IOmark-VDI

NetApp HCI

Test Report: VDI-HC-190802-a

Test Report Date: 2, August 2019

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Executive Summary

This document is the official benchmark report for NetApp HCI, tested as a hyper-converged system using the IOmark-VDI workload.

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

The measurement criteria for IOmark-VDI is storage performance, with the restriction that all storage workloads must be supported by the tested system. For IOmark-VDI, CPU and memory considerations, are not tested or considered by the workload.

Systems tested as hyperconverged solutions report IOmark-VDI-HC results and include compute and memory resources in addition to storage.

- NetApp HCI achieved the highest number of IOmark-VDI-HC for hyperconverged systems
- IOmark-VDI-HC certifies entire HCI system for 3,200 desktops at $176.56 / IOmark-VDI-HC
    - Configuration: 12 compute nodes + 5 storage nodes
    - System total = $565,000.00 ($565,000 / 3,200 = $176.56)

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 VDI application workloads:
    - All workloads must reside entirely on the tested system
    - 70% of response times for I/O's must not exceed 30ms
    - The replay time must complete within 1 hour and 15 seconds for each 1-hour workload
- 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

NetApp HCI

NetApp HCI is designed for enterprise environments that require the ability to scale storage performance and capacity independently from computing, in order to match application requirements efficiently. NetApp HCI's architecture provides enterprise capabilities along with NetApp Data Fabric components to extend usage, data protection and deployment options.

- **Independent Scale-Out** – Scale storage capacity independently from compute performance
- **Data Efficiency** – In-line deduplication, compression and thin provisioning increase storage efficiency by 5 – 10x
- **Storage Capacity** – From 11.5 TB - 1.8 PB raw capacity (50 TB - 5 PB+ usable with data reduction)
- **Clustering** – Compute scales to 64 nodes per cluster, storage nodes scales from 4 – 40 nodes
- **Quality of Service** – Integrated QoS provides ability to control I/O to isolate applications
- **Data Resiliency** – Dual redundant copies of data distributed to all nodes, automated drive rebuilds

- **Data Protection** – Native snapshot-based backup and restore functionality to object storage via S3 or SWIFT compatible API
- **DR & Replication** – Synchronous, asynchronous and snapshot replication locally and between remote clusters
- **Availability** – Automated failover and failback available between a cluster and up to four other clusters
- **Data Security** – Encryption with 256-bit AES for environments requiring data at rest protection
- **Connectivity** – Storage connectivity via iSCSI, Fibre Channel, and container native storage via NetApp Trident

IOmark-VDI-HC Test Summary

For the tested configuration, the following data is provided.

Item	Value
Testing Identifier:	VDI-HC-190802-a
Product(s):	5 x NetApp H410S – storage nodes 12 x NetApp H410C compute nodes
Test Sponsor:	NetApp
Auditor:	Evaluator Group Inc.

Table 1: Test Identifier Information

Item	Value
IOmark-VDI Version:	Version: IOmark-VDI-HC-190802-a
Testing Completed:	June 2019
Equipment Availability:	March 2019
Audit Certification Date:	31, July 2019
Report Date:	1, August 2019

Table 2: Test Revision and Dates

IOmark-VDI-HC Results

Shown below are the IOmark-VDI-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. Table 3 below shows an overview of the IOmark-VDI-HC results.

VDI Mode	IOmark-VDI Standard	Tested Logical Capacity	Total Price	Price / User
Linked Clone	N/A	N/A	N/A	N/A
Fully Provisioned	3,200	25 TB	$565,000.00	$176.56

Table 3: IOmark-VDI-HC Standard Price-Performance Results

Note: Pricing shown is list price and does not include hypervisor licenses, pricing details in Table8.

The "Standard" workload is measured during a steady-state period during the VDI-HC workload. The measurement period for the "Standard" workload discards the startup and end portions of the workload and measures a 60-minute window during the middle of a 180-minute workload. The response time summary is shown below in Table 4, with further details shown in Figures 3 and 4.

Details of passing results shown below in Table 4:

VDI Mode	Test RAID Level	Average Read Resp. Time	Average Write Resp. Time	Average Response Time / VDI User
Linked Clone	N/A	N/A	N/A	N/A
Fully Provisioned	Double Helix	21.69	14.26	17.92

Table 4: IOmark-VDI-HC Passing Standard Result Details

As shown above in Table 4, the 3,200 Fully Provisioned Standard users had an average response time 17.92 ms, which is lower (better) than the required response time.

