An Evaluation of Distributed Concurrency Control

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Introduction

- Evaluation of performance of protocols across various tests.
- Rise of Distributed Database Management Systems (DBMS)
- Data Partitioning
- Serializability
- Deneva
    - Deployed on Amazon EC2 with 8 virtualized CPU cores and 32 GB of memory

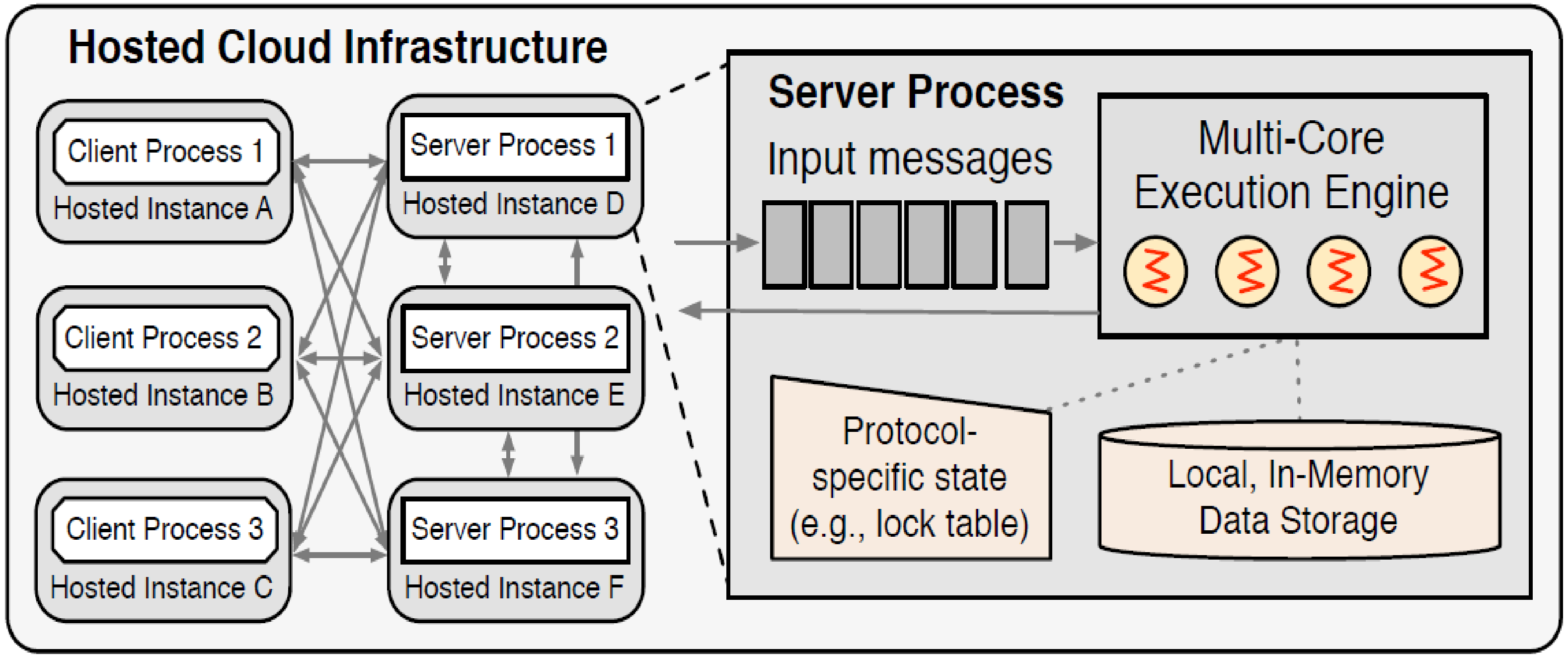
Protocols Being Tested

1. Two Phase Lock (2PL)
   a) NO_WAIT
   b) WAIT_DIE
2. Timestamp Ordering
   a) TIMESTAMP
   b) Multi-Version Concurrency Control (MVCC)
3. Optimistic Concurrency Control (OCC)
4. Deterministic (CALVIN)

Tests Overview

- Only serializable executions are analyzed.
- Online Transaction Processing are done through thread-safe sockets over TCP/IP.
- The queries are executed by 4 threads in a non-blocking manner unless a shared resource is being worked on.
- No logging, checkpoint, and recovery.
- Table partitions are preloaded on servers.
- Each server will carry 10,000 open client connection.
- When a transaction aborts, it restarts after a penalized period.

Architectural Overview



- Each server can host more than one partition, but each partition exists only on one server.
- Does not provide replication or fault tolerance.

