SDC
STORAGE DEVELOPER CONFERENCE
SNIA SANTA CLARA, 2016

MarFS: Near-POSIX Access to Objects

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Motivation

- See Gary Grider's keynote presentation (Tuesday)
  - $B of POSIX
  - cost of replication (for those that care)
  - scalable BW
  - scalable namespace
  - cheap reliable capacity
- Trinity
  - 2 PB RAM
  - ~10 GB/s to archive
  - 5 tiers from RAM to tape

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Projected Trinity Reqs

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Tier	lifespan	bandwidth	change	capacity	change
RAM	hours	9.1 PB/s		2 PB	
BurstBuffer	hours	4 TB/s	x0.0005	4 PB	x2
Lustre	weeks	1.2 TB/s	x0.3	100 PB	x25
MarFS	year(s)	30 GB/s ++	x0.025	30 PB ++	x0.3
Tape	forever	10 GB/s	x0.33	60 PB ++	x2

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Cost-Modeling (1/4)

- study examined cost of cheap EC disks for long-term archive
  - relevant, but not the same as LANL MarFS deployment
- Archive BW may be an HPC-specific concern
- "Cost of Tape versus Disk for Archival Storage" (CLOUD'14)
  - Linear Programming
  - spreadsheet -> CSV -> constraint eqs -> solver
  - real-world requirements for capacity and BW, per year
  - projected technological capabilities
  - choose disks or tape in any given year
  - buy tape-drives & tapes or JBODs, per-year
  - parameter studies

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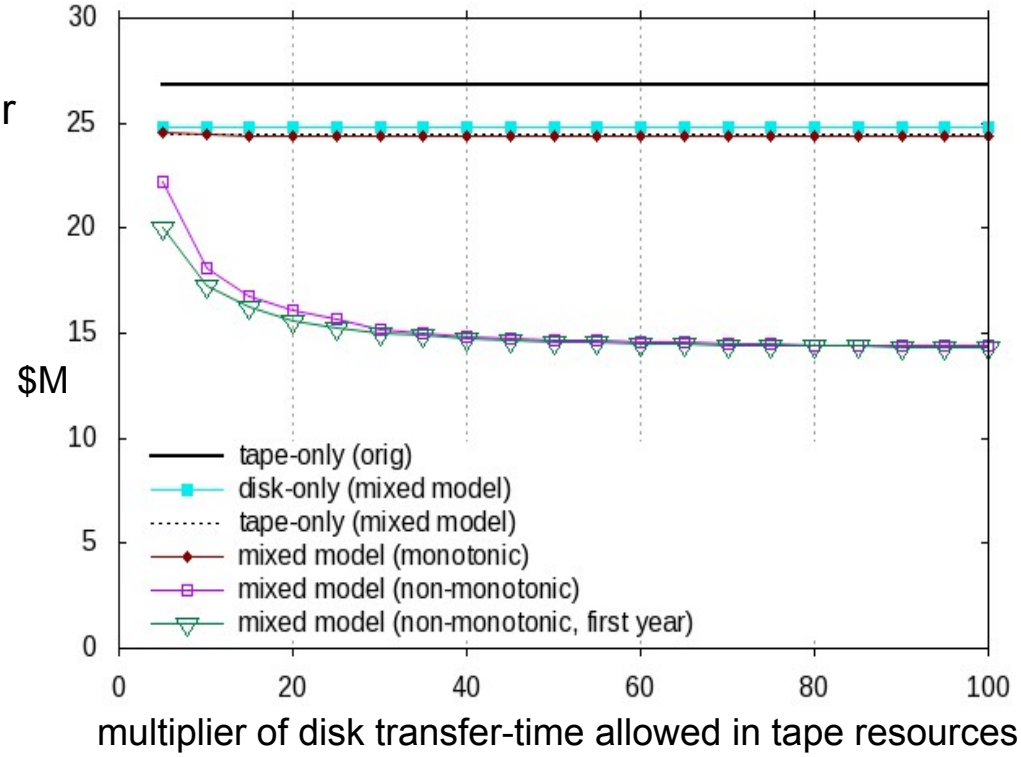
Cost Modeling (2/4)

Linear Programming reduced total projected costs of archives through 2025

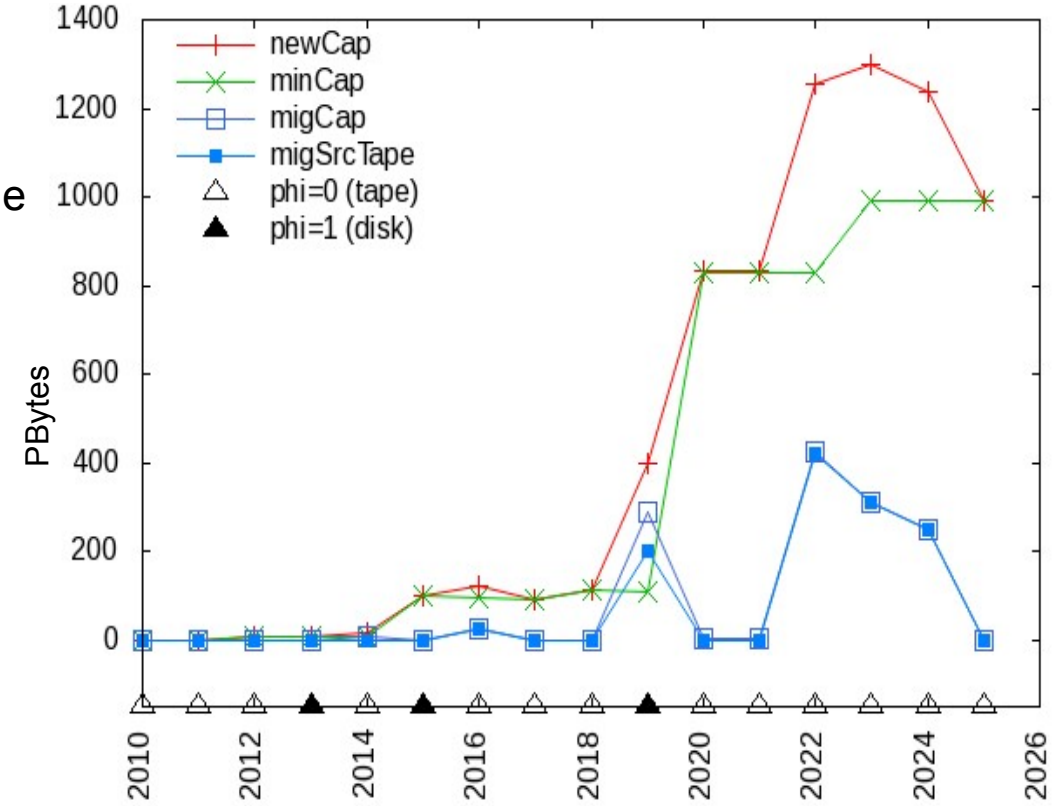
- parameter-study varies tape-parms
- rigid tape-only solution: 8% cheaper
- disk-only solution: similar
- flexible per-year: ≤ 46% cheaper



