



Contents

About the Author	v
Preface	xxiii
Acknowledgments	xxv
Introduction	xxvii
How This Book Is Organized	xxviii
Key Points	xxxiii
Part One Data Center Basics	1
Chapter 1 No Time for Downtime	3
Causes of Downtime	7
Cost of Downtime	10
Key Points	15
Chapter 2 The High-Availability Continuum	17
High-Availability Metrics	19
Availability Choices: How Much Availability Is Enough?	20
Level 1: Depend on Built-in Hardware Reliability	20
Level 2: Data Protection	21
Level 3: Fault-Tolerant Servers	21
Level 4: Server Redundancy or Clustering	21
Level 5: Disaster Recovery	22
Commercial Cluster Management Software	22
Key Points	23

Part Two	Data Center Architecture	25
Chapter 3	Data Center Requirements	27
	Data Center Prerequisites	27
	Required Physical Area for Equipment and Unoccupied Space	28
	Required Power to Run All the Devices	29
	Required Cooling and HVAC	29
	Required Weight	30
	Required Network Bandwidth	31
	Budget Constraints	32
	Selecting a Geographic Location	33
	Safe from Natural Hazards	33
	Safe from Man-Made Disasters	34
	Availability of Local Technical Talent	35
	Abundant and Inexpensive Utilities Such as Power and Water	35
	Selecting an Existing Building (Retrofitting)	35
	Key Points	36
Chapter 4	Data Center Design	37
	Characteristics of an Outstanding Design	38
	Guidelines for Planning a Data Center	38
	Data Center Structures	39
	No-Raised or Raised Floor	39
	Aisles	41
	Ramp	41
	Compulsory Local Building Codes	41
	Raised Floor Design and Deployment	42
	Plenum	42
	Floor Tiles	42
	Equipment Weight and Tile Strength	44
	Electrical Wireways	44
	Cable Trays	45
	Design and Plan against Vandalism	45
	Best Practices	46
	Data-Center Design Case Studies	46
	Celebrity Travels	47
	Designer Dresses	48
	Key Points	49
Chapter 5	Network Infrastructure in a Data Center	51
	Modular Cabling Design	52
	Points of Distribution (PODs)	54
	Internet Access	55
	ISP Network Infrastructure	55
	ISP WAN Links	56
	Best Practices	57
	Key Points	60

Chapter 6	Data Center Maintenance	61
	Network Operations Center (NOC)	61
	Network Monitoring	62
	Monitoring Requirements	62
	SNMP	62
	In-Band and Out-of-Band Monitoring	64
	Data-Center Physical Security	64
	Data-Center Logical Security	65
	Data-Center Cleaning	66
	Approved Cleaning Supplies	66
	Floor Surface Cleaning	67
	Subfloor and Above-Ceiling Plenum Cleaning	67
	Equipment Cleaning	67
	Best Practices	68
	Key Points	69
Chapter 7	Power Distribution in a Data Center	71
	Estimating Your Power Needs	71
	Uninterruptible Power Supply (UPS)	73
	Generators	75
	Power Conditioning	76
	Single-Phase and Three-Phase Power	76
	Power Distribution Units (PDUs)	77
	Electrostatic Discharge (ESD)	78
	Key Points	78
Chapter 8	Data Center HVAC	79
	Reasons for Strict Environmental Requirements	80
	Need for Energy-Efficient HVAC Systems	82
	Air-Conditioning Systems	83
	Cold-Liquid Air-Conditioning Systems	83
	Dry Air-Conditioning Systems	83
	Air Circulation in a Data Center	86
	Placement of Hardware Racks	86
	Bottom-to-Top Cooled Racks	87
	Top-to-Bottom Cooled Racks	87
	Front-to-Front Cooled Racks	87
	Front-to-Back Cooled Racks	89
	Best Practices	90
	Key Points	91
Part Three	Data Center Consolidation	93
Chapter 9	Reasons for Data Center Consolidation	95
	Reasons for Data Center Consolidation	96
	Consolidation Opportunities	97
	Server Consolidation	97
	Storage Consolidation	98

