Lustre Community BOF
Lustre in HPC, AI and the Cloud

November 19, 2019

SC19 Denver, CO hpc is now.

EOFS European Open File System

OpenSFS

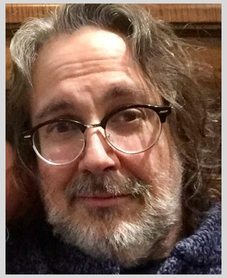
Agenda

- Welcome - OpenSFS / EOFS
- Lustre Trademark
- Community Events
- Lustre Community Release Update
- Lustre Features and Roadmap
- HPC
- AI / Cloud

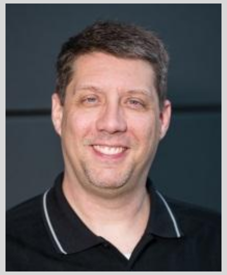
OpenSFS and the Lustre Community

- OpenSFS facilitates a community around Lustre
  - Organization for both Vendors (Participants) and Users (Members) to discuss features and directions
- Promote Lustre and the Lustre community
  - Ensure Lustre remains vendor-neutral, open, and freely downloadable
- Organize the Lustre Users Group conference
- Does Not
  - Fund Lustre development
  - Provide Lustre support (but we can help!)

2019 OpenSFS Board



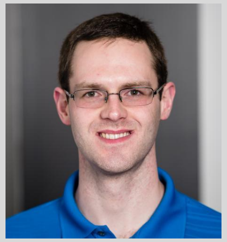
President: **Steve Simms**
IU



Vice President: **Kevin Harms**
ANL

Secretary: **Ken Rawlings**
IU

Treasurer: **Kirill Lozinskiy**
LBNL / NERSC



Director at Large: **Shawn Hall**
BP

Director-at-Large: **Sarp Oral**
ORNL

OpenSFS Supporters

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SIG SUSQUEHANNA

Sandia National Laboratories

SRCC

TACC

UF UNIVERSITY of FLORIDA

Advanced Technologies Group UBER

OpenSFS®

OpenSFS Membership

- Thank you to all our current and past Supporters
- Member
  - $1,000 annually
  - For Lustre users
- Participant
  - $5,000 annually
  - For Lustre providers
- If you are at this meeting and not a Supporter, why?

Lustre Trademark

- Seagate has transferred ownership of the Lustre trademark to the combined ownership OpenSFS and EOFS
  - Thank you to Seagate!

- Seagate retains rights to use trademark as part of the agreement

Lustre Community Release Update

- Peter Jones - Director Of Engineering at Whamcloud, Inc
  - Lustre Working Group Co-Chair

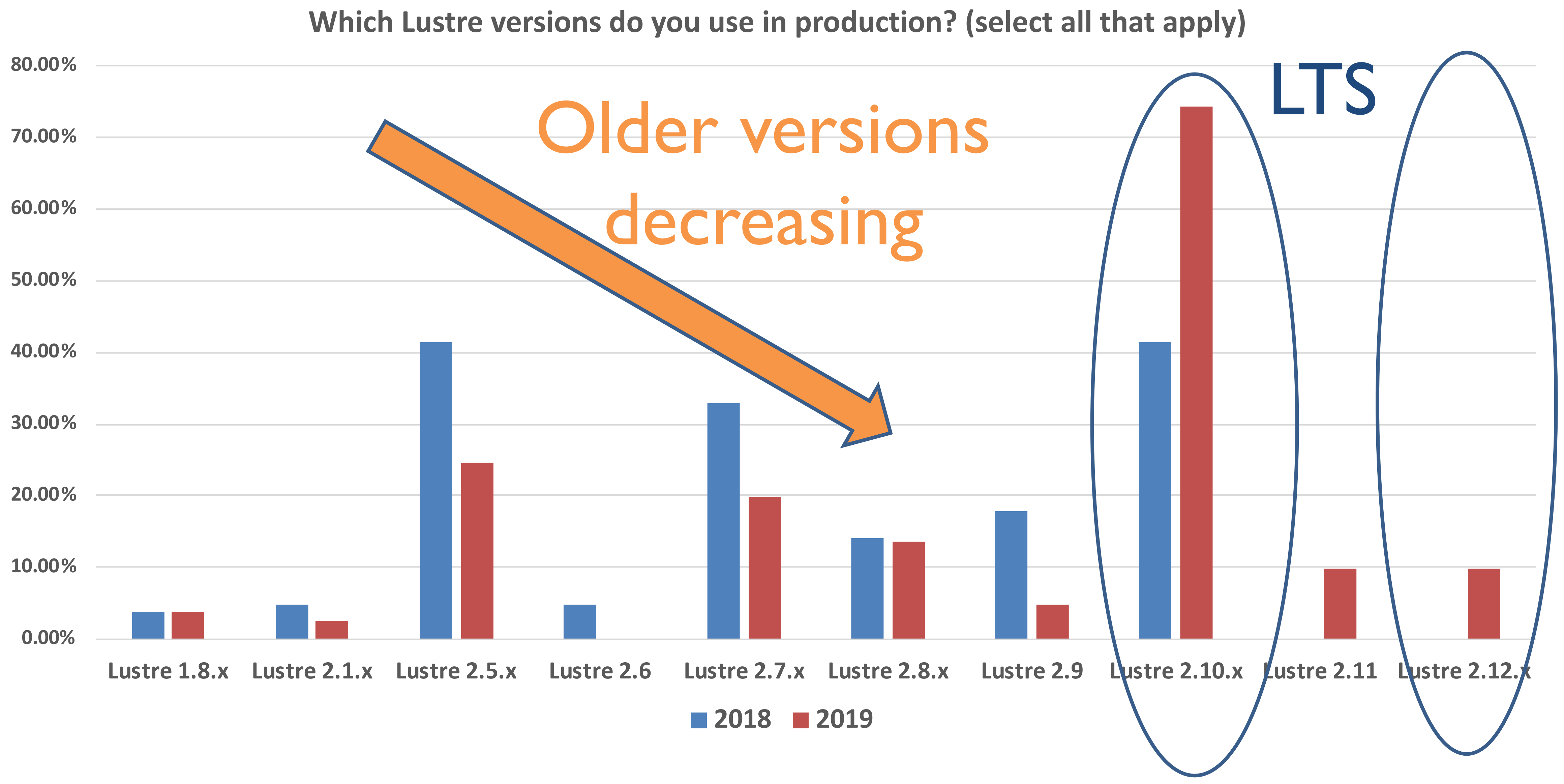
- Lustre Working Group (LWG)
  - Peter Jones (Whamcloud) & Dustin Leverman (Oak Ridge)
  - Every other Thursday - 11AM PT / 12PM MT / 1PM CT / 2PM ET
  - Dialin: +1 (916) 469-2710 - Conference ID: 71884717
  - http://wiki.opensfs.org/Lustre_Working_Group

Lustre Community Release Update

SC19

Peter Jones, Whamcloud
OpenSFS Lustre Working Group

Lustre Community Survey (Mar 2019)



Lustre 2.10.x LTS is the most widely-used production release

Lustre LTS Transition

- LTS change from 2.10.x to 2.12.x announced at SC18
  - Driver was amount of change to support newer kernels
- Some concerns have been raised that two years is not LT ☺
- Large numbers of sites deployed 2.10.x LTS releases
  - Some sites upgraded fully to 2.12.x
  - Some sites using 2.12.x clients
  - Some sites work with vendors who offer longer support versions
  - Some sites using changes ported back to 2.10.x if required
- Will again seek community input before any future changes

