Multi-versioning in Main-memory Databases: Limitations and Opportunities

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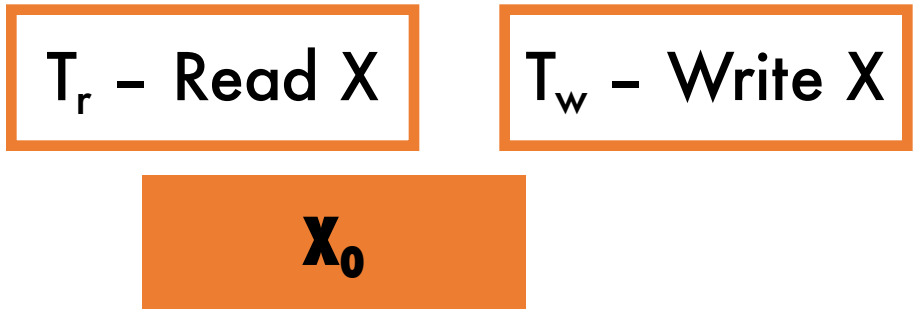
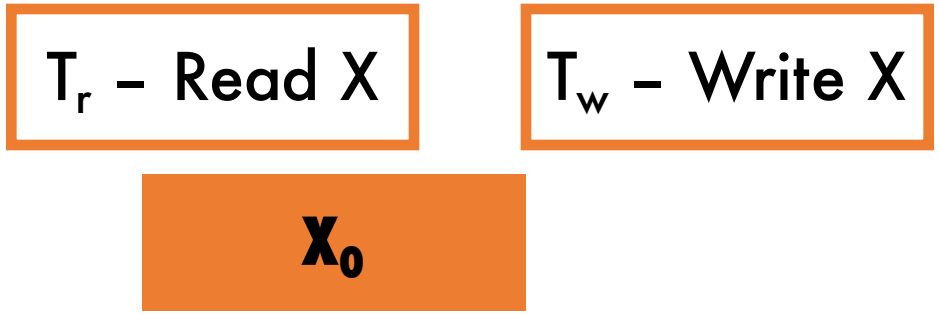
Theory: Single- vs Multi-version Systems

Single-version system

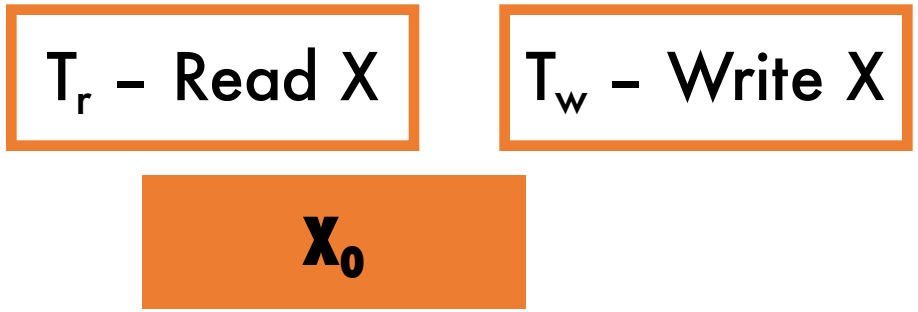


Multi-version system



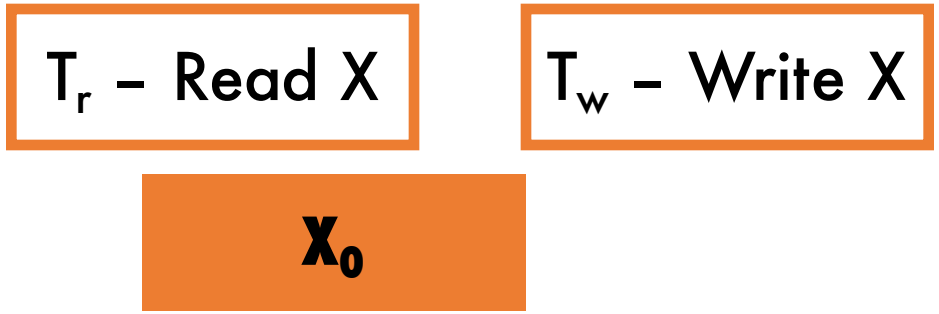
Theory: Single- vs Multi-version Systems

Single-version system



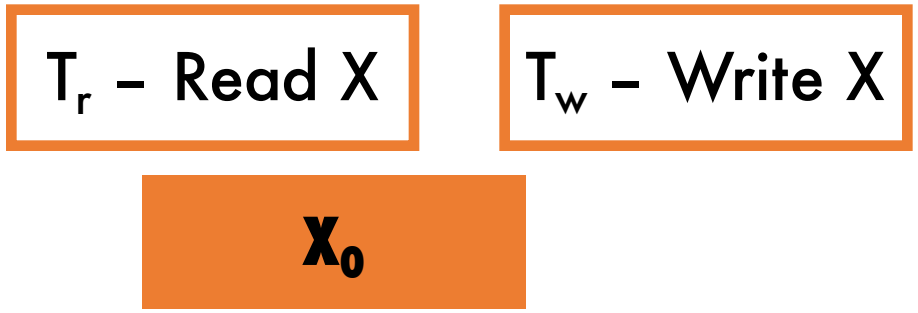
T_r and T_w cannot simultaneously execute

Multi-version system



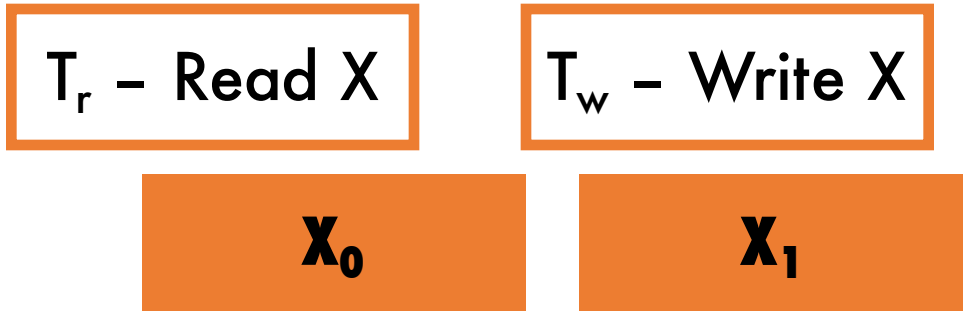
Theory: Single- vs Multi-version Systems

Single-version system



T_r and T_w cannot simultaneously execute

Multi-version system



T_r and T_w can both simultaneously make progress

Theory: Single- vs Multi-version Systems

Multi-versioning obviously buys more concurrency, right?

