TEST REPORT
JANUARY 2009

Windows Media Load Simulator performance comparison: Solid-state drives vs. hard disk drives

Executive summary

Intel Corporation (Intel) commissioned Principled Technologies (PT) to compare the performance and power of two types of disk drives when streaming Windows Media:

- Intel X25-E Extreme SATA solid-state drives (SSDs)
- Standard 15K RPM SAS hard disk drives (HDDs)

We used the Windows Media Load Simulator (WMLS) test tool. WMLS tests a server's ability to accommodate a large number of streaming connections from Microsoft's Windows Media Server. WMLS runs on one or more client desktop systems, each of which opens a tester-designated number of streaming connections to the server. Each connection streams a tester-designated video. We increased the number of simultaneous streams until the streaming video no longer played smoothly and the connections began to fail.

KEY FINDINGS

- Four SSDs delivered up to 73 percent higher and better peak performance in our WMLS tests than a full 24-disk enclosure of HDDs. (See Figure 1.)
- We calculate that the SSDs used nearly 97 percent less power when active and approximately 98 percent less power when idle than the HDDs. (See Figures 2 and 3.)
- The SSD enclosure and drives delivered as much as 345 percent more performance per watt than the HDD enclosure and drives. (See Figure 4.)

In our testing, we used the WMLS test tool to determine the maximum number of test video streams that each storage solution could handle acceptably.

We tested four Intel X25-E Extreme SATA 32GB SSDs and 24 Seagate Savvio 15K RPM SAS 73GB HDDs; in both cases, we used a Newisys NDS-2240 enclosure. We used a server with two quad-core Intel Xeon X5355 processors at 2.66 GHz and with 8 GB of RAM.

Four Intel X25-E Extreme SATA 32GB SSDs delivered up to 73 percent better streaming media performance than 24 Seagate Savvio 15K RPM SAS 73GB HDDs. The SSDs delivered as much as 345 percent better performance per watt than the HDDs. (We measured power at the enclosure, so power measurements include power usage of the enclosure and drives.) Finally, the SSD enclosure and drives together used nearly 61 percent less power when active and approximately 60 percent less power when idle than the HDD enclosure and drives.

Figure 1 shows the WMLS peak results for the two storage configurations we tested. Each result is the median of three test runs and is the number of streaming media players the storage configuration was able to support. A higher number of streaming players means that the storage configuration can handle a heavier workload and supply more media connections. Higher numbers thus indicate better performance.

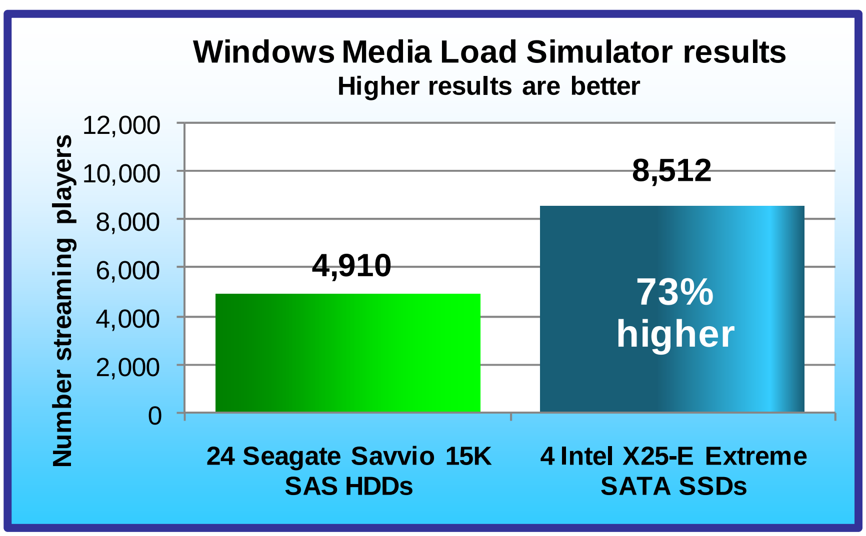

Figure 1: WMLS performance results for the two storage configurations. A higher WMLS score is better.

