Managing Soft-errors in Transactional Systems

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What are Soft-errors?

- Transient faults that may happen anytime during application execution
- Caused by physical phenomena (e.g., cosmic particle strikes, electric noise)
- E.g., Soft-error can cause a single bit in a CPU register to flip causing transient failures

Do soft-errors represent a problem?

- Soft-errors are:
  - Random: Can occur anytime
  - Undetectable: No hardware interrupt is triggered
  - Corrupting: Can silently corrupt program data or crash the program

Soft-errors effect

CPU mathematical operation

101011101011

+

100010101001

=

1001110010100

Soft-errors effect

CPU mathematical operation

101011101011

+

100010101001

=

1001110010100

But if a soft-error happened

101011101011

+

100010101001

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1001110010100

Soft-errors effect

CPU mathematical operation

101011101011

+

100010101001

=

1001110010100

But if a soft-error happened

101011101011

+

000010101001

=

1001110010100

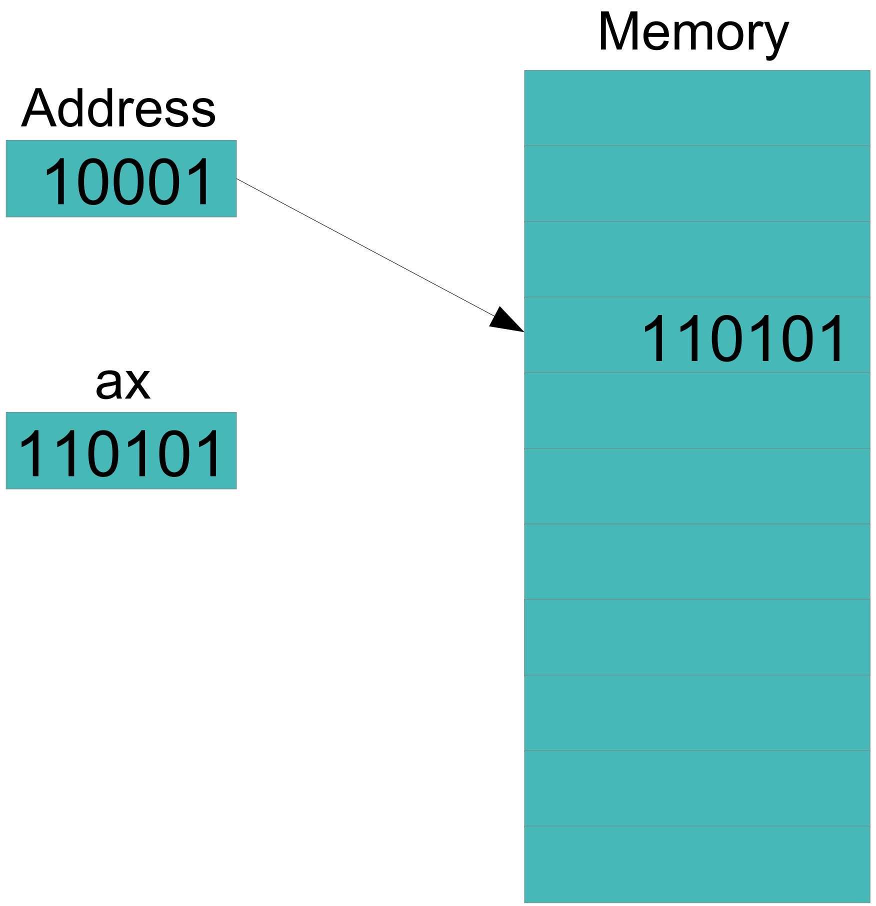
Soft-errors effect

CPU mathematical operation	But if a soft-error happened
101011101011	101011101011
+	+
100010101001	000010101001
=	=
1001110010100	0101110010100

Soft-errors effect

Memory store

e.g., mov [address], ax



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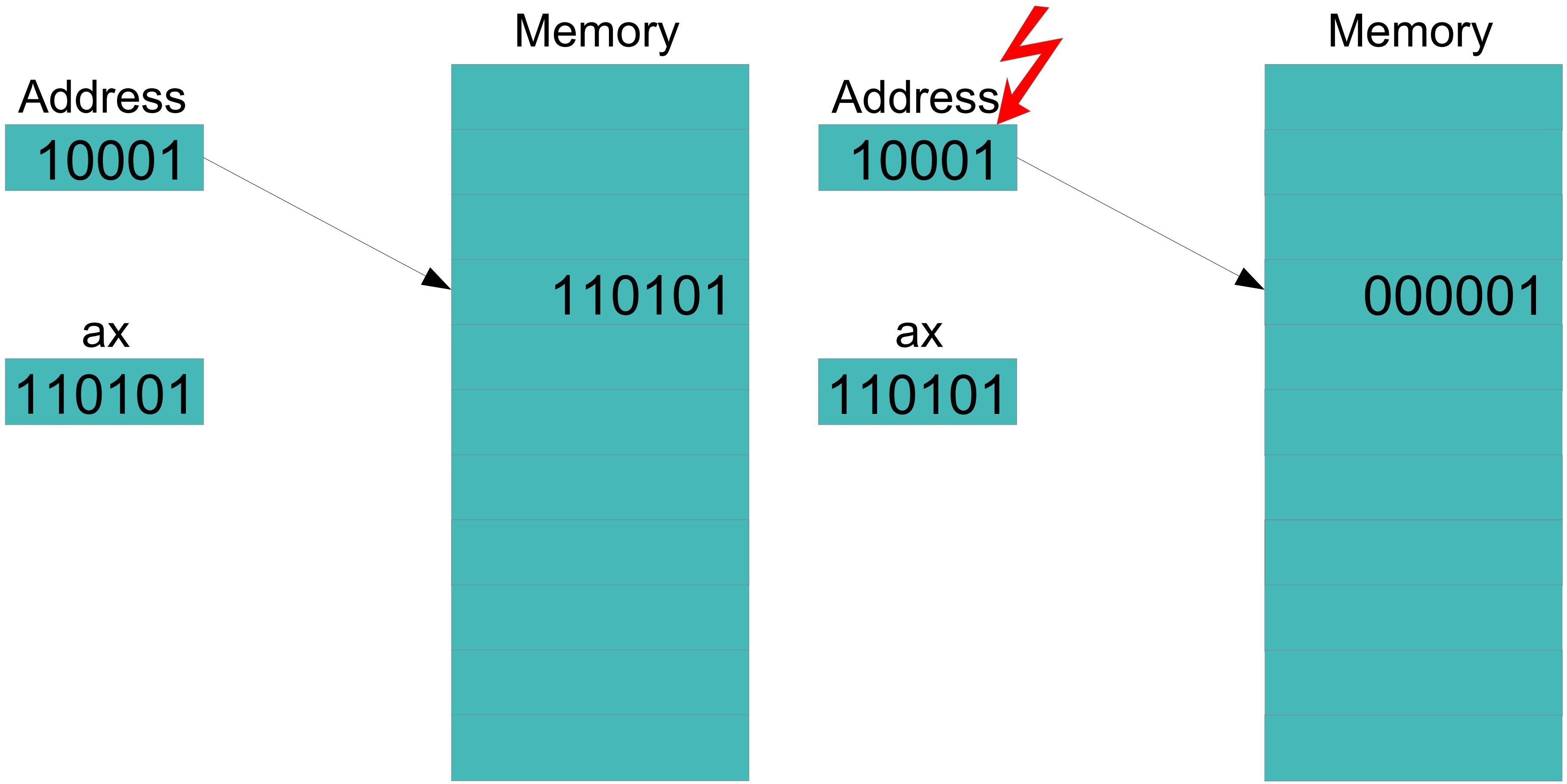

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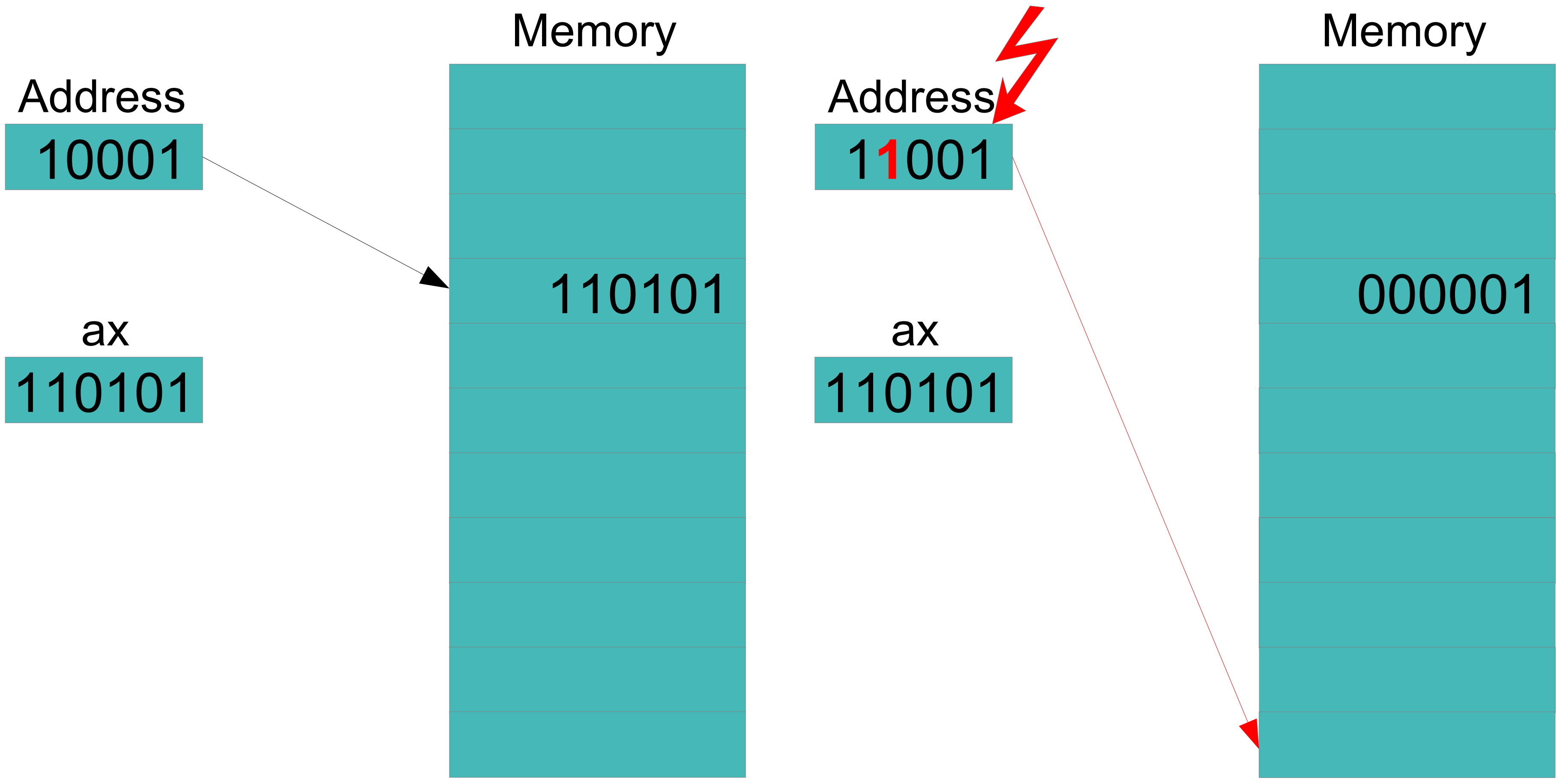

