SOLUTION READINESS

Microsoft® SQL Server on VMware® Best Practices Guide

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1. Introduction

1.1 Overview

Microsoft® SQL Server is one of the most widely deployed database platforms in the world, with many organizations having dozens or even hundreds of instances deployed in their environments. The flexibility of SQL Server, with its rich application capabilities combined with the low costs of x86 computing, has led to an explosion of SQL Servers ranging from large data warehouses to small, highly specialized departmental and application databases. The flexibility at the database layer translates directly into application flexibility, giving end-users more useful application features and ultimately improving productivity.

But, application flexibility comes at a cost to operations. As the number of applications in the enterprise continues to grow, an increasing number of SQL Servers are brought under lifecycle management. Each application has its own set of requirements for the database layer, resulting in multiple versions, patch levels, and maintenance processes. For this reason, many application owners insist on having a SQL Server dedicated to their application. As application workloads vary widely, many of these SQL Servers are allocated more hardware than they need, while others are starved for compute resources.

The challenge for the administrator is to provide database services to application owners with the flexibility and autonomy they expect while keeping the infrastructure as simple and economical as possible. The proliferation of large, multi-socket, multi-core servers has led many organizations to attempt traditional database consolidation, moving small databases into large shared database environments. Migrating to such a model can be an extremely complex endeavor requiring in-depth application remediation at the forefront and rigorous attention to operational processes once implemented for version control and continued application compatibility.

Virtualizing Microsoft SQL Server with VMware vSphere™ can allow the best of both worlds, simultaneously optimizing compute resources through server consolidation and maintaining application flexibility through role isolation. SQL Servers can be migrated in their current state without expensive and error-prone application remediation and without changing operating system or application version or patch level. For high performance databases, VMware and partners have demonstrated the capabilities of vSphere to run the most challenging SQL Server workloads. For smaller, specialized databases, vSphere offers high consolidation ratios and advanced resource scheduling features, giving application owners the flexibility and performance they need while simplifying and lowering costs for the enterprise.

As an added bonus, SQL Server virtual machines (VMs) are much easier to manage than physical servers. For example, VMware vMotion™ can help to reduce the impact of business or infrastructure changes by migrating live virtual machines to another physical server in case of hardware changes or upgrades, without interrupting the users or their applications. VMware DRS can be used to dynamically balance SQL Server workloads and VMware HA and FT can provide simple and reliable protection for SQL Server virtual machines. VMware vSphere is the key to satisfying your organization's need for a rich application environment reliant on flexible database services while simultaneously providing substantial cost savings and unprecedented management capabilities.

1.2 Purpose

This guide provides best practice guidelines for deploying Microsoft SQL Server on vSphere. The recommendations in this guide are not specific to any particular set of hardware or to the size and scope of any particular SQL Server implementation. The examples and considerations in this document provide guidance only and do not represent strict design requirements, as varying application requirements would force a near infinite number of valid configuration possibilities.

1.3 Target Audience

This guide assumes a basic knowledge and understanding of Vmware vSphere and SQL Server.

- Architectural staff can reference this document to gain an understanding of how the system will work as a whole as they design and implement various components.
- Engineers and administrators can use this document as a catalog of technical capabilities.
- DBA staff can reference this document to gain an understanding of how SQL might fit into a virtual infrastructure.
- Management staff and process owners can use this document to help model business processes to take advantage of the savings and operational efficiencies achieved with virtualization.

1.4 Scope

The scope of this document is limited to the following topics:

- **VMware ESX™ Host Best Practices for SQL Server** – This section provides best practice guidelines for properly preparing the vSphere platform to run SQL Server. This section includes guidance in the areas of CPU, memory, storage, and networking.
- **SQL Server Performance on vSphere** – This section provides background information on SQL Server performance in a virtual machine. It also provides guidelines for conducting and measuring internal performance tests.
- **Migrating SQL Server to vSphere** – From requirements gathering to performance baselining, this section discusses migration and consolidation of SQL Server instances to the vSphere platform.
- **vSphere Enhancements for Deployment and Operations** – This section provides a brief look at vSphere features and add-ons that enhance deployment and management of SQL Server.

The following topics are out of scope for this document, but may be addressed in other documentation in this Solution Kit:

- **Availability and Recovery Options** – Although this Best Practices Guide briefly covers VMware features that can enhance availability and recovery, a more in-depth discussion of this subject is covered in the *Microsoft SQL Server on VMware: Availability and Recovery Options* document included in this Solution Kit.
- **Support and Licensing** – This information can be found in the *Microsoft SQL Server on VMware: Support and Licensing Guide* included in this Solution Kit. All information in this section is based on the most current Microsoft material at the time of this writing and is subject to change without notice.

It is important to note that this and other guides in this Solution Kit are limited in focus to deploying SQL Server on vSphere. SQL Server deployments cover a wide subject area, and SQL Server design principles should *always* follow Microsoft guidelines for best results.

2. VMware ESX Host Best Practices for SQL Server

A solidly designed ESX host platform is crucial to the successful implementation of enterprise applications such as SQL Server. Before we address best practices specific to the SQL Server application, the following sections outline general best practices for designing your ESX hosts.

2.1 General Guidelines

The following sections discuss general best practice guidelines.

2.1.1 Use vSphere or VMware Infrastructure 3

VMware Server, VMware Workstation, and even VMware Fusion are hosted products and are all technically capable of running SQL Server. However, we strongly recommend using the VMware enterprise-class hypervisor, ESX or the free version ESXi, to deploy any virtualized SQL Server instances, even for development and test environments. When using the hosted products, depending on configurations and guest OS support, the disk IO caching performed by the host operating system can provide unpredictable performance and application availability results under specific conditions.

2.1.2 Use Recent Hardware

x86-based servers and storage systems continue to become more capable than ever, with ever-decreasing costs. With support for multi-core CPUs, larger processor caches, and hundreds of gigabytes of RAM, x86-based servers can now rival mainframe systems. Furthermore, both Intel and AMD have made significant improvements in the performance of hardware-assisted virtualization, allowing virtualized workloads to achieve near-native performance. These hardware advances can significantly alleviate CPU, memory, and disk IO bottlenecks when consolidating SQL Server VMs on an ESX host.

- Follow SQL Server Best Practices. Microsoft offers extensive best practices for deploying SQL Server. Best practices are documented on Microsoft TechNet in SQL Server TechCenter http://technet.microsoft.com/en-us/sqlserver/bb671430.aspx. These best practices are based on real world guidelines and expert tips, and should be followed for virtual SQL Server deployments as well.
- The ESX hosts should be sized with adequate capacity to provide resources for all the running virtual machines and have enough headroom to account for the normal workload variability. This is especially important when the various virtual machines exhibit similar workload profiles, and are likely to bottleneck in contention for the same resources.

2.2 CPU Configuration Guidelines

The SQL Server virtual machine configuration usually depends upon the specific database profile. A thorough virtualization exercise greatly simplifies VM sizing. In general, the guidelines discussed in the following sections apply.

2.2.1 Physical and Virtual CPUs

VMware uses the terms *virtual CPU* (vCPU) and *physical CPU* (pCPU) to distinguish between the processors within the virtual machine and the underlying physical x86/x64-based processor cores. Virtual machines with more than one virtual CPU are also called *symmetric multi-processing* (SMP) virtual machines. The *virtual machine monitor* (VMM) is responsible for virtualizing the CPUs. When a virtual machine starts running, control transfers to the VMM, which is responsible for virtualizing guest OS instructions.

2.2.2 Virtual SMP

VMware *Virtual Symmetric Multi-processing* (Virtual SMP) enhances virtual machine performance by enabling a single virtual machine to use multiple physical processor cores simultaneously. vSphere supports use of up to eight virtual CPUs per virtual machine. The biggest advantage of an SMP system is the ability to use multiple processors to execute multiple tasks concurrently, thereby increasing throughput (for example, the number of transactions per second). Only workloads that support parallelization (including multiple processes or multiple threads that can run in parallel) can really benefit from SMP.

The virtual processors from SMP-enabled virtual machines are co-scheduled. That is, if physical processor cores are available, the virtual processors are mapped one-to-one onto physical processors and are then run simultaneously. In other words, if one vCPU in the virtual machine is running, a second vCPU is co-scheduled so that they execute nearly synchronously. The following points should be considered when using multiple vCPUs:

- Simplistically, if multiple, idle physical CPUs are not available when the virtual machine wants to run, the virtual machine remains in a special wait state. The time a virtual machine spends in this wait state is called *ready time*.
- Even idle processors perform a limited amount of work in an operating system. In addition to this minimal amount, the ESX host manages these idle processors, resulting in some additional work by the hypervisor. These low-utilization vCPUs compete with other vCPUs for system resources.

In VMware vSphere 4, the CPU scheduler has undergone several improvements to provide better performance and scalability. For details, see the paper *VMware vSphere 4: The CPU Scheduler in VMware ESX 4*. For example, in ESX 4, the relaxed co-scheduling algorithm has been refined so that scheduling constraints due to co-scheduling requirements are further reduced. These improvements have resulted in better linear scalability and performance of SQL workloads, as described in the Section 3 of this document, while reducing inefficiencies introduced by idle vSMP virtual machines. Consequently, in vSphere, the larger 4-way and 8-way virtual machines exhibit great scalability and are a much more viable option if there is a requirement to scale up versus scale out.

2.2.3 Allocating CPU to SQL Server Virtual Machines

VMware recommends the following practices for allocating CPU to SQL Server virtual machines:

- **Start with a thorough understanding of your workload.** Database server utilization varies widely by application and deployment topology. If the application is commercial, be sure to follow published guidelines where appropriate. If the application is custom-written, work with the application developers to determine resource requirements. VMware Capacity Planner can analyze your current environment and provide resource utilization metrics that can aid in the sizing process.
- **If the exact workload is not known, start with fewer virtual CPUs and increase the number later if necessary.** Only allocate multiple vCPUs to a virtual machine if the anticipated SQL workload can truly take advantage of all the vCPUs. Over-provisioning vCPUs may result in higher virtualization overhead. VMware performance testing for SQL Server has shown that even a single vCPU VM can support high transaction throughput and may be enough for many SQL Server databases.
- **For tightly-controlled, highly-consolidated production environments, be sure to account for some virtualization overhead (8%-15%, depending on the workload).** If you leave enough CPU headroom to account for this additional CPU utilization, you can achieve transaction throughput rates that are on par with physical SQL Servers.
- **In Windows Server 2003 guests, when using single-processor virtual machines, configure with a UP HAL (hardware abstraction layer) or kernel.** Multi-processor virtual machines must be configured with an SMP HAL/kernel. Windows Server 2008 will automatically select the HAL appropriate for the underlying hardware.

- **When consolidating multiple virtual machines on single ESX host, proper hardware sizing is critical for optimal performance.** You should make sure that cumulative physical CPU resources on a host are adequate to meet the needs the guest VMs by testing your workload in the planned virtualized environment. CPU over-commitment should be carefully planned around factual performance data to avoid adversely affecting VM performance. For performance-critical SQL Server virtual machines (production systems), make sure that sufficient CPU resources are available, and CPU over-commitment is not the reason for any performance degradation.
- **Install the latest version of VMware Tools in the guest operating system.** Be sure to update VMware Tools after each ESX upgrade.
- **To leverage vMotion for your virtual deployment, you must verify CPU compatibility constraints that make vMotion possible only between certain revisions of CPUs.** For further details, refer the white paper *VMware VMotion and CPU Compatibility*.

