Test Validation

Tintri Storage Performance in Virtual Environments

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Evaluator Group

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Table of Contents 3

Executive Summary

Virtualization technologies, including hypervisors and containers, are now the default method used to deliver IT infrastructure in both enterprise and private cloud environments. While virtualization provides a technical foundation for these environments, it is imperative that the infrastructure also delivers the operational benefits necessary for businesses to run smoothly. There are many aspects to efficiency, including performance and economic measures, along with operational elements.

One challenge has been managing resources within a virtual infrastructure, while maintaining insight into the application. Storage in particular has been an issue, with storage using logical volumes that do not map to virtual machines or their applications. IT administrators need visibility into resources in order to optimize application performance while minimizing consumption. Without visibility into utilization on a VM level, application management breaks down. This can have significant impact on application performance and efficiency, and the economics of the data center.

In this paper, we examine the performance and economic benefits of a storage system designed for virtual server and cloud environments. Traditional storage management is focused on managing storage resource capacity and allocating those resources to multiple hosts. Performance, analytics and optimization of individual virtual machines or virtualized applications are typically outside the realm of storage management, particularly in cloud and heavily virtualized environments.

This evaluation of Tintri Storage focuses on two areas: 1) virtual application performance and 2) overall infrastructure efficiency and ease of use. Storage in virtual environments is one of the critical components that determines the application economics and performance, and has implications for management efficiency

Evaluation Summary

Evaluator Group assessed performance and manageability of a Tintri all-flash VMstore appliance in a VMware environment running both virtual server applications and virtual desktop (VDI) workloads. The testing focused on quantitative data, such as performance and metrics related to usability. Additional testing evaluated qualitative factors, such as the relative ease of use or efficiency of the product in target environments along with usability metrics.

Evaluator Group comments: The price/performance results Tintri achieved for both VDI and VM workloads highlights the economic benefits an all-flash Tintri system can provide. Additionally, the storage efficiency, due to Tintri's data reduction, surpassed any system tested to date, providing further economic value.

Performance testing of the Tintri all-flash system produced the following results:

- The Tintri VMstore T5060 system was able to support 3,000 VDI users, running a VDI benchmark:
  - The Tintri system was certified at 3,000 IOmark-VDI Office users
  - The Tintri system was able to boot all 3,000 VDI VM's in 1,004 seconds (16m:44s)
  - The price per IOmark-VDI user was $75 / user[1] using a list price of $225,000
- The Tintri VMstore T5060 system was able to support 480 server applications:
  - The Tintri system was certified at 480 IOmark-VM's
  - The price per IOmark-VM was $468 / VM[2] using a list price of $225,000

Analyzing qualitative and economics of Tintri all-flash yielded the following results:

- Storage efficiency was the highest of any system tested using IOmark-VDI and IOmark-VM
  - Space savings for VDI workloads was 60:1 (2x compress, 10x dedupe, 3x thin provisioning)
  - Space savings for VM workloads was artificially limited to 3x (2x compress, 1.5 thin provisioning per IOmark-VM testing guidelines)
- Application insight and performance metrics
  - Tintri enabled tracking performance and capacity metrics on a per-VM and virtual disk basis, unlike competing block storage which does not provide these details
- Management of Tintri compared to block storage systems
  - Storage Management was significantly reduced, requiring no volume management
    - Eliminated storage provisioning for new VMs from an average of 5 minutes per 50 virtual machines to zero using Tintri (**Note: 5-minute average based on Evaluator Group experience**)
    - For 480 VMs, the time spent on volume management is typically 50 minutes when using traditional block storage systems vs. zero minutes with Tintri
  - Tracking space consumption on Tintri was significantly better than competing systems
    - Tintri dynamically updated space consumption, thus reducing the potential of running out of storage capacity, particularly when using thin provisioning and data reduction

[1] IOmark.org Tintri IOmark-VDI Report **www.iomark.org/results**
[2] IOmark.org Tintri IOmark-VM Report **www.iomark.org/results**

Evaluation Overview

Evaluator Group utilized two different virtualized application workloads used in enterprise and private cloud deployments, virtual desktop VMs (VDI) and virtual application servers. These workloads were generated utilizing the standard IOmark-VDI and IOmark-VM benchmarks.

> ***Evaluator Group comments: Application benchmarks were used to provide real-world performance and price/performance results. Unlike artificial workloads, the certified IOmark results provide measurable application performance and price/performance data that is critical for IT organizations choosing storage for their environments.***

Storage Considerations in Virtual Environments

Virtual workloads place high demands on the storage infrastructure, primarily in terms of the performance requirements. Additionally, managing applications can be challenging in virtual environments, due to the lack of direct visibility into the causes of performance problems. Storage systems for virtual application environments need to meet the management and performance requirements:

- Predictable high-performance, ideally using all flash to eliminate latency spikes of HDD media
- Capacity efficiency through use of in-line data reduction technologies including thin-provisioning, data compression and deduplication
- Integration with the hypervisors to facilitate management of the virtual infrastructure by a hypervisor admin or IT generalist, without requiring dedicated storage admins
- Qualitatively, a low management overhead to minimize the amount of time spent managing storage rather than managing applications

Tintri Test Configurations

Testing Tintri performance utilized standard benchmarks, designed to measure performance in virtual environments, using application-focused testing.

