RESOURCE ALLOCATION IN COORDINATED MULTIPOINT LONG TERM EVOLUTION –ADVANCED NETWORKS

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Dedicated to my beloved hubby, parents, siblings and sons.

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ABSTRACT

Coordinated Multipoint (CoMP) in Long Term Evolution-Advanced (LTE-Advanced) improves the cell-edge data rates and the network spectral efficiency through base station coordination. In order to achieve high quality of service (QoS) in CoMP network, resource allocation approach is one of the main challenges. The resource allocation strategies of cells in CoMP network affect each other's performance. Thus, the resource allocation approach should consider various diversities offered in multiuser wireless networks, particularly in frequency, spatial and time dimensions. The primary objective of this research is to develop resource allocation strategy for CoMP network that can provide high QoS. The resource allocation algorithm is developed through three phases, namely Low-Complexity Resource Allocation (LRA), Optimized Resource Allocation (ORA) and Cross-Layer Design of ORA (CLD-ORA). The LRA algorithm is a three-step resource allocation scheme that consists of user selection module, subcarrier allocation module and power allocation module which are performed sequentially in a multi-antenna CoMP network. The proposed ORA algorithm enhances throughput in LRA while ensuring fairness. ORA is formulated based on Lagrangian method and optimized using Particle Swarm Optimization (PSO). The design of CLD-ORA algorithm is an enhancement of the ORA algorithm with resource block (RB) scheduling scheme at medium access control (MAC) layer. Simulation study shows that the ORA algorithm improves the network sum-rate and fairness index up to 70% and 25%, respectively and reduces the average transmit power by 41% in relative to LRA algorithm. The CLD-ORA algorithm has further enhanced the LRA and ORA algorithms with network sum-rate improvement of 77% and 33%, respectively. The proposed resource allocation algorithm has been proven to provide a significant improved performance for CoMP LTE-Advanced network and can be extended to future 5G network.

ABSTRAK

Pengkoordinatan Berbilang Punca (CoMP) dalam Evolusi Jangka Panjang-Termaju (LTE-Advanced) meningkatkan kadar data dan keberkesanan spektrum rangkaian melalui pengkoordinatan stesen pangkalan (BS). Bagi mencapai kualiti perkhidmatan (QoS) yang tinggi dalam rangkaian CoMP, pendekatan pengagihan sumber menjadi satu cabaran utama. Strategi pengagihan sumber oleh sel-sel dalam rangkaian CoMP memberi kesan terhadap prestasi setiap sel. Oleh itu, pendekatan pengagihan sumber perlu mempertimbang kepelbagaian dalam rangkaian tanpa wayar berbilang pengguna, terutama dalam dimensi frekuensi, ruang dan masa. Objektif utama kajian ini ialah membangunkan strategi pengagihan sumber bagi rangkaian CoMP yang memberikan QoS yang tinggi. Algoritma pengagihan sumber ini dibangunkan melalui tiga fasa, iaitu Pengagihan Kuasa Kekompleksan Rendah (LRA), Pengagihan Kuasa Teroptimum (ORA) dan Rekabentuk Silang Lapisan ORA (CLD-ORA). Algoritma LRA ialah kaedah pengagihan kuasa tiga-langkah terdiri daripada modul pemilihan pengguna, modul pengagihan subpembawa dan modul pengagihan kuasa yang dijalankan secara berturutan dalam rangkaian CoMP berbilang antena. Algoritma ORA yang dicadangkan meningkatkan daya pemprosesan LRA di samping memastikan keadilan. ORA diformulasi berdasarkan kaedah Lagrangian dan dioptimum menggunakan Pengoptimuman Kerumunan Zarah (PSO). Rekabentuk CLD-ORA adalah penambahbaikan ORA dengan kaedah penjadualan blok sumber (RB) di lapisan kawalan capaian medium (MAC). Kajian simulasi menunjukkan ORA meningkatkan hasil tambah kadar rangkaian dan keadilan sehingga 70% dan 25%, dan mengurangkan kuasa pancaran purata sehingga 41% berbanding LRA. CLD-ORA menambahbaik LRA dan ORA dengan peningkatan hasil tambah kadar 77% dan 33%. Algoritma pengagihan sumber yang dicadangkan terbukti meningkatkan prestasi rangkaian CoMP LTE-Advanced dan boleh dipanjangkan kepada rangkaian 5G masa hadapan.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

