UNIVERSITY OF CAMBRIDGE

Lustre HSM at Cambridge

Early user experience using Intel Lemur HSM agent

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Research Computing Services @ Cambridge

- University-wide service with broad remit to provide research computing and data services to the whole University
- 700 active users from 42 University departments
- Housed within University's purpose-built DC - ~100 racks for Research computing

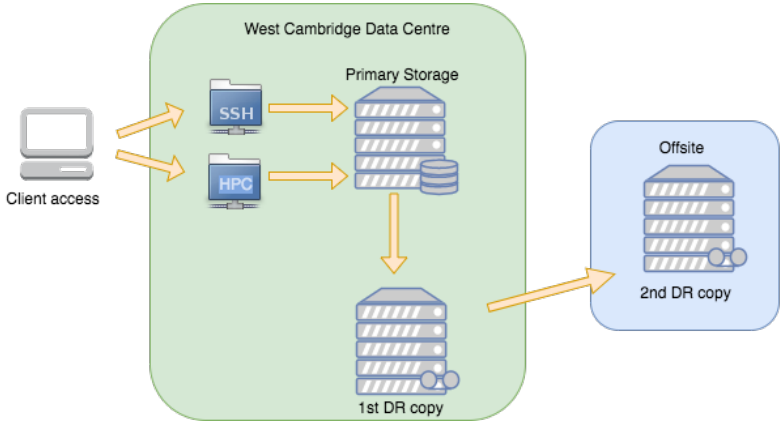
Infrastructure @ Cambridge

- **Darwin: 600 node** (9600 core) sandy bridge
- **Wilkes: 128 node** 256 card Nvidia K20 GPU cluster
- **5 PB** Scratch Lustre (v2.1)
- **20PB** of Tape archival storage
- **CSD3:** New services for Oct 2017
    - **Wilkes2: 90 node** 360 Nvidia Tesla P100
    - **New 768 node** Skylake cluster with Omnipath
    - **342 KNL nodes -** Dell C6320p with KNL7210
    - **5PB** of new Lustre
- **Hadoop & spark:** 200 nodes – Broadwell FDR IB
- **OpenStack**: 80 hypervisor nodes, 3 controller nodes, 1PB replicated storage

Research Storage @ Cambridge

Research Data Store

- Persistent storage, designed to provide capacity-oriented, low-cost area for active research data to complement a smaller, performance-optimised scratch area
- 1.4PB Lustre filesystem, with Robinhood for filesystem management
- Tape library with disk-cache as HSM backend
    - We run a periodic HSM archival policy over the whole filesystem as a disaster recovery copy

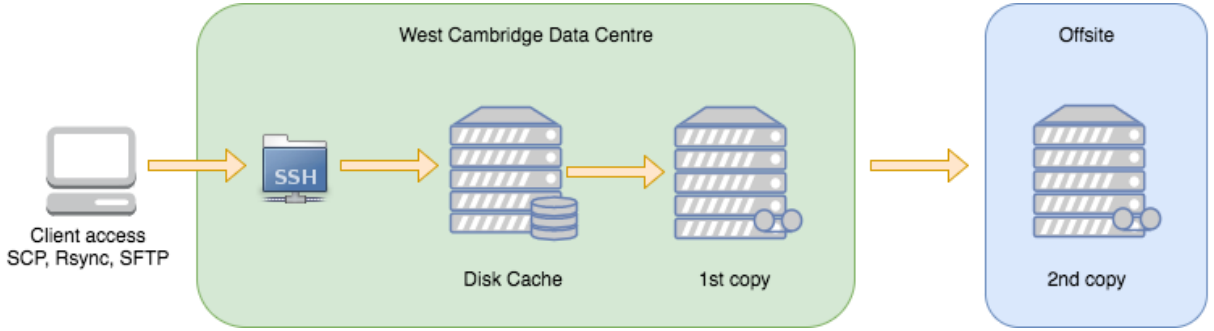


Research Storage @ Cambridge

Research Cold Store

- Archival storage area for long term storage

- 200TB Lustre filesystem with continual HSM archival and release policies
  - More aggressive release policy to keep Lustre ‘cache’ from filling up
  - Larger Tape-filesystem disk-cache to improve recovery responsiveness



