Parallels® Virtuozzo Containers

White Paper

Performance evaluation of a LAMP stack application in competing virtualized environments

Revealing the power of OS Containers for Virtual Private Server (VPS) offerings

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Version 1.0

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Disclaimer

The following results and information are from an internal bench test performed by Parallels engineers utilizing identical hardware and testing configurations across several virtualization technologies. Tests were designed to help determine the best configuration for the number of vCPUs and number of guests to maximize server performance or to maximize the number of virtual environments (VPS) per server. The results of these tests in this document can be duplicated by following the same methodology employed by the Parallels team. Additional details on the testing methodology can be obtained by contacting Parallels. Results presented in this paper are believed to be accurate.

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Introduction

This test studies performance and scaling of Parallels Virtuozzo Containers, VMware ESXi and Linux KVM for running the industry-standard Linux web application stack (LAMP stack). Dell's DVD-Store (**http://www.delltechcenter.com/page/DVD+Store**) was used as the LAMP stack application that utilizes Linux, MySQL, Apache and PHP and represents a fully functional online store for DVDs.

DVD-Store development and production scenarios were defined to study the benefits of virtualization during the full lifecycle of a typical LAMP application: from development and testing to staging and production hosting (in-house or in a cloud). All tests were performed on a an Intel Server with 16 GB RAM and Dual Quad Core Nehalem Xeon X5570 (launched Q1'09) with Hyper threading enabled (total 16 hyper-threads available to OS). The same server was configured in multi-boot configuration to test the same workload on the same hardware utilizing Parallels Containers, VMware ESXi and Linux KVM.

PRODUCTION SCENARIO: OVERHEAD AND PERFORMANCE

Virtualization of high-performance production workloads is typically associated with performance penalty due to the virtualization layer overhead. This series studies a virtualized production-scaled DVD-Store web application under extreme web client payload, similar to a typical e-commerce web site. First, the scalability of a single virtualized instance of DVD-Store is studied to determine vCPU scale-up capabilities of the selected LAMP stack. Then multiple virtualized LAMP instances are tested simultaneously to determine the scale-out capabilities of the LAMP stack in different virtualization technologies. Finally, test results are compared to determine the scalability and overhead of selected virtualization solutions for running LAMP stack in production.

LIGHT USE VPS SCENARIO: DENSITY

Many different types of VPS offerings including those used for small business websites, standardized developer environments, website staging as well as QA testing do not require a large amount of dedicated resources. This test scenario studies how many "small" virtualized LAMP stack environments can be run simultaneously on a single physical server. The results show the scalability of the virtualization solutions as well as the operations per minute at each level. This study helps the hosting provider or the internal IT manager to understand the impact on performance as each solution increases in density per server.

Test Results

TEST #1: PRODUCTION LAMP SCALE-UP: SINGLE GUEST PERFORMANCE WITH SCALED NUMBER OF VCPUS

This scale-up scenario was executed to set the baseline metric for the selected configuration of the DVD-Store environment. The objective was to learn how a single virtualized LAMP guest scales in performance by scaling the number of vCPUs. This test correlates to a managed dedicated server where a single container or single virtual machine is used to simplify administration for the hosting provider. The identical test was run with the three different technologies including Parallels Virtuozzo Containers for Linux, VMWare ESXi and Linux KVM. The DVD-Store guest was configured with 2GB RAM to handle Medium (1 GB) DVD-Store database.

Figure 1 below shows that performance score as measured in Operations Per MInute (OPM) grows with an increase in the amount of vCPUs in all three virtualization solutions until a maximum is reached. As anticipated, the performance gain is higher when upgrading from 1 to 2 to 4 vCPUs. The velocity of this measurement begins to slow down as the test moves from four to six to eight virtual CPUs. Unexpectedly, performance scores slightly increase or stay the same with eight to sixteen vCPUs assigned to guest. It is believed that the lack of scale at higher vCPUs is due to a combination of LAMP stack scalability and hyper threading scalability. The test results over eight vCPUs are only available for Parallels Virtuozzo Containers and KVM since VMware ESXi supports a maximum eight vCPUs per guest.

