BatchFS++

In search of the right way for extreme-scale HPC file system metadata

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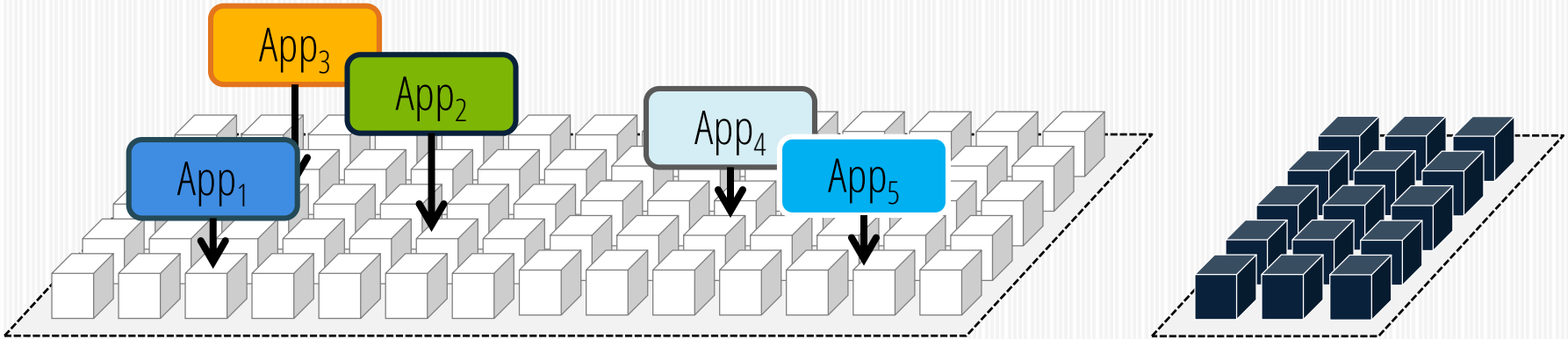
[LA-UR-15-25703]

HPC defined by …

- parallel scientific applications
  - running on compute nodes with pooled storage for highly parallel I/O

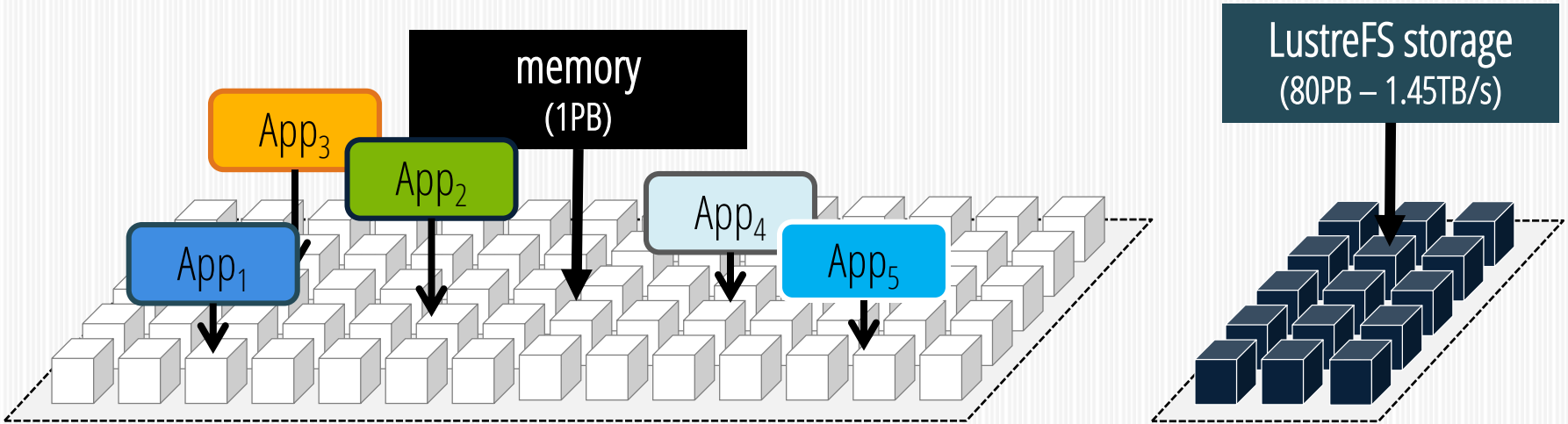


compute nodes w/ fast interconnect
(10,000+)

pooled storage nodes
(100+)

