Benefits of Automatic Data Tiering in OLTP Database Environments with Dell EqualLogic Hybrid Arrays

ABSTRACT

The Dell™ EqualLogic™ hybrid arrays - PS6010XVS and PS6000XVS - are designed to support fast access to high demand “hot” data in a multi-tiered dataset. The use of two drive types - SSD and SAS - in a single array as well as automatic data tiering between these two drive types makes these hybrid arrays a very effective and cost efficient option for OLTP databases and other mission-critical applications, where a portion of the dataset sees significantly more I/O traffic than the rest. In this technical report, we provide a proof point for performance improvements in OLTP applications when using EqualLogic PS6010XVS arrays based on testing performed at Dell Labs in February 2011.
Thank you for your interest in Dell EqualLogic™ PS Series storage products. We hope you will find the PS Series products intuitive and simple to configure and manage.

PS Series arrays optimize resources by automating volume and network load balancing. Additionally, PS Series arrays offer all-inclusive array management software, host software, and free firmware updates. The following value-add features and products integrate with PS Series arrays and are available at no additional cost:

- **PS Series Array Software**
  - **Firmware** – Installed on each array, this software allows you to manage your storage environment and provides capabilities such as volume snapshots, clones, and replicas to ensure data hosted on the arrays can be protected in the event of an error or disaster.
    - **Group Manager GUI**: Provides a graphical user interface for managing your array
    - **Group Manager CLI**: Provides a command line interface for managing your array.
  - **Manual Transfer Utility (MTU)**: Runs on Windows and Linux host systems and enables secure transfer of large amounts of data to a replication partner site when configuring disaster tolerance. You use portable media to eliminate network congestion, minimize downtime, and quick-start replication.

- **Host Software for Windows**
  - **Host Integration Tools**
    - **Remote Setup Wizard (RSW)**: Initializes new PS Series arrays, configures host connections to PS Series SANs, and configures and manages multipathing.
    - **Multipath I/O Device Specific Module (MPIO DSM)**: Includes a connection awareness-module that understands PS Series network load balancing and facilitates host connections to PS Series volumes.
    - **VSS and VDS Provider Services**: Allows 3rd party backup software vendors to perform off-host backups.
    - **Auto-Snapshot Manager/Microsoft Edition (ASM/ME)**: Provides point-in-time SAN protection of critical application data using PS Series snapshots, clones, and replicas of supported applications such as SQL Server, Exchange Server, Hyper-V, and NTFS file shares.
      - **SAN HeadQuarters (SANHQ)**: Provides centralized monitoring, historical performance trending, and event reporting for multiple PS Series groups.

- **Host Software for VMware**
  - **Storage Adapter for Site Recovery Manager (SRM)**: Allows SRM to understand and recognize PS Series replication for full SRM integration.
  - **Auto-Snapshot Manager/VMware Edition (ASM/VE)**: Integrates with VMware Virtual Center and PS Series snapshots to allow administrators to enable Smart Copy protection of Virtual Center folders, datastores, and virtual machines.
  - **Multipathing Extension Module for VMware® vSphere**: Provides connection awareness enhancements to the existing VMware multipathing functionality that understands PS Series network load balancing and facilitates host connections to PS Series volumes.

Current Customers Please Note: You may not be running the latest versions of the tools and software listed above. If you are under valid warranty or support agreements for your PS Series array, you are entitled to obtain the latest updates and new releases as they become available.

To learn more about any of these products, contact your local sales representative or visit the Dell EqualLogic™ site at [http://www.equallogic.com](http://www.equallogic.com). To set up a Dell EqualLogic support account to download the latest available PS Series firmware and software kits visit: [https://www.equallogic.com/secure/login.aspx](https://www.equallogic.com/secure/login.aspx)
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**REVISION INFORMATION**

The following table describes the release history of this Technical Report.

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<td>Initial Release</td>
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The following table shows the software and firmware used for the preparation of this Technical Report.

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Executive Summary

Dell Labs conducted a performance study in February 2011 to compare the benefits of using Dell™ EqualLogic™ hybrid arrays over all-HDD arrays in an OLTP database application environment. Engineers at Dell Labs simulated multiple runs of an OLTP benchmark load on identically configured infrastructure with Microsoft® SQL Server® databases hosted on an EqualLogic PS6010XV, an all 15K SAS drive array, and an EqualLogic PS6010XVS, a mixed SSD and 15K SAS drive array, and compared the performance of each array in terms of total number of concurrent users supported, transactions completed and IOPS delivered for each array such that read or write I/O latency was less than or equal to 20 milliseconds. Figure 1 shows the OLTP environment simulated in this study.

