Strongly Consistent Transactions for Enterprise Applications

Using Software Transactional Memory to Improve Consistency and Performance of Read-Dominated Workloads

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TÉCNICO LISBOA

July 4th, 2014

inesc id lisboa

Consistency Matters

- Concurrent programming is difficult
- Strong consistency makes it easier

“To be sure of **correctness** you should always use the **serializable** isolation level.”

-- Martin Fowler (PoEAA, 2002)

"To be sure of **correctness** you should always use the **serializable** isolation level."

So... why don't we always enforce it?

-- Martin Fowler (PoEAA, 2002)

“To be sure of **correctness** you should always use the **serializable** isolation level.”

“[…] choosing serializable really messes up the liveness of a system, […] you often have to reduce serializability […] to increase throughput.”

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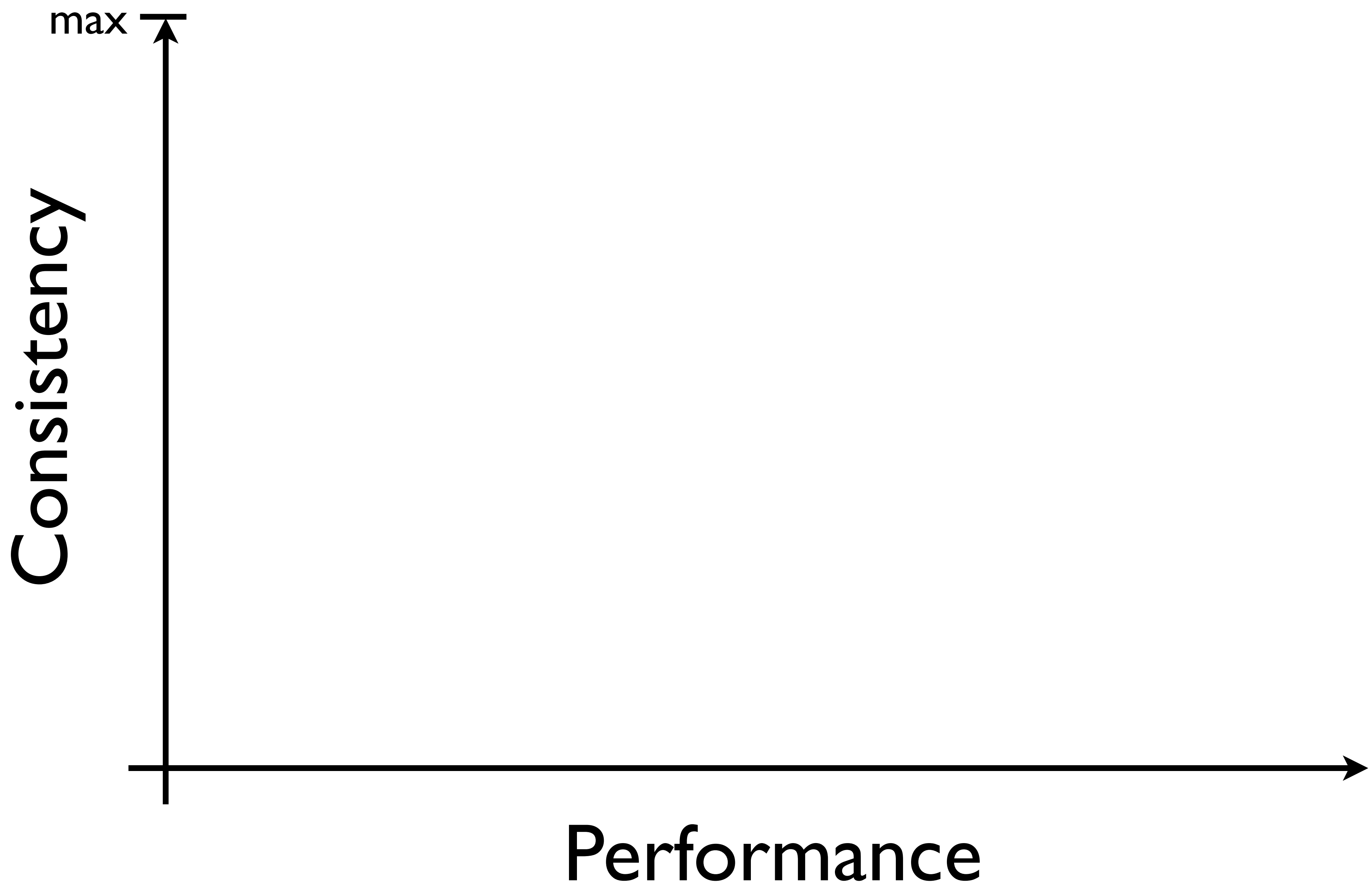
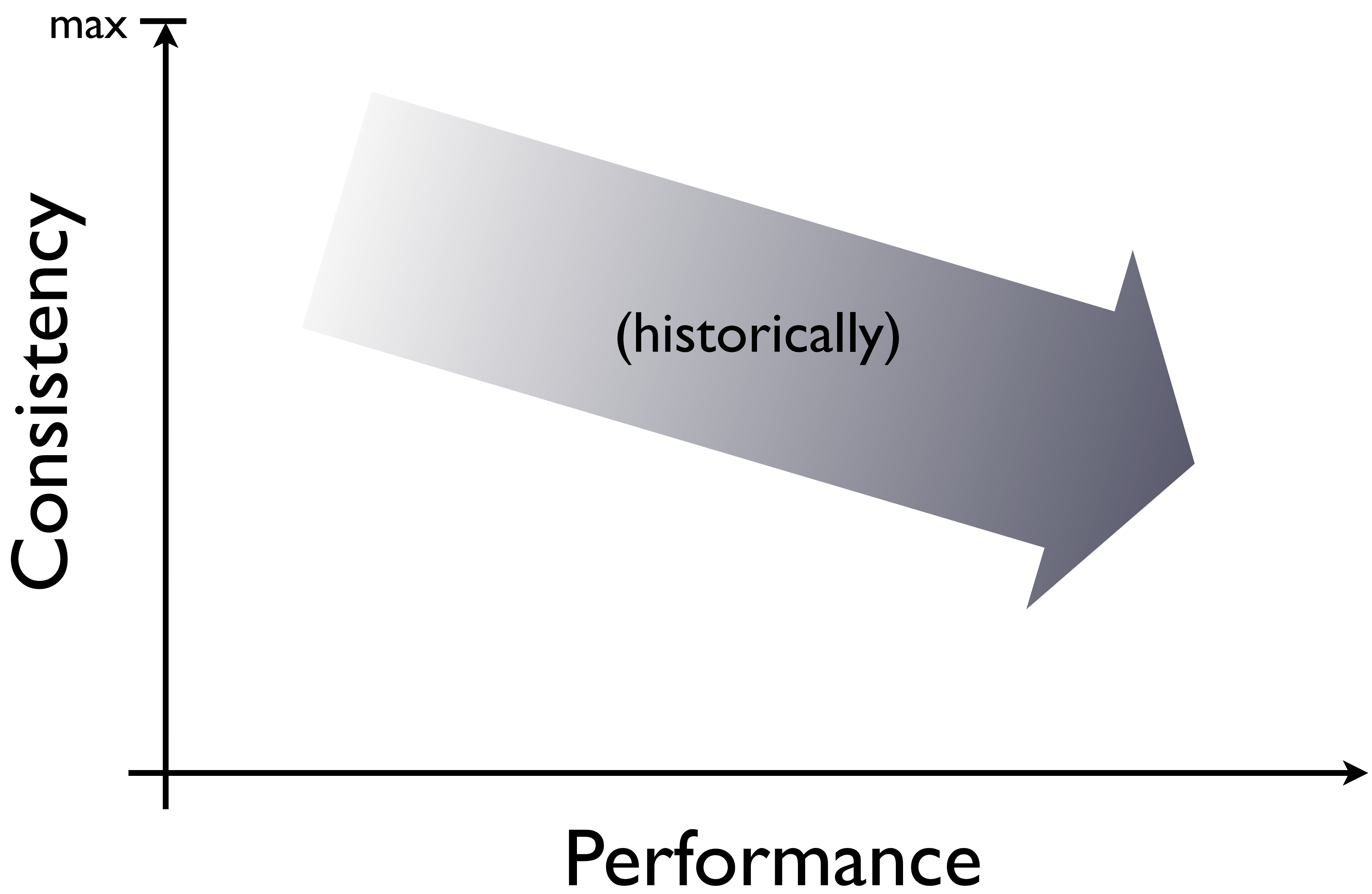
“[…] choosing serializable really messes up the liveness of a system, […] you often have to reduce serializability […] to increase throughput.”

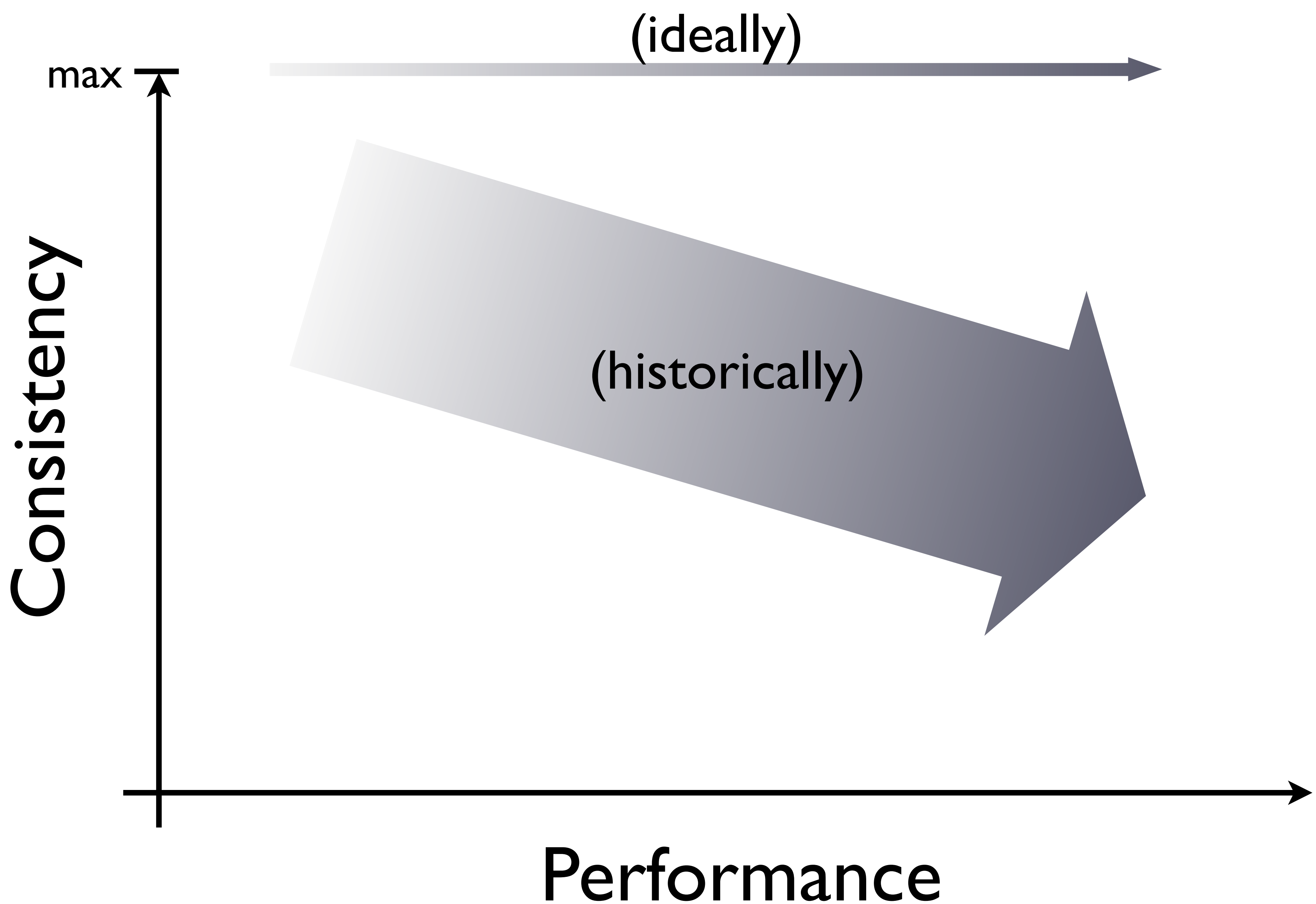
“You have to decide what risks you want take and make your own trade-off of **errors** versus **performance**.”

-- Martin Fowler (PoEAA, 2002)



max
Consistency
Performance


max
Consistency
(historically)
Performance



(ideally)
max
Consistency
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Performance

Consistency Really Matters

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-- Google's F1 team (Shute et al, VLBD, 2013)

Consistency Really Matters

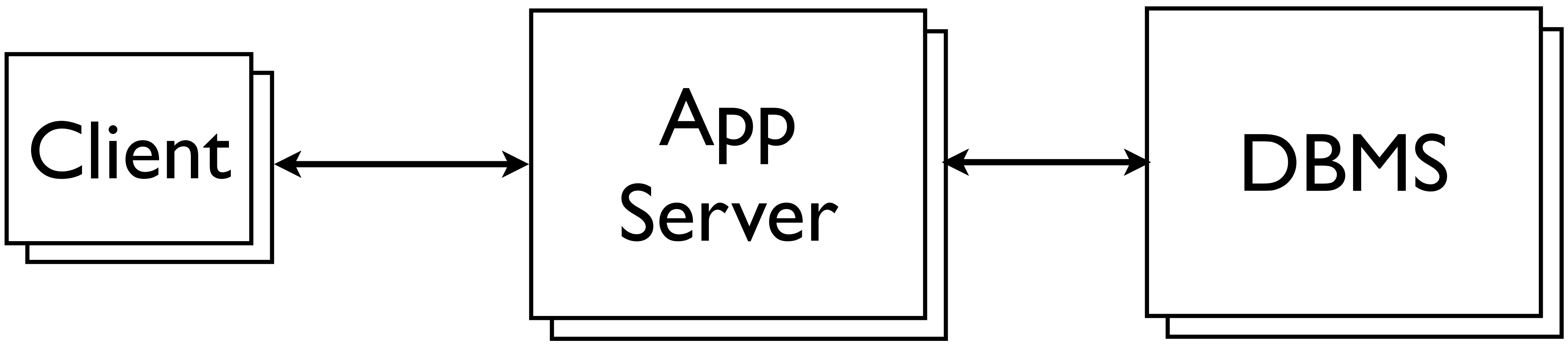
"The system […] must always present […] **consistent data**."

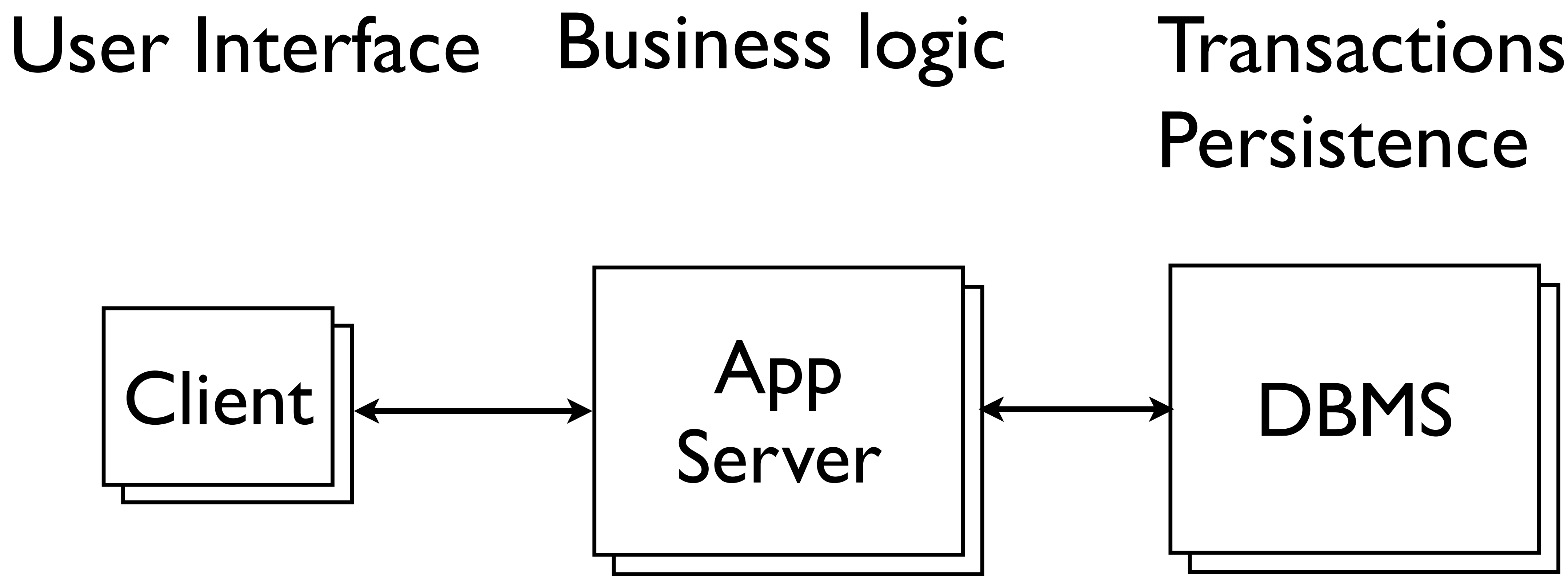
"[…] to cope with concurrency anomalies […] is very **error-prone**, **time-consuming**, and ultimately **not worth the performance gains**."

-- Google's F1 team (Shute et al, VLBD, 2013)

Thesis Statement

"Using an STM-based middleware, it is possible to have both **strong consistency** and **better performance**, for the typical workloads of enterprise applications."


Client
App
Server
DBMS


User Interface
Business logic
Transactions
Persistence
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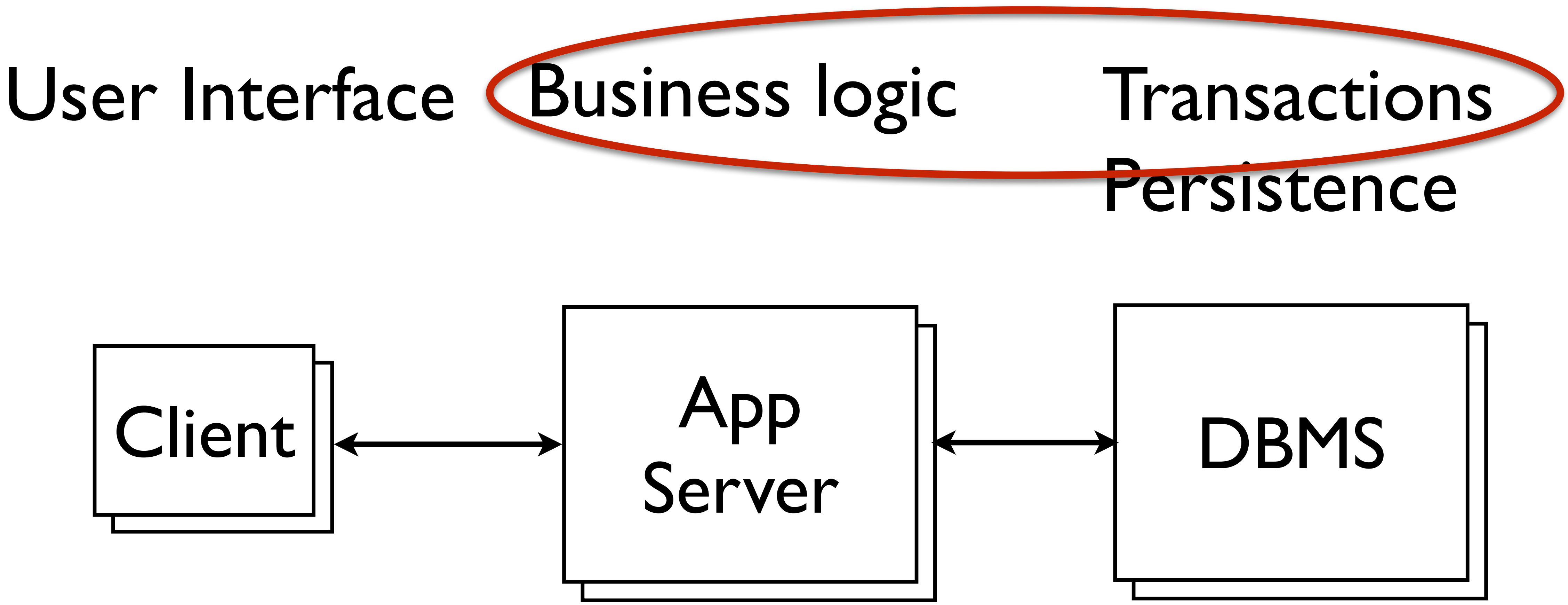
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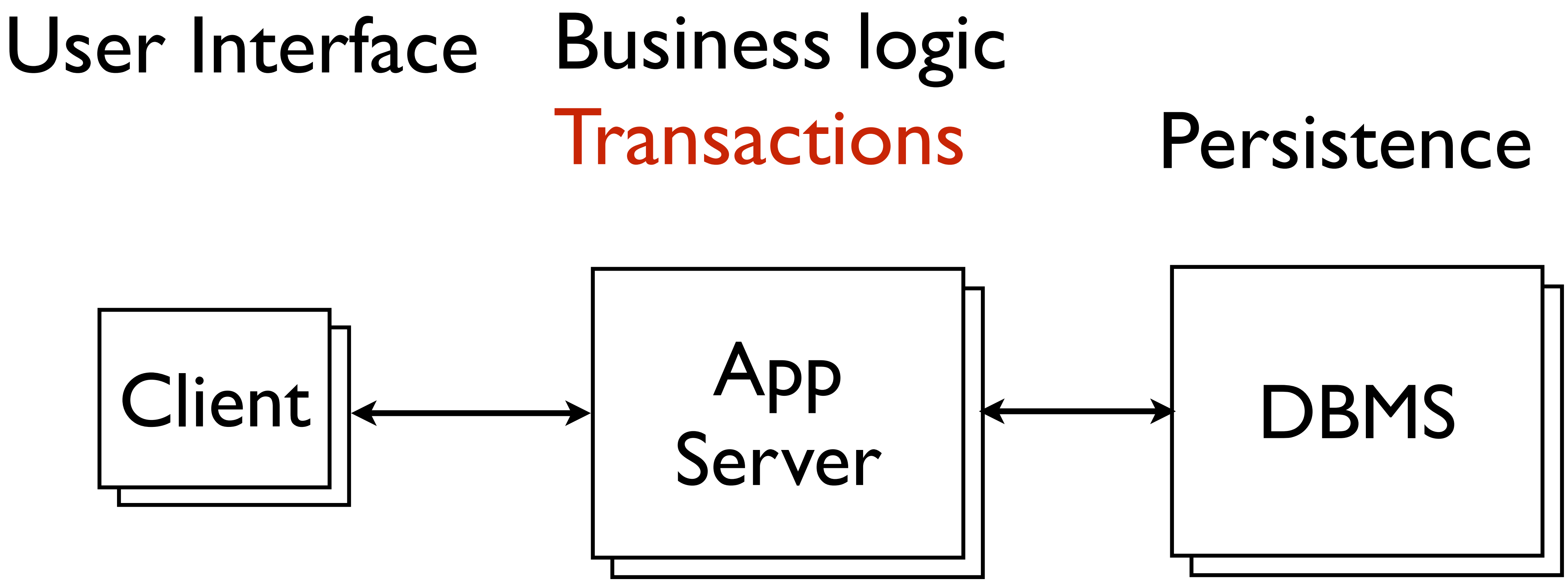
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Desired Properties

