

**A Performance
Characterization of
Microsoft® SQL Server
2005 Virtual Machines on
Dell™ PowerEdge™
Servers Running
VMware® ESX Server 3.5**



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Executive Summary

Understanding how applications will perform when used in conjunction with virtualization is important. Many Information Technology (IT) organizations in large and small companies have adopted virtualization technologies to take advantage of management flexibility, cost savings through consolidation, and many other reasons.

In order to understand how Microsoft SQL Server 2005 performs in a virtualized environment, Dell engineers tested both stand alone virtual machines (VMs), multiple VMs, and how these VMs performed during migration from one physical server to another. It was found that performance scaled well when additional processing power was assigned to a VM and when multiple VMs were run on the same server. Additionally the impact of a VMotion migration on a SQL Server VM was minimal, meaning that administrators would be free to use this feature during normal production day – without noticeable impact.

Introduction

With virtualization implementations gaining acceptance and moving beyond legacy server consolidation, applications that were first considered bad candidates as VMs can be re-considered. Many IT organizations feel much more comfortable running their important applications in VMs after they have gained some operational experience.

A key tier of many applications is Microsoft SQL Server. It is a widely used database that supports other Microsoft applications such as SharePoint and System Center. ERP applications such as SAP and PeopleSoft can use Microsoft SQL Server, and many custom applications are written using Microsoft SQL Server as the database tier.

To get an indication of how Microsoft SQL Server 2005 performs when running inside virtual machines, Dell TechCenter engineers ran a series of tests to characterize the performance. The testing was designed and run in three phases. Performance was first measured for a single SQL Server VM, then for multiple SQL Server VMs, and for a SQL Server VM during a VMotion migration between physical systems.

This whitepaper provides performance results and analysis about how SQL Server 2005 VMs, running on Dell PowerEdge servers, perform with a hypothetical Online Transaction Processing OLTP workload. Performance scaling with this typical OLTP application should be indicative of how other similar OLTP applications would scale within VMs.

Test Configuration

Server Hardware

Dell PowerEdge servers provide an excellent platform for SQL Server 2005 with 64-bit capable processors, external high speed storage options, and a variety of enterprise class support options. Dell engineers have done testing in order to provide sizing and configuration guidance for running SQL Server 2005. This information is available as an online sizing tool and also in a whitepaper located at <http://www.dell.com/sql>. In addition to testing SQL Server 2005, Dell engineers also test, validate and certify VMware Infrastructure on Dell PowerEdge servers. The advisor tool for sizing VMware ESX server is located at <http://www.dell.com/vmware>.

The server used in this testing was a Dell PowerEdge 2950 III two-socket rack based system, configured with quad-core processors and 32GB of RAM. Detailed system configuration is shown in Table 1. The system was installed with VMware ESX Server 3.5 and all patches available as of February 2008. A PowerEdge 1950 was installed with Microsoft Windows Server 2003 and used to stress the VMs. Additionally, a PowerEdge 1855 blade server was used as a VMware Virtual Center management server/console.

Dell PowerEdge 2950 III	
Virtualization Software	VMware ESX Server 3.5
CPU	2 x 3.16 GHz Quad-Core Intel Xeon X5460 with 2x6MB Cache
Memory	32 GB (8 x 4 GB FB DIMMs)
Internal Disks	2 x 146 GB 10K RPM SAS
NICs	2 x 10/100/1000 Mb/s (Internal)
Disk Controller	PERC 6/i
Fiber Channel HBA	QLogic QLE 2462 – dual port FC4 PCI-Express
Remote Management	Dell Remote Access Card, 5 th Generation

Table 1: PowerEdge 2950 III server configuration.

SAN Storage

Storage was provided by a Storage Area Network (SAN)-attached Dell/EMC CX3-80 fibre channel storage array. The ESX Server was attached to the SAN via a dual-port QLogic 2462 Host Bus Adapter. The storage components in the test are shown in Table 2.

