Lustre* 2.9 and Beyond

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Overview of Features

Features completed for 2.8

- LFSCK Phase 4 – Performance Improvements (Intel, OpenSFS)
- DNE Phase 2 Striped Directories – Asynchronous Commits (Intel, OpenSFS)
- Client IO Simplification (Intel, OpenSFS)
- Multiple metadata-modifying RPCs (multi-slot **last_rcvd**) (Bull= Atos)
- Kerberos/GSS revival (Bull=Atos, Seagate)

Features starting development for 2.9 and later

- UID/GID mapping (IU)
- ZFS* Enhancements (Intel, LLNL)
- Project quotas (DDN)
- Shared-key/GSS crypto (IU)
- Progressive File Layout Prototype (Intel & ORNL)
- Data on MDT Prototype (Intel)

ZFS Enhancements (Intel/LLNL, 2.9+)

Changes for ZFS OSD (2.9)

- 1MB+ ZFS blocksize (IO performance, LLNL)
- Read IO optimization (IO performance, Intel)
- ZIL support for fast sync (IO & metadata performance, Intel)

Changes to core ZFS code (2.9+)

- Inode quota accounting (base functionality, Intel)
- Large dnodes (metadata performance, LLNL)
- Parity declustering (reliability & availability, Intel)
- Distributed hot spares (reliability & availability, Intel)

Miscellaneous features

Code cleanups (Cray*/Intel®/ORNL)

- Update to match upstream kernel coding style
- Port patches to/from upstream kernel
- Clean up and/or eliminate server kernel/ldiskfs patches

Project Quotas (DDN*)

- Allow quota tracking on directory subtrees independent of UID/GID
- Not strictly hierarchical, can be multiple trees with the same project

Network Authentication and Encryption (Bull*/IU*/Seagate*)

- Kerberos user/node authentication, RPC encryption
- Shared Secret Key node authentication, RPC encryption

Data on MDT (Intel, 2.10+)

Efficiently store small files on the MDT(s)

- Avoid OST BRW RPC + disk seek + OST lock for each file access
- Use small-file optimized MDT storage (RAID-10/SSD/NVRAM)
- Avoid RAID-5/6 read-modify-write for small writes

Space usage on MDT(s) managed by quota

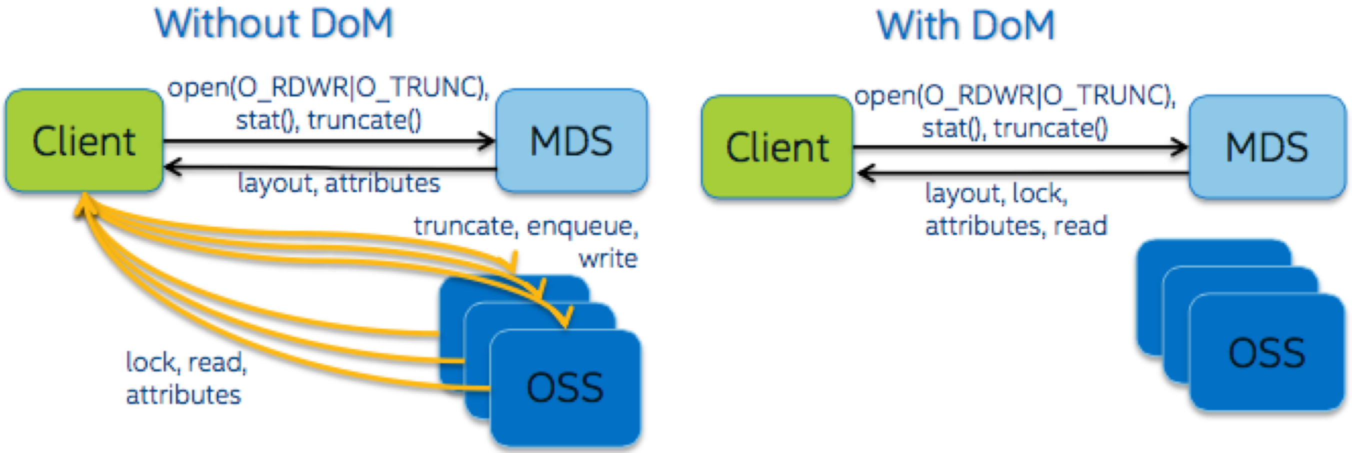
Small files are determined by the file layout

- Maximum MDT file size can be specified by min(user, admin)
- Typically expected to be <= 1MB, dependent on MDT space

Complementary with DNE 2 striped directories

- Scale small file IOPS horizontally with multiple MDTs

Data on MDT Implementation (Intel, 2.10+)



