GPU Direct Storage: performance comparison

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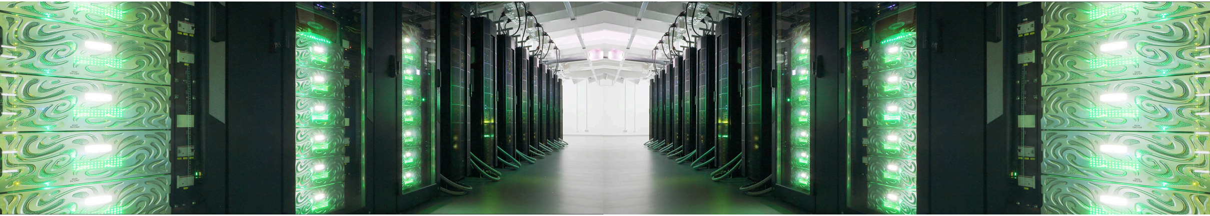

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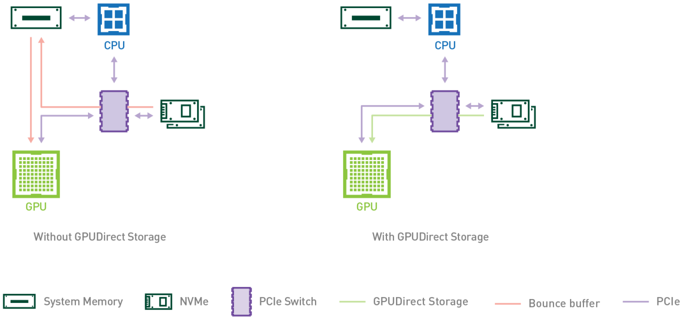
What is GPUDirect Storage

Nvidia GPUDirect Storage (GDS) or Nvidia Magnum IO provides a direct DMA path between GPU and PCIe attached storage via the `cuFile` API in a Nvidia ConnectX-4+ based fabric.



Without GPUDirect Storage

With GPUDirect Storage

Source: https://developer.nvidia.com/blog/gpudirect-storage/

Examples for useable storage: local NVME drives, Lustre, BeeGFS, GPFS, WekaFS, VASTData, NetApp ONTAP, RDMA enabled NFS

Hardware: NHR System Grete

- 34 nodes
- 2 Epyc Milan 7513 32 Core CPUs per node
- 4 Nvidia A100 40GB GPUs per node
- 2 Intel P4510 1TB PCIe 3 NVME SSDs per node
- Dual rail Infiniband HDR interconnect
- Cluster local GPU Direct enabled SSD storage (2 DDN ES400NVX with ExaScaler 6.1)

Benchmarktool: elbencho

- Combined benchmarking tool for multiple purposes
- I/O and metadata benchmarking
- Metrics similar to fio available (bandwidth, iops)
- POSIX IO, CUDA, GDS via cuFile API and S3
- Client/server model for multi node testing
- Tools for parameter tuning and visualization
- Used 4k, 512k and 4M blocksizes (very nice I/O patterns)
- CPU based POSIX I/O, CUDA I/O with all GPUs and cuFile API via option (-gds)

Results 1

local NVME	CPU POSIX	CUDA	cuFile (GDS)
4k rand read IOPS	934.276	349.722	828.364
4M seq read MiB/s	5.336	5.325	5.311
4k rand write IOPS	348.002	138.581	171.072
4M seq write MiB/s	2.129		

Results 2

Lustre 1 node	CPU POSIX	CUDA	cuFile (GDS)
4k rand read IOPS	1.124.942	263.014	1.054.308
4M seq read MiB/s	37.521	22.139	38.389
4k rand write IOPS	88.652	84.524	88.794
4M seq write MiB/s	21.879	10.260	20.575

Results 3

Lustre 2 nodes	CPU POSIX	CUDA	cuFile (GDS)
4k rand read IOPS	2.190.572	497.150	2.215.756
4M seq read MiB/s	45.988	26.347	70.726
4k rand write IOPS	152.127	146.593	147.537
4M seq write MiB/s	30.287	24.153	29.728

Strange observation

Suspicous error message in `cufile.log`:

```
27-09-2023 18:05:21:334 [pid=21356 tid=21356] ERROR  cufio-fs:152 EXT4
 journal options not found in mount table for device,can’t verify
  data=ordered mode journalling
27-09-2023 18:05:21:334 [pid=21356 tid=21356] NOTICE  cufio:1538
 cuFileHandleRegister GDS not supported or disabled by config,
  using cuFile posix read/write with compat mode enabled
```

Results 4

Bypassing GDS for blocksizes <1MB on Lustre with 2 nodes:

Lustre 2 nodes	cuFile (POSIX)	cuFile (GDS)
4k rand read IOPS	1.933.847	2.215.756
512k rand read MiB/s	57.396	55.650

MLPerf Storage

MLPerf Storage is a benchmark suite to characterize the performance of storage systems that support machine learning workloads.

Available at `https://github.com/mlcommons/storage`

Based on work of the *Deep Learning I/O (DLIO) Benchmark*, available at `https://github.com/argonne-lcf/dlio_benchmark`

Aims to simulate I/O parttern of different deep learning workloads to drive a certain amount of processors (e.g. simulated Nvidia V100).

Rather low peak bandwidths, but consistent low latencies are important.

IO500

- Benchmark collection with different configurations based on ior, mdtest, mdworkbench and pfind
- MPI enabled for multinode operation to benchmark large scale systems
- POSIX IO and for some benchmarks MPIIO and/or S3 object IO.
- Results show a frame for expectable performance for a user
- Easy benchmarks are a upper limit, hard benchmarks lower limit for sensible IO
- Individual benchmarks for metadata and objectdata, streaming and randiom IO, small files and large file, memory aligned large IO sizes and unaligned small IO sizes, individual files and shared files
- Measurement of write, read and (for metadata) delete performance
- Recently updated to include GPU based storage benchmarks
- Traditional focus on peak bandwidth and IOPS

Summary

- I/O based on `cuFile API` provides large performance gains for reading compared to traditional CUDA I/O
- GPUDirect storage limited to systems with Nvidia interconnect and installed MOFED
- Several GDS enabled storage plattforms available, even DIY based on RDMA enabled NFS possible
- Additional performance gains of GDS vs cuFile API in POSIX compatibility mode seems small
- Additional benchmarks with other tools are needed for full overview
- MLPerf Storage interesting approach to generate workloads that are more realistic for actual user workloads
- Nothing prevents a storage system from choking on stupid I/O decisions of its users