2.3 Memory Configuration Guidelines

This section provides guidelines for allocation of memory to SQL Server virtual machines. The guidelines outlined here take into account vSphere memory overhead and the virtual machine memory settings.

2.3.1 ESX Memory Management Concepts

vSphere virtualizes guest physical memory by adding an extra level of address translation. Hardware-assisted virtualization technologies can make it possible to provide this additional translation with little or no overhead. Managing memory in the hypervisor enables the following:

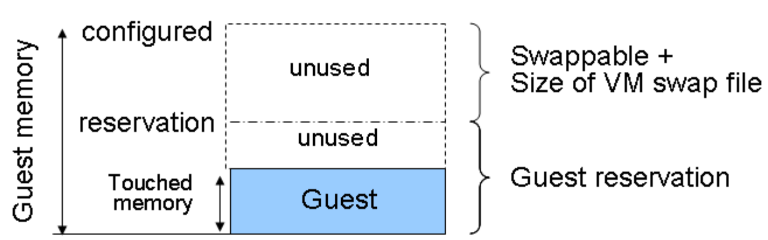
- Memory sharing across virtual machines that have similar data (i.e., same guest operating systems)
- Memory over-commitment, which means allocating more memory to virtual machines than is physically available on the ESX host. Over-commitment is not necessarily a bad thing. Many customers can achieve high levels of consolidation and efficiency using it. However, over-commitment must be carefully monitored to avoid negative performance impact.
- A memory balloon technique, whereby virtual machines that do not need all the memory they have been allocated give memory to virtual machines that require additional allocated memory

For more details about vSphere memory management concepts, consult the *VMware vSphere Resource Management Guide*.

2.3.2 Virtual Machine Memory Concepts

Figure 1 illustrates the use of memory settings parameters in the virtual machine.

Figure 1. Virtual Machine Memory Settings



The vSphere memory settings for a virtual machine include the following parameters:

- Configured memory = memory size of virtual machine assigned at creation.
- Touched memory = memory actually used by the virtual machine. vSphere only allocates guest operating system memory on demand.
- Swappable = virtual machine memory that can be reclaimed by the balloon driver or by vSphere swapping. Ballooning occurs before vSphere swapping. If this memory is in use by the virtual machine (i.e., touched and in use), the balloon driver causes the guest operating system to swap. Also, this value is the size of the per-virtual machine swap file that is created on the VMware Virtual Machine File System (VMFS) file system (.vswp file).
- If the balloon driver is unable to reclaim memory quickly enough, or is disabled or not installed, vSphere forcibly reclaims memory from the virtual machine using the VMkernel swap file.

2.3.3 Allocating Memory to SQL Server Virtual Machines

As SQL Server workloads can be memory-intensive and performance is often a key factor (especially in production environments), VMware recommends the following practices:

- **Start with a thorough understanding of your workload.** The amount of memory you need for a SQL Server virtual machine depends on the database workload you plan to host in that virtual machine. A thorough VMware Capacity Planner™ exercise can easily help determine memory needed by a SQL Server virtual machine.

  VMware Capacity Planner is an IT capacity planning tool that collects comprehensive resource utilization data in heterogeneous IT environments, and compares it to industry standard reference data to provide analysis and decision support modeling. Additional information about Capacity Planner is available at http://www.vmware.com/products/capacity-planner/overview.html.
- **Enable Memory Page Sharing and Memory Ballooning.** ESX provides optimizations such as memory sharing and memory ballooning to reduce the amount of physical memory used on the underlying host. In some cases these optimizations can save more memory than is taken up by the virtualization overhead.
- **Database performance is heavily dependent on the amount of memory available.** A common tuning technique is to increase the database buffer cache to reduce or avoid disk I/O and thus improve SQL Server performance. vSphere supports up to 255GB of memory per virtual machine. This enables you to configure SQL Server databases with large in-memory caches for better performance.
- **Ensure that cumulative physical memory available on a server is adequate to meet the needs of the virtual machines by testing target workloads in the virtualized environment.** Memory over-commitment should not adversely affect virtual machine performance as long as the actual virtual machine memory requirements are less than the total memory available on the system. For performance-critical SQL Server virtual machines (production systems), make sure that sufficient memory resources are available and that memory over-commitment is not causing any performance degradation. If memory is overcommitted on the host, set reservations for performance-critical SQL Server virtual machines to guarantee that the memory for those virtual machines is not ballooned or swapped out.
- **If you set the SQL Server lock pages in memory parameter, be sure to set the virtual machine's reservations to match the amount of memory you set in the virtual machine configuration.** This setting can interfere with the ESX balloon driver. Setting reservations stops the balloon driver from inflating into the virtual machine's memory space.

- **To avoid performance latency resulting from remote memory accesses, you should size a SQL Server virtual machine's memory so it is less than the amount available per NUMA node.** Both ESX and SQL Server support NUMA. As with SQL Server, vSphere has intelligent, adaptive NUMA scheduling and memory placement policies that can manage all virtual machines transparently, so you do not need to deal with the complexity of manually balancing virtual machines among nodes.
- **vSphere supports** *large pages* **in the guest operating system.** If the operating system or application can benefit from large pages on a native system, that operating system or application can potentially achieve a similar performance improvement in a virtual machine. The use of large pages results in reduced memory management overhead and can therefore increase hypervisor performance. For details, refer to http://www.vmware.com/files/pdf/large_pg_performance.pdf

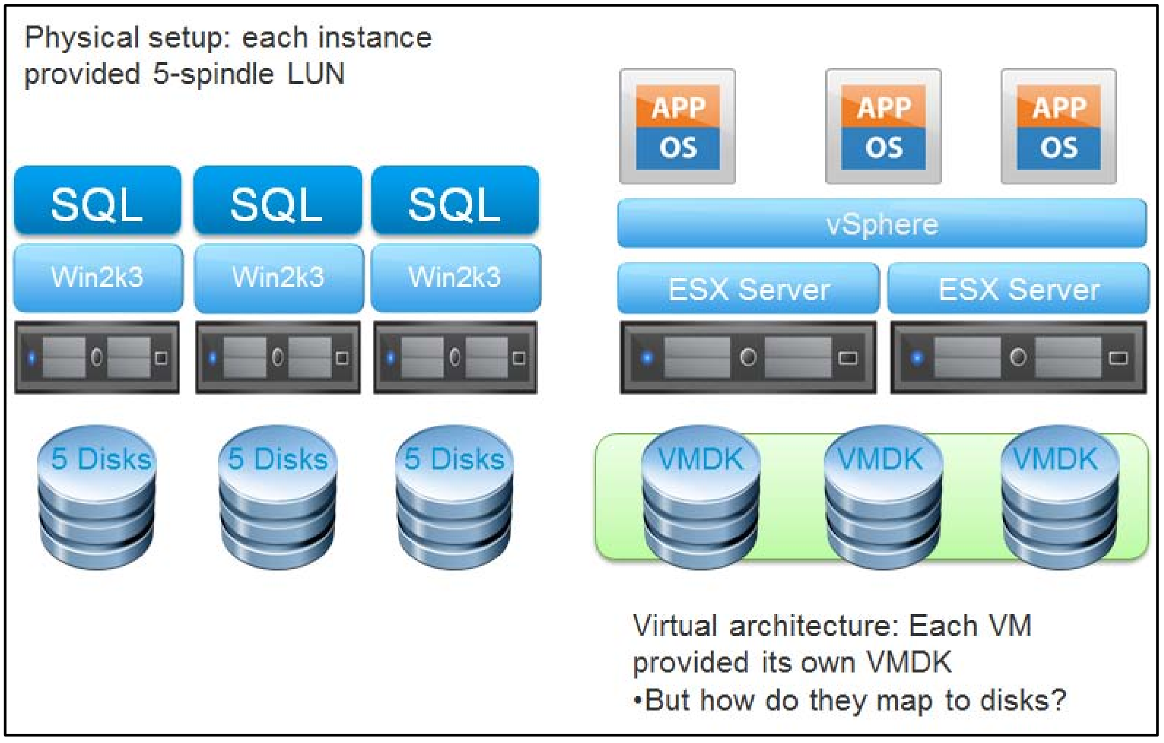
2.4 Storage Configuration Guidelines

Storage configuration is critical to any successful database deployment, especially in virtual environments where you may consolidate many different SQL Server workloads on a single ESX host. Your storage subsystem should provide sufficient I/O throughput as well as storage capacity to accommodate the cumulative needs of all virtual machines running on your ESX hosts.

Most traditional physical SQL Server environments created many islands of information. When you move to virtualized SQL Server deployments, a shared storage model strategy provides many benefits, such as more effective storage resource utilization, reduced storage white space, better provisioning, and mobility using VMware vMotion and VMware Storage vMotion.

Most SQL Server performance issues in virtual environments can be traced to improper storage configuration. Microsoft provides a Web page about best practices for SQL Server storage configuration entitled *Storage Top 10 Best Practices*. Be sure to follow these along with the best practices in this guide.

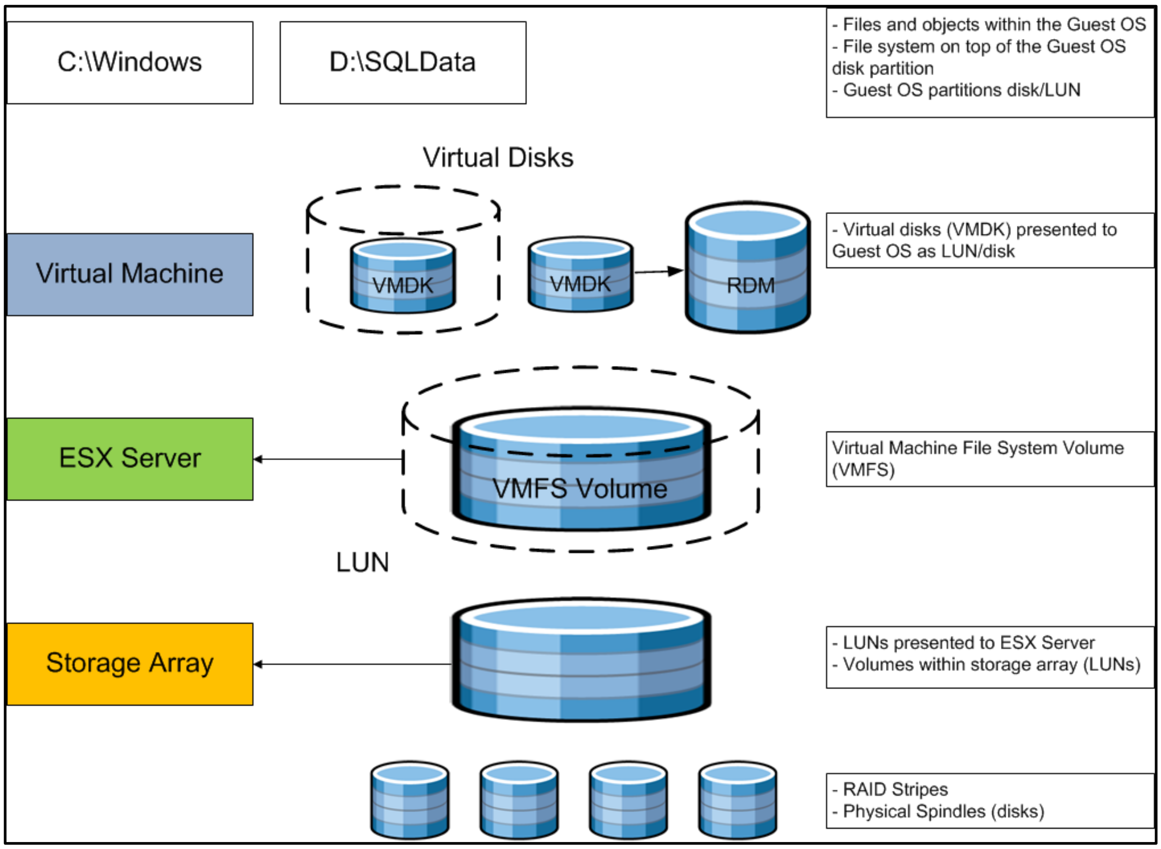
Figure 2. Keep Spindle Count Consistent When Migrating from Physical to Virtual



2.4.1 Storage Virtualization Concepts

As illustrated in Figure 3, VMware storage virtualization can be categorized into three layers of storage technology. The storage array is the bottom layer, consisting of physical disks presented as logical disks (storage array volumes or LUNs) to the layer above, with the virtual environment occupied by vSphere. Storage array LUNs that are formatted as VMFS volumes in which virtual disks can be created. Virtual machines consist of virtual disks that are presented to the guest operating system as disks that can be partitioned and used in file systems.

