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Silicon Graphics, Inc.

XFS Overview & Internals 15 - DMAPI

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sgi®

DMAPI

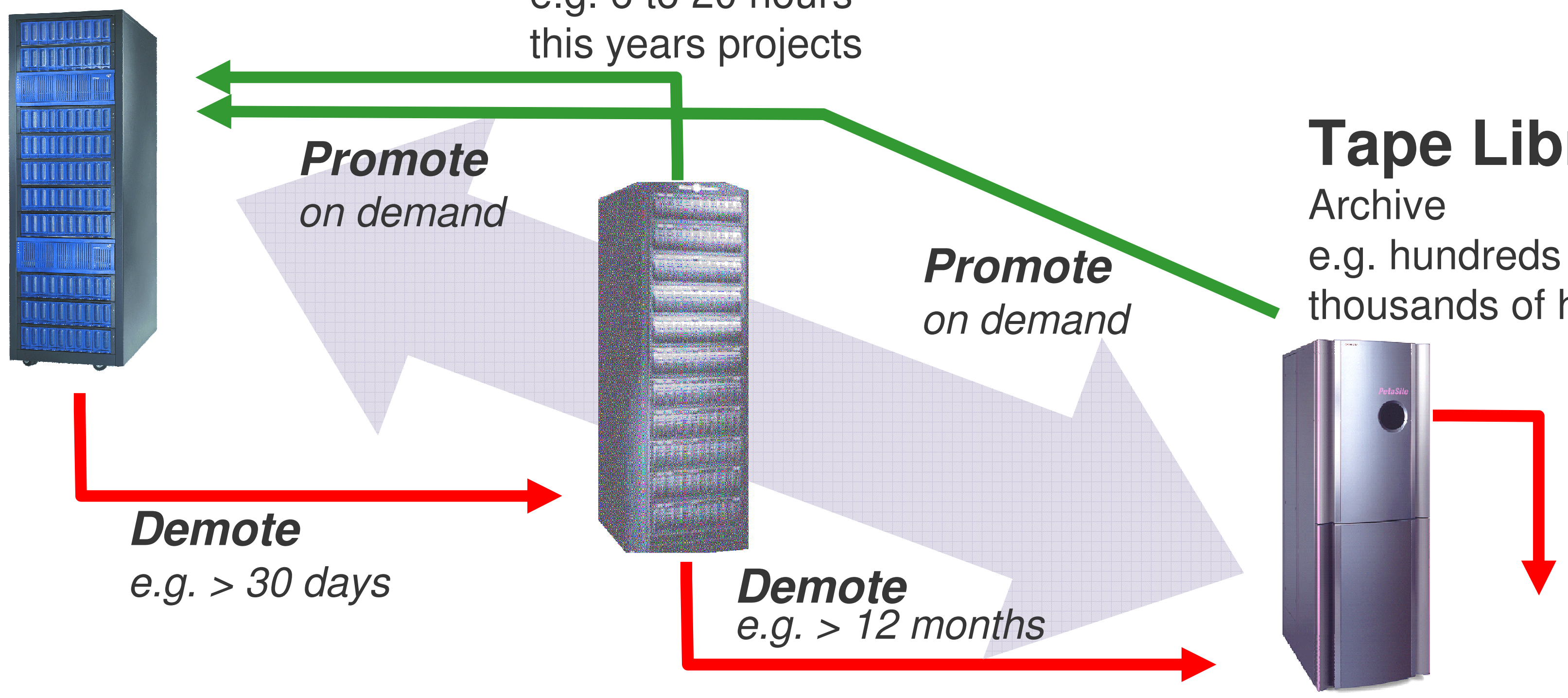
- **D**ata **M**anagement **A**pplications **P**rogramming **I**nterface
- Developed by Data Management Interfaces Group consortium (DMIG), 1993-1996
- Provides standardized access to filesystems for Hierarchical Storage Managers (HSMs) and backup packages
- DMAPI in SLES is used by vendors other than just SGI
  - IBM
  - HP

HSM Example

Primary Storage
Online high-performance disk
e.g. 2 to 10 hours
current projects

Nearline Disk
High Capacity, Low cost,
Lower performance
e.g. 6 to 20 hours
this years projects