Controller	1 Dell/EMC CX3-80
Disk Enclosures	6 Dell/EMC DAE3P
Disks	99 x 146 GB/ 15K RPM
LUNs	8 10-Disk RAID 1/0 LUNs for Database 4 2-Disk RAID 1 LUNs for Logs 2 5-Disk RAID 5 LUN for VM Boot Disks 1 HotSpare Disk

Table 2: Dell/EMC Storage

Software

Microsoft SQL Server 2005

Microsoft SQL Server 2005 utilizes a 64-bit architecture to provide improved performance and capacity over previous versions. In particular the 64-bit architecture improves memory utilization by allowing the system to directly address more memory than the previous 32-bit versions of Microsoft SQL Server.

VMware Infrastructure 3

VMware provides a server virtualization platform, referred to as VMware Infrastructure 3, based on ESX Server and Virtual Center. This provides the features of 64-bit VM support, VMotion (live migration), VMware HA (high availability) and management.

SQL Server 2005 Virtual Machines

There were four SQL Server virtual machines created for testing. An initial VM was created and installed with Windows Server 2003 Enterprise x64 edition with service pack 1. SQL Server 2005 x64 with service pack 2 was then installed. After attaching the storage described in the above section, the large (100 GB) version Dell DVD Store was loaded.

This initial VM was then cloned via the Virtual Center guest customization wizard three times, for a total of four SQL Server VMs. Each VM had its own dedicated 20 data disks and 2 log disks. To ensure that disks were not a bottleneck in any test, the 4 vCPU VM was tested initially to ensure that it had enough disk I/O capacity to fulfill all 4 vCPUs. Once it was determined that 20 data disks and 2 log disks provided enough I/O capacity, that disk configuration was used for all tests.

	1 vCPU VM	2 vCPU VM	4 vCPU VM
RAM	8 GB	8 GB	8 GB
Data Disks	20	20	20
Log Disks	2	2	2
vCPU	1	2	4
vNIC	1	1	1

Table 3: Configuration of SQL Server 2005 VM used in testing.

Dell DVD Store

The Dell DVD Store is an open source online ecommerce test application created and maintained by Dell (<http://www.delltechcenter.com/page/DVD+Store>). It includes database creation and indexing scripts, stored procedures, data loading scripts, and client simulation driver programs. For this test, the large (over 100GB) version of DVD Store database was loaded on each of the four SQL Server VMs used for testing. To simulate a load on the database, the client driver program included with the DVD Store kit was used. The driver program was run on a separate system and connected over the network to the VMs. The driver program allows the amount of work to be varied by increasing the number of active threads. Each thread performs a complete cycle of logging on, browsing, and purchasing from the DVD store simulating the same steps that a real user would perform. The difference between real users and the driver program is the amount of delay or think time between steps. A real user would take several seconds between each step, but the driver program by default will have zero delay. A much smaller number of threads can be used to simulate the amount of workload that a larger amount of real users would generate.

Performance Characterization Testing

In order to test how well SQL Server performs when running inside a virtual machine on ESX 3.5, there were two phases to the testing. The initial phase of testing measured the performance for a single SQL Server VM with 1, 2, or 4 vCPUs. This test was designed to show how well SQL Server performance scaled with the addition of vCPUs. The second phase of testing was oriented around the performance of multiple SQL Server VMs. Up to four SQL Server VMs were put under stress simultaneously to see how well SQL Server performance on ESX Server reacted to heavy and overloaded states.

Processor Scaling within a Single VM

In order to get a good measure of relative performance, each VM configuration was measured at 80% CPU utilization. In order to push the CPU utilization to 80% the number of threads specified in the DVD Store driver program was increased while keeping all other parameters the same. Figure 1 shows the results of the testing for a 1vCPU, 2vCPU, and 4vCPU VM.

