Solid State Drive vs. Hard Disk Drive Price and Performance Study

A Dell Technical White Paper

Dell PowerVault Storage Systems

Vamsee Kasavajhala
Dell PowerVault Technical Marketing

May 2011

ABSTRACT

Solid state drives (SSDs) offer exceptional performance; however, compared to hard disk drives (HDDs) they have much less capacity per drive and are much more expensive. Additionally, each enterprise application workload has different capacity and performance requirements. Consequently, the challenge before IT departments is to navigate the price, performance, and capacity trade-offs between SSDs and HDDs to determine the best, most cost effective drive type for each application workload type.

This technical report provides price vs. performance results from tests performed at Dell™ Labs for SSD and HDD drives under various simulated workloads. The objective is to provide customers with recommendations on drive types that are best suited for some common applications. The report also includes an overview of Dell storage arrays suited to both SSD and HDD drive types, as well as an overview of tiered SSD/HDD storage, which enables IT departments to cost effectively take advantage of the best properties of both drive types.

Contents

Introduction

The traditional mainstay in storage technology has been the hard disk drive (HDD). However, while the capacity of HDDs has increased 40% annually, their random input/output (I/O) performance has increased only 2% annually. This means that for some of today's enterprise, web, cloud, and virtualized applications that require both high capacity and performance, HDDs may not deliver a cost-effective storage solution, even with their significant drop in cost per GB. Recently, an alternative storage device technology, the solid state drive (SSD), has started to gain prominence. SSDs offer exceptionally high performance but have much less capacity per drive. They are also relatively expensive when compared to HDDs, and have a write endurance limit.

Given the properties of HDDs and SSDs, IT departments now have a choice, but also a challenge, in determining the best way to cost-effectively fulfill the performance and capacity requirements of their enterprise applications. To meet this challenge and determine how they should integrate HDDs and SSDs into their storage fabric, IT departments must first quantify the performance, capacity, and cost value of SSDs vs. HDDs for different applications.

This white paper provides the results of SSD and HDD standalone performance testing at Dell Labs with various simulated application workloads. The objective is to provide IT departments with the information they need to most effectively take advantage of the different cost, performance, and capacity characteristics provided by HDDs and SSDs.

In addition, this white paper provides an overview of the Dell PowerVault™ MD Storage and PowerEdge™ server families and shows how the architecture seamlessly integrates with both HDDs and SSDs. The paper concludes by showing how IT departments can leverage automatic tiering between SSD and HDD drives in an EqualLogic™ PS Series SAN to both reduce cost and improve performance.

NOTE: For this analysis, we assumed that the SSD write endurance limit would not affect the cost of ownership, and that the write duty cycle (amount of time spent writing in a 24 hour period) is approximately 10%.

Brief Overview of HDD and SSD Technologies

HDDs are spinning disks, and their mechanical actions can create a delay in data retrieval. SSDs, built from silicon memory chips, have no moving parts, no rotational delay, and near zero seek time, which dramatically reduces response times. SSDs can be extremely valuable to applications that need high performance as measured by access latency and input/output operations per second (IOPS) from a limited capacity.

Measuring HDD and SSD Workload Performance

We set up eleven application I/O workload profiles (Table 1). For each profile, we used the IOmeter application to simulate the workload and measure the corresponding I/O. The analysis was done with the IOmeter 2006 version, which has more randomized data content than the 2008 version. For more information about the IOmeter, see http://www.IOmeter.org.

Table 1. Application I/O Workload Profiles

Application	Application I/O Workload Profile			
	Block Size in Bytes	Read/Write Percentage	Random/Sequential Percentage	I/O Performance Metric*
Web File Server	4KB, 8KB, 64KB	95%/5%	75%/25%	IOPS
Database Online Transaction Processing (OLTP)	8KB	70%/30%	100%/0%	IOPS
Exchange Email	4KB	67%/33%	100%/0%	IOPS
OS Drive	8KB	70%/30%	100%/0%	IOPS
Decision Support Systems (DSS)	1MB	100%/0%	100%/0%	IOPS
File Server	8KB	90%/10%	75%/25%	IOPS
Video on Demand	512KB	100%/0%	100%/0%	IOPS
Web Server Logging	8KB	0%/100%	0%/100%	MBPS
SQL Server Logging	64KB	0%/100%	0%/100%	MBPS
OS Paging	64KB	90%/10%	0%/100%	MBPS
Media Streaming	64KB	98%/2%	0%/100%	MBPS
*Metric measurements: IOPS = I/O operations per second MBPS = Megabytes per second				