Tested Configuration Details

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

Hyper-Converged System Details

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

Hardware Features	Value
Rack Footprint*	12 NetApp Compute Nodes + 5 NetApp HCI Data Nodes = 10 U (6U for compute + 4U for storage)
Number of Nodes per Appliance	H410 chassis supports 4 nodes per 2U rack unit
Number of Drives per Appliance	Cache: 8 GB NVRAM card / storage node = 40GB total Capacity: 6 x 2 TB SSD / data node = 30 total
CPUs (for VM workload)	2 per node → total of 24 sockets, 480 cores (6.6 desktops / core)
Memory (for VDI workload)	768 GB per node → 9.2 TB total, (2.8 GB / VDI desktop)
Networking Ports (10/25 GbE)	(2 per Compute Node + 2 per storage node)

Table 5: Hyper-Converged Hardware Features

- **** Note:** The CPU and memory reported above are for the compute nodes only and does not include the CPU and memory utilized by the storage nodes.*

The tested configuration utilized multiple servers with VMware vSphere ESXi software for the hyperconverged compute environment, utilizing storage provided by the 5 NetApp H410S storage nodes running Element OS.

The CPU and memory necessary to support the reported 3,200 IOmark-VDI-HC instances, running a VMware View workload (via IOmark-VDI standard) required 12 compute nodes, using 2 x Intel Xeon Scalable 6138 processors w/ 768 GB of DRAM. Evaluator Group certifies that this configuration is capable of achieving the reported results, based upon testing and other publicly available guidelines for VMware View configuration.

Each desktop was sized with 2vCPU's and 2.8 GB RAM. With 480 total cores available, this provides 1 core for every 13 virtual desktop vCPU's.

With these guidelines, the tested Hyper-Converged system achieved the storage performance required and has sufficient computing resources to achieve the stated results.

Hypervisor Configuration for IOmark-VDI-HC Workload

- Testing certified the use of iSCSI LUNs
- A total of 50 iSCSI LUNs were created, with VMFS 6 datastore
- RAID level was assigned using NetApp HCI default of Double Helix (mirrored copies)
- QoS settings were applied on a per VM basis based upon policies
    - All workloads were assigned "default" IO rate using QoS
    - Note: Use of QoS was not required to achieve passing IOmark-VDI results
- NetApp HCI utilizes thin provisioned disks with data deduplication and compression

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

Storage System Parameter	Value
vCenter version	VMware vSphere™ ESXi 6.5 (8307201)
Number of interfaces to the storage system:	2 per node
Connectivity to storage system:	2 @ 10Gb Ethernet ports per node (vSAN interconnect)
Hypervisor storage protocol used:	iSCSI
Hypervisor version:	VMware ESXi 6.5 (5969303)
Thin provisioning:	Yes - enabled
Hypervisor Storage Access:	Ethernet
Datastore Filesystem:	VMFS 6
VAAI:	Yes
SATP:	VMW_SATP_DEFAULT_AA
PSP:	VMW_PSP_RR
Total capacity of system allocated to IOmark-VM:	5 Nodes: 45 TB raw

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-VDI-HC Workload

- A total of 50 - VMFS6 datastores were utilizing capacity pooled across all 5 storage nodes
- VMDK's were created for each VDI workload utilizing IOmark tools
- Each VM's VMDK was allocated using "thin provisioning" per NetApp HCI default

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	Element OS 11.1
High Availability Access to all LUNs	Yes (active / active)
Total raw capacity of system under test (SUT)	45 TB (across all 5 nodes – no deduplication)
Total usable capacity of system under test (SUT)	460 TB (including thin, dedupe and compression)
Thin provisioning:	Yes
RAID Level(s)	Double Helix (RAID 1 like mirrored copies)
Total Cache Capacity:	8 GB x 5 storage nodes = 40 GB total
Read Cache:	N/A
Write Cache:	8 GB NVDIMM per storage node
VAAI Features Enabled:	Yes
- Block Zero	Yes
- Full Copy	Yes
- UNMAP	Yes
- Thin Stun	Yes
- HW Locking	Yes
Automated tiering within the storage system:	N/A (All Flash)
Deduplication or compression of data:	Both
Storage system clones / writeable snapshots:	Clones available, not used for testing
Type of storage system clone:	N/A
Storage Media Utilized:	-
- SSD's (Capacity Tier only, Cache noted above)	NetApp HCI - 2.0 TB TLC SSD
- HDD	N/A

Table 7: Storage System Configuration Parameters

Configuration Diagram

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

ISCSI LUNs were created on the HCI system and then exported to the compute nodes using default NetApp HCI configuration guidelines. Jumbo frames were enabled and access was established to all compute nodes via multi-pathing as noted previously.