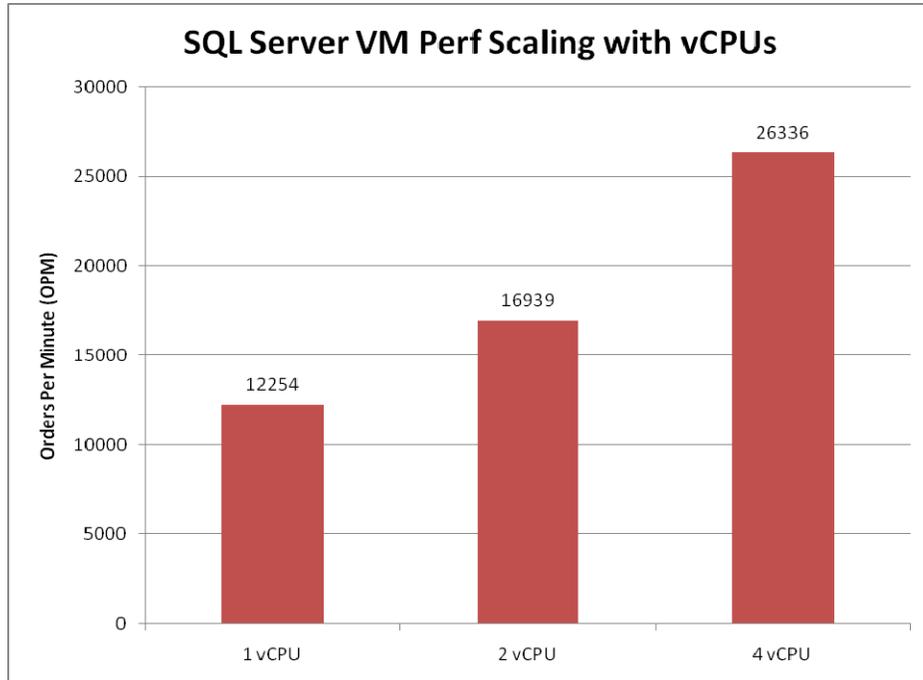


Figure 1 – Orders Per Minutes Increases as additional vCPUs are added.

Performance scaling was very good with increases in Orders Per Minute of 38% for 1vCPU to 2vCPU and 55% for 2vCPU to 4vCPU. This shows that by simply adding more virtual CPUs performance can increase significantly.

Multiple VM Performance

The initial single VM testing results were used as a starting point for the multiple VM testing. In the single VM testing, the resources of the 2950 III server were never fully utilized. This was because each VM was only assigned up to 4 vCPUs and 8GB of RAM, while the server has a total of 8 cores and 32 GB of RAM. With the multiple VM tests some of the configurations would commit or over commit all of the server resources. In these scenarios the test begins to measure the ability of ESX Server to manage these resources between the VMs.

During testing it was necessary to reduce the amount of RAM per VM from 8GB to 7.5GB for the four VM tests. If this had not been done, the performance would have degraded due to a lack of memory resources for ESX Server when all four VMs were assigned 8GB. By reducing each of the VM's RAM by 512MB, we were able to give ESX Server the headroom it needed. This reduction in RAM to the VMs actually improved their performance, because ESX now had dedicated resources and did not have to compete with the VMs.

The scaling with the 1vCPU VMs was good. With the 4 1vCPU VM test only half of the total processing power of the server was assigned to VMs, but almost all of the RAM. Linear scalability would have resulted in each of the four VMs individually attaining the same result as the single VM. In this test the average OPM for the four VM case was 10766, which is 12% lower than 12,254 that the single VM achieved. See Figure 2 for complete results.

