UNIVERSITI PUTRA MALAYSIA

ENERGY EFFICIENT COORDINATED MULTIPOINT USING BRANCH-AND-BOUND AND HYBRID TECHNIQUES IN LTE-ADVANCED

ZAINATUL YUSHANIZA MOHAMED YUSOFF

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By

ZAINATUL YUSHANIZA MOHAMED YUSOFF

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

January 2018

DEDICATIONS

In the name of Allah, Most Gracious, Most Merciful

This thesis is dedicated to:

My caring and devoted parents for their unconditional love and support

Abstract of 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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Chairman : Fazirulhisyam Hashim, PhD
Faculty : Engineering

Over the years, the traditional mobile wireless networks have been focusing mainly on ubiquitous access and large capacity. However, as energy saving and environmental protection become global demands and inevitable trends, researchers and engineers have shifted their focus to energy-efficiency-oriented design, which is an important element for designing green communication systems. Long Term Evolution-Advanced (LTE-A) is one of the mobile networks affected by this new design paradigm. In line of this, LTE-A via 3GPP Standard Release 10 has introduced the concept of coordinated multipoint (CoMP) for both uplink and downlink transmission. CoMP is one of the new technologies introduced in LTE-A which helps to achieve the requirements of 4G issued by International Telecommunication Unit (ITU). At the same time, it is also one of the techniques for Inter-cell Interference Coordination (ICIC) that assists to eliminate the interference caused by neighbouring base stations. In addition, CoMP is also able to improve the channel capacity of the system. It can be implement for user who experiencing weak signals especially user at the cell-edge because CoMP will coordinate several base stations for data transmission. However, there are some challenges that CoMP technique faced and one of them is on its energy efficiency. The main aim of this thesis is to analyze the energy efficiency performance of CoMP and non-CoMP technique, as well as to enhance the energy efficiency performance of CoMP by using branch and bound also hybrid technique. While branch and bound focuses on optimizing the design parameter of coordinated scheduling /coordinated beamforming (CoMP-CS/CB), the hybrid CoMP combines the advantages of both CoMP-CS/CB and coordinated multipoint joint transmission (CoMP-JT). This thesis focuses on downlink part only. Several important aspects related to energy efficiency and power consumption of CoMP have been considered such as transmit power, base stations or power and backhaul power. To apply the CoMP-JT and CoMP-CS/CB techniques, it is depending on the coordination approach of data transmission and signalling from multiple base stations. CoMP-JT coordinates the transmission from a number of base stations and send them to the receiver. On the other hand, CoMP-CS/CB use several base stations for scheduling

the data, but the transmission of data and signalling only involve a base station point. From these two techniques CoMP-JT system offers better quality of service performance and energy efficiency but lacks of the significant backhaul problem which hampered its implementation in the real world. Therefore, CoMP-CS/CB can be regard as a better solution despite its energy efficiency limitation. A generic analytical equation for CoMP is formulated and later is used for analyzing the energy efficiency of CoMP-JT and CoMP-CS/CB. Owing to the analysis, the proposed branch and bound method provides a sophisticated solution with more than 41.62% improvement compared to the standard CoMP-CS/CB, while CoMP-hybrid produce the output 7.74% different between CoMP-JT.

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

KECEKAPAN TENAGA *COODINATED MULTIPOINT* DIOPTIMUMKAN MENGGUNAKAN *BRANCH-AND-BOUND* DAN *HYBRID TECHNIQUES* DALAM *LTE-ADVANCED*

