



Virtualizing Storage Tiers to Enable Active Archiving

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1. The Growing Need for Active Archiving

With volumes of stored data growing seemingly without limits, organizations are struggling to meet their burgeoning storage demands. While the acquisition cost of high-performance disk storage continues to decrease, the cost of maintaining and managing large volumes of primary storage makes a storage strategy based solely on primary tier disk arrays extremely expensive. The only alternative for many has been manually archiving data from primary disk to a more cost-effective tier, such as MAID (Massive Array of Idle Disks), or tape—a time-consuming and error-prone process that can inhibit or even prevent access to critical data when it's needed.

Increasingly, active archiving is being discussed as the solution to the chaos produced by rapidly growing data stores, excessive quantities of primary storage, and manual data archiving. The goal of active archiving is to rationalize the management of large volumes of data. With an active archive, each file is uniquely classified and then managed throughout its lifecycle to ensure that it is stored on appropriate storage and given an appropriate level of data protection. Naturally, appropriate storage and protection may change as a file ages.

In most cases, data goes through a fairly predictable lifecycle. It is accessed most heavily in the first few weeks after creation, and then frequency of access drops off significantly as data ages. Data may eventually be deleted, but an increasing amount of data must be retained indefinitely. In some cases, data retention is mandated by corporate governance and regulatory requirements.

The steps required in active archiving are summarized in Figure 1. The process begins with categorizing all data to be managed. Categorization can be done manually, or can be dramatically enhanced and automated with metadata or digital asset management frameworks such as SGI® LiveArc™. Whether it is done manually or in an automated workflow, the decision must be made on how different data types need to be accessed, and thus what type of storage is most appropriate for a given class of data.

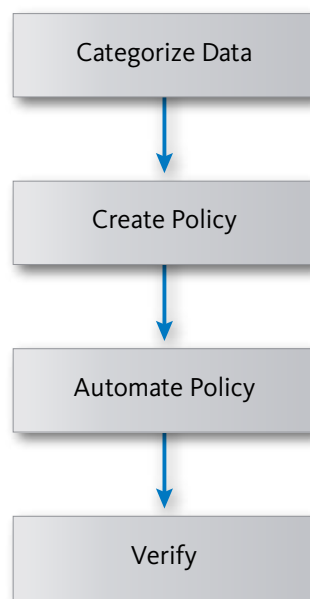


Figure 1. Active Archiving decision points

For example, data that must be preserved for regulatory compliance will be treated much differently than office data, or scratch data. Each requires different types of access and preservation strategies. The problem is that typically this has also meant that different types of storage become incompatible silos, or a distribution of network shares that make centralized management, protection and archiving very difficult.

Once the data has been categorized, policies are created to ensure that each category has an appropriate level of access, the required level of data protection, disaster recovery, etc. These policies can then be automated using a storage hierarchy. The final step is to verify that the system is working as defined and that corporate governance and regulatory requirements are being met.

Regardless of data access patterns or retention requirements, any active archiving solution must meet a number of key requirements:

- Improve data management while reducing total cost of ownership (TCO).
- Ensure adequate data protection by providing security, guaranteeing data integrity, and facilitating backup.
- Recognize and accommodate the fact that not all data is equal. The most critical or most frequently accessed data may require high performance storage, high levels of data protection, and provisions for online disaster recovery. At the other extreme, non-critical data might be best accommodated on nearline or offline storage and have relatively modest data protection requirements.
- Adapt to new technologies. For instance, the availability of inexpensive serial ATA (SATA) disk storage offers an alternative to primary disk with cost and performance characteristics that reside between disk and tape.

Organizations engaged in data-intensive pursuits such as manufacturing, digital media, oil exploration, or scientific research are feeling the effects of rapid and accelerating data growth even more than those in other industries. These users require solutions that can accommodate extremely large datasets (terabytes to exabytes), while assuring that data is always accessible without user or administrator intervention.