Network Consolidation	101
Application Consolidation	103
Service Consolidation	104
Process Consolidation	104
Staff Consolidation	105
Key Points	105
Chapter 10 Data Center Consolidation Phases	107
Phase 1: Study and Document the Current Environment	107
Evaluate Application Requirements	108
Evaluate Hardware Infrastructure	110
Evaluate Storage Requirements	111
Evaluate Networking Requirements	111
Evaluate Operations Requirements	112
Evaluate Risk	112
Phase 2: Architect the Target Consolidated Environment	113
Design Step 1: Analyze the Collected Data	113
Design Step 2: List Architectural Requirements	114
Design Step 3: Create an Initial Architecture	116
Design Step 4: Size All Equipment	116
Design Step 5: Create a Prototype of the Proposed Solution	117
Design Step 6: Test the Prototype	117
Design Step 7: Revise the Proposed Architecture	118
Design Step 8: Document the Proposed Architecture	118
Phase 3: Implement the New Architecture	118
Draft All Low-Level Specifications	119
Construct the New Environment	119
Create a Data Migration Process	120
Back Up Data in the Old Environment	121
Migrate Data and Services to the New Environment	121
Train the Operations Staff	122
Phase 4: Control and Administer the Consolidated Environment	123
Key Points	125
Part Four Data Center Servers	127
Chapter 11 Server Performance Metrics	129
What Is a Benchmark?	130
Benchmark Organizations	130
Aspects of System Performance	131
Utilization	131
Latency	131
Throughput	131
Efficiency	132
Factors Impacting CPU Performance	132
SPEC Benchmarks	133
SPEC Integer Benchmarks	134
SPEC Floating-Point Benchmarks	135

SPEC Web Benchmarks	135
SPEC OpenMP Benchmark Suite	135
SPEC NFS Benchmarks	136
SPEC Java Benchmarks	136
SPEC Graphics Benchmarks	136
SPEC Mail Benchmarks	137
Linpack Benchmarks	137
TPC Benchmarks	138
TPC-C	138
TPC-H	139
TPC-R	140
TPC-W	140
Obsolete TPC Benchmarks	141
NotesBench Mail	141
Key Points	142
Chapter 12 Server Capacity Planning	143
Server Sizing and Capacity Planning	144
Identifying the Slowest Link	145
Capacity Planning for Servers	146
Phase 1: Define the Customer’s Requirements	146
Phase 2: Measure or Estimate Current Resource Utilization	148
Phase 3: Size the New Server	151
Key Points	155
Chapter 13 Best Practices in IT	157
Defining Best Practices	158
Deploying Best Practices	159
Benefits of Best Practices	160
Systems Management Best Practices	161
Systems Deployment	161
Power Sources	162
Hardware Maintenance	162
Software Deployment	163
Server Cluster Best Practices	163
Data Storage Best Practices	164
Network Management Best Practices	165
What-If Analysis	165
Baselining and Trending	166
Exception Management	167
Quality of Service Management	167
Network Port Auto-Negotiation	168
Documentation Best Practices	168
Methodology Documents	169
Proposal Documents	169
Event Analysis Documents	170
Technical Documentation	171

Network Diagram Documentation	171
Documentation Formats	172
Key Points	173
Chapter 14 Server Security	175
General Host Security Guidelines	176
UNIX Security Guidelines	177
Internet Security Issues	178
Sources of Information on Security	185
Key Points	185
Chapter 15 Server Administration	187
Best Practices for System Administration	188
System Administration Work Automation	191
What Should Be Automated?	192
Types of Automation	193
Automation Guidelines	193
Common Automation Tools	196
Examples of Automation	199
Key Points	201
Chapter 16 Device Naming	203
Naming Practices	204
NIS	205
NIS+	206
DNS	207
DNS Caching	210
Registering Your Domain Name in DNS	212
LDAP	212
Designing a Directory Information Tree (DIT)	215
Key Points	216
Chapter 17 Load Balancing	217
Load-Balancing Terminology	218
Advantages	219
Fault Tolerance	219
Service Availability	219
Performance	220
Scalability	220
Flexibility	220
Cost Savings	220
Security	220
Types of Load Balancing	221
Software-Based Methods	221
Hardware-Based Methods	223
Implementing a Network with Load-Balancing Switches	225
Virtual and Real Servers	228
Best Practices for Load Balancing	230
Key Points	231

