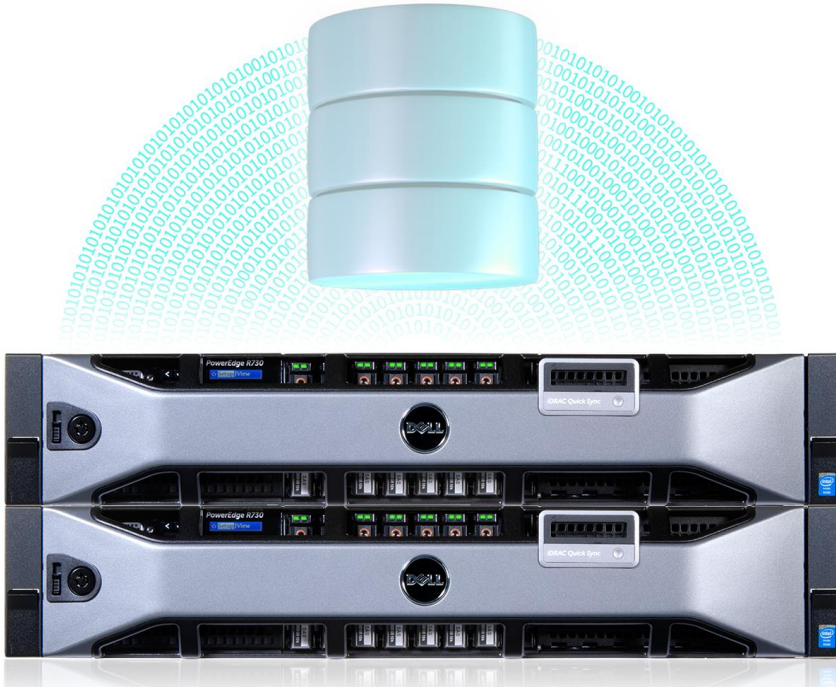


DELL ACCELERATION APPLIANCE FOR DATABASES VS. IBM FLASHSYSTEM 900: CAPACITY, COST, AND PERFORMANCE

Better Oracle® Database 12c performance and more cost-efficient storage with Dell™ Acceleration Appliance for Databases



37%

lower cost per terabyte, with more transactions per minute,* in a highly available configuration

*versus IBM® FlashSystem™ 900 appliance, which does not support HA functionality

Even with powerful database servers, it's important to give your business every possible advantage to keep up with the growing numbers of users and applications accessing your company's resources. Upgrading your storage infrastructure for your database applications with the highly available Dell Acceleration Appliance for Databases (DAAD) 2.0 powered by Intel Xeon processors E5-2667 v3 – a high-performance flash storage solution – can help you achieve this goal.

In the Principled Technologies datacenter, we compared the Oracle Database 12c performance of two environments: one with a highly available Dell Acceleration Appliance for Databases (DAAD 2.0 solution) and one using an IBM FlashSystem 900 storage appliance (IBM solution). We found that the highly available DAAD solution comes at a 37.0 percent lower cost per terabyte of storage space compared to the IBM FlashSystem 900 appliance, so you get more storage capacity for your dollar. The DAAD solution also provided 2.9 percent better transactional database performance than the IBM solution, while offering critical redundancy to reduce the possibility of devastating downtime in case of a failure. According to IBM, FlashSystem 900 does not come in a highly available configuration, which could lead to lost revenue and more importantly lost data, if a failure happens. If you're looking to maximize database performance and optimize storage capacity per dollar, the Dell Acceleration Appliance for Databases can meet your needs.



HOW IT WORKS

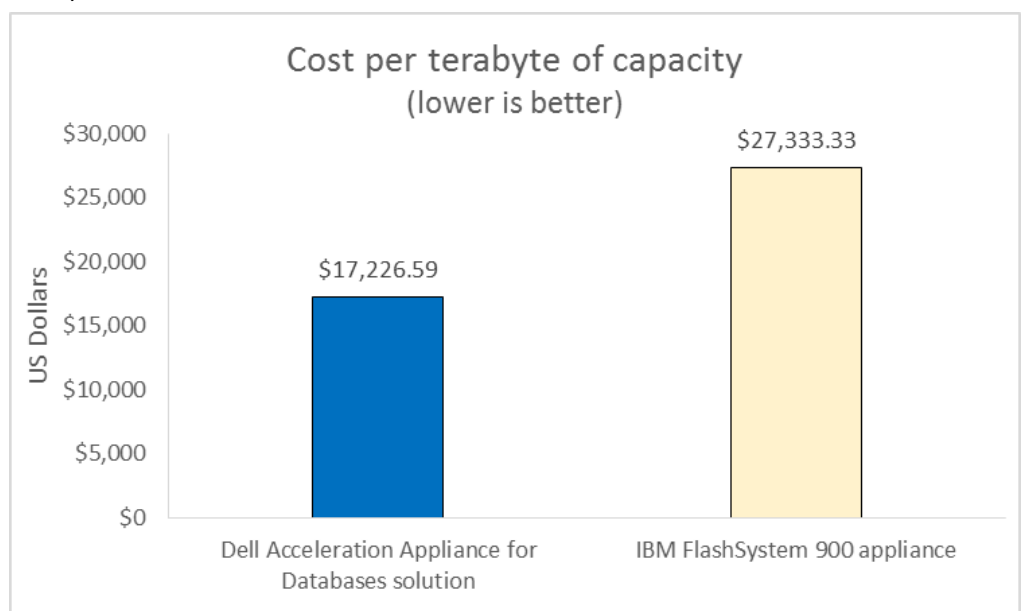
The Dell Acceleration Appliance for Databases 2.0 is a pre-integrated server/software combination consisting of one or two Dell PowerEdge R730 servers with Intel Xeon processors E5-2667 v3, DAAD ION Accelerator software, and Fusion SX300 ioMemory drives, which are high-capacity NAND Flash PCIe SSDs. Available in 12.8TB and 25.6TB capacities, DAAD 2.0 supports Fibre Channel, iSCSI, and Infiniband/SRP front-end fabrics. Designed to work with many database platforms and front-end servers, DAAD makes appliance resources available to the application server and uses I/O acceleration to optimize database requests, leveraging DRAM to improve performance. Boosting database performance with DAAD can help you work within your existing infrastructure, so you don't have to purchase more disk or compute resources, incur additional database licensing costs, or take up vast amounts of extra datacenter space. To learn more about the Dell Acceleration Appliance for Databases, visit en.community.dell.com/techcenter/enterprise-solutions/m/oracle_db_gallery/20441362/download.

