

Contents at a Glance

Foreword	xxix
CHAPTER 1: Introduction	1
CHAPTER 2: Case Study Background	13
PART I: FUNDAMENTAL CLOUD COMPUTING	
CHAPTER 3: Understanding Cloud Computing	25
CHAPTER 4: Fundamental Concepts and Models	51
CHAPTER 5: Cloud-Enabling Technology	79
CHAPTER 6: Fundamental Cloud Security	117
PART II: CLOUD COMPUTING MECHANISMS	
CHAPTER 7: Cloud Infrastructure Mechanisms	139
CHAPTER 8: Specialized Cloud Mechanisms	169
CHAPTER 9: Cloud Management Mechanisms	213
CHAPTER 10: Cloud Security Mechanisms	229
PART III: CLOUD COMPUTING ARCHITECTURE	
CHAPTER 11: Fundamental Cloud Architectures	255
CHAPTER 12: Advanced Cloud Architectures	281
CHAPTER 13: Specialized Cloud Architectures	323
PART IV: WORKING WITH CLOUDS	
CHAPTER 14: Cloud Delivery Model Considerations	359
CHAPTER 15: Cost Metrics and Pricing Models	379
CHAPTER 16: Service Quality Metrics and SLAs	403
PART V: APPENDICES	
APPENDIX A: Case Study Conclusions	421
APPENDIX B: Industry Standards Organizations	427
APPENDIX C: Mapping Mechanisms to Characteristics	433
APPENDIX D: Data Center Facilities (TIA-942)	437
APPENDIX E: Cloud-Adapted Risk Management Framework	443
APPENDIX F: Cloud Provisioning Contracts	451
APPENDIX G: Cloud Business Case Template	463
About the Authors	467
About the Contributors	469
Index	473

Contents

Foreword	xxix
Acknowledgments	xxxiii
CHAPTER 1: Introduction	1
1.1 Objectives of This Book	3
1.2 What This Book Does Not Cover	4
1.3 Who This Book Is For	4
1.4 How This Book Is Organized	4
Part I: Fundamental Cloud Computing	5
Chapter 3: Understanding Cloud Computing	5
Chapter 4: Fundamental Concepts and Models	5
Chapter 5: Cloud-Enabling Technology	5
Chapter 6: Fundamental Cloud Security	5
Part II: Cloud Computing Mechanisms	5
Chapter 7: Cloud Infrastructure Mechanisms	6
Chapter 8: Specialized Cloud Mechanisms	6
Chapter 9: Cloud Management Mechanisms	6
Chapter 10: Cloud Security Mechanisms	6
Part III: Cloud Computing Architecture	6
Chapter 11: Fundamental Cloud Architectures	6
Chapter 12: Advanced Cloud Architectures	7
Chapter 13: Specialized Cloud Architectures	7
Part IV: Working with Clouds	7
Chapter 14: Cloud Delivery Model Considerations	7
Chapter 15: Cost Metrics and Pricing Models	8
Chapter 16: Service Quality Metrics and SLAs	8
Part V: Appendices	8
Appendix A: Case Study Conclusions	8
Appendix B: Industry Standards Organizations	8
Appendix C: Mapping Mechanisms to Characteristics	8
Appendix D: Data Center Facilities (TIA-942)	8
Appendix E: Emerging Technologies	8
Appendix F: Cloud Provisioning Contracts	9
Appendix G: Cloud Business Case Template	9

1.5 Conventions	9
Symbols and Figures	9
Summary of Key Points	9
1.6 Additional Information	9
Updates, Errata, and Resources (www.servicetechbooks.com)	9
Referenced Specifications (www.servicetechspecs.com)	10
The Service Technology Magazine (www.servicetechmag.com)	10
International Service Technology Symposium (www.servicetechsymposium.com)	10
What Is Cloud? (www.whatiscloud.com)	10
What Is REST? (www.whatisrest.com)	10
Cloud Computing Design Patterns (www.cloudpatterns.org)	10
Service-Orientation (www.serviceorientation.com)	11
CloudSchool.com™ Certified Cloud (CCP) Professional (www.cloudschool.com)	11
SOASchool.com® SOA Certified (SOACP) Professional (www.soaschool.com)	11
Notification Service	11
CHAPTER 2: Case Study Background	13
2.1 Case Study #1: ATN	14
Technical Infrastructure and Environment	14
Business Goals and New Strategy	15
Roadmap and Implementation Strategy	15
2.2 Case Study #2: DTGOV	16
Technical Infrastructure and Environment	17
Business Goals and New Strategy	18
Roadmap and Implementation Strategy	19
2.3 Case Study #3: Innovartus Technologies Inc.	20
Technical Infrastructure and Environment	20
Business Goals and Strategy	20
Roadmap and Implementation Strategy	21