Practice: Multi-version Systems

T_0:
```
if savings + checking >= 100
      savings -= 100
```

T_1:
```
if savings + checking >= 75
      checking -= 75
```

Savings: 100

Checking: 50

Constraint:
savings + checking >= 0

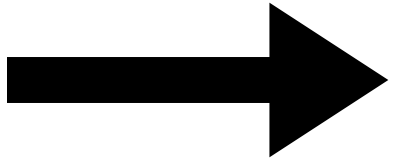
Practice: Multi-version Systems

T_0 commits

```
T0:
if savings + checking >= 100
      savings -= 100
```

```
T1:
if savings + checking >= 75
      checking -= 75
```

Savings: 100



Savings: 0

Checking: 50

Constraint:
savings + checking >= 0

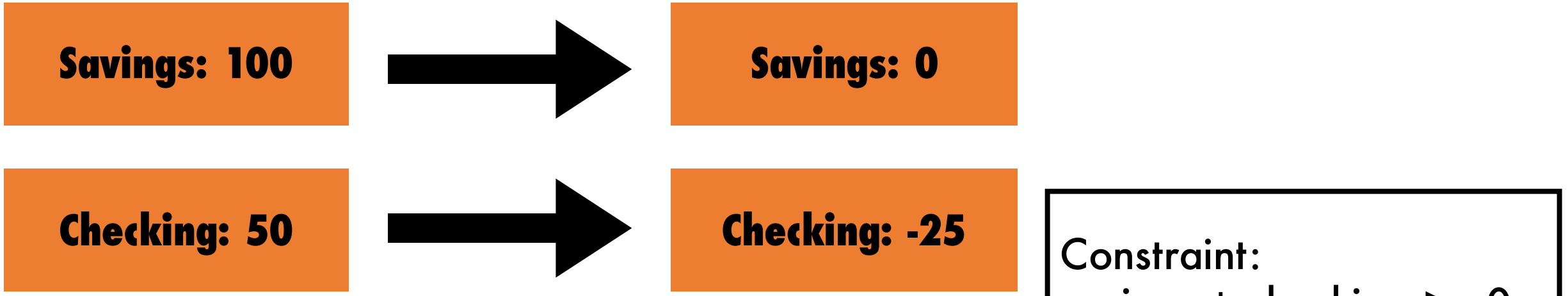
Practice: Multi-version Systems

T_0 commits

```
T0:
if savings + checking >= 100
      savings -= 100
```

T_1 commits

```
T1:
if savings + checking >= 75
      checking -= 75
```



Practice: Multi-version Systems

T_0 commits

```
T0:
if savings + checking >= 100
    savings -= 100
```

T_1 commits

```
T1:
if savings + checking >= 75
    checking -= 75
```

Savings: 100 → Savings: 0

Checking: 50 → Checking: -25

Constraint:
savings + checking >= 0

Practice: Multi-version Systems

"Solution": Use conservative isolation techniques similar to single-version systems

Practice: Multi-version Systems

T_0:

```
savings += 100
```

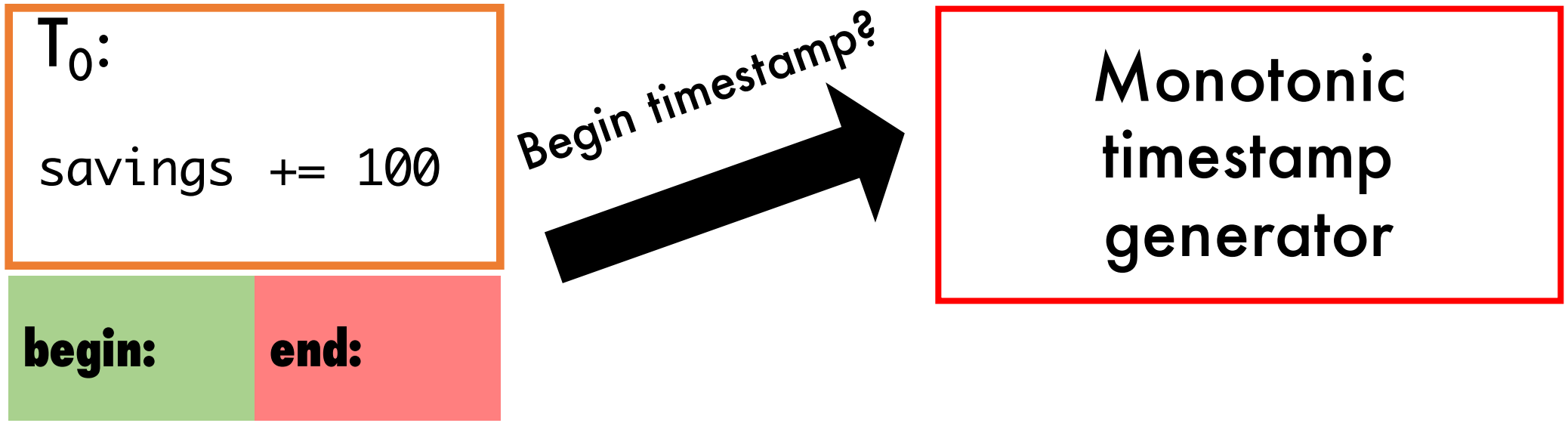
begin:	end:

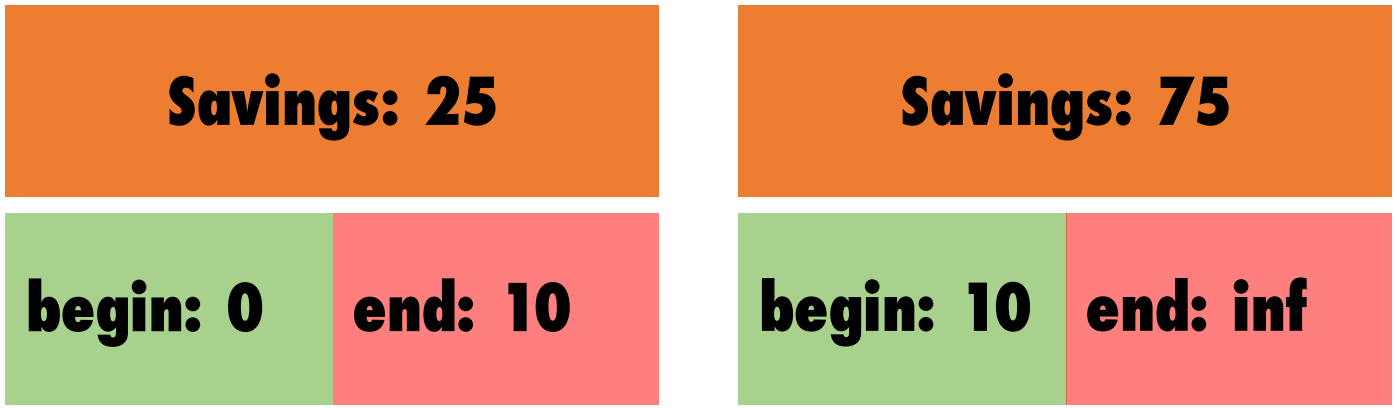
Monotonic timestamp generator

Savings: 25	
begin: 0	end: 10

Savings: 75	
begin: 10	end: inf

Practice: Multi-version Systems





Practice: Multi-version Systems

T_0:

```
savings += 100
```

begin: 12	end:

