AnalyzeThis: An Analysis Workflow-Aware Storage System

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Motivation

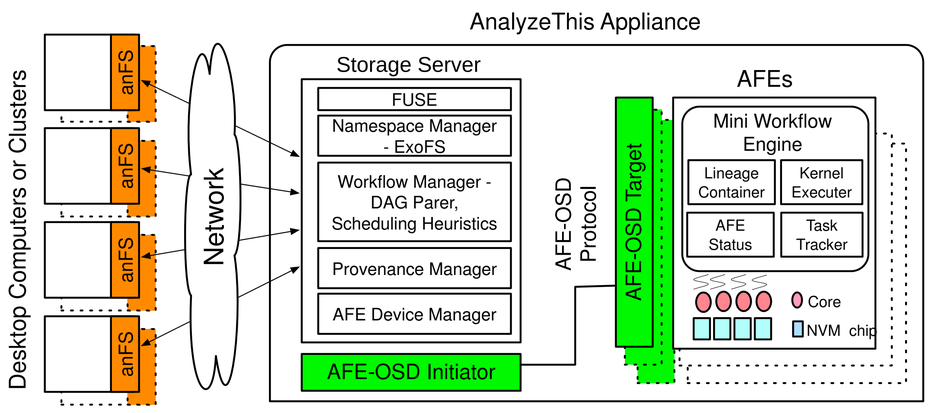
- *Storage Wall* on large-scale systems
  - Titan: 27 PFLOPs and 1 TB/s on 18,688 nodes, 56 MB/s per a node
  - Raw simulation data is read repeatedely for multiple analysis jobs
- Enabling trend, *Active Flash*
  - Running computations using SSD controllers
  - Oasis (MSST'11), iSSD (ICS'13), Active Flash (MSST'12, FAST'13)

AnalyzeThis: Goals

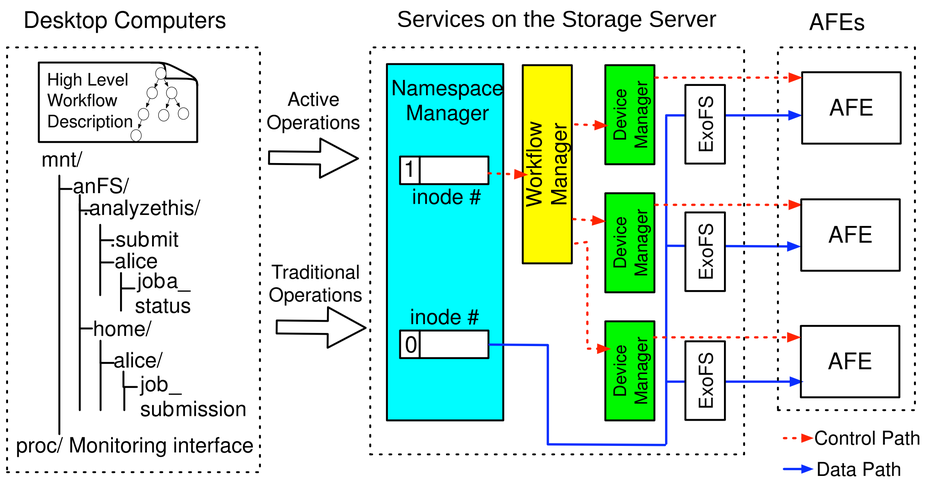
- Analysis awareness: introduce analysis-aware semantics into the storage system, where data already resides
- Reduce data movement: minimize inter- and intra-data movement
- Capture lineage: track provenance and intermediate data products for future references
- Easy-to-use file system interface: provide easy-to-use and familiar interface for submitting and monitoring jobs

AnalyzeThis: Design and Implementation

- Analysis data object abstraction: integrally tie together the dataset, analysis sequence and lineage
  - Powerful construct that is much more than just a pointer to a byte stream
  - Realized using SCSI T10 OSD2 standard
  - Analysis object overlaid on Active Flash refers to an Active Flash Element (AFE)
- Integrate workflow scheduling into the storage system
  - Mimic how user interacts with batch computing systems and integrate similar semantics into the storage system
  - Scheduling heuristics across AFEs: RR (Round Robin), IL (Input Locality), MW (Minimum wait), and HY (hybrid)
- `anFS` file system interface
  - A FUSE filesystem atop an array of AFEs
  - `/proc`-like virutal interface for users to submit and track jobs
- AFEs and `anFS` together track provenance