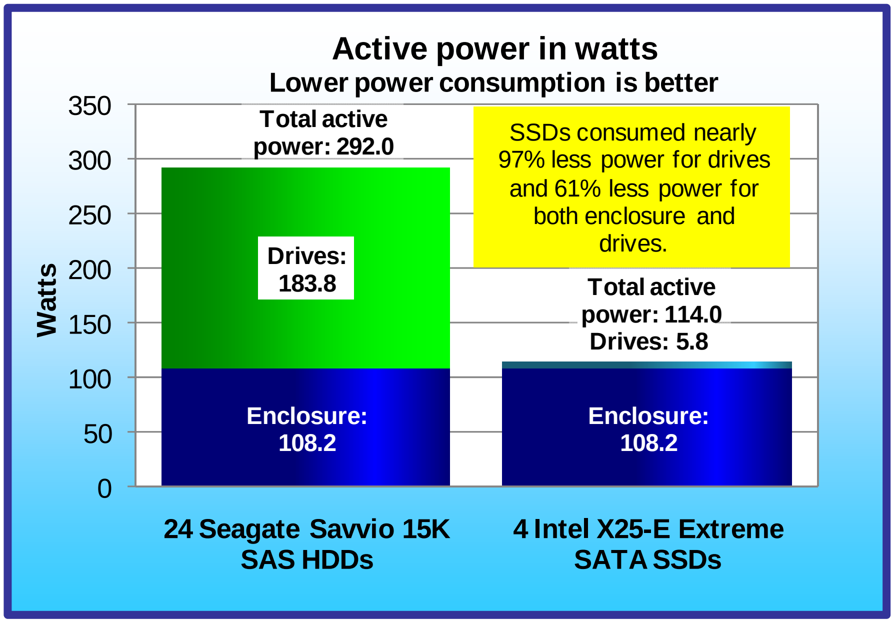

Figure 2: Active power consumption in watts for the two storage configurations. Lower active power consumption is better.

Four SSDs achieved a peak of 8,512 streaming players versus a peak of 4,910 streaming players for the HDDs, for a 73 percent improvement in WMLS performance.

We used power analyzers to log power consumption (in watts) at 1-second intervals during the tests.

Figure 2 shows the active power consumption of the storage arrays for 2 minutes of peak performance during the median run for each storage configuration. This is the same run we illustrate in Figure 1. The 2 minutes are those immediately before the configuration achieves its peak number of steaming players. The power measurements include both the enclosure and drives. We measured the power consumption of the enclosure alone while idle, and then subtracted that power from the active power for the drives and enclosure. We attribute the remaining power, 5.8 watts for the SSDs and 183.8 watts for the HDDs, to the drives.

We also logged power consumption (in watts) of the enclosure, including the drives, for 2 minutes while the server and storage arrays were idle, or near idle, at the beginning of the test. Figure 3 presents those results.

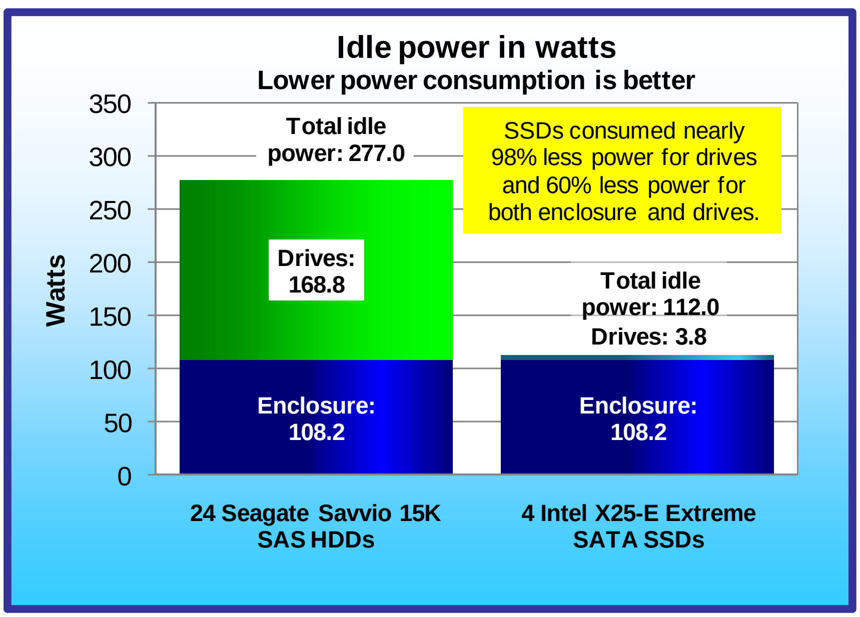

Figure 3: Idle power consumption in watts for the two storage configurations. Lower idle power consumption is better.

During an idle period at the beginning of the test, the SSD configuration used less power than the HDD configuration: 112 watts for the SSD configuration vs. 277 watts for the HDD configuration.

We subtracted the idle power measurement for the enclosure alone from the idle power for the drives and enclosure. We attribute the remaining power, 3.8 watts for the SSD configuration and 168.8 watts for the HDD configuration, to the drives.

