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pNFS, POSIX, and MPI-IO: A Tale of Three Semantics

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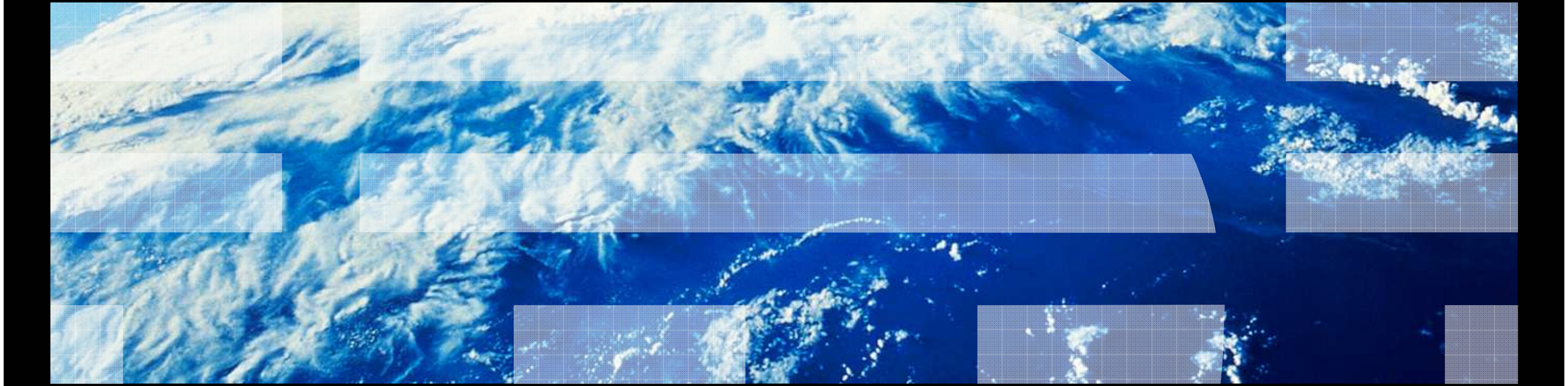


Agenda

Motivation

pNFS

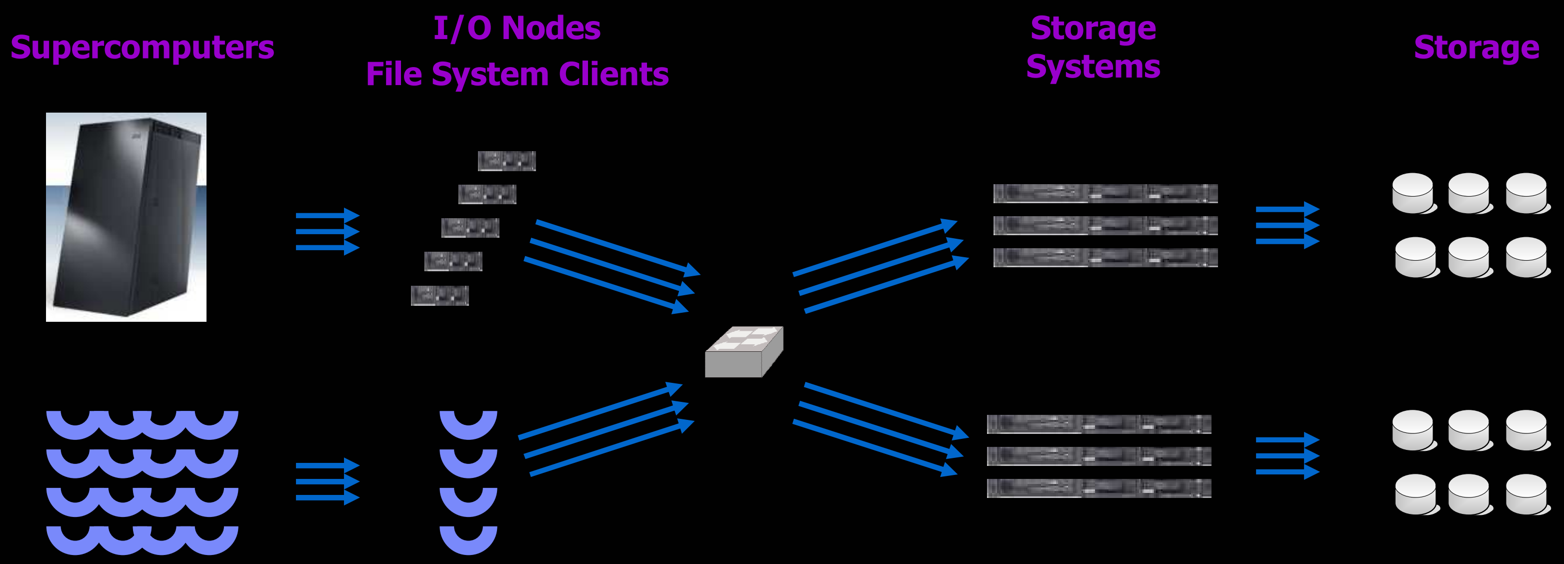
HPC consistency requirements

Protocol consistency semantics

NFSv3 ADIO driver

pNFS ADIO driver

Motivation: Commodity parallel file system clients



- Supercomputers can be connected with multiple parallel file systems
  - GPFS, PVFS2, PanFS, Lustre
- Want single file system client to access all available storage systems

