30,000 Mailbox Resiliency Solution for Microsoft Exchange 2013 using Lenovo Converged HX7510 Appliances and AHV

Last update: 30 August 2016

Provides a technical overview of Lenovo Converged HX Solution for Microsoft Exchange 2013

Contains performance results for 30,000 Mailboxes using Microsoft ESRP Storage Program

Uses HX7510 appliances with Nutanix Acropolis Hypervisor (AHV)

Shows class-leading hyper-converged performance of HX7510 appliance

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Table of Contents

1 Overview 1

1.1 Disclaimer 1

2 Technical overview of HX Series appliances 2

2.1 Server Components 2

2.2 Software components 2

2.3 Networking components 5

2.4 Reliability and performance features 8

3 Microsoft Exchange 12

3.1 Solution overview 12

3.2 Component model 13

3.3 Exchange deployment best practices 15

3.4 DAG architecture overview 16

3.5 Targeted customer profile 18

3.6 Tested deployment environment 18

3.7 Performance test results 20

4 Conclusion 23

Appendix A – Test results 24

24-Hour stress/reliability test results 24

2-Hour performance test results 26

Database backup test results 28

Soft recovery test results 30

Appendix B - Resources 32

1 Overview

This document provides information on Lenovo Converged HX7510 solution for Microsoft Exchange Server, based the Microsoft Exchange *Solution Reviewed Program (ESRP) – Storage* program[1].

The intended audience for this document is technical IT architects, system administrators, and managers who are interested in executing virtualized Microsoft Exchange workloads on the Lenovo Converged HX Series Nutanix Appliances. The abbreviated term of HX Series is used in the remainder of this document.

HX Series appliances provide a hyper-converged infrastructure which seamlessly pools compute and storage to deliver high performance for the virtual workloads and provides flexibility to combine the local storage using a distributed file system to eliminate shared storage such as SAN or NAS. These factors make the solution cost effective without compromising the performance.

This document describes the solution for executing 30,000 mailboxes with Microsoft Exchange Server 2013 on Lenovo Converged HX7510 appliances using the Nutanix Acropolis Hypervisor (AHV). The mailbox resiliency data group with two database copies executes on 2 four node clusters.

The cluster of 4 Lenovo Converged HX7510 appliances proved more than capable of handling the high IOPs generated by 30,000 mailboxes. Part of the reason for this is because each Lenovo Converged HX7510 appliance uses 3 HBAs for the 24 drives. As a consequence the cluster has an average IOPS rate that is 23% better and an average latency improvement of 2 milliseconds over other systems with less HBAs.

Chapter 2 provides a technical overview of the HX Series appliances and explains why the combination of Lenovo servers and Nutanix software provides best of breed system performance and reliability.

Chapter 3 provides a solution overview of Microsoft Exchange on Lenovo Converged HX7510 appliances with the deployment best practices, recommended appliance configuration, and the performance test results from the Microsoft ESRP storage test. The detailed log files are in appendix A.

1.1 Disclaimer

This document has been produced independently of Microsoft Corporation. Microsoft Corporation expressly disclaims responsibility for, and makes no warranty, express or implied, with respect to, the accuracy of the contents of this document.

The information contained in this document represents the current view of Lenovo on the issues discussed as of the date of publication. Due to changing market conditions, it should not be interpreted to be a commitment on the part of Lenovo, and Lenovo cannot guarantee the accuracy of any information presented after the date of publication.

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[1] The *ESRP – Storage* program was developed by Microsoft Corporation to provide a common storage testing framework for vendors to provide information on its storage solutions for Microsoft Exchange Server software. For more details on the *Microsoft ESRP – Storage* program, use the following website: http://technet.microsoft.com/en-us/exchange/ff182054.aspx.

2 Technical overview of HX Series appliances

Lenovo Converged HX Series appliances are designed to help you simplify IT infrastructure, reduce costs, and accelerate time to value. These hyper-converged appliances from Lenovo combine industry-leading hyper-convergence software from Nutanix with Lenovo enterprise platforms.

2.1 Server Components

The Lenovo Converged HX series appliances are available in a variety of E5-2600 v4 processor-based models to support different workloads. In particular the Lenovo Converged HX7510 is recommended for Microsoft Exchange and is shown below

The table below provides a summary of the configuration options for the HX7510.

Appliance Model	Form Factor	Solid State Drives (SSD)	Hard Disk Drives (HDD)	Memory	CPU	Dual port NIC	GPUs
HX7510	2.5" drives 2U	Standard 4 x 480 GB 4 x 800 GB 4 x 1200 GB 4 x 1600 GB Encrypted 4 x 400 GB 4 x 800 GB 4 x 1600 GB	Standard 20 x 1TB 20 x 2TB Encrypted 20 x 2TB	128 GB 256 GB 384 GB 512 GB 768 GB	2 x 2643 v4 2 x 2680 v4 2 x 2697 v4 2 x 2699 v4	1 or 2	N/A

For more information see the product guide for Lenovo Converged HX7510: lenovopress.com/lp0507

2.2 Software components

This section gives an overview of the software components used in the solution.

2.2.1 Hypervisor

The HX Series appliances support the following hypervisors:

- Nutanix Acropolis Hypervisor based on KVM (AHV)
- VMware ESXi 5.5 U3B
- VMware ESXi 6.0 U1B
- VMware ESXi 6.0 U2
- Microsoft Windows 2012 R2 DataCenter Edition (Hyper-V)

The HX Series appliances come standard with the AHV preloaded in the factory. The other hypervisors are supported as a field-installable option using the Nutanix Foundation tool.

2.2.2 Nutanix Prism

Nutanix Prism gives administrators a simple and elegant way to manage virtual environments. Powered by advanced data analytics and heuristics, Prism simplifies and streamlines common workflows within a data center. Nutanix Prism is a part of the Nutanix software preloaded on the appliances and offers the following features:

- Single point of control
    - Accelerates enterprise-wide deployment
    - Manages capacity centrally
    - Adds nodes in minutes
    - Supports non-disruptive software upgrades with zero downtime
    - Integrates with REST APIs and PowerShell
- Monitoring and alerting
    - Tracks infrastructure utilization (storage, processor, memory)
    - Centrally monitors multiple clusters across multiple sites
    - Monitors per virtual machine (VM) performance and resource usage
    - Checks system health
    - Generates alerts and notifications
- Integrated data protection
    - Offers customizable RPO/RTO and retention policies
    - Supports configurable per-VM replication (1:1, 1:many and many:1)
    - Provides efficient VM recovery
    - Deploys affordable data recovery (DR) and backup to the cloud
- Diagnostics and troubleshooting
    - Provides time-based historical views of VM activity
    - Performs proactive alert analysis
    - Correlates alerts and events to quickly diagnose issues
    - Generates actionable alerts and reduces resolution times
    - Analyzes trending patterns for accurate capacity planning

2.2.3 Nutanix Controller VM

The Nutanix Controller VM (CVM) is the key to hyper-converged capability and each node in a cluster has its own instance. Figure 1 shows the main components of the CVM.

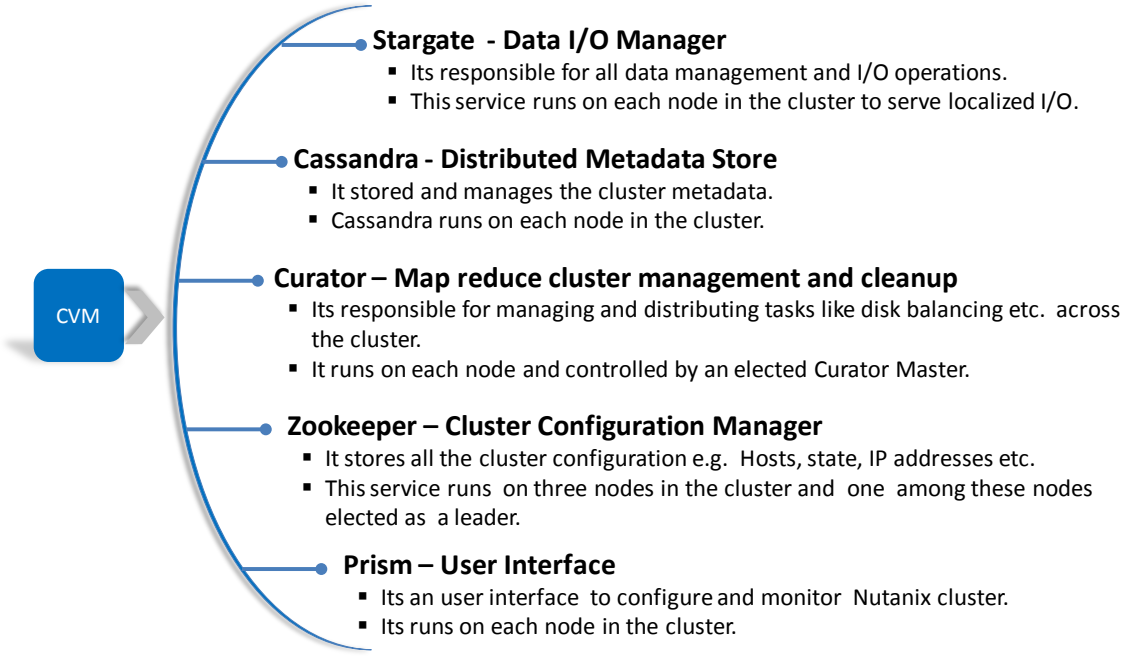

Figure 1: Controller VM components

The CVM works as interface between the storage and hypervisor to manage all I/O operations for the hypervisor and user VMs running on the nodes as shown in Figure 2.

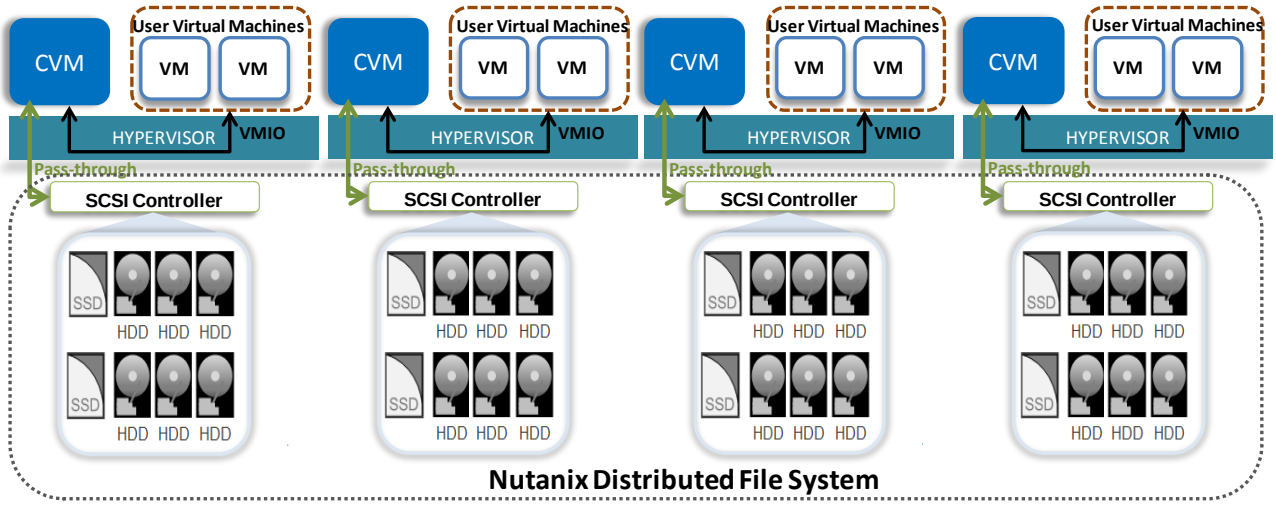

Figure 2: CVM interaction with Hypervisor and User VMs

CVM virtualizes all the local storage attached to each node in a cluster and presents it as centralized storage array using Nutanix Distributed File System (NDFS). All I/O operations are handled locally to provide the highest performance. See section 2.4 for more details on the performance features of NDFS.