APP	-	Application layer
BS	-	Base Station
CEU	-	Cell-edge User
CLD	-	Cross-Layer Design
CLD-ORA	-	Cross-Layer Design of Optimized Resource Allocation
CoMP	-	Coordinated Multipoint
CS/CB	-	Coordinated Scheduling/Coordinated Beamforming
CSI	-	Channel State Information
DCS	-	Dynamic Cell Selection
GA	-	Genetic Algorithm
ICI	-	Inter-Cell Interference
ICIC	-	Inter-Cell Interference Coordination
JFI	-	Jain's Fairness Index
JP	-	Joint Processing
JT	-	Joint Transmission
KKT	-	Karush-Kuhn-Tucker
LRA	-	Low-Complexity Resource Allocation
LTE	-	Long Term Evolution
LTE-A	-	Long Term Evolution – Advanced
MAC	-	Medium Access Control
MIMO	-	Multiple-Input Multiple-Output
MU-MIMO	-	Multi-User MIMO
NEE	-	Network Energy Efficiency
NSR	-	Noise-to-Signal Ratio
OAM	-	Operation and Management
OFDM	-	Orthogonal Frequency Division Multiplexing

OFDMA	-	Orthogonal Frequency Division Multiple Access
OPO	-	Orthogonal Projection Operator
ORA	-	Optimized Resource Allocation
PDCP	-	Packet Data Control Protocol
PF	-	Proportional Fairness
PFS	-	Proportional Fair Scheduling
PHY	-	Physical layer
PRB	-	Physical Resource Block
PSO	-	Particle Swarm Optimization
QoS	-	Quality of Service
RB	-	Resource Block
RF	-	Radio Frequency
RLC	-	Radio Link Control
RR	-	Round-Robin
RRM	-	Radio Resource Management
SC	-	Selective Combining
SE	-	Spectral Efficiency
SNR	-	Signal-to-Noise Ratio
SINR	-	Signal-to-Interference plus Noise Ratio
SISO	-	Single-Input Single Output
SRM	-	Sum-Rate Maximization
SVD	-	Singular Value Decomposition
TTI	-	Transmission Time Interval
UE	-	User End
UMTS	-	Universal Mobile Terrestrial System
WF	-	Water-Filling
WSRM	-	Weighted Sum-Rate Maximization
3GPP	-	The Third Generation Partnership Project

LIST OF SYMBOLS

$\boldsymbol{\mathcal{A}}$	-	selected user set
$\boldsymbol{B}$	-	network bandwidth
$\boldsymbol{C_i}$	-	cell $\boldsymbol{i}$
c_1,c_2	-	acceleration coefficients
D	-	number of swarm particles
$\boldsymbol{D_i}$	-	signal transmitted by cell $\boldsymbol{i}$
E_0,E_1,E_2, E_3	-	reference signals for four antenna ports MIMO transmission
F	-	fitness
G_best_{iter}	-	global best position
$\boldsymbol{H_{k_j,n}}$	-	channel matrix of UE $\boldsymbol{k_j}$ over subcarrier $\boldsymbol{n}$
$\boldsymbol{H^j_{k_j,n}}$	-	channel matrix of UE $\boldsymbol{k_j}$ in cell $\boldsymbol{j}$ over subcarrier $\boldsymbol{n}$
$\boldsymbol{I_{k_l,n,l}}$	-	interference caused by UE $\boldsymbol{k_l}$ in cell $\boldsymbol{l}$ over subcarrier $\boldsymbol{n}$
$I_{n,j,l}$	-	interference received over subcarrier n in cell j
$\boldsymbol{J}$	-	total number of BSs in the CoMP network
JFI_{CE}	-	fairness index achieved by cell-edge UEs
$\boldsymbol{K}$	-	total number of UEs in the CoMP network
$\boldsymbol{K_j}$	-	total number of UE in cell $\boldsymbol{j}$
$\boldsymbol{K_l}$	-	total number of UE in cell $\boldsymbol{l}$
$\boldsymbol{k_j}$	-	corresponding UE in cell $\boldsymbol{j}$
$\boldsymbol{k_l}$	-	corresponding UE in cell $\boldsymbol{l}$
L	-	number of other cells in the CoMP network
$L_{k_j,j}$	-	path loss between BS j and UE k_j
max_{iter}	-	maximum number of iteration
N	-	total number of subcarriers in the system
N_o	-	noise power