Quantitative Testing

The performance evaluation consisted of running a VDI application workload (IOmark-VDI) and separately running a virtual server application workload (IOmark-VM). The storage system was optimized to establish the maximum level while running a particular workload. The maximum performance of a configuration was determined by adding more workloads until the storage response time's thresholds rose above IOmark's required maximum values. The details of IOmark-VDI and IOmark-VM are documented in Appendix B along with further details in the IOmark certified test reports published on the IOmark.org web site.

Qualitative Testing

The experiential testing occurred during configuration, setup and management of the Tintri system required during normal operations, and during configuration of performance and other testing. Qualitative assessments and statements are based upon Evaluator Group's experience using other storage systems and our experience configuring systems that have been tested in the Evaluator Group labs.

Tintri Quantitative Test Results

It is critical to evaluate a system based upon the applications that will be used in production. Each application has its own I/O profile, and performance on one type of application is not indicative of performance of another application. In addition to the differences in workloads, the capacity utilization along with the provisioning of storage for workloads can differ greatly. We evaluated the two most common application types used in virtual environments, virtual desktops (aka. VDI) as well as virtual server workloads.

Virtual Desktop Testing

VDI is a unique use case and is different than other application types, with the following characteristics:

- Performance is often a critical factor in end-user acceptance of VDI
  - Many early deployments using HDD or hybrid systems failed, due to poor performance
  - Very high random I/O generated on storage, often higher than other workloads of a similar capacity
- Capacity and management implications based upon VDI type
  - Choice of persistent or non-persistent (aka. Linked Clone) desktop types
  - Significant capacity implication differences between these models
    - Persistent desktops typically provisioned at 30 GB / desktop, with approximately 16 GB in use.
      - Opportunity for data reduction, reducing use below 16 GB
    - Non-persistent desktops were not tested, but have similar data reduction rates
  - Significant management differences between persistent and non-persistent
    - Non-persistent desktops enable VM admins to rapidly provision and refresh desktops back to an initial state
    - Persistent desktops enable VDI users to customize desktop and make updates that are maintained
    - Patch management is handled differently, with non-persistent desktops offering advantages and time savings for IT admins, but with less control by users

Tintri VDI Performance

- Comparisons below are based upon published IOmark-VDI results at a list price of $225,000
- Tintri performance of 3,000 VDI users, price per VDI user was $75 / user

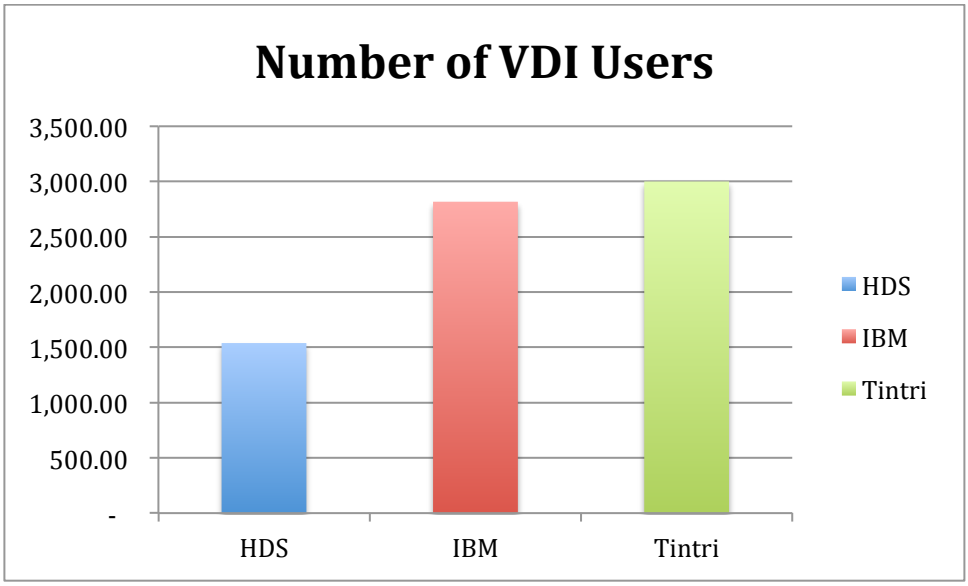

Figure 1: Comparison of VDI Performance (IOmark-VDI - Fully Provisioned VDI Users)

Note: The IBM and HDS systems performance referenced in Figures 1 and 2 are taken from their certified IOmark results, available on **www.iomark.org**.