Chapter 18	Fault Tolerance	233
	Need for Fault Tolerance	234
	Component Reliability Terms	234
	Fault-Tolerant Systems Versus Clusters	235
	Fault-Tolerant Disk Subsystems	236
	Hot-Swappable and Hot-Spare Drives	236
	Cooling Systems	236
	Power Supplies	236
	Robust Self-Monitoring Enclosures	237
	Disk Redundancy Using RAID Levels	237
	Redundant Controllers within a Disk Subsystem	238
	Host-Based Adapters (HBAs) within a Server	238
	Cache in the Subsystem Controller	238
	Best Practices	239
	Key Points	240
Chapter 19	RAID	241
	RAID-0 (Striping)	242
	RAID-1 (Mirroring)	243
	RAID 0+1 (Mirrored Stripes)	244
	RAID 1+0 or RAID 10 (Striped Mirrors)	245
	RAID-2	247
	Parity-Based RAID (RAID-3, -4, and -5)	247
	RAID-3	248
	RAID-4	248
	RAID-5	249
	Key Points	251
Part Five	Data Storage Technologies	253
Chapter 20	Data Storage Solutions	255
	Rapid Data Growth	256
	Data Storage Requirements	258
	Storage Access Modes	259
	DAS Versus SAN	259
	NAS Versus SAN	261
	Benefits of SAN	262
	Consolidation of Storage Resources	262
	Concurrent Access by Multiple Hosts	263
	Reduced Total Cost of Ownership (TCO)	263
	LAN-Free and Server-Free Data Transfers	263
	Maximum Distance between Nodes and Use in Disaster	
	Recovery Applications	264
	High Performance	265
	Scalability and Flexibility	266
	Server Clustering	267
	Applications Best Suited for SAN	267

Considerations before Designing a SAN	268
Application Requirements	268
Know Your Site	268
Type of Cables and Devices for Your Site	268
Need for Present and Future SAN Features	269
Expected Traffic Volume	269
Distance between Nodes	269
Number of Devices	269
Do You Need to Accommodate Existing Direct-Attached Components?	270
Cost	270
NAS/SAN Hybrid	270
Key Points	271
Chapter 21 Storage Area Networks	273
What Is a SAN?	273
Fibre Channel (FC)	277
Fiber Cable Connectors	277
Single-Mode Fiber or Multimode Fiber	278
Wavelength Shortwave or Longwave	279
SAN Components	280
SAN Topologies	281
Point-to-Point Topology	281
Fibre Channel–Arbitrated Loop (FC-AL)	283
Switched-Fabric Topology	286
Best Practices	296
Key Points	296
Chapter 22 Configuring a SAN	299
SAN Design Phases	299
Phase 1: Gather Requirements	300
Phase 2: Gather Existing Environment Information	300
Phase 3: Select a Mass Storage Solution	300
Phase 4: Connect Storage and Servers	300
Example of SAN Design Phases	301
SAN Implementation Phases	303
Phase 1: Create Local SANs	303
Phase 2: Build Enterprise-Wide SAN	303
Phase 3: Protect the SAN Data	303
Best Practices for SAN Deployment	307
Key Points	307
Chapter 23 Using SANs for High Availability	309
Configuring an HA SAN	309
Level 1: Path-Level Redundancy	310
Level 2: Switch-Level Redundancy	311
Level 3: Fabric-Level Redundancy	311

