

Meet the Lenovo® Storage N4610 Windows Server® Storage appliance.

9.8K IOPS
write-only workload

28.2K IOPS
read-only workload

5.0K IOPS
mixed-read workload



Powered by the Intel® Xeon® processor E5-2600 v3 product family

Strong storage performance is vital to getting the most from your business's server infrastructure. Storage subsystems are often the slowest segment of your database infrastructure, so having fast storage can increase application performance. The Lenovo Storage N4610 is a Windows Storage Server network-attached storage (NAS) appliance that based on the Intel Grantley platform with large memory capacity and expandable storage options. Utilizing innovations from Lenovo's ThinkServer line, Lenovo Storage N4610 comes with Microsoft Windows Storage Server preloaded to get you up and running quickly.

In the Principled Technologies labs, we tested the input/output (I/O) performance of the Lenovo Storage N4610 appliance. We used the Iometer benchmark utility to test 12 different I/O profiles. We ran each of the 12 tests two ways—first, by mounting the appliance volume using the Common Internet File System (CIFS), and second, by mounting the appliance volume as an iSCSI volume.



LENOVO STORAGE N4610 STORAGE DENSITY AND FLEXIBILITY

The Lenovo Storage N4610 brings together the strengths of the Lenovo ThinkServer innovations and Windows Storage Server 2012 R2, which supports the latest Storage Spaces capabilities, virtualizing your storage environment to provide continuously available file and block storage. It offers many advantages:

- **Storage density.** With up to 12 drive bays, Lenovo Storage N4610 can provide up to 72 TB of internal storage. If that isn't enough, the N4610 is interoperable with the ThinkServer SA120 JBOD, which expands storage capacity and supports tiering and caching. With tiering and caching, you can improve performance by allowing frequently accessed data to reside on faster storage while maintaining good capacity.
- **Flexibility.** Lenovo AnyFabric and AnyRAID technology give you up to four 10Gb Ethernet ports and choice of RAID adapter, without using any PCIe slots. Using Lenovo AnyRAID design, you can integrate data protection in a fault-tolerant design, which helps reduce downtime while keeping your data secure and available.
- **Processing power.** The Lenovo Storage N4610 uses the latest Intel Grantley platform, which supports the new Haswell processors and C610 series chipset.
- **Reliability.** Because the N4610 uses ThinkServer technology, it can run at 45 degrees Celsius (113 degrees Fahrenheit) for days with no performance degradation.¹ The appliance also boasts the following high-reliability features: Error Correcting Code (ECC) memory, hot-swap hard disk drive and SSD capability, and hot-swap/redundant power and cooling.
- **Convenience.** Microsoft Windows Storage Server comes preloaded on the N4610, saving you time.

Learn more about Lenovo Storage N4610 at

shop.lenovo.com/us/en/systems/storage/nas/LenovoStorage/n4610/.

ABOUT MICROSOFT WINDOWS STORAGE SERVER 2012 R2

Lenovo Storage N4610 takes advantage of the latest features available in Windows Storage Server 2012 R2. Enhancements include the following:

- **Failover clustering.** Improvements to virtual machine availability, Cluster Shared Volumes (CSV), dynamic cluster quorums, cluster node health detection, deployment, updating and monitoring.

¹ See the Principled Technologies report, "Lenovo ThinkServer RD650: Continuous performance in extreme temperatures," available at www.principledtechnologies.com/Lenovo/RD650_extreme_heat_1214.pdf.

- **DFS replication.** Increases in scalability, the ability to do database cloning and corruption recovery, a Windows PowerShell module, a new WMI provider, faster replication on high-bandwidth connections, and recovery tools for conflicts.
- **Storage Spaces.** Storage tiering, SSD write-back caches for storage spaces, parity storage spaces on failover clusters, dual parity storage spaces, and faster rebuilding of storage spaces after disk failures.
- **Data deduplication.** Support for Cluster Shared Volumes and deduplication of live Virtual Desktop Infrastructure (VDI) VMs that reside on a file server connected via SMB.

To learn more about Windows Server 2012 R2, visit

<https://technet.microsoft.com/en-us/library/jj643303.aspx>.

THE DIFFERENCE BETWEEN CIFS AND ISCSI

CIFS is a NAS technology that presents storage volumes to a server via the network as a file share. The server or storage appliance that holds the shared volume is responsible for all file system tasks. Windows Storage Server 2012 R2 uses the SMB 3.0 protocol that we leveraged for our testing. SMB 3.0 offers several features including automatic path discovery, automatic multipathing, and transparent failover technologies.

With iSCSI connections, however, the client accesses the storage on the storage appliance as a block device, not a file share. The machine accessing the storage is then responsible for all file-system tasks. The storage appliance has no direct control over the contents of its volume.

OUR TESTING

To measure the I/O performance of the Lenovo Storage N4610, we used the Iometer benchmark utility to synthetically emulate 12 I/O profiles, which we selected to represent a broad I/O spectrum. We tested each profile twice, once using a CIFS connection and once using an iSCSI connection. (For the configuration details of our test servers and storage, see [Appendix A](#). For the details of our test procedure and information about Iometer, see [Appendix B](#).)

