

Contents

1 M2M	1
1.1 Usage scenarios	2
1.1.1 Smart grids	3
1.1.2 Smart cities	3
1.2 Cellular M2M	4
1.3 M2M in current cellular networks	6
1.3.1 GSM	6
1.3.2 UMTS	8
1.3.3 Beyond 3G, LTE	8
1.4 M2M standardization	9
1.4.1 M2M activities in 3GPP	10
2 LTE	15
2.1 LTE ¹ architecture	16
2.2 eNB functionalities	18
2.3 The radio interface	19
2.4 Transmission schemes	22
2.5 Frame structure	23
3 NS3 and LENA	27
3.1 LTE Model	29
3.2 EPC Model	30
3.3 MAC	31
3.3.1 Resource Allocation Model	32
3.3.2 Adaptive Modulation and Coding	32
3.3.3 Round Robin scheduler	33
3.3.4 Developed scheduler	33
3.4 RLC and PDCP	37
3.5 RRC	38

¹Long Term Evolution

3.6	PHY	39
3.7	Fading model	39
3.8	M2M application description	40
3.8.1	m2mClient	42
3.8.2	m2mServer	44
3.8.3	Helper	45
4	Performance evaluation	47
4.1	Performance metrics	47
4.2	LTE configuration	47
4.3	Calibration batch	48
4.3.1	First simulation	48
4.3.2	Simulation parameters	51
4.3.3	Second simulation	52
4.4	First batch	56
4.4.1	First simulation	56
4.5	Second batch	61
4.5.1	First simulation	61
4.5.2	Second simulation	65
4.6	Third batch	68
4.6.1	First simulation	68
4.6.2	Second simulation	69
4.7	Conclusion	74
5	Conclusions	75
6	Acknowledgments	77
A	Emulation experiences	79
A.1	Acronyms	88

List of Figures

1.1	Access network possibilities: wired (left), capillary+cellular (center), cellular only (right)	2
1.2	A typical 7-cell cellular cluster	4
1.3	Cellular network components	5
1.4	GSM channels graphical representation	7
1.5	3GPP TS22.368 first scenario	11
1.6	3GPP TS22.368 second scenario	11
1.7	3GPP TS22.368 third scenario	11
2.1	Flat LTE architecture and SAE	17
2.2	E-UTRAN architecture	18
2.3	User plane and control plane protocol stack	19
2.4	Frequency-time representation of an OFDM signal	23
2.5	Comparison between classic OFDM and OFDMA	23
2.6	Frequency-time representation of an SC-FDMA signal	24
2.7	Structure for <i>Type 1</i> frame	24
2.8	Structure for <i>Type 2</i> frame	25
2.9	Downlink transmission scheme	25
3.1	LTE-EPC simulation model overall architecture	29
3.2	EPC data plane protocol stack	32
3.3	RR-LENA and developed scheduler uplink throughput comparison	37
3.4	sinr trend for fading_trace_EPA_3kmph.fad	41
3.5	M2M protocol representation	41
3.6	M2M client application state transitions	42
3.7	M2M server application state transitions	45
4.1	Calibration batch, first simulation's topology	48
4.2	SINR decaying at increasing UE/eNB distances	49
4.3	taggedNode perceived SINR at various distances for 20 run	50
4.4	Calibration batch, second simulation's topology	53

4.5	Calibration batch, second simulation's interfering UEs placement	53
4.6	M2M message exchange duration	55
4.7	Cumulative distribution function, 10 interferents	57
4.8	Cumulative distribution function, 20 interferents	57
4.9	Cumulative distribution function, 30 interferents	58
4.10	Cumulative distribution function, 40 interferents	58
4.11	Failure probability at 90th percentile	59
4.12	Average uplink cell throughput	60
4.13	Average message exchange protocol duration	60
4.14	Cumulative distribution function, 0 interferents	62
4.15	Cumulative distribution function, 10 interferents	62
4.16	Cumulative distribution function, 20 interferents	63
4.17	Cumulative distribution function, 30 interferents	63
4.18	Cumulative distribution function, 40 interferents	64
4.19	Failure probability at 90th percentile	64
4.20	Average uplink cell throughput	65
4.21	Average message exchange protocol duration	66
4.22	Cumulative distribution function, 10 interferents	67
4.23	Cumulative distribution function at 90th percentile	67
4.24	Cumulative distribution function	69
4.25	Failure probability at 90th percentile	70
4.26	Average uplink cell throughput	70
4.27	Average M2M packet delay	71
4.28	Cumulative distribution function	72
4.29	Failure probability at 90th percentile	72
4.30	Average uplink cell throughput	73
4.31	Average M2M packet delay	73
A.1	Emulation scenario first idea	79
A.2	PC2 logical view	80
A.3	PC2 logical view, second approach	81
A.4	PC2 NICs configuration (left) and routing forced paths (right)	82