Femtocell and Fractional Frequency Reuse (FFR) for LTE Network Performance Enhancement

by

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TABLE OF CONTENTS

PAGE THESIS DECLARATION	i
ACKNOWLEDGEMENT	ii
TABLE OF CONTENTS	iii
LIST OF FIGURES	ix
LIST OF TABLES	xvi
LIST OF ABBREVIATIONS	xvii
ABSTRAK	xxiii
ABSTRACT	xxiv

CHAPTER 1 INTRODUCTION

1.1	Background	1
1.2	Motivation	4
1.3	Problem Statement	6
1.4	Research Objectives and Scopes	6
1.5	Thesis Outlines	7

CHAPTER 2 LITERATURE REVIEW

2.1	Introduction	9
2.2	LTE-A Cellular E-UTRAN overview	10
2.2.1	Logical Channels, Transport Channels and Physical Channels	14

2.3	LTE Multiple Access Technologies (OFDMA-based)	17
2.3.1	Mobile Cellular Network System	20
2.3.2	Inter-cell Interference (ICI)	22
2.4	Frequency Planning Technique	23
2.4.1	Fractional Frequency Reuse (FFR)	24
2.4.2	FFR Deployment Classification	25
2.4.3	Dynamic FFR and Static FFR	25
2.5	Femtocell	28
2.5.1	Femtocell Concept and Architecture	30
2.5.2	Femtocell Accessing modes	31
2.5.3	Femtocell Interference Scenarios	32
2.6	Femtocell Power Control	35
2.7	Recent work on Inter-cell Interference (ICI) Management	37
2.8	Recent work on Inter-cell Interference Coordination through FFR Resource assignment	39
2.9	Summary	42

CHAPTER 3 RESEARCH METHODOLOGY

3.1	Introduction	44
3.2	Cellular Network Simulation	47
3.2.1	Simulated Macrocellular Network	48
3.2.1.1	Macrocellular Network Design Parameters	50
3.2.1.2	Femtocellular Network Design Parameters	52
3.3	Modeling Performance Metrics	53
3.3.1	Signal to Interference plus Noise Ratio (SINR) Modeling	53
3.3.2	Data Rate Modeling	56
3.3.2.1	PHY Data Rate	57

3.3.2.2 MAC Data Rate 62
3.3.3 Subcarrier Efficiency Modeling 64
3.3.4 Spectral Efficiency Modeling 65
3.3.5 Slot Utilization Modeling 66
3.4 Summary 68

CHAPTER 4 PROPOSED TECHNIQUES AND ALGORITHMS

4.1 Introduction 69
4.2 Inner Region Radius Identification 69
4.2.1 Angle-oriented Inner Radius Scheme 71
4.3 Orthogonal Resource Allocation (ORA) 75
4.3.1 ORA for Macrocell 75
4.3.2 ORA for Femtocell 78
4.3.3 Modulation Coding Scheme (MCS) for Hybrid Network 81
4.3.4 ORA Algorithm 82
4.4 Dynamic Femtocell Resource Allocation (DFRA) 85
4.4.1 Calibration 86
4.4.2 Implementation of DFRA Scheme 90
4.5 SINR Based Neighboring Femtocell Base Station Power Control (SNPC) 93
4.5.1 Minimum Distance Between Femtocells 93
4.5.2 Implementation of SNPC 100
4.6 Overall Algorithm 101
4.7 Summary 111

