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How to exploit parallelism of HPC storage based on Lustre File System and Hierarchical Data Format

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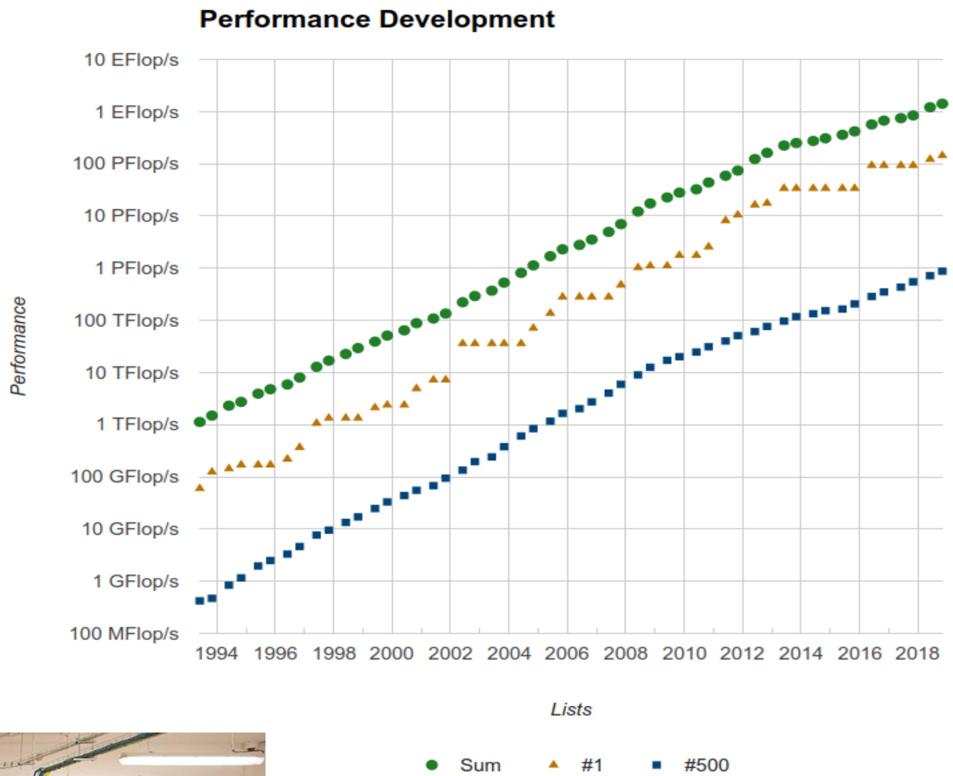
Presentation plan

- Introduction
- HPC Storage in practice
  - Lustre case study
- HDF
- Test results
- Conclusions

- HPC Systems are a key instrument in multiple fields of science
- Exponential growth of performance
- What is a HPC System?
  - compute (cpu + memory)
  - network
  - storage
  - software... etc.
- How is storage doing?



Test system

- Infiniband 4x FDR (56Gb/s)
- Lustre FS as main storage:
  - scratch: 5 PB @ 120 GB/s
  - archive: 5 PB @ 60 GB/s
- No. of disks:
  - scratch: 1600
  - archive: 1080
- We do use NFS!
  - $HOME dirs
  - software

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Lustre filesystem

- Parallel distributed file system used in large-scale computing
- In contrast to a standard filesystem:
  - components of the system communicate with each other using network
  - multiple clients can share files and homogeneous space
    - data access, file locks, permissions etc.
  - data is stored on OSTs (actually disks)

The key components of Lustre filesystem:

- Object Storage Servers (OSS)
- Object Storage Targets (OST)
- Metadata Servers (MDS)
- Metadata Targets (MDT)

