LTE-Advanced Physical Layer Optimum Performance Parameters

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Abstract: This paper provides an overview of Advanced Long Term Evolution (Advanced-LTE) telecommunication network and investigates system performance against variations in system parameters trying to reach the parameter values that give best system performance.
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I. Introduction

In times when mobile devices are getting more popular the mobile networks are becoming more and more important, too. Websites are not the same they used to be 10 years ago. They consist of with high quality pictures, and animations. All those things leading to an increase of the amount of data. So it is just a matter of time until current telecommunication networks reach their limits. Worldwide Interoperability for Microwave Access (WiMAX) and Long-Term Evolution.

LTE promise to bring better transfer rates, lower latency, better availability and more to fullfill the needs of the customers, but they also have to be more effective. This paper discusses the most advanced telecommunication systems - advanced LTE-performance and its system parameters. The remainder of this paper is organized as follows: First, a closer look at LTE telecommunication network will be taken, investigating the most important blocks in the system, followed by the parameters affecting the performance of system physical layer trying to reach a recommendation for system parameters to be used to give optimum performance. The final part of this paper discusses results and gives conclusions.

II. Overview

Currently the mobile network infrastructure comprises overlay networks including 2G and 3G technologies. Global System for Mobile Communications (GSM) is a 2nd generation mobile network and provides circuit-switched communication. It was enhanced by General Packet Radio Service (GPRS), also known as 2.5G, and Enhanced Data rates for GSM Evolution (EDGE), also known as 2.75G. On the side of the 3rd generation communication networks, there is Universal Mobile Telecommunications System (UMTS) and its enhancements High-Speed Downlink Packet Access (HSDPA) and High-Speed Uplink Packet Access (HSUPA), both also known as 3.5G networks **[1].** Figure 1 shows the current different telecommunication networks. All these technologies have been standardized by either the 3rd Generation Partnership Project (3GPP) or the Institute of Electrical and Electronic Engineers (IEEE).

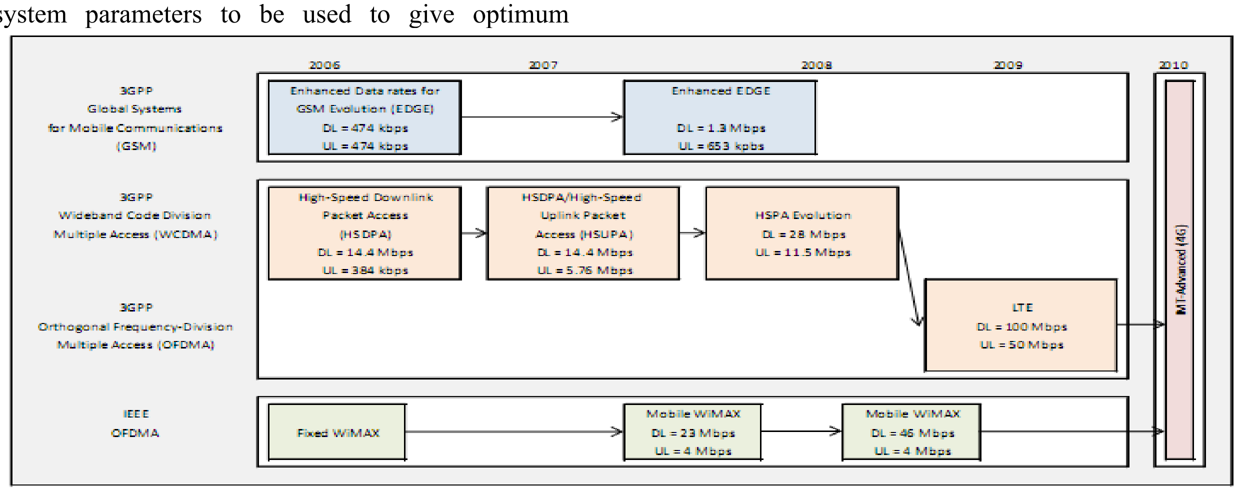

Fig. 1. Overview of the current telecommunication networks

Third generation mobile networks can reach quite high transfer rates compared to 2nd generation networks but they have higher service costs. Compared to GSM, UMTS and HSDPA do not provide full coverage. In order to form new communication standards regarding 4G, the International Telecommunication Union (ITU) launched the International Mobile Telecommunications (IMT)-Advanced initiative **[2].** LTE meets most of the requirements of IMT-Advanced, however they are just considered as 3.9G even though telecommunication companies use the term 4G when marketing LTE.

