DISTRIBUTED RESOURCE ALLOCATION FOR INTER CELL INTERFERENCE MITIGATION IN IRREGULAR GEOMETRY MULTICELL NETWORKS

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To my beloved parents; Safdar Khan Bhatti (Abu) & Noor Jahan Begum (Ami),

my beloved wife; Qurratulain

my adorable childrens; Daiyan, Aiza and Rayyan

my supportive brother; Qasim Safdar

my sweet sisters; Deeba, Alia, Laila and Iram

and *my uncles, aunties, nephews and nieces.*

Thank for your support and prayers.

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ABSTRACT

Extensive increase in mobile broadband applications and proliferation of smart phones and gadgets require higher data rates of wireless cellular networks. However, limited frequency spectrum has led to aggressive frequency reuse to improve network capacity at the expense of increased Inter Cell Interference (ICI). Fractional Frequency Reuse (FFR) has been acknowledged as an effective ICI mitigation scheme but in irregular geometric multicellular network, ICI mitigation poses a very challenging issue. The thesis developed a decentralized ICI mitigation scheme to improve both spectral and energy efficiency in irregular geometric multicellular networks. ICI mitigation was realized through Distributed Resource Allocation (DRA) deployed at the cell level and region level of an irregular geometric cell. The irregular geometric cell consists of a minimum of four regions comprising three sectors and a central region. DRA at the cell level is defined as Multi Sector DRA (MSDRA), and at the region level is defined as Distributed Channel Selection and Power Allocation (DCSPA). MSDRA allocates discrete power to every region in a cell based on Game Theory and Regret Learning Process with correlated equilibrium as the optimum decision level. The DCSPA allocates power to every channel in a region based on non-coalesce liquid droplet phenomena by selecting optimum channels in a region and reserving appropriate power for the selected channels. The performance was evaluated through simulation in terms of data rate, spectral efficiency and energy efficiency. The results showed that MSDRA significantly improved cell data rate by 58.64% and 37.92% in comparision to Generalized FFR and Fractional Frequency Reuse-3 (FFR-3) schemes, respectively. The performance of MSDRA at the cell level showed that its spectral and energy efficiency improved 32% and 22%, respectively in comparison to FFR-3. When the number of sectors increased from three to four, data rate was improved by 30.26% and for three to six sectors, it was improved by 56.32%. The DCSPA further improved data rate by 41.07% when compared with Geometric Water Filling, and 86.46% in comparison to Asynchronous Iterative Water Filling. The DCSPA enhanced data rate achieved in MSDRA by 15.6%. Overall, DRA has shown to have significant improvement in data rate by 53.6%, and spectral efficiency by 38.10% as compared to FFR-3. As a conclusion, the DRA scheme is a potential candidate for Long Term Evaluation – Advanced, Fifth Generation networks and can be deployed in future heterogeneous irregular geometric multicellular Orthogonal Frequency Division Multiple Access networks.

ABSTRAK

Peningkatan meluas aplikasi jalur lebar mudah alih dan pertumbuhan pesat telefon pintar dan alatannya memerlukan kadar data berkelajuan tinggi bagi rangkaian selular tanpa wayar. Namun begitu, spektrum frekuensi terhad membawa kepada penggunaan semula frekuensi secara agresif untuk meningkatkan kapasiti rangkaian dengan mengorbankan peningkatan Gangguan Antara Sel (ICI). Penggunaan Semula Frekuensi Pecahan (FFR) diakui sebagai skim pengurangan ICI yang berkesan tetapi di dalam rangkaian selular berbilang geometri tidak sekata, pengurangan ICI menimbulkan isu yang amat mencabar. Tesis ini membangunkan skim pengurangan ICI tidak berpusat yang boleh meningkatkan kecekapan spektrum dan tenaga dalam rangkaian selular berbilang geometri tidak sekata. Pengurangan ICI direalisasikan melalui Peruntukan Sumber Teragih (DRA) yang ditakrifkan pada peringkat sel dan peringkat kawasan sel geometri tidak sekata. Sel geometri tidak sekata terdiri daripada sekurang-kurangnya empat kawasan, iaitu tiga sektor dan satu kawasan pusat. DRA pada peringkat sel ditakrifkan sebagai DRA Berbilang Sektor (MSDRA) dan DRA di peringkat kawasan ditakrifkan sebagai Pemilihan Saluran dan Peruntukan Kuasa Teragih (DCSPA). MSDRA membahagikan kuasa diskret di setiap kawasan dalam sel berdasarkan Teori Permainan dan Proses Pembelajaran Sesal dengan keseimbangan tersekait sebagai tahap keputusan yang optimum. DCSPA memperuntukkan kuasa bagi setiap saluran dalam suatu kawasan berdasarkan fenomena titisan cecair tidak bertaut dengan memilih saluran optimum di suatu kawasan dan menyimpan kuasa yang sesuai untuk saluran yang terpilih. Prestasinya dinilai melalui simulasi dari segi kadar data, kecekapan spektrum, dan kecekapan tenaga. Dapatan kajian menunjukkan MSDRA telah meningkatkan kadar data sel dengan ketara yang masing-masing sebanyak 58.64% dan 37.92% berbanding skim FFR Teritlak dan Penggunaan Semula Frekuensi Pecahan-3 (FFR-3). Prestasi MSDRA pada tahap sel menunjukkan kecekapan spektrum dan tenaga yang masing-masing meningkat sebanyak 32% dan 22% apabila dibandingkan dengan FFR-3. Dengan peningkatan bilangan sektor daripada tiga kepada empat, kadar data meningkat sebanyak 30.26% manakala bagi tiga kepada enam sektor, meningkat sebanyak 56.32%. DCSPA meningkatkan lagi kadar data masing-masing sebanyak 41.07% apabila dibandingkan dengan Geometri Pengisian Air, dan 86.46% apabila dibandingkan dengan Pengisian Air Lelaran Tak Seragam. DCSPA meningkatkan kadar data yang dicapai dalam MSDRA sebanyak 15.6%. Pada keseluruhannya, DRA menunjukkan peningkatan kadar data yang ketara sebanyak 53.6% dan kecekapan spektrum sebanyak 38.10% berbanding FFR-3. Kesimpulannya, skim DRA berpotensi bagi Penilaian Jangka Panjang-Termaju, rangkaian Generasi Kelima dan boleh digunakan dalam rangkaian selular berbilang heterogen geometri tidak sekata Capaian Berbilang Bahagian Frekuensi Ortogon pada masa hadapan.