PART I: FUNDAMENTAL CLOUD COMPUTING

CHAPTER 3: Understanding Cloud Computing25

3.1	Origins and Influences	26
	A Brief History	26
	Definitions	27
	Business Drivers	28
	Capacity Planning	28
	Cost Reduction	29
	Organizational Agility	30
	Technology Innovations	30
	Clustering	31
	Grid Computing	31
	Virtualization	32
	Technology Innovations vs. Enabling Technologies	32
3.2	Basic Concepts and Terminology	33
	Cloud	33
	IT Resource	34
	On-Premise	36
	Cloud Consumers and Cloud Providers	36
	Scaling	37
	Horizontal Scaling	37
	Vertical Scaling	37
	Cloud Service	38
	Cloud Service Consumer	40
3.3	Goals and Benefits	40
	Reduced Investments and Proportional Costs	41
	Increased Scalability	42
	Increased Availability and Reliability	43
3.4	Risks and Challenges	45
	Increased Security Vulnerabilities	45
	Reduced Operational Governance Control	45
	Limited Portability Between Cloud Providers	47
	Multi-Regional Compliance and Legal Issues	48

CHAPTER 4: Fundamental Concepts and Models	51
4.1 Roles and Boundaries	52
Cloud Provider	52
Cloud Consumer	52
Cloud Service Owner	53
Cloud Resource Administrator	54
Additional Roles	56
Organizational Boundary	56
Trust Boundary	57
4.2 Cloud Characteristics	58
On-Demand Usage	59
Ubiquitous Access	59
Multitenancy (and Resource Pooling)	59
Elasticity	61
Measured Usage	61
Resiliency	61
4.3 Cloud Delivery Models	63
Infrastructure-as-a-Service (IaaS)	64
Platform-as-a-Service (PaaS)	65
Software-as-a-Service (SaaS)	66
Comparing Cloud Delivery Models	67
Combining Cloud Delivery Models	69
IaaS + PaaS	69
IaaS + PaaS + SaaS	72
4.4 Cloud Deployment Models	73
Public Clouds	73
Community Clouds	74
Private Clouds	75
Hybrid Clouds	77
Other Cloud Deployment Models	78

CHAPTER 5: Cloud-Enabling Technology79

5.1 Broadband Networks and Internet Architecture	80
Internet Service Providers (ISPs)	80
Connectionless Packet Switching (Datagram Networks)	83
Router-Based Interconnectivity	83
Physical Network	84
Transport Layer Protocol	84
Application Layer Protocol	85
Technical and Business Considerations	85
Connectivity Issues	85
Network Bandwidth and Latency Issues	88
Cloud Carrier and Cloud Provider Selection	89
5.2 Data Center Technology	90
Virtualization	90
Standardization and Modularity	90
Automation	91
Remote Operation and Management	92
High Availability	92
Security-Aware Design, Operation, and Management	92
Facilities	92
Computing Hardware	93
Storage Hardware	93
Network Hardware	95
Carrier and External Networks Interconnection	95
Web-Tier Load Balancing and Acceleration	95
LAN Fabric	95
SAN Fabric	95
NAS Gateways	95
Other Considerations	96
5.3 Virtualization Technology	97
Hardware Independence	98
Server Consolidation	98
Resource Replication	98
Operating System-Based Virtualization	99
Hardware-Based Virtualization	101
Virtualization Management	102
Other Considerations	102