Each profile was executed on a server connected to the target drives under test in a standalone mode via an H200 internal RAID adapter in a non-RAID configuration. The target drives used were 10K RPM SAS HDD, Enterprise Value SSD, and Enterprise Mainstream Performance SSD. Table 2 outlines the differences between the two SSD types (Enterprise Value and Enterprise Mainstream Performance).

Table 2. Differences Between Enterprise Mainstream Performance SSD and Enterprise Value SSD

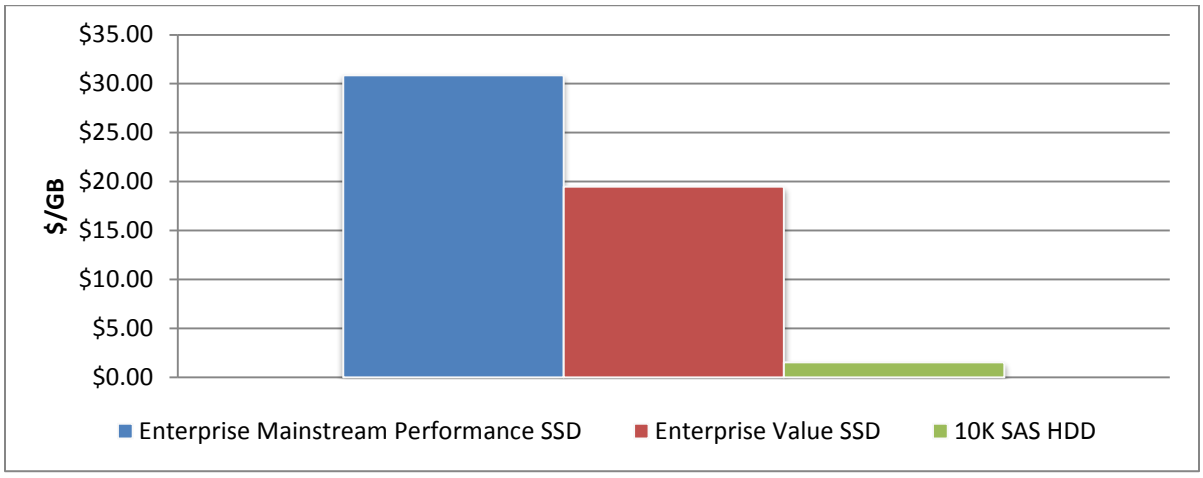
Characteristics	Enterprise Mainstream Performance SSD (Pliant 149GB)	Enterprise Value SSD (Samsung SS805)
Host Interface	SAS	SATA
Performance (8K transfers, 70/30 R/W, QD = 4)	7K—10K IOPS	4K—6K IOPS
Flash Memory Technology	SLC NAND	SLC NAND
Capacity	149 GB	100 GB
Target Storage and Server	Mid- to High-Range Storage and Server	Low- to Mid-Range Storage and Server

Price vs. Performance Test Results

In this section, we present two sample test results—one each for sequential and random-access workloads—that clearly demonstrate the performance and cost differences between SSD and HDD. The prices comparisons of the three drives in terms of price (US$) per GB capacity is shown in Figure 1.

NOTE: For all tests described in this white paper, we used the Dell Americas region list prices as of the publication date of this paper. In addition, the price was normalized to US dollars per 100 GB. For example, the normalized price for a 150 GB drive with a list price of US $90.00 is: 90*100/150 GB = $60.00.

Figure 1. Price/GB Comparison: Enterprise Mainstream Performance SSD, Enterprise Value SSD, and 10K SAS HDD



Sequential Access Workload—Media Streaming

Media streaming is an example of a sequential access workload. Media streaming servers are systems that provide web-casting, video conferencing, Internet entertainment (for example, Internet TV or radio), and multimedia services. These systems generally require a balance between storage capacity, availability, redundancy, and performance.

