Lustre at DKRZ

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Overview •			
Lustre a	at DKRZ		

The Mistral supercomputer was shipped with Lustre

- 4 PFLOP/s peak system, 3361 nodes, 102k cores
- 52 PiB Lustre storage
- Roughly 6 M EURO
- See: https://www.vi4io.org/hpsl/2017/de/dkrz/mistral
- System was procured in two phases
 - 2015: Phase 1 with 31 PiB storage
 - 2016: Phase 2 with 21 PiB storage
- Other systems/services at DKRZ use Mistral's Lustre storage
- Lustre aspects
 - RobinHood for QoS and policy management
 - Lustre 2.5 Seagate edition (with patches from 2.7+)
 - University of Hamburg is IPCC for Lustre Researching file-system compression

 Overview
 Mistral
 Mistral's I/O Performance
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I/O Architecture (Phase 1)

- 31 ClusterStor 9000 Scalable Storage Units (SSUs)
 - SSU: Active/Active failover server pair
- Single Object Storage Server (OSS)
 - 1 FDR uplink
 - GridRaid: (Object Storage Target (OST))
 - 41 HDDs, de-clustered RAID6 with 8+2(+2 spare blocks)
 - 1 SSD for the Log/Journal
 - 6 TByte disks
- 31 Extension units (JBODs)
 - Do not provide network connections
 - Storage by an extension is managed by the connected SSU
- Multiple metadata servers
 - Root MDS + 4 DNE MDS
 - Active/Active failover (DNEs, Root MDS with Mgmt)
 - DNE phase 1: Assign responsible MDS per directory



I/O Architecture (Phase 2)

- Adds another file system (Now two)
 - Both mounted on all compute nodes
- 34 ClusterStor L300 Scalable Storage Units (SSUs)
 - Uses a slightly different softwareF
- 34 Extension units (JBODs)
- Storage hardware
 - Seagate Enterprise Capacity V5 (8 TB) disks
- Multiple metadata servers
 - Root MDS + 7 DNE MDS

Parallel File System

Lustre 2.5 (Seagate edition, some backports from 2.7+)

Filesystem setup

- We have two file systems: /mnt/lustre0[1,2]
- Symlinks (for convenience): /work, /scratch, /home, ...
- For mv, each metadata server behaves like a file system

Assignment of MDTs to Directories

- In the current version, directories must be assigned to MDTs
 - /home/* on MDT0
 - /work/[projects] are distributed across MDT1-4
 - /scratch/[a,b,g,k,m,u] are distributed across MDT1-4
- Data transfer between MDTs is currently slow (mv becomes cp)
- We transfer projects to the phase 2 file system
 - New projects are only created on the phase 2 system

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Phase 1 + 2

- 65 SSUs · (2 OSS/SSU + 2 JBODs/SSU)
- **1** Infiniband FDR-14: 6 GiB/s \Rightarrow 780 GiB/s
- 1 ClusterStor9000 (CPU + 6 GBit SAS): 5.4 GiB/s
- L300 yield IB speed, still we consider 5.4 GiB/s ⇒ aggregated performance **704 GiB/s**
- Phase 2: obd-filter survey demonstrates that 480 GB/s and 580 GB/s can be delivered

	Mistral's I/O Performance	
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Performance Results from Acceptance Tests

- Throughput in GB/s (% to peak) measured with IOR
 - Buffer size 2,000,000 (unaligned) on 42 OSS (Phase 1), 64 (P 2)
 - In the phase 2 testing, the RAID of at least one OSS is rebuilding

	Phase 1		Phase 2	
Туре	Read	Write	Read	Write
POSIX, independent ¹	160 (70%)	157 (69%)	215 (62%)	290 (84%)
MPI-IO, shared	52 (23%)	41 (18%)	65 (19%)	122 (35%)
PNetCDF, shared	81 (36%)	38 (17%)	63 (18%)	66 (19%)
HDF5, shared	23 (10%)	24 (11%)	62 (18%)	68 (20%)
POSIX, single stream	1.1 (5%)	1.05 (5%)	0.98 (5%)	1.08 (5%)

Metadata measured with Parabench / md-real-io pattern

- Phase 1: 80 kOPs/s
 - 25 kOP/s for root MDS; 15 kOP/s for DNEs
- Phase 2: 210 kOPs/s
 - 25 kOP/s for root MDS; 30-35 kOP/s for DNEs

¹1 stripe per file

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Experien	ce with L	ustre		

Performance issues

Nearly full storage, performance drops considerably (expected)

- File open/close degrades significantly
- Read latency of small files untolerable for interactive usage
 - We keep the software tree on Lustre
 - 10s to start certain apps (with hot cache!)
 - Mounting EXT4 volume on top of Lustre is faster (1s)
 - Evaluation of FUSE to cache data better
- DNE Phase 1: mv between directories trigers data movement instead of metadata movement
- Many tunables in kernel, application level
 - Defining number of stripes
 - Suboptimal data sieving in MPI-IO
- Test partition (1% capacity) to identify hw issues would be good

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Experience with Lustre (2)

Reliability

- Had reliability issues with HA (firmware bug), caused bi-weekly reboot of the cluster
- Monthly verification of RAID integrity nice but impacts performance, now runs 2 weeks per month with low priority
- Experience frequent disconnects from clients to servers (100+ per day across the cluster)
- OST down for 1 hour+, shutdown of system not possible

Usability for Admins

- Load balancing between OSTs uses a homebrew solution
- Migrating data between the two file systems is painful
- RobinHood is active development
- Compatibility of Lustre clients sometimes suboptimal

Performance Monitoring

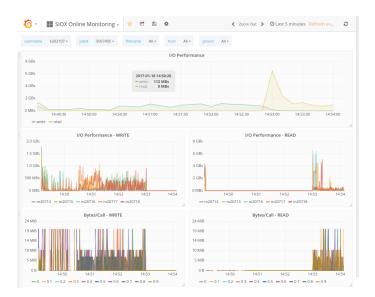
DKRZ's Approach

- We use Grafana for visualization
- Slurm job info is transferred to Lustre OSTs
 - Grafana allows visualization of OST performance per job
- Slurm extensions for client-side monitoring
 - Enable monitoring via: sbatch –monitoring
 - Client side monitoring of Lustre statistics (and cache efficiency)
- Monitoring of client I/O (and mmap) using FUSE with SIOX
 - Provides further information, traces of I/O possible
 - Online support
 - On demand mountable

Regression testing

- Daily regression testing with Jenkins using IOR
 - 20+ patterns, various stripe sizes, used APIs, workloads

Online Monitoring Example



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Performance Regression with Full Servers