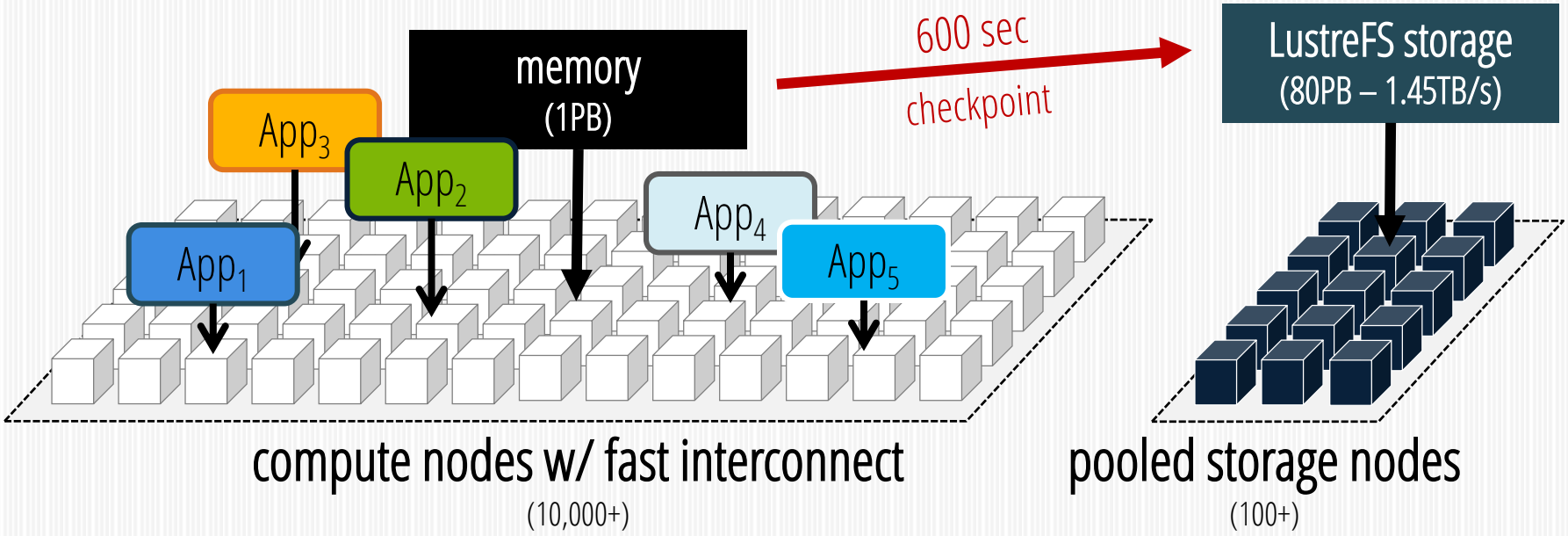
HPC Checkpointing

- copying memory from compute nodes to a backend file system



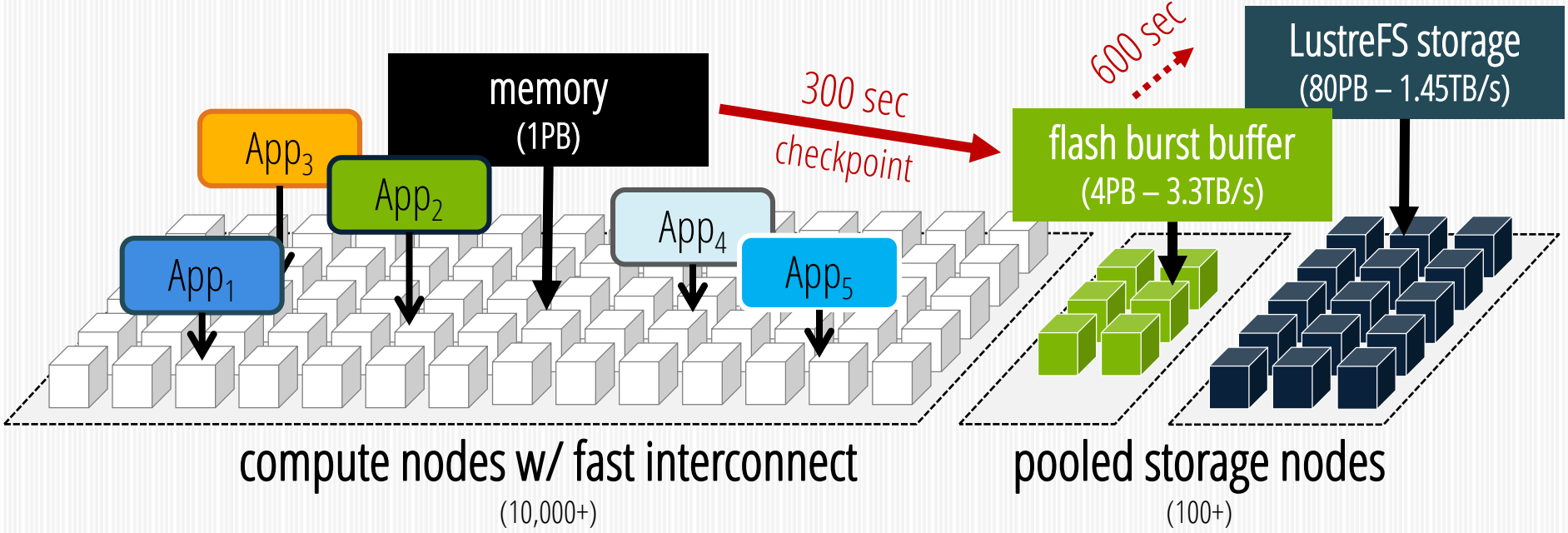
HPC Checkpointing

- copying memory from compute nodes to a parallel file system



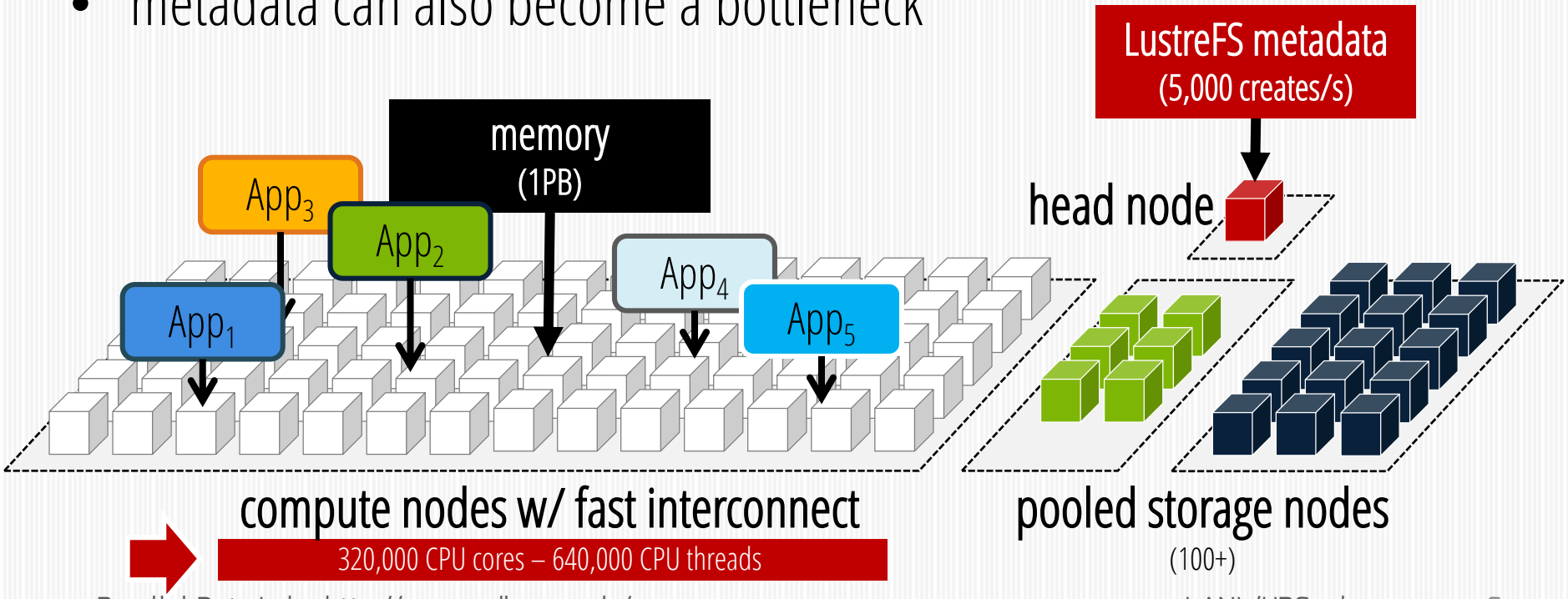
HPC Checkpointing

- two-tier storage for higher bandwidth



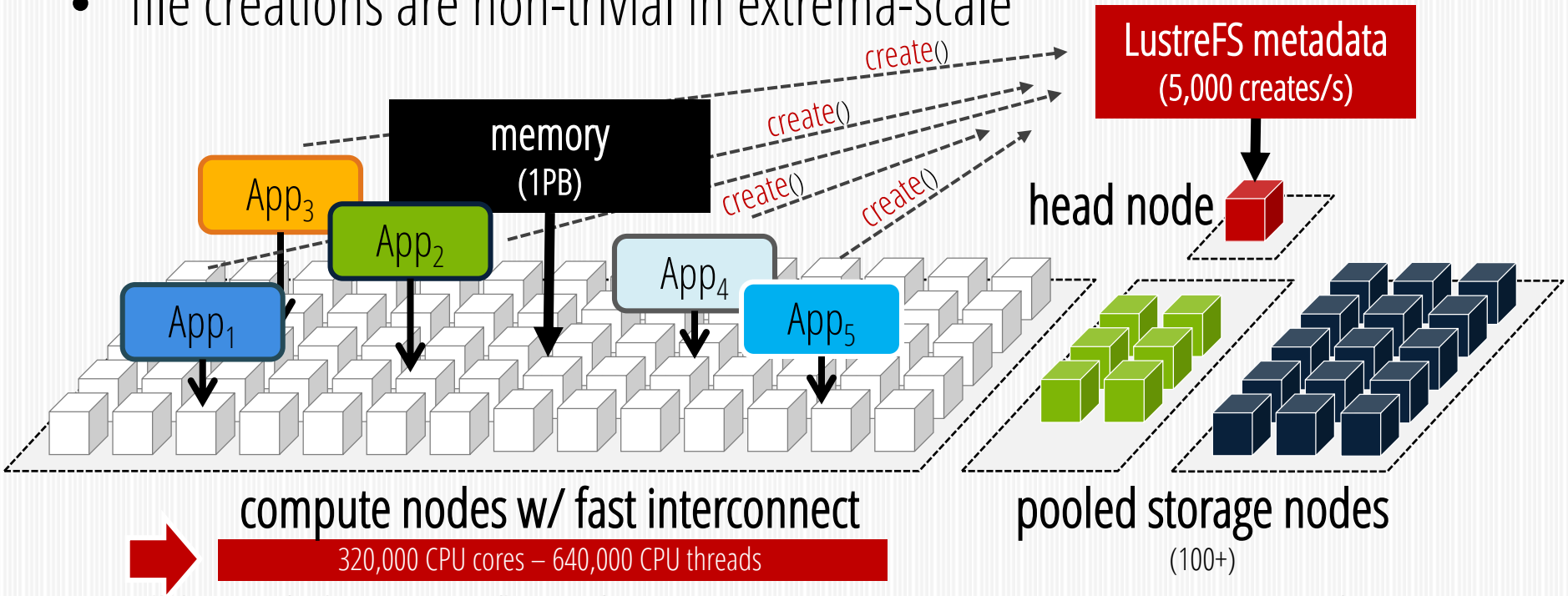
HPC Checkpointing

- metadata can also become a bottleneck



HPC Checkpointing

- file creations are non-trivial in extrema-scale

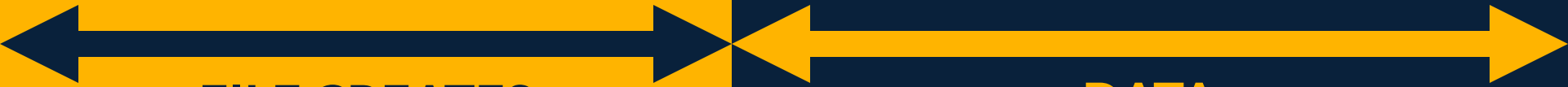



128s
300s
FILE CREATES
DATA

2X CPU cores and 2X storage bandwidth

256s

