IOmark-VM

IBM

IBM FlashSystem V9000

Test Report: VM-151205-a

Test Report Date: 5, December 2015

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Executive Summary

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

This document is the official benchmark report for the tested configuration using IBM FlashSystem V9000 appliance. The result of the benchmark showed the tested IBM FlashSystem V9000 supported 1,600 virtual machines at a cost of $470.00 per VM, meeting the storage response time requirements. In addition IOmark-VM requires several hypervisor operations as part of the benchmark, including "Clone and Deploy" and vMotion. IBM FlashSystem V9000 met the required minimums for these operations as indicated.

A full description of the configuration tested along with pricing information are provided in the following document, with application workload details in Appendix A.

The criteria and performance requirements are as follows:

- For all application workloads:
  - All workloads must reside entirely on the tested 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 30ms
  - 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

Vendor Supplied Product Description

IBM FlashSystem V9000

IBM FlashSystem® V9000 is a comprehensive all-flash enterprise storage solution. FlashSystem V9000 delivers the full capabilities of IBM FlashCore™ technology plus a rich set of storage virtualization features. FlashSystem V9000 delivers industry-leading value to enterprises along three dimensions: Performance, Economics, and Integration. The V9000 FlashSystem is production-ready within 15 minutes and can be used for any virtualization project where simplicity is key. The IBM V9000 FlashSystem features the following:

- Three dimensions of value: Scalable Performance, Enduring Economics, Agile Integration
- Accelerate time to value with agile, easy-to-implement, fully-integrated systems

- Data protection with a full suite of DR tools including snapshots, clones and replication
- Provides advanced virtualization, provisioning and performance management with IBM Virtual Storage Center

IOmark-VM Test Summary

For the tested configuration, the following data is provided

Item	Value
Testing Identifier:	VM-151205-a
Product:	IBM FlashSystem V9000
Test Sponsor:	IBM Corporation
Auditor:	Evaluator Group Inc.

Table 1: Test Identifier Information

Item	Value
IOmark-VM Version:	IOmark-VM 3.8
Testing Completed:	November 2015
Equipment Availability:	December 2014
Audit Certification Date:	1, December 2015
Report Date:	5, December 2015

Table 2: Test Revision and Dates

IOmark-VM Results

Shown below are the IOmark-VM 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 7 in this report.

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

IOmark-VM Total VM's	IOmark-VM Response Avg.	Tested Capacity	Tested RAID Level	Total Price	IOmark-VM : $ / VM
1,600	3.88 ms	18.5 TB	RAID 5	$752,000.00	$470.00

Table 3: IOmark-VM Result Details

The results detailed below in Table 4 provide more information regarding the passing results of the tested storage system. The total virtual machines supported is shown above in Table 3, based on supporting IOmark-VM workload sets shown in Table 4 below. As described, applications sets of eight workloads must be run together for passing results.

The vCenter 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 21 sets or greater.

Details of passing results shown below in Table 4:

IOmark-VM Application Sets	Read Resp. Average	Write Resp. Average	# vCenter Clone and Deploy	# vCenter storage vMotion	Hypervisor Workload Score (1 - inf.)
200	1.66 ms	4.43 ms	7	5	2.24

Table 4: IOmark-VM Passing Result Details

Tested Configuration Details

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

Hypervisor Configuration for IOmark-VM Workload

Detailed hypervisor configuration parameters for the system under test, including connectivity are provided below in Table 5.

Storage System Parameter	Value
Hypervisor	VMware ESXi vSphere
Number of interfaces to the storage system:	4 @ 16 Gb FC / Controller (8 total)
Host Connectivity to the storage system:	4 @ 16Gb FC
Hypervisor storage protocol used:	FCP (SCSI over FC)
Hypervisor version:	VMware ESXi 5.5 U2
Thin provisioning:	Utilized in VMFS
Hypervisor Storage Access:	VMFS datastore
Datastore Filesystem:	VMFS 5.6 – 1 MB block size
VAAI:	VAAI supported
SATP:	VMW_SATP_ALUA
PSP:	VMW_PSP_RR (Round Robin)
Total capacity of system allocated to IOmark-VM:	18.5 TB (Actual used w/ thin provisioning)

Table 5: Hypervisor Configuration Parameters

Storage Configuration for IOmark-VM Workload

- A total of 133 SCSI logical units (LUNs) were utilized on the IBM FlashSystem V9000
- VMFS datastore type, with "VMFS 5" chosen
- Each virtual machine was allocated using "thin provisioning" as VMware datastore type

Detailed Storage System configuration parameters for the storage system under test, including connectivity is provided below in Table 6.