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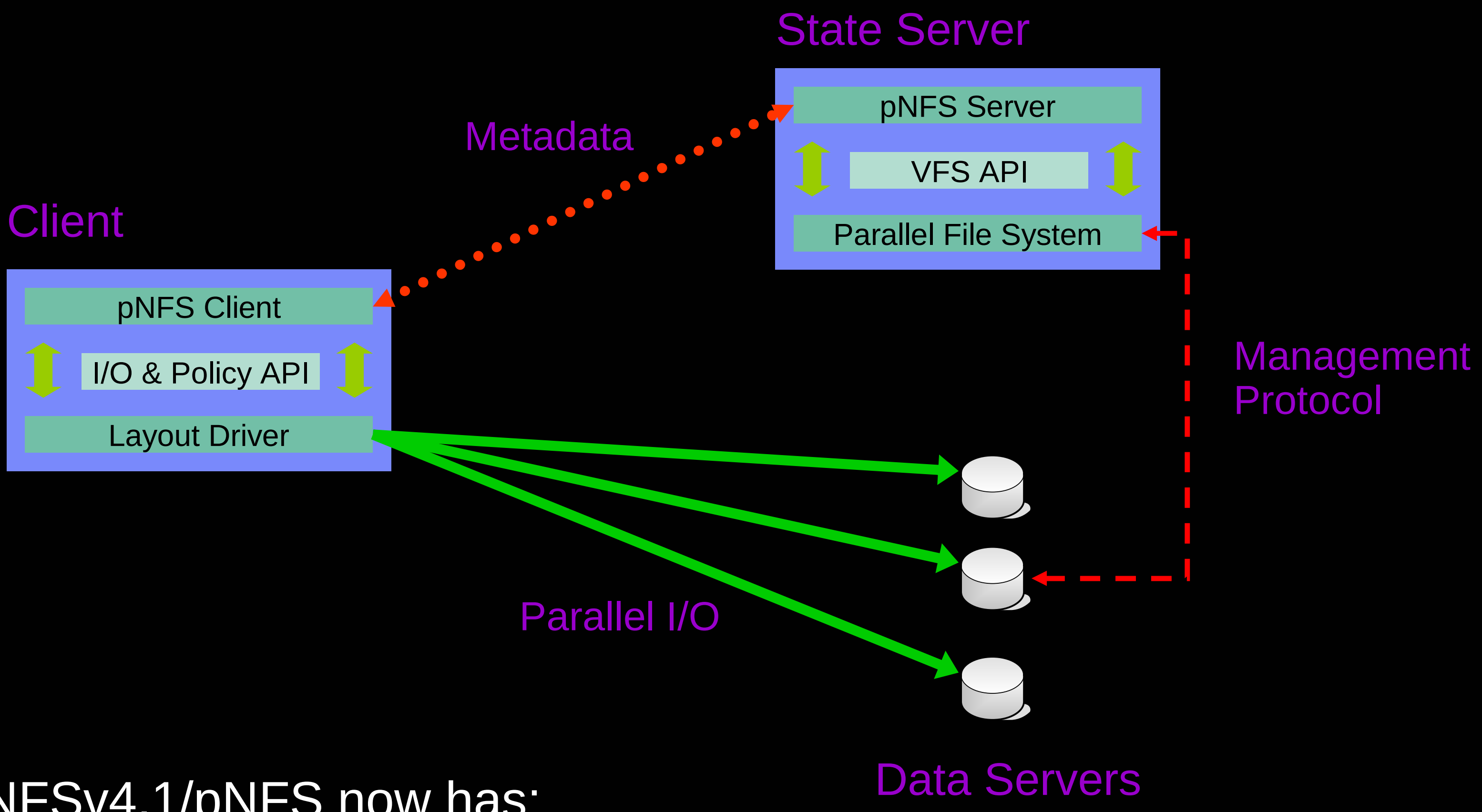
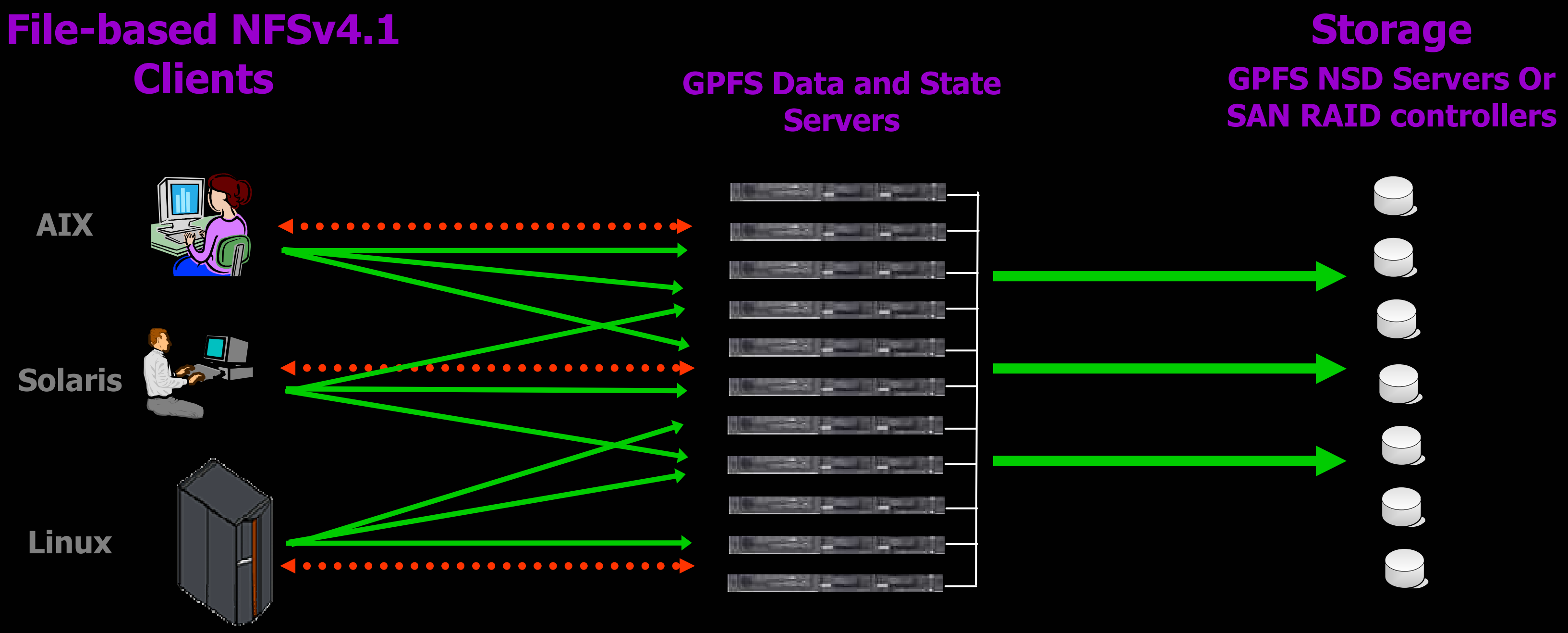
pNFS



