Enabling Transparent Asynchronous I/O using Background Threads

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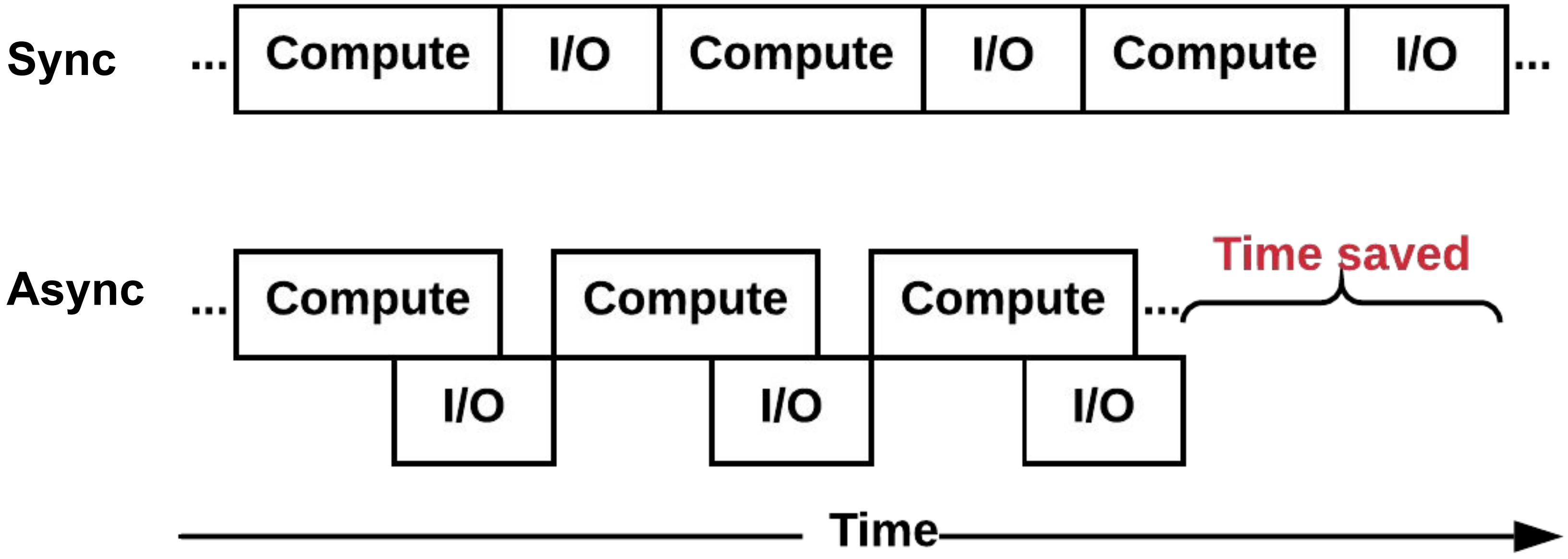
EXASCALE COMPUTING PROJECT

HPC I/O

- **Synchronous**
  - Code executes in sequence.
  - Computation is blocked by I/O, waste system resources.

- **Asynchronous**
  - Code may execute out of order.
  - I/O is non-blocking, can overlap with computation.

Synchronous vs. Asynchronous



Existing Asynchronous I/O Solutions

- POSIX I/O: `aio_*`
- MPI-IO: `MPI_File_i*`

⇨ **Limited number of low level asynchronous APIs**

- ADIOS/DataSpaces
- PDC (Proactive Data Containers)

