Robust Storage Management in the Machine Room and Beyond

Presented by

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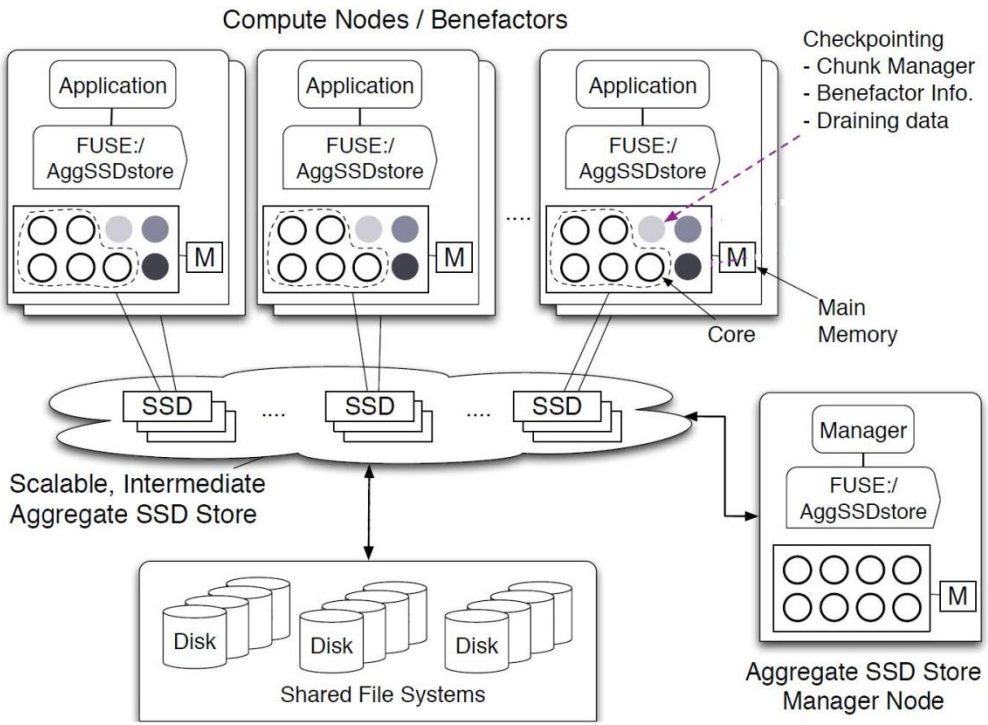
Problem space: HPC storage crisis

- Data checkpointing, staging, and offloading are all affected by data unavailability and I/O bandwidth bottleneck issues
  - Checkpointing terabytes of data to a traditional file system results in an I/O bottleneck
  - Compute time wasted on staging at the beginning of the job
  - Early staging and late offloading waste scratch space
  - Delayed offloading renders result data vulnerable to purging
  - Upshot
    - Increased turnaround time, checkpoint bottleneck
    - Increased job wait times due to staging/offloading and storage delays/errors
    - Poor end-user data delivery options

Stdchk: An aggregate SSD/memory-based checkpoint storage system

- Aggregates storage space from compute node-local SSD/memory to present a collective, intermediate checkpoint storage or a staging ground
  - Job's own allocated nodes can contribute storage space
- Transparent FS interface to the storage using FUSE (e.g., /AggregateSSDstore)
- Benefactor process contributes SSD space or memory buffers to a manager
- Manager maintains metadata on benefactor status, contributions and chunk to benefactor mapping