While there are many industry discussions about active archiving, real solutions that can meet the requirements are rare. Some vendors are trying to position old products that have little or nothing to do with managing data over time as players in this field. Meanwhile, hundreds of SGI customers with data intensive environments are already meeting their critical data storage and management requirements using the SGI® InfiniteStorage DMF 5 tier virtualization solution. DMF allows data to be transparently migrated from primary disk to secondary disk, and to MAID (Massive Array of Idle Disks) and/or tape automatically according to site-defined policies. The location of data is fully transparent to the user, and data is recalled to primary storage immediately on first access without the need for user or administrator intervention.

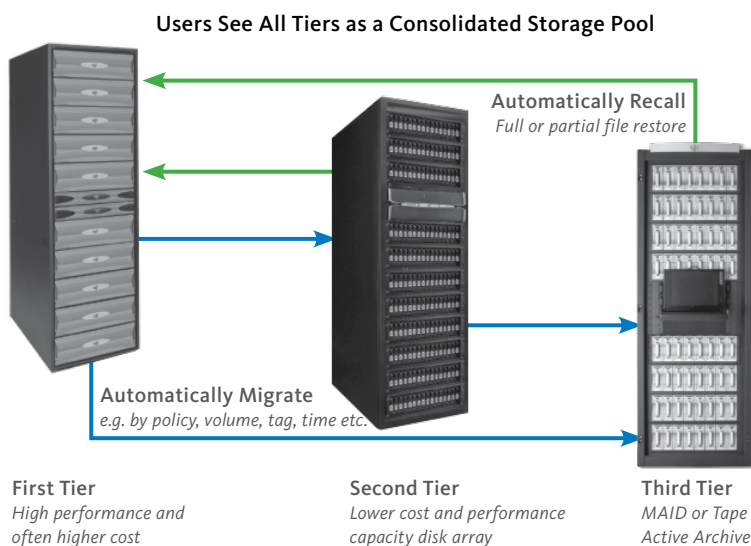


Figure 2. Example three-tier DMF deployment with high-performance primary disk, lower cost near-line disk (SATA), and MAID or Tape. Data moves automatically and transparently up or down the storage hierarchy based on user-defined criteria such as time of access, size, owner and group.

DMF virtualizes storage assets, creating a scalable storage pool transparent to user applications. This fully automated, tiered approach to data storage adapts automatically to changing usage patterns to ensure data is always accessible and users are always productive while greatly simplifying storage management tasks for busy administrators, dramatically reducing the cost of the overall storage infrastructure.

Key Features of DMF include:

- **Unsurpassed Capacity.** SGI customers are already using DMF to enable online access to storage infrastructures larger than 40 petabytes at a fraction of the cost of single tier solutions.
- **Scalable Performance.** DMF offers fast access, low system overhead and efficient scheduling. The most active DMF sites today are moving up to 120TB a day between primary and secondary storage. DMF—in combination with SGI servers—has the parallelism and scalability to keep ahead of the most demanding data environments.
- **Data Integrity.** DMF provides positive, verifiable data security with auditing, media checking, recovery, journaling and two-phase commits. DMF can be configured to maintain up to 64 separate copies of the same file in multiple locations (two copies is typical) to protect against data loss.
- **All Data Always Appears Online and is Easily Accessible.** With typical archiving solutions, locating data often requires users or administrators to manually locate the needed tapes and restore data to disk. DMF ensures that data remains accessible without user or administrator intervention. Users don't have to know where their data is to access it.
- **Ease of Administration.** Once DMF is configured, everything happens automatically, reducing the administrative burden associated with managing large data stores and the manual archival and retrieval of data.
- **Reduced TCO.** By growing data storage with less expensive SATA disk, MAID or tape, the total cost of deploying many petabytes of new storage can be dramatically reduced. With the removal of manual data migration one administrator can manage much more data, greatly reducing administration costs.

This paper explores the benefits of DMF for streamlining data management for the most data-intensive environments. Usage scenarios are discussed along with the core technologies that have made DMF so successful.

2. Reducing TCO with InfiniteStorage DMF

The cost of acquiring storage and of managing data is greatly reduced by the introduction of DMF. In some environments SGI customers have grown data under management from the tens of terabytes to the hundreds of terabytes with no additional storage administration resources.