Switch Features for Improving HA and Performance	313
Using SANs to Deploy Campus or Metropolitan Clusters	314
Key Points	317
Chapter 24 IP-Based Storage Communications	319
Why Use IP Storage?	319
Types of IP Storage	320
iSCSI	320
Fibre Channel over IP (FCIP)	323
Internet Fibre Channel Protocol (iFCP)	325
Extending SAN over ATM, IP, or SONET for Disaster Recovery	325
Adopting IP Storage	328
Best Practices for IP-Based Storage Networks	328
Key Points	329
Part Six Data Center Clusters	331
Chapter 25 Cluster Architecture	333
Asymmetric Two-Node Clusters	335
Symmetric Two-Node Clusters	336
Complex Cluster Configurations	338
Many-to-One Failover Model	339
One-to-Many Failover Model	340
Any-to-Any Failover Model	340
Failover Policies	341
Failover Pairs	341
N+1 Policy	342
N+M Policy	342
Failover-Ring Policy	342
Random Policy	343
Best Practices	343
Key Points	344
Chapter 26 Cluster Requirements	345
Required Hardware Cluster Components	346
Servers	346
Private (Heartbeat) Networks	346
Administrative (Maintenance) Network	349
Public or Service Network	349
Shared Disks	349
Adapter SCSI ID Requirements	350
Local Disks	351
Cluster Software Requirements	351
System Crash	354
System Hang	354

Planned Maintenance	355
Heartbeat Link Failure	355
Cluster Startup Problems	355
What Happens During Service Failover	356
Ownership of Shared Disks	356
Network Identity	356
Cluster Services	358
Cluster Installation Checklist	358
Key Points	359
Chapter 27 Designing Cluster-Friendly Applications	361
Automating Operations	362
Controlling Application Failover Time	363
Reducing Data Loss During Failover	364
Minimizing Application Failures	365
Designing Node-Independent Applications	365
Minimizing Planned Downtime	366
Restoring Client Connections	367
Key Points	368
Part Seven Network Design, Implementation, and Security	369
Chapter 28 Network Devices	371
Network Devices	371
Hubs Versus Switches	376
Routers	376
Network Cables	381
Coaxial Cables (Copper)	382
Twisted-Pair Cables (Copper)	383
Fiber-Optic Cables (Glass)	383
Key Points	387
Chapter 29 Network Protocols	389
Transmission Control Protocol/Internet Protocol (TCP/IP)	392
TCP and UDP as Transport (Layer 4) Protocols	393
Ports	394
Key Points	395
Chapter 30 IP Addressing	397
Subnet Masks	402
Class C Subnet Masks	405
Class B Subnet Masks	407
IP Version 6	409
Key Points	411
Chapter 31 Network Technologies	413
LAN Technologies	413
Asynchronous Transfer Mode (ATM)	414
Digital Signal (DS) and T and E Carriers	415

Ethernet	416
Fiber Distributed Data Interface (FDDI)	419
Synchronous Optical Network (SONET) or Optical Carrier (OC)	420
Token Ring	421
Usage Trends	423
WAN Technologies	423
WAN Dial-In Technologies	424
WAN Trunk Technologies	430
Key Points	434
Chapter 32 Network Topologies	435
Architecture-Based Network Topologies	435
Bus Topology	436
Tree Topology	437
Ring Topology	437
Single-Star Topology	437
Hierarchical-Star Topology	438
Wireless Topology	440
Point-to-Point Topology	441
Meshed Topology	441
Distance-Based Network Topologies	442
Local Area Network (LAN)	444
Metropolitan Area Network (MAN)	445
Wide Area Network (WAN)	445
VLAN Concepts	446
Key Points	446
Chapter 33 Network Design	447
Three-Layer Hierarchical Network Design	447
Access Layer	449
Distribution Layer	450
Core Layer	452
Benefits of Hierarchical Design	453
Campus Network Design	453
Host-to-Switch Connection	454
The Switch-to-Router Configuration	456
Network Backbones	457
Switched and Routed Backbones	458
Enterprise Network Design Phases	461
Phase 1: Identify the Customer's Business and Technical Objectives	462
Phase 2: Evaluate the Customer's Current Network	464
Phase 3: Design a New Network Topology	464
Phase 4: Document All Findings and Proposed Design	467
Best Practices for Network Design	468
Key Points	470