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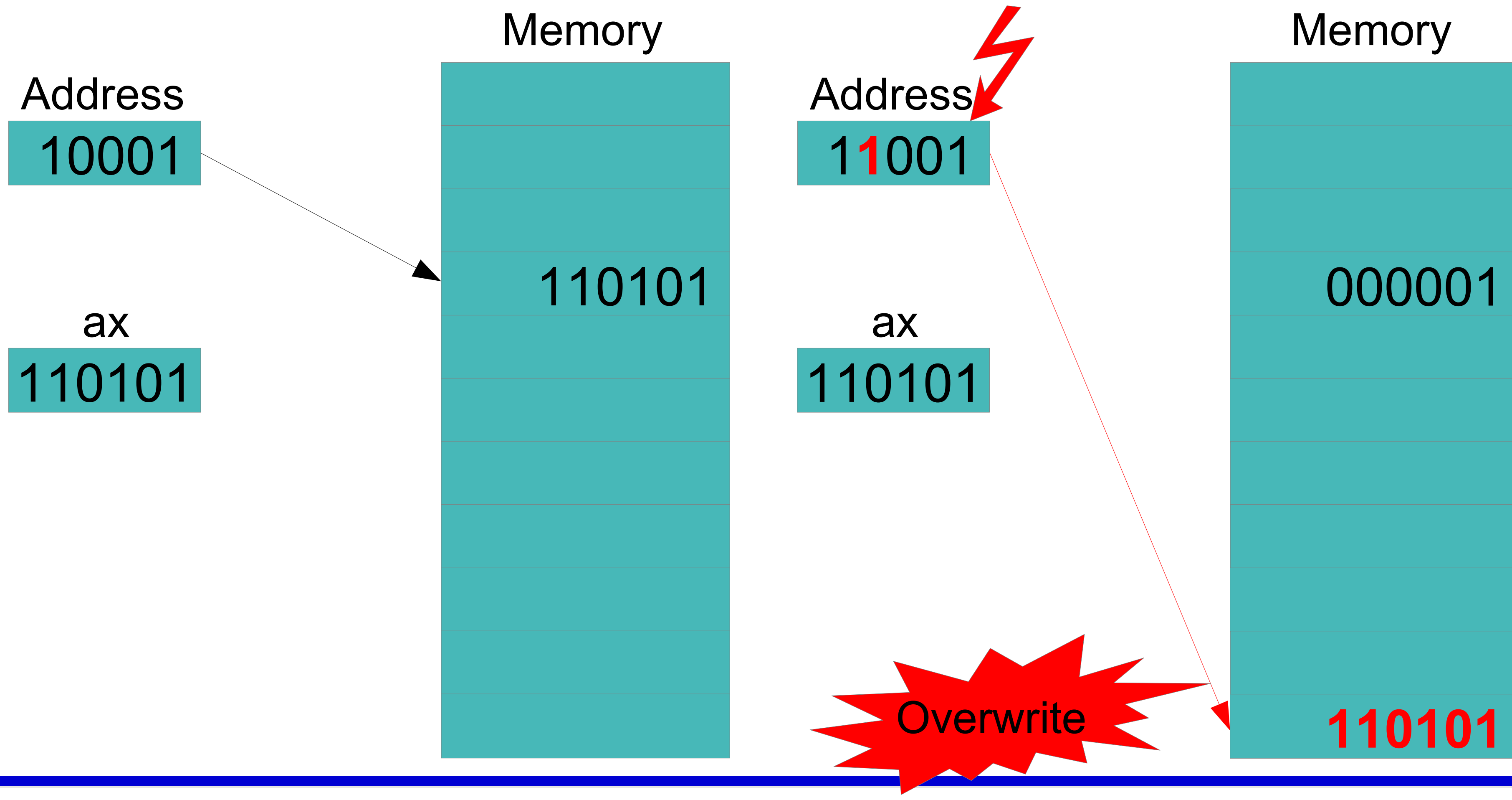

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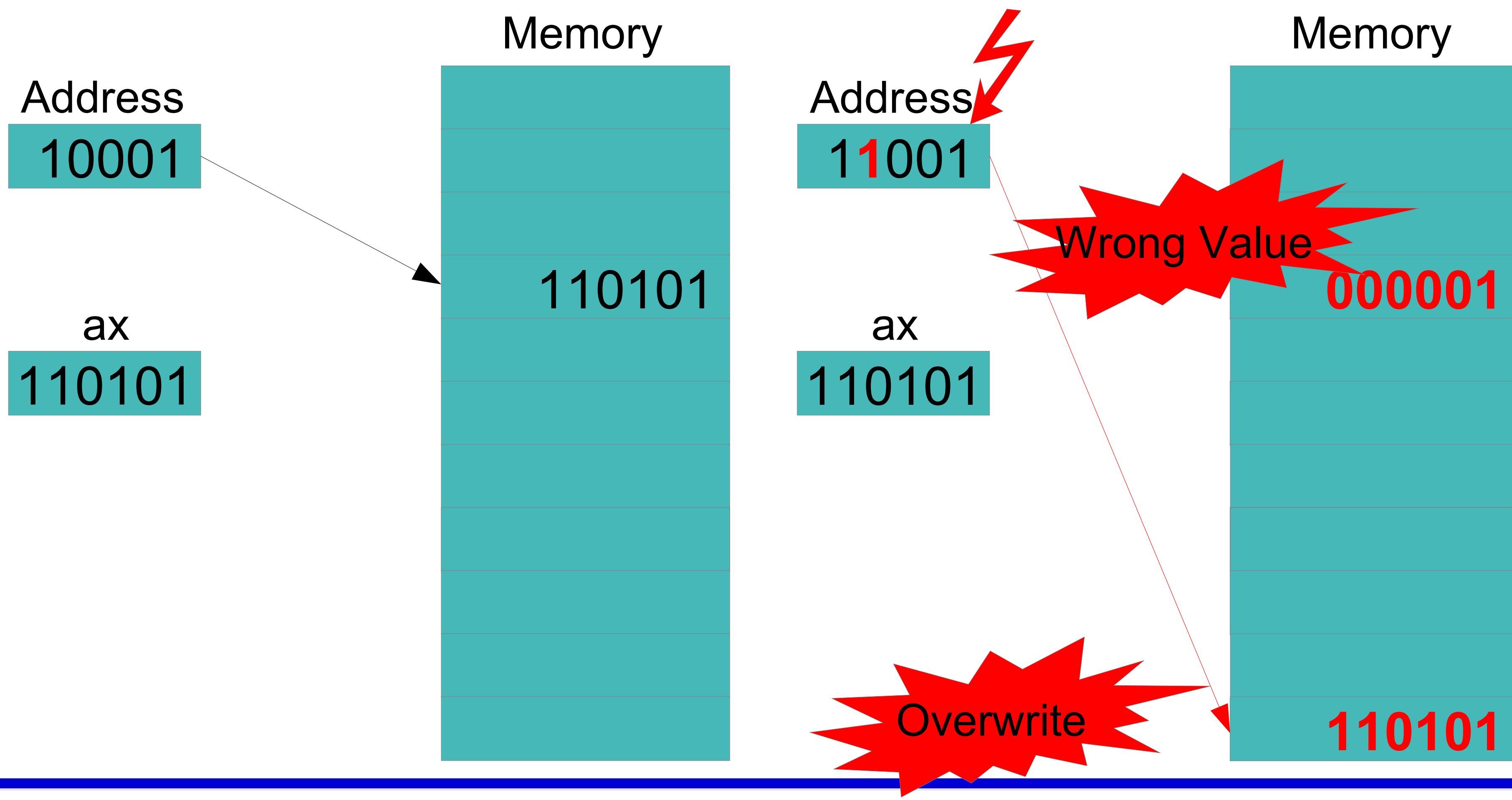

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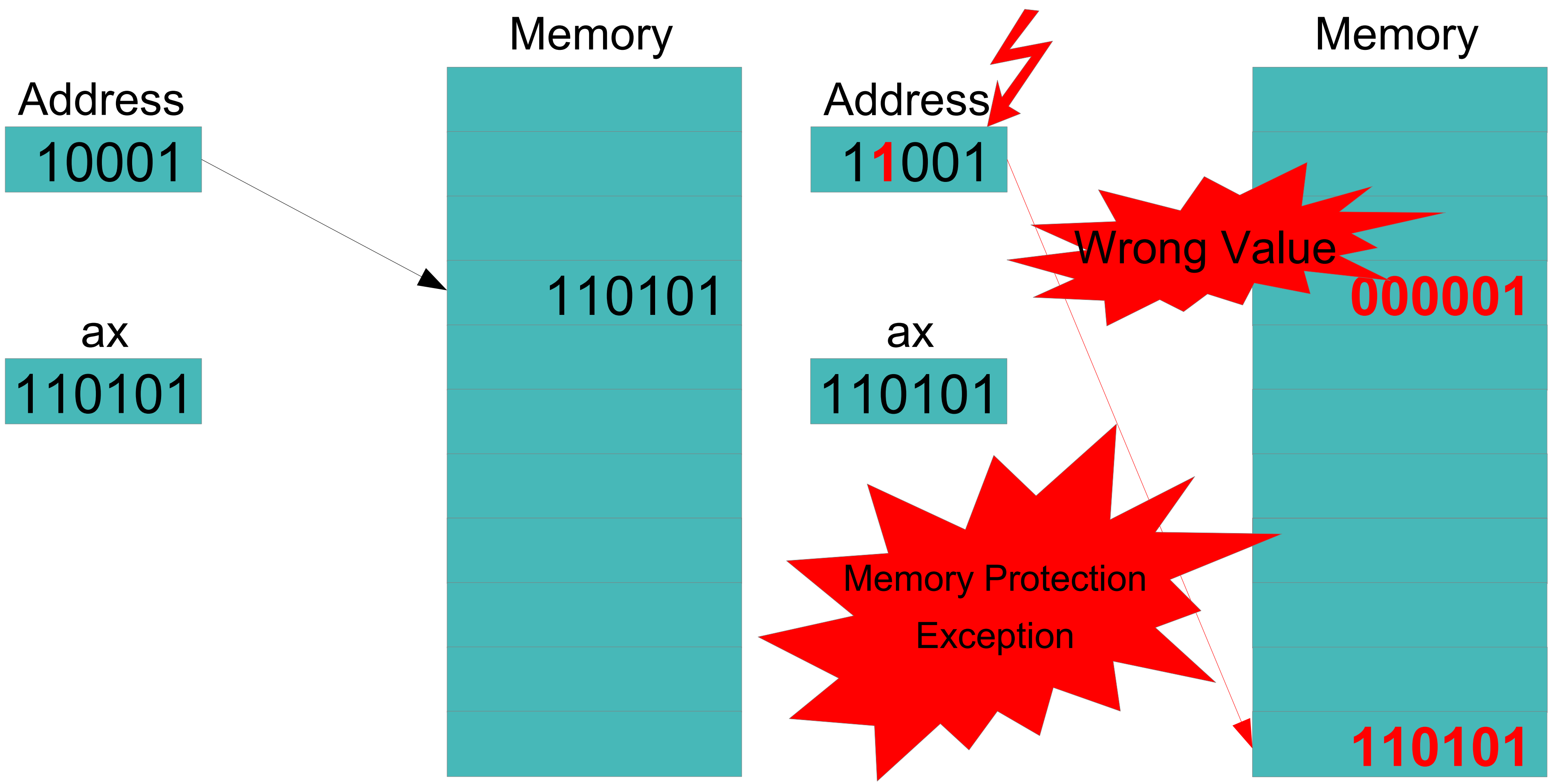
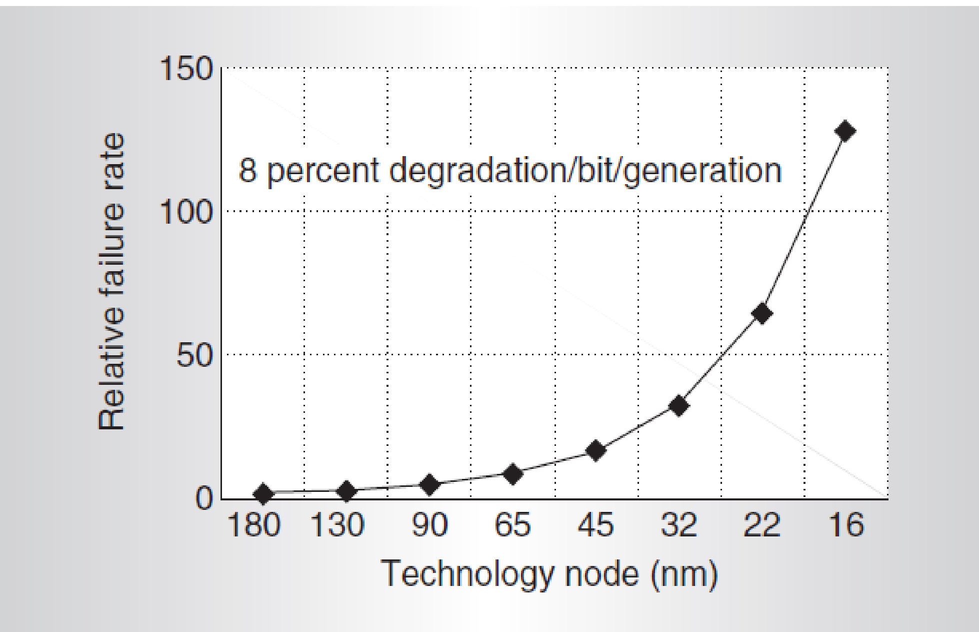
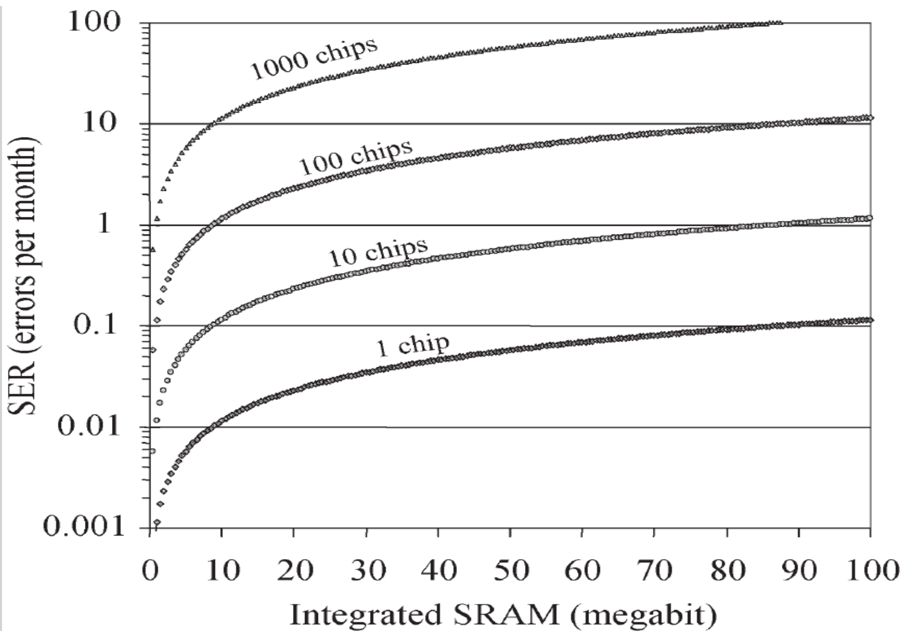


Soft-errors in multicore architectures

- Soft-errors rate is growing in the current and emerging multicore architectures
  - Smaller transistors (e.g., Intel Haswell uses 22nm)
  - More components on same chip (e.g., more cores)



Soft-error failure-in-time of a chip [1]



SER as a function of the number of chips [2]

How to tolerate soft-errors?

