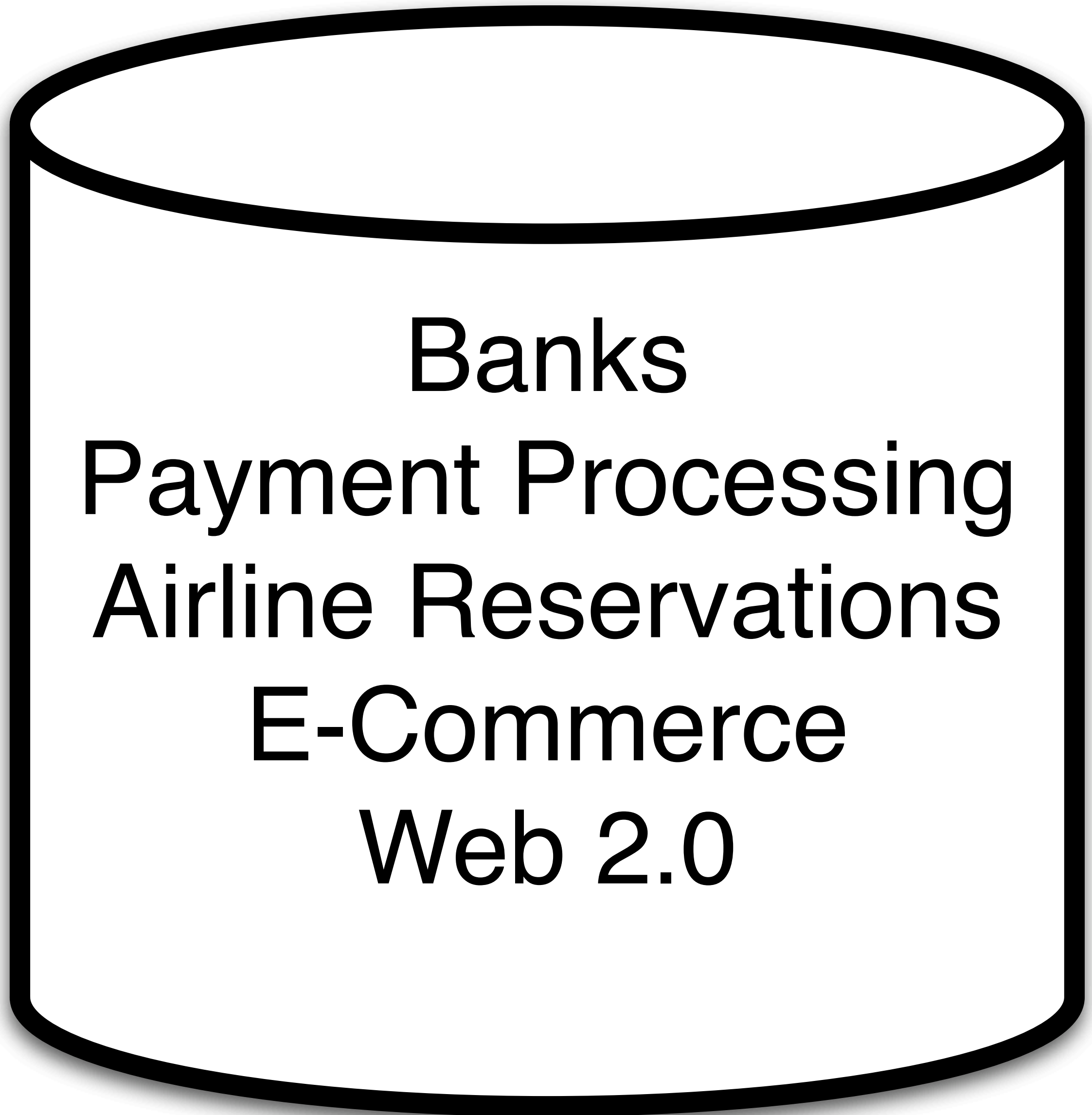
Low Overhead Concurrency Control for Partitioned Main Memory Databases

Evan P. C. Jones   Daniel J. Abadi   Samuel Madden


Banks
Payment Processing
Airline Reservations
E-Commerce
Web 2.0

Problem:

Millions of transactions per second

Problem:

Millions of transactions per second




Problem:

Millions of transactions per second

=

$$$$

Alternative: H-Store Project

Redesign specifically for OLTP

Prototype: ~10X throughput

Idea: Remove un-needed features

Source: Stonebraker et. al, “The End of an Architectural Era”, VLDB 2007.

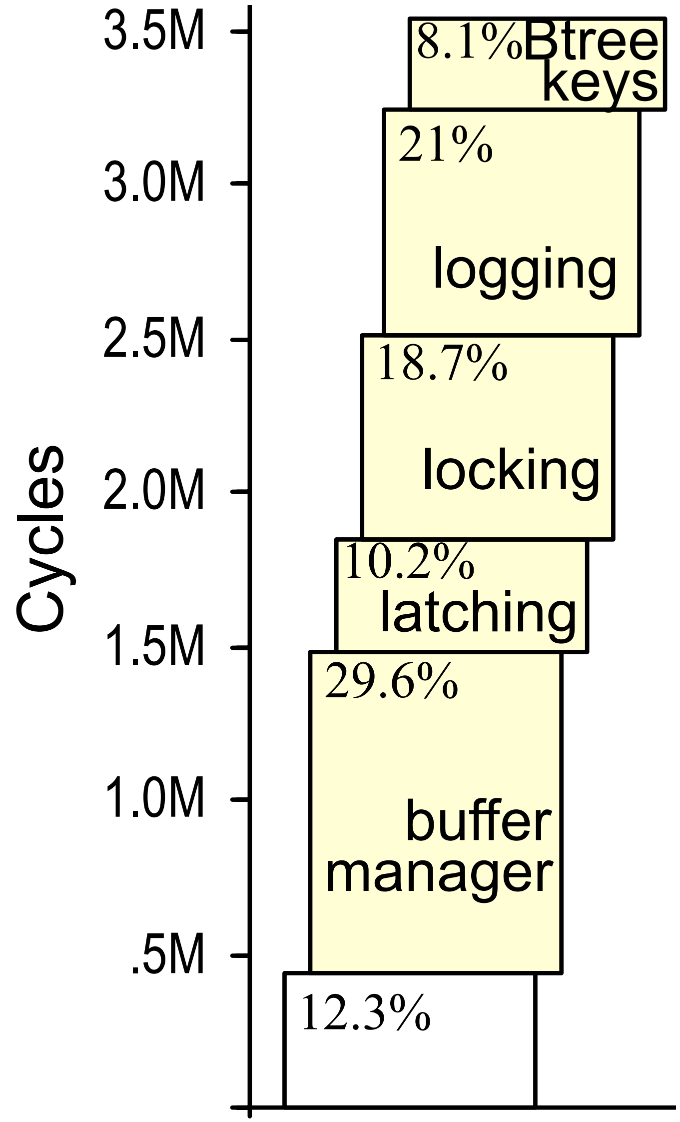
H-Store: High Throughput OLTP

Redesign DB specifically for OLTP

Prototype: ~10X throughput

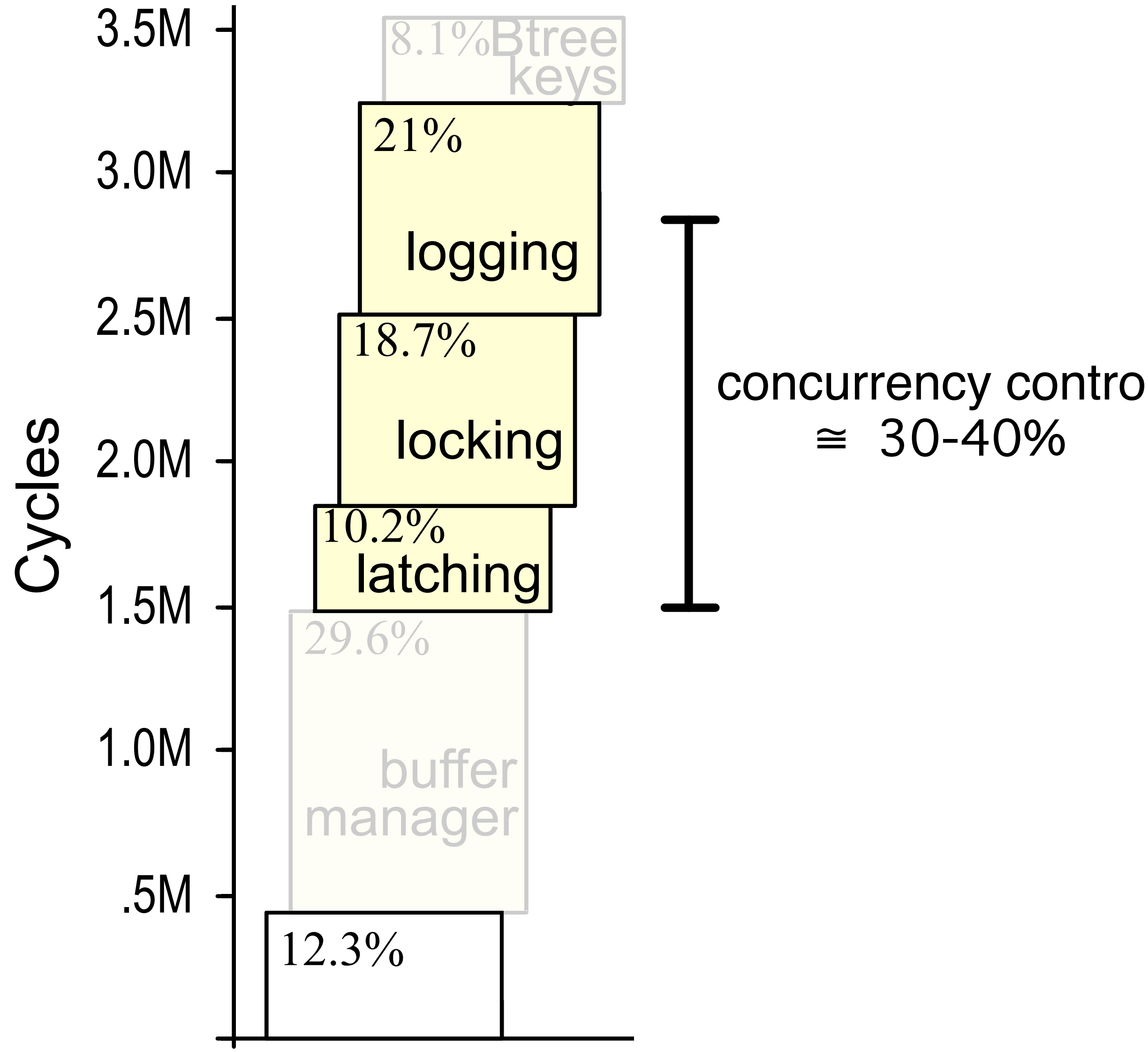
Main memory database

Concurrency control consumes ~30-40% of CPU time



CPU Cycle Breakdown for Shore on TPC-C New Order

Source: Harizopoulos, Abadi, Madden and Stonebraker, “OLTP Under the Looking Glass”, SIGMOD 2008



CPU Cycle Breakdown for Shore on TPC-C New Order

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Speculative Concurrency Control

Eliminate fine-grained access tracking (locks or read/write sets)

Eliminate undo logs (where possible)

Up to 2X faster than locking for appropriate workloads

Why Support Concurrency?

Use idle resources:

disk stalls	main memory
user stalls	stored procedures

Physical resources:

multiple CPUs	partition per core
multiple disks	

Long running txns: don’t do them

H-Store: Single thread engine

Assumptions:

Database divided into partitions

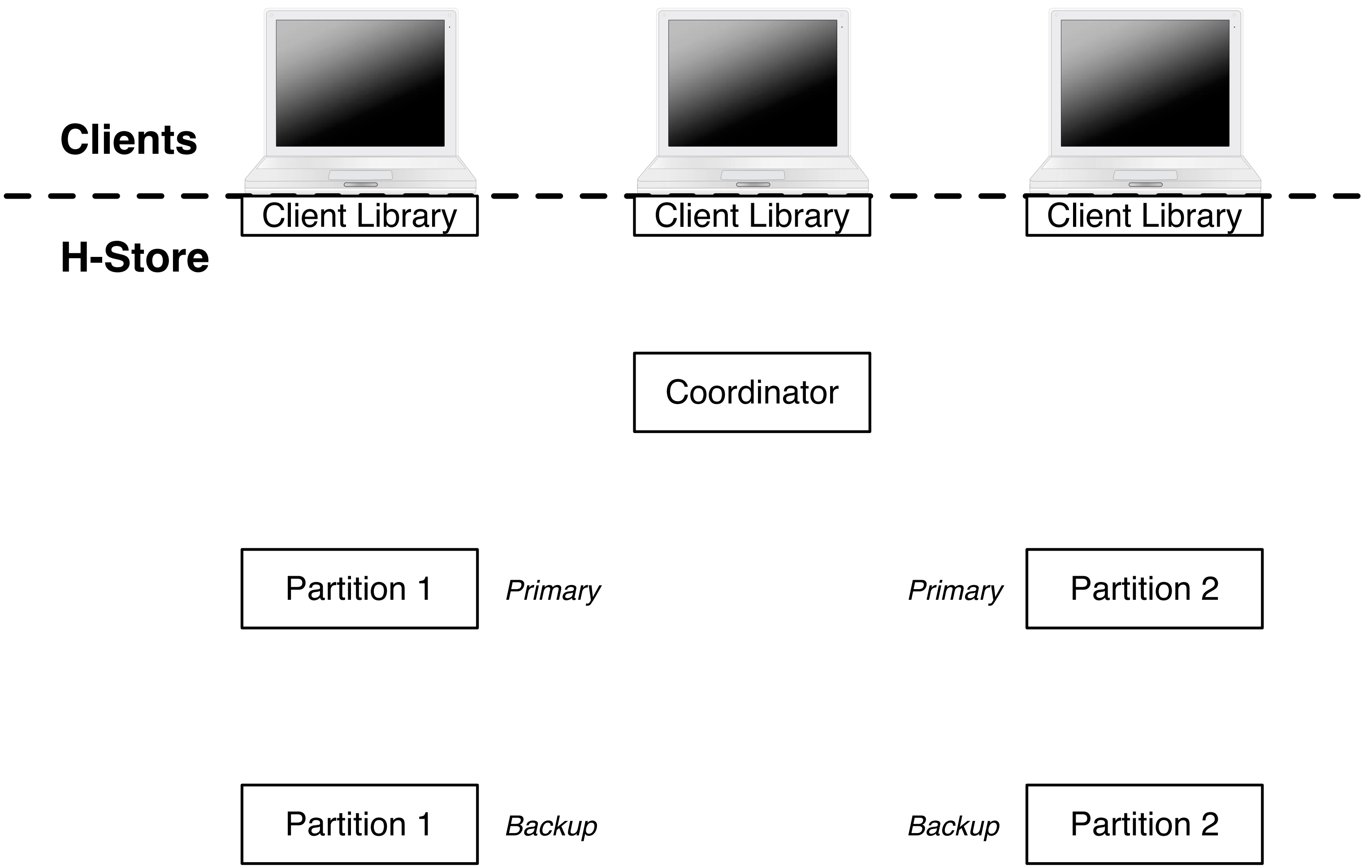
Transactions access one partition (mostly)

Mapping procedures to partitions is given

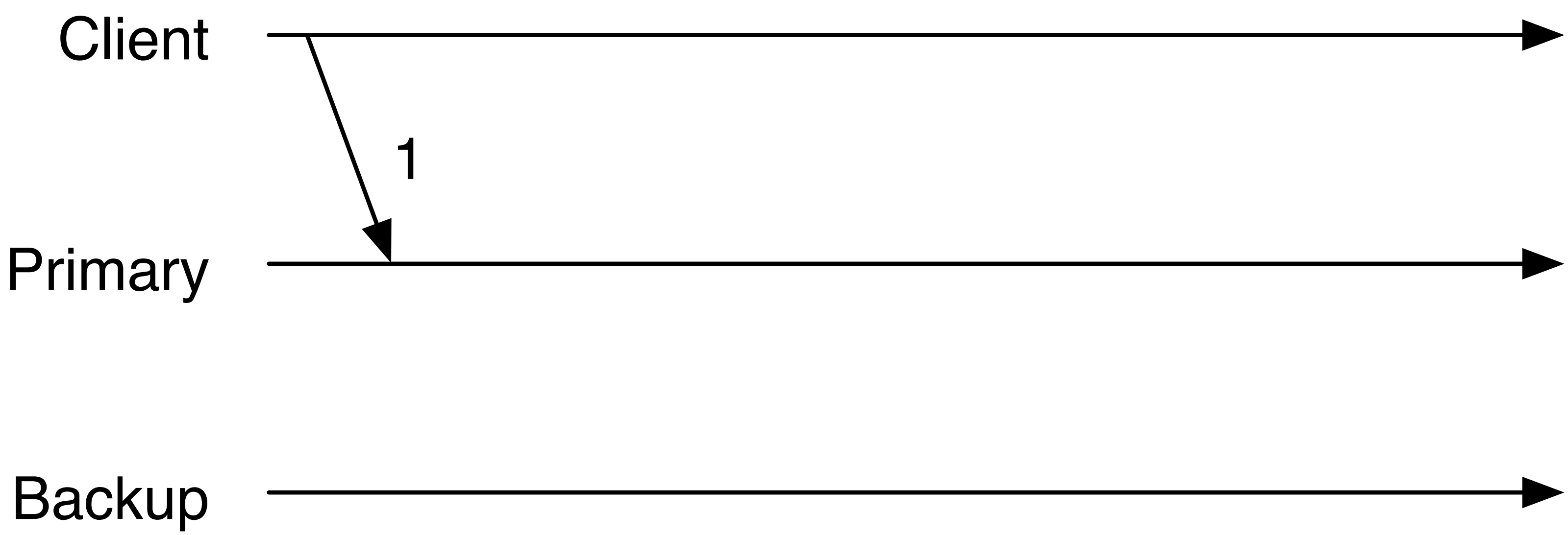
Total data fits in memory of N machines

Partitions are replicated on 2 machines

System Overview



Single Partition Transaction



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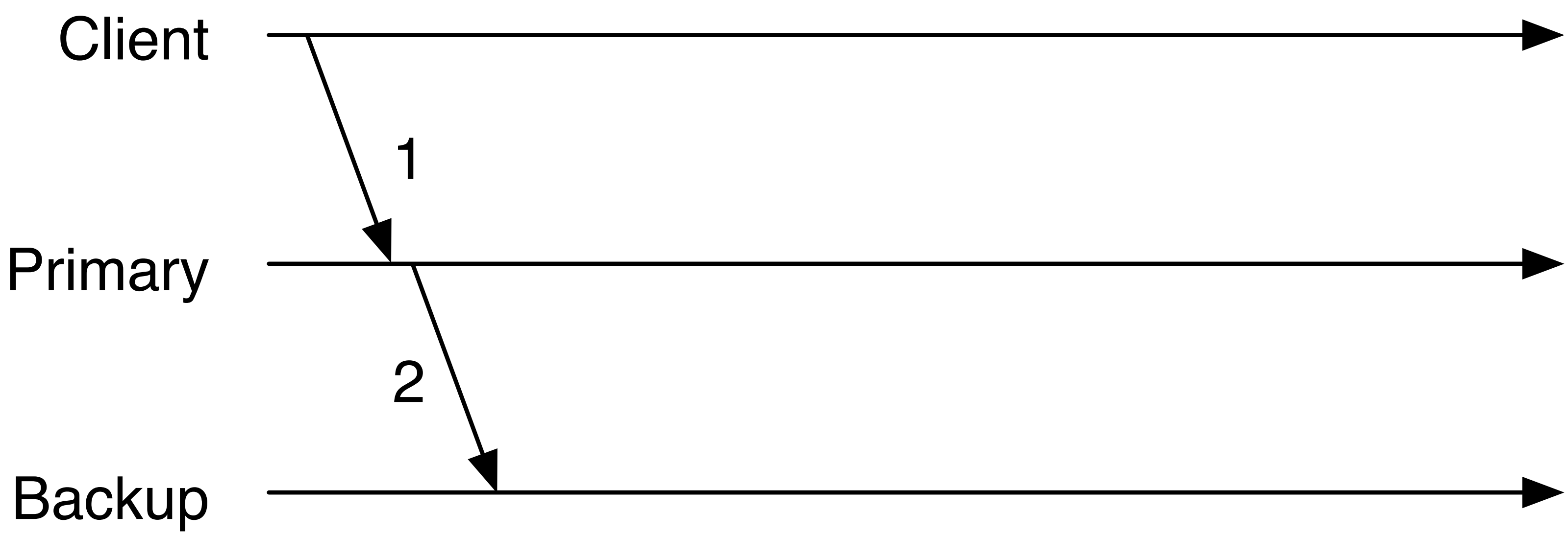

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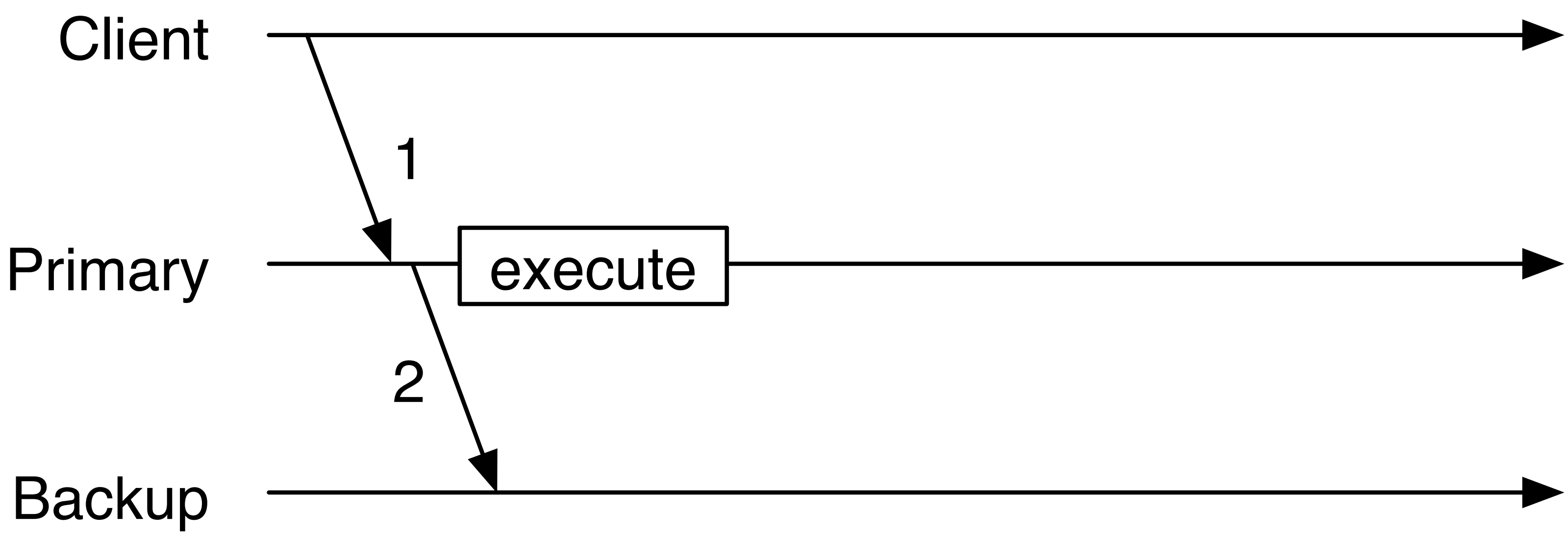

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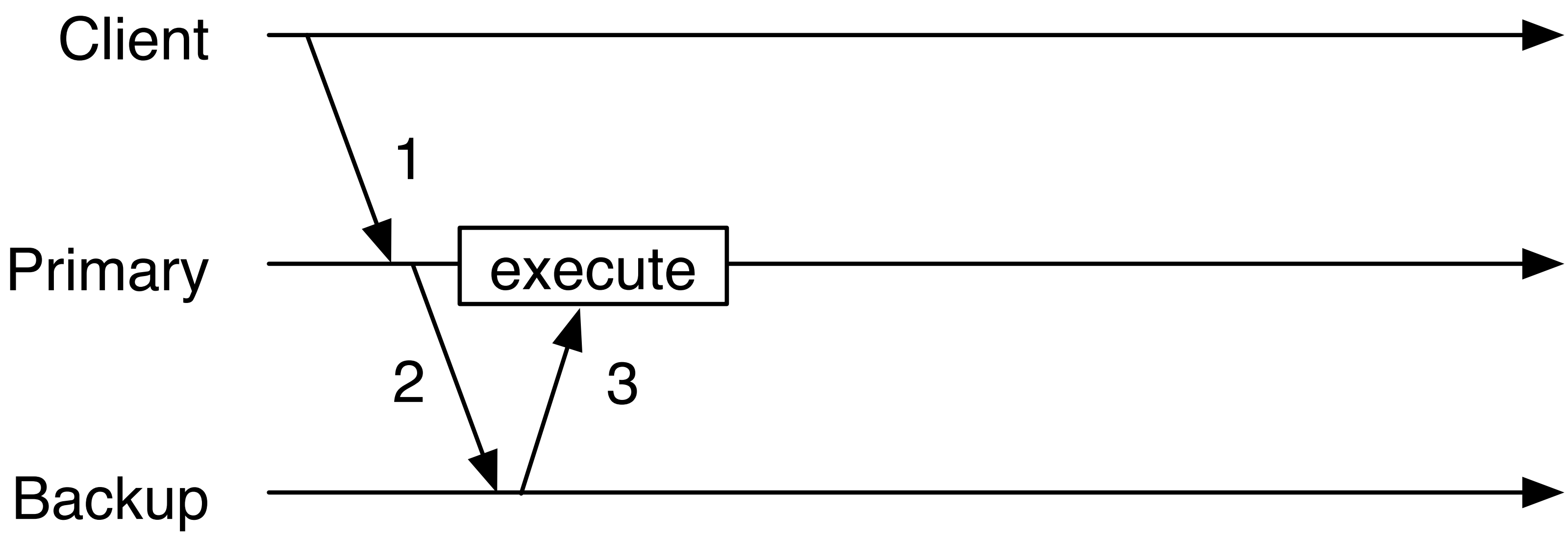
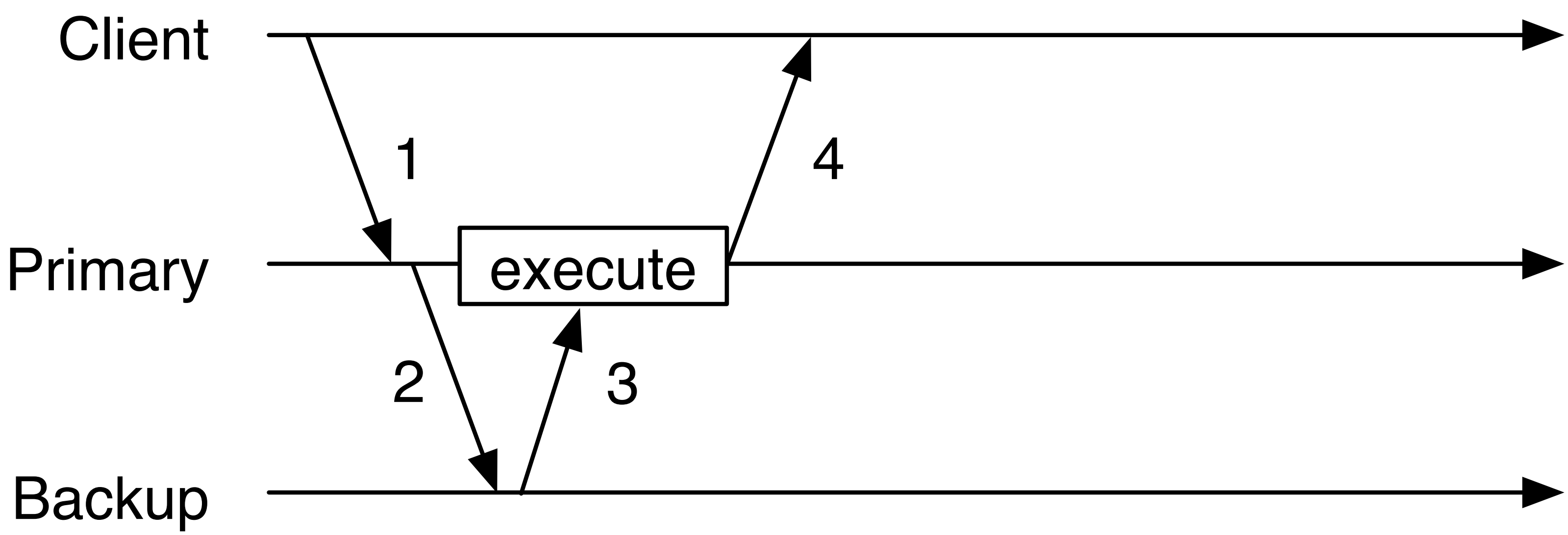