Figure 3. VMware Storage Virtualization Stack



2.4.1.1. VMware Virtual Machine File System (VMFS)

VMFS is a cluster file system that provides storage virtualization optimized for virtual machines. Each virtual machine is encapsulated in a small set of files and VMFS is the default storage system for these files on physical SCSI disks and partitions. VMware supports Fibre-Channel and iSCSI protocols for VMFS.

2.4.1.2. Raw Device Mapping

VMware also supports Raw Device Mapping (RDM). RDM allows a virtual machine to directly access a volume on the physical storage subsystem, and can only be used with Fibre Channel or iSCSI. RDM can be thought of as providing a symbolic link from a VMFS volume to a raw volume. The mapping makes volumes appear as files in a VMFS volume. The mapping file, not the raw volume, is referenced in the virtual machine configuration.

2.4.2 VMFS versus RDM for SQL Server

2.4.2.1. Performance

VMware is often asked, which offers better performance, VMFS or RDM? The answer depends on the specific workload, but this section and the associated white paper can help in the decision making process.

From a performance perspective, both VMFS and RDM volumes can provide similar transaction throughput. We've summarized some of our performance testing below, but for more details, refer to the *Performance Characterization of VMFS and RDM Using a SAN* white paper.

Figure 4. Random Mixed (50% read/50% write) I/O Operations per Second (higher is better) (link)

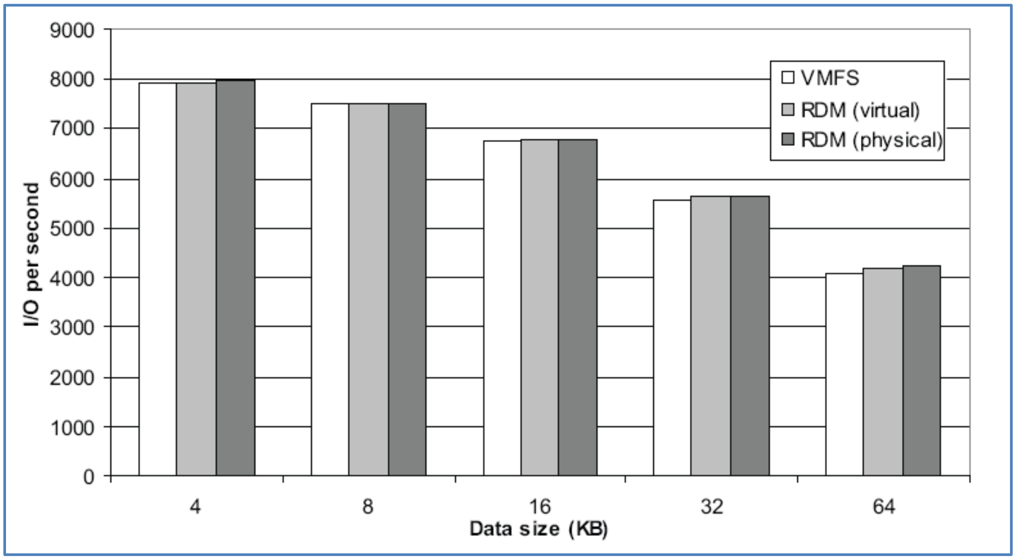
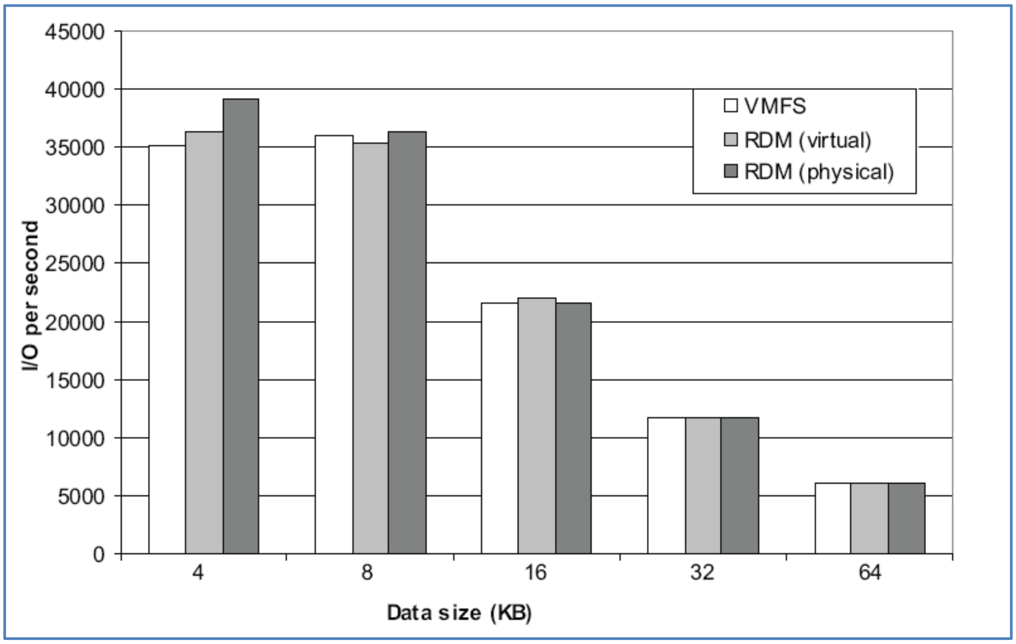


Figure 5. Sequential Read I/O Operations per Second (higher is better) (link)



2.4.2.2. Functionality

There are no concrete recommendations for using VMFS or RDM in SQL Server deployments, although the following table summarizes some of the options and trade-offs. For a more complete discussion, please consult the *VMware SAN System Design and Deployment Guide*.

Table 1. VMFS and Raw Disk Mapping Trade-offs

VMFS	RDM
• Volume can host many virtual machines (or can be dedicated to one virtual machine). • Increases storage utilization, provides better flexibility, easier administration and management. • Large third-party ecosystem with V2P products to aid in certain support situations. • Does not support quorum disks required for third-party clustering software. • Fully supports VMware vCenter™ Site Recovery Manager (SRM).	• Maps a single LUN to one virtual machine so only one virtual machine is possible per LUN. • More LUNs are required, so it is easier to reach the LUN limit of 256 that can be presented to an ESX host. • Uses RDM to leverage array-level backup and replication tools integrated with SQL Server databases. • RDM volumes can help facilitate migrating physical SQL Server instances to virtual machines. • Required for third-party clustering software (e.g., MSCS). Cluster data and quorum disks should be configured with RDM. • Some customers use RDMs for SQL Server databases and logs to guarantee that no other VMs are provisioned to those LUNs. • Fully supports VMware vCenter Site Recovery Manager.

2.4.2.3. Allocating Disk to SQL Server Virtual Machines

Consider the following use cases for VMFS and RDM:

- Where existing systems already make use of third-party storage management software, RDM can be used to leverage practices based on these products such as storage-based backups to disk.
- RDM is required when using third-party clustering software.
- RDM is useful for migrating between physical servers and virtual machines. Running the database on an RDM volume gives an administrator the option of pointing both virtual machines and physical servers to the same storage.
- Deploying multiple, non-production SQL Server systems on VMFS facilitates easier management and administration of template cloning, snapshots, and storage consolidation.
- A mixed storage configuration is viable for a SQL Server virtual machine. The guest OS is installed on VMFS, and the SQL Server database and log files on RDM. VMware template cloning can be used for the guest OS and database files can be managed by third-party storage management software.
- Database datafiles should be spread out over multiple LUNs, similar to those in native setups, following the storage vendor or ISV guidelines for database layout, LUN and spindle configuration.
- Maintain a 1:1 mapping between the number of virtual machines and LUNs to avoid any disk I/O contention.

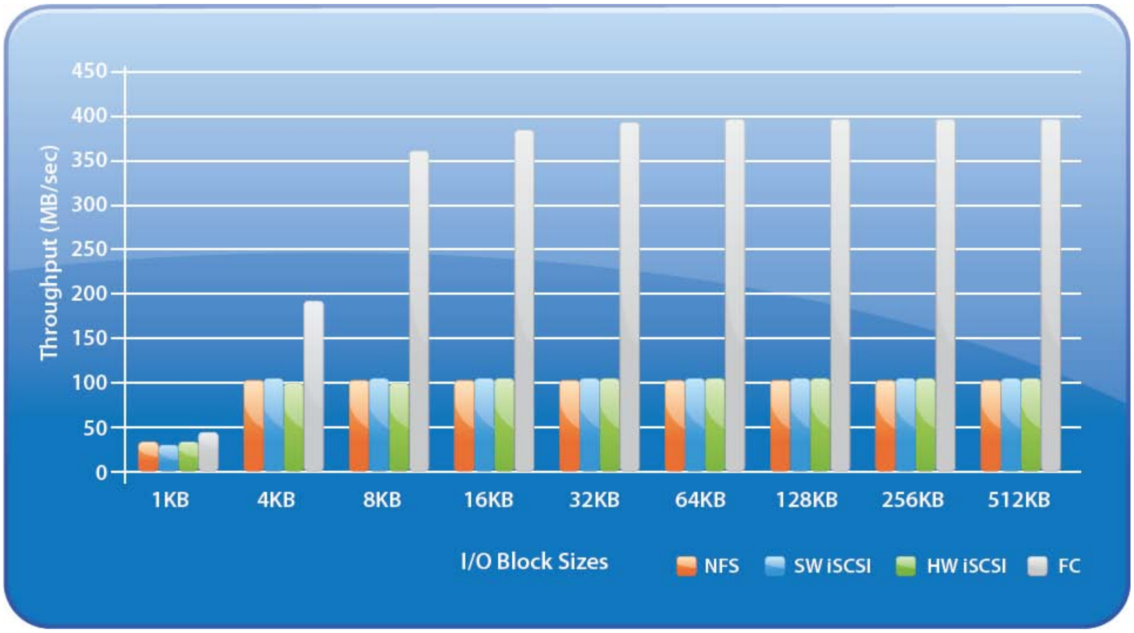
- Create VMDK files as `eagerzeroedthick` by either using `vmkfstools` or checking the **enable for fault tolerance** check box from within vCenter.
- Follow the guidelines in the "Hardware Storage Considerations" and "Guest Operating Systems" sections of *Performance Best Practices for VMware vSphere 4*.

