UNIVERSITI PUTRA MALAYSIA

CHANNEL QUALITY INDICATOR FOR LONG TERM EVOLUTION SYSTEM BASED ON ADAPTIVE THRESHOLD FEEDBACK COMPRESSION SCHEME

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By

MUNTADHER QASIM ABDULHASAN

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Master of Science

July 2014

DEDICATION

قال تعالى :

{وَمَن يَتَّقِ ٱللَّهَ يَجْعَل لَّهُ مَخْرَجاً * وَيَرْزُقْهُ مِنْ حَيْثُ لاَ يَحْتَسِب}

(3) ФыГ

This thesis is dedicated to:
My lovely parents that their tears gave me the power,
My nearest person my wife that stand with me,
My brother and sisters,
My uncle Dr.Azet Sadik,
Special thanks to my dear Prof. Nor Kamariah Noordin and Dr. Chee Kyun Ng that without them I couldn't do anything,
All of my friends,
Special thanks to my dearest brother Bilal Fouad
My beloved first and second country Iraq and Malaysia

Abstract of the thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Master of Science

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MUNTADHER QASIM ABDULHASAN

July 2014

Chairman: Prof. Nor Kamariah Noordin

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The huge demands for mobile wireless data traffics are increasing rapidly during the recent years. Long-term evolution (LTE) has been standardized by the Third-Generation Partnership Project (3GPP) as a new access technology to meet the tremendous requirements of current mobile systems. To further support the network infrastructure and satisfy all the diverse sets of requirements, LTE adopted an advanced and powerful technique such as Multiple-in multiple-out (MIMO) and orthogonal frequency division multiplexing OFDM.

CQI feedback is an essential technique in describing the channel state information of LTE system. Hence, CQI calculations highly depend on the accuracy of the channel estimation process. A precious channel estimation scheme is necessary to indicate the instantaneous channel condition. Many practical problems in LTE occur when LTE feedback is calculated by CQI. If the user needs to report precise channel state condition, the amount of CQI reported to the eNodeB must be increased. However, increasing the amount of such feedback inevitably results in extra signaling overhead and system performance degradation. Therefore, an appropriate method for CQI estimation and CQI feedback overhead reduction is important. This thesis proposes an adaptive feedback algorithm that uses a threshold scheme to enhance the system throughput while maintaining low Block Error Rate (BLER), Bit Error Rate (BER), and overhead. This proposed feedback mechanism considers the channel quality condition, modulation order, and code rate for various antenna configurations and different user speeds.

Results show that the system throughput increases with a stable LTE BLER target and system overhead by using the adaptive threshold of the CQI feedback scheme. This proposed adaptive scheme dynamically adapts the threshold level to Signal to Noise Ratio (SNR) variations, thus increasing the throughput and reducing the CQI feedback overhead. This adaptive approach also enhances the tradeoff between system throughput and BLER. Compared with conventional CQI feedback schemes, such as the full feedback, averaging best-m CQI methods, the proposed scheme significantly improves the system throughput while maintaining the BLER target and

overhead. The percentage difference from the adaptive threshold CQI feedback scheme is around 2.4% compared with the averaging method, wherein a 2% system improvement occurs across all SNR values. The percentage difference is 2.1%, compared with the full feedback method, with only 0.5% degradation. The results demonstrate that although increasing the antenna was improved the system throughput remarkably but it comes at the cost of BLER performance. Using MIMO 2x2 is highly recommended since it achieves a reasonable results compared with high and low order antenna configurations.

Abstrak tesis ini dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Master Sains