Cost Modeling (3/4)

What the optimizer did in the best solution from previous slide

- solid-triangles: all-disk
- empty-triangles: all-tape
- red: per-year new archive storage
- green: min archive requirement
- blue: migration (from tape)



Cost-Modeling (4/4)

- take-away
  - clever all-tape deployment: reduced archive costs
  - clever all-disk deployment: similarly-reduced costs
  - cleverly-alternating storage: much cheaper
- Study was “Disk **versus** Tape for **Archival** Storage”
  - at LANL, MarFS occupies a BW tier above tape
  - 5-tier architecture should reduce archive demands
  - model assumes tape-drives can run 24/7/365
  - model doesn’t include labor costs
- One could use MarFS for the all-disk technology in the models
  - more-accessible metadata for cloud storage

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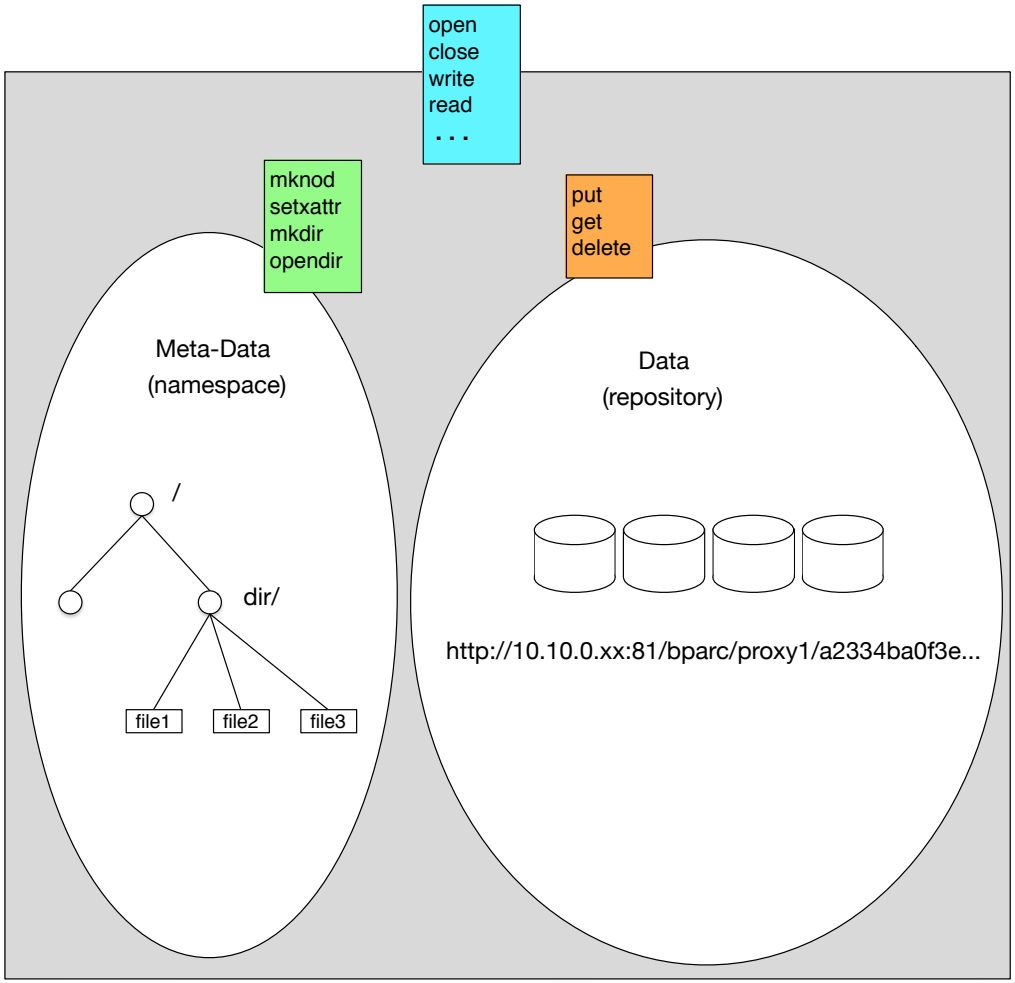
Objects vs Files

- directories/files are human-friendly (familiar)
  - **/users/jti/projects/git/marfs/fuse/src/mdal.h**
  - *namespace* -- explicit structure & context
  - compartmented data, search, security
  - $Billions in apps that assume files
- objects are scalable and resilient
  - **http://host:port/bucket/09bac9f…**
  - *repository* -- cheap scalable capacity
  - awkward metadata access

MarFS Basic Structure



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MarFS File-Types

- DIRECT (legacy files)

- Uni (1 file -> 1 object)
- Multi (1 file -> N objects)
- Packed (M files -> 1 object)
  - offline packer
  - GC / repacker
  - pftool

- recovery-info at tail of file storage, after file-data
  - travels with packed files

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MetaData File

- regular file
  - chown/chmod/rename/etc, as usual
  - truncated to size
  - xattrs (invisible to users)
    - objid: proxy/repo2/ver.001_004/ns.jti/F___/inode.0000027328/md_ctime.20160829_130133-0600_1/obj_ctime.20160829_130135-0600_1/unq.0/chnksz.40000000/chnkno.0
    - post: ver.001_004/U/off.0/objs.1/bytes.0/corr.0000000000000000/crypt.0000000000000000/flags.00/mdfs.
    - [restart]

“Near” POSIX?