CHAPTER 5 RESULT ANALYSIS

5.1	Introduction	112
5.2	Performance Analysis and Evaluation of Orthogonal Resource Assignment (ORA)	112
5.3	Performance Analysis and Evaluation of Dynamic Femtocell Resource Assignment (DFRA)	116
5.3.1	Number of Discarded User for DFRA scheme	118
5.3.2	Number of Active User for DFRA scheme	120
5.3.3	Slot Utilization for DFRA scheme	122
5.3.4	Subcarrier Efficiency for DFRA scheme	124
5.3.5	Data Rate for DFRA scheme	128
5.3.6	Spectral Efficiency for DFRA scheme	129
5.4	Performance Analysis and Evaluation of Power based Femtocell Base Station Power Control (PPC)	131
5.4.1	Number of Discarded User for PPC and DFRA-PPC scheme	132
5.4.2	Number of Active User for PPC and DFRA-PPC scheme	136
5.4.3	Slot Utilization for PPC and DFRA-PPC scheme	137
5.4.4	Subcarrier Efficiency for PPC and DFRA-PPC scheme	138
5.4.5	Data Rate for PPC and DFRA-PPC scheme	139
5.4.6	Spectral Efficiency for PPC and DFRA-PPC scheme	141
5.5	Performance Analysis and Evaluation of SINR based Femtocell Base Station Power Control (SPC)	142
5.5.1	Number of Discarded User for SPC and DFRA-SPC scheme	142
5.5.2	Number of Active User for SPC and DFRA-SPC scheme	144
5.5.3	Slot Utilization for SPC and DFRA-SPC scheme	146
5.5.4	Subcarrier Efficiency for SPC and DFRA-SPC scheme	147
5.5.5	Data Rate for SPC and DFRA-SPC scheme	148
5.5.6	Spectral Efficiency for SPC and DFRA-SPC scheme	149

5.6 Performance Analysis and Evaluation of SINR based Neighboring Power Control (SNPC) 151

5.6.1 Number of Discarded User for DFRA-SPC and DFRA-SPC-SNPC scheme 151

5.6.2 Number of Active User for DFRA-SPC and DFRA-SPC-SNPC scheme 154

5.6.3 Slot Utilization for DFRA-SPC and DFRA-SPC-SNPC scheme 155

5.6.4 Subcarrier Efficiency for DFRA-SPC and DFRA-SPC-SNPC scheme 156

5.6.5 Data Rate for DFRA-SPC and DFRA-SPC-SNPC scheme 156

5.6.6 Spectral Efficiency for DFRA-SPC and DFRA-SPC-SNPC scheme 157

5.7 Overall Performance 158

5.7.1 Number of Discarded User for overall performance 158

5.7.2 Number of Active User for overall performance 159

5.7.3 Slot Utilization for overall performance 160

5.7.4 Subcarrier Efficiency for overall performance 161

5.7.5 Data Rate for overall performance 162

5.7.6 Spectral Efficiency for overall performance 163

5.7.7 DFRA-SPC-SNPC Performance for 7-adjacent-Femtocell Network 164

5.8 Summary 165

CHAPTER 6 CONCLUSIONS AND FUTURE WORK

6.1 Conclusion 167

6.2 Contribution of This Research 168

6.3 Recommendations for Future Work 171

REFERENCES 173

LIST OF PUBLICATIONS 181

LIST OF FIGURES

NO.		PAGE
1.1	Interference in HetNet using universal frequency	2
1.2	Fractional Frequency Reuse (FFR)	3
2.1	Logical high level architecture for the evolved system	12
2.2	Overall E-UTRAN Architecture with deployed HeNB GW	13
2.3	Transport protocols used on air interface	14
2.4	Downlink Channel Mapping	17
2.5	Uplink Channel Mapping	17
2.6	Cluster size N = 7 and frequency reuse factor = 1/7	21
2.7	Classical Frequency Planning Schemes, (a) FRF of 1 (b) FRF of 3	23
2.8	Deployment of FFR scheme (a) DL frequency distribution in cells (b) Frequency distribution in subcarrier vs. time table	24
2.9	HNB access network reference model	30
2.10a	Interference scenarios for downlink	34
2.10b	Interference scenarios for uplink	34
2.11	Power based Femtocell Base Station Power Control (PPC)	35
2.12	SINR based Femtocell Base Station Power Control (SPC)	37
3.1	Methodology flow	46

