



DBA Guide to Databases on VMware

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1. Introduction

Virtualization is rapidly eliminating the old “one server one application” model and has freed applications from physical constraints. You can virtualize the hardware resources of an x86-based machine to create a fully functional virtual machine that can run its own operating system and applications just like a physical computer. By encapsulating an entire machine, including CPU, memory, operating system, and network devices, a virtual machine is completely compatible with all standard x86 operating systems, applications, and device drivers. Virtualization lets you run multiple virtual machines on a single physical machine as well as pool hardware to deliver resources to the applications that need them when they need them. Different virtual machines can run different operating systems and multiple applications on the same physical computer.

Organizations are increasingly virtualizing their enterprise applications in production and databases are no exception. Experienced Database Administrators (DBAs) recognize that virtualization unlocks capabilities that were impossible in physical environments. In this guide, we discuss database performance on VMware, examine general tasks for DBAs, and introduce VMware technologies and tools that assist DBAs in designing, implementing, testing, operating, and maintaining databases in a virtual environment.

DBAs are being challenged to provide 24x7 database services to application owners with the flexibility and autonomy they expect while keeping the infrastructure as simple and economical as possible. Traditional databases running on fixed physical hardware are often oversized, underutilized, protected by complex, expensive clustering solutions, and require rigorous processes for version control and continued application compatibility.

VMware virtualization creates a layer of abstraction between the resources required by an application and operating system, and the underlying hardware that provides those resources. By decoupling the operating system and applications from the underlying hardware, VMware vSphere® enables virtualized databases to dynamically react to changes in underlying system resources such as CPU, memory, storage, and network, to deliver near native database performance with minimal overhead. By running multiple virtual machines on a single physical server, throughput can be scaled to match fluctuating demands. From a single management console, you can use virtual images to easily deploy thousands of database servers to remote locations.

Today, virtual machines on VMware vSphere 5 can scale to 32 virtual CPUs, 1TB of memory per virtual machine, and over 1,000,000 disk IOPS, while keeping overhead limited between 2 – 10 percent. That’s a 20x performance increase over ESX 2. This clearly demonstrates that virtual machines running on VMware vSphere can scale to meet mainframe-size workload demands. Additionally, vSphere maximizes the performance achieved from physical hosts by enabling multiple databases to efficiently share the large capacity of multicore servers.

Today’s new 64-bit servers come with growing numbers of CPU cores, higher memory limits, and increased network bandwidth. The majority of the database applications can run comfortably with a fraction of the server capacity. The traditional deployment model of one application per server is not keeping pace with the latest developments in hardware and virtualization. Virtualizing databases on vSphere simultaneously consolidates the databases and optimizes compute resources, while maintaining application flexibility by isolating each database in its own virtual machine. You can migrate databases from physical to virtual environments in their current state without expensive and error-prone application migrations.

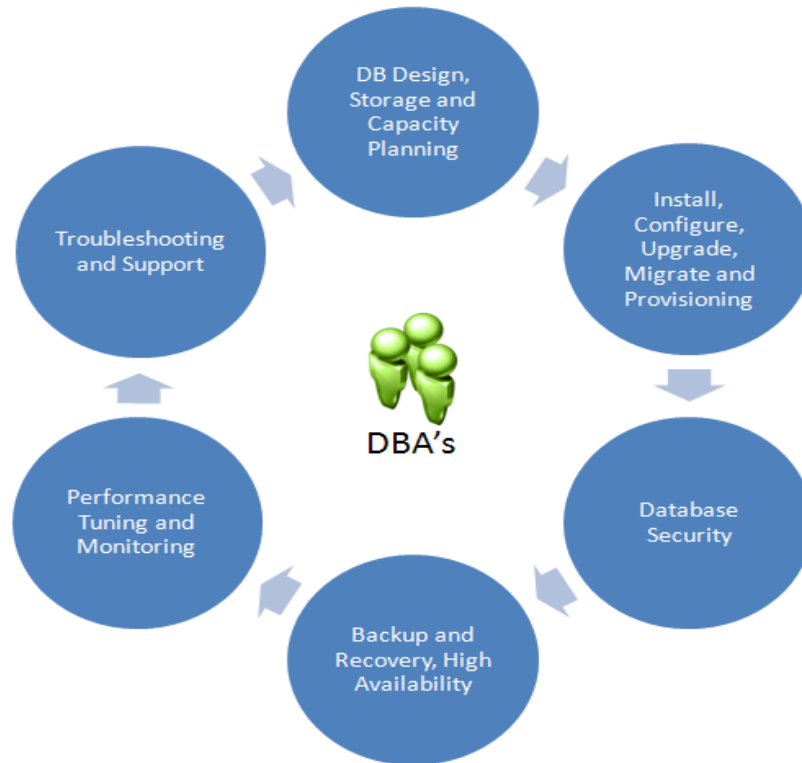
The value of virtualization goes far beyond basic consolidation. Virtualizing database applications on vSphere can improve application Quality of Services (QoS), and accelerate application lifecycles while significantly reducing application costs.

- Improve application Quality of Service – Databases are very difficult to size on physical servers. With VMware, databases can scale dynamically to meet changing throughput requirements. You can leverage vSphere High Availability (HA), vSphere Fault Tolerance (FT), VMware vSphere vMotion®, Dynamic Resource Scheduling (DRS) and VMware vCenter Site Recovery Manager™ to create robust availability with minimal configuration changes. If needed, these solutions can also be combined with more traditional database clustering and replication options to provide even higher levels of availability.
- Accelerate application delivery – Provision new databases on demand in a matter of minutes from preconfigured virtual appliances. Test multitier applications quickly and efficiently by easily cloning production databases. Automate release cycles and deploy standard, preconfigured databases at the click of a button, promoting consistency across production databases and minimizing manual configuration overhead and configuration drift.
- Reduce application costs – Databases are among the most over-provisioned applications in the datacenter. Because of this massive over-provisioning, databases have tremendous consolidation potential. With server consolidation, not only are hardware footprints reduced, but the costs for expensive database licenses are also reduced.

2. DBA Roles and Responsibilities

DBAs wear many hats and play many roles within an organization. A DBA is the administrator who designs, implements, tests, operates, and maintains databases for an organization. The following diagram depicts general tasks for DBAs.

Figure 1. General Tasks for DBAs



- Database design, storage and capacity planning – DBAs play a major role in designing the database along with planning on how much disk storage is required and how much it will grow over a period of time. Watching growth trends is important so that the DBA can advise management on long-term capacity plans.
- Install, configure, upgrade, migrate and provision – Although system administrators are generally responsible for the hardware and operating system on a given server, installation of the database software is typically up to the DBA. The DBA role requires knowledge of the hardware prerequisites for an efficient database server, and communicating those requirements to the system administrator. The DBA installs the database software and selects from various options in the product to configure it for the purpose for which it is being deployed. As new releases and patches are developed, it's the DBA's job to decide which are appropriate and to install them. If the server is a replacement for an existing one, it's the DBA's job to get the data from the old server to the new one. DBAs are tasked to provision DB servers on demand for development, testing, QA, and reporting.

- Database security – Databases centralize the storage of data and are attractive targets for hackers. DBAs must understand the particular security model that the database product uses and how to use it effectively to control access to the data. The three basic security tasks are authentication (setting up user accounts to control logins to the database), authorization (setting permissions on various parts of the database), and auditing (tracking who did what with the database). The auditing task is particularly important as regulatory laws such as Sarbanes-Oxley and HIPAA have reporting requirements that must be met.
- Backup and recovery, high availability – DBAs are responsible for developing, implementing, and periodically testing a backup and recovery plan for the databases they manage. Even in large shops where a separate system administrator performs server backups, the DBA has final responsibility for making sure that the backups are being done as scheduled and that they include all of the files needed to make database recovery possible after a failure. When failures do occur, the DBA needs to know how to use the backups to return the database to operational status as quickly as possible, without losing any transactions that were committed. There are several ways a database can fail, and the DBA must have a strategy to recover from each type of failure. From a business standpoint, there is a cost to doing backups, and the DBA makes management aware of the cost/risk tradeoffs of various backup methods. DBAs use techniques such as online backups, clustering, replication, and standby databases to provide higher availability.
- Performance tuning and monitoring – DBAs are responsible for monitoring the database server on a regular basis to identify bottlenecks and remedy them. Database server tuning is performed at multiple levels. The capacity of the server hardware and the way the operating system is configured can become limiting factors, as can the database software configuration. The way the database is physically laid out on the disk drives and the types of indexing chosen also have an effect. The way queries against the database are coded can dramatically change how quickly results are returned. A DBA needs to understand which monitoring tools are available at each of these levels and how to use them to tune the system. Proactive tuning involves designing performance into an application from the start, rather than waiting for problems to occur and fixing them. It requires working closely with developers of applications that run against the database to make sure that best practices are followed so that good performance will result.
- Troubleshooting and Support – When things go wrong with the database server, the DBA needs to know how to quickly ascertain the problem and to correct it without losing data or making the situation worse. DBA provides 24x7 supports.

3. Understanding VMware Performance

There is still a perception in the DBA community that virtualization introduces a performance constraint on larger applications, especially IO-intensive applications such as databases. This perception may have originated with early versions of the VMware hypervisor, which had scalability limitations and material overhead. However, the latest versions of VMware vSphere 5.0 have advanced by leaps and bounds over the early product generations. VMware placed a significant focus on maximizing the performance of virtual machines and vSphere 5.0 offers tremendous progress in IO, CPU, and memory scalability over early product generations.