We began by installing Windows Server 2012 R2 and all relevant updates on the RD530 server that drove the Iometer workload. We then installed Iometer and created the Iometer test file (200 GB) on the Lenovo Storage N4610 volume.

Figure 1 illustrates our test bed.

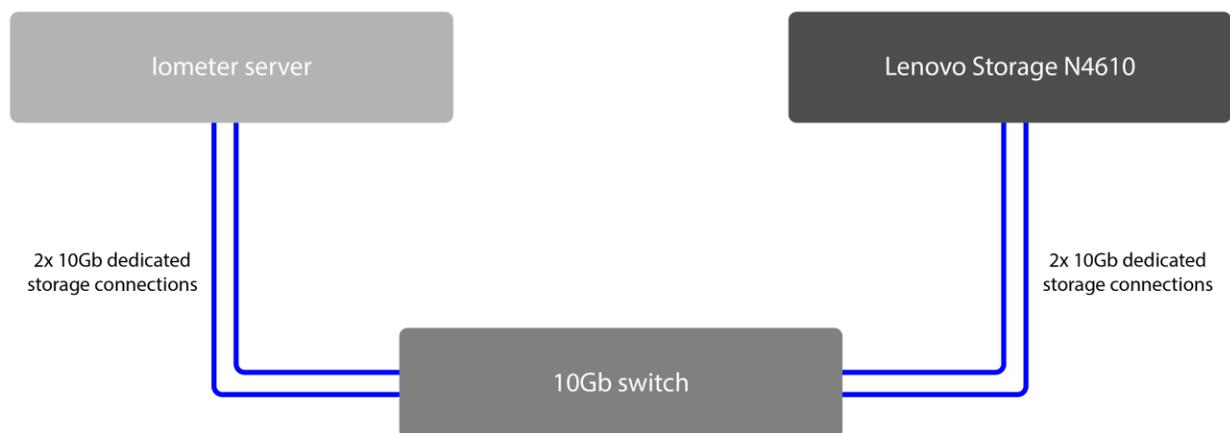


Figure 1: Test bed diagram.

CIFS testing

We connected the Iometer server to the N4610 appliance via CIFS and used Iometer to run 12 I/O profiles. We used four different access specifications tested each with three different block sizes. For all 12 profiles, we used a single worker, and set the number of outstanding I/Os to 64. Figure 2 summarizes our results.

Access specification name and block size	IOPS	Latency	Throughput
100% writes, 100% sequential, 32KB	9,778.90	6.54	320.43
100% writes, 100% sequential, 64KB	7,623.27	8.39	499.60
100% writes, 100% sequential, 128KB	6,219.89	10.29	815.25
100% reads, 100% sequential, 32KB	28,213.96	2.27	924.51
100% reads, 100% sequential, 64KB	17,536.79	3.65	1,149.29
100% reads, 100% sequential, 128KB	8,962.90	7.14	1,174.79
80% reads/20% writes, 100% random, 2KB	4,959.67	12.90	10.16
80% reads/20% writes, 100% random, 4KB	4,896.74	13.07	20.06
80% reads/20% writes, 100% random, 8KB	4,759.60	13.44	38.99
67% reads/33% writes, 100% random, 2KB	4,543.12	14.09	9.30
67% reads/33% writes, 100% random, 4KB	4,519.47	14.16	18.51
67% reads/33% writes, 100% random, 8KB	4,467.65	14.32	36.60

Figure 2: Iometer results for the Lenovo Storage N4610 connected via CIFS.

As Figures 3 and 4 show, for the two sequential access specifications in our CIFS testing, the number of IOPS increased as the block size decreased. Halving the block size from 128 KB to 64 KB increased IOPS by 23 percent in the 100 percent writes test and by 96 percent in the 100 percent reads test. Halving the block size from 64 KB to 32 KB increased IOPS by 28 percent in the 100 percent writes test and by 61 percent in the 100 percent reads test.

Figure 3: CIFS Iometer results for 100% writes, 100% sequential access specification at the three block sizes we tested.