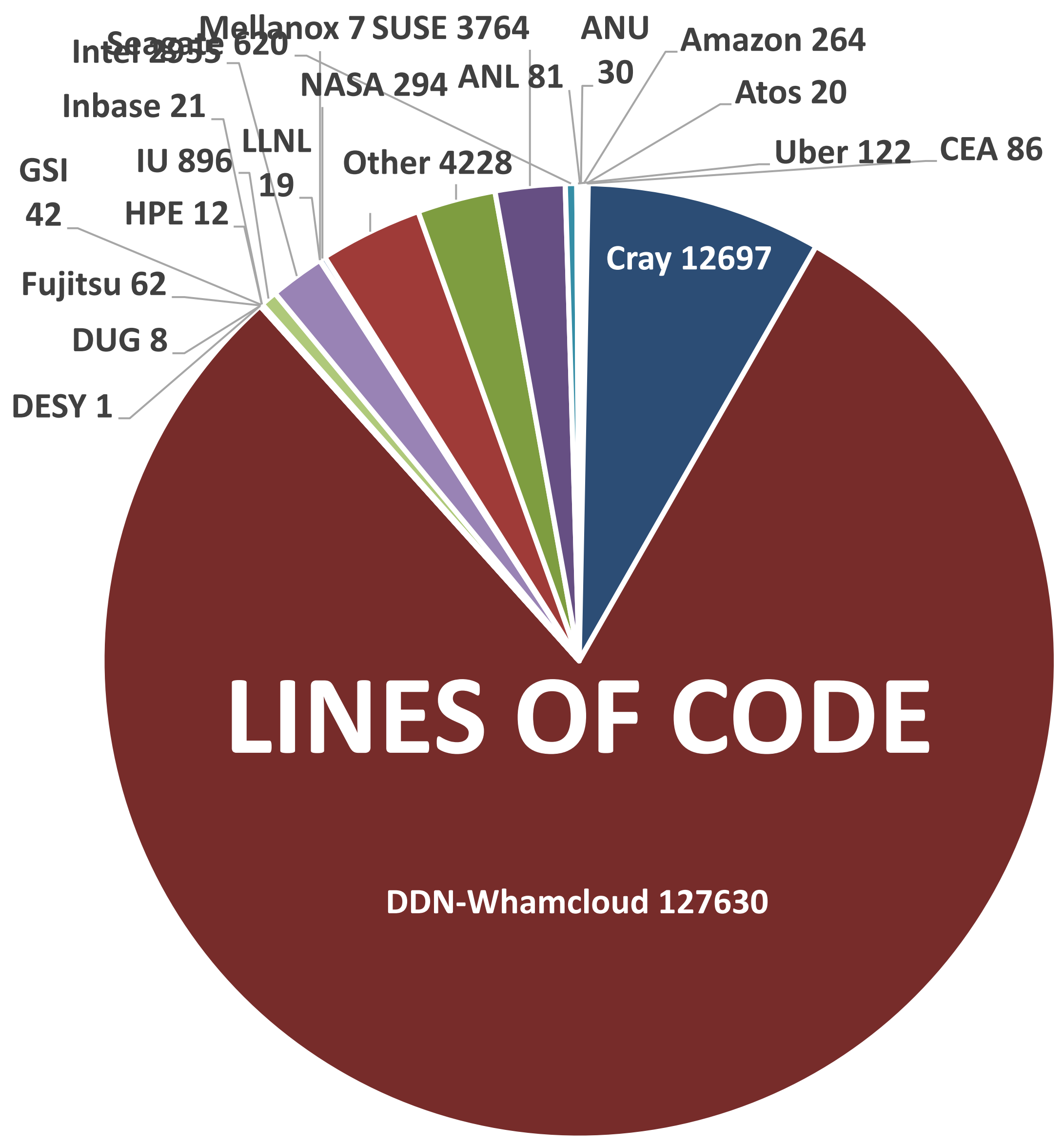
Lustre 2.12.x LTS

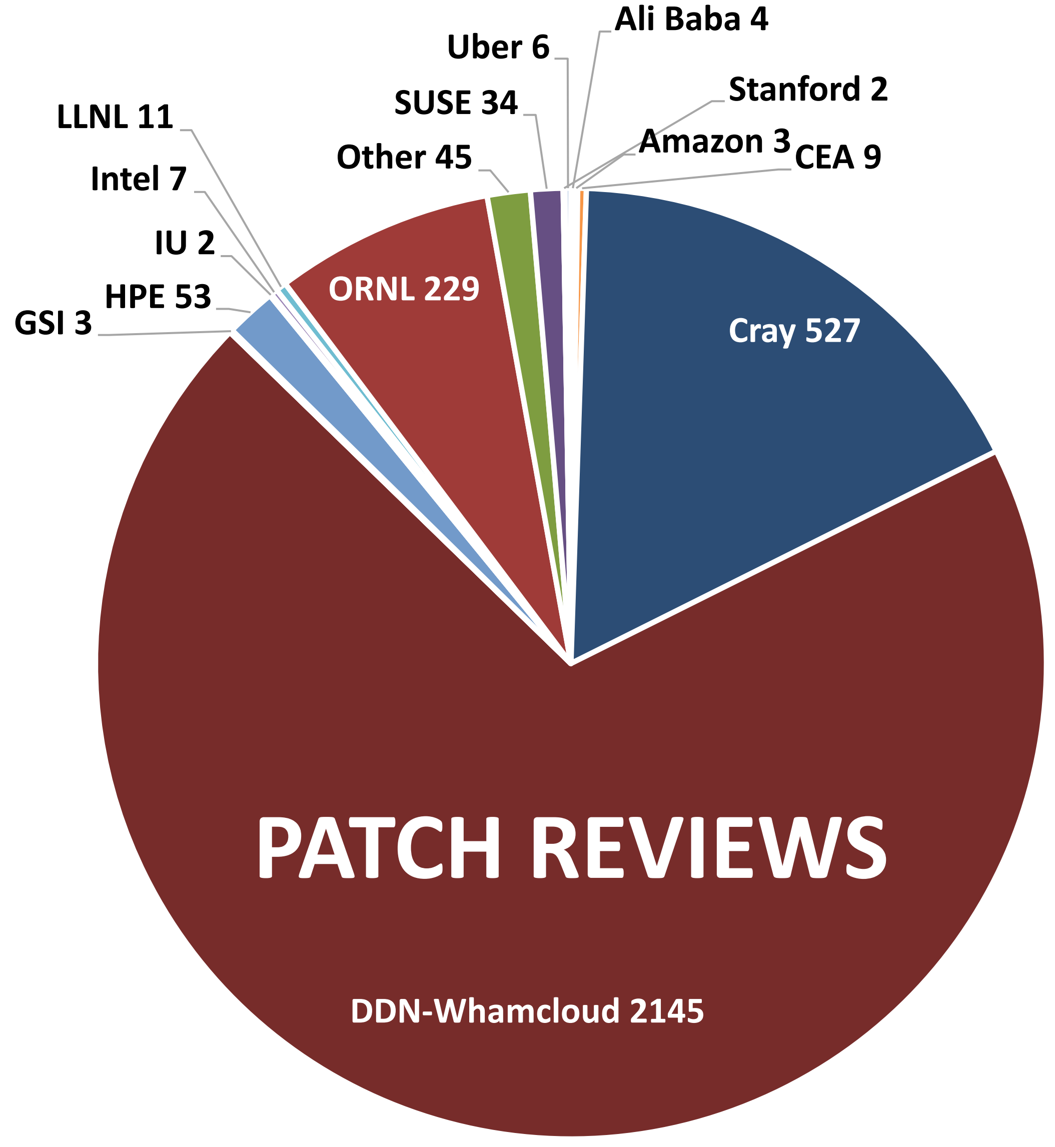
- Lustre 2.12.3 went GA Oct 21st
  - RHEL 7.7 server and client support
  - RHEL 8.0 client support
  - MOFED 4.7
  - ZFS 0.7.13
  - Bug fixes from early 2.12.x deployments
  - http://wiki.lustre.org/Lustre_2.12.3_Changelog
- Lustre 2.12.4 targeted for late Q4
  - RHEL 8.1 client support

Lustre 2.13

- RC1 in release testing ATM; hopefully GA by end of month
- OS support
  - RHEL 7.7 servers/clients
  - RHEL8.0/SLES12 SP4/Ubuntu 18.04 clients
- Interop/upgrades from latest Lustre 2.12.x
- ZFS version ships with ZFS 0.7.13 by default
- Number of useful features
  - Persistent Client Cache (LU-10092)
  - Overstriping (LU-9846)
  - Self Extending Layouts (LU-10070)
- http://wiki.lustre.org/Release_2.13.0

Lustre 2.13 Contributions





Aggregated data by organization between 2.12.50 and 2.12.90 tags

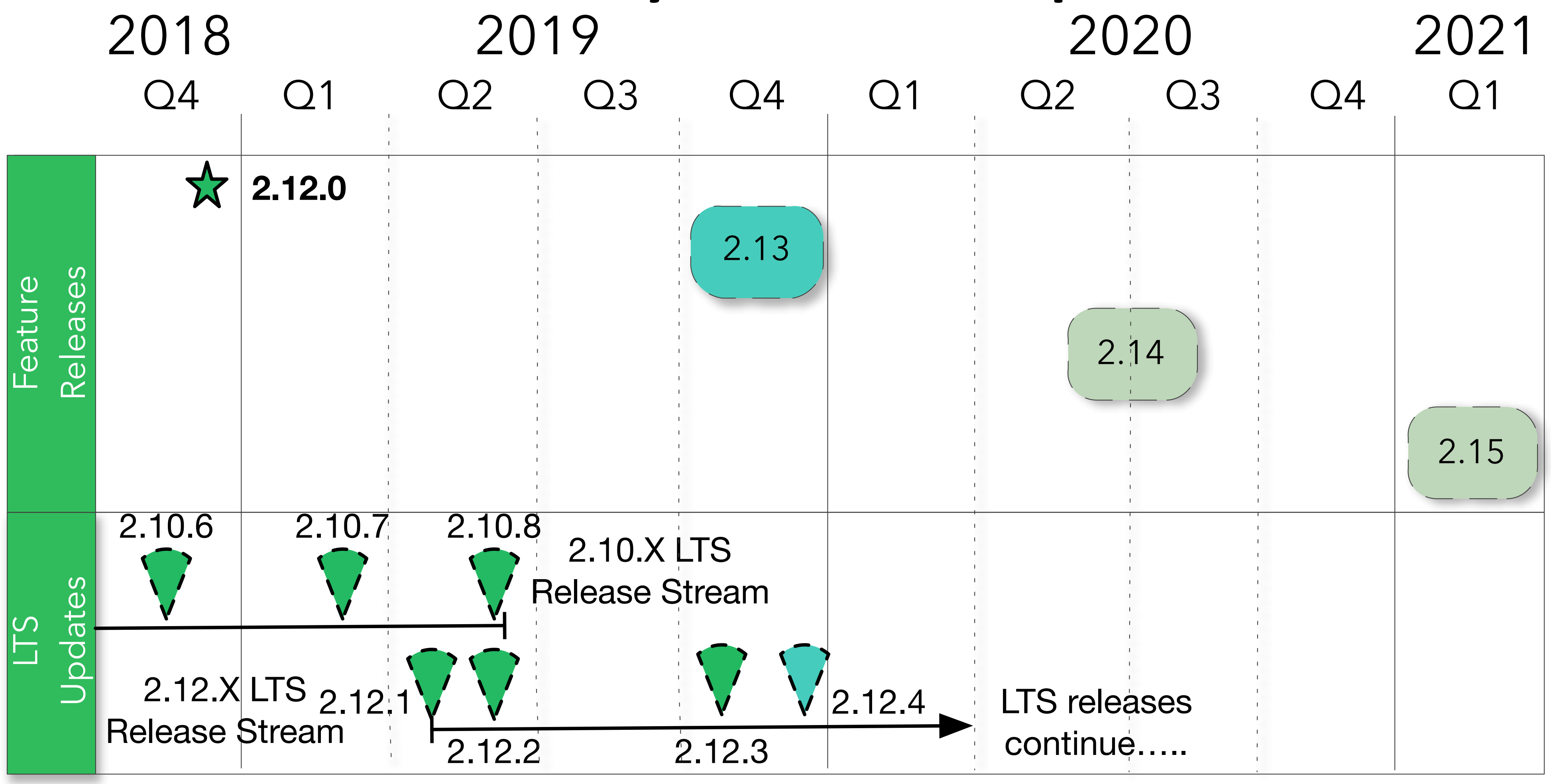
Source: http://git.whamcloud.com/fs/lustre-release.git/shortlog/refs/heads/master

