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The Best Network Attached Storage Choice for Oracle Database and Software Environments

A Comparison of Oracle's Sun ZFS Storage 7420 With the NetApp FAS3250

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Executive Overview

Oracle's Sun ZFS Storage Appliances offer significant advantages for Oracle Database and Oracle software solutions. This paper compares the Sun ZFS Storage 7420 cluster to a NetApp FAS3250 cluster and describes how Oracle's integrated approach to storage increases the value of Oracle solutions.

The advantages of Sun ZFS Storage Appliances are gaining more recognition in the marketplace and enterprises are using Sun ZFS Storage Appliances to deliver added value with Oracle Database and Oracle Applications.

Oracle is also running more than 200 PB of storage on Sun ZFS Storage Appliances to support Oracle Cloud services and Oracle's internal global IT and product development initiatives. Some of these internal storage environments had originally been based on NetApp appliances and were replaced in a consolidation effort that reduced the number of storage systems by a 3:1 ratio and resulted in significant improvements in performance and operational efficiency. Oracle Managed Cloud Services (formerly Oracle On Demand) has achieved nearly a 2:1 improvement in management efficiency after a major storage upgrade replacing NetApp systems with Sun ZFS Storage Appliances.

Oracle's Sun ZFS Storage Appliances deliver enterprise-class network attached storage (NAS) capabilities with Oracle integration and leading simplicity, efficiency, performance, and TCO. They combine best-in-class storage analytics with an innovative storage architecture and management software to deliver unparalleled ease of deployment and use. Sun ZFS Storage Appliances also support common Storage Area Networking (SAN) access protocols including iSCSI and fibre channel to increase deployment flexibility.

Figures 1 and 2 highlight the key advantages of the Sun ZFS Storage 7420 appliance versus the NetApp FAS3250. The remaining sections of this document provide further details about these advantages and how they are achieved.

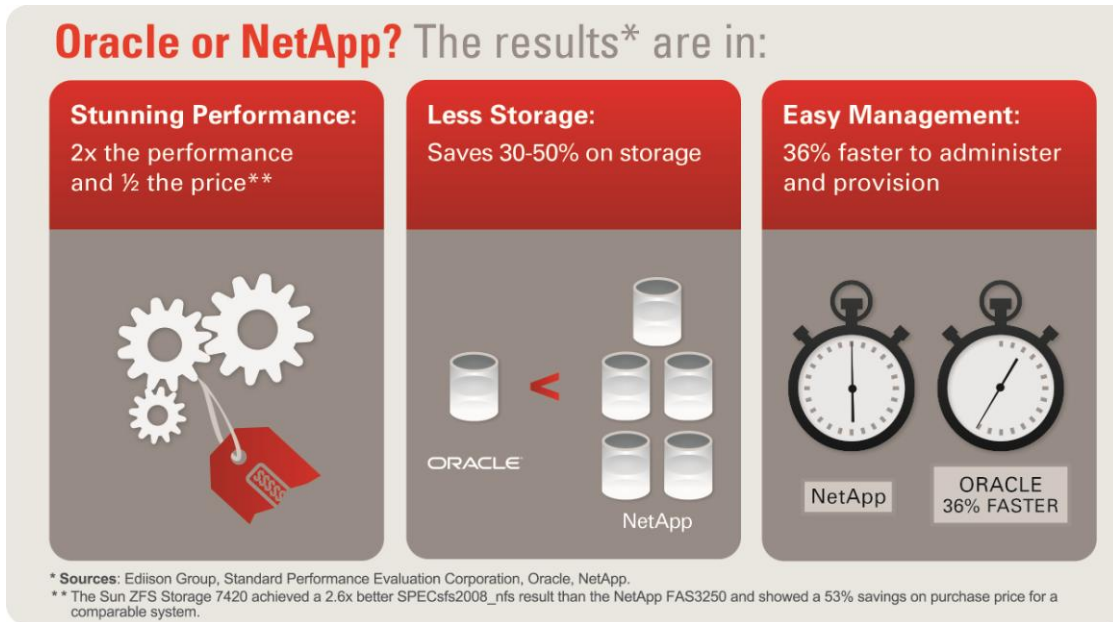


Figure 1. Comparison highlights.

| Feature/Capability | NetApp FAS3250 | Sun ZFS Storage 7420 | Oracle Advantage |
|--|------------------------------------|---|---|
| NFS I/O performance* | 100,922 SPECsfs2008_nfs ops/sec | 267,928 SPECsfs2008_nfs ops/sec | 2.6x better performance (See page 4 for details) |
| SAN I/O performance** | N/A | 137,066 SPC-1 IOPS and \$2.99/ SPC-1 IOPS | Ask NetApp for comparative results (See page 5 for details) |
| Hybrid Columnar Compression | X | ✓ | 10x - 50x compression for 3x to 5x reduction in storage space (See page 11 for details) |
| Purchase price for complete system with production software licenses | \$397,362 | \$188,428 | 53% savings (See page 9 for details) |
| Management efficiency | Limited observability | Real-time dashboard, fewer steps, DTrace Analytics | 36% easier and faster to administer according to Edison Group (See page 15 for details) |
| Integration | Stand-alone appliance | Integration throughout Oracle hardware and software stack | Increased value with Oracle hardware and software (See page 13 for details) |

* SPECsfs2008 results for Sun ZFS Storage 7420 and NetApp FAS3250 are as of November 2012 and are available at <http://www.spec.org/sfs2008/results/>. SPEC® and the benchmark name SPECsfs2008® are registered trademarks of the Standard Performance Evaluation Corporation. For more information about SPECsfs2008, see www.spec.org/sfs2008/.

** Oracle Sun ZFS Storage 7420 SPC-1 results as of October 3, 2011 available at http://www.storageperformance.org/results/benchmark_results_spc1#a00108. SPC-1 IOPS represents the maximum I/O request throughput at the 100% load point. The SPC-1/E benchmark consists of the complete set of SPC-1 performance measurement and reporting plus the measurement and reporting of energy use.

Figure 2. Summary comparison of Sun ZFS Storage 7420 versus NetApp FAS3250.

Twice the I/O Performance for Enterprise Data

Today's enterprise applications and cloud infrastructures depend more than ever on storage throughput for overall performance. With data growth showing no sign of abating, the speed with which data can be stored, retrieved, and protected can either make or break the success of an enterprise IT service.

Sun ZFS Storage Appliances are playing an increasing role in today's enterprise IT, Web and cloud infrastructures. These enterprise infrastructure environments require a high level of storage I/O throughput for a variety of data sources, applications, and protocols. Even backup environments for enterprise applications are challenged to deliver faster performance so that larger volumes of data can be protected within increasingly short backup and restore windows.

Advancements in technology with Oracle's Sun ZFS Storage Appliances enable the appliances to deliver high performance along with outstanding efficiency. These advancements are coupled with integration and testing across Oracle's complete application to disk portfolio, enabling enterprises to:

- Accelerate business applications and increase user productivity
- Address larger user populations
- Protect increasing amounts of enterprise data such as in Oracle Databases with fast archival storage
- Replace more costly and complex NetApp storage infrastructures
- Deploy cost-effective storage solutions that have ample room to grow

Table 1 shows a summary of the key performance advantages for the Sun ZFS Storage 7420 system. The subsections that follow describe the technical advantages of the Sun ZFS Storage 7420 and why it can outperform the NetApp FAS3250 filer.