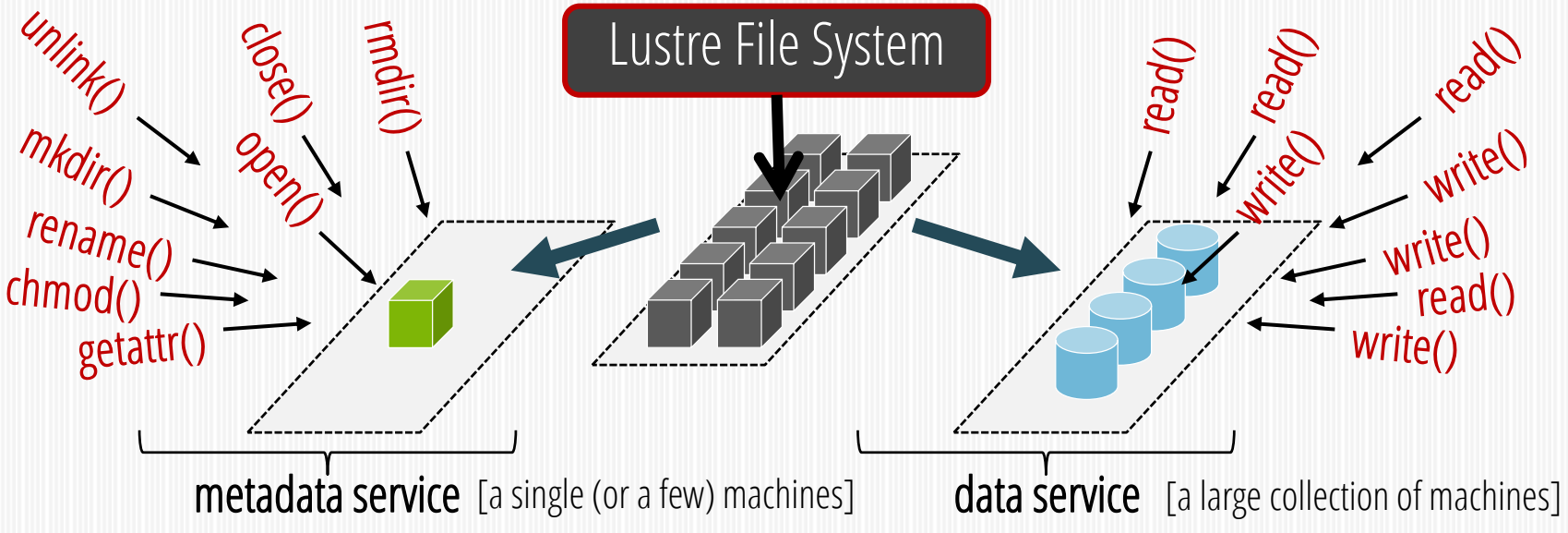
300s



FILE CREATES

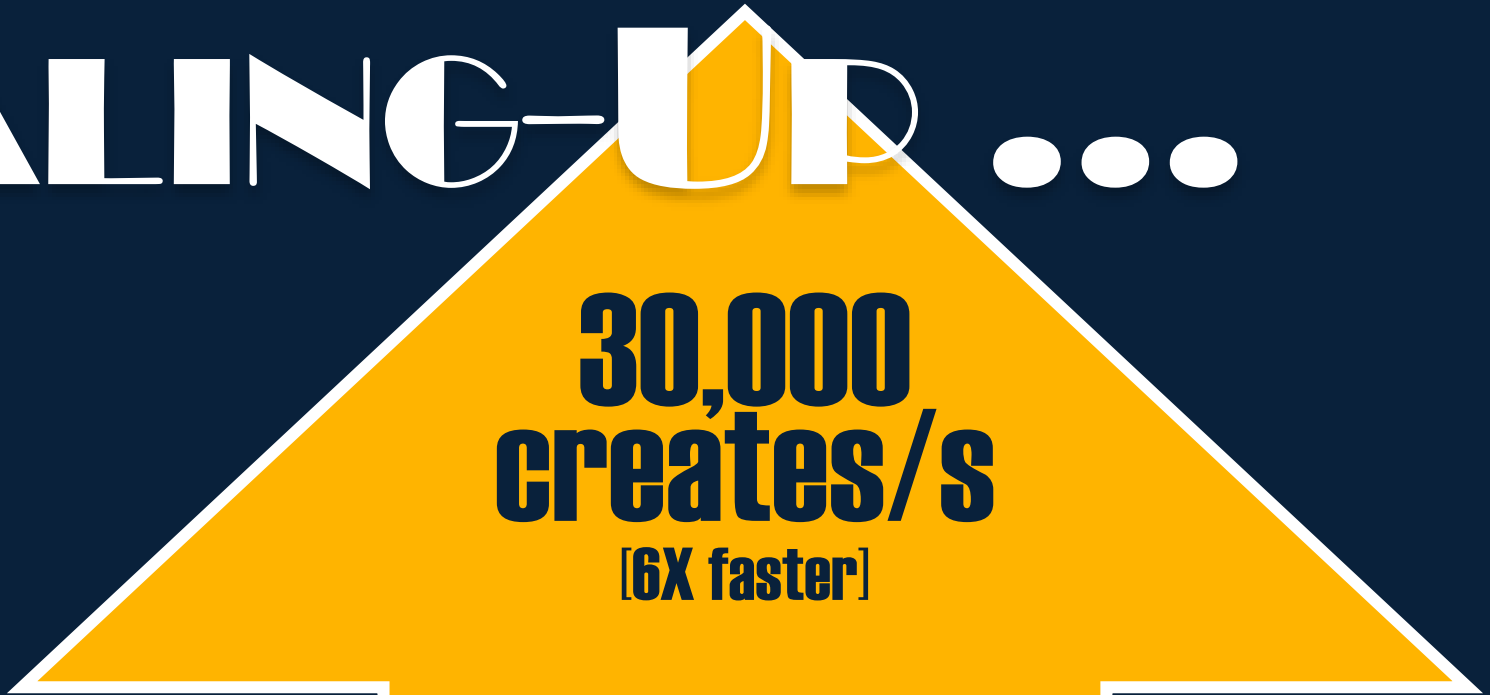
DATA

Bias for data …



metadata eventually a problem !!

Scaling-Up …



Harden Lustre File System

Scaling-Up …

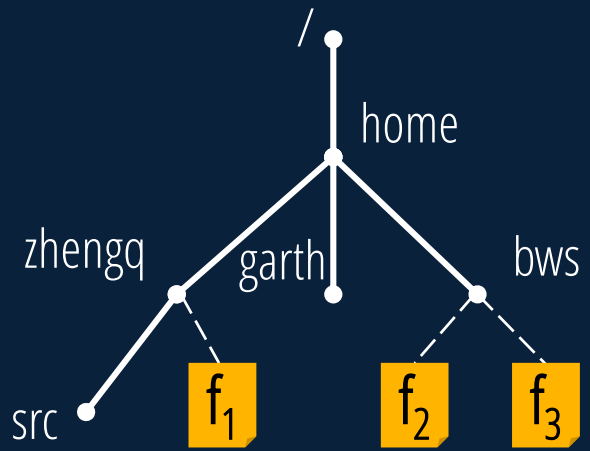
expensive w/ limited improvements

Scaling-Out ...

Use multiple dedicated machines to serve file system metadata

DISTRIBUTED METADATA

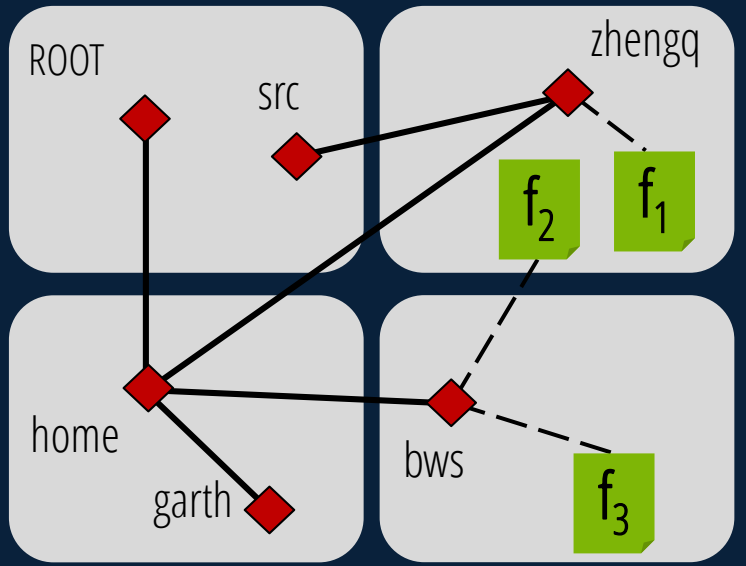
Scaling-Out ...



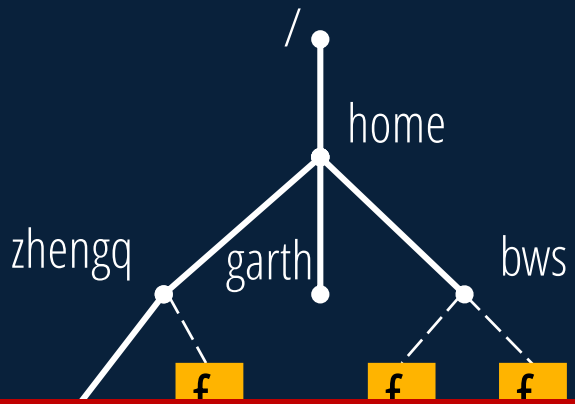
hierarchical directory structure

IndexFS

dynamic directory
allocation & splitting

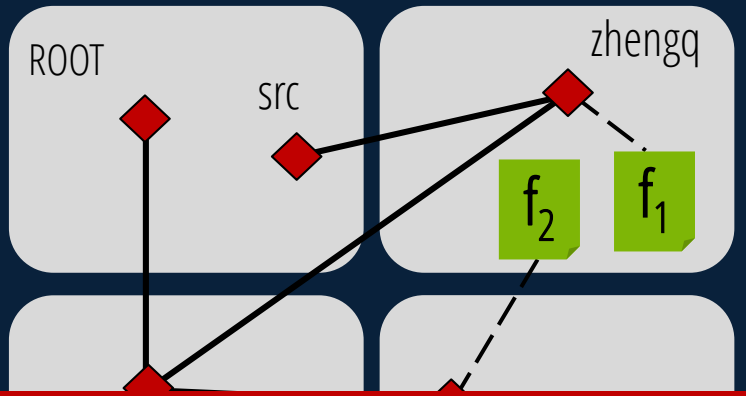


Scaling-Out ...



