

Contents

Abstract	3
Kurzfassung.....	5
Contents	7
1 Introduction	13
1.1 Motivation	13
1.2 Objectives	14
1.3 Contributions of This Thesis.....	14
1.4 Outline	15
2 LTE / LTE-Advanced Radio Access.....	17
2.1 Introduction	17
2.1.1 Previous Generation of Mobile Communication.....	17
2.1.2 The Mobile Radio Landscape	18
2.1.3 3GPP Standardisation.....	19
2.1.4 IMT-Advanced	20
2.2 Architecture Overview	21
2.2.1 The Core Network (CN) - EPC.....	22
2.2.2 The Access Network (E-UTRAN)	24
2.3 Radio Access Protocol Architecture.....	24
2.3.1 Radio Resource Control (RRC).....	26
2.3.2 The Packet Data Convergence Protocol (PDCP).....	27
2.3.3 Radio Link Control (RLC).....	27

- 2.3.4 Logical Channels 28
- 2.3.5 Medium Access Control (MAC) 29
- 2.3.6 Transport Channels..... 32
- 2.3.7 Physical Layer (PHY) 33
- 2.3.8 Physical Channels..... 38
- 2.4 Quality of Service and EPS Bearers 40
- 2.5 Components introduced by LTE-Advanced 40
- 2.6 Load and Interference Management Over X2 E-UTRAN
Network Interface 41
 - 2.6.1 Inter-Cell Interference Coordination Signalling in Downlink
..... 42
 - 2.6.2 Inter-Cell Interference Coordination Signalling in Uplink 43
 - 2.6.3 Enhanced Inter-Cell Interference Coordination in LTE-
Advanced..... 43
- 2.7 Coordinated Multipoint (CoMP) Transmission in LTE-
Advanced 44
- 3 MIMO Techniques.....47
 - 3.1 Introduction..... 47
 - 3.2 Comments and Technique Choice..... 48
 - 3.3 Model of Beamformer According to Godara 1997 50
 - 3.3.1 Conventional Beamformer 53
 - 3.3.2 Zero Forcing Beamformer 53
 - 3.3.3 Optimal Beamformer 54
 - 3.3.4 Optimal Beamformer with Reference Signal 56
 - 3.3.5 Spatial Filtering for Interference Reduction..... 57
 - 3.3.6 Spatial Division Multiple Access (SDMA) 58

3.4	Fixed Beamforming.....	59
3.5	Open- versus Closed-Loop MIMO.....	60
4	The Model of the Analytical Evaluation and the IMT-Advanced Channel	61
4.1	Introduction	61
4.2	ITU-R Evaluation Guidelines.....	62
4.2.1	Deployment Scenarios.....	63
4.2.2	Antenna Model.....	65
4.2.3	Antenna Model with Beamforming.....	67
4.3	Radio Channel Model.....	68
4.3.1	Pathloss Model	68
4.3.2	Line-of-sight Propagation Probability.....	69
4.3.3	Overview of the System Level Evaluation Model	70
4.3.4	Receive Power and Signal to Interference Plus Noise Ratio	72
4.3.5	Link Permutation Probability.....	73
4.3.6	Beam Permutation Probability	74
4.3.7	Mean SINR and Probability of SINR.....	76
4.4	Channel Model Validation	78
4.5	Link-to-System Model	80
4.5.1	Link-to-System-Level Mapping	80
4.5.2	Mean Data Rate and Probability of Data Rate	83
4.5.3	Distribution of Number of MSs per Cell.....	84
4.5.4	Scheduling Strategies and Probability of MS Throughput.....	85
4.5.5	Cell Spectral Efficiency (CSE).....	86
4.5.6	Cell Edge - User Spectral Efficiency (CE-USE)	87

- 4.6 LTE-Advanced System-Level Validation 87
- 5 Inter-cell Interference Coordination..... 89
 - 5.1 Frequency Reuse Schemes 90
 - 5.2 Coordinated Beamforming Schemes..... 92
 - 5.3 Coordination for Adaptive Beamforming with SDMA 95
 - 5.3.1 Coordination for Adaptive Beamforming with SDMA - Scheme I 96
 - 5.3.2 Region Coordination for Adaptive Beamforming with SDMA - Schemes II and III 101
 - 5.4 Synchronised Cycles of Coordinated Beams (CyBeamCo) .. 106
 - 5.4.1 Cell Type Specific Beam Coordination 107
 - 5.4.2 Algorithm for Seeking Beneficial Fixed Beam Combinations 109
 - 5.4.3 Beam Coordination under SFR..... 112
 - 5.4.4 Beam Coordination of Cells of the Same Site 112
 - 5.4.5 Fair Evaluation of the Coordination Algorithm..... 113
 - 5.4.6 Creation of a Coordination Matrix in a Real System 114
 - 5.4.7 Dynamic Beam Coordination – An Outlook..... 115
- 6 Analytical Performance Evaluation 117
 - 6.1 Beam Coordination Performance versus other System Types 118
 - 6.2 Impact of Scheduling Strategies on Beam Coordination Performance..... 123
 - 6.3 SFR - Derivation of an Operating Point 126
 - 6.3.1 Different Scheduling Strategies Operated under SFR 126
 - 6.3.2 Different System Types Operated under SFR..... 128
 - 6.4 Impact of Frequency Reuse Schemes on Beam Coordination Performance..... 130

6.5	Impact of the Codebook Size on Beam Coordination Performance	134
7	Conclusion and Outlook	139
A	Additional Results	141
A.1	Example Coordination Matrices	144
B	Performance Evaluation of CB for adaptive BF with SDMA (Scheme I) - Assumptions and Results.....	147
B.1	Simulation Scenario	147
B.1.1	Simulator and Traffic Model	148
B.1.2	Link Adaptation and Error Modelling.....	149
B.1.3	WiMAX Frame Structure and Overhead	149
B.1.4	Other Simulation Parameters	150
B.2	Simulation Results.....	151
B.3	Conclusion.....	154
C	Performance Evaluation of Region Coordination for Adaptive BF with SDMA (Scheme II and III) - Assumptions and Results	157
C.1	Simulation Results.....	157
C.1.1	Constant Bit Rate Downlink Traffic with 30 MSs.....	157
C.1.2	Variable Bit Rate Uplink Traffic	160
C.2	Conclusion.....	162
	List of Figures	165
	List of Tables.....	171
	List of Abbreviations	173
	Bibliography	177
	Acknowledgement.....	185