TABLE OF CONTENTS

CHAPTER	TITLE	PAGE
	DECLARATION	ii
	DEDICATION	iii
	ACKNOWLEDGEMENT	iv
	ABSTRACT	v
	ABSTRAK	vi
	TABLE OF CONTENTS	vii
	LIST OF TABLES	xi
	LIST OF FIGURES	xii
	LIST OF ABBREVIATIONS	xv
	LIST OF SYMBOLS	xvii
	LIST OF APPENDICES	xx
1	**INTRODUCTION**	1
	1.1 Background	1
	1.2 Problem Statement	3
	1.3 Research Objectives	4
	1.4 Scope of the Research	4
	1.5 Research Contribution	6
	1.6 Significance of the Research	7
	1.7 Thesis Outlines	8
2	**LITERATURE REVIEW**	10
	2.1 Introduction	10
	2.2 Overview of OFDMA in cellular network	10
	2.3 Modeling Cellular Network Topology	14
	2.3.1 Regular Geometry Model	15
	2.3.2 Irregular Geometry Model	16
	2.4 Distributed Resource Allocation	19
	2.4.1 Resource representation	20

		2.4.1.1	Continuous Resources	20
		2.4.1.2	Discrete Resources	21
	2.4.2	Distributed Resource Allocation Schemes.		23
		2.4.2.1	Intelligent Based DRA Schemes	23
		2.4.2.2	Policy Based DRA Schemes	25
2.5	Interference Management Techniques			26
2.6	Frequency Reuse Based Inter Cell Interference Mitigation			29
	2.6.1	Strict Frequency Reuse Scheme		29
	2.6.2	Fractional Frequency Reuse Scheme		31
	2.6.3	Sectored-FFR scheme		31
	2.6.4	Soft Frequency Reuse		32
2.7	Optimization Tools			33
	2.7.1	Game Theory		33
		2.7.1.1	Individual Utility Function	35
		2.7.1.2	Solution Concept and Learning Process	35
	2.7.2	Nature Inspired Optimization		36
		2.7.2.1	Non-coalesce Droplets Concept.	38
2.8	Related Work			41
	2.8.1	FFR Approaches in Cellular Networks		42
	2.8.2	DRA Approaches		44
2.9	Summary			47

3	**RESEARCH METHODOLOGY**			49
	3.1	Introduction		49
	3.2	Framework of Proposed DRA Scheme		50
		3.2.1	MSDRA Scheme	52
		3.2.2	DCSPA Scheme	59
	3.3	System Model		62
		3.3.1	Network Model	62
		3.3.2	Channel Model	64
		3.3.2.1	Pathloss Model	65
		3.3.2.2	Interference Model	66
	3.4	Performance Metrics		67
	3.5	Numerical Simulation Tools		69

