On the Viability of Speculative Transactional Replication in Database Systems: a Case Study with PostgreSQL

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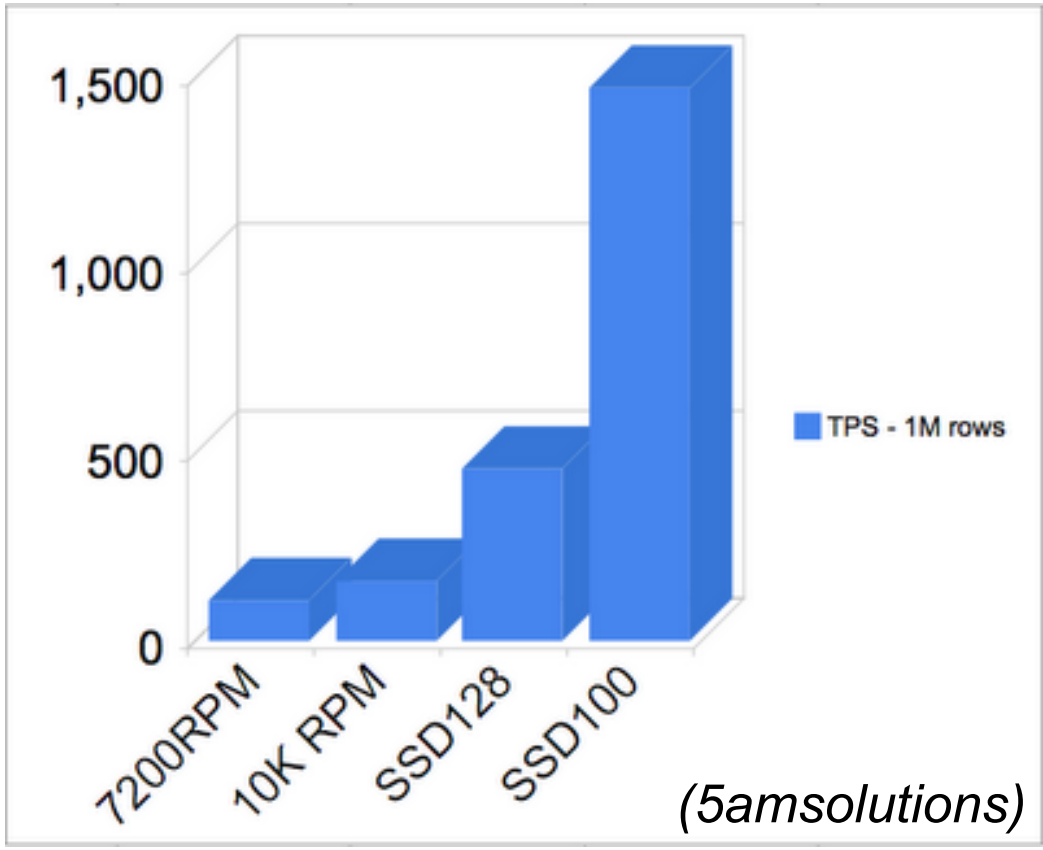
The 12th IEEE International Symposium on Network Computing and Applications (IEEE NCA13)

Solid State Drives (SSDs)

A data storage device that uses solid-state memory to persist data

- PostgreSQL benchmark over one million rows
- SSD
  - 1472 TPS = 679,35 µsec/Tx
- HHD (10K RPM)
  - 23 TPS = 43,47 msec/Tx



Context

- Fault tolerance is a desirable property of transactional systems
- Replication is the typical mean
- Replication protocol suited for distributed transactional systems relying on:
  - Active Replication, as a paradigm for coordinating replicas;
  - Speculative processing, for boosting local processing.

Why Active Replication?