$\boldsymbol{N_R}$	-	total number of receive antennas
N_{sub}	-	number of subcarriers fixed for each user in LRA
$\boldsymbol{N_T}$	-	total number of transmit antennas
n_{k_j}	-	corresponding subcarrier of UE k_j
$\boldsymbol{n_R}$	-	number of transmit antennas at UE device
$\boldsymbol{n_T}$	-	number of transmit antennas at the BS
$\mathbb{N}_i$	-	white noise at the receiver in cell i
$P\_best^a_{iter}$	-	personal best position of particle a
P_{BSmax}	-	maximum BS transmit power
P_{BSave}	-	average transmit power
P_{k_j}	-	total power allocated for user k_j over the set of subcarriers Ω_{k_j}
$\boldsymbol{p_{k_j,n,j}}$	-	power allocated to UE $\boldsymbol{k_j}$ in cell $\boldsymbol{j}$ over subcarrier $\boldsymbol{n}$
$p^*_{k_j,n,j}$	-	optimal power allocated to UE k_j in cell j over subcarrier n
$p_{k_l,n,l}$	-	power allocated to UE k_l in cell l over subcarrier n
Q^a_{iter}, q^a_{iter}	-	random numbers uniformly distributed on (0,1)
$R_{j,CE}$	-	total achievable rate of cell-edge UEs in cell j
$R_{k_j,n,j}$	-	achievable rate of UE k_j in cell j over subcarrier n
R_{k_j}	-	achievable rate of UE k_j
$R_{k_j,req}$	-	minimum rate requirement of UE k_j
$R_{k_j,total}$	-	total achieved rate in a previous time window of fixed duration
$r_{k_j,b}(t)$	-	achievable rate for the k_j-th user over b-th RB at time TTI t
$\boldsymbol{S}$	-	rank of $\boldsymbol{H_{k_j,n,j}}$
$\boldsymbol{U_{k_j,n,j}}$	-	unitary matrix of UE $\boldsymbol{k_j}$ in cell $\boldsymbol{j}$ over subcarrier $\boldsymbol{n}$
$u^{(s)}_{k_j,n,j}$	-	right singular vector of $H_{k_j,n,j}$on spatial layer s
$\boldsymbol{V_{k_j,n,j}}$	-	vector matrix of UE $\boldsymbol{k_j}$ in cell $\boldsymbol{j}$ over subcarrier $\boldsymbol{n}$
$v^{(s)}_{k_j,n,j}$	-	left singular vector of $H_{k_j,n,j}$ on spatial layer s
w	-	inertia weight
$\boldsymbol{W_i}$	-	precoding matrix at cell $\boldsymbol{i}$
w_{max}	-	final weight
w_{min}	-	initial weight

$X_{i.0}^{a}$	-	current position of particle a
α	-	Lagrange multiplier
$\gamma_{k_j,n,j}$	-	subcarrier allocation indicator
$\Psi_{\boldsymbol{k_j},\boldsymbol{n},\boldsymbol{j}}$	-	singular matrix of user $\boldsymbol{k_j}$ in cell $\boldsymbol{j}$ over subcarrier $\boldsymbol{n}$
$\lambda_{k_j,n,j}^{(s)}$	-	singular value of $H_{k_j,n,j}$ on spatial layer s
$\lambda_{k_l,n,l}^{(s)}$	-	singular value of $H_{k_l,n,l}$ on spatial layer s
Ω_{k_j}	-	subset of subcarriers allocated for user $k_j$in cell j
$\sigma_{n,j}^{2}$	-	noise power over subcarrier n in cell j
φ	-	Lagrange multiplier
μ	-	Lagrange multiplier

LIST OF APPENDIX

CHAPTER 1

INTRODUCTION

1.1 Overview

The Third Generation Partnership Project (3GPP) Long Term Evolution (LTE)-Advanced is envisaged as the fourth generation cellular standard, and is aligned with existing third generation deployments, e.g., Universal Mobile Telecommunications System (UMTS). The goals of LTE-Advanced are to improve the peak throughput by increasing the numbers of transmit and receive antennas. One of the key enabling technologies of LTE-Advanced is coordinated multipoint (CoMP) that targets to improve the cell-edge performance as well as overall network spectral efficiency through base stations (BSs) coordination.

The continually increasing number of users and the rise of resource-demanding services require a higher link rate. Due to the limited resources at the base station (BS) such as bandwidth and power, intelligent allocation of these resources is crucial for delivering the best possible quality of service (QoS) to the consumer with the least cost. This is especially important with the high data rates envisioned for the future wireless standards.

In this thesis, resource allocation algorithm for CoMP LTE-Advanced network that provides high QoS while is proposed. The proposed algorithm takes advantage of frequency, spatial and time diversities in the time-varying wireless channel to increase the CoMP network performance.

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