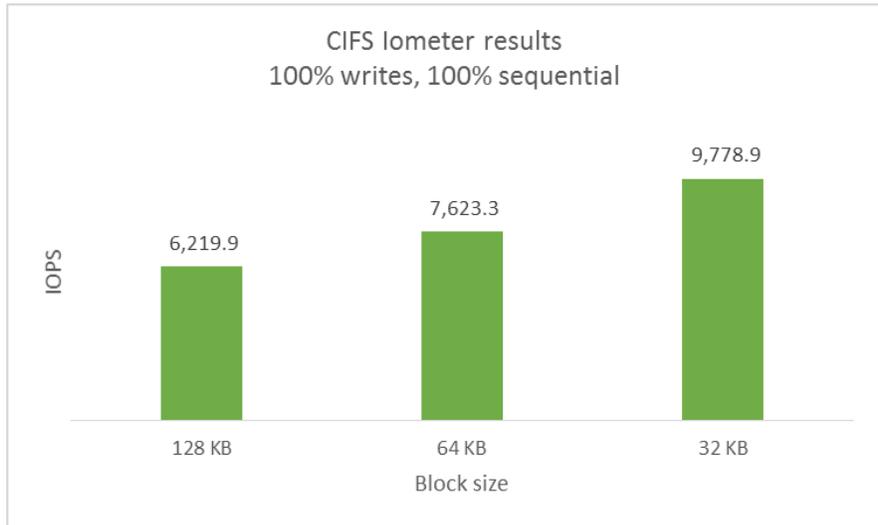
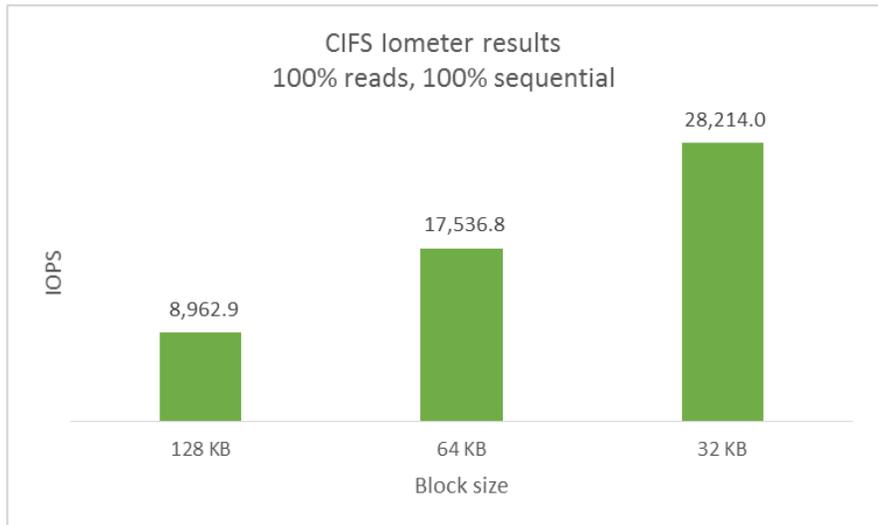


Figure 4: CIFS Iometer results for 100% reads, 100% sequential access specification at the three block sizes we tested.



As Figures 5 and 6 show, in two random access specifications in our CIFS testing, the number of IOPS increased much less dramatically as the block size decreased. Halving the block size from 8 KB to 4 KB increased IOPS by 3 percent in the 80 percent reads/20 percent writes test and by only 1 percent in the 67 percent reads/33 percent writes test. Halving the block size from 4 KB to 2 KB increased IOPS by 1 percent in the 80 percent reads/20 percent writes test and by less than 1 percent in the 67 percent reads/33 percent writes test.

Figure 5: CIFS Iometer results for 80% reads/20% writes, 100% random access specification at the three block sizes we tested.

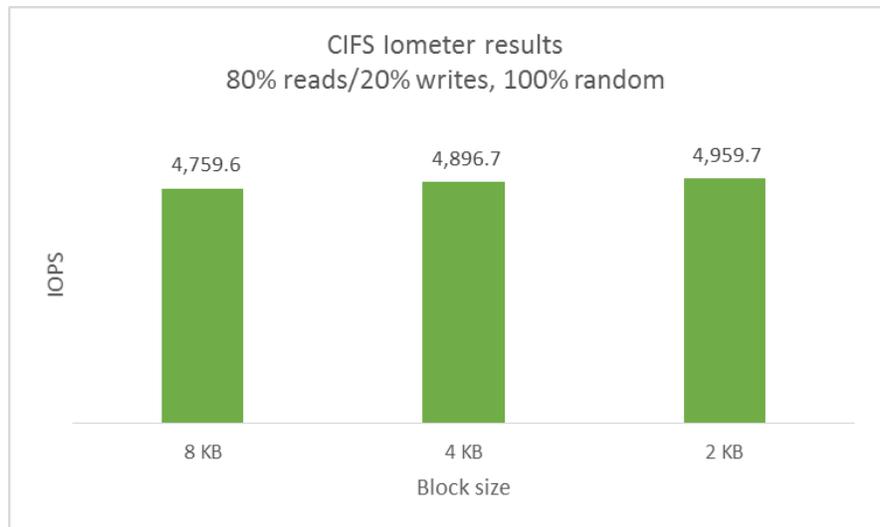
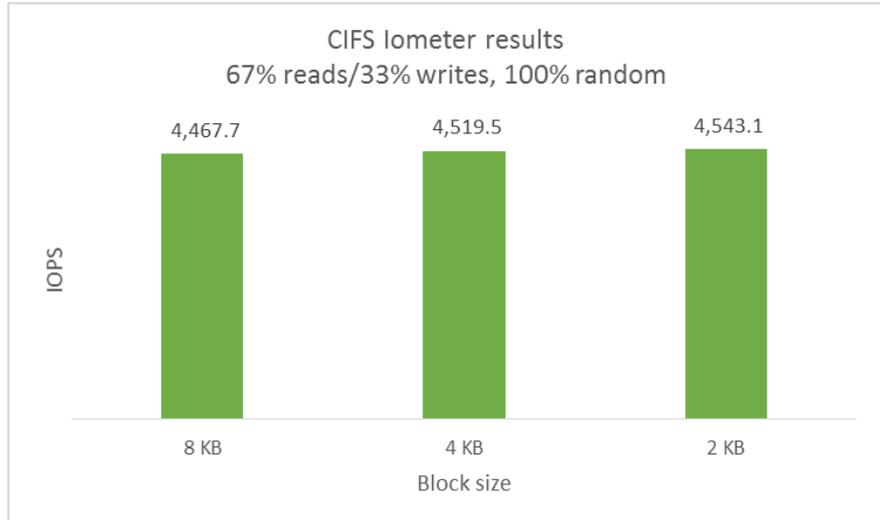


Figure 6: CIFS Iometer results for 67% reads/33% writes, 100% random access specification at the three block sizes we tested.