HSM Design

Lustre

IEEL 3.0.1

Provisioned through Intel IML

Tier 1

Robinhood

v3.0.0

HSM Copy Agents

Intel Lemur 0.5.1

Run multiple copies as stateless VM instances inside Openstack

QStar Archive Manager

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Provides Posix Filesystem interface to Tape library along with 300TB Disk cache

QSTAR TECHNOLOGIES

Tier 1.5

Spectra Logic T950

2x Libraries with ~10PB of Tape per DC

QStar copies data to two tapes - one in each DC

Tier 2

Lustre Hardware

Type	Quantity	Specs
MDS Server	2	Dell R630 - Dual E5-2667v3 3.2GHz 8 Core 128GB RAM FDR IB, 10GB Ethernet
MDT Storage	1	Dell PowerVault MD3420 20x 300GB SAS 15K HDDs Dual RAID controller with 8GB cache
OSS Server	6	Dell R630 - Dual E5-2623v3 3.0GHz 4 Core 64GB RAM FDR IB, 10GB Ethernet
OSS Storage	6	Dell PowerVault MD3460 60x 6TB NL-SAS HDDs Dual RAID controller with 8GB cache
Network	Infiniband	Mellanox SX6036 FDR IB switches 36x 56Gb FDR
	Ethernet	Mellanox SN2410 Spectrum switches 48x 10GbE + 8x 100GbE

- Intel Enterprise Edition for Lustre v3.0.1
- All storage configured in HA-failover pairs

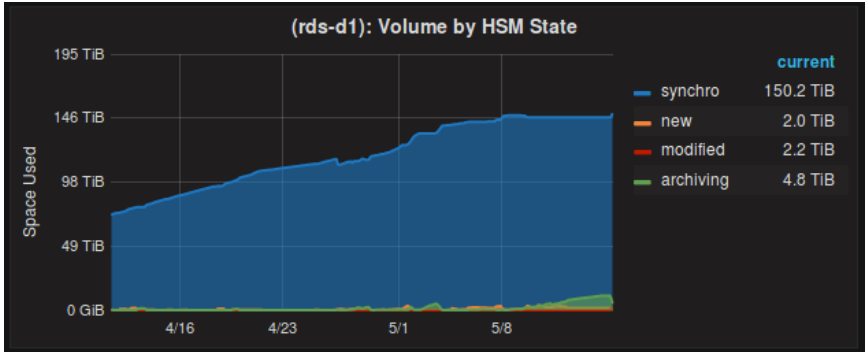
Lustre HSM with Lemur

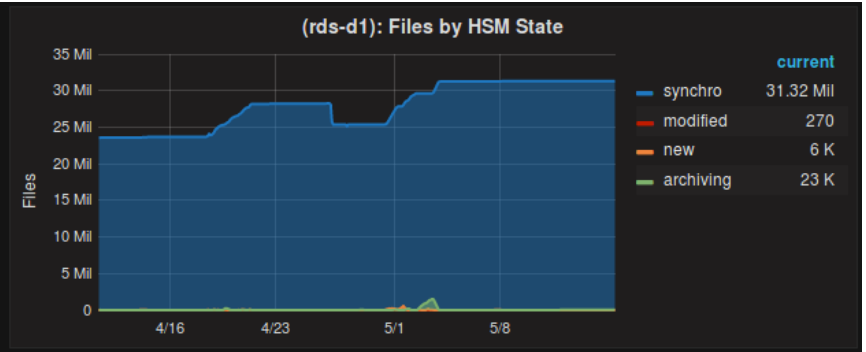
- Moved over to Lemur in Oct 2016 after initial problem with scaling up lhsmtool_posix
- Our immediate experience using Lemur were a major improvement
  - Lemur multi-threaded architecture enabled us to easily increase data throughput such that we could saturate our HSM backend (~1GB/s)
  - Lemur HSM job throughput was also much faster, could run with much higher setting for ‘max_requests’
  - Very pleasant to manage, single systemd service also manages Lustre filesystem mounts - made it very easy to deploy as stateless Lustre copy agent VMs in our Openstack environment

