Red Hat Reference Architecture Series

Virtualized Oracle Database Deployments using Red Hat Enterprise Linux with KVM

End-to-end hardware infrastructure from Dell allows business continuity with seamless VM migrations

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1 Executive Summary

Red Hat partnered with Dell to demonstrate deploying an Oracle database in a virtualized environment on an end-to-end Dell hardware infrastructure. The test configuration includes Oracle 11g R2 running on Red Hat Enterprise Linux 6 with the Kernel-based Virtual Machine (KVM) hypervisor on Dell PowerEdge R710 servers with Dell EqualLogic PS6010 virtualized iSCSI storage. The architecture is a set of Dell rack-mount servers connected to the PS Series iSCSI-based storage array over 10 Gigabit Ethernet (10 GbE).This document includes the specifications and instructions for recreating the deployment of virtual machines (VMs), achieving consistent performance, and a high-availability scenario for the Oracle database.

Multiple VMs running Oracle are set up on two physical hosts and an online transaction processing (OLTP) workload is executed on each of them in order to illustrate how to make mission-critical Oracle deployments highly available in a virtualized environment,. The VMs are then migrated back and forth between hosts while the OLTP workload continues to run uninterrupted.

Migrating VMs between hosts demonstrates one aspect of the enterprise-class service capability of Red Hat Enterprise Linux and inherent scalability and stability of a KVM-based virtualization infrastructure.

2 Test Configuration

The following commercially available, industry-standard hardware and software components are used to build the system under test (SUT) configuration.

Table 1: Hardware Configuration

Server	Dell PowerEdge R710 server 2 Socket – 8 Cores Intel (R) Xeon(R) X56570 @2.93 GHz 64 GB RAM (32 GB per NUMA node) Dual port Intel 82599EB 10-Gigabit HBA
Storage	Dell EqualLogic PS6010 array
Network Switch	Dell PowerConnect 8024F

Table 2: Software Configuration

Operating System (Host)	Red Hat Enterprise Linux 6.3 (2.6.32.279.el6.x86_64) qemu-kvm-0.12.1.2-2.295.el6.x86_64
Operating System (Virtual Machines)	Red Hat Enterprise Linux 6.3 (2.6.32.279.el6.x86_64)
Database	Oracle Database 11g Release 2 (11.2.0.3)
Storage	Dell EqualLogic Host Integration Tools for Linux 1.2

2.1 Hardware Configuration

Figure 1 illustrates the physical connectivity of the hardware used in the demonstration test bed.

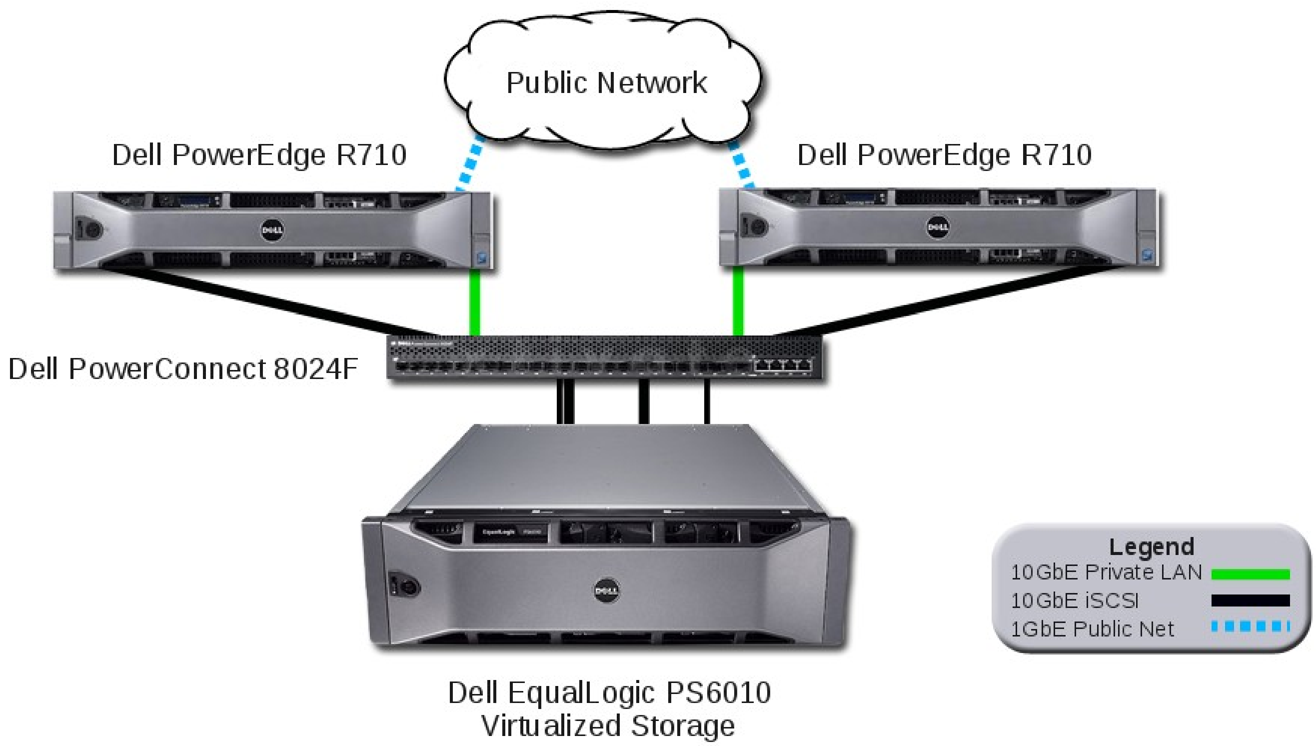


Figure 1: Hardware Connectivity

A dual-port Intel 82599EB 10GbE host bus adapter (HBA) is installed in each server and configured into two subnets to separate network traffic from data traffic. Both ports on each card are physically connected to the Dell PowerConnect switch.

The first port is for data connection to the Dell EqualLogic PS6010 storage array. While only a single port is configured for iSCSI traffic in this particular case, the best practice would be to configure multiple I/O ports for redundancy and bandwidth.

The second port is configured using a different subnet as a private LAN connection between the two hosts, used for networking traffic during the VM migrations.

The Dell EqualLogic PS6010 storage array is connected to the Dell PowerConnect switch and configured via the dedicated subnet used for iSCSI traffic.

2.2 Software Configuration

The Red Hat Enterprise Linux 6 operating system is installed on two identically configured Dell PowerEdge R710 servers by selecting the **Virtual Host** optional package group during the installation. This option installs the kernel as well as the KVM and Virtual Machine Manager tools required to create a host for VMs.

Additional details and screen captures of the installation procedures using the **Virtual Host** option are documented in Chapter 16.19 of the Red Hat Enterprise Linux 6 installation guide located at https://access.redhat.com/knowledge/docs/en-US/Red_Hat_Enterprise_Linux/6/html/Installation_Guide/index.html.

2.2.1 Storage Configuration

Volumes on the array allocated as VM system disks are configured as described in Table 3.

Table 3: Storage Array VM System Disk Configuration

Volume Name	Size	Purpose
kvm1	20GB	System disk for VM1
kvm2	20GB	System disk for VM2
kvm3	20GB	System disk for VM3
kvm4	20GB	System disk for VM4

Those volumes allocated as VM data disks are configured as described in Table 4.

Table 4: Storage Array VM Data Disk Configuration

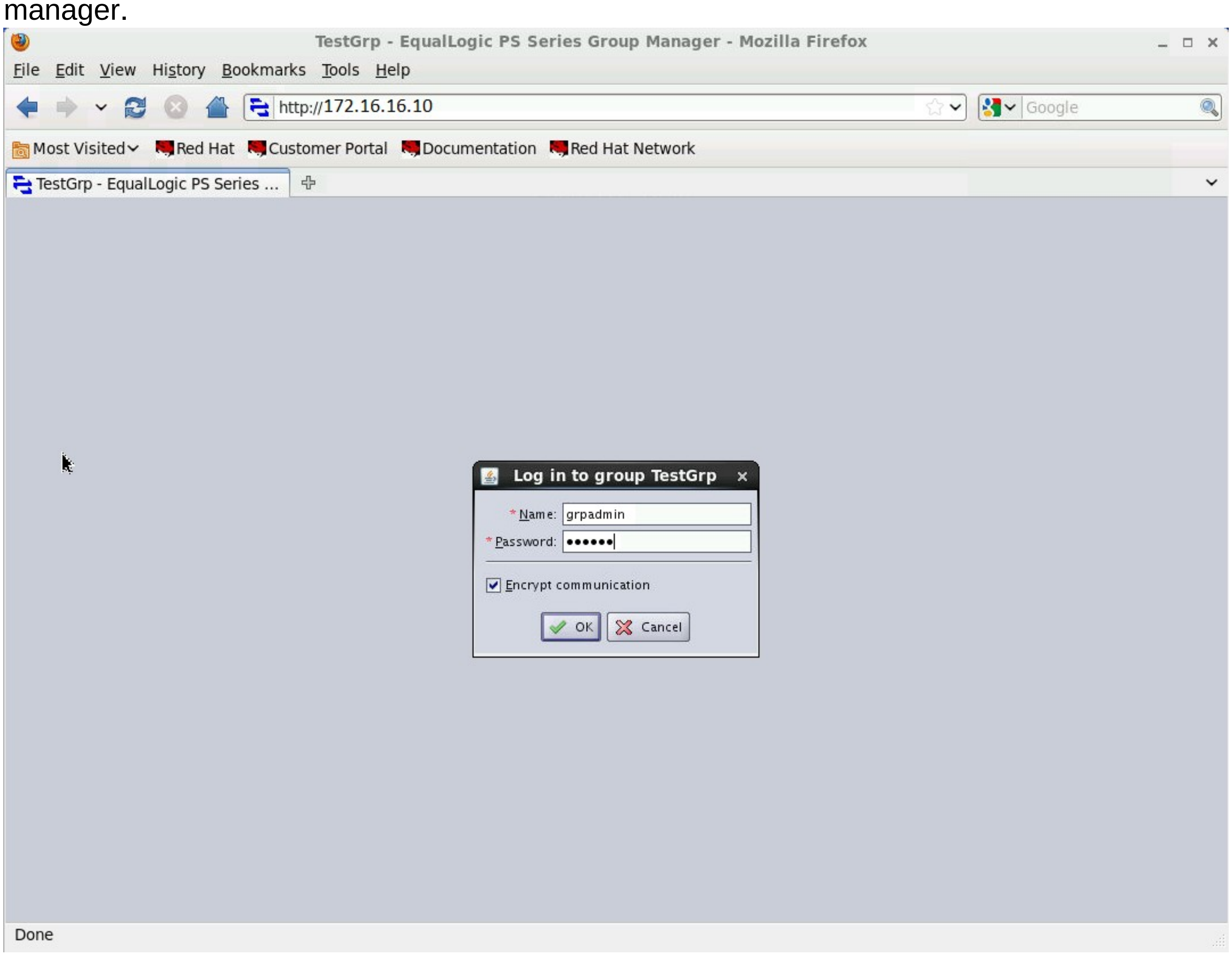
Volume Name	Size	Purpose
G1data1	100GB	Data disk 1 for VM1
G1data2	80GB	Data disk 2 for VM1
G2data1	100GB	Data disk 1 for VM2
G2data2	80GB	Data disk 2 for VM2
G3data1	100GB	Data disk 1 for VM3
G3data2	80GB	Data disk 2 for VM3
G4data1	100GB	Data disk 1 for VM4
G4data2	80GB	Data disk 2 for VM4

The volumes detailed in tables 3 and 4 can be created and configured by any one of the following means:

- using an SSH session into the storage array and issuing the CLI commands directly
- using the Dell EqualLogic Host Scripting Tools on the command line or an automated procedure within a perl or python script
- HTML access to the storage array GUI

2.2.1.1 Volumes and Access

Using the HTML GUI, open a browser to connect to the storage array and log into the group manager.



After login, the **Volumes** window at left contains the group name(s). Create the data disks for each of the four VMs using the following procedure.

