IOmark-VM

VMware VSAN

Intel Servers + VMware VSAN Storage SW

Test Report: VM-HC-160816-a

Test Report Date: 16, August 2016

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Executive Summary

This document is the official benchmark report for the tested configuration using Intel® S2600WT server platforms together with VMware Virtual SAN (VSAN) storage software as a hyper-converged system.

IOmark is a storage specific workload and benchmark designed to test storage systems performance using a variety of real world, application centric workloads. The IOmark-VM benchmark is a specific workload, which measures Server Virtualization workloads (VMs) run against storage systems. Results are published after audit and certified approval by IOmark authorized auditors.

IOmark-VM-HC is a benchmark that certifies Hyper-Converged systems for virtual server results. The measurement criteria are storage performance, with the restriction that all storage workloads must be supported by the tested Hyper-Converged system. Although there are CPU and memory considerations, these aspects are not tested by the IOmark-VM workload.

The results achieved by Intel hardware with VSAN SW running IOmark-VM are as follows:

- A four-node cluster supported 320 IOmark-VM's at a cost of $645.62 per VM
- A six-node cluster supported 480 IOmark-VM's at a cost of $545.27 per VM

A full description of the configurations tested along with pricing information is provided in this document. The criteria and performance requirements are as follows:

- For all application workloads:
  - All workloads must reside entirely on the tested hyper-converged system
  - Workloads are scaled in sets of 8 workloads
  - 70% of response times for I/Os must not exceed 20ms
  - The average response time for each application type must not exceed 20ms
  - The execution time must complete within 1 hour and 15 seconds for each workload
- For hypervisor operations:
  - Clone, deploy, boot, software upgrade, VM deletion
  - Storage migration (aka Storage vMotion) between storage volumes
- For IOmark-HC benchmarks
  - The system CPU and memory must be sufficient to run the equivalent applications
  - The storage subsystem is measured by IOmark, with system CPU and memory compared to relevant published performance metrics

Vendor Supplied Product Description

Intel Servers with VMware Virtual SAN

Data-center economics are driving new solutions for delivering enterprise class storage. Using Intel based server platforms together with VMware Virtual SAN software-defined storage provides a flexible model for enterprise computing and hyper-converged solutions. With the scale-out architecture, adding additional nodes scales CPU, memory and storage capacity and performance capabilities for the entire system. Server-based storage systems can provide high levels of performance along with economic benefits as shown by the leading price / performance levels achieved during testing.

Intel® E5-2600v4 processor based platforms feature enhancements vs. previous chips, including:

- A 22% increase in the maximum number of threads of execution (22 cores, 44 threads)

- New Intel resource technology enables hypervisors to control the amount of cache per VM
- Enhanced context switching performance, further enhances multi-threaded and virtual apps
- New instructions to improve encryption and other processor enhancements
- Increased memory support up to 2.4 TB and CRC correction on memory transfers

VMware Virtual SAN provides enterprise storage features:

- Hypervisor-embedded storage for ease of management and deployment using existing tools
- Flexible, scale-out and scale-up storage supports adding storage and/or compute on demand
- Enterprise storage with high-availability, async replication, and stretched clustering
- New features in Virtual SAN 6.2 include: deduplication, compression and RAID-5 & RAID-6
- QoS and policy-based storage management enable per-VM and per-object management

IOmark-VM-HC Test Summary

For the tested configuration, the following data is provided

Item	Value
Testing Identifier:	VM-HC-160816-a
Product(s):	4 x Intel S2600WT with Intel E5-2699v4 CPU + Intel Flash Media (Intel® DC P3700 NVMe) + Intel Flash Media (Intel® DC S3700 SSD) + VMware Virtual SAN 6.2
Test Sponsor:	Intel
Auditor:	Evaluator Group Inc.

Table 1: Test Identifier Information

Item	Value
IOmark-VM Version:	Version: IOmark-VM 3.8
Testing Completed:	April 2016
Equipment Availability:	March 2016
Audit Certification Date:	16, August 2016
Report Date:	16, August 2016

Table 2: Test Revision and Dates

IOmark-VM-HC Results

Shown below are the IOmark-VM-HC results for the system under test. The definition and workload characteristics of the benchmark are provided in Appendix A.

Price information provided below is explained in detail in Table 8 in this report.

Table 3 below shows an overview of the IOmark-VM results.

