Running Business-Critical Applications on Oracle RAC, VMware and NetApp

Lessons Learned from Green Mountain Power

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Introduction

There is a wealth of published information that describes how and why to virtualize Oracle databases and Oracle applications with VMware and NetApp technologies (see "References" at the end of the document). This white paper complements those documents by examining a recent deployment at Green Mountain Power. This real-world case study both validates the value of VMware and NetApp as a platform for Oracle and yields important insights and lessons that can be applied to other customers. To set the context for this discussion, let's take a look at the Green Mountain installation.

Green Mountain Power Goes Virtual

One in four Vermont homes relies on Green Mountain Power for electric service—about 100,000 households in all. The hundred-year-old utility prides itself on its increasing use of renewable energy sources such as wind and solar and is investing heavily in Smart Grid, a cutting-edge technology that will improve reliability, boost efficiency, and provide customer with information about their own energy use. A regulated utility with 250 employees, Green Mountain recently acquired another Vermont utility—a move that tripled its customers and revenues.

Business Challenges

In developing its strategic plans for Smart Grid and other initiatives, Green Mountain assessed its IT infrastructure. Smart Grid will generate a large volume of data, which has to be both stored safely and reliably and processed rapidly and accurately to control power generation and distribution, drive billing and other business processes, and inform decision-making. While the existing IT platform was adequate for present needs, it would not be able to support Smart Grid and other initiatives in the utility's strategic plans. Add in the need to assimilate the IT infrastructure of a company larger than itself, and it was clear to Green Mountain's management that they needed to rethink their IT infrastructure. (For more details on the challenges facing Green Mountain, see "Reaching the Limits of the RISC Infrastructure.")

When the project started in late 2010, Green Mountain had an extensive deployment of business-critical applications and Oracle database software and a relatively lean support staff for the associated server and storage platform. To accommodate the massive increase in data, the utility wanted to scale out the database and platform while minimizing operating costs; therefore, improving the efficiency of the infrastructure was paramount. Green Mountain also planned to take other steps to cut expenses, for example, migrating from Unix to Linux and converting to NAS storage from their current SAN model.

There were additional challenges facing the utility. Provisioning new environments was a time-consuming, manual procedure that simply wasn't flexible enough to keep up with the growth in Green Mountain's business. The storage infrastructure needed to be upgraded to handle the anticipated flood of Smart Grid data. The utility also wanted to improve its business continuity plan, a smart thing to do in a place like Vermont where the weather can be harsh and unforgiving on people and equipment. Virtualization technology was the obvious approach to achieve these objectives—but which one?

REACHING THE LIMITS OF THE LEGACY RISC INFRASTRUCTURE

Green Mountain experienced a problem that is all too common for large organizations today, namely, reaching the limits of its legacy RISC infrastructure. This situation affected the utility in several key areas: business agility, staffing, and operating expenses.

Inflexible Legacy Infrastructure

The existing environment was inflexible from both a server and cabling perspective. While Green Mountain considered the possibility of upgrading the current platform or even migrating to another RISC platform, the IT group's analysis showed that these options would not reduce complexity or significantly reduce operating costs. At the same time, new demands such as Smart Grid and the growing number of users required greater scalability, more capacity, and better utilization—requirements that simply could not be met with a RISC infrastructure.

New demands and user growth leads to increased need for greater scalability, capacity and better utilization

Staffing Challenges

To meet the coming wave of IT challenges, Green Mountain's management wanted to hire additional technical staff. However, it became apparent that there was a mismatch between the available talent pool and the current needs. Today's graduates are trained primarily on x86 platforms running either Linux or Windows operating systems—few have extensive experience in RISC architectures or UNIX. The utility realized that staying with its legacy RISC/UNIX infrastructure would require substantial investment in training and an increased reliance on a shrinking pool of technical staff with RISC/UNIX backgrounds.