IndexFS

dynamic directory allocation & splitting



requires a large # of dedicated machines

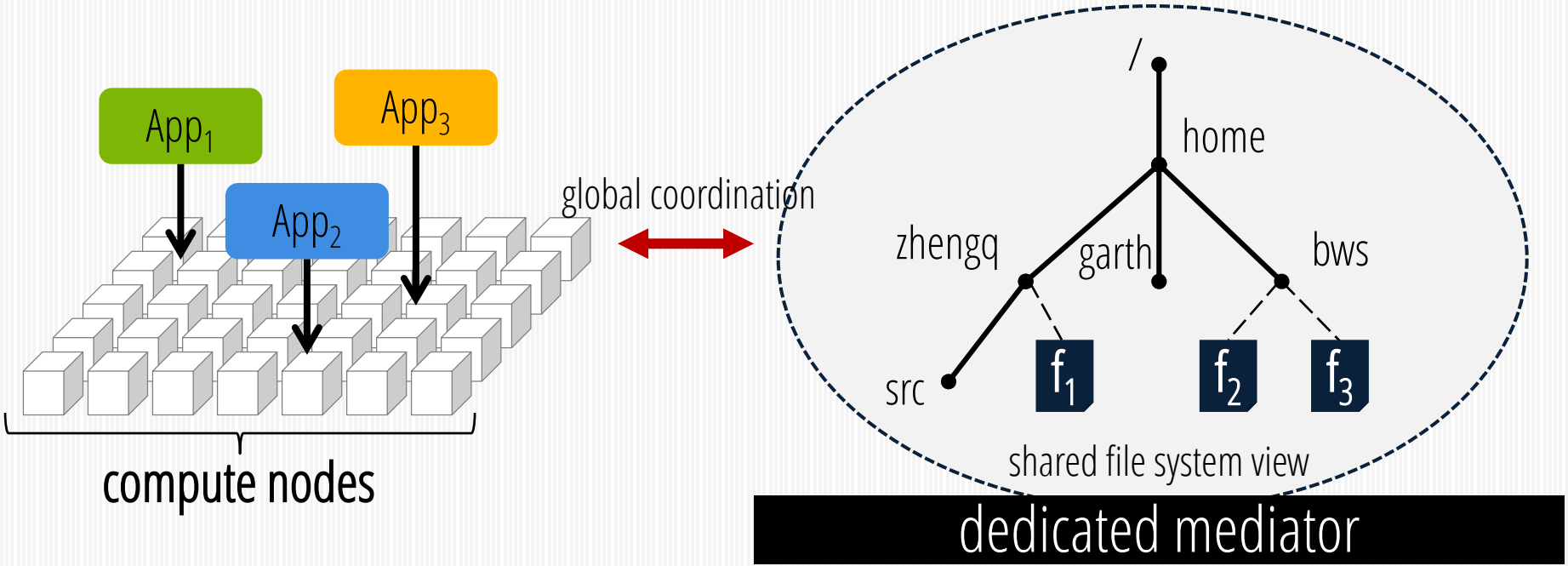
GOAL

Cost-effective highly-parallel metadata

Orders of magnitude faster then LustreFS


BatchFS++

Traditional Metadata Model



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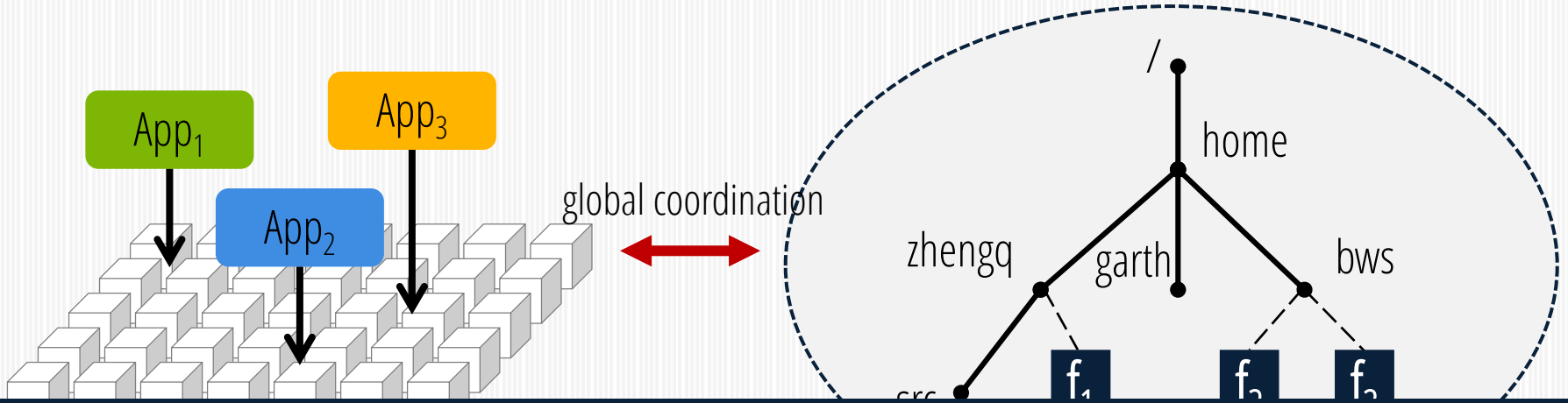
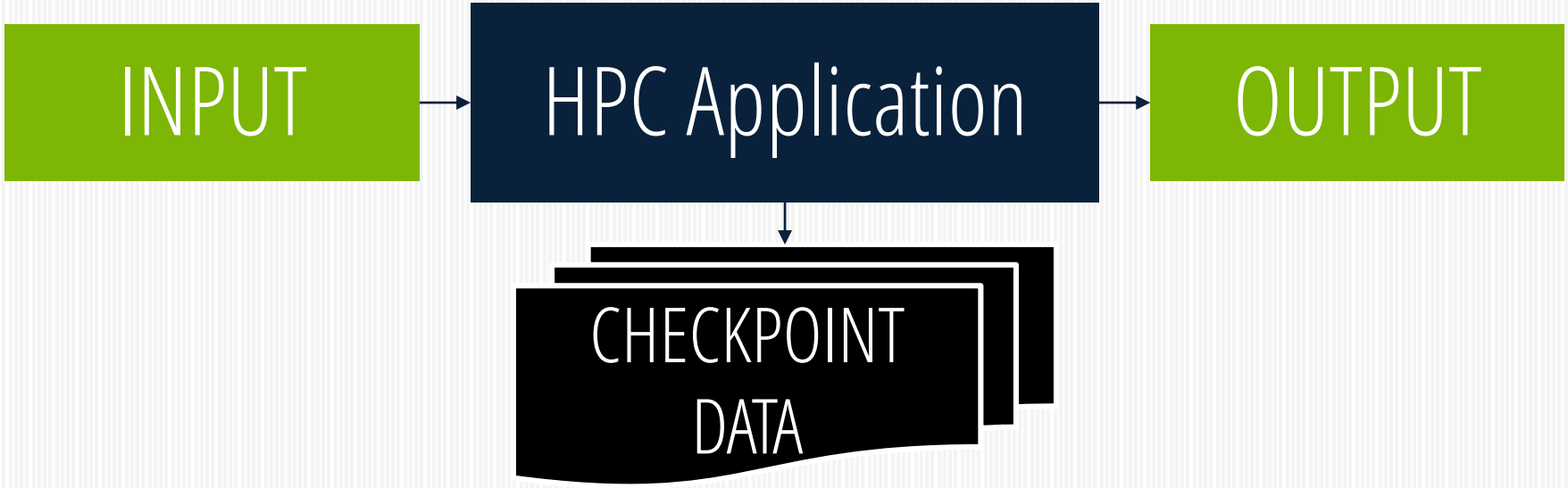


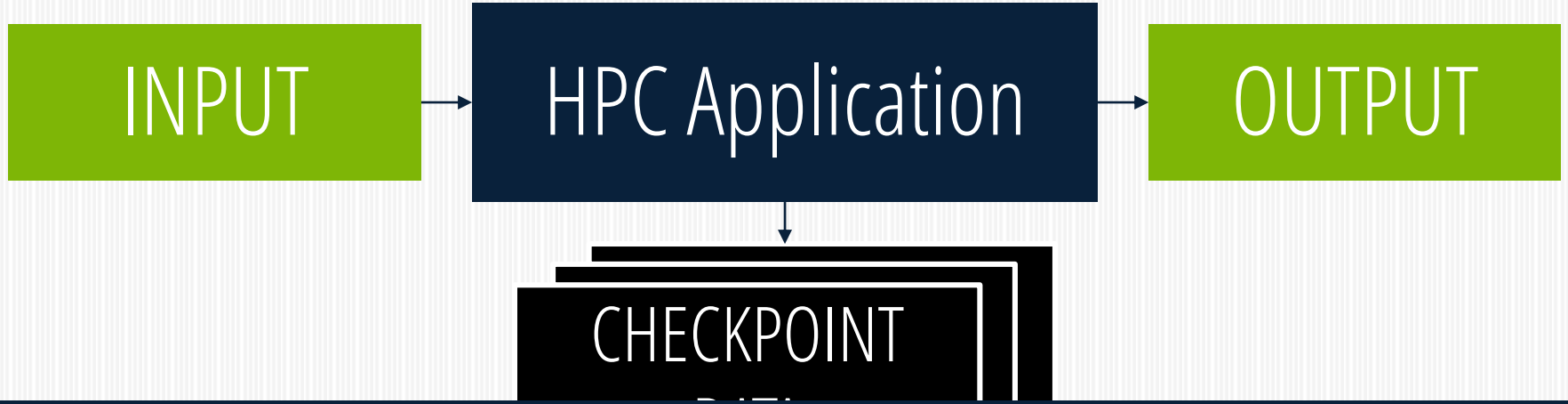
A single authoritative view of the file system

