PowerEdge™ Expandable RAID Controller 6 Performance Analysis Report

This paper provides an analysis of the performance of the PowerEdge™ Expandable RAID controller 6 (PERC6). The measurement of RAID controller performance is often referred to being an "art" as much as a "science". Many factors come into play including the controller itself, the number and type of drives that are attached, the operating system being used, the I/O subsystem of the server and the application in question.

Our performance analysis uses I/O file size, workload type, number of disks, cache enabling/disabling and RAID level as the input test parameters. The reader of this report is expected to be technical wanting to collect more information and/or get an idea about the performance characteristics of this product

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PERC6 RAID controller

PERC6 is a dual channel second generation SAS (Serial Attached SCSI) controller designed for high performance, high availability, high storage capacity and manageability. The wide array of RAID capabilities of the PERC6 offers a high level of integrity, accessibility, redundancy, and performance.

Features overview

(Please see the PERC6 users guide for more details – http://support.dell.com/support/edocs/storage/RAID/PERC6ir/en/PDF/en_ug.pdf)

- LSI SAS 1078 RAID on Chip
- DDRII cache (256MB or (up to 512MB PERC6/E Only))
- RAID levels 0, 1, 5, 6, 10, 50, and 60
- RAID level Migration (RLM)
- Auto-resume on array rebuild
- Auto-resume array reconstruction
- Patrol read for media scanning and repairing
- Fast initialization for quick array setup
- Check Consistency for background data integrity
- Online Capacity Expansion (OCE)
- Hot Spare support
  - Automatic rebuild
  - Global and dedicated
  - Enclosure affinity
- Enclosure management
  - SES (in band)
- DDF compliant Configuration on Disk (COD)
- S.M.A.R.T support (Self-Monitoring Analysis and Reporting Technology)
- 8 SAS Ports (2x4 External PERC6/E and 2X4 Internal PERC6/i)
- x8 PCI Express 1.0a compliant PCI Power Management Specification 1.1 compliant
- Standard height, three quarters length (6.5"X 4.5")

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- Operating Voltage +3.3V
- Operating Wattage Mean (13W) Max (17.5W)
- Audible alarm circuit
- OpenManage™ supported
- Broad OS Support including
  - Microsoft® Windows Server® 2003
  - Microsoft Windows Server 2008
  - Microsoft Windows® XP
  - Microsoft Windows Vista®
  - Red Hat® Enterprise Linux® Versions 4 and 5
  - SUSE® Linux Enterprise Server Versions 9 and 10.

Major Advantages

Using 3Gb/s SAS technology, PowerEdge™ Expandable RAID Controller 6 was observed in testing to be able to transfer up to 1484 MB/s (the theoretical upper limit by RAID On Chip (ROC) is better than 1.5 GB/s) using sequential reads and employing both of the external channels. Streaming video and data backup applications are capable of running extremely fast with up to 1MB stripe configurations. This is compared to the previous generation PERC5 with a maximum available 128KB stripe size.

The PERC6 supports all key RAID levels including RAID 6 and 60. RAID 6 tolerates two simultaneous failures, and thus the ability to manage unrecoverable media errors during rebuilds. This is useful especially when many high capacity, half duplex, lower cost SATA disks are utilized.

The battery backed cache offers a large addressable memory space that can increase throughput in several applications and preserves cache contents up to 24 hours using a 7WH Lithium Ion rechargeable battery.

Test environment

In the tests, Dell Labs used the IOmeter benchmark tool to stress the disk sub-system. With IOmeter we generated 12 different types of workloads to represent different application patterns commonly used by Dell customers. Different application platforms pass data and commands to the RAID controller in different block sizes. These blocks are called I/O files. To simulate different platforms we used the payload sizes listed below to represent a variety of applications using IO sizes ranging from small to large.

