

THE LAST WORD IN FILE SYSTEMS JUST GOT BETTER

Solaris ZFS™ File System Features and Enhancements in the
Solaris™ Operating System for Enterprise Users

White Paper
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Abstract

As file-based data continues to grow and consume storage resources in the enterprise, datacenter managers are turning to the Solaris™ 10 Operating System, OpenSolaris™ operating system, and Solaris ZFS™ file system to help streamline storage management. Now, new features and enhancements in the Solaris ZFS file system can help companies take advantage of open storage platforms, enhance data services, and ease administration, as evidenced by many Sun customers worldwide.

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Chapter 1

Changing the Way Data is Managed

Traditional data sources, as well as electronic mail (email), electronic documents, articles, blogs, spreadsheets, presentations, video clips, and more provide valuable information to enterprises. The continued expansion and reliance on such file-based information is anticipated to have a dramatic impact on businesses. Indeed, IDC estimates that more than half of the petabytes of storage capacity purchased in 2008 is slated to hold file-level data. This trend is expected to accelerate, with file-based data consuming over 75 percent of new storage capacity in 2011.

As file-level data continues to consume a greater portion of disk storage capacity, datacenter managers must allocate more planning and storage resources to the management and protection of large pools of file-based information that is so critical to the enterprise. In fact, the management and organization of such information is rapidly becoming the primary task for storage administrators in corporate datacenters. Administrators now are focused on finding ways to ensure files can be stored, accessed, retained, and retrieved to meet user demand. Assessing storage system performance, handling storage provisioning and legacy storage retirement, and archiving infrequently accessed information for changing business and regulatory purposes are essential elements of successful storage management.

Today, organizations looking to consolidate systems or reduce management complexity rely on third-party solutions that deliver file services. Yet exponential growth in the amount and type of unstructured data is changing organizational needs for file services — needs these solutions often fail to address. For example, companies are looking to optimize performance and capacity utilization based on the type, size, or read/write access requirements for files. Intelligent features, such as automatic file migration, protection, and policy-based recovery are emerging as capabilities that datacenter managers recognize can change the way cost-effective storage management is done. As a result, enterprises need more than basic file systems and data copy functions — a wider array of file services is needed to meet increasingly complex needs.

The right answer is to integrate file services into the operating system. Because the operating system occupies a critical position in the computing system hierarchy — below applications and above hardware — it can integrate data services directly in the operating system and provide an ideal platform for network attached storage (NAS) appliances or storage servers. Now, both the Solaris™ 10 Operating System (OS) and OpenSolaris™ operating system include built-in file services to support applications with data integrity, simplified data management, and integrated volume management. Integrating the Solaris ZFS™ file system, these operating systems are changing the way datacenters approach file-based storage management.

OurStage Business Results

OurStage migrated from Linux to the OpenSolaris operating system and Solaris ZFS file system and:

- Increased I/O performance
- Eased system administration with improved management tools
- Scaled its storage platform
- Improved Web and application servers

Changing Minds

Over the last few years, companies deployed the Linux operating environment in an effort to take advantage of open source community innovation and lower licensing costs. However, enterprises are now recognizing that the storage performance and scalability characteristics of the Linux environment and its tools are hampering datacenter effectiveness. Today, many of these organizations are turning to Sun's operating system distributions to take advantage of Solaris ZFS file system innovation and reduce storage management complexity. With this groundbreaking technology that automates common administrative tasks, protects data from corruption, and provides virtually unlimited scalability, datacenters are reaping the benefits of better and more cost-effective data management.

For example, OurStage moved its production storage systems to the OpenSolaris operating system to improve load balancing and I/O performance¹. An online music discovery company, OurStage hosts a Web site that gives artists a chance to have their work seen and heard. From the beginning, the OurStage IT infrastructure ran its production site and application servers on the Linux environment. About six months after going live with its Web site, OurStage began experiencing problems with storage I/O performance on its network file server due to sluggish Linux Network File System (NFS) performance.

With Web traffic rising, OurStage began looking at alternative storage solutions, and turned to the Solaris ZFS file system on the OpenSolaris operating system. After testing proved that the OpenSolaris operating system provided better load balancing capabilities and could scale easily to meet future needs, it was an easy decision for the company to switch its production storage systems to the OpenSolaris platform. Since then, the company has built two more storage systems, each supporting 16 TB of capacity. As a result, OurStage was able to deploy fewer servers, keeping hardware and administrative costs down and the storage environment simple.