TABLE 1. SUN ZFS STORAGE 7420 PERFORMANCE ADVANTAGES SUMMARY

| | SUN ZFS STORAGE 7420 | NETAPP FAS3250 |
|---|---|------------------------------------|
| SPECsfs2008 benchmark results* | 267,928 SPECsfs2008_nfs ops/sec | 100,922 SPECsfs2008_nfs ops/sec |
| SPC-1 or SPC-1/E benchmark results** | 137,066 SPC-1 IOPS and \$2.99/SPC-1 IOPS | Ask NetApp for SPC-1 results. |
| Maximum CPU cores per two-node cluster | 80 | 16 |
| Maximum block size for transfers | 128 KB | 4 KB (for block protocol) |
| InfiniBand client support | Yes | No |
| Maximum main memory per two-node cluster | 2 TB | 40 GB |
| Maximum read-cache per two-node cluster | 4 TB | 2 TB |
| Persistent write cache per two-node cluster | Up to 10.5 TB | 4GB |

* SPECsfs2008 results for Sun ZFS Storage 7420 and NetApp FAS3250 are as of November 2012 and are available at <http://www.spec.org/sfs2008/results/>. SPECsfs2008 characterizes file server performance based on typical CIFS (Common Internet File System) and NFS (Network File System) workloads.

** Oracle Sun ZFS Storage 7420 SPC-1 results as of October 3, 2011 available at http://www.storageperformance.org/results/benchmark_results_spc1#a00108. SPC-1 IOPS represents the maximum I/O request throughput at the 100% load point.

Twice the Performance in SPECsfs2008 Benchmark

The SPECsfs2008 benchmark offers an industry-accepted method for comparing storage performance with NFS (Network File System) workloads as well as CIFS (Common Internet File System) workloads. The Sun ZFS Storage 7420 Appliance delivered 267,928 SPECsfs2008_nfs ops/sec with an overall response time (ORT) of 1.31 ms on the SPECsfs2008_nfs benchmark for network file system throughput.¹ This result beat the NetApp FAS3250 filer by more than 2.5x as illustrated in Figure 3 and detailed in Table 2.

¹ SPECsfs2008_nfs results as of November 2012. For more information, see www.spec.org.

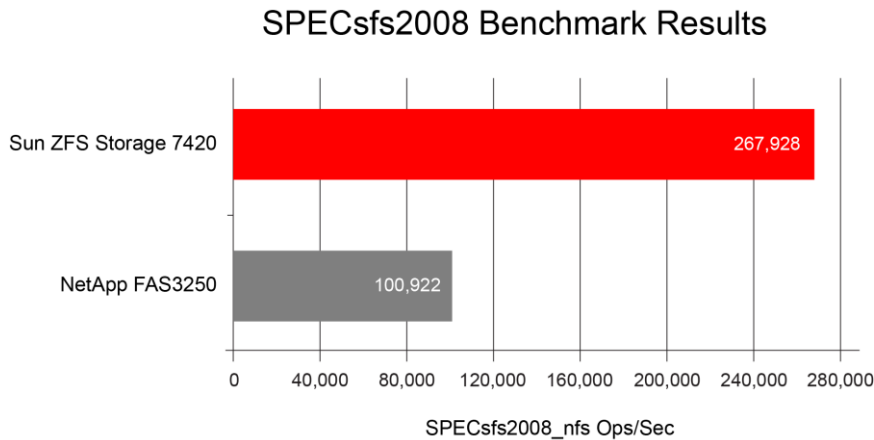


Figure 3. Sun ZFS Storage 7420 offers more than 2.5x better NFS performance based on SPECsfs2008 results.

TABLE 2. SPECsfs2008 BENCHMARK RESULTS

| | SUN ZFS STORAGE 7420c | NETAPP FAS3250 |
|-----------------------------|-----------------------|----------------|
| SPECsfs2008_nfs ops/sec | 267,928 | 100,922 |
| Overall Response Time (ORT) | 1.31 msec | 1.76 msec |

* Results as of November 2012. For more information, see www.spec.org. Sun ZFS Storage 7420 Appliance: 267,928 SPECsfs2008_nfs ops/sec, 1.31 ms ORT. NetApp FAS3250: 100,922 SPECsfs2008_nfs ops/sec, 1.76 ms ORT.

Audited SPC-1 Benchmark Results Detail

To verify SAN performance with the Sun ZFS Storage 7420 configuration, Oracle ran benchmark tests in accordance with Storage Performance Council's SPC-1 benchmark. The SPC-1 benchmark provides a source of comparative storage performance information that is objective, relevant, and verifiable.

While NetApp has not submitted SPC-1 results for the NetApp FAS3250, the Sun ZFS Storage 7420 result does show more than 2x better price-performance than the two most recent NetApp submissions for SPC-1 and SPC-1/E (as of January 25, 2013).

The NetApp FAS3270A had a price-performance of \$7.48/SPC-1 IOPS as of November 9, 2010 and the NetApp FAS6240 had a price-performance of \$6.69/SPC-1 IOPS as of June 18, 2012. Both of these results are more than twice the price-performance of the Sun ZFS Storage 7420.²

² NetApp FAS6240 SPC-1 results as of June 18, 2012 available at http://www.storageperformance.org/results/benchmark_results_sp1#a00115. NetApp FAS3270A SPC-1/E results as of October 3, 2011 available at http://www.storageperformance.org/results/benchmark_results_sp1#ae00004.

The Sun ZFS Storage 7420 also offers comparable or better performance than many other more expensive storage systems. For example, the Fujitsu ETERNUS DX440 S2 had a result of 102,989 SPC-1 IOPS³, which is less than the 137,066 SPC-1 IOPS achieved with the Sun ZFS Storage 7420. Yet the Fujitsu ETERNUS DX440 S2 configuration price is more than double that of the Sun ZFS Storage 7420. Therefore, the Fujitsu ETERNUS DX440 S2 price-performance result of \$8.62/SPC-1 IOPS is nearly 3x that of the Sun ZFS Storage 7420, which is 2.99.

Figure 4 shows a graphical summary of the SPC-1 price-performance results for each of the above-mentioned systems.

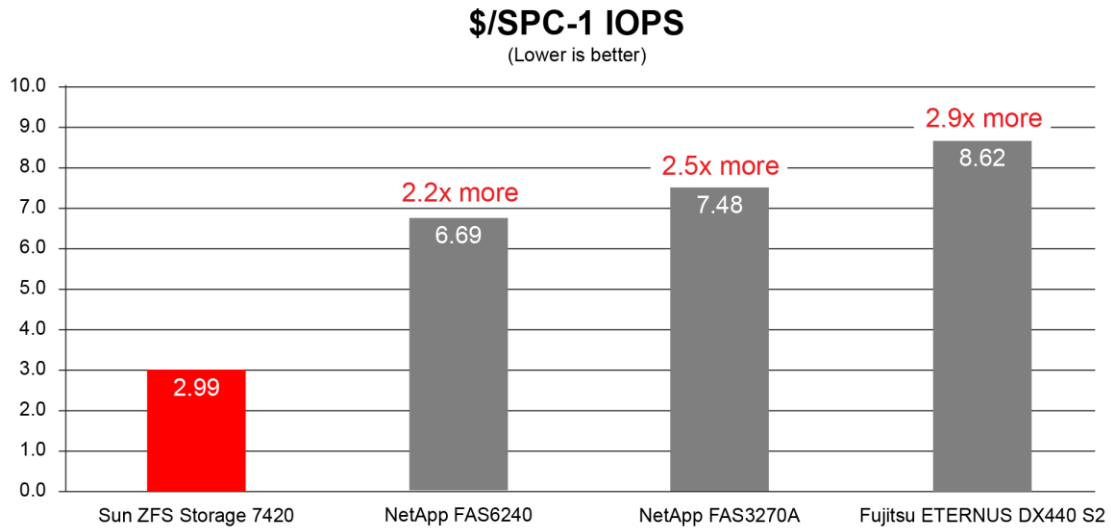


Figure 4. Comparison of \$/SPC-1 IOPS.

Highly Scalable Multithreaded Operating System

Sun ZFS Storage Appliances leverage the highly scalable Oracle Solaris operating system to take advantage of multiple cores and processors, enabling the Sun ZFS Storage 7420 to provide faster performance and deliver innovative data services.

