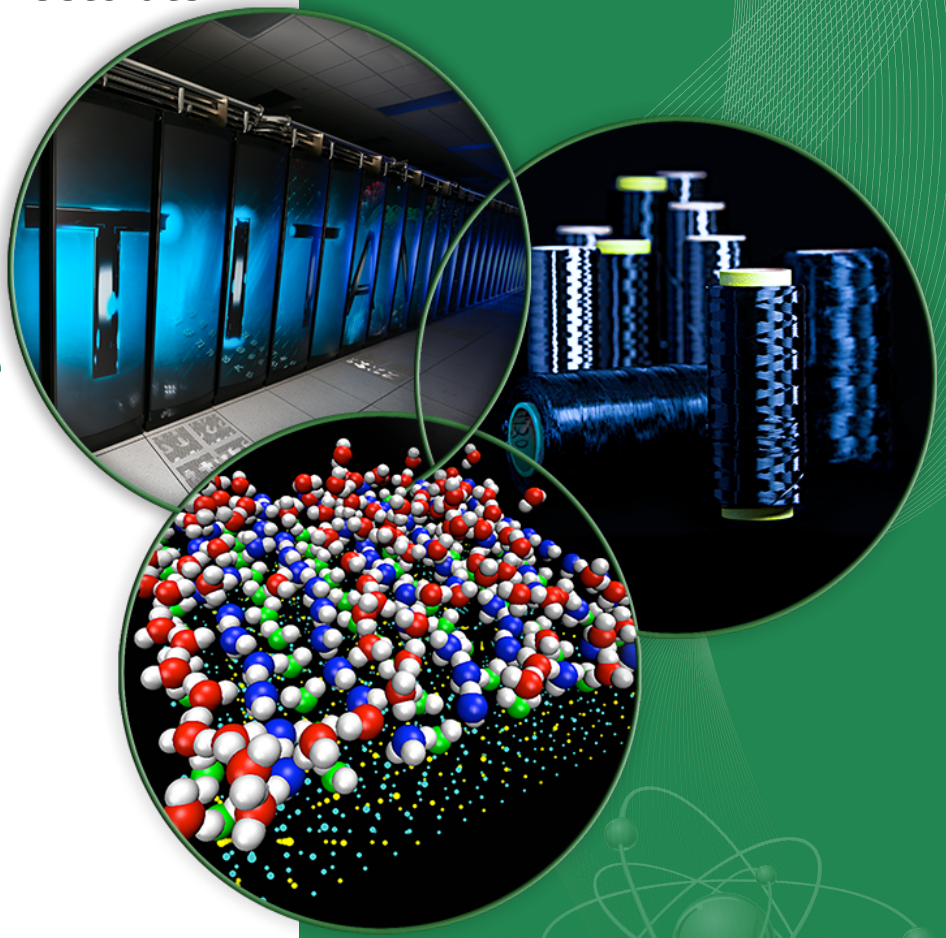
Oak Ridge National Laboratory

Computing and Computational Sciences Directorate



Hardware Selection and Benchmarking for Lustre

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Outline of Topics

- Part I: Hardware Selection
  - Selection criteria
  - Server guidelines for MGS/MDS/OSS
  - Networking guidelines
  - Client guidelines
- Part II: Benchmarking Methods
  - Purpose of benchmarking
  - Bottom-up approach to benchmarking
  - Benchmarking tools and techniques

Part I: Hardware Selection

Overview of Selection Process

- Appropriate hardware choices will be driven by many factors
- Consider higher level goals
  - Typical use (production, test/development, evaluation)
  - Policies and procedures
  - Integration with existing resources
- Narrow choices by considering performance requirements
  - Storage capacity and bandwidth
  - Network bandwidth and latency