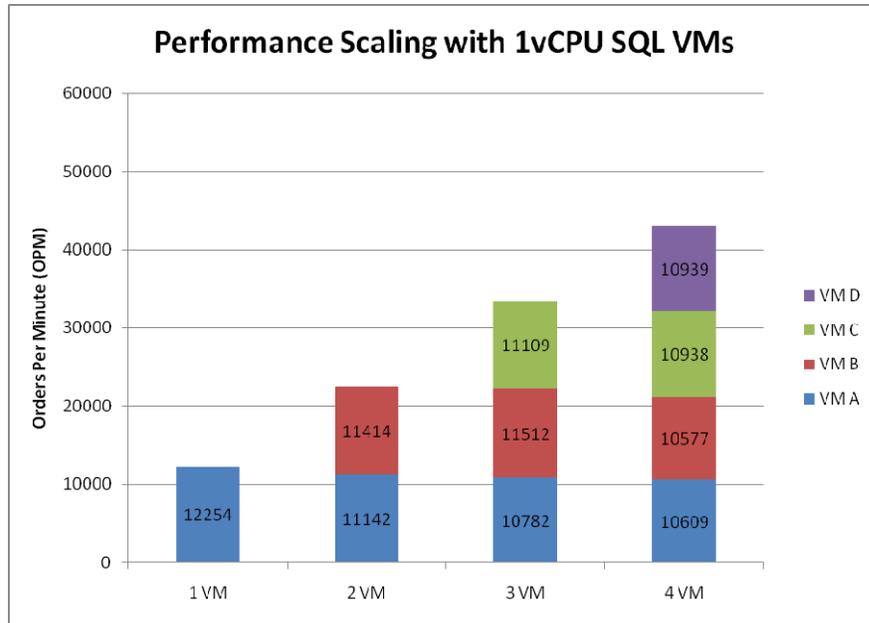


Figure 2 – Performance scaling with 1vCPU SQL Server VMs.

In the 2vCPU tests, scalability remained good as additional VMs were added. In the 4 VM test, all of the processing power and almost all RAM in the server was assigned to VMs. The average OPM for the 4 VM test was 13,470 which is 19%

below the 16,939 of the 1 VM test. Figure 3 shows the complete results for the 2vCPU tests.

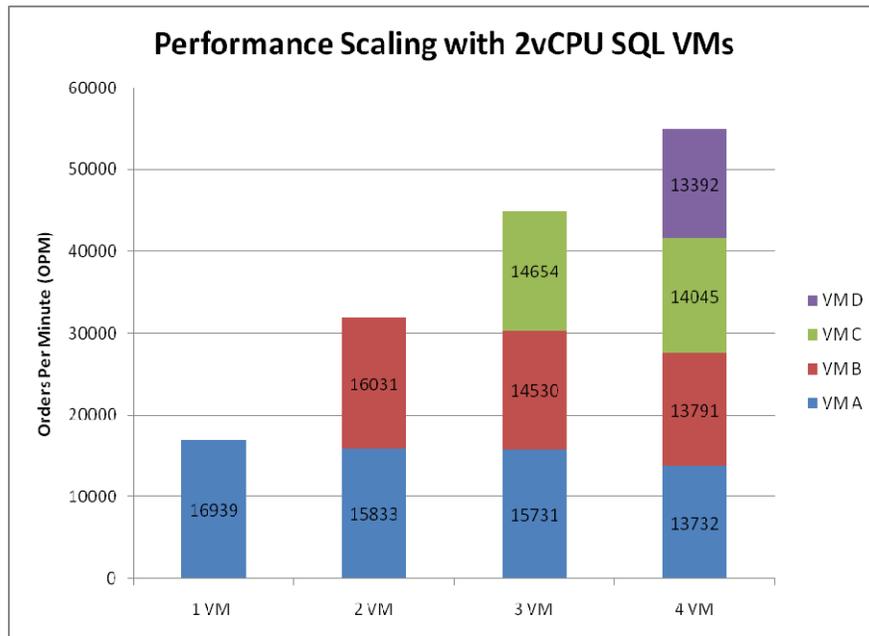


Figure 3 - Performance scaling with 2vCPU SQL Server VMs.