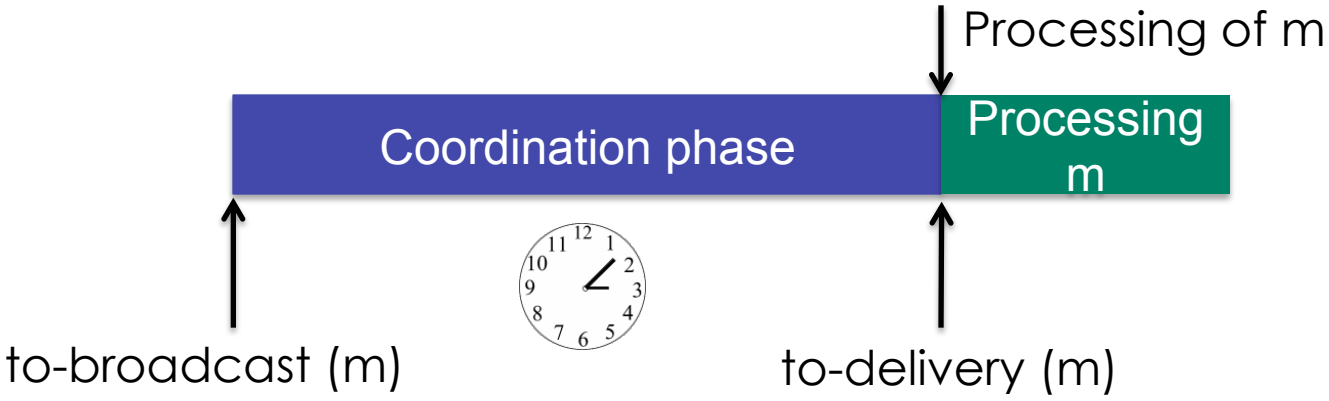
- Each replica keeps all shared data and executes the same transactions in the same order
- PRO (+)
  - Full failure masking
  - No coordination for read-only transactions
  - No communication during transaction processing
  - Prone to target performance issues
- CONS (-)
  - Agreement on common execution order
  - Deterministic business logic

Why Speculative Processing?

- A way to exploit as much as possible available resources (tailored for multicore architectures)
- A mean of anticipating work filling waiting periods

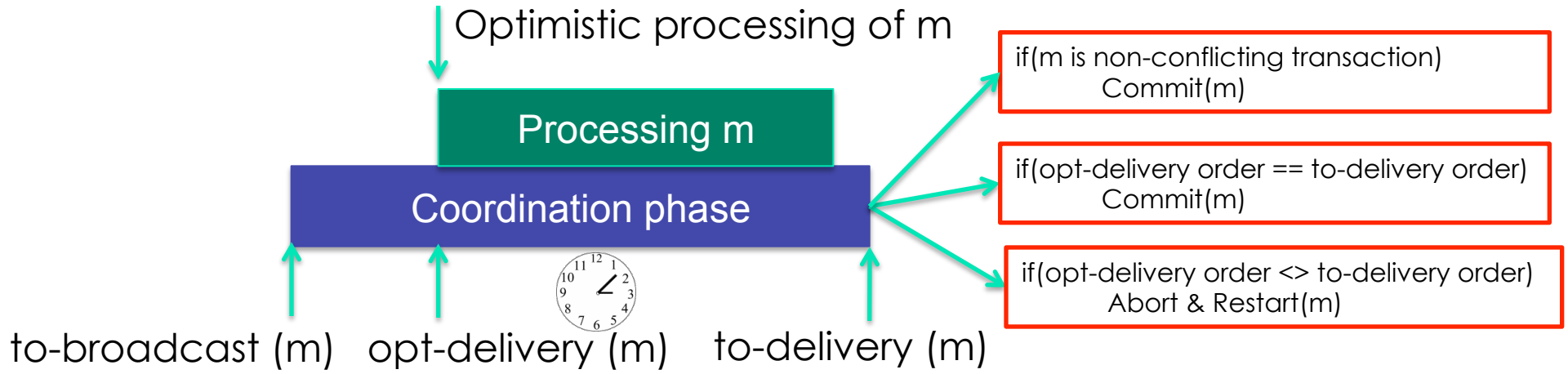
State Machine Approach (SM)

