MOBILITY MANAGEMENT FOR SEAMLESS HANDOVER IN CARRIER AGGREGATION HETEROGENEOUS NETWORKS DEPLOYMENT SCENARIO OF LONG TERM EVOLUTION-ADVANCED

MARIAM OVAYIOZA AHMED-ABDULAZEEZ

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By

MARIAM OVAYIOZA AHMED-ABDULAZEEZ

**Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia,
in Fulfilment of the Requirements for the Degree of Doctor of Philosophy**

November 2018

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DEDICATION

To My Family:
Little SAUDAT (My treasure), ABBA, CHIEF and GOGGO.
Husband (My Soul Mate)
Also, the most important person in my life: my mother, for her love and care.
"Without Your Support, Prayers and Encouragement,
My Success Wouldn't Have Been Possible."

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirement for the degree of Doctor of Philosophy

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November 2018

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Accessibility of spectrum is a fundamental challenge in future generation networks as current cellular networks suffer severe bandwidth congestion. The Long Term Evolution (LTE)-Advanced which is a roadmap to future generation networks are designed to achieve high data rates, ultra-low latency and improves spectrum usage efficiency. These cannot easily be achieved as no single network operator can provide the required contiguous spectrum for wider bandwidth. Also, insufficient macro base station (eNodeB) coverage, presents another challenges that result in high outage probability and low spectral efficiency. In line with these problems, Third Generation partnership project (3GPP) enabling technologies such as Carrier Aggregation (CA) is envision to tackle the problem of Spectrum inadequacy and high outage probability. CA is a technique where multiple component carriers (CCs) are aggregated and jointly used to improve transmission reliability and spectral efficiency. Therefore, the desire to achieve high data rates by increasing the transmission bandwidths over those that can be supported by a single carrier or channel becomes a necessity. 3GPP have standardized some classical Carrier Aggregation Deployment Scenarios (CADS) in release 10 to 12 (Rel. 10 to 12) to provide wider coverage, enhance system throughput and reduces outage probability using fixed Modulation and Coding Scheme (MCS). These CADS still provide low spectral efficiency and high outage probability because of the insufficient contiguous macro station (eNodeB) coverage and using of fixed MCS. So, achieving the expected capacity and system throughput enhancement is still a challenge. Therefore, this study proposes a new Carrier Aggregation Deployment Scenarios (CADSs) that utilizes Component Carriers (CC) from different spectrum bands to increase the overall transmission bandwidth and connection reliability. Meanwhile, CA technique induces a new handover scenario in which by employing Hard Handover (HHO) scheme may result to high Handover Probability (HOP), Ping-Pong Handover (PPHO) effect, radio Link failure, outage probability and throughput degradation. Load Balancing Optimization (LBO) and Handover Parameter

Optimization (HPO) functions have also been included in the LTE-Advanced standard to minimize handover related issues. But issues related to non-optimal algorithm for selecting the appropriate Handover Control Parameters (HCPs) needs further attention. Attaining an optimal solution for HCPs selection is subjected to compromise between LBO and HPO functions, thus leading to inefficient handover decision making. Therefore, the objective of the research is to propose an enhanced CADS (Het-Nets) and implement efficient adaptive handover techniques in LTE-Advanced system. Firstly, a novel Het-Nets CADS is proposed, integrated with Adaptive Modulation and Coding with Cell Range Expansion (AMC-CRE) scheme. Secondly, a Hybrid Handover Parameters Optimization algorithm based on Enhanced Weight Performance (HHPO) is introduced to optimize, select suitable Handover Control Parameters (HCP) and to manage the conflict that may occur among self-optimization functions. Finally, multiple criteria Handover Decision (MC-HOD) algorithm is proposed to take an intact decision on handover execution. System level simulation results show that the Het-Net CADS with the integration of AMC-CRE scheme outperformed the other CADS considered in this work in terms of spectral efficiency and outage probabilities. The HHPO and the MC-HOD algorithms achieves significant enhancement compared to the conventional and other algorithms examined. Moreover, Het-Net CADS enhanced spectral efficiency up to 98%, 31% and 51%, while the outage probability is reduced by 25.5%, 57% and 56% over 3GPP's CADSs #1, CADS#5 and CC-CADS respectively.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGURUSAN MOBILITI UNTUK SERAHAN LANCAR DALAM SENARIO PENGGUNAAN JARINGAN HETEROGENUS AGREGAT PEMBAWA (HET-NETS CADS) EVOLUSI LANJUTAN JANGKA PANJANG

