AIN SHAMS UNIVERSITY
FACULTY OF ENGINEERING
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Electronics and Communications Engineering Department

Performance Evaluation of LTE Downlink with higher order Modulation Schemes

Dissertation submitted to the Faculty of the Engineering – Ain-Shams University in partial fulfillment of the requirements for the degree of Master of Science in Electrical Engineering

submitted by

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Degree: **Master of Science in Electrical Engineering**

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STATEMENT

This dissertation is submitted to Ain Shams University in partial fulfillment of the degree of Masters of Science in Electrical Engineering.

The work included in this dissertation was carried out by the author in the department of Electronics and Communications Engineering, Ain Shams University.

No part of this dissertation has been submitted for a degree or a qualification at any other university or institute.

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Abstract

Long Term Evolution (LTE), developed by Third Generation Partnership Project (3GPP), is the access part of the Evolved Packet System (EPS). LTE physical layer is based on Orthogonal Frequency Division Multiple Access (OFDMA) with Quadrature Amplitude Modulation (QAM). Although there have been lots of enhancements in the LTE physical layer, yet higher order modulation schemes were not introduced in the specification until Release 12.

This thesis investigates the performance of LTE with 256-QAM. At the start of this work, the 3GPP didn't introduce higher order modulation scheme (256-QAM) in LTE-A (LTE-Advanced) specification. It wasn't until release 12.3 that such an enhancement has been introduced. Adopting a higher order modulation scheme aims to enhance the spectral efficiency of the system and increase the peak user data rates. This is one of the various aspects that targets to fulfill the massively increasing demand in the transmitted data volume over mobile networks.

When proposing higher order modulation to an existing standard, a question arises regarding the efficiency of the transmission and whether the error protection and correction techniques that are defined in the standard will have the ability to mitigate the increased BER in the system. In addition, and in light of this question, it is also needed to quantify the gain of the proposed modification. Quantifying such gain is essential when making decisions of investment in new systems.

The first part of the study is based on a MATLAB system model simulation. Channel models that were tested included Additive White Gaussian Noise (AWGN), Pedestrian B (PedB) and Vehicular A (VehA) channels, which are ITU standardized modeling channels. Bit Error Rate (BER) values were populated for the probable Signal to Noise Ratio (SNR) operating ranges. The minimum required SNR for the operation of different Modulation and Coding Schemes (MCS) was identified, having the criteria of achieving a maximum of 10^{-6} BER for reliable transmission. In addition, a capacity and coverage study has been conducted to quantify the cell capacity gain and the coverage range for each modulation scheme.

Results demonstrate that LTE-A can adopt the 256-QAM higher order modulation and have its main gain of enabling a 33% increase in the user's maximum allowed bit rate, although a relatively few users will be able to enjoy this throughput upsurge. Nomadic users are more likely to enjoy the enhanced user experience, although vehicular users have the privilege as well in the case of facing good radio conditions that can be mapped to having good coverage in a non-busy hour case to avoid exposure to high system interference.

The analysis over the cell level has also shown that cell capacity gain reaches up to 1.5%, while the cell coverage range and expected footprint falls in a 140m coverage area. The capacity gain is not high when inspected on a cell level basis, where this is a consequence of the small coverage range. This may stand as a challenging deal for operators who seek to enhance the user experience while direct revenues (expected from the higher users consumption rates, i.e due to their use of 256-QAM) may not cover the incurred expected costs of the upgrades to LTE-A release 12.3.

It is thus recommended to implement the modulation upgrade on specific cells that serve open areas, which have hot spots close to the cell site location, in a relatively low to medium data rate consumption urban/suburban locations. Typical applications target airports, railway stations, football stadiums and similar zones.

Keywords:
256-QAM, Bit Error Rate (BER), Long Term Evolution (LTE), Long Term Evolution Advanced (LTE-A), Modulation, Physical Layer, Quadrature Amplitude Modulation (QAM), Throughput

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PERFORMANCE EVALUATION OF LTE DOWNLINK WITH HIGHER ORDER MODULATION SCHEMES

A THESIS
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I would like to dedicate this thesis to my beloved parents. The reason for who I am today. Thanks for your great support and continuous care.

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LIST OF ACRONYMS

1G	1st Generation
3GPP	3rd Generation Partnership Project
AMC	Adaptive Modulation and Coding
AMPS	Advanced Mobile Phone Systems
ARQ	Automatic Repeat Request
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK	Binary Phase Shift Keying
BPSK	Binary Phase Shift Keying
BS	Base Station
BW	Bandwidth
CCPCH	Communication Control Physical Channel
CDMA	Code Division Multiple Access
CIR	Channel Impulse Response
CLSM	Closed Loop Spatial Multiplexing
CoMP	Coordinated Multi Point operation
CP	Cyclic Prefix
CQI	Channel Quality Information
CRC	Cyclic Redundancy Check
DAC	Digital to Analog Conversion
DFT	Discrete Fourier Transform
DL-SCH	Downlink Shared Channel
DPSK	Differential Phase Shift Keying
DQPSK	Differential Quadrature Phase Shift Keying
DwPTS	Downlink Pilot Slot

EDGE	Enhanced Data Rate for GSM Evolution
EPC	Evolved Packet Core
EPS	Evolved Packet System
FBMC	Filter Bank Multi Carrier
FDD	Frequency Division Duplex
FDMA	Frequency division multiple access
FFT	Fast Fourier Transform
FSK	Frequency Shift Keying
GMSK	Gaussian minimum-shift keying
GPRS	General Packet Radio Service
GSM	Global System for Mobile Communication
HARQ	Hybrid automatic repeat request
IDFT	Inverse Discrete Fourier Transform
IFFT	Inverse Fast Fourier Transform
ITU	International Telecommunication Union
LOS	Line of Sight
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
M2M	Machine to Machine
M-ASK	Multi Amplitude-shift keying
MCS	Modulation and Coding Schemes
MIMO	Multiple-Input and Multiple-Output
MPLS	Multi-Protocol Label Switching
MSK	Minimum-shift keying
NLOS	None Line of Sight
OFDMA	Orthogonal Frequency Division Multiple Access
OLSM	Open Loop Spatial Multiplexing
OQPSK	Offset Quadrature Phase Shift Keying
PAPR	Peak to Average Power Ratio