NFSv4.1/pNFS now has:

- Integrated locking protocol
- Open/Close with per-object change attribute

pNFS with GPFS


File-based NFSv4.1 Clients
GPFS Data and State Servers
Storage
GPFS NSD Servers Or SAN RAID controllers
AIX
Solaris
Linux

- Fully-symmetric GPFS architecture - scalable data *and metadata*
  - pNFS client can mount and retrieve layout from any GPFS node
  - metadata requests can be load balanced across cluster
- pNFS server and native GPFS clients can share the same file system
  - Backup, dedup, and other mgmt functions don't need to be done over NFS
- Need robust interface between NFSD and GPFS

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HPC consistency requirements

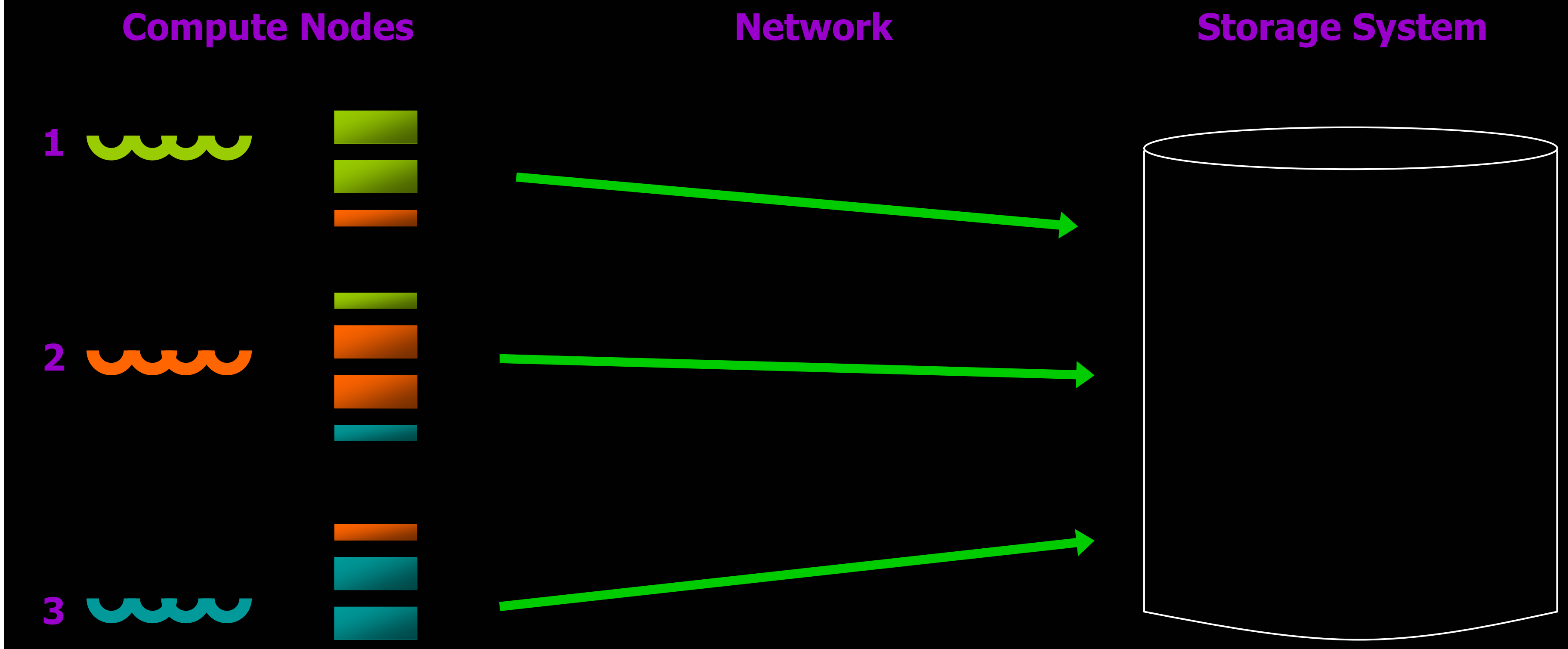
- Different I/O workloads have different requirements
  - Checkpoint
    - Write-only
    - No revalidation to new file
  - Ingest/Restart
    - Read-only
    - Revalidation on Open
  - sync-barrier-sync
    - Sync data to disk
    - Force revalidate/invalidate
  - Others?

