Lustre* 2.11 and Beyond

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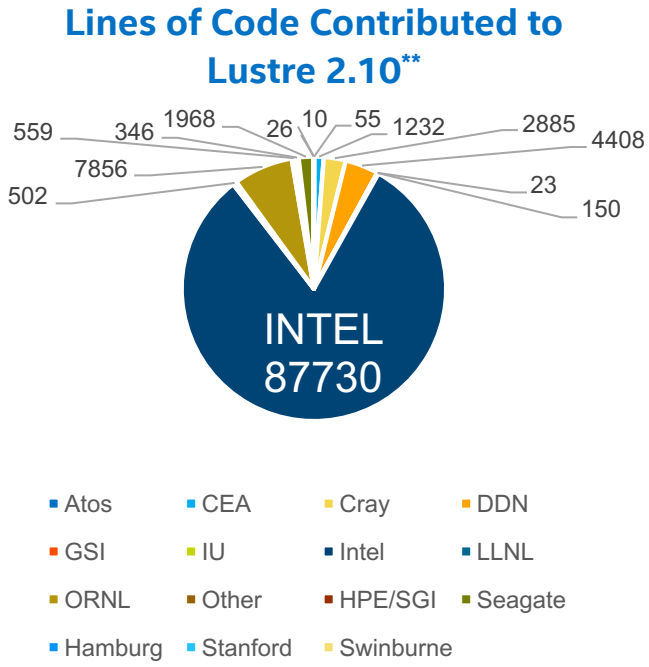
Intel & Lustre* Software

Intel continues to invest in Lustre with:

- The latest **Major Releases** of Lustre
- **Next generation Feature Development** and enhancements
- Public **LTS Maintenance Releases** providing ongoing updates
- Expansion of the **Worldwide Lustre Support** ecosystem
- **Ongoing Investment** in test, validation, and release processes
- **Community Participation** in OpenSFS and EOFS



**Data courtesy of Dustin Leverman (ORNL)

Upcoming Feature Highlights

2.11 landings in progress with several features landed or underway

- File DLM lockahead
- Data-on-MDT for improved small file performance/latency
- File Level Redundancy begins (FLR Phase 1 Delayed Resync)

2.12/2.13 plans continued functional and performance improvements

- File Level Redundancy continues (FLR Phase 2 Immediate Resync)
- DNE2 directory auto-stripe to improve usability and performance
- FLR Phase 3 Erasure Coded Striped Files
- Persistent Client Cache

LNet Dynamic Discovery (LU-9480 2.11)
LNet Network Health (LU-9120 2.12)

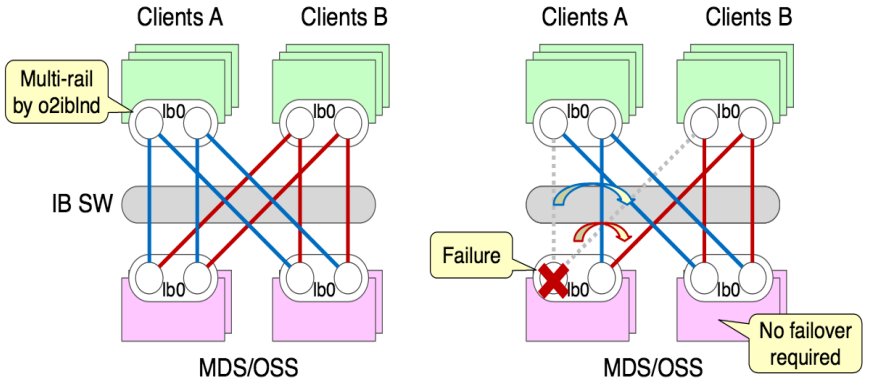
Builds on LNet Multi-Rail in Lustre 2.10 (Intel, HPE/SGI*)

LNet Dynamic Discovery

- *Automatically* configure peers that share multiple LNet networks
- Avoids need for admin to specify Multi-Rail configuration for nodes

LNet Network Health

- Detect network interface, router faults
- Handle LNet fault w/o Lustre recovery
- Restore connection when available



