

Table of Contents

1. INTRODUCTION	1
1.1 THE TELECOMMUNICATIONS MANAGEMENT NETWORK	1
1.2 THESIS MOTIVATION	3
1.3 PROBLEM STATEMENT AND APPROACH	5
1.4 THE ENVIRONMENT AND EVOLUTION OF THIS RESEARCH WORK.....	9
1.5 THE DIFFICULT PATH TO THE ACHIEVEMENTS	13
1.6 OVERVIEW AND STYLE OF THIS THESIS	16
2. OSI SYSTEMS MANAGEMENT AND THE TELECOMMUNICATIONS MANAGEMENT NETWORK	19
2.1 INTRODUCTION	19
2.2 OSI SYSTEMS MANAGEMENT	21
2.2.1 <i>Management Functional Areas</i>	21
2.2.2 <i>The Manager-Agent Model</i>	23
2.2.3 <i>The Management Information Model</i>	25
2.2.4 <i>The Access Paradigm</i>	30
2.2.5 <i>Generic Management Functionality</i>	34
2.3 THE TELECOMMUNICATIONS MANAGEMENT NETWORK	39
2.3.1 <i>The TMN in the Broadband ISDN Context</i>	39
2.3.2 <i>TMN Architecture</i>	43
2.3.2.1 <i>Functional Architecture</i>	45
2.3.2.2 <i>Physical Architecture</i>	47
2.3.2.3 <i>Logical Layering</i>	48
2.3.2.4 <i>Interface Specification Methodology</i>	55
2.3.2.5 <i>Functional Components</i>	56
2.4 MODIFICATIONS AND EXTENSIONS TO THE TMN MODEL AND ARCHITECTURE.....	59
2.4.1 <i>Distribution and Discovery Aspects</i>	59
2.4.2 <i>Issues on Adaptation and Mediation</i>	67
2.4.2.1 <i>Aspects of adaptation</i>	67
2.4.2.2 <i>Aspects and taxonomy of types of mediation</i>	70
2.4.3 <i>Workstations and the F Interface</i>	74
2.4.4 <i>The Architecture Revisited</i>	77
2.4.5 <i>Discussion</i>	82
2.5 SUMMARY.....	85
2.5.1 <i>Research Contribution</i>	85
2.5.2 <i>Towards the Realisation of the TMN</i>	87

3. MAPPING THE OSI-SM / TMN MODEL ONTO OBJECT-ORIENTED PROGRAMMING ENVIRONMENTS.....	89
3.1 INTRODUCTION	89
3.2 OBJECT-ORIENTED DISTRIBUTED SYSTEMS	91
3.2.1 <i>Object-Oriented Development Principles</i>	91
3.2.2 <i>Object-Oriented Distribution Frameworks</i>	93
3.3 ISSUES IN REALISING THE PROTOCOL PART OF THE Q ₃ INTERFACE.....	97
3.3.1 <i>The Q₃ Protocol Stack</i>	97
3.3.2 <i>Issues in Realising the Upper Layer Part of Q₃</i>	101
3.3.2.1 General Issues in Realising Upper Layer Infrastructures	101
3.3.2.2 Related Work on CMISE APIs.....	102
3.3.2.3 Issues in Realising CMISE Over ROSE	104
3.3.2.4 Alternative Mappings for CMISE	113
3.3.2.5 Summary.....	118
3.4 ISSUES IN OBJECT-ORIENTED ASN.1 MANIPULATION	119
3.5 ISSUES IN REALISING OBJECT-ORIENTED MANAGER INFRASTRUCTURES.....	127
3.5.1 <i>Introduction</i>	127
3.5.2 <i>Related Work</i>	128
3.5.3 <i>The Remote MIB Manager Infrastructure</i>	129
3.5.3.1 Design Issues and Objectives.....	130
3.5.3.2 The RMIB Model.....	132
3.5.3.3 The RMIB API.....	135
3.5.4 <i>The Shadow MIB Managed Object Level Infrastructure</i>	139
3.5.4.1 The SMIB Model	139
3.5.4.2 The SMIB API	142
3.5.4.3 Manager Mapping of GDMO to O-O Programming Languages	143
3.5.5 <i>The Tcl-RMIB Scripting Manager Infrastructure</i>	147
3.5.6 <i>The Management Information Repository</i>	149
3.5.7 <i>Summary</i>	153
3.6 ISSUES IN REALISING OBJECT-ORIENTED AGENT INFRASTRUCTURES.....	155
3.6.1 <i>Introduction</i>	155
3.6.2 <i>Related Work</i>	156
3.6.3 <i>The Overall Architecture</i>	158
3.6.4 <i>A GDMO to C++ Mapping for Managed Objects</i>	161
3.6.5 <i>The Relationship of Managed Objects and Associated Resources</i>	166
3.6.6 <i>Realisation of the “Difficult” Agent Aspects</i>	167
3.6.7 <i>Systems Management Functions</i>	168
3.6.8 <i>Summary</i>	170