PENUNJUK KUALITI SALURAN UNTUK SISTEM EVOLUSI JANGKA PANJANG BERDASARKAN SKIM MAMPATAN PENYESUAIAN AMBANG MAKLUM BALAS

Oleh

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Permintaan yang amat besar untuk trafik data tanpa wayar telah bertambah dengan pesat pada beberapa tahun kebelakangan. Evolusi Jangka Panjang (LTE) telah dipiawaikan oleh Projek Perkongsian Jenerasi Ke Tiga (3GPP) sebagai teknologi capaian yang baharu untuk memenuhi keperluan besar sistem bergerak masa kini. Untuk terus menyokong prasarana rangkaian dan memenuhi semua set keperluan yang pelbagai, LTE telah mengambil teknik yang termaju dan berkuasa seperti Berbilang Masukan Berbilang Keluaran (MIMO) dan Frekuensi Ortogonal Pemultipleksan Bahagian (OFDM). Pengiraan CQI banyak bergantung kepada ketepatan proses jangkaan saluran. Skim jangkaan saluran yang berharga adalah diperlukan untuk menunjukkan keadaan saluran serta-merta.
Banyak masalah yang praktikal dalam LTE berlaku apabila maklum balas LTE dikira oleh CQI. Jika pengguna perlu melaporkan keadaan saluran yang tepat, jumlah CQI yang dilaporkan ke eNodeB mesti ditambahkan. Walau bagaimanapun, menambah jumlah maklum balas akan mengujudkan overhed pengisyaratan dan penurunan prestasi sistem. Justeru, kaedah yang sesuai untuk penganggaran dan pengurangan overhed maklum balas CQI adalah penting. Tesis ini mencadangkan algoritma penyesuaian maklum balas mekanisme keadaan kualiti saluran untuk skim ambang untuk meningkatkan daya pemprosesan system sambil mengekalkan Blok Kadar Ralat (BLER), Kadar Ralat Bit (BER) dan overhed. Ia mencadangkan mekanisme maklum balas yang mempertimbangkan keadaan kualiti saluran, turutan modulasi dan kadar kod untuk pelbagai konfigurasi antenna dan kelajuan pengguna yang berbeza.

Keputusan menunjukkan sistem daya pemprosesan meningkat dengan sasaran BLER LTE dan overhed sistem dengan menggunakan penyesuaian ambang skim maklum balas CQI. Ini mencadangkan skim penyesuaian menyesuai secara dinamik tingkat ambang kepada variasi Isyarat ke Nisbah Hingar (SNR), oleh itu menambahkan daya pemprosesan dan mengurangkan overhed maklum balas CQI. Pendekatan penyesuaian ini juga meningkatkan keseimbangan antara daya pemprosesan dan

BLER. Berbanding dengan skim maklum balas konvensional seperti maklum balas penuh dengan purata kaedah terbaik-m CQI, skim yang dicadangkan meningkat dengan ketara sambil sasaran BLER dan overhed. Perbezaan peratusan daripada maklum balas ambang penyesuaian adalah sekitar 2.4% berbanding dengan kaedah purata, di mana peningkatan sistem sebanyak 2% berlaku di dalam semua nilai SNR. Perbezaan peratusan adalah sebanyak 2.1% berbanding dengan kaedah maklum balas penuh dengan hanya penurunan sebanyak 0.5%. Keputusan ini menunjukkan walaupun peningkatan antenna telah meningkatkan daya pemprosesan sistem secara ketara tetapi ia datang dengan kos prestasi BLER. Menggunakan MIMO 2x2 adalah amat dicadangkan sebab ia mencapai keputusan yang munasabah dengan konfigurasi antenna turutan tinggi dan rendah.

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I certify that a Thesis Examination Committee has met on 23 July 2014 to conduct the final examination of Muntadher Qasim Abdulhasan on his thesis entitled "Channel Quality Indicator for Long Term Evolution System Based on Adaptive Threshold Feedback Compression Scheme" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

3GPP	Third Generation Partnership Project
4G	Fourth Generation
AB-CQI	Absolute CQI
ALMMSE	Approximate Linear Minimum Mean Square Error
AMC	Adaptive Modulation and Coding
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
BER	Bit Error Rate
BICM	Bit Interleaved Coded Modulation
BLER	Block Error Rate
BPSK	Binary Phase Shift Keying
CA	Carrier Aggregation
CCs	Component Carriers
CDMA	Code Division Multiple Access
CL	Closed Loop
CLSM	Closed Loop Spatial Multiplexing
CoMP	Coordinated Multi-Point Transmission
CP	Cyclic Prefix
CQI	Channel Quality Indicator
CS	Compressive Sensing
CSI	Channel State Information
CW	Code Word
DCT	Discrete Cosine Transform
DL	Down Link
DM	Differential Modulation
EESM	Exponential Effective SINR Mapping
eNodeB	Evolved Node B
EPC	Evolved packet core
ESM	Effective SINR Mapping
E-UTRAN	Evolved-Universal Terrestrial Radio Access Network
EV-DO	Evolution Data Voice
E_S/N_0	Energy symbol per noise power spectral density
FDD	Frequency-Division Duplex
FEC	Frame Error Correction
FFT	Fast Fourier Transform
FIFO	First-in First-out
HARQ	Hybrid Automatic Repeat Request
HSPA	High-Speed Packet Access
HSS	Home-Subscriber-Server
IFFT	Inverse FFT
IMS	IP Multimedia Subsystem
IMT	International Mobile Telephony
IMT-Advanced	International Mobile Telecommunications-Advanced
IP	Internet protocol
ISI	Inter-Symbol Interference
ITU	International Telecommunication Union