Today, virtual machines on vSphere 5.0 can scale to 32 virtual CPUs, 1TB of memory, and over 1,000,000 disk IOPS, while keeping overhead limited between 2 to 10 percent for the majority of applications.

Figure 2. Application Performance on ESX

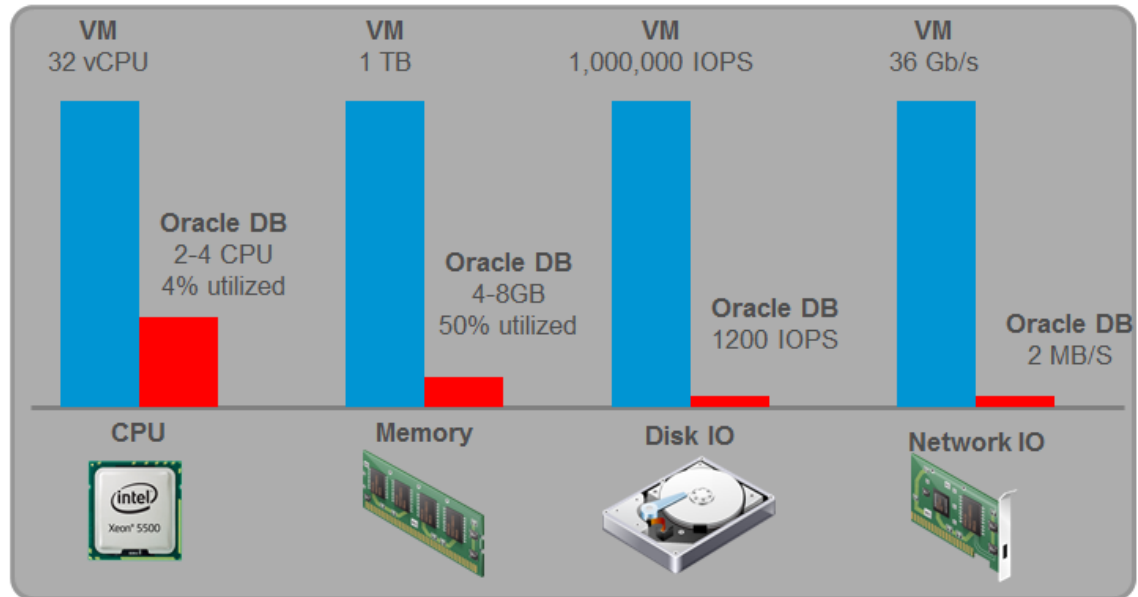
Application's Performance Requirements

| 95% of Apps Require | | ESX 1 | ESX 2 | VMware Inf. 3.0/3.5 | VMware vSphere 4 | VMware vSphere 5 | |
|---------------------|---------|----------------|-------------|---------------------|------------------|------------------|-----------------|
| % of Applications | CPU | 1 to 2 CPUs | 1 VCPUs | 2 VCPUs | 4 VCPUs | 8 VCPUs | 32 VCPUs |
| | Memory | < 4 GB at peak | 2 GB per VM | 3.6 GB per VM | 16/64 GB per VM | 256 GB per VM | 1,000 GB per VM |
| | Network | <2.4 Mb/s | <.5Gb/s | .9 Gb/s | 9 Gb/s | 30 Gb/s | >36Gb/s |
| | IOPS | < 10,000 | <5,000 | 7,000 | 100,000 | 300,000 | 1,000,000 |

In February 2009, VMware vSphere set a new benchmark in virtualized database performance. VMware vSphere was benchmarked with one of the most demanding workloads for virtualization: a resource-intensive OLTP database based on a fair-use implementation of TPC-C. This application is significantly more resource-intensive than average production databases, and puts a heavy load on the hypervisor. Even for this difficult workload, a single virtual machine in VMware vSphere running Oracle 11g and Linux achieved 85 percent of native performance with near-linear scalability from one virtual CPU to eight virtual CPUs. The virtual machine supported 8,900 transactions per second and drove about 60,000 disk IOPS—a massive amount of throughput that only a small fraction of databases actually require.

There are some exceptionally large databases out there, but it is rare that a database can exceed the performance capabilities provided by VMware vSphere. The reality is that almost all databases can run comfortably on VMware vSphere, with plenty of processing headroom to spare. Based on VMware Capacity Planner data compiled from tens of thousands of production servers in customer environments, the average production Oracle database requires only a fraction of the capacity that a virtual machine can deliver.

Figure 3. Average Oracle Database Fits Easily in a Virtual Machine



Source: VMware Capacity Planner analysis of > 700,000 servers in customer production environments

For additional information on Oracle database performance on VMware, see the performance study white paper, *Virtualizing Performance-Critical Database Applications in VMware vSphere* (http://vmware.com/pdf/Perf_ESX40_Oracle-eval.pdf).

Also see Performance and Scalability of Microsoft SQL Server on VMware vSphere 4 (http://www.vmware.com/files/pdf/perf_vsphere_sql_scalability.pdf) for details of Microsoft SQL Server performance on VMware.

4. Designing Databases on VMware

By decoupling the application and OS from the physical hardware, the VMware virtualization platform addresses many difficult design problems such as scalability, high availability, and resource isolation that traditionally exist in the physical environment. With VMware features and tools, you can design database solutions that scale on demand to meet any throughput or organizational growth requirements; implement higher availability and disaster recovery solutions with less complexity; and leverage available hardware resources while maintaining full application isolation.

4.1 Design with Scalability on Demand

Capacity planning is one of the most challenging tasks in designing a database solution. How much resource (CPU, memory, storage, network) do you need? Do you have enough resource to handle peak server load? What is the expected growth rate? What happens when the company decides to support another GEO with the application? Those are all difficult problems that DBAs face daily in the physical environment. Undersizing a system might cause performance issues that affect business operations or event downtime. Often, DBAs have no choice but to size a physical server many times bigger than the workload just to deal with spikes during peak hours that may only happen once a year, or to handle any unexpected resource needs.

With VMware vSphere, resources are managed in pools. CPU, memory, storage, or network can be increased or decreased dynamically, or manually with just a few mouse clicks.

4.1.1 VMware Hosts, Clusters, and Resource Pools

VMware hosts, clusters, and resource pools provide flexible and dynamic ways to organize the aggregated computing and memory resources in the virtual environment and link them back to the underlying physical resources.

A host represents the aggregate computing and memory resources of a physical x86 server. A cluster acts and can be managed as a single entity. It represents the aggregate computing and memory resources of a group of physical x86 servers sharing the same network and storage arrays. For example, if the group contains eight servers with four dual-core CPUs each running at 4GHz and 32GB of memory. The cluster then has an aggregate 256GHz of computing power and 256GB of memory available for running virtual machines.

Resource pools are partitions of computing and memory resources from a single host or a cluster. Resource pools can be hierarchical and nested. You can partition any resource pool into smaller resource pools to further divide and assign resources to different groups or for different purposes.

4.1.2 VMware Hot Add

The VMware Hot Add feature enables hot adding CPU and/or memory to a running virtual machine. As applications grow over time and require more CPU or memory resources, a DBA can scale up virtual machines dynamically and on the fly. Both Oracle and SQL Server can detect the new capacity, and make use of the additional resource in subsequent operations.

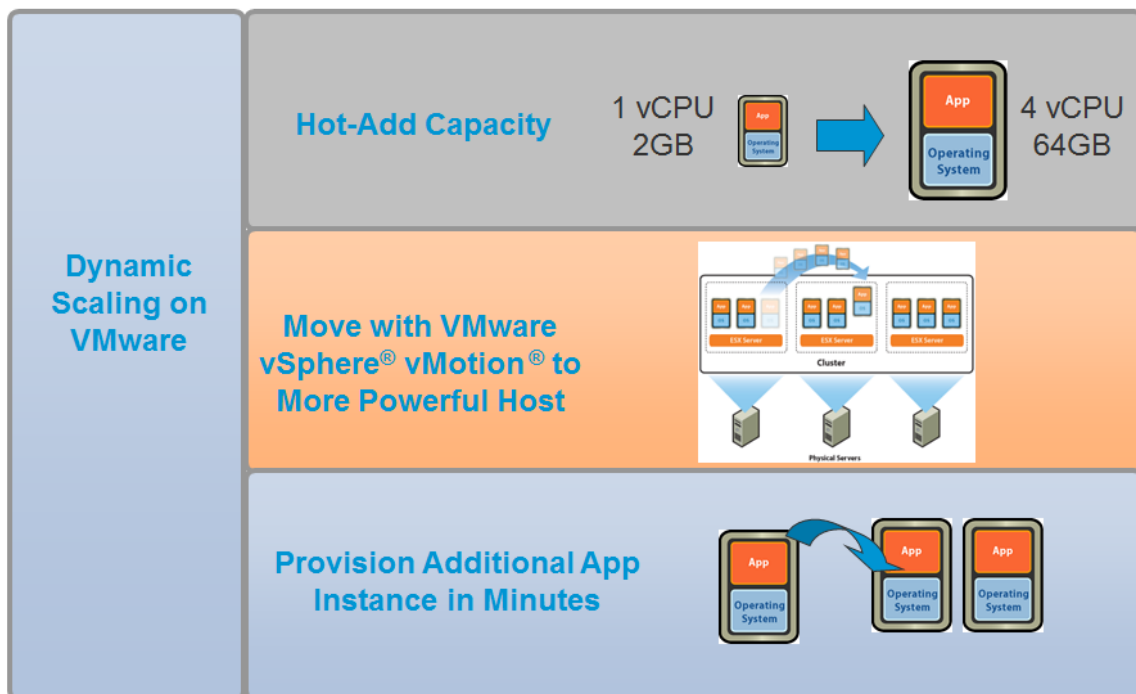
4.1.3 VMware vSphere vMotion

VMware vSphere vMotion enables live migration of virtual machines from one physical server to another without service interruption. vMotion uses the VMware cluster file system to control access to a virtual machine's storage. During a vMotion migration, the active memory and precise execution state of a virtual machine is rapidly transmitted over a high speed network from one physical server to another and access to the virtual machines disk storage is instantly switched to the new physical host. Because the network is also virtualized by the VMware host, the virtual machine retains its network identity and connections, resulting in a seamless migration process.