Single Partition Transaction



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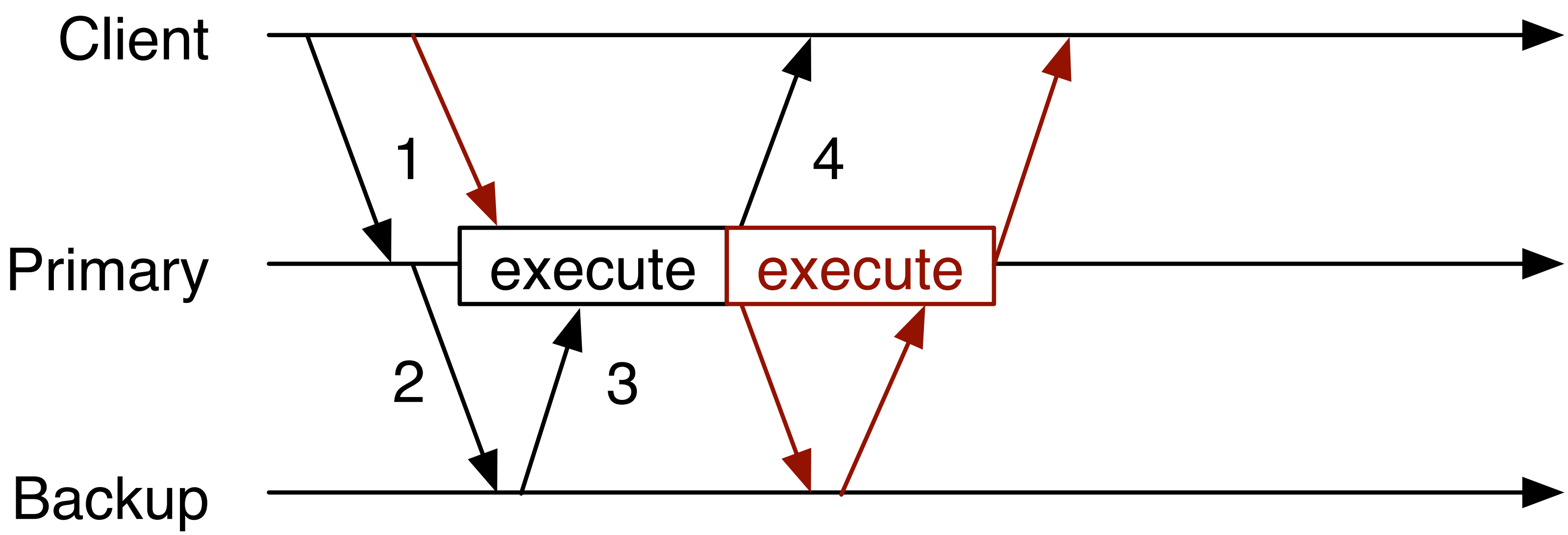
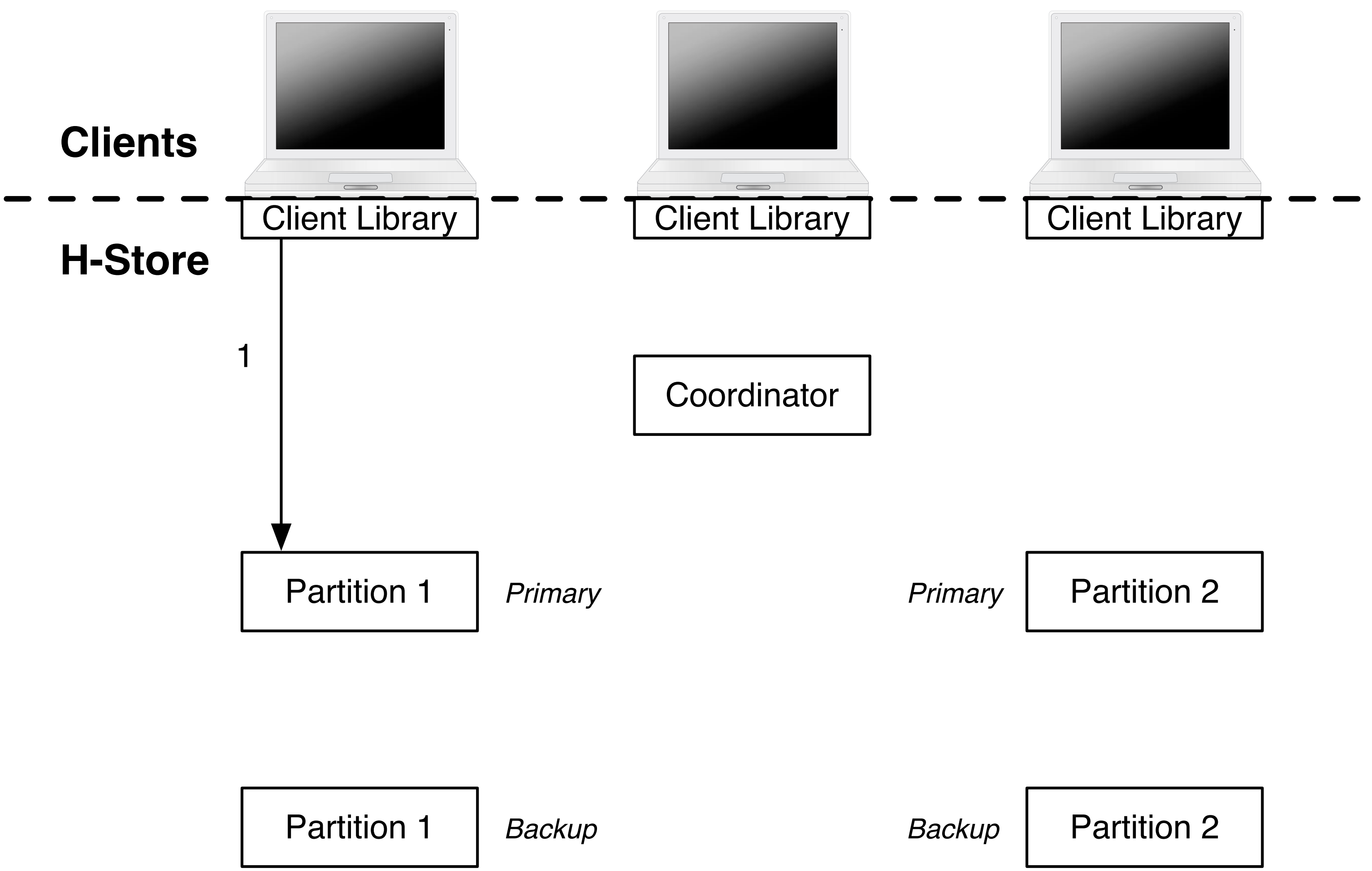
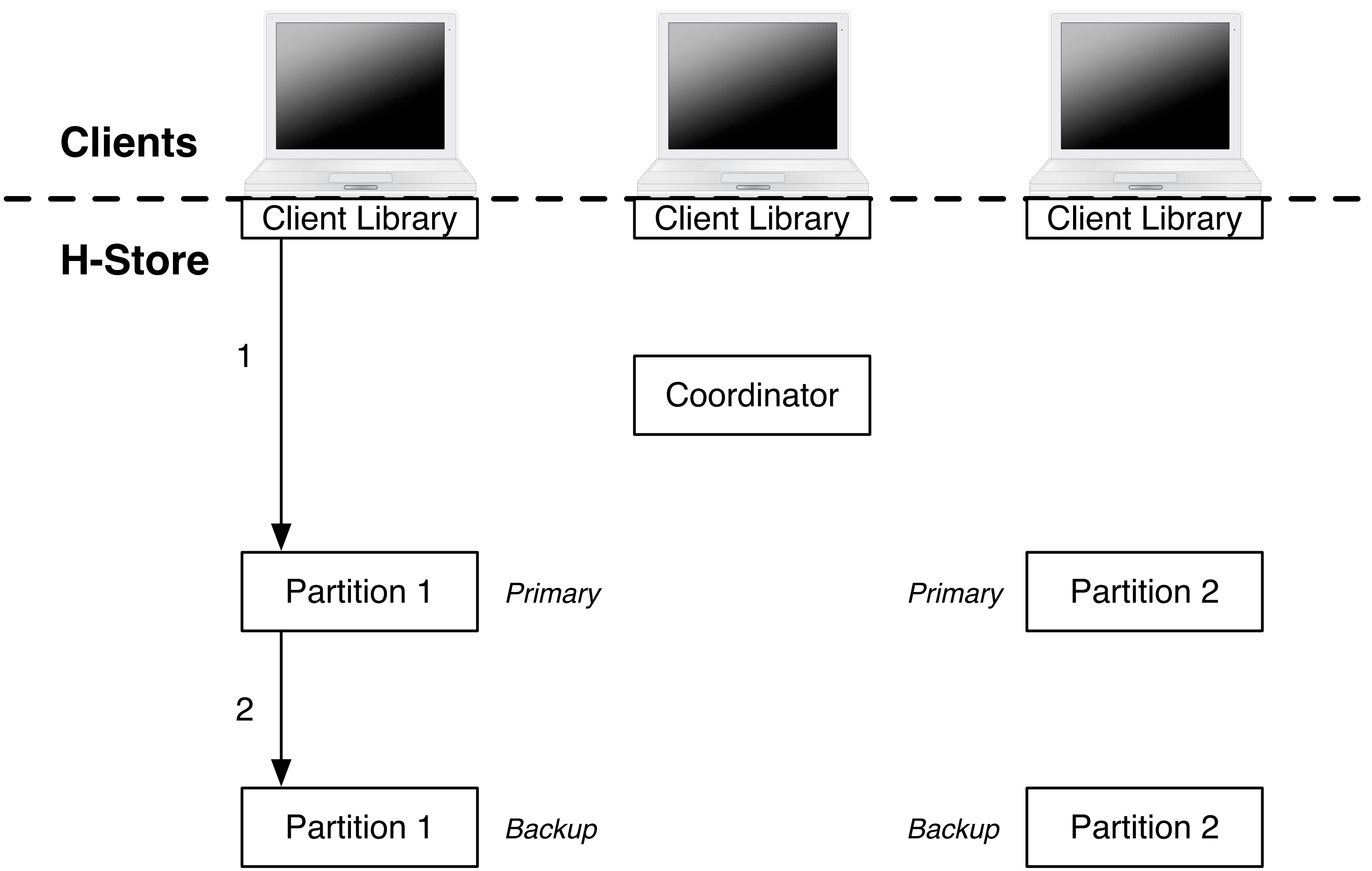


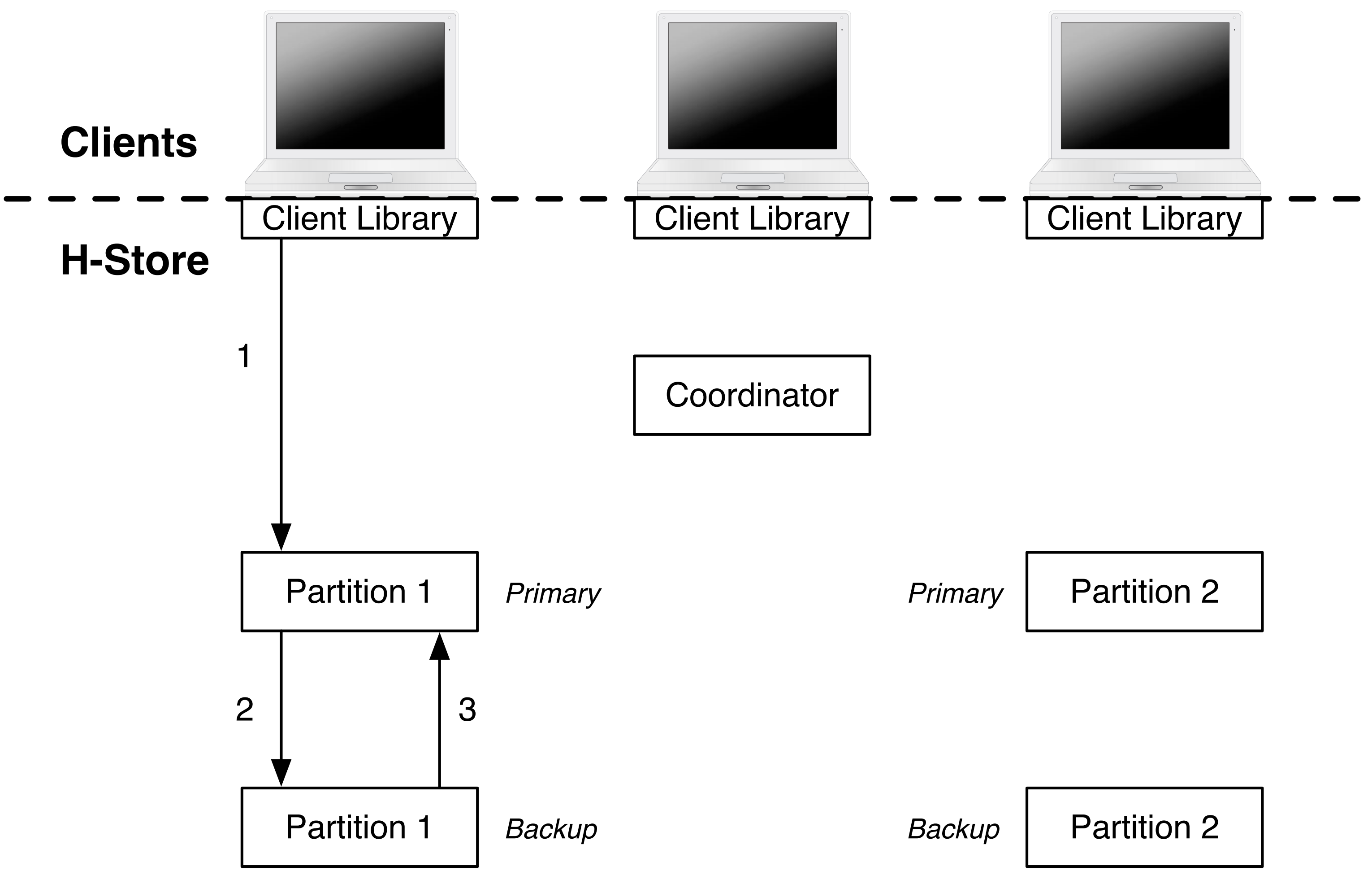
Single Partition Transaction



Single Partition Transaction



Single Partition Transaction



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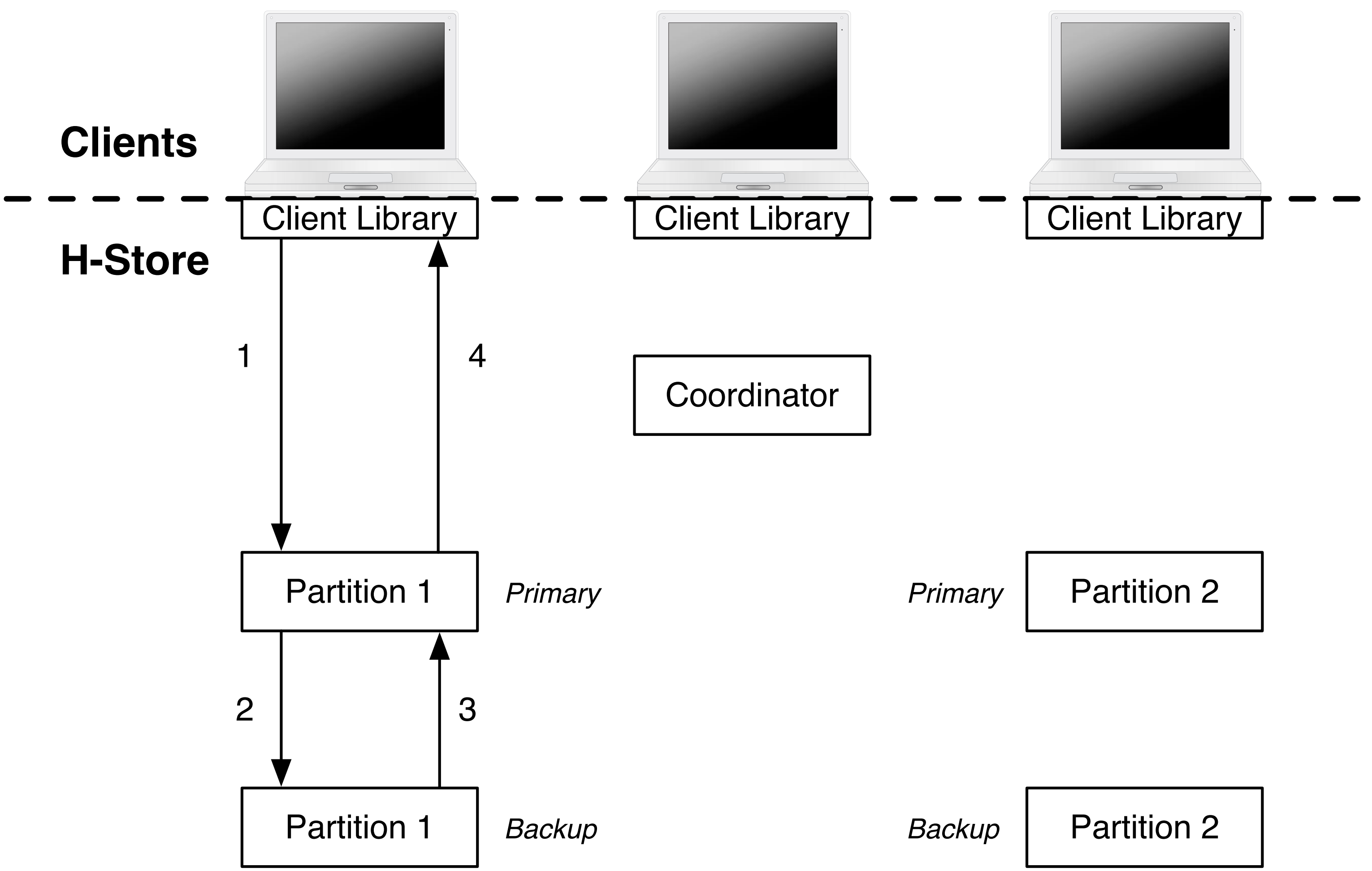

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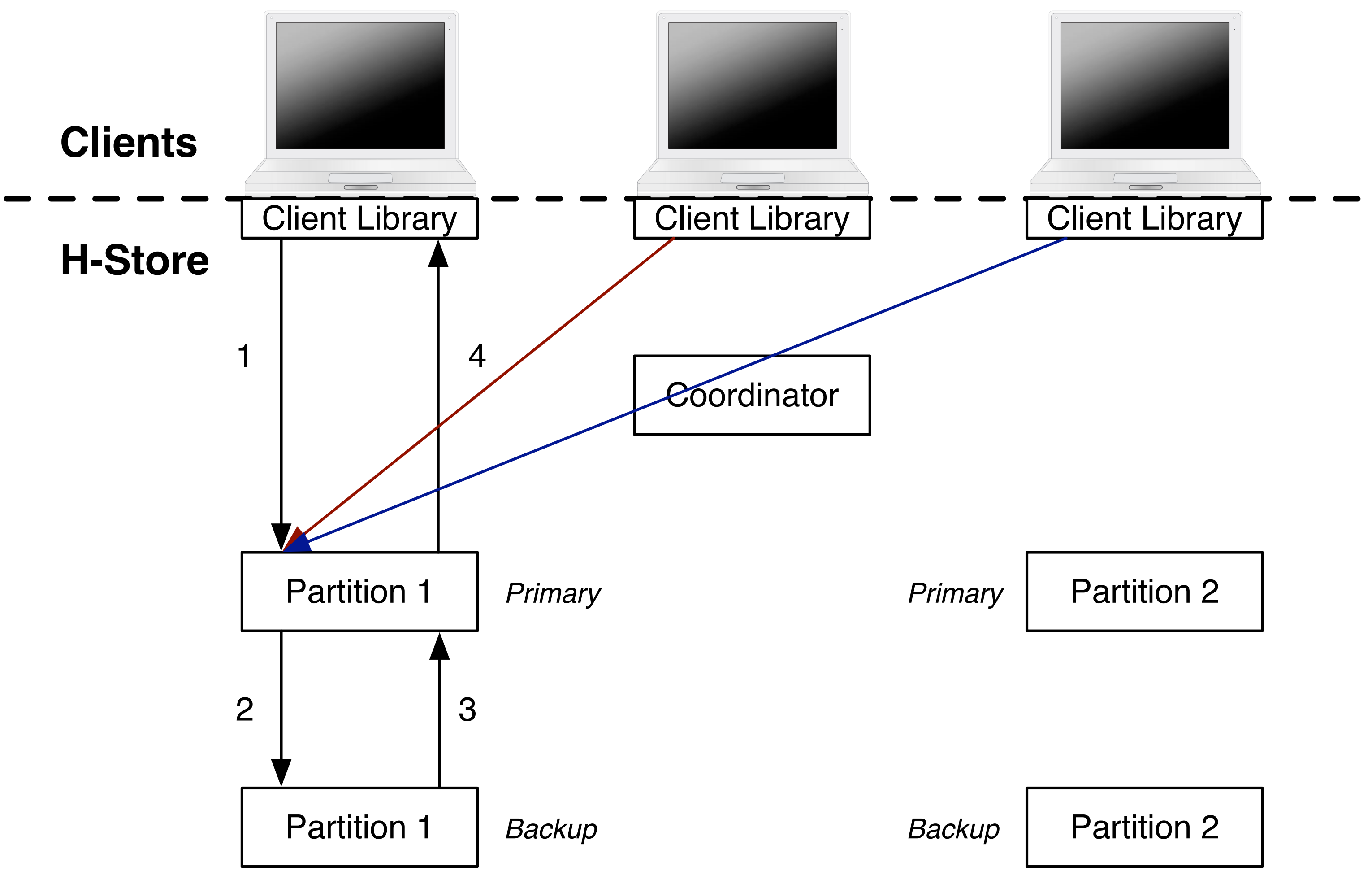
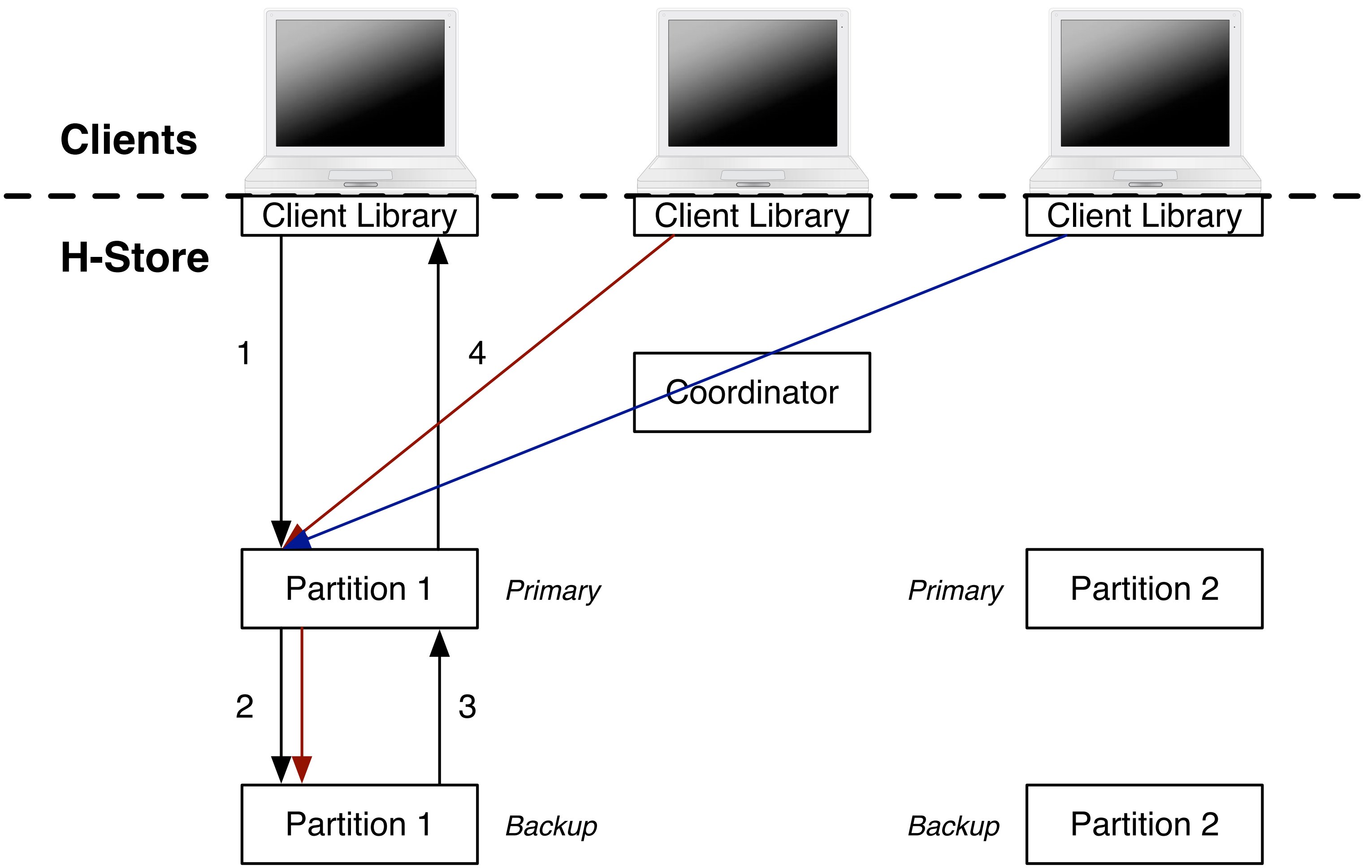
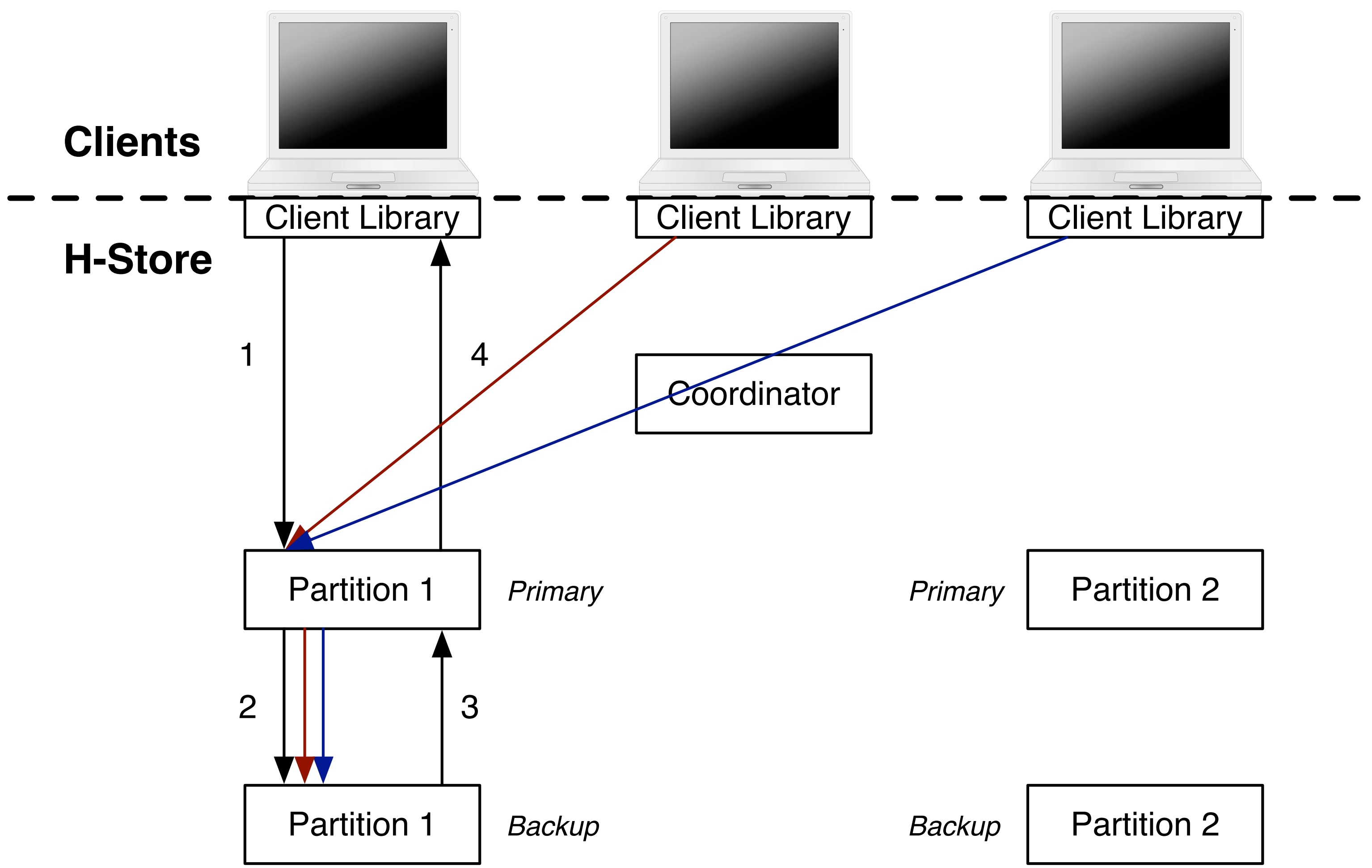


