Contents

Resumen **1**

Resum **5**

Abstract **9**

1 Introduction **13**

1.1 Motivation and Scope 13

1.2 Contributions 15

1.3 Structure 17

2 The Group Membership Problem **19**

2.1 The Group Membership Problem in Distributed Systems 19

2.1.1 Consensus and Impossibility 21

2.1.2 Failure Detection 22

2.1.3 Notation 23

2.2 Related Work: Group Membership Services 24

2.2.1 Classical Systems 24

2.2.2 Large Scale Systems, WAN Networks 26

2.2.3 Systems with Specific Needs 31

2.3 The Formal Specification of the Problem 36

3 The Group Membership Architecture **39**

3.1 The Basic Membership Problem . . . 39
3.1.1 System Model . . . 39
3.1.2 Basic Specification of the Group Membership Problem . . . 41
3.2 Generic Interface . . . 42
3.3 Modular Architecture . . . 44

4 The HMS Protocol 47
4.1 The System Model . . . 47
4.2 Basic Elements . . . 48
4.2.1 View Identifiers . . . 48
4.2.2 State . . . 50
4.2.3 Messages . . . 52
4.2.4 Membership Events . . . 53
4.2.5 Underlying Services . . . 54
4.3 The Protocol . . . 55
4.3.1 States . . . 55
4.3.2 Basic Operation . . . 68
4.3.3 Minority Operation . . . 73
4.4 Performance of HMS . . . 78
4.5 Properties of HMS: Additional Uniform View Agreement . . . 85
4.5.1 Example Case of Use . . . 85

5 Halo Membership Service 89
5.1 Large Scale Client–Server Scenario . . . 89
5.2 The System Model . . . 91
5.3 The Client Membership Service Specification . . . 92
5.3.1 Notation . . . 93
5.3.2 Formal Specification . . . 93

5.3.3 Scenario of Applicability 96
5.4 HaloMS 98
5.4.1 Architecture 98
5.4.2 Basic Elements 100
5.4.3 The HaloMS Protocol 104
5.4.4 Basic Operation 114
5.4.5 Core Failures and Token Recovery 116
5.4.6 Token Processing 120
5.4.7 Majority Recovery 123

6 Membership On–Demand 125
6.1 Mobile Ad Hoc Networks 125
6.2 The System Model 127
6.3 On–Demand Membership Service 129
6.3.1 Specification of the On–Demand Membership Service 129
6.4 MODUS 131
6.4.1 Architecture 131
6.4.2 Basic Ingredients 132
6.4.3 Protocol Operation 134
6.4.4 Analysis and Performance 139
6.5 A Practical Case of Use 165

7 Membership Estimation for Dynamic Networks 167
7.1 Specific Membership Service for Ad Hoc Networks 167
7.1.1 An Alternative Membership Architecture 168
7.2 Membership Estimation Service 169
7.3 Interaction of Routing and Membership Estimation 170
7.3.1 Routing Protocols 170

7.3.2 Epidemic Style Membership Estimation . . . 172
7.4 Experimental Study . . . 175
7.4.1 Observable Quantities . . . 175
7.4.2 Experiments . . . 176
7.4.3 Results . . . 178
7.5 Discussion . . . 179

8 Conclusions **185**

Bibliography **188**

A Proof of Correctness of the Presented Protocols **199**
A.1 HMS Protocol . . . 199
A.1.1 Notation . . . 199
A.1.2 Safety Properties . . . 200
A.1.3 Liveness Properties . . . 206
A.1.4 Additional Uniform Majority Agreement . . . 207
A.2 HaloMS Protocol . . . 211
A.2.1 Safety Properties . . . 211
A.2.2 Liveness Properties . . . 212
A.3 MODUS Protocol . . . 213
A.3.1 Consistent Membership (Property OD.1) . . . 213
A.3.2 Active Membership Precision (Property OD.2) . . . 213
A.3.3 Eventual Stop (Property OD.3) . . . 214

B Input/Output Automata. Formalisation of Algorithms **217**
B.1 The Input/Output Automata Formalism . . . 217
B.2 The Implementation of IOA in Java . . . 219
B.3 Formalisation of the Membership Protocols . . . 223

B.3.1 HMS 223
B.3.2 HaloMS 235
B.3.3 MODUS 243