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Visit our Dell TechCenter wiki at http://www.delltechcenter.com/page/iSCSI+and+VMware for more details on how to attach Dell iSCSI storage to VMware, to discuss this paper, and to contribute your expertise on iSCSI for VMware.

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Executive Summary

New iSCSI storage arrays from Dell Inc. provide cost-effective, easy-to-deploy shared storage solutions for applications like the VMware Infrastructure 3 server virtualization software. In this paper features and performance of the Dell™ PowerVault™ NX1950, the Dell/EMC CX3 line of Fibre Channel/iSCSI combination storage arrays, and the Dell/EMC AX150i are compared, instructions for using with VMware are given, and recommendations are made when to use which.
Introduction

Server virtualization programs such as VMware run best when the datacenter is organized into “farms” of servers that are connected to shared storage. By placing the virtual machines’ virtual disks on storage area networks accessible to all the virtualized servers, the virtual machines can be migrated from one server to another within the farm for purposes of load balancing or failover. VMware Infrastructure 3 uses the VMotion live migration facility in its Distributed Resource Scheduling feature and provides a High Availability component which takes advantage of shared storage to quickly boot up a virtual machine on a different ESX server after the original ESX server fails. Shared storage is key to enabling VMotion because, when a virtual machine is migrated from one physical server to another, the virtual machine’s virtual disk doesn’t actually move. Only the virtual disk’s ownership is changed while it continues to reside in the same place.

The traditional networking technology employed in such storage area networks uses the Fibre Channel (FC) interface. Products such as the Dell/EMC line of Fibre Channel storage arrays provide excellent performance, reliability and functionality but can require specialized hardware and skills to set up and maintain. The Fibre Channel storage network starts with the fabric, which involves the use of FC host bus adapters (HBAs) in each server, connected by fiber cables to one or more FC switches, which in turn can network multiple storage arrays, each supporting a scalable number of high speed disk enclosures. An application’s request for an input or output (IO) to storage originates as a SCSI (Small Computer System Interface) request, is packed into an FC packet by the FC HBA, and sent down the fiber cable to the FC switch for dispatch to the storage array that contains the requested data, similar to the way Internet Protocol (IP) packets are sent over Ethernet.

For smaller IT shops or for those that are just starting out in the virtualization arena, an alternate shared storage paradigm is emerging that employs iSCSI (Internet SCSI) to connect the servers to the storage. In this case the communication between the server and the data storage uses standard Ethernet network interface cards (NICs), switches and cables. SCSI IO requests are packed into standard Internet protocol packets and routed to the iSCSI storage through Ethernet switches and routers. With iSCSI customers can leverage existing networking expertise and equipment to simplify their implementation of a storage network. Like Fibre Channel, iSCSI supports block-level data transmission for all applications, not just VMware. For security iSCSI provides CHAP authentication as well as IPSEC encryption. An excellent introduction to iSCSI can be found in Travis Vigil’s article in the May 2007 Power Solutions, “iSCSI: Changing the Economics of Storage, Part 1-Understanding iSCSI in Enterprise Environments” (http://www.dell.com/downloads/global/power/ps2q07-20070335-Vigil.pdf).

Servers can communicate with iSCSI storage using two methods. The first involves the use of an add-in card called an iSCSI hardware initiator or host bus adapter, analogous to the Fibre Channel HBA, which connects directly to the datacenter’s Ethernet infrastructure. The second does the iSCSI conversion in software and sends the Ethernet packets through the standard Ethernet NIC in
the server. This study focuses on the use of the software initiator, which is supported by VMware.

In the past two years Dell has introduced three iSCSI platforms, the Dell PowerVault NX1950, the Dell/EMC CX3 line of combination storage processors (which offer both iSCSI and Fibre Channel connectors) and the Dell/EMC AX150i. The three are designed for different sized customers and varying environments but all are easy to configure to provide storage to VMware hosts.

This paper will describe Dell’s three iSCSI storage offerings, document how to configure them with VMware, and then, using a database workload running on two virtual machines, present performance results comparing the three platforms.

