White paper

Virtualizing Microsoft SQL Server 2008 with Citrix XenServer

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Introduction

Virtualization technology, already proven to provide significant benefits in the server environment, can now be extended to enterprise application platforms. In technical white papers in 2008, Citrix demonstrated that Citrix® XenServer™ is a solid virtualization platform for Citrix® XenApp™ and Microsoft® Exchange. For example, we demonstrated how XenServer was able to deliver performance similar to or, in some cases, better than, physical Exchange Server 2007 performance. In this technical white paper, we intend to demonstrate that Microsoft SQL Server® 2008 is equally well-suited for virtualization using XenServer.

The benefits of virtualizing SQL Server 2008 are similar to those of virtualizing Exchange 2007 on XenServer:

- Server consolidation
- Increased manageability and flexibility
- Increased availability
- Scalability

Server consolidation and scalability

We will demonstrate how XenServer can stem physical server proliferation by consolidating SQL Server workloads and leveraging the ever-increasing capacities of today's physical server components. SQL Server administrators have consolidated workloads on fewer, larger servers in the past, but at the expense of availability and manageability. Since XenServer decouples hardware from software, it allows server consolidation to take place without the expense.

Increased manageability and flexibility

Virtual machine (VM) workloads can be easily migrated from one host server to another to accommodate needed maintenance or upgrading of physical servers without impact to users.

Increased availability

SQL Server is one of the most mission-critical applications for many organizations. Often, extensive and expensive steps are necessary to ensure high availability (HA), since any lack of availability can have an immediate and significantly negative impact upon server productivity. Virtualization inherently addresses the challenge of availability by operating virtual server workloads independently of one another.

When running multiple instances of SQL Server on physical servers, if anything should happen to one instance, it could have catastrophic consequence to all of the instances operating alongside. Virtual server workloads, however, can stop and start, or even fail completely with no impact to others running on the same host server. In the event of complete host server failure, virtual SQL Server workloads can be restarted on other host servers in a matter of minutes and, in the case of storage or network connection failures, recovery can be nearly instantaneous.

While these HA features are available from products in the physical domain, they tend to be complex and expensive to implement. By contrast, HA capabilities for virtual SQL Server workloads on XenServer are built in to XenServer 5.0 or available from everRun™ VM, provided by Citrix partner, Marathon Technologies.

Scalability

Scalability is easily achieved by deploying additional virtual SQL Server workloads in a matter of minutes vs. physical SQL Server configuration and deployment methodologies which often take hours or even days.

Test method

As with any new approach to server deployment, a careful examination needs to be performed to estimate its impact vs. traditional methods. In this study, we will compare the performance of virtual SQL Server workloads to that of physical SQL Server workloads. We will do this using multiple physical and virtual host server configurations of from four to sixteen CPUs and from 14GB to 56GB of RAM. Comparisons will be made to physical servers hosting single instances and multiple instances of SQL Server 2008 with that of XenServer hosts running single and multiple SQL Server VMs. Finally, comparisons will be made of virtual SQL Server 2008 workloads running on XenServer vs. another virtualization technology provider. In this way, customers will see how XenServer performs in a wide variety of circumstances, and will have the information and tools with which to conduct their own evaluation tests to deploying virtualized SQL Server workloads in their own production environments.

The challenge

IT managers, regardless of the software platforms they run, are challenged with demands to control capital and operational expenditures costs in the datacenter. Those who depend on SQL Server as a mission critical application for their businesses must balance that together with maintaining the highest possible levels of application availability and reliability. As a result, those responsible for managing SQL server environments are now talking about virtualization. Questions range from “Is it possible to virtualize SQL Server?” to “What are the benefits and the possible risks?” and “I know we want to virtualize, but how do I know if I’m doing it right?” Many administrators also believe that the benefits of virtualization can only be obtained if their SQL servers are generally under-utilized, experiencing only occasional peaks in volume, while others have SQL servers that are consistently near or at full-utilization. Both ask the question, “What benefits can we get out of virtualizing my SQL servers?” The good news is that virtualization has many potential benefits whether SQL servers are under-utilized or not.

At present, only a small percentage of SQL administrators have completely virtualized their SQL Server farms. Their efforts are largely the result of experimentation with various configurations until they found the best one for their particular SQL environment. There are few, if any, best practice documents to use as guides and only limited examples of prior SQL server virtualization projects that they were able to use to predict the project scope and potential outcomes before getting started. Early adopters rarely have the benefit of others’ experiences to go by. However, most customers don’t necessarily put themselves in the category of early adopters since, for them, the perceived risks outweigh the benefits.

It’s for that reason we chose to use this opportunity to not only develop a document that included implementation best practices—thereby limiting the amount of unproductive experimentation a customer might have to go through—but to also provide a relatively broad range of test scenarios that customers could compare themselves to in order to estimate what a virtualized SQL Server environment might be like for them. In this way, customers can leverage valuable experience before they even get started and thus increase the likelihood of success.

The solution

Citrix XenServer 5

Citrix XenServer, a member of the Citrix Delivery Center™ family, is open, powerful server virtualization that radically reduces datacenter costs by transforming static datacenter computing into a more dynamic, easy to manage server workload delivery center. Based on the open source Xen® hypervisor, XenServer delivers a second generation, mature server virtualization platform with near bare-metal performance.

The powerful virtual provisioning capabilities available in XenServer software make it the only platform than can integrate the deployment and management of virtual and physical servers into a unified dynamic virtualized infrastructure—a flexible aggregated pool of computing and storage resources.

With XenServer, businesses can increase server and storage utilization and reduce costs of equipment, power, cooling and real estate. Virtualization-powered consolidation enables businesses to decommission older systems that are expensive to support and prone to failure, replacing several of them with a single newer, more supportable, less power-hungry system.

By combining servers and storage into resource pools that can be apportioned to the applications with the highest business need, IT operations can be aligned to changing demand and business priorities. With Citrix® XenMotion™, live virtual machines can be migrated to new servers with no service interruption, allowing essential workloads to get needed resources, enabling zero-downtime maintenance and better application virtualization.

XenServer 5.0 delivers:

- The industry's best virtualization TCO, through low initial and ongoing costs, more efficient server utilization and administration, dramatically reduced facilities and power costs, and reduction of storage requirements by up to 90 percent.
- Open architecture based on the open source Xen hypervisor, for a platform that is compact, fast and reliable, with seamless integration with existing infrastructure and management tools.
- Easy setup and administration, as it is available as an option on over 50 percent of new servers from Dell, HP, Lenovo and NEC, requiring only a license key to start, with the light-weight yet powerful Citrix® XenCenter™ management console and wizard-based tools to accelerate installation, maintenance and support.
- A thin, light and efficient 64-bit architecture delivering bare-metal performance and better workload consolidation ratios.
- Easy to use Windows® and Linux virtualization solutions with built-in virtual machine lifecycle management, at breakthrough price and performance.
- Enterprise high availability through comprehensive fault detection and fast, automated recovery from server failure, exceeding *four-9s* availability, with replicated management and configuration data across all servers in a pool to eliminate single points of failure.
- Continuous application availability for applications with XenMotion live migration, allowing virtual machines to move seamlessly, eliminating nearly all planned downtime.
- Dynamic workload management that consolidates workload images and streams workloads on-demand to any virtual or physical server.
- Snap-in storage integration supporting all storage architectures, offering deep integration with leading storage platforms, reducing cost and complexity by leveraging existing storage systems and associated storage services directly.

- Support for the latest and most popular server and desktop versions of Microsoft Windows, as well as major Linux server distributions.
- Virtual machine format compatibility and portability with Microsoft Hyper-V.
- XenConvert physical-to-virtual (P2V) conversion tool and v2xva virtual-to-virtual (V2V) conversion tool.

Study description

The purpose of this study was to determine the transaction processing performance of SQL Server 2008 using XenServer 5.0 virtual machine SQL servers as compared to physical SQL servers. Further comparisons would also be made to determine the performance differences between XenServer and that of another industry leading server virtualization provider (described in this technical white paper as Vendor X) in a SQL Server 2008 environment.

