to provide a considerably higher level of performance that is in line with the requirements of LTE. The System Architecture Evolution offers many advantages over previous topologies and systems used for cellular core networks based upon the GSM / WCDMA. As a result, it is anticipated that it will be widely adopted by the cellular operators. There are several common principles used in the development of the LTE SAE network:

- A common gateway node and anchor point for all technologies.
- Provide optimized architecture for the user plane.
- All IP based system and protocols used on all interfaces.
- A radio access network / core network functional split similar to that use on WCDMA / HSPA.
- Integration of non-3GPP access technologies.
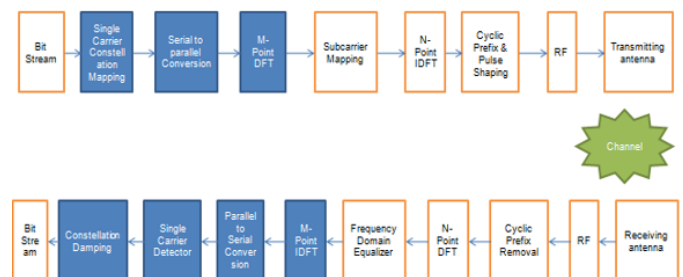
SC-FDMA Specific Additional Functional Blocks
Common Functional Blocks of OFDMA and SC-FDMA

Figure-3: OFDMA and SC-FDMA Transmitter and Receiver

2.3 DIGITAL MODULATION AND CHANNEL MODELS

Modulation is a process for encoding the message that transmits through the channel. The multipath fading condition in the mobile radio channel with the modulation technique is a challenging task. Digital modulation offers greater advantages such as noise immunity, robustness, and security over analog modulation. The digital modulation offers more information capacity, compatibility with digital data services, higher data security, better quality communications, and quicker system availability. The Vienna LTE link level simulator used different modulation techniques among them we used 16QAM modulation for the research work. The QAM is the combined form of two amplitude-modulated (AM) signals into a single channel, so doubling the effective bandwidth. The QAM signal has I-signal and Q-signal, each having the same frequency but differing in phase by 90 degrees. We used some channels for communication in the simulation and try to find a better channel model for the environment. Here, we mention some channels that were used in the simulation.

I.   AWGN CHANNEL

The Additive White Gaussian Noise (AWGN) channel model is the linear addition of wideband as well as white noise with a constant spectral density and a Gaussian distribution of amplitude. White noise has the property that energy density is constant regardless of frequency. The channel is called "Additive" due to it added any noise in the information systems. The term "White" in AWGN refers to the spectral density of the noise means the power of the noise within a given frequency range. The term "Gaussian" refers that the channel has a normal distribution in the time domain.
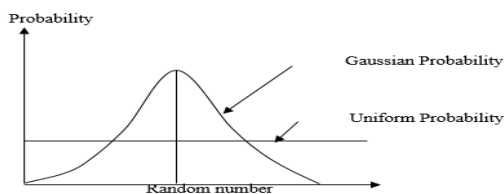
Figure-4: Gaussian and Uniform Random Probability Distributions.

II.   FLAT RAYLEIGH CHANNEL

The transmitted signal is corrupted with multipath fading which causes fluctuations in amplitude, phase, and angle of arrival of the received signal. The central limit theorem can be applied for a large number of paths to model the time-variant impulse response of the channel as a complex-valued Gaussian random process. The impulse response is modeled as a zero-mean complex-valued Gaussian process. The Rayleigh distribution is commonly used to describe the statistical time-varying nature of the received envelope of a flat fading signal [1].
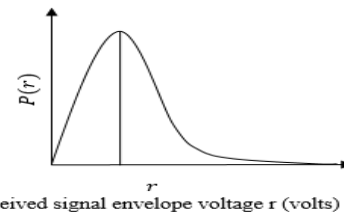

Figure-5: Rayleigh Probability Density Function

III.   PEDESTRAIN AND VECHICULAR CHANNEL

The ITU power delay profiles including the Vehicular (VehA & VehB) and Pedestrian (PedA & PedB) channel models for mobile communication systems. The channel model is operating in various LTE wireless environment systems and provides receiver robustness during high-speed operation. The vehicular channels generally are randomly time-varying, measurements, statistical characterization, and modeling. The characteristics and performance of vehicular propagation channels depend on the nature of the surrounding environment and applicable for urban, suburban, highway rural, and some hazard conditions. The system performance evaluation by simulation and the analysis of novel signal processing algorithms, radio channel models are needed, which allow computing the input-output behavior of vehicular propagation channels. Three types of radio channel models are available such as tap delay models, ray-based models, and geometry-based stochastic models which provide vehicular channels [6]. The Vienna LTE link level simulator used tap delay vehicular and pedestrian channel models. The pedestrian channel characteristics and performance depends on the environment wheatear the object is moving or stationary [7].

4. LTE SIMULATORS

The development, standardization, and further improvement of modern cellular systems simulation are necessary for proper communication systems. Vienna University of Technology (TU Wien), Austria developed two "Vienna LTE Simulator" such as "Vienna LTE Link Level Simulator" and "Vienna LTE System Level Simulator". Link level simulations accommodate the investigation of channel estimation, tracking and prediction algorithms, synchronization algorithms, Multiple-Input Multiple-Output (MIMO) gains, Adaptive Modulation and Coding (AMC), and feedback techniques [7].