The performance results shown in this paper represent a single, high-level view of the performance of the different arrays with a simple virtualization workload running on only 5 disks in each array. Typical customer use scenarios will employ larger disk arrays supporting a variety of applications, which may result in varying performance results.
The Dell iSCSI Storage Arrays

The PowerVault NX1950

The PowerVault NX1950 is an integrated solution that provides both block-level application data via iSCSI as well as file data via the standard Ethernet network protocols NFS (for Linux) and CIFS (for Windows). The PowerVault NX1950 High Availability model consists of two clustered 1 rack unit (1U), two-socket servers running Microsoft® Windows® Unified Data Storage Server 2003 (WUDSS), connected via serially attached SCSI (SAS) to an MD3000 disk array with redundant embedded RAID controllers containing a total of 1GB cache. WUDSS provides an integrated console for storage system management. The PowerVault NX1950 offers customers an attractive entry point into storage virtualization. With this unified storage solution small and midsized businesses and remote offices have the opportunity to both consolidate file data and virtualize application data in one device.

The PowerVault NX1950 comes integrated with an MD3000 disk array and can be expanded to allow for future growth with up to 2 MD1000 Disk Expansion Enclosures (with up to 15 drives each). For this test a configuration with 15 146GB 15K RPM SAS drives (shown in Figure 1) was used.

Figure 1: The Dell PowerVault NX1950 High Availability storage array

The Dell/EMC FC/iSCSI Arrays

The Dell/EMC CX3 FC/iSCSI arrays provide both end-to-end 4 Gb/s Fibre Channel and iSCSI storage area network capability. The line includes the CX3-10c, CX3-20c and CX3-40c, with features as shown in Table 1. Each array includes two redundant Storage Processors (SP) and a Standby Power Supply to enable the use of write cache on the storage processors. Management is provided by Navisphere, part of an extended suite of EMC management and backup tools. While both the FC and iSCSI ports of an array may be used at the same time, a given host can connect to an array through only one of these.
protocols at a time. This study tested the CX3-20c and the CX3-40c, both with one DAE4P disk array with 15 73 GB 15K RPM drives (as shown in Figure 2).

<table>
<thead>
<tr>
<th>Feature</th>
<th>CX3-10c</th>
<th>CX3-20c</th>
<th>CX3-40c</th>
</tr>
</thead>
<tbody>
<tr>
<td>Physical Size including Standby Power Supply and 1 Disk Array Enclosure (1.75” rack units)</td>
<td>5U</td>
<td>5U</td>
<td>5U</td>
</tr>
<tr>
<td>CPUs</td>
<td>2x 1.8GHz</td>
<td>2x 2.8GHz</td>
<td>4x 2.8 GHz</td>
</tr>
<tr>
<td>Cache (GB)</td>
<td>2</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>Front-end FC ports</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Front-end iSCSI ports</td>
<td>4</td>
<td>8</td>
<td>8</td>
</tr>
<tr>
<td>Back-end FC loops</td>
<td>1</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>Maximum Hard Drives</td>
<td>60</td>
<td>120</td>
<td>240</td>
</tr>
</tbody>
</table>

Table 1: CX3 FC/iSCSI Array Features – all figures are for two Storage Processors

The Dell/EMC AX150i

Positioned as an entry-level storage array within the Dell/EMC line, the Dell/EMC AX150i can house two storage processors and twelve 3.5-inch Serial ATA II drives in a single 2U rack enclosure. iSCSI connectivity is provided through four 1 Gb/s Ethernet ports. The dual storage processor system contains 1 GB mirrored cache which uses an Uninterruptable Power Supply to enable the write cache. Navisphere Express, a simplified version of Navisphere, manages the array. The system used in the test was a dual storage processor system with 12 250GB 7.2K RPM drives (shown in Figure 3).
The features of the four Dell iSCSI storage arrays tested are shown in Table 2.