Config	IOmark-VM Total VM's	IOmark-VM Response Avg.	Tested Capacity	Tested RAID Level	Total Price	IOmark-VM $ / VM
4 Nodes	320	3.43 ms	16 TB	RAID 5 + 10	$206,599.84	$645.62
6 Nodes	480	3.43 ms	16 TB	RAID 5 + 10	$261,731.52	$545.27

Table 3: IOmark-VM-HC Result Details

The total number of IOmark-VM virtual machines supported is shown above in Table 3, based on the IOmark-VM workload sets shown in Table 4 below. Each application set consists of 8 virtual machines, thus 40 application sets yields 320 VM's and 60 sets results in 480 IOmark-VM's reported.

The VMware vCenter Server™ operation values are also shown below, with two components being reported. The "Clone and Deploy" portion of the workload creates a clone from a specific VM template, starts the VM running and then upgrades its version of VMware tools installed. The reported value indicates how many operation cycles were completed during the 1-hour test run. Similarly, the storage vMotion value reported indicates how many migration cycles were completed during the 1-hour test run. A combined score is calculated, known as the "Hypervisor Workload Score," which is the ratio of reported results to the minimum required results. The minimum numbers of vCenter operations for passing the test are 6 clone and deploy and 3 storage vMotion operations respectively for configurations supporting 21 IOmark-VM sets or more.

Details of passing results shown below in Table 4:

Config	IOmark-VM Sets	Read Resp. Average	Write Resp. Average	# vCenter Clone and Deploy	# vCenter storage vMotion	Hypervisor Workload Score (1 - inf.)
4 Nodes	40	1.12 ms	4.11 ms	6	4	2.0
6 Nodes	60	1.08 ms	3.95 ms	8	4	3.2

Table 4: IOmark-VM Passing Result Details

Tested Configuration Details

This section covers the connectivity, configuration and pricing information for the system under test.

Hyper-Converged System Details

Detailed server hardware features for the system under test are provided below in Table 5.

Hardware Features	Value
Rack Footprint	8U (2U for per S2600WT system)
Number of Nodes per Appliance	1 compute/storage node
Number of Drives per Appliance	4 Intel DC P3700 NVMe / system = 16 total (4 node = 4 Intel DC P3700 NVMe /node) (6 node = 3 Intel DC P3700 NVMe + 6 SSD / node)
CPUs per system / total	2 CPUs (2.2GHz Intel E5-2699v4) per system @22 Hyperthreaded Cores each, for a total of 8 CPUs with 176 Hyperthreaded Cores
Memory	512 GB / node => (2 TB for 4 node, 3 TB for 6 node configuration)*
Networking Ports (1/10 GbE)	8 10GbE Ports (2 Per Node)

Table 5: Hyper-Converged Hardware Features

- **** Note:*** *Each of the systems was configured with 512 GB of RAM, which was determined to be the amount required to run the reported number of IOmark-VM applications. The determination of 512 GB / system was made based on the following footnoted references below, based upon systems running VMmark 2.5 workloads noted.*

The 4 storage and compute node system achieved an IOmark-VM-HC workload of 40 application sets, a 4 storage and compute nodes plus 2 compute only nodes achieved 60 IOmark-VM application sets. Each IOmark-VM application set is equivalent to one VMmark 2.5 tile.

The Intel E5-2699v4 CPUs provide 22-25% greater performance than previous generation E5-2600v3 CPU's, based upon the greater number of cores, and improved architecture[1]. These improvements enable a 4-node system to run 320 applications (or 40 VMmark tiles), with sufficient CPU capacity necessary to support the CPU utilization of the Virtual SAN software. VMware has certified multiple systems able to support 40 VMmark tiles[2]; all of which required 144 total CPU cores, which is less than the number of CPU cores available in the tested configuration.

By comparison, the tested configuration had faster clock and bus speed for the CPU along with the same amount of DRAM. With these guidelines, the tested Hyper-Converged system achieved the storage performance required and has sufficient computing resources to achieve the stated results.

NOTE: IOmark-VM requires less memory than VMmark. Although the tested systems did not use 512 GB of DRAM for IOmark-VM; in order to achieve the VMmark workload levels the configurations used 512 GB / node, for 2 TB total for a 4 node system in order to allow direct comparisons to VMmark.

[1] Intel documentation: Intel_xeon-e5-ProductBrief.pdf

[2] VMware VMmark results: www.vmware.com_VMmark_144-core_Results

Hypervisor Configuration for IOmark-VM-HC Workload

- No traditional LUNs or volumes were created, instead a single Virtual SAN datastore was used
- A virtual disk was created for each of the reported IOmark-VM's certified (320 or 480)
- Data layout and RAID level was determined on a per VMDK basis based upon policies applied
  - RAID-1 mirroring policy was utilized for DS2DB and MAILS application disks
  - RAID-5 policy was used for remaining application disks
- Virtual SAN by default utilizes thin provisioned disks

Detailed hypervisor configuration parameters for the system under test, including connectivity are provided below in Table 6.