According to Mark Niedzielski, infrastructure manager at OurStage, "With ZFS, I can manipulate large numbers of disks easily and predictably with just one tool set. In contrast, to manage a Linux system, separate tools are required for the file system, volume management, RAID hardware, the operating system, and smart monitoring tools. The Linux tools all work together, but that's more by happenstance than by design. One set of tools in ZFS takes care of all of that, top to bottom. And frankly, in my mind, that's what makes OpenSolaris an enterprise solution."

Gaining Momentum

For over 15 years, the Solaris OS has provided the foundation for enterprise computing environments. Now, the Solaris ecosystem consists of the Solaris 10 OS and the OpenSolaris operating system. A proven, industry-leading environment, the Solaris 10 OS provides the latest updates to supplement existing Solaris OS

1. Source: <http://www.sun.com/customers/software/ourstage.xml>

deployments, access to thousands of third-party software applications, unmatched enterprise support offerings, and a 10+ year support life cycle to create rock solid long-term deployments like those implemented by Internet Brands Inc., Siteworx, Inc., and Altair Engineering.

Based on the Solaris OS, the popular OpenSolaris operating system gives developers and enterprises, like Joyent Inc. and DigiTar, access to the latest features before they are integrated into the Solaris 10 OS. By offering organizations advanced technology, access to the latest innovations from the OpenSolaris community, innovations in packaging, and the assurance of Sun's proven, extensive testing processes and worldwide support, the OpenSolaris operating system makes it faster and easier than ever to develop and deploy enterprise applications and services.

Unlike other freely licensed environments, the Solaris OS support model does not force companies to choose between free and supportable versions. Solaris OS and OpenSolaris releases are both free to acquire, and optional support services are available for both systems. As a result, enterprises can choose the platform and features that best suit business needs.

Delivering on the Promise of Open Storage

As enterprises struggle to cope with the phenomenal rise in digital data volumes and budget pressures, they are looking for storage architectures that provide greater flexibility and better economics. For years, enterprises utilized servers and storage systems that were closed, proprietary, and expensive. Just as open systems changed high-scale computing with affordable architectures, open storage is revolutionizing data management with innovation and choice. By delivering industry standard hardware and open source software, OpenSolaris with ZFS provides an ideal platform for developing and deploying new storage faster. Sun is breaking down the barriers to traditional state-of-the-art storage systems with truly open architectures — giving companies the ability to select the right hardware and software components to meet business needs.

Storage software is the last major infrastructure component to become open source, and Sun's OpenSolaris community and Solaris ZFS file system are leading the change. Unlike traditional storage deployments, Sun's Open Storage environments let enterprises freely mix, match, and maximize computing and storage components as business needs change. Hardware can be repurposed and reused simply by adding new software to an open platform. Such freedom holds promise for companies in any industry. Web 2.0, eco-responsible IT, high performance computing (HPC), and virtualization environments can take advantage of open storage and open source software to handle growth, manage storage I/O bandwidth and latency needs, and consolidate systems to affect better resource utilization and reduce storage costs by up to 90 percent.

Chapter 2

The Solaris ZFS™ File System

Traditional file systems — whether integrated with operating systems or implemented as add-on solutions — have failed to keep pace with the rapidly evolving demands and growing data volumes of enterprises. With massive amounts of existing information and more being generated daily, corporate datacenters are struggling to manage it all. Different tools are needed to manage NFS, Common Internet File System (CIFS), and other device and file system types, creating undue complexity. In addition, each environment uses different mechanisms for creating and labeling partitions and volumes, provisioning storage, and adding capacity, and places size limits on file systems and their contents.

Perhaps most important, companies are experiencing silent data corruption. Any defect in a disk, controller, cable, device driver, laser, or firmware can corrupt data without warning. Combined with poor performance due to fixed block sizes, unsophisticated prefetch algorithms, painful RAID rebuild times and more, enterprises are growing frustrated with the limitations and performance and management characteristics of existing solutions.