4.1.4 vSphere Distributed Resource Scheduler

vSphere Distributed Resource Scheduler (DRS) takes the vSphere vMotion capability a step further by adding an intelligent scheduler. DRS allows you to set resource assignment policies that reflect business needs. vSphere DRS does the calculations and automatically handles the details of physical resource assignments. It dynamically monitors the workload of the running virtual machines and the resource utilization of the physical servers within a cluster.

Figure 4. Scale Applications on Demand



VMware resource pools, hot-add, vMotion, and DRS features enable DBAs to design database solutions to scale on demand, and in a “future-proof” manner. For example, a retail database may be normally 10% utilized, but during the Christmas shopping season, it might be 95% utilized. The Christmas shopping season only lasts for 45 days. Instead of initially sizing the database for the Christmas peak capacity, wasting resources for the other 320 days, you can size the database virtual machine for normal workloads, live migrate the database to a more powerful host using vMotion, and hot-add CPU and memory to the virtual machine before Christmas shopping season starts to proactively address the increased load during the holiday season.

4.2 Design for High Availability

Databases such as Oracle and SQL Server provide a variety of options for high availability and disaster recovery; for example, SQL Server failover clustering, database mirroring, log shipping, Oracle RAC, and Data Guard. Though all of these are good choices for database recovery, the application-centric nature of these technologies are typically costly, complex to set up, with high operational overheads, and are single database-, or single instance-based. Implementing high availability and disaster recovery for every database in a physical environment is often not practical.

The VMware vSphere platform ships with built in high availability. By decoupling the operating system and application from the underlying physical server hardware, a virtual machine can easily move from one physical server to another.

4.2.1 vSphere High Availability

vSphere High Availability (HA) monitors virtual machines to detect operating system and hardware failures, restarts virtual machines on other physical servers without manual intervention when hardware failure is detected, and protects applications from operating system failures by automatically restarting virtual machines when an operating system failure is detected. DBAs no longer have to worry about the database going down because of failures associated with the operating system, HBA, network card, or other hardware components.

Because HA can be configured with a single click from within the vSphere Client interface to provide failover protection for all virtual machines without requiring the complex setup and configuration of clustering, DBAs can design uniform, cost effective failover protections against operating system and server failures for all databases regardless of the server hardware or operating system used by the database virtual machine. vSphere HA can provide a simple and reliable first line of defense for all databases without the cost and the hassle of traditional database high availability options. vSphere HA can also be used in combination with native database high availability options such as SQL Server database mirroring or Oracle Data Guard to provide complete protection from both hardware and application software failure.

4.3 Design Simple and Reliable Database Disaster Recovery

A VMware virtual machine is essentially a software container that bundles or encapsulates a complete set of virtual hardware resources, as well as an operating system and all its applications, inside a software package. Encapsulation makes virtual machines portable and easy to manage. An entire database virtual machine can be contained in a small set of files, and can be moved or copied from one location to another just like any data files. What does that mean to a DBA? Database disaster recovery is as easy as managing file copies.

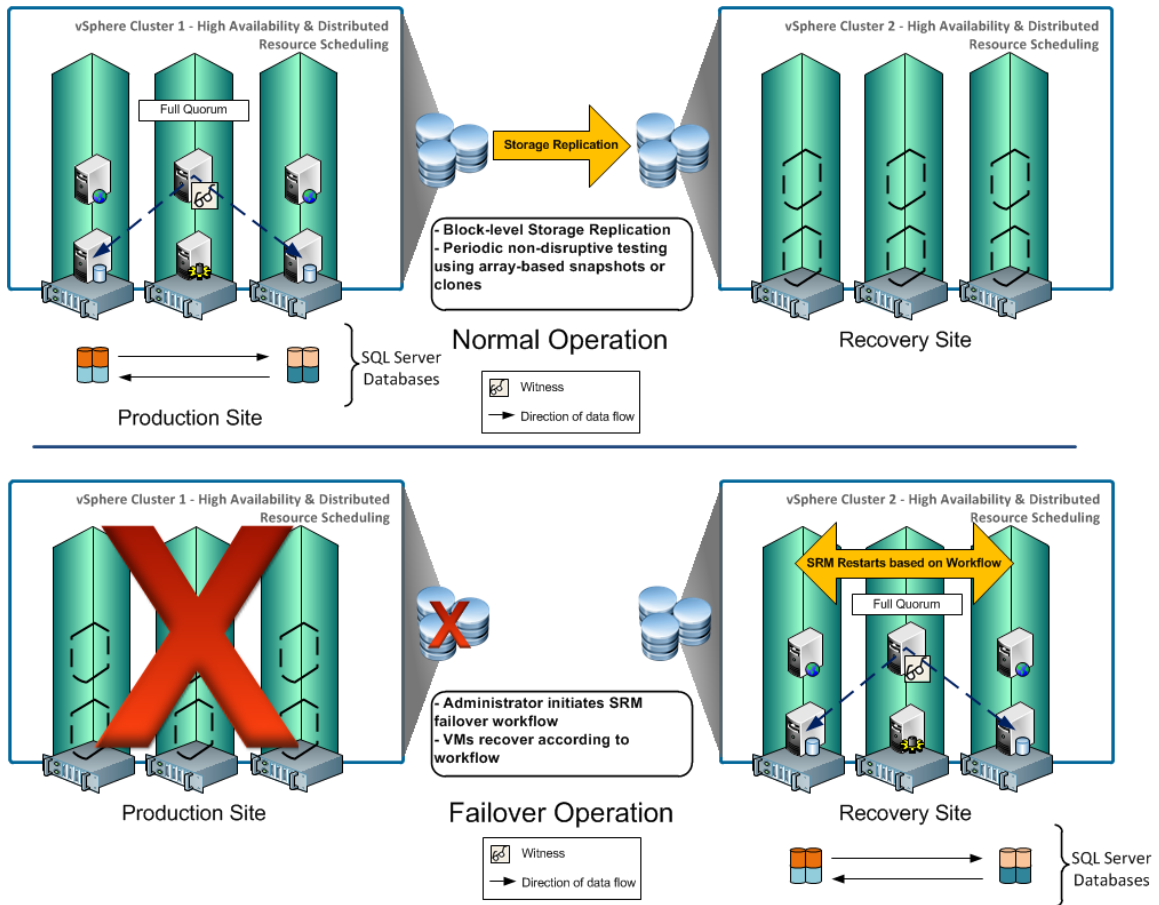
4.3.1 VMware vCenter Site Recovery Manager

VMware vCenter Site Recovery Manager (SRM) integrates with storage replication technologies provided by leading storage vendors to automate the process of recovering from a disaster event for an entire datacenter. SRM guides users through the process of building, managing and executing disaster recovery plans. It significantly simplifies the process of recovering from a disaster event, eliminates complex manual recovery steps, and removes the risk and worry from disaster recovery.

For information about storage vendors who support storage configuration and infrastructure replication with VMware vCenter Site Recovery Manager, visit <http://www.vmware.com/products/site-recovery-manager/resource.html>.

SRM further simplifies database disaster recovery by enabling DBAs to automate and manage database recovery per datacenter. SRM works in combination with vSphere HA and native database high availability options such as Oracle RAC, SQL Server failover clustering, and SQL Server database mirroring to provide 24x7 uptime services to businesses.

Figure 5. VMware vCenter Site Recovery Manager with SQL Server Database Mirroring



4.4 Determine Consolidation Strategy

Nearly all applications require their own database, and many organizations are faced with escalating database sprawl. This is especially the case with SQL Server given how easy it is to install a SQL Server instance. Some developers are running SQL Server instances on their desktops. Does the SQL Server need backing up? Does it contain sensitive data? This creates a significant administration challenge for DBAs.

Databases also tend to be the most over-provisioned applications in the datacenter, and can be very expensive due to high license costs and top-tier infrastructure requirements.

As computing power for servers continues to increase, many organizations are moving toward database consolidation. The question for a DBA is often how to consolidate. Conventional database consolidation is typically performed by either running multiple instances of the database software on a shared OS image (*multi-instancing*), or by running multiple databases within an instance (*shared instancing*). These traditional approaches can be successful, but also pose significant challenges:

- There is generally a lack of OS configuration, security, fault, and resource isolation between database instances. A single OS or database failure could result in dozens of databases and applications being down simultaneously.
- Load balancing between physical hosts is a complex undertaking that requires re-provisioning databases. A large workload spike on one physical host could result in unacceptable performance for many databases at the same time.
- It can be difficult to guarantee resources to any individual database. One misbehaving database could take the resources of other, more critical databases.