Storage System Parameter	Value
Hypervisor	VMware vSphere™ ESXi 6
Number of interfaces to the storage system:	2 Per Node (10 total)
Connectivity to storage system:	1 @ 10Gb Ethernet / node (VSAN interconnect)
Hypervisor storage protocol used:	VSAN (Proprietary IP Protocol)
Hypervisor version:	VMware ESXi 6.0U2 (3620759)
Thin provisioning:	Utilized in VSAN datastore
Hypervisor Storage Access:	VSAN datastore
Datastore Filesystem:	VSAN - VirstoFS
VAAI:	N/A
SATP:	VSAN proprietary
PSP:	VSAN proprietary
Total capacity of system allocated to IOmark-VM:	4 Node: 10.7 TB 6 Node: 16.0 TB * Note: Does not include 4 x 600 GB cache

Table 6: Hypervisor Configuration Parameters

NOTE: Per IOmark requirements, a "write-only" workload is run prior to the actual workload. This pre writes data to all storage locations referenced during testing. By pre-writing data prior to actual workload testing, there is no write allocation penalty associated with thin provisioning. This also ensures that when reads are performed the storage system reads the media, rather than returning zero's for unallocated addresses.

Storage Configuration for IOmark-VM-HC Workload

- A single Virtual SAN datastore was created using the pooled capacity across all nodes
- Policy-based management was used to allocate VMDK's to each VM for each workload
- A policy of "RAID-5" was chosen for Olio DB, Olio Web, the standby and 3 DVD Web apps
- A policy of "RAID-10" was chosen for the Exchange Mail and DVD store database apps
- Each VM's VMDK was allocated using "thin provisioning" per VSAN default

Detailed Storage System configuration parameters for the storage system under test, including connectivity is provided below in Table 7.

Storage System Parameter	Value
Storage System firmware	VSAN 6.2
High Availability Access to all LUNs	Yes (active / active)
Total raw capacity of system under test (SUT)	10.7 TB (4 nodes) / 16.0 TB (6 nodes)
Total usable capacity of system under test (SUT)	Dependent upon RAID level chosen
Disk groups	4 Node: 1 VSAN disk group per node 6 Node: 2 VSAN disk groups per node
Thin provisioning:	Yes
RAID Level(s)	Network RAID 5 + 10 (both utilized)
Total Cache Capacity:	Configuration dependent
Read Cache:	N/A (Not used in all flash configurations)
Write Cache:	600 GB / node NVMe device (3.2 TB total)
VAAI Features Enabled:	Yes
- Block Zero	Yes
- Full Copy	Yes
- HW Locking	Yes
Automated tiering within the storage system:	N/A
Deduplication or compression of data:	Available not enabled on tested configurations
Storage system clones / writeable snapshots:	No
Type of storage system clone:	N/A
Storage Media Utilized:	-
- SSD's	4 Node: 1 x 1600 GB + 2 X 800 = 10.7 TB total 6 Node: 2 x 800GB + 2 x 1600 GB = 16.0 TB total
- 15K RPM	NA
- 10K RPM	NA
- 7.2K RPM	NA

Table 7: Storage System Configuration Parameters

Configuration Diagram

The logical data layout of the test configuration is shown below in Figure 1. Since VSAN utilizes policy-based storage management, individual LUNs and datastores were not utilized. Instead, individual virtual disks were assigned directly to VM's as required for each workload. The VMDK's for each VM's workload all were allocated from the same VSAN Datastore capacity pool created by VSAN across the 4 storage and compute nodes.

Note*: Given the available servers and drive configurations, a single Virtual SAN disk group was created per node for the 4-node configuration, with 2 disk groups for the 6-node configuration. VSAN best practices suggest 2 or more disk groups per node to deliver optimal performance. Higher performance may be achievable with additional drives and meeting all best practices for the VSAN configuration.*

Note*: Since VSAN leverages a single datastore and policies to adjust per-VM capabilities, storage vMotion within that VSAN datastore is not applicable. VSAN supports storage vMotion to external storage systems. In order to provide a valid comparison to other reported IOmark-VM results a secondary, remote iSCSI device was utilized as a target for storage vMotion operations. In order to create the same level of vMotion I/O, two storage vMotion operations occurred in parallel, one moving the VM from the external iSCSI LUN to VSAN, and another moving the VM from VSAN to the remote iSCSI target. The number of storage vMotion operations reported in Table 4 is ½ the number that were actually performed. That is, the bidirectional storage vMotion operations were counted only as a single operation. In this way the results are directly comparable to other tested IOmark-VM results.*