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- Strong consistency

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- Performance
- DB-independent consistency
- Transparent persistence
- Support clustering

Key Elements

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- STM-based transactions

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- DB abstraction

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- STM-based transactions
- DB abstraction
- Add persistence to STM
- STM-aware cache
- Distributed synchronization protocol

TMM:
Transactional Memory Middleware

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Transactional Memory Middleware

1. STM integration

2. Data persistence

3. Clustering

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Transactional Memory Middleware

1. STM integration
   - Repository interface
   - JVSTM
2. Data persistence

3. Clustering

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   - JVSTM
2. Data persistence
   - Data mapping
   - Commit extension
   - Cache/Identity Map
3. Clustering

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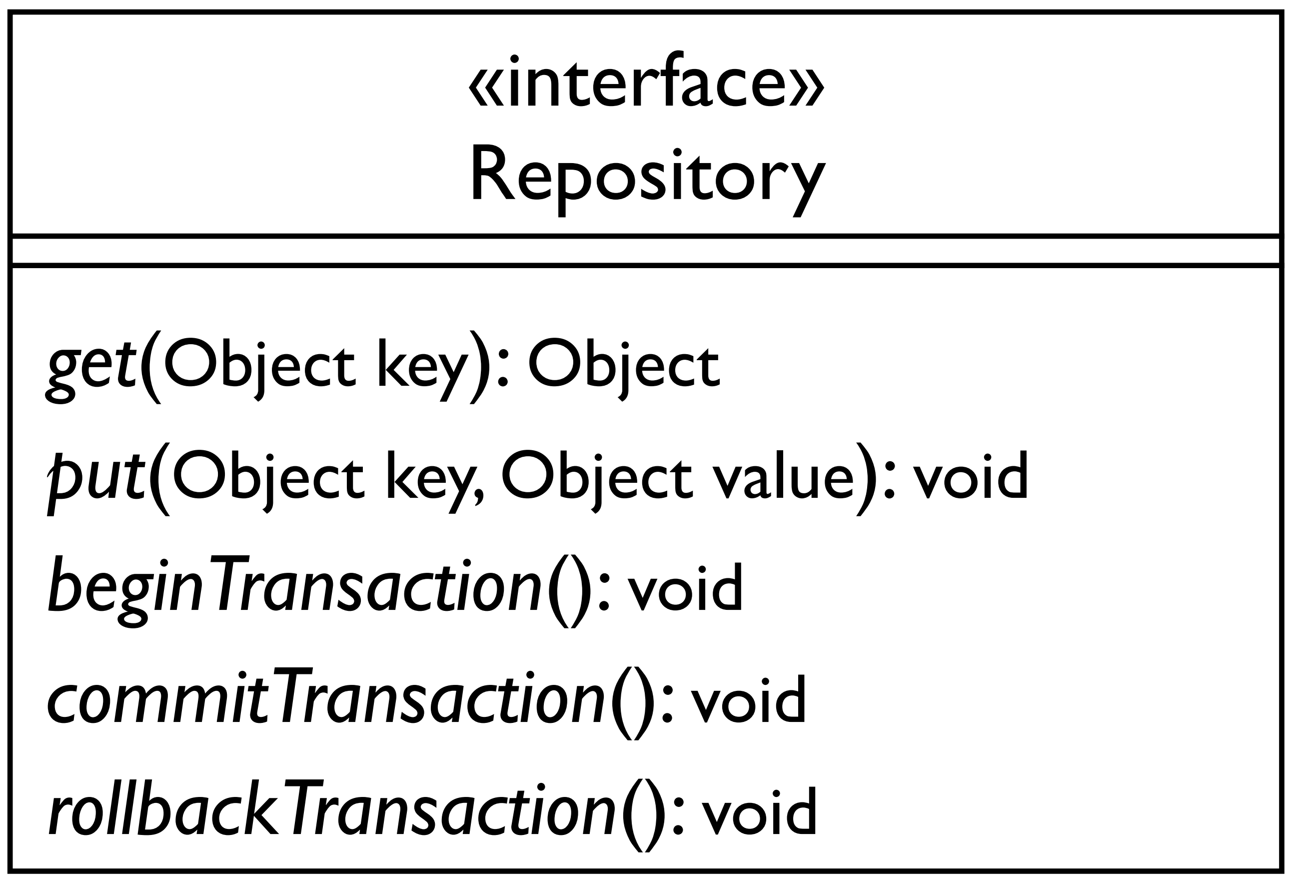
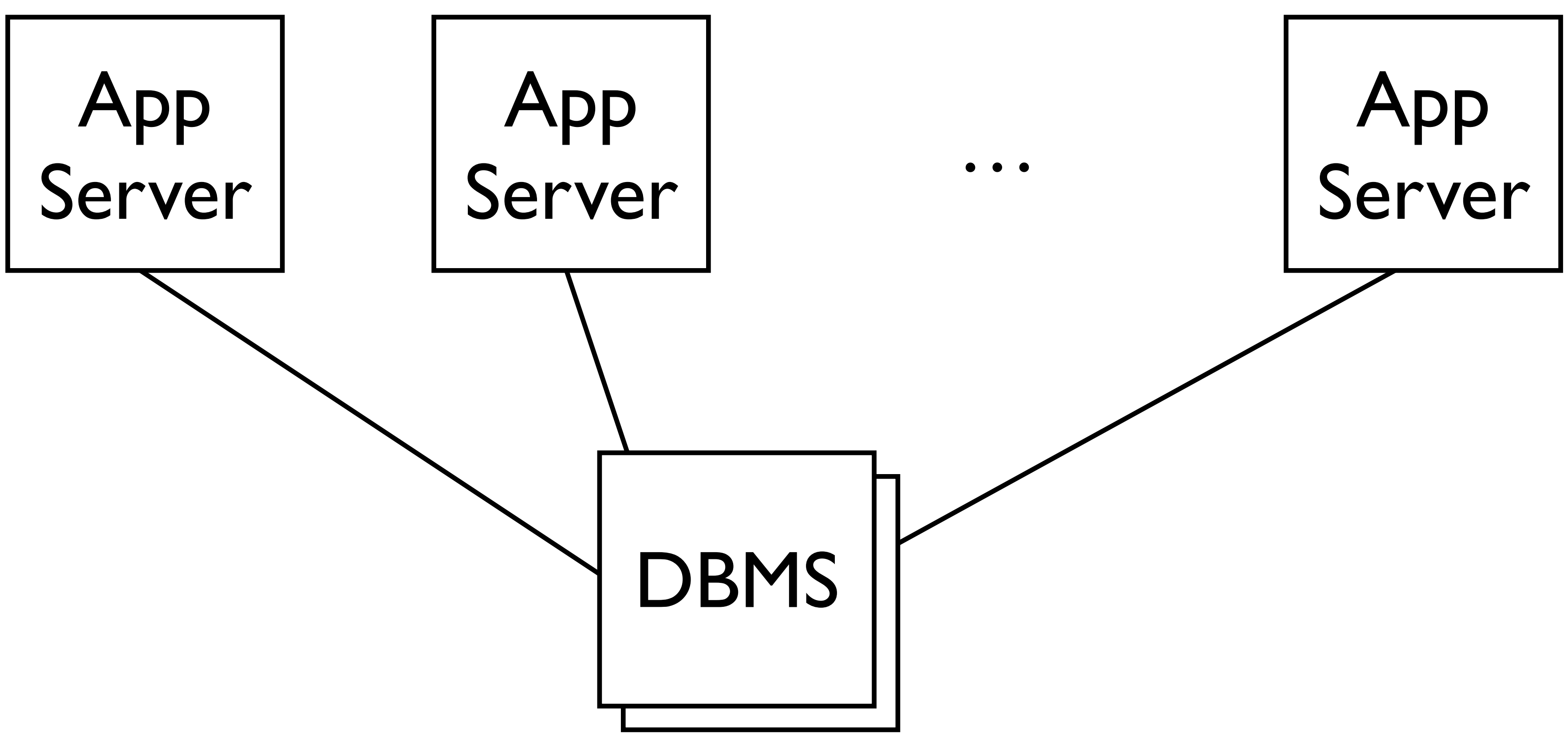
Minimal Repository Requirements



Clustering



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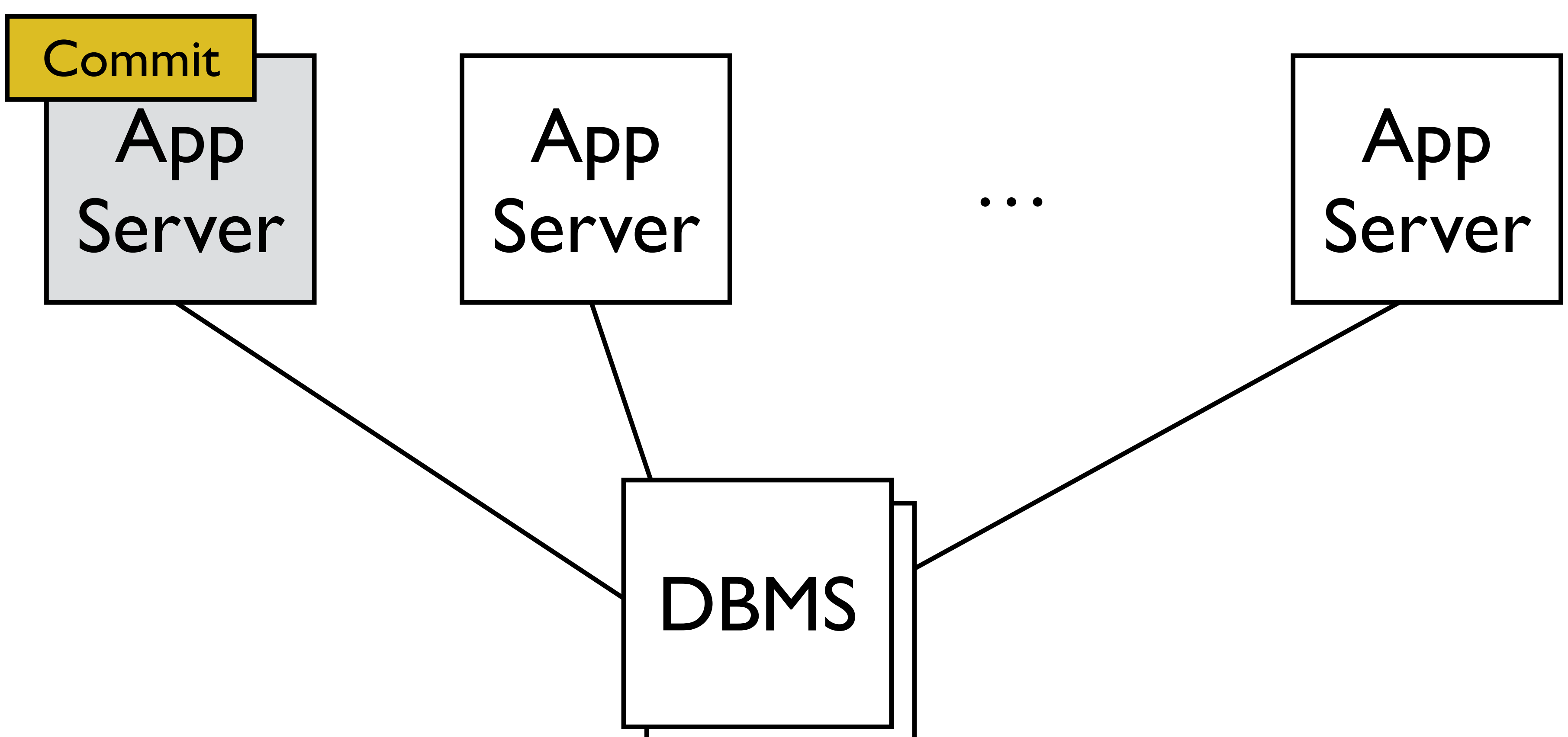

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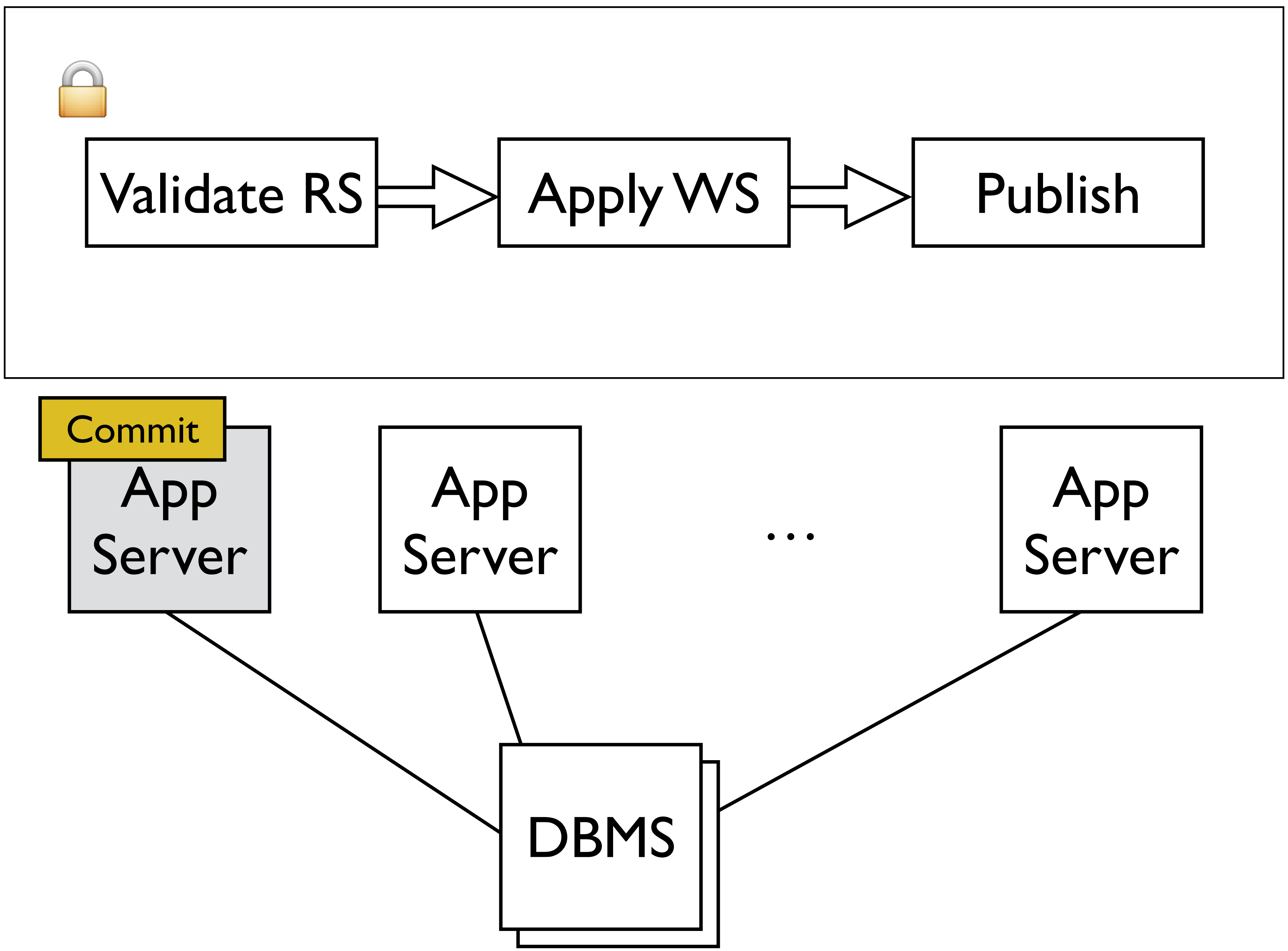
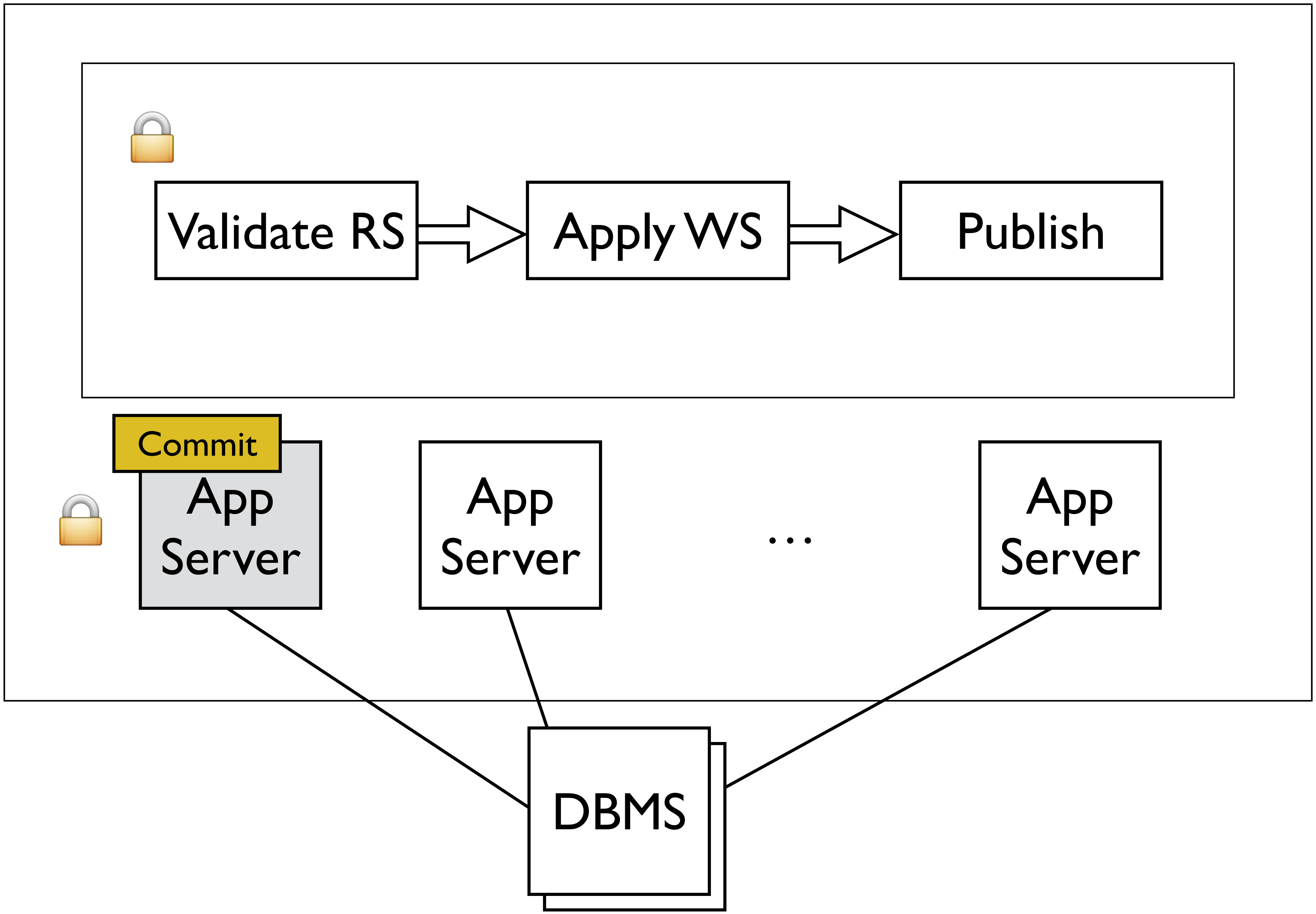


