Log-structured Files for Fast Checkpointing

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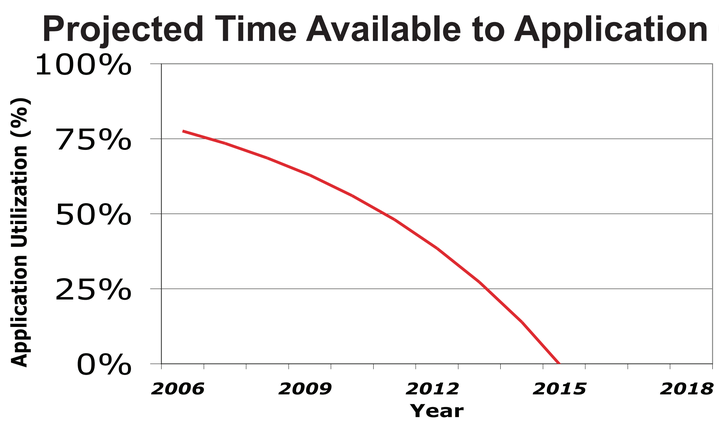
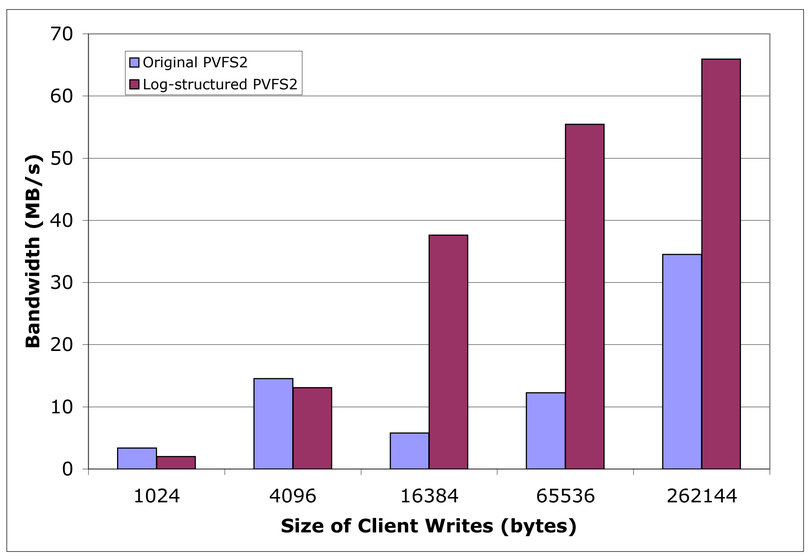
Motivation

- **Approaching a checkpointing catatrasophe in HPC:**
  - **Systems with more nodes, failures**
  - **Larger datasets**
  - **Longer running, more frequent checkpoints**
- **At current trends, checkpoints will prevent most useful application work within the next decade**

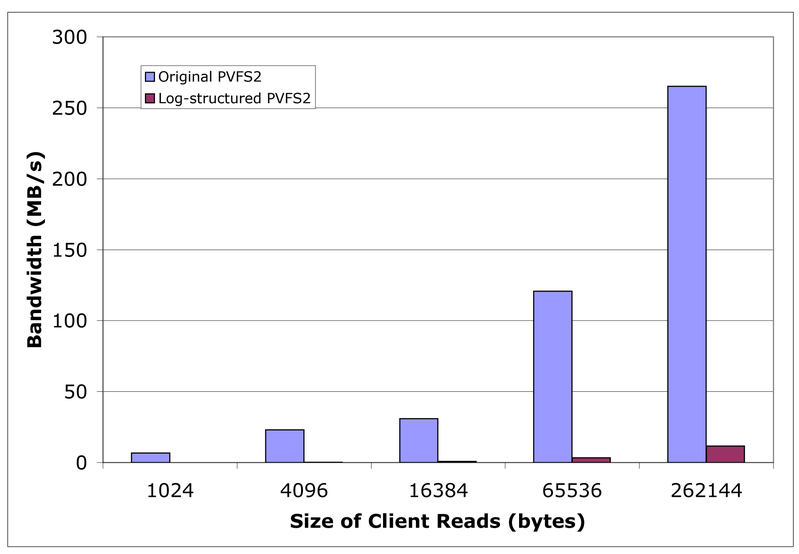


Write Performance



- **Best benefit seen for 16k writes**
- **1k writes penalized by header overhead**
- **4k writes have alignment issues**

Read Performance



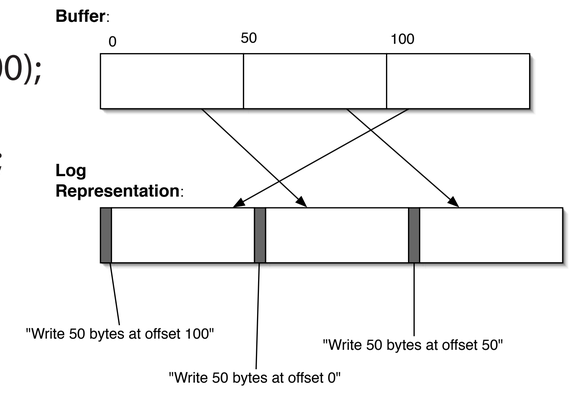
- **Performance poor as reads scan entire file for applicable writes**

Checkpointing

- **Technique for fault tolerance**
- **Compute nodes barrier sync, write state to storage**
- **No useful work until checkpoint complete**
- **Concurrent strided writers introduce more seeks**
- **Most checkpoints never used**
  - **1996 log of jobs from LLNL had orders of magnitude fewer failed jobs than checkpoints**

Log-Structured Writing

```
pwrite(file, buffer[100], 50, 100);
pwrite(file, buffer, 50, 0);
pwrite(file, buffer[50], 50, 50);
```



- **Writes on disk in temporal order rather than logical**
- **Reduces time lost to write seeks, but can slow reading**
- **Not appropriate for all workloads, all files**
- **Appropriate for checkpoints (“write-once, read-maybe”)**
- **Our idea: Per-file log representations**

Implementation

- **Assigned as class project in Advanced Storage Systems**
- **Implemented in PVFS2, a parallel distributed filesystem**
- **Writes checkpoint files in a log structure**
  - **Each write is written to the end of the file with a header**
  - **Header contains logical location and size of the write**
- **Reads serviced naively by scanning file for all headers**
  - **Simple implementation**
  - **Checkpoints rarely read**
  - **Students not graded on read performance**
- **Evaluated with `mpi_io_test` using 10 clients**

Current Status

- **Student implementations show good write performance**
- **Promising potential for further work**

- **Read path improvements**
  - **Use footers for earlier terminated backwards scan**
  - **Flatten on first read**
  - **Separate index structure**

- **Generalize per-file representation technology**
  - **Per-file RAID**
  - **Optimized formats for scientific files**

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