SERVER STORAGEIO® LAB REVIEW

INSIGHT FOR EFFECTIVE SERVER STORAGE I/O DECISION MAKING

INTRODUCTION

This StorageIO™ Industry Trends Perspectives Solution Brief and Lab Review looks at the Equus Computer Systems (www.equuscs.com) converged Content Solution platforms with Seagate Enterprise Hard Disk Drive (HDDs). I was given the opportunity to do some hands-on testing running different application workloads with a 2U content solution platform along with various Seagate Enterprise 2.5" HDDs handle different application workloads. This includes Seagate's Enterprise Performance HDDs with the enhanced caching feature. If you are in a hurry, simply jump to page 7 and view the results, otherwise, take your time and read the background material.

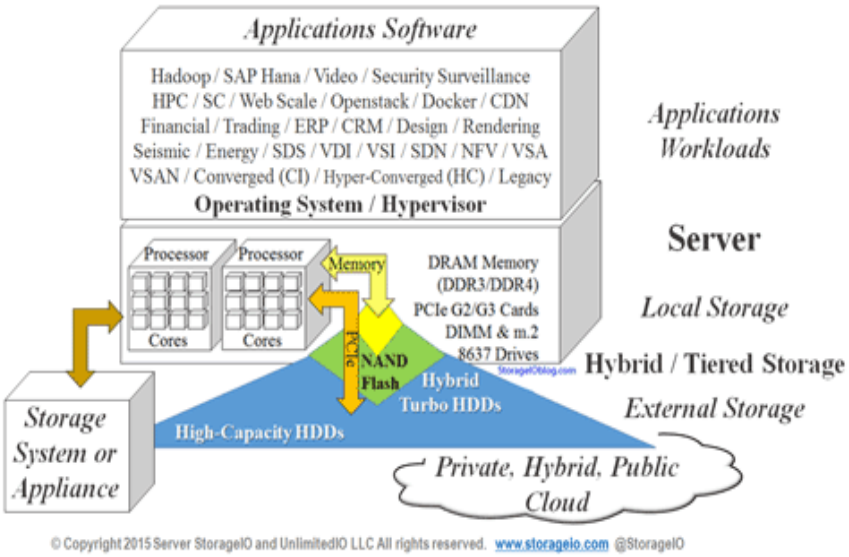
ISSUES AND CHALLENGES

Even though Non-Volatile Memory (NVM) including NAND flash solid state devices (SSDs) have become popular storage for use internal as well as external to servers, there remains the need for HDDs. Like many of you who need to make informed server, storage, I/O hardware, software and configuration selection decisions, time is often in short supply.

A common industry trend is to use SSD and HDD based storage mediums together in hybrid configurations. Another industry trend is that HDDs continue to be enhanced with larger space capacity in the same or smaller footprint, as well as with performance improvements. Thus a common challenge is what type of HDD to use for various content and application workloads balancing performance, availability, capacity and economics.

FAST CONTENT NEEDS FAST SOLUTIONS

Content solutions span from video (4K, HD, SD and legacy streaming video, pre-/post-production and editing), audio, imaging (photo, seismic, energy, healthcare, etc.) to security surveillance (including Intelligent Video Surveillance [ISV] as well as Intelligence Surveillance and Reconnaissance [ISR]). In addition to big fast data, other content solution applications include content distribution network (CDN) and caching, network function virtualization (NFV) and software defined network (SDN), to cloud and other rich unstructured big fast media data, analytics along with little data (e.g. SQL and NoSQL database, key-value stores, repositories and meta-data) among others.



An industry and customer trend is that information and data are getting larger, living longer, as well as there is more of it. This ties to the fundamental theme that applications and their underlying hardware platforms exist to process, move, protect, preserve and serve information.

CONTENT SOLUTIONS AND OPPORTUNITIES

A common theme with content solutions is that they get *defined* with some amount of hardware (compute, memory and storage, I/O networking connectivity) as well as some type of content software. Fast content applications need fast software, multi-core processors (compute), vast memory (DRAM, NAND flash, SSD and HDDs) along with fast server storage I/O network connectivity. Content based applications benefit from having frequently accessed data as close as possible to the application (e.g. locality of reference).

TEST OBJECTIVES

In short period of time, collect performance and other server, storage I/O decision making information on various HDDs running different content workloads.

Content solution and application servers need flexibility in terms of compute options (number of sockets, cores, threads), main memory (DRAM DIMMs), PCIe expansion slots, storage slots and other connectivity. An industry trend is leveraging platforms with multi-socket processors, dozens of cores and threads (e.g. logical processors) to support parallel or high-concurrent content applications. These servers have large amounts of local storage space capacity (NAND flash SSD and HDD) and associated I/O performance (PCIe, NVMe, 40 GbE, 10 GbE, 12 Gbps SAS etc.) in addition to using external shared storage (local and cloud).

CONTENT SOLUTION TEST OBJECTIVES

Working with the Equus Computer Systems staff a suitable content solution platform test configuration was created. In addition to providing two Intel based content servers, Equus Computer Systems worked with their partner Seagate to arrange for various enterprise class HDDs to be evaluated. For these series of content application tests, being short on time, I chose to do run some simple workloads including database, basic file (large and small) processing and general performance characterization.

CONTENT SOLUTION DECISION MAKING

Knowing how Non-Volatile Memory (NVM) NAND flash SSD[1] devices (drives and PCIe cards) perform, what would be the best HDD based storage option for my given set of applications? Different applications have various performance, capacity and budget considerations. Different types of Seagate Enterprise class 2.5" Small Form Factor (SFF) HDDs were tested. While revolutions per minute (RPM) still plays a role in HDD performance, there are other factors including internal processing capabilities, software or firmware algorithm optimization, and caching. Most HDDs today have some amount of DRAM for read caching and other operations. Seagate Enterprise Performance HDDs with the enhanced caching feature[2] are examples of devices accelerate storage I/O speed vs. traditional 10K and 15K RPM drives.

PROJECT PLANNING AND PREPARATION

Project testing consisted of five phases, some of which overlapped with others:

Phase 1 – Plan — Identify candidate workloads that could be run in the given amount of time, determine time schedules and resource availability, create a project plan.

Phase 2 – Define — Hardware define and software define the test platform.

Phase 3 – Setup — Objective was to assess plug-play capability of the server, storage and I/O networking hardware with a Linux OS before moving on to the reported workloads in the next phase. Initial setup and configuration of hardware and software, installation of additional devices along with software configuration, trouble-shooting and learning as applicable. This phase consisted of using Ubuntu Linux 14.04 server as the operating system (OS) along with MySQL 5.6 as a database server during initial hands-on experience.

1 Refer to Seagate 1200 12 Gbps Enterprise SAS SSD StorageIO lab review
http://storageioblog.com/seagate-1200-12gbs-enterprise-sas-ssd-server-storgeio-lab-review/

2 Refer to Enterprise SSHD and Flash SSD Part of an Enterprise Tiered Storage Strategy
http://storageioblog.com/enterprise-sshd-and-flash-ssd-part-of-an-enterprise-tiered-storage-strategy/

Phase 4 - Execute This consisted of using Windows 2012 R2 server as the OS along with Microsoft SQL Server on the system under test (SUT) to support various workloads. Results of this phase are reported below.

Phase 5 - Analyze Results from the workloads run in phase 3 were analyzed and summarized into this document.

WORKLOADS TO PROFILE
- ✓ Database read/writes
- ✓ Large file processing
- ✓ Small file processing
- ✓ General I/O profile

PLANNING AND PREPARING THE TESTS

As with most any project there were constraints to contend with and work around.