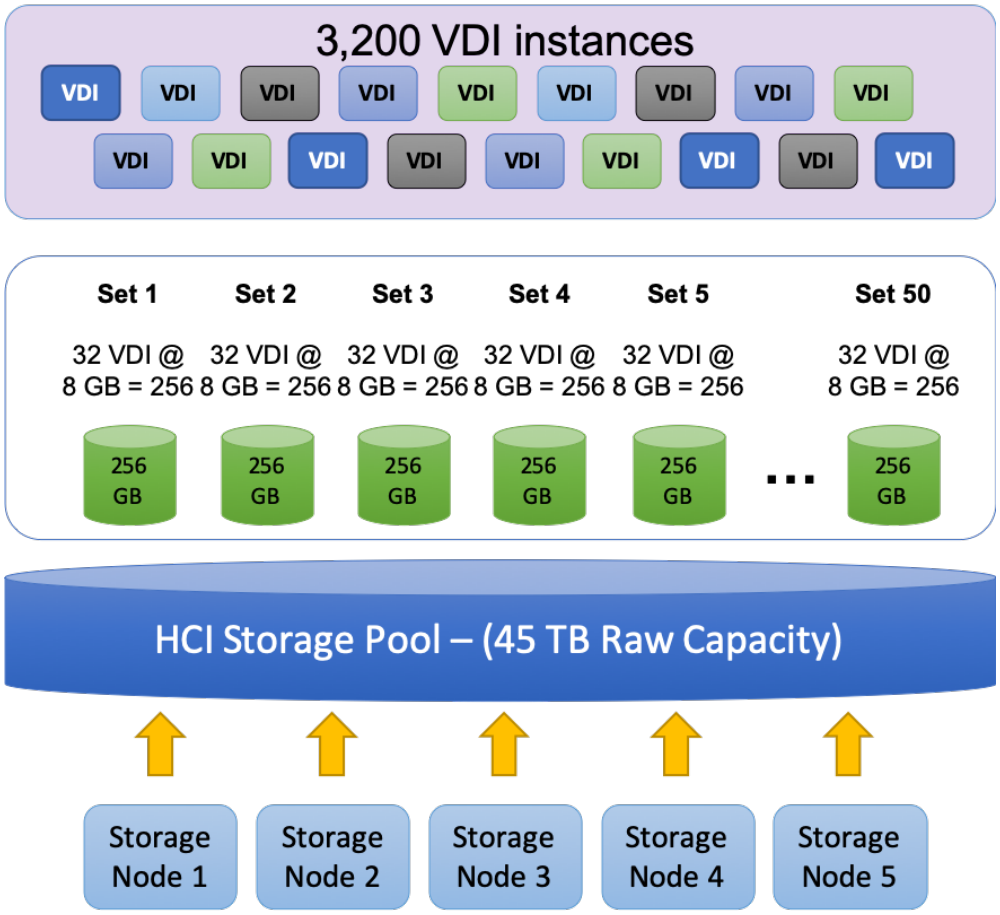

Figure 1: Logical System Configuration

Connectivity

The storage connectivity was 10GbE for both VMware management and the iSCSI LUNs. NetApp HCI best practices allow for 6 connections per node, or 2 connections per node. The test setup utilized 2 x 10GbE network connection setup, with each node connected to a separate redundant switch for availability per NetApp best practices.

The configuration connectivity diagram is shown below in Figure 2.

