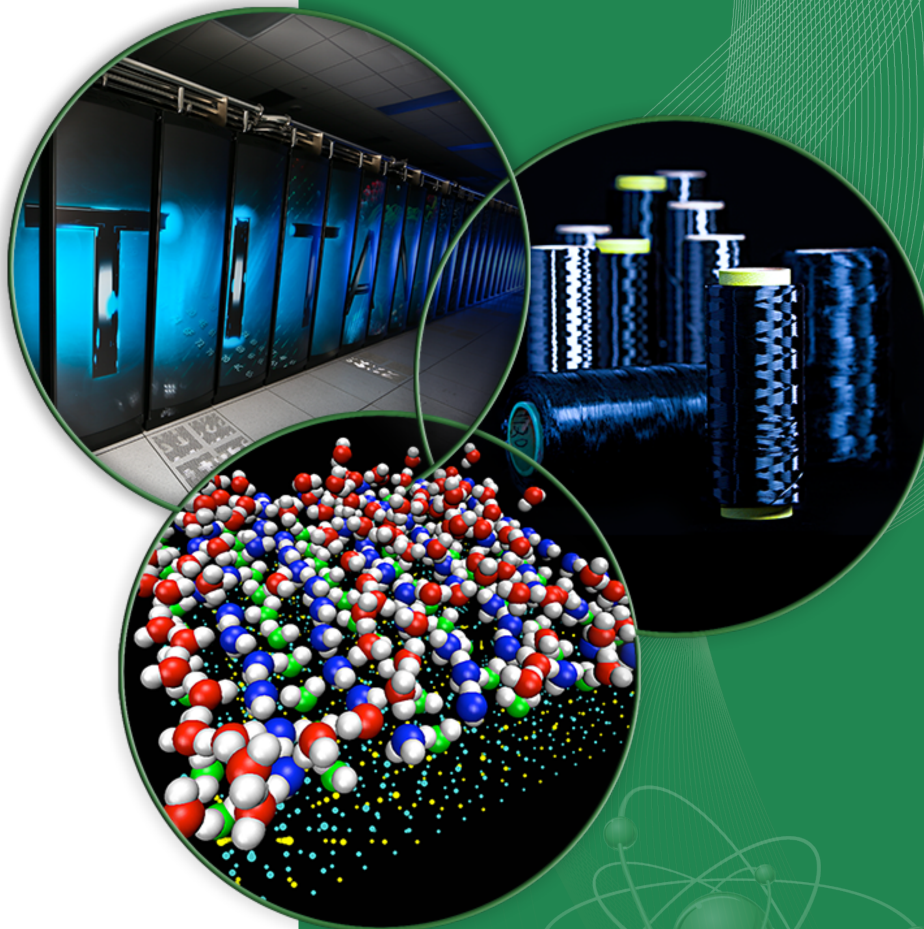
Oak Ridge National Laboratory
Computing and Computational Sciences Directorate



Evaluating Progressive File Layouts for Lustre

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Agenda

- Progressive File Layout (PFL) Overview
- PFL Prototype Implementation
- Streaming I/O Tests
- Comparison to Synthetic Dynamic Striping
- Object Placement Testing

Lustre File Layouts Today

- Several Lustre parameters control file layout
  - Stripe size
  - Stripe count
  - Stripe index
  - 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

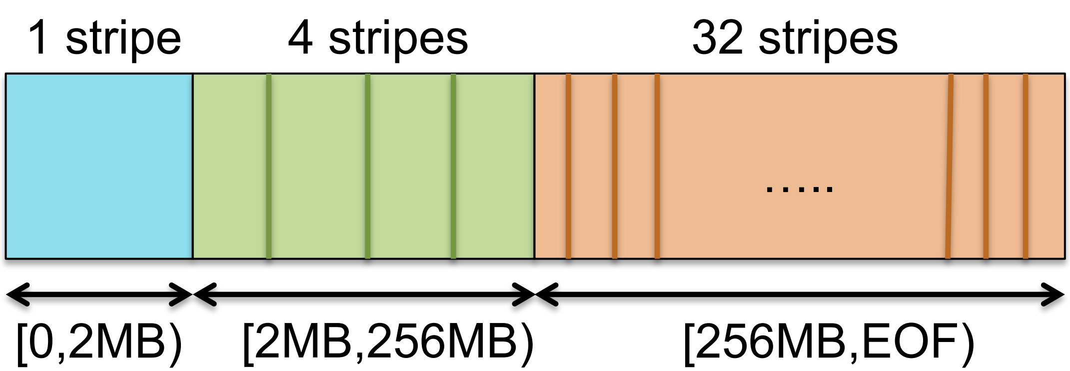
Layout Enhancement

- 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
  - Simplify Lustre usage for novice users
- Change stripe layout as file grows
- 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