4.1 VIENNA LTE LINK LEVEL SIMULATOR

Link level simulator is a software implementation of one or multiple links between the Evolved Base Station (eNB) and the User Equipment's (UEs) with a channel model to reflect the actual transmission of the waveform generated [8]. The link level simulator is associated with the physical layer and the system level simulator associated with the network

layer. The Vienna LTE Link Level Simulator version 1.7r1089 is used for our research.

4.2 LTE LINK LEVEL SIMULATOR STRUCTURE

The link level simulator is divided into three basic building blocks such as a transmitter, channel model, and receiver. The transmitter and receiver blocks are linked by the channel model that can be used to transmit the downlink data at the same time signaling and uplink feedback is assumed to be error-free. LTE link level simulator overall structure is shown in the Figure-6[10].
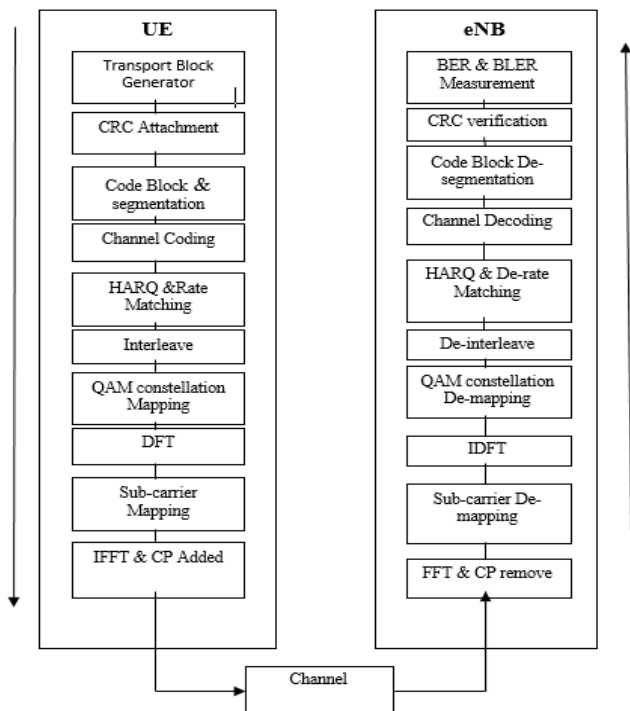

Figure-6: LTE link level simulator overall structure

LTE link level simulator flow diagram is shown in Figure-6[9]. The LTE link level simulator is a flexible designee and a complete set of parameters configuration. LTE link level simulator provides SINR value, (where to represent all sources of noise), channel model (outdoor/indoor, pedestrian/vehicular), MIMO channel (correlated or uncorrelated), MIMO transmits/receive procedures, modulation and bandwidth, channel coding rate, and resource allocation. The physical channel is associated with BER vs. SINR, log-likelihood ratio (LLR) per each M-QAM signal for different MIMO techniques, and mobile radio channel models.

5. SIMULATION RESULTS AND PERFORMANCE EVALUATINONS

Link level simulator simulates the features of transmission between the base station and the terminal. This simulator is a MATLAB based physical layer simulator for LTE. The main

objective of the simulation is compared with different channels and observed different retransmission. The comparison is done by BER, throughput vs. SNR with different retransmission. This simulation is implemented only for the parameters Single-Input Single-output (SISO), Transmission Diversity (TxD), and Open Loop Spatial Multiplexing (OLSM) modes. The following parameters are used for the simulation as shown in Table-2.

Table-2: Simulation parameters

Parameters	Value
Number of User Equipment's	1
Bandwidth	1.4MHz
Retransmissions	0, 2 and 3
Channel type	AWGN, PedB, VehB and TU
Filtering	Block Fading
Receiver type	Soft Sphere Decoder
Simulation length	300 Sub-fames
Transmission mode	SISO, TxD and OLSM
Retransmission algorithm	HARQ
Debug Level	5
Channel Quality Indicator	7
Modulation	16QAM
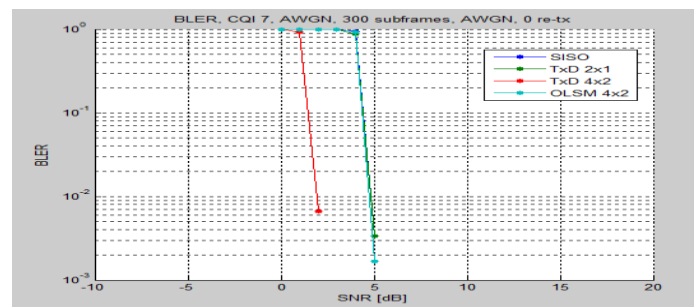
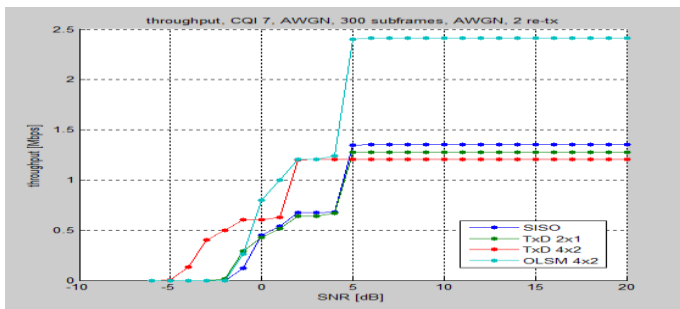
(a) BLER vs. SNR for AWGN channel
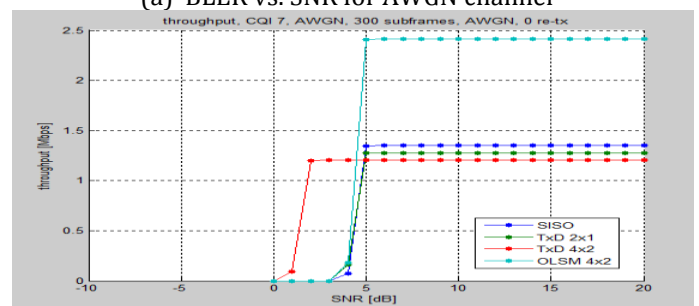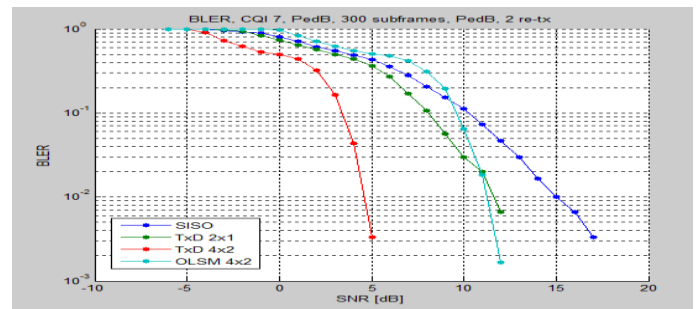