What Makes the Solaris ZFS File System Different

Sun designed a revolutionary, integrated file system that helps eliminate storage management complexity. Solaris ZFS is an enterprise-class, general-purpose file system that provides virtually unlimited file system scalability and increased data integrity to large-scale solutions. Providing up to 21 billion YottaBytes of capacity, this 128-bit, open source file system integrates traditional file system functionality with built-in volume management techniques. By automatically allocating space from pooled storage when needed, Solaris ZFS simplifies storage management and gives organizations the flexibility to optimize data for performance.

Integrated Volume Management and Virtual Storage Pools

Unlike traditional file systems that require a separate volume manager, Solaris ZFS introduces the integration of volume management functions. Breaking free of the typical one-to-one mapping between the file system and its associated volumes, Solaris ZFS introduces the storage pool model.

Solaris ZFS decouples the file system from physical storage in the same way that virtual memory abstracts the address space from physical memory, allowing for more efficient use of storage devices. Space is shared dynamically between multiple file systems from a single storage pool, and is parceled out of the pool as file systems request it. Physical storage can be added to storage pools dynamically,

without interrupting services, providing new levels of flexibility, availability, and performance. When capacity is no longer required by one file system in the pool, it becomes available to other file systems.

Data Integrity

Solaris ZFS uses several techniques to keep on-disk data self consistent and eliminate silent data corruption, such as copy-on-write and end-to-end checksumming. Data is written to a new block on the media before changing the pointers to the data and committing the write. Because the file system is always consistent, time-consuming recovery procedures like fsck are not required if the system is shut down in an unclean manner. In addition, data is read and checked constantly to help ensure correctness, and any errors detected in a mirrored pool are automatically repaired to protect against costly and time-consuming data loss and previously undetectable silent data corruption. Corrections are made possible by a RAID-Z implementation that uses parity, striping, and atomic operations to aid the reconstruction of corrupted data.

Simplified Administration

Solaris ZFS automates many administrative tasks to speed performance and eliminate common errors. Creating file systems is fast and easy. There is no need to configure, or reconfigure, underlying storage devices or volumes — these tasks are handled automatically when devices are added to a storage pool. Administrators can guarantee a minimum capacity for file systems, or set quotas to limit maximum sizes.

New ZFS Features in the Solaris™ OS 10/08 Release

The latest release of the Solaris 10 OS includes important new features that let enterprises boot SPARC® processor-based and x64 systems from Solaris ZFS file systems, take advantage of open storage platforms, enhance data services, and ease administration.

Bootability

Enterprises can take advantage of improved install and boot capabilities for the Solaris OS. Now, administrators can install Solaris ZFS root file systems on existing or newly deployed SPARC processor-based and x64 systems, and boot from those file systems. Support for swap and dump devices is also provided. In addition, existing UFS root file systems can be migrated to a Solaris ZFS root file system using the Solaris Live Upgrade software. Once the migration is complete, the system can boot either the UFS or Solaris ZFS file system.

Storage Features and Enhancements

New features and enhancements to Solaris ZFS are designed to help enterprises manage storage devices and file data more efficiently and cost-effectively. These features, combined with the native storage capabilities of the Solaris 10 OS and industry-standard storage systems, provide an ideal platform for companies managing large volumes of file information.

- *Hybrid storage pools* — New storage environments are now possible that combine the strengths of hard disk drive technology with enterprise solid state disks (SSDs). Enterprise SSDs can be placed in a new storage tier to assist hard disk drives by holding frequently accessed data to minimize the impact of disk latencies and improve application performance. By utilizing enterprise SSDs to handle certain types of I/O, and hard disk drives to store massive data sets, a hybrid storage pool gives organizations significant performance gains without sacrificing capacity. (This feature currently available only in the OpenSolaris operating system.)
- *Gzip compression* — Solaris ZFS now supports multiple compression algorithms, including lzjb, gzip, and gzip-N, to reduce the amount of disk space used to hold files and increase data throughput. Compression is performed on a per block basis to help improve storage device utilization.

Data Services Enhancements

Keeping valuable corporate information safe is paramount. New Solaris ZFS data services enhancements can help enterprises manage and protect data on local or remote systems.

