



Contents

Foreword	xvii
Introduction	xix
Section I Storage System	1
Chapter 1 Introduction to Information Storage and Management	3
1.1 Information Storage	5
1.1.1 Data	5
1.1.2 Types of Data	7
1.1.3 Information	7
1.1.4 Storage	8
1.2 Evolution of Storage Technology and Architecture	9
1.3 Data Center Infrastructure	10
1.3.1 Core Elements	10
1.3.2 Key Requirements for Data Center Elements	11
1.3.3 Managing Storage Infrastructure	13
1.4 Key Challenges in Managing Information	14
1.5 Information Lifecycle	14
1.5.1 Information Lifecycle Management	15
1.5.2 ILM Implementation	16
1.5.3 ILM Benefits	17
Summary	18
Chapter 2 Storage System Environment	21
2.1 Components of a Storage System Environment	21
2.1.1 Host	22
2.1.2 Connectivity	24
2.1.3 Storage	26

2.2 Disk Drive Components	27
2.2.1 Platter	28
2.2.2 Spindle	28
2.2.3 Read/Write Head	28
2.2.4 Actuator Arm Assembly	29
2.2.5 Controller	29
2.2.6 Physical Disk Structure	30
2.2.7 Zoned Bit Recording	31
2.2.8 Logical Block Addressing	32
2.3 Disk Drive Performance	33
2.3.1 Disk Service Time	33
2.4 Fundamental Laws Governing Disk Performance	35
2.5 Logical Components of the Host	38
2.5.1 Operating System	39
2.5.2 Device Driver	39
2.5.3 Volume Manager	39
2.5.4 File System	41
2.5.5 Application	44
2.6 Application Requirements and Disk Performance	45
Summary	48
Chapter 3 Data Protection: RAID	51
3.1 Implementation of RAID	52
3.1.1 Software RAID	52
3.1.2 Hardware RAID	52
3.2 RAID Array Components	53
3.3 RAID Levels	54
3.3.1 Striping	54
3.3.2 Mirroring	55
3.3.3 Parity	56
3.3.4 RAID 0	57
3.3.5 RAID 1	57
3.3.6 Nested RAID	59
3.3.7 RAID 3	59
3.3.8 RAID 4	61
3.3.9 RAID 5	62
3.3.10 RAID 6	62
3.4 RAID Comparison	63
3.5 RAID Impact on Disk Performance	66
3.5.1 Application IOPS and RAID Configurations	67
3.6 Hot Spares	68
Summary	68
Chapter 4 Intelligent Storage System	71
4.1 Components of an Intelligent Storage System	72
4.1.1 Front End	72
4.1.2 Cache	74
4.1.3 Back End	79
4.1.4 Physical Disk	79

4.2 Intelligent Storage Array	82
4.2.1 High-end Storage Systems	82
4.2.2 Midrange Storage System	83
4.3 Concepts in Practice: EMC CLARiiON and Symmetrix	84
4.3.1 CLARiiON Storage Array	85
4.3.2 CLARiiON CX4 Architecture	86
4.3.3 Managing the CLARiiON	88
4.3.4 Symmetrix Storage Array	89
4.3.5 Symmetrix Component Overview	91
4.3.6 Direct Matrix Architecture	93
Summary	95
Section II Storage Networking Technologies and Virtualization	97
Chapter 5 Direct-Attached Storage and Introduction to SCSI	99
5.1 Types of DAS	99
5.1.1 Internal DAS	100
5.1.2 External DAS	100
5.2 DAS Benefits and Limitations	101
5.3 Disk Drive Interfaces	101
5.3.1 IDE/ATA	101
5.3.2 SATA	102
5.3.3 Parallel SCSI	103
5.4 Introduction to Parallel SCSI	104
5.4.1 Evolution of SCSI	104
5.4.2 SCSI Interfaces	105
5.4.3 SCSI-3 Architecture	107
5.4.4 Parallel SCSI Addressing	111
5.5 SCSI Command Model	112
5.5.1 CDB Structure	112
5.5.2 Operation Code	112
5.5.3 Control Field	114
5.5.4 Status	114
Summary	115
Chapter 6 Storage Area Networks	117
6.1 Fibre Channel: Overview	118
6.2 The SAN and Its Evolution	119
6.3 Components of SAN	120
6.3.1 Node Ports	120
6.3.2 Cabling	122
6.3.3 Interconnect Devices	123
6.3.4 Storage Arrays	124
6.3.5 SAN Management Software	124
6.4 FC Connectivity	125
6.4.1 Point-to-Point	125
6.4.2 Fibre Channel Arbitrated Loop	125
6.4.3 Fibre Channel Switched Fabric	127

