Experience Running DMF7 on Lustre

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Data Management Framework 7
Data Management Framework 7

Overview

- Designed for Tiered Data Management
- Redesigned from the ground up
  - Build on lessons from DMF 6
- Designed for horizontal scaling
  - Scale by adding more servers
  - Distributed NoSQL database
- Many single-purpose components working together
- Most components are filesystem-agnostic
- Multiple supported filesystem types
  1. HPE XFS
  2. Lustre
  3. IBM Spectrum Scale ("GPFS") in development
Data Management Framework 7 on Lustre

Roles of DMF7 nodes

- **DMF Core Servers**
  - Manage the other nodes
  - Provide the registry
  - Manage namespaces / filesystems

- **DMF Database Servers**
  - Manage the DMF database
  - Policy Agent

- **DMF Data Movers**
  - Move data between filesystem and backend

- **DMF Lustre Agents**
  - Changelog processor
  - Filesystem scanner
  - Database scrubber

- **DMF Clients**
  - DMF CLI available

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DMF Core Servers
- MGT/MGS
- MDT/MDS
- OST/OSS

DMF Database Servers
- Database Servers

Lustre Agents
- Core Servers

DMF Data Movers
- Data Movers

Lustre Clients
- Object Store

DMF Clients
- Other

Hewlett Packard Enterprise
Filesystem Reflection

- Synchronized copy of filesystem metadata
  - Inode metadata
  - Directory tree
  - Extended attributes
  - HSM state
- Maps Lustre FIDs to Object Store
- Cassandra database
  - Maintained by the Lustre Agents
  - Filesystem scanner
  - Changelog processor
  - Database scrubber
- Used by policy engine
  - Parallel data mover framework
  - Copytool interfaces with Lustre HSM
Changelog
Lustre Changelog

# mkdir tmp
2112648 02MKDIR 09:30:25.501859712 2018.08.24 0x0
t=[0x200019271:0x2:0x0] ef=0xf u=0:0 nid=192.168.131.17@tcp1
p=[0x2000000007:0x1:0x0] tmp

# chmod a+rwxt tmp
2112649 14SATTR 09:30:28.739566509 2018.08.24 0x14
t=[0x200019271:0x2:0x0] ef=0xf u=0:0 nid=192.168.131.17@tcp1

xfs_mkfile 1m file.1m
2112650 01CREAT 09:31:11.661327380 2018.08.24 0x0
p=[0x200019271:0x2:0x0] file.1m

2112651 13TRUNC 09:31:11.741270796 2018.08.24 0xe
t=[0x200019271:0x3:0x0] ef=0xf u=0:0 nid=192.168.131.17@tcp1

2112652 11CLOSE 09:31:11.747861801 2018.08.24 0x243
t=[0x200019271:0x3:0x0] ef=0xf u=0:0 nid=192.168.131.17@tcp1

# touch file.1m
2112653 11CLOSE 09:36:18.556856115 2018.08.24 0x42
t=[0x200019271:0x3:0x0] ef=0xf u=0:0 nid=192.168.131.17@tcp1

– Tracks Metadata changes
  – Updated by MDS
  – Stored on MDT
  – Part of filesystem transactions

– Can only be read on Lustre client nodes
  – Must be root or equivalent

– Three types of metadata changes
  – Namespace
  – Side effects
  – Audit trail

– Controlled by per-MDT event mask

– Not a full log of the filesystem actions
  – Tracks that something changed…
  – …but not necessarily what changed
We saw the same stream of records for:
- lustre-MDT0000
- lustre1-MDT0000

Did not happen on all nodes.

Cause:
- “lustre” filesystem name is a prefix of “lustre1”
- Code matches prefix instead of full string
- This is a side effect of LU-12650

Workaround:
- No filesystem name that is a prefix of another
Processing Changelog Records

- Processing a changelog record is work
  - Avoid doing duplicate work
  - Read ahead and drop duplicate updates

- DMF7 coordinates through the reflection:
  - Reflection updates cannot be postponed long
  - The maximum deduplication window is small

- Deduplication is required for correctness:
  - Database timestamps have limited resolution
  - Limit to one update to a row within a window
  - Deduplication window has a minimum size

- Deduplication adds performance:
  - Reduce frequency of filesystem access
  - Reduce number of database updates
  - Gains are limited due to small window
Stepping through the Changelog

- Asynchronous processing of records:
  - White: unread records
  - **Yellow**: records read
    - Deduplicate as records are read
  - **Orange**: records being processed
    - Update of database requested
  - **Green**: completed records
    - Deduplicated records
    - Update of database confirmed
  - **Dark Blue**: cleared records
    - Clear contiguous blocks of completed records

- Recordkeeping tracks *out of order* records
  - Changelog processing got stuck
Out of Order Changelog Records

**LU-11426**: 2/2 Olafs agree: changelog entries are emitted out of order

- Sometimes the indices of subsequent entries are like this:
  - 2112648
  - 2112649
  - 2112651
  - 2112650
  - 2112652
  - 2112653

- Happens across all Lustre versions
  - Only requirement is sufficient concurrent activity on the filesystem
  - Easy to reproduce by running a cluster in VMs on a laptop

- Implicated in a number of issues:
  - **LU-11426**: 2/2 Olafs agree: changelog entries are emitted out of order
    - **LU-11205**: Failure to clear the changelog for user 1 on MDT
    - **LU-11581**: Not all changelog entries are returned to userspace
Sometimes a changelog record is missing:
- Generated for an operation
- Present in the on-disk log
- But not returned to userspace
- This is a side effect of LU-11426

When a record does not appear at first:
- It may be out of order and appear later
- It may be missing and never appear