Oleh

MARIAM OVAYIOZA AHMED-ABDULAZEEZ

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Kebolehaksesan spektrum adalah satu cabaran asas dalam jaringan generasi akan datang sebagai jaringan selular semasa mengalami kesesakan jalur lebar yang teruk. Long Term Evolution (LTE)-Advanced yang menjadi panduan kepada jaringan generasi masa depan direkabentuk untuk mencapai kadar data yang tinggi, latensi paling rendah dan memperbaiki keberkesanan penggunaan spektrum. Ini tidak boleh dicapai dengan mudah apabila tidak ada satu pun operator jaringan boleh memberi spektrum yang diperlukan untuk jalur lebar yang lebih besar. Seterusnya, liputan stesyen pangkalan makro yang tidak mencukupi (eNodeB), membentangkan satu lagi cabaran yang membawa kepada kemungkinan luaran yang tinggi dan kecekapan spektral yang rendah. Seiring dengan masalah-masalah ini, projek usahasama Generasi Ketiga (3GPP) membolehkan agar teknologi-teknologi seperti Agregat Pembawa (CA) dapat mengendalikan masalah ketidaksesuaian spektrum dan kebarangkalian luaran yang tinggi. CA adalah satu teknik di mana pembawa-pembawa komponen yang pelbagai (CCs) diberi agregat dan digunakan bersama untuk menambahbaik kebolehpercayaan transmisi dan kecekapan spektra. Oleh itu, keinginan untuk mencapai kadar data yang tinggi dengan cara meningkatkan jalur lebar transmisi ke atas jalur-jalur lebar yang boleh disokong oleh satu pembawa atau saluran, menjadi satu kemestian. 3GPP telah mempiawaikan beberapa Senario Penggunaan Agregasi Pembawa atau Carrier Aggregation Deployment Scenarios (CADS) dalam pembebasan 10 sehingga 12 (Rel. 10 to 12) untuk menyediakan liputan yang lebih luas, meningkatkan sistem throughput (daya pemprosesan) dan mengurangkan kebarangkalian luaran menggunakan Skim Modulasi dan Kod yang tetap (MCS). CADS ini masih menyediakan kecekapan spektra yang rendah dan kebarangkalian luaran yang tinggi disebabkan oleh liputan stesyen makro berkembar yang tidak mencukupi (eNodeB) dan menggunakan MCS yang telah ditetapkan. Oleh itu, meningkatkan kapasiti yang dijangka dan throughput sistem masih menjadi satu cabaran. Oleh itu, mencadangkan satu Carrier Aggregation Deployment Scenarios (CADSs) yang baru yang menggunakan pembawa komponen (CC) dari kumpulan spektrum yang berbeza untuk meningkatkan kebolehpercayaan kepada transmisi dan sambungan jalurlebar secara keseluruhannya. Sementara itu, teknik CA memulakan satu senario baru dengan menggunakan skim Hard Handover (HHO) yang boleh membawa kepada Handover Probability (HOP), kesan Ping-Pong Handover (PPHO), kegagalan pautan radio, kebarangkalian luaran dan degradasi throughput. Fungsi-fungsi Load Balancing Optimization (LBO) dan Handover Parameter Optimization (HPO) juga disertakan sekali dengan piawaian LTE-Advanced untuk mengurangkan isu-isu yang berkaitan dengan serahan. Namun demikian, isu-isu yang berkenaan dengan algoritma bukan optima dalam memilih Parameter Handover Control (HCPs) yang sesuai perlu diberi perhatian khusus. Mencapai satu penyelesaian yang baik dalam pemilihan HCPs tertakluk kepada kompromi di antara fungsi-fungsi LBO dan HPO, dan ini membawa kepada pembuatan keputusan yang tidak cekap tentang serahan tersebut. Oleh itu, objektif kajian ini ialah untuk mencadangkan satu CADS (Het-Nets) lanjutan dan melaksanakan teknik-teknik handover adaptif yang baik dalam sistem LTE-Advanced ini. Pertama, Het-Nets CADS yang baru telah disarankan, diintegrasi dengan skim Modulasi Adaptif dan Pengekodan dengan Pengembangan Julat Sel (AMC-CRE). Kedua, satu algoritma Hybrid Handover Parameters Optimization yang berdasarkan kepada Enhanced Weight Performance (HHPO) diperkenalkan untuk mengoptima, memilih Handover Control Parameters (HCP) yang sesuai dan seterusnya menguruskan konflik yang mungkin berlaku di kalangan fungsi-fungsi pengoptimaan-kendiri. Akhir sekali, pelbagai kriteria algoritma Handover Decision (MC-HOD) telah disarankan untuk mengambil keputusan yang sempurna ke atas pelaksanaan serahan. Keputusan simulasi aras sistem menunjukkan bahawa Het-Net CADS dengan integrasi skim AMC-CRE lebih baik prestasinya daripada CADS yang dipertimbangkan dalam kajian ini dari aspek keberkesanan spektral dan kebarangkalian luaran. Algoritma HHPO dan MC-HOD yang mencapai peningkatan yang signifikan berbanding dengan algoritma konvensyional dan lain-lain telah dikaji. Tambahan lagi, Het-Net CADS meningkatkan kecekapan spektral sehingga 98%, 31% dan 51%, sementara kebarangkalian luaran dikurangkan sebanyak 25.5%, 57% dan 56% di atas 3GPP's CADSs #1, CADS#5 dan CC-CADS masing-masing.

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LIST OF ABBREVIATIONS

2G	second generation
3G	third generation
3GPP	3rd generation partnership project
4G	fourth generation
5G	fifth generation
16-QAM	16-quadrature amplitude modulation
64-QAM	64-quadrature amplitude modulation
AMC-HOD	adaptive multi-criteria handover decision
AHO-D	adaptive handover algorithm based on distance
AHO-V	adaptive handover algorithm based on UE's velocity
AMC	adaptive modulation and coding
AWF	Adaptive Weight Function
BBM	break before Make
BCC	best component carrier
BER	bit error rate
BSs	base stations
BW	bandwidth
CA	carrier aggregation
CADS	carrier aggregation deployment scenario
CADS-1	carrier aggregation deployment scenario #1
CADS-2	carrier aggregation deployment scenario #2
CADS-3	carrier aggregation deployment scenario #3
CADS-4	carrier aggregation deployment scenario #4
CADS-5	carrier aggregation deployment scenario #5
CC	component carrier
CC-CADS	coordinated contiguous carrier aggregation deployment Scenario

CCO	coverage and capacity optimization
CDF	cumulative distribution function
CDR	call dropping rate
CHO-TOR	coordination handover optimization algorithm based on truncating
OR	output range
CIO	cell specific offset
CoMP	coordinated multipoint
CP	cyclic prefix
CR	code rate
DCP	drop call probability
DCR	dropped calls rate
DL	downlink
ENodeB	E-UTRAN node b, also known as evolved Node B
EWPF	enhanced weight performance function
EPC	evolved packet core
EUTRAN	evolved universal terrestrial radio access network
FCS	fast cell selection
FDD	frequency division duplex
FRF	frequency reuse factor
FSHO	fractional soft handover
HCP	handover control parameter
Het-Net	heterogeneous network
HFP	handover failure probability
HHO	hard handover
HHPO	hybrid handover parameter optimization
HO	handover
HOD	handover decision