High Operating Costs

The current RISC infrastructure was becoming increasingly expensive to operate. Environmental costs for facilities, power, and cooling were high, as were support and maintenance costs. The complexity of the legacy environment drove up the cost of data center administration. Software licensing costs for RISC platforms were also rising. Taken together, these factors threatened to erode operating margins for years to come. The utility's management realized that it had reached the limits of the RISC/UNIX environment—to meet its strategic goals, the entire data center needed to be rearchitected.

The Right Solution: VMware Virtualization and NetApp Storage

Green Mountain Power had a good relationship with Oracle, in fact, the two companies issued a joint press release in early 2011 regarding Green Mountain's selection of the Oracle utility infrastructure software. Therefore, when the utility decided to virtualize, Oracle VM was a strong candidate. However, the choice of virtualization technology had massive implications well into the future, so Green Mountain Power needed to be sure before making a decision.

After a thorough analysis of the available solutions, the IT team selected VMware vSphere as the best choice for the Smart Grid and other initiatives planned for Green Mountain Power. The selection was contingent on VMware standing up to extensive performance testing with the Oracle Application Testing Suite.

Choosing a storage vendor was equally important. Green Mountain's research showed that most performance problems in virtualized environments occur at the storage tier. NetApp's unified storage architecture, reputation for performance and reliability, and the close integration of VMware and NetApp products and services led the utility to opt for NetApp as the storage supplier for the new infrastructure.

Fortunately, the IT group had the complete support of the utility's management, which approved a plan to virtualize their infrastructure with VMware vSphere and NetApp FAS3000 series storage. They set an ambitious target of moving from a largely physical environment to 100 percent virtualization: after eight months, the Green Mountain environment was 75 percent virtualized. Given the misconceptions in the marketplace about virtualizing Oracle, it was a bold decision, but the Green Mountain IT team had done its homework and was confident about their choice.

Deploying the Infrastructure with a Small Staff

When the project kicked off in early 2011, VMware and NetApp met with all the stakeholders at Green Mountain team in the project, including the virtual infrastructure administrators, storage administrators, DBAs, and the network team, to secure organizational buy-in. Two Green Mountain employees—a DBA and a VI administrator—were assigned to deploy the entire infrastructure. This lean staff was able to meet their deadlines by leveraging tools such as:

- vSphere host profiles: Brings up virtual machines in minutes instead of hours
- vSphere templates: Recipes that simplify the creation of multiple identical virtual machines
- vMotion: Migrates live databases between hosts
- NetApp SnapManager for Oracle: Manages backup, recovery, and cloning for Oracle databases and middleware
- NetApp SnapManager for Virtual Infrastructure: Manages backup and recovery of virtual machines
- NetApp SnapMirror: Replicates data between locations for disaster recovery

Migrating to the Virtual Platform

Once the platform was in place, the first task was to virtualize the Oracle database deployment—eight RAC databases each running two instances over Automatic Storage Management (ASM), an Oracle feature that simplifies the storage of database files. As the year went on, they migrated other Oracle applications including (see Figure 1):

- Oracle Utility Customer Care and Billing
- Oracle Meter Data Management
- Oracle Business Intelligence
- Oracle WebCenter Suite
- Oracle Fusion Middleware and Service Bus

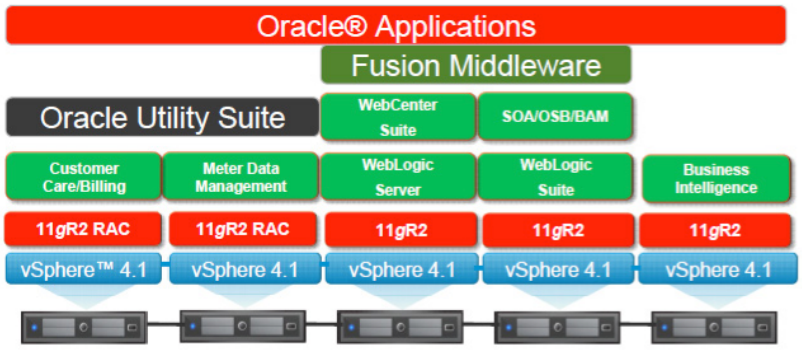

Figure 1. Oracle applications and databases run on a virtualized environment of vSphere software and NetApp storage systems.

