

Contents

Theme I Challenges for Wireless Sensor Networks

1 Composition and Scaling Challenges in Sensor Networks: An Interaction-centric View	29
Tarek Abdelzaher	
1.1 Introduction	29
1.2 Functional Interactions	30
1.2.1 Troubleshooting Interactive Complexity	31
1.2.2 Troubleshooting Examples	32
1.3 Data Interactions	35
1.3.1 Privacy and Data Aggregation	36
1.3.2 Perturbation Examples and Time-series Data	37
1.4 Temporal Interactions	42
1.4.1 Temporal Analysis of Distributed Systems	43
1.4.2 Reduction-based Analysis and Delay Composition Algebra	44
1.5 Interactions of System Dynamics	47
1.5.1 Sources of Dynamics in Software	47
1.5.2 Examples of Dynamic Interactions	49
1.6 Summary	53
References	53

Theme II Models, Topology, Connectivity

2 Scheduling and Power Assignments in the Physical Model	57
Alexander Fanghänel and Berthold Vöcking	
2.1 Introduction	58
2.2 Notation and Preliminaries	60
2.2.1 Robustness of the Physical Model	61
2.3 Scheduling with the Linear Power Assignment	62
2.3.1 Measure of Interference and Lower Bounds	62

2.3.2	Upper Bounds for the Linear Power Assignment	66
2.4	Scheduling with the Square Root Power Assignment	72
2.4.1	Scheduling Directed Requests	72
2.4.2	Scheduling Bidirectional Requests	75
2.5	The Gap of Oblivious Power Schemes	77
2.6	Summary and Open Problems	80
	References	81
3	Maintaining Connectivity in Sensor Networks Using Directional Antennae	83
	Evangelos Kranakis and Danny Krizanc and Oscar Morales	
3.1	Introduction	84
3.1.1	Antenna orientation problem	86
3.1.2	Preliminaries and notation	86
3.1.3	Related work	87
3.1.4	Outline of the presentation	89
3.2	Orienting the Sensors of a Point-set	90
3.2.1	Sensors with one antenna	90
3.2.2	Sensors with multiple antennae	93
3.3	Lower bounds	97
3.3.1	One antenna per sensor	97
3.3.2	Two antennae per sensor	98
3.4	Sum of angles of antennae	99
3.5	Orienting Planar Spanners	102
3.5.1	Basic construction	103
3.6	Conclusion	107
	References	108
4	Optimal Placement of Ad-Hoc Devices under a VCG-style Routing Protocol	111
	Luzi Anderegg, Stephan Eidenbenz, Leon Peeters, and Peter Widmayer	
4.1	Introduction	111
4.1.1	Model and Notation	112
4.1.2	The Device Placement Problem	113
4.1.3	Related Work	114
4.2	Placing Multiple Identical Devices for a Single Commodity	115
4.2.1	The Optimal Position of a Single Additional Device	115
4.2.2	Multiple Identical Devices	117
4.3	Single Device Placement for Multiple Commodities	118
4.3.1	Single Maximization Diagram Approach	118
4.3.2	Multiple Maximization Diagrams Approach	120
4.4	Placing Multiple Individual Devices for a Single Commodity	122
4.5	Placing Multiple Devices for Multiple Commodities	123
	References	132

Contents	13
5 Population Protocols and Related Models	135
Paul G. Spirakis	
5.1 Introduction	135
5.2 Population Protocols	140
5.2.1 The Model	140
5.2.2 Stable Computation	143
5.3 Mediated Population Protocols	146
5.3.1 Formal Definition	147
5.3.2 Computational Power	150
5.4 The GDM model	152
5.4.1 Formal Definition	152
5.4.2 Weakly Connected Graphs	153
5.4.3 All Possible Directed Graphs	157
5.5 Community Protocols	157
5.5.1 The Model	158
5.5.2 Computational Power	160
5.6 Logarithmic-Space Machines	162
5.7 Algorithmic Verification of Population Protocols	166
5.7.1 Necessary Definitions	166
5.7.2 NP-hardness Results	170
5.7.3 An Efficiently Solvable Special Case	177
5.7.4 Algorithmic Solutions for BPVER	179
5.8 Open Problems	182
References	183
6 Theoretical Aspects of Graph Models for MANETs	187
Josep Díaz, Dieter Mitsche, and Paolo Santi	
6.1 Introduction	187
6.2 Static Properties	189
6.3 Mobility models for MANETs	192
6.4 Structural properties of Random WayPoint mobile networks	195
6.4.1 RWP node spatial distribution	196
6.4.2 RWP average nodal speed	199
6.4.3 The “perfect” simulation	201
6.5 Formal studies of connectivity on MANETs’ models	202
6.5.1 Connectivity threshold for mobility models	202
6.5.2 Connectivity periods on mobile models	203
6.5.3 The effect of mobility to speed up message dissemination in sparse networks	207
6.6 Conclusions	212
References	213