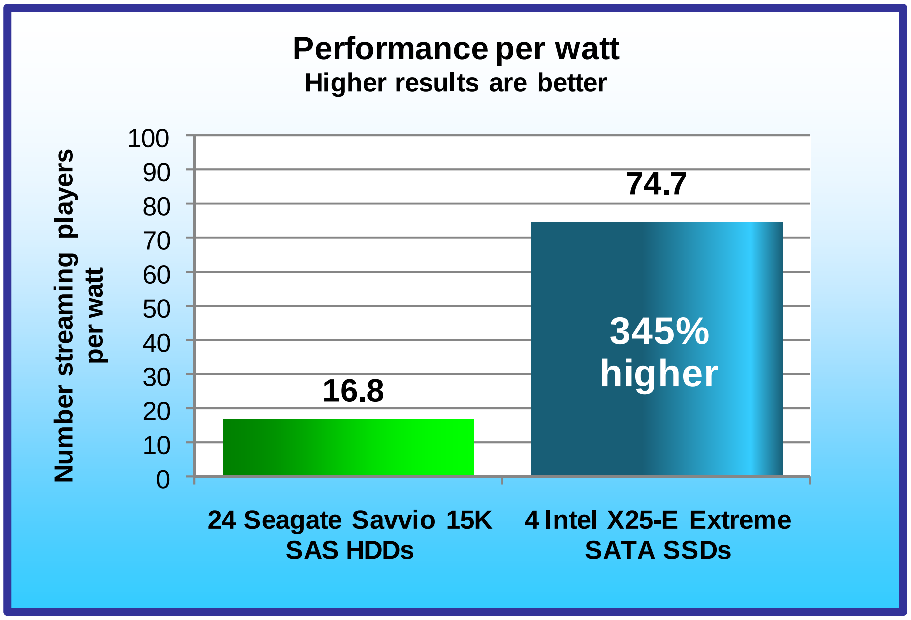

Figure 4 shows the performance per watt for the two configurations, which we calculated by dividing performance as measured in number of streaming players (see Figure 1) by average watts of active power consumption (see Figure 2). Four SSDs delivered nearly 3.45 times greater performance per watt than 24 HDDs while active: 74.7 streaming servers per watt for the SSDs vs. 16.8 streaming servers per watt for the HDDs. Higher performance per watt is better.

Figure 4: Performance per watt results. Higher performance per watt is better.

We also measured processor utilization during the peak testing time, the period of steady activity and maximum I/O. The three SSDs drove the processors up to 471.9 percent more than the 24 HDDs; 18.3 percent for the SSDs and 3.2 percent for the HDDs.

Workload

We used Microsoft Windows Media Load Simulator 9 to simulate multiple instances of Microsoft Windows Media Player accessing the storage solution. The test slowly increases the number of virtual clients streaming video from the storage solution. While the test ran, we used Windows Performance Monitor counters to track the total late sends, total late reads, and current streaming players count at 1-second intervals. When a storage solution could no longer successfully handle the test load, it began producing late sends and late reads, which caused the Media Player client that received them to have to wait for the data it requested.

Each of our number of streaming player results is the current number of streaming players that Windows Performance Monitor reported at the time it first detected late sends or late reads during a test run. In all our tests, late sends occurred well before late reads.

We measured active and idle power consumption at the enclosure for the enclosure and drives. Active power measurements are from the one of our three test runs that produced the median number of streaming players. Active power is the average power consumption in watts we recorded with a power analyzer attached to the enclosure for the 2 minutes when the storage configuration was delivering peak performance. Peak performance ends at the point when the storage configuration started producing late sends and delivered its peak number of streaming players. Idle power for the enclosure and drives is the average power consumption during the first 2 minutes of the test, while the test is streaming zero to a few streaming players. These power measurements include the power consumption of the enclosure and the power of the drives, but do not include the power consumption of the server. We also measured the power at the enclosure empty of drives while the server was idle.

Test results

Figure 5 provides test results for the two storage configurations. It includes the number of streaming players for the three test runs and the power measurements from the run that produced the median number of streaming players. Figures 1 through 4 show results for that median run. Figure 5 also includes idle power consumption that we measured at the enclosure while the server was idle and the drives were empty.

	Four Intel X25-E Extreme SATA SSDs	24 Seagate Savvio 15K SAS HDDs
Number of streaming players results for the three runs (higher is better)		
Run 1	8,512	4,813
Run 2	8,595	4,910
Run 3	8,400	5,149
Median number of streaming players	8,512	4,910
Power measurements from median run		
Idle power (enclosure and drives)	112.0 Watts	277.0 Watts
Idle power (empty enclosure)	108.2 Watts	108.2 Watts
Average power (enclosure and drives)	114.0 Watts	292.0 Watts
Performance per watt	74.7	16.8

Figure 5: Test results for the two storage configurations.

