

CLOUD COMPUTING

Methodology, Systems,
and Applications

Edited by

Lizhe Wang • Rajiv Ranjan
Jinjun Chen • Boualem Benatallah



CRC Press
Taylor & Francis Group
Boca Raton London New York

CRC Press is an imprint of the
Taylor & Francis Group, an **Informa** business

Contents

List of Figures	xv
List of Tables	xxv
Foreword	xxvii
Preface	xxix
Contributors	xxxiii
I Fundamentals of Cloud Computing: Concept, Methodology, and Overview	1
1 Cloud Computing: An Overview	3
<i>Abhishek Kalapatapu and Mahasweta Sarkar</i>	
1.1 Introduction	3
1.2 Cloud Computing: Past, Present, and Future	4
1.3 Cloud Computing Methodologies	7
1.4 The Cloud Architecture and Cloud Deployment Techniques	8
1.5 Cloud Services	13
1.6 Cloud Applications	16
1.7 Issues with Cloud Computing	17
1.8 Cloud Computing and Grid Computing: A Comparative Study	19
1.9 Conclusion	25
2 Cloud Computing and Startups	31
<i>Åke Edlund and Ilja Livenson</i>	
2.1 Introduction	31
2.2 Time to Market	32
2.3 Cloud Computing Implications	33
2.4 Changes to the Startup Ecosystem	35
2.5 Evolution of the Cloud-Based Company	39
2.6 Summary	43

3 A Taxonomy of Interoperability for IaaS	45
<i>Ralf Teckelmann, Anthony Sulistio, and Christoph Reich</i>	
3.1 Introduction	46
3.2 Interoperability of Cloud Platforms	49
3.3 Taxonomy of Interoperability for IaaS	50
3.4 Related Work	70
3.5 Conclusion and Future Work	71
4 A Taxonomy Study on Cloud Computing Systems and Technologies	73
<i>Christian Baun and Marcel Kunze</i>	
4.1 Deployment Models	74
4.2 Delivery Models	76
4.3 Cloud Resource Management	82
4.4 Conclusion	88
5 A Network-Oriented Survey and Open Issues in Cloud Computing	91
<i>Luigi Atzori, Fabrizio Granelli, and Antonio Pescapé</i>	
5.1 Introduction	92
5.2 A Brief View of Cloud Computing	93
5.3 Research Challenges for Engineering Cloud Computing Architectures	98
5.4 Conclusions and Final Remarks	107
6 A Taxonomy of QoS Management and Service Selection Methodologies for Cloud Computing	109
<i>Amir Vahid Dastjerdi and Rajkumar Buyya</i>	
6.1 Introduction	110
6.2 General Model of Web Service Selection	111
6.3 Taxonomy	113
6.4 Future Directions and Conclusion	131
7 An Introduction to Open-Source IaaS Cloud Middleware	133
<i>Peter Sempolinski and Douglas Thain</i>	
7.1 Introduction	134
7.2 Previous Work	135
7.3 Components of an Open-Source Cloud	135
7.4 Open-Source Cloud Implementations	137
7.5 A Cloud Builder's Checklist	141
7.6 The Cloud Computing Software Stack	142
7.7 Future Opportunities	148
7.8 Conclusion	149
7.9 Acknowledgments	149

8 Cloud Computing: Performance Analysis	151
<i>Hamzeh Khazaei, Jelena Mišić, and Vojislav B. Mišić</i>	
8.1 Introduction	152
8.2 Related Work	153
8.3 The Analytical Model	155
8.4 Numerical Validation	160
8.5 Conclusions	165
8.6 Glossary	165
9 Intercloud: The Future of Cloud Computing. Concepts and Advantages	167
<i>Antonio Celesti, Francesco Tusa, Massimo Villari, and Antonio Puliafito</i>	
9.1 Introduction	168
9.2 Federation: From the Political World to the IT	169
9.3 Intercloud Resource Sharing Models	176
9.4 Advantages and New Business Opportunities	178
9.5 “High Cooperation Federation” Establishment	184
9.6 Technologies for Achieving the Intercloud: an Overview	187
9.7 Conclusions and Future Research Challenges	193
II Cloud Computing Functionalities and Provisioning	195
10 TS3: A Trust Enhanced Secure Cloud Storage Service	197
<i>Surya Nepal, Shiping Chen, and Jinhui Yao</i>	
10.1 Introduction	198
10.2 The Framework — TrustStore	200
10.3 Trust Enhanced Secure Cloud Storage Service (TS3)	203
10.4 Prototype Implementation	211
10.5 Related Work	217
10.6 Conclusions and Future Work	219
11 High Performance Computing Clouds	221
<i>Andrzej Goscinski, Michael Brock, and Philip Church</i>	
11.1 Introduction	223
11.2 High Performance Computing (HPC) vs. Cloud Computing	224
11.3 Taxonomy of HPC Clouds	226
11.4 HPC Cloud Challenges	231
11.5 HPC Cloud Solution: Proposal	234
11.6 Cloud Benchmark of HPC Applications	242
11.7 Conclusions and Future Trends	258

