Resilient Data Staging Through MxN Distributed Transactions

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Motivation

- Data staging techniques provide no guarantees about the data movement
- NoSQL-style eventual consistency not applicable for interactive online workflows
- Large number of resources increases potential for faults
- Database-style ACID transactions have not been applied to an MxN environment

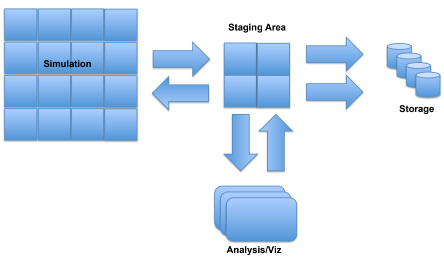

Fig. 1: Example Staging Area

Challenges

- HPC environments have unique characteristics
  - Operate at extreme scales
  - Extremely large data volumes
- Data staging systems hold data in volatile memory
  - Any crashes can lead to permanent loss of data
  - High performance requirements limit ability to delay computation to ensure correctness and completeness of our I/O operations.
- Online workflows require data guarantees
  - Data movement/processing complete prior to the next phase starting
  - Only correct (non-corrupted) data sets should be visible and processed
  - Data should not be removed from one queue prior to the successful insertion into the next (and the insert/delete done atomically)

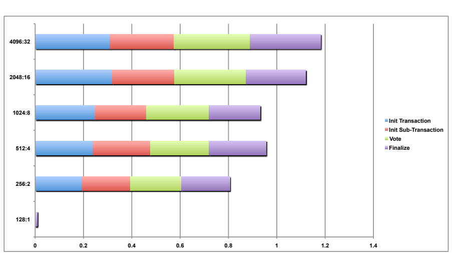

Fig. 3: Preliminary Results

Project Goals

- Bring ACID style guarantees to data staging
  - Atomicity allows us to ensure successful completion of our operations
  - Consistency allows us to ensure our data is up to date
  - Isolation shields operations from interfering with each other
  - Durability ensures that once our operations have completed, they are not lost in the face of system failures

Solution

- Distributed MxN transactions
  - Extend current distributed transaction (1xN) semantics
  - Distributed Transactions with many coordinated clients (M) and many coordinated servers (N)
- Must be scalable
  - Large number of clients and servers leads to high message volumes (MxN)
  - Too much overhead will reduce the gains associated with using data staging

Initial Implementation

- Dual Coordinators
  - Reduces problem to 1 to 1 coordination and thus reduces the volume of messages by avoiding all-to-all communication
  - Improves scalability
  - But, localized bottlenecks that may not scale
- 3 stages in a given transaction
  - **Init Phase:** client side initializes transactions and sub-transactions
  - **Read/Write Phase:** Clients perform read/write
  - **Commit-Request Phase:** Participants decide on success of operations
- Transactions and Sub-Transactions
  - I/O consists of many writes of many variables
  - **Transaction:** Groups operations in one output phase
  - **Sub-transaction:** represents one operation (or variable) in the overall transaction

Benefits

- Atomicity
  - Protocol extends upon traditional 2-Phase commit to operate in MxN environments
  - Provides guarantee that all operations have completed (atomic = all or none)
  - Correctness can be ensured by adding hashes (SHA-1, MD5, etc) to data
  - Applications are shielded from incomplete or erroneous data sets
- Durability, Consistency, Isolation
  - Future work
  - Durability: can be implemented by replicating operations on other nodes. Also possible to investigate an in memory RAID system or local SSD
  - Consistency: eventual consistency models fall short for HPC, as re-processing stale data yields no scientific insight.
  - Isolation: must ensure operations do not interfere with each other. Especially important as shared staging becomes more prominent

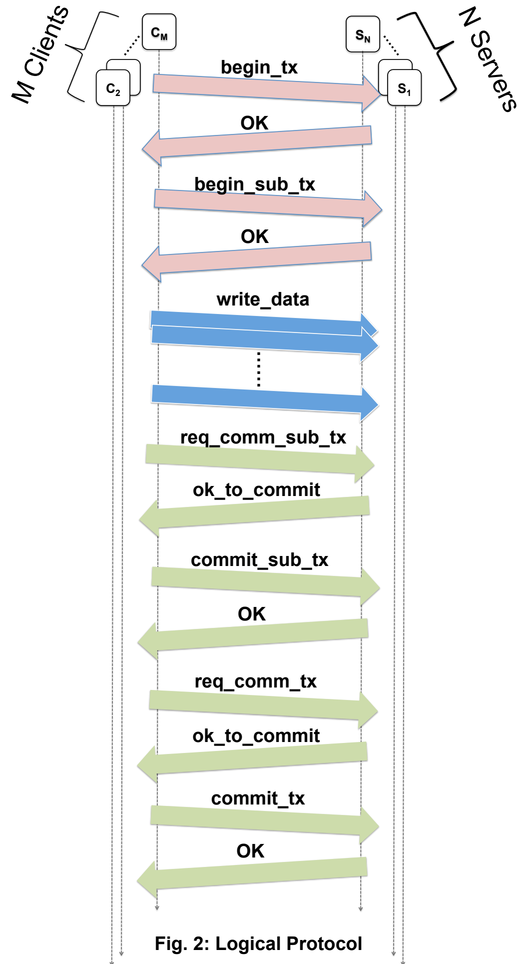

Fig. 2: Logical Protocol

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