PFL Prototype Implementation

- Intel, under contract from ORNL, has been 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

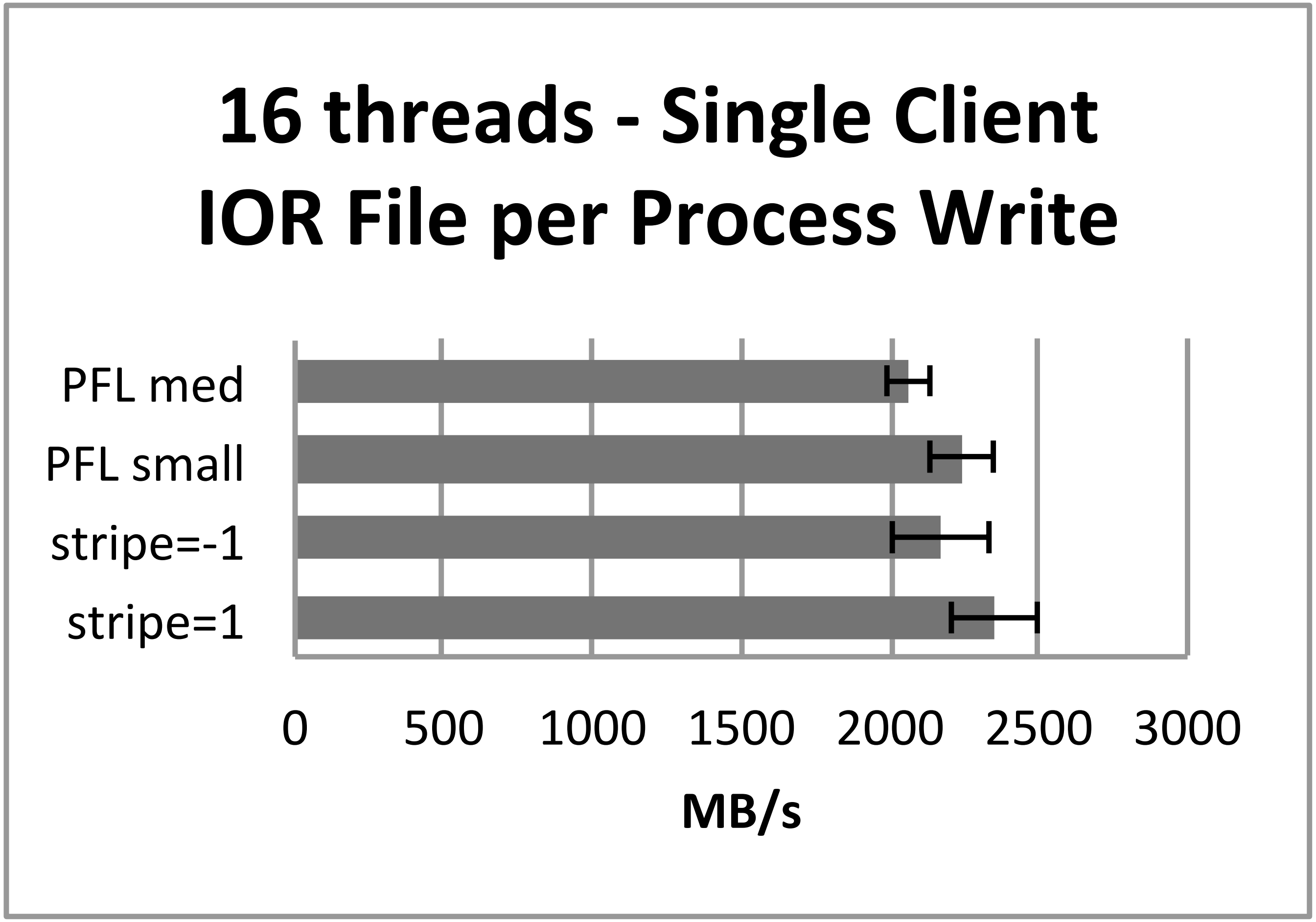
- Several different tests were run to evaluate the functionality and performance of PFL prototype
- Streaming IOR and mdtest (Intel)
  - Comparison with traditional Lustre striping
  - Single client and multiple clients
  - Shared file and file per process
- Comparison to Synthetic Dynamic Striping (ORNL)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