- Implements Active Replication paradigm
- Based on Atomic Broadcast as group communication system
- Does not exploit any kind of optimism



Optimistic Approach (OPT)

- Based on Optimistic Atomic Broadcast as a group communication system
- It processes in optimistic manner:
  - At most one conflicting transaction
  - Any non-conflicting transactions



Limited Overlapping

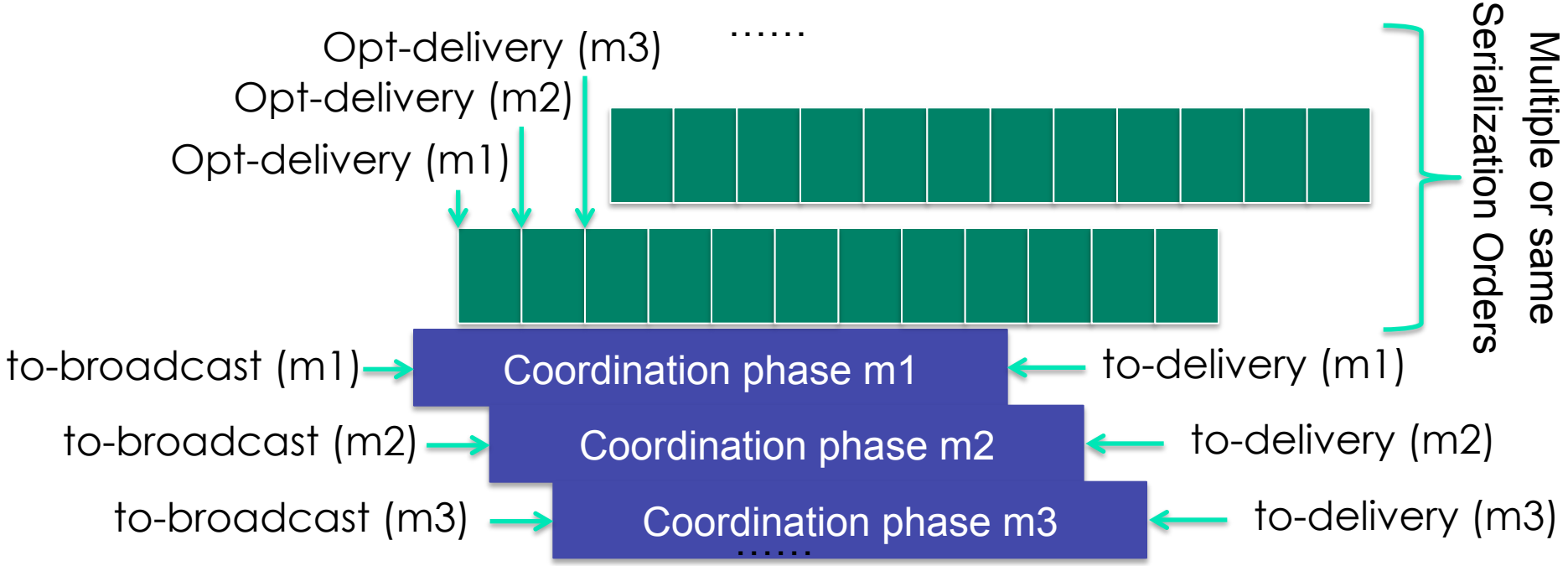
- In case of fine-grain transactions, the overlapping between the coordination phase and local processing is very limited