Three most important constraints and considerations for this project were:

CONSTRAINTS
- ✓ Short-time window
- ✓ Hardware availability
- ✓ Amount of hardware
- ✓ Software availability

Time This was a project with a very short time "runway", something common in most customer environments who are looking to make informed server, storage I/O decisions.

Amount of hardware Limited amount of DRAM main memory, sixteen 2.5" internal hot-swap storage slots for HDDs as well as SSDs. Note that for a production content solution platform, additional DRAM can easily be added, along with extra external storage enclosures to scale memory and storage capacity to fit your needs.

Software availability Utilize common software and management tools publically available so anybody could leverage those in their own environment and tests.

The following content application workloads were profiled:

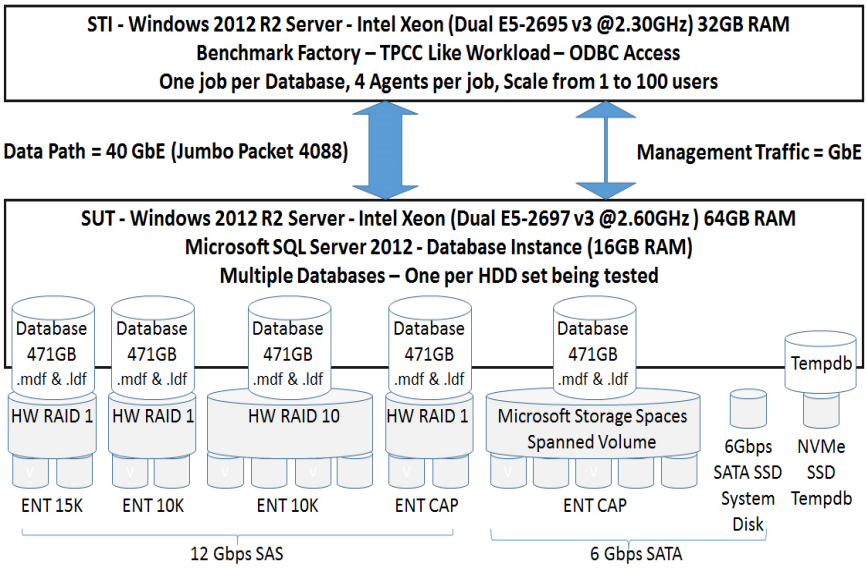
- Database reads/writes – Updates, inserts, read queries for a content environment
- Large file processing – Streaming of large video, images or other content objects.
- Small file processing – Processing of many small files found in some content applications
- General I/O profile – IOP, bandwidth and response time relevant to content applications

DEFINING HARDWARE SOFTWARE ENVIRONMENT

Equus Computer Systems content platforms are software defined and hardware defined to your specific solution needs. For my test-drive, I used a pair of 2U Content Solution platforms, one for a client System Test Initiator (STI[3]), the other as server SUT shown in figure-1 (next page). With the STI configured and SUT setup Seagate Enterprise class 2.5" 12Gbps SAS HDDs were added to the configuration.

[3] STI was hardware defined with dual Intel Xeon E5-2695 v3 (2.30 GHz) processors, 32GB RAM running Windows Server 2012 R2 with two network connections to the SUT. Network connections from the STI to SUT included an Intel GbE X540-AT2 as well as an Intel XL710 Q2 40 GbE Converged Network Adapter (CNA). In addition to software defining the STI with Windows Server 2012 R2, Dell Benchmark Factory (V7.1 64b bit 496) part of the Database Administrators (DBA) Toad Tools (including free versions) was also used. For those familiar with HammerDB, Sysbench among others, Benchmark Factory is an alternative that supports various workloads and

SUT setup[4] included four Enterprise 10K and two 15K Performance drives with enhanced performance caching feature enabled, along with two Enterprise Capacity 2TB HDDs, all were attached to an internal 12Gbps SAS RAID controller. With the STI configured and SUT setup Seagate Enterprise class 2.5" 12Gbps SAS HDDs were added to the configuration.



This included four Enterprise 10K and two 15K Performance drives with enhanced performance caching feature enabled, along with two Enterprise Capacity 2TB HDDs, all were attached to an internal 12Gbps SAS RAID controller. Five 6 Gbps SATA Enterprise Capacity 2TB HDDs were setup using Microsoft Windows as a spanned volume. System disk was a 6Gbps flash SSD and an NVMe flash SSD drive was used for database temp space.

WHAT ABOUT NVM FLASH SSD?

NAND flash and other Non-Volaitile Memory (NVM) memory and SSD complement content solution. A little bit of flash SSD in the right place can have a big impact. The focus for theses tests is HDDs, however some flash SSDs were used as system boot and database temp (e.g. tempdb) space. Refer to StorageIO Lab reviews and visit www.thessdplace.com

[4] SUT dual Intel Xeon E5-2697 v3 (2.60 GHz) providing 54 logical processors, 64GB of RAM (expandable to 768GB with 32GB DIMMs, or 3TB with 128GB DIMMs) and two network connections. Network connections from the STI to SUT consisting of an Intel 1 GbE X540-AT2 as well as an Intel XL710 Q2 40 GbE CNA. The GbE LAN connection was used for management purposes while the 40 GbE was used for data traffic. System disk was a 6Gbs SATA flash SSD. Seagate Enterprise class HDDs were installed into the 16 available 2.5" small form factor (SFF) drive slots. Eight (left most) drive slots were connected to an Intel RMS3CC080 12 Gbps SAS RAID internal controller. The "Blue" drives in the middle were connected to both an NVMe PCIe card and motherboard 6 Gbps SATA controller using an SFF-8637 connector. The four right most drives were also connected to the motherboard 6 Gbps SATA controller.

SEAGATE ENTERPRISE HDDS USED DURING TESTING

Various Seagate Enterprise HDD specifications use in the testing are shown below in table-1.

Qty	Seagate HDDs	Capacity	RPM	Interface	Size	Model	Equus Price Each	Configuration
4	Enterprise 10K Performance	1.8TB	10K with cache	12 Gbps SAS	2.5"	ST1800MM0128 with enhanced cache	$875.00 USD	HW[5] RAID 10 and RAID 1
2	Enterprise Capacity 7.2K	2TB	7.2K	12 Gbps SAS	2.5"	ST2000NX0273	$399.00 USD	HW RAID 1
2	Enterprise 15K Performance	600GB	15K with cache	12 Gbps SAS	2.5"	ST600MX0082 with enhanced cache	$595.00 USD	HW RAID 1
5	Enterprise Capacity 7.2K	2TB	7.2K	6 Gbps SATA	2.5"	ST2000NX0273	$399.00 USD	SW[6] RAID Span Volume

Table-1 Seagate Enterprise HDD specification and Equus Computer Systems pricing

URLs for additional Equus Computer Systems content platform information:

http://www.serversdirect.com/solutions/content-solutions

http://www.serversdirect.com/solutions/content-solutions/video-streaming

http://www.serversdirect.com/File%20Library/Data%20Sheets/Intel-SDR-2P16D-001-ds2.pdf

http://www.serversdirect.com/Servers/id-SDR-2P16D-001/Intel_SDR-2P16D-001

URLs for additional Seagate Enterprise HDD information:

http://www.serversdirect.com/Components/Drives/id-HD1558/Seagate_ST2000NX0273_2TB_Hard_Drive

http://www.serversdirect.com/Components/Drives/id-HD1557/Seagate_Thunderbolt_10K_8_ST1800MM0128_HD

http://www.serversdirect.com/Components/Drives/id-HD1559/Seagate_ST600MX0082_SSHD

[5] Hardware (HW) RAID using Intel server on-board LSI based 12 Gbps SAS RAID card, RAID 1 with two (2) drives, RAID 10 with four (4) drives. RAID configured in write-through mode with default stripe / chunk size.