Data courtesy of Dustin Leverman (ORNL)

Lustre 2.14

- Targeting late Q2/early Q3 release
- OS support
  - RHEL 8.1 servers/clients
  - RHEL 8.1/SLES15 SP1/Ubuntu 20.04 clients
- Interop/upgrades from 2.13 and latest Lustre 2.12.x
- ZFS version ships with ZFS 0.8.2 by default
- Number of useful features
  - FLR Erasure Coding (LU-10911)
  - Pool Quota (11023)
  - DNE Auto Restriping (LU-11025)
- http://wiki.lustre.org/Release_2.14.0

Lustre Community Roadmap



LEGEND:

🟦	Expected Timeline
▨	Timeline TBD
🟩	Completed
↓	LTS Branch

2.12
- Lazy Size on MDT
- LNet Health
- DNE Dir Restriping

2.13
- Persistent Client Cache
- Multi-Rail Routing
- Overstriping

2.14
- FLR Erasure Coding
- Pool Quota
- DNE Auto Restriping

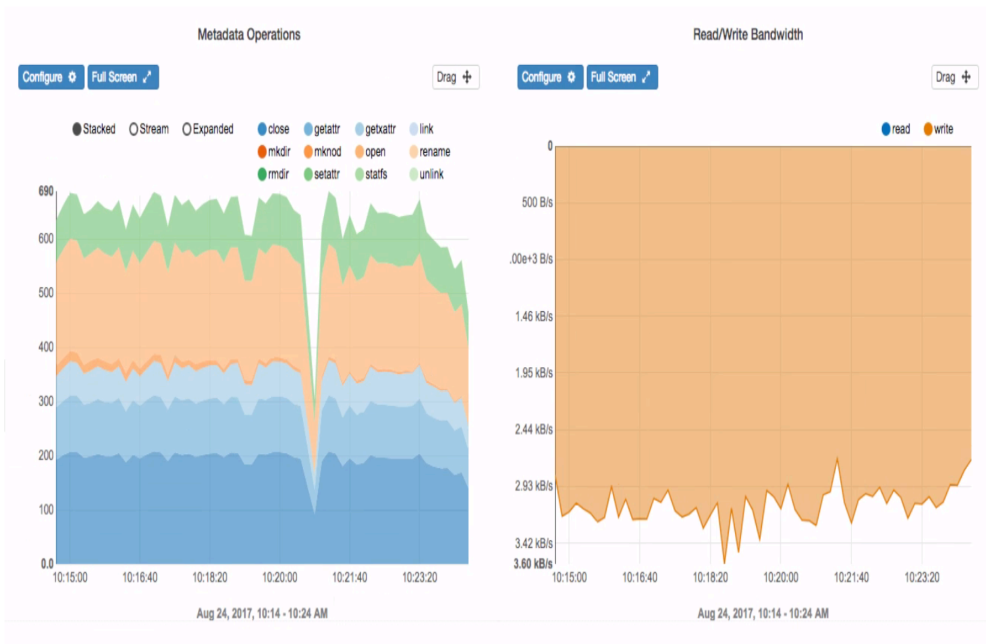
2.15
- Client Encryption
- Writeback Cache

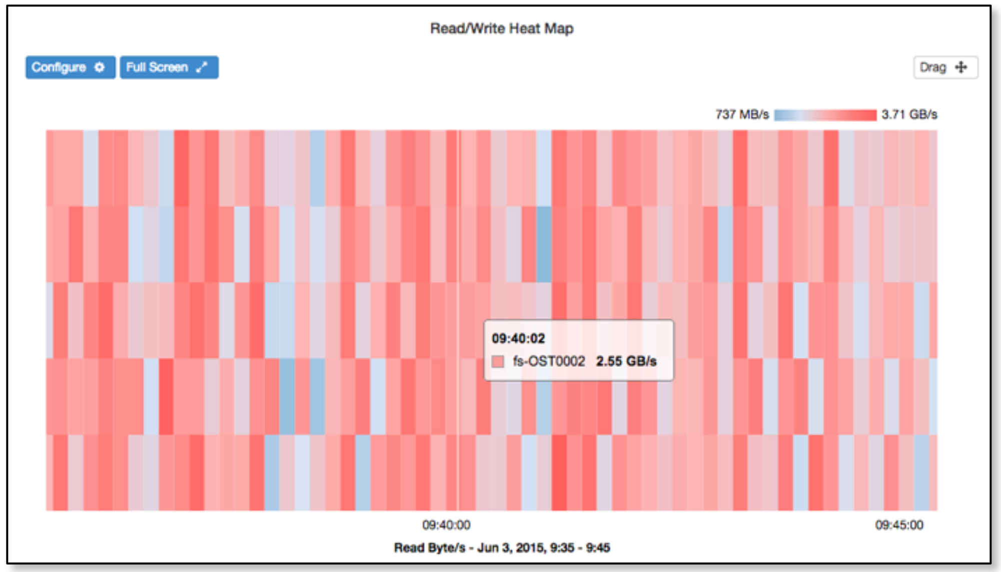
* Estimates are not commitments and are provided for informational purposes only
* Fuller details of features in development are available at http://wiki.lustre.org/Projects

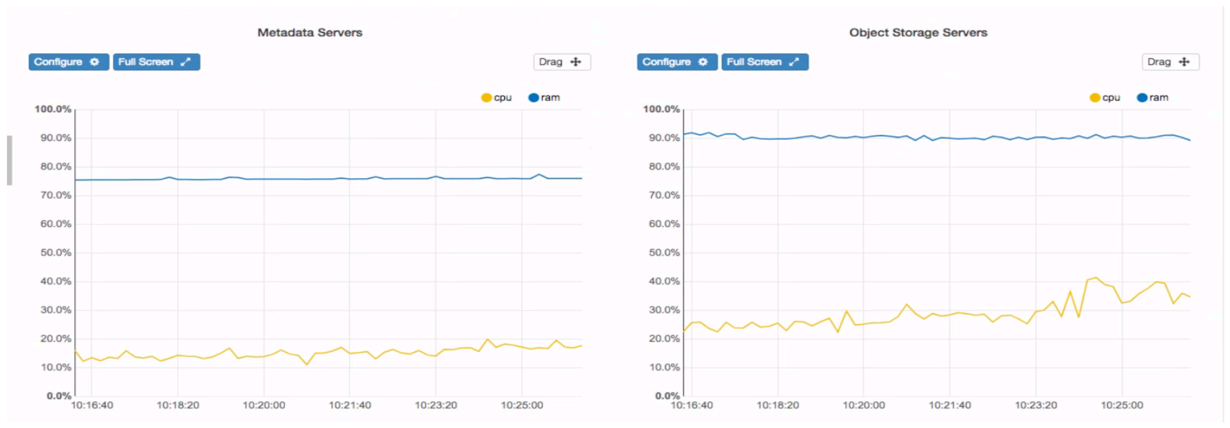
Integrated Manager for Lustre

https://github.com/whamcloud/integrated-manager-for-lustre/releases

- IML 5.0 GA in May
  - Lower manager/agent resource usage
- IML 5.1 now GA
  - https://github.com/whamcloud/integrated-manager-for-lustre/releases/tag/v5.1.0
  - Lustre 2.12.3 support
  - Parallel deploy servers with CLI







Lustre's Longevity

- Project active for over 20 years
- Maintaining stability and performance in the most demanding environments is not an easy problem to solve
- Constant evolution to deal with changing requirements of hardware and usage
- Permissive open source license has meant many organizations can use and contribute effectively
- For some further Lustre heritage…

https://hps.vi4io.org/_media/events/2019/hpc-iodc-lustre_next_20_years-dilger.pdf

Lustre at SC19

- **Sat Nov 16th**
  - HPCAST (Grand Hyatt) 8 am
- **Tue Nov 19th**
  - DDN booth (#617) 1:15pm
  - IO-500 BOF (205-207) 12:15pm
  - Arm BOF (301-303) 5:15pm
  - OpenSFS Lustre BOF (205-207) 5:15pm
- **Weds Nov 20th**
  - SUSE booth (#1917) 3pm
  - Stanford booth (#1255) 3:30pm
- **Thur Nov 21st**
  - Stanford booth (#1255) 1:30pm

Summary

- LTS model has been well adopted
- Lustre 2.12.3 and IML 5.1 GA
- Lustre 2.13 and 2.12.4 coming soon
- Lustre 2.14 targeted for late summer 2020
- LWG http://wiki.opensfs.org/Lustre_Working_Group

Thank you

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www.opensfs.org

Lustre Features and Roadmap

- Andreas Dilger - Chief Technical Officer at Whamcloud, Inc.

Lustre 2.14 and Beyond

Andreas Dilger, Whamcloud

Upcoming Release Feature Highlights

- **2.13** feature complete, November, 2019
  - Persistent Client Cache (PCC) – store file data in client-local NVMe/NVRAM
  - LNet Multi-Rail Routing – extend MR to/through routers, handle mixed interfaces
  - DNE space balanced remote directory – improve load/space balance across MDTs
  - Layout OST Overstriping – allow multiple objects from one OST in a striped file
  - Self-Extending Layouts (SEL) – better handle OST out-of-space in the middle of a file
- **2.14** has several important features under active development
  - DNE directory auto-split – improve usability and performance with multiple MDTs
  - File Level Redundancy - Erasure Coding (EC) – efficiently store striped file redundancy
  - OST Pool Quotas – manage space on tiered storage targets using OST pools
- **2.15** plans continued functional and performance improvements
  - Metadata Writeback Cache (WBC) – low latency file operations in client RAM
  - Client-side data encryption – persistent encryption from client to disk

