Towards a Fully-articulated Pessimistic Distributed Transacitonal Memory

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Software Transactional Memory

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def thread:
    lock_a.acquire()
    lock_b.acquire()
    a = b
    lock_a.release()
    b = b + 1
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Advantages:

- ease of use on top
- efficient concurrency control under the hood

Transaction Abstraction

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T_i [op_1, op_2, ..., op_n]

where $op = \{\ r(x)v,\ w(x)v,\ ...\ \}$

and x is some shared object

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Commitment:

$$\{x = 1\} \quad T_i \; [\; w(x)2 \;] \quad \{x = 2\}$$

Rollback:

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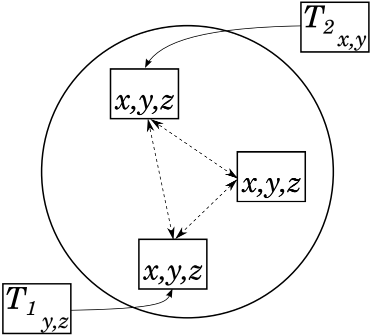
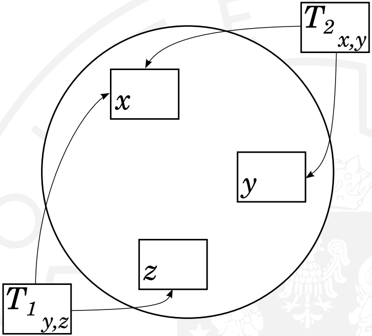
$$\{x = 1\} \quad T_i \; [\; w(x)2,\; \text{retry} \quad \rightarrow \quad T_i' \; [\; w(x)2 \;] \quad \{x = 2\}$$

Distributed TM



Replicated TM



Distributed TM

Optimistic Approach

Run simultaneously in case there are no conflicts

$$\{x = 1\} \quad T_1 \left[\ r(x)1, w(x)2\ \right] \ \middle|\ T_2 \left[\ r(x)2, w(x)3\ \right] \quad \{x = 3\}$$

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Conflict: two or more transactions access x and at least one of them writes to x.

The Problem of Irrevocable Operations

Irrevocable operations $T_i[\ ..., ir, ...\ ]$

- 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- effect cannot be withdrawn (barring compensation)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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Workarounds

- forbid irrevocable operations

  Haskell

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- multiple versions of objects

  H. Attiya and E. Hillel
  Single-version STMs can be multi-version permissive
  ICDCD'11

Pessimistic Approach

Defer execution to prevent conflicts

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

$$\searrow$$

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Rollbacks are not forced, irrevocable operations are not re-run

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There are pros and cons to both approaches:

- high/low contention
- predictability of read sets and write sets

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Rollback is still needed for

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```
def thread:
    transaction.start()
    flight.reserved = MY_ID

    if not hotel.reserved:
        hotel.reserved = MY_ID
        transaction.commit()
    else:
        transaction.rollback()
```

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```

```
def thread:
    transaction.start()
    flight_copy = copy(flight)
    flight.reserved = MY_ID

    if not hotel.reserved:
        hotel.reserved = MY_ID
        transaction.commit()
    else:
        flight = copy(flight_copy)
        del flight_copy
        transaction.commit()
```

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```

- necessary for fault tolerance

Rollback and Pessimistic TM

Balancing correctness and rollback capability

- programmer-induced rollback
- never abort transactions with irrevocable operations

Maintaining efficiency and distribution

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

Transactions only block objects they use

$$\{x=1, y=1\} \quad T_1 \, \left[\ w(x)2\ \right] \,\Big|\, T_2 \, \left[\ w(y)2\ \right] \quad \{x=2, y=2\}$$

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Exclusive access (in order of versions)

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Early release on last use

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

$$\searrow$$

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No rollbacks, 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

Wait for commit of previous transactions

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

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

SVA+R Characteristics

Wait for commit of previous transactions

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Cascading rollback

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

$$\mid T_2\ \big[\ \searrow r(x)2, w(x)3\ \searrow \text{retry} \to \ldots$$

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Cascading rollback with irrevocable operations

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

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

$$\searrow$$

$$|\; T_2 \; [\; r(x)1, ir, w(x)2 \;]$$

Properties

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  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.

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- *Deadlock-freedom*
- Probably not *Livelock-freedom*
- Probably susceptible to *Parasitic Transactions*

?