7 Networked distributed source coding	217
Shizheng Li and Aditya Ramamoorthy	
7.1 Introduction	217
7.2 Basics of distributed source coding.....	219
7.2.1 Slepian-Wolf Theorem	220
7.2.2 Equivalence between Slepian-Wolf coding and channel coding	221
7.2.3 Distributed source coding with a fidelity criterion	223
7.3 Networked distributed source coding: An introduction	225
7.4 Networked distributed source coding: Single terminal	227
7.4.1 Optimal rate and flow allocation	229
7.5 Networked distributed source coding: Multiple terminals	235
7.5.1 A network coding primer	236
7.5.2 Multicasting correlated sources over a network	237
7.5.3 Separating distributed source coding and network coding	239
7.5.4 Practical joint distributed source coding and network coding.....	240
7.5.5 Resource allocation for multicasting correlated sources over a network	243
7.6 Conclusion.....	246
References	247

Theme III Localization, Time Synchronization, Coordination

8 The Spatial Smoothing Method of Clock Synchronization in Wireless Networks	253
Arvind Giridhar and P. R. Kumar	
8.1 Introduction	253
8.2 Synchronizing two clocks	255
8.3 A network of clocks	258
8.4 Estimating node offsets from edge offsets	259
8.4.1 Geometric graphs	261
8.5 Spatial smoothing	263
8.6 Estimating nodal skews	264
8.7 Properties of the least-squares solution	265
8.8 The Distributed Spatial Smoothing Algorithm Based on Coordinate Descent	272
8.9 Convergence Analysis of the Spatial Smoothing Algorithm	274
8.10 Decomposition Techniques to Speed up Convergence	277
8.11 Conclusion.....	279
References	280

Contents	15
9 Algorithmic Aspects of Sensor Localization	283
Sajal K. Das and Jing Wang and R. K. Ghosh and Rupert Reiger	
9.1 Introduction	284
9.1.1 Importance of Localization	284
9.1.2 Generic Approach to Solution	285
9.1.3 Known Algorithmic Approaches	286
9.1.4 Inherent Challenges	287
9.1.5 Chapter Organization	288
9.2 Range-free Localization	288
9.2.1 Anchor-based Approaches	289
9.2.2 Anchor-free Approaches	292
9.3 Range-based Localization	292
9.3.1 Range Measurements	292
9.3.2 Localization Problems Using Range Measurements	293
9.3.3 Anchor-based Approaches	295
9.3.4 Anchor-free Approaches	298
9.4 Techniques with Additional Hardware	299
9.4.1 Angle Measurement	299
9.4.2 Localization with Angle Measurement	300
9.5 Techniques based on Iterative Process	301
9.6 Mobility-assisted Localization	302
9.7 Statistical Techniques	305
9.8 Summary on Localization Techniques	309
9.8.1 Localization Accuracy	309
9.8.2 Computation and Communication Costs	310
9.8.3 Network and Anchors Density	311
9.8.4 Summary of Performances	311
9.9 Open Issues	312
9.10 Conclusions	313
References	314
10 Spatio-Temporal Context in Wireless Sensor Networks	319
Anahit Martirosyan and Azzedine Boukerche	
10.1 Introduction	319
10.1.1 What is Context?	320
10.2 Node Localization in WSNs	321
10.2.1 The Task of Localization Algorithms for WSNs	321
10.2.2 Estimation of Distances and Angles	322
10.2.3 Trilateration	323
10.2.4 Multilateration	324
10.2.5 Localization Algorithms for WSNs	325
10.3 Temporal Event Ordering in WSNs	329
10.3.1 Delaying Techniques	330
10.3.2 Heartbeat	330
10.3.3 Temporal Message Ordering Scheme	331