Table 3 outlines the I/O parameters used for the media-streaming test case.

Table 3. Media Streaming Server I/O Workload Profile

Block Size in KB	Sequential/Random Percentage	Read/Write Percentage	I/O Performance Metric
64 KB	100%/0%	98%/2%	MBPS (Megabytes per second)

Figure 2. Media Streaming Server Performance

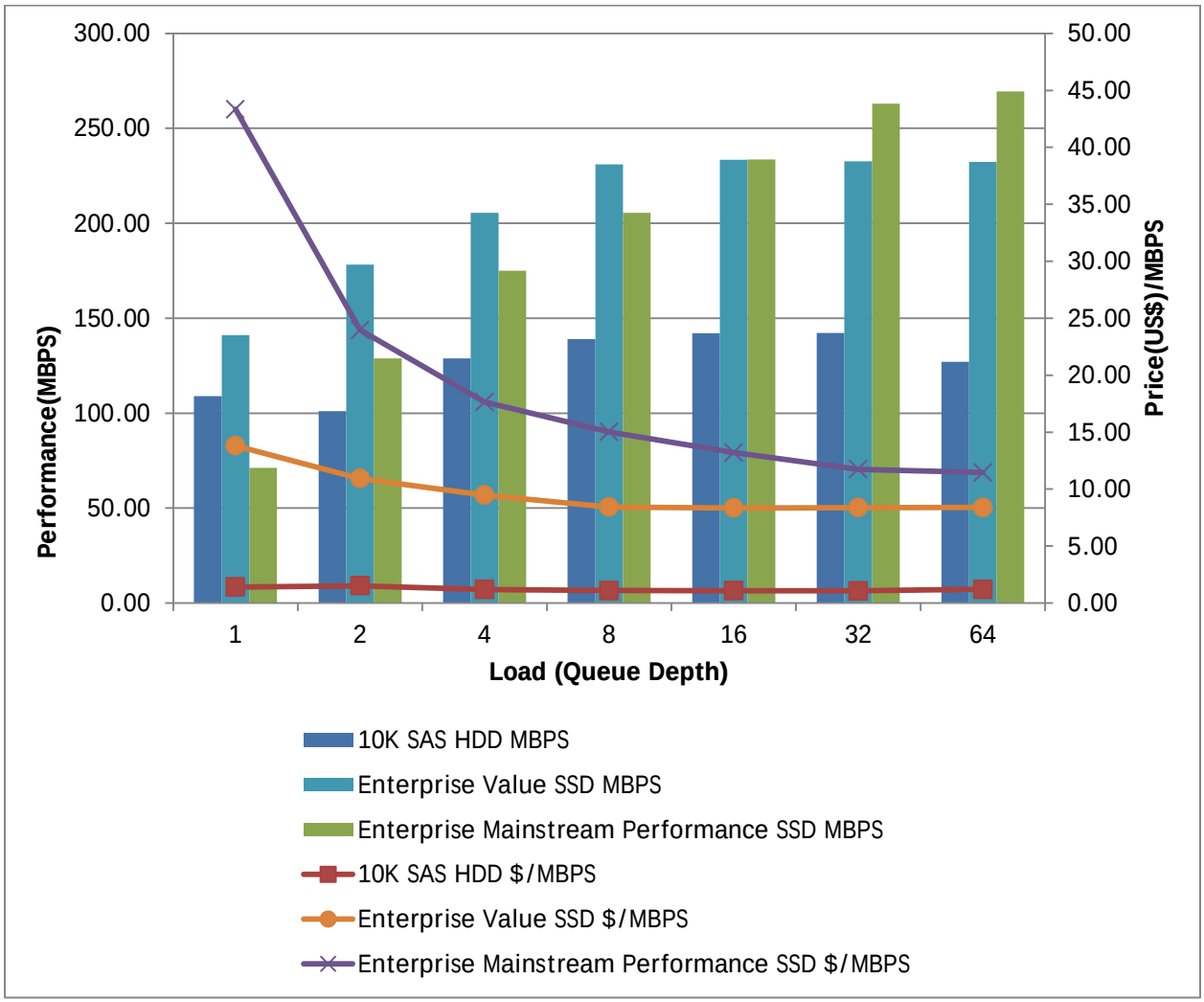


Table 4. HDD and SSD Performance and Price/MBPS Ratio Comparison

Drive Type Comparison	Price (US$)/MBPS Ratio (At Load = 8)	Performance Ratio (At Load = 8)
Enterprise Value SSD vs. 10K SAS HDD	8.44/1.1 = 7.67	231/138 = 1.67
Enterprise Mainstream Performance SSD vs. 10K SAS HDD	15.02/1.1 = 13	205.5/138 = 1.5

From Figure 2 and Table 4, we can see that for sequential access workloads, such as media streaming applications, the price/MBPS ratio is much greater than the corresponding performance ratio when moving from HDDs to SSDs. In other words, IT administrators will pay significantly more for SSD drives (13 times, if moving to Enterprise Mainstream Performance SSD) than they get in performance improvements (1.5 times, if moving to Enterprise Mainstream Performance SSD). Therefore, for sequential access applications, traditional hard drives offer a more cost effective solution.

If additional performance is necessary, then Enterprise Value SSDs are a good option (see Table 4). Enterprise Value SSDs cost much less than Enterprise Mainstream Performance SSDs (see Figure 1) and offer similar if not better performance at most queue depths.

IT departments considering SSDs should take both the performance and the price/performance ratios into consideration before making a choice. For some IT operations, the additional cost might not justify the performance improvement.

Random Access Workload—Microsoft Exchange Email

The storage requirements for email servers can vary depending on the size and number of emails and the type and number of users. While small departmental email servers may need only limited storage and features, large corporate email servers normally require greater storage capacity and a high level of availability, performance, and scalability. I/O profiles will vary depending on the number of users and the size of emails and their attachments.

Table 5 outlines the I/O parameters for the Microsoft Exchange Email test case.

Table 5. I/O Workload Profile for Exchange Email

Block Size in KB	Sequential/Random Percentage	Read/Write Percentage	I/O Performance Metric
4 KB	0%/100%	67%/33%	IOPS (I/O operations per second)

