Whamcloud

Lustre 2.16 and Beyond

Oleg Drokin

Lustre Principal Engineer

Planned Feature Release Highlights

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- **2.16** currently landing new feature patches
  - **LNet IPv6 addressing** – allow 160-bit NIDs, more flexible server configuration (SuSE, ORNL)
  - **Optimized Directory Traversal** (WBC1) – cross-directory statahead (WC)
- **2.17** has some major features already lined up
  - **Client-side data compression** – use client to reduce network and storage (WC, UHamburg)
  - **Metadata Writeback Cache** (WBC2) – low latency file operations in client RAM (WC)
- **2.18** feature proposals in early discussion stages
  - **File Level Redundancy - Erasure Coding (EC)** – efficiently store file redundancy (ORNL?)
  - **Lustre Metadata Redundancy (LMR1)** – MDT0000 service redundancy

LNet Improvements

- Multiple TCP sockets for 100GigE+ performance (LU-12815, WC)
  - Add `conns_per_peer=N` for `socklnd` (4.1GB/s->9.5GB/s on 100GbE)
  - Auto-configure based on interface speed (e.g. 10Gbps=>**N=2**, 100Gbps=>**N=4**, …)
- LNet Network Selection Policy (UDSP) (LU-9121, WC)
  - Allow policies for local/remote interface prioritization by NID

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    - e.g. primary IB with TCP backup, select "best" router NID for client/server
- IPv6 NID support (LU-10391, SuSE, ORNL)
  - Variable-sized NIDs (8-bit type, 8-bit size, 16-bit network, 128-bit+ address)
  - Interoperable with existing current LNDs whenever possible
- Improved network discovery/peer health (HPE, WC)
- Simplified/dynamic server node addressing (LU-14668, WC)
  - Detect added/changed server interfaces automatically (LU-10360)
  - Reduce (and eventually eliminate) static NIDs in Lustre config logs
  - Simplified handling for IPv6 NIDs by clients

Client Improvements

- **GPU Direct RDMA** - directly into GPU, bypass CPU (LU-14798, WC, NVIDIA, HPE)
  - A100 2x200Gb IB 36GB/s write, 39GB/s read, 174GB/s with 8x200Gb IB
- **Parallel large DIO** optimization (LU-13798, LU-13799, HPE, WC)
  - Improve single-thread `read()`/`write()` (1.5GB/s->15.8GB/s!)
  - Particular benefits for AIO/DIO and `io_uring` in client kernels 5.1 and later

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- Client-side filename encryption, migration/mirror (LU-13717, LU-14677, WC)

2.16
- `o2iblnd` cleanups for in-kernel OFED (LU-8874, ORNL)
- Encrypted file backup/restore/HSM (LU-14677, WC)
- Buffered/DIO/mmap performance/efficiency improvements (LU-13805, WC)
- Ongoing code style/structure cleanup for upstream submission (ORNL)
- Ongoing updates for newer kernels, usually within 1-2 minor releases (ORNL, SuSE)

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- Client-side Data Compression (LU-10026, WC, UHamburg, Intel)

Client Data Compression (LU-10026) (WC, UHamburg 2.17+)

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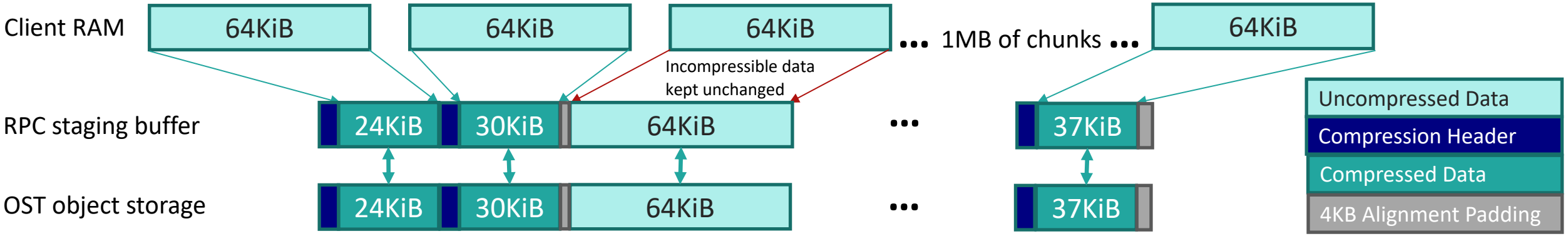
- Reduce space usage for all-flash OSTs to reduce storage cost
- Compress (`lzo`, `lz4`, `gzip`,…) full RPC on client in chunks (64KiB-1MiB+)
  - Algorithm, level, chunk size can be selected per directory or file component (PFL, FLR)
  - Keep "uncompressed" chunks for incompressible data/file (`.gz`, `.jpg`, `.mpg`, …)