Chapter 34	Designing Fault-Tolerant Networks	471
	Importance of Highly Available Networks	471
	Implementing High-Availability Networks	472
	Availability through Fault-Tolerant Devices	473
	Availability through Redundant NICs in a Host	473
	Availability through Redundant Network Topologies	476
	Best Practices	478
	Key Points	480
Chapter 35	Internet Access Technologies and VPNs	481
	Virtual Private Networks (VPNs)	483
	Remote-Access VPN	485
	Site-to-Site VPNs	486
	VPN Security	486
	Firewalls	486
	Encryption	487
	Data Integrity	488
	IPSec	490
	AAA Server	490
	Authentication	491
	Tunneling	492
	Remote-Access Tunneling	493
	Site-to-Site Tunneling	493
	Key Points	494
Chapter 36	Firewalls	495
	DMZ Areas	496
	Firewall Rules or Filters	497
	What Does a Firewall Protect You From?	500
	Global Addresses Can Hide Internal Networks	501
	Firewall Best Practices	503
	Key Points	503
Chapter 37	Network Security	505
	Computer Viruses	506
	Internet Worms	507
	The Security Philosophy	508
	Traffic-Based Security	510
	User-Based Security	511
	AAA Model	513
	Authentication	513
	Authorization	514
	Accounting	515
	AAA Implementations	516
	Key Points	516

Part Eight	Disaster Recovery	519
Chapter 38	Disaster Recovery	521
	When Bad Things Happen to Good People	522
	High Availability (HA) and Disaster Recovery (DR)	524
	Five Phases of DR	525
	Phase 1: Find the Funds	526
	Phase 2: Assess Existing Environment and Risks	527
	Phase 3: Create DR Procedures	528
	Phase 4: Test the Procedures	528
	Phase 5: Adjust Your DR Plan to Site Changes and Technical Advancements	529
	Designing a Disaster-Tolerant Architecture	529
	Online Replication Techniques	531
	User-Level Replication	531
	Software-Based Replication	532
	Device Driver-Level Replication	532
	Disk-Subsystem Hardware-Based Replication	533
	Database Replication	533
	Transaction-Based Replication	533
	Process-Level State Replication	534
	Best Practices	534
	Key Points	536
Chapter 39	DR Architectures	537
	Campus Clusters	539
	Metropolitan Clusters	540
	Continental Clusters	541
	Key Points	542
Part Nine	Future Considerations	543
Chapter 40	Voice over IP and Converged Infrastructure	545
	Component 1: Independent Data Networks	546
	Component 2: Independent Storage Networks	549
	Component 3: Independent Voice Networks	551
	Important Telephone- and VoIP-Related Terms	553
	Converged Infrastructure	554
	Storage over IP (SoIP)	555
	Voice over IP (VoIP)	559
	Building VoIP Networks	560
	Business Case for Voice over IP	565
	Issues with VoIP	565
	Toward a Complete Enterprise Convergence	567
	Hardware Convergence	567
	Software Convergence	568
	Internal Staff Convergence	568
	Vendor Convergence	569
	Key Points	569

Chapter 41	What's Next	571
	Network Convergence Technologies	572
	Storage Virtualization	572
	Embedded Systems	574
	InfiniBand (IB)	575
	Blade Servers	577
	Bluetooth	577
	System Area Networks (SANs)	579
	Key Points	580
Part Ten	Appendix	581
Appendix A	Storage and Networking Solutions	583
	Glossary	587
	Index	601