Contents

1 Introduction 1

2 Wireless Sensor Networks: Concepts and Components 5
- 2.1 Network Components 5
- 2.2 Hardware Platforms 7
- 2.3 Wireless Sensor Operating Software 8
  - 2.3.1 TinyOS 8
  - 2.3.2 SOS 8
  - 2.3.3 Contiki 9
  - 2.3.4 MANTIS 9
  - 2.3.5 SensorOS 9
  - 2.3.6 MagnetOS 9
  - 2.3.7 Nano-RK 10
  - 2.3.8 ERIKA 10
  - 2.3.9 RETOS 10
  - 2.3.10 LiteOS 11
- 2.4 Network Topologies 11
  - 2.4.1 Star Topology 12
  - 2.4.2 Tree Topology 13
  - 2.4.3 Mesh Topology 13
  - 2.4.4 Hybrid Topology 14
- 2.5 Data Models 15
- 2.6 Routing Techniques 15
- References 23

3 Application Scenarios 27
- 3.1 Industrial Monitoring and Control 28
- 3.2 Environmental Monitoring 29
- 3.3 Agriculture Applications 30
- 3.4 Smart Buildings 31
- 3.5 Warehouse Tracking 32

Wireless sensors in heterogeneous networked systems
2014

digitalisiert durch
IDS Basel/Bern, im Auftrag der
Schweizerischen Nationalbibliothek

3.6 Transport Logistics 32
3.7 Surveillance 33
3.8 Health Care 35
References 36

4 Existing Middleware Solutions for Wireless Sensor Networks 39
4.1 Taxonomy of Operating Software for Wireless Sensor Data 40
4.2 Remote (Re)configuration Approaches 42
4.3 Middleware Architectures Inside the WSN 47
4.3.1 Database Abstractions 47
4.3.2 Mobile Agents 48
4.3.3 Virtual Machines 50
4.3.4 Application-Driven and Message-Oriented Middleware 50
4.4 Internet-Based Integration of Sensor Data 52
4.5 IP-Based Homogeneous Middleware 53
References 55

5 Middleware Mechanisms for Heterogeneous Wireless Sensor Networks 61
5.1 Middleware Requirements 61
5.2 Architecture 62
5.3 Platform and Communication Protocol Independency (Drivers) 65
5.4 The Catalog 68
5.5 Node Referencing and Heterogeneity 68
5.6 Publish/Subscribe External Interface 69
5.7 Data and Processing Model 72
5.8 Operations 74
5.9 User API 75

6 Middleware Implementation Details: A Case Study 77
6.1 Node Component Architecture 77
6.2 NC-Kernel 79
6.2.1 Communication (I/O Adapter) 80
6.2.2 Agent Manager (NC-Kernel-AM) 80
6.3 SOMApp 80
6.3.1 Acquisition and Actuation (NC-SOMApp-AA) 80
6.3.2 Configuration Management (NC-SOMApp-CM) 81
6.3.3 Data Collector (NC-SOMApp-DC) 82
6.3.4 SOM Processor (NC-SOMApp-GP) 82
6.3.5 Extensibility of SOMApp 84
6.4 Remote Configuration Component (RConfig) 85
6.5 Custom Code Agents 86
Reference 87

7 Programming Paradigms and Stream Processing for WSN 89
7.1 Programming Abstractions for WSNs 89
7.2 Basics of High-Level Stream Processing 90
7.3 Language and Architectural Features 91
7.4 A Stream Processing Language for Heterogeneous Networks with Wireless Sensors 94
7.5 The Per-Node Database Management System 100
7.5.1 Data Storage Organization 100
7.5.2 Stream Relational Algebra and Algorithm 101
7.5.3 Constrained Group By 103
7.5.4 Join Algorithm 105
References 106

8 Experimental Validation of Middleware: Platforms, Performance and Related Issues 107
8.1 Evaluation of NC for Multiple Platforms 108
8.1.1 Development and Porting Between Platforms 108
8.1.2 Memory and Performance 109
8.2 Operation Processing in Constrained Devices 112
8.2.1 Memory Footprint 112
8.2.2 Performance and Energy Consumption: RAM Versus Flash 114
8.2.3 Data Processing Versus Lifetime 116
8.3 Networked Execution and Performance Evaluation 118
8.3.1 Experimental Setup 119
8.3.2 Command Configuration and Latency 119
8.3.3 Monitoring Operation 121
8.3.4 Closed Loop over Heterogeneous Devices 123
References 126

Appendices 127
Appendix 1: Communication Driver: Code Example 127
Appendix 2: User API 128
A.2.1 Node 129
A.2.2 Operations and Filters 130
A.2.3 Alarms 133
A.2.4 Actions 134
A.2.5 Actuations 135
A.2.6 Publish/Subscribe 135
A.2.7 Agents 136

Index 139