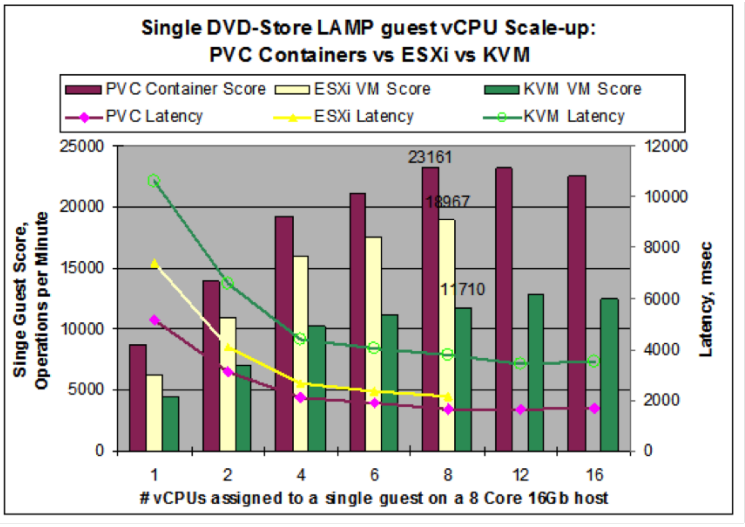


Figure 1 – Scale up performance test one to sixteen vCPUs on a single guest operating system.

The results of the test demonstrates that a single virtualized LAMP stack with an extremely high workload running within a Parallels Virtual Container yields approximately 20% more Operations per Minute (OPM) than a VMware ESXi virtual machine and about 50% more than in a Linux KVM virtual machine. The performance advantage for Parallels Virtuozzo Containers was shown to sustain itself across all vCPU configurations tested. This advantage for Parallels is attributed to the near zero overhead introduced by the Parallels Virtuozzo Containers virtualization technology.

TEST #2: PRODUCTION LAMP SCALE-OUT: CONSOLIDATED PERFORMANCE OF MULTIPLE DVD-STORE GUESTS WITH 1, 2, 4 AND 8 VCPUS

This Scale-out series measures how well virtualization technologies handle multiple guest environments when there is no over subscription. The test was setup to run the same DVD-Store LAMP stack under the same web clients payload used in the scale-up test series.

The scale-out approach helps to avoid the impact of individual applications scalability issues by running multiple instances of the same application simultaneously. This test is derived to determine the maximum performance of a server and how the different virtualization technologies impact that measurement. In this series, multiple instances were tested with different vCPU configurations to determine the optimal combination of the number of guests and number vCPUs that yield best consolidated performance score (operations per minute) .

Although the main goal of the test was to compare without oversubscription, multiple scenarios were run in the oversubscribed state to determine the actual impact of this activity. In figure 2 below, the performance results for tests over eight guests demonstrate over-subscription and the resulting degradation.

The consolidated score from all guests were aggregated to determine a maximum number of operations per minute. The average response time of the test application was also captured to make sure the test demonstrated an acceptable operating environment.

INDIVIDUAL SCALE OUT TEST RESULTS

Parallels Virtuozzo Containers

Figure two below shows that Parallels Virtuozzo Containers yields maximum score of 72,737 operations per minute (OPM) when configured with six scaled-out guests, each using eighty vCPUs. This is aggregated result is 314% of maximum score of a single scaled-up Container demonstrating that virtualization can improve overall performance of server hardware even when applications are not optimized.

Throughout the test series Parallels Virtuozzo Containers consistency demonstrated over 60,000 OPM in a wide range of configurations, from four quad vCPU guests up to ten dual vCPU guests. This indicates that the virtualization overhead stays constant regardless of the number of guests and vCPUs in Parallels Virtuozzo Containers.