HOD-D-RSS	handover decision algorithm based on distance and relative received signal strength
HOD-IINR	handover decision algorithm based on interference to other-Interferences-plus-noise ratio
HOD-RSS	handover decision algorithm based on the received Signal strength
HOD-SINR	handover decision algorithm utilizing signal-to-interference-plus noise ratio
HOM	handover margin
HO-Model	handover - model
HOP	handover probability
HOPPP	handover ping-pong probability
HOS	handover scenario
HPACA	handover parameters adjustment for conflict avoidance
HPI	handover performance indicator
HPO	handover parameters optimization
HPPP	handover ping-pong probability
HPR	handover probability ratio
I-eNodeB-CF	inter-eNodeB coordination-free
IINR	interference to other-interference-plus-noise ratio
IMT-Advanced	international mobile telecommunications-advanced
INT	interruption time
ITU	international telecommunication union
LBHA	location-based handover algorithm
LBO	load balancing optimization
LHHAARC	LTE hard handover algorithm with average received signal reference power constraint
LM	load margin
LTE	long term evolution
LTE-Advanced	long term evolution-advanced
MCS	modulation and coding scheme

MCC	numbers of component carrier
MIF-AHOD	multiple influence factors for adaptive handover decision
MIMO	multiple-input and multiple-output
MME	mobility management entity
MR	measurement report
MS	modulation scheme
MSymb	modulation symbol
MVEDM	macro vehicular environment deployment model
NAS	non-access stratum
NCC	numbers of component carrier
NHPO-WPF	novel handover parameters optimization algorithm based on weight performance function
OFDMA	orthogonal frequency -division multiple access
PCC	primary component carrier
PHO	primary handover
PRB	physical resource block
QPSK	quadrature phase shift keying
QoS	quality of service
Rel.	release
Rel.8	releases 8 of LTE system
Rel.9	releases 9 of LTE system
Rel.10	releases 10 of LTE-Advanced system
Rel.11	releases 11 of LTE-Advanced system
Rel.12	releases 12 of LTE-Advanced system
RE	resource element
RG	resource grid
RLF	radio link failure

CHAPTER 1

INTRODUCTION

In the business world, demand and supply has always been inversely proportional. This hypothesis has given researchers across different fields, including engineering, a serious concern. In this modern technological era, **e**xponential increase in the demand for wireless communication services pushes for the revision and development of new telecommunication technologies that offers higher data rates and wider bandwidths because of its importance in the people's life. Meaning that, developing mobile network beyond the Third Generation (3G) toward the Fourth Generation (4G) and Fifth Generation (5G) has become a necessity. This chapter describes the background information that apprises this study, taking into perspective the trend in bandwidth expansion as a result of high data demand over different wireless generations. It emphasizes on the significance of carrier aggregation technique and the deployment of heterogeneous networks in carrier aggregation technology as a solution to data rate escalation. The objectives, brief description of methodology, and outline of the thesis are also presented.

1.1 Background

Next generation networks require high data rate to meet the workability of various applications in the face of the explosive growth in wireless communication services such as video streaming, 3D online games and telemedicine. The pace of growth has resulted in cellular networks undergoing major evolution and enhancement to provide cost effective high data rate to the user equipment's (UEs). In line with this development, there have been several agitations for release of more spectrum to meet the demand for high data[1]. For example, millimeter-wave cellular system is envisaged to have the potentials of releasing about 30GHz which amount to 30 times the United State**s** useable spectrum.

However, realization of this process is not technically visible in a short time. Far back in 2011, there was an agitation for 1000x data challenge. The Third Generation partnership project (3GPP) took this challenge as its main objective in LTE-Advanced to achieve the 1000x capacity increase [2]. The idea has been approached from the angle of shortage in infrastructure rather than spectrum shortage which necessitates developing a mobile network beyond the Third Generation (3G) toward the Fifth Generation (5G). Long Term Evolution-Advanced (LTE-Advanced) technology is one of the most prominent 4G and 5G standards. It is being deployed by mobile operators on top of the legacy **S**econd and Third Generation (2G) and 3G mobile systems. The LTE-Advanced system with new specifications, characteristics, functions, and key technologies is seen as the major evolutionary step in the continual development of LTE network for future generation mobile systems. LTE-Advanced systems consist of the following features:

- (i) Carrier Aggregation (CA) technique,
- (ii) Heterogeneous networks,
- (iii) Multi-antenna technique,
- (iv) Coordinated Multi Point (CoMP) transmission and reception, and Support for Relay Nodes (RN) [2].

With these features, the LTE-Advanced system is expected to provide high data rate in the Downlink (DL) up to 1 Gbps at low mobility and 1 Mbps at high mobility speed Moreover, some other features such as improved Handover (HO) mechanisms that will provide short handover interruption time and supports mobility speeds up to 500 km/hour are introduced in LTE-Advanced to enhance system performances [4]. Carrier aggregation (CA) technique and heterogeneous Networks (Het-Nets), being the most significant technologies introduced in LTE-Advanced system, is to further enhance the system throughput, coverage area and support User Equipment's (UEs) mobility [3]. The CA technique is defined as a way of aggregating several smaller Component Carriers (CCs) to achieve higher transmission data rate over an effective larger bandwidth up to 100 MHz [4]. These aggregated multiple CCs can be assigned to a user; thus, each UE has the capability to transmit on multiple CCs simultaneously. One of the Cs is always configured as a Primary Component Carrier (PCC), while the others ones are configured as Secondary Component Carriers (SCCs) (Figure 1.1). The PCC is considered mainly for transmission of the control information and the UE data, while the SCC is used only to carry the UE data. The CCs beams orientation, and the operating frequencies vary according to the configuration of the system. Five different Carrier Aggregation Deployment Scenarios (CADSs) are supported LTE-Advanced system[5]–[7]. These CADSs provide wide range of system configurations and performance characteristics.