The three major test groups for the study were:

Test group #1: Small – 4 Core/14GB physical or virtual host server

- Single instance physical server vs. single VM server
- Two instance physical server vs. two VM server

Test group #2: Medium – 8 Core/28GB physical or virtual host server

- Single instance physical server vs. single VM server
- Two instance physical server vs. two VM server
- Four instance physical server vs. four VM server

Test group #3: Large – 16 Core/56GB physical or virtual host server

- Single instance physical server (baseline only, no VM comparison test)
- Two instance physical server vs. two VM server
- Four instance physical server vs. four VM server
- Eight instance physical server vs. eight VM server

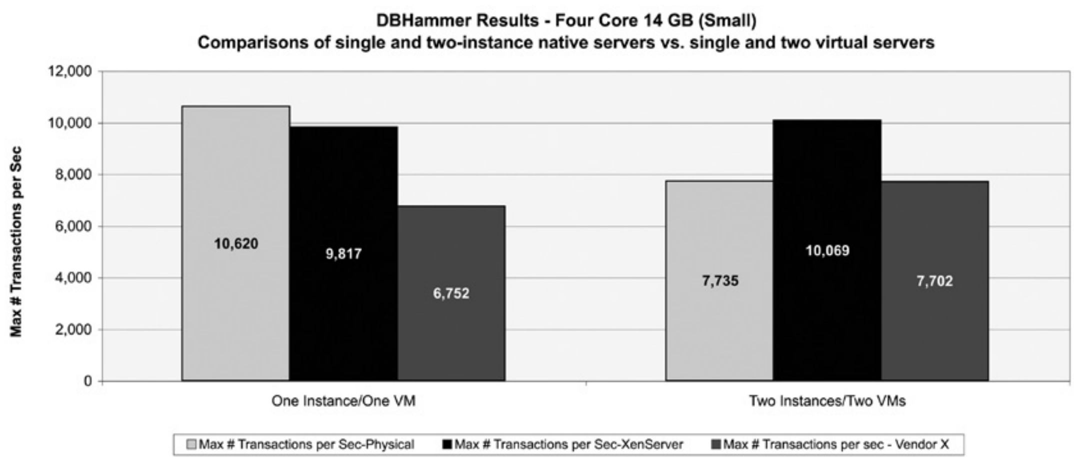
Detailed descriptions of study methodology, architecture and tools utilized are available in Appendix A of this white paper.

Detailed test descriptions and test group configurations are available in Appendix B of this white paper.

Results

Detailed descriptions of all study results are available in Appendix C of this white paper.

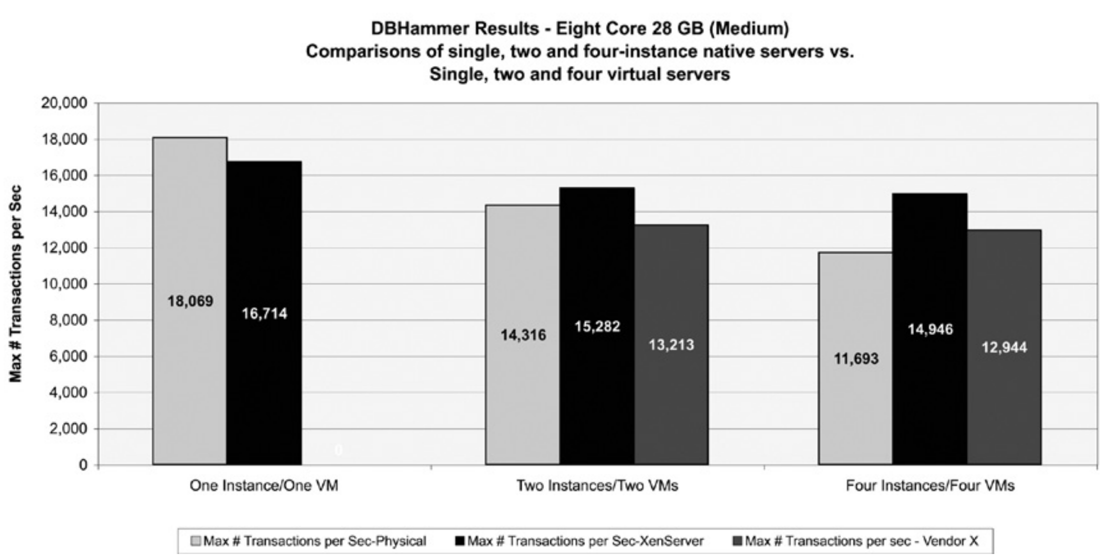
Test Group #1: 4 Core/14GB physical or virtual host server



Results: One and two instances of SQL Server on virtual servers vs. the same number on one physical server

- One instance of SQL Server
  XenServer virtualized a single instance of SQL Server with a 7.6% virtualization overhead vs. 36.4% for Vendor X.
- Two instances of SQL Server
  XenServer out-performed the physical SQL Server by 30% and Vendor X by 31%.

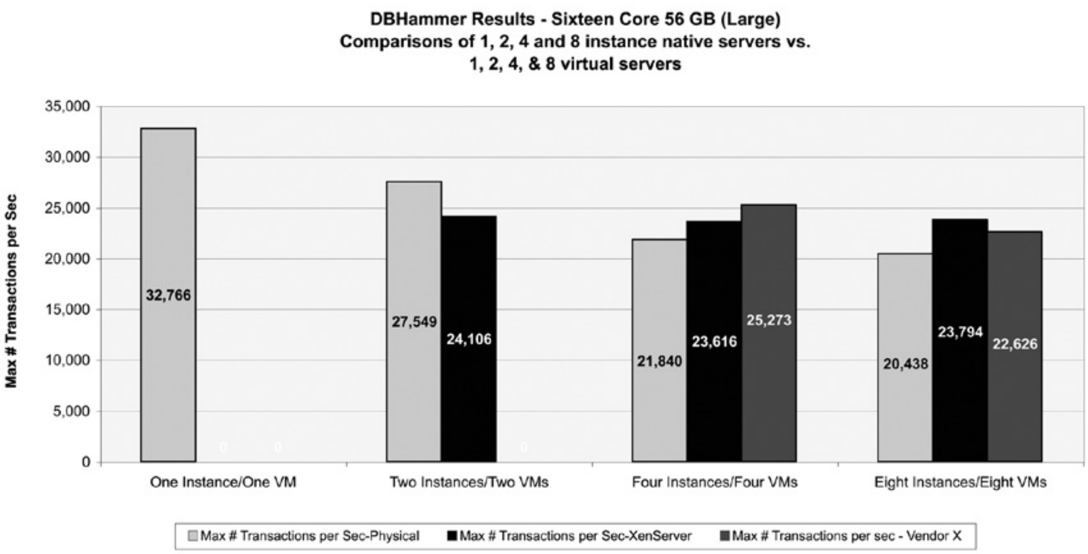
Test Group #2: 8 Core/28GB physical or virtual host server



Results: One, two and four instances of SQL Server on virtual servers vs. the same number on one physical server

- XenServer virtualized a single VM workload with only 7.5% virtualization overhead. Due to an inability to support more than four vCPUs, Vendor X was unable to compete with XenServer in this single instance vs. single VM, 8 core/28GB test.
- XenServer out-performed the physical server in the two and four instance tests, 6.7% and 27.8% better, respectively.
- XenServer out-performed Vendor X in the in the two and four instance tests, 15.7% and 15.5% better, respectively.

Test Group #3: 16 Core/56 GB physical or virtual host server



Results: One, two, four and eight instances of SQL Server on virtual servers vs. the same number on one physical server

- XenServer and Vendor X were unable to participate in the single instance, single VM test due to the inability of both to have sixteen vCPUs assigned to a single VM.
- Vendor X was unable to participate in the two instance, two VM tests due to its inability to support eight vCPUs in a single VM.
- The physical server performed best with a single instance of SQL Server. As additional instances were created and tested, performance declined steadily.
- XenServer outperformed the physical server in the four and eight instance tests.
- XenServer outperformed Vendor X in the eight VM test. Vendor X outperformed XenServer slightly in the four VM test, the only time Vendor X out-performed XenServer in these tests.
- Vendor X performance declined by 10.5% when scaling from four to eight VMs.

Conclusion

This virtualization test study has successfully proven that Citrix XenServer 5 is well suited to virtualizing Microsoft SQL Server 2008 in a wide variety of customer use scenarios. In doing so, XenServer should add operational flexibility and optimize resource utilization for most organizations' Microsoft SQL Server 2008 deployments.

The following are the highlights of the test findings:

1. Virtualizing single instance SQL server farms using XenServer is possible with very little virtualization overhead.

- XenServer overhead averaged 7.6% and 7.5% for the two single SQL Server vs. single VM tests respectively.
- By comparison, Vendor X averaged 36.4% overhead in the single test that it was able to participate in.

2. The benefits of virtualization and the strength of XenServer specifically are most pronounced with multiple instances of SQL Server.

- Multiple XenServer VMs are increasingly more productive than physical SQL servers as the number of instances increase.
- XenServer out-performs both physical SQL servers running multiple SQL Server instances and vendor X running multiple VMs in the majority of test cases.

3. Virtualizing SQL Server 2008 on XenServer doesn't require a Fibre Channel SAN. In these tests, we utilized standard, relatively inexpensive iSCSI-based storage.

We demonstrated in our earlier "Virtualizing Exchange Server 2007 on XenServer" technical white paper that the use of VM servers as building blocks is in many ways more effective for scaling the server farm vs. adding multiple physical servers. This is no less true for a SQL Server 2008 server farm. However, there are additional, practical benefits of using multiple XenServer VMs instead of multiple instances of SQL Server running concurrently. Like multiple instances of SQL, each XenServer VM operates independently of the others. However, since multiple instances running on a physical server share the resources of a single host server OS, each instance is susceptible to the failure of either the OS or of the host server itself. XenServer VMs, on the other hand, each have a unique instance of the OS running on each VM. The failure of one VM has no effect on the others. Additionally, in the event of the failure of a XenServer VM or the XenServer host, the resident HA feature of XenServer 5 will ensure that the restart of each VM takes place on another available host server within minutes. The recovery of a physical server running multiple instances of SQL is a far more complex and, often, expensive process to enable.