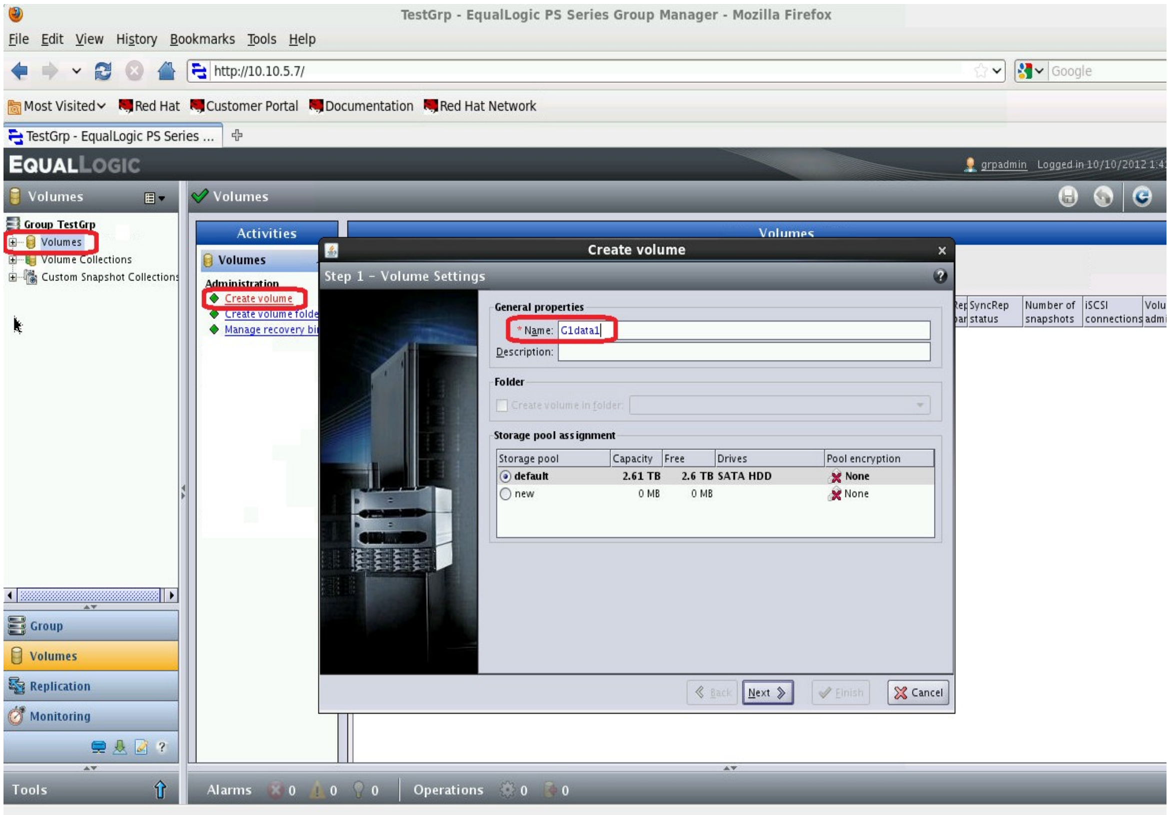
1. Create a volume.

   a) Select the **Volumes** icon beneath the target group name to display information for all volumes within that group.

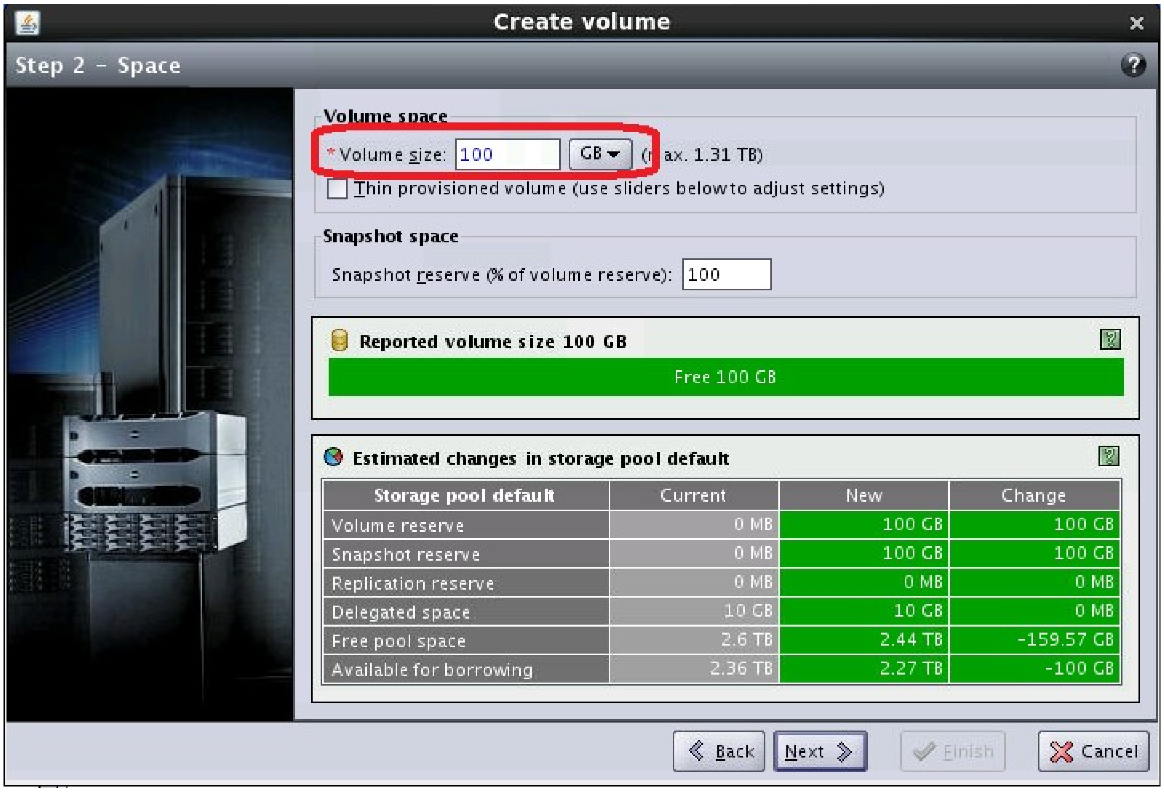
   b) Select **Create volume** in the **Activities** window.

   c) Enter the desired volume ***Name*** in the resulting pop-up window (e.g., G1data1).

   d) Click **Next**.



2. Set the desired ***Volume size*** and click **Next**.



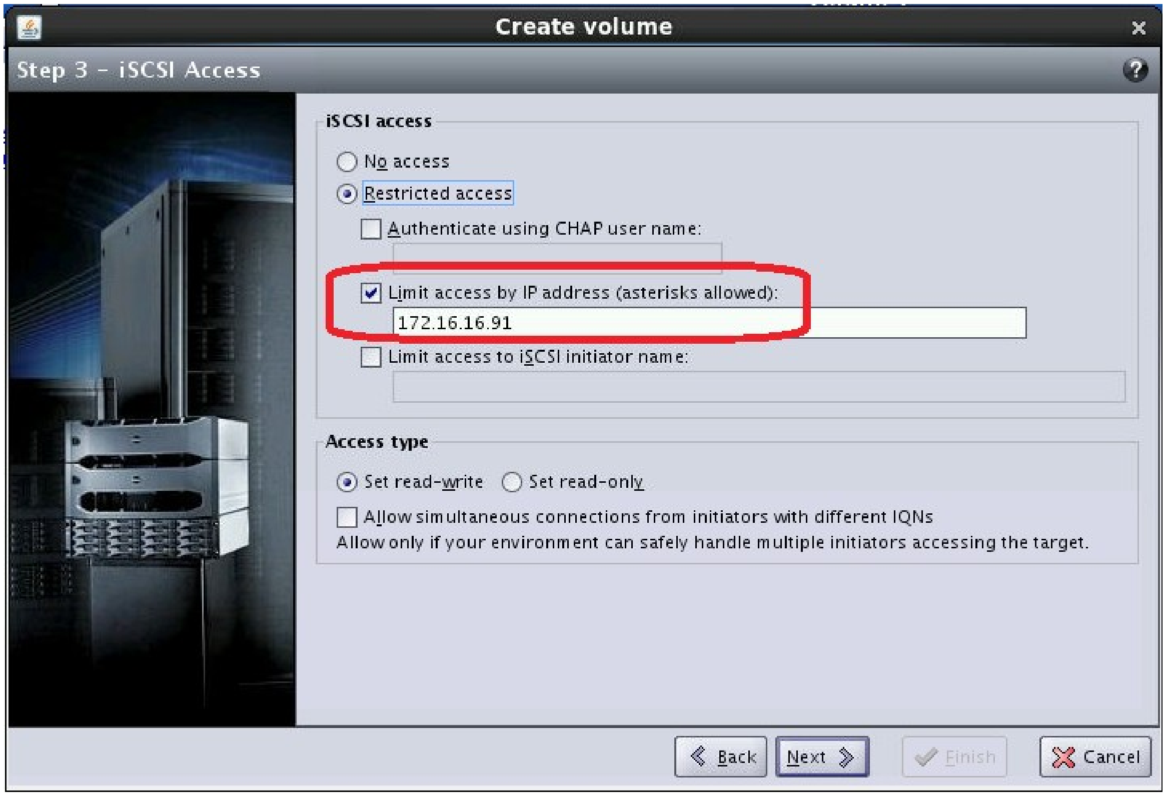
3. Set the iSCSI access and Access type.

   a) Select the **Restricted access** option for iSCSI access.

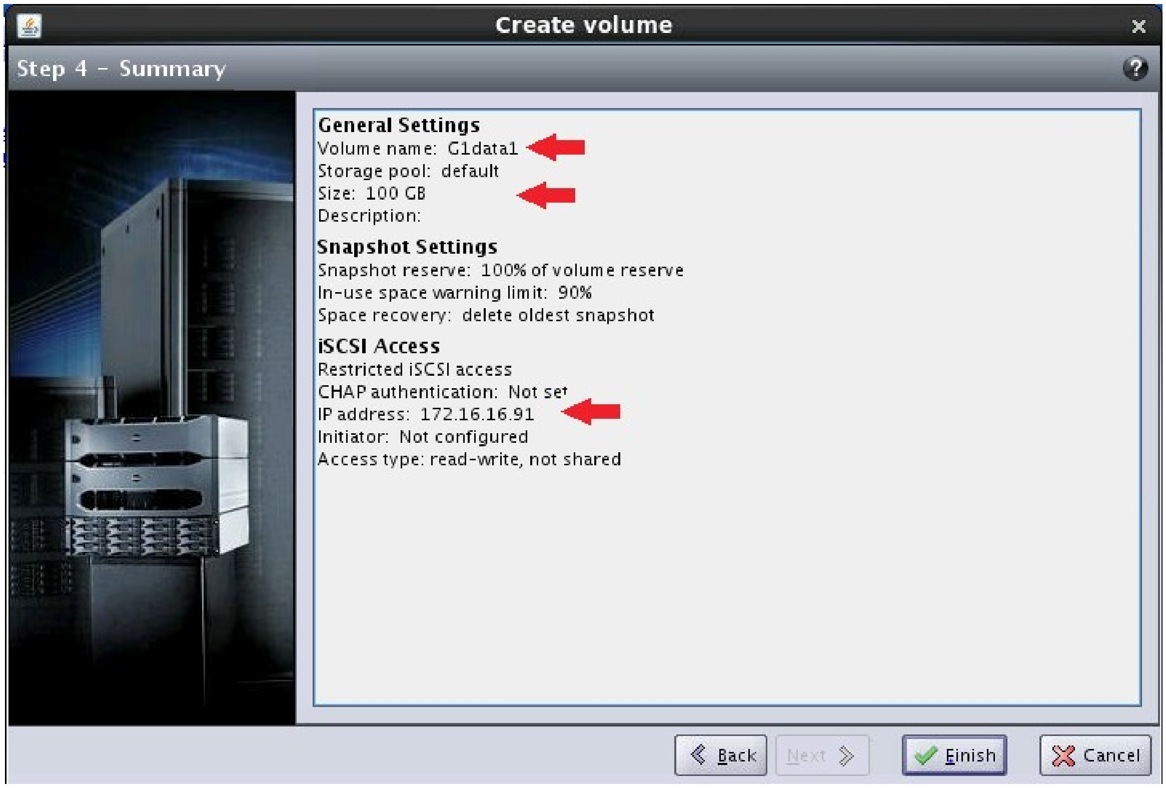
   b) Check the box to **Limit access by IP address and provide the address** of the VM for which the volume is being created.

   c) Set the Access type to **Set read-write**.

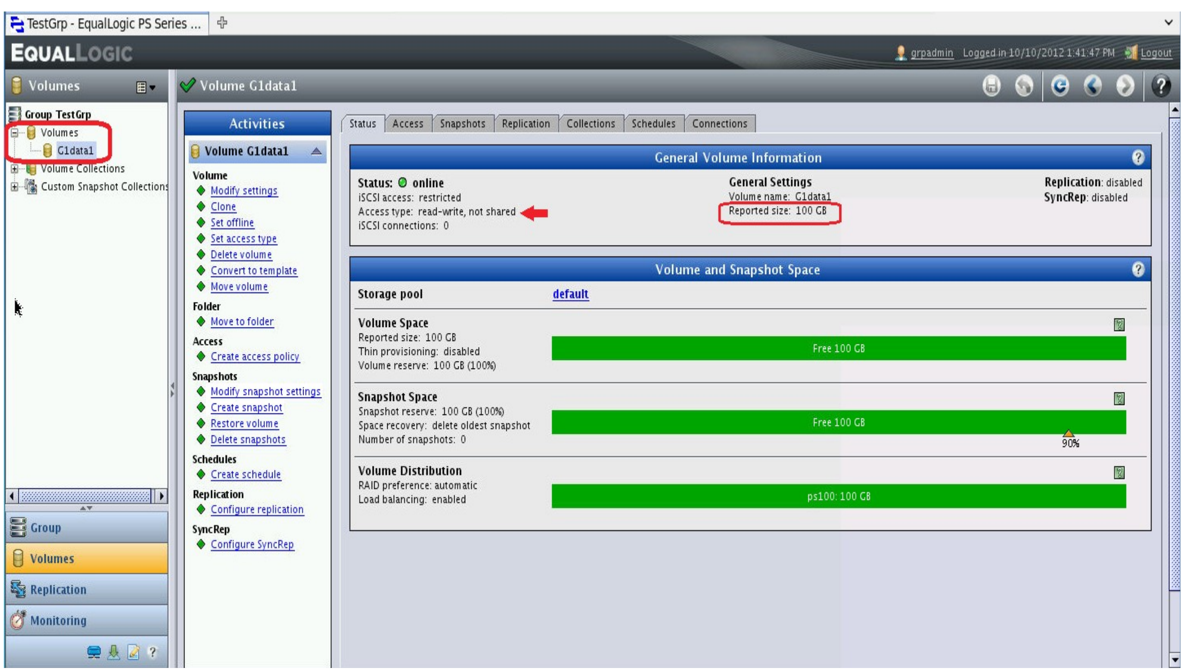
   d) Click **Next**.