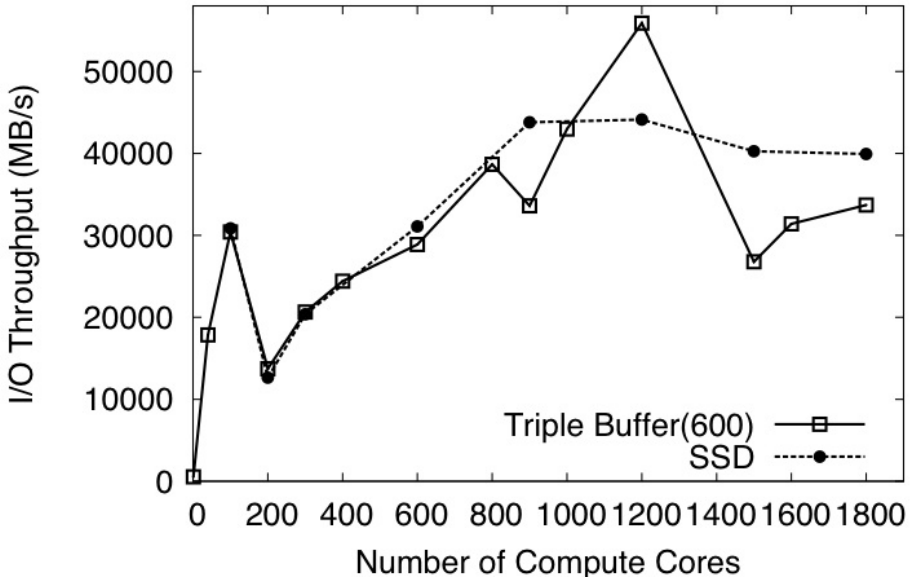
- Application writes to the mount point translated into striping of chunks across a stripe width of benefactors
  - Parallel I/O across distributed SSD or memory

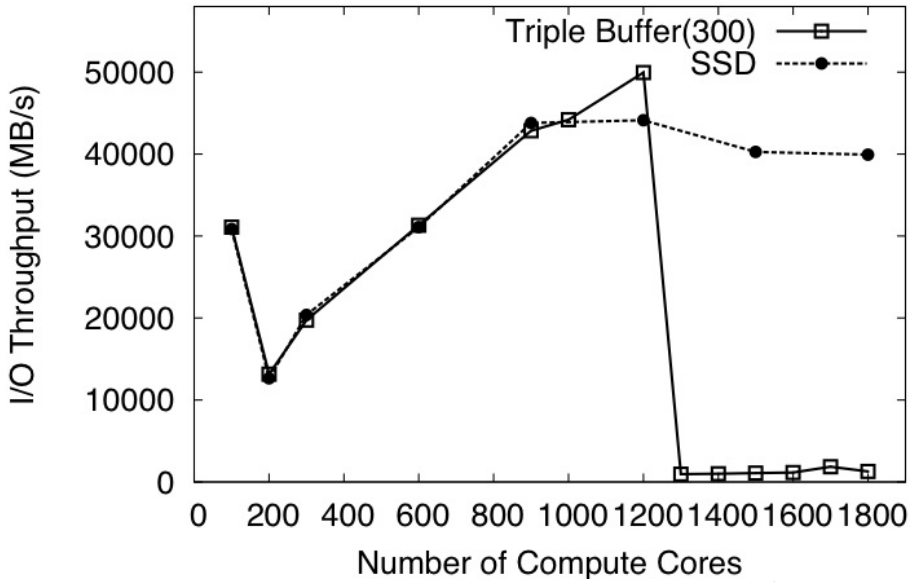
Stdchk (cont'd)

- Features
  - Draining of checkpoint images to a parallel file system
  - Striping policies factor in SSD locality (i.e., preference to node-local SSD)
  - Incremental checkpointing and pruning of checkpoint files
    - Compare chunk hashes from two successive intervals
    - Initial experiments suggest a 10–25% reduction in size for BLCR checkpoints
    - Purge images from previous interval once the current image is safely stored
    - File system is unable to perform such optimizations
  - A multitiered storage of aggregate memory and aggregate SSD layers
  - Applications can also mmap() into the aggregate SSD storage to perform out-of-core computations