Figure 3. Exchange Email Server Performance

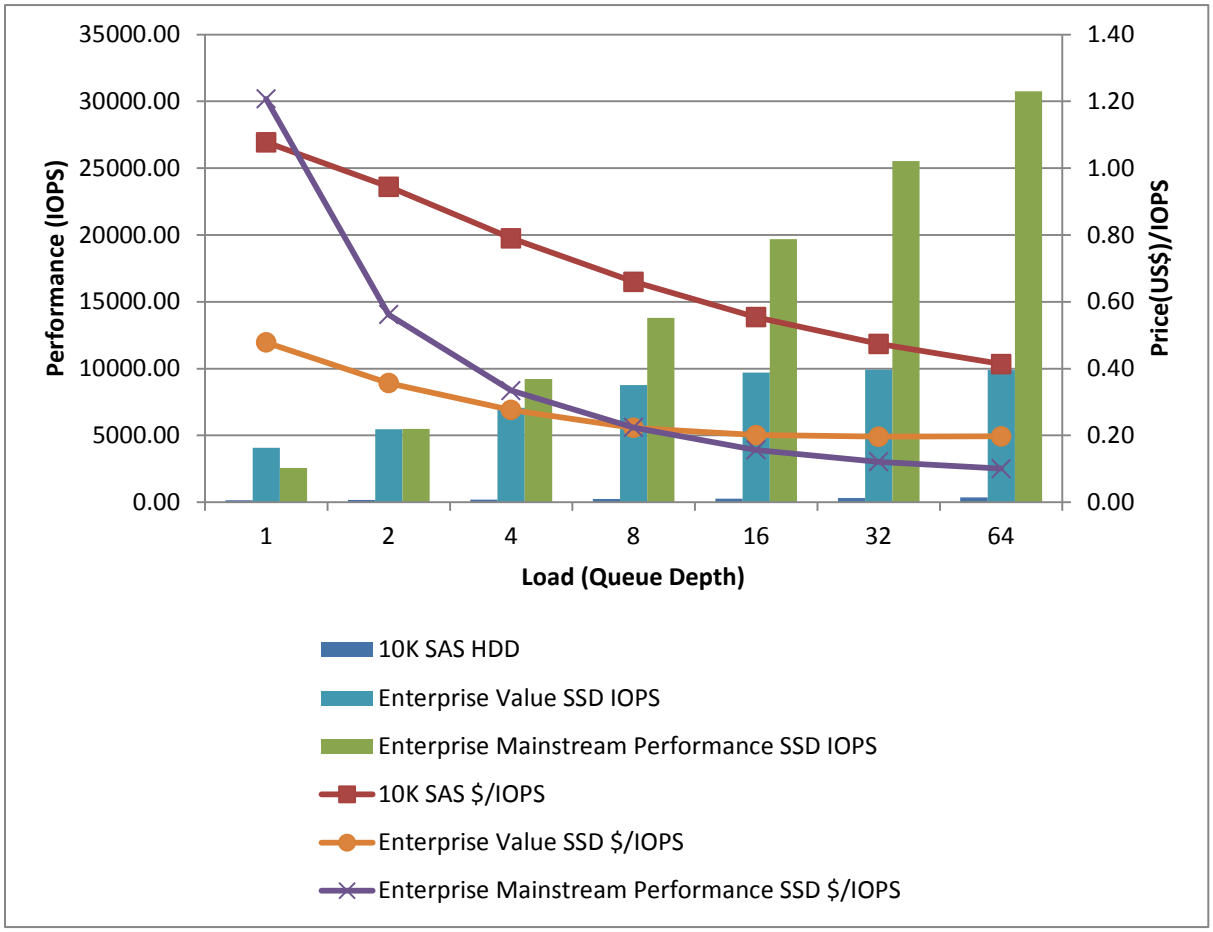


Table 6. HDD and SSD Performance and Price/IOPS Ratio Comparison

Drive Type Comparison	Performance Ratio (At Load = 8)	Price/IOPS Ratio (At Load = 8)
Enterprise Value SSD vs. 10K SAS HDD	8761.3/232.19 = 37.6	0.22/0.66 = 0.33
Enterprise Mainstream Performance SSD vs. 10K SAS HDD	13794/232.19 = 59.46	0.22/0.66 = 0.33

SSDs are best suited for applications that use random data accesses and small payload sizes. From Figure 3 and Table 6, we can see that at queue depth 8, Enterprise Mainstream Performance SSDs offer almost 60 times better performance than traditional hard drives, and yet their price/IOPS ratio is 1/3 of that of HDDs. In other words, IT administrators will see significant performance gains at a good cost point when moving from HDDs to SSDs. And this ratio only improves as the queue depth increases.

Therefore, for completely random applications like Exchange Mail, SSDs offer huge performance improvements and deliver solid cost value.

Summary

Customers should take both performance and the price/performance ratios into consideration when deciding between SSDs and HDDs. SSDs offer significant benefits for specific workloads. However, if your workloads do not require high performance, or have a higher than 10% write duty cycle and are not tierable, an investment in SSDs may not be cost-effective. While your system may perform well, it could be over-provisioned and under-utilized for what the applications can leverage.

Sequential Workloads

For typical sequential workloads, traditional hard drives offer a combination of capacity and performance for a very good price. Although SSDs can offer performance improvement over HDDs even for sequential applications, the performance improvement does not justify their cost. Therefore, we recommend hard disk drives for predominantly sequential applications.

Random Workloads

For typical random workloads, SSDs offer tremendous performance improvements and no worries about write endurance/wear out. The performance improves further as applications become more parallel and utilize the full capability of the SSDs. The performance improvements gained from SSDs for random workloads definitely outweigh their additional cost. Therefore, we recommend SSDs for random I/O applications, especially with tiering software or a low write duty cycle environment.

A summary of Dell recommendations is in Table 7.