VMware virtualization technology offers a much simpler and more efficient alternative for database consolidation. Consolidating databases with VMware vSphere delivers several unique benefits over conventional approaches:

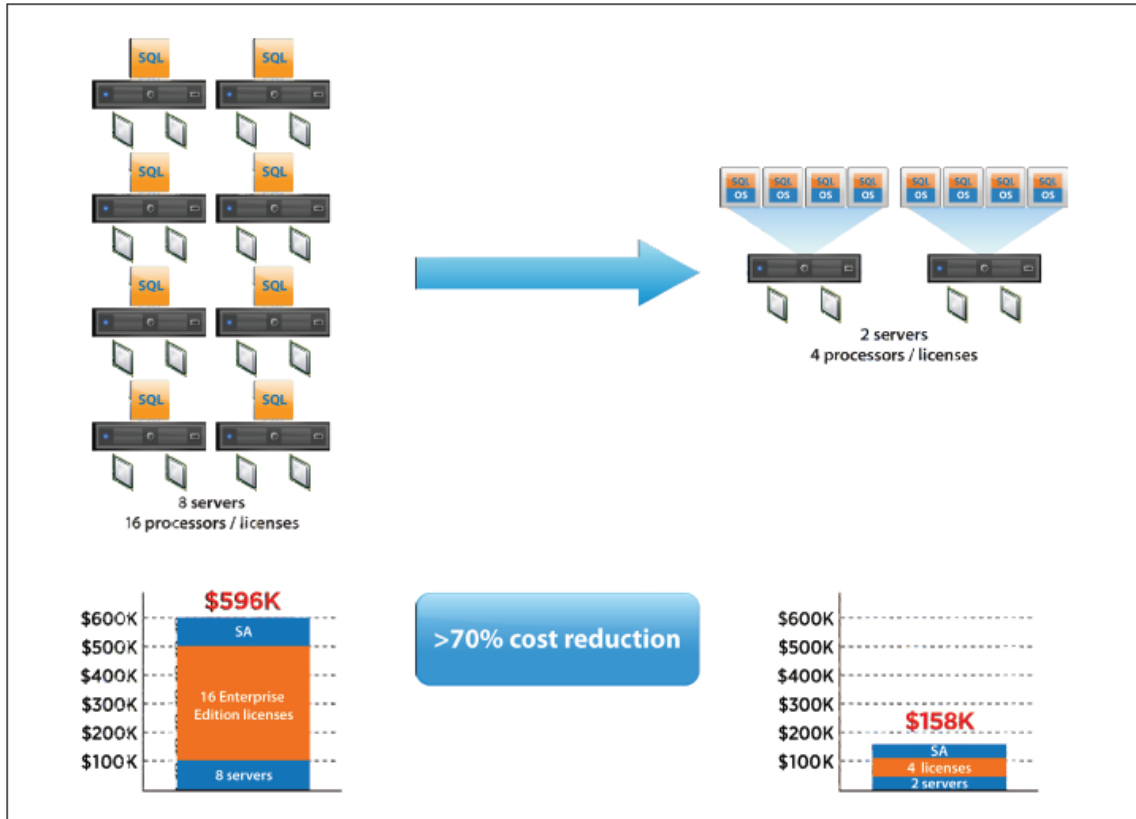
- **Fast consolidation with P2V** – With VMware vSphere, consolidating existing databases is simple. Databases can be migrated with a physical-to-virtual (P2V) migration, or re-provisioned in a virtual machine with their existing OS and database configurations. This eliminates the need to re-test and update databases to run on standardized OS and database configurations.
- **Isolation** – Databases consolidated on VMware vSphere preserve perfect isolation between instances (configuration, fault, security, and resource isolation). Databases can run on their own OS and database version, and a single OS failure only impacts a single database. This is an obvious benefit of virtualization that is not possible with conventional database consolidation approaches.
- **Resource guarantees** – Guarantee and control resources with precision to make sure that each database delivers its required service levels, with no risk of misbehaving databases taking critical resources from other databases.
- **Load balancing** – With VMware vSphere, when a host is running out of capacity, databases can be migrated in real time with no downtime to other hosts. This eliminates the need to over-provision and increases consolidation ratios while maximizing database service levels.

4.4.1 Consolidate Software Licenses

Consolidation with virtualization can deliver tremendous cost savings not only on infrastructure, but also on software licenses. Many database applications are licensed by physical processor. When processors are utilized only at 5-15 percent of their capacity, the software licenses are also under-utilized at the same levels. This is the case for Microsoft SQL Server per processor licensing, as well as for Oracle database licenses.

If you are running a relatively large number of SQL Servers licensed per physical processor, you should consider creating dedicated vSphere clusters to run the SQL Server applications. After all the physical processors have been licensed, some SQL Server editions allow you to run an unlimited number of SQL Server virtual machines on a physical host. Figure 6 shows a customer who moved eight individual databases each running on a dedicated host to one shared cluster running eight DB instances. With an unlimited number of virtual machines supported for the SQL Server edition selected, the customer was able to reduce the required licenses from 16 down to 8, and reduce overall costs by more than 70 percent. For detailed information about licensing SQL Server for virtualization scenarios, refer to the *SQL Server on VMware – Support and Licensing Guide* (<http://www.vmware.com/files/pdf/vmware-sql-support-licensing-guide-wp-en.pdf>).

Figure 6. Customer Scenario on Consolidating SQL Server Licenses



5. Developing and Testing Databases on VMware

DBAs often need to create test environments for developers and QAs. Deploying a new database server can take many hours to acquire the hardware, install the operating system and patches, and install the database software and updates. In the physical environment, the process may take days or weeks. Often, the time needed to create the test environments exceeds the amount of time the environment is actually used.

VMware *templates* allow you to clone, convert, and deploy virtual machines based on a base image. You can set up and configure a single database virtual machine that incorporates best practices, then use the VMware template feature to convert the virtual machine into a template. The template can then serve as the “golden” image and be used for subsequent database virtual machine deployments. This not only saves countless hours during new database system deployments, but also results in all deployed systems having identical configurations that follow best practices.

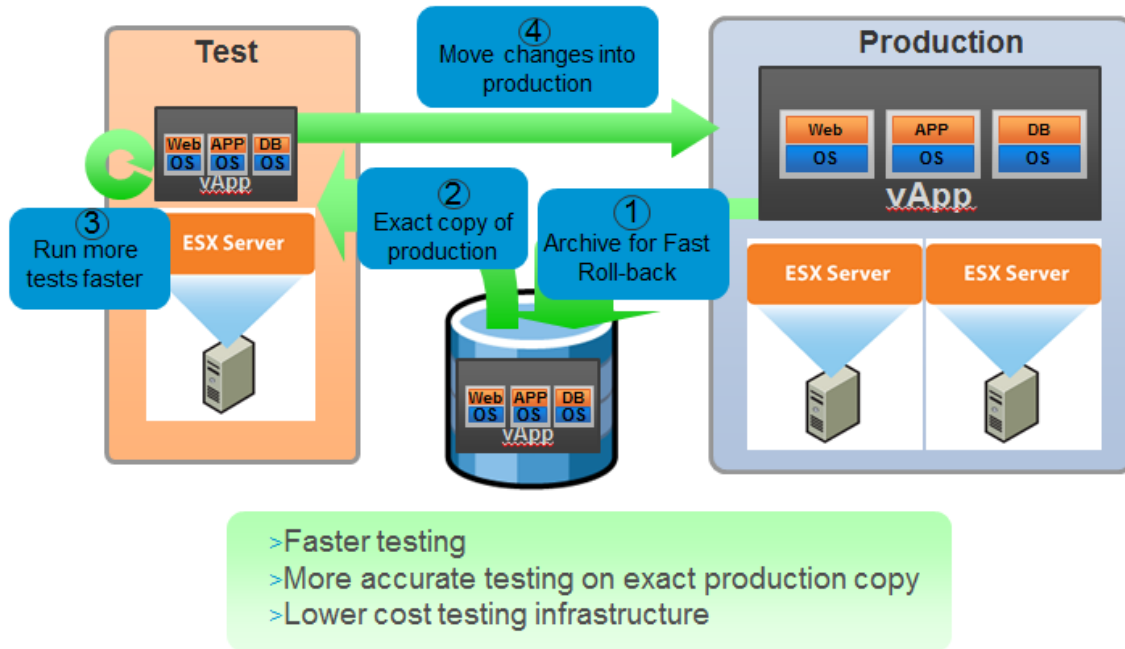
Alternatively, via a self-service portal, VMware vCloud® Director™ allows developers to create, share, and configure their own development and test environments without having to request these environments from the IT department. Because these test environments live in a virtual world they can be deployed, used, and retired without risk to the production environment.

5.1 Testing and Troubleshooting with Production Clones

Database query performance can vary drastically with different database configuration settings, changes in server resources, or differences in data shape. Reproducing and troubleshooting a production database issue can be challenging due to differences in production and testing environments.

VMware clones and snapshots are powerful tools for testing and troubleshooting any virtual machine. Cloning a virtual machine allows administrators to make an exact, independent copy of any virtual machine in their environment. Live snapshots can be used to instantly roll back a virtual machine to a specific state. DBAs can easily build a test environment with a production replica—this capability is especially valuable in complex application environments supported by databases. VMware-enabled troubleshooting can help to substantially shorten time to resolution of critical issues and reduce their overall impact on the production environment.

