Consolidating Web Applications Using VMware Infrastructure

VMware® Infrastructure 3

Enterprises continue to move their technologies and services onto the Web. Today, the Web servers that provide these services are distributed across multiple systems. As the number of Web applications increases, it is very common for the number of physical systems in the data center hosting these Web applications to increase along with them. Studies from IDC, among others, describe the challenges IT managers face administering the proliferation of servers used to run Web applications.

Virtualization can help businesses to consolidate their Web computing needs onto fewer high-performance servers. This approach can simplify management, save operating costs, and increase the efficiency of delivering Web services.

In this paper we explore the configuration and testing of VMware® Infrastructure 3 as a consolidation platform for multiple Apache Web servers. It describes the processes and methodologies we used in the consolidation study. In addition, we describe the results of our performance testing using the industry standard SPECweb2005 workload to determine the effectiveness of this consolidation approach.

This paper covers the following topics:

Technologies Used

The key technologies we used in these tests were VMware® Infrastructure 3, the Apache Web server, the PHP scripting language, and the SPECweb2005 workload.

VMware Infrastructure 3

VMware Infrastructure 3 is the industry-leading infrastructure software suite that virtualizes servers, storage, and networking, allowing multiple unmodified operating systems and their applications to run independently in virtual machines while sharing physical resources. The software suite consists of VMware ESX (hypervisor) and several other products that work together not only to provide the benefits of consolidation but also to foster flexibility by featuring unique technologies such as VMware VMotion that enables moving an entire running virtual machine from one physical server to another and VMware HA that

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provides cost-effective failover protection by eliminating the need for dedicated standby servers or additional software, and VMware DRS that dynamically allocates and balances available computing resources among the virtual machines.

In essence, VMware Infrastructure 3 enables organizations to decouple the entire software environment from their underlying hardware infrastructure. This virtualization approach provides an ideal platform for consolidating multiple Web server deployments onto fewer hardware systems.

Web Server Software

The choice of Web serving application and software depends greatly on customer requirements. Studies from the Netcraft show the Apache Web server has the largest market share today among all Web servers. In our performance evaluation tests, we used the widely deployed Apache/PHP as the Web serving platform.

PHP is a scripting language. Before the code is executed, it is parsed and converted to low-level binary instructions called opcodes. In the absence of any opcode cache, the opcodes generated are flushed from memory after execution. Deploying an opcode cache avoids this flushing and improves PHP performance. In our testing configuration, we employed APC cache as the opcode cache.

SPECweb2005

SPECweb2005 is the SPEC benchmark for measuring a system's ability to act as a Web server. In response to rapidly advancing Web technology, the SPECweb2005 benchmark includes many sophisticated and state-of-the-art enhancements to meet the demands of modern Web users.

SPECweb2005 is designed with three workloads: banking, e-commerce, and support. The banking component emulates a banking site that transfers encrypted information using HTTPS. The e-commerce component emulates an e-commerce site that uses unencrypted HTTP when browsing and secure HTTPS when the user enters the shopping cart. The support component emulates a vendor support site that provides downloads—such as driver updates and documentation—over HTTP.

The SPECweb2005 architecture represents a typical Web architecture that consists of the clients, Web server software, and a back-end application and database server. The benchmark drivers that generate the HTTP requests run on one or more client machines. The back-end simulator (BeSim) emulates a back-end application and database server. To process the SPECweb2005 requests, the Web server software needs to communicate with the BeSim in order to retrieve specific information that needs to be included in the HTTP response. Because the HTTP response is dynamically constructed, the Web server software should include the PHP or JSP support needed to generate the dynamic Web content.

The performance score of each of three workloads (banking, e-commerce, and support) indicates the number of simultaneous user sessions the system under test can support while meeting the quality of service requirements of the benchmark workload. The aggregate metric reported by the SPECweb2005 benchmark is a normalized metric based on performance scores obtained on all three workloads. For more information about the benchmark, see the SPEC Web site (see "References" on page 10 for a link).

Consolidation Using VMware Infrastructure 3

VMware ESX provides an ideal platform for consolidating multiple Web server deployments by enabling each Web server to run in a different virtual machine. ESX implements abstractions that allow each virtual machine to have its own virtual CPU, memory, disk, and network interfaces. In addition, each virtual machine runs a unique guest operating system. This kernel-level isolation provides maximum security and independence for the Web server deployments. In addition, our testing discussed in this paper demonstrates that such a consolidation approach makes effective use of the underlying compute and memory resources available in today's powerful multicore machines and yields better performance than using a single kernel image and a single Web server deployment.

This paper describes a methodology to consolidate multiple Web servers onto a single physical server. For this consolidation project, we created six virtual machines. This section describes the configuration of the physical machine and the virtual machines.

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CPU and Memory

In our test configuration, the system under test was an HP ProLiant DL380 G5 server with dual-socket, quad-core Intel Xeon E5345 2.3GHz processors and 32GB memory. We configured the system under test with VMware ESX 3.5. Each virtual machine was configured with one virtual CPU, 4GB of memory, running a 64-bit Red Hat Enterprise Linux 5 Update 1 operating system. The Web server software consisted of Apache 2.2.6, PHP 5.2.5, and APC 3.0.15.

Network Configuration

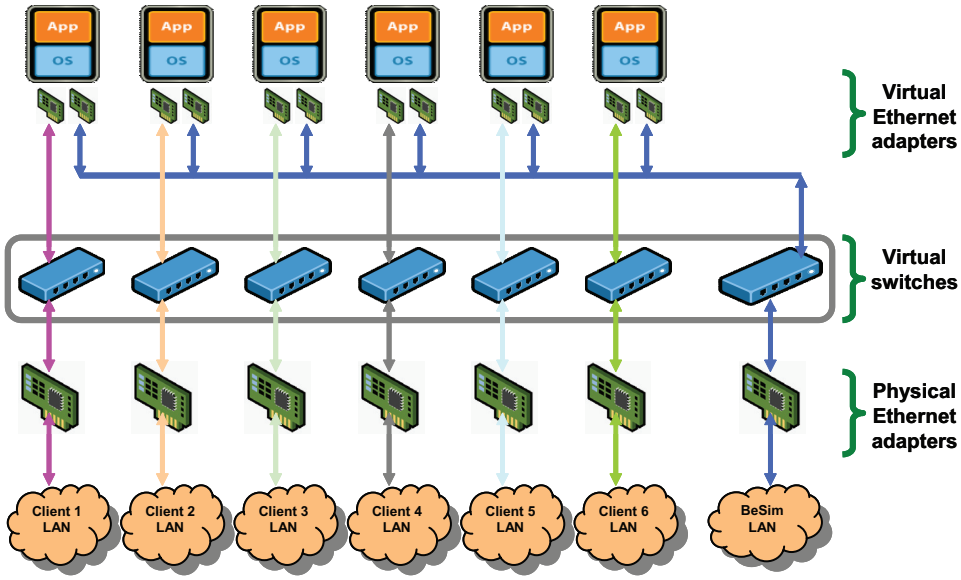
The SPECweb2005 workload is quite network intensive. We therefore configured the system under test seven physical 1Gbps Ethernet adapters, each associated with a unique subnet. We used six client systems, each of which was connected to the server over a separate private subnet using crossover cables. These six systems carried the client traffic. We also connected the BeSim (back-end database simulator) to the server on a private subnet using a crossover cable.

