From lab to enterprise - growing the Lustre* ecosystem

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High Performance Data Division

Drivers for change

Lustre has always supported high performance computing

- Extreme performance at extreme scale

New challenges for Lustre as HPC expands into new IT domains and markets

- Performance requirements are changing
  - Not just about massive streaming IO performance and huge files
  - Small random IO to large files, massive collections of tiny files
  - Diverse and unstructured
- Reliability, Availability, and Serviceability (RAS)
  - Resilience, service level agreements (many 9’s uptime)
  - Disaster recovery across sites
- Security of data in flight and at rest

Requirements of key market segments

Life sciences

- Small file workloads – very large file populations, millions of files
- Security and privacy – personal data, protected health information

Weather and climate

- Reliability – mission-critical workloads for forecasts and emergency modelling
- Small files – mixed workloads, but small file workloads are prevalent

Media, Manufacturing and EDA

- Small files, Reliability

Financial services

- Small files, Reliability, Security

Scaling metadata performance

Increasing single client metadata performance

- Lustre currently limits each client to 1 in-flight metadata modifying RPC
  - Single last_rcvd slot on MDT for each client to reconstruct RPC reply
- Change to dynamic log removes in-flight limit
  - Improved client multi-threading

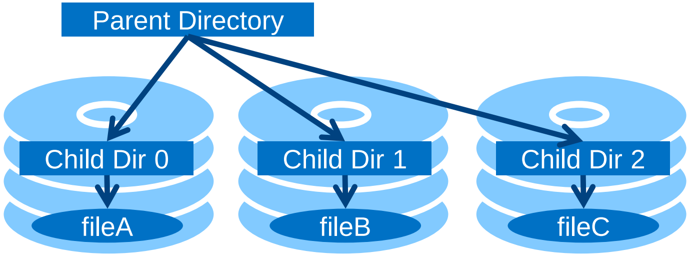
Scaling metadata performance

Horizontally scaling metadata performance

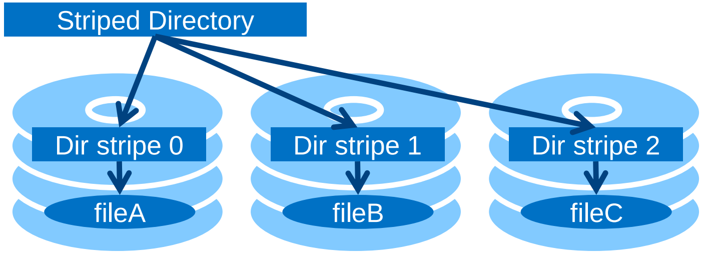
- Phase 1: Remote directories distribute a directory tree onto a separate MDT
- Phase 2: Striped directories distribute a single directory across multiple MDTs

Efficient general purpose distributed transaction protocol

- Remove disk sync latency from critical RPC path
- Assured recovery on client and/or server failure



DNE Phase 1

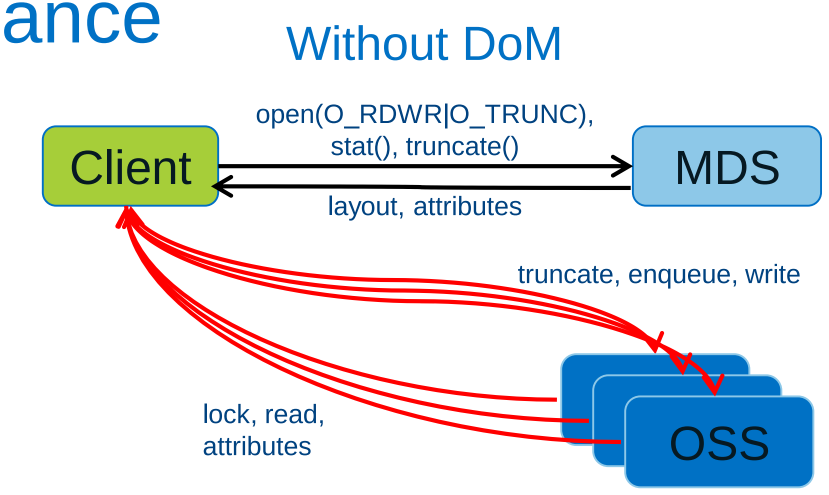


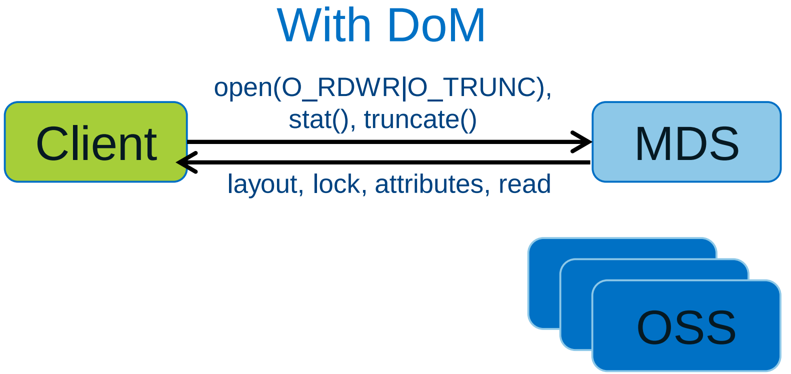
DNE Phase 2

Scaling small file performance

Data on MDT

- Co-locate data and metadata for small files
- Large streaming IO on OSTs not disturbed
- Further optimize IO rates with flash storage
- Scale out performance with striped directories