Validate RS
Apply WS
Publish
Commit
App Server
App Server
...
App Server
DBMS

Clustering



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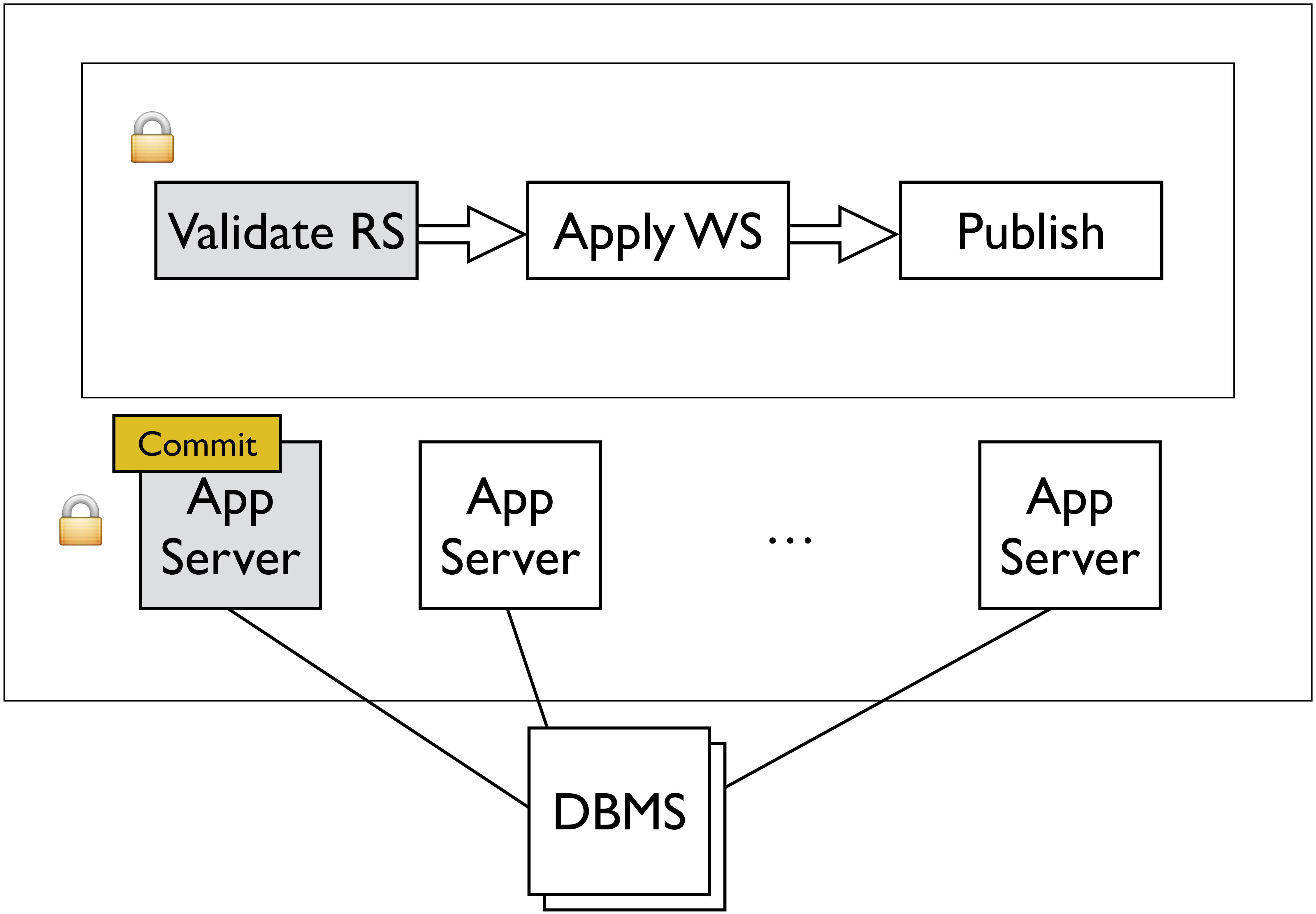

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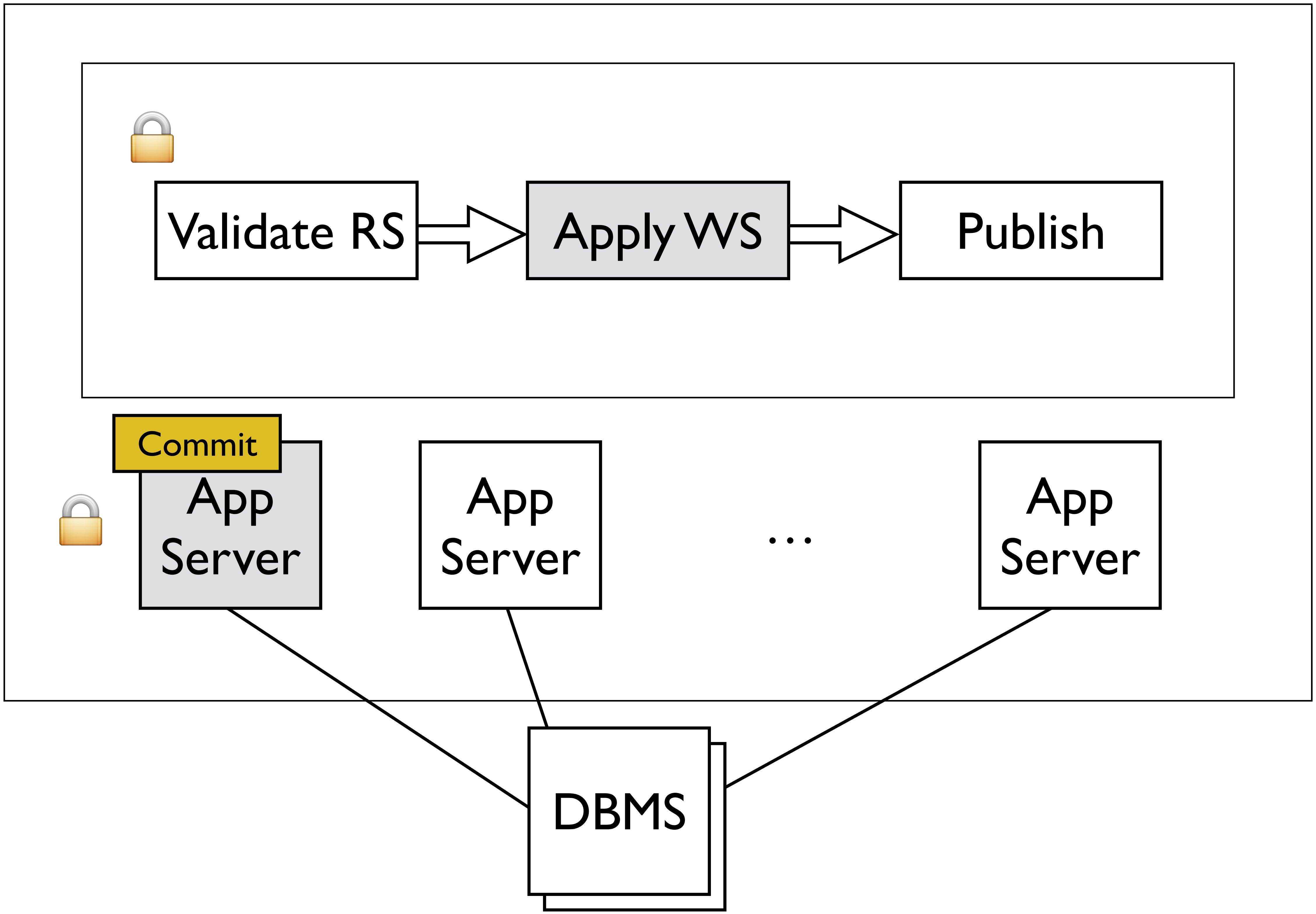
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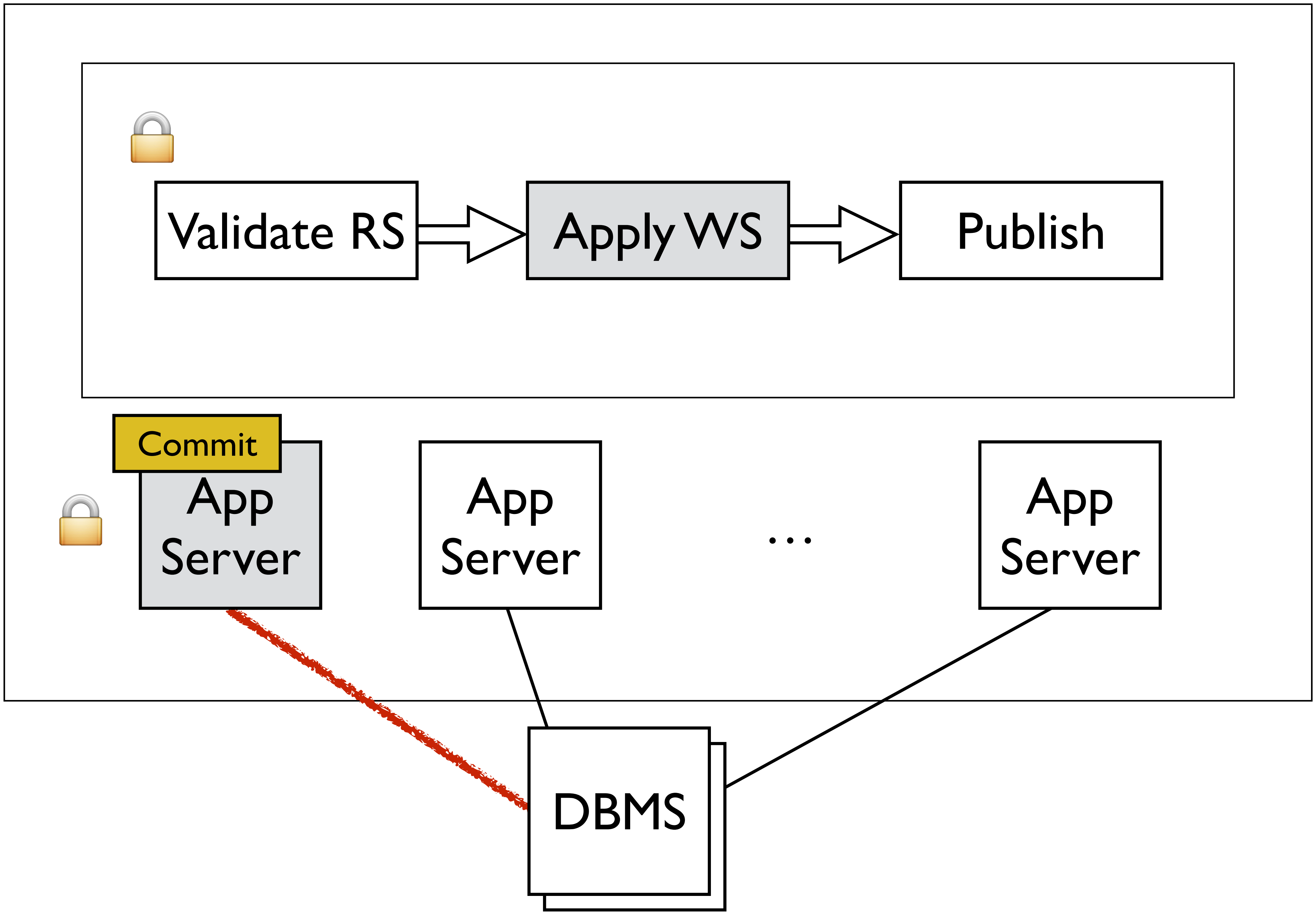
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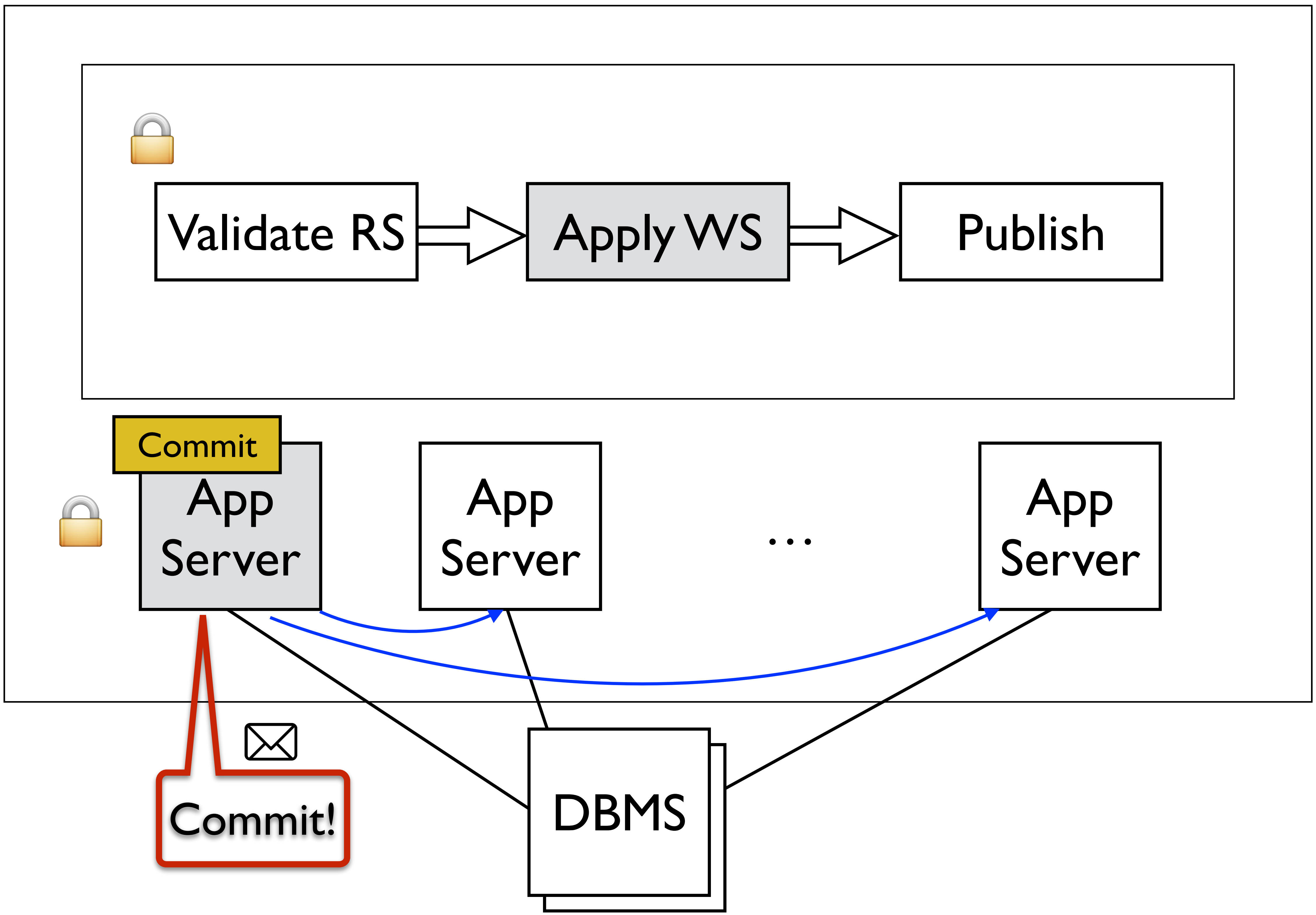

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...
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Commit!
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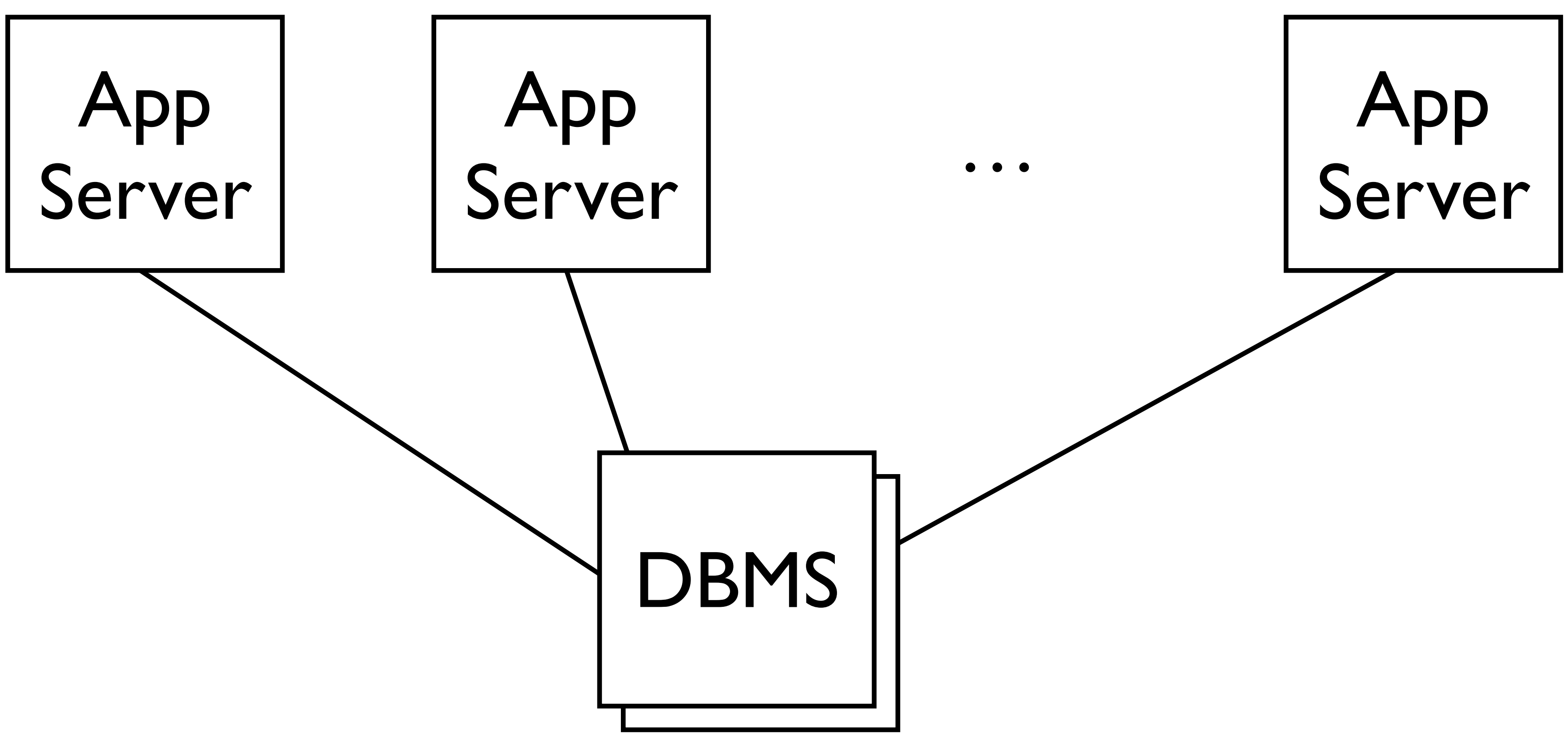
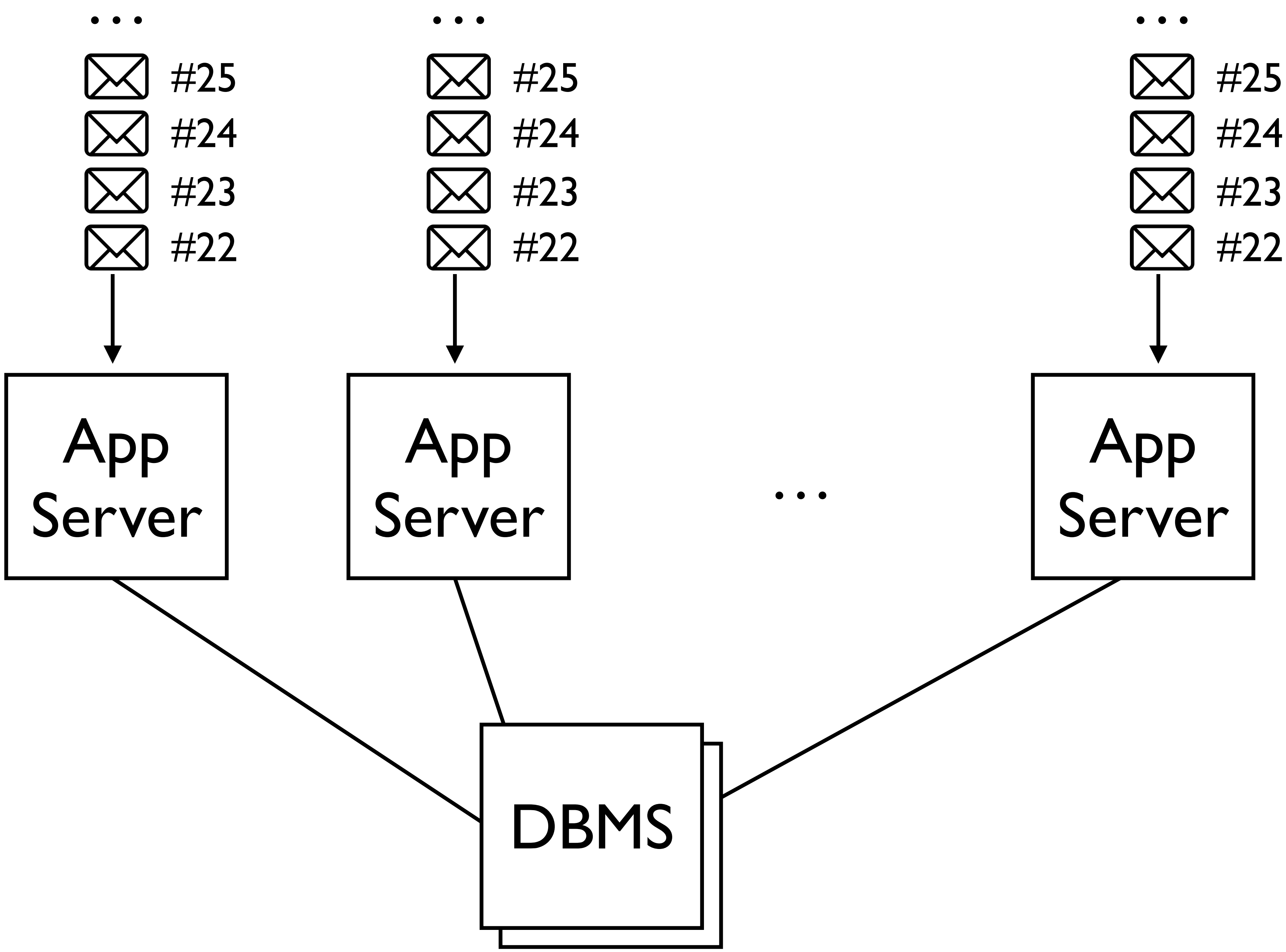