ISCSI testing

Next, we connected the Iometer server to the N4610 via iSCSI, and ran the same 12 I/O profiles using Iometer. For all profiles, we used one worker, and set the number of outstanding I/Os to 64. Figure 7 summarizes our results.

Access specification name and block size	IOPS	Latency	Throughput
100% writes, 100% sequential, 32KB	5,570.61	11.49	182.54
100% writes, 100% sequential, 64KB	3,862.36	16.57	253.12
100% writes, 100% sequential, 128KB	3,503.24	18.27	459.18
100% reads, 100% sequential, 32KB	15,861.66	4.03	519.75
100% reads, 100% sequential, 64KB	10,432.28	6.13	683.69
100% reads, 100% sequential, 128KB	7,462.63	8.57	978.14
80% reads/20% writes, 100% random, 2KB	1,716.64	37.28	3.52
80% reads/20% writes, 100% random, 4KB	1,820.35	35.16	7.46
80% reads/20% writes, 100% random, 8KB	1,914.72	33.42	15.69
67% reads/33% writes, 100% random, 2KB	1,957.44	32.69	4.01
67% reads/33% writes, 100% random, 4KB	1,808.10	35.39	7.41
67% reads/33% writes, 100% random, 8KB	1,839.00	34.80	15.07

Figure 7: Iometer results for the Lenovo Storage N4610 connected via iSCSI.

As Figures 8 and 9 show, for the two sequential access specifications in our iSCSI testing, the number of IOPS increased as the block size decreased. Halving the block size from 128 KB to 64 KB increased IOPS by 10 percent in the 100 percent writes test and by 40 percent in the 100 percent reads test. Halving the block size from 64 KB to 32 KB increased IOPS by 44 percent in the 100 percent writes test and by 52 percent in the 100 percent reads test.

Figure 8: ISCSI Iometer results for 100% writes, 100% sequential access specification at the three block sizes we tested.

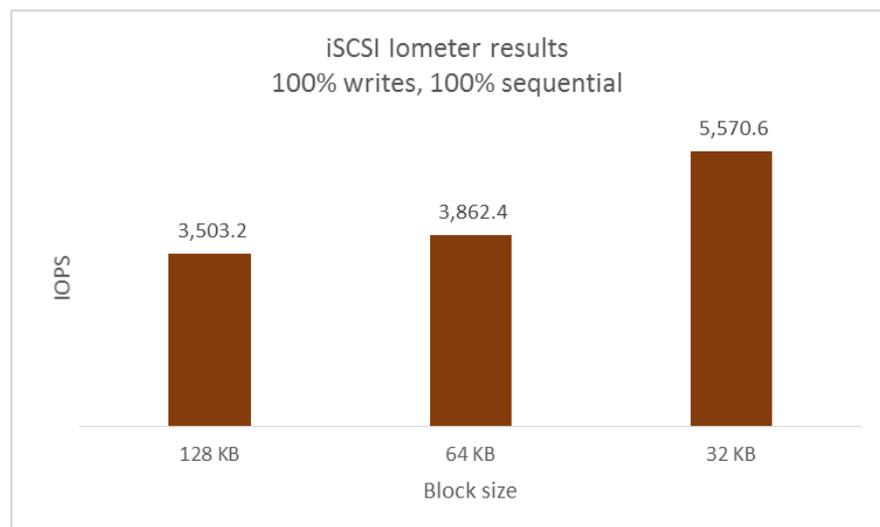
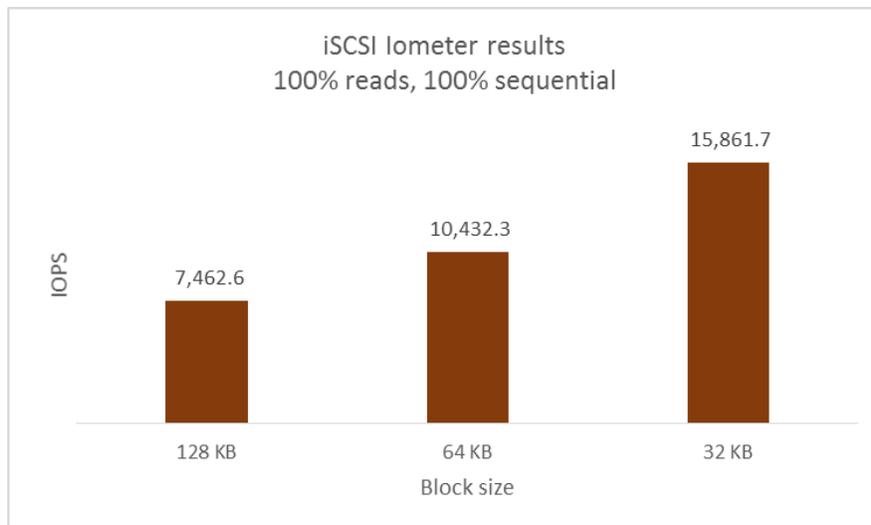
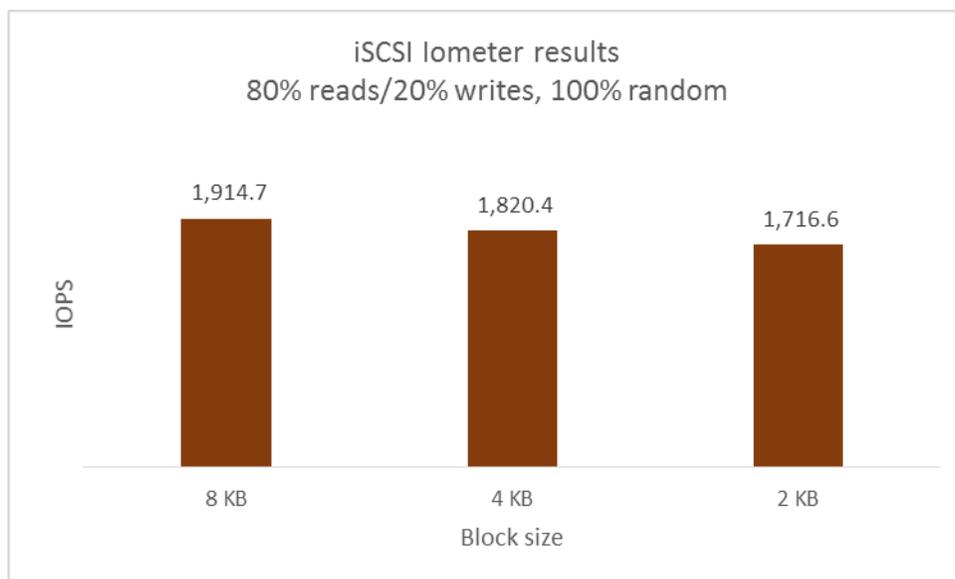