4. Verify the volume name and size in the **General Settings** section are correct as well as the **iSCSI Access** IP address and click the **Finish** button.



5. The details of the newly created volume are displayed. Note the addition of the new volume (e.g., G1data1) in the **Volumes** window at left as well as its access type (read-write, not shared) and size in the **General Volume Information** section.



6. Repeat steps 1 through 5 to create the two data disks for each of the four VMs as described in Table 4.

Create the system disks for each of the four VMs using the following procedure.

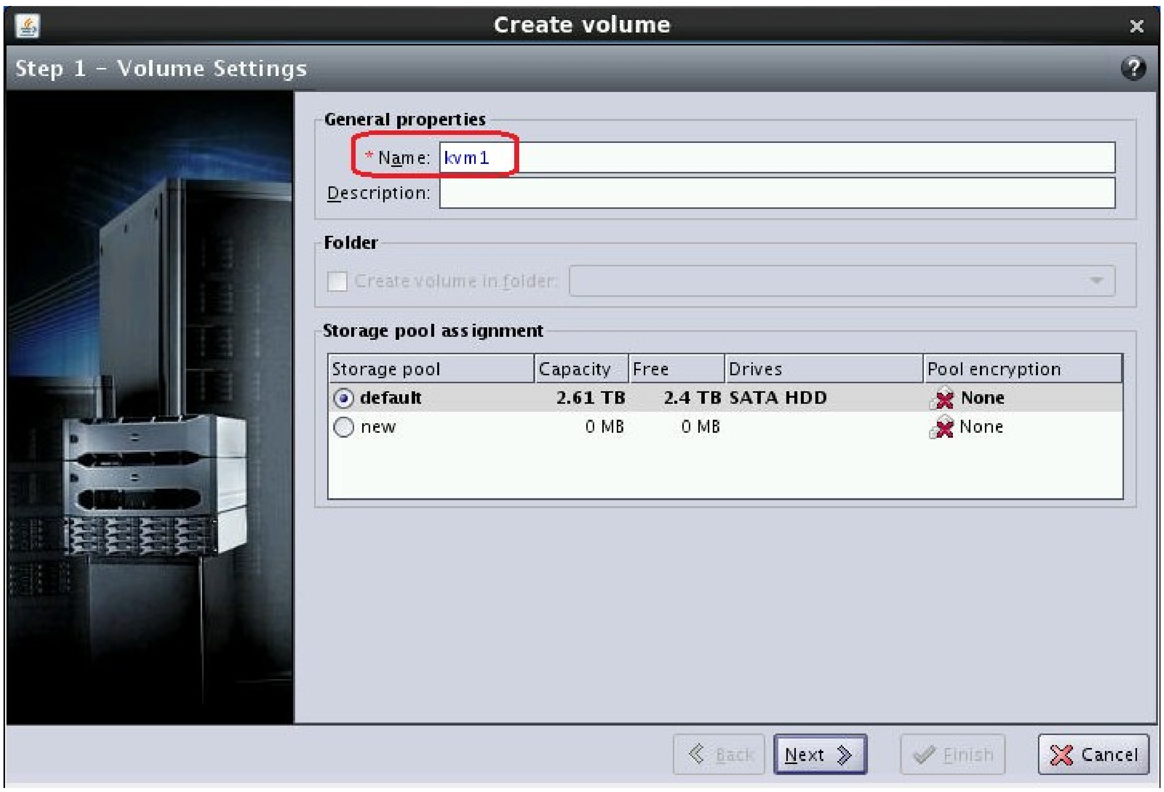
1. Create a volume.

   a) Select the **Volumes** icon beneath the target group name to display information for all volumes within that group.

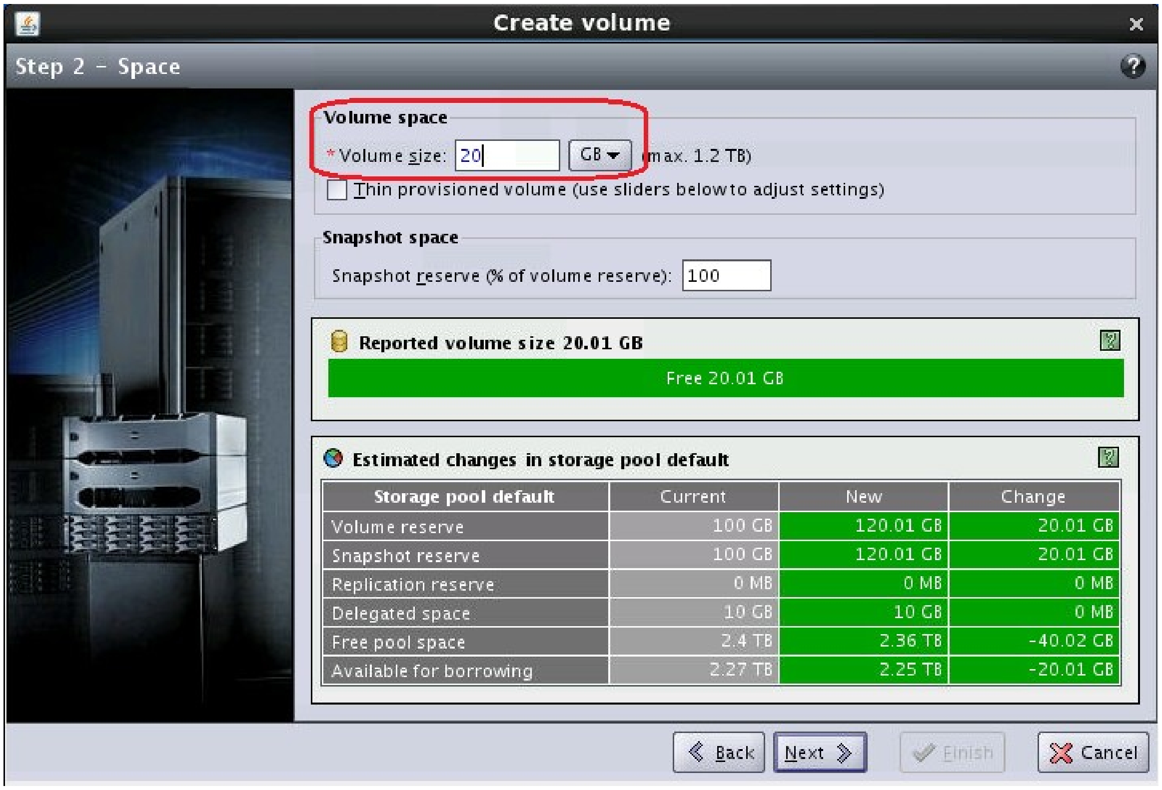
   b) Select **Create volume** in the **Activities** window.

   c) Enter the desired volume ***Name*** in the pop-up window (e.g., kvm1).

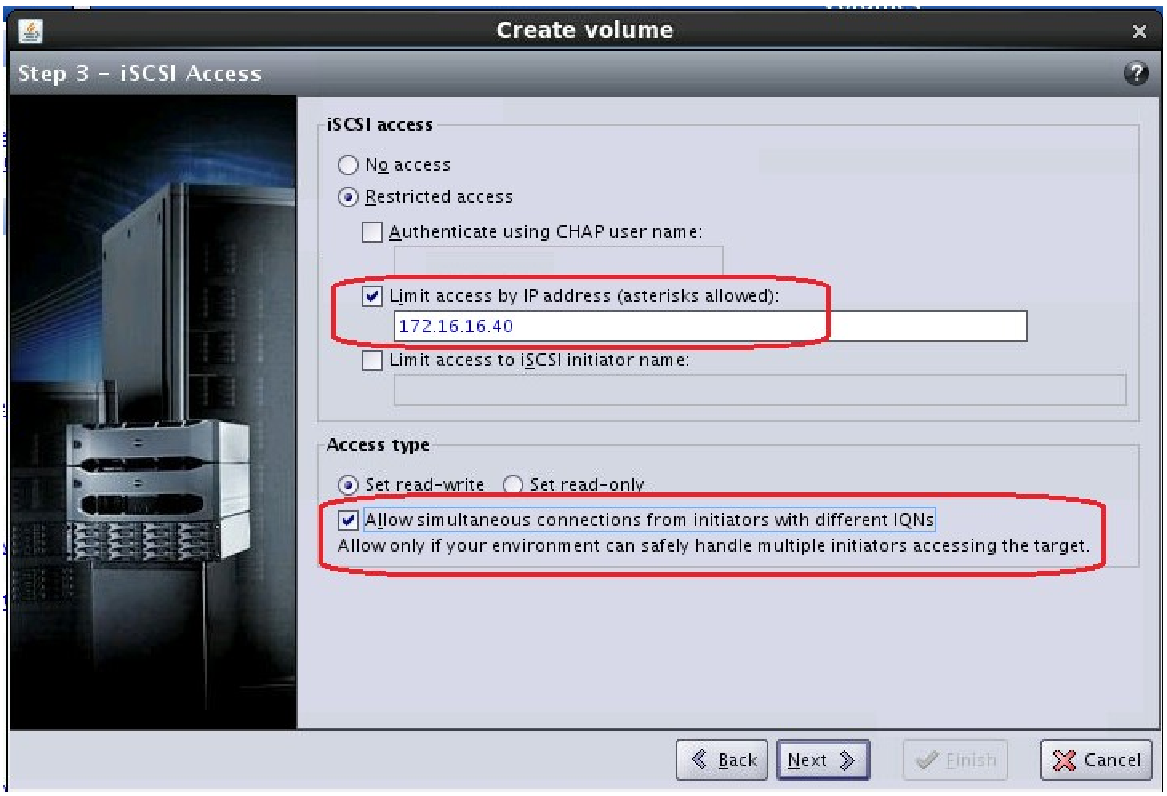
   d) Click **Next**.



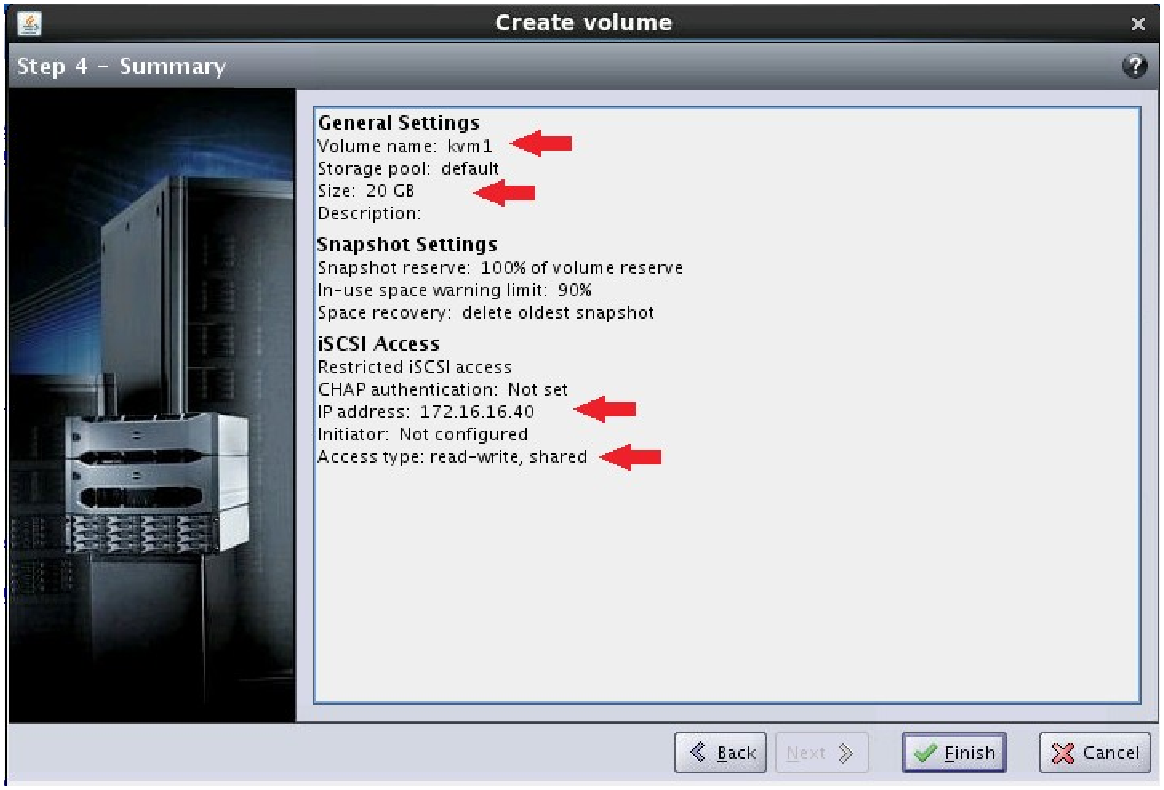
2. Set the desired ***Volume size*** and click **Next**.