3.7 ISSUES ON SYNCHRONOUS VS. ASYNCHRONOUS REMOTE EXECUTION MODELS.....	171
3.7.1 Remote Procedure Call and Message Passing Paradigms	171
3.7.2 The OSIMIS Coordination Mechanism.....	174
3.8 PERFORMANCE ANALYSIS AND EVALUATION	177
3.8.1 The Environment and Methodology Used in the Experiments.....	177
3.8.2 Program Size	180
3.8.3 Response Times.....	185
3.8.4 Packet Sizes	190
3.8.5 Summary.....	193
3.9 VALIDATION	195
3.9.1 The Proposed Environment as an Object-Oriented Distributed Framework.....	195
3.9.2 Object-Oriented Support for TMN Operations Systems	197
3.9.3 Support for Peer-to-Peer Interactions	199
3.9.4 Implementability in Terms of the Overall Required Software.....	199
3.9.5 Further Validation	200
3.10 SUMMARY	201
3.10.1 Overview of this Chapter.....	201
3.10.2 Research Contribution	203
4. MAPPING THE OSI-SM / TMN MODEL ONTO EMERGING DISTRIBUTED OBJECT FRAMEWORKS.....	207
4.1 INTRODUCTION	207
4.2 OPEN DISTRIBUTED PROCESSING.....	209
4.2.1 The ODP Model.....	209
4.2.2 The ODP Distribution Transparencies	211
4.2.3 The ODP Trading Function.....	212
4.2.4 The ODP Viewpoints	214
4.2.5 OSI-SM / TMN and the ODP Viewpoints	216
4.3 ODP-BASED TECHNOLOGIES.....	219
4.3.1 The Advanced Networked Systems Architecture.....	219
4.3.2 The OSF Distributed Computing and Management Environment.....	221
4.3.3 The OMG Common Object Request Broker Architecture	223
4.3.3.1 The Object Request Broker Model.....	223
4.3.3.2 The Information Model.....	225
4.3.3.3 The Access Paradigm	228
4.3.3.4 Summary	231
4.3.4 A Summary of the Relevant Technologies.....	231

Table of Contents

4.4 USING DISTRIBUTED OBJECT TECHNOLOGIES IN TMN	233
4.4.1 Mapping OSI-SM to ODP	233
4.4.2 Mapping OSI-SM GDMO to CORBA IDL	235
4.4.3 An Initial Mapping of the OSI-SM Model to CORBA.....	239
4.4.3.1 A ODP-Oriented Approach Using Discovery Through Trading.....	239
4.4.3.2 A TMN-Oriented Approach Using Discovery Through Naming and Containment.....	242
4.4.3.3 Adding Object Lifecycle and Event Dissemination Aspects.....	244
4.4.3.4 Summary and the Proposed Architecture.....	246
4.4.4 A Complete Mapping of the OSI-SM Model to CORBA	248
4.4.4.1 Related Research Work	248
4.4.4.2 Adding Multiple Attribute Access and Filtering.....	250
4.4.4.3 Fine-grain Event Dissemination and Multiple Object Access Through the Management Broker	253
4.4.4.4 Design, Implementation and OSI-SM to CORBA Migration Aspects.....	261
4.5 PERFORMANCE ANALYSIS AND EVALUATION	265
4.5.1 Program Size	266
4.5.2 Response Times.....	268
4.5.3 Packet Sizes	270
4.6 SUMMARY.....	271
4.6.1 Overview of this Chapter.....	271
4.6.2 Research Contribution	273
5. SUMMARY AND CONCLUSIONS	275
5.1 THE CONTRIBUTION AND MAIN FINDINGS OF THIS THESIS.....	275
5.2 POSSIBLE FUTURE WORK	281
APPENDICES	285
APPENDIX A: WORK BASED ON THE PROPOSED TMN DEVELOPMENT ENVIRONMENT	285
APPENDIX B: THE OBJECT MODELLING TECHNIQUE NOTATION	291
APPENDIX C: SPECIFICATION OF THE MANAGED OBJECT CLASSES USED IN THE EXAMPLES.....	293
APPENDIX D: A STRING LANGUAGE FOR CMIS FILTERS.....	299
APPENDIX E: LIGHTWEIGHT CMIS/P SPECIFICATION.....	301
ACRONYMS AND ABBREVIATIONS.....	303
LIST OF CAPTIONS.....	311
LIST OF FIGURES	311
LIST OF TABLES	315
LIST OF CODE CAPTIONS	317
BIBLIOGRAPHY	319