MPI-IO: sync-barrier-sync

- Applications sometimes need to share computed results among processes/nodes
- Want to avoid MPI atomic mode to improve performance
  - Requires enforcing strict consistency semantics
  - Writes must be immediately visible by other processes
- Allows compute nodes to synchronize I/O operations between themselves
  - Sync #1 guarantees that the data written by all nodes is transferred to storage.
  - Barrier ensures that writes on all nodes complete prior to reads.
  - Sync #2 guarantees that all transferred data is visible to all processes.

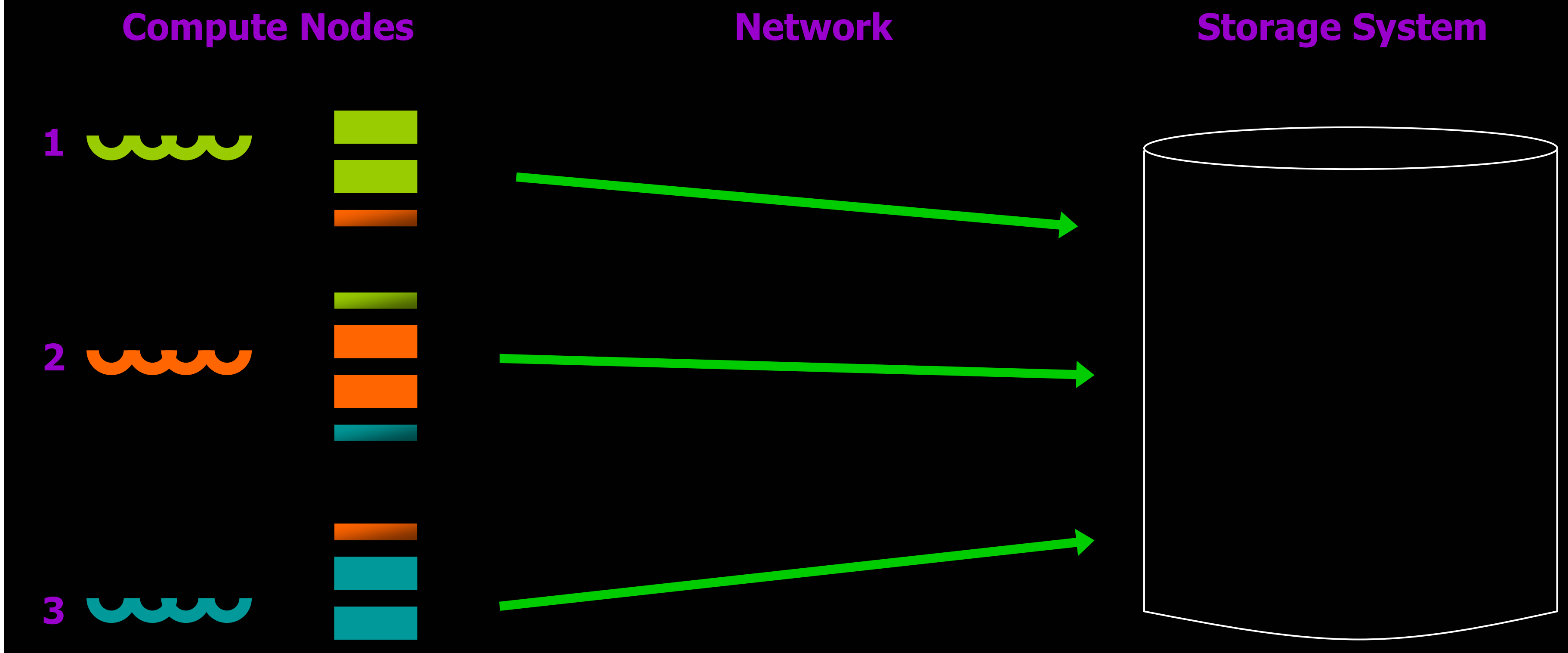
Sync-Barrier-Sync

Each node has data in its cache



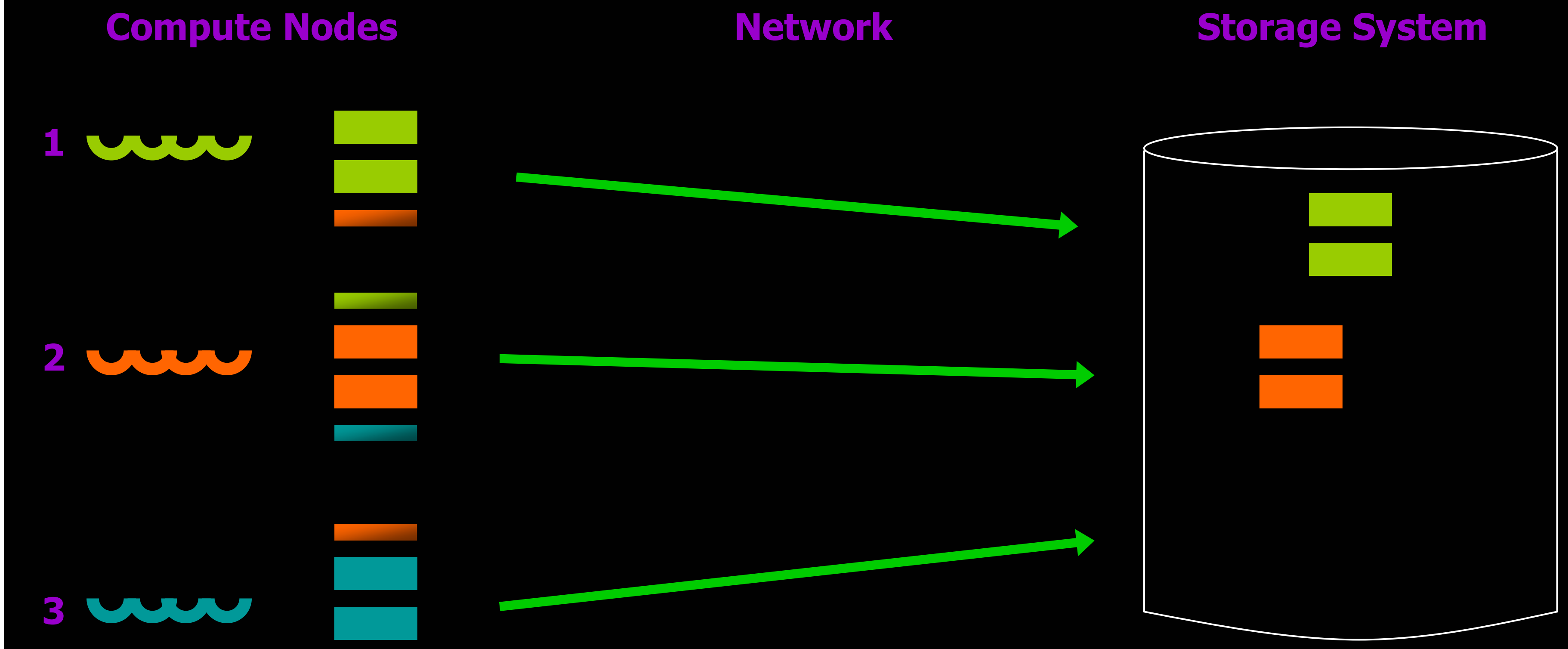
Sync-Barrier-Sync

1. SYNC: Place written data on filing servers



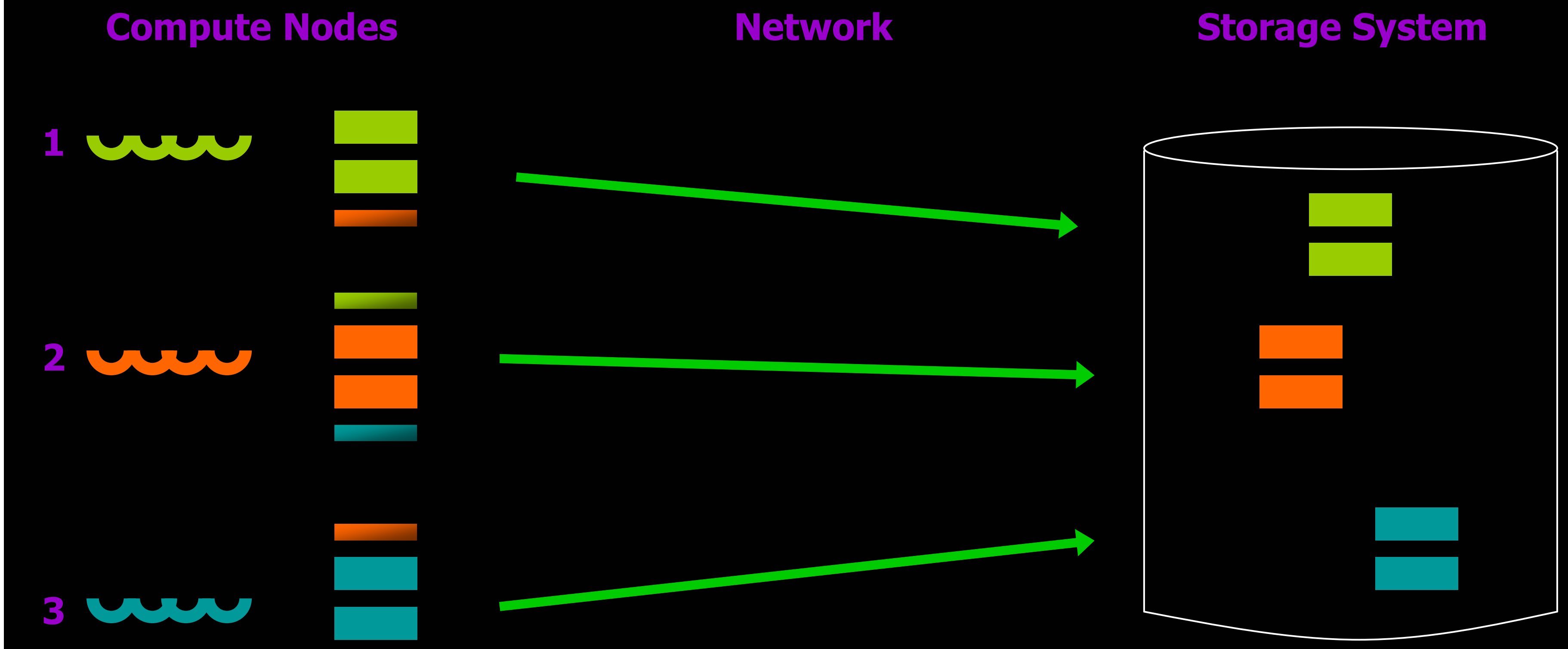
Sync-Barrier-Sync

2. BARRIER: Clients wait for other clients to flush dirty data to the servers, ensuring that no client issues read requests until all clients have the same view of file contents.