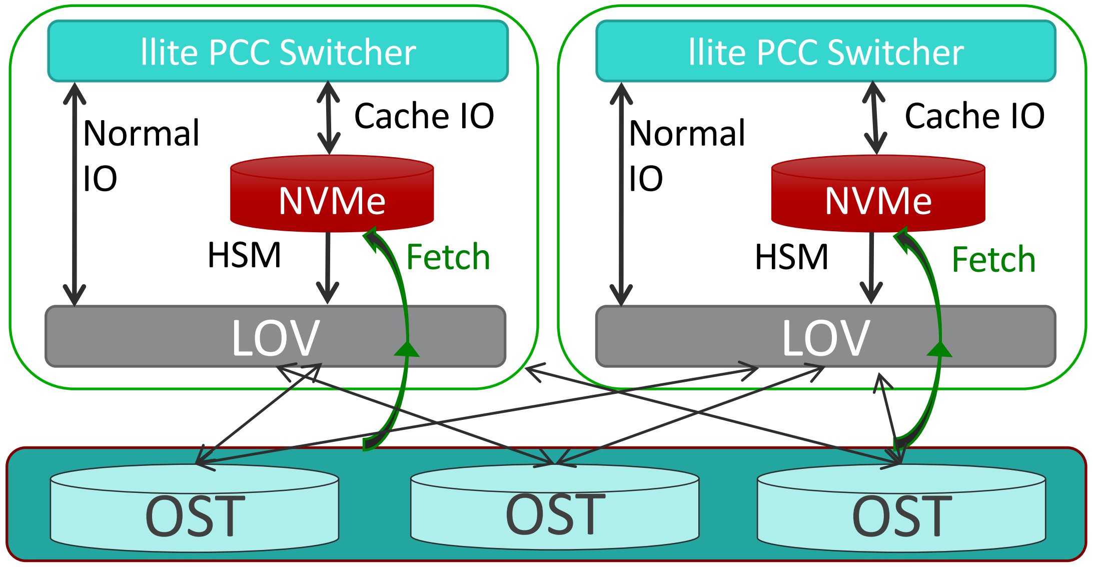
Persistent Client Cache (PCC) (LU-10092, DDN,WC) (2.13)

Whamcloud

- **Reduce latency**, improve small/unaligned IOPS, reduce network traffic
- PCC integrates Lustre with a persistent per-client **local cache storage**
  - **A local filesystem** (e.g. `ext4` or `ldiskfs`) is created on client device (SSD/NVMe/NVRAM)
  - **Data is local to client**, no global/visible namespace is provided by PCC
  - **HSM POSIX copytool** fetches whole files into PCC by user command, job script, or policy
  - New files created in PCC are *also* created on Lustre MDS
- Lustre uses local PCC data, or normal OST RPCs
  - Further file read/write access "directly" to cache file
  - No data/IOPS/attributes off client while file in PCC
  - 2.13 File migrated out of PCC via HSM upon remote access

2.14

- Separate **shared read** vs. **exclusive write** cache
- Integrate with DAX for NVRAM cache device
  - Use dedicated NVRAM filesystem (e.g. NOVA) for speed

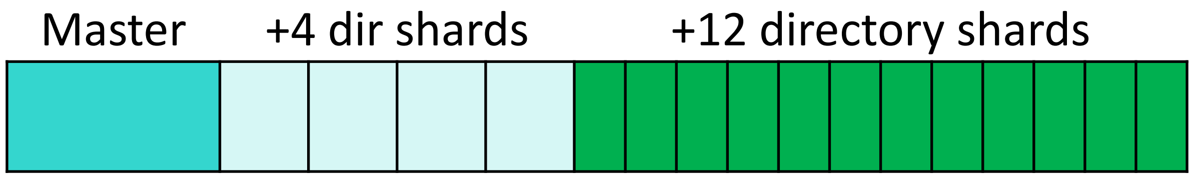


DNE Usability and Performance Improvements (2.13+)

- ▶ **Space balance new directories** on "best" MDT based on available inodes/space
  - Simplifies multiple MDTs without overhead of striping all directories, similar to OST balance
  - 2.12 Explicitly when creating a new directory with "`lfs mkdir -i -1`" (LU-10277, WC)

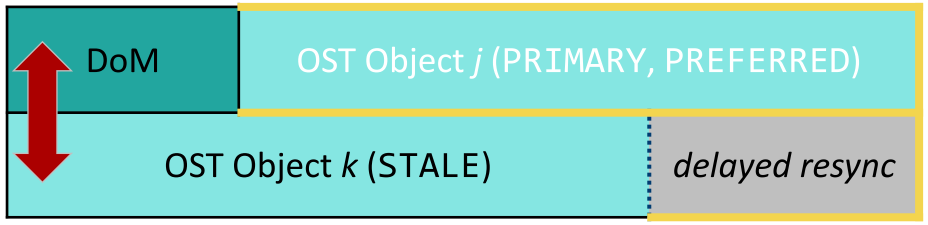
  - Transparently select "best" MDT for normal `mkdir()` based on parent policy (LU-10784, WC)
    - Set default policy on parent via "`lfs setdirstripe -i -1 dir`" (LU-11213, WC)
    - Most useful for root directory and top-level user directories
- 2.13 ▶ **Improved DNE file create performance** for clients (LU-11999, Uber)

- 2.14 ▶ **Automatic directory restriping** as directory size grows (LU-11025, WC)
  - Create one-stripe directory for low overhead, scale shards/capacity/performance with size
  - Add extra directory shards when master directory grows large enough (e.g. 10k entries)
  - Move existing dirents (not inodes) to new directory shards
  - New dirents and inodes created on new MDTs



Data-on-MDT (DoM) Improvements (WC) (2.13+)

- Convert write locks to read locks w/o cache flush (LU-10175)
- General usability and stability improvements
- FLR mirror/migrate DoM file (LU-11421)
  - Mirror DoM data to OST object
  - Migrate DoM data to/from OST object
  - No MDT-MDT mirroring yet



- Performance and functional improvements
  - 2.13 Target IO-500 `mdtest-hard-{write,read}` (3901-byte parallel file create in shared dir)

2.14
- Dynamic DoM component size by MDT free space (LU-12785)
- Merge data write with MDS_CLOSE RPC (LU-11428)
- Cross-file data prefetch via statahead (LU-10280)
- Allow MDT-only filesystem (LU-10995)

Improved Client Efficiency for AI/ML (2.13+)

- **Single thread DNE create** performance (LU-11999, Uber)
  - Reduce locking overhead/latency *for single-threaded* workloads (780/sec -> 2044/sec)
- **Parallel client readahead** performance (LU-8709, LU-12043, WC)
  - Improved *single-threaded readahead* (e.g. "dd") from 1.9GB/s -> 4.0GB/s
- **Overstriping OST objects** better large/fast OSTs on fewer clients (LU-9846, Cray, WC)
  - "`lfs setstripe -C|--overstripe-count` *`stripe_count`*" for multiple objects per OST
- **Improved small file handling** (IO-500 `mdtest-hard-{write,read}` performance)
  - Cache small files after create (LU-11623, LU-12325, LU-10948, ..., WC)
- **Improved strided readahead** (IO-500 `ior-hard-read` performance)
  - 2.13 Detect and handle page-unaligned strided reads (LU-12644, WC)
  - 2.14 Allow readahead to continue for slightly "imprecise" strides
- **Local client mount on OST/MDT** for data mover/resync (LU-10191, WC)
  - Beginning of optimization for local IO path to avoid RPC + data copy

Server Performance Improvements for Flash (2.12+)

- **Reduce server CPU** overhead to improve small flash IOPS (LU-11164, WC, DDN)
  - Reduced CPU usage translates directly to improved IOPS
- **Avoid page cache** on flash OSS (LU-11347, WC)
  - Avoids CPU/lock overhead/lock for page eviction
- **TRIM flash storage** on ldiskfs (LU-11355, DDN)
  - Release unused blocks of filesystem via `fstrim`

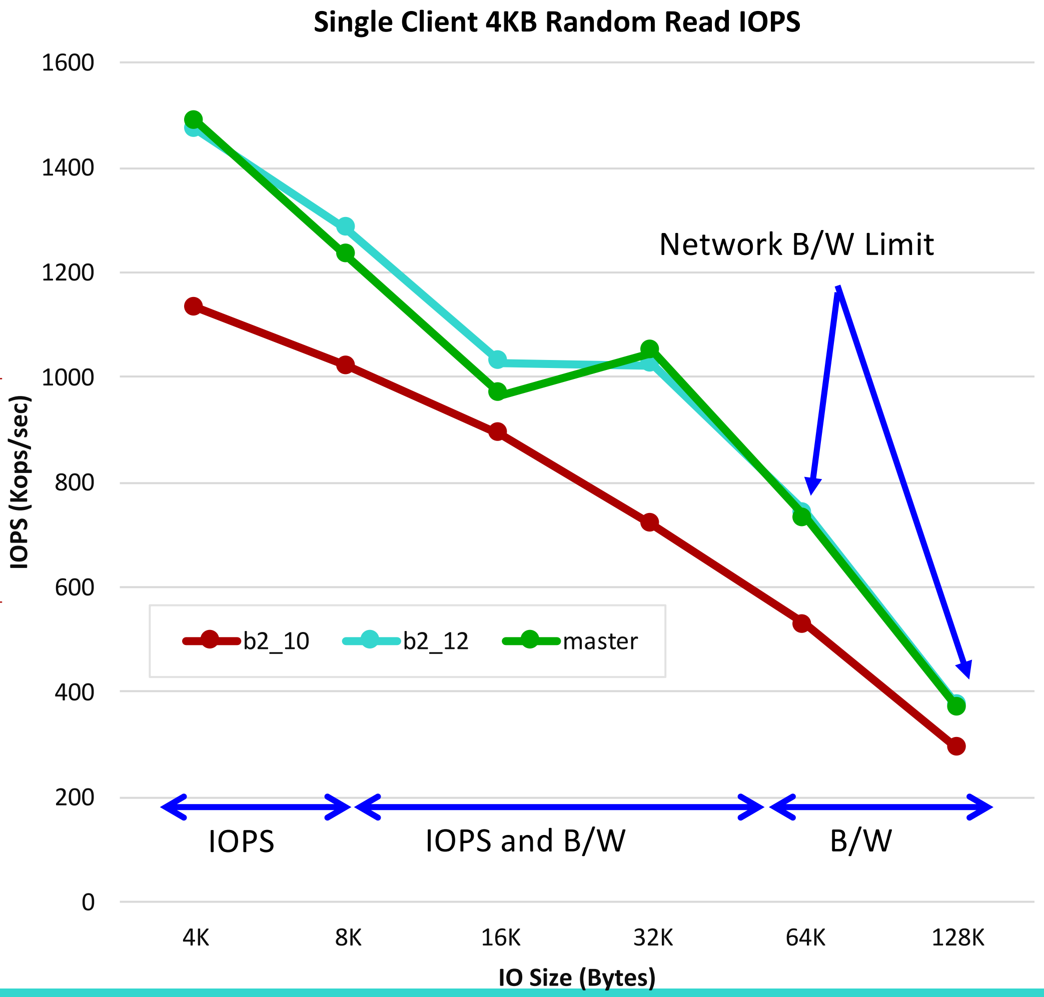
2.12

- **Self Extending Layouts** (LU-10070, Cray)
  - Avoids out-of-space in the middle of files
  - Good for PFL with smaller flash OSTs than disk OSTs