2.4.3 Storage Protocol Selection

There are three storage protocol options available to SQL Servers running on vSphere: Fibre Channel, iSCSI, and NFS. During its testing, VMware has found that wire speed is the limiting factor for I/O throughput when comparing the storage protocols. VMware ESX can reach the link speeds in single VM environment, and also maintain the throughput up to 32 concurrent virtual machines for each storage connection option supported. For details, refer to the *Comparison of Storage Protocol Performance in VMware vSphere 4* white paper. Fibre Channel may provide maximum I/O throughput, but iSCSI and NFS may offer a better price-performance ratio.

Figure 6 shows for each of the storage protocols the sequential read throughput (in MB/sec) of running a single virtual machine in a standard workload configuration for different I/O block sizes.

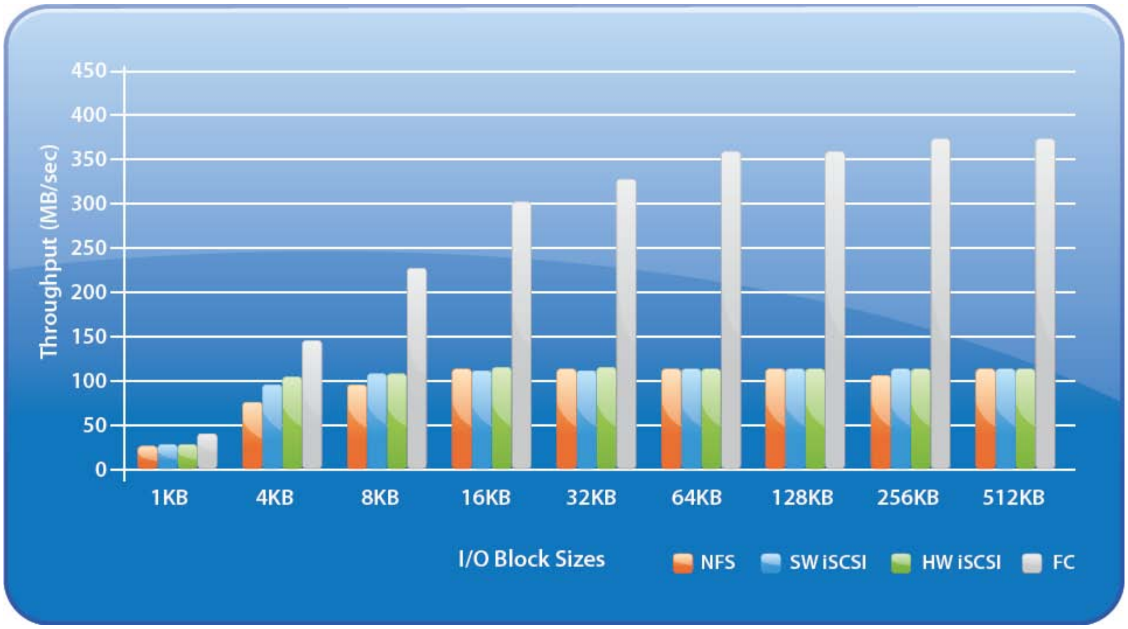
Figure 6. Read Throughput for Different I/O Block Sizes (link)



For Fibre Channel, read throughput is limited by the bandwidth of the 4Gb Fibre Channel link for I/O sizes at or above 64KB. For IP-based protocols, read throughput is limited by the bandwidth of the 1Gb Ethernet link for I/O sizes at or above 32KB.

Figure 7 shows for each of the storage protocols the sequential write throughput (in MB/sec) of running a single virtual machine in a standard workload configuration for different I/O block sizes.

Figure 7. Write Throughput for Different I/O Block Sizes (link)



For Fibre Channel, the maximum write throughput for any I/O block size is consistently lower than read throughput of the same I/O block size. This is the result of disk write bandwidth limitations on the storage array. For the IP-based protocols, write throughput for block sizes at or above 16KB is limited by the bandwidth of the 1Gb Ethernet link.

To summarize, a single Iometer thread running in a virtual machine can saturate the bandwidth of the respective networks for all four storage protocols, for both read and write. Fibre Channel throughput performance is higher because of the higher bandwidth of the Fibre Channel link. For the IP-based protocols, there is no significant throughput difference for most block sizes.

2.4.4 Partition Alignment

Aligning file system partitions is a well-known storage best practice for database workloads. Partition alignment on both physical machines and VMware VMFS partitions prevents performance I/O degradation caused by I/O crossing track boundaries. VMware test results show that aligning VMFS partitions to 64KB track boundaries results in reduced latency and increased throughput. VMFS partitions created using vCenter are aligned on 64KB boundaries as recommended by storage and operating system vendors.

It is considered a best practice to:

- Create VMFS partitions from within vCenter. They are aligned by default.
- Align the data disk for heavy IO workloads using `diskpart` or, if Windows Server 2008, using Disk Manager for alignment.
- Consult with the storage vendor for alignment recommendations on their hardware.

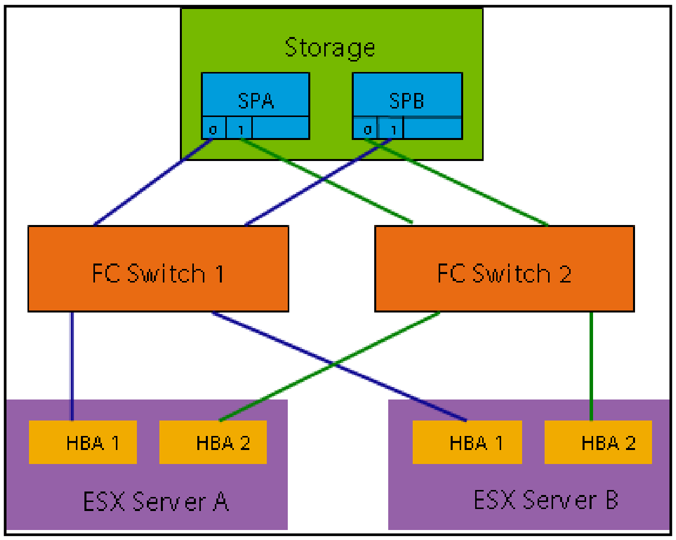
For more information about this topic see the white paper entitled *Performance Best Practices for VMware vSphere 4.0*.

2.4.5 Storage Multipathing

It is preferable to deploy virtual machine files on shared storage to take advantage of VMware vMotion, VMware High Availability (HA), and VMware Distributed Resource Scheduler (DRS). This is considered a best practice for mission-critical SQL Server deployments that are often installed on third-party, shared-storage management solutions.

VMware recommends that you set up a minimum of four paths from an ESX host to a storage array. This means that each host requires at least two HBA ports.

Figure 8. Storage Multipathing Requirements for vSphere



The terms used in Figure 8 are:

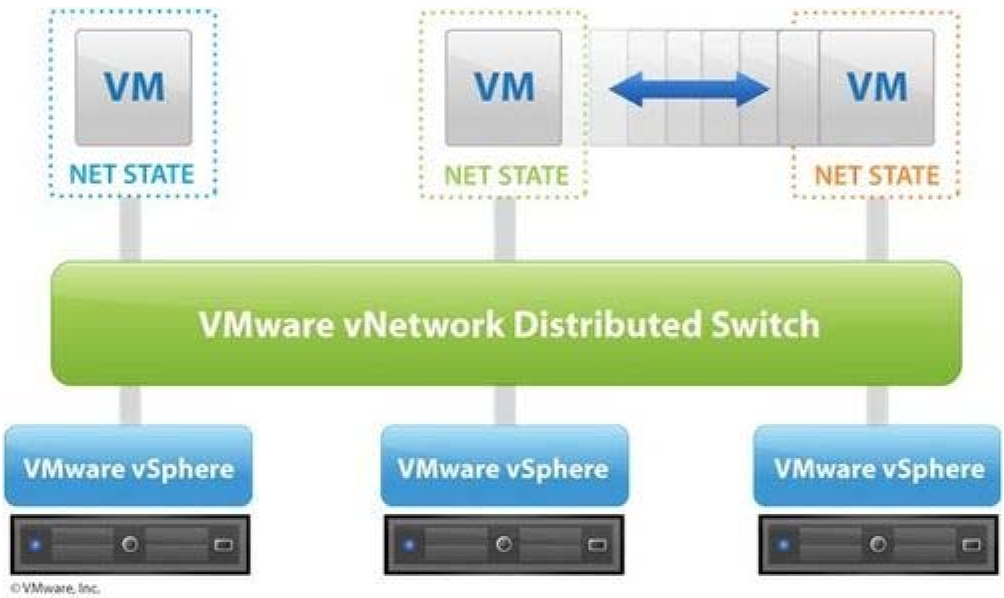
- *HBA* (*Host Bus Adapter*) – A device that connects one or more peripheral units to a computer and manages data storage and I/O processing.
- *FC* (*Fibre Channel*) – A gigabit-speed networking technology used to build storage area networks (SANs) and to transmit data.
- *SP* (*Storage Processor*) – A SAN component that processes HBA requests routed through an FC switch and handles the RAID/volume functionality of the disk array.

2.5 Networking Configuration Guidelines

The following guidelines generally apply to provisioning the network for a SQL Server virtualization project.

- Use the NIC teaming and VLAN trunking support in ESX for better redundancy and isolation for SQL Server virtual machines.
- Use VLANs to separate production users, management, virtual machine network, and iSCSI storage traffic within the virtualized infrastructure. Separating these types of traffic makes sure that management or iSCSI storage network traffic does not affect the production environment that the virtual machine is serving.
- Use the VMXNET network adapter for optimal performance. The Enhanced VMXNET driver also supports jumbo frames and TSO for better network performance. To use the Enhanced VMXNET device you must explicitly select **Enhanced VMXNET** on the VI/vSphere Client hardware configuration page.
- Network communications between co-located virtual machines usually outperforms physical 1Gbps network speed so, if possible, place the various virtual machines that make up an application stack on the same ESX host.

Figure 9. VMware vSphere vNetwork Distributed Switch



3. SQL Server Performance on vSphere

VMware vSphere 4 contains numerous performance related enhancements that make it easy to virtualize a resource heavy database with minimal impact to performance. The improved resource management capabilities in vSphere facilitate more effective consolidation of multiple SQL Server virtual machines on a single host without compromising performance or scalability. Greater consolidation can significantly reduce the cost of physical infrastructure and of licensing SQL Server, even in smaller-scale environments.

In 2009, VMware conducted a detailed performance analysis of Microsoft SQL Server 2008 running on vSphere. The performance test placed a significant load on the CPU, memory, storage, and network subsystems. The results demonstrate efficient and highly scalable performance for an enterprise database workload running on a virtual platform.

To demonstrate the performance and scalability of the vSphere platform, the test:

- Measured performance of SQL Server 2008 in an 8 virtual CPU (vCPU), 58GB virtual machine using a high-end OLTP workload derived from TPC-E1.
- Scaled the workload, database, and virtual machine resources from 1 vCPU to 8 vCPUs (scale up tests).
- Consolidated multiple 2 vCPU virtual machines from 1 to 8 virtual machines, effectively overcommitting the physical CPUs (scale out tests).
- Quantified the performance gains from some of the key new features in vSphere.

The following metrics were used to quantify performance:

- Single virtual machine OLTP throughput relative to native (physical machine) performance in the same configuration.
- Aggregate throughput in a consolidation environment.