In this study, we configured two 25.6 TB DAAD appliance nodes as an HA cluster pair. For information about the DAAD and our other test components, see [Appendix A](#). For detailed system configuration, see [Appendix B](#). For step-by-step testing details, see [Appendix C](#).

WHAT WE FOUND

As Figure 1 shows, we found that the highly available DAAD solution cost 37.0 percent less per terabyte of storage. This means that with a fixed budget, you can have more usable storage capacity to handle growing business needs. (See Figure 2 for details.)

Figure 1: The highly available Dell Acceleration Appliance for Databases solution has a 37.0 percent lower cost per terabyte than the IBM FlashSystem 900 appliance.



	Usable storage capacity (TB)	Cost (USD) ¹	Cost/terabyte
DAAD solution	25.6 ²	\$441,000.76	\$17,226.59
IBM FlashSystem 900	7.2	\$196,800.00	\$27,333.33

Figure 2: Storage capacity and cost comparison for the two solutions.

In addition to more storage capacity and a lower cost per terabyte, we found that the highly available Dell Acceleration Appliance for Databases with Intel Xeon processors E5-2667 v3 also outperformed the IBM solution. The DAAD solution provided 2.9 percent better OLTP Oracle Database 12c performance than the IBM FlashSystem 900 solution (see Figure 3). In our tests, we ran a TPC-C-derived workload and used HammerDB.

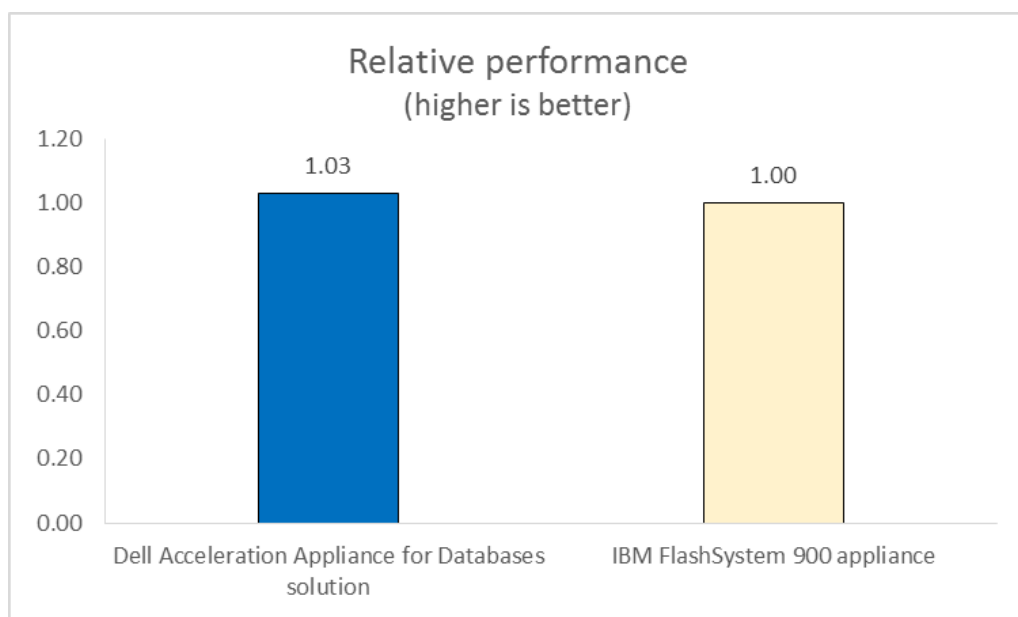


Figure 3: Using the Dell Acceleration Appliance for Databases solution provided 2.9 percent better database performance. The results we report are from the median of three runs.

When you're deciding which flash storage solution to buy to upgrade your storage infrastructure for your database applications, your goal is to accommodate existing users while leaving headroom for expanding needs as your business grows. With a DAAD, you get a performance boost for your applications, as well as the protection that a highly available configuration offers in the event of a failure.

¹ DAAD solution price was provided by Dell as of 6/2/2015 and IBM FlashSystem900 price is from an IBM reseller as of 6/2/2015. Prices are list prices and do not include discounts, tax, or shipping costs.

² A two-node, highly available DAAD configuration provided the 25.6 TB usable capacity.

CONCLUSION

There's no better time to upgrade your database environment than when your business is expanding and you need more performance to keep up with growing demand. Flash storage is an attractive solution because it provides significant performance boosts over spinning disks and traditional storage arrays, but selecting the fastest solution with the best storage capacity isn't always easy. We found that a highly available Dell Acceleration Appliance for Databases solution provided 2.9 percent better database performance than the IBM FlashSystem 900, plus 37.0 percent lower cost per terabyte of storage capacity, which resulted in incredible performance at an efficient price per TB.

APPENDIX A – ABOUT THE COMPONENTS

About the Dell Acceleration Appliance for Databases 2.0 hardware

The two 2U Dell PowerEdge R730 rack servers used in the highly available DAAD configuration are each powered by two Intel Xeon processors E5-2667 v3, 384 GB of DDR4 RAM, and QLogic QLE2662 16Gb Fibre Channel HBAs, providing functional flexibility in the datacenter. The Dell PowerEdge R730 rack servers are each powered by four 6400 GB SanDisk SX300 ioMemory PCIe® SSDs to reduce storage bottlenecks.

With redundant power supply units, hot-swappable hardware, and Dual SDTM card for Failsafe Hypervisors, the Dell PowerEdge R730 supports hardware high availability. The PowerEdge R730 comes standard with iDRAC8 with Lifecycle Controller and Dell OpenManage, which all work to streamline management. For more details on the Dell PowerEdge R730, visit www.dell.com/us/business/p/poweredge-r730/pd?oc=pe_r730_1356&model_id=poweredge-r730&l=en&s=bsd. For more details on the Intel Xeon processor E5-2600 v3 series, visit www.intel.com/content/dam/www/public/us/en/documents/product-briefs/xeon-e5-brief.pdf.