- Client writes/reads whole chunk(s), (de-)compresses to/from RPC staging buffer
  - Independent/parallel compression for each chunk on separate core to reach GB/s speeds
  - Larger chunks improve compression, but higher read-modify-write overhead
- Optional write to uncompressed file mirror for random IO pattern
- Optional data (re-)compression during mirror/migrate (via transfer agent)

Backend OSD Improvements

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- `fallocate()` and `FALLOCATE_FL_PUNCH_HOLE` for ZFS (LU-14157, AEON)
- Improved ldiskfs mballoc efficiency for large filesystems (LU-14438, Google, WC, HPE)
  - O(1) lookup of power-of-two free blocks, bias allocations to start of HDDs
- OST object directory scalability for large OSTs (LU-11912, WC)
  - Large OSTs (500-1000TB) have billions of objects, only 32 subdirs per MDT => 10M+ obj/dir!
  - Wider directory fanout not better, object create/remove accesses all dirs randomly
  - More OST FID Sequences (once per 32M vs. 4B objs), groups objs by age to improve efficiency

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- Parallel e2fsck for pass2/3 (directory entries, name linkage) (LU-14679, WC)
  - Now slowest part of e2fsck (**was** 7% of total time, now **70%** after pass1/pass5 speedups)

MDT DNE Improvements (WC 2.15+)

- **DNE MDT Space Balance** - load balancing with normal `mkdir` (LU-13417, LU-13440)
  - Round-robin/balanced subdirs, prefer to stay on parent, limited layout inheritance depth
  - Keep MDTs within free inodes/space (`mdt.*.mdt_qos_threshold_rr=5%`)
- Single-dir migration - `"lfs migrate -m -d <dir>"` (LU-14975)
  - Move only one directory level, instead recursing down full subdirectory tree
- Balanced migration - `"lfs migrate -m -1 <dir>"` (LU-13076)

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  - Auto-select less-full MDTs for each directory, keep inodes local to parent

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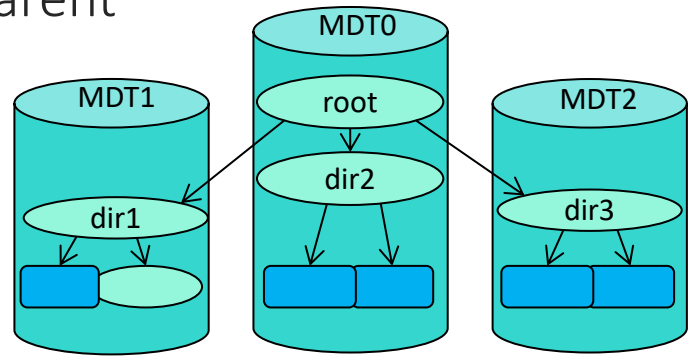
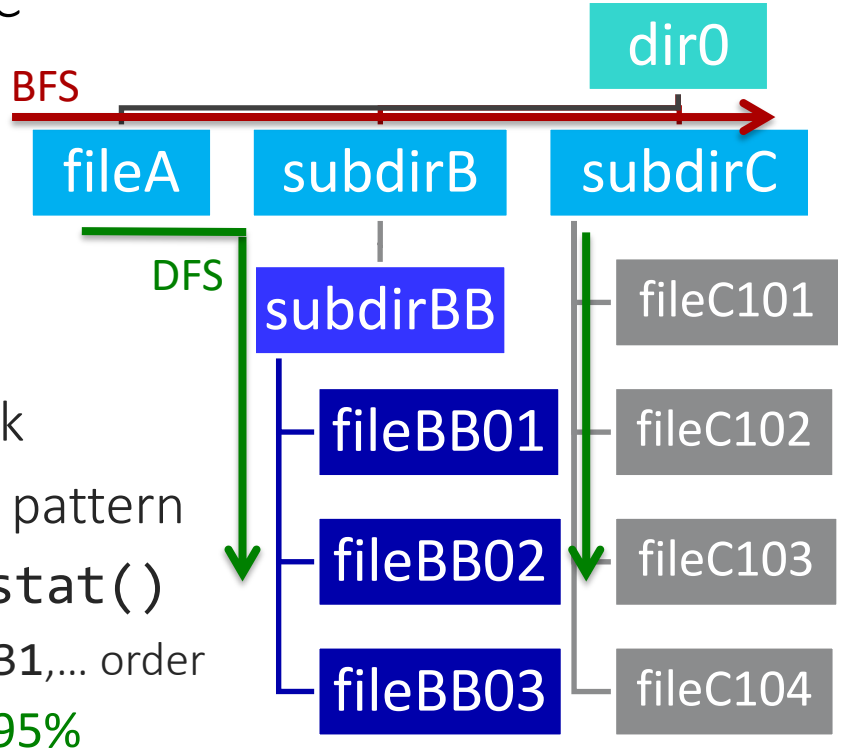
- DNE inode migration improvements (LU-14719)
  - Pre-check target space, stop on error, improved CRUSH2 hash
- DNE locking, remote RPC optimization (LU-15528)
  - Better distributed transaction performance, reduce lock contention