Mean Transaction Execution Time

Traditional Scenarios	Modern Scenarios
≈ 2m/10m sec	≈ 2m/500μ sec

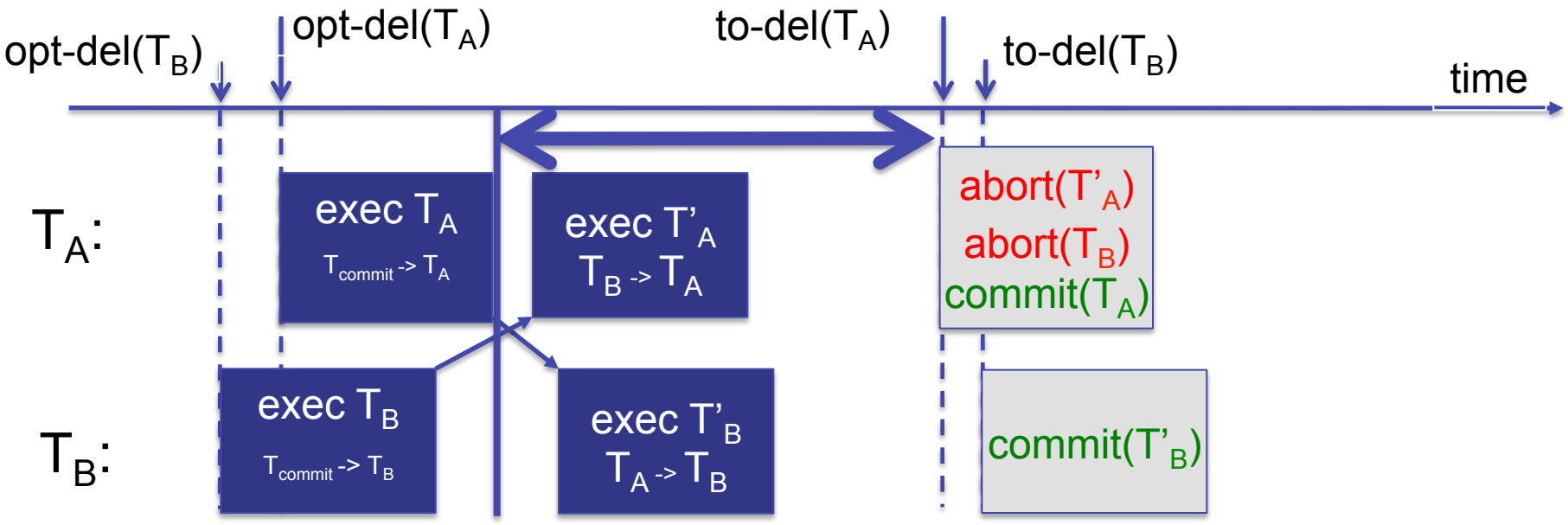
Target: Maximize the overlap

- Coordination delay Vs Local transaction processing



How: Speculative Processing

- Basic ideas:
  - Activate all transactions as soon as they are optimistic delivered
  - Explore (in depth and/or in breadth) multiple serialization orders



Contribution

- Integration of the active replication paradigm with speculation in existing PostgreSQL
  - Centralized
  - Non fault-tolerant
  - Open-source DBMS