(b) Throughput vs. SNR for AWGN channel
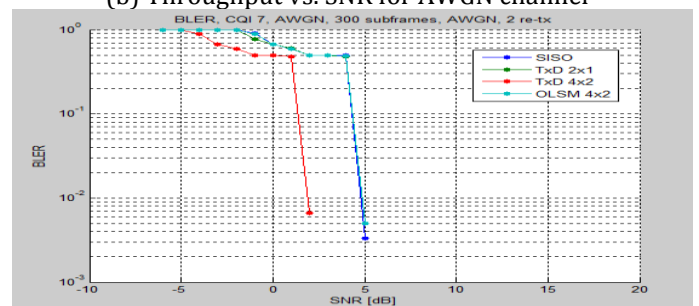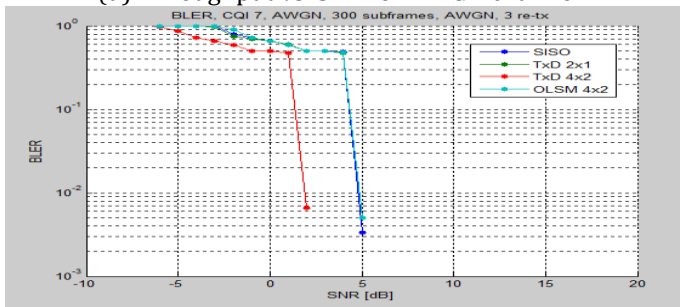

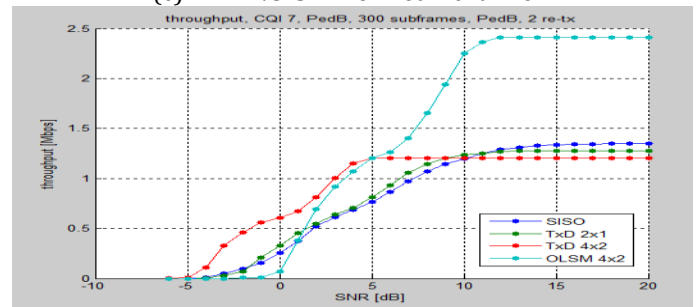(c) BLER vs. SNR for AWGN channel
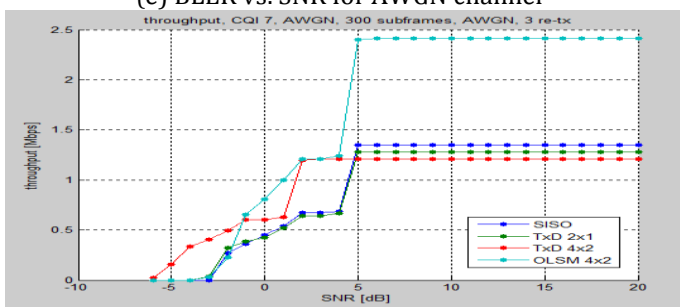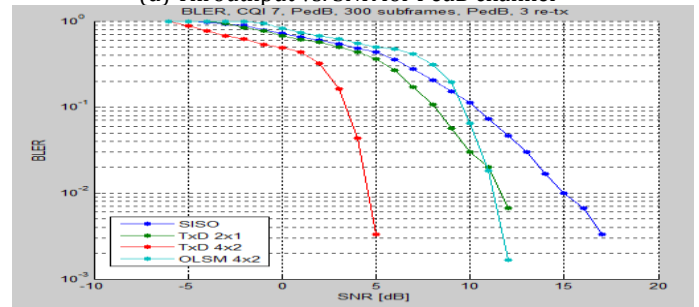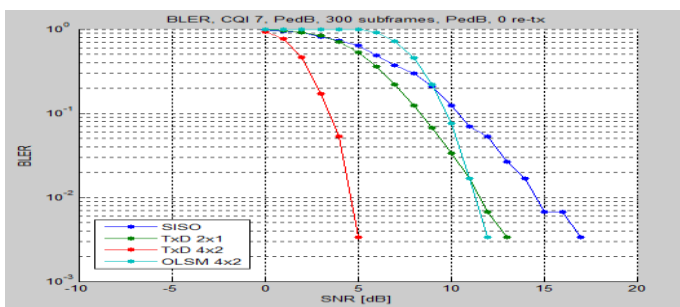
(d) Throughput vs. SNR for AWGN channel