TESTS

Contention

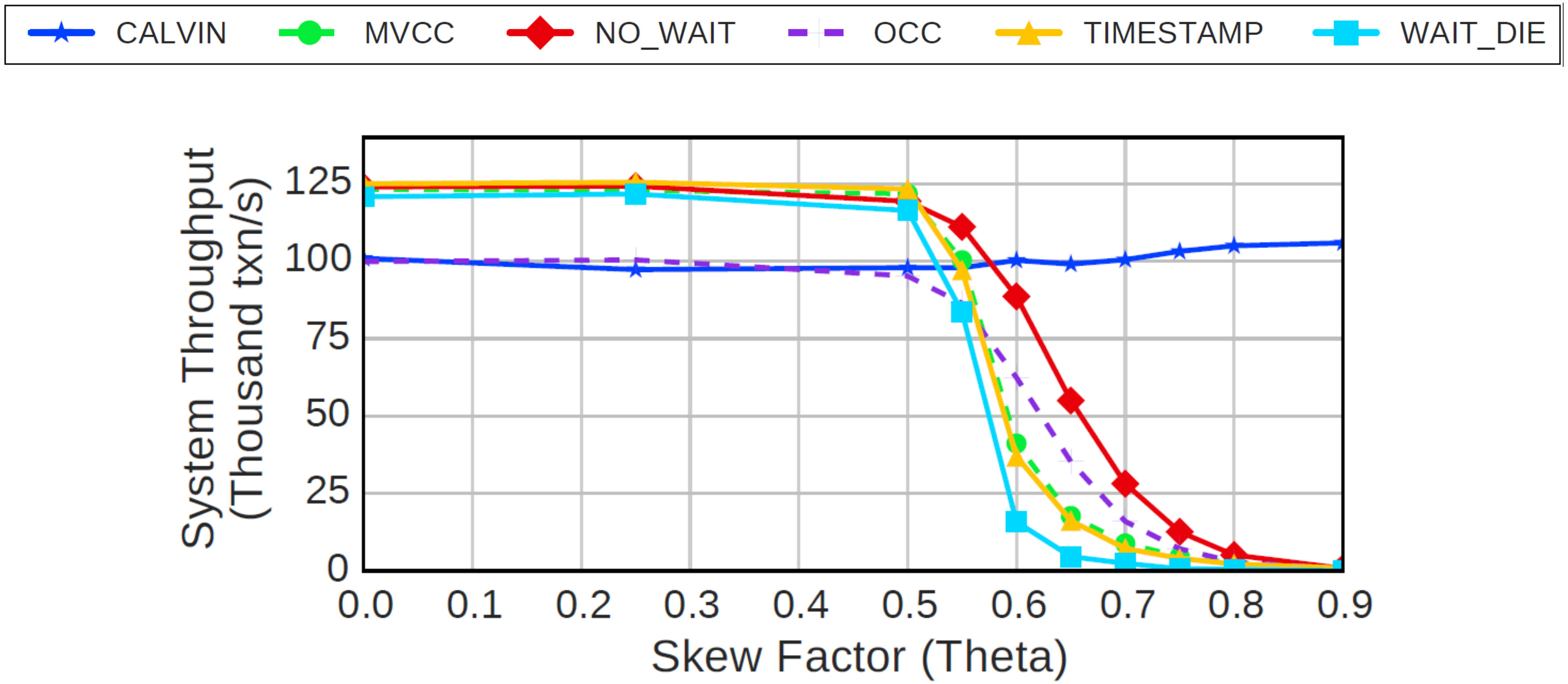


Figure 2: Contention – The measured throughput of the protocols on 16 servers when varying the skew factor in the YCSB workload.

1. Contention

- CALVIN is initially bottlenecked because of thee single threaded schedulers, but it is the only protocol to maintain good performance despite high skew.
- This is because locks are released much quicker once the read data is made available.
- OCC performs badly under low contention due to the overheads of copy and validation even when chances of modifications are the least.
- However, at higher levels the benefit of tolerating more conflicts and thus avoiding unnecessary aborts outweighs these overheads.
- The rest have a steep drop because of excessive wait times caused by data locks.