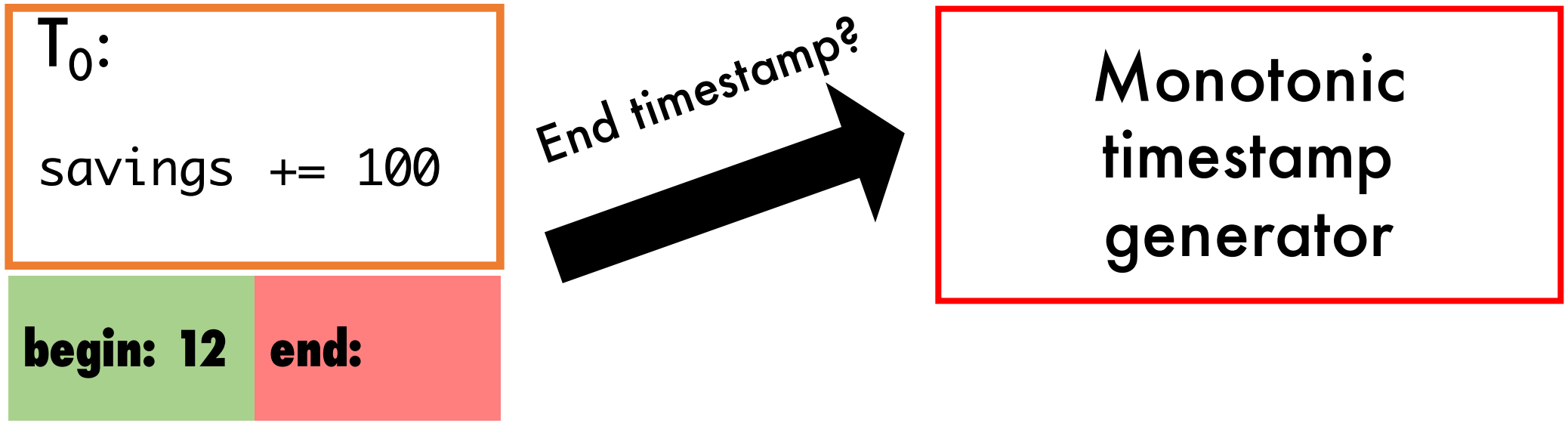
Monotonic timestamp generator

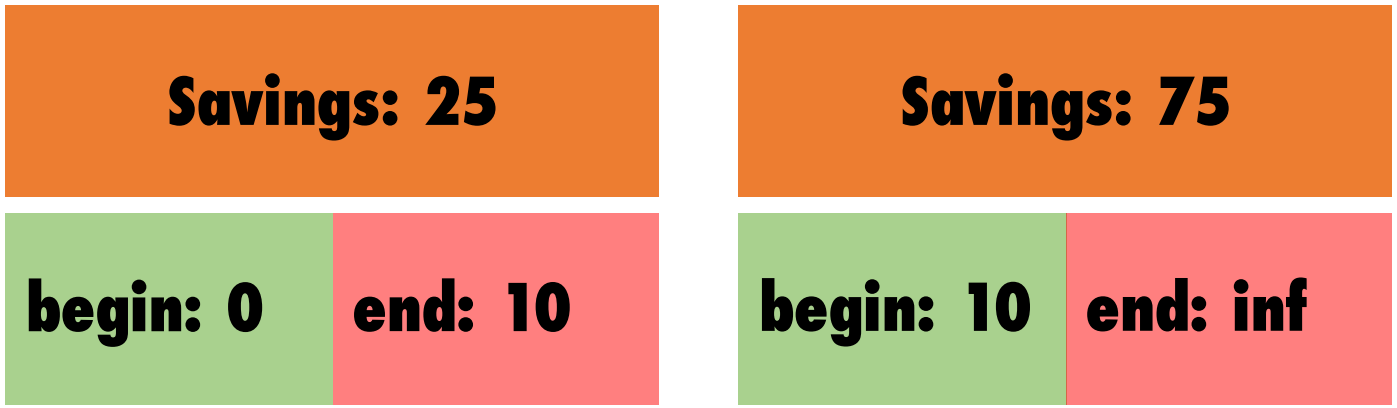
Determines snapshot visible to txn

Savings: 25	
begin: 0	end: 10

Savings: 75	
begin: 10	end: inf

Practice: Multi-version Systems





Practice: Multi-version Systems

T_0:

```
savings += 100
```

begin: 12 | **end: 18**

Determines visibility of txn's writes

Monotonic timestamp generator

Savings: 25		**Savings: 75**		**Savings: 175**	
begin: 0	**end: 10**	**begin: 10**	**end: 18**	**begin: 18**	**end: inf**

Practice: Multi-version Systems

T_0:

savings += 100

Monotonic timestamp generator

Global counter

Scalability bottleneck!

Savings: 175

begin: 0 | end: 10

begin: 10 | end: 18

begin: 18 | end: inf

Practice: Multi-version Systems

Version management overhead

Practice: Multi-version Systems

- Offer the same amount of concurrency as single-version systems
  - Do not effectively exploit multi-versioning

- Significant sources of overhead
  - Contended counters
  - Version management

Practice: Multi-version Systems

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Fundamental issue with concurrency control protocols

Severe performance degradation on multi-core main-memory systems

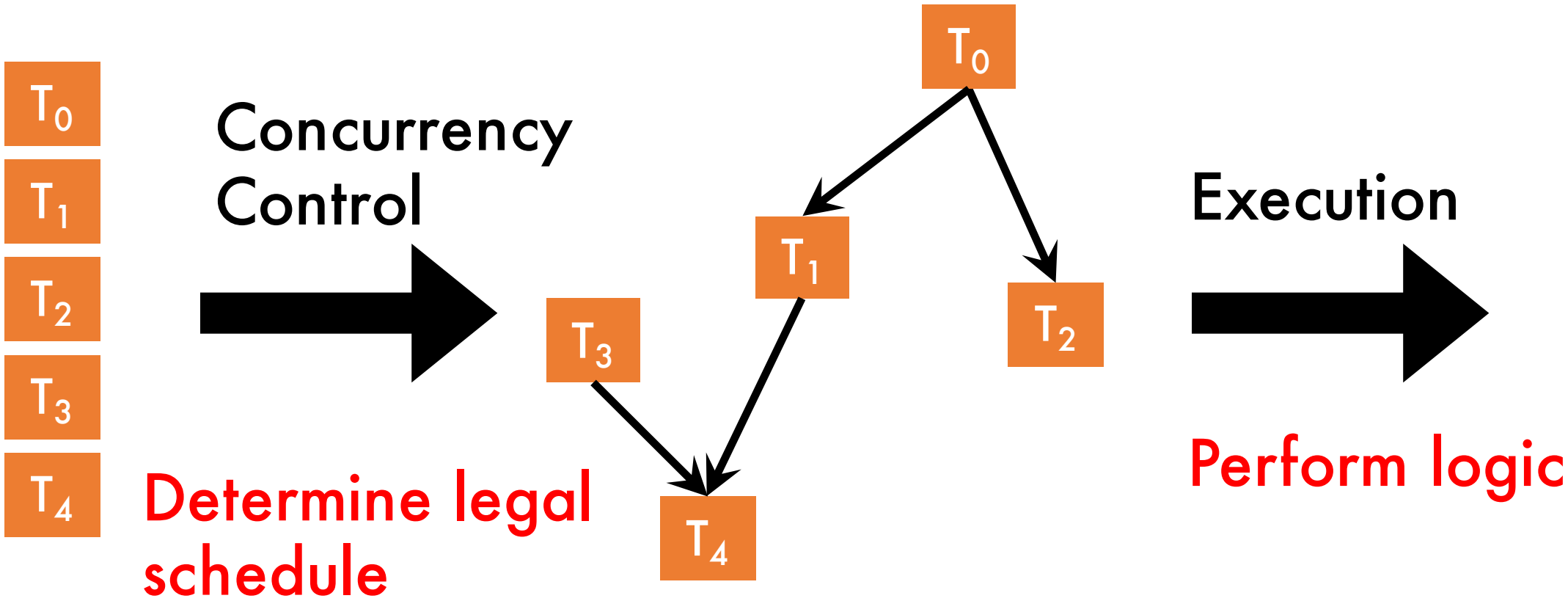
Root Cause

- Multi-version databases enforce serial order **dynamically**
  - Concurrency control occurs during transaction execution
- Requires conservative concurrency control
  - Same read-write concurrency as single-versioning
- Concurrency control meta-data prone to contention

Our Approach: Bohm

- Separate concurrency control from transaction execution
- Concurrency control determines transaction order and version visibility
- Execution performs logic given concurrency control ordering