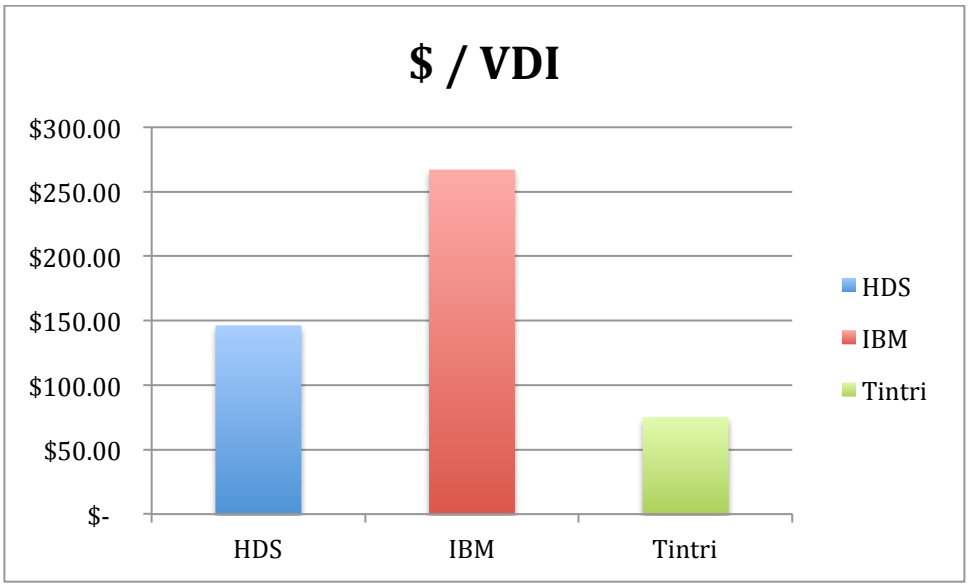

Figure 2: Comparison VDI Price - Performance (IOmark-VDI - Lower is Better)

Tintri VDI Management

Management in VDI environments was measured in the following manner:

- Amount of time to clone virtual desktop VMs using Tintri's Cloning methods
- The tested performance exceeded Tintri's performance claim
  - Evaluator Group cloned 30 VMs in 1 minute and 44 seconds (3.46 seconds / VM)
  - Tintri claims the ability to clone 1,000 VMs in 1 hour and 37 minutes (5.82 seconds / VM)
- Ability to refresh a cloned VM from base image using Tintri's "Refresh" capability
  - Evaluator Group verified the ability to update a clone with updates to the base image
  - **Note:** Evaluator Group did not measure the time required to refresh VM's
- Capacity utilization of virtual desktop VMs
  - Persistent desktops cloned using Tintri cloning resulted in nearly 60:1 total data reduction
    - (60:1 is the product of 2:1 compression, 10:1 deduplication, 3:1 thin provisioning)
  - Capacity of less than 1 GB / VM was measured after running VDI workloads for 24 hours

In Figure 3 the Tintri dashboard shows capacity use for 32 VDI desktops, with 60:1 data reduction.