NOTE: Dell believes the best way to leverage SSD technology is to use a tiered storage approach, which delivers the best price and performance results for arrays containing a mix of SSD and HDD technologies. See "Putting it All Together—Manual and Automatic Tiering Implementation".

Table 7. Drive Recommendations for Each Application Workload I/O Profile

Application	Payload Size in Bytes	Read/Write Percentage Mix	Random/Sequential Percentage Mix	Recommended Drive Type
Web File Server	4KB, 8KB, 64KB	95%/5%	75%/25%	SSD
Database Online Transaction Processing (OLTP)	8KB	70%/30%	100%/0%	SSD
Exchange Email	4KB	67%/33%	100%/0%	SSD
OS Drive	8KB	70%/30%	100%/0%	SSD
Decision Support Systems (DSS)	1MB	100%/0%	100%/0%	SSD
File Server	8KB	90%/10%	75%/25%	SSD

Application	Payload Size in Bytes	Read/Write Percentage Mix	Random/Sequential Percentage Mix	Recommended Drive Type
Video on Demand	512KB	100%/0%	100%/0%	SSD
Web Server Logging	8KB	0%/100%	0%/100%	HDD
SQL Server Logging	64KB	0%/100%	0%/100%	HDD
OS Paging	64KB	90%/10%	0%/100%	HDD
Media Streaming	64KB	98%/2%	0%/100%	HDD

NOTE: In this analysis, we assumed that the SSD write endurance limit would not affect the cost of ownership. It is assumed that the write duty cycle (amount of time spent writing in a 24 hour period) is approximately 10%.

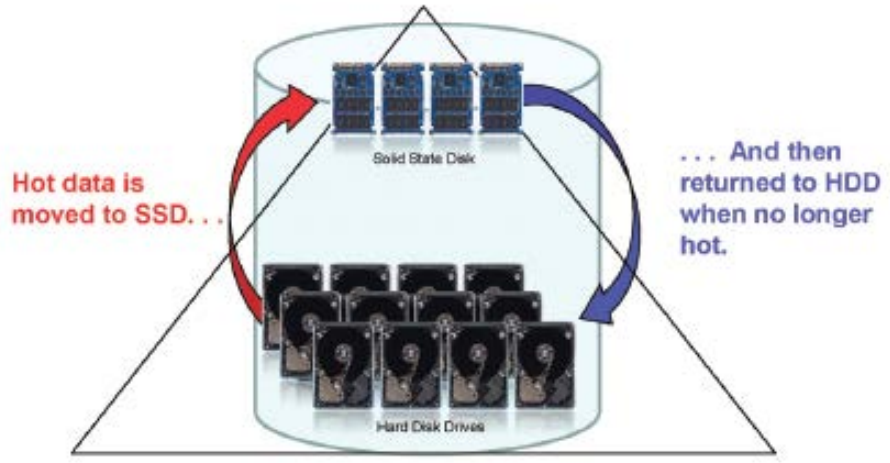
Putting it All Together—Manual and Automatic Tiering Implementation

Storage tiering increases efficiency by matching business needs with the most appropriate storage media. By tiering storage, enterprise IT organizations can direct high I/O operations like OLTP or certain Web-facing applications to high-performance SSD and serial attached SCSI (SAS) arrays. Similarly, inert file or application data can be directed to more affordable Nearline SAS/SATA SAN arrays.

Designed from the outset to offer high ease-of-use and low total cost of ownership, Dell EqualLogic PS Series virtualized iSCSI SANs provide IT organizations with a number of features for automating tiered storage. These features extend the automation at the core of the PS Series design, while allowing customization and control of storage tiers to suit a wide range of business and organizational requirements.

An enterprise runs a mix of applications in the course of business operations, each with its own particular set of performance requirements and environmental considerations. To support this application mix, storage architects can configure their PS Series SAN as a heterogeneous storage pool with multiple arrays, each running a different RAID policy. The EqualLogic Auto-Tiering features monitor volume size and I/O workloads, and then over time, automatically migrate volumes to arrays with the most appropriate disk technologies and RAID policies. Expansion is simple — just add an array to the SAN. The PS Series SAN automatically redistributes workloads across all arrays to best suit the application mix. The new array will add processor and throughput resources, in addition to disk capacity and spindles, all of which improve overall SAN performance.