PERC6 IOmeter test patterns

Test Pattern	Payload size	Percent Read/Write	Percent Random(R)/Sequential(S)
Web File Server	4K	95/5	75/25(R)
Web File Server	8K	95/5	75/25(R)
Web File Server	64K	95/5	75/25(R)
DSS	1M	100/0	100/0(R)
Media Streaming	64K	98/2	0/100(S)
SQL Server Log	64K	0/100	0/100(S)
OS Paging	64K	90/10	0/100(S)
Web Server Log	8K	0/100	0/100(S)
DB-OLTP	8K	70/30	100/0(R)

Exchange Email	4K	67/33	100/0(R)
OS Drive	8K	70/30	100/0(R)
Video on Demand	512K	100/0	100/0(R)

The PERC6 offers RAID levels with the choice of stripe sizes 8K, 16K, 32K, 64K, 128K, 256K, 512K, and 1MB with the default being 64K. We chose 512K and tested RAID levels 0, 1, 5, 6 and 10. We tested at 2, 4, and 8 disks for the PERC6 Internal, and at 15, 30, 45, 60, and 90 disks for the PERC6 External. Higher stripe sizes create less physical I/O operations and improve PCI-Express bus utilization. 512K was selected as it is commonly used in Linux® and was determined to have the best combination of benefit for large I/O and least detriment for small I/O on this controller across multiple Operating Systems. The number of external drives was determined due to a PowerVault™ MD1000 storage enclosure having a 15 hard drive capacity. In all tests, Seagate Cheetah 3.5" SAS 73GB 15K.5 RPM drives were used.

The PERC6 adjustable task rates can improve reliability, data protection, and increase preventative monitoring of the storage attached. The I/O rate is usually traded off to add clock cycles for these functions. For all tests, the following rates were set to 0.

Rebuild Rate. Adjustable in percent from 0 to 100 to control the rate at which a rebuild will be performed on a disk drive when one is necessary. The higher the number, the faster the rebuild will occur (and the system I/O rate may be slower as a result).

Patrol Rate. Adjustable in percent from 0 to 100 to control the rate at which patrol reads will be performed. Patrol read is a preventive procedure that monitors physical disks to find and resolve any potential problem that might cause disk failure. The higher the number, the faster the patrol read will occur (and the system I/O rate may be slower as a result).

Background Initialization (BGI) Rate. Adjustable in percent from 0 to 100 to control the rate at which virtual disks are initialized "in the background." Background initialization makes the virtual disk immediately available for use, even while the initialization is occurring. The higher the number, the faster the initialization will occur (and the system I/O rate may be slower as a result).

Check Consistency Rate. Adjustable in percent from 0 to 100 to control the rate at which a consistency check is done. A consistency check scans the consistency data on a fault tolerant virtual disk to determine if the data has become corrupted. The higher the number, the faster the consistency check is done (and the system I/O rate may be slower as a result).

Reconstruction Rate. Adjustable in percent from 0 to 100 to control the rate at which reconstruction of a virtual disk occurs. The higher the number, the faster the reconstruction will occur (and the system I/O rate may be slower as a result).

Disks in arrays are distributed across all channels evenly for all tests. Disk caching was not enabled per the factory default for SAS drives. Detailed system test configuration information can be found in Appendix A. The test system was optimized for high throughputs. Disk arrays can be initialized for many practical purposes. From a performance point of view it is not suggested to use the disk sub-system until initialization or Background Initialization is complete. It should also be noted that with larger capacity SATA disk arrays this initialization has been measured in days and not hours.

The total physical I/O produced per each logical read and write request depending on the RAID level are given in the table below. Although a logical read request results in one physical read, a logical write request can result in many physical reads/writes depending on the RAID level selected.

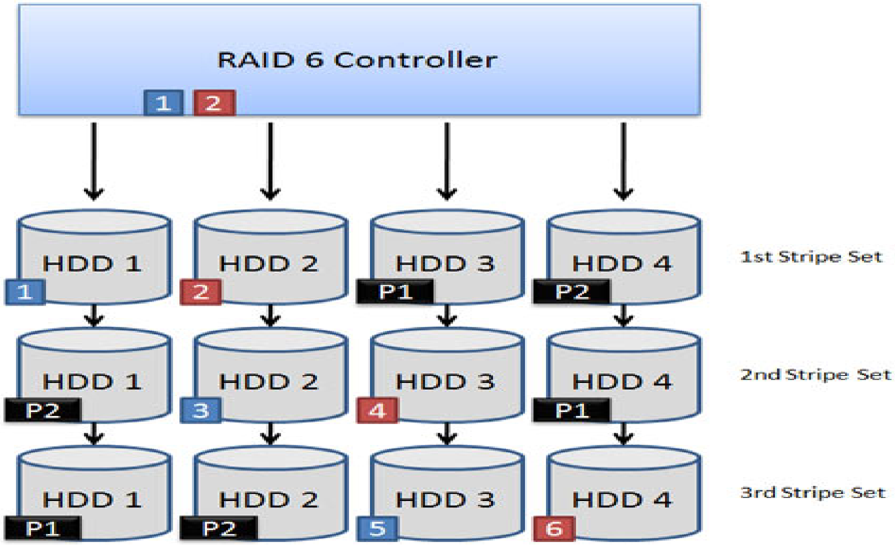
	RAID 0	RAID 5	RAID 6	RAID 10	
1 Logical Read	1	1	1	1	Physical Read I/O
	0	0	0	0	Physical Write I/O
1 Logical Write	0	2	3	0	Physical Read I/O
	1	2	3	2	Physical Write I/O