	3.6	Chapter Summary		70
4	**MULTI SECTOR DISTRIBUTED RESOURCE ALLOCATION SCHEME**			71
	4.1	Introduction		71
	4.2	Formulation of MSDRA Scheme		71
	4.3	Development of MSDRA Scheme		74
		4.3.1	Cell Regions Formation	75
		4.3.2	Game Theoretical Discrete Dynamic Power Allocation	81
			4.3.2.1 Power Allocation Actions and Regulation	83
			4.3.2.2 Regret Learning Power Allocation Optimization	85
	4.4	Performance Analysis of MSDRA Scheme		93
		4.4.1	Performance of MSDRA-3	95
			4.4.1.1 Data Rate	96
			4.4.1.2 Spectral Efficiency	99
			4.4.1.3 Energy Efficiency	100
		4.4.2	Performance of Different MSDRA Scheme	101
	4.5	Chapter Summary		102
5	**DISTRIBUTED CHANNEL SELECTION AND POWER ALLOCATION SCHEME**			104
	5.1	Introduction		104
	5.2	Formulation of DCSPA Scheme		104
	5.3	Development of DCSPA Scheme		108
		5.3.1	Channel Shaping	110
		5.3.2	Overlapped Channel Removal	113
		5.3.3	Power Weightage	115
		5.3.4	Power Shifting and Channel Selection	116
		5.3.5	Channel Removal and Re-allocation of Power	119
	5.4	Performance Analysis of DCSPA Scheme		122
		5.4.1	Non-Coalesce Behavior	122
		5.4.2	Benchmark Comparison	124
		5.4.3	Cell Data Rate	126

		5.4.4	Effect of DRA Schemes	127
		5.4.5	Spectral Efficiency of DRA Schemes	128
	5.5	Chapter Summary		128
6	**CONCLUSIONS AND FUTURE WORK**			131
	6.1	Conclusion		131
		6.1.1	MSDRA scheme in the irregular geometry multicellular network	131
		6.1.2	DCSPA scheme of irregular geometry multicellular network	133
		6.1.3	DRA Scheme	133
	6.2	Future work		134
REFERENCES				137
Appendices A				151 – 152

LIST OF TABLES

TABLE NO.	TITLE	PAGE
2.1	Related Work for FFR Schemes	45
2.2	Related Work for DRA Schemes	46
3.1	Cell Region Realization	56
3.2	Simulation Parameters	64

LIST OF FIGURES

FIGURE NO.	TITLE	PAGE
2.1	Time-Frequency Representation of OFDM Signal	11
2.2	OFDMA Time-Frequency Grid	12
2.3	Hexagon Grid Model	15
2.4	1-D Wyner Model	16
2.5	PPP Model	17
2.6	PHCP Model	18
2.7	Distributed Interaction of BS	20
2.8	Continuous Resource Representation	21
2.9	Discrete Resource Representation	22
2.10	Single BS Reinforcement Learning	24
2.11	Centralized ICI Mitigation Approach	28
2.12	Decentralized ICI Mitigation Approach	28
2.13	Frequency Reuse-1	30
2.14	Frequency Reuse -3	30
2.15	Fractional Frequency Reuse Scheme	31
2.16	Sectored-FFR Scheme	32
2.17	Soft Frequency Reuse	33
2.18	Nature Inspired Modelling	37
2.19	Nature Inspired Design Process	38
2.20	Non-Coalesce Droplets (Floating)	39
2.21	Non-Coalesce Droplets (Cluster Forming)	39
2.22	Non-Coalesce Droplets (Bouncing and Repel)	40
2.23	Behaviour of Non-coalesce Droplet (a) Initial State (b) Re-location (c) Equilibrium	40
3.1	ICI Mitigation at Cell and Region Level	50
3.2	DRA Framework	51
3.3	Basic Flow Diagram of Proposed DRA	52
3.4	MSDRA Design Framework	53
3.5	Components of MSDRA Scheme	54
3.6	MSDRA Flow Diagram	55

3.7	(a) Cell Regions Formation (b) Discrete Dynamic Power Allocation	58
3.8	DCSPA Framework	59
3.9	DCSPA Flow Diagram	61
3.10	System Model	62
3.11	PHCP Irregular geometry based multicellular network topology	63
3.12	Functional Architecture of Numerical Simulation Evaluation	70
4.1	Overall Flow Diagram of the Proposed MSDRA scheme	75
4.2	Region Formation Flow Chart	77
4.3	Region Formation with Three Edge Area Sectors	78
4.4	Region Formation with Four Edge Area Sectors	78
4.5	Region Formation with Six Edge Area Sectors	79
4.6	Region's Possible Actions	85
4.7	Discrete Dynamic Power Allocation Flow chart	91
4.8	Power Allocation (Initial)	94
4.9	Power Allocation (Convergence)	95
4.10	CDF of the Cell Users Data Rate	97
4.11	CDF of the Center Region Users Data Rate	98
4.12	CDF of the Edge Region Users Data Rate	99
4.13	Mean Spectral Efficieny Vs Data Rate Demand	100
4.14	Energy Efficiency Vs Data Rate Demand	101
4.15	Comparison of Cell Data Rate by Increasing Edge Area Sectoring	102
5.1	Power Allocation during MSDRA Scheme	105
5.2	Basic Flow Diagram of DCSPA	109
5.3	Channels Shaping Flow Chart	111
5.4	Effect of α on Channels	112
5.5	Non-coalesce Channels Selection Flow Chart	113
5.6	Effect of β on Non-Coalesce Channels Selection	115
5.7	Power Weightage Calculation Flow Chart	116
5.8	Power Shift Process	117
5.9	Power Shift Flow Chart	119
5.10	Channel Removal and Re-allocation of Power Process	120
5.11	Channel Removal and Power Re-allocation Flow Chart	121
5.12	Irregular Multicellular Network	122
5.13	Initial Power Allocation	123
5.14	Power Allocation at Convergence.	124
5.15	Benchmark Comparison	125