ITU-R	International Telecommunication Union and radio
LA	Link Adaption
LS	least squares
LTE	Long Term Evolution
LTE-A	Long Term Evolution Advanced
M2M	Machine to Machine
MCS	Modulation and Coding Scheme
MIESM	Mutual Information Effective SINR Mapping
MIMO	Multiple-in multiple-out
MME	Mobility-Management-Entity
MMSE	Minimum Mean Square Error
MSE	Mean Square Error
MU-MIMO	Multi-User MIMO
NACK	Non-acknowledgment
OFDM	Orthogonal Frequency Division Multiple
OFDMA	Orthogonal Frequency Division Multiple Access
OLLA	Outer Loop LA
PAPR	Peak to Average Power Ratio
PCFICH	Physical Control Format Indicator Channel
P-CQI	Prediction-based CQI reporting method
P-CQI	Prediction CQI
PCRF	Policy and Charging-Rules-Functions
PDNG	Packet-Data-Network-Gateway
PDN-GW	Packet Data Network Gateway
PDSCH	Physical Downlink Shared Channel
PDSCH	Physical Downlink Shared Channel
PFPS	Proportional Fairness Packet Scheduling Algorithm
PHICH	physical (HARQ) indicator channel
PMI	Precoding Matrix Indicator
PRACH	Physical Random-Access Channel
PRB	Physical Resource Block
PSTN	Public Switched Telephone Network
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QAM	Quadrature amplitude modulation
QPSK	Quadrature Phase Shift Keying
RAN	Radio Access Network
RB	Resource Block
RE	Resource Element
Rel-8	Release 8
RI	Rank Indicator
RRM	Radio Resource Management
RS	Reference Signal
SC-FDMA	Single Carrier Frequency Division Multiple Accesses
SGW	Serving-Gateway
SINR	Signal-to-Interference-plus-Noise Ratio
SLNR	Signal to Leakage plus Noise Ratio
SM	Spatial Multiplexing
SNR	Signal to Noise Ratio

SVD	Singular Value Decomposition
TCP-OFB	Transmitter Controlled Precoding and Opportunistic
TDB	Time Decimated Bitmap
TDD	Time Division Duplex
TD-SCDMA	Time Division Synchronous Code Division Multiple
TH-CQI	Threshold CQI
TTI	Transmission Time Interval
TxD	Transmit Diversity
UE	User Equipment
UTRAN	Universal Terrestrial Radio Access Network
WCDMA	Wide-band Code Division Multiple Access
ZF	Zero Forcing
ZFBF	Zero-Forcing Beam-Forming

CHAPTER 1

INTRODUCTION

1.1 Background

The data traffic of wireless communications devices from around the world has been expanding remarkably, recording a 66-fold increase between 2008 and 2013 [1]. The forecasted demands of data traffic come from a variety of devices, such as smart phones, laptops, tablets, and machine-to-machine (M2M) systems. This demand is foreseen to increase rapidly until 2018. As illustrated in [2] the annual growth rate of mobile data traffics grew 81% in 2013 and is expected to be 15.9 exabyte per month by 2018, recording a 11-fold increase over 2013.

The latest statistics show that approximately three-quarters of the world‘s inhabitants have access to mobile phones [3]. This unpredicted increase in heterogeneous devices has pushed researchers to develop additional advanced features to accommodate enormous data traffic. Therefore, long-term evolution (LTE) has been standardized by the Third-Generation Partnership Project (3GPP) as a new access technology to meet the tremendous requirements of current mobile systems. To support the network infrastructure and satisfy the requirements drawn by the International Mobile Telecommunications Advanced, LTE-advanced (LTE-A) has been introduced as a fourth generation (4G) cellular system that is fully endorsed by the Radio communication Sector of the International Telecommunication Union (ITU-R) [4].