3.2 Macrocellular network layout, (a) Cell layout with static frequency allocation (b) DL Subframe Structure 48

3.3 Constellation diagrams for QPSK, 16QAM and 64QAM 58

3.4 Resource block in time and frequency domain 60

3.5 TDD frame structure 61

3.6 TDD special subframe 62

3.7 LTE DL Resource Grid for TDD: 10MHz, 1 Antenna, Normal cyclic Prefix 63

4.1 SINR versus Distance of Macrouser from Macrocell center 70

4.2 Enlarged view of SINR plot while moving the user in Y-axis 72

4.3a Interference experienced by a user at 0 degree 72

4.3b Interference experienced by a user at 90 degree 73

4.4 Inner region radius versus different user location angles at constant SINR (5dB) 73

4.5 Flowchart of Angle oriented inner region radius approach 74

4.6 Step by step implementation of Angle Oriented Inner Region Radius approach 75

4.7 Proposed PDSCH DL subframe resource allocation without overhead for Macrocell 77

4.8a Resource allocation for Macrocellular network 79

4.8b Resource allocation for Femtocellular network 79

4.9 Proposed PDSCH DL subframe resource allocation without Overhead for Femtocell 80

4.10 Flowchart of Revisited FFR scheme 83

4.11a Step by step Implementation for Revisited FFR Scheme (Part 1) 84

4.11b Step by step Implementation for Revisited FFR Scheme (Part 2) 85

4.12 Calibration for DFRA scheme 87

4.13 SINR plot of Macrouser when Femtocell is moving close to and away from Macrouser 88

4.14 Flowchart of DFRA scheme 91

4.15 Step by step implementation of DFRA scheme 92

4.16 Setup to analyze Femtocell interference towards adjacent Femtocell 94

4.17 Flowchart of Femtocell's minimum distance Identification 95

4.18 Step by step implementation for Femtocell's minimum distance identification 96

4.19a SINR plot for Femtouser U1 when Femtocell F1 at [26,0], Femtouser U1 at [36,0], Femtocell F2 at [39,0], Femtouser U2 at [37,0] 98

4.19b SINR plot for Femtouser U2 when Femtocell F1 at [26,0], Femtouser U1 at [36,0], Femtocell F2 at [39,0], Femtouser U2 at [37,0] 98

4.20a SINR plot for Femtouser U1 when Femtocell F1 at [26,0], Femtouser U1 at [36,0], Femtocell F2 at [40,0], Femtouser U2 at [38,0] 99

4.20b SINR plot for Femtouser U2 when Femtocell F1 at [26,0], Femtouser U1 at [36,0], Femtocell F2 at [40,0], Femtouser U2 at [38,0] 99

4.21 Up to seven Femtocells next to each others 100

4.22a Flowchart of overall algorithm (Part 1) 102

4.22b Flowchart of overall algorithm (Part 2) 103

4.22c Flowchart of overall algorithm (Part 3) 104

4.22d Flowchart of overall algorithm (Part 4) 105

4.22e Flowchart of overall algorithm (Part 5) 106

4.22f Flowchart of overall algorithm (Part 6) 107

4.23a Step by step implementation for overall algorithm (Part 1) 107

4.23b Step by step implementation for overall algorithm (Part 2) 108

4.23c Step by step implementation for overall algorithm (Part 3) 109

4.23d Step by step implementation for overall algorithm (Part 4) 110

5.1a Spectrum allocation for Macrocell network 114

5.1b Macrocellular network SINR distribution 114

5.2a Spectrum allocation for hybrid network 115

5.2b Hybrid cellular network SINR distribution(non orthogonal Femtocell resource allocation) 115

5.3 Hybrid cellular network SINR distribution (orthogonal Femtocell resource allocation) 116

5.4 Number of Femtocell relocation (out of 100 trials) 118

5.5a Number of discarded user with reference configuration (without DFRA scheme) 118

5.5b Number of discarded user for DFRA scheme 119

5.6 Average number of active user for reference and DFRA scheme configuration 121

5.7 Average number of slot utilization for reference and DFRA scheme configuration 123

5.8a Subcarrier efficiency with reference configuration (without DFRA scheme) 125