[6] Software (SW) RAID using Microsoft Windows Server 2012 R2 (span). Hardware RAID used write-through cache (e.g. no buffering) with read-ahead enabled and a default 256KB stripe/chunk size.

SEAGATE PERFORMANCE ENHANCED CACHE FEATURE

The Enterprise 10K and 15K Performance HDDs tested had the enhanced cache feature enabled. This feature provides a "turbo" boost like acceleration for both reads and write I/O operations. HDDs with enhanced cache feature leverage the fact that some NVM such as flash in the right place can have a big impact on performance[7]. In addition to their performance benefit, combing a best of or hybrid storage model (combing flash with HDDs along with software defined cache algorithms), these devices are "plug-and-play". By being "plug-and-play" no extra special adapters, controllers, device drivers, tiering or cache management software tools are required. The Seagate Enterprise Performance 10K and 15K with enhanced cache feature are a good example of how there is more to performance in today's HDDs than simply comparing RPMs, drive form factor or interface.

DATABASE READS/WRITES

Transaction Processing Council (TPC) TPC-C like workloads were run against the SUT from the STI. These workloads simulated transactional, content management, meta-data and key-value processing. Microsoft SQL Server 2012 was configured and used with databases (each 470GB e.g. scale 6000) created and workload generated by virtual users via Benchmark Factory (running on STI Windows 2012 R2).

A single SQL Server database instance[8] was used on the SUT, however unique databases were created for each HDD set being tested. Both the main database file (.mdf) and the log file (.ldf) were placed on the same drive set being tested, keep in mind the constraints mentioned above. As time was a constraint, database workloads were run concurrent[9] with each other except for the Enterprise 10K RAID 1 and RAID 10. Workload was run with two 10K HDDs in a RAID 1 configuration, then another workload run with a four drive RAID 10. In a production environment, ideally the .mdf and .ldf would be placed on separate HDDs and SSDs.

To improve cache buffering the SQL Server database instance memory could be increased from 16GB to a larger number that would yield higher TPS numbers. Keep in mind the objective was not to see how fast I could make the databases run, rather how the different drives handled the workload.

7 Refer to Enterprise SSHD and Flash SSD Part of an Enterprise Tiered Storage Strategy
http://storageioblog.com/enterprise-sshd-and-flash-ssd-part-of-an-enterprise-tiered-storage-strategy/

8 The SQL Server Tempdb was placed on a separate NVMe flash SSD, also the database instance memory size was set to 16GB which was shared by all databases and virtual users accessing it.

9 Each user step was run for 90 minutes with a 30 minute warm-up preamble to measure steady-state operation.

TABLE-2 SHOWS TPCC DATABASE WORKLOAD RESULTS

	Users	TPCC Like TPS	Single Drive Cost per TPS	Drive Cost per TPS	Single Drive Cost / Per GB Raw Cap.	Cost / Per GB Usable (Protected) Cap.	Drive Cost (Multiple Drives)	Protect Space Over head	Cost per usable GB per TPS	Resp. Time (Sec.)
ENT 15K R1	1	23.9	$24.94	$49.89	$0.99	$0.99	$1,190	100%	$49.89	0.01
ENT 10K R1	1	23.4	$37.38	$74.77	$0.49	$0.49	$1,750	100%	$74.77	0.01
ENT CAP R1	1	16.4	$24.26	$48.52	$0.20	$0.20	$ 798	100%	$48.52	0.03
ENT 10K R10	1	23.2	$37.70	$150.78	$0.49	$0.97	$3,500	100%	$150.78	0.07
ENT CAP SWR5	1	17.0	$23.45	$117.24	$0.20	$0.25	$1,995	20%	$117.24	0.02
ENT 15K R1	20	362.3	$1.64	$3.28	$0.99	$0.99	$1,190	100%	$3.28	0.02
ENT 10K R1	20	339.3	$2.58	$5.16	$0.49	$0.49	$1,750	100%	$5.16	0.01
ENT CAP R1	20	213.4	$1.87	$3.74	$0.20	$0.20	$ 798	100%	$3.74	0.06
ENT 10K R10	20	389.0	$2.25	$9.00	$0.49	$0.97	$3,500	100%	$9.00	0.02
ENT CAP SWR5	20	216.8	$1.84	$9.20	$0.20	$0.25	$1,995	20%	$9.20	0.06
ENT 15K R1	50	417.3	$1.43	$2.85	$0.99	$0.99	$1,190	100%	$2.85	0.08
ENT 10K R1	50	385.8	$2.27	$4.54	$0.49	$0.49	$1,750	100%	$4.54	0.09
ENT CAP R1	50	103.5	$3.85	$7.71	$0.20	$0.20	$ 798	100%	$7.71	0.45
ENT 10K R10	50	778.3	$1.12	$4.50	$0.49	$0.97	$3,500	100%	$4.50	0.03
ENT CAP SWR5	50	109.3	$3.65	$18.26	$0.20	$0.25	$1,995	20%	$18.26	0.42
ENT 15K R1	100	190.7	$3.12	$6.24	$0.99	$0.99	$1,190	100%	$6.24	0.49
ENT 10K R1	100	175.9	$4.98	$9.95	$0.49	$0.49	$1,750	100%	$9.95	0.53
ENT CAP R1	100	59.1	$6.76	$13.51	$0.20	$0.20	$ 798	100%	$13.51	1.66
ENT 10K R10	100	560.6	$1.56	$6.24	$0.49	$0.97	$3,500	100%	$6.24	0.14
ENT CAP SWR5	100	62.2	$6.42	$32.10	$0.20	$0.25	$1,995	20%	$32.10	1.57

Table-2 TPC-C workload results various number of users across different drive configurations

FIGURE-2 TPC-C TRANSACTIONS PER SECOND (TPS)

Figure-2 shows TPC-C TPS (red dashed line) workload scaling over various number of users (1, 20, 50, and 100) with peak TPS per drive shown. Also shown is the used space capacity (in green), with total raw storage capacity in blue cross hatch. Looking at the multiple metrics in context shows that the 600GB Enterprise 15K HDD with performance enhanced cache is a premium option as an alternative, or, to complement flash SSD solutions.