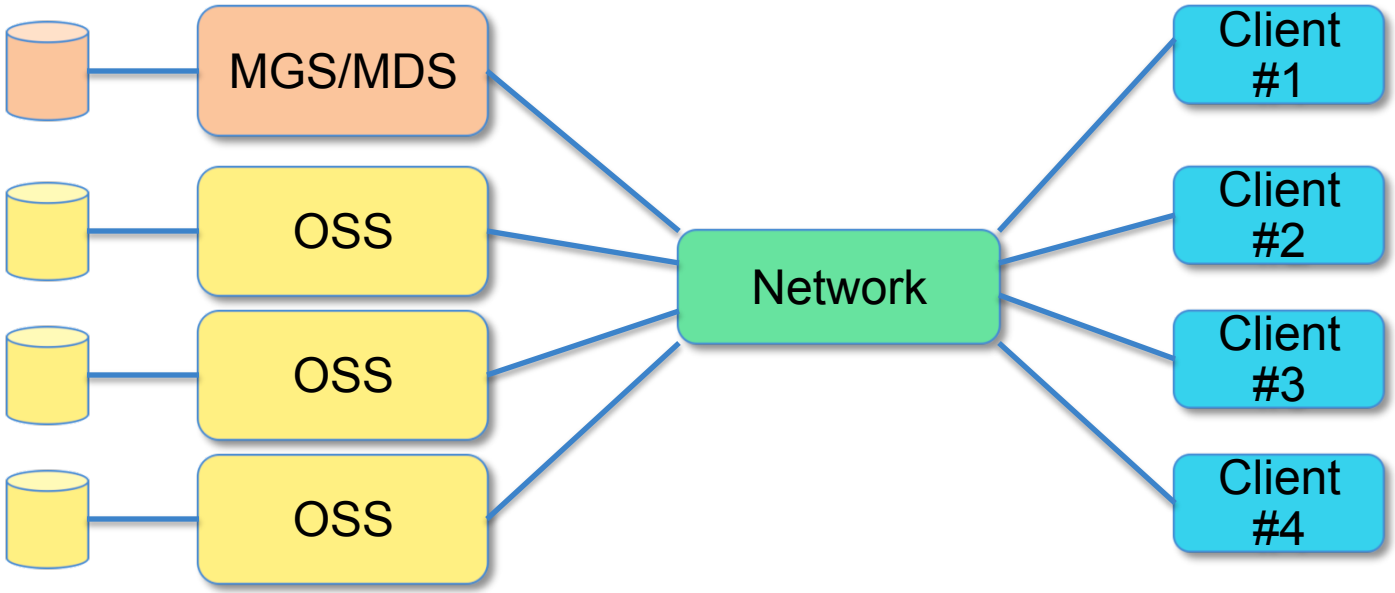
Selection Criteria

- Typical use for file system
  - Production → Consider RAID level (data protection), hardware redundancy/failover (improved uptime)
  - Testing/Development → Closely mimic existing (or expected) file system hardware
  - Evaluation → Flexibility to integrate different types of resources
- Policies and procedures
  - Security policy restrictions
  - Scratch space vs. Long-term storage

Selection Criteria (cont.)

- Integration with existing resources
  - Compatibility with currently deployed hardware
  - System management requirements
- Performance requirements
  - Capacity
  - Bandwidth (disk and network)
  - Latency
- Application I/O patterns
  - If file system is intended to support a small set of specific applications, gather info about typical workflows

Simple Lustre Setup



- Combined MDS/MGS
- All hosts directly attached to the same network fabric (no routing)
- Exact number of servers/clients in this example is not important

MGS/MDS Server Guidelines

- MGS and MDS can coexist on same server, but separate servers can be beneficial
  - Multiple file systems can use same MGS
  - MGS server can server as backup MDS server
- MDS is CPU intensive
  - Minimum 4 processor cores recommended
  - Faster cores are usually better
- More memory allows MDS to cache more metadata
  - Helps reduce lots of small I/O requests to disks
  - Allows server to maintain more client locks

MGS/MDS Storage Guidelines

- MGT Storage
  - Space requirements are small
  - Infrequent access, so performance not critical
  - Data is important so be sure to mirror disks
- MDT Storage
  - Access pattern is database-like (many seeks, small I/O)
  - Use fast disks if possible (high-RPM SAS ,SSD)
  - Data is critical! Use RAID-10.
  - External journal can improve performance
- Failover → Accessibility from multiple servers.