In summary, virtualization can add operational flexibility and optimize resource utilization for most organizations' SQL Server 2008 deployments. XenServer 5 provides unprecedented TCO gains via bare-metal performance, and increases the scalability and responsiveness of the Exchange platform. Rather than offering trade-offs between performance and flexibility, XenServer allows IT organizations to maximize both performance and manageability.

Appendix

Appendix A

i. Study methodology

Prior to the start of testing, we measured the I/O capacity of the physical server, XenServer and Vendor X configurations using Microsoft SQLIO. Measurements were taken for both 8K random and 64K sequential reads and writes.

DBHammer for SQL was used to generate the database and the load necessary to conduct the study. DBHammer created a 10 million-record database and then used the database to generate transaction processing workloads to simulate an actual SQL Server 2008 client workload. DBHammer workloads were created from small to large, starting with 100 clients. Workloads ran for 30 minute periods. At the end of the first 10 minutes of each test, measurements were taken using Microsoft performance monitor (perfmon) for the remaining 20 minutes of the test. Perfmon measured two key performance counters:

1. Maximum # of transactions per second attained, and

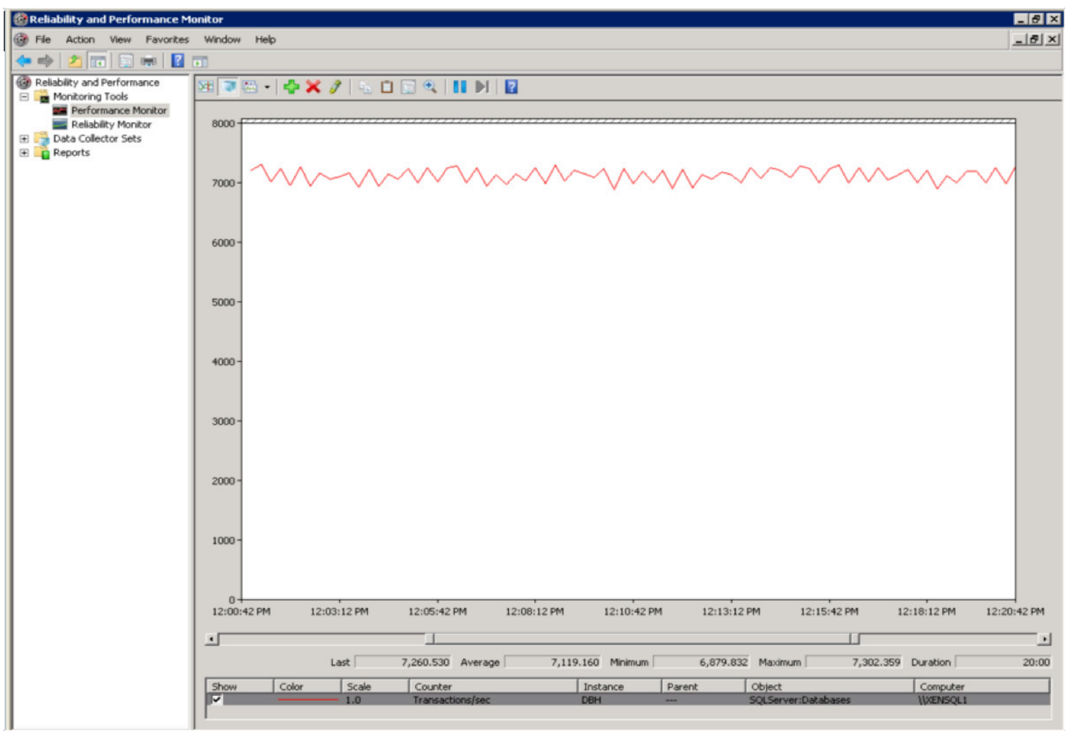


Figure 2. Transactions per second monitor screen

2. Average level of CPU utilization

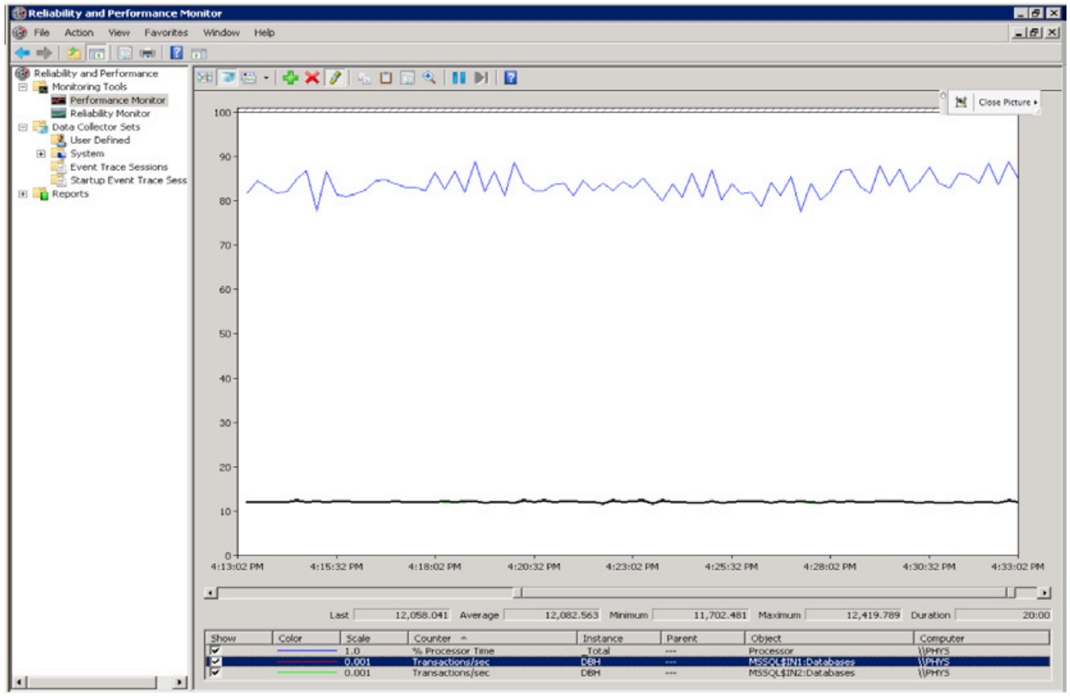


Figure 3. Average CPU utilization monitor screen

Measurements were taken every fifteen seconds until the 30 minute test period had elapsed. Vendor X mandated the use of a proprietary performance measurement tool to capture CPU utilization instead of perfmon due to the fact that unlike XenServer, performance measurements for the VM needed to be taken via the host server and not from within the VM itself. This is because of timing issues from within the VM, not present with XenServer pass-through hypervisor technology. Using that tool, we sampled the same results at the default sample length of 20 seconds per measurement. Increments of from 100-400 clients, depending on the size of the configuration, were added until the maximum average CPU utilization level of 90 percent was reached. When average CPU utilization of 90 percent was reached, it was determined that the system CPU resources were saturated and testing for that particular configuration was ended.

When measuring maximum transactions-per-second in the Vendor X VMs, we used perfmon, but per Vendor X recommendations, we kept the sampling period of 20 seconds the same as for CPU utilization.

Configurations varied based on host server hardware limitations and the per VM limitations of XenServer and Vendor X. Configurations consisted of single physical instances of SQL Server vs. virtual as well as multiple physical instances vs. multiple VMs. In each case, resources were the same for both the physical and virtual servers tested.

The three major components of the test study were:

Test group #1: Small – 4 Core/14GB physical or virtual host server
Test group #2: Medium – 8 Core/28 GB physical or virtual host server
Test group #3: Large – 16 Core/56 GB physical or virtual host server

Detailed descriptions of these test group configurations are available in Appendix B of this white paper.

ii. Architecture

Hardware

Physical and virtual (XenServer & Vendor X) host server:

- Dell® PowerEdge® R900, Four quad-core Intel® E7310 1.6Ghz CPUs, 64GB RAM

DBHammer for SQL load generation client servers (XenServer VMs):

- Intel 64bit host server, 24 CPU cores (4 x 6 cores Intel E7450), 2.4Ghz/32GB

Storage

- Dell EqualLogic PS5000, 16x138GB Disks, Raid 10/913GB
- 50GB database, 50GB log LUNs per SQL Server/VM

Network

- NetGear®, 24 port gigabit switch, model #GS724T
- NICs: Intel gigabit VT Quad Port Server Adapter, 3 ports

