A Framework for High Performance Simulation of Transactional Data Grid Platforms

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Target: In-Memory Data Platforms

• In the last few years a new generation of in-memory transactional data platforms (NoSQL data grids) has proliferated
  ○ VMware vFabric GemFire
  ○ Oracle Coherence
  ○ Red Hat’s Infinispan
  ○ Apache Cassandra

• They well meet elasticity requirements imposed by the pay-per-use cost model of cloud computing:
  ○ Rely on a simplified key-value data model
  ○ Employ efficient in-memory replication mechanisms to achieve data durability
  ○ Natively offer facilities for dynamically resizing the amount of hosts within the platform
All that glitters isn’t gold!

Deploying a distributed transaction key-value store platform poses a number of performance/reliability/availability issues:

- How many nodes in the platform?
- Which concurrency control algorithm?
- How many replicas of data?
- Which data placement scheme?

and on top of that:

- Given a platform setting, does it also well fit in different scenarios (e.g. when the workload changes)?
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and on top of that:

• Given a platform setting, does it also well fit in different scenarios (e.g. when the workload changes)?

Experience suggests that, e.g., an oversized platform (too many nodes) causes a performance drop (and is more expensive) 😞😞😞
And what about dynamic reconfiguration?

Traditional solutions to dimensioning entail:

• Analytical models
• Machine learning
• Petri nets
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Timely what-if analysis could enable for runtime reconfiguration
Goals

• We propose a solution based on high-performance simulation
• A discrete-event simulation library allows easy development of data grid models to support what-if analysis when varying:
  ○ Number of cache servers
  ○ Degree of replication of data objects
  ○ Placement of data-copies across the platform
• The library natively supports:
  ○ 2PC
  ○ Repeatable read semantics (based on lazy locking)
  ○ Primary data ownership
  ○ Multi-master schemes
• Implementing new strategies is an easy task for the modeler
• The library is run on top of ROOT-Sim
CloudTM

This project has been developed in the context of CloudTM FP-7 Project

http://www.cloudtm.eu

Goal: Self-tuning of In-Memory Data Grids
Simulation Framework

Client

Cache Server

Transaction Manager (TM)

CPU

Concurrency Control (CC)

Distribution Manager (DM)

begin
put
get
commit
begin_return
put_return
get_return
commit_return
abort

remote_get
remote_prepare
abort
commit

next_tx
(for open systems only)

tx_wait
prepare_reply
read_done
commit_done
CPU_complete

Event
Function call

from other cache servers
to other cache servers
- Modeled as a G/M/K queue
- Allows capturing scenarios with multiple cores
- Expected to be adequate wrt more complex models, because core dynamics are associated with logical contention
- Different cpu models can be easily integrated
Distribution Manager

- Keeps track of the data placement on the nodes of the system.
- Tells TM where to direct requests for reading/writing.
- Notifies TM which is the primary owner of a copy of the data object to be accessed.
Transaction Manager

- Acts as a frontend for event processing
- Interacts with the CPU module to compute completion time and update CPU load
- Several events are sent to TM, and trigger specific actions.
Transaction Manager processes these events from clients:

- **begin**: Used to notify that a new transactional interaction has been issued by some client
- **get**: Used to notify that a read operation on some data object has been issued by the client within a transaction
- **put**: Used to notify that a write operation on some data object has been issued by the client within a transaction
- **commit**: Used to indicate that the client ended issuing transactional operations
Concurrency Control

- Invoked by the TM front end
- Depending on the rules of the concurrency algorithm, CC can reply:
  - *continue*: the transaction's execution can proceed
  - *abort*: the transaction must be aborted
  - *wait*: the transaction is temporarily blocked
- The simulation modeler can easily implement other concurrency control algorithms
Concurrency Control: An Example

```plaintext
record TxInfo {
    TxId
} //end record

CC-logic(input: task T, pointer CC-Table) {
    if (CC-table == NULL)
        allocate and initialize [wait-for,active-tx] table;
        // keys are data object identifiers or TxId values
        // entries are lists of TxInfo records or TxId values
        set CC-table point to the allocated table
    case T.type
    prepare:
        link T.TxInfo.TxId to CC-Table.active-tx
        AllPrepareKeys = T.TxWriteSet
        link T.TxInfo to CC-Table.wait-for[AllPrepareKeys]
```
Concurrency Control: An Example (2)

```plaintext
if T.TxInfo not top standing for some key
    generate event TX_WAIT[T.TxInfo]
    generate event TIMEOUT[T.TxInfo]
else generate event PREPARE_DONE[T.TxInfo]

timeout or commit:
    unlink T.TxInfo.TxId from CC-Table.active-tx
    unlink T.TxInfo from CC-Table[AllOccurrences]
    if (T.type == commit) generate COMMIT_DONE[T.TxInfo]
    else generate PREPARE_FAIL[T.TxInfo]
    for all TxInfo top standing in CC-Table[AnyPresenceRow]
        generate event PREPARE_DONE[TxInfo]

return CC-Table
```
The modeler can specify various settings:

- The system model (open vs closed)
- Number of concurrent clients, and threads per client
- Transaction generation rate/trace
- A number of different transaction profiles, and for each one:
  - Number of transactions to be executed
  - type (put vs. get) and operations per transaction
  - data access distribution
  - inter-operation think time
- transaction back-off time (when aborted)
Validation

TPC-C on RedHat Infinispan, deployed on Amazon EC2.

Throughput - 4 Servers

Confidence Interval (95%) for the Estimated Throughput - 4 Servers
Enabling for timely what-if analysis

• 12 seconds to predict the behaviour of a system is too much
• The framework has been deployed on top of ROOT-Sim

• Up to 1024 simulation objects, 1/8 being cache servers.
• Iso-scaling in terms of both model complexity and underlying computing power
• Run on a couple of HP Proliant servers:
  ○ 64-bits NUMA machines
  ○ four 2GHz AMD Opteron 6128 processors and 64GB of RAM
  ○ Each processor has 8 CPU-cores (for a total of 32 CPU-cores)
Enabling for timely what-if analysis (2)
Thanks for your attention

Questions?

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Framework:
https://github.com/cloudtm/cloudtm-autonomic-manager/tree/master/src/dags

ROOT-Sim:
http://www.dis.uniroma1.it/~ROOT-Sim