- Restart the application!
  - It may not crash!
  - Not suitable for critical business applications
    - We need to maintain availability/reliability constraints
- Hardware
  - High end systems
  - Expensive
- Replication
  - Multiple isolated copies of the application data
  - Fully mask faults
  - But, it is designed for distributed system

Motivation

- Apply the same distributed replication mechanisms in centralized multicore systems
- Is that enough?
  - Significantly degraded performance
  - Expensive

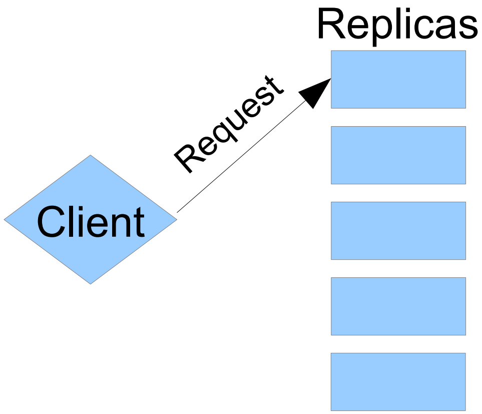
Byzantine faults

- Byzantine Faults are arbitrary faults
  - Omission faults
  - Commission faults
- Soft-errors can be categorized as Byzantine Faults
- Byzantine fault-tolerant systems are usually based on state-machine replication

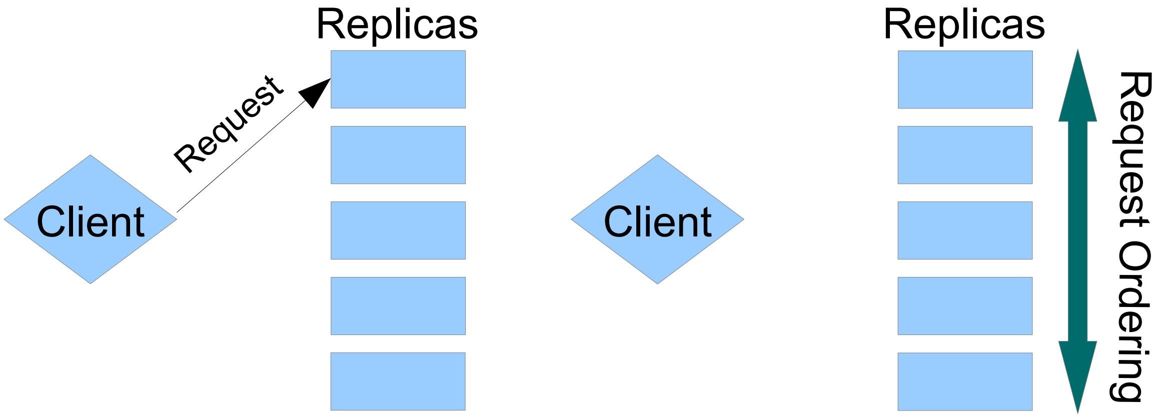
Byzantine fault-tolerant (BFT) systems

- System clients + Multiple replicas (servers)
  - Requests sent by clients are totally ordered.
  - All replicas execute the requests in the same order independently
  - Client receives a reply from each replica
  - Different reply means an error has occurred
- Require $3f+1$ replica to tolerate f faults
- Target arbitrary faults and malicious activities

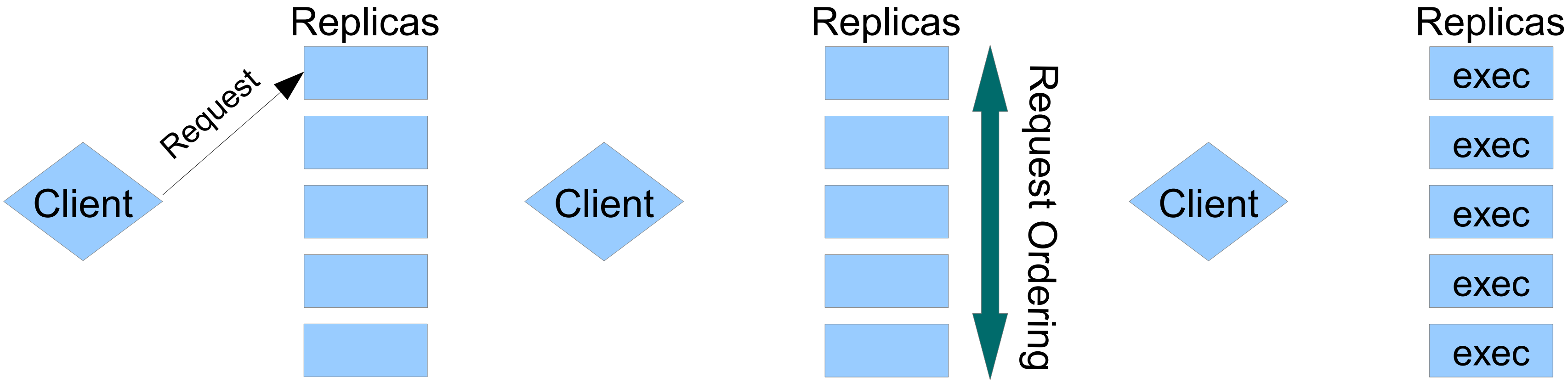
BFT Systems



BFT Systems


Replicas
Client
Request
Replicas
Client
Request Ordering

BFT Systems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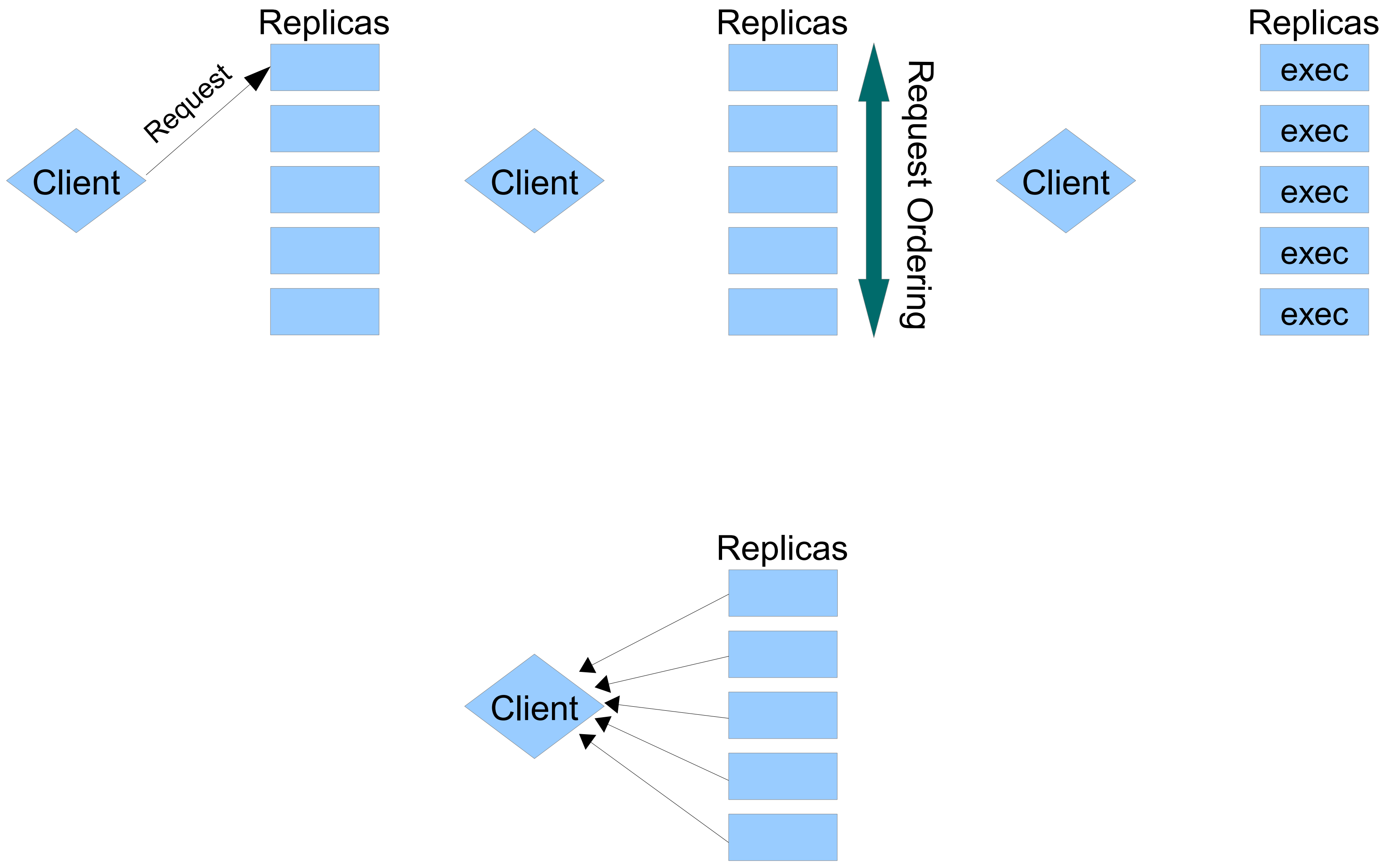
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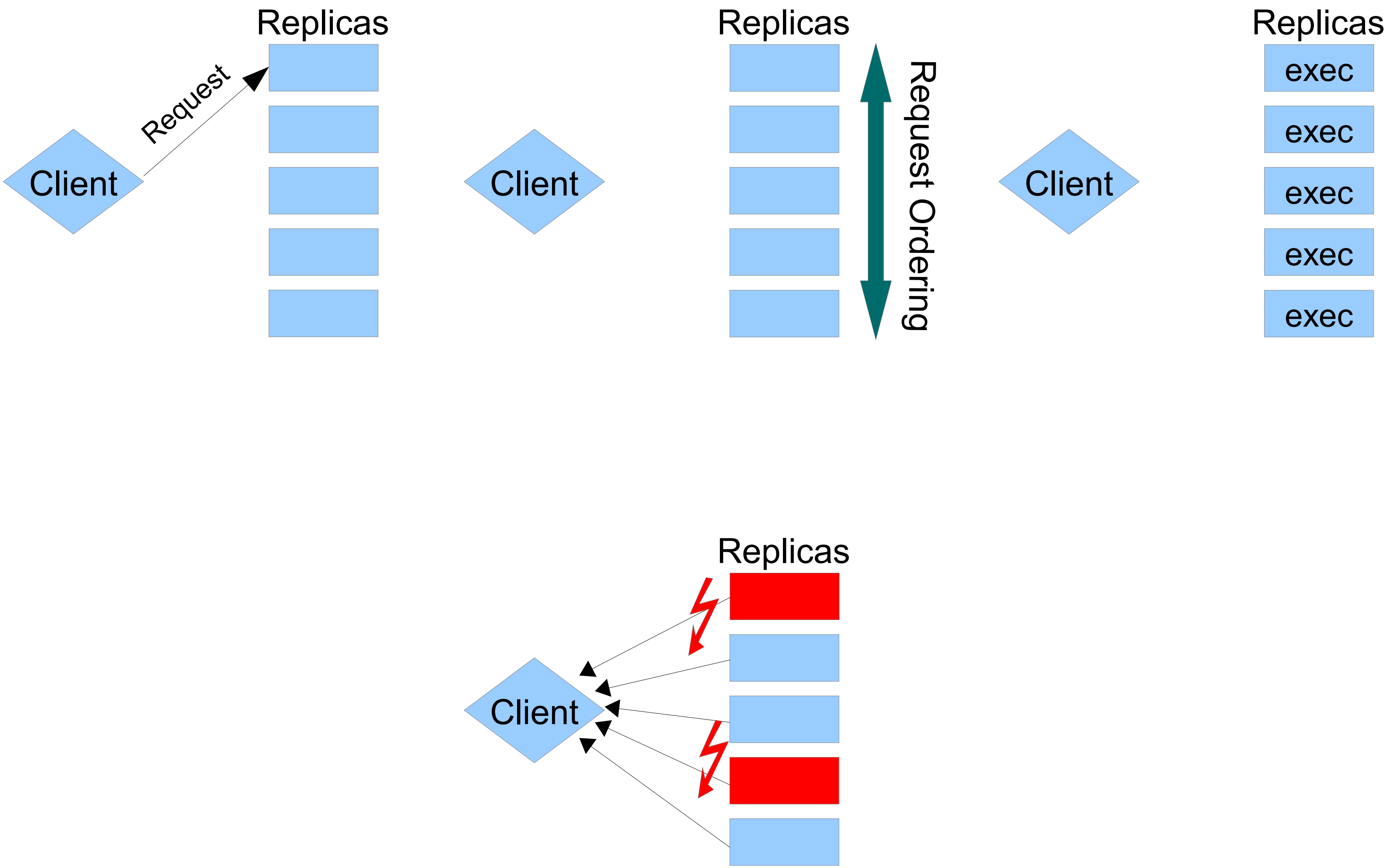
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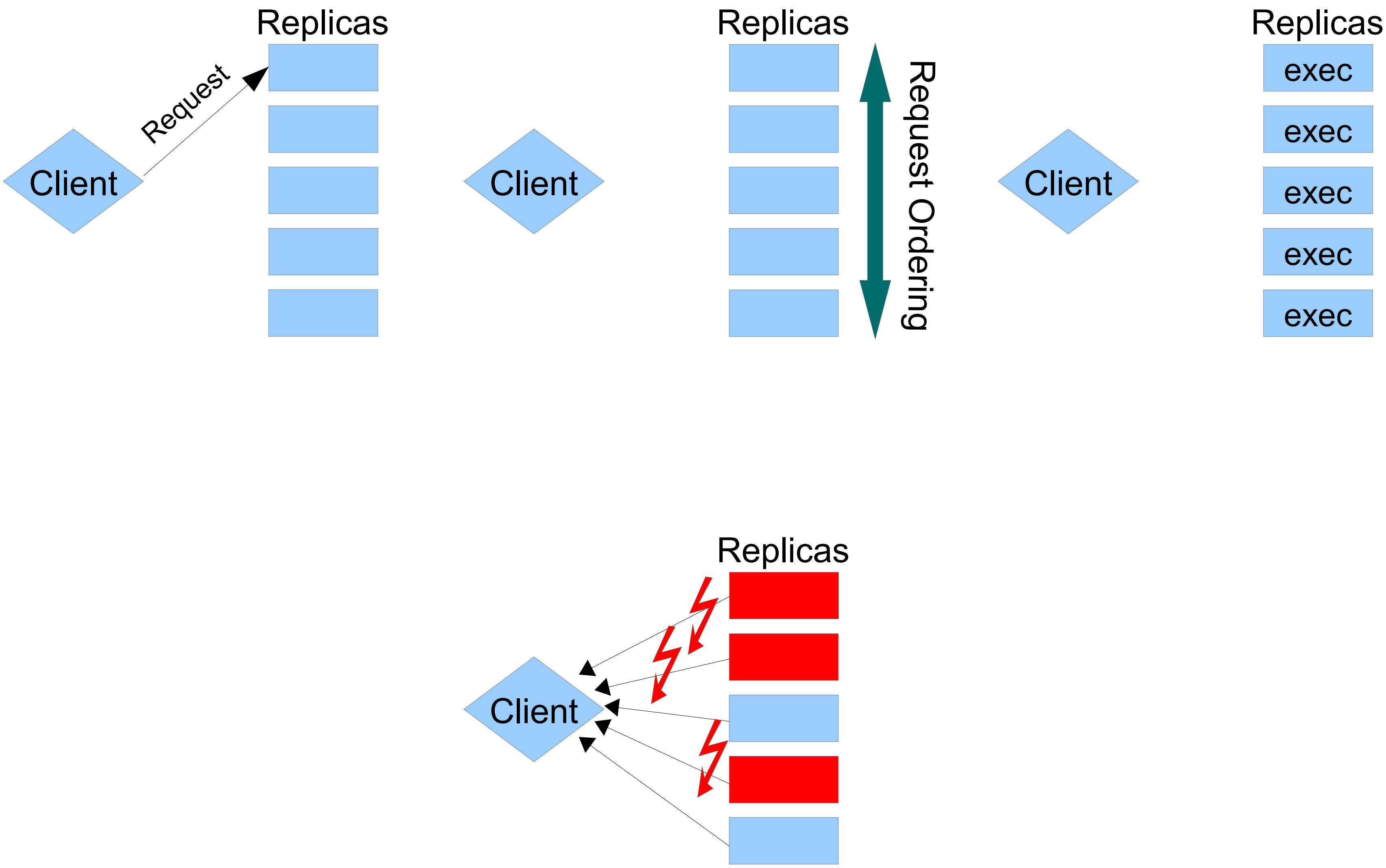

