No False Negatives: Accepting All Useful Schedules in a Fast Serializable Many-Core System

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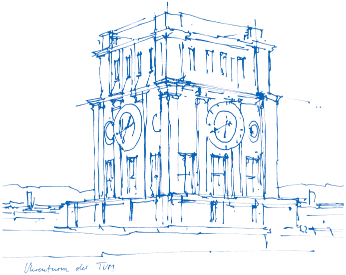
Technische Universität München



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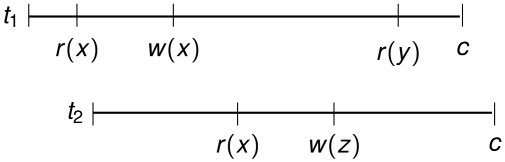

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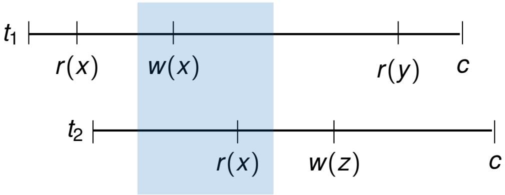

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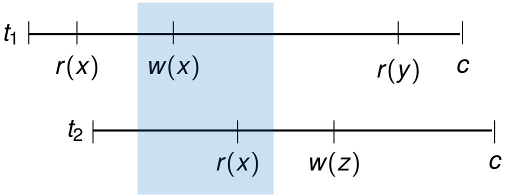
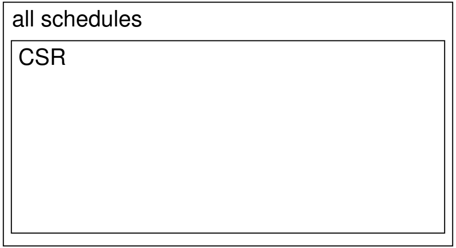


- Only Serialization Graph Testing (SGT) accepts all valid schedules
- SGT seems to be too expensive and not scalable

Motivation: Desired Schedules

- Conflict graphs allow to accept all conflict serializable schedules



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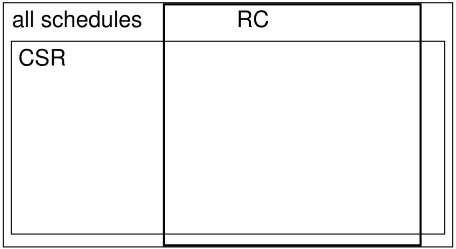

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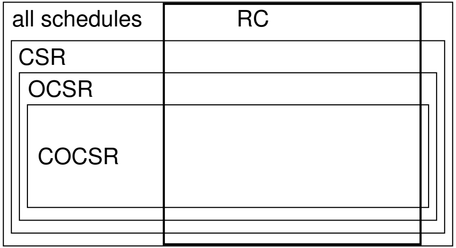

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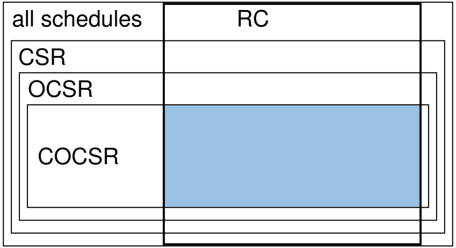
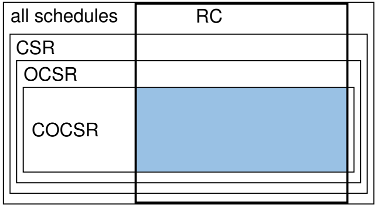


Note that $S2PL \subsetneq COCSR \cap RC$

Contribution

Our approach leverages the conflict graph and

1. accepts all useful $COCSR \cap RC$ schedules
2. meets users' expectations
3. has low overhead for maintaining the graph
4. scales to many-core systems



Serialization Graph Testing (SGT)

- Theorem: $s \in CSR \Leftrightarrow CG(s)$ is acylic
- Update $CG(s)$ at operation arrival and allow if $CG(s)$ is acyclic
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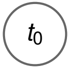

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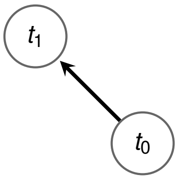

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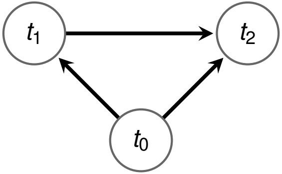