Oleh

ZAINATUL YUSHANIZA MOHAMED YUSOFF

Januari 2018

Pengerusi : Fazirulhisyam Hashim, PhD
Fakulti : Kejuruteraan

Selama bertahun-tahun, sistem rangkaian mudah alih tanpa wayar terutamanya rekabentuk tertumpu kepada akses yang menyeluruh dan kapasiti besar. Walaubagaimanapun, seperti penjimatan tenaga dan perlindungan alam sekitar menjadi permintaan global dan trend yang tidak dapat dielakkan. Penyelidik dan jurutera menjadi lebih agresif dan mereka mengubah pandangan mereka dan memberi tumpuan kepada elemen-elemen baru untuk mereka bentuk projek *action-effectiveness-east* yang sangat penting untuk sistem hijau bumi. Evolusi *Long Term Evolution - Advanced (LTE-A)* adalah salah satu rangkaian mudah alih yang baru. Teknologi baru ini menjejaskan paradigma reka bentuk baru pada era moden yang baru. Selain itu, LTE-A ini melalui pelepasan 10 Standard 3GPP telah memperkenalkan konsep *coodinated multipoint* (CoMP) untuk kedua-dua penghantaran muat-naik dan muat-turun. CoMP adalah salah satu teknologi baru yang diperkenalkan dalam LTE-A yang membantu mencapai keperluan 4G yang dikeluarkan oleh Unit Telekomunikasi Antarabangsa (ITU). Ia juga merupakan salah satu teknik untuk penyelarasan *Inter-cell Interference Coordination (ICIC)* yang membantu untuk menghapuskan gangguan oleh stesen pangkalan jiran. CoMP membantu dan mampu meningkatkan keupayaan saluran sistem dan boleh dilaksanakan untuk pengguna. CoMP akan menyelaraskan beberapa stesen pangkalan ke dalam penghantaran data untuk pengguna yang mengalami isyarat lemah terutama di pinggir sel. Walaubagaimanapun, terdapat beberapa cabaran yang dihadapi oleh teknik CoMP dan berkaitan dengan kecekapan tenaga. Perkara ini akan menjadi isu utama dalam kajian ini. Tesis ini bertujuan untuk menganalisis prestasi kecekapan tenaga CoMP dan teknik bukan CoMP, serta cadangan *branch and bound* dan *hybrid* cawangan meningkatkan prestasi kecekapan tenaga CoMP. Walaupun *branch and bound* menumpukan pada mengoptimumkan parameter reka bentuk *coordinated Scheduling / coordinated beamforming* (CoMP-CS/CB), *coodinated multipoint hybrid*(CoMP-Hybrid) mengabungkan kelebihan kedua-dua CoMP-CS/CB dan *coordinated multipoint joint transmission*(CoMP-JT). Walaubagaimanapun, tesis ini hanya memberi tumpuan kepada bahagian muat-turun sahaja. Beberapa aspek penting yang

berkaitan dengan kecekapan tenaga dan penggunaan kuasa CoMP telah dipertimbangkan seperti kuasa penghantaran, stesen pangkalan atau kuasa stesen pangkalan dan kuasa *backhaul*. Untuk menggunakan teknik CoMP-JT dan CoMP-CS/CB, ia bergantung kepada pendekatan koordinasi penghantaran data dan isyarat dari pelbagai stesen pangkalan. CoMP-JT menyelaraskan penghantaran dari beberapa stesen pangkalan dan menghantarnya ke penerima. Sebaliknya, CoMP-CS/CB menggunakan beberapa stesen pangkalan untuk menjadualkan data, namun penghantaran data dan isyarat hanya melibatkan satu titik stesen pangkalan. Daripada kedua teknik ini sistem CoMP-JT menawarkan prestasi perkhidmatan yang lebih baik dan kecekapan tenaga tetapi mengalami masalah *backhaul* yang signifikan yang menghalang pelaksanaannya di dunia nyata. Oleh itu, CoMP-CS/CB boleh dianggap sebagai penyelesaian yang lebih baik walaupun kecekapan tenaga terbatas. Persamaan analitik generik untuk CoMP diformulasikan dan kemudian digunakan untuk menganalisis kecekapan tenaga dari CoMP-JT dan CoMP-CS/CB. Daripada analisis, cadangan kaedah *branch and bound* ialah menyediakan penyelesaian yang canggih dengan lebih daripada 41.62% peningkatan daripada CoMP-CS/CB, sementara CoMP-Hybrid menghasilkan pengeluaran 7.74% berbeza antara CoMP-JT.