Replicas
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Replicas
exec
exec
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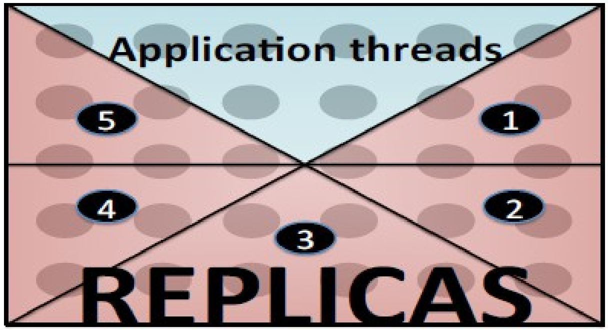
Client
Replicas
Client

Proposed Solution

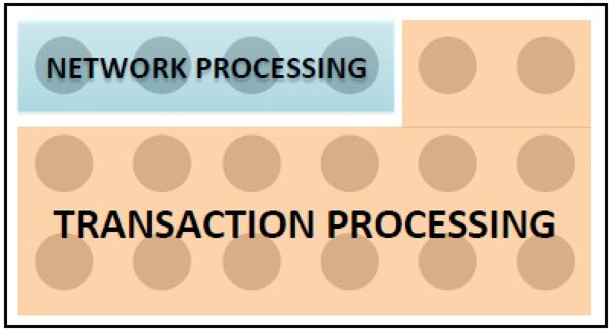
- A state-machine replication-based system customized for centralize systems
  - An Optimized network protocol
    - Decentralized
    - Supports optimistic delivery
  - An innovative concurrency control algorithm
    - Allows concurrent requests execution using STM
    - Preserves a predefined commit order

Proposed Solution

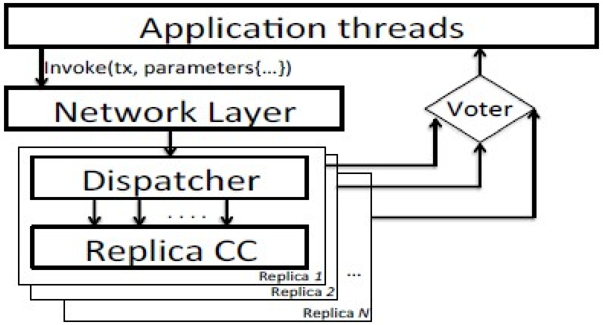
- Partition available resources into replicas and application threads
- ObCC: Ordering-based Concurrency Control.
- Replicas immediately optimistically deliver request
  - Replicas: Start total ordering phase
  - ObCC: Execute request speculatively using STM



(a) System



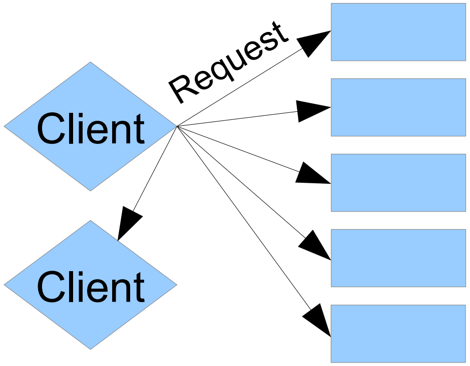
(b) Replica



(c) Software

Network Layer

Network Layer



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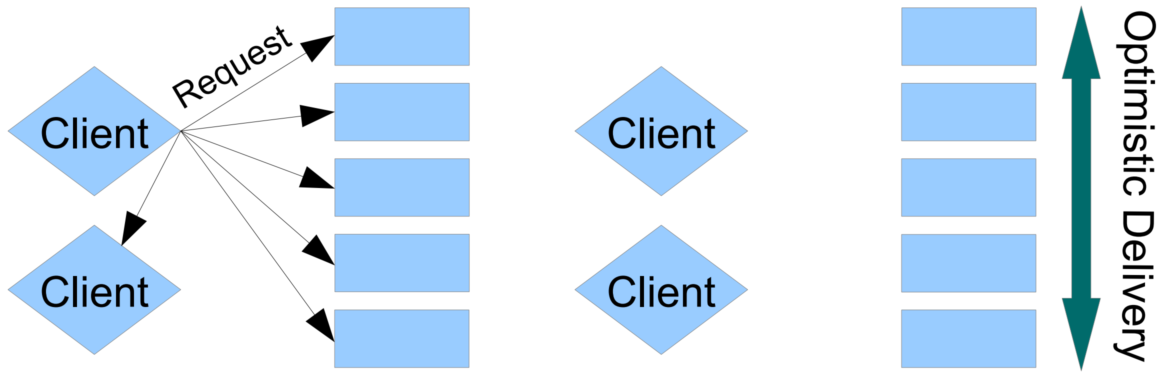

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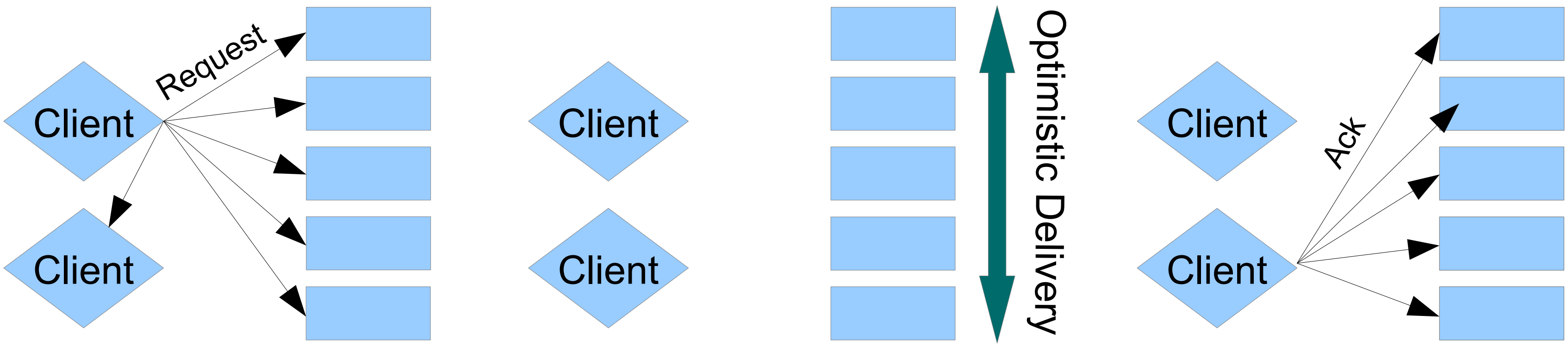