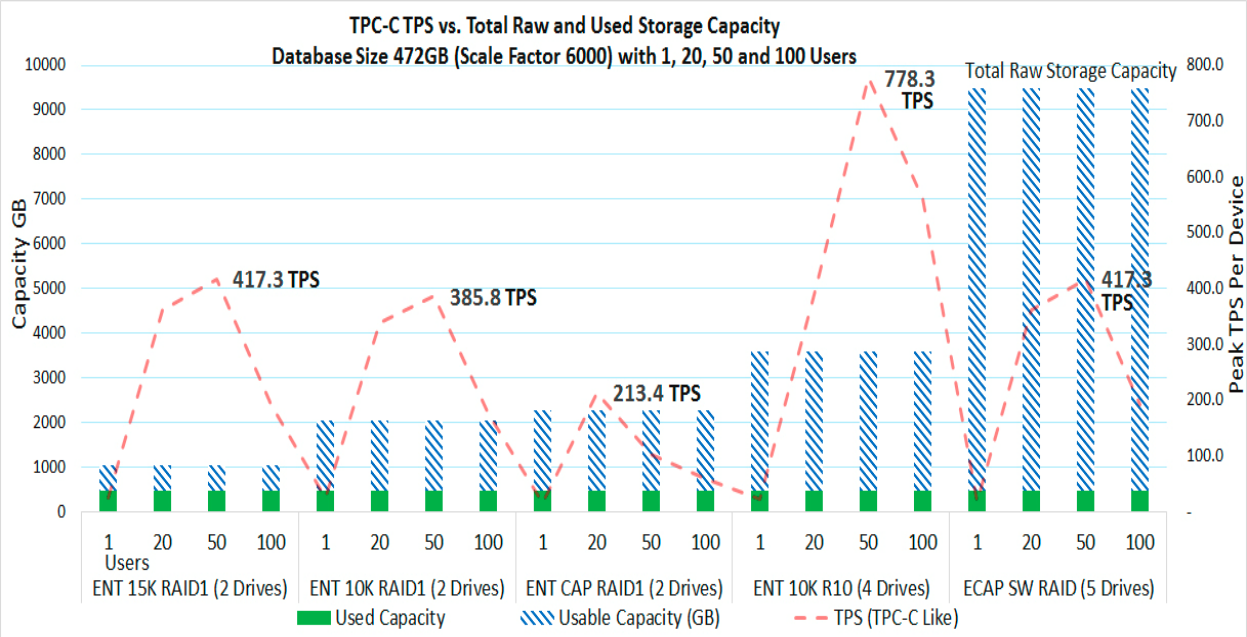


Figure-2 472GB Database TPS scaling along with cost per TPS and storage space used

In figure-2, the 1.8TB Enterprise 10K HDD with performance enhanced cache while not as fast as the 15K, provides a good balance of performance, space capacity and cost effectiveness. A good use for the 10K drives is where some amount of performance is needed as well as a large amount of storage space for less frequently accessed content.

A low cost, low performance option would be the 2TB Enterprise Capacity HDDs that have a good cost per capacity, however lack the performance of the 15K and 10K drives with enhanced performance cache. A four drive RAID 10 along with a five drive software volume (Microsoft WIndows) are also shown. For apples to apples comparison look at costs vs. capacity including number of drives needed for a given level of performance.

FIGURE-3 TPC-C TPS AND RESPONSE TIME SCALING

Figure-3 is a variation of figure-2 showing TPC-C TPS (blue bar) and response time (red-dashed line) scaling across 1, 20, 50 and 100 users. Once again the Enterprise 15K with enhanced performance cache feature enabled has good performance in an apples to apples RAID 1 comparison.

Note that the best performance was with the four drive RAID 10 using 10K HDDs. Given popularity, a four drive RAID 10 configuration with the 10K drives was used. Not surprising the four 10K drives performed better than the RAID 1 15Ks. Also note using five drives in a software spanned volume provides a large amount of storage capacity and good performance however with a larger drive footprint.

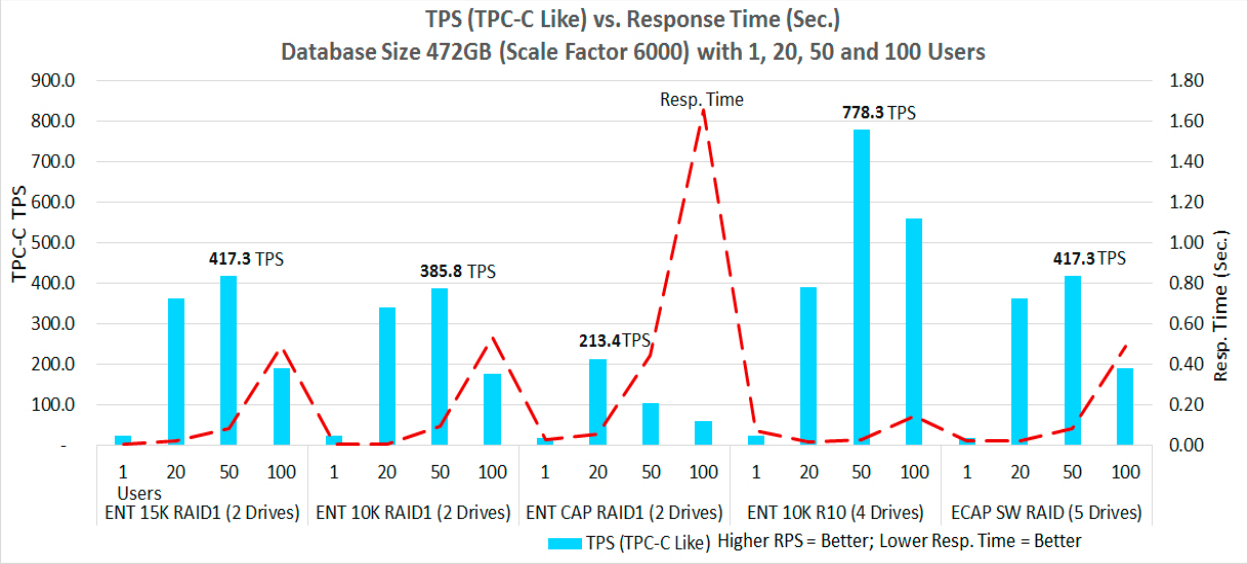


Figure-3 472GB Database TPS scaling along with response time (latency)

From a cost per space capacity perspective, the Enterprise Capacity drives have a good cost per GB. A hybrid solution for environment that do not need ultra-high performance would be to pair a small amount of flash SSD[10] (drives or PCIe cards), as well as the 10K and 15K performance enhanced drives with the Enterprise Capacity HDD[11] along with cache or tiering software.

10 Refer to Seagate 1200 12 Gbps Enterprise SAS SSD StorageIO lab review
http://storageioblog.com/seagate-1200-12gbs-enterprise-sas-ssd-server-storgeio-lab-review/
11 Refer to Enterprise SSHD and Flash SSD Part of an Enterprise Tiered Storage Strategy
http://storageioblog.com/enterprise-sshd-and-flash-ssd-part-of-an-enterprise-tiered-storage-strategy/

FILE PERFORMANCE ACTIVITY

Two separate file processing workloads were run[12], one with a relative small number of large files, and another with a large number of small files. For the large file processing (table-3), 5 GByte sized files were created and then accessed via 128 Kbyte (128KB) sized I/O over a 10 hour period with 90% read using 64 threads (workers). Large file workload simulates what might be seen with higher definition video, image or other content streaming. The 10% writes are intended to reflect some update activity for new content or other changes to content. Note that 128KB per second translates to roughly 1 Gbps streaming content such as higher definition video. However 4K video (not optimized) would require a higher speed as well as resulting in larger file sizes. Table-3 shows the performance during the large file access period showing average read /write rates and response time, bandwidth (MBps), average open and close rates with response time.

TIP

Content solutions use files in various ways. Use the following to gain perspective how various HDDs handle workloads similar to your specific needs.