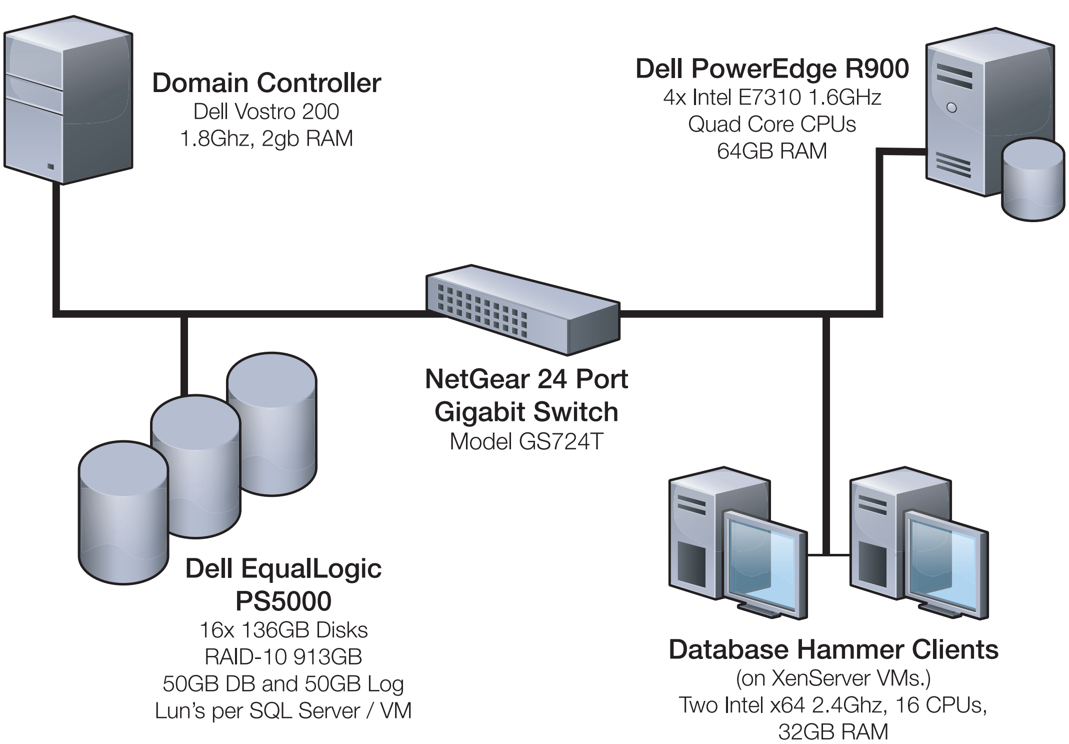


Figure 4. Test environment hardware configuration

Software

Physical server:

- Microsoft Server 2008 Windows Server 2008 Enterprise Service Pack 1 Build 6001
- Microsoft SQL Server 2008 (RTM) – 10.0.1600.22 (X64)

XenServer:

- XenServer 5.0 Dell OEM Edition

XenServer virtual machine servers:

- Microsoft Server 2008 Windows Server 2008 Enterprise Service Pack 1 Build 6001
- Microsoft SQL Server 2008 (RTM) – 10.0.1600.22 (X64)

iii. Tools

Workload generator

- DBHammer for SQL Server: Provided by Microsoft. Initially deployed with the SQL 2000 resource kit.

Performance measurement

- Microsoft SQLIO: SQLIO is a Microsoft tool used to determine the I/O capacity of a given configuration. Capacity is measured in terms of the maximum possible reads and writes per second for 8K random and 64K sequential.
- Microsoft Performance Monitor (perfmon): Used to measure average CPU utilization levels internal to physical SQL servers and XenServer VMs. Perfmon is also used in all cases to measure maximum transactions-per-second.
- An alternative, perfmon-like performance measurement tool provided by Vendor X was utilized to measure average CPU utilization and transaction levels. This tool took measurements from within the Vendor X host server and not within individual VMs per Vendor X instructions.

Appendix B

Test descriptions

i. SQLIO

SQLIO is a Microsoft tool that was used to determine the I/O capacity of the configurations used in the test program. The purpose of running SQLIO was to establish the benchmark for disk reads and writes for the host server configurations used in the DBHammer tests. It was not our intention to use SQLIO data to optimize storage configurations, but to determine how virtual SQL Servers disk reads and writes performance as compared to the benchmark standard after configuring storage using prescribed defaults. Significant deviations from the benchmark would be considered an indication that a potential problem existed that might adversely affect test results (no such indications were found).

We tested a single configuration with SQLIO, the smallest of the three that would be tested with DBHammer, one with four CPU cores and 14 GB RAM. We did not test the larger configurations since Vendor X has a limit of four vCPUs per individual VM. XenServer limitation is eight per VM, making a direct SQLIO comparison of all three not possible in the two larger host server sizes.

Measurements were taken of disk reads and writes using two SQLIO sizes, 8K (random) and 64K (sequential), since both are typically present in SQL Server depending on how the customer has optimized for I/O. By their nature, random data reads and writes are not efficient and are performed in smaller increments (8K) to minimize I/O request servicing latency. Sequential disk reads and writes are more efficient, produce less latency and can therefore be performed in larger (64K) increments. Customers will typically optimize their SQL Server environments to minimize the amount of random vs. sequential reads and writes. However, the routine occurrence of both random and sequential I/O activity is expected.

ii. DBHammer for SQL

DBHammer for SQL Server: A Microsoft tool and a Visual Basic (VB) 6.0 code sample that creates a table, populates the table with 10 million rows of data, then lets you simulate hundreds of concurrent SELECT and UPDATE operations.

To approximate a wide variety of physical SQL Server computing environments, we chose to group configurations into one of three physical SQL Server sizes which we referred to as small, medium and large. For each physical SQL Server configuration tested, we tested identical virtual SQL Server configurations on XenServer and on Vendor X. In all cases, CPU and RAM available to the instances running on the physical server or to the virtual servers compared to the physical instances were the same.

The first test was to establish performance benchmarks for a single physical server operating a single SQL server instance. This was repeated for each of two, four and eight separate instances of DBHammer for SQL running concurrently on the one physical server and on the virtual servers.

This is a necessary method for comparison since it is not possible to split a single instance of SQL Server onto two virtual SQL Servers and load balance evenly. When splitting the workload of SQL server onto two separate servers, SQL Server requires each server to have its own unique database. To accomplish this, you must create separate instances of SQL server in a physical environment while creating separate virtual SQL Servers in a virtual environment. For the purpose of these tests, performance of multiple virtual SQL Servers was compared to the same number of physical SQL Servers.

DBHammer test group configurations:

Physical	XenServer	Vendor X
a. Single instance, four CPU cores/14GB RAM	a. Single VM, four vCPU cores/14GB RAM	a. Single VM, four vCPU cores, 14GB RAM
b. Two instances, four CPU cores/14GB RAM, shared	b. Two VMs, two vCPU cores/7GB RAM each	b. Two VMs, two vCPU cores/7GB RAM each

#1 (small) - 4 Core/14GB

Physical	XenServer	Vendor X*
a. Single instance, eight CPU cores/28GB RAM	a. Single VM, eight vCPU cores/28GB RAM	a. Single VM: N/A*
b. Two instances, eight CPU cores/28GB RAM, shared	b. Two VMs, four vCPU cores/14GB RAM each	b. Two VMs, four vCPU cores/14GB RAM each
c. Four instances, eight CPU cores/28GB RAM, shared	c. Four VMs, two vCPU cores/7GB RAM each	c. Four VMs, two vCPU cores/7GB RAM each

#2 (medium) - 8 Core/28 GB

Physical**	XenServer**	Vendor X**
a. One instance, sixteen CPU cores, 56GB RAM (benchmark)	a. One VM: N/A**	a. One VM: N/A*
b. Two instances, sixteen CPU cores/56GB RAM, shared	b. Two VMs, eight vCPU cores/28GB RAM each	b. Two VMs: N/A **
c. Four instances, sixteen CPU cores/56GB RAM, shared	c. Four VMs, four vCPU cores, 14GB RAM each	c. Four VMs, four vCPU cores, 14GB RAM each
d. Eight instances, sixteen CPU cores/56 GB RAM, shared	d. Eight VMs, two vCPU cores, 7GB RAM each	d. Eight VMs, two vCPU cores, 7GB RAM each

#3 (large) - 16 Core/56 GB

* Exceeds Vendor X per individual vCPU per VM limit of four
** Exceeds Vendor X per individual vCPU per VM limit of four and XenServer limit of eight

DBHammer test configuration matrix:

	# Physical instances or VMs				CPUs per instance (shared) or per VM				RAM per instance (shared) or per VM			
#1 SMALL – 4 Core/ 14GB	**1**	**2**	**4**	**8**	**2**	**4**	**8**	**16**	**7**	**14**	**28**	**56**
Physical (1a)	●					●				●		
Physical (1b)		●				●				●		
XenServer(1a)	●					●				●		
XenServer(1b)		●			●				●			
Vendor X(1a)	●					●				●		
Vendor X (1b)		●			●				●			
#2 MEDIUM - 8 Core/28GB	**1**	**2**	**4**	**8**	**2**	**4**	**8**	**16**	**7**	**14**	**28**	**56**
Physical (2a)	●						●				●	
Physical (2b)		●					●				●	
Physical (2c)			●				●				●	
XenServer (2a)	●						●				●	
XenServer (2b)		●				●				●		
XenServer (2c)			●		●				●			
Vendor X (2a)	*						*				*	
Vendor X (2b)		●				●				●		
Vendor X (2c)			●		●				●			
#3 LARGE - 16 Core/56 GB	**1**	**2**	**4**	**8**	**2**	**4**	**8**	**16**	**7**	**14**	**28**	**56**
Physical (3a-benchmark)	●							●				●
Physical (3b)		●						●				●
Physical (3c)			●					●				●
Physical (3d)				●				●				●
XenServer (3a)		●					●				●	
XenServer (3b)			●			●				●		
XenServer (3c)				●	●				●			
Vendor X (3a)		*					*				*	
Vendor X (3b)			●			●				●		
Vendor X (3c)				●	●				●			

Figure 5. Test configuration matrix

* Exceeds Vendor X per individual VM vCPU limit of four

Appendix C

Result details

i. SQLIO

Since a single core VM would exceed the single VM limits for Vendor X (limited to 4 cores), we selected the 4 core/14GB server configuration to baseline the disk IOPS performance of the three solutions being tested. SQLIO results for the physical vs. two virtual server platforms are within acceptable performance standards for SQL Server. The physical server, XenServer and Vendor X performed nearly the same in 8K random and 64k sequential disk reads and writes per second performance. Overall, disk IOPS for the three was more than acceptable for the test program as configured. No discernable advantages or disadvantages for any of the test participants as a result of disk IOPS were found.

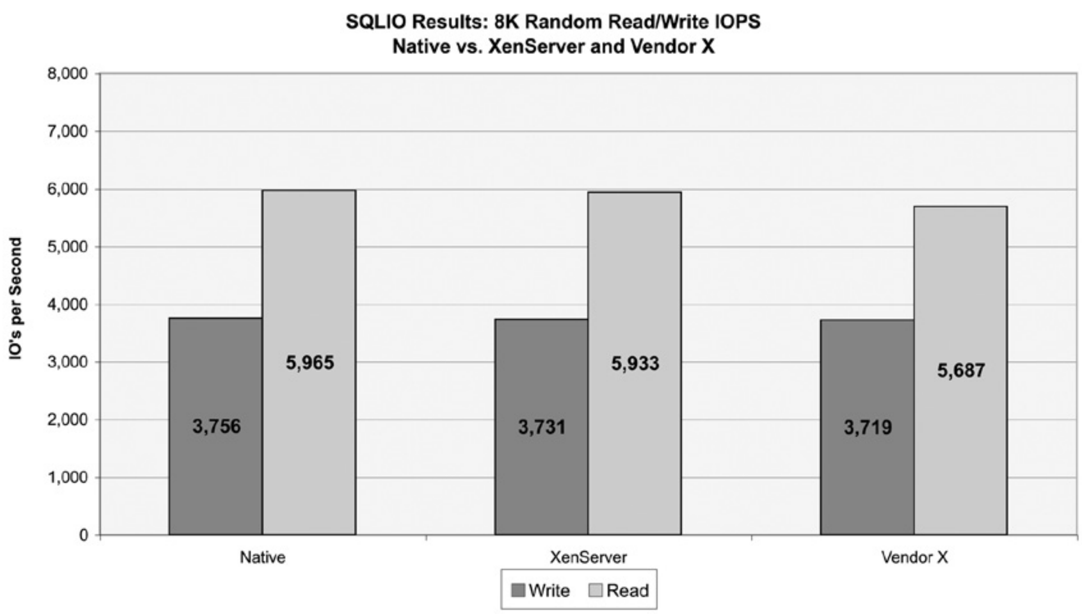


Figure 6. SQLIO 8K Random test results

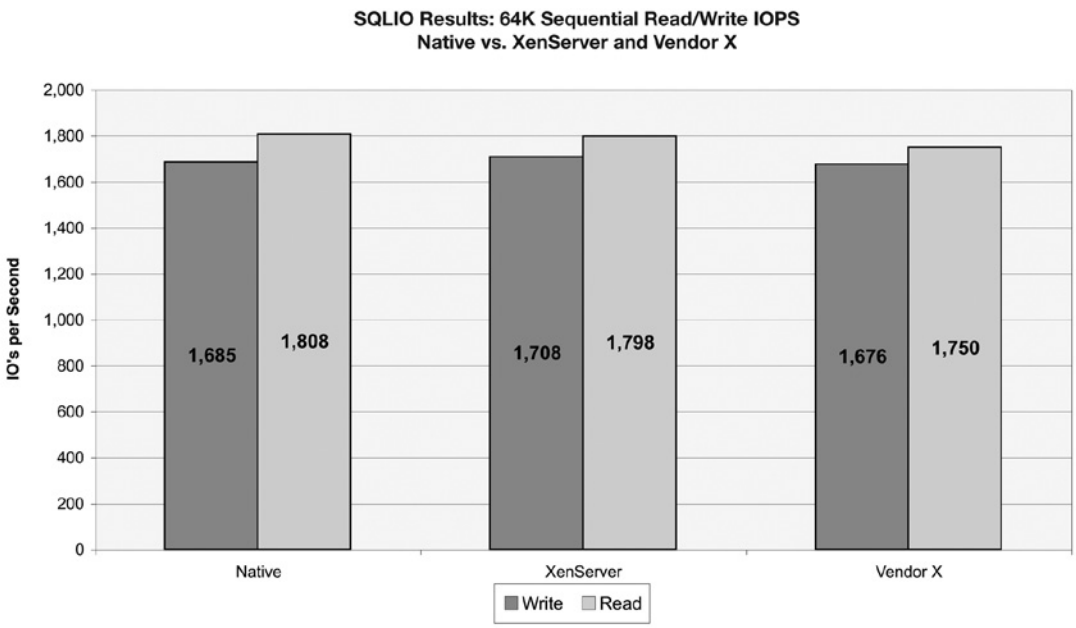


Figure 7. SQLIO 64k Sequential test results

ii. DBHammer

DBHammer results are the key performance indicators for this test program. Results will be presented here by the three test configuration groups:

Test group #1: Small – 4 Core/14GB physical or virtual host server
Test group #2: Medium – 8 Core/28GB physical or virtual host server
Test group #3: Large – 16 Core/56GB physical or virtual host server

Results: Test group #1, 4 Core/14GB (small)

A. Single instance physical vs. single XenServer and Vendor X virtual servers.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
100	7.8	10.7	19.9	916	917	914
200	16.2	18.6	32.1	1,831	1,834	1,827
300	23.6	27.6	43.7	2,743	2,746	2,647
400	31.1	36.5	54.7	3,658	3,660	3,581
500	37.9	44.6	67.0	4,575	4,573	4,328
600	46.1	54.7	76.8	5,487	5,484	5,098
700	54.3	62.7	86.7	6,394	6,400	5,960
800	62.1	72.1	93.6	7,314	7,302	6,752
900	70.9	78.4		8,167	8,192	
1000	77.9	86.2		9,139	9,019	
1100	86.3	90.9		9,807	9,817	
1200	92.8			10,620		

Figure 8. DBHammer Test group #1, test A results spreadsheet

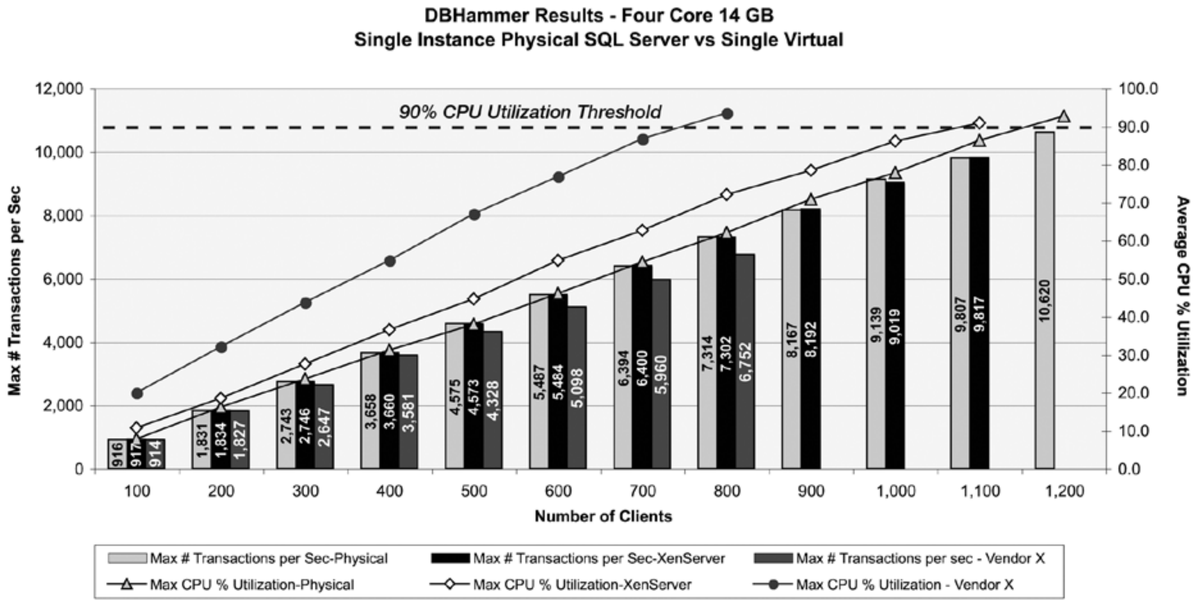


Figure 9. DBHammer Test group #1, test A results chart

Summary – Test 1A:

- **Physical server performance**
  Resources were efficiently handling increases in workload without loss of performance. When average CPU utilization reached 90%, 1,200 clients were delivering a maximum of 10,620 transactions per second.
- **XenServer performance**
  Consistent throughout, with average CPU usage slightly higher than the physical. Through 1,100 clients, the difference in maximum transactions per second were only 10 and CPU utilization differed by only 4.6%. When average CPU utilization reached 90%, maximum number of transactions per second was 9,817, only 7.6% fewer than the physical.
- **Vendor X performance**
  CPU utilization averaged nearly twice that of XenServer and two and one half times of physical with the first 100 clients. When average CPU utilization reached 93.6%, only 800 clients were generating a maximum of 6,752 transactions per second, 36.4% less than physical and 31.2% less than XenServer.

B. Two instance physical vs. two XenServer and Vendor X virtual servers.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
100	9.7	9.4	18.2	917	917	908
200	19.9	16.0	28.5	1,832	1,832	1,829
300	28.7	26.2	39.2	2,744	2,747	2,741
400	37.1	34.8	49.5	3,654	3,657	3,630
500	49.1	42.7	59.1	4,533	4,574	4,437
600	59.8	51.3	69.3	5,360	5,402	5,252
700	72.8	59.7	78.7	6,188	6,323	6,123
800	82.8	70.2	88.6	6,976	7,082	6,941
900	91.1	75.4	94.8	7,735	8,062	7,702
1000		83.3			8,703	
1100		88.5			9,613	
1200		93.5			10,069	

Figure 10. DBHammer Test group #1, test B results spreadsheet

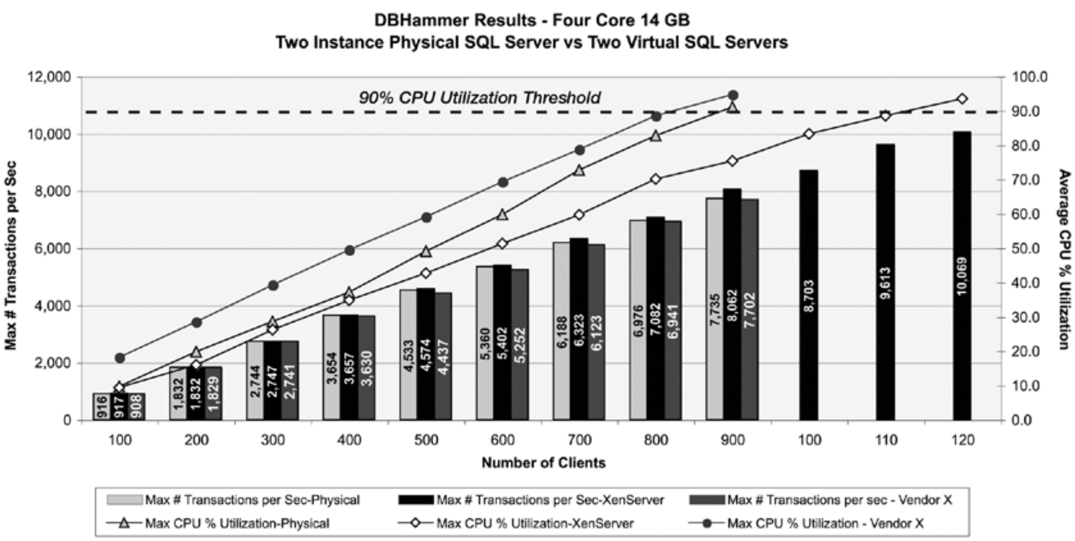


Figure 11. DBHammer Test group #1, test B results chart

Summary – Test 1B:

- **Physical server performance**
  Resources were shared between two active instances running concurrently. Performance degraded 27% as the maximum number of transactions per second fell from 10,620 to 7,725.

  CPU utilization was considerably higher. When average CPU utilization reached 90%, only 900 clients were actively conducting transactions vs. 1,200 clients in the previous test.

- **XenServer performance**
  XenServer performed better across two VMs than the previous single VM test by 2.5%, as the maximum number of transactions per second increased from 9,817 to 10,069.

  XenServer out-performed the two instance physical SQL Server by 30%, and Vendor X by nearly 31% (10,069 vs. 7,702 transactions per second).
- **Vendor X performance**
  Vendor X performance improved 14 percent vs. the previous single VM test, reaching a maximum of 7,702 vs. the previous 6,752 transactions.

  Vendor X was able to support 900 clients before reaching the maximum CPU level of 90%, vs. 800 clients in the previous test. Overall, Vendor X performance was close to that of physical.

Results: Test group #2, 8 Core/28GB (medium)

A. Single instance physical vs. single XenServer.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
200	10.0	12.9	n/a	1832	1833	n/a
400	19.5	25.3	n/a	3660	3661	n/a
600	29.5	36.3	n/a	5488	5488	n/a
800	38.5	47.5	n/a	7316	7317	n/a
1000	49.1	58.0	n/a	9144	9101	n/a
1200	58.7	67.7	n/a	10817	10764	n/a
1400	66.5	77.4	n/a	12792	12553	n/a
1600	75.1	83.6	n/a	14587	14029	n/a
1800	82.6	87.9	n/a	16294	15297	n/a
2000	89.7	92.0	n/a	18069	16714	n/a

Figure 12. DBHammer Test group #2, test A results spreadsheet

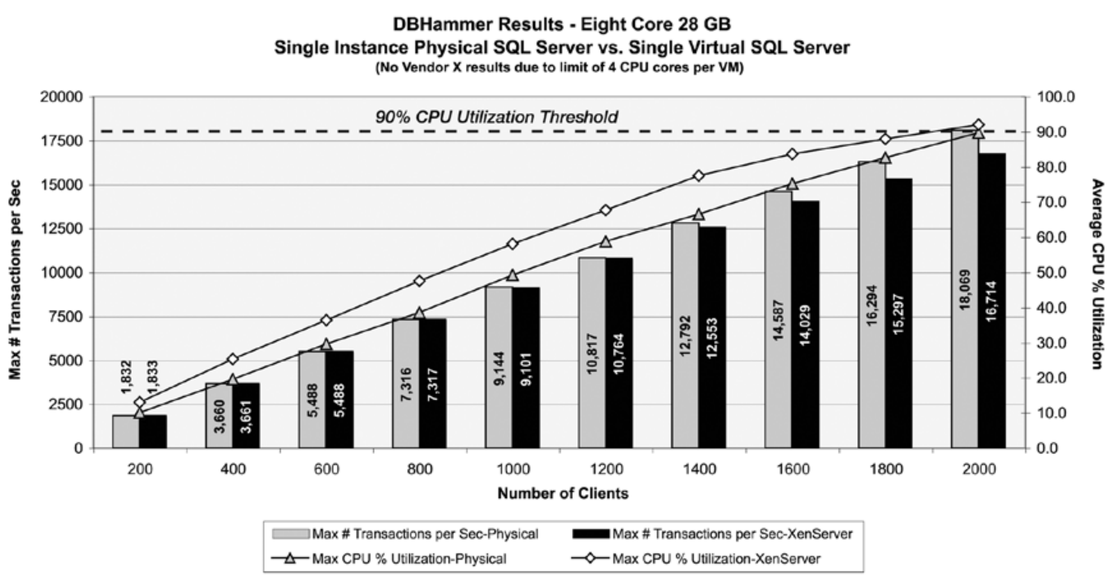


Figure 13. DBHammer Test group #2, test A results chart

Summary – Test 2A

- **Physical vs. XenServer performance**
  The physical server and XenServer VM generated close to the same number of transactions per second from 200-1,200 client workloads. Physical server performance exceeded XenServer above 1,400 clients.
- The physical server and XenServer generated a 2,000 client workload. When average CPU utilization reached 90% the physical server produced 18,069 maximum transactions per second vs. 16,714 for XenServer, a difference of 1,355 transactions or < 7.5%.

