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A Simulation Design of LTE Communication System under Adaptive Modulation Schemes

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Abstract — Long-Term Evolution (LTE) is a standard for high-speed wireless communication for mobile phones and data terminals, based on the GSM/EDGE and UMTS/HSPA technologies. It increases the capacity and speed using a different radio interface together with core network improvements. The LTE standard uses three different modulation schemes to adapt to various channel conditions in order to improve achievable data rates. These modulation schemes are the QPSK, 16-QAM and 64-QAM. This paper presents an overview of a LTE digital communication system. A Simulation model, designed in order to study the effects of the different modulation schemes on the basis of BER performance with an AWGN channel model. Different subsystems within the transmitter and receiver blocks are implemented in MATLAB. It is noted that the LTE system uses different coding techniques to offer reliable and secure services to the users. Depending on the assumed channel condition (clear, medium clear or noisy), the 64-QAM, 16-QAM or QPSK modulation scheme, on the transmitter side as well as the corresponding demodulation scheme, on the receiver side is used. Based on the recovered data bits, the obtained bit error rates are analyzed, compared and discussed.

Keyword*- LTE, Adaptive modulation schemes, coding techniques, BER, SNR.*

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1. INTRODUCTION

LTE stands for Long Term Evolution and is a registered trademark owned by ETSI (European Telecommunications Standards Institute) for the wireless data communications technology and a development of the GSM/UMTS standards. However, other nations and companies do play an active role in the LTE project. The goal of LTE was to increase the capacity and speed of wireless data networks using new DSP (digital signal processing) techniques and modulations that were developed around the turn of the millennium. The simulation of the LTE communication system at its Physical Layer is crucial in order to assess and understand why and how the selection of a particular modulation scheme can affect its reliability in terms of its BER performance. One of the main distinguishing features of the LTE technology remains its ability to provide very high capacity and throughput services. In order to maintain such important features the LTE system has to adapt its modulation scheme to the communication channel's conditions. This adaptation of the LTE modulation scheme impacts on the reliability of the system since it affects its BER performance [1].This paper presents a mathematical foundation and associated algorithms of the LTE enabling technologies. This design study uniquely contributes to the understanding of the LTE digital communication PHY models and the improvement of the BER performance of the system. The focus of this paper is then turned towards implementing a fully operational LTE digital communication model by synchronizing and integrating its different subsystems. This study particularly evaluates the impact of both the channel conditions based adaptive modulation and the channel coding on the BER performance of the system.

As opposed to other related works, this design explores the isolated effect of LTE changes in the modulation schemes on the BER of the system.It then after explores the combination effects of modulation schemes adaptation and channel coding on the reliability of the communication system evaluated by means of the obtained

BER performance. A theoretical BER performance model for the AWGN channel model is first analysed before the simulated BER results are obtained from the simulation of the fully integrated LTE model. The study of three modulation schemes are analysed, discussed and compared to the theoretically expected results before being compared to each other. OFDM as transmitter, the signal is defined in the frequency domain. It is a sampled signal, and it is defined such that the discrete Fourier spectrum exists only at distinct frequencies. Each OFDM carriers corresponds to one element of this discrete Fourier spectrum.

The LTE specification provides downlink peak rates of at least 100 Mbps, an uplink of at least 50 Mbps and RAN round-trip times of less than 10 ms. LTE supports scalable carrier bandwidths, from 1.4 MHz to 20 MHz and supports both frequency division duplexing (FDD) and time
division duplexing (TDD).

2. Related Work

Long Term Evolution (LTE) is the new upgrade path for carrier with both GSM/UMTS networks and CDMA 2000 networks. The LTE is targeting to become the first global mobile phone standard regardless of the different LTE frequencies and bands use in other countries barrier. Adaptive Modulation and Coding (AMC) is used to increase the network capacity or downlink data rates. Various modulation types have been discussed such as Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM). Spatial multiplexing techniques for 4×4 MIMO antenna configuration is been studied. With channel station information feedback from the mobile receiver to the base station transmitter, adaptive modulation and coding can be applied to adapt to the mobile wireless channels condition to increase spectral efficiencies without increasing bit error rate in noisy channels. In High-Speed Downlink Packet Access (HSDPA) in Universal Mobile Telecommunications System (UMTS), AMC can be used to choose modulation types and forward error correction (FEC) coding rate.

In [1] paper presents an overview of a LTE digital communication system Simulink model, designed in order to study the effects of the QPSK, 16-QAM and 64-QAM modulation schemes on the BER performance with an AWGN channel model. Different subsystems within the transmitter and receiver blocks are implemented in Simulink. It is noted that the LTE system uses Turbo channel coding and bit level scrambling to offer reliable and secure services to the users. Depending on the assumed channel condition (clear, medium clear or noisy), the 64-QAM, 16-QAM or QPSK modulation scheme, on the transmitter side; as well as the corresponding demodulation scheme, on the receiver side; are automatically selected. In [2] various modulation types are discussed such as Quadrature Phase Shift Keying (QPSK), Quadrature Amplitude Modulation (QAM). Spatial multiplexing techniques for 4×4 MIMO antenna configuration is studied. With channel station information feedback from the mobile receiver to the base station transmitter, adaptive modulation and coding can be applied to adapt to the mobile wireless channels condition to increase spectral efficiencies without increasing bit error rate in noisy channels. .In High-Speed Downlink Packet Access (HSDPA) in Universal Mobile Telecommunications System (UMTS), AMC can be used to choose modulation types and forward error correction (FEC) coding rate. In paper [4] channel coding and link adaptation in LTE was considered, which important issues are in modern digital communication systems. With channel coding, errors caused by distortion during transmission are detected and/or corrected. In LTE both convolutional and Turbo codes are used. The structure of convolutional codes in LTE is presented here. Turbo codes and internal contention free interleaver, which is an important part of the Turbo encoder are also topics of this work. The concept of the circular buffer, which is used in the rate matching module and HARQ was discussed, too. Another key feature used in LTE is the link adaptation. Link adaptation makes the efficient use of the channel capacity possible, matching the transmission parameters, modulation scheme and coding rate to the channel conditions.