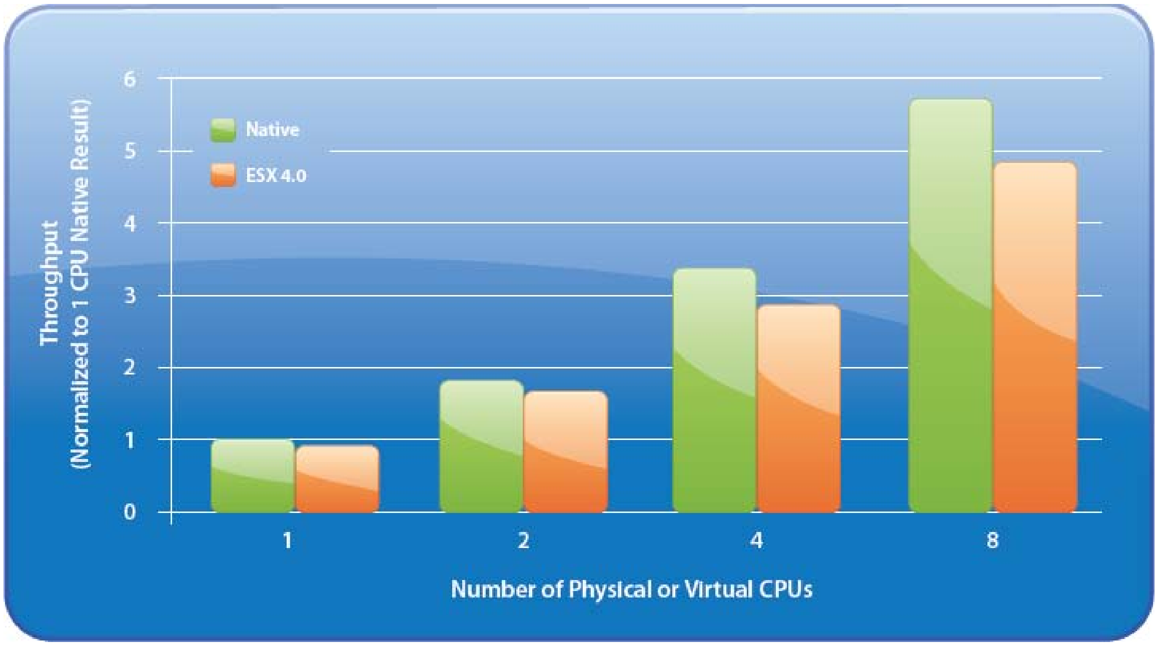
The following sections summarize the performance results of experiments with the Brokerage workload on SQL Server in a native and virtual environment. Single and multiple virtual machine results are examined, and results are given that show improvements due to specific ESX 4.0 features.

The information in this guide is limited to a summary of test results. You can find the full white paper at http://www.vmware.com/files/pdf/perf_vsphere_sql_scalability.pdf.

3.1 Single Virtual Machine Performance Relative to Native

Figure 10 shows how vSphere 4 performs and scales relative to native. The results are normalized to the throughput observed in a 1 CPU native configuration.

Figure 10. Scale-up Performance in vSphere 4 Compared with Native



The graph demonstrates the 1 and 2 vCPU virtual machines performing at 92 percent of native. The 4 and 8 vCPU virtual machines achieve 88 and 86 percent of the non-virtual throughput, respectively. At 1, 2, and 4 vCPUs on the 8 CPU server, ESX is able to effectively offload certain tasks such as I/O processing to idle cores. Having idle processors also gives ESX resource management more flexibility in making virtual CPU scheduling decisions. However, even with 8 vCPUs on a fully committed system, vSphere still delivers excellent performance relative to the native system.

The scaling in the graph represents the throughput as all aspects of the system are scaled such as number of CPUs, size of the benchmark database, and SQL Server buffer cache memory. Table 1 shows ESX scaling comparable to the native configuration's ability to scale performance.

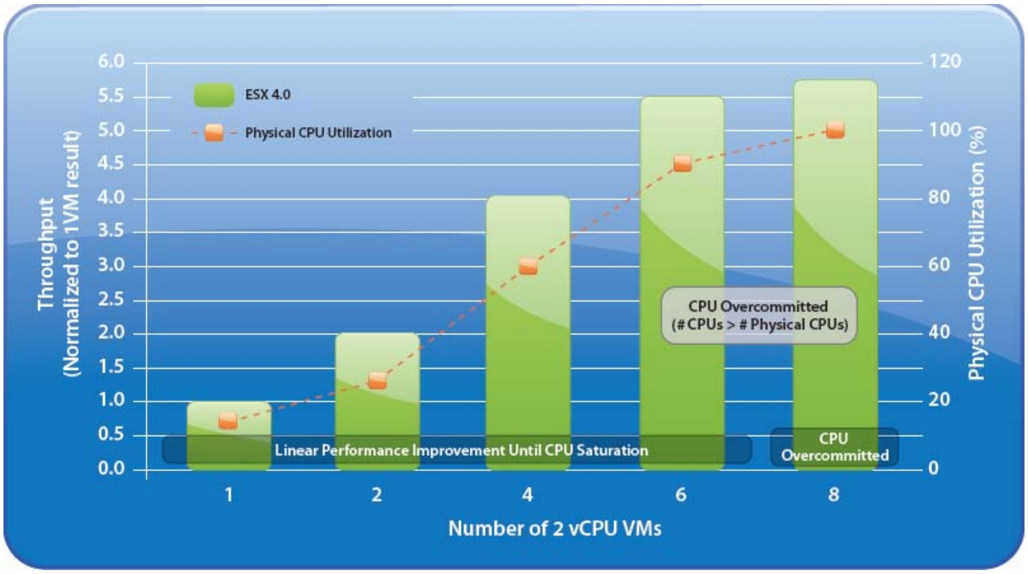
Table 1. Scale Up Performance

Comparison	Performance Gain
Native 8 CPU vs. 4 CPU	1.71
vSphere 8 vCPU vs. 4 vCPU	1.67

3.2 Multiple Virtual Machine Performance and Scalability

These experiments demonstrate that multiple heavy SQL Server virtual machines can be consolidated to achieve scalable aggregate throughput with minimal performance impact to individual virtual machines. Figure 4 shows the total benchmark throughput as eight 2 vCPU SQL Server virtual machines are added to the Brokerage workload onto the single 8-way host.

Figure 11. Consolidation of Multiple SQL Server Virtual Machines



Each 2 vCPU virtual machine consumes about 15 percent of the total physical CPUs, 5GB of memory in the SQL Server buffer cache, and performs about 3600 I/Os per second (IOPS).

As the graph illustrates, the throughput increases linearly as up to four virtual machines (8 vCPUs) are added. As the physical CPUs were overcommitted by increasing the number of virtual machines from four to six (a factor of 1.5), the aggregate throughput increases by a factor of 1.4.

Adding eight virtual machines to this saturates the physical CPUs on this host. ESX 4.0 now schedules 16 vCPUs onto eight physical CPUs, yet the benchmark aggregate throughput increases a further 5 percent as the ESX scheduler is able to deliver more throughput using the few idle cycles left over in the 6 vCPU configuration. Figure 12 shows the ability of ESX to fairly distribute resources in the 8 vCPU configuration.

Figure 12. Overcommit Fairness for 8 Virtual Machines

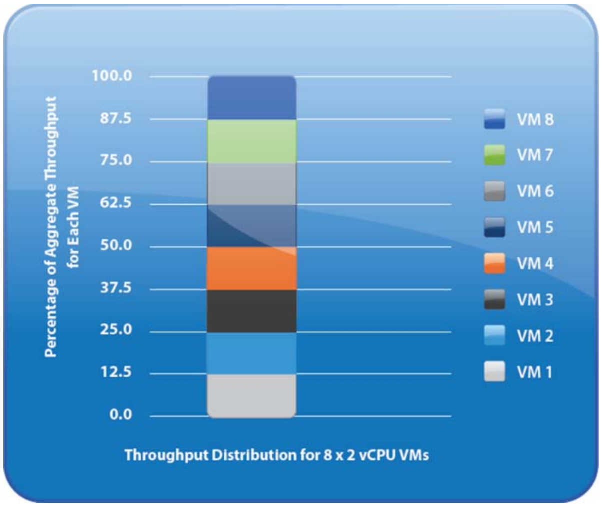


Table 2 highlights the resource-intensive nature of the eight virtual machines that were used for the scale out experiments.

Table 2. Aggregate System Metrics for Eight SQL Server Virtual Machines

Aggregate Throughput in Transactions per Second	Host CPU Utilization	Disk I/O Throughput (IOPS)	Network Packet Rate	Network Bandwidth
2760	100%	23K	8 K/s receive 7.5 K/s send	9 Mb/sec receive 98 Mb/sec send

3.3 Ongoing Performance Monitoring and Tuning

Traditional SQL Server performance monitoring leverages Microsoft's Windows performance monitor tool, PerfMon, to collect statistics. SQL integrates with PerfMon to provide familiar counters that indicate system performance. However, as with all in-guest measurement tools, time-based performance measurements are subject to error. The degree to which the measurements are inaccurate depends on the total load of the VMware ESX host. Always use the VI/vSphere Client, `esxtop`, or `resxtop` to measure resource utilization. CPU and memory usage reported within the guest can be different from what ESX reports.

SQL administrators should pay close attention to the following counters, referring to online documentation on performance monitoring and analysis for more information on these counters and their interpretation.

Table 3. Performance Counters of Interest to SQL Administrators

Subsystem	esxtop Counters	vCenter Counter
CPU	%RDY	Ready (milliseconds in a 20,000 ms window)
	%USED	Usage
Memory	%ACTV	Active
	SWW/s	Swapin Rate
	SWR/s	Swapout Rate
Storage	ACTV	Commands
	DAVG/cmd	deviceWriteLatency & deviceReadLatency
	KAVG/cmd	kernelWriteLatency & kernelReadLatency
Network	MbRX/s	packetsRx
	MbTX/s	packetsTx

Table 3 lists a few key counters that should be added to the list of inspection points for SQL administrators. 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 SQL performance problems except when large amounts of iSCSI storage traffic are using a single network line. Check total throughput on the NICs to see if the network is saturated.

4. Migrating SQL Server to vSphere

When considering SQL Server instances as candidates for virtualization, you need a clear understanding of the business and technical requirements for each instance. These requirements span several dimensions, such as availability, performance, scalability, growth and headroom, patching, and backups.

Follow the steps outlined below to simplify the process of identifying SQL Server candidates for virtualization.