About the benchmark we used - HammerDB

HammerDB is an open-source benchmark tool that tests the database performance of many databases, including Oracle Database, Microsoft® SQL Server®, PostgreSQL®, MySQL™, and more. The benchmark includes built-in workloads derived from industry-standard benchmarks, such as a transactional (TPC-C-derived) workload and a data warehouse (TPC-H-like) workload. For this study, we used the transactional workload. The TPC-C HammerDB workload is derived from TPC-C and as such is not comparable to published TPC-C results. For more information, visit www.hammerora.sourceforge.net.

APPENDIX B – SYSTEM CONFIGURATION INFORMATION

Figure 4 provides detailed configuration information for the test systems.

System	Dell PowerEdge R720 (Oracle Database server)	Dell Acceleration Appliance for Databases 2.0
Power supplies		
Total number	1	2 (HA pair)
Vendor and model number	Dell 05NF18X02	Dell 0G6W6KX02
Wattage of each (W)	750	750
General		
Number of processor packages	2	2
Number of cores per processor	8	8
Number of hardware threads per core	2	2
System power management policy	Performance	Performance
CPU		
Vendor	Intel	Intel
Name	Xeon	Xeon
Model number	E5-2650 v2	E5-2667 v3
Socket type	LGA 2011	FCLGA2011-3
Core frequency (GHz)	2.6	3.2
Bus frequency	7.2 GT/s	9.6 GT/s
L1 cache	32 + 32 KB (per core)	32 + 32 KB (per core)
L2 cache	256 KB (per core)	256 KB (per core)
L3 cache	20 MB	20 MB
Platform		
Vendor and model number	Dell PowerEdge R720	Dell PowerEdge R730
Motherboard model number	0M1GCR	0599V5
BIOS name and version	2.4.3	1.1.4
BIOS settings	Defaults	Defaults
Memory module(s)		
Total RAM in system (GB)	128	384
Vendor and model number	Hynix HMT31GR7BFR4A-H9	Hynix HMA42GR7MFR4N-TFT1
Type	PC3-10600	PC4-17000
Speed (MHz)	1,333	2,133
Speed running in the system (MHz)	1,333	2,133
Size (GB)	8	16
Number of RAM module(s)	16	24
Chip organization	Double-sided	Double-sided
Rank	2Rx4	2Rx4
Operating system		
Name	Red Hat® Enterprise Linux®	DAAD ION Accelerator
Build number	6.6	2.5.1-413
File system	ext4	btrfs

System	Dell PowerEdge R720 (Oracle Database server)	Dell Acceleration Appliance for Databases 2.0
Kernel	2.6.32-504.el6.x86_64	3.0.101-0.15.1.6651.0.PTF-default (x86_64)
Language	English	English
RAID controller		
Vendor and model number	Dell PERC H710P Mini	Dell PERC H730P Mini
Firmware version	21.3.0-0009	25.2.1.0037
Cache size (GB)	1	2
RAID configuration	1 x RAID50	1 x RAID1
Hard disk types		
Hard disks (OS)		
Vendor and model number	Dell ST9146852SS	Dell ST300MM0006
Number of disks	16	2
Size (GB)	146	300
RPM	15K	10K
Type	SAS	SAS
PCIe SSDs		
Vendor and model number	N/A	Fusion ioMemory SX300
Number of disks	N/A	4
Size (GB)	N/A	6,400
Type	N/A	PCIe
Ethernet adapters		
Vendor and model number	Intel I350 Quad-port 1GbE	Broadcom® NetXtreme® BCM5720 Quad-port 1 GbE
Firmware	14.5.9	7.10.18
Type	rNDC	rNDC
Fibre Channel adapters		
Vendor and model number	QLogic® QLE2672 16Gb Fibre Channel Adapter	QLogic QLE2672 16Gb Fibre Channel adapter
Firmware	03.11.09	03.11.09
Type	PCIe	PCIe
USB ports		
Number	4	4
Type	USB 2.0	USB 2.0

Figure 4: Detailed information for the test storage.

Figure 5 shows the configuration information for the IBM FlashSystem 900 appliance.

Storage array	IBM FlashSystem 900
Firmware revision	1.2.0.11
Disks – PCIe SSDs	
Number of disks	6
Disk vendor and model number	IBM MicroLatency Module
Disk size	1.2 TB

Figure 5: Detailed information for the test storage.

APPENDIX C – SETTING UP THE STORAGE

Dell Acceleration Appliance for Databases solution

For the Dell solution, we replaced the IBM FlashSystem 900 with the highly available Dell Acceleration Appliance for Databases, storing our data, logs, and backups on LUNs created on the DAAD. For our storage area network (SAN), we attached the R720's 16Gb Fibre Channel HBA as well as the DAAD's 16Gb Fibre Channel HBAs to a Brocade SW6505 Fibre Channel switch.