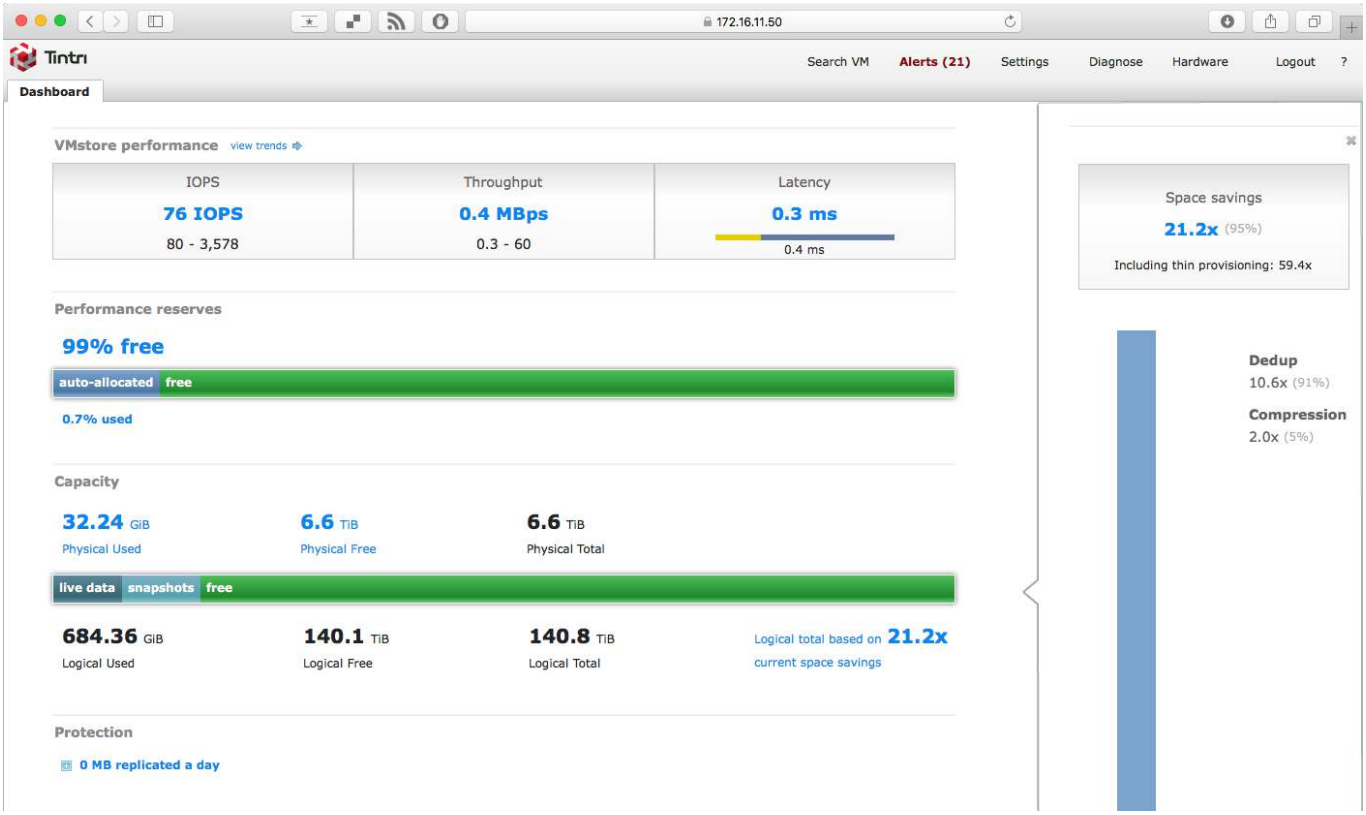

Figure 3: Tintri T5060 Capacity Utilization for 32 VDI Users

Evaluator Group comments: The measured data reduction rates of 60:1 exceed the best results Evaluator Group has seen to date by any vendor for VDI. The ability to provide persistent VDI desktops, while using less capacity than non-persistent desktops, is a significant differentiator. The high data reduction coupled with certified performance of 3,000 users provides compelling economic advantages for the Tintri T5060 system in VDI environments.

Virtual Server Testing

The term "virtual server" is generic, giving little insight into the applications running. Evaluator Group's performance testing of virtual servers utilized IOmark-VM, which recreates the standard VMmark 2.5 application server workload. As described in the appendix, the IOmark-VM workload includes three database applications, an Exchange Email server, an Olio database application and a DVD storage database. These applications are database driven and create a very heavy random I/O on the underlying storage.

- Characteristics of I/O for virtual server (IOmark-VM) workloads
  - Very high, random I/O rates
  - Different block sizes and read vs. write ratios for each individual workload
  - Set of 8 virtual server applications must be run together, correlating to 1 VMmark tile
- Data reduction can be a factor for virtual server workloads
  - The primary opportunity for data reduction is compression of data, typically 2:1
    - Data compression chosen was 2:1 (2x compressible data)
  - Data deduplication is a minor factor, due to differences between virtual applications and virtual server configurations
    - Data deduplication rate chosen was 1:1 (no data deduplication)

Tintri Virtual Server Performance

As noted previously, the performance and price/performance as measured by IOmark-VM were:

- The Tintri T5060 system was certified at 480 IOmark-VMs
- The price per IOmark-VM was $468, using a list price of $225,000 for the system as configured

Evaluator Group comments: By reporting certified benchmark results for both VDI and virtual server workloads, Tintri is providing proof points behind their claims of number of VDI and virtual servers that their systems can support. Vendors often make performance claims, using internal metrics, which do not provide verifiable or comparable data points. With these results Tintri has established their credentials for the performance and economic value of Tintri all-flash systems in enterprise and private cloud environments.

Tintri Usability Testing

Usability Criteria

The many qualitative factors involved with using a system are often just as important as the price / performance attributes. However, these features are often harder to directly compare, due to the difficulty in accurately capturing these subjective aspects of a product. Therefore, the analysis of Tintri in this area is more comparative and subjective, rather than having specific data.

> ***Evaluator Group comments: The ease of use and management efficiency for the Tintri system was very good. In comparison to other systems tested, Tintri required less initial setup time and fewer steps. After initial setup, the Tintri system required significantly less administration time than block systems tested, since no volume management was needed. Additionally, QoS settings can be applied on a per virtual machine or application basis, which is the appropriate management level, rather than managing a volume.***

Evaluator Group looked specifically at several areas of using a system, including the following:

- Integration with the hypervisor, as measured by the system's:
  - Ability to ascertain capacity data on a per-VM and per-virtual-disk (vmdk) basis
  - Ability to ascertain performance data on a per-VM and per-virtual-disk (vmdk) basis
  - Ability to create snapshots and clones of VMs within the hypervisor management
  - Ability to create snapshots and clones of VMs using the storage manager, ensuring that actions are registered with the hypervisor manager
- Manageability of storage system
  - Number of steps and time required to initialize system
  - Number of steps and time required to provision storage for applications
  - System settings and other management requirements

Note: Tintri refers to their systems as "VAS" for VM-aware Storage. Tintri VMstore All-Flash T5000 series is a virtual machine specific storage system supporting only virtual machine hypervisor environments, doing so with NFS and SMB attached storage.

Usability Results

Shown below in Figure 4 is an overview of a Tintri system's performance from within the VMware vCenter application plugin. Additional management details on a per-VM basis are also available, including both performance and capacity utilization.