	Avg. File Read Rate	Avg. Read Resp. Time Sec.	Avg. File Write Rate	Avg. Write Resp. Time Sec.	Avg. CPU % Total	Avg. CPU % System	Avg. MBps Read	Avg. MBps Write
ENT 15K R1	580.7	107.9	64.5	19.7	52.2	35.5	72.6	8.1
ENT 10K R1	455.4	135.5	50.6	44.6	34.0	22.7	56.9	6.3
ENT CAP R1	285.5	221.9	31.8	19.0	43.9	28.3	37.7	4.0
ENT 10K R10	690.9	87.21	76.8	48.6	35.0	21.8	86.4	9.6

Table-3 Performance summary for large file access operations (90% read)

[12] File processing workloads were run using Vdbench 5.04 and file anchors with sample script configuration below

VdbenchFSBigTest.txt
# Sample script for big files testing
fsd=fsd1,anchor=H:,depth=1,width=5,files=20,size=5G
fwd=fwd1,fsd=fsd1,rdpct=90,xfersize=128k,fileselect=random,fileio=random,threads=64
rd=rd1,fwd=fwd1,fwdrate=max,format=yes,elapsed=10h,interval=30

vdbench -f VdbenchFSBigTest.txt -m 16 -o Results_FSbig_H_060615

VdbenchFSSmallTest.txt
# Sample script for big files testing
fsd=fsd1,anchor=H:,depth=1,width=64,files=25600,size=16k
fwd=fwd1,fsd=fsd1,rdpct=90,xfersize=1k,fileselect=random,fileio=random,threads=64
rd=rd1,fwd=fwd1,fwdrate=max,format=yes,elapsed=10h,interval=30

vdbench -f VdbenchFSSmallTest.txt -m 16 -o Results_FSsmall_H_060615

Table-3 shows that for two-drive RAID 1, the Enterprise 15K are the fastest performance, however using a RAID 10 with four 10K HDDs with enhanced cache features provide a good price, performance and space capacity option. Software RAID was used in this workload test.

FIGURE-4 LARGE FILE PERFORMANCE ACTIVITY

Figure-4 shows the relative performance of various HDD options handling large files, keep in mind that for the response line lower is better, while for the activity rate higher is better.

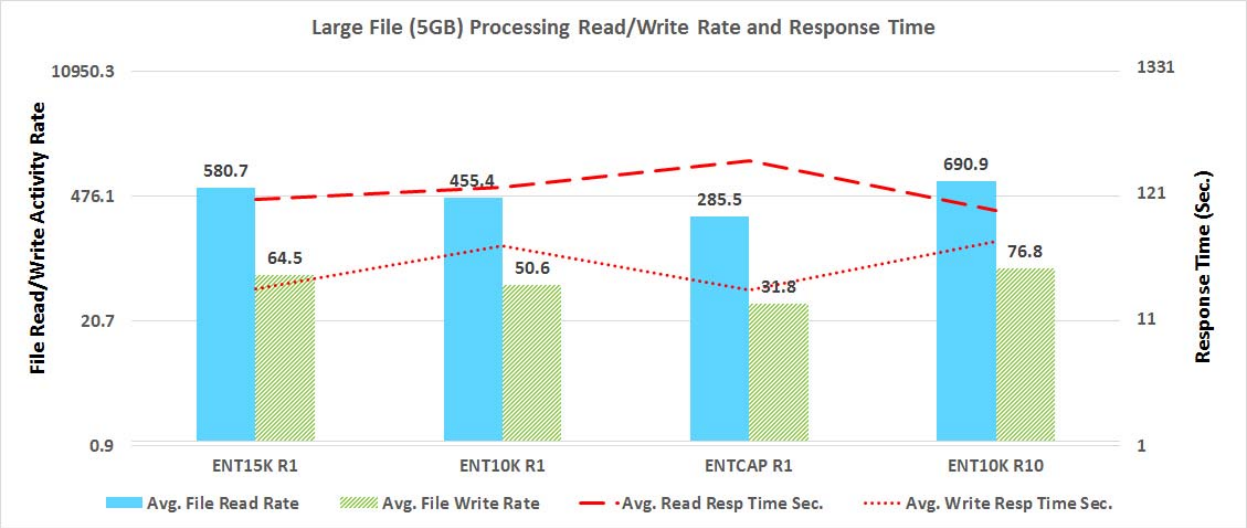


Figure-4 Large file processing 90% read, 10% write rate and response time

In figure-4 you can see the performance in terms of response time (reads larger dashed line, writes smaller dotted line) along with number of file read operations per second (reads solid blue column bar, writes green column bar). Reminder that lower response time, and higher activity rates are better. Performance declines moving from left to right, from 15K to 10K Enterprise Performance with enhanced cache feature to Enterprise Capacity (7.2K), all of which were hardware RAID 1. Also shown is a hardware RAID 10 (four x 10K HDDs).

Results in figure-4 above and table-4 below show how various drives can be configured to balance their performance, capacity and costs to meet different needs. Table-4 below shows an analysis looking at average file reads per second (RPS) performance vs. HDD costs, usable capacity and protection level.

TABLE-4 LARGE FILE PERFORMANCE ACTIVITY DETAILS

Table-4 is an example of looking at multiple metrics to make informed decisions as to which HDD would be best suited to your specific needs. For example RAID 10 using four 10K drives provides good performance and protection along with large usable space, however that also comes at a budget cost (e.g. price)

	Avg. File Reads Per Sec. (RPS)	Single Drive Cost per RPS	Multi-Drive Cost per RPS	Single Drive Cost / Per GB Capacity	Cost / Per GB Usable (Protected) Cap.	Drive Cost (Multiple Drives)	Protection Overhead (Space Capacity for RAID)	Cost per usable GB per RPS	Avg. File Read Resp. (Sec.)
ENT 15K R1	580.7	$1.02	$2.05	$ 0.99	$0.99	$1,190	100%	$2.1	107.9
ENT 10K R1	455.5	1.92	3.84	0.49	0.49	1,750	100%	3.8	135.5
ENT CAP R1	285.5	1.40	2.80	0.20	0.20	798	100%	2.8	271.9
ENT 10K R10	690.9	1.27	5.07	0.49	0.97	3,500	100%	5.1	87.2

Table-4 Performance, capacity and cost analysis for big file processing

SMALL FILE SIZE PROCESSING

To simulate a general file sharing environment, or content streaming with many smaller objects, 1,638,464 16KB sized files were created on each device being tested (table-5). These files were spread across 64 directories (25,600 files each) and accessed via 64 threads (workers) doing 90% reads with a 1KB I/O size over a ten hour time frame. Like the large file test, and database activity, all workloads were run at the same time (e.g. test devices were concurrently busy).

TABLE-5 SMALL FILE SIZE PERFORMANCE DETAIL

	Avg. File Read Rate	Avg. Read Resp. Time Sec.	Avg. File Write Rate	Avg. Write Resp. Time Sec.	Avg. CPU % Total	Avg. CPU % System	Avg. MBps Read	Avg. MBps Write
ENT 15K R1	3,415.7	1.5	379.4	132.2	24.9	19.5	3.3	0.4
ENT 10K R1	2,203.4	2.9	244.7	172.8	24.7	19.3	2.2	0.2
ENT CAP R1	1,063.1	12.7	118.1	303.3	24.6	19.2	1.1	0.1
ENT 10K R10	4,590.5	0.7	509.9	101.7	27.7	22.1	4.5	0.5

Table-5 Performance summary for small sized (16KB) file access operations (90% read)

FIGURE-5 SMALL FILE SIZE PROCESSING PERFORMANCE

Figure-5 shows the relative performance of various HDD options handling large files, keep in mind that for the response line lower is better, while for the activity rate higher is better.

