Accelerating your application I/O with UnifyFS

EXASCALE COMPUTING PROJECT

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Lawrence Livermore National Laboratory

OAK RIDGE National Laboratory

NCSA

LLNL: **KATHRYN MOHROR** (PI), ADAM MOODY, CAMERON STANAVIGE, TONY HUTTER

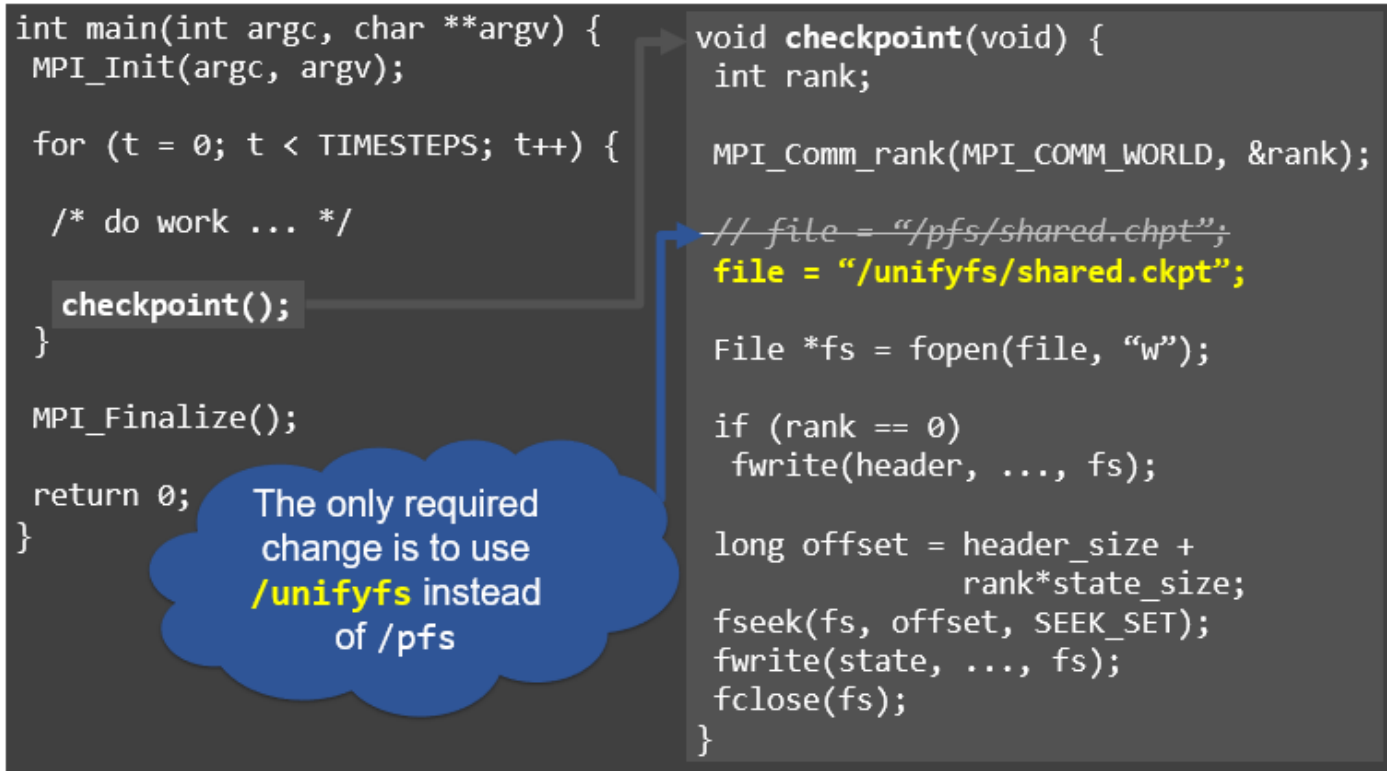
ORNL: SARP ORAL (ORNL-PI), HYOGI SIM, FEIYI WANG, MIKE BRIM, SWEN BOEHM

NCSA: CELSO MENDES, CRAIG STEFFEN

LLNL-PRES-811832

What is UnifyFS?

- Simply put, it's a file system for burst buffers
- Our goal is to make using burst buffers on exascale systems as *easy* as writing to the parallel file system and orders of magnitude *faster*