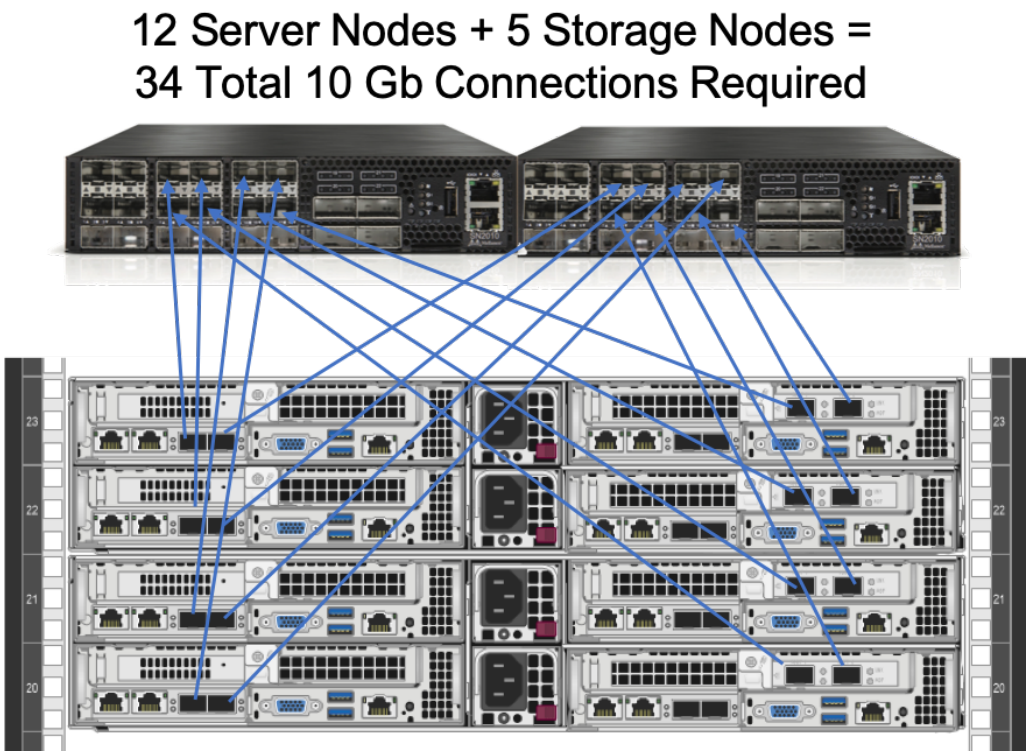

Figure 2: Physical System Connectivity

Certified Configuration Pricing

The certified configuration pricing is shown below, all list prices were provided by NetApp.

Item	Description	Qty.	List Price
1	NetApp H410C-25025* (2 @ 20 core CPUs, 768 GB DRAM + 2 @ 10 Gb Ethernet)	12 nodes compute	$15,000
2	NetApp H410S-31110* (Storage Controller, NVRAM, + 6 x 2 TB SSD and 2 @ 10 Gb Ethernet)	5 nodes storage	$77,000
Total	**List Price**		$565,000

Table 8: IOmark-VDI-HC Price Information (list pricing provided by NetApp)

Detailed Results

IOmark-VDI-HC performance results are measured by application workload. The cumulative distribution function percentages are shown in Figure 3, with response times reported per application in Table 8.