⇨ **Requires extra server processes**

Manual dependency management

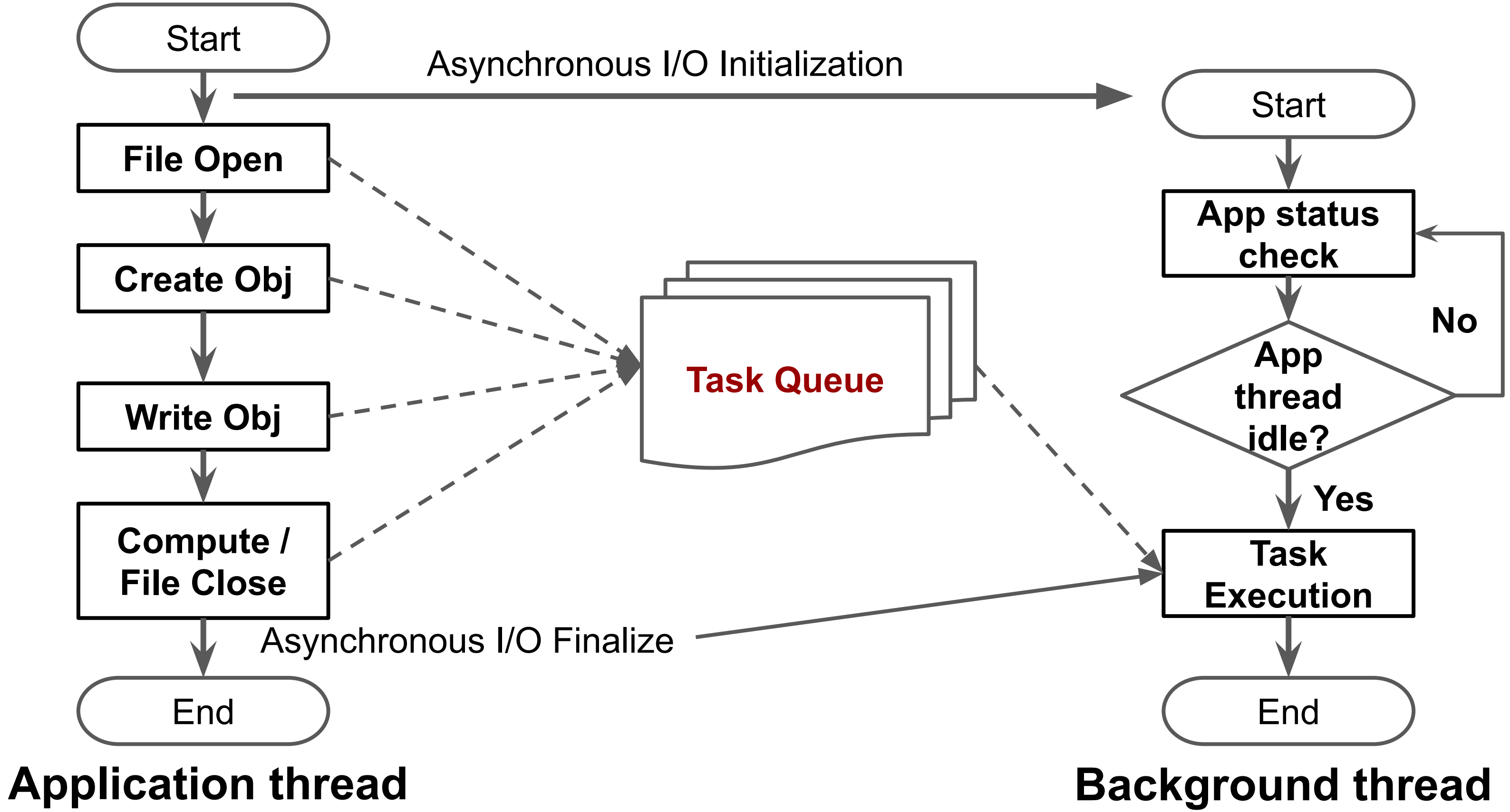
Asynchronous I/O Design Goals

- Effective to execute **all** I/O operations asynchronously.
- Requires **no additional resources** (e.g. server processes).
- **Automatic** data dependency management.
- **Minimal** application code changes.

