Exploring Trade-offs in Transactional Parallel Data Movement

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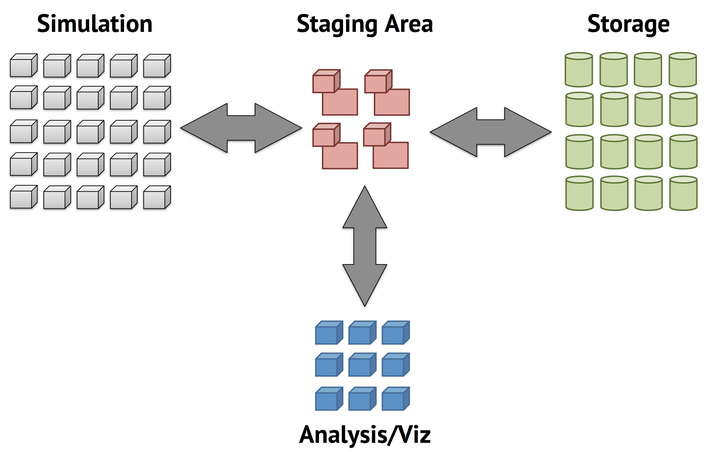
The Road to Exascale

Exascale systems that are slated for the end of this decade will include up to a million compute nodes running about a billion execution threads. In this scenario, traditional methods that ameliorate I/O bottlenecks do not work anymore. *I/O Staging* [1 2] proposes designating of a portion of the nodes to manage I/O.



The Need for Transactions

Transferring a checkpoint or analysis output to the staging area (or from the staging area to long-term storage) is challenging, even at current petaflop scales. Transactions provide a framework in which users can easily reason about data movement across the I/O stack.

The Challenge

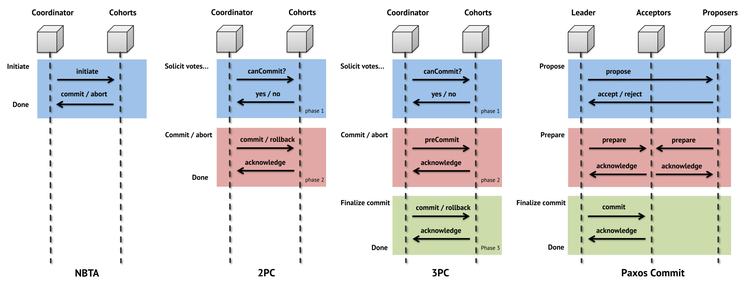
Traditionally, transactional systems assume that requests are initiated from a single client, and that each client's transaction are relatively independent of each other. HPC workloads don't fit these assumptions since all clients work in unison producing simulation output. A user would like to observe atomic and durable transfers across the I/O stack.

I/O stack requirements

In order to solve the multi-client scenario, recent work [3 4] proposes abstracting the storage with basic concurrency control capabilities and thus allow clients to manage isolation semantics. One way this can be achieved is by having storage servers that implement:

1. Multi-versioning concurrency control.
2. Object visibility control.

Consensus Protocols



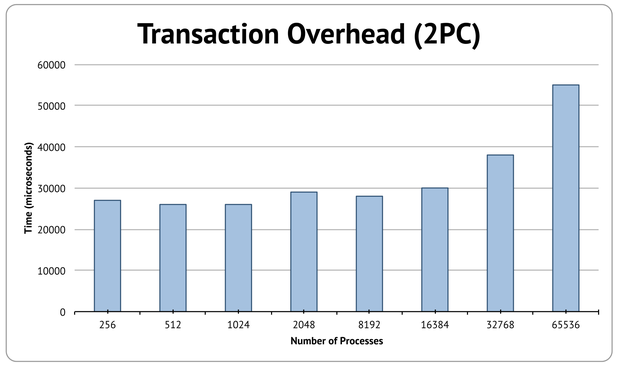
Performance/Usability Aspects

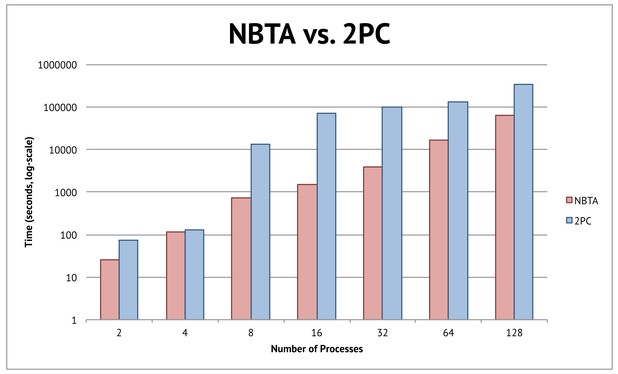
Protocol	Fault Model	Blocking	Async	Replication	Overhead
NBTA	none	Yes	No	No	0
2PC	fail-stop	Yes	No	No	1
3PC	fail-stop	No	No	No	2
Paxos	fail-recover	No	Yes	Yes	3

Table 1. Several consensus protocols and their features. The NBTA protocol is a variation of the *Highly Available Transactions* [5] formalization, providing *Read Committed* isolation guarantees.

Our goal is to explore the trade-offs across the transaction coordination spectrum, identifying precisely where overheads are at and thus provide a toolkit for scientists to allow them to pick the most appropriate alternative for their workloads.

Preliminary Evaluation





Related Work

- The DOE's Fast Forward Storage and I/O project is implementing transactional features into a next-generation stack. The FastForward protocol used to implement transactions is similar to the NBTA protocol referenced here.
- Many proposals for fault-tolerance [6] in HPC make use of consensus protocols to identify faulty processes. Our work is complementary to these efforts.

[1] Liu et al., *On the Role of Burst Buffers in Leadership-class Storage Systems.* MSST '12. http://dx.doi.org/10.1109/MSST.2012.6232369
[2] Lofstead et al., *Adaptable, metadata rich IO methods for portable high performance IO.* IPDPS '09. http://dx.doi.org/10.1109/IPDPS.2009.5161052
[3] Lofstead et al., *D2T: Doubly Distributed Transactions for High Performance and Distributed Computing.* CLUSTER '12. http://dx.doi.org/10.1109/CLUSTER.2012.79
[4] *DOE Extreme-Scale Technology Acceleration. FastForward* https://asc.llnl.gov/fastforward/
[5] Bailis et al. *Highly Available Transactions.* VLDB '14. http://arxiv.org/abs/1302.0309
[6] Stearley et al. *Investigating An API for Resilient Exascale Computing.* Tech Report. http://prod.sandia.gov/techlib/access-control.cgi/2013/133790.pdf.