5.16	CDF Plot of Average Cell Data rate	126
5.17	CDF Plot of MSDRA and DCSPA	127
5.18	CDF Plot of DRA Scheme and FFR-3	128
5.19	Mean Spectral Efficieny Vs Data Rate Demand	129

LIST OF ABBREVIATIONS

3GPP	-	3rd Generation Partnership Project
4G	-	Fourth Generation
5G	-	Fifth Generation
ACO	-	Ant Colony Optimization
AIWF	-	Asynchronous Iterative Water Filling
BS	-	Base Station
CAGR	-	Compound Annual Growth Rate
CCI	-	Co-Channel Interference
CE	-	Correlated Equilbrium
CAPEX	-	Capital Expenditures
CDF	-	Cummulative Distribution Function
DCSPA	-	Distributed Channel Selection and Power Allocation
DRA	-	Distributed Resource Allocation
D2D	-	Device to Device
EB	-	Exabyte
EE	-	Energy Efficiency
FR	-	Frequency Reuse
FFR	-	Fractional Frequency Reuse
FDD	-	Frequency Division Duplex
FBS	-	Femto Base Station
GFFR	-	Generalized Fractional Frequency Reuse
GWF	-	Geometric Water Filling
ITU	-	International Telecommunication Union
IMT-A	-	International Mobile Telecommunication Advanced
ICI	-	Inter Cell Interference
IOT	-	Internet of Things
LTE	-	Long Term Evolution

LTE-A	-	Long Term Evolution Advanced
MBS	-	Macro Base Station
M2M	-	Machine to Machine
MSDRA	-	Multi Sector Distributed Resource Allocation
MIMO	-	Multiple Input Multiple Output
M-QAM	-	Multi-Level Quadrature Amplitude Modulation
NE	-	Nash Equilibrium
OFDMA	-	Orthogonal Frequency Division Multiple Access
OPEX	-	Operational Expenditures
PSO	-	Particle Swarm Optimization
PHCP	-	Poisson Hard Core Process
PPP	-	Poisson Point Process
RB	-	Resource Block
RL	-	Regret Learning
SFR	-	Soft Frequency Reuse
SINR	-	Signal to Interference Noise Ratio
SE	-	Spectral Efficiency
SI	-	Self Interested
SS	-	Self Sacrificed
VNI	-	Visual Networking Index
WIMAX	-	Worldwide Interoperability for Microwave Access

LIST OF SYMBOLS

γ	-	SINR
γ_{TH}	-	SINR Threshold
θ	-	Sectoring Angle
S	-	Number of Sectors
$\mathbb{R}^2$	-	Euclidian Plane
$\mathcal{D}$	-	Distance
y	-	BS
$\mathcal{L}(y)$	-	Voronoi Cell
Y	-	Set of BSs
K	-	Number of Users
N	-	Number of Channels
n	-	One Channel
k	-	One User
$P_{r,k}^{(n)}$	-	Power Received by a user
$P_{t,k}^{(n)}$	-	Power Transmitted to user
$G_{i,k}^{(n)}$	-	Channel Gain
$H_{i,k}^{(n)}$	-	Small Scale Fading Gain
$PL(D_i^{(k)})$	-	Large Scale Path Loss
$D_i^{(k)}$	-	Distance between BS and User
Y_σ	-	Log Normal Shadowing
σ	-	Standard Deviation
$I_k^{(n)}$	-	SINR
$\gamma_k^{(n)}$	-	SINR from user
$\triangle f$	-	Channel Spacing
η	-	Power Spectral Density of the AWGN