Update Rate

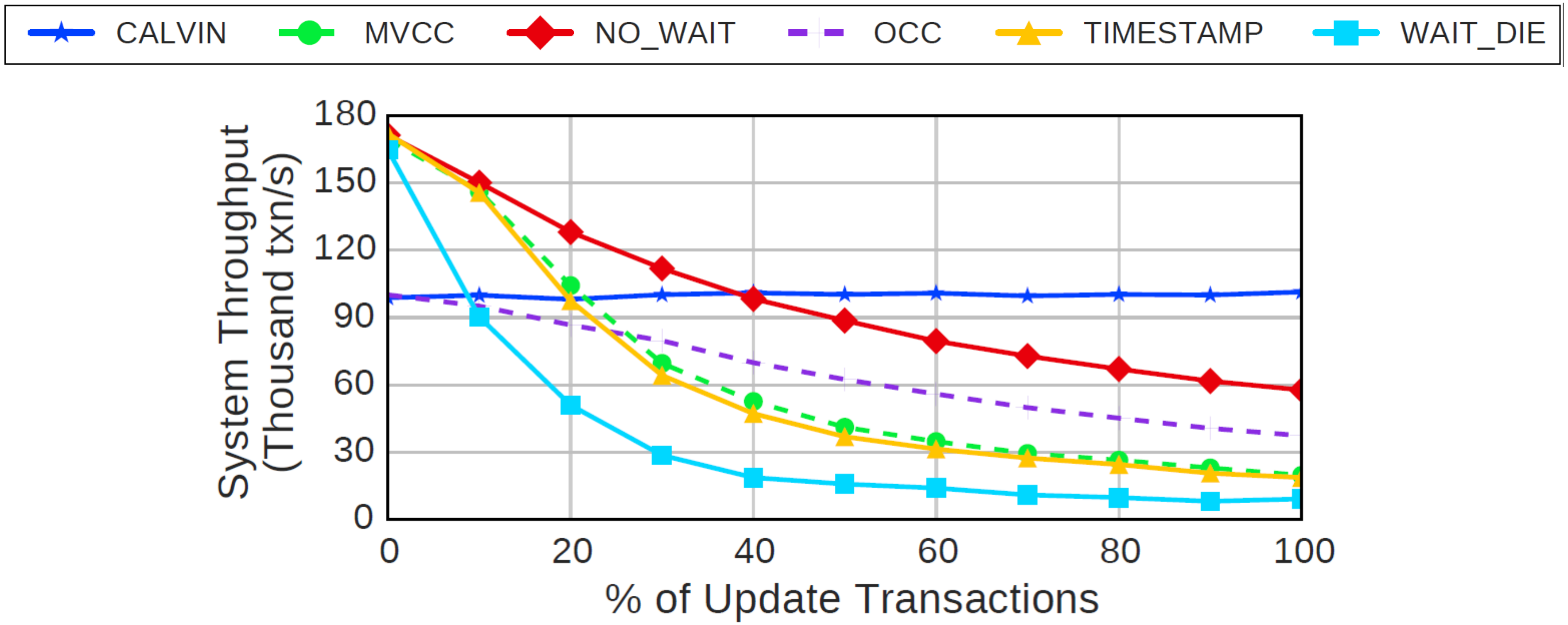


Figure 3: Update Rate – The measured throughput of the protocols on 16 servers when varying the number of update transactions (5 reads / 5 updates) versus read-only transactions (10 reads) in the workload mixture for YCSB with medium contention (*theta*=0.6).

2. Update Rate

- As the update% goes up, WAIT_DIE drops drastically and more transaction get queued into wait state as hot records are locked by various transactions.
- These transactions waste a lot of resource because they non-deterministically bypass the queues and prolong the natural flow of transactions. Even after all this waiting, they grow old and are aborted.
- NO_WAIT on the other hand is not affected because there is no waiting. The transactions abort straight away if the lock is not available.
- TIMESTAMP and MVCC suffer from the wait time caused by locks that are held by active transactions.
- OCC suffers from lower rates initially due to unnecessary validation checks, but at higher update% it is relatively faster as locks are not acquired.
- CALVIN's advantage and disadvantage from contention carry over to update rates.