Bohm Overview

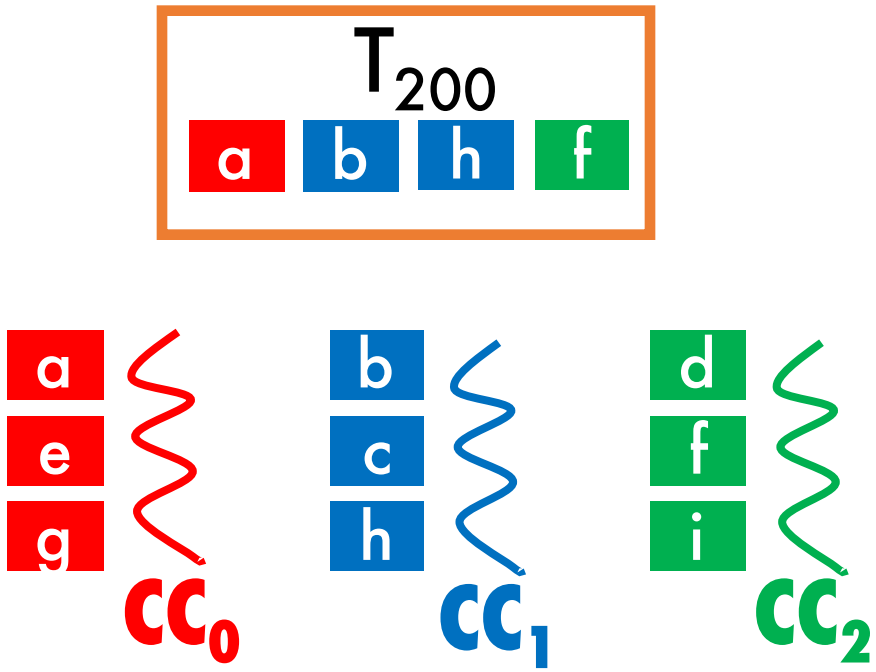


Extra Requirements

- Transactions' entire logic must be submitted in one piece
- Transactions' write-sets must be deducible prior to their execution

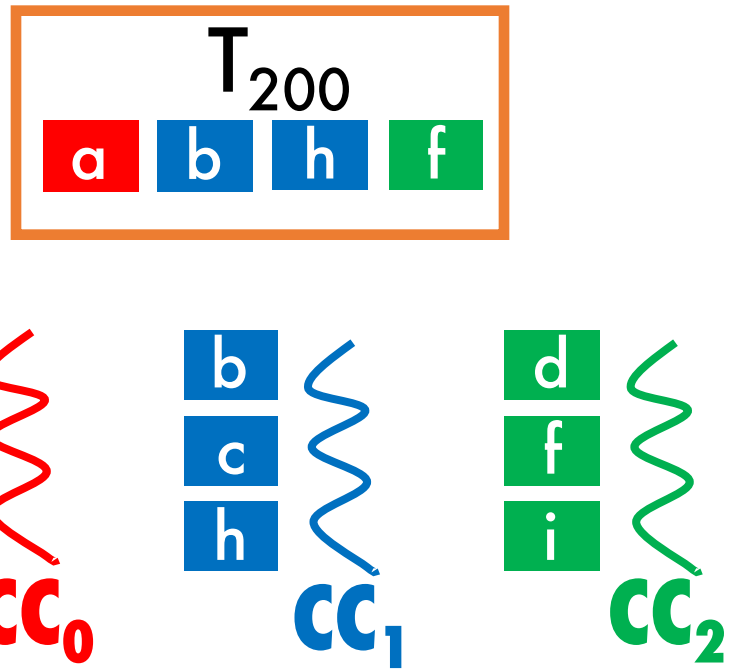
Concurrency Control Layer

- Partition data across multiple threads



Concurrency Control Layer

- Partition data across multiple threads
- For every write, create a new version



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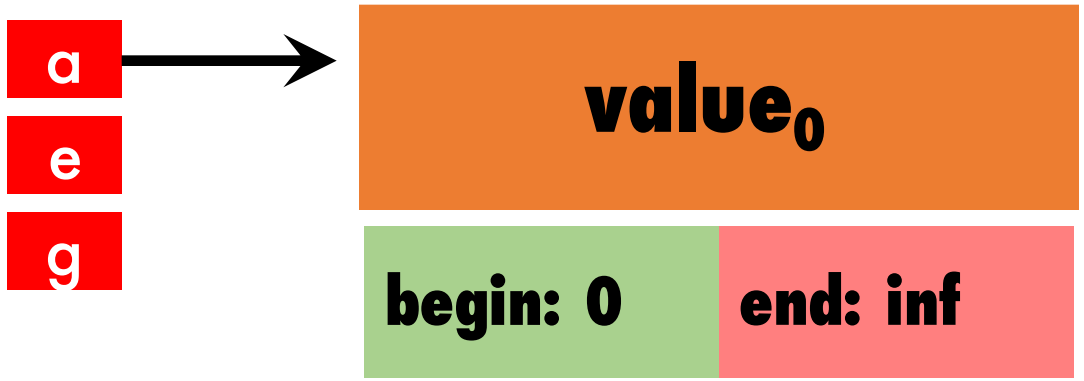

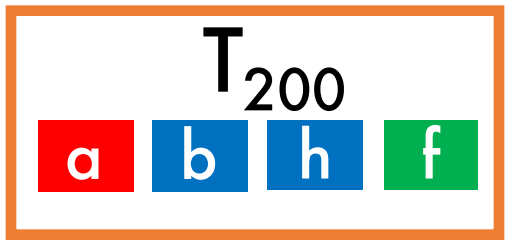

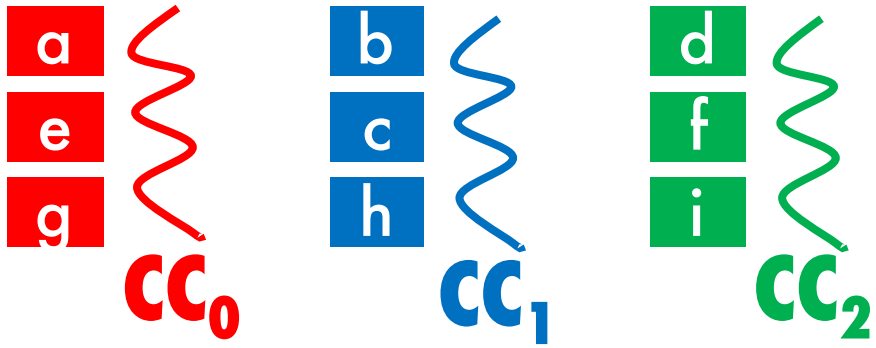

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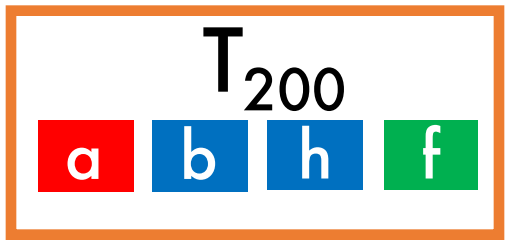

