

# TABLE OF CONTENTS

---

Preface . . . . .	VII
About the authors . . . . .	IX
Acknowledgements . . . . .	XI
<b>1 DISK AND STORAGE SYSTEM BASICS . . . . .</b>	<b>1</b>
1.1 Overview . . . . .	1
1.1.1 Storage Hardware Situation and Outlook. . . . .	1
1.1.2 Physical Limits . . . . .	3
1.1.3 Trying to Fix the Problems - and Failing! . . . . .	7
1.1.4 SAN-Attached Hard Disks. . . . .	10
1.1.5 Storage Arrays and LUNs . . . . .	10
1.1.6 Common Problems . . . . .	15
1.1.7 Physical Disks vs. LUNs. . . . .	17
1.2 Disk Addressing and Layout. . . . .	19
1.3 Paths and path redundancy. . . . .	23
1.4 The Trouble with Networked Disk Access . . . . .	30
1.4.1 Summary . . . . .	36
<b>2 EXPLORING VXVM . . . . .</b>	<b>39</b>
2.1 Getting Started . . . . .	39
2.1.1 Hello, Volumel!. . . . .	40
2.1.2 vxdisksetup: Turning Disks into VM Disks. . . . .	40
2.1.3 Disk Groups: Putting VM Disks into Virtual Storage Boxes . . . . .	42
2.2 The Hard Way: a Low-level Walkthrough . . . . .	45
2.2.1 Subdisks: Extents for Persistent Backing Store . . . . .	45
2.2.2 Plexes: Mapping Virtual Extents to Physical Extents . . . . .	46
2.2.3 Volumes: Virtual Partitions for Any Purpose . . . . .	48
2.2.4 Volume Start: Prepare for Takeoff . . . . .	52
2.3 The Easy Way: vxassist . . . . .	53
2.3.1 Summary . . . . .	53
<b>3 INCORPORATING DISKS INTO VXVM . . . . .</b>	<b>55</b>
3.1 Solaris Disk Handling . . . . .	56
3.1.1 Getting a New Disk into Solaris . . . . .	56
3.1.2 You Don't Format with "format" . . . . .	57
3.1.3 Finding New Disks in VxVM . . . . .	57
3.1.4 What if My New Disk is Not Found? . . . . .	59
3.1.5 Leaving Physics Behind – Welcome to VxVM! . . . . .	61

## Table Of Contents

---

3.2	VxVM disk handling . . . . .	62
3.2.1	VxVM Disk Formats . . . . .	62
3.2.2	cdsdisk and sliced . . . . .	63
3.2.3	How to Mix CDS and Sliced Disks in a Disk Group? . . . . .	66
3.2.4	Other Disk Formats . . . . .	66
3.2.5	Encapsulation Overview – Integrating Legacy Data. . . . .	67
3.2.6	Summary . . . . .	69
<b>4</b>	<b>DISK GROUPS . . . . .</b>	<b>71</b>
4.1	Overview . . . . .	71
4.1.1	What is a Disk Group? . . . . .	71
4.2	Simple Disk Group Operations . . . . .	74
4.3	Advanced Disk Group Operations . . . . .	80
4.3.1	Options for Importing or Exporting a DG . . . . .	81
4.3.2	Disk Group Operations for Off-Host Processing . . . . .	83
4.3.3	Miscellaneous Disk Group Operations . . . . .	85
4.3.4	Summary . . . . .	87
4.4	Disk Group Implementation Details . . . . .	89
4.4.1	Major and Minor Numbers for Volumes and Partitions . . . . .	97
<b>5</b>	<b>VOLUMES . . . . .</b>	<b>99</b>
5.1	Overview . . . . .	99
5.1.1	What is a Volume? . . . . .	99
5.2	Simple Volume Operations . . . . .	101
5.2.1	Creating, Using and Displaying a Volume. . . . .	101
5.2.2	Useful vxprint Flags Explained . . . . .	103
5.2.3	Starting and Stopping Volumes . . . . .	105
5.3	Volume Layouts and RAID Levels . . . . .	106
5.3.1	Volume Features Supported by VxVM . . . . .	106
5.4	Volume Maintenance . . . . .	114
5.5	Tuning vxassist Behavior. . . . .	120
5.5.1	Storage Attributes – Specifying Allocation Strategies . . . . .	120
5.5.2	Skipping Initial Mirror Synchronisation . . . . .	126
5.5.3	Changing the Layout of a Volume . . . . .	127
5.6	Methods of Synchronisation . . . . .	130
5.6.1	Atomic Copy . . . . .	131
5.6.2	Read-Writeback, Schrödinger's Cat, and Quantum Physics . . . . .	132
5.7	Volume Features in Detail . . . . .	137
5.7.1	concat . . . . .	137
5.7.2	stripe . . . . .	137
5.7.3	mirror . . . . .	139
5.7.4	RAID-4 and RAID-5. . . . .	142
5.7.5	mirror-concat . . . . .	146