Tape Library
Archive
e.g. hundreds to
thousands of hours



HSM Economic Benefit

Example Environment

2TB data less than 30 days old
6TB data between 30 days and one year old
30TB data over one year old

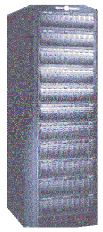
Without HSM

High-Perf. Disk
30TB

With HSM

High-Perf. Disk
2TB

Low Cost
Disk
6TB



Tape Library
30TB

System	c/MB	w/o DMF	With DMF
High-Perf. Disk	4c	$900K	$80K
Low Cost Disk	0.8c	-	$50K
Tape Library	0.37c	-	$110K
DMF		-	$110K
Total Investment		**$900K**	**$350K**

What do HSMs need?

- To be notified of accesses/changes to a file's metadata
- To be able to accept or reject such accesses and changes
- To have user processes block until the change has been approved
- To be able to access a file without knowing a pathname
- To be notified of changes to a file's metadata
- To be able to read and change the contents of a file without blocking
- To save HSM-specific information persistently with a file
- To scan all files in a filesystem quickly
- To be notified when filesystems become full

DMAPI Standard

- DMAPI Versions 2.1 and 2.3
- X/Open Data Storage Management API (XDSM) - 2/97

- Not a rigorous standard.
  - ~70 function calls
  - ~40 structures
  - 24 events

- Spec available free in HTML format from http://www.opengroup.org/pubs/catalog/c429.htm

- Alex Miroshnichenko's paper from AUUG 1996:
- http://www.csu.edu.au/special/auugwww96/proceedings/alex/alex.html

Handles

- Allow file access without pathnames
  - Similar to NFS file handles
- A handle is an opaque persistent identifier which is unique per host
  - Should not change for the life of the object
- Handles are represented as variable length byte streams
  - void* and size_t
- An existence of a valid handle does not guarantee existence of the object referenced by it.
  - The only way to guarantee the existence of the object referred to by a handle is to either obtain a right or hold on the object

- Three handle types:
  - Global handle - (used only in mount requests)
  - Filesystem handle - (fsid hash)
  - File handle - (fsid hash/fid_t structure)

Handles - DMAPI Functions

- dm_path_to_handle
  - create file handle from pathname
- dm_fd_to_handle
  - create file handle from file descriptor
- dm_path_to_fshandle
  - create filesystem handle from file descriptor
- dm_handle_to_fshandle
  - extract the filesystem handle from a file handle
- dm_handle_cmp
  - file handle comparison
- dm_handle_is_valid
  - determine if a handle is valid
- dm_handle_hash
  - hash contents of a handle
- dm_handle_free
  - free storage allocated to a handle
- dm_handle_to_path
  - get a pathname from two handles

DMAPI Events and Tokens

- Events are messages from the kernel to a DMAPI application
- Provide notification of accesses/changes to a file or filesystem
- When a synchronous event is generated, the user process is suspended in the kernel until a DMAPI application issues an explicit response to the event
  - A token is a reference to the kernel state associated with a synchronous event
- Asynchronous events are for notification purpose only
  - May indicate a completion (or failure) of certain operations
  - Do not block user processes
- All contain handles, directory names, etc.

Events - Filesystem Admin

- mount
  - a filesystem is about to be mounted
- preunmount
  - a filesystem is about to unmount
- unmount
  - an unmount succeeded/failed
- nospace
  - filesystem has run out of space

- Not implemented by XFS:
  - debut
    - inode has been read from disk

Events - Namespace

- create/postcreate
  - create a file or directory
- remove/postremove
  - unlink a filesystem object
- rename/postrename
  - rename a filesystem object
- link/postlink
  - (hard) link a filesystem object
- symlink/postsymlink
  - create a symlink

Events - Data

- read
  - the specified file byte range is about to be read
- write
  - the specified file byte range is about to be written
- truncate
  - file is about to be truncated to the specified address (away from or towards zero)

Events - Metadata

- attribute
  - a filesystem object's attribute has changed
- destroy
  - a filesystem object has been destroyed