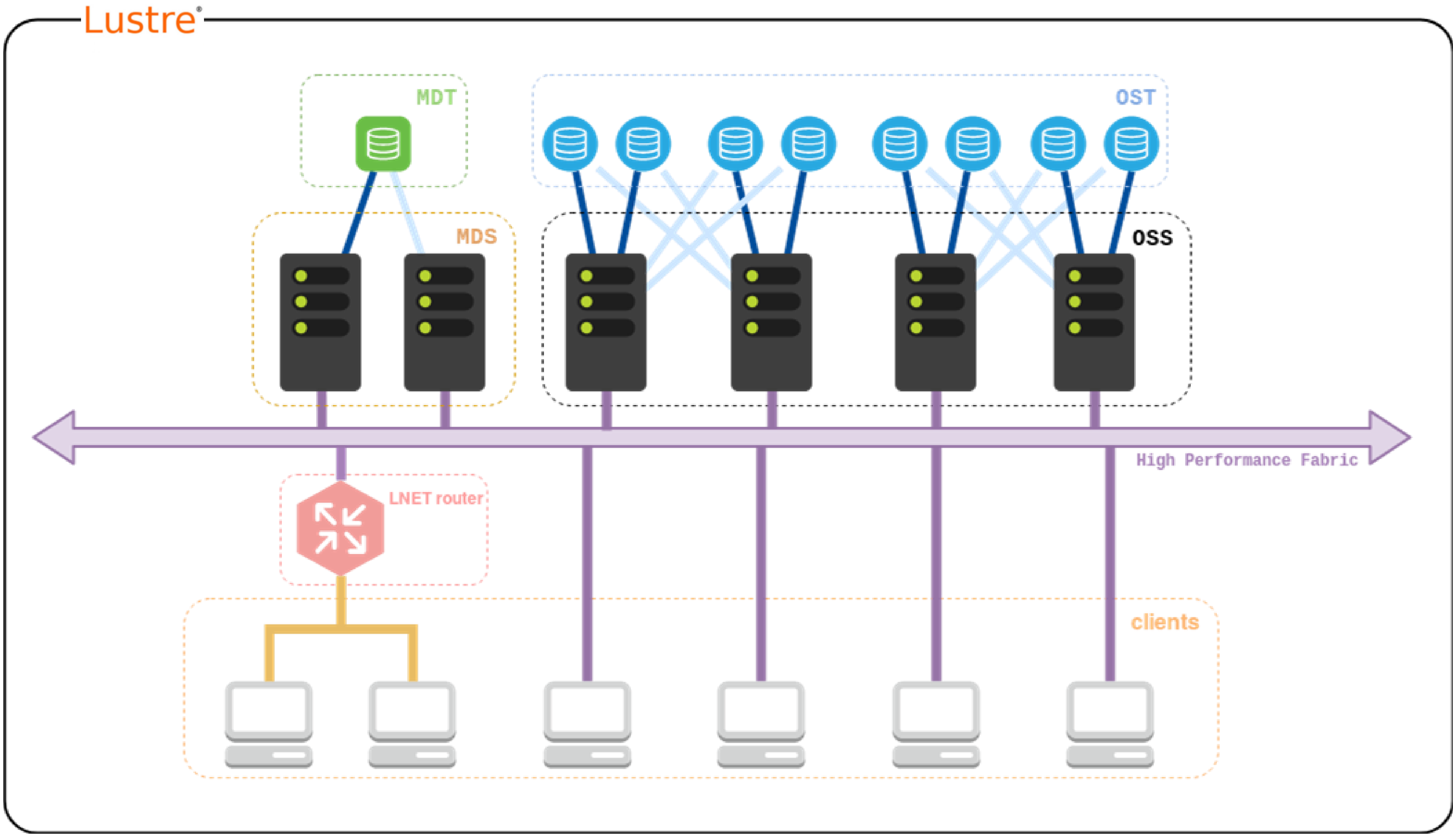
scratch

- 16 OSS
- 160 OST
- 2 MDS
- 1 MDT

archive

- 8 OSS
- 108 OST
- 2 MDS
- 1 MDT

Lustre fs architecture



Lustre installation

- Works mainly in kernel space
- Can be used in small and large-scale enterprise environments
- Available backend filesystems:
  - ldiskfs
    - based on ext4 filesystem
  - ZFS
    - additional recovery, compression, improved performance and security of stored data