5X More Processing Power

The Sun ZFS Storage 7420 system offers up to 40 cores per controller, which represents five times as many cores as the NetApp FAS3250 filer. This enables the appliance to perform complex processing for compression, deduplication, real-time storage analytics, and other data services without slowing down I/O throughput. The Sun ZFS Storage 7420 system can be configured with up to four 8-core or

³ Fujitsu ETERNUS DX440 S2 SPC-1 results as of June 26, 2012 available at http://www.storageperformance.org/results/benchmark_results_spc1#a00117.

10-core Intel® Xeon® processors per controller. This contrasts with only two 4-core Intel Xeon processors in a NetApp FAS3250 controller.

Up to 4X Faster Link Bandwidth

Interconnect speed is also important for storage performance because limited bandwidth out of the storage device can become a bottleneck when multiple systems or applications are storing and retrieving data. Oracle is the only leading NAS vendor to support InfiniBand as a storage network for transferring data to and from network clients. This provides the Sun ZFS Storage Appliances up to 40 Gb/sec per port of bandwidth for I/O to application and database servers, a rate that is four times better than what NetApp can achieve with their 10 Gb/sec Ethernet connectivity.

Fast Streaming Data and Backup

Sun ZFS Storage Appliances have been designed from the ground up to excel at both IOPS intensive workloads and streaming workloads. One of the most critical requirements for I/O throughput is for backup and recovery of Oracle Exadata Database Machines where Sun ZFS Storage Appliances use their more powerful controller architecture and direct connection to the Exadata system's InfiniBand fabric to achieve over 20 TB/hr of backup and 10 TB/hr of restore performance. When coupled with the substantially lower TCO of an all Oracle solution, this results in shorter backup windows and excellent recovery point objectives (RPOs). This enhanced performance is in addition to the significant price-performance advantage over the NetApp FAS3250 filer.

Enterprises interested in backup as the primary application for their storage purchase should consider Oracle's Sun ZFS Backup Appliance, which provides an integrated, high-performance backup and recovery solution for Oracle's engineered systems. More information about the Sun ZFS Backup Appliance is available at <http://www.oracle.com/us/products/servers-storage/storage/nas/zfs-backup-appliance/overview/>.

128 KB Block Size Dwarfs NetApp's 4 KB Limit⁴ for Block Protocols in Sequential I/O Applications

Another factor that affects I/O performance is the block size for block protocol reads and writes. The bigger block size of Sun ZFS Storage Appliances enables greater throughput for sequential I/O. NetApp has a fixed 4 KB block size, which slows performance for block sequential I/O by adding overhead for processing more blocks of data. Sun ZFS Storage Appliances offer a variable block size that can be up to 128 KB bytes. The fact that Sun ZFS Storage Appliances offer a block size that is variable allows administrators to tune their environment by selecting a large block size if the primary

⁴ Source: IBM System Storage N series Software Guide, pp 30. Published October 2012. Accessed at <http://www.redbooks.ibm.com/abstracts/sg247129.html?Open> on October 31, 2012.

application uses sequential I/O, or a smaller block size if the emphasis is on achieving higher duplication ratios for improved storage efficiency.

50x Larger Memory and 2x Larger Cache for Performance Acceleration

Both Oracle and NetApp appliances include a method of performance acceleration that leverages DRAM as an L1 cache and a flash-based L2 cache to drive greater I/O throughput. However, Oracle's Sun ZFS Storage Appliances support much larger memory and cache, which means there is a higher probability that requested data will be in cache or memory for faster data access and thus faster application performance.

The NetApp FAS3250 can hold a maximum of 20 GB of main memory per controller. The Sun ZFS Storage 7420 system supports up to 1 TB of main memory per controller, which is 50 times the main memory capacity of NetApp FAS3250 filers. Memory and cache size differences are important because I/O performance can be dramatically improved if data is read from or written to DRAM or cache rather than hard disk drives. Sophisticated file system algorithms on Sun ZFS Storage Appliances enhance client read performance by pre-staging data into memory (DRAM) as well as read-optimized SSDs, which can further improve IOPS performance. The Sun ZFS Storage 7420 cluster is further differentiated by supporting up to 4 TB of read-optimized cache, which is 2x that of the NetApp FAS3250 cluster.

Sun ZFS Storage 7420 write I/O performance automatically benefits from write-optimized SSDs when available. These SSDs act as a low latency data store to improve throughput by enabling writes to be committed to disk at a later time. This fast write I/O performance in turn, improves overall business performance and productivity.

Sun ZFS Storage Appliances utilize Hybrid Storage Pools (HSPs) to automate performance acceleration and take advantage of the appliances' large read and write cache areas. HSPs continuously monitor data usage patterns to determine whether and how to use the different storage media on the appliance. For example, large synchronous writes, such as video streaming, do not benefit from caching, so there is no attempt to place this type of data to write cache. Similarly, the read cache is populated based on an intelligent algorithm that takes into account not only the most recently used data, but also anticipated read requests and estimated data to be held in DRAM. Both read-optimized SSDs and write-optimized SSDs are hot-swappable, making it easy to extend cache to increase the performance of the appliance.

Lower Costs for Meeting Growing Storage Needs

The Sun ZFS Storage 7420 system is more cost-effective than the NetApp FAS3250 for a variety of reasons.

- *Lower initial purchase price* – The following subsection provides a list price comparison showing 53 percent savings over a similarly configured NetApp FAS3250 solution.
- *Reducing storage purchases* – By using industry leading Hybrid Columnar Compression with Sun ZFS Storage Appliances, customers using in-database archiving for data warehousing, OLTP and mixed-

use Oracle Database environments can reduce their storage footprint and acquisition costs as further described in the later subsection on storage efficiency. By reducing physical storage requirements, customers will also reduce floorspace, power and cooling requirements.

- *Handling larger loads*—The increased performance and greater storage efficiency offered by the Sun ZFS Storage 7420 appliance means that customers do not need to purchase a larger system to meet greater I/O throughput requirements or to store more data. Meeting performance and capacity requirements with a smaller storage system means additional savings in power and cooling costs.
- *Reducing annual software maintenance fees*—Because most data services are included in Sun ZFS Storage Appliances, annual software maintenance fees are greatly reduced compared to NetApp. Total software license fees on the Sun ZFS Storage 7420 configuration are \$45,000 versus \$122,220 for the NetApp FAS3250 cluster (see Table 3 below for details). Since software maintenance fees are usually a percentage of the original license fees, this difference of nearly 2x in original license fees is likely to result in lower annual software maintenance costs.
- *Reducing administration costs*—An Edison Group study described in the later section titled, “Easier to Manage,” states that better management efficiency translates directly into reduced storage administration expenses of approximately 36 percent compared to NetApp filers.⁵
- *Avoiding integration costs*—Because the appliance is pre-integrated with a number of Oracle solutions and is fully tested with other Oracle hardware and software, the time and cost for on-site integration and testing can be reduced.

List Price Comparison for Complete System with Production Software Licenses

Table 3 shows undiscounted list prices for a comparably configured Sun ZFS Storage 7420 cluster and NetApp FAS3250 cluster. The Sun ZFS Storage 7420 cluster is less than half the cost of the NetApp FAS3250 cluster.⁶ List prices shown in the table include the proper software licenses for deploying the NAS appliance in a heterogeneous environment where requirements include network access via NFS and CIFS protocols as well as Fibre Channel connectivity, remote replication, and the ability to restore from snapshots.

⁵ Gaining Business Advantage through Storage Management Efficiency with Oracle’s Sun ZFS Storage Appliance." Edison Group, February 2011.

⁶ NetApp pricing was obtained from publicly available sources with pricing as of November 2012. The Sun ZFS Storage 7420 pricing is based on Oracle list prices as of February 27, 2013.

