OAK RIDGE National Laboratory

Efficient Metadata Scanning Using ZFS and NVMe-over-Fabrics

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Introduction

First things first: THIS IS A PROTOTYPE!

- We haven't implemented this in production (and probably won't)

Why do this?

- Want to know what's happening on our filesystem
- Traditional techniques don't scale well
  - Running `find` from a client can take hours (or more likely, days) and can heavily load the MDS
  - `lfs find` is better but still not fast enough
  - Lustre changelog can't keep up

Basic Design Goals

- Efficiently & quickly scan the filesystem
  - In this case, “quickly” means “an hour or so”
  - Actually, anything faster than one day is acceptable
- Don’t overload the MDS
  - We don’t want the scanning operation to noticeably slow down normal filesystem operations
- Incremental scans are preferred, but we do need to be able to do a full rescan if necessary.
  - Incremental scans are probably necessary to meet the two previous requirements

ZFS Snapshots?

ZFS snapshots are potentially very useful:

- Low cost to create & destroy (nearly instant)
- Keeping them around only uses space for files that have changed
- They allow us to have a consistent view into the filesystem
- `zfs diff` can report differences between two snapshots

This all sounds promising, BUT…

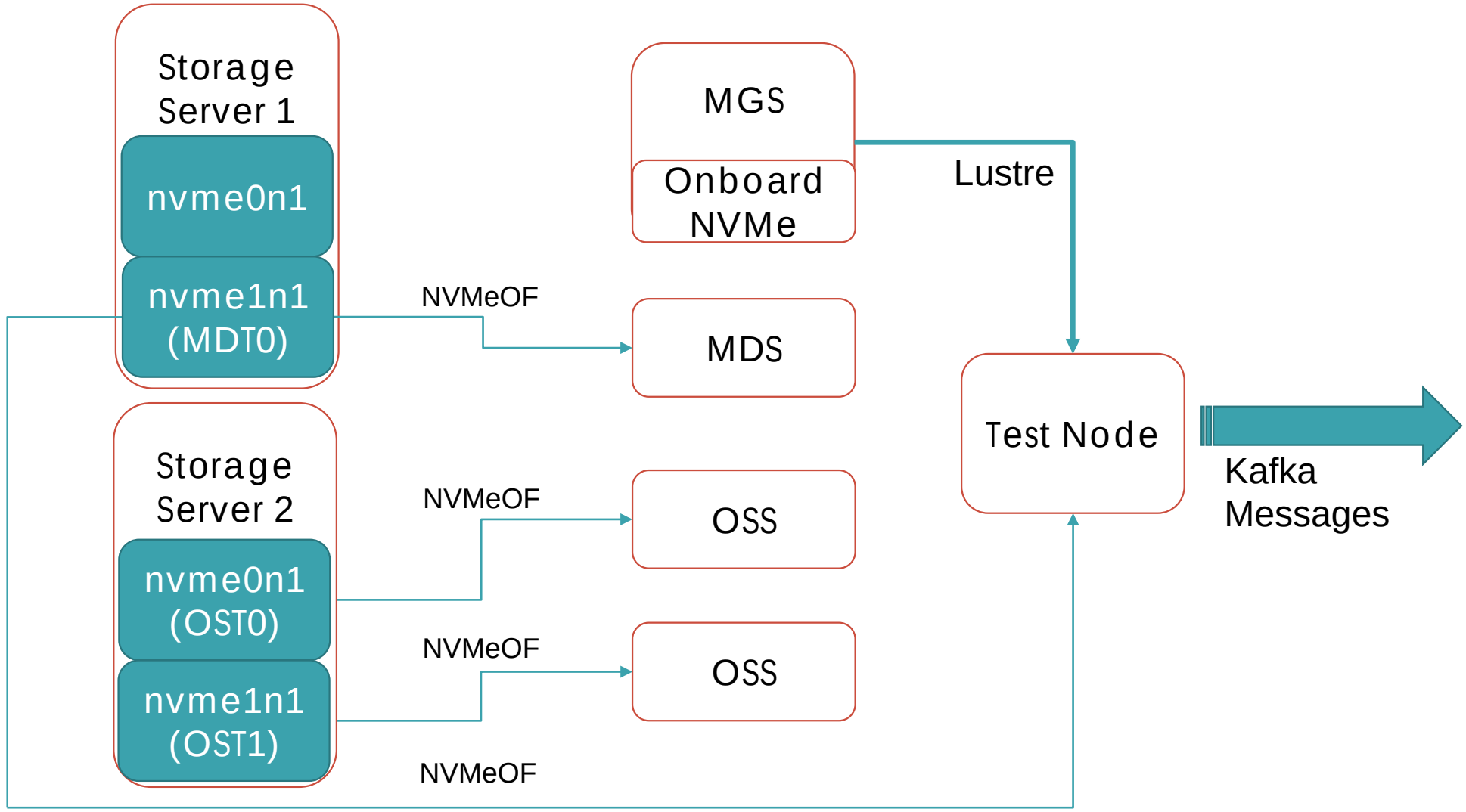
…"Normal" ZFS diff won't work

- In order to actually run `zfs diff`, the ZFS filesystem has to be mounted
- For performance reasons, Lustre doesn't actually mount the ZFS filesystem(s) that are the backing-store for OSTs & MDTs.

How to resolve this impasse?

Use NVMe-Over-Fabrics to DUAL MOUNT the zpool for the MDT(!)

Test Hardware



Order of Operations

1. Create a new snapshot - lctl snapshot_create
2. Import the zpool read-only
3. Mount filesystem (again, read-only)
4. Mount the Lustre snapshot (also read-only)
5. Run zfs diff on the 2 most recent snapshots
    a. Pipe the diff output into a parser script that will stat the files, do any pre-processing and push the results out to Kafka & Elasticsearch.
6. Unmount Lustre & ZFS filesystems and export the zpool
7. (Optional) Delete old snapshot

Ensuring No Writes To The ZPool