Intel Testing

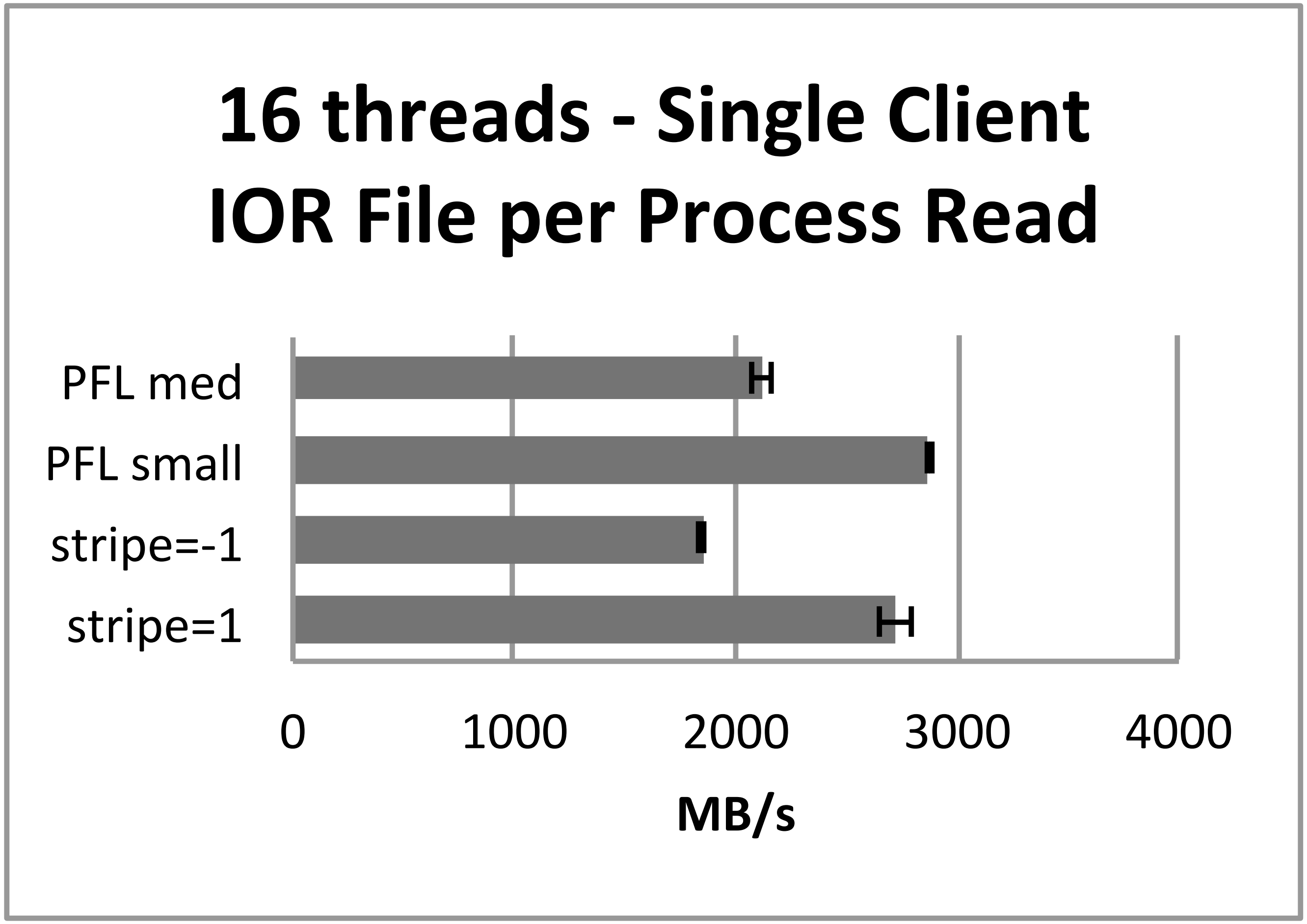
- Intel’s tests were run on Hyperion at LLNL
  - 32 Lustre clients
  - 16 Lustre servers with 52 OSTs (ldiskfs)
  - Mellanox DDR Infiniband
- IOR
  - Single client (16 threads) file per process
  - 32 clients (512 threads) file per process
  - 32 clients (512 threads) shared file
  - Each thread reads/writes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