2.2.4 Nutanix Foundation

Nutanix Foundation is a separate utility that you use to orchestrate the installation of hypervisors and Nutanix software on one or more nodes. The maximum number of nodes that can be deployed at one time is 20.

Foundation is available both as a stand-alone VM and also integrated into the CVM. Because CVM is

pre-installed in the factory, the CVM integration of Foundation simplifies the deployment and cluster creation of new servers delivered from the factory.

2.3 Networking components

A cluster of HX Series appliances requires both a 10 GbE network for data and a 1GbE network for hardware management.

2.3.1 10GbE networking

Each Lenovo Converged HX Series appliance contains 1 or 2 dual-port 10GbE network adapters as well as 4 on-board 1GbE ports. The hypervisors are configured by the Nutanix software so that all of the network ports on the appliance (both 10GbE and 1 GbE) are pooled. The hypervisor VM management network should use the same 10GbE network.

Because all of the network ports are pooled, each appliance only needs two network IP addresses; one for the hypervisor and one for the Nutanix CVM. These IP addresses should be all on the same subnet.

It is recommended that two top of rack (TOR) switches are used for redundancy. The second network adapter provides an additional level of redundancy in case one of the network adapters fails entirely. Redundancy across the two TORs is provided using bonded Inter-Switch-Links (ISL).

Figure 3 shows 4 HX Series appliances each with one dual-port NIC connected to two TOR switches.

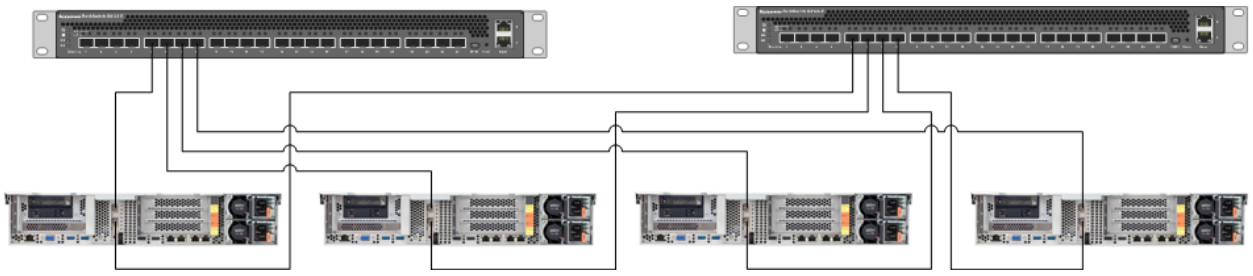

Figure 3: One NIC and two TOR switches

Figure 4 shows 4 HX Series appliances each with two dual-port NICs connected to two TOR switches.

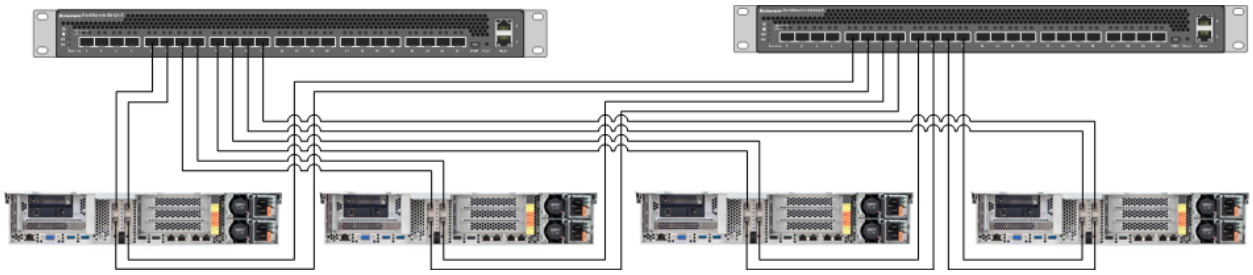

Figure 4: Two NICs and two TOR switches

The following Lenovo 10GbE TOR switches are recommended for use in a HX Series cluster:

- Lenovo RackSwitch G8124E
- Lenovo RackSwitch G8272

Lenovo RackSwitch G8124E

The Lenovo RackSwitch™ G8124E (as shown in Figure 5) is a 10 GbE switch that is specifically designed for the data center and provides a virtualized, cooler, and easier network solution. The G8124E offers 24 10 GbE ports in a 1U footprint. Designed with top performance in mind, the RackSwitch G8124E provides line-rate, high-bandwidth switching, filtering, and traffic queuing without delaying data and large data center grade buffers to keep traffic moving.

The G8124E switch is virtualized by providing rack-level virtualization of networking interfaces. The G8124E switch also supports Virtual Fabric, which allows for the distribution of a physical NIC into 2 to 8 vNICs and creates a virtual pipe between the adapter and the switch. The G8124E switch is easier to manage with server-oriented provisioning by using point-and-click management interfaces.

Figure 5: Lenovo RackSwitch G8124E

For more information, see this website: lenovopress.com/tips0787

Lenovo RackSwitch G8272

The Lenovo RackSwitch G8272 uses 10Gb SFP+ and 40Gb QSFP+ Ethernet technology and is specifically designed for the data center. It is an enterprise class Layer 2 and Layer 3 full featured switch that delivers line-rate, high-bandwidth switching, filtering, and traffic queuing without delaying data. Large data center-grade buffers help keep traffic moving, while the hot-swap redundant power supplies and fans (along with numerous high-availability features) help provide high availability for business sensitive traffic.

The RackSwitch G8272 (shown in Figure 6), is ideal for latency sensitive applications, such as high-performance computing clusters and financial applications. In addition to the 10 Gb Ethernet (GbE) and 40 GbE connections, the G8272 can use 1 GbE connections.

Figure 6: Lenovo RackSwitch G8272

The RackSwitch G8272 supports Lenovo Virtual Fabric, which helps clients significantly reduce cost and complexity that are related to I/O requirements of many virtualization deployments. Virtual Fabric helps reduce the number of multiple I/O adapters to a single dual-port 10 GbE adapter and the number of cables and required upstream switch ports.

By using Virtual Fabric, you can carve a dual-port 10 Gb server adapter into eight virtual network ports (vPorts) and create dedicated virtual pipes between the adapter and switch for optimal performance, higher availability, and improved security. With Virtual Fabric, you can make dynamic changes and allocate bandwidth per vPort so that you can adjust it over time without downtime.

For more information, see this website: lenovopress.com/tips1267

2.3.2 1 GbE networking

The dedicated IMM port on all of the Lenovo Converged HX series appliances needs to be connected to a 1GbE TOR switch as shown in Figure 7.

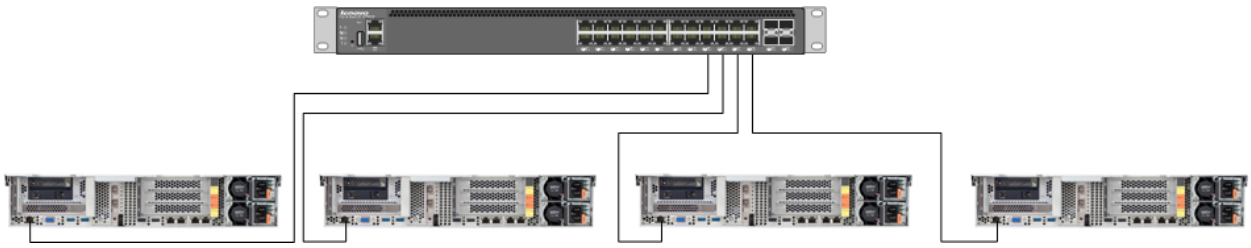

Figure 7: IMM 1GbE management network

The following Lenovo 1GbE TOR switches are recommended for use in a HX Series cluster:

- Lenovo RackSwitch G7028
- Lenovo RackSwitch G8052

Lenovo RackSwitch G7028

The Lenovo RackSwitch G7028 (as shown in Figure 8) is a 1 Gb top-of-rack switch that delivers line-rate Layer 2 performance at an attractive price. G7028 has 24 10/100/1000BASE-T RJ45 ports and four 10 Gb Ethernet SFP+ ports. It typically uses only 45 W of power, which helps improve energy efficiency.

Figure 8. Lenovo RackSwitch G7028

For more information, see this website: lenovopress.com/tips1268.

Lenovo RackSwitch G8052

The Lenovo System Networking RackSwitch G8052 (as shown in Figure 9) is an Ethernet switch that is designed for the data center and provides a virtualized, cooler, and simpler network solution. The Lenovo RackSwitch G8052 offers up to 48 1 GbE ports and up to four 10 GbE ports in a 1U footprint. The G8052 switch is always available for business-sensitive traffic by using redundant power supplies, fans, and numerous high-availability features.

Figure 9: Lenovo RackSwitch G8052

For more information, see this website: lenovopress.com/tips0813.

2.3.3 VLANs

It is a networking best practice to use VLANs to logically separate different kinds of network traffic. The following standard VLANs are recommended:

- Management Used for all management traffic for the hyerpvisor
- Storage network Used for NDFS storage traffic

In addition, each workload application might require one or more VLANs for its logical networks. For larger networks with many workloads, it is easy to run out of unique VLANs. In this case, VXLANs could be used.

The procedure for configuring VLANs in a cluster of HX Series appliances is outside of the scope of this document.

2.4 Reliability and performance features

Reliability and excellent performance are important for any workload but particularly for hyper-converged infrastructures like the HX Series appliances.

Reliability, high availability and excellent performance are provided through the following design features of Nutanix software combined with Lenovo Servers.

Hardware reliability

Lenovo uses the highest quality hardware components combined with firmware that is thoroughly tested. As a consequence Lenovo System x servers have been rated #1 in hardware reliability for the last 2 years. This is important as it lowers the frequency of a server failure which in turn lowers OPEX.

A HX appliance has redundant hardware components by including two power supplies, multiple chassis fans, two Intel CPUs, multiple memory DIMMs, multiple SSDs and HDDs, and optionally up to two dual-port network interface cards.

Hardware performance

The HX Series appliances have been carefully designed for performance. In addition to all of the usual attributes like processors and memory, the 24 drive HX7510 uses three HBA controllers instead of the one. As a consequence the latency is halved for some workloads that heavily utilize the cold tier. This allows a higher throughput and improved transaction rates.