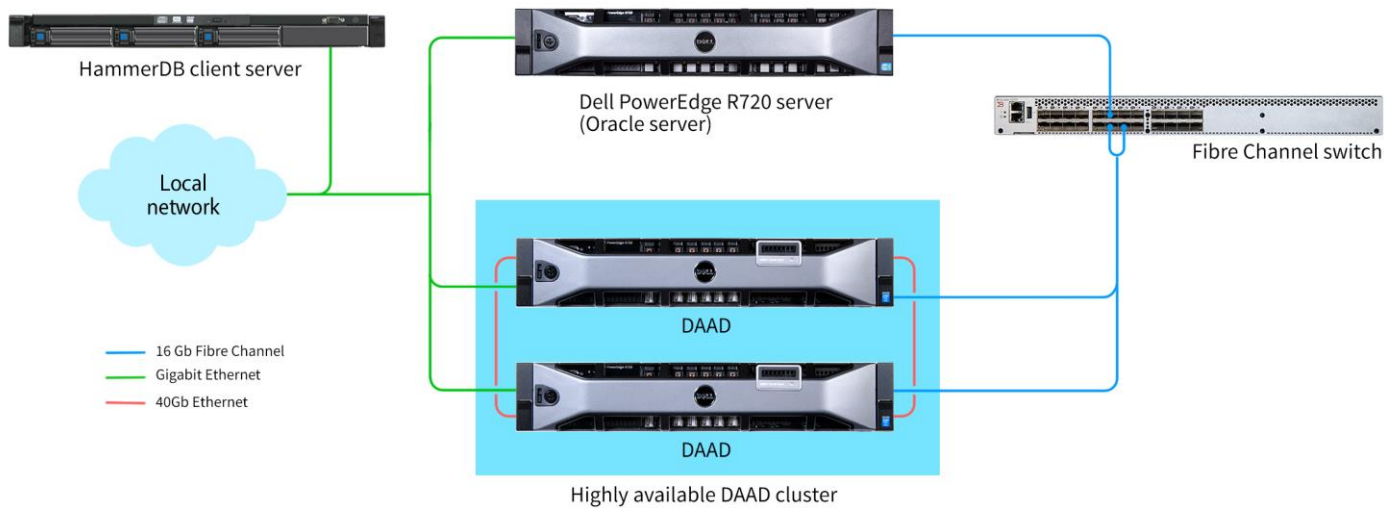


Figure 6: The highly available DAAD configuration we tested.

IBM FlashSystem 900 solution

For the IBM solution, we configured a Dell PowerEdge R720 server with Red Hat Enterprise Linux 6.6. We then configured a standalone Oracle Database 12c Enterprise Edition installation with a 5,000-warehouse database. We used Oracle Automatic Storage Management (ASM), storing our data, logs, and backups on LUNs created on the IBM FlashSystem 900. For our storage area network (SAN), we attached the R720's 16Gb Fibre Channel HBA as well as the IBM FlashSystem 900's 16Gb Fibre Channel HBAs to a Brocade SW6505 Fibre Channel switch.

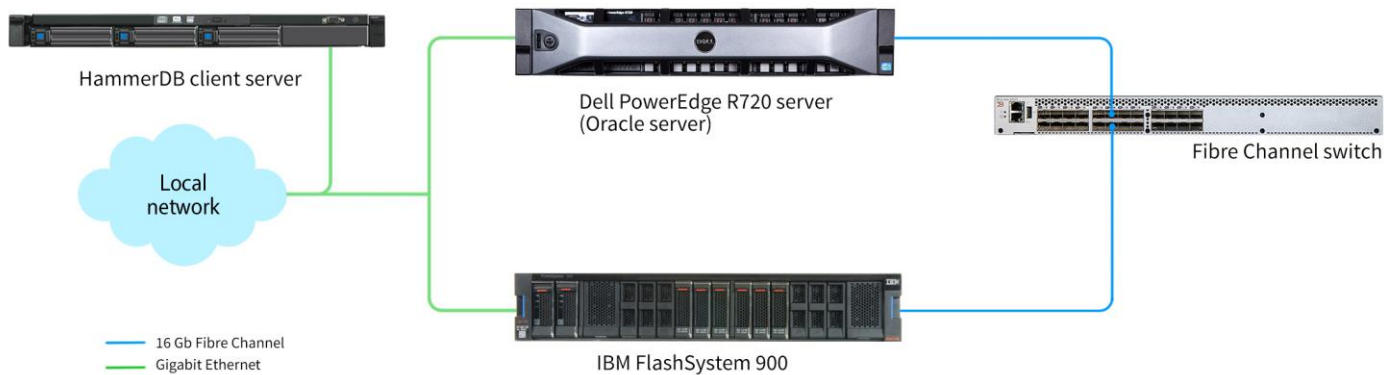


Figure 7: The IBM FlashSystem 900 configuration we tested.

Setting up storage on the DAAD

1. In a terminal, ssh into one of the DAAD nodes with the admin credentials.
2. Enter the following commands to create mirrored volumes across the DAAD nodes, an initiator group, and then eight LUNs to be presented to the database server.

```
profile:create direct
volume:create -n ion01 -n ion02 fcion_v_a1 50% jbod_pool-1
volume:create -n ion02 -n ion01 fcion_v_a2 100% jbod_pool-1
volume:create -n ion01 -n ion02 fcion_v_b1 50% jbod_pool-2
volume:create -n ion02 -n ion01 fcion_v_b2 100% jbod_pool-2
volume:create -n ion01 -n ion02 fcion_v_c1 50% jbod_pool-3
volume:create -n ion02 -n ion01 fcion_v_c2 100% jbod_pool-3
volume:create -n ion01 -n ion02 fcion_v_d1 50% jbod_pool-4
volume:create -n ion02 -n ion01 fcion_v_d2 100% jbod_pool-4
inigroup:create ig_all 20:01:00:0e:1e:09:d6:1c 20:01:00:0e:1e:09:d6:1d
lun:create fcion_v_a1 ig_all -b 512 -a
lun:create fcion_v_a2 ig_all -b 512 -a
lun:create fcion_v_b1 ig_all -b 512 -a
lun:create fcion_v_b2 ig_all -b 512 -a
lun:create fcion_v_c1 ig_all -b 512 -a
lun:create fcion_v_c2 ig_all -b 512 -a
lun:create fcion_v_d1 ig_all -b 512 -a
lun:create fcion_v_d2 ig_all -b 512 -a
```

Setting up storage on the IBM FlashSystem 900

We performed the initial setup steps provided with the system documentation to connect it to our network.

1. Navigate to the IBM FlashSystem 900's IP address in a browser, and log in with administrator credentials.
2. In the left dock, hover over the Volumes icon, and click Volumes.
3. Click Create Volumes.
4. Provide a name, size, and number of volumes.
5. We created two 1000 GB volumes named `backup`, four 300 GB volumes named `data`, and four 100 GB volumes named `logs`.
6. In the left dock, hover over the Hosts icon, and click Hosts.
7. Click Add Host.
8. Enter a name for the host. We used `OracleR720`.
9. Click the drop-down menu next to Host port (WWPN), and select one of the ports.
10. Click the + button, and do the same with the other port.
11. Click Add.
12. In the left dock, hover over the Hosts icon, and select Volumes by Host.
13. Select all of the volumes in the Unmapped Volumes list, right-click them, and select Map to Host.
14. Make sure the desired host is selected, and click Map.