Test File Layouts

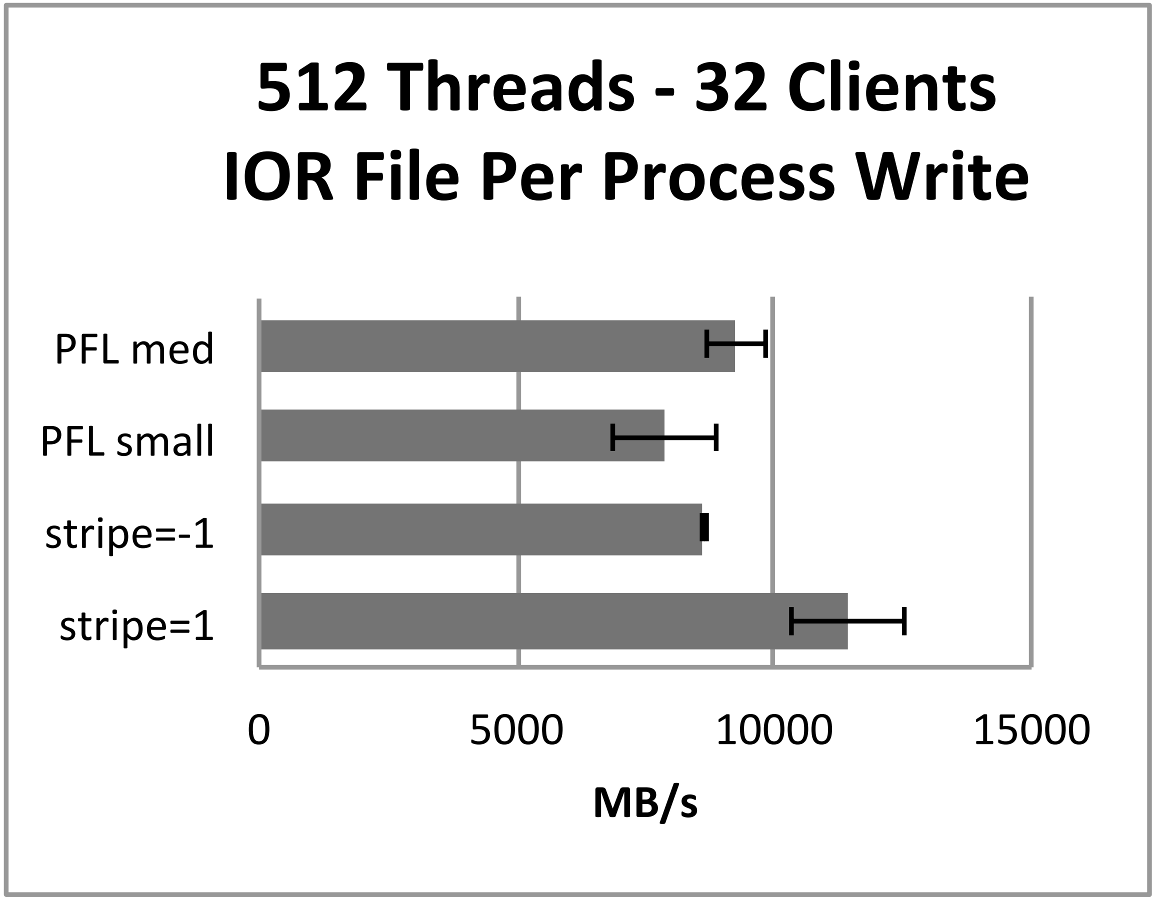
- Tests compared several different layouts
  - Traditional
    - stripe_count = 1 and stripe_count = -1
  - PFL small
    - [0,EOF) → stripe_count=1
  - PFL medium
    - [0,16M) → stripe_count=1
    - [16M, EOF) → stripe_count=4
  - PFL large
    - [0,16M) → stripe_count=1
    - [16M, 128M) → stripe_count=4
    - [128M, EOF) → stripe_count=47