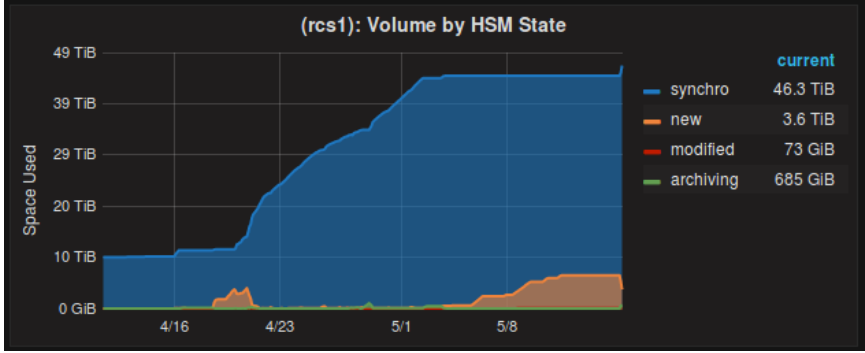
Lemur Feature Wishlist

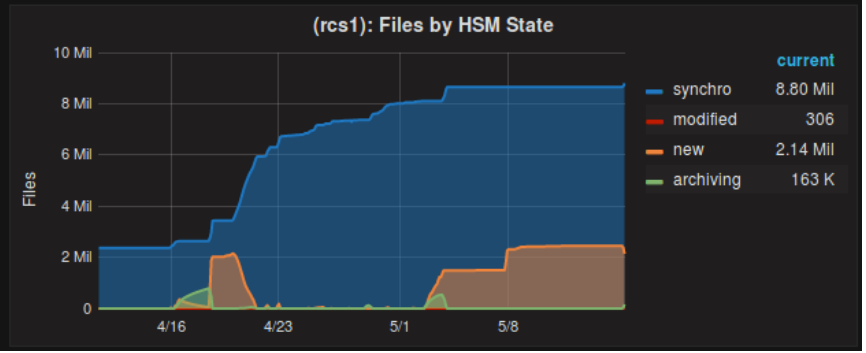
- Our main hope is for greater integration with Robinhood in future
- Lemur version 0.5.0 brought compatibility with Robinhood v3 by changing how it stores the file HSM UUID EA - so Robinhood now correctly stores the UUID from HSM_ARCHIVE operations
- We had trouble getting rbh-undelete functionality to work, and have instead written our own simplistic 'rbh-undelete' scripts built around the Lemur CLI functionality 'lhsm import' released in Lemur 0.5.1
- Lemur has some extremely interesting experimental features such as doing in-flight checksums in the copytool - perhaps this could be stored in the Robinhood DB in some way?

HSM Experiences









HSM Experiences

- Lemur resolved our issues with HSM copytool performance
- HSM coordinator throughput is our main bottleneck now
  - As the number of jobs in the HSM coordinator queue grows large (~few hundred thousand jobs) both the rate at which jobs are fulfilled by the copytools, and the rate at which jobs are ingested, slows down
  - Requires us to closely monitor the size of the coordinator queue and tune Robinhood policy runs as necessary
  - Believe the issue has been noticed last year in LU-7988 and LU-8626
  - We would definitely welcome the suggestion in LU-8626 for a configurable limit on the number of jobs that can submitted to the coordinator queue

HSM Coordinator Wishlist

- As previous LUG/LAD presentations have noted, reducing the value for max_requests in coordinator can cause number of active_requests to grow unbounded (LU-7920)

- More controls, manipulation options for the coordinator's queue would be really welcome such as:
  - Not just FIFO - allow configuring ratios of different types of HSM operation so that some amount of high-priority operations (RESTORE) can be submitted to copytools when there is a large backlog of ARCHIVE operations (LU-8324 has a patch for this that we are planning to test soon)

  - Perhaps allow HSM agents to inform the coordinator how many jobs it can process at a time (eg: per-agent max_requests) - allow for more dynamic scaling up and down the number of HSM agents as needed.