Figure 9: iSCSI lometer results for 100% reads, 100% sequential access specification at the three block sizes we tested.



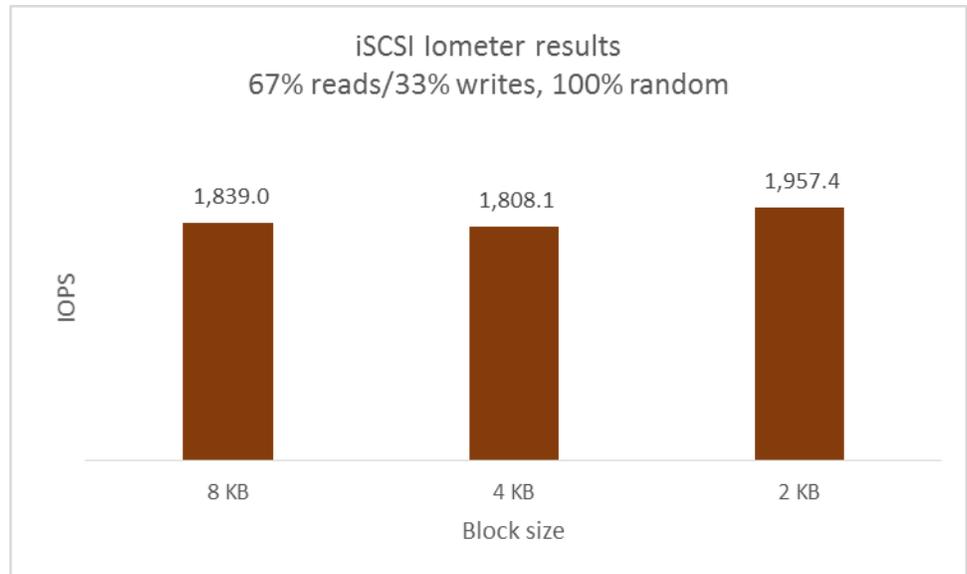
As Figure 10 shows, in the 80 percent reads/20 percent writes random access iSCSI test, the number of IOPS decreased as the block size decreased. Halving the block size from 8 KB to 4 KB decreased IOPS by 5 percent and halving the block size from 4 KB to 2 KB decreased IOPS by 6 percent.

Figure 10: iSCSI lometer results for 80% reads/20% writes, 100% random access specification at the three block sizes we tested.



As Figure 11 shows, in the 67 percent reads/33 percent writes random access iSCSI test, halving the block size from 8 KB to 4 KB decreased IOPS by 5 percent and halving the block size from 4 KB to 2 KB increased IOPS by 8 percent.

Figure 11: iSCSI iometer results for 67% reads/33% writes, 100% random access specification at the three block sizes we tested.



