Evaluating Lustre's Metadata Server on a Multi-Socket Platform

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Motivation

Metadata performance can be crucial to overall system performance

- Applications create thousands of files (file-per-process)
    - Normal output files
    - Store their current state, snapshots files
- Stat operation, to check application's state
- Clean "old"- snapshot files and temporary files

Solutions:

- Improve metadata architectures and algorithms
- Use more sophisticated hardware on the metadata servers
    - Increase processing power in the same server, add cores and sockets
    - Replace HDDs with SSDs

Our work

Evaluate Lustre Metadata Server Performance
when using Multi-Socket Platforms

Contributions:

- An extensive performance evaluation and analysis of the *create* and *unlink* operations in Lustre
- A comparison of Lustre's metadata performance with the local file systems `ext4` and `XFS`
- The identification of hardware best suited for Lustre's metadata server

Related Work

Lustre Metadata performance:

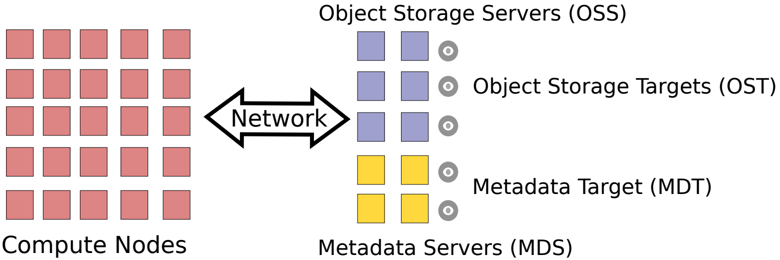
- Alam et al. "Parallel I/O and the metadata wall," PDSW '11
  - Measured the implications of the network overhead on the file systems' scalability
  - Evaluate performance improvements when using SSDs instead of HDDs
- Shipman et al. "Lessons Learned in Deploying the World s Largest Scale Lustre File System," ORNL Tech. Rep. 2010
  - Configurations that can optimize metadata performance in Lustre

Performance scaling with the number of cores:

- Boyd-Wickizer et al. "An analysis of Linux scalability to many cores," OSDI'10
  - Performed an analysis of the Linux kernel while running on a 48-core server

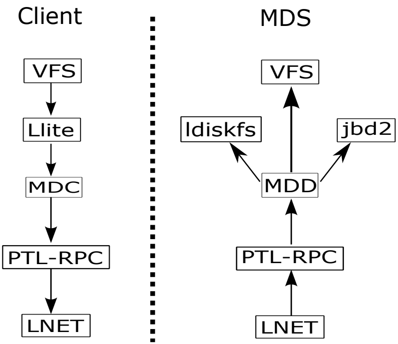
Lustre Overview

- Parallel distributed file system
- Separates metadata to data servers
- 2.6 version supports distributed metadata
- Uses back end file-system to store data (`ldiskfs` and `ZFS`)



Lustre metadata operation path

- Complex path - goes through many layers
- VFS since it is POSIX compliant
- LNET network communication protocol
- File data stored in OSSs
- Lustre inode store object-id ost mapping



Methodology

- Use a single multi-socket server
- Use mdtest metadata generator benchmark to stress the MDS
- Compare with `XFS` and `ext4`
  - `ext4`, since `ldiskfs` is based on it
  - `XFS`, that is a high-performance local node file system
  - `ZFS`, has poor metadata performance that's we do not include it
- Measure *creat* and *unlink* operations
  - *stat* performance heavily depends in the OSSs

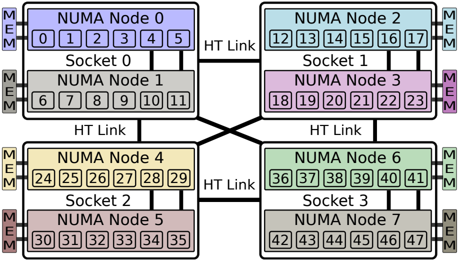
Collect system statistics:

- CPU utilization
- Block device utilization
- OProfile stats: % of CPU consumed by Lustre's modules

Hardware specifications

We use a four socket server consisting of:

- Supermicro motherboard model H8QG6
- 4× AMD Opteron 6168 Magny-Cours 12-core processors 1.9 GHz
- 128 GB of DDR3 main memory running at 1,333 MHz
- Western Digital Caviar Green 2 TB SATA2 HDD and
- 2× Samsung 840 Pro Series 128 GB SATA3 SSDs
- Memory throughput: 8.7 GB/s for local and 4.0 GB/s for remote



Testbed Setup

- CentOS 6.4 with the patched Lustre kernel version 2.6.32-358.6.2.el6
- Lustre 2.4 version RPMS provided by Intel (Whamcloud)
- Linux governor is set to `performance`, which operates all the cores at the maximum frequency and gets the maximum memory bandwidth
- An SSD for the OST
- For the `ext4` and `XFS` experiments, we use an SSD
- cfg device scheduler for the MDT

mdtest Benchmark

MPI-parallelized benchmark that runs in phases, where in each phase a single type of POSIX metadata operation is issued to the underlying file system.