A simple example illustrates the impact of DMF on storage total cost of ownership. Consider a typical SGI customer with 200TB of disk storage. To meet rapidly growing storage needs, this customer needs to expand total storage to 2PB in one year. With DMF, the back-end expansion of the overall storage infrastructure is decoupled from user space, enabling painless expansion of the environment without needing to disrupt users.

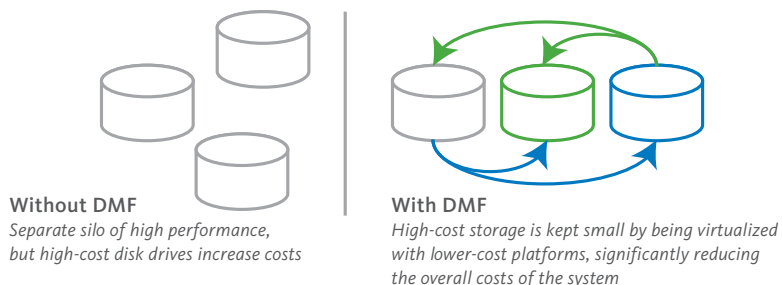


Figure 3. DMF tier virtualization enables IT managers to provide performance for large storage environments without paying for large amounts of high-cost disk.

Thus, the cost advantages of deploying DMF are significant, even ignoring potential savings in electricity, cooling, and administration. For this customer, having 10% of total storage capacity as high-performance disk was adequate to ensure that there was always room on disk for all active data sets. Other customers faced with the same scenario but requiring a higher percentage of disks might opt to add additional high performance disk or less expensive near-line disk to increase total capacity, and still achieve substantial savings through the deployment and use of DMF as an adjunct to primary disk storage.

In DMF environments, the percentage of high-performance disk versus total storage typically ranges from 2% to 10% with the average being around 3%. In other words, for each 1 PB of total storage, DMF users typically maintain between 20TB and 100TB of primary disk storage.

3. Storage Growth in Data-Intensive Environments

Data centers supporting scientific, technical and creative applications are facing a serious dilemma. The cost to expand these systems becomes disproportionately high. New processes, more detailed calculations, and increased productivity are being limited due to the expense of scaling storage capacity and related storage bottlenecks. In the following customer examples, the need for increased storage capacity in the next year ranges from 2X to 20X current levels. Given the huge amounts of disk storage that many of these customers have, not employing a tiered virtualization solution will make that expansion prohibitively expensive and cumbersome.

3.1 Energy

The energy industry relies on increasingly large volumes of complex scientific and engineering data to make investment and management decisions to discover and extract oil and gas from underground reservoirs. Success in this industry depends on advanced visualization of data assets and the ability to leverage the expertise of individuals scattered across the globe.

For example, an oil company has increased its recovery rate exponentially by including advanced visualization in its seismic modeling process. In order to visualize the model data, the data must be made accessible from the compute systems to the visualization system, remote data centers, and geographically distributed modeling and analysis experts across the corporate network. The data sets are increasing with some models now moving into the 100s of terabytes requiring a 5X increase in storage capacity for each data set stored. With this amount of data, a data set cannot even be moved in an entire day using more traditional data management methods.

3.2 Manufacturing

In the manufacturing industry, success often hinges on leveraging the latest technologies—such as solid modeling, computer-aided engineering, conceptual and large assembly design, manufacturing process simulation, and visually collaborative design review—to achieve and sustain competitive advantages. As a result of these innovations, product design and manufacturing have become increasingly data driven. Reliable storage, data delivery, and data management are critical to ensure the success of the digital processes on which advanced product design depends. Advanced computing systems are becoming more capable every year, enabling more-detailed engineering simulations that in turn require significantly greater storage resources.

3.3 Media

The media industry is becoming ever more data-driven as it migrates to all digital processes. By managing multiple projects with effective content dataflow, companies are achieving greater productivity and more timely delivery of higher-quality projects.

For example, consider a sports league with 50 years of footage from multiple angles from thousands of games. At any moment content from current games as well as historical footage might be needed. By using DMF to virtualize more than 7PB of online data, any portion of all this content is available instantly to a wide array of different user types. Less than 200TB of production disk is needed to provide online access to this growing active archive.