(e) BLER vs. SNR for AWGN channel

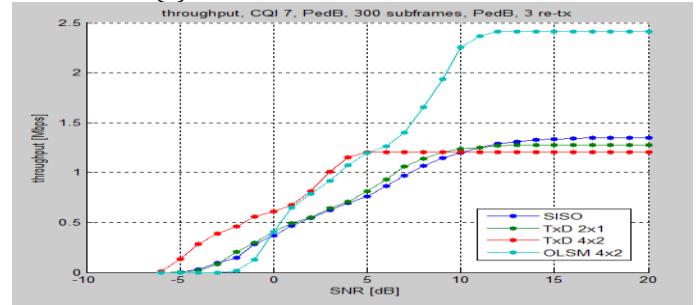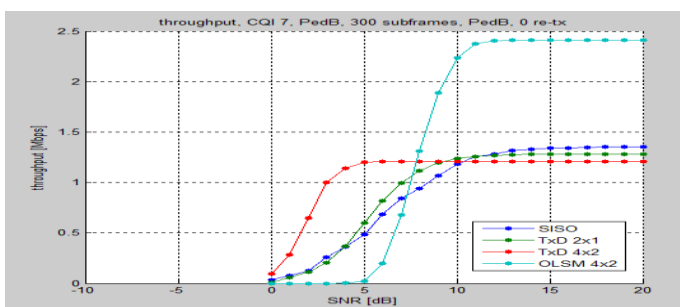(f) Throughput vs. SNR for AWGN channel

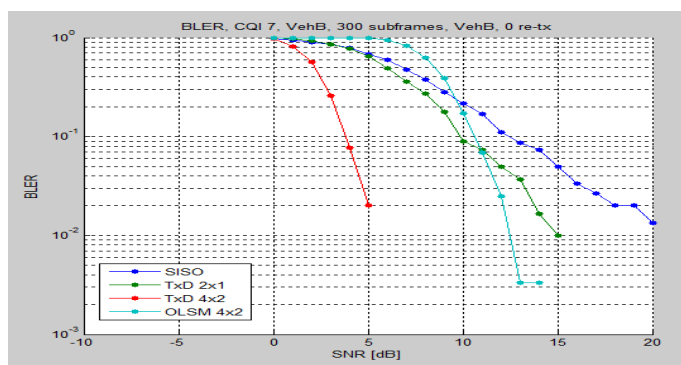**Figure-7**: BLER, Throughput vs. SNR for AWGN channel with 0, 2 and 3 retransmission.
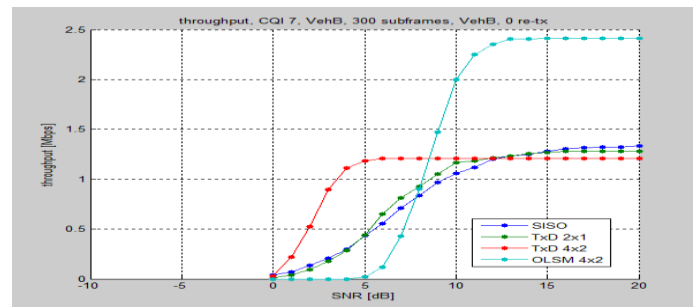

(a) BLER vs. SNR for PedB channel

(b) Throughput vs. SNR for PedB channel

(c) BLER vs. SNR for PedB channel

(d) Throuthput vs. SNR for PedB channel

(e) BLER vs SNR for PedB channel

(f) Throughput vs. SNR for PedB channel

Figure-8: BLER, Throughput vs. SNR for PedB channel with 0, 2 and 3 retransmissions

A Block Error Ratio (BLER) is defined as the ratio of the number of erroneous blocks received to the total number of blocks sent, where the erroneous block is defined as a Transport Block. Throughput is the rate for successful message delivery over a communication channel. The retransmissions algorithm 2, 3 HARQ was used for simulation. For transmission over AWGN, PedB, VehB, and TU channels, simulation has been performed on 300 sub-frames. To perform and compare the channels, prefer different transmissions modes settings: SU-SISO (111), SU-MIMO transmits diversity (222 and 242), and SU-MIMO

open-loop spatial multiplexing (322 and 342). The simulation result for the AWGN channel is shown in Figure-7 for 0, 2, and 3 retransmissions. From Figure-7, we observe that the BLER vs. SNR and Throughput vs. SNR response for the AWGN channel. We observe the results for four parameters such as SISO, TxD 2x1, TxD 4x2, and OLSM 4x2. We can understand from Figure-7 (a), that the TxD 4x2 performances are better at low SNR value than other parameters. Figure-7, (c), and (e), also shows that the TxD 4x2 performance is better than others. The throughput vs. SNR performance is shown in Figure-7(b), (d), and (f) for 0, 2, and 3 retransmissions respectively. Figure-7 (b) is explained by considering that the OLSM 4x2 performance is poor at low SNR, but better at high SNR and also observed that the TxD 4x2 performance is better at low SNR, but considerably poor at high SNR than OLSM 4x2. The SISO and TxD 2x1 are shown comparatively the same performance. The same explanation is considered in Figure-7(d) and (f) for 2 and 3 retransmissions respectively. In the case of high SNR, we can explain that the TxD 4x2 technique gives a constant throughput because the data rate is saturated whereas independent data streams are transmitted for OLSM 4x2. This provides us with another option to achieve optimal BLER and throughput while we use the minimum number of antennas in case of high SNR transmission.

