Addressing I/O Bottleneck for Large-Scale Deep Learning Applications On HPC Systems

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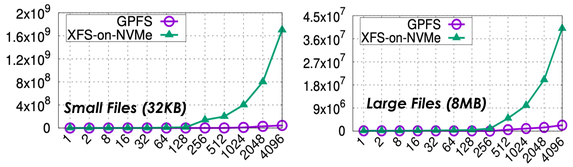
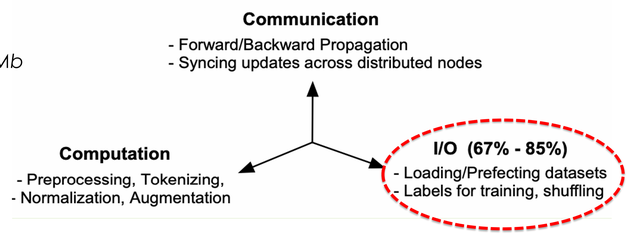
Introduction

- Deep Learning (DL) applications are becoming an increasingly important workloads on HPC systems such as ***Summit and Frontier***
- To efficiently ***Run and Scale DL Applications*** to leverage state-of-the-art HPC system remains challenging
- Existing prefetching and caching solutions pose non-trivial challenges such as
  - ***Fail to fully utilize the compute node-local NVMes,***
  - ***Require modifications to applications or input I/O pipeline***
  - ***Incur additional metadata overhead and bottlenecks***

Motivation and Research Challenges

- I/O optimization for DL Applications is non-trivial challenge
  - ***Dataset characteristics, DL Access patterns, and I/O properties***
- DL applications running at large-scale training environments spend
  67-85% of their ***execution time performing I/O to PFS***
- MDTest on Summit for DL workload access patterns
  - ***(Open-Read-Close)*** *with two different file sizes, 32Kb and 8Mb*



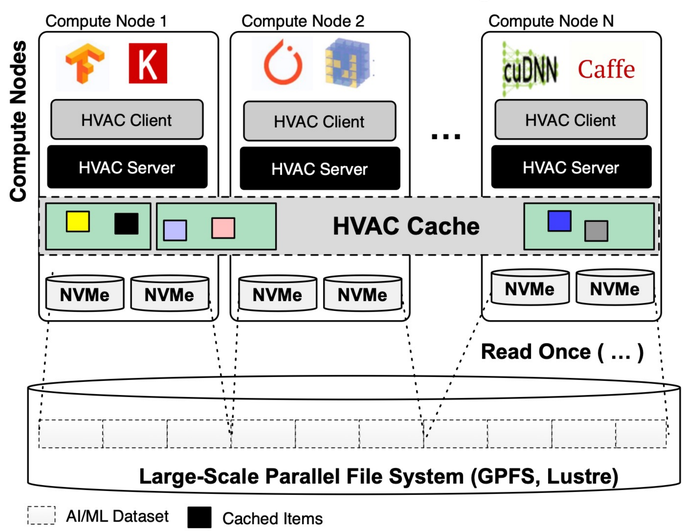


- ***Opportunity to exploit node-local or near-node local storage on compute nodes and solve I/O Scalability limitations by layering a caching system***
  - With diverse deployment model, portable and POSIX support, no metadata slowdown, no repeated rereads from PFS

An overview of High-Velocity AI Caching System

"To Scale on thousands of compute nodes on leadership-class supercomputer such as Summit and Frontier without modifying DL applications and additional metadata bottlenecks and storage overhead"

- A simple, lightweight and transparent library intended to accelerate I/O accesses for DL applications that utilize read-only data with a ***high re-read rate***
- Architecture agnostic and can be deployed on node-local, near-node local or rack-local storage
- Supports POSIX operations (open, read and close) via ***LD_PRELOAD*** and fully portable, requiring no changes to application or PFS
- Guarantees ***no repeated re-reads*** from underlying PFS, once files are cached in node-local storage
- Consists of two components:
  - ***Client:*** intercepts the application I/O calls
  - ***Server:*** processes the I/O operations and cache dataset locally on node-local NVMe