2.13

2.14

- Continued reductions of overhead and latency
  - Improve small, unaligned and interleaved writes
  - Lockless unaligned IO submission from clients
  - Writeback cache with IO merging on servers
  - Improve IO-500 `ior-hard-write`



File Level Redundancy (FLR) Enhancements (WC) (2.13+)

Whamcloud

- **Lustre-level mirroring for files**, configured arbitrarily per file/directory
- **Mirror NOSYNC flag** + timestamp to allow *file version/snapshot* (LU-11400)
- Mount client directly on OSS without impacting recovery (LU-12722)

2.13
- "`lfs mirror resync/delete --pool`" to simplify tiering (LU-11022)

2.14
- **Erasure coding** adds redundancy without 2x/3x mirror overhead (LU-10911)
  - Add erasure coding to new/old striped files *after* write done
  - Leverage CPU-optimized EC code (Intel ISA-L) for best client performance
  - For striped files - add N parity per M data *stripes* (e.g. 16d+3p)
  - **Fixed RAID-4 parity** layout *per file,* **declustered Parity** across files to avoid IO bottlenecks

2.15
- HSM in composite layout (LU-10606)
  - Allow multiple archives per file (S3, tape, ...)
  - Allow partial file restore from archive

TBD
- File version/reflink within namespace?
  - Access like VAX/VMS using "`filename,1`"?

Replica 0	Flash Object *j* (PRIMARY, PREFERRED)	
Replica 1	HDD Object *k* (STALE)	*delayed resync*
Replica 2	HSM S3 Archive	

Miscellaneous Improvements (2.13/2.14)

Whamcloud

- **Overstriping** allows multiple file stripes per OST (LU-9846, Cray, WC)
  - Useful for shared-file workloads or very large OSTs
- **`lfs find`** integration with Lazy Size-on-MDT (LU-11367, WC)

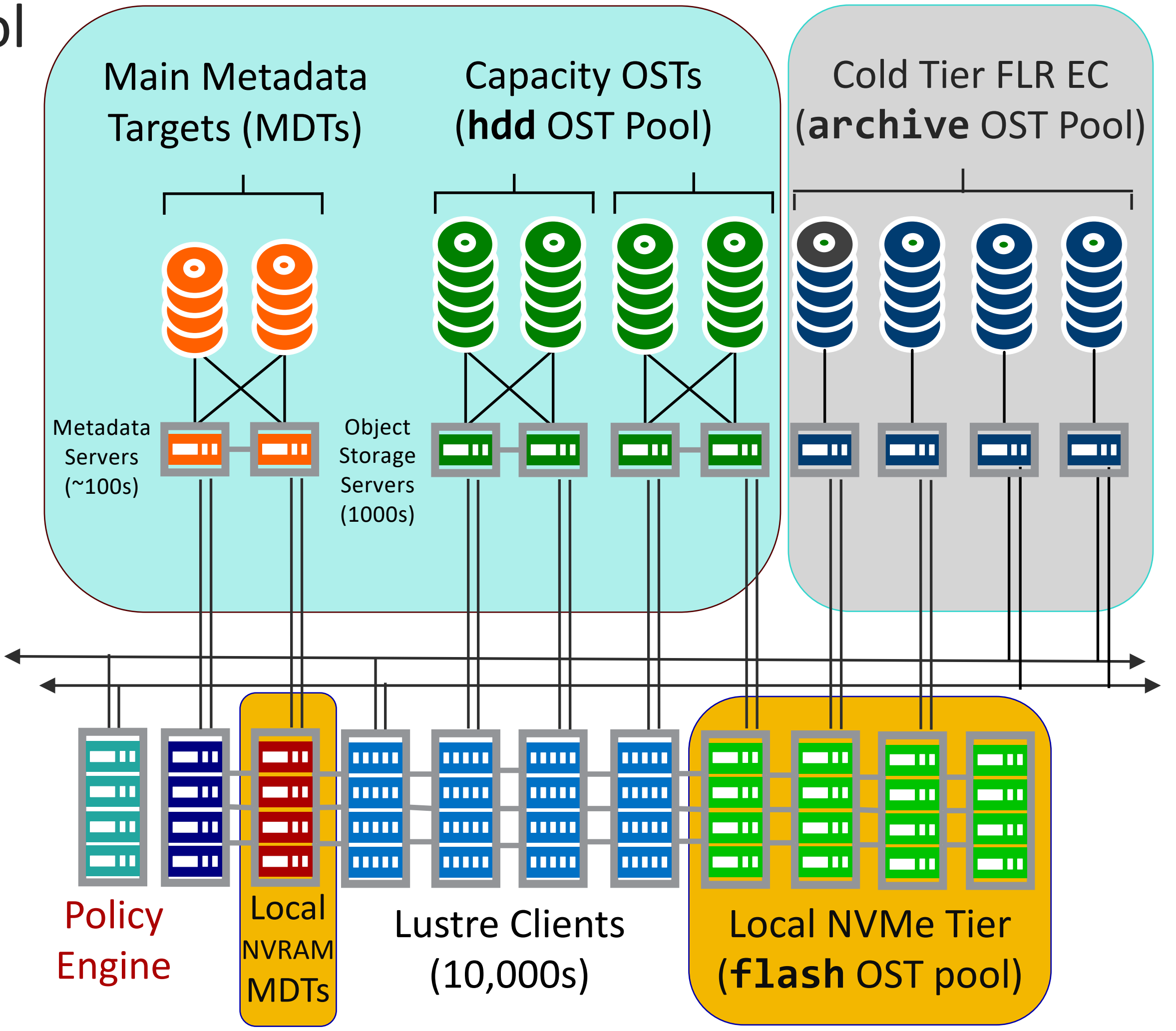
2.13
- **Upstream kernel client cleanups** still in active development/merge (ORNL, SuSE)

2.14
- **Pool Selection Policy** by filename extension, NID, UID/GID (LU-11234, WC)
- **Dynamic OSS page cache** based on RPC IO size (LU-12071, WC)
- **`fallocate()`** for file preallocation (ldiskfs only), hole punch (LU-3606, WC, User)
- **`statx()`** for lightweight attribute fetching (LU-10934, WC)
- **`O_TMPFILE`** for creating temporary files outside namespace (LU-9512)

Pool Quotas for OSTs (LU-11023, Cray) (2.14+)

- ▶ Account/limit space for OSTs in a specific pool
  - Control usage of small flash OSTs in tiered config
- ▶ Use existing Lustre quota infrastructure
  - OST already tracks space per UID/GID/ProjID
  - Pool usage based on sum of current OSTs in pool
- ▶ Add pool quota limits per UID/GID/ProjID
  - No extra accounting on the OSTs
  - 2.14 Only new aggregation/reporting by MDS

- TBD ▶ Integrate OST selection with quota usage
  - Avoid OSTs with no/little quota available
- ▶ Add MDT pools after OST pools complete
  - Manage/balance DoM MDT space usage
  - Handle MDT storage classes (e.g. NVRAM vs. NAND)


Main Metadata Targets (MDTs)
Capacity OSTs (hdd OST Pool)
Cold Tier FLR EC (archive OST Pool)
Metadata Servers (~100s)
Object Storage Servers (1000s)
Policy Engine
Local NVRAM MDTs
Lustre Clients (10,000s)
Local NVMe Tier (flash OST pool)

Client-Side Data Encryption at Rest (LU-12755, WC) (2.15)

Whamcloud

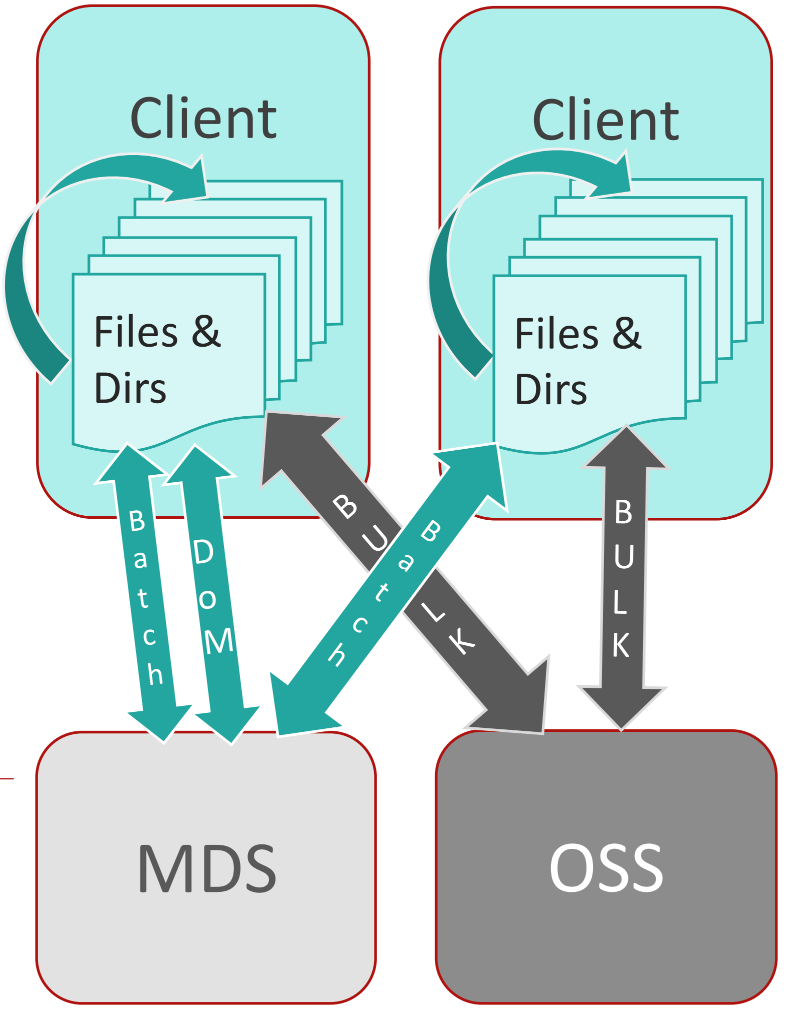
- Protect from storage theft/mistakes network/admin snooping
- **Encryption on Lustre client** down to storage
  - Data is **encrypted before sending** to servers
  - Data is **decrypted after receiving** from servers
  - Servers/storage only see encrypted data/filenames
  - Only client nodes need access to user encryption keys
  - **Transparent to backend** filesystem/storage (ldiskfs/ZFS)
  - Utilize larger client CPU/accelerator capacity
- **Ext4/f2fs `fscrypt` library/tools base** (don't invent it!)
  - Tunable encryption setting/key(s) per directory tree
  - **Per-file encryption key(s)**, itself encrypted by user key
    - **Fast and secure deletion** of file once per-file key is erased
  - Filenames encrypted in MDT directory entries