The simulation result for the PedB channel is shown in Figure-8 for 0, 2, and 3 retransmissions. From Figure-8, the throughput and BLER of SISO, TxD 2x1, TxD 4x2, and OLSM 4x2 is compared when transmitting over an uncorrelated ITU Pedestrian B channel. We can see that at low SNR, the TxD 4x2 technique gives the best performance in terms of BLER as compared with the other parameters. In the case of high SNR, it is also observed that the OLSM 4x2 technique outperforms the transmit diversity technique in terms of throughput vs. SNR.
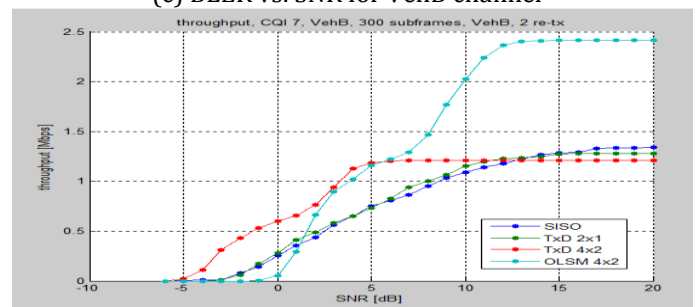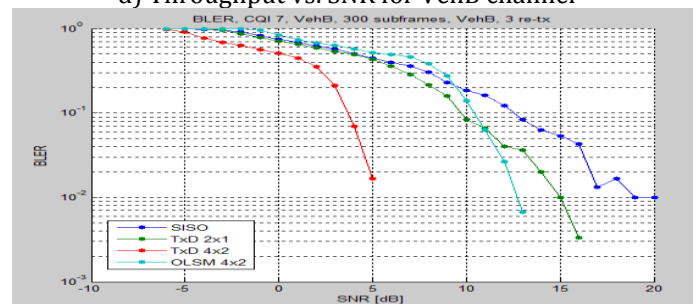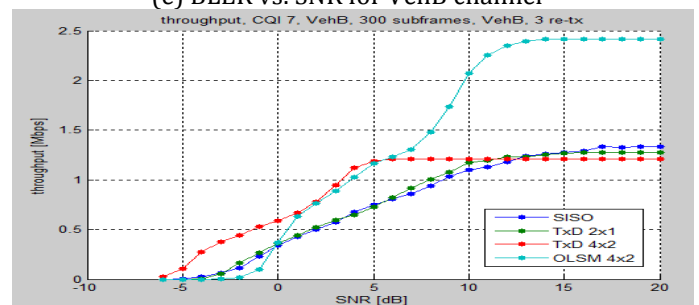

(b) Throughput vs. SNR for VehB channel
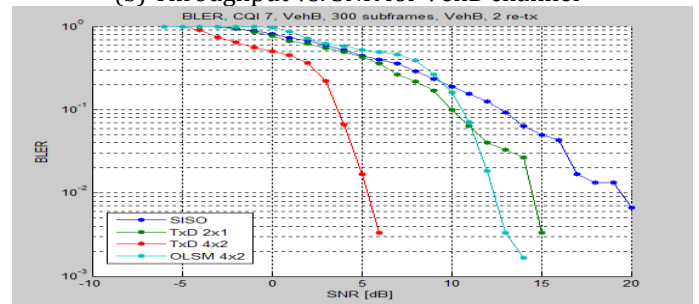
(c) BLER vs. SNR for VehB channel

d) Throughput vs. SNR for VehB channel

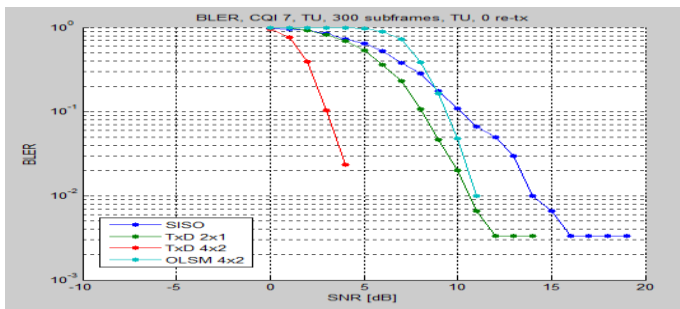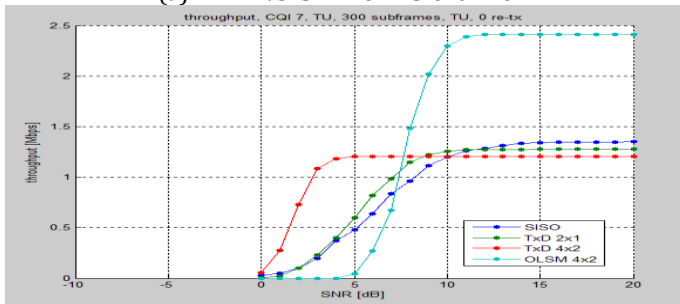
(e) BLER vs. SNR for VehB channel