Storage System Parameter	Value
Storage System firmware	IBM V9000 firmware version 7.5.1
High Availability Access to all LUNs	Yes (active / active)
Total raw capacity of system under test (SUT)	34.8 TB
Total usable capacity of system under test (SUT)	26.0 TB
Thin provisioning:	Yes
RAID Level(s)	V9000 default - RAID 5 (multi-level chip R5)
Total Cache Capacity:	128 GB (dual V9000 controllers R/W cache)
Read Cache:	Dynamic Read Ahead
Write Cache:	Dynamic Write Back
VAAI Features Enabled:	Yes
- Block Zero	Yes
- Full Copy	Yes
- HW Locking	Yes
- NAS Clone	N/A
- NAS Reserve	N/A
Automated tiering within the storage system:	No - All flash storage media
Deduplication or compression of data:	No
Storage system clones / writeable snapshots:	No
Type of storage system clone:	No
Storage Media Utilized:	-
- SSD's	12 x 2.9 TB flash module = 34.8 TB
- 15K RPM	NA
- 10K RPM	NA
- 7.2K RPM	NA

Table 6: Storage System Configuration Parameters

Configuration Diagram

The logical data layout of the test configuration is shown below in Figure 1.

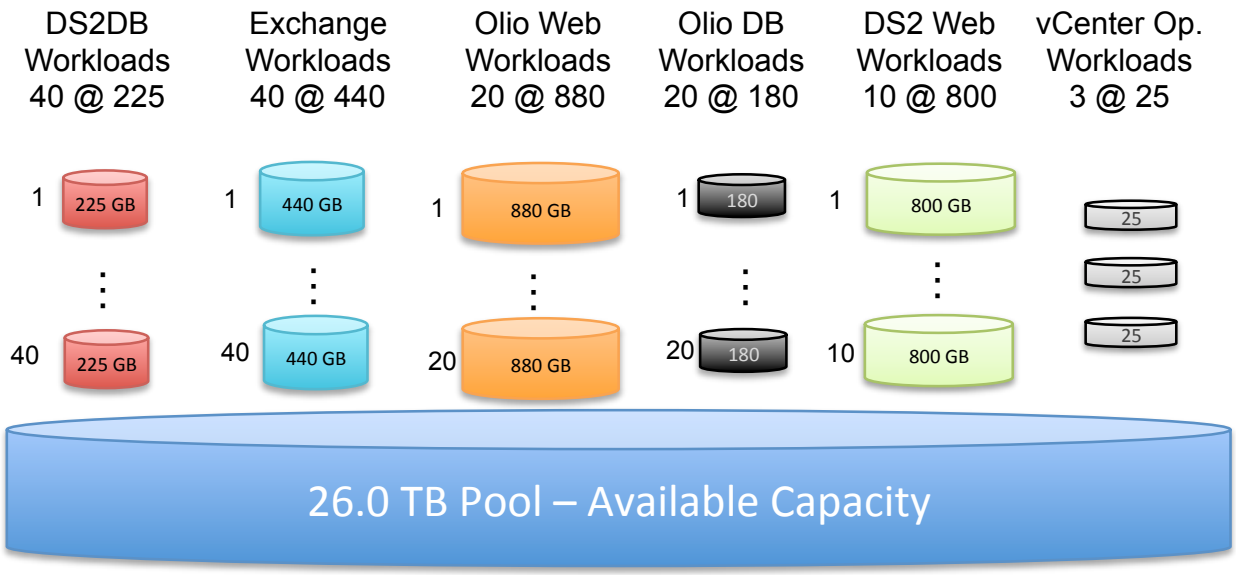

Figure 1: Logical System Configuration

Connectivity

The storage connectivity was 16 Gb Fibre Channel. Each V9000 controller utilized 8 connections to the Brocade FC switch, and the V9000 storage module also used 8 FC connections, for a total of 24 @ 16 Gb FC connections for the storage. Not shown was an additional 4 @ 16 GB FC host connections.

A diagram is shown below in Figure 2.