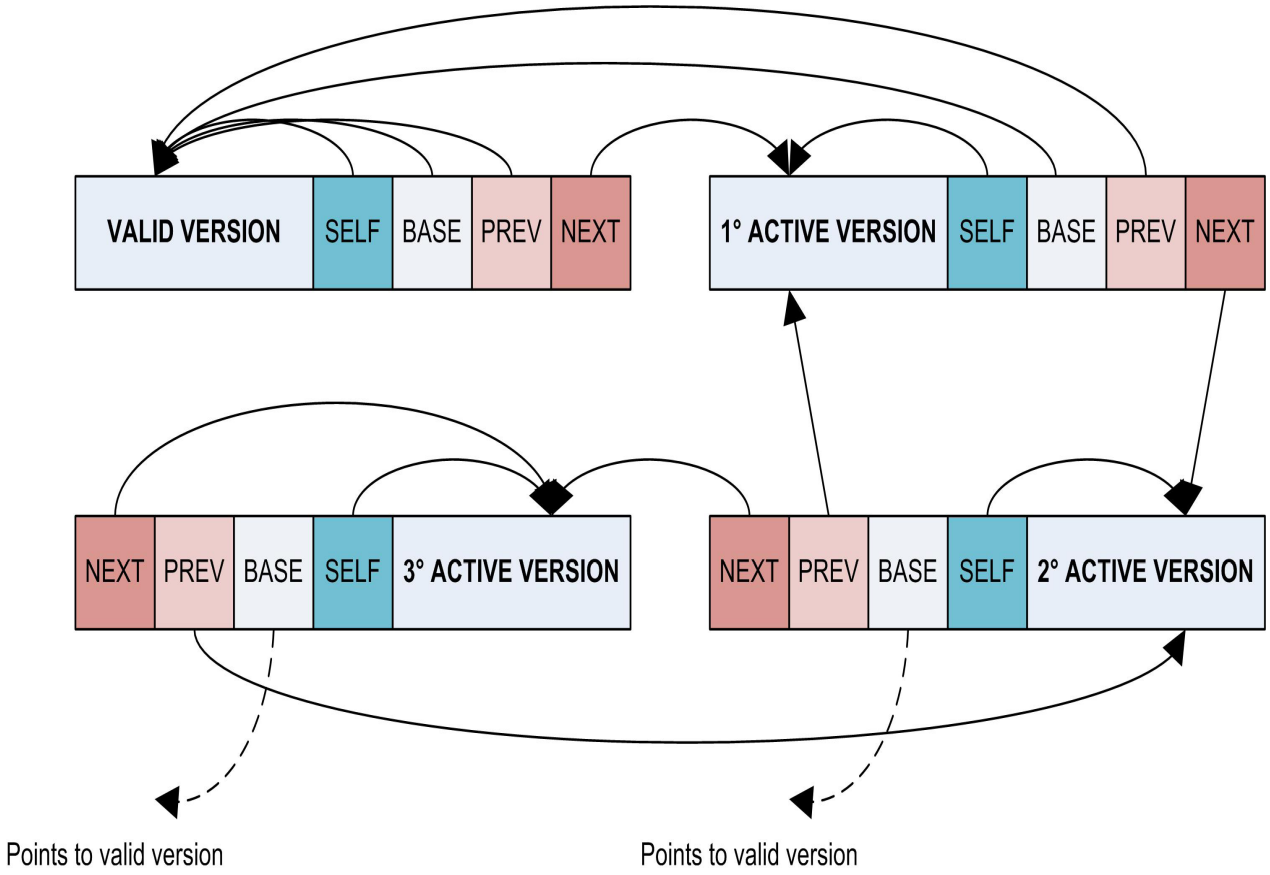
- Speculative supports embedded:
  - Transaction Demarcation and Commit
  - Enhanced Multiversioning
  - Speculative Transactions Forking

Transaction Demarcation and Commit

- Each transaction requested submitted by clients is a transaction *family*
- Speculative transactions belonging to the same *family* (activated on different snapshots) are *siblings*
- Transactions are identified with:
  - FAMILY ID: the family's identification
  - INSTANCE ID: the unique id valid in the context a family
- Hash-Map stores families' information and their speculative transactions to always have a picture of the current execution status.