In the test series you will also notice that a ten guest configuration performs reasonably well in oversubscribed memory configuration, a good indication of efficient memory sharing between virtual environments with Parallels Virtuozzo Containers.

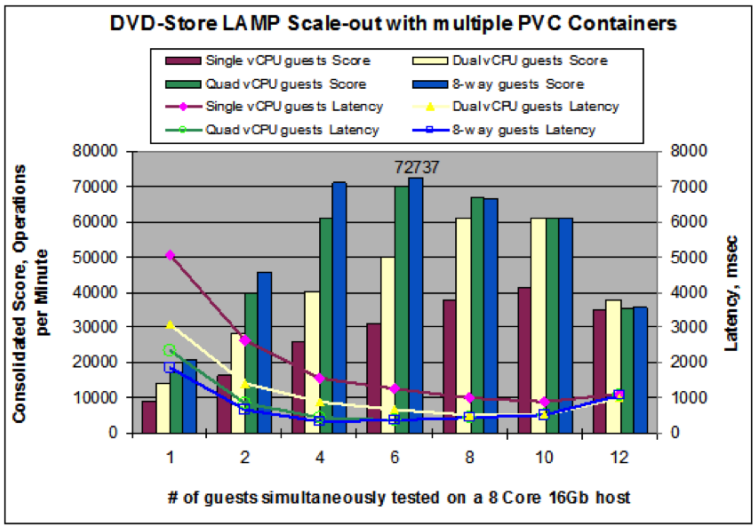


Figure 2 – Scale out series with Parallels Virtuozzo Containers demonstrates maximum server capacity at six guest environments

VMware ESXi

Figure three below shows that VMware ESXi yields maximum score of 47,673 operations per minute with 6 scaled-out guests, each using four vCPUs. This is 251% of maximum score of a single scaled-up virtual machine. Comparable results with over 40,000 OPMs are received with four to eight guests configurations, score drops with ten and more guests, that shows inefficiency in slightly oversubscribed configuration.

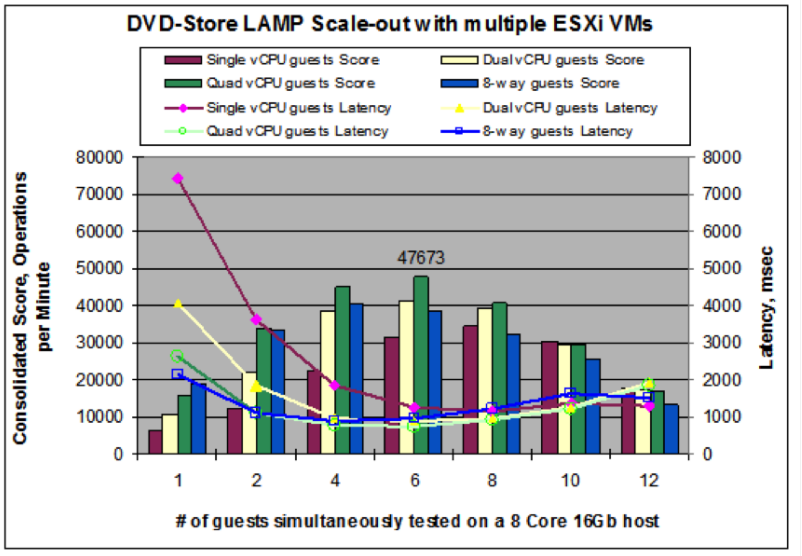


Figure 3 – Scale out series with VMware ESXi demonstrates maximum server capacity at six guest environments

Kernel Virtual Machine (KVM)

Figure four below shows that KVM yields maximum score of 29,215 operations per minute with four scaled-out guests, each using four vCPUs. This is 249% of maximum score of a single scaled-up VM. KVM yields comparable performance with four to eight guest configurations.

Noticeable performance degradation is observed for eight and four-vCPU configurations with six guests or more. Figure shows that the more KVM guests are used to scale-out, the less vCPUs should be assigned to guests to yield better results.