Figure 7. Streamline Testing with Snapshots and Clones



6. Migrating Existing Databases to VMware

There are two main approaches when migrating an existing database from physical servers to virtual servers. The first approach is to use a conversion tool to migrate the database as is. The second approach is to perform a new installation of the database software in the virtual environment, and migrate the data from the legacy physical server.

6.1 Physical-to-Virtual Conversion

VMware vCenter Converter™ can be used to convert existing physical database servers to virtual machines through a process commonly referred to as physical-to-virtual (P2V) conversion. VMware vCenter Converter simplifies the P2V conversion through intuitive wizard-driven automation. With vCenter Converter, DBAs can convert multiple local and remote physical database servers simultaneously from a centralized management console.

To maintain consistency of the database, it is recommended that you stop the database services (but leave the OS running) during hot cloning of the physical database server.

P2V conversion through vCenter Converter accomplishes a one-to-one mapping between the physical server and the virtual server. That is, if there are multiple instances and/or multiple databases running on the physical server, the resulting virtual machine will have the same number of instances and/or databases. This may not be the best approach for achieving optimal resource utilization or isolation with consolidation.

6.2 New Database Installation

Existing physical databases can be migrated to a virtual machine by performing a new installation of the database software on the virtual machine, and then migrating the data to the virtual machine from the source physical server.

This approach allows you to upgrade the database version along with migration. For example, if you have a SQL Server 2005 server that you are virtualizing, you can choose to upgrade the SQL Server 2005 instance by installing a new SQL Server 2008 R2 instance on the virtual machine, and then restoring a backup copy of the SQL Server 2005 database onto the SQL Server 2008 R2 instance.

If Raw Disk Mapping (RDM) is used in the database virtual machine, database files can be detached from the physical database, and attached to the database on the virtual machine. The entire backup/copy/restore process is eliminated, so cutting over from the physical server to the virtual server could be accomplished in seconds. This is especially useful for migrating databases with large on disk footprints and/or for mission critical databases that demand high uptime.

For mission critical databases that demand high uptime this migration approach also enables the use of native database replication features such as SQL Server database mirroring, and log shipping to perform zero downtime P2V migration. With database replication features such as SQL Server database mirroring, the physical database and the virtual database can run side-by-side as database mirroring partners. While data is being replicated onto the virtual database, the physical database continues to accept user requests. After the data is completely synchronized on the virtual machine, you can perform a manual failover to the virtual machine and remove the physical server from the mirroring partnership.

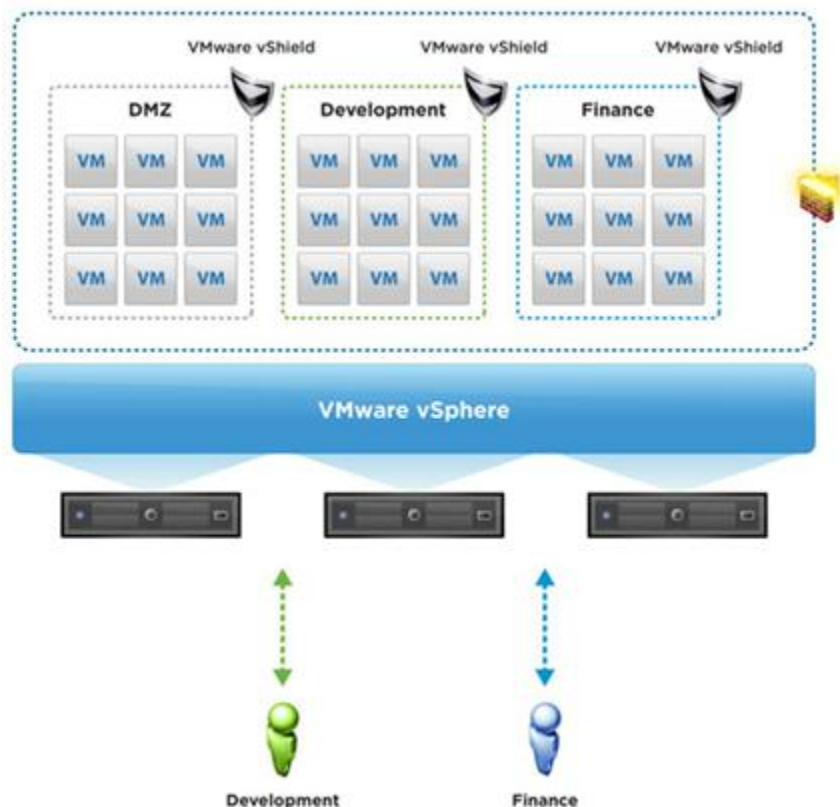
For rapid deployment of multiple database servers, you can use templates and clones to set up and configure a single database virtual machine according to best practices. Subsequent database virtual machines can be deployed through cloning.

7. Securing the Databases

Your Human Resources database may be governed by specific regulatory compliance that requires more strict security than your other production databases, but the databases in your training lab may require little or no hardening. VMware security features support databases belonging to different trust levels on the same virtual datacenter. For example, production and development, finance and sales, classified and non-classified databases.

VMware vShield App™ is a hypervisor-based application-aware firewall solution. vShield App protects applications against internal network-based threats and reduces the risk of policy violations within the corporate security perimeter using application-aware firewalls with deep packet inspection and connection control based on source and destination IP addresses. vShield App installs on each VMware ESX®/ESXi™ host and controls and monitors all traffic between virtual machines using business-relevant policies. Apply these policies to logical, dynamic application boundaries (security groups) instead of physical boundaries.

Figure 8. vShield App Securing Business Critical Applications



VMware vShield App addresses common challenges to application security within virtualized environments as you:

- Eliminate blind spots – Define and enforce granular policies for all traffic between applications, increasing visibility into traffic while helping to eliminate detours to physical firewalls.
- Maintain change-aware protection – Prevent network topology changes from impacting application security with continuous firewall protection for virtual machines as they migrate from host to host.
- Accelerate IT compliance – Get increased visibility and control over virtual machine network security with the logging and auditing controls you need to demonstrate compliance with internal policies and external regulatory requirements.

The hypervisor-level firewall in VMware vShield enforces proper segmentation and trust zones for all database deployments. vShield App also works in combination with native database encryption features such as transparent data encryption and backup encryption to protect data from unauthorized access.

8. Running Databases on VMware vSphere

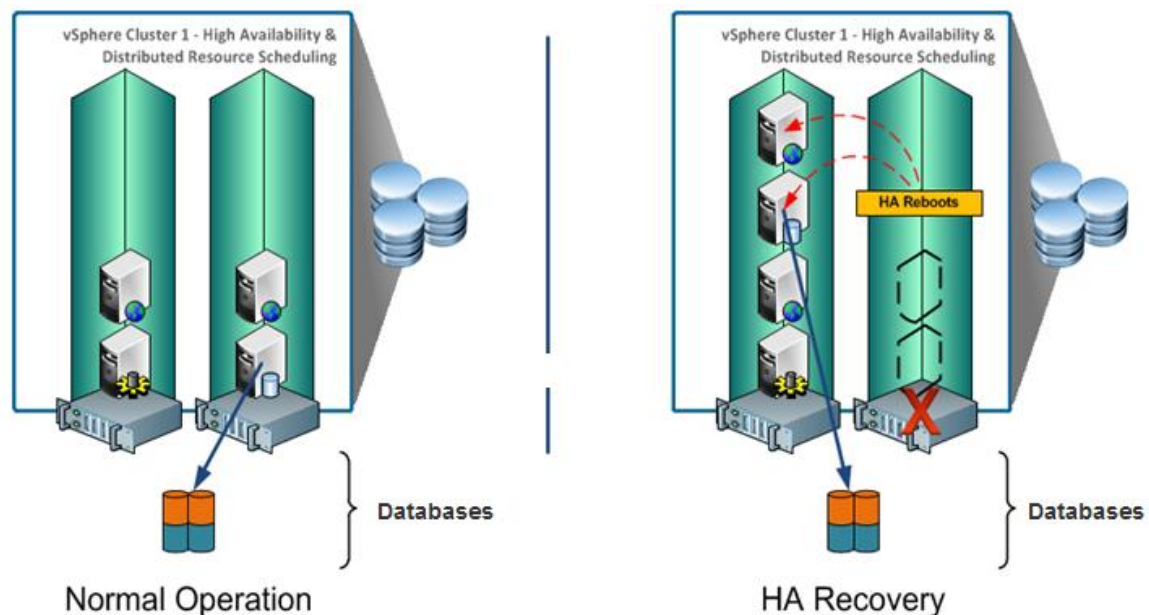
Running databases on VMware vSphere enables you to reduce planned and unplanned downtime. You can more easily manage patch updates, backup and recovery, and legacy databases.

8.1 Reduce Planned Downtime

In the physical environment, when a system administrator updates firmware or BIOS, fixes broken hardware, or moves hardware around the database, the databases running on the hardware are out of service.

Virtual machines decouple the operating system and applications from the underlying hardware. vSphere vMotion allows a virtual machine to be live migrated across physical servers—even servers from different vendors with different hardware configurations can be migrated without interruption of service. vSphere DRS even automates pre-maintenance vMotion migrations when a server is placed in maintenance mode. As a DBA, you no longer have to worry about downtime due to hardware maintenance affecting your SLA because you can vMotion the database virtual machine to another physical host before any scheduled hardware maintenance. You can use your maintenance window on database maintenance, which may require more time given typically rapid growth of the data.

