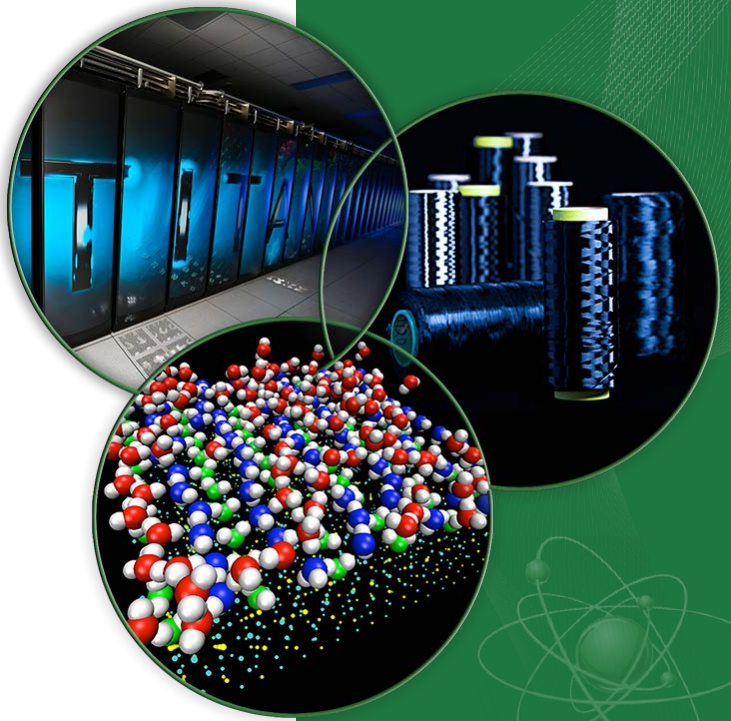
Oak Ridge National Laboratory
Computing and Computational Sciences Directorate

Evaluating Progressive File Layouts for Lustre



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Lustre User Group
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ORNL is managed by UT-Battelle
for the US Department of Energy

Collaborators

ORNL

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Outline

- Current state of Lustre layouts
- Progressive File Layout (PFL) overview
- PFL prototype implementation
- PFL evaluation tests
  - Streaming IOR tests
  - Comparison to synthetic dynamic striping
  - Object placement testing
- Summary and future work

Lustre File Layouts Today

- Several Lustre parameters control file layout
  - Stripe size/count/index
  - OST pool
- In practice, stripe size and count are primarily used
- Layout constraints
  - One set of parameters for entire file
  - Parameters chosen at time of file creation
  - Only one layout type (RAID-0) supported

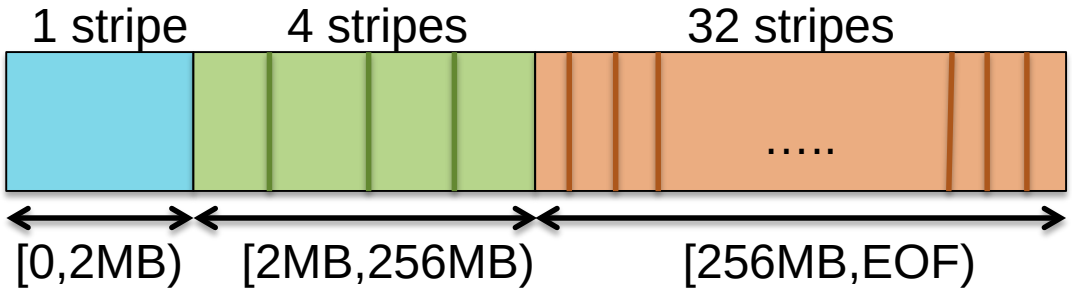
Layout Enhancement

- Under OpenSFS contract SFS-DEV-003, Intel's High Performance Data Division produced a new design for file layouts
- High Level Design document describes several new layouts
  - Composite layouts
  - RAID layouts
  - Compact layouts
  - Large layouts

http://wiki.lustre.org/Layout_Enhancement_High_Level_Design

Progressive File Layout (PFL)

- Progressive File Layout feature is built using Composite Layouts
  - File layout is described by a series of components
  - Each component covers a non-overlapping extent of the file
  - Each component has its own striping parameters



Progressive File Layout Goals

- Single layout definition for multiple file sizes
  - Reasonable performance for a variety of I/O patterns
  - Change stripe layout as file grows
  - Simplify Lustre usage for novice users
- More striping options for advanced users
  - Customization for non-uniform files
  - Different regions of file on different storage
- Stepping stone to more features in the future
  - HSM for file components, new uses for Composite Layouts, etc.