Distributed file system

The Nutanix Distributed file system (NDFS) is an intelligent file system which virtualizes the local attached storage (SSD/HDD) on all the nodes in a cluster and presents it as single storage entity to cluster. Figure 10 shows the high level structure of NDFS:

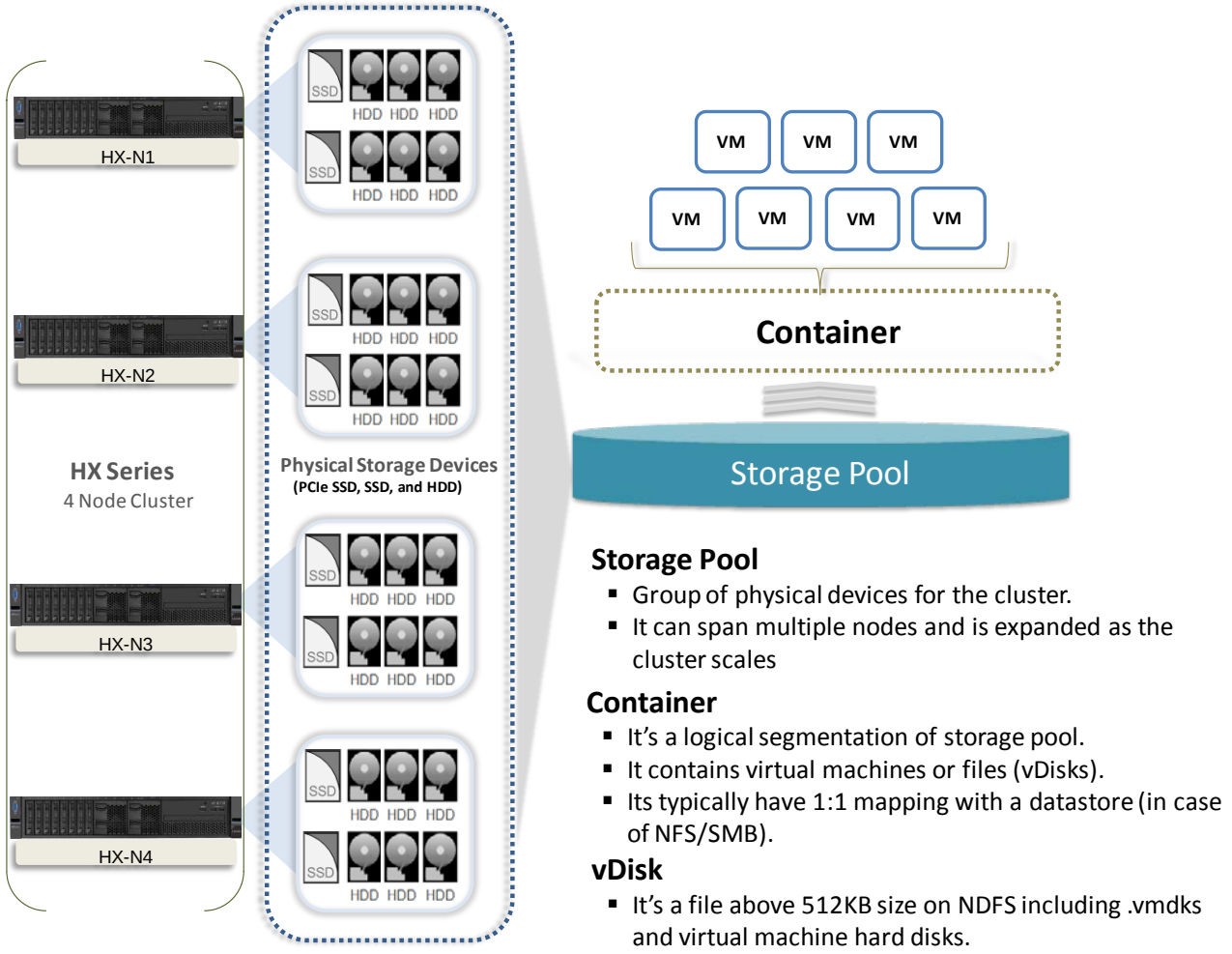

Figure 10: Nutanix Distributed File System

Data protection via replication

The Nutanix platform replication factor (RF) and checksum is used to ensure data redundancy and accessibility in the event of a node or disk failure or corruption. It uses an OpLog which acts as a staging area for incoming writes on low latency SSDs which are then replicated to the OpLogs for one or two other Controller VMs before acknowledging a successful write. This approach ensures that data available in at least two to three different locations and is fault tolerant. While the data is being written a checksum is calculated and stored as part of its metadata.

In the case of a drive or node failure, that data is replicated out to more nodes to maintain the replication factor. A checksum is computed every time the data is read to ensure the data validity. If the checksum and data mismatch, then the data replica is read to replace the invalid copy.

Performance with data tiering

Nutanix uses a disk tiering concept in which disk resources (SSD and HDD) are pooled together to form a cluster wide storage tier. This tier can be accessed by any node within the cluster for data placement and can leverage the full tier capacity. The following data tiering functions are provided:

- The SSD on a local node always has the highest tier priority for write I/O.
- If the local node's SSD is full then the other SSDs in the cluster are used for I/O.
- The NDFS Information Lifecycle Management (ILM) component migrates cold data from the local SSD to HDD to free up SSD space. It also moves heavily accessed data to the local SSD to provide high performance.

Performance by data locality

Data locality is a crucial factor for cluster and VM performance. In order to minimize latency the CVM will work to ensure that all I/O happens locally. This ensures optimal performance and provides very low latencies and high data transfer speeds that cannot be achieved easily with shared storage arrays, even if all-flash.

The following occurs in case of a VM migration or high availability event that moves a VM from Node-A to Node-B:

- The VM's data is provided by the CVM running on Node-B.
- All write I/O requests occur locally i.e. to the local storage of Node-B.
- When a request comes for reading old data, the I/O request is forwarded by Node-B to Node-A. NDFS detects that the I/O request originated from different node and migrates the data locally in the background i.e. from Node-A to Node-B so that all subsequent read I/Os are served locally. This approach (migration only on a read) helps to avoid network flooding.

Performance of snapshots and clones

NDFS provides support for offloaded snapshots and clones using a redirect-on-write algorithm. When a snapshot or clone is created, the base vDisk is marked as read only and another vDisk is created with read/write permissions as shown in Figure 11 and Figure 12 below.

At this point both vDisks have the same block map - a metadata mapping of the vDisk to its corresponding extents. This approach reduces the overhead of creating snapshots and allows snapshots to be taken very quickly with little performance impact.

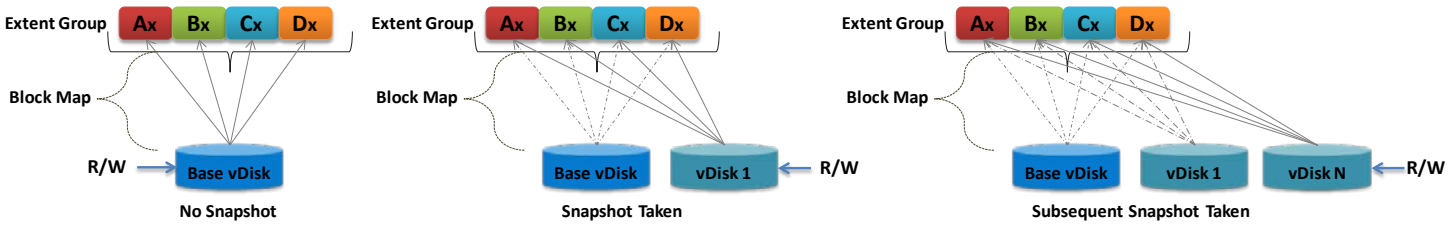

Figure 11: VM snapshots

When a VM is cloned the current block map is locked and then clones are created. These updates are metadata only so again no actual I/O takes place. The logic applies for clones of clones as well where a previously cloned VM acts as a base vDisk. All the clones inherit the prior block map and any new writes take place on the individual block maps.

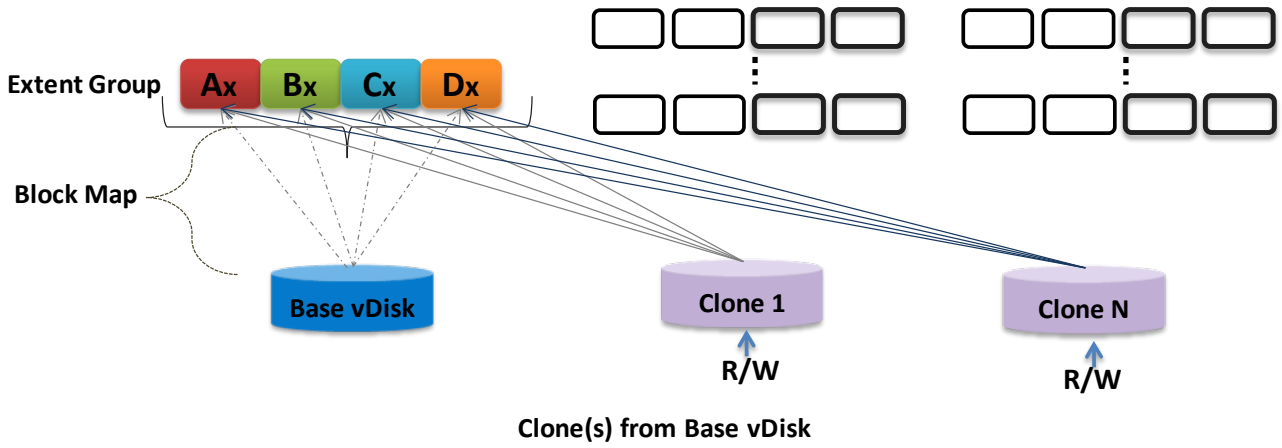

Figure 12: VM clones

Storage reduction via De-duplication and Compression

The Nutanix elastic de-duplication engine increases the effective capacity of a disk, as well as the RAM and cache of the system by removing duplicate data. It's an intelligent technology which performs following actions to increase storage efficiency:

- Sequential streams of data fingerprinted at 4K granularity
- Single instance of the shared VM data is loaded into the cache upon read
- Each node in a cluster performs its own fingerprinting and deduplication

The Nutanix capacity optimization engine is responsible for performing data transformations and compression to achieve data optimization. NDFS provides following compression methods:

- In-line compression sequential streams of data or large I/O sizes are compressed in memory before written to the disk
- Post-process compression whereby data is written in an uncompressed state and the curator framework is used to compress the data in a cluster wide manner

The Nutanix capacity optimization engine uses the Google snappy compression library to deliver good compression ratios with minimal compute overhead and very fast compression or decompression rates.

Elimination of "split-brain" errors

In a distributed system it is possible for one participant to become disconnected which will cause differences in the stored data. NDFS uses the proven "Paxos" algorithm to eliminate these "split-brain" issues by reaching a consensus (quorum) among the participants in a distributed system before the writes are made.

Drive reliability via active monitoring

The CVM actively monitors the performance of every drive in a node. The deterioration of a drive's performance may indicate that the drive is about to fail. The CVM proactively moves data off the drive before it fails and marks the drive offline and in need to replacement. The idea is to avoid the expensive data transfers to maintain data redundancy and possible loss of data.

3 Microsoft Exchange

Microsoft Exchange Server 2013 is the market leader in enterprise messaging and collaboration. Exchange Server 2013 builds upon the Exchange Server 2010 architecture and was redesigned for simplicity of scale, improved hardware utilization, and increased failure isolation. The goal of Exchange Server 2013 is to support people and organizations as their work habits evolve from a communication focus to a collaboration focus.

3.1 Solution overview

Figure 13 shows the architectural overview of the Microsoft Exchange solution using Lenovo Converged HX7510 appliances. This chapter does not address integrating Exchange with unified messaging solutions and handling edge transport routing and distribution.