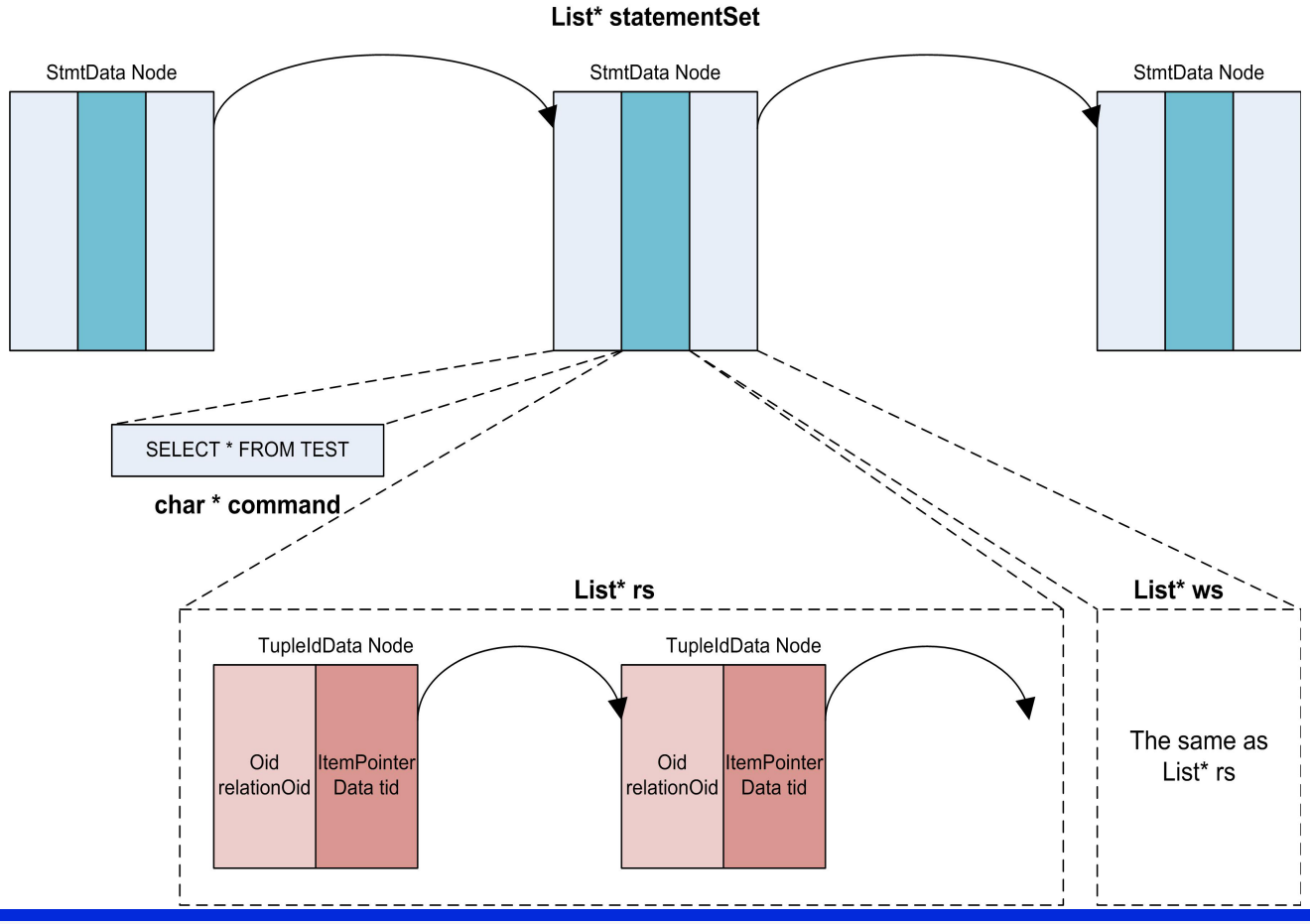
Enhanced Multiversioning

- Speculation requires non- blocking tuple access
- Post-images of inserted/updated tuples must be visible before the writing transaction is committed