Checkpoint throughput

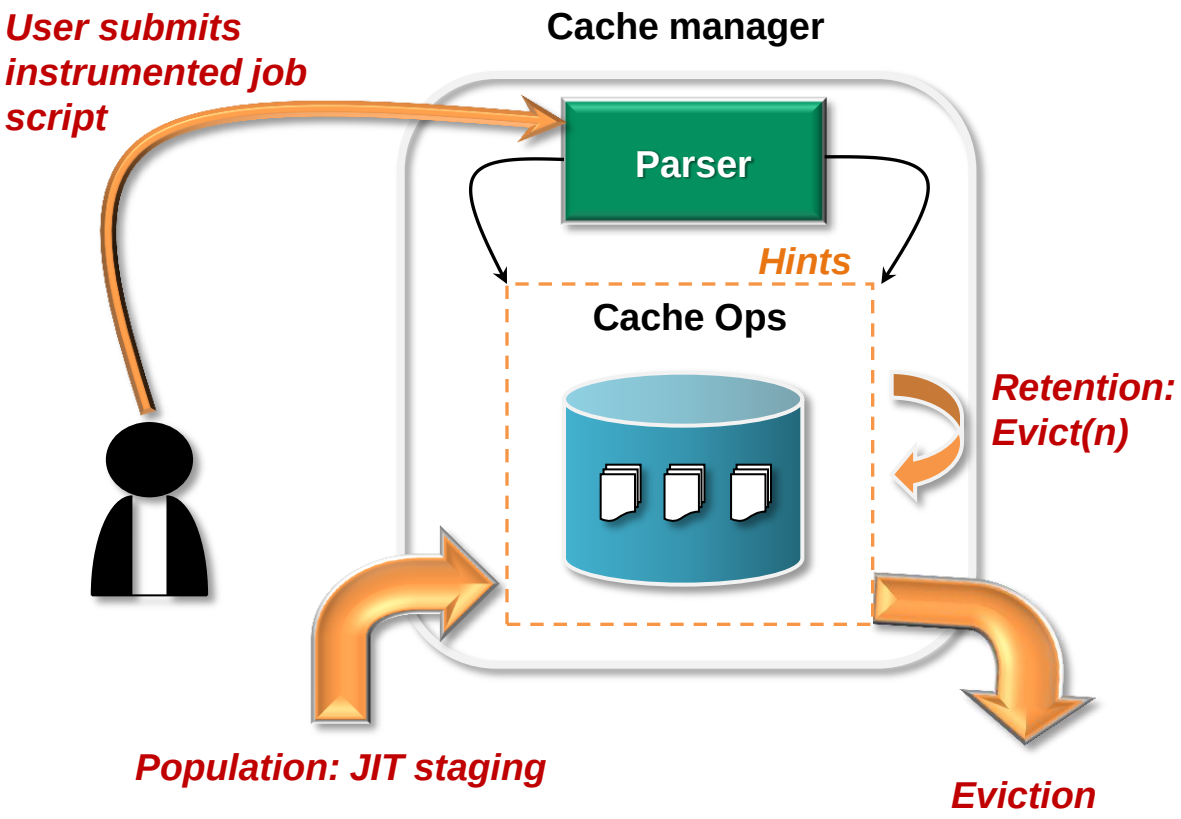
- Results
  - Up to 1800 cores checkpointing 0.25 GB each ~ 0.5 TB overall
  - Aggregate SSD Store
    - 32 GB each
    - Ramdisk SSD emulator ~ 175 MB/s
    - Peak aggregate SSD throughput of 45 GB/s
  - Aggregate Memory Store
    - 600 benefactors with 1 GB each
    - 300 benefactors with 1 GB shows the effect of draining to PFS
    - Peak aggregate memory throughput of 56 GB/s