In the virtual environment, ESX supports up to four virtual network adapters within each virtual machine. Each virtual network adapter is connected to a physical network adapter through a virtual switch interface. A virtual adapter is given its own unique MAC address and a unique IP address, so from the client's networking standpoint, the virtual network adapter of a virtual machine appears the same as the physical network adapter of a physical machine.

In our test configuration, we configured each virtual machine with two virtual network interfaces. We used one interface for the client network traffic and the second interface for the BeSim (back-end database simulator) traffic. All the virtual machines used the same virtual switch, and so shared the same physical network interface to communicate with the BeSim server. Each of the virtual machines used a unique virtual switch for client traffic and, in essence, used a unique physical network interface to communicate with its client. In other words, the test configuration consisted of six virtual machines, each of which was communicating with a different client on a unique physical network interface.

Figure 1 shows the networking configuration in the virtual environment.

Figure 1. Network Configuration in the Virtual Environment



VMware Infrastructure 3 provides various choices for virtual network adapters. In our tests, we used enhanced vmxnet, a virtual network adapter that is designed for high performance. This is a paravirtualized device that can be used only if VMware Tools is installed in the virtual machine.

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Storage Configuration

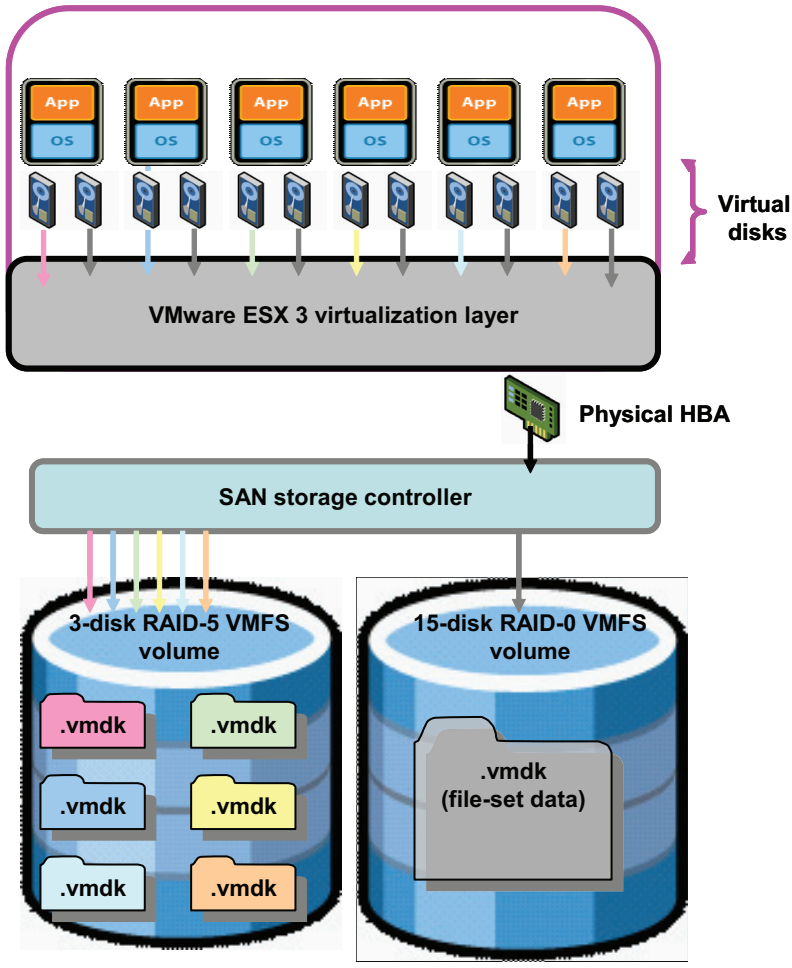
VMware Infrastructure 3 storage configuration completely hides the physical storage infrastructure from the virtual machines. The virtual machines access the underlying physical storage as though it were SCSI disks within the virtual machine. ESX stores the virtual disks as files (files in virtual machine disk format with `.vmdk` extensions) stored on a high-speed VMware Virtual Machine File System (VMFS) volume. The VMFS volumes can reside either on a locally attached RAID controller or a remote storage area network (SAN) device.

In our testing configuration, we connected the server to a remote Fibre Channel SAN. Each virtual machine used two virtual disks. The first virtual disk held the guest operating system image and the application (Apache/PHP) binaries and associated log files. The second virtual disk held the file-set data used by the Apache Web server.

Each of the virtual machines used an independent virtual disk (`.vmdk` file) for its guest operating system image. We stored all these `.vmdk` files on a three-disk highly-available RAID-5 VMFS volume hosted on a SAN. For the file-set data, all the virtual machines shared the same base image (`.vmdk` file), which we stored on a 15-disk RAID-0 VMFS volume hosted on the same SAN. To share the base image, we set the mode of the virtual disk that was used for file-set data as independent and nonpersistent. When the file-set data is very large, sharing a single base image can save time and disk space.

Figure 2 shows how we configured the storage in the virtual environment.

Figure 2. Storage Configuration in the Virtual Environment



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System Tuning

In general, the default configuration of the Apache Web server performs well and does not need much tuning. The only tuning that applies in most environments is to increase the number of Web server processes available to process the HTTP requests. To do this, increase the values for `MaxClients` and the `ServerLimit` in the `httpd.conf` file. In our tests, we increased the values of both of these variables from the default `256` to `10000`. For more information, on these variables, refer to the Apache documentation (see "References" on page 10 for a link).