3. Set the **iSCSI access** and **Access type**.
   a) Select the ***Restricted access*** option for iSCSI access.
   b) Check the box to ***Limit access by IP address*** and provide the address to one of the two host servers.
   c) Set the Access type to ***Set read-write***.
   d) Check the box to ***Allow simultaneous connections from initiators with different IQNs***.
   e) Click **Next**.



4. Verify the volume name and size in the **General Settings** section are correct as well as the **iSCSI Access** IP address and access type. Click the **Finish** button.

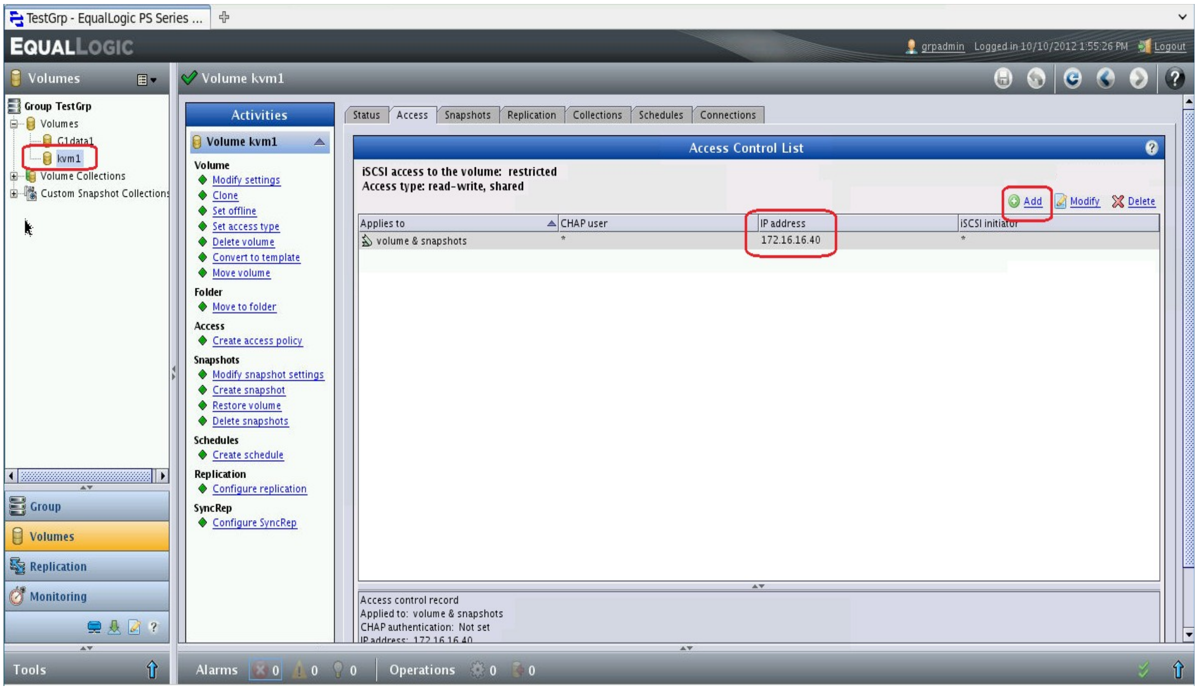


5. Configure multi-host access to the VM system disks.

a) Select the newly created VM volume in the **Volumes** window (e.g., kvm1).

b) Click the *Access* tab in the Volume information window which should already list the entry for the first host.

c) Click the ***Add*** link to create another access control record for the second host.

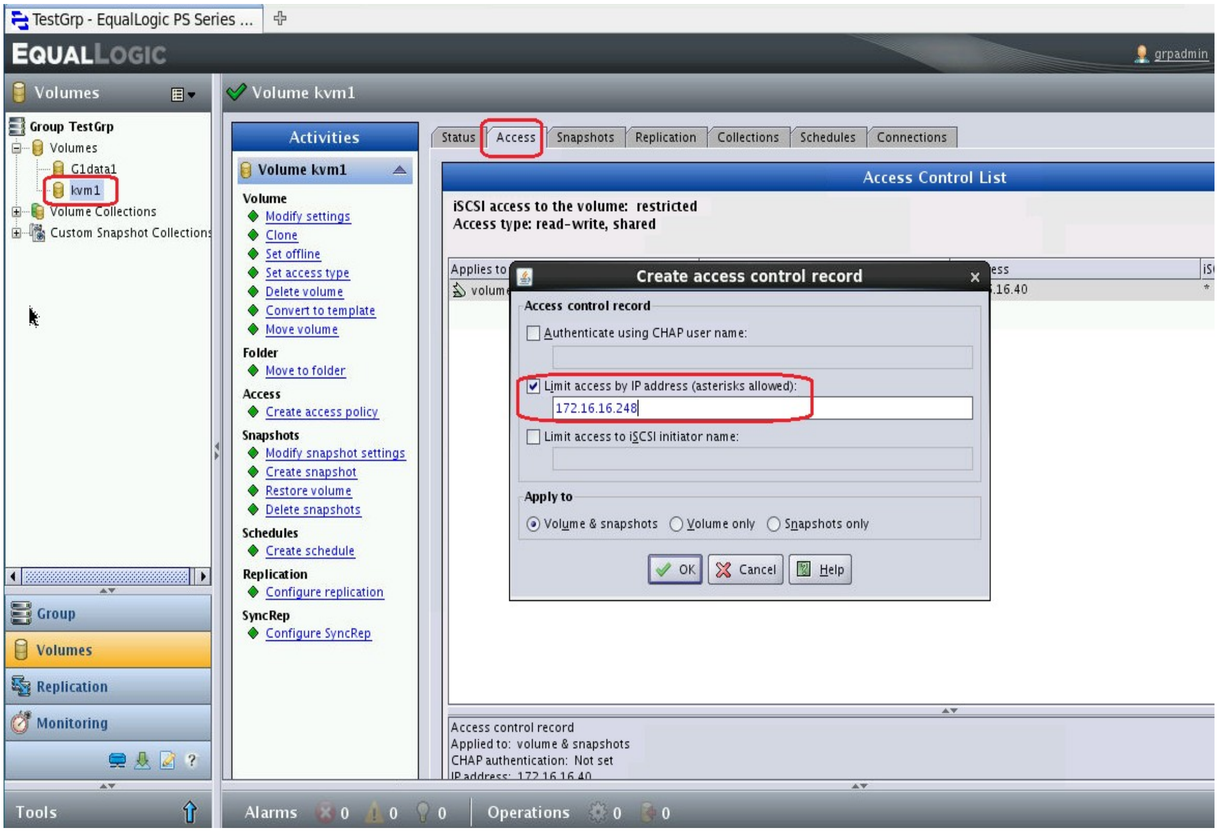


6. In the resulting pop-up window,

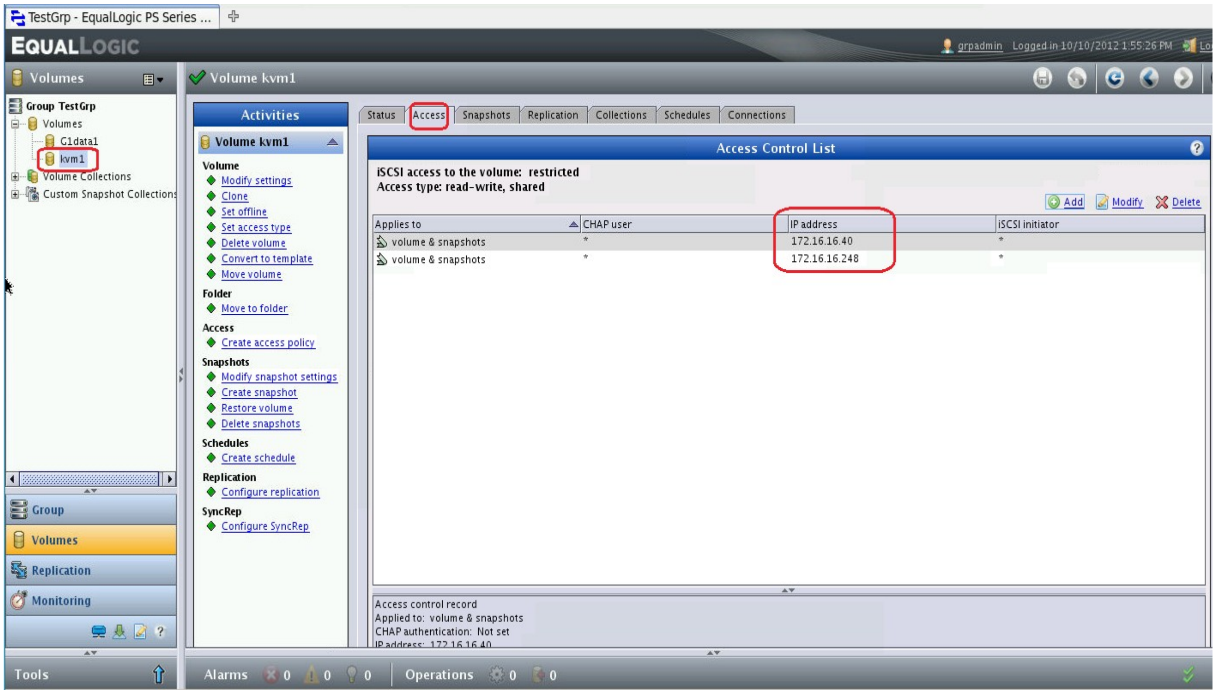
   a) Check the box to **Limit access by IP address** and provide the address to the other host server.

   b) Leave the **Volume & snapshots** option selected.

   c) Click **OK**.



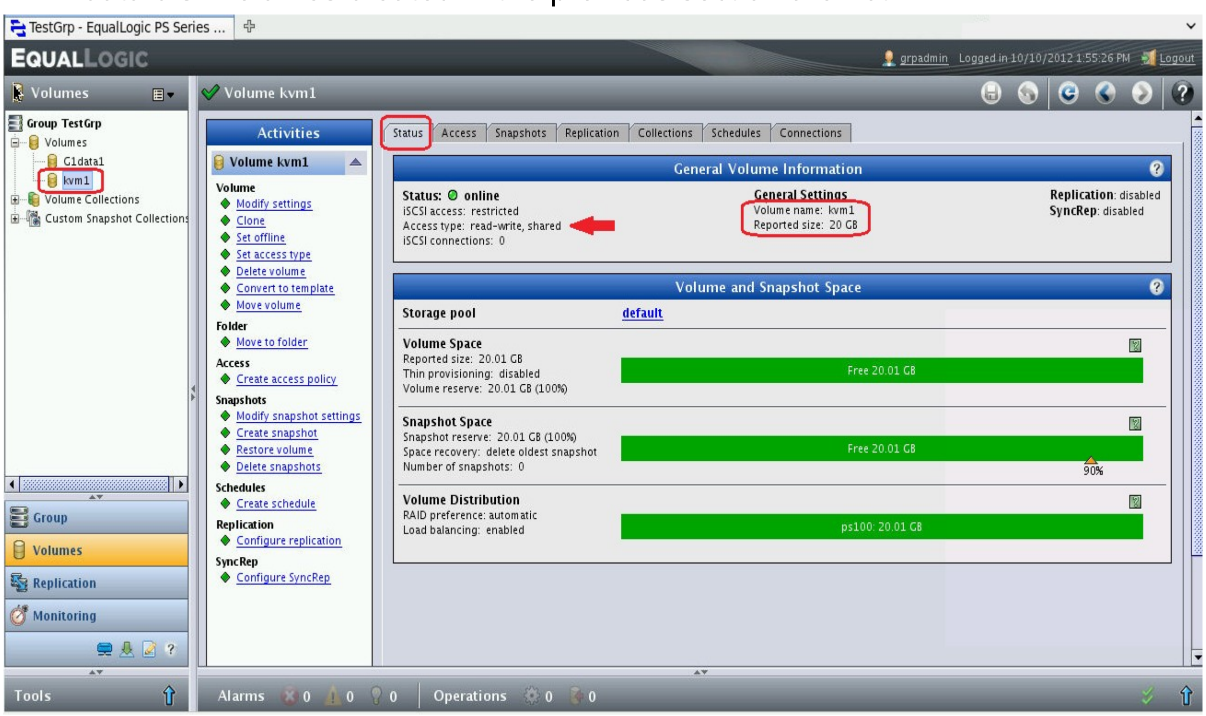
7. Verify the entry for each host server in the resulting iSCSI access control list.