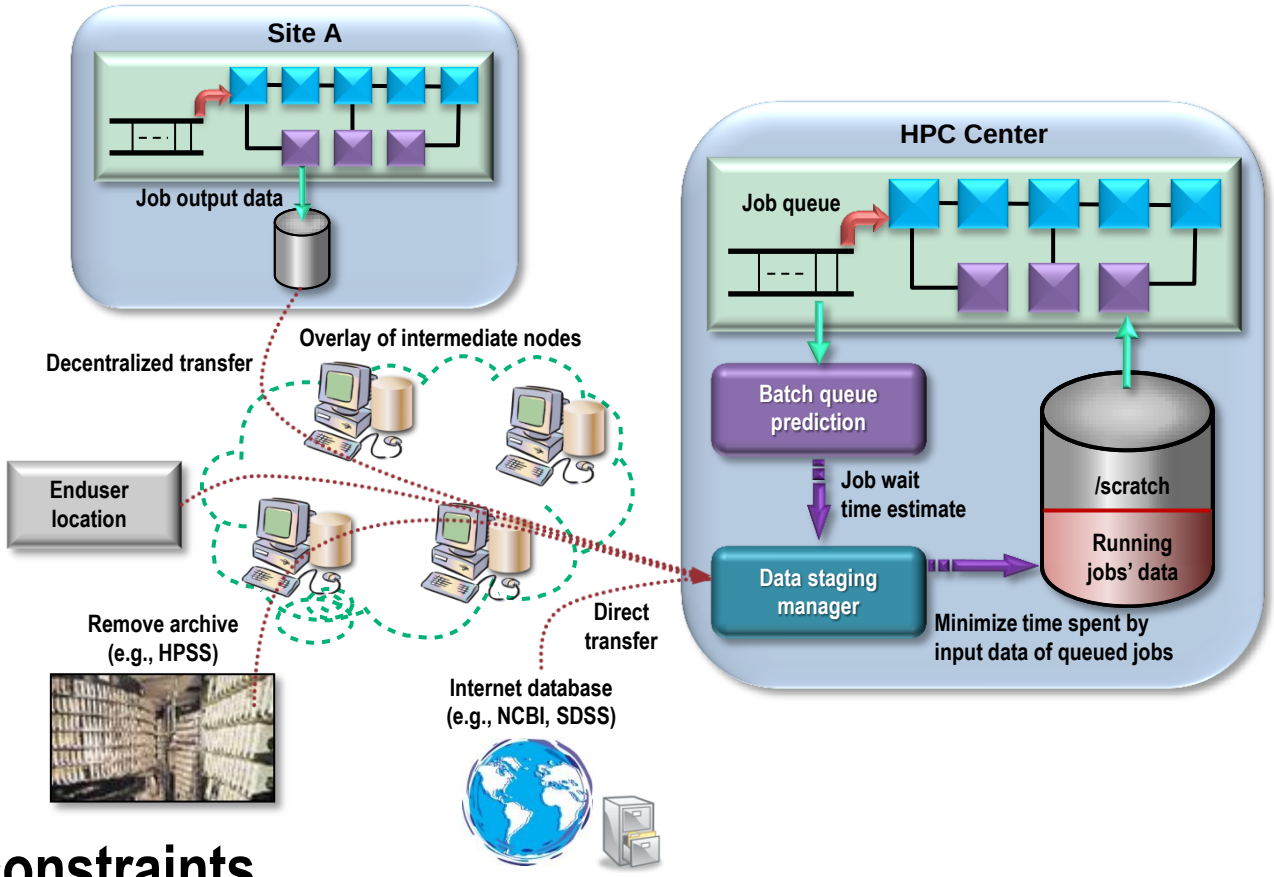
Scratch as cache

- Globally manage the scratch cache
- Data movement is performed using cache population and eviction tools
- Users cannot arbitrarily move data
- Input and output data are not retained beyond the lifetime of the application run