6.5 Fibre Channel Ports	129
6.6 Fibre Channel Architecture	131
6.6.1 Fibre Channel Protocol Stack	132
6.6.2 Fibre Channel Addressing	133
6.6.3 FC Frame	135
6.6.4. Structure and Organization of FC Data	137
6.6.5 Flow Control	137
6.6.6 Classes of Service	138
6.7 Zoning	138
6.8 Fibre Channel Login Types	141
6.9 FC Topologies	141
6.9.1 Core-Edge Fabric	142
6.9.2 Mesh Topology	144
6.10 Concepts in Practice: EMC Connectrix	145
Summary	148
Chapter 7 Network-Attached Storage	149
7.1 General-Purpose Servers vs. NAS Devices	150
7.2 Benefits of NAS	150
7.3 NAS File I/O	151
7.3.1 File Systems and Remote File Sharing	152
7.3.2 Accessing a File System	152
7.3.3 File Sharing	152
7.4 Components of NAS	153
7.5 NAS Implementations	154
7.5.1 Integrated NAS	154
7.5.2 Gateway NAS	155
7.5.3 Integrated NAS Connectivity	155
7.5.4 Gateway NAS Connectivity	156
7.6 NAS File-Sharing Protocols	157
7.6.1 NFS	158
7.6.2 CIFS	158
7.7 NAS I/O Operations	159
7.7.1 Hosting and Accessing Files on NAS	160
7.8 Factors Affecting NAS Performance and Availability	160
7.9 Concepts in Practice: EMC Celerra	164
7.9.1 Architecture	164
7.9.2 Celerra Product Family	167
Summary	168
Chapter 8 IP SAN	171
8.1 iSCSI	173
8.1.1 Components of iSCSI	173
8.1.2 iSCSI Host Connectivity	174
8.1.3 Topologies for iSCSI Connectivity	175
8.1.4 iSCSI Protocol Stack	176
8.1.5 iSCSI Discovery	177

8.1.6 iSCSI Names	178
8.1.7 iSCSI Session	179
8.1.8 iSCSI PDU	180
8.1.9 Ordering and Numbering	181
8.1.10 iSCSI Error Handling and Security	182
8.2 FCIP	183
8.2.1 FCIP Topology	184
8.2.2 FCIP Performance and Security	185
Summary	186
Chapter 9 Content-Addressed Storage	189
9.1 Fixed Content and Archives	190
9.2 Types of Archives	191
9.3 Features and Benefits of CAS	192
9.4 CAS Architecture	193
9.5 Object Storage and Retrieval in CAS	196
9.6 CAS Examples	198
9.6.1 Health Care Solution: Storing Patient Studies	198
9.6.2 Finance Solution: Storing Financial Records	199
9.7 Concepts in Practice: EMC Centera	200
9.7.1 EMC Centera Models	201
9.7.2 EMC Centera Architecture	201
9.7.3 Centera Tools	203
9.7.4 EMC Centera Universal Access	204
Summary	205
Chapter 10 Storage Virtualization	207
10.1 Forms of Virtualization	207
10.1.1 Memory Virtualization	208
10.1.2 Network Virtualization	208
10.1.3 Server Virtualization	209
10.1.4 Storage Virtualization	210
10.2 SNIA Storage Virtualization Taxonomy	212
10.3 Storage Virtualization Configurations	213
10.4 Storage Virtualization Challenges	214
10.4.1 Scalability	215
10.4.2 Functionality	215
10.4.3 Manageability	215
10.4.4 Support	216
10.5 Types of Storage Virtualization	216
10.5.1 Block-Level Storage Virtualization	216
10.5.2 File-Level Virtualization	217
10.6 Concepts in Practice	219
10.6.1 EMC Invista	219
10.6.2 Rainfinity	222
Summary	225