8. In the information window of the newly created VM system disk volume, click the *Status* tab to view the general volume information.

   a) Verify the addition of the new volume (e.g. kvm1) in the **Volumes** window at left and its size.

   b) Note the volume access type for a VM system disk volume is shared while the VM data disk volumes created in the previous section are not.



9. Repeat steps 1 through 8 to create volumes for the other VM system disks.

As previously mentioned, the Dell EqualLogic Host Scripting Tools provide a command line interface that can be scripted to create the volumes and set their characteristics (e.g., access control). Appendix D contains an example of a python script and import file that accomplishes the same results as the GUI instructions above. Note that the Host Scripting Tools must be installed on the host server from which the scripts execute.

2.2.1.2 Discovery and Login

Using the HIT/Linux software, the iSCSI target discovery and login can be accomplished using the following command syntax.

```
# ehcmcli login --target <volname> --portal <portal_IP>
```

On each host, use the `ehcmcli` command to log into the each of the four volumes allocated as VM system disks on the iSCSI server. This command does so for the volume *kvm1*.

```
# ehcmcli login --target kvm1 --portal 172.16.16.10
Looking up volume by name (kvm1)
  Found: iqn.2001-05.com.equallogic:0-8a0906-e928c9f07-b970000003950341-kvm1
(172.16.16.10)
Login succeeded.  Device to mount:
/dev/eql/kvm1p1
/dev/eql/kvm1p2
```

Use `ehcmcli` to verify each host is managing all system disk volumes.

```
# ehcmcli status
Generating diagnostic data, please wait...

========================================================
Adapter List
========================================================
  Name: br2
    IP Address: 172.16.16.40
    HW addr: 00:1B:21:61:02:10

========================================================
Volume list
========================================================
  Volume: kvm1
    Target name: iqn.2001-05.com.equallogic:0-8a0906-e928c9f07-b970000003950341-
kvm1
    Device to mount: /dev/eql/kvm1p1
    Device to mount: /dev/eql/kvm1p2
    Status: Normal: Gathering information for new volume
    Session: 5     /dev/sdd   172.16.16.40   ->   172.16.16.11   00:00:06

  Volume: kvm2
    Target name: iqn.2001-05.com.equallogic:0-8a0906-9568c9f07-5930000003c50342-
kvm2
    Device to mount: /dev/eql/kvm2p1
    Device to mount: /dev/eql/kvm2p2
    Status: Normal: Per-member session count reduced due to number of available
host and array NICs
```

```
    Session: 1     /dev/sdb   172.16.16.40   ->   172.16.16.11   3d 23:27:13

  Volume: kvm3
    Target name: iqn.2001-05.com.equallogic:0-8a0906-ba08c9f07-b770000003f50342-
kvm3
    Device to mount: /dev/eql/kvm3p1
    Device to mount: /dev/eql/kvm3p2
    Status: Normal: Per-member session count reduced due to number of available
host and array NICs
    Session: 2     /dev/sdc   172.16.16.40   ->   172.16.16.11   3d 23:27:13

  Volume: kvm4
    Target name: iqn.2001-05.com.equallogic:0-8a0906-ba68c9f07-fb10000004250342-
kvm4
    Device to mount: /dev/eql/kvm4p1
    Device to mount: /dev/eql/kvm4p2
    Status: Normal: Per-member session count reduced due to number of available
host and array NICs
    Session: 4     /dev/sde   172.16.16.40   ->   172.16.16.11   3d 23:27:13

========================================================
Summary
========================================================
  Adapters:          1
  Managed Volumes:   4
  iSCSI Sessions:    4
  Errors:            0
  Warnings:          0
  Suggestions:       0
```

On each VM, use the `ehcmcli` command to log into each of the two volumes allocated as database disks for that VM. This command does so for the volume *g2data1* on VM2.

```
# ehcmcli login --target g2data1 --portal 172.16.16.10
Looking up volume by name (g2data1)
  Found: iqn.2001-05.com.equallogic:0-8a0906-4c28c9f07-481000000275033d-g2data1
(172.16.16.10)
Login succeeded.  Device to mount:
/dev/eql/g2data1p1
/dev/eql/g2data1p2
```

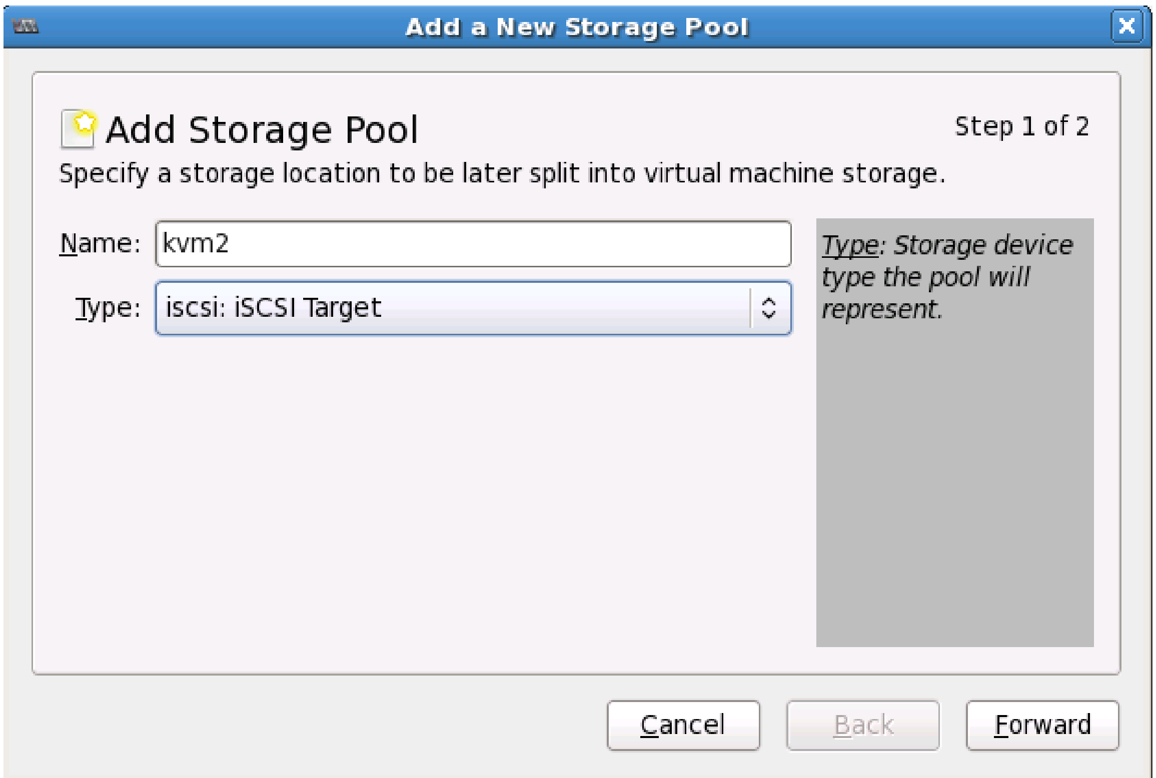
The EqualLogic connection manager (EHCMD) provides LUN persistence. After logging into the volumes using `ehcmcli`, the */dev/eql/* directory contains the volume mount points to use for the database data and log files.

```
# ls -l /dev/eql
total 0
lrwxrwxrwx. 1 root root 7 Oct 17 16:59 g2data1 -> ../dm-3
lrwxrwxrwx. 1 root root 7 Oct 17 16:59 g2data2 -> ../dm-7
```

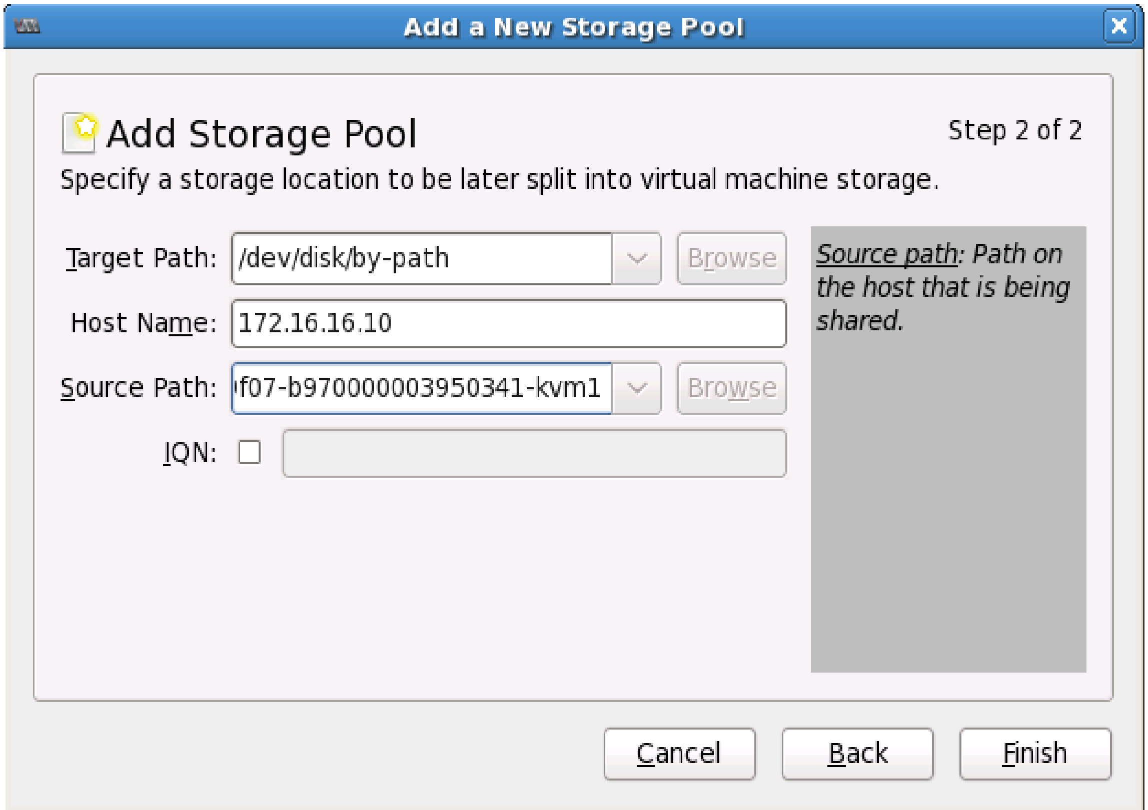
2.2.2 KVM Storage Pool Configuration

To migrate the VMs from one physical host to the other, both hosts require access to the system disks of each VM. To accomplish this, storage pools are created on each host using `virt-manager`:

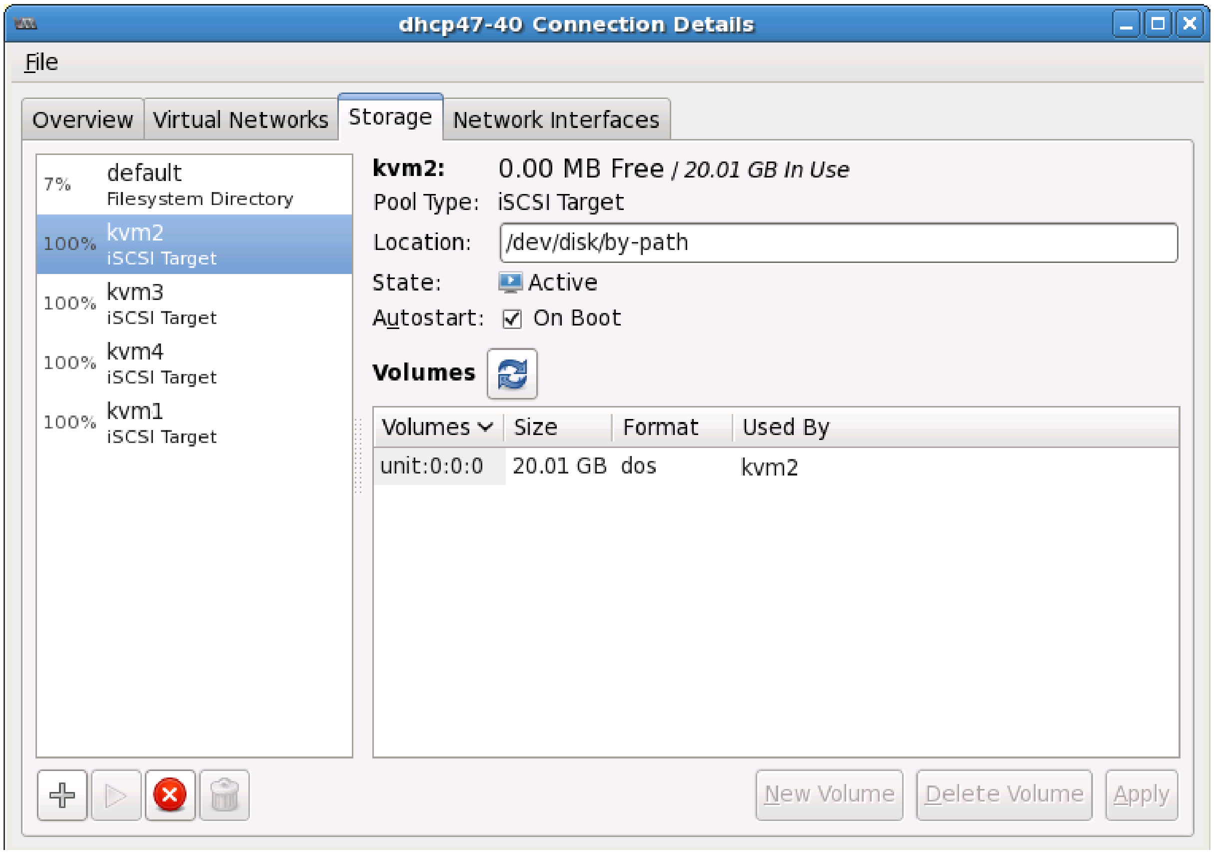
1. From the virt-manager Edit menu, select Connection Details.
2. In the Storage tab, click the "**+**" sign in the lower left of the screen.
3. Specify a ***Name*** for the pool and select the "iscsi: iSCSI Target" option from the ***Type*** pull-down menu. Click **Forward**.