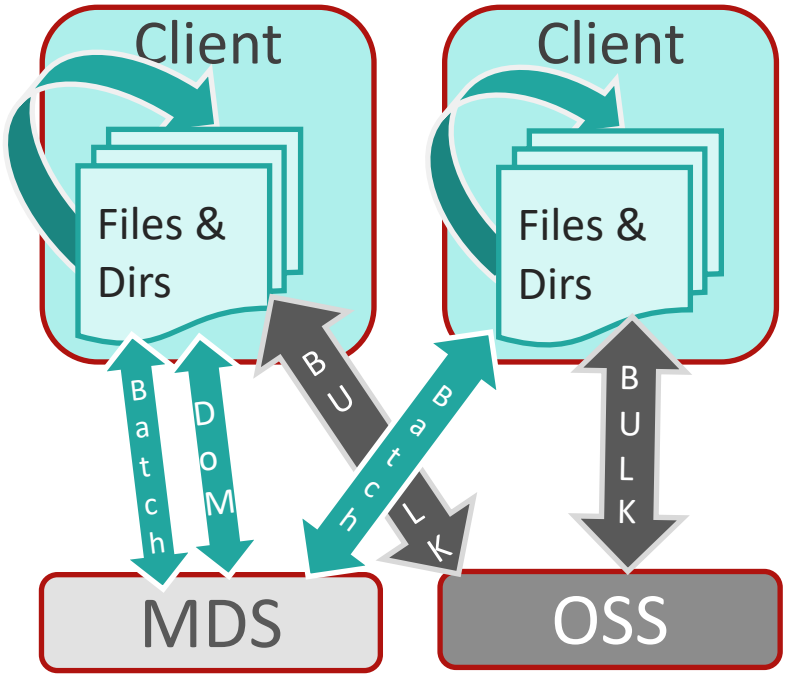
Batched Cross-Directory Statahead (WBC1) (WC 2.16)

- **Batched RPCs** for multi-update operations (LU-13045)
  - Allow multiple getattrs/updates packed into a single MDS RPC
  - More efficient network and server-side request handling
- **Batched statahead** for `ls -l`, `find`, etc. (LU-14139)
  - Aggregate getattr RPCs for existing statahead mechanism
- **Cross-Directory statahead** pattern matching (LU-14380)
  - Detect breadth-first (BFS) depth-first (DFS) directory tree walk
  - Direct statahead to next file/subdirectory based on tree walk pattern
  - Detect strided pattern for alphanumeric ordered traversal + `stat()`
    - e.g. `file00001`,`file001001`,`file002001`... or `file1`,`file17`,`file31`,... order
- IO500 `mdtest-{easy/hard}-stat` performance improved 77%/95%



Metadata Writeback Cache (WBC2) (LU-10983) (WC 2.17+)

