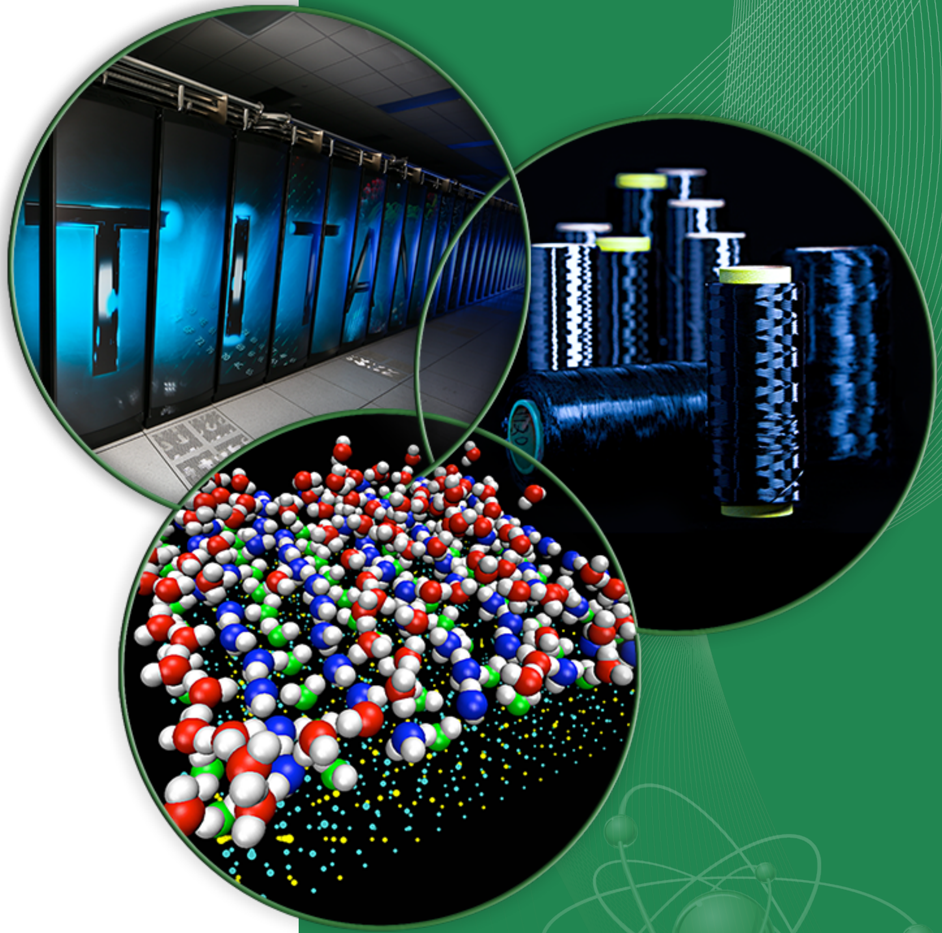
Oak Ridge National Laboratory

Computing and Computational Sciences Directorate



Introduction to Lustre

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Outline of Topics

- What is Lustre?
- Lustre features
- Lustre architecture overview
- LNET transport layer
- Example Lustre setups
- File striping concepts
- I/O optimization for Lustre

The Need for Parallel File Systems

- High Performance Computing (HPC) has outgrown the ability of any single host
- The same holds true for Big Data problems:
  - (data set sizes) > (drive capacities)
  - Single server bandwidth is not sufficient to support access to all data from thousands of clients
- Need a parallel file system that can:
  - Scale capacity/bandwidth
  - Support large numbers of clients
- Lustre is a popular choice to meet these needs

What is Lustre?