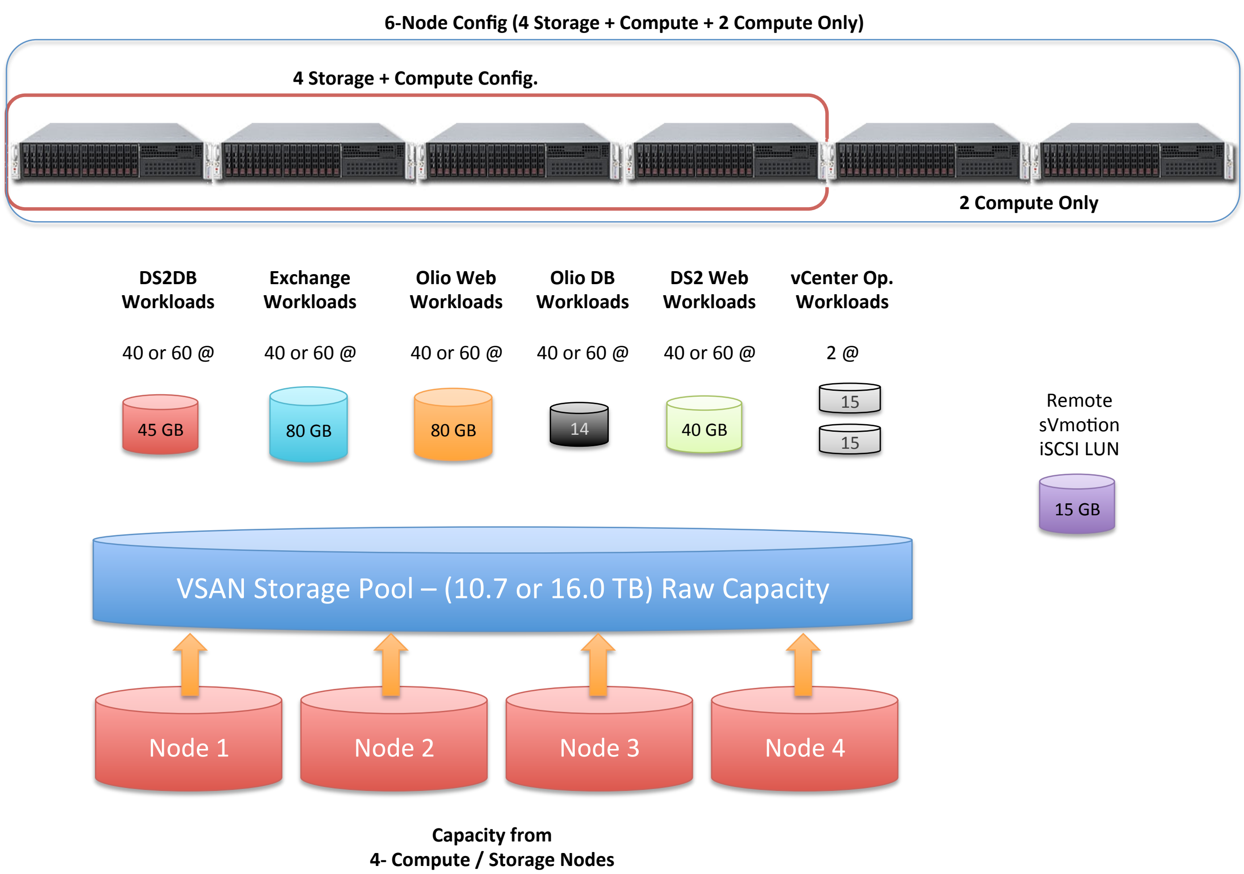

Figure 1: Logical System Configuration

Connectivity

The storage connectivity was 10GbE for both VMware management and VSAN, using a distributed virtual switch per VSAN recommendations. Each node used 2 10GbE links to a 10 GbT Ethernet switch, for a total of 8 connections for the 4-node configuration and 12 for 6 nodes. Testing did not utilize a redundant HA configuration, although production deployment assumes connectivity to a HA network infrastructure.

Note: A single 10 Gb connection to an external iSCSI storage device used for storage vMotion testing is not shown.

The tested configuration connectivity diagram is shown below in Figure 2.