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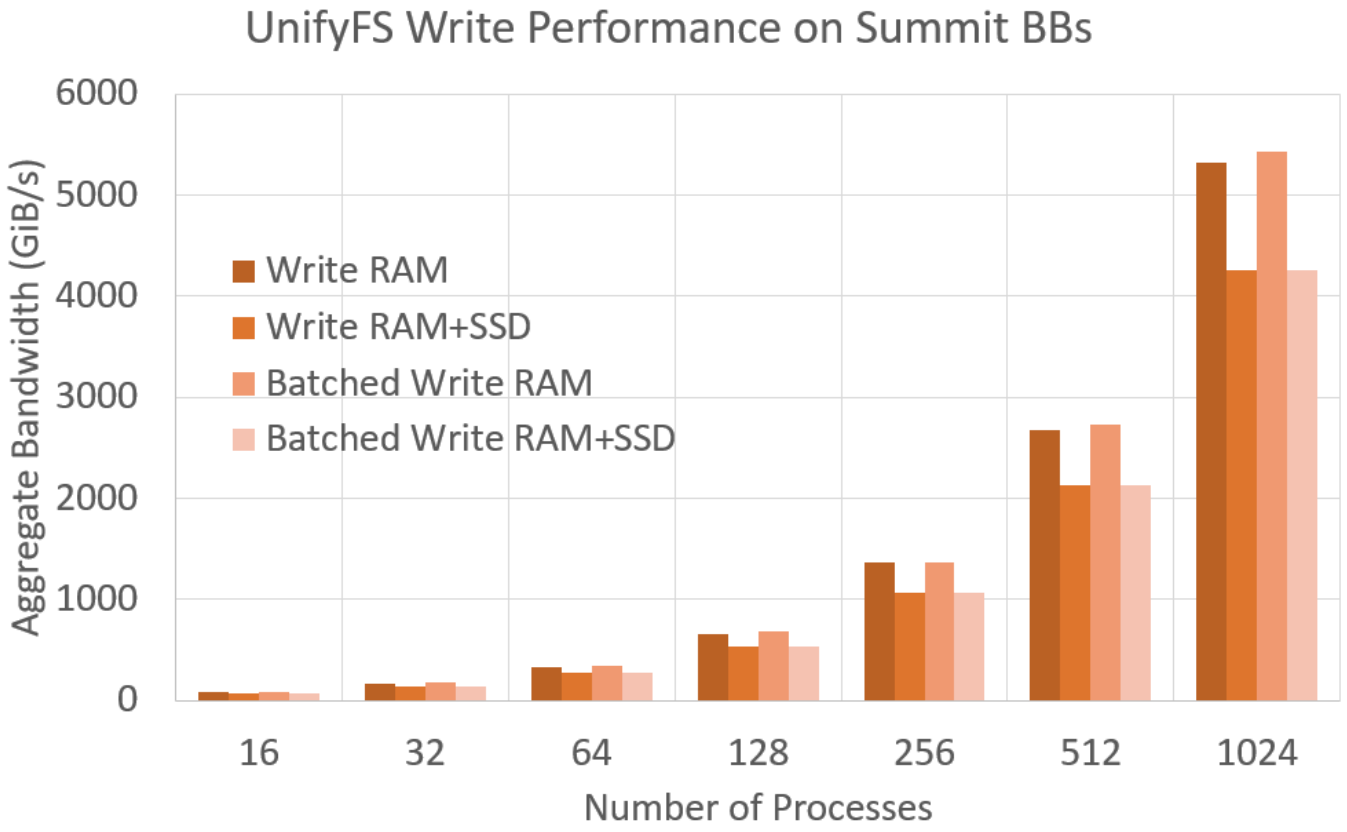
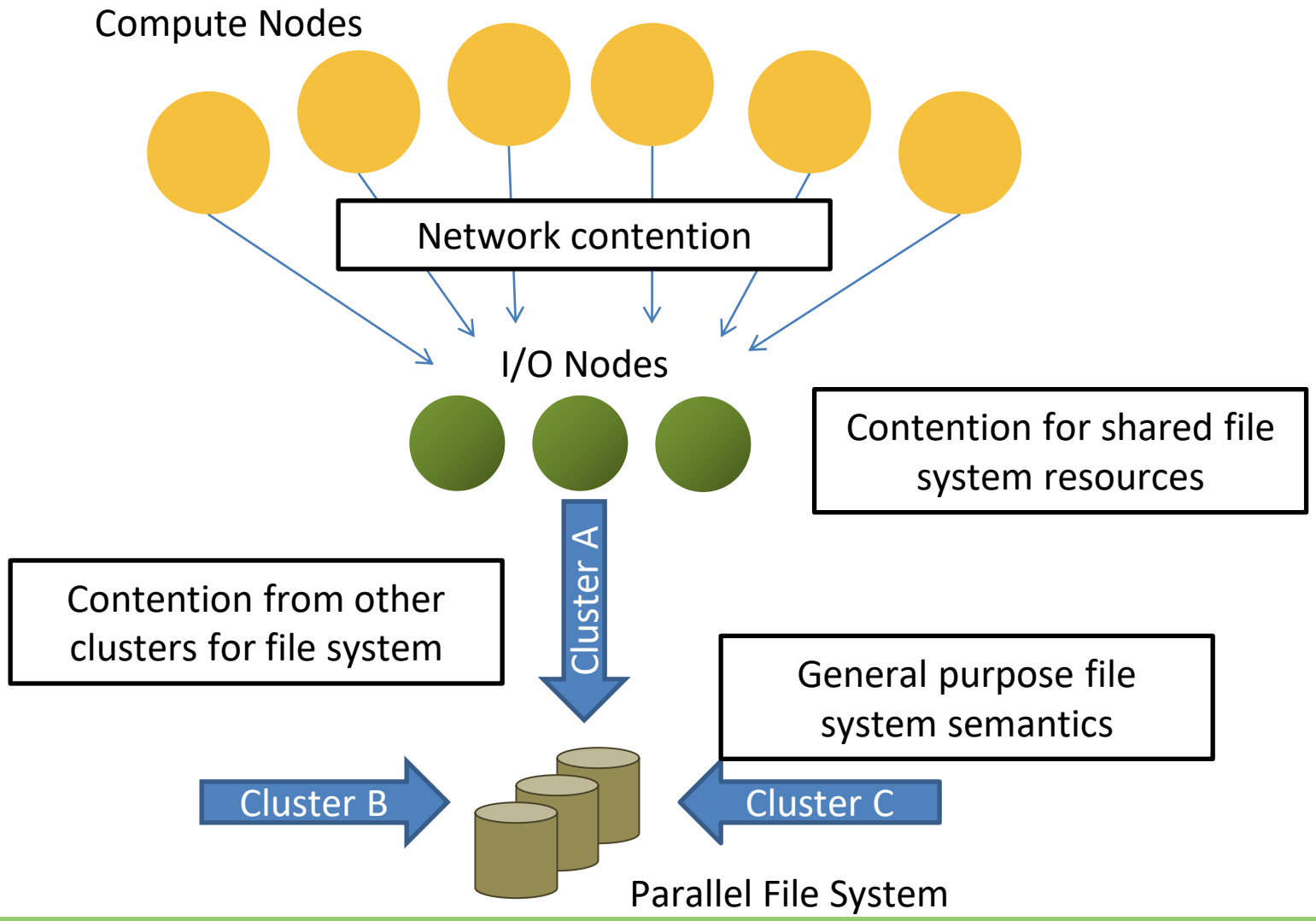
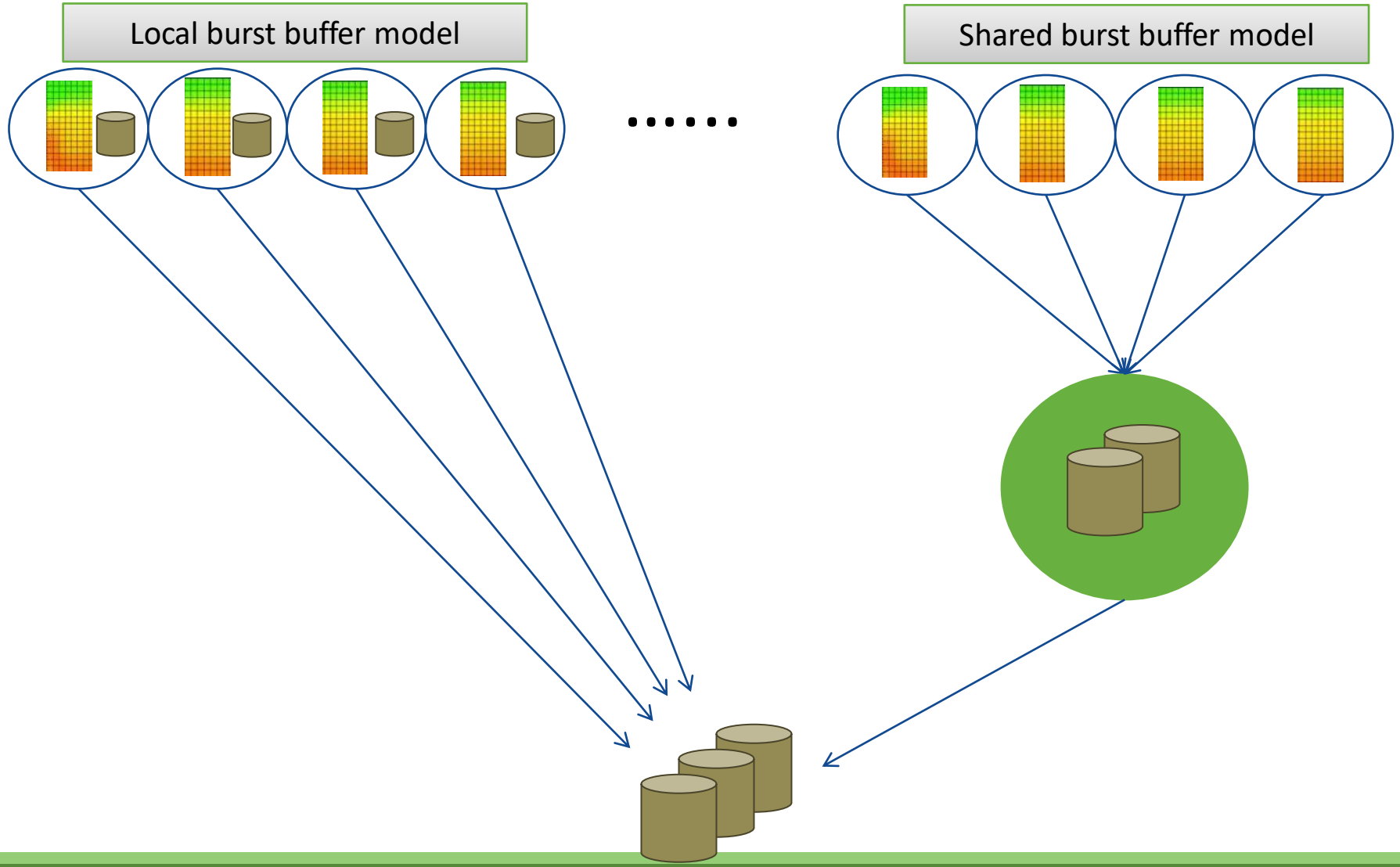
- Results on Summit show scalable write performance for UnifyFS with shared files on burst buffers