With the 4vCPU tests the cores now must be shared between the VMs in the 3 and 4 VM tests. The results are clear in the graph below where the processor becomes the bottleneck in the 3 VM and 4 VM tests. Total OPM does not increase even though each of the VMs has its own memory and disk resources. Each VM achieves approximately the same performance in all tests. This shows that ESX Server is doing a good job of managing the server resources across the VMs.

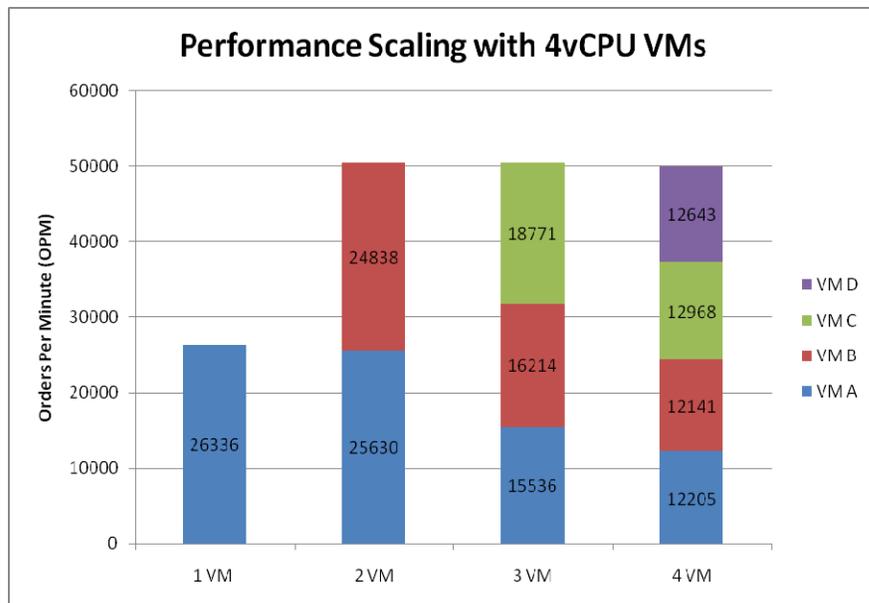


Figure 4 - Performance Scaling with 4vCPU SQL Server VMs.

VMotion Testing

Another aspect of performance with VMs running on ESX Server is how they perform during VMotion events. In order to measure this, the same SQL Server VMs used in the performance testing were put under stress and migrated between two identical physical servers via VMotion.

VMotion Test Setup

In order create a strenuous VMotion test, the VMs were moved every 12 minutes over a 90 minute period. A Java program using the Virtual Infrastructure SDK was written to automate the VMotion events and ensure they occurred at the same interval for all tests.

The VM was put under moderate stress of about half that used in the performance test, or approximately 40% CPU utilization on the VM. This was done to model an average load, whereas in the performance testing we were trying to model the high end of the acceptable range of utilization.

To record the performance of the SQL Server VM during the VMotion events, Windows performance monitor (perfmon) was used in combination with VMware Virtual Center's performance monitoring, and the output from the DVD Store driver program.

VMotion Test Results

The time to complete a VMotion is measured from the time the command is issued, until the VM is on the new server. During most of this time, the ESX Servers involved are preparing for the move and the VM remains fully available. It is only at the very end of the VMotion operation, when the VM will actually move, that the VM becomes inaccessible. This time is usually under 1 second and is undetectable to almost all users and applications. Table 4 shows the results for the VMotion testing.

	Small VM	Medium VM	Large VM
vCPUs	1	2	4
RAM	8 GB	8 GB	8 GB
DS2 Driver Threads	4	5	8
Avg Time for VMotion (minutes:seconds)	1:49	2:04	3:06

Table 4: VMotion testing results.

All VMotion migrations completed successfully without errors or warnings. The Windows Event Log and SQL Server error logs were clear of errors as well. The amount of time for a VMotion event to complete did increase when the VM was configured with more vCPUs. This was in part due to the increased workload that was used to keep the test VM at approximately 40% CPU.