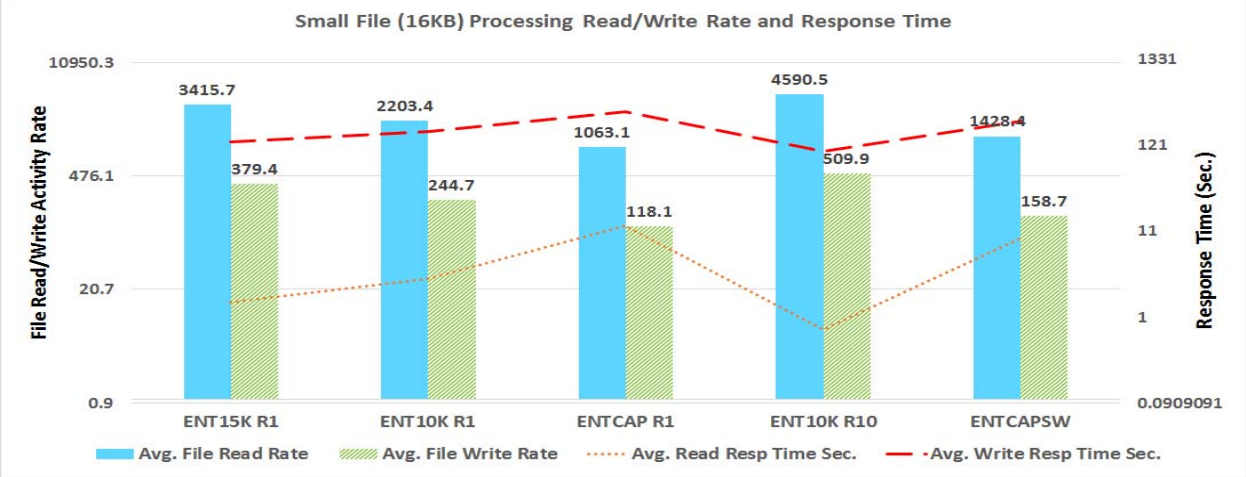


Figure-5 Small file processing 90% read, 10% write rate and response time

In figure-5 you can see the performance in terms of response time (reads larger dashed line, writes smaller dotted line) along with number of file read operations per second (reads solid blue column bar, writes green column bar). Reminder that lower response time, and higher activity rates are better. Performance declines moving from left to right, from 15K to 10K Enterprise Performance with enhanced cache feature to Enterprise Capacity (7.2K), all of which were hardware RAID 1. Also shown is a hardware RAID 10 (four x 10K HDDs) that has higher performance and capacity along with costs (table-5).

Results in figure-5 above and table-5 below show how various drives can be configured to balance their performance, capacity and costs to meet different needs. Table-6 below shows an analysis looking at average file reads per second (RPS) performance vs. HDD costs, usable capacity and protection level.

TABLE-6 SMALL FILE PERFORMANCE COST ANALYSIS

Table-6 is an example of looking at multiple metrics to make informed decisions as to which HDD would be best suited to your specific needs. For example RAID 10 using four 10K drives provides good performance and protection along with large usable space, however that also comes at a budget cost (e.g. price).

	Avg. File Reads Per Sec. (RPS)	Single Drive Cost per RPS	Multi-Drive Cost per RPS	Single Drive Cost / Per GB Capacity	Cost / Per GB Usable (Protected) Cap.	Drive Cost (Multiple Drives)	Protection Overhead (Space Capacity for RAID)	Cost per usable GB per RPS	Avg. File Read Resp. (Sec.)
ENT 15K R1	3,415.7	$0.17	$0.35	$0.99	$0.99	$1,190	100%	$0.35	1.51
ENT 10K R1	2,203.4	0.40	0.79	0.49	0.49	1,750	100%	0.79	2.90
ENT CAP R1	1,063.1	0.38	0.75	0.20	0.20	798	100%	0.75	12.70
ENT 10K R10	4,590.5	0.19	0.76	0.49	0.97	3,500	100%	0.76	0.70

Table-6 Performance, capacity and cost analysis for small file processing

Looking at the small file processing analysis in table-5 shows that the 15K HDDs on an apples to apples basis (e.g. same RAID level and number of drives) provide the best performance. However when also factoring in space capacity, performance, different RAID level or other protection schemes along with cost, there are other considerations. On the other hand the Enterprise Capacity 2TB HDDs have a low cost per capacity, however do not have the performance of other options, assuming your applications need more performance.

Thus the right HDD for one application may not be the best one for a different scenario as well as multiple metrics as shown in table-5 need to be included in an informed storage decision making process.

GENERAL I/O PERFORMANCE

In addition to running database and file (large and small) processing workloads, Vdbench was also used to collect basic small (8KB) and large (128KB) sized I/O operations. This consisted of random and sequential reads as well as writes with the results shown below.

These workloads used Vdbench configured[13] to do direct I/O to a Windows file system mounted device using as much of the available disk space as possible. All workloads used 16 threads and were run concurrently similar to database and file processing tests.

TABLE-7 8KB RANDOM IOPS 75% READS/WRITES

Table-7 shows workload results for 8KB random IOPs 75% reads and 75% writes including IOPs, bandwidth and response time.

	ENT 15K RAID1		ENT 10K RAID1		ENT CAP RAID1		ENT 10K R10 (4 Drives)		ECAP SW RAID (5 Drives)	
	75% Read	25% Read	75% Read	25% Read	75% Read	25% Read	75% Read	25% Read	75% Read	25% Read
I/O Rate (IOPs)	597.11	559.26	514	475	285	293	979	984	491	644
MB/sec	4.7	4.4	4.0	3.7	2.2	2.3	7.7	7.7	3.8	5.0
Resp. Time (Sec.)	25.9	27.6	30.2	32.7	55.5	53.7	16.3	16.3	32.6	24.8

Table-7 8KB sized random IOPs workload results

[13] Sample vdbench configuration for general I/O, note different settings were used for various tests

```
# seqrxx.txt
sd=sd1,lun=H:TEMPIO1.tmp,openflags=directio,size=500G
wd=mix,sd=sd1
rd=mix4corner,wd=mix,elapsed=1h,interval=30,iorate=max,forthreads=(16),forxfersize=(128k),forseekpct=(0),for
rdpct=(100,0),openflags=direct


vdbench -f SIO_seqrxx.txt -o 128KSEQReadWrite_061515
```

FIGURE-6 8KB RANDOM IOPS 75% READS/WRITES

Figure-6 shows small (8KB) random I/O (75% read and 25% read) across different HDD configurations. Performance including activity rates (e.g. IOPs), bandwidth and response time for mixed reads / writes are shown. Note how response time increases with the Enterprise Capacity configurations vs. other performance optimized drives.

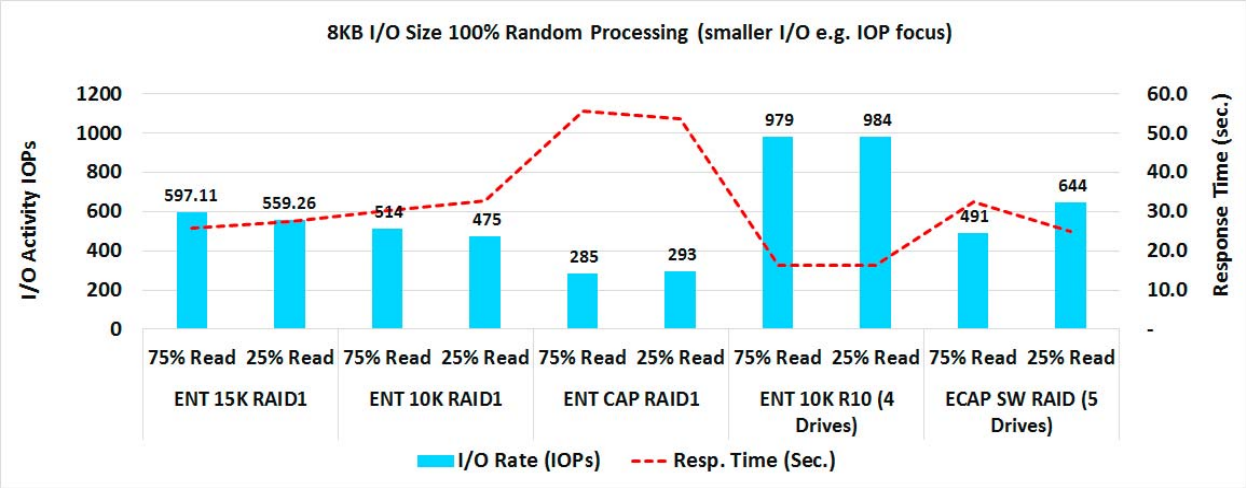


Figure-6 8KB random reads and write showing IOP activity, bandwidth and response time

TABLE-8 8KB SEQUENTIAL IOPS 75% READS/WRITES

Table-8 below shows workload results for 8GB sized I/Os 100% sequential with 75% reads and 75% writes including IOPs, MB/sec and response time in seconds.