Lustre benefits

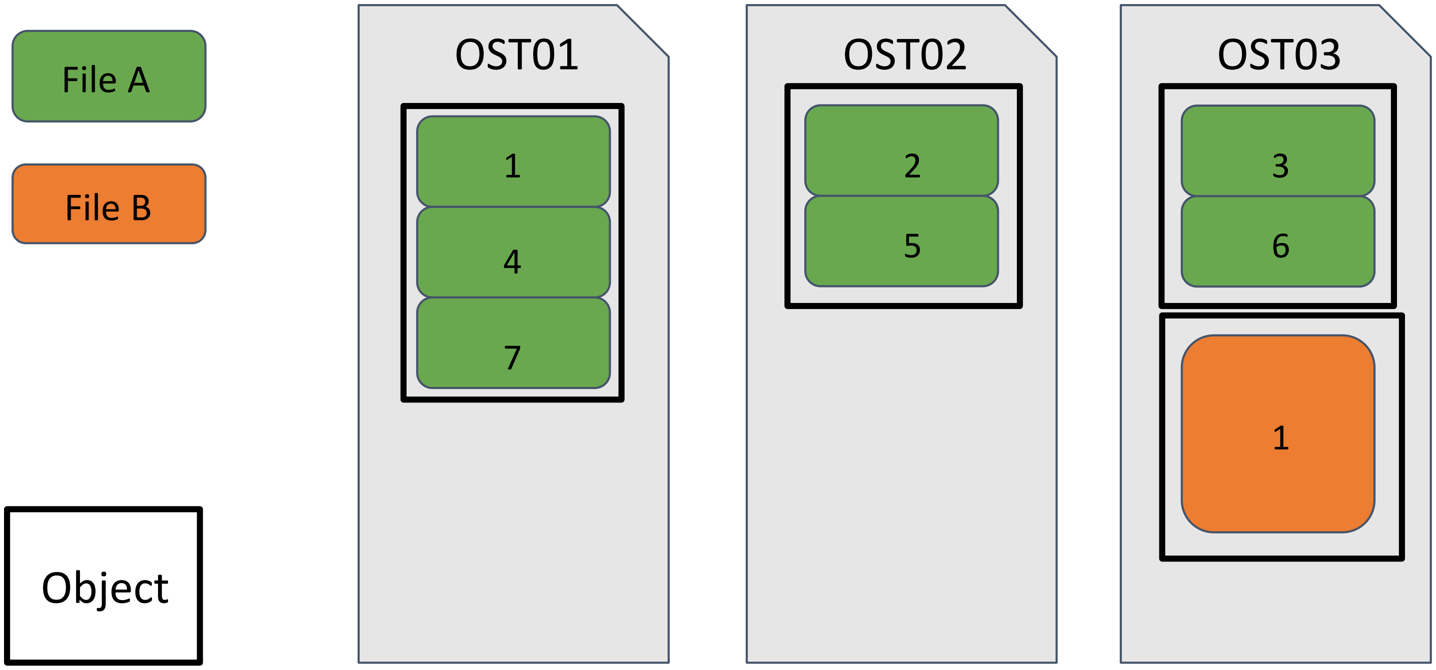
- Allows for significant increases in performance of read/write operations
  - reading from and writing to disks in parallel
- Security and high availability (HA)
  - HA stack reduces risks origination from single point of failure
  - storage consistency verification and security mechanisms
- Simple and well-known user interface
  - operations on files via standard Linux/Unix commands and functions supplied by implementing POSIX

Lustre file stripping

- Stripe count
  - number of objects that make up a file hosted by Lustre
- Stripe size
  - amount of sequential data that is written to an object before moving on to another object