Allows different apps to shared data and achieve synchronization

HPC I/O is much simpler …



HPC I/O is much simpler …



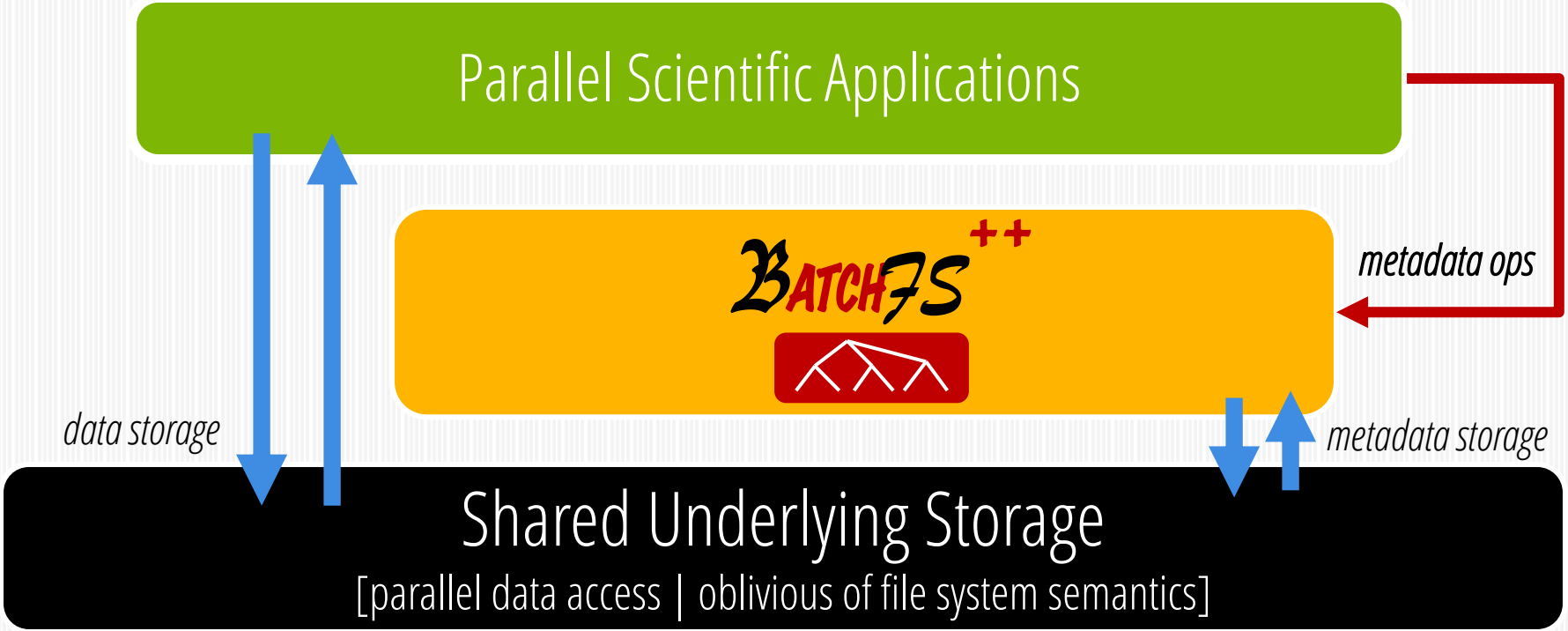
HPC applications don't need the FS to achieve synchronization
Different apps operate on different sets of files

HPC I/O is much simpler …

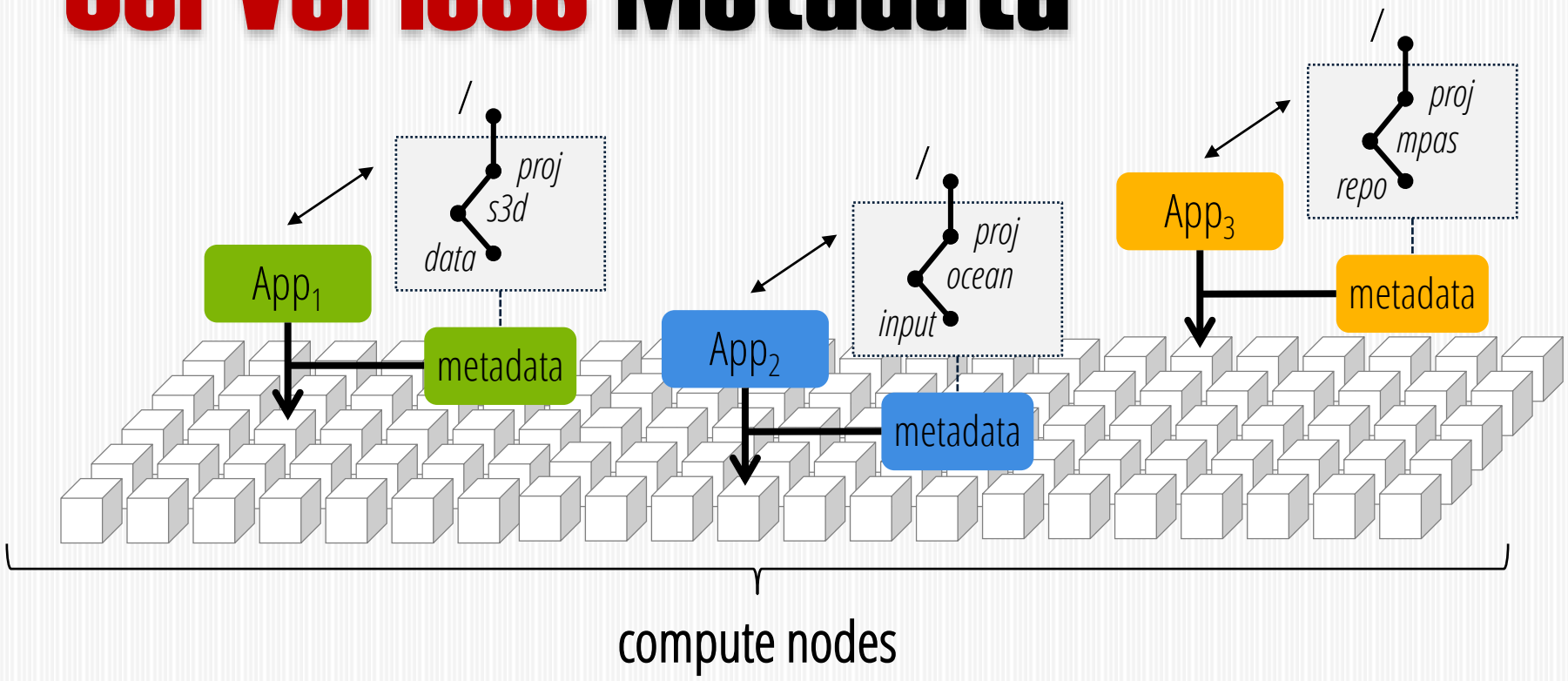
A single unified file system view overkill for HPC applications
Global coordination via a dedicated service bad for performance

HPC applications don't need the FS to achieve synchronization
Different apps operate on different sets of files

