Lustre* Features In Development

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Ongoing performance and functional improvements

- ZFS* feature and performance improvements (Intel, LLNL)
  - Performance improvement, global snapshot, …
  - MMP, large dnode, …
- Composite File Layout for performance and ease of use (Intel, ORNL)
  - Low stat overhead for small file, high IO bandwidth for large file
  - Infrastructure for others: DoM, FLR, HSM partial restore, …
- Multi-Rail LNet for network performance and reliability
- Data-on-MDT for small file performance/latency
- File Level Redundancy for reliability and performance
- Miscellaneous features and researches

Statements regarding future functionality are estimates only and are subject to change without notice

Multi-Rail LNet (Intel, SGI*)

Allow LNet across multiple network interfaces

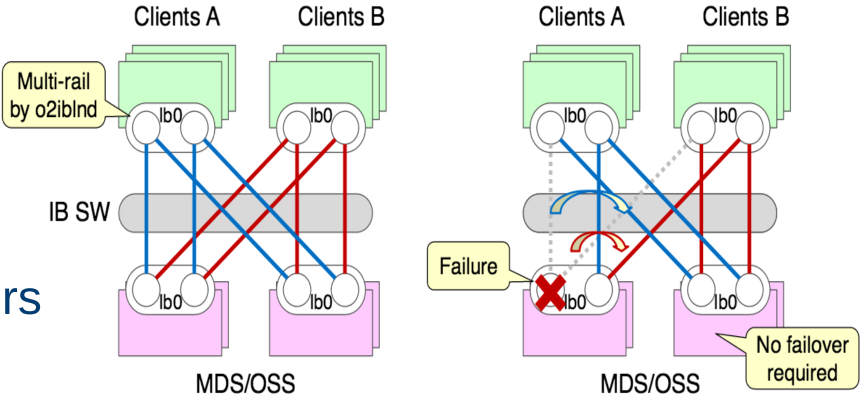
- Supports all LNet networks – LNet layer instead of LND layer
- Allows concurrent use of different LNDs (e.g. both TCP and IB at one time)

Scales performance

- Aggregates multiple network interfaces

Improves reliability

- Active-active network links between peers



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Improve small file performance (Intel)

Data-on-MDT (DoM) optimizes small file IO

- Avoid OST RPC overhead (data and lock RPCs)
- Use high-IOPS MDT storage (mirrored SSD vs. RAID-6 HDD)
- Pre-fetch file data with metadata
- Size on MDT for regular files
- Manage MDT space usage by quota

Client RPC	MDT reply	OST reply
open + truncate	layout, lock (DOM), full attributes (including size), data (pre-fetch)	N/A
write	N/A	-

T1: partial write small file with DoM

Client RPC	MDT reply	OST reply
open	layout, partial attributes	N/A
truncate	N/A	-
glimpse lock	N/A	size + time
extent lock	N/A	lock
read	N/A	data
write	N/A	-

T2: partial write small file without DoM

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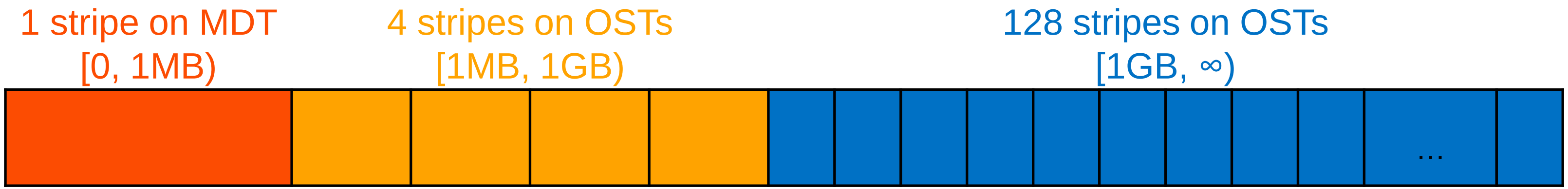
Improve small file performance (con’t)

Use PFL to handle enlarging small file

- Extend larger file from MDT to OST(s)