- Understand the database workload requirements for each instance of SQL Server
- Understand availability and recovery requirements, including uptime guarantees (number of *nines*) and site recovery
- Capture resource utilization baselines for existing databases (on physical)
- Plan the migration to vSphere
- Understand database consolidation approaches

4.1 Representative Customer Data

VMware has worked with many enterprise customers to understand how they use SQL Server in their environments. Virtualization assessments using VMware Capacity Planner showed the following key characteristics of production physical SQL Servers:

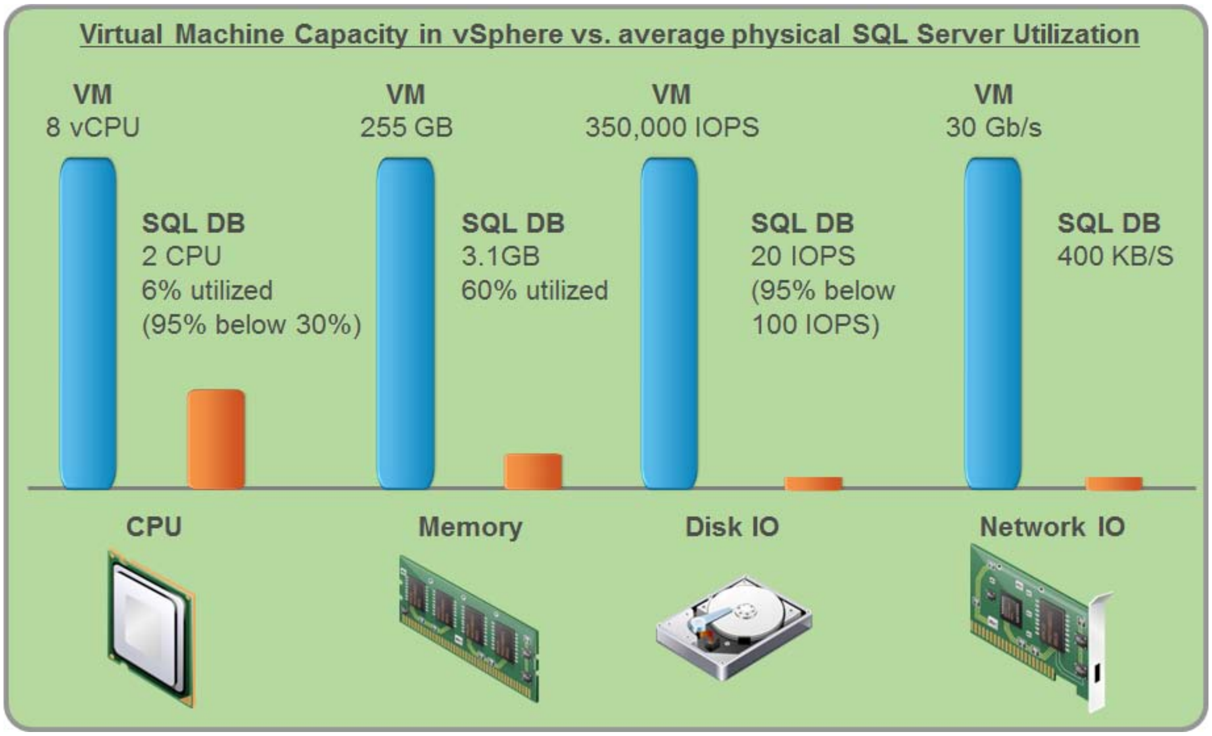
- SQL Server typically runs on two physical cores.
- Average CPU utilization was less than six percent, with 85 percent of the SQL Server hosts using less than 10 percent of CPU and 95 percent of hosts below 30 percent.
- On average, 3.1GB of memory was installed in a host, with 60 percent used.
- Average I/O was 20 IOPS, with 95 percent of hosts below 100 IOPS.
- Average network traffic was 400KB/sec or 3.2Mbps.

These relatively small, lightly loaded SQL Server databases represent a large consolidation opportunity. Such databases are regularly, successfully migrated to virtual machines running on VMware ESX.

Table 4. Average Physical Production SQL Server Utilization

CPU	Total MHz	RAM MB Used	%CPU	Paging/Sec	Disk Busy	Disk Bytes	Disk IO/Sec
2.00	4,812	123,112	6.21	21	5.76	634,039	33.00

Figure 13. VMware Capacity Planner Analysis of >700,000 Servers in Customer Production Environments



Recent VMware customer surveys also indicate that:

- A very high percentage of customers virtualize SQL Server in development and test environments.
- A significant and growing percentage of customers have successfully virtualized their production SQL Server instances.
- A significant percentage are strongly considering, evaluating, or going into production with virtualized SQL Server in 2010.
- A majority of customers prefer a homogeneous virtualization approach in which a given ESX host supports only multiple SQL Server virtual machines or instances. That is, they prefer to not mix SQL Server and other workloads on a given host.

Of course, there are certainly instances of SQL Server that exhibit resource utilization levels higher than the averages shown above, but these instances are actually quite rare. In fact, 95% of SQL Servers deployed in production for our customers would easily fit into vSphere virtual machines.

4.2 Understand Database Workloads

The SQL Server database platform can support a very wide variety of applications. Before deploying SQL Server on vSphere, it is important to understand the database workload requirements of the applications that your SQL Servers will support. Each application will have different requirements for capacity, performance, availability, etc. and consequently, each database should be designed to optimally support those requirements. Many organizations classify databases into multiple management tiers, using application requirements to define service level agreements (SLAs). The classification of a database server will often dictate the resources allocated to it.

- Mission critical databases (sometimes referred to as *tier 1* databases) are considered absolutely essential to your company's core operations. Mission critical databases and the applications they support often have SLAs that require very high levels of performance and availability. SQL Server virtual machines running mission critical databases might require more careful resource allocation (CPU, memory, disk) to achieve optimal performance. They might also be candidates for database mirroring or failover clustering.
- Other databases and applications are busy only during specific periods for such tasks as reporting, batch jobs, and application integration or ETL workloads. These databases and applications might be essential to your company's operations, but they have much less stringent requirements for performance and availability. They may, nonetheless, have other very stringent business requirements, such as data validation and audit trails.
- Still other smaller, lightly used databases typically support departmental applications that may not adversely affect your company's real-time operations if there is an outage. You can tolerate such databases and applications being down for extended periods.

Resource needs for SQL Server deployments are defined in terms of CPU, memory, disk/network I/O, user connections, transaction throughput, query execution efficiency/latencies, and database size. Some customers have established targets for system utilization on hosts running SQL Server, such as 80% CPU utilization, leaving enough headroom for any usage spikes.

Understanding database workloads and how to allocate resources to meet service levels will help you define appropriate virtual machine configurations for individual SQL Server databases. Because you can consolidate multiple workloads on a single ESX host, this characterization also helps you design an ESX and storage hardware configuration that provides all the resources you need to deploy the multiple workloads successfully on vSphere.

4.3 Understand Availability and Recovery Requirements

Running Microsoft SQL Server on vSphere offers many options for database availability and disaster recovery utilizing the best features from both VMware and Microsoft. For example, VMware vMotion and DRS can help to reduce planned downtime and balance workloads dynamically, and VMware HA can help to recover SQL Servers in the case of host failure.

4.3.1 VMware HA, DRS and vMotion for High-availability

4.3.1.1. VMware HA

VMware HA provides easy-to-use, cost-effective, high availability for applications running in virtual machines. In the event of physical server failure, affected virtual machines are automatically restarted on other production servers that have spare capacity. Additionally, if there is an OS-related failure within a virtual machine, the failure is detected by VMware HA and the affected virtual machine is restarted on the same physical server.

4.3.1.2. VMware Distributed Resource Scheduler (DRS)

VMware DRS collects resource usage information for all hosts and virtual machines and generates recommendations for virtual machine placement. These recommendations can be applied manually or automatically. VMware DRS can dynamically load balance all virtual machines in the environment by shifting workloads across the entire pool of VMware ESX™ hosts. This makes sure that critical SQL Server virtual machines in the environment will always have the CPU and RAM resources needed to maintain optimal performance.

4.3.1.3. VMware vMotion

VMware vMotion leverages the complete virtualization of servers, storage and networking to move a running virtual machine from one physical server to another. This migration is done with no impact to running workloads or connected users. During a vMotion, the active memory and execution state of the virtual machine is rapidly transmitted over the network to the new physical server, all the while maintaining its network identity and connections.

4.3.2 Native SQL Server Capabilities

At the application level, all Microsoft features and techniques are supported on vSphere, including: database mirroring, failover clustering, and log shipping. With the exception of failover clustering, these Microsoft features can be *combined* with vSphere features to create flexible availability and recovery scenarios, applying the most efficient and appropriate tools for each use case.

The following table lists SQL Server availability options and their ability to meet various recovery time objectives (RTO) and recovery point objectives (RPO). Before choosing any one option, evaluate your own business requirements to determine which scenario best meets your specific needs.

Table 5. SQL Server 2008 High Availability Options

Technology	Granularity	RPO- Data Loss	RTO - Downtime
Database Mirroring (High Safety Mode with Automatic Failover)	Database	None	< 3secs
Database Mirroring (High Safety Mode without Automatic Failover)	Database	None	Administrator Recovery
Database Mirroring (High Performance Configuration)	Database	Some	Administrator Recovery
Failover Clustering	Server	None	~30sec + recovery
Log Shipping	Database	Possible transaction log	Administrator Recovery

For more in-depth treatment of availability and recovery options for SQL Server, see:

- *SQL Server on VMware – Availability and Recovery Options*
- *Availability Guide for Microsoft SQL® on VMware vSphere 4*

4.3.3 Backup and Restore

The feature set available to an application, when deployed in a virtual environment, is no different than what is available with a physical deployment. In fact, there are more options available for protecting entire virtual machines. This is especially useful for applications that require extensive configuration. For SQL Server the standard methods for backup are supported. These tend to be deployed using a third-party backup agent that uses a VSS requestor to coordinate with the VSS writer to prepare the database files for backup. Regardless of the backup solution required, VMware and VMware partners have provided solutions for most situations.

To backup and restore SQL Server virtual machines, consider using one of the following options:

- In-guest, software agent-based backup
- VMware Data Recovery (VDR)
- Array-based backup solutions

Each of these options is covered in more depth in another document in this Solutions Kit, *SQL Server on VMware – Availability and Recovery Options*.

4.4 Capture Resource Utilization Baseline for Existing Databases

After you clearly understand your organization's needs—business and technical requirements, availability and other operational requirements for implementing SQL Server—the next important step is to establish a baseline, using data from the current, running physical deployment. The best way to accomplish this is to use the Virtualization Assessment service delivered by VMware or its partners. Using VMware Capacity Planner, this service collects all essential performance metrics, including processor, disk, memory, and network statistics, and specific SQL Server metrics on existing database servers in the environment. Capacity Planner analyzes this data to recommend server consolidation opportunities. You can monitor these metrics, in addition to the essential system metrics, if you want to capture the baseline information yourself. It is important to collect the data over a period of time long enough to reflect all variations in the usage patterns of SQL Server in your organization. The duration can range from one week to one month, depending on seasonal or cyclical usage peaks such as when they occur, their intensity, how long they last, and other factors. This exercise not only helps you understand what resources your current physical SQL Servers are using, it also makes it easier for you to create a short list of SQL Server instances to virtualize and to determine the order in which you should virtualize the SQL Server instances.

4.5 Plan the Migration

After you establish baseline profiles for your existing SQL Server databases, the next step is to design a vSphere architecture that meets these profiles. The best practices described in the Section 2 can help you optimize your vSphere environment for SQL Server.

Microsoft offers extensive information on best practices for deploying SQL Server in the SQL Server Tech Center on Microsoft Technet. These best practices papers provide real-world guidelines and expert tips, and you should follow them for SQL Server deployments on vSphere as well. Similarly, VMware recommends following vendor-specific best practice guidelines for configuring your server hardware, storage subsystems, and network. In general, best practices in physical environments also apply to deployments on VMware vSphere without any changes.

Virtualizing SQL Server should provide benefits that go beyond server consolidation and lower total cost of ownership. A successful SQL Server deployment using vSphere provides better management and administration flexibility as well as will higher levels of availability at lower price.