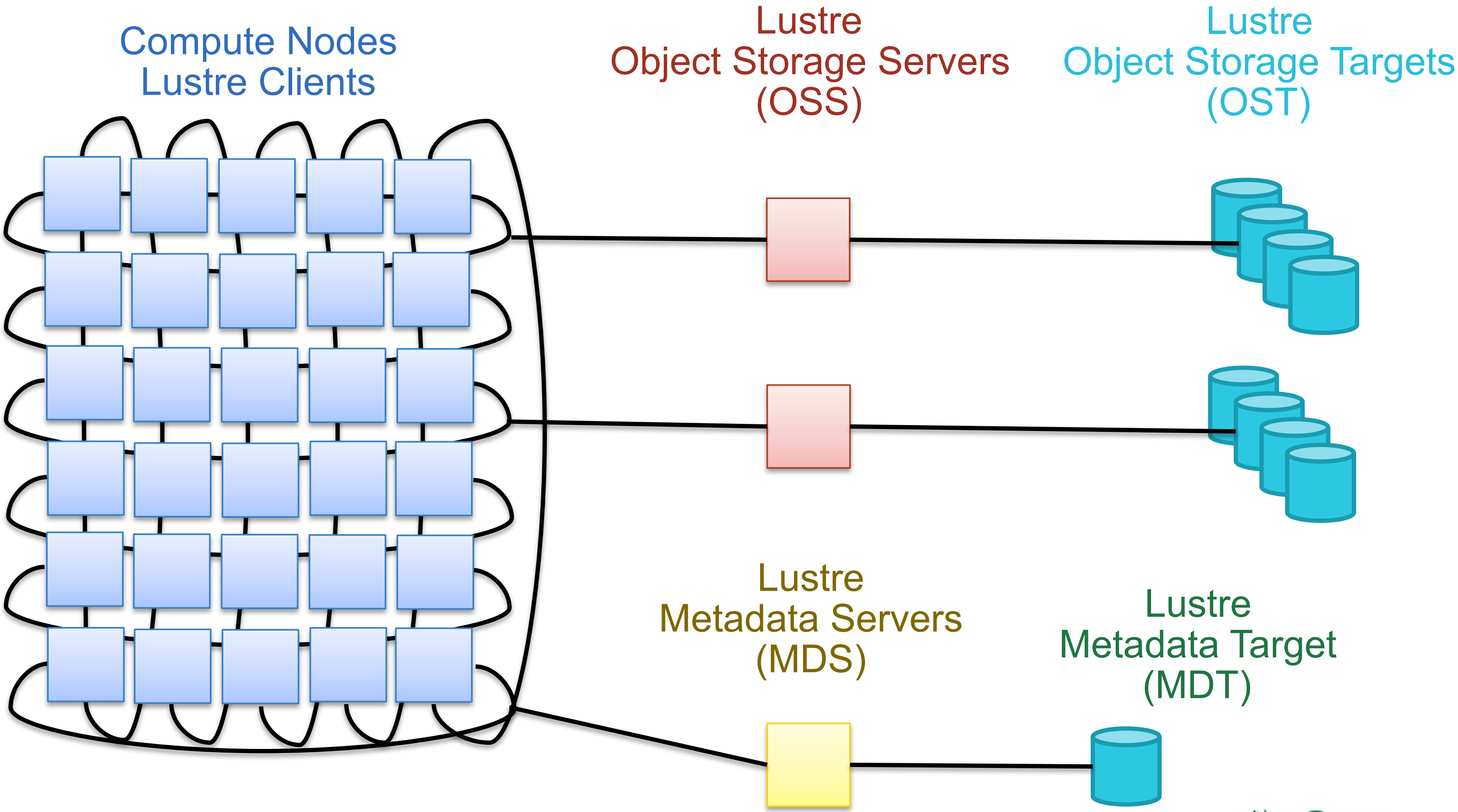
- Lustre is a massively parallel distributed file system that supports:
  - Thousands of clients
  - Large capacities (55 PB at LLNL)
  - High bandwidths (1.4 TB/s at ORNL)
  - POSIX semantics for I/O access
- Lustre is Open Source under GPLv2
- Used by many of the TOP500 supercomputers
- Not just for HPC (e.g., PayPal)

Lustre Features

- File striping across disks and servers
- Multiple metadata servers
- Online file system checking
- HSM integration
- Ability to add servers to existing file system
- User and group quotas
- Pluggable Network Request Scheduler

- RDMA support
- High availability
- I/O routing between networks
- Multiple backend storage formats (ldiskfs and ZFS)
- Storage pools
- CPU partitions
- Recovery features