Status and Future of Lustre* HSM

John L. Hammond

Intel HPDD

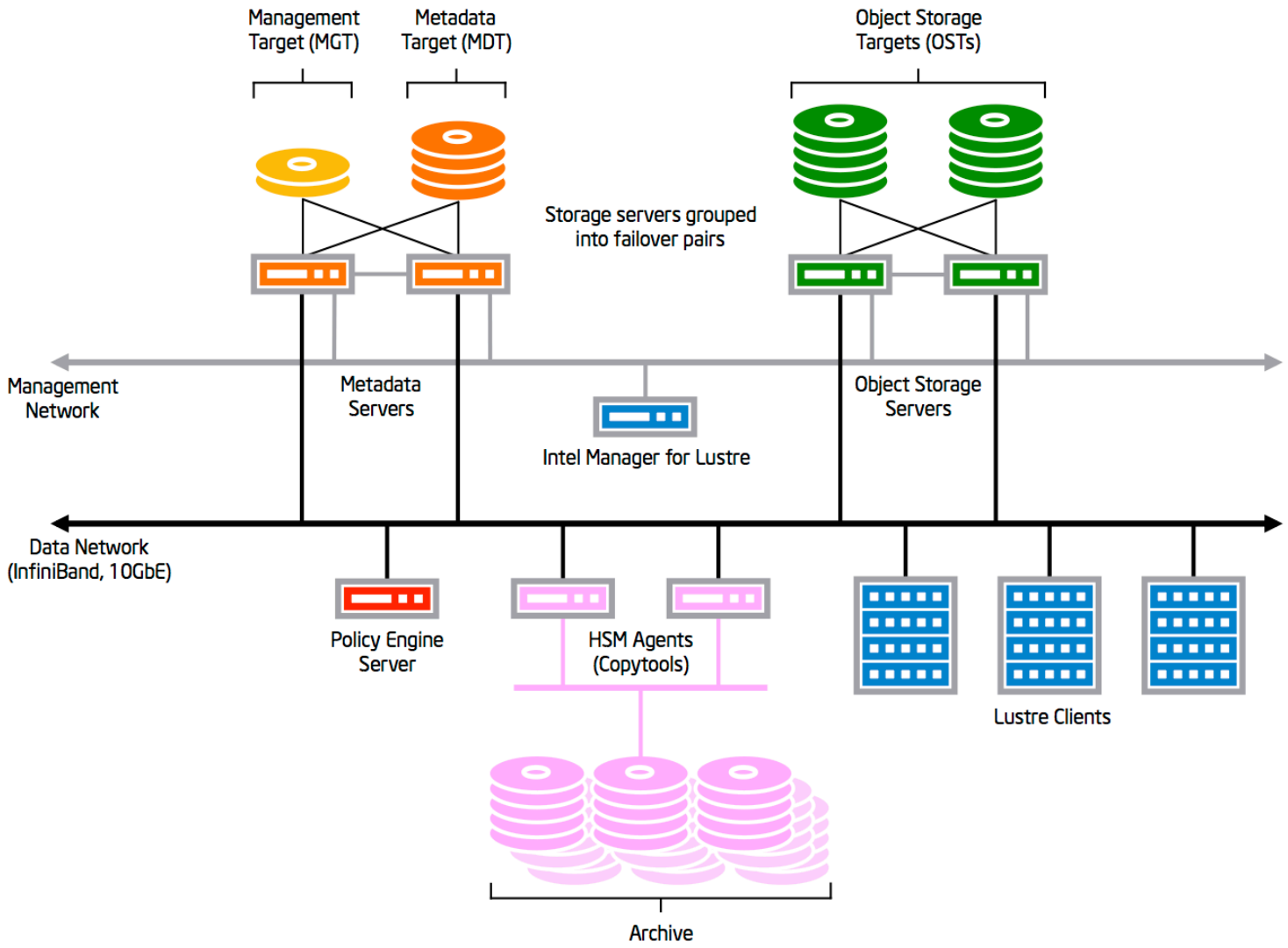
May 2017

*Other names and brands may be claimed as the property of others.