- Writes must be sequential (per chunk)
  - relaxed for well-behaved parallel writers (pftool)
  - parallel access through pftool
- No update-in-place
  - overwrite entire file
- No sparse files
  - no seek() for writing
  - each chunk of a Multi is full-size (except maybe last)
  - easy computation of offset -> chunk

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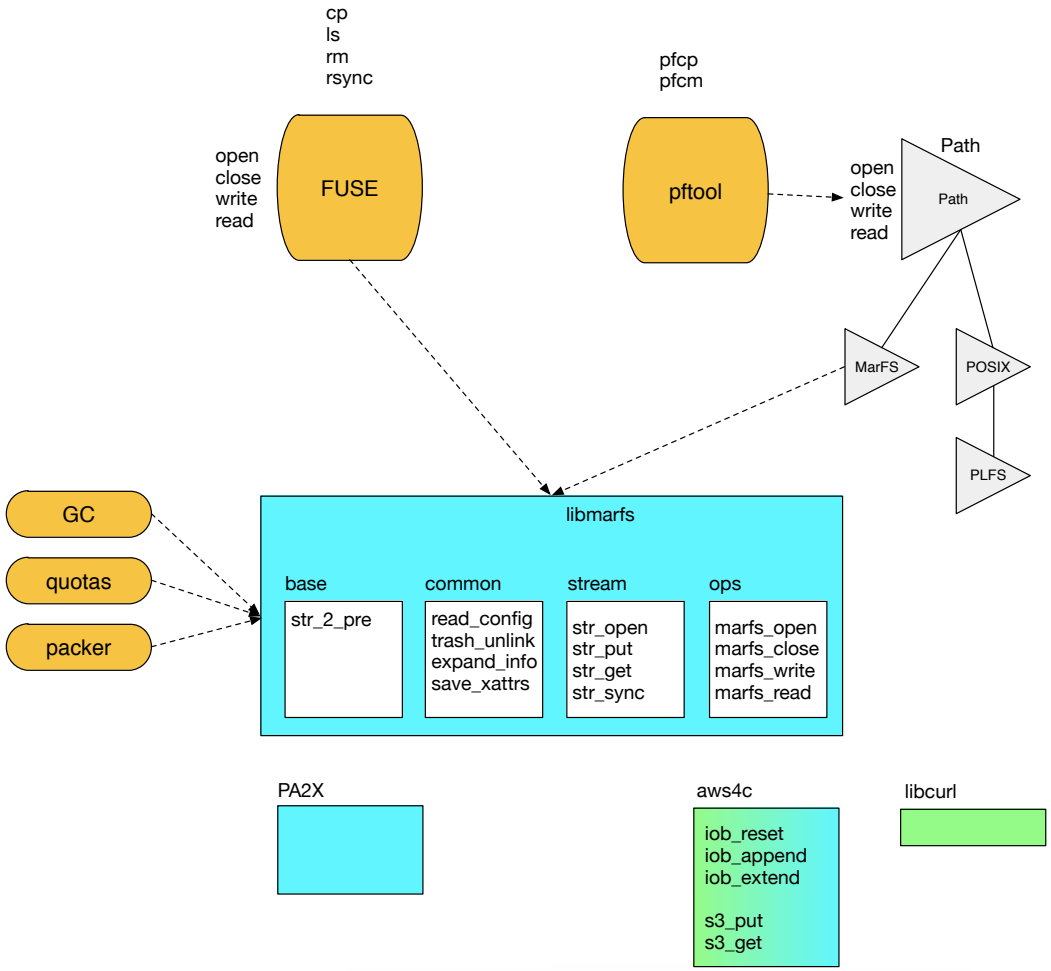
Libraries, Applications, etc.



Configuration (top-level)

```
<config>

    <name>ODSU Testbed</name>
    <version>1.0</version>
    <mnt_top>/campaign</mnt_top>

    [repositories ...]

    [namespaces ...]

</config>
```

Configuration (repo)

```
<repo>
   <name>bparc</name>

   # 10.10.0.1 - 10.10.0.12
   <host>10.10.0.%d:81</host>
   <host_offset>1</host_offset>
   <host_count>12</host_count>

   <update_in_place>no</update_in_place>
   <access_method>SPROXYD</access_method>
   <chunk_size>1073741824</chunk_size> # 1GB

   <security_method>HTTP_DIGEST</security_method>

   <enc_type>NONE</enc_type>
   <comp_type>NONE</comp_type>
   <correct_type>NONE</correct_type>
   <latency>10000</latency>
</repo>
```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Configuration (namespace)

```
<namespace>
   <name>admins</name>
   <alias>proxy1</alias>
   <mnt_path>/admins</mnt_path>

   <iperms> RM,WM,RD,WD,TD,UD</iperms>       # interactive (fuse)
   <iwrite_repo_name>bparc</iwrite_repo_name>  # matches some <repo> spec

   <bperms>RM,WM,RD,WD,TD,UD</bperms>  # batch (pftool)
   <range>                  # batch writes for files in given size-range
      <min_size>0</min_size>
      <max_size>-1</max_size>
      <repo_name>bparc</repo_name>
   </range>

   <md_path>/gpfs/project/admins/mdfs</md_path>
   <trash_md_path>/gpfs/project/trash</trash_md_path>
   <fsinfo_path>/gpfs/foo/project/fsinfo</fsinfo_path>

   <quota_space>-1</quota_space>
   <quota_names>-1</quota_names>
</namespace>
```

open(RDONLY)

- can read at arbitrary offset
  - GET starts in read(), not open()
- concurrent reads OK
  - multiple file-handles coordinated at repo
  - single file-handle serialized (NFS)
- GET req has range = [open_offset, rest_of_chunk]
  - max GET req size can be configured