Key Findings

As shown in Figure 2, the results from Dell Labs testing indicate that in a TPC-C benchmark environment an EqualLogic PS6010XVS array can accommodate up to 170% more concurrent users and complete up to 170% more transactions per minute in comparison with an EqualLogic PS6010XV for the same application response time. The same test results also indicate that in a OLTP benchmark environment an EqualLogic PS6010XVS can deliver up to 360% more IOPS than an EqualLogic PS6010XV while keeping the read and write I/O latency equal to or below 20 milliseconds.
Introduction

Rapid access to high-demand data is essential for good user experience in multi-user Online Transaction Processing (OLTP) database applications. Use of high-cost low-latency solid state drives (SSDs) in all hard disk drive (HDD) storage arrays can improve application performance. However, as database applications become increasingly consolidated to increase storage efficiency, the traditional methods of identifying, tiering and load balancing the high demand data across SSDs and HDDs can be complex as well as cost-prohibitive.

Overcoming limitations of traditional multi-tiered load balancing

When high-demand and low-access data coexist in the same volume, it is often difficult to manually separate frequently and sparingly accessed data due to the dynamic nature of data access patterns. The advantages of traditional tiering and load balancing OLTP application data are marginalized over time.

A cost-effective approach to reduce access time for frequently used data is to have automatic tiering at a sub-volume level where the relatively small-sized but high-accessed data is placed on high-performance SSD drives with the rest of the data residing on lower-performance but higher-capacity HDD drives. Dell™ EqualLogic™ PS6010XVS and EqualLogic PS6000XVS hybrid arrays consisting of both SSD and HDD in the same enclosure follow this strategy to efficiently implement tiering and load balancing for multi-tiered application workloads such as OLTP databases.

Dell EqualLogic PS6000XVS and EqualLogic PS6010XVS array capabilities

The Dell EqualLogic PS6010XVS and EqualLogic PS6000XVS arrays are designed to support fast access to high demand “hot” data in multi-tiered datasets. They have sixteen drives – eight high performance SSD drives and eight high capacity 15,000 rpm Serial Attached SCSI (SAS) hard disk drives. 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 use of two drive types – SSD and SAS – in a single array as well as automatic tiering of application data between these two drive types makes EqualLogic PS6010XVS a very cost efficient option for meeting service levels in performance sensitive OLTP environments. In a typical OLTP database application, a significantly higher percentage of I/O is directed towards a relatively small segment of data (“hot” database objects). EqualLogic PS6010XVS 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 out to the SAS drives as and when needed (Figure 3).
In this technical report, we provide a proof point for OLTP application performance improvements when using EqualLogic hybrid arrays over all-HDD arrays (PS6010XVS vs. PS6010XV). We present the overall architecture, test configuration, as well as a summary of the EqualLogic PS6010XVS and EqualLogic PS6010XV array performance results from testing performed at Dell Labs.

**Test configuration and tools**

To measure performance of consolidated OLTP applications, we ran TPC-C benchmark on ten databases hosted on two identically configured environments. First, we created ten 200 GB volumes on each EqualLogic array – PS6010XV and PS6010XVS. A SQL Server® database was created (and populated) in each of these volumes. Thus, both the EqualLogic PS6010XV and EqualLogic PS6010XVS arrays were set up with ten identical databases.

In Test A, we ran ten TPC-C benchmark clients simultaneously against each of these ten databases hosted on EqualLogic PS6010XV and increased the workload until the read or write IO latency exceeded 20 milliseconds. Next, in Test B we repeated the benchmark for databases hosted on the EqualLogic PS6010XVS array. We then compared the total number of concurrent users supported, transactions completed and IOPS delivered at the same transaction response time to determine the performance improvements when using EqualLogic PS6010XVS over EqualLogic PS6010XV. There were sufficient server and network resources in both test environments.

**Benchmark Factory TPC-C**

TPC-C is an OLTP benchmark that simulates an order-entry environment where a number of concurrent end-users execute transactions against a database. The benchmark is comprised of transactions which include entering and delivering orders, recording payments, checking the status of orders, and monitoring the level of stock at the warehouses. The performance metric of this benchmark can be expressed in terms of transactions per second (TPS) - the number of orders that can be fully processed per second.

