Detecting Data Races on Storage Systems Using Recorder

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Recorder

- A holistic tracing tool that traces MPI, MPI-IO, POSIX, and HDF5 calls.
  - Stores all function parameters
- [https://github.com/uiuc-hpc/Recorder](https://github.com/uiuc-hpc/Recorder)

Potentially constant trace size

Post-processing tools and visualizations
Data Races?

Is P2’s read guaranteed to return the data written by P1? (Do they form a data race?)
Data Races?

Is P2’s read guaranteed to return the data written by P1? (Do they form a data race?)

We can’t answer this question because we haven’t defined the *consistency model*. 
Sequential Consistency (POSIX)

POSIX requires that a write should become immediately visible to all subsequent reads.

Examples of POSIX systems: Lustre, GPFS, BeeGFS, etc.
Commit Consistency

Commit consistency requires an explicit “commit” operation to make the update visible.

Examples of Commit systems: UnifyFS, BurstFS, BSCFS, etc.
Other Models

Session Consistency:
- P1: Write → Close
- P2: Open → Read
- Happens-before

Examples: NFS, Gfram/BB, etc.

MPI-IO Consistency:
- P1: Write → Barrier → Sync → Barrier
- P1 and P2
- P2: Read
- Happens-before
Data Race $\Rightarrow$ Potentially Wrong Result

An application that runs correctly on one model may not run correctly run on a different model.

How to check?

- A trace-driven approach!
- Idea: Check if all conflicting accesses are properly synchronized.
Algorithm for Detecting Data Races

Step 1: Build a happens-before graph from the traces
Step 2: Identify all conflicting accesses
Step 3: Check if all conflicting accesses are properly synchronized

Properly synchronized under POSIX and Commit Consistency (but not for Session Consistency)
What Do We Need?

1. I/O calls and their parameters
2. Communication calls and their parameters
3. Program order
4. Synchronizations

Recorder captures all the information needed.

Code included in Recorder.
Results and Remarks

We tested 17 HPC applications. 7 show conflicting accesses.

- No data race under Sequential/Commit Consistency
- 1 has data races under Session Consistency.

Most HPC applications should be able to take advantage of storage systems with relaxed consistency models.

Questions?

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Backup Slides
Algorithm for Detecting Data Races

Step 1: Build a happens-before graph from Recorder traces.

1. I/O
2. Communication - matching MPI calls.
3. Program order
Algorithm for Detecting Data Races

Step 2: Identify all conflicting accesses.

1. Need to examine every I/O operations (data and metadata).

2. Compare their access ranges.
   - pwrite() with explicit offset
   - fwrite() without explicit offset.
   - Nested open/close?
Algorithm for Detecting Data Races

Step 3: Check if all conflicting accesses are properly synchronized.

- A reachability problem (can be done quickly for DAG)

Properly synchronized under POSIX but not Commit Consistency
## The 17 Apps

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