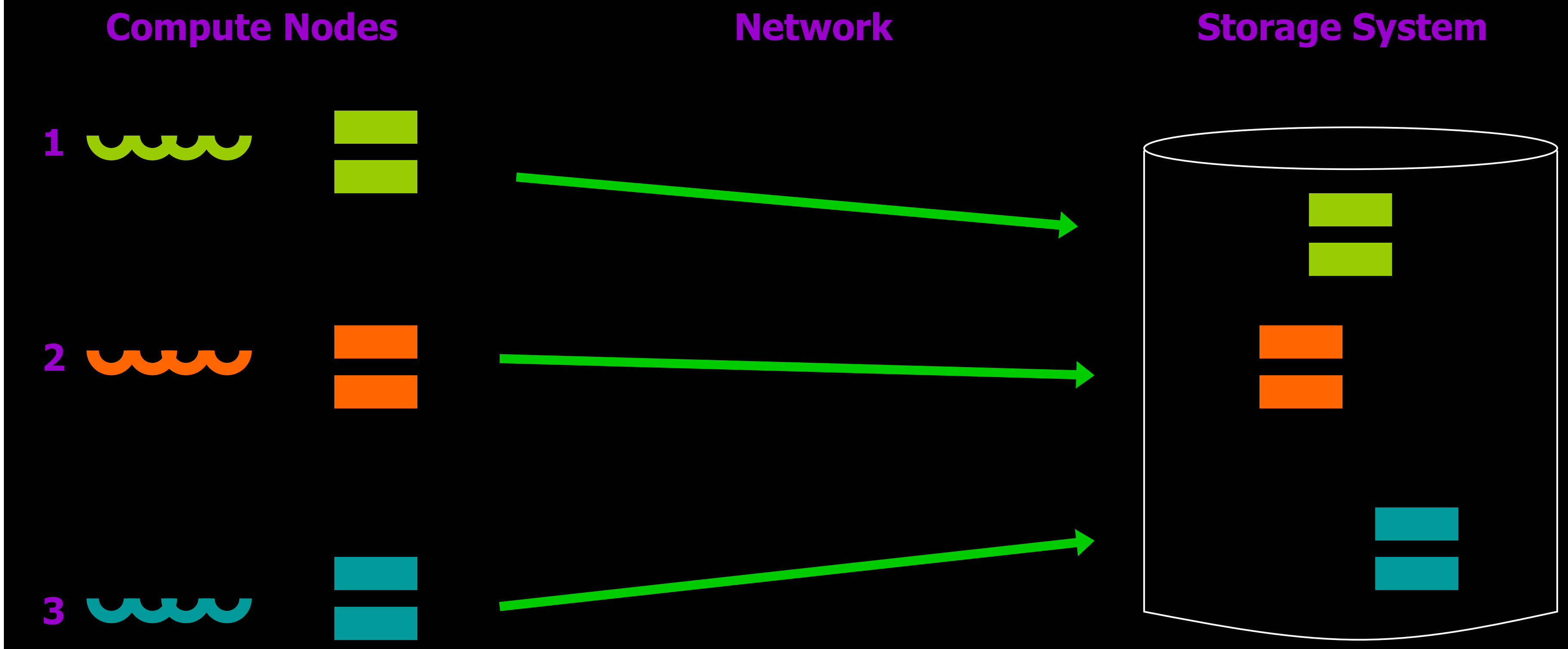
Sync-Barrier-Sync

3. SYNC: Perform file revalidation by ensuring written data is visible to all nodes.



Sync-Barrier-Sync

Nodes read new data



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Protocol consistency semantics

	Revalidation	Data Flush
POSIX Last writer wins	Open Read	Fsync Close
MPI-IO (non-atomic)	MPI_File_Sync MPI_File_Open	MPI_File_Sync MPI_File_Close