- Not implemented by XFS:
  - cancel
    - a previously issued event is cancelled
  - close
    - a filesystem object has been closed

Events - Pseudo

- user event
  - a message between cooperating DMAPI processes

Sessions and Dispositions

- DMAPI uses sessions as the primary communication channels between DM application and the kernel component of DMAPI
  - Almost all DMAPI calls require a session argument
- Sessions and event lists allow DM application to exercise a fine control of the event delivery and generations
  - Applications may direct different event types to different sessions and avoid session overloading
- Dispositions indicate which event types should be delivered to this session.
  - A DM application creates a session by calling dm_open_session() and then may register event dispositions for this session by calling dm_set_disp()

Connecting Events with Sessions

- Select desired events to be generated
  - dm_eventlist_t bitmap
- Set by filesystem
  - not persistent
- Set by file
  - persistent
- Set globally
  - to trigger mount events
- Next set disposition of those events
  - recipient session

Connecting Events - DMAPI Functions

- dm_get_eventlist
  - get list of enabled events for object
- dm_set_eventlist
  - set list of enabled events for object
- dm_set_disp
  - set disposition of events on a filesystem to a particular session
- dm_set_return_on_destroy
  - specify a DMAPI attribute to return with destroy events

Managing Sessions - DMAPI functions

- dm_create_session
  - create a new session
- dm_query_session
  - query a session for information
- dm_destroy_session
  - destroy the specified session
- dm_getall_sessions
  - get all extant sessions

Processing Events - DMAPI Functions

- dm_get_events
  - get next available event messages
- dm_respond-event
  - respond to one event
- dm_pending
  - notify FS of slow application event
- dm_create_userevent
  - generate a user pseudo-event
- dm_send_msg
  - send message to indicated session
- dm_move_event
  - move event to another session

Session Recovery

- dm_getall_sessions
  - get all extant sessions
- dm_query_session
  - query a session for info
- dm_create_session
  - create/assume a session
- dm_getall_tokens
  - get outstanding tokens for a session
- dm_find_eventmsg
  - get message for an event
- dm_getall_disp
  - get event dispositions for all filesystems for a session

Managed Regions

- A managed regions is the mechanism for an application to control file data access at a granularity level less than file size. It is an extent in the logical file space
  - starting offset
  - length
  - event generation flags
- Provide byte-granularity events for all accesses/modifications of a file's data
  - Only apply to file objects
- Cover non-overlapping byte ranges in a file
- Separately detect reads, writes, truncates
- Only one, persistent in XFS

Managed Regions – DMAPI Functions

- dm_get_region
  - get managed regions for a file
- dm_set_region
  - set managed regions for a file

File Access and Modification

- Must not change mtime or atime (ctime changes)
  - TODO: Bug
- Must not block
- Must not generate events

File Access and Modification – DMAPI Functions

- dm_probe_hole
  - return rounded result of the area where a hole is to be punched
- dm_punch_hole
  - create a hole in a file
- dm_read_invis
  - read a file bypassing DMAPI events
- dm_write_invis
  - write a file bypassing events
- dm_sync_by_handle
  - sync a file's data to disk
- dm_get_fileattr
  - return file attributes
- dm_set_fileattr
  - set file time stamps, ownership, mode, length, etc.
- dm_get_allocinfo
  - return allocation info for a file

Persistent DMAPI Data

- Stored per file as SGI_DMI_xxx extended attribute
- Persistent across reboots
- DMF stores in SGI_DMI_DMFATTR
  - bfid, file state
  - version info
  - Flags
- inodes should be 512 bytes (-i size=512)

Persistent DMAPI Data – DMAPI Functions

- dm_get_dmattr
  - retrieve a DMAPI attribute
- dm_set_dmattr
  - set/replace a DMAPI attribute
- dm_remove_dmattr
  - remove a DMAPI attribute
- dm_getall_dmattr
  - retrieve all DMAPI attributes for a file

Scanning Filesystems Quickly

- dm_init_attrloc
  - initialize a bulk attribute location offset
- dm_get_bulkattr
  - get bulk attributes for entire filesystem