R_x	-	Region Data Rate
d_x	-	Region Data Rate Demand
X	-	Total Number of Regions
x	-	Single Region
p_x	-	Power Allocated to Regions
EE_x	-	Region's Energy Efficiency
SE_x	-	Region's Spectral Efficiency
N_x	-	Region's Channel
p_k	-	Power Allocated to User
$R_{k,n}$	-	User Data Rate on a Channel
R_k^i	-	Overall Data Rate
X_C	-	Center Region
X_E	-	Edge Region
$\mathcal{K}_\mathcal{C}$	-	Center Region Users
$\mathcal{K}_E$	-	Edge Region Users
$\mathcal{K}_s$	-	Sector Users
B^T	-	Total Bandwidth
B_C	-	Center Region Sub-band
B_E	-	Edge Region Sub-band
$p_C^{(n_C)}$	-	Power Allocated to Center Region
$p_E^{(n_E)}$	-	Power Allocated to Edge Region
R_C	-	Center Region Data Rate
R_E	-	Edge Region Data Rate
R_s	-	Sector Data Rate
$R_{k_x}^{(n_x)}$	-	Data Rate by a Region
$R_{k_x,min}^{(n_x)}$	-	Minimum Region Data Rate
G	-	Game
U_x	-	Region Utility
$U_x^{(SI)}$	-	Self Interested Utility
$U_x^{(SS)}$	-	Self Sacrificed Utility

ϱ	-	Resource Control Factor
$\vartheta(p_x)$	-	Correlated Equilibrium
μ	-	Factor of Normalization
$Q_x^{[t]}\left(p_x^{'}, p_{-x}^{[t]}\right)$	-	Mean Regret Value at Time t
$A_x^t(p_x^{'}, p_{-x})$	-	Average Utility at Time t
ρ_x	-	Confidence Parameter
$Q_{x,sum}^{[t]}(p_x^{[t]})$	-	Sum Regret
$Q_{x,sum,max}^{[t]}(p_x^{[t]})$	-	Maximum Sum Regret
$z^{[t]}$	-	empirical probability distribution
$\tau_{x,shift}^{(n_x)}$	-	Power Shift Indicator
α	-	Cohesion Parameter
β	-	Non-coalesce Parameter
$m_{coh}(n_x, \alpha)$	-	Channel Shapping Function
$f_{coh}(n_x, \alpha)$	-	Cohesion Function
$W_{x,coh,}^{(n_x)}$	-	Channel Weight during Cohesion
$f_{ncoal}(n_x, \beta)$	-	Non-coalesce Function
$W_{x,ncoal,}^{(n_x)}$	-	Non-coalesce Channel Weightage
$W_{x,}^{(n_x)}(\alpha, \beta)$	-	Channel Power Weightage
SL	-	Interference to Power Ratio

LIST OF APPENDICES

APPENDIX	TITLE	PAGE
A	Derivation of Equation 4.34	151

CHAPTER 1

INTRODUCTION

1.1 Background

The growth in the cellular system is increasing extensively with the passage of time. This extensive increase is due to new smart gadgets such as smart phones, tablets and other data hungry equipment's. There is a huge increase in the demand of broadband application services with the passage of time over the last couple of years [1]. Recently a mobility report is published indicating that the exponential rise in the mobile data will reach to 9 fold escalation by the year 2020 [2]. The Global mobile data traffic increased by 66 percent as predicted during 2013-2014, which was raised from 1.5 Exabyte's (EB) to 2.5 EB per month. The expected increase in future data rate up to 24.3 EB per month by 2019 is reported recently by Cisco [3]. It is reported also that mobile data traffic will increase by 57 percent from 2014 to 2019 at a compound annual growth rate (CAGR).

International Telecommunication Union (ITU) defined a new standard for Next generation wireless communication systems which target the higher data rates, increased network capacity, extended coverage, low complexity and latency. The formulation of the Long Term Evolution (LTE) transformed into LTE-Advanced (LTE-A), making it possible to meet the International Mobile Telecommunication Advanced (IMT-A) criteria (peak downlink data rates of 1Gbit/s and peak uplink data rate of 500Mbit/s) for the Fourth Generation (4G) mobile communication [4]. It is mentioned in Cisco Visual Networking index (VNI) report [5] that 4G has generated 10 fold more data traffic in comparison of non-4G in 2014 and its boost 40 percent of the total mobile data traffic. The statistics show that 4G mobile technology is the most acceptable choice for the mobile traffic in near future.

The increase in the mobile data traffic, encourages the mobile network operators to enhance their system capacity along with coverage. Therefore, efficient radio resource management is gaining more consideration in wireless communication as it could open new opportunities for capacity and coverage enhancements [6]. These trends have prompted the development of new cellular standards, which incorporates the Orthogonal Frequency Division Multiple Access (OFDMA) as a radio access technique because of its capacity gain through frequency domain diversity along with multi-user diversity [7].