Configuration:

- Private directories per process
- 500.000 files for Lustre
- 3.000.000 files for `ext4` and `XFS`
- Unmount the file system and flush kernel caches after each operation

Configurations

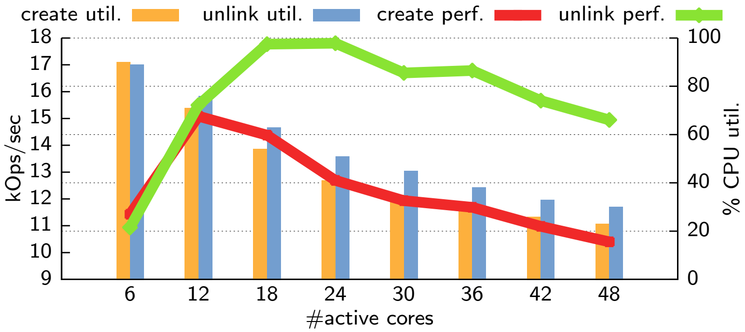
1. Scaling with the number of cores
   - Increase the workload and the active cores
2. Bind mdtest processes to specific sockets
   - Same workload and divide the mdtest processes among the active sockets
3. Use of multiple mount points
   - Increase the mount points used to access the file system
4. Back-end device limitation
   - Measure MDS performance while using kernel RAMDISK as MDT

Configuration:

Scaling with the number of cores

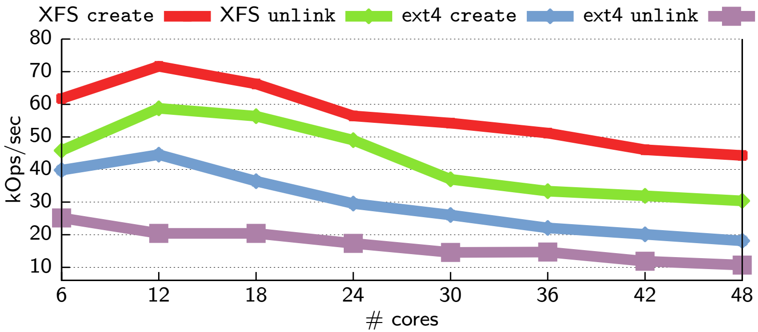
Lustre's performance vs. Active cores

- #mdtest processes equals 2× #active cores
- 6 mount points
- Lustre's modules CPU usage drops by 2x from 12 to 24 sockets



ext4 and XFS performance vs. Active cores

- #mdtest processes equals 2× #active cores
- 6 mount points

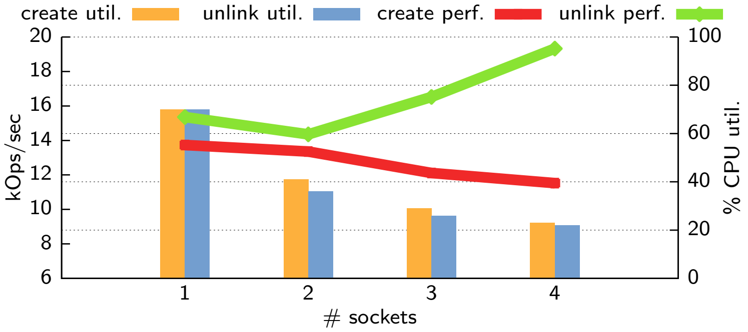


Configuration:

Bind mdtest processes per socket

Lustre performance, bind per socket configuration

- All cores are active
- Group mdtest processes per socket
- 12 mdtest processes
- 12 mount points

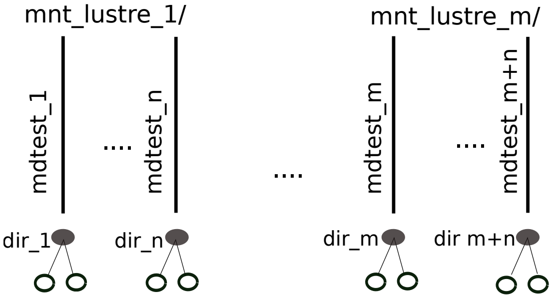


Configuration:

Use of multiple mount points (MPs)