3.4 Sciences

Researchers in fields ranging from climatology to molecular modeling are struggling to cope with rapidly expanding data sets in the face of shrinking funding. For example, a scientific imaging research facility is combining current and historic brain-mapping image data to enable time-study research for local and global users. Researchers need to grow from 100TB to over 1.5PB of globally accessible image data to support their research mandate and to qualify for program funding. Furthermore, they need to do this in such a way that all data remains available to all users in the most efficient manner possible, without additional head count for administration. They need to grow their data stored by 20X and make it available to a global user community in the most cost-effective way possible.

3.5 Government

Government and defense institutions increasingly depend on digital technology to carry out their missions. As a result, these institutions are now trying to cope with quantities of data that would have been unthinkable just a few years ago. It is not unusual to find data sets ranging from hundreds of terabytes to petabytes and beyond. For example, one government institution takes a live satellite feed into a compute center where multiple operators analyze the feed. The institution's mission for the coming year is to increase the granularity of its results and the frequency of reporting—a requirement that will increase data set sizes by 2X and time per job to almost two hours with the current infrastructure. The institutions simply cannot meet their future mission goals with current tools.

4. Understanding DMF

SGL customers have been leveraging DMF for over 20 years in hundreds of large data centers around the world with active archive environments. Most customers report that once they assign policies for each category of data they can rapidly implement those policies with DMF and then simply forget about it. DMF does all the work of data management with very little administrator overhead.

To fully appreciate the flexibility and robustness of DMF, it is necessary to know a little bit about how DMF works. DMF has successfully withstood the rigors of use in data-intensive environments because of a number of factors:

- **Data Integrity.** DMF features ensure that the highest levels of data integrity are maintained at all times. All database operations use journaling and two-phase commit. DMF also maintains multiple copies of each migrated file to protect against media failures.
- **Parallelism.** DMF is designed so that multiple operations occur in parallel. User operations don't wait for other operations to complete. Maximum bandwidth is typically only limited by the aggregate bandwidth of attached near-line storage (for example, in configurations with tape, the number and types of tape drives are typically the limiting factor).
- **Scalability.** DMF is architected to manage up to 2 billion migrated files at one time, 18 million terabytes in a single instance, and single file sizes up to 9 million terabytes.
- **Simple Administration.** Once DMF is configured, there are few ongoing tasks for an administrator to perform, guaranteeing that a virtually limitless amount of storage can be maintained by very few personnel.

4.1 File Migration

DMF automatically manages the free space on primary disk storage to ensure that disk space is always available, freeing system administrators from the time consuming task of constantly monitoring and provisioning storage.

File migration occurs in two stages:

- **Stage One:** A file is copied (migrated) to secondary storage
- **Stage Two:** After the copy is secure, the file is eligible to have its data blocks released (this usually occurs only after a minimum space threshold is reached)

A file with all near-line copies completed is called fully migrated. A file that is fully migrated but whose data blocks have not yet been released is called a 'dual-state files'; its data exists both online and near line simultaneously. After a file's data blocks have been released, the file is called a near-line file.

The daemon process *dmfsmon* monitors the file systems managed by DMF and takes action according to a number of key parameters that can be configured separately for each managed file system:

- **FREE_SPACE_MINIMUM** specifies the minimum percentage of file system space that must be free. When this value is reached, *dmfsmon* will take action to migrate and free enough files to bring the file system into compliance. For example, setting this parameter to 10 indicates that when less than 10% of the file system space is free, *dmfsmon* will migrate and free files to achieve the percentage of free space specified by **FREE_SPACE_TARGET**.
- **FREE_SPACE_TARGET** specifies the percentage of free file system space *dmfsmon* will try to achieve if free space falls below **FREE_SPACE_MINIMUM**. For example, if this parameter is set to 15 and **FREE_SPACE_MINIMUM** is set to 10, *dmfsmon* takes action when the file system is less than 10% free and migrates and frees files until 15% of the file system is available.
- **MIGRATION_TARGET** specifies the percentage of file system capacity that is maintained as a reserve of space that is free or occupied by dual-state files. DMF attempts to maintain this reserve in the event that the file system free space reaches or falls below **FREE_SPACE_MINIMUM**.