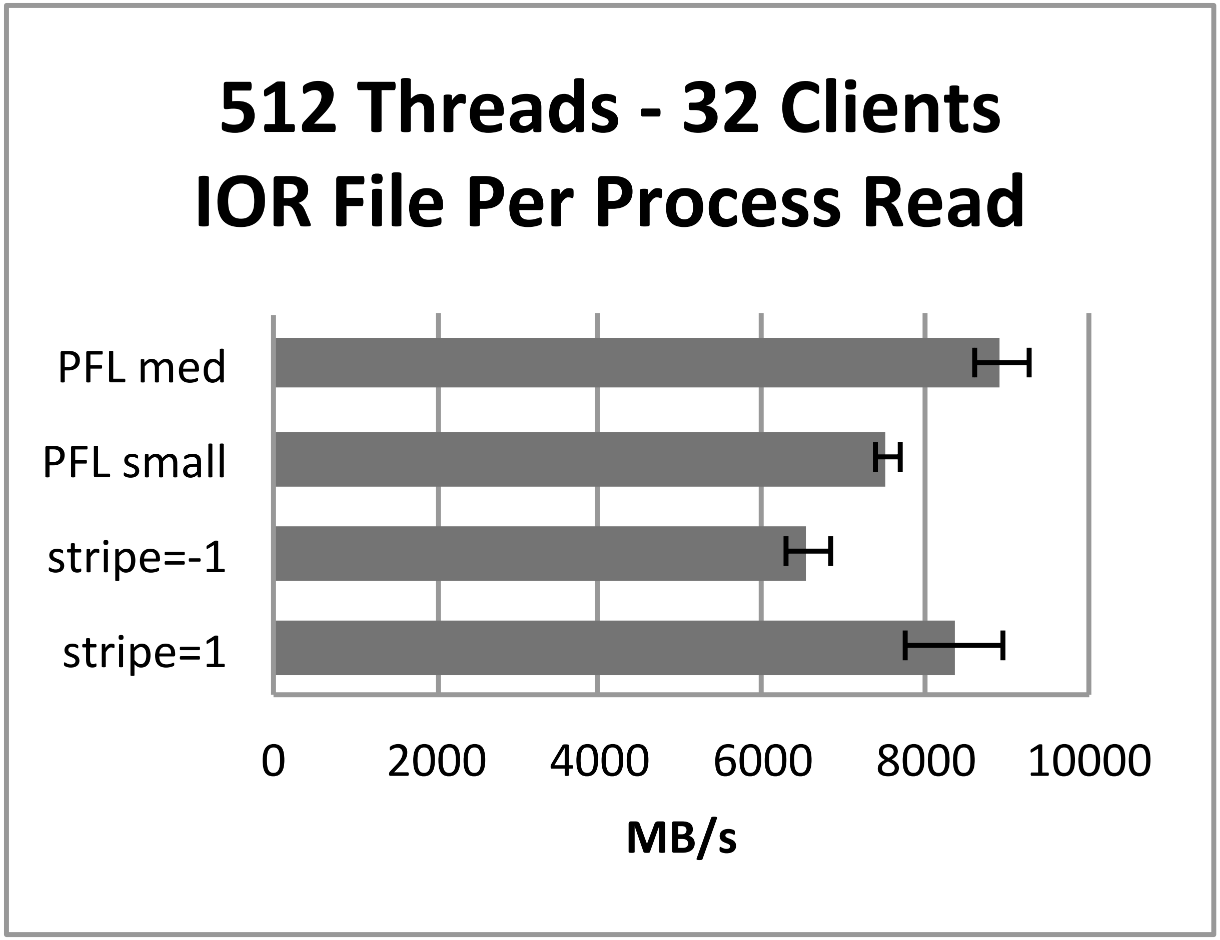
- Performance of PFL small and stripe=1 are comparable
- Performance of PFL med is lower than stripe=-1, but they are within error margins