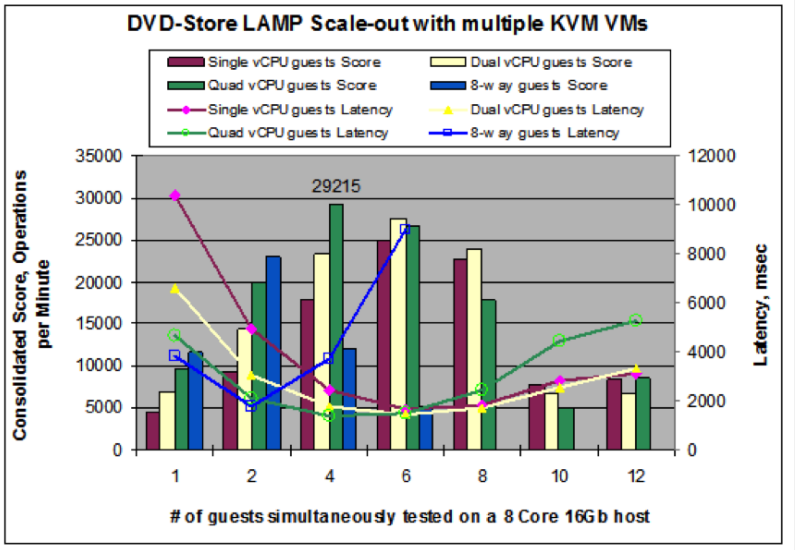


Figure 4 - Scale out series Linux KVM demonstrates maximum server capacity at four guest environments

PRODUCTION SCALE-OUT: VIRTUALIZATION EFFICIENCY COMPARISON

The prior test series presented a numerical representation on how selected DVD-Store LAMP stack environments scale in each of the virtualized solutions. The next series of figures will compare virtualization solutions head to head for the same DVD-Store scale-out configurations.

The test series will exclude multiple 1 vCPU guests from the comparison as it yields lowest performance score. This section will show and review how well Parallels Virtuozzo Containers, VMware ESXi and Linux KVM handle multiple DVD-Store guests scale-out with 2, 4 and 8 vCPU configurations.

Figures below show the consolidated performance score of multiple virtualized DVD-Store guests, created as Parallels Virtuozzo Containers, VMware ESXi VMs and KVM VMs. The performance score of each virtualization solution is compared for a given number of simultaneously running guests. The web client payload is the same in all tests and is equally divided among all guests participating in the test run.

Figures below indicate that the performance maximum for all test configurations was acheived. The performance maximum can be clearly identified on all figures, followed by decreased performance coupled with increased response times.

Multiple Dual-vCPU guests scale-out

Figure five below shows that Parallels Virtuozzo Containers reaches maximum of 60,958 operations per minute with ten guests, while VMware ESXi and KVM peak with six guests yielding 41,341 and 27,515 operations per minute respectively.

This test demonstrates the performance superiority of Parallels Virtuozzo Containers in a scale-out test with a score of 2-vCPU containers 47% more than VMware ESXi.