Configuring Red Hat Enterprise Linux and Oracle Database 12c

We installed Red Hat Enterprise Linux on the Dell PowerEdge R720 server and configured settings as we specify below. Screen outputs are in grey boxes.

Installing Red Hat Enterprise Linux

1. Insert the Red Hat Enterprise Linux 6.6 DVD into the server and boot to it.
2. Select Install or upgrade an existing system.
3. If you are unsure of the fidelity of your installation disk, select OK to test the installation media; otherwise, select Skip.
4. In the opening splash screen, select Next.
5. Choose the language you wish to use, and click Next.
6. Select the keyboard layout, and click Next.
7. Select Basic Storage Devices, and click Next.
8. Click Yes, discard any data at the Storage Device Warning.
9. Insert your hostname, and click Next.
10. Select the nearest city in your time zone, and click Next.
11. Enter your root password, and click Next.
12. Select Create Custom Layout, and click Next.
13. Select the install drive and click Create. (Create the following volumes and size: Root = 300GB, Home = 500GB, Boot = 200MB, SWAP = 20GB)
14. Click Next.
15. Click Write changes to disk.
16. Select the appropriate Data Store Devices and select where the Bootloader will go, and click Next.
17. Select Software Basic Server, and click Next. Linux installation begins.
18. When the installation completes, select Reboot to restart the server.

Performing initial configuration tasks

Complete the following steps to provide the base functionality that Oracle Database requires. We performed all of these tasks as `root`.

1. Disable SELINUX.

```
vi /etc/selinux/config
SELINUX=disabled
```
2. Set CPU Governor type.

```
vi /etc/sysconfig/cpuspeed
GOVERNOR=performance
```
3. Disable the firewall for IPv4 and IPv6.

```
chkconfig iptables off
chkconfig ip6tables off
```
4. To update the operating system packages, type the following:

```
yum update -y
```
5. To install additional packages, type the following commands:

```
yum install -y acpid cpuspeed wget vim nfs-utils openssh-clients man  
lsscsi unzip smartmontools numactl ipmitool OpenIPMI
```

6. Reboot the server.

```
reboot
```

7. Install additional packages with the following commands:

```
yum install -y \  
binutils \  
compat-libcap1 \  
compat-libstdc++-33 \  
compat-libstdc++-33.i686 \  
device-mapper-multipath \  
gcc \  
gcc-c++ \  
glibc \  
glibc.i686 \  
glibc-devel \  
glibc-devel.i686 \  
ksh \  
libgcc \  
libgcc.i686 \  
libstdc++ \  
libstdc++.i686 \  
libstdc++-devel \  
libstdc++-devel.i686 \  
libaio \  
libaio.i686 \  
libaio-devel \  
libaio-devel.i686 \  
libXext \  
libXext.i686 \  
libXtst \  
libXtst.i686 \  
libX11 \  
libX11.i686 \  
libXau \  
libXau.i686 \  
libxcb \  
libxcb.i686 \  
libXi \  
libXi.i686 \  
make \  

```

```
sysstat \  
unixODBC \  
unixODBC-devel \  
xorg-x11-xauth \  
xorg-x11-utils
```

8. Edit the sysctl file.

```
vim /etc/sysctl.conf  
fs.file-max = 6815744  
kernel.sem = 250 32000 100 128  
kernel.shmmni = 4096  
kernel.shmall = 1073741824  
kernel.shmmax = 4398046511104  
net.core.rmem_default = 262144  
net.core.rmem_max = 4194304  
net.core.wmem_default = 262144  
net.core.wmem_max = 1048576  
fs.aio-max-nr = 1048576  
net.ipv4.ip_local_port_range = 9000 65500  
vm.nr_hugepages = 52248  
vm.hugetlb_shm_group = 54321
```

9. Apply the changes with the following command:

```
sysctl -p
```

10. Edit the security limits configuration.

```
vim /etc/security/limits.conf  
oracle soft nofile 1024  
oracle hard nofile 65536  
oracle soft nproc 2047  
oracle hard nproc 16384  
oracle soft stack 10240  
oracle hard stack 32768  
grid - nofile 65536  
grid - nproc 16384  
grid - stack 32768  
oracle soft memlock 536870912  
oracle hard memlock 536870912
```

11. Add the necessary groups and users.

```
groupadd -g 1001 oinstall  
groupadd -g 1002 dba  
groupadd -g 1003 asmadmin  
groupadd -g 1004 asmdba  
useradd -m -u 1002 -g oinstall -G dba,asmadmin,asmdba oracle  
useradd -m -u 1003 -g oinstall -G dba,asmadmin,asmdba grid
```

12. Add the following lines to the .bash_profile file for the oracle user:

```
export TMP=/tmp  
export TMPDIR=$TMP  
export ORACLE_HOSTNAME=hostname  
export ORACLE_UNQNAME=ORCL
```

```

export ORACLE_BASE=/u01/app/oracle
export GRID_HOME=/u01/app/12.1.0/grid
export DB_HOME=$ORACLE_BASE/product/12.1.0/dbhome_1
export ORACLE_HOME=$DB_HOME
export ORACLE_SID=orcl
export ORACLE_TERM=xterm
export BASE_PATH=/usr/sbin:$PATH
export PATH=$ORACLE_HOME/bin:$BASE_PATH
export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib

```

13. Add the following lines to the `.bash_profile` file for the `grid` user:

```

export TMP=/tmp
export TMPDIR=$TMP
export ORACLE_HOSTNAME=hostname
export ORACLE_BASE=/u01/app/grid
export GRID_HOME=/u01/app/12.1.0/grid
export ORACLE_HOME=$GRID_HOME
export ORACLE_SID=+ASM1
export ORACLE_TERM=xterm
export BASE_PATH=/usr/sbin:$PATH
export PATH=$ORACLE_HOME/bin:$BASE_PATH
export LD_LIBRARY_PATH=$ORACLE_HOME/lib:/lib:/usr/lib
export CLASSPATH=$ORACLE_HOME/JRE:$ORACLE_HOME/jlib:$ORACLE_HOME/rdbms/jlib

