UNIVERSITI PUTRA MALAYSIA

BACKHAUL LOAD AND PERFORMANCE OPTIMALITY OF PARTIAL JOINT PROCESSING SCHEMES IN LTE-A NETWORKS

MOHAMMAD KOUSHA

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By

MOHAMMAD KOUSHA

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

December 2014

DEDICATIONS

In the name of Allah, Most Gracious, Most Merciful
This thesis is dedicated to:

My beloved wife, Maryam, for her unconditional help and whole-hearted support
And
My dear parents, for their unlimited 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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Chair: Fazirulhisyam Hashim, PhD
Faculty: Engineering

Surging demand for more new mobile broadband services everywhere, urged 3GPP to take advantage of small cells and frequency reuse factor of one in 4G LTE. However, the problem of performance degradation caused by Inter-Cell-Interference (ICI) also raised for cell-edge users. Coordinated Multipoint Transmission and Reception (COMP) is a cutting edge solution to ICI in LTE-Advanced. COMP techniques are divided into Coordinated Scheduling / Beamforming and Joint Processing. This thesis focuses on downlink joint processing, where each user receives data from various transmission points, improving the signal strength and cancelling interference. Joint processing transmission strategy is further divided into two schemes: Joint Transmission (JT) in which, multiple points transmit simultaneously to a user and Dynamic Point Selection (DPS) where, a single transmitter accommodates a user at each Transmission Time Interval (TTI). Joint processing demands for considerable amount of backhauling, signaling and data sharing that put a doubt on its feasibility. Previously, Partial Joint Processing has been proposed and evaluated for joint transmission as the most demanding scheme for backhaul in a static cluster for a flat fading Rayleigh channel. By limiting the cooperation in an active set of Evolved Node B (eNBs) for each user, the feedback and backhaul load is reduced with some performance degradation. In this thesis, Centralized and Partial Joint Processing are mathematically defined and evaluated for both JT and DPS in a multi-path environment using the WINNER II channel model which has been developed for LTE-Advanced. Centralized means full cooperation when complete channel matrix presents in the beamformer. But, partial joint processing translates in sparse channel matrices available at the central precoder entity and leads in the rank deficiency of channel correlation matrix in the zero forcing beamformer (ZFBF). A dynamic user-wise algorithm is proposed to resolve this problem. In depth

comparison among these schemes using different metrics like average sum-rate per cell, data rate and feedback rate demonstrates the better performance of centralized cooperation over partial cooperation with higher backhaul load. Joint transmission outperforms dynamic point selection but with higher backhaul requirements. The utility of PJP schemes for three different traffic types shows that DPS is preferred over JT for elastic and adaptive applications. The significance of the proposed algorithm is also proven in comparison with previous approach by maintaining the same performance while reducing the backhaul load up to 30%. The proposed algorithm also leverages the location dependency of the joint processing. All these achieved because the proposed algorithm targets those users located at the cluster borders who more likely cause rank deficiency.
Keywords: Inter-Cell Interference, 3GPP, CoMP, 4G LTE, Partial Joint Processing, WINNER, Precoder, Beamforming, Zero-Forcing.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk ijazah master sains