As the Oracle databases and applications were virtualized, the IT team conducted user acceptance tests. The results were impressive: users didn't even realize that they were running on a different platform. These and other performance tests convinced Green Mountain that the VMware-NetApp environment could deliver the required performance and reliability.

Hurricane Irene: The Ultimate Test

In August 2011, while the virtualization project was in progress, Hurricane Irene slammed into the east coast of the United States, causing Vermont's worst flooding in 83 years. Nearly half of Green Mountain's customers—as many as 50,000—lost power, causing support call volumes to triple. The IT team had to ensure that business-critical services such as global information and outage management systems were available and performing well.

By design, the migration started with the most business-critical applications, consequently, all of them had been virtualized by the time the hurricane struck. The Green Mountain team decided to shut down some non-critical applications and move others to alternate hardware using vMotion, which provided additional computing power for applications that were vital to the emergency response. The strategy worked: storm managers reported that those programs performed well throughout the crisis and played a vital role in the fast restoration of power to Green Mountain's customers.

When the storm was over, the IT team had problems getting four physical hosts back in operation. They moved the affected virtual machines to other hosts—15 in all—repaired the affected servers, and then restored the virtual machines. Green Mountain Power service personnel continued to work and were completely unaware of the problem—no complaints were received. This event was a graphic illustration to Green Mountain of the value of its investment in a virtualized environment.

> *"Physical versus virtual servers? We recovered those 15 virtual servers in about two hours—impossible with physical systems."*
>
> Paula Fortin
> Senior Enterprise Systems Administrator

Seventy Percent Virtualized—and Counting

Having survived Hurricane Irene, Green Mountain is continuing with its aggressive move to a fully virtualized environment. As of May 2012, the utility is more than 70% virtualized (see Figure 2), with 36 host servers running more than 125 virtual machines.

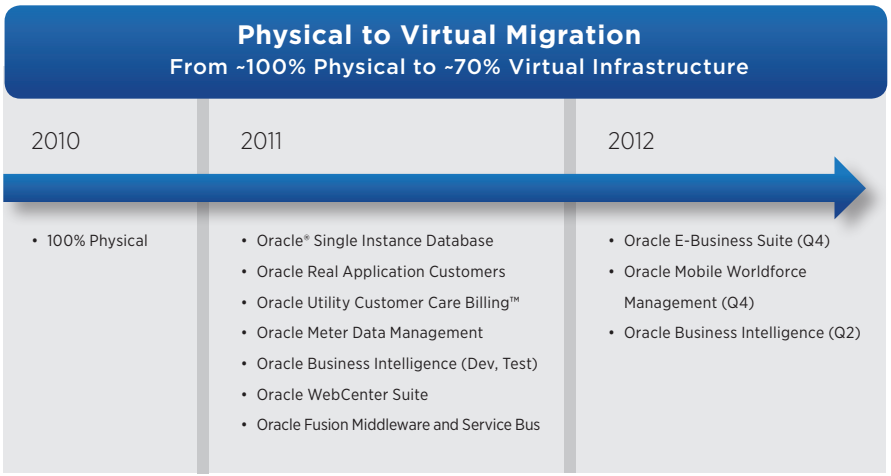

Figure 2. By the end of 2012, Green Mountain plans to have its entire Oracle environment running on a virtualized VMware-NetApp platform.

How Green Mountain Benefits

Green Mountain Power is well on the way to achieving its goals, from better agility and higher availability to more reliable disaster recovery. This section highlights some of the benefits that the utility has realized to date from its decision to move to a virtualized VMware-NetApp infrastructure.

Improved Agility and Higher Availability

VMware vCenter is the primary tool used to manage Green Mountain's infrastructure. Working together with NetApp Virtual Storage Console (VSC), which provides information on the storage subsystem, vCenter provides an integrated view of the infrastructure from server to storage. VMware vCenter allows Green Mountain's IT to configure, provision, and manage the lifecycle of virtual machines and storage, all from a single console.