Figure 9. vSphere HA, DRS Protecting Databases from Server Failure



8.2 Reduce Unplanned Downtime

VMware also helps to reduce unplanned downtime by providing new capabilities and by making existing solutions simpler and more cost-effective. For example, standby servers can be easily created by provisioning virtual machines to underutilized servers without requiring the purchase of additional hardware. This significantly reduces the costs for implementing native database high availability solutions such as Oracle RAC, SQL Server failover cluster, SQL Server database mirroring, and log shipping.

Support for servers with multiple network and storage interfaces is built into VMware ESX/ESXi, significantly cutting the cost of fault-tolerance by sharing redundant hardware between multiple virtual machines. vSphere HA provides protection from server hardware failure. vSphere Distributed Resource Scheduler (DRS) can reduce unplanned downtime by automating the use of vMotion to migrate running applications away from servers that cross utilization thresholds.

8.3 Manage Patch Upgrades

Similar to a running a database in the physical environment, it is a best practice to patch database virtual machines regularly to keep up-to-date with bug fixes, security updates, and so on. Most database environments have change control procedures that require patches to go through some form of testing before production deployment.

8.3.1 VMware Snapshots and Clones

VMware snapshots and clones can be used to streamline the testing of configuration changes, patches, or upgrades to your database servers. When you need to upgrade your production database systems, cloning allows you to quickly recreate an exact copy of the production environment in the lab, increasing the reliability of testing. After the patches or upgrades have been applied and validated, the same upgrade procedure can be reproduced in the production environment.

Similar to patching/upgrading in a physical environment, a reboot may be required as part of the patch/upgrade process. You can use a native database high availability feature such as Oracle RAC, SQL Server failover cluster, or SQL Server database mirroring in conjunction with a database virtual machine to reduce downtime during updates. For example, if you implement SQL Server database mirroring, it is possible to apply Windows and SQL Server updates including service packs in a rolling upgrade fashion to minimize server downtime.

Regardless of the method you use to patch or upgrade your database virtual machines there is always a risk of introducing new bugs or regressions that can take down the database server. Uninstalling a patch/upgrade may not be an option. In the physical environment, rolling back a patch could be a major undertaking that involves uninstalling and reinstalling the database binary and restoring the database from the backup disk. VMware snapshot technology can save a tremendous amount of time in these scenarios.

VMware snapshots allow you to create a snapshot of the state and data of a virtual machine at a specific point in time. Take a snapshot of the virtual machine before any upgrades are performed on the database server. If everything goes smoothly, the updates can be incorporated into the base image of the virtual machine. If something goes wrong, you can revert back to the original state of the virtual machine before the upgrade. This gives DBAs instant recoverability in case upgrades do not go smoothly.

8.4 Manage Backup and Recovery

The same amount of attention should be giving to backing up a database on a virtual machine as is given to backing up a database on physical server. When deployed in a virtual environment, all of the native backup tools included by database vendors are supported. VMware and VMware partners provide other options for protecting entire virtual machines.

8.4.1 In-Guest Software Solutions

Similar to backing up a database on a physical server, all of the native backup tools included by database vendors and any supported third-party backup solutions from database vendors can be used the same way in the virtual machine environment. Backup administrators can continue to deploy and manage the backup agents, jobs, and restores as though they are running on physical systems.

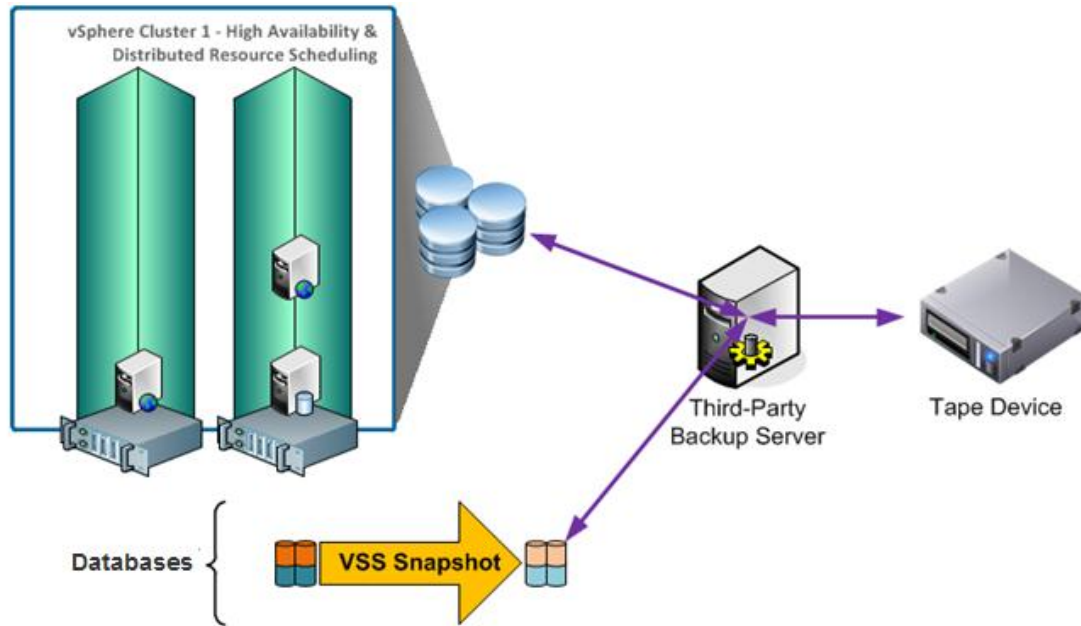
8.4.2 VMware Data Recovery

VMware® Data Recovery (VDR) protects your data at the virtual machine level, capturing application and system data as a full virtual machine image. VDR runs at the ESX/ESXi host level as a virtual appliance to provide streamlined deployment and full integration with VMware vCenter Server™. VDR stores multiple restore points for each virtual machine using deduplication technology, not only to provide point-in-time restore capabilities, but to efficiently use available disk space.

As most DBAs know, the use of a database-aware backup agent provides database health checking and log truncation. Though VDR can use the Volume Shadow Copy Service (VSS) framework to back up guest virtual machines it does not contain the required database VSS requestor to properly backup and restore a database. You can write custom scripts to involve the appropriate database VSS writer.

8.4.3 Array-based Backup Solutions

As is the case with the in-guest solutions, array-based solutions provided by many of the leading storage vendors continue to work with databases running VMware vSphere. Array-based backup solutions for SQL Server or Oracle use the VSS to produce near-instant, application-aware clones or snapshots of databases. These local clones or snapshots can then be backed up to disk, tape, or cloned offsite for disaster recovery purposes. Consult your storage vendor for guidance on array-based backup support in a virtualized environment.

Figure 10. Array-based Backup Solution

8.5 Manage Legacy Databases

Many organizations need to support applications for extended periods of time due to regulatory and compliance requirements, or for other reasons. DBAs are tasked to maintain those legacy database systems. Often, legacy applications are not able to run on newer hardware due to vendor support and/or compatibility issues. Older hardware may fail more frequently and equipment replacement may require more database downtime, which can adversely impact an organization's availability requirements and service level agreements.

VMware virtualization technology abstracts the operating system and application from the underlying hardware on which it runs. This helps to minimize the impact of hardware changes and enables organizations to benefit from the performance of the latest x86 platforms and derive cost savings from maintaining a unified set of latest generation servers.

9. Monitor and Troubleshoot Databases Performance

Virtualization adds new software layers and new types of interactions between the database and the hardware components. Though the general methodology for monitoring and troubleshooting database performance does not change, VMware provides additional tools for monitoring and troubleshooting at the physical host level.

9.1 Performance Monitoring Tools

When monitoring database performance, you can use the database virtual machine-level performance monitoring tools as the primary tools for identifying problem areas and resource bottlenecks. The methodologies are the same as performance monitoring a physical database server. VMware provides additional tools for host-level performance monitoring. You can further correlate performance data collected from the database virtual machine-level with data from the host-level. By focusing on key performance metrics you can quickly isolate issues to a particular resource area.

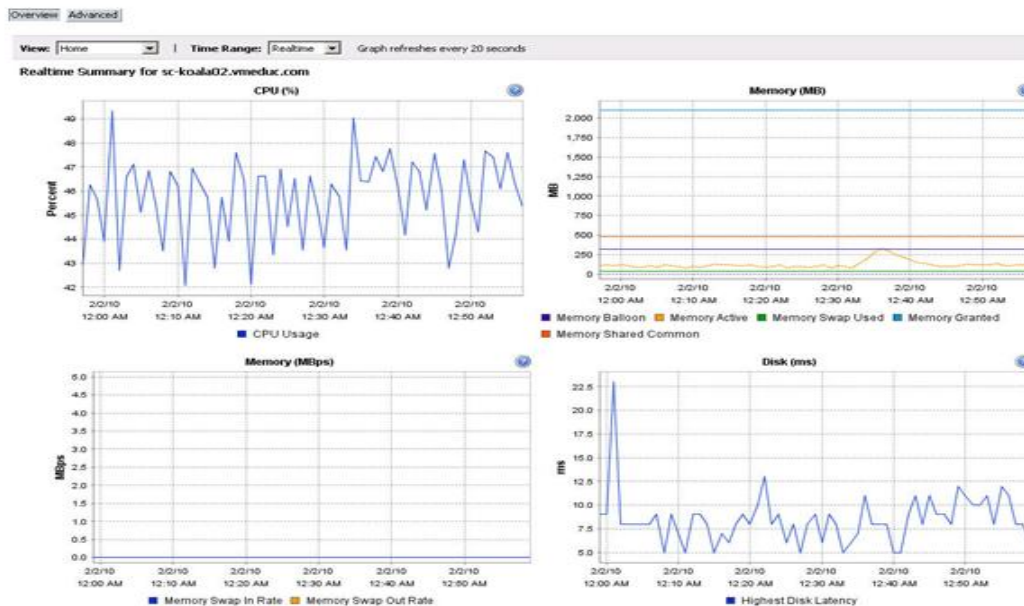
9.1.1 Host Level Monitoring Tools

vSphere provides two main tools for observing and collecting performance data: the vSphere Client, and the `esxtop` and `resxtop` utilities.