5.8b Subcarrier efficiency for DFRA scheme 125

5.9 Average subcarrier efficiency for reference and DFRA scheme configuration 126

5.10 Average data rate for reference and DFRA scheme configuration 128

5.11a Spectral efficiency with reference configuration (without DFRA scheme) 129

5.11b Spectral efficiency for DFRA scheme 130

5.12 Average subcarrier efficiency for reference and DFRA scheme configuration 131

5.13 Average number of user being discarded for various Femtocell radius, *fr* 133

5.14a Number of discarded user for PPC scheme 133

5.14b Number of discarded user for DFRA-PPC scheme 134

5.15 Average number of discarded user for PPC and DFRA-PPC scheme 135

5.16 Average number of active user for PPC and DFRA-PPC scheme 136

5.17 Average number of slot utilization for PPC and DFRA-PPC scheme 137

5.18 Subcarrier efficiency for PPC and DFRA-PPC scheme 138

5.19 Average data rate for PPC and DFRA-PPC scheme 140

5.20 Average spectral efficiency for PPC and DFRA-PPC scheme 141

5.21a Number of discarded user for SPC scheme 143

5.21b Number of discarded user for DFRA-SPC scheme 143

5.22 Average number of discarded user for SPC and DFRA-SPC scheme 144

5.23 Average number of active user for SPC and DFRA-SPC scheme 145

5.24 Average number of slot utilization for SPC and DFRA-SPC scheme 146

5.25 Average subcarrier efficiency for SPC and DFRA-SPC scheme 148

5.26 Average data rate for SPC and DFRA-SPC scheme 149

5.27 Average spectral efficiency for SPC and DFRA-SPC scheme 150

5.28a Number of discarded user for SNPC scheme 152

5.28b Number of discarded user for DFRA-SPC-SNPC scheme 152

5.29 Average number of discarded user for SNPC and DFRA-SPC-SNPC scheme 153

5.30 Number of discarded user for case reference, DFRA-SPC and DFRA-SPC-SNPC with number of Femtocell = 150 153

5.31 Average number of active user for case reference, DFRA-SPC and DFRA-SPC-SNPC with number of Femtocell = 150 154

5.32 Average number of slot utilization for case reference, DFRA-SPC and DFRA-SPC-SNPC with number of Femtocell = 150 155

5.33 Average subcarrier efficiency for case reference, DFRA-SPC and DFRA-SPC-SNPC with number of Femtocell = 150 156

5.34 Average data rate for case reference, DFRA-SPC and DFRA-SPC-SNPC with number of Femtocell = 150 157

5.35 Average spectral efficiency for case reference, DFRA-SPC and DFRA-SPC-SNPC with number of Femtocell = 150 158

LIST OF TABLES

NO.		PAGE
2.1	Interference scenarios (summary)	34
2.2	Compare of ICI mitigation techniques	38
2.3	Compare of FFR resource allocation techniques	40
3.1	Proposed schemes	45
3.2	Macrocellular network design parameters	50
3.3	Femtocellular network design parameters	52
3.4	Resource block for LTE channel bandwidth	58
4.1	Angle of Macrouser's location to the inner region radius	74
4.2	PDSCH resource planning	76
4.3	CQI index versus reference SINR table	82
4.4	Distance of Macrouser from Macrocell vs. minimum distance of neighboring Femtocell from Macrouser	89
4.5	Summary of variables for Figure 4.16	97
5.1	Average number of discarded user	159
5.2	Average number of active user	160
5.3	Average number of slot utilization	160
5.4	Average subcarrier efficiency	162
5.5	Average data rate	163
5.6	Average spectral efficiency	163
5.7	Performance of 150 Femtocells with 7 Femtocells adjacent to each other	164
5.8	Summary of outstanding scheme	166