10.3.4	Ordering by Confirmation	332
10.3.5	An Efficient Algorithm for Preserving Events' Temporal Relationships in Wireless Sensor Actor Networks	333
10.3.6	Comparison of Features of the Temporal Event Ordering Algorithms.....	334
10.4	Time Synchronization in WSNs	335
10.4.1	Time Synchronization Techniques.....	336
10.4.2	Synchronization Algorithms for WSNs	338
10.4.3	Comparison of Features of the Time Synchronization Algorithms	341
10.5	Summary	342
	References	343
11	Coordination problems in ad hoc radio networks	347
	Dariusz R. Kowalski	
11.1	Introduction	347
11.1.1	Model and problems	348
11.1.2	Results	350
11.2	Wake-up on a multiple access channel	354
11.2.1	Deterministic synchronization	354
11.2.2	Randomized synchronization	360
11.2.3	Explicit constructions	362
11.3	Wake-up in multi-hop radio networks	363
11.3.1	Deterministic wake-up	363
11.3.2	Randomized wake-up	366
11.4	Leader election and clock synchronization	366
11.4.1	Leader election protocol	367
11.4.2	Clock synchronization	369
11.5	Mutual exclusion	370
11.5.1	From wake-up to mutual exclusion	372
11.6	Remarks and open problems	376
	References	377
Theme IV Data Propagation and Collection		
12	Probabilistic Data Propagation in Wireless Sensor Networks	383
	Sotiris Nikoletseas and Paul G. Spirakis	
12.1	Introduction	383
12.1.1	A Brief Overview of Wireless Sensor Networks	383
12.1.2	Critical Challenges	384
12.1.3	Models and Relations between them	385
12.1.4	The Energy Efficiency Challenge in Routing	387
12.2	LTP: A Single-Path Data Propagation Protocol	388
12.2.1	The Protocol.....	389
12.2.2	Analysis of the expected hops efficiency	389

12.2.3	Local Optimization: The Min-two Uniform Targets Protocol (M2TP)	392
12.2.4	Tight upper bounds to the hops distribution of the general target protocol	393
12.3	PFR - A Probabilistic Multi-path Forwarding Protocol	394
12.3.1	The Protocol	395
12.3.2	Properties of PFR	397
12.3.3	The Correctness of PFR	397
12.3.4	The Energy Efficiency of PFR	399
12.3.5	The Robustness of PFR	403
12.4	An experimental comparison of LTP, PFR	404
12.5	Conclusions	409
	References	410
13	Oblivious Routing for Sensor Network Topologies	413
	Costas Busch and Malik Magdon-Ismail and Jing Xi	
13.1	Introduction	414
13.1.1	Geometric Networks	414
13.1.2	Mesh Networks	416
13.2	Geometric Networks	417
13.2.1	Preliminaries on Geometric Networks	417
13.2.2	Oblivious Routing on Geometric Networks	419
13.2.3	Applications of Geometric Networks	428
13.3	Mesh Networks	430
13.3.1	Preliminaries on Mesh Networks	430
13.3.2	Oblivious Routing on 2-Dimensional Mesh Networks	430
	References	436
14	Scheduling Algorithms for Tree-Based Data Collection in Wireless Sensor Networks	439
	Ozlem Durmaz Incel and Amitabha Ghosh and Bhaskar Krishnamachari	
14.1	Introduction	439
14.2	Classification Approach and Methodology	442
14.2.1	Design Objectives	443
14.2.2	Design Constraints and Assumptions	444
14.3	Scheduling Algorithms for Data Collection	446
14.3.1	Algorithms on Minimizing Schedule Length	446
14.3.2	Algorithms on Minimizing Latency	460
14.3.3	Algorithms with Other Objectives	462
14.3.4	Algorithms with Joint Objectives	467
14.3.5	Taxonomy	469
14.4	Future Research Directions / Open Problems	472
14.5	Conclusions	473
	References	474

15 Position-based routing in wireless ad-hoc and sensor networks	479
Nathalie Mitton and Tahir Razafindralambo and David Simplot-Ryl	
15.1 Introduction	479
15.2 Geometric routing based on geographic coordinates	481
15.2.1 Greedy and directional approaches	481
15.2.2 Guaranteed delivery approaches	485
15.2.3 Anycasting	493
15.3 Virtual coordinates systems	494
15.3.1 Landmark-based coordinate system	494
15.3.2 Tree-based coordinate system	500
15.4 Conclusion	508
References	508