Test methodology

We installed either the four SSDs or the 24 HDDs into the Newisys NDS-2240 enclosure, which we connected to a server via an LSI Logic MegaRAID SAS 8888ELP RAID Controller. Figure 6 presents the drives we tested.

	Four Intel X25-E Extreme SATA SSDs	24 Seagate Savvio 15K SAS HDDs
Vendor and model number	Intel SSDSA2SH032G1GN	Seagate ST973451SS
Number of drives in system	4	24
Size (GB)	32	73
RPM	N/A	15,000
Type	SATA 3.0 Gb/s	SAS 3.0 Gb/s
Controller	LSI Logic MegaRAID SAS 8888ELP RAID Controller	LSI Logic MegaRAID SAS 8888ELP RAID Controller
Controller driver	LSI 3.8.0.64 (08/12/2008)	LSI 3.8.0.64 (08/12/2008)

Figure 6: The drives we tested.

Storage configuration

Appendix A provides more detailed information on the storage configuration.

We conducted all tests in a climate-controlled room. Intel selected and provided the storage array, HDDs, and SSDs. PT provided the server.

Test bed configuration

We installed a Microsoft Windows Server 2003 x64 on the server and loaded the Microsoft Windows Media Load Simulator 9 onto the server. We created a test bed that included the Intel Xeon processor X7460-based server. Appendix B provides detailed configuration information for that server. We attached the storage array to the server via a RAID Controller.

The server contained one drive. We configured the internal server drives for the operating system and the WMLS software.
To ensure that the media would not fit in cache, we made sure that the memory of the server was less than the size of our media collection. Figure 7 shows the configuration for the server.

Intel Xeon processor X7460-based server	
Processors	Two Quad-core Intel Xeon X5355 processors at 2.66 GHz
Memory	8 GB of PC2-5300 FB-DDR2 memory
Internal disk	One 160GB, 7,200RPM Hitachi Deskstar T7K250 SATA drive
NICs	Intel PRO/1000 EB NIC and Intel PRO/1000 MT Quad Port NIC
OS	Microsoft Windows Server 2003 x64 SP2
Software	Windows Media Load Simulator 9

Figure 7: Test server configuration.

To generate the workload, we used eight physical clients in the configuration in Figure 8.