5.4 Web Technology	103
Basic Web Technology	104
Web Applications	104
5.5 Multitenant Technology	106
5.6 Service Technology	108
Web Services	109
REST Services	110
Service Agents	111
Service Middleware	112
5.7 Case Study Example	113
CHAPTER 6: Fundamental Cloud Security	117
6.1 Basic Terms and Concepts	118
Confidentiality	118
Integrity	119
Authenticity	119
Availability	119
Threat	120
Vulnerability	120
Risk	120
Security Controls	120
Security Mechanisms	121
Security Policies	121
6.2 Threat Agents	121
Anonymous Attacker	122
Malicious Service Agent	123
Trusted Attacker	123
Malicious Insider	123
6.3 Cloud Security Threats	124
Traffic Eavesdropping	124
Malicious Intermediary	124
Denial of Service	126
Insufficient Authorization	127
Virtualization Attack	127
Overlapping Trust Boundaries	129

6.4 Additional Considerations	131
Flawed Implementations	131
Security Policy Disparity	132
Contracts	132
Risk Management	133
6.5 Case Study Example	135

PART II: CLOUD COMPUTING MECHANISMS

CHAPTER 7: Cloud Infrastructure Mechanisms 139

7.1 Logical Network Perimeter	140
Case Study Example	142
7.2 Virtual Server	144
Case Study Example	145
7.3 Cloud Storage Device	149
Cloud Storage Levels	149
Network Storage Interfaces	150
Object Storage Interfaces	151
Database Storage Interfaces	151
<i>Relational Data Storage</i>	151
<i>Non-Relational Data Storage</i>	152
Case Study Example	152
7.4 Cloud Usage Monitor	155
Monitoring Agent	155
Resource Agent	155
Polling Agent	157
Case Study Example	157
7.5 Resource Replication	161
Case Study Example	162
7.6 Ready-Made Environment	166
Case Study Example	167

CHAPTER 8: Specialized Cloud Mechanisms	169
8.1 Automated Scaling Listener	170
Case Study Example	172
8.2 Load Balancer	176
Case Study Example	177
8.3 SLA Monitor	178
Case Study Example	180
SLA Monitor Polling Agent	180
SLA Monitoring Agent	180
8.4 Pay-Per-Use Monitor	184
Case Study Example	187
8.5 Audit Monitor	189
Case Study Example	189
8.6 Failover System	191
Active-Active	191
Active-Passive	194
Case Study Example	196
8.7 Hypervisor	200
Case Study Example	201
8.8 Resource Cluster	203
Case Study Example	206
8.9 Multi-Device Broker	208
Case Study Example	209
8.10 State Management Database	210
Case Study Example	211

CHAPTER 9: Cloud Management Mechanisms213

- 9.1 Remote Administration System214
 - Case Study Example219
- 9.2 Resource Management System219
 - Case Study Example221
- 9.3 SLA Management System.222
 - Case Study Example224
- 9.4 Billing Management System225
 - Case Study Example227

CHAPTER 10: Cloud Security Mechanisms229

- 10.1 Encryption230
 - Symmetric Encryption231
 - Asymmetric Encryption231
 - Case Study Example233
- 10.2 Hashing.234
 - Case Study Example235
- 10.3 Digital Signature236
 - Case Study Example238
- 10.4 Public Key Infrastructure (PKI)240
 - Case Study Example242
- 10.5 Identity and Access Management (IAM)243
 - Case Study Example244
- 10.6 Single Sign-On (SSO)244
 - Case Study Example246
- 10.7 Cloud-Based Security Groups247
 - Case Study Example249
- 10.8 Hardened Virtual Server Images.251
 - Case Study Example252

PART III: CLOUD COMPUTING ARCHITECTURE

CHAPTER 11: Fundamental Cloud Architectures255

11.1	Workload Distribution Architecture	256
11.2	Resource Pooling Architecture	257
11.3	Dynamic Scalability Architecture	262
11.4	Elastic Resource Capacity Architecture	265
11.5	Service Load Balancing Architecture	268
11.6	Cloud Bursting Architecture	271
11.7	Elastic Disk Provisioning Architecture	272
11.8	Redundant Storage Architecture	275
11.9	Case Study Example	277