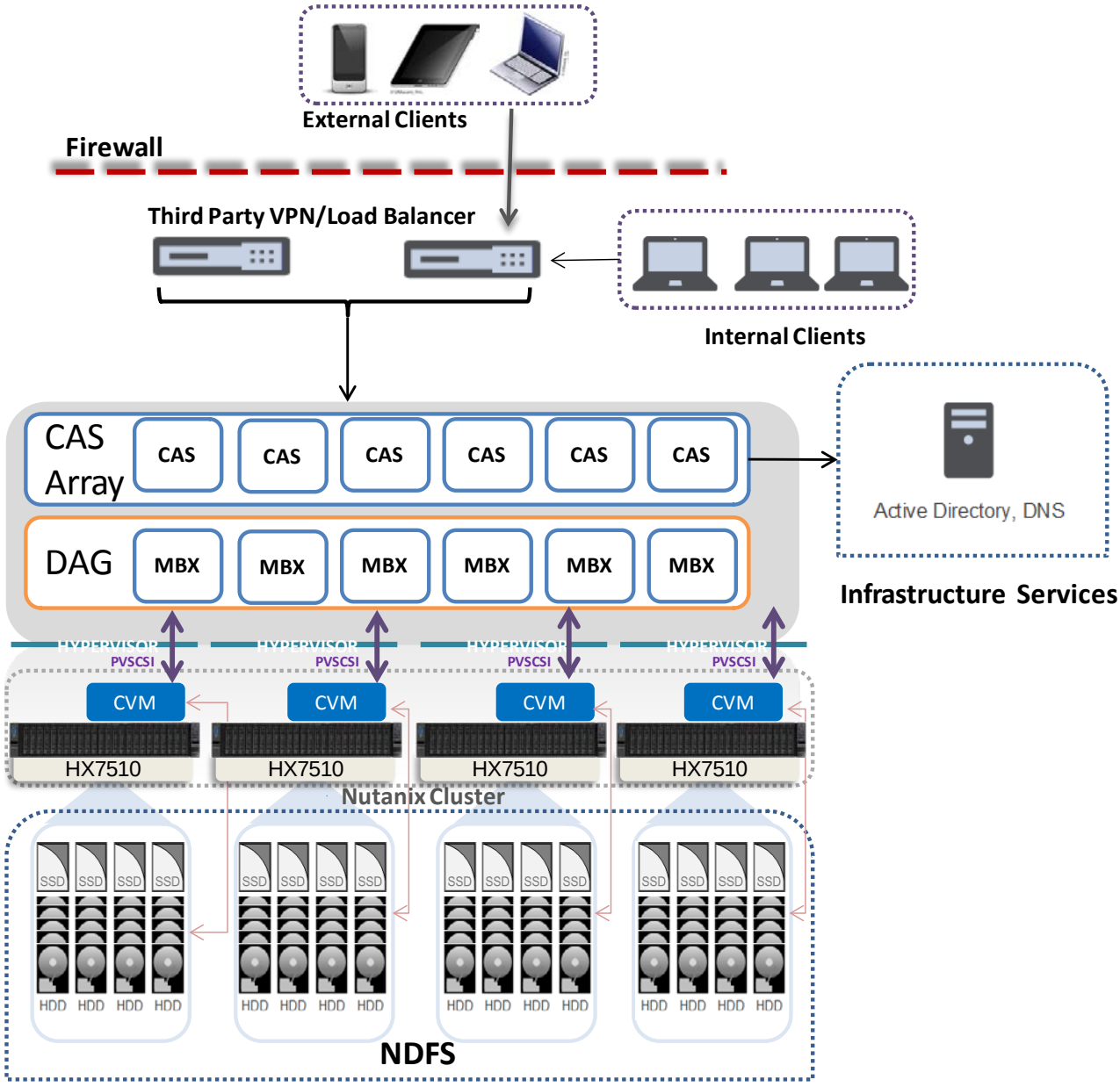

Figure 13. Lenovo Converged HX Series solution with Microsoft Exchange

The Client Access Server (CAS) role provides client protocols, SMTP, and unified messaging support. The Mailbox Server (MBX) role provides all of the data processing services. Lenovo recommends that these roles are combined into a multi-role server.

For load balancing into the CAS layer either a network load balancer can be used with a CAS array object or a layer 4 or layer 7 load balancer can be used without the need for configuring a CAS array.

3.2 Component model

This section describes the logical component view of the Exchange Server 2013 environment. Figure 14 shows a high-level component model.

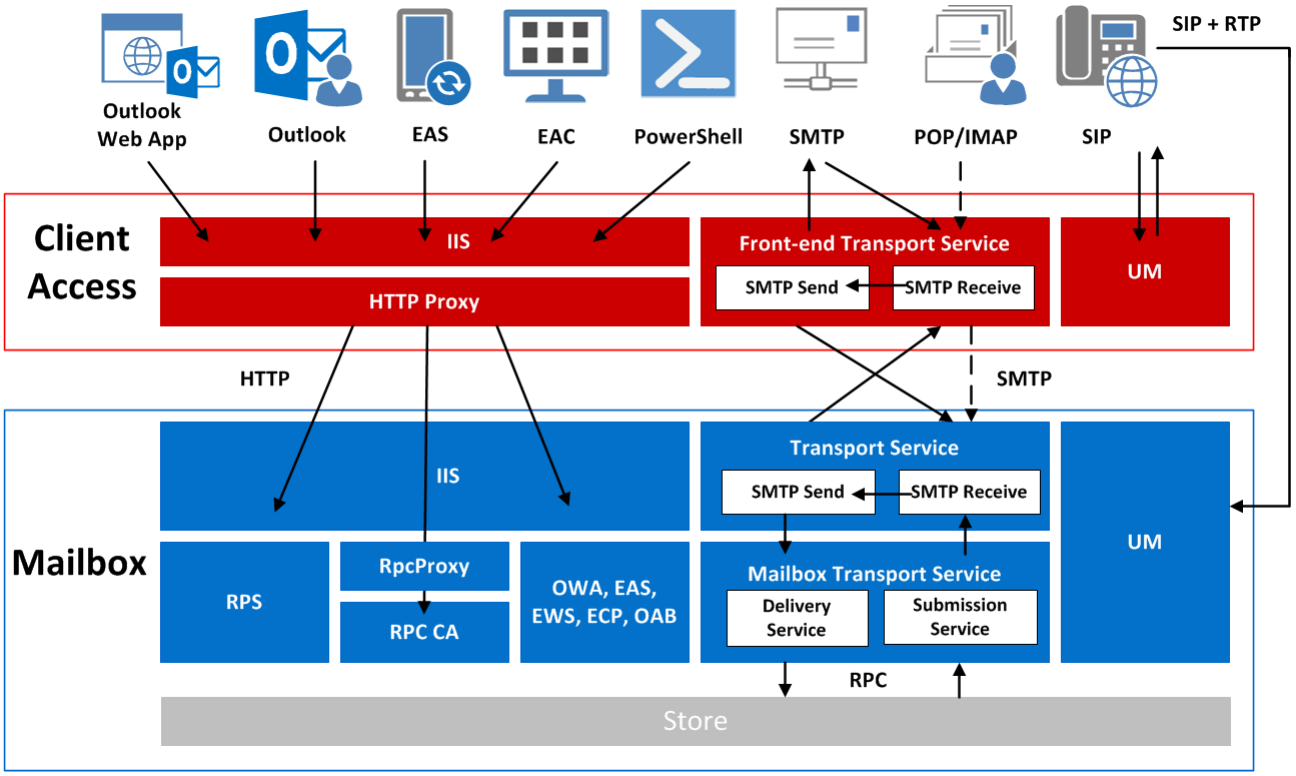

Figure 14. Exchange Server 2013 logical component view

The following basic concepts and terminology are used throughout this section:

Exchange Admin Center (EAC) – The EAC is the web-based management console in Microsoft Exchange Server 2013 that is optimized for on-premises, online, and hybrid Exchange deployments. The EAC replaces the Exchange Management Console (EMC) and the Exchange Control Panel (ECP), which were the two interfaces used to manage Exchange Server 2010.

Exchange Control Panel (ECP) – The ECP is a web application that runs on a Client Access Server and provides services for the Exchange organization.

Exchange Web Services (EWS) – EWS provides the functionality to enable client applications to communicate with the Exchange server.

Internet Information Services (IIS) – IIS is an extensible web server that was created by Microsoft for use with Windows NT family.

Internet Message Access Protocol (IMAP) – IMAP is a communications protocol for email retrieval and storage developed as an alternative to POP.

Microsoft Exchange ActiveSync (EAS) – EAS is a communications protocol that is designed for the synchronization of email, contacts, calendar, tasks, and notes from a messaging server to a smartphone or other mobile device.

Microsoft Outlook® Web App (OWA) – OWA (formerly Outlook Web Access) is a browser-based email client with which users can access their Microsoft Exchange Server mailbox from almost any web browser.

Offline Address Book (OAB) – The OAB is a copy of an address list collection that was downloaded so a Microsoft Outlook user can access the address book while disconnected from the server. Microsoft Exchange generates the new OAB files and then compresses the files and places them on a local share.

Outlook Anywhere – Outlook Anywhere is a service that provides RPC/MAPI connectivity for Outlook clients over HTTP or HTTPS by using the Windows RPC over HTTP component. In previous versions of Exchange Server, this function was used for remote or external access only. However, in Exchange Server 2013, all Outlook connectivity is via HTTP/HTTPS (even for internal clients).

Post Office Protocol (POP) – The POP is an application-layer Internet standard protocol that is used by local email clients to retrieve email from a remote server over a TCP/IP connection

Real-time Transport Protocol (RTP) – RTP is a network protocol for delivering audio and video over IP networks.

Remote PowerShell (RPS) – RPS allows you to use Windows PowerShell on your local computer to create a remote Shell session to an Exchange server if you do not have the Exchange management tools installed.

RPC Client Access (RPC) – In Microsoft Exchange Server 2007, the Client Access server role was introduced to handle incoming client connections to Exchange mailboxes. Although most types of client connections were made to the Client Access server, Microsoft Office Outlook still connected directly to the Mailbox server when it was running internally with the MAPI protocol.

A new service was introduced with Exchange Server 2010 to allow these MAPI connections to be handled by the Client Access server. The RPC Client Access service provides data access through a single, common path of the Client Access server, with the exception of public folder requests (which are still made directly to the Mailbox server). This change applies business logic to clients more consistently and provides a better client experience when failover occurs.

Remote Procedure Call over HTTP – The RPC over HTTP component wraps RPCs in an HTTP layer that allows traffic to traverse network firewalls without requiring RPC ports to be opened. In Exchange 2013, this feature is enabled by default because Exchange 2013 does not allow direct RPC connectivity.

Session Initiation Protocol (SIP) – SIP is a protocol that is used for starting, modifying, and ending an interactive user session that involves multimedia elements, such as video, voice, and instant messaging.

Simple Mail Transfer Protocol (SMTP) – SMTP is an Internet standard for email transmission.

Unified Messaging (UM) – UM allows an Exchange Server mailbox account that was enabled for UM to receive email, voice, and fax messages in the Inbox.

3.3 Exchange deployment best practices

This section describes recommended best practices for Microsoft Exchange mailboxes. See also this website for Nutanix Best Practices Guide: Virtualizing Microsoft Exchange: go.nutanix.com/virtualizing-microsoft-exchange-converged-infrastructure.html.

3.3.1 Data optimization

By default all Nutanix storage containers are thin provisioned which reduces unused capacity and automatically provisions additional storage capacity when needed. It is also very easy to add additional storage capacity for mailboxes by simply adding nodes to the cluster. It is also possible to set a storage reservation to guarantee a minimum amount of storage capacity.

Data compression can be used to further increase data capacity especially for data that is less frequently accessed. Lenovo recommends enabling compression with a delay of 1440 minutes (1 day) which minimizes the performance impact on I/O writes.

Data de-duplication is not recommended and should be disabled for active Exchange mailboxes because of the frequency of changes. Note that de-duplication may be beneficial for backup volumes which are not changed very often.

A resiliency factor of 2 is the default. This provides a minimum level of data redundancy but a resiliency factor of 3 might be important in some environments. Using erasure coding saves significant storage capacity but it only recommended for archive data.

3.3.2 Cluster high availability

The minimum number of nodes in each cluster is 3 and should be at least 4 to provide failover. The following high availability features are recommended for an AHV-based cluster:

A database availability group (DAG) is the base component of the high availability and site resilience framework that is built into Microsoft Exchange Server 2013. A DAG is a group of up to 16 mailbox servers that hosts a set of mailbox databases and provides automatic database-level recovery from failures that affect individual servers or databases.

A DAG is a boundary for mailbox database replication, database and server switchovers, failovers, and an internal component called *Active Manager*. Active Manager, which runs on every server in a DAG, manages switchovers and failovers.

Any server in a DAG can host a copy of a mailbox database from any other server in the DAG. When a server is added to a DAG, it works with the other servers in the DAG to provide automatic recovery from failures that affect mailbox databases (such as a disk failure or server failure).

Lenovo recommends a DAG configuration of 2 database copies and optionally one lagged copy. With a data resiliency factor of 2, the effective number of copies of each mailbox is 4 and this allows two disk failures without losing data.

DR across datacenters can also be done using DAGs assuming there is sufficient band-width between the sites. The scenarios for active-active and active-passive DR sites using DAGs are outside the scope of this document.