Writing data to the parallel file system is expensive



HPC Storage is becoming more complex



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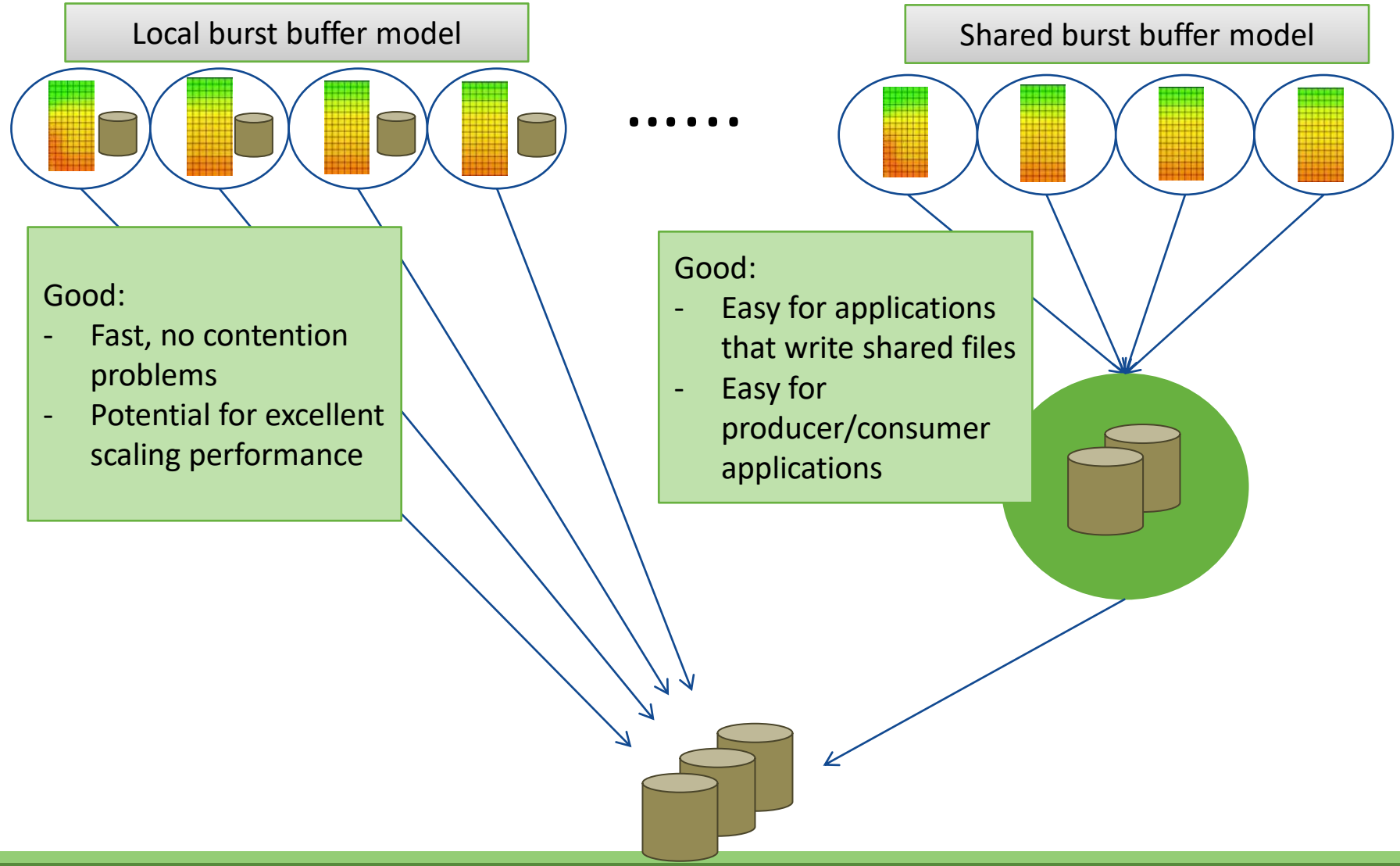

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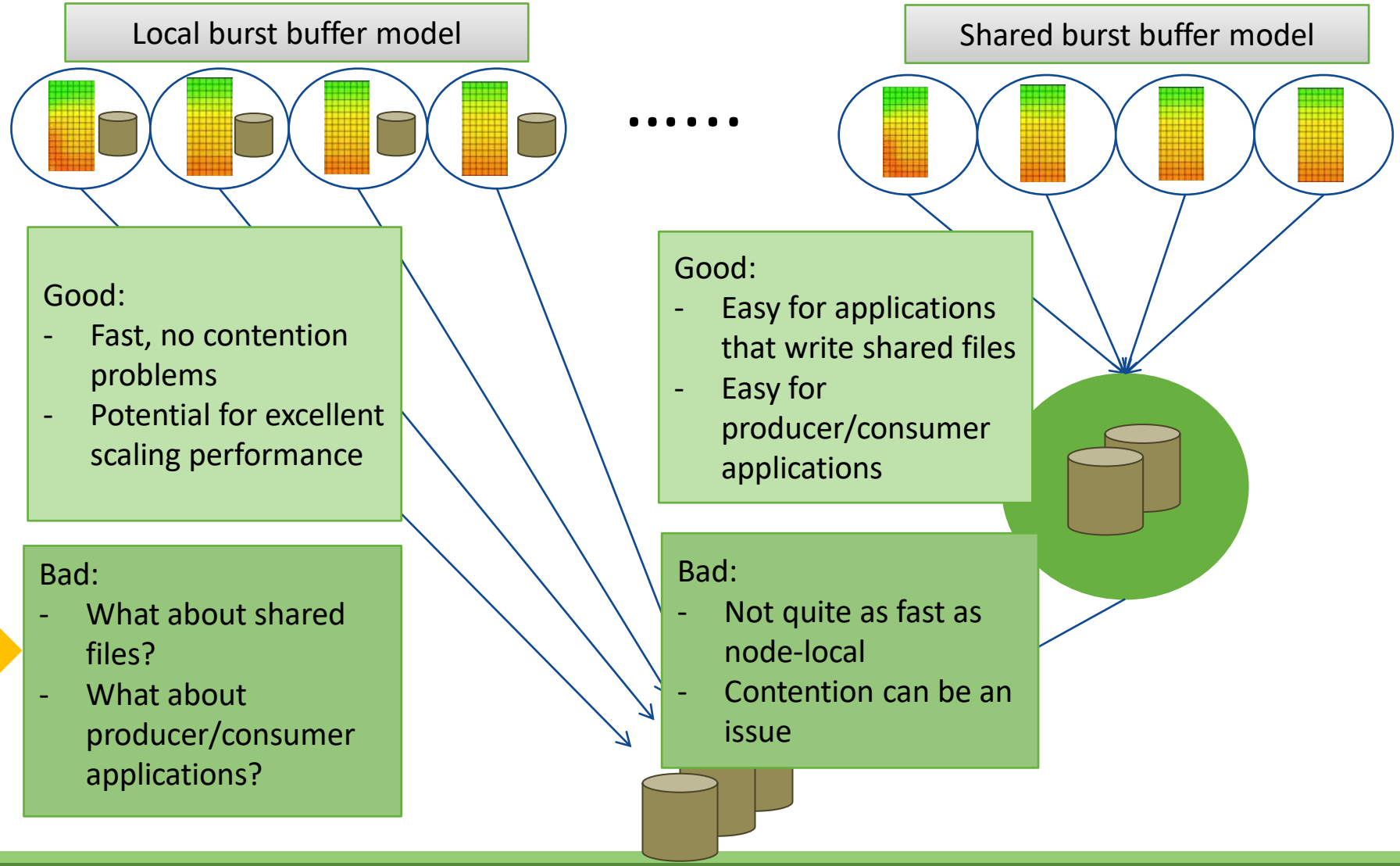
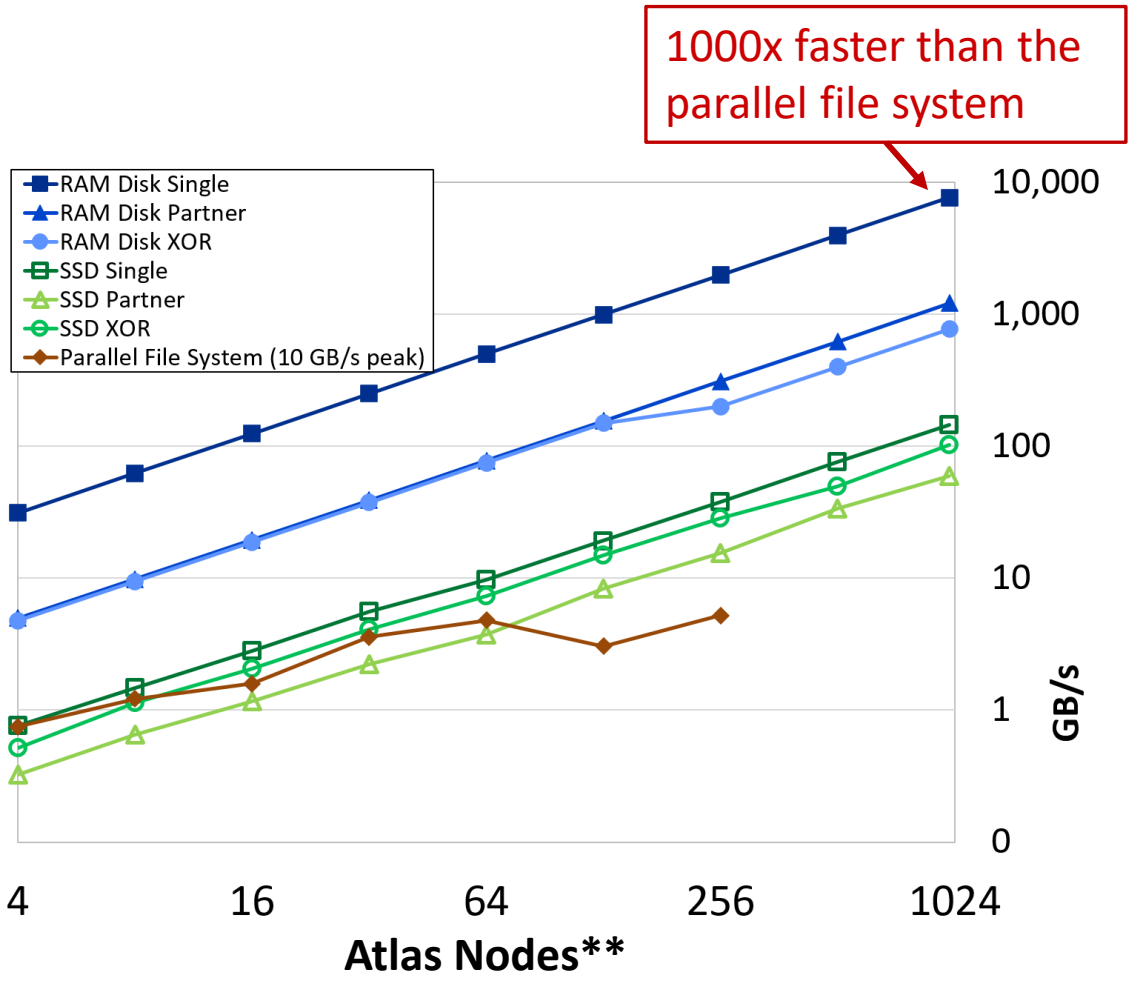
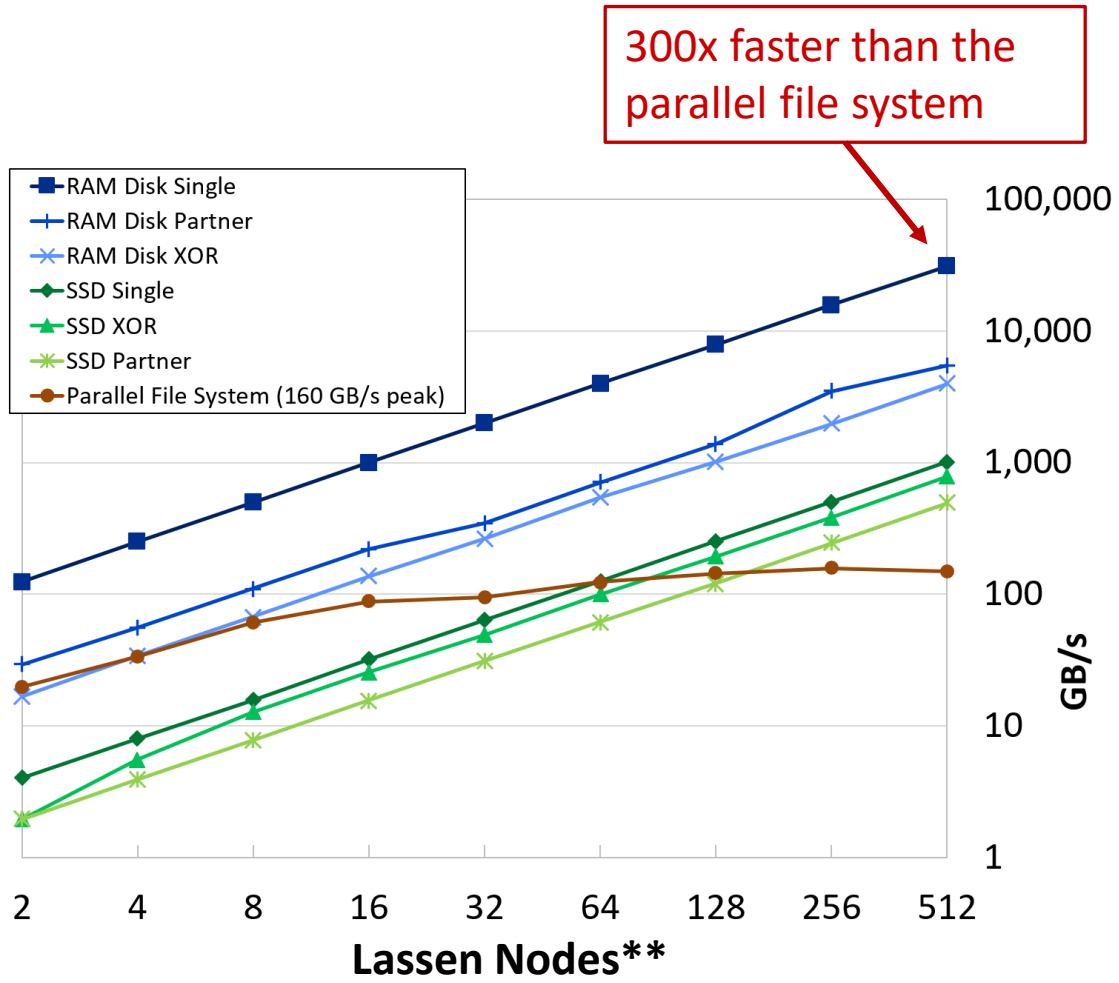