BEBAN ANGKUT BALIK DAN KEOPTIMUMAN PRESTASI SKIM PEMPROSESAN SEPARA BERSAMA dALAM RANGKAIAN LTE-A

Oleh

MOHAMMAD KOUSHA

December 2014

Pengerusi: Fazirulhisyam Hashim, PhD
Fakulti: Kejuruteraan

permintaan bagi lebih banyak perkhidmatan jalur lebar mudah alih yang baru di mana-mana, menggesa 3GPP untuk memanfaatkan kelebihan daripada sel-sel kecil dan faktor satu frekuensi penggunaan semula dalam 4G LTE. Walau bagaimanapun, masalah penurunan prestasi yang disebabkan oleh Ganguan-Anta ra-Cell (ICI) juga meningkat khususnya untuk pengguna-pengguna sel-tepian. Penghantaran Berbilang Titik Terkoordinasi dan Penerimaan (COMP) adalah penyelesaian tercanggih untuk ICI dalam LTE-Lanjutan. Teknik COMP terbahagi kepada Penjadualan/Pembentuk Alur Terkoordinasi dan Pemprosesan Bersama. Tesis ini memfokuskan kepada pemprosesan bersama pautan turun, dimana setiap pengguna menerima data dari pelbagai titik-titik penghantaran, memperbaiki kekuatan isyarat dan membatalkan ganguan. Strategi penghantaran pemprosesan bersama terbahagi pula kepada dua skim: Penghantaran Bersama (JT) dimana, beberapa titik menghantar pada masa yang sama kepada seorang pengguna dan Pemilihan Titik Dinamik (DPS) dimana, sebuah pemancar tunggal menempatkan seorang pengguna pada setiap Sela Masa Penghantaran (TTI). Pemprosesan bersama menuntut kepada sejumlah besar angkut balik, pengisyaratan dan perkon gsian data yang meletakkan keraguan pada kebolehlaksanaannya. Sebelum ini, Pemprosesan Separa Bersama telah dicadangkan dan dinilai untuk penghantaran bersama sebagai skim yang paling dituntut untuk angkut balik dalam kelompok statik bagi sesebuah saluran Rayleigh pudaran rata. Dengan menghadkan kerjasama dalam sesebuah set aktif Nod B Terevolusi (eNBs) untuk setiap pengguna, beban suap balik dan angkut balik telah dikurangkan dengan beberapa penurunan prestasi. Dalam tesis ini, Pemusatan dan Pemprosesan Separa Bersama telah ditentukan dan dinilai untuk kedua-dua JT dan DPS dalam persekitaran berbilang laluan yang menggunakan model saluran WINNER II yang telah dibangunkan untuk LTE-Lanjutan. Pemusatan bermak-

sud kerjasama sepenuhnya apabila matriks saluran lengkap wujud dalam pembentuk alur itu. Tetapi, terjemahan pemprosesan separa bersama dalam matriks saluran jarang ada tersedia pada entiti prapengekod pusat dan membawa kepada penurunan taraf bagi matriks korelasi saluran dalam pembentuk alur pemaksaan sifar (ZFBF). Satu algoritma dinamik bijak-pengguna telah dicadangkan untuk menyelesaikan masalah ini. Perbandingan mendalam antara skim-skim ini menggunakan metrik berbeza seperti purata jumlah-kadar setiap sel, kadar rata dan kadar suap balik menunjukkan bahawa prestasi kerjasama berpusat adalah lebih baik berbanding kerjasama separa dengan beban angkut balik yang lebih tinggi. Penghantaran bersama mengatasi prestasi pemilihan titik dinamik tetapi memerlukan angkut balik yang lebih tinggi. Utiliti skim-skim PJP untuk tiga jenis trafik yang berlainan menunjukkan bahawa DPS lebih menjadi pilihan berbanding JT untuk aplikasi anjal dan mudah suai. Kebererertian algoritma yang telah dicadangkan juga terbukti melalui perbandingan dengan pendekatan lain sebelumnya berdasarkan prestasi dan beban angkut balik. Algoritma yang telah dicadangkan ini juga memanfaatkan pergantungan lokasi pemprosesan bersama. Semua ini tercapai kerana algoritma yang telah dicadangkan mensasarkan pengguna-pengguna yang terletak di sempadan-sempadan kelompok yang lebih cenderung untuk menyebabkan penurunan taraf.

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I certify that a Thesis Examination Committee has met on **5/12/2014** to conduct the final examination of **Mohammad Kousha** on his thesis entitled "**BACKHAUL LOAD AND PERFORMANCE OPTIMALITY OF PARTIAL JOINT PROCESSING SCHEMES IN LTE-A NETWORKS**" 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 **Masters of Science**.

Members of the Thesis Examination Committee were as follows:

Shaiful Jahari Hashim, PhD
Senior Lecturer
Faculty of Engineering / Department Of Computer And Communication Systems Engineering
Universiti Putra Malaysia
(Chairperson)

Nor Kamariah bt. Noordin, PhD
Professor
Faculty of Engineering / Department Of Computer And Communication Systems Engineering
Universiti Putra Malaysia
(Internal Examiner)

Mohd Fadlee A.Rasid, PhD
Associate Professor
Faculty of Engineering / Department Of Computer And Communication Systems Engineering
Universiti Putra Malaysia
(Internal Examiner)

Badlishah Ahmad, PhD
Professor
Faculty of Engineering / Department Of Computer And Communication Engineering
Universiti Malaysia Perlis
Malaysia
(External Examiner)

ZULKARNAIN ZAINAL, PhD
Professor and Deputy Dean
School of Graduate Studies
Universiti Putra Malaysia

Date:

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)

Borhanuddin Mohd Ali, PhD
Professor
Faculty of Engineering
Universiti Putra Malaysia
(Member)

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

BUJANG KIM HUAT, PhD
Professor and Dean
School of Graduate Studies
Universiti Putra Malaysia

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Signature:	
Name of Chairman of Supervisory Committee:	Fazirulhisyam Hashim, PhD