Other PFL Use Cases

- Layout with increasing stripe count not the only use case
  - Striping parameters for each component are independent
  - Choose striping parameters to match the problem
- Examples
  - File striping based on number of processes
    - First component contains shared header (stripe_count=1)
    - Second component contains data for each process (stripe_count=N)
  - Decreasing stripe count
    - First component contains large amounts of raw data
    - Second component contains small post-processed data

PFL Prototype Implementation

- Intel, under contract from ORNL, is developing PFL feature
- A prototype implementation was delivered in the first half of 2015 for evaluation and testing
  - Some limits on functionality
    - No dynamic allocation of new components
    - No support for setting PFL on directories
- Continuing development
  - PFL inheritance from parent directory
  - Integration with existing Lustre code base

PFL Evaluation Tests

- Several different tests were run to evaluate the functionality and performance of PFL prototype
- Streaming IOR and mdtest (Intel)
  - Comparison with traditional Lustre striping
  - Single client and multiple clients
  - Shared file and file per process
- Comparison to Synthetic Dynamic Striping (ORNL)
- Object placement (ORNL)
  - Compare OST object placement for PFL and traditional striping

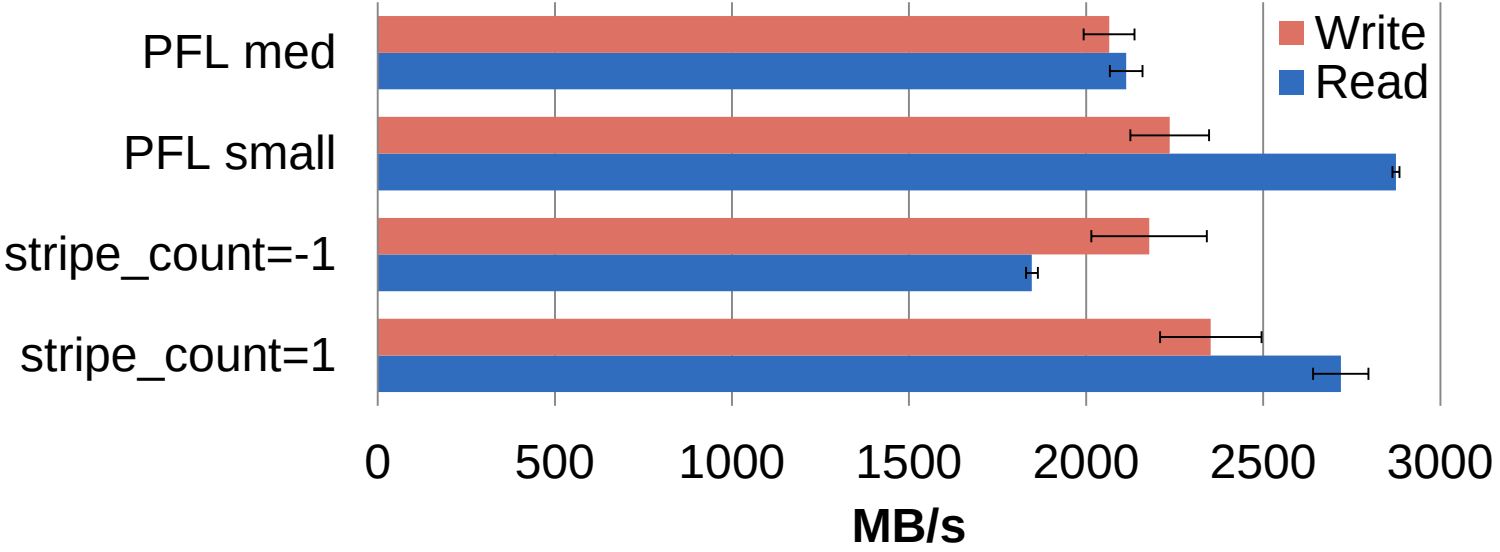
Intel Testing

- Intel's tests were run on Hyperion at LLNL
  - 32 Lustre clients
  - 16 Lustre servers with 52 OSTs (ldiskfs)
  - Mellanox DDR Infiniband
- IOR
  - Single client (16 threads) file per process
  - 32 clients (512 threads) file per process
  - 32 clients (512 threads) shared file
  - Each thread reads/writes 4 GB of data

Test File Layouts

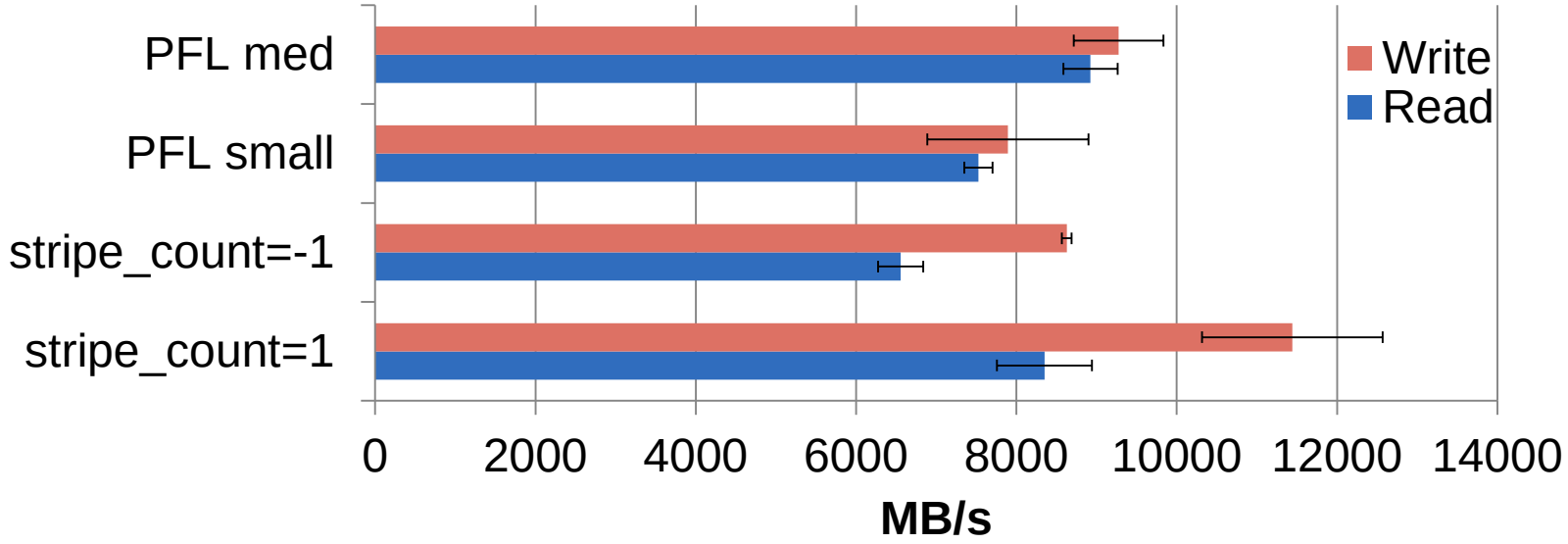
- Traditional
  - stripe_count = 1
  - stripe_count = -1
- PFL small
  - [0,EOF) stripe_count=1
- PFL medium
  - [0,16M) stripe_count=1
  - [16M, EOF) stripe_count=4
- PFL large
  - [0,16M) stripe_count=1
  - [16M, 128M) stripe_count=4
  - [128M, EOF) stripe_count=47