- Create new dirs/files **in client RAM without RPCs**
  - Lock **new** directory exclusively at `mkdir` time
  - Cache new files/dirs/data in RAM until cache flush or remote access
- **No RPC round-trips** for file modifications in new directory
- Batch RPC for efficient directory fetch and cache flush
- **Files globally visible on remote client access**
  - Flush top-level entries, exclusively lock new subdirs, unlock parent
  - Repeat as needed for subdirectories being accessed remotely
  - Flush rest of tree in background to MDS/OSS by age or size limits
- Productization of WBC code well underway
  - Some complexity handling partially-cached directories
  - Need to integrate space usage with quota/grant
- WBC in pre-existing directories in later release
  - Read all directory entries before create to avoid duplicates



Lustre Metadata Redundancy (LU-12310) (2.18+)

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In early discussion and architecture stages

- LMR1a: Replicate services to other MDTs
  - Mirror FLDB, Quota, `flock()` across MDTs
- LMR1b: DNE transaction performance
  - Transactions currently have excessive ordering/sync
  - Need to improve if all mkdir are mirrored transactions

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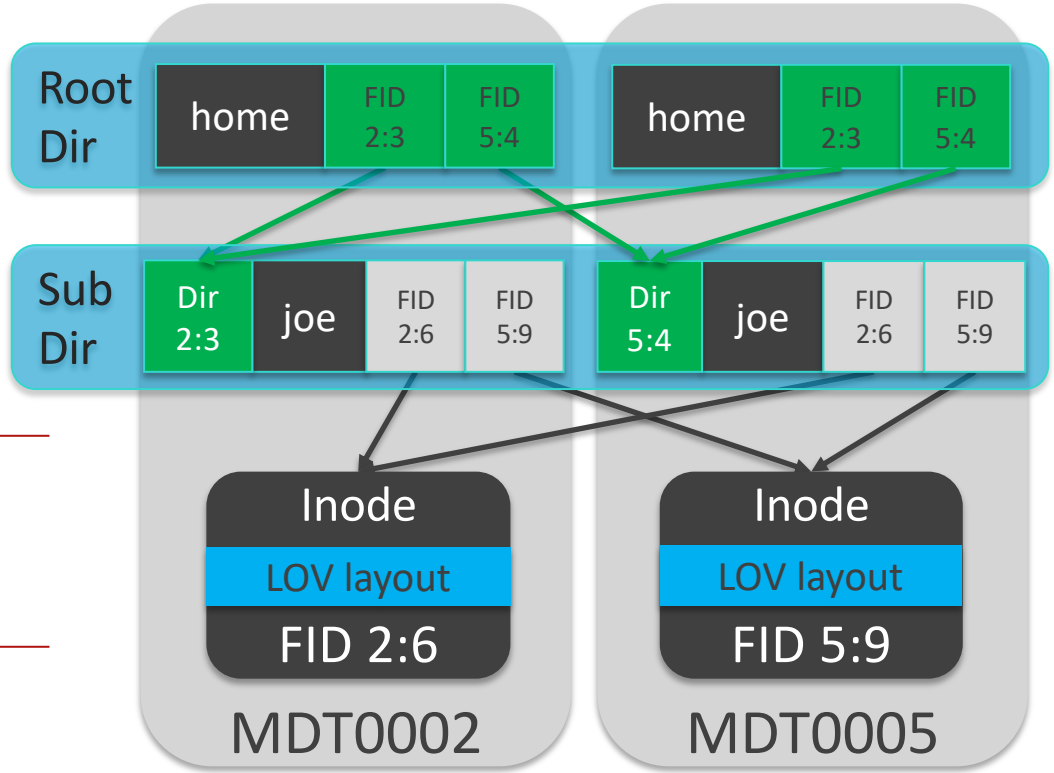
  - Improves **all** DNE operation performance
- LMR1c: Replicate top-level dirs for availability
  - `ROOT/` dir (rarely changed) mirrored over MDTs

2.19+

  - No replication for regular file inodes initially
- LMR2/3 phases needed for full redundancy
  - Full tree directory replication, file inode replication
  - Configurable replication setting per directory/tree
  - Recovery, LFSCK, rebuild replicated directories if full MDT loss



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Thank You!

Questions?