Metadata Writeback Cache (WBC) (LU-10983, WC) (2.15+)

- ▶ Create new dirs/files **without RPCs in client RAM** (or local NVMe)
  - Lock new directory exclusively at mkdir time
  - Cache new files/dirs/data only in RAM/local NVMe until cache flush
- ▶ **No RPC round-trips** for file modifications in new directory
- ▶ **Files globally visible on flush** to MDS, *normal afterward*
  - Flush top directory to MDS upon other client access, lock conflict
    - o Create top-level entries, exclusively lock new subdirs, release parent
    - o Repeat as needed for portion of namespace being accessed remotely
  - Flush rest of tree in background to MDS/OSS by age or size limits
- ▶ Basic WBC prototype developed to test concept
  - No cache/quota/space limits, no background flushing, no batching, ...

2.15 • 10-20x *single-client* speedup in early testing (`untar`, `make`, ...)

2.16 ▶ **Aggregate operations to server** to improve performance
  - Batch operations in one RCP to reduce network traffic/handling
  - Batch operations to **filesystem to reduce disk IOPS**



Whamcloud

Thank You!
Questions?

Ongoing ldiskfs Improvements (2.13+)

- Major `ldiskfs` features merged into upstream `ext4/e2fsprogs` (WC, Cray)
  - Large xattrs (up to 64KB/xattr) stored in separate inode (**`ea_inode`**)
  - Large directories over 10M entries/2GB (**`large_dir`**)
  - 2.13 Project quota accounting/enforcement (**`project`**)

- 2.14 One more Lustre-specific feature remains to be merged to `ext4/e2fsprogs`
  - Extended data in directory (**`dirdata`**) - needs unit test interface before merge
- Existing `ext4` features available that could be used by Lustre on `ldiskfs`
  - Efficient block allocation for large OSTs (**`bigalloc`**)
  - Tiny files (1-600/3800ish bytes) stored directly in the MDT 1KB/4KB inode (**`inline_data`**)

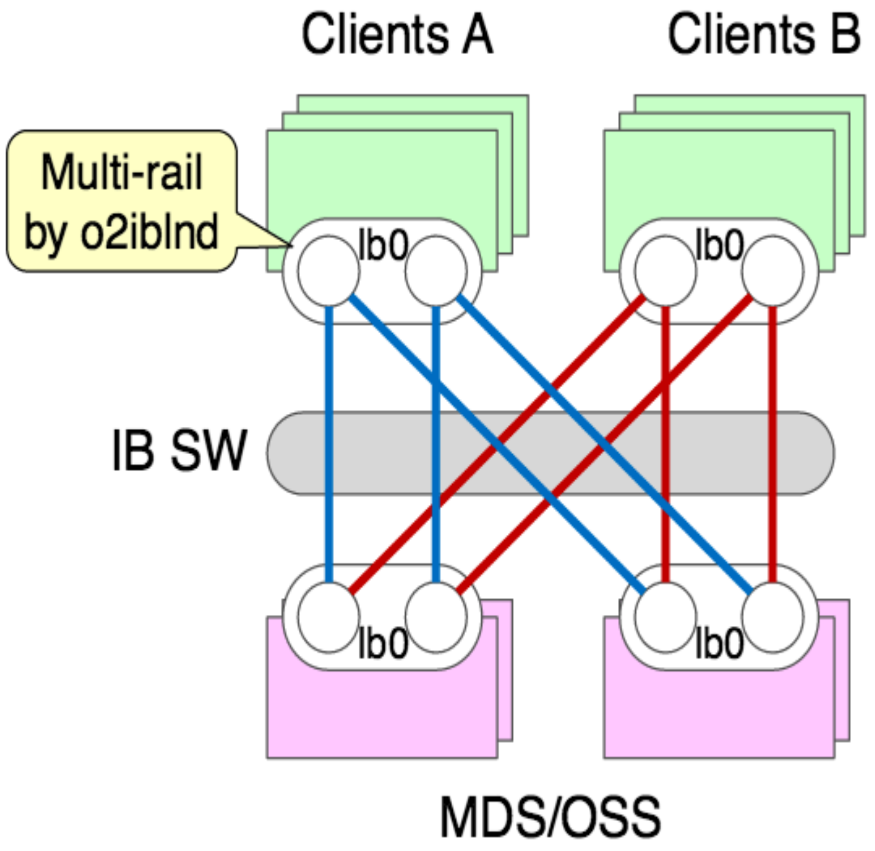
  - 2.15 Metadata integrity checksums (**`metadata_csum`**)
- New `ext4` features currently under development
  - **Data Verity** – Merkle tree of data checksums stored persistently on *read-only* files
  - **Directory shrink** – reduce directory block allocation as files deleted

LNet Multi-Rail Selection Policy (2.13+)

- Multi-Rail routing (LU-11299, WC, Cray)
  - Extend LNet Multi-Rail to router nodes
  - 2.13 Improve handling of mixed MR/single networks

2.14

- User Defined Selection Policy (LU-9121, WC)
  - Fine grained control of interface selection
    - TCP vs. IB networks, primary vs. backup
  - Optimize RAM/CPU/PCI data transfers
  - Useful for large NUMA machines



Community Events

Gaël Delbary - CEA

Kristy Kallback-Rose - NERSC

FROM RESEARCH TO INDUSTRY

LAD 2020

November 19th, 2019

Gaël DELBARY

LAD 2020

- **Thanks to attendees, speakers who came to the last LAD**

- **Thanks to fill up the survey (> 50% of attendees)**

- **Next LAD:**
  - As requested in the survey, we will try to open sooner the registration, like the call for papers. Dates TBD
  - Period: From 09/07/2020 to 09/30/2020. 3 days conference.
  - Venue: Maybe another city that Paris, perhaps Bordeaux, TBD

Questions?

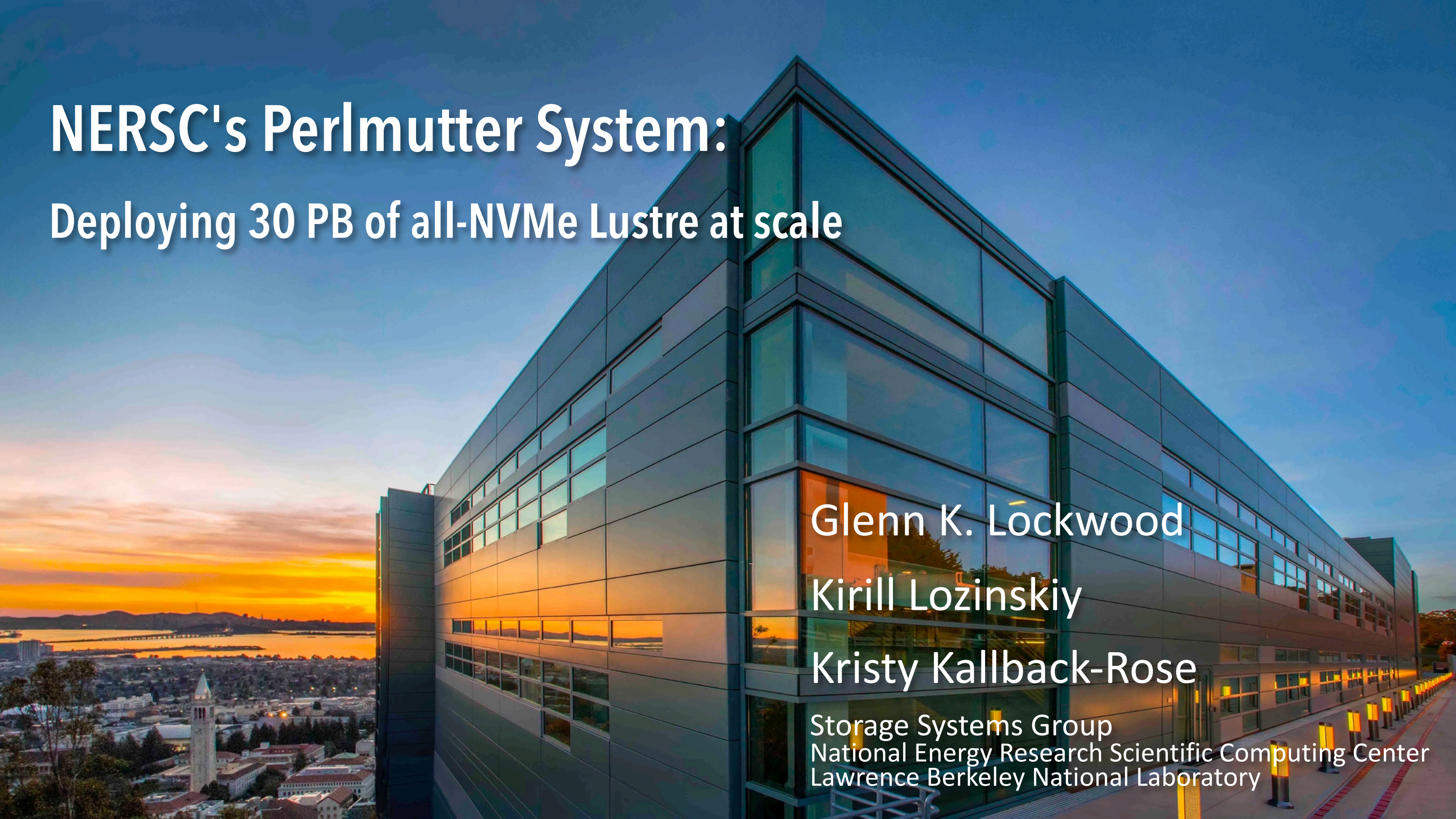
SAVE THE DATE

LUSTRE USER GROUP (LUG) 2020

JUNE 9 - 12, 2020

BERKELEY, CALIFORNIA

Hosted by LBNL/NERSC, UC Berkeley Research IT, and OpenSFS



NERSC's Perlmutter System:

Deploying 30 PB of all-NVMe Lustre at scale

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Storage Systems Group
National Energy Research Scientific Computing Center
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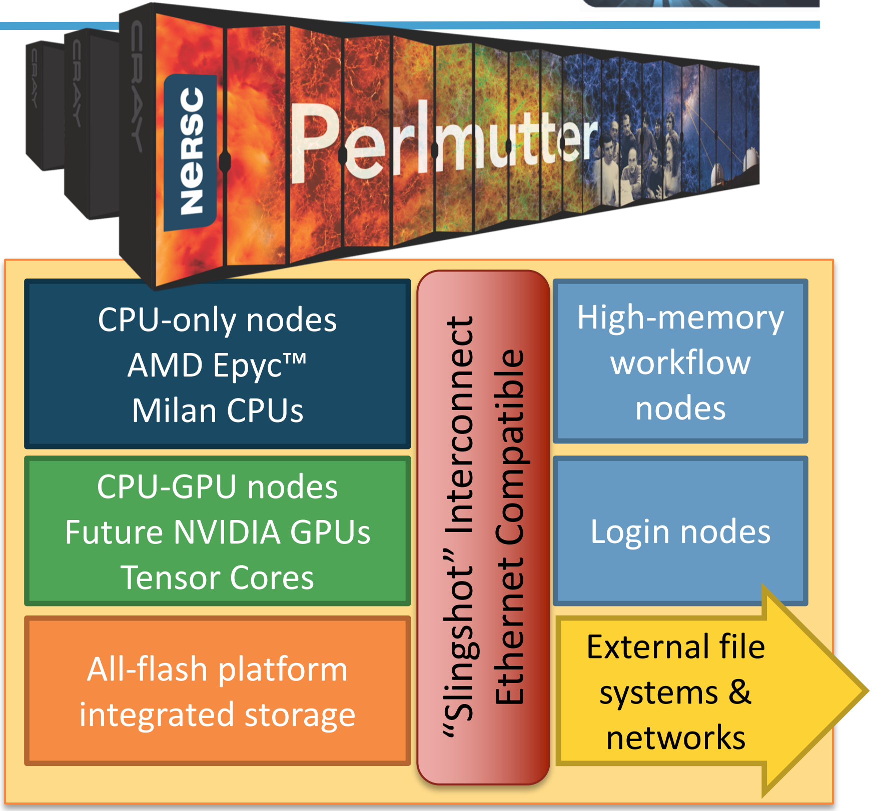
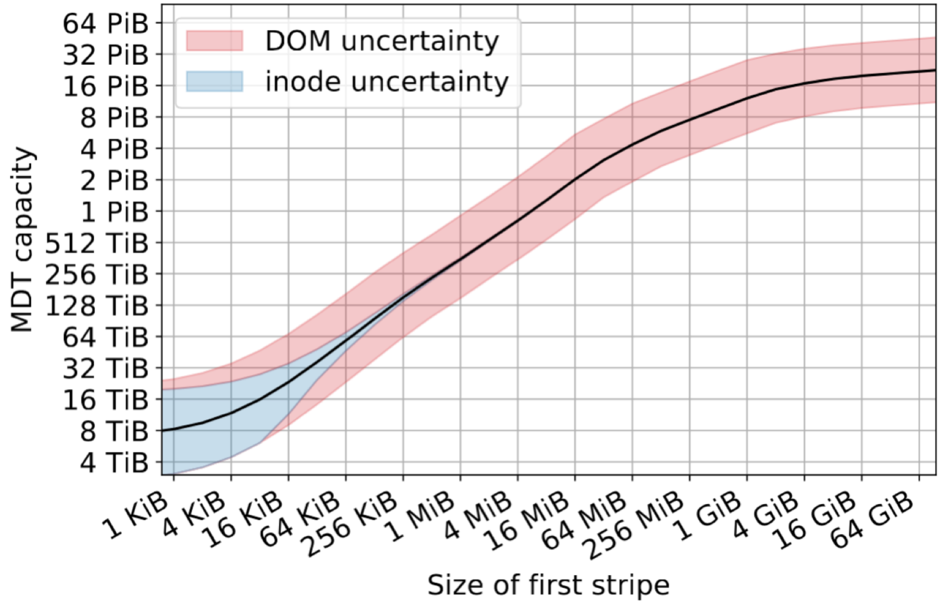
NERSC's 2020 System: Perlmutter

- **Cray Shasta**
  - 3x to 4x capability of Cori
  - GPU-accelerated and CPU-only nodes
  - Cray Slingshot interconnect
- **Single-tier, all-flash Lustre**
  - Cray E1000F-based system
  - 30 PB usable capacity
  - ≥ 4.0 TB/s sustained bandwidth
  - ≥ 7,000,000 IOPS (read *and* write)
  - ≥ 3,200,000 file creates/sec



NERSC-Cray Collaboration

- How much capacity? How much endurance?
- DNE, DOM configuration?
- ldiskfs or ZFS? Which meets performance spec?



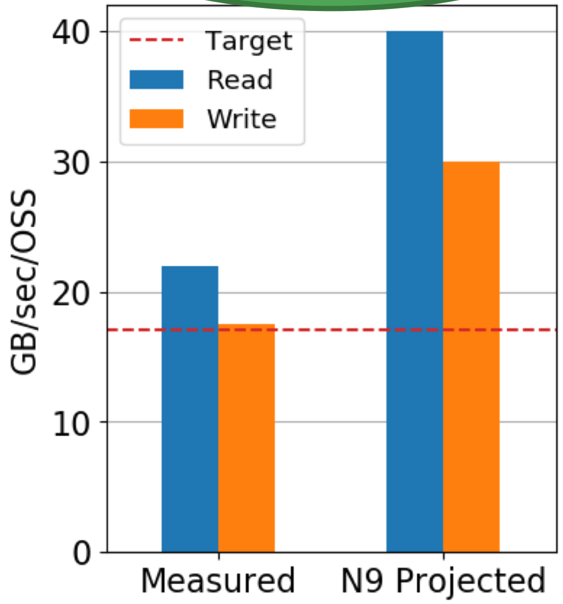
Above: optimal MDT capacity for different DOM component sizes. See Lockwood et al.,"A Quantitative Approach to Architecting All-Flash Lustre File Systems" in High Performance Computing, Chapter 16. https://doi.org/10.1007/978-3-030-34356-9_16

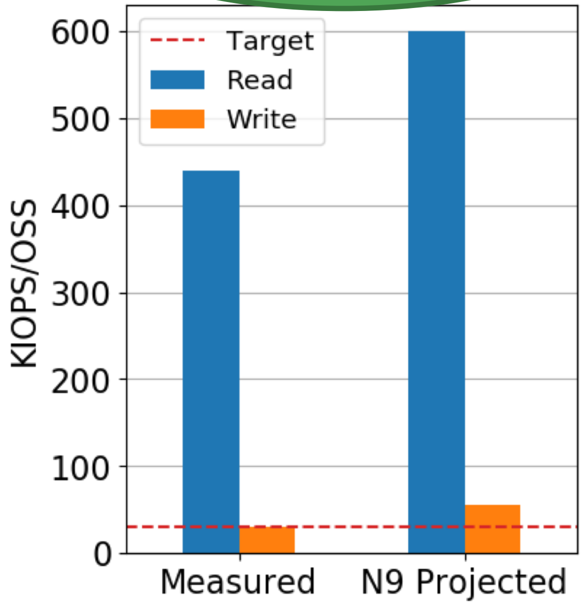
Cray's work on all-NVMe Performance - IOR

Cray's Test OSS	Perlmutter (Cray E1000F)
24c AMD Rome	≥24c AMD Rome
2x EDR (100G)	≥2x Slingshot (200G)
PCIe Gen3 SSDs	PCIe Gen4 SSDs
Cray Lustre (community + forward-ported patches)	
Declustered RAID6 8+2+1 (GridRAID)	

22 GB/s/OSS read
18 GB/s/OSS write

440 KIOPS/OSS read
30 KIOPS/OSS write





NERSC

Thank you—and we're hiring!