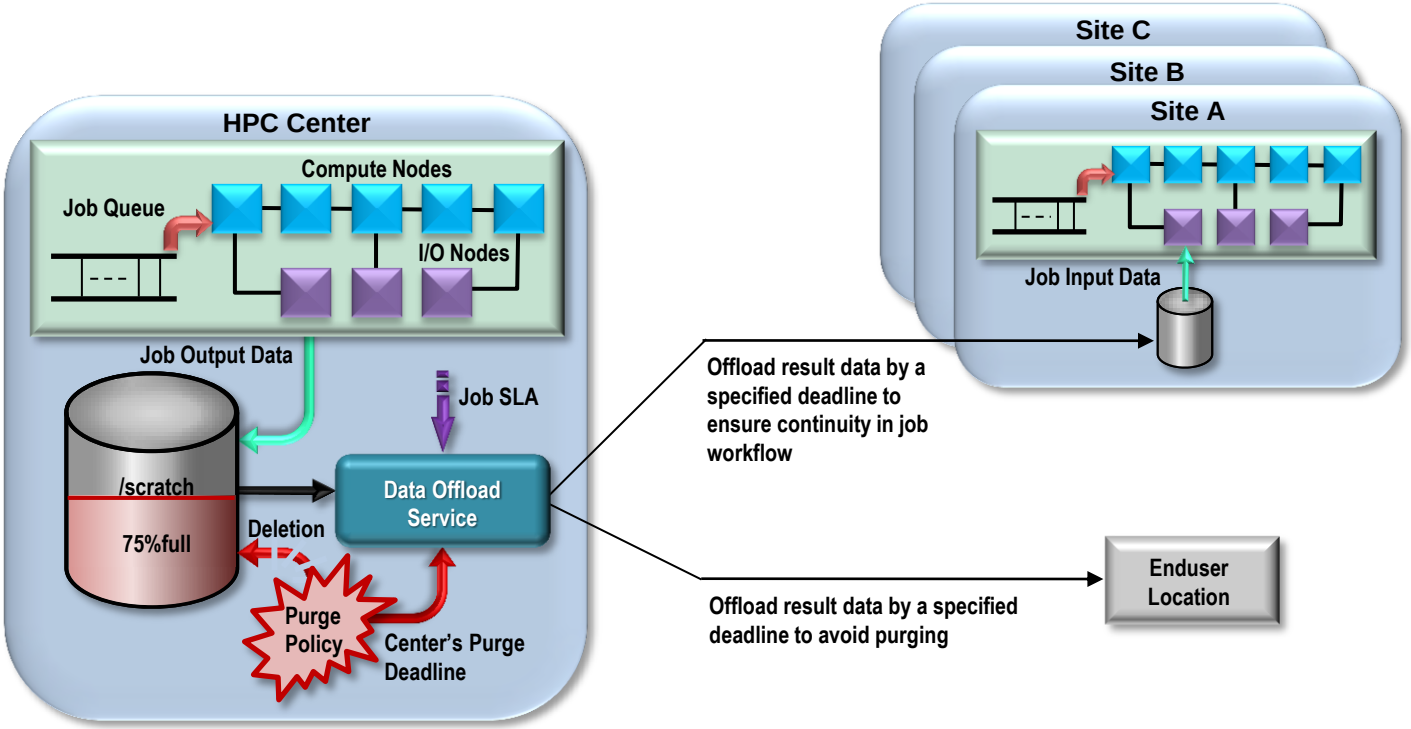
Addresses many of the problems of disjoint management!