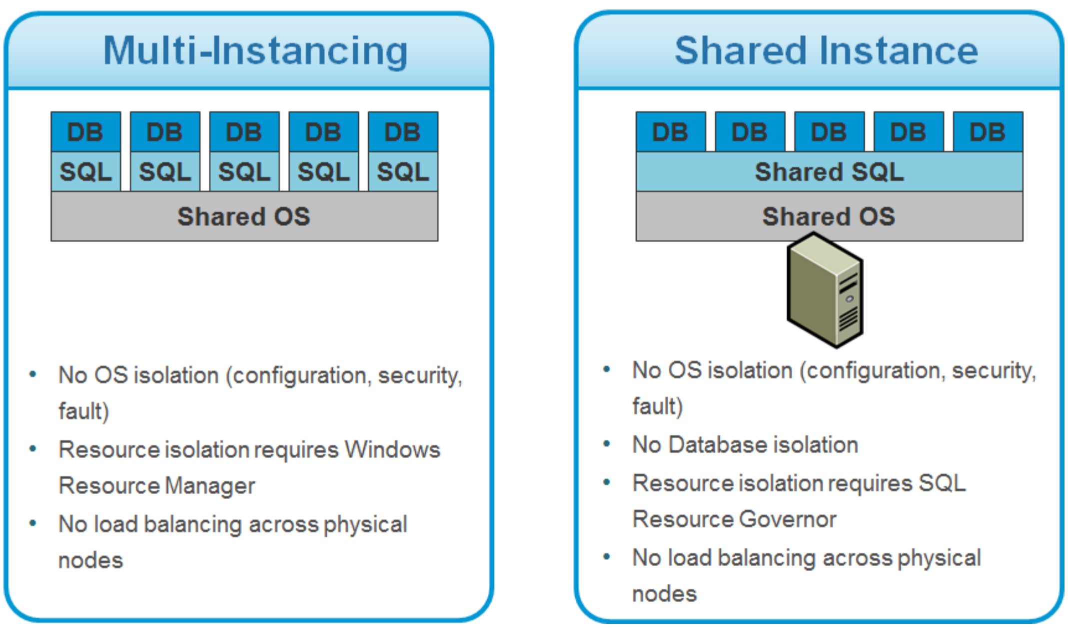
SQL Server databases in an organization have unique deployment needs because of the variety of applications they serve. These applications can require 32-bit or 64-bit versions of the operating system and SQL Server, particular service packs or hot fixes, security and other access control settings, and support for specific legacy application components. When you consolidate such SQL Server databases in physical environments, these specific requirements often force you to take a least common denominator approach to configuration, thus compromising optimal performance. Because a VMware vSphere environment enables you to run both 32-bit and 64-bit virtual machines side-by-side but isolated from each other, virtualized consolidation is much more flexible and much less constrained. However, understanding these specific deployment requirements can help you refine the virtualization approaches that work best. This understanding can help you decide whether to adopt a scale-up approach with multiple databases in a single large virtual machine or a scale-out approach with one or only a few databases per virtual machine. You can also identify the optimal workload, security, and other application-specific optimal configurations that need to be locked at the virtual machine level for your databases.

In planning a migration to a virtual environment, you should also understand other deployment and operational requirements, such as those for patching the operating system and SQL Server and those for rolling out and maintaining applications in test and development environments as well as production environments. Understanding these requirements can help you define how you should create, stage, and provision virtual machines in your datacenter, leveraging VMware Converter or the templates and cloning features in vSphere.

4.6 Understand Database Consolidation Approaches

Most legacy database applications were traditionally deployed on dedicated physical hardware. Each database instance provisioned onto its own database server. This approach allows the database administration team to provide predictable service levels to their customer base through isolation of those physical resources. Rogue database instances cannot consume resources from other databases and impact their service levels. A significant limitation of this approach is that each of these databases is bounded by the physical resources available on its physical server and consequently, are usually significantly overprovisioned. VMware captured capacity planning data from the servers of our customer base and found that physical database servers use between 5% and 15% of available resources on average (see Figure 14). This is a very inefficient use of server hardware, power and cooling resources, as well as database software licenses. Customers have recognized the inefficiency in this approach and in some cases have looked at physical database consolidation as a solution.

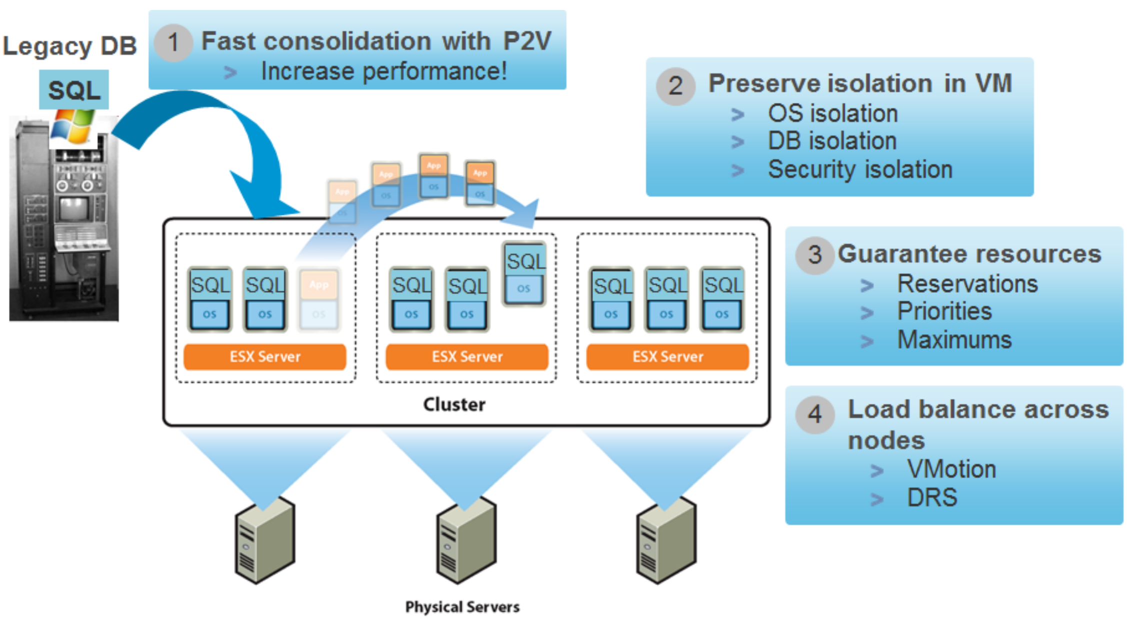
Figure 14. Traditional Physical Database Consolidation



Physical database consolidation involves consolidating multiple SQL Server databases onto a single physical server. This approach is attractive because it enables the consolidation of databases onto fewer physical servers. However, this approach requires making compromises regarding application compatibility, workload isolation, flexibility for maintenance, availability requirements, and security. There are two primary approaches to database consolidation; *Multi Instance* and *Shared Instance* consolidation. Both approaches require building a standardized software stack on which to deploy the database instances. Multi Instance database consolidation requires a single standard version of Windows with multiple SQL Server instances, possibly at different version levels, deployed on that single version of Windows. Each instance would have multiple databases. Shared Instance consolidation goes a step further and provides for consolidation on a single SQL Server instance, with multiple databases on that instance.

Each approach can be challenging to implement. Application owners must determine the compatibility issues associated with their applications and the Windows/SQL Server version(s) selected for the consolidation. They must also consider the potential service level implications of both a shared physical infrastructure and a shared software stack. Resources must be governed at the Windows level or within SQL server to limit the potential impact of heavy database activity from one application on the other applications hosted within the consolidated databases. Security models must be re-thought; administrative privilege now provides access to a much broader footprint of applications with new implications. A single bad Windows or SQL Server patch has the potential to impact many more users. These are manageable issues but upfront planning is required to properly address them.

Figure 15. Database Consolidation on vSphere



Database consolidation within a virtual infrastructure provides the benefits of physical database consolidation while also significantly reducing the described implementation challenges. Many customers approach virtual database consolidation by doing a Physical to Virtual (P2V) conversion of each of their physical servers. What's important to note is that the new virtual machine contains the entire isolated software stack that was on the physical server, so there is no reduction in resource isolation from a Windows or SQL Server perspective. There is no need to re-architect the security model within the new Windows guest operating system. vSphere provides the ability to present resources (CPU, memory and storage) to your VM as it is needed and to guarantee them for applications that require it. These capabilities reduce the need to overprovision the VM to handle peak workloads. The VMs also now get increased service levels associated with VMware High Availability, Fault Tolerance and vMotion.

When consolidating databases within a virtual infrastructure, database administrators can adopt a *scale-up* or *scale-out* approach to deploy SQL Server on vSphere.

Figure 16. Scale-Up versus Scale-Out Approaches

Scale-Up Approach

Multiple databases or SQL instances per VM

- Fewer VMware ESX VMs
- Single point of failure
- Larger VM
  - SMP overheads
- OS bottleneck, especially for 32-bit environments

Scale-Out Approach

Single database per VM

- Better SQL Instance and workload isolation
  - DSS vs. OLTP separation
- Easier change management
- DRS more effective with smaller VMs
- Faster migration

The scale-up approach involves consolidating multiple SQL Server instances in a single large VM. The scale-up approach is attractive because it enables you to consolidate onto fewer physical servers and may provide some Windows licensing advantages; however, this approach requires making similar compromises discussed earlier regarding application compatibility, workload isolation, flexibility for maintenance, availability requirements, and security. Furthermore, in a virtual infrastructure, deploying additional virtual machines to house additional instances of SQL Server is relatively painless.

The larger VMs also exhibit higher performance overheads associated with the scaling of SMP virtual processors. The scale-up approach may result in bottlenecks in the operating system itself, especially if you run into the 32-bit OS memory limits. Additionally, using larger VMs also makes it harder for VMware DRS to move around the VM due to the greater demand placed on available resources.

In a virtual infrastructure, these drawbacks to the scale-up approach generally outweigh the benefits. The scale-out approach is generally more appropriate for a virtual infrastructure. With the scale-out approach, you deploy fewer SQL instances per VM and customize the configuration as needed. The usual drawbacks to a scale-out approach that you encounter in a physical infrastructure, such as server sprawl and high TCO, are minimized when you deploy a virtual infrastructure. Not only does this approach provide better workload and security isolation, it also allows easier maintenance and change management because of the increased granularity of deploying fewer SQL instances per VM. VMware DRS can function more effectively with smaller VMs, with the added benefit of faster vMotion migrations.

5. vSphere Enhancements for Deployment and Operations

You can leverage vSphere to provide significant benefits in a virtualized SQL datacenter, including:

- **Increased operational flexibility and efficiency** – Rapid software applications and services deployment in shorter time frames.
- **Efficient change management** – Increased productivity when testing the latest Windows and SQL Server software patches and upgrades.
- **Minimized risk and enhanced IT service levels** – Zero-downtime maintenance capabilities, rapid recovery times for high availability, and streamlined disaster recovery across the datacenter.

5.1 VMware vMotion, VMware DRS, and VMware HA

VMware vMotion technology enables the migration of virtual machines from one physical server to another without service interruption. This migration allows you to move SQL Server virtual machines from a heavily-loaded server to one that is lightly loaded, or to offload them to allow for hardware maintenance without any downtime.

VMware Distributed Resource Scheduler (DRS) takes the VMware vMotion capability a step further by adding an intelligent scheduler. DRS allows you to set resource assignment policies that reflect business needs. VMware 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.