pNFS Close-to-open	Open Fnctl lock “ ______ “	Close Fnctl ulock Fsync

Notes:

- POSIX does not require revalidation primitive
- NFS lacks primitive to leverage per-object change attribute

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NFSv3 ADIO driver

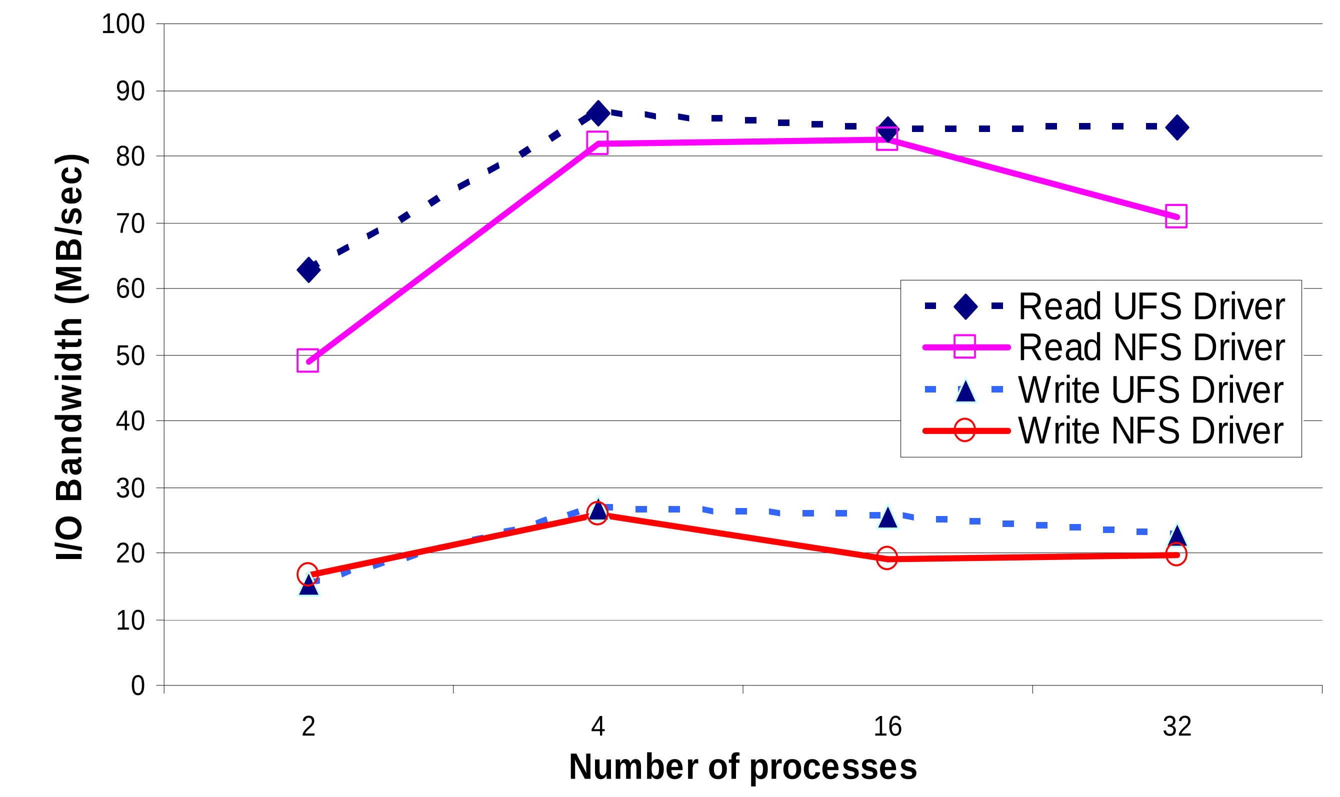
ROMIO/ADIO

- ROMIO is an I/O implementation of MPI-IO
- ADIO is a portable parallel I/O API that allows file systems to implement MPI-IO semantics