LIST OF ABBREVIATIONS

1G	First Generation System
2G	Second Generation System
3.9G	3.9 Generation System, beyond 3G but pre4G
3G	Third Generation System
3GPP	Third Generation Partnership Project
4G	Fourth Generation System
ADSL	Asynchronous Digital Subscriber Line
AFRF	Average Frequency Reuse Factor
ARQ	Automatic Repeat Request
AWGN	Additive White Gaussian Noise
BCCH	Broadcast Control Channel
BCH	Broadcast Channel
BP	Belief Propagation
BS	Base station
BW	Bandwidth
CCCH	Common Control Channel
CP	cyclic prefix
CQI	Channel quality indicator
CRC	Cyclic Redundancy Check
CRS	Collision of Reference Signal
CSG	Closed Subscription Group
DAS	Distributed Antenna System
DCCH	Dedicated Control Channel
DCI	Downlink control information

DCT	Dynamic Coordinated Transmission
DFP	Dynamic Frequency Planning
DFRA	Dynamic Femtocell Resource Allocation
DL	Downlink
DL-SCH	Downlink Shared Channel
DSL	Digital Subscriber Line
DTCH	Dedicated Traffic Channel
EBW	Effective bandwidth
EFRS	Enhanced frequency reuse scheme
eNB	Evolved Node B
EPC	Evolved Packet Core
EPS	Evolved Packet System
E-UTRA	Evolved UTRA
E-UTRAN	Evolved UMTS Terrestrial Radio Access Network
f	Frequency
FDD	Frequency Division Duplexing
FFR	Fractional Frequency Reuse
FFT	Fast Fourier Transform
FRF	Frequency Reuse Factor
GSM	Global System for Mobile
HARQ	Hybrid-Automatic Repeat Request
HeNB	Home eNB
HeNB GW	Home eNB Gateway
HetNet	Heterogeneous Network
IC	Inter-cell Interference Cancelation
ICI	Inter-cell Interference
ICIC	Inter-cell Interference Coordination

IDMA	Interleave Division Multiple Access
IIM	Inter-cell Interference Management
IIWF	Improved Interactive Water-filling algorithm
IMT	International Mobile Telecommunications
IMT-A	International Mobile Telecommunications-Advanced
IP	Internet Protocol
ISI	Inter-symbol interference
ITU	International Telecommunications Union
Liw	Indoor Walls Loss
Low	Outdoor Walls Loss
LTE	Long Term Evolution
LTE-A	Long Term Evolution-Advanced
MAC	Medium Access Control
MBMS	Multimedia Broadcast/Multicast Service
MBSFN	Multicast Broadcast Single Frequency Network
MCCH	Multicast Control Channel
MCH	Multicast Channel
MCS	Modulation and coding rate
MIMO	Multiple Input Multiple Output
MME	Mobility Management Entity
MSINR	maximum SINR
MTCH	Multicast Traffic Channel
NB	Node B, Base station
NFFT	Fast Fourier Transform Size
OFDMA	Orthogonal Frequency-division Multiple Access
ORA	Orthogonal Resource Allocation
PAPR	Peak-to-average-power ratio

PBCH	Physical Broadcast Channel
PCCH	Paging Control Channel
PCFICH	Physical Control Format Indicator Channel
PCH	Paging Channel
PDCCH	Physical Downlink Control Channel
PDCP	Packet Data Convergence Protocol
PDSCH	Physical Downlink Shared Channel
PHICH	Physical Hybrid-ARQ indicator Channel
PHY	Physical layer
PLMN	Public Land Mobile Network
PMCH	Physical Multicast Channel
PMI	Pre-coding Matrix Indicator
PPC	Power based Femtocell Base Station Power Control
PRACH	Physical Random-Access Channel
PSTN	Public Switched Telephone Network
PUCCH	Physical Uplink Control Channel
PUSCH	Physical Uplink Shared Channel
QoS	Quality of Service
R	Macrocell radius
r	Macrocell inner radius
RACH	Random-Access Channel
RB	Resource block
RE	Resource Element
RI	Rank indicator
RLC	Radio Link Control
RNC	Radio Network Controller
RR	Round Robin