Signature:	
Name of Member of Supervisory Committee:	Borhanuddin Mohd Ali, PhD

Signature:	
Name of Member of Supervisory Committee:	Aduwati Sali, PhD

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LIST OF ABBREVIATIONS

1G	First Generation
2G	Second Generation
3G	Third Generation
4G	Fourth Generation
3GPP	Third Generation Partnership Project
AS	Active Set
AMC	Adaptive Modulation and Coding
ACS	Array Coordinate System
AMPS	Advanced Mobile Phone System
BC	Broadcast Channel
BEC	Backward Error Correction
CDMA	Code Division Multiple Access
COMP	Coordinated Multipoint Transmission and Reception
CSI	Channel State Information
CQI	Channel Quality Indicator
CN	Core Network
CU	Central Unit
CJP	Centralized Joint Processing
CDPS	Centralized Dynamic Point Selection
DAS	Distributed Antenna System
DL	Downlink
DMRS	Demodulation Reference Signal
DPS	Dynamic Point Selection
DFT	Discrete Fourier Transform
DPC	Dirty Paper Coding
EDGE	Enhanced Data rates for GSM Evolution
eNB	evolved Node B
EPC	Evolved Packet Core
ECS	Element Coordinate System
E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FPGA	Field Programmable Gate Array
FEC	Forward Error Correction
FFT	Fast Fourier Transform
FDD	Frequency Division Duplex
GSM	Global System Mobile
GPRS	General Packet Radio Service
GCS	Global Coordinate System
GERAN	GSM EDGE Radio Access Network
HSPA	High Speed Packet Access
HARQ	Hybrid Automatic Retransmission Request
ITU	International Telecommunication Union
IMT	International Mobile Telecommunications
IEEE	Institute of Electrical and Electronics Engineers
ICI	Inter Cell Interference

ICIC	Inter Cell Interference Coordination
JP	Joint Processing
JT	Joint Transmission
JPCOB	Joint Power Control and Optimal Beamforming
LTE	Long Term Evolution
LO	Local Oscillator
LOS	Line of Sight
MIMO	Multi-Input Multi-Output
MMSE	Minimum Mean Square Error
MRC	Maximum Ratio Combining
MU-MIMO	Multi-User MIMU
MAC	Medium Access Control
MCS	Modulation Coding Scheme
MME	Mobility Management Entity
MT	Mobile Terminal
MU	Mobile User
NLOS	Non Line of Sight
NMT	Nordic Mobile Telephone System
OFDM	Orthogonal Frequency Division Multiplexing
OFDMA	Multi-User Orthogonal Frequency Division Multiple Access
PJP	Partial Joint Processing
PJT	Partial Joint Transmission
PFFR	Partial Fractional Frequency Reuse
PGW	Packet Gate Way
PMI	Precoding Matrix Indicator
PDCCH	Physical Downlink Control Channel
PUCCH	Physical Uplink Control Channel
PDPS	Partial Dynamic Point Selection
QAM	Multi-User Quadrature Amplitude Modulation
QOS	Quality of Service
QPSK	Quadrature Phase Shift keying
RB	Resource Block
RRM	Radio Resource Management
RI	Rank Indicator
RSRP	Reference Signal Received Power
RRC	Radio Resource Control
ROF	Radio over Fiber
RAN	Radio Access Network
SFFR	Soft Fractional Frequency Reuse
SC-FDMA	Single Carrier Frequency Division Multiple Access
SE	Spectral Efficiency
SGW	Serving Gateway
SU-MIMO	Single User MIMU
SCM	Spatial Channel Model
SCME	Spatial Channel Model Extended
SNR	Signal to Noise Ratio
SINR	Signal to Interference plus Noise Ratio

TACS	Total Access Communications System
TDMA	Time Division Multiple Access
TR	Technical Report
TDD	Time Division Duplex
TTI	Transmission Time Interval
UMTS	Universal Mobile Telecommunications System
UL	Uplink
UE	User Equipment
ULA	Uniform Linear Array
WCDMA	Wide band Code Division Multiple Access
WiMAX	Worldwide Interoperability for Microwave Access
Wi-Fi	Wireless Fidelity
ZFBF	Zero Forcing Beamforming

CHAPTER 1

INTRODUCTION

1.1 Background

To accommodate the users with increasing demand for the ubiquitous mobile data, the evolution of mobile communications has extended through several new generations. This evolution started with First generation (1G), and continued to (2G), Third (3G) and 4th Generation (4G) of cellular network as depicted in Figure 1.1.

