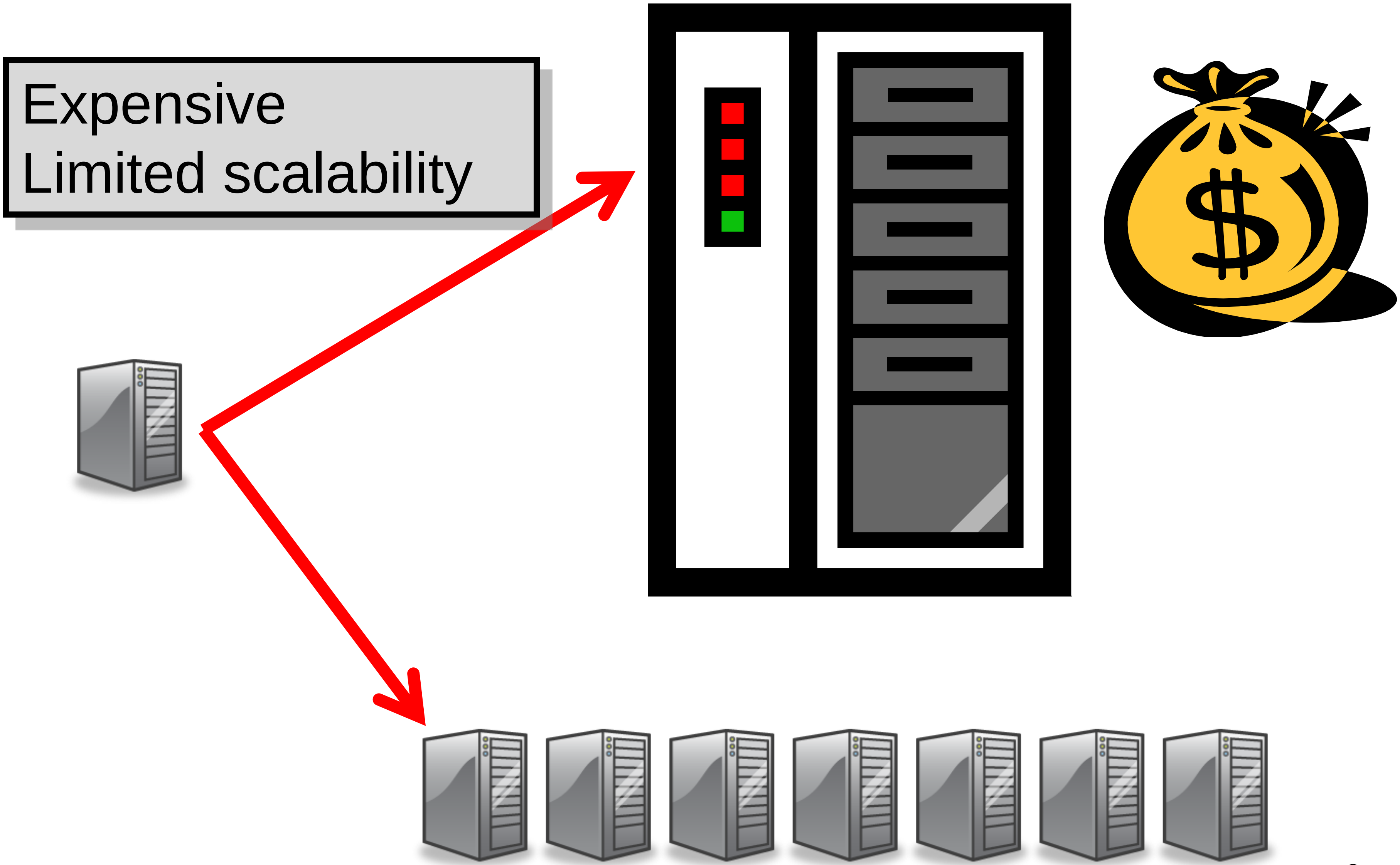
Database Replication in Tashkent

CSEP 545 Transaction Processing

Sameh Elnikety

Replication for Performance



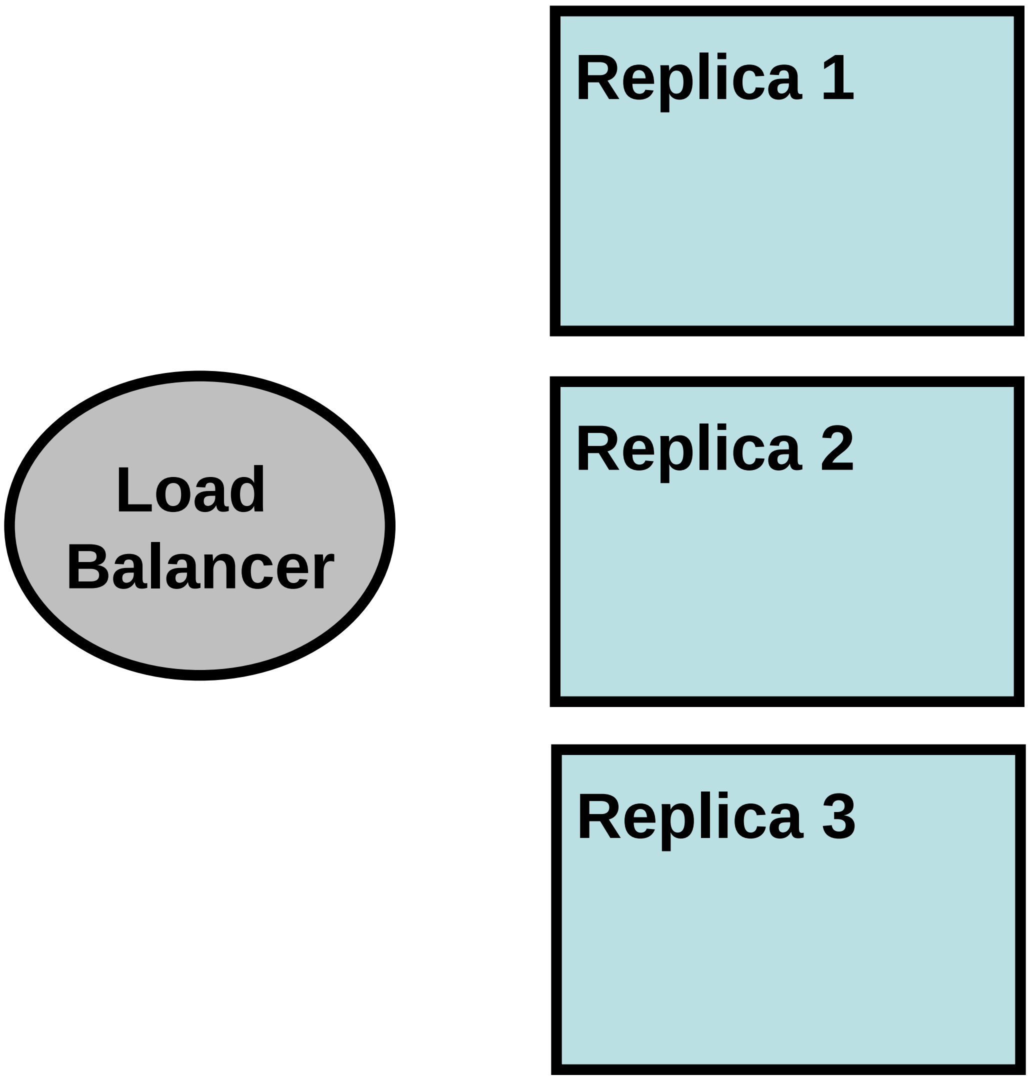
DB Replication is Challenging

- Single database system
  - Large, persistent state
  - Transactions
  - Complex software
- Replication challenges
  - Maintain consistency
  - Middleware replication

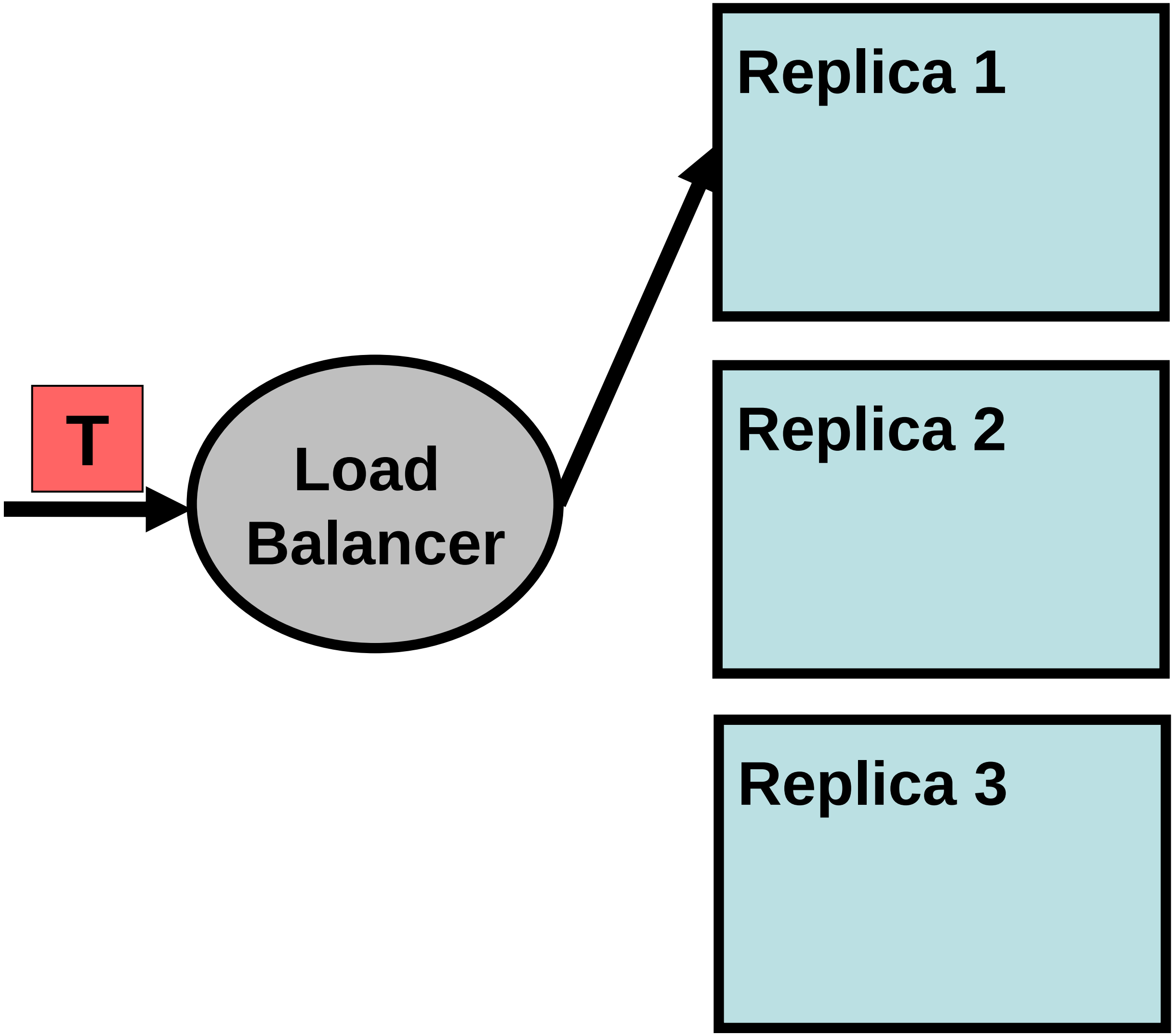
Background

Standalone DBMS

Background

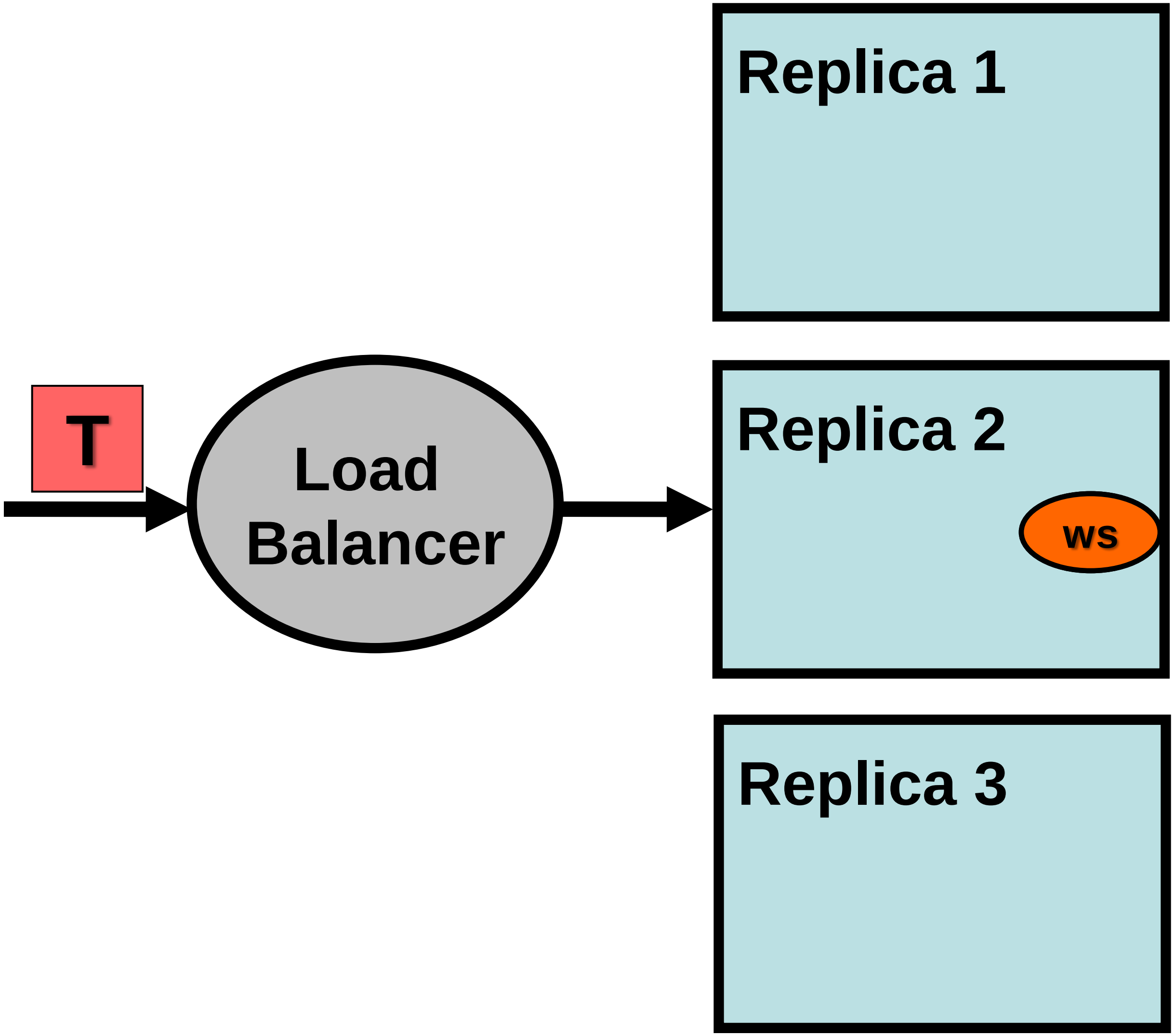


Read Tx



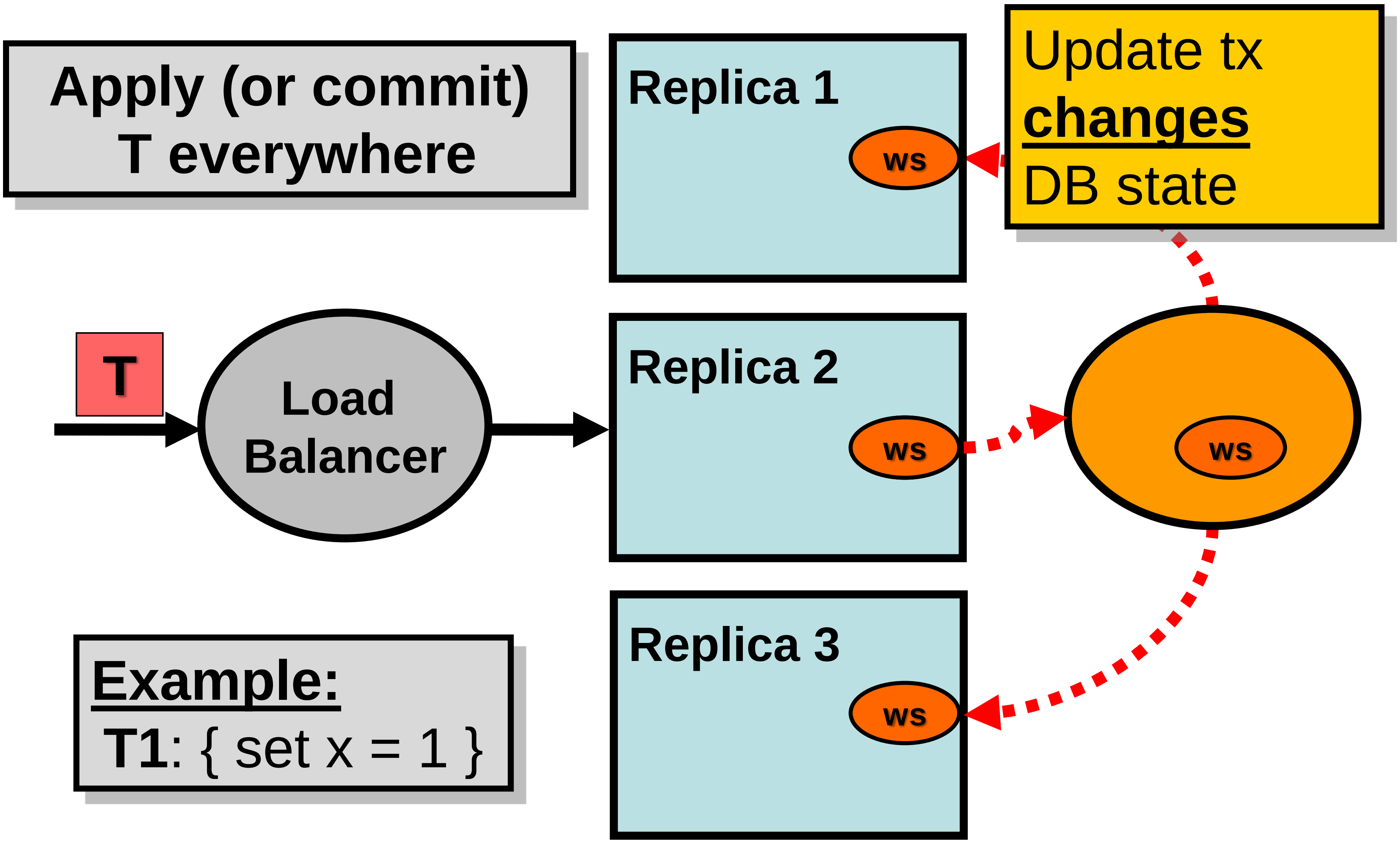
Read tx does **not** change DB state

Update Tx 1/2



Update tx **changes** DB state

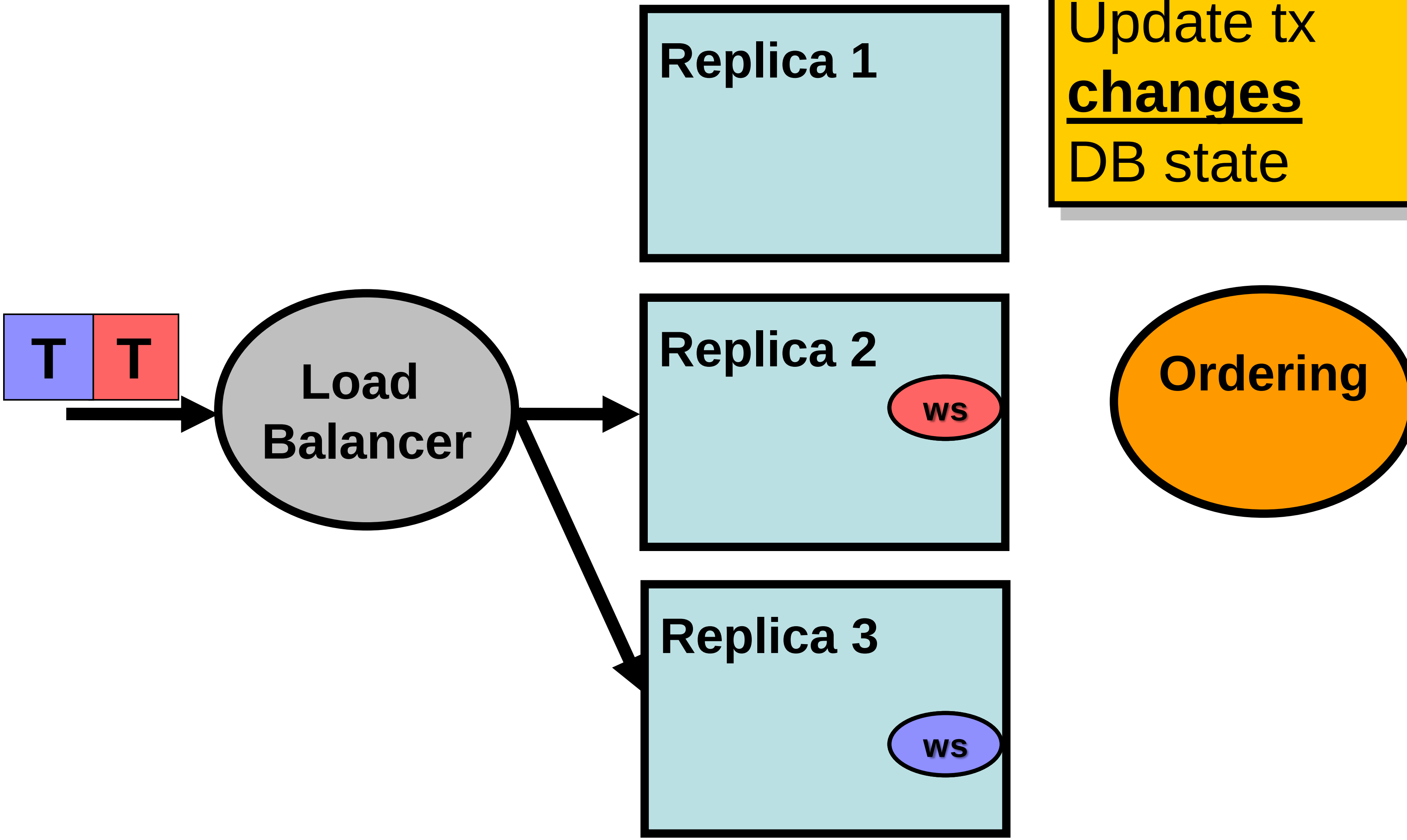
Update Tx 1/2



Apply (or commit)
T everywhere
Replica 1
ws
Update tx
changes
DB state
T
Load
Balancer
Replica 2
ws
ws
Replica 3
ws
Example:
T1: { set x = 1 }

Update Tx 2/2

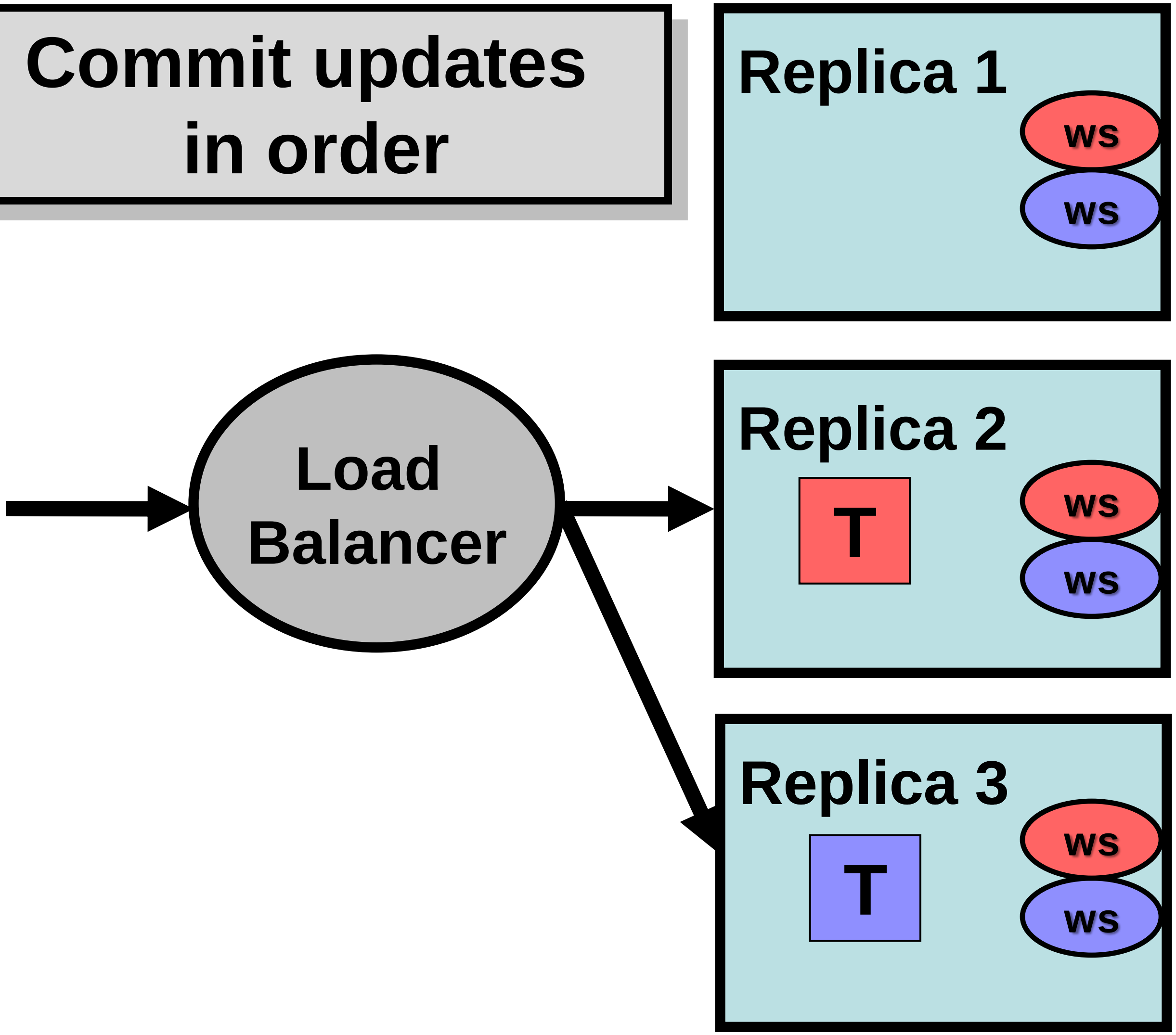
Update tx
changes
DB state

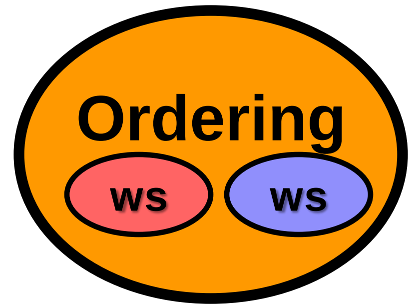


Update Tx 2/2

Commit updates in order

Update tx **changes** DB state



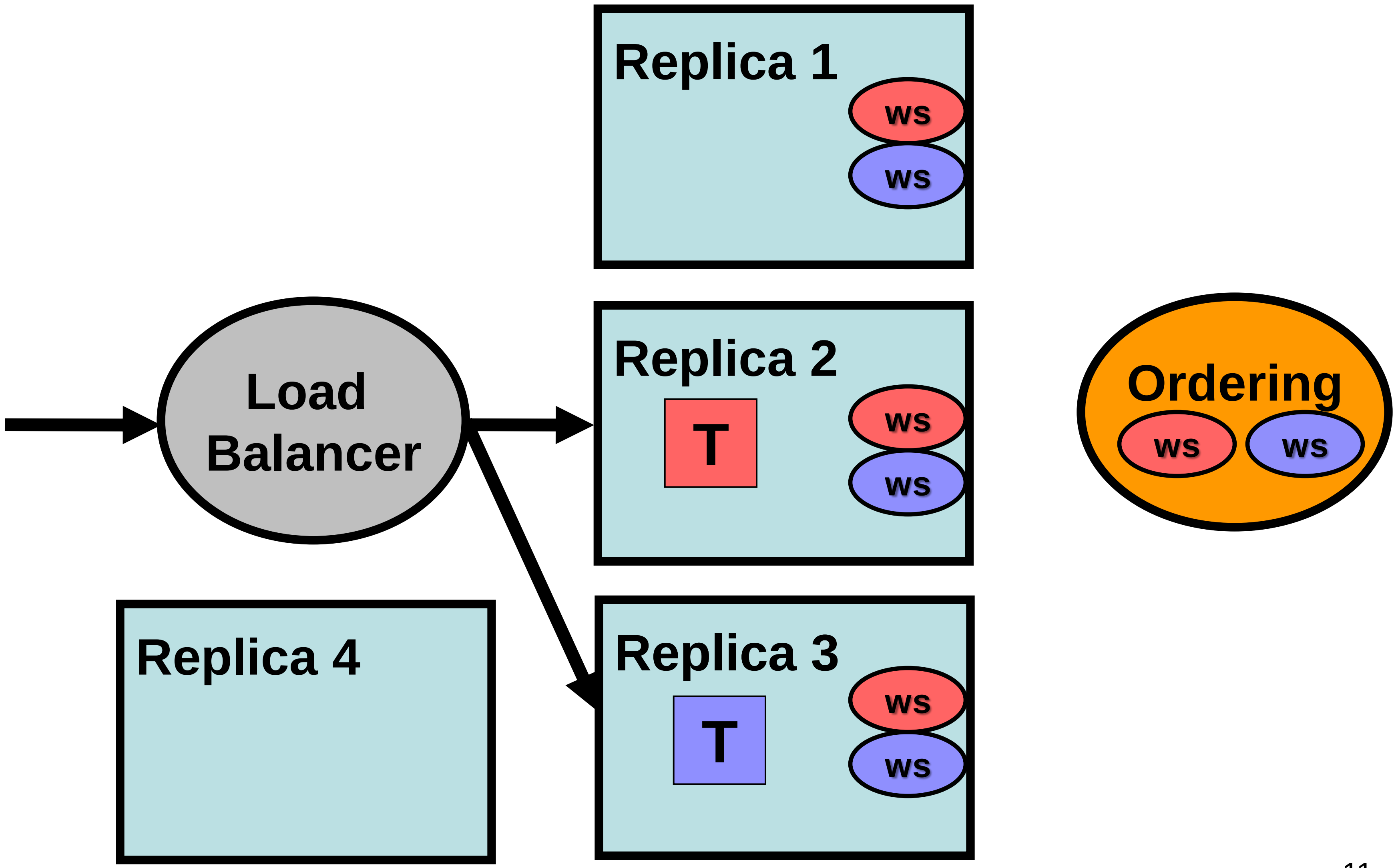


Example:

T1: { set x = 1 }

T2: { set x = 7 }

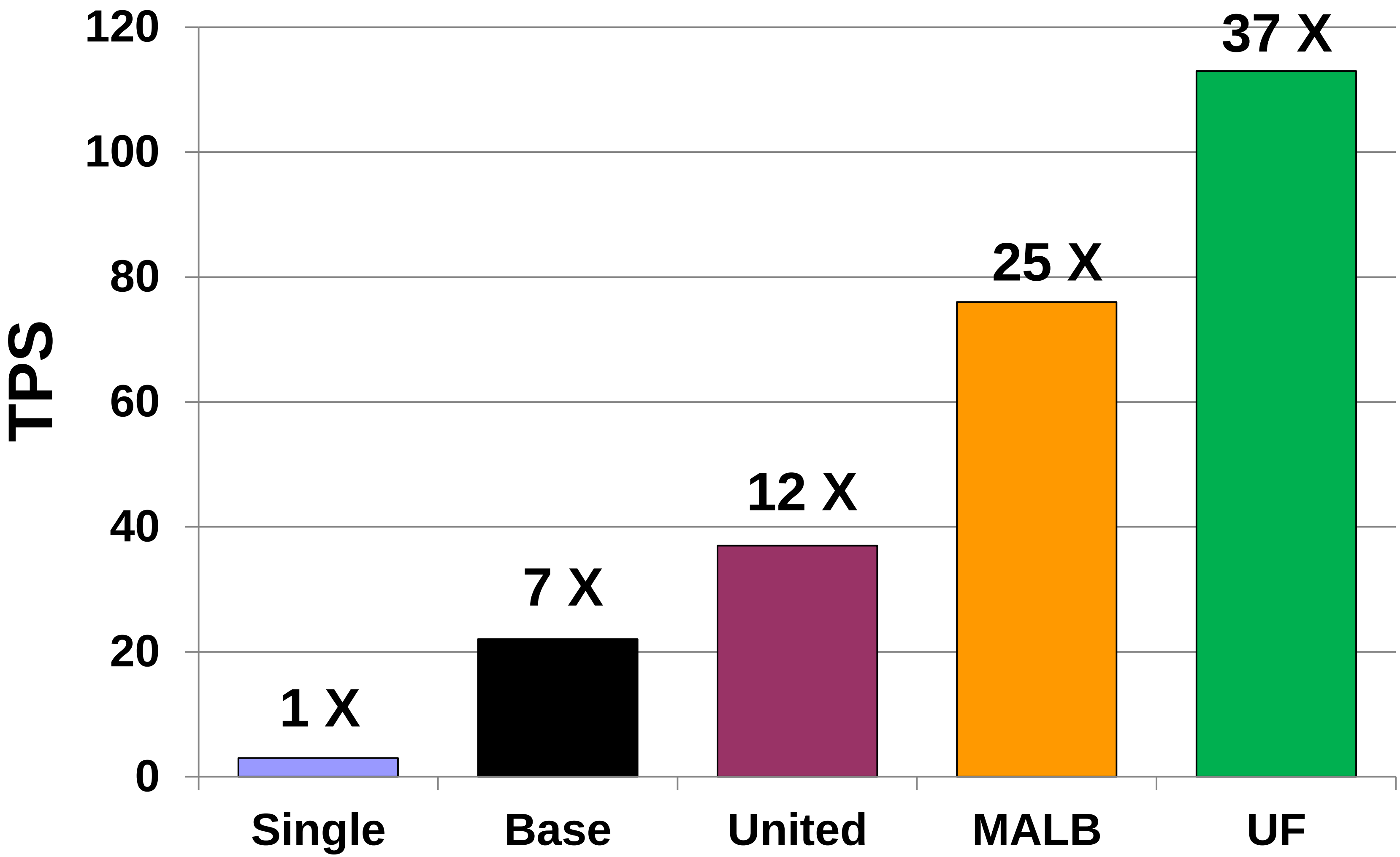
Sub-linear Scalability Wall



This Talk

- General scaling techniques
  - Address fundamental bottlenecks
  - Synergistic, implemented in middleware
  - Evaluated experimentally

Super-linear Scalability



Big Picture: Let’s Oversimplify

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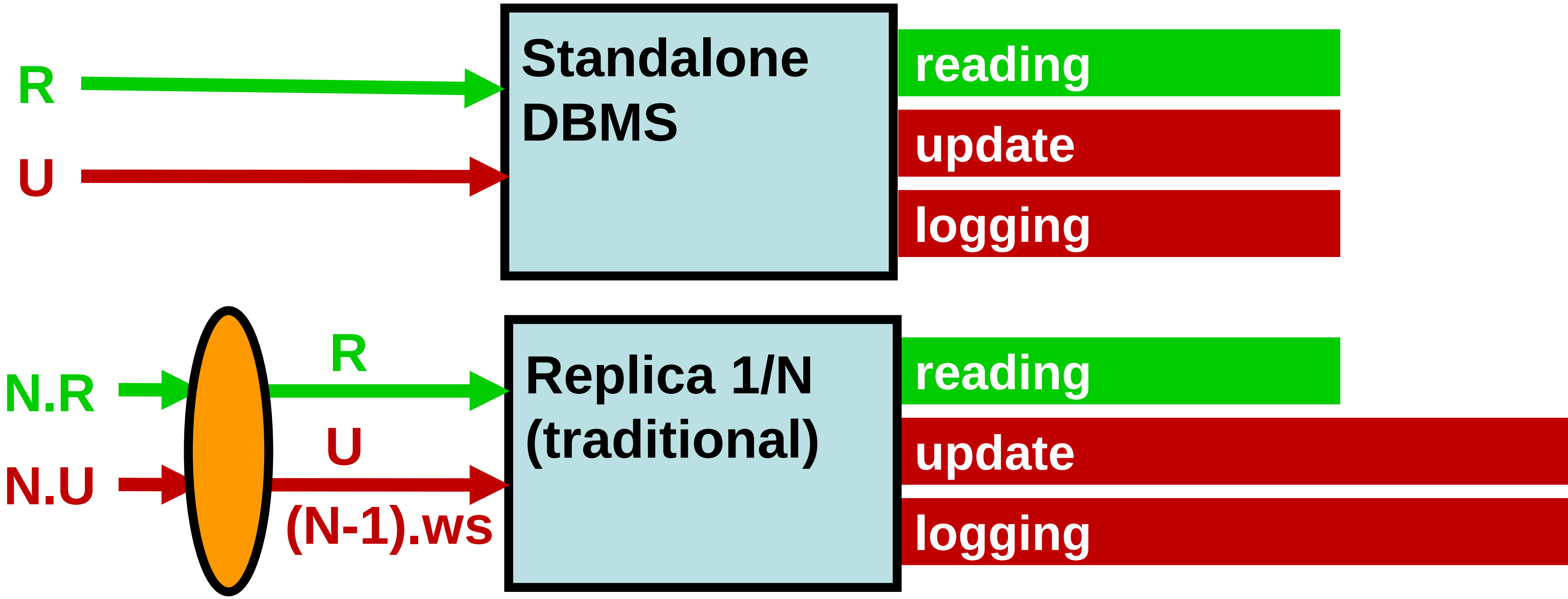
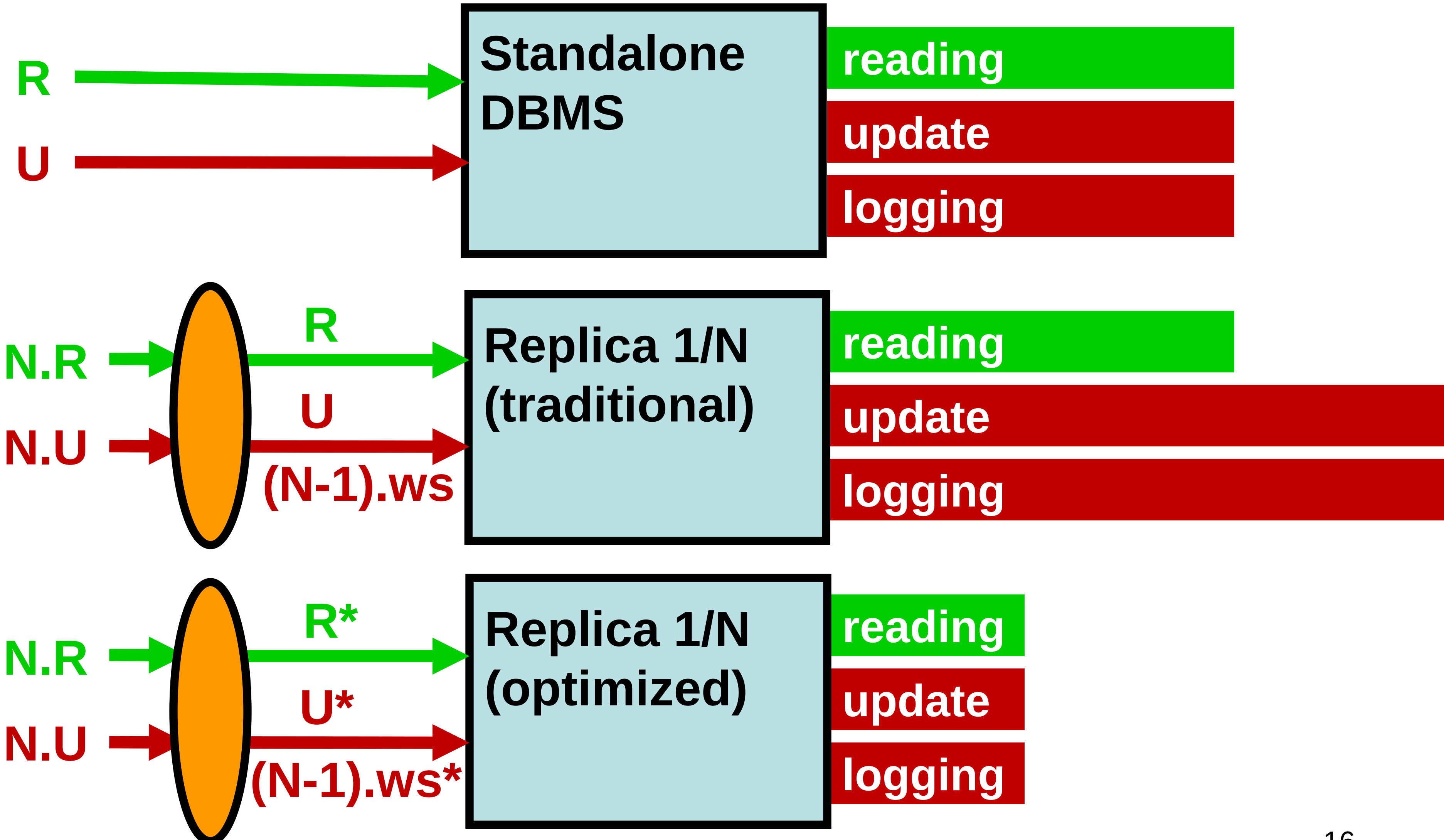
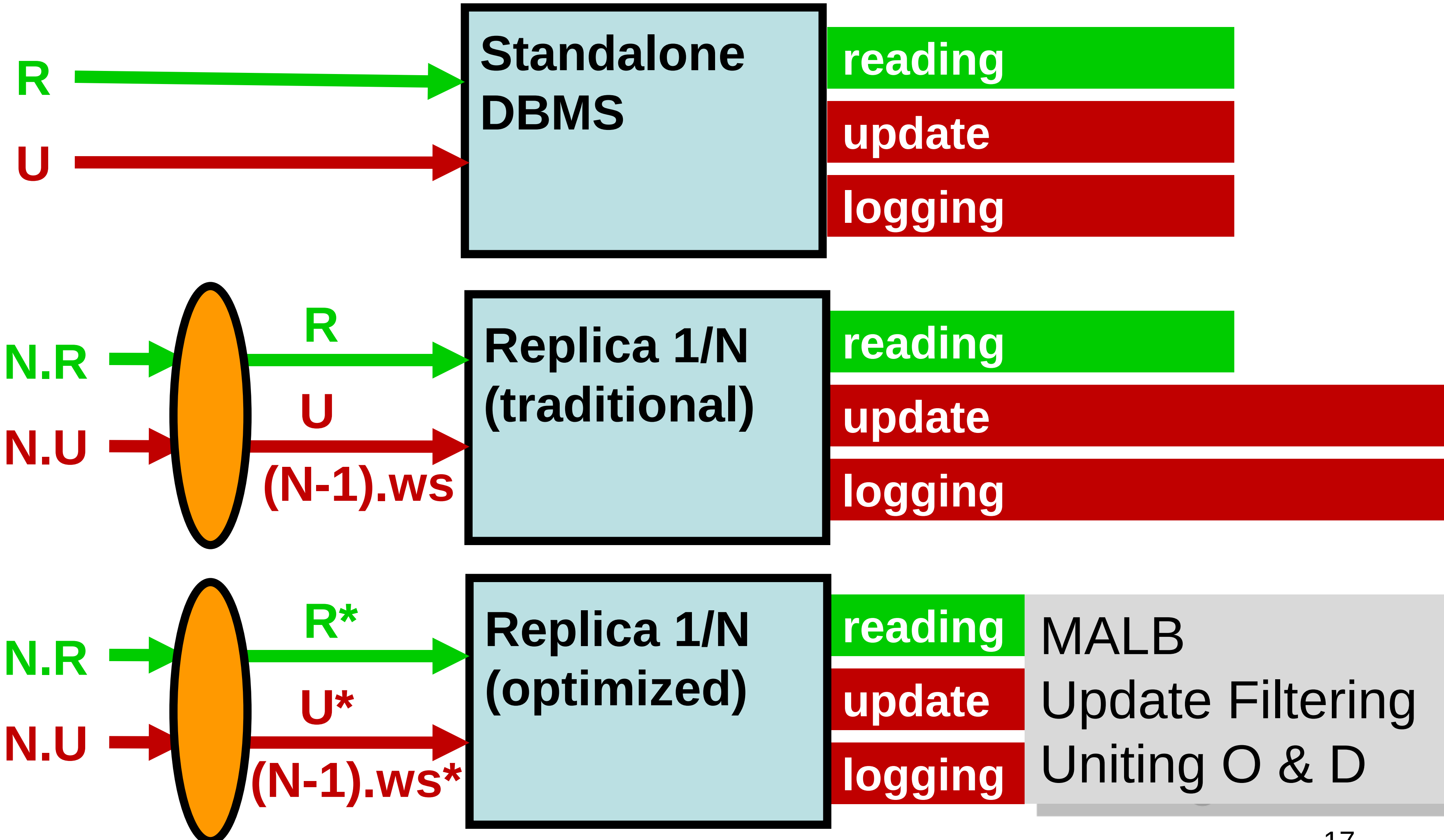


Big Picture: Let's Oversimplify



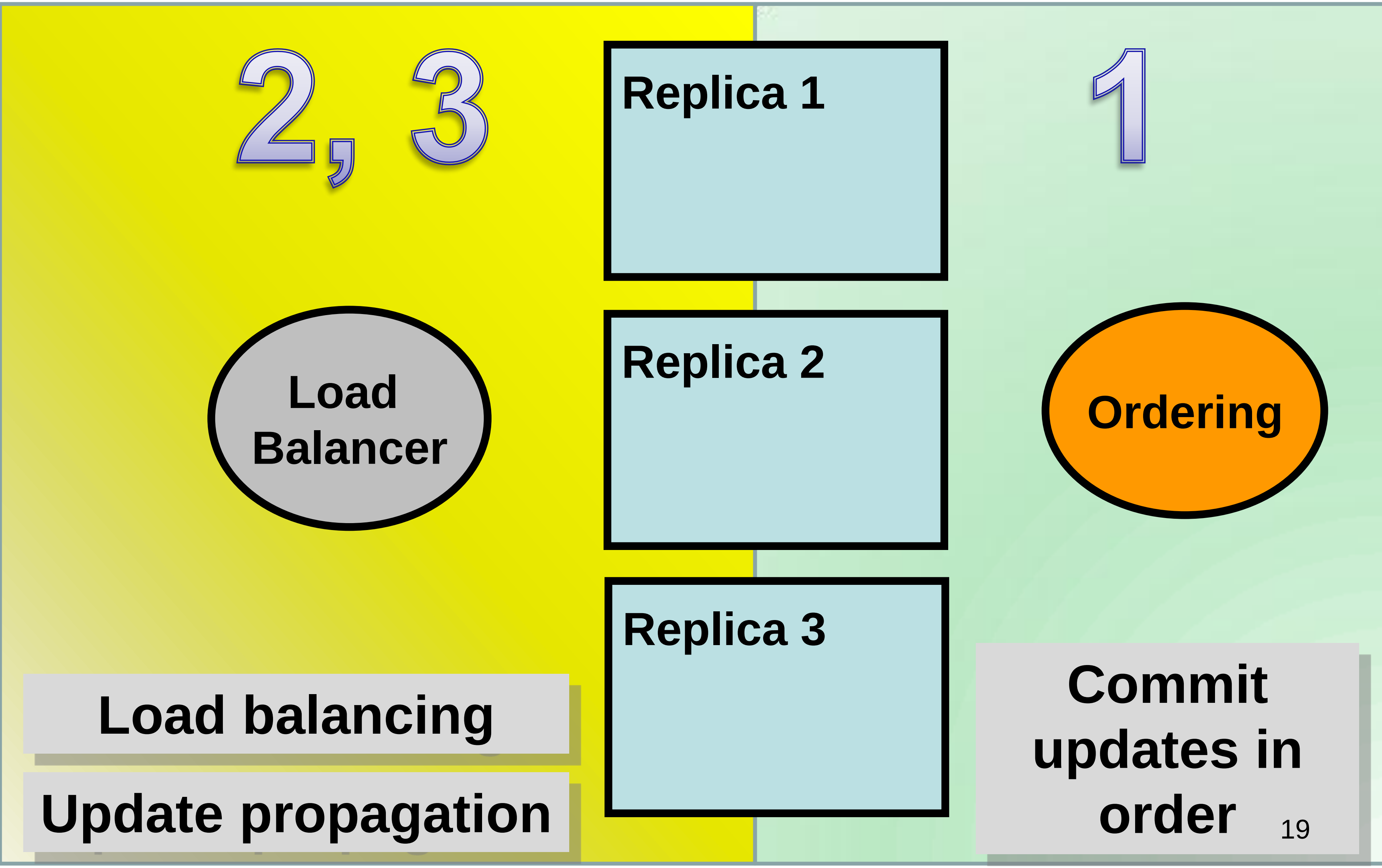
Big Picture: Let's Oversimplify



Key Points

1. **Commit updates in order**
   - Perform serial synchronous disk writes
   - Unite ordering and durability
2. **Load balancing**
   - Optimize for equal load: memory contention
   - MALB: optimize for in-memory execution
3. **Update propagation**
   - Propagate updates everywhere
   - Update filtering: propagate to where needed

Roadmap



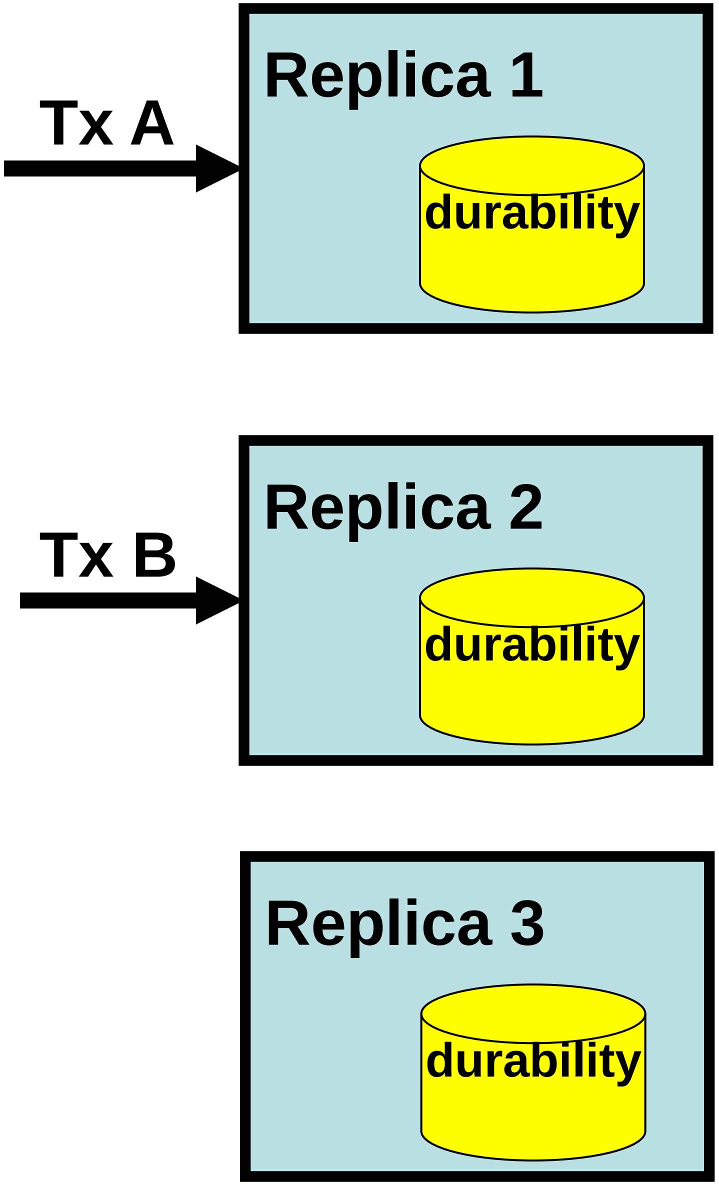
2, 3
1
Replica 1
Replica 2
Replica 3
Load Balancer
Ordering
Load balancing
Update propagation
Commit updates in order

Key Idea

- **Traditionally:**
  - Commit ordering and durability are separated

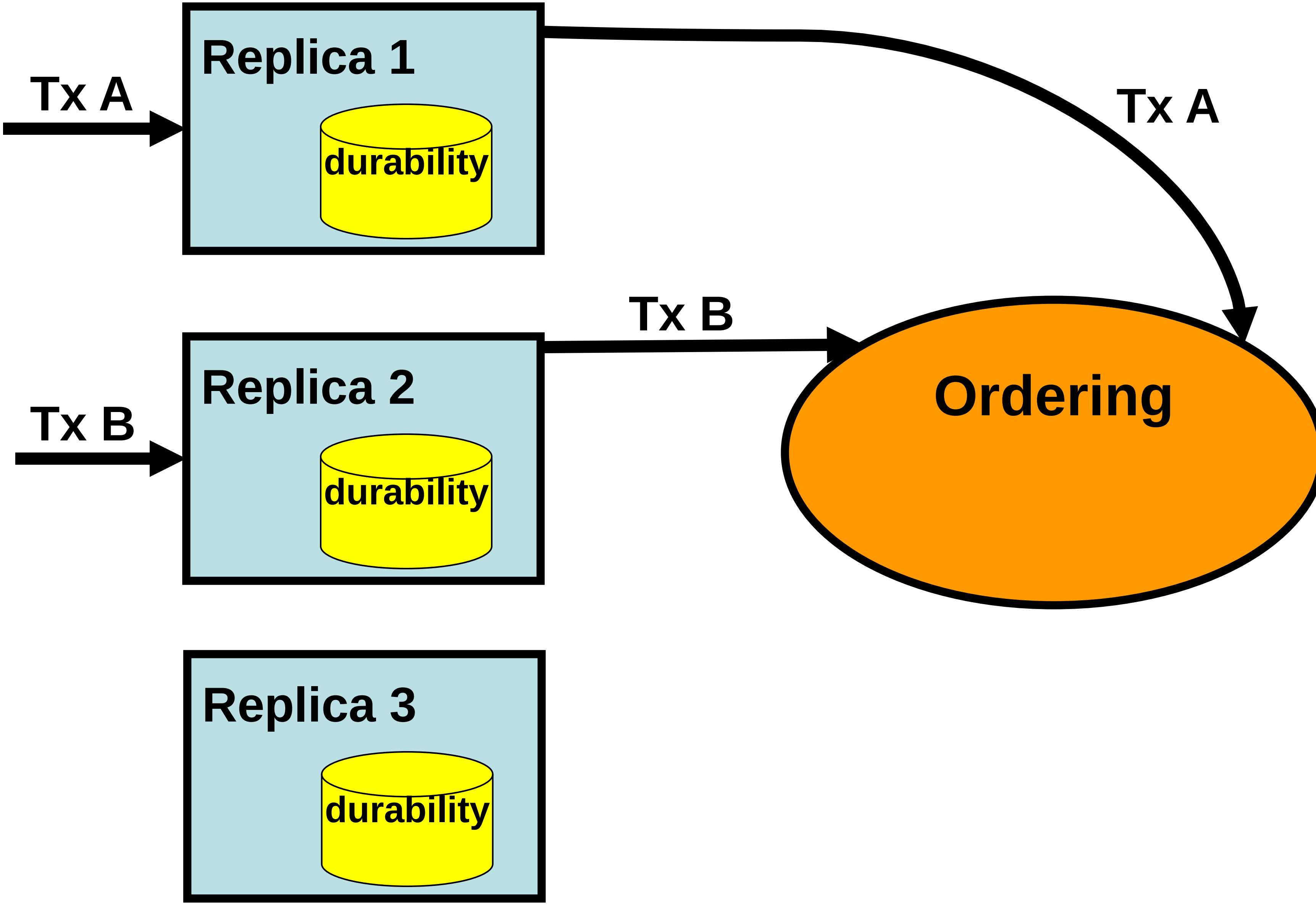
- **Key idea:**
  - Unite commit ordering and durability