DoM layout chosen at file creation time like files on OSTs

- Can’t do it after write because objects are allocated at **open()**
- Default DoM striping on subdirectories inherited by newly created files

http://cdn.opensfs.org/wp-content/uploads/2014/04/D1_S10_LustreFeatureDetails_Pershin.pdf

http://wiki.opensfs.org/images/b/be/DataonMDSDesign_HighLevelDesign.pdf

Composite Layouts (Intel, 2.10)

Add Composite Layouts for regular files

- Allow describing more complex file structures and interactions
- A composite layout contains multiple *components* (**LOV_MAGIC_V[13]**)
- Composite layouts do not restrict components themselves
- Specific features may impose their own restrictions

```
Struct lov_comp_md_v1 {
        __u32 lcm_magic;           /* LCM_MAGIC_V1 */
        __u32 lcm_size;            /* overall size including this structure */
        __u32 lcm_layout_gen;      /* incremented each time layout changes */
        __u16 lcm_flags;           /* LCM_FL_RS_READ_ONLY, LCM_FL_RS_SYNC_PENDING, ... */
        __u16 lcm_entry_count;     /* number of components in lcm_entries[] */
        __u64 lcm_padding[2];
        struct lov_comp_md_entry_v1 lcm_entries[];
};
```

Composite Layouts Components

- A *Component* describes one extent of a composite file
- Each component is a separate *plain* layout within a file
  - Currently **LOV_MAGIC_V[13]** (RAID-0) layouts are handled
  - Other layout patterns can be added in the future (**LOV_MAGIC_DOM,** …)
- Components cannot be nested
- Objects are not shared between components

```
Struct lov_comp_md_entry_v1 {
        __u32 lcme_id;            /* unique identifier of component within composite */
        __u32 lcme_flags;         /* LCME_FL_STALE, LCME_FL_PRIMARY, LCME_FL_PREFERED */
        struct lu_extent lcme_extents;   /* file logical extent for component */
        __u32 lcme_offset;        /* offset of component layout from start of composite */
        __u16 lcme_size;          /* size of component layout data in bytes */
        __u64 lcm_padding;
};
```

What can be done with Composite Layouts?

Progressive File Layouts

- Non-overlapping component layouts for different parts of the file
- Increasing stripe count as file grows larger is expected, but not required

File Level Replication

- Overlapping component layouts provide redundancy
- Replica components can be marked stale or offline if OST failure is detected
- Resync stale components when OST online or add new replicas for failed OSTs

File versioning

- Replica components that are not updated by later writes or resync'd
- Old versions could be accessed via **lfs** or via **ioctl()** on open file descriptor

HSMv2 partial file restore

- One component for each archived copy, along with a timestamp/version for age
- Regular file component(s) for online data, may not cover whole file

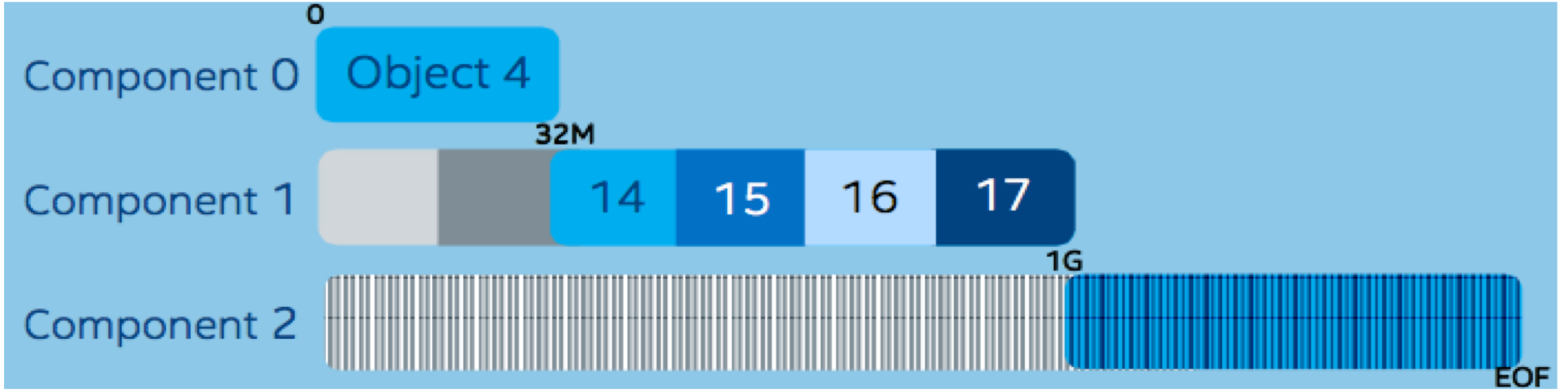
Progressive File Layouts (Intel/ORNL, 2.10)