Clustering



...
#25
#24
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#25
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#22
App Server
App Server
...
App Server
DBMS

Consistency Guarantees

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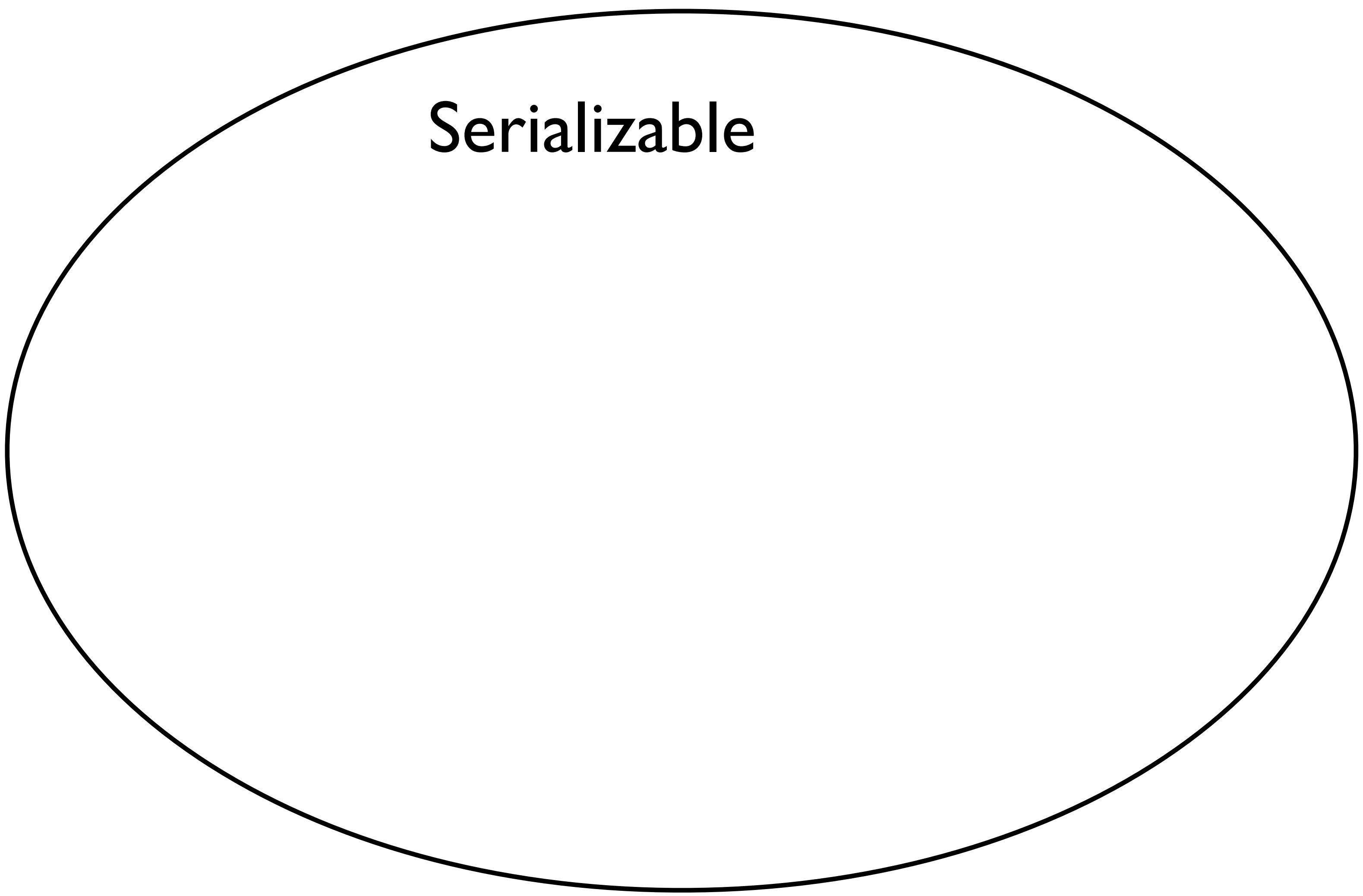

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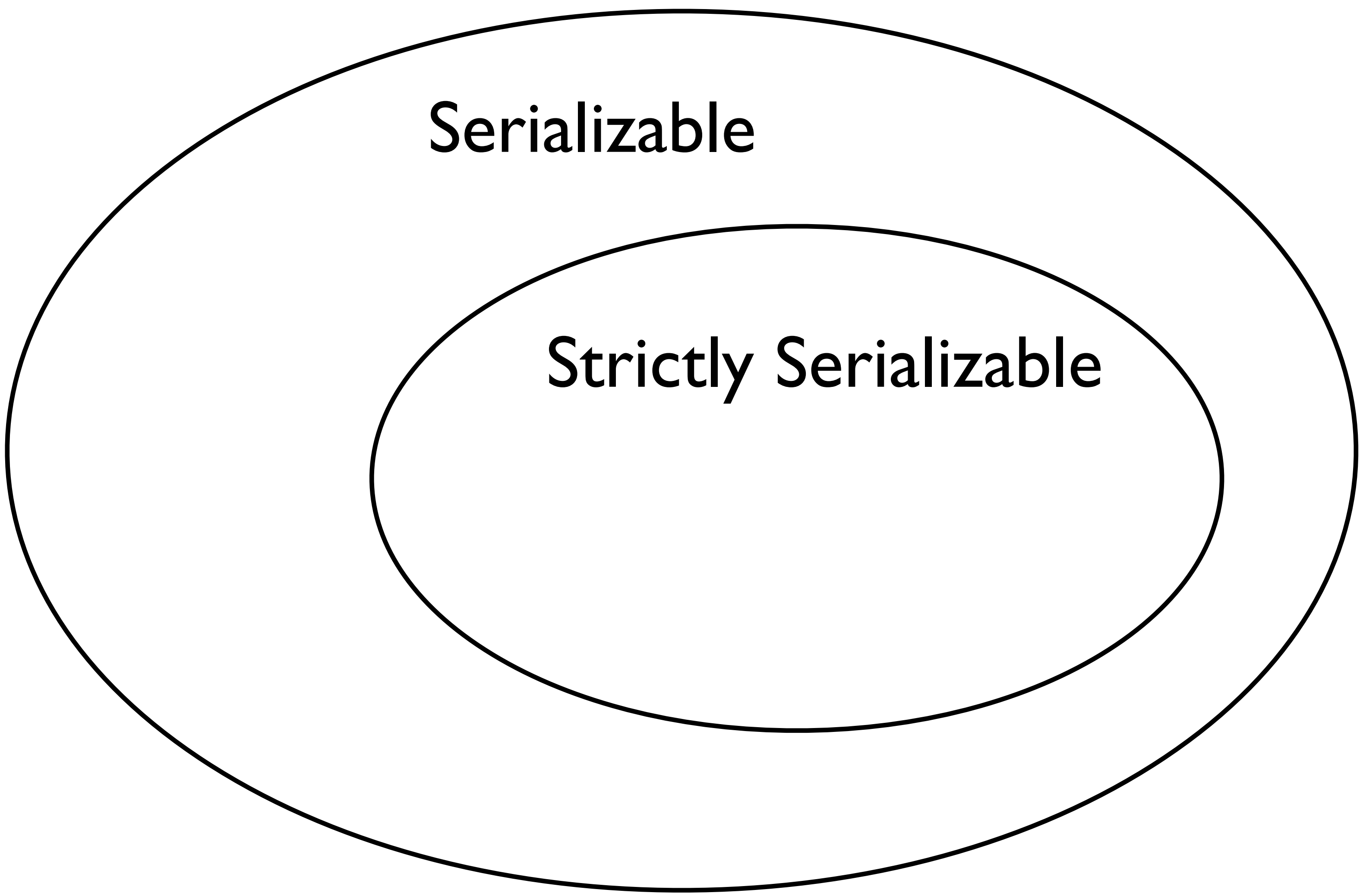

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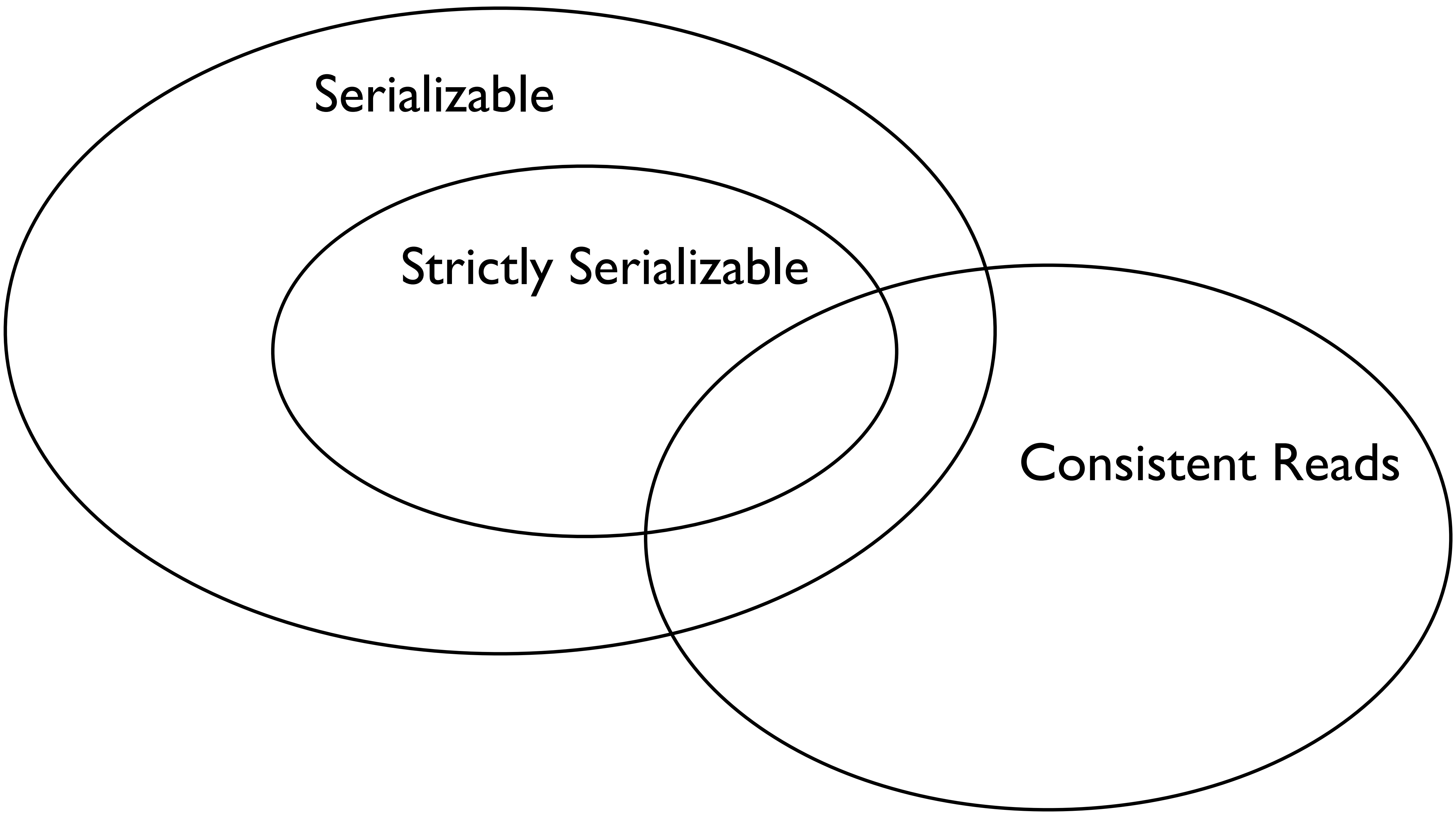

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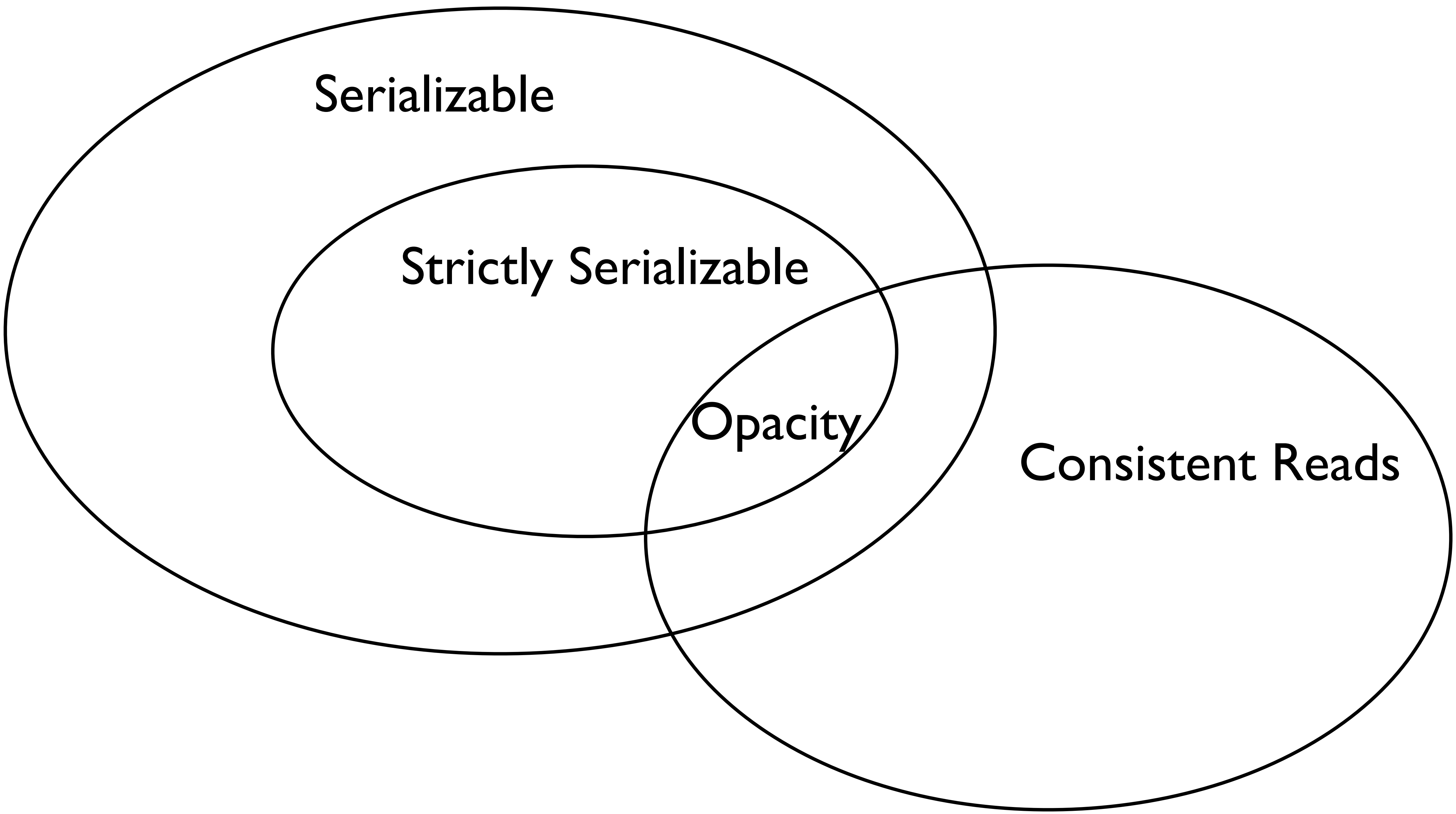

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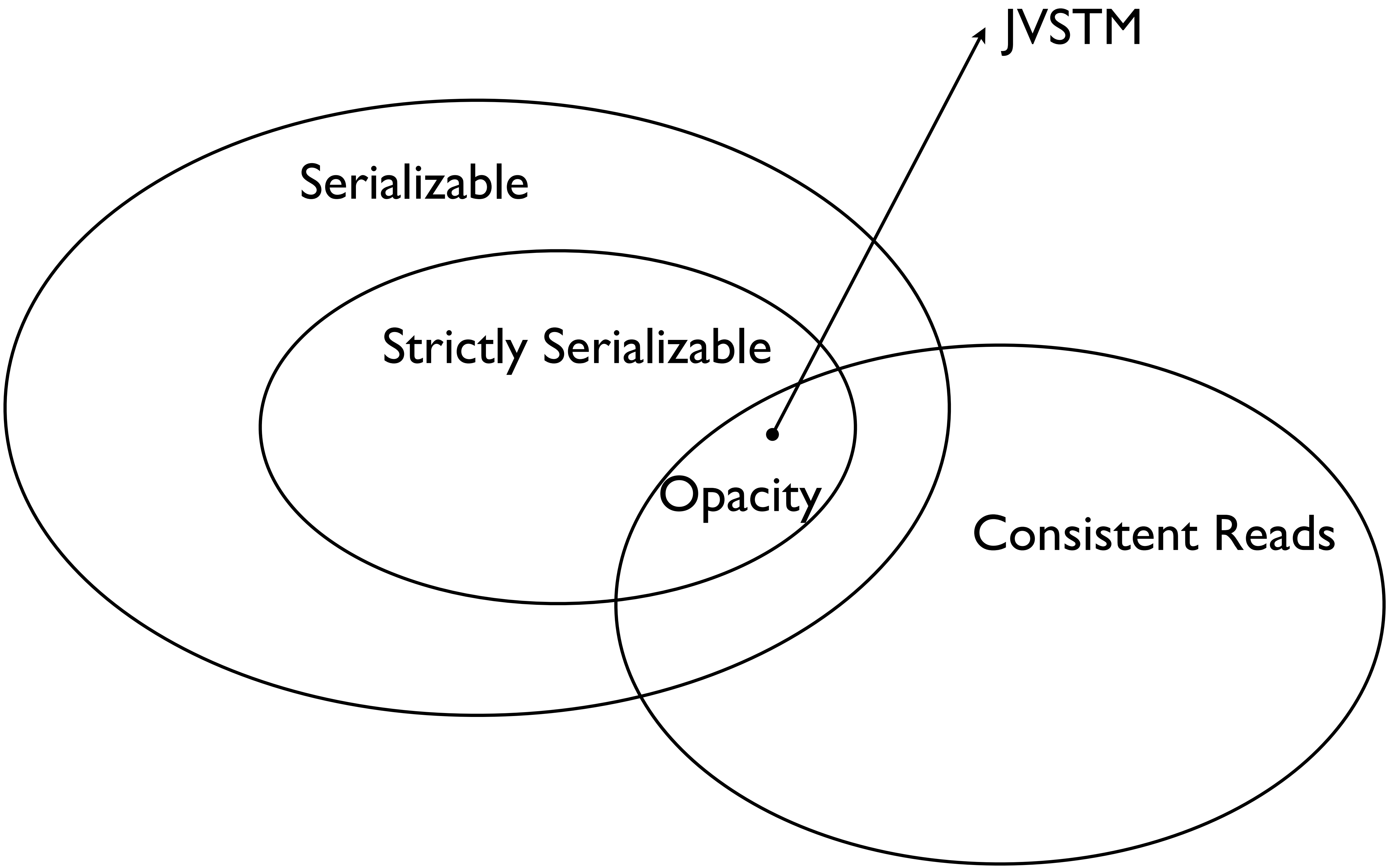