3.3.3 Other best practices

Consider the following points regarding virtualizing Exchange:

- All Exchange 2013 server roles should be supported in a single VM.
- Some hypervisors include features for taking snapshots of VMs. VM snapshots capture the state of a VM while it is running. This feature enables you to take multiple snapshots of a VM and then revert the VM to any of the previous states by applying a snapshot to the VM. However, VM snapshots are not application aware, and the use of snapshots can have unintended and unexpected consequences for a server application that maintains state data, such as Exchange. Therefore, making VM snapshots of an Exchange guest VM is not supported.
- Disable Hyper-threading.
- The operating system for an Exchange guest machine must use a disk that has a size equal to at least 15 GB plus the size of the virtual memory that is allocated to the guest machine. This requirement is necessary to account for the operating system and paging file disk requirements. For example, if the guest machine is allocated 16 GB of memory, the minimum disk space that is needed for the guest operating system disk is 31 GB.

3.4 DAG architecture overview

The following section illustrates the Lenovo Converged HX7510 based Exchange 2013 mailbox resiliency solution Lenovo implemented for ESRP testing.

Compute per node: 2 x Intel E5-2699v4 (22 cores @ 2.2 GHz) processors

RAM per node: 512GB

Raw storage per node: SSD: 4 x 800GB SATA SSDs – 3.2TB
HDD: 20 x 2TB SATA HDDs – 40TB

Raw storage per cluster: SSD: 16 x 800GB SATA SSDs – 12.8TB
HDD: 80 x 2TB SATA HDDs – 160 TB

Figure 15 describes the high level DAG architecture of the 30,000 mailbox virtualized Exchange 2013 mailbox resiliency solution. This solution comprises of two Lenovo Converged HX7510 clusters with 4 nodes per cluster. Each node uses the Nutanix Acropolis Hypervisor (AHV).

The DAG has six Exchange 2013 mailbox servers and two database copies. The two database copies were placed on two physically isolated clusters.

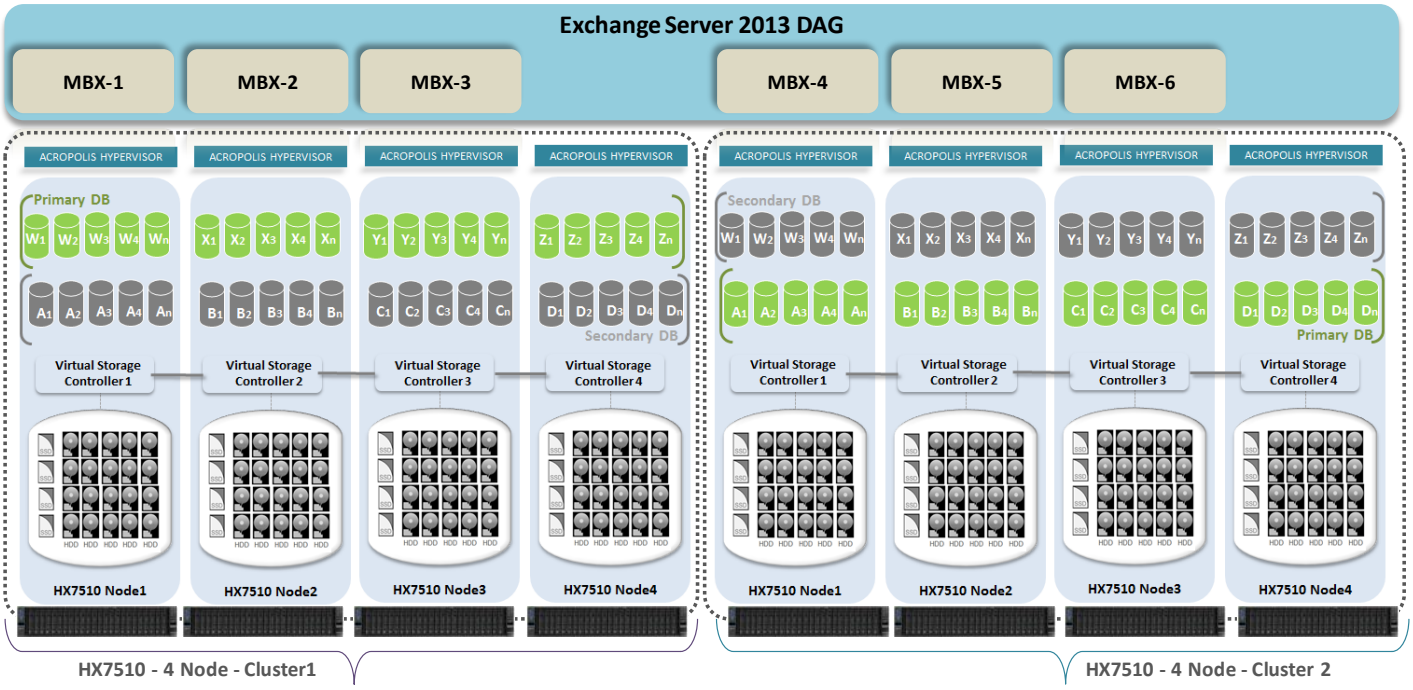

Figure 15. DAG Architecture using Exchange 2013 and Lenovo Converged HX7510 (30,000 Mailboxes)

On both Cluster1 and Cluster2, the Mailbox server (MBX) VMs were created on three nodes. All the Database/Logs volumes were connected to Mailbox servers using the NFS protocol. The primary database copy and secondary database copy are stored on two physically separated and isolated clusters. The two clusters can be located at the same datacentre or two different datacenters.

Each Mailbox Server VM is configured as follows:

- 24 vCPUs
- 400 GB RAM
- Windows Server 2012 R2
- Microsoft Exchange 2013 with 10,000 mailboxes

The ESRP-Storage program focuses on storage solution testing to address performance and reliability issues with storage design. However, storage is not the only factor to take into consideration when designing a scale up Exchange solution. Other factors which affect the server scalability are: server processor utilization, server physical and virtual memory limitations, resource requirements for other applications, directory and network service latencies, network infrastructure limitations, replication and recovery requirements, and client usage profiles. All these factors are beyond the scope for ESRP-Storage. Therefore, the number of mailboxes hosted per server as part of the tested configuration may not necessarily be viable for some customer deployment.

For more information on identifying and addressing performance bottlenecks in an Exchange system, please refer to Microsoft's Troubleshooting Microsoft Exchange Server Performance, available at http://technet.microsoft.com/en-us/library/dd335215.aspx.

3.5 Targeted customer profile

The target customer profile for a medium enterprise Microsoft Exchange 2013 environment is as follows:

- 30,000 mailboxes of 1GB
- 6x Exchange 2013 servers (3x Tested)
- 0.06 IOPS per mailbox
- 24/7 background database maintenance
- Mailbox resiliency factor of 2
- 10 databases per host

3.6 Tested deployment environment

The section describes the tested deployment environment.

3.6.1 Simulated exchange configuration

The following table summarizes the simulated Exchange configuration.

Number of Exchange mailboxes simulated	30,000
Number of Database Availability Groups (DAGs)	1
Number of servers/DAG	6 (3 tested)
Number of active mailboxes/server	5,000 (5,000 active and 5,000 passive mailboxes per server and tested 10,000 active mailboxes per server)
Number of databases/host	10
Number of copies/database	2
Number of mailboxes/database	1000
Simulated profile: I/O's per second per mailbox (IOPS, include 20% headroom)	0.06 IOPs / Mailbox
Database/LUN size	1.5 TB
Total database size for performance testing	30 TB
% storage capacity used by Exchange database[2]	63.46%

[2] Storage performance characteristics change based on the percentage utilization of the individual disks. Tests that use a small percentage of the storage (~25%) may exhibit reduced throughput if the storage capacity utilization is significantly increased beyond what is tested in this paper.

3.6.2 Storage hardware

The following table summarizes the storage hardware.

Storage Connectivity (Fiber Channel, SAS, SATA, iSCSI)	NFS
Storage model and OS/firmware revision	HX7510 running Acropolis 4.6.3
Storage cache	76.8GB per node
Number of storage controllers	4x virtual controller virtual machines
Number of storage ports	2x 10 Gbe Port
Maximum bandwidth of storage connectivity to host	20 Gbps per node
Switch type/model/firmware revision	Lenovo RackSwitch G8124E (10GbE) Firmware version: 7.7.5
HBA model and firmware	N2215 SAS/SATA HBA
Number of HBA's/host	3
Host server type	3x Lenovo Converged HX7510 (2 x Intel E5-2699v4 @ 2.2 GHz) 512GB RAM
Total number of disks tested in solution	96 (4 node cluster)
Maximum number of spindles can be hosted in the storage	96 (cluster can be scaled to 40+ nodes)

3.6.3 Storage software

The following table summarizes the storage software.

HBA driver	VirtIOnetwork device 1.7.1
HBA QueueTarget Setting	N/A
HBA QueueDepth Setting	N/A
Hypervisor	Nutanix Acropolis Hypervisor (AHV)
Exchange VM guest OS	Windows Server 2012 R2
ESE.dll file version	15.00.0847.030
Replication solution name/version	N/A

3.6.4 Storage disk configuration (mailbox store disks)

The following table summarizes the storage disk configuration.

Disk type, speed and firmware revision	Per Node: 4x Intel S3610 800 GB SATA G3HS 2.5" SSD 20x 2 TB 7.2K 6Gbps NL SATA 2.5" G3HS 512e HDD
Raw capacity per disk (GB)	2048 GB (2 TB)
Number of physical disks in test	96 (16x 800 GB + 80x 2 TB)
Total raw storage capacity (GB)	172,800 GB
Disk slice size (GB)	N/A
Number of slices or disks per LUN	N/A
Raid level	Nutanix Replication Factor 2 (RAID 1)
Total formatted capacity	70.82 GB
Storage capacity utilization	40.9%
Database capacity utilization	17.3%

3.7 Performance test results

This section provides a high-level summary of the results of executing the Microsoft ESRP storage test version 4.0 on the configuration of 4 Lenovo Converged HX7510 appliances as described in the previous section. ESRP storage test results include reliability, storage performance, and database backup/restore.

Note that the ESRP program is not designed to be a benchmarking program and tests are not designed to get the maximum throughput for a giving solution. Rather, the program is focused on producing recommendations from vendors for the Exchange application. Therefore, the data presented in this document should not be used for direct comparisons among the solutions and customers should not quote the data directly for their pre-deployment verifications. It is recommended that a proof of concept is carried out to validate the storage design for a specific customer environment.

The results in this section were developed by Lenovo and reviewed by the Microsoft Exchange Product team.

3.7.1 Reliability

Several of the tests in the ESP test framework are used to check reliability and run for 24 hours. The test objective is to verify that the storage can handle high I/O workloads for extensive periods. Log and database files are analyzed for integrity after the stress test to ensure there is no database or log corruption.

Executing this test on the Lenovo Converged HX7510 appliances showed:

- No errors reported in the saved event log file.
- No errors reported during the database and log checksum process.

For detailed log results see “24-Hour stress/reliability test results” on page 24.

3.7.2 Storage performance results

The primary storage performance test in the ESP test framework is designed to exercise the storage with a maximum sustainable Exchange I/O pattern for 2 hours. The purpose is to reveal how long it takes for the storage to respond to I/O operations under a load.

For detailed log results see “2-Hour performance test results” on page 26.

Individual server metrics

Table 1 shows the sum of I/O’s and the average latency across all storage groups on a per server basis.

Table 1: Individual Server Performance

	Node 1	**Node 2**	**Node 3**
Database I/O			
Database Disks Transfers/sec	1200.51	1171.40	1166.28
Database Disks Reads/sec	844.80	825.31	821.81
Database Disks Write/sec	355.71	346.08	344.47
Average Database Disk Read Latency (ms)	14.0	13.8	14.1
Average Database Disk Write Latency (ms)	8.5	8.2	9.1
Transaction Log I/O			
Log Disks Writes/sec	83.74	81.71	81.17
Average Log Disk Write Latency(ms)	3.03	2.93	3.08

Aggregate performance metrics across all servers

Table 2 shows the sum of I/O’s and the average latency across the 3 primary servers in the solution.