"We are now much more agile, provisioning environments for our customers in minutes instead of hours. vMotion helps us manage the workload, and DRS balances resources and maintains our SLAs."

Nayab Saiyad
Senior Oracle Database Administrator

Because of the critical nature of the business, the utility must avoid downtime as much as possible. VMware vMotion gives Green Mountain a powerful tool for achieving that objective. Take server maintenance. Before the virtualization project, taking a physical server offline for repairs or routine maintenance also took down the application running on that server: in other words, application downtime was an unavoidable byproduct of server downtime.

Today, it's a different story. Applications run on virtual machines, which can easily be moved from one physical server to another, with no impact on users. Live migrations of Oracle databases—once impossible—are now routine. Application availability has improved dramatically, as demonstrated throughout Hurricane Irene. DBAs now have more time to spend on strategic tasks, thanks to vMotion (see Figure 3).

Faster Backups

Every DBA is familiar with using Oracle Recovery Manager (RMAN) for backing up and recovering Oracle databases. At Green Mountain, those tasks have been taken over by NetApp software. NetApp SnapManager for Oracle shortens the backup time from hours to minutes and also speeds restoring files (see Table 1). The NetApp Snapshot function provides an alternate method of quickly backing up the database as well as creating clones for development and testing.

Reducing the backup time increases application availability, because the performance of the Oracle database is compromised during the RMAN backup process. NetApp SnapManager for Virtual Infrastructure backs up individual virtual machines so that they can be quickly recovered as needed.

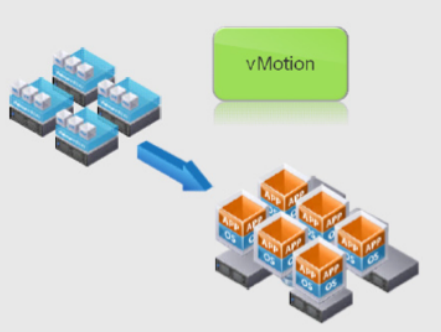

Figure 3. With vMotion, live Oracle database migrations facilitate routine maintenance and help increase availability.

Database Size = 8 TB, Schema = OAST

Schema = OAST	Backup Time (Full Database)	Restore & Recovery Time (two corrupt data files)
SnapManager for Oracle(SMO)	00:01:47	00:04:27
Oracle Recovery Manager(RMAN)	06:38:00	00:09:12
RMAN with Binary Compression	26:48:40	00:16:28

Table 1. Comparison of VMware versus Oracle Backup and Recovery Times

Enhanced Disaster Recovery

Green Mountain has upgraded its business continuity approach by installing SnapMirror, which replicates information from the main datacenter in Colchester to a disaster recovery site in Montpelier (see Figure 4). In the near future, the utility is planning to install VMware vCenter Site Recovery Manager to enable repeatable, reliable disaster recovery and streamline recovery operations in the event of a disruption.

The upgraded DR plan will function as follows: When Green Mountain initiates its disaster recovery plan, Site Recovery Manager suspends the SnapMirror replication between the two datacenters, connects the replicated data to hosts in the DR site, powers down non-critical virtual machines, and switches the utility's business-critical applications to Montpelier. Tight integration between VMware Site Recovery Manager and NetApp SnapMirror ensures a rapid switchover with minimal loss of information[1]. In addition, Site Recovery Manager and NetApp FlexClone will allow Green Mountain to test their DR plan with virtually no impact on the utility's ongoing operations.