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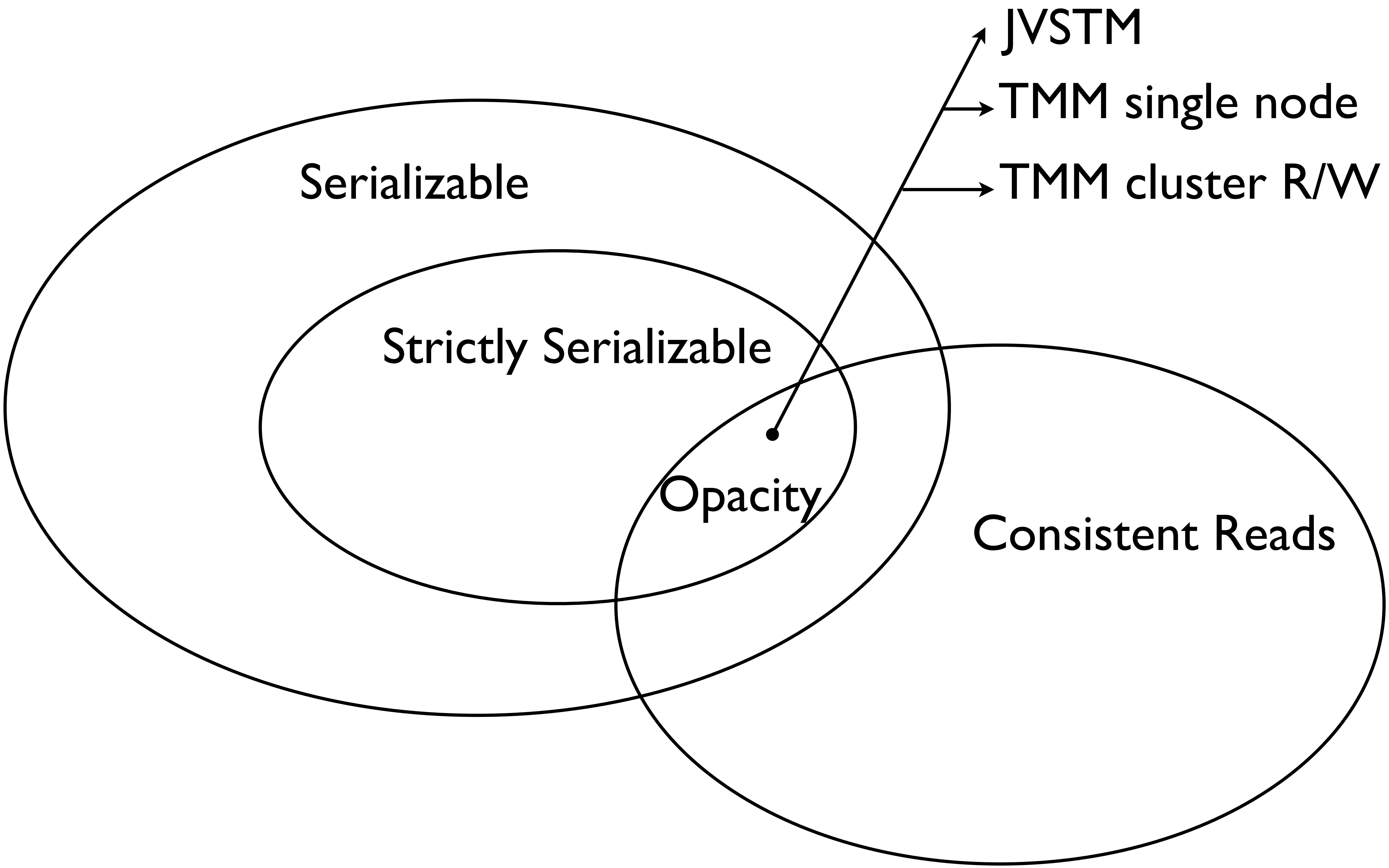

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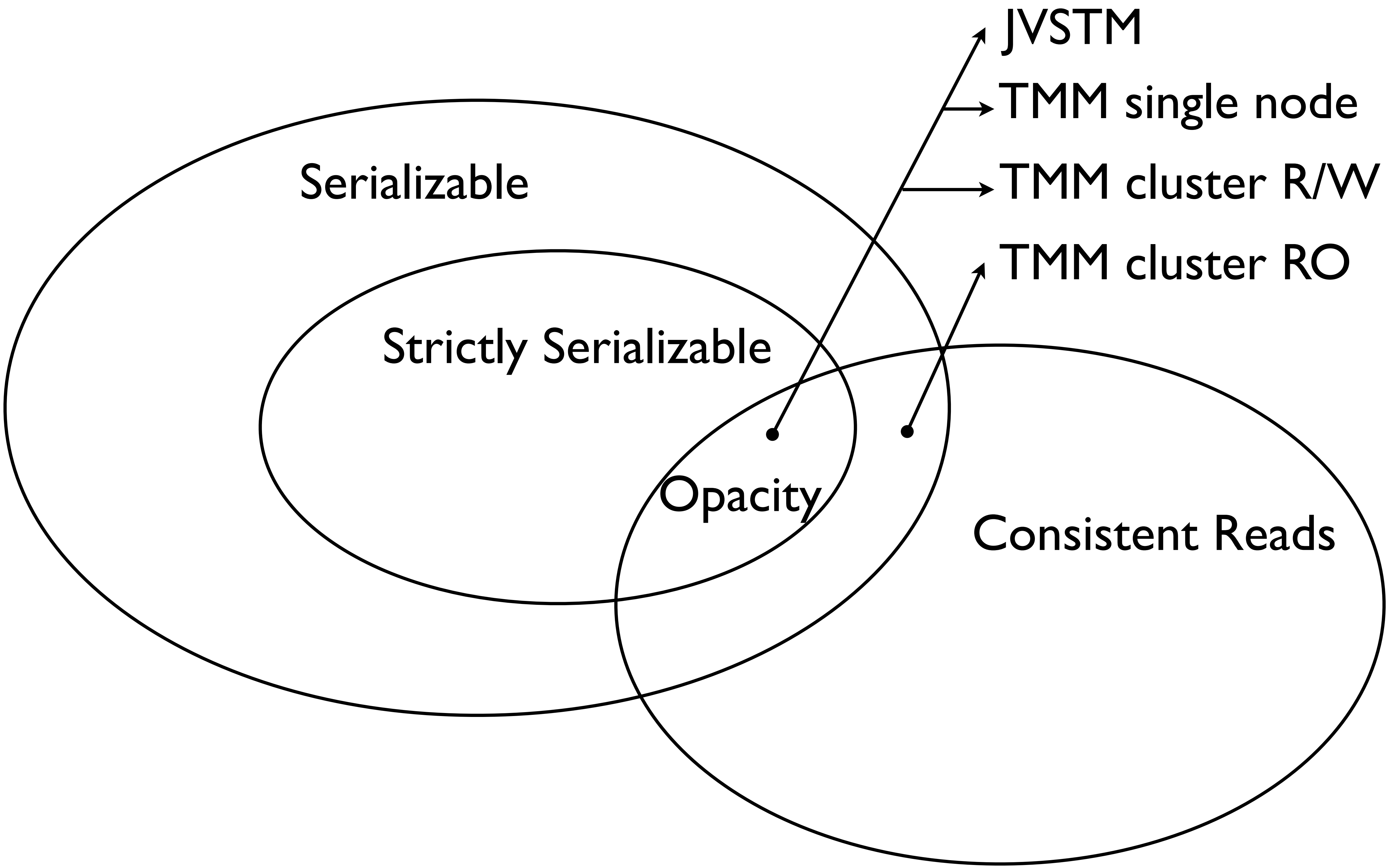

Evaluation

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- RadarGun

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- Single node
- Cluster: 2 to 12 nodes

Results

Results

- Outstanding single-node performance

    From 2x to 100x faster

Results

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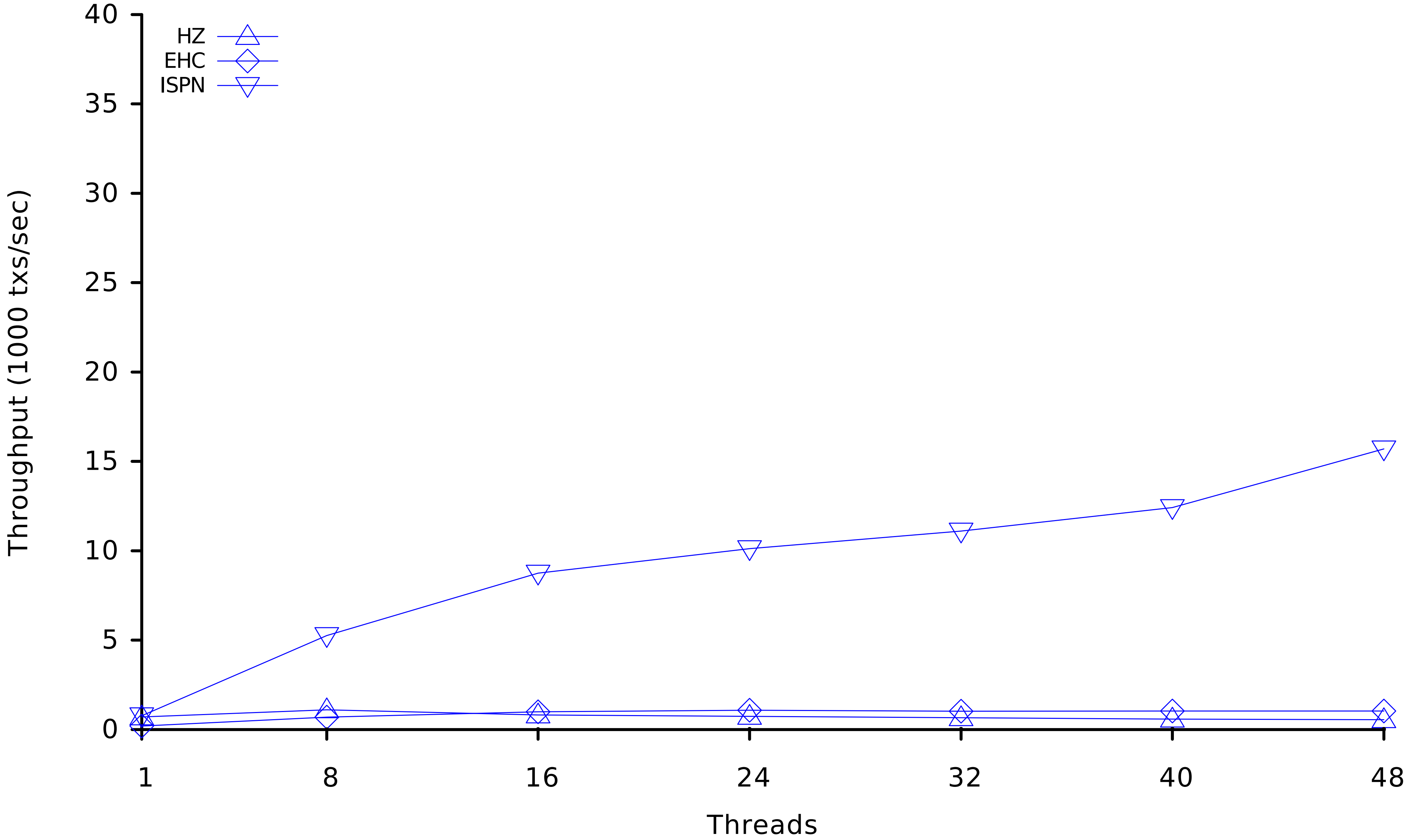
  From 2x to 100x faster

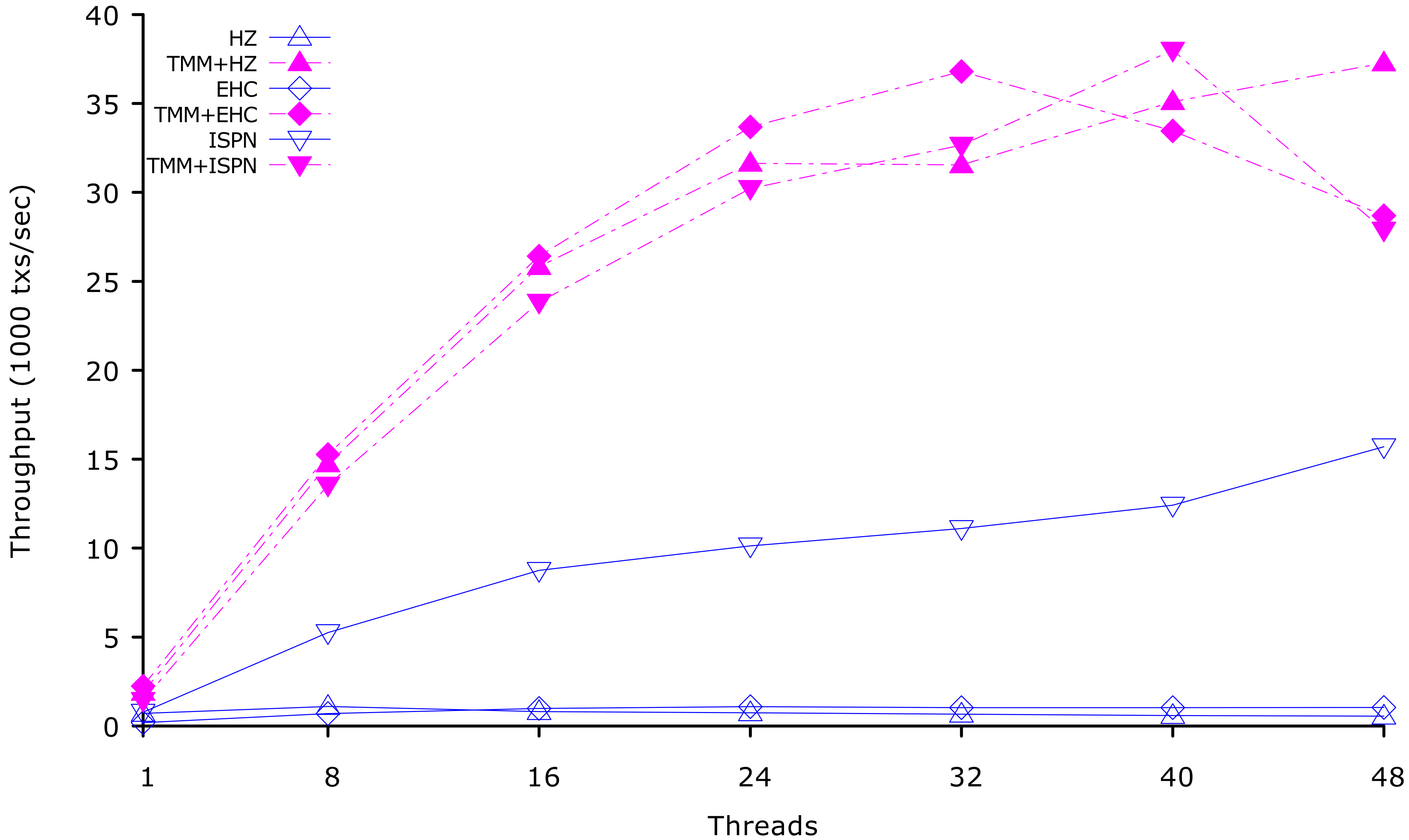
- Poor scalability in cluster

Results (Single node)



Results (Single node)

TMM vs. TDGs



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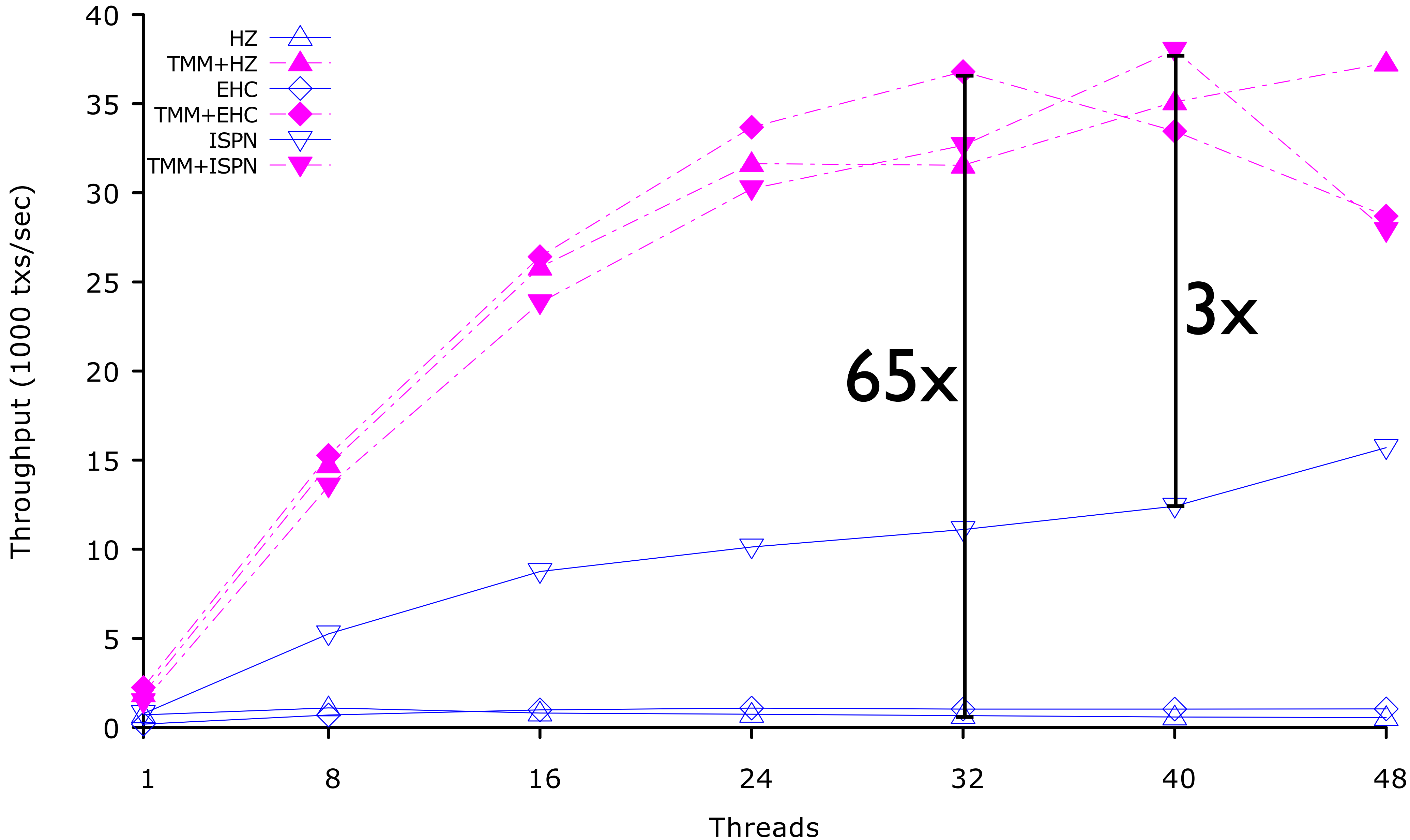
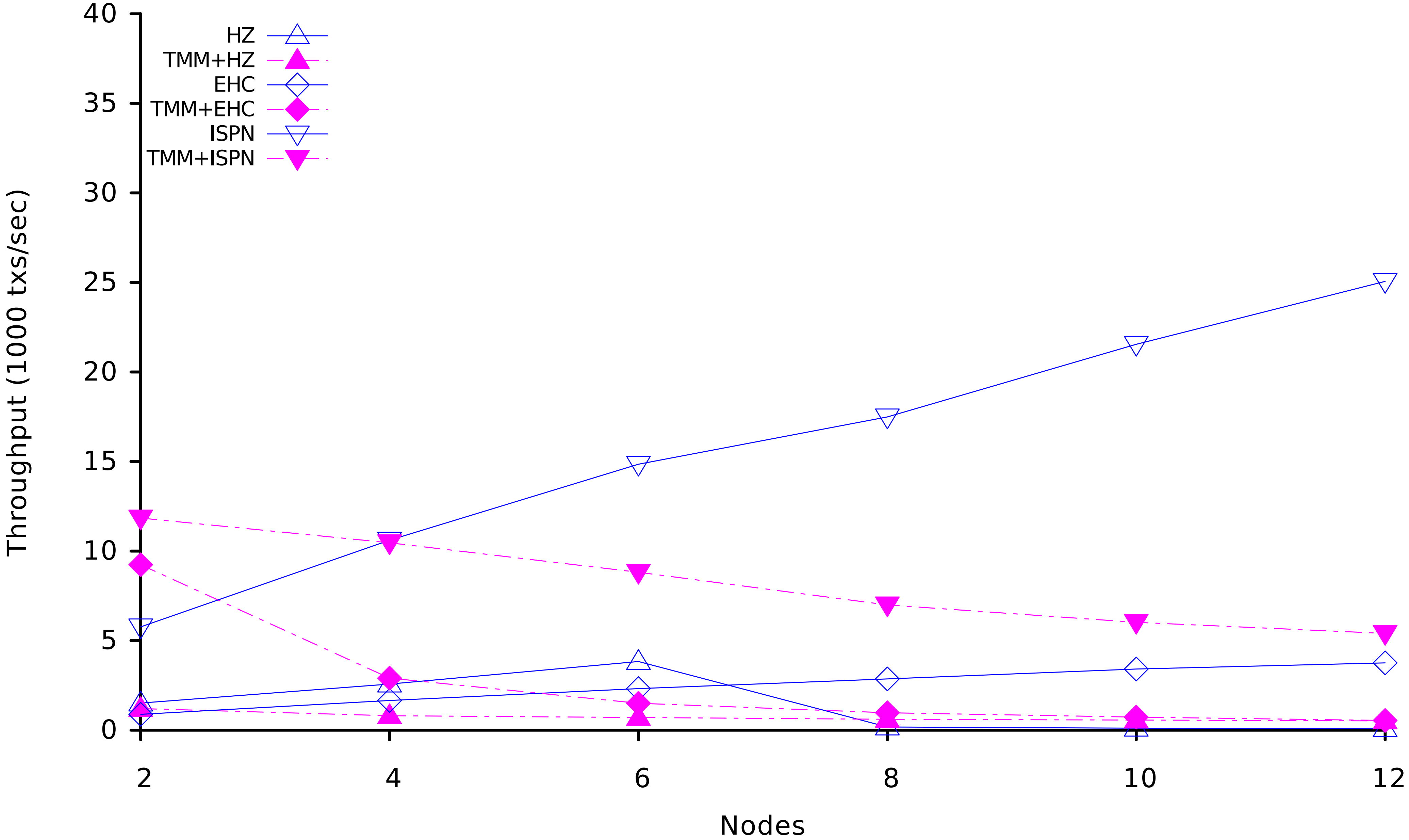