UnifyFS targets local burst buffers because they are fast and scalable

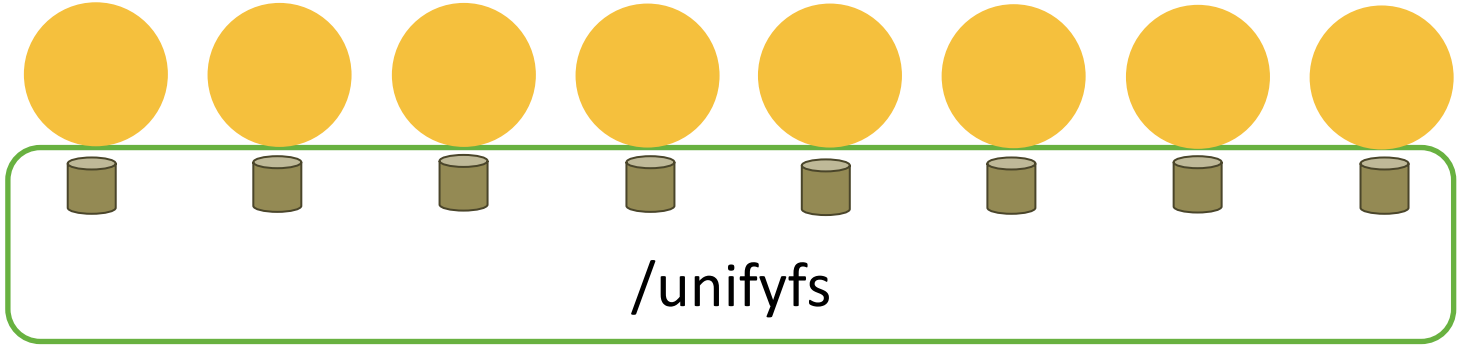




**Measurements of local storage performance taken with SCR (The Scalable Checkpoint/Restart Library) https://github.com/llnl/scr

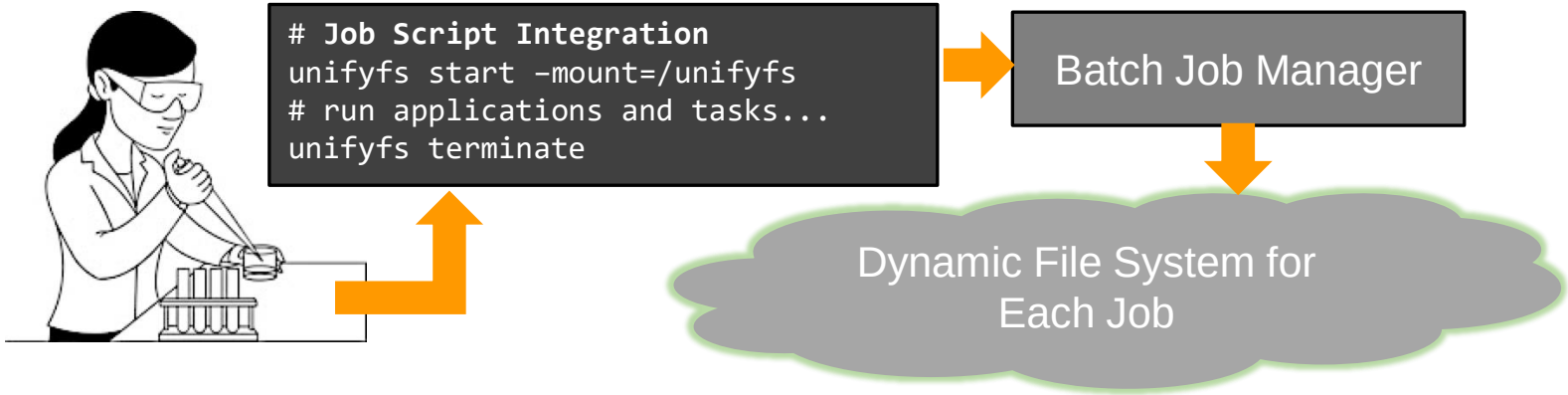
UnifyFS makes sharing files on node-local burst buffers easy and fast