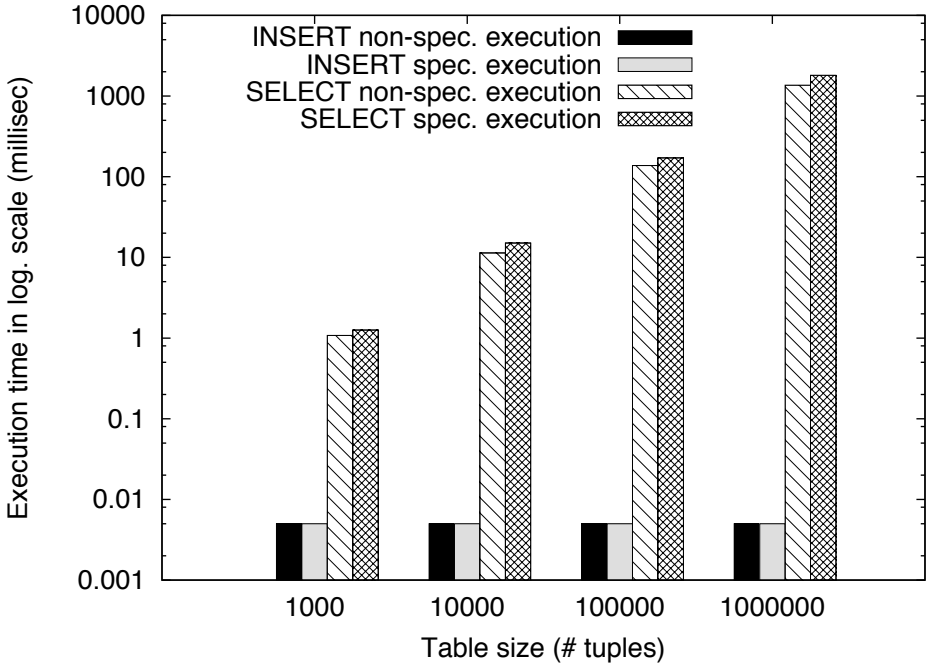
Speculative Transactions Forking

- Read operations return more than one version per tuple
- A forking mechanism is needed for allowing transactions to explore different serialization order

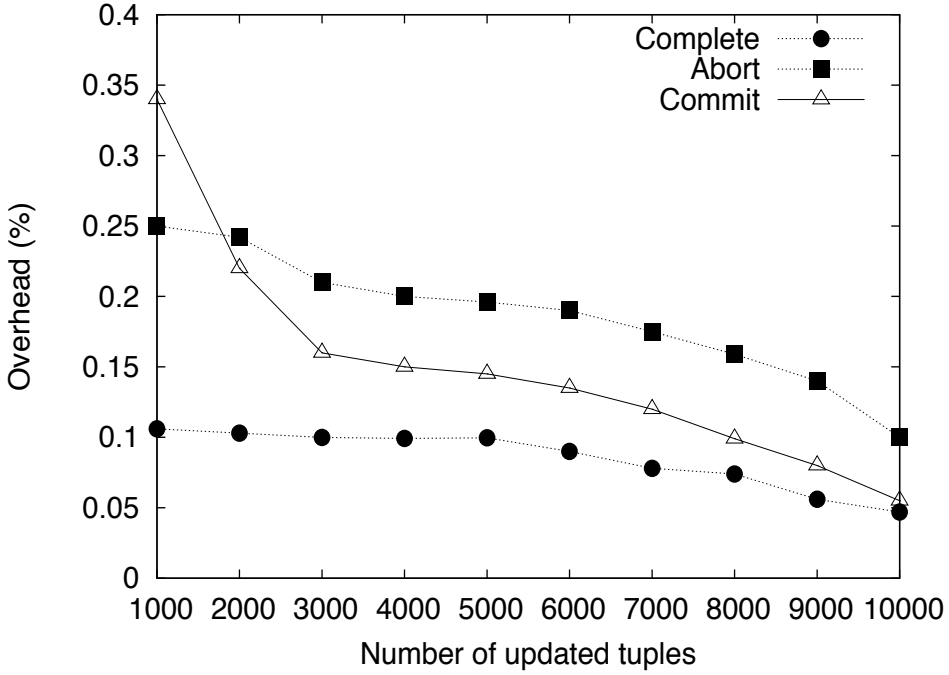


Evaluation

- Synthetic benchmarks and TPC-C
- 32 core machine HP ProLiant server, equipped with four 2GHz AMD Opteron 6128 and 64GB RAM



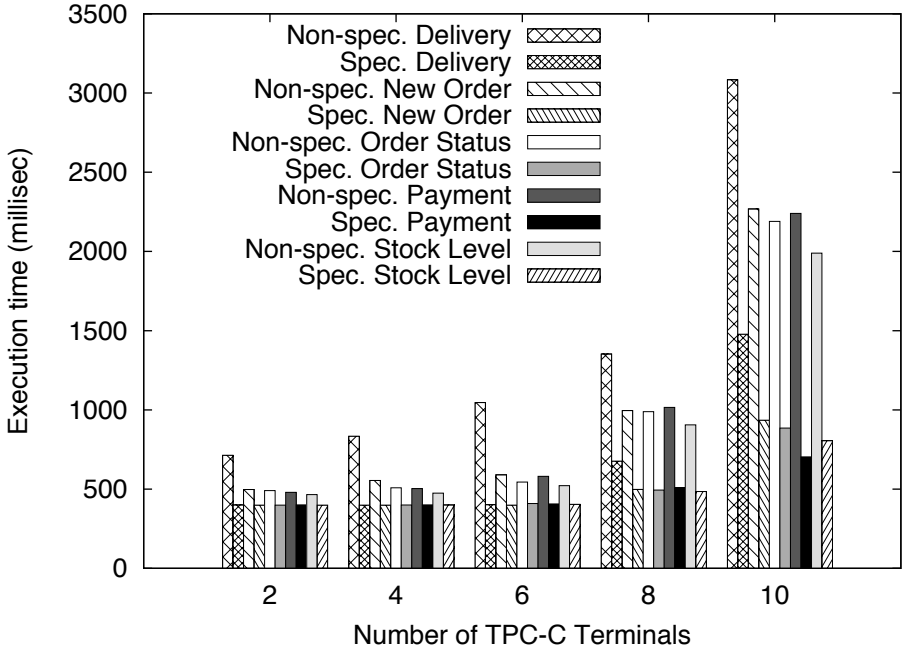
Overhead of synthetic bench SELECT commands



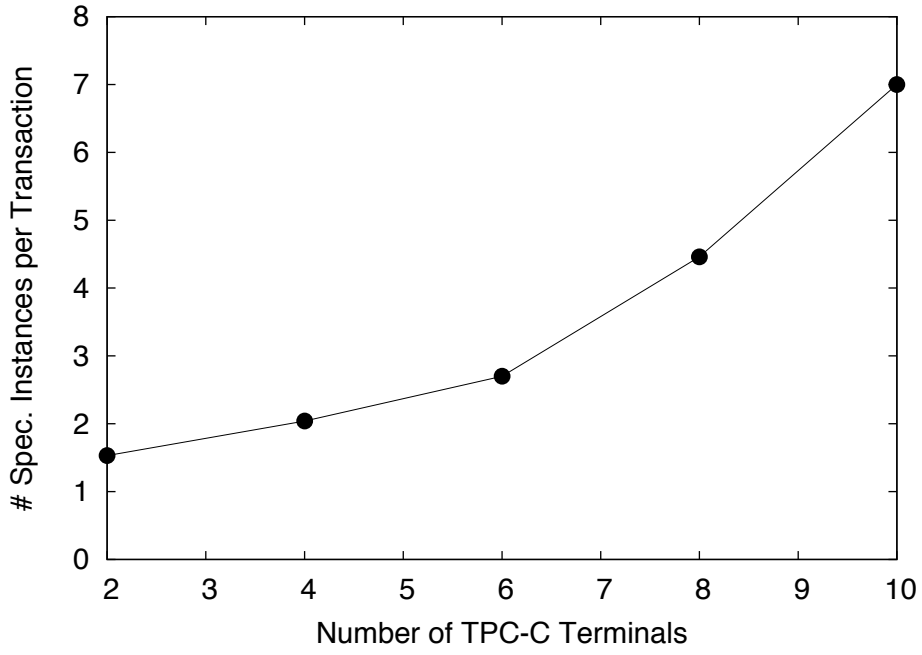
Overhead of synthetic bench UPDATE commands

Evaluation

- Performance of TPC-C



Performance comparison
Spec Vs Non Spec execution



Actual number of speculative transactions generated

Lesson, Conclusion & Questions

- Speculative processing in DBMS is doable
- Overhead is limited especially having multicore architecture
- The number of speculative transactions generated depends on the concurrency control rules