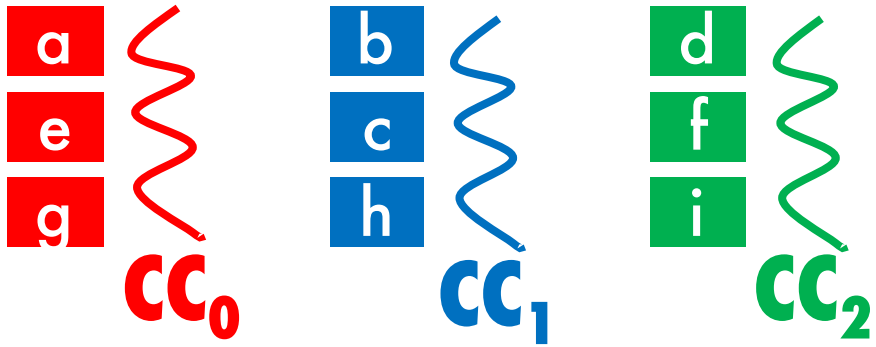

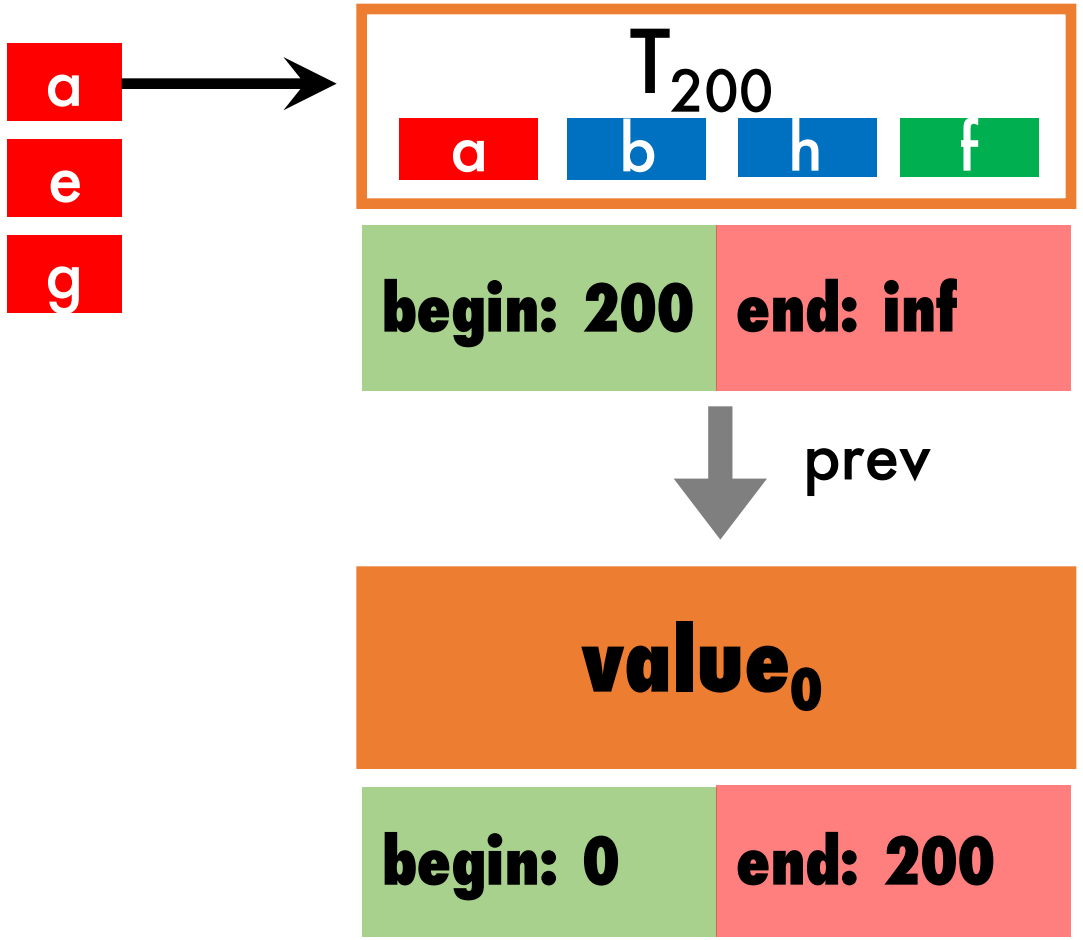

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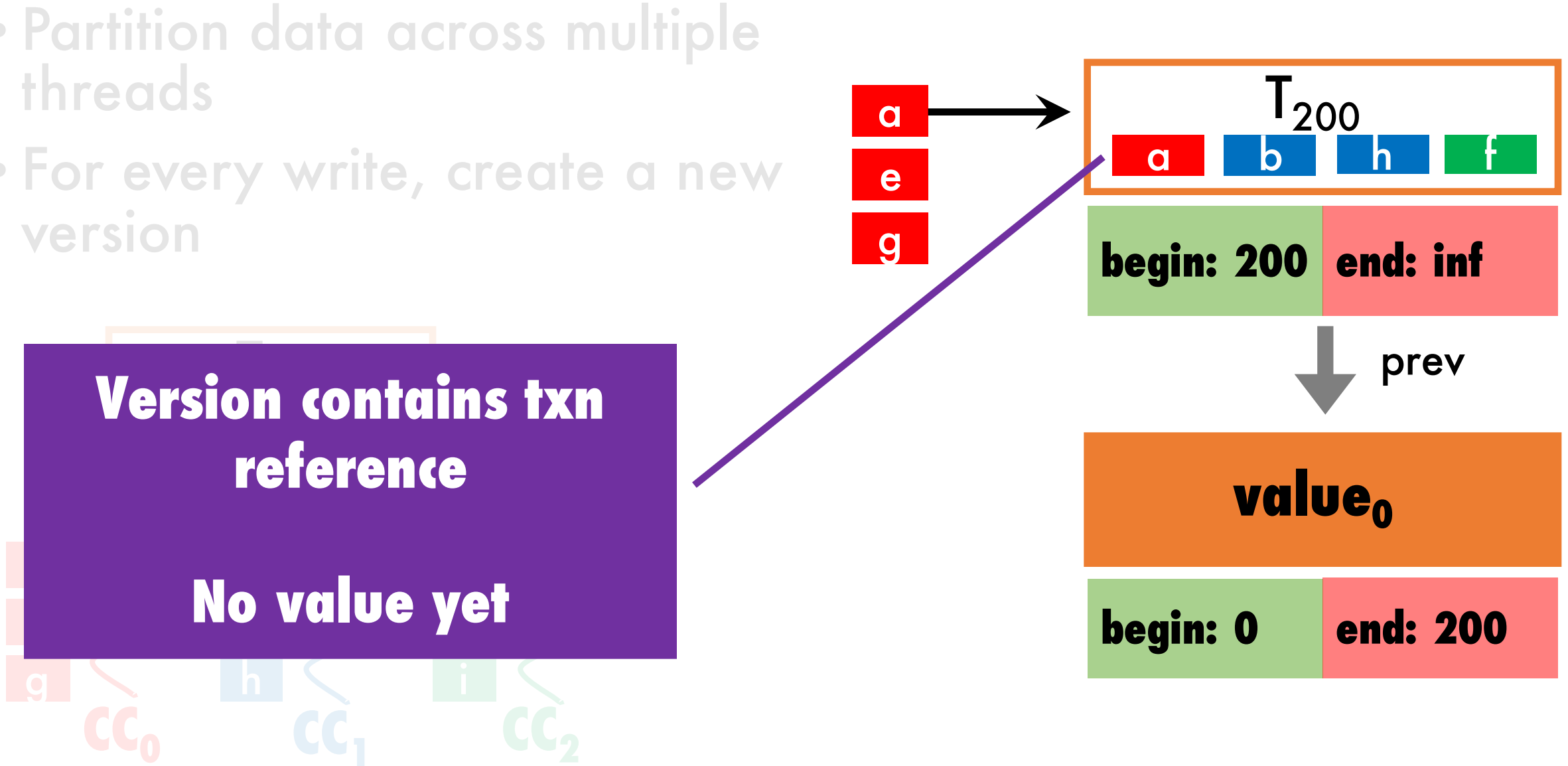
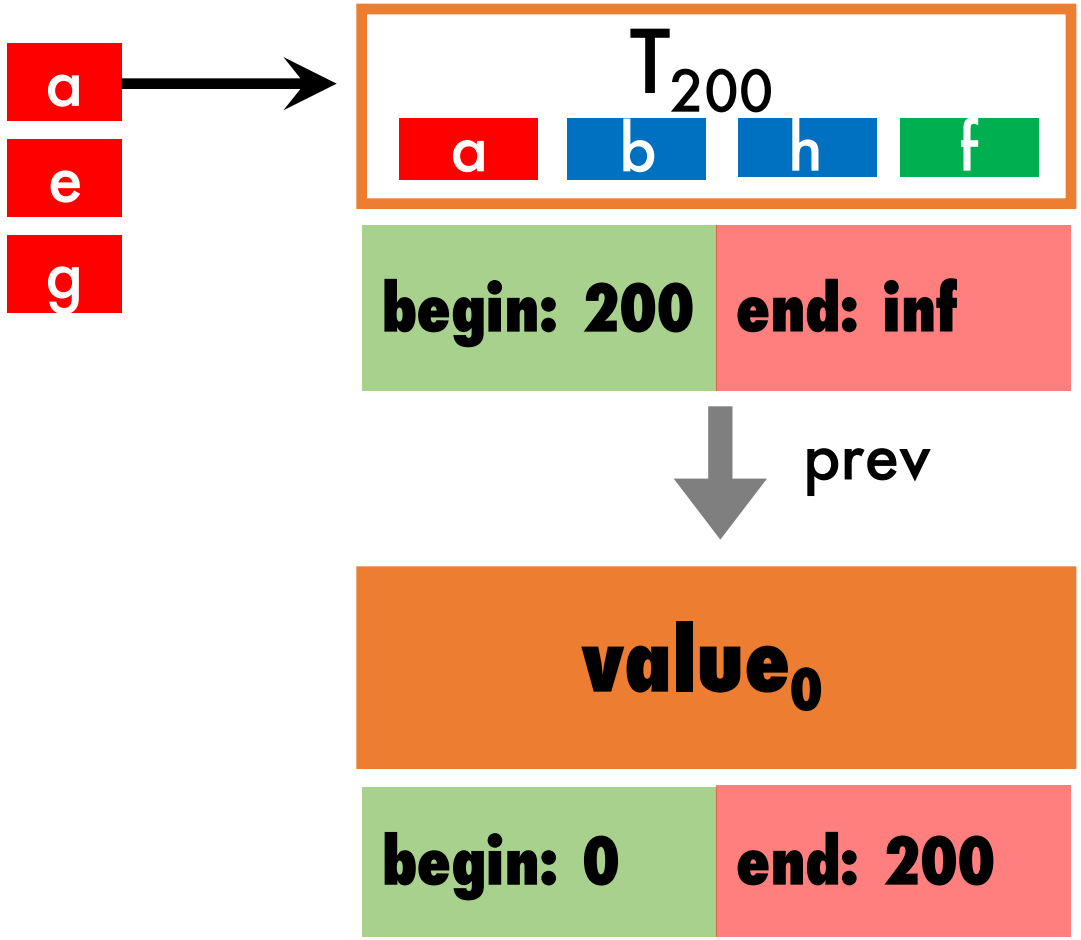