TABLE 3. LIST PRICE COMPARISON

| PRODUCT | SUN ZFS STORAGE | NETAPP |
|------------------------------------|--------------------|------------------|
| | 7420 CLUSTER | FAS3250 CLUSTER |
| Hardware list price ⁷ | \$143,428 | \$275,142 |
| NFS protocol | \$0 | \$0 |
| Fibre Channel protocol | \$0 | \$23,450 |
| Cloning | \$15,000 | \$20,570 |
| CIFS protocol | 0 | \$23,450 |
| Snapshot restores | 0 | \$11,060 |
| Replication | \$30,000 | \$43,690 |
| TOTAL (US LIST) | \$188,428 | \$397,362 |
| PERCENT SAVINGS WITH ORACLE | 53% Savings | |

Cost-Effective Growth

Another important consideration in TCO is the cost of upgrades. Sun ZFS Storage 7420 appliances offer multiple ways to upgrade performance granularly to keep upgrade costs low. It is possible to add more memory, read cache, or write cache to address specific performance needs. When NetApp customers run out of performance headroom, their limited options include adding more PAM cards for read cache, adding more drives, or upgrading to a bigger storage system. Even just adding PAM cards on an existing NetApp FAS3250 filer is much more expensive than adding SSDs to a Sun ZFS Storage Appliance. And adding more drives or upgrading to a larger NetApp filer can get very expensive.

⁷ The Sun ZFS Storage 7420 configuration includes two controllers and both contain 128 GB DRAM, four 8-core CPUs, 1 TB of read-optimized SSDs, and two FC cards. It also includes two trays of disk with 44 x 3TB 7,200 RPM SAS-2 drives and two Write Flash Accelerators in the first tray, yielding a total of 132 TB of capacity. The NetApp FAS3250 configuration includes two controllers that have two PAM cards, 20 GB RAM, and two 4-core CPUs each. It includes two trays with 48 x 3TB 7,200 RPM SATA disk drives for a total of 144TB of capacity. NetApp pricing was obtained from publicly available sources with pricing as of November 2012. The Sun ZFS Storage 7420 pricing is based on Oracle list prices as of February 27, 2013. Both Oracle and NetApp software license prices are based on a 2-node cluster and thus the software license prices shown in the table represent the total for two software licenses.

Superior Storage Efficiency to Help Control Rising Storage Costs

Storage is often the largest item in IT budgets, making storage efficiency a hot topic. Greater utilization of storage resources decreases storage consumption, which not only reduces capital outlays but can also save on data center floorspace, power, and cooling costs.

Sun ZFS Storage Appliances offer leading storage efficiency, including the following key advantages over NetApp:

- Hybrid Columnar Compression for Oracle Database environments with in-database archiving that typically achieves between 10x and 50x compression.
- Highly efficient storage for development and test environments through the use of virtually unlimited, space-efficient snapshots and clones. NetApp has a limitation of 255 snapshot copies per volume.⁸ Oracle Database and storage administrators are able to create virtually unlimited database local-backups. This provides the option to restore at more granular points in time and enables administrators to make copies for different purposes—all without having to worry about managing the number of database copies or snapshots.

These features enable a comprehensive approach to maximizing storage utilization to help control rising costs.

10x-50x Compression with Oracle's Unique Hybrid Columnar Compression

Oracle's Sun ZFS Storage Appliance is the only NAS system to support Hybrid Columnar Compression to efficiently store and access data that is used in read-oriented Oracle Database environments. Data warehouses are the most common use case for this capability, but it also can be utilized in OLTP and mixed-use environments where database archives are required for business or regulatory reasons. Hybrid Columnar Compression typically achieves between 10x and 50x compression ratio. NetApp filers do not support Hybrid Columnar Compression, so customers who are currently running read-oriented Oracle Database environments with NetApp NAS devices can see an immediate 3x to 5x reduction in their storage footprint by migrating to Sun ZFS Storage appliances. Furthermore, the Hybrid Columnar Compression format is also used to transfer data to the database server so customers will see the full 10x to 50x reduction in I/O traffic and reduced memory utilization for these databases on their servers.

Flexible File Compression in Sun ZFS Storage Appliance Software

Not all workloads are the same and different compression algorithms will work better for different workloads. Sun ZFS Storage Appliance software includes more compression algorithms than NetApp systems, allowing administrators to choose the compression algorithm best suited for their particular

⁸ NetApp limitation of 255 snapshot copies source from NetApp web site at <http://www.netapp.com/us/products/platform-os/snapshot.aspx>.

application environment. The best way to determine the effect of compression for a given application environment is to run tests with actual data using various kinds of compression and observe the results on disk utilization and application performance.

Sun ZFS Storage Appliance software provides built-in compression that can help reduce the amount of space required to store user data. This in turn increases the effective storage capacity available to applications. Having compression built into the file system (as opposed to deploying an appliance between the client application and storage) not only simplifies the management of complex storage architectures, but can also help minimize the impact on application performance. In addition, there are some cases in which compression can improve system performance due to the fact that compression results in fewer bytes of data, and therefore less I/O traffic to and from disks.

Compression typically provides good results for unstructured data in a file sharing environment, often yielding as much as 50 percent or more savings in storage space as opposed to non-compressed data. The four levels of compression available in Sun ZFS Storage Appliances include:

- LZJB (fastest)
- GZIP-2 (fast)
- GZIP (default)
- GZIP-9 (best compression)

These compression options give administrators the opportunity to flexibly tailor the compression approach for different workloads, enabling optimization of workload performance and space efficiency.

More Efficient Oracle Database Clones for Development and Test

Sun ZFS Storage Appliances greatly simplify the process of replicating the database for development and test purposes and also offers features that help conserve storage space when multiple copies of data are required. In many cases, multiple clones are required because there are many development and test activities associated with large production systems. Sun ZFS Storage Appliances make it affordable for developers to have their own copies of the database using the cloning feature on Sun ZFS Storage Appliances.

To establish multiple copies of the full Oracle Database for development and test purposes, a full backup of the production database is first created and stored on a Sun ZFS Storage Appliance using Oracle Recovery Manager (RMAN). If desired, this backup copy can be kept current by using Oracle Data Guard to apply updates on a continuous basis. The full database backup on the Sun ZFS Storage Appliance can then be cloned as many times as needed for development and test environments. The cloning feature of the appliance stores only changed data, thus allowing developers to each utilize their own copy of the database without requiring much physical storage space.

An important advantage of using Oracle storage for these cloned databases is that Sun ZFS Storage Appliances can provide full system operation on cloned data while preserving the space savings provided by Oracle's Hybrid Columnar Compression. Oracle storage systems enable snapshots of

compressed database tables to be cloned without decompression overhead, and then used in the compressed format for development, test, quality assurance, reporting, etc. By contrast, NetApp storage systems will result in 10x to 50x greater storage capacity requirement in order to support secondary processing of database tables that were compressed using Hybrid Columnar Compression. This is because the tables must be decompressed before being accessible from a third party storage system.

Seamless Storage Integration for Increased Value

Traditional IT architectures have evolved in such a way that applications, data, and storage are treated as separate elements that are then bundled together to deliver IT services. In today's environment, however, this approach is increasingly under pressure as enterprises struggle to deliver better performance and achieve greater storage efficiency.

In its 2012 annual digital universe study, IDC has made a projection that the total amount of digital information will reach 40,000 Exabytes by 2020. This represents an astounding 300x growth from 2005 to 2020.⁹ This massive growth of data means that a paradigm shift is needed in how we deploy IT infrastructure. Oracle believes that tomorrow's data centers will require a tighter integration between applications, data storage, and the servers that transform the data in order to meet ever-increasing performance and efficiency requirements.

As highlighted in Figure 5, Oracle is integrating storage into its entire software and hardware stack to bring applications, data, and storage closer together. Oracle's goal is to help enterprises realize a big leap in performance and storage efficiency so that applications can be dramatically faster and much more data can be stored with less physical storage capacity.



Figure 5. Oracle's strategy is to tightly integrate storage across its entire stack from application to disk.