III. Lte-Advanced

Long Term Evolution also known as LTE was developed by the 3rd Generation Partnership Project (3GPP), collaboration between groups of telecommunication associations. It was released in the 4th quarter of 2008. The LTE standard is officially known as "document 3GPP Release 8". LTE-Advanced was released in 2011 and officially known as "3GPP Release 10". LTE supports peak data rates of 100 Mbps in downlink and 50 Mbps in uplink, both reached with 20 MHz spectrum.

When using MIMO techniques LTE can even reach up to 300 Mbit/s downlink data rates. It has a variable spectrum, which can be used with 1.25, 2.5, 5, 10, 15 and 20 MHz. A cell can cover up to 100 km area **[3]** with slight degradation after 30 km and reach over 200 users per cell (with 5 MHz spectrum). LTE is optimized for low speeds like 0 - 15 km/h but it supports also speeds up to 350 km/h. Round-trip times below 10 ms can be accomplished **[4].** LTE uses also orthogonal frequency-division multiple access (OFDMA) in the downlink, but it uses single carrier frequency-division multiple access (SCFDMA) in the uplink. [5&6]OFDMA is power inefficient, because of the high peak-to-average-power ratio (PAPR), but since the downlink is part of the base station (e-Node-B in 3GPP terminology) it does not matter that much. In the uplink, where the transmission starts from the mobile devices that use batteries, LTE uses SCFDMA, which brings a reduced peak-to-average-power ratio (PAPR). It saves power without degrading system flexibility or performance ensuring a better mobility since the higher power efficiency is important for mobile devices **[7].** SCFDMA is an alternative solution to OFDMA. **[8]** The performance of OFDMA can be better than SCFDMA but it is less power efficient. LTE also offers quality of service. To achieve that, it uses reservation-based access as well and creates time frames. LTE provides security mechanisms such as using security keys between transmitter and receiver to ensure a secure connection and encrypting the communication. In flat fading channels, the capacity of LTE increases linearly with n, where n is the minimum of the amount of receiving or transmitting antennas **[9].**

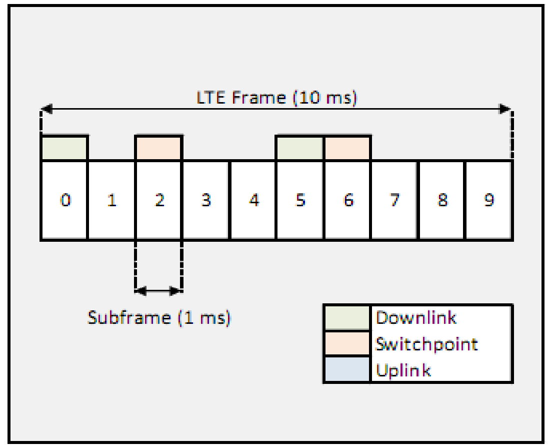

Fig.2. LTE frame

Table 1: Summary of Lte-Advanced Specifications

	LTE-Advanced (3GPP Release 10)
Generation	4G
Expected release	2011
Physical layer	DL: OFDMA UL: SCFDMA
Duplex mode	time- and frequency division duplex (TDD & FDD)
User mobility	up to 350 kmph
Coverage	up to 100 km
Channel bandwidth	up to 100 MHz
Peak data rates	DL: 1 Gbps UL: 300 Mbps
Spectral efficiency	DL: 30 bps / Hz UL: 15 bps / Hz
Latency	Link layer: < 5 ms Handoff: < 50 ms
VoIP capacity	>80 users per sector / MHz (FDD)
other qualities	Full IP-based architecture 3G compatible QoS support

MIMO increases the data rates and the coverage distance without adding more bandwidth or power. Table 1 shows all important features of LTE-Advanced also known as the 3GPP Release 10.

IV. Lte-Advanced Physical Layer

This section presents a performance evaluation of LTE downlink physical layer. Particularly, the main features at the LTE physical layer, like spatial multiplexing or adaptive modulation and coding, are described and analyzed. In LTE, data and control streams are encoded/decoded from/to MAC layer using QPSK, 16-QAM or 64-QAM to offer transport and control services over the radio transmission link.