Results (Clustered)



Scalability Bottleneck

Coarse Locks Do Not Scale

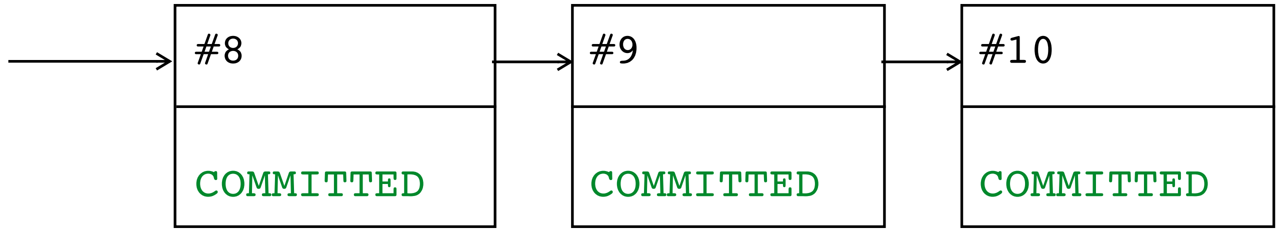
Lock-free Commit Design

Lock-free Commit Design

- Preserve original stages

Lock-free Commit Design

- Concurrent validation



Lock-free Commit Design

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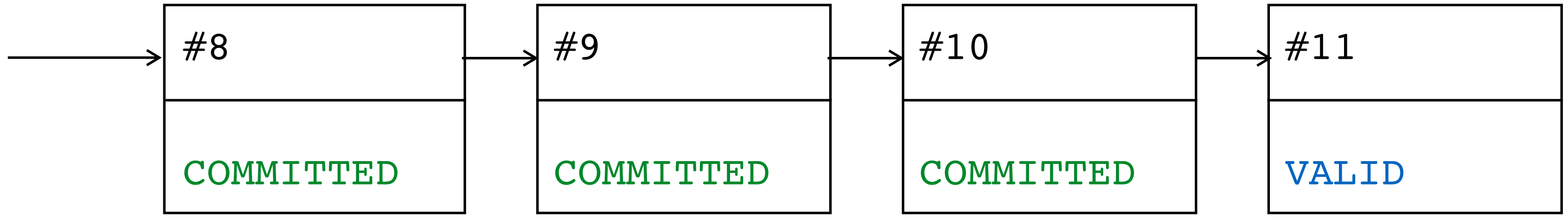

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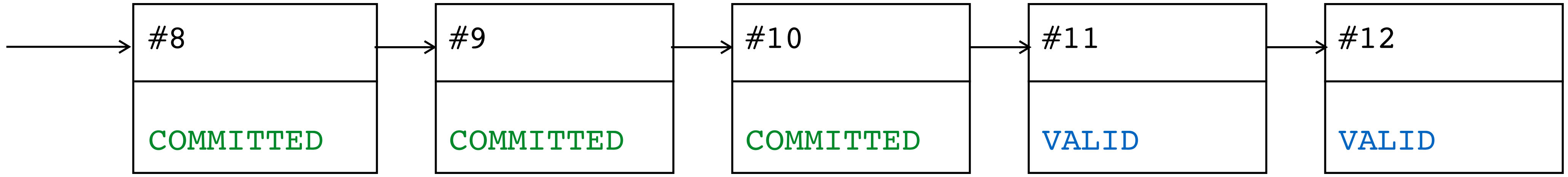

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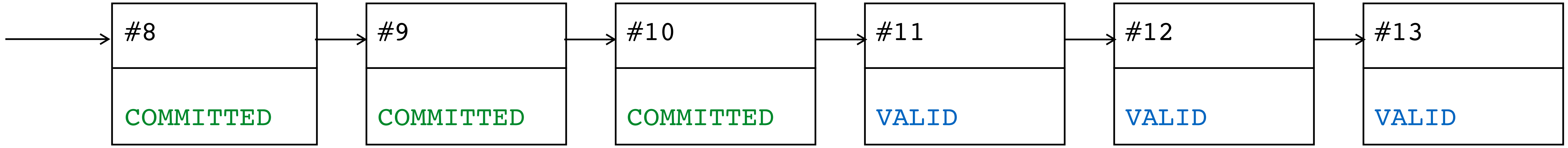

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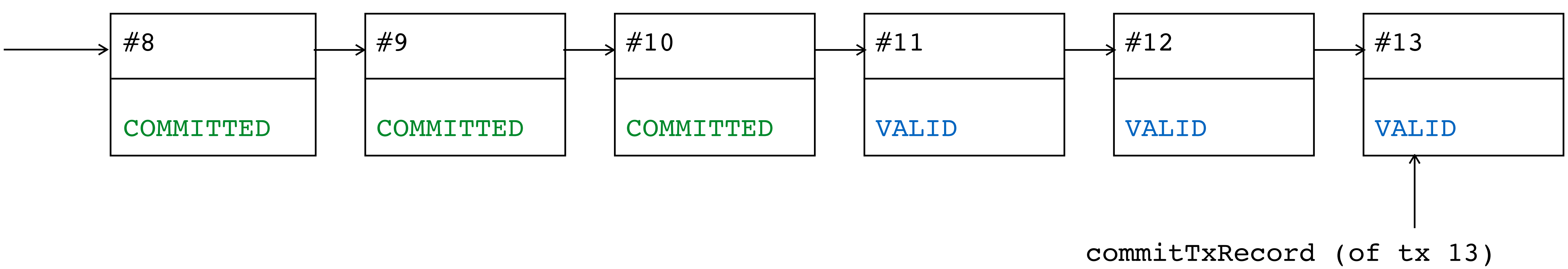
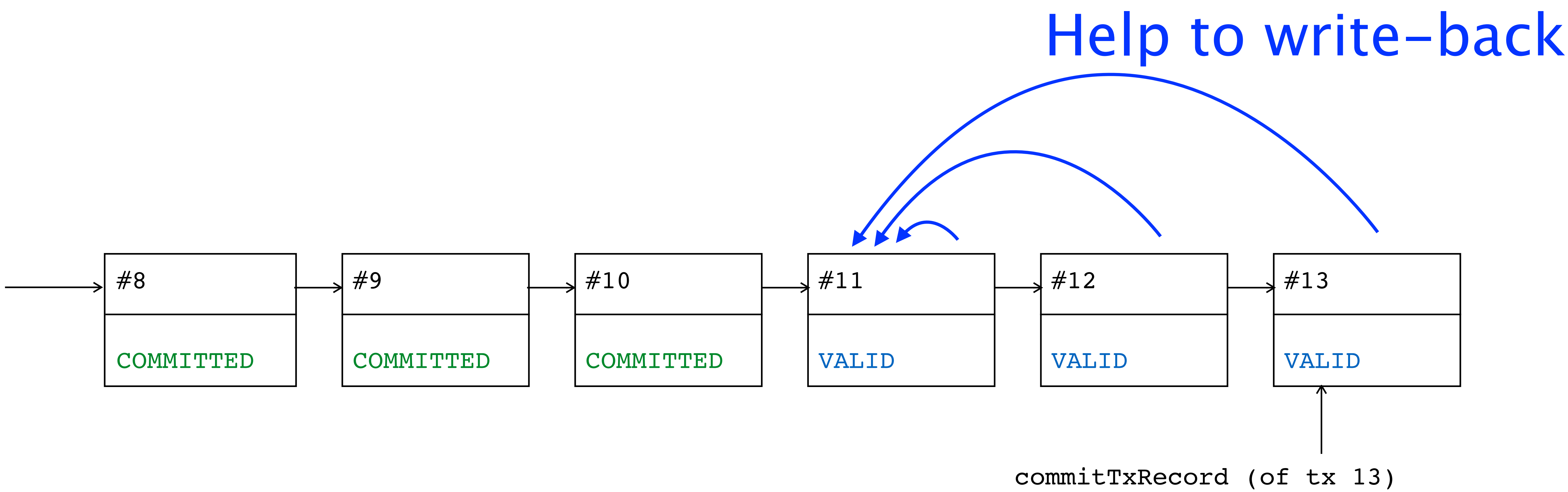


Lock-free Commit Design

- Thread helping



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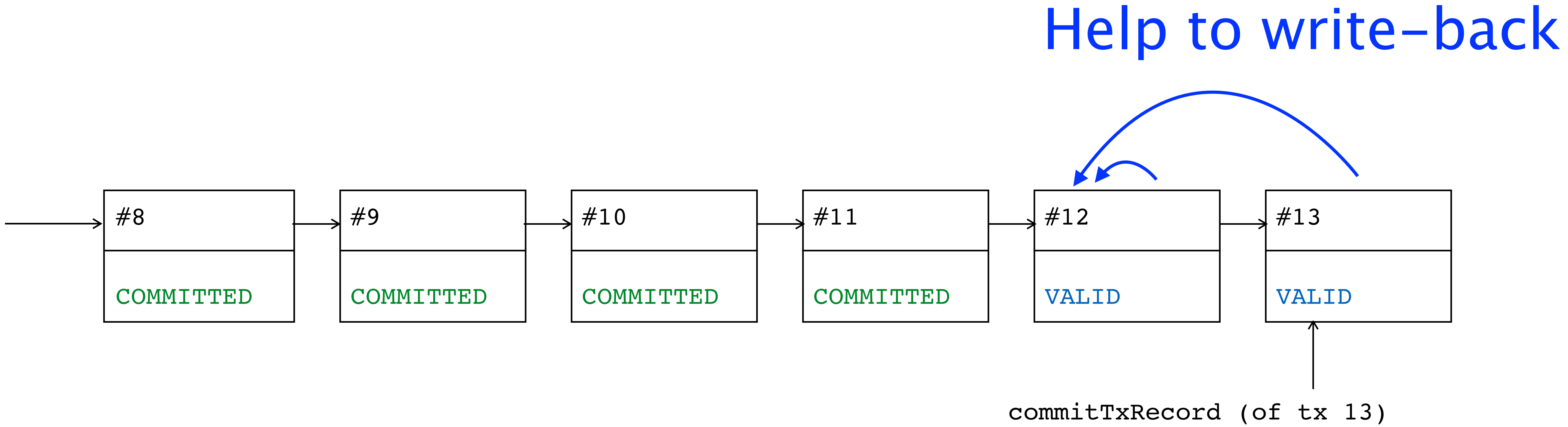

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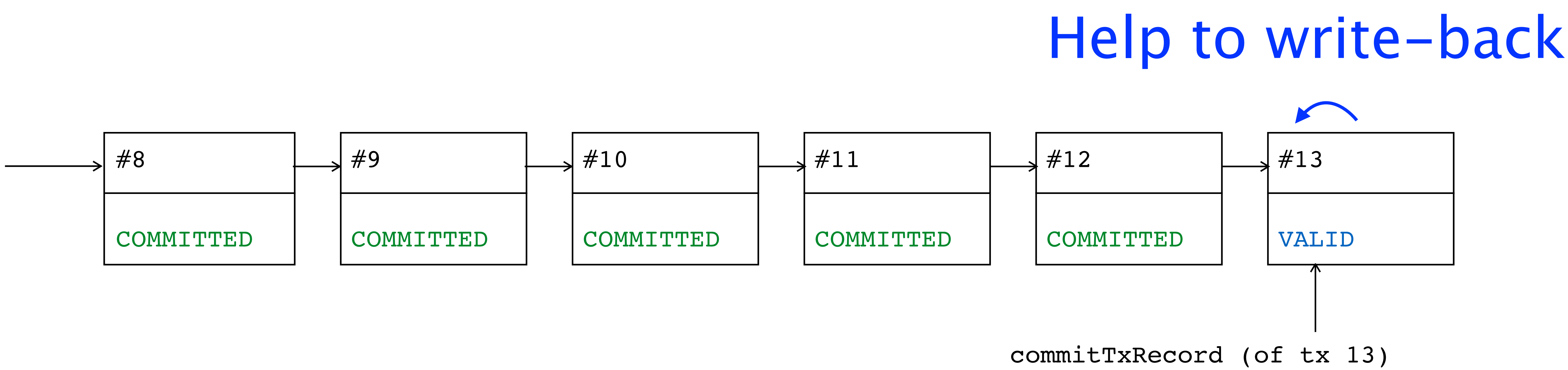

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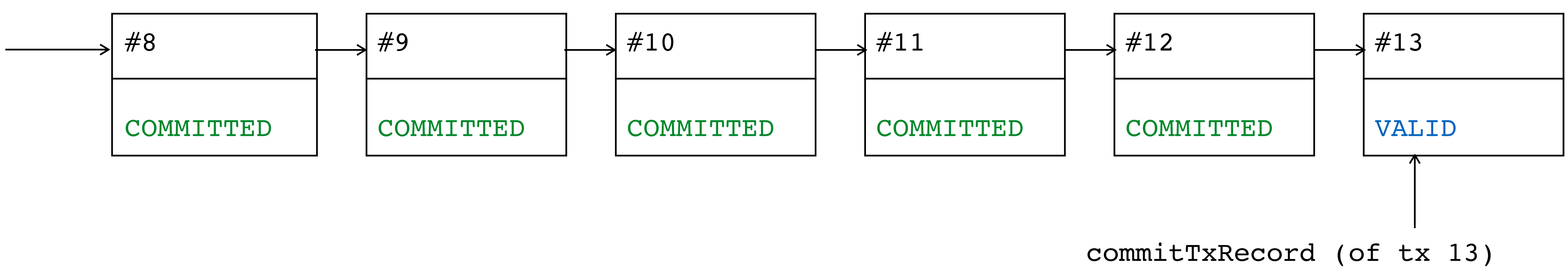
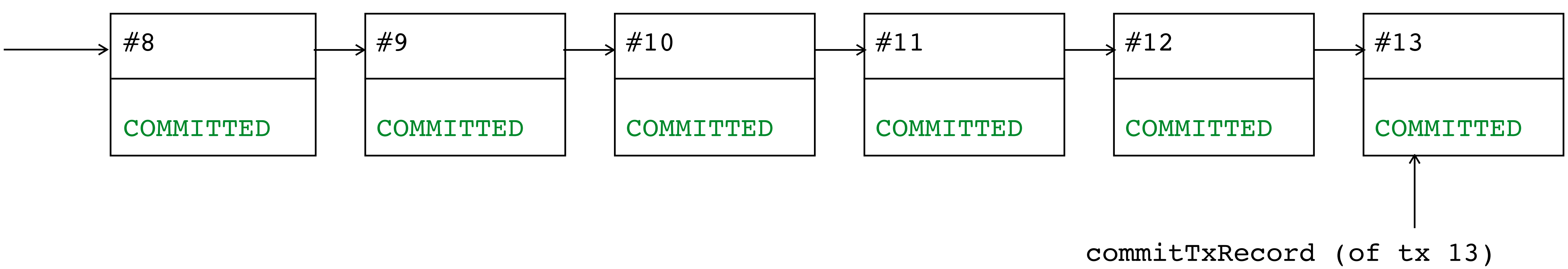