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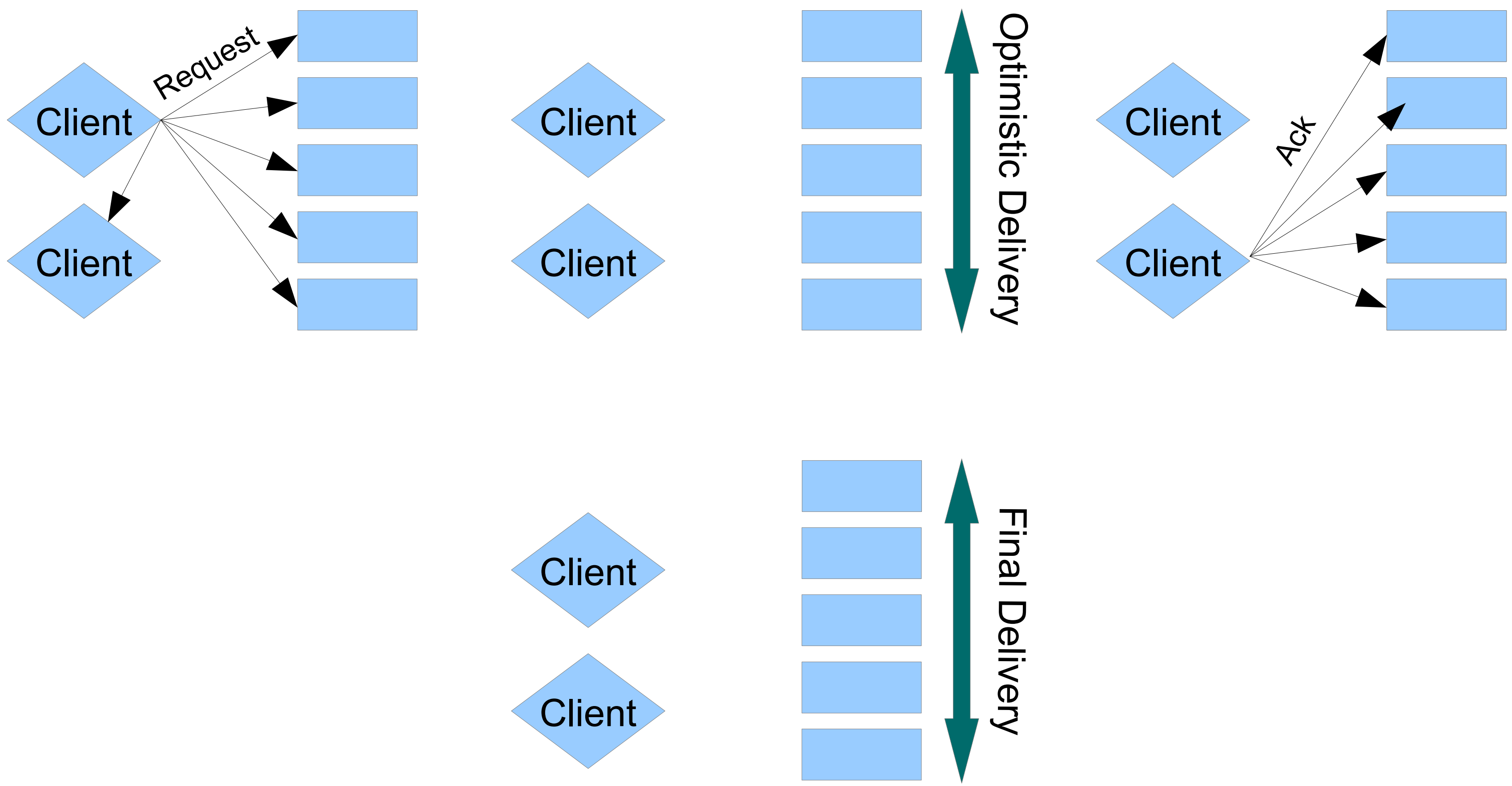


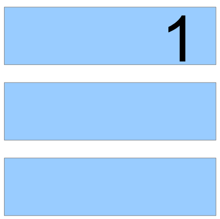
Network Layer

- Decentralized Ordering
- Assumptions
  - Reliable Network
  - Thread FIFO: thread requests are received in the same order
  - Synchronized Clock

Network Layer Decentralized Ordering

Replicas have a queue for each client

Example on a system with 3 clients



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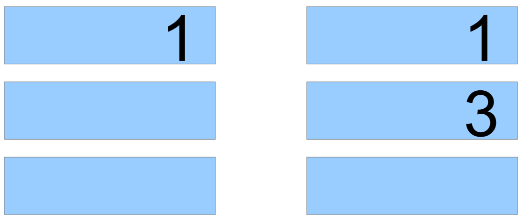

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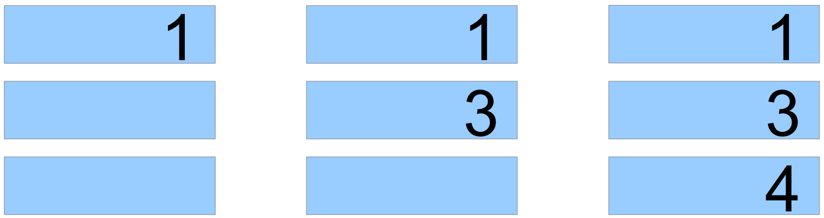

Network Layer Decentralized Ordering

Replicas have a queue for each client

Example on a system with 3 clients

1	1	1	**1**
	3	3	3
		4	4

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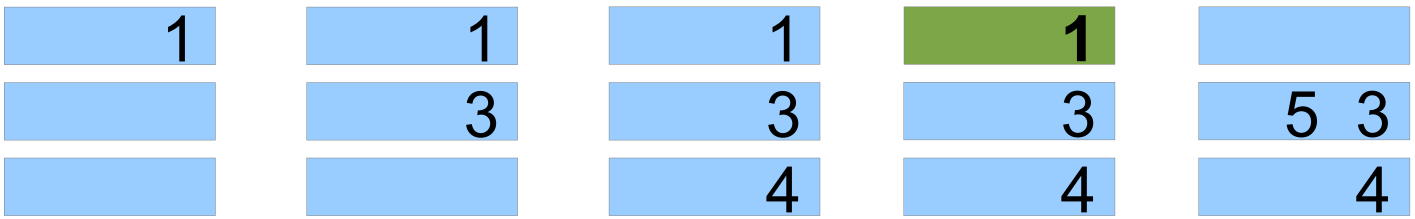

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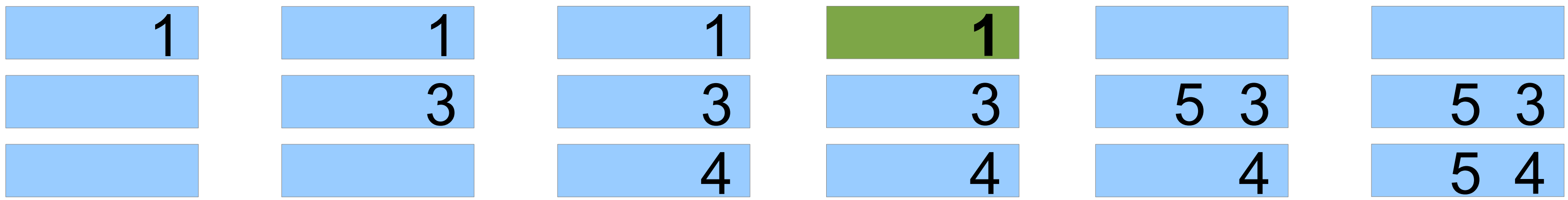

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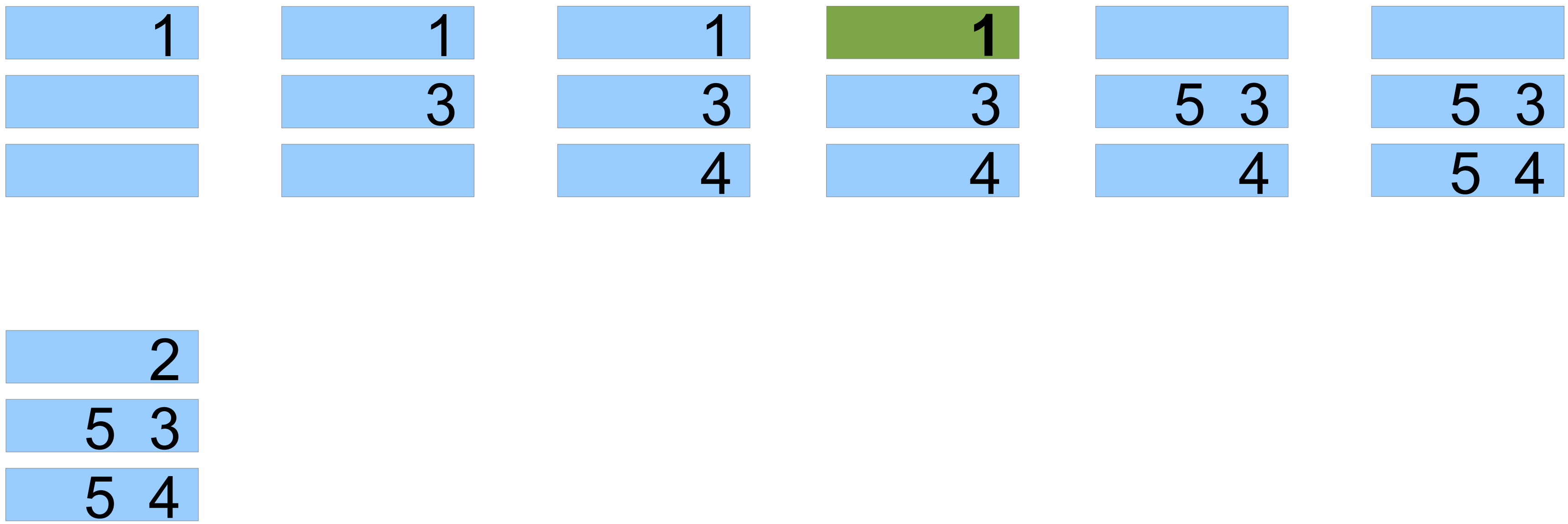

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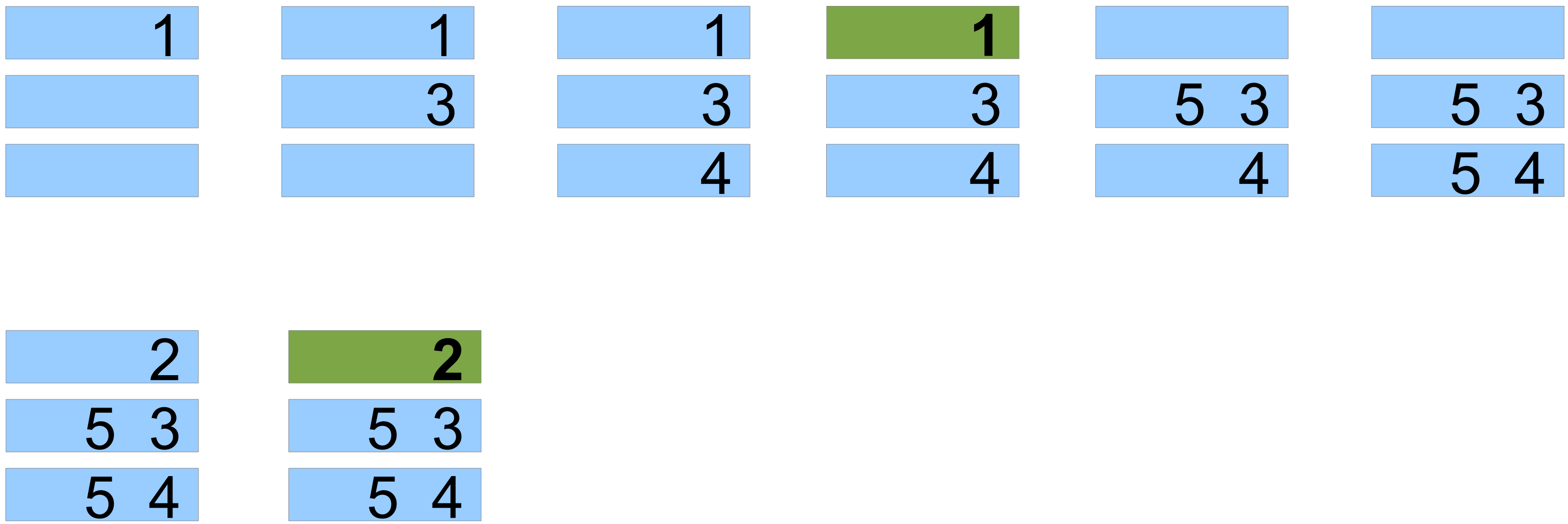