VMware vMotion and VMware DRS perform best under the following conditions:

- The source and target ESX hosts must be connected to the same gigabit network and the same shared storage.
- A dedicated gigabit network for VMware vMotion is recommended.
- The destination host must have enough resources.
- The virtual machine must not use physical devices such as CD ROM or floppy.
- The source and destination hosts must have compatible CPU models or migration with VMware vMotion will fail. For a listing of servers with compatible CPUs, consult VMware vMotion compatibility guides from specific hardware vendors.
- To minimize network traffic it is best to keep virtual machines that communicate with each other together on the same host machine.
- Virtual machines with smaller memory sizes are better candidates for migration than larger ones.

Note VMware does not currently support VMware vMotion or VMware DRS for Microsoft Cluster nodes; however, a cold migration is possible after the guest OS is properly shut down.

With VMware High Availability (HA), SQL Server virtual machines on a failed ESX host can be restarted on another ESX host. This feature provides a cost-effective failover alternative to expensive third-party clustering and replication solutions. If you use VMware HA, be aware that:

- VMware HA handles ESX host hardware failure but does not monitor the status of the SQL Server services—these must be monitored separately.
- Proper DNS hostname resolution is required for each ESX host in a VMware HA cluster.
- VMware HA heartbeat is sent via the vSphere service console network, so redundancy in this network is recommended.

5.2 Templates

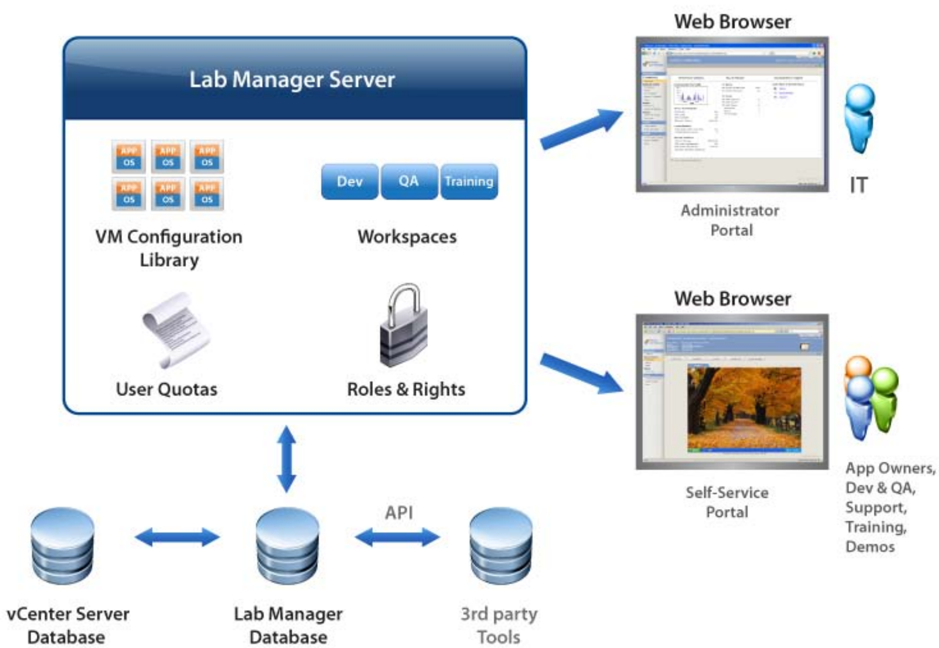
VMware template cloning can increase system administration and testing productivity in SQL Server environments. A VMware template is a *golden image* of a virtual machine that can be used as a master copy to create and provision new virtual machines. It includes the guest operating system and SQL Server application data. You can use virtual machine templates to provision a new preconfigured SQL Server system. In native environments, this process can consume significant time, requiring you to procure hardware and install the operating system. Cloning provides a controlled virtual machine configuration so that deployment is less error prone and less time-consuming.

5.3 VMware vCenter Lab Manager

Patching and upgrading SQL Server can be a time-consuming process, especially with roll-up patches being released every couple of months. Most environments have change control procedures that require these patches go through some form of testing before production deployment. In addition, SQL Server is often part of a multi-tiered application system requiring a separate lab environment that might not exactly mimic your production environment. This can result in flawed test scenarios that can lead to failed upgrades to production and extended downtime. VMware vCenter Lab Manager can streamline the testing of configuration changes, patches, or upgrades to your SQL Servers. When you need to make changes to the production SQL Server systems, Lab Manager allows you to take a clone of the current application environment and apply the changes to an identically configured, running test bed to validate the installation.

The application environment clone is an exact replica of the production system, including all network settings, host names, and IP addresses. VMware vCenter Lab Manager deploys the clone in a *fenced network* to prevent network collisions. The fenced networking feature allows simultaneous deployment of multiple instances of the exact same application configuration, which allows multiple teams to work in parallel without interrupting or conflicting with one another. After the patches or upgrades have been applied and validated, the same upgrade procedure can be reproduced in the production environment.

Figure 17. VMware vCenter Lab Manager

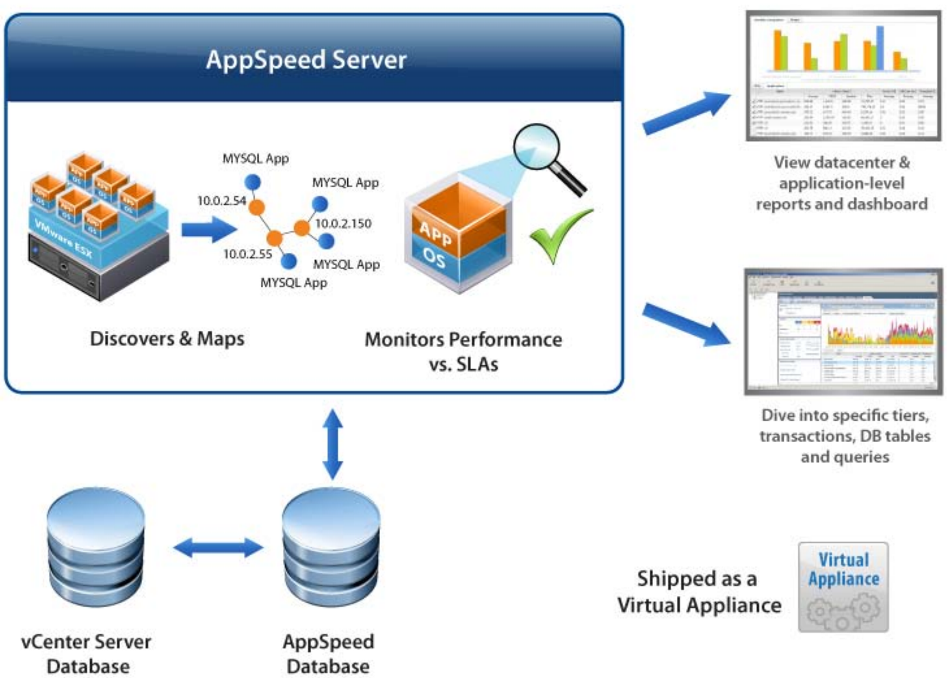


5.4 VMware vCenter AppSpeed

VMware vCenter AppSpeed provides a real-time view of end-user application performance without impacting overall system performance. AppSpeed inspects traffic flowing over the vSwitch to discover and map the applications and protocols found traversing the virtual network. The data collected by AppSpeed is then used to measure actual performance against SLAs and enables root cause analysis. Because the AppSpeed server and probes are deployed as virtual appliances they integrate directly into your existing vCenter environment.

When virtualizing a multi-tier application supported by SQL Server, knowing the virtual network trends between the application components can assist in establishing baseline trends and SLAs. Each application tier has dependencies with other tiers and infrastructure services (DNS). Having the ability to map these dependencies can reduce time needed for troubleshooting.

Figure 18. VMware vCenter AppSpeed



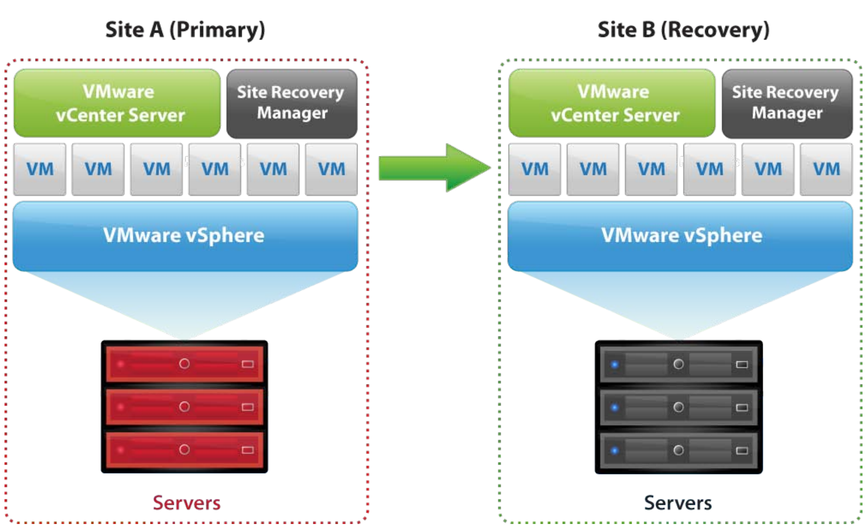
5.5 VMware vCenter Site Recovery Manager

VMware vCenter Site Recovery Manager (SRM) takes advantage of virtual machine encapsulation to make testing and initiating DR fail-over a simple, integrated vCenter process. SRM runs alongside vCenter Server to provide planning, testing and automated recovery in the case of a disaster. By using replication technology from leading storage vendors SRM eliminates the manual steps required during a fail-over scenario to provide consistent and predictable results each time. At a high-level the steps that can be performed during a fail-over test or actual run are as follows:

- Shutdown production virtual machines (fail-over)
- Promote recovery storage to primary (fail-over)
- Take and mount snapshot of recovery storage in read/write mode (test only)
- Rescan ESX hosts to make recovery snapshot visible
- Register recovery virtual machines
- Power-on virtual machines at recovery site
- Reconfigure IP settings and update DNS if required
- Verify VMware Tools starts successfully on recovered virtual machines
- Power-off recovered virtual machines (test only)
- Unregister virtual machines (test only)
- Remove storage snapshot from recovery side (test only)

SQL Server has a variety of options for disaster recovery, including mirroring, failover clustering, and log shipping. While all of these are fine choices for SQL Server recovery, the application-centric nature of these technologies may not be in line with a company's disaster recovery plans. SRM is not a replacement for application-aware clustering solutions that may be deployed within the guest OS. SRM provides integration of the storage replication solution, VMware vSphere and customer-developed scripts to provide a simple, repeatable and reportable process for disaster recovery of the entire virtual environment, regardless of the application.

Figure 19. VMware vCenter Site Recovery Manager



5.6 VMware vCenter CapacityIQ

VMware vCenter CapacityIQ™ adds capacity monitoring and reporting capabilities that fully understand the vSphere landscape. Deployed as a virtual appliance and seamlessly integrated into vCenter Server, CapacityIQ ensures that your virtualized infrastructure capacity is predictable and efficiently used. Out of the box reports include current capacity utilization, forecasting based on the historical deployment and usage characteristics, as well as planning tools and “what-if” scenarios.

SQL Server deployments tend to overprovision virtual hardware in anticipation of the unknown. Following guidance from Microsoft as to the CPU and memory configurations usually works out well, but in some situations the usage may prove to be less than anticipated. Without proper monitoring these resources can appear to be consumed even though they are not being efficiently used. CapacityIQ helps identify and reclaim inefficient or unused capacity. By identifying idle or inactive VMs you can decide whether to bring them down to the right size or simply decommission them.

Figure 20. VMware vCenter CapacityIQ