Implicit Background Thread Approach

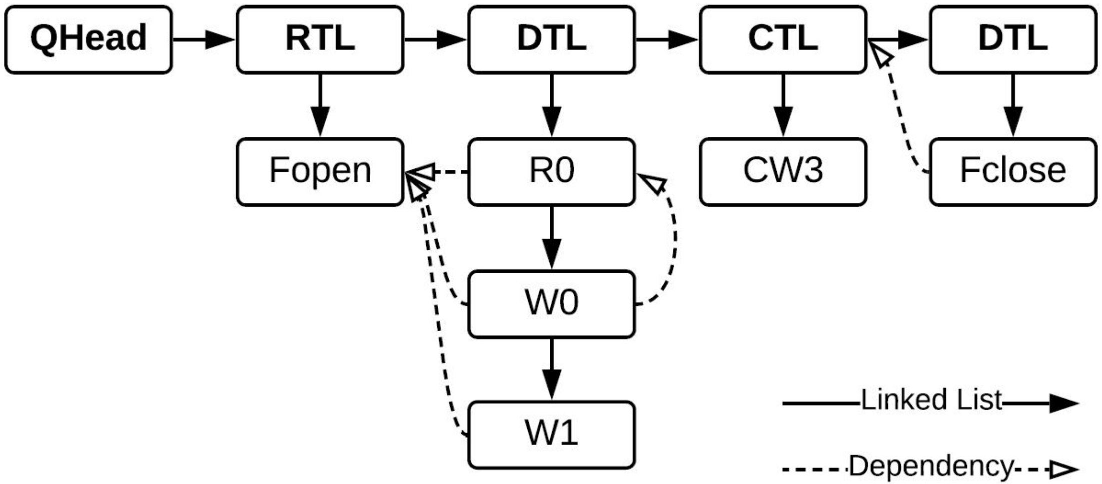
- Transparent from the application, no major code changes.
- Execute I/O operations in the background thread.
  - Allow application to queue a number of operations.
  - Start execution when application is not busy issuing I/O requests.
- Lightweight and low overhead for all I/O operations.
- No need to launch and maintain extra server processes.

Dependency management



Queue Management

- Regular task
- Dependent task
- Collective task



Dependency management

- File create/open execute first.
- File close waits for all existing tasks to finish.
- Any read/write operations execute after prior write to same object, in app’s order.
- Any write executes after prior reads of same object, in app’s order.
- Collective operations, in order, one at a time.

HDF5 Implementation

- VOL connector
- HDF5 I/O operations
- Additional functions
- Background thread w/ Argobots
- Error reporting

Virtual **O**bject **L**ayer
- HDF5 data model and API.
- Switch I/O implementation.

Enable by:
- Environmental variable, or
- `H5Pset_vol_async()`

HDF5 Implementation

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Metadata operations

- *Initiation*: create, open.
- *Modification*: extend dimension.
- *Query*: get datatype.
- *Close*: close the file.

Raw data operations

- Read and write.

HDF5 Implementation

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- **`H5Pset_vol_async`**
- **`H5Pset_dxpl_async_cp_limit`**
- **`H5Dtest`**
- **`H5Dwait`**
- **`H5Ftest`**
- **`H5Fwait`**