The impact of the VMotion events on the performance of the SQL Server VMs was minimal. In order to measure this impact, the VM was run with the same number of threads both with and without VMotion occurring. The difference in the OPM between the two tests is shown in Table 5.

	Small VM	Medium VM	Large VM
vCPUs	1	2	4
RAM	8 GB	8 GB	8 GB
DS2 Driver Threads	4	5	8
Orders Per Minute with VMotion	7164	8355	11312
Orders Per Minute without VMotion	7556	8745	12281

Table 5: Measuring the impact of VMotion on SQL Server performance.

Perhaps the easiest way to see the impact of the VMotion events is in the CPU% of the VM. With each VMotion event there is a slight rise in utilization which can be seen in Figure 5 below.

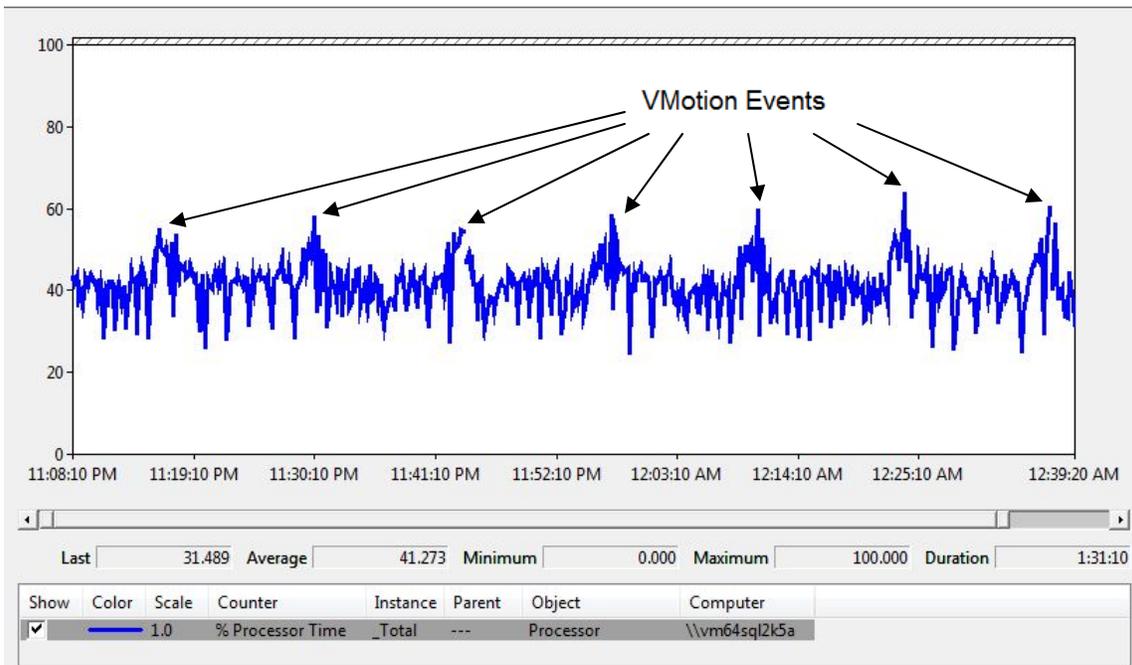


Figure 5: Windows performance monitor graph of CPU% Utilization of the SQL Server VM with 2vCPU users during VMotion test. Each VMotion event can be seen in the brief spikes.

Conclusions

The performance of SQL Server 2005 running within a VM on VMware ESX Server 3.5 on a Dell server is very good. Within a VM, performance scaled over 50% when doubling the number of virtual processors from 2 to 4. Performance was near linear when adding additional VMs. Additionally, it was easy to use VMotion to move a VM from one physical server to another while under load. During that process the performance of that VM was only slightly impacted. If a VM is properly sized with enough disk resources, the performance of SQL Server 2005 remains good as additional resources are added, up to the maximum level of the server.

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