We applied some minimal tunings to the Red Hat Enterprise Linux 5 operating system, notably increasing the default number of open file descriptors available to the Apache Web server and also increasing the range of TCP/IP ports available to user processes. The tunings are listed in the "Appendix: Detailed SPECweb2005 Results" on page 11.

In our virtualized tests, we increased transmit coalescing size in the vmxnet virtual NIC to meet the high network throughput demands of the support workload. Most customer workloads are latency sensitive, so the default dynamic tuning works well. However, if the network throughput demands of the workload are very high (close to or exceeding 1Gbps), this parameter can be tuned to favor throughput over latency.

In our virtualized environment, we also used the manual processor affinity feature to assign the virtual machines to different physical cores on the system under test. We did this to better understand and track the CPU usage of the individual virtual machines. With eight cores on the dual-socket system under test, we assigned three virtual machines to three cores of the CPU in one socket and the remaining three virtual machines to three cores of the CPU in the second socket.

In our virtualized environment, we also pinned the network interrupts. The network interrupts of the physical NICs associated with each virtual machine were pinned to the idle core on the corresponding CPU. For instance, we assigned virtual machine-1, virtual machine-2, and virtual machine-3 to core-1, core-2, and core-3 of the first socket, and the network interrupts of the physical NICs associated with each of these three virtual machines were pinned to core-0 of the same socket. This configuration enabled us to make slightly better use of the shared memory caches on the chip, and yielded about 5 percent to 8 percent improvement in performance.

Increasing Transmit Coalescing

To increase transmit coalescing size, perform the following steps:

1. Using VI Client (VMware Infrastructure Client) choose the ESX host where the virtual machine is deployed.
2. Select the **Configuration** tab.
3. Click **Advanced Settings** in the **Software** panel.
4. Click the **Net** tab.
5. Edit the value of `Net.vmxnetThroughputWeight`, changing it from the default of `0` to`128`, then click **OK**.
6. Reboot the virtual machine.

NOTE This configuration change applies to all the vmxnet devices on the server.

Setting Processor Affinity

To set processor affinity, perform the following steps:

1. Using VI Client, right-click a virtual machine and choose **Edit Settings**.
2. In the Virtual Machine Properties dialog box, click the **Configuration** tab and choose **Advanced CPU**.
3. In the Scheduling Affinity panel, set the processor affinity.

NOTE Setting processor affinity manually can interfere with some advanced VMware Infrastructure features, such as VMotion.

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Pinning Network Interrupts

To pin the network interrupts, perform the following steps:

1 Check the core usage for interrupt processing by typing the following command in the service console.

```
cat /proc/vmware/intr-tracker
```

2 Unload the USB driver if the previous task shows all the interrupt processing is occurring on core-0.

By default, VMkernel dynamically distributes interrupt processing among the cores. However, this behavior might not be observed when the devices managed by VMkernel (such as physical network controllers) and the devices managed by the service console (such as the USB controller) share the interrupt lines (see "References" on page 10 for a link to VMware knowledge base article "ESX Server 3.5 Might Display Performance Issues Due to IRQ Sharing"). Because the service console is bound to core-0, you might notice that most interrupt processing occurs on core-0. You can avoid this behavior by disabling the unused controllers (usually USB) sharing the interrupt lines, as described in the next step.

3 Unload the USB driver by typing the following commands in the service console.

```
rmmod usb-uhci
rmmod ehci-hcd
```

4 Obtain the interrupt vector information of the physical network controllers by typing the following command in the service console.

```
cat /proc/vmware/interrupts
```

5 Enter the command to pin the vector to the intended core.

```
echo move <vector> <core> > /proc/vmware/intr-tracker
```

For example, if the interrupt line of a physical network controller is at vector `0x71`, type the following command in the service console to pin the vector to core-2.

```
echo move 0x71 2 > /proc/vmware/intr-tracker
```

NOTE Pinning network interrupts manually can interfere with some advanced VMware Infrastructure features, such as VMotion.

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Performance and Scalability

VMware has already documented performance of the SPECweb2005 workload on a single virtual machine running on ESX 3.5 (see "References" on page 10 for a link to the earlier paper). We carried out extensive tests to characterize various aspects of performance, such as latency, throughput, and CPU resource utilization when running a highly network intensive SPECweb2005 workload in a virtualized data center environment. We published the results of that study in January 2008. The focus of this paper is to understand the scaling aspects of the widely used Apache/PHP Web serving configuration in both native and virtual environments using the SPECweb2005 workload.

We first evaluated the scaling aspects of SPECweb2005 workload in the native environment without any virtualization. We tested various configurations in the native environment by varying the number of CPUs and the amount of memory at boot time. We tested the native configurations shown in Table 1.

Table 1. Native Configurations Tested

Number of CPUs	Memory
1	4GB
2	8GB
3	12GB
4	16GB
5	20GB
6	24GB
7	28GB
8	32GB

In all the native configurations, we used a conventional, single operating environment that consisted of one Red Hat Enterprise Linux 5 kernel system image and one Apache/PHP deployment. In the native environment, the file-set data was on a 15-disk RAID-0 LUN formatted with the ext2 file system. The LUN was on the same Fibre Channel SAN that we used in the virtualized tests. We configured the Apache Web server to listen on all the network interfaces. We applied all the well documented performance tunings to Apache/PHP configuration—for example, increasing the number of Apache worker processes and using an opcode cache to improve PHP performance. We also tried different Apache models including multiprocess and multithreaded models.

Figure 3 shows the scaling results of the SPECweb2005 workload in the native environment. The three scaling curves in the figure correspond to the three SPECweb2005 workloads: banking, e-commerce, and support. The three workloads have vastly different characteristics, and we thus look at results from all three. Each scaling curve plots the maximum throughput (number of simultaneous user sessions) as we increased the number of processors. In our test configuration, there were no bottlenecks in the hardware environment. The utilizations we observed on the network and disk I/O subsystems were well below saturation levels.