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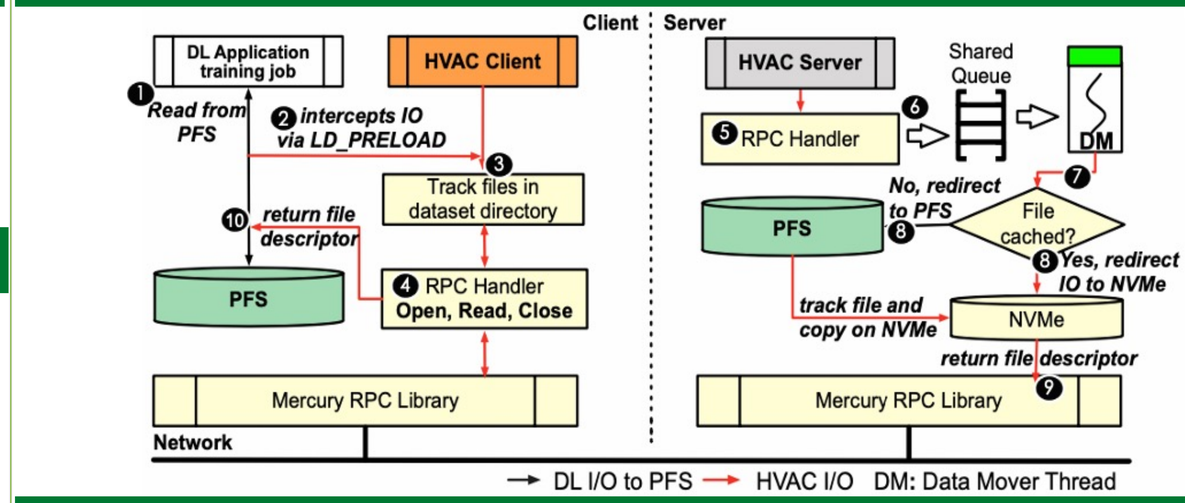
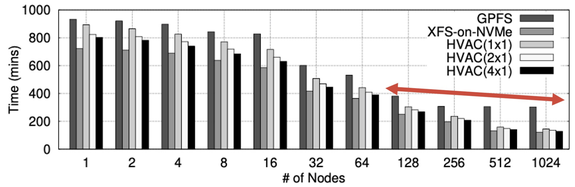
Accelerated I/O Service Flow

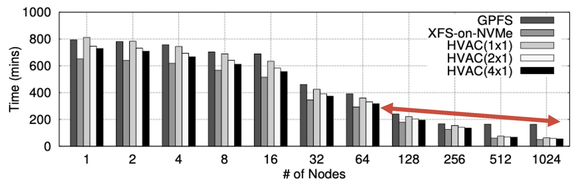


Scalability Study on Summit

- HVAC compared against ***GPFS***, ***XFS-on-NVMe*** (pre-staged whole dataset to each node-local storage)
  - ***HVAC (i x1): no. of HVAC server*** instance(s) running on each compute node
- Scalability analysis with ***increasing no. of compute nodes***
  - Average performance improvement is over 50% for all HVAC variants atop GPFS

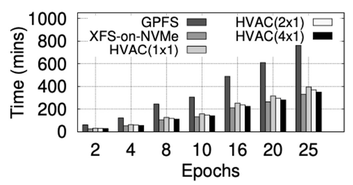


(a) ResNet50 [BS:50, Eps:10, nProcs/node:2]

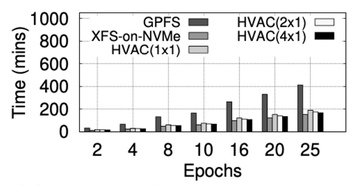


(b) CosmoFlow [BS:80, Eps:10, nProcs/node:2]

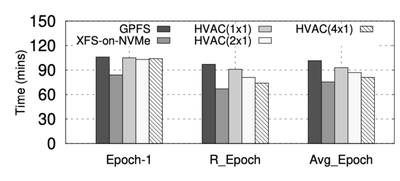
- Scalability analysis with ***increasing no. of epochs***



(a) ResNet50 [BS:80, nNodes:512]



(b) CosmoFlow [BS:4, Eps:10, nNodes:512]



(c) Per Epoch Analysis

Conclusion

- HVAC is a scalable read-only caching system for HPC systems such as Summit and Frontier
- Exploits compute node-local storage and builds an aggregate cache layer atop to accelerate the DL application training
- Scales linearly on 1024 summit nodes and shows an average 25% performance improvement atop GPFS and 9% drop with XFS-on-NVMe

Work In Progress (WIP)

- Open-sourcing the HVAC software library and deployment on Frontier
- Comparison with State-of-art works using large-scale DL models such as DeepCAM, OpenCatalyst
- Prefetching and chunk-granularity caching to fully utilize multiple node-local SSDs in Frontier compute nodes, i.e., two node-local NVMes per compute node