All Replicas Must Agree

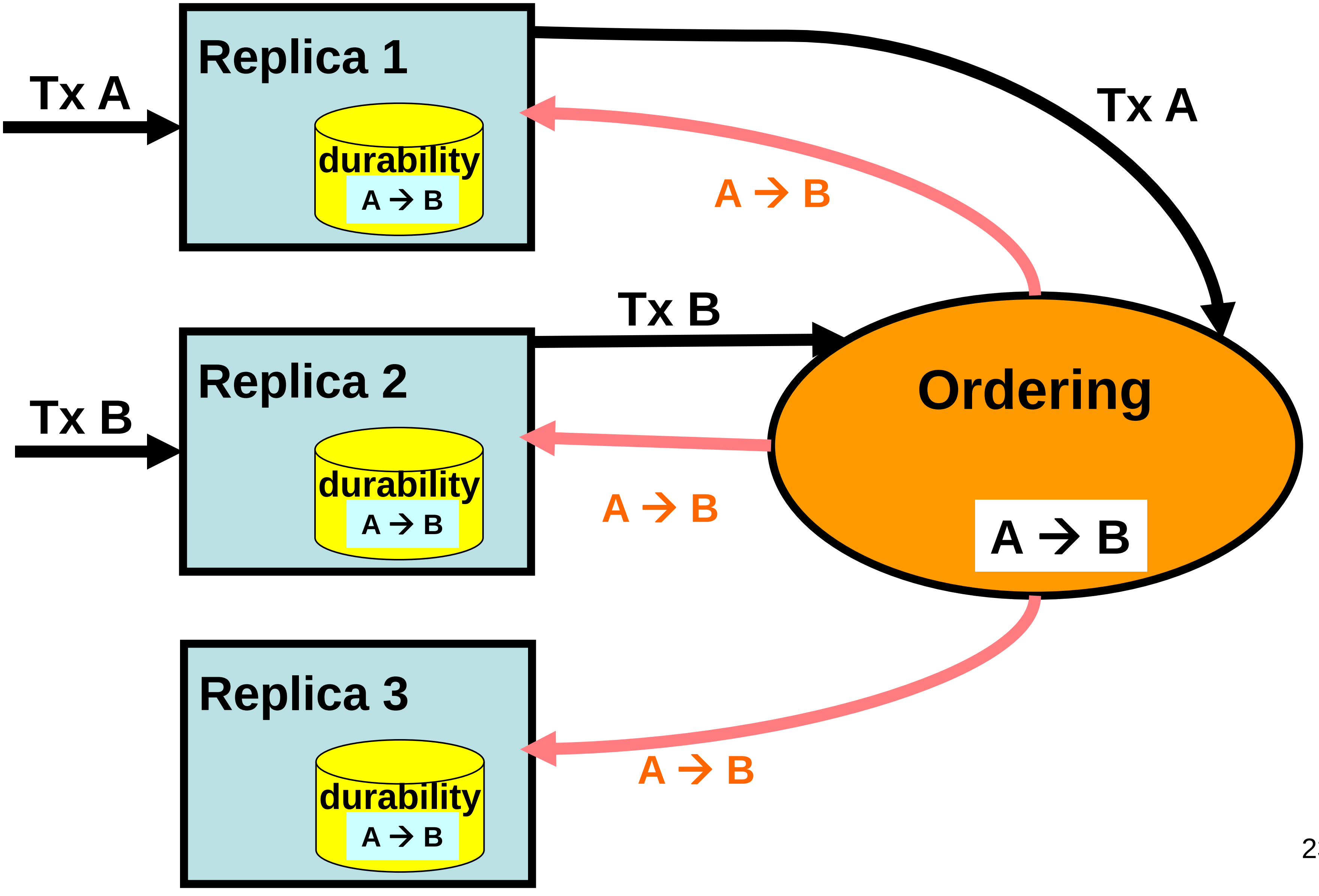


- All replicas agree on
  - which update tx commit
  - their commit order
- Total order
  - Determined by middleware
  - Followed by each replica

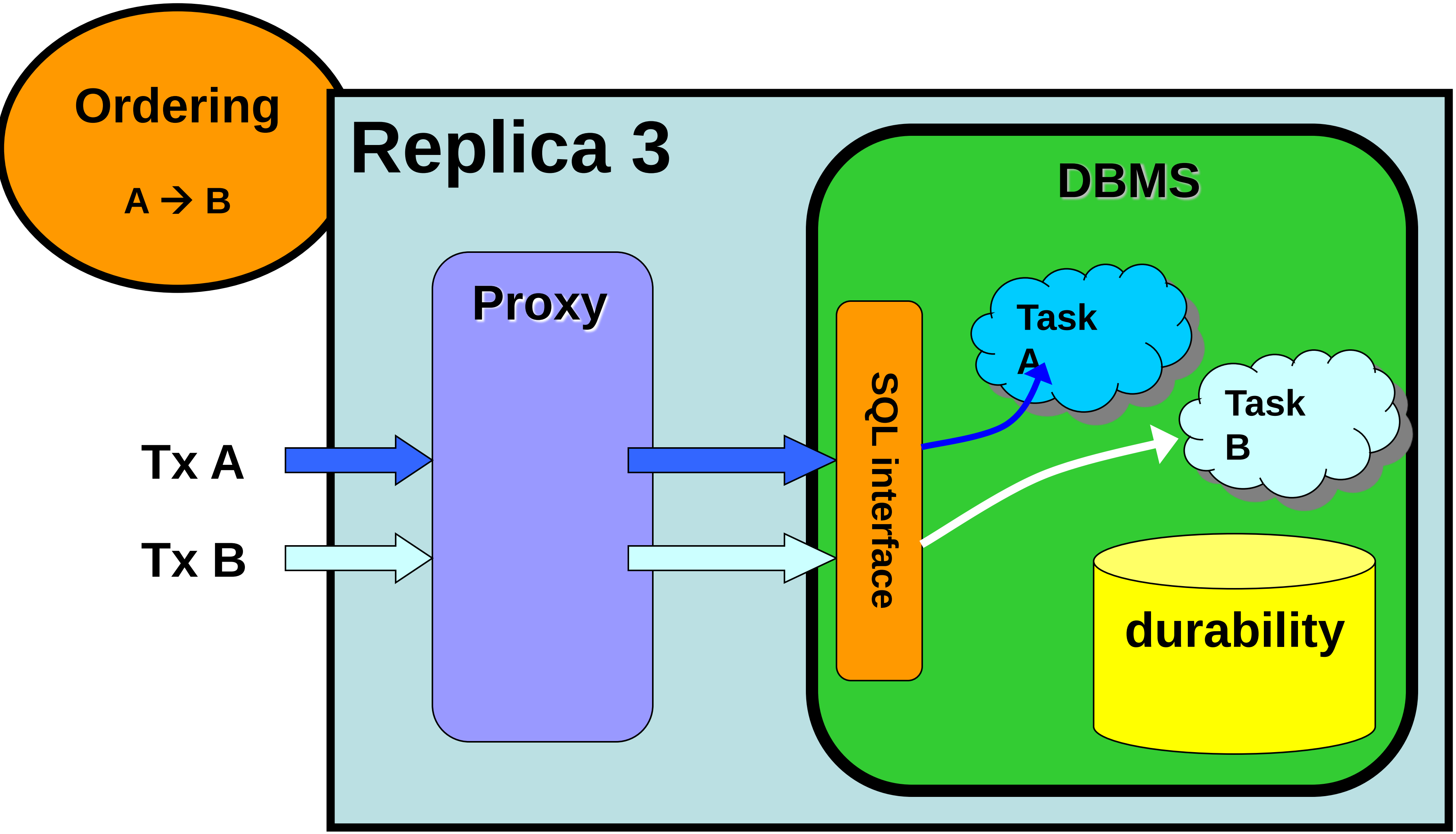
Order Outside DBMS



Order Outside DBMS



Enforce External Commit Order



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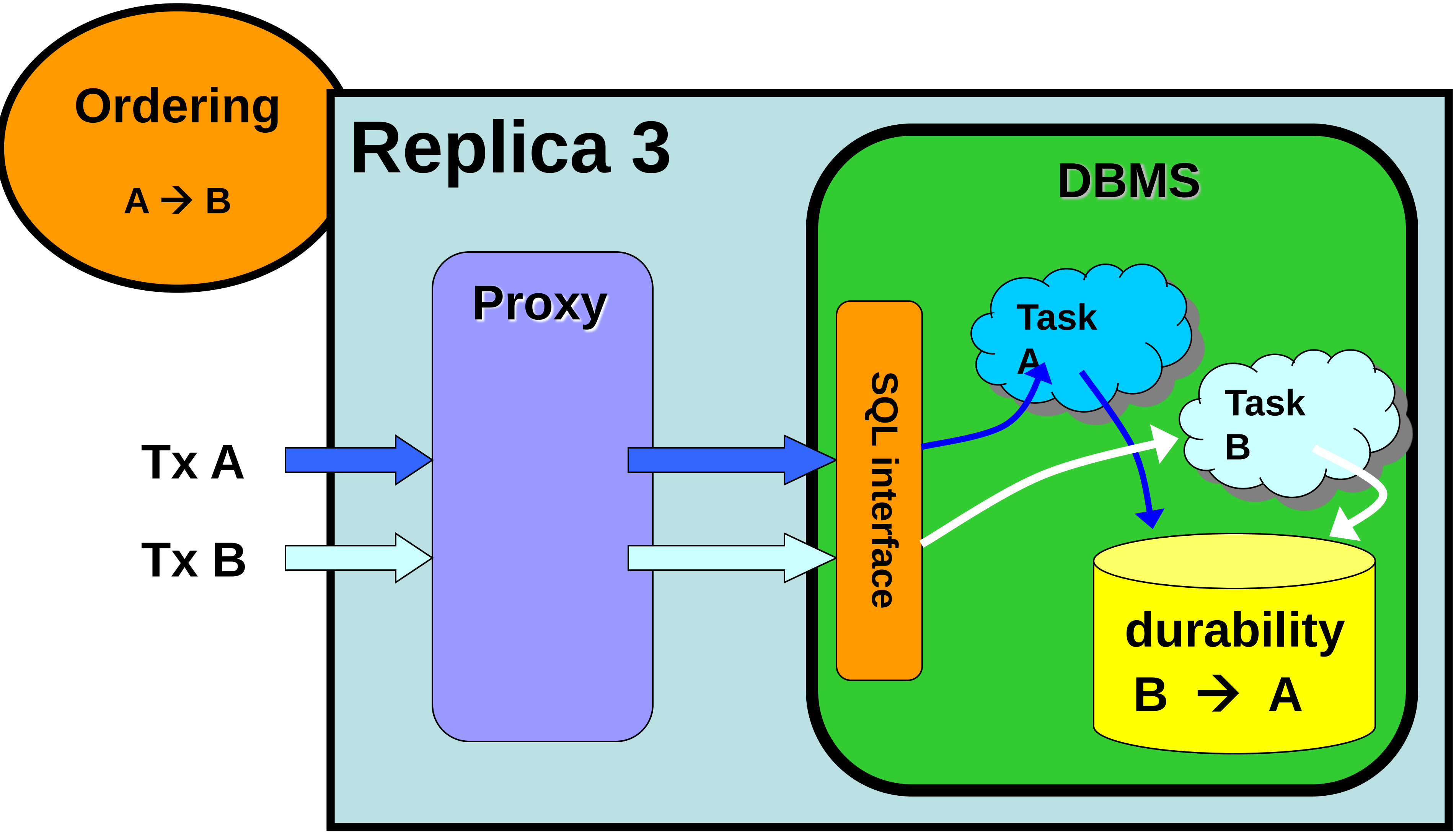
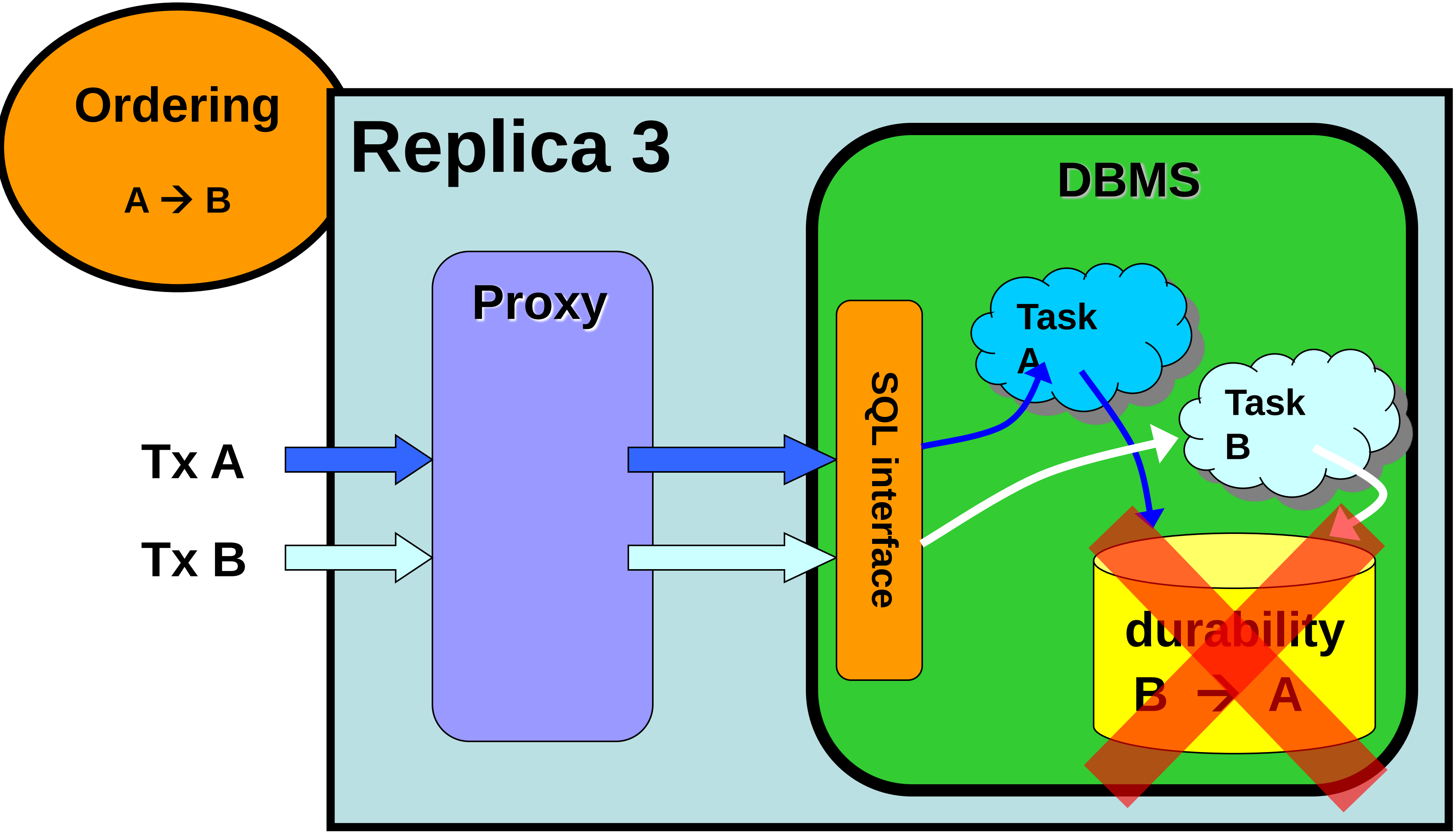
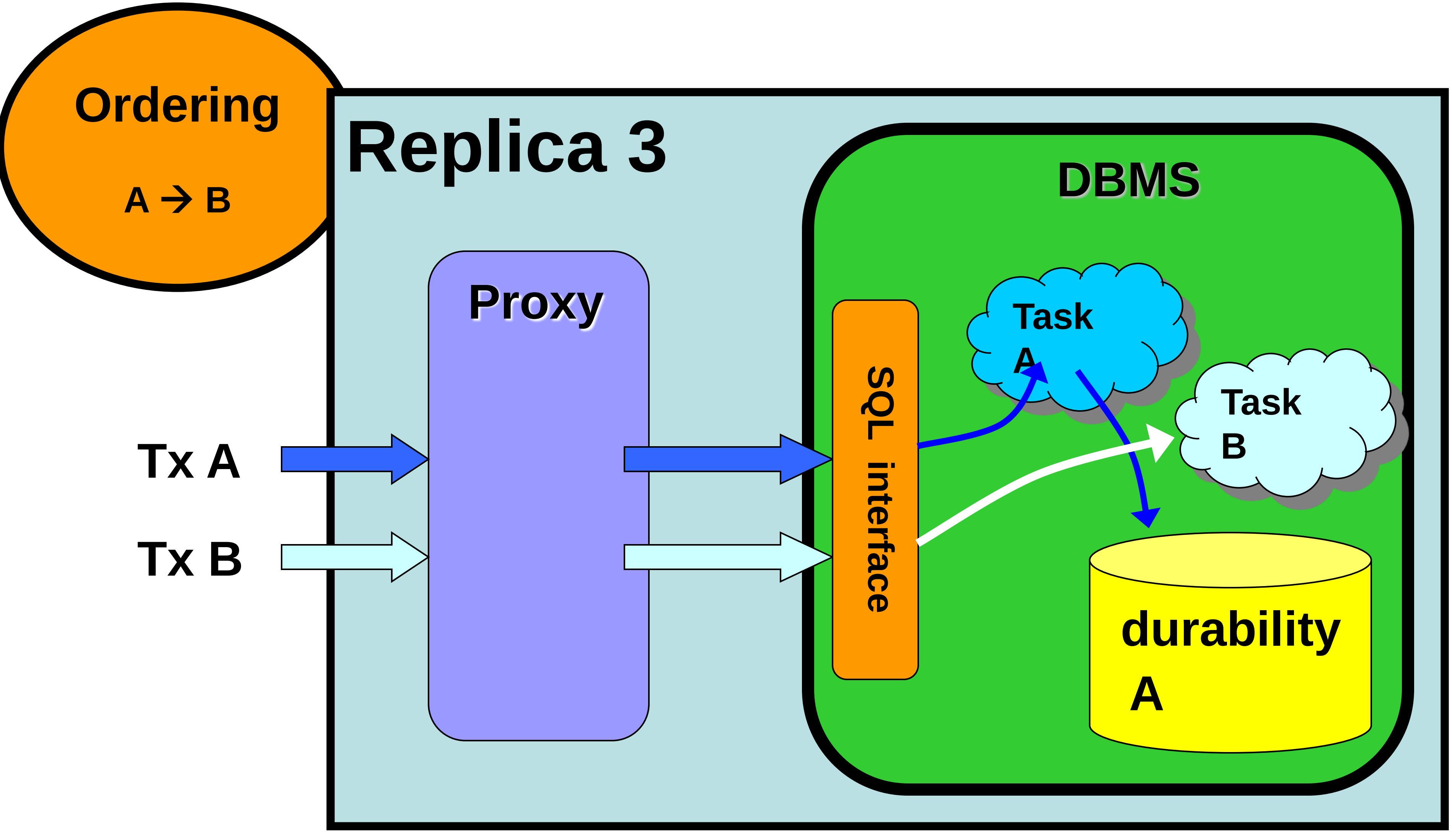


Enforce External Commit Order

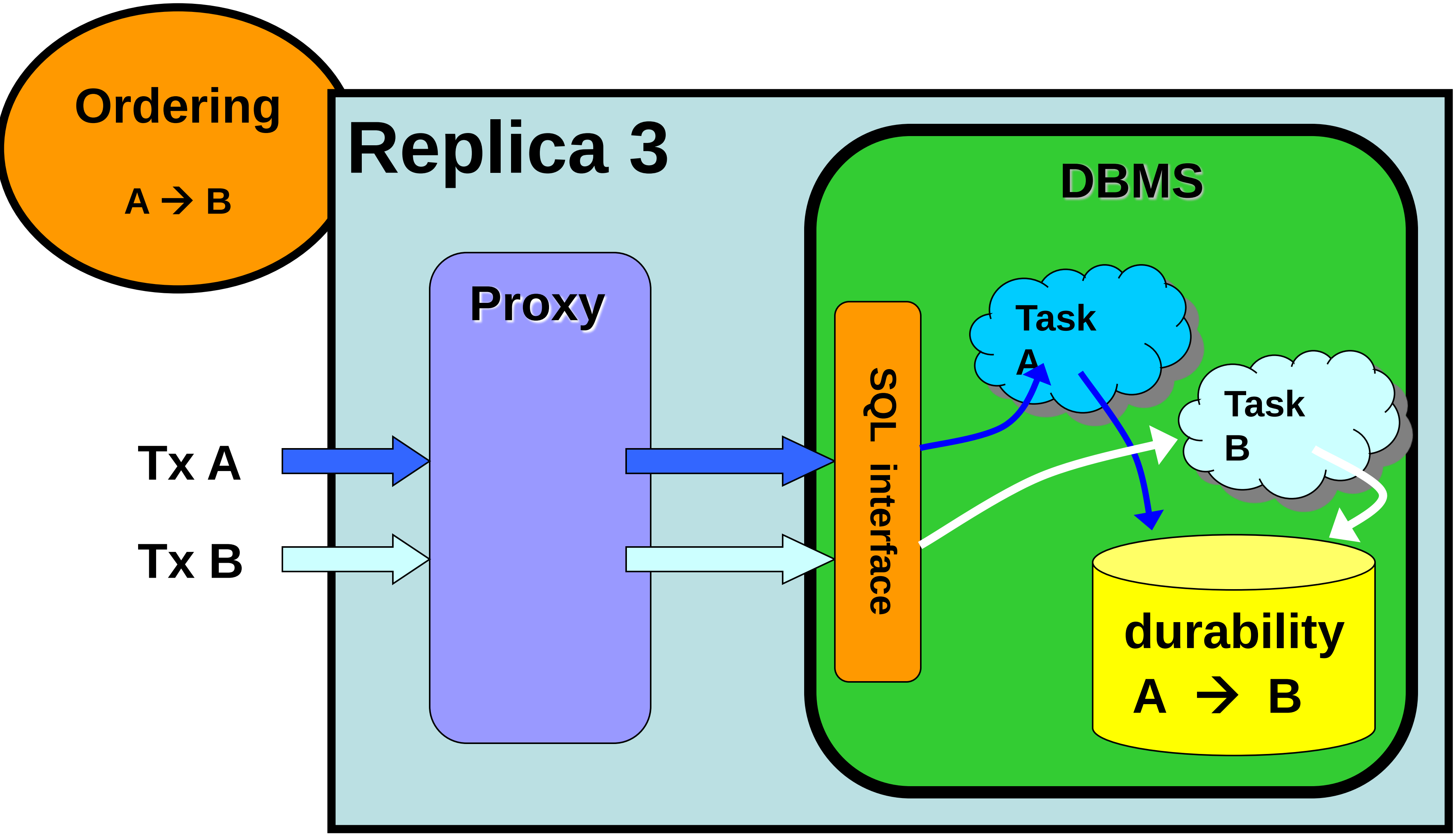


Cannot commit A & B concurrently!