```

14. Create the following directories, and assign the following permissions.

```

mkdir -p /u01/app/oracle
mkdir /u01/app/grid
chown -R oracle:oinstall /u01/app
chmod -R g+w /u01/app

```

15. Create passwords for the `oracle` and `grid` accounts with `passwd`.

16. Edit the `hosts` file.

```

vim /etc/hosts

127.0.0.1          R720 R720.localhost.localdomain localhost
localhost.localdomain localhost4 localhost4.localdomain4
::1              R720 R720.localhost.localdomain localhost
localhost.localdomain localhost6 localhost6.localdomain6

```

17. Edit the `/etc/fstab` file.

```
vim /etc/fstab
```

Adding this line:

```
tmpfs /dev/shm tmpfs defaults,size=89G 0 0
```

18. Edit the `90-nproc.conf` file.

```
vim /etc/security/limits.d/90-nproc.conf
```

Modifying this line:

```
* soft nproc 1024
```

To reflect this change:

```
* - nproc 16384
```

19. Download IONTuner from Fusion-IO and install with `rpm -i iontuner_1.1.0_1.el6.noarch.rpm`. This is available to download from www.fusionio.com/files/ion-optimization-scripts.

20. Edit the `/boot/grub/menu.lst` file:

```
vim /boot/grub/menu.lst
```

Append this to the kernel line:

```
intel_idle.max_cstate=0 processor.max_cstate=0
```

21. Enable the multipath configuration file and start the multipath daemon:

```
mpathconf --enable --with_multipathd y.
```

22. For the DAAD configurations, edit `/etc/multipath.conf` to add the following:

```
vim /etc/multipath.conf
defaults {
    user_friendly_names    yes
    queue_without_daemon  no
}
devices {
    device {
        vendor                "FUSIONIO"
        features                " 3 queue_if_no_path pg_init_retries 50"
        hardware_handler      "1 alua"
        path_grouping_policy   group_by_prio
        path_selector          "queue-length 0"
        failback               immediate
        path_checker           tur
        prio                   alua

        fast_io_fail_tmo      15
        dev_loss_tmo          60
    }
    device {
        vendor                "IBM"
        product                "FlashSystem-9840"
        path_selector          "round-robin 0"
        path_grouping_policy   multibus
        path_checker           tur
        rr_min_io_rq           4
        rr_weight              uniform
        no_path_retry          fail
        dev_loss_tmo          300
        fast_io_fail_tmo      25
    }
}
```

23. Perform a Loop Initialization Protocol and rescan the Fibre Channel interconnects with `echo "1" >`

`/sys/class/fc_host/hostX/issue_lip`, replacing X with each of the hosts being used on the system.

24. Restart the multipath service with `service multipathd restart`.

25. Verify that multipath is working with `multipath -ll`.

26. Create a primary partition with the `fdisk` utility on each multipath disk with the following:
 - a. `fdisk /dev/mapper/mpathX`, where X is the identifier of the disk in question.
 - b. `n`
 - c. `p`
 - d. `1`
 - e. `1`
 - f. Press Enter.
 - g. `w`
27. Reboot the server to make the kernel use the new table.
28. Edit the `scsi_id` file.


```
echo "options=-g" > /etc/scsi_id.config
```

Presenting DAAD and IBM LUNs to Oracle ASM

We used the steps below to configure the multipathed storage LUNs prior to setting up ASM.

1. Edit the `99-oracle-asmdevices` rules file.

```
vim /etc/udev/rules.d/99-oracle-asmdevices.rules
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-26230373534643030",
SYMLINK+="oracleasm/DAADdata1", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-26565316265346439",
SYMLINK+="oracleasm/DAADdata2", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-23261306136633365",
SYMLINK+="oracleasm/DAADdata3", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-23436316433663237",
SYMLINK+="oracleasm/DAADdata4", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-26235623336316364",
SYMLINK+="oracleasm/DAADdata5", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-26364393665633631",
SYMLINK+="oracleasm/DAADdata6", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-26539376463663337",
SYMLINK+="oracleasm/DAADlogs1", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-23736666233353565",
SYMLINK+="oracleasm/DAADlogs2", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6937",
SYMLINK+="oracleasm/IBMdata1", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6939",
SYMLINK+="oracleasm/IBMdata2", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6941",
SYMLINK+="oracleasm/IBMdata3", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6943",
SYMLINK+="oracleasm/IBMdata4", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6945",
SYMLINK+="oracleasm/IBMlogs1", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6947",
SYMLINK+="oracleasm/IBMlogs2", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e6949",
SYMLINK+="oracleasm/IBMlogs3", OWNER="oracle", GROUP="dba", MODE="0660"
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e694b",
SYMLINK+="oracleasm/IBMlogs4", OWNER="oracle", GROUP="dba", MODE="0660"
```



```
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e694d",  
SYMLINK+="oracleasm/IBMbackup1", OWNER="oracle", GROUP="dba", MODE="0660"  
KERNEL=="dm-*", ENV{DM_UUID}=="mpath-360a980004431455a345d4733696e694f",  
SYMLINK+="oracleasm/IBMbackup2", OWNER="oracle", GROUP="dba", MODE="0660"
```

2. Execute `udevadm` and start `udev`.
`udevadm control --reload-rules`
`start_udev`

3. List the ASM devices.
`ls -l /dev/oracleasm/`

```
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADdata1 -> ../dm-13  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADdata2 -> ../dm-19  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADdata3 -> ../dm-14  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADdata4 -> ../dm-20  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADdata5 -> ../dm-15  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADdata6 -> ../dm-21  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADlogs1 -> ../dm-16  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 DAADlogs2 -> ../dm-22  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 IBMbackup1 -> ../dm-10  
lrwxrwxrwx 1 root root 8 Mar 20 11:29 IBMbackup2 -> ../dm-11  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMdata1 -> ../dm-3  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMdata2 -> ../dm-4  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMdata3 -> ../dm-2  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMdata4 -> ../dm-5  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMlogs1 -> ../dm-7  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMlogs2 -> ../dm-6  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMlogs3 -> ../dm-8  
lrwxrwxrwx 1 root root 7 Mar 20 11:29 IBMlogs4 -> ../dm-9
```

Installing Oracle Grid Infrastructure for Standalone Server 12c

Prior to starting the steps below, we downloaded the Oracle 12c Grid installation and extracted it to the `/grid` directory.