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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:

Fazirulhisyam Hashim, PhD
Senior Lecturer
Faculty of Engineering
Universiti Putra Malaysia
(Chairperson)

Aduwati Binti Sali, PhD
Associate Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

ROBIAH BINTI YUNUS, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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Name and Matric No.: Zainatul Yushaniza Mohamed Yusoff (GS38737)

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Signature: ______________________________
Name of
Chairman of
Supervisory
Committee: FAZIRULHISYAM HASHIM

Signature: ______________________________
Name of
Member of
Supervisory
Committee: ADUWATI BINTI SALI

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LIST OF ABBREVIATIONS

3GPP	Third Generation Partnership Project
AMPS	Advanced Mobile Phone System
AUs	Antenna Units
AWGN	Additive White Gaussian Noise
BnB	Branch and Bound
BSC	Base Station Controller
CA	Carrier Aggregation
CBS	Coordinated Beam-Switching
CC	Component Carriers
CDMA	Code Division Multiple Access
CO_2	Carbon Dioxide
CoMP	Coordinated Multipoint
CQI	Chanel Quality Indicator
CRS	Common Reporting Standard
CS/CB	Coordinated Scheduling/Coordinated Beamforming
CoMP-CS	Coordinated Switching
CSI	Channel State Information
D-AMPS	Digital-Advanced Mobile Phone System
DAS	Distributed Antenna System
DCS	Dynamic Cell Selection
DL	Downlink
DPS	Dynamic Point Selection
EDGE	Enhanced Data rates for GSM Evolution (EDGE)
eICIC	Enhanced inter-cell interference coordination
EE	Energy Efficiency
eMBMS	Evolved Multimedia Broadcast and Multicast Service
eNBs	Base Stations or eNodeB
EPC	Evolved Packet Core
EPDCCH	Enhanced Physical Downlink Channel
EPS	Evolved Packet System
E-UTRA	Evolution of UMTS Ground Radio Acces
E-UTRAN	Evolved-UMTS Terrestrial Radio Access Network
FDMA	Frequency Division Multiple Access
FEC	Forward Error Correction
FFR	Fractional Frequency Reuse
GGSN	Gateway GPRS Support Node
GPRS	General Packet Radio Service
GSM	Global Systems for Mobile Communications
GUB	Global Upper Bound
GW	Gateway
HSPA	High Speed Packet Access
HeNB	Home eNB or Home eNodeB
ICI	Inter-Cell Interference
ICIC	Inter-Cell Interference Coordination
ICT	Information and Communication Technology
IDC	Coexistence In-Device
IMT-A	International Mobile Telecommunications-Advanced

ITU-T	International Telecommunication Union-Telecommunication
JP	Joint Processing
JT	Joint Transmission
LCS	Location Services
LB	Lower Bound
LP	Linear programming
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
MDT	Minimization of Drive Tests
MME	Mobility Management Entity
MIMO	Multiple Input Multiple Output
MTC	Engine Communication
NAS	Non-Access Stratum
NMT	While Nordic Mobile
Non-CoMP	Conventional System
NP-Hard	Non-Deterministic Polynomial-Time Hard
OFDMA	Orthogonal Frequency Division Multiple Access
OFDM	Orthogonal Frequency Division Multiple
PCRP	Policy and Charging Rule Process
PCRF	Policy and Charging Rule Function
PDN	Packet Data Network Gateway
P-GW	PDN Gateway
PDCCH	Physical Downlink Control Channel
PDSCH	Physical Downlink Shared Channel
PMI	Matrix Precision Index
PONs	Passive Optical Network
QoS	Quality of Service
RAM	Random Access Memory
RF	Radio Frequency
RNC	Radio Network Controller
RRE	Remote Radio Equipment
RRH	Remote Radio Head
SAE	System Architecture Evolution
SC-FDMA	Single Carrier - Frequency Division Multiple Access
SE	Spectral Efficiency
SGSN	Serving GPRS Support Node
S-GW	Serving Gateway
SINR	Signal to Interference Noise Ratio
SONS	Self-Optimizing Networks
TACS	Total Access Communication System
TD-CDMA	Time Division-Code Division Multiple Access
TDMA	Time Division Multiple Access
TD-SCDMA	Time Division Synchronous Code Division Multiple Access
UB	Upper Bound
UE	User Equipment
UL	Uplink
UMTS	Universal Mobile Telecommunications System
UTRAN	UMTS Terrestrial Radio Access Network
W-CDMA	Wideband Code Division Multiple Access