In addition to the CA technique introduced in LTE-Advanced system, the infrastructural shortage is approached through cell increment by deploying low power nodes (LPN) (Femtocell, Pico cell and radio remote head) overlaid on the existing macro cell. This deployment is referred to as heterogeneous networks (Het-Nets). Het-Nets deployment is aimed at improving throughput of both outdoor and indoor users.

Het-Nets deployment is the integration of regular (planned) macro base stations (eNodeB) with high transmitting power level and LPN such as femto, Pico and radio remote heads (RRH) deployed in an unplanned way[8][9]. LPNs are categorized according to backhaul connectivity, transmission power, deployment methods and access mode. LPNs are used to eliminate the coverage holes in macro only network, offload traffic and increase capacity in hot spot environments [10]–[14]. Examining the deployment scenarios give insight into the potential initiatives to bolstering bandwidth in order to achieve high data rate.

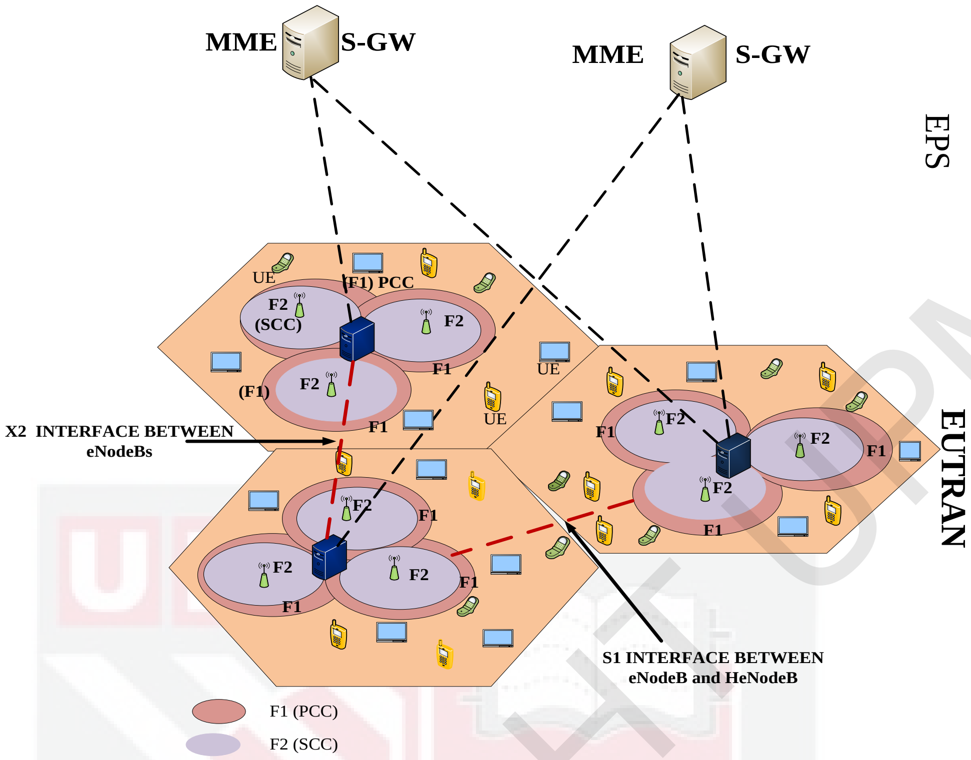

Figure 1.1 : LTE-Advanced system architecture with CA technique and small cell MME: Mobility Management Entity, SGW: Serving Gateway, EPC: Evolved Packet Core, PCC and SCC Primary and Secondary Component Carrier respectively

Aside the bandwidth demand, mobile users and the resulting data usage are random, varies with time and often unbalanced as they move from one cell boundary to another. This causes an unequal load scenario for the neighboring cells which results in degradation of network performance. So, Self-Optimization (SO) was introduced in LTE-Advanced to enhanced system performance [15]–[17]. Self-Optimization is one of the components of Self-organization network (SON) which has the capacity to automate the network management process with minimum human involvement by dynamically adjusting system parameters to the unexpected loading condition caused by sudden rise in data usage[15]. Thus, providing higher end user Quality of Service (QoS) and less operational/ maintenance cost. Handover Parameters Optimization (HPO) and Load Balancing Optimization (LBO) are among the significant features of SON. While the LBO adjusts load in an overloaded cell, HPO regulates the handover parameters (Time-To-Trigger (TTT) and Handover Margin (HOM) based on handover parameter indicators (HPI) (i.e., Radio link failure (RLF), low signal interference to noise ratio (SINR) and handover ping-pong HOPP) that reflect the handover performance of the network [18]. Although HPO and LBO optimization algorithms adjust different control parameters, they counteract each other and reduce the desired effects thereby negatively impacting the entire system performance. It is, therefore, necessary to resolve the conflict between them to achieve robust and seamless handover.

Conventional handover process in LTE systems exchanges UE link from the serving cell to the target cell to maintain the quality of the received signal [18]. This changing of serving cells in LTE and LTE-Advanced systems is performed only by utilizing Hard Handover (HHO) technique, also referred to as Break before Make (BBM) process. Introduction of CA technique in LTE-Advanced systems led to a new handover scenario which takes place when the UE link is exchanged between different CCs in the system [19][20]. The CCs may be contiguous, noncontiguous and inter-band. This new handover scenario is performed to maintain the UE signal quality and connectivity. However, the CCs handover may increase the handover probability, causing unnecessary handover and radio link failure probabilities. Therefore, handover control parameters (HCPs) estimation to improve handover performance and load balance in LTE-Advanced system is a new research field to be investigated. Furthermore, there is a question raised regarding the suitability of the existing handover decision algorithms to be used for CA system to yield high handover performance. The two issues are addressed in this thesis by introducing new HPO and Handover Decision (HOD) algorithms that mitigate the handover failure (HOF) probabilities, unnecessary handover (PPHO), Radio Link Failure (RLF), outage probability, an at the same time enhances Spectral Efficiency (SE) in CADS scenarios.