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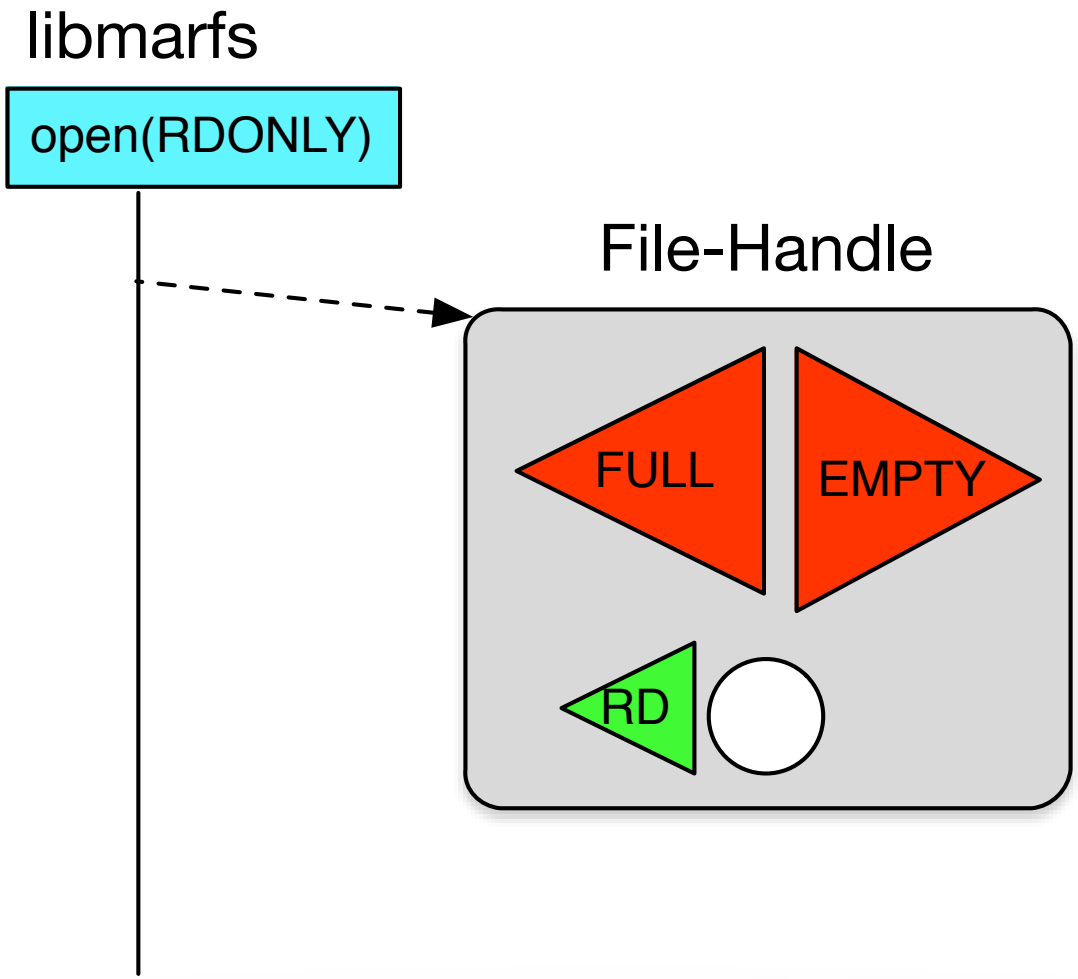
open(RDONLY)



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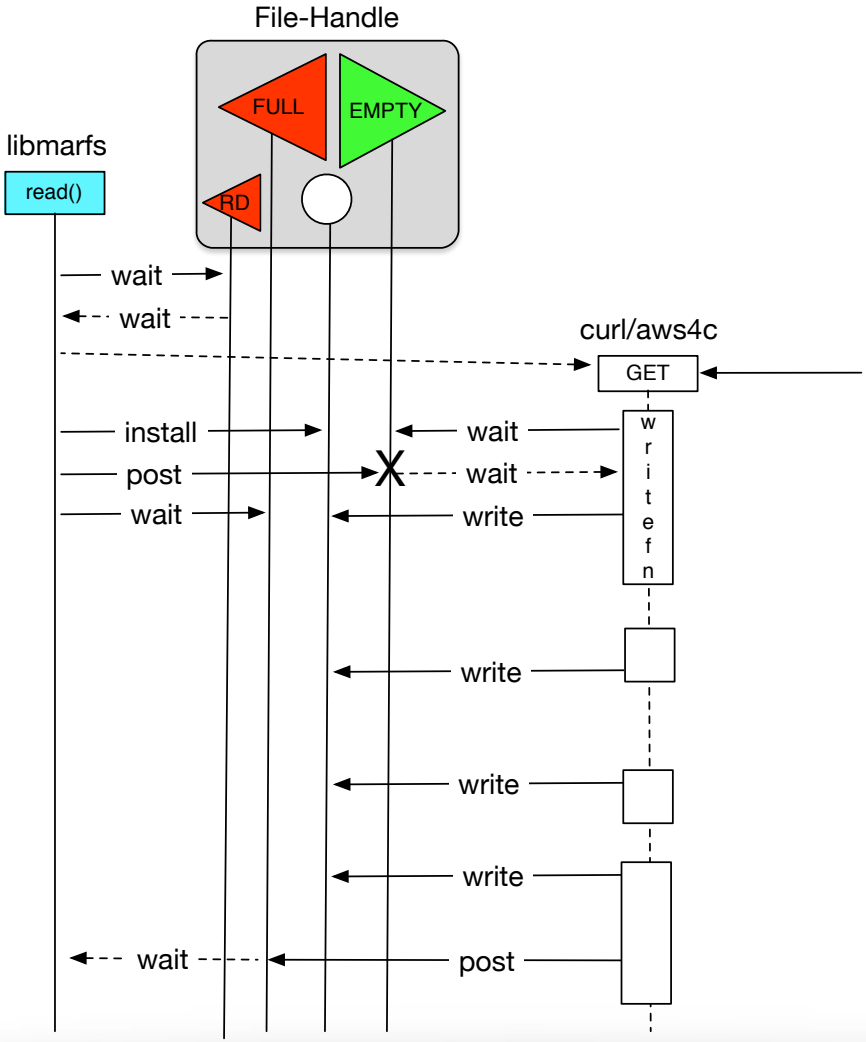
read()



Read Notes

- cross chunk boundaries
- non-contiguous reads mean close/reopen
  - costly!
- NFS
  - multiple offsets / thread
  - multiple threads / file-handle
  - multiple file-handles

Stupid NFS Tricks

- defer close/reopen to wait for other readers
  - detect multiple-threaded reads
  - enqueue out-of-order requests
  - request-timeout -> close/reopen

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open(WRONLY)

- no need for file-handle locks at open
  - require open-offset % chunk_size == 0
    - (accounting for recovery-info)
  - concurrent writes to different chunks via pftool
  - fuse writes overwrite
  - RESTART xattr locks file for read
- trash

