Clustered Metadata

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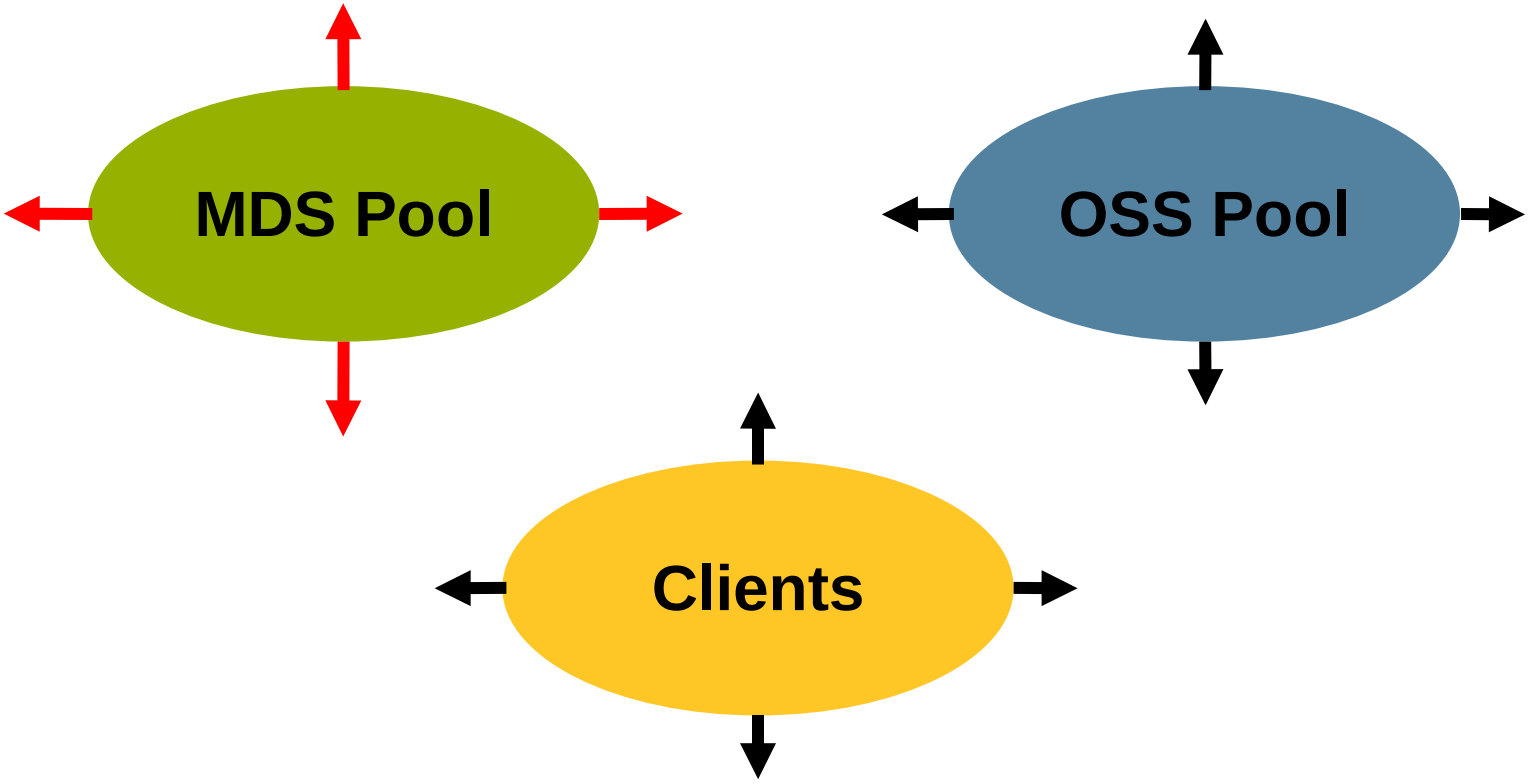
Agenda

- What is CMD?
- How does it work?
- What are FIDs?
- CMD features
- CMD tricks
- Upcoming development

Lustre Scalability with CMD



Capacity will be 100's of billion of files

Throughput will grow to a million operations per second

What is CMD?