Middleware Design



Serverless Metadata



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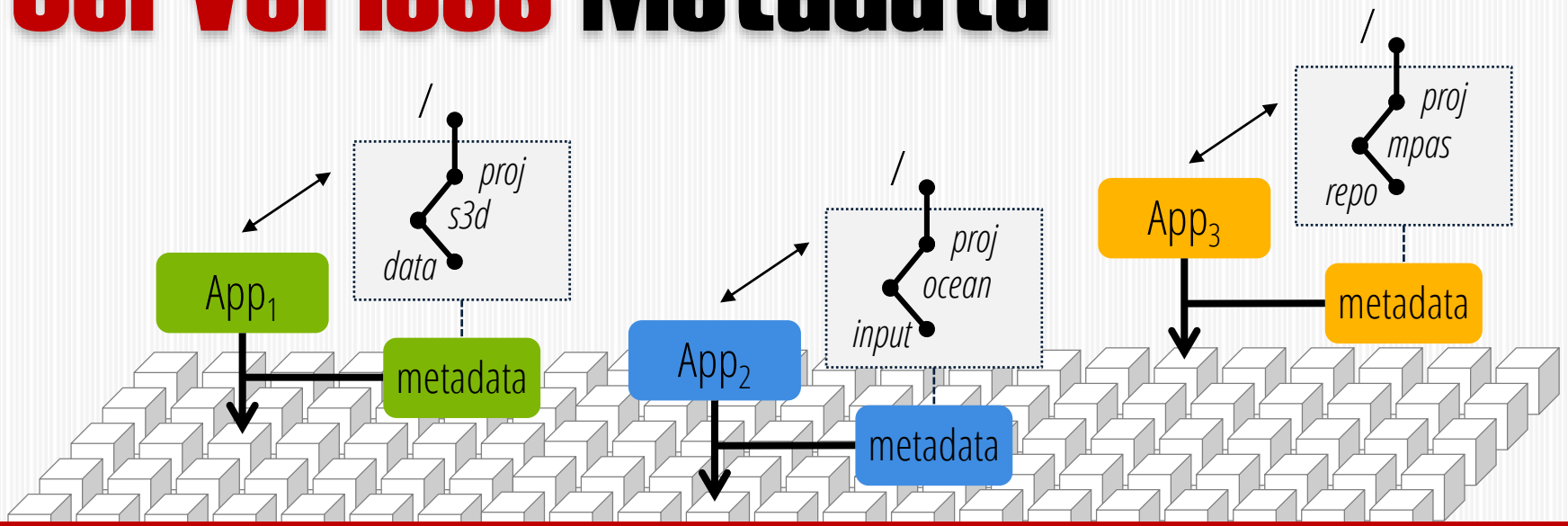
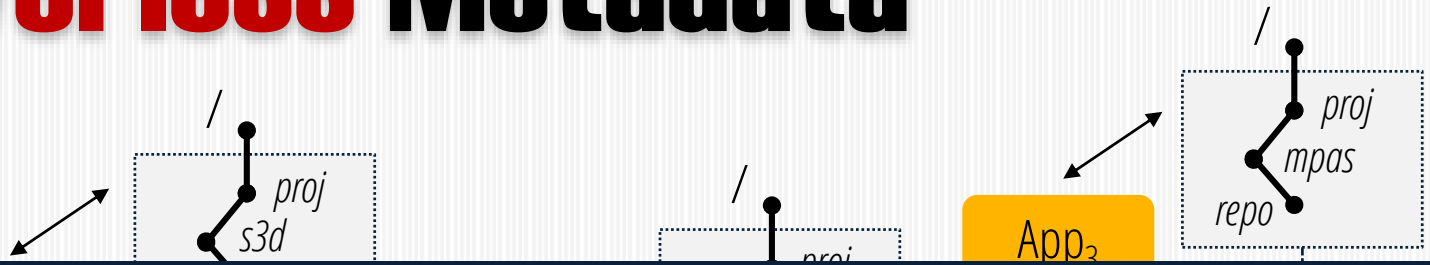


No such global namespace managed by a centralized mediator

Each app only communicates with its private metadata servers

Serverless Metadata



Fundamental Assumption

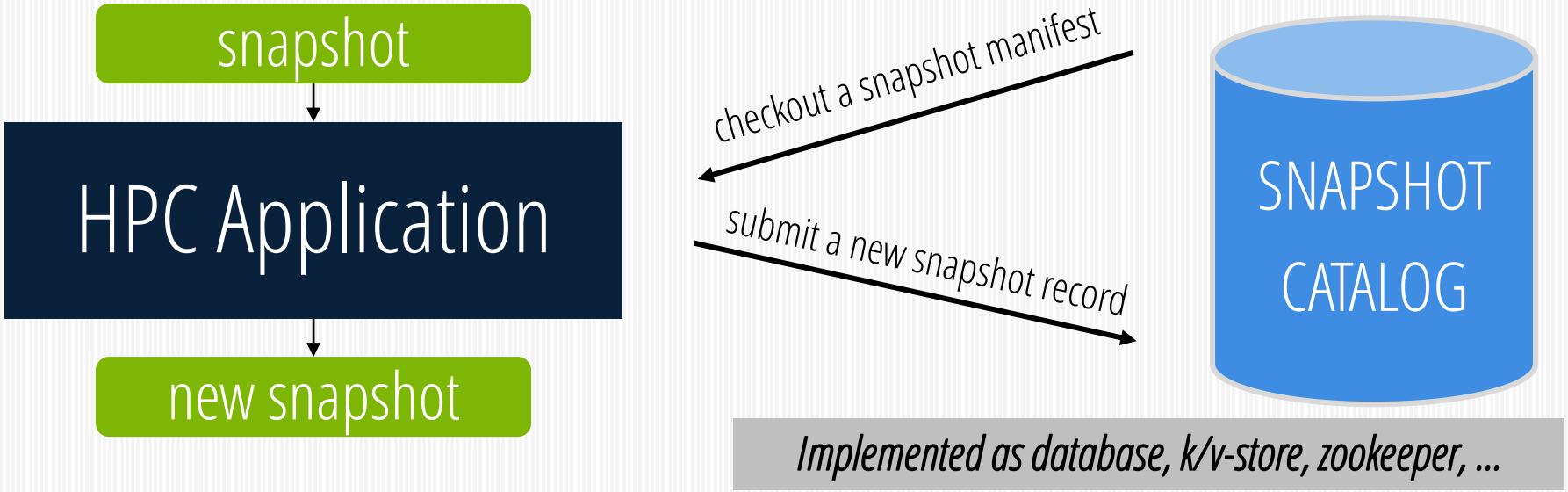
HPC applications don't communicate with each other

No such global namespace managed by a centralized mediator

Each app only communicates with its private metadata servers

App Execution Model

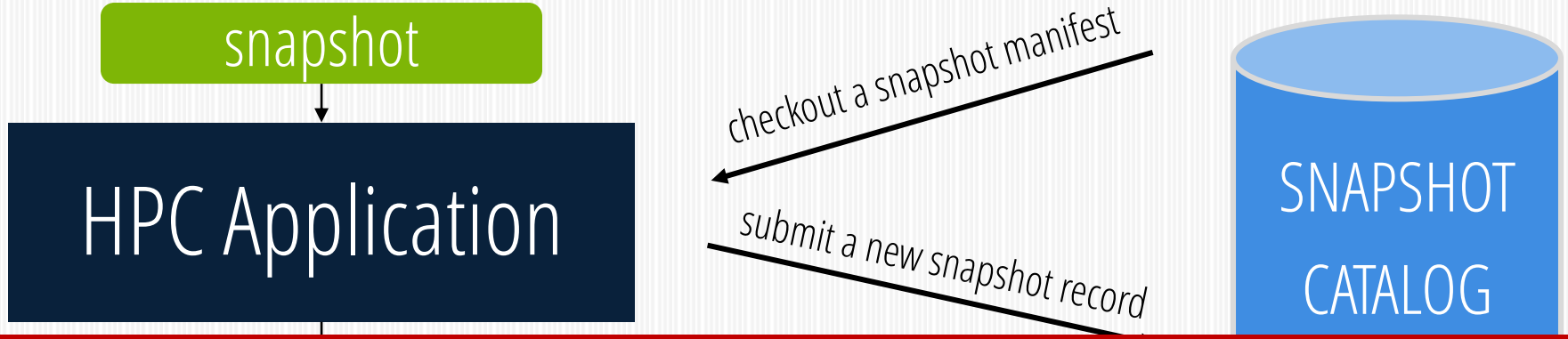
[snapshot = static view of a file system]



Implemented as database, k/v-store, zookeeper, ...