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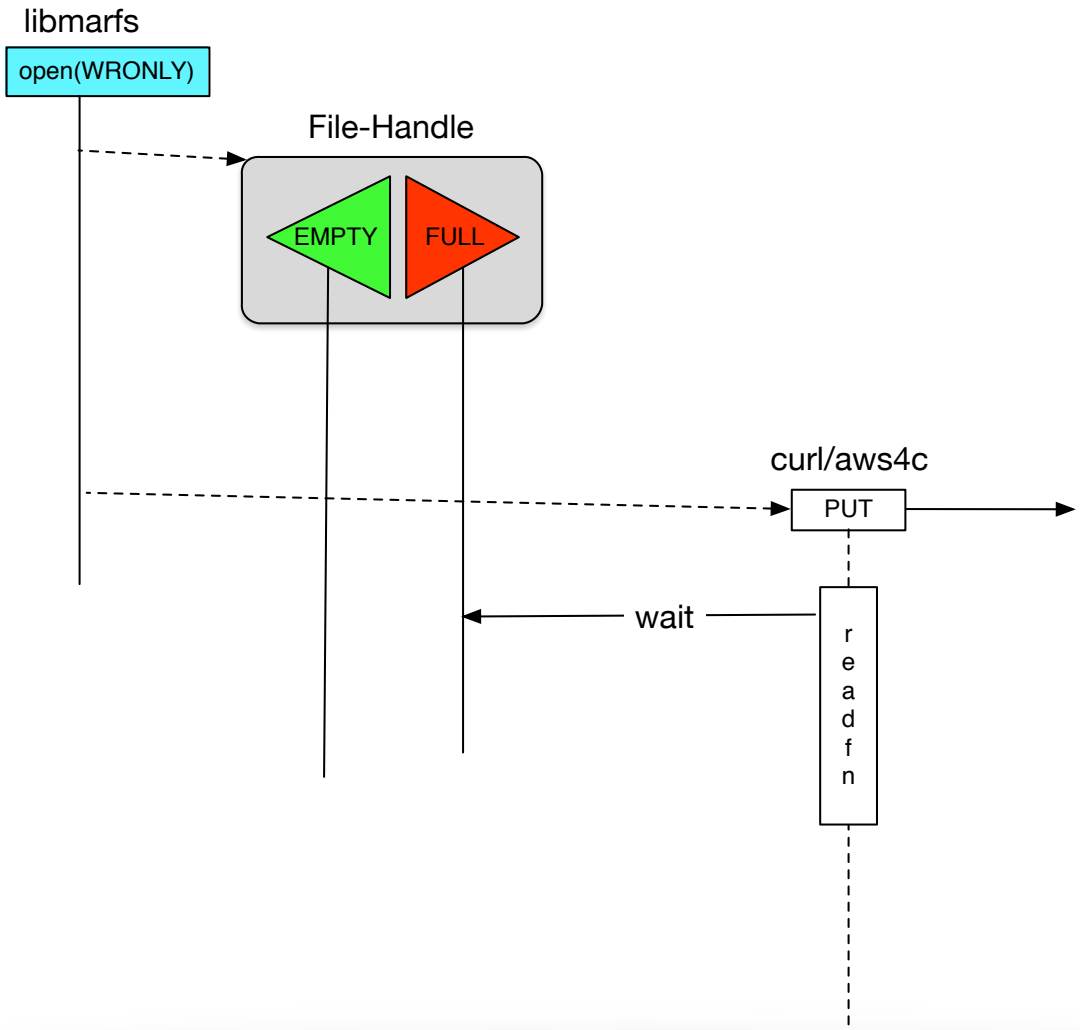
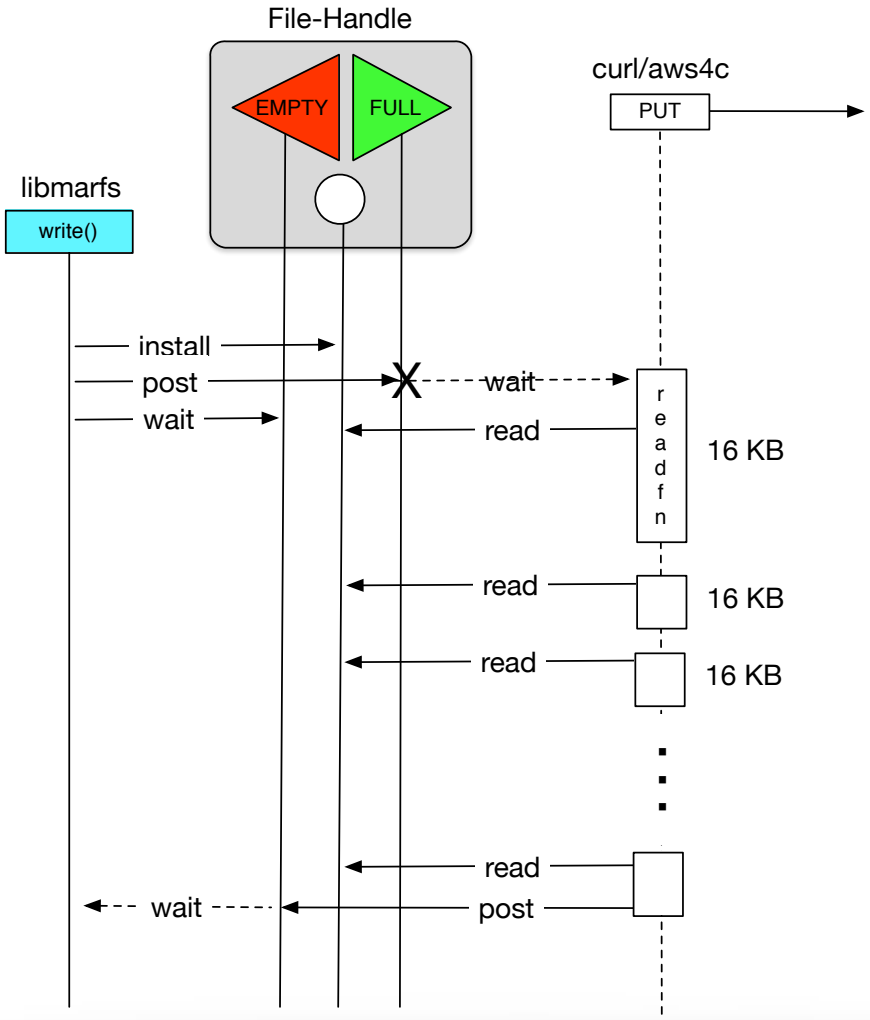
open(WRONLY)



write()



Write Notes

- optimized for non-zero writes
  - starting PUT in open() is hard on MD benchmarks
    - cost of PUT zero-sized object (plus recovery-info)
  - work-around via DAL (explained later)
- NFS
  - arbitrary write-offsets illegal
  - work-around via DAL (different one)