Section III	Business Continuity	227
Chapter 11	Introduction to Business Continuity	229
	11.1 Information Availability	230
	11.1.1 Causes of Information Unavailability	230
	11.1.2 Measuring Information Availability	231
	11.1.3 Consequences of Downtime	232
	11.2 BC Terminology	233
	11.3 BC Planning Lifecycle	235
	11.4 Failure Analysis	238
	11.4.1 Single Point of Failure	238
	11.4.2 Fault Tolerance	238
	11.4.3 Multipathing Software	240
	11.5 Business Impact Analysis	240
	11.6 BC Technology Solutions	241
	11.7 Concept in Practice: EMC PowerPath	241
	11.7.1 PowerPath Features	242
	11.7.2 Dynamic Load Balancing	242
	11.7.3 Automatic Path Failover	244
	Summary	247
Chapter 12	Backup and Recovery	251
	12.1 Backup Purpose	252
	12.1.1 Disaster Recovery	252
	12.1.2 Operational Backup	252
	12.1.3 Archival	252
	12.2 Backup Considerations	253
	12.3 Backup Granularity	254
	12.4 Recovery Considerations	257
	12.5 Backup Methods	258
	12.6 Backup Process	259
	12.7 Backup and Restore Operations	260
	12.8 Backup Topologies	262
	12.8.1 Serverless Backup	265
	12.9 Backup in NAS Environments	265
	12.10 Backup Technologies	269
	12.10.1 Backup to Tape	269
	12.10.2 Physical Tape Library	270
	12.10.3 Backup to Disk	272
	12.10.4 Virtual Tape Library	273
	12.11 Concepts in Practice: EMC NetWorker	276
	12.11.1 NetWorker Backup Operation	277
	12.11.2 NetWorker Recovery	278
	12.11.3 EmailXtender	278
	12.11.4 DiskXtender	279
	12.11.5 Avamar	279
	12.11.6 EMC Disk Library (EDL)	280
	Summary	280

Chapter 13	Local Replication	283
	13.1 Source and Target	284
	13.2 Uses of Local Replicas	284
	13.3 Data Consistency	285
	13.3.1 Consistency of a Replicated File System	285
	13.3.2 Consistency of a Replicated Database	286
	13.4 Local Replication Technologies	288
	13.4.1 Host-Based Local Replication	288
	13.4.2 Storage Array-Based Replication	290
	13.5 Restore and Restart Considerations	297
	13.5.1 Tracking Changes to Source and Target	298
	13.6 Creating Multiple Replicas	300
	13.7 Management Interface	301
	13.8 Concepts in Practice: EMC TimeFinder and EMC SnapView	301
	13.8.1 TimeFinder/Clone	302
	13.8.2 TimeFinder/Mirror	302
	13.8.3 EMC SnapView	304
	13.8.4 EMC SnapSure	305
	Summary	306
Chapter 14	Remote Replication	309
	14.1 Modes of Remote Replication	309
	14.2 Remote Replication Technologies	311
	14.2.1. Host-Based Remote Replication	311
	14.2.2 Storage Array-Based Remote Replication	314
	14.2.3 SAN-Based Remote Replication	321
	14.3 Network Infrastructure	323
	14.3.1 DWDM	324
	14.3.2 SONET	324
	14.4 Concepts in Practice: EMC SRDF, EMC SAN Copy, and EMC MirrorView	325
	14.4.1 SRDF Family	325
	14.4.2 Disaster Recovery with SRDF	326
	14.4.3 SRDF Operations for Concurrent Access	327
	14.4.4 EMC SAN Copy	328
	14.4.5 EMC MirrorView	329
	Summary	330
Section IV	Storage Security and Management	333
Chapter 15	Securing the Storage Infrastructure	335
	15.1 Storage Security Framework	335
	15.2 Risk Triad	336
	15.2.1 Assets	337
	15.2.2 Threats	338
	15.2.3 Vulnerability	339

15.3 Storage Security Domains	340
15.3.1 Securing the Application Access Domain	341
15.3.2 Securing the Management Access Domain	344
15.3.3 Securing Backup, Recovery, and Archive (BURA)	347
15.4 Security Implementations in Storage Networking	348
15.4.1 SAN	348
15.4.2 NAS	353
15.4.3 IP SAN	359
Summary	360
Chapter 16 Managing the Storage Infrastructure	363
16.1 Monitoring the Storage Infrastructure	364
16.1.1 Parameters Monitored	364
16.1.2 Components Monitored	365
16.1.3 Monitoring Examples	368
16.1.4 Alerts	374
16.2 Storage Management Activities	375
16.2.1 Availability management	375
16.2.2 Capacity management	375
16.2.3 Performance management	376
16.2.4 Security Management	376
16.2.5 Reporting	376
16.2.6 Storage Management Examples	377
16.3 Storage Infrastructure Management Challenges	382
16.4 Developing an Ideal Solution	382
16.4.1 Storage Management Initiative	383
16.4.2 Enterprise Management Platforms	385
16.5 Concepts in Practice: EMC ControlCenter	386
16.5.1 ControlCenter Features and Functionality	386
16.5.2 ControlCenter Architecture	387
Summary	392
Appendix	395
Glossary	407
Index	439