Towards a Fully-Articulated Pessimistic Distributed Transactional Memory

Brief Announcement

Konrad Siek and Paweł T. Wojciechowski
Poznań University of Technology
{konrad.siek,pawel.t.wojciechowski}@cs.put.edu.pl

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Distributed Systems Group

http://dsg.cs.put.poznan.pl

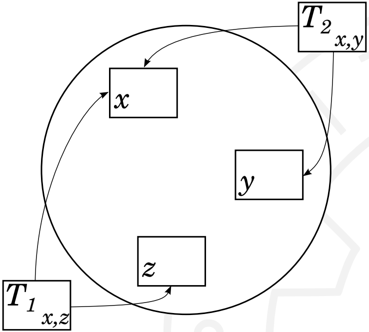
Optimistic Approach

Run simultaneously in case there are no conflicts

In case of conflicts, rollback and retry

$$
\begin{aligned}
\{x = 1\} \quad & T_1 \left[\ r(x)1, w(x)2\ \right] \\
& \mid T_2 \left[\ r(x)1, w(x)2 \circlearrowleft \ldots T_2' \left[\ r(x)2, w(x)3\ \right] \quad \{x = 3\} \right.
\end{aligned}
$$

Distributed TM



Distributed Transactions

The Problem of Irrevocable Operations

Irrevocable operations $T_i[\ ..., {\color{red}ir}, ...\ ]$

- do not operate on shared data
- visible effects on the system
- effect cannot be withdrawn (barring compensation)

Examples: network messages, system calls, I/O operations

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$$\{x = 1\}\ T_1\ [\ r(x)1, w(x)2\ ]$$
$$\mid T_2\ [\ r(x)1, \textcolor{red}{ir}, w(x)2 \circlearrowleft \ldots T_2'\ [\ r(x)2, \textcolor{red}{ir}, w(x)3\ ]\ \{x = 3\}$$

The Problem of Irrevocable Operations

Some workarounds

- forbid irrevocable operations
- buffer irrevocable operations and execute them on commit
- run irrevocable transactions one-at-a-time
- multiple versions of objects

Pessimistic Approach

Defer execution to prevent conflicts

$$\{x = 1\} \quad T_1 \; \Big[\; r(x)1, w(x)2 \; \Big]$$

$$\quad | \; T_2 \; \Big[\qquad\qquad\qquad r(x)2, w(x)3 \; \Big] \quad \{x = 3\}$$

Pessimistic Approach

Defer execution to prevent conflicts

$$\{x = 1\} \quad T_1 \left[\ r(x)1, w(x)2\ \right]$$

$$\searrow$$

$$|\ T_2 \left[\ \qquad\qquad\qquad r(x)2, w(x)3\ \right] \quad \{x = 3\}$$

No rollbacks/aborts, irrevocable operations are not re-run

$$\{x = 1\} \quad T_1 \left[\ r(x)1, w(x)2\ \right]$$

$$\searrow$$

$$|\ T_2 \left[\ \qquad\qquad\qquad r(x)2, {\color{red} ir}, w(x)3\ \right] \quad \{x = 3\}$$

Rollbacks

Rollback is still needed for

- expressiveness
- efficiency (i.e. limiting network traffic)
- necessary for fault tolerance

Supremum Versioning Algorithm

Transactions know which objects they use and how many times (suprema)

start:

lock all used objects
assign object's next version to transaction
release locks

access x:

wait until x is released by transaction with the previous version of x
access x
if last use of x: release x

commit:

release all objects

SVA Characteristics

Early release on last use

$$\{x = 1, y = 1\} \quad T_1 \; [\; r(x)1, w(x)2, r(y)1, w(y)2 \;]$$

$$| \; T_2 \; [\qquad\qquad r(x)2, w(x)3 \;] \quad \{x = 3, y = 2\}$$

No aborts, no issues with irrevocable operations

SVA + Rollback

start:

lock all used objects
assign object's next version to transaction
release locks

access x:

wait until x is released by transaction with the previous version of x
if first use of x: make copy of x
access x
if last use of x: release x

commit:

wait until transaction with the previous version of x commits
if previous transaction rolls back: also roll back
release all objects

rollback:

wait until transaction with the previous version of x commits
restore all objects from copies and release them

SVA+R Characteristics

Cascading rollback

$$\{x = 1, y = 1\}\ T_1\ [\ r(x)1, w(x)2, r(y)1, w(y)2,\ \text{abort}$$

$$|\ T_2\ [\qquad r(x)2, w(x)3 \qquad \circlearrowleft \ldots$$

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Cascading rollback with irrevocable operations

$\{x = 1, y = 1\}\ T_1\ [\ r(x)1, w(x)2, r(y)1, w(y)2,\ \text{abort}$

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Fixing Cascading Rollback in SVA+R

Cascading rollback conditions in SVA:

- There are two or more transactions that access some object x
- The first of those transactions releases x early
- Some younger transaction accesses x
- The first transaction aborts

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Cascading rollback conditions in SVA:

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Transactions containing irrevocable operations cannot access objects that were released early (by transactions which may abort)

$$T_1 \ [\ r(x)1, w(x)2, r(y)1, w(y)2, \ \text{abort}$$

$$|\ T_2 \ [\ \qquad\qquad\qquad\qquad\qquad\qquad r(x)2, ir, w(x)2\ ]$$

Properties

- **Opacity** (Safety)

  There is some equivalent sequential history that preserves the real-time order of the transactional history and every transaction in the transactional history is legal in the sequential history.

  - Real-time order from version order
  - Legality from exclusive access to committed objects

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- **Strong Progressiveness** (Liveness)

  When two transactions conflict on some object, one of them will not be forced to abort.

  - Impossibile for all transactions to roll back due to cascading rollback conditions and version order

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- **Strong Progressiveness** (Liveness)

  When two transactions conflict on some object, one of them will not be forced to abort.

  - Impossibile for all transactions to roll back due to cascading rollback conditions and version order
- *Deadlock-freedom*
- Probably not *Livelock-freedom*
- Probably susceptible to *Parasitic Transactions*

Conclusions

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- Irrevocable operations and Pessimistic TMs
- Incorporating Rollback into Pessimistic Distributed TM
- Safety and Progress

Related Papers:

Konrad Siek, Paweł T. Wojciechowski. *Brief Announcement: Towards a Fully-Articulated Pessimistic Distributed Transactional Memory*. In Proceedings of SPAA 2013: the 25th ACM Symposium on Parallelism in Algorithms and Architectures. July 2013.

Paweł T. Wojciechowski, Olivier Rütti and André Schiper. *SAMOA: A Framework for a Synchronisation-Augmented Microprotocol Approach.* In the Proceedings of IPDPS 2004: the 18th IEEE Parallel and Distributed Processing Symposium. April 2004.

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