ZFS* as backend file system for Lustre* the current status, how to optimize, where to improve

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Agenda

The objective of this presentation is to identify the areas where development is focused in order to fill gap in performance or functionalities.

- Benefit of ZFS and Lustre implementation
- Performance
- Reliability
- Availability
- Serviceability
- How to design
- How to tune

Benefit

ZFS is an attractive technology to be used as backend for Lustre

- Copy on Write improves random or misaligned writes
- Zero offline fsck time
- Rebuild time based on the HDD utilization
- Compression (can also improve I/O performance)
- Efficient snapshotting
- Checksum and on block data corruption protection
- Enabling efficient JBOD solutions
- Integrated flash storage hierarchal management

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How do Lustre and ZFS interact ?

Lustre depends on the “ZFS on Linux” implementation of ZFS

- Lustre targets run on a local file system on Lustre servers. Object Storage Device (OSD) layer supported are:
  - ldiskfs (EXT4) is the commonly used driver
  - ZFS is the 2nd use of the OSD layer based on OpenZFS implementation
- Targets can be different types (for example LDISKFS as MDTs and ZFS as OSTs)
- Lustre Clients are unaffected by the choice of OSD file system
- ZFS as backend is functional since Lustre 2.4
- ZFS fully supported by Intel

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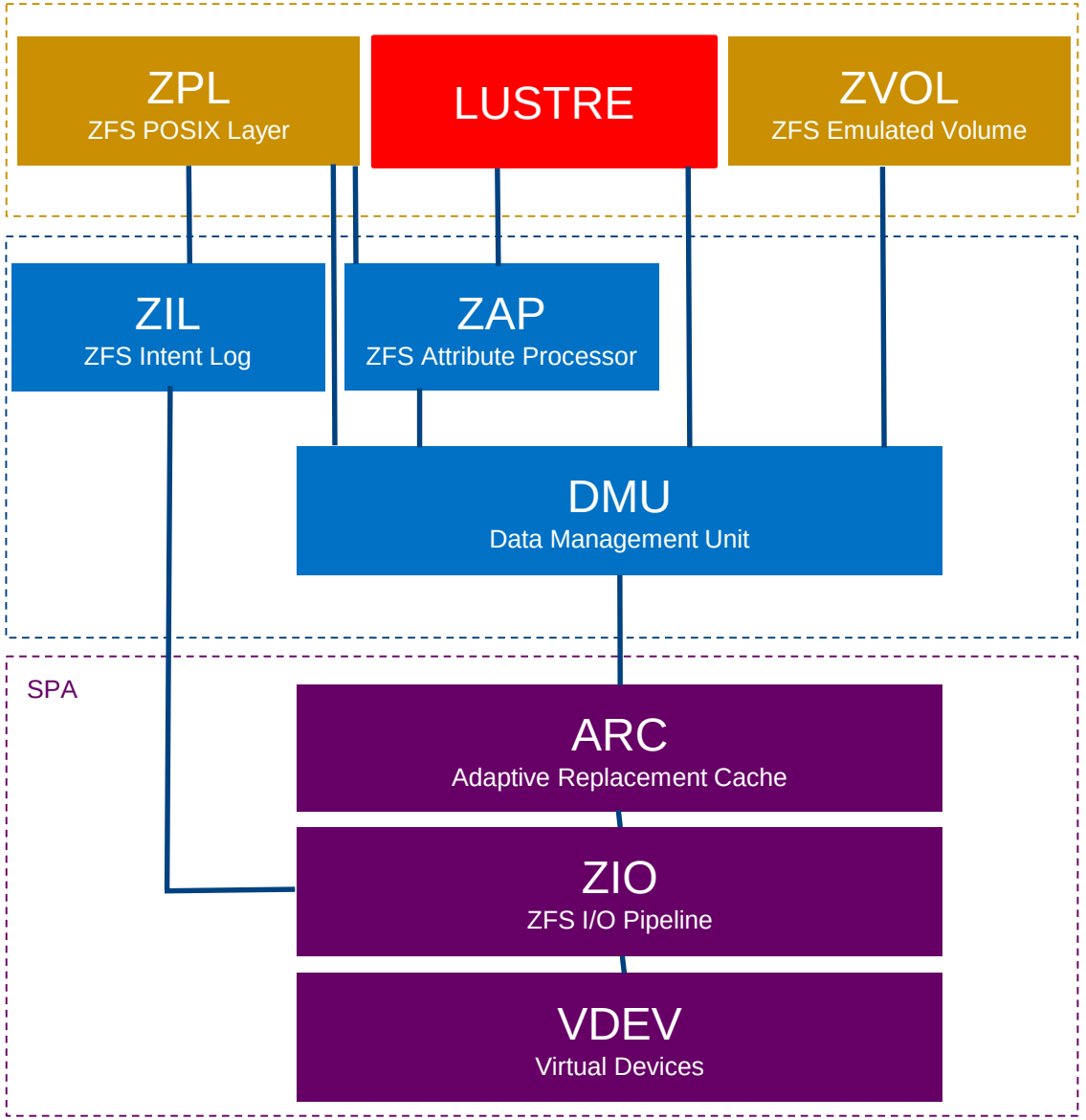
ZFS I/O Stack