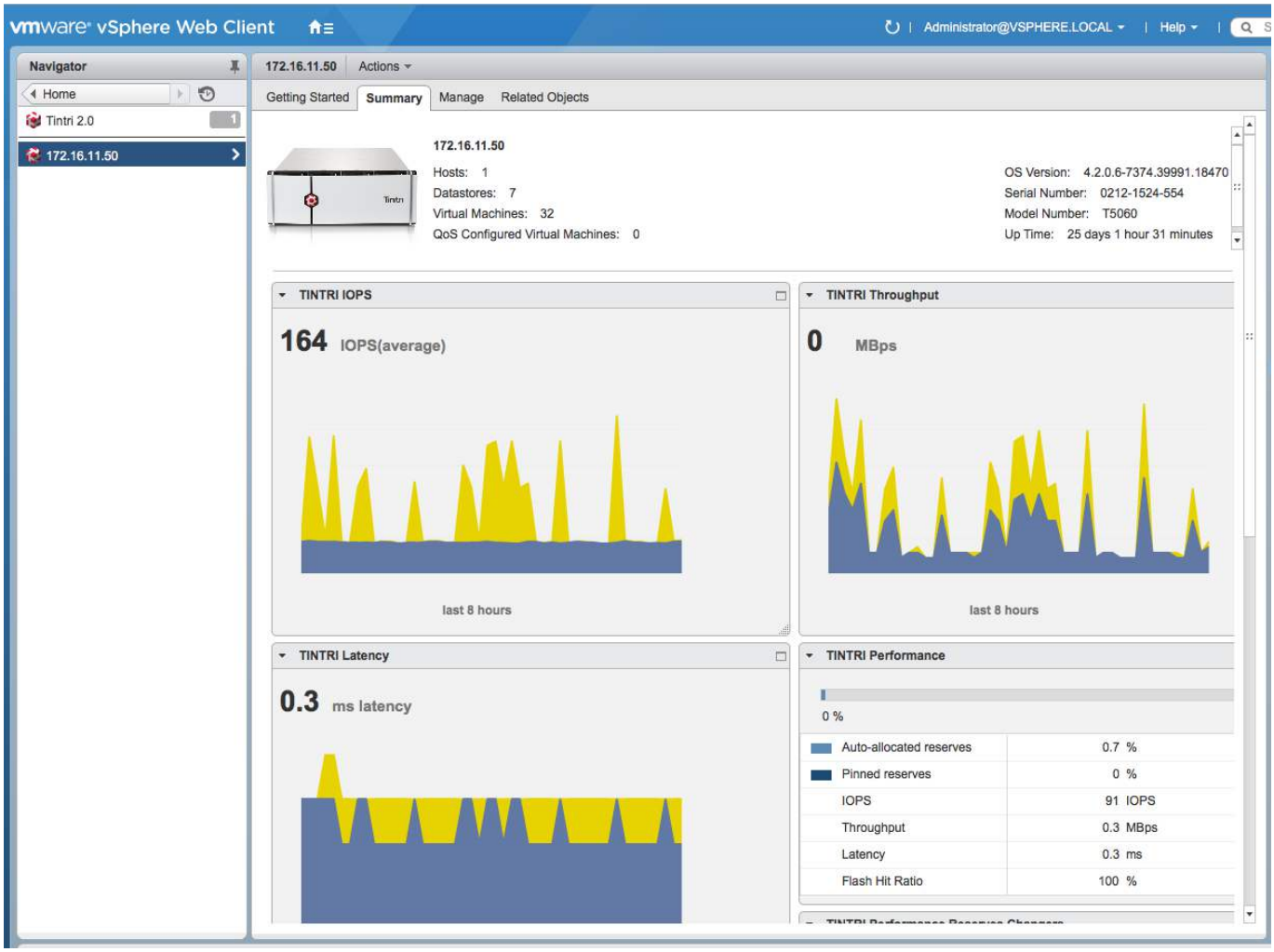

Figure 4: Tintri VMware vCenter plugin - Performance View

Evaluator Group comments: The ability to view Tintri storage performance details from within vCenter is a productivity benefit for hypervisor administrators, who prefer to utilize vCenter as their primary management tool.

Shown below in Figure 5 is the first level of drill-down details available on a per-VM basis, showing a summary of performance and capacity for selected virtual machines. Additional details are available by viewing individual virtual machines.