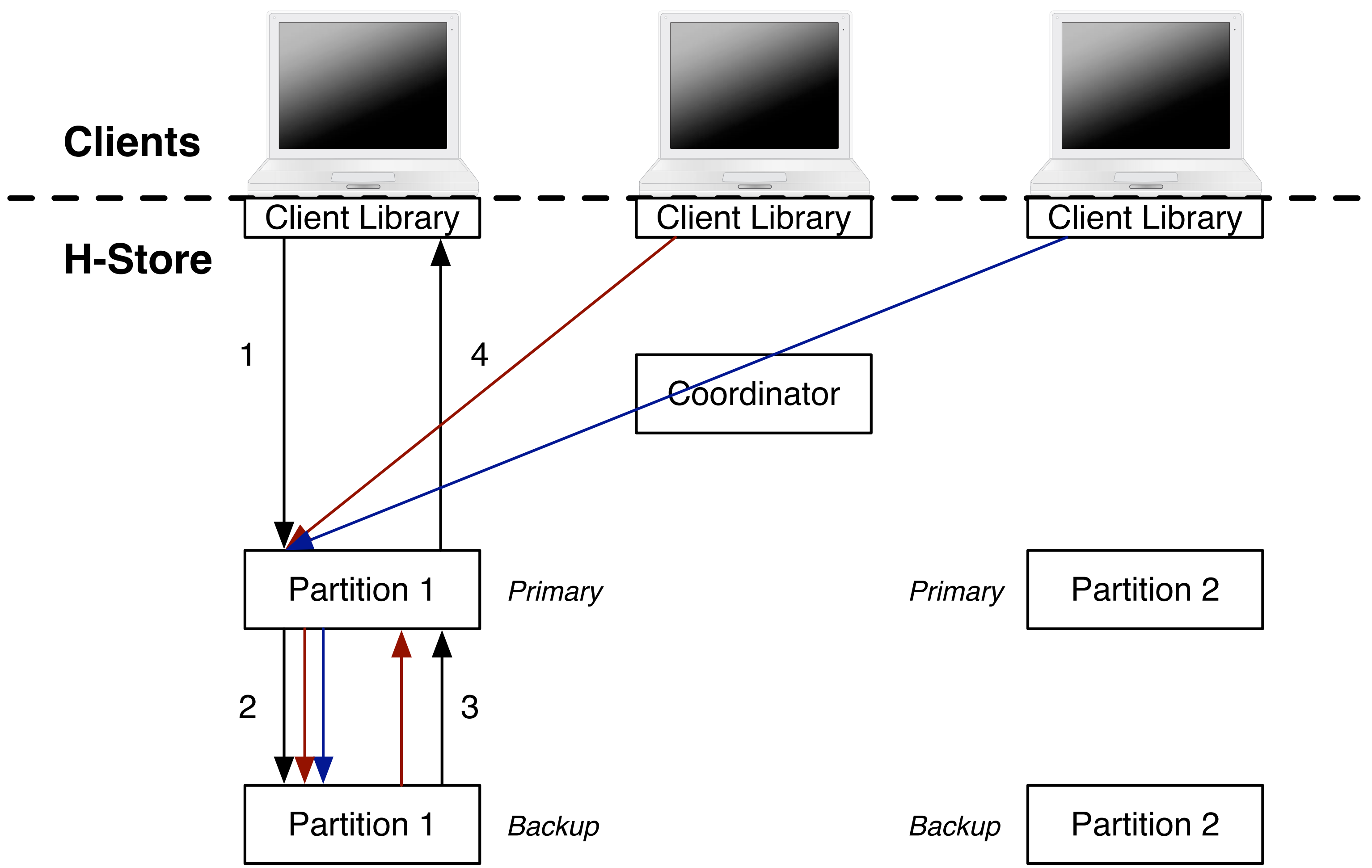
Single Partition Transaction



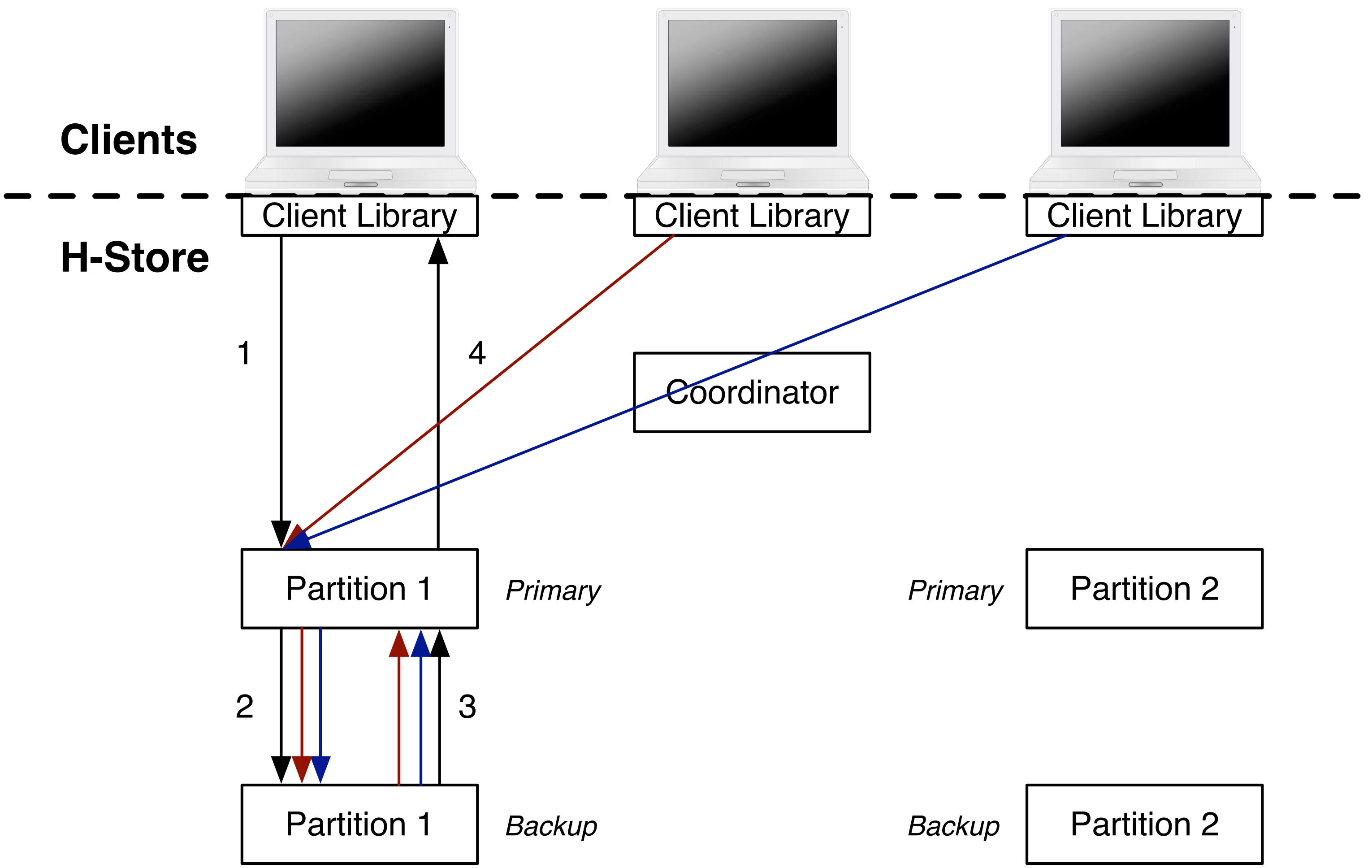
Single Partition Transaction



Single Partition Transaction



Single Partition Transaction



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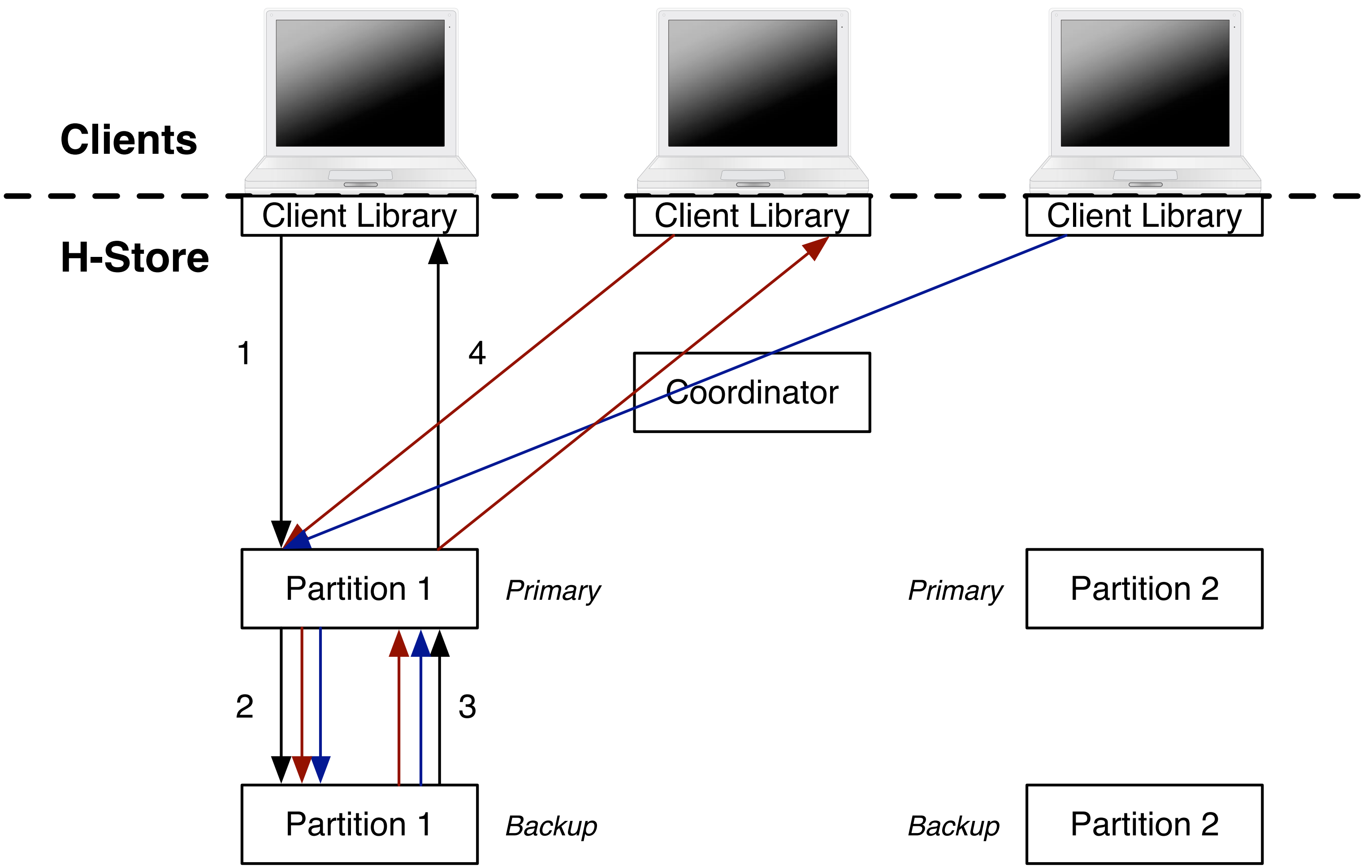

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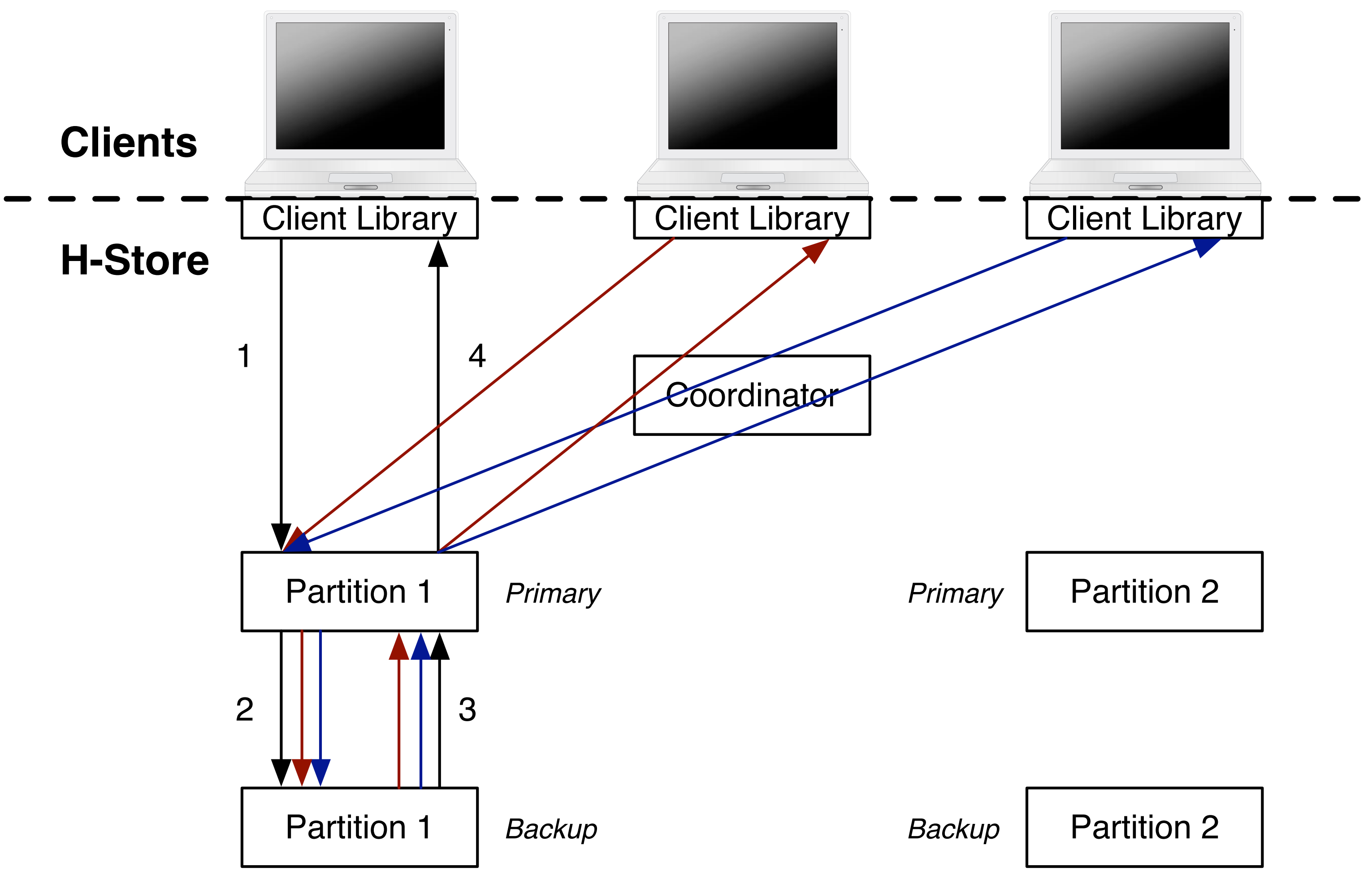


Not Perfectly Partionable?

Example: users and groups

Many applications are *mostly* partitionable

e.g. TPC-C: 11% multi-partition transactions

Distributed Transactions

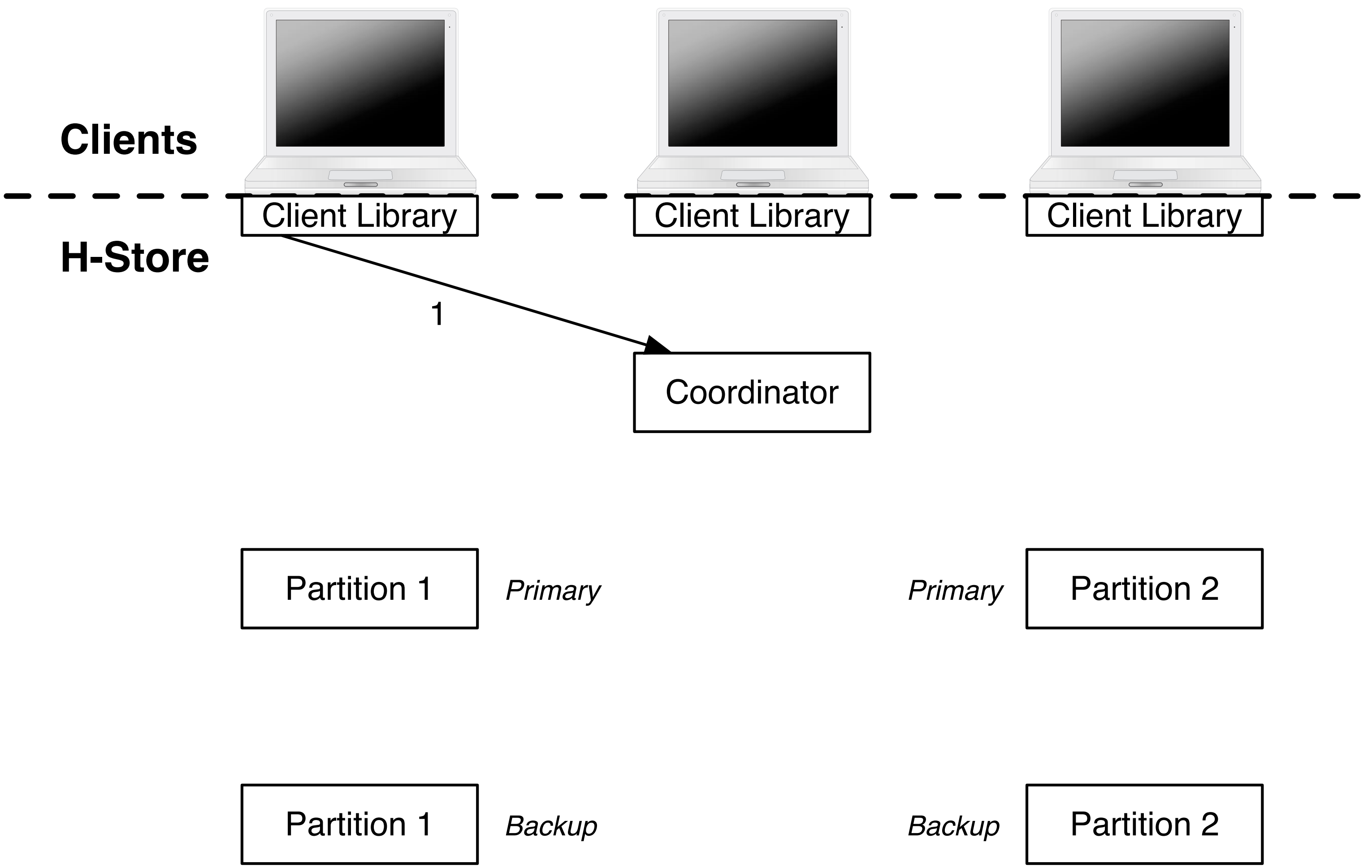
Need two-phase commit (consensus)

Simple solution:

block until the transaction finishes

Introduces network stall (**bad**)

Blocking Multi-Partition



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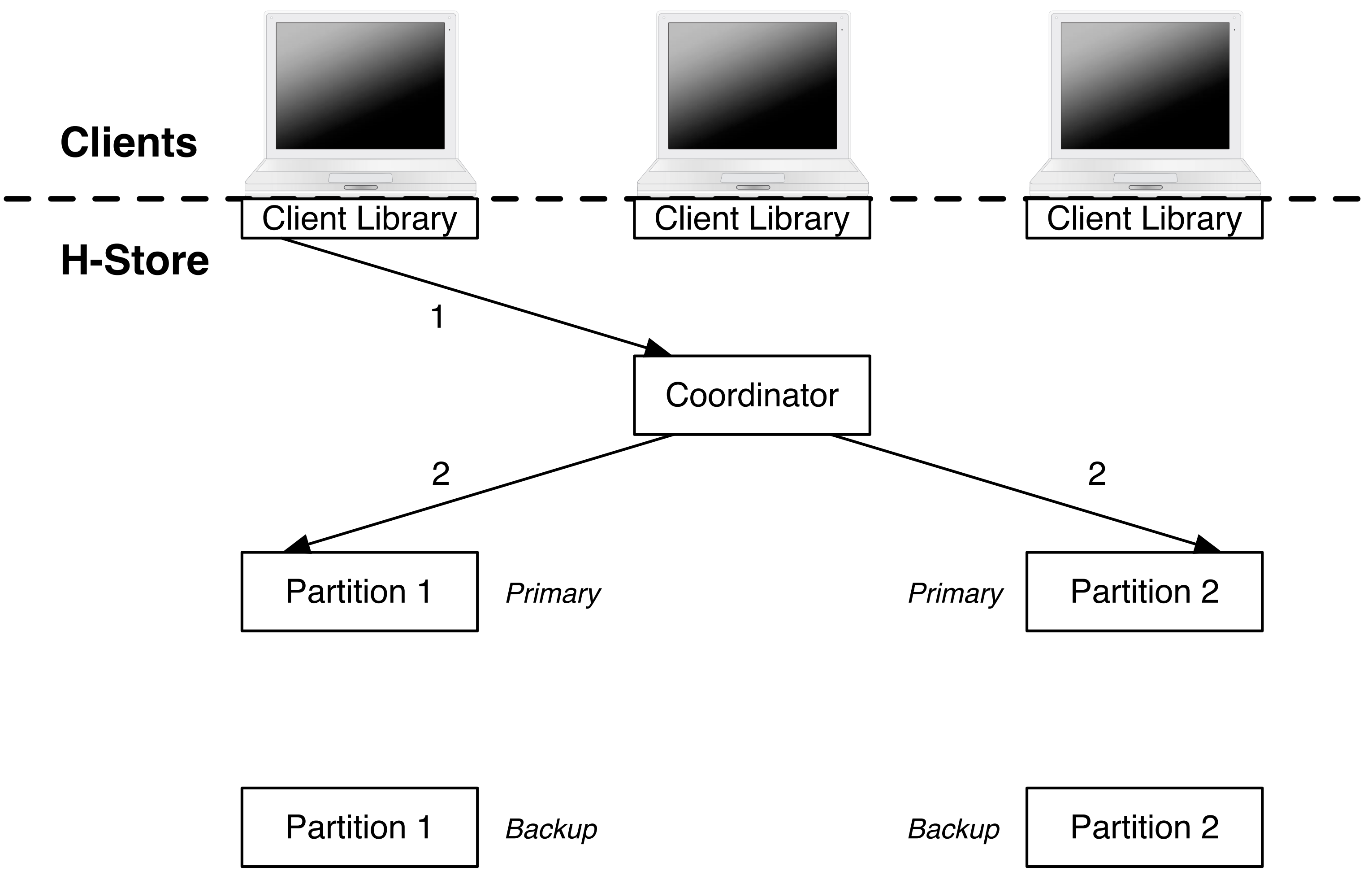

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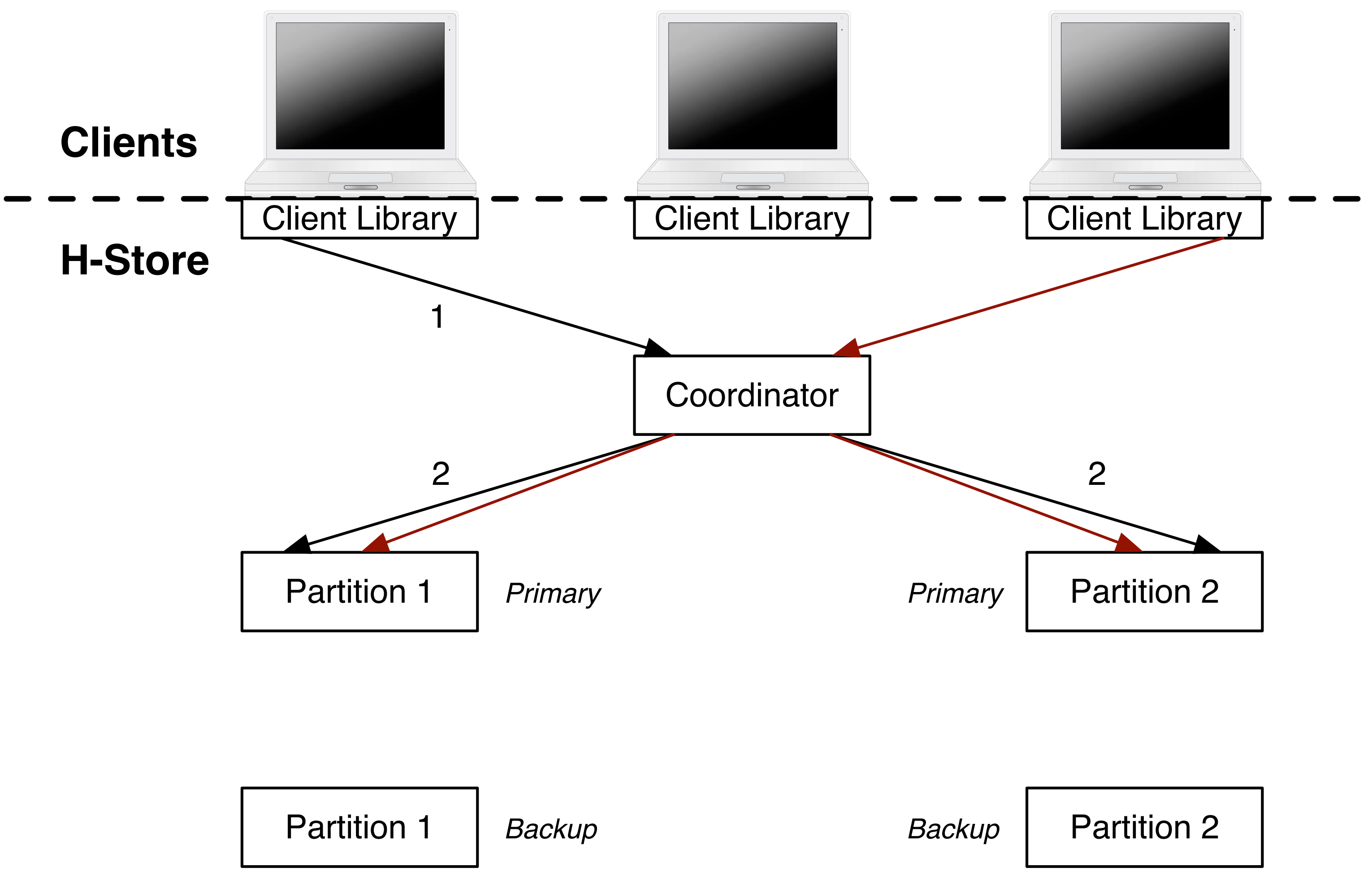

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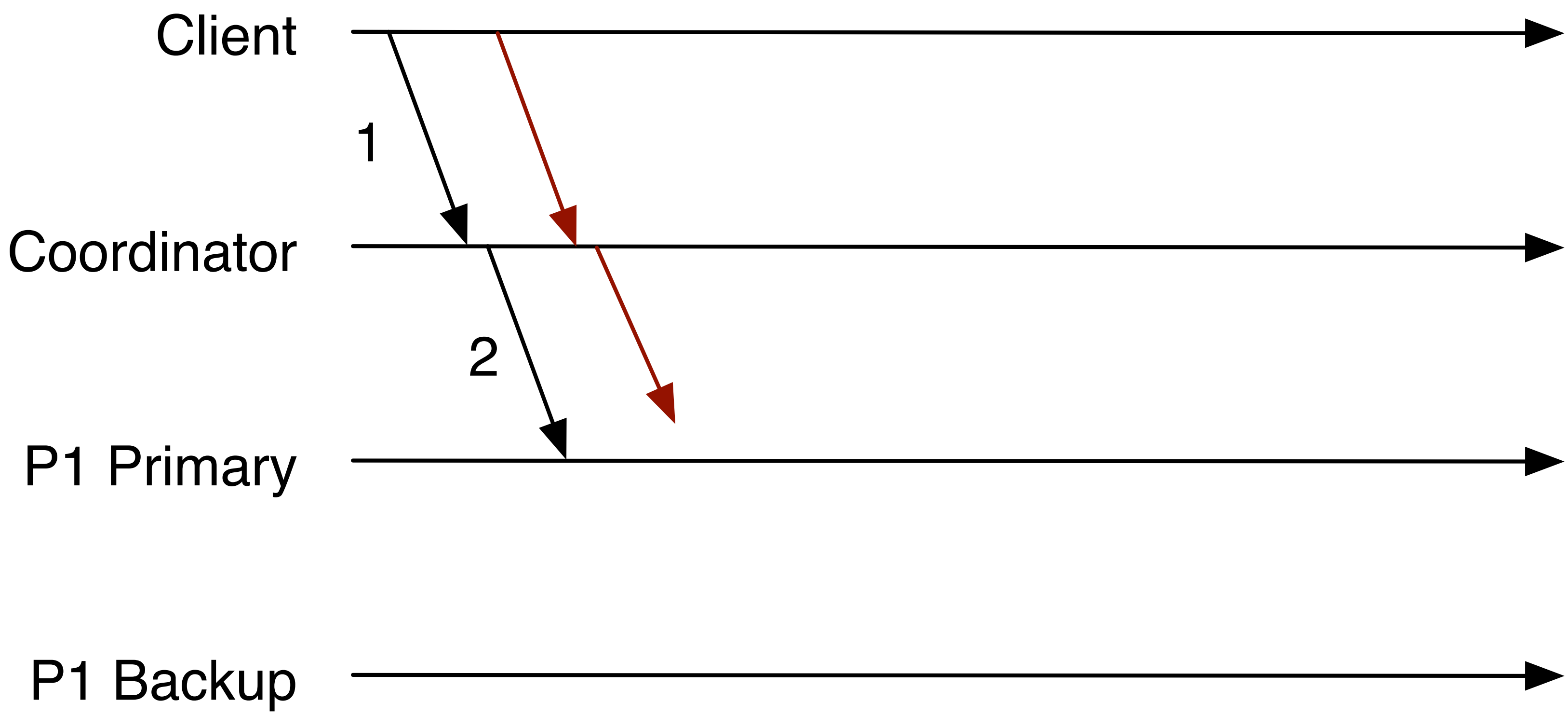