MGS/MDS Storage Guidelines (cont.)

- MGT requires <100 MB of disk space
- MDT space requirements are more complex
  - Size of MDT determines number of inodes available in the file system
  - Backend storage format (ldiskfs vs. ZFS) can affect calculations
  - Rough estimate: 1-2% of total file system capacity
  - Better estimate: Plan for 2 KB per inode
    - If N = (number of desired inodes for file system), then

      (MDT size) = 2 x (N x 2 KB) ← 2x fudge factor
  - If in doubt, err on the side of caution and get more space

OSS Server Guidelines

- OSS is not CPU intensive
  - Much of the time is spent waiting for I/O requests
  - May be desirable to get newer CPUs for better bus and memory access speeds
- More memory allows OSS to cache more data
  - Not necessary to enable caching, but for certain I/O patterns caching may reduce number of disk accesses
- Network interfaces, busses and motherboards
  - Pay close attention to possible hidden bottlenecks
    - PCI bus slower than your Infiniband card
    - Multiple network interface on shared PCI bus

OSS Storage Guidelines

- OSTs provide the file system storage space
- OSS servers typically serve 2-8 OSTs
- OSTs can use various technologies
  - Hardware storage controllers (e.g., DDN, EMC, etc.)
  - External JBODs w/ ZFS
  - Internal drives with LVM and/or software RAID
- Cost vs. Performance vs. Capacity vs. Complexity
- RAID is a must (even for scratch space)
  - Need to keep running in the event of drive failures
  - RAID6 (8+2) is often a good choice

Network Guidelines

- Network technology may be determined by various site factors
  - Are admins trained? Works with existing hardware?
- Make sure Lustre has LNET support for the network
  - Ethernet and Infiniband are common, but there's also support for specialized networks (e.g., Cray Aries)
- Balance network vs. disk bandwidth per OSS

network_bw > disk_bw	disk_bw > network_bw
• Network may be underutilized • Might be OK if expansion is planned	• Often the case if capacity is needed • Helps increase disk utilization if I/O pattern not optimal

Lustre Client Guidelines

- Not many hardware constraints on Lustre clients (although 64-bit clients are recommended)
- Lustre client architecture/endianess can be different from the server
  - Caveat: The PAGE_SIZE kernel macro on the client must be as large as the PAGE_SIZE on the server
    - Lustre client on ia64 with 64 KB pages can run with x86 servers with 4 KB pages
    - If servers are ia64 and clients are x86, the ia64 kernel must be compiled with 4KB pages
- In general, don't use Lustre servers as Lustre clients too

Case Study: Atlas Hardware

- Atlas is OLCF's site-wide Lustre resource
  - Two types of storage used:
    - DDN SFA12KX for OSTs with RAID-6 (8+2)
    - NetApp 5524 for MDTs with RAID-10
  - OSS Servers
    - Dual socket with 8-core 2.6 GHz Ivy Bridge processors
    - 64 GB RAM
  - MDS/MGS Servers
    - Dual socket with 6-core 2.6 GHz Sandy Bridge processors
    - 256 GB RAM
  - FDR Infiniband network

Part II: Benchmarking Methods

Goals of Benchmarking

- Benchmarking has several purposes
  - Verify hardware performance
    - Make sure hardware lives up to vendor's claims
    - Discover faulty hardware early
  - Discover hidden bottlenecks
    - Design looks good on paper, but in practice it doesn't work well
  - Record baseline behavior
    - Helps quantify what is "normal" and identify regressions later
- Need to use a bottom-up approach
  - Test individual hardware components
  - Add software/hardware layers incrementally