Major impact on DMF:
- Changelog processing got stuck
  - Hole in contiguous block of records
- Heuristic enables progress
  - Assume loss after reading \( N \) more records
- Filesystem reflection misses an update
  - Filesystem scan required
Also Affects RobinHood

**LU-11205**: Failure to clear the changelog for user 1 on MDT

- RobinHood is also affected
  - RobinHood processes the changelog in a different way
  - Thus very different symptoms

- Syslog messages:
  ```
  ... kernel: Lustre: 11137:0:(mdd_device.c:1577:mdd_changelog_clear()) fs-MDD0000:
  Failure to clear the changelog for user 1: -22
  ```

- RobinHood log messages:
  ```
  ... [13766/22] ChangeLog | ERROR: llapi_changelog_clear("fs-MDT0000", "cl1", 13975842301) returned -22
  ... [13766/22] EntryProc | Error -22 performing callback at stage STAGE_CHGLOG_CLR.
  ... [13766/16] llapi | cannot purge records for 'cl1'
  ```

- This is a side effect of **LU-11426**
HSM Workflow

- Multiple ways to initiate data movement
  - Migration policy
  - Recall on access
  - Manual through CLI

- Data Mover nodes handle bulk traffic
  - Modified version of copytool on agent nodes
  - Mover nodes do actual data movement

- Coordination through the reflection
  - Reflection tracks HSM state

- Interacts with Lustre HSM coordinator
  - Part of Lustre kernel code
  - We encountered some issues
HSM Coordinator Restart Panics

**LU-11675**: Don’t allow new HSM requests during CDT_INIT

```bash
# cd /sys/fs/lustre/mdt/lustre-MDT0002
# echo shutdown > hsm_control
# cat hsm_control
stopping
# cat hsm_control
stopped
# echo enabled > hsm_control
# cat hsm_control
init
# cat hsm_control
enabled
```

- Restart the HSM coordinator
- In *init* it looks for pending HSM requests
- In *init* phase it accepted new HSM requests
  - These could be given a duplicate ID
  - This triggered an assert
- Fixed under **LU-11675**
  - Fix is to not accept new requests during *init*
HSM Files Not Marked Dirty

**LU-11369**: hsm: files are not dirtied when modified by someone else than their owner

```bash
[alice] $ touch /mnt/lustre/alice/file
[alice] $ chmod o+w /mnt/lustre/alice/file
[alice] $ exit
logout

[root] # lfs hsm_archive /mnt/lustre/alice/file
[root] # lfs hsm_state /mnt/lustre/alice/file
/mnt/lustre/alice/file: (0x00000009) exists archived, archive_id:1
[root] # su - bob
[bob] $ echo "123" > /mnt/lustre/alice/file
[bob] $ exit
logout

[root] # lfs hsm_state /mnt/lustre/alice/file
/mnt/lustre/alice/file: (0x00000009) exists archived, archive_id:1
```

- An *archived* file has an identical copy stored
- A *dirty* file has an older copy stored
- Modifying an archived file marks it dirty
- This did not happen for files not owned by the modifying user
- Fixed under [LU-11369](https://example.com/lu-11369)
  - Code had permission to modify file
  - But not to modify file HSM state
Attributes Not Updated on Restored Files

**LU-11925**: Attributes not updated after open+append and write to archived, released file

```
# echo -n "123" > /mnt/lustre/file
# lfs hsm_archive /mnt/lustre/file
# lfs hsm_release /mnt/lustre/file
stat -c %s /mnt/lustre/file
3
# lfs hsm_restore /mnt/lustre/file
# echo -n "456" >> /mnt/lustre/file
# stat -c %s /mnt/lustre/file
3
```

- Query the size of a released file
- Append to file
- File size does not change
- Fixed under [LU-11925](#)
  - File size was obtained with an UPDATE lock
  - On restore any such lock must be canceled
Small Files
What is a Small File?

- Tape is cheap bulk storage
  - If you can afford it
- Tape is slow
  - Physically moving a cartridge in a library
  - Mounting a tape
- Tape is fast
  - LTO-8 native transfer rates are > 300 MB/s
- Tape is big
  - LTO-8 cartridge holds 12 TB uncompressed
- Tape needs a continuous stream of data
  - A good I/O size is between 15 and 20 GB
- A file sized < 18 GB is a small file
Handling Small Files

Tape Zones

- DMF collects small files into tape zones
  - “Tape” for historical reasons
  - DMF does this for all files
    - Big files are split across zones
  - Large transfer units are good for S3 as well
    - Especially if you have to pay per transfer
- Zone is written and read as a single unit
  - Can be constructed as a temporary file
  - We prefer a “scatter-gather I/O” approach
- An 18 GB zone may hold many files
  - The files all migrate at the same time
  - All are open simultaneously
- At least one active zone per tape drive
  - 4 to 10 tape drives is typical

An Example for Context

- Take a fresh clone of the Lustre git repo
  - 160 MB
  - 1,923 files and directories
- In an 18GB zone
  - Lustre source fits 112 times
  - Zone then contains 215,376 files
- Assume 5 tape drives
  - 5 active zones
  - Lustre source fits 560 times
  - 1,076,880 files are migrating
- We have seen worse cases
The Small File Problem

– With small files, we can easily have several million files migrating at the same time
– The Lustre HSM coordinator thus needs to track several million active requests
– There is a maximum number of active HSM requests per MDT
– This limit is tunable
– The default is 3
– The current HSM coordinator was not designed for large numbers of requests
– Direct migration to and from high-latency media requires rethinking the HSM coordinator
  – Handle large numbers of requests
  – Keep blocks of requests together
    – Submit all requests for a zone as a single logical block
    – The entire block is sent to a single copytool
Questioned Answers
Thank you

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