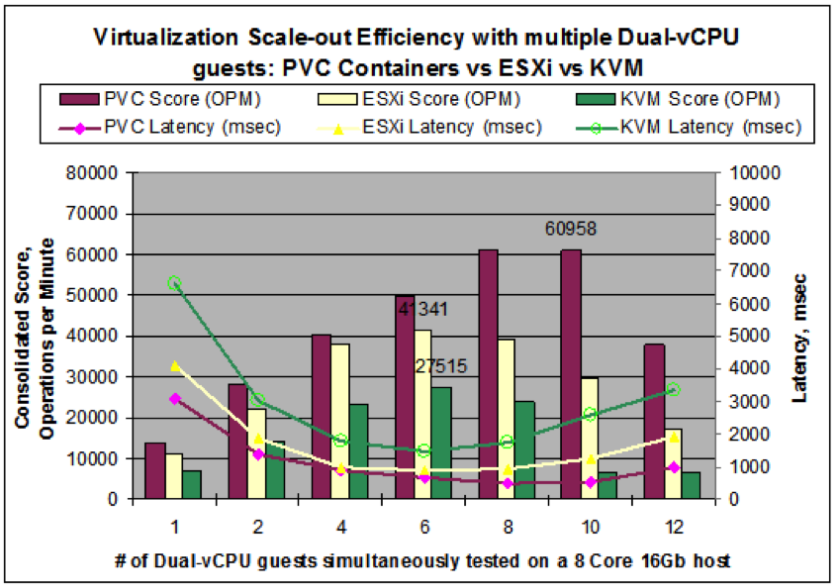


Figure 5 – Scale out comparison with dual vCPU configurations.

Multiple 8-vCPU guests scale-out

Figure six below shows that only Parallels Virtuozzo Containers is able to handle LAMP environment with eight-vCPUs and show an increased performance score. VMware ESXi and KVM yield results less than four-vCPU configurations. VMware ESXi and especially KVM have noticeably higher overhead to scale-out multiple eight-vCPU guests. This represents an exponential impact of virtualization overhead as the number of guests are increased. Eight-vCPU scale-out highlights lowest overhead of Parallels Virtuozzo Containers solution as compared to hypervisors, as scale-out score of eight-vCPU containers is 80% more than runner up VMware ESXi. The common take away from the results is that in all measured vCPU configurations Parallels Virtuozzo Containers yield best consolidated score among tested virtualization technologies. The Parallels advantage increases as the amount of guests and vCPUs used in scale-out configurations increase.