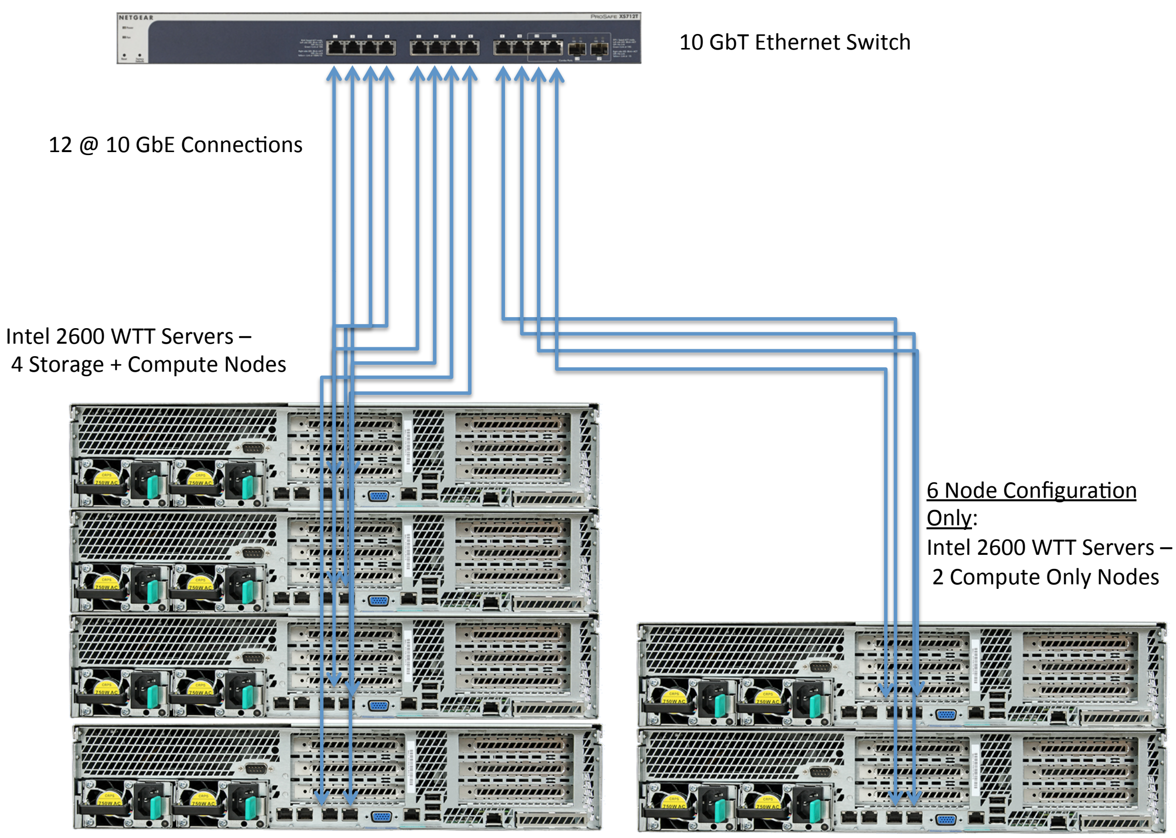

Figure 2: Physical System Connectivity

Tested Configuration Pricing

Item	Description	Qty.	Ext. List Price
1	Intel S2600WT Standard Servers (2 @ 22 core CPUs, 512 GB DRAM + 2 @ 10 Gb Ethernet)	4 servers	$46,224.00
2	VMware vSphere Enterprise Plus	8 sockets	$27,960.00
3	VMware vSphere VSAN Adv. + Flash	8 sockets	$31,960.00
4	Intel DC P3700 NVMe Storage Devices	16 media	$48,463.84
5	3 Years Support HW (Intel media 5 year warranty only)	4 servers	$7,052.00
6	3 Years VMware SW Support	8 sockets	$44,940.00
Total	**List Price HW + SW + 3 year service & support**		**$206,599.84**

Table 8: IOmark-VM-HC Price Information (4 Node Configuration)

Item	Description	Qty.	Ext. List Price
1	Intel S2600WT Standard Servers (2 @ 22 core CPUs, 512 GB DRAM + 2 @ 10 Gb Ethernet)	6 servers	$69,336.00
2	VMware vSphere Enterprise Plus	12 sockets	$41,940.00
3	VMware vSphere VSAN Adv. + Flash	8 sockets	$31,960.00
4	Intel DC P3700 NVMe media	12 media	$24,239.88
5	Intel DC S3700 SSD media	24 media	$28,252.64
6	3 Years Support HW (Intel media 5 year warranty only)	6 servers	$10,578.00
7	3 Years VMware SW Support	12 sockets	$55,425.00
Total	**List Price HW + SW + 3 year service & support**		**$261,731.52**

Table 9: IOmark-VM-HC Price Information (6 Node Configuration)

Note: Support included for all hardware and software, excluding Intel flash media, which is covered by a 5-year warranty.[3]

[3] http://www.intel.com/content/www/us/en/support/solid-state-drives/000006281.html

Detailed Results

IOmark-VM performance results are measured by application workload. The eight applications that comprise a workload set are shown below in Table 9, with average response times reported per application type.