- Sharing files on node-local burst buffers is not natively supported



- UnifyFS makes sharing files **easy**
  - UnifyFS presents a shared namespace across distributed storage
  - Used directly by applications or indirectly via higher level libraries like VeloC, MPI-IO, HDF5, PnetCDF, ADIOS, etc.
- UnifyFS is **fast**
  - Tailored for specific HPC workloads, e.g., checkpoint/restart, visualization output
  - Each UnifyFS instance exists only within a single job, no contention with other jobs on the system

UnifyFS is designed to work completely in user space for a single user's job



HPC Application
(N-1, N-N Checkpointing, Collective I/O with Scientific I/O Libraries)

Checkpoint/Restart Lib: SCR, VeloC	Scientific I/O Lib: HDF5, MPI-IO, …	Standard POSIX I/O

UnifyFS

User level I/O interception	Fast data writes to node local storage
Data visible globally after "lamination"	Transer API to move data to/from parallel file system

UnifyFS optimizes on typical HPC application I/O behavior

```
int main(int argc, char* argv[]) {
  MPI_Init(argc, argv);

  read_input();

  for(int t = 0; t < TIMESTEPS; t++)
  {
    /* ... Do work ... */
    /* ... Synchronization ... */

      write_output();

  }

  MPI_Finalize();
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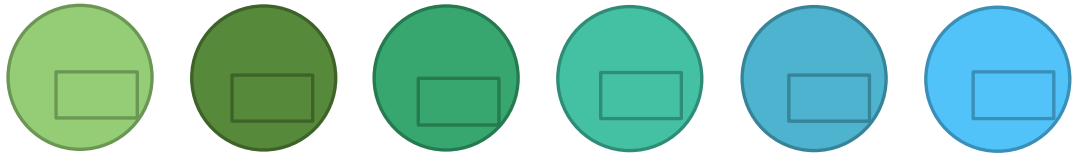

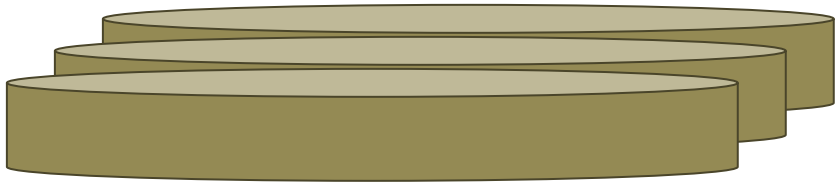

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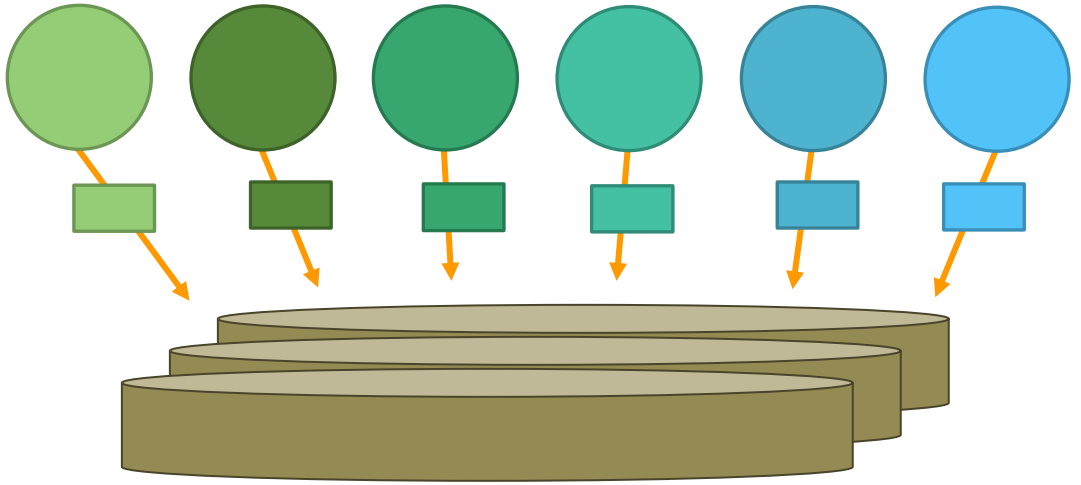

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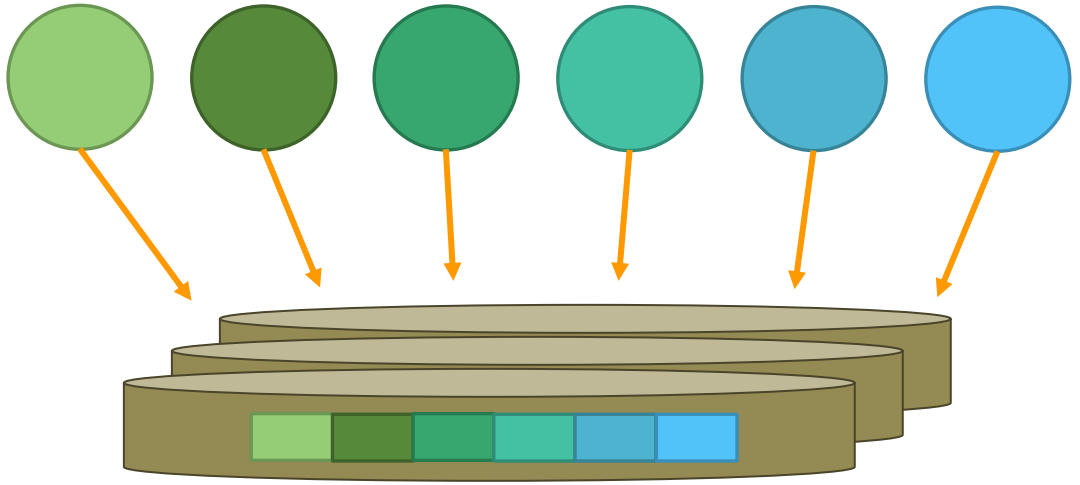

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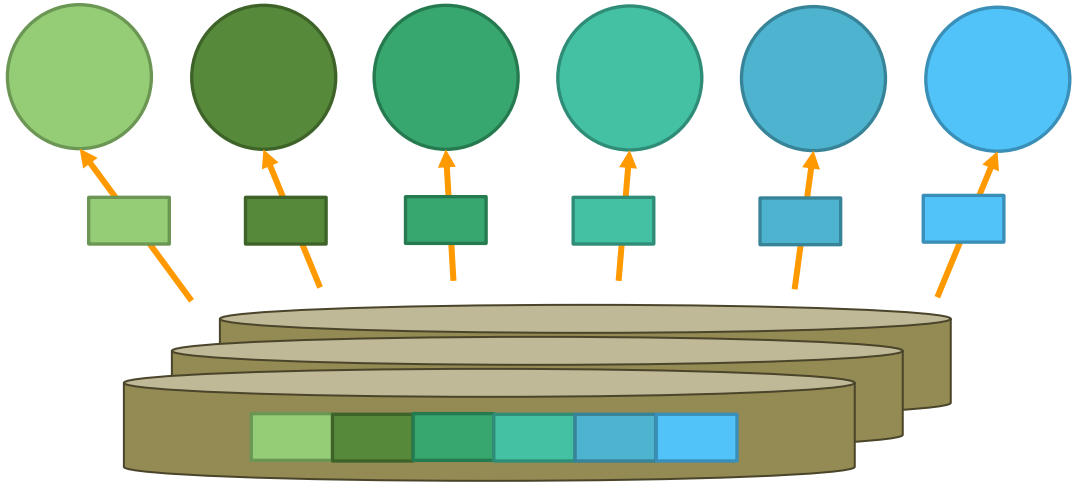

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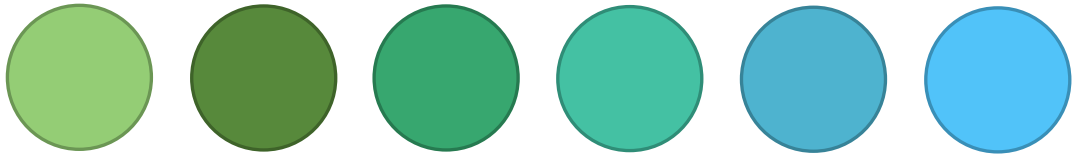

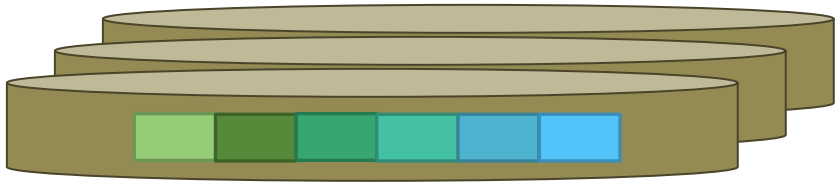

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- Reads and writes are performed to regular offsets in files (not random writes or reads)
- When reading, a process will most likely access data it wrote
- These behaviors are typical of common HPC workloads
  - Checkpoint/restart, periodic output, producer/consumer

UnifyFS files are globally visible after “lamination”

- Based on typical I/O behavior in HPC applications we utilize “lamination semantics”
- Before lamination processes may not see updates written by processes on another node
- Once processes are done modifying a file, they initiate lamination
  - The lamination process renders your file read-only and synchronizes file data across nodes in your job
  - Now any process on any node can read the final state of the file
  - And you can transfer data to external storage

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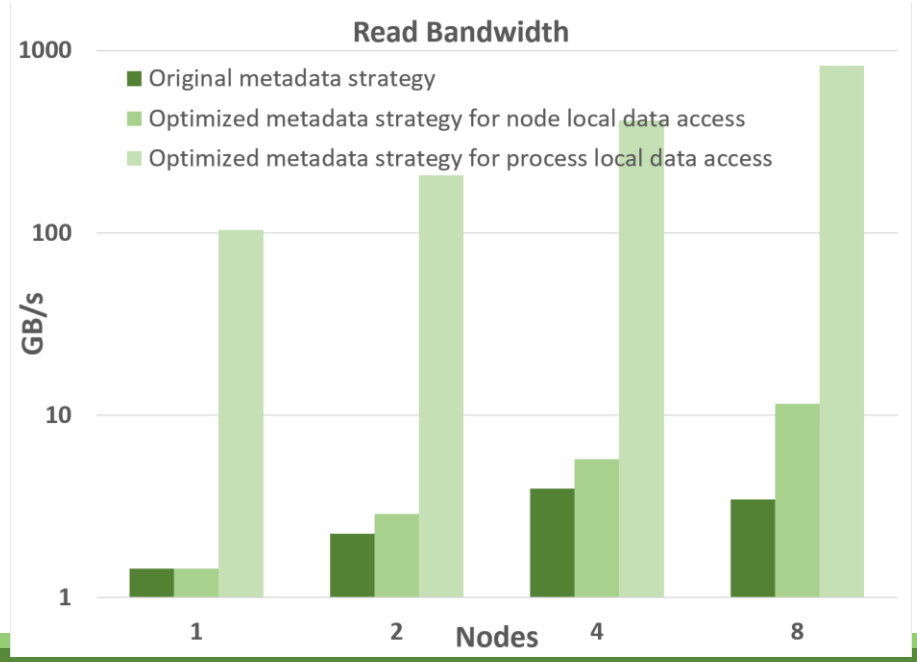
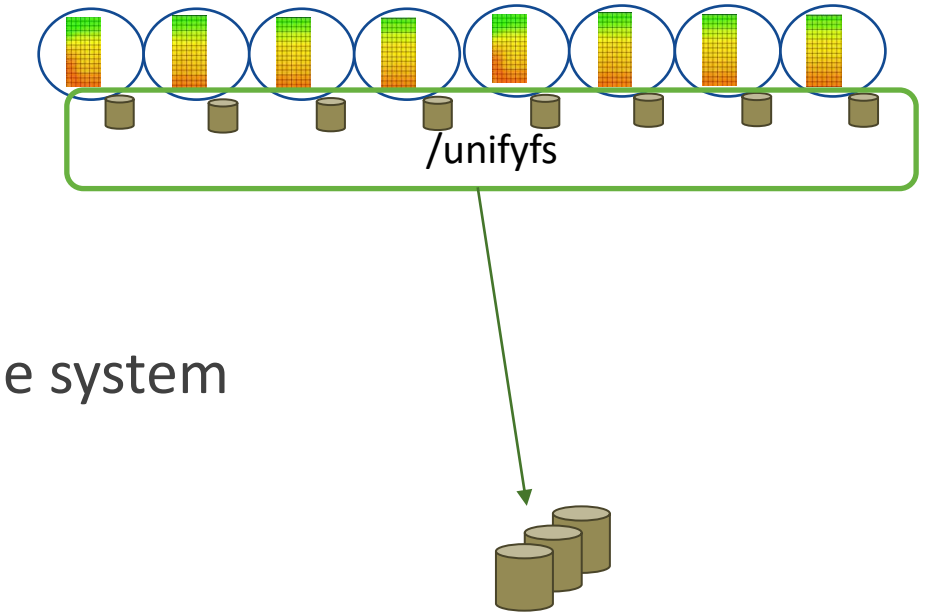


Now for a tutorial…

- get and build UnifyFS
- build your application to use UnifyFS
- run your application with UnifyFS
- move your data between UnifyFS and the parallel file system



How do I get and build UnifyFS?

Got Spack?