4. Leave the default ***Target Path*** "/dev/disk/by-path".
5. Set ***Host Name*** to the IP address of the iSCSI group.
6. Enter the ***Source Path*** using the IQN of the target device.
7. Click **Finish**.



8. On each host, repeat steps 2 through 7 for each of the four volumes allocated as VM system disks (see Table 3).



2.3 Configuring the Hosts for Migration

A private LAN subnet is created exclusively for the VM migration and to minimize the impact of additional network traffic on the public LAN. The private LAN is created using 10 GbE to provide adequate bandwidth required for the VM migration. The time required to migrate a VM from one physical host to another is directly proportional to the size of VM's memory and the amount of memory activity occurring at the time of migration.

Two network bridges are created to provide each VM access to the public network and the iSCSI storage. One bridge (*br0*, using interface *em1*) is used for public network traffic and the other (*br2*, using interface *p2p1*) for the iSCSI storage traffic. The iSCSI storage traffic interface is configured to use jumbo frames.

The network interface configuration files used in this demonstration are included in Appendix B.

Add firewall rules to allow SSH and libvirt traffic.

```
# iptables -A INPUT -p tcp --dport 22 -j ACCEPT
# iptables -A OUTPUT -p tcp --sport 22 -j ACCEPT
# iptables -I INPUT -p tcp --dport 49152:49261 -j ACCEPT
```

Configure passwordless SSH between hosts and VMs.

```
# ssh-keygen -t rsa -P ""
# for i in 1 2 3 4 ; do ssh-copy-id -i ~/.ssh/id_rsa.pub vm$i ; done
```

Set the maximum migration bandwidth to take advantage of the 10GbE interconnect.

```
# virsh migrate-setspeed vm1 100000
# virsh migrate-setspeed vm2 100000
# virsh migrate-setspeed vm3 100000
# virsh migrate-setspeed vm4 100000
```

2.4 Virtual Machine Creation

Four VMs are created using the four volumes in the storage pool as system disks. Two virtual network interfaces are created on each VM, one using *br0* and the other using *br2*. Red Hat Enterprise Linux 6 is installed on each VM.

2.5 Install Oracle

After the VMs are installed and configured, install the RPMs for the Oracle database on each. The database software and OLTP workload kit are then installed. Each VM accesses and mounts the database data and log disks allocated for it (e.g., */dev/eql/g1data1, /dev/eql/g1data2*).

3 Testing

Figure 3-1 illustrates how both Host 1 and Host 2 are able to access the storage array. VM1 and VM2 are initially running on Host 1 while VM3 and VM4 are running on Host 2.

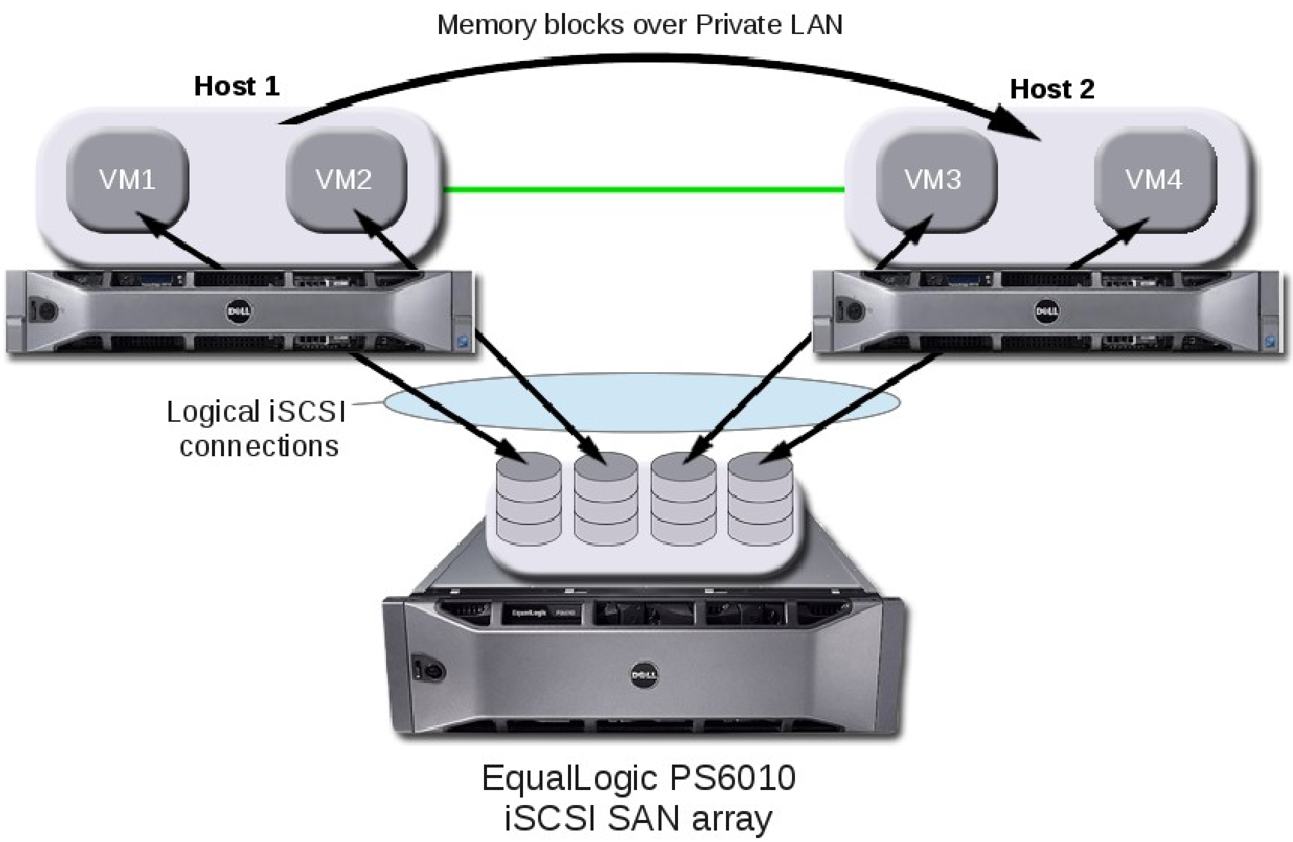


Figure 3-1: VM Migration Activity

3.1 Performing the Migration

Both hosts having physical paths to the storage array allows VMs access to their respective data from either host so that during the migration, only the memory content of the VM needs to be moved from one host to the other. Upon a significant event such as component failure or service outage on Host 1, VM1 and VM2 are instructed to migrate to Host 2.

```
# virsh migrate --live --verbose vm1 qemu+ssh://root@host2/system
# virsh migrate --live --verbose vm2 qemu+ssh://root@host2/system
```

As soon as the migration command is issued to the VMs residing on Host 1, the respective VM is initiated on Host 2 and its memory blocks are moved over the private LAN. The VMs continue to operate while the migration activity takes place in the background. Any changes that occur to the memory pages during migration are copied again.

After all memory is successfully moved, the VM shuts down on Host 1 and becomes fully operational on Host 2. During this procedure, the database OLTP workload in the VMs continues without interruption.

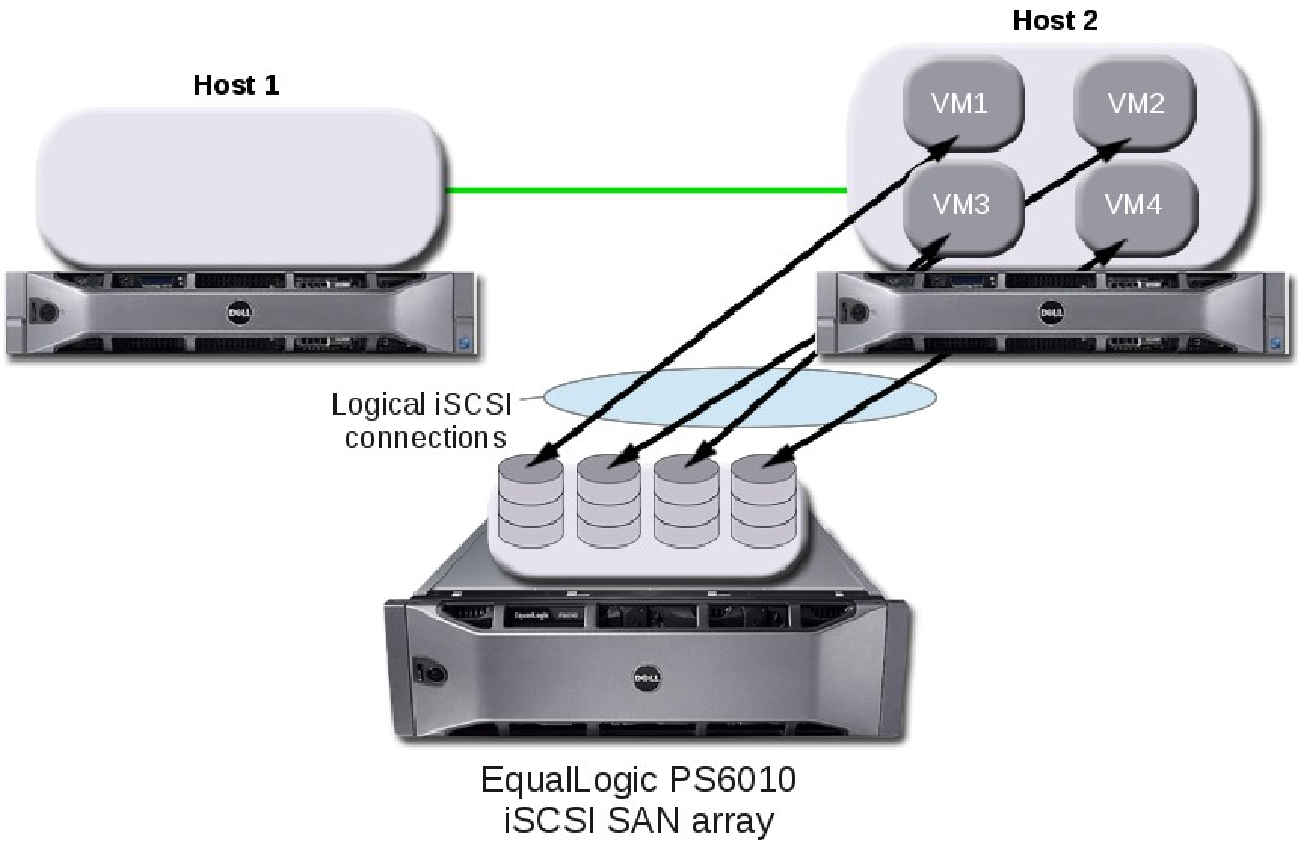


Figure 3.1-1: Post-Migration VM Layout

After the migrations complete and Host 1 becomes available again, the VMs can be spread out across the hosts for optimal balance of resources.

```
# virsh migrate --live --verbose vm1 qemu+ssh://root@host1/system
# virsh migrate --live --verbose vm2 qemu+ssh://root@host1/system
```

After the migrations to Host 1 complete, the VMs return to their preferred residence and again, the database workload in the migrated VMs continues uninterrupted.