Lock-free Commit Design

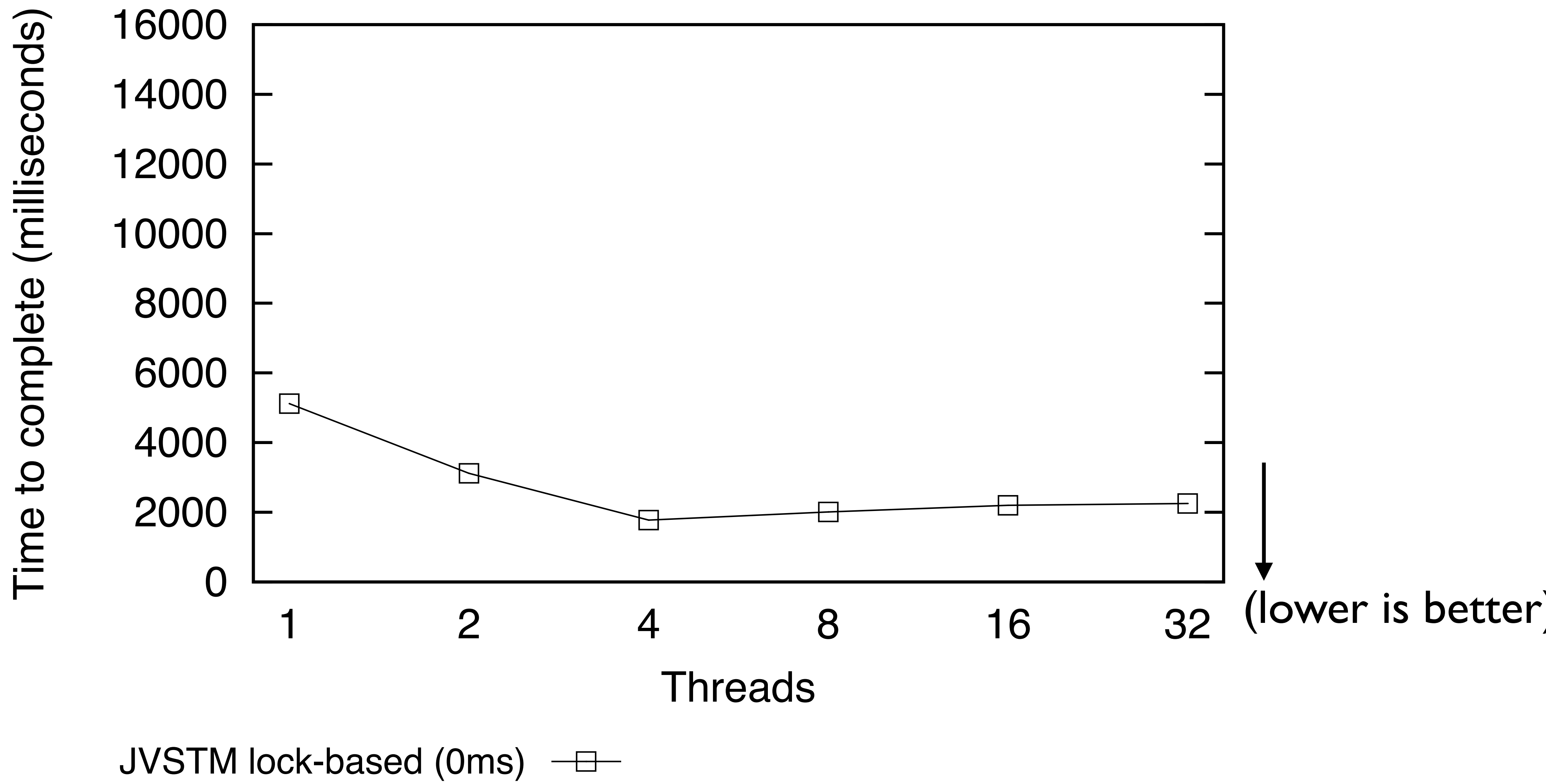
- Linearization point



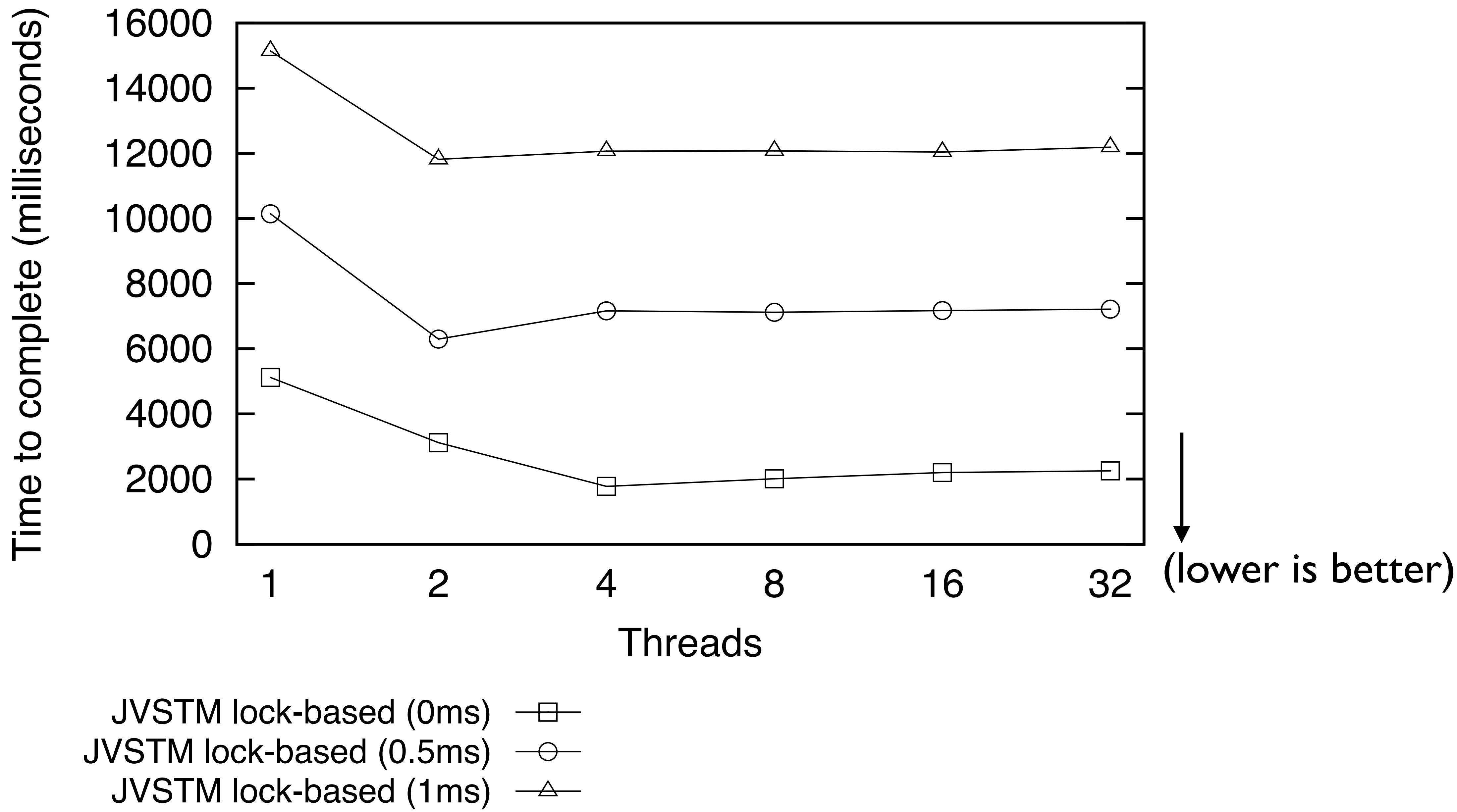
Results

- Full lock-free STM
- Reads unaffected
- More complex algorithm
- Scalable design
- Comparable with top-performing STMs

Results


Time to complete (milliseconds)
16000
14000
12000
10000
8000
6000
4000
2000
0
1
2
4
8
16
32
Threads
(lower is better)
JVSTM lock-based (0ms)

Results



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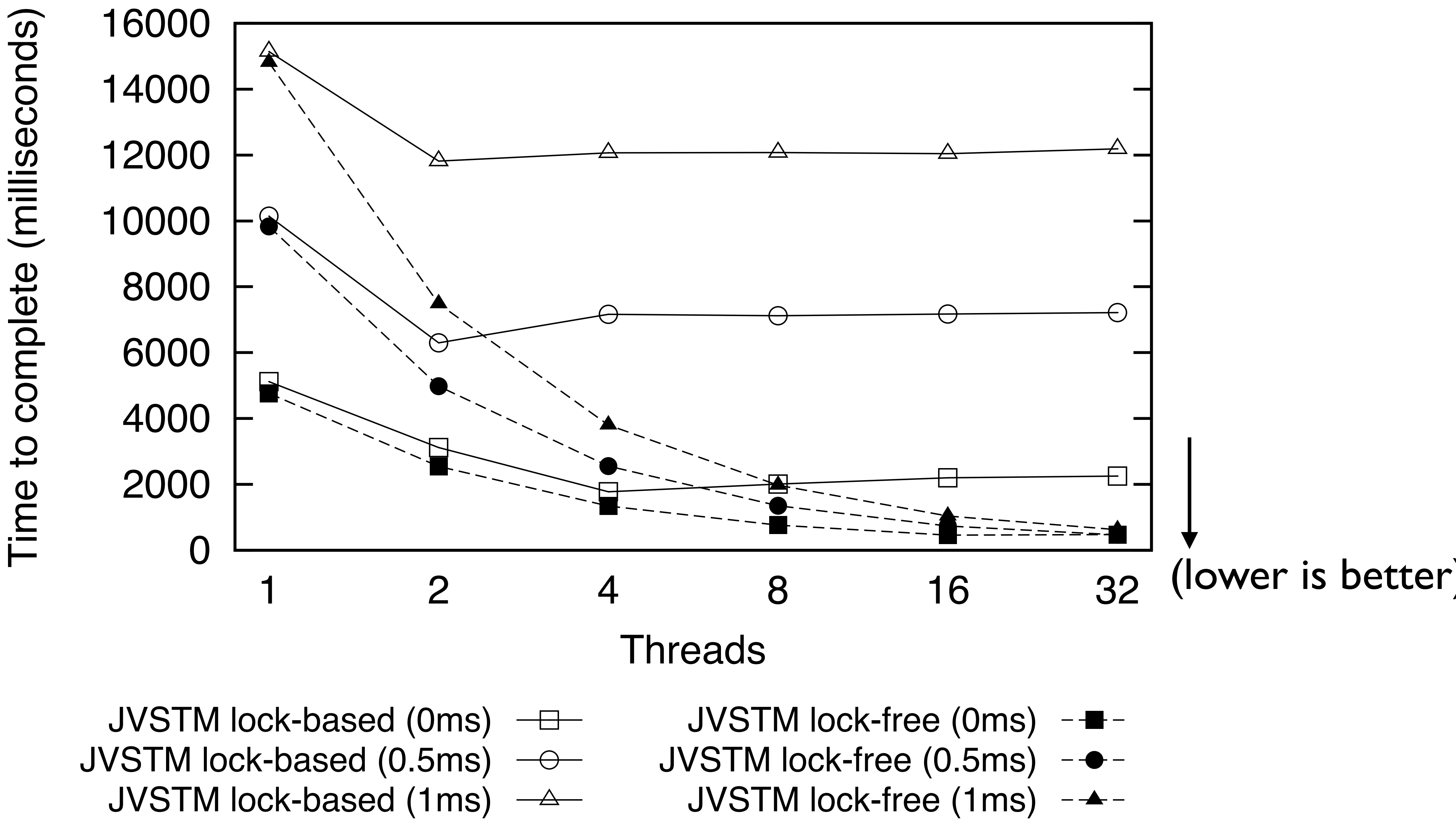
JVSTM lock-based (0ms)
JVSTM lock-based (0.5ms)
JVSTM lock-based (1ms)

Results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JVSTM lock-based (0ms)
JVSTM lock-based (0.5ms)
JVSTM lock-based (1ms)
JVSTM lock-free (0ms)
JVSTM lock-free (0.5ms)
JVSTM lock-free (1ms)

Nonblocking TMM

= TMM + LF JVSTM

NbTMM: Goals

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- Improve clustered performance

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- Preserve TMM's properties

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- Nonblocking algorithms only

NbTMM: Goals

- Improve clustered performance
- Preserve TMM's properties
- Nonblocking algorithms only
- Minimize communication costs

NbTMM: Design highlights

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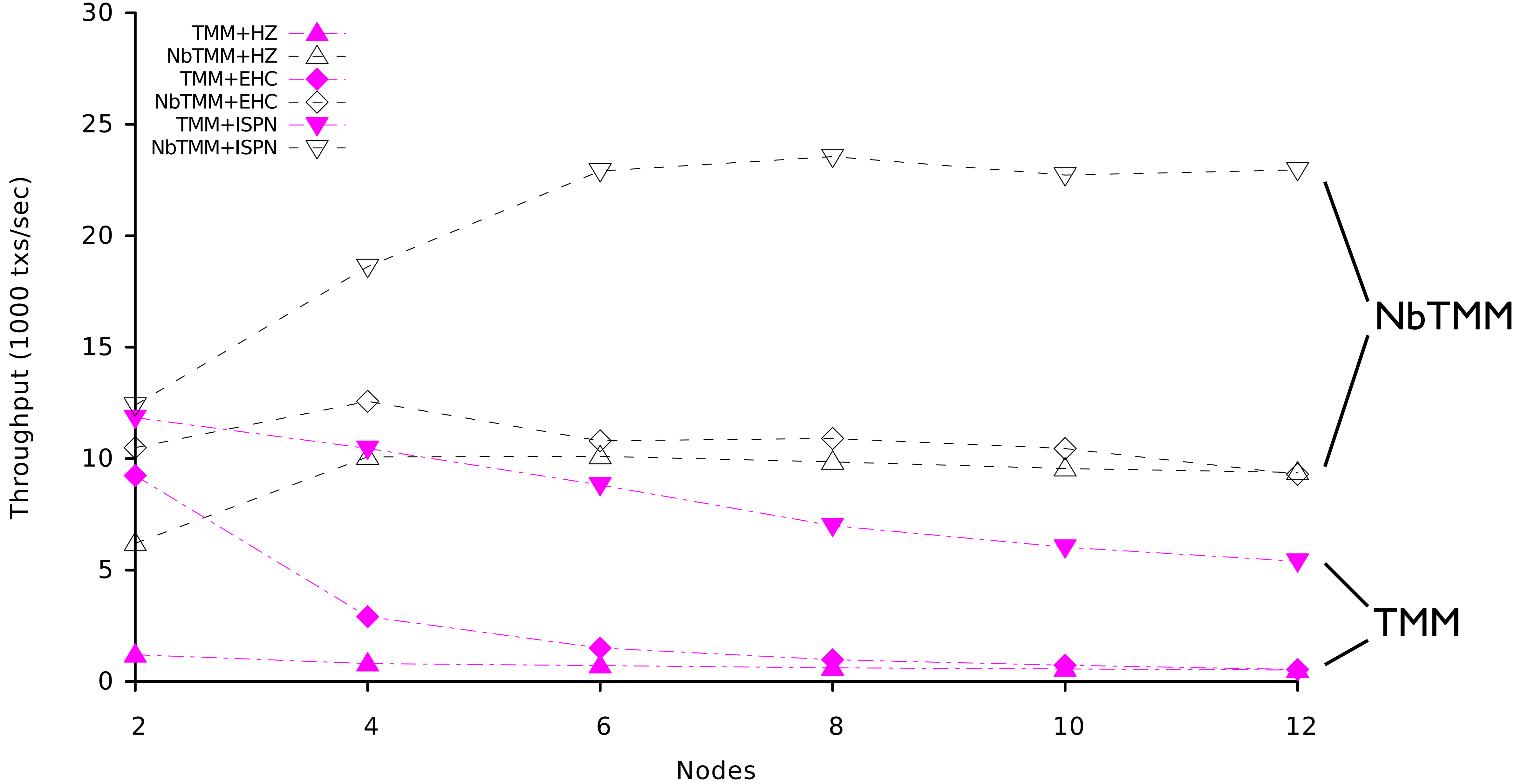
- Read set not shared
- Only persist write set once
- Unique write set keys
- Immutable data mappings
- Broadcast commit intentions
- Deterministic, independent commit decision

Results (Clustered)

TMM vs. NbTMM

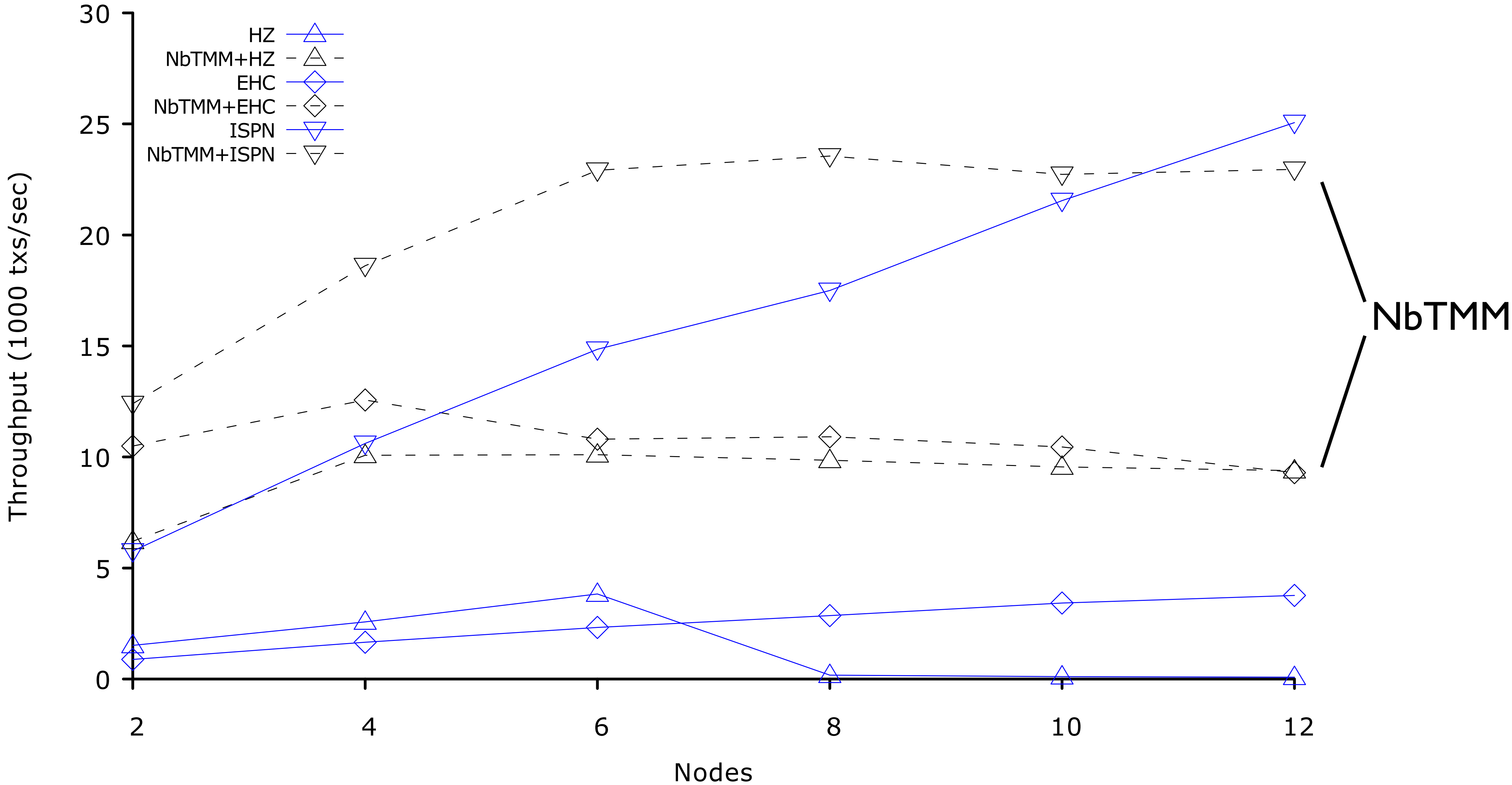
Results (Clustered)

TMM vs. NbTMM



Results (Clustered)