Generally, the first generation of cellular networks came up in the 1980s, using analog mobile radio systems followed by 2G which revealed the first digital system named as GSM (Global System for Mobile Communications). After that, 3G network, which was the pioneer mobile system in handling multimedia data transmission besides voice communications was lunched. Later on, Long Term Evolution (LTE) and its major enhancement LTE-Advanced were introduced just a few years back in 2009 and 2010. This generation is usually referred to as 4G and envisaged as a big improvement in wireless systems, promising a wide range of coverage with high data rates up to 100 Mbps for LTE and 1 Gbps for LTE-A. Third Generation Partnership Project (3GPP) organization was following the predefined requirements by ITU-IMT-2000. All generations developed by 3GPP are as follows:

First-generation cellular networks (1G) arrived in the late 1970s. It was analog-based and limited to voice services only. In the early 1980s, 1G mobile communication systems were populated. Limited spectral efficiency of first generation of networks led up to the evolution toward 2G tackling the drawbacks of 1G.

Second-generation (2G) first introduced digital communication which was promised to address the disadvantages of 1G and enhance the spectral efficiency and voice quality. In the second generation, GSM (Global System for Mobile Communications) and CDMA (Code Division Multiple Access) networks were widely deployed all over the globe [1]. Employing slow frequency hopping for voice communication and Time Division Multiple Access (TDMA) transmission methods in GSM networks, could outperform other analog counterparts.

Third-generation Universal Mobile Telecommunications System (UMTS) is the improved version of the GSM standard. The UMTS Terrestrial Radio Access Network (UTRAN) is the base of the 3G built on Wide band Code Division Multiple Access (WCDMA) radio technology. The radio technology enhancement owes to using 5 MHz bandwidth and GSM/EDGE Radio Access Network (GERAN) [2].

As the first step toward 4G mobile broadband network, Long-Term Evolution (LTE) standard launched by 3GPP in 2004 [3]. The LTE technology was supposed to enable service provisioning and high peak data rates, low latency and the greatest spectral efficiency so far. Owing to the flat and IP-based architecture of LTE, it supports a large variety of services such as voice, data and video (LTE will be discussed in Section 2.3).

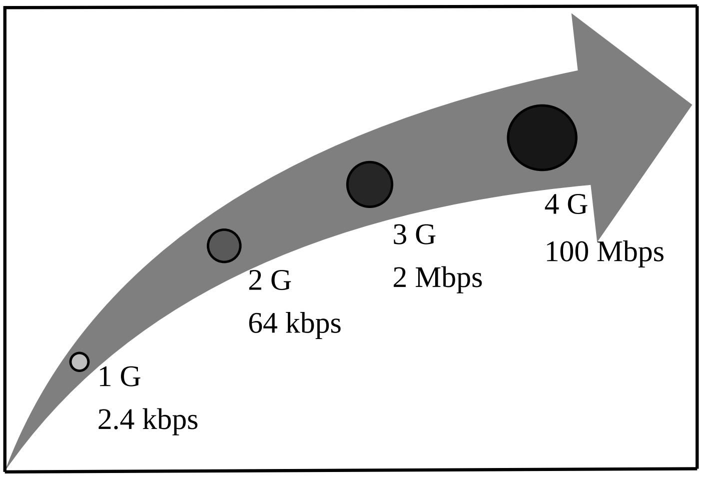

Figure 1.1: The evolution of communication networks.

Moving forward from previous cellular networks toward new mobile communications, necessitates fundamental changes in the size of the cells and frequency reuse strategies. The scarcity of bandwidth, spectrum and power on one hand and the demand for higher broadband data rates on the other hand, in wireless systems have highlighted the need for new solutions to achieve more spectral efficient communication. As it is illustrated in Figure 1.2, keeping an eye on the trend of communication networks during past decades reveals the tendency of using smaller cells and bigger frequency reuse factors. It leads to providing more resources to be assigned to users being served in each cell. Small cells and heterogeneous networks are the key features used in 3GPP Long Term Evolution (LTE) network. The most problematic issue arising in 4G systems utilizing small cells and aggressive frequency reuse is Inter-Cell Interference (ICI) that affects the data rates of the users at the cell-edge which degrades the average cell spectral efficiency.

In the context of LTE-advanced, some new technologies have been proposed to overcome the problematic ICI. One such technology is COMP whereby, the cell-edge user performance will be enhanced as well as average cell performance through coordination among cells by means of beamforming, scheduling or joint processing. A consortium named 'EASY-C' project was defined in order to investigate the real world feasibility of such conceptual research with field trials,