1. Run the GUI installer for Oracle Database using the following commands:
`ssh -Y grid@R720_IP_address`
`cd /grid`
`./runInstaller`
2. Launch the Oracle Grid Infrastructure installation wizard.
3. In Software Updates, select Skip software updates, and click Next.
4. In Installation Options, select Install and Configure Oracle Grid Infrastructure for a Standalone Server, and click Next.
5. In Product Languages, select English and click the right-pointing arrow between the two selection panels to add English to the Selected languages panel. Click Next.
6. In Create ASM Disk Group, set the Disk group name to DATA.
7. Click Change Discovery Path.
8. Enter `/dev/oracleasm` for the Disk Discovery Path, and click OK.
9. Check the boxes for the appropriate data disks, and Click Next.
 - a. For the DAAD-only configuration, select only the DAADs' data disks.

- b. For the IBM-only configuration, select only the IBM's data disks.
10. In ASM Password, select Use same passwords for these accounts. Enter and confirm the password, and click Next.
11. In Operating System Groups, set Oracle ASM Administrator Group to asmadmin, and Oracle ASM DBA Group to asmdba, and click Next.
12. In Installation Location, accept the default locations provided, and click Next.
13. In Create Inventory, accept the defaults, and click Next.
14. In Root Script Execution, check the box for Automatically run configuration scripts.
15. Select Use "root" user credential, and provide the root password. Click Next.
16. In Summary, review the information, and click Install to begin installation.
17. Click Yes to confirm using the privileged user for the installer.
18. In Finish, click Close to exit the installer.

Installing Oracle Database 12c

Prior to starting the steps below, we downloaded the Oracle Database 12c installation and extracted it to the /database directory.

1. Run the GUI installer for Oracle Database using the following commands:

```
ssh -Y oracle@R720_IP_address
cd /database
./runInstaller
```
2. Launch the Oracle Database 12c Release 1 Installer.
3. In Configure Security Updates, uncheck the I wish to receive security updates via My Oracle Support checkbox. Click Next.
4. Click Yes to confirm no email provided, and continue.
5. In Software Updates, select Skip software updates, and click Next.
6. In Installation Options, select Install database software only, and click Next.
7. In Grid Installation Options, select Single instance database installation, and click Next.
8. In Product Languages, select English and click the right-pointing arrow located between the two selection panels to add English to the Selected languages panel. Click Next.
9. In Database Edition, select Enterprise Edition, and click Next.
10. In Installation Location, accept the default locations provided, and click Next.
11. In Operating System Groups, accept the defaults, and click Next.
12. In Summary, review the information, and click Install to begin installation.
13. When prompted, follow the instructions to execute the scripts. Click OK when the scripts have completed.
14. In Finish, click Close to exit the installer.

Creating Oracle ASM disk groups for the database

1. Log into the system as the grid user.
2. Start the ASM configuration assistant, asmca.
3. On the Disk Groups tab, click Create.
4. On the Create Disk Group pop-up screen, enter LOGS for the Disk Group Name.

5. Select External (None) for Redundancy.
6. Select /dev/oracleasm/ for the Disk Path.
7. Select the two logs disks.
 - a. To start with the DAAD-only configuration, select only the DAADs' logs disks.
 - b. When switching to another configuration later, launch asmca again, and perform the Drop Disks and Add Disks operations as necessary to achieve the correct arrangements,
 - i. For the IBM configuration, the DATA disk group should contain the IBM data disks, the LOGS disk group should contain the IBM logs disks, and the BACKUP disk group should contain the IBM backup disks.
 - ii. For the DAAD configuration, the DATA disk group should contain six of the DAAD disks, the LOGS disk group should contain other two DAAD disks, and the BACKUP disk group should still contain the IBM backup disks.
8. Click OK to create the LOGS disk group, and click OK on the completed-task pop-up screen
9. Repeat steps 4 through 9 to create a BACKUP disk group with the IBM backup disks.
10. Click Exit to close the ASM configuration assistant.

Creating the Oracle Database (using DBCA)

1. Log into the system as the Oracle user.
2. Launch the Database Configuration Assistant (DBCA).
3. In Database Operations, select Create Database, and click Next.
4. In Creation Mode, select Advanced Mode, and click Next.
5. In Database Template, select the Template for General Purpose or Transaction Processing, and click Next.
6. If prompted about continuing without upgrade, click Yes.
7. In Database Identification, type `orcl` for the Global Database Name.
8. Type `orcl` for the SID. Click Next.
9. In Management Options, select Configure Enterprise Manager (EM) Database Express. Click Next.
10. In Database Credentials, select Use the Same Administrative Password for All Accounts.
11. Enter and confirm the administrative password, and click Next.
12. In Network Configuration, check the boxes for all listeners, and click Next.
13. In Storage Locations, select ASM for Database Storage Type.
14. Select User Common Location for All Database Files, and type `+DATA` into the Database Files Location field.
15. Select ASM for Recovery files Storage Type.
16. Specify Fast Recovery Area. Type `+BACKUP` in the Fast Recovery Area field.
17. Set the Fast Recovery Area size to 1850 GB, and click Next.
18. In Database Options, accept the defaults, and click Next.
19. In Initialization Parameters and under typical settings, set the Memory Size to 40%, and click next.
20. In Creation Options, select Create Database.
21. Click Next.
22. Review the Summary. To complete the database creation, click Finish.