⁹ "IDC Digital Universe Study, sponsored by EMC," December 2012. Available at <http://www.emc.com/leadership/digital-universe/index.htm>.

By addressing the full stack, Oracle is creating unique storage integrations that other storage vendors, including NetApp, cannot achieve. These innovations are already driving a tenfold improvement in application performance and storage efficiency with engineered systems such as the Oracle Exadata Database Machine and Oracle Exalogic Elastic Cloud. In addition to engineered systems, Oracle's integrated offerings also include Oracle Optimized Solutions for everything from Oracle E-Business Suite to Oracle WebCenter Content. In addition, all Oracle software products are tested across the full suite of Oracle hardware offerings to reduce the risk of production deployment issues for Oracle customers. Furthermore, customers benefit from support from a single vendor as well.

Sun ZFS Storage Appliances are stand-alone storage systems that include integrated hardware and software and are designed to work with any server or desktop system that uses industry-standard protocols. They also offer unique Oracle integration with Hybrid Columnar Compression for Oracle Database, Oracle VM Storage Connect for Virtualization, Oracle Enterprise Manager for application to disk data center management, concurrent support of SAN connected Oracle Databases, and many other integrations with Oracle hardware and software.

Examples of Oracle offerings that include Sun ZFS Storage Appliance integration include:

- *SPARC SuperCluster*
- *Oracle Exalogic Elastic Cloud*
- *Oracle Optimized Solution for Enterprise Cloud Infrastructure*
- *Oracle Exadata Database Machine Backup and Recovery Solution*
- *Oracle Database Test and Development Solution*
- *Oracle Optimized Solution for Tiered Storage Infrastructure*
- *Oracle Optimized Solution for Oracle Database*
- *Oracle Optimized Solution for Agile Product Lifecycle Management*
- *Oracle's Integrated Desktop Virtualization and Storage Solution*
- *Oracle Fusion Middleware Disaster Recovery Solution*

These integrated offerings enable enterprises to achieve greater value from their storage investments by realizing greater application performance, reduced in-house integration costs, simplified storage management, and greater storage efficiency.

Easier to Manage

Many organizations are realizing that the rate of growth of their data is such that old approaches to managing the data are no longer viable. Today's enterprises need tools that simplify storage management so administrators can manage larger volumes of data and do it more efficiently. Another important factor in storage management is visibility into performance issues and data usage patterns. Sun ZFS Storage Appliances give administrators a big edge over NetApp administrators by providing visibility and analytics that are unmatched in the industry.

The subsections below describe the features and technical advantages of Sun ZFS Storage Appliances and these are contrasted with NetApp’s limitations that complicate management of NetApp filers.

Browser User Interface (BUI) and Real-Time Dashboard

Sun ZFS Storage Appliances come with an elegantly simple to use graphical browser user interface (BUI) that gives administrators access to storage management with the rapid familiarity of a point-and-click browser user interface. A real-time dashboard (Figure 6) acts as an administrative home page from which all administration tasks can be initiated. The dashboard provides continuous monitoring of key performance metrics as well as a real-time feed of relevant alerts. Administrators can use the dashboard for at-a-glance usage statistics or as an entry point for running more-advanced DTrace Analytics that show detailed usage statistics. An easy-to-learn command-line interface (CLI) can also be used for scripting, including remote access using the SSH protocol for security.

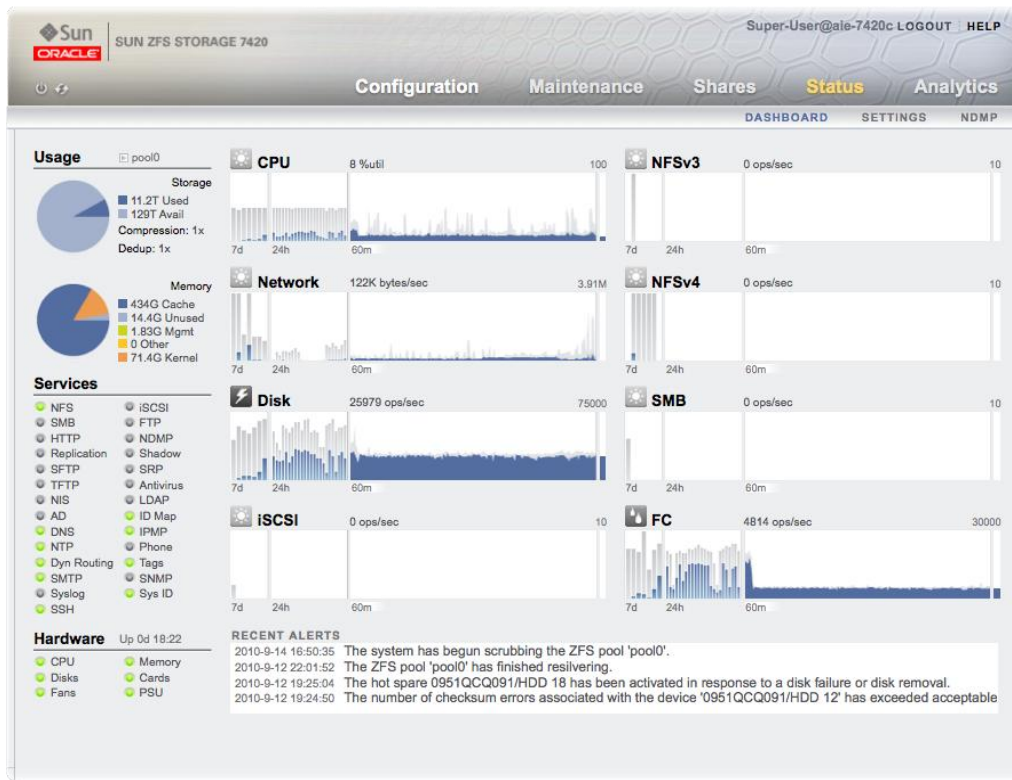


Figure 6. The Sun ZFS Storage Appliance real-time dashboard helps simplify management.

Third-party Confirmation of Management Efficiency

The intuitive management interface on Sun ZFS Storage Appliances enables administrators to accomplish many administrative tasks with fewer steps than are required for NetApp filer management. A recent study by Edison Group confirmed that Sun ZFS Storage Appliances could be managed more efficiently than comparable NetApp filers and could also offer faster deployment and easier troubleshooting.

The Edison Group study identified the following advantages for Sun ZFS Storage Appliances¹⁰:

- 36 percent faster for provisioning and configuring Sun ZFS Storage Appliance storage pools and connectivity
- 36 percent faster for administrative tasks using BUI and provisioning wizard.
- 44 percent faster to monitor and troubleshoot issues using DTrace Analytics

NetApp Limitations That Complicate Management

There are several limitations with NetApp FAS3250 filers that complicate administration and management. Some key issues and their ramifications include:

- RAID levels supported are not as robust as Oracle RAID levels
 NetApp does not support RAID 10, which offers the highest level of performance with drive redundancy. Figure 7 highlights the differences in RAID levels supported by Sun ZFS Storage Appliances versus NetApp filers.

| RAID Level | NetApp FAS3250 | Sun ZFS Storage 7420 |
|----------------------|-------------------------------------|----------------------|
| RAID 0 | X | ✓ |
| RAID 10 | X | ✓ |
| RAID 5 or equivalent | ✓ (RAID 4, Parity not rotating) | ✓ (RAID Z) |
| RAID 6 or equivalent | ✓ (RAID DP, Parity not rotating) | ✓ (RAID Z2) |
| RAID Triple Parity | X | ✓ (RAID Z3) |
| RAID Triple Mirror | X | ✓ |

Figure 7. Sun ZFS Storage Appliance RAID levels vs. NetApp FAS3250 RAID levels.