```
$ spack install unifyfs

$ spack load unifyfs
```

https://github.com/spack/spack

How do I modify my MPI application for UnifyFS?

```
int main(int argc, char * argv[]) {
    FILE *fp;
     //program initialization
     //MPI setup

     //perform I/O
    fp = fopen("/lustre/out.txt", "w");
    fprintf(fp, "Hello World! I'm rank %d", rank);
    fclose(fp);









     //clean up
    return 0;
}
```

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int main(int argc, char * argv[]) {
    FILE *fp;
     //program initialization
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     //perform I/O
    fp = fopen("/unifyfs/out.txt", "w");
    fprintf(fp, "Hello World! I'm rank %d", rank);
    fclose(fp);

    // "laminate" the file to indicate to UnifyFS you
are done modifying this file
    chmod("/unifyfs/out.txt", 0444);

     //clean up
    return 0;
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     //clean up
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- "chmod" is currently supported method for lamination
- (Near-)future methods we plan to support
  - Laminate on close()
  - Laminate on unmount() (either explicit API call or auto-mount)
  - Laminate with API call, e.g., unifyfs_laminate
- Expect to be able to specify which method you want when you start up UnifyFS

How does UnifyFS intercept I/O calls?

- Static Linking

```
$ mpicc -o hello `<unifyfs>/bin/unifyfs-config --pre-ld-flags` \
  hello.c `<unifyfs>/bin/unifyfs-config --post-ld-flags`
```

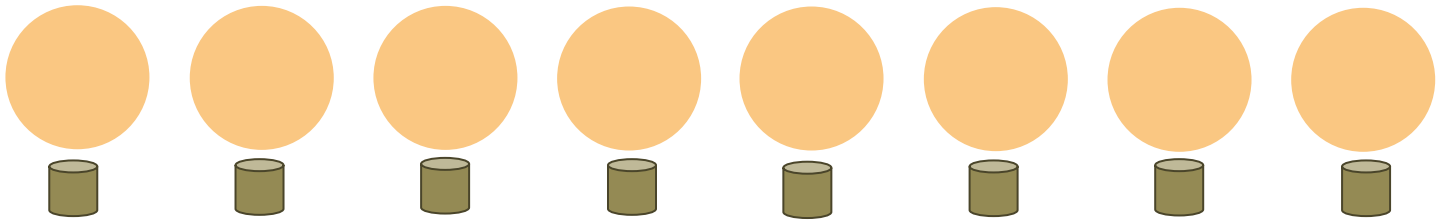
- Dynamic Linking (Recommended method)
  - Using Spack makes this very easy! (just “spack load unifyfs”)
  - We use the Gotcha library for dynamic interception