Single Client IOR (FPP) – 16 Threads



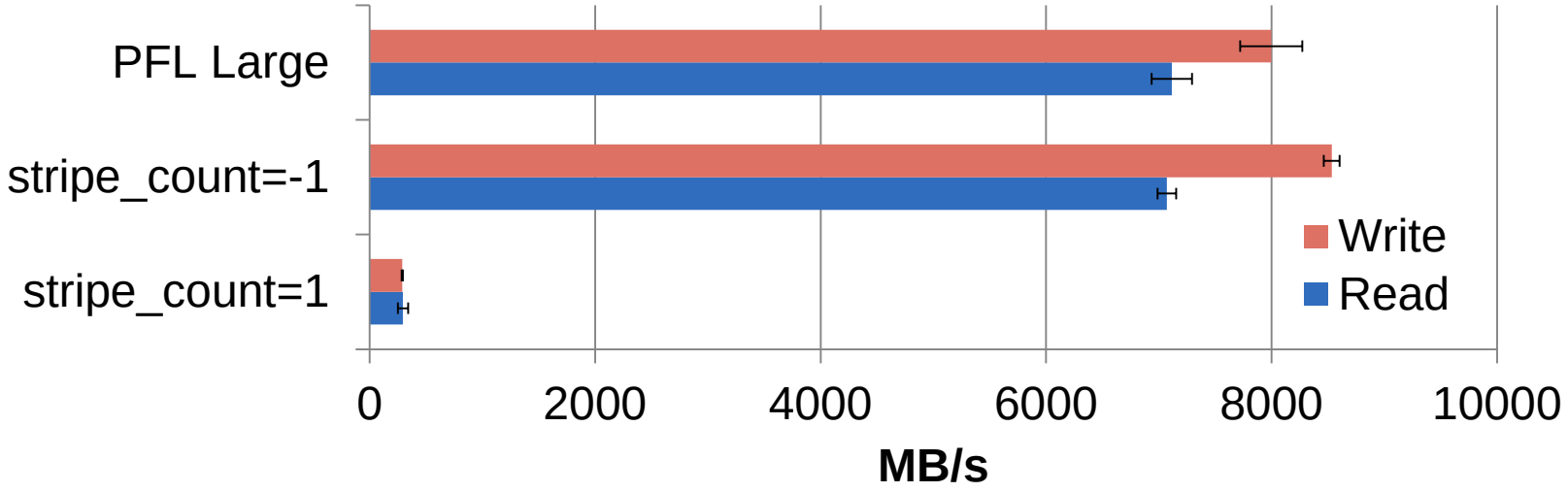
- PFL small and stripe_count=1 are comparable for reads and writes
- PFL med reads are faster than stripe_count=-1 due to less contention
- PFL med write speed is less than stripe_count=-1 (somewhat surprising)
- Higher variance in write speeds possibly due to contention on system

Multi-Client IOR (FPP) – 512 Threads



- Read performance of PFL small is comparable to stripe_count=1
- Write performance of PFL small is much less than stripe_count=1 (large variances could be due to contention on shared test system)
- PFL med performance is better than stripe_count=-1 (less contention)

Multi-Client IOR (Shared) – 512 Threads



- Performance of PFL large and stripe_count=-1 are comparable
- Performance for stripe_count=1 is much lower due to contention (as expected)

ORNL Lustre Testbed

- 8x OSS Servers (Dell R720)
  - 2x Intel Xeon 2630 v2
  - 64 GB RAM
  - Mellanox ConnectX-3 FDR HCA
- 2x MDS Servers (Dell R720)
  - Same as OSS servers except with 128 GB RAM
- 8 OSTs per OSS server
  - OSTs use ZFS backend

Synthetic Dynamic Striping

- Prior to the PFL prototype, a simulated form of dynamic striping was tested
  - Files were split into smaller components
  - Each component was created in a different directory with different stripe counts
  - Applications were modified to perform I/O to file components
    - IOR
    - BLAST