Table 2: Aggregate Server Performance

Database I/O	
Database Disks Transfers/sec	3538.19
Database Disks Reads/sec	2491.92
Database Disks Writes/sec	1046.26
Average Database Disk Read Latency (ms)	13.96
Average Database Disk Write Latency (ms)	8.6
Transaction Log I/O	
Log Disks Writes/sec	246.62
Average Log Disk Write Latency (ms)	3.01

3.7.3 Database backup/recovery performance

Several of the tests in the ESP test framework are used to measure the sequential read rate of the database files and the recovery/replay performance (playing transaction logs into the database).

The database read-only performance test measures the maximum rate at which databases could be backed up using Microsoft Volume Shadow Copy Service (VSS). Table 3 shows the average read performance for a backing up a single database file and all ten database files on a single node.

Table 3: Database backup read-only performance results

MB read/sec per database	58.38
MB read/sec total per node (10 databases)	583.82

For detailed log results see “Database backup test results” on page 28.

3.7.4 Transaction log recovery/replay performance

The test is to measure the maximum rate at which the log files can be played against the databases. Table 4 shows the average rate for 500 log files played in a single storage group. Each log file is 1 MB in size.

Table 4: Transaction Log Recovery/Replay Performance

Average time to play one Log file (sec)	2.82

For detailed log results see “Soft recovery test results” on page 30.

4 Conclusion

This document is developed by storage solution providers, and reviewed by Microsoft Exchange Product team. The test results/data presented in this document is based on the tests introduced in the ESRP test framework. Customer should not quote the data directly for his/her pre-deployment verification. It is still necessary to go through the exercises to validate the storage design for a specific customer environment.

ESRP program is not designed to be a benchmarking program; tests are not designed to getting the maximum throughput for a giving solution. Rather, it is focused on producing recommendations from vendors for Exchange application. So the data presented in this document should not be used for direct comparisons among the solutions.

The cluster of 4 Lenovo Converged HX7510 appliances proved more than capable of handling the high IOPs generated by 30,000 mailboxes. Part of the reason for this is because each Lenovo Converged HX7510 appliance uses 3 HBAs for the 24 drives. As a consequence the cluster has an average IOPS rate that is 23% better and an average latency improvement of 2 milliseconds over other systems with less HBAs.

Appendix A – Test results

This section provides test results from 1 of the 3 primary mailbox servers under test: VM1. All server's test results are comparable to each another.

24-Hour stress/reliability test results

Checksum Statistics - All

Database	Seen pages	Bad pages	Correctable pages	Wrong page-number pages	File length / seconds taken
F:\Jetstress001001.edb	32242432	0	0	0	1007576 MB/19351 sec
G:\Jetstress002001.edb	32243200	0	0	0	1007600 MB/18633 sec
H:\Jetstress003001.edb	32243456	0	0	0	1007608 MB/18571 sec
I:\Jetstress004001.edb	32242944	0	0	0	1007592 MB/18561 sec
J:\Jetstress005001.edb	32243200	0	0	0	1007600 MB/18554 sec
K:\Jetstress006001.edb	32243712	0	0	0	1007616 MB/18569 sec
L:\Jetstress007001.edb	32243712	0	0	0	1007616 MB/18597 sec
M:\Jetstress008001.edb	32242688	0	0	0	1007584 MB/18631 sec
N:\Jetstress009001.edb	32243712	0	0	0	1007616 MB/18737 sec
O:\Jetstress010001.edb	32243712	0	0	0	1007616 MB/18841 sec
(Sum)	322432768	0	0	0	10076024 MB/19352 sec

Disk Subsystem Performance (of checksum)

LogicalDisk	Avg. Disk sec/Read	Avg. Disk sec/Write	Disk Reads/sec	Disk Writes/sec	Avg. Disk Bytes/Read
F:	0.037	0.000	829.545	0.000	65535.988
G:	0.035	0.000	861.902	0.000	65536.000
H:	0.035	0.000	866.735	0.000	65536.000
I:	0.035	0.000	868.391	0.000	65536.000
J:	0.035	0.000	869.333	0.000	65536.000
K:	0.035	0.000	867.131	0.000	65536.000
L:	0.035	0.000	865.259	0.000	65536.000
M:	0.035	0.000	862.267	0.000	65536.000
N:	0.036	0.000	859.674	0.000	65536.000
O:	0.036	0.000	852.182	0.000	65536.000

Memory System Performance (of checksum)

Counter	Average	Minimum	Maximum
% Processor Time	0.719	0.304	1.184
Available MBytes	201605.419	201552.000	201638.000
Free System Page Table Entries	16461092.643	16460471.000	16461849.000
Transition Pages RePurposed/sec	0.000	0.000	0.000
Pool Nonpaged Bytes	72055210.137	71757824.000	72478720.000
Pool Paged Bytes	169404600.447	169390080.000	169537536.000

Test Log

8/10/2016 12:51:35 PM -- Preparing for testing ...
8/10/2016 12:51:45 PM -- Attaching databases ...
8/10/2016 12:51:45 PM -- Preparations for testing are complete.
8/10/2016 12:51:45 PM -- Starting transaction dispatch ..
8/10/2016 12:51:45 PM -- Database cache settings: (minimum: 320.0 MB, maximum: 2.5 GB)
8/10/2016 12:51:45 PM -- Database flush thresholds: (start: 25.6 MB, stop: 51.2 MB)
8/10/2016 12:51:56 PM -- Database read latency thresholds: (average: 20 msec/read, maximum: 200 msec/read).
8/10/2016 12:51:56 PM -- Log write latency thresholds: (average: 10 msec/write, maximum: 200 msec/write).
8/10/2016 12:51:57 PM -- Operation mix: Sessions 22, Inserts 40%, Deletes 20%, Replaces 5%, Reads 35%, Lazy Commits 70%.
8/10/2016 12:51:57 PM -- Performance logging started (interval: 15000 ms).
8/10/2016 12:51:57 PM -- Attaining prerequisites:
8/10/2016 12:54:34 PM -- \MSExchange Database(JetstressWin)\Database Cache Size, Last: 2425139000.0 (lower bound: 2415919000.0, upper bound: none)
8/11/2016 12:54:35 PM -- Performance logging has ended.
8/11/2016 12:54:35 PM -- JetInterop batch transaction stats: 245838, 245838, 245838, 245837, 245837, 245837, 245837, 245837, 245837 and 245837.
8/11/2016 12:54:35 PM -- Dispatching transactions ends.
8/11/2016 12:54:35 PM -- Shutting down databases ...
8/11/2016 12:54:39 PM -- Instance3488.1 (complete), Instance3488.2 (complete), Instance3488.3 (complete), Instance3488.4 (complete), Instance3488.5 (complete), Instance3488.6 (complete), Instance3488.7 (complete), Instance3488.8 (complete), Instance3488.9 (complete) and Instance3488.10 (complete)
8/11/2016 12:54:39 PM -- C:\Program Files\Exchange Jetstress\24Hr Test\Stress_2016_8_10_12_51_56.blg has 5758 samples.
8/11/2016 12:54:39 PM -- Creating test report ...
8/11/2016 12:58:44 PM -- Instance3488.1 has 14.1 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.1 has 3.0 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.1 has 3.0 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.2 has 12.9 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.2 has 3.0 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.2 has 3.0 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.3 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.3 has 3.0 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.3 has 3.0 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.4 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.4 has 3.0 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.4 has 3.0 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.5 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.5 has 2.9 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.5 has 2.9 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.6 has 12.7 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.6 has 2.9 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.6 has 2.9 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.7 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.7 has 2.8 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.7 has 2.8 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.8 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.8 has 2.9 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.8 has 2.9 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.9 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.9 has 2.9 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.9 has 2.9 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.10 has 12.8 for I/O Database Reads Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.10 has 2.8 for I/O Log Writes Average Latency.
8/11/2016 12:58:44 PM -- Instance3488.10 has 2.8 for I/O Log Reads Average Latency.
8/11/2016 12:58:44 PM -- Test has 0 Maximum Database Page Fault Stalls/sec.
8/11/2016 12:58:44 PM -- The test has 0 Database Page Fault Stalls/sec samples higher than 0.
8/11/2016 12:58:44 PM -- C:\Program Files\Exchange Jetstress\24Hr Test\Stress_2016_8_10_12_51_56.xml has 5747 samples queried.
8/11/2016 12:58:44 PM -- C:\Program Files\Exchange Jetstress\24Hr Test\Stress_2016_8_10_12_51_56.html was saved.
8/11/2016 12:58:44 PM -- Performance logging started (interval: 30000 ms).
8/11/2016 12:58:44 PM -- Verifying database checksums ...
8/11/2016 6:21:17 PM -- F: (100% processed), G: (100% processed), H: (100% processed), I: (100% processed), J: (100% processed), K: (100% processed), L: (100% processed), M: (100% processed), N: (100% processed) and O: (100% processed)
8/11/2016 6:21:17 PM -- Performance logging has ended.

2-Hour performance test results

Test Summary

Overall Test Result	**Pass**
Machine Name	VMB1
Test Description	
Test Start Time	8/10/2016 5:19:28 AM
Test End Time	8/10/2016 7:22:57 AM
Collection Start Time	8/10/2016 5:22:53 AM
Collection End Time	8/10/2016 7:22:50 AM
Jetstress Version	15.01.0318.000
ESE Version	15.00.0847.030
Operating System	Windows Server 2012 R2 Datacenter (6.2.9200.0)
Performance Log	C:\Program Files\Exchange Jetstress\2Hr Test\Performance_2016_8_10_5_19_49.blg

Database Sizing and Throughput

Achieved Transactional I/O per Second	1110.138
Target Transactional I/O per Second	600
Initial Database Size (bytes)	10528206356480
Final Database Size (bytes)	10531024928768
Database Files (Count)	10

Jetstress System Parameters

Thread Count	22
Minimum Database Cache	320.0 MB
Maximum Database Cache	2560.0 MB
Insert Operations	40%
Delete Operations	20%
Replace Operations	5%
Read Operations	35%
Lazy Commits	70%
Run Background Database Maintenance	True
Number of Copies per Database	2

Database Configuration

Instance3488.1	Log path: F:\Logs Database: F:\Jetstress001001.edb
Instance3488.2	Log path: G:\Logs Database: G:\Jetstress002001.edb
Instance3488.3	Log path: H:\Logs Database: H:\Jetstress003001.edb
Instance3488.4	Log path: I:\Logs Database: I:\Jetstress004001.edb
Instance3488.5	Log path: J:\Logs Database: J:\Jetstress005001.edb
Instance3488.6	Log path: K:\Logs Database: K:\Jetstress006001.edb
Instance3488.7	Log path: L:\Logs Database: L:\Jetstress007001.edb
Instance3488.8	Log path: M:\Logs Database: M:\Jetstress008001.edb
Instance3488.9	Log path: N:\Logs Database: N:\Jetstress009001.edb
Instance3488.10	Log path: O:\Logs Database: O:\Jetstress010001.edb