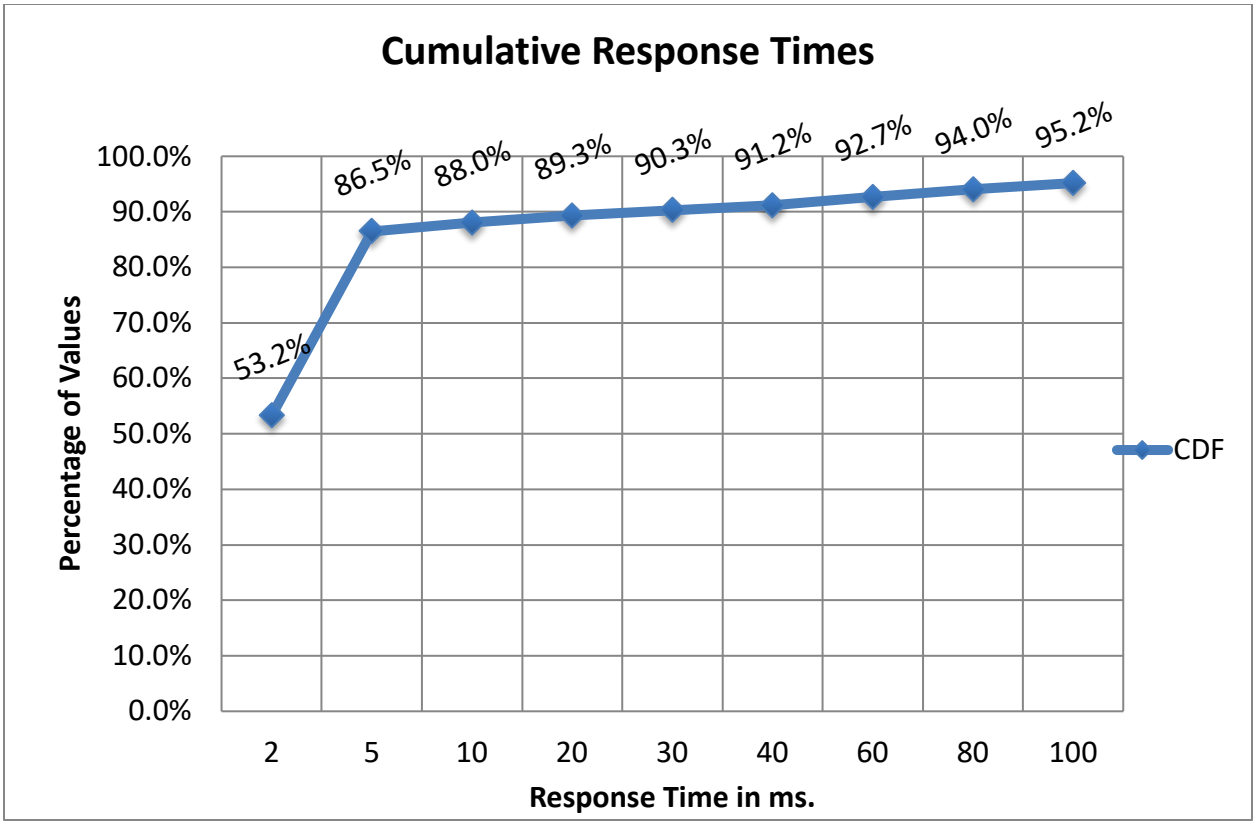

Figure 3: Percentage of Total Response Times at Measured Value

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

- Over 86% of response times were less than 5 ms. for the cluster
- 90% of response times were less than 30 ms. for the cluster

Appendix A - IOmark-VDI 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-VDI benchmark recreates a storage workload that typically occurs in virtual desktop infrastructure environments. The workload is non-synthetic and recreates several applications that are commonly found in virtualized server environments.

Why the Need for IOmark-VDI

Currently, several application generators have been developed that are able to generate VDI workloads. However, there is no standard reference configuration, with the primary focus is on the server infrastructure. There are no existing benchmark workloads focusing on storage and storage system performance while running VDI applications.

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-VDI 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.

How IOmark-VDI Operates

IOmark-VDI 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 order to scale up the workload on a storage system, additional VDI workloads 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-VDI recreates accurate read vs. write and random vs. sequential I/O requests. Another benefit of IOmark-VDI is the fact that it creates accurate access patterns, thus enabling storage cache algorithms to work properly.

Finally, IOmark-VDI 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-VDI maintains an accurate ratio of I/O to capacity, producing results applicable to IT users.

Benchmark Application Workload Set

VDI Workload

1. View steady state operation
   a. Heavy Worker Profile – Average / VDI User
      i. 12.52 iops. / User
      ii. 1.06 MBps / User
   b. Standard Worker Profile – Average / VDI User
      i. 6.26 iops. / User
      ii. 0.53 MBps / User
2. Benchmark Criteria:
   - 70% of I/O response times must not exceed 30ms
   - All storage utilized must reside on/within the storage system under test

VDI Benchmark Parameters

- Operating System disk size is 20 GB (thinly provisioned)
- All user sessions were running Windows 7 as their guest OS
- No user data disk utilized
- VMware Linked clones may be utilized (as noted)
- Storage linked clones may be utilized (as noted)
- Heavy Profile:
  - The workload is non synthetic, actual I/O patterns are issued based on application capture
  - The size of I/O's is variable, ranging from 512, up to 2 MB transfers based on application
- Standard User Profile:
  - The workload is non synthetic, actual I/O patterns are issued as captured
  - Rates are 50% of "Heavy" user profile
  - The size of I/O's is variable, ranging from 512, up to 2 MB transfers

VDI Workload Generation

The workload generator used to generate the VDI workload was VMware View Planner. This application workload generator controlled running the 8 listed applications above, in a Windows 7 64 bit OS environment, running as a guest VM in a hypervisor environment.

VDI Workload Details

The specific applications comprising a VDI workload set are detailed below in Table 8.

Application	Storage Capacity / Instance
Guest OS (Microsoft Win 7 64bit)	20 GB
MS Office (Word, Excel, PowerPoint and Outlook)	N/A
MS Internet Explorer	N/A
Adobe Acrobat Reader	N/A
Windows Media Server	N/A
Windows 7 zip	N/A
Total VDI Guest Environment	Total = 20 GB

Table 8: IOmark-VDI Guest Application Overview

The total capacity required for each VDI user is approximately 20 GB of logical capacity. The capacity required for linked clone users is 4 GB, and the capacity required for fully provisioned users is 14 GB without data deduplication or compression.

Understanding Results

IOmark-VDI produces results indicating the response time of a storage system given a particular workload. Based on established criteria, these results indicate how many VDI sessions are supported by a specific storage configuration with a maximum allowed 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-VDI workload. The performance requirements are established as follows:

- For all application workloads:
  - 70% of response times for I/O's 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

More Information about IOmark-VDI

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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