- *Take advantage of faster local data protection*

The latest release of the Solaris 10 OS enhances the snapshot capabilities of the Solaris ZFS file system to save and restore snapshot data and file systems. Now, all incremental streams from a snapshot can be sent to a cumulative snapshot. In addition, an incremental stream from an original snapshot can be used to create a snapshot clone to protect file data as an alternative to local backups. Replicated streams of descendent file systems can be sent to named snapshot, preserving properties, snapshots, file systems, and clones.
- *Perform remote replication*

Unlike traditional volume management software that often mirrors devices across a WAN, Solaris ZFS remote replication capabilities let administrators copy a file system from one server to another. As a result, administrators can recreate a file system on a storage pool on a different server, and specify different configuration levels, using identical file system data.

- *Save multiple copies of data per file system*

Storing multiple copies of data (ditto blocks) can help improve data retention by allowing recovery from unrecoverable block read faults, and enhance data protection even when only a single disk drive is available for use. With Solaris ZFS, administrators can store multiple copies of user data per file system. File system metadata is stored multiple times across different disks automatically, if possible, and data protection policies can be set on a per file system basis.

Administration Features

Easing storage management complexity and simplifying administrative tasks are key components of any cost reduction strategy. New features in the Solaris ZFS file system can help administrators save time, improve monitoring, and better utilize storage infrastructure.

- *Delegated administration* — Administrators now can delegate fine-grained permissions to perform administration tasks to non-privileged users.
- *Increase utilization with quotas and reservations* — Quotas and reservations can be used in space consumption accounting for file system data to help improve storage asset utilization and administrative efforts.
- *Roll back datasets without unmounting* — Administrators can now roll back datasets non-disruptively, simplifying administration and keeping data available.
- *Rename snapshots recursively* — Now administrators can recursively rename all descendent file system snapshots with a single command.
- *Monitor storage pools more efficiently* — Enhancements to the zpool history command provide several new features that facilitate storage pool monitoring and simplify administration. The features include the display of file system event information, long information, and internal event information that can be used for diagnostic purposes.
- *Foster data stability with separate Solaris ZFS logging devices* — Databases often require transactions to reside on stable storage devices when returning from a system call, and NFS and other applications use synchronization commands to help ensure data stability. Toward this end, the Solaris ZFS file system implements a ZFS intent log (ZIL) to satisfy POSIX requirements for synchronous transactions and improve performance. The log is used to record modifications to the file system, and is allocated from blocks within the main storage pool by default. However, separate intent log devices located in NVRAM or on dedicated disks can help improve performance for certain applications and environments.

An Open Source Community for Storage

The rapid success of open source software ushered in a new era of community development, and its benefits continue to spread widely. Open source gives developers access to freely available software and the ability to customize software to meet business or project goals. IT organizations reap the benefits of software and application innovation and choice, break free from vendor lock-in, and lower operating costs.

Today Sun's OpenSolaris project includes over 105,000 registered members². More than 60,000 people have viewed or participated in the OpenSolaris storage community initiative, which started with a couple of open source storage projects and now tracks 39 projects, including seven new projects since April, 2008. Comprising more than 4,200 members and multiple communities, the OpenSolaris storage community is one of the fastest growing open source communities in the world. Storage industry leaders such as Hitachi Data Systems, QLogic, Emulex, and Brocade have contributed software to the OpenSolaris storage community, and companies across the IT landscape are using OpenSolaris technology within storage product offerings.

The ZFS community focuses on continuing to innovate and find better ways to manage industry-standard storage systems. Indeed, the newest project in the ZFS community aims to provide on-disk encryption and decryption support for the ZFS file system.

2. See <http://www.opensolaris.org/os/community/advocacy/metrics/> for the latest statistics.

“The ZFS file system feature of the Solaris 10 OS is a marvel. It creates a common storage pool where all storage performs as fast as if it were local. Our administrators can grow, add or remove storage on the fly in a single step. Just 2 people administer 24 terabytes.”

Oscar Mondragon,
Chief Technology Officer, Sapotek

Chapter 3

The Solaris ZFS File System At Work

Reducing datacenter storage management complexity and cost while increasing service levels sounds daunting. Doing it all is possible — and it can yield tremendous benefits. Today many enterprises take advantage of the Solaris 10 OS or OpenSolaris operating system and Solaris ZFS file system to simplify storage management and reduce operating costs.