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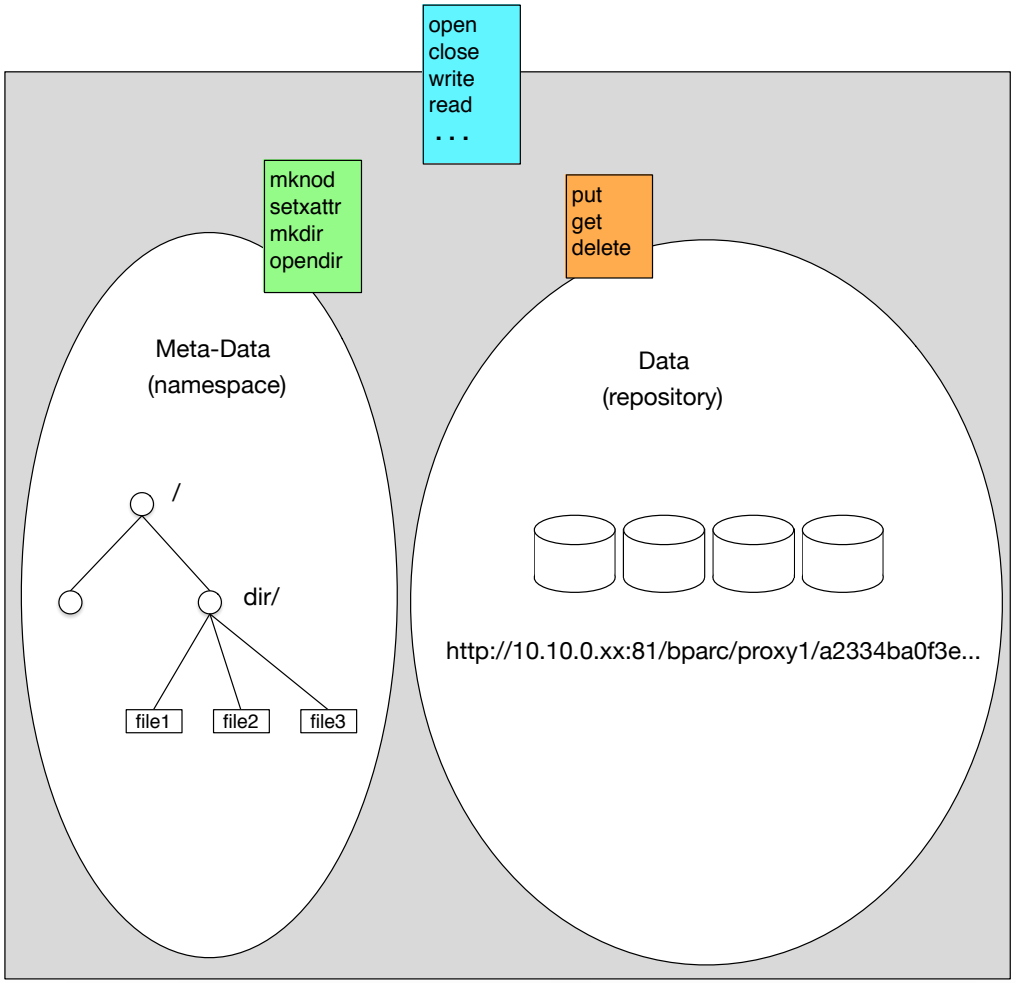
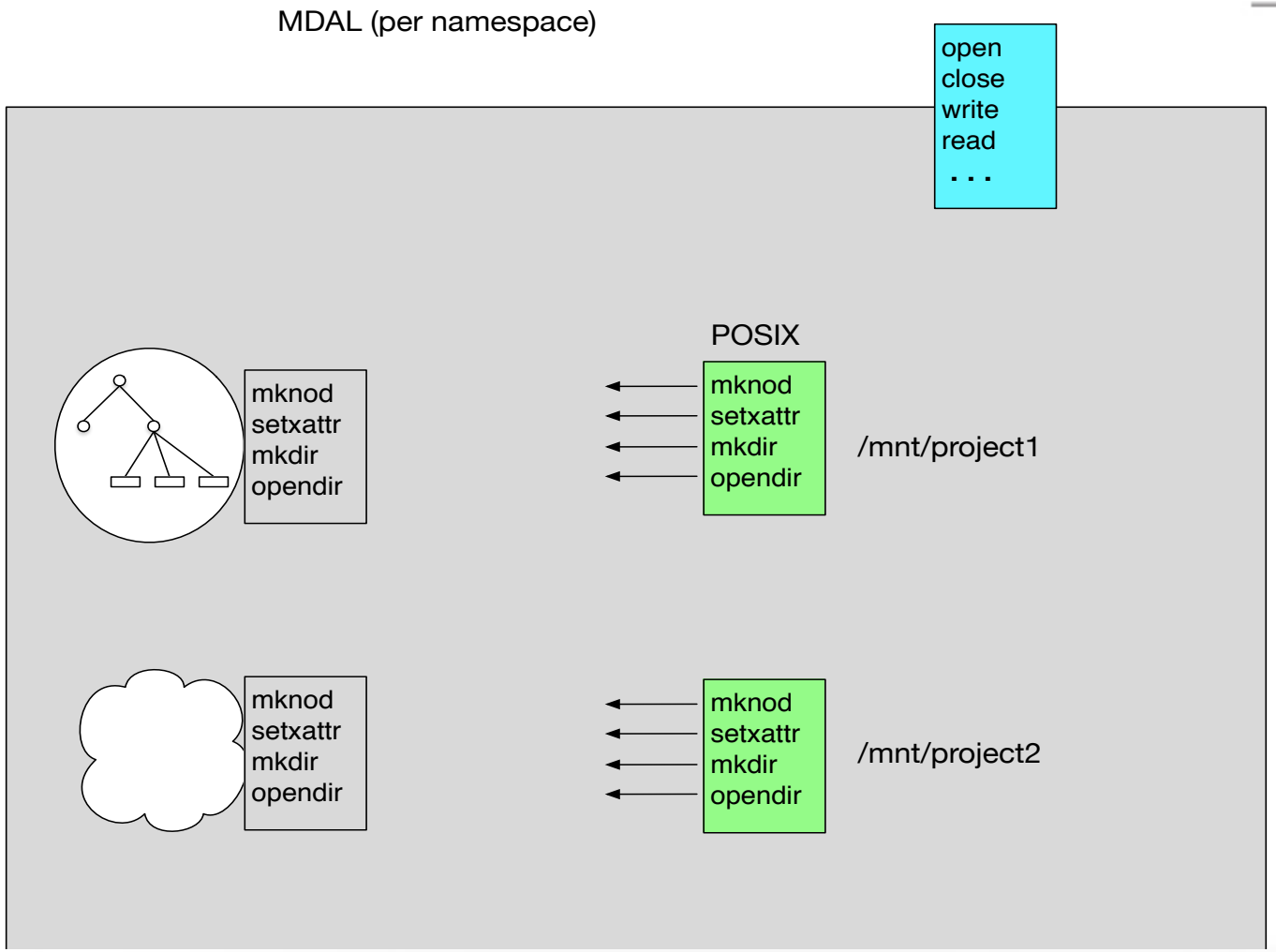
MarFS Basic Structure (review)



MD Abstraction Layer (MDAL)



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MDAL Implementations

- **init**
  - init custom-context, in MarFS file-handle
  - access to per-MDAL static state
- context-based ops: **open/close/read/write**/etc
  - use state in custom-context
- context-free ops: **mknod/unlink/setxattr**/etc
  - operate on paths
- **destroy**
  - clean-up custom-context, etc.