- Clustered MetaData allows storing the filesystem namespace spread over multiple MDTs
- First version was developed about 4 years ago as a part of Hendrix project
- Working on 3rd version of CMD and it is currently being tested internally

CMD Benefits

- Better metadata performance due to parallel access from different clients
- Scale memory, network, and disk IO cost-effectively
- Increase total metadata capacity
- Parallel object creation on OSTs from different MDSes
- Parallelize big directories by splitting and storing them on multiple MDTs

How does it work?

- Cluster has a number of MDS nodes which communicate with each other
- Each MDS has an independent MDT file system for storage
- All clients connect to all MDSes and request root data and volume stats
- All clients do operations (getattr, setattr, unlink) directly with the MDS that holds needed part of namespace

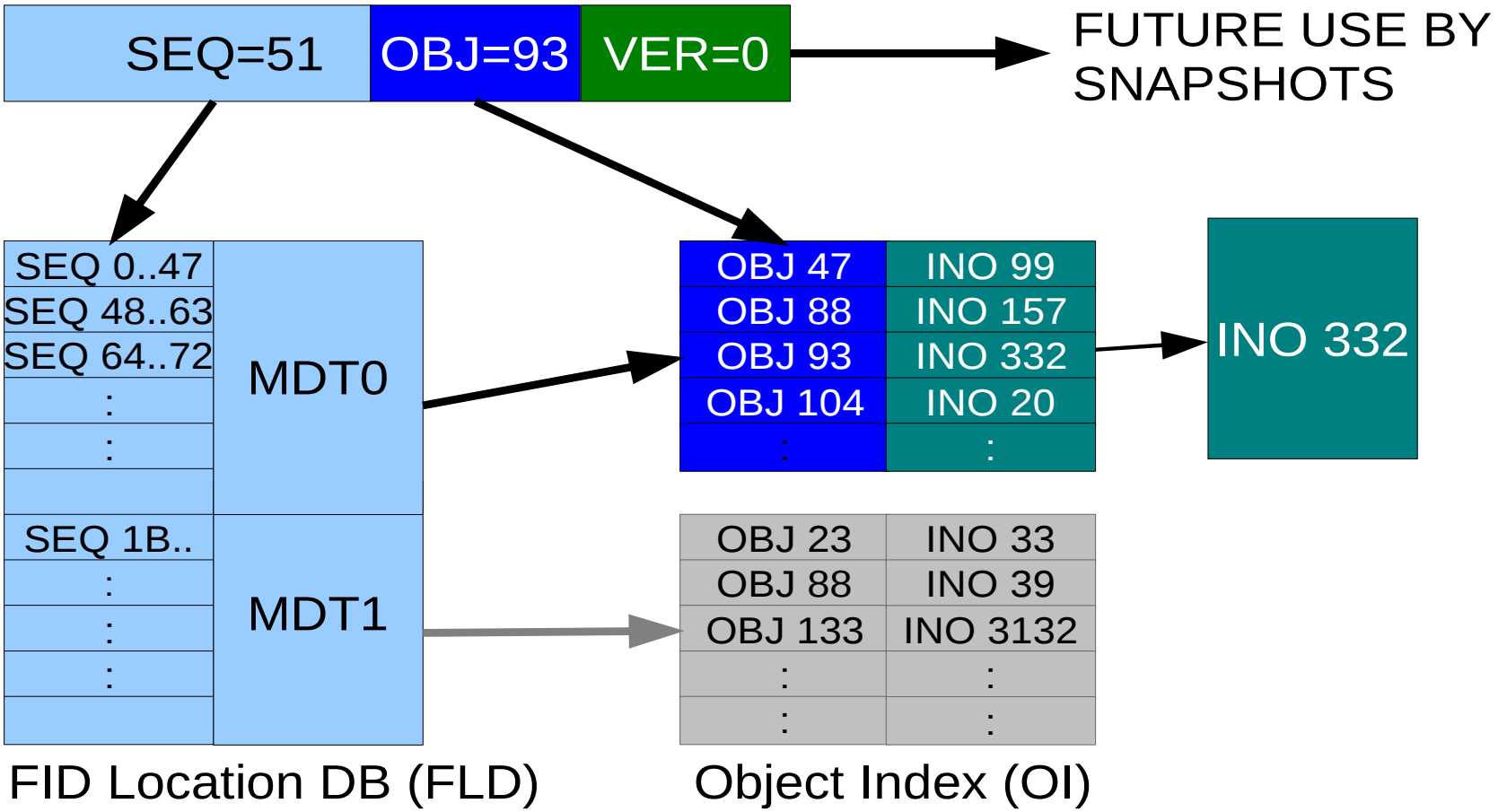
What are FIDs?