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Example: $s = r_0[x]\ w_0[x]\ r_1[x]\ r_2[x]\ w_2[x]\ w_2[y]\ c_2\ c_0\ c_1$

$$\begin{tikzcd} t_1 \arrow[rr] & & t_2 \\ & t_0 \arrow[ul] \arrow[ur] & \end{tikzcd}$$

$\Rightarrow s \in CSR$

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- SGT has the best theoretical properties of accepting all valid schedules
- However, previous work fails to implement SGT efficiently in practice

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- However, previous work fails to implement SGT efficiently in practice

We developed the first practical and scalable algorithm that leverages
the theoretical superior concept of graph-based serialization testing

Prerequisites for Node Deletions

Pitfall: Deletion of a committed node t_c

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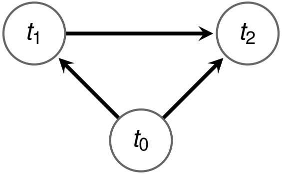

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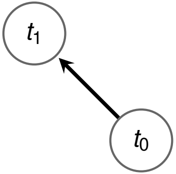

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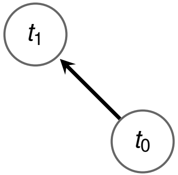

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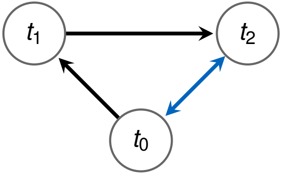

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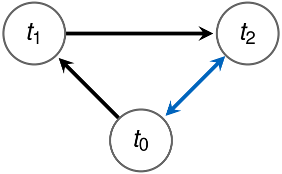

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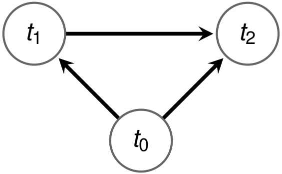
Deletion of committed node is only allowed if all incoming edges are removed

(Log-) Recoverability Constraints

Every transaction commit needs to wait until it is not dependent on in-flight results

Example: $s = r_0[x]\, w_0[x]\, r_1[x]\, r_2[x]\, w_2[x]\, w_2[y]\, c_2\, c_0\, c_1$



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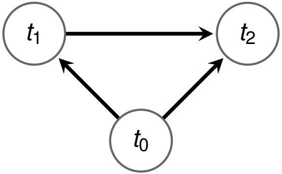

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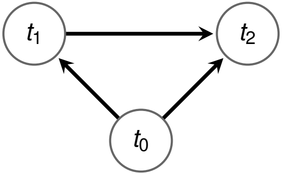

No incoming write-read, write-write edge from an uncommitted node allowed

Preserving the Commit Order

No (uncommitted) incoming edge at commit time to preserve the commit order

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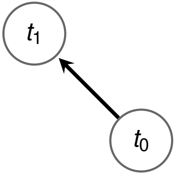

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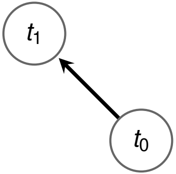

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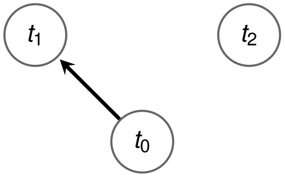

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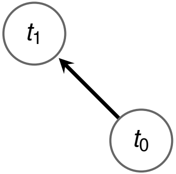

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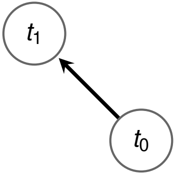

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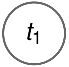

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$s_{orig} = r_0[x]\ w_1[x]\ c_1\ r_2[y]\ c_2\ w_0[y]\ c_0$

with $s' = t_2\ t_0\ t_1$, but $s_{orig} \notin COCSR$

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All useful $COCSR \cap RC$ schedules accepted due to commit delays

Committed nodes are deleted directly including all outgoing edges

Scaling of our SGT-based Approach

- No incoming edges to commit simplifies cycle check
- Conflict graph is accessed concurrently by multiple threads
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Transaction local shared/exclusive locks help to scale the graph

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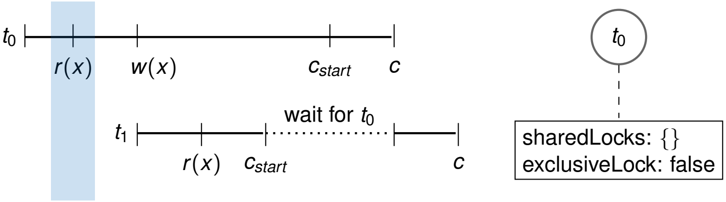

