

Inhaltsverzeichnis

Abstract	III
Kurzfassung	V
Acronyms	XI
1 An Introduction to <i>ICT</i> Infrastructures for Smart Distribution Grids	1
1.1 Motivation	1
1.2 Application Scenarios and Requirements Analysis	3
1.2.1 Key Applications in Smart Distribution Grids	3
1.2.2 Smart Grid Topologies from the <i>ICT</i> Perspective	8
1.2.3 High-Level System Architecture Design and Terminology .	12
1.3 State-of-the-Art Wireless <i>ICT</i> Technologies for the Smart Grid . .	15
1.3.1 Mobile Communication Systems for the Smart Grid	17
1.3.2 Frequency Spectrum Needs for the Smart Grid	19
1.4 Research Scope and Scientific Contributions	23
1.4.1 Thesis Outline	24
2 Methodologies for Analyzing Smart Grid Communications	27
2.1 Overview on Solution Approaches	27
2.2 Evaluation Scenarios for Distribution Grid Applications	29
2.3 Related Work and Methodologies for Channel Modeling in Smart Grid Scenarios	34
2.3.1 Urban Macro-Cell Propagation Scenarios	35
2.3.2 Suburban Macro-Cell Propagation Scenarios	38
2.3.3 Rural Macro-Cell Propagation Scenarios	40
2.3.4 Building Penetration Propagation Scenarios	42
2.4 Evaluation Methodologies for Smart Grid Traffic	47
2.4.1 Stochastic Traffic Models based on Markovian Model	47
2.4.2 Deterministic Traffic Models based on Network Calculus Theory	49
2.4.3 Discrete-Event Simulation of Smart Grid Traffic	50
2.5 Summary of Methodologies and Their Application in this Work . .	52

3	Extensions of Radio Propagation Models for Smart Grid-specific Scenarios	55
3.1	Propagation Model Adaption and Modification for Smart Grid Scenarios	55
3.1.1	Frequency Adaptation of Outdoor-to-Indoor Channel Models	58
3.1.2	Building Penetration and Installation Enhancements	60
3.1.3	Topology Considerations	62
3.2	Outdoor-to-Indoor Reference Measurements under different propagation conditions	63
4	Coverage Analysis of Mobile Communication Systems for Distribution Grid Services	67
4.1	Small-Scale Analysis of Building Penetration Capabilities at <i>LOS</i> Conditions	67
4.1.1	Carrier Frequency Analysis for Building Penetration	71
4.1.2	Orientation of Houses Towards the Transmitter	79
4.1.3	Impact of Building Types and Building Materials	82
4.1.4	Impact of Installation and Deployment Scenarios	83
4.2	Small-Scale Analysis of Building Penetration Capabilities at <i>NLOS</i> Conditions	86
4.2.1	Rural and Suburban Topologies under <i>NLOS</i> conditions	89
4.2.2	Influence of Building Density under <i>NLOS</i> conditions	91
4.3	Large-Scale Coverage Analysis of Wireless Access Networks for Distribution Grid Services	93
4.3.1	Link Budget Calculation for Different Technologies	94
4.4	Interim Conclusion	97
5	Data Traffic Analysis and Network Planning of Mobile Communication Systems for Smart Distribution Grids	101
5.1	Smart Grid Traffic Characteristics	101
5.1.1	Requirements and Characteristics of Smart Grid Traffic	102
5.1.2	Classification of Traffic Service Classes	103
5.2	Quantitative Assessment of Bandwidth Demand and Capacity Requirements: A Case Study	106
5.2.1	Traffic Estimation	107
5.2.2	Scenario Analysis and Bandwidth Requirements	111
5.3	Capacity Analysis of Mobile Communication Networks under Different Link Conditions	115
5.3.1	Cell Throughput Analysis under Different Link Conditions	115
5.4	Matching Network Options with Smart Grid Requirements	124
6	Conclusion and Outlook	127

A	Appendix	131
A.1	Overview on mathematical formulae of channel models	131
A.2	Calculation of Dielectric Constants for Ray Tracing Simulation . .	133
A.3	Matlab Implementation of the Traffic Simulation Model	137
B	Scientific Activity Report	141
B.1	Author's Publications	142
B.2	Scientific Activities	145
B.3	Supervised Student Theses	145
	Bibliography	147