Figure 4. Automatic Tiering Between SSD and HDD



The PS6000XVS/6010XVS is a highly specialized SAN array that combines low-latency SSD and 15,000 RPM SAS drives within a single enclosure, further advancing EqualLogic Auto-Tiering. Whereas other PS Series arrays operate at the volume level, the XVS performs tiering on data sets at a sub-volume level. Within the XVS, sub-volume workloads are categorized as high I/O, medium I/O, or low I/O, and then placed as appropriate onto either SSD or SAS tiers. The XVS systems can add tremendous value to such multi-tiered workloads as virtual desktop implementation (VDI) and catalog-oriented database applications, which contain both static and highly dynamic components. With EqualLogic multi-tiering arrays, IT departments can:

- Reduce costs, through the alignment of low-IOPS data with capacity-optimized Nearline disk resources.
- Improve performance, through the assignment of SSD and SAS resources to high-IOPS data stores.
- Optimize SAN storage for multi-tiered workloads such as virtual desktop deployments.
- Simplify architecting, implementing and fine-tuning tiered storage settings in live production environments, with minimal disruption of operations.

For more information about Dell automatic tiering solutions, download information from the following:

www.equallogic.com/resourcecenter/assetview.aspx?id=9279

www.equallogic.com/solutions/default.aspx?id=9687

Appendix A: Overview of Dell Storage Arrays

In this section, we provide an overview of Dell's PowerVault, EqualLogic, and PowerEdge storage arrays, the types of drives they can house, and their performance.

PowerVault Storage Solutions Overview

Today, IT organizations need to store and manage rapidly increasing amounts of data with limited resources and budgets. The Dell PowerVault MD family addresses these challenges with versatile solutions optimized for smaller-scale storage consolidation and virtualization projects. PowerVault MD products include a series of high-performance SAN and direct-attached storage arrays, high-capacity expansion enclosures, and robust management software that together deliver exceptional flexibility, scalability, and value.

- Storage consolidation and virtualization—The PowerVault MD3600i and MD3620i Series of iSCSI SAN arrays is ideal for network storage consolidation and virtualization deployments of up to 64 physical servers.
- High availability storage—The PowerVault MD3200 and MD3220 Series of storage arrays incorporates 6 Gb/s SAS technology for shared storage and virtualized environments on PowerEdge servers. These next-generation arrays offer exceptional flexibility, scalability, and performance. Dual-controller models can connect up to four high-availability servers or eight non-redundant servers for balanced performance in mixed virtualized environments.
- Simplified expansion—The PowerVault MD1200 and MD1220 are direct-attach 6 GB/s SAS expansion enclosures that can connect to MD3200 Series arrays and Dell PowerEdge servers to provide additional capacity for high performance and data-intensive applications.
- Unmatched performance—The PowerVault MD1220 delivers the speed, flexibility, and reliability to satisfy data-hungry, performance-intensive applications that store active and frequently changing information.
- Scalable capacity—The PowerVault MD1200 expansion enclosure is ideal for applications that move large amounts of data and require extended storage capacity. Up to twelve (12) 3.5" or 2.5" SAS HDDs or SSDs can be housed in this 2U array family to provide up to 24 TB of storage. Both drive sizes can be combined behind a single PowerEdge RAID Controller.

Table 8. PowerVault MD Series Hybrid Storage Arrays

Feature	MD1200	MD1220	MD3200	MD3200i	MD3220	MD3220i
Array Capacity	24 TB	24 TB	12 TB			
Disk Drives	3.5 and 2.5-inch SAS/NL SAS HDD; 2.5-inch SSD	2.5-inch SAS/NL SAS HDD; 2.5-inch SSDs	3.5 and 2.5-inch SAS/NL SAS HDDs; 2.5-inch SSDs		2.5-inch SAS/NL SAS HDDs; 2.5-inch SSDs	
Performance	6 Gbps SAS HDDs; 3 Gbps SSDs					