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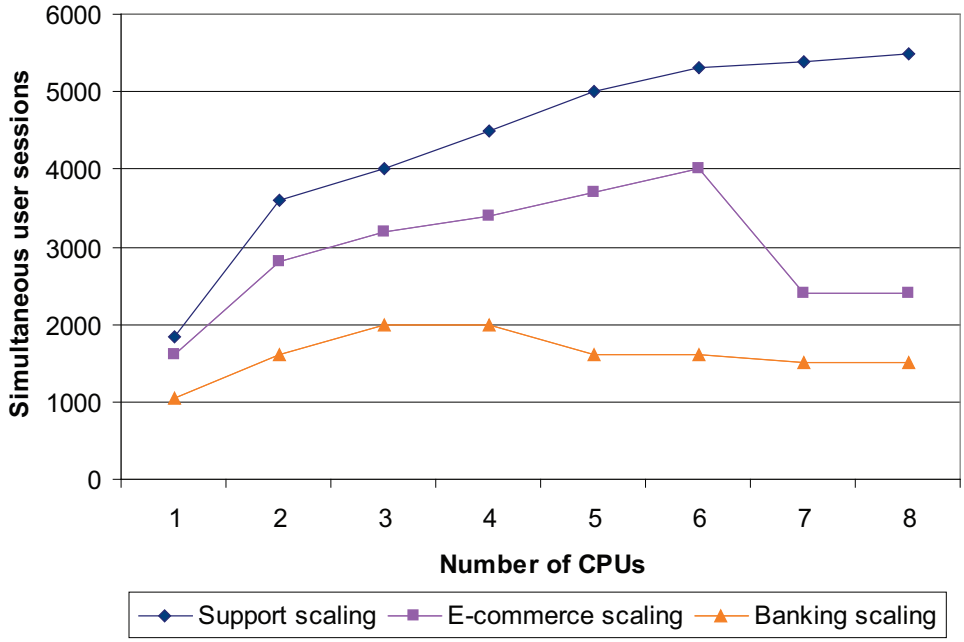
Figure 3. SPECweb2005 Scaling in the Native Environment



As shown in Figure 3, for all the three workloads the scalability was severely limited as we increased the number of processors. In a single CPU configuration, we achieved processor utilizations above 95 percent for all three workloads. But as we increased the number of processors, we failed to achieve such high processor utilizations for all the three workloads. The performance was severely limited by some intrinsic software serialization points present in the Apache/PHP/SPECweb2005 operating environment. Serialization points (the number of operations that must be performed sequentially) limit the processor utilization achievable.

Although each of the three SPECweb2005 workloads exhibited different serialization penalties, the support workload suffered the least. This may be a result of the fact that the support workload lacks any session state. Both the banking and e-commerce workloads have a session state, possibly resulting in higher serialization, compared to the support workload. In our tests, the banking workload performance degraded at five CPUs after reaching its peak performance at three CPUs. The e-commerce workload exhibited similar negative scaling, albeit the negative scaling occurred much later—at seven CPUs. Even when there were ample compute resources available on the system, a slight increase in the load contributed to unacceptable increase in application latency and the test runs failed to meet the quality of service requirements specified by the SPECweb2005 benchmark.

SPECweb2005/PHP performance issues caused by serialization, such as those seen in our test environment, were also observed in tests conducted by Intel and IBM using the IIS Web server (see "References" on page 10 for a link). Thus the scaling behavior shown in Figure 3 is not unique to our environment using Red Hat Enterprise Linux, Apache, PHP, APC-Cache, and SPECweb2005. Similar behavior is exhibited by many operating environments that have a large instance of a single monolithic application deployed within a single operating system. Amdahl's law (see "Validity of the single-processor approach to achieving large-scale computing capabilities" and "Chip Level Multiprocessing" in "References" on page 10) clearly explains the severe penalty imposed by serialization code on the speed-up. According to this law, even 10 percent of serialization code in an application reduces the scalability or speedup of the application to just 4.76 when the processor count increases to eight. In our testing, using eight CPUs we found the speedup to be just about 2.89 for the support workload and a meager 1.5 with the e-commerce and banking workloads, indicating a very large serialization component.

To identify and fix such serialization points in complex operating environments such as one using Red Hat Enterprise Linux, Apache, PHP, APC-Cache, and SPECweb2005 is not trivial. The points are hard to identify without good profiling tools or proper instrumentation. In our tests, using the Intel VTune performance analyzer we observed increasing hot spot contention as we increased the number of CPUs. For the same size workload—1,800 banking sessions—the CPI (clocks per instructions) jumped by a factor of four or so as we increased the number of CPUs from three to eight, clearly indicating software scaling issues. As we observed

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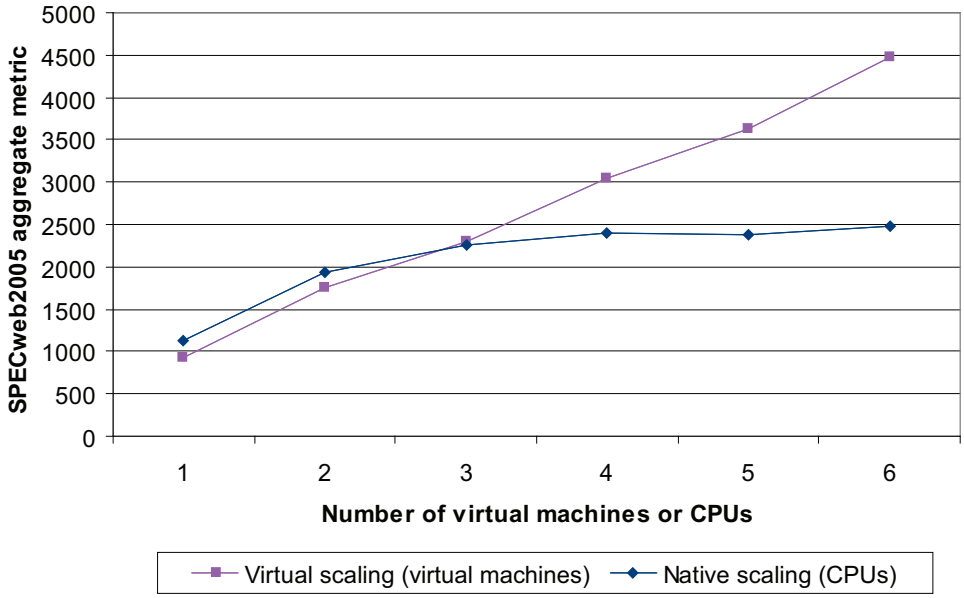
in our test configuration, such software scaling issues often show up as unacceptable latency times even when there are plenty of compute resources available on the system. More often than not, diagnosing and fixing these issues is not practical in the time available.

Virtualization offers an easier alternative to avoid such scaling issues and make the best use of the compute resources available on the system. Virtualization enables several complex operating environments that are not easily scalable—and sometimes several unoptimized operating environments—to run concurrently on a single physical machine and exploit the vast compute resources offered by today's powerful multicore systems. To determine the effectiveness of this approach we measured SPECweb2005 performance by deploying multiple Apache/PHP configurations in a virtual environment. We have submitted our test results to the SPEC committee and they are under review.