Execution Layer

- Begins executing a batch after concurrency control completes
- Perform txn logic, write out data



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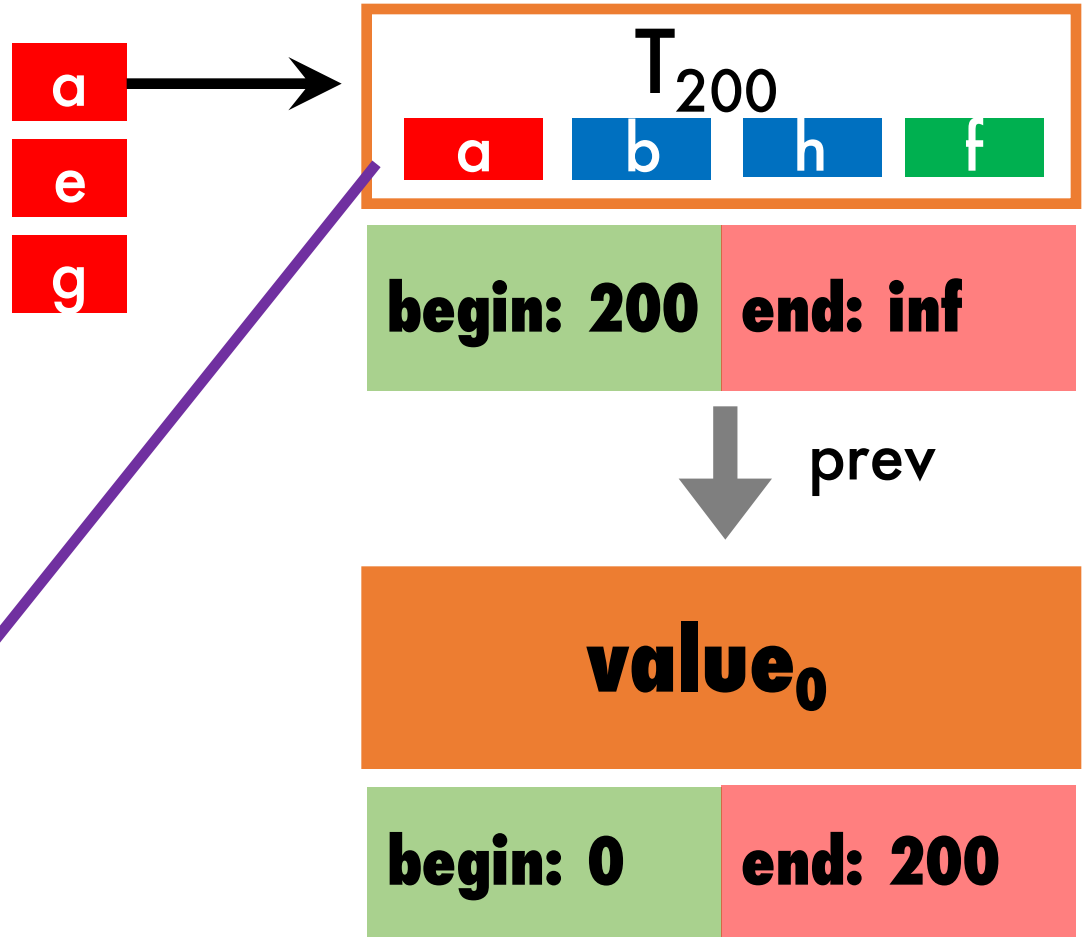
Replace txn reference with actual data