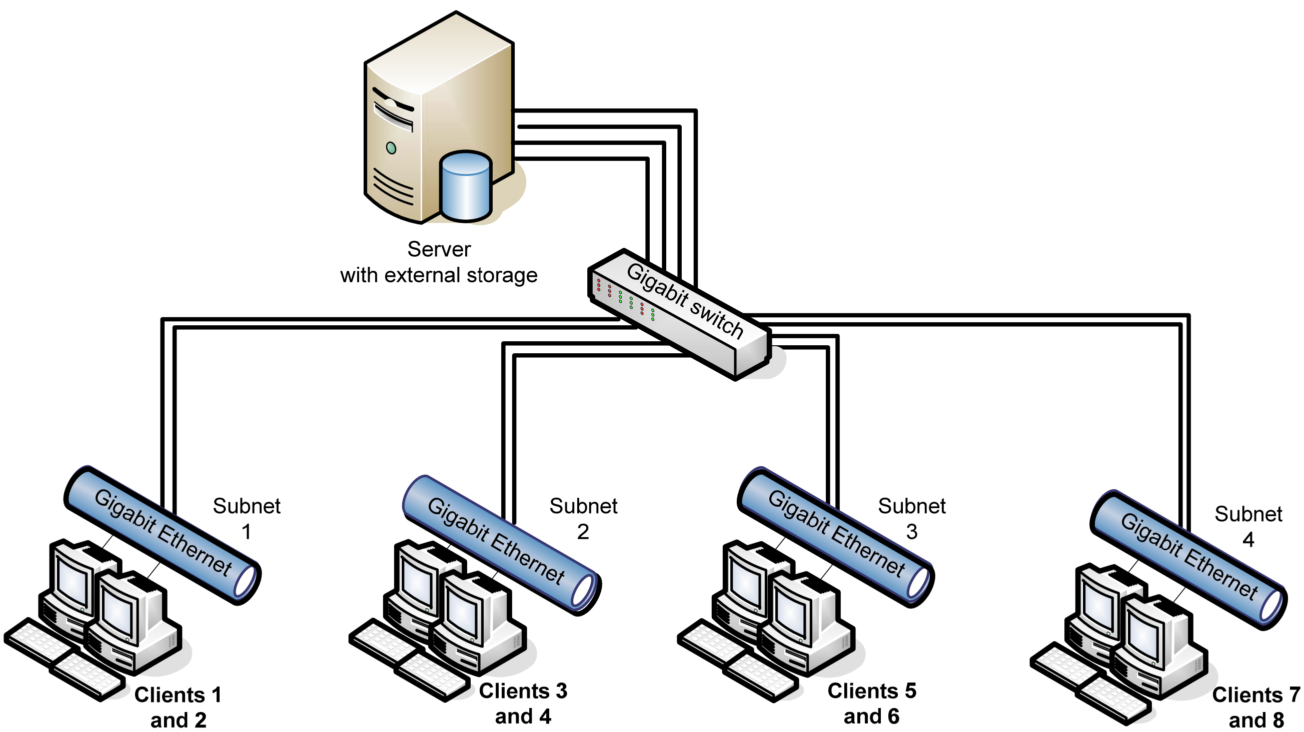

Figure 8: The network test bed configuration for the WMLS test.

We connected the eight physical clients to the server with one NETGEAR GS724T Gigabit Smart Switch. We connected four total connections from the server to the switch and eight connections from the switch to the clients. We divided the subnets into one server connection and two clients in order to avoid a network-based limitation.

Appendix B provides more detailed information on the test environment.

We followed the steps we describe in the rest of this section to set up and conduct the tests.

Setting up the storage disks

We installed either the four SSDs or the 24 HDDs into the Newisys NDS-2240 enclosure, which we connected to a server via an LSI Logic MegaRAID SAS 8888ELP RAID Controller. Before we ran the tests, we configured each of the storage disks as RAID 0, enabled the disk cache, ran Iometer on the SSDs to season them, and used Diskpart to align all drives on a 4KB boundary.

The rest of this section provides instructions for each of those steps.

Setting up the RAID (SSDs and HDDs)

1. Enter the MegaRAID BIOS Configuration Utility.
2. Select your adapter, and click Next.
3. Click Configuration Wizard.
4. Select New Configuration, and click Next.
5. At the This is a Destructive Operation! screen, click Yes.
6. Select Custom Configuration, and click Next.
7. Assign all of the drives in your array to your RAID, and click Accept DG.
8. Click Next.
9. Click Add to SPAN.
10. Click Next.
11. Set the RAID level to RAID 0, set Disk Cache to enabled, and change Select Size to the suggested RAID 0 size on the right.
12. Click Next.
13. Click Accept.
14. Click Yes.
15. Click Yes.
16. Click Home.
17. Click Exit.

Seasoning the drives (SSDs only)

Note: We preconditioned the drives so that our tests would deliver accurate sustained performance values. Without preconditioning, tests could deliver highly variable performance.

1. Plug in an SSD that you have securely erased or freshly performed a low-level format on.
2. Initialize the disk, and format it as NTFS.
3. With Iometer, run a 1-second 128K sequential read test to the entire logical block addressing (LBA) drive space. This enables all LBAs to have some content so the SSD does not have an artificially high reserve space. Note: We used Iometer 2008-06-22-rc1, available from http://sourceforge.net/projects/iometer.
4. Delete the IOBW.tst file from the SSD drive.
5. With Iometer, run a 5,700-second 128K sequential read test (request size aligned on 4K sector boundaries) on 100 percent of the drive. This preconditions the drive.

Formatting the drive array with Diskpart (SSDs and HDDs)

1. Open a command prompt.
2. Type `cd c:\windows\system32`
3. Type `diskpart.exe`
4. Type `List Disk` to determine the name of your RAID array.
5. Type `Select Disk #` where Disk # is the name of your RAID array.
6. Type `Create partition primary align=4`
7. Type `Assign Letter=E` to assign this new partition the letter E.
8. Type `Exit`

9. In Windows, click Start, right-click My Computer, and select Manage.
10. Click Disk Management.
11. Right-click the partition, and select Format.
12. Name the partition according to what kind of drives you are using, and format the drives as NTFS.

Connecting the Extech Power Analyzer/Datalogger

To record each storage configuration's power consumption during testing, we used an Extech Instruments (www.extech.com) 380803 Power Analyzer/Datalogger. Because the server had two power supplies, we measured the power draw of the server by using a single Extech Power Analyzer with a splitter cable.
We used a second Extech Power Analyzer to measure the power draw of the drive array. The enclosure also had dual power supplies, so we used a splitter cable to measure the power draw through a single meter.
We connected the Extech Power Analyzers via a RS-232 cable to a separate power monitoring system to record the power draw of the devices under test. We used the Power Analyzer's Data Acquisition Software (version 2.11) installed on the power monitoring system to capture all the recordings.