12 Multitenancy: A New Architecture for Clouds	261
<i>Enrique Jiménez-Domingo, Ángel Lagares-Lemos, and Juan Miguel Gómez-Berbís</i>	
12.1 Abstract	261
12.2 Introduction: Concepts and Features	262
12.3 Background	264
12.4 Features, Advantages and Problems	266
12.5 Modeling Multitenancy	267
12.6 An Original Example	270
12.7 Future Research Directions	274
12.8 Conclusions	275
13 SOA and QoS Management for Cloud Computing	277
<i>Vincent C. Emeakaroha, Michael Maurer, Ivan Breskovic, Ivona Brandic and Schahram Dustdar</i>	
13.1 Introduction	278
13.2 Related Work	279
13.3 Background and Motivations	281
13.4 Design of the LoM2HiS Framework	282
13.5 Knowledge Management	288
13.6 Evaluations	292
13.7 Conclusion and Future Work	299
14 Auto-Scaling, Load Balancing and Monitoring in Commercial and Open-Source Clouds	301
<i>Eddy Caron, Frédéric Desprez, Luis Rodero-Merino, and Adrian Muresan</i>	
14.1 Introduction	303
14.2 Cloud Auto-Scaling	304
14.3 Cloud Client Load Balancing	309
14.4 Cloud Client Resource Monitoring	315
14.5 Conclusions	322
15 Monitoring: A Fundamental Process to Provide QoS Guarantees in Cloud-Based Platforms	325
<i>Gregory Katsaros, Roland Kübert, Georgina Gallizo, and Tinghe Wang</i>	
15.1 Introduction	326
15.2 Monitoring in the Cloud	326
15.3 Available Monitoring Tools/Solution	329
15.4 Monitoring Infrastructure: A Generic Approach	336
15.5 Conclusions	341

16 Cloud Bursting: Managing Peak Loads by Leasing Public Cloud Services	343
<i>Michael Mattess, Christian Vecchiola, Saurabh Kumar Garg, and Rajkumar Buyya</i>	
16.1 Introduction	344
16.2 Aneka	346
16.3 Hybrid Cloud Deployment Using Aneka	348
16.4 Motivation: Case Study Example	350
16.5 Resource Provisioning Policies	352
16.6 Performance Analysis	356
16.7 Related Work	365
16.8 Conclusions	367
17 Energy-Efficiency Models for Resource Provisioning and Application Migration in Clouds	369
<i>Young Choon Lee, Dilkushan T. M. Karunaratne, Chen Wang, and Albert Y. Zomaya</i>	
17.1 Introduction	370
17.2 Energy Efficiency in LDCSs	372
17.3 Energy Efficiency and Applications	374
17.4 Energy Efficient VM Consolidation	378
17.5 Summary and Conclusion	387
18 Security, Privacy and Trust Management Issues for Cloud Computing	389
<i>Sara Kadry Hamouda and John Glauert</i>	
18.1 Chapter Overview	391
18.2 Introduction	392
18.3 What Is Cloud Computing Security?	393
18.4 Cloud Computing Security Scenarios	397
18.5 Cloud Security Challenges	399
18.6 How to Handle Cloud Security Challenges	401
18.7 Cloud Computing Privacy	411
18.8 Trust Management	413
18.9 Recommendation	415
18.10 Summary	417
18.11 Glossary	418
III Case Studies, Applications, and Future Directions	423
19 Fundamentals of Cloud Application Architecture	425
<i>Justin Y. Shi</i>	
19.1 Introduction	426
19.2 Necessary and Sufficient Conditions	427