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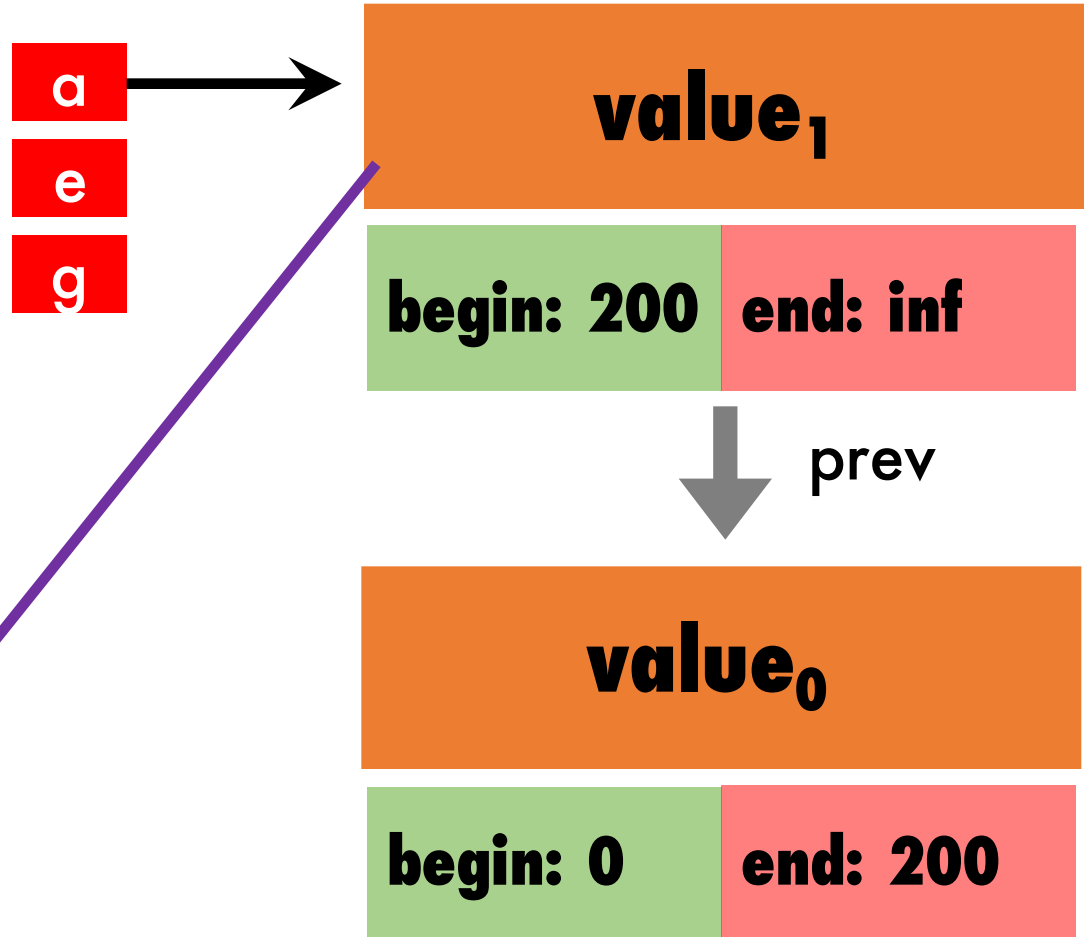
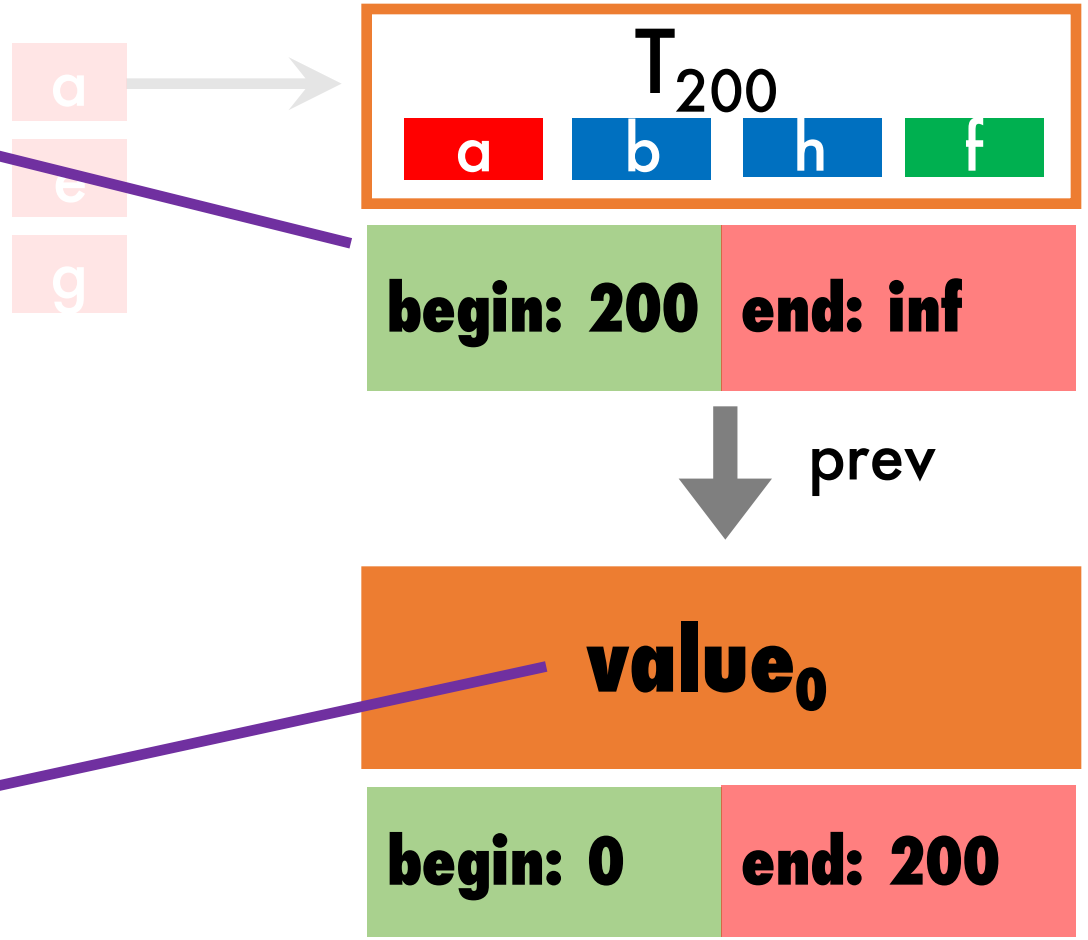


Implications of Design

Concurrency control fixes txn snapshots prior to their execution



Execution only produces values

No logical locking/validation

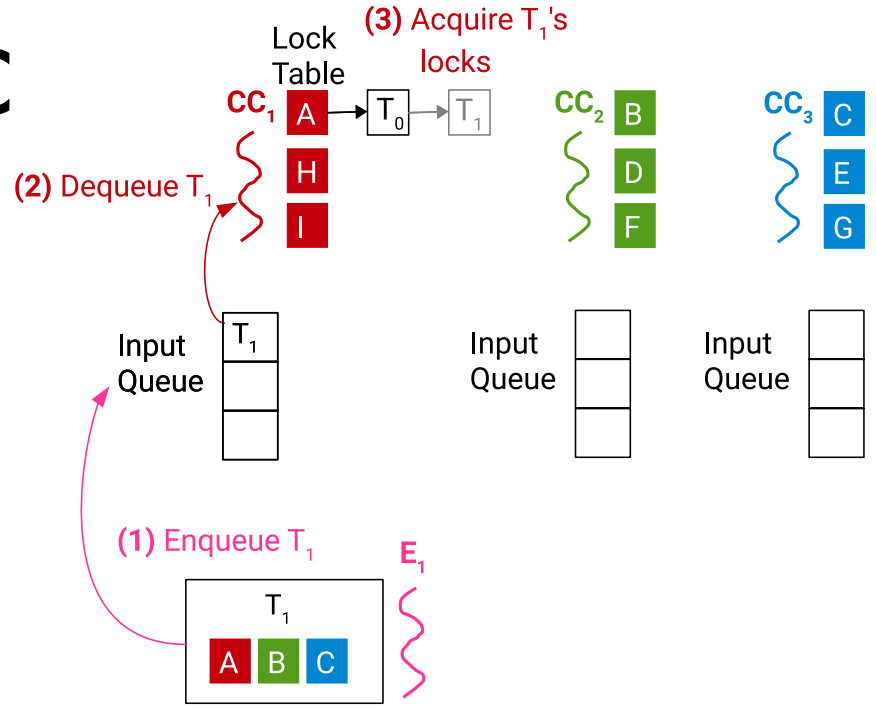
What have we gained?