(a) BLER vs. SNR for VehB channel
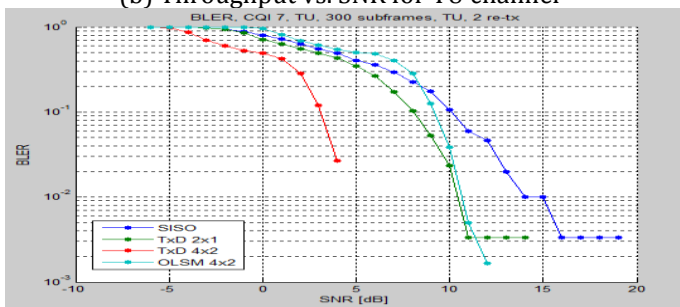

(f) Throughput vs. SNR for VehB channel
Figure-9: BLER, Throughput vs. SNR for VehB channel with 0, 2 and 3 retransmissions
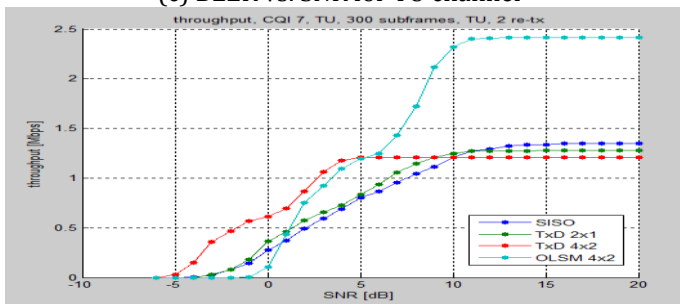
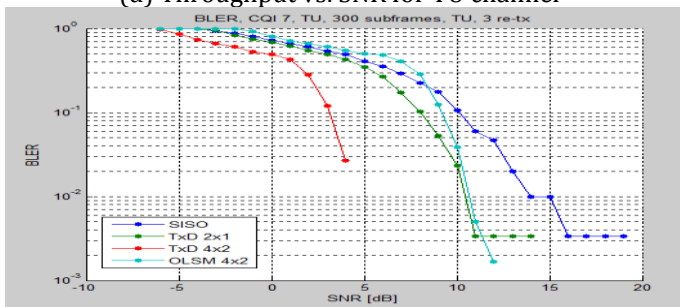(a) BLER vs. SNR for TU channel

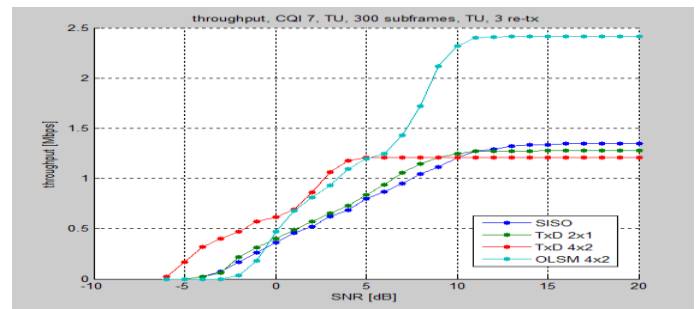(b) Throughput vs. SNR for TU channel

(c) BLER vs. SNR for TU channel


(d) Throughput vs. SNR for TU channel

(e) BLER vs. SNR for TU channel

(f) Throughput vs. SNR for TU channel

**Figure10**: BLER, Throughput vs. SNR for TU channel with 0, 2 and 3 retransmissions

The simulation result for the VehB channel shows in Figure-9 for 0, 2, and 3 retransmissions. From Figure-9 (a), (c) and (e), we also observe that TxD 4x2 gives the best performance in terms of BLER and from (b), (d), and (f) the OLSM gives the best performance in terms of throughput is compared than other parameters. The simulation result for the TU channel shows in Figure-10 for 0, 2, and 3 retransmissions. We can also understand from Figure-10, that TxD 4x2 and OLSM performance is comparatively better than others. The TxD 4x2 performances are larger than OLSM 4x2 in terms of BLER but the gain value decreases because we use the 16QAM modulation that is very sensitive to the multipath effect.
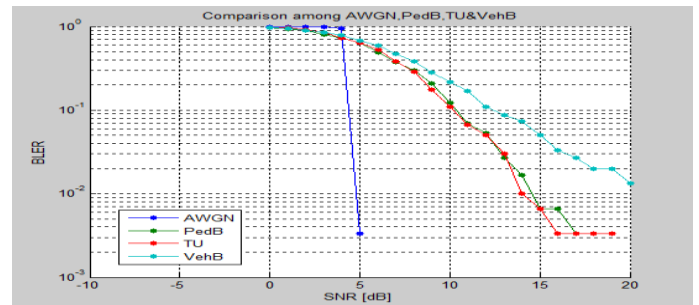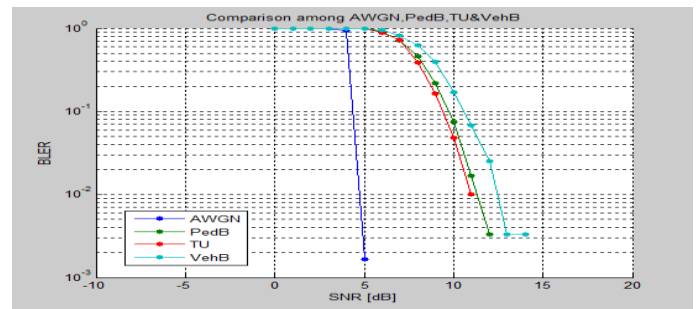