- NFSv3 ADIO driver
  - Forcing NFSv3 to comply with MPI-IO semantics hurts performance
  - Performs multiple close/open or lock/locku to revalidate file
    - Inconsistent NFSv3 implementations
    - Protocol and implementation problems with the NFSv3 lockd daemon.
    - Disallows attribute caching

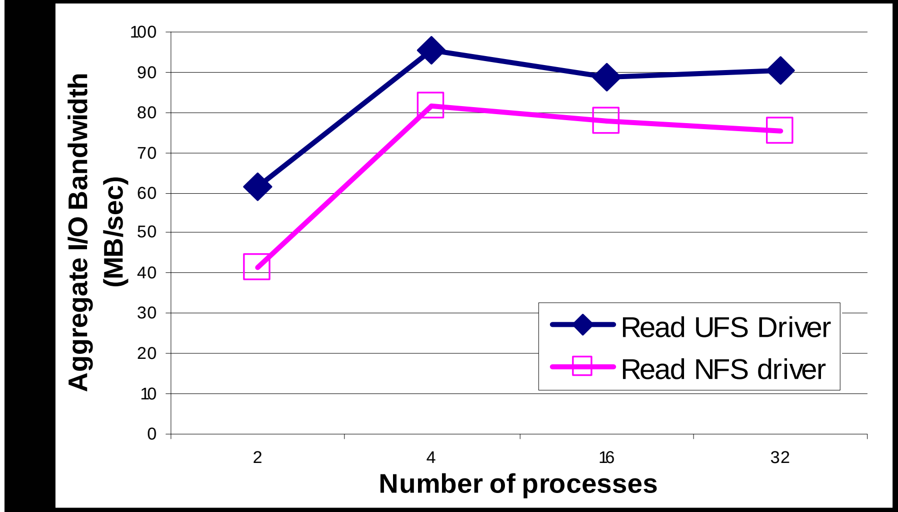
- UFS ADIO driver
  - POSIX compliant file systems

POP-IO NFSv4/Ext3 Read and Write

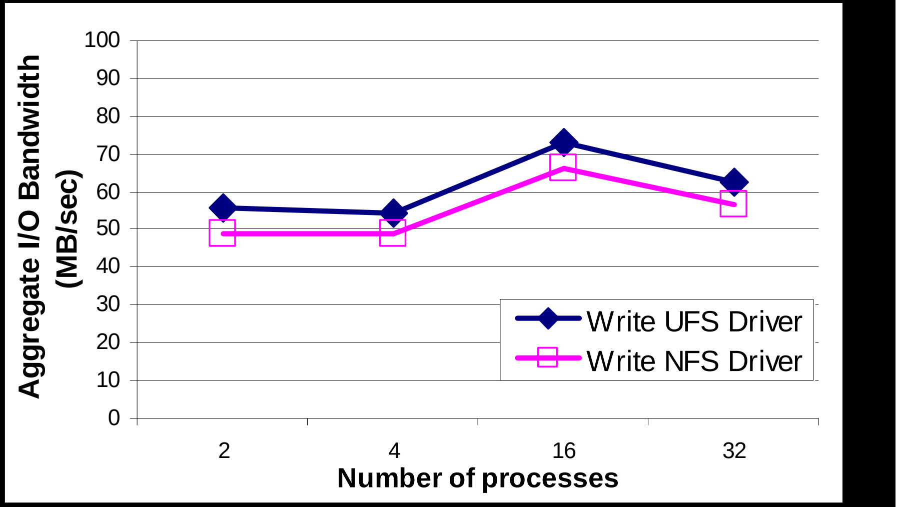


POP-IO pNFS/GPFS Read and Write

READ



WRITE



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Looking forward: pNFS ADIO driver possibilities

- Some I/O workloads, e.g., checkpointing, require minimal data coherence
  - Try to optimize "all read" or "all write" workloads
- For applications that perform sync-barrier-sync:
  - HEC POSIX extensions for HPC
    - O_LAZY, lazyio_propagate(), lazyio_synchronize()
  - Direct I/O
    - No read or writeback cache
    - Possibly only on read path
  - Non-portable techniques:
    - Manually invalidate entire page cache
    - Fadvise
  - open/close and/or lock/ulock
    - Data must be written to disk
  - User-space client with customized interface
    - Support?
  - Others?

Summary

Good: MPI-IO and pNFS share similar relaxed semantics

Bad: HPC apps require on-demand file sync and revalidation (Lazy I/O)

Ugly: Interface to file system through POSIX interface

Lacks on-demand file revalidation

Need to investigate possible workarounds

Thank You!