WDM	Multiplexing Division Wavelength
WMSC	Wideband CDMA Mobile Switching Center

CHAPTER 1

INTRODUCTION

1.1 Background

LTE (Long Term Evolution) is a project name given to development of a high performance air interface for cellular mobile communication systems. It is the last step towards the 4^{th} generation (4G) of radio technologies designed to increase the capacity and speed of mobile telephone networks. While the former generation of mobile telecommunication networks are collectively known as 2G or 3G, LTE is marketed as 4G. Although there are major changes between LTE and its 3G predecessors, it is often nevertheless looked upon as an evolution of the UMTS/3GPP 3G standards. LTE uses a different form of radio interface (OFDMA/SC-FDMA instead of CDMA), but there are many similarities with the earlier forms of 3G architecture and opportunities for reuse of some elements of 3G network architecture. LTE can be seen as providing an evolution of functionality, which could increase speeds and improve general performance compared to 3G. LTE has introduced a number of new technologies when compared to previous cellular systems. They enable LTE to operate more efficient with respect to the use of spectrum, and also provide the much higher data rates that are now required by various application [1].

Different from predecessor, system is aimed to achieve high spectral efficiency (SE) through the use of a one-cell-reuse frequency allocation system that allocates the same frequency to adjacent cells in a one-cell-reuse system. However, there is much interference between cells, which may prevent sufficient throughput from being obtained at cell-edges. This problem is known as Inter-Cell Interference (ICI). This type of interference can be reduced by allocating different frequency band to adjacent cells (frequency reuse), but this narrows the band that can be used by each cell, which eventually reduces the throughput. This is why frequency reuse is not executed in normal LTE system, which instead use only one frequency in a method called "frequency-reuse 1". To resolve this issue, a method called fractional frequency reuse (FFR) was developed. FFR method separates the frequency bands allocated to the nearer base station area where no signal interference from adjacent base station occurs. Inter-cell interference coordination (ICIC) used FFR method for reducing ICI and improving throughput at cell-edges [2].

LTE-A (Long-Term Evolution-Advanced) is the next generation wireless network technology. It is an enhanced version of current wireless technology, LTE. Although current LTE technology has provided users with high quality services, LTE-A will improve the performance continuously in terms of peak data rate, latency, spectrum efficiency, cell-edge user throughput and so on [3]. One of the state-of-the-art features of LTE-A is cooperative communications. As the term implies, cooperative communications mean the traditional cellular system will become a cooperative or linked system. Various potential advantages will be offered by cooperative communications as it not only changes the overview of cellular system but offers significant improvements over the services provided. One of the main cooperative communications techniques of LTE-A is coordinated multipoint (CoMP) transmission. It is a general framework of coordination between more than one base station in LTE-A. This framework is believed to be able for improving the performance of cell-edge users without further complication of imposed system which is the serving base stations and neighbouring cells. This coordination technique can be implement due to the emergence of Multiple Input Multiple Output (MIMO) capabilities. Strategy of resource scheduling will be provided by the CoMP. CoMP is introduced in LTE-A serves as a strategy to mitigate the ICI. Cell-edge users will experience signal attenuation due to the long distance from its serving base stations. With the implementation of CoMP, the ICI experienced by the cell-edge users will not only be mitigated, but used as useful information for coordination of base station which in turn improves the user experience.

CoMP consists of different techniques to perform the coordination of the transmission which are joint processing (JP) and coordinated scheduling / coordinated beamforming (CS/CB). Under JP, can be divided two techniques, which are joint transmission (JT) and dynamic cell selection (DCS). These techniques perform the coordination of the transmission in different ways. Coordinated multipoint joint transmission (CoMP-JT) coordinates the transmission from multiple base stations and send it to the receiver while coordinated multipoint coordinated scheduling / coordinated beamforming (CoMP-CS/CB) transmits data from one transmission point only. It will decide which transmission point to transmit the data based on schedule information from all the coordinated base stations. Dynamic cell selection is randomly selecting one of the transmission points dynamically during the transmission process. Different CoMP techniques suitable to be used is depends on the scenario of the network. Despite its efficiency in improving the data rate, SE and so on, the existing literatures fail to address the energy efficiency (EE) issue of CoMP.