Lustre Architecture



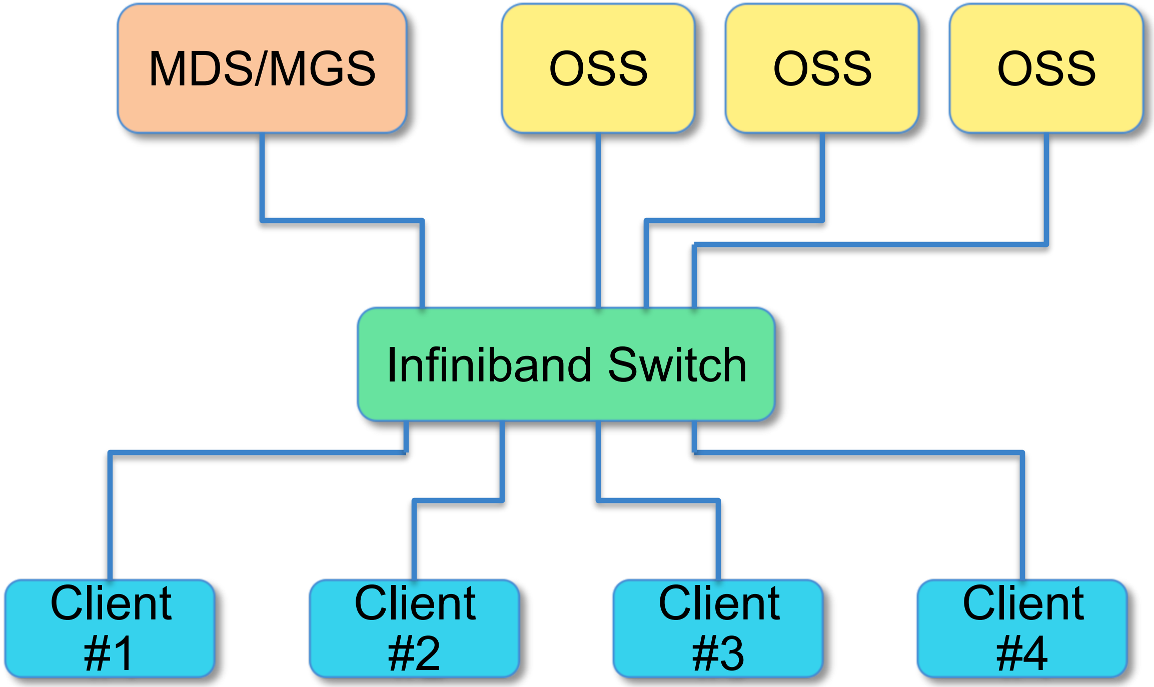
Lustre Components

- MDS – Manages filenames and directories, file stripe locations, locking, ACLs, etc.
- MDT – Block device used by MDS to store metadata information
- OSS – Handles I/O requests for file data
- OST – Block device used by OSS to store file data. Each OSS usually serves multiple OSTs.
- MGS – Management server. Stores configuration information for one or more Lustre file systems.
- MGT - Block device used by MGS for data storage