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Performance

- Sequential I/O
  - Writes are as good as LDISKFS (or better due the clustering provided by CoW)
  - Reads are affected by the small block size (128K) - LU-6152 + ZFS #2865 planned for 0.6.5
  - Several other minor improvement expected
- Random I/O
  - Random reads I/O can be enhanced using L2ARC devices
  - Writes can be improved by COW but fsync() is a problem without ZIL – LU-4009
- Metadata
  - ZFS Attribute Processor used for all Lustre index files.
  - Increase indirect and leaf block size can help – LU-5391
  - Active OI ZAP blocks should be cached as much as possible to avoid repeated I/Os – LU-5164/LU-5041

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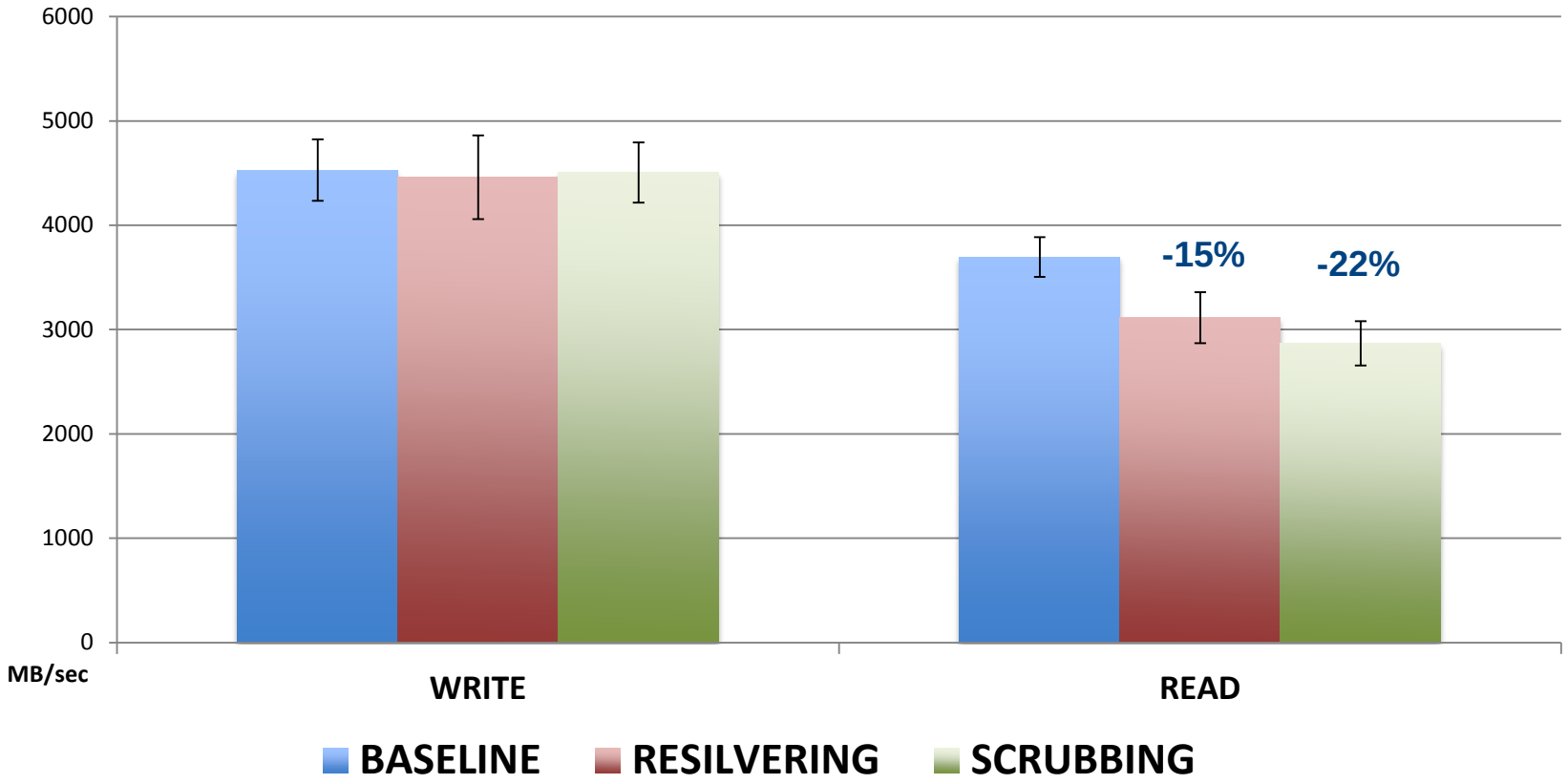
Reliability