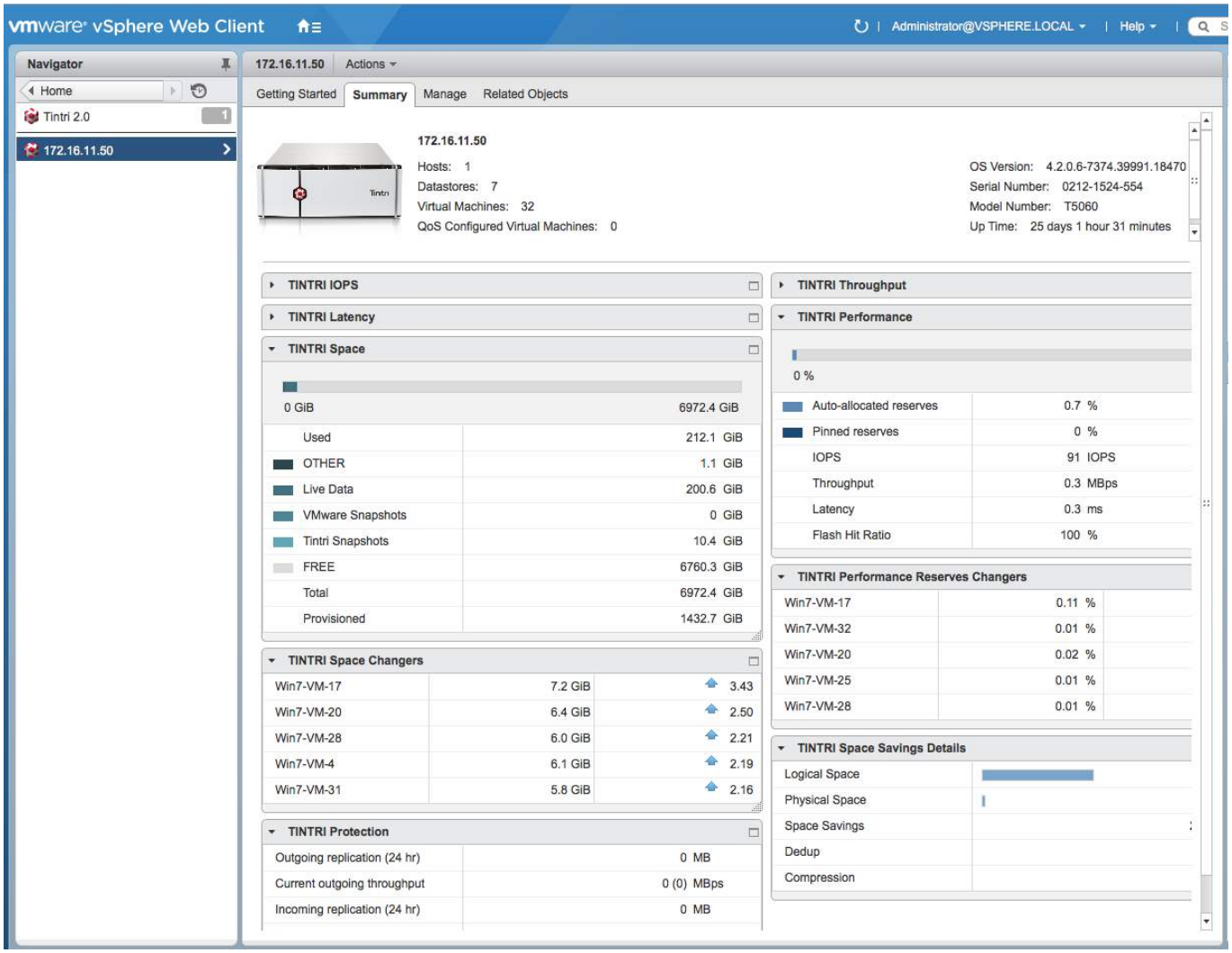

Figure 5: Tintri plugin - Top details of VM Performance and Capacity (Plugin in VMware vCenter)

Evaluator Group comments: There are multiple Tintri metrics viewable from within vCenter as shown in Figure 5, including per VM and per vmdk performance and capacity data points.

Shown below are the Tintri Clone dialog boxes from within vCenter and Tintri natively, providing the same experience and capabilities regardless of the management tool used.

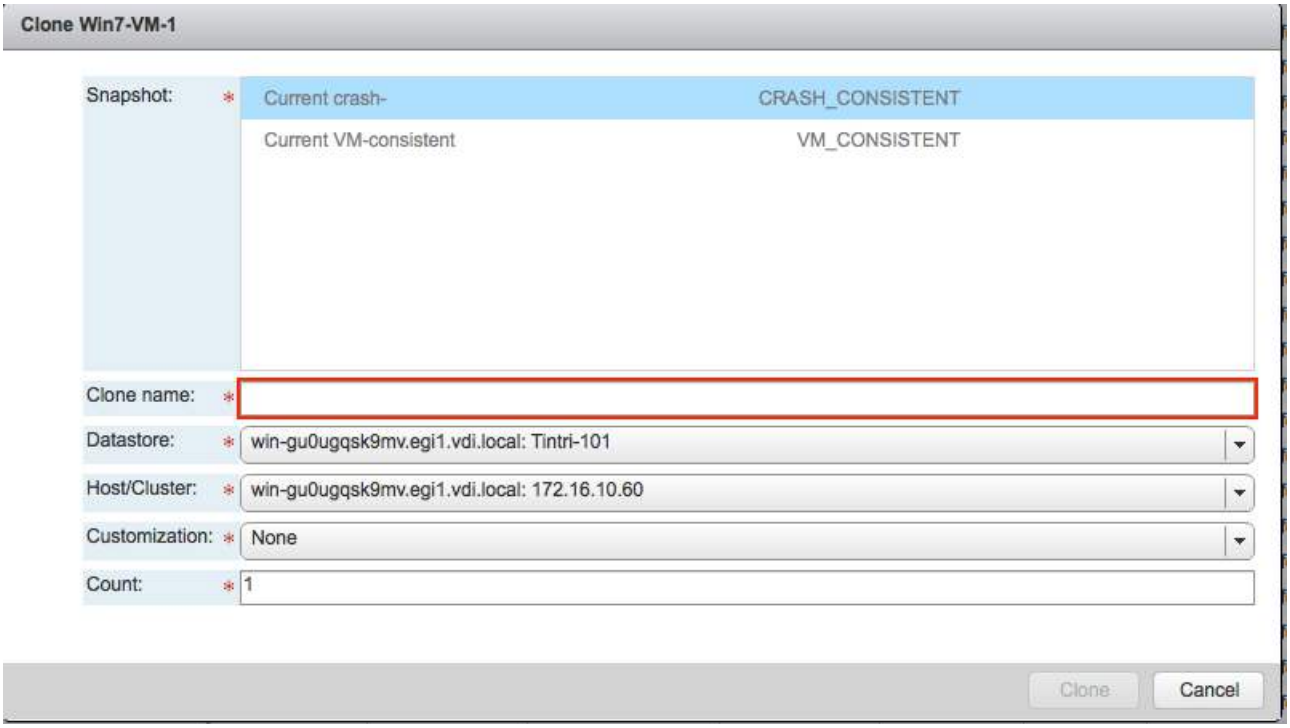

Figure 6: Tintri Clone dialog (Using plugin in VMware vCenter)