NbTMM vs. TDGs



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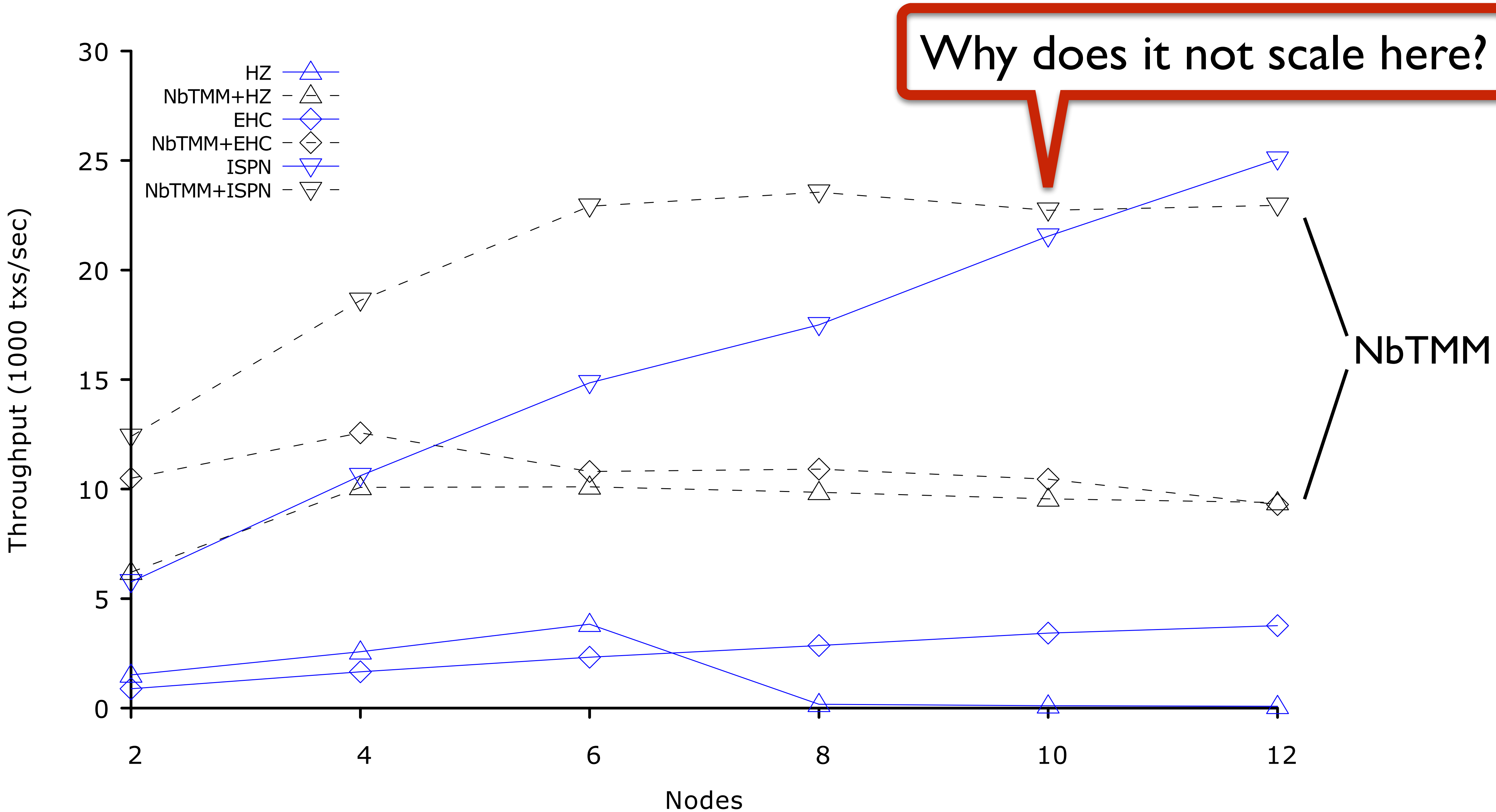
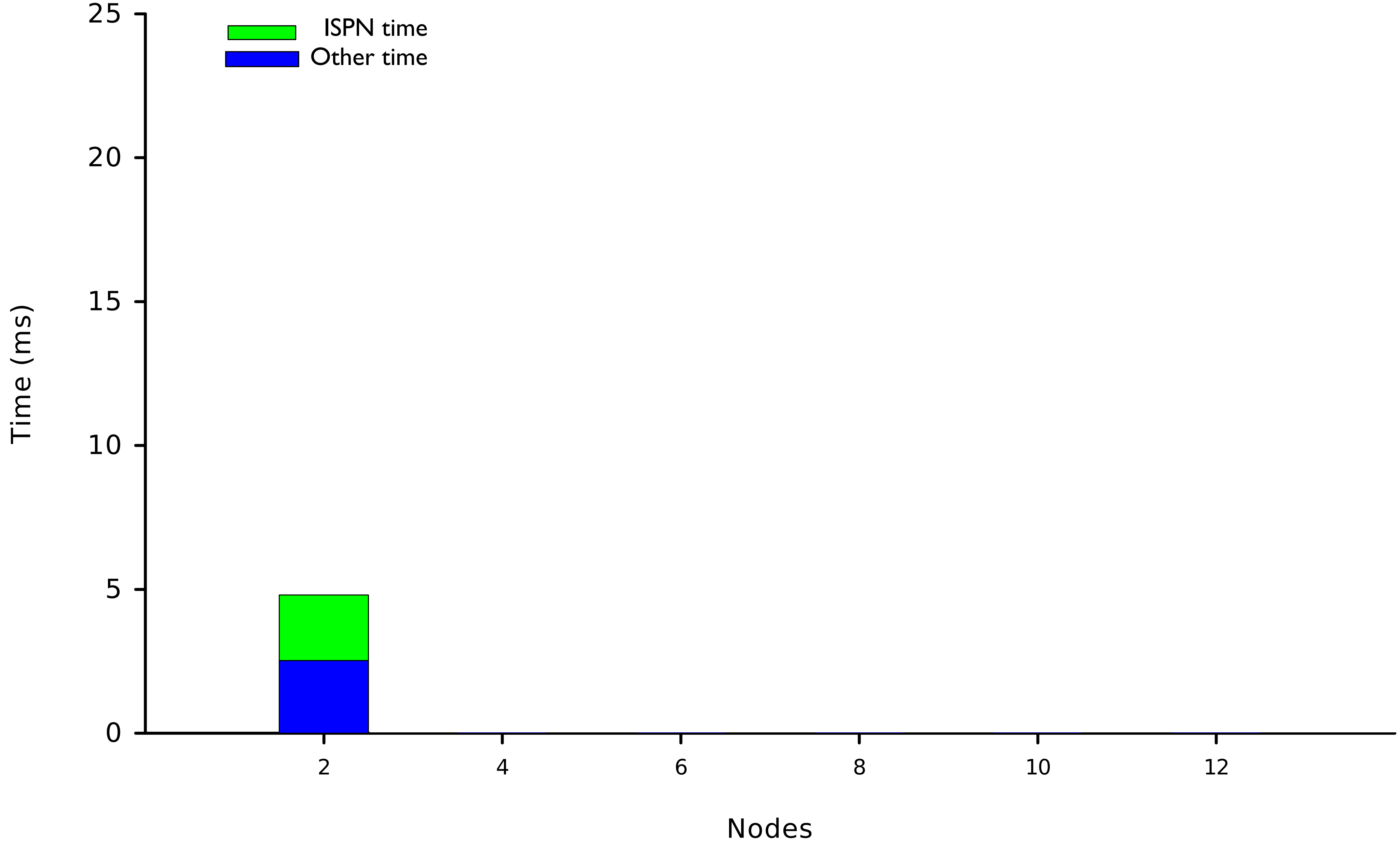
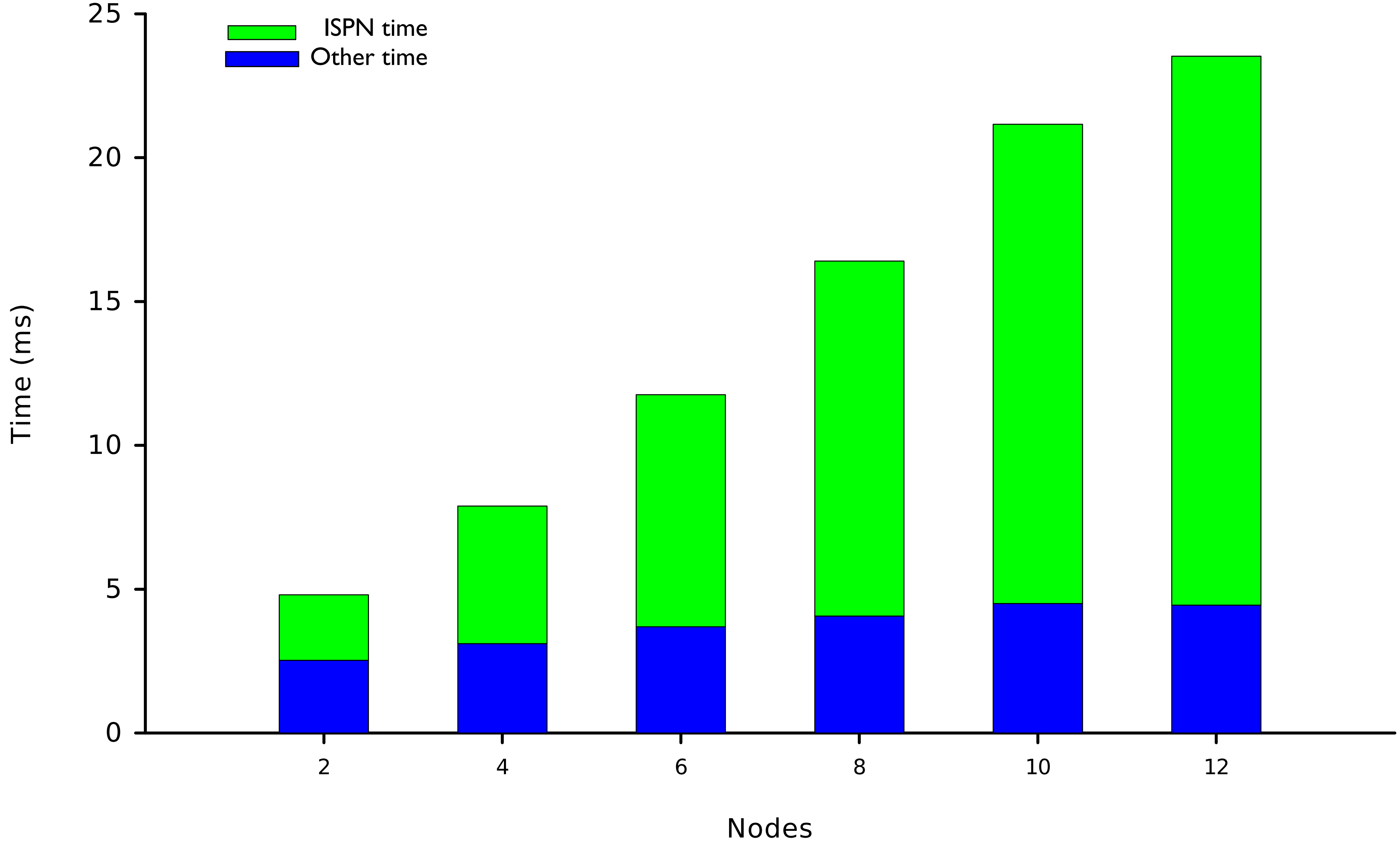


Results (Clustered)
Avg. Commit Time

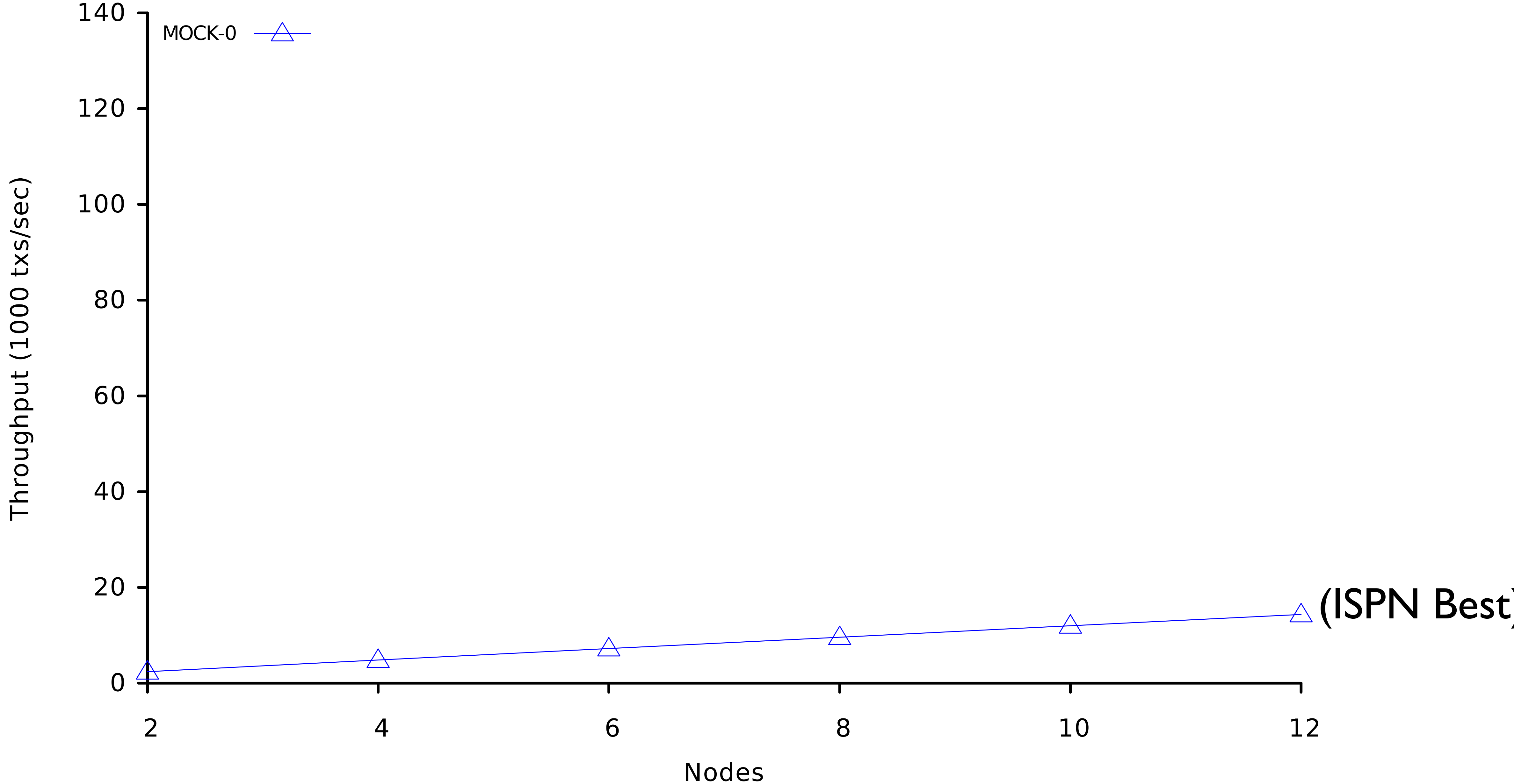


Results (Clustered)

Avg. Commit Time



Results (Clustered)
Simulated ISPN



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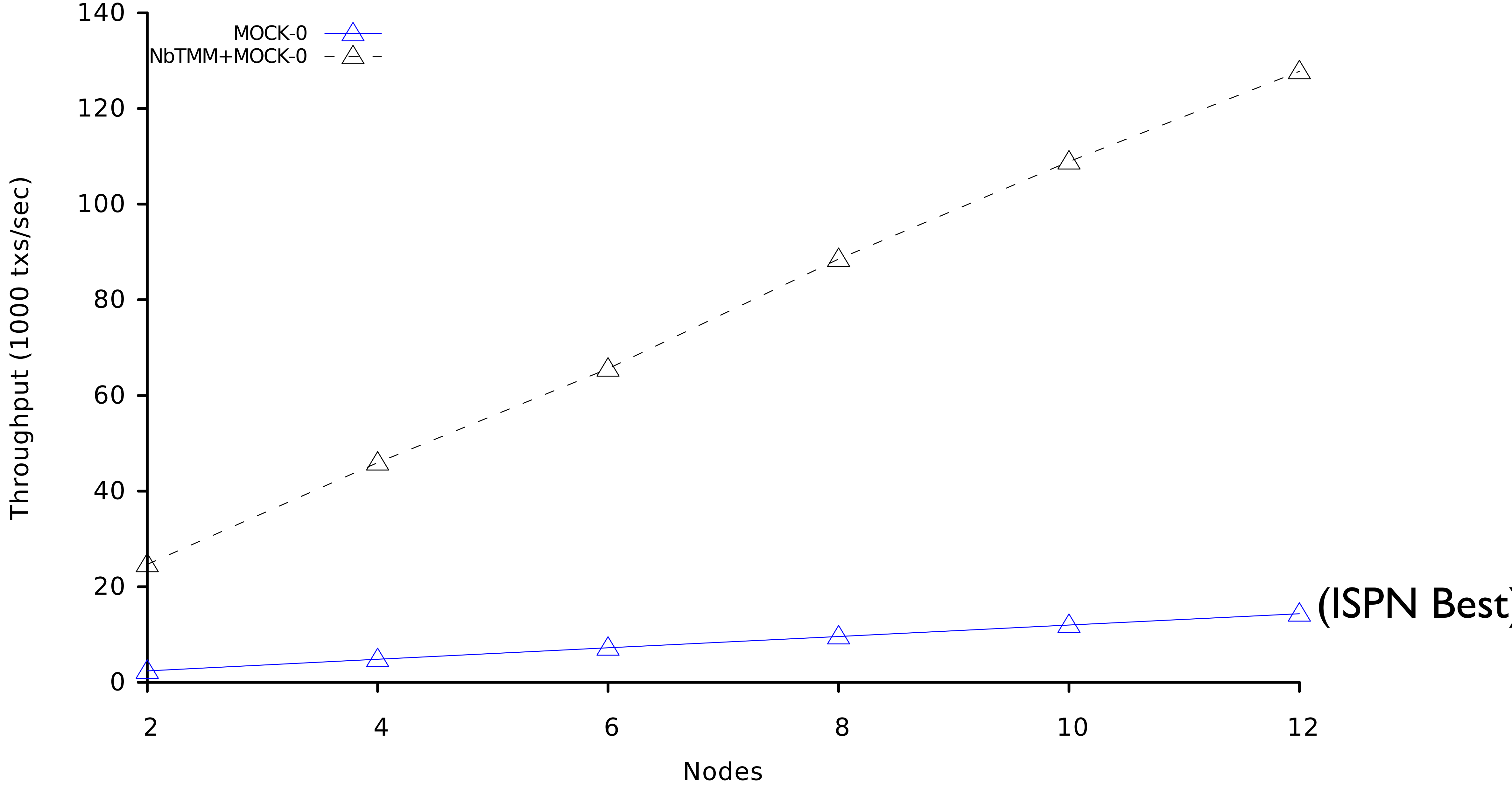

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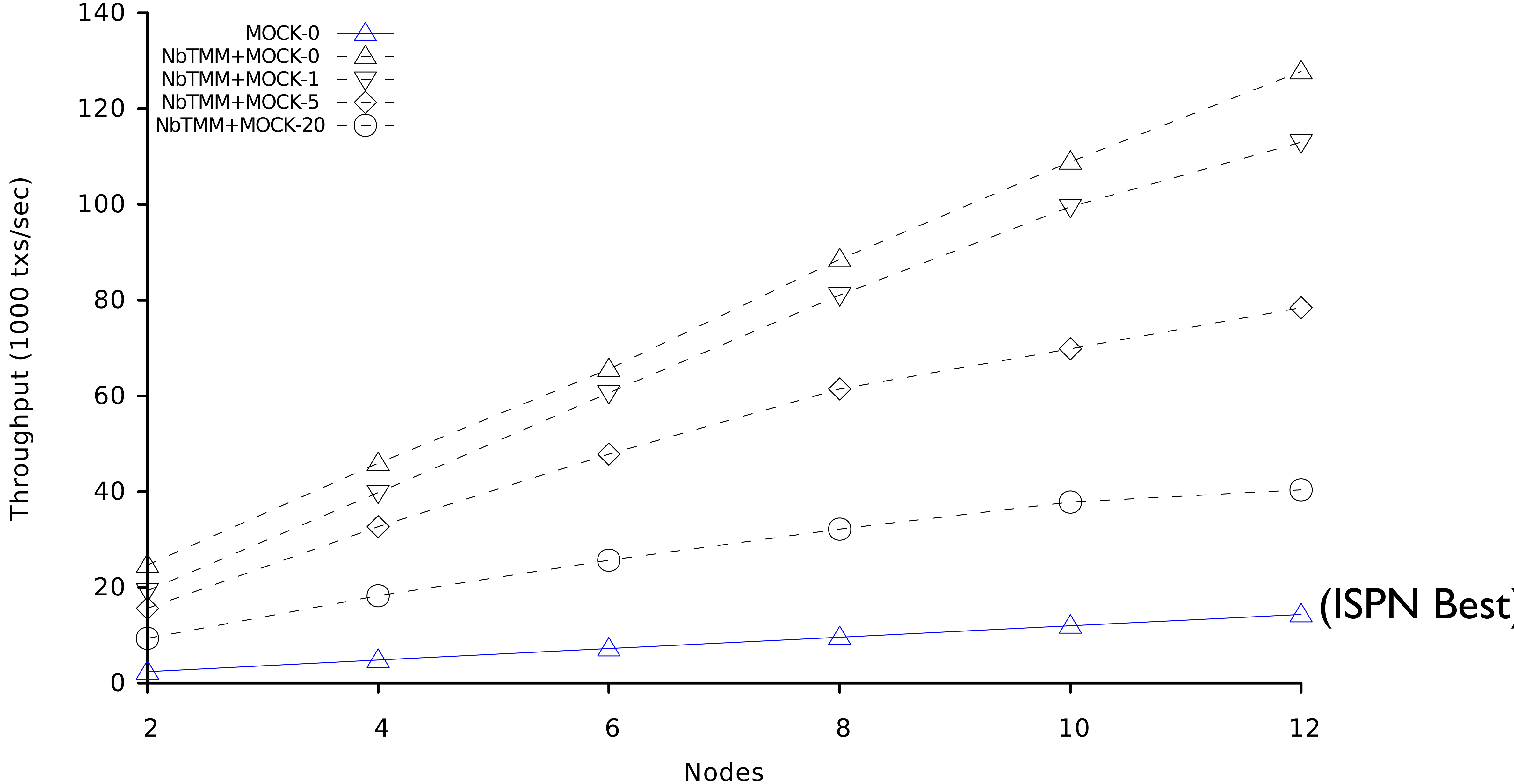

Main Contributions

Design and implementation of:

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- Efficient lock-free multi-version STM

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- Transactional middleware for enterprise applications based on STM
- Efficient lock-free multi-version STM
- NbTMM alternative to TMM using nonblocking algorithms

Publications

- **<u>Sérgio Fernandes</u>** and João Cachopo. *A scalable and efficient commit algorithm for the JVSTM*. 5th ACM SIGPLAN Workshop on Transactional Computing, April 2010.
- **<u>Sérgio Fernandes</u>** and João Cachopo. *Lock-free and scalable multi-version Software Transactional Memory*. 16th ACM SIGPLAN Annual Symposium on Principles and Practice of Parallel Programming, 179-188, February 2011.
- **<u>Sérgio Fernandes</u>** and João Cachopo. *Strict Serializability is Harmless: A New Architecture for Enterprise Applications*. SPLASH Wavefront 2011, Portland, Oregon, USA, October 2011.
- Jorge Martins, João Pereira, **<u>Sérgio Fernandes</u>** and João Cachopo. *Towards a simple programming model in Cloud Computing platforms*. IEEE First Symposium on Network Cloud Computing and Applications , Toulouse, France, 83-90, November 2011.
- Nuno Diegues, **<u>Sérgio Fernandes</u>** and João Cachopo. *Parallel nesting in a lock-free multi-version Software Transactional Memory*. 7th ACM SIGPLAN Workshop on Transactional Computing, February 2012.

Strongly Consistent Transactions for Enterprise Applications

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Thank You!