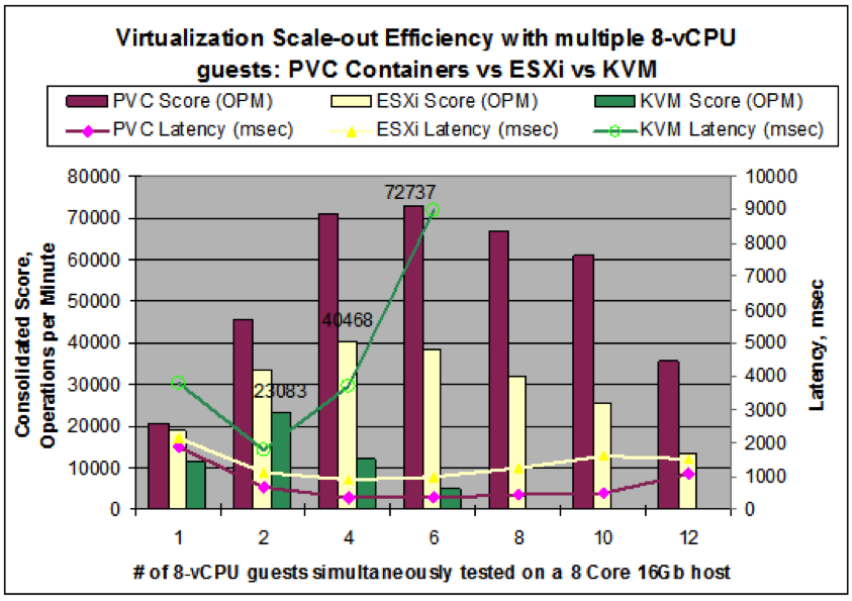


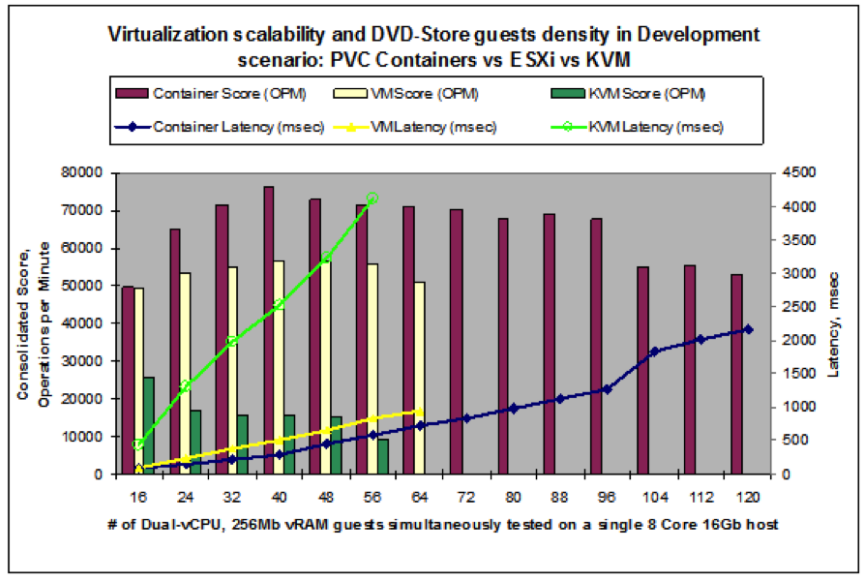
Figure 6 – Scale out comparison with eight vCPU configurations

TEST #3: LIGHT USE VPS SCENARIO TO MAXIMIZE SERVER DENSITY

Things become more complicated with increased amount of guests, as we move to Development scenario with smaller LAMP stack. Containers scale linearly to up to 120 dual vCPU Guests, while KVMs and VMs seem to have a noticeable issue handling over 60 Guests. The load pattern is noticeably different between technologies and most probably depends on the way Guests scheduling is implemented and tuned.

Containers and KVMs handle the increased amount of guests with linearly increasing response time, that at some point it becomes unacceptable (for KVM) or host completely runs out of memory (containers). VMs on the other hand, seem to "shake off" the excessive load by timing out some web clients, excluding them from further load testing. As a result, not more than 60 VM guests successfully complete the full cycle of load testing, while up to 96 guests started the test.

Efficient memory sharing and vCPU scheduling allow Containers demonstrate 2x density compared to hypervisors on the given 16 Gb server. Each one of 120 Containers was assigned 256 MB memory limit, which means twice the amount of physical RAM (256MBx120=30GB) was assigned. It is amazing that up to 120 Containers were able to successfully complete the test series in this oversubscribed scenario! This also means that the small DVD-Store LAMP guest instance only needs 128Mb of unique RAM to complete the test series, otherwise running 120 Containers under load on 16Gb machine would not be possible.



Contac Us

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Performance evaluation of a LAMP stack application in competing virtualized environments – Test Configuration Appendix

HARDWARE

- Processor: Intel® Xeon® processor X5570; 2.93 GHz; 2-way x 4 cores = 8 cores (16 hyper threads)
- Memory: 16 GB RAM
- Storage: 2x250 GB SATA HDD for the OS; 12x1TB in RAID0 for Guests (iSCSI over 10Gb Ethernet)

SOFTWARE

Guest LAMP

The same Guest OS configuration was used in all tests:

Linux: Red Hat Enterprise Linux Server release 5.4 (Tikanga) x86_64

Apache: httpd-2.2.3-31.el5

MySQL: mysql-server-5.0.77-3.el5

PHP: php-5.1.6-23.2.el5_3

DVD Store Configuration

DVD Store DB Size				
Database	**Size**	**Customers**	**Orders**	**Products**
Small	10 MB	20,000	1,000/month	10,000
Medium	1 GB	2,000,000	100,000/month	100,000
Large	100 GB	200,000,000	10,000,000/month	1,000,000

DVD Store MySQL Parameters					
Test Scenario	**DS DB size**	**Guest Memory**	**MySQL Memory buffer: innodb_ buffer_ pool_size**	**MySQL Max Connections**	**Apache prefork: MaxClients and ServerLimit**
Production & Performance	Medium	2 GB	1.6GB	560	560
Density	Small	256 MB	128 MB	256	256

DVD Store web load generator

DVD Store Test Client Parameters	
Production & Performance	**Density**
run_time=10 (min) warmup_time=2 (min) db_size_str=**M** ramp_rate=10 pct_newcustomers=10 think_time=0.25 (sec) **n_threads=800** (equally split among participated # of Guests)	run_time=10 (min) warmup_time=3 (min) db_size_str=**S** ramp_rate=10 pct_newcustomers=10 think_time=0.25 (sec) **n_threads=18** (per each participated Guest)

SLES 11 x86_64-based machines running on dual Quad Core (8 Cores) and 16 GB RAM server were used to generate LAMP stack web load using the DVD-Store Web Driver (ds2webdriver_mono.exe).