Multi-Partition Transactions

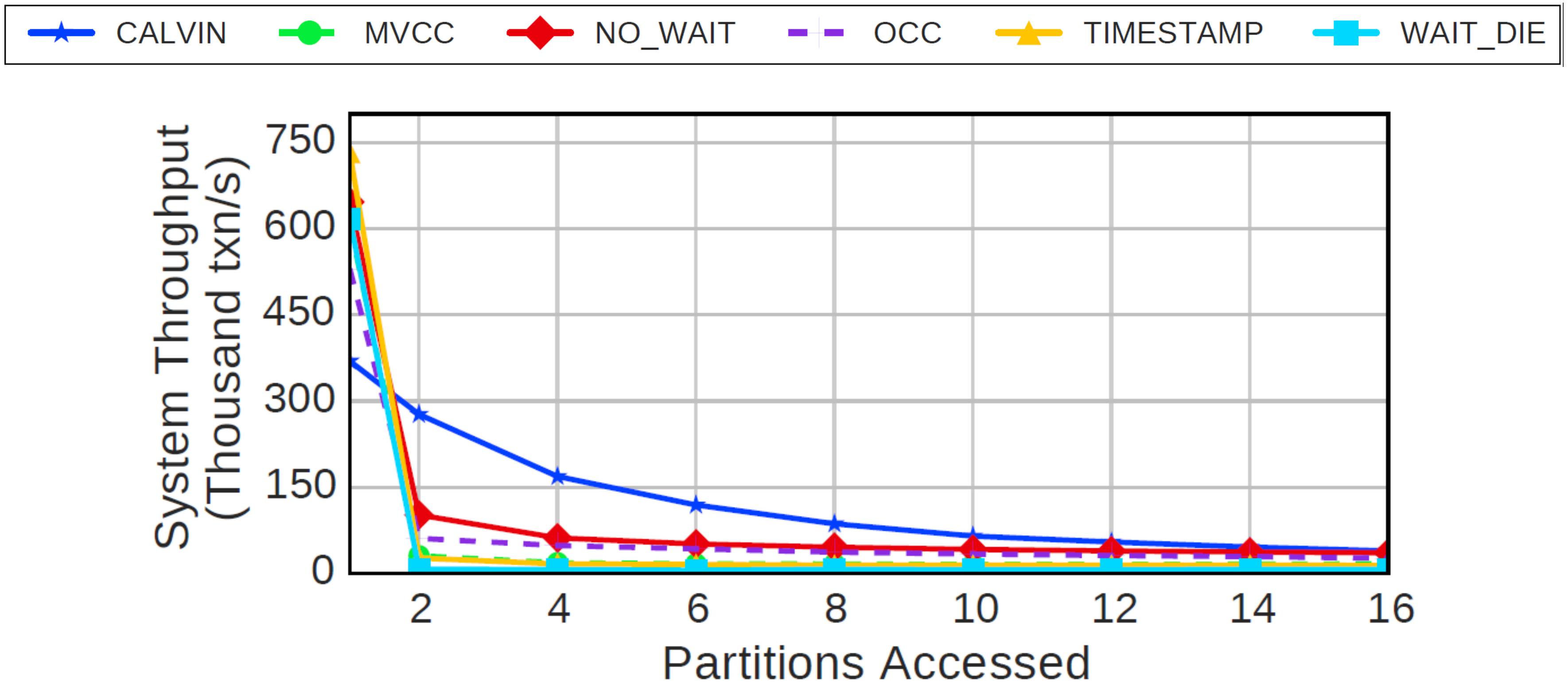


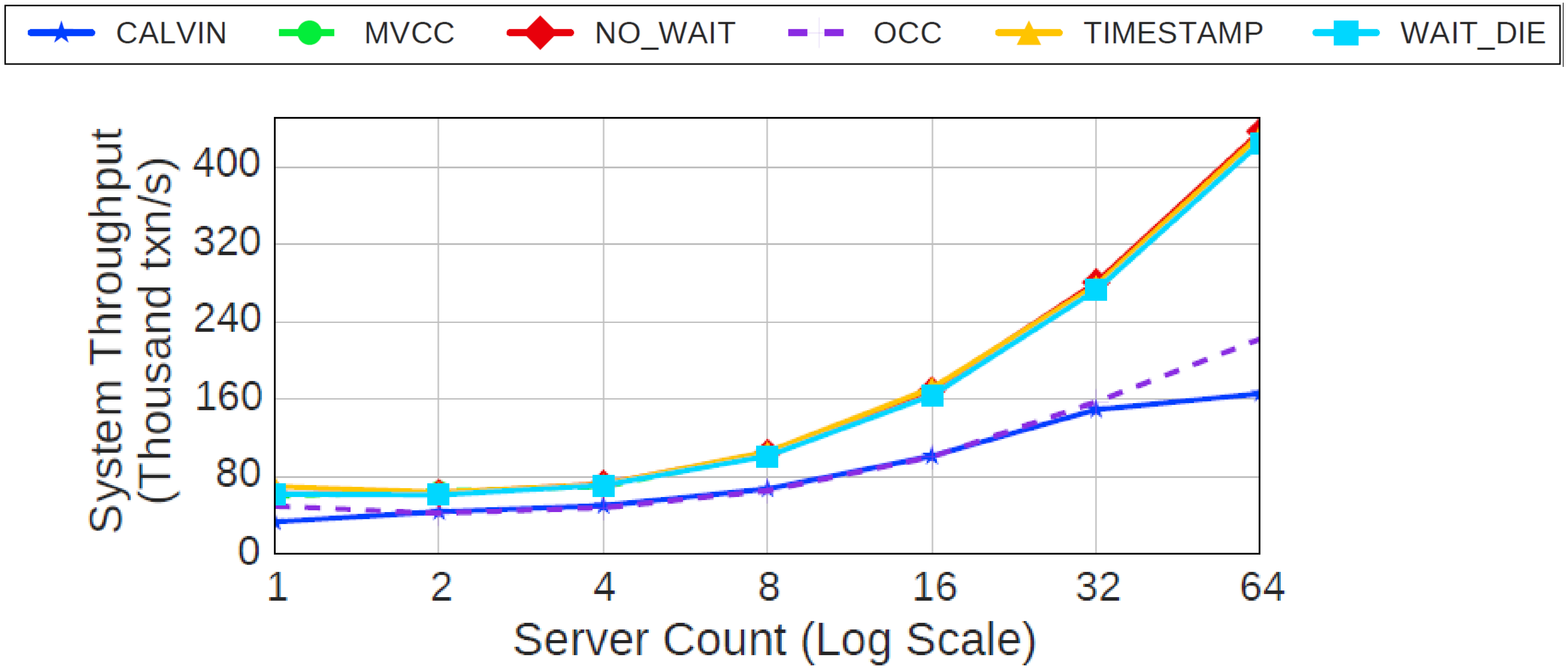
Figure 4: Multi-Partition Transactions – Throughput with a varying number of partitions accessed by each YCSB transaction.

3. Multi-Partition Transactions

- Pretty much all protocols plummet equally except CALVIN.
- Part of the reason is because CALVIN does not make use of 2 Phase Commit protocol (2PC).
- There is also the overhead caused by multiple requests and responses between different server messages.
- CALVIN on the other hand synchronizes its schedulers every 5ms and hence the transactions are automatically forwarded to the target partitions.

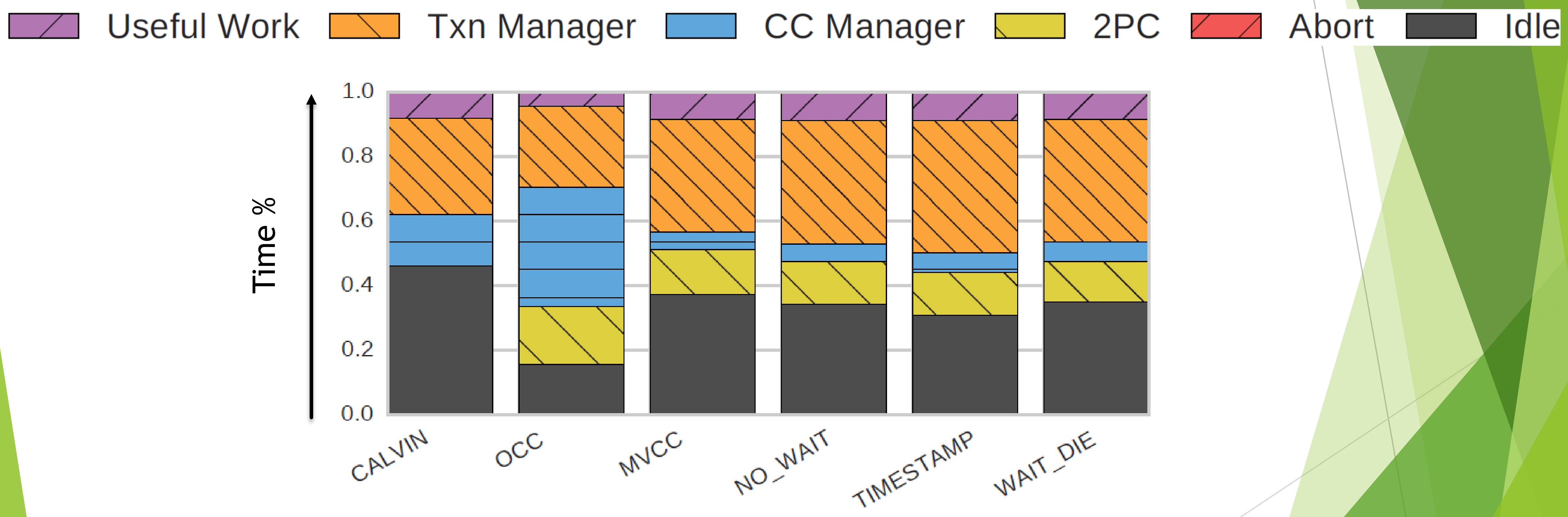
4. Scalability

A) Read-only Workload



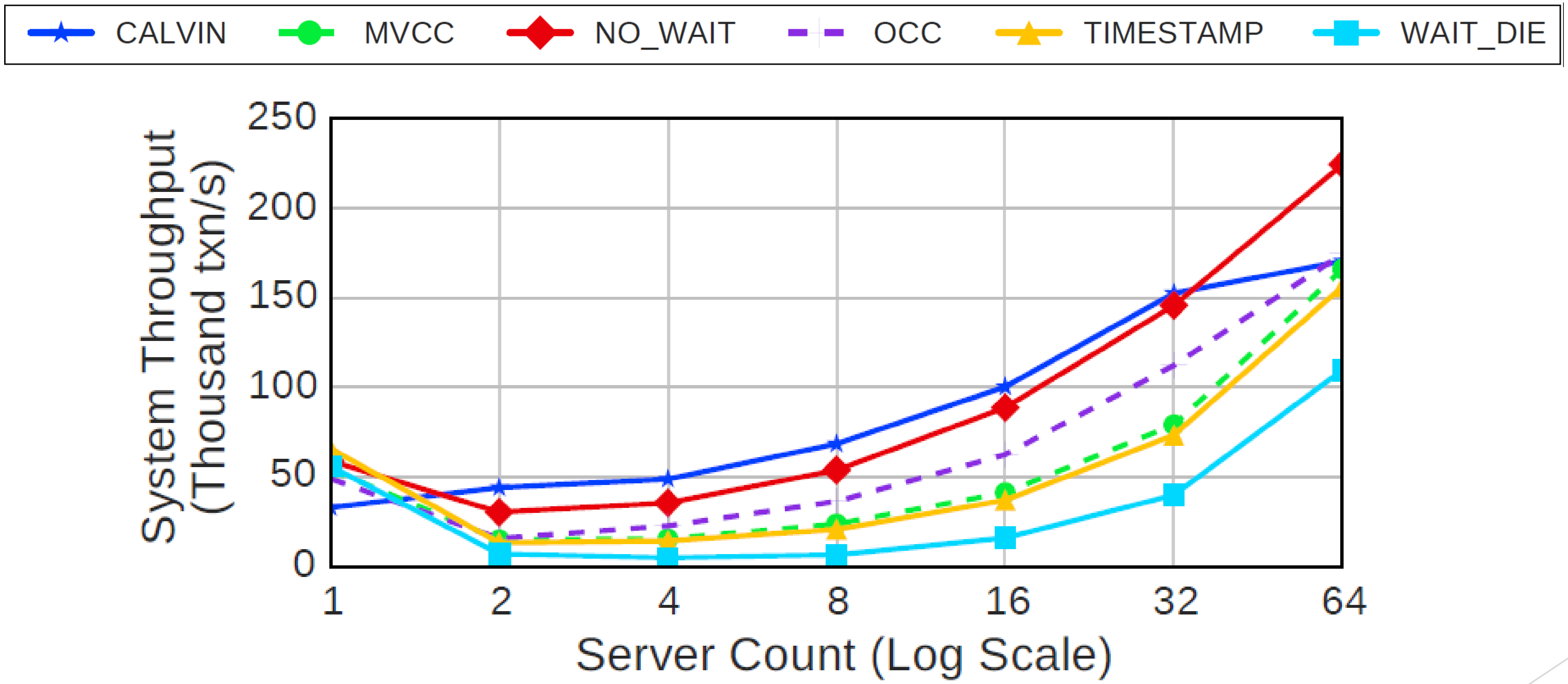
(a) Read-Only (No Contention)

Time % Graph



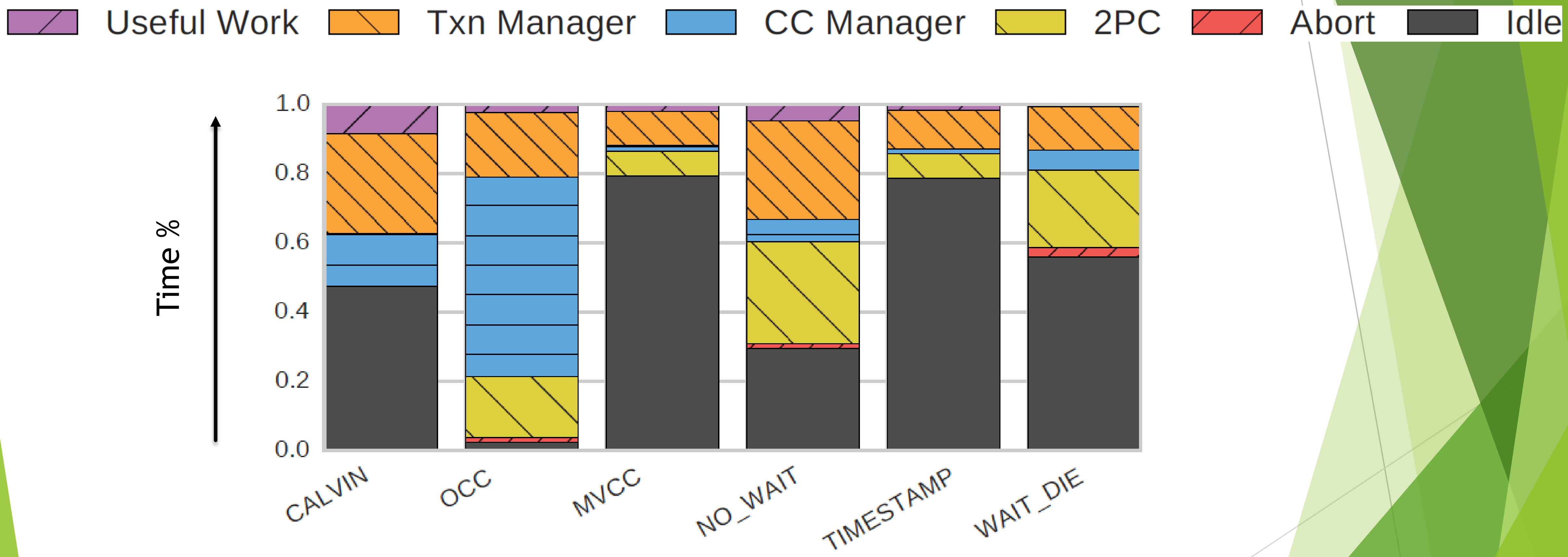
(a) Read-Only (No Contention)

B) Read-Write (Medium Contention)



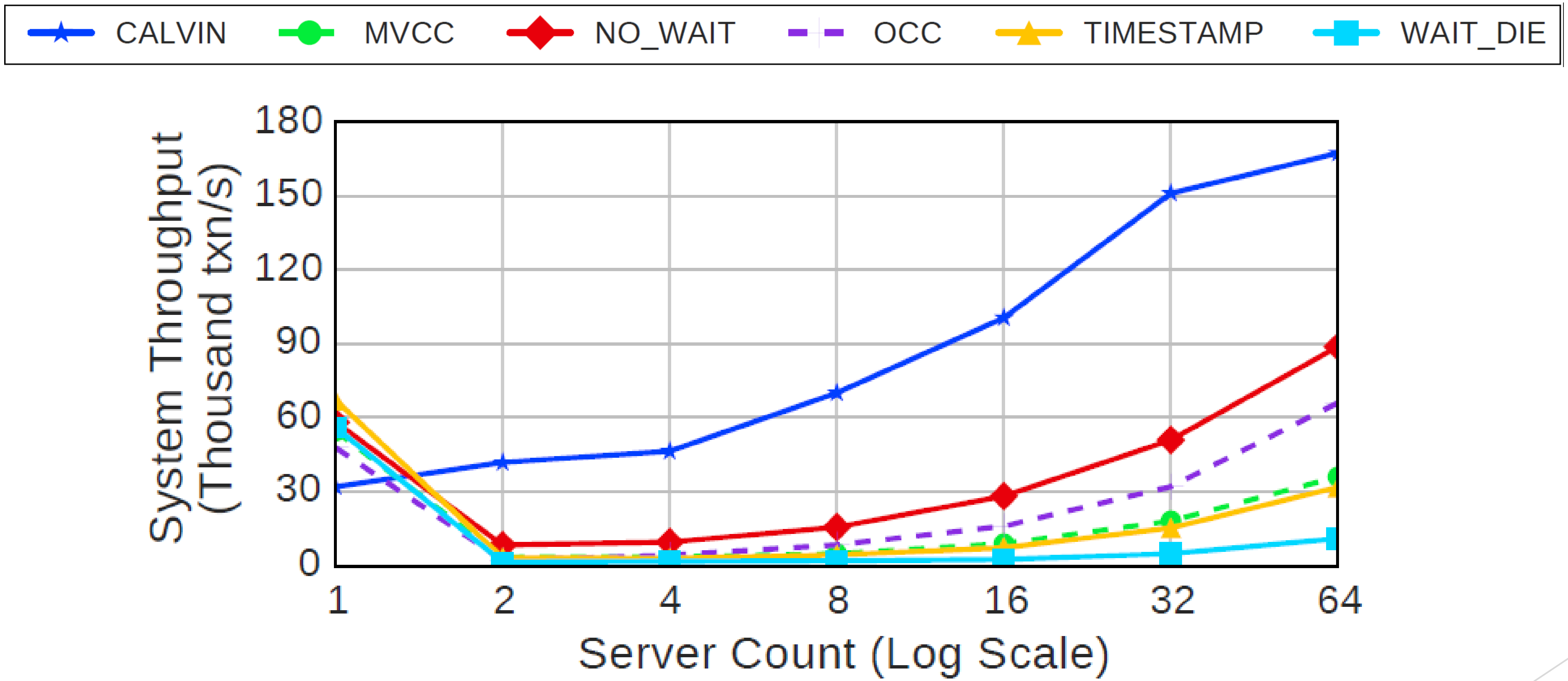
(b) Read-Write (Medium Contention)

Time % Graph



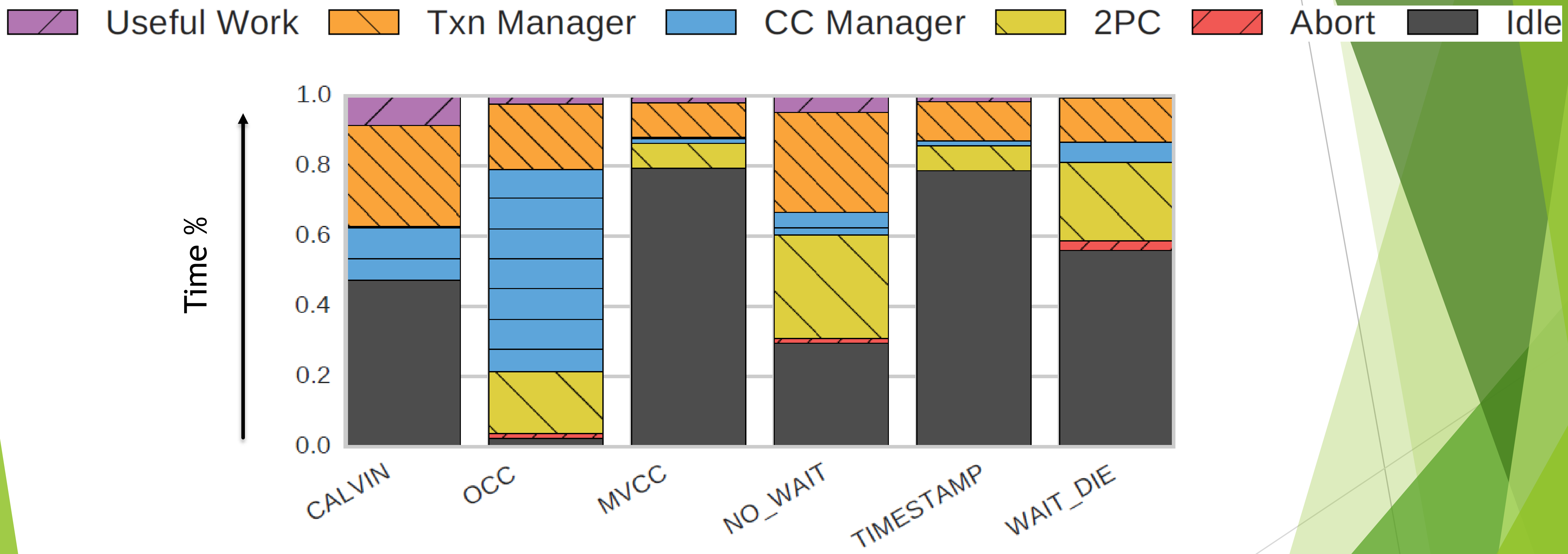
(b) Read-Write (Medium Contention)

C) Read-Write (High Contention)



(c) Read-Write (High contention)

Time % Graph



(b) Read-Write (Medium Contention)

5. Network Speed

- Protocols that use 2PC strategy experienced the most loss in throughput as the commits required delivery of transactional messages.
- CALVIN does not need to exchange any messages between servers between its read and write phase. Hence, it performs the best.
- WAIT_DIE sees the worst performance as not only are the messages being lagged, the lagging is causing a lot of the waiting transactions to age and abort. The high abort rate in the main reason for the significant loss in performance.
- TIMESTAMP and MVCC also suffer loss in performance because of delay in transactional messages, but don't suffer as bad a rate for aborts.

Network Speed

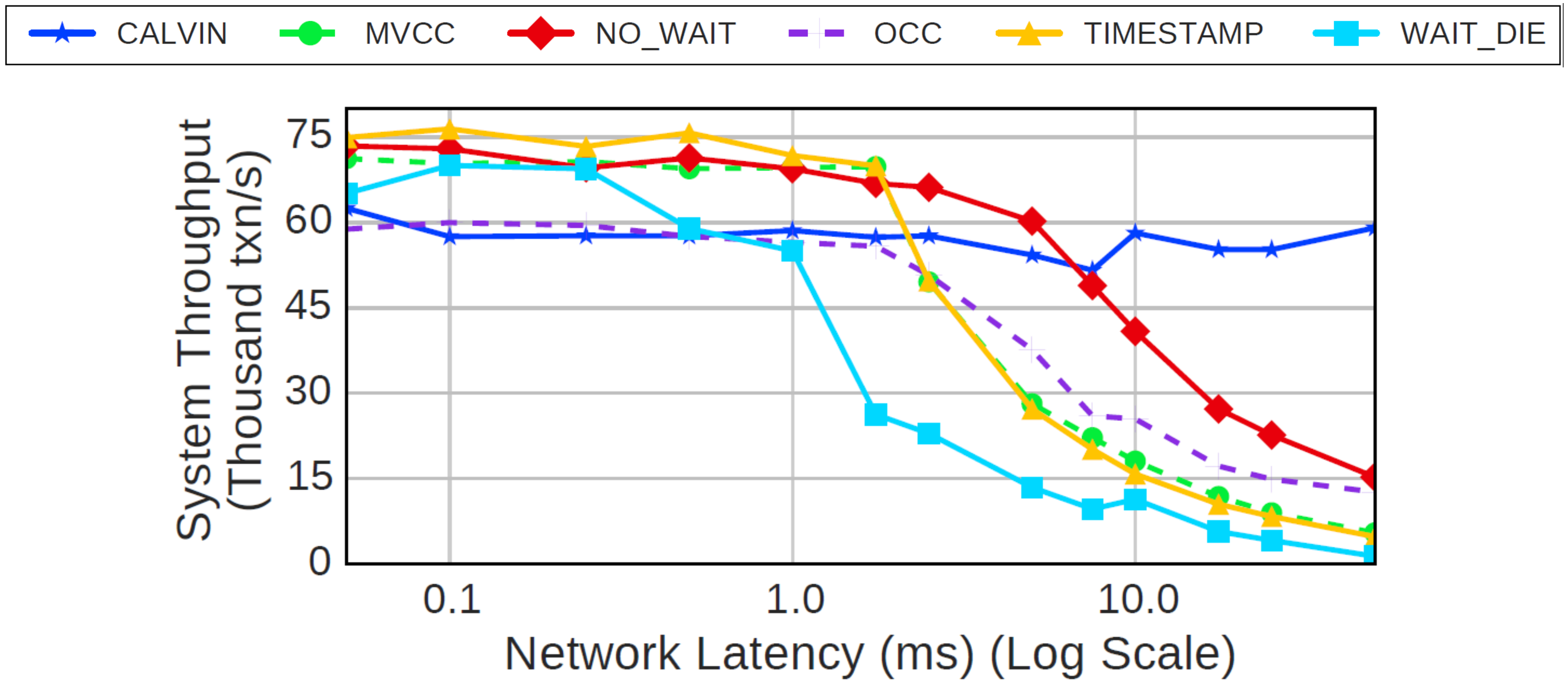


Figure 9: Network Speed – The sustained throughput measured for the concurrency protocols for YCSB with artificial network delays.

Points to Consider

- Effect of platform constraints on protocols
  - Number of requests allowed
  - The back-off penalty
  - Number of Servers/Partitions
  - Type of Transactions
- Testing on Transaction Processing Performance Council - Type C (TPC-C)

Conclusion

- 2PL performs poorly under high contention due to aborts.
- Timestamp-ordered concurrency control does not perform well under high contention due to buffering.
- Optimistic concurrency control has validation overhead.
- Deterministic protocol maintains performance across a range of adverse load and data skew but has limited performance due to transaction scheduling.
- There exists a serious scalability problem, especially when the partitions do not exist in a single data center.
- Possible Solution

Thank You