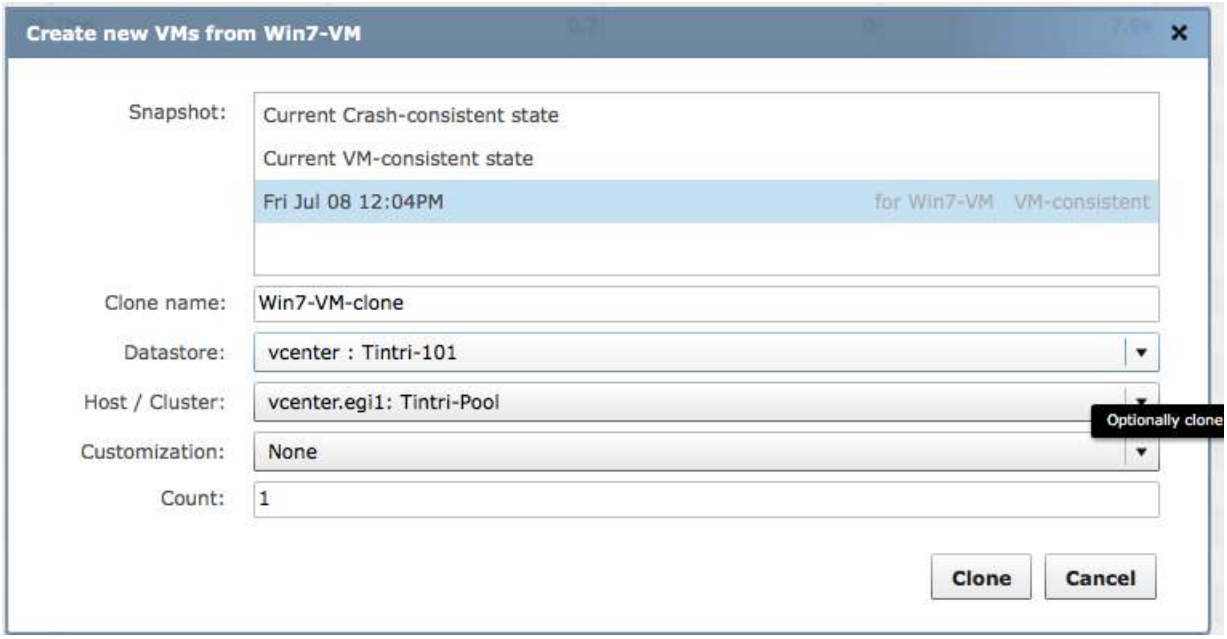

Figure 7: Tintri Clone dialog (Using Tintri Global Center)

Tintri VM-aware All-Flash Storage

Tintri VMstore All-Flash T5000 series is a virtual machine specific storage system supporting only virtual machine hypervisor environments, doing so with NFS and SMB attached storage. With the use of native NAS protocols Tintri has the ability to manage virtualized objects on a granular level, since the virtualized resources are simply files. They have optimized and customized their system design and graphical user interface (GUI) to operate as an extension of VMware vCenter and Microsoft Systems Center Virtual Machine Manager using Tintri Global Center software. The following are the highlights from Evaluator Group Product Analysis coverage:

- VM-aware Storage
  - Support for NFS v3, VVols and SMB3 simultaneously
  - Network attach with 4 - 6 @ 10 GbE ports, supporting VLAN and LACP
  - Dual controller, active-standby HA storage
- Characteristics
  - Performance
    - Performance Isolation can eliminate "noisy-neighbors" using Tintri automated QoS
    - Quality of Service management at the VM level, down to individual vdisks
  - Manageability
    - Storage Policy Based Management (SPBM) available using Tintri Global Center and also available with VMware VVol (optional)
    - Real-time storage analytics, provides insight on a per-VM and per-vdisk basis
    - Ability to effect changes in real-time to correct issues found with storage analytics
    - Multi-hypervisor support, VMware, Hyper-V, RHEV, XenServer and OpenStack
  - Scalability
    - VM scale-out, pools of storage managed using Tintri Global Center Advanced
    - Three all-flash systems from 6 - 92 TB raw, or 17 - 308 TB effective capacity
    - In-line data reduction, including thin provisioning, deduplication and compression
  - VM level management
    - Ability to create snapshots, clones and replication at the VM and vdisk level
    - Hypervisor plugins facilitate single pane-of-glass management for VM admins
  - Capacity management
    - In-line data reduction, including deduplication, compression and thin-provisioning
    - Zero block optimization, eliminates "zero" data across all VMs
    - Dynamic capacity updates to VMware vCenter, reflects current logical capacity limits of Tintri VMstore appliances for accurate capacity monitoring

Evaluation Summary

Efficiency in virtual application environments requires equipment that provides good price/performance and integrates with the infrastructure to increase operational efficiency. The proven performance of Tintri for both VDI and server VM workloads are validation of the strong economics of the Tintri system tested.

