

Contents

List of acronyms	xi
1 Introduction	1
1.1 Background	1
1.1.1 Next generation wireless systems	1
1.1.2 Ultra Dense Networks deployment	4
1.2 State of the art analysis	5
1.2.1 Limits of densification	5
1.2.2 Distributed Antenna Systems	7
1.2.3 Massive MIMO in millimeter waves	9
1.2.4 ICIC in cellular networks	12
1.3 Open problems identified from the literature review	16
1.4 Objectives and Thesis scope	18
1.5 Thesis outline and main contributions	19
1.6 List of publications	21
2 Asymptotic analysis of Ultra Dense Networks	23
2.1 Introduction	23
2.2 System model	24
2.2.1 Deployment description	25
2.2.2 Resource and power allocation models	26
2.2.3 Achievable rates	27
2.2.4 Summary of the system model strengths	28
2.3 Achievable rates with $d_B > 0$	29
2.3.1 Rates versus UE position	30
2.3.2 Rates versus inter-BS distance	33
2.4 Achievable rates in the limits of densification	35
2.5 Conclusion	37

CONTENTS

3	Hybrid precoding for urban-micro deployments using millimeter wave band	39
3.1	Introduction	39
3.2	Hybrid Architecture for millimeter waves	40
3.3	MIMO Precoding Techniques	43
3.3.1	Fully digital precoding	43
3.3.2	RF beamforming	44
3.3.3	Hybrid beamforming/precoding	45
3.4	System model and evaluated schemes	46
3.4.1	System model description	46
3.4.2	Evaluated precoding schemes	46
3.4.3	Simulation setup	49
3.5	Performance with ideal assumptions	52
3.5.1	Single-user case	52
3.5.2	Multi-user case	55
3.6	Performance with non-ideal assumptions	58
3.6.1	Effect of outdated Channel State Information	58
3.6.2	Effect of per antenna power constraints	61
3.6.3	Effect of phase-shifter errors	63
3.6.4	Effect of combiner losses	64
3.7	Conclusions	68
4	Distributed hybrid precoding for indoor deployments using millimeter wave band	71
4.1	Introduction	71
4.2	System model	73
4.3	Distributed Hybrid Precoding for DAS	73
4.4	Simulation setup and evaluated precoding schemes	76
4.4.1	Deployment strategies	76
4.4.2	Evaluated precoding schemes	77
4.4.3	Setup configuration	80
4.5	Performance comparison of ideal indoor deployment strategies	80
4.5.1	Results using fully digital precoding	81
4.5.2	Results using hybrid precoding	84
4.6	Performance comparison of non-ideal indoor deployment strategies	88
4.6.1	Outdated Channel State Information	88
4.6.2	Combiner losses	90
4.7	Conclusion	93

5	eICIC technique for ultra dense small cell indoor deployments	95
5.1	Introduction	95
5.2	System model	97
5.3	Dynamic Time and Frequency Reuse (DTFR) coordinated scheduling for UDNs	98
5.3.1	DTFR pattern configuration phase	98
5.3.2	User scheduling optimization phase	99
5.4	Results and discussion	102
5.4.1	Simulation setup and algorithms configuration	102
5.4.2	Performance with increasing number of users	105
5.4.3	Performance with increasing number of cells	111
5.5	Conclusions	117
6	Conclusions and future work	119
6.1	Concluding remarks	119
6.2	Future research lines	122
References		125