Sapotek, Inc.

Sapotek Inc. delivers on-demand solutions such as an online desktop in a software-as-a-service model, reaching approximately 200,000 users worldwide. To help facilitate continued growth, Sapotek open-sourced its product and an active free software community — Sapodesk — is now expanding its capabilities. As of mid-2007, the challenge was to see if the company’s infrastructure could scale as fast as the popularity of its service.

Sapotek migrated from the Linux environment to the Solaris OS to improve scalability, performance, and availability. The move resulted in a six-fold increase in server performance. In addition, availability has risen to 99.99 percent with the Solaris 10 OS, up from 96 percent with Linux. Using the Solaris ZFS file system, Sapotek streamlined storage management. Today 24 TB of capacity are administered by two people. The company also uses the snapshot feature in the Solaris ZFS file system, and has reduced backup and recovery times by 99 percent — down from hours or even days to just minutes³.

University of Calgary

The Sun Center of Excellence for Visual Genomics at the University of Calgary is a non-profit organization that is advancing technology for computational biology based on Sun solutions. The center needs to provide a reliable, flexible, scalable, and efficient solution for data-intensive processing needs, and deliver broad, secure access to innovative applications. A robust and cost-efficient storage technology is essential for the tens of millions of files that must be stored in perpetuity and served quickly.

In addition to powerful Sun servers, the center leverages the stability and binary compatibility of the Solaris 10 Operating System to run its applications, including applications developed 14 years ago. With Solaris Containers, the center can easily create virtual servers that isolate test environments. It also uses Solaris ZFS to store backup images of the operating system⁴.

3. Source: <http://www.sun.com/customers/servers/sapotek.xml>

4. Source: <http://www.sun.com/customers/servers/calgary.xml>

“ZFS is enabling 50 percent disk compression on the fly, so in a sense we’re getting 50 percent more storage capacity. And it ensures data integrity with a self-healing checksum feature that catches any silent data corruption we may have in older storage arrays. That lets us extend the lifespan of three older disk arrays that we’d otherwise retire. By not replacing them, we save \$75,000.”

Gene Down,
Senior Infrastructure Engineer,
Dow Corning

Nomura Bank Results

- Tenfold faster response time and backup time
- Dramatically reduced maintenance costs
- Increased scalability enhances investment protection
- Comprehensive data security and failover
- Significant savings from strong price-performance ratio

The storage solution includes Sun™ Storage Archive Manager with the Quick File System (SAM-QFS) software in a 229 terabyte four-tier architecture that provides policy-based data serving from a range of Sun StorageTek™ disk and tape hardware solutions. This comprehensive Sun platform boosts productivity. Today, two system administrators proactively manage an operation that includes many domains on more than 100 computing systems, over 500,000 Web site hits monthly, and 28 databases.

Dow Corning Corporation

Dow Corning Corporation develops, manufactures, and markets a wide portfolio of silicon-based products and services. To support operations at its 47 locations worldwide, the company depends on applications hosted on 110 Sun and third-party Solaris OS based servers connected to 250 terabytes of disk storage⁵. Most of this infrastructure runs on the Solaris 10 Operating System and is managed by an IT UNIX® team of just three people. To succeed, the team relies on Solaris 10 OS features that enable virtualization, remote management, and a self-healing file system.

Dow Corning is able to virtualize and manage servers quickly and efficiently by exploiting the Solaris Containers and Solaris ZFS features in the Solaris 10 Operating System as a key part of its adaptive computing model. Solaris Containers are flexible, software-defined boundaries that can be used to create virtual servers, so that multiple environments can run on a single server box. Solaris Containers now enable 130 virtual servers to be housed on 36 physical servers.

Dow Corning has adopted a modular approach to capacity, acquiring blocks of server resources in anticipation to near term demand. Once installed, these resources are allocated and deployed using Solaris Containers and Solaris ZFS. Solaris ZFS streamlines the company’s global IBM Tivoli Storage Manager data protection environment and utilizes on-the-fly disk compression to better utilize storage capacity.

Nomura Bank (Switzerland) Ltd.