<table>
<thead>
<tr>
<th>Model</th>
<th>No. of Disks</th>
<th>Disk Size (GB)</th>
<th>Disk Speed (RPM)</th>
<th>Disk Type</th>
<th>Size including Standby Power Supply (1.75&quot; Rack Units)</th>
<th>Cache Size</th>
<th>Max Number of Disks</th>
<th>List Price Including Storage Software *</th>
<th>Starting At Price **</th>
</tr>
</thead>
<tbody>
<tr>
<td>AX150i</td>
<td>12</td>
<td>250</td>
<td>7.2K</td>
<td>SATA II</td>
<td>3U</td>
<td>1 GB</td>
<td>12</td>
<td>$17,239</td>
<td>$5,900</td>
</tr>
<tr>
<td>NX1950</td>
<td>15</td>
<td>146</td>
<td>15K</td>
<td>SAS</td>
<td>5U</td>
<td>1 GB</td>
<td>45</td>
<td>$48,719</td>
<td>$20,391</td>
</tr>
<tr>
<td>CX3-20c</td>
<td>15</td>
<td>73</td>
<td>15K</td>
<td>FC4</td>
<td>5U</td>
<td>4 GB</td>
<td>120</td>
<td>$77,052</td>
<td>$52,862</td>
</tr>
<tr>
<td>CX3-40c</td>
<td>15</td>
<td>73</td>
<td>15K</td>
<td>FC4</td>
<td>5U</td>
<td>8 GB</td>
<td>240</td>
<td>$110,559</td>
<td>$86,369</td>
</tr>
</tbody>
</table>

*The list prices shown include the Workgroup version of Navisphere and on-site SAN implementation services.

** Starting At Price configurations:
AX150i: Single SP, 3x250GB/7.2K SATA II drives
NX1950: Single NX head, Std Edition OS, 2x36GB/15K SAS drives
CX3-20c: Departmental Navisphere, 5x146GB/10K drives
CX3-40c: Departmental Navisphere, 5x146GB/10K drives

All prices are as of 5/16/07

Table 2: Dell iSCSI Storage array Features
VMware and iSCSI

This section will describe the steps needed to attach iSCSI storage to a VMware ESX server host. Once attached and formatted, the storage can be provided to guest virtual machines as virtual disks that appear as local storage to the guest. An alternate method, in which the guest is attached directly to iSCSI storage through a software iSCSI initiator supplied with the guest’s operating system, was not employed in this test.

ESX Configuration

Connectivity from a host running VMware’s ESX server to iSCSI storage is provided through a built-in software initiator (support for hardware iSCSI initiators will be provided at a later date). The physical network interface cards (NICs) that connect to the Ethernet network in which the iSCSI storage is located must be included within a VMware virtual switch that also includes the ESX Service Console and the VMkernel (which supports VMotion traffic as well as iSCSI packets). For a two-NIC system it is recommended that the NICs be teamed as shown in Figure 4. This provides NIC/cable failover and iSCSI traffic load balancing across the NICs to multiple iSCSI targets with different IP addresses. Since the VM and iSCSI traffic are mixed in this configuration, CHAP

Figure 4: ESX Two NIC Configuration for iSCSI
authentication and IPSEC encryption should be employed in the iSCSI connection. (Alternately, in a two-NIC configuration the VM and iSCSI traffic can be each placed on their own non-teamed NICs for total isolation). The network configuration is created in Virtual Center (VC) using the Virtual Infrastructure Client. The ESX server to be connected is highlighted, then the Configuration tab is selected, then Networking.

If there are more than two NICs available in the ESX server host, it is recommended that two virtual switches be created, one which hosts the Service Console and VMkernel (including iSCSI and VMotion traffic), and one which is dedicated to virtual machine (VM) traffic. The two NICs carrying iSCSI traffic should be cabled to redundant Ethernet switches. An example for four NICs showing two 2-NIC teams is shown in Figure 5.

![Virtual Switch: vSwitch0](image)

![Virtual Switch: vSwitch1](image)

Figure 5: ESX Four NIC Configuration for iSCSI

### Connecting the ESX Server Host to the iSCSI Array

The process to connect an ESX Server host to an iSCSI storage array has three steps: First, the iSCSI software initiator in ESX is configured to point to the storage target. Then the target storage array is configured to enable access from the ESX host and the host's disk LUNs (Logical Unit Numbers) are created. Finally it is necessary to format the storage with the VMware File System (VMFS).