The PERC6 supports RAID levels 0, 1, 5, 6, 10, 50, and 60. Again, when deciding which level is right for a particular workload – storage capacity and data reliability must be weighed against performance.

Mirroring and parity techniques have different impacts to data capacity and data reliability. This is highlighted in the following table.

RAID level	Capacity Loss	Data Reliability
RAID 0	No loss	Array fails if one disk fails
RAID 1	Half	Single disk can fail
RAID 5	One disk worth of data	Single disk can fail
RAID 6	Two disks worth of data	Two disks can fail consecutively
RAID 10	One disk per span	One disk from each spanned array
RAID 50	One disk per span	One disk from each spanned array
RAID 60	Two disks per span	Two disks from each spanned array

RAID 50 is a stripe of two or more RAID 5 arrays. RAID 60 is a stripe of two or more RAID 6 arrays. RAID 50 can lose one disk for each span and still have data reliability. 60 can lose two disks for each span and still have data reliability.



The performance of a given RAID level varies depending on workload. For example, RAID1 generally does not provide improved write performance over a single disk. It does provide a read performance gain over a single disk. RAID 1 is best suited when the overall capacity can be served by a single drive and data reliability is a requirement. Since RAID 10 is RAID 1 spanned, mirroring by the processor is identical.

RAID 0 generally is the performance baseline as it does not have any reliability features. The following table generally compares the performance of a logical array configured into RAID 0, 5, 6, 10, 50 and 60. Each configuration has the same number of disks in the array. Each RAID level was configured with default PERC6 controller settings; sequential operations used 64K transfers and random operations used an 8K transfer size.

RAID level	Sequential Reads (MB/s)	Sequential Writes (MB/s)	Random Reads (IOPS)	Random Writes (IOPS)
RAID 0	Best	Best	Best	Best
RAID 5	Best	Better	Best	Good
RAID 6	Better	Better	Better	Good
RAID 10	Better	Better	Best	Better
RAID 50	Best	Better	Best	Good
RAID 60	Better	Better	Better	Good

Read operation performance is generally driven by the number of data drives available. RAID 5 is slightly faster than RAID 50 due to the additional parity information. Random read functions best with RAID 10 as this workload takes advantage of all the disks in the array.

The write operation performance is impacted when using mirror or parity. RAID 10 has half the write performance of RAID 0 due to mirroring. RAID 5, 6, 50 and 60 write performance is impacted by the parity write penalty. Random writes are worse than sequential with RAID 5, 6, 50 and 60 due to the smaller random transfer size preventing full stripe writes. RAID 6 and 60 will always give worse write performance than RAID 5 and 50 due to the double write parity penalty on recalculation.

Test Results

The following tables are based on running hundreds of hours of PERC6 IOmeter tests in Dell labs between August and October 2007. The first table contains the adapter settings to achieve the maximum throughput scores in the second table. The second table contains the highest relative scores for each RAID level in MBps throughput.

The PowerEdge™ Expandable RAID Controller 6 default operational mode is Write Back Adaptive Read Ahead mode. This is due to lower latency times on write activity compared to Write Through mode which will wait on the write transaction until the write is complete. For most customers the default settings are preferred, for some customers the default adapter settings may not always offer best performance so Dell gives you a choice.