Nomura Bank provides brokerage services, securities underwriting, investment banking advisory services, merchant banking, and asset management for a broad range of international clients. To support future growth, Nomura Bank (Switzerland) Ltd. replaced an aging HP infrastructure with a highly scalable Sun solution that included Sun servers, storage, and the Solaris 10 Operating System⁶. The bank’s new infrastructure consists of high-performance Sun Fire V490 and Sun Fire V445 servers running the Solaris 10 OS. To address its storage needs and improve data transfer rates, Nomura deployed a storage area network (SAN) based on one scalable Sun StorageTek 6140 array and two high-capacity Sun StorageTek LTO 3 tape drives.

5. Source: http://www.sun.com/customers/servers/dow_corning.xml

6. Source: <http://www.sun.com/customers/servers/nomura.xml>

“We have found the appropriate level of operating system support we need to run our business through the OpenSolaris storage community, which saves significant time and money.”

Jason Williams, COO and CTO, DigiTar

Storage administration at the bank has been simplified by the Solaris ZFS file system. With traditional storage volumes, storage is fragmented and stranded. Solaris ZFS creates a common storage pool, with no partitions to manage. It enables administrators to provision or grow storage, and add or remove a file system with a single, simple command instead of many complicated steps. The Solaris ZFS file system also safeguards data at the bank by running 64-bit checksums that detect and correct silent data corruption.

DigiTar

DigiTar is a Web 2.0 company that drives value to customers through state-of-the-art technology development. The company’s services enhance existing messaging systems with next-generation capabilities such as “DNA-based” spam filtering that uses deep contextual analysis to block spam with an unprecedented accuracy rate of 99+ percent. As a company that views pushing the technology envelope as a way of life, DigiTar does not settle for standard performance in the server, storage, and communications infrastructure that underlies its services.

DigiTar put Sun Fire™ T2000 servers through their paces, testing their ability to run the MySQL™ database component of the company’s messaging services and comparing performance to DigiTar’s existing HP DL145 G2 database servers⁷. DigiTar’s tests showed that the two Sun servers, based on Sun’s UltraSPARC® T1 processor and running the Solaris 10 Operating System, could deliver performance equal to 10 to 20 of the HP servers for the cost of only four. With the Sun Fire T2000 servers now in production, DigiTar estimates a 4.5X performance improvement per server, a doubling of its database processing capacity, and a 75 percent reduction in operating costs for its MySQL applications. Part of the cost savings result from an 83 percent reduction in power consumption and heat generated, representing a 5 percent decrease in total datacenter power consumption.

DigiTar is using OpenSolaris operating system to further improve the performance and efficiency of its Sun Fire T2000 database servers. The Solaris OS allows DigiTar to optimize server utilization by running multiple instances of the MySQL database on the same server. In addition, the Solaris ZFS file system automates and simplifies database storage administration, reducing the administration time required for tasks such as identifying and fixing database corruption by days or even weeks. The company is now leveraging a Sun Open Storage solution based on the Sun Fire X4500 server with Solaris ZFS technology as the primary storage for its databases.

DigiTar Results

- Consolidated eight HP servers onto two Sun Fire T2000 servers
- Gained a 2x increase in processing capacity
- Reduced operating costs for MySQL applications by 75 percent
- Automated and simplified database storage administration

7. Source: <http://www.sun.com/customers/servers/digitar.xml>

Chapter 4

For More Information

To learn more about how the Solaris 10 OS and Solaris ZFS file system can help transform enterprise storage management infrastructure, contact a Sun sales representative or visit the Web sites listed in Table 4-1.

Table 4-1. Web sites for more information.

Description	URL
Blogs About OpenSolaris	blogs.sun.com/main/tags/opensolaris
Blogs About the Solaris OS	blogs.sun.com/main/tags/solaris
Blogs About Solaris ZFS	blogs.sun.com/main/tags/zfs opensolaris.org/os/community/zfs/blogs
OpenSolaris Community: Storage	opensolaris.org/os/community/storage
OpenSolaris Community: ZFS	opensolaris.org/os/community/zfs
OpenSolaris Project	opensolaris.org
Solaris Operating System	sun.com/solaris
Solaris ZFS File System	sun.com/solaris/zfs sun.com/software/solaris/ds/zfs.jsp



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