We used Quest Software’s Benchmark Factory® for Databases for the TPC-C benchmark load generation. One Benchmark Factory client was run against one
database under test, for a total of ten clients running simultaneously against the ten databases hosted in an EqualLogic array. We used two ESXi 4.1 hosts (Dell™ PowerEdge™ R710 servers with dual-socket quad-core Intel® Xeon® X5560, 2.7 GHz processors and 96 GB memory), each with five client VMs. Each client ran in a Windows® Server 2003 R2, 32-bit VM.

A Benchmark Factory TPC-C schema was created and populated with approximately 120 GB of data, including tables and indexes, for each of the ten databases. This ensured approximately all of the 200 GB allocated per database was in use. Specifically for the EqualLogic PS6010XVS array, it ensured that almost 80% (2 TB) of its capacity was in actual use. As the capacity in use was very large compared to the SSD storage capacity in the EqualLogic PS6010XVS array, there was little probability that the databases were cached in SSDs.

**SQL Server**

Microsoft® SQL Server® 2008 SP1, 64-bit, provided the database services for the TPC-C clients. The SQL Server® was hosted on a Dell PowerEdge R710 server with dual-socket quad-core Intel Xeon X5560, 2.7 GHz processors and 96 GB memory. However, the goal of these tests was to compare the relative performance of EqualLogic PS6010XVS and EqualLogic PS6010XV arrays, rather than to establish the highest possible TPS that could be obtained in this configuration. Therefore SQL Server® was configured to use a maximum of 4 GB of cache, thereby forcing high I/O rates to the storage arrays.

The SQL Server® utilized EqualLogic MPIO DSM for Windows® Server 2008 and was connected to the SAN via two 10 GbE NICs connected to a Dell™ PowerConnect™ 8024F switch.

**EqualLogic storage arrays**

The EqualLogic 6010XVS and EqualLogic 6010XV arrays under test were connected to the SQL Server® via a Dell PowerConnect 8024F switch. This network was dedicated for the storage traffic. At any point in time, only one of the arrays was under test. The EqualLogic PS6010XV had sixteen 15,000 rpm 450 GB SAS drives and was configured in RAID 10 for maximum possible OLTP database performance. The PS6010XVS array had eight 100 GB SSD drives and eight 15,000 rpm 450 GB SAS drives and the default accelerated RAID 6 configuration was used.

**EqualLogic SAN Headquarters**

I/O characteristics on the EqualLogic PS6010XV and EqualLogic PS6010XVS arrays

![Figure 4: Illustration of the test configuration](image-url)
were monitored by the EqualLogic SAN Headquarters (SANHQ) software. SANHQ is a storage monitoring solution designed for and included with the Dell EqualLogic PS Series iSCSI SAN arrays as part of its all-inclusive software package. It delivers consolidated and centralized storage performance, capacity, and network monitoring. SANHQ can dramatically reduce the time required to identify performance bottlenecks, correlate them to events in the virtual and/or physical server infrastructure, and develop remediation strategies.

Overall test configuration

Figure 4 illustrates the overall test configuration used for the benchmark testing. Multiple VMs using Benchmark Factory for Databases software concurrently executed the TPC-C benchmark at increasing user loads. All transactions performed database access through one Microsoft® SQL Server®. Each Benchmark Factory client accessed its own database located on the EqualLogic PS6010XV array in one run (Test A) and then on the EqualLogic PS6010XVS array in a different run (Test B).

Test results

During the tests we used all the default settings of the TPC-C benchmark, including transaction weightings and think times.

Test A: EqualLogic PS6010XV test results

The TPC-C benchmark was run against ten databases on the EqualLogic PS6010XV array. Aggregate number of users was stepped from 50 to 6,400 in increments of 50. Each step was run for 30 minutes. Figure 5 illustrates the measured relationship of aggregate number of users and the corresponding transactions per second (TPS), whereas Figure 6 illustrates the same for average transaction response time and the 90th percentile response time.
Figure 7 shows the SANHQ charts for Test A using EqualLogic PS6010XV. When the test was simulating 2,650 concurrent users with about 137 transactions per second (TPS), the PS6010XV array was delivering approximately 2,000 IOPS with read and write latency less than or equal to 20 millisecond.