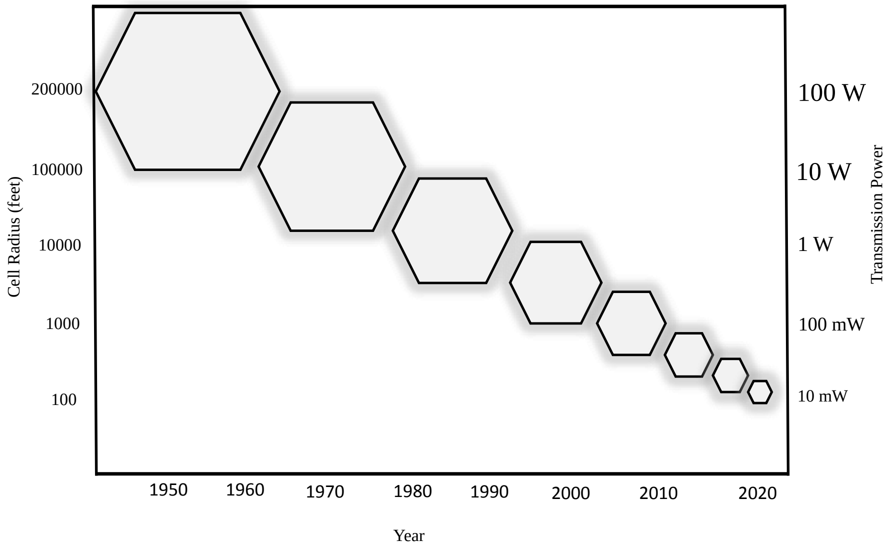

Figure 1.2: Trend of cellular networks [4].

aiming for low latency, fairness and high spectral efficiency. EASY-C is the first testbed started in June 2009, deploying COMP in Dresden, Germany [5]. In January 2010, a new European research project, ARTIST4G was launched with the goal of exploring further use of COMP towards the next generation of wireless cellular systems [6].

In conventional cellular systems, eNBs are placed in the cell center covering a limited surrounding area. The signals coming from neighboring cells cause interference. It is especially a severe problem in the cell-edge, leading to degraded spectral efficiency. By making the channel state information (CSI) of all links available in an entity namely central unit (CU), interference from other cells can be avoided by means of beamforming. This interference, pre-cancellation by beamforming and power allocation is called Precoding. In this context, dirty Paper Coding (DPC) can be seen as a sophisticated precoding technique which can efficiently remove the interference at the transmitter in a Gaussian channel [7]. In multiuser-MIMO, DPC is a capacity increasing strategy, but is not viable in practice, because it needs non-casual CSI to be known at the transmitter. Therefore, sub-optimal beamforming techniques like Zero Forcing Beamformer (ZFBF) and Minimum Mean Square Error (MMSE) beamformer are more practical for implementation. ZFBF can reach a sum-rate that of DPC with well-planned user selection. It can be applied at the transmitter with increasing the average transmit power, but interference cancellation methods at the user side are not favorable because it poses the problem of space constraint (not less than two antennas at the mobile terminal) and battery power draining. As a result the interference cancellation rationally needs to be carried out at the eNB.

COMP transmission is defined as cooperation of multiple eNBs or network points when transmitting to a user, collaborating to remove interference. Aiming this to happen, the CSI data of all the eNBs need to be available at the central unit to do precoding. This comprises the centralized joint processing algorithm, where a set of eNBs form a cluster of cooperative cells. However, coordination among eNBs holding coherent joint processing necessitates tremendous requirements for high speed and low latency backhauling on fiber or over microwave links to make the CSI available at the central unit [8]. Hence, various joint processing sub-schemes are proposed to reduce the backhauling burden on the network. One of such schemes is partial joint processing algorithm, where only a subset of eNBs are chosen based on a threshold value allowed to share the CSI and user data to take part into the transmission. This way, the backhaul load will drop. As long as transmission is conducted from multiple distant antennas, COMP transmission is also known as network MIMO and distributed antenna system.

Distributed antenna systems provide much tremendous performance gains over conventional techniques. Foschini In [9], has proved the capacity will increase with the minimum number of antennas in the transmitter (Tx) and the receiver (Rx), for a constant bandwidth or power. MIMO brings some fantastic benefits like array gain, diversity gain, multiplexing gain, interference reduction and avoidance, but exploiting all of this may be impossible. Nonetheless, the performance spectral efficiency gains owing to the coordination of multiple antennas is illustrated in [10], A significant increase in spectral efficiency has been shown as the number of coordinated antennas increase. Coordinating multipoint transmission generally is referred to as Network MIMO (NW MIMO) or Distributed Antenna Systems (DAS).