Furthermore, LTE also targets for a smooth evolution from previous 3GPP and 3GPP2 systems by supporting both frequency-division duplex (FDD) and time-division duplex (TDD), as well as operating in scalable bandwidths (1.4 to 20 MHz) [5]. It is evolution of 3GPP such as; wide-band code division multiple access (WCDMA) and high-speed packet access (HSPA) based FDD as well as time division synchronous code division multiple access (TD-SCDMA) and HSPA based TDD. Moreover, it is evolution of 3GPP2 systems such as code division multiple access (CDMA) 2000 and Evolution Data Voice (EV-DO) [6]. Figure 1.1 reflects the evolution of current wireless generation. Finally, LTE also constitutes a major step toward international mobile telephony (IMT)-Advanced. In fact, the first release of LTE already includes many of the features originally considered for future fourth-generation systems. The framework of the current wireless evolution of 3GPP was starting to develop since December 2004 [7].

This chapter is organized as follows. Section 1.2 discusses the research problems and research issues under investigation. Section 1.3 describes the research aims and objectives. The thesis’s scope in addition to demonstrate the study module in a block diagram forms is stated in Section 1.4. Section 1.5 carries out the research contribution. Finally, Section 1.6 outlines thesis organization and remainder of the coming chapters.

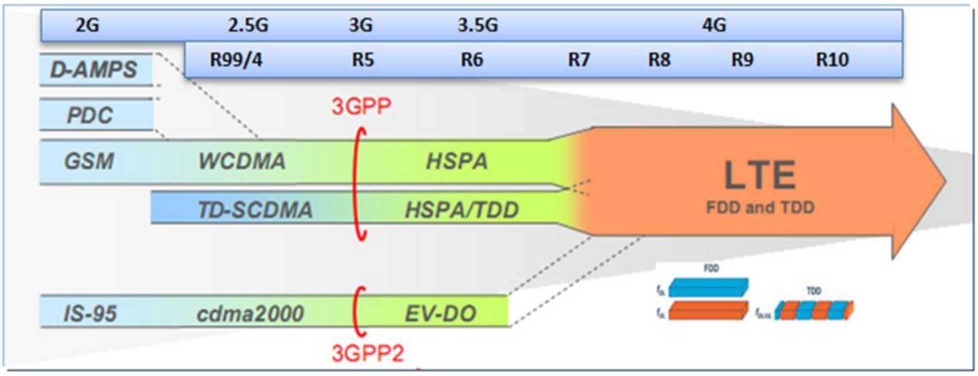

Figure 1.1. Evolution of current wireless generation

1.2 Problem Statement

Multiple-in multiple-out (MIMO) is a technique that provides significant improvements in data rate, data coverage, and spectral efficiency without increasing power transmission or frequency bandwidth [8]. Many powerful techniques have been employed to improve the performance and reliability of LTE and LTE-A systems; these techniques include multi-user MIMO (MU-MIMO) [9], coordinated multi-point transmission (CoMP), carrier aggregation, heterogeneous network, and relay network [10].
From a practical implementation perspective, an appropriate feedback mechanism for reporting channel quality indicator (CQI) is crucial [11-14]. CQI is a measurement that maps channel status to enable adaptive modulation and coding (AMC) and scheduling decision [15-17].

Considerable practical problems in LTE occur when calculating feedback denoted by CQI [18]. If a user needs to report precise channel state information, the amount of CQI reported back to the eNodeB must be increased. This increase is required to avoid the mismatch between the user feedback signal-to-interference-plus-noise ratio (SINR) and the SINR actually detects in the aftermath of scheduling. Offering such feedback inevitably results in extra signaling overhead and in the degradation of system performance [19]. Hence, CQI calculation highly depends on the accuracy of the channel estimation process [15]. Failing to estimate CQI results in the incorrect assignment of radio resources during the scheduling process and inaccurate employment of AMC [20]. A fast fading channel produced by high user speed requires a robust channel estimation mechanism to feedback the most accurate channel status. However, such estimation mechanisms usually suffer from lack of reliability because of some computational processes [21]. Accordingly, the challenge of CQI feedback becomes much serious under fast user mobility [22]. Thus, an easy mechanism for obtaining a reliable and accurate CQI that is then fed back to the serving eNodeB has become an important research topic today. Thus, an easy mechanism for obtaining a reliable and accurate CQI that is then fed back to the serving eNodeB has become an important research topic today.

Existing research focused on the adaptation in modulation and adjusting the data rate based on CQI value [23]. Such a problem becomes challenging with limited resources and in heterogeneous environments such as LTE systems [24]. Feedback overhead costs a substantial amount of resources and leads to the considerable degradation of system performance. These challenges motivate us to find an easy mechanism for channel estimation and compression of feedback overhead. Moreover, a joint optimization solution that accounts for channel estimation error, feedback overhead, and complexity must be obtained.