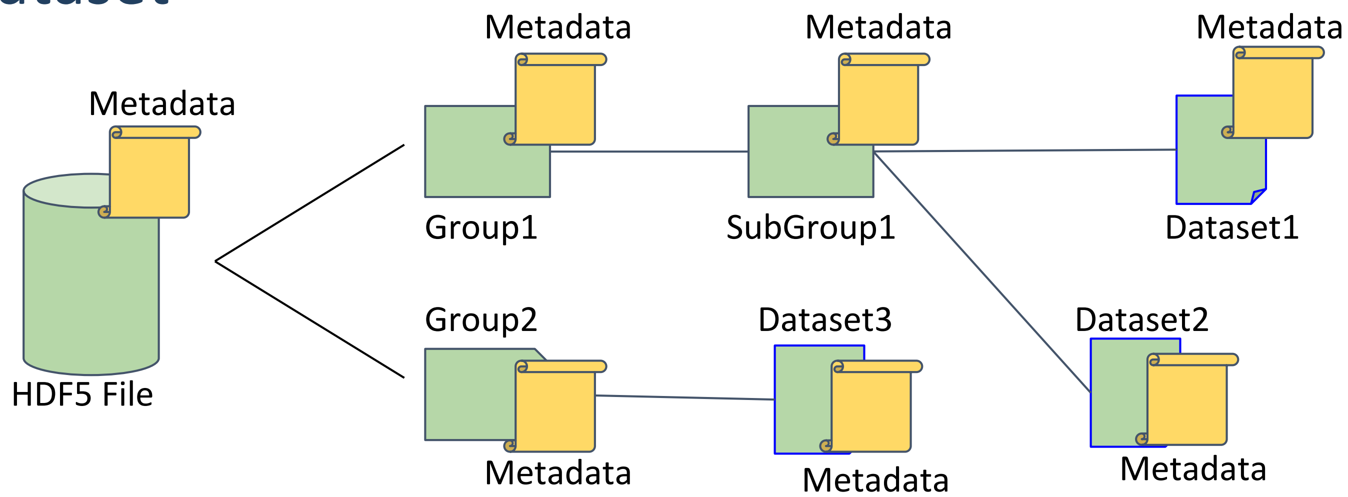
Lustre file stripping

- Parallel reading/writing across multiple OSTs
- Increase aggregate bandwidth linearly
- File size not limited to constraints of single OST



HDF (HDF5): Hierarchical Data Format, set of libraries and tools

- Data stored in a hierarchical and structured way
  - Groups and subgroups - container structures, correspond to directories
  - Datasets - form of a multidimensional arrays with fixed dimensions of a homogenous type, correspond to files
  - Metadata - attributes allowing to describe a group or a dataset



HDF benefits

- Hierarchical data storage system
  - data organization
  - self descriptive data
- Implements functions for parallel access to data
- One big file instead of many small files
  - heterogeneous data (+ metadata)
  - great for Lustre!
- Portable software library
  - high-level API with C, C++, Fortran 90, Java, Python (and many more) interfaces

HDF access to data

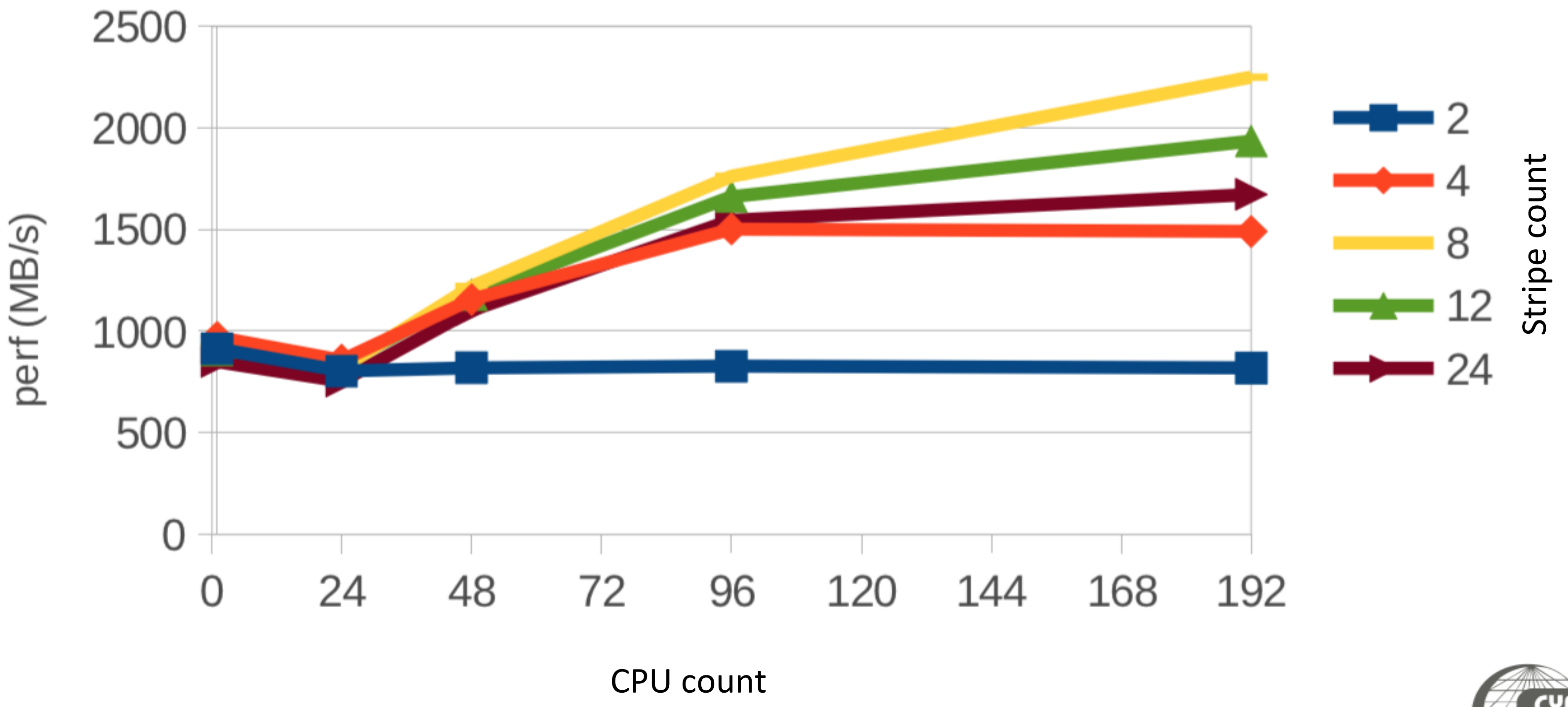
- Parallel access with multiple approaches:
  - all CPUs write to one file
  - one node writes to one file; each node has its own file
  - each CPU writes to one file
- Modes:
  - Collective (additional optimization)
  - Independent