Although COMP can be applied in uplink (UL) and downlink (DL), the focus of this thesis is on the Coordinated Multipoint Transmission. So that, throughout this document COMP refers to the DL transmission. According to [11] and [12], two sub-schemes of coordinated multipoint in downlink are:

- Coordinated scheduling among multiple cells.
  It is an improved version of ICI coordination in Release 8 of LTE specifications. In next 3GPP LTE standards like TR36.814 this scheme is referred to as Coordinated Scheduling or Coordinated Beamforming. Whereby, the data to a User Equipment (UE) is transmitted from one of the eNBs while the scheduling decisions are coordinated. (See Figure 1.3(a)). Due to this, only the generated beams and scheduling decisions need to be coordinated. The user data only needs to be present at one serving eNB.

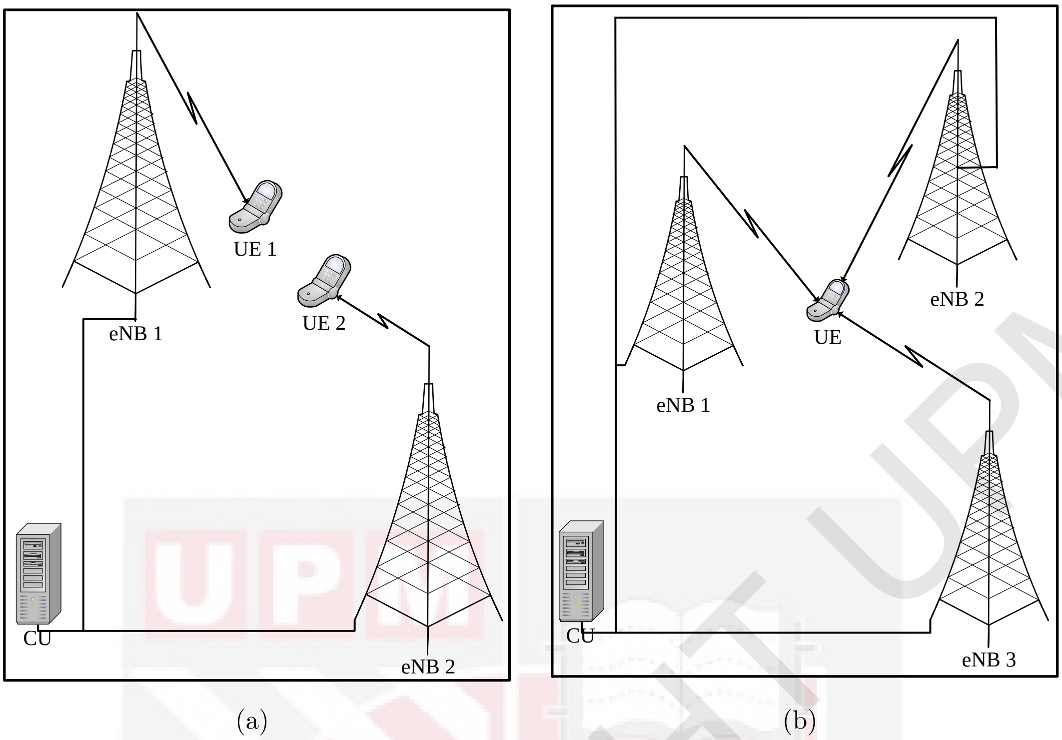

Figure 1.3: JP schemes with centralized topology. (a) Centralized coordinated scheduling/beamforming. (b) Centralized coordinated joint processing. (Parts of this figure are drawn based on [14])

- Joint Processing among multiple cells.
  When a particular mobile user receives its data from multiple eNBs, 3GPP TR 36.814 referred this as Joint Processing. Hence, removing the interference and increasing the signal strength is achieved. (See Figure 1.3(b)). Coherent joint processing requires huge backhaul capacity, as the user data needs to be shared among all the coordinating eNBs. Joint processing COMP attains potentially larger theoretical gains in terms of average and cell-edge user's throughput in comparison with coordinated scheduling/beamforming [13]. However, Joint Processing schemes are discussed in this thesis.

The performance improvement brought to new communication networks by COMP, comes with some challenges to be addressed. Main challenging issues in realizing COMP are listed as follows:

- Non-causal CSI: Perceiving the future channel condition to employ more complex coding like DPC results in capacity improvement in MU-MIMO, but because of the involved complexity, this is practically unfeasible.

- Delay: The CSI mismatch caused by time delay while sharing information among eNBs results in the inefficiency of precoding based on expired channel knowledge. Therefore, the gains achieved by COMP highly depend on update CSI at the transmitter side.

- Synchronization: For schemes like Coherent Joint Transmission synchronization of shared control signals between eNBs in time and phase is really crucial. This strict synchronization brings intense requirements for high speed backhauling. Implementation of COMP algorithms on FPGA (Field Programmable Gate Array) can help better synchronization [15].