- Not implemented by XFS:
  - dm_get_bulkall
    - get data management attributes for entire filesystem

Rights

- DM applications use the tokens to obtain access rights to file system objects to guarantee stability of the objects.
  - Allow session to control access/updates
  - Provide for atomic updates over many functions

- Access rights may be *shared* and *exclusive*
  - Shared right allows read-only access (DM_RIGHT_SHARED)
  - Exclusive right allows modification to the object (DM_RIGHT_NULL)

- Pseudo-available in XFS

Rights – DMAPI Functions

- dm_release_right
  - release all access rights to an object
- dm_query_right
  - determine set of access rights to an object
- dm_upgrade_right
  - upgrade current right to exclusive
- dm_downgrade_right
  - downgrade current right to shared

- Not implemented in XFS:
  - dm_request_right
    - request a specific access right

XFS DMAPI Mount Options

- Options must be used together
- dmapi
  - Enable the DMAPI event callouts
  - xdsm and dmi options are equivalent
- mtpt=mountpoint
  - The mountpoint specified here will be included in the DMAPI mount event, and should be the path of the actual mountpoint that is used.

```
> grep dmapi /etc/fstab
/dev/sdb1 /mnt/scratch1 xfs dmapi,mtpt=/mnt/scratch1,defaults 0 0

> mount
...
/dev/sdb1 on /mnt/scratch1 type xfs (rw,dmapi,mtpt=/mnt/scratch1)
...
```

What if there is no DMAPI module?

```
# mount -o logdev=/dev/sdb,dmapi,mtpt=/mnt/data /dev/sdd /mnt/data
mount: wrong fs type, bad option, bad superblock on /dev/sdd,
       missing codepage or other error
       In some cases useful info is found in syslog - try
       dmesg | tail  or so
# dmesg | tail | grep dmapi
XFS: unknown mount option [dmapi].
```

- Check that DMAPI is probed on boot and loaded
  - SLES10 set DMAPI_PROBE to yes in /etc/sysconfig/sysctl
- Without rebooting XFS with load dmapi with

```
# echo 1 > /proc/sys/fs/xfs/probe_dmapi
# lsmod | grep dmapi
xfs_dmapi                22936  1
dmapi                    39728  1 xfs_dmapi,[permanent]
xfs                     479796  4 xfs_dmapi,xfs_quota
```

DMAPI Implementation

- Not all DMAPI interfaces used by SGI's HSM product
  - Many of the bugs recently fixed in DMAPI did not impact SGI's HSM
- Some DMAPI interfaces are not implemented by XFS
- Maintaining 2.4/2.6 compatible code makes it difficult to read
  - Plan is to remove 2.4 support from this code base
- DMAPI requires two kernel changes that are not in mainline
  - mprotect
  - open_exec

DMAPI Libraries

```
> rpm -qpl dmapi-2.2.3-12.2.ia64.rpm
/lib/libdm.so.0
/lib/libdm.so.0.0.4
/usr/share/doc/packages/dmapi
/usr/share/doc/packages/dmapi/CHANGES.gz
/usr/share/doc/packages/dmapi/COPYING
/usr/share/doc/packages/dmapi/PORTING
/usr/share/doc/packages/dmapi/README
```

DMAPI Development Package

```
> rpm -qpl dmapi-devel-2.2.3-12.2.ia64.rpm
/lib/libdm.so
/usr/include/xfs/dmapi.h
/usr/lib/libdm.a
/usr/lib/libdm.la
/usr/lib/libdm.so
/usr/share/man/man3/dmapi.3.gz
```

DMAPI Kernel Modules

```
> rpm -qpl kernel-default-2.6.16.21-0.8.ia64.rpm | grep dmapi
/lib/modules/2.6.16.21-0.8-default/kernel/fs/dmapi
/lib/modules/2.6.16.21-0.8-default/kernel/fs/dmapi/dmapi.ko
```

- Filesystem independent module

```
/lib/modules/2.6.16.21-0.8-default/kernel/fs/xfs/dmapi
/lib/modules/2.6.16.21-0.8-default/kernel/fs/xfs/dmapi/xfs_dmapi.ko
```

- XFS dependent module

DMAPI Triage