CHAPTER 12: Advanced Cloud Architectures281

12.1	Hypervisor Clustering Architecture	282
12.2	Load Balanced Virtual Server Instances Architecture	288
12.3	Non-Disruptive Service Relocation Architecture	293
12.4	Zero Downtime Architecture	298
12.5	Cloud Balancing Architecture	299
12.6	Resource Reservation Architecture	301
12.7	Dynamic Failure Detection and Recovery Architecture	306
12.8	Bare-Metal Provisioning Architecture	309
12.9	Rapid Provisioning Architecture	312
12.10	Storage Workload Management Architecture	315
12.11	Case Study Example	321

CHAPTER 13: Specialized Cloud Architectures323

- 13.1 Direct I/O Access Architecture324
- 13.2 Direct LUN Access Architecture326
- 13.3 Dynamic Data Normalization Architecture.329
- 13.4 Elastic Network Capacity Architecture330
- 13.5 Cross-Storage Device Vertical Tiering Architecture332
- 13.6 Intra-Storage Device Vertical Data Tiering Architecture .337
- 13.7 Load Balanced Virtual Switches Architecture340
- 13.8 Multipath Resource Access Architecture342
- 13.9 Persistent Virtual Network Configuration Architecture . .344
- 13.10 Redundant Physical Connection for Virtual Servers
Architecture347
- 13.11 Storage Maintenance Window Architecture350

PART IV: WORKING WITH CLOUDS

CHAPTER 14: Cloud Delivery Model Considerations.359

- 14.1 Cloud Delivery Models: The Cloud Provider
Perspective360
 - Building IaaS Environments360
 - Data Centers361
 - Scalability and Reliability363
 - Monitoring363
 - Security364
 - Equipping PaaS Environments.364
 - Scalability and Reliability365
 - Monitoring367
 - Security367
 - Optimizing SaaS Environments367
 - Security370

14.2 Cloud Delivery Models: The Cloud Consumer Perspective	370
Working with IaaS Environments	370
IT Resource Provisioning Considerations	372
Working with PaaS Environments	373
IT Resource Provisioning Considerations	373
Working with SaaS Services	374
14.3 Case Study Example	375

CHAPTER 15: Cost Metrics and Pricing Models379

15.1 Business Cost Metrics	380
Up-Front and On-Going Costs	380
Additional Costs	381
Case Study Example	382
Product Catalog Browser	382
On-Premise Up-Front Costs	382
On-Premise On-Going Costs	383
Cloud-Based Up-Front Costs	383
Cloud-Based On-Going Costs	383
Client Database	385
On-Premise Up-Front Costs	385
On-Premise On-Going Costs	385
Cloud-Based Up-Front Costs	385
Cloud-Based On-Going Costs	385
15.2 Cloud Usage Cost Metrics	387
Network Usage	387
Inbound Network Usage Metric	387
Outbound Network Usage Metric	388
Intra-Cloud WAN Usage Metric	388
Server Usage	389
On-Demand Virtual Machine Instance Allocation Metric	389
Reserved Virtual Machine Instance Allocation Metric	389
Cloud Storage Device Usage	390
On-Demand Storage Space Allocation Metric	390
I/O Data Transferred Metric	390

Cloud Service Usage	390
<i>Application Subscription Duration Metric</i>	<i>390</i>
<i>Number of Nominated Users Metric</i>	<i>391</i>
<i>Number of Transactions Users Metric</i>	<i>391</i>
15.3 Cost Management Considerations	391
Pricing Models	393
Additional Considerations	395
Case Study Example	396
Virtual Server On-Demand Instance Allocation	397
Virtual Server Reserved Instance Allocation	399
Cloud Storage Device	401
WAN Traffic.	401