- CSI Availability:

  – Exploiting Time Division Duplex (TDD) can enable utilizing the reciprocal nature of UL and DL so that the CSI estimated at the eNB from the UL can be used in the DL. Hence, no need for user to feed back the CSI. This reciprocity of wireless channel works well because the frequency used in both UL and DL is within the coherence bandwidth (Bc 1/TD, Bc is the bandwidth over which the fading remains correlated. TD is the delay spread) of the channel [16].

  – In Frequency Division Duplex (FDD), the UL and DL transmissions are exploited on different frequencies and it necessitates the CSI feedback from UE.

- Impact of feedback errors: Errors occurring due to data compression or quantization algorithms used in UE to feedback the CSI will affect the cooperation.

1.2 Problem Statement

As it has been recently investigated in [17], with current real world network backbone capacity, COMP strategies are less likely practical because of their high required backhaul load. This is specially more severe for joint processing schemes as they are more demanding for backhaul and feedback load. Partial joint processing is a solution to reduce the backhaul requirements of joint processing with some performance degradation. Partial Joint Transmission (PJT) schemes have been defined and evaluated first for Rayleigh fading channels in [18]. According to the current research, Dynamic point selection JP opposes less burden on the backhaul in comparison with joint transmission JP. It motivates an in depth analysis of PJP for both JT and DPS in a more realistic propagation environment emulated by WINNER II channel model for LTE-A. A user-wise algorithm is also proposed to define the cooperation area in a way that the rank deficiency of channel coefficients matrix in ZFBF is addressed. Eventually, joint transmission and dynamic point selection schemes are evaluated based on their ability in maintaining QOS for three different online applications.

1.3 Aims and Objectives

In this thesis different Partial joint processing schemes will be characterized and evaluated for both JT and DPS considering their performance and required backhaul. Moreover, a dynamic active set threshold value selection algorithm will be suggested to address the rank deficiency that outperforms the one suggested in [19]. The key contribution of this work is to perform an in depth analysis among all possible Partial joint processing algorithms and to propose an algorithm that can dynamically maintain a certain level of cooperation in which ZFBF is working properly. To achieve this, the fulfillment of these objectives is crucial as part of this thesis:

- To mathematically define different Partial Joint Processing schemes.
- To evaluate the joint processing schemes regarding their backhaul requirements and also their performance based on two different metrics: acquired sum-rate and utility for three internet applications.
- To propose a dynamic thresholding algorithm to address the rank deficiency of channel coefficients matrix.

1.4 Scope of the Thesis

In this thesis, joint processing schemes introduced in [18] are further expanded to Dynamic point selection as well as joint transmission in a frequency selective channel utilizing WINNER II channel model. An OFDM approach is used to exploit the frequency selective nature of the channel. In fact, implementing an OFDM approach, joint processing algorithms are applied in every resource block (RB). To take the worst case scenario into consideration, all users are assumed to be scheduled on all RBs in each TTI.

The main focus is on the impact of Partial Joint Processing (PJP) algorithms for both JT and DPS. As expected Based on the numerical results, the PJT schemes have higher average sum-rate per cell per RB compared to PDPS with the cost of more backhaul load and complexity. Partial schemes can satisfy the QOS requirements of users with less backhaul load requirement.

Limited number of links give rise to the presence of sparse CSI at the central unit to exploit interference cancellation. As a drawback, for low values of active set threshold and for users closer to the eNB the rank deficiency of the scaled channel correlation matrices occurs in the partial zero-forcing beamformer design. Hence, a dynamic active set thresholding algorithm is proposed that defines the cooperation strategy over the cluster where the cooperation strategy expands the coverage for all users. This algorithm more optimally chooses a joint processing scheme in comparison with the previous proposed algorithm to solve the rank deficiency.

As the main purpose of each communication system is to accommodate users properly, a utility factor is used to measure the ability of joint processing schemes in assuring the QOS for three different traffic types. The provided utility gains by JT and DPS for hard real-time, adaptive, and elastic applications plus their required feedback load can help to optimally select a JP scheme.

1.5 Study Module

The chosen strategy to conduct this study is illustrated in Figure 1.4, where solid lines determine the direction toward the defined goals and the dashed boxes represent the other areas of research around interference mitigation.