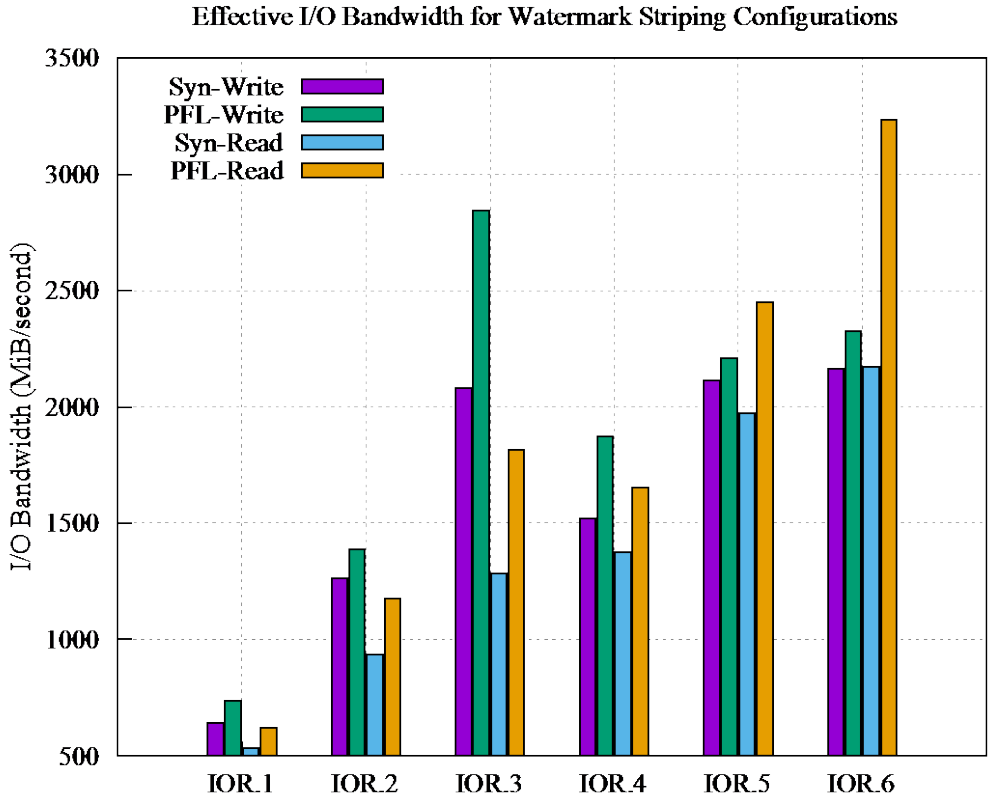
http://arxiv.org/pdf/1504.06833v1.pdf

Dynamic Striping and PFL Test Cases

- IOR POSIX shared file
  - 16 compute nodes with 4 processes per node
  - 4 TB total file size

Standard	Dynamic / PFL
[IOR.1] Entire file: stripe_count=4	[IOR.4] 0-1TB: stripe_count=4 Remainder: stripe_count=8
[IOR.2] Entire file: stripe_count=8	[IOR.5] 0-1 TB: stripe_count=4 Remainder: stripe_count=16
[IOR.3] Entire file: stripe_count=16	[IOR.6] 0-1 TB: stripe_count=4 1-2 TB: stripe_count=8 Remainder: stripe_count=16

PFL vs. Synthetic Dynamic Striping



- Direct comparison of bandwidth between PFL and synthetic striping not really “fair” since different Lustre versions used
- Important result is that PFL behavior follows same trend as synthetic striping