HDF5 Implementation

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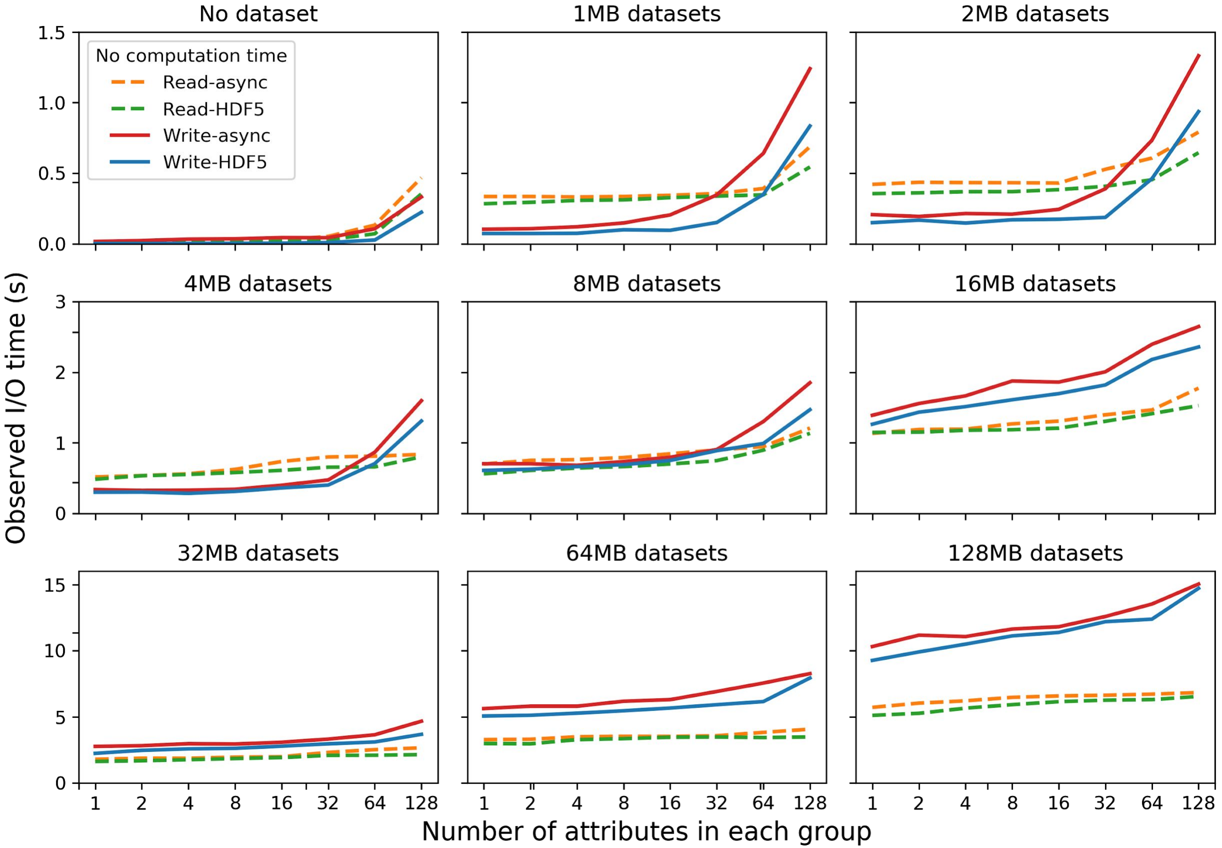
Experimental Setup

System	Cori @ NERSC
Benchmarks	Single process Multiple process *Workloads* - Metadata heavy - Raw data heavy - Mixed