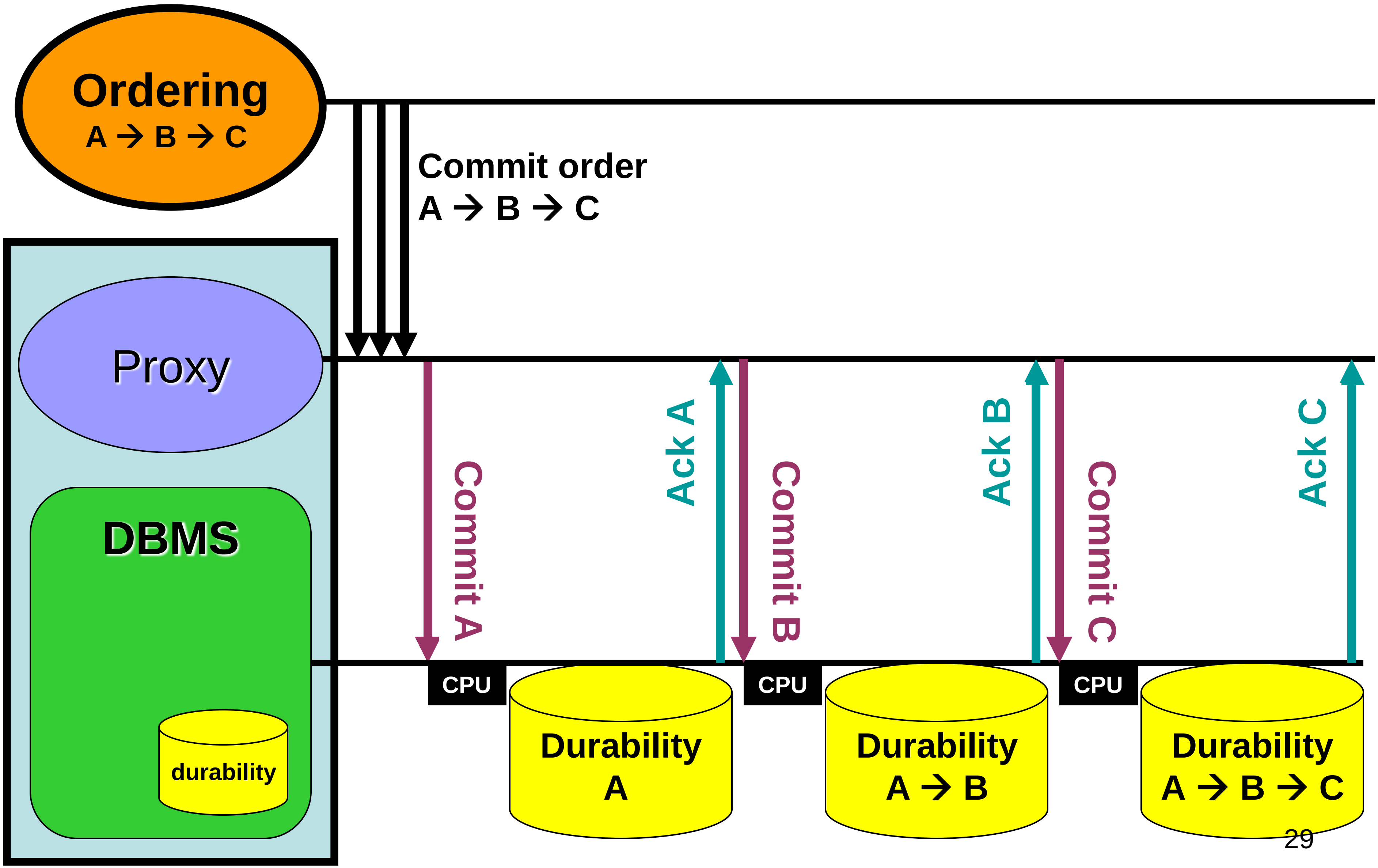
Enforce Order = Serial Commit



Enforce Order = Serial Commit



Commit Serialization is Slow



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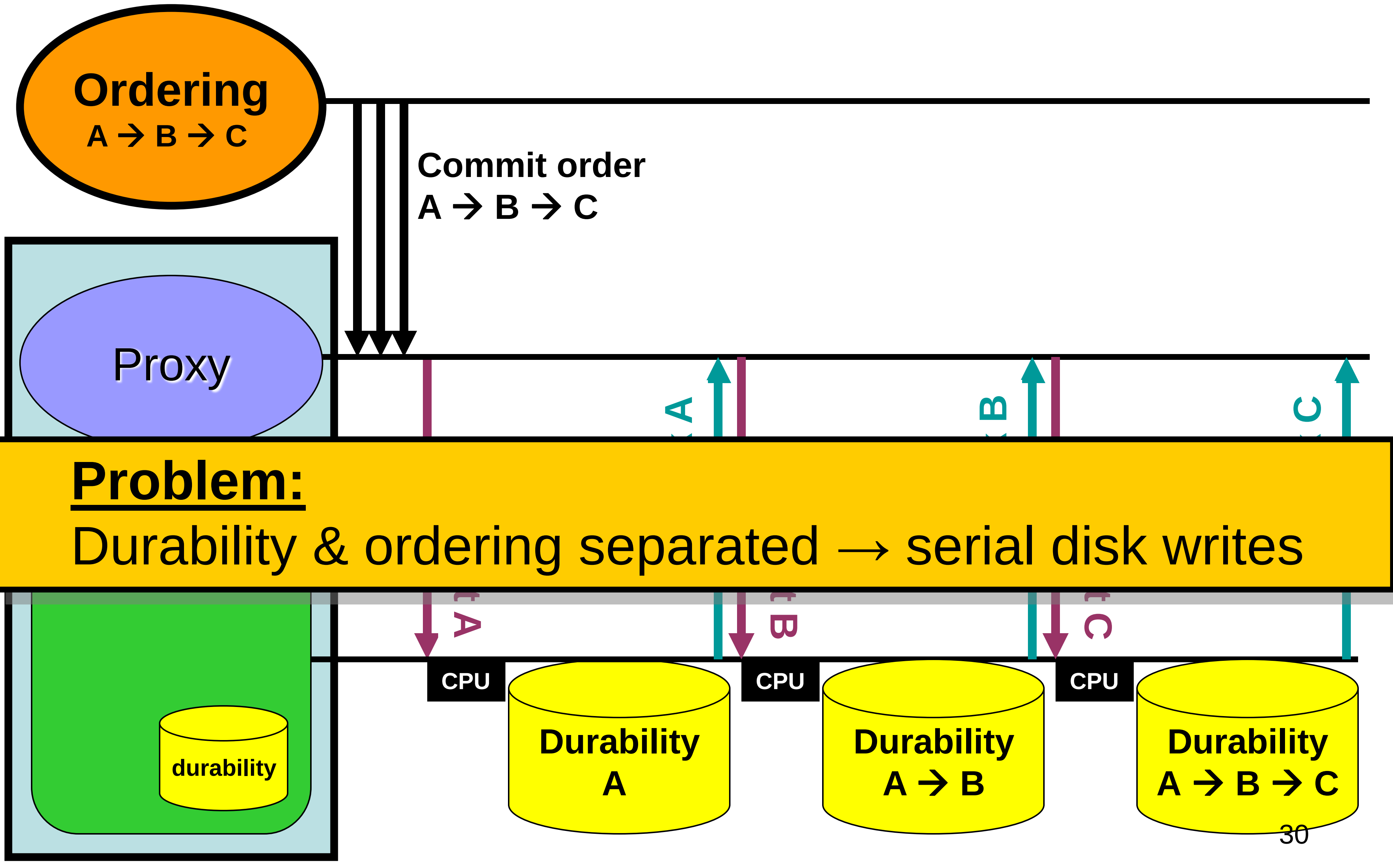
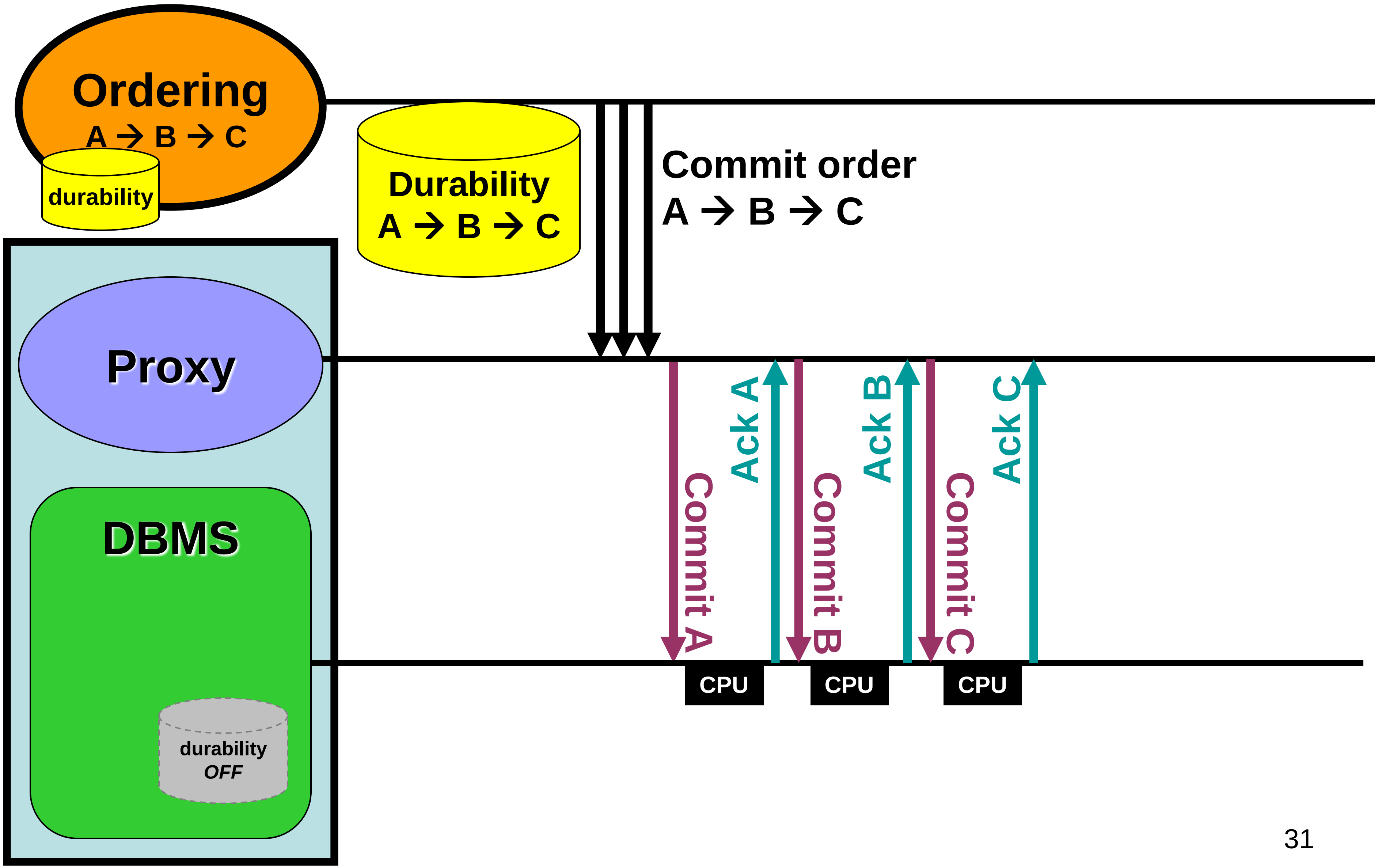


Problem:

Durability & ordering separated → serial disk writes

Unite D. & O. in Middleware



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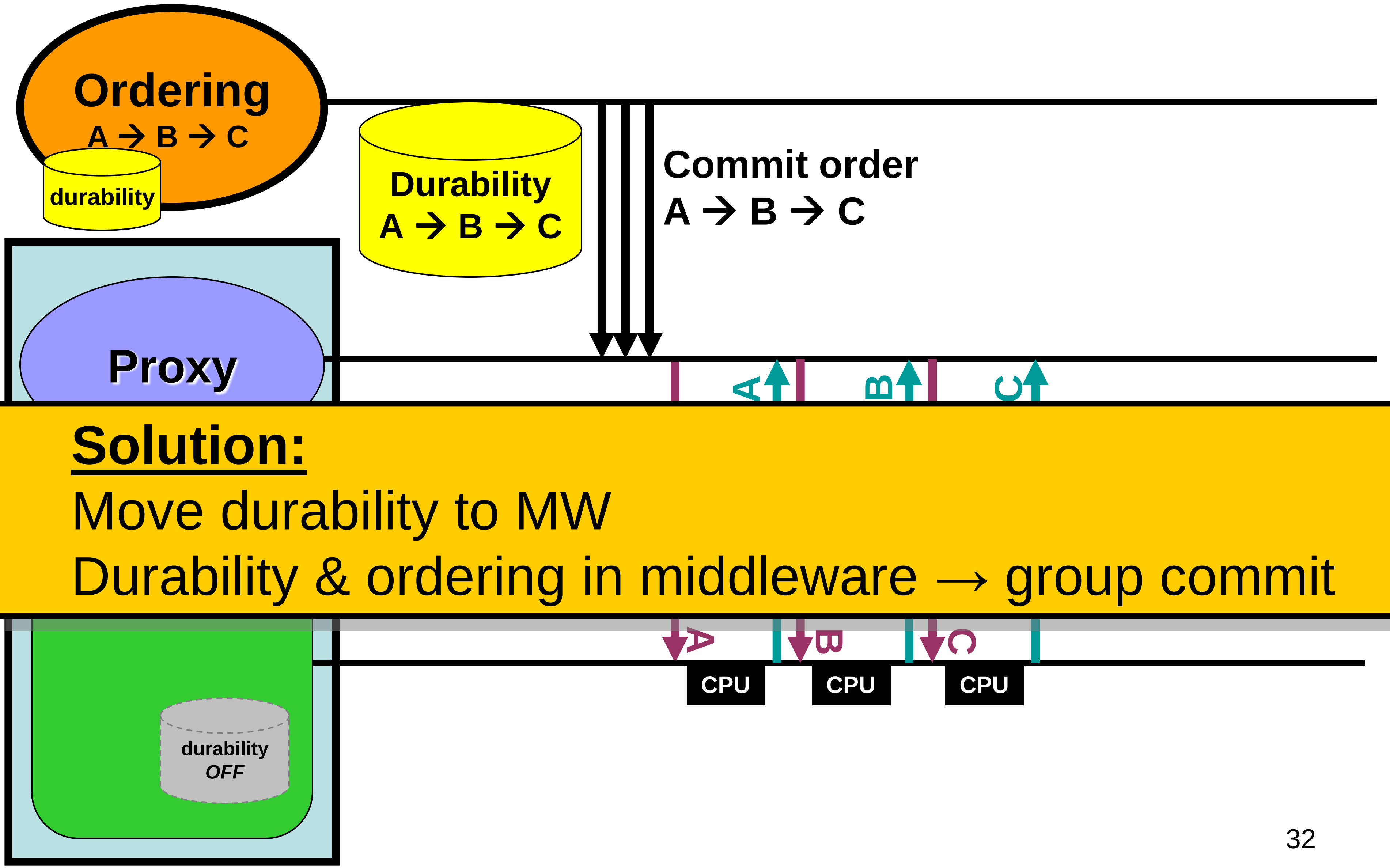


Solution:

Move durability to MW

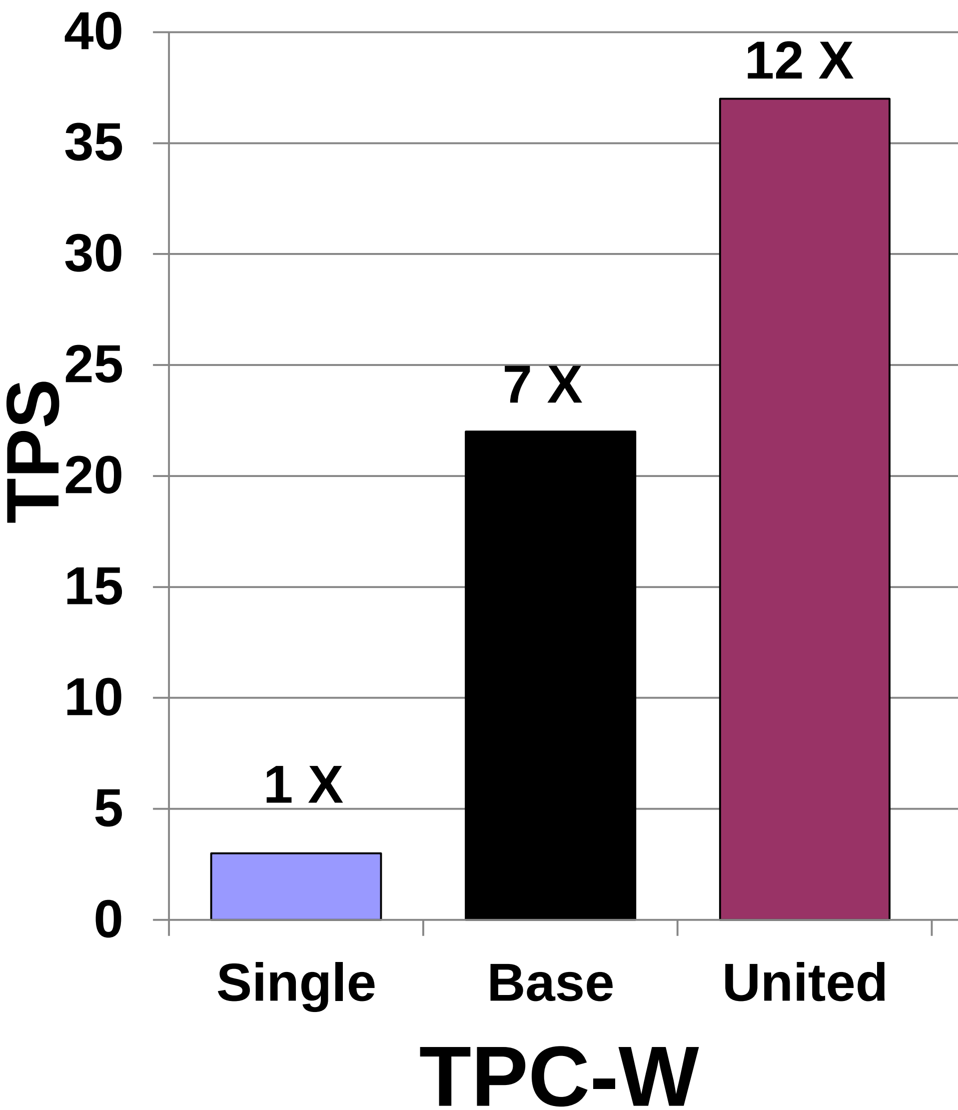
Durability & ordering in middleware → group commit

Implementation: Uniting D & O in MW

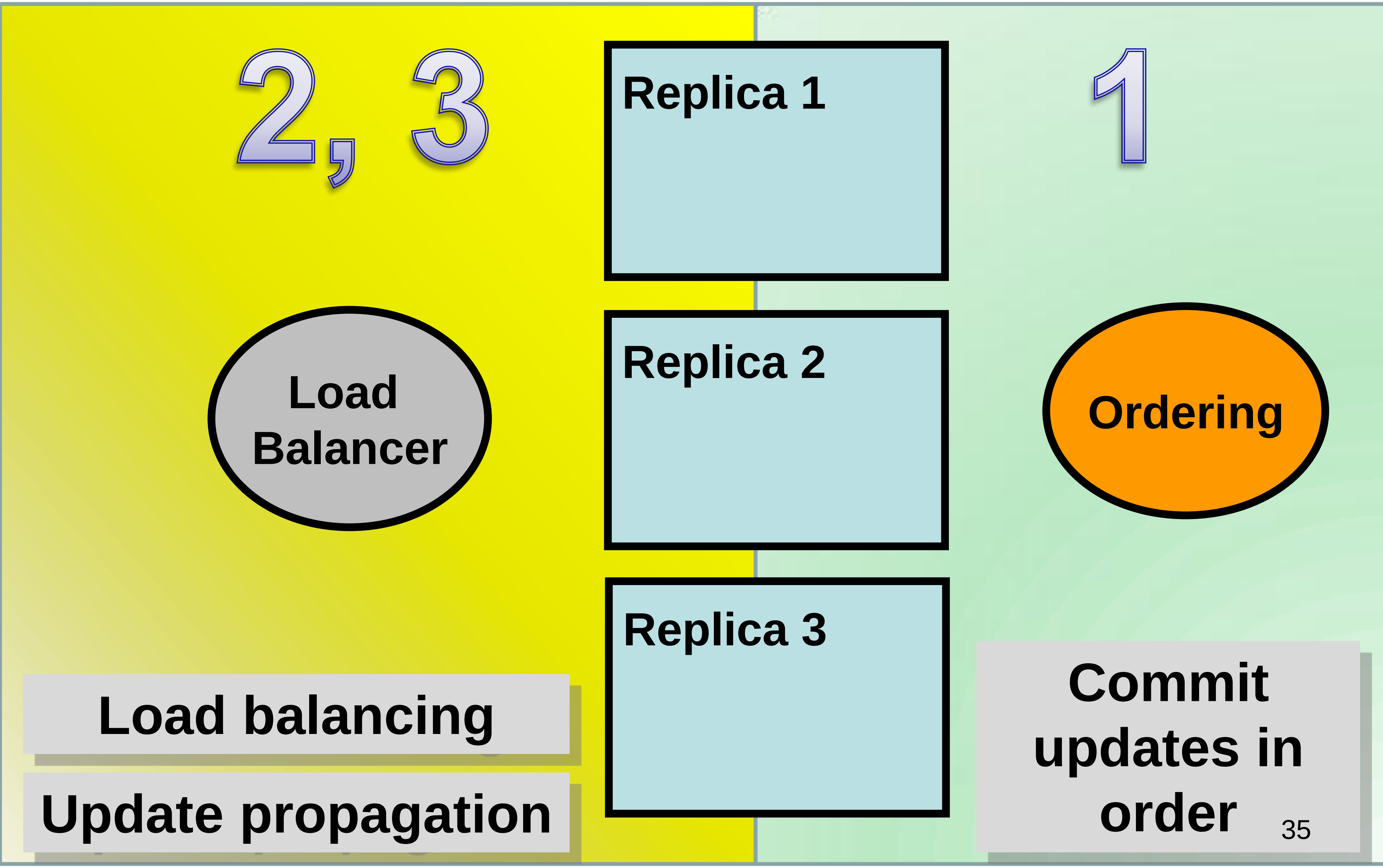
- Middleware logs tx effects
  - Durability of update tx
    - Guaranteed in middleware
    - Turn durability off at database
- Middleware performs durability & ordering
  - United → group commit → fast
- Database commits update tx serially
  - Commit = quick main memory operation

Uniting Improves Throughput

- **Metric**
  - Throughput
- **Workload**
  - TPC-W Ordering (50% updates)
- **System**
  - Linux cluster
  - PostgreSQL
  - 16 replicas
  - Serializable exec.



Roadmap


2, 3
Replica 1
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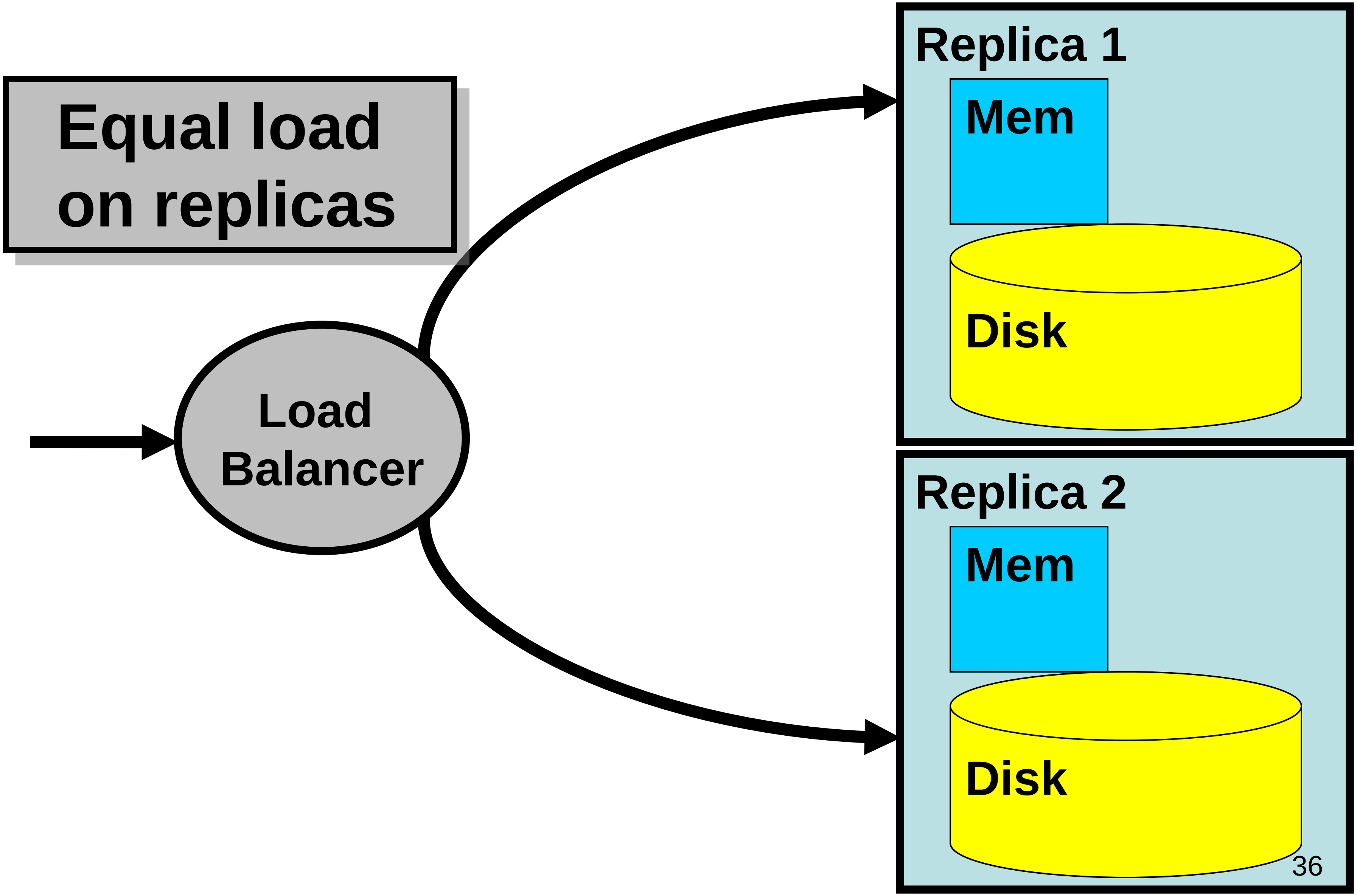
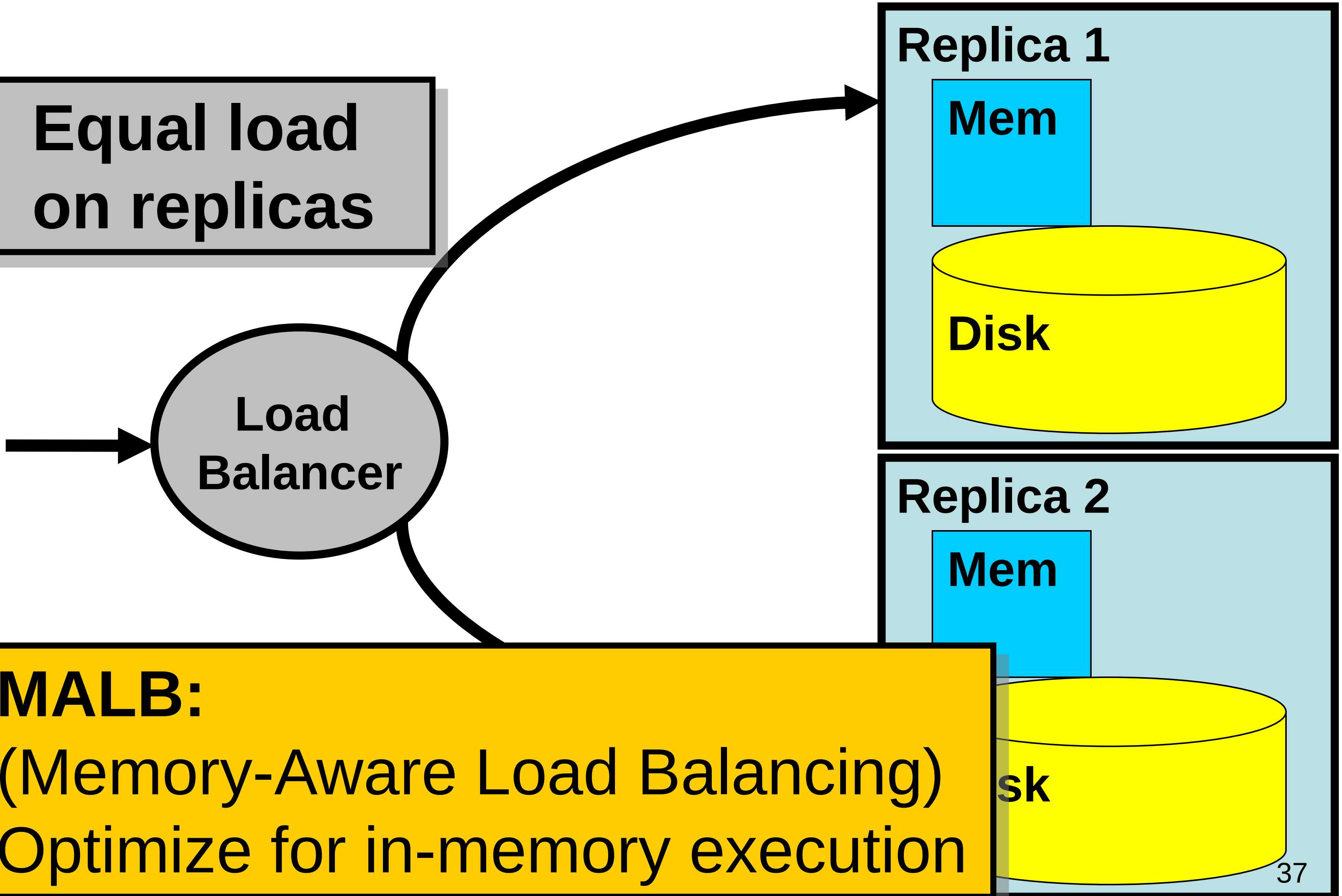
Replica 3
Load balancing
Update propagation
Commit updates in order

Key Idea


Equal load
on replicas
Load
Balancer
Replica 1
Mem
Disk
Replica 2
Mem
Disk

Key Idea



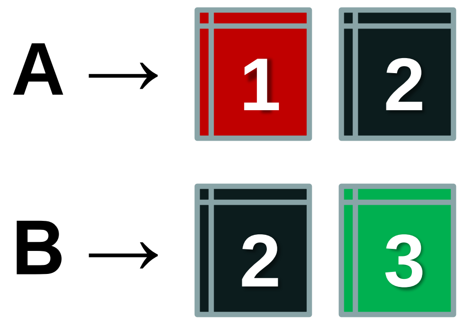
Equal load on replicas

MALB:
(Memory-Aware Load Balancing)
Optimize for in-memory execution

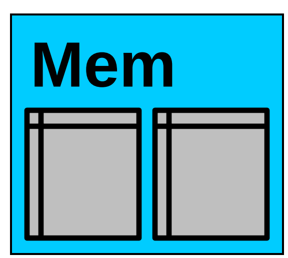
How Does MALB Work?