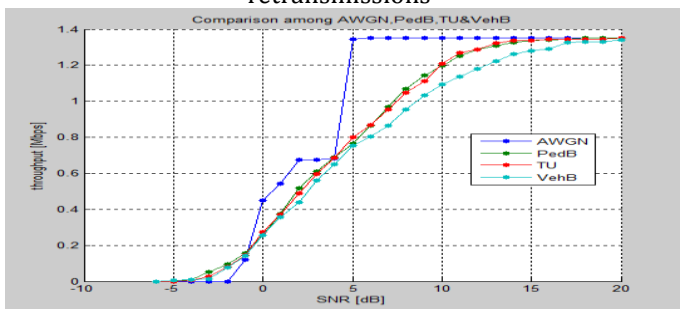(a) Comparison among Channels for SISO, 0 retransmissions
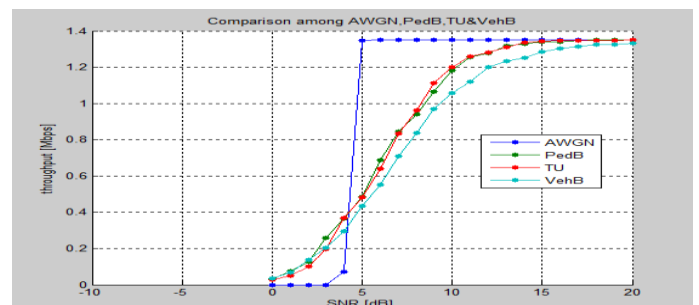
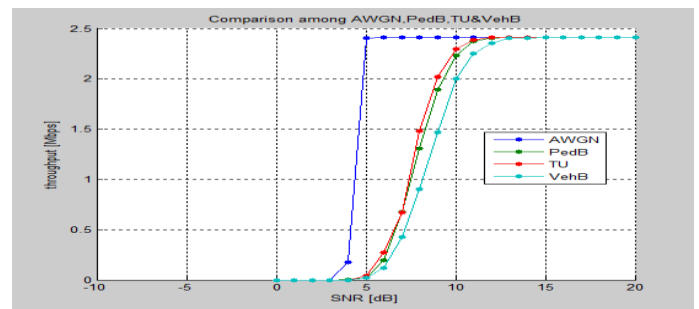(b) Comparison among Channels for SISO, 0-retransmissions
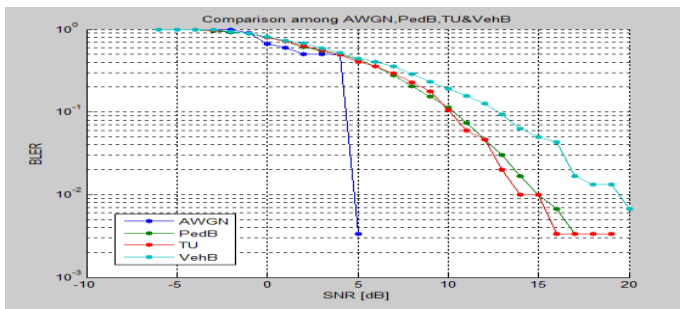
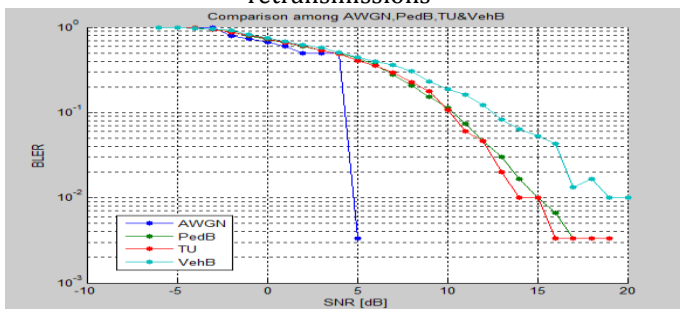(c) Comparison among Channels for SISO, 2-retransmissions

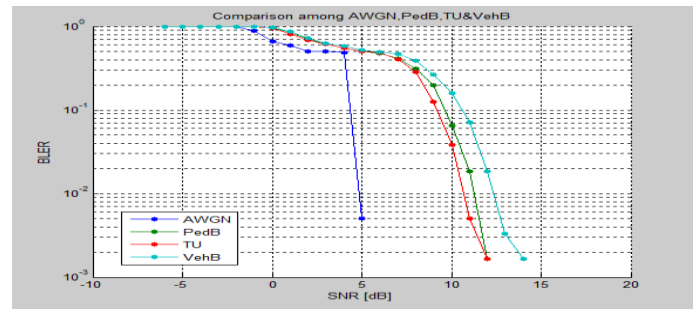(a) Comparison among Channels for OLSM 4x2, 0-retransmissions