In our virtualized tests, we configured the virtual machines in accordance with the general performance best practices recommended in the paper "Performance Tuning Best Practices for ESX Server 3" (for a link, see "References" on page 10). We did not overcommit processor and memory resources for the virtual machines. We assigned one virtual CPU and 4GB of memory to each virtual machine. We varied the number of virtual machines from one to six, thereby ensuring the ESX host had enough resources to handle virtual machine scheduling, network processing, and other housekeeping tasks. In other words, we tested a single virtual machine, two virtual machines in parallel, three virtual machines in parallel, and so on, up to six virtual machines in parallel. We chose these configurations to simulate the resources available to the single native node in the native tests.

Figure 4 compares the SPECweb2005 scaling results from the native and virtual environments. In our virtual tests, we observed very similar throughput scaling for all three SPECweb2005 workloads. So, for easier comparison, we plotted the aggregate SPECweb2005 metric, which is a normalized metric based on the throughput scores obtained on all the three workloads—banking, e-commerce, and support.

Figure 4. Comparison of SPECweb2005 Native and Virtual Scaling



As shown in Figure 4, we observed good scaling in the virtual environment as we increased the number of virtual machines. The aggregate SPECweb2005 performance obtained in the test with a single virtual machine was about 16 percent lower than the performance observed in a one-CPU native configuration. This difference in performance is caused by the virtualization overhead. Although virtualization overhead varies depending on the workload, the observed 16 percent performance degradation is an expected result when running the highly I/O-intensive SPECweb2005 workload. But when we added the second processor, the performance difference between the two-CPU native configuration and the virtual configuration that consisted of two virtual machines running in parallel quickly diminished to 9 percent. As we further increased the number of processors, the configuration using multiple virtual machines did not exhibit the scalability bottlenecks observed on the single native node, and the cumulative performance of the configuration with multiple virtual machines well exceeded the performance of a single native node.

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This result is not very surprising given that the multiple virtual machines behave as though they were a cluster of single-processor nodes. In such a configuration, the penalty imposed by serialization points is alleviated. For instance, a large session lock protecting all the sessions in a large SMP native configuration is implicitly broken down to a number of smaller session locks corresponding to the number of virtual machines. Such a configuration, in essence, leads to fine-grained locking, with each lock protecting a smaller region, resulting in reduced contention and better scalability. Thus, while the performance of each single-VCPU virtual machine is slightly lower than that of a one-CPU native machine (because of virtualization overhead), the cumulative performance of the multiple virtual machines well exceeds the performance of a large SMP native machine (because serialization penalties are reduced).

These results clearly demonstrate the benefit of using VMware Infrastructure to bypass the software deficiencies exhibited in native systems with multiple CPUs and improve the scalability of real-life workloads.

Conclusions

Reduced complexity and improved efficiency in power and space usage are well-understood benefits of consolidation. In this paper, we focused on evaluating the performance and scalability benefits of server consolidation.

We used the industry standard SPECweb2005 workload to compare the performance and scalability of Apache/PHP Web server software in a conventional, single-system native environment with performance and scalability in a VMware Infrastructure 3 environment.

Using the VMware Infrastructure software enabled us to consolidate multiple Apache/PHP Web server operating environments in separate virtual machines running on the same physical system. Our performance testing shows that such a consolidation approach does not suffer the software scalability issues faced in the native environment and provides very good system-level throughput performance. With added benefits such as higher availability and fault tolerance, VMware Infrastructure can serve as an ideal Web services consolidation platform.

References

- "Apache Performance Tuning"
  see the documentation for your version of Apache at http://httpd.apache.org/
- "Chip Level Multiprocessing"
  http://www.solarisintenrals.com/wiki/index.php/Chip_Level_Multiprocessing
- "ESX Server 3.5 Might Display Performance Issues Due to IRQ Sharing"
  http://kb.vmware.com/kb/1003710
- "Performance Tuning Best Practices for ESX Server 3"
  http://www.vmware.com/resources/techresources/707
- "Server and Storage Consolidation 2004: Executive Interview Summary Reports," IDC, March 2004
- SPECweb2005 Web site
  http://www.spec.org/web2005
- "SPECweb2005 Performance on VMware ESX Server 3.5"
  http://www.vmware.com/resources/techresources/1031
- "SPECweb2005 in the Real World: Using Internet Information Server (IIS) and PHP"
  http://www.spec.org/workshops/2008/sanfrancisco/papers/Warner.doc
- "Validity of the single-processor approach to achieving large-scale computing capabilities," G. M. Amdahl, 1967, Proceedings of AFIPS Conference
  http://www.ieee.org/portal/site/sscs/menuitem.f07ee9e3b2a01d06bb9305765bac26c8/index.jsp?&pName=sscs_level1_article&TheCat=2171&path=sscs/07Summer&file=Amdahl67.xml
- Web Server Survey Report 2006: "Apache Now the Leader in SSL Servers"
  http://news.netcraft.com/archives/2006/04/26/apache_now_the_leader_in_ssl_servers.html

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Appendix: Detailed SPECweb2005 Results

This appendix presents the full results of the SPECweb2005 tests in the virtual environment.

SPECweb2005 Result

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Hewlett-Packard: HP ProLiant DL 380 G5 (with VMware ESX Server 3.5)
Apache Source Foundation: Apache 2.2.6
PHP Net: PHP 5.2.5

SPECweb2005 = 4466

SPECweb2005_Banking = 4900
SPECweb2005_Ecommerce = 6200
SPECweb2005_Support = 6500

Tested By: VMware Inc., USA SPEC License #: 2933 Test Date: Apr-2008

Performance

Banking

Simultaneous User Sessions	Test Iteration	Aggregate QOS Compliance			Validation Errors
		Good	Tolerable	Fail	
4900	1	98.1%	99.6%	0.4%	0
	2	98.1%	99.5%	0.5%	0
	3	98.0%	99.5%	0.5%	1

Ecommerce

Simultaneous User Sessions	Test Iteration	Aggregate QOS Compliance			Validation Errors
		Good	Tolerable	Fail	
6200	1	97.9%	99.1%	0.9%	0
	2	97.8%	99.1%	0.9%	2
	3	97.9%	99.1%	0.9%	2