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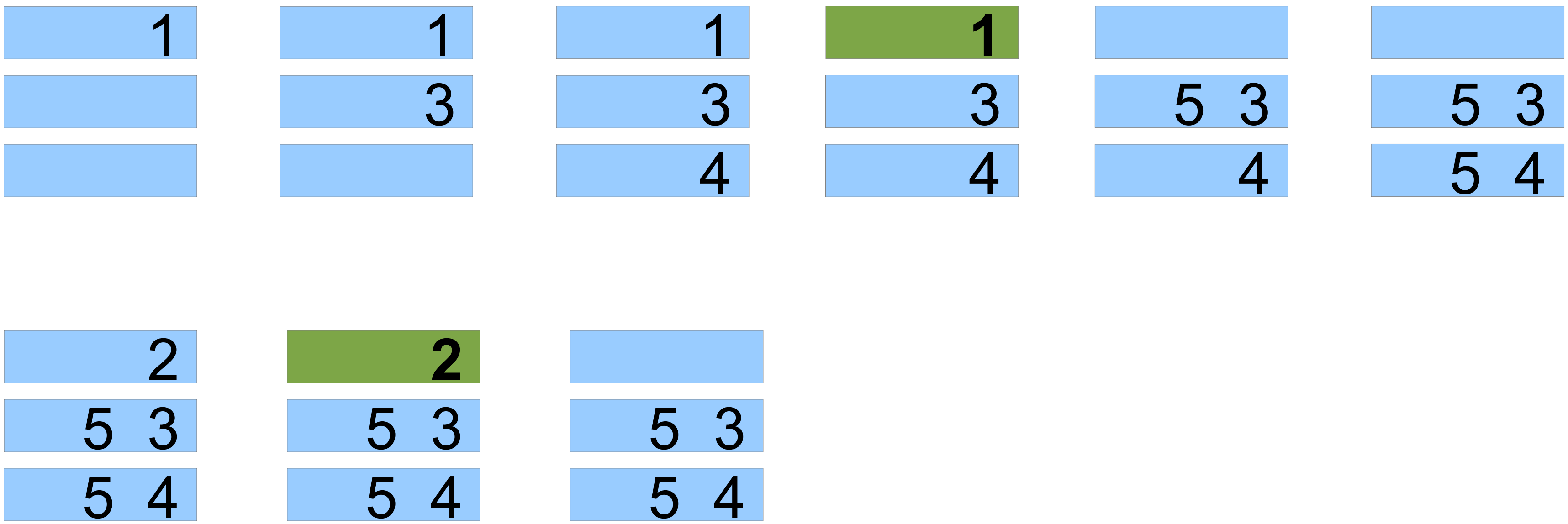

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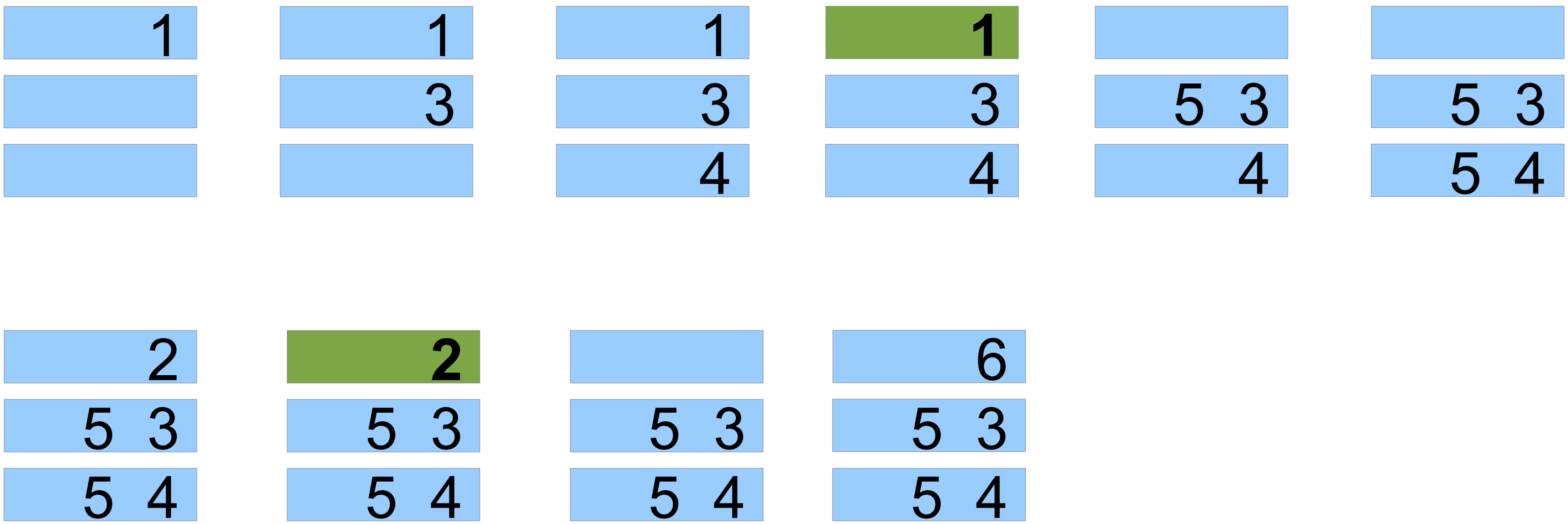

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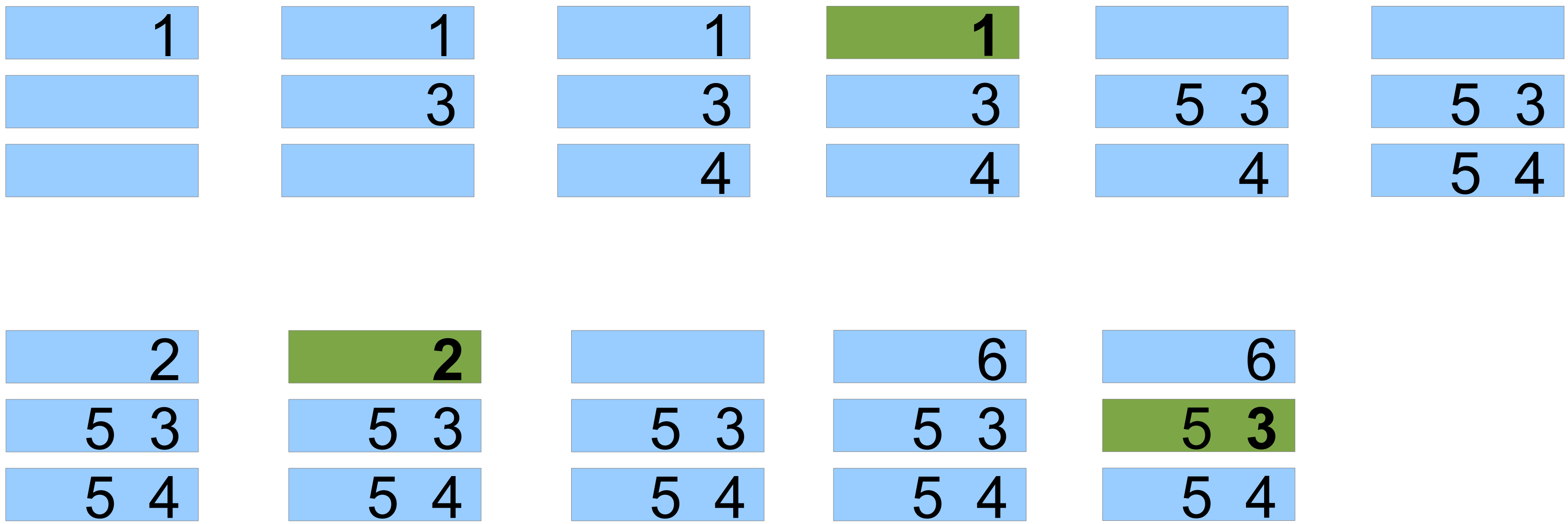

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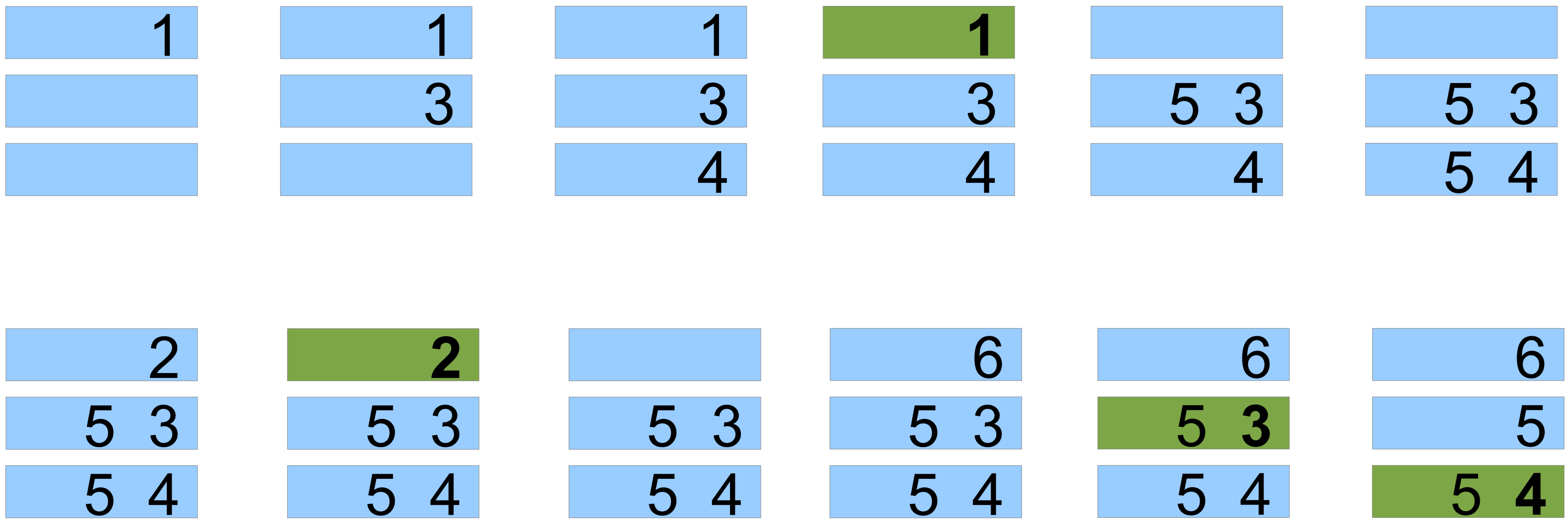

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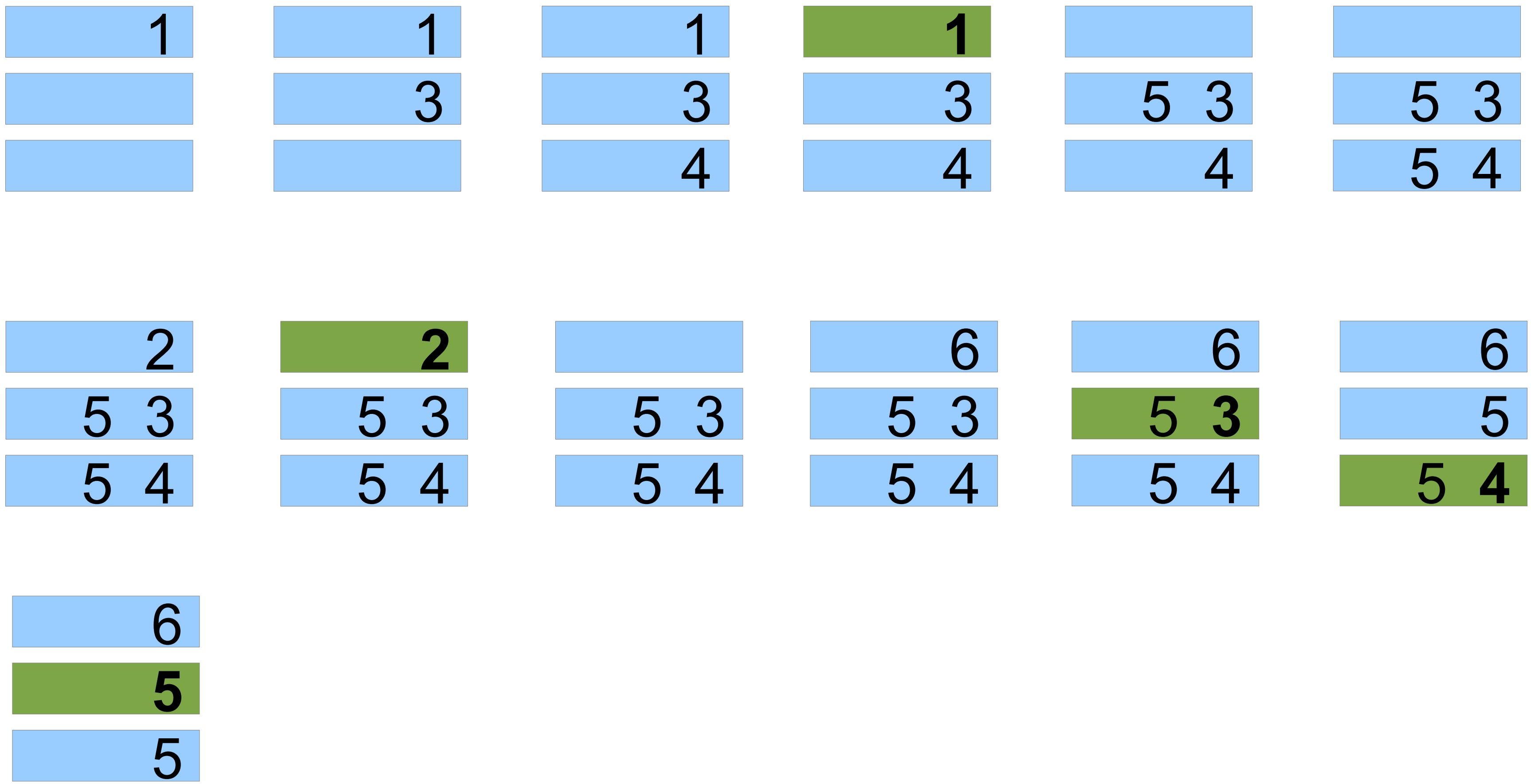