Transactional I/O Performance

MSExchange Database ==> Instances	I/O Database Reads Average Latency (msec)	I/O Database Writes Average Latency (msec)	I/O Database Reads/sec	I/O Database Writes/sec	I/O Database Reads Average Bytes	I/O Database Writes Average Bytes	I/O Log Reads Average Latency (msec)	I/O Log Writes Average Latency (msec)	I/O Log Reads/sec	I/O Log Writes/sec	I/O Log Reads Average Bytes	I/O Log Writes Average Bytes
Instance3488.1	15.411	9.014	75.322	35.303	35500.231	34655.120	0.000	3.068	0.000	8.295	0.000	20474.384
Instance3488.2	13.961	9.546	75.369	35.389	35401.758	34636.023	0.000	3.515	0.000	8.306	0.000	20525.268
Instance3488.3	13.784	8.610	75.170	35.398	35452.233	34667.729	0.000	3.024	0.000	8.374	0.000	20674.740
Instance3488.4	13.851	8.756	75.470	35.425	35369.257	34638.170	0.000	3.040	0.000	8.293	0.000	20396.533
Instance3488.5	13.924	8.890	75.205	35.344	35386.193	34652.054	0.000	3.197	0.000	8.436	0.000	20381.456
Instance3488.6	13.851	8.115	75.583	35.735	35327.536	34648.332	0.000	2.807	0.000	8.412	0.000	20336.783
Instance3488.7	13.821	8.105	75.798	36.095	35238.752	34638.134	0.000	2.780	0.000	8.435	0.000	20330.243
Instance3488.8	13.908	8.530	75.647	35.871	35309.280	34636.309	0.000	3.057	0.000	8.471	0.000	20378.766
Instance3488.9	13.710	8.188	75.463	35.652	35312.111	34623.816	0.000	2.780	0.000	8.372	0.000	20489.269
Instance3488.10	13.832	8.226	75.400	35.498	35316.919	34625.217	0.000	3.104	0.000	8.352	0.000	20418.419

Background Database Maintenance I/O Performance

MSExchange Database ==> Instances	Database Maintenance IO Reads/sec	Database Maintenance IO Reads Average Bytes
Instance3488.1	9.048	261671.374
Instance3488.2	9.034	261718.000
Instance3488.3	9.036	261786.693
Instance3488.4	9.038	261666.736
Instance3488.5	9.040	261698.023
Instance3488.6	9.035	261776.182
Instance3488.7	9.038	261669.386
Instance3488.8	9.033	261736.093
Instance3488.9	9.038	261798.738
Instance3488.10	9.033	261814.740

Log Replication I/O Performance

MSExchange Database ==> Instances	I/O Log Reads/sec	I/O Log Reads Average Bytes
Instance3488.1	0.719	219906.071
Instance3488.2	0.724	219425.443
Instance3488.3	0.732	220399.818
Instance3488.4	0.723	218452.381
Instance3488.5	0.733	220885.036
Instance3488.6	0.729	219425.443
Instance3488.7	0.734	220387.998
Instance3488.8	0.735	218818.878
Instance3488.9	0.730	218985.566
Instance3488.10	0.727	217965.850

Total I/O Performance

MSExchange Database ==> Instances	I/O Database Reads Average Latency (msec)	I/O Database Writes Average Latency (msec)	I/O Database Reads/sec	I/O Database Writes/sec	I/O Database Reads Average Bytes	I/O Database Writes Average Bytes	I/O Log Reads Average Latency (msec)	I/O Log Writes Average Latency (msec)	I/O Log Reads/sec	I/O Log Writes/sec	I/O Log Reads Average Bytes	I/O Log Writes Average Bytes
Instance3488.1	15.411	9.014	84.370	35.303	59756.173	34655.120	2.477	3.068	0.719	8.295	219906.071	20474.384
Instance3488.2	13.961	9.546	84.403	35.389	59625.368	34636.023	2.380	3.515	0.724	8.306	219425.443	20525.268
Instance3488.3	13.784	8.610	84.207	35.398	59740.716	34667.729	2.334	3.024	0.732	8.374	220399.818	20674.740
Instance3488.4	13.851	8.756	84.508	35.425	59570.860	34638.170	2.303	3.040	0.723	8.293	218452.381	20396.533
Instance3488.5	13.924	8.890	84.245	35.344	59671.659	34652.054	2.336	3.197	0.733	8.436	220885.036	20381.456
Instance3488.6	13.851	8.115	84.618	35.735	59507.496	34648.332	2.342	2.807	0.729	8.412	219425.443	20336.783
Instance3488.7	13.821	8.105	84.836	36.095	59360.922	34638.134	2.311	2.780	0.734	8.435	220387.998	20330.243
Instance3488.8	13.908	8.530	84.681	35.871	59463.453	34636.309	2.466	3.057	0.735	8.471	218818.878	20378.766
Instance3488.9	13.710	8.188	84.501	35.652	59535.304	34623.816	2.288	2.780	0.730	8.372	218985.566	20489.269
Instance3488.10	13.832	8.226	84.433	35.498	59548.782	34625.217	2.298	3.104	0.727	8.352	217965.850	20418.419

Host System Performance

Counter	Average	Minimum	Maximum
% Processor Time	0.760	0.177	1.247
Available MBytes	198964.315	198945.000	199052.000
Free System Page Table Entries	16461274.017	16461013.000	16461469.000
Transition Pages RePurposed/sec	0.000	0.000	0.000
Pool Nonpaged Bytes	67834916.342	67764224.000	68038656.000
Pool Paged Bytes	163028213.846	162983936.000	163049472.000
Database Page Fault Stalls/sec	0.000	0.000	0.000

Test Log

8/10/2016 5:19:28 AM -- Preparing for testing ...
8/10/2016 5:19:38 AM -- Attaching databases ...
8/10/2016 5:19:38 AM -- Preparations for testing are complete.
8/10/2016 5:19:38 AM -- Starting transaction dispatch ..
8/10/2016 5:19:38 AM -- Database cache settings: (minimum: 320.0 MB, maximum: 2.5 GB)
8/10/2016 5:19:38 AM -- Database flush thresholds: (start: 25.6 MB, stop: 51.2 MB)
8/10/2016 5:19:49 AM -- Database read latency thresholds: (average: 20 msec/read, maximum: 100 msec/read).
8/10/2016 5:19:49 AM -- Log write latency thresholds: (average: 10 msec/write, maximum: 100 msec/write).
8/10/2016 5:19:50 AM -- Operation mix: Sessions 22, Inserts 40%, Deletes 20%, Replaces 5%, Reads 35%, Lazy Commits 70%.
8/10/2016 5:19:50 AM -- Performance logging started (interval: 15000 ms).
8/10/2016 5:19:50 AM -- Attaining prerequisites:
8/10/2016 5:22:53 AM -- \MSExchange Database(JetstressWin)\Database Cache Size, Last: 2417054000.0 (lower bound: 2415919000.0, upper bound: none)
8/10/2016 7:22:54 AM -- Performance logging has ended.
8/10/2016 7:22:54 AM -- JetInterop batch transaction stats: 20188, 20188, 20187, 20187, 20187, 20187, 20187, 20187, 20187 and 20187.
8/10/2016 7:22:54 AM -- Dispatching transactions ends.
8/10/2016 7:22:54 AM -- Shutting down databases ...
8/10/2016 7:22:57 AM -- Instance3488.1 (complete), Instance3488.2 (complete), Instance3488.3 (complete), Instance3488.4 (complete), Instance3488.5 (complete), Instance3488.6 (complete), Instance3488.7 (complete), Instance3488.8 (complete), Instance3488.9 (complete) and Instance3488.10 (complete)
8/10/2016 7:22:57 AM -- C:\Program Files\Exchange Jetstress\2Hr Test\Performance_2016_8_10_5_19_49.blg has 491 samples.
8/10/2016 7:22:57 AM -- Creating test report ...
8/10/2016 7:23:01 AM -- Instance3488.1 has 15.4 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.1 has 3.1 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.1 has 3.1 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.2 has 14.0 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.2 has 3.5 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.2 has 3.5 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.3 has 13.8 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.3 has 3.0 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.3 has 3.0 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.4 has 13.9 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.4 has 3.0 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.4 has 3.0 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.5 has 13.9 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.5 has 3.2 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.5 has 3.2 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.6 has 13.9 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.6 has 2.8 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.6 has 2.8 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.7 has 13.8 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.7 has 2.8 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.7 has 2.8 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.8 has 13.9 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.8 has 3.1 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.8 has 3.1 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.9 has 13.7 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.9 has 2.8 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.9 has 2.8 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.10 has 13.8 for I/O Database Reads Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.10 has 3.1 for I/O Log Writes Average Latency.
8/10/2016 7:23:01 AM -- Instance3488.10 has 3.1 for I/O Log Reads Average Latency.
8/10/2016 7:23:01 AM -- Test has 0 Maximum Database Page Fault Stalls/sec.
8/10/2016 7:23:01 AM -- The test has 0 Database Page Fault Stalls/sec samples higher than 0.
8/10/2016 7:23:01 AM -- C:\Program Files\Exchange Jetstress\2Hr Test\Performance_2016_8_10_5_19_49.xml has 478 samples queried.

Database backup test results

Database Backup Statistics - All

Database Instance	Database Size (MBytes)	Elapsed Backup Time	MBytes Transferred/sec
Instance3488.1	1007568.03	05:27:46	51.23
Instance3488.2	1007592.03	04:58:20	56.29
Instance3488.3	1007600.03	04:56:53	56.56
Instance3488.4	1007584.03	05:00:43	55.84
Instance3488.5	1007592.03	04:56:44	56.59
Instance3488.6	1007608.03	04:56:53	56.57
Instance3488.7	1007608.03	04:57:31	56.45
Instance3488.8	1007576.03	04:56:49	56.58
Instance3488.9	1007608.03	05:02:03	55.60
Instance3488.10	1007608.03	04:56:55	56.56
Avg			55.83
Sum			558.26

Jetstress System Parameters

Thread Count	22
Minimum Database Cache	320.0 MB
Maximum Database Cache	2560.0 MB
Insert Operations	40%
Delete Operations	20%
Replace Operations	5%
Read Operations	35%
Lazy Commits	70%

Database Configuration

Instance3488.1 Log path: F:\Logs
Database: F:\Jetstress001001.edb

Instance3488.2 Log path: G:\Logs
Database: G:\Jetstress002001.edb

Instance3488.3 Log path: H:\Logs
Database: H:\Jetstress003001.edb

Instance3488.4 Log path: I:\Logs
Database: I:\Jetstress004001.edb

Instance3488.5 Log path: J:\Logs
Database: J:\Jetstress005001.edb

Instance3488.6 Log path: K:\Logs
Database: K:\Jetstress006001.edb

Instance3488.7 Log path: L:\Logs
Database: L:\Jetstress007001.edb

Instance3488.8 Log path: M:\Logs
Database: M:\Jetstress008001.edb

Instance3488.9 Log path: N:\Logs
Database: N:\Jetstress009001.edb

Instance3488.10 Log path: O:\Logs
Database: O:\Jetstress010001.edb

Transactional I/O Performance

MSExchange Database ==> Instances	I/O Database Reads Average Latency (msec)	I/O Database Writes Average Latency (msec)	I/O Database Reads/sec	I/O Database Writes/sec	I/O Database Reads Average Bytes	I/O Database Writes Average Bytes	I/O Log Reads Average Latency (msec)	I/O Log Writes Average Latency (msec)	I/O Log Reads/sec	I/O Log Writes/sec	I/O Log Reads Average Bytes	I/O Log Writes Average Bytes
Instance3488.1	5.534	0.000	204.786	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.2	4.932	0.000	224.777	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.3	4.898	0.000	225.886	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.4	4.960	0.000	223.264	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.5	4.884	0.000	226.280	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.6	4.893	0.000	225.884	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.7	4.891	0.000	225.025	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.8	4.891	0.000	226.061	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.9	4.975	0.000	221.557	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Instance3488.10	4.886	0.000	225.812	0.000	262144.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Host System Performance

Counter	Average	Minimum	Maximum
% Processor Time	1.490	0.250	2.767
Available MBytes	201614.711	201606.000	201618.000
Free System Page Table Entries	16461689.591	16461459.000	16461871.000
Transition Pages RePurposed/sec	0.000	0.000	0.000
Pool Nonpaged Bytes	71665366.962	71606272.000	71745536.000
Pool Paged Bytes	169509933.337	169508864.000	169525248.000
Database Page Fault Stalls/sec	0.000	0.000	0.000

Test Log

8/11/2016 6:25:53 PM -- Preparing for testing ...
8/11/2016 6:26:03 PM -- Attaching databases ...
8/11/2016 6:26:03 PM -- Preparations for testing are complete.
8/11/2016 6:26:14 PM -- Performance logging started (interval: 30000 ms).
8/11/2016 6:26:14 PM -- Backing up databases ...
8/11/2016 11:54:01 PM -- Performance logging has ended.
8/11/2016 11:54:01 PM -- Instance3488.1 (100% processed), Instance3488.2 (100% processed), Instance3488.3 (100% processed), Instance3488.4 (100% processed), Instance3488.5 (100% processed), Instance3488.6 (100% processed), Instance3488.7 (100% processed), Instance3488.8 (100% processed), Instance3488.9 (100% processed) and Instance3488.10 (100% processed)
8/11/2016 11:54:01 PM -- C:\Program Files\Exchange Jetstress\DB_Backup\DatabaseBackup_2016_8_11_18_26_3.blg has 655 samples.
8/11/2016 11:54:01 PM -- Creating test report ...