- FID (File identifier) is cluster-wide 128-bit unique identifier
- FID contains 64-bit sequence number (SEQ), 32-bit object id (OBJ), and 32-bit version number (VER)
- FID itself does not contain backing-store related information like inode number/generation, or MDS number
- Uses sequence number as index in FID Location Database to find MDT
- FID also stored in OI (object index) for FID->inode mapping on each MDT

FID Location Database

- FLD (FID Location Database) records which MDT holds each FID sequence
- All FIDs in one sequence live in the same MDT
- CMD uses FLD to find out which MDT should be contacted to perform an operation on an object

FID Location DB/Object Index



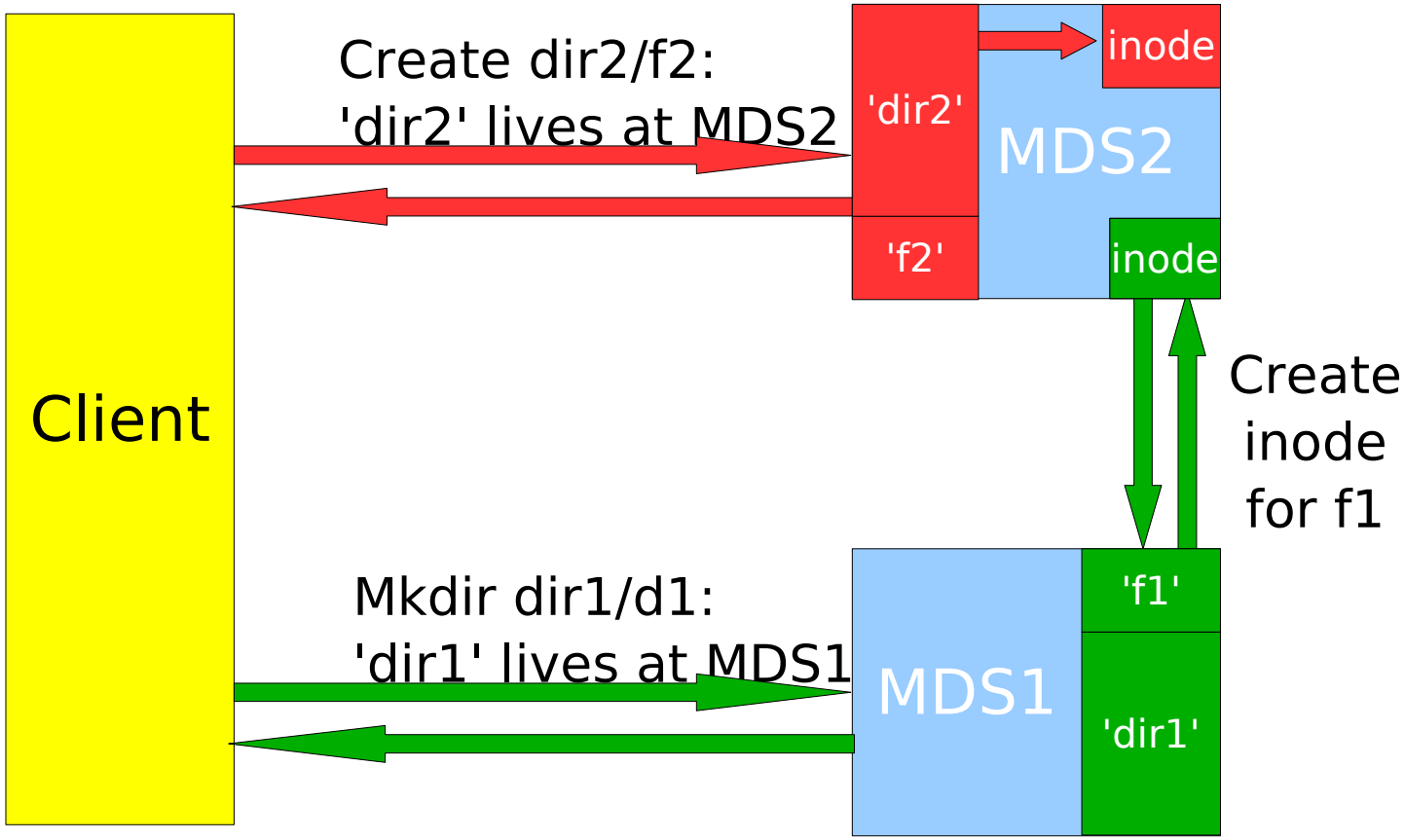
Create a File (local inode)