#### Configure iSCSI Software Initiator in ESX

As a security measure iSCSI access is disabled by default in ESX. To enable it, from the ESX host in VC:
ESX Server → Configuration → Security Profile → Properties → enable Software iSCSI Client

Next, select Configuration → Storage Adapters, and then highlight iSCSI Software Adapter. Notice the SAN Identifier. In this test, for host r3esx1950c, the identifier is iqn.1998-01.com.vmware:r3esx1950c-7b658143. In the Details pane select Properties to bring up the iSCSI Initiator Properties page. Select Configure and then select Status: Enabled if necessary. Finally, select the Dynamic Discovery tab, select Add and on the Add Send Targets Server page enter the IP address of the iSCSI storage array and change the Port from its 3260 default if necessary.

Configure Target Storage Array and Create the LUNs

First, the LUNs that will be assigned to VMware are created on the target storage array. For the NX1950 use the built-in WUDSS console. For the CX3 arrays and AX150i use Navisphere and Navisphere Express, respectively.

The ESX server iSCSI identifier needs to be entered into the target array: On the NX1950 management console select Microsoft iSCSI Software Target → iSCSI Target, right click on the NX1950 that has the LUNs to be assigned, and select Properties. In the iSCSI Initiators tab select Add, select Identifier Type IQN and enter the full SAN Identifier in the Value field.

In the CX arrays right click on the array in Navisphere, select Connectivity Status, then New to create a new Initiator Record. Specify the full SAN Identifier as both Initiator Name and Host name and specify the IP address of the ESX host. Then using Connect Hosts add this initiator to the Storage Group containing the disk LUN to be provided to the ESX server.

Format Storage

Back in Virtual Center select ESX Server → Configuration → Storage Adapters and then select Rescan → Scan for New Storage Devices. The LUN(s) defined on the iSCSI storage array should show up.

If this is the first host to access this LUN it is necessary to format the storage with the VMware file system, VMFS3. From the Configuration tab select Storage (SCSI, SAN and NFS) and click on Add Storage. Select Disk/LUN, and then select the LUN to be formatted. Supply a Datastore Name (for example, NX1950-1). For Disk/LUN Formatting accept the default maximum file size (256 GB), block size (1MB), and capacity or change them if desired. The datastore should show up in the list of storage devices. When the next ESX server is connected to the same iSCSI storage array the datastore should show up after the Scan for New Storage step.

Once the storage LUN has been added to an ESX host, VMs can be created on that ESX host with their virtual disks using the LUN storage. Since the LUN is shared between all ESX server hosts connected to the iSCSI storage array the VMs may be live migrated from one host to another using VMotion.

Complete details of this process, with screen shots, are available at the Dell TechCenter wiki at http://www.delltechcenter.com/page/iSCSI+and+VMware.
The Test Setup

iSCSI Performance Comparison

To provide a basic performance comparison between the three iSCSI storage offerings, a PowerEdge 1950 ESX host with two Intel® quadcore Xeon® X5355 processors running at 2.66GHz and with 8GB memory was connected as described in the previous section to five-disk RAID 5 LUNs on all four storage arrays. For the tests in this study, conducted by the Dell Enterprise Technology Center in April, 2007, a two-NIC team was used for the ESX Service Console, VMkernel (including iSCSI traffic) and the virtual machine (VM) traffic as shown in Figure 4.

Two Windows Server 2003 R2 VMs with Microsoft SQL Server 2005 running a medium size (1 GB) version of the Dell DVD Store database test application (available as open source from linux.dell.com/dvdstore) were created with their 10GB virtual disks stored on the five-disk LUN on one array. The VMs were then cloned three times with the copies' virtual disks placed on similar LUNs on each of the other three arrays. The VMs were configured with 4 virtual CPUs and 512MB each so that each virtual CPU roughly had the resources of a single processor core.

