Use of a New I/O Stack for Extreme-scale Systems in Scientific Applications

Michael Breitenfeld, Neil Fortner, Jerome Soumagne

The HDF Group

Mohamad Chaarawi, Intel

Quincey Koziol, Lawrence Berkeley National Laboratory

Collaborators: Intel and LBNL
ESSIO Storage Architecture

- **Compute Node NVRAM**
  - Hot data
    - High valence & velocity
    - Brute-force, ad-hoc analysis
    - Extreme scale-out
  - Full fabric bandwidth
    - $O(1PB/s) \rightarrow O(10PB/s)$
  - Extremely low fabric & NVRAM latency
    - Extreme fine grain
    - New programming models

- **I/O Node NVRAM/SSD**
  - Semi-hot data/staging buffer
  - Fractional fabric bandwidth
    - $O(10TB/s) \rightarrow O(100TB/s)$

- **Parallel Filesystem**
  - NVRAM/SSD/Disk
    - Site-wide shared warm storage
      - SAN limited – $O(1TB/s) \rightarrow O(10TB/s)$
A **transaction** consists of a set of updates to a container

- container ≈ file
- Updates are added to a transaction, not made directly to a container
- Updates include additions, deletions, and modifications
HACC - Hardware/Hybrid Accelerated Cosmology Code

N-body cosmology code framework where a typical simulation of the universe demands extreme scale simulation capabilities

Primary data model

- 9 arrays at full scale of application
  - Position in 3-D, Velocity in 3-D, Simulation Info, Science Data
- Additional metadata augmenting provenance, etc
Application creates custom binary files
Application creates custom binary files

- All application metadata stored in HDF5 container
- HDF5 format is self-describing, using groups, datasets and attributes
- Any visualization or analysis process can be used to investigate science results
Application stores and verifies checksum from memory to the file and back

? (with checksums)
Application stores and verifies checksum from memory to the file and back

- Each process calculates and passes checksum of the local array section to HDF5
- HDF5 optionally verifies buffer, and passes checksum with data down the stack
- Checksum verified for every data buffer operation from HDF5 to storage and back
HACC — Fault Tolerance: Currently

Application retries I/O until completed

(with checksums)
HACC — Fault Tolerance: ESSIO

Application retries I/O until completed

- Each process writes all checkpoint data to transaction
- Transaction is committed to storage, possibly asynchronously
- If asynchronous, application can test/wait to guarantee data is persistent
- *Future work*: replay event stack on error
High-level HDF5 ESSIO stack libraries

Objective

Have the high-level I/O code manage the transaction requests and isolate the application code from the ESSIO stack

Ported Two High-level HDF5 based I/O libraries

(1) NetCDF – A set of software libraries used to facilitate the creation, access, and sharing of array-oriented scientific data in self-describing, machine-independent data formats

(2) Parallel I/O (PIO) – A high-level I/O library which uses as its backend NetCDF
• Global stack variables are passed as arguments to NetCDF and from the application
  • Stack parameters are controlled from within PIO

Application (ACME)

Initialize stack:
  Read context id, Version number, Event stack id, transaction id

PIO

Write Array

netCDF

• Writes data to stack via multiple netCDF APIs
• Increments and automatically handles FF variables
New superset of DAOS – **DAOS-M**

**Distributed Persistent Memory Class Storage Model**

- DAOS-M server will access memory class storage using a Persistent Memory programming model that directly utilizes load-store access to NVRAM DIMMs
- Extends the current DAOS API to support key-value objects natively

Port and benchmark to DAOS-M:

1. Legion Programming System (not presented here)
2. NetCDF to DAOS-M