RRC	Radio Resource Control
RSRP	Reference signal received power
SAE	System Architecture Evolution
Sb	Subband
S-BS	Strong BS
SC-FDMA	Single-Carrier Frequency Division Multiple Access
SFR	Soft Frequency Reuse
SG1	Subframe Group 1
SG2	Subframe Group 2
S-GW	Serving Gateway
SINR	Signal to Interference Noise Ratio
SISO	Single Input Single Output
SMS	Short Message Service
SNPC	SINR based Femtocell Base Station Power Control-SINR based Neighbouring Femtocell Power Control
SNR	Signal to Noise Ratio
SPC	SINR based Femtocell Base Station Power Control
TDD	Time Division Multiplexing
UCI	Uplink control information
UE	User Equipment
UL	Uplink
UL-SCH	Uplink Shared Channel
UMTS	Universal Mobile Telephone System
UTRA	UMTS Terrestrial Radio Access
W-BS	Weak BS
WCDMA	Wideband Code Division Multiple Access
WF	Water-filling

WiMAX	Worldwide Interoperability for Microwave Access
WLAN	Wireless Local Area Network

Peningkatan Prestasi Sel Femto Dan Kaedah Penggunaan Semula Sebahagian Frekuensi (FFR) untuk Rangkaian Selular LTE

ABSTRAK

Dengan memperkenalkan Sel Femto yang berkuasa rendah dan kawasan rangkuman kecil di dalam rangkaian Sel Makro, liputan perkhidmatan dilanjutkan. Akan tetapi, ini telah menyebabkan gangguan Inter-sel (ICI) berlaku. ICI berlaku disebabkan perkongsian sumber antara sel-sel bersebelahan. Di antara kaedah yang boleh mengurangkan gangguan, kuasa manipulasi dan peruntukan frekuensi adalah fokus tesis ini. Kaedah Penggunaan Semula Sebahagian Frekuensi (FFR) adalah salah satu teknik penyelarasan antara sel untuk meningkatkan kualiti isyarat. Cabaran yang dihadapi apabila menggunakan FFR adalah rekacipta dengan peruntukan sumber dengan cekap. Dengan FFR, perkongsian spektrum antara Sel Makro dan Sel Femto ranakaian menyebabkan ketiadaan sumber berdedikasi dan dengan itu lebih teruk ICI berlaku. Tambahan pula, apabila semata-mata skim kawalan kuasa digunakan, kekerapan universal guna semula (FRF=1) menyebabkan masalah ICI lebih teruk dalam rangkaian sesak. Pemodelan pautan turun LTE-A rangkaian heterogen (HetNet) dilakukan dengan menggunakan MATLAB dalam kajian ini. Kajian semula Kaedah FFR dibuat dan menggunakan kaedah Peruntukan Ortogon Sumber (ORA) untuk memperolehi sumber mengikut wilayah dalam rangkaian heterogen. Selain itu, skim Peruntukan Dynamic Sel Femto Sumber (DFRA) dicadangkan untuk memastikan sumber-sumber yang diberikan kepada Sel Femto saling eksklusif dengan Macrousers atau sel Femto bersebelahan. Semasa menghadapi isu kepadatan Sel Femto dan penghabisan sumber ortogon, skim kawalan kuasa seperti skim Kawalan Kuasa berdasarkan Kuasa Sel Femto Stesen Pangkalan (PPC), skim Kawalan Kuasa berdasarkan isyarat nisbah gangguan dan hingar (SINR) (SPC) dan Kawalan Kuasa berdasarkan Jiran Sel Femto SINR (SNPC) telah disepadukan ke dalam sistem. Berbanding dengan penggunaan FFR klasik, penggunaan Skim Kajian Semula FFR dan rangkaian Hybrid (dengan Sel Femto yang kurang sesak) meningkatkan penggunaan sumber dan bilangan pengguna aktif dengan 8.7% dan 8.72% untuk skim kombinasi DFRA-PPC dan skim kombinasi DFRA-SPC masing-masing. Selain ini, kadar data ditingkatkan kepada 15.73% dan 15.51% dengan penggunaan skim DFRA-PPC dan DFRA-SPC. Dari perspektif kecekapan spektrum, dua teknik ini telah meningkatkan prestasi kepada 15.68% dan 15.48% masing-masing. Sebaliknya, dalam rangkaian sesak (150 sel Femto), penggunaan sumber dan bilangan pengguna aktif ditingkatkan kepada 11.43% untuk kombinasi skim Peruntukan Dynamic Sel Femto Sumber bersama Kawalan Kuasa berdasarkan Jiran Sel Femto SINR (DFRA-SNPC). Selain itu, dengan melaksanakan skim DFRA-SNPC ini, kadar data dan kecekapan spektrum dalam rangkaian sesak ini meningkat sebanyak 13.52% dan 13.53% masing-masing. Mekanisme yang dicadangkan, ORA, DFRA, SPC, PPC dan SNPC telah meningkatkan prestasi sistem dari segi penggunaan sumber, kadar data dan kecekapan spektrum.