Support

Simultaneous User Sessions	Test Iteration	Aggregate QOS Compliance			Validation Errors
		Good	Tolerable	Fail	
6500	1	98.8%	99.7%	0.3%	0
	2	98.9%	99.7%	0.3%	0
	3	98.9%	99.7%	0.3%	0

Configuration

Availability Dates

SUT Hardware	Jan-2007
Backend Simulator	Jan-2007
Web Server Software	Jan-2007 Jan-2007
Operating System	Mar-2008
Other Components	N/A

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System Under Test (SUT)

# of SUTs	1
Vendor	Hewlett-Packard
Model	HP ProLiant DL 380 G5 (with VMware ESX Server 3.5)
Processor	Intel Xeon E5345
Processor Speed (MHz)	2333
# Processors	8 (8 cores, 2 chips, 4 cores/chip)
Primary Cache	32KB(I) + 32KB(D) on chip, per core
Secondary Cache	8 MB I+D on chip per chip, 4 MB shared / 2 cores
Other Cache	N/A
Memory	32 GB SDRAM
Disk Subsystem	1 x 73GB SCSI (VMware ESX 3.5), 3*133.68GB SCSI RAID-5 volume(RHEL5 VMs), 15*133.68GB SCSI RAID-0 volume(fileset data)
Disk Controllers	Onboard Smart Array P400 controller, QLogic Corp. QLA2432 Fibre Channel Adapter
Operating System	RedHat Enterprise Linux 5 Update 1 (2.6.18-53.1.4.el5) as Guest OS, VMware ESX Server 3.5 (Hypervisor)
File System	ext2
Other Hardware	Network and Storage virtualization do not require additional hardware
Other Software	JDK-1.6.0_01-linux-amd64

SUT Network

# of Controllers	7
Network Controllers	Intel PRO/1000 PT Quad Port PCIe Gigabit Ethernet Controller, Broadcom NetXtreme II BCM5708 1000Base-T, Intel 82571EB Gigabit Ethernet Controller
# of Networks	7
Network Type	Fast Ethernet
Network Speed	1 Gb/s
MSL (sec)	30 (Non RFC1122)
Time-Wait (sec)	60 (Non RFC1122)
MTU Size	1500

HTTP Software

Vendor	Apache Source Foundation
Name/Version	Apache 2.2.6
Dynamic Scripts	null
Server Cache	N/A
Log Mode	Common Log Format

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Script Engine

Vendor	PHP Net
Name/Version	PHP 5.2.5
Dynamic Scripts	PHP
Server Cache	APC 3.0.15
Log Mode	Common Log Format

Clients

# of Clients	6
Model	Dell Poweredge 1950
Processor	Intel Xeon 5160
Processor Speed (MHz)	3000
# Processors	2
Memory	8192 MB SDRAM
Network Controller	Broadcom Corporation NetXtreme II BCM5708 Gigabit Ethernet
Operating System	RedHat Enterprise Linux Update 4 (2.6.9-42.ELsmp)
JVM Version	Java(TM) SE Runtime Environment (build 1.6.0_01-b06)
JIT Version	Java HotSpot(TM) 64-Bit Server VM (build 1.6.0_01-b06, mixed mode)
Other Hardware	N/A
Other Software	N/A

Backend Simulator (BESIM)

# of Simulators	1
Model	Dell Poweredge 1950
Processor	Intel Xeon 5160
Processor Speed (MHz)	3000
# of Processors	2
Memory	8192 MB SDRAM
Network Controller	Broadcom Corporation NetXtreme II BCM5708 Gigabit Ethernet
Operating System	RedHat Enterprise Linux 5 Update 1 (2.6.18-8.el5xen)
File System	ext2
Web Server	Rock Web Server v1.4.2
Server Scripts	ISAPI
Other Hardware	N/A
Other Software	N/A

Common Workload Notes

SUT Notes

- VMware ESX 3.5 used as the hypervisor. There were six Virtual Machines running, each Virtual Machine (VM) used one vCPU configured with 4GB memory running RHEL 5 up1 64bit. Each VM ran its own instance of Apache/PHP Web server
- Of the 8 cores on the systems, 2 cores (core-0 and core-4) were used for interrupt processing.

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- Each of the six VMs were pinned to different cores: core-1, core-2, core-3, core-5, core-6, core-7
- ESX had all eight cores to its disposal, but each of the VMs was configured with one vCPU only
- Each of VMs was configured with three virtual network adapters. The first adapter is used to talk to primary client, the second is used to talk to Besim Server, and the third used for client traffic. Each virtual adapter was connected to a physical network adapter through a virtual switch interface
- All the VMs used the same virtual switch, and so the same physical network interface (vmnic7) to talk to Besim
- Each of the VMs used a unique virtual switch, and thereby used unique physical network interface to talk to its client
- VM1 used vmnic2, VM2 used vmnic3, VM3 used vmnic9, VM4 used vmnic4, VM5 used vmnic8, VM6 used vmnic5 for client traffic
- The interrupt vectors of vmnic2,vmnic4 and vmnic8 were pinned to core 4
- The interrupt vectors of vmnic3,vmnic5,vmnic7 and vmnic9 were pinned to core 0
- vmxnet is used as the virtual network adapter (available as part of VMware Tools)
- The Net.vmxnetThroughputWeight was increased from the default 0 to 128, to favor the throughput in the vmxnet behaviour
- All the VMs had two virtual disks configured. One disk contained the RHEL5 image, and the other fileset data
- The actual physical (.vmdk) files that correspond to virtual disks are located on one EMC Clarion SAN Array
- All the virtual disks that contained the RHEL5 os images, Apache images, access logfiles were stored on a 3-disk RAID-5 VMFS LUN
- All the VMs shared the same fileset data, that is the same physical .vmdk file which was located on 15-disk RAID-0 VMFS LUN
- Each of the VMs were configured with the default virtual LSI Logic SCSI adapter

Operating System Notes

- Guest OS: Used following tunings on RHEL5
- net.ipv4.tcp_timestamps = 0
- net.ipv4.tcp_timestamps = 0 # default 1
- net.ipv4.tcp_max_tw_buckets = 1500000 # sets TCP time-wait buckets pool size, default 180000
- net.ipv4.tcp_rmem = 5000000 5000000 5000000 # maximum receive socket buffer size, default 131071
- net.ipv4.tcp_wmem = 5000000 5000000 5000000 # maximum TCP write-buffer space allocatable, default 4096 16384 131072
- net.ipv4.tcp_mem = 5000000 5000000 5000000 # maximum TCP buffer space allocatable, default 392192 392704 393216
- net.ipv4.tcp_window_scaling = 0 # turns TCP window scaling support off, default on
- net.ipv4.tcp_tso_win_divisor = 8
- net.core.rmem_max = 1048576 # maximum receive socket buffer size, default 131071
- net.core.wmem_max = 1048576 # maximum send socket buffer size, default 131071
- net.core.rmem_default = 1048576 # default receive socket buffer size, default 135168
- net.core.wmem_default = 1048576 # default send socket buffer size, default 135168