Most customer sites generally use the default values that DMF uses for these parameters because they have been found to work well for large file systems. For instance, a 100TB file system with **FREE_SPACE_MINIMUM** set to the default value of 5%, **FREE_SPACE_TARGET** set to 10%, and **MIGRATION_TARGET** set to 80% maintains a minimum of 500GB to 1TB of free space. Dual-state files occupy up to 8TB of the file system while regular files occupy the remaining 2 TB.

Some customers set **MIGRATION_TARGET** even higher (up to 90%) depending on the number of unmigratable files the file system contains. A high value maximizes the number of dual-state files in the file system, which gives DMF the most flexibility if there's a sudden burst of file creation activity. The space occupied by these files can be immediately freed should that become necessary.

The following figure illustrates the relationship between these parameters and shows how DMF controls free space in the file system.

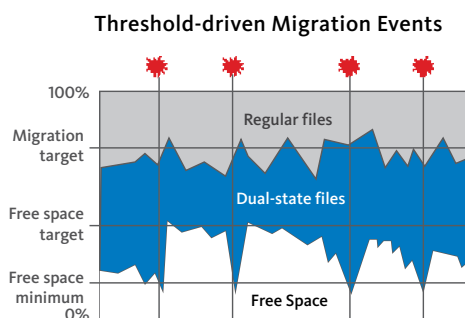


Figure 4. Automated free space management by DMF

By pre-migrating files to maintain a pool of dual-state files, DMF ensures that disk space can be freed rapidly whenever it becomes necessary. When `dmfsmon` detects a file system that has fallen below `FREE_SPACE_MINIMUM`, it triggers the `dmfsfree` process that creates a list of files to be migrated. These files are weighted by time of last access, size, user id, group id and whether the file is currently dual-state. DMF can also be customized to weight files based on other site-defined criteria.

Most customer sites implement policies based primarily on file size. For instance, many sites migrate small files to faster tape devices to ensure rapid access while larger files are targeted to high capacity tape storage. However, many sites have implemented unique policies based on other criteria to achieve particular goals. Some sites use particular group ids to ensure that critical files are always migrated offsite for increased data protection. Files can be assigned to special groups automatically or as necessary to ensure migration. Other sites share their DMF infrastructure between multiple departments. A given department may purchase its own second or third tier storage and media and then create a policy based on user id and/or group id to ensure that its files go to the resources it owns.

Once `dmfsfree` creates its migration candidate list based on site-defined selection criteria, each file on the list is passed to the `dmfdaemon` (the master daemon at the heart of DMF operations) which requests that the appropriate processes handle the migration of each file with the appropriate media.

The state of each managed file is maintained in the file's inode. The file's inode also contains the DMF key (Bit File Identifier – BFID) that maps the file to the DMF daemon database. Great care has been taken to ensure the robustness of this database. This is one of the keys to the overall effectiveness of DMF. The DMF database employs full transaction journaling and two-phase commit. The combination of these two features ensures that DMF applies only whole transactions to its database. In the event of an unscheduled system interrupt, it is always possible to replay the database journals in order to restore consistency between the DMF databases and the file system.