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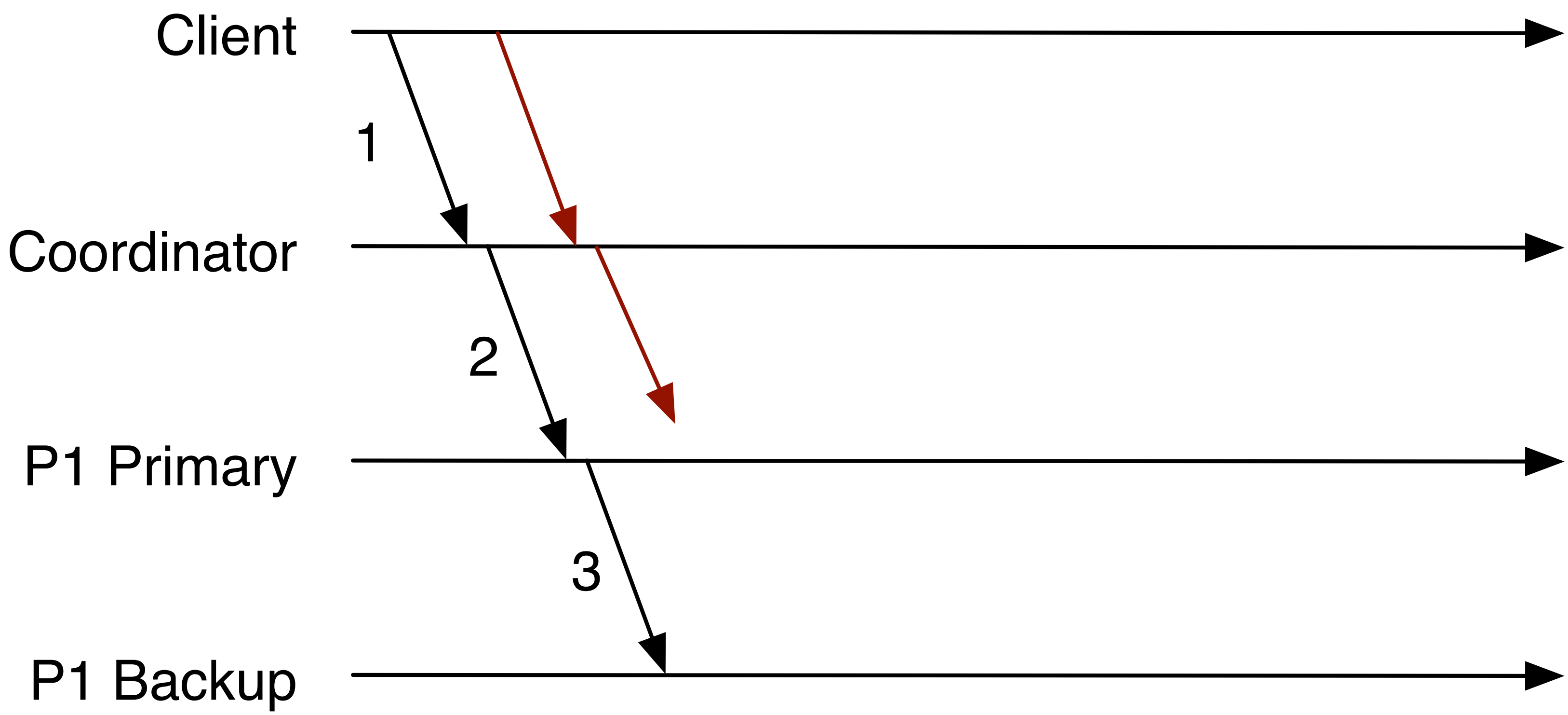

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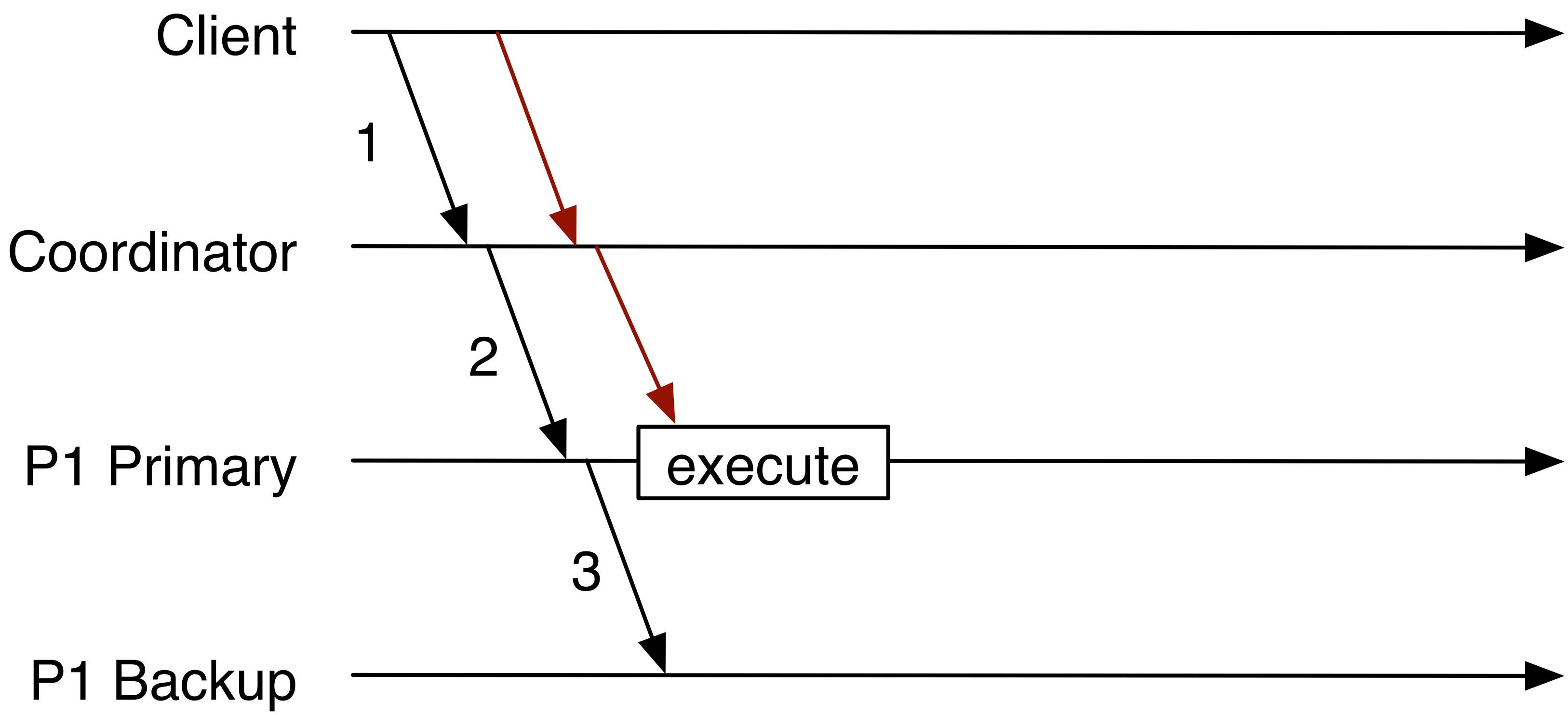

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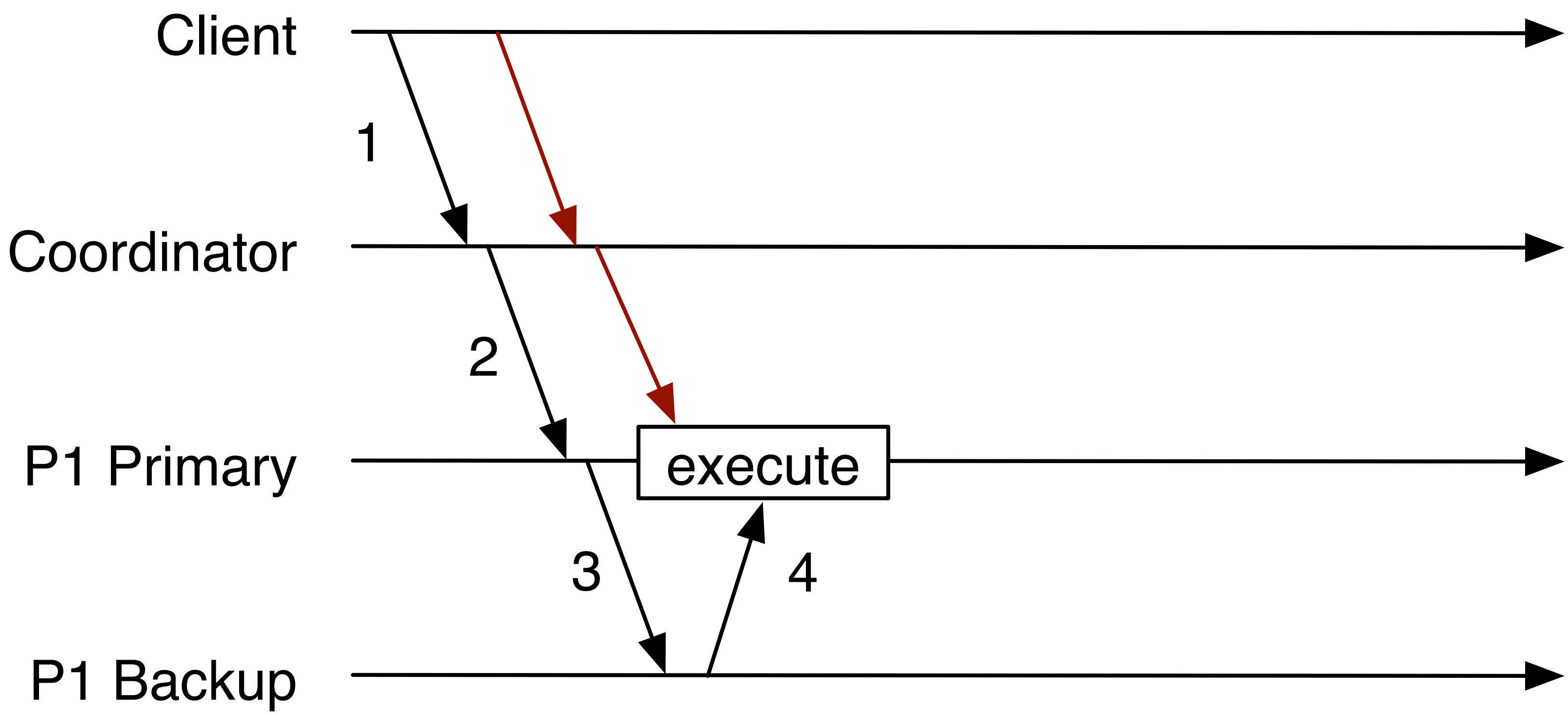

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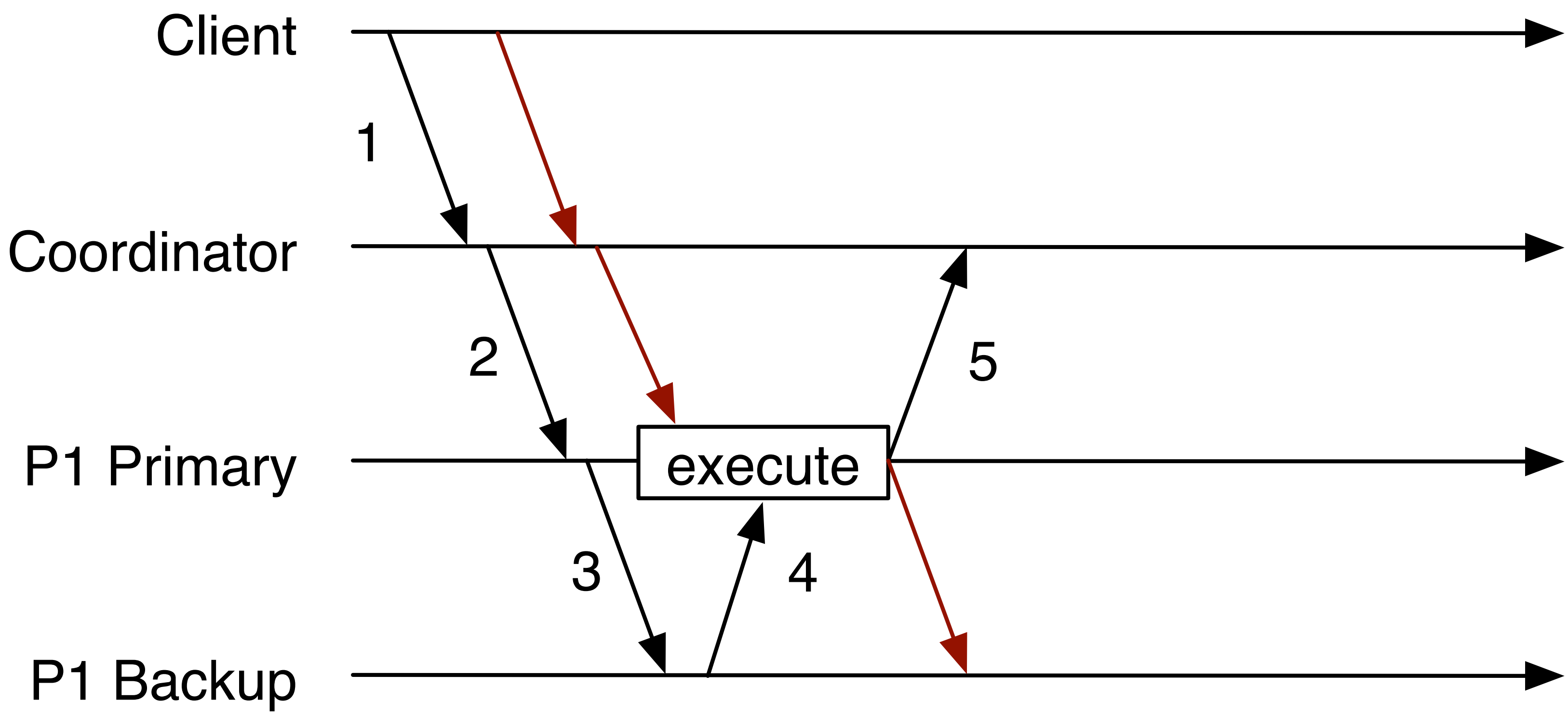

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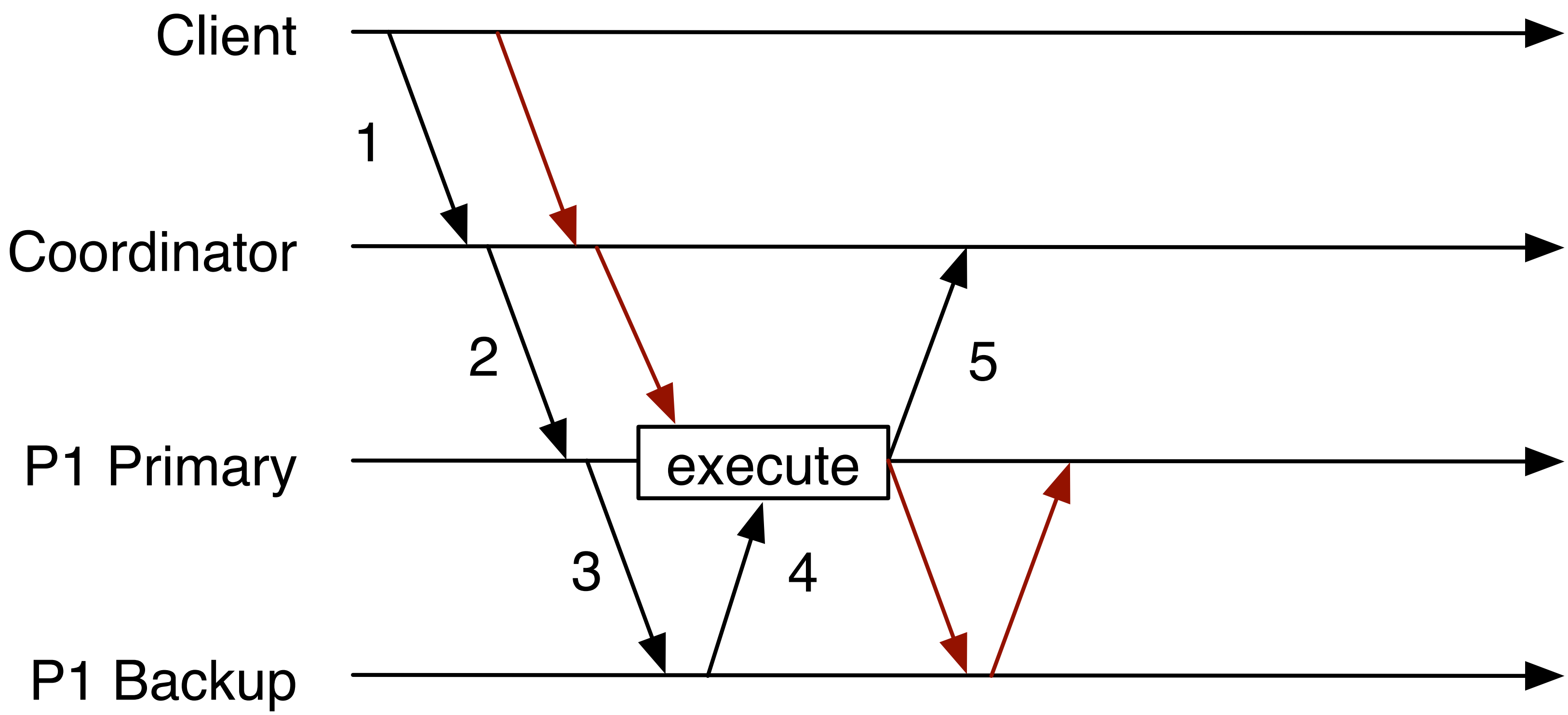

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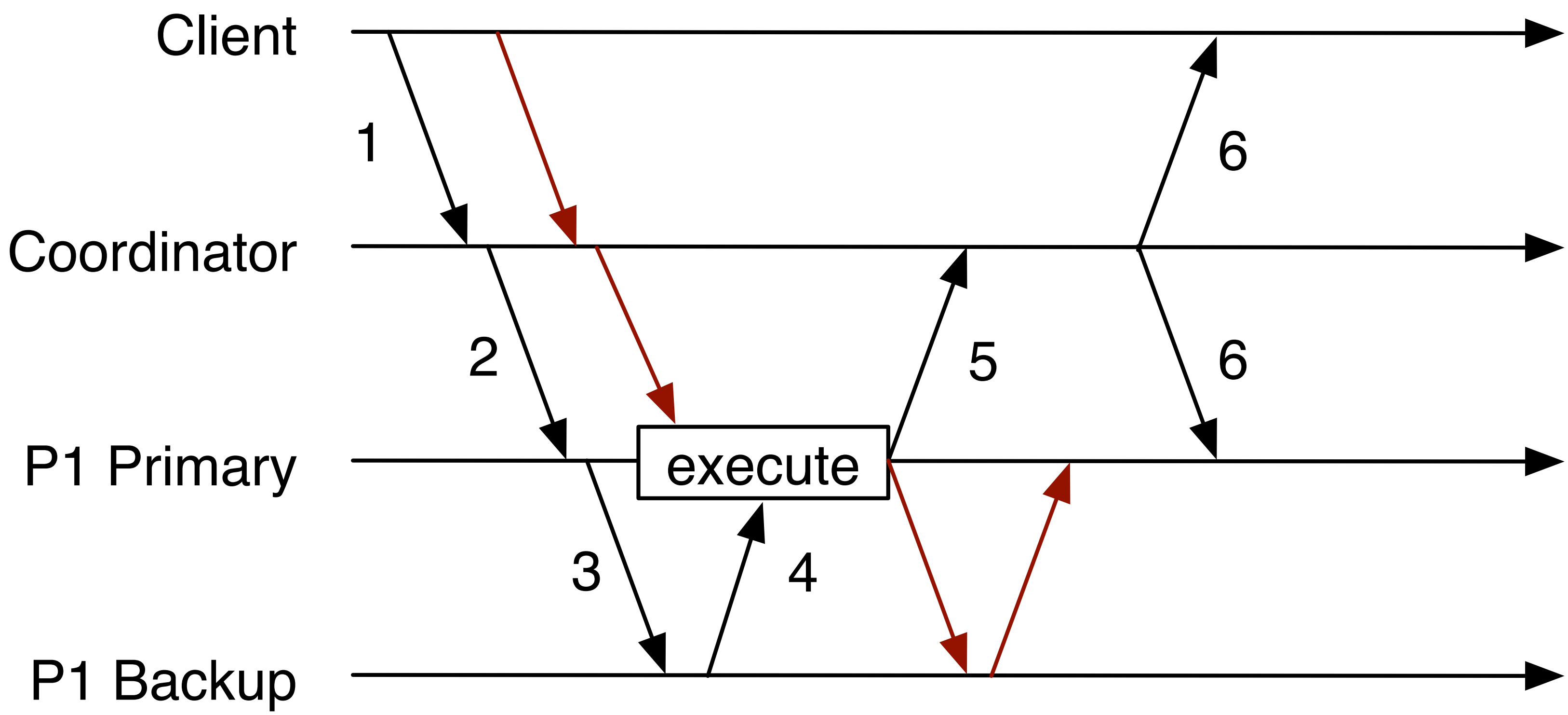

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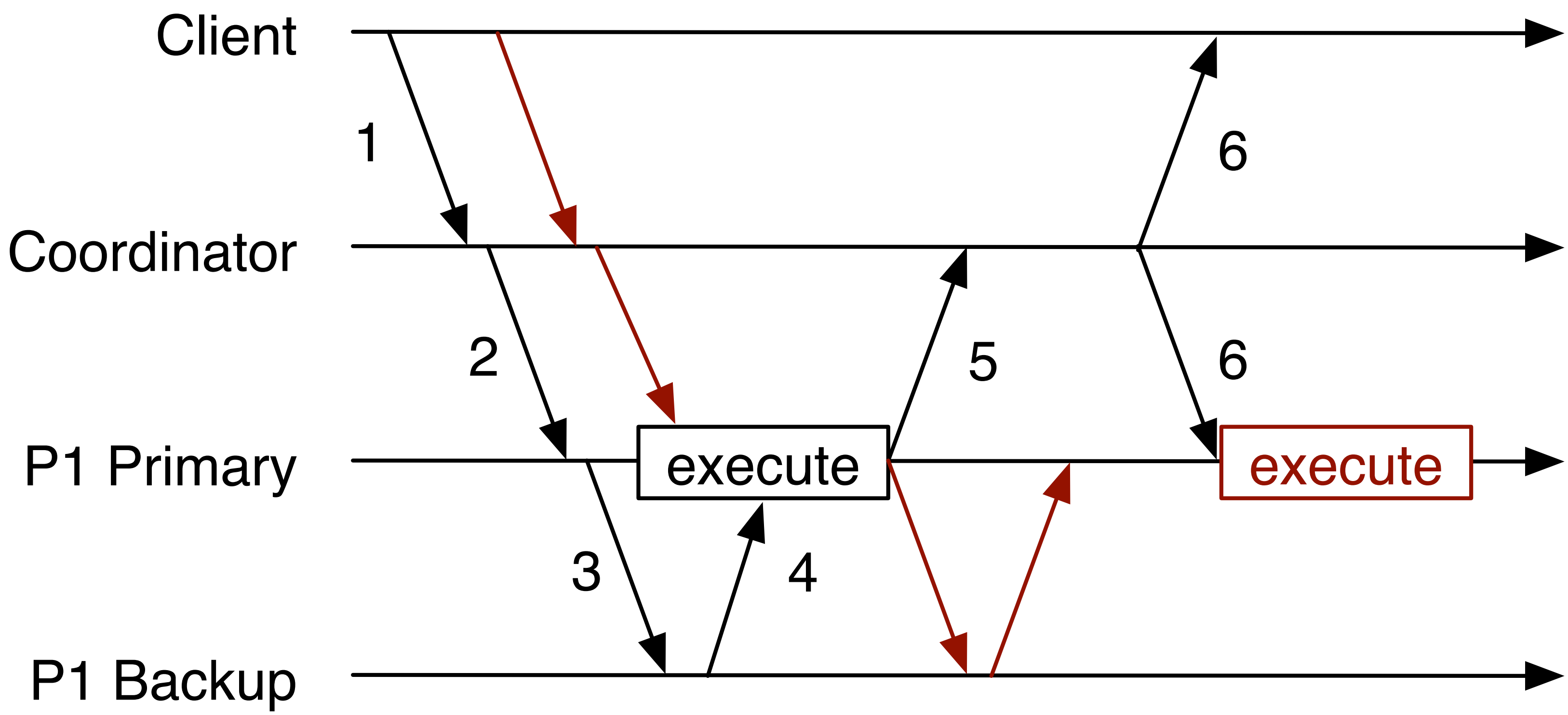

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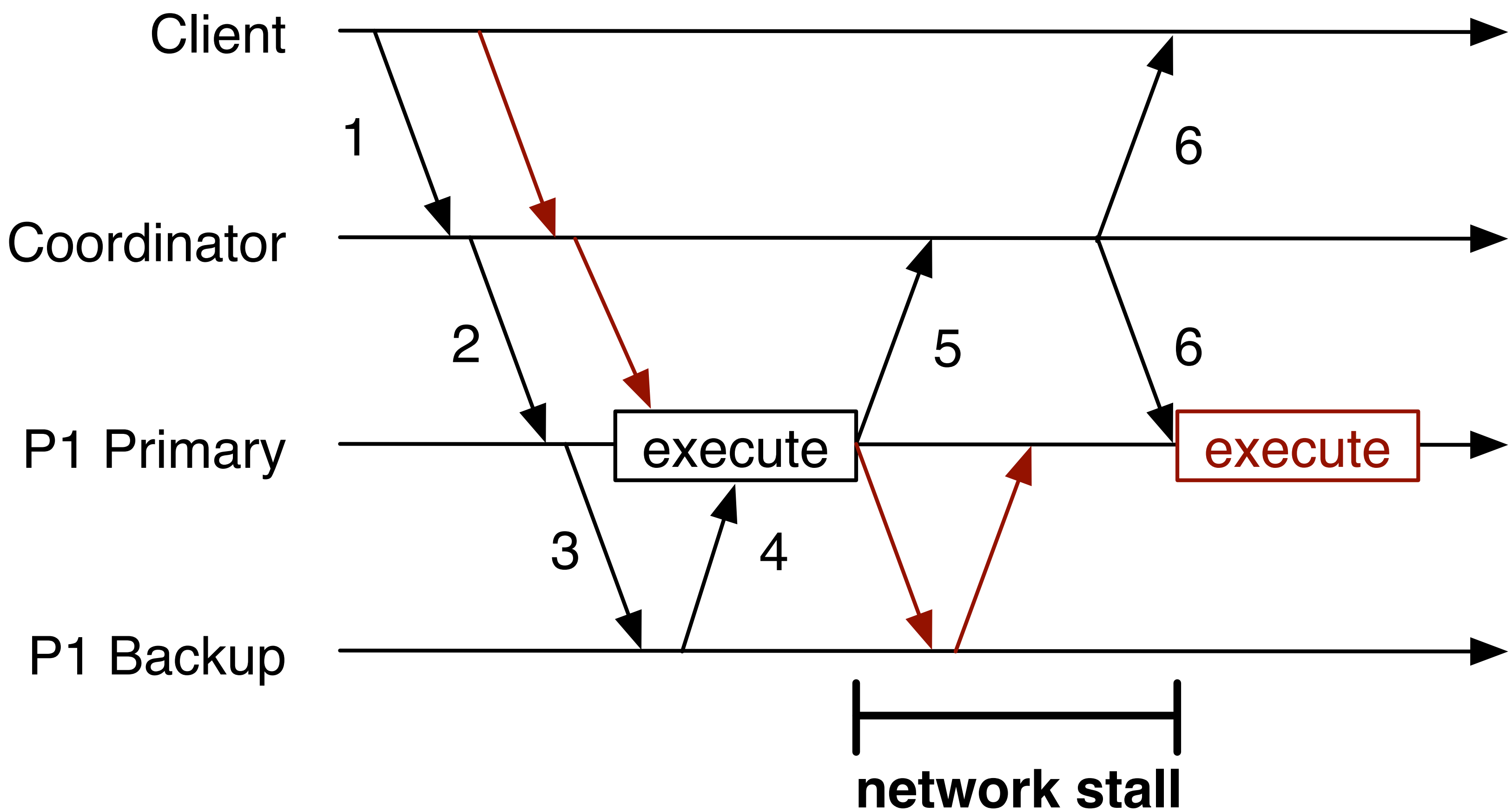