ZFS is a robust file system, really designed for high reliability

- Lustre+ZFS is end-to-end checksummed
  - but not integrated with the RPC checksum
- Resilvering = Rebuild based on the utilization of the failed disk
  - Increasing resilvering bandwidth using declustered ZFS – future work
- Corrupted blocks on disks are automatically triggered and scrubbed

Performance regression during repair



Only READS are affected during repair.

Resilvering and scrubbing are autotuned by the ZFS I/O scheduler.

This experiment was conducted using the IOR benchmark on 16 compute nodes across 8 OSTs on 4 OSS.

1 OST was impacted by the repair activity during all the IOR run.

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Availability

- ZFS pools are imported in a persistent manner. Set the "cachefile" property to "none" while creating the pool disable local persistent file.
- Pacemaker’s scripts can be easily developed to:
  - import/export pools
  - mount/umount Lustre targets
- Multi Mount Protection is not yet available – future development

Serviceability

ZFS and online LFSCK can move the serviceability of Lustre to a higher level

- Zero offline fsck time always consistent on disk
- *lctl LFSCK* can repair logical lustre errors online
- Sys Admin challenges with ZFS, JBODs and RAIDZ
  - Multipath configuration. RedHat* version can't allow to set priority, SuSE does. Alignment between RAIDZ array, SAS expander, SAS HBA and OST is critical.
  - How to find a failed disk? sdparm can help with sas_disk_blink script or SCSI Enclosure Services (SES)
- ZFS Event Daemon – can be trigger by errors and make actions/notifications
- DKMS simplify upgrade and management

How to design a ZFS storage server

- CPU
  - Higher performance single core CPU is critical with RAIDZ2
  - If ZFS is used on top of HW RAID (LLNL's mode), CPU doesn't matter
- RAM
  - ECC memory to better detect in-memory corruption
    - If you have corruption in memory, you can get corruption in ZFS (CoW)
  - The faster memory is better for performance reasons
  - A lot of memory (128GB+)
- Storage
  - Design for storage is still 8+2 also for RAIDZ2
  - Lowering the number of OSTs striping together several RAIDZ2 vdev
- We can take advantage of L2ARC devices (and ZIL devices in the future) for OST
  - L2ARC can be installed locally on the server (cache dropped at every import/export)
  - Great **read** IOPS improvement on OST
  - L2ARC device can be attached to a single pool (not shared between pools)