CONCLUSION

In the Principled Technologies labs, we measured the performance the Lenovo Storage N4610 appliance delivered across 12 different I/O profiles in two storage configurations, one with the appliance volume mounted using the Common Internet File System (CIFS) and one with the appliance volume mounted as an iSCSI volume.

Along with delivering high storage capacity, the Lenovo Storage N4610 also leverages the processing power of the Intel Grantley platform. In addition, it provides Lenovo ThinkServer technologies, and saves you time by having Microsoft Windows Storage Server preloaded.

APPENDIX A – DETAILED SERVER CONFIGURATION

Figure 11 provides detailed configuration information for the test systems.

System	Lenovo ThinkServer RD530	Lenovo Storage N4610
General		
Number of processor packages	2	1
Number of cores per processor	6	8
Number of hardware threads per core	2	2
System power management policy	Balanced	Balanced
CPU		
Vendor	Intel	Intel
Name	Xeon	Xeon
Model number	E5-2640 0	E5-2640 v3
Stepping	7	2
Socket type	FCLGA2011	FCLGA2011-3
Core frequency (GHz)	2.5	2.6
Bus frequency	7.2 GT/s	8 GT/s
L1 cache	32 KB + 32 KB (per core)	32 KB + 32 KB (per core)
L2 cache	256KB (per core)	256KB (per core)
L3 cache	15 MB (shared)	20 MB (shared)
Platform		
Vendor and model number	Lenovo ThinkServer RD530	Lenovo Storage N4610
BIOS name and version	Lenovo 2.05	PB2TS133 1.33.0
BIOS settings	Default	Default
Memory modules		
Total RAM in system (GB)	64 GB	8 GB
Vendor and model number	SK Hynix HMT31GR7CFR4C-PB	SK Hynix HMA41GR7MFR4N-TF
Type	PC3-12800R	PC4-2133P
Speed (MHz)	1600	2133
Speed running in the system (MHz)	1333	1866
Size (GB)	8	8
Number of RAM module(s)	8	1
Chip organization	Double-sided	Double-sided
Rank	Dual	Single
RAID controller		
Vendor and model number	LSI® MegaRAID® SAS 9260-8i	Lenovo ThinkServer RAID 720ix AnyRAID Adapter
Firmware version	2.120.183-141	24.6.0-0040
Hard drives 1		
Vendor and model number	Seagate® ST9146802SS	Seagate ST4000NM0023
Number of drives	2	12
Size (GB)	146GB	4TB
RPM	10000	7200

System	Lenovo ThinkServer RD530	Lenovo Storage N4610
Type	SAS	SAS
Hard drives 2		
Vendor and model number	N/A	Seagate ST9500620NS
Number of drives	N/A	2
Size (GB)	N/A	500GB
RPM	N/A	7200
Type	N/A	SATA
Networking adapter 1		
Vendor and model number	Intel I350	Lenovo ThinkServer I350-T4 AnyFabric
Speed	1Gb	1Gb
Networking adapter 2		
Vendor and model number	Intel X540-T2	Intel X540-T2
Speed	10Gb	10Gb
Networking adapter 3		
Vendor and model number	Intel 82574L	N/A
Speed	1Gb	N/A

Figure 11: Detailed configuration information for the test systems.

APPENDIX B – DETAILED TEST METHODOLOGY

About lometer

lometer measures IOPS on single and clustered systems. lometer performs I/O operations to stress a system, and then records the performance of these I/O operations and the system stress they create. We used lometer version 1.1.0 on each solution to simulate the same file workloads on the solutions. For more details about lometer, see www.lometer.org.

Installing Microsoft Windows Server 2012 R2 Datacenter Edition on the lometer Server

1. Insert the installation media into the CD/DVD drive of the lometer server, and restart the server.
2. When the option appears, press F11 to enter the Boot Manager.
3. Select BIOS Boot Menu.
4. Select SATA Optical Drive, and press Enter.
5. Press any key when prompted to boot from DVD.
6. When the installation screen appears, click My language is English (United States).
7. Leave language, time/currency format, and input method as default, and click Next.
8. Click Install now.
9. When the installation prompts you, enter the product key.
10. Select Windows Server 2012 Datacenter (Server with a GUI), and click Next.
11. Check I accept the license terms, and click Next.
12. Click Custom: Install Windows only (advanced).
13. Select the drive on which you want to install the OS, and click Next, at which point Windows begins automatically, and restarts automatically after completing.
14. When the Settings page appears, fill in the Password and Reenter Password fields with the same password.
15. Log in with the password you set up previously.

Configuring Windows Update

1. Open Windows Server Manager
2. Click Local Server.
3. Next to Windows Update, click Not configured.
4. Click Let me choose my settings.
5. Never check for updates (not recommended), and click OK.
6. Click Check for updates, and install all available updates.
7. Close the Windows Update window.

Configuring Private Network

We configured two 10Gb ports on both the server and the storage appliance for dedicated storage traffic. We configured our 10Gb switch to use jumbo frames.