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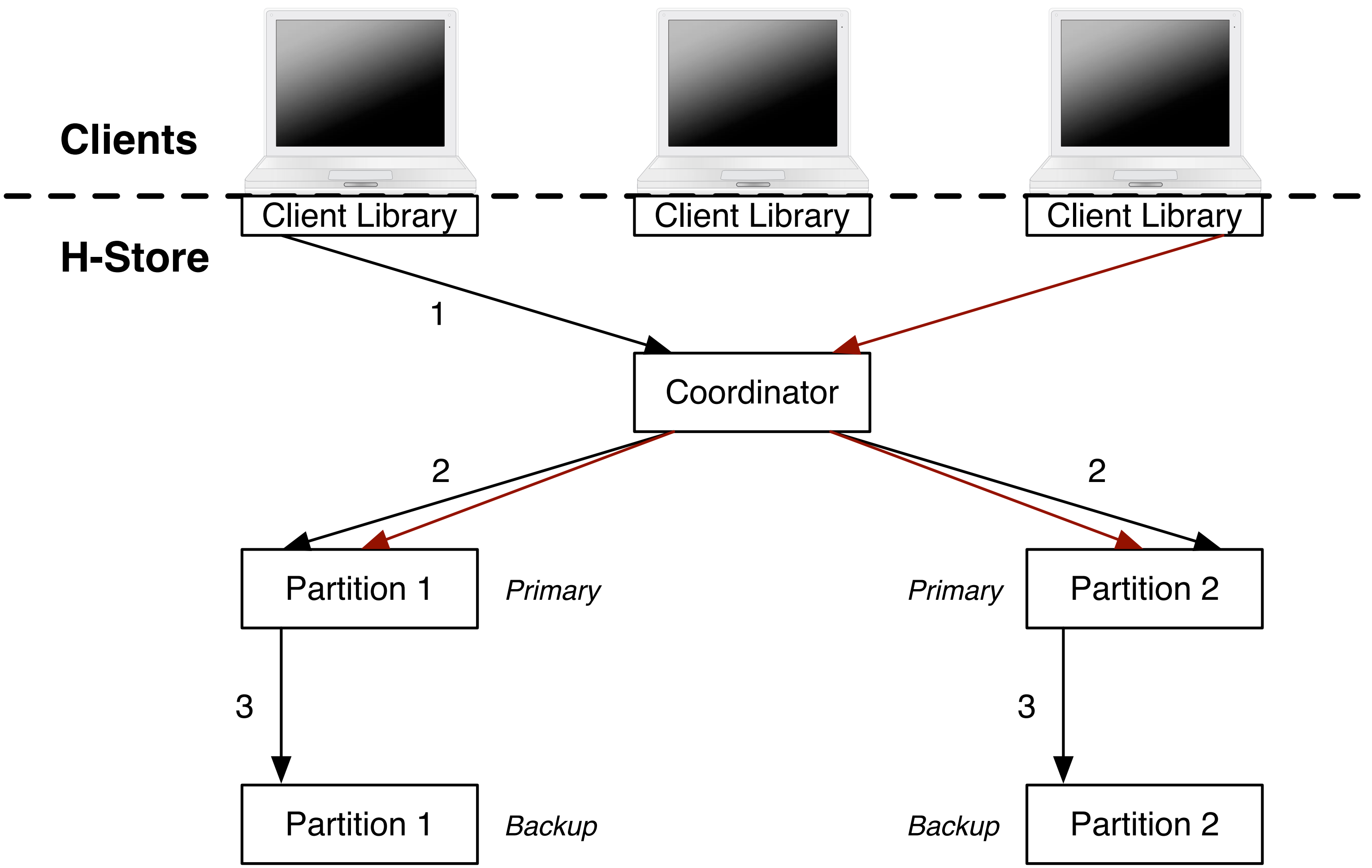

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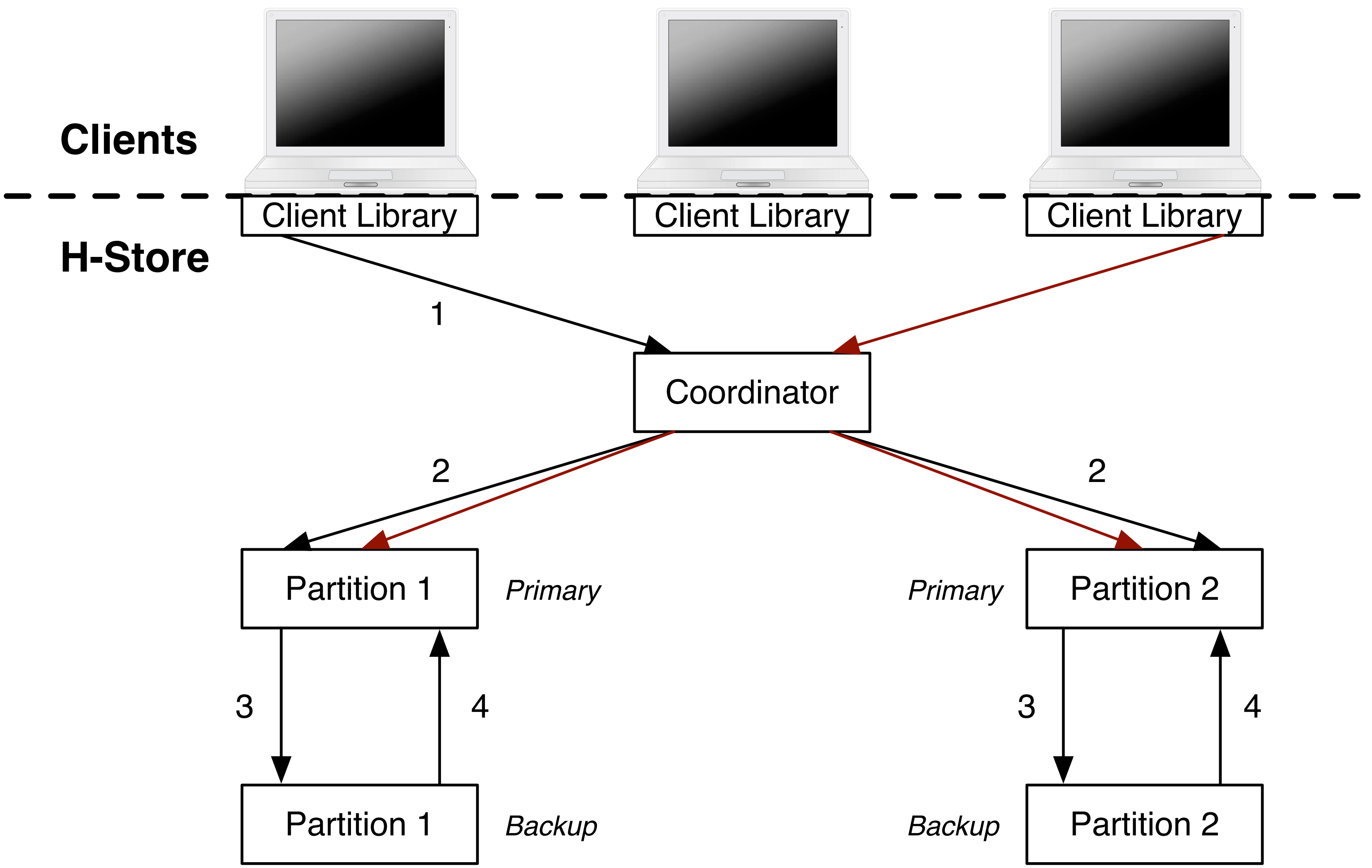

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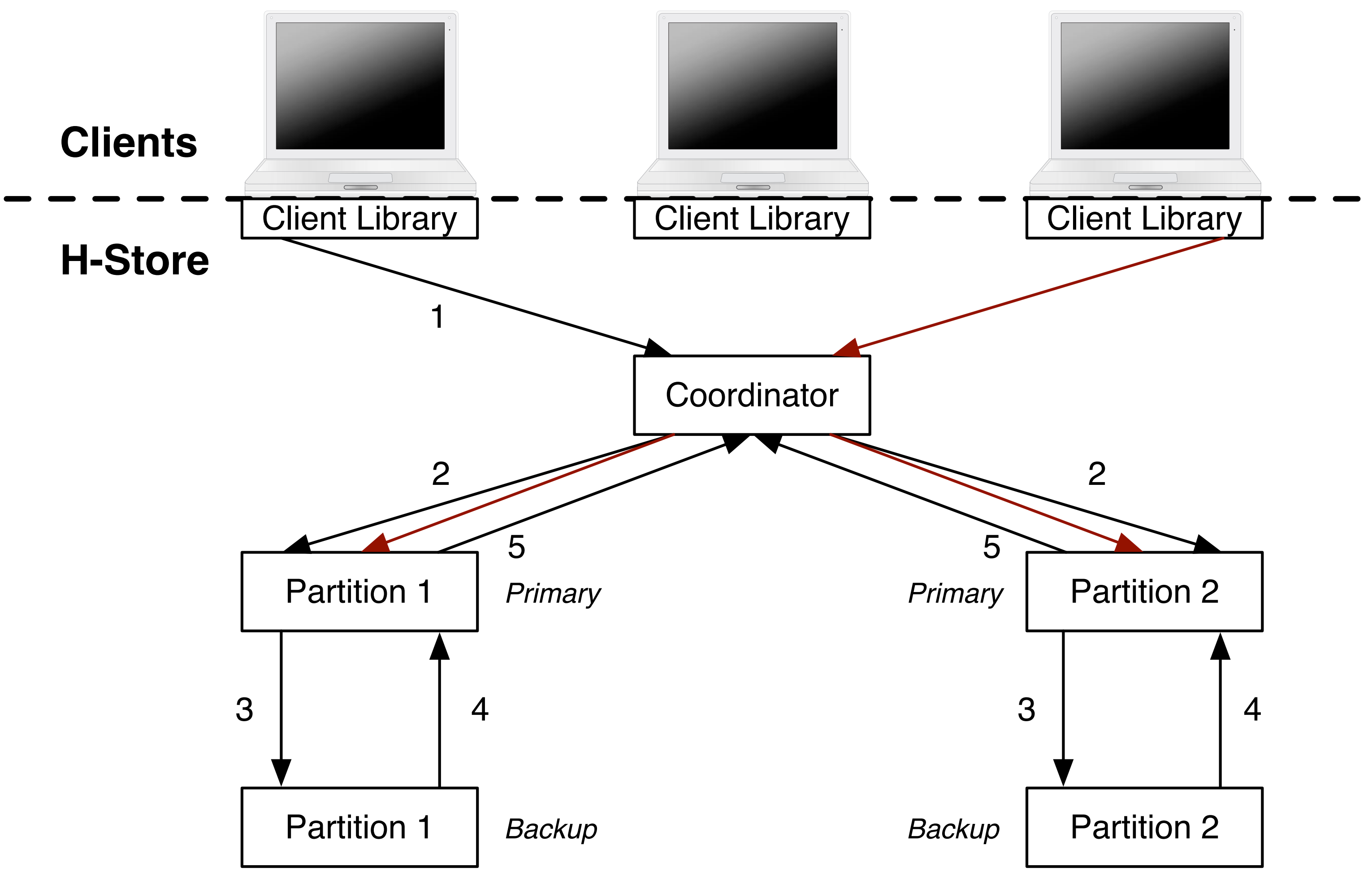

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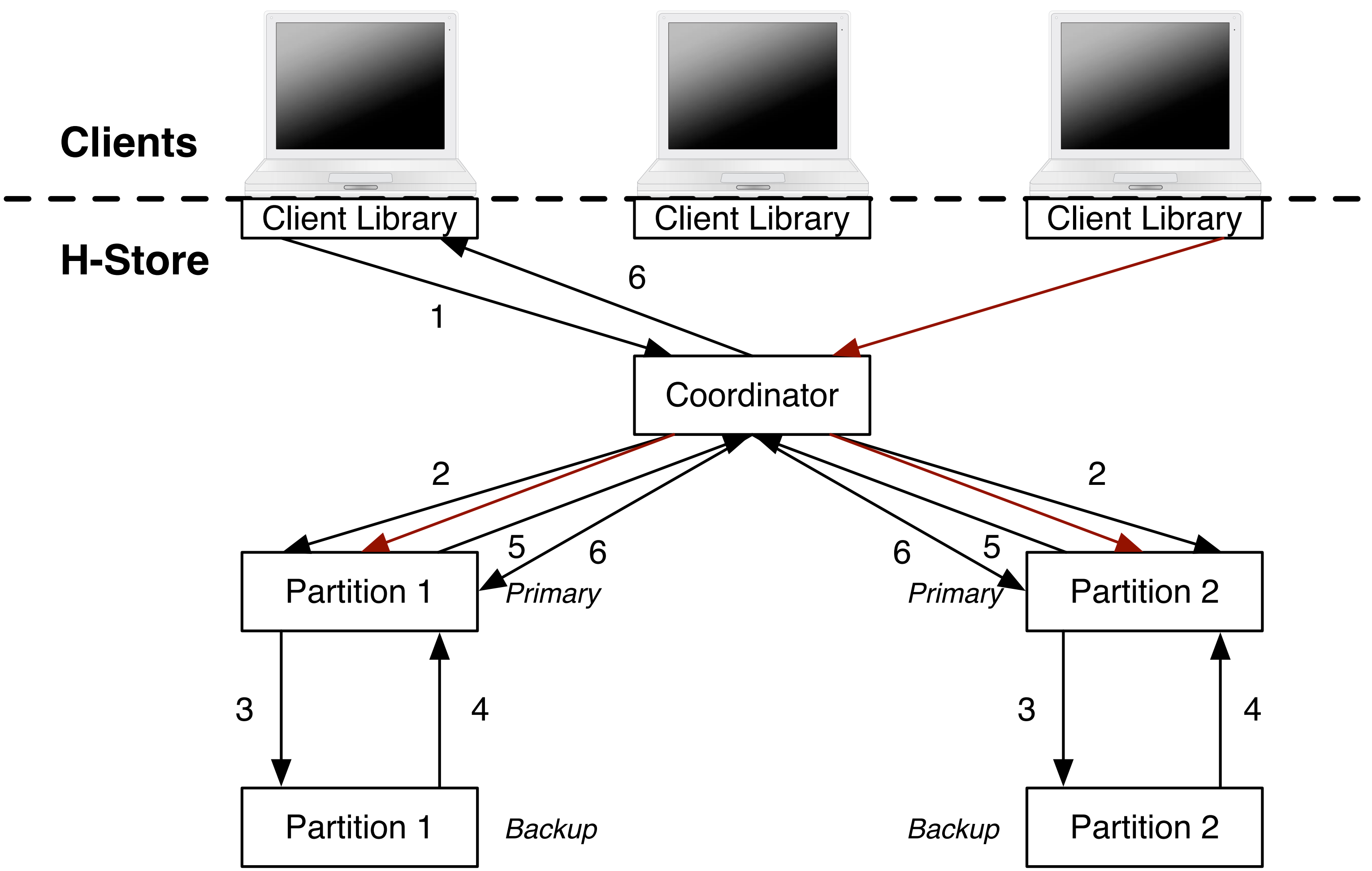

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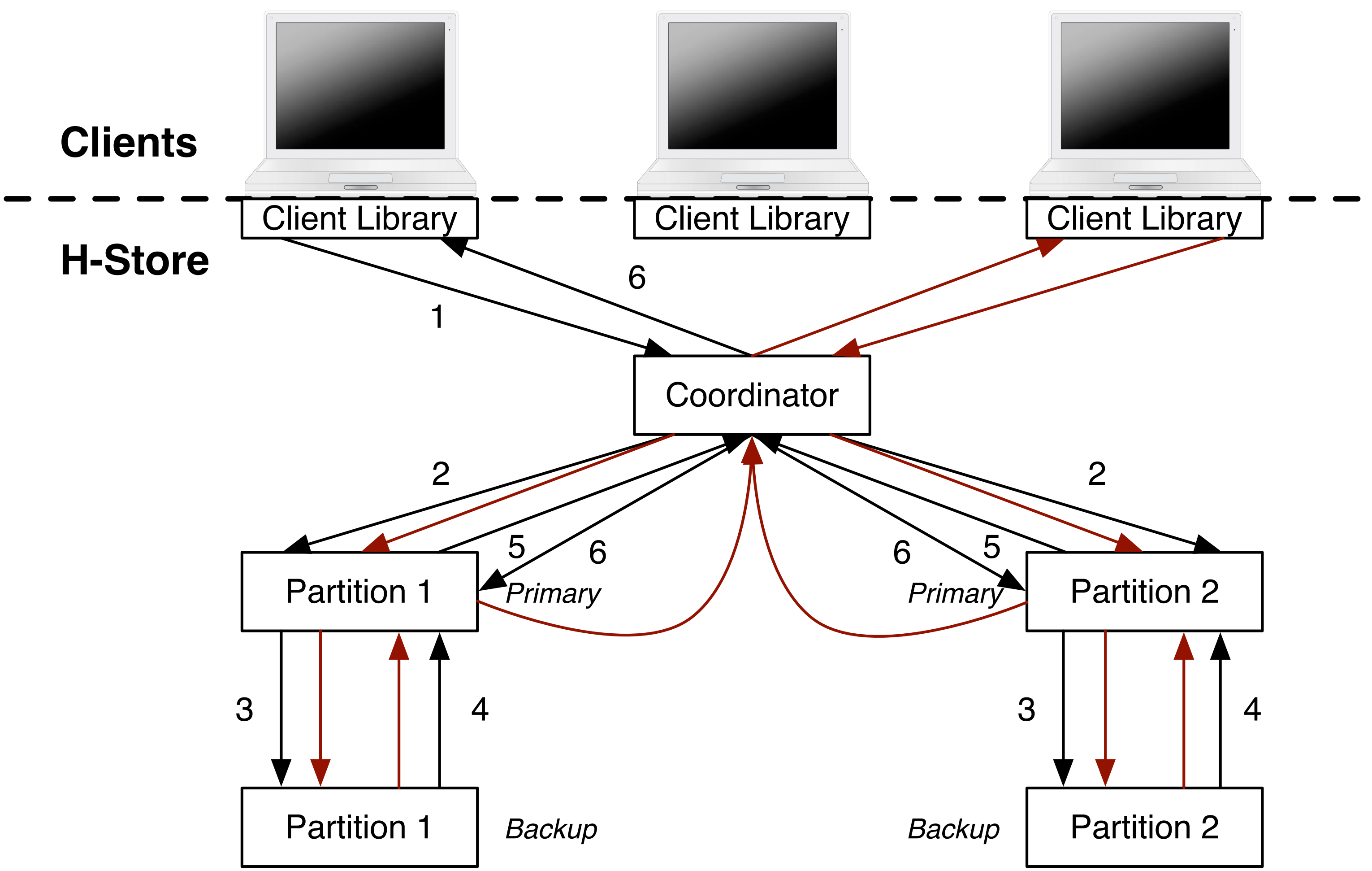


Two-Phase Locking

+ Execute non-conflicting txns during stall
+ No need to order in advance
– Locking overhead
– Deadlocks

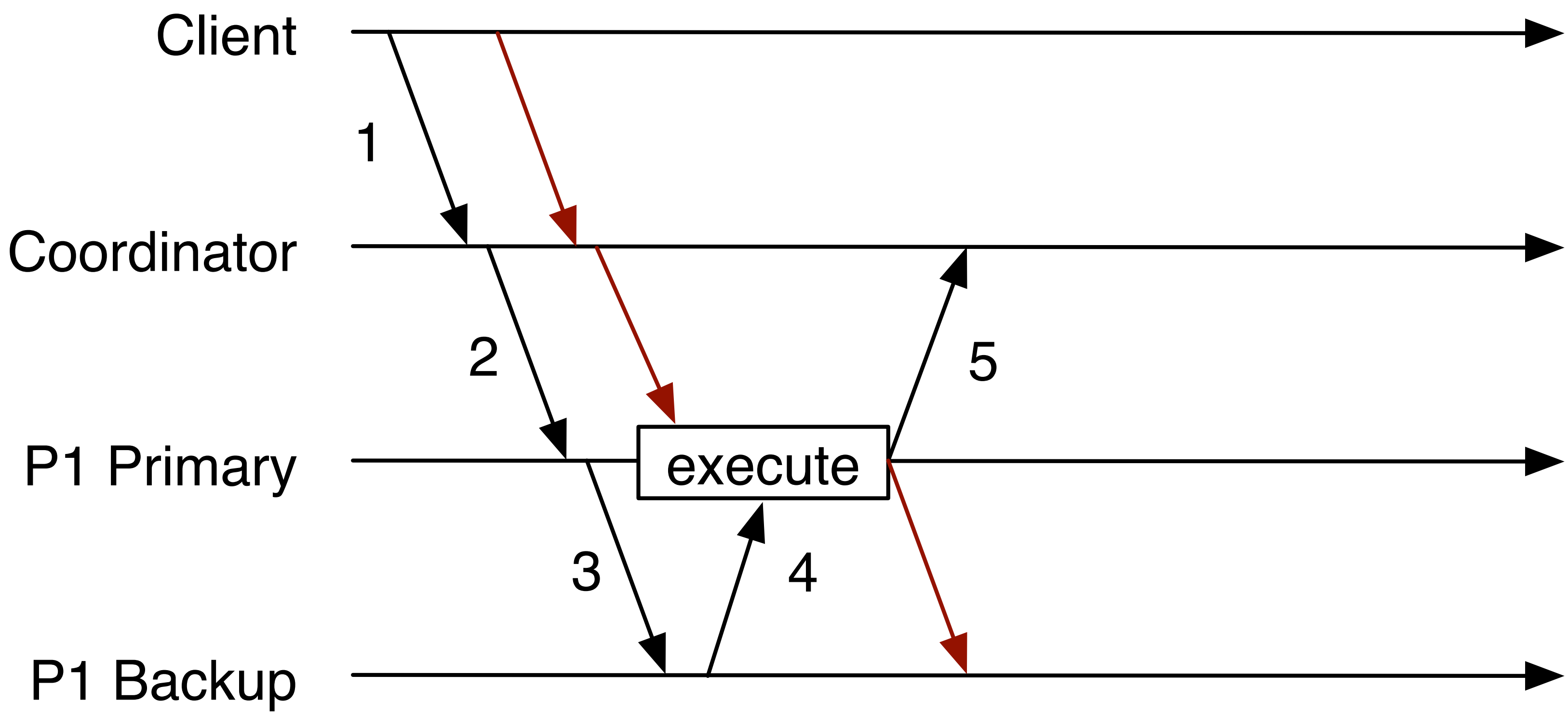
Optimization: turn off locks and undo logging when no multi-partition transactions

Speculative CC

While waiting for commit/abort, speculatively execute other transactions

+ No locks; no read/write sets
– Need global transaction order
– Cascading aborts

Speculative Multi-Partition



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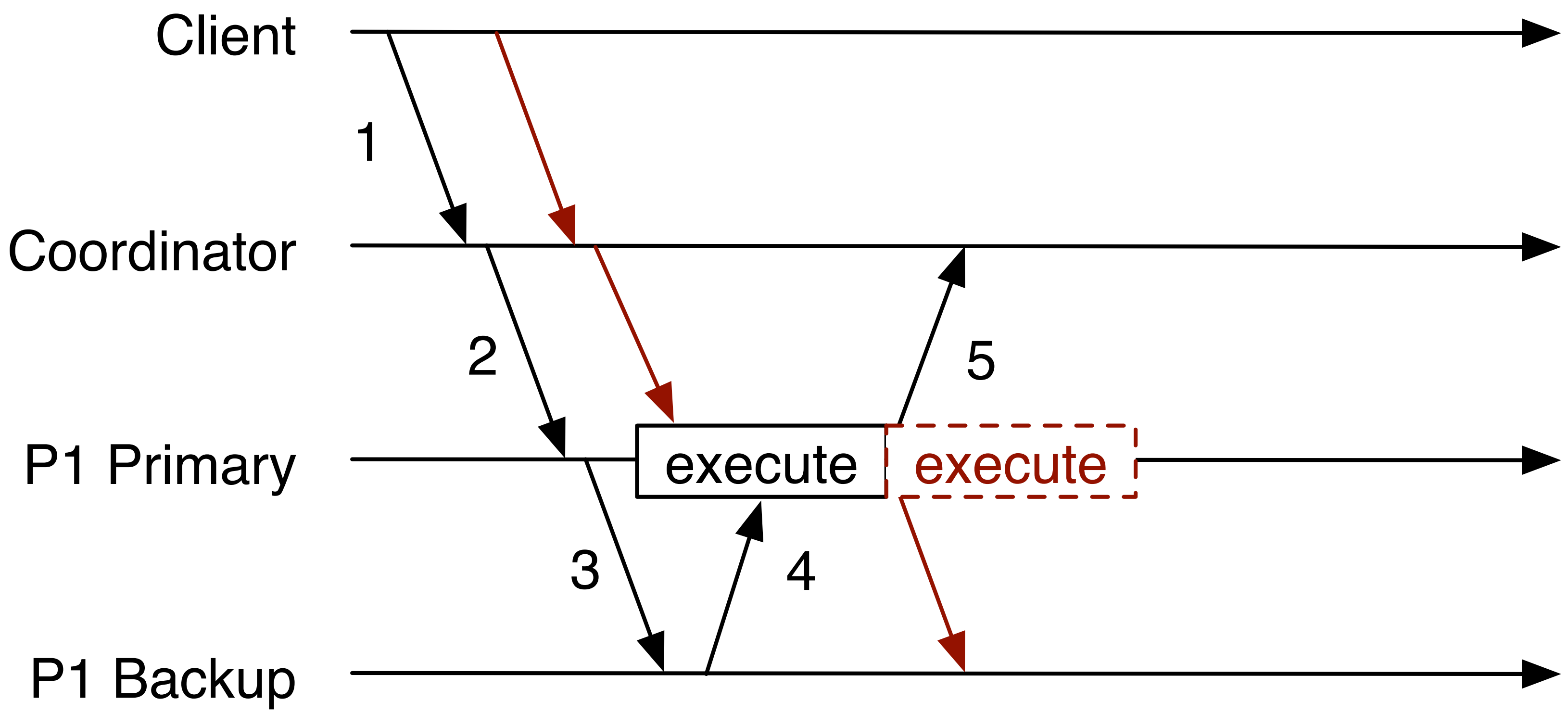

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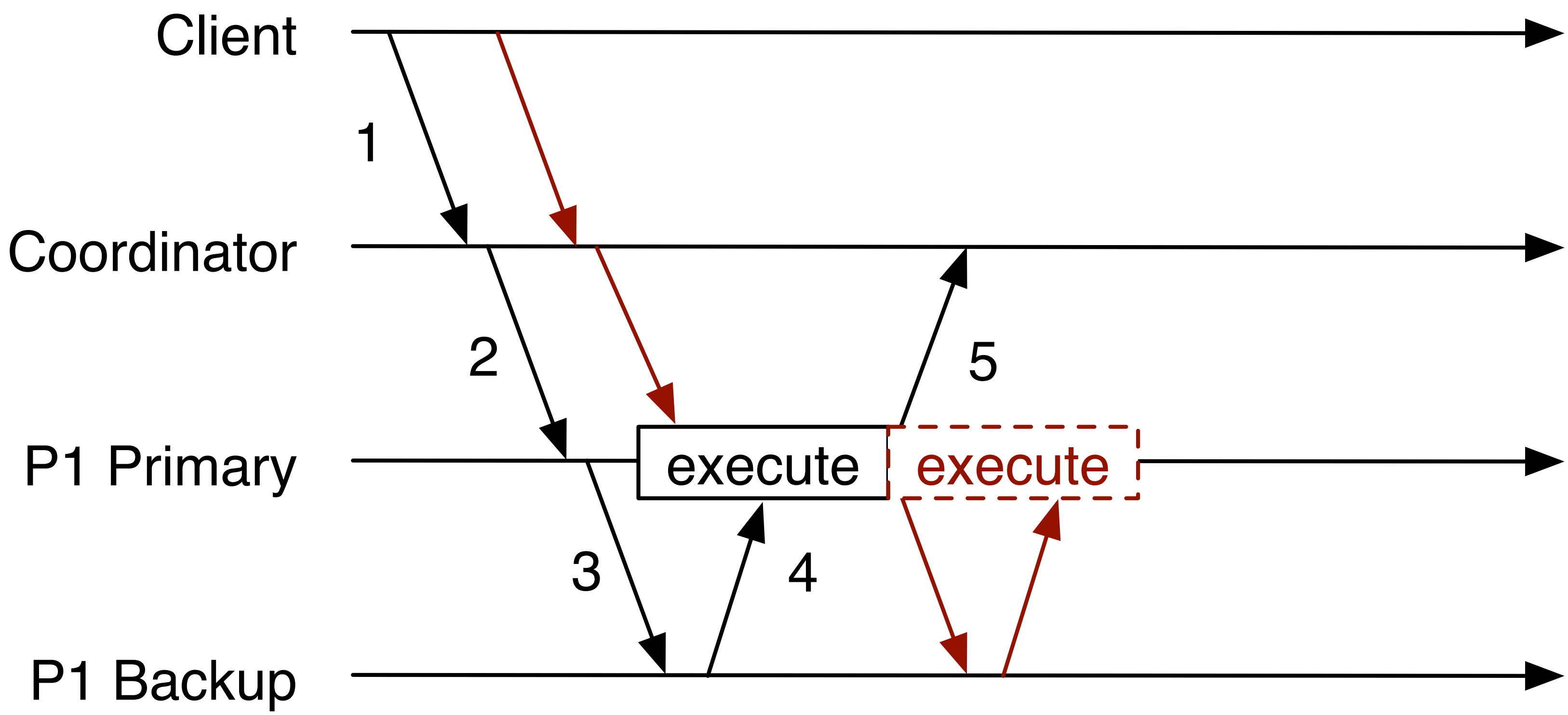