Web Driver is written in Microsoft .net and the "Mono" framework (http://ftp.novell.com/pub/mono/download-stable/SLE_11/x86_64/) was used to run tests from Linux:

 # rpm -qa|grep mono
mono-core-2.6.4-38.1

Virtualization Technologies

Virtualization engines and guests provisioning summary			
	PVC	**KVM**	**ESXi**
Version	Parallels Virtuozzo Containers, 4.0.0	KVM from RHEL 5 updates	VMware ESXi, 4.0.0, 208167
Components	vzkernel-2.6.18-028stab069.6	kernel-2.6.18-194.el5 kmod-kvm-83-164.el5_5.9 kvm-83-164.el5_5.9	

Virtualization engines and guests provisioning summary			
	PVC	**KVM**	**ESXi**
Guest provisioning, using cli over ssh	Container clone (master and clone linked to RHEL EZ Template): *# vzmlocal -C* *lamp3-M-ctmaster:$ctid* Where: *# vzpkg list -O lamp3-M-ctmaster* *redhat-el5-x86_64*	VM "Linked clone" (clone VM linked to master disk image), using: *# /bin/cp -afv lamp3-M-lkvm-rw-mastersnapshot.img $newimg* Where: *# qemu-img info lamp3-M-lkvm-rw-mastersnapshot.img* *image: lamp3-M-lkvm-rw-mastersnapshot.img* *file format: qcow2* *virtual size: 10G (10737418240 bytes)* *disk size: 260K* *cluster_size: 65536* *backing file: lamp3-M-lkvm-ro-lclonemaster.img (actual path: lamp3-M-lkvm-ro-lclonemaster.img)* *# qemu-img info lamp3-M-lkvm-ro-lclonemaster.img* *image: lamp3-M-lkvm-ro-lclonemaster.img* *file format: qcow2* *virtual size: 10G (10737418240 bytes)* *disk size: 3.9G* *cluster_size: 4096*	VM "Linked clone" (clone VM linked to master disk image), using: *# sh ghetto-esxi-linked-clones.sh /vmfs/volumes/Storage1/lamp3-M-lclonemaster/lamp3-M-lclonemaster.vmx lamp3-M-lclonevm 1 12* Note: Linked clones were provisioned once and snapshotted. Snapshots were reverted before each test run, as it was much faster operation than linked clone creation, using: *# vim-cmd vmsvc/snapshot.revert $vmid 0 1*
Guest start, using cli over ssh	*# vzctl start $ctid*	*# qemu-kvm -m $ram -smp $cpus -name $name -drive file=${newimg}, boot=on,cache=writethrough -net nic,macaddr=$mac,vlan=0,model=virtio -net tap,script=/vz/kvm/qemu-ifup,vlan=0,ifname=kvmnet$i -parallel none -usb -k en-us -monitor pty -serial pty -nographic -daemonize -snapshot*	*# vim-cmd vmsvc/power.on $vmid*
Guest Network	DHCP	DHCP	DHCP

TEST PROCESS

The same server was used in multi-boot configuration to test all technologies. The same environment with different kernels was installed for PVC and KVM, while ESXi was installed on a dedicated partition. Host was rebooted at the beginning of each test run. Then guests were deployed for every test run to ensure consistency of results. Once all guests were created and started, test web load clients are executed to stress each guest.

The results from each test client were saved to individual files and later parsed to produce a consolidated performance metric OPM (Orders per Minute) and Average Response Time for all Guests involved in the test run.