Channel coding is a method to reduce the **BLER** at the expense of a reduction of the users information rate**, throughput**, and increase reliability. Channel coding is a combination of error detection, error correcting, rate matching, interleaving and transport channel or control information mapping onto/splitting from physical channels. The output of channel coding processes (coded bits) are stored in a buffer where redundancy versions are formed. A redundancy version (RV) is the retransmission unit in the hybrid automatic repeat request HARQ and values of 0,1,2 and 3 of RVs is allowed in LTE. The channel codings schemes applied to transport channels (TrCHs) are two, tail biting convolutional coding is used for broadcast channel and Turbo Coding is used for the rest of TrCHs. The baseband signal transmission of LTE downlink physical channels is performed by the following steps:

Firstly, scrambling of coded bits in each of the code words to be transmitted on a physical channel; next modulation of scrambled bits to generate complex valued modulation symbols; then mapping of the complex-valued modulation symbols onto one or several transmission layers; after the layer mapper, precoding of the complex-valued modulation symbols on each layer for transmission on the antenna ports; then mapping of complex-valued modulation symbols for each antenna port to resource elements; and finally, generation of complex-valued time-domain OFDM signal for each antenna port. Then the receiver performs the inverse processes of transmitter in order to detect the transmitted symbols in order to decode them to recover the original transmitted bit streams. Moreover, the receiver has also to estimate the MIMO channel and the instantaneous SNR; feedback the channel quality indicator (CQI) to the transmitter and generate the soft bit information, what is called Log-Liklihood Ratio LLR, that is the input for the turbo decoder. Therefore, the LLR is calculated per each transmitted and reflects its reliability. Then, the receiver performs the HARQ process and in case of a bit error occurs, request up to 3 retransmission of redundancy version are allowed. Simulation parameters used are; CQI=7; No HARQ; 5000 subframe; BW=1.4 Mhz unless others stated.

IV. Simulation Results

A. Effect of MIMO Antenna Configuration

The performance of physical layer was studied with against antenna different configuration. SISO, MIMO 2x1 transmit diversity (TxD) and 4x2 was investigated. Figure 3 shows its effect on throughput and bit error rate.

Results showed that MIMO enhances the performance greatly over SISO. Moreover, system gain increases linearly with the number of transmitting and receiving antenna. If more transmit antennas are utilized for the transmission, more pilot symbols are inserted in the OFDM frame and thus lower maximum throughput can be achieved. In the case of TXD(4x2), we can satisfy the maximum throughput and the worst at SISO using.

From Figure 3b the SISO mode has higher gain 6dB than TXD(2x1), also TXD(2x1) has higher gain also 6dB than TXD(4x2) at BLER=10^{-2}. So we can obvious conclude that the SNR decreases at using more antennas and the best SNR at TXD(4x2).

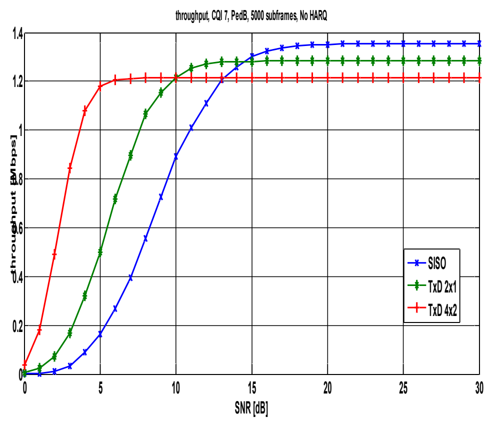

Fig 3a Throughput performance of using SISO or MIMO different modes

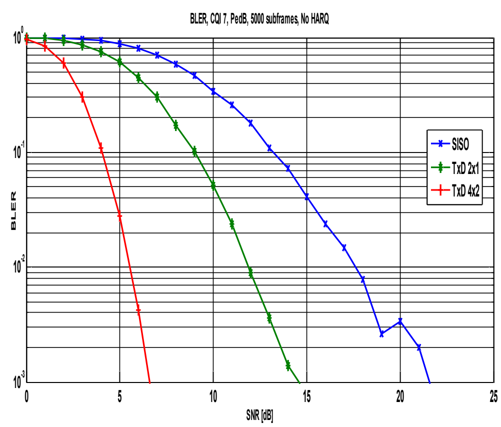

Fig 3b Bit error rate performance with MIMIO different modes

B. Effect of channel characteristics

The SISO OFDM physical channel has been validated comparing AWGN BER performance to the Flat Reyleigh BER, Figure 4. The AWGN channel is ideal channel noise that cause low BLER, the worst BLER is occurred at Flat Rayleigh channel since it causes fading.