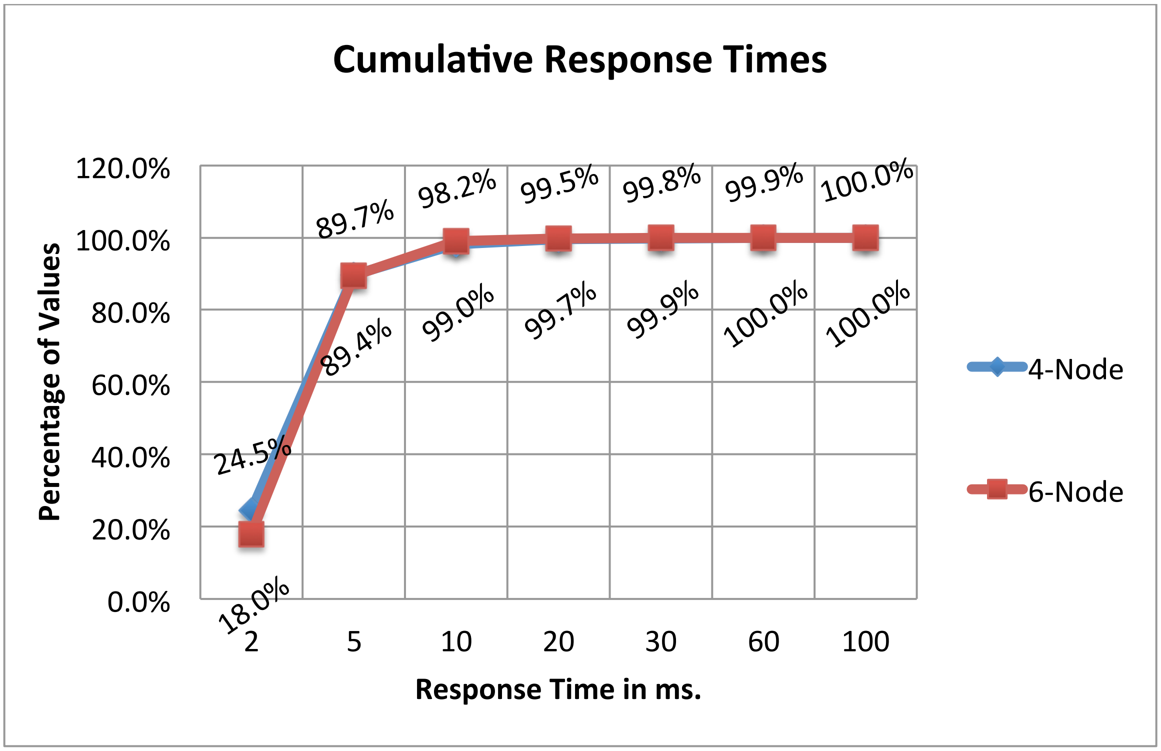

Figure 3: Percentage of Total Response Times at Measured Value

From Figure 3 above, the primary response time(s) of interest are:

- Nearly 90% of response times were less than 5 ms. for both configurations
- 99.5% and 99.7% of response times were less than 20 ms. for 4-Node and 6-Node

Application Workload	Avg. Response Time	
	4 Node	6 Node
DVD Store DB	2.97 ms	2.21 ms
Exchange Mail Server	3.22 ms	3.22 ms
Olio Database Server	2.04 ms	2.20 ms
Olio Web Server	4.19 ms	4.42 ms
DVD Store Web App 1	4.73 ms	5.11 ms
DVD Store Web App 2	4.73 ms	5.11 ms
DVD Store Web App 3	4.73 ms	5.11 ms
Windows Standby	4.73 ms	5.11 ms

Table 10: Application Workload Response Times

Appendix A - IOmark-VM Overview

The ability to recreate a known workload is important for comparing a system against potential alternatives. Establishing a reference or benchmark workload enables system vendors as well as resellers and IT users to compare several systems utilizing a known workload.