Soft recovery test results

Soft-Recovery Statistics - All

Database Instance	Log files replayed	Elapsed seconds
Instance3488.1	502	1286.7343856
Instance3488.2	509	1456.5938303
Instance3488.3	501	1427.9999745
Instance3488.4	508	1459.5000199
Instance3488.5	506	1457.6407003
Instance3488.6	503	1461.8749583
Instance3488.7	504	1498.3750112
Instance3488.8	501	1432.515613
Instance3488.9	506	1442.5781177
Instance3488.10	508	1492.0156994
Avg	504	1441.583
Sum	5048	14415.8283102

Database Configuration

Instance3488.1 Log path: F:\Logs
Database: F:\Jetstress001001.edb

Instance3488.2 Log path: G:\Logs
Database: G:\Jetstress002001.edb

Instance3488.3 Log path: H:\Logs
Database: H:\Jetstress003001.edb

Instance3488.4 Log path: I:\Logs
Database: I:\Jetstress004001.edb

Instance3488.5 Log path: J:\Logs
Database: J:\Jetstress005001.edb

Instance3488.6 Log path: K:\Logs
Database: K:\Jetstress006001.edb

Instance3488.7 Log path: L:\Logs
Database: L:\Jetstress007001.edb

Instance3488.8 Log path: M:\Logs
Database: M:\Jetstress008001.edb

Instance3488.9 Log path: N:\Logs
Database: N:\Jetstress009001.edb

Instance3488.10 Log path: O:\Logs
Database: O:\Jetstress010001.edb

Transactional I/O Performance

MSExchange Database ==> Instances	I/O Database Reads Average Latency (msec)	I/O Database Writes Average Latency (msec)	I/O Database Reads/sec	I/O Database Writes/sec	I/O Database Reads Average Bytes	I/O Database Writes Average Bytes	I/O Log Reads Average Latency (msec)	I/O Log Writes Average Latency (msec)	I/O Log Reads/sec	I/O Log Writes/sec	I/O Log Reads Average Bytes	I/O Log Writes Average Bytes
Instance3488.1	158.237	10.773	208.646	1.555	37783.795	24858.483	2.411	0.000	1.944	0.000	158424.319	0.000
Instance3488.2	73.836	1.542	184.160	1.380	37910.316	25869.474	2.806	0.000	1.724	0.000	165629.555	0.000
Instance3488.3	69.361	1.452	188.905	1.387	37938.571	25640.497	2.355	0.000	1.734	0.000	162914.350	0.000
Instance3488.4	83.222	4.107	181.789	1.379	37940.349	25616.972	2.328	0.000	1.723	0.000	163908.582	0.000
Instance3488.5	89.729	5.062	181.828	1.387	37833.690	25254.895	2.521	0.000	1.740	0.000	161568.481	0.000
Instance3488.6	82.940	24.922	185.797	1.375	38081.184	25817.212	2.221	0.000	1.725	0.000	164098.437	0.000
Instance3488.7	79.037	2.857	179.069	1.344	37832.132	25368.774	2.283	0.000	1.680	0.000	162360.155	0.000
Instance3488.8	124.273	2.081	184.782	1.380	37668.823	25660.575	2.309	0.000	1.726	0.000	164227.678	0.000
Instance3488.9	99.804	3.436	186.214	1.397	38106.932	25354.011	2.257	0.000	1.746	0.000	162265.672	0.000
Instance3488.10	67.841	1.520	181.629	1.359	38120.582	26125.838	2.161	0.000	1.699	0.000	166640.201	0.000

Background Database Maintenance I/O Performance

MSExchange Database ==> Instances	Database Maintenance IO Reads/sec	Database Maintenance IO Reads Average Bytes
Instance3488.1	0.000	0.000
Instance3488.2	0.000	0.000
Instance3488.3	0.000	0.000
Instance3488.4	0.000	0.000
Instance3488.5	0.000	0.000
Instance3488.6	0.000	0.000
Instance3488.7	0.000	0.000
Instance3488.8	0.000	0.000
Instance3488.9	0.000	0.000
Instance3488.10	0.000	0.000

Total I/O Performance

MSExchange Database ==> Instances	I/O Database Reads Average Latency (msec)	I/O Database Writes Average Latency (msec)	I/O Database Reads/sec	I/O Database Writes/sec	I/O Database Reads Average Bytes	I/O Database Writes Average Bytes	I/O Log Reads Average Latency (msec)	I/O Log Writes Average Latency (msec)	I/O Log Reads/sec	I/O Log Writes/sec	I/O Log Reads Average Bytes	I/O Log Writes Average Bytes
Instance3488.1	158.237	10.773	208.646	1.555	37783.795	24858.483	2.411	0.000	1.944	0.000	158424.319	0.000
Instance3488.2	73.836	1.542	184.160	1.380	37910.316	25869.474	2.806	0.000	1.724	0.000	165629.555	0.000
Instance3488.3	69.361	1.452	188.905	1.387	37938.571	25640.497	2.355	0.000	1.734	0.000	162914.350	0.000
Instance3488.4	83.222	4.107	181.789	1.379	37940.349	25616.972	2.328	0.000	1.723	0.000	163908.582	0.000
Instance3488.5	89.729	5.062	181.828	1.387	37833.690	25254.895	2.521	0.000	1.740	0.000	161568.481	0.000
Instance3488.6	82.940	24.922	185.797	1.375	38081.184	25817.212	2.221	0.000	1.725	0.000	164098.437	0.000
Instance3488.7	79.037	2.857	179.069	1.344	37832.132	25368.774	2.283	0.000	1.680	0.000	162360.155	0.000
Instance3488.8	124.273	2.081	184.782	1.380	37668.823	25660.575	2.309	0.000	1.726	0.000	164227.678	0.000
Instance3488.9	99.804	3.436	186.214	1.397	38106.932	25354.011	2.257	0.000	1.746	0.000	162265.672	0.000
Instance3488.10	67.841	1.520	181.629	1.359	38120.582	26125.838	2.161	0.000	1.699	0.000	166640.201	0.000

Host System Performance

Counter	Average	Minimum	Maximum
% Processor Time	1.036	0.000	2.746
Available MBytes	199014.121	198904.000	201500.000
Free System Page Table Entries	16461485.051	16461258.000	16461627.000
Transition Pages RePurposed/sec	0.000	0.000	0.000
Pool Nonpaged Bytes	72458261.962	72163328.000	72699904.000
Pool Paged Bytes	170132510.198	170127360.000	170151936.000
Database Page Fault Stalls/sec	0.000	0.000	0.000

Test Log

```
8/12/2016 3:35:45 AM -- Preparing for testing ...
8/12/2016 3:35:55 AM -- Attaching databases ...
8/12/2016 3:35:55 AM -- Preparations for testing are complete.
8/12/2016 3:35:55 AM -- Starting transaction dispatch ..
8/12/2016 3:35:55 AM -- Database cache settings: (minimum: 320.0 MB, maximum: 2.5 GB)
8/12/2016 3:35:55 AM -- Database flush thresholds: (start: 25.6 MB, stop: 51.2 MB)
8/12/2016 3:36:06 AM -- Database read latency thresholds: (average: 20 msec/read, maximum: 100 msec/read).
8/12/2016 3:36:06 AM -- Log write latency thresholds: (average: 10 msec/write, maximum: 100 msec/write).
8/12/2016 3:36:07 AM -- Operation mix: Sessions 22, Inserts 40%, Deletes 20%, Replaces 5%, Reads 35%, Lazy Commits 70%.
8/12/2016 3:36:07 AM -- Performance logging started (interval: 15000 ms).
8/12/2016 3:36:07 AM -- Generating log files ...
8/12/2016 5:10:02 AM -- F:\Logs (100.4% generated), G:\Logs (101.8% generated), H:\Logs (100.2% generated), I:\Logs (101.6% generated), J:\Logs (101.2% generated),
K:\Logs (100.6% generated), L:\Logs (100.8% generated), M:\Logs (100.2% generated), N:\Logs (101.2% generated) and O:\Logs (101.6% generated)
8/12/2016 5:10:02 AM -- Performance logging has ended.
8/12/2016 5:10:02 AM -- JetInterop batch transaction stats: 17120, 17120, 17120, 17120, 17120, 17120, 17119, 17119, 17119 and 17119.
8/12/2016 5:10:02 AM -- Dispatching transactions ends.
8/12/2016 5:10:02 AM -- Shutting down databases ...
8/12/2016 5:10:05 AM -- Instance3488.1 (complete), Instance3488.2 (complete), Instance3488.3 (complete), Instance3488.4 (complete), Instance3488.5 (complete),
Instance3488.6 (complete), Instance3488.7 (complete), Instance3488.8 (complete), Instance3488.9 (complete) and Instance3488.10 (complete)
8/12/2016 5:10:05 AM -- C:\Program Files\Exchange Jetstress\Soft_Recovery\Performance_2016_8_12_3_36_6.blg has 375 samples.
8/12/2016 5:10:05 AM -- Creating test report ...
8/12/2016 5:10:08 AM -- Instance3488.1 has 13.9 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.1 has 2.9 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.1 has 2.9 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.2 has 12.7 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.2 has 2.8 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.2 has 2.8 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.3 has 12.6 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.3 has 3.0 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.3 has 3.0 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.4 has 12.6 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.4 has 2.7 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.4 has 2.7 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.5 has 12.5 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.5 has 2.7 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.5 has 2.7 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.6 has 12.6 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.6 has 2.7 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.6 has 2.7 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.7 has 12.6 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.7 has 2.7 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.7 has 2.7 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.8 has 12.5 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.8 has 2.7 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.8 has 2.7 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.9 has 12.5 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.9 has 2.6 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.9 has 2.6 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.10 has 12.6 for I/O Database Reads Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.10 has 2.6 for I/O Log Writes Average Latency.
8/12/2016 5:10:08 AM -- Instance3488.10 has 2.6 for I/O Log Reads Average Latency.
8/12/2016 5:10:08 AM -- Test has 0 Maximum Database Page Fault Stalls/sec.
8/12/2016 5:10:08 AM -- The test has 0 Database Page Fault Stalls/sec samples higher than 0.
8/12/2016 5:10:08 AM -- C:\Program Files\Exchange Jetstress\Soft_Recovery\Performance_2016_8_12_3_36_6.xml has 374 samples queried.
8/12/2016 5:10:08 AM -- C:\Program Files\Exchange Jetstress\Soft_Recovery\Performance_2016_8_12_3_36_6.html was saved.
8/12/2016 5:10:08 AM -- Performance logging started (interval: 4000 ms).
8/12/2016 5:10:08 AM -- Recovering databases ...
8/12/2016 5:35:08 AM -- Performance logging has ended.
```

Appendix B - Resources

- Lenovo Converged HX Series Product Guide
  lenovopress.com/lp0059
- Lenovo Converged HX Series landing page
  shop.lenovo.com/us/en/systems/converged-systems/hx_series
- Nutanix Portal (requires registration)
  portal.nutanix.com
- Nutanix Bible
  nutanixbible.com/
- Nutanix Tech Note: VMware vSphere Networking on Nutanix
  go.nutanix.com/rs/nutanix/images/Nutanix_TechNote-VMware_vSphere_Networking_with_Nutanix.pdf

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