1. From the Start menu on the N4610, select Control Panel.
2. Click Network and Internet.

3. Under Network and Sharing Center, click View network status and tasks.
4. Select the port currently used in the private network.
5. Click Properties.
6. Select the IPv4 connection and click Properties.
7. Assign a static IP address.
8. Click Advanced...
9. In the DNS tab uncheck Register this connection's addresses in DNS, and click OK.
10. Click OK.
11. Click Configure.
12. On the Advanced tab, choose the Storage Server Profile from the dropdown menu.
13. Scroll through Settings, and highlight Jumbo Packet.
14. Choose 9014 Bytes in the Value dropdown menu.
15. Click OK.
16. Repeat steps 2 through 12 on the second NIC, and both NICs on the Iometer server.

Installing Iometer on the Iometer server

1. On the Iometer server, open Internet Explorer.
2. Navigate to www.iometer.org/doc/downloads.html
3. Click the download link for Iometer 1.1.0 for Windows x86-64.
4. Once the download finishes, unzip iometer-1.1.0-win64.x86_64-bin.zip.
5. Double-click on IOmeter.exe and follow the on-screen instructions to install Iometer on the Iometer server using all default settings.

Configuring the Iometer server for iSCSI

1. On the Iometer server, open Windows Server Manager.
2. Click Add roles and features.
3. On the Before you begin screen, click Next.
4. Choose Role-based or feature-based installation, and click Next.
5. Choose the local server, and click Next.
6. Leave default server roles, and click Next.
7. Choose Multipath I/O, and click Next.
8. Click Install.
9. Click Close.
10. Press start, type `MPIO`, and click on the MPIO icon that pops up in the search results.
11. Select the Discover Multi-Paths tab.
12. Check Add support for iSCSI devices, and click Add.
13. Click Yes when prompted for reboot.
14. When the computer has finished rebooting, follow step 10 to launch MPIO properties again.
15. Verify that `MSFT2005iSCSIBusType_0x9` is listed in the Device Hardware Id window.
16. Click OK.

17. Click Start, type `iSCSI Initiator`, and click on the iSCSI Initiator icon in the search results.
18. Click Yes to enable the iSCSI service.
19. On the Targets tab, type the host name of the appliance server, and click Quick Connect...
20. On the Quick Connect screen, click done.
21. On the Favorite Targets tab, highlight the iqn listed, and click Remove.
22. Return to the Targets tab, and click Properties.
23. Check the box of the identifier listed, and click Disconnect.
24. Click Add session.
25. Check the box for Enable multi-path, and click Advanced...
26. In the Local Adapter dropdown list, choose Microsoft iSCSI Initiator.
27. In the Initiator IP window, select the first static IP of the Iometer server.
28. In the Target portal IP, select the first static IP of the storage appliance.
29. Click OK to close the advanced settings window.
30. Click OK to close the target window.
31. Repeat steps 24 through 30 to create an identifier using the 2nd IPs of both servers.
32. To verify each target, select the Favorite Targets tab.
33. Highlight each target, and click Details.
34. Verify that the Source IP and Target IPs are correct.

Add the iSCSI target role on the N4610

We added the Windows iSCSI role to the storage appliance to allow the Iometer server to connect via iSCSI.

1. Open Windows server manager, and click Manage → Add Roles and Features
2. On the Before you begin page, click Next.
3. Choose Role-based or feature-based installation, and click Next.
4. Choose the local server, and click Next.
5. Expand File and Storage Services Role, and expand File and iSCSI Services.
6. Check the box for iSCSI Target Server, and choose Install on the required services popup. Click Next.
7. Leave default features, and click Next.
8. Click Install.

Creating the iSCSI virtual disk and server target on the N4610

We created a RAID 10 volume consisting of all 12 front bay drives, and mounted it as D: on the N4610.

1. Open Windows Server Manager, and select File and Storage Services → iSCSI
2. Click To create an iSCSI virtual disk, start the New iSCSI Virtual Disk Wizard.
3. Choose the D: volume for the virtual disk location, and click Next.
4. Name your virtual disk, and click Next.
5. Choose 1TB for the size, and set to Fixed size. Click Next.
6. Choose New iSCSI Target, and click Next.
7. Enter a target name, and click Next.
8. Click Add...

9. Choose Enter a value for the selected type.
10. Choose IQN from the dropdown menu, and enter the iqn address of the lometer server (found on the iSCSI Initiator Configuration tab on the lometer server), and click Next.
11. Leave defaults on Enable Authentication, and click Next.
12. Click Create.
13. When the creation is finished, click Close.

Mounting the virtual disk to the lometer server

1. If prompted, initialize the volume using GPT.
2. Right-click the volume, and choose New Simple Volume. Click Next.
3. Accept the maximum default size, and click Next.
4. Accept the default drive letter, and click Next.
5. Choose NTFS, type a name for your volume, and choose quick format. Click Next.
6. Click Finish.