23. Review the information on the screen, and click Exit.

24. To exit the DBCA, click Close.

Configuring the Oracle Tablespace and redo logs

Alter the tablespace and redo logs as follows:

```
ALTER DATABASE ADD LOGFILE GROUP 4 ( '/tmp/temp1.log' ) SIZE 50M;
ALTER DATABASE ADD LOGFILE GROUP 5 ( '/tmp/temp2.log' ) SIZE 50M;

ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM CHECKPOINT;

ALTER DATABASE DROP LOGFILE GROUP 1;
ALTER DATABASE DROP LOGFILE GROUP 2;
ALTER DATABASE DROP LOGFILE GROUP 3;

ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM CHECKPOINT;

ALTER DATABASE DROP LOGFILE GROUP 1;
ALTER DATABASE DROP LOGFILE GROUP 2;
ALTER DATABASE DROP LOGFILE GROUP 3;

-- DELETE LOGS IN ASM HERE --

ALTER DATABASE ADD LOGFILE GROUP 1 ( '+LOGS/ORCL/ONLINELOG/redo01.log' ) SIZE
20G;
ALTER DATABASE ADD LOGFILE GROUP 2 ( '+LOGS/ORCL/ONLINELOG/redo02.log' ) SIZE
20G;
ALTER DATABASE ADD LOGFILE GROUP 3 ( '+LOGS/ORCL/ONLINELOG/redo03.log' ) SIZE
20G;

ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM CHECKPOINT;

ALTER DATABASE DROP LOGFILE GROUP 4;
ALTER DATABASE DROP LOGFILE GROUP 5;

ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM SWITCH LOGFILE;
ALTER SYSTEM CHECKPOINT;

ALTER DATABASE DROP LOGFILE GROUP 4;
ALTER DATABASE DROP LOGFILE GROUP 5;

HOST rm -f /tmp/temp*.log

CREATE BIGFILE TABLESPACE "TPCC"
```

```
DATAFILE '+DATA/orcl/tpcc.dbf' SIZE 400G AUTOEXTEND ON NEXT 1G
BLOCKSIZE 8K
EXTENT MANAGEMENT LOCAL AUTOALLOCATE
SEGMENT SPACE MANAGEMENT AUTO;
```

```
CREATE BIGFILE TABLESPACE "TPCC_OL"
DATAFILE '+DATA/orcl/tpcc_ol.dbf' SIZE 150G AUTOEXTEND ON NEXT 1G
BLOCKSIZE 16K
EXTENT MANAGEMENT LOCAL AUTOALLOCATE
SEGMENT SPACE MANAGEMENT AUTO;
```

```
ALTER DATABASE DATAFILE '+DATA/ORCL/DATAFILE/UNDOTBS1.260.873465895' RESIZE
32760M;
```

Configuring the Oracle pfile

Alter the Oracle pfile as follows:

```
orcl.__oracle_base='/u01/app/oracle'#ORACLE_BASE set from environment
_enable_NUMA_support=TRUE
_kgl_hot_object_copies=2
_shared_io_pool_size=512m
audit_file_dest='/u01/app/oracle/admin/orcl/adump'
audit_trail='NONE'
compatible='12.1.0.2.0'
control_files='+DATA/ORCL/CONTROLFILE/current.261.873465981','+BACKUP/ORCL/CONTROLFILE/current.256.873465981'#Restore Controlfile
db_16k_cache_size=16g
db_block_size=8192
db_cache_size=64g
db_create_file_dest='+DATA'
db_domain=''
db_name='orcl'
db_recovery_file_dest_size=1850g
db_recovery_file_dest='+BACKUP'
diagnostic_dest='/u01/app/oracle'
disk_asynch_io=TRUE
dispatchers='(PROTOCOL=TCP) (SERVICE=orclXDB)'
dml_locks=500
fast_start_mttr_target=300
java_pool_size=4g
job_queue_processes=0
large_pool_size=1g
local_listener='LISTENER_ORCL'
lock_sga=TRUE
log_buffer=536870912#log buffer update
log_checkpoint_interval=0
log_checkpoint_timeout=0
log_checkpoints_to_alert=TRUE
open_cursors=3000
parallel_max_servers=0
pga_aggregate_target=6g
recovery_parallelism=4
```

```
remote_login_passwordfile='EXCLUSIVE'  
resource_manager_plan='FORCE'  
shared_pool_size=3g  
undo_management='AUTO'  
undo_retention=1  
undo_tablespace='UNDOTBS1'  
use_large_pages='ONLY'
```

Setting up the HammerDB client

We used a dual-socket server running Red Hat Enterprise Linux 6.6 for the HammerDB client. We followed the installation steps at the beginning of this appendix to install Red Hat Enterprise Linux, and also installed the GUI. We then installed the HammerDB client software.

Installing HammerDB

Download and install version 2.16 on the Red Hat client. We downloaded HammerDB from the following location: hammerora.sourceforge.net/download.html. We installed HammerDB according to the installation guide (hammerora.sourceforge.net/hammerdb_install_guide.pdf).

Installing HammerDB Oracle libraries

Complete the following steps on the application server.

1. Launch the Oracle Client Installer.
2. In Select Installation Type, select Administrator (1.8 GB) as the installation type, and click Next.
3. In Software Updates, select Skip software updates, and click Next.
4. In Select Product Languages, select English and click the right-pointing arrow located between the two selection panels to add English to the Selected languages panel. Click Next.
5. In Specify Installation Location, accept the default locations provided, and click Next.
6. In Create Inventory, accept the defaults, and click Next.
7. In Summary, review the information, and click Install to begin installation.
8. In Install Product, follow the instructions to execute the scripts. Click OK when the scripts have completed.
9. In Finish, click Close to exit the installer.

Configuring the database

We used the TPC-C build schema build options for Oracle inside HammerDB to build the database. We set the following options in the build schema.

```
Oracle Service Name = R720_IP_address/orcl  
System User = SYSTEM  
System User Password = Password1  
TPC-C User = tpcc  
TPC-C User Password = tpcc  
TPC-C Default Tablespace = tpcc  
Order Line Tablespace = tpcc_ol  
TPC-C Temporary Tablespace = temp  
TimesTen Database Compatible = unchecked  
Partition Order Line Table = checked  
Number of Warehouses = 5000  
Virtual Users to Build Schema = 20
```

```
Use PL/SQL Server Side Load = unchecked  
Server Side Log Directory = /tmp
```

Running HammerDB

We ran HammerDB by filling in the appropriate information for the driver options. We tested with 10,000,000 transactions per user, a 20-minute ramp up time and 20-minute test duration. We used 101 virtual users with 0-ms user delay and repeat delay. We used rman to back up the database before testing, and we ran restores between runs.

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