Theme V Energy Optimization

16 Energy Balanced Data Propagation in Wireless Sensor Networks	513
Pierre Leone, Sotiris Nikoletseas and Jose Rolim	
16.1 Introduction	514
16.2 The Model and the Problem	515
16.3 The EBP Distributed Data Propagation Protocol	517
16.4 Basic Definitions-Preliminaries	518
16.5 The General Solution	519
16.6 A closed form for the forwarding probability	526
16.7 A generalized algorithm	527
16.7.1 A remark about the underlying assumption	531
16.8 On the optimality of energy-balance protocols	532
16.8.1 Learning the protocol's parameters	536
16.8.2 A simple distributed strategy	540
16.9 Conclusions	542
References	542
17 Dense, Concentric and Non-uniform Multi-hop Sensor Networks	545
Sajal K. Das, Alfredo Navarra and Cristina M. Pinotti	
17.1 Introduction	546
17.2 Related work	548
17.2.1 About localization	548
17.2.2 About the energy hole problem	550
17.3 Our model and assumptions	553
17.3.1 Basic modular arithmetic	554
17.4 Localization problem	555
17.4.1 Correctness and performance analysis	559
17.4.2 Improvements	563
17.4.3 The Cooperative Protocol	564
17.4.4 Experimental results	568
17.5 Energy hole problem	569
17.5.1 General non-uniform sensors distribution strategy	570

Contents	19
17.5.2 Energy depletion analysis	571
17.5.3 Sub-balanced energy depletion	572
17.5.4 q -Switch routing and comparison with other node distribution strategies	574
17.6 Concluding remarks	577
References	578
18 Prolong The Lifetime of Wireless Sensor Networks Through Mobility: A General Optimization Framework	583
Jun Luo and Liu Xiang	
18.1 Mobile Elements in Wireless Sensor Networks: Stir Up the Pond	583
18.2 Balancing Traffic Load with Mobile Sinks: The Case of Constrained Mobility	586
18.2.1 Network Model and Problem Formulation	587
18.2.2 Complexity Analysis of MNL	589
18.2.3 Duality Theory and TMNTM	591
18.2.4 A Primal-Dual Algorithm to Solve MNL	593
18.2.5 Numerical Results	597
18.2.6 Summary	601
18.3 Balancing Traffic Load with Mobile Sinks: The Case of Unconstrained Mobility	601
18.3.1 Node-Associated Transmission Energy	602
18.3.2 Link-Associated Transmission Energy	603
18.3.3 Summary	606
18.4 Energy Conservation with Mobile Nodes: The Extreme Usage of The Substitution Effect	607
18.4.1 MNL with Multiple Mobile Nodes (MNL-MMN)	607
18.4.2 Theorem, Complexity, and Algorithm	608
18.4.3 Numerical Results	610
18.4.4 Summary	611
18.5 Energy Conservation with Mobile Relays: Using Mechanical Data Transportation Smartly	611
18.5.1 The Single Mobile Relay Positioning (SMRP) Problem ..	612
18.5.2 A Variation of SMRP	613
18.5.3 Summary	616
18.6 Conclusion.....	616
References	617
Theme VI Mobility Management	
19 Information Spreading in Dynamic Networks: An Analytical Approach	621
Andrea Clementi and Francesco Pasquale	
19.1 Introduction	621
19.1.1 Warm-up and Road Map	622

19.2	Edge-Markovian Evolving Graphs	625
19.2.1	The upper bound	627
19.2.2	The lower bounds	628
19.3	Stationary Markovian Evolving Graphs	632
19.3.1	Flooding Time and Expansion Properties	632
19.3.2	Stationary Edge-MEGs	634
19.3.3	Parsimonious flooding in stationary Edge-MEGs	635
19.3.4	Stationary Geometric MEGs	636
19.3.5	Stationary Geometric MEGs under the connectivity threshold.....	639
19.4	Radio Broadcasting in Dynamic Networks	641
19.4.1	The worst-case evolving graph	641
19.4.2	The random evolving graph: case p known	642
19.4.3	The random evolving graph: case p unknown	645
19.5	Conclusions and Open problems	646
	References	647
20	Self-Stabilizing and Self-Organizing Virtual Infrastructures for Mobile Networks	651
	Shlomi Dolev and Nir Tzachar	
20.1	Introduction	652
20.2	Self-Stabilizing and Self-Organizing distributed algorithms	655
20.3	System Settings	656
20.4	Expander Extraction	658
20.4.1	The Complete Graph	658
20.4.2	An Arbitrary Expander	660
20.5	Expansion Monitoring	661
20.5.1	Monitoring by Random Sampling	662
20.5.2	Mixing Rate Based Monitoring	663
20.5.3	Self-Stabilizing Distributed Monitoring	667
20.6	Distributed Hierarchical Spanner Construction	678
	References	680
21	Computing by Mobile Robotic Sensors	685
	Paola Flocchini, Giuseppe Prencipe, and Nicola Santoro	
21.1	Introduction	685
21.1.1	Distributed Computing and Mobile Entities	685
21.1.2	Robots, Sensors, and Mobility	686
21.1.3	Mobile Robotic Sensors	687
21.2	Modeling Mobile Robotic Sensors	689
21.2.1	Capabilities	689
21.2.2	Behavior	690
21.2.3	Synchronization	690
21.2.4	Memory	691
21.3	Self Deployment	692
21.3.1	Introduction	692