Specifically, the IOmark-VM benchmark recreates a storage workload that typically occurs in a virtual infrastructure environment. The workload is non-synthetic and recreates several applications that are commonly found in virtualized server environments.

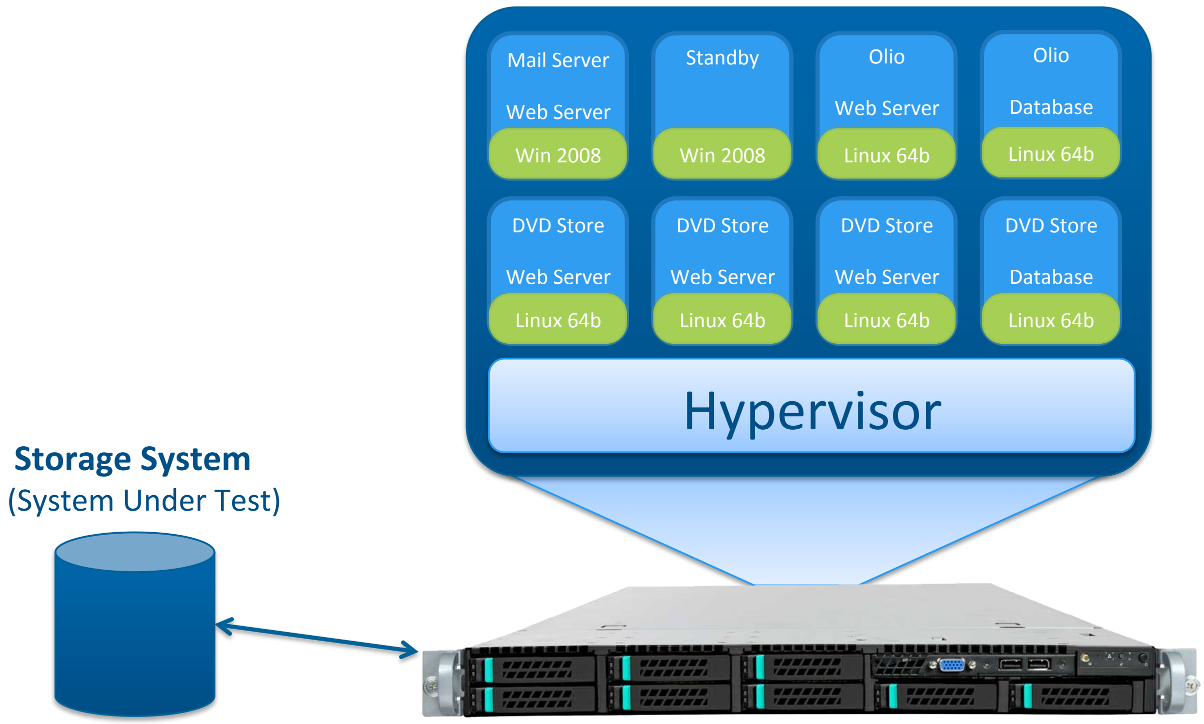

Figure 3: IOmark-VM Conceptual Overview

IOmark-VM Measurements and Use

Datacenters running applications in a virtual infrastructure contain multiple workloads running on a virtualization platform. Often multiple physical servers share the resources of a single storage system providing primary storage for both virtual machine OS and applications.

Currently, several benchmarks have been developed that focus on the server aspects of infrastructure, including the CPU, memory and I/O bandwidth capabilities of the infrastructure. However, there has been no corresponding development of standardized workloads designed to drive storage workloads for these application environments.

By establishing a set of standard applications and capturing their I/O streams, it is possible to recreate application based storage workloads for these complex environments. IOmark-VM is designed utilizing these concepts, and as such is the first benchmark designed to accurately generate application workloads for storage systems, enabling direct comparison of storage system configurations and their ability to support a specific number of applications.

Additionally, IOmark-VM realizes that a significant impact on storage may occur from administrative functions common in virtual infrastructures. For this reason, several hypervisor-based functions are a part of the IOmark-VM workload. These additional operations include; cloning a virtual machine, booting a VM and updating software, while also migrating a virtual machine from one storage volume to another.

How IOmark-VM Operates

IOmark-VM uses the concept of workload replay. I/O streams are captured from actual running applications and then "replayed" so that the exact sequence and I/O commands are issued. This allows the creation of a workload that is indistinguishable from an actual workload to the system under test, while being reproducible and requiring fewer resources. Additionally, the test environment is less expensive, easier and faster to create since actual applications are not required. Because CPU and memory are not consumed running applications, a much higher I/O workload may be generated with a set of server resources than is possible using native applications. This ratio is typically 10:1, but may vary.

