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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- 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) ☹☹☹

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- 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

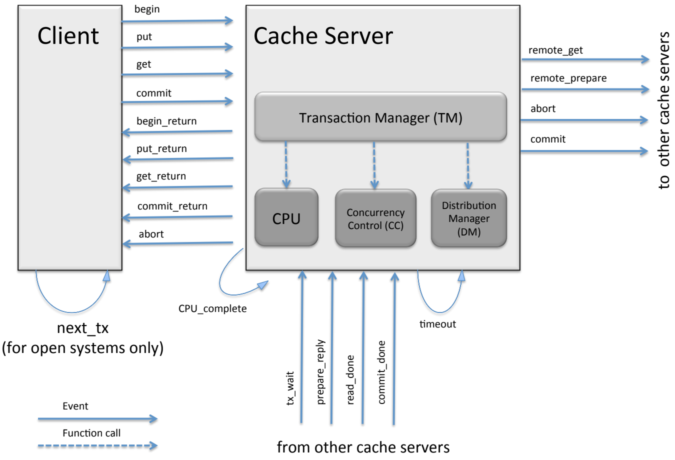
CloudTM

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

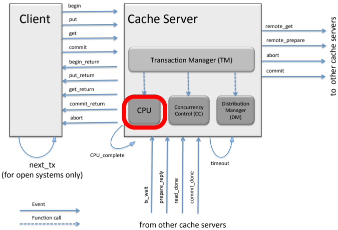
http://www.cloudtm.eu

Goal: Self-tuning of In-Memory Data Grids

Simulation Framework

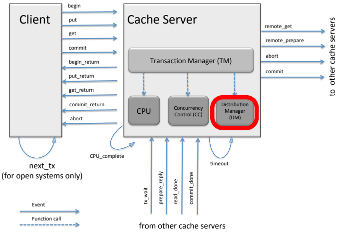


CPU



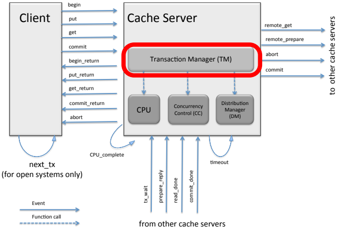
- Modeled as a G/M/K queue
- Allows capturing scenarios with multiple cores
- Expected to be adequate wrt more complex models, because core dynamics are associated with logical contention
- Different cpu models can be easily integrated

Distribution Manager



- Keeps track of the of data placement on the nodes of 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



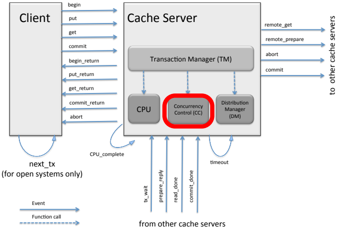
- Acts as a frontend for event processing
- Interacts with the CPU module to compute completion time and update CPU load
- Several events are sent to TM, and trigger specific actions.

Transaction Manager (2)

Transaction Manager processes these events from clients:

- `begin`: Used to nofity that a new transactional interaction has been issued by some client
- `get`: Used to nofity 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

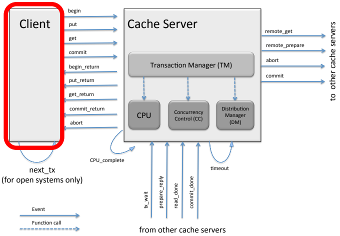
Concurrency Control: An Example

```
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)

```
        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
} //end CC
```

Client

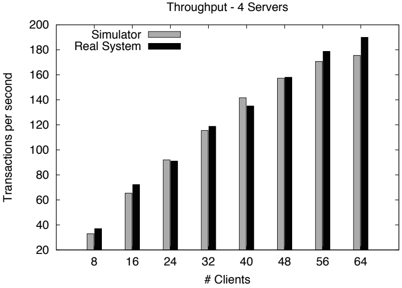


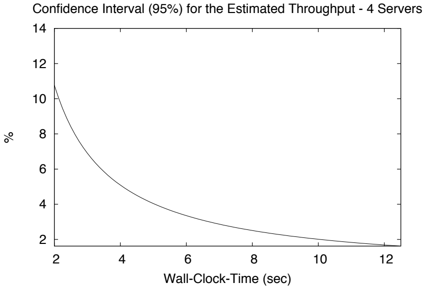
The modeler can specify various settings:

- 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.



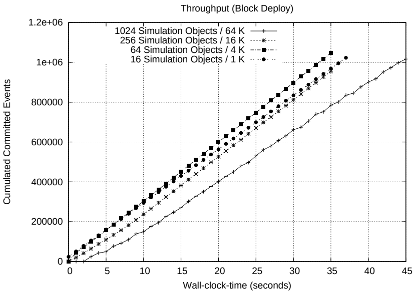


Enabling for timely what-if analysis

- 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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Research Group:

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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