LNET Transport Layer

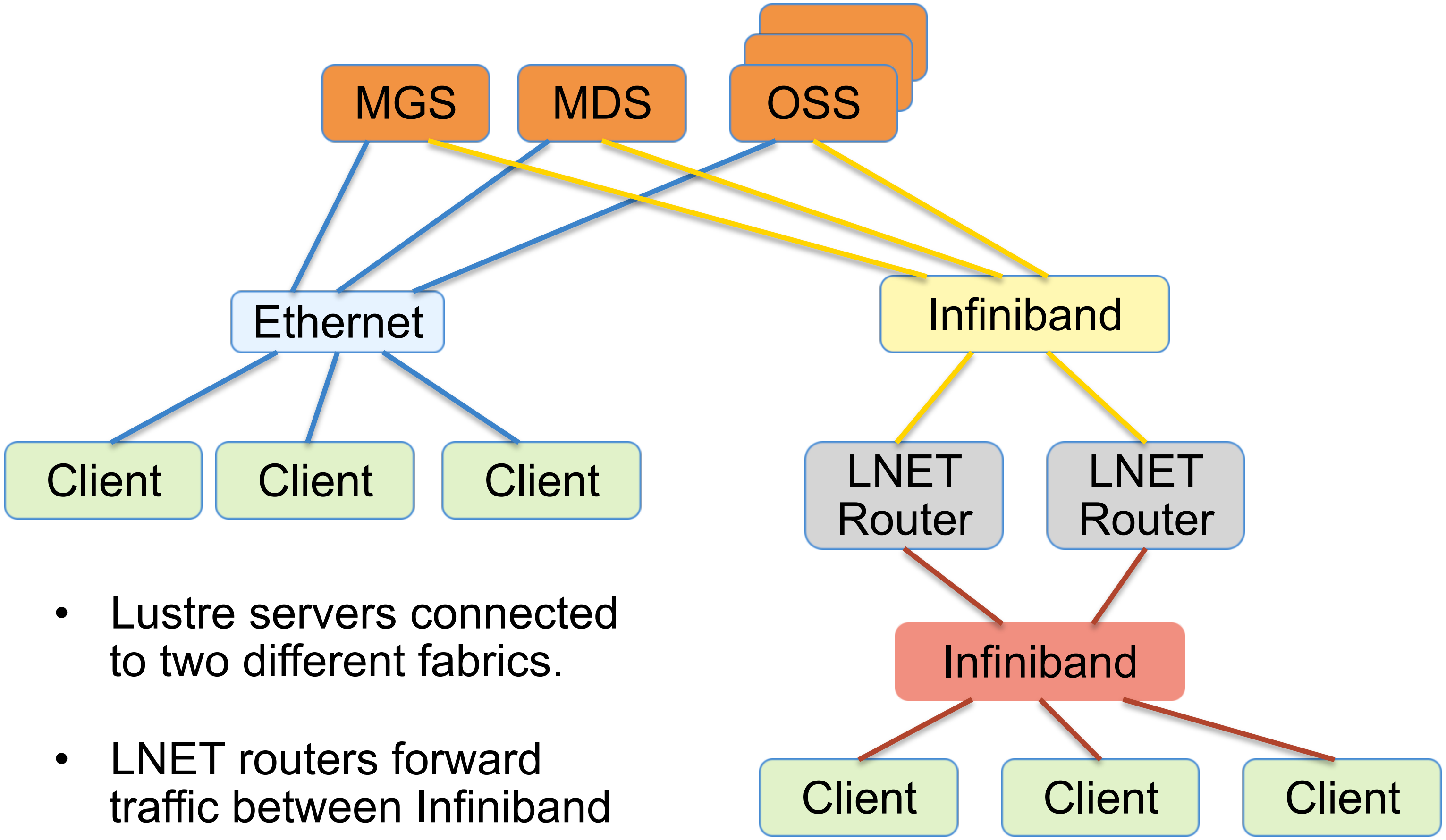
- Lustre Networking (LNET) provides the underlying communication infrastructure
- LNET is an abstraction for underlying network type
- Supported network types include:
  - TCP/IP
  - Infiniband
  - Cray high-speed interconnects (Gemini, Aries)
- LNET routing capabilities allow fine-grained control of data flow

Example: Simple Lustre Setup



- Combined MDS/MGS
- All hosts directly attached to the same Infiniband fabric (no routing)