PowerEdge Servers Overview

Dell PowerEdge servers are purpose-built to focus on the key business and non-business related challenges facing IT departments, including:

- Reliability
- Manageability
- Energy Efficiency
- Memory Scalability and Capacity
- Virtualization Performance
- Business Value

Rack and Tower Servers

Dell provides a complete portfolio of 1, 2, and 4 socket rack servers designed to reduce complexity and deliver superior value. PowerEdge rack servers feature excellent performance and functionality, along with outstanding reliability. Dell also provides a complete tower server portfolio with a wide choice of performance and functionality, giving organizations of all sizes a solid foundation from which to run IT operations. The PowerEdge server towers are designed to deliver high quality and reliability at a consistently low acquisition cost, with exceptional price for performance.

Blade and Cloud Servers

The Dell PowerEdge M-Series blade servers address the challenges of an evolving IT environment by delivering leading enterprise-class features and functionality. The M-Series delivers a unique array of options configured to meet the needs of IT environments today and in the future. Dell hyperscale-inspired servers are designed to deliver the most compute power in the least amount of space.

- Simple Manageability—Dell's blade solutions deliver an array of enterprise-class management capabilities, including centralized, chassis-based tools to maximize data center productivity.
- Increased Flexibility—Designed to lead the industry in rapid deployment, Dell's fully modular blade enclosure provides an effective solution for scaling I/O infrastructure that delivers savings in time, cabling and switch port costs.
- Energy Efficiency—Dell M-series blades are designed for energy efficiency and density to address growing power consumption and space constraints in the data center.

EqualLogic Storage Solutions Overview

Built on patented peer storage architecture, the Dell EqualLogic PS Series Internet SCSI (iSCSI) storage arrays offer high performance, reliability, intelligent automation, and seamless virtualization of storage to enable simplified enterprise storage deployment and management, and comprehensive data protection. The EqualLogic PS6000XVS and the PS6010XVS arrays contain the latest in SSD and SAS HDD technology to automatically tier and deliver fast access to high demand hot data in a multi-tiered workload.

The on-board intelligence of the EqualLogic firmware provides automatic tiering between the two drive types—SSD and SAS, as well as automatic load balancing across multiple drives of each type, helping deliver the appropriate balance of responsiveness and capacity for multi-tiered workloads. The EqualLogic PS6000XVS array uses intelligent and dynamic data placement algorithms to move hot data to the SSD drives from SAS drives and move cold or warm data from the SSD drives to the SAS drives as needed. In addition, with an all-inclusive pricing model for enterprise software features like snapshot,

remote replication, and application integration, Dell EqualLogic PS Series iSCSI storage arrays offer a fundamental change in the way enterprises think about purchasing and managing storage.

Table 9. EqualLogic PS6000 Series Hybrid Storage Arrays

Feature	PS6000XVS	PS6000S	PS6010XVS	PS6010S
Array Capacity	4.4 TB	400, 800 GB, or 1.6 TB	4.4 TB	800 GB or 1.6 TB
Disk Drives	SAS HDD; SSD	SSD	SAS HDD; SSD	SSD
Performance	6 Gbps SAS HDDs; 3 Gbps SSDs			

Appendix B: Related Publications

- *Dell PowerVault MD Family*
  http://www.dell.com/downloads/global/products/pvaul/en/powervault-md-storage-family-brochure-en.pdf

- *Dell EqualLogic PS Series*
  http://www.equallogic.com/resourcecenter/assetview.aspx?id=8341

- *Dell PowerEdge Servers Portfolio Guide*
  http://www.dell.com/downloads/global/products/pedge/en/pedge-portfolio-brochure.pdf

- *Automate Storage Tiering Simply and Efficiently with Dell EqualLogic PS Series Virtualized iSCSI SANs*
  http://www.equallogic.com/resourcecenter/assetview.aspx?id=9279

- *Optimize Storage for Multi-Tiered Workloads with Dell EqualLogic PS6000XVS & PS6010XVS iSCSI SAN Arrays*
  http://www.equallogic.com/solutions/default.aspx?id=9687
  Appendix B: Related Publications