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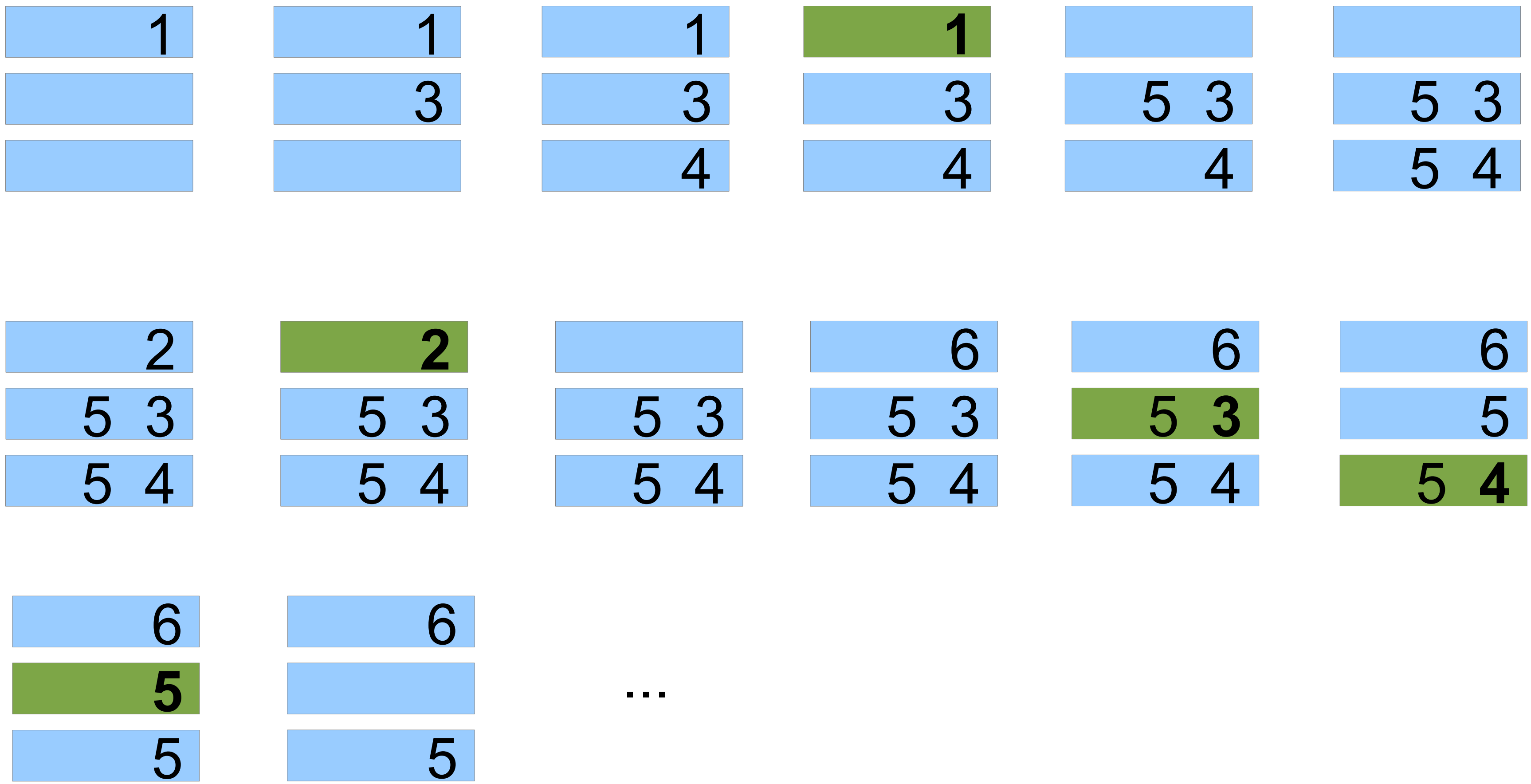

Concurrency Control

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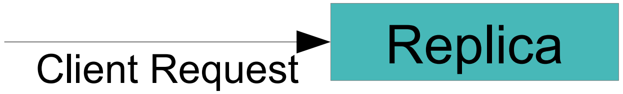

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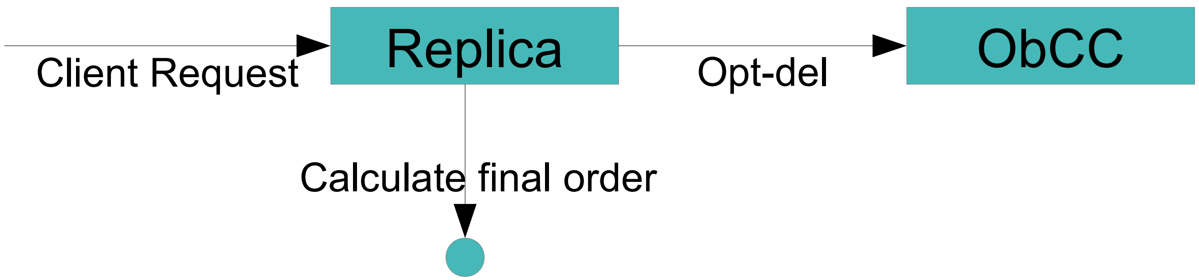

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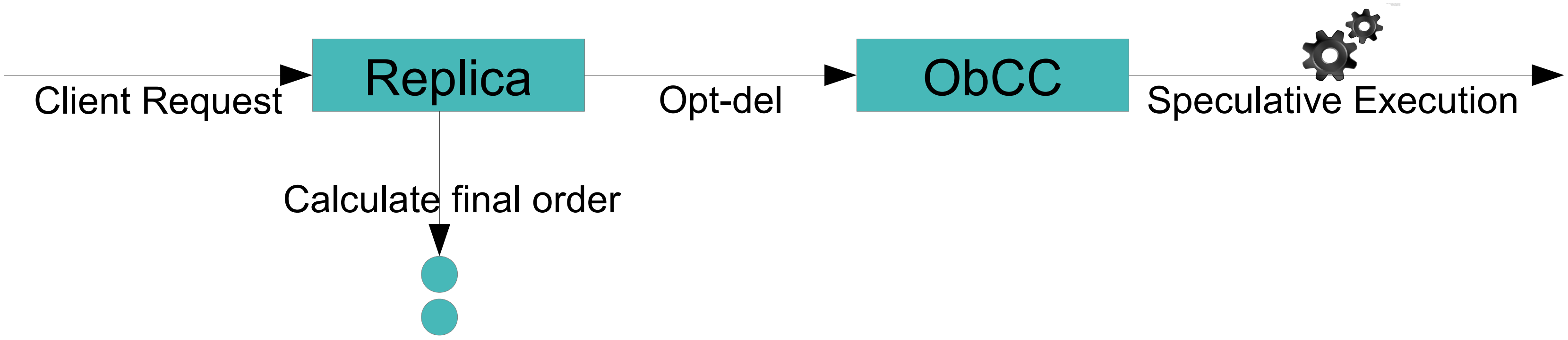

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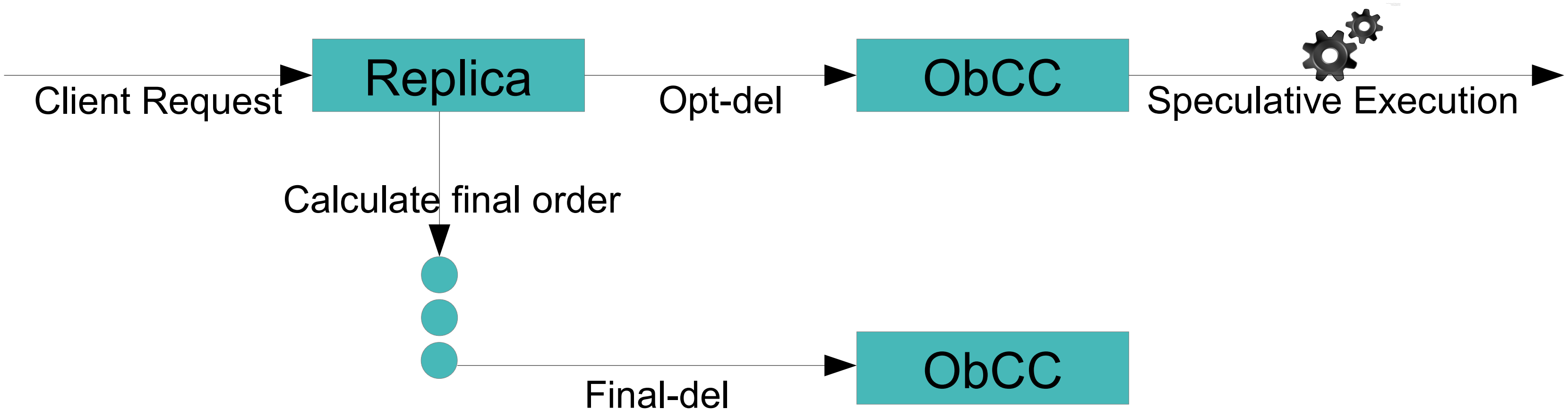

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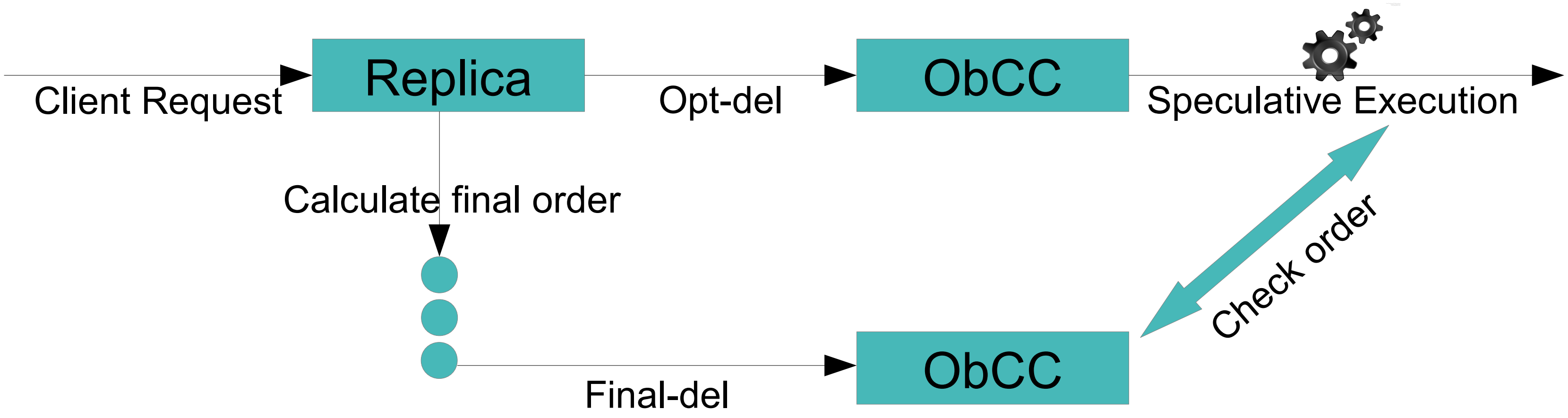