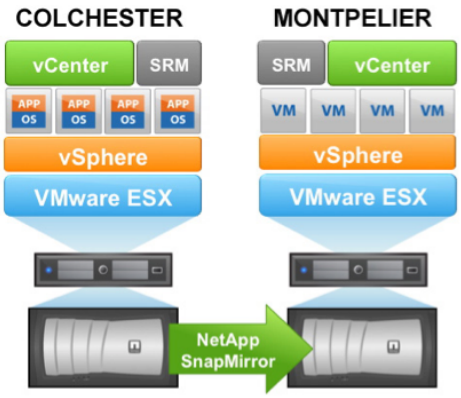

Figure 4. VMware vCenter Site Recovery Manager and NetApp SnapMirror work together to shorten the Recovery Time Objective (RTO) for disaster recovery.

Efficient Resource Allocation

Running quarterly reports and other compute-intensive tasks can create resource contention among the VMs hosting those applications. Another VMware feature, vSphere Distributed Resource Scheduler (DRS), automatically helps balance resource allocation within a cluster in response to unusually high needs for computing power. For example, DRS can limit the number of VMs on a particular host while it is running resource-heavy applications.

DRS can also be configured to automatically respond when VMs start to slow down as a result of resource limitations. It can migrate those VMs to other physical servers that have available headroom based on priorities set by the Green Mountain IT team. DRS ensures that capacity is preferentially dedicated to the highest-priority applications, while at the same time maximizing overall resource utilization.

Cost Savings through Consolidation and Deduplication

The new platform is saving Green Mountain money for Oracle licenses. For servers running Oracle databases and applications, Oracle requires that the entire machine be licensed, even if some cores are running non-Oracle software. Virtualization allowed Green Mountain to consolidate its Oracle workload onto fewer physical servers, cutting the utility's licensing expenses significantly.

NetApp deduplication technology has reduced Green Mountain's storage needs. The utility estimates savings of up to 60% on capital outlays for storage systems.

[1] NetApp Technical Report, "Deploying VMware vCenter Site Recovery Manager 4 with NetApp FAS/V-Series Storage Systems," February 2012.

Lessons Learned at Green Mountain

Green Mountain has been running the virtualized VMware environment since late 2011. The utility is recognizing the benefits of its investment in VMware and NetApp in a wide range of areas such as server and storage management, availability, resource utilization, cost savings, and—most importantly—business continuity, which was demonstrated in a big way by Hurricane Irene.

This section captures the most important lessons learned in the areas such as architecture, performance, support, licensing, and disaster recovery

1. Successful Virtualization Requires Executive Sponsorship.

Virtualizing the infrastructure is a decision that has profound strategic implications—and thus reaches the highest tiers of the organization. The level of resources and commitment that it takes to be successful can only be commanded from the executive suite. Green Mountain's management staff understood that, to achieve the company's ambitious goals, they would have to invest in a substantial transformation of the infrastructure. At the same time, they needed to be convinced that virtualization would accomplish those goals—and provide a reasonable return on investment.

VMware and NetApp worked closely with Green Mountain's executives and technical personnel to explain the benefits of virtualization—including expected capital and operational expense savings. Some executives questioned the level of Oracle support, but those concerns were quickly addressed (see "VMware, NetApp and Oracle Collaborate for Excellent Support" below.) By the time that Green Mountain's IT group submitted the formal request for funding, the executive staff was on board, and the project proceeded without delay.

2. Oracle RAC Offers Predictable Performance in a Virtualized Environment.

To solidify the decision to virtualize, Green Mountain had to be sure that the performance of their virtualized environment would meet their ambitious goals (see box "Performance In A Virtualized Environment: Predictability Is Key.").

When it came to relative performance, there was convincing published evidence: VMware's vSphere 4 internal testing[2] and an independent test commissioned by Intel Corporation in 2010[3].

Green Mountain's IT group relied on this and other publicly available information, but they also wanted to verify its performance in their own environment. The stakes were so high that Green Mountain developed a contingency plan to switch back to physical servers if they ran into substantial performance issues on the virtualized platform.

The contingency plan was never needed. In a series of performance tests using the Oracle Application Testing Suite, the VMware platform exceeded the utility's expectations. "We have used the Oracle testing suite to test each and every application," says Nayab Saiyad, senior DBA and architect for Green Mountain Power. "We had no complaints on performance."