- Client generates FID for new file and sends create RPC to the MDS which holds the parent directory
- This MDS inserts {filename, FID} into the directory and allocates a local inode
- This happens for all non-directory inodes, so is the common case for file creates
- FID is chosen by client to put inode on the same MDS as the parent directory

Create a directory (remote inode)

- Client generates FID for new object and sends create RPC to the MDS which holds the parent directory (call this MDT1)
- MDT1 inserts {filename, FID} in dir
- MDS1 finds (through FID Location Database) which MDS should hold new file inode (call this MDS2)
- Create RPC sent from MDS1 to MDS2 to create the new directory with FID
- This happens for new subdirectories to balance load across MDSes, and also in the case of hard-links across MDSes

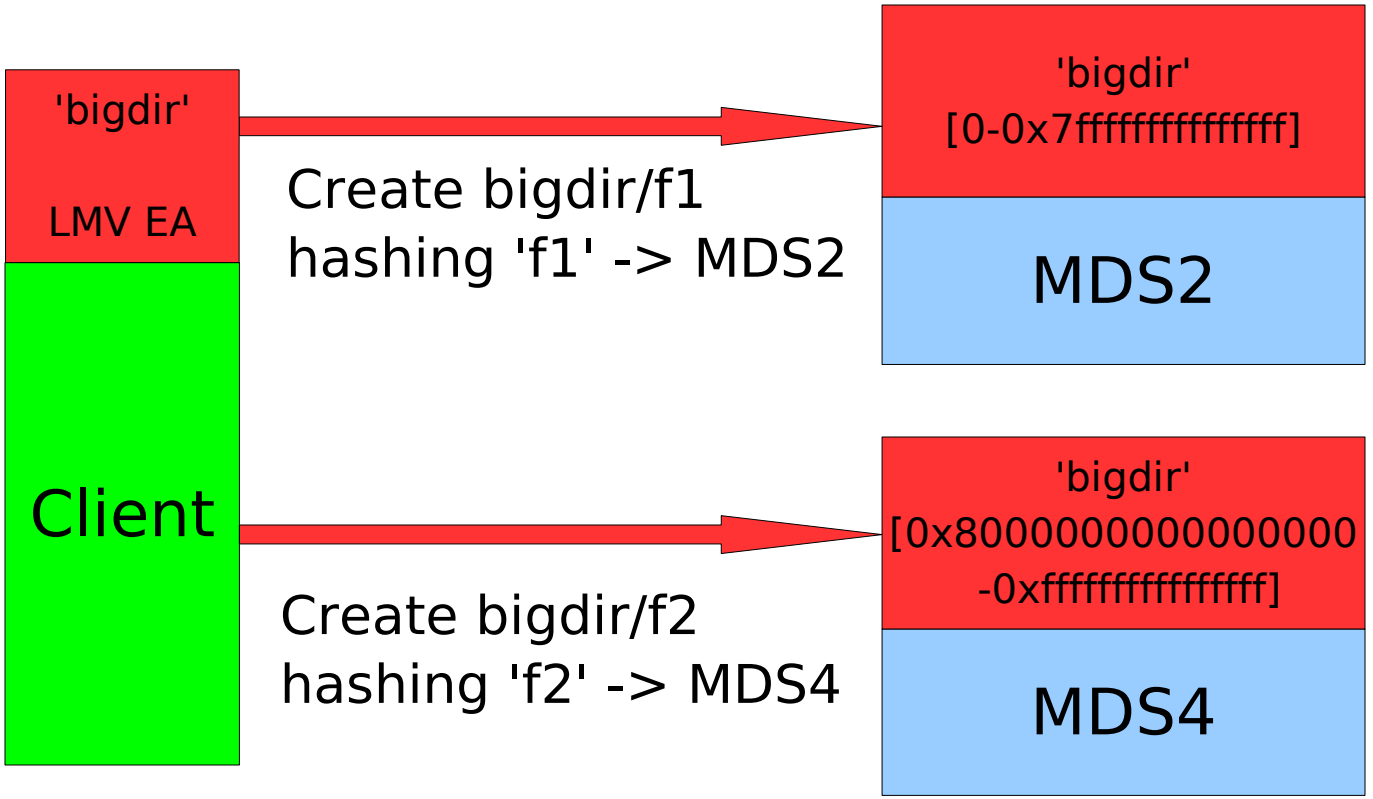
Creates on Local and Remote MDS



Split Directories

- One user-visible directory stored in multiple MDT directory objects
- Hash of filename + directory layout map filename to MDT + directory object
- If we create file in split directory, directory 'striping' attribute allows client to decide which MDT holds a given filename for RPCs
- This allows parallel access and more scalability for single directories
- Currently specified at mkdir time
- Very similar to striped files

2-MDS Split Directory



Operations and Updates

- An *Operation* is a complete change in the filesystem namespace
  - Corresponds to a VFS-level syscall