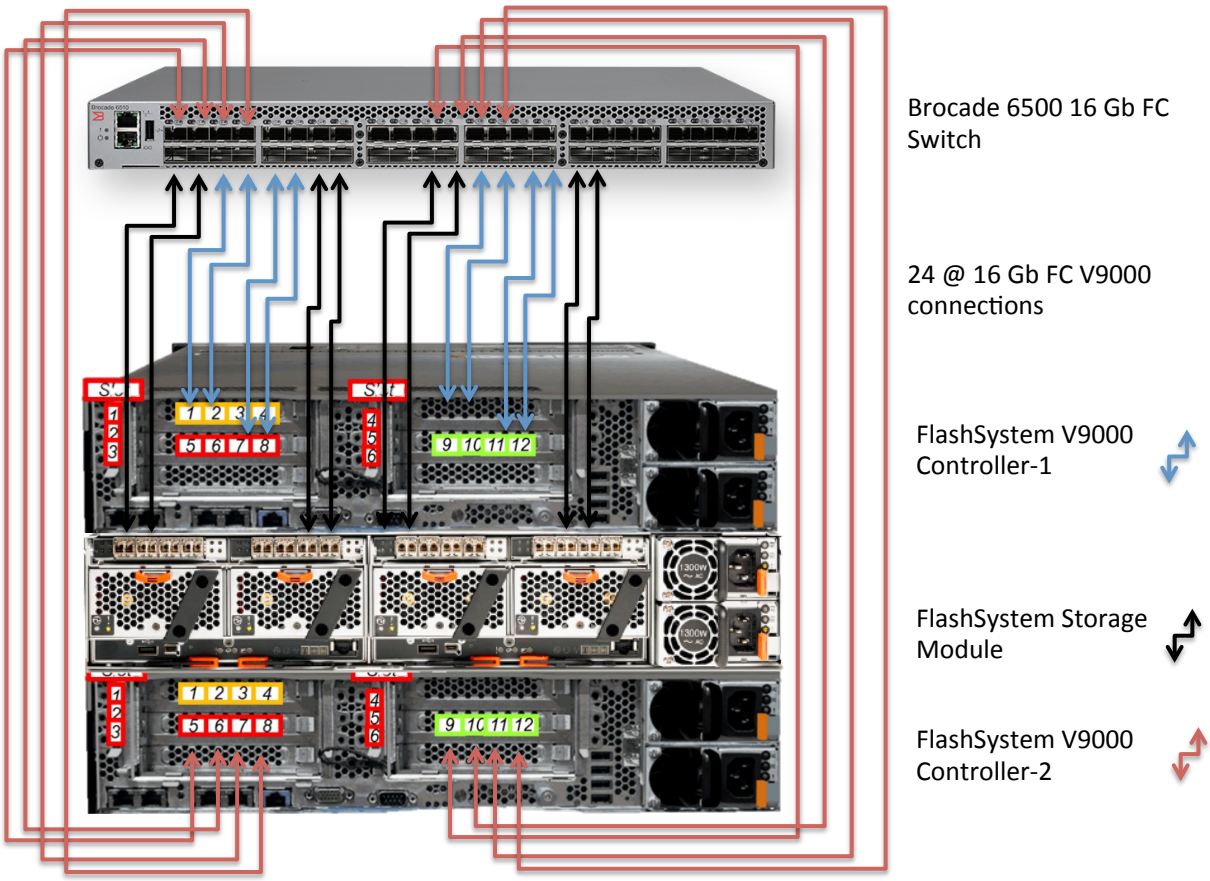

Figure 2: Physical System Connectivity

Tested Configuration Pricing

Item	Description	Qty.	List Price
1	IBM V9000, w/ 29 TB usable capacity	1	$752,000
Total	**List Price HW + 3 year service & support**		**$752,000**

Table 7: IOmark-VM Price Information

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.