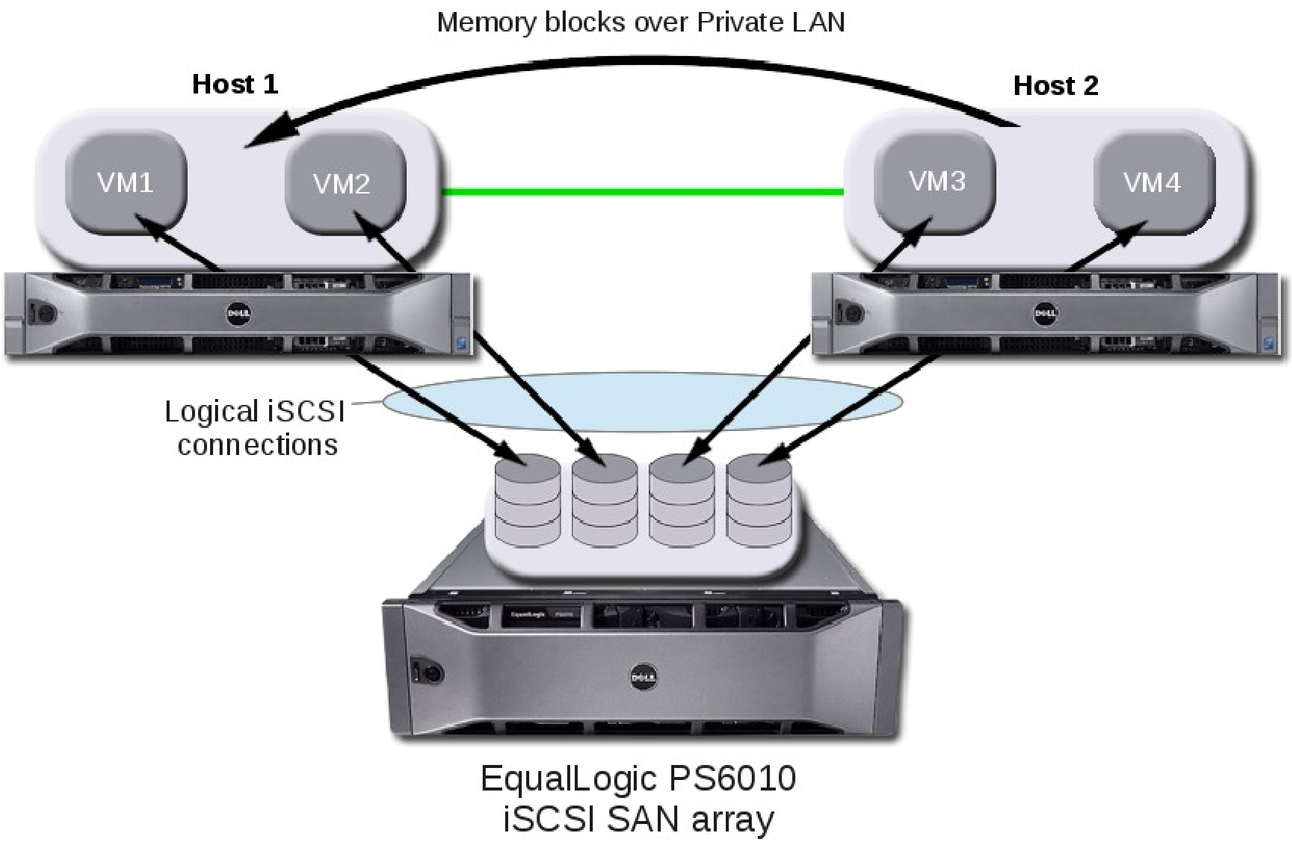
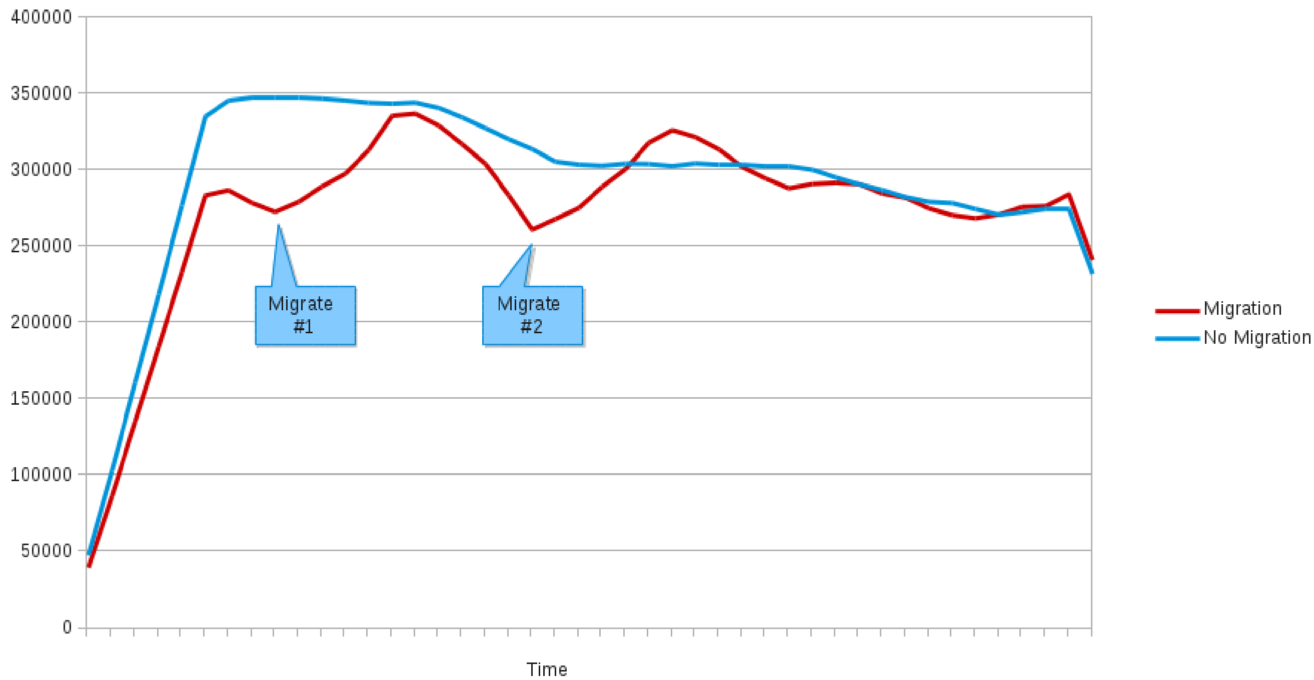


Figure 3.1-2: VM Migration Activity

3.2 Migration Performance

Figure 3.2-1 graphs the aggregate transactions per minute (TPM) of four VMs running the database workload twice. This was done once leaving all VMs balanced across hosts and again with the VMs migrated back and forth between hosts.



- Four Virtual Machines migrated between the 2 hosts back and forth
- Workload continues uninterrupted.
- Brief drop in performance, returns back to expected levels once migration is complete

Figure 3.2-1: Migration Performance over Time

The total time represented in Figure 3.2-1 was only five minutes in order to better highlight the performance dips during migration. As a result, the initial burst of transactions is observed at first before the workload levels off. A typical longer test reflects a more even level of performance but the performance dips are less noticeable.

4 Tuning and Monitoring Tools

4.1 RHEL Performance Tuning and Optimization

This section describes the tools used for optimizing performance.

4.1.1 Tuned

Tuned is a daemon that configures the system for various performance profiles. It monitors the use of system components and dynamically tunes system settings based on that information. Dynamic tuning accounts for the way that various system components are used differently throughout the uptime for any given system. For example, the hard drive is used heavily during startup and login, but is barely used later when a user might mainly work with applications like OpenOffice or email clients. Similarly, the CPU and network devices are used differently at different times. *Tuned* monitors the activity of these components and reacts to changes in their use. This testing used `tuned-adm` to apply the *virtual-host* and *virtual-guest* profile accordingly.

```
# yum -y install tuned*
  ...

# chkconfig tuned on

# service tuned start
Starting tuned:                                            [  OK  ]

# tuned-adm profile virtual-host       # executed on each host server
Reverting to saved sysctl settings:                        [  OK  ]
Calling '/etc/ktune.d/tunedadm.sh stop':                   [  OK  ]
Reverting to cfq elevator: dm-0 dm-1 sda sdb sdc sdd sde   [  OK  ]
Stopping tuned:                                            [  OK  ]
Switching to profile 'virtual-host'
Applying ktune sysctl settings:
/etc/ktune.d/tunedadm.conf:                                [  OK  ]
Calling '/etc/ktune.d/tunedadm.sh start':                  [  OK  ]
Applying sysctl settings from /etc/sysctl.conf
Applying deadline elevator: dm-0 dm-1 sda sdb sdc sdd sde  [  OK  ]
Starting tuned:                                            [  OK  ]

# tuned-adm profile virtual-guest      # executed on each VM
Reverting to saved sysctl settings:                        [  OK  ]
Calling '/etc/ktune.d/tunedadm.sh stop':                   [  OK  ]
Reverting to cfq elevator: dm-0 dm-1 dm-2 dm-3 sda sdb sdc [  OK  ]
Stopping tuned:                                            [  OK  ]
Switching to profile 'virtual-guest'
Applying ktune sysctl settings:
/etc/ktune.d/tunedadm.conf:                                [  OK  ]
Calling '/etc/ktune.d/tunedadm.sh start':                  [  OK  ]
Applying sysctl settings from /etc/sysctl.conf
Applying deadline elevator: dm-0 dm-1 dm-2 dm-3 sda sdb sdc[  OK  ]
Starting tuned:                                            [  OK  ]
```

4.1.2 Numad

The *numad* package provides a user-level daemon for Non-Uniform Memory Architecture (NUMA) systems that monitors available system resources on a per-node basis and assigns processes to align data in working memory for optimal access by the processor working on the data. As an alternative to manual static CPU pinning and memory assignment, *numad* provides dynamic adjustment to minimize memory latency on an ongoing basis. The package also provides an interface that can be used to query the `numad` daemon for the best manual placement of an application and was used to bind KVM VMs optimally on multi-socket x86_64 servers.

```
# service numad start
Starting numad:
Looks like transparent hugepage scan time in
/sys/kernel/mm/redhat_transparent_hugepage/khugepaged/scan_sleep_millisecs is
10000 ms.
Consider increasing the frequency of THP scanning,
by echoing a smaller number (e.g. 100) to
/sys/kernel/mm/redhat_transparent_hugepage/khugepaged/scan_sleep_millisecs
to more aggressively (re)construct THPs.  For example:
# echo 100 >
/sys/kernel/mm/redhat_transparent_hugepage/khugepaged/scan_sleep_millisecs
```

4.2 RHEL Performance Monitoring

This section describes the tools used for monitoring system performance.

4.2.1 Perf

`perf` is an easy to use statistical profiling tool that ships with Red Hat Enterprise Linux 6. It provides a number of useful performance counters that let the user assess the impact of commands on their system and is useful in locating system resource bottlenecks. It can report live profiling or record a profile over a length of time and can report on the saved data later. Further information on the **`perf`** tool can be found at https://access.redhat.com/knowledge/docs/en-US/Red_Hat_Enterprise_Linux/6/html/Developer_Guide/perf.html.

4.2.2 Tuna

`tuna` is designed to be used on a running system where changes take place immediately and can be used to modify thread attributes (processor affinity, scheduling policy, and scheduler priority) and interrupts (processor affinity). This allows any application-specific measurement tools to observe and analyze system performance immediately after the changes have been made.

4.2.3 Numastat

numastat displays per-node NUMA hit and miss system statistics and can display per-node memory allocation information for the specified pattern provided.

This example shows the memory pages of all four VMs spread across both NUMA nodes on the host without *numad*.

```
# numastat -c qemu

Per-node process memory usage (in MBs)
PID              Node 0 Node 1 Total
---------------  ------ ------ -----
32412 (qemu-kvm)   6477   3170  9647
32444 (qemu-kvm)   9511    165  9676
32580 (qemu-kvm)   1392   7805  9197
32706 (qemu-kvm)   5434   4227  9661
---------------  ------ ------ -----
Total             22814  15367 38181
```

This example shows the memory page locales of each VM on the host running the *numad* service. Note how VM memory no longer crosses NUMA node boundaries.

```
# numastat -c qemu

Per-node process memory usage (in MBs)
PID              Node 0 Node 1 Total
---------------  ------ ------ -----
29467 (qemu-kvm)      0   9634  9634
29571 (qemu-kvm)   9160      5  9165
29675 (qemu-kvm)   9606      5  9611
29785 (qemu-kvm)      0   9613  9613
---------------  ------ ------ -----
Total             18766  19257 38023
```

4.3 Dell EqualLogic Storage Tools

Dell EqualLogic PS Series storage implements an all-inclusive software model, with a rich collection of capabilities in host integration, storage management and monitoring. The Host Integration Tools (HIT) for Linux software simplifies Linux host iSCSI configuration and storage administration. HIT/Linux includes **eqltune**, for automated host analysis and configuration. In addition, HIT/Linux provides intelligent Multipath IO management, optimizing both network and SAN hardware utilization. Additionally, the Host Scripting Tools allow PS Series group management commands to be scripted in perl or python host-side scripts.

The PS Series Group Manager is provided in both GUI and command line versions. The GUI version is a web browser based, portable java application. The Group Manager includes wizard-based storage configuration features, along with a simple and intuitive user interface.