B. Two instance physical vs. two XenServer and two Vendor X virtual servers.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
200	11.4	11.7	21.2	1834	1834	1804
400	24.0	21.3	33.4	3661	3664	3627
600	32.9	31.8	44.4	5456	5492	5167
800	43.8	42.0	57.8	7314	7317	7126
1000	57.1	53.0	69.4	8883	9141	8791
1200	67.0	64.4	79.1	10626	10925	10230
1400	81.8	78.1	89.6	12493	12631	11981
1600	91.7	86.3	96.0	14316	14173	13213
1800		92.1			15282	

Figure 14. DBHammer Test group #2, test B results spreadsheet

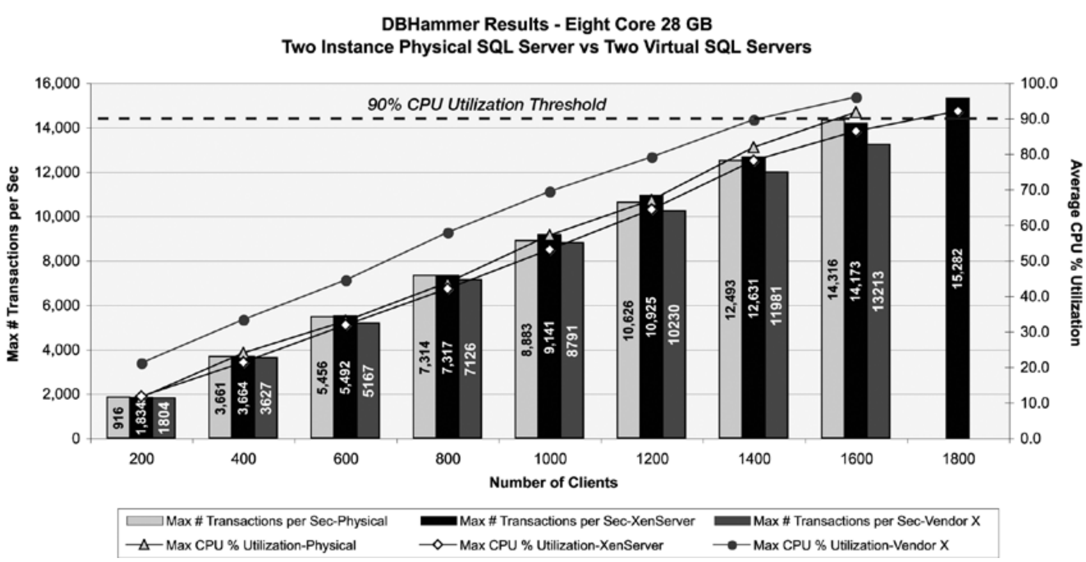


Figure 15. DBHammer Test group #2, test B results chart

Summary – Test 2B

- **Native and XenServer performance**
  The physical server and XenServer VM generated close to the same number of transactions per second through 1,600 client workloads, where the physical server reached the 90% average CPU utilization. XenServer took on 1,800 client workloads before reaching maximum CPU capacity.

  XenServer generated a maximum transaction per second rate of 15,282 vs. 14,316 for the physical server, an increase of 6.7%.
- **Vendor X**
  Underperformed the physical server by 1,103 transactions per second or 7.7%, and XenServer by 2,069 transactions per second or 13.5%.

C. Four instance physical vs. four XenServer and four Vendor X virtual servers.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
200	13.9	9.5	17.9	1837	1836	1830
400	27.7	19.2	29.2	3667	3664	3648
600	41.6	28.2	39.7	5492	5492	5463
800	56.1	39.3	51.0	7318	7314	7138
1000	68.8	50.0	60.2	9120	9107	8739
1200	78.3	60.4	67.8	10566	10496	10378
1400	98.6	72.5	80.8	11693	12357	11776
1600		83.7	96.5		13864	12944
1800		91.0			14946	

Figure 14. DBHammer Test group #2, test C results spreadsheet

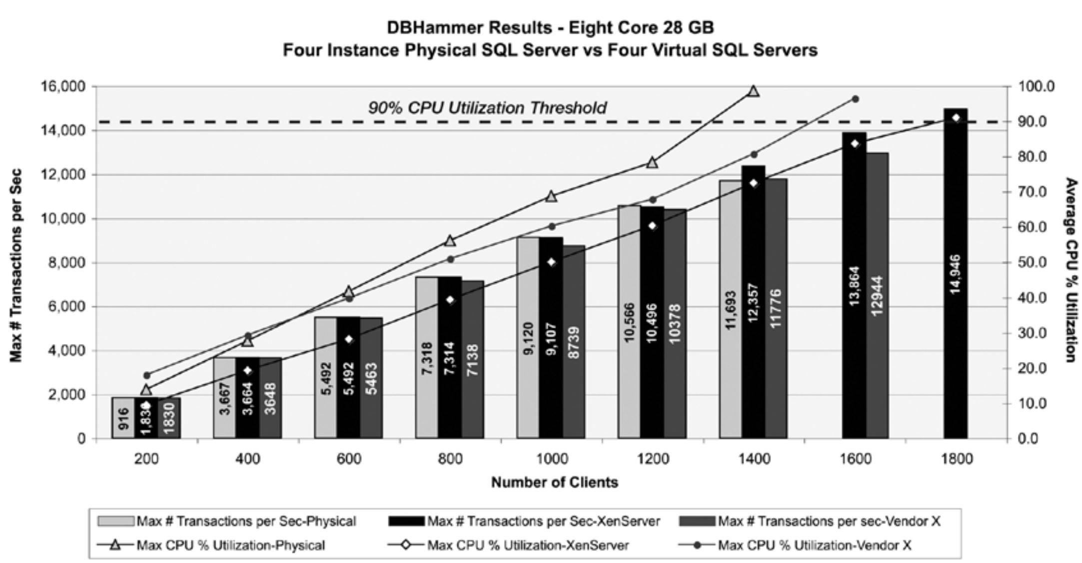


Figure 15. DBHammer Test group #2, test C results chart

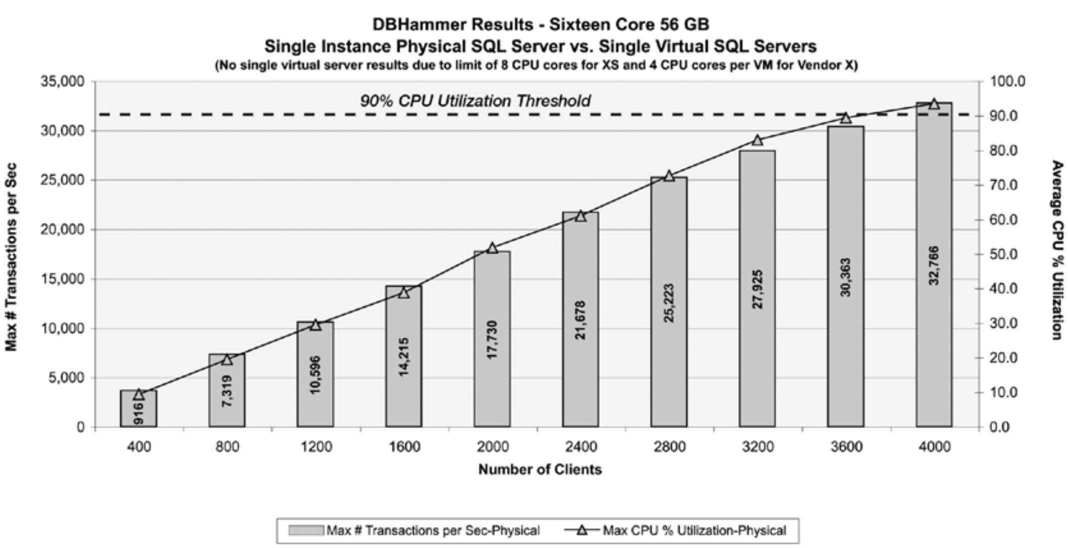
Summary – Test 2C

- **Physical server performance**
  Deteriorated quickly as CPU utilization rates increased sharply at 800 clients. Overall, the four instance physical server peaked at 1,400 clients, generating just 11,693 maximum transactions per second.
- **XenServer**
  Peaked at 1,800 clients and 14,946 transactions per second, 27.8% higher than physical.
- **Vendor X**
  Peaked at 1,600 clients and 12,944 transactions per second, 10.7% better than physical but 13.4% less than XenServer.