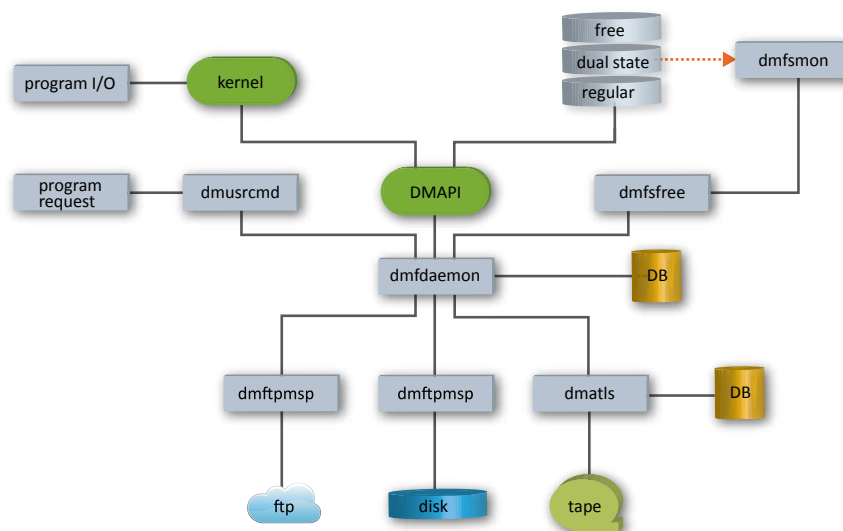


Figure 5. Block diagram showing DMF and its major components

4.2 Choosing Migration Targets

Near-line media is the destination of all migrated data and is managed by daemon-like DMF components called the media-specific process (MSP) and the library server (LS). Multiple copies of each file can be created (two copies is standard) and these can be directed to different MSPs. This increases the robustness of DMF and allows it to be flexibly configured for a variety of purposes including disaster recovery. MSPs are available for:

- Disk—Provides migration to disks (fibre, SATA, or other) and other random access devices like NFS-mounted file systems
- FTP—Supports migration of data across IP networks to local or remote locations
- MAID (Massive Array of Idle Disks)—An innovative technology found in the SGI® COPAN persistent data platform that completely removes power from the disk systems when they are not being used. They enable dramatic cost savings over conventional disk arrays.
- Tape—Tape libraries are still a common migration target currently in use

The FTP MSP (dmftmpsp) uses the FTP protocol to transfer to and from disks of another system on the network. The disk MSP (dmfskmsp) is similar, but uses a file system mounted on the DMF server itself. The tape MSP (dmats) uses either SGI® OpenVault™ or Tape Management Facility (TMF) as a mounting service and to organize and control tape operations.

All of the MSPs have the ability to create multiple read—and/or write—children so that a large number of operations can occur in parallel to increase DMF throughput.

4.3 N-tier Migration

Less expensive disk resources, such as SATA disk arrays, can be used in n-tier migration hierarchies. For example, in a three-tier configuration, a secondary disk tier is configured as a disk MSP and designated to run in Disk Cache Manager (DCM) mode to serve as a cache between primary disk and third tier tape or MAID. Smaller or frequently recalled files can be kept in cache rather than on the third tier to enhance the speed with which they can be recovered to primary disk, while short-lived files may never reach tier three at all.

Files move automatically from cache to tier three when their recall rates decline. Files that don't reside in the cache can be recalled directly from tier three to primary storage as necessary. Customers wishing to implement data protection policies via DMF can also maintain a second copy of each cached file on tier three storage.

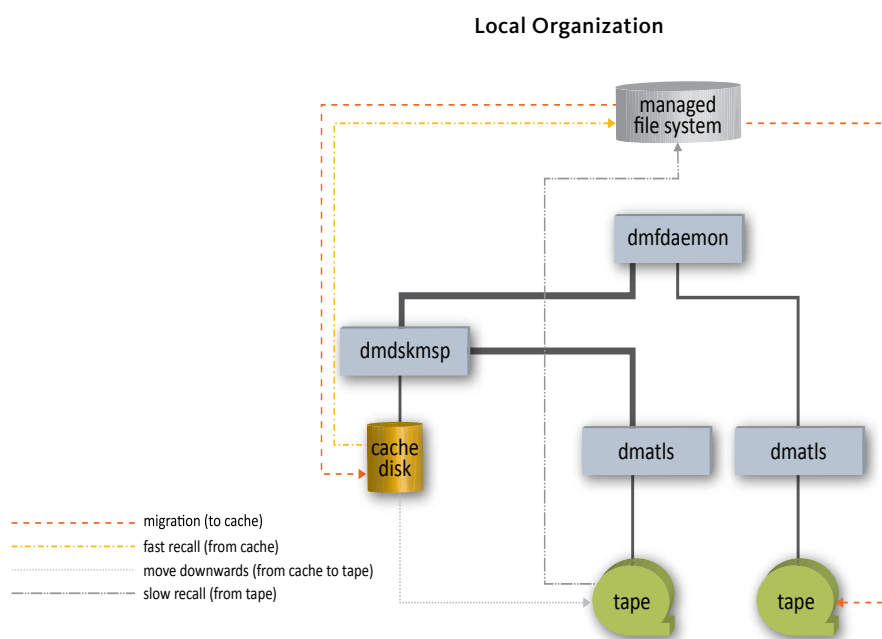


Figure 6. Example of a three-tier migration hierarchy

4.4 User Access to DMF

DMF integrates closely with the XFS® file system and can be accessed by users in two ways:

- Through normal file I/O requests
- Through explicit user commands

4.4.1 DMF Access through Normal File I/O Requests

Any user or application request to read or write data in a file system managed by DMF may trigger a recall of a file to primary disk if that file has been migrated. Note that an XFS file system utilizing DMF can be mounted and accessed by NFS, CIFS (SAMBAs®), or CXFS™ as normal. In other words, the presence of DMF on the file or metadata server is transparent to remote users. File recall occurs automatically if a file is migrated just as it does for a local user or application.

The XFS file system integrates with DMF using the industry standard Data Migration Application Programmer's Interface (DMAPI). File systems that are used with DMF must be mounted with the DMAPI option:

```
On Linux: mount -o dmapi
```

When DMF migrates a file to secondary storage it sets DMAPI events in the file's inode, which remains on disk. When the kernel commences I/O to a migrated file, DMAPI sends those events to the dmfd daemon, which triggers a recall of the file's data from secondary storage. The user's request is delayed while the file is recalled to disk; otherwise, all activity is transparent.

4.4.2 DMF Access through Explicit Commands

There are some situations where it is advantageous to know or manipulate the migration state of a file. For instance, at the completion of a large project it may be desirable to explicitly migrate files to free up disk space for new projects.

DMF provides a full suite of user level commands and a programming library to allow users and applications to explicitly monitor and control file migration. DMF user commands exist to check the migration state of a file, explicitly migrate or recall a file, and a few other common functions. Library routines provide similar functionality for programmers so that applications can take explicit advantage of DMF. When the appropriate command or library call is made, the dmfd daemon is notified. It takes the appropriate action (recall to primary storage, migrate to tape, etc.) and clears or sets DMAPI events in the file's inode accordingly.

Explicit command access to DMF is also available for remote user access. To utilize these, remote systems must have the DMF client software installed. Remote DMF requests are sent to an instance of dmusr cmd running on the local system and then relayed to the DMF server.

4.5 DMF Administration

Before DMF is installed, a site must first categorize its data and design the proper policies for managing data in each category. At this point, DMF can then be configured to implement these policies. The initial configuration of DMF also involves choosing the appropriate hardware to deliver the necessary primary disk capacity, secondary disk capacity, tape library capacity and the necessary number of tape drives. Additional thought must be given to bandwidth between the DMF server and storage subsystems to ensure that data can be migrated and recalled at the rate necessary to achieve operational goals. Once the hardware is in place, configuring DMF involves choosing the migration parameters for each file system to be managed and configuring the selection criteria by which files will be chosen for migration to implement active archiving policies.

SGI Professional Services is available to assist customers with DMF planning, deployment, configuration and management, helping to tailor the DMF environment to meet the most specific and demanding requirements. Experienced SGI personnel will assess site needs, identify inefficiencies, estimate future requirements, and tailor a streamlined DMF solution to meet the most exacting active archiving requirements.

Once DMF is configured, most maintenance tasks can be configured to run automatically on a periodic basis. Convenient scripts are provided with DMF that allow these tasks to be regularly scheduled using DMF's built-in task scheduler:

- DMF can automatically merge tapes that are becoming sparse—that is, tapes that include gaps left when the owner has deleted data. By configuring DMF to merge sparse tapes, the media pool is examined on a regular basis to reclaim unusable space.
- Recording media eventually becomes unreliable. Sometimes, media transports become misaligned so that a volume written on one cannot be read from another. Two utilities are provided that detect failing media. The `dmatsnf` utility is used to scan a DMF volume for flaws, and `dmaread` is used for recovering data. The volume merge process is also capable of recovering data from failing media. DMF can detect and recover data from failing media in many cases. However, some media failures may be unrecoverable. For this reason, DMF is normally configured to maintain a minimum of two copies of each near-line file.