I/O kernels	VPIC-IO, *time-series plasma physics particle data write* BD-CATS-IO, *time-series particle data read, analysis*

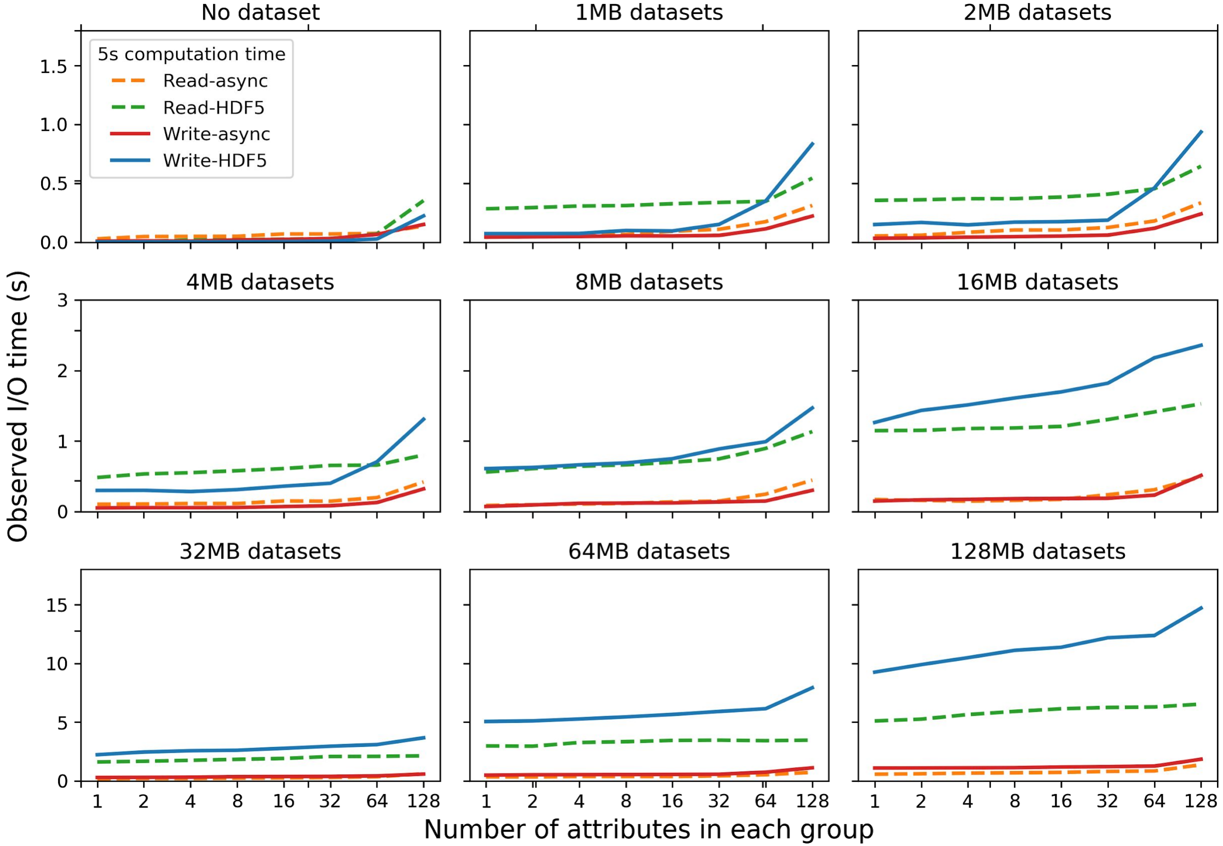
Single Process - No Computation (Overhead)