	ENT 15K RAID1		ENT 10K RAID1		ENT CAP RAID1		ENT 10K R10 (4 Drives)		ECAP SW RAID (5 Drives)	
	75% Read	25% Read	75% Read	25% Read	75% Read	25% Read	75% Read	25% Read	75% Read	25% Read
I/O Rate (IOPs)	3,778	3,414	3,761	3,986	3,379	1,274	11,840	8,368	2,891	1,146
MB/sec	29.5	26.7	29.4	31.1	26.4	10.0	92.5	65.4	22.6	9.0
Resp. Time (Sec.)	2.2	3.1	2.3	2.4	2.7	10.9	1.3	1.9	5.5	14.0

Table-8 8KB sized sequential workload results

FIGURE-7 8KB SEQUENTIAL IOPS 75% READS/WRITES

Figure-7 shows small 8KB sequential mixed reads and writes (75% read and 75% write), while the Enterprise Capacity 2TB HDD has a large amount of space capacity, its performance in a RAID 1 vs. other similar configured drives is slower.

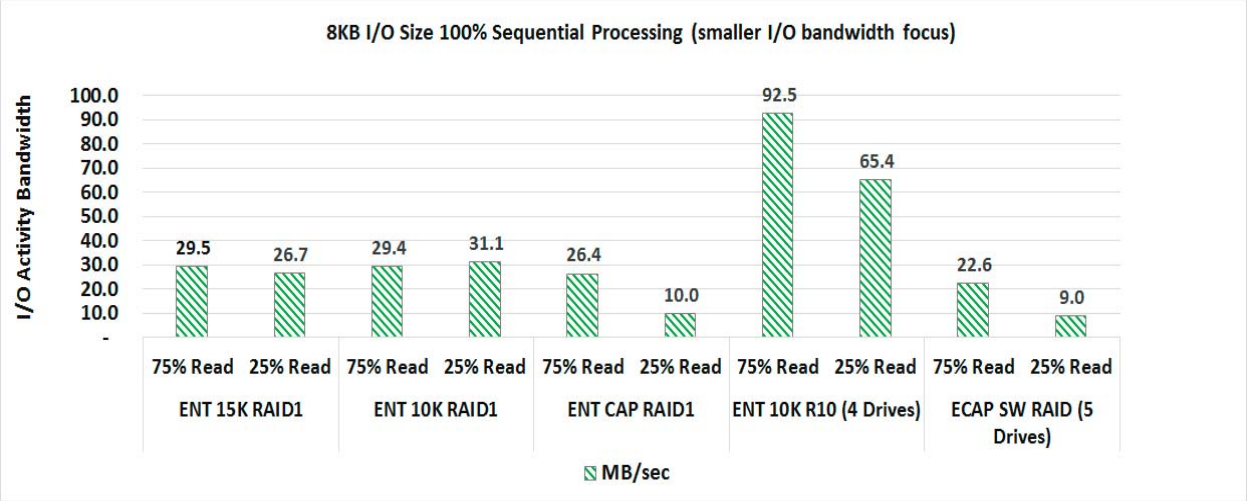


Figure-7 8KB sequential 75% reads and 75% write showing bandwidth activity

TABLE-9 128KB SEQUENTIAL IOPS 100% READS/WRITES

Table-9 shows workload results for 100% sequential, 100% read and 100% write 128KB sized I/Os including IOPs, bandwidth and response time.

	ENT 15K RAID1		ENT 10K RAID1		ENT CAP RAID1		ENT 10K R10 (4 Drives)		ECAP SW RAID (5 Drives)	
	Read	Write	Read	Write	Read	Write	Read	Write	Read	Write
I/O Rate (IOPs)	1,798	1,771	1,716	1,688	921	912	3,552	3,486	780	721
MB/sec	224.7	221.3	214.5	210.9	115.2	114.0	444.0	435.8	97.4	90.1
Resp. Time (Sec.)	8.9	9.0	9.3	9.5	17.4	17.5	4.5	4.6	19.3	20.2

Table-9 128KB sized sequential workload results

FIGURE-8 128KB SEQUENTIAL IOPS 100% READS/WRITES

Figure-8 shows sequential or streaming operations of larger I/O (100% read and 100% write) requests sizes (128KB) that would be found with large content applications. Figure-8 highlights the relationship between lower response time and increased IOPs as well as bandwidth.

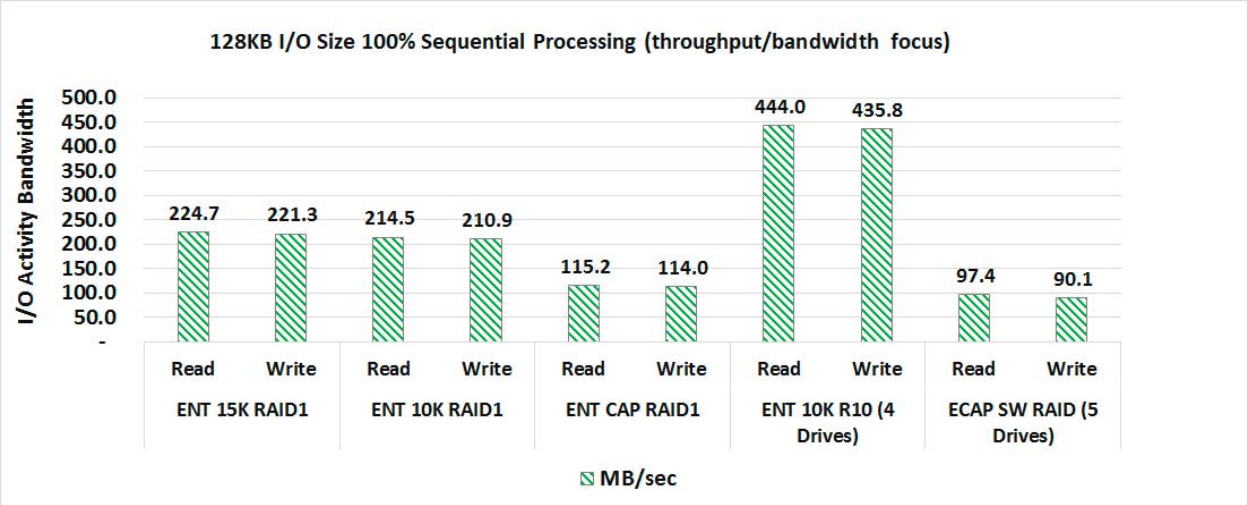


Figure-8 128KB sequential reads and write showing IOP activity, bandwidth and response time

COMPARING ENTERPRISE 10K AND 15K HDD GENERATIONS

There is more to HDD performance than RPM speed of the device. RPM plays an important role, however there are other things that impact HDD performance. A common myth is that HDDs have not improved on performance over the past several years with each successive generation. Table-10 shows a sampling of various generations of enterprise 10K and 15K HDDs including different form factors and how their performance continues to improve.