Example: Complex Lustre Setup

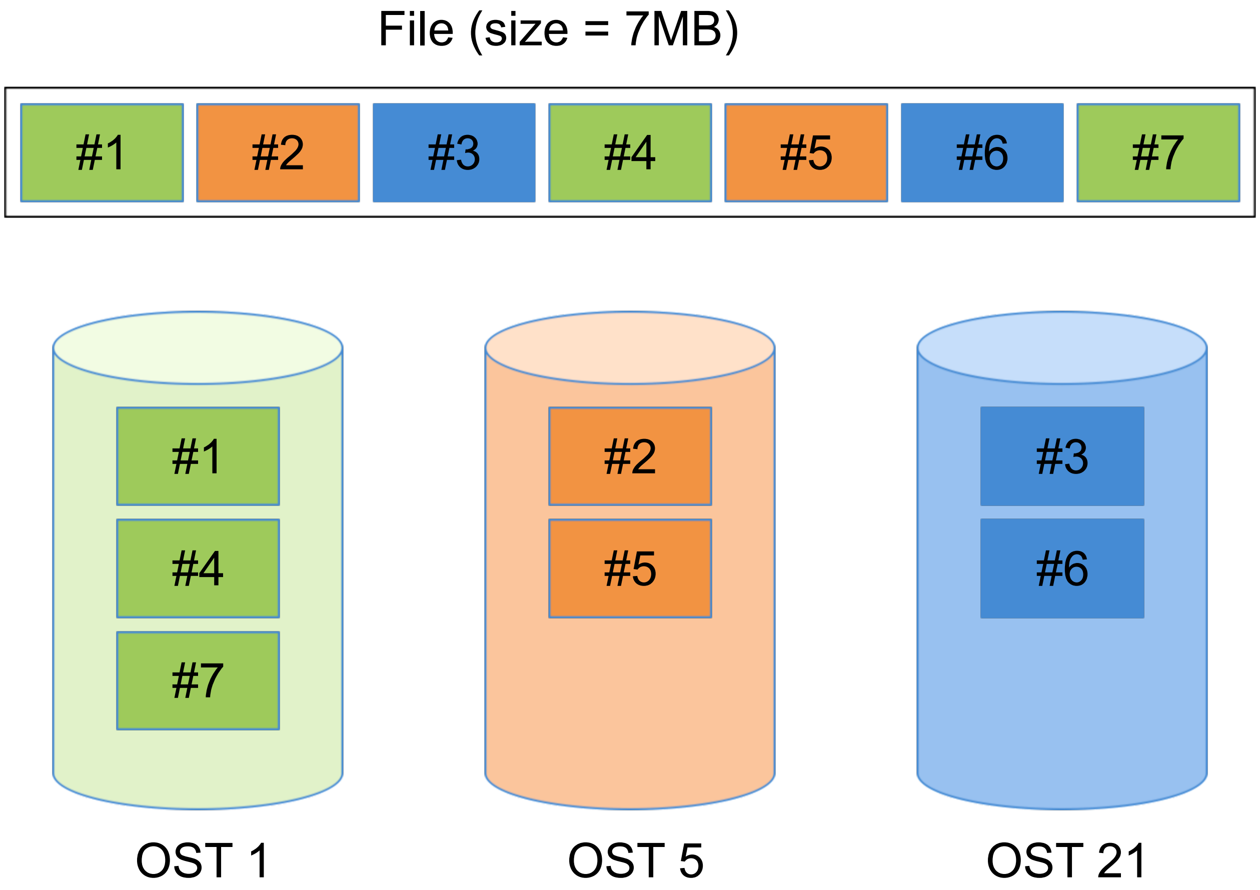


- Lustre servers connected to two different fabrics.
- LNET routers forward traffic between Infiniband networks.

File Striping Concepts

- The two most basic properties of a Lustre file are:
  - *stripe_count* (the number of OSTs to stripe across)
  - *stripe_size* (how much data is written to an OST)
- Users can control these parameters using "`lfs setstripe <file>`" or allow the file to inherit the global defaults
- When a file is created, Lustre will select *stripe_count* OSTs to use for the file.
- The first *stripe_size* bytes are written to the first OST, the second *stripe_size* bytes to the second OST, etc.

File Striping Example



stripe_count = 3 stripe_size = 1 MB

I/O Flow: A Client Perspective

- When the client opens a file, it sends a request to the MDS server
- The MDS server responds to the client with information about how the file is striped (which OSTs are used, stripe size of file, etc.)
- Based on the file offset, client can calculate which OST holds the data
- Client directly contacts appropriate OST to read/write data

I/O Optimization

- There are no hard-and-fast rules on how to optimize I/O for a Lustre file system.
- Full optimization requires in-depth knowledge of the application's I/O pattern (and may even require changes to the application).
- Optimization can also depend upon characteristics of the file system itself.
- Fortunately, significant benefits can often be achieved with relatively small changes

Lustre I/O Suggestions

- Avoid over-striping
  - More stripes does not necessarily mean faster access
  - For file sizes of O(1GB), stripe_count=1 may be best
- Avoid under-striping
  - Very large files with stripe_count=1 can fill up an OST
  - If many clients are writing to separate portions of the same large shared file, a low stripe_count could cause contention on OSTs
- Avoid small I/O requests
  - If possible, buffer many small writes into larger requests
- Know your application's I/O pattern!

Summary

- Lustre is a scalable parallel file system that can handle some very demanding I/O loads
- Lustre can support simple small-scale configurations as well as very complex large-scale configurations
- Careful tuning of file striping parameters can yield significant improvements in application performance by avoiding I/O contention

Acknowledgements

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