dBug: Systematic Evaluation of Distributed Systems

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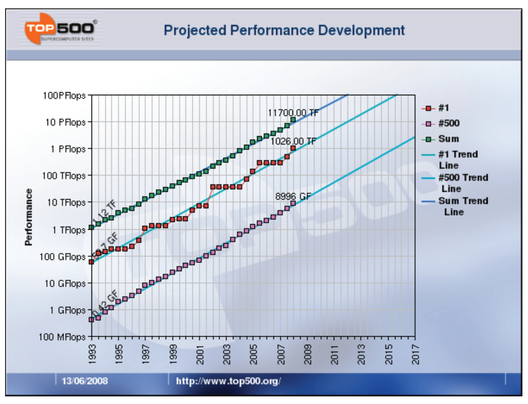
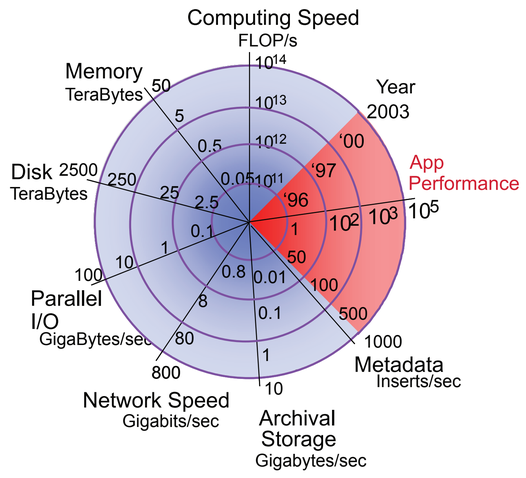
Problem Setup

- HPC computing speed grows 2X per year
- Disk bandwidth grows only 20% per year
- Random access rate grows only 7% per year
- As a result, parallel FSs grow in:
  - disks, parallelism, prefetching, delaying
- Implementing and stabilizing more complex code at HPC scales is harder each year





Background: Proving Correctness

- Model checking tools in use:
  - MaceMC, SLAM, HAVOC, Terminator, SPIN, Slayer, ...
- No one-fits-all tool
- Typical limitations:
  - Limited range of properties / language constructs
  - Manual effort to annotate / specify / verify required
  - Proves correctness under assumptions

Background: Bug Finding

- Concrete / Symbolic execution tools in use:
  - MoDist, KLEE, eXplode, DART, VeriSoft, ...
- Execute real code in a test harness
- Typical limitations:
  - Under-constraining environment
  - Limited ability to setup test cases

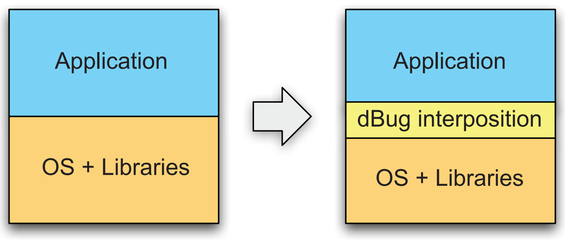
Distributed System Verification Challenges

- Number of behaviors grows exponentially with number of concurrent events
- Non-determinism arises due to interactions with environment
- Conflicting requirements, such as performance versus consistency, imply high complexity
- (Formal) Specifications of distributed systems inaccurate, outdated, or non-existent

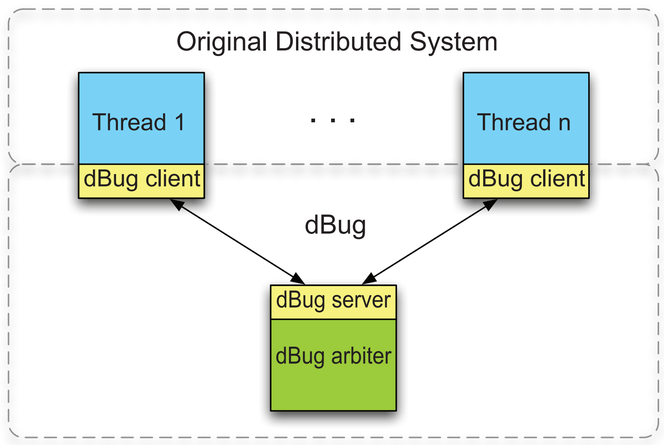
Case Studies: PVFS and FAWN

- Our Goal: systematic evaluation of distributed systems
- Initial cases: PVFS and FAWN-based distributed key-value store
- Integration of both systems with dBug ~ 100 LOC
- Additional annotations used for:
  - Accelerating exploration of dBug
  - Reducing the number of behaviors needed to explore
- Verified 10 workloads; found known & unknown bugs
  - E.g., a FAWN bug was violating strong consistency guarantee

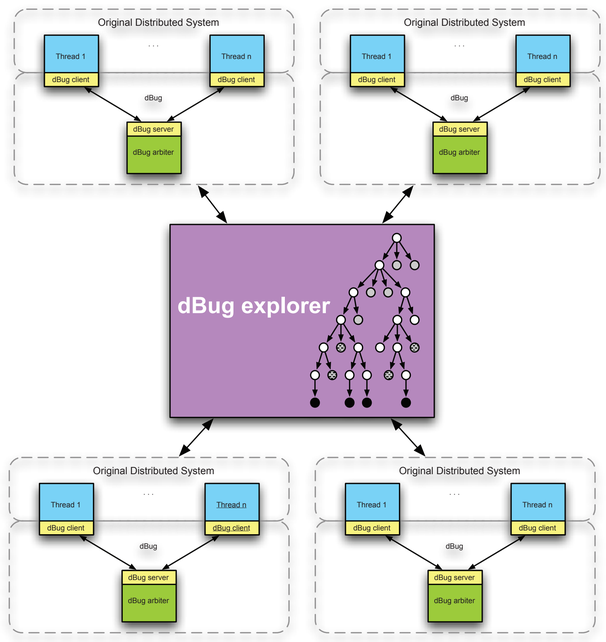
dBug Approach: Design & Implementation



Avoid annotation of source code by interposing on popular library interfaces



Use centralized arbiter to control execution order of concurrent events



Through arbiter scheduling, systematically explore different execution orders

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