Database

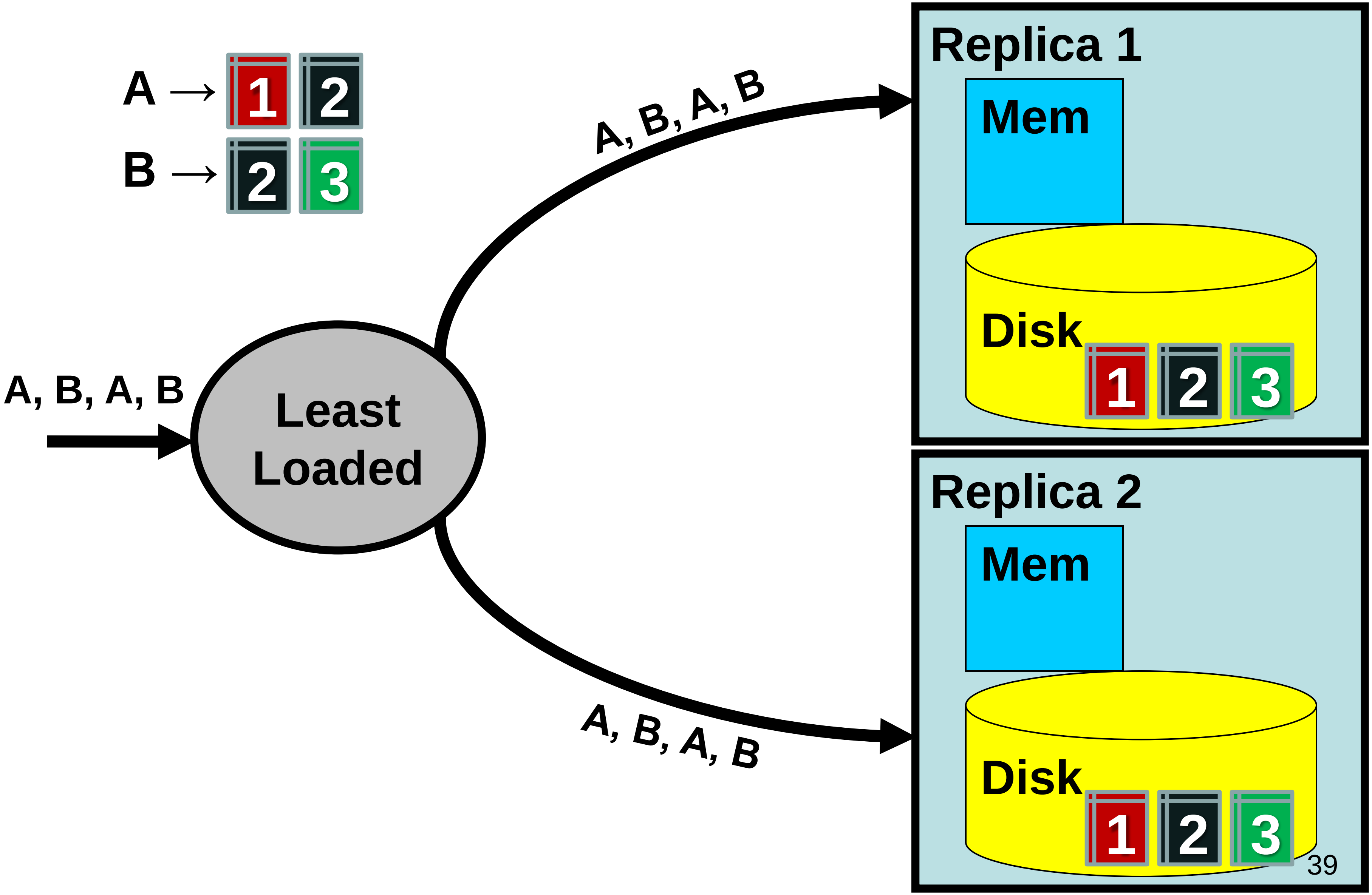
Workload



Memory



Read Data From Disk



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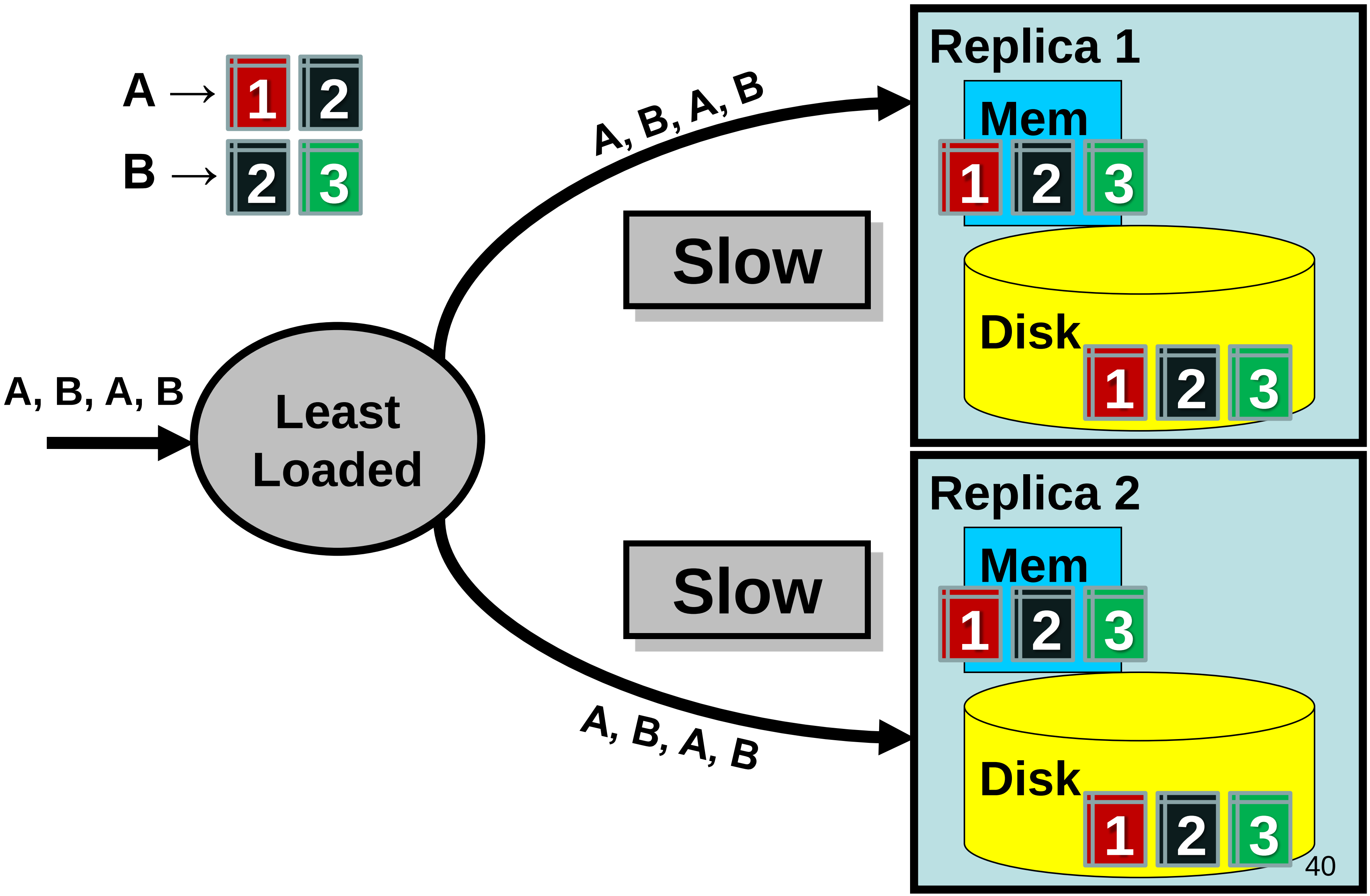
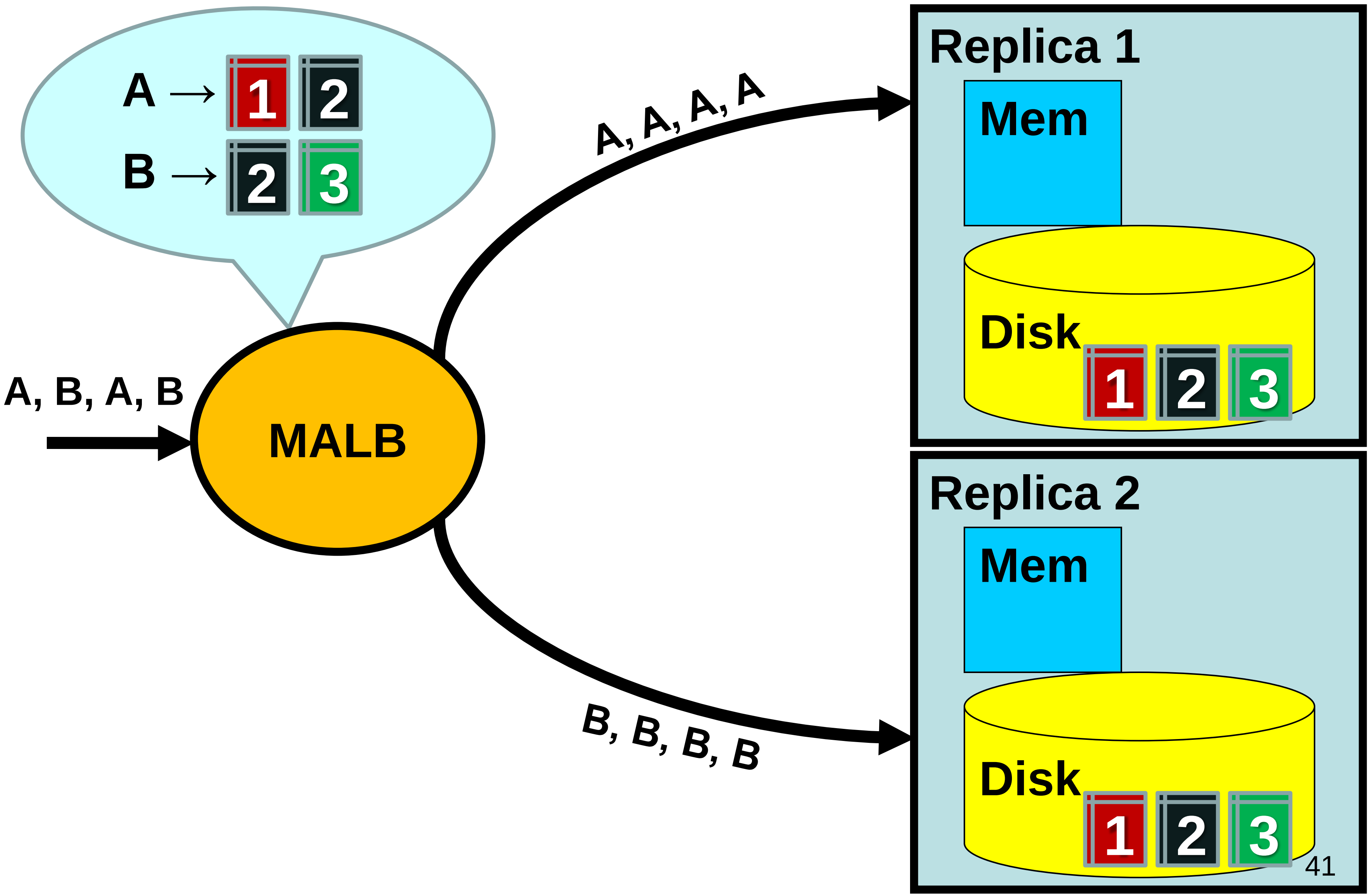


Data Fits in Memory



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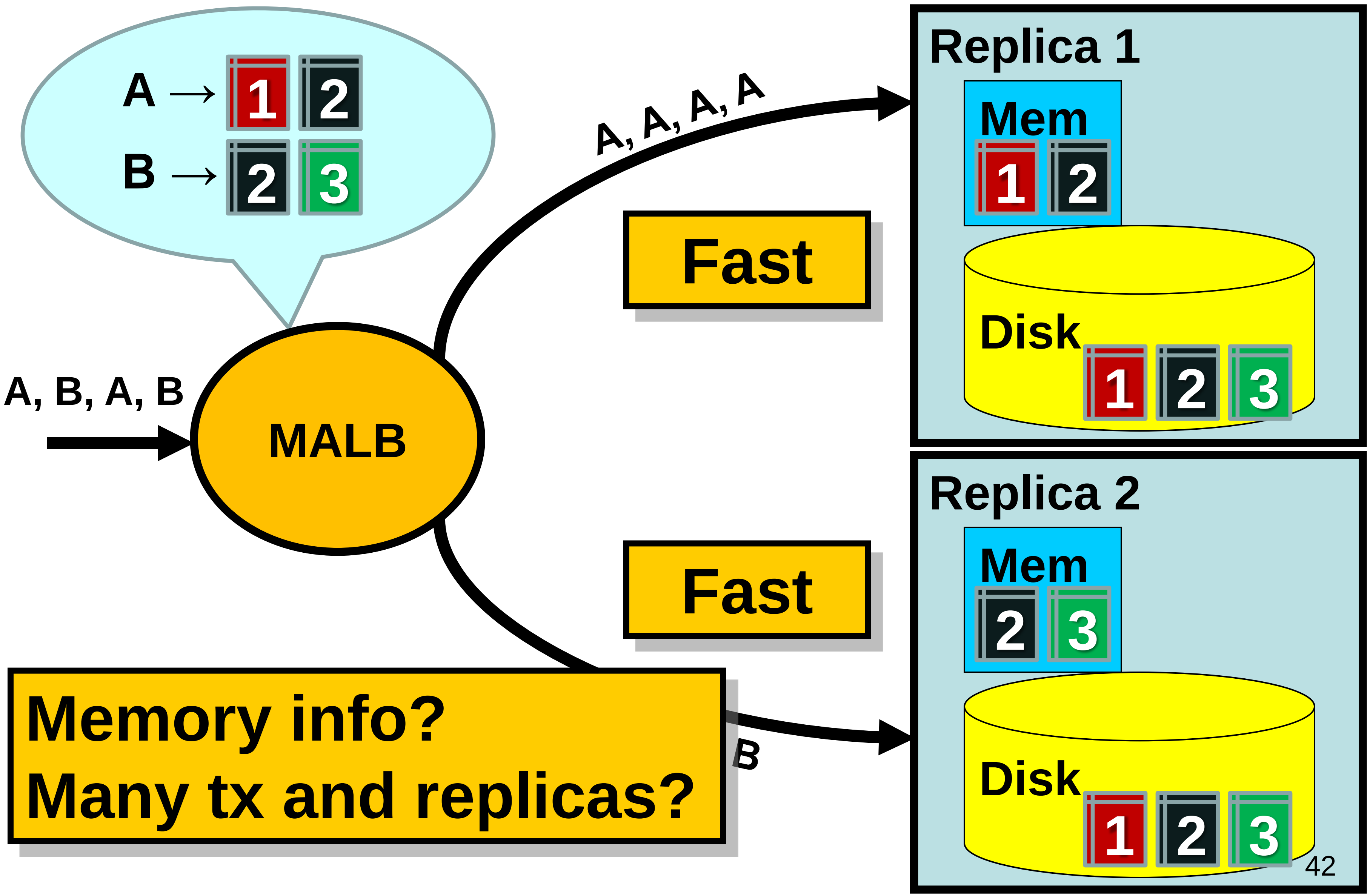


Memory info?
Many tx and replicas?

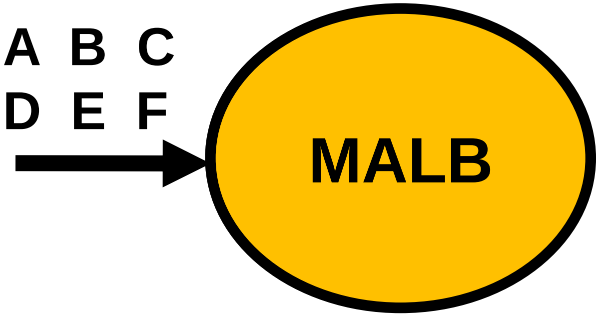
Estimate Tx Memory Needs

- **Exploit tx execution plan**
  - Which tables & indices are accessed
  - Their access pattern
    - Linear scan, direct access
- **Metadata from database**
  - Sizes of tables and indices

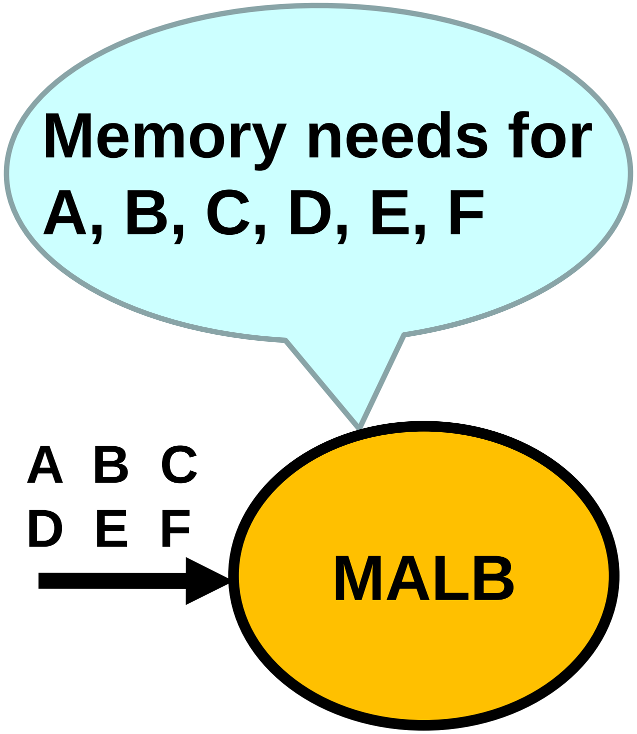
Grouping Transactions

- **Objective**
  – Construct tx groups that fit together in memory
- **Bin packing**
  – Item: tx memory needs
  – Bin: memory of replica
  – Heuristic: Best Fit Decreasing
- **Allocate replicas to tx groups**
  – Adjust for group loads

MALB in Action



MALB in Action



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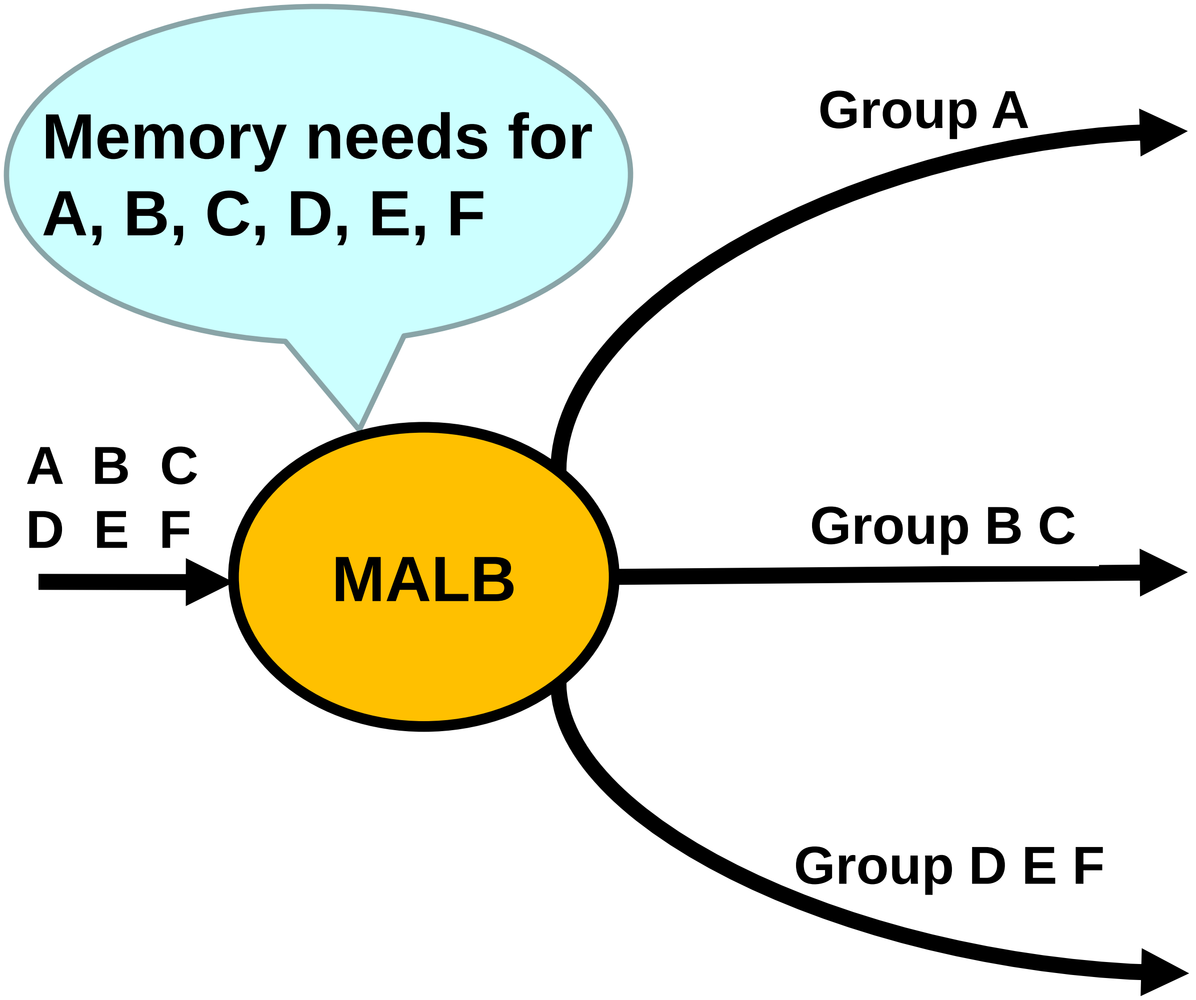

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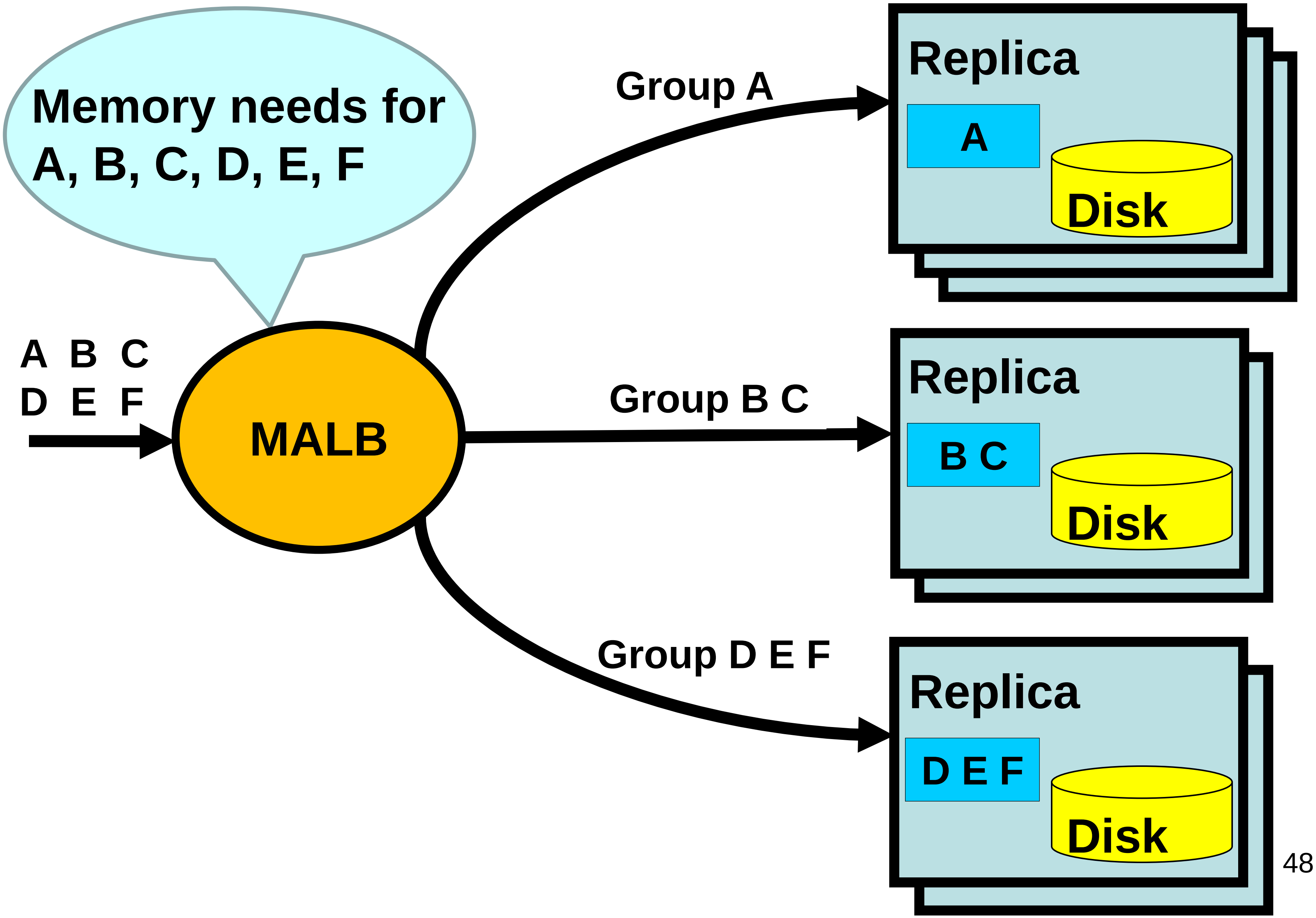