19.3	Unit of Transmission (UT)	431
19.4	Mission Critical Application Architecture: A First Example	431
19.5	Maximally Survivable Transaction Processing	435
19.6	Maximally Survivable High Performance Computing	448
19.7	Summary	464
19.8	Acknowledgments	466
20	An Ontology for the Cloud in mOSAIC	467
<i>Francesco Moscato, Rocco Aversa, Beniamino Di Martino, Massimiliano Rak and Salvatore Venticinque, and Dana Petcu</i>		
20.1	Introduction	468
20.2	The mOSAIC Project	469
20.3	Languages for Ontologies Definition	471
20.4	Cloud Standards and Proposals	474
20.5	mOSAIC Ontology	476
20.6	Conclusions	484
21	On the Spectrum of Web Scale Data Management	487
<i>Liang Zhao, Sherif Sakr, and Anna Liu</i>		
21.1	Introduction	488
21.2	NoSQL Key Systems	491
21.3	NoSQL Open Source Projects	496
21.4	Database-as-a-Service	498
21.5	Web Scale Data Management: Trade-Offs	503
21.6	Discussion and Conclusions	506
22	Leasing Videoconference Resources on Hybrid Clouds	511
<i>Javier Cerviño, Fernando Escrivano, Pedro Rodríguez, Irena Trajkovska, and Joaquín Salvachúa</i>		
22.1	Introduction	512
22.2	Related Work	513
22.3	Motivation	515
22.4	Implementation	517
22.5	Validation of the Hybrid Cloud	520
22.6	Conclusion	525
23	Advanced Computing Services for Radiotherapy Treatment Planning	529
<i>Luis M. Carril, Zahara Martín-Rodríguez, Carlos Mouríño, Andrés Gómez, Rubén Díaz, and Carlos Fernández</i>		
23.1	Introduction	530
23.2	IMRT Verification	532
23.3	Architecture	538

23.4	eIMRT as SaaS in a Cloud Infrastructure	539
23.5	Testbeds	543
23.6	Experimental Results	546
23.7	Discussion	548
23.8	Future Work	549
23.9	Conclusions	550
24	Cloud Security Requirements Analysis and Security Policy Development Using HOOMT	553
<i>Kenneth Kofi Fletcher and Xiaoqing (Frank) Liu</i>		
24.1	Introduction	554
24.2	Related Work	557
24.3	The Approach	559
24.4	Illustrative Examples	563
24.5	Case Study—Application Example	569
24.6	Conclusion	579
25	Exploring the Use of Hybrid HPC-Grids/Clouds Infrastructure for Science and Engineering	583
<i>Hyunjoo Kim, Yaakoub El-Khamra, Shantenu Jha, and Manish Parashar</i>		
25.1	Introduction	584
25.2	The Hybrid HPC-Grids/Clouds Infrastructure	586
25.3	Autonomic Application Management Using CometCloud . .	587
25.4	Scientific Application Workflow	590
25.5	An Experimental Investigation of HPC Grids–Cloud Hybrid Usage Modes	592
25.6	Acceleration Usage Mode: Application and Infrastructure Adaptivity	600
25.7	Conclusion	610
26	RestFS: The Filesystem as a Connector Abstraction for Flexible Resource and Service Composition	613
<i>Joseph Kaylor, Konstantin Läufer, and George K. Thiruvathukal</i>		
26.1	Related Work	615
26.2	Composition of Web Services through the Filesystem	618
26.3	Building Application Filesystems with the Naked Object Filesystem (NOFS)	629
26.4	Architecture and Details of RestFS	638
26.5	Summary	643

27 Aneka Cloud Application Platform and Its Integration with Windows Azure	645
<i>Yi Wei, Karthik Sukumar, Christian Vecchiola, Dileban Karunamoorthy, and Rajkumar Buyya</i>	
27.1 Introduction	647
27.2 Background	649
27.3 Design	659
27.4 Implementation	664
27.5 Experiments	672
27.6 Related Work	673
27.7 Sample Applications of Aneka	676
27.8 Conclusions and Future Directions	678
Bibliography	681
Index	743