Information and communication technology (ICT) is playing an increasingly important role in global greenhouse gas emissions since the amount of energy consumption for ICT has been increasing dramatically. Therefore, pursuing high EE is becoming a mainstream concern in future wireless communications design [3]. Nowadays, cellular networks consumed a lot of energy. In addition, consumption of this energy has caused the emission of CO_2 which leads to greenhouse effect and further causes the global warming to happen. Besides the environmental concerns, there is a strong economical motivation for network operators to decrease the power consumption of the network. The main consumers are data servers, backhaul routers and base stations, which constitutes between 60% to 80% of the overall network power consumption. EE can be improved in two main ways, which are by reducing the power consumption of the main consumer and intelligent network deployment strategies where using high density deployment of low power, small base stations is believed to decrease the power consumption compared to low density deployment of high power macro base stations [4]. Many researchers have focused their research on QoS, throughput and EE on uplink parts, but lack of analysis on EE in downlink parts. This study tries focuses address on the problem by optimizing the scheme of CoMP-CS/CB and proposing a hybrid technique.

1.2 Problem Statement

EE is becoming increasingly important for the next generation wireless networks as well as other key performance indicators such as SE. Since LTE-A has become the key technology for cellular networks, the significance of studying the EE of LTE-A systems is increasing tremendously. Researchers on [5] give a major overview on the issue of EE. EE can be generally defined as the achievable capacity divided by the total consumed power. LTE-A is a multi-user multi antenna enabled system. It can improve SE via the spatial multiplexing / diversity gain, but it would cause higher circuit power due to the configuration of multiple RF chains. Hence, from the EE perspective, the system parameters including antenna number, power would affect in a comprehensive manner. Revealing the relationship between the EE and system parameters, and then designing adequate adaptation schemes become critical issues for the green wireless networks [5].

SE, specified as the system throughput per unit of bandwidth, is an extensively accepted criterion for wireless network optimization. The peak value of SE is always among the major performance indicators of 3GPP evolution. According to the authors in [5], for instance, the target downlink SE of 3GPP increases from 0.05 b/s/Hz to 5 b/s/Hz as the system evolves from GSM to LTE. On the contrary, EE was previously ignored by most research efforts and was not taken into account by 3GPP as a significant performance indicator until very of late [5]. As the green evolution becomes a major trend, energy efficient transmission becomes more and more important. Unfortunately, some research studies [5][6] show that SE and EE are not always consistent and sometimes conflict with each other. Research studies show that performance gain can be substantially improved if the downlink transmissions to a given mobile from the various [7][8].

Researchers on [3] give a feedback in terms of cell-edge EE, which CoMP-JT provides more EE whereas CoMP-CS/CB provides less overhead. But neither of those shows a performance as a pragmatic solution due to overhead complexity at both cell-center and cell-edge for intra and inter transmissions in term of backhaul power (in the case of CoMP-JT) and system performance (in the case of CoMP-CS/CB). The aim of this thesis is to analyze the EE performance evaluation of conventional CoMP in LTE-A downlink networks. At the same time, it also proposes branch and bound (BnB) method to optimize the output of CoMP-CS/CB energy efficient and later proposes a hybrid technique which exploits the advantages of CoMP-CS/CB and CoMP-JT that it can be used in a system for controlling the main power consumers consumption come from data servers, backhaul router and base stations.

1.3 Aim and Objectives

The aim of this thesis is to analyze the EE performance evaluation of conventional CoMP in LTE-A downlink networks. To achieve the goal, the following objectives is an essential part of this thesis:

- To analyze the EE performance of CoMP on the downlink part of LTE-A.
- To optimize the CoMP-CS/CB EE by using branch and bound (BnB) method.
- To propose a hybrid approach which combines two technique into one system called CoMP-hybrid for decreasing the main power consumers consumption and increase EE.