9.1.1.1 vSphere Client

The *vSphere Client* is a graphical interface tool that, when connected directly to an ESX/ESXi host, can display real-time performance data about the host and virtual machines. When connected to a VMware vCenter host, the vSphere Client can also display historical performance data about all of the hosts and virtual machines managed by that server. The advantages of the vSphere Client are that it is easy to use, provides access to the most important configuration and performance information, and does not require high levels of privilege to access the performance data. The vSphere Client is the primary tool for observing daily performance and configuration data for ESX/ESXi hosts.

Figure 11. Performance Chart Viewed with vSphere Client



9.1.1.2. esxstop and resxstop

The `esxstop` and `resxstop` utilities provide access to detailed performance data from a single ESX or ESXi host. `esxstop` is used with an ESX host. `resxstop` is used with an ESXi host. Beyond the performance metrics available through the vSphere Client, these utilities provide access to advanced performance metrics that are not available elsewhere. The advantages of `esxstop/resxstop` are the amount of available data and the speed with which they make it possible to observe a large number of performance metrics. The disadvantage of `esxstop/resxstop` is that they require root-level access privileges to the ESX/ESXi host. Use the `esxstop/resxstop` utilities for advanced troubleshooting when more detailed performance data is needed.

Figure 12. `resxstop` CPU Metrics

```

10:03:24am up 1 day 8:29, 115 worlds: CPU load average: 0.23, 0.26, 0.22
PCPU USED(%): 20.6 24.5 AVG: 22.6
PCPU UTIL(%): 21.3 25.1 AVG: 23.2
CCPU(%): 0 us, 3 sy, 97 id, 0 wa ; cs/sec: 119

```

| ID | GID NAME | NWLD | %USED | %RUN | %SYS | %WAIT | %RDY |
|----|--------------------|------|--------|--------|------|---------|-------|
| 1 | 1 idle | 2 | 154.99 | 157.03 | 0.00 | 0.00 | 43.00 |
| 2 | 2 system | 6 | 0.01 | 0.01 | 0.00 | 600.00 | 0.00 |
| 6 | 6 helper | 64 | 0.19 | 0.19 | 0.00 | 6400.00 | 0.12 |
| 7 | 7 drivers | 9 | 0.01 | 0.01 | 0.00 | 900.00 | 0.02 |
| 8 | 8 vmotion | 4 | 0.00 | 0.00 | 0.00 | 400.00 | 0.00 |
| 10 | 10 console | 2 | 3.04 | 3.34 | 0.00 | 195.87 | 0.82 |
| 15 | 15 vmkapiomod | 4 | 0.01 | 0.01 | 0.00 | 400.00 | 0.01 |
| 17 | 17 FT | 1 | 0.00 | 0.00 | 0.00 | 100.00 | 0.00 |
| 18 | 18 vobd.4209 | 8 | 0.00 | 0.00 | 0.00 | 800.00 | 0.00 |
| 19 | 19 vmware-vmkauthd | 1 | 0.00 | 0.00 | 0.00 | 100.00 | 0.00 |
| 24 | 24 cpuBurn-CLONE | 5 | 28.58 | 28.77 | 0.00 | 465.14 | 5.29 |
| 26 | 26 VM-for-StudentB | 4 | 4.20 | 4.21 | 0.00 | 395.05 | 0.81 |
| 27 | 27 VM-for-StudentA | 5 | 6.28 | 6.28 | 0.00 | 492.13 | 1.55 |

Type v to filter the output to show just virtual machines.

```

10:04:39am up 1 day 8:30, 115 worlds: CPU load average: 0.22, 0.26, 0.23
PCPU USED(%): 20.9 21.5 AVG: 21.2
PCPU UTIL(%): 21.7 22.4 AVG: 22.0
CCPU(%): 0 us, 1 sy, 99 id, 0 wa ; cs/sec: 76

```

```

v#view VM only

```

| ID | GID NAME | NWLD | %USED | %RUN | %SYS | %WAIT | %RDY |
|----|--------------------|------|-------|-------|------|--------|------|
| 24 | 24 cpuBurn-CLONE | 5 | 27.56 | 27.58 | 0.00 | 466.92 | 5.05 |
| 26 | 26 VM-for-StudentB | 4 | 4.56 | 4.56 | 0.00 | 394.52 | 0.87 |
| 27 | 27 VM-for-StudentA | 5 | 6.27 | 6.27 | 0.00 | 491.65 | 1.92 |

9.1.2 Database Virtual Machine-Level Monitoring Tools

Databases such as Microsoft SQL Server and Oracle provide a number of tools and utilities to assist with performance monitoring and tuning. For example, SQL Server Perfmon counters, SQL Server Dynamic Management Views (DMVs), and Oracle Statspack. In a virtualized database environment, these are still the primary tools for monitoring the internal health of the database system. However, DBAs should be aware that any time-based measurements reported from a virtual machine-level monitoring tool may not be accurate. The accuracy of in-guest tools depends on the guest OS and kernel version being used, and the total load of the VMware ESX/ESXi host.

For effective monitoring and troubleshooting a database performance problem in VMware, it's recommended that you focus on identifying performance bottlenecks instead of time-based measurements. For example, to troubleshoot a SQL Server performance issue, you may focus on the Process Queue Length for identifying a CPU bottleneck instead of looking at the counter for % Processor Time. Similarly, you can effectively identify a disk bottleneck if the Disk Queue Length is high and a high number of SQL Server users are waiting on `PAGEIOLATCH_EX`, `PAGEIOLATCH_SH`. After a resource bottleneck is identified on the database virtual machine, you can then correlate statistics collected from vSphere Client and `esxstop` or `resxstop` to identify any host level configuration issue that's affecting database virtual machine performance.

9.2 Key Performance Metrics on vSphere

The following table provides a list of key metrics for performance data exposed by vSphere that can help DBAs quickly isolate issues to a specific resource area such as CPU, memory, storage, or network. See VMware Communities: Interpreting esxtop Statistics (<http://communities.vmware.com/docs/DOC-9279>) and vCenter Performance Counters (<http://communities.vmware.com/docs/DOC-5600>) for a full list of counters.

Note The measurement units reported in `esxtop` or `resxtop` and vSphere Client may be different. See the above VMware community links for details.

| Resource | Metric (esxtop/resxtop) | Metric (vSphere Client) | Host/Virtual Machine | Description |
|----------|-------------------------|-------------------------|----------------------|---|
| CPU | %USED | Used | Both | CPU used over the collection interval (%) |
| | %RDY | Ready | Virtual Machine | CPU time spent in ready state |
| | %SYS | System | Both | Percentage of time spent in the ESX/ESXi Server VMKernel |
| Memory | Swapin, Swapout | Swapinrate, Swapoutrate | Both | Memory ESX/ESXi host swaps in/out from/to disk (per virtual machine, or cumulative over host) |
| | MCTLSZ (MB) | vmmemctl | Both | Amount of memory reclaimed from resource pool by way of ballooning |
| Disk | READs/s, WRITEs/s | NumberRead, NumberWrite | Both | Reads and Writes issued in the collection interval |
| | DAVG/cmd | deviceLatency | Both | Average latency (ms) of the device (LUN) |
| | KAVG/cmd | KernelLatency | Both | Average latency (ms) in the VMkernel, also known as "queuing time" |
| | GAVG/cmd | TotalLatency | Both | Average latency (ms) in the guest. GAVG = DAVG + KAVG |
| Network | MbRX/s, MbTX/s | Received, Transmitted | Both | Amount of data transmitted per second |
| | PKTRX/s, PKTTX/s | PacketsRx, PacketsTx | Both | Packets transmitted per second |
| | %DRPRX, %DRPTX | DroppedRx, DroppedTx | Both | Dropped packets per second |

Of the CPU counters, the total used time indicates system load. Ready time indicates overloaded CPU resources. A significant swap rate in the memory counters is a clear indication of a shortage of memory, and high device latencies in the storage section point to an overloaded or misconfigured array. Network traffic is not frequently the cause of most database performance problems.

10. Frequently Asked Questions

10.1 Common Questions from SQL Server DBAs

What is Microsoft's Support Policy for running SQL Server on VMware?