```
$ mpicc -o hello -L<unifyfs>/lib hello.c -lunifyfs_gotcha
```

How do I run my code with UnifyFS?

- Easiest method: Start & stop UnifyFS in your batch script

```
### allocate nodes and options for resource manager
#BSUB –nnodes 8 …
```



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### shell command portion of batch script
unifyfs start --share-dir=/shared/file/system/path --mount=/unifyfs
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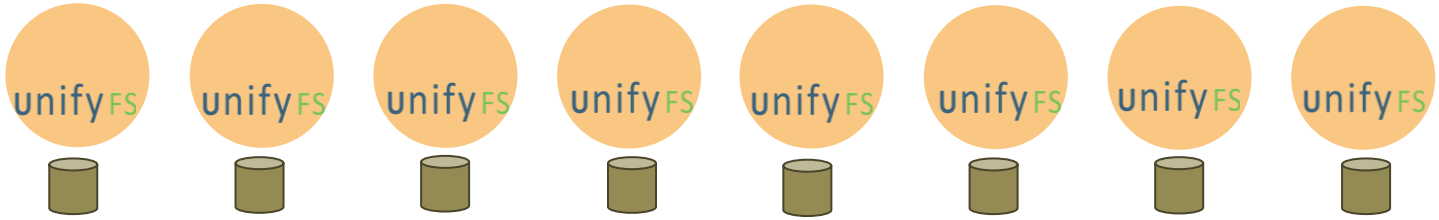

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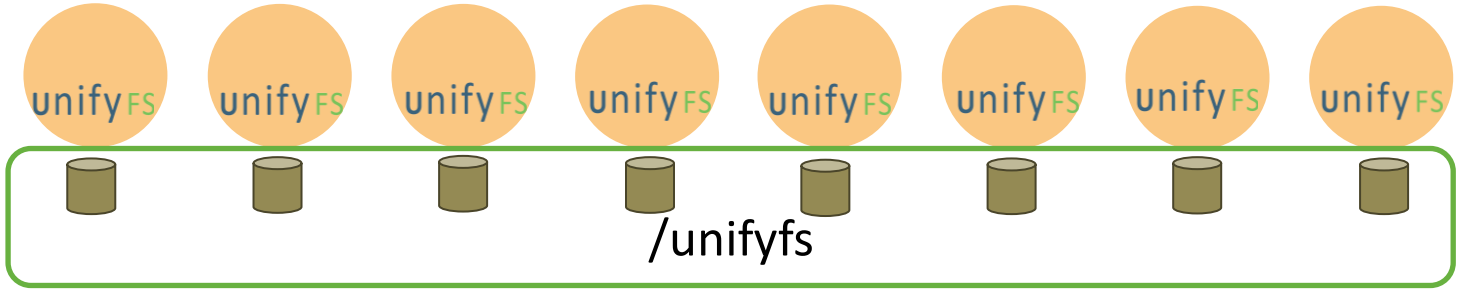

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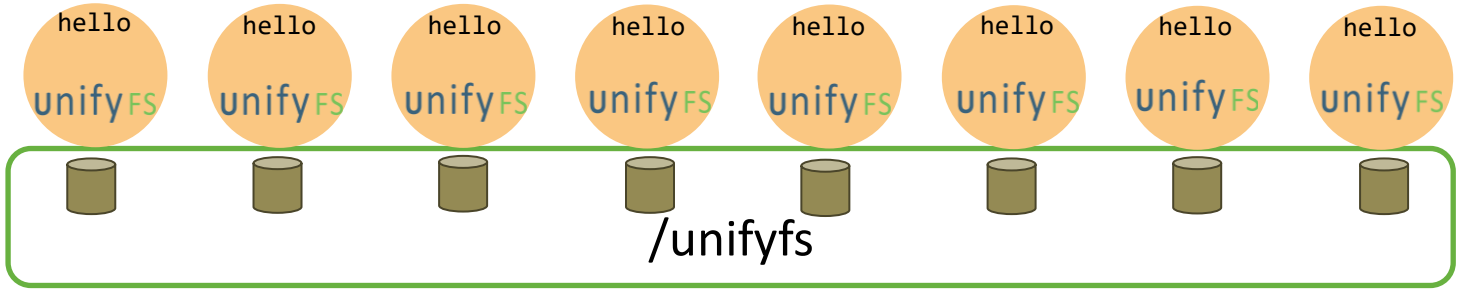

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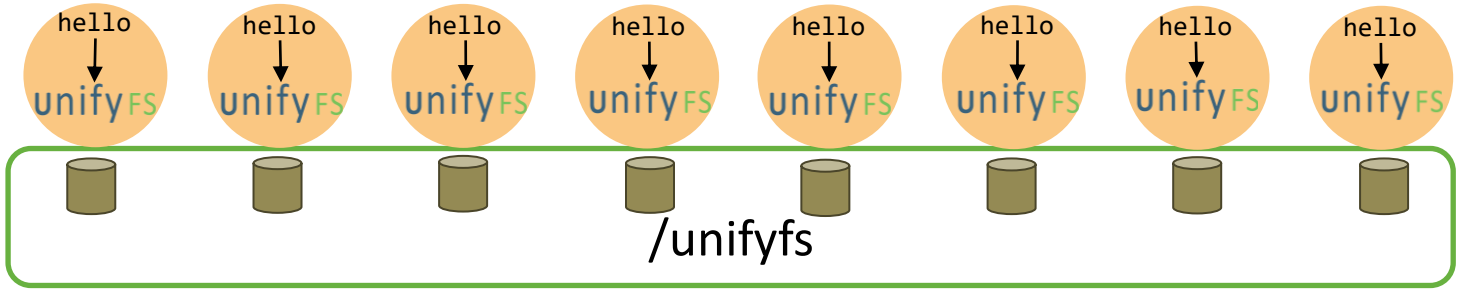

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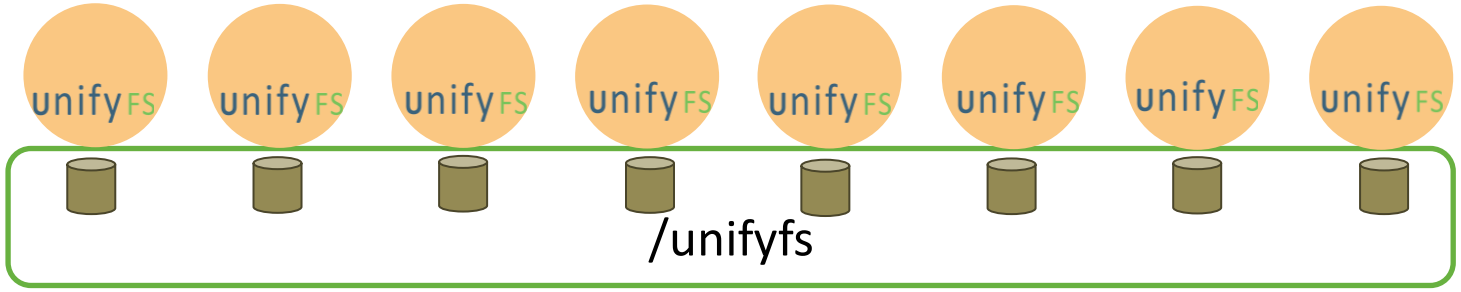

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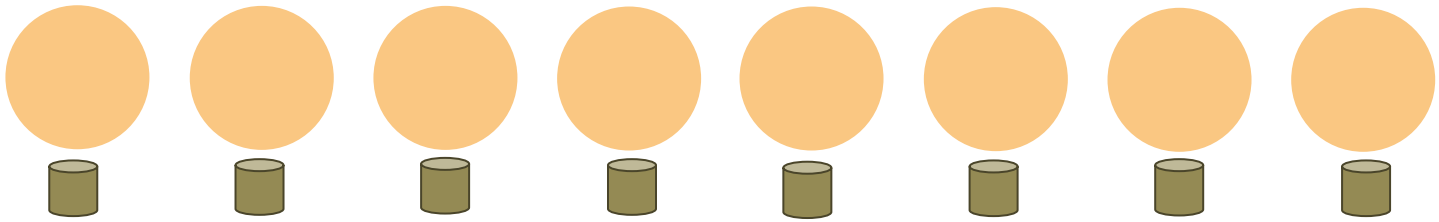
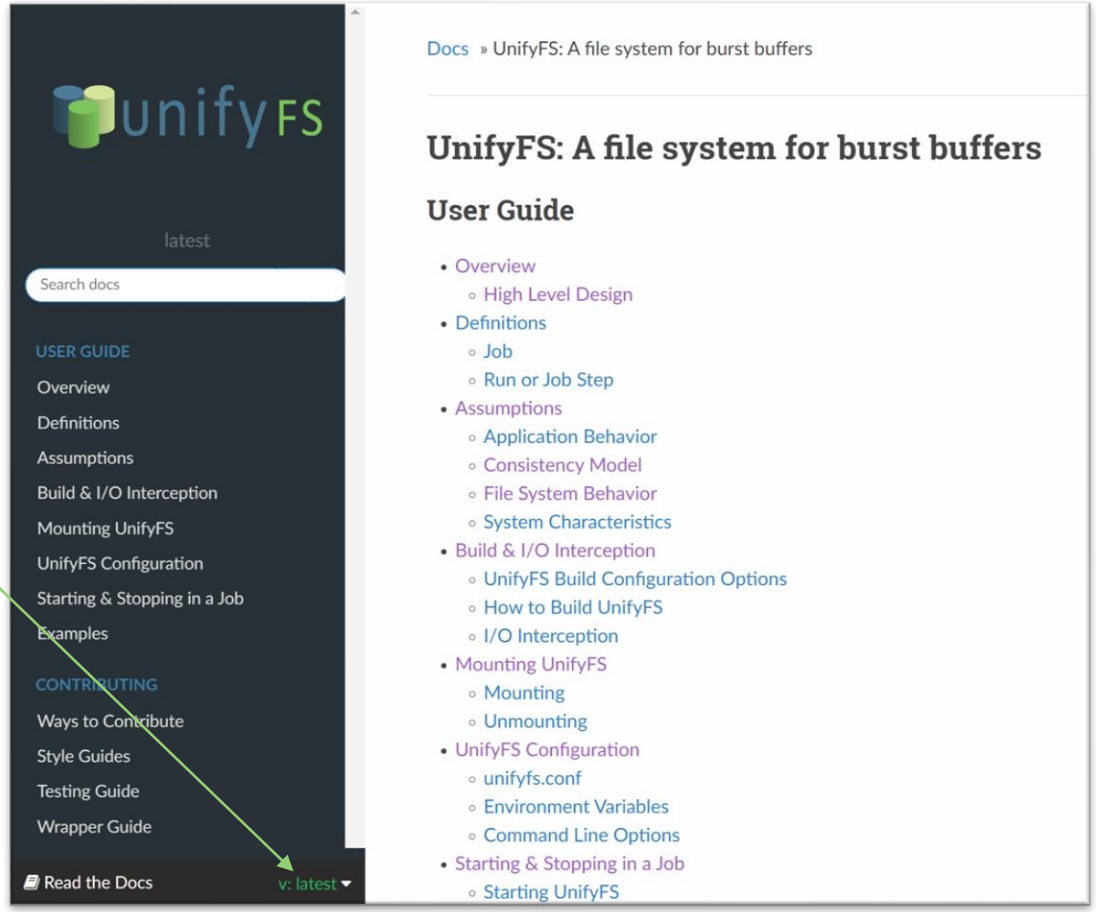


How do I move my data into and out of UnifyFS?

- Three ways to move data between UnifyFS and the parallel file system
- UnifyFS transfer program