The SQL Server database on each VM is created on that VM’s local disk so it, too, is stored on the LUN. Since the database size (1 GB) exceeds the memory available to the VM (512 MB), SQL Server will have to access its content from the LUN during the test.

The two VMs attached to a single iSCSI storage array were then stressed using an order entry simulator (included as part of the DVD Store kit) which models users logging into the online DVD Store, browsing for DVDs by title, artist or category, and finally making a DVD purchase. A complete cycle of logging in, browsing, and purchasing counts as one order. The number of users and the amount of time they spend thinking during an order can be controlled by the simulator. In this test, the think time was set to 0 seconds so that each driver thread can be thought of as a super user entering orders without stopping.

Starting with 2 such driver threads per VM, a workload was applied to each VM pair for 4 minutes and the average orders per minute and response time recorded. Then the VMs’ databases were restored to their original state and a larger workload applied. The workload was increased until the orders per minute rate stopped increasing. At that point the storage array could handle no more IOs per second (IOPS) even as the applied workload increased. The test was then repeated in turn on VMs residing on the other three iSCSI storage arrays. The test setup is shown in Figure 6.
Figure 6: Test Setup (AX150i, CX3-20c and CX3-40c not shown)
Results

iSCSI Performance Comparison

The results from the iSCSI storage test are shown in Table 3 and plotted in Figure 7.

<table>
<thead>
<tr>
<th># of Driver Threads Per VM</th>
<th>CX3-40c - iSCSI</th>
<th>CX3-20c - iSCSI</th>
<th>NX1950</th>
<th>AX150i</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Orders per Minute</td>
<td>Resp Time (ms)</td>
<td>Orders per Minute</td>
<td>Resp Time (ms)</td>
</tr>
<tr>
<td>2</td>
<td>10543</td>
<td>21</td>
<td>9282</td>
<td>23</td>
</tr>
<tr>
<td>5</td>
<td>21426</td>
<td>25</td>
<td>18349</td>
<td>30</td>
</tr>
<tr>
<td>10</td>
<td>29570</td>
<td>37</td>
<td>26655</td>
<td>41</td>
</tr>
<tr>
<td>15</td>
<td>33803</td>
<td>49</td>
<td>28891</td>
<td>58</td>
</tr>
<tr>
<td>20</td>
<td>35074</td>
<td>63</td>
<td>29937</td>
<td>75</td>
</tr>
<tr>
<td>25</td>
<td>35173</td>
<td>80</td>
<td>30894</td>
<td>92</td>
</tr>
</tbody>
</table>

Table 3: iSCSI Performance Data

Figure 7: iSCSI Performance
For this workload the CX3-40c, CX3-20c, NX1950 and AX150i max out at around 35,000, 31,000, 15,500 and 10,000 orders per minute, respectively. It should be emphasized that these are maximum performance rates for five-disk LUNs on the four storage arrays but in typical use each storage array will drive many such LUNs from a much larger number of VMs (and non-VMware sources) across multiple disk cabinets. Think of these results as a performance “snapshot”, giving relative performance of a particular OLTP application on similarly configured disk sets on the four storage arrays. Real world performance of the arrays depends greatly on the actual application.
Conclusions and Recommendations

The three Dell iSCSI platforms tested provide a range of performance and functionality that match the various levels of iSCSI storage applications and user environments.

For those datacenters requiring fast and robust storage, especially those who already have made investments in Dell/EMC hardware and expertise, the CX3 FC/iSCSI series provides a ready means to deploy large iSCSI SANs either standalone or in conjunction with existing Dell/EMC Fibre Channel SANs.

The Dell PowerVault NX1950 is a good entry level iSCSI virtualization solution and is ideal for customers who have file-intensive environments and are looking to deploy virtualization for a small subset of application data. As a unified solution the PowerVault NX1950 provides customers a compelling value proposition offering versatility, ease of use and expandability at an affordable price.

Those customers looking solely for an iSCSI SAN should consider the Dell/EMC AX150i as it is a purpose-built entry level, easy-to-use, low cost iSCSI storage array for workgroups, small to medium-sized businesses or branch offices of large corporations.
Acknowledgements

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