Contents	21
21.3.2 Uniform Deployment On Linear Borders	694
21.3.3 Uniform Deployment Along Circular Borders	695
21.3.4 Uniform Deployment in Rectangular Spaces	700
21.3.5 Incremental Deployment and Filling	703
21.4 Pattern Formation	707
21.4.1 Forming Scale-Free Patterns	708
21.4.2 Circle Formation	709
21.5 Gathering	712
21.5.1 Asynchronous Gathering	712
21.5.2 Semi Synchronous Gathering	715
21.5.3 Fully Synchronous Gathering	717
21.5.4 Coalescence	718
21.6 Conclusions and Open Problems	719
References	721

Theme VII Security Aspects

22 Security and Trust in Sensor Networks	729
Przemysław Blaśkiewicz, Mirosław Kutyłowski	
22.1 Security in (wireless) sensor networks	729
22.2 Information and node authentication	732
22.2.1 Chaining protocols	733
22.2.2 Asymmetric methods	740
22.2.3 Sensing mobile artefacts	748
22.2.4 Communication authentication: a framework example ..	752
22.3 Key management	753
22.3.1 Master key schemes	754
22.3.2 Random assignment schemes	754
22.3.3 Polynomial share	757
22.3.4 Multi-group deployment	758
22.3.5 Powerful third-party	759
22.3.6 Dynamic key structures	760
22.3.7 LEAP: a full key infrastructure	762
22.4 Encoding	764
22.4.1 Multiple paths	764
22.4.2 Block ciphers	765
22.5 Compromised node detection	767
22.5.1 Alert based protocols	767
22.5.2 Detect and tolerate	768
22.5.3 Suicidal pointer	769
References	769

23 Key Management in Sensor Networks	773
Dahai Xu, Jeffrey DwoSkin, Jianwei Huang, Tian Lan, Ruby Lee, Mung Chiang	
23.1 Introduction	774
23.1.1 Motivation	774
23.1.2 Summary of our study between representative probabilistic and deterministic schemes	775
23.2 Fragility Analysis for Probabilistic Key Management	777
23.2.1 SAP for a static network	778
23.2.2 SAP for a mobile network	778
23.3 Secret-Protecting Processor Architecture	784
23.3.1 Reduced Hardware Architecture	784
23.3.2 Expanded Sensor-mode SP Architecture	786
23.4 Security and Economics Analysis of SP Architecture Based Solution	788
23.4.1 Attacks on Protected Keys	788
23.4.2 Attacks on Changing the TSM or the Device Key	789
23.4.3 Economics Analysis	789
23.5 Simulation Results	790
23.5.1 Comparison of Probabilistic and Deterministic Key Predistribution	790
23.5.2 Security Improvement with SP architecture	794
23.6 Implications to Related Work	797
23.6.1 Reinforcements on the Basic EG Scheme	797
23.6.2 Selective Node Capture	798
23.7 Key Establishment Approach	799
23.7.1 An Analytical Framework for Key Establishment	800
23.7.2 Characterization of Optimal Resilience	803
23.7.3 Low-Complexity Algorithm for Key Establishment	804
23.7.4 Numerical Simulations	810
23.7.5 Proof of Theorem 1	812
23.7.6 Proof of Theorem 2	815
23.8 Concluding Remarks	816
References	817
24 Key Predistribution in Wireless Sensor Networks when Sensors are within Communication Range	819
Sushmita Ruj, Amiya Nayak and Ivan Stojmenovic	
24.1 Introduction	820
24.1.1 Shared-key discovery	822
24.1.2 Network models	826
24.1.3 Performance measures and notation	828
24.1.4 Identifying compromised nodes	829
24.1.5 Node and key revocation	833
24.2 Key predistribution schemes in WSN	834