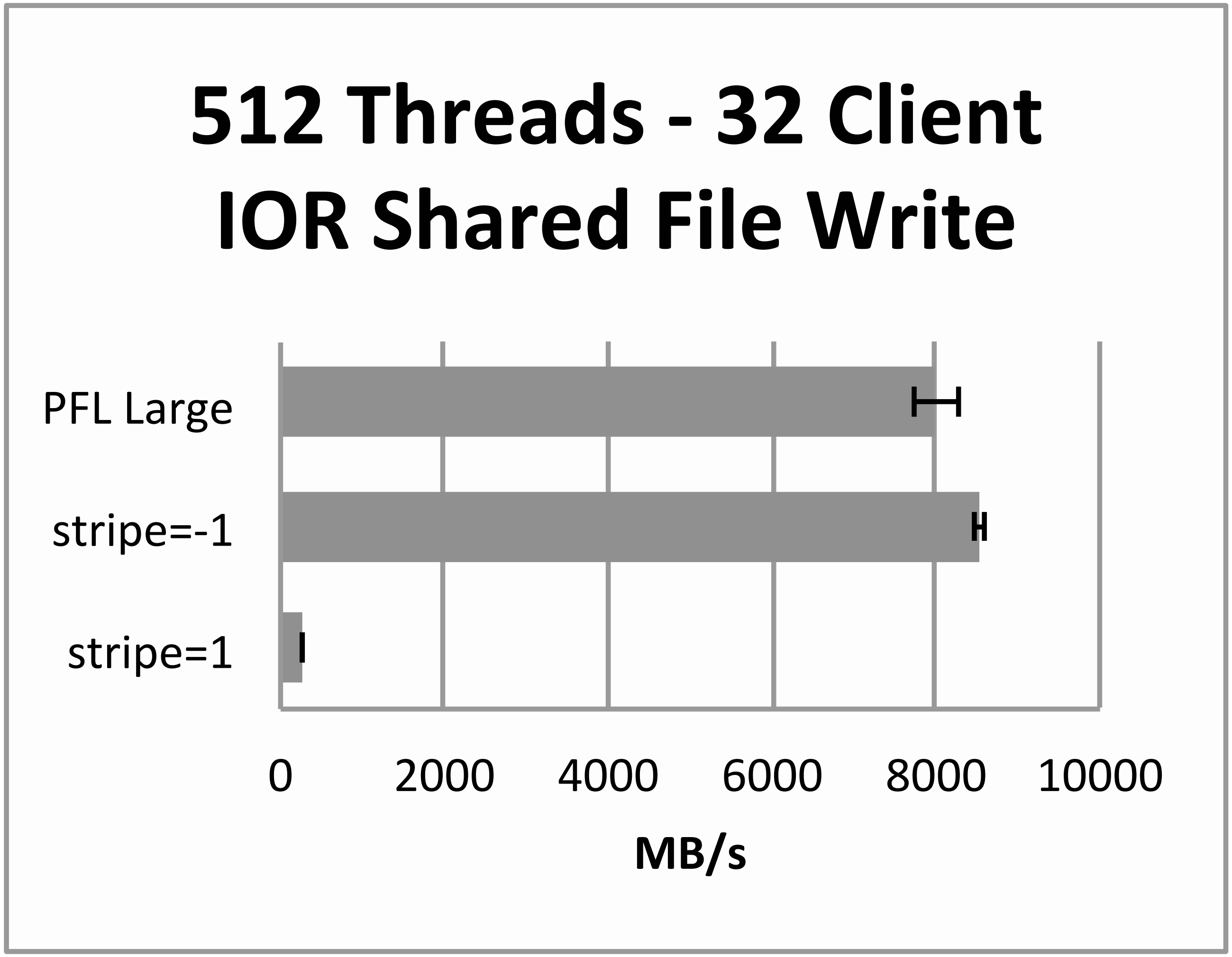
- Performance of PFL small is slightly better than stripe=1, but still comparable
- Performance of stripe=-1 is lower than PFL med due to more contention at OST level



- Performance of stripe=-1 is less than stripe=1 due to increased contention on the OSTs
- Performance for PFL small is less than stripe=1 (which is not expected). Large variances may indicate contention from other processes on test file system.