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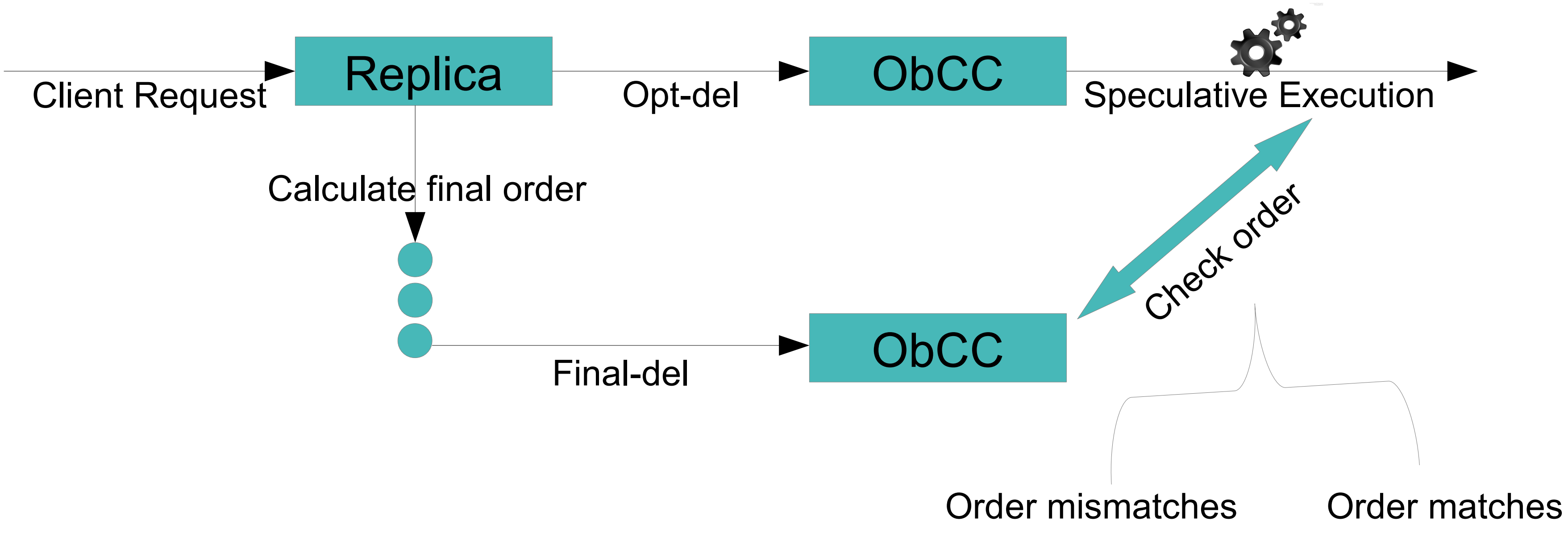

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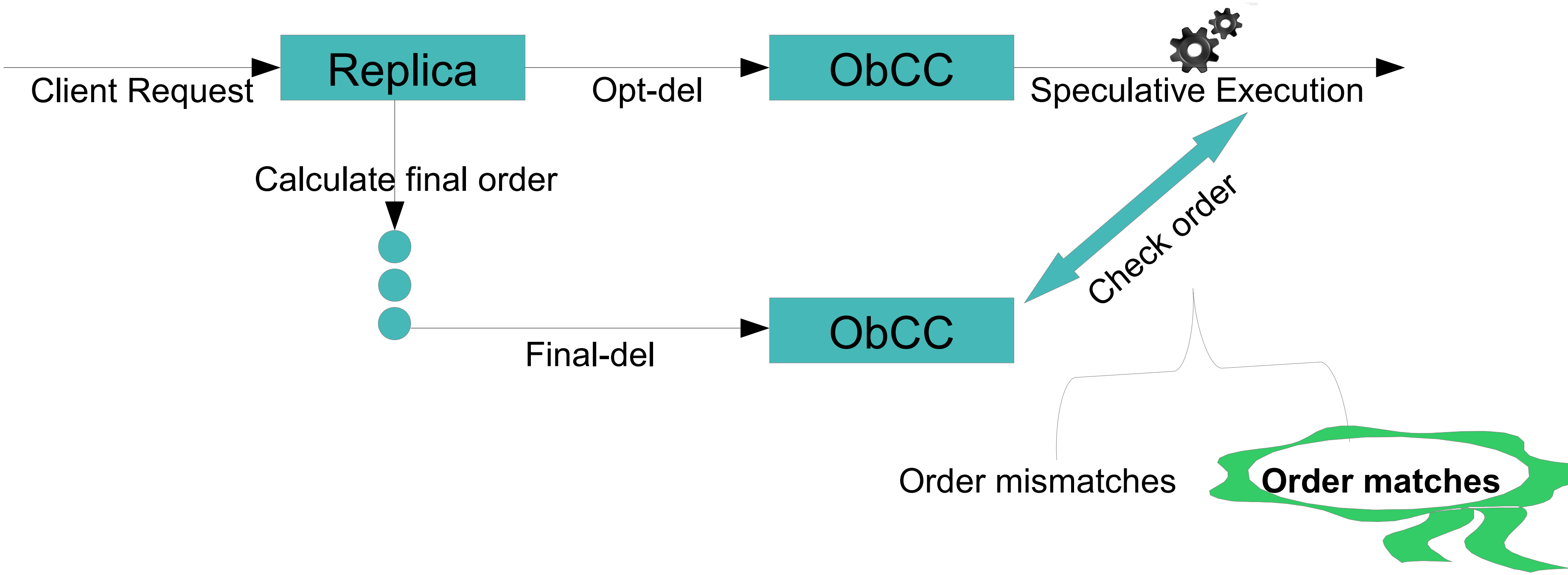

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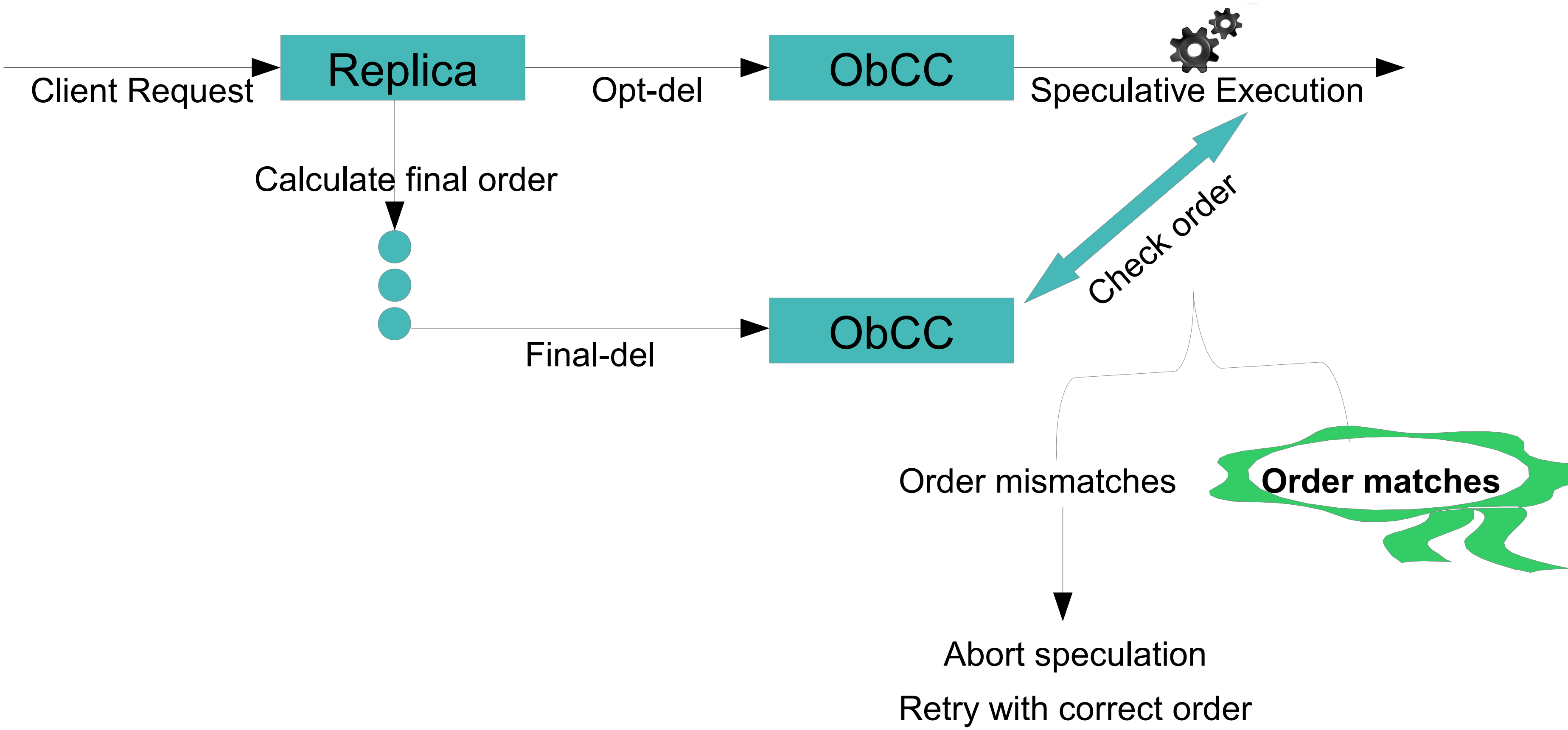


Concurrency Control

- More concurrency
  - Run multiple requests concurrently
    - Conflicts?
    - Order?

Concurrency Control

- Conflict detection and resolution
  - Two threads accessing same object and one access is write
    - Resolution: Thread that precedes wins
- Uses encounter time write-locks
  - Writing to a locked object
    - Conflict
  - Reading locked object
    - Conflict?

Concurrency Control

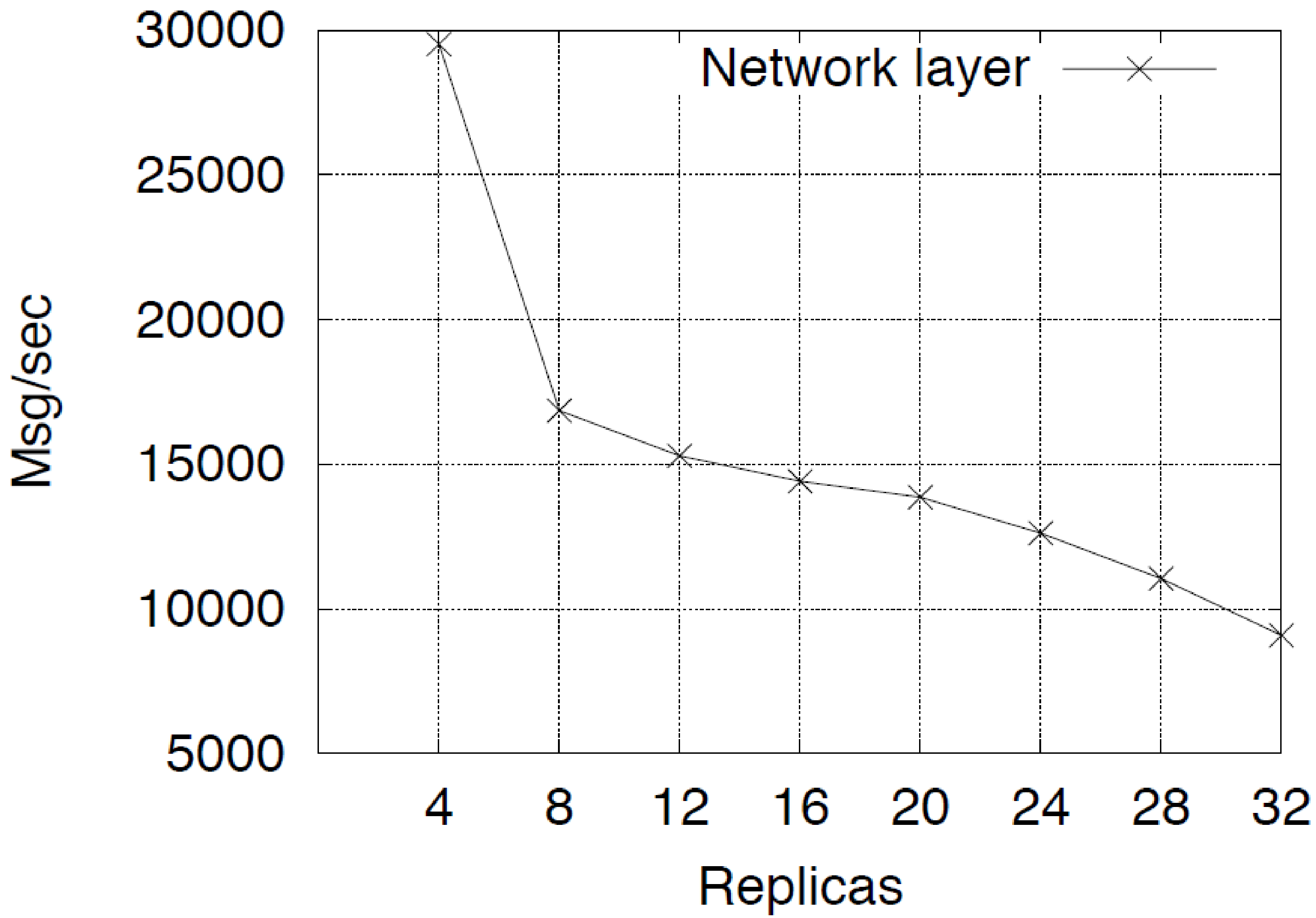
- Another enhancement: Committer mode
  - Minimal instrumentation/overhead
  - Guaranteed to commit

Evaluation

- System is implemented in C++
- Concurrency control implemented on top of RSTM [17]
- Testbed: 36-core Tilera TILEGx cooprocessor
  - 1.0 GHz clock speed
  - 8 GB DDR3 memory
  - Message-passing (