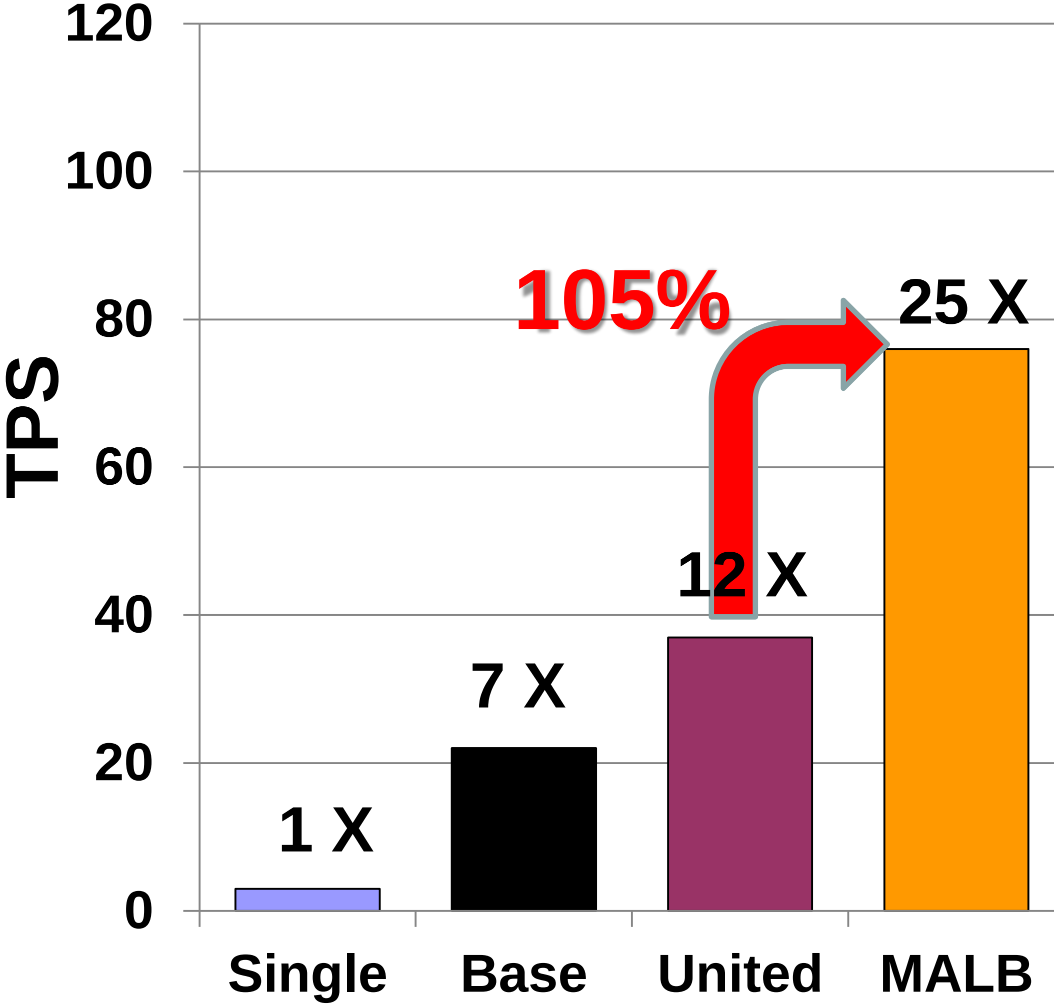
MALB Summary

- **Objective**
  – Optimize for in-memory execution
- **Method**
  – Estimate tx memory needs
  – Construct tx groups
  – Allocate replicas to tx groups

Experimental Evaluation

- **Implementation**
  - No change in consistency
  - Still middleware
- **Compare**
  - **United**: efficient baseline system
  - **MALB**: exploits working set information
- **Same environment**
  - Linux cluster running PostgreSQL
  - Workload: TPC-W Ordering (50% update txs)

MALB Doubles Throughput

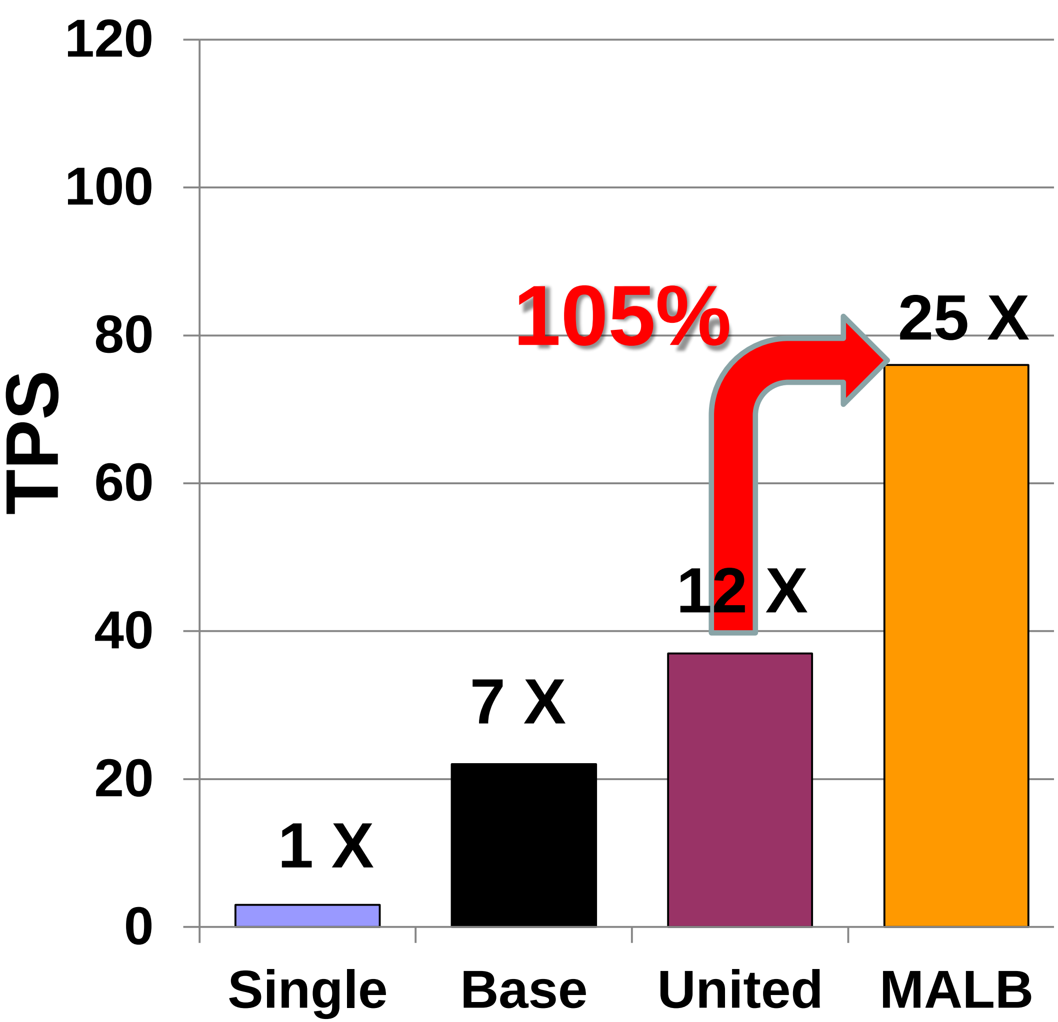


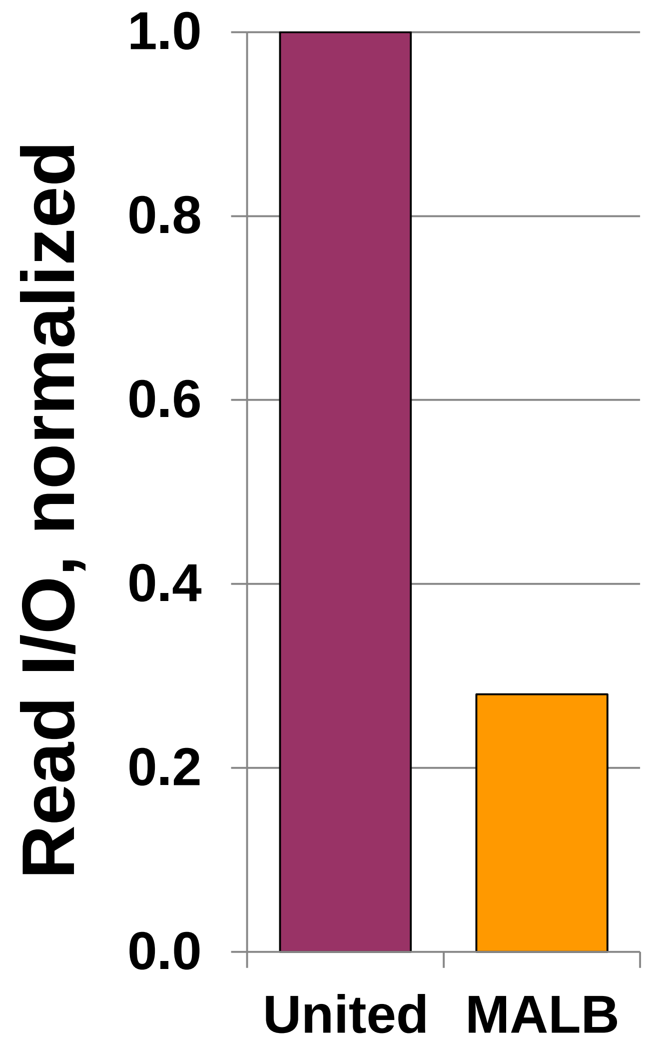
TPC-W

Ordering

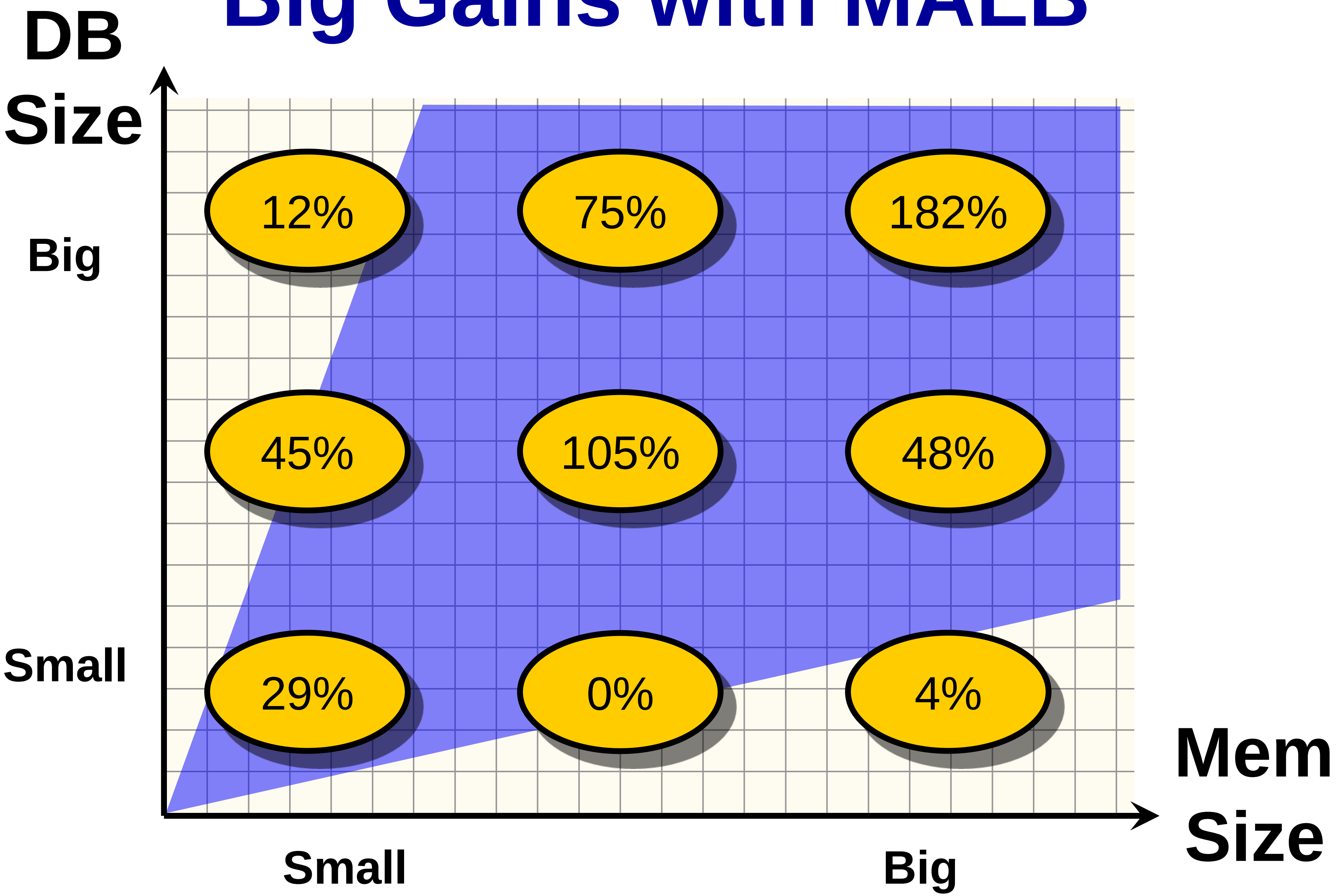
16 replicas

MALB Doubles Throughput





Big Gains with MALB



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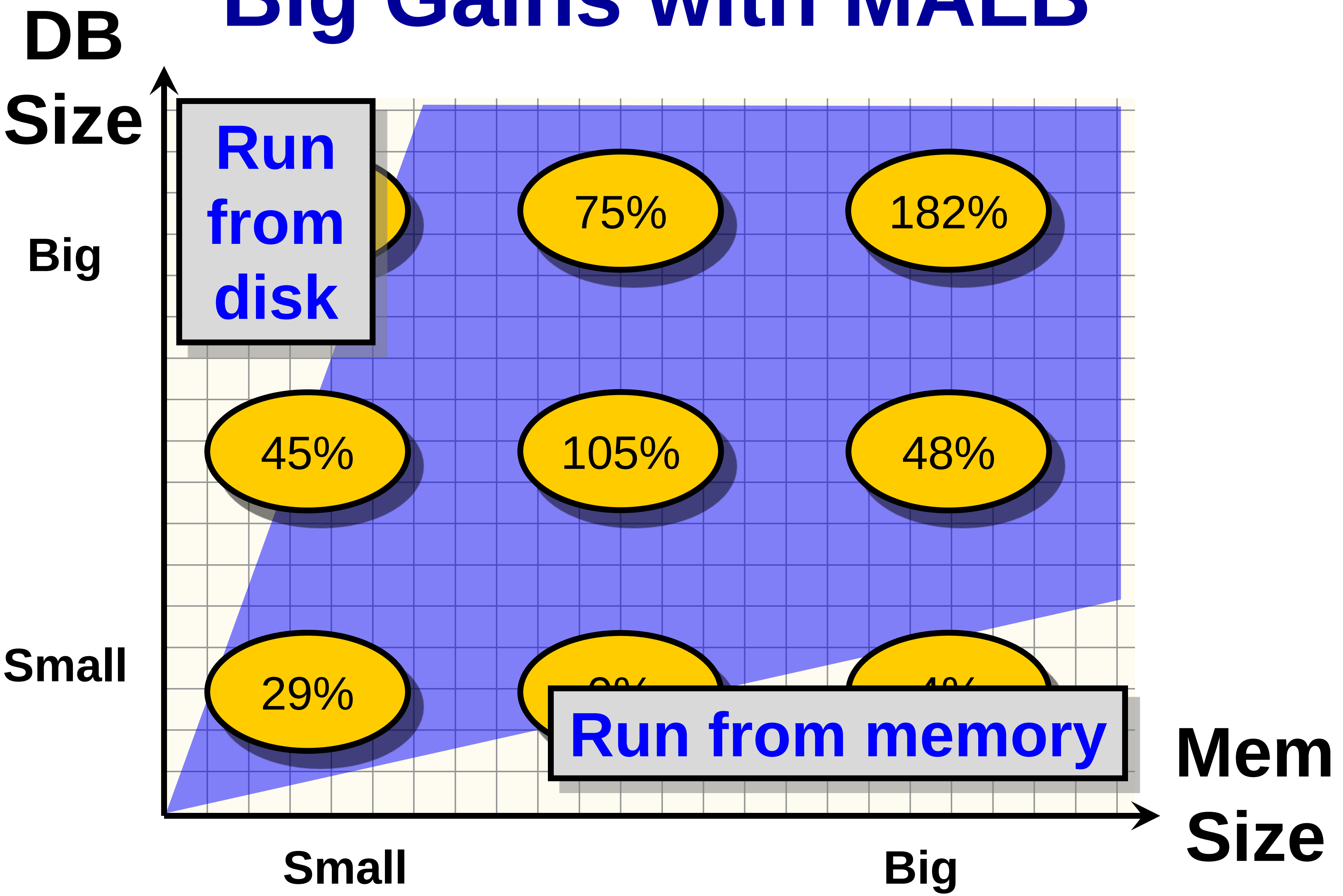
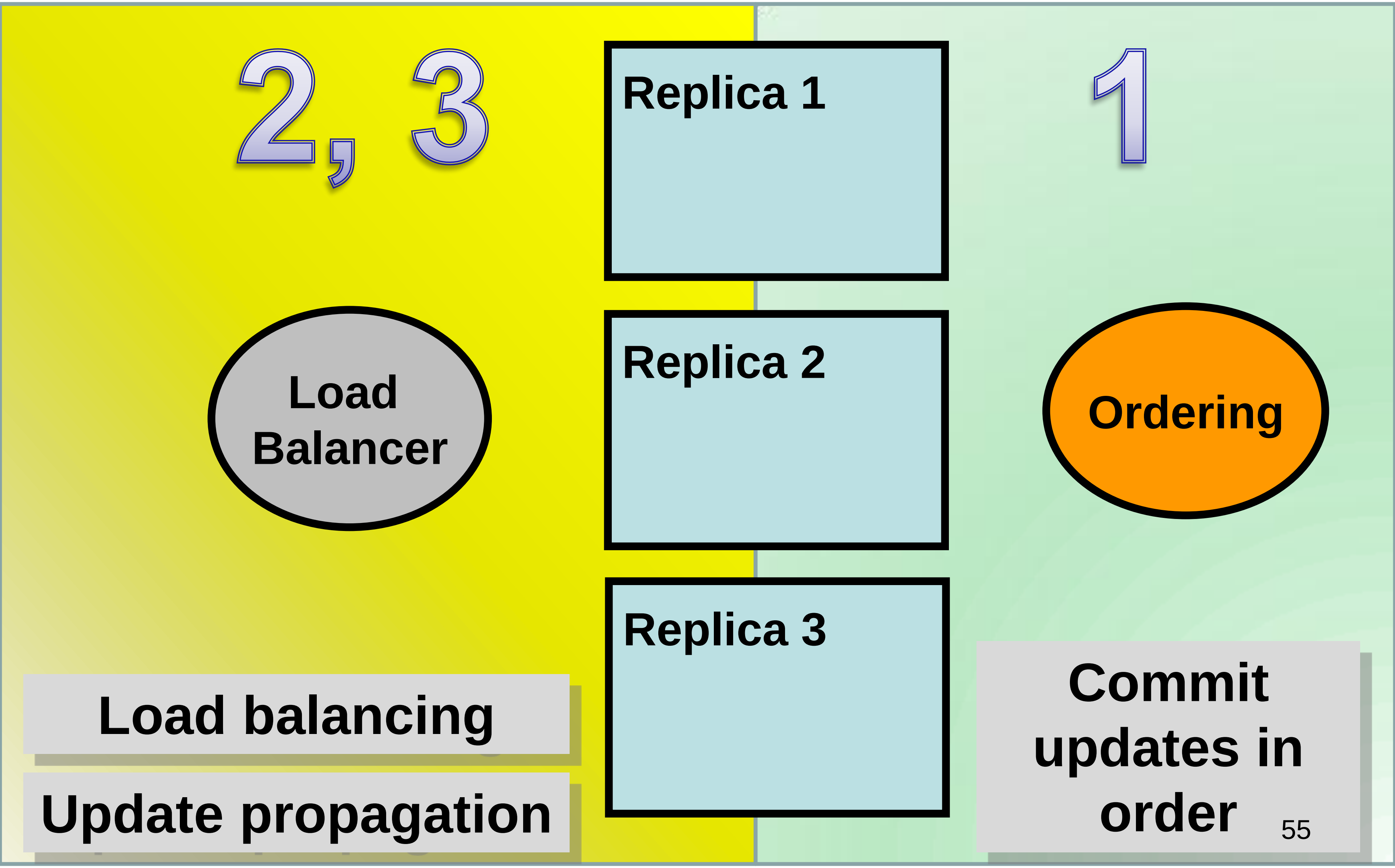


Roadmap



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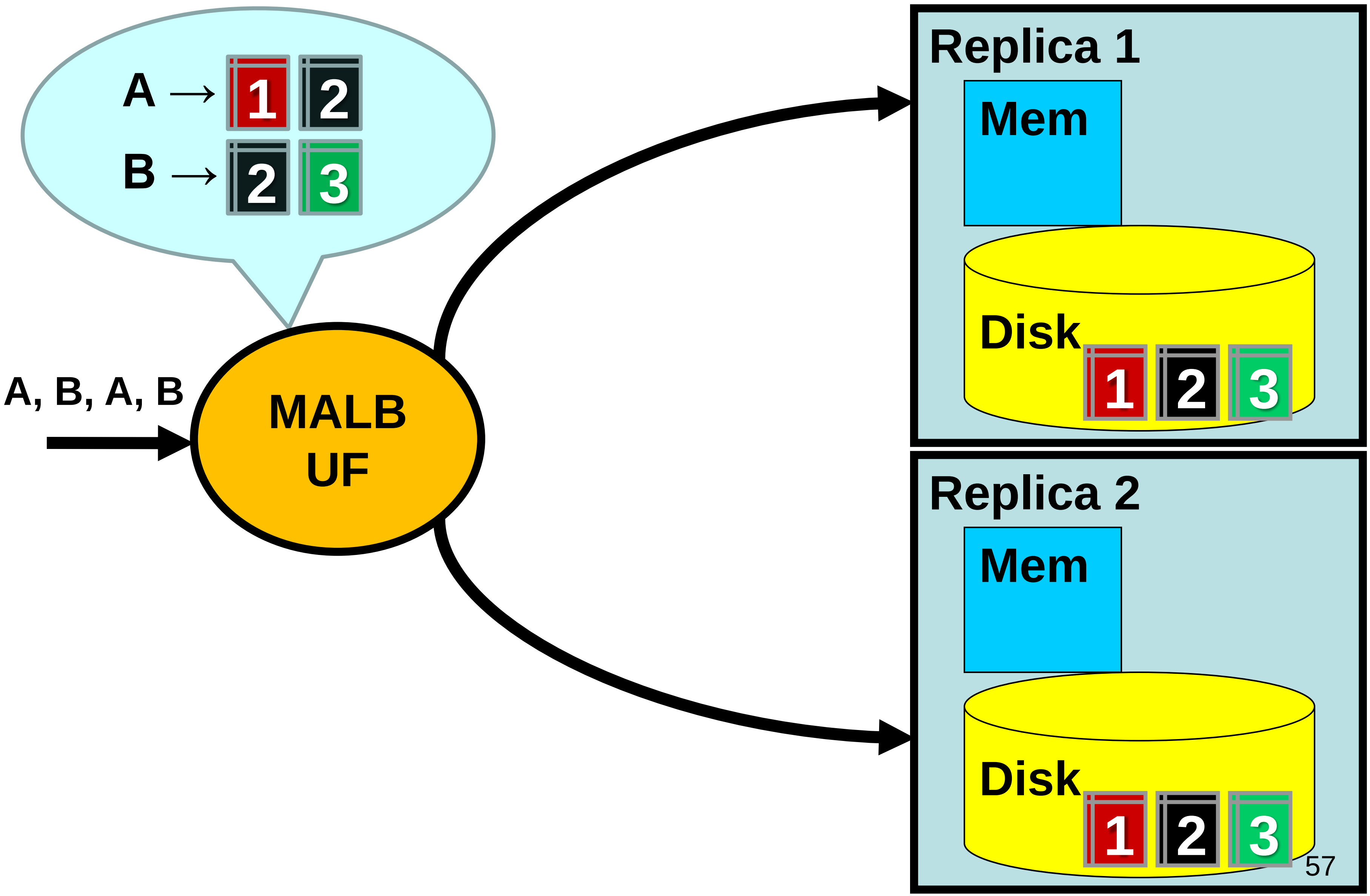
Replica 1
Replica 2
Replica 3
Load Balancer
Ordering
Load balancing
Update propagation
Commit updates in order

Key Idea

- **Traditional:**
  - Propagate updates everywhere
- **Update Filtering:**
  - Propagate updates to where they are needed

Update Filtering Example



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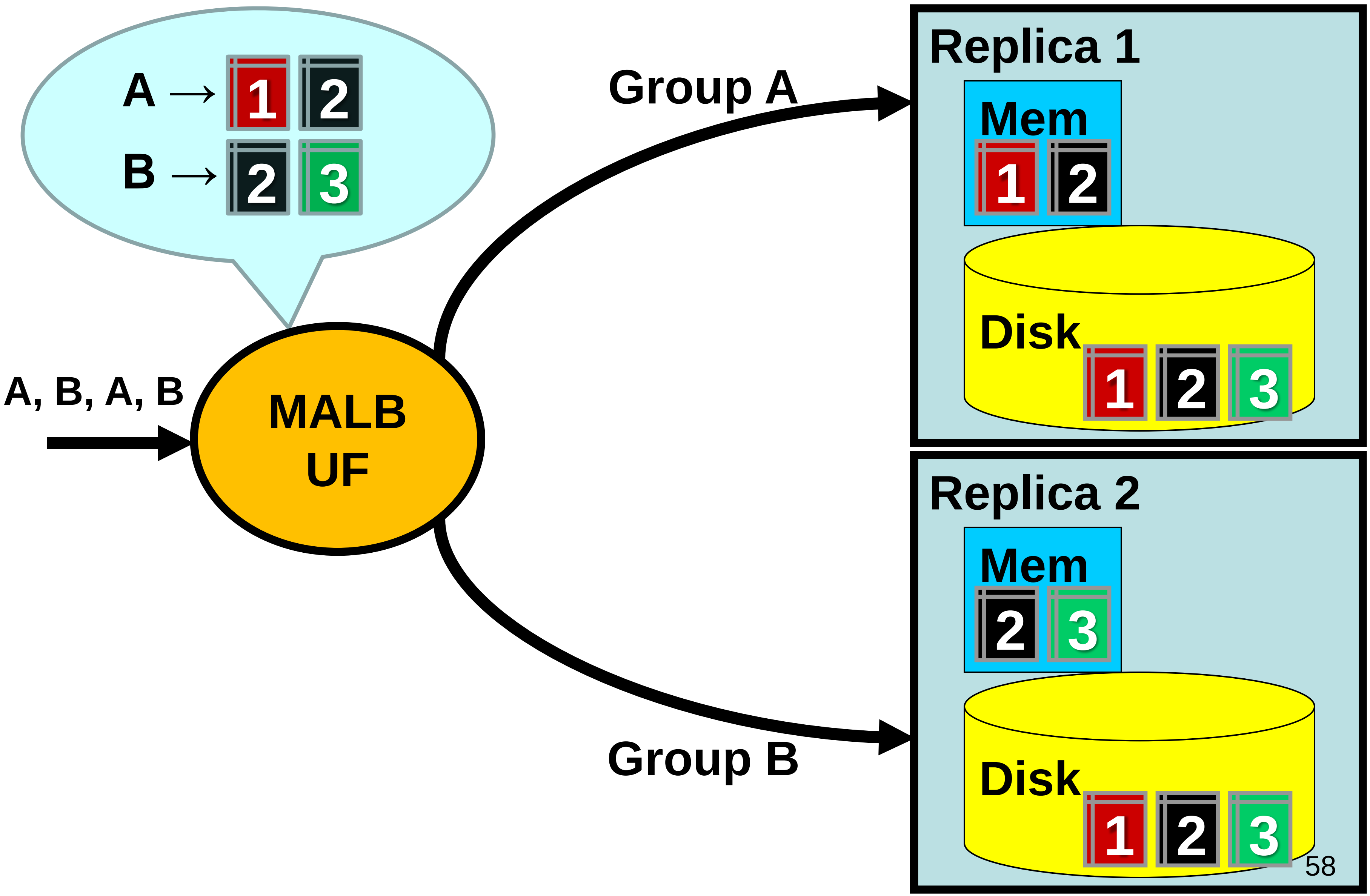