1.3 Aim and Objectives

The main aim of this research is to improve the throughput and reduce the error rate in LTE and LTE-A system by developing an effective channel-state feedback approach with adaptive threshold mechanism that reduces the feedback overhead without affecting the system performance.

i) Minimizing the mean error rate by using an appropriate minimum mean square error (MMSE) estimation mechanism that takes in consideration the instantaneous channel condition.
ii) Enhancing the LTE system performance in terms of improving system throughput and reducing the error rate by employing an efficient feedback mechanism without costing too much overhead.
iii) Modifying the word size equation in order to calculate the CQI feedback overhead based on system bandwidth.

1.4 Research Scope

In the present work, we are focused on LTE systems that use MIMO and OFDM. The eNodeB and user are efficiently synchronized with each other in time and frequency. In such systems, scarce resources, including subcarriers per resource block (RB) and power, must be shared by all users. This condition allows the scheduling of users with low signal quality and guarantees that no user obtains all resources at the expense of others. An effective signal-to-noise ratio (SNR) for each sub-band is deployed as a channel quality metric, which in turn depends on the frequency response of each subcarrier, on the normalized AWGN power density, and on the number of subcarriers used [25]. To reduce the overhead and the complexity of signal processing, user scheduling is performed based on the RBs [16].

The present study follows the same trend of the 3GPP standard. CQI reporting in LTE systems is aimed at fully exploiting the available radio resources. Fading channels are denoted as time varying, and users must estimate their channel state information and report these estimation values to the eNodeB for the assignment of available resources with proper modulation and effective code rate. This study investigates the most powerful estimation techniques in LTE and LTE-A systems under low and high user mobility. Then, select effective and reliable channel quality information. Moreover, find a simple mapping algorithm that considers instantaneous channel realization while utilizing post-processing SINR to measure the effective SNR. CQI is obtained by computing for the effective SNR [26]. This study is looking through the CQI reporting methods and finding a good tradeoff between accurate channel quality estimation and decreased signaling overhead [23, 27].

Recent studies have found that throughput degrades during user mobility because of inaccurate CQI reporting [28]. Moreover, exploiting the channel adaptive signaling in LTE systems yields significant improvements in system performance. In terms of their practical implementation, many types of channel adaptive schemes are deemed unrealistic because of the challenge in obtaining channel information from the eNodeB. This study explicit closed loop (CL) transmission technique that depends on CQI feedback. Although the issue on CQI feedback has been explored by many researchers [29], its solution remains unclear. Thus, the present work aims to fill this knowledge gap by shedding light on the field of channel estimation and feedback in LTE systems. The study module shown in Figure 1.2, illustrated the general steps that have been viewed in this area of research.