Due to the limitation of the spectrum, the Frequency Reuse (FR) scheme is used to enhance network capacity by allowing spectrum reuse in the OFDMA based cellular network. However, the aggressive frequency reuse introduces Inter Cell Interference (ICI) or Co-Channel Interference (CCI), because of same spectrum and power being used by the neighboring cells. There is a tradeoff between frequency reuse and interference. Fractional Frequency Reuse (FFR) scheme is considered as an enhancement of Frequency Reuse for interference mitigation technique in the OFDMA based cellular systems [8]. The basic concept behind the FFR corresponds to the spatial partition of the cell coverage area into regions. In addition to the regions, the spectrum and power are allocated to each region in a way to avoid the ICI.

Wireless cellular networks, signal power and interference received by the Base Station (BS) or users are distance dependent [9]. The use of the same channels with respect to BSs have a high impact on the interference for the receiver. The Signal to Interference plus Noise Ratio (SINR) is dependent on user distance and the location of interference sources as well as the channel gains. Similarly, the network topology has an important effect on the received SINR. Hence, the wireless cellular network performance is dependent on the spatially configuration of BSs and network topology [10].

Finally, to realize the requirement of both cellular operators and users in a cost effective way, recent developments have triggered the induction of distributed decision making (i.e. self-organization) into the future cellular networks. Distributed Resource Allocation (DRA) mechanism is a novel approach to give network components the ability to choose its own resources to improve network performance. DRA helps to offload the burden of signaling and enforce to distributed intelligence among the participating components. DRA helps to remove the effect of centralized network, by giving an opportunity to take decisions independently and therefore, results in reducing operational cost.

1.2 Problem Statement

The frequency reuse concept is being used in order to overcome the problem of frequency spectrum scarcity due to the excessive increase in the demand of capacity for the various mobile broadband services and applications [11]. The most aggressive reuse of the frequency is Frequency Reuse-1 (FR-1), where in, all the available radio resources are allocated at every cell of the network. The frequency reuse can increase the spectrum efficiency on the price of CCI or ICI [8]. Therefore, the challenging issue is to mitigate ICI to achieve a desired data rate and maximize the network performance. Furthermore, the ICI problem is more severe at the cell edges [12].

Due to the above mentioned challenge, interference mitigation is the primary interest of both the academic and industry communities [13]. Review on the present interference management approaches for OFDMA based cellular networks are investigated in Chapter 2. It is found that, to enhance the performance of the cellular network, FFR is a key interference mitigation scheme [4–6]. FFR is attractive due to low complexity and significant coverage improvement for cell edge users [14]. The main purpose of FFR is to improve the SINR and system data rate by avoiding the ICI through orthogonal sub-band allocation at the cell edge region. In FFR, each cell is distributing its resources in a pattern to reduce the overall interference experienced in the network and to maximize the spectrum reuse [15].

In literature, FFR has been used with hexagonal cellular geometry models, where each cell has a symmetrical coverage region [16]. However, in a realistic cellular network, where the cellular layout is irregular, not only propagation conditions vary significantly from cell to cell, but also azimuths are not aligned and hence, cells experience vast difference of ICI [17]. As a consequences, the cell edge region may differ in terms of size and interference levels. It is difficult to give fixed power to cell regions to avoid ICI or replace the whole sub - band of regions of one part of the cell to another part to avoid ICI. Therefore, the performance of basic FFR techniques is poor in the irregular geometry cellular deployment [18]. In an irregular geometric multicellular network, ICI mitigation in the irregular cell shape poses a very challenging issue.

Thus, the network model along with resource allocation considered for any interference mitigation scheme is key to analyze the performance. The network topology along with resource distribution consideration has boomed recent research on FFR with irregular geometry cellular networks [15, 19–21]. However, most of the previous work is on FFR for irregular geometry cellular model, considered a Standard FFR technique with only two cell regions (center region and edge region) and no edge region sectoring is considered [22] along with fixed power for the sub-band of cell center and cell edge region [20]. Moreover, the dynamic power allocation has not been taken in the FFR for irregular geometry multicellular networks in order to control the interference condition and regions data rate demands. Thus, there is a need to develop an ICI mitigation scheme using FFR which considers multiple cell regions and dynamic power allocation for irregular cellular geometry based OFDMA multicellular network while utilizing full frequency.

1.3 Research Objectives

The main purpose of this research is to mitigate ICI in irregular geometry OFDMA multicellular network through dynamic power allocation. The proposed schemes mitigates co-tier interference in multicellular network to improve the spectral efficiency, energy efficiency and enhances the system data rate. Thus, the specific research objectives are;

- To develop DRA scheme at the cell level for ICI mitigation in the irregular geometry multicellular network to allocate discrete dynamic power.
- To develop DRA scheme at region level for ICI mitigation to allocate power and optimal channel selection.