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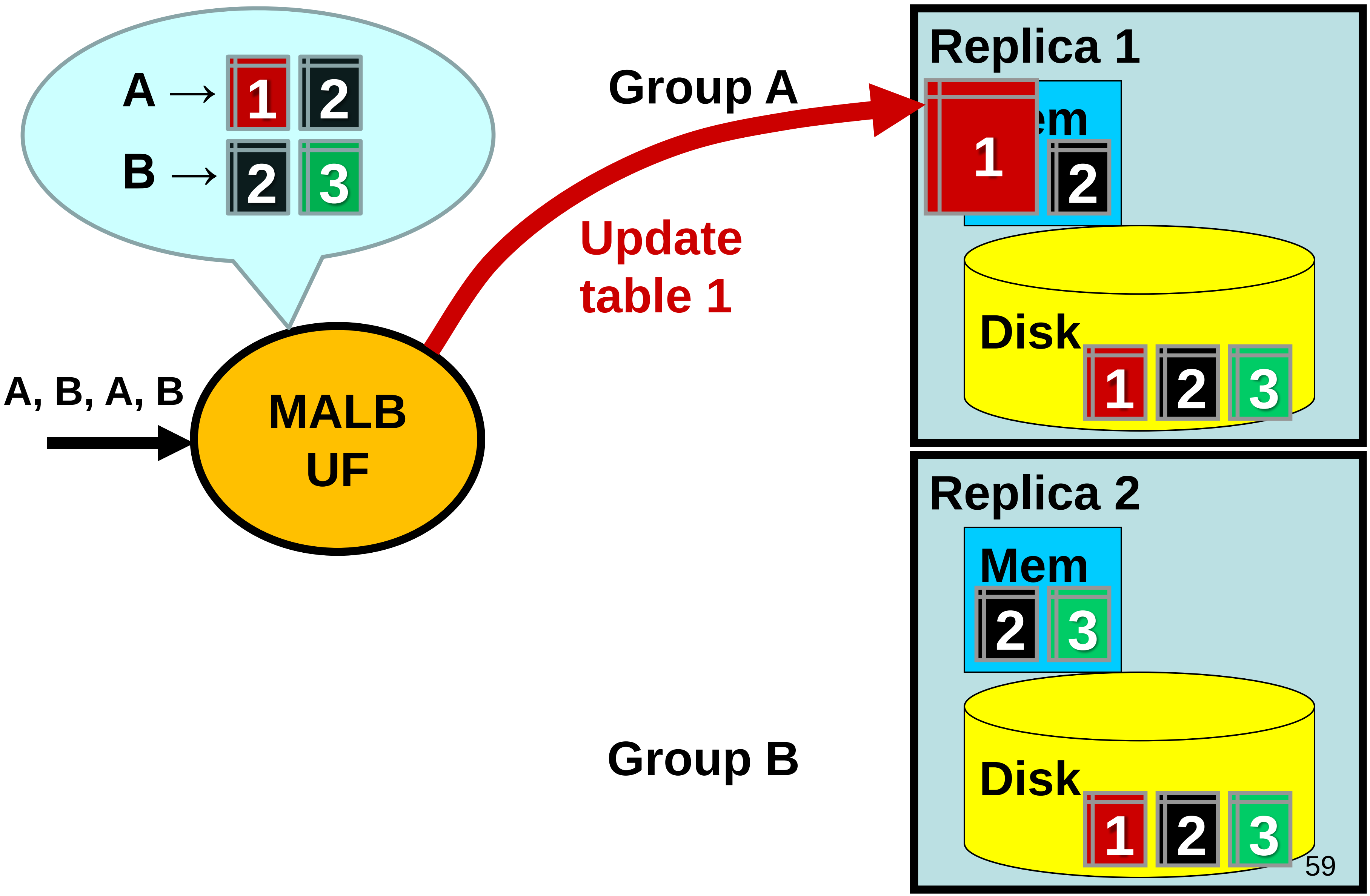

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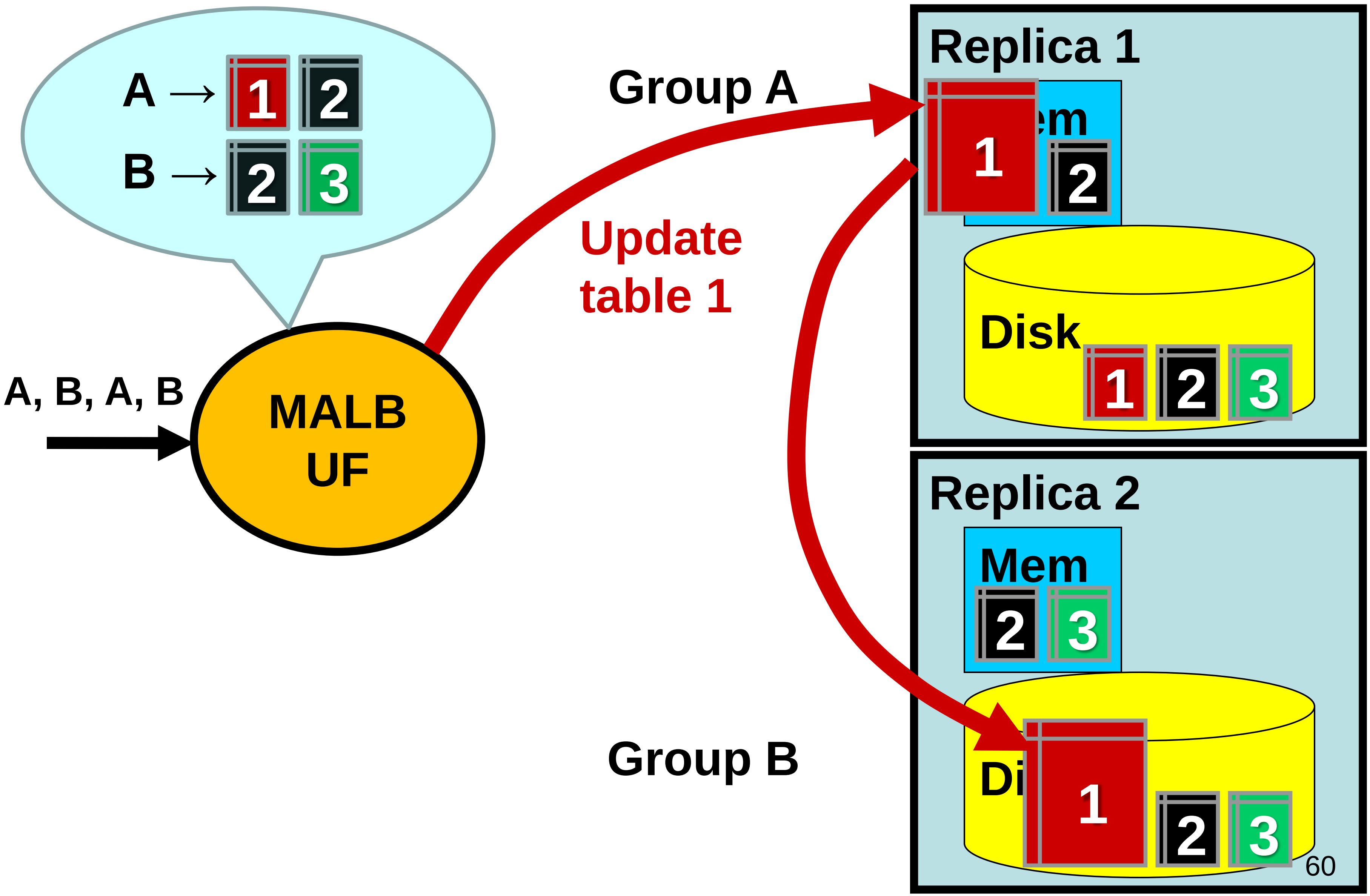

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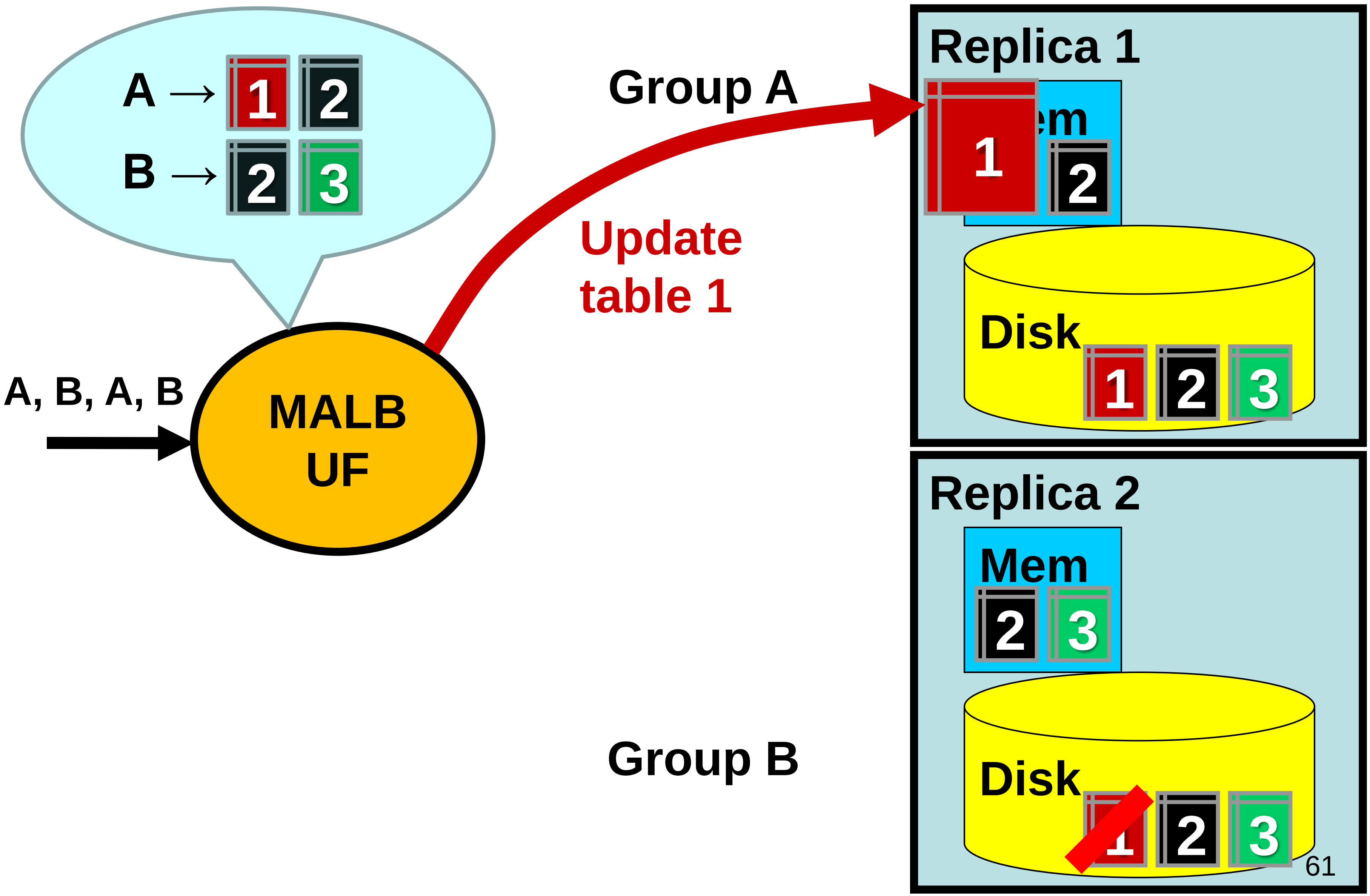

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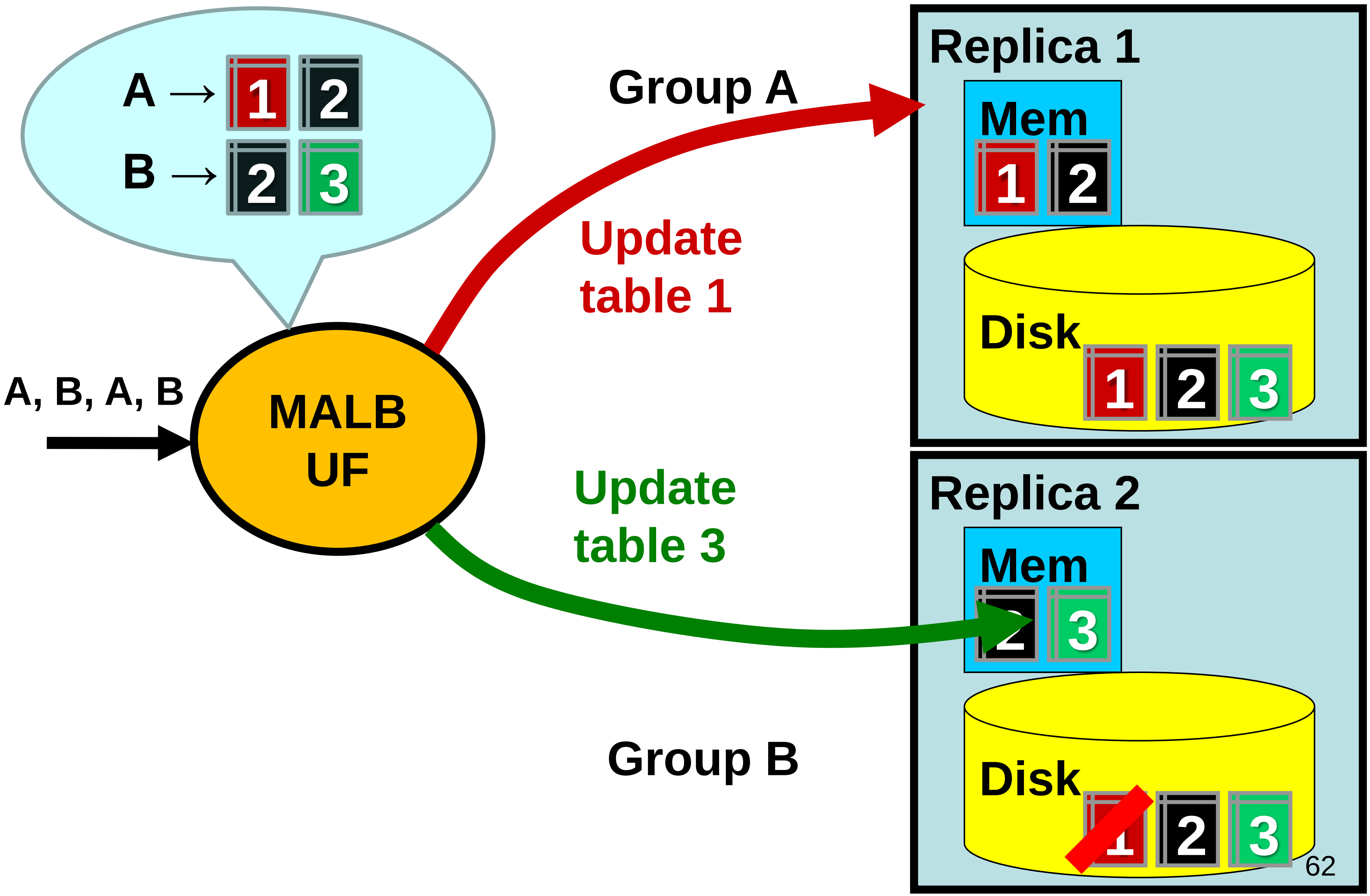

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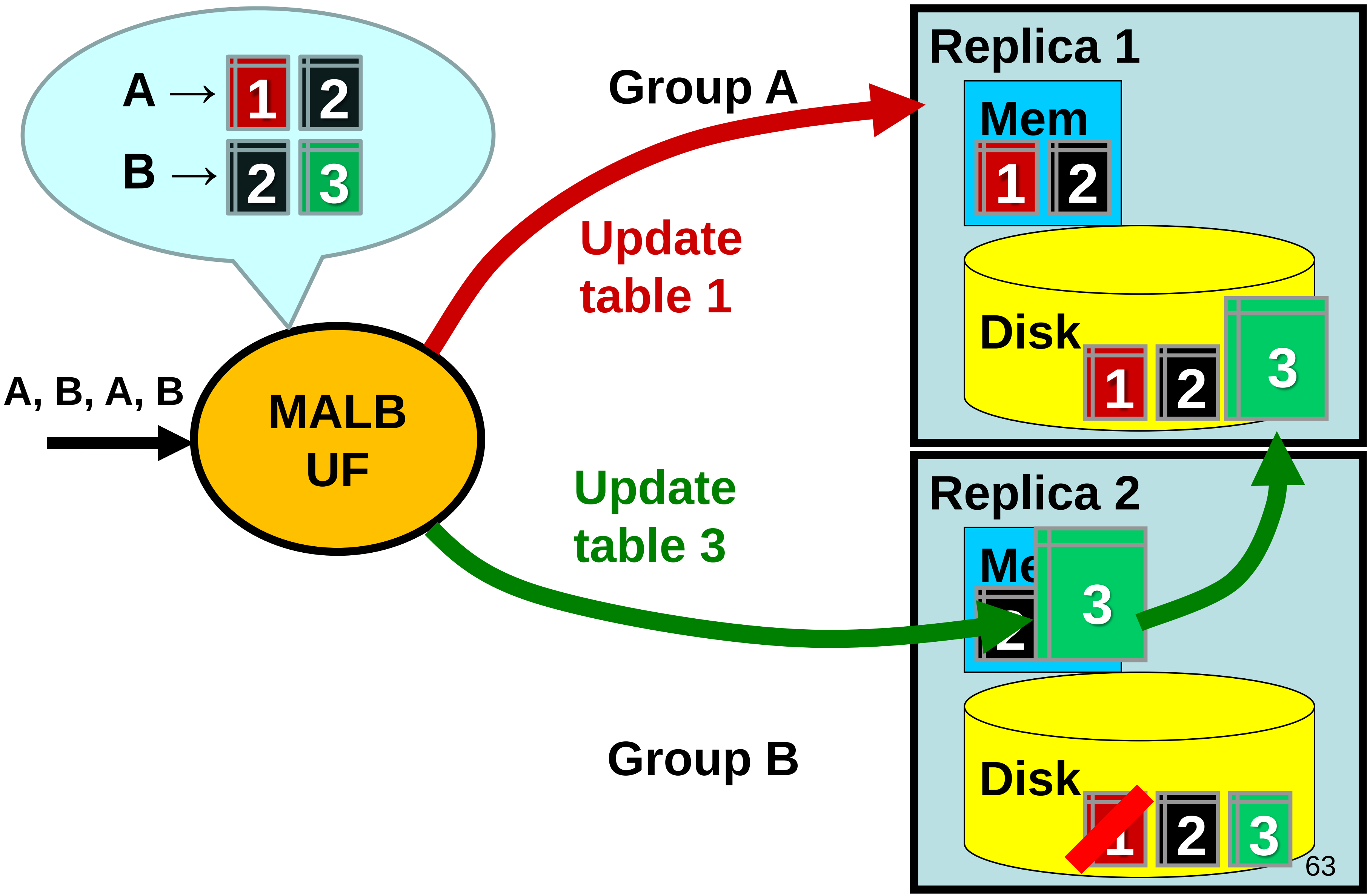

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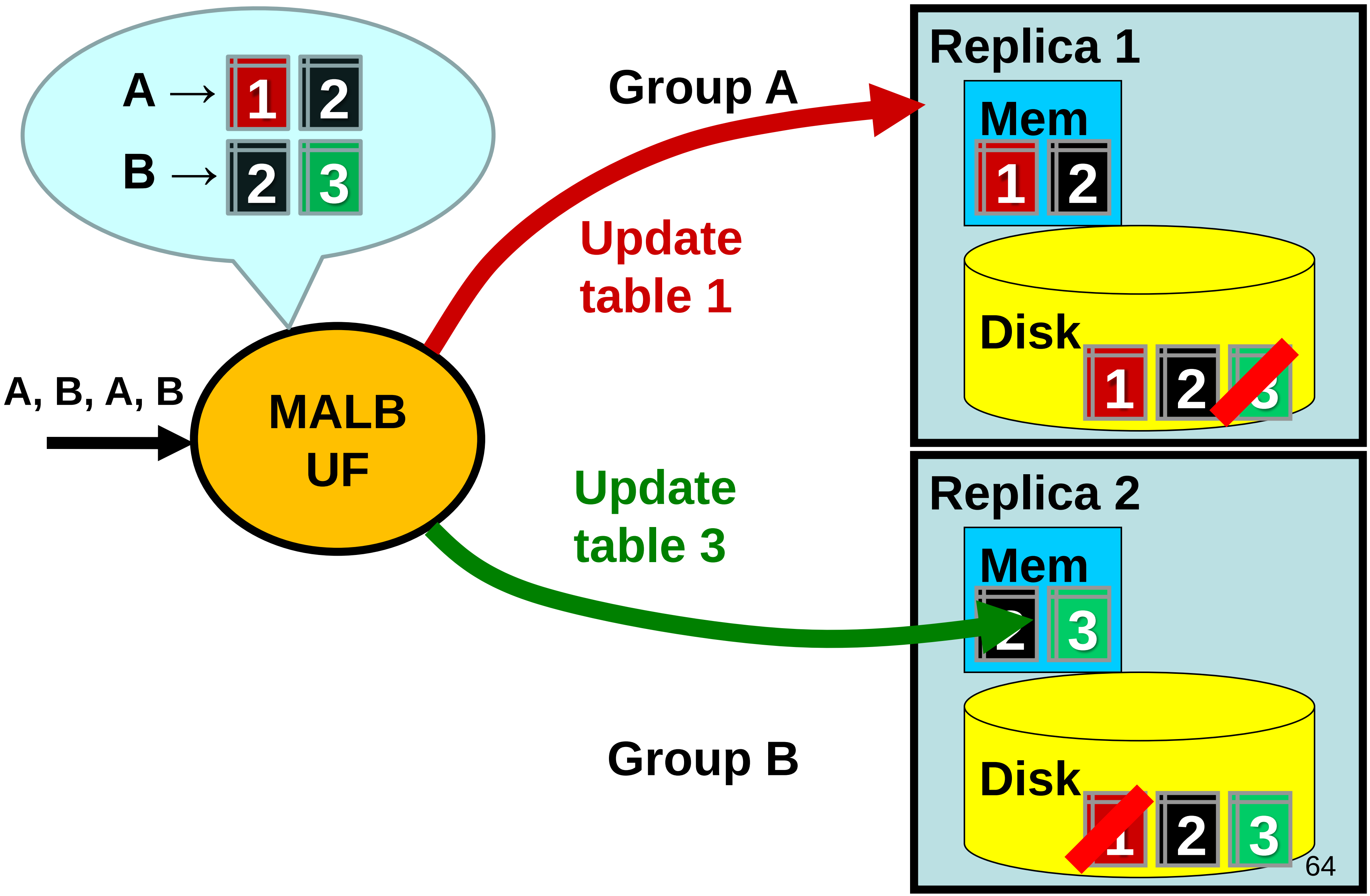
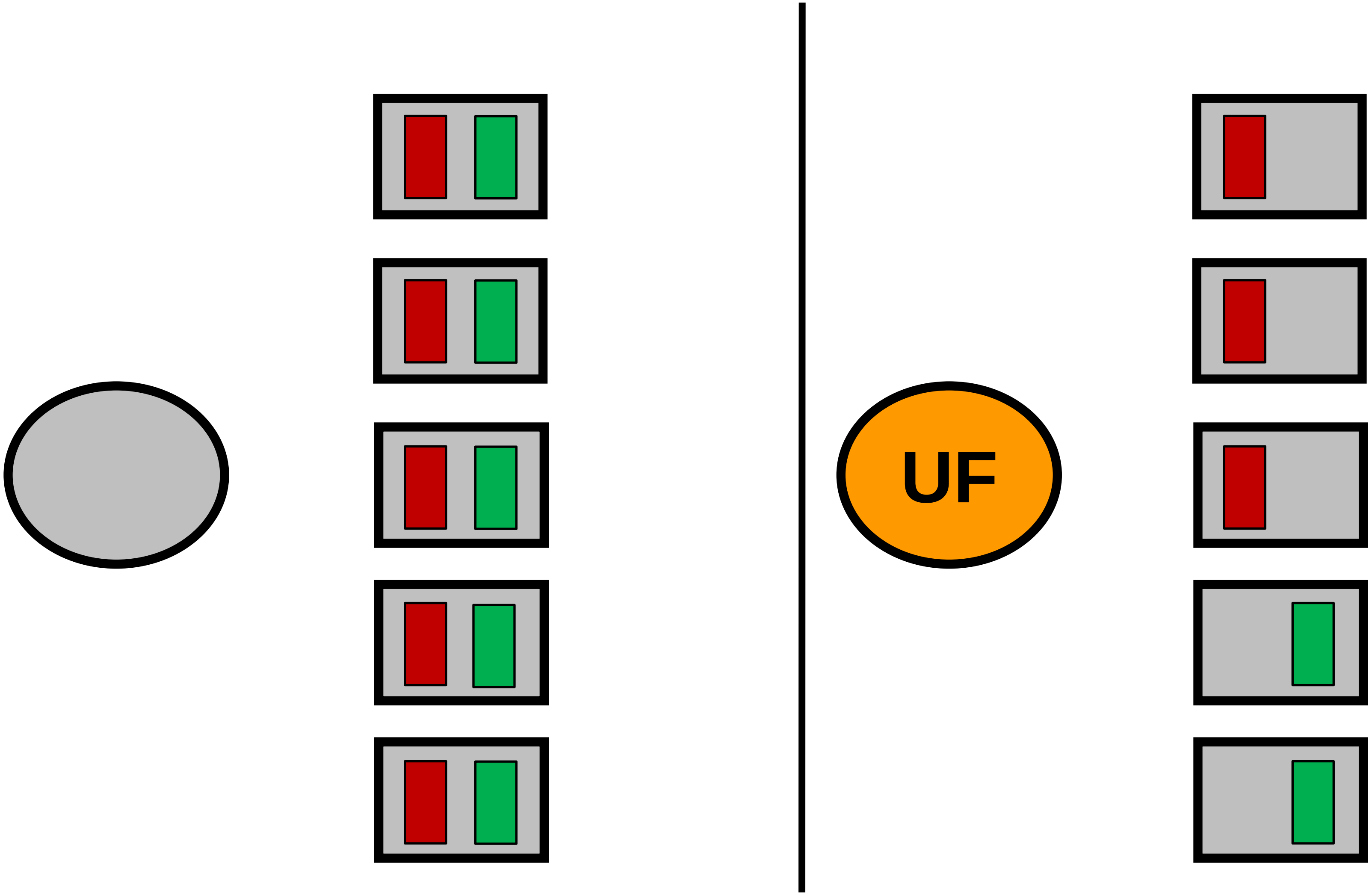