Installing Microsoft Windows 2003 Server x64 Enterprise Edition Service Pack 2 on the server

We installed a fresh copy of Microsoft Windows 2003 Server x64 Enterprise Edition Service Pack 2 on the test server. We followed this process for each installation:

1. Assign a computer name of `Server`
2. For the licensing mode, use the default setting of five concurrent connections.
3. Enter a password for the administrator log on.
4. Select Eastern Time Zone.
5. Use typical settings for the Network installation.
6. Type `Testbed` for the workgroup.

Creating the video content

To use the WMLS test tool, the Windows Media Server must have a source video to stream to the clients. We created our own video so that we could control the specific size and bit-rate format of the video. Prior to testing, we ran preliminary tests and determined that a higher bit rate caused more disk drive usage, so we used a 750Kbps bit rate.

To create this streaming file, we pulled content from the DVD video, Stevie Ray Vaughan and Double Trouble: Live at the El Mocambo (www.amazon.com/gp/product/6305019681/qid=1148058106/sr=1-2/ref=sr_1_2/102-0027141-8108150?s=dvd&v=glance&n=130) and created an AVI file using AutoGK, available from the Doom 9 AGK development forum (www.autogk.me.uk).

We then used Windows Media Encoder 9 (www.microsoft.com/windows/windowsmedia/forpros/encoder/default.mspx) to convert the AVI file into a streaming video (WMV) file for the Windows Media Server. We used the following compression settings to convert the streaming video:

- Destination: Windows Media Server (streaming)
- Video: Multiple bit rates video (CBR)
- Audio: Voice quality audio (CBR)
- Bit rates: 750 Kbps, 29.97 fps, 320 x 240 output size

Installing and setting up Windows Media Services

We performed the following steps to install and configure Windows Media Services on the server:

1. Use the Manage Your Server wizard to install Windows Media Services.
2. When this installation completes, the Windows Media Services root directory will be C:\WMPub\WMRoot. Copy the test WMV file into this root directory.
3. The installation process will create several .asf files in the Windows Media Services root directory. Copy one of these files, and place it in the same directory with the test WMV file. (Which file you select is not

important because the WMLS client looks for wmload.asf when you start it.) Rename the copy `wmload.asf`

4. Open the Windows Media Services management console by clicking Start->Administrative Tools-> Windows Media Services.
5. Select the server name, then choose Properties->Control Protocol->ENABLE WMS HTTP Server Control Protocol. (See Figure 9.)

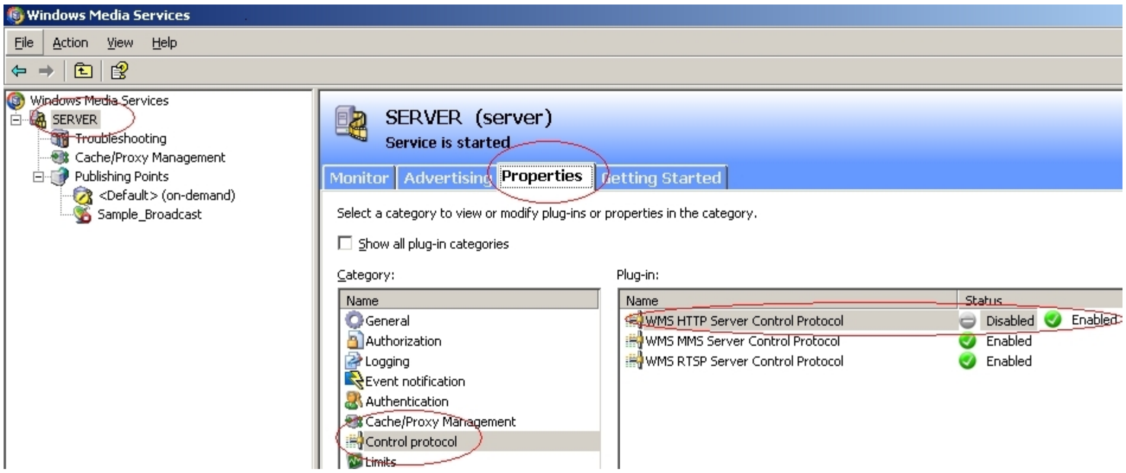

Figure 9: Enabling the WMS HTTP Server Control Protocol using the Windows Media Services management console.

6. To start the media server, select the Publishing Point: <Default> (on-demand)>Monitor>. Click the  button to allow new connections. (See Figure 10.)