1.4 Scope of the Thesis

This study, focuses on downlink EE performance CoMP in LTE-A. CoMP is one of the key technologies of LTE-A. With CoMP, it can fulfill the demand of user for high data rate and SE. This thesis describes the details of CoMP such as architecture, advantage, classification of CoMP and the main focus of this project which is the EE of CoMP. The scope of this studies is to compare the EE between the network with CoMP and without CoMP. In addition, comparing the EE between the techniques of CoMP is also the scope of this project. Through the comparison, the system with the best EE has been identified. This study will focus on downlink scheme which is CoMP-JT, CoMP-CS/CB and conventional system (non-CoMP). This study will suggests branch and bound (BnB) method to optimize the output of CoMP-CS/CB energy efficient and propose hybrid technique which exploits the advantages of CoMP-CS/CB and CoMP-JT that can be use in a system for controlling the main power consumers consumption.

1.5 Study Module

The summary of chosen approach in this thesis is presented in Figure 1.1, where the shade boxes with solid lines denote the follow directions to achieve determined objectives and the white box with dashed lines show the other research of EE which hove not been covered in this thesis. This studies will focus on downlink scheme which is CoMP-JT, CoMP-CS/CB and non-CoMP. This study suggests branch and bound (BnB) method to optimize the output of CoMP-CS/CB energy efficient and propose hybrid technique which exploits the advantages of CoMP-CS/CB and CoMP-JT.

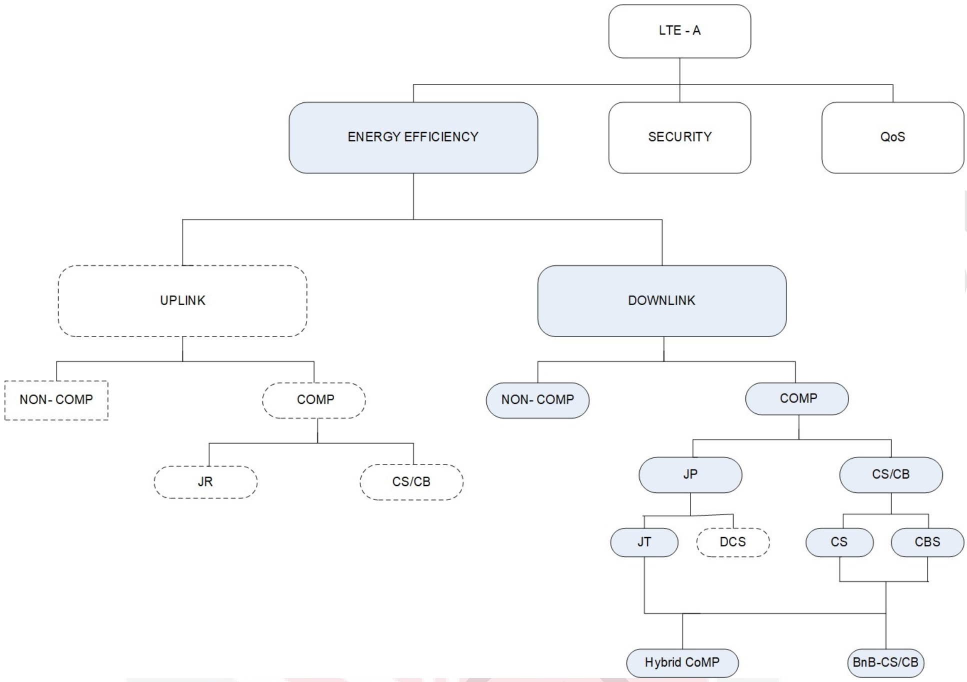

Figure 1.1: Study Module.

1.6 Thesis Organization

The overall structure of the study takes the form of five chapters as follows:

Chapter 1 provides a brief introduction to the LTE-A network and the CoMP technology. It consists of problem statement, aim and objectives, scope of the thesis and study module.

Chapter 2 highlights the main idea and fundamental element of the system especially CoMP in order to understand the system and establishes the necessity of this research through its background and previous works.

Chapter 3 discusses the system model in details. It describes the overall process of the studies in general and shows the system model developed the energy model, branch and bound concept and application and hybrid technique.

Chapter 4 discusses simulation results and shows the performance analysis from the outcome of simulation.

Chapter 5 provides the conclusions, thesis contributions and recommended future research works.

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