1.2 Problem Statement

The introduction of CADS in LTE-Advanced system is to provide the required bandwidth and enhance system performance by enhancing the network capacity/coverage to improved user experience. Practically, increasing the capacity by simply adding more infrastructures to existing CADS of contiguous band for high data rate demand poses some challenges due to the fragmented nature of the existing spectrum band. This has hindered service providers to benefit from the advantages of CA. Also issues related to insufficient coverage of macro cell base station (MeNode) and high data rate demand by the users require more attention. Even though the deployment of components carriers in separate bands (inter-band non-contiguous) has been introduced in LTE-Advanced, it has not gained the required attention. Technically, CA technology added new mobility challenges that need to be addressed in LTE-Advanced system.

The conception of CA technique in LTE-Advanced has attracted researchers to investigate the performance of different CADSs on the user mobility. The impact of different CADSs on UE's performance has been investigated by [21] [22]. The investigation is performed in terms of path losses, signal quality, outage probability, spectral efficiency and user throughput. As part of the drawbacks of the standard CADSs in LTE-Advanced systems, the use of fixed Modulation and Coding Scheme (MCS) may cause more degradation in the spectral efficiency and outage probability. This is because, the fixed MCS utilizes a fixed Signal-to-Interference-Plus-Noise Ratio (SINR) threshold level and coding rate to modulate the signal. Whereas, the instantaneous SINR level over each CC may vary according to the UE mobility and environment. When considering inter-band non-contiguous deployment where the aggregated CCs are deployed in different networks (Macro and LPNs) may result in load imbalance and underutilization of resources. This will severely degrade the performance of cell edge UEs in terms of increased outage probability and low spectral efficiency. Therefore, there is urgent need for alternative solution to improving user experience and satisfaction in terms of system performance.

Apart from user's experience, the handover performance faces challenges with the introduction of the CA technique. In LTE-Advanced systems, a new handover scenario (CC to CC) resulting from configuring multiple CCs, increases the handover probability compared to LTE systems. This new handover scenario aims to switch the PCC which is mainly based on the signal quality, channel conditions as well as handover control parameters (HCPs) values. Thus, investigating the handover performance in the presence of CA technique in LTE-Advanced systems and proposing methods to optimize the HCPs values is important to improve the user experience and enhances the system performance. Typically, the UE performs handover based on a set of HCPs estimated in the system. The improvement achieved by optimizing the HCPs values may be hindered without an efficient handover decision (HOD) algorithm since the HOD algorithm triggers the handover request when the HCPs criteria are met. In addition, implementing an efficient HOD is equivalent to the optimum estimation of the HCPs values since it is the first line of the handover process. Optimizing the HCPs value estimation and HOD algorithms is key to improving the handover performance. Though, most of the work in the HOD algorithms is proposed for single CC scenarios. As multiple CCs are aggregated in CA technique, impact of the existing HOD on the performance is yet to be thoroughly studied. Moreover, most of the proposed algorithms implements the handover decision based on a single parameter. Adaptation of existing HOD algorithms in aggregated CCs and the proposed CADSs in LTE-Advanced system will not yield the optimal result, leaving the scientific community research gap to fill.

In conclusion, adopting the techniques of carrier aggregation with different deployment scenarios and deployment of LPNs could resolve issues of bandwidth increment and better network performance. This study proposes new algorithms suitable to provide adequate network coverage and performance. The main problems to be addressed in LTE-Advanced system Release 12 and beyond can be summarized as follows:

1. Low spectrum efficiency and resources underutilization as a result of coverage holes and high outage probability at the cell edge of the aggregated CCs in the existing carrier aggregation deployment scenario (contiguous band) implementing fixed modulation and coding scheme.
2. Non-optimal algorithm for selecting HCPs in CADS. Though, 3GPP has standardized the handover parameters optimization to improve the system performance, optimal solution for load balancing and handover parameter optimization constitute a complex relation and conflict problem. An efficient handover procedures in CADS requires an optimal setting of these parameters. Considering the numerous number of CCs and handover threshold to be optimized in a network, the technical complexities and requirements of these parameters optimization are too difficult to be tackled manually.

3. Advent of CA has increased the handover probability through user mobility. Handover decision becomes crucial for mobile UEs especially at the cell edge to achieve seamless and robust handover. Though, a handover may be successful but into a wrong cell when the selected cell is not the best in terms of bandwidth and signal quality. The conventional cell selection that is based on S-criteria is inadequate particularly when CA technology is employed. This consequently leads to handover failure (HOF), ping-pong handover (PPHO) and throughput degradation.

1.3 Aims and Objectives

To meet the surge in demand for higher data rates through CADS in LTE-Advanced, the deployment scheme should not only ensure coverage and capacity increment for outside UEs but to be able to increase the capacity for indoor UEs with high quality services. Besides, efficient handover process, decision and optimization of handover parameters should be able to resolve the handover issues induced through user mobility. Addressing this imperfection requires effective CADS that will extend coverage/ capacity to the indoor UEs, maintain high quality of service, and handover processes that will result in fast and seamless handover for the mobile UEs. The aim of this current study, therefore, is to deploy a new carrier aggregation scenario that will enhance services to users and improve handover performance in LTE-Advanced system. In addition, initial CC association is adequately addressed. To achieve this general aim, the study intends:

1. To propose and deploy an enhanced heterogeneous networks CADS utilizing macro and femtocells to improve the spectrum utilization.
2. To develop an adaptive handover parameter optimization algorithm that will reduce the negative effect of handover failure rate, ping-pong and unsuccessful hand over probabilities in carrier aggregation deployment scenario.
3. To design an efficient handover algorithm that is capable of making handover decision based on multi-criteria decision with existence of carrier aggregation technique.