CHAPTER 16: Service Quality Metrics and SLAs403

16.1 Service Quality Metrics	404
Service Availability Metrics.	405
<i>Availability Rate Metric</i>	<i>405</i>
<i>Outage Duration Metric</i>	<i>406</i>
Service Reliability Metrics	407
<i>Mean-Time Between Failures (MTBF) Metric</i>	<i>407</i>
<i>Reliability Rate Metric</i>	<i>407</i>
Service Performance Metrics.	407
<i>Network Capacity Metric</i>	<i>408</i>
<i>Storage Device Capacity Metric</i>	<i>408</i>
<i>Server Capacity Metric</i>	<i>408</i>
<i>Web Application Capacity Metric</i>	<i>408</i>
<i>Instance Starting Time Metric</i>	<i>409</i>
<i>Response Time Metric</i>	<i>409</i>
<i>Completion Time Metric</i>	<i>409</i>
Service Scalability Metrics	409
<i>Storage Scalability (Horizontal) Metric</i>	<i>410</i>
<i>Server Scalability (Horizontal) Metric</i>	<i>410</i>
<i>Server Scalability (Vertical) Metric</i>	<i>410</i>
Service Resiliency Metrics	411
<i>Mean-Time to Switchover (MTSO) Metric</i>	<i>411</i>
<i>Mean-Time System Recovery (MTR) Metric</i>	<i>412</i>
16.2 Case Study Example.	412

16.3 SLA Guidelines 413

16.4 Case Study Example 416

Scope and Applicability 416

Service Quality Guarantees 416

Definitions 417

Usage of Financial Credits 417

SLA Exclusions 418

PART V: APPENDICES

Appendix A: Case Study Conclusions421

A.1 ATN422

A.2 DTGOV422

A.3 Innovartus424

Appendix B: Industry Standards Organizations427

B.1 National Institute of Standards and Technology (NIST) ..428

B.2 Cloud Security Alliance (CSA)429

B.3 Distributed Management Task Force (DMTF).....429

B.4 Storage Networking Industry Association (SNIA)430

B.5 Organization for the Advancement of Structured
Information Standards (OASIS)430

B.6 The Open Group.....430

B.7 Open Cloud Consortium (OCC)431

B.8 European Telecommunications Standards
Institute (ETSI)431

B.9 Telecommunications Industry Association (TIA)431

B.10 Liberty Alliance432

B.11 Open Grid Forum (OGF)432

Appendix C: Mapping Mechanisms to Characteristics. . . 433

Appendix D: Data Center Facilities (TIA-942) 437

- D.1 Primary Rooms 438
 - Electrical Room 438
 - Mechanical Room 438
 - Storage and Staging 438
 - Offices, Operations Center, and Support. 438
 - Telecommunications Entrance 438
 - Computer Room. 439
- D.2 Environmental Controls. 440
 - External Electrical Power Provider Interconnection 440
 - Power Distribution 441
 - Uninterruptible Power Source (UPS) 441
 - Power Engine-Generator 441
- D.3 Infrastructure Redundancy Summary. 442

Appendix E: Cloud-Adapted Risk Management Framework 443

- E.1 Security Conservation Principle. 446
- E.2 The Risk Management Framework 448

Appendix F: Cloud Provisioning Contracts 451

- F.1 Cloud Provisioning Contract Structure 452
 - Terms of Service. 454
 - Service Usage Policy* 454
 - Security and Privacy Policy* 455
 - Warranties and Liabilities.* 457
 - Rights and Responsibilities.* 457
 - Termination and Renewal* 458
 - Specifications and SLAs 458
 - Pricing and Billing. 459

Other Issues	459
<i>Legal and Compliance Issues</i>	459
<i>Auditability and Accountability</i>	459
<i>Changes in the Contract Terms and Conditions</i>	459
F.2 Cloud Provider Selection Guidelines	460
Cloud Provider Viability	460
Appendix G: Cloud Business Case Template	463
G.1 Business Case Identification	464
G.2 Business Needs	464
G.3 Target Cloud Environment	465
G.4 Technical Issues	466
G.5 Economic Factors	466
About the Authors	467
Thomas Erl	467
Zaigham Mahmood	467
Ricardo Puttini	468
About the Contributors	469
Pamela J. Wise-Martinez, MSc	469
Gustavo Azzolin, BSc, MSc	470
Dr. Michaela Iorga, Ph.D.	470
Amin Naserpour	471
Vinicius Pacheco, MSc	471
Matthias Ziegler	471
Index	473