Data-on-MDT Small File Perf (LU-3285 Intel 2.11)

Avoid OST overhead (data, lock RPCs)

High-IOPS MDTs (mirrored SSD vs. RAID-6 HDD)

Avoid contention with streaming IO to OSTs

Prefetch file data with metadata

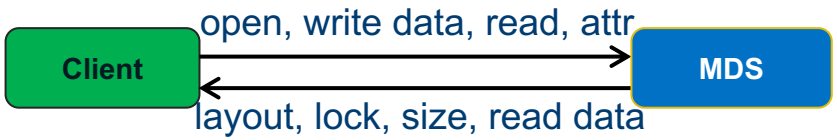
Size on MDT for small files

Integrates with PFL to simplify usage

- Start file on MDT, grow onto OSTs if larger

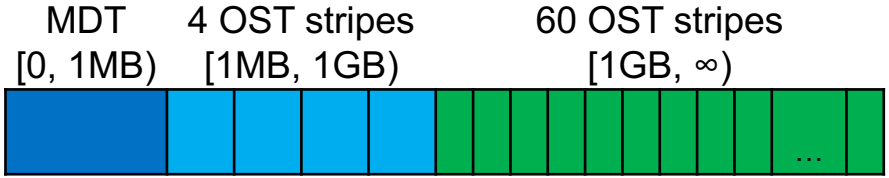
Complementary with DNE 2 striped directories

- Scale small file IOPS with multiple MDTs



Small file IO directly to MDS

Example DoM/PFL File Layout



https://jira.hpdd.intel.com/browse/LU-3285

DNE Improvements (LU-4684 Intel 2.11/2.12)

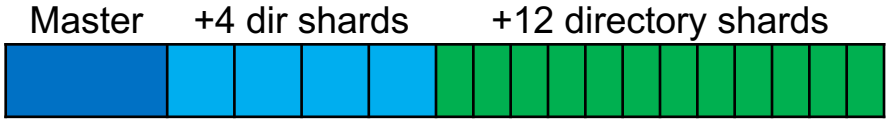
Directory migration from single to striped/sharded directories

- Rebalance space usage, improve large directory performance
- Inodes are also migrated along with directory entries

Automatic directory restriping to reduce/avoid need for explicit striping at create

- Start with single-stripe directory for low overhead in common use cases
- Add extra shards when master directory grows large enough (e.g. 32k entries)
- New entries+inodes created in new directory shards on MDTs to distribute load
- Performance scales as directory grows

MDT Pools for space/class management



ZFS Enhancements Related to Lustre (2.11+)

Lustre 2.10.1/2.11 `osd-zfs` updated to use ZFS 0.7.1

- File create performance (parallel lock/alloc, new APIs) (Intel)
- LFSCK ZFS OI Scrub, ldiskfs->ZFS backup/restore (LU-7585 Intel)

Features in ZFS 0.7.x

- Dynamic dnode size for better xattr performance/space (LLNL)
- Optimized parallel dnode allocation (Delphix*, LLNL, Intel)
- Improved kernel IO buffers allocation (ABD) (others, Intel)
- Multi-mount protection (MMP) for improved HA safety (LLNL)
- Optimized CPU and QAT h/w checksums, parity (others, Intel)
- Better JBOD/drive handling (LEDs, auto drive resilver) (LLNL)

OpenZFS

Features for ZFS 0.8.x

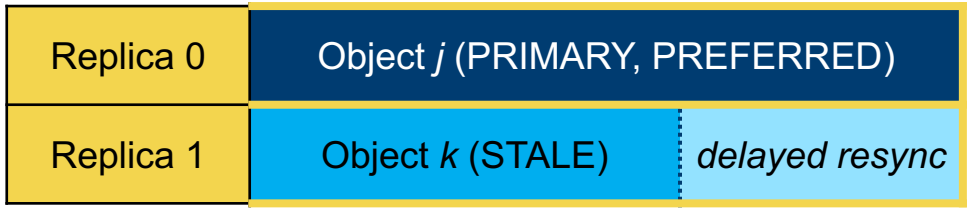
- On-disk encryption (Datto*)
- Project quota accounting (Intel)
- Declustered RAID (dRAID) (Intel)
- Metadata Allocation Class (Intel)
- Likely lots more...