FPL example for extending enlarged DoM file with 3 components



1 stripe on MDT
[0, 1MB)

4 stripes on OSTs
[1MB, 1GB)

128 stripes on OSTs
[1GB, ∞)

Complementary with DNE 2 striped directory

- Scale small file IOPS with multiple MDTs

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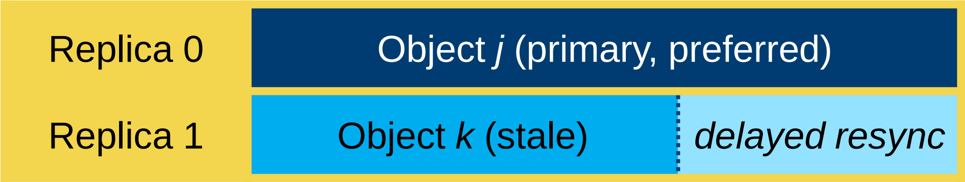
File Level Redundancy (FLR) (Intel)

Provides significant value and functionality for both HPC and Enterprise use

- Select layout on a per-file/dir basis (e.g. mirror all input data, one daily checkpoint)
- Higher availability for server/network failure - finally better than HA failover
- Robustness against data loss/corruption - mirror or M+N erasure coding for stripes
- Increased read speed for widely shared files - mirror input data across many OSTs

Replicate/migrate files between storage classes

- NVRAM->SSD->HDD
- Local vs. remote replicas



Replica 0 | Object *j* (primary, preferred)

Replica 1 | Object *k* (stale) | *delayed resync*

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FLR phased implementation approach

Phases 2/3/4 can be implemented in any order

Phase 0: Composite Layouts from PFL project (Intel, ORNL)

- Plus OST pool inheritance, Project/Pool Quotas

Phase 1: Delayed read-only mirroring – depends on Phase 0

- Manually replicate and migrate data across multiple tiers

Phase 2: Integration with policy engine/copytool - with/after Phase 1

- Automated migration between tiers based on admin policy/space

Phase 3: Immediate write replication – depends on Phase 1

Phase 4: Erasure coding for striped files - with/after Phase 1

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FLR with erasure coding

Erasure coding provides redundancy without 2x or 3x overhead of mirrors

Add redundancy component to existing striped files *after* write is finished

- Can add parity component to any existing RAID-0 file

Suitable for striped files - add N parity per M data stripes (e.g. 16d+3p)

- Parity declustering avoids IO bottlenecks, CPU overhead of too many parities
- Should take failure domains into account (avoid data and parity on same OSS)
  - e.g. split 128-stripe file into 8x (16 data + 3 parity) with 24 parity stripes

dat0	dat1	...	dat15	par0	par1	par2	dat16	dat17	...	dat31	par3	par4	par5	...
0MB	1MB	...	15M	p0.0	q0.0	r0.0	16M	17M	...	31M	p1.0	q1.0	r1.0	...
128	129	...	143	p0.1	q0.1	r0.1	144	145	...	159	p1.1	q1.1	r1.1	...
256	257	...	271	p0.2	q0.2	r0.2	272	273	...	287	p1.2	q1.2	r1.2	...

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Miscellaneous features and researches

Client DLM lockahead (Cray*)

- Allow libraries/apps to pre-fetch locks for striped or arbitrary IO patterns

Code cleanups (ORNL, Intel, Cray)

- Lustre* code kernel stylization, port patches to/from kernel
- RHEL weak symbol versioning, patchless server kernels

Uni Hamburg + German Client Research Centre (DKRZ)

- Client-side data compression
- Adaptive optimized ZFS* data compression

Lawrence Berkeley National Laboratory

- Spark* and Hadoop* on Lustre

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Potential development proposals for the future...

DNE enhancements

- Dynamic metadata migration among shards of striped directory
- Metadata Redundancy via DNE2 distributed transactions

Tiered storage with Composite Layouts and File Level Redundancy

- Integration with RobinHood to manage migration between tiers, rebuild replicas

Local persistent cache on client with fscache or local OSD

- Use FLR to ensure availability in case of client failure

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