3. OFDM With System Model

The model of the LTE transmission system is depicted in Fig.1. An information bit vector b = (b1, . . . , bm, . . . , blb), including 24 Cyclic Redundancy Check (CRC) bits, is encoded by asystematic rate-1/3 Turbo encoder, consisting of two Parallel Concatenated Convolutional Codes (PCCCs) with octal generator polynomials GCC = (1, 15/13) 8 and constraint length £ + 1 = 4. The encoded bits are then separated into three streams. The first contains the systematic bits b, while the second and third contain the parity bits of the two constituent encoders cI = (c1I ,…, cmI ,…, clbI) and cII = (c1II ,…, cmII ,…, clbII), respectively. Then, all streams are individually interleaved by so-called sub-interleavers πb, π1 and π2 and written to a ring buffer. At first, all systematic bits˜b are written to the ring buffer. Then, the parity bits of both streams ˜cI and ˜Cii

Are interlaced and also written to the ring buffer according to the structure shown in Fig. 1. Finally, a block y = (y1, . . . ,yn, . . . ,yly) of ly encoded bits is selected for transmission resulting in an effective code rate rRM = lb/ly after rate matching. The bits selected for transmission are finally assigned to complex modulation symbols S according to the specifie dmodulation schemes QPSK, 16QAM, or 64QAM. On the receiving side, the demodulated complex symbols Z are fed into a soft demapper which delivers reliability information in terms of Log-Likelihood Ratios (LLRs) L[Chan] DM(b) ,L[Chan] DM (cI) . L[Chan] DM (cII) on the interleaved, systematic information bits and the parity bits of the two constituent encoders. The deinterleaved LLRs are then passed onto the Turbo decoder which uses the Bahl-Cocke-Jelinek-Raviv (BCJR) algorithm for soft channel decoding. After a fixed number of decoding iterations, b is estimated from the resulting a posterior iLLRs. If the CRC detects an erroneous frame, the receiver will request for a transmission of additional (incremental) redundancy about the same frame by sending a Negative acknowledge (NACK) to the transmitter. Otherwise, an acknowledge (ACK) is fed back resulting in the transmission of consecutive (new) frames. The feedback channel is indicated by the dashed line in Fig. 1. The LTE HARQ scheme allows for up to K = 4 transmissions of different combinations of systematic and parity bits, the so-called Redundancy Versions (RVs). Obviously, each RV transmission implicitly decreases the effective code rate which results in a decreased throughput and increased latency. According to [1], the initial reading position $\theta\varrho$ in the ring buffer of a distinct RV ϱ $(1 \le \varrho \le K)$ is given by

$$\theta p = \Psi (2 (p-1) [3(lb + 4) / 8\Psi] + 2) ,$$

$\Psi = [lb + 4 / 32]$ (1) where [.] rounds up its argument to nearest integer value.

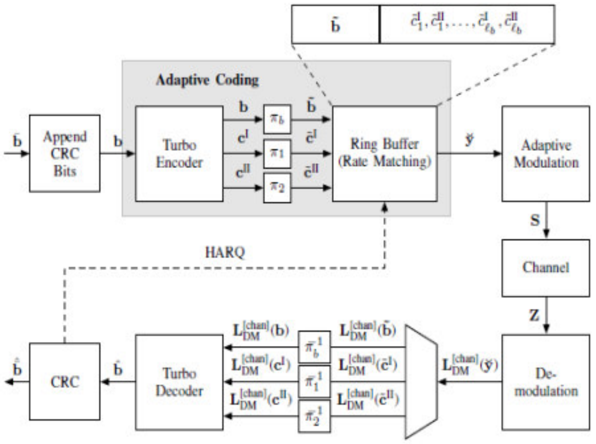

Fig. 1 Model of LTE physical layer

4. Modulation Scheme

In cellular communication systems, the quality of a signal received by a UE depends on the distance between the desired and interfering base stations, multipath or shadow fading, noise etc,. In order to improve system capacity, peak data rate and coverage reliability of the cellular systems, the signal transmitted to and by a particular user is modified to signal quality variation to provide maximum system throughput and flexible data rate for services. This can be achieved by adapting AMC schemes. The AMC scheme adjust the modulation and coding scheme to the channel state conditions (CSCs) to accomplish the highest spectral efficiency at all times by overcome the fading and other interference. LTE network supports QPSKor4-QAM, 16-QAM and 64-QAM modulation schemes in order to provide different data rates for different kind of mobile broadband services by reacting dynamically to the channel fluctuation. The users closer to the eNB (enhanced Base Station) exploits the 64-QAM scheme to provide higher data rates for services, but the modulation order and/or code rate will decrease as the distance from eNB increases. The AMC schemes are generally represented by M- QAM, where M represents the modulation order or number of conditions or constellation points are available to provide high transmission data rates by transmitting more bits per symbol with high spectral efficiency [7].In general the constellation points for M-QAM can be generated as [8, 9].

5. Conclusion

In this paper we have presented an overview of a LTE digital communication system with different modulation schemes. The main focus of this paper is on QoS improvement by efficiently utilizing available spectrum in LTE. The main objective is to obtain higher system throughput for LTE compared to standard LTE solution. It is been observed that by using proper modulation scheme in LTE the BER performance and reliability of communication channel can be improved.

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