- Performance of PFL small is similar to stripe=1 although somewhat less. (Again, large variance for stripe=1 may indicate contention.)
- Performance of PFL med is better than stripe=-1 due to less contention on OSTs



- Performance for stripe=1 much less than stripe=-1 (as expected)
- Performance of PFL large is on par with stripe=-1

ORNL Lustre Testbed

- 8x OSS Servers (Dell R720)
  - 2x Intel Xeon 2630 v2
  - 64 GB RAM
  - 250 GB 7.2K RPM SATA3 drive
  - Mellanox ConnectX-3 FDR HCA
- 2x MDS Servers (Dell R720)
  - Same as OSS servers except:
    - 128 GB RAM
    - 6x 300 GB 15K RPM SAS drives
- 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

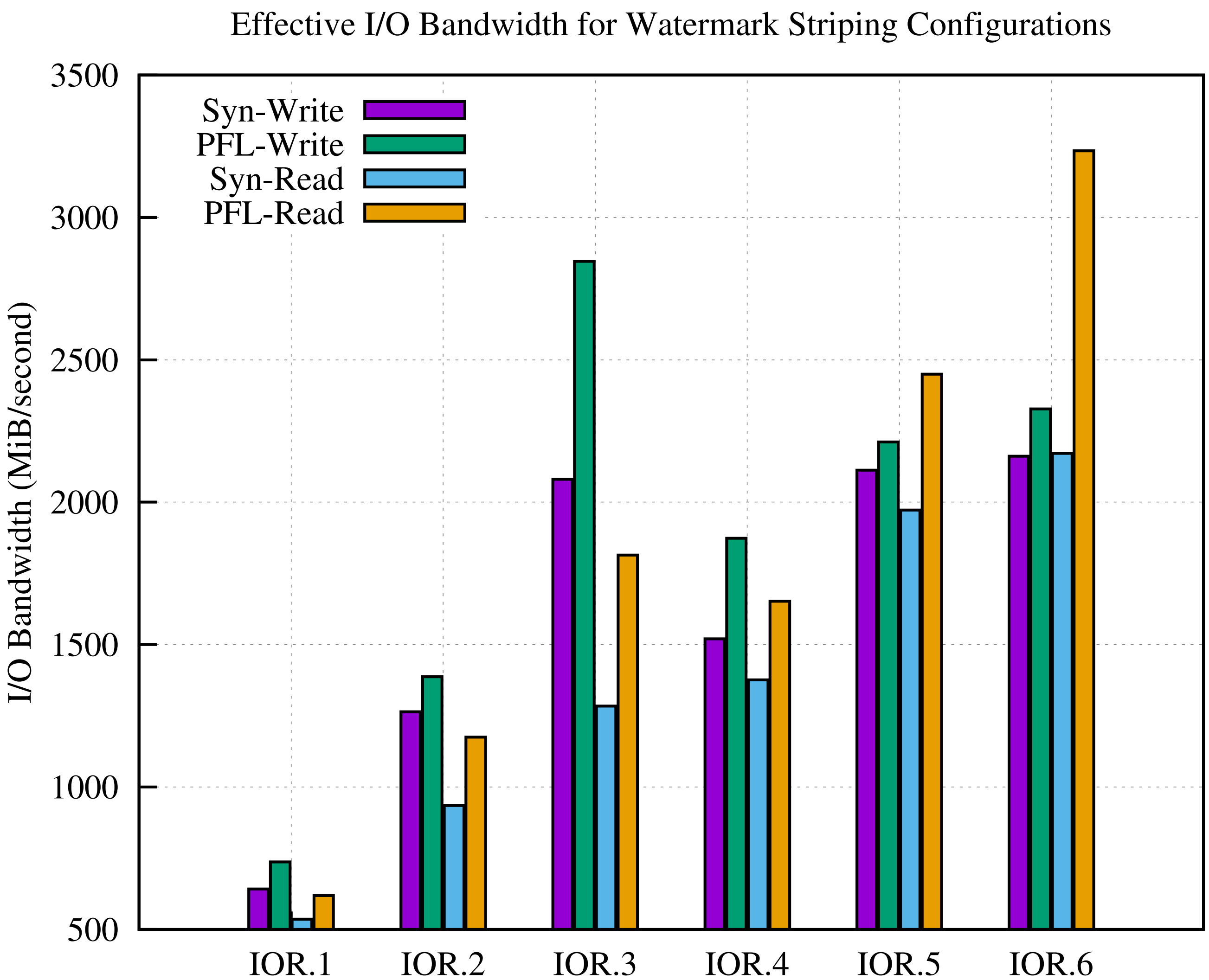
http://arxiv.org/pdf/1504.06833v1.pdf

Dynamic Striping Test Cases

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

Standard	PFL
[IOR.1] Entire file: stripe_count=4	[IOR.4] 0-1 TB: 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 Results