The DRA scheme, Multi Sector DRA (MSDRA) and Distributed Channel Selection and Power Allocation (DCSPA) at the cell level in irregular geometry allocates discrete dynamic power to all regions based on Game Theory and Regret Learning. Secondly, allocates power at region level based on non-coalesce liquid droplet phenomena by selecting optimum channels in the region and reserving appropriate power for the selected channels. The performance is evaluated through data rate maximization.

1.4 Scope of the Research

In the OFDMA multicellular network, improper resource allocation can cause the problem of ICI when overlapping regions are operating with the same frequency band and power. This research focuses mainly on the co-tier interference matter in the OFDMA based multicellular network. The OFDMA is consider as a multiple access technique as it offers the flexibility while allocating the resources based on channel quality. The Frequency Division Duplexing (FDD) [23] access mode of the OFDMA is assumed in this thesis.

This research emphasizes on DRA schemes for efficient resource allocation in irregular geometry based OFDMA multicellular networks to mitigate ICI. The BSs position is abstracted from stochastic geometry, which allows practical interference calculations by considering the randomness among the distances of neighboring cells. Consequently, the coverage region of each cell is considered irregular or follow Voronoi Tessellation, where Voronoi Tessellation is a partitioning of a plane into cells based on distance to BSs in a specific subset of plane. That set of BSs is specified beforehand, and for each BS there is a corresponding cell. These cells are called as Voronoi cells. Each cell is the total coverage area covered by the BS. The cell coverage area is dependent on the transmitting power of the BS and channel condition. The users are considered to be connected to the nearest BSs with higher SINR. Distributed ICI mitigation schemes are developed for the irregular geometry based OFDMA multicellular network. The proposed schemes are intelligent in the scope that each cell of the network autonomously decides its power distribution based on the region data rate demands, power requirements and channel conditions. Therefore, the proposed interference mitigation schemes are aware of the diverse users and regions data rate demand and the channel quality.

First, DRA scheme Multi Sector DRA (MSDRA) is developed to allocate power at the cell level of the irregular geometry based OFDMA multicellular network to mitigate ICI. Initially, the regions are formed by partition irregular cells into two spatial partitioning (center and edge). The partition and division of cell coverage area into multiple portions are called regions. In our configuration minimum of 4 and maximum of 7 regions are considered based on cell spatial partitioning and edge area sectoring. Furthermore, the division of edge area into multiple regions are called sectors. In our configuration minimum of 3 and maximum of 6 sectors are considered. The orthogonal set of channels (sub-band) are allocated to these regions. All these regions are unique in their size, shape and coverage due to the irregularity of the cell. Therefore, region's data rate demand is unique too. Game theory is used to allocate discretized power levels and to analyze competitive interaction among selfish regions. Distributed Regret Learning enforces effective decision making towards optimum decision level to improve network performance.

Secondly, DRA scheme Distributed Channel Selection and Power Allocation (DCSPA) is the enhancement of MSDRA at region level. The scheme is based on non-coalesce liquid droplet considering the selection of optimal channels and allocation continuous power. Each region is allocated with the optimal set of channels and appropriate power and further improvement in the ICI mitigation at region level is achieved.

In this research, users are equipped with Omni-directional antenna configuration while the BSs are equipped with Omni-directional transmission antenna configuration for the center region and directional antenna transmission configuration for the edge region. The pattern of the directional antenna depends on the sectoring pattern of edge region. Moreover, the work is considered as power allocation, the antenna settings are considered with power control ability. The power distribution across the amount of the sub-band is not uniformly considered due to the irregularity of the cells. Furthermore, this research is considered with the regions and their users are with different resource demand. The proposed schemes are evaluated and simulated through MATLAB while considering the 3rd Generation Partnership Project (3GPP) parameter and model settings.

1.5 Research Contribution

The major contributions of the thesis are listed as follows;

- **Regions Formation and Sub-band allocation at Cell Level in the Irregular Geometry Multicellular Network**

  FFR has been considered as an effective scheme to avoid the ICI in OFDMA multicellular systems. The basic mechanism of FFR is to partitioning of the cell coverage area in spatial regions, where each region is assigned with different frequency sub-band along with fixed power level in order to avoid interference. However, in case of irregular geometry cellular network, partitioning of the cell coverage gives regions of varying coverage, number or users and data rate demand conditions. Therefore, each region has a different resource requirement. In literature, almost all of the previous works on FFR with irregular geometry network models account for two regions, cell center and cell edge. In this thesis, FFR with irregular geometry network, where the cell coverage area is spatially partitioned into cell center and cell edge region, the cell edge region is further divided into a number of sectors. The frequency spectrum is accordingly partitioned into a number of fixed sub-bands, for each region of the cell. The sectoring of the edge region makes it possible to fully utilize the frequency spectrum, by orthogonally allocating the fixed spectrum sub-band to each edge region.