Creating the lometer file and profiles

1. Open lometer.
2. On the disk target tab, highlight the worker and check the box of the target disk.
3. Enter the number of sectors for the size of the file you wish to create. We created a 200GB file.
4. On the access specification tab, choose Idle, and click Add.
5. Click the Start button, naming the test file whatever you choose.
6. Once the test file has been created, reboot the server.
7. Once the server has rebooted, open lometer.
8. On the disk target tab, enter the number of outstanding I/Os relevant to your first workload profile (we used 64 per worker for all profiles).
9. On the access specification tab, click New.
10. Using the relevant sliders, adjust the settings to match the first workload profile.
11. Name the profile, and click save.
12. Highlight the server on the left hand side.
13. Choose the profile you created, and click Add.
14. Highlight each worker and ensure that the profile has been added to each one.
15. On the run settings tab, choose 5 minutes for ramp up time, and 15 minutes for run time.
16. Save the profile.
17. Repeat steps 8 through 16 for each of the remaining workloads.

Configuring the lometer Server for CIFS

We created a RAID 10 from the 12 front bay disks on the N4610, and mounted the volume in Windows as a standard drive. We created a folder to hold the lometer file in the root of the volume.

1. On the lometer server, open File Manager.
2. Right Click This PC, and choose Map a Network Drive...

3. Choose the drive letter in the dropdown menu.
4. Enter the path to the N4610 lometer folder. (Example: [\\N4610HostName\D:\lometerFolder](#))
5. Check the box for “Log in with different credentials,” and click Finish.
6. Enter the username and password for the N4610, and check “remember my credentials”
7. Click OK.

Running the test

We executed the following steps for both iSCSI and CIFS testing. We created a folder on the lometer server’s C: drive containing all of the lometer profiles we used in testing. We ran each profile three times alternating between 100% sequential profiles and 100% random profiles.

1. On the lometer server, open the folder containing the lometer profiles.
2. Double click on the first profile and let the test run in lometer.
3. Repeat step 2 for all profiles, waiting for the previous run to finish before beginning a new run.
4. Reboot the both servers.
5. Repeat steps 1 through 3.
6. Reboot the both servers.
7. Repeat steps 1 through 3.

ABOUT PRINCIPLED TECHNOLOGIES



Principled Technologies, Inc.
1007 Slater Road, Suite 300
Durham, NC, 27703
www.principledtechnologies.com

We provide industry-leading technology assessment and fact-based marketing services. We bring to every assignment extensive experience with and expertise in all aspects of technology testing and analysis, from researching new technologies, to developing new methodologies, to testing with existing and new tools.

When the assessment is complete, we know how to present the results to a broad range of target audiences. We provide our clients with the materials they need, from market-focused data to use in their own collateral to custom sales aids, such as test reports, performance assessments, and white papers. Every document reflects the results of our trusted independent analysis.

We provide customized services that focus on our clients' individual requirements. Whether the technology involves hardware, software, Web sites, or services, we offer the experience, expertise, and tools to help our clients assess how it will fare against its competition, its performance, its market readiness, and its quality and reliability.

Our founders, Mark L. Van Name and Bill Catchings, have worked together in technology assessment for over 20 years. As journalists, they published over a thousand articles on a wide array of technology subjects. They created and led the Ziff-Davis Benchmark Operation, which developed such industry-standard benchmarks as Ziff Davis Media's Winstone and WebBench. They founded and led eTesting Labs, and after the acquisition of that company by Lionbridge Technologies were the head and CTO of VeriTest.

Principled Technologies is a registered trademark of Principled Technologies, Inc.
All other product names are the trademarks of their respective owners.

Disclaimer of Warranties; Limitation of Liability:

PRINCIPLED TECHNOLOGIES, INC. HAS MADE REASONABLE EFFORTS TO ENSURE THE ACCURACY AND VALIDITY OF ITS TESTING, HOWEVER, PRINCIPLED TECHNOLOGIES, INC. SPECIFICALLY DISCLAIMS ANY WARRANTY, EXPRESSED OR IMPLIED, RELATING TO THE TEST RESULTS AND ANALYSIS, THEIR ACCURACY, COMPLETENESS OR QUALITY, INCLUDING ANY IMPLIED WARRANTY OF FITNESS FOR ANY PARTICULAR PURPOSE. ALL PERSONS OR ENTITIES RELYING ON THE RESULTS OF ANY TESTING DO SO AT THEIR OWN RISK, AND AGREE THAT PRINCIPLED TECHNOLOGIES, INC., ITS EMPLOYEES AND ITS SUBCONTRACTORS SHALL HAVE NO LIABILITY WHATSOEVER FROM ANY CLAIM OF LOSS OR DAMAGE ON ACCOUNT OF ANY ALLEGED ERROR OR DEFECT IN ANY TESTING PROCEDURE OR RESULT.

IN NO EVENT SHALL PRINCIPLED TECHNOLOGIES, INC. BE LIABLE FOR INDIRECT, SPECIAL, INCIDENTAL, OR CONSEQUENTIAL DAMAGES IN CONNECTION WITH ITS TESTING, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGES. IN NO EVENT SHALL PRINCIPLED TECHNOLOGIES, INC.'S LIABILITY, INCLUDING FOR DIRECT DAMAGES, EXCEED THE AMOUNTS PAID IN CONNECTION WITH PRINCIPLED TECHNOLOGIES, INC.'S TESTING. CUSTOMER'S SOLE AND EXCLUSIVE REMEDIES ARE AS SET FORTH HEREIN.