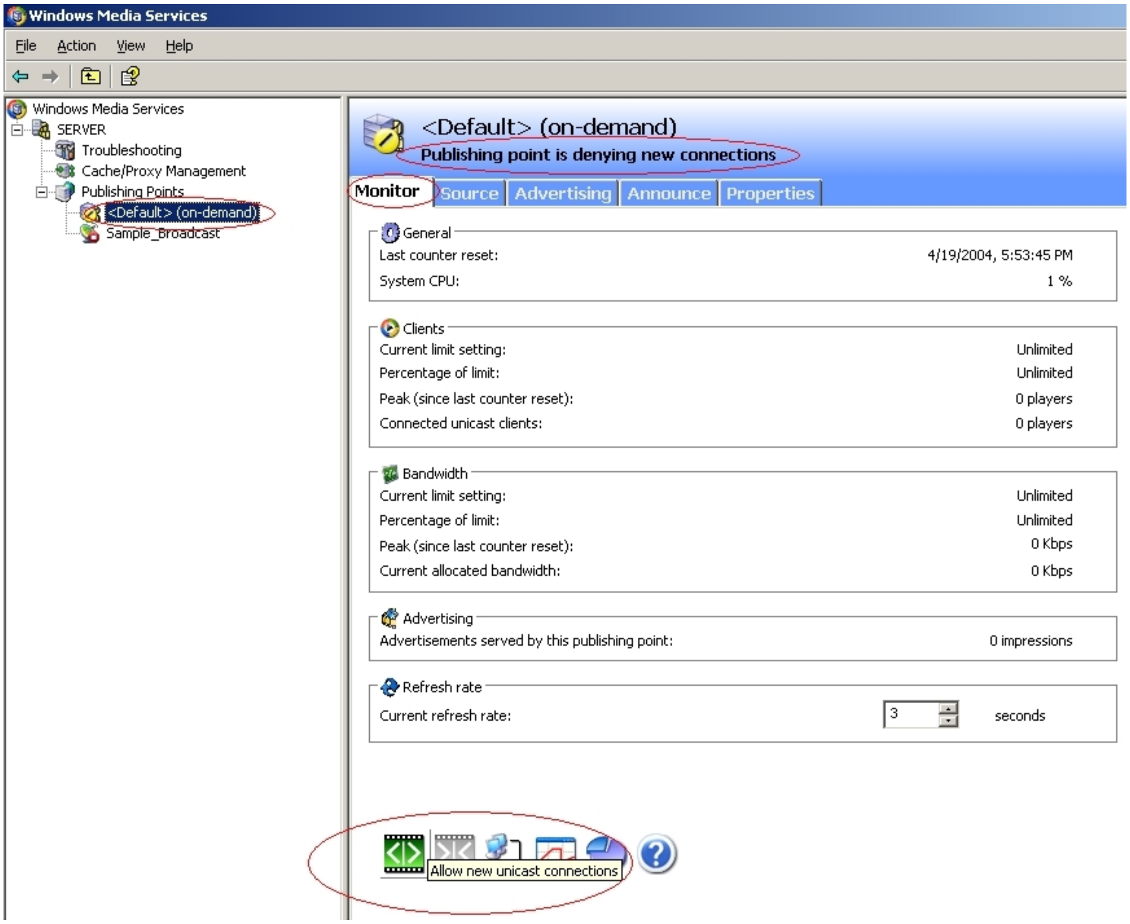

Figure 10: Allowing new connections using the Windows Media Services management console.

Installing the workload simulator on each client system

We performed the following steps to prepare the clients to run the WMLS test tool:

1. Download the test tool from Microsoft's Web site: www.microsoft.com/downloads/details.aspx?FamilyID=0304afa3-e414-4dec-82a4-2d58ac75c833&displaylang=en&Hash=NY6FCJ9.
2. Place the executable file (wmloadsetup.exe) on each client.
3. Start the installation by double-clicking the file.
4. At the EULA agreement box, click Yes.
5. After the installation process completes, start the simulator by clicking Start->All Programs->Windows Media Load Simulator->Windows Media Load Simulator.

Running the WMLS test tool

Because our objective was to determine the highest number of streams the storage solution could handle, we had to monitor the storage solution's performance carefully. We used the Performance Monitor in Windows Server 2003 to monitor total processor utilization.

After booting up the server and eight clients, we began the test by launching the WMLS tool on the first client. We then initiated 700 (or 1,400, depending on the drive medium we tested) connections on the first client to start the load on the server. Once the client ramped up to 700 (or 1,400) connections, we waited at least 1 minute to allow the server to stabilize. We then initiated the second client and launched another group of connections of the same size as the first group. We again waited at least 1 minute for the server to stabilize. We continued to add clients until the server issued late sends, which indicated that the server couldn't add any more connections while maintaining quality streaming to the existing connections.