	RAID 0	RAID 5	RAID 6	RAID 10
Web File Server (4K)	WT-NORA	WT-NORA	WT-NORA	WT-NORA
Web File Server (8K)	WT-NORA	WT-NORA	WT-NORA	WT-NORA
Web File Server (64K)	WT-NORA	WT-NORA	WT-NORA	WT-NORA
DSS (1M)	WB-NORA	WT-NORA	WT-NORA	WT-NORA
Media Streaming (64K)	WT-NORA	WT-NORA	WT-NORA	WT-NORA
SQL Server Log (64K)	WB-ARA	WB-NORA	WB-NORA	WT-NORA
OS Paging (64K)	WT-NORA	WB-NORA	WB-NORA	WB-NORA
Web Server Log (8K)	WT-NORA	WB-NORA	WB-NORA	WB-ARA
DB-OLTP (8K)	WT-NORA	WT-NORA	WT-NORA	WB-NORA
Exchange Email (4K)	WT-NORA	WT-NORA	WT-NORA	WT-NORA
OS Drive (8K)	WT-NORA	WT-NORA	WT-NORA	WT-NORA
Video on Demand (512K)	WB-NORA	WB-NORA	WB-NORA	WT-ARA

WT-NORA = Write Through No Read Ahead
WT- ARA = Write Through Adaptive Read Ahead
WB-NORA = Write Back No Read Ahead
WB- ARA = Write Back Adaptive Read Ahead

	RAID 0	RAID 5	RAID 6	RAID 10
Web File Server (4K)	99.19	83.04	64.22 - 32	120.67
Web File Server (8K)	195.18	156.69	123.23 - 32	234.70
Web File Server (64K)	1209.52	729.17	362.55 - 16	1301.97
DSS (1M)	1484.50 - 32	1459.82	1464.31 - 16	1476.53 - 8
Media Streaming (64K)	1348.83	972.86	863.65 - 16	1343.14
SQL Server Log (64K)	1147.14	488.04	409.24	601.43 -32
OS Paging (64K)	1389.98	556.57	507.28	1313.90
Web Server Log (8K)	367.46	372.11	329.35	491.40

DB-OLTP (8K)	175.92	89.02	29.40 - 16	126.50 - 32
Exchange Email (4K)	89.07	44.73	14.33 - 8	86.64
OS Drive (8K)	175.92	89.11	29.30 - 16	174.11
Video on Demand (512K)	1459.58 -32	1380.41-32	1427.88	1198.53-8

The highest values were usually at an outstanding queue depth of 64 IOps unless noted by a – following the value (i.e. - 16 means at a queue depth of 16 outstanding IOs.)

RAID 0 Analysis

RAID 0 offers no fault tolerance. As it only stripes the data across the disk array, we will see higher throughput rates with RAID 0 among other RAID levels. The group reliability decreases as more disks are added to RAID 0. RAID 0 should only be considered where performance is critical and data loss is acceptable.

When the workload is write intensive and mostly random the PERC6 write back cache buys increased performance. While the block size with RAID 0 can be as small as a byte, each drive seeks independently when reading or writing data on the drive. The percentage the drives act independently depends on the access pattern from the file system. For reads and writes that are larger than the stripe size, such as copying files or video playback, the disks will be seeking to the same position on each disk, the seek time of the array will be the same as that of a single drive. For reads and writes that are smaller than the stripe size, such as database access, the drives will be able to seek independently. If the sectors accessed are spread evenly between the two drives, the apparent seek time of the array will be half that of a single drive (assuming the disks in the array have identical access time characteristics). The transfer speed of the array will be the transfer speed of all the disks added together, limited only by the speed of the PERC6.

When the workload is mostly sequential reads or writes it is generally better to disable the read-ahead and adaptive read ahead features of the PERC6. In a sequential environment, even though the I/O size is the same, the stripe is used more efficiently; this is due to a natural result between track to track VS. random seek times.

RAID 5 Analysis

RAID 5 offers fault tolerance with generating and using block level parity information. For this reason, the overall performance and disk space usage is not as good as RAID 0. It is popular choice due to its low cost for redundancy.

At RAID levels 5, 6, 50 and 60, if a disk should fail in the array, the parity blocks from the surviving disks are combined mathematically with the data blocks from the surviving disks to reconstruct the data on the failed drive "on the fly".