**Test B: EqualLogic PS6010XVS test results**

In Test B the same TPC-C benchmark was run against ten databases on an EqualLogic PS6010XVS array. Aggregate number of users was stepped from 500 to 10,000 in increments of 50. Each step was run for 30 minutes. Figure 8 illustrates the measured relationship of aggregate number of users and the corresponding transactions/second, whereas Figure 9 illustrates the same for average transaction response time and the 90th percentile response time.
Figure 7: SANHQ metrics using EqualLogic PS6010XV array

Figure 8: Users vs. TPS using EqualLogic PS6010XVS

Figure 9: Users vs. Transaction Response Times using EqualLogic PS6010XVS

Figure 10 shows the SANHQ charts for Test B. When the test was simulating 7,150 concurrent users delivering about 371 transactions per second (TPS), the
EqualLogic PS6010XVS array was delivering approximately 9,200 IOPS with a read/write IO latency that is less than 20 milliseconds.

Figure 10: SANHQ metrics using EqualLogic PS6010XVS array

Summary and Analysis of Test Results

The results from the TPC-C benchmark workload simulation tests using PS6010XV and PS6010XVS arrays are summarized in Table 1 and Figures 11 and 12. At relatively high capacity utilization the EqualLogic PS6010XVS array was able to support 170% more concurrent users and complete 170% more transactions per second than an EqualLogic PS6010XV array for the same OLTP workload while maintaining the same user experience.

Table 1: Summary of Test Results

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<th>Test Attributes</th>
<th>End-User Experience Attributes</th>
<th>TPC-C Benchmark Performance Results</th>
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<tr>
<td>Test Attributes</td>
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<td>TPC-C Benchmark Performance Results</td>
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<td>Improvement in PS6010XVS over PS6010XV</td>
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These test results indicate that in an OLTP database application environment with identical hardware and software infrastructure when sufficient server and network resources are available in the environment, an EqualLogic hybrid array can provide a significantly higher application performance over an EqualLogic 15K SAS HDD array for the same end-user experience. The reasons for such high improvement in performance of an EqualLogic hybrid array become clear when we examine the data access pattern of an OLTP application workload and the size of the frequently accessed data set as compared to the total size of the database. In fact, SANHQ can provide such insights into any workload out of the box.

An analysis of the SANHQ output from the EqualLogic PS6010XVS test reveals that as the test progressed, the frequently used portion of the dataset (shown as High Load in the Group IO Load Source Distribution chart in Figure 10) increased to about 300 GB (15% of the total database size of 2 TB) and the moderately used portion of the dataset (shown as Medium Load in the Group IO Load Source Distribution chart in Figure 10) increased to about 500 GB (25% of the total database size of 2 TB). Moreover, as shown in Figure 13, as the test progressed, the EqualLogic PS6010XVS auto-tiering firmware successfully moved most of the frequently and moderately used
datasets in the SSD tier delivering about 80% of the total IOPS from the SSD drives which occupied about 20% of the total array capacity of 2.5TB.

Figure 13: Disk drive IOPS distribution using EqualLogic PS6010XVS

**Conclusion:** EqualLogic hybrid arrays deliver high performance for OLTP database applications

Many OLTP database applications in real production environments also exhibit characteristics similar to the TPC-C benchmark workload tested in the simulated environment at Dell Labs. Their access patterns are such that a high percentage of the I/O traffic is distributed to a small percentage of the total dataset. EqualLogic PS6010XVS excels in automatic tiering of these types of OLTP application datasets as it intelligently and automatically moves the frequently used “hot” datasets to the SSD tiers. Additionally, automated tiering monitors the data access patterns continuously and rebalances the hot datasets in the SSD tier so that even as workload access pattern changes, performance continues to be optimized without any manual intervention. This automated data tiering by EqualLogic hybrid arrays greatly simplifies database performance optimization. EqualLogic hybrid arrays strike an optimal balance between storage performance and capacity making them exceptionally well suited to OLTP database application workload environments.
Technical support and customer service

Dell’s support service is available to answer your questions about PS Series SAN arrays. If you have an Express Service Code, have it ready when you call. The code helps Dell’s automated-support telephone system direct your call more efficiently.

Contacting Dell

Dell provides several online and telephone-based support and service options. Availability varies by country and product, and some services might not be available in your area.

For customers in the United States, call 800-945-3355.

Note: If you do not have access to an Internet connection, contact information is printed on your invoice, packing slip, bill, or Dell product catalog.

Use the following procedure to contact Dell for sales, technical support, or customer service issues:

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2. Select your locale. Use the locale menu or click on the link that specifies your country or region.
3. Select the required service. Click the “Contact Us” link, or select the Dell support service from the list of services provided.
4. Choose your preferred method of contacting Dell support, such as e-mail or telephone.

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2. Use the locale menu or click on the link that specifies your country or region.