- Aggregate sizes are limited to 70 TB for FAS3250
 When using Aggregates, administrators cannot create file systems larger than 105 TB on NetApp FAS3250 filers and the maximum volume size is further limited to 70 TB.¹¹ By contrast Sun ZFS Storage Appliances use the 128-bit Oracle Solaris ZFS file system, which provides $1.8 * 10^{19}$ (18 quintillion) times more capacity than even 64-bit file systems.

¹⁰ "Oracle's Sun ZFS Storage Appliance Comparative Management Costs Study." Edison Group, August 2010.

¹¹ NetApp FAS3200 series tech specs at <http://www.netapp.com/us/products/storage-systems/fas3200/fas3200-tech-specs.html>.

- Limited observability makes performance tuning much more difficult
NetApp has nothing close to Oracle's DTrace Analytics. Thus NetApp storage administrators have poor visibility into their storage system's behavior and performance. In many cases, customers can only get help with their performance issues through an expensive professional services engagement or by buying more disk drives to help drive better performance.

Better Management Visibility with DTrace Analytics

Because NetApp's management interface does not provide detailed visibility into storage subsystems and I/O traffic patterns, enterprises trying to optimize storage performance must use a trial and error process that often leads to subpar results. Many are forced to seek the help of NetApp service engineers to pinpoint bottlenecks and identify remedies for improved performance. When service level issues arise, data logs are commonly sent to a NetApp service engineer for analysis, a process that can take hours or days rather than the few minutes it can take to pinpoint issues with Oracle's DTrace Analytics software.

DTrace Analytics provides the industry's first comprehensive and intuitive business analytics environment for storage systems. It uses built-in instrumentation to provide real-time visibility throughout the data path, empowering administrators to act quickly to identify performance issues and perform in-depth analysis of key storage subsystems. Graphical displays of performance and utilization statistics can be used to pinpoint bottlenecks and optimize storage performance and capacity usage—all while systems continue running in production.

Figure 8 shows an example of the kind of data that can be visualized with DTrace Analytics. The top part of the screen shows NFS operations per second broken down by client. This kind of detail makes it easy to identify peak usage periods and also provides insight into which clients are putting the heaviest load on the storage system. The bottom part of the screen shows network I/O coming in and going out of the storage system, giving administrators a chance to see how the storage system is responding in terms of total throughput.

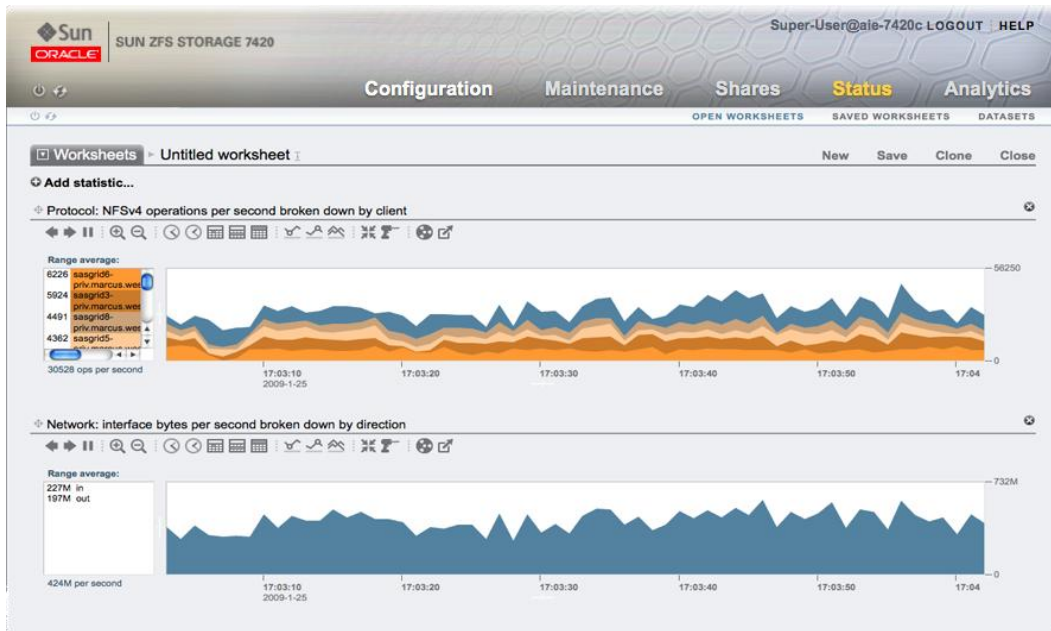


Figure 8. DTrace Analytics screenshot showing real-time storage performance statistics.

DTrace Analytics provides many ways to view performance information. Administrators can drill down into the I/O traffic patterns from applications running on different systems to find the source of performance issues (Figure 9). This level of observability is an industry first and enables administrators to identify application bottlenecks that might previously have gone undetected.

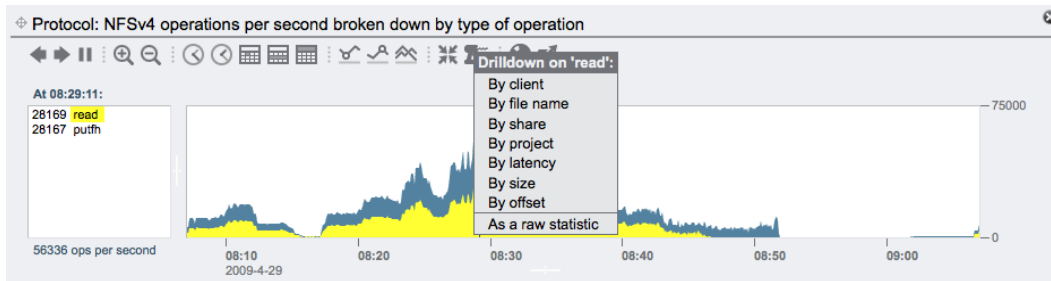


Figure 9. Administrators can use DTrace Analytics to drill down into the storage system's statistics.

Not only does DTrace Analytics give administrators the tools they need to respond to issues and maintain SLAs but it also enables them to proactively manage the environment by providing answers for questions such as:

- How do write-optimized and read-optimized SSDs help specific storage workloads?
- Are CPU, memory, or networking causing bottlenecks?
- What is the read/write/metadata mix of a particular workload?
- How do configuration and application changes affect the storage system?

Sun ZFS Appliance Monitor

Oracle's Sun ZFS Appliance Monitor provides remote access to administrative features via commonly used mobile devices such as the Apple iPhone and iPad. Administrators can view detailed metrics such as pool capacity and usage, active problems, faults, and component status. DTrace Analytics is also available to offer real-time visual analysis of storage performance. Optimized for mobile devices, Sun ZFS Appliance Monitor simplifies the task of monitoring and troubleshooting a global storage infrastructure.

Reducing Risk Through Advanced Data Integrity

Today's vast repositories of data represent valuable intellectual property that must be protected to ensure the livelihood of the enterprise. While backup and archival capabilities are designed to guard against data loss, they do not necessarily protect against silent data corruption. Furthermore, in the event of a problem, the process of restoring archived data generally entails downtime and thus lost productivity. Even worse, not all restore operations are successful and can result in permanent data loss.

The best scenario, of course, is to prevent data loss in the primary disk storage system. Basic data protection techniques such as RAID and component or interconnect redundancy are employed by both Oracle and NetApp. However, Oracle's Sun ZFS Storage Appliance software has several capabilities that extend data protection to additional levels. These advanced data protection features can help increase productivity by improving data availability, thus reducing the risk of time-consuming recovery procedures and protecting the integrity of archived data.

Sun ZFS Storage Appliance software keeps on-disk data self-consistent and eliminates silent data corruption. It combines a copy on write approach (data is written to a new block on the media before the pointers to the data are changed and the write is committed) with end-to-end checksumming (explained below) to keep the file system internally consistent. Because the file system is always consistent, time-consuming recovery procedures such as `fsck(1)` are not required if the system is shut down in an unclean manner, thus improving service levels for users.