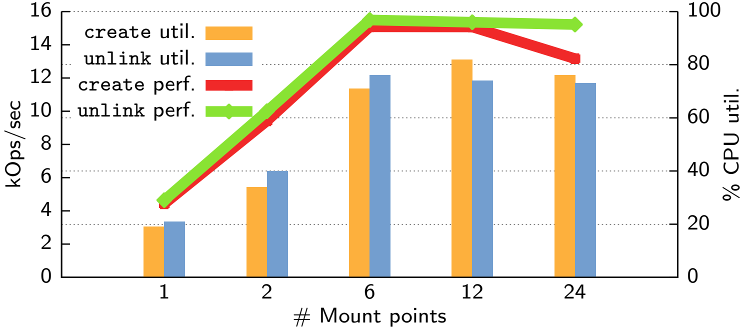
Multiple mount point configuration

- Mount the file system in several directories
- Access the file system from different paths



Lustre's performance vs. Mount points

- 24 mdtest processes
- 12 active cores
- Lustre's modules CPU usage increases by 5x from 1 MP to 12 MPs



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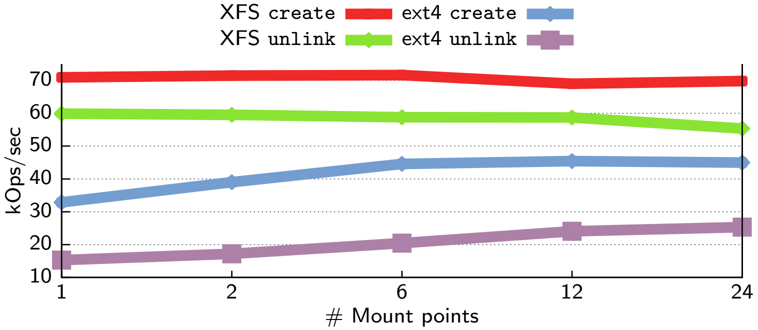
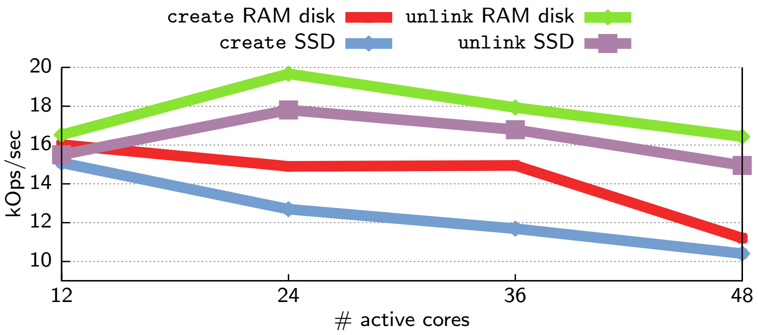


Configuration:

Back-end device limitation

Lustre's performance using different back-end devices

- #mdtest processes equals 2× #active cores
- 6 mount points



Conclusions

Main observations:

- Lustre MDS performance improvement is limited to a single socket
- MDT device does not seem to be the bottleneck
- Using multiple mount points per client can significantly increase performance

Previous work:

- The number of cores is less significant than the CPU clock

Thank you - Questions?

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Lustre modules usage increasing the number of active cores

	create		unlink	
Module	**12 C**	**24 C**	**12 C**	**24 C**
obdclass	6.38	3.58	12.96	8.57
mdtest	4.22	3.59	$<$0.1	$<$0.1
ldiskfs	5.30	2.26	3.01	1.70
lnet	$<$0.1	$<$0.1	3.24	2.17
libcfs	2.61	1.28	3.30	2.04
osd_ldiskfs	2.16	0.86	2.06	1.11
jbd2	1.76	0.97	1.23	0.78
lvfs	1.41	0.98	1.93	1.60
lustre	1.32	0.56	1.81	0.88
mdd	1.65	0.30	0.9	0.42
mdt	1.65	0.73	1.84	0.97

Lustre modules usage increasing the number of MPs

	create		unlink	
Module	**1 M**	**12 M**	**1 M**	**12 M**
ptl-rcp	2.38	11.38	3.04	11.67
obdclass	1.56	7.53	3.03	12.86
ldiskfs	1.30	6.53	0.62	3.12
lnet	0.82	3.75	<0.1	<0.1
libcfs	0.68	3.06	<0.1	<0.1
osd_ldiskfs	0.47	2.61	0.43	2.10
jbd2	0.45	2.15	0.38	1.26
mdt	0.36	2.11	<0.1	<0.1
lvfs	0.30	1.74	0.44	1.97
lustre	0.29	1.70	0.42	1.84
lod	0.18	1.06	<0.1	<0.1
mdd	0.18	1.03	<0.1	<0.1
mdc	0.13	0.71	<0.1	<0.1
mdt	<0.1	<0.1	0.42	1.87