---

5.7.6	mirror-stripe . . . . .	146
5.7.7	Mixed Layouts . . . . .	146
5.8	Relayout in Detail . . . . .	147
<b>6</b>	<b>LAYERED VOLUMES . . . . .</b>	<b>153</b>
6.1	Overview . . . . .	153
6.1.1	Why Use Layered Volumes? . . . . .	153
6.2	Introducing Layered Volumes . . . . .	158
6.2.1	concat-mirror . . . . .	160
6.2.2	stripe-mirror . . . . .	161
6.2.3	Understanding vxprint Output for Layered Volumes . . . . .	162
6.3	Understanding Layered Volumes . . . . .	165
6.3.1	Manually Creating a Layered Volume . . . . .	165
6.3.2	Mirroring RAID-5 Volumes . . . . .	169
<b>7</b>	<b>LOGS . . . . .</b>	<b>173</b>
7.1	Overview . . . . .	173
7.1.1	What is a Log? . . . . .	174
7.1.2	Simple Log Operations . . . . .	175
7.2	Log Maintenance . . . . .	177
7.3	Details About Logs . . . . .	180
7.3.1	DRL (Dirty Region Log) . . . . .	180
7.3.2	DCL/DCO (Data Change Log / Data Change Object) . . . . .	184
7.3.3	raid5log . . . . .	188
<b>8</b>	<b>DUAL DATA CENTERS . . . . .</b>	<b>191</b>
8.1	Volume Management in Dual Data Centers . . . . .	191
8.1.1	Growing a Mirrored Volume Across Sites . . . . .	192
8.1.2	Growing Existing Volumes Across Sites . . . . .	196
8.1.3	Mirroring Site-Aware Volumes Across Sites . . . . .	204
8.1.4	Summary . . . . .	212
8.2	Replication Across Data Centers . . . . .	213
8.2.1	Replication vs. Mirroring . . . . .	213
8.2.2	The Speed of Light and Latency . . . . .	214
8.2.3	Replication Using Storage Array Logic . . . . .	217
8.2.4	Replication Using Kernel Mode Logic . . . . .	220
8.3	Estimating Replication Speed . . . . .	223
<b>9</b>	<b>POINT IN TIME COPIES (SNAPSHOTS) . . . . .</b>	<b>233</b>
9.1	Overview . . . . .	233
9.1.1	Types of Snapshots . . . . .	233
9.1.2	Consistency Problems for Snapshots . . . . .	235
9.2	Physical Raw Device Snapshots . . . . .	237

## Table Of Contents

---

9.2.1	Overview . . . . .	237
9.2.2	A Look at What Goes on Inside . . . . .	238
9.2.3	A Logical File System Snapshot . . . . .	245
9.3	Features of and Improvements on the Raw Device Snapshot . . . . .	249
9.3.1	Snapshot Region Logging by the Data Change Log . . . . .	249
9.3.2	Reverting the Resynchronization Direction . . . . .	253
9.3.3	The Snap Objects . . . . .	254
9.3.4	Clearing the Snapshot Relation . . . . .	256
9.3.5	Deleting the Snapshot . . . . .	257
9.3.6	Offhost Processing . . . . .	258
9.3.7	Full Sized Volume Based Instant Snapshots . . . . .	262
9.3.8	Snapshot Refresh . . . . .	267
9.3.9	Space Optimized Volume Based Instant Snapshots . . . . .	268
9.3.10	Autogrow Related Attributes . . . . .	274
9.3.11	Cascading Snapshots . . . . .	278
9.3.12	A Final Example for Volume Snapshots . . . . .	279
9.4	Veritas File System Based Snapshots . . . . .	282
9.4.1	Cache Overflow on a Traditional Snapshot . . . . .	282
9.4.2	VxFS Storage Checkpoints . . . . .	286
9.5	Creating a Full Sized Volume Snapshot Using Low-Level Commands . . . . .	300
9.6	Legacy Snapshot Commands . . . . .	303
9.6.1	Full Sized Snapshot without FMR . . . . .	303
9.6.2	Full Sized Snapshot with Kernel Based FMR . . . . .	306
9.6.3	Full Sized Snapshot with DCL Volume Based FMR Version 0 . . . . .	307
9.7	DCO Version 0 and Version 20 . . . . .	308
9.8	VxFS Storage Checkpoint Behavior . . . . .	313
<b>10</b>	<b>ENCAPSULATION AND ROOT MIRRORING . . . . .</b>	<b>319</b>
10.1	Introduction and Overview . . . . .	319
10.2	The Secrets of Encapsulation . . . . .	321
10.3	Root Disk Encapsulation . . . . .	323
10.4	Root Disk Mirroring . . . . .	324
10.5	Remarks to vxencap and OS Mirroring . . . . .	327
10.6	The Ghost Subdisk . . . . .	330
10.7	Manual Encapsulation Walkthrough . . . . .	338
10.7.1	Assumptions and Prerequisites . . . . .	338
10.7.2	Basic Considerations . . . . .	339
10.7.3	Storing the Disk Layout . . . . .	340
10.7.4	Defining Private and Public Region . . . . .	340
10.7.5	Creating Subdisks, Plexes, and Volumes . . . . .	341
10.7.6	Mirroring and Preparing for CDS . . . . .	345
10.7.7	Converting to CDS . . . . .	348