List of Figures

Figure 1-1 European Research Projects and OSIMIS Evolution	12
Figure 2-1 The Manager-Agent Model	23
Figure 2-2 Models of Management Organisation	25
Figure 2-3 Example OSI Inheritance and Containment Hierarchies	27
Figure 2-4 OSI-SM Protocol Stack	31
Figure 2-5 CMIS Interactions	32
Figure 2-6 TMN Relationship to a Telecommunications Network (from [M3010]).....	40
Figure 2-7 TMN Function Blocks and Reference Points (from [M3010])	46
Figure 2-8 Relationship of Reference Points and Interfaces	48
Figure 2-9 Cascaded Hierarchical Communication (from [M3010])	49
Figure 2-10 Logical Layered Architecture (from [M3010]).....	50
Figure 2-11 TMN Functional and Example Layered Physical Architecture.....	52
Figure 2-12 Classes of q and x Reference Points.....	53
Figure 2-13 Updated Classes of q and x Reference Points	54
Figure 2-14 OSF Decomposition into Functional Components	57
Figure 2-15 X.500 Directory Organisational and Administrative Model	60
Figure 2-16 The Universal Directory and Management Name Space	62
Figure 2-17 The Directory Schema for Distribution and Discovery (from [X750])	65
Figure 2-18 Adaptation and Mediation Class B	68
Figure 2-19 Mediation Class A	71
Figure 2-20 The WS-OSF Function Block.....	75
Figure 2-21 TMN and Directory Integration.....	78
Figure 2-22 Revised TMN Functional Architecture	79
Figure 2-23 Revised OSF Decomposition into Functional Components	80
Figure 3-1 Lower Layer Protocol Profile for the Q3 Interface (from [Q811])	97

List of Figures

Figure 3-2 Upper Layer Protocol Profile for the Q3 Interface.....	99
Figure 3-3 OSI Invoker and Performer Interactions.....	100
Figure 3-4 The OSIMIS CMISE Realisation	112
Figure 3-5 The CMOT Protocol Stack	114
Figure 3-6 The Lightweight and String-based CMIP Protocol Stack.....	116
Figure 3-7 Example ASN.1 Class Hierarchy	122
Figure 3-8 C++ Class Generation for ASN.1 Types.....	126
Figure 3-9 Remote MIB Model and Interactions	132
Figure 3-10 Shadow MIB Model and Interactions.....	140
Figure 3-11 OMT Relationships of the RMIB and SMIB Classes	141
Figure 3-12 Information Produced Through the GDMO/ASN.1 Model	152
Figure 3-13 Object-Oriented OSI-SM Agent Decomposition.....	159
Figure 3-14 The Internal Layout of a uxObj Instance and Associated Meta-Class Objects...	164
Figure 3-15 The OSIMIS Co-ordination Model	174
Figure 3-16 OMT Relationships of the Co-ordination Classes.....	175
Figure 3-17 The Experiment Environment	178
Figure 3-18 Service Access Points for the Performance Measurements.....	179
Figure 3-19 Application Sizes at the Various Service Access Points.....	182
Figure 3-20 Response Times for Association Establishment and Release.....	185
Figure 3-21 Response Times for an Echo Operation	187
Figure 3-22 Connection Establishment, Release and Echo Operation Packet Sizes.....	192
Figure 3-23 Object-Oriented Decomposition of a TMN OS	197
Figure 4-1 The ODP Framework.....	210
Figure 4-2 ODP Distribution Transparencies.....	211
Figure 4-3 The ODP Trading Function.....	212
Figure 4-4 The ODP Viewpoints	214