We evaluated the server's status throughout the test with Performance Monitor. When the Late sends counter showed one or more late sends, we recorded the number of streaming clients successfully active at that point and report that as the number of streaming clients for the test run.

Appendix A: Storage configuration

Figure 11 shows the storage hardware.

	Four Intel X25-E Extreme SATA SSDs	24 Seagate Savvio 15K SAS HDDs
Storage connectivity	SATA	SAS
Storage model	Newisys NDS-2240	Newisys NDS-2240
Number of storage controllers	1	1
HBA model and firmware	MegaRAID SAS 8888ELP 1.40.02-0514	MegaRAID SAS 8888ELP 1.40.02-0514
Number of HBAs/host	1	1

Figure 11: Primary storage hardware.

Figure 12 shows the storage drive configuration.

	Four Intel X25-E Extreme SATA SSDs	24 Seagate Savvio 15K SAS HDDs
Drive type, speed	SSD	SAS, 15K RPM
Firmware	8620	SM04
Raw capacity per drive (GB)	32	73
Number of physical drives in test	4	24
Total raw storage capacity (GB)	144	1,752
RAID level	RAID 0	RAID 0
Total formatted capacity (GB)	144	144

Figure 12: Primary storage drive configuration.

Appendix B: Test environment

We used one server to generate the workload and create demand on the storage. Figure 13 provides detailed configuration information for that server.

Intel Processor X5355-based server	
General	
Number of processor packages	2
Number of cores per processor package	4
Number of hardware threads per core	1
System Power Management Policy	Always on
CPU	
Vendor	Intel
Name	Xeon X5355
Stepping	7
Socket type	Socket 771-LGA
Core frequency (GHz)	2.66
Front-side bus frequency (MHz)	1,333
L1 cache	32 KB + 32 KB (per core)
L2 cache	8 MB (2 x 4MB shared)
Platform	
Motherboard model number	X7DB8+
Motherboard chipset	Intel 5000P
Motherboard revision number	92
BIOS name and version	Phoenix Technologies 2.1
BIOS settings	Default
Chipset INF driver	Intel 9.0.0.1011
Memory module(s)	
Vendor and model number	Samsung M395T5750CZ4-CE66
Type	FB-DDR2 PC-5300
Speed (MHz)	667
Speed in the system currently running @ (MHz)	667
Timing/latency (tCL-tRCD-iRP-tRASmin)	5-5-5-15
Size (MB)	8,192
Number of RAM modules	4 x 2,048 MB
Chip organization	Double-sided
Channel	Dual
Hard disk	
Vendor and model number	Hitachi Deskstar T7K250
Number of disks in system	1
Size (GB)	160
Buffer size (MB)	8
RPM	7,200
Type	SATA 3.0 Gb/s
Controller	Intel 6321ESB
Controller driver	Intel 9.1.1.1003 (6/28/2008)
Operating system	
Name	Windows Server 2003 Enterprise x64 Edition
Build number	3790
Service Pack	SP2
File system	NTFS

Intel Processor X5355-based server	
Operating system	
Language	English
Microsoft DirectX version	9.0c
Graphics	
Vendor and model number	ATI Rage XL PCI
Chipset	ATI Rage XL
BIOS version	GR-xlints3y.09a-4.332
Type	Integrated
Memory size (MB)	8
Resolution	1,280 x 1,024 x 32-bit
Driver	ATI 6.14.10.6025 (12/3/2004)
Network card/subsystem	
Vendor and model number	Intel PRO/1000 EB Server Adapter
Type	Integrated
Driver	9.12.13.0 (9/26/2008)
Vendor and model number	Intel PRO/1000 MT Quad Port Server Adapter
Type	PCI-E
Driver	8.10.3.0 (8/20/2008)
Optical drive	
Vendor and model number	LITE-ON COMBO SOHC-5236V
Type	CD/DVD-ROM
Interface	SATA
Dual/single layer	Dual
USB ports	
Number of ports	4
Type of ports (USB 1.1, USB 2.0)	2.0

Figure 13: Detailed system configuration information for the test server.

Our test network included eight clients, which we describe in Figure 14.

Client #	Make/model	Processor speed	Memory size and type
Segment/subnet 1			
Client 1	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Client 2	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Segment/subnet 2			
Client 3	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Client 4	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Segment/subnet 3			
Client 5	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Client 6	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Segment/subnet 4			
Client 7	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200
Client 8	Intel Desktop Board D915GMH	Intel Pentium 4 3.0GHz w/HT	1,024 MB PC3200

Figure 14: Detailed configuration information for the test network clients.

About Principled Technologies

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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 you assess how it will fare against its competition, its performance, whether it's ready to go to market, 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.

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