End-to-End Checksumming

Sun ZFS Storage Appliance software is built using the Oracle Solaris operating system, which is designed to provide end-to-end checksumming for all data. Sun ZFS Storage Appliance software constantly reads and checks data to help ensure that it is correct. And, if it detects an error in a mirrored pool, the technology can automatically repair the corrupt data. This relentless vigilance on behalf of availability protects against costly and time-consuming data loss—even previously undetectable silent data corruption. Corrections are facilitated by a RAID-Z implementation that uses parity, striping, and atomic operations to aid in the reconstruction of corrupted data.

As shown in Figure 10, Sun ZFS Storage Appliances perform checksum operations across the entire data tree, thus validating the entire I/O path. Since this approach validates much more than the media (bit rot), Sun ZFS Storage Appliances can catch issues such as phantom writes, driver bugs, and accidental overwrites.

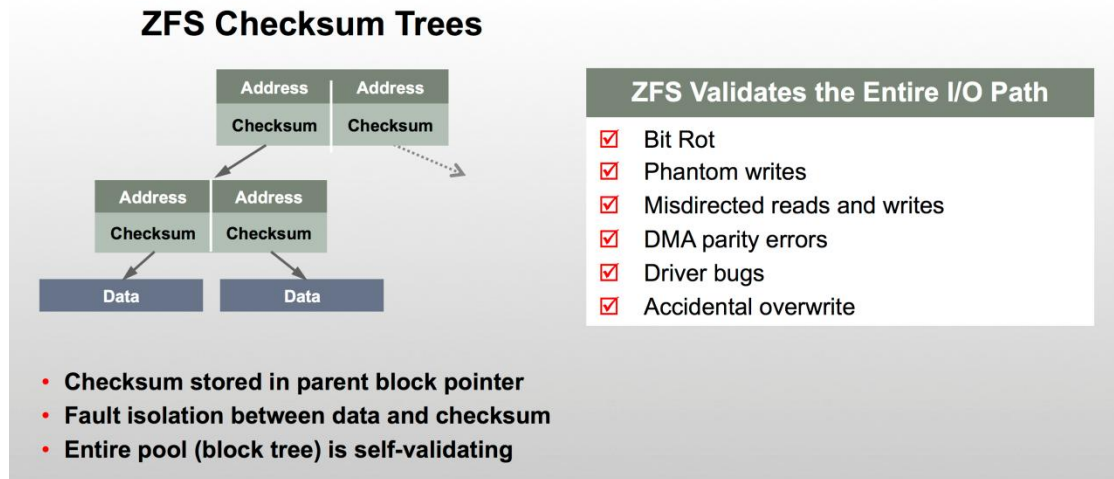


Figure 10. Sun ZFS Storage Appliance software uses checksums to validate the entire data block tree.

Self-Healing

If Sun ZFS Storage Appliance software detects a bit error, it can heal it by using good data from the mirrored disk as shown in Figure 11. It returns good data from the mirrored disk to the application and then repairs the damaged data block. Thus Sun ZFS Storage Appliance software can help ensure that mirrored drives stay in synch with each other. This capability is especially important now that disk drive capacities have grown to two or three TBs, leaving more possibility for inconsistencies to crop up across mirrored disk drives.

Sun ZFS Storage Appliance software takes advantage of the Oracle Solaris Fault Management Architecture to automatically and silently detect and diagnose underlying hardware problems using an extensible set of agents. When a faulty hardware component is discovered, the self-healing capability automatically responds by taking the faulty component offline.

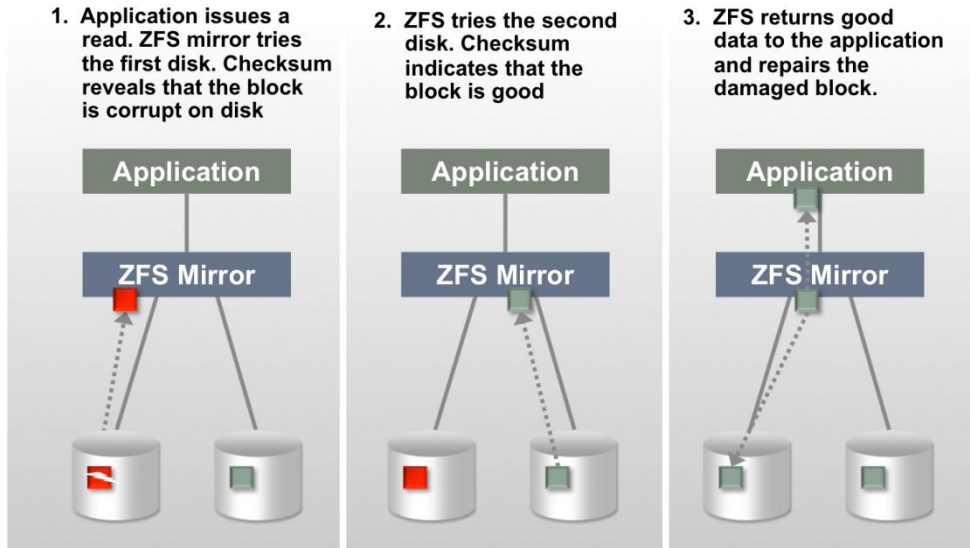


Figure 11. Sun ZFS Storage Appliance software's self-healing capability helps keep mirrored drives in synch with each other.

Triple-parity RAID and Triple Mirroring

Sun ZFS Storage Appliance software is the only software that protects data from as many as three drive failures with triple-parity RAID. With disk drives getting larger and many organizations implementing wider striping across more drives for increased performance, a third-parity bit helps reduce the risk of data loss. Triple mirroring, which maintains two extra copies of a storage volume, is also supported by Sun ZFS Storage Appliance software. Triple mirroring provides additional data protection as well as an easy way to increase random read performance for application workloads such as the Oracle database.

Extra Protection for Oracle Database Backups

When supporting backups for Oracle Database, Sun ZFS Storage Appliances work with Oracle Recovery Manager (RMAN) to help protect against data corruption. While RMAN helps ensure that Oracle Database backups are generated free from errors and have transaction integrity, Sun ZFS Storage Appliances help ensure that the backup copies remain free from errors over time using the unique data integrity features described above.

External Validation of Sun ZFS Storage Appliances

Sun ZFS Storage Appliances are gaining recognition for their ease of deployment and management, leading performance, and overall business value.

Ease of Management

A recent report from The Enterprise Strategy Group, validated that initial deployment of a Sun ZFS Storage Appliance was quick and painless and that configuring and managing the system through its well-designed user interface was easy.¹²

Another validation point for ease of management was provided in the earlier reference to an Edison Group study, which reported that Sun ZFS Storage Appliances are 36 percent easier and faster to administer and provision compared to NetApp filers.

Oracle Internal IT Surpasses 200 PB of Storage on Sun ZFS Storage Appliances

Oracle's internal IT business units deliver IT services for well over 100,000 Oracle employees while also managing numerous internal mission-critical databases and Oracle's customer-facing cloud businesses. From a storage workload perspective, these IT services result in some of the most challenging storage requirements imaginable. To serve the storage needs of this highly diverse and demanding IT environment, Oracle relies on Sun ZFS Storage Appliances.

Over the past few years, Oracle IT has been working toward standardization and consolidation of a wide variety of NAS workloads onto Sun ZFS Storage Appliances, including mission-critical Oracle Database storage. In August 2012, Oracle IT surpassed 200 PB of storage on the Sun ZFS Storage Appliance platform. Thousands of database instances and millions of users both inside and outside of Oracle run on Sun ZFS Storage Appliances within Oracle IT every day.