Figure 4-5 The OMG CORBA Model	224
Figure 4-6 Peer-to-Peer Object Interaction for Events and Asynchronous Operations	226
Figure 4-7 The CORBA IIOP Protocol Stack	229
Figure 4-8 IDL Inheritance Hierarchy Resulting from GDMO Mapping.....	237
Figure 4-9 Object Discovery Through Trading	240
Figure 4-10 A Basic Architecture for OSI-SM to CORBA Mapping.....	247
Figure 4-11 A Complete Architecture for OSI-SM to CORBA Mapping.....	255
Figure 4-12 Dual Q ₃ and CORBA Agent.....	262
Figure 4-13 The Management Broker as an Agent Computational Object.....	263
Figure B-1 OMT Notation for Inheritance, Containment and Other Relationships	291

List of Figures

List of Tables

Table 2-1	OSI Systems Management Functions	35
Table 2-2	Relationship of Function Blocks and Functional Components	58
Table 2-3	Characteristics of the M, Q _x and Q ₃ Interfaces	73
Table 2-4	Revised Relationship of Function Blocks and Functional Components	80
Table 3-1	ROSE Primitives and Associated Parameters	105
Table 3-2	CMIS Primitives and Associated Parameters	106
Table 3-3	(Part of) The MSAP CMIS API	110
Table 3-4	String-based CMIP PDUs	117
Table 3-5	Tcl-RMIB Management Commands	148
Table 3-6	Application Sizes at the Various Service Access Points	181
Table 3-7	Summary of Q ₃ Memory Overheads	184
Table 3-8	Response Times for Association Establishment and Release	185
Table 3-9	Response Times for an Echo Operation	187
Table 3-10	Packet Sizes for Connection Establishment	191
Table 3-11	Packet Sizes for Connection Release	191
Table 3-12	Packet Sizes for the Echo Operation (zero length string)	192
Table 3-13	Amount of Software in the OSIMIS TMN Platform	200
Table 4-1	A Comparison of Distributed Object Technologies	232
Table 4-2	Summary of the CORBA Memory Overheads	267
Table D-1	Lexemes Used for CMIS Filter Assertions	300

List of Tables

List of Code Captions

Code 3-1 The Generic Attr Class that Models an ASN.1 Type.....	121
Code 3-2 The AVA Class	124
Code 3-3 Example Use of the O-O ASN.1 API.....	125
Code 3-4 Proposed Modification of the CMIS/P EventReport PDU	135
Code 3-5 The RMIB O-O API	136
Code 3-6 Example Use of the RMIB Infrastructure	137
Code 3-7 Example Use of the SMIB Infrastructure.....	143
Code 3-8 The C++ Mapping “Problem” with GDMO Actions	145
Code 3-9 Proposed Modification of the GDMO Action Template.....	146
Code 3-10 Structure of the OSIMIS Management Information Repository	151
Code 3-11 The MIB Agent to Managed Object Interface	161
Code 3-12 The Polymorphic Managed Object Methods.....	163
Code 3-13 The O-O Coordination API - the KS Class	176
Code 3-14 The uxObj Instance Used for the Memory Measurements.....	183
Code 4-1 The Top and UxObj Managed Object IDL Interfaces.....	238
Code 4-2 The i_ManagedObject IDL Interface	243
Code 4-3 The i_uxObjFactory IDL Interface	245
Code 4-4 Multiple Attribute Access and Filtering	251
Code 4-5 Single Object CMIS-like Access in IDL	258
Code 4-6 Multiple Object CMIS-like Access in IDL.....	259
Code 4-7 The Generic CMIS-like Manager Interface	260

List of Code Captions