General Benchmark Plan

- Should create a benchmark plan as part of the file system deployment plan
  - Benchmark plan will likely have site-specific tests
  - Benchmarking may be part of formal system acceptance from vendor
- In general, benchmarks should test:
  - Storage
  - Network fabric
  - Lustre Lnet transport layer
  - Lustre file system

Storage Benchmarking

- Test performance of the block devices that will be used for MDT and OST storage. These could be:
  - Individual disks
  - LUNs exported to host by external storage controller
  - Software RAID devices
- OST benchmarks typically focus on streaming I/O performance with large (1MB+) request sizes
  - This gauges max speed of OST which ultimately determines max speed of entire file system
- MDT benchmarks focus on random I/O with small request sizes (usually 4KB)

Storage Benchmarking (cont.)

- Lustre comes with an I/O kit containing several benchmark tools, including `sgpdd-survey`
  - `sgpdd-survey` is a shell script that uses `sgp_dd` command to perform I/O
  - Measures “bare metal” performance, bypassing kernel block device layers and buffer cache
  - Runs multiple tests with varying numbers of threads and regions to create a performance profile
- This tool is useful for testing performance of a single OST or MDT
- Lustre manual has a section on `sgpdd-survey`
  - http://lustre.org/documentation/

Storage Benchmarking Tools

- In addition to Lustre I/O kit, there are many other benchmark tools available.
- XDD (eXtreme dd toolset)
  - Multi-threaded capabilities. Supports I/O to block devices or files
  - https://github.com/bws/xdd
- fair-lio
  - Developed at ORNL. Uses libaio (async I/O library).
  - Basis for OLCF benchmark suite
  - https://www.olcf.ornl.gov/wp-content/uploads/2010/03/olcf-benchmark-suite-final-rev-1.tar.gz

Network Benchmarking

- Test the speeds of network links between hosts
- Use tools appropriate to the network fabric
- Ethernet
  - iperf (https://github.com/esnet/iperf)
  - netperf (http://www.netperf.org/netperf/)
- Infiniband
  - qperf (https://www.openfabrics.org/downloads/qperf/)
    - Can test RDMA and IP performance
  - perftest (https://www.openfabrics.org/downloads/perftest/)
    - Contains ib_write_bw, ib_send_lat, etc.

LNet Benchmarking

- Lustre comes with a kernel module (lnet_selftest) that can be used to test the LNet transport layer.
- Can be used to send/receive bulk I/O data between multiple nodes simultaneously
  - Good for trying to saturate the network
  - Useful to compare LNet bandwidth test results to network bandwidth test results
- Capable of testing paths through LNet routers
- For details, see the Lustre manual.

Lustre Benchmarking

- Once hardware components have been tested and verified to be working as expected, file system benchmarks can be run.
- There are many tools available, but one of the most commonly used is IOR.
  - https://github.com/chaos/ior
  - Uses MPI to coordinate processes across multiple nodes
  - Supports file-per-process and shared file testing
  - Can be built with support for POSIX, MPIIO, and HDF5
  - Many options available to support various read/write tests
  - See doc/USER_GUIDE included in IOR source

Lustre Benchmarking (cont.)

- Different scenarios to test:
  - Max OST bandwidth
    - Use file-per-process test with all files located on a single OST
    - Test varying numbers of processes (n=1,2,4,....)
  - Max OSS bandwidth
    - Run previous test across all OSTs on one OSS server concurrently
  - Max client bandwidth
    - Multiple processes writing to different files on different OSTs
  - Max file system bandwidth (i.e. – Hero Run)
    - Best results usually achieved using file-per-process across many clients with stripe_count=1
    - May want to manually assign files to OSTs to achieve maximum throughput

Summary

- Lustre hardware choices may require sites to consider more than just capacity and bandwidth.
- The Lustre manual is a valuable resource for understanding the technical requirements and planning a file system deployment.
- A methodical, bottom-up approach to benchmarking can help prevent hidden surprises or hours of debugging when things don't work.
- Many benchmarking tools exist to help ensure sites can get the most out of their Lustre file system.

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