- Strong concurrency guarantees
  - Reads **never** block writes
  - Write-write conflicts **never** lead to aborts
- Significant reduction in contention
  - Shared-nothing concurrency control
  - Shared-everything execution

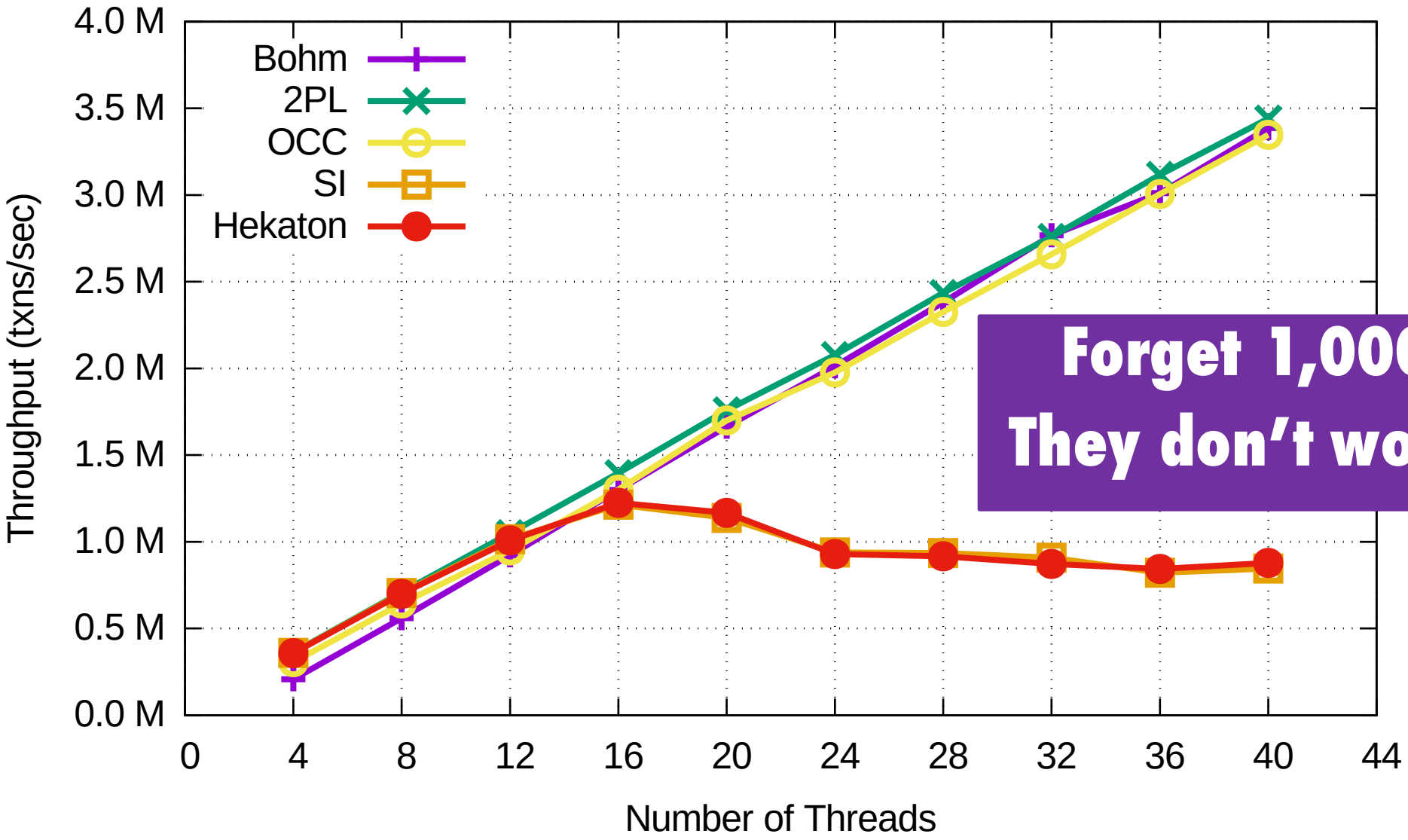
Broader lessons

Decoupling concurrency control and execution is useful

- Broader implications beyond MVCC
- Inspired by systems/TM crowd
  - Barrelfish, fos
  - Flat combining, remote core locking
- Design Principles for Scaling Multi-core OLTP Under High Contention
  - To appear at SIGMOD '16

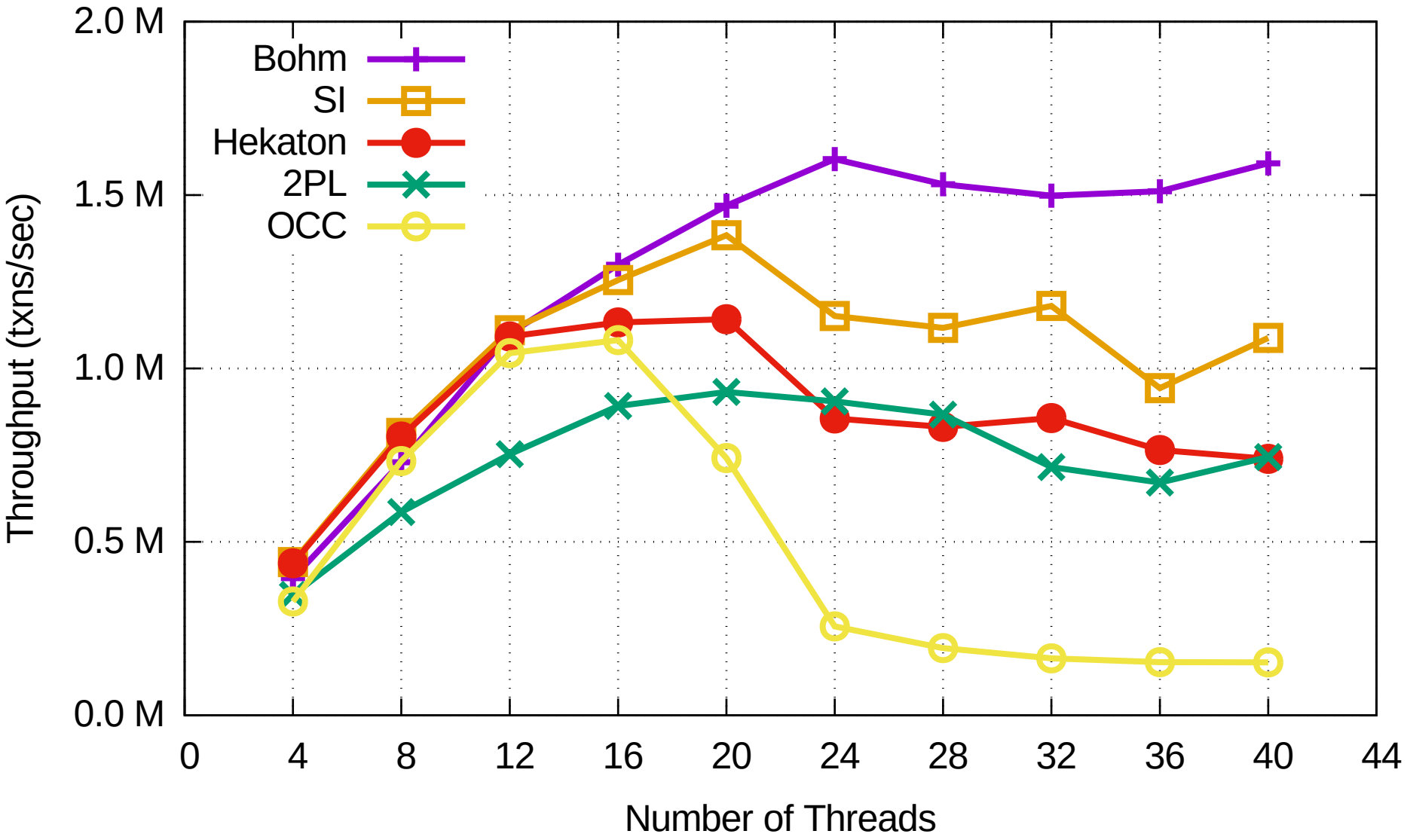


Global counters don't work



Forget 1,000 cores.
They don't work at 40.

Conflict-induced aborts are a bummer



Conclusions

- Serializable multi-version databases can't exploit versioning to increase concurrency
- Bohm: Separate concurrency control from execution
- Bohm makes strong concurrency guarantees (under assumptions)
  - Reads never block writes
  - Write-write conflicts don't lead to aborts