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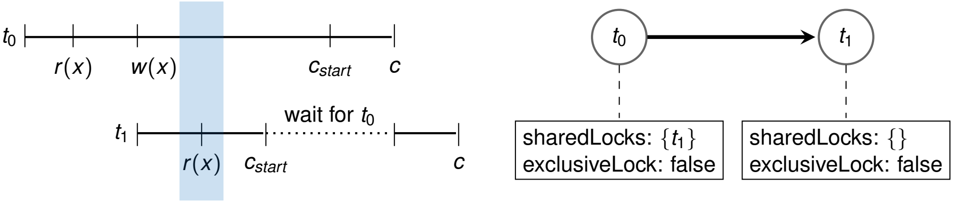

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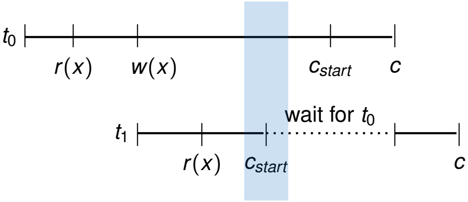

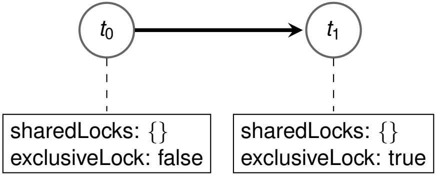

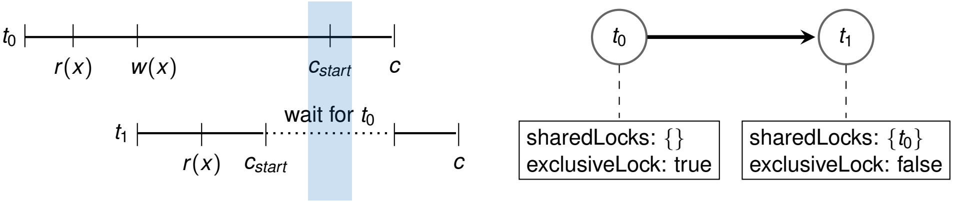
t_0
$r(x)$
$w(x)$
c_{start}
c
wait for t_0
t_1
$r(x)$
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c
t_0
t_1
sharedLocks: $\{\}$
exclusiveLock: true
sharedLocks: $\{t_0\}$
exclusiveLock: false

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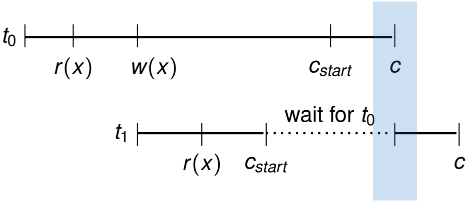
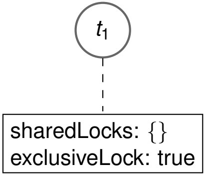




Experimental Evaluation

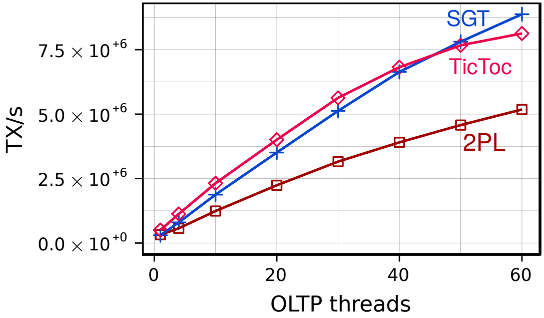
Setup:

- 4-socket Intel Xeon server (60 cores) with 1TB DRAM
- Every transaction is scheduled on one worker thread
- Aborts require undos and restarts of the aborted transactions

Algorithms:

- Our SGT-based approach
- TicToc
- 2PL with row based atomic read-write locks and deadlock prevention

SmallBank Medium Contention (1000 Customers)