File Level Redundancy (LU-9771 Intel 2.11/2.12)

Based on Progressive File Layout (PFL) feature in Lustre 2.10 (Intel, ORNL)

Significant value and functionality added for HPC and other environments

- Optionally set on a per-file/dir basis (e.g. mirror input files and one daily checkpoint)
- Higher availability for server/network failure – finally better than HA failover
- Robustness against data loss/corruption – mirror (and later M+N erasure coding)
- Increased read speed for widely shared input files – N-way mirror over many OSTs
- Mirror/migrate files over multiple storage classes – NVRAM->SSD->HDD (e.g. Burst Buffer)
- Local vs. remote replicas (WAN)
- Partial HSM file restore
- File versioning (no resync replica)
- Many more possibilities ...



Upstream Kernel Client (LU-9679 ORNL)

Kernel 4.14 updated to approximately Lustre 2.8, with some fixes from Lustre 2.9

Lustre 2.10 updated to work with kernel ~4.12 (LU-9558)

Improve kernel internal time handling (LU-9019)

- 64-bit clean to avoid Y2038 issues
- remove `jiffies` and `cfs_time_*()` wrapper functions

Continued user header changes (LU-6401)

- Allow building user tools against upstream kernel

Kernel tracepoints for logging/debugging/perf analysis (LU-8980)

- Replace `CDEBUG()` macros and Lustre kernel debug logs
- Has potential to improve (or not?) debugging of Lustre problems, needs careful review

Improved client efficiency (2.11/2.12+)

Small file write optimizations (LU-1575, LU-9409 Cray*, Intel)

- Reduce client and RPC/server overhead for small (<= 4KB) reads/writes

Disconnect idle clients from servers (LU-7236 Intel)

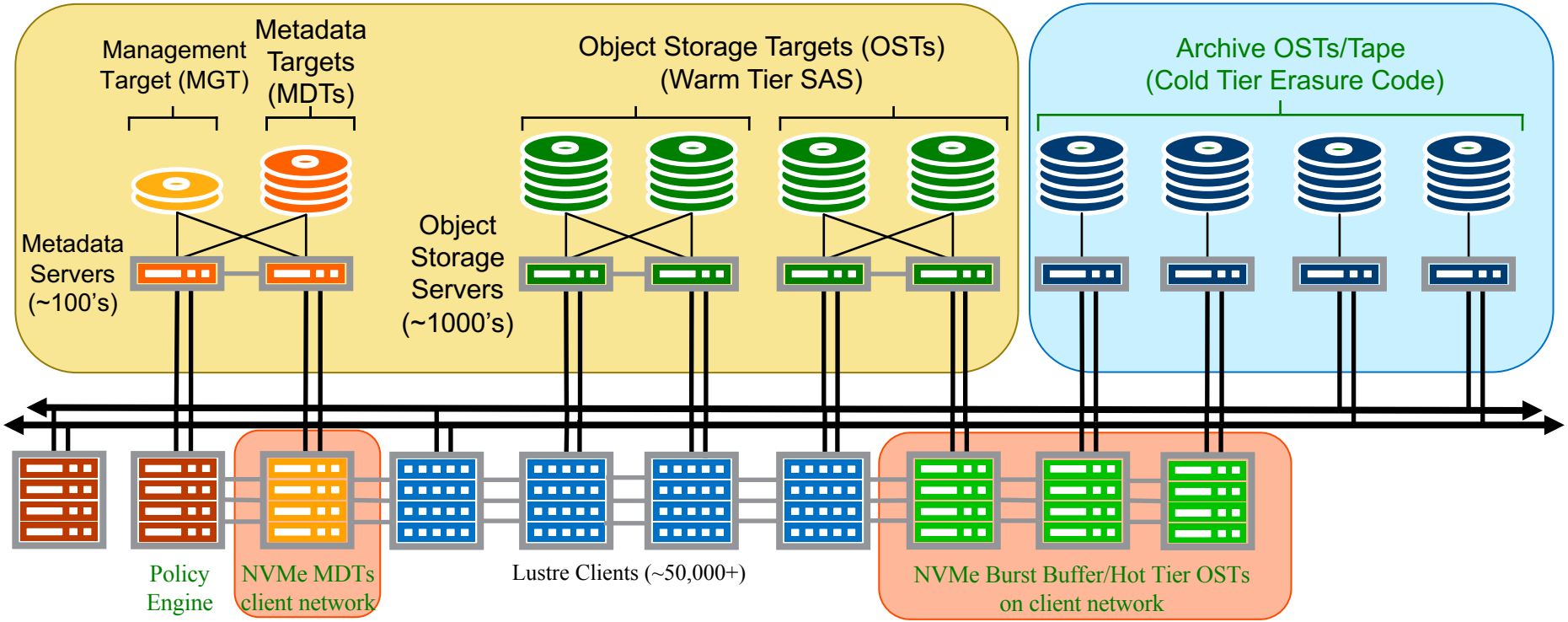
- Reduce memory usage on client and server for large systems
- Reduce network pings and recovery times
- Aggregate `statfs()` RPCs on the MDS (LU-10018)