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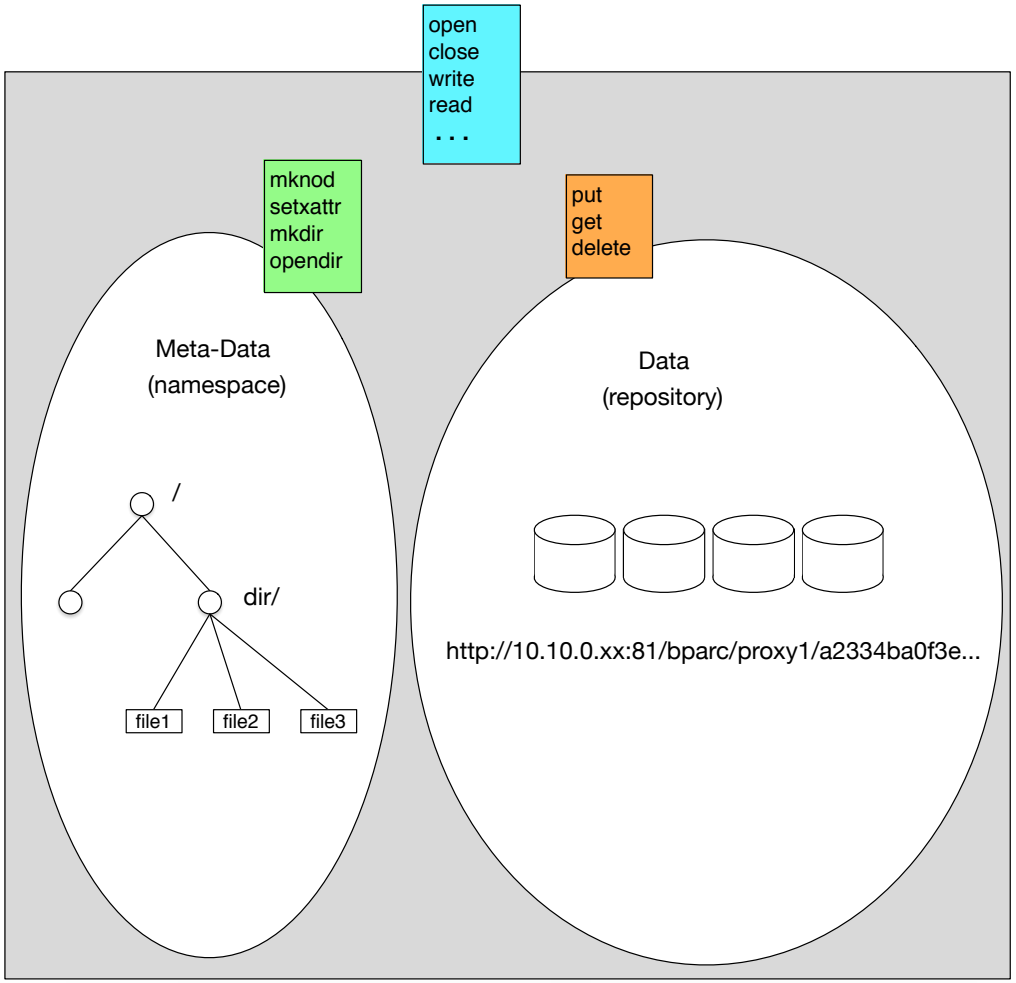
MarFS Basic Structure (review)



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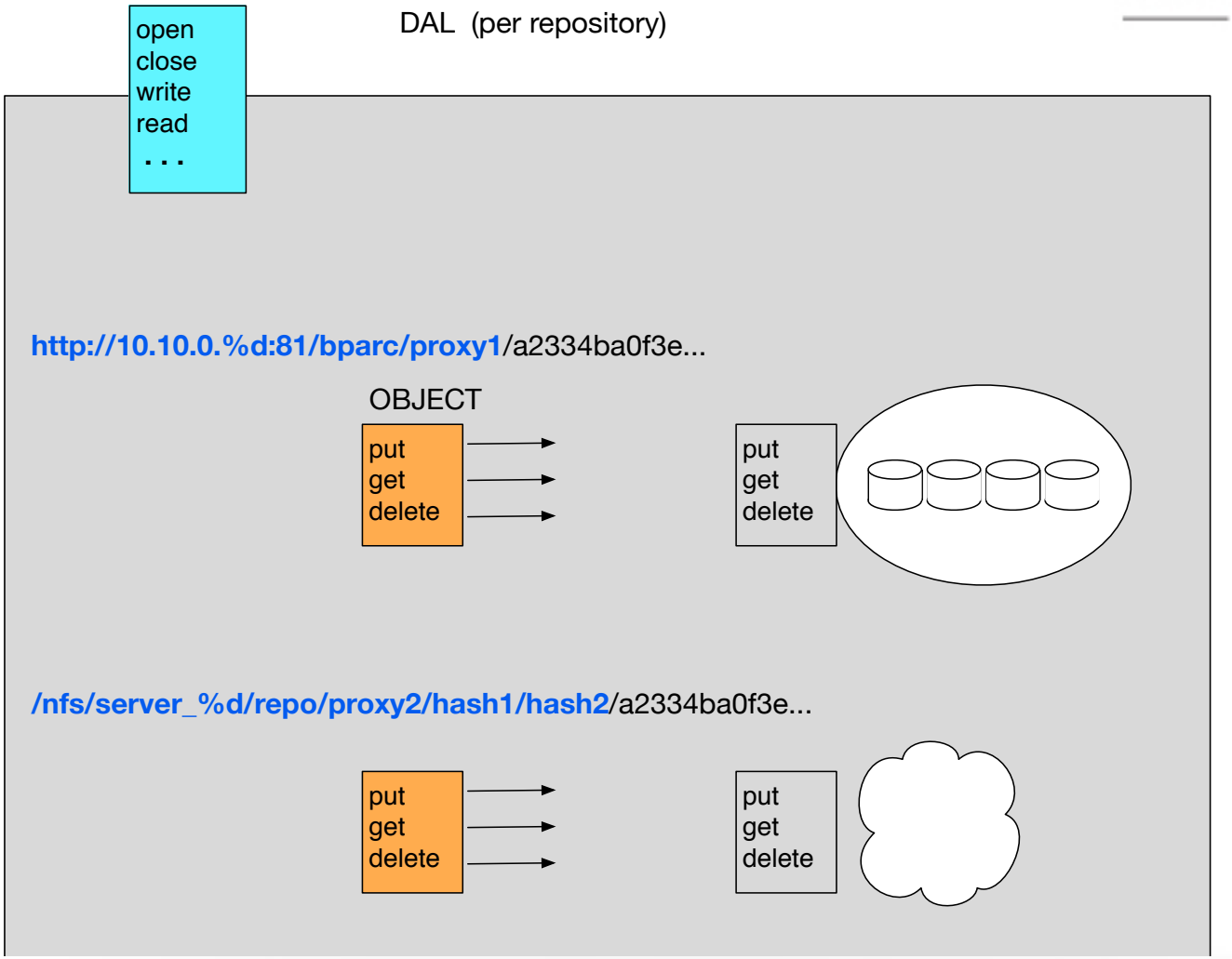
Data Abstraction Layer (DAL)



DAL Implementations

- init
  - init custom context, in MarFS file-handle
  - access to per-DAL static state
- context-based ops: **open/close/get/put**
  - use state in custom-context
- context-free ops: **delete**
  - operate on paths
- destroy
  - clean-up custom-context, etc.