App Execution Model

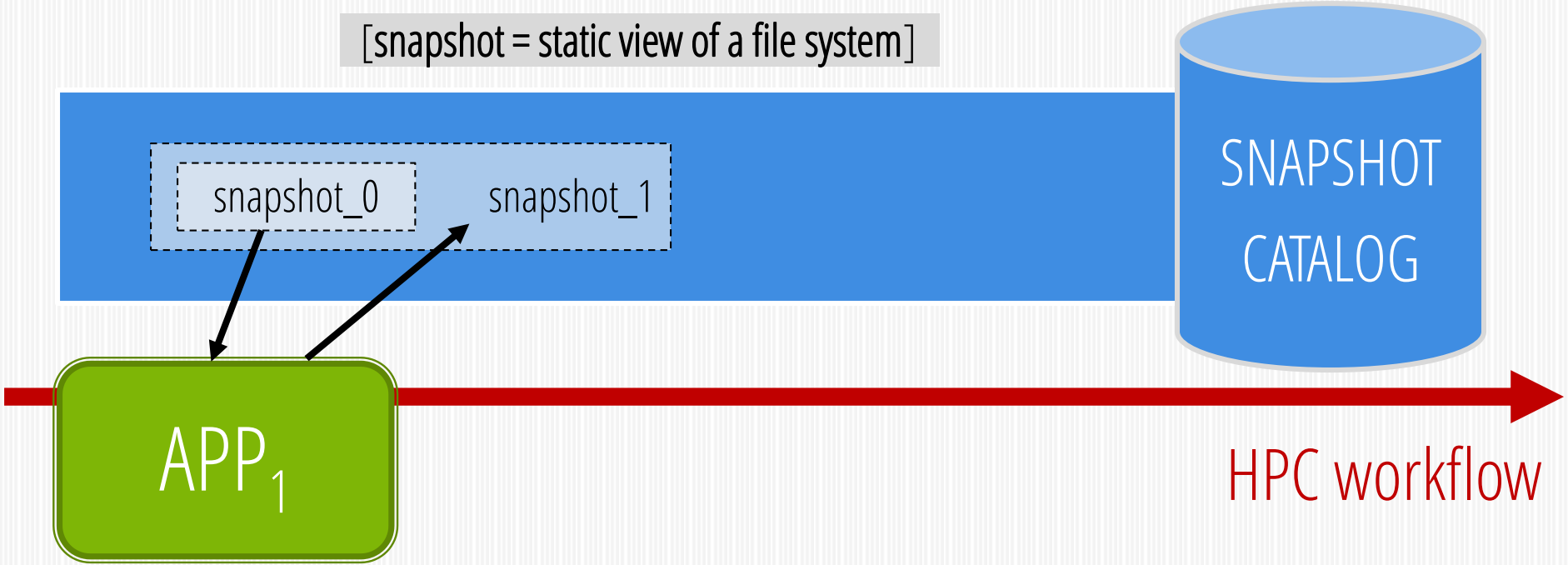
[snapshot = static view of a file system]



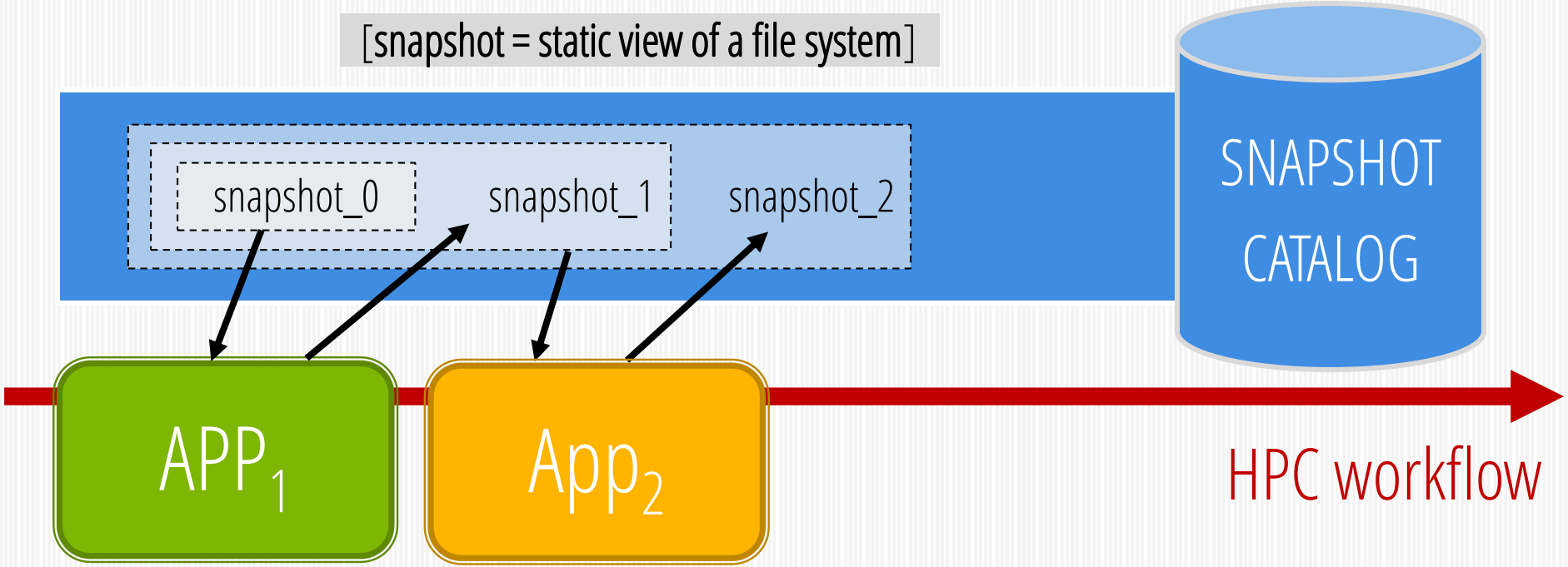
Keeps each app isolated from other running apps

Truly parallel metadata processing among different apps

Sharing Data Between Apps



Sharing Data Between Apps



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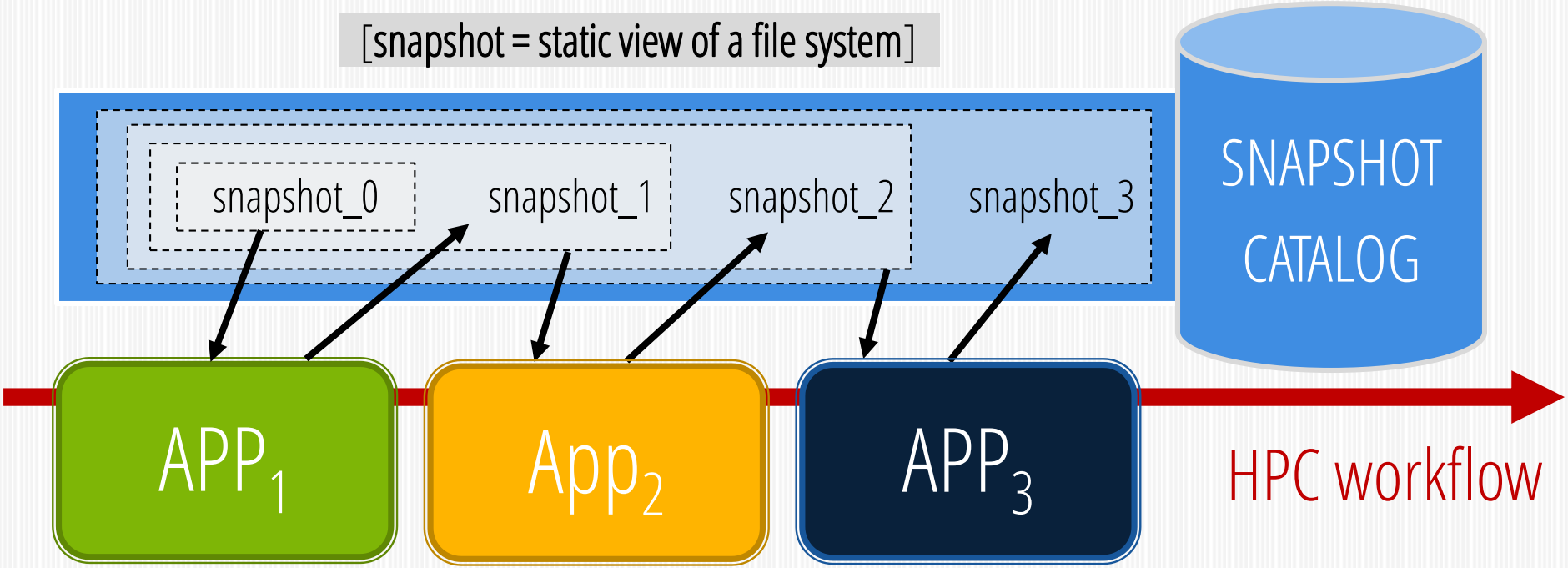

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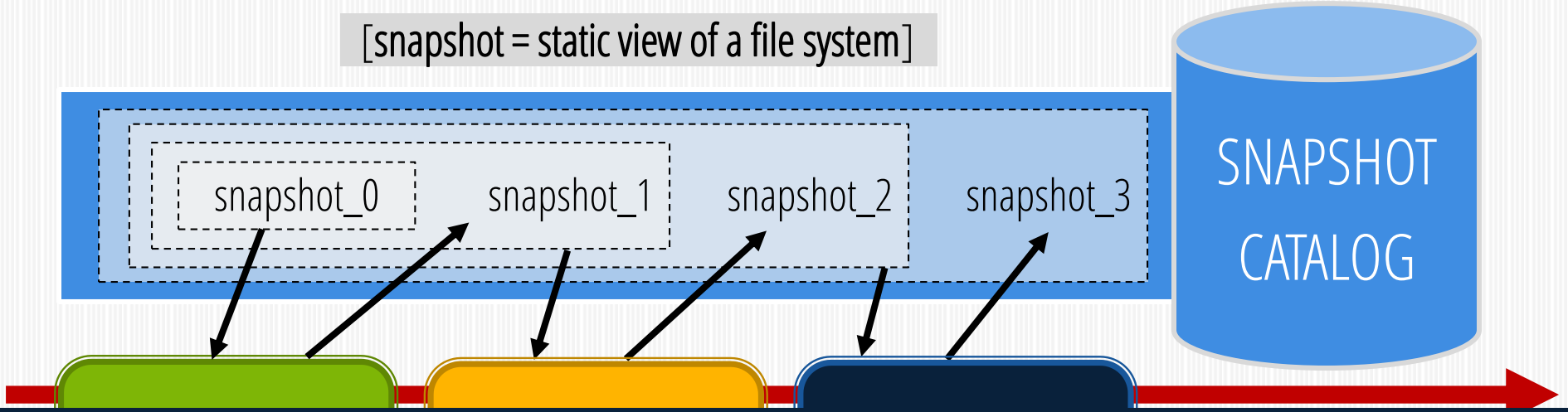
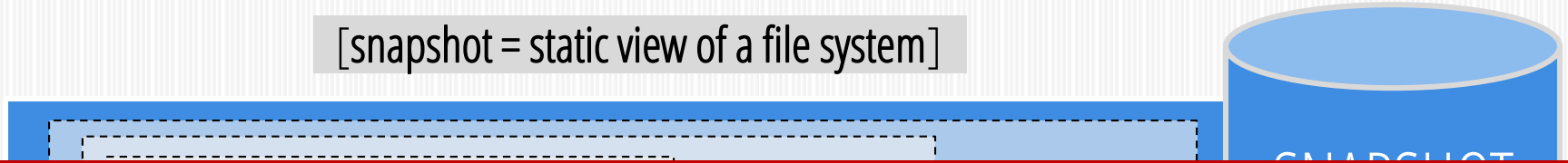