1.4 Research Questions

As a necessity to resolve the capacity/coverage and handover issues in CADS to meet the high data rate expectation of LTE-Advanced motivates, the following research questions will be answered through the research.

1. How to design and model Het-Nets CADS that will increase the capacity and quality of services of both indoor and outdoor UEs that reflect the UE mobility?
2. Considering the operational conflict between HPO and LBO in SON, how can handover parameter be optimized to improve system performance in Het-Nets CADS?
3. Taking the different characteristic of Het-Nets and various UE speeds into consideration, what are the metrics to be combined in designing efficient algorithm that will take an intact decision for seamless handover in Het-Nets CA deployment scenario?

1.5 Brief Methodology

This research intends to model Seamless handover mechanism for LTE-Advanced based on carrier aggregation deployment scenario and heterogeneous network. However, simulation of typical scenarios of the proposal was adopted, as experimental test bed could not be set up for the work which is considered as a limitation of the research. In accordance with the objectives listed earlier the methods is classified into four phases. The study was initiated with a theoretical review of the literature to identify specific research problems related to bandwidth expansion and mobility management in LTE-Advanced. This equally leads to identifying potentially new and novel solutions to the identified problems. Thereafter, schemes at different handover phases was proposed. This stage is being carried out concurrently with other stages throughout the period of this research work to ensure that developments in other areas are continuously fedback.

The second stage involves modelling of Het-Nets CADS based on two CCs. The CCs are configured on macro and femtocell, hereafter referred to as MeNodeB and FeNodeB respectively. The modeled CADS resolved the coverage/capacity issue and offload traffic to achieve better performance and high data rate. Cell range expansion and Adaptive modulation and coding (CRE-AMC) scheme in conjunction with RSRP was employed for the initial CC search for UE to be associated when radio resource connection (RRC) is established. The CRE is to extend the coverage area of FeNodeB in order for some UEs to be offloaded from the MeNodeB. AMC on the other hand dynamically adapts to different channel conditions by changing from one modulation level to another (high and low) to increase spectral efficiency without increase in bit error rate in noisy channel. The conceptual model is meant to minimize the cell search/selection period, outage probability and increase spectral efficiency. The strength and advantages of the developed scheme are identified and presented in chapter 3.

Thirdly, a new Hybrid handover parameter optimization (HHPO) algorithm is proposed to dynamically adjust handover control parameter values based on mathematical formulation and is evaluated according to UE's signal interference to noise ratio (SINR) and cell's load of the UE's velocity. The algorithm is validated over Het-Nets CADS employing an AMC scheme under various mobility conditions and the performance compared with other handover algorithms in terms of handover performance (HO), handover ping-pong (HOPP), handover failure HOF, radio link failure RLF probabilities and Interruption Time $(\mathrm{T_{INT}})$. The strength and advantages of the algorithm identified are discussed in chapter 4.

Finally, a new handover decision algorithm that is based on the framework developed in stage three were implemented using multi-criteria handover decision (MCHD) algorithm to eliminate the conflict and to further enhance system performance through the UE's mobility. The simulation results are presented and discussed in terms of average HOP, HPPP, HFP, RLF and $\mathrm{T_{INT}}$. In addition, the proposed algorithm is to further enhance UE's SINR and spectral efficiency with minimum outage probability. The strength and advantages of the algorithm identified are discussed in chapter 5.

Simulations and performance evaluation was carried out by building the simulation environment and models that consist of the Het-Nets CADS system, mobility, handover and propagation models. Then, a set of performance metrics were identified for the triggering of the handover algorithm. Three different reference algorithms were identified, simulated and evaluated. Their performances were compared against the proposed handover control parameter optimization and handover decision algorithms.

The last stage presented the conclusion which presents the summary of the study and recommendations for future research and development. The overall methodological plan is depicted in Figure 1.2