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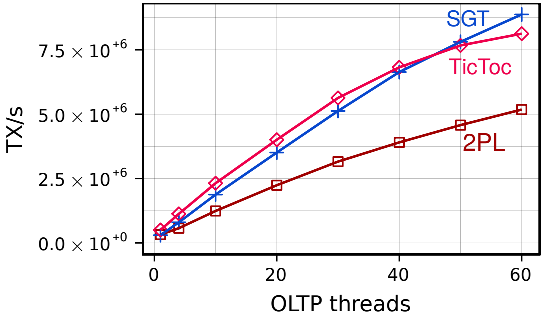
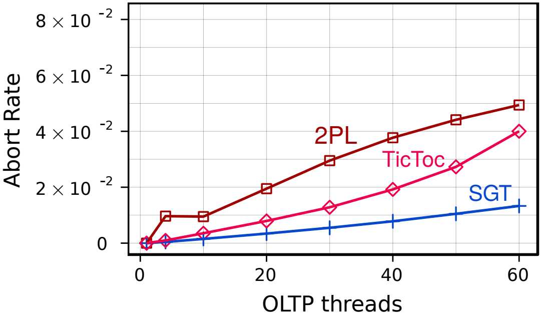
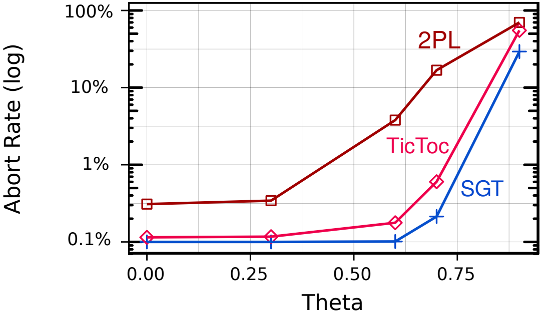




YCSB-A, 50% writes, 16 queries/tx, 60 threads



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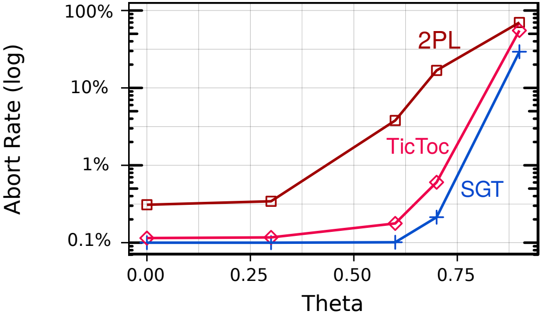
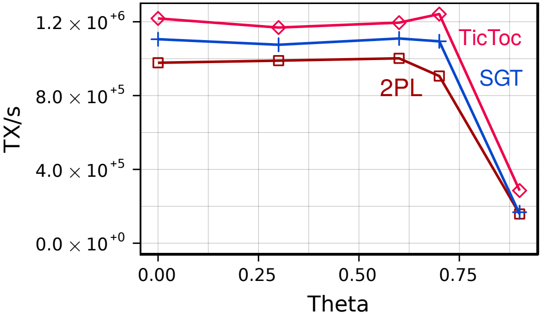
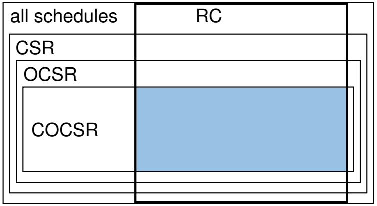




Our SGT has competitive throughput while reducing aborts significantly!

Summary: Our graph-based concurrency control algorithm

accepts all useful
COCSR ∩ *RC* schedules



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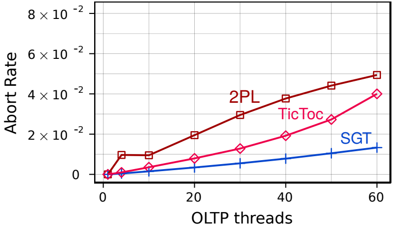

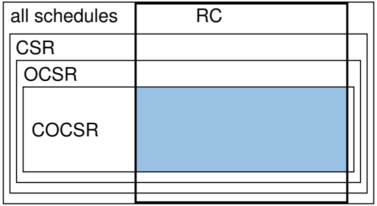

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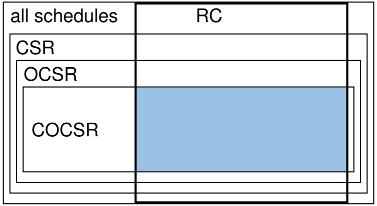

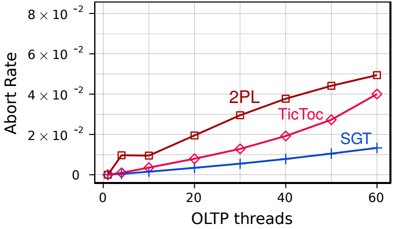

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