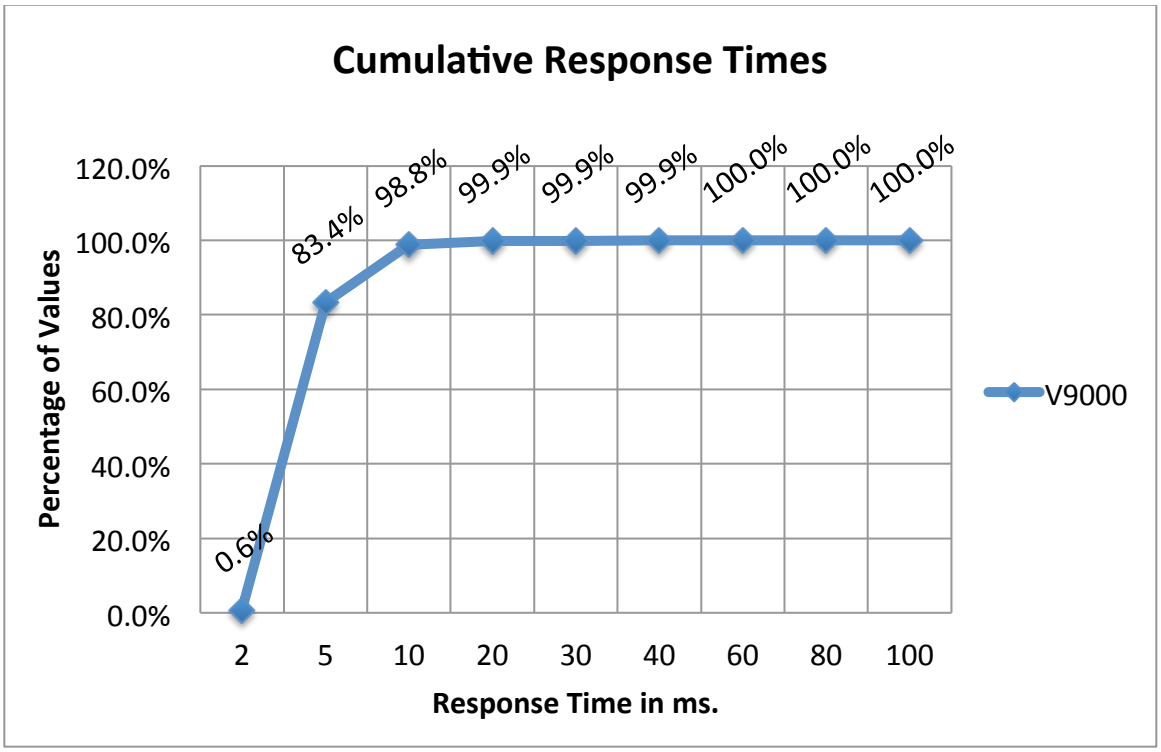

Figure 3: Percentage of Total Response Times at Measured Value

From Figure 3 above, the primary response time of interest is:

- 99.9% of response times were less than 20ms

Application Workload	Avg. Response Time
DVD Store DB	3.94 ms
Exchange Mail Server	3.18 ms
Olio Database Server	3.60 ms
Olio Web Server	4.17 ms
DVD Store Web App 1	4.50 ms
DVD Store Web App 2	4.50 ms
DVD Store Web App 3	4.50 ms
Windows Standby	4.50 ms

Table 9: 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.

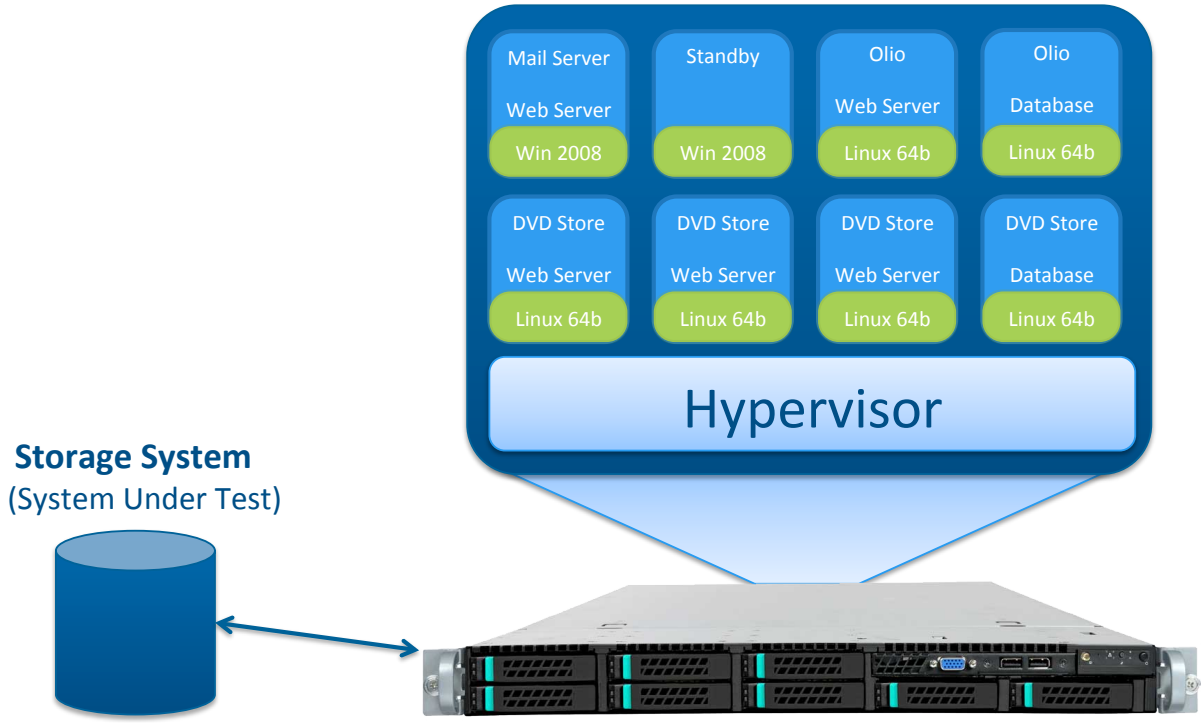

Figure 3: IOmark-VM Conceptual Overview

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.

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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