Converts online to batched offline sharing

Allows apps to decide file visibility and timings for communication

Sharing Data Between Apps

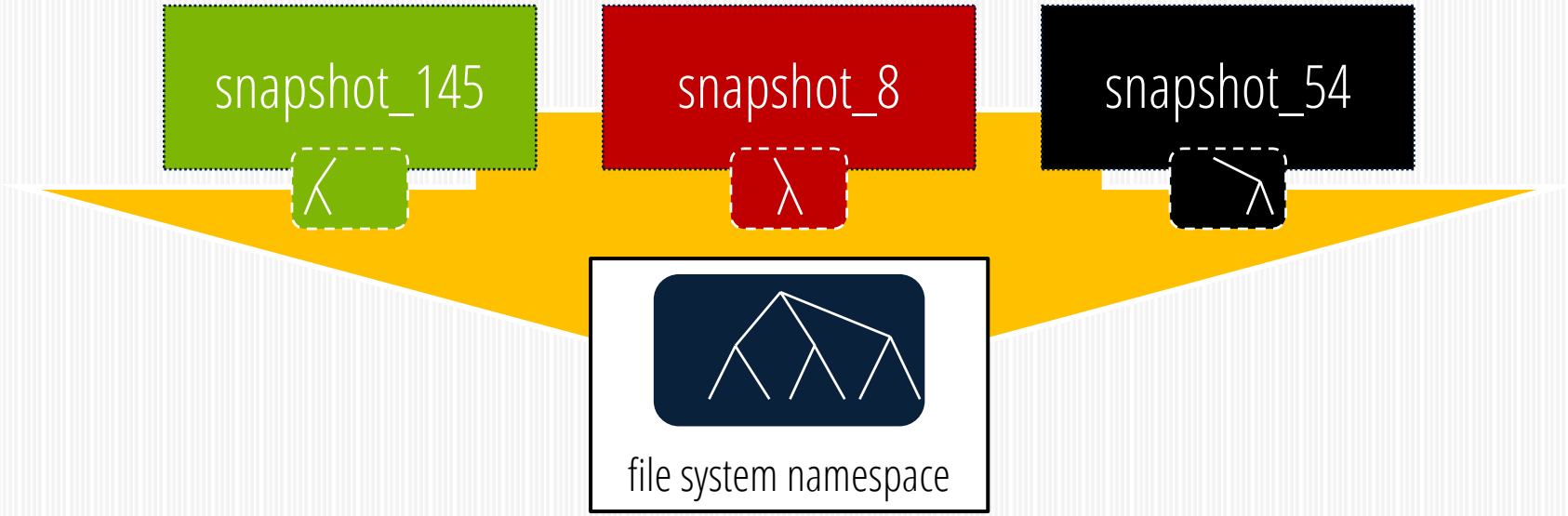
[snapshot = static view of a file system]



Avoids unnecessary coordination
synchronously enforced by a centralized metadata service

Converts online to batched offline sharing
Allows apps to decide file visibility and timings for communication

Snapshot Merging



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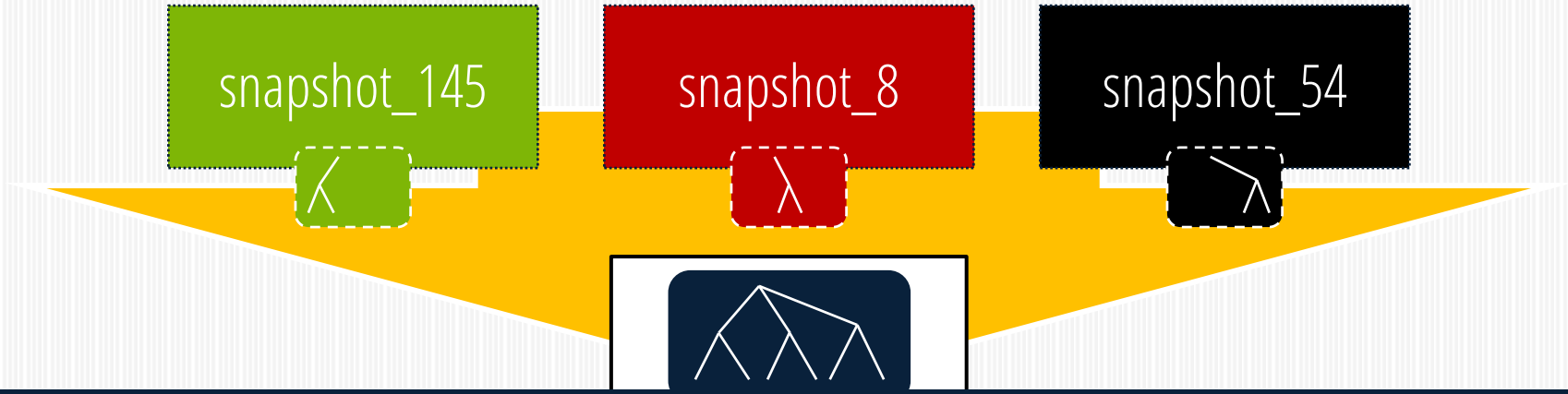
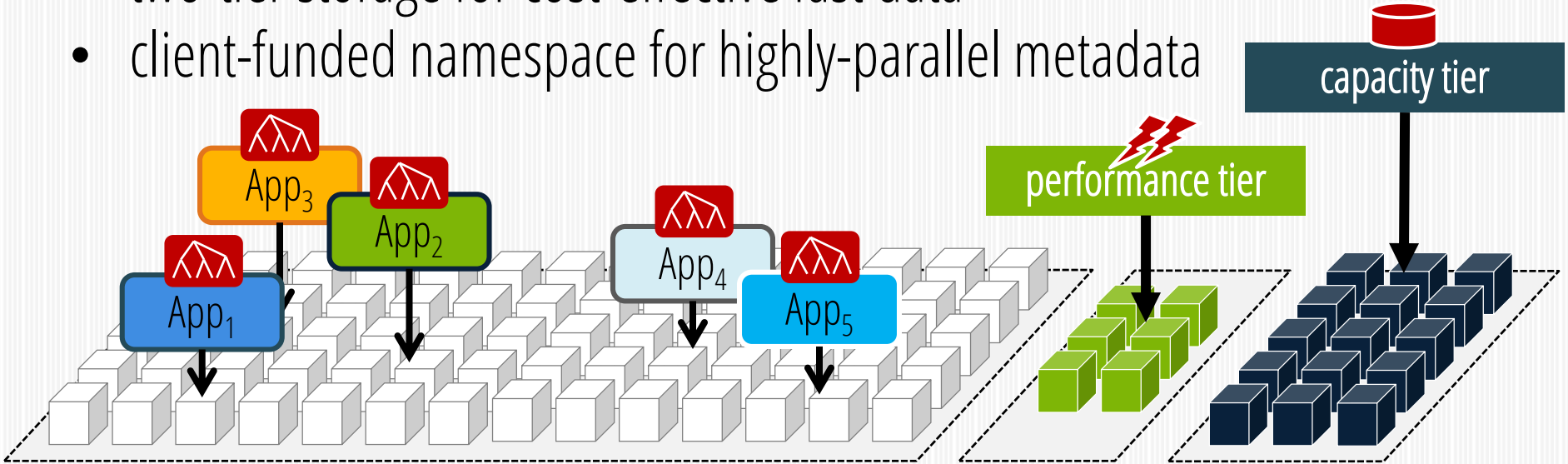


Conflicts resolved at read path to avoid unnecessary computation

Resolution performed by apps instead of a super authority

HPC in 10 years …

- two-tier storage for cost-effective fast data
- client-funded namespace for highly-parallel metadata



Reference

BatchFS | Scaling the File System Control Plane with Client-Funded Metadata Servers (PDSW14)

IndexFS | Scaling File System Metadata Performance with Stateless Caching and Bulk Insertion (SC14)

QUESTIONS