Object Placement Testing

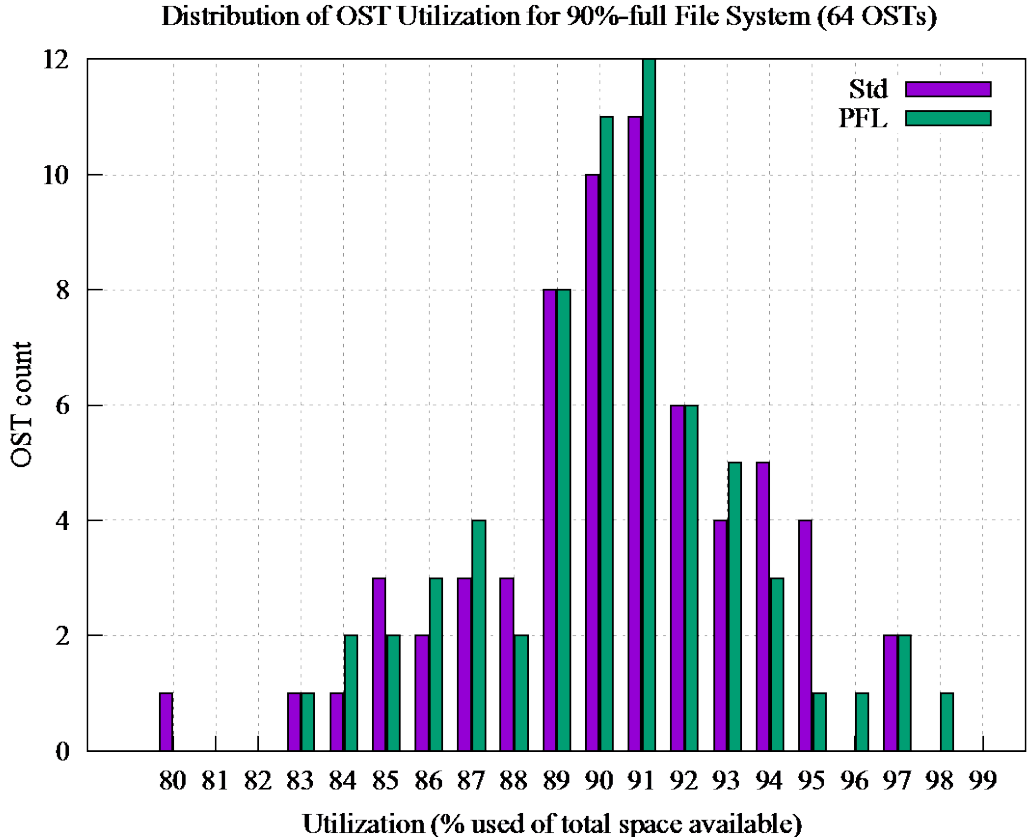
- Users often choose poor striping patterns
  - Large file, small stripe count → Imbalanced OST usage
  - Small file, large stripe count → Sub-optimal performance
- PFL can use increasing stripe count to accommodate multiple file sizes
  - How does using a single PFL layout for all files compare to “ideal” traditional striping?
  - Test scenario
    - Create files with traditional striping and single PFL layout
    - Compare distribution of OST usage

Object Placement Testing (cont.)

- Choose file size distribution (based on OLCF stats)
- Choose PFL Layout
  - [0, 1MB) stripe_count=1
  - [1MB, 64MB) stripe_count=4
  - [64MB, 128GB) stripe_count=16
  - [128GB, EOF) stripe_count=48
- Fill file system to 90% capacity

File Size	Percent	Stripe Count
1 MB	70%	1
64 MB	20%	4
128 GB	9%	16
4 TB	1%	48

Object Placement Results



- Distribution of OST utilization for PFL files is very similar to the distribution seen using “ideal” striping

Summary

- Progressive File Layouts provide additional flexibility when defining the striping configuration for a file
- PFL performance appears to be on par with traditional Lustre (and in some cases better)
- Single PFL layout can be used for files of varying sizes
  - Can simplify Lustre usage for users
  - Will save some headaches for sys admins
- For more test results, see

http://lustre.ornl.gov/ecosystem/documents/papers/LustreEco2016-Mohr-PFL.pdf

Future Work

- PFL Implementation
  - Layout inheritance from parent directory
  - Define PFL layout as default for file system
  - Improved OST allocator
  - Dynamic component instantiation
- PFL Testing
  - More data intensive workloads
  - Increase scaling

Acknowledgements

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Questions?