Femtocell And Fractional Frequency Reuse (FFR) for LTE Network Performance Enhancement

ABSTRACT

The introduction of low-power and small-service-area Femtocell into Long Term Evolution-Advance (LTE-A) Macrocell network, the service coverage is extended but causes more severe inter-cell interference (ICI). ICI occurs due to sharing of resource between adjacent cells. Among the methods to mitigate interference, power and frequency allocation schemes are deployed in this thesis. Fractional Frequency Reuse (FFR) is one of the ICI technique for signal quality enhancement. The challenges of FFR is to design an efficient resource allocation scheme. With FFR, spectrum sharing between Macrocell and Femtocell network causes unavailability of dedicated resource and thus more severe ICI occurs. Furthermore, when solely power control scheme is used, universal frequency reuse (FRF=1) causes more severe ICI problem in crowded network. The modeling of downlink LTE-A Heterogeneous network (HetNet) is done using MATLAB in this research. The FFR method is revisited and Orthogonal Resource Allocation (ORA) scheme is proposed to allocate resource by region. Besides, the suggested Dynamic Femtocell Resource Allocation (DFRA) scheme is deployed to ensure the resources assigned to Femtocells are mutually exclusive with adjacent Macrousers or Femtocells. In the scenario of high density Femtocells (orthogonal resource exhausted), the power control schemes such as Power based Femtocell Base Station Power Control (PPC) and SINR based Femtocell Base Station Power Control (SPC) are combined into the system. The power of Femtocell Base station is further optimized with the proposed SINR based Neighbouring Femtocell Power Control (SNPC) scheme to take care of interference between Femtocells. In comparison with the deployment of contemporary FFR approach in HetNet, the deployment of Dynamic Frequency Allocation-Power based Femtocell Base Station Power Control (DFRA-PPC) and Dynamic Frequency Allocation-Signal to Interference & Noise Ratio (SINR) based Femtocell Base Station Power Control (DFRA-SPC) approach increases the resource utilization and number of active user by 8.7% and 8.72% respectively in sparsely populated Femtocells. Apart from this, data rate is augmented by 15.73% and 15.51% with the improvement done in DFRA-PPC and DFRA-SPC mechanisms. From the perspective of spectral efficiency, these two techniques enhanced the performance by 15.68% and 15.48% correspondingly. On the other hand, in congested network (with 150 randomly located Femtocells), the resource utilization and number of active user grows by 11.43% for Dynamic Frequency Allocation-SINR based Femtocell Base Station Power Control-SINR based Neighbouring Femtocell Power Control (DFRA-SPC-SNPC) scheme. Besides, by deploying this scheme, the data rate and spectral efficiency in this congested network are improved by 13.52% and 13.53% respectively. The proposed mechanisms ORA, DFRA, SPC, PPC and SNPC improved the system performance in terms of resource utilization, subcarrier efficiency, data rate and spectral efficiency.