Reduce wakeups and background tasks on idle clients (LU-9660 Intel)

- Synchronize wakeups between threads/clients (per jobid?) to minimize jitter
- Still need to avoid DOS of server if all clients ping/reconnect at same time

Tiered Storage and File Level Redundancy

Data locality, with *direct access* from clients to all storage tiers as needed



Tiered storage with Composite Layouts (2.12/2.13)

Policy engine to manage migration over tiers, rebuild replicas, ChangeLogs

- Policies for pathname, user, extension, age, OST pool, mirror copies, ...
- FLR provides mechanisms for safe migration of (potentially in-use) data
- Integration with job scheduler and workflow for prestage/drain/archive

Multiple policy and scanning engines presented at LUG'17

Multiple presentations on tiered storage at LAD'17

- Integrated burst buffers are a natural starting point

This is largely a userspace integration task, with some hooks into Lustre

Client-Side Data Compression (LU-10026 2.12)
University Hamburg

Piecewise compression

- Compressed in 32KB chunks
- Allows sub-block read/write

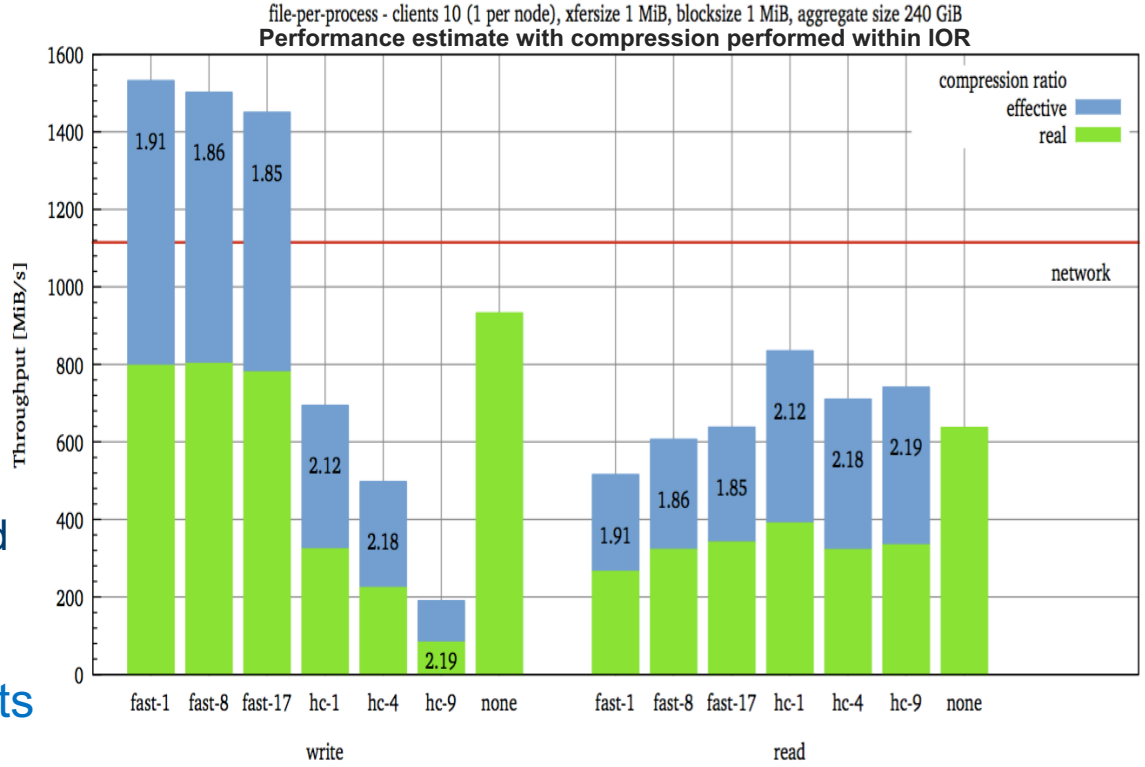
Integrated with ZFS data blocks

- Leverage per-block type/size
- Code/disk format changes needed

Avoid de-/re-compressing data

Good performance/space benefits

- Graph courtesy Uni Hamburg



Persistent Client-side Cache (LU-10092 DDN* 2.12)

Leverage fast client-local NVMe or NVRAM device

Mount filesystem image file directly on clients

- Used ad-hoc today - single client RW/shared RO mount
- Integrate handling into Lustre transparently

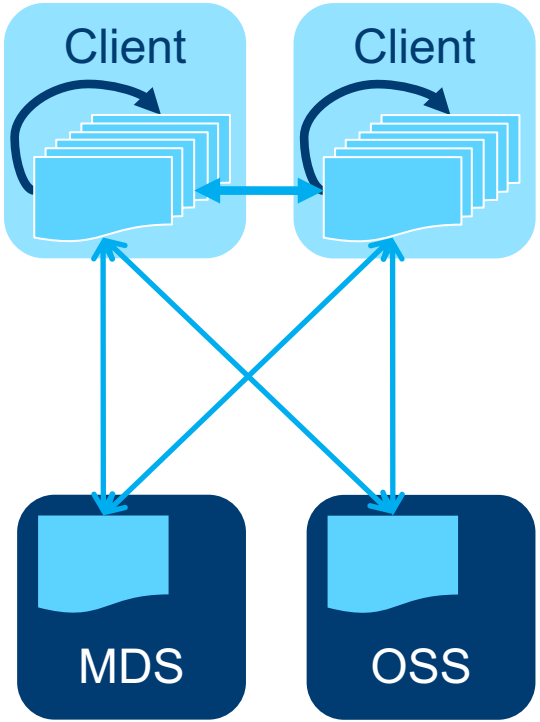
Automatic client-local mount of filesystem image file

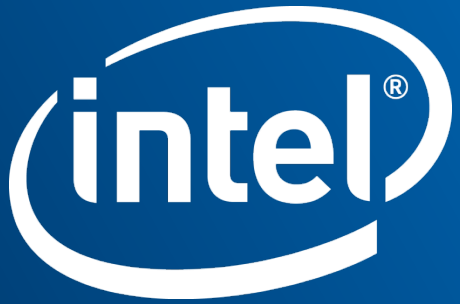
- Image is one object on OST, whole directory tree on client
- **Low overhead**, few Lustre locks, **100k+ IOPS/client**
- Access, migrate, replicate with **large reads/writes to OST**

OSS/MDS/client can export directly for shared use

- Use Data-on-MDT to re-export image to other clients
- HSM migrates *from* client, FLR to mirror to OST

Archive whole filesystem tree to tape when unused

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