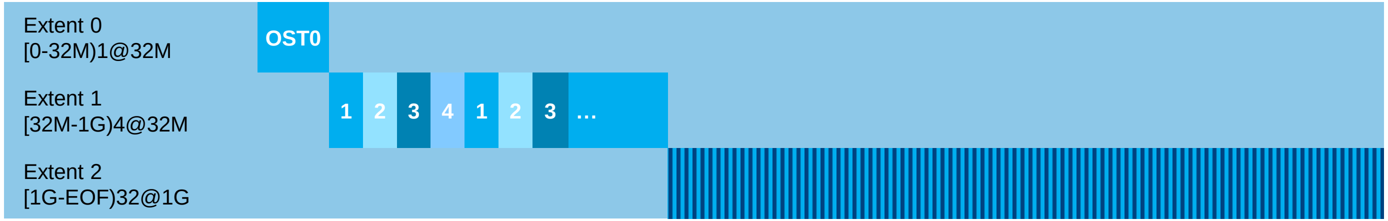
Layout enhancement

Allow file layouts beyond simple striping

- Different layouts for different ranges of each file
- Layouts can overlap (mirror) and be on different types of storage

Progressive File Layout

- Increase stripe count as file size increases
- Automatic layout for optimal performance of small and large files
- Layout extents can be disjoint or overlapping
  - RAID-1 mirroring → overlapping [0, EOF), [0, EOF)



Fault tolerance

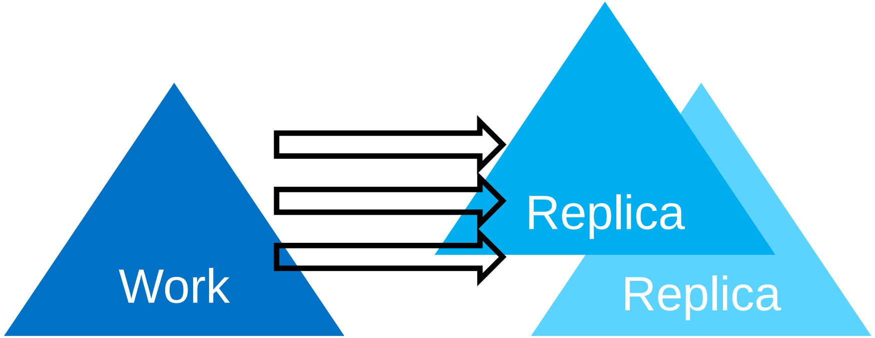
Replication within the filesystem

4 stripes 3 mirrors	0	1	2	3	0	1	2	…
	0’	1’	2’	3’	0’	1’	2’	…
	0’’	1’’	2’’	3’’	0’’	1’’	2’’	…

- Improve reliability of commodity storage hardware
- Increased data availability
  - No need to wait for failover
- Delayed or immediate mirroring of writes to replicas (overhead vs. availability)
- Improved read performance from multiple replicas

Replication to external storage

- Off-site disaster recovery
- Multi-version backups
- Requires…
  - Incremental update
  - Safe, reliable, efficient data migration



Snapshot

Data protection mechanism for checkpointing a file system

Several purposes

- Quick undo / undelete / roll-back in case of user/administrator error
- Prepare a consistent, read-only view of data for backup
- Prepare for software upgrade

ZFS* Snapshot

- Leverage the native snapshot in ZFS
- Create a coordinated snapshot across all storage targets

Security – market drivers

Demand for control of restricted information

- Life sciences, including health care (HIPAA regulation)
- Government, e.g. defense (ICD 503 directive)
- Aerospace, shipbuilding

Increased regulation of personally identifiable information

Movement of workloads to cloud – access must be constrained, data secured

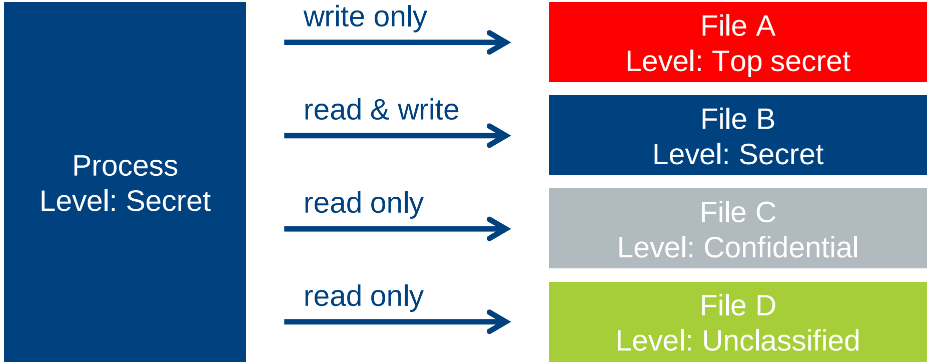
Financial impact of data theft is significant

- Healthcare average cost per breach $3.5M in 2013, some cases significantly larger
- Loss of credibility, loss of revenue as people move to other providers

Access control

SELinux provides fine-grained, mandatory and role-based access control

- MAC – administrative control of policy definitions
  - Mandatory means enforcement by the OS – users cannot bypass
- RBAC – access controls are assigned to roles, not users
  - Users are then assigned to one or more roles
- MLS – multi-level security:



Encryption

Encryption of data in flight

- Native implementation in Lustre
  - IU Shared-Key Crypto
  - Kerberos

Encryption of data at rest

- Block device encryption with DM-Crypt / LUKS – no change to Lustre required
- Potential for client-side encryption / decryption integrated into Lustre client

Summary

The Lustre community must continue to drive innovation in HPC storage

Increase Lustre’s versatility for an ever-widening spectrum of applications

- Deliver performance across a wide range of workloads

Enterprise data management

- Fault tolerance for critical production data
- HSM
- Replication for disaster recovery
- Snapshot

Security and encryption for sensitive data

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