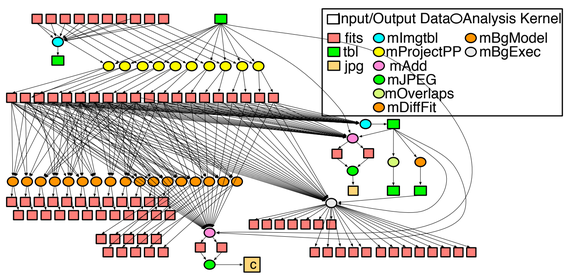


(a) *AnalyzeThis* Architecture

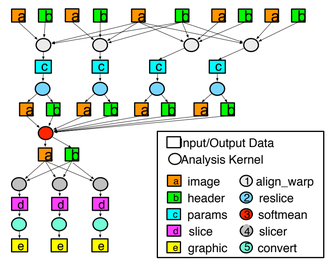


(b) anFS Architecture and Data and Control Paths

AnalyzeThis: Usage



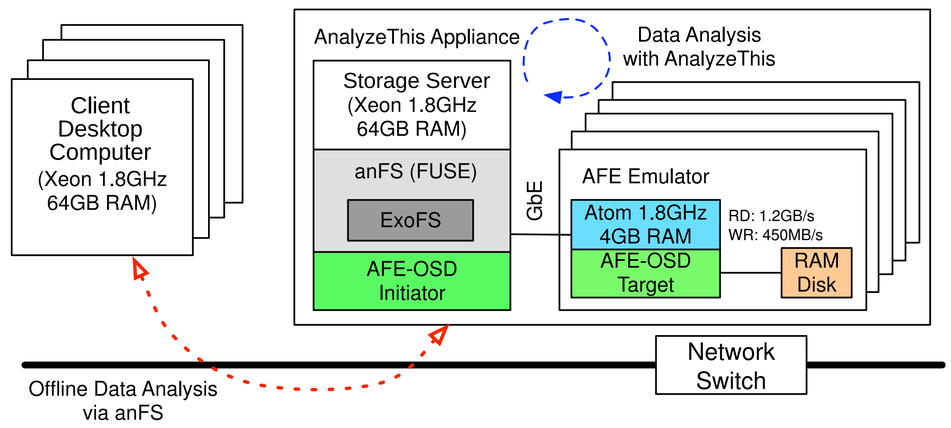
(a) Montage Workflow



(b) Brain Atlas Workflow

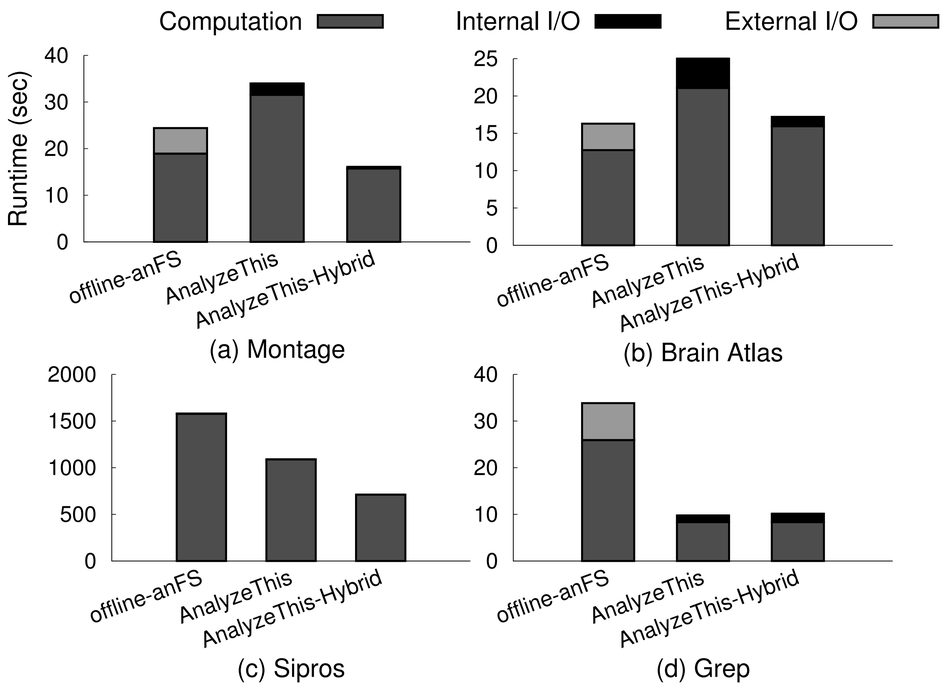
```
$ echo /mnt/anFS/me/job1 > /mnt/anFS/.analyzethis/.submit
$ cat /mnt/anFS/.analyzethis/me/job1/status ...
```