As Nayab points out, the user experience is the acid test for performance when it comes to deploying virtualized databases in a production environment. The overhead that vSphere presents to the database and application users is insignificant, which was convincingly proved when the virtualized environment was switched over to the unit acceptance testers and production users. Neither group realized that the switch had taken place: in their eyes, the virtual environment performed just as well as the physical environment.

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[2] VMware Performance Study, "Virtualizing Performance-Critical Database Applications in VMware® vSphere™," 2009.

[3] Prowess Consulting performance test commissioned by Intel Corporation, "How mission-critical database workloads perform when virtualized with Intel® Xeon® processor 7500 series-based servers and VMware® vSphere™," May 2010.

PERFORMANCE IN A VIRTUALIZED ENVIRONMENT: PREDICTABILITY IS KEY

When switching a database environment from a physical to a virtualized environment, performance is always a concern. But there are several ways to look at performance:

- Absolute performance: Measured under ideal conditions, absolute performance is the least relevant metric for most deployments.
- Relative performance: Comparing the performance of the virtual environment to the legacy physical environment, this metric can be helpful in validating the decision to virtualize and in sizing the physical environment to support the virtual workload.
- Real-world performance: Measured under actual operating conditions, this metric is usually the best determinant of how well the virtualized environment will satisfy the needs of users in their day-to-day work. The more predictable the real-world performance under the full range of workloads, the higher the level of user satisfaction and productivity.

3. VMware, NetApp and Oracle Collaborate for Excellent Support

Before committing to virtualizing its Oracle environment, Green Mountain wanted to be sure that they would receive technical support from all parties. The VMware and NetApp sales teams addressed this issue with the facts:

- Both Oracle[4] and VMware[5] are on record as providing support for Oracle databases and Oracle RAC on vSphere.
- NetApp, VMware[6] and Oracle have a collaborative support agreement that uses the TSANet[7] infrastructure to facilitate cross-vendor problem resolution.

Green Mountain's experience with Oracle support has lived up to those promises and more. "We have 30 or 40 SRs [service requests] open," says Nayab Saiyad, senior DBA and architect. "We've never been denied any support from Oracle since we've been virtualized."

TSANet streamlines the Oracle support process because anyone involved—Green Mountain, VMware, NetApp, or Oracle—can request escalation for an existing SR. From that point, the three vendors work out a joint response without any further involvement from Green Mountain with no fingerpointing—just fast and effective resolution of problems.

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[4] Oracle Support, "Support Position for Oracle Products Running on VMware Virtualized Environments," Metalink article 249212.1.

[5] VMware Blog, "Yes, Oracle is supported on VMware," 04/04/11, http://blogs.vmware.com/apps/2011/04/yes-oracle-is-supported-on-vmware-.html.

[6] VMware Support, "Oracle Support Policy," http://www.vmware.com/support/policies/oracle-support.html.

4. Careful Architectural Planning Minimizes Oracle Licensing Costs.[8]

To run Oracle database or middleware software, Oracles require that the entire physical server must be licensed, even if only some of the cores are used for the Oracle database or application. Once the physical server is licensed, however, all virtual servers on that host can run the Oracle software for no extra expense.

Green Mountain leveraged these concepts to reduce their Oracle licensing expenses. They used Host Affinity—a feature of vSphere Distributed Resource Scheduler—to restrict the virtual machines running Oracle applications and databases to a small number of physical hosts. In effect, Host Affinity created a logical cluster of Oracle applications. Only the servers hosting the logical cluster required Oracle licenses (see Figure 5).