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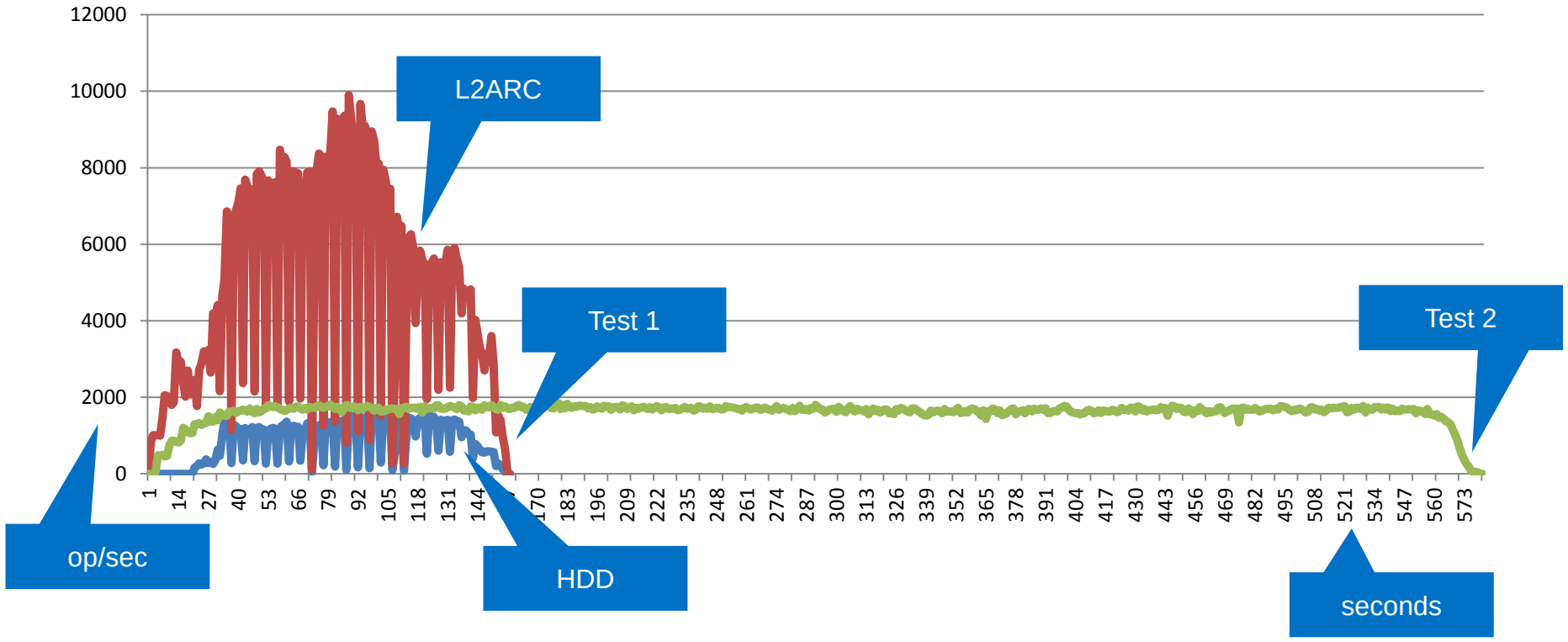
L2ARC benefit



L2ARC device can improve by 8x n. IOPS of a single OST

Test 1 with L2ARC completes in 157 sec

Test 2 without L2ARC completes in 581 sec

Reading 3.84M files each 64K from 16 clients in parallel. Lustre configured using ZFS on 4 OSS. On each OSS, Intel configured 1 OST using 16 HDD and 1 Intel DCP 3700 SSD as L2ARC device. In the chart: operations/sec during both experiments from a single OST

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How to tune – General parameters

Parameter	Notes	Default	Suggested
osd_object_sync_delay_us	To improve fsync() performance until ZIL device, it is possible disable the code which causes Lustre to block waiting on a TXG to sync.		Wait for ZIL support
zfs_prefetch_disable	ZFS's prefetch algorithm was designed to handle common server and desktop workloads.	0	1
metaslab_debug_unload	This option prevents ZFS from unloading the spacemap from a metaslab once it is read in.	0	1
spl_kmem_cache_slab_limit	The SPL slab is known to suffer from a significant level of fragmentation under certain workloads.		16384
spl_kmem_cache_reclaim	By default only a single pass is made over the SPL slabs when reclaim is needed.	1	0

Out-of-the-box ZFS is not tuned for Lustre. Various parameters should be modified for Lustre and reviewed for the specific workload.