Update Filtering in Action



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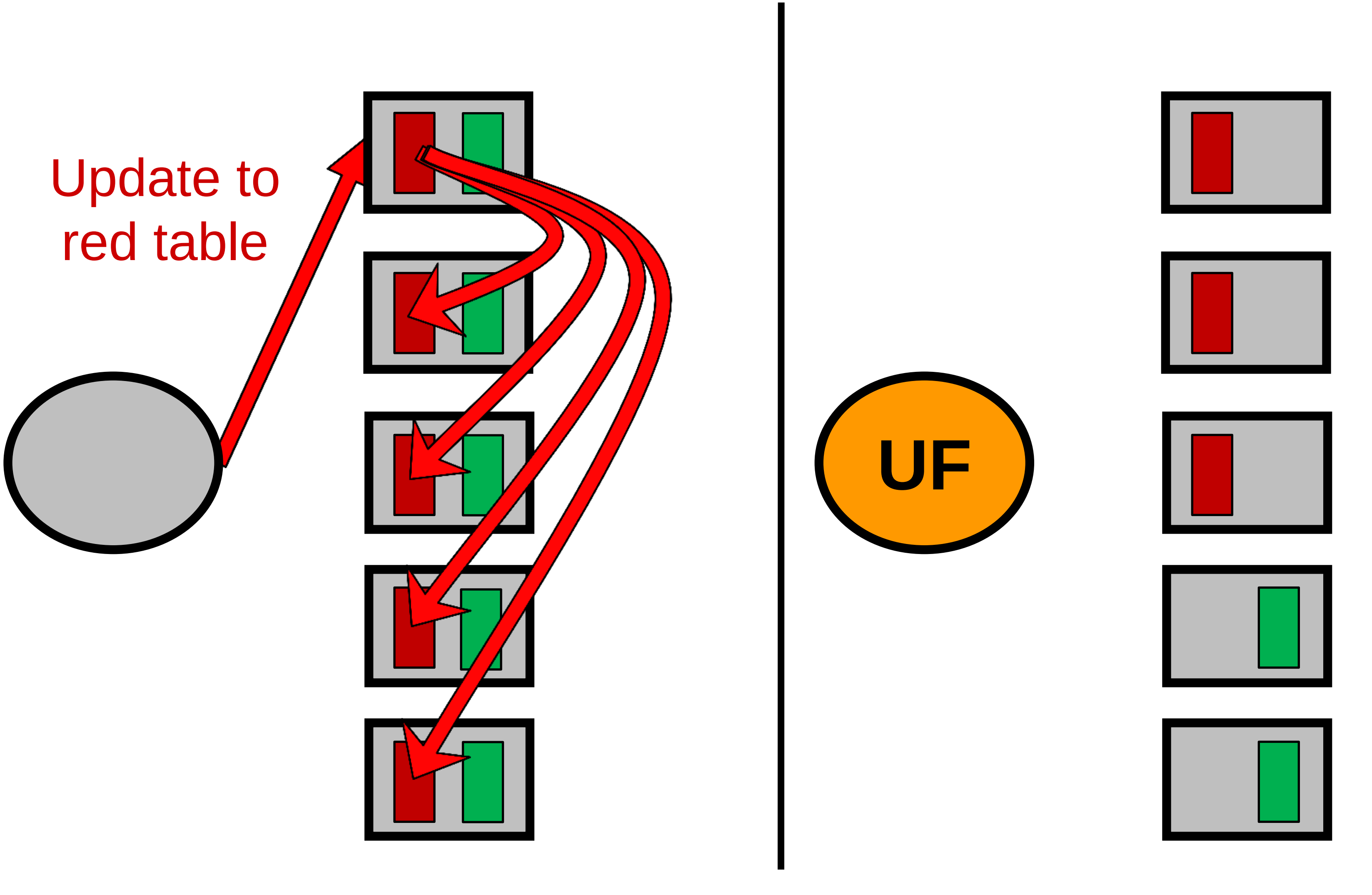

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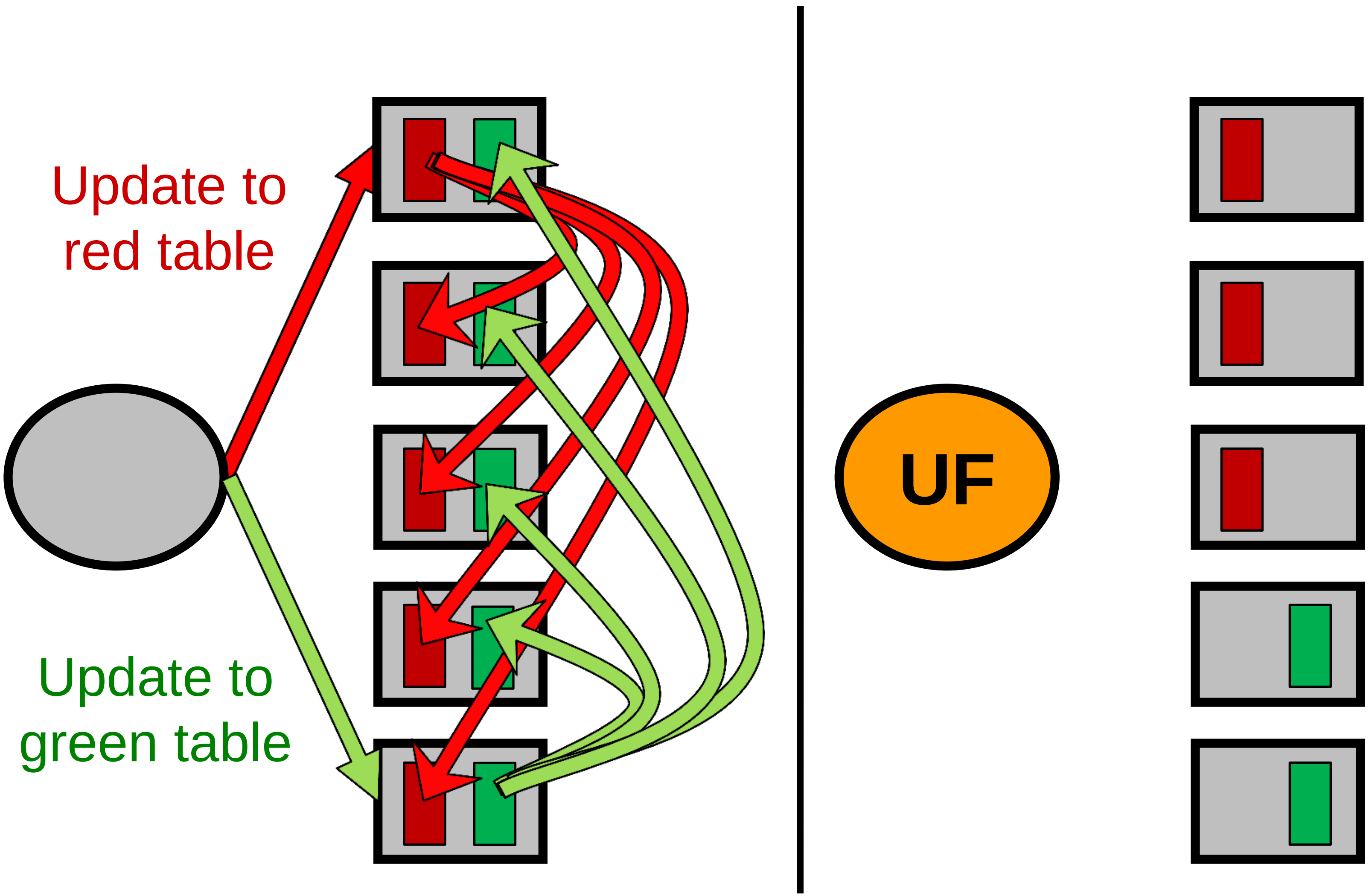

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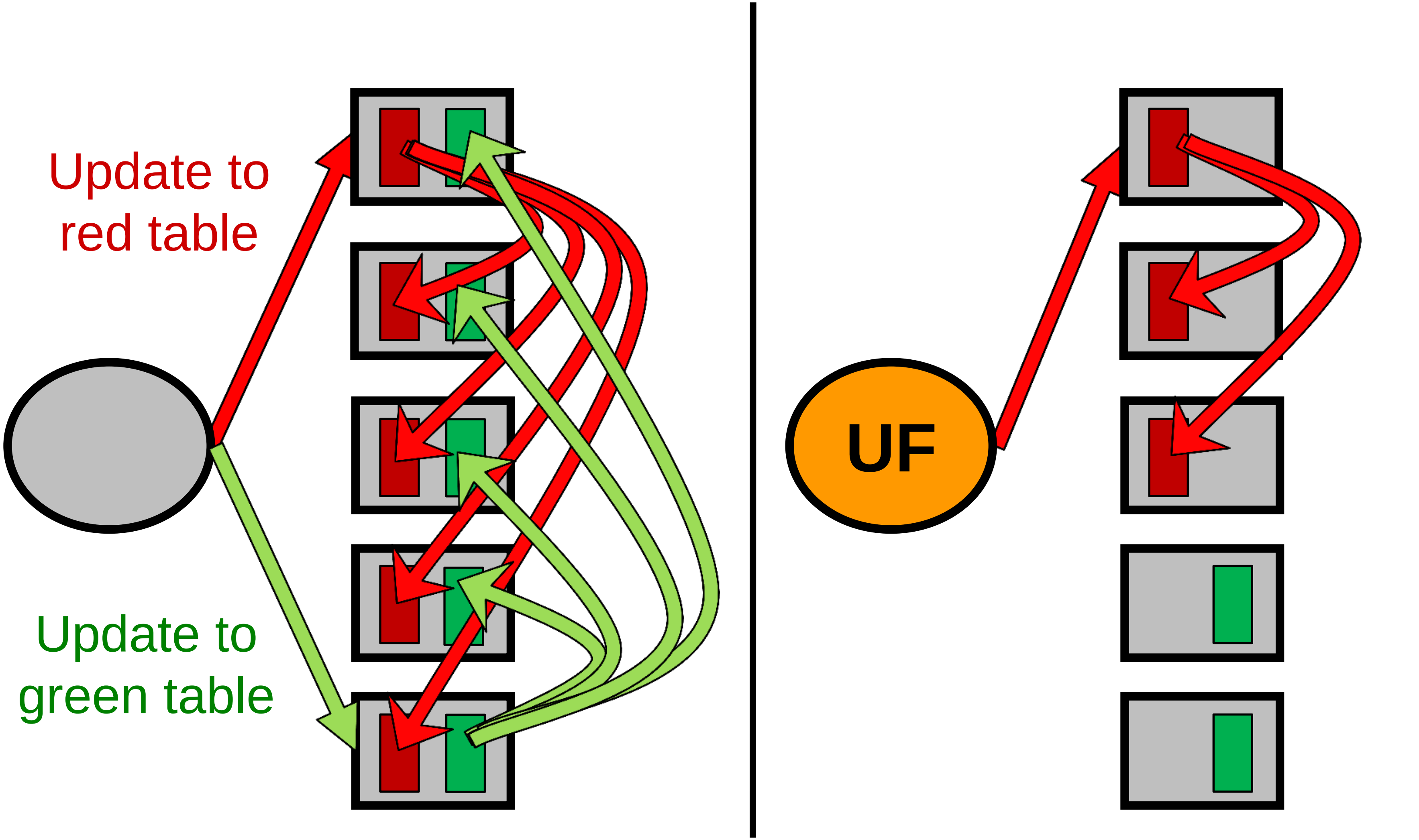

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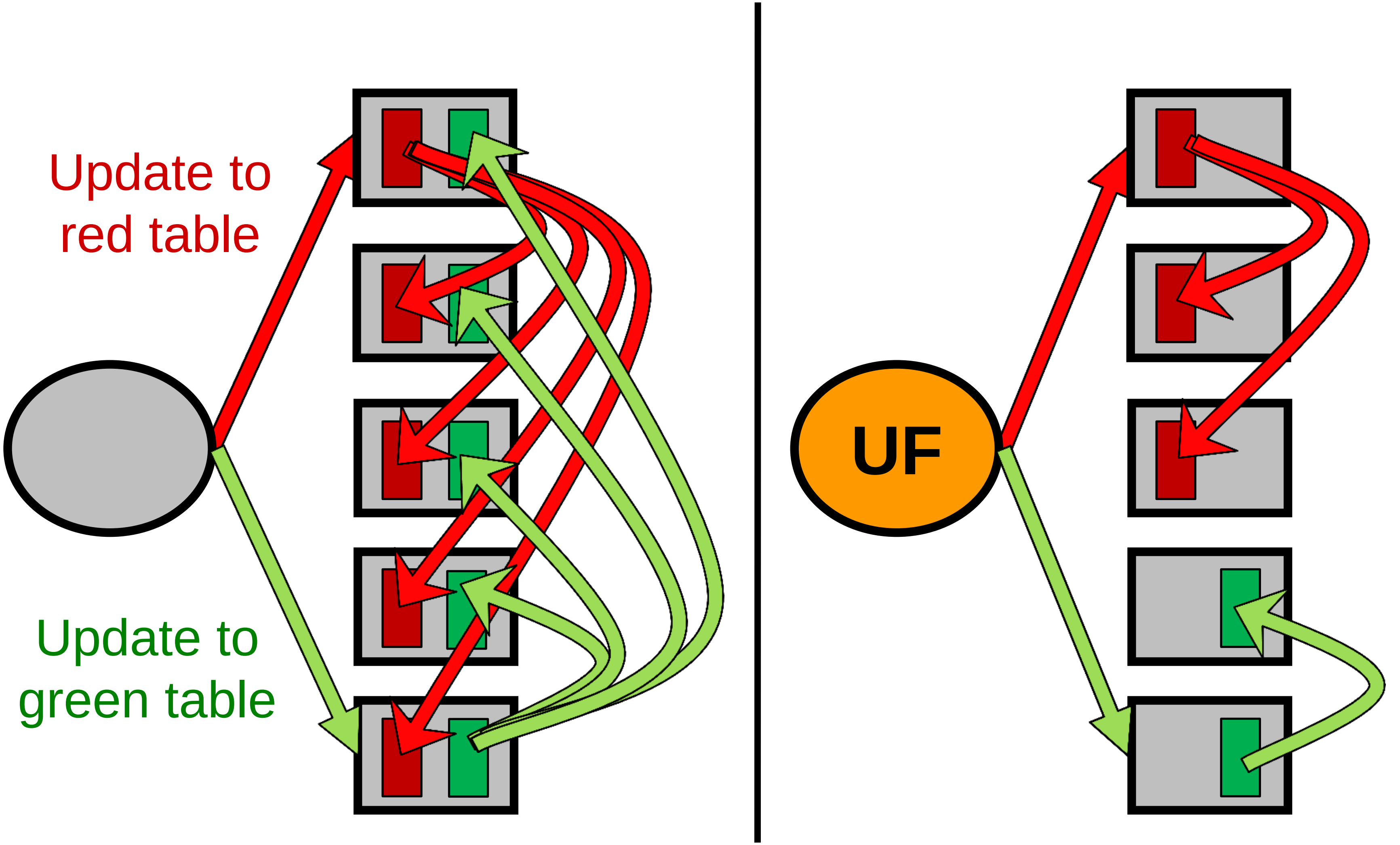
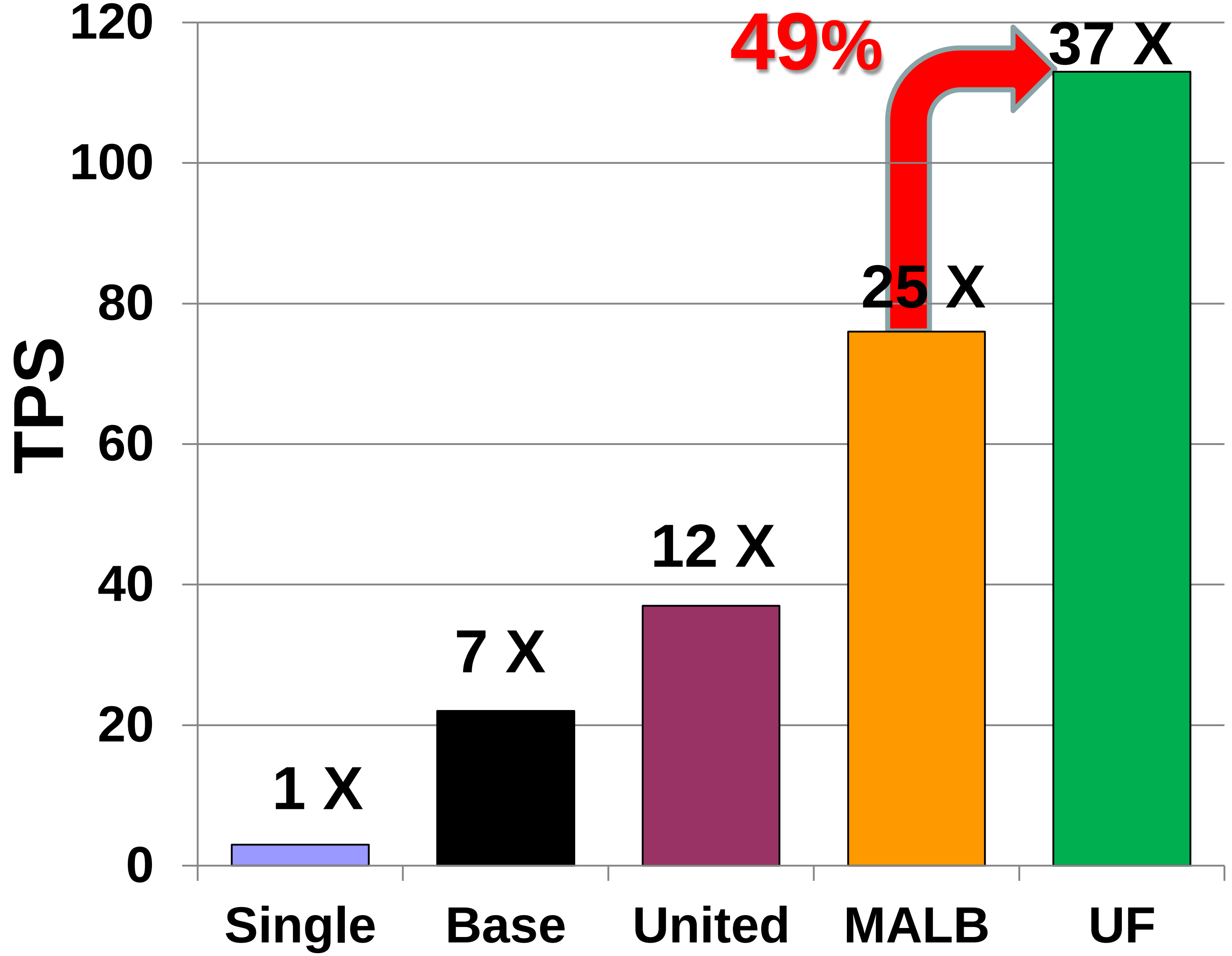


MALB+UF Triples Throughput

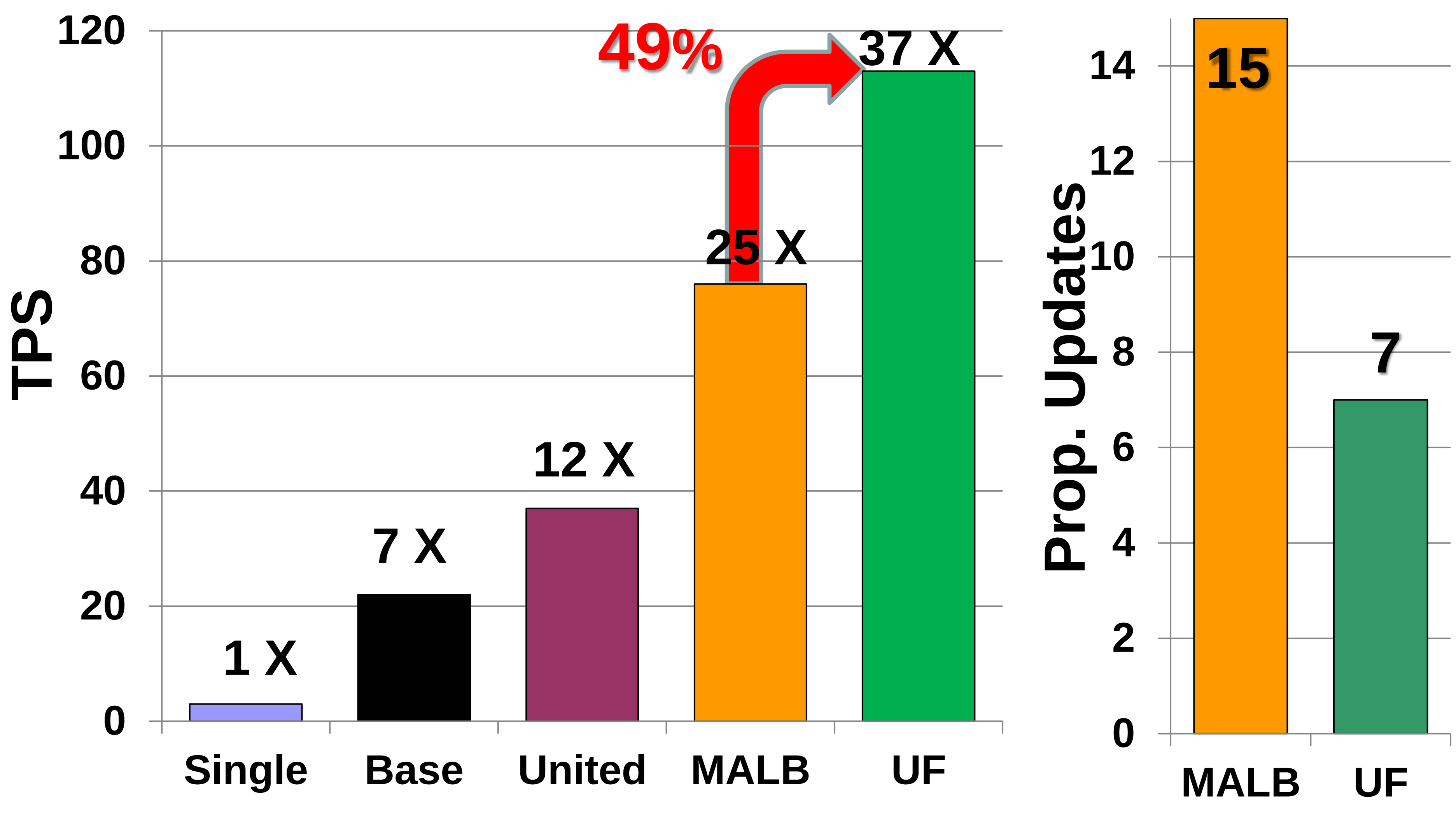


TPC-W

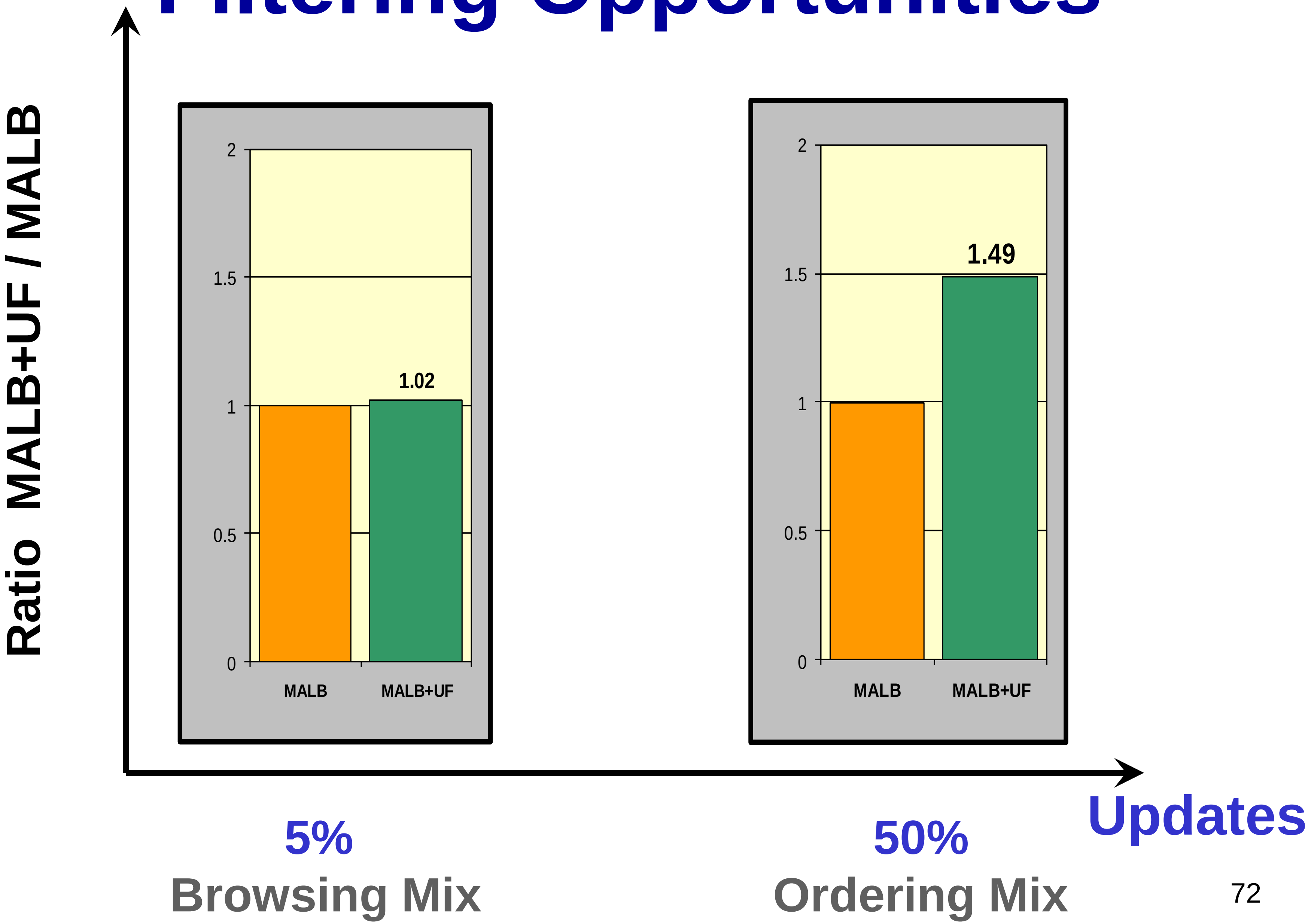
Ordering

16 replicas

MALB+UF Triples Throughput



Filtering Opportunities



Conclusions

1. **Commit updates in order**
   – Perform serial synchronous disk writes
   – Unite ordering and durability
2. **Load balancing**
   – Optimize for equal load: memory contention
   – MALB: optimize for in-memory execution
3. **Update propagation**
   – Propagate updates everywhere
   – Update filtering: propagate to where needed