Test setup

- Goal: optimize data write from a job with multiple processes
- Gathered data from tests performed on archive space
- Environment:
  - library: Parallel hdf5-1.8.12
  - Data set size: 4394,53MB
  - Stripe size: 1MB
  - Process count: 1/24/48/96/192 (multiples of 24 cores/node)

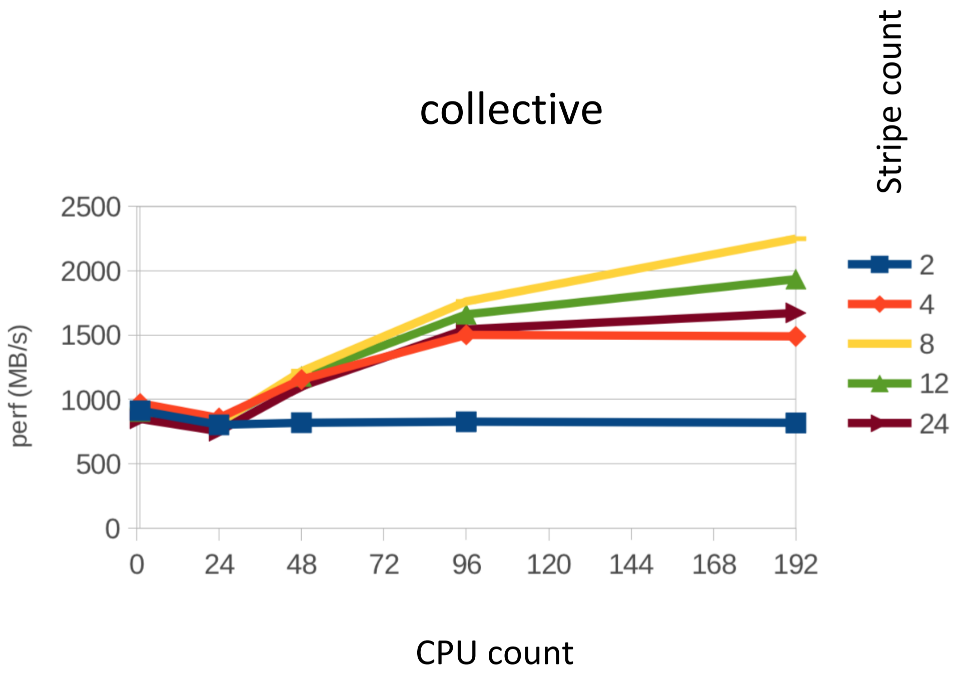
Stripe count

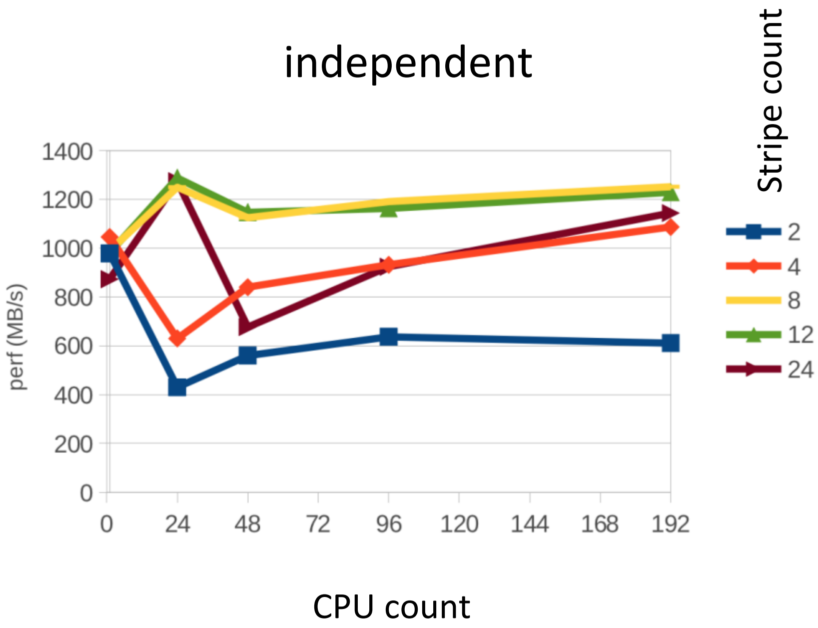
- Setup
  - One output file for all CPUs
  - Collective mode
- Goal: What amount of stripes works best?



Collective vs independent

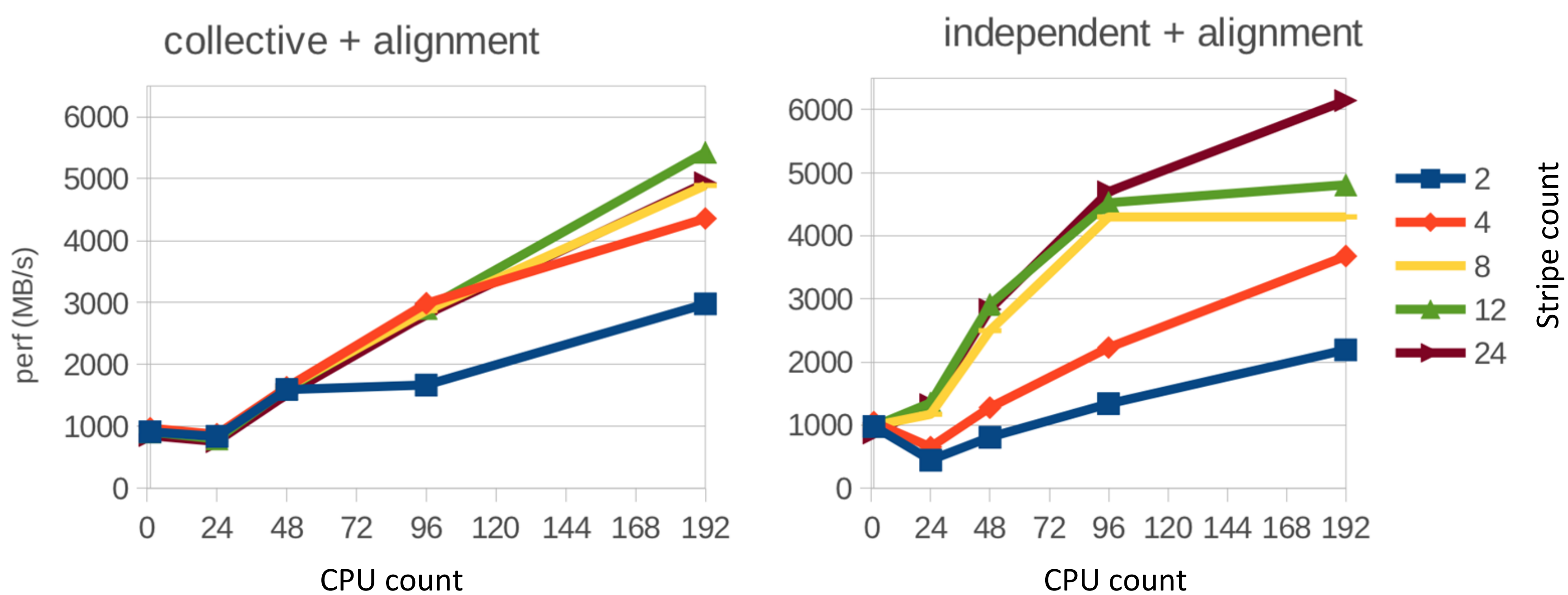
- Setup
  - One output file for all CPUs