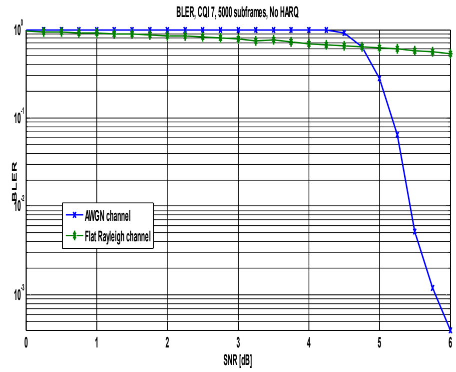

Fig 4 BER validation of different channels characteristics

C. Performance evaluation of Modulation-Coding schemes

LTE downlink performance was investigated under various modulation coding schemes, MSC, to investigate which MSC will be suggested to be used. Figure 4 shows the BER performance results of the DL link level simulations for different modulations schemes. It was shown that, the higher order modulation require greater SNR than the lower order modulation to achieve the same BLER. For example, at BLER=10^{-2} ,64-QAM requires SNR greater than 16-QAM by 4dB and 16-QAM requires greater SNR than QPSK by 5dB. So, we can say that: if the user far from the antenna QPSK is strongly suggested to be used as the power is weak and SNR is small, however 16-QAM & 64-QAM is to be used when user is near from the antenna because the SNR is already high. On the other hand, studing the effect of MSC on throughput was done, Fig. 4b, and it was found to have increased throughput with higher MCS as the number of data bits per frame is increased.

D. Effect of code rate on BER and Throughput

This simulation was done to investigate the performance of code rate on both LTE throughput and BLER. From the Fig. 5a we obtain that at a certain modulation technique, increasing the code rate which means reducing the redundancy and hence increasing the amount of useful information so throughput is increased.

On contrary, BER was also studied and curves showed that for a certain modulation technique, increasing the code rate, reduce the redundancy that added for error correction so, the BLER become worst. These simulations were done at 1.4MHz bandwidth.