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- net.core.optmem_max = 5000000 # default 10240, maximum amount of option memory buffers, default 20480
- net.core.netdev_max_backlog = 81920 # maximum length of the input queues for the processors, default 300
- net.ipv4.tcp_max_syn_backlog = 8192
- net.ipv4.conf.all.arp_filter=1 # enables source route verification, default 0
- net.ipv4.ip_local_port_range = 4096 63000 # enables more local ports
- ulimit -n 102400, increases the number of open file descriptors, default 1024
- changed the guest timer interrupts to 100Hz using divider=10 in the boot options #default is 1000Hz

HTTP Software Notes

- The following tunes made in webserver.conf:
- MaxKeepAliveRequests 0
- ServerLimit 4000
- StartServers 64
- MinSpareServers 32
- MaxSpareServers 32
- MaxClients 4000
- MaxRequestsPerChild 4000
- HTTP Script Notes
- SPEC-provided PHP scripts used without modification
- Smarty v2.6.7 used

Client Notes

- Following tunings were used on the client system
- ulimit -n 102400, increase the file descriptors
- net.ipv4.ip_local_port_range = 1024 65535, increase the local TCP/IP ports
- java -Xms768m -Xmx768m -XX:+UseParNewGC -XX:+UseConcMarkSweepGC, options used for client driver processes

BESIM Notes

- Operating System Notes: No non-default tunings
- validate_static -1
- validate_httpmod -1
- header_etag_on 0
- header_server_on 0
- log_buf_size 1048576
- tcp_send_buf_size 102400
- keepalive_max 10000000
- connection_timeout 36000
- host:81
- document_root /usr/httpd/etc/specweb05

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- access_log access.log
- error_log error.log
- cgi_type isapi
- cgi_where internal

Other Notes

- Result prepared by Sreekanth Setty

Banking Run Details

Test results for each iteration

Iteration	Request Type	Total Reqs	QOS			Weighted ABR	Avg Resp Time (sec)	Average Bytes/Req
			Good	Tolerable	Fail			
1	login	284056	278302	4389	1365	14,968.6	0.708	35258
	account_summary	200040	196806	2433	801	8,567.6	0.404	28656
	check_detail_html	112069	110003	1591	475	4,283.0	0.381	25570
	bill_pay	182289	179335	2223	731	7,296.6	0.383	26781
	add_payee	14650	14409	180	61	603.6	0.388	27567
	payee_info	10500	10316	129	55	710.1	0.571	45246
	quick_pay	87340	85659	1273	408	4,540.7	0.477	34785
	billpay_status	29085	28597	376	112	1,491.9	0.454	34319
	chg_profile	16039	15794	190	55	1,065.1	0.545	44431
	post_profile	11562	11380	133	49	652.2	0.488	37741
	req_checks	15970	15556	329	85	2,142.8	1.083	89773
	post_chk_order	11551	11369	141	41	592.9	0.450	34343
	req_xfer_form	22824	22465	263	96	797.3	0.348	23371
	post_fund_xfer	16519	16227	211	81	634.9	0.381	25716
	logout	81202	79729	1074	399	9,194.1	1.061	75757
	check_image	224172	219453	3863	856	3,585.4	0.314	10701
	Total	**1319868**	**1295400**	**18798**	**5670**	**61,126.6**	**0.507**	**30,986**

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Iteration	Request Type	Total Reqs	QOS			Weighted ABR	Avg Resp Time (sec)	Average Bytes/Req
			Good	Tolerable	Fail			
2	login	283548	277952	4238	1358	14,778.1	0.707	35235
	account_summary	199381	196051	2424	906	8,449.3	0.411	28650
	check_detail_html	111807	109794	1475	538	4,229.6	0.388	25575
	bill_pay	182312	179290	2156	866	7,222.8	0.389	26784
	add_payee	14786	14581	152	53	602.7	0.383	27557
	payee_info	10626	10446	131	49	711.1	0.576	45240
	quick_pay	87050	85392	1223	435	4,479.3	0.485	34787
	billpay_status	29118	28630	359	129	1,478.7	0.458	34332
	chg_profile	16080	15783	231	66	1,057.1	0.560	44444
	post_profile	11581	11399	132	50	647.0	0.491	37770
	req_checks	15988	15567	304	117	2,122.7	1.100	89759
	post_chk_order	11536	11349	147	40	586.1	0.466	34349
	req_xfer_form	22938	22607	234	97	792.2	0.348	23347
	post_fund_xfer	16548	16266	221	61	629.6	0.381	25721
	logout	80876	79442	1068	366	9,066.8	1.060	75791
	check_image	223622	218765	3886	971	3,540.2	0.329	10702
	Total	**1317797**	**1293314**	**18381**	**6102**	**60,393.3**	**0.512**	**30,982**
3	login	284061	278248	4218	1595	14,656.2	0.713	35242
	account_summary	199241	195890	2454 897	8,357.6	0.412	28652	
	check_detail_html	111614	109453	1599	562	4,179.5	0.392	25577
	bill_pay	182692	179600	2210	882	7,163.1	0.390	26781
	add_payee	14869	14651	162	56	599.9	0.387	27559
	payee_info	10659	10458	137	64	706.1	0.582	45251
	quick_pay	87243	85440	1288	515	4,443.3	0.493	34787
	billpay_status	29191	28680	375	136	1,467.	2 0.463	34331
	chg_profile	16030	15717	233	80	1,043.0	0.566	44444
	post_profile	11570	11378	141	51	639.6	0.494	37761
	req_checks	15984	15533	319	132	2,100.7	1.106	89771
	post_chk_order	11555	11362	138	55	581.1	0.463	34352
	req_xfer_form	22962	22570	283	109	785.2	0.362	23356
	post_fund_xfer	16526	16235	204	87	622.2	0.389	25718
	logout	80858	79334	1085	439	8,968.0	1.065	75757
	check_image	223296	217850	4278	1167	3,497.5	0.339	10698
	Total	**1318351**	**1292399**	**19124**	**6827**	**59,810.5**	**0.518**	**30,987**