Oracle Managed Cloud Services (formerly Oracle On Demand) has achieved nearly a 2:1 improvement in management efficiency after a major storage upgrade replacing NetApp systems with Sun ZFS Storage Appliances. Throughout the ongoing migration process from NetApp systems to Sun ZFS Storage Appliances, many benefits have been realized. By leveraging the superior performance and management efficiency benefits along with the industry's best storage analytics environment (Oracle's DTrace Analytics), overall performance has improved while operating expenses associated with management time have decreased. An internal study found nearly a 2:1 improvement in headcount/GB efficiency. In other words, storage administrators can now manage twice the storage footprint that they had been able to manage with NetApp systems.

Oracle Managed Cloud Services is a business within Oracle IT that handles operation, administration, and management of customer-facing IT resources. It is responsible for administration and management of a complete Oracle stack architecture in cloud deployments and uses Sun ZFS Storage Appliances extensively for mission-critical storage. Cloud application offerings that reside on Sun ZFS Storage Appliances include Oracle E-Business Suite, Oracle Express, Oracle Email Center, Oracle iLearning, Agile, Oracle Beehive, Oracle's PeopleSoft product portfolio, Oracle's Siebel products,

¹² "Lab Validation: Sun ZFS Storage Appliance," The Enterprise Strategy Group, July 2012. Available in the white papers section of the resources listed at <http://www.oracle.com/us/products/servers-storage/storage/nas/resources/>.

Oracle Hyperion products, Oracle's JD Edwards EnterpriseOne, and many others, including some third-party software offerings.

This Oracle Managed Cloud Services infrastructure consists of more than 17,000 VMs running on more than 4,000 physical servers. Storage for the environment is NFS, and more than 5,300 customer instances representing more than 2,400 customers now utilize Sun ZFS Storage Appliances for their storage infrastructures. The typical customer environment involves a complete software stack, from the OS level (Oracle Linux or Oracle Solaris) with Oracle Database (including Oracle RAC, in some cases), Oracle Fusion Middleware, and Oracle Fusion Applications running on top. Each customer gets his or her own VM or physical server, but storage for multiple customers may be consolidated on Sun ZFS Storage Appliances via NFS protocol and 10 GbE infrastructure. To ensure complete customer isolation and security, Oracle VM machine files and OS files for any given customer are compartmentalized, and storage access is controlled at the filesystem level. This allows multitenancy on the Sun ZFS Storage Appliances while preventing data access across customer accounts.

Summary—Realize More Value from Storage Investments

The compelling advantages that Sun ZFS Storage Appliances have over NetApp make Sun ZFS Storage Appliances an obvious choice for Oracle software environments and for customers running enterprise environments with multi-vendor applications and hardware. Sun ZFS Storage Appliances have clear leadership for workloads that demand high-levels of IOPS, high throughput, consolidation efficiency, or any combination of these requirements.

Table 4 summarizes the key advantages of the Sun ZFS Storage 7420.

TABLE 4. SUN ZFS STORAGE 7420 ADVANTAGES OVER NETAPP FAS3250

| | |
|---|--|
| Twice the I/O Performance for Enterprise Data | <ul style="list-style-type: none"> • More than 2.6x the performance of NetApp FAS3250 clusters for network file system throughput as measured by the SPECsfs2008 benchmark for NFS workloads.¹³ And although NetApp has not submitted SPC-1 benchmark results for the NetApp FAS3250, Oracle's Sun ZFS Storage 7420 offers more than 2x better price-performance than the two most recent NetApp submissions for the NetApp FAS6240 and FAS3270A.¹⁴ • Enables support for more users and higher levels of service. |
|---|--|

¹³ SPECsfs2008 results for Sun ZFS Storage 7420 and NetApp FAS3250 are as of November 2012 and are available at <http://www.spec.org/sfs2008/results/>.

¹⁴ Oracle Sun ZFS Storage 7420 SPC-1 result of 2.99 \$/SPC-1 IOPS as of October 3, 2011 available at http://www.storageperformance.org/results/benchmark_results_spc1#a00108. NetApp FAS6240 SPC-1 result of 6.69 \$/SPC-1 IOPS as of June 18, 2012 available at http://www.storageperformance.org/results/benchmark_results_spc1#a00115. NetApp FAS3270A SPC-1/E result of 7.48 \$/SPC-1 IOPS as of October 3, 2011 available at http://www.storageperformance.org/results/benchmark_results_spc1#ae00004. SPC-1 IOPS represents the maximum I/O request throughput at the 100% load point. The SPC-1/E benchmark consists of the complete set of SPC-1 performance measurement and reporting plus the measurement and reporting of energy use.

TABLE 4. SUN ZFS STORAGE 7420 ADVANTAGES OVER NETAPP FAS3250

| | |
|--|---|
| Superior Performance for Streaming Data | <ul style="list-style-type: none"> • Highest streaming data throughput available from NAS systems • 20 TB/hr backup throughput and 10 TB/hr restore throughput for Exadata backup and restore performance • Helps reduce backup windows and improve recovery point objectives at a low price point |
| 3x to 5x Less Storage Required for Oracle Database | <ul style="list-style-type: none"> • Leverage Hybrid Columnar Compression, which is unique to Oracle storage • Achieve 3x to 5x reductions in storage footprints by replacing NetApp storage with Oracle's Sun ZFS Storage Appliances • Achieve 10x to 50x reductions in data volumes for Oracle databases with in-database archives for OLTP, Data Warehousing or mixed workloads |
| Superior Storage Efficiency to Help Control Rising Storage Costs | <ul style="list-style-type: none"> • Hybrid Columnar Compression for Oracle Database environments enables 10x and 50x savings for in-database archives and typical results in 3x to 5x total capacity savings. • Helps reduce the number of NAS systems that organizations need to purchase, deploy, and manage |
| Lower Costs for Meeting Growing Storage Needs | <ul style="list-style-type: none"> • Up to 53% savings on the initial purchase compared to NetApp • Lower ongoing costs versus NetApp • Enables enterprises to meet growing storage needs without breaking their budget |
| 36% Easier and Faster to Manage | <ul style="list-style-type: none"> • Edison Group reports that Sun ZFS Storage Appliances are 36% easier and faster to administer and provision compared to NetApp. • In data centers with multiple NAS systems and multiple storage administrators, customers can reduce spending by hundreds of thousands of dollars per year based on administrative costs alone |
| Reduced Risk Through Data Integrity | <ul style="list-style-type: none"> • The only systems from a major storage vendor with triple mirroring and triple parity • End-to-end checksumming with validation of the entire data block tree • Self healing capabilities so that enterprise data is safely protected |
| Seamless Storage Integration for Increased Value | <ul style="list-style-type: none"> • Seamless integration across the Oracle hardware and software stack. • Support for Hybrid Columnar Compression with Oracle Database, Oracle VM Storage Connect, and Oracle Enterprise Manager • Utilized in Oracle Optimized Solutions and Oracle engineered systems |

For More Information

To analyze a specific situation and identify potential savings with Sun ZFS Storage Appliances, use the online Sun ZFS Storage savings calculator at <http://www.oracle.com/us/media/calculator/zfs> or contact a local Oracle representative.

Visit the Web sites listed in Table 5 for additional information.

| TABLE 5. WEB SITES FOR ADDITIONAL INFORMATION | |
|--|---|
| PRODUCT OR SOLUTION AREA | WEB SITE URL |
| Sun ZFS Storage Appliances | http://www.oracle.com/us/products/servers-storage/storage/unified-storage |
| Sun ZFS Storage savings calculator | http://www.oracle.com/us/media/calculator/zfs |
| Accelerating Database Test and Development with Oracle's Sun ZFS Storage Appliance | http://www.oracle.com/us/products/servers-storage/storage/unified-storage/accelerating-db-test-dev-352128.html |
| Sun ZFS Appliance Monitor | http://www.oracle.com/goto/zam |
| Sun ZFS Storage Appliance simulator | http://www.oracle.com/go/?&Src=7618051&Act=24&pcode=WWMK12044552MPP030 |



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Hardware and Software, Engineered to Work Together