Overhead

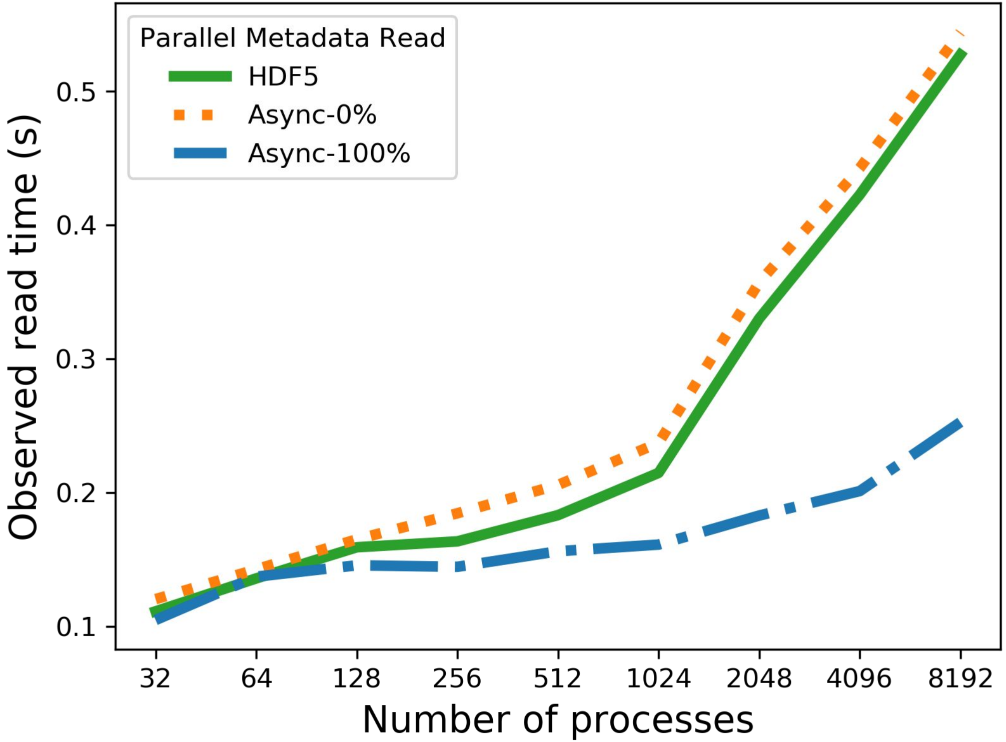
5% average

Single Process - With Computation



Speedup
2 - 9X

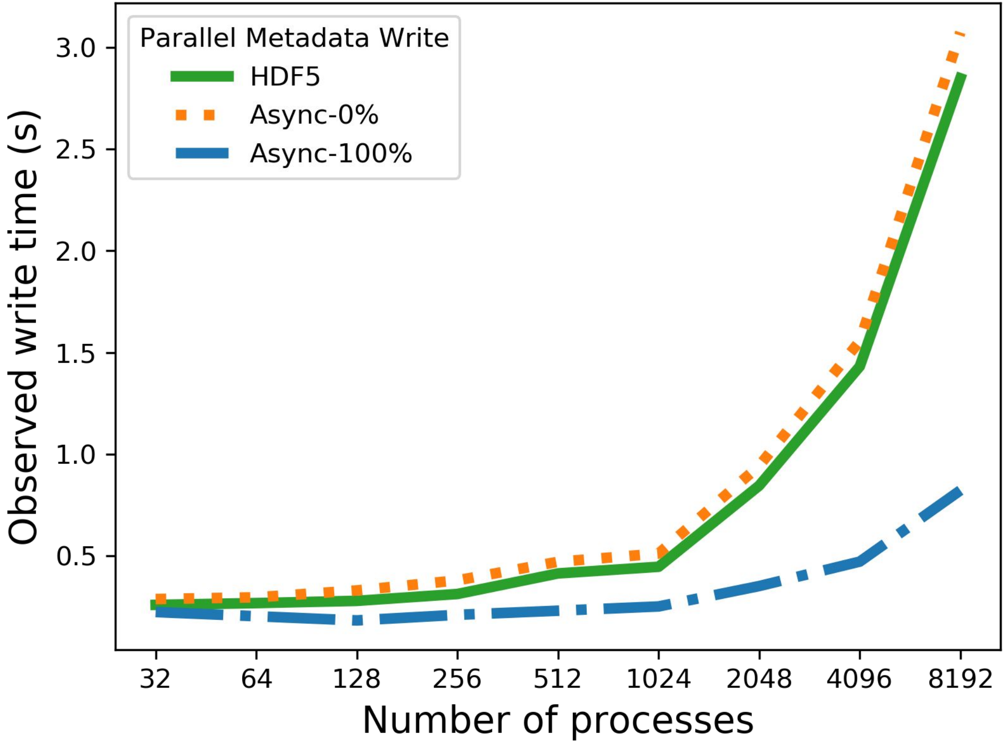
Multiple Process - Metadata Intensive Read