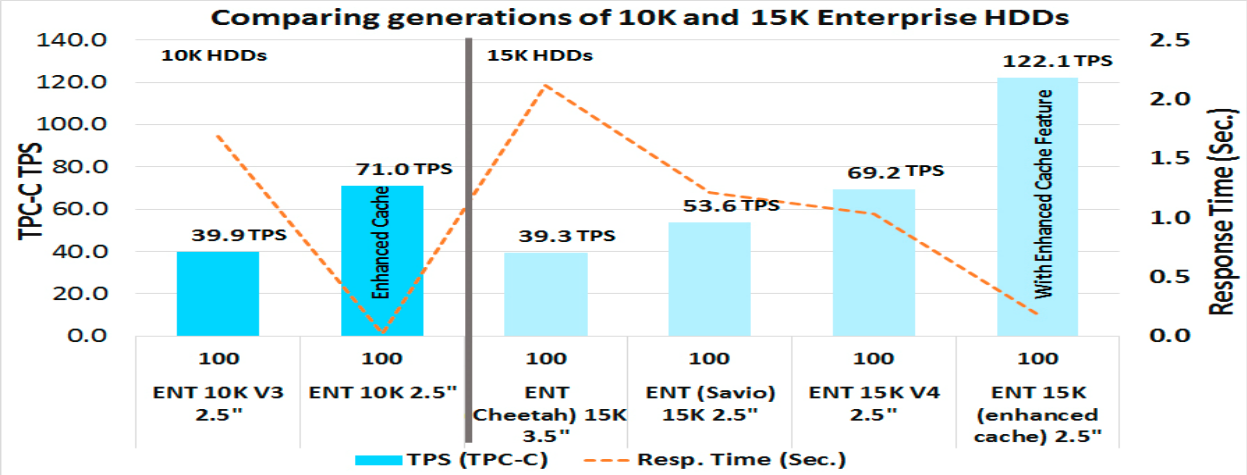


Figure-9 10K and 15K HDD performance improvements

Figure-9 shows how performance continues to improve with 10K and 15K HDDs with each new generation including those with enhanced cache features. The result is that with improvements in cache software within the drives, along with enhanced persistent non-volatile memory (NVM) and incremental mechanical drive improvements, both read and write performance continues to be enhanced.

Figure-9 puts into perspective the continued performance enhancements of HDDs comparing various enterprise 10K and 15K devices. The workload is the same TPC-C tests used earlier in a similar[14] (with no RAID). 100 simulated users are shown in figure-9 accessing a database on each of the different drives all running concurrently. The older 15K 3.5" Cheetah and 2.5" Savio used had a capacity of 146GB which used a database scale factor of 1500 or 134GB. All other drives used a scale factor 3000 or 276GB. Figure-9 also highlights the improvements in both TPS performance as well as lower response time with new HDDs including those with performance enhanced cache feature.

14 10K and 15K generational comparisons were run on a separate comparable server to what was used for other test workloads. Workload configuration settings were the same as other database workloads including using Microsoft SQL Server 2012 on a Windows 2012 R2 system with Benchmark Factory driving the workload. Database memory sized was reduced however to only 8GB vs. 16GB used in other tests.

TABLE-10 ENTERPRISE 10K AND 15K HDD GENERATIONS

The workloads run are same as the TPC-C ones shown earlier, however these drives were not configured with any RAID. The TPC-C activity used Benchmark Factory with similar setup and configuration to those used earlier including on a multi-socket, multi-core Windows 2012 R2 server supporting a Microsoft SQL Server 2012 database with a database for each drive type.

ENT 10K V3 2.5"

Users	1	20	50	100
TPS (TPC-C)	14.8	50.9	30.3	39.9
Resp. Time (Sec.)	0.0	0.4	1.6	1.7

ENT (Cheetah) 15K 3.5"

Users	1	20	50	100
TPS (TPC-C)	14.6	51.3	27.1	39.3
Resp. Time (Sec.)	0.0	0.3	1.8	2.1

ENT 10K 2.5" (with cache)

Users	1	20	50	100
TPS (TPC-C)	19.2	146.3	72.6	71.0
Resp. Time (Sec.)	0.0	0.1	0.7	0.0

ENT (Savio) 15K 2.5"

Users	1	20	50	100
TPS (TPC-C)	15.8	59.1	40.2	53.6
Resp. Time (Sec.)	0.0	0.3	1.2	1.2

ENT 15K V4 2.5"

Users	1	20	50	100
TPS (TPC-C)	19.7	119.8	75.3	69.2
Resp. Time (Sec.)	0.0	0.1	0.6	1.0

ENT 15K (enhanced cache) 2.5"

Users	1	20	50	100
TPS (TPC-C)	20.1	184.1	113.7	122.1
Resp. Time (Sec.)	0.0	0.1	0.4	0.2

Table-10 Continued Enterprise 10K and 15K HDD performance improvements

WHAT THIS ALL MEANS

A little bit of flash in the right place with applicable algorithms goes a long way, an example being the Seagate Enterprise HDDs with enhanced cache feature. Likewise, HDDs are very much alive complementing SSD and vice versa. For high-performance content application workloads flash SSD solutions including NVMe, 12Gbps SAS and 6Gbps SATA devices are cost effective solutions. HDDs continue to be cost-effective data storage devices for both capacity, as well as environments that do not need the performance of flash SSD.

For some environments using a combination of flash and HDDs complementing each other along with cache software can be a cost-effective solution. The previous workload examples provide insight for making cost-effective informed storage decisions.

Evaluate todays HDDs on their effective performance running workloads as close as similar to your own, or, actually try them out with your applications. Today there is more to HDD performance than just RPM speed, particular with the Seagate Enterprise Performance 10K and 15K HDDs with enhanced caching feature. However the Enterprise Performance 10K with enhanced cache feature provides a good balance of capacity, performance while being cost-effective. If you are using older 3.5" 15K or even previous generation 2.5" 15K RPM and "non-performance enhanced" HDDs, take a look at how the newer generation HDDs perform, looking beyond the RPM of the device.

WRAP UP AND SUMMARY, CALL TO ACTION

Fast content applications need fast content and flexible content solution platforms such as those from Equus Computer Systems. Key to a successful content application deployment is having the flexibility to hardware define and software defined the platform to meet your needs. Just as there are many different types of content applications along with diverse environments, content solution platforms need to be flexible, scalable and robust, not to mention cost effective.

ABOUT THE AUTHOR

Greg Schulz is Founder and Sr. Analyst of independent IT advisory consultancy firm Server StorageIO and UnlimitedIO LLC (e.g. StorageIO®). He has worked in IT at an electrical utility, financial services and transportation firms in roles ranging from business applications development to systems management, architecture, strategy and capacity planning. Mr. Schulz is author of the Intel Recommended Reading List books "Cloud and Virtual Data Storage Networking" and "The Green and Virtual Data Center" via CRC Press and "Resilient Storage Networks" (Elsevier). Greg is a Microsoft MVP and VMware vExpert. Learn more at www.storageio.com and www.storageioblog.com follow on twitter @StorageIO.

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