Integrity of data is a central concern to the DMF administrator. Regular attention to the following items helps ensure the highest level of data integrity:

- Regular backups must still be performed to protect unmigrated files, inodes, and directory structures because DMF moves only the data associated with files, not the file inodes or directories. The process of backup can be simplified by creating a policy of migrating 100% of DMF-managed file systems, leaving only a small amount of data to be backed up. Backup can be performed using backup programs that are DMF—and DMAP!—aware.
- DMF databases record all information about stored data. The DMF databases must be synchronized with the file systems that DMF manages. Much of the work done by DMF ensures that the DMF databases remain aligned with the file systems. DMF can be configured to automatically examine the consistency and integrity of the DMF daemon and MSP databases. These databases must also be periodically backed up to protect them from loss, and DMF includes a script to accomplish this. This task also uses the `dmdbcheck` utility to ensure the integrity of the databases before saving them.
- DMF journal files must be retained and protected between full backups of the DMF databases. After a database backup is performed, old journal and log files may be removed to prevent the spool directory from filling up. Tools are provided which can be scheduled to run after database backup to remove these old files.

5. Solving Real-World Data Management Problems

Returning now to the earlier industry examples, the solutions the customer selected in each case can be investigated. Most of the customers in the earlier examples actually faced two related problems:

1. Economically and efficiently storing data
2. Accessing that data to create effective workflows

Many customers chose to implement DMF together with SGI® InfiniteStorage Shared File system CXFS™ —SGI's industry-leading solution for heterogeneous, high-speed data access over a SAN. The combination of DMF and CXFS gives all servers connected to a SAN—running the most commonly used operating systems—unparalleled access to important data without the bottlenecks associated with traditional storage solutions.

5.1 Energy

The oil company discussed previously required a 5X increase in data storage. At the same time, they needed to move data much more efficiently between compute and visualization systems. The pairing of CXFS with DMF

provides their local data centers with the bandwidth and storage capacity they need to efficiently process and store huge data sets, accelerating workflow. CXFS allows data to be shared between globally dispersed data centers at high bandwidth, without replication, making it possible for this company to process and visualize data without resorting to copying, saving countless hours. DMF has allowed the company to dramatically and cost-effectively scale storage capacity without sacrificing the ability to rapidly access archived data.

5.2 Media

In our media example, the company would have required over 7 petabytes of disk storage to meet its needs. By combining less than 200TB of primary disk storage in three different production SANs with CXFS, and a 10PB and growing tape library all managed with DMF, the customer was able to dramatically reduce its storage costs to a fraction of all other available options, while dramatically increasing productivity of legacy systems.

In addition, CXFS allowed the company to increase workflow by virtually eliminating unproductive data copying. Now, instead of wasting valuable time waiting for digital assets to be copied, the staff simply accesses those assets directly as needed with no waiting. Each staff member's productivity has increased dramatically, allowing the company to keep up with the growing demands on their content. The increase in workflow and elimination of data copies has actually reduced the company's total storage requirement.

5.4 Sciences

For the brain mapping research facility, CXFS gives all visual workstations and servers in the facility shared high-speed access to the growing pool of brain image data. DMF allows researchers to store most of their image data in tape libraries, dramatically reducing storage costs. A relatively small pool of high-performance disk is used as primary storage for active data. Data is transparently migrated from disk to tape as it becomes inactive. Attempts to access migrated data result in the data being automatically recalled to primary storage for use. The combination of CXFS and DMF has worked out extremely well. Researchers are happy because they can access any data set whenever they need it, without worrying about where it is stored; plus, performance is far better than it was in the past.

5.5 Government

The satellite data acquisition site had a need to increase both workflow and storage capacity. The use of CXFS and high-performance disk arrays are allowing researchers to improve their workflow by 3X using their existing computing systems. CXFS virtually eliminates the data extraction that consumed so much of their previous workflow, allowing them to spend more time processing data and less time moving and managing it. DMF on the back end manages the rapidly growing pool of archived data. Expanding storage with tape and DMF instead of disk saved them over 50% of the cost of expanding their storage pool. As demands continue to grow, the new storage architecture will continue to scale in place for many years to come.

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