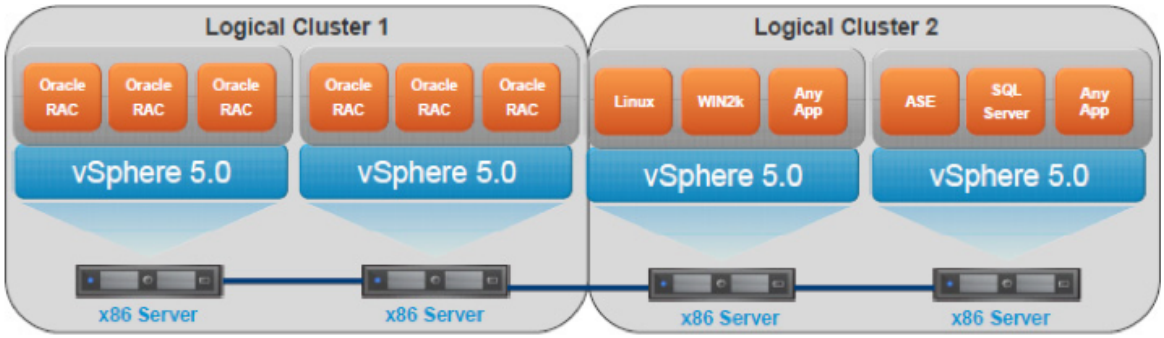

Figure 5. By restricting Oracle virtual machines to a small number of physical hosts, Green Mountain significantly reduced its Oracle licensing costs.

5. Virtualize the Entire Application Stack—Including the Database.

Despite substantial evidence showing the benefits of virtualizing database platforms, some DBAs are still reluctant to do so—they advocate running the database on physical servers even when the applications are virtualized.

Saiyad emphatically disagrees: "Don't leave the database on a physical server. In order to get the full benefits of virtualization, you have to virtualize the entire stack, otherwise, you can't use vMotion and other tools to resolve bottlenecks. If we had not virtualized everything, we would not have been able to keep our mission-critical applications online during Hurricane Irene."

6. Small Staff Can Administer Oracle on VMware-NetApp Platform

As stated above, a single senior DBA, Nayab Saiyad, is charged with administering Green Mountain's Oracle environment. He discovered what experts have observed in other virtualization projects, namely, DBAs do not have to learn a new skill set to work in a virtualized environment. All of Saiyad's Oracle knowledge is directly transferable to the VMware-NetApp platform.

VMware has created a simple guide[9] specifically for DBAs like Saiyad who are knowledgeable about Oracle and just need some guidance in transferring that knowledge to a virtualized environment.

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[8] This section represents Green Mountain's experience but is not a definitive explanation of Oracle licensing policies. Always discuss licensing decisions with Oracle or your ISV.

[9] VMware Technical Resource Center, "Oracle on VMware vSphere Essential Database Deployments Tips," March 12, 2010, http://www.vmware.com/resources/techresources/10101.

Design Tips for RAC

The Green Mountain experience generated a number of designs tips, which are presented in summary form here. If you are planning a deployment similar to Green Mountain, consult with VMware, NetApp, or your ISV for more information.

Synchronize All RAC vSphere Hosts to the Same NTP Server.

Synchronizing all Oracle hosts to the same NTP server is considered a universal best practice to prevent false positives, which can occur due to time discrepancies between hosts. This technique is particularly important for RAC; otherwise, nodes that are running can appear to be down and thus be ejected from the cluster. The VMware knowledge base explains how to synchronize vSphere hosts to an NTP server and other configuration tasks[10].

Use dNFS with NetApp Storage.

Oracle Direct NFS[11] (dNFS) is a free, optimized NFS client that provides faster and more scalable access to NFS storage located on NetApp and other NAS storage devices. Green Mountain chose dNFS because it provides higher performance and eliminates much of the overhead usually associated with NFS. However, Oracle RAC requires standard NFS, so the Green Mountain environment contains a mix of dNFS and NFS.

Don't Overcommit CPU and Memory Resources in Production Environments.

If the host CPU capacity is overloaded, database performance can degrade. This situation is usually not a serious problem in development and test environments, but can impact users in production. As noted earlier, DRS can be configured to prevent this problem by using vMotion to automatically move virtual machines to a host with sufficient resources.

Managing the memory commitment is also important. The recommended memory reservation for production environments is:

virtual memory size = Oracle System Global Area + operating system

See VMware technical materials for more specific recommendations[12] .