Experimental Setup



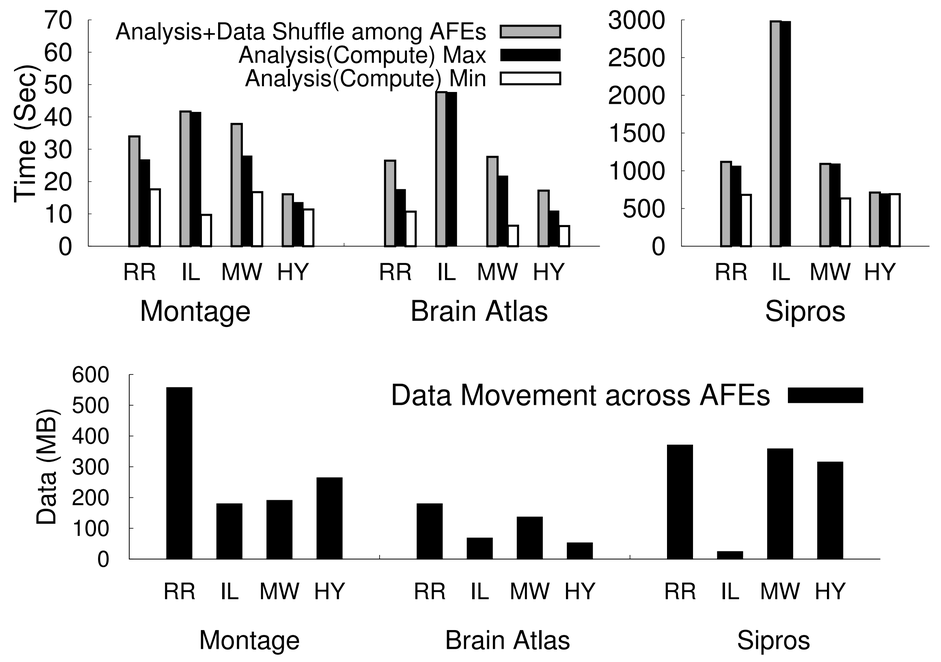
- AFEs are emulated with Atom-based machines
- Scientific workflows: Montage, Brain Atlas, Sipros, and Grep

Results: AnalyzeThis Performance



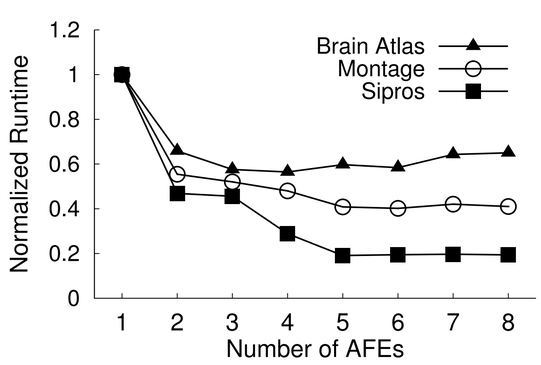
- AnalyzeThis effectively reduces the external data movement
- AnalyzeThis excels for jobs with high parallelism and data intensity

Results: Scheduling Heuristics



- MW/HY perform best reconciling AFE utilization and data movement cost

Results: AFE Scaling



- Different speedup curves with the increase in AFEs
  - Degree of parallelism in a workflow
  - Data dependencies among tasks
  - Input and output data size of each task

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