Exploiting Locality in Scientific Workflow System: A Cross-Layer Solution

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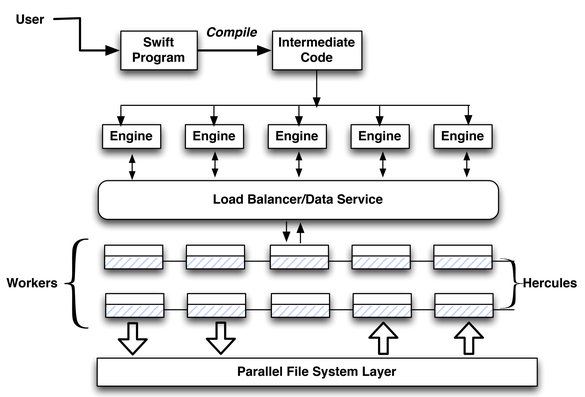
1. Motivation

- Workflows are one of the solutions for complex scientific app.
- Workflows run upon a parallel file system (PFS)
- This leads to significant I/O overhead:
  - Input/Output data needs to be transfered
  - Intermediate data needs to be stored in parallel file system (PFS)
  - Checkpoints need to be stored in PFS
- One solution: **Exploit the Data Locality**
  - If the data is stored in compute nodes, near the workflow tasks, we can obtain locality.
    - Build a files system in compute nodes
    - Use their local resources (memory, SSDs)

2. Background

In this research, we take Swift/T and Hercules as the basis to exploit data locality.

- Swift/T is a workflow system.
- Hercules is a compute-node side storage.



3. Challenges of Existing Solution: Swift/T with Hercules

```
1  file fs[] = glob("in/*.txt");
2  file outs[];
3
4  app (file out) sort (file in)
5  {
6      "/usr/bin/sort" "-o" out in;
7  }
8
9  app (void signal) mpitask (file f[], string mpi)
10 {
11     "/usr/bin/mpiexec" mpi f;
12 }
13
14 foreach v,i in fs
15 {
16     file y<sprintf("out/%i",i)> = sort(v);
17     outs[i] = y;
18 }
19
20 mpitask(outs, mpiprogram);
```

Take left program as an example, it is hard to exploit data locality in current systems.

- Hercules does not support explicit control over locations. Scientists have to estimate location and tell Swift.
- Swift compiler does not collect metadata regarding data and tasks, like data size or task complexity to help schedule in runtime system.
- Swift runtime does not feedback to storage systems to direct data organization or movements.

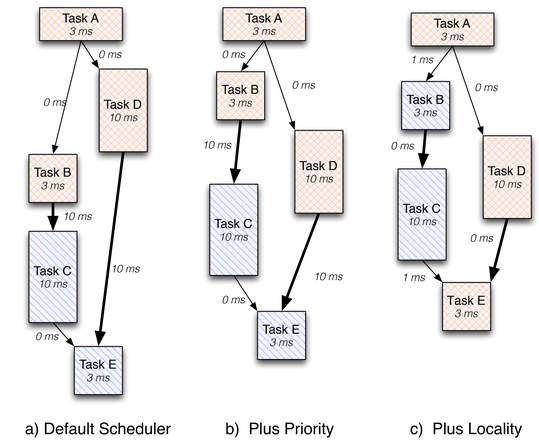
4. A Cross-Layer Solution to Exploit Data Locality

- **Location-Aware File System Extension**
  - Extend POSIX APIs to be location-aware
    - Add a new mode argument (`S_LOC`) for the `O_CREAT` flag of the `OPEN` function.
    - Store location information of a file in its `xattr` attributes. Obtained using `getxattr()`.
  - Build distributed location service
    - Store file in *real-loc*, but the location metadata is stored in *orig-hash-loc*.
- **Hint-Assist Workflow Compiler**
  - `@size` indicates the size of an existing file.
  - `@task` indicates the key parameters for a task.
  - `@compute-complex` indicates the computation cost of a task.
  - `@input-output-ratio` indicates the output size of a task regarding to its inputs.
- **Locality-Aware Workflow Scheduler**
  - A heuristic priority for task selection
    - The task that is far away from the final step in the topological order is assigned higher priority
  - Proactive scheduling: schedule "almost-ready" tasks
    - The scheduling of an almost-ready task will feedback to file system
    - File system will prefetech intermediate results to target node

5. Preliminary Results

To demonstrate the benefits of the proposed system, we conduct a preliminary evaluation:

- Use a synthetic Swift workflow. Each task is manually controlled to spend a certain time and generate outputs.
- Check performance under three cases: 1) default scheduler; 2) plus priority; 3) plus locality.



6. Summary & Future Work

- **Summary**
  - We identify the challenges of exploiting data locality in scientific workflow systems even with a compute-node side file system.
  - We propose a cross-layer solution to tackle these challenges.
- **Future Work**
  - Full system implementation
  - Extend this cross-layer idea into task level
  - More detailed performance analysis

References

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[2] Wozniak, J. M., Wilde, M., and Foster, I. T. Language Features for Scalable Distributed-Memory Dataflow Computing. In *Data-Flow Execution Models for Extreme Scale Computing (DFM), 2014 Fourth Workshop on* (2014), IEEE, pp. 50–53.

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