SAN Headquarters is part of the all-inclusive software suite provided with Dell EqualLogic PS Series storage. A full featured SAN performance monitoring and capacity analysis tool, SAN HQ provides both live data capture capabilities and detailed historical reporting. It also can connect to multiple PS Series Groups, providing multi-site monitoring from a single client.

5 What Does It All Mean?

The testing conducted by Red Hat and Dell proves that Red Hat Enterprise Linux with the KVM hypervisor is an ideal platform for building highly-available virtualized Oracle databases on commodity x86 hardware. Built on top of end-to-end Dell hardware infrastructure, this solution represents collaborative efforts in which Red Hat and its industry partners participate to ensure interoperability and performance that directly benefit their mutual customers. The Dell EqualLogic Host Integration Tools simplify configuration and automate iSCSI storage operations. This type of testing removes the burden from customers of having to try out every solution in their own environment or the uncertainty of having to deploy an untested solution.

Testing also demonstrates that customers deploying databases and applications in virtualized environments not only have an opportunity to increase physical server utilization, but also increase availability of their enterprise infrastructure by seamlessly migrating VM instances to different physical hardware without degradation of services provided. Additionally, customers could rely on VM migrations in the following cases:

- Hardware upgrades – By moving the VMs to newer hardware, users can take advantage of performance improvements without having to change the operating environment of their applications.
- Hardware maintenance – Users do not have to bring down their operating environments for standard maintenance, but instead can migrate to different hardware, complete the maintenance effort on affected systems, and migrate the VMs back to the original hardware.
- Failover – In the event of a physical host failure VMs can be started on another (standby or even active) host. When the outage ends, those VMs can be migrated without interruption back to the original host. While that automated functionality is outside the scope of this document it could be accomplished with Red Hat Cluster Suite (RHCS) software. Refer to list of supporting documentation in Appendix A for further information.

In conclusion, if your organization is looking to ensure business continuity by maintaining access to your mission-critical databases, Red Hat and Dell offer best practices and proven implementation steps for setting up the Oracle Database and storage, and configuring, running, and migrating VMs. The latest features of Red Hat Enterprise Linux automatically manage memory locality and the footprint of several VMs in multi-tenancy environments.

Appendix A: References and Further Information

1. For details on how to deploy Oracle Database 11*g* on Red Hat Enterprise Linux 6 for several types of back-end storage, including Fusion-io ioDrives, see *Oracle Database 11g Release 2 on Red Hat Enterprise Linux 6: Deployment Recommendations* March 2012, http://www.redhat.com/resourcelibrary/reference-architectures/deploying-oracle-11gr2-on-rhel-6
2. For more information on Red Hat Cluster Suite deployment and best practices watch this free webinar, *Deploying a highly available service with Red Hat Cluster Suite*, https://www.redhat.com/about/events-webinars/webinars/2012-05-08-taste-of-training-deploying-a-highly-available-service-with-red-hat-cluster-suite
3. Other Red Hat Reference Architectures and performance briefs including *Red Hat Enterprise Linux KVM Hypervisor I/O* are located on the Red Hat Reference Architecture page at http://www.redhat.com/resourcelibrary/reference-architectures/
4. For information on Dell EqualLogic PS Series virtualized storage, http://www.dell.com/equallogic
5. To download Dell EqualLogic PS Series software (HIT/Linux, Host Scripting Tools, …), log on to the EqualLogic Support site, https://support.equallogic.com/secure/login.aspx
6. For information on Dell PowerEdge Servers, http://www.dell.com/poweredge
7. For information on Dell PowerConnect Switches, http://www.dell.com/us/enterprise/p/switch-powerconnect

Appendix B: Network Configuration Files

This appendix provides example contents of the host server network interface configurations files.

B.1 Ifcfg-em2

This interface was configured for use as the local network between hosts and VMs.

```
DEVICE="em2"
BOOTPROTO="static"
HWADDR="00:26:B9:34:98:DD"
NM_CONTROLLED="no"
ONBOOT="yes"
TYPE="Ethernet"
BRIDGE="br1"
```

B.2 ifcfg-p2p1

This interface was configured for use as 10GbE storage access.

```
DEVICE="p2p1"
BOOTPROTO="none"
ONBOOT="yes"
TYPE="Ethernet"
BRIDGE="br2"
MTU=9000
```

B.3 ifcfg-p2p2

This interface was configured for use as the 10GbE VM migration path.

```
DEVICE="p2p2"
BOOTPROTO="none"
HWADDR="00:1B:21:61:02:11"
NM_CONTROLLED="no"
ONBOOT="yes"
TYPE="Ethernet"
IPADDR=172.17.1.40
NETMASK=255.255.255.0
MTU=9000
```

B.4 ifcfg-br1

This software bridge was configured to allow VMs access to the local network.

```
DEVICE="br1"
BOOTPROTO="static"
ONBOOT="yes"
IPADDR=10.10.1.10
NETMASK=255.255.255.0
TYPE="Bridge"
DELAY="0"
```

B.5 ifcfg-br2

This software bridge was configured to allow VMs access to the iSCSI storage.

```
DEVICE="br2"
BOOTPROTO="none"
IPADDR=172.16.16.40
NETMASK=255.255.255.0
ONBOOT="yes"
TYPE="Bridge"
DELAY="0"
MTU="9000"
```

Appendix C: KVM Configuration Files

C.1 vm1.xml

The following is an example of a VM configuration file used in this demonstration.

```
<domain type='kvm' id='5'>
  <name>vm1</name>
  <uuid>4f7f53e4-89c4-9643-f549-47090af0b0c6</uuid>
  <memory unit='KiB'>12582912</memory>
  <currentMemory unit='KiB'>12582912</currentMemory>
  <vcpu placement='static'>4</vcpu>
  <os>
    <type arch='x86_64' machine='rhel6.3.0'>hvm</type>
    <boot dev='hd'/>
  </os>
  <features>
    <acpi/>
    <apic/>
    <pae/>
  </features>
  <clock offset='utc'/>
  <on_poweroff>destroy</on_poweroff>
  <on_reboot>restart</on_reboot>
  <on_crash>restart</on_crash>
  <devices>
    <emulator>/usr/libexec/qemu-kvm</emulator>
    <disk type='block' device='disk'>
      <driver name='qemu' type='raw' cache='none' io='native'/>
      <source dev='/dev/disk/by-path/ip-172.16.16.10:3260-iscsi-iqn.2001-
05.com.equallogic:0-8a0906-e928c9f07-b970000003950341-kvm1-lun-0'/>
      <target dev='vda' bus='virtio'/>
      <alias name='virtio-disk0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x05'
function='0x0'/>
    </disk>
    <controller type='usb' index='0'>
      <alias name='usb0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x01'
function='0x2'/>
    </controller>
    <interface type='bridge'>
      <mac address='52:54:00:62:6d:3f'/>
      <source bridge='br0'/>
      <target dev='vnet0'/>
      <model type='virtio'/>
      <alias name='net0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x03'
function='0x0'/>
    </interface>
    <interface type='bridge'>
      <mac address='52:54:00:76:b9:46'/>
      <source bridge='br2'/>
```

```
      <target dev='vnet1'/>
      <model type='virtio'/>
      <alias name='net1'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x07'
function='0x0'/>
    </interface>
    <interface type='bridge'>
      <mac address='52:54:00:84:45:6e'/>
      <source bridge='br1'/>
      <target dev='vnet2'/>
      <model type='virtio'/>
      <alias name='net2'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x08'
function='0x0'/>
    </interface>
    <serial type='pty'>
      <source path='/dev/pts/1'/>
      <target port='0'/>
      <alias name='serial0'/>
    </serial>
    <console type='pty' tty='/dev/pts/1'>
      <source path='/dev/pts/1'/>
      <target type='serial' port='0'/>
      <alias name='serial0'/>
    </console>
    <input type='tablet' bus='usb'>
      <alias name='input0'/>
    </input>
    <input type='mouse' bus='ps2'/>
    <graphics type='vnc' port='5900' autoport='yes'/>
    <sound model='ich6'>
      <alias name='sound0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x04'
function='0x0'/>
    </sound>
    <video>
      <model type='cirrus' vram='9216' heads='1'/>
      <alias name='video0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x02'
function='0x0'/>
    </video>
    <memballoon model='virtio'>
      <alias name='balloon0'/>
      <address type='pci' domain='0x0000' bus='0x00' slot='0x06'
function='0x0'/>
    </memballoon>
  </devices>
  <seclabel type='dynamic' model='selinux' relabel='yes'>
    <label>system_u:system_r:svirt_t:s0:c457,c513</label>
    <imagelabel>system_u:object_r:svirt_image_t:s0:c457,c513</imagelabel>
  </seclabel>
</domain>
```

C.2 kvm1.xml

The following is an example of a VM storage pool configuration file used in this demonstration.

```
  <name>kvm1</name>
  <uuid>a856af0c-442c-e1e2-b84b-a00e92f4f978</uuid>
  <capacity unit='bytes'>21485322240</capacity>
  <allocation unit='bytes'>21485322240</allocation>
  <available unit='bytes'>0</available>
  <source>
    <host name='172.16.16.10'/>
    <device path='iqn.2001-05.com.equallogic:0-8a0906-9568c9f07-
5930000003c50342-kvm1'/>
  </source>
  <target>
    <path>/dev/disk/by-path</path>
    <permissions>
      <mode>0700</mode>
      <owner>-1</owner>
      <group>-1</group>
    </permissions>
  </target>
</pool>
```

Appendix D: Host Scripting Tools - Automation Script

The following python script (*kvmsetup.py*) and import file (*voldata.py*) can be used to create the volumes required for this reference architecture. Note this code requires installation of the Dell EqualLogic Host Scripting Tools, see Appendix A.

D.1 kvmsetup.py

```
#!/usr/bin/env python
#
# Automate creation of volumes for the Red Hat KVM Live Migration demo
#

import sys
import re
import eqlscript
from voldata import *      # contains the site & volume specific settings

# Log into the PSS
remote = eqlscript.session (PSgrpIP, user, pwd, telnet)
if remote.err ():
    print "Failed to login to PS Group %s", PSgrpIP
    print remote.err ()
    sys.exit (1)

# Now walk through VOLDATA and create the volumes
i = 0
for list in voldata:
    volName = voldata[i][0]
    volSize = voldata[i][1]
#
# Send the volume create command and extract the output
    res1 = remote.cmd ("volume create %s %s" % (volName, volSize))
    if remote.err ():
        print "Failed to create volume", volName, "size", volSize
        print remote.err ()
        sys.exit (1)
#
# On success, extract the iSCSI target name from the output
    targre = re.compile (r"iscsi target name is\s+(.*)$", re.I | re.M)
    m = targre.search ("\n".join (res1))
    if m:
        targName = m.group (1)
        print "Volume", volName, "iSCSI name", targName, "created
successfully"
#
# check to see if this volume requires Shared multi-host access
# then set the Volume Access parameters
    volShared = voldata[i][2]
    volre2 = re.compile (r"multi", re.I)
```

```
    if volre2.match (volShared):
        volIP1 = voldata[i][3]
        volIP2 = voldata[i][4]
        res2 = remote.cmd ("volume select %s multihost-access enable" %
(volName))
        res2 = remote.cmd ("volume select %s access create ipaddress %s" %
(volName, volIP1))
        res2 = remote.cmd ("volume select %s access create ipaddress %s" %
(volName, volIP2))
        print "Multi-host access set to: ", volIP1, volIP2
    else:
        volIP = voldata[i][3]
        res2 = remote.cmd ("volume select %s access create ipaddress %s" %
(volName, volIP))
        print "Single host access set to: ", volIP
#
# set list index for next voldata
    i = i + 1

# END FOR

remote.logout ()
print "Complete - created %s volumes on %s" % (i, PSgrpIP)
sys.exit (0)
```

D.2 voldata.py

```
#!/usr/bin/env python
#
# Defines site specific values, storage array group settings
# and Volume characteristics
#

# PS Group settings
PSgrpIP = "172.16.25.20"
user = "grpadmin"
pwd = "<password>"
telnet = False

# Volume characteristics: name, size, access, IP(s)
voldata = [
['G1data1', '100GB', 'single', '172.16.16.91'],
['G1data2', '80GB', 'single', '172.16.16.91'],
['G2data1', '100GB', 'single', '172.16.16.92'],
['G2data2', '80GB', 'single', '172.16.16.92'],
['G3data1', '100GB', 'single', '172.16.16.93'],
['G3data2', '80GB', 'single', '172.16.16.93'],
['G4data1', '100GB', 'single', '172.16.16.94'],
['G4data2', '80GB', 'single', '172.16.16.94'],
['kvm1', '20GB', 'multi', '172.16.16.40', '172.16.16.248'],
['kvm2', '20GB', 'multi', '172.16.16.40', '172.16.16.248'],
['kvm3', '20GB', 'multi', '172.16.16.40', '172.16.16.248'],
['kvm4', '20GB', 'multi', '172.16.16.40', '172.16.16.248']]
# END voldata
```