ZFS*: Metadata Performance

LAD’16

Alexey Zhuravlev, HPDD, Intel
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ZFS metadata performance

• Initial focus on correctness, can now focus on performance
• Performance often reported to be below expectations
• Internal benchmarks confirm this

<table>
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<tr>
<th>Dataset</th>
<th>Type</th>
<th>Method</th>
<th>Create</th>
<th>Stat</th>
<th>Unlink</th>
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<td>400</td>
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</table>
Lustre* on ZFS - Server Layering

MDT

MDD

OST

OFD

OSD-
ldiskfs

OSD-
zfs

Idiskfs

ZFS

(DMU)

OSD-
ldiskfs

OSD-
zfs

Idiskfs

ZFS

(DMU)
ZFS vs ldiskfs: 1M creates, directory/thread

File Creates

Threads

Hardware specification on slide 22
Lustre: mds-survey

- Lustre 2.8 / ZFS 0.6.5
- 2.8 / ldiskfs

File Creates

Threads

Hardware specification on slide 22

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Declaration time: ZFS vs Idiskfs

Hardware specification on slide 22
Declarations: expensive

- The more specific, the more expensive
  - `dmu_tx_hold_zap()` does lookup if name specified
  - `dmu_tx_count_write()` may check few blocks
  - Few calls to `dbuf_find()`
  - Few ZIOs allocated and destroyed with no real need
  - Say, 100K / second
- Lustre uses very specific declarations
  - Which is not required
Declaration time: fixed in LU-7898, landed to 2.9

Hardware specification on slide 22
ZFS: large dnodes

- zfs 0.6.5 supports 512 bytes dnodes
- all EAs Lustre need (LMA, LinkEA, LOV, VBR) do not fit
  - Extra 2 4K blocks are allocated (so called spill block + redundant copy)
  - 8+ GBs to write to create 1M files
- Large dnode patch landed to ZFS master (for inclusion in 0.7 release)
  - Dnode size can vary: 0.5K to few K
  - 1 GB to write to create 1M files
  - Half head seeks to access files (no need to read spill block)
Dnode accounting (ZFS dnode quota)

- ZFS didn’t support dnode accounting
- Lustre implements own primitive schema to support file quota
  - Doesn’t scale well
  - Update 2 accounting files on every file creation – very expensive
- Intel created patch to add native dnode accounting to ZFS (LU-2435)
  - Accounting is implemented in the syncing thread
  - Updates accounting file once
  - Almost ready for landing
Dnode accounting: performance estimation

File Creates

Threads

Hardware specification on slide 22
Lustre: step by step (mds-survey)

![Graph showing file creates vs. threads for different Lustre and ZFS versions.]

- Lustre 2.8 / ZFS 0.6.5
- Lustre 2.9 / ZFS 0.6.5
- Lustre 2.9 / ZFS 0.7
- Lustre 2.10 / ZFS 0.7
- 2.8 / Idiskfs

Hardware specification on slide 22

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ZFS: more optimizations coming

- Active collaboration with upstream ZFS community
- Special thanks to Matt Ahrens @ Delphix who identified multiple bottlenecks
- Few experiments made to see potential improvement
  - Graph in a few slides
DMU object allocation

- `dmu_object_alloc()` serializes all object allocations with a single mutex
- Rescan every few thousand allocations
  - to reuse potentially freed dnodes
  - so-called *revisit problem*
- Every allocation looks up `dbuf` in the global hash table
- Then allocate and fill in-core structures from `dbuf`
- Summary:
  - very expensive
  - doesn’t scale
ZFS: profiling with FlameGraph
ZFS: object allocation

- Possible improvement:
  - Smarter revisit algorithm to skip recently allocated dnodes
  - Concurrent allocation with metadnode broken into chunks
  - Cache last used dbuf to improve single-thread performance
Look at the source

- DMU API uses dnode numbers instead of dnode_t *
  - Even internally
- Results in many dbuf lookups
- Doesn’t scale well with cores
- Lustre file create needs 14 lookups at least (even with all the fixes to Lustre)
- Options:
  - global dnode cache – additional locking
  - local per-cpu/transaction – additional lookups
ZFS: possible improvements

- **dn_struct_rwlock**
  - Used to access dnode fields, taken mostly shared
- **sa_lock**
  - Used to map specific set of EAs into a number encoding this set
  - Doesn’t need to be exclusive
- **ds_bp_rwlock**
  - Used for debugging, can be disabled
- **ds_lock** in dnode_setdirty()
  - Use multilist
ZFS: performance estimations

File Creates

Threads

baseline
no revisit
dnode hold
per-thread alloc
dn_struct_rwlock
sa_lock
ds_bp_rwlock
ds_lock
Summary

• Lustre 2.9 improves metadata performance with ZFS
  • 2x in some cases using same ZFS 0.6.5.7
  • ZFS 0.7 and Lustre 2.10 should bring ZFS in line (or even ahead) of ldiskfs
• Significantly better numbers are expected in the future
• As ZFS gets fixes for the problems discussed above
Test configuration

- 2 x Intel(R) Xeon(R) CPU E5-2660 v2 @ 2.20GHz – 20 cores
- 64GB RAM
- 3 x 500GB local SATA HDD 7200 RPM
- CentOS 7.2.1511
- 3.10.0-327.28.2.el7 kernel (RHEL7)
- No remote clients, just local MDS testing (mds-survey script)