- **Discrete Dynamic Power Allocation at Cell Level**

  The proposed MSDRA scheme for cell regions is based on Game theoretic to allocate discrete dynamic power to regions and regulate region's decision making through their utility function as a measure of satisfaction. The Regret learning process provides distributed learning capability that ensures near optimal convergence. Conclusively, ICI mitigation and data rate maximization while fulfilling the data rate demand of the region is achieved.

- **Dynamic Power Allocation at Region Level**

  The enhancement of MSDRA is considered. In this, the pre-allocated resources (power and channels) to regions at cell level is further allocated to users based non-coalesce droplet phenomenon. The DCSPA scheme tackles the resource allocation by selecting the optimum channel and allocates appropriate power for these selected channels. This scheme furthers help to mitigate ICI at region level and maximize the network performance by enhancing overall data rate for users.

1.6 Significance of the Research

The proposed DRA scheme in irregular geometry OFDMA multicellular system can contribute towards the realizing self-organizing network. Due to the proposed MSDRA and DCSPA schemes, which are able to adopt network variations at cell level and region level and automatically implement the proposed power allocation schemes as per the requirement when the fixed power allocation is not valid anymore. Note that the implementation of the proposed distributed power allocation schemes are not limited only to single tier multicellular network. The proposed scheme can be deployed in the case of multi-tier network.

In multi-tier femtocell network, Femto Base Stations (FBSs) are randomly and independently deployed by the user within the coverage area of Macro Base Stations (MBSs). The FBS location and number can vary continuously due to its random deployment. The existing classical network planning tool is not useful to configure the femtocell network. Therefore, FBSs need to be self-configured in order to independently adjust into the radio access network [24]. Moreover, the same radio resources are shared by the femtocell and macrocell to enhance spectrum efficiency. However, this sort of deployment results in cross-tier interference due to co-channel deployment. The proposed DRA scheme can alleviate the problem of cross-tier interference by intelligently allocating power to the orthogonal spectrum band of femtocell and macrocell. Therefore the proposed DRA scheme is feasible in the successful deployment of the multi-tier network.

The next generation mobile networks will be highly dense deployment for the enhancement of the network capacity to 100-1000 times from the current existing networks. This will lead the mobile network to more distributed, personalized and infrastructure less [25]. This is apparent that Device-to-Device (D2D) is infrastructure less co-channel deployment which can cause co-tier interference that would limit the performance of this technology. The proposed DRA scheme can perfectly fit in the D2D to avoid co-channel deployment either in single tier or multi-tier network. Similarly, in the Machine-to-Machine (M2M) communication [26], which has been proved to provide ubiquitous connectivity among the devices in a distributive way, thus enabling in parts the Internet of Things (IoT) [27]. Therefore, the proposed DRA schemes are a benchmark for the distributed network elements become more independent and self-adjustable with lowest minimum or without the need for resource management mechanism. DRA is attractive not only for deployment independently but also to control the operational expenses and reducing capital cost.

1.7 Thesis Outlines

This thesis is structured as follows. Chapter 2 is composed of two main discussions, the literature review along with a theoretical background. The theoretical background elaborates the technical features and fundamental aspects of OFDMA based systems, cellular network modeling, and game theory and Regret Learning method. The literature review part of the Chapter 2 covers the discussions on the existing centralized and decentralized interference management and mitigation approaches available in the literature, both for regular and irregular geometric OFDMA networks. With a focus on decentralized interference management, DRA techniques are covered in the literature review. The prior techniques to mitigate ICI and DRA are investigated based on their potentials and shortcomings which eventually leads towards the research motivations of this thesis.

Chapter 3 presents the framework of the proposed DRA scheme with ICI mitigation in irregular geometry based OFDMA multicellular networks. The basic design concept of MSDRA and DCSPA schemes are presented in detail. The algorithmic flow charts for the proposed schemes are provided and discuss in detail. Moreover, Chapter 3 also provides the specific detail of the system model, network model and channel model. System performance metrics used to evaluate the network performance of the proposed schemes are provided and described. Furthermore, the chapter includes the description of the numerical and simulation tool, whereas its implementation concept is elaborated using a function block diagram.

Chapter 4 gives the formulation of MSDRA to mitigate ICI in the irregular geometry multicellular networks. The formulation is followed by the detail description of the MSDRA scheme. Then the performance analysis of the MSDRA scheme in comparison to the basic FFR-3 and GFFR schemes, when applied to irregular geometry networks, is presented.

The formulation of the DCSPA scheme is presented in Chapter 5. The formulations are followed by the detail description and details of cohesion and non-coalesce based resource allocation. Then the performance analysis of the DCSPA scheme in comparison with Geometric Water Filling (GWF) and Asynchronous iterative water filling (AIWF) schemes is provided.

Finally, Chapter 6 summarizes the significant achievements of MSDRA and DCSPA schemes along with recommendations for the future works.

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