    - mkdir, rmdir, create, link, unlink, symlink, rename
  - May involve one or multiple MDTs
  - Need to ensure Operation consistency
- An *Update* is a component of an Operation
  - An operation may have 1 or more updates
  - Cannot possibly do updates atomically

Recovery with CMD

- Multi-node operations need to be atomic to ensure namespace coherency
- This is *hard*
- Keep operations local if possible
  - Create files on same MDT as parent
  - Most getattr, unlink to one RPC
  - Faster, can use local filesystem recovery
- Non-local operations order updates for safety
  - Create remote inode first, commit
  - Insert local directory entry second, async
  - Any crash leaves consistent namespace
  - At worst unused inode is leaked, clean later

Minor Issues

- Split operations depend on updates on 2-4 MDTs
  - Latency is twice as long, and recovery crosses multiple nodes
  - Multiple MDTs can make up for reduced performance for the less-common ops
- Check for rename of directory into subdirectory is more complex as it needs to check more than one MDS
  - Cross-MDS renames not very common
  - Only needed for multi-parent renames
- Replication for FLD, root inode

Current State of CMD

- Largely finished development, and it passed many tests
- Users can currently investigate this feature, without any warranty
- Recovery not yet complete
- 2.0 release (end 2009) has much of the CMD functionality, unsupported
- Likely released as production in 2.2 release (late 2010)

Thank you

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