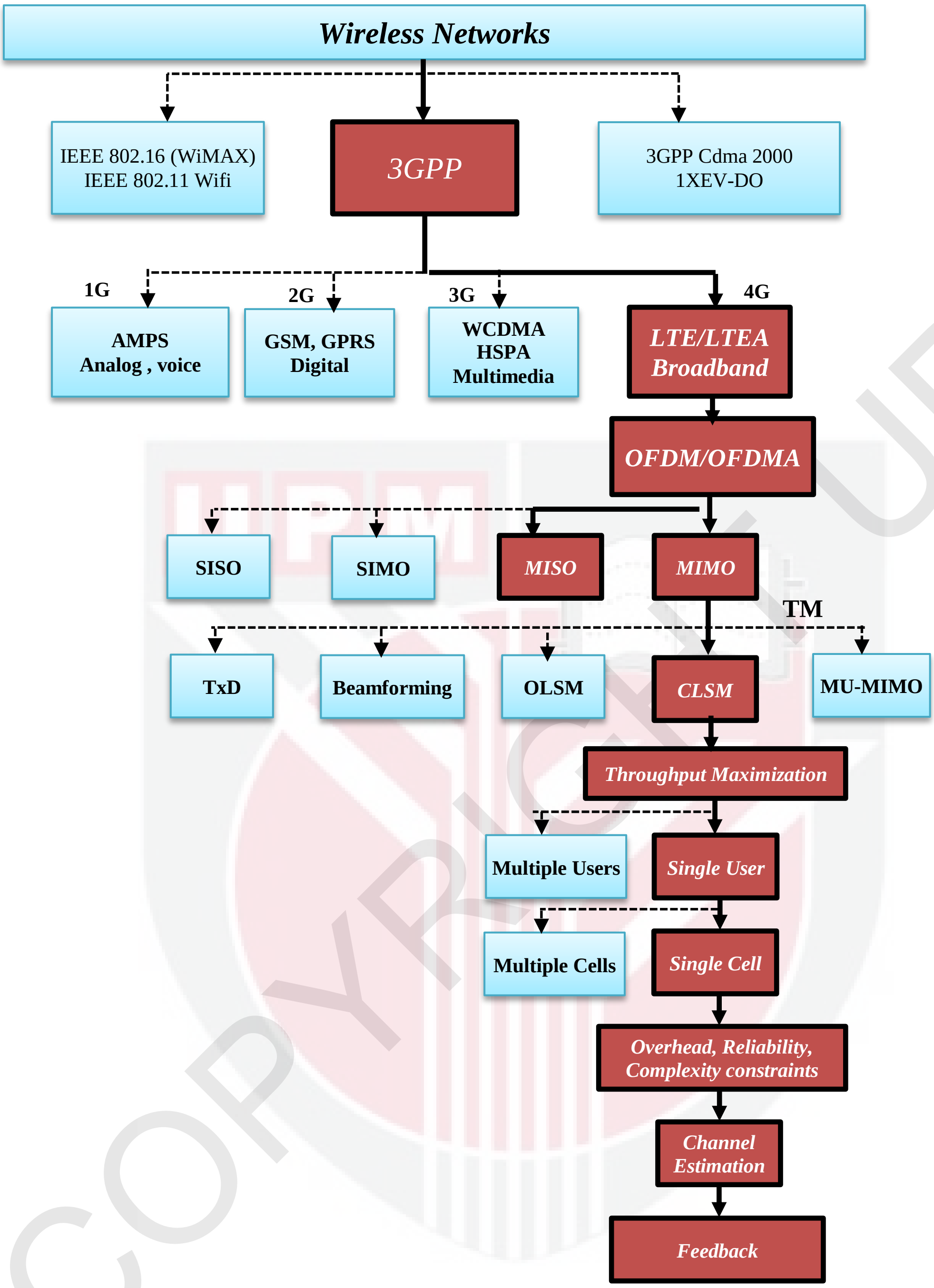

Figure 1.2: Study Modules.

1.5 Research Contributions

Accurate, efficient, and fast channel state information from the user to eNodeB is essential to improve system performance. Providing such information becomes unreliable when the user speed increases. In other words, if the user speed is low, unneeded channel information may be still provided even when the channel condition infrequently changes. Consequently, channel state information with a fixed CQI feedback period is unrealistic under the coexisting user with a different speed. This scenario gives past channel condition for the high user speed. On the other hand it leads to a signaling overhead with unnecessary information for the low user speed.
In this thesis, the focus is on developing an efficient and adaptive feedback algorithm considering the system overhead and taking into account the channel state information of the users. This algorithm is accounting for the user with bad channel condition especially at high user speed. Thus, accurate modulation and efficient code rate will be targeted to improve the system performance.

The main contributions of this thesis are:

- To improve the system performance in terms of increasing the throughput while maintaining the error rate requirement and feedback overhead.
- To introduce an adaptive threshold based CQI feedback scheme which considers the channel state condition.
- To modify the word size equation to in order calculate the CQI feedback overhead based on system bandwidth.

1.6 Thesis Organization

The remaining chapters of this thesis are structured as follow;

Chapter 2 provides brief introduction about the wireless communication systems and LTE networks. Moreover, MIMO and OFDM based on the structure of LTE stander are carried out. Link adaption (LA) and scheduling process are short-term explained. Then, the CQI procedure, CQI estimation, CQI mapping and CQI feedback with the factors that affect CQI reliability are depicted. Finally, the state-of-the-art CQI feedback compression schemes and the proposed methods to lessen the overhead are reviewed.

In Chapter 3 the methodology of the proposed low feedback overhead algorithm and complexity perspective for LTE single cell system is described. Moreover, accounting for the user with bad channel condition and guaranteeing not to degrade the system performance is carried out.

Chapter 4 is centered on presenting and discussing the simulation parameters and results of the proposed adaptive feedback algorithms in LTE systems.
Chapter 5: This chapter depicts the conclusion obtained from this area of research as well as suggesting some ideas for future research.

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