In Figure 3 on the previous page, a single set of applications is depicted running on a single physical host in a virtual infrastructure. In order to scale up the workload on a storage system, additional applications sets may be added to the same, or to other physical hosts. The only limitation to the scale of the test is the physical infrastructure supporting the workload. Sufficient, CPU, memory and I/O capabilities must be available to run additional workload sets.

Unlike artificial workload generation tools, IOmark-VM recreates accurate read vs. write and random vs. sequential I/O requests. Another measurement of IOmark-VM is that it creates accurate access patterns, thus enabling storage cache algorithms to work properly.

Finally, IOmark-VM maintains an accurate ratio of performance to capacity as workloads are scaled, ensuring that storage performance is measured with respect to storage capacity accurately. As a result, IOmark-VM maintains an accurate ratio of I/O to capacity, producing results applicable to IT users.

Benchmark Application Workload Set

A concept utilized for testing multiple applications is that of "Application sets", also known as "tiles." A set of 8 applications is run together, along with several common hypervisor infrastructure operations. In order to scale the workload up and place a higher load on the storage system, additional application sets are run. Application sets are always run together for official benchmark results, along with a defined set of infrastructure operations.

The specific applications comprising a workload set are detailed below in Table 10.

Application	Guest OS	Storage Capacity / Instance
Microsoft Exchange 2007	Microsoft Windows Server 2008, Enterprise, 64 bit	80 GB
Olio Database	SuSE Linux Enterprise Server 11, 64bit	14 GB
Olio Web server	SuSE Linux Enterprise 11, 64bit	80 GB
Idle Windows Server	Microsoft Windows Server 2003 SP2 Enterprise Edition, 32-bit	10 GB
DVD Store Database	SuSE Linux Enterprise 11, 64bit	45 GB
DVD Store Web Server 1	SuSE Linux Enterprise 11, 64bit	10 GB
DVD Store Web Server 2	SuSE Linux Enterprise 11, 64bit	10 GB
DVD Store Web Server 3	SuSE Linux Enterprise 11, 64bit	10 GB
Hypervisor Clone & Deploy	N/A - VMware vCenter required	15 GB
Hypervisor Storage Migration	N/A - VMware vCenter required	30 GB
--	--	Total = 305 GB

Table 10: IOmark-VM Application Overview

The total capacity required for each set of applications is approximately 305 GB of capacity. Each additional workload set requires an additional 305 GB of capacity.

Workload Details

The Olio application consists of both a database server, and a web client running on different virtual machines with a pre-loaded data set. For more details on Olio see: http://incubator.apache.org/olio/

The DVD application consists of a single database server along with three web clients, each running on a different virtual machine using predefined workload and data set. For more details on the publicly available DVD database application see: http://linux.dell.com/dvdstore/

The Exchange server is a Microsoft messaging and email server. Only the server portion of Exchange is recreated in this workload set, with the client workloads not being a part of the I/O, only indirectly through their requests to the messaging server.

The two hypervisor workloads are based on common operations performed in virtual infrastructure environments and require the availability of a VMware vCenter server to perform the operations.

Understanding Results

IOmark-VM produces results indicating the response time of a storage system given a particular workload. Based on established criteria, these results in turn dictate how many total virtual machine sets are supported by a specific storage configuration and the average response time. The report is audited for accuracy and issued by Evaluator Group, Inc., an independent storage analyst firm.

Note: IOmark-VM response times cannot be directly compared to VMmark response times. IOmark measures response times of individual I/O requests, whereas VMmark measures transaction response times, consisting of multiple I/O operations along with data calculations.

Benchmark Criteria

IOmark has established the benchmark criteria for the IOmark-VM workload. The performance requirements are established as follows:

- For all application workloads:
  - Workloads are scaled in sets of 8 workloads
  - 70% of response times for I/O's must not exceed 20ms
  - The average response time for each application must not exceed 30ms
  - All storage must reside on the storage system under test
  - The replay time must complete within 1 hour and 15 seconds for each 1 hour workload
- For hypervisor operations:
  - Clone, deploy, boot, software upgrade, VM deletion
  - Storage migration (aka Storage vMotion) between storage volumes

More Information about IOmark-VM

For more information about the IOmark benchmark, a theory of operations guide, published results and more, visit the official website at http://www.iomark.org. Some content is restricted to registered users, so please register on the site to obtain all available information and the latest results.

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