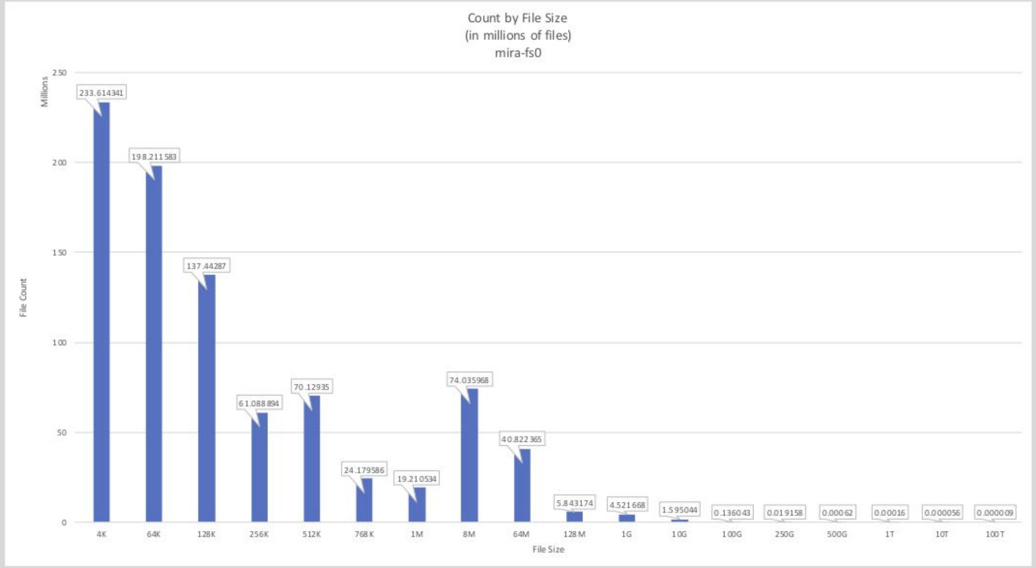
Ask any NERSC staff for more info

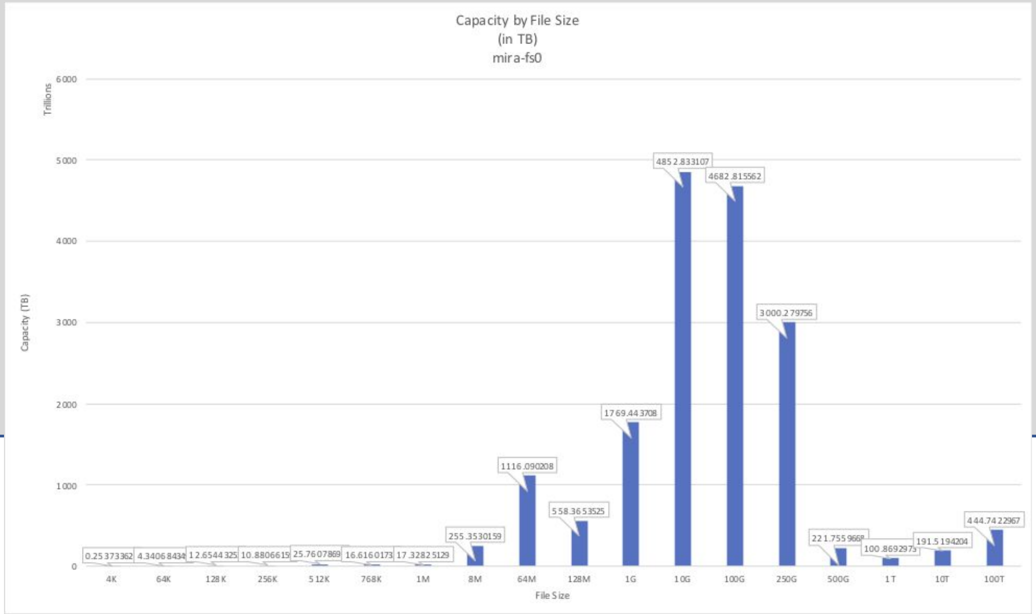
HPC

Argonne Leadership Computing Facility
Data-on-Metadata Projections

- ALCF acquiring new Global (or Centerwide) File System
  - Cray E-1000 - Lustre
  - 150 PB @ 1000 GB/s

- ALCF has existing large scale file system in production since 2012
  - DDN 12k - GPFS
  - 20 PB @ 200 GB/s





European Open File System

ALCF
DoM Projections

scaling	7.5x
total files	870,420,000
files >64M	52,820,845
files >8M	126,820,845
md cap	12.26
target NVM	320.00
DoM available	**307.74**

DoM Size	Naïve Est.	File Count Est.
64K	389.11 365.50 332.41	**291.21** **267.59** **234.51**
128K	778.22 730.99 664.83	487.29 440.06 373.90
512K	3112.86 2923.96 2659.32	1186.14 997.24 732.60
1024K	6225.73 5847.92 5318.64	1751.45 1373.64 844.35

DoM Size	Savings files ≥64M	Savings files ≥8M
64K	(8%) 23.61	(19%) 56.69
128K	(10%) 47.23	(23%) 113.39
512K	(16%) 188.90	(38%) 453.55
1024K	(22%) 377.80	(52%) 907.09

BP migration to PFL

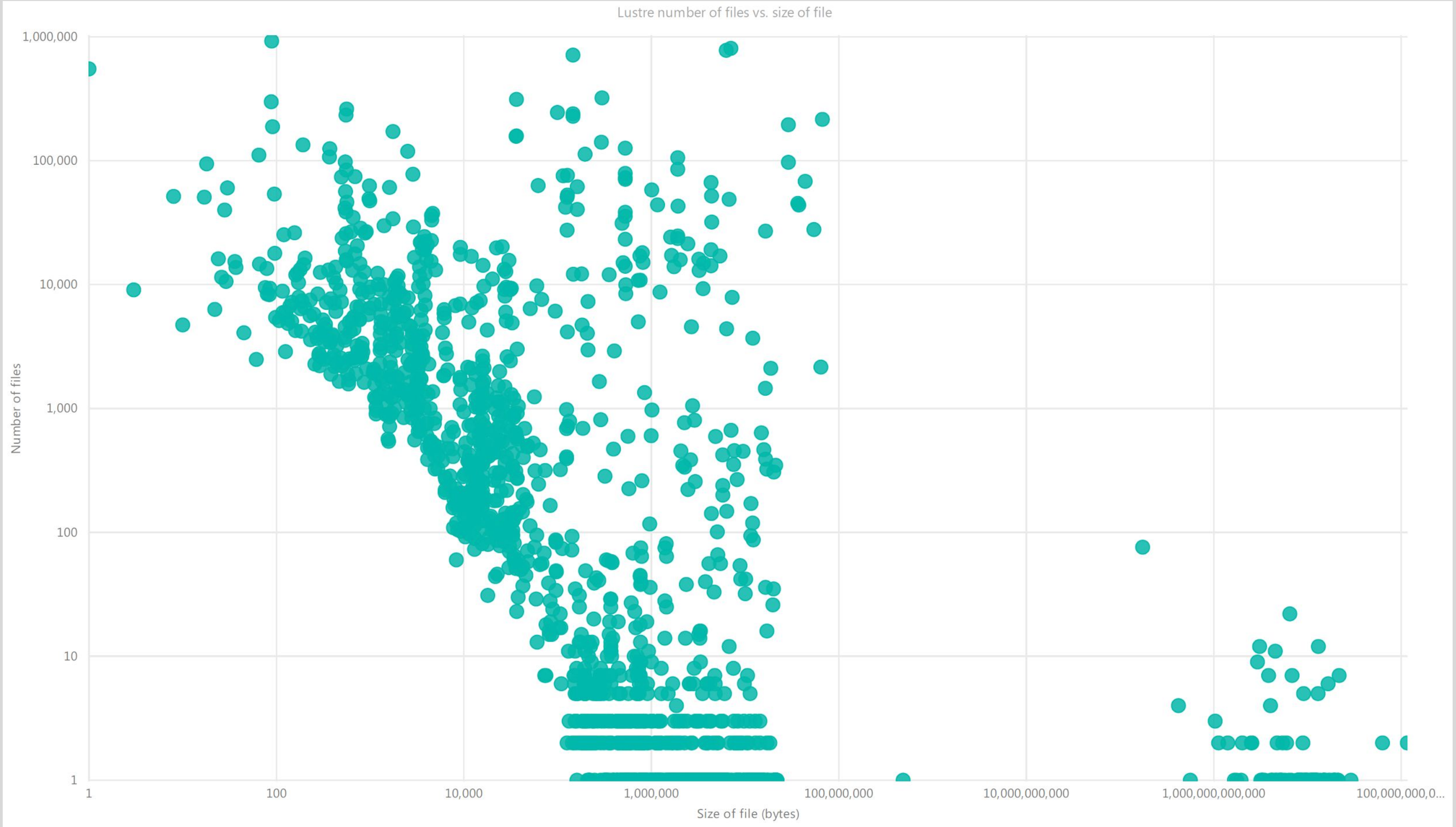
- Upgraded all 4 file systems in place to Lustre 2.10.5 in Oct. 2018
- Recursively changed default directory striping to PFL in Dec. 2018
- All new files have been PFL ever since

BP realized benefits of PFL

- No more OST imbalance and full OSTs
- No more jobs hammering a single OST
- Every job better utilizing the file system

BP interest in DoM

- 79.7% of our files are <= 1 MB


Lustre number of files vs. size of file
Number of files
1,000,000
100,000
10,000
1,000
100
10
1
1
100
10,000
1,000,000
100,000,000
10,000,000,000
1,000,000,000,000
100,000,000,0...
Size of file (bytes)

BP interest in DoM

- Recently acquired new file system with 30 TB usable NVMe for MDT
- Plan on using DoM + PFL
- Expecting good improvements for small files

Stanford: DoM/PFL on Sherlock

DoM/PFL in production since February 2019 with ~1,500 clients

- DoM
    - **Performance problems with shared files** with multiple writers, because locking is made on the whole DoM region (no extent locking; see **LU-10664**)
    - Double sentence: **impact on filesystem metadata performance**
- PFL
    - **Multiple benefits in dynamic file striping with PFL:** automatically improve performance for large files and avoid OST usage unbalance
    - Appending to a PFL file will cause **all** layout components to be instantiated; **FIXED in Lustre 2.13** but not backported to 2.12 yet; see **LU-9341**

AI & Cloud

AI & Cloud Discussion

- End Users
  - Who is using Lustre in the cloud?
  - For what workloads?
  - Why cloud vs on-prem?
- Service Providers
  - Are you using Lustre for your AI customers?
  - What configuration are you using?

Additional Discussion Topics

- What conferences should we target to generate interest in Lustre?
- How to improve user experience?
- How to simplify layout specifications?

- What are we missing?

Mark Your Calendars: Community Events

- LUG'20
  - June 9 - 12 - Berkeley, CA
- ISC'20 Lustre BOF
  - June 21 - 25 - Frankfurt, Germany
- LAD'20
  - September - Paris, France

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