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Performance Evaluation of LTE Physical Layer Using OFDMA And SC-FDMA

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استهلال

بسم الله الرحمن الرحيم

(أَلَمْ تَرَ أَنَّ اللَّهَ أَنزَلَ مِنَ السَّمَاء مَاء فَأَخْرَجْنَا بِهِ ثَمَرَاتٍ مُّخْتَلِفًا أَلْوَانُهَا وَمِنَ الْجِبَالِ جُدَدٌ بِيضٌ وَحُمْرٌ مُّخْتَلِفٌ أَلْوَانُهَا وَغَرَابِيبُ سُودٌ وَمِنَ النَّاسِ وَالدَّوَابِّ وَالْأَنْعَامِ مُخْتَلِفٌ أَلْوَانُهُ كَذَلِكَ إِنَّمَا يَخْشَى اللَّهَ مِنْ عِبَادِهِ الْعُلَمَاء إِنَّ اللَّهَ عَزِيزٌ غَفُورٌ)

Dedication

We dedicate this work to the souls of those whom we love since our childhood and it remains forever, our beloved mothers, fathers. the moments and days with them shall not be forgotten.

Acknowledgement

First of all we give thanks to Allah for blessing us and giving us the power to achieve this work. With a deep sense of gratitude, we wish to express our sincere thanks to our supervisor Dr. Mohamed Hussein Mohamed, we truly appreciate his esteemed guidance, encouragement and constructive criticisms from the beginning to the end of this thesis, without his help and support this thesis wouldn't has been done.

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Abstract

Since past few decades different types of cellular networks were launched and went successful on the radio links such as WiMAX, that became very popular because of its high data rate (70Mbps) and support for providing wireless internet services over 50km distance. The UMTS Long Term Evolution (LTE) is an emerging technology in the evolution of 3G cellular services. LTE runs on an evolution of the existing UMTS infrastructure already used by over 80 percent of mobile subscribers globally. We have very limited resources in cellular technologies and it is important to utilize them with high efficiency.

Single Carrier Frequency Division Multiple Access (SC-FDMA) & Orthogonal Division Multiple Access (OFDMA) are major part of LTE. OFDMA was well utilized for achieving high spectral efficiency in communication system. SC-FDMA is introduced recently and it became handy candidate for uplink multiple access scheme in LTE system that is a project of Third Generation Partnership Project (3GPP).

The Multiple Access Scheme in Advanced Mobile radio system has to meet the challenging requirements for example high throughput, good robustness, efficient Bit Error Rate (BER), high spectral efficiency, low delays, low computational complexity, low Peak to Average Power Ratio (PAPR), low error probability etc. Error probability is playing vital role in channel estimation and there are many ways to do channel estimation, like Wiener Channel Estimation, Bayesian Demodulation etc.

In our thesis, we investigate the performance of SC-FDMA and OFDMA of LTE physical layer by considering different modulation schemes (BPSK, QPSK, 16QAM and 64QAM) on the basis of PAPR, BER, power spectral density (PSD) and error probability by simulating the model of SC-FDMA & OFDMA.

المستخلص

أُطلقت منذ العقود السابقة أنواع مختلفة من الشبكات الخلوية ونجحت في الاتصالات الراديوية مثل شبكة واي ماكس التي أصبحت منتشرة جداً بسبب ارتفاع معدل نقل البيانات التي تصل إلى 70 ميجا بت للثانية كما أنها توفر خدمات الانترنت لاسلكياً لمسافة تصل لمسافة 50 كيلو متر.

الجيل الرابع (تطوير طويل الأجل) هي تقنية ناشئة من تطوير الجيل الثالث للخدمات الخلوية تعمل على تطوير البنية التحتية المستخدمة حالياً التي تمثل 80% من مستخدمين الهاتف النقال على مستوى العالم، لدنيا موارد بسيطة جداً في مجال التكنولوجيا الخلوية وانه من المهم الاستفادة منها بكفاءة عالية.

تقنية الوصول المتعدد ذات تردد الحامل الواحد وتقنية الوصول المتعدد ذات الترددات المتعامدة هما الجزء الأساسي في الجيل الرابع. تستخدم تقنية الوصول المتعدد ذات الترددات المتعامدة لتحقيق كفاءة طيفية عالية في نظام الاتصالات أما تقنية الوصول المتعدد ذات تردد الحامل الواحد عرضت مؤخراً واستخدمت لنظام الإرسال متعدد الوصول في الجيل الرابع (تطور طويل الأجل).

تقنية الوصول المتعدد في الأنظمة الراديوية المتنقلة المطورة تواجه تحديات لتلبية متطلبات صعبة على سبيل المثال إنتاجية عالية ، متانة جيدة ، كفاءة نسبة الخطأ في البت ، الكفاءة الطيفية العالية ، التأخير ، انخفاض التعديل الحسابي ، انخفاض الذروة إلى مستوى الطاقة وانخفاض احتمالية الخطأ. احتمال حدوث الخطأ يلعب دوراً حيوياً في تقييم القناة وهناك عدة طرق لتقييم القناة مثل وينير لتقيم القناة وبايزين الاستخلاص الخ.