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
  - Create files with single PFL layout
  - Compare distribution of OST usage

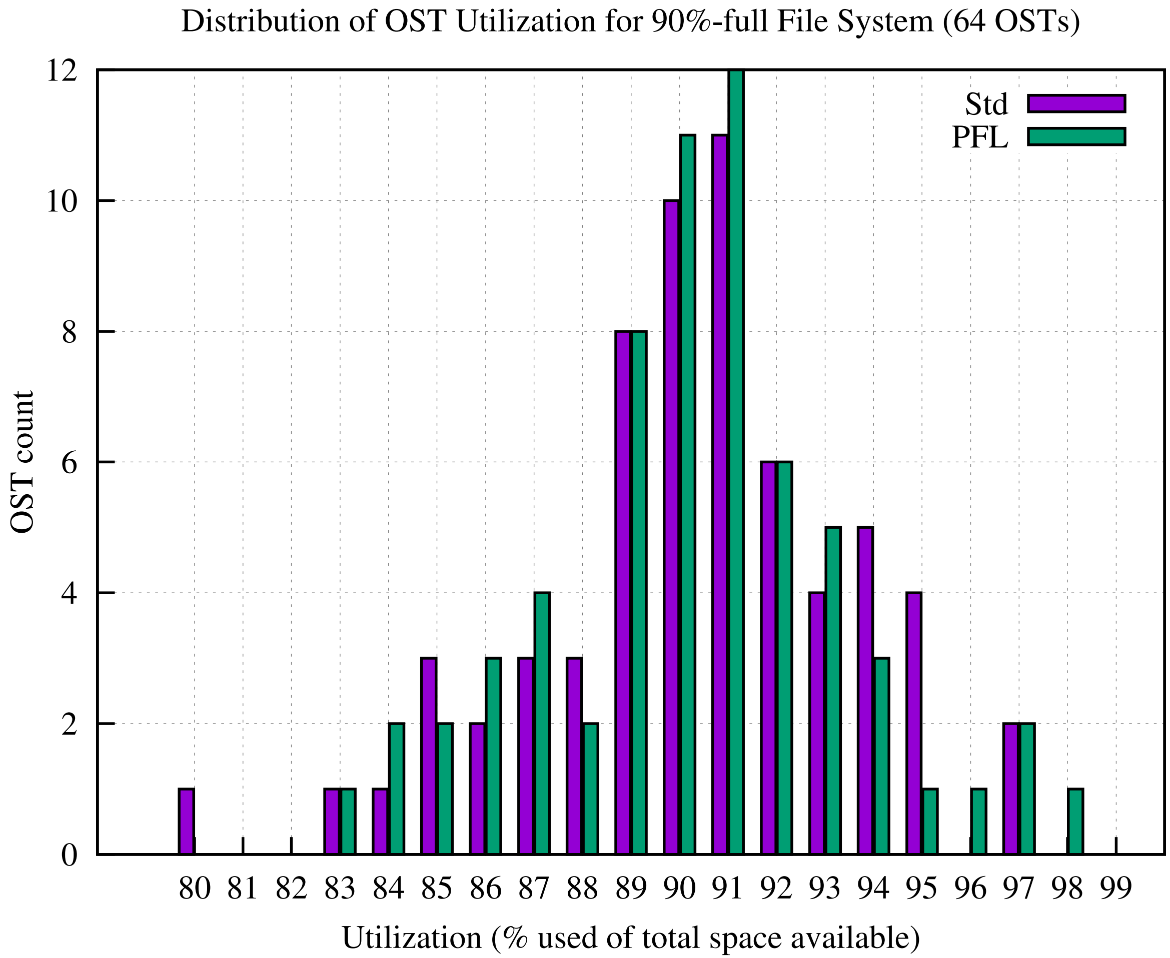
Object Placement Testing (cont.)

- Choose file size distribution (based on OLCF stats)

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

- 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

Object Placement Results



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

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 effectively used for files of widely varying sizes
  - Can help simplify Lustre usage for users
  - Will save some headaches for sys admins

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?