This is sometimes called Interim Data Recovery Mode or Array Rebuilding. The computer knows that a disk drive has failed, but this is only so that the operating system can notify the administrator that a drive needs replacement; applications running on the computer are unaware of the failure. Reading and writing to the drive array continues seamlessly, though with some performance degradation.

In RAID 5 one logical read ends with one physical read. One logical write ends with two physical reads and two physical writes. Parity read and the recalculation process takes place in writes. Write back cache enabled becomes a benefit as the parity calculation is performed much faster with cache.

RAID 6 Analysis

RAID 6 is new for this second generation of SAS PERC controller. RAID 6 is not as efficient as RAID 5 or 10 when used with a small number of drives, but as arrays become bigger and have more drives the loss in storage capacity becomes less important and the probability of two disks failing at once is larger. RAID 6 provides protection against double disk failures as well as failures while a single disk is rebuilding. In the case where there is only one array, it may make more sense to use RAID 6 over having a hot spare disk.

According to SNIA (Storage Networking Industry Association), the definition of RAID 6 is: "Any form of RAID that can continue to execute read and write requests to all of a RAID array's virtual disks in the presence of any two concurrent disk failures. Several methods, including dual check data computations, orthogonal dual parity check data, and diagonal parity are used to implement RAID Level 6." The PERC 6 uses dual check data computations.

RAID 10 Analysis

RAID 10 helps ensure fault tolerance and availability with a striped and mirrored disk pair sub-system. As every disk has a mirrored copy, this RAID level consumes more disk space than any other RAID level, it is thereby more expensive. It must be noted that especially for RAID 10, disk distribution across the channel is very important. For example, for reads we will utilize only half the disks in the array since the other half are just mirrored copies.

RAID 10 has many administrative advantages. For instance, in some environments, it is possible to "split the mirror": declare one disk as inactive, do a backup of that disk, and then "rebuild" the mirror. This is useful in situations where the file system must be constantly available. This requires that the application supports recovery from the image of data on the disk at the point of the mirror split. Several of the application workloads measured for this paper support that feature.

Conclusion

- The PERC6 is a feature rich RAID controller that provides excellent throughput.
- To tailor the benefits of the PERC6 for maximum customer benefit, careful consideration should be given to the applications they are using in the environment, throughput requirements, and fault tolerance expectations.

Appendix A

Test platform – PowerEdge™ 2900	
Processor	Quad Core EM64T Family 6 Model 15 Stepping 7 Genuine Intel® ~2328Mhz
System BIOS/Firmware	A02
Processor bus speed	1,333Mhz @ 10.6 GB/s
L2 cache	2X4MB
Chipset	ESB2-D
Memory	24,574.98 MB
OS	Microsoft® Windows Server® 2003 Standard x64 Edition
Service Pack	5.2.3790 Service Pack 1 Build 3790
IOmeter version	2006.07.27

PowerEdge™ Expandable RAID Controller 6	
Processor	LSI SAS 1078 RAID on Chip (ROC) – 500 MHZ PowerPC Processor
PCI – Express Interface	X8 lane PCI-Express 1.0a compliant PCI Power Management Specification 1.1 compliant
Data Transfer Rates	Up to 3GB/s per port
Cache Memory	256MB or (512MB PERC6 E) DDR II SDRAM (PERC 6 I =256 integrated)
Caching Methods	No/Always/Adaptive, Write Back, Write Through
Battery Backup	24 hour 7WH Lithium Ion
Stripe size used	512Kb
Hot Plug PCI-Express support	Supported
Hot Spare	Supported
S.M.A.R.T. drive	Supported
Array creation limits	144 drives per controller

PowerVault MD 1000	
System BIOS/ Firmware	X05
Hard drives	Seagate Cheetah 15K.5 RPM 73GB “3.5 SAS drives
Model	ST373455SS
Hard Disk Firmware	S513

Appendix B

References

1. T10 Technical Committee: www.T10.org
2. PCI – SIG www.pcisig.com
3. LSI Logic Corporation www.LSI.Com
4. SNIA www.snia.org
5. IOmeter Benchmark tool: http://sourceforge.net/projects/iometer
6. Webopedia www.webopedia.com