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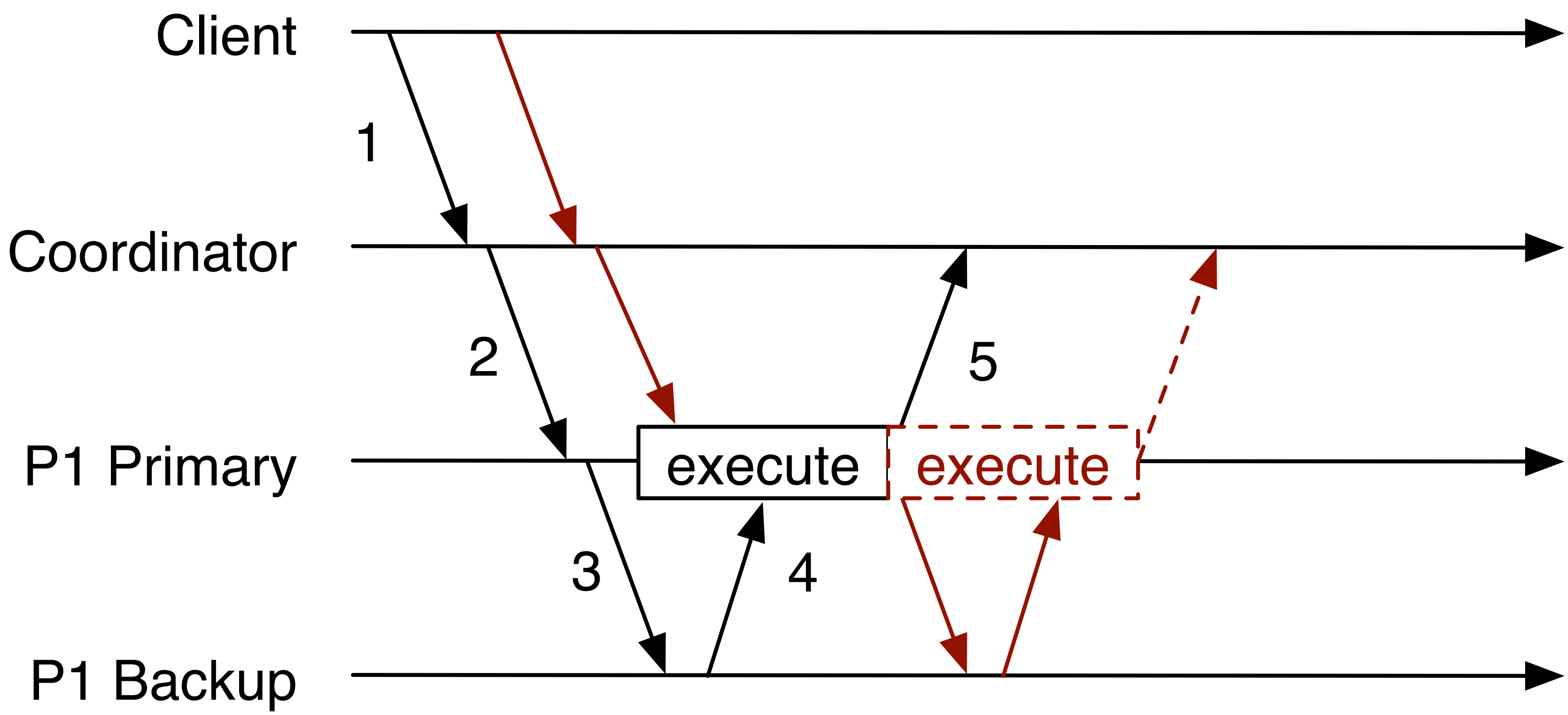

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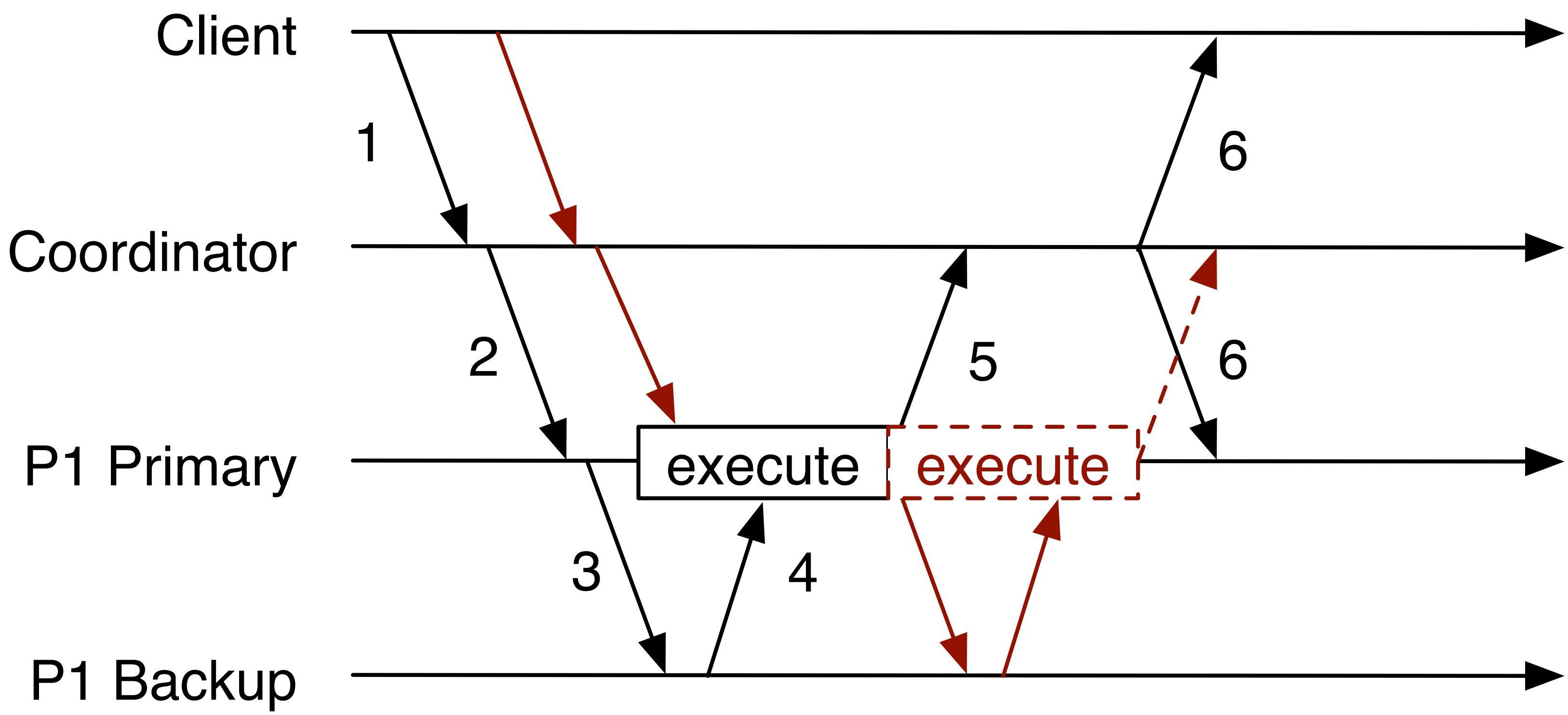

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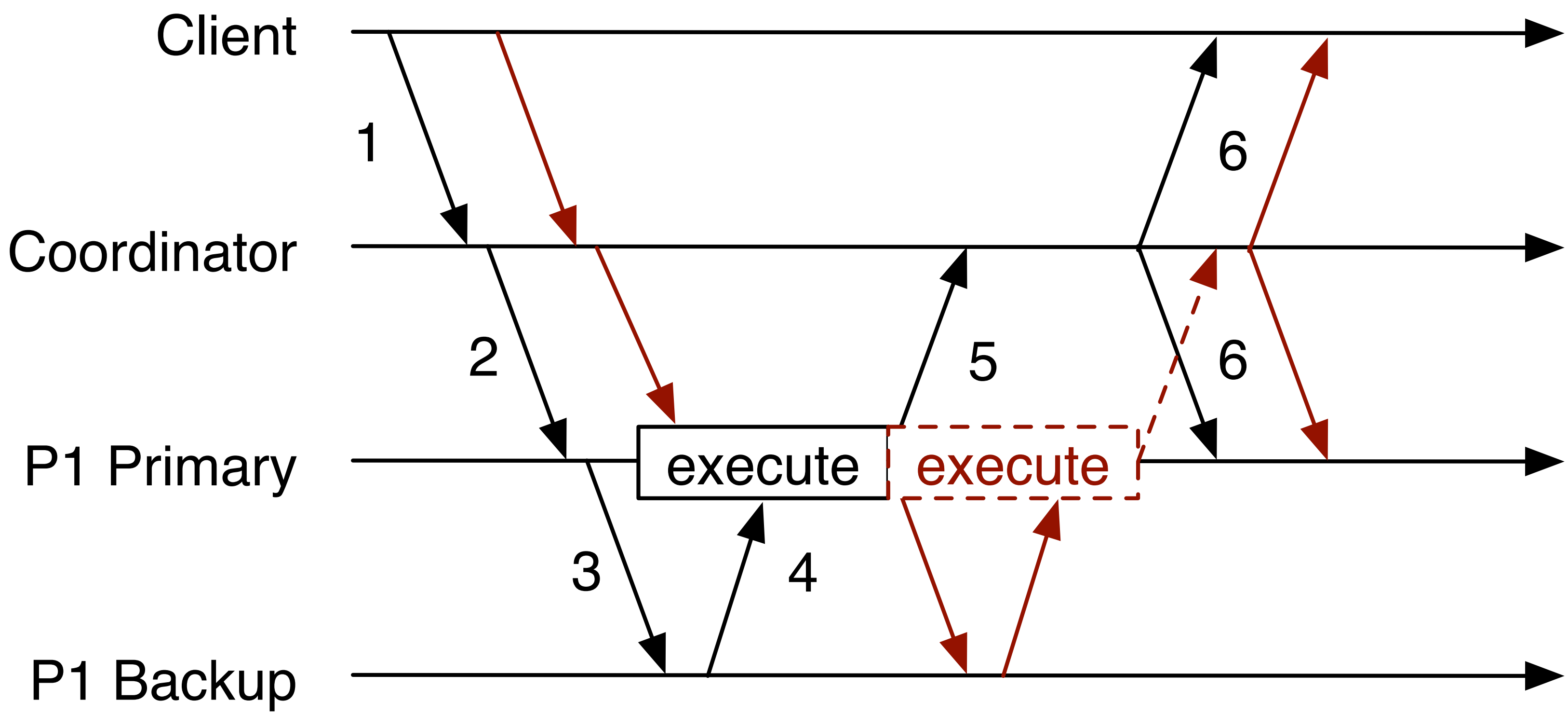


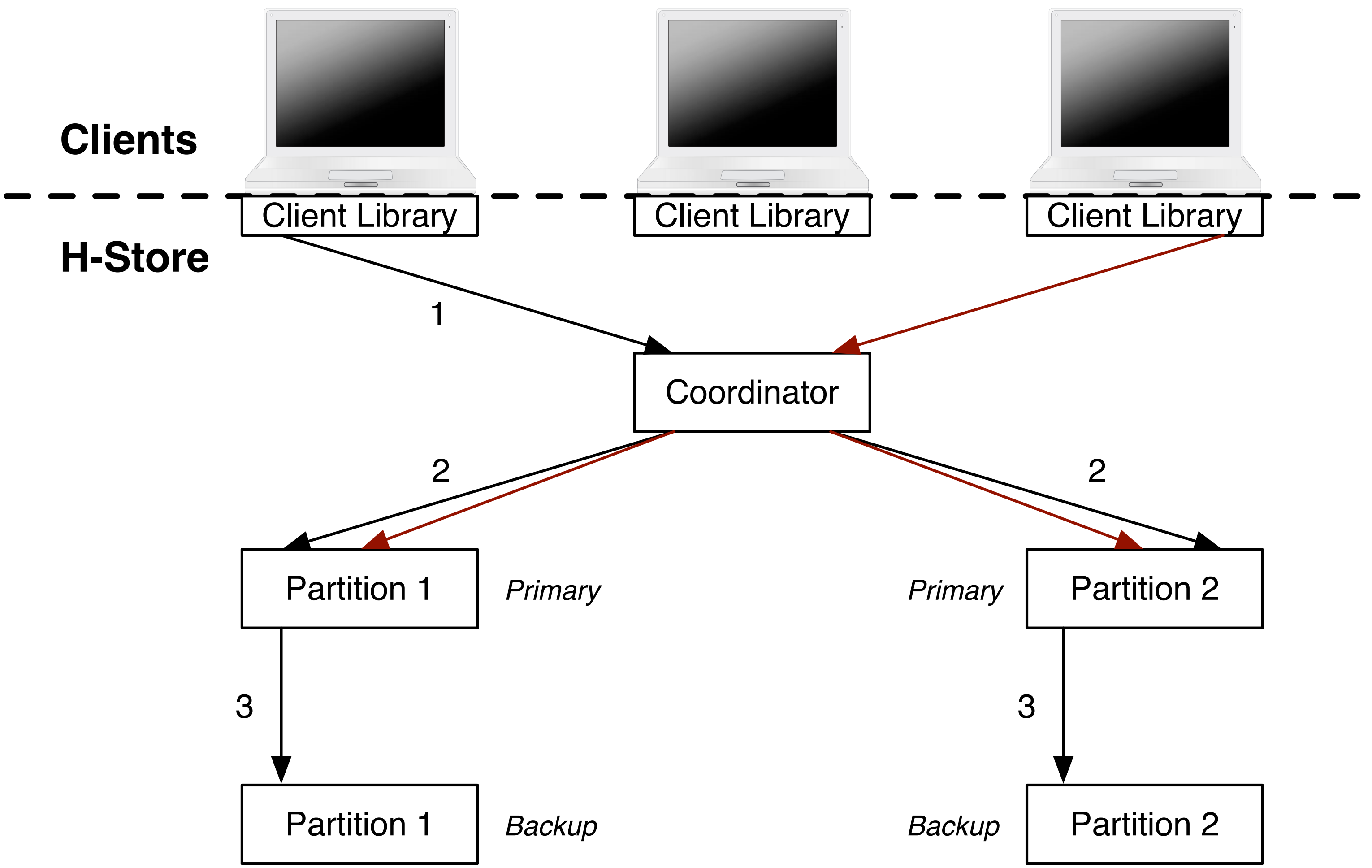
Speculation Limitation

Transactions with multiple “rounds” of work: need network stall

Example:

1. Read x on partition 1, y on partition 2
2. Update x = f(x, y); y = f(x, y)

Speculative Multi-Partition



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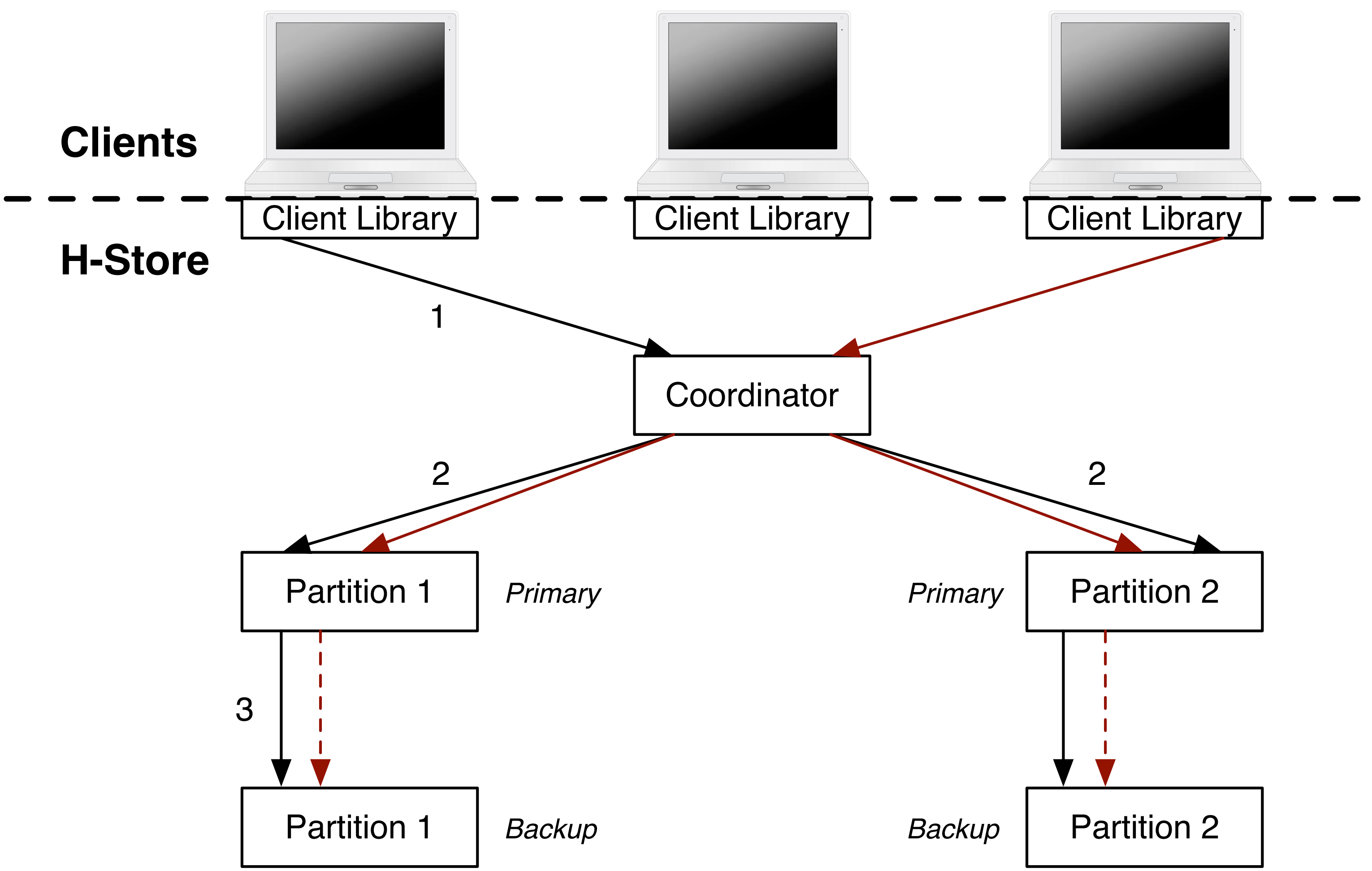

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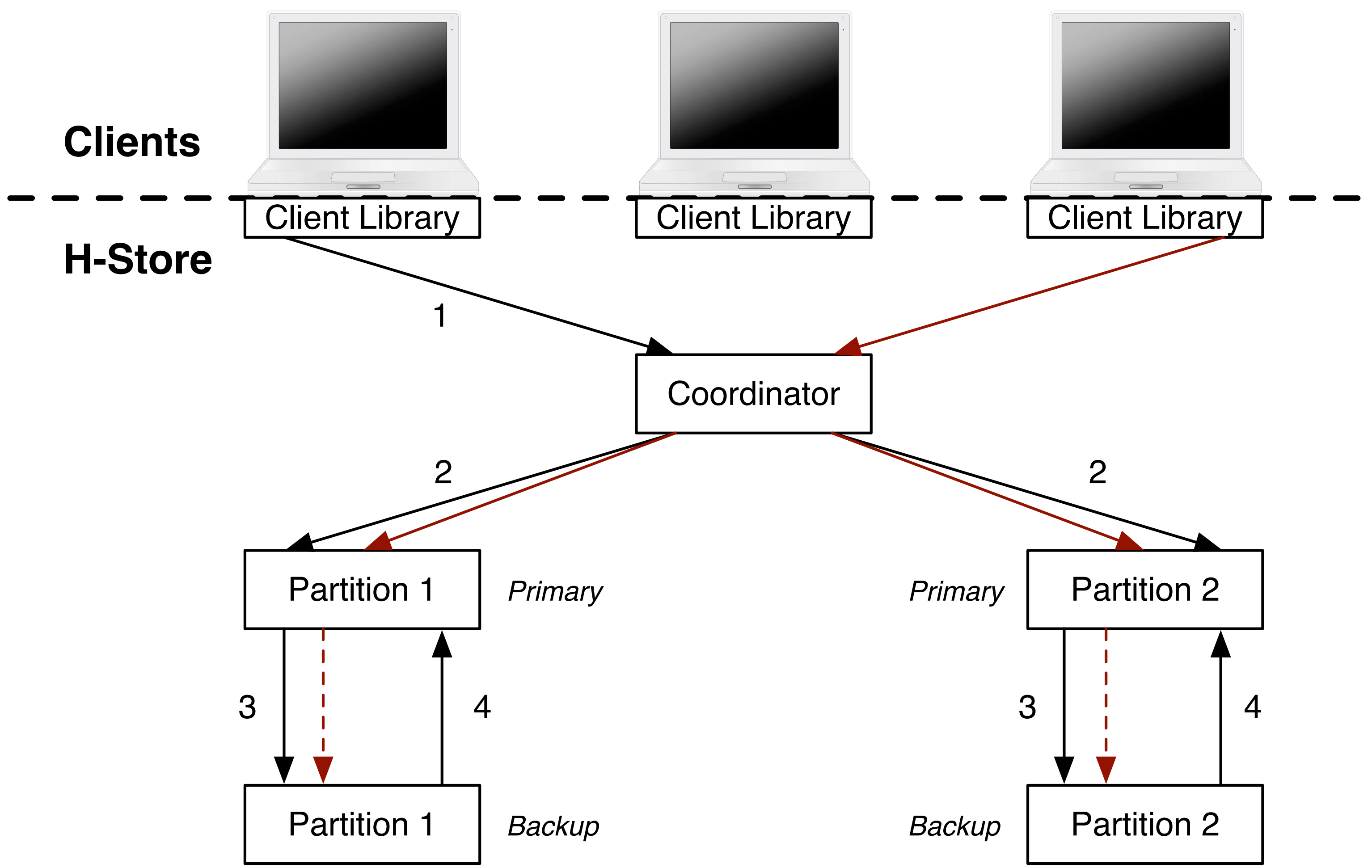

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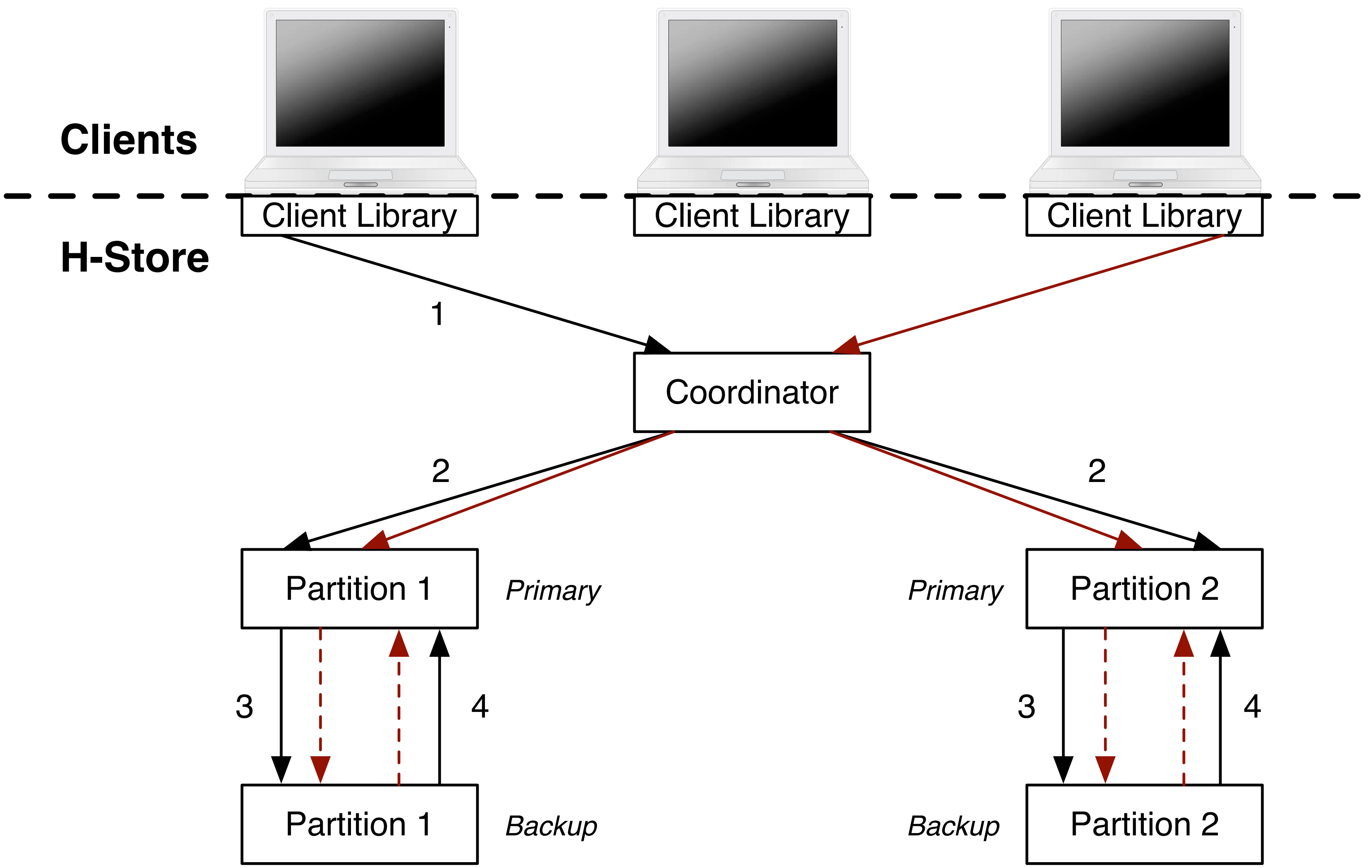

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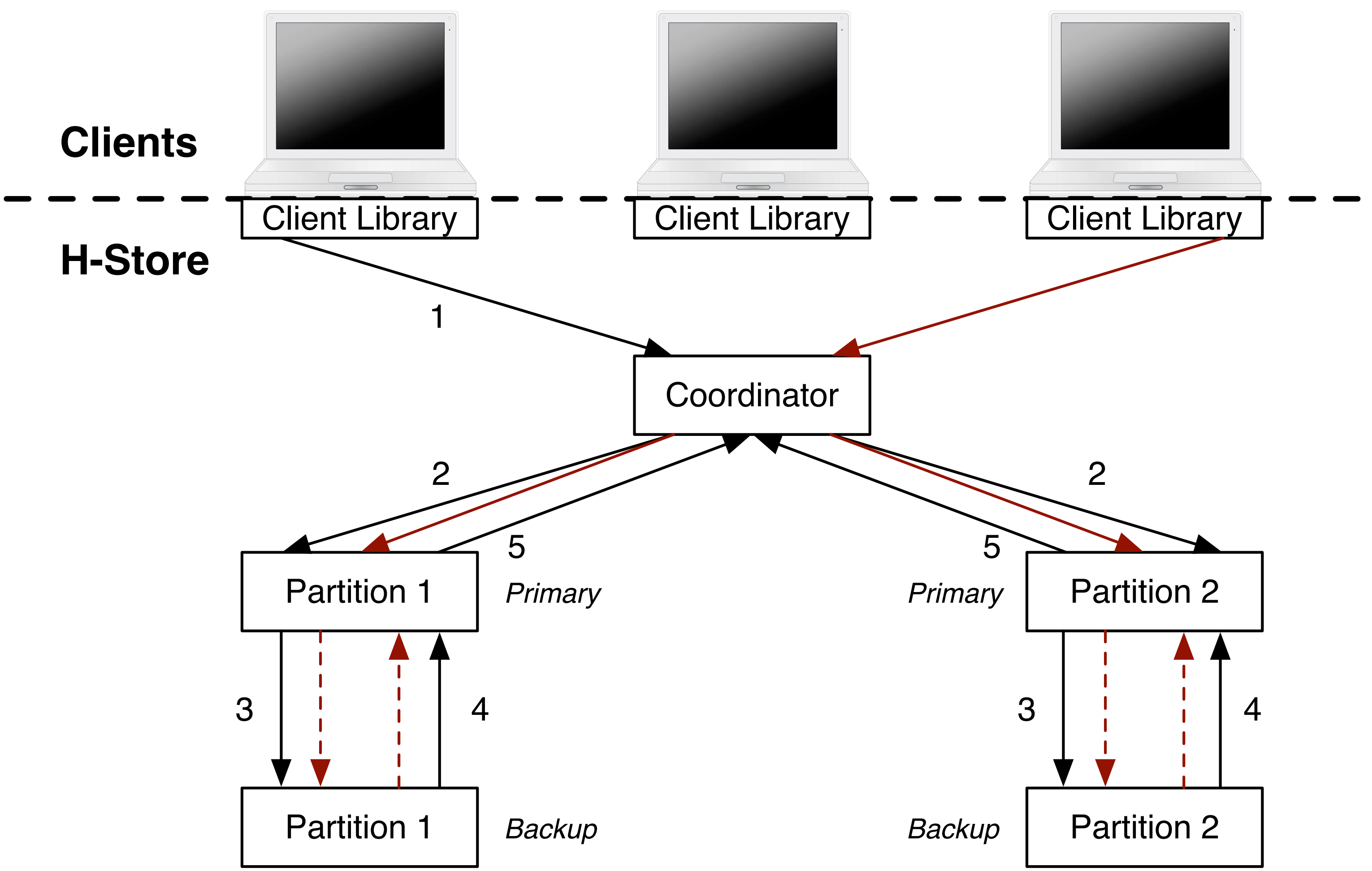