في مشروعنا سنتحقق من كفاءة أدائية تقنية الوصول المتعدد ذو تردد الحامل الواحد. وتقنية الوصول المتعدد ذو الترددات المتعامدة في نظام الجيل الرابع (تطور طويل الأجل) باستخدام تقنيات تعديل مختلفة عن طريق الذروة على متوسط نسبة الطاقة ، نسبة الخطأ في البت ، كثافة قدرة الطاقة واحتمالية حدوث الخطأ وذلك بمحاكاة تقنية الوصول المتعدد ذات الترددات المتعامدة وتقنية الوصول المتعدد ذات تردد الحامل الواحد.

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ABBREVIATIONS

3GPP	3rd Generation Partnership Project
ACK	Acknowledgment
ARQ	Automatic Repeat Request
ASK	Amplitude Shift Keying
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BPSK `	Binary Phase Shift Keying
CCE	Control Channel Elements
CDMA	Code Division Multiple Access
CP	Cyclic Prefix
CQI	Channel Quality Indicators
CDMA	Code Division Multiple Access
CIR	Channel Impulse Response
DCI	Downlink Control Information
DFT	Discrete Fourier Transform
DL	Downlink
DM-RS	Demodulation Reference Signals
FDD	Frequency Division Duplex
FFT	Fast Fourier Transform
FSK	Frequency Shift Keying
GSM	Global System for Mobile Communication
HARQ	Hybrid Automatic Repeat Request
ICI	Inter Carriers Interference
IDFT	Inverse Discrete Fourier Transform
IFFT	Inverse Fast Fourier Transform
ISI	Inter Symbol Interference
LTE	Long Term Evolution
MAC	Medium Access Control Layer

MBMS	Multimedia Broadcast and Multicast Services
MIB	Master Information Block
MIMO	Multiple Input Multiple Output
NACK	Negative Acknowledgment
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Orthogonal Frequency Division Multiplex Access
PAPR	Peak-to-Average Power Ratio
PBCH	Physical Broadcast Channel
Pe	Error Probability
PCFICH	Physical Control Format Indicator Channel
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PDU	Protocol Data Unit
PHICH	Physical Hybrid ARQ Indicator Channel
PHY	Physical Layer
PMI	Precoding Matrix Indicator
PRACH	Physical Random Access Channel
PSD	Power Spectral Density
PSS	Primary Synchronization Sequence
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature Amplitude Modulation
QPSK	Quadrature Phase Shift Keying
SC-FDMA	Single Carrier Frequency Division Multiple Access
SFBC	Space Frequency Block Code
SDMA	Space Division Multiple Access
SNR	Signal to Noise Ratio
SRS	Sounding Reference Signal
SSS	Synchronization Sequence
TB	Transport Block

TDD	Time Division Duplex
TTI	Transmission Time Interval
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunication System
WCDMA	Wideband Code Division Multiple Access

Chapter One

Introduction

1.1 Preface

The long term evolution (LTE) is one of the latest steps in cellular 3G services. LTE is launched by 3rd Generation Partnership Project (3GPP) and that project was started in 2004. It brought many benefits to cellular networks in terms of bandwidth, latency, data rates, spectral efficiencies etc.

The OFDM is used in LTE as multiplexing scheme, LTE uses SC-FDMA for uplink and OFDMA for downlink transmission. SC-FDMA was introduced in LTE in order to save power from uplink transmission.

The LTE increases the system capacity and widens the spectrum from existing technology up to 20MHz. It can be deployed in any bandwidth combination because of its flexible usage of spectrum (1.4 MHz to 20 MHz). It uses Frequency Division Duplex (FDD) and Time Division Duplex (TDD) to suit all types of spectrum resources. [8]

1.2 Problem statement

A principal weakness of OFDM is the high peak-to-average power ratio (PAPR). The transmitted signal is the sum of all the modulated subcarriers and high amplitude peaks are inevitable because many of the subcarriers are in phase for some input sequences. The amplitude peaks impose a heavy burden on the power amplifier of a transmitter. Relative to time-domain transmission techniques, OFDM is also more vulnerable to frequency offset and frequency selective fading.

1.3 Proposed solution

OFDMA is well utilized for achieving high spectral efficiency in communication systems. To overcome the drawbacks of OFDMA specially the PAPR a modified form of OFDMA which referred to as Single Carrier Frequency Division Multiple Access (SC-FDMA) has proposed for uplink transmission.

1.4 Research Objectives:

- Using different modulation techniques (BPSK, QPSK, 16-QAM and 64-QAM) for the above two systems.
- To evaluate the performance of LTE physical layer in term of SNR, BER, PSD, PAPR and Probability of Error.

1.5 Methodology

MATLAB was used to simulate SC-FDMA and OFDMA systems with description of transmission and receiving processes with adaptive modulation techniques BPSK, QPSK, 16-QAM and 64-QAM. We have considered SNR, BER, PSD, bit error probability and PAPR parameters to evaluate the performance of LTE physical layer for both uplink and downlink.

1.6 Research Outlines

The following is the outline of the remainder of the thesis:

Chapter 2: introduces introduction and motivation of LTE, literature review, LTE performance demand, frequency and bandwidth, multiple access schemes of OFDMA and SC-FDMA and MIMO basics.

Chapter 3: discusses LTE physical layer in details.

Chapter 4: analyzes OFDMA and SC-FDMA system design and simulation results.

Chapter 5: introduces summary of the work and a few recommendations for future work.