- `zpool import` has a read-only flag
- Checked with the developers and confirmed by inspecting the ZFS source code: when the read-only flag is used, the zdev devices are all opened read-only

- Considered using cgroups to add an additional level of safety
  - Didn't get a chance to actually try this out though

Performance Numbers

(For test setup using a single NVMe device for the MDT)

- Diff's / second: ~1900 (~100% CPU)
- Stat's / second: ~11K (~98% CPU)
- Kafka message ingest rate: >50K
- Combined (diff+stat+message publication): 1900/s (~135% CPU)

Does this scale up?

`zfs diff` seems to be the limiting factor: 1 thread, 100% CPU.

- That's 6.8M changed files per hour.
- In a filesystem with 5 billion files, that's 0.13%. Is that sufficient?

The Expense Of ‘stat’

- A lot of the expense of the stat() function comes from the need to get size data from every single OSS that the file is striped across.
- For this application, LSOM (Lazy Size On MDT) would be sufficient.
  - Landed in v2.12
- Need some mechanism to tell Lustre to reply to stat requests with lazy size
  - LU-10934 implements this (using the statx() call instead of stat())
  - Landed in v2.14

Incremental Scan vs. Full Scan

Diffing two snapshots is efficient for incremental scans, but what if we have to do a full (re)scan of the filesystem?

Answer: Take a snapshot right after the filesystem is set up and keep it forever. To do a full (re)scan, diff the latest snapshot against this baseline snapshot.

- Since the filesystem is empty when the base snapshot is created, there's essentially zero cost to keeping this snapshot.

Thoughts & Conclusions

- This design only works for a fairly niche use-case:
  - MDT's must use ZFS and NVMe devices
  - Networking that supports NVMe-over-Fabrics
  - A system large enough that other methods don't work
  - Normal workloads that aren't limited by IOPS
- Actual operations would be perilous
  - One simple mistake – forgetting the read-only flag on the import – could result in your MDT being destroyed
  - It was also unclear if we could ever *prove* that this technique is safe
    - Best we could say was "It didn't corrupt the MDT during our testing."

Closing Remarks & Questions

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