The ability to analyze capacity and performance on a per-virtual-machine basis provides operational efficiencies and is a differentiating factor for Tintri. This is due in part to the fact Tintri storage systems can provide resolution on a per-virtual-object basis, rather than at a volume or LUN level, as is typical with block storage systems. Additionally, Tintri adds tools and monitoring capabilities that go beyond those of competing storage systems.

Storage capacity efficiency is another aspect that directly impacts the economics of the overall solution. All-flash storage systems have become key part of most solutions designed to achieve predictable high-performance across multiple virtual applications. However, due to the cost of NAND flash media, it is imperative that the capacity is utilized efficiently, leveraging data reduction technologies when possible to decrease the amount of capacity required. For this reason, storage capacity efficiency, or a system's ability to minimize physical capacity consumed for a given amount of data stored, is another aspect that directly impacts the economics of the overall solution.

Tintri's data reduction technologies proved to be more efficient than any system Evaluator Group has tested to date. For virtualized server workloads, the data reduction rates achieved by Tintri were identical to the data reduction potential of the data being stored. Using server application data with 2 to 1 compressibility yielded data reduction rates of 2 to 1. For persistent VDI workloads, Tintri achieved data reduction rates 60 times that of systems without data reduction. These rates are higher than VMware and Citrix claims for their linked clones or non-persistent desktops. This is a significant outcome, enabling IT administrators to chose the type of VDI deployment based on manageability rather than considering the space efficiency advantage non-persistent desktops typically have using other storage systems.

These certified benchmarks reported by Tintri for both VDI and VM workloads provide a method of comparing Tintri's price/performance to other systems, using a standard benchmark designed for virtual desktop and virtual server applications.

Issues and Concerns

During testing, no problems were encountered. In order to maximize performance, Evaluator Group discussed configuration options with Tintri's sales engineers. This is a common practice and did not go beyond recommendations or consultations a typical customer would experience. Tintri's recommendations did help to improve performance due to the unique test environment of Evaluator

Group test infrastructure. There were no reliability or system unavailability events over the course of multiple weeks of testing.

Final Observations

Performance is one important consideration when determining infrastructure components. However, the more important factor is a system's price for a given level of performance, particularly for workloads that scale out. In today's highly virtual datacenters, workloads are scaled out across multiple physical servers and storage systems, with no one application consuming an entire server or storage system. IT architects have found it far more economical to use this scale-out model for the majority of applications, leaving only a few applications to run on physical systems. With scale-out workloads, the price/performance of a system is more important than the top line performance.

Beyond the economics of price/performance, are the storage capacity considerations, along with manageability. Typically, IT administrators assume that capacity utilization is constant across different storage systems, with one system providing nearly the same levels of efficiency as another. However, this is not true, particularly for some special workloads such as VDI that can achieve very high efficiencies when data reduction is applied at a per-virtual-disk level.

Although many storage vendors have plug-ins for hypervisors, the degree of integration provided by Tintri enabled seamless management from either the VMware vCenter console, or Tintri's web management interface. All needed features, including snapshots and cloning, along with performance and capacity tracking, were available via either interface. Together, these features reduce the management overhead and allow IT administrators to focus on the VMs and applications rather than the underlying storage infrastructure.

Finally, Tintri's ability to manage objects at a native virtual machine and disk level provide much better capacity optimization than alternative systems. This enables IT architects to choose deployment options that align better with their users needs, rather than being forced to choose options based on limitations of their storage infrastructure. Tintri's ability to manage the QoS settings of individual applications is an important consideration for highly consolidated environments typified in virtual and cloud infrastructures.

Appendix A - System Test Environment

Hardware Test Environment

System Configuration

Physical Servers Used for Testing

- 2 @ x86 Servers used
  - 2 x Intel E5-2600v3 CPU's (16 CPU cores @ 2.0 GHz w/ hyper-threading)
  - Systems utilized 192 GB DRAM
  - Dual, 10 GbE network connectivity to storage

Storage System Tested

- Tintri VMstore T5060 all-flash array
  - 12 TB of raw capacity, with 6 TB of usable capacity
    - Effective capacity of 35 TB
  - Dual controller, active-passive failover
  - Dual, 10 GbE network connectivity, with LACP configured

Software Test Environment

Hypervisor

The VMware ESXi, hypervisor was utilized on all nodes used for testing:

- VMware ESXi, 6.0U2
  - Dedicated SSD boot device used for ESXi, not part of workload testing
  - Application VM's and all virtual disks resided on the Tintri T5060

Application Environment

The IOmark-VDI and IOmark-VM application workloads were used to generate the workload for tested configurations. See IOmark certification reports at **www.iomark.org** for details

About Evaluator Group

*Evaluator Group Inc. is dedicated to helping **IT professionals** and vendors create and implement strategies that make the most of the value of their storage and digital information. Evaluator Group services deliver **in-depth, unbiased analysis** on storage architectures, infrastructures and management for IT professionals. Since 1997 Evaluator Group has provided services for thousands of end users and vendor professionals through product and market evaluations, competitive analysis and **education**. **www.evaluatorgroup.com** Follow us on Twitter @evaluator_group*

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