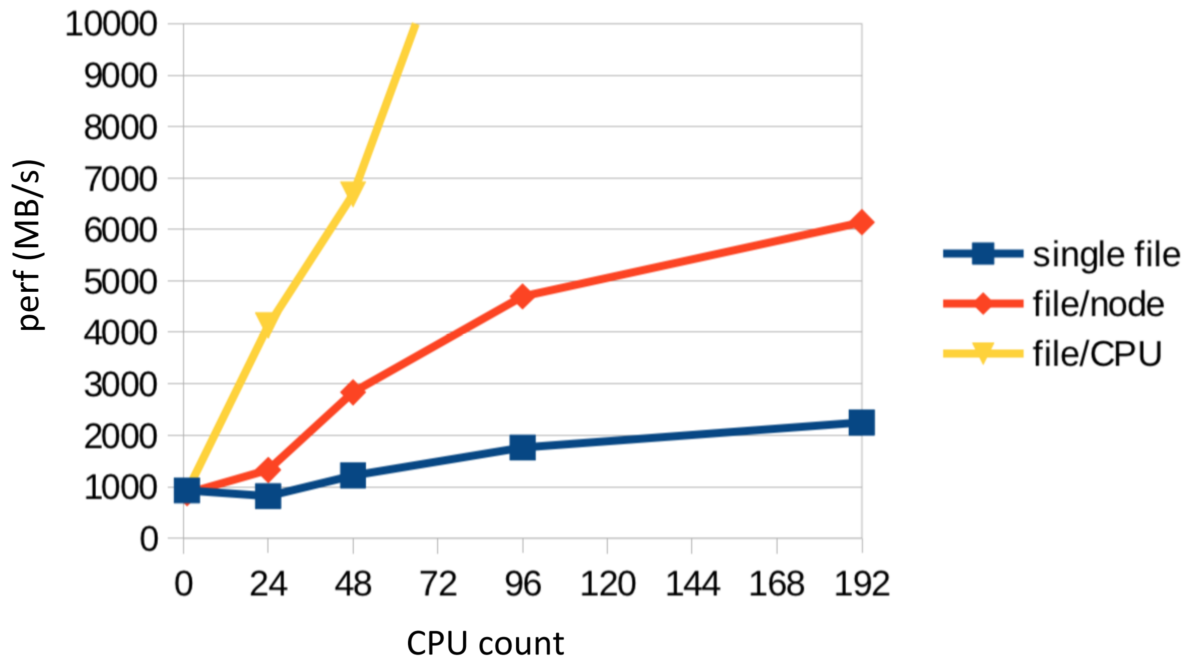
Collective vs independent

- Setup
  - One file per node (24 CPUs)



Write strategy comparison

- Setup
  - all CPUs write to one file
  - one node writes to one file; each node has its own file
  - each CPU writes to one file
- What strategy works best for studied use case?
(best settings for individual strategies)



Conclusions

- It is possible to achieve significant performance improvements by optimizing access to storage
- File per cpu strategy/node/job provides biggest difference
- Many small files suggest collective, few larger ones independent
- Higher stripe count usually provides better performance, for jobs with many CPUs working with few files
- There is no “best approach” to implementing IO operations in HPC applications

References

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Thank you for attention! Questions?

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short url

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