Contents	23
24.2.1 Blom's Scheme	835
24.2.2 Blundo et al's Scheme.....	835
24.3 The Basic and Q -composite Schemes.....	837
24.4 Random pairwise schemes.....	839
24.4.1 Chan-Perrig-Song scheme	839
24.4.2 Liu-Ning-Li polynomial-pool-based key predistribution ..	839
24.4.3 Probabilistic scheme of Zhu et al.....	840
24.5 Grid-based key predistribution schemes.....	841
24.5.1 PIKE scheme of Chan and Perrig	841
24.5.2 Liu-Ning-Du Scheme	842
24.5.3 Martin-Paterson-Stinson's improvement of Liu et al's scheme	844
24.6 Key predistribution using combinatorial structures.....	846
24.6.1 Çamtepe and Yener's scheme	847
24.6.2 Lee and Stinson's schemes	849
24.6.3 Chakrabarti-Maitra-Roy Scheme	850
24.6.4 Ruj and Roy Scheme	851
24.6.5 Key predistribution schemes using codes	854
24.7 Key predistribution in Multi-hop networks	856
24.8 Conclusion.....	857
References	859

Theme VIII Tools, Applications and Use Cases

25 Realistic Applications for Wireless Sensor Networks	869
John A. Stankovic, Anthony D. Wood, Tian He	
25.1 Introduction	869
25.2 Challenges	870
25.2.1 From Raw Data to Knowledge.....	870
25.2.2 Robust System Operation	871
25.2.3 Openness and Heterogeneity	871
25.2.4 Security	872
25.2.5 Privacy	872
25.2.6 Real-Time.....	872
25.2.7 Energy Management	873
25.2.8 Control and Actuation.....	873
25.2.9 Challenges and Applications	874
25.3 Surveillance Application – VigilNet.....	874
25.3.1 Application Requirements	875
25.3.2 VigilNet Architecture	876
25.3.3 The Programming Interface	881
25.3.4 System Work Flow	882
25.3.5 VigilNet Summary	883
25.4 Healthcare Applications – AlarmNet	883
25.4.1 Application Requirements	884

25.4.2	AlarmNet Architecture	884
25.4.3	Query Management	886
25.4.4	Circadian Activity Rhythms	888
25.4.5	Dynamic Context-Aware Privacy	890
25.4.6	AlarmNet Summary	892
25.5	Environmental Science Applications - Luster	892
25.5.1	Application Requirements	893
25.5.2	Luster's Architecture	893
25.5.3	Luster Summary	895
25.6	Summary	896
25.7	Acknowledgements	896
	References	896
26	High-level Application Development for Sensor Networks:	
	Data-driven Approach	899
	Animesh Pathak and Viktor K. Prasanna	
26.1	Introduction	899
26.1.1	Node-level Programming	900
26.1.2	High-Level Abstractions for WSNs	901
26.1.3	Macroprogram Compilation	903
26.2	Data-driven Macroprogramming	905
26.2.1	Programming Model	905
26.2.2	Runtime System	907
26.3	Compilation Process	908
26.3.1	Input	908
26.3.2	Output	909
26.3.3	Process Overview	909
26.3.4	Challenges	911
26.4	Compilation Framework	911
26.5	<i>Srijan</i> : Graphical Toolkit for Data-driven WSN Macroprogramming	915
26.6	Evaluation	917
26.6.1	Reference Applications	917
26.6.2	Evaluation of the Compiler	919
26.6.3	Evaluation of the Toolkit	921
26.7	Concluding Remarks	922
	References	923
27	Towards integrated real world sensing environment - applications and challenges	927
	Srdjan Krco and Konrad Wrona	
27.1	Introduction	927
27.2	Military perspective	928
27.3	Civilian perspective	930
27.4	Selected WSN applications and traffic models	932
27.4.1	Control and automation domain applications	933
27.4.2	Transport applications	934

Contents	25
27.4.3 Environmental monitoring for emergency services	934
27.4.4 Health monitoring application traffic model	935
27.4.5 Traffic model summary	935
27.5 Characteristics of the WCDMA networks	936
27.6 Network dimensioning methodology	938
27.7 Results	940
27.7.1 Common channels analysis	943
27.8 Conclusions	946
References	947
Index	951