Results: Test group #3, 16 Core/56GB (Large)

A. Single instance physical (benchmark only)

	Average % CPU Utilization	# Transactions per sec Max
# Clients	Physical	Physical
400	9.4	3659
800	19.4	7319
1200	29.4	10596
1600	38.7	14215
2000	51.7	17730
2400	61.0	21678
2800	72.5	25223
3200	82.8	27925
3600	89.3	30363
4000	93.4	32766



B. Two instance physical vs. two XenServer VMs.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
400	11.9	15.8	n/a	3662	3662	n/a
800	22.0	29.4	n/a	7301	7320	n/a
1200	33.3	45.1	n/a	10901	10960	n/a
1600	47.4	56.9	n/a	14518	14514	n/a
2000	59.1	69.9	n/a	17773	17642	n/a
2400	71.1	80.0	n/a	21201	20604	n/a
2800	83.6	85.9	n/a	24827	22768	n/a
3200	92.9	90.5	n/a	27549	24106	n/a

Figure 16. DBHammer Test group #3, test A results spreadsheet

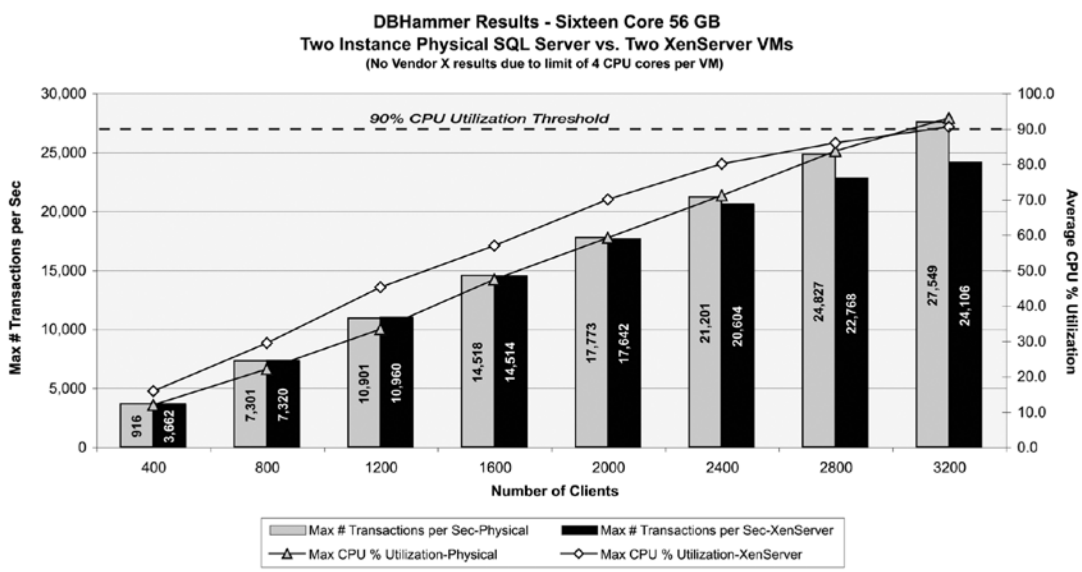


Figure 17. DBHammer Test group #3, test A results chart

Summary – Test 3B:

- **Physical server and XenServer performance**
  Performance of the two is relatively similar in transactions per second through the 2,000 client workload level. CPU utilization levels are higher for XenServer than for physical, but the gap begins to close at the 2,400 client level and XenServer ends slightly lower than physical at the 3,200 client workload level.

  The physical server attained a maximum transaction per second rate of 27,549 vs. XenServer at 24,106.

  XenServer virtualization overhead was 12.5%. This is the first time that a two-instance physical server out-performed XenServer in these tests.

C. Four instance physical vs. four XenServer and four Vendor X VMs.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
400	15.2	13.6	22.2	3662	3667	3624
800	30.8	25.0	35.0	7290	7323	7206
1200	41.4	38.9	47.8	10664	10950	10381
1600	56.5	53.5	59.8	14191	14438	13768
2000	71.9	68.1	69.3	17846	17724	16876
2400	86.4	78.8	77.3	21478	20427	19030
2800	99.0	86.8	84.4	21840	22628	21934
3200		86.8	88.9		22628	23657
3600		90.6	90.4		23616	25273

Figure 18. DBHammer Test group #3, test A results spreadsheet

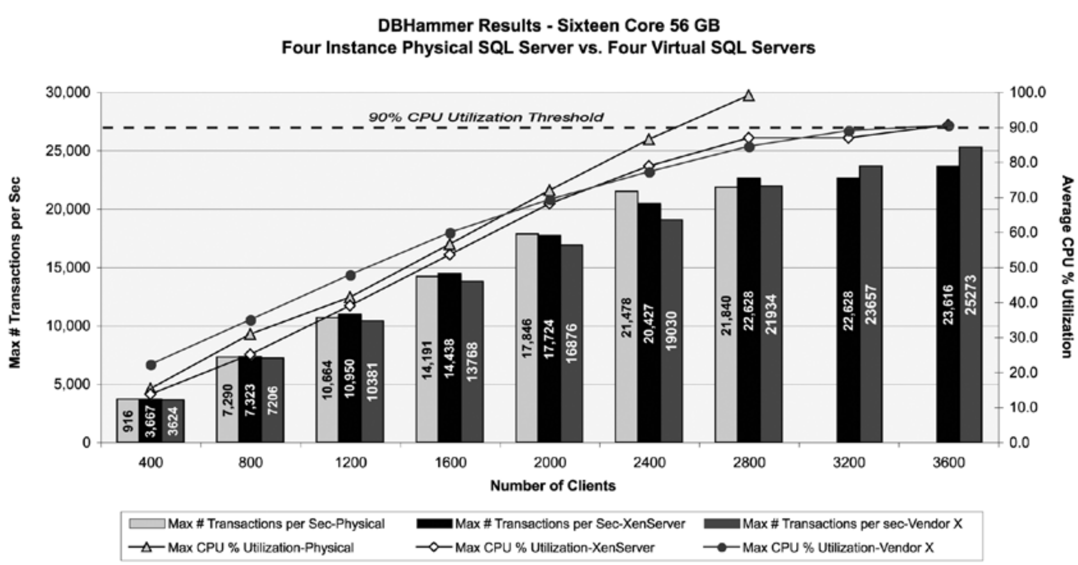


Figure 19. DBHammer Test group #3, test A results chart

Summary – Test 3C

- **Physical server performance**
  Average CPU utilization reached 90% with 2,400 clients. It topped off at 2,800 clients generating a maximum transaction per second rate of 21,840.
- **XenServer and Vendor X performance**
  Out-performed the physical server by handling 3,600 client workloads before reaching the CPU limit. For the first time, Vendor X out-performed XenServer with an overall 25,273 maximum transactions per second as compared with 23,616 (7.0%) more than XenServer.

D. Eight instance physical vs. eight XenServer and eight Vendor X VMs.

	Average % CPU Utilization			# Transactions per sec Max		
# Clients	Physical	XenServer	Vendor X	Physical	XenServer	Vendor X
400	16.1	11.4	21.2	3663	3671	3645
800	31.7	24.4	35.0	7301	7316	6741
1200	46.2	37.8	46.7	10933	10861	10304
1600	62.3	46.9	57.4	14279	14151	12895
2000	74.9	61.1	66.1	17592	16750	15562
2400	93.2	71.0	74.3	20438	19218	17473
2800		76.3	82.6		21551	19780
3200		84.3	88.5		22670	21264
3600		87.7	92.0		23242	22626
4000		90.3			23794	

Figure 20. DBHammer Test group #3, test C results spreadsheet

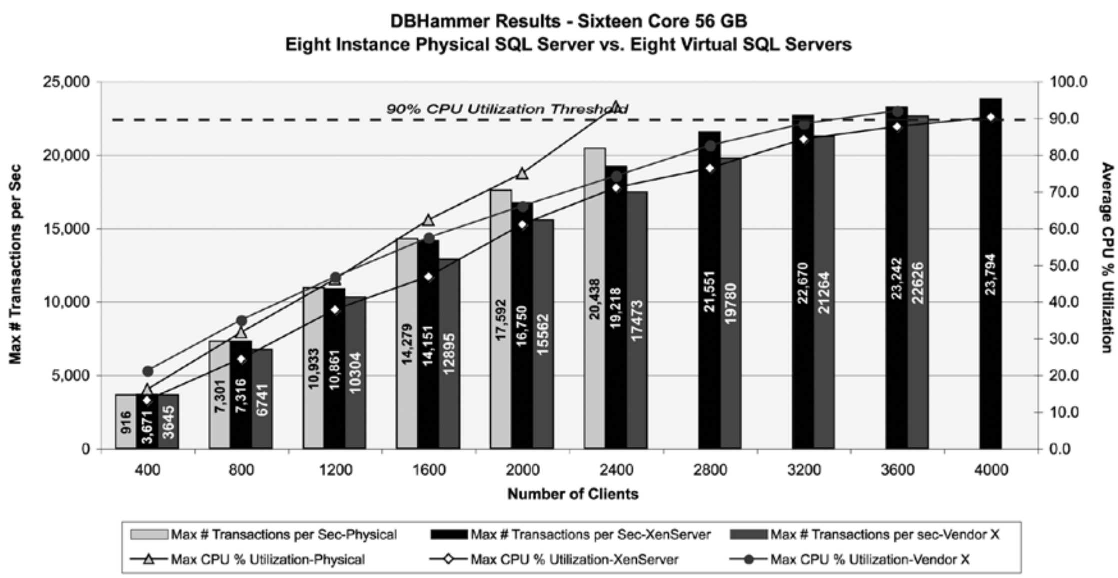


Figure 21. DBHammer Test group #3, test C results chart

Summary – Test 3D

- **Physical server performance**
  Reached a maximum of 2,400 clients and 20,438 transactions per second, less than in either of the two previous tests. As the number of physical instances increases, performance decreases.
- **XenServer performance**
  Sustained a workload of 4,000 DBHammer clients over eight VMs, generating a maximum of 23,794 transactions per second, 16.4% better than the physical server and 5.2% better than Vendor X.

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