(d) Comparison among Channels for SISO, 2-retransmissions

(b) Comparison among Channels for OLSM 4x2, 0-retransmissions

(e) Comparison among Channels for SISO, 3-retransmissions

(c) Comparison among Channels for OLSM 4x2, 2-retransmissions

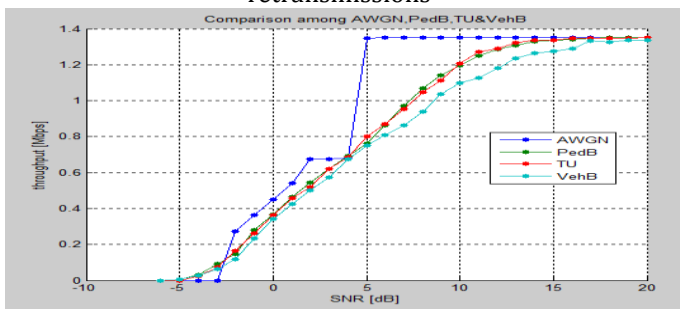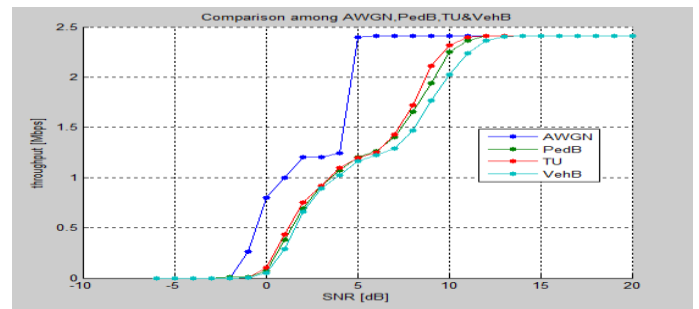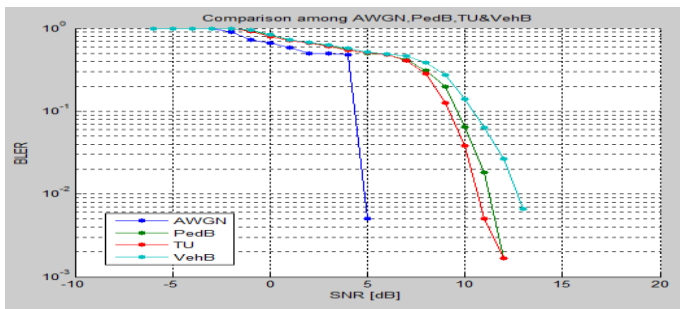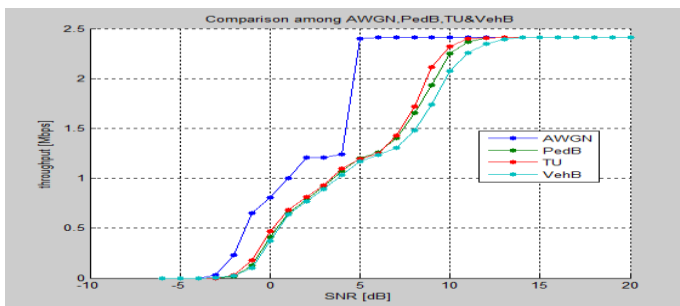

(f) Comparison among Channels for SISO, 3-retransmissions

Figure-11: Comparison among Channels for SISO parameter with 0, 2 and 3 retransmissions

(d) Comparison among Channels for OLSM 4x2, 2-retransmissions

(e) Comparison among Channels for OLSM 4x2, 3-retransmissions

(f) Comparison among Channels for OLSM 4x2, 3-retransmissions

Figure-12: Comparison among channels for OLSM 4x2 parameter with 0, 2 and 3 retransmissions

The comparison among channels shows in Figure-11 and Figure-12 for the parameters SISO and OLSM 4x2 with different retransmissions (0, 2, and 3) respectively. The comparison depends on the BLER, throughput, and SNR. Figure-11 (a), (c), and (e) are explained by considering that AWGN channel performance is better than other channels such as PedB, VehB, and TU. We can understand from Figure-11 (a), AWGN channel throughput is poor at low SNR but the better response at high SNR than other channels. The AWGN channel gives a constant throughput at high SNR. In the case of Figure-11 (d) and (f), it is also observed that AWGN channel performance is better. The simulation results have shown that the VehB channel has performed poorly at high SNR means comparatively low throughput. The PedB and TU channels have shown comparatively the same response.

The compression among channels for OLSM 4x2 is shown in Figure-12 for 0, 2, and 3 retransmissions. We can observe from Figure-12, that the AWGN channel model is performing better at preferable SNR for 0, 2 and 3 retransmissions in terms of BLER and also throughput is high at low and high SNR for OLSM 4x2. Vehicular B channels have shown poor performance at high SNR means comparatively low throughput. Analysis has shown that the AWGN channel model performed better than other channels.

6. CONCLUSIONS

In this paper, we evaluate the performances of the LTE system in multi-path channels and we compare among the channels. We showed that the TxD 4x2 technique achieved a considerable gain compare to the OLSM 4x2 techniques in terms of BLER. But the OLSM 4x2 techniques outperforms the TxD 4x2 technique in term of throughput in case of high SNR. The simulation results have shown that the AWGN channel has performed well because of its low BLER and high throughout response for high SNR. Analysis has shown that the AWGN channel Model performed better than PedB, VehB, and TU channels but channel utilization depends on the wireless environment. The channel utilization depends on the demand for applications. In this paper, we have presented the Vienna LTE Link Level Simulator and shown our simulation results by used link level simulator. Different parameters have been used for better simulation results.

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