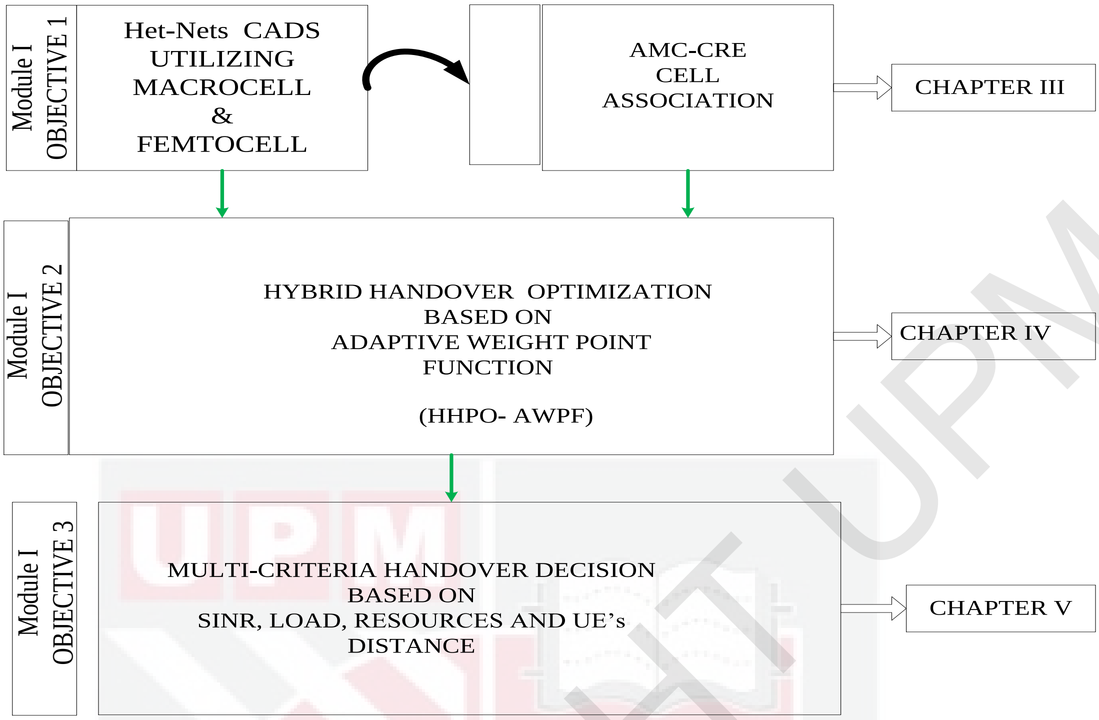

Figure 1.2 : Methodology Block diagram

1.6 Contributions

The main contribution of this thesis is presented as follows:

- Increasing bandwidth through the deployment of Het-Nets CADS with two CCs aggregated provides wider system coverage and high capacity for UEs. CA capability of cross scheduling mitigates inter-cell-interference especially at the cell edges. This improves the SINR for UEs at handover region and enhanced the coverage properties of the eNodeB.
- Improving Cell association in Het-Net CADS. Cell range expansion and adaptive modulation coding (CRE-AMC) scheme accelerates the component carrier selection, offload traffic and reduce load balance in the proposed CADS. The algorithm increases the throughput and spectral efficiency and reduces outage probability.
- Hybrid handover parameters optimization (HHPO) scheme was introduced. This scheme dynamically optimizes the handover control parameters by balancing cell load independently which resolved conflict between HPO and LBO. The algorithm reduces the HOF, PPHO andT_{INT}.
- Handover process was improved: Multi-criteria handover decision (MC-HOD) algorithm is implemented by considering the UE's SINR, cell load UE distance from the serving cell, and handover scenario type for the appropriate handover decision. This algorithm reduces signaling overhead, outage probability handover failure rate and increase the throughput.

1.7 Scope of the Study

This thesis focuses on Het-Nets CADS comprises of macro cell/Femtocell with two component carriers Though, more up to five component carriers can be aggregated but this current study is limited to only two component carriers which is currently practically viable. However, handover can easily be optimized in this scenario, but handover to other scenarios is out of the scope of this thesis. Figure 1.3 illustrate the flow of the thesis scope in which the bold lines shows the scope followed by the thesis, while the doted lines shows that outside the scope of this thesis.

1.8 Significant of Study

The significant of this work to knowledge are summarized to include the following:

An interworking architecture of inter band carrier aggregation and heterogeneous networks of macro and femtocell is not only the cost effective way to solve the consumers quest for high data rate, but assist the network operators to achieve wider bandwidth. In addition, it allows the operators to make use of their fragmented spectrum through inter-band contiguity. This will go a long way to improve both indoor and outdoor coverage, increase the capacity and significantly offload traffic from macro base station. Also this deployment will help in minimizing system power consumption. With the outstanding benefit of femtocell, both the network providers and consumers will benefit from this deployment by increasing user throughput, reduced power consumption, improve indoor coverage and attain consumer satisfaction. At the same time increase service provider revenue by reduced both initial installation, operation and maintenance cost.

1.9 Thesis Outline

This thesis is organized into six chapters. Chapter 1 gives a brief and general background about the study, main focus, motivation of research and the current research problems. Thereafter, the research’s objectives and contributions are clearly explained.

Chapter 2 gives the evolution of LTE and LTE-Advanced systems from Release (Rel.) 8 to 13), background of LTE-Advanced system. It also provides a detailed overview of CA technique in LTE- Advanced system, an overview of the handover is presented, which include: handover with the existing CA technique, handover procedure and handover decision algorithm. Then, follow by a brief description of self-optimization algorithms and biasing. Lastly, the research challenges are discussed and related works are presented.

Chapter 3 aims to address the low spectrum efficiency, load imbalance and high outage probability that are associated with the standard 3GPP CADSs. This chapter present the thesis objective 1 which proposes a new Het-Nets CADS incorporating AMC-CRE to address the problem of insufficient coverage with the existing CADS, resulting in low spectral efficiency and high outage probability. The proposed Het-Net CADS is implemented and its performances are presented and discussed.

In chapter 4, a hybrid handover parameter optimization (HHPO) algorithm is proposed to dynamically adjust HCPs values and balancing the cell load. This algorithm has the capability to estimate the suitable HCP values for each UE independently as an aggregation of weighted parameters that influences the handover rate. The proposed HHPO has the capability to reflect both the network (quality of services and cell load) and UE (velocity and UE distance) related matrices. The HHPO algorithm dynamically estimate the HCP values for each UE based on the proposed bounded functions and their weights. The algorithm also addresses the conflict issues between the HPO and the LBO by combining the two optimization metrics and validated over Het-Nets CADS under various mobility conditions. The performance are compared with other handover parameter optimization algorithms in terms of HOP, HPPP, HOFP, RLF andT_{INT}.

Chapter 5 focuses on eliminating the Handover decision problem by proposing an efficient multi-criteria handover decision (MC-HOD) algorithm to enhance system performance through the UE's mobility. The simulation results are presented and discussed in terms of average probabilities of handover (PHO), handover ping-pong (HOPP), handover failure (HOF) probabilities , radio link failure (RLF) and interruption time (T_{INT}).

Finally, Chapter 6 concludes this thesis, presenting in briefly, summary of the findings and recommendations for future works.