Notes for Banking Workload

None

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Errors for Banking Workload

Quality of Service Errors

- No QOS Errors Found

Validation Errors

- 1 Validation Errors for Iteration 3 : turpan02:1097 - check_image

Ecommerce Run Details

Test results for each iteration

Iteration	Request Type	Total Reqs	QOS			Weighted ABR	Avg Resp Time (sec)	Average Bytes/Req
			Good	Tolerable	Fail			
1	index	134799	131817	1679	1303	11,520.7	1.651	140138
	search	67098	66384	431	283	7,674.5	1.952	187545
	browse	120895	117998	1641	1256	11,569.4	1.788	156916
	browse_productline	102997	101153	1047	797	12,634.2	2.154	201136
	productdetail	82407	78131	2797	1479	2,734.2	1.345	54403
	customize1	174693	172637	1185	871	17,703.9	1.751	166172
	customize2	92490	91427	612	451	9,326.6	1.743	165346
	customize3	63542	61133	1461	948	6,973.4	2.022	179948
	cart	54635	53304	760	571	2,527.7	1.039	75862
	login	38967	38278	421	268	1,179.4	0.727	49627
	shipping	36702	36350	182	170	962.2	0.605	42988
	billing	34869	34359	287	223	739.1	0.574	34754
	confirm	26228	25903	181	144	537.0	0.531	33568
	Total	**1030322**	**1008874**	**12684**	**8764**	**86,082.4**	**1.591**	**136,995**
2	index	134931	131919	1581	1429	11,460.5	1.660	140205
	search	67241	66514	389	338	7,639.6	1.960	187548
	browse	120940	117981	1529	1430	11,493.2	1.802	156872
	browse_productline	103212	101297	1130	785	12,575.4	2.158	201125
	productdetail	82488	77976	2906	1606	2,726.0	1.362	54551
	customize1	174714	172622	1165	927	17,588.3	1.756	166176
	customize2	92471	91370	597	504	9,262.3	1.749	165343
	customize3	63450	61062	1354	1034	6,917.2	2.036	179959
	cart	54450	53015	761	674	2,497.3	1.061	75708
	login	38907	38166	417	324	1,166.3	0.742	49481
	shipping	36614	36226	188	200	953.5	0.617	42988
	billing	34756	34216	247	293	731.8	0.590	34755
	confirm	26073	25721	170	182	530.2	0.540	33568
	Total	**1030247**	**1008085**	**12434**	**9726**	**85,541.5**	**1.602**	**137,059**

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Iteration	Request Type	Total Reqs	QOS			Weighted ABR	Avg Resp Time (sec)	Average Bytes/Req
			Good	Tolerable	Fail			
3	index	134835	131867	1724	1244	11,509.2	1.649	140201
	search	67290	66592	414	284	7,683.4	1.953	187548
	browse	121096	118287	1598	1211	11,565.2	1.788	156867
	browse_productline	103319	101381	1163	775	12,652.5	2.156	201144
	productdetail	82604	78105	2800	1699	2,741.9	1.364	54521
	customize1	174625	172569	1191	864	17,666.7	1.753	166172
	customize2	92496	91478	606	411	9,311.1	1.741	165343
	customize3	63378	61083	1356	939	6,943.6	2.023	179950
	cart	54365	53092	707	566	2,503.6	1.038	75641
	login	38849	38168	412	269	1,172.6	0.726	49579
	shipping	36608	36244	201	163	958.1	0.611	42988
	billing	34820	34316	266	238	736.8	0.575	34754
	confirm	26091	25778	146	167	533.2	0.537	33568
	Total	**1030376**	**1008960**	**12584**	**8830**	**85,978.1**	**1.594**	**137,056**

Notes for Ecommerce Workload

None

Errors for Ecommerce Workload

Quality of Service Errors

- No QOS Errors Found

Validation Errors

- 2 Validation Errors for Iteration 2 : turpan02:1090 - index
- 1 Validation Errors for Iteration 3 : turpan02:1095 - customize1
- 1 Validation Errors for Iteration 3 : turpan02:1095 - customize2

Support Run Details

Test results for each iteration

Iteration	Request Type	Total Reqs	QOS			Weighted ABR	Avg Resp Time (sec)	Average Bytes/Req
			Good	Tolerable	Fail			
1	home	93550	92958	441	151	895.8	0.696	60229
	search	145662	145013	445	204	625.3	0.353	27000
	catalog	134671	134132	386	153	721.1	0.413	33680
	product	285536	281390	3010	1136	3,075.7	0.834	67753
	fileCatalog	260102	255794	3079	1229	4,405.9	1.213	106544
	file	156131	153288	2033	810	3,094.8	1.393	124674
	download	77966	77774	16	176	84,987.3	68.566	6856296
	Total	**1153618**	**1140349**	**9410**	**3859**	**97,806.0**	**5.452**	**533,265**

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Iteration	Request Type	Total Reqs	QOS			Weighted ABR	Avg Resp Time (sec)	Average Bytes/Req
			Good	Tolerable	Fail			
2	home	93593	92989	422	182	889.3	0.699	60245
	search	146060	145407	452	201	622.0	0.354	27003
	catalog	134681	134164	352	165	715.3	0.415	33675
	product	285136	281028	2920	1188	3,047.5	0.836	67765
	fileCatalog	259673	255716	2758	1199	4,364.0	1.210	106557
	file	156000	153333	1882	785	3,067.6	1.391	124678
	download	77982	77810	15	157	85,120.9	69.212	6920941
	Total	**1153125**	**1140447**	**8801**	**3877**	**97,826.6**	**5.498**	**537,902**
3	home	93478	92880	435	163	890.2	0.704	60248
	search	146097	145475	427	195	623.5	0.354	26999
	catalog	134605	134084	376	145	716.4	0.414	33673
	product	285019	281089	2754	1176	3,052.8	0.837	67766
	fileCatalog	259621	255642	2820	1159	4,372.3	1.213	106551
	file	156002	153341	1930	731	3,074.2	1.393	124679
	download	77869	77666	27	176	85,068.2	69.120	6911827
	Total	**1152691**	**1140177**	**8769**	**3745**	**97,797.6**	**5.488**	**536,790**

Notes for Support Workload

None

Errors for Support Workload

Quality of Service Errors

- No QOS Errors Found

Validation Errors

- No Validation Errors Found

For questions about this result, please contact the submitter: VMware Inc., USA

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