  - `jsrun -r1 transfer /unifyfs/file1 /scratch/mydir/file1`
- UnifyFS transfer API
  - `unifyfs_transfer_file_parallel("/unifyfs/out.txt", "/scratch/out.txt");`
- Stage in and out options with UnifyFS command "unifyfs start"
  - `unifyfs start --stage-in=/path/to/parallel/file/system/inputs --stage-out=/path/to/parallel/file/system/outputs`

Wanna learn more?

- New features and improvements being added all the time
- Documentation and user support
  - User Guide: http://unifyfs.readthedocs.io
    - Down at the bottom, where it says “Read the Docs” chose “v: latest” to get the latest information
  - unifyfs@exascaleproject.org
- Example programs available in the “examples” directory in the source code



We need you!

- Our goal is to provide **easy, portable,** and **fast** support for burst buffers for ECP applications
- We need early users
- What features are most important to you
- Available on github: https://github.com/LLNL/UnifyFS
  - MIT license
- Documentation and user support
  - User Guide: http://unifyfs.readthedocs.io
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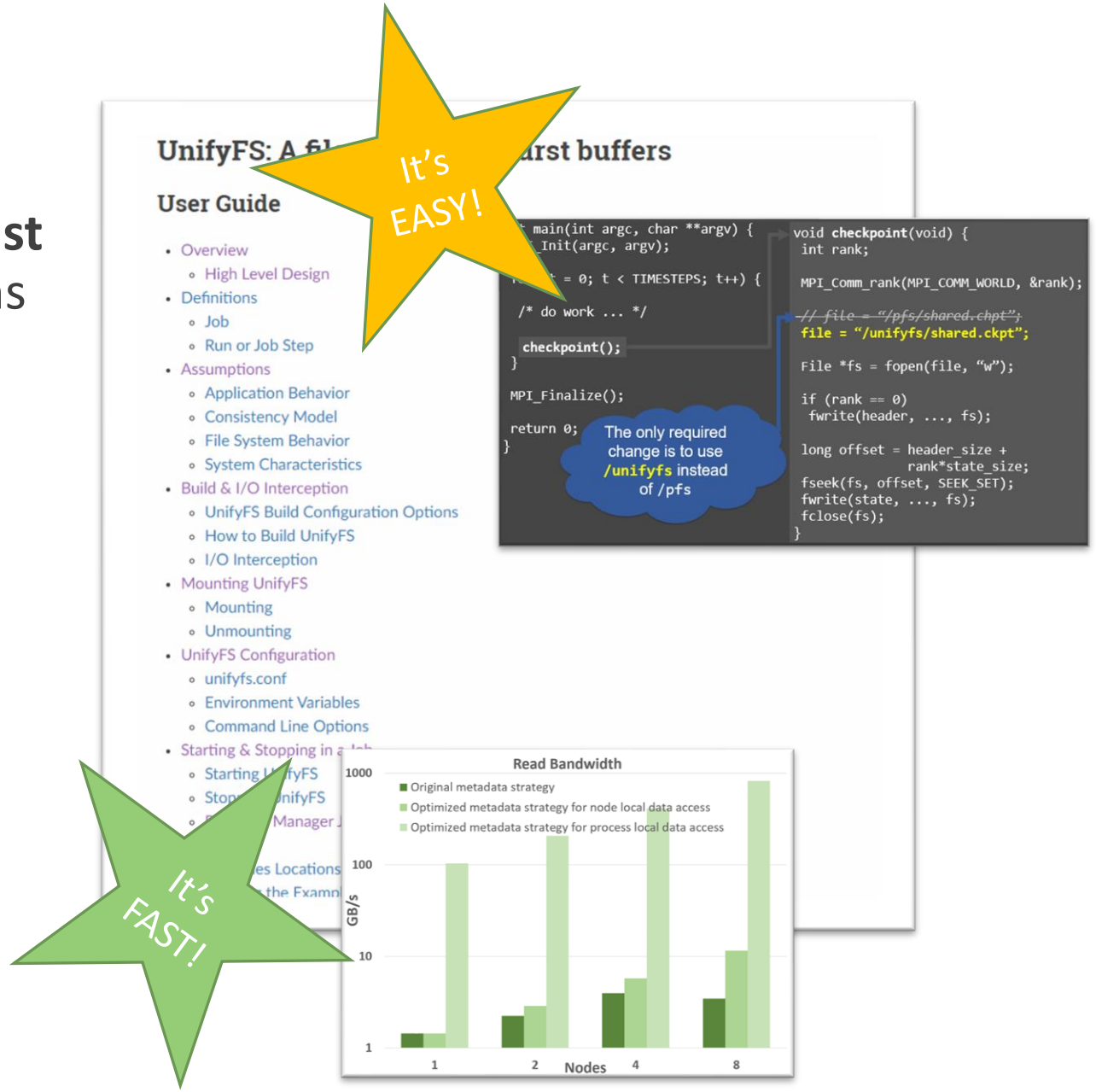

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