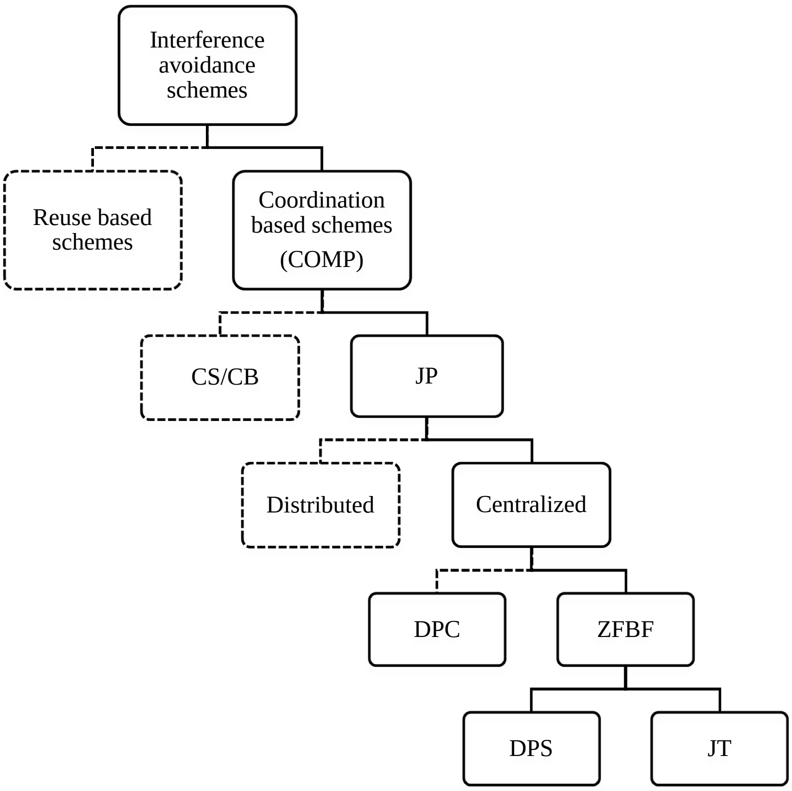

Figure 1.4: Study module.

1.6 Thesis Organization

This section presents the organization of this document. This dissertation will proceed as follows:
Chapter 2 establishes the necessity of this research through its background and previous works. Inter-cell interference is explained and the importance of inter-cell interference cancellation in 4G LTE is established. Coordinated multipoint transmission is identified as a key technique in LTE-A in line with its predecessors to address ICI. And finally, partial joint processing is introduced as a solution to high demand of JP for backaul load.

In chapter 3, the system model is defined in details. This chapter gives a mathematical description of different schemes under study, which primarily consists of the joint processing algorithms being applied to the WINNER II channel model. The layout of the assumed scenario, including the cluster area together with the generation of the channel matrix, antennas for the eNB/UE are discussed under the section named WINNER II channel model.

Chapter 4 includes a brief explanation of simulation setup and presentation of results through comparison of different schemes. Throughout this chapter, centralized schemes versus partial schemes and dynamic point selection schemes versus joint transmission schemes are compared and evaluated based on their average sum-rate, backhaul load and utility factor. The efficiency of the proposed algorithm is also examined in contrast with one other previous approach.

The conclusions derived from this thesis, which also highlights possible future works in line with this WINNER/Joint Processing framework are mentioned in section 5. Finally, publications out of this work are appended in a final chapter named publication.

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BIODATA OF STUDENT

The student, **Mohammad Kousha**, was born in 1985. he obtained his Bachelor of Engineering (Telecommunications) degree in 2011 from Azad University of NAJAFABAD, IRAN.

The student can be contacted via his supervisor, Dr. Fazirulhisyam Hashim, by address:

Department of Computer and Communication,
Faculty of Engineering,
Universiti Putra Malaysia,
43400 Serdang,
Selangor,
Malaysia.

Email: fazirul@eng.upm.edu.my
Telephone: +60-3-89464319

LIST OF PUBLICATIONS

Publications that arise from the study are:

1. M. Nasimi, **M. Kousha**, F. Hashim. QoE-Oriented Cross-Layer Downlink Scheduling for Heterogeneous Traffics in LTE Networks. In *2013 IEEE Malaysia International Conference on Communication (MICC 2013), pages 61–66, Kuala Lumpur, Malaysia, November 2013.*

2. **Mohammad Kousha**, Fazirulhisyam Hashim. Backhaul and Performance of Joint Processing Schemes Over the Cluster Area. In *2014 IEEE Symposium on Computer Applications and Industrial Electronics (ISCAIE 2014), pages 198–202, Penang, Malaysia, April 2014.*

3. **Mohammad Kousha**, F azirulhisyam Hashim, Borhanuddin Ali and Aduwati Sali. On The Coordinated Multipoint Transmission in New Cellular Networks. Submitted in *IETE Technical Review, November 2014.*

4. **Mohammad Kousha**, Fazirulhisyam Hashim, Borhanuddin Ali and Aduwati Sali. Backhaul Load and Performance Gain of Joint Transmission and Dynamic Point Selection Schemes. Submitted in *Transactions on Emerging Telecommunications Technologies, November 2014.*