Just In Time (JIT) staging



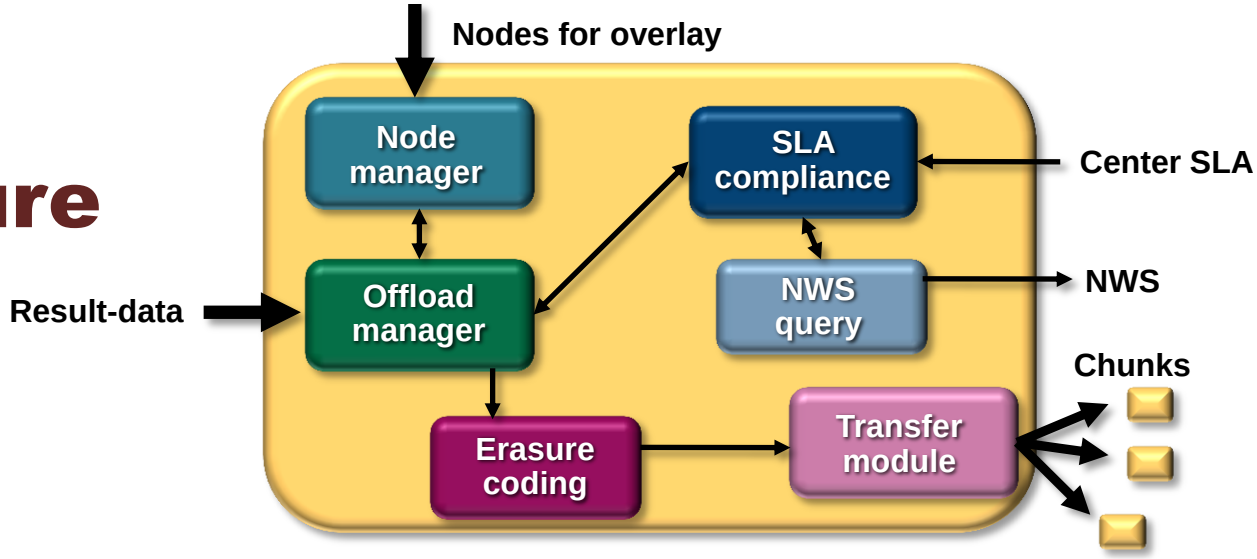
- **Staging constraints**
  - $Max(T_j) \leq T_{JobStartup}$
  - Exposure window of each input dataset, $E_{wj} = T_{JobStartup} - Max(T_j)$; $E_w = Sum(E_{wj})$
  - The closer E_w is to 0, the better

Eager offloading of result data

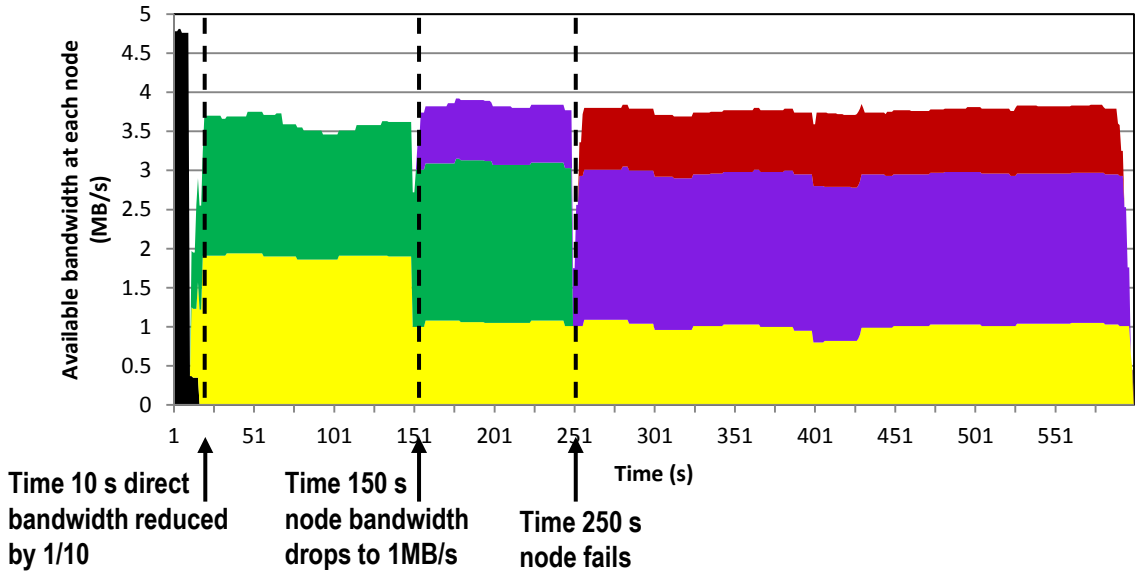


- **Eager offloading features:**
  - Reconcile offload constraint: before center purge and by the user-specified deadline: $T_{offload} < Min(D_{purge}, J_{SLA})$
  - Use replication and erasure coding of chunks for redundancy
  - Integration with PBS, NWS, and Bittorrent

Eager offloading architecture



Results: Adapting to dynamic network behavior



A staged offload is capable of adapting to bandwidth changes or failures

SLA is 600 seconds

Transferring 2.1 GB file

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