---

<b>11</b>	<b>TROUBLESHOOTING</b>	349
11.1	Introduction	349
11.2	Disk Outage	352
11.2.1	Disk Permanently damaged	355
11.2.2	Disk Temporarily Unavailable	358
11.2.3	Replacing an OS Disk	359
11.3	Disk Outage in Detail	362
11.3.1	A Complete Disk Array Temporarily Unavailable	362
11.3.2	A Disk Group Temporarily Inaccessible	363
11.3.3	A Partially Failed Disk ("Failing")	365
11.3.4	Hot Relocation	367
11.3.5	Hot Spare	374
11.4	Synchronization Tasks	380
11.4.1	Optimizing Resynchronization	380
11.4.2	Controlling Synchronization Behavior	383
11.5	Restore of Lost VxVM Objects	391
11.5.1	vxprint and vxmake Capabilities	391
11.5.2	Restore of All Volumes in a Disk Group	392
11.5.3	Restore of Some Volumes in a Disk Group	393
11.5.4	Restore of the Entire Disk Group Configuration	394
11.5.5	Restore of a Destroyed Disk Group	398
11.5.6	Serial Split Brain of a Disk Group	401
11.6	Booting without VxVM	406
11.7	More than Two OS Mirrors: Emergency Disk	412
11.8	Hot Relocation Troubles	420
11.8.1	Plex Synchronization Skipped	420
11.8.2	Unrelocation of Split Subdisks	424
11.9	Plex States Overview	426
<b>12</b>	<b>FILE SYSTEMS</b>	429
12.1	Block Based File Systems	429
12.1.1	Just for Fun: Commodore 64's Rudimentary File Access	430
12.1.2	FAT – Not a Big Improvement	430
12.1.3	UFS – Finally Something Decent	432
12.2	Extent Based File Systems	434
12.2.1	VxFS	434
12.3	Advanced File System Operations	441
12.3.1	Summary	445
<b>13</b>	<b>TUNING STORAGE FOUNDATION</b>	447
13.1	Basics About Tuning Storage Foundation	447
13.1.1	Tuning VxVM by Using Reasonable Parameters	449
13.1.2	Understanding and Modifying VxVM Defaults	451

## Table Of Contents

---

13.1.3	Tuning VxFS . . . . .	454
13.2	Tools for Performance Tuning VxVM on SAN Storage . . . . .	461
13.3	Performance Tuning . . . . .	468
13.3.1	Overview and Disclaimer . . . . .	468
13.3.2	Identifying Performance and Performance Requirements . . . . .	468
13.3.3	Comparative Benchmarks of Various Volume Layouts . . . . .	473
13.3.4	Summary . . . . .	477
<b>14</b>	<b>MISCELLANEOUS . . . . .</b>	<b>479</b>
14.1	Disk Flags . . . . .	479
14.1.1	Summary . . . . .	485
<b>15</b>	<b>STORAGE FOUNDATION SOFTWARE STACK . . . . .</b>	<b>487</b>
15.1	Software Overview . . . . .	487
15.1.1	Structure of Storage Foundation Components . . . . .	488
15.2	Kernel Space Drivers . . . . .	491
15.3	User Space Processes . . . . .	494
15.4	Reducing VxVM's Footprint . . . . .	495
15.4.1	Essential VxVM Processes . . . . .	496
15.4.2	Unessential VxVM Processes . . . . .	496
15.4.3	Potentially Undesirable VxVM Processes . . . . .	497
<b>16</b>	<b>INDEX. . . . .</b>	<b>501</b>



<http://www.springer.com/978-3-540-85022-9>

Storage Management in Data Centers  
Understanding, Exploiting, Tuning, and Troubleshooting  
Veritas Storage Foundation  
Herminghaus, V.; Scriba, A.  
2009, XVIII, 524 p. 84 illus., Hardcover  
ISBN: 978-3-540-85022-9