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Work In Progress ...

- scalable metadata
- scalable file-based storage
  - NFS

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Scalable MetaData (1/3)

- Namespace (MDAL)
- remove practical limits on MD capacity
- scalable performance
- directory-MD – directory-tree MD only
  - **/mnt/dmds/ns/path/to/parentdir/**
  - access-perms cached
  - hash parentdir inode -> hash1
- file-MD – sharded directories
  - NFS exports from multiple servers
  - hash fname -> hash2
  - **/mnt/fmds[S]/ns/scatter[M]/parentdir.inode/file**

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Scalable MD (2/3)

```
# Tentative extensions to namespace config to support scalable MD
# (assumes an array of NFS exports)
<namespace>
   <name> mds </name>
   <md_type>      SHARDED </md_type>

   <d_md_path> /mnt/dmds/mds/ </d_md_path>
   <f_md_path>  /mnt/fmds%d/mds/scatter%d/%s.%d </f_md_path>
   <shards>        S </shards>          # number of fmd servers
   <hash_width> M </hash_width>  # width of "scatter-tree"

   <trash_md_path>…</trash_md_path>
   <fsinfo_path>…</fsinfo_path>
</namespace>
```

Scalable MD (3/3)

- benchmarking with distributed app
- “NO-OP” DAL
  - open for write still issues PUT
  - DAL-impl reports success
  - no consistency issues with zero-length files
- “MDScale” MDAL
  - Use context in MPI
  - no xattrs in /dev/shm
- object-IDs refer to non-existent objects

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Multi-Component Data Store (1/3)

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- Repository (DAL)
- store data in files instead of objects
  - Cf. DIRECT storage
- scalable storage
  - 48 JBOD DSUs, w/ ZFS
  - DAL implements EC + GET/PUT/DEL to NFS mounts
  - **/mnt/repo10+2/stripe[4]/blk[12]/cap[C]/parN/scatter[M]/objID**
  - hash fname % 4 -> “stripe” of 12 servers
  - hash fname % C -> capacity group
  - parN dir-names support load-balancing
  - hash fname % M -> scatter (for inode scaling)
  - object-IDs stringified into single filename (no ‘/’)

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MC Data Store (2/3)

```
# Extensions to config for file-based repo using x2 replication
# (assumes an array of NFS exports)
<repo>
   <name>repo_copy2</name>
   <access_method>  MC_COPY 2  </access_method>

   # /mnt/repo_copy2/srv[48]/cap[C]/parN/scatter[M]/objID
   <host> /mnt/copy3/srv%d/cap%d </host>
   <host_count>        48   </host_count>
   <host_cap_count>  C  <host_cap_count> # hash to cap

   <host_sub>     /%s/scatter%d </host_sub>
   <hash_width>  M                  </hash_width>
</repo>
```

MC Data Store (3/3)

```
# Extensions to config for a file-based repo using 10+2 EC
# (assumes an array of NFS exports)
<repo>
   <name> repo10+2 </name>
   <access_method>  MC_ERASURE 10 2  </access_method>

   # /mnt/repo10+2/stripe[4]/blk[12]/cap[C]/parN/scatter[M]/objID
   <host> /mnt/repo10+2/stripe%d/blk%d/cap%d </host>
   <host_count>          4   </host_count>       # hash to "stripe"
   # block-count  is 10+2
   <host_cap_count>  C  <host_cap_count> # hash to cap

   <host_sub>     /%s/scatter%d </host_sub>
   <hash_width>  M                    </hash_width>
</repo>
```

Production Architecture (1/2)

- object-based storage
- “interactive” nodes
  - MarFS FUSE mount
  - RM,WM,RD,~~WD~~,TD,UD
  - marfs pipe tool (tar –czv files | marfs_pipe /marfs/…)
  - *pfcp* spawns to “batch” nodes
- “batch” nodes
  - no interactive logins
  - MDFS mount
  - run pftool MPI jobs

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Production Architecture (2/2)

- **Multi-Component storage**
- "interactive" nodes
  - **MarFS NFS mount**
  - RM,WM,RD,~~WD~~,TD,UD
  - marfs pipe tool (tar –czv files | marfs_pipe /marfs/…)
  - *pfcp* spawns to "batch" nodes
- "batch" nodes
  - no interactive logins
  - MDFS mount
  - **NFS export MarFS FUSE (w/ DAL to MC storage)**
  - run pftool MPI jobs

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Team

- Dave Bonnie
- Hsing-Bung Chen
- Ron Croonenberg
- Chris DeJager
- Greg Geller
- Gary Grider
- Chris Hoffman
- Jeff Inman
- Brett Kettering
- Kyle Lamb
- Chris Mitchel
- Garrett Ransom
- George Sparrow
- Alfred Torrez
- Will Vining

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Acknowledgements

- Gary Grider
- Vlad Korolev (vlad@v-lad.org)
  - aws4c library
  - git@github.com:vladistan/aws4c.git
  - (git@github.com:jti-lanl/aws4c.git)

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Questions?

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https://github.com/mar-file-system/marfs
https://github.com/pftool/pftool

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Object IDs

http://xx.xx.xx.xx:port
/proxy/repo2/ver.001_004/ns.jti/F___/inode.0000027328
/md_ctime.20160829_130133-0600_1
/obj_ctime.20160829_130135-0600_1
/unq.0/chnksz.40000000/chnkno.0

- sproxyd:
  - “proxy” is NS alias, matching httpd FastCGI line
  - “repo2” is Repo, matching sproxyd driver-alias
- S3:
  - “proxy” is NS alias, matching created bucket
- Multi-Component:
  - entire “/proxy/repo2/…” has all ‘/’ translated to ‘#’, becomes a file-name