VMware ESX 3.5 Update 2 was the first hypervisor to be listed under the Microsoft Server Virtualization Validation Program (SVVP). This certification assures access to cooperative technical support from Microsoft and VMware if you run ESX 3.5 Update 2 or later (including vSphere), Windows Server 2008, and SQL Server 2005/2008. Additionally, if escalation is required, VMware can escalate mutual issues rapidly and work directly with Microsoft engineers to expedite resolution. With this support program in place customers can take advantage of the many benefits that come with virtualization of SQL Server on vSphere. For more information visit: <http://www.vmware.com/files/pdf/vmware-sql-support-licensing-guide-wp-en.pdf>.

Will SQL Server perform adequately on vSphere?

SQL Server is an excellent candidate for virtualization and runs at 85-95% of native performance. VMware conducted several performance studies with heavy workloads and aggressive consolidation densities to demonstrate the high performance of SQL Server virtual machines. For detailed performance information, see *Performance and Scalability of Microsoft SQL Server on VMware vSphere 4* at http://www.vmware.com/files/pdf/perf_vsphere_sql_scalability.pdf. Also, see customer success stories on <http://www.vmware.com/solutions/business-critical-apps/sql/resources.html>.

How do I properly size my environment for virtualization?

There is very little difference between sizing SQL Server virtual machines and sizing physical SQL Servers. Follow Microsoft guidelines and take into account application requirements. As you begin to understand the performance characteristics of the environment, you can instantly adjust processor and memory with VMware Hot-add (Windows and SQL Server 2008 only). For details on sizing and deployment guidelines, see the *Microsoft SQL Server on VMware Best Practices Guide* at http://www.vmware.com/files/pdf/sql_server_best_practices_guide.pdf.

Do I need to learn a new skill set in order to deploy SQL Server on VMware?

The successful deployment of SQL Server on VMware virtual infrastructure is not significantly different from deploying SQL Server on physical servers. 98 percent Most of SQL Server database physical tuning and optimization is directly applicable to the virtual world. DBAs can fully leverage their current skill set, while delivering all the benefits associated with virtualization.

What are my licensing options for SQL Server on vSphere?

SQL Server virtual machines can be licensed at the virtual machine level by vCPU or at the host level by pCPU. Licensing can be a complex topic. Refer to the *SQL Server on VMware – Support and Licensing Guide* (<http://www.vmware.com/files/pdf/vmware-sql-support-licensing-guide-wp-en.pdf>) for specific usage scenarios.

Do I need additional SQL Server licenses for vMotion or DRS?

Microsoft has updated its licensing policy for over 40 server applications, including SQL Server, to more effectively accommodate their use in a virtual environment. The application licenses are still tied to a physical server, but Microsoft has removed the clause that had restricted reassignment of an application license between servers to once every 90-days for SQL Server Enterprise and Data Center editions. The new amendment allows customers to more freely reassign application licenses to from one server to another, effectively removing the need for an excessive number of application licenses to remain compliant while performing virtual machine migration (vSphere vMotion) and providing high availability in a virtual environment (vSphere HA). Additional information can be found in the *Microsoft Application Server License Mobility Brief* at:

http://download.microsoft.com/download/3/d/4/3d42bdc2-6725-4b29-b75a-a5b04179958b/Application_Server_License_Mobility_VL_Brief.doc.

How do I know my SQL Server is running on a virtual machine?

As of ESX 3.0 and later, vSphere integrates virtual machine performance counters into Windows Perfmon. The installation of VMware Tools installs two performance objects along with various associated counters. You can identify SQL Server running in vSphere by checking counters for VM Memory and VM Processor in Windows Perfmon.

10.2 Common Questions from Oracle DBAs**Do we need special skills to deploy Oracle Databases on VMware?**

No. Oracle DBAs can use their current skill set to deploy oracle databases on VMware just as they do when deploying to physical servers. Database owners can create faithful replicas of production systems for patch testing and seamlessly transition updated system configurations across testing, staging, and production environments connected to different networks, server, and storage systems. DBAs can fully leverage their current skill set, while delivering all of the benefits associated with virtualization.

Oracle Databases are too resource-intensive. Do they perform well on VMware vSphere?

Database workloads are widely acknowledged to be extremely resource-intensive, and they perform well on a VMware vSphere. Virtualization enables Oracle database administrators to meet their performance goals. See the performance study white paper, *Virtualizing Performance-Critical Database Applications in VMware vSphere* (http://vmware.com/pdf/Perf_ESX40_Oracle_eval.pdf).

VMware vSphere enables the deployment of multiple virtual machines running different Oracle database solutions on the same physical server, resulting in increased CPU utilization and reduction in overall server requirements. There is a workload characterization effort conducted by Cisco, EMC and VMware to profile an OLTP workload against virtualized Oracle databases (version 11gR2) on VMware vSphere ESXi 4.1 in various single and multi-virtual machine configurations. See the workload characterization study white paper, *Oracle Databases on VMware – Workload characterization study* (http://vmware.com/files/pdf/partners/oracle/Oracle_Databases_on_VMware_-_Workload_Characterization_Study.pdf). Also see customer success stories on <http://www.vmware.com/solutions/partners/alliances/oracle-database-customers.html>.

Does VMware provide best practices and availability guidelines for deploying Oracle databases on VMware vSphere?

Yes. VMware provides both best practices and availability guidelines. Information about best practice guidelines for deploying Oracle databases on VMware vSphere are available in *Oracle Databases on VMware – Best Practices Guide* (http://vmware.com/files/pdf/partners/oracle/Oracle_Databases_on_VMware_-_Best_Practices_Guide.pdf). High availability scenarios designed to protect a VMware virtualized Oracle database to minimize downtime within the same datacenter are provided in *Oracle Database on VMware – High Availability Guide* (http://vmware.com/files/pdf/partners/oracle/Oracle_Databases_on_VMware_-_High_Availability_Guidelines.pdf)

How do I migrate Oracle databases from UNIX to Linux (x86)?

Endianness is the byte ordering of blocks in a file system, which differs between host operating systems. Platforms such as Linux, Windows, OpenVMS, and Tru64 are small endian platforms, and Solaris, HP-UX (Intel IA64 and PA-RISC), AIX, IBM zSeries-based Linux, and IBM Power-based Linux are big endian platforms.

For example, Solaris SPARC is big endian and Solaris x86 is little endian. They are not compatible and copying related files will not work. Conversion is a straightforward matter; the document MyOracleSupport DocID 243303.1 describes the migration process. Essentially, the DBA uses Transportable Tablespaces to create an export of the metadata and then uses RMAN to convert the datafiles to the correct endian. For Oracle, this is a very well-understood process.

As proof of this, VMware is showcasing successful RISX/UNIX to x86 migrations for vSphere. We have an excellent case study showing the move from Power/AIX to Linux/vSphere for Oracle at Indiana University. The details of that successful customer migration can be found at <http://www.vmware.com/a/customers/customer/610/Indiana+University>.

What is the Oracle Support Policy for running Oracle Databases on VMware vSphere?

Oracle's support note 249212.1 for VMware, published in MyOracleSupport, defines Oracle's policy for supporting applications on VMware. This support policy is very similar to the types of support provided by other ISVs. Based on our experience with many VMware customers running Oracle in production on VMware, what it comes down to is that Oracle's support organization will provide support when customers call.

The following are facts from Oracle's support statement:

- Oracle will accept support requests on VMware for bugs already known to Oracle.
- Oracle may accept support requests on VMware for bugs that are not seen by Oracle as being caused by virtualization.
- Oracle maintains the right to require physical reproduction if they suspect VMware is "at fault." This applies for any vendor.
- Oracle RAC support is now included for 11.2.0.2 and above (Updated Nov 8, 2010).

VMware Technology and System Integration partners also have support commitments for Oracle on VMware. For examples, see the following support statements:

- [VMware Oracle Support Policy: https://www.vmware.com/support/policies/oracle-support.html](https://www.vmware.com/support/policies/oracle-support.html)
- [Technology Partner for Oracle Support - EMC: http://www.emc.com/solutions/application-environment/oracle/oracle-virtualization-vmware.htm](http://www.emc.com/solutions/application-environment/oracle/oracle-virtualization-vmware.htm)
- [Service and Integration Partner for Oracle Support – House of Brick: http://www.houseofbrick.com/oracle-on-vmware](http://www.houseofbrick.com/oracle-on-vmware)

How to deploy Oracle 11gr2 RAC on VMware vSphere using VMFS?

The multi-writer option allows VMFS-backed disks to be shared by multiple virtual machines. Follow VMware KB article [1034165](http://www.vmware.com/kb/1034165) ("Disabling simultaneous write protection provided by VMFS using the multi-writer flag" to deploy RAC on VMFS. Oracle RAC on VMware vSphere Deployment Guide can be accessed from <http://www.vmware.com/files/pdf/partners/oracle/vmware-oracle-rac-deploy-guide.pdf>

11. Conclusion

Running databases on the VMware virtualization platform provides many benefits not available on physical machines. By decoupling the application from the physical hardware, the VMware virtualization platform addresses challenges such as scalability, high availability, and resource isolation that typically exist in the physical environment. VMware features and tools significantly improve DBA productivity by simplifying daily database administration tasks for the design, implementation, testing, operation, and maintenance of databases.

For more information:

- Visit <http://www.vmware.com/solutions/business-critical-apps/sql> for more information about virtualizing Microsoft SQL Server databases on VMware.
- Visit <http://www.vmware.com/solutions/partners/alliances/oracle-database.html> for more information about virtualizing Oracle databases on VMware,