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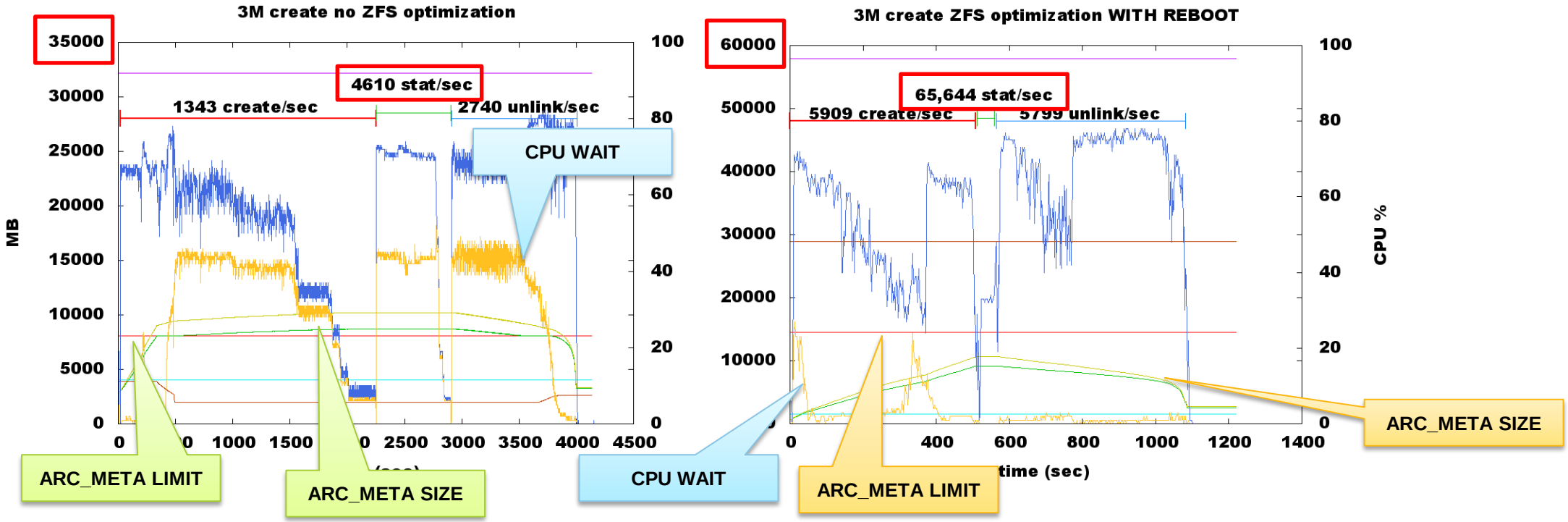
How to tune – ZFS memory management



Parameter	Notes	Default	Suggested
zfs_arc_max	Maximum size of the ARC.	½ RAM	¾ RAM
zfs_arc_meta_limit	Increasing this value will improve performance if the workload involves operations on a large number of files and directories, or frequent metadata operations, at the cost of less file data fitting in the ARC.	¼ ARC	¾ ARC for the MDS only

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How to tune – ZFS I/O scheduler

Parameter	Notes	Default	Suggested
zfs_dirty_data_max	Amount of dirty data on the system, Able to absorb more workload variation before throttling	10% RAM	1 - 4GB
zfs_vdev_async_write_min_active	Minimum outstanding writes per VDEV	1	5
zfs_vdev_async_write_max_active	Maximum outstanding writes per VDEV	10	15
zfs_vdev_async_write_active_min_dirty_percent	Minimum of dirty data to start delay write operations	30	20
zfs_vdev_scheduler	VDEV scheduler	noop	deadline

When dirty data is less than 30% of zfs_dirty_data_max, ZFS keeps 1 outstanding writes per VDEV. Then dirty data would build up very quickly, since there's only 1 outstanding write per disk, ZFS would start to delay or even halt writes.

The zfs_dirty_data_max should ideally match the backend storage capability. The code simply uses 10% of system memory as the default.

Conclusion and future directions

There’s a lot of interesting work already and more to come

- Performance
  - Increasing ZFS block size, Metadata performance, optimizing Lustre code for ZFS
  - Supporting the ZFS Intent Log device
  - Implementing ZFS’s tunables for Lustre during mkfs and mount
- Reliability
  - Implementing De-clustering ZFS
- Availability
  - Implementing Multi Mount Protection for ZFS
- Serviceability
  - ZFS Event Daemon specific scripts for Lustre

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