Outline

- Review of Hierarchical Storage Management
- Coordinator Issues
- Copytool Issues
- Lemur vs lhsmtool_posix

HSM Architecture



HSM Coordinator (CDT)

- Part of a Lustre MDT
- Maintains a log on disk of HSM actions (waiting, started, done…)
- Manages layout locking (LDLM) for restores
- Maintains list of registered copytools
- Sends HSM actions (archive, restore, …) to copytools
- Receives progress RPCs from copytools

Coordinator Issue 1: Action Log Scalability

- Submitting new actions is slow when log is already large
  - Adding an action involves linear scan of log for existing compatible action
  - TODO Put in memory hash in front of log (easy)
  - TODO Use a better data structure like index (harder)
- Log update requires linear scan
  - Cache action record locations (LU-9312)
- Compound ID prevents batching
  - Same compound ID assigned to all requests in a list at submit
  - Only requests with same Compound ID submitted together to CT

Coordinator Issue 2: LDLM Locking

LDLM locking used unnecessarily (and inconsistently):

- HSM state needs protection but local locking would suffice
- Avoid interactions between HSM and xattr caching (for example)
- Clients access HSM state through specialized RPCs (not xattrs)
- LDLM Layout Locking still needed for release and restore

Benefits:

- Faster updates (archive start, archive complete, set dirty)
- Updates not blocked by unresponsive clients

(MDT and) HSM Coordinator Progress

- LU-7988 CDT scalability and stability (2 changes in 2.10, 8 in progress)
- LU-9803 handle early requests vs CT registering
- LU-9927 bypass quota enforcement for HSM release (in 2.10)
- LU-9312 HSM coordinator llog scalability (3 in 2.10, 1 in progress)
- LU-9338 cache agent record locations (1 in progress)
- LU-9385 remove XATTR locking from mdt_add_dirty_flag() (in 2.10)
- LU-9403 prevent HSM leak on re-archive (in 2.10)
- LU-9404 set HSM xattr only when needed (in 2.10)
- LU-9464 use OBD_ALLOC_LARGE() for hsm_scan_data (in 2.10)
- LU-9540 cache HSM actions in memory by FID (in progress)

Copytools

lhsmtool_posix

- The “reference” copytool
- Included in lustre-release
- Integrated into Lustre* test framework, HPDD CI

lemur

- New copytool, pluggable, flexible
- Available at https://github.com/intel-hpdd/lemur
- Not integrated into Lustre* test framework
- Does not support archives created by lhsmtool_posix

Copytools

- Attaches to a Lustre client mount point
- Serves one or more backend archives
- Receives HSM action requests from CDT
- Archives file data from Lustre FS to archive
- Restores file data from archive back to Lustre FS

Using reference implementation and llapi you too can write a copytool!

Copytool Issue 1: FID use

- lhsmtool_posix uses file FID as primary id in archive
- An expedient short cut
- Make disaster recovery from RobinHood + archive hard
- Makes import hard (requires rename in archive)
- Incompatible with MDT file migration

- Fixed in lemur by storing HSM archive ID in file extended attribute

Copytool Issue 2: HAL, KUC

CDT sends actions to CT through KUC

- Inflexible message format
- Complicated

  LDLM lock cancel -> FIFO write

  CT reads from FIFO
- Actions broadcast to all CTs running on a node

Affects lhsmtool_posix and lemur

Copytool Issue 3: Flow Control

- CT starts a new thread for each request
- No in-CT limits on thread count
- No in-CDT limits on active requests per CT

Too many threads degrades performance…

Summary

- Many HSM stability improvements in Lustre 2.10 release
- More will come in subsequent 2.10.x maintenance releases
- Multiple options under consideration for Coordinator performance
- Lemur copytool available for community evaluation and input

Notices and Disclaimers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