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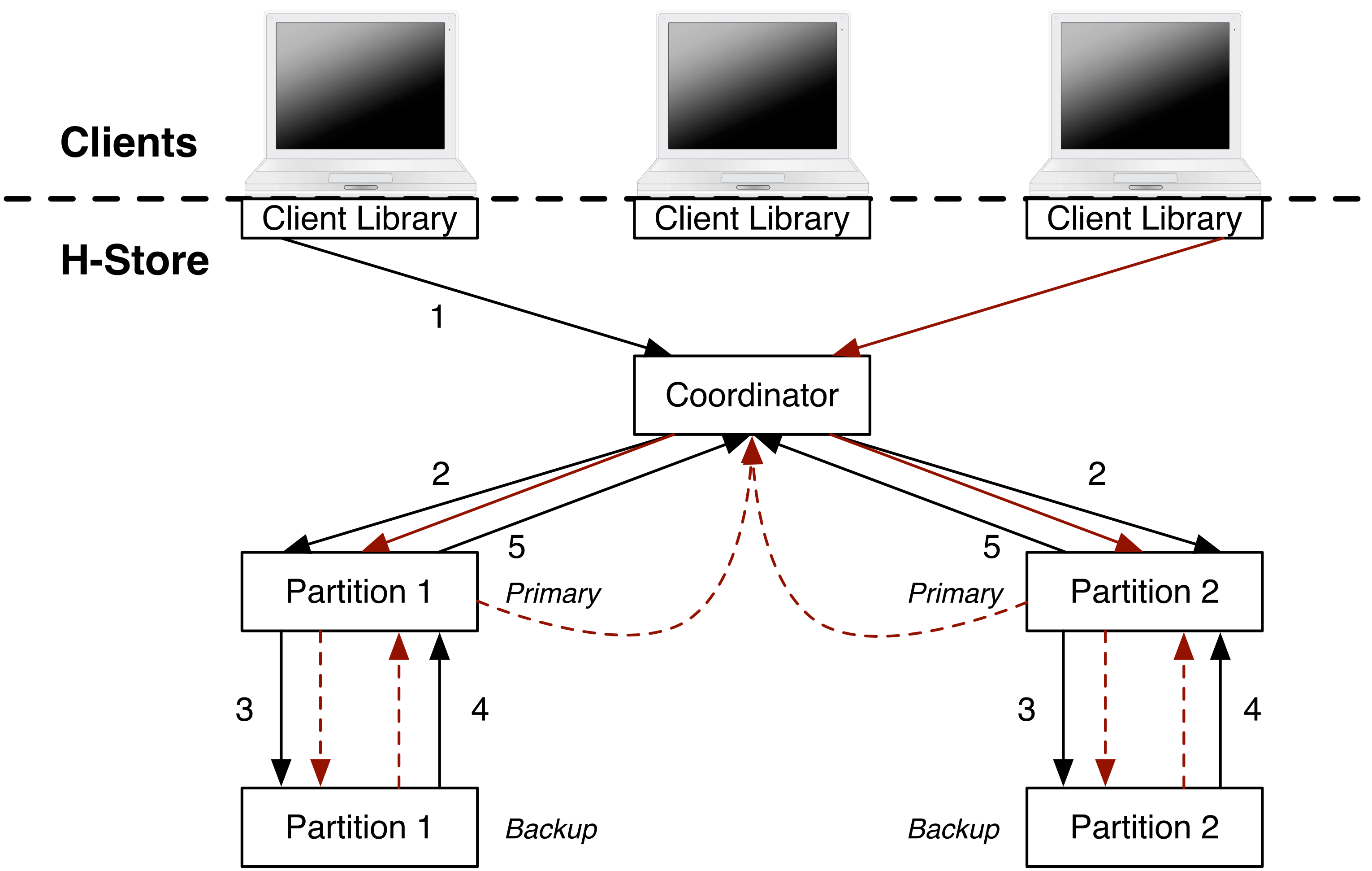

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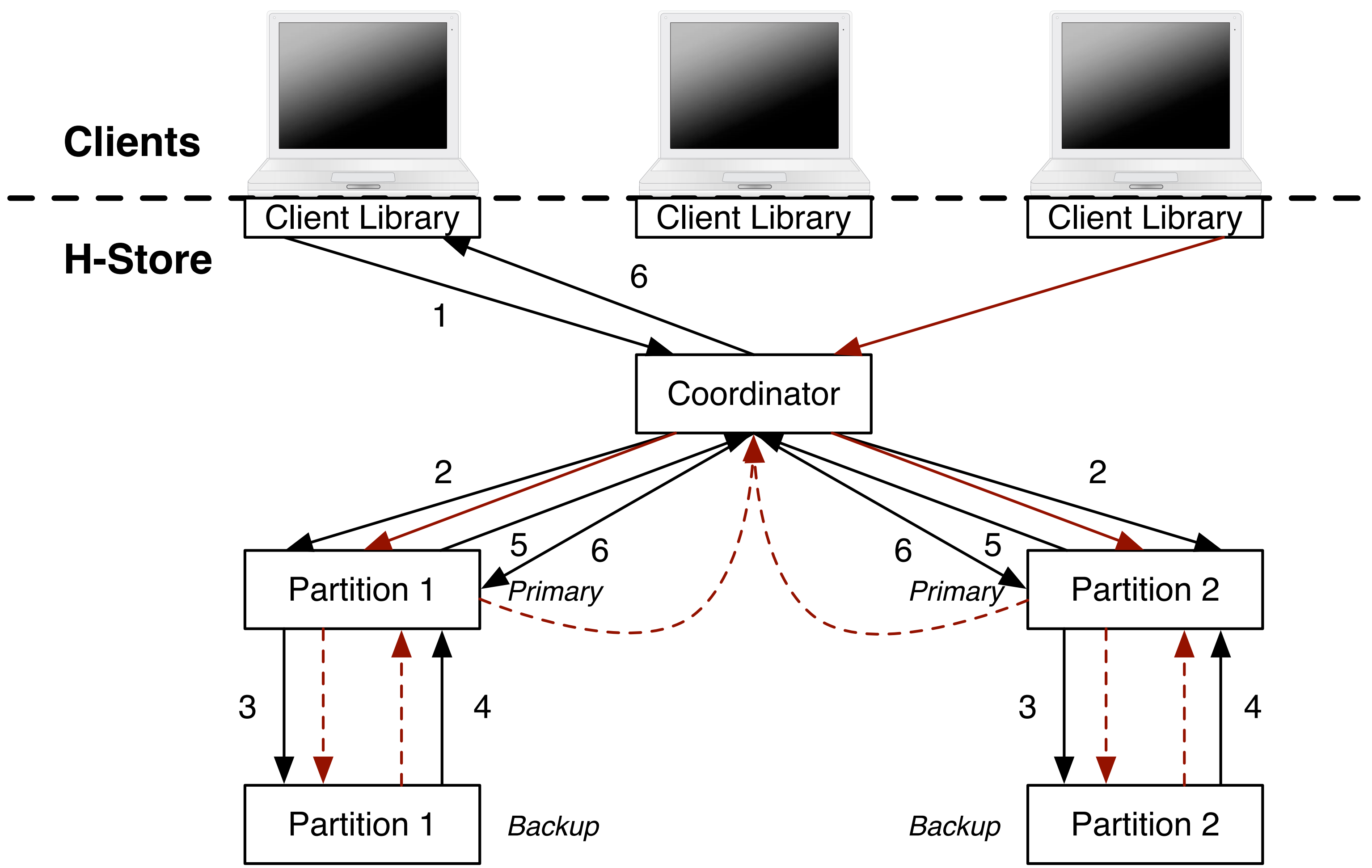

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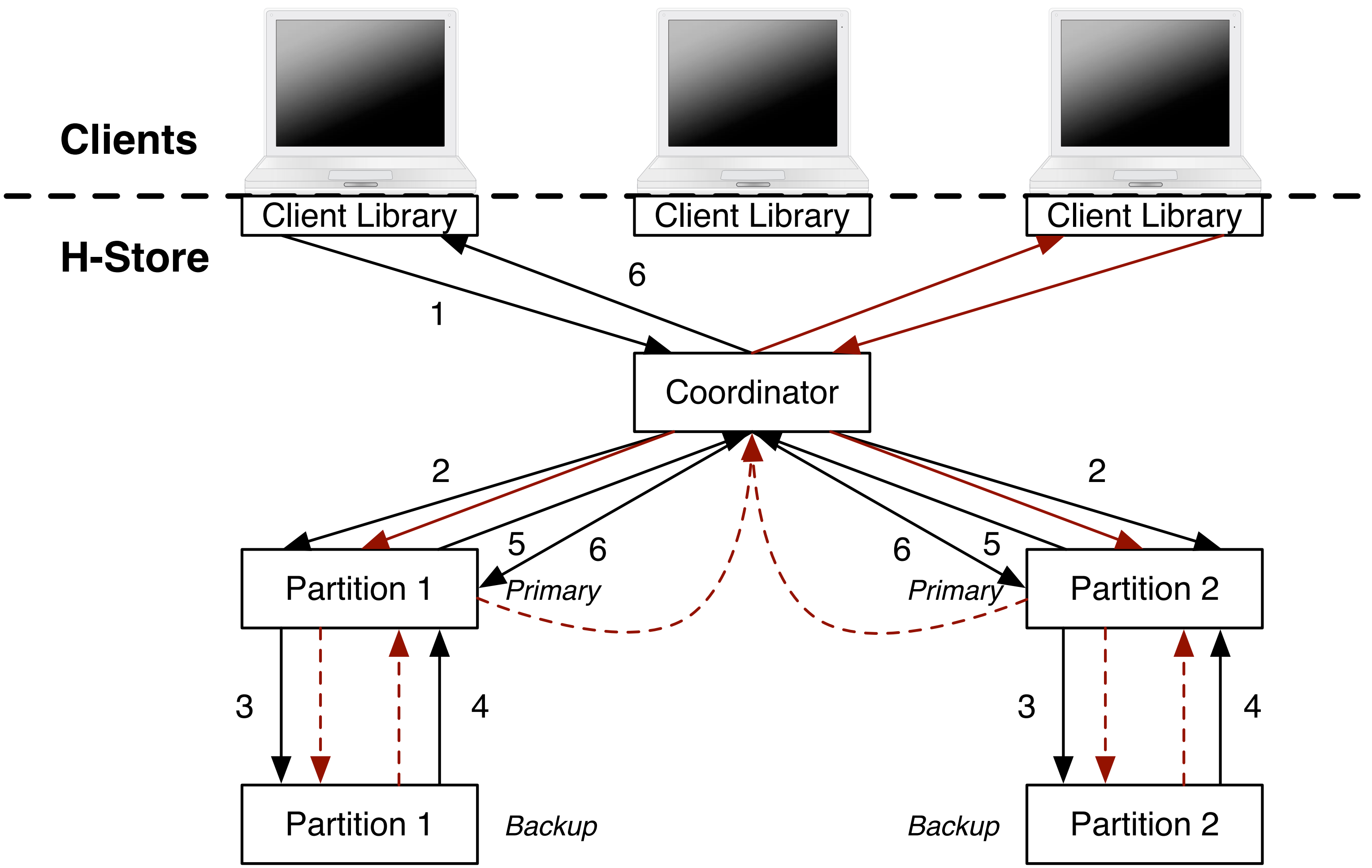
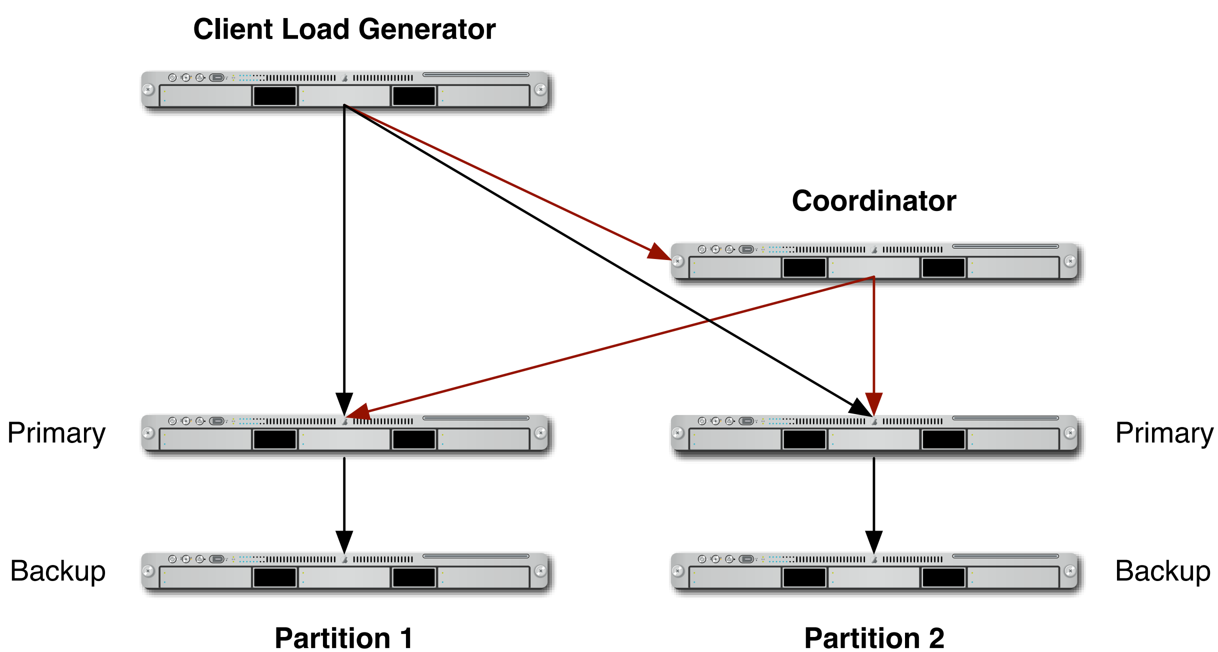


Microbenchmark

Two partitions of a single table

`(id INTEGER PRIMARY KEY, value INTEGER)`



Microbenchmark

Single partition transaction:

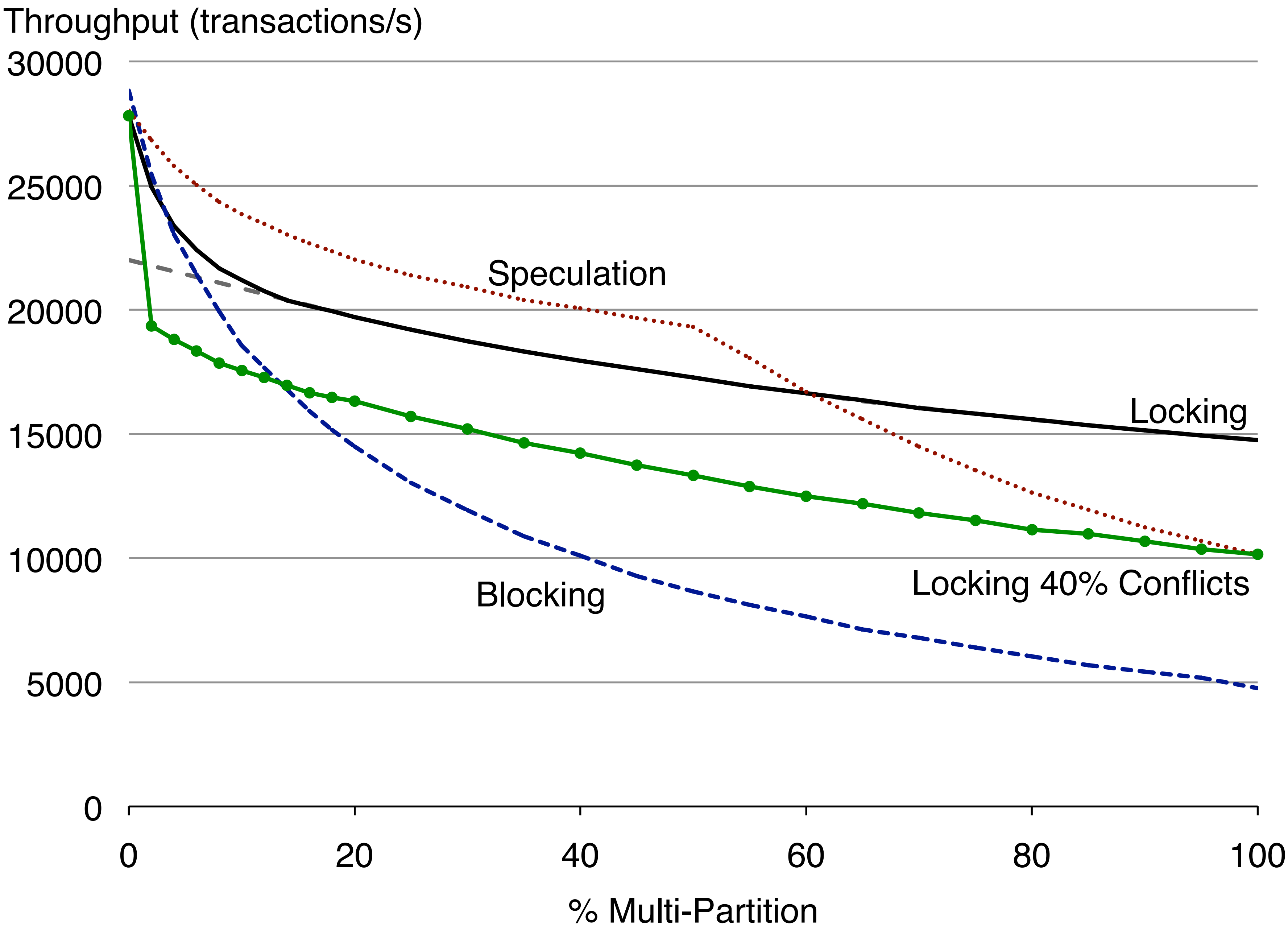
read/write keys on one partition

Multi-partition transaction:

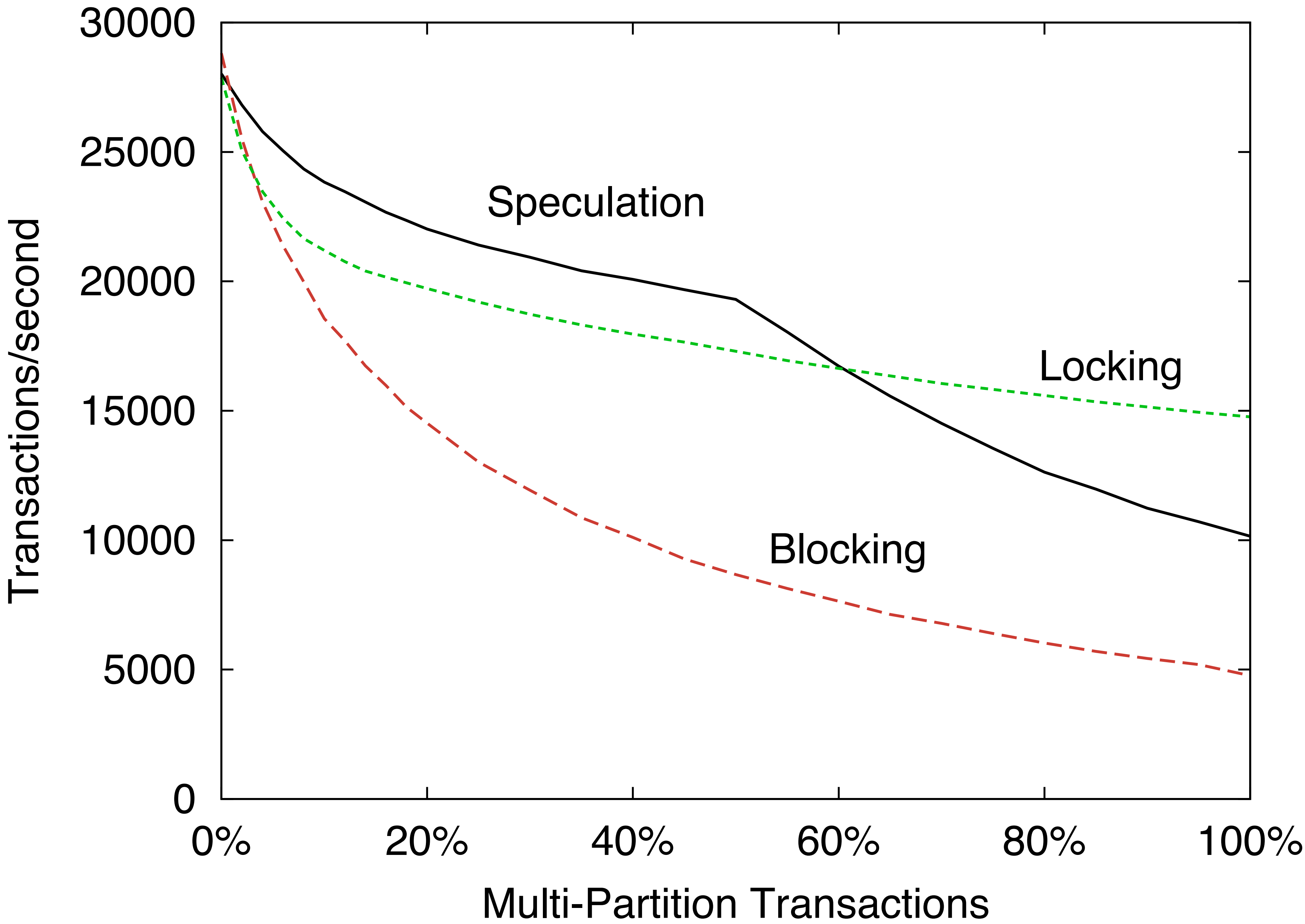
access half keys from each partition

single partition work = multi-partition work

No deadlocks, no aborts, no conflicts



Throughput (transactions/s)
30000
25000
20000
15000
10000
5000
0
0
20
40
60
80
100
% Multi-Partition
Speculation
Locking
Locking 40% Conflicts
Blocking



30000
25000
20000
15000
10000
5000
0
Transactions/second
0%
20%
40%
60%
80%
100%
Multi-Partition Transactions
Speculation
Locking
Blocking

TPC-C Based

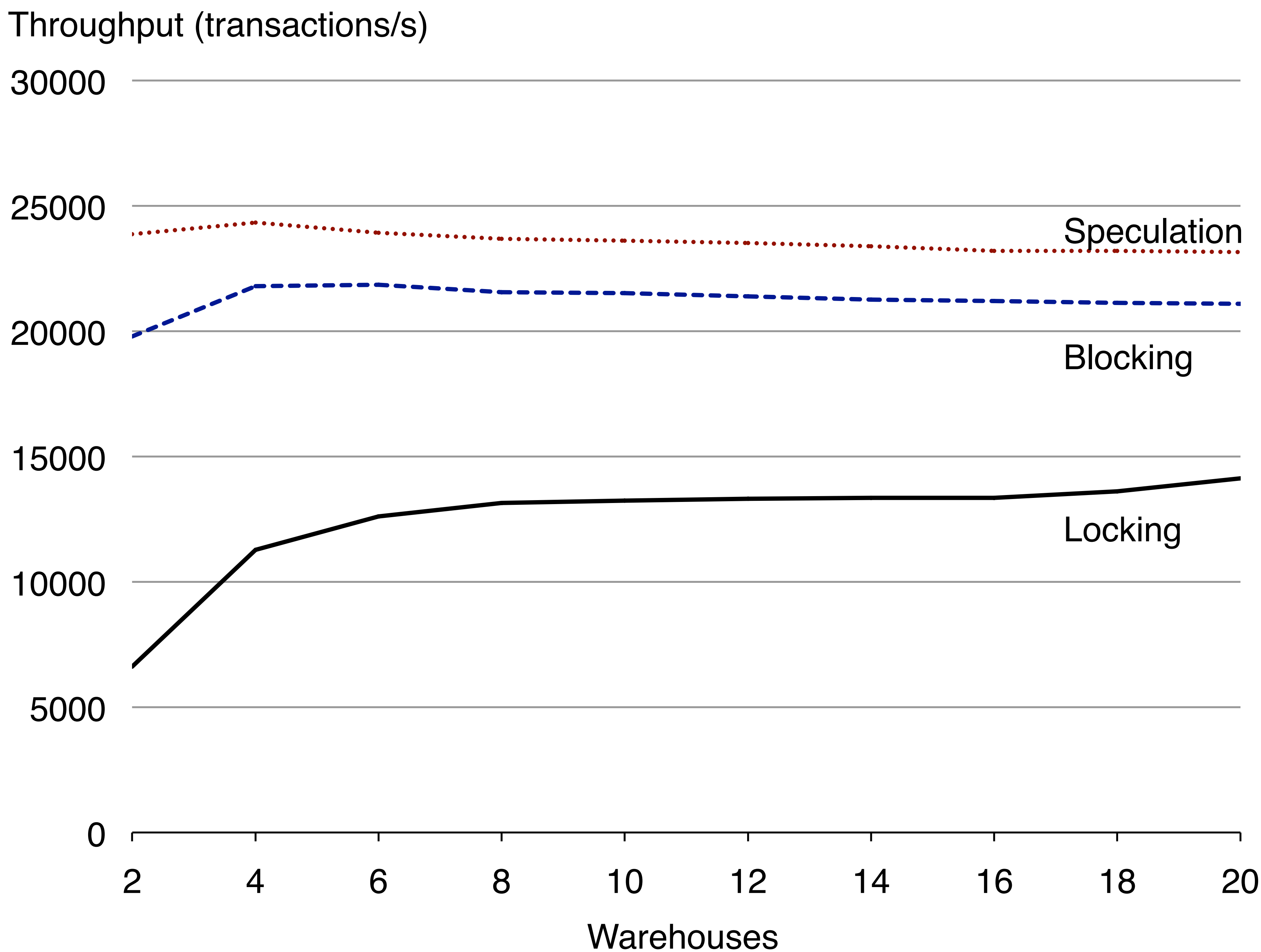
~11% multi-partition transactions

More complex locking

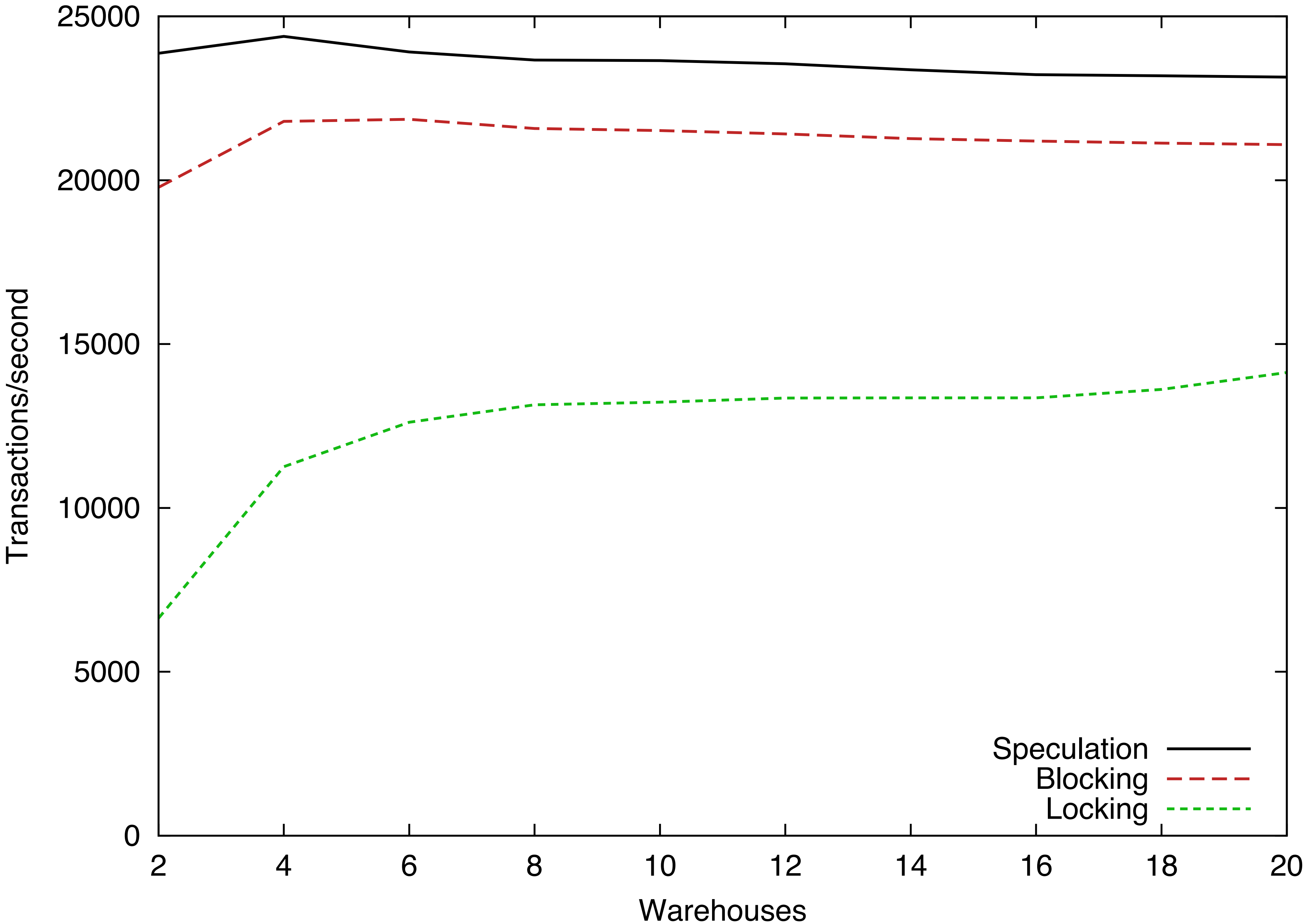
Many conflicts

Some deadlocks

Some aborts



Throughput (transactions/s)
30000
25000
20000
15000
10000
5000
0
2
4
6
8
10
12
14
16
18
20
Warehouses
Speculation
Blocking
Locking