Speedup

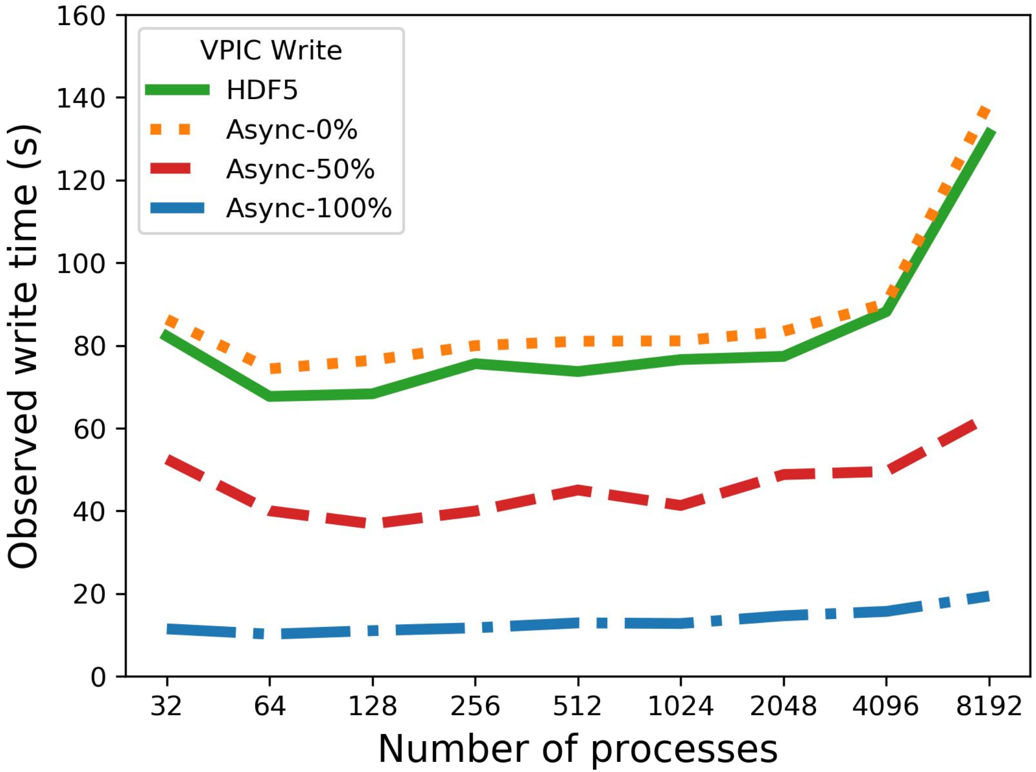
1.1 - 3.5X

Multiple Process - Metadata Intensive Write



Speedup
1.1 - 2.1X

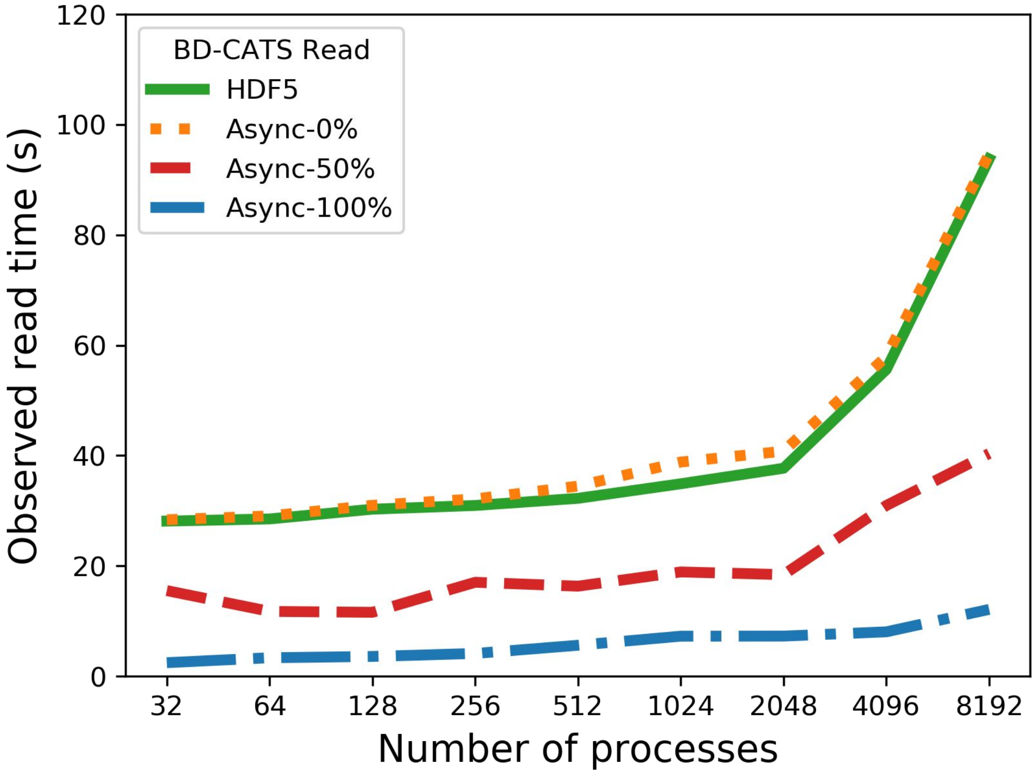
Multiple Process - VPIC-IO



Speedup

5 - 7X

Multiple Process - BD-CATS-IO



Speedup
5 - 9X

Conclusion

- **An asynchronous I/O framework**
  - Highly effective and low overhead.
  - Support all I/O operations.
  - Require no additional server processes.
  - Transparent from application.

- **Future work**
  - Apply this work to more applications and I/O libraries, further performance optimization.
  - “Event tokens” for explicit tracking and controlling the asynchronous I/O tasks.

Thanks!

Questions?

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