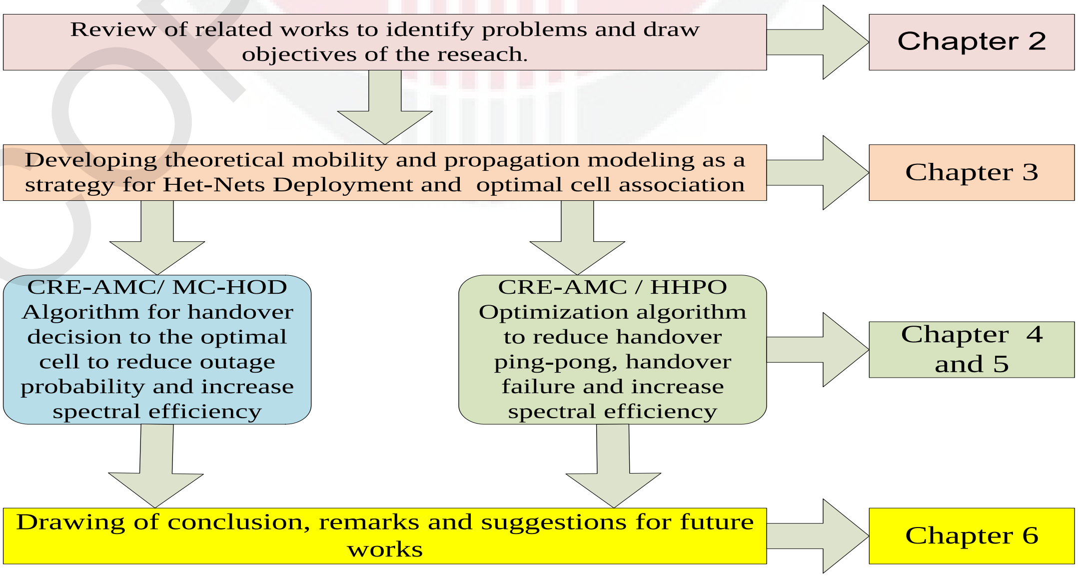

Figure 1.3 : Organization of Thesis

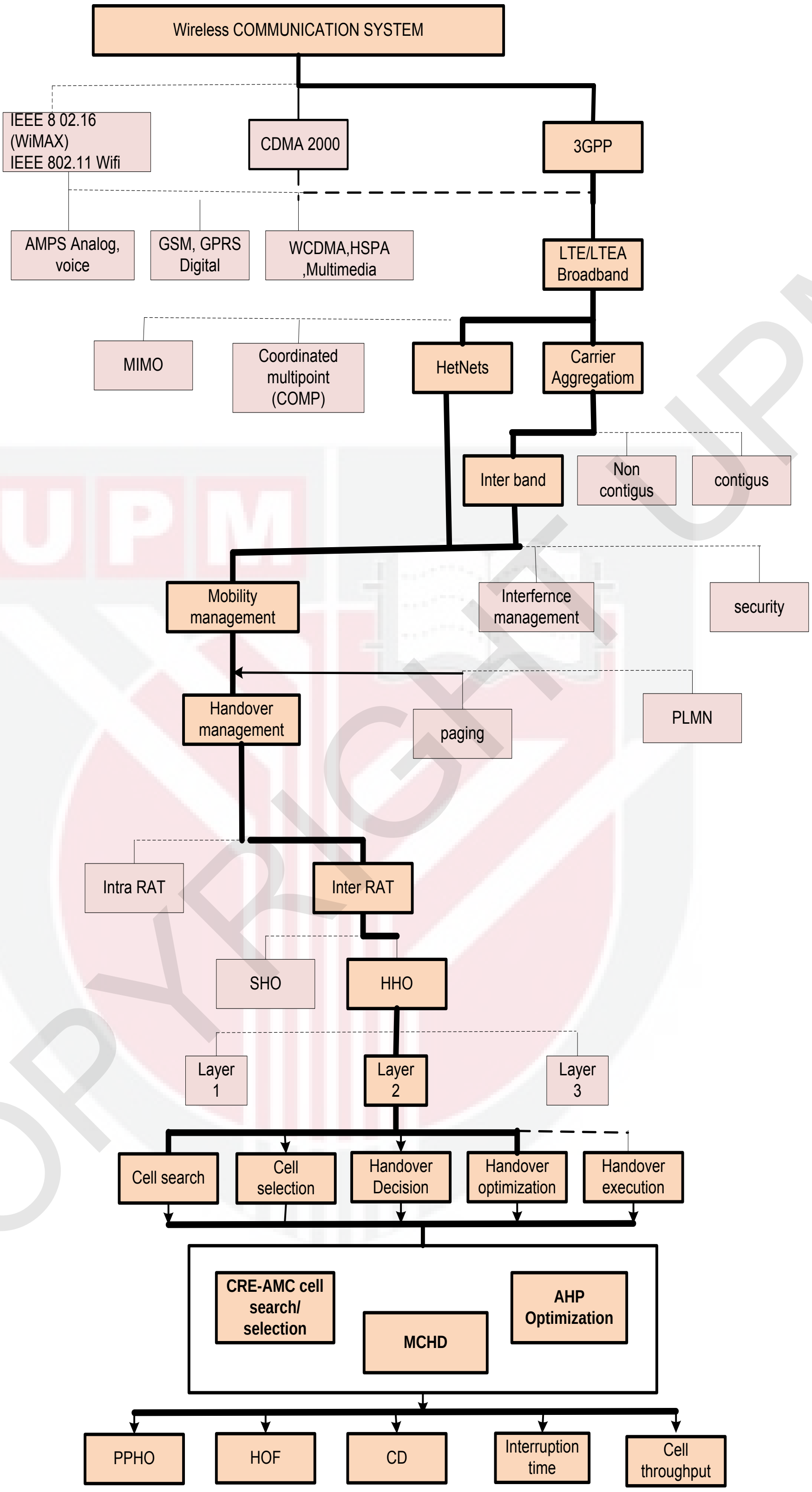

Figure 1.4 : Study module

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