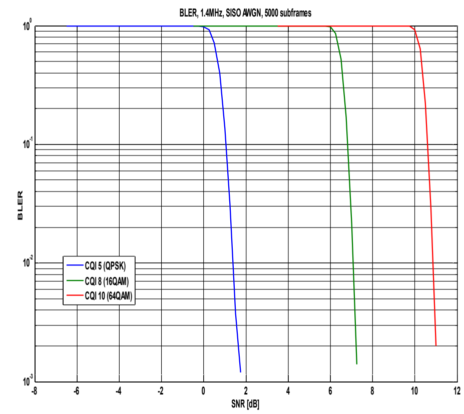

Figure 5a The Effect of modulation schemes on BLER

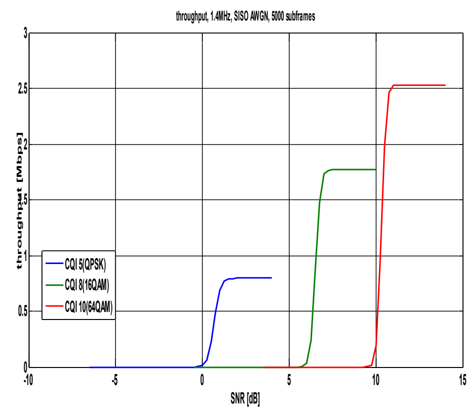

Figure 5b The Effect of modulation schemes on throughput

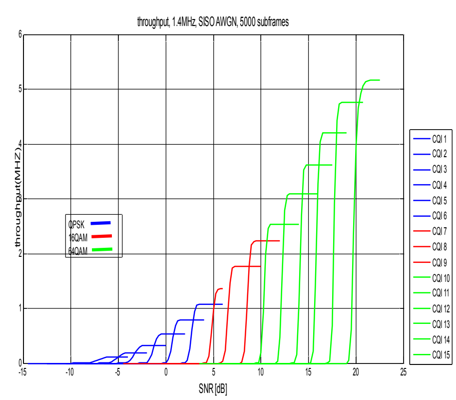

Figure 6a The Effect of the code rate on Throughput

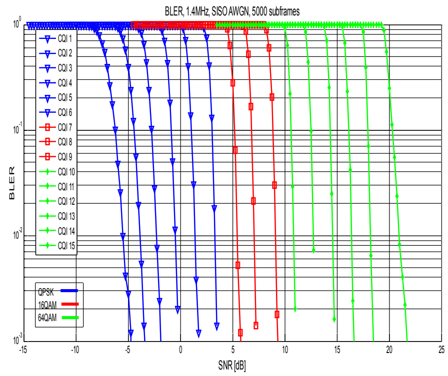

Figure 6b The Effect of the code rate on BLER

E. Effect of Channel Bandwidth

As well known, LTE channel bandwidth is scalable i.e it is allocated according to the service done. Different Channel bandwidths are 1.4,3,5,10 or 20 MHz. From simulations, we find that at a certain SNR, increasing the B.W will enhance throughput. We can't say that the worst case is to operate at B.W=1.4 Mhz and the best case is at B.W=20Mhz, because each application requires a certain Bandwidth and hence has certain throughput. Fig.7 confirm our results. Simulation done at AWGN, 500 subframe and NO HARQ.

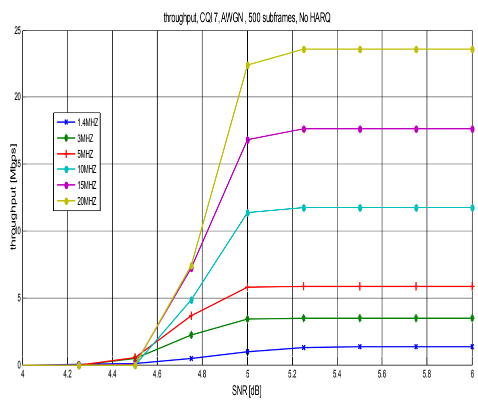

Figure 7a Effect of Bandwidth on Throughput

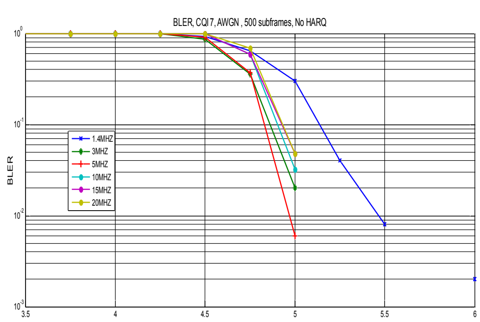

Figure 7b Effect of Bandwidth on BLER

F. Effect of HARQ

Several modes of HARQ are available so one of the important parameters to be studied is LTE performance against HARQ modes. Modes of 0, 1,2 or 3 retransmissons were investigated for both SISO or MIMO. Fig 8 shows that when use HARQ with 3 retransmissons with MIMO consideration is the best case, the worst was obtained when HARQ not included with MIMO mode. So to obtain maximum throughput MIMO with HARQ is suggested. Simulation was done at 5000 subframe and CQI=7.

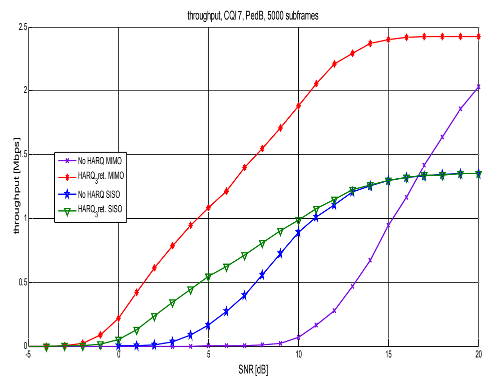

Figure 8. Throughput of different retransmissions for HARQ

V. Conclusions

Through this paper, MATLAB environment was used to simulate LTE physical layer. Many simulations were done to evaluate its performance under different conditions. After these simulations we come to believe that:

- 4x2 MIMO mode is strongly suggested over 2x1 and SISO mode.
- When user is near from base station so high SNR is available then 64QAM is to be used to increase data rate. When user goes farer from base station, MCS switches to 16QAM and QPSK so SNR required could be reduced on the expense of data rate.
- Code rate affects the performance of both BER and throughput. It was found that BER is decreased with increasing code rate where throughput is increased with higher code rates.
- Bandwidth is scalable i.e. it could be allocated according to the service provided, mainly for bandwidth conservation. Under the same conditions 5 MHz BW was found to give the best BER performance where the wider the bandwidth the better throughput is.
- HARQ is strongly suggested to be used with MIMO to give enhanced performance.

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