Hypervisor Efficiency is More Important than Number of Virtual CPUs.

Virtualization vendors vary in terms of the maximum number of virtual CPUs that they support. However, Oracle software is not a heavy CPU consumer, so hypervisor efficiency counts more than vCPU count. When virtualizing Oracle RAC, the recommended design practice is to focus on efficient use of a small number of vCPUs. Unused or lightly used vCPUs consume timer interrupts and therefore can hurt overall performance.

Align the File System to the Storage for Maximum Performance.

Partition alignment for VMware Virtual Machine File System (VMFS) partitions prevents performance degradation caused by I/O access across track boundaries[13]. Proper system alignment can make a big difference in performance—as much as 50%—for high I/O workloads such as Oracle database. The alignment value differs by storage vendor: NetApp recommends a 32K offset. VMware vCenter is used to create partitions for VMware (VMFS).

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[10] VMware Knowledge Base, "Installing and Configuring NTP on an ESX Host," http://kb.vmware.com/kb/1339

[11] Oracle White Paper, "Oracle Database 11g Direct NFS Client," July 2007.

[12] VMware Technical Resource Center, "Oracle on VMware vSphere Essential Database Deployments Tips," March 12, 2010, http://www.vmware.com/resources/techresources/10101

[13] VMware Best Practices Guide, "Oracle Databases on VMware," 2011, http://www.vmware.com/files/pdf/partners/oracle/Oracle_Databases_on_VMware_-_Best_Practices_Guide.pdf

Use Paravirtualized SCSI Adapters for Demanding I/O Workloads

To achieve maximum performance for Oracle database files, Green Mountain installed a PVSCSI adapter for the associated memory array. Tests show that paravirtualized SCSI (PVSCSI) adapters offer up to a 12% improvement in throughput and 18% less CPU usage compared to LSI SCSI for I/O workloads above 2000 IOPS. Major operating systems such as Windows Server, Windows 7, Red Hat Enterprise Linux, SUSE Linux Enterprise, and Ubuntu include PVSCSI support. The VMware Knowledge Base has detailed information about how to configure disks for PVSCSI adapters[14].

Enable Jumbo Frames for IP-based Storage

vSphere 4.0 introduced support for jumbo frames, which can improve performance for some network configurations, especially when the storage protocol is IP-based. However, jumbo frames must be implemented end to end, in both the physical and virtual infrastructure, to avoid incompatibles.

Green Mountain chose to implement jumbo frames. This decision required setting the MTU to 9000 in both the NetApp System Manager and vSphere (the VMware Networking Blog[15] has detailed instructions for configuring vSphere for jumbo frames.)

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[14]VMware Knowledge Base, "Configuring Disks to Use VMware Paravirtual SCSI (PVSCSI) Adapters," http://kb.vmware.com/kb/1010398.

[15]VMware Networking Blog, "Jumbo Frames in vSphere 4.0," March 28, 2010, http://blogs.vmware.com/networking/2010/03/jumbo-frames-in-vsphere-40.html.

References

The following documents provide additional information that can be useful when designing and deploying a virtualized environment for business-critical Oracle applications based on VMware and NetApp technology.

Oracle Dev/Test on VMware vSphere and NetApp Storage Solutions Overview, NetApp/ VMware Technical Report, July 2010.

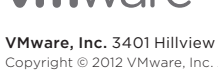
A solution guide for rapid deployment of space-efficient Oracle Database copies using VMware vSphere and NetApp FlexClone.

Virtualizing Performance-Critical Database Applications in VMware® vSphere™, VMware Performance Study, 2009.

Benchmark tests comparing the scalability and performance of vSphere 4 compared to native environment.

Oracle Databases on VMware: Best Practices Guide, VMware document, 2011.

Best practice guidelines for deploying Oracle databases on VMware vSphere®. The recommendations in this guide are not specific to any particular set of hardware and complement the design tips presented in this white paper.



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