Allow stripe count to increase for larger files

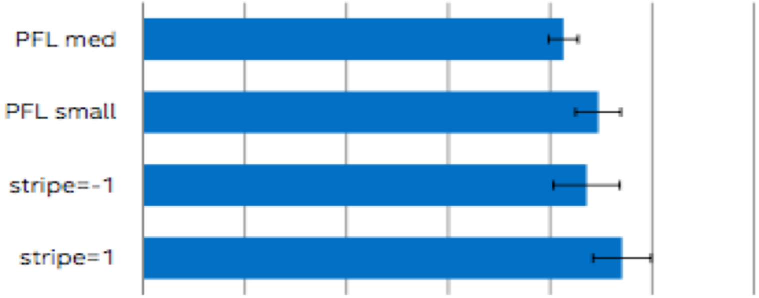
- Improve aggregate IO bandwidth for large files
- Do not add overhead for small files
- Start with one stripe, add stripes incrementally as file size increases

Covered (grey) region of component is inaccessible/sparse

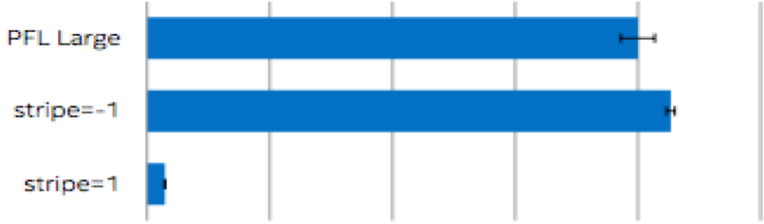
- Allows merging/replication/separation of components for plain files



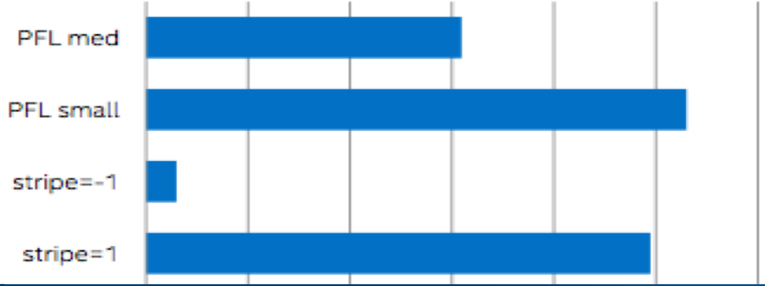
PFL Prototype Performance Comparison



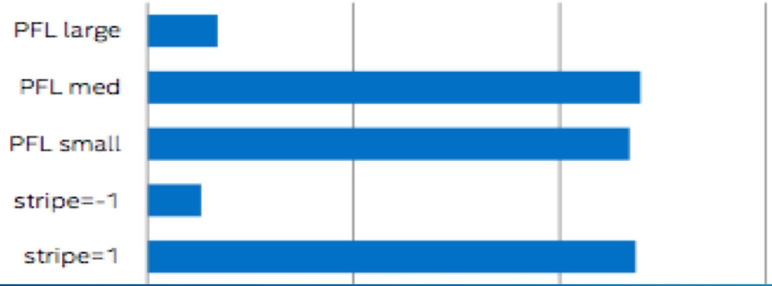
16 threads – Single Client
IOR File per Process Write



512 Threads – 32 Client
IOR Shared File Write



16 threads – Single Client
mdtest file stat/sec



512 Threads – 32 Client
mdtest file stat/sec

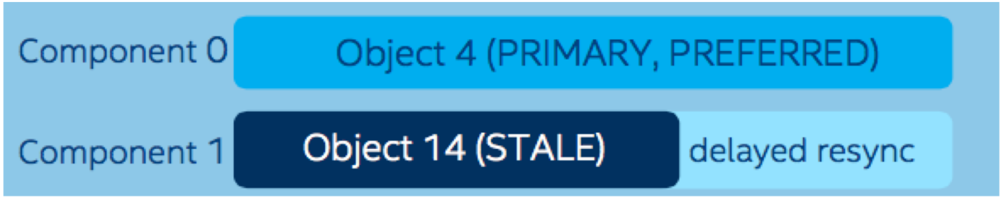
File Level Replication

Allow redundancy at the file level

- Avoid the need for multi-path storage or failover (local server storage OK)
- Redundancy can be selected/added/removed on a per-file basis
- Reads balanced between replicas, recover read errors from replica
- Can tune IO overhead/performance vs. file availability

Phase 1: Delayed replication by external resync tool

- For read-mostly workloads, minimizes write overhead at client
- Only primary replica modifed, non-primary replica(s) marked stale on first write
- ChangeLog/copytool drives resync tool after write finished, or if OST is offline in Phase 2



Phase 2: Replica updated immediately by client

- Client sends writes to each OST, marks component stale if write fails

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