25000
20000
15000
10000
5000
0
Transactions/second
2
4
6
8
10
12
14
16
18
20
Warehouses
Speculation
Blocking
Locking

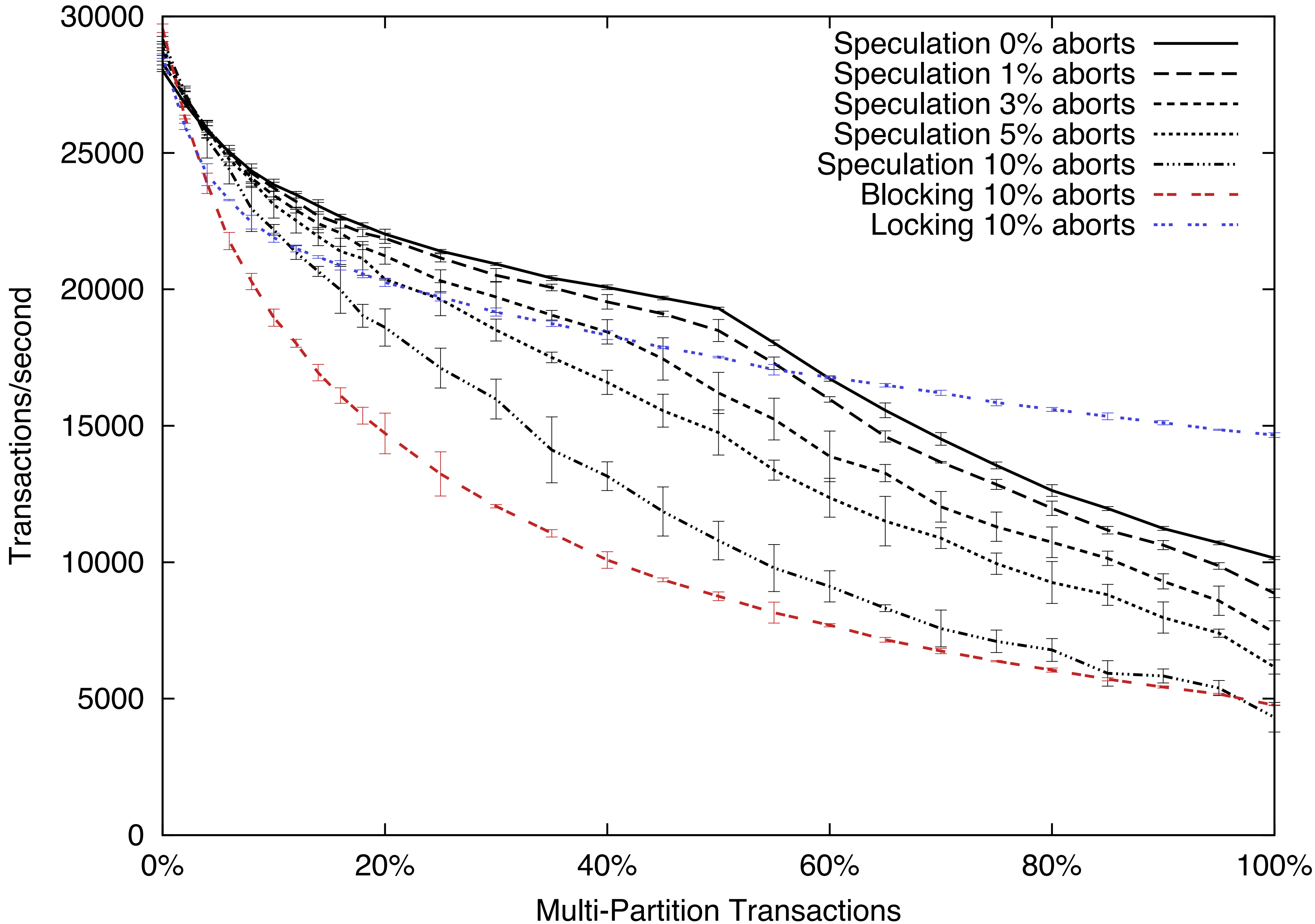
Speculative CC

better for “mostly partitionable” apps on main memory DBs

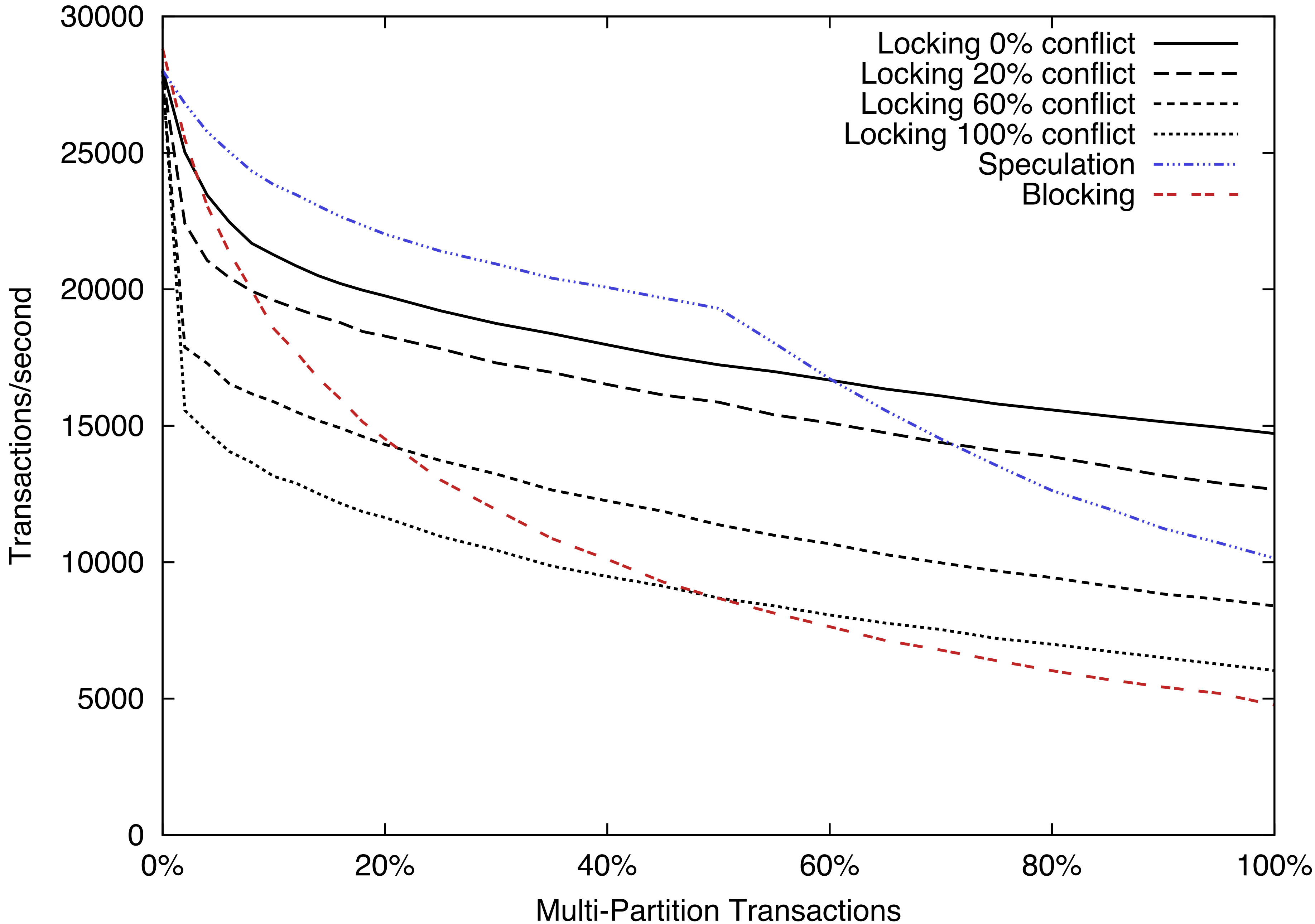
Up to 2X throughput

No locking overhead

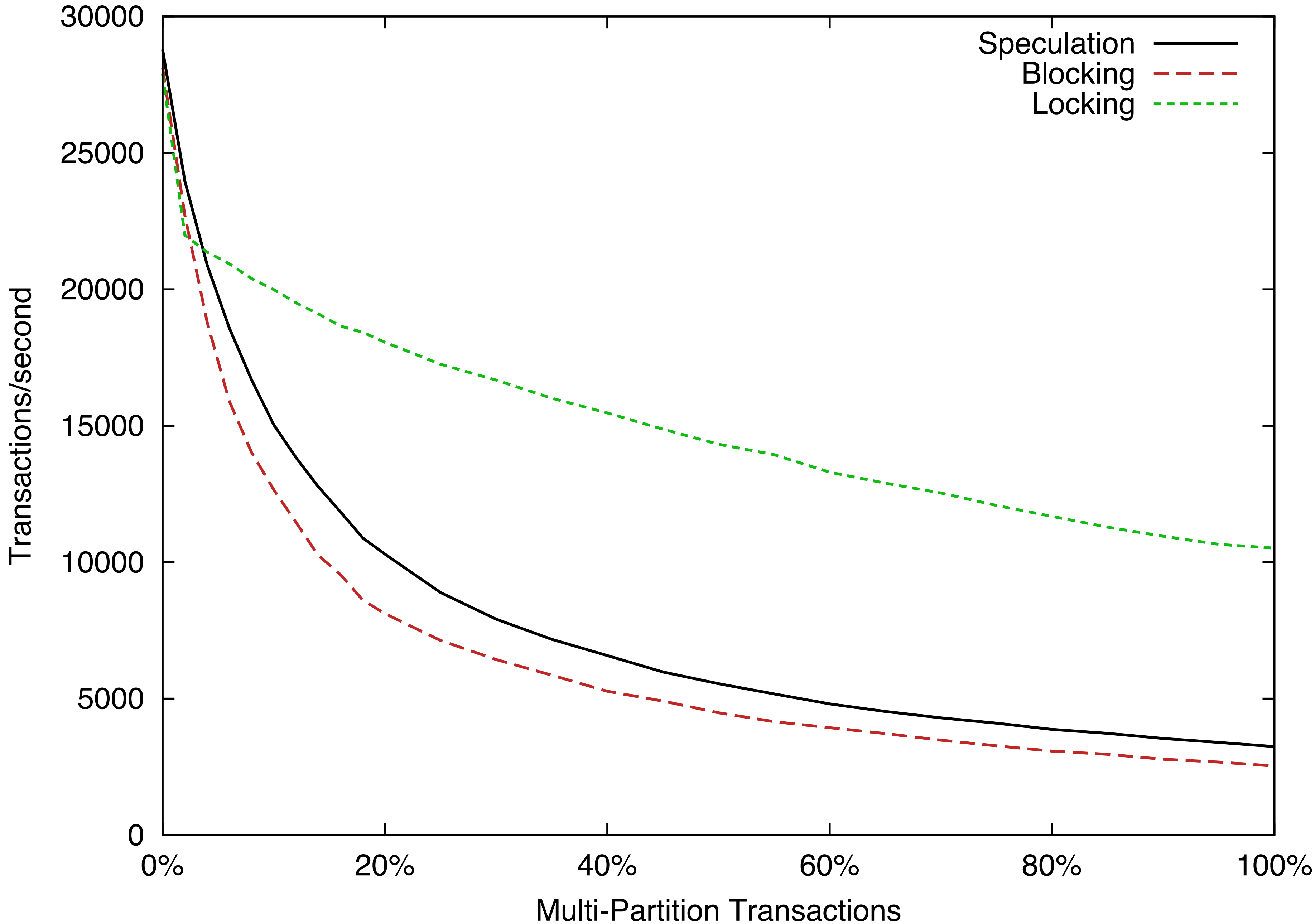
No deadlocks



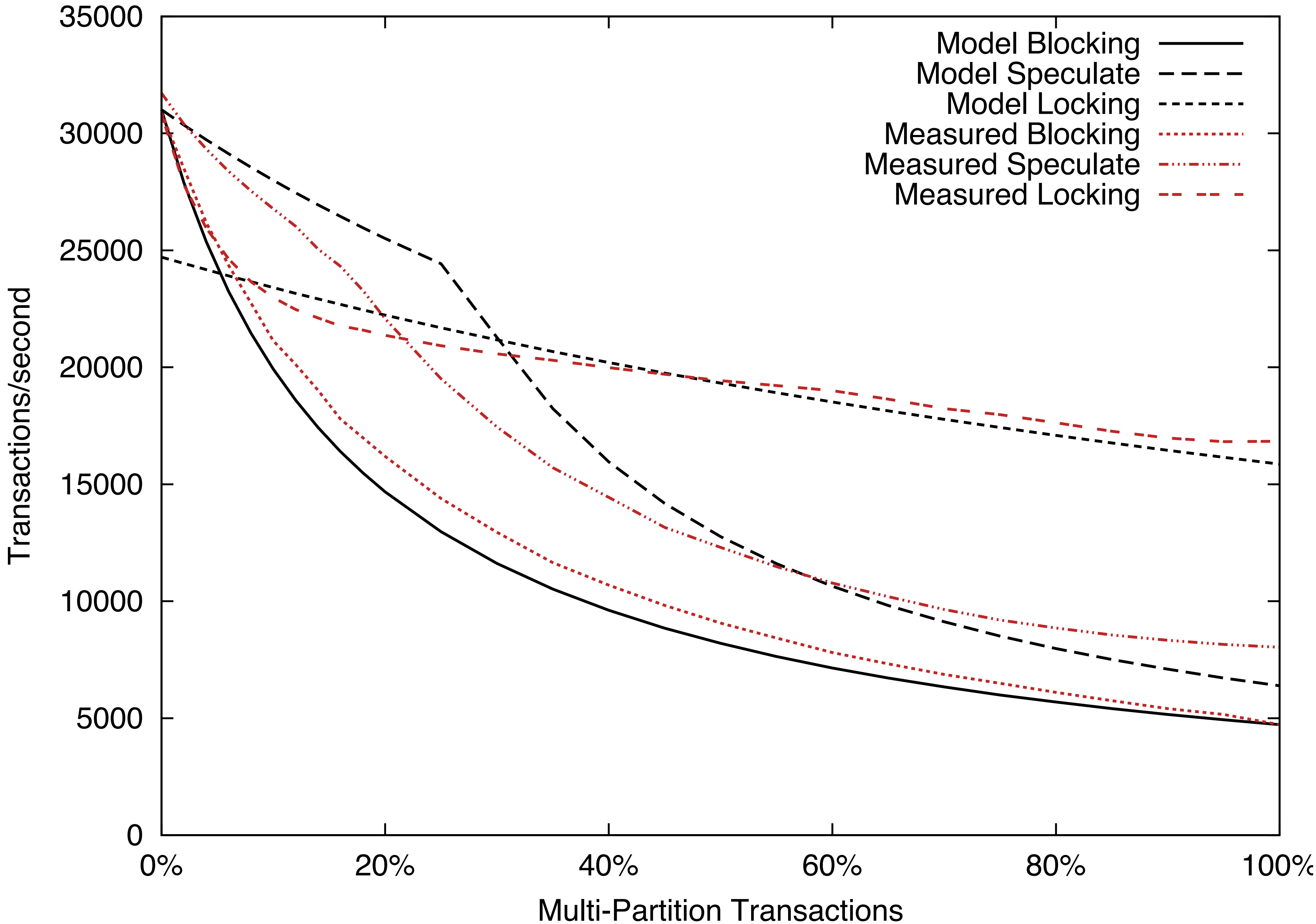
Speculation 0% aborts
Speculation 1% aborts
Speculation 3% aborts
Speculation 5% aborts
Speculation 10% aborts
Blocking 10% aborts
Locking 10% aborts
Transactions/second
Multi-Partition Transactions
30000
25000
20000
15000
10000
5000
0
0%
20%
40%
60%
80%
100%

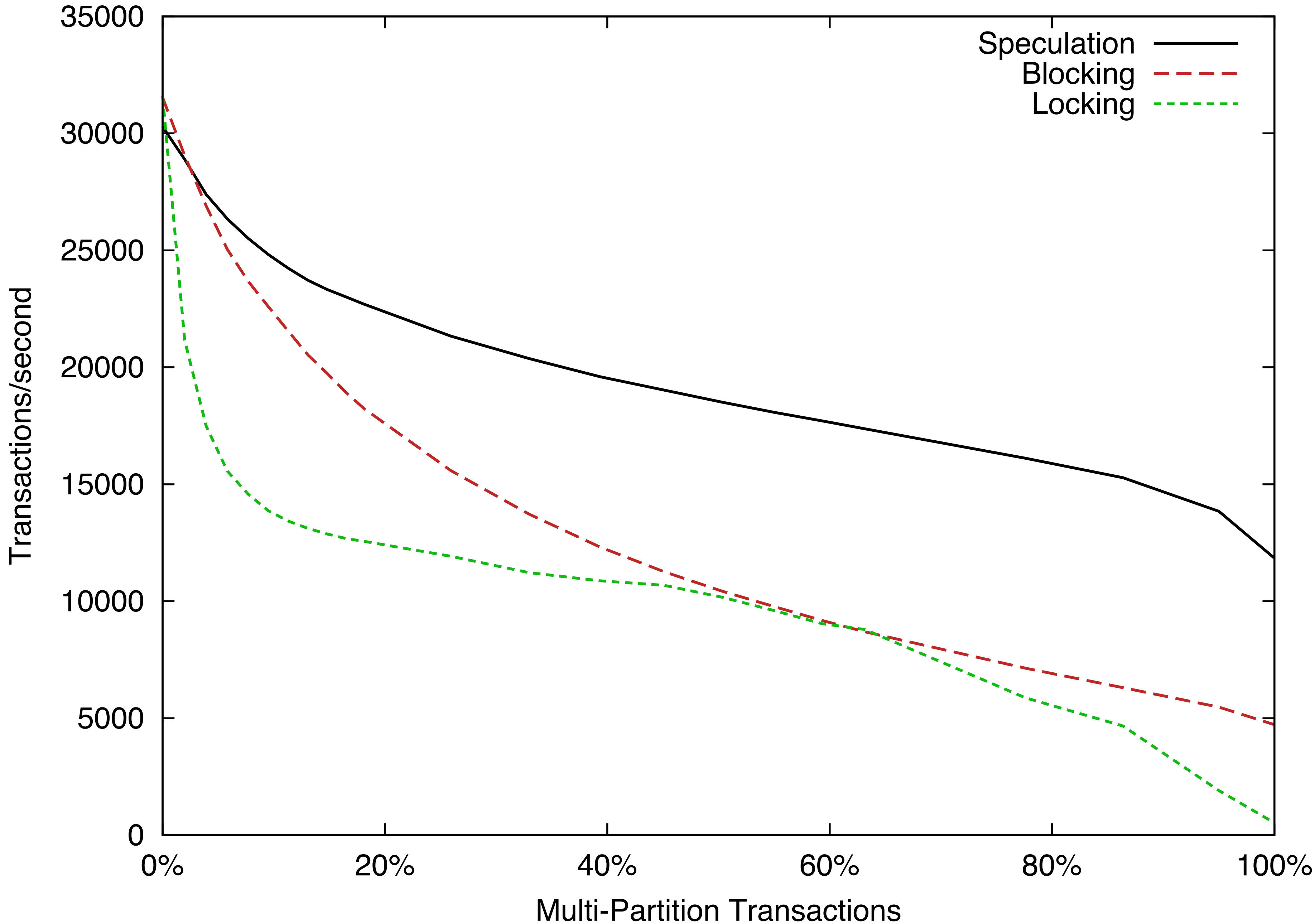


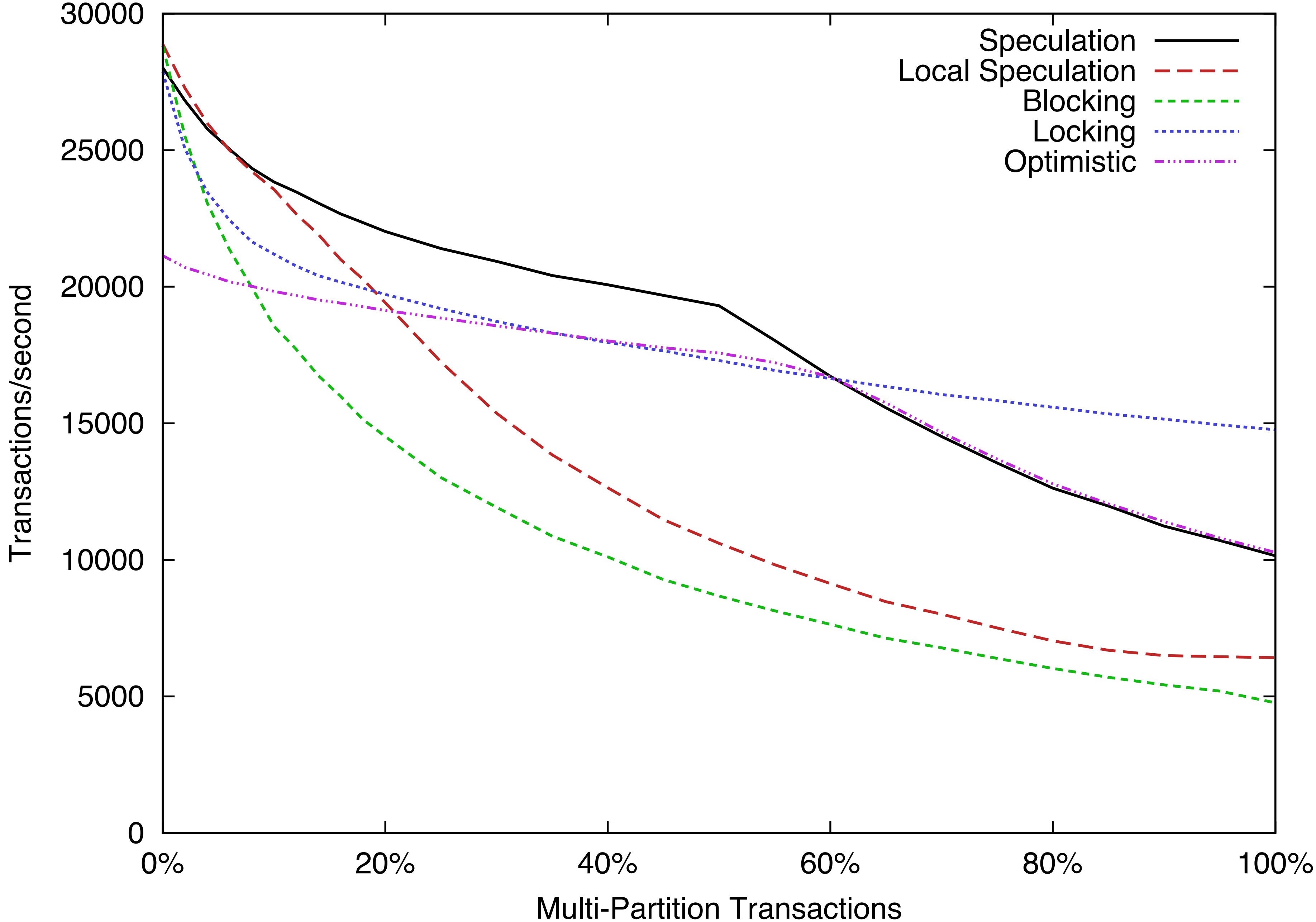
Locking 0% conflict
Locking 20% conflict
Locking 60% conflict
Locking 100% conflict
Speculation
Blocking
30000
25000
20000
15000
10000
5000
0
0%
20%
40%
60%
80%
100%
Transactions/second
Multi-Partition Transactions



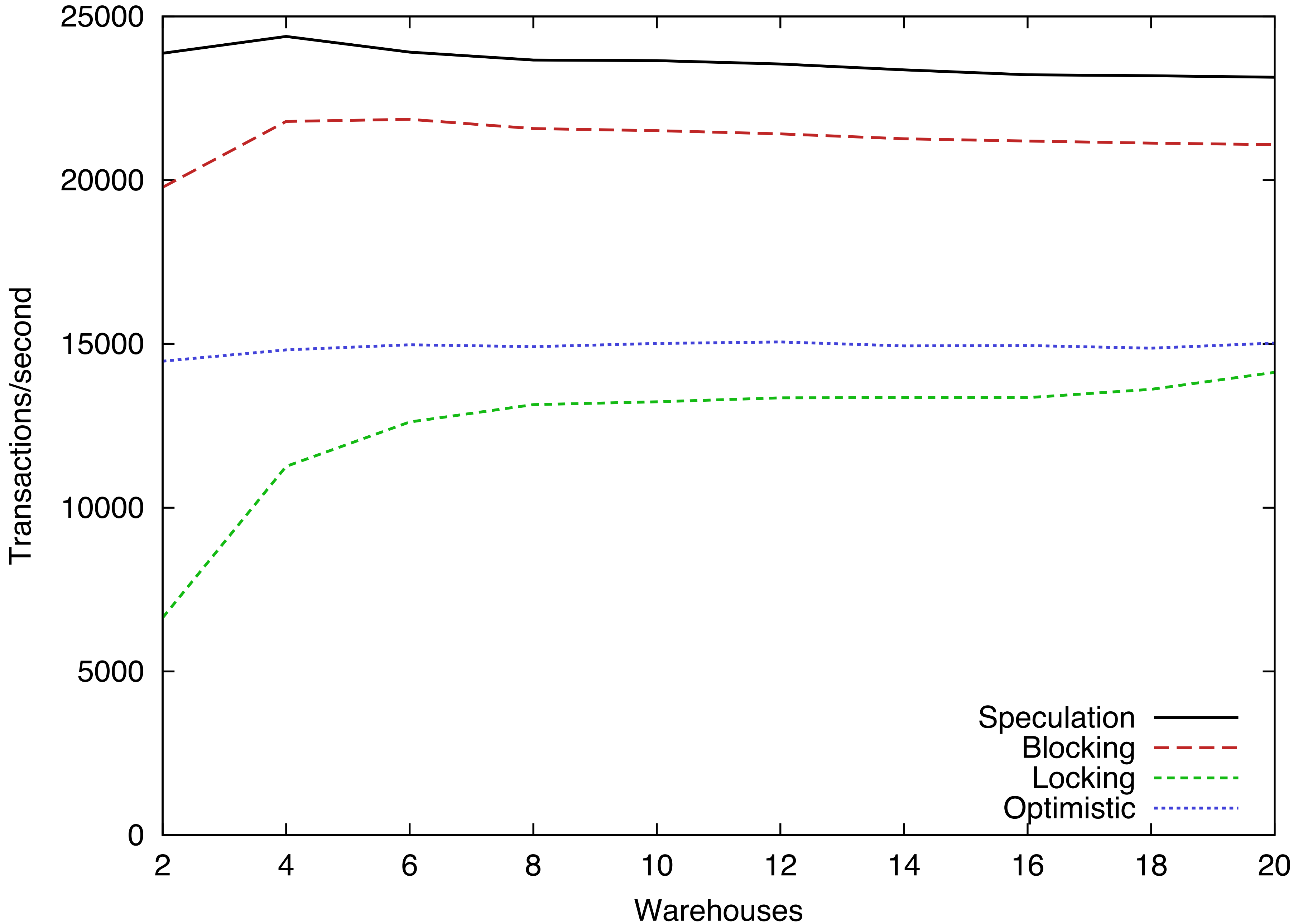
Speculation
Blocking
Locking
Transactions/second
Multi-Partition Transactions
0
5000
10000
15000
20000
25000
30000
0%
20%
40%
60%
80%
100%


Model Blocking
Model Speculate
Model Locking
Measured Blocking
Measured Speculate
Measured Locking
35000
30000
25000
20000
15000
10000
5000
0
Transactions/second
0%
20%
40%
60%
80%
100%
Multi-Partition Transactions


Speculation
Blocking
Locking
35000
30000
25000
20000
15000
10000
5000
0
0%
20%
40%
60%
80%
100%
Transactions/second
Multi-Partition Transactions



Speculation
Local Speculation
Blocking
Locking
Optimistic
Transactions/second
30000
25000
20000
15000
10000
5000
0
0%
20%
40%
60%
80%
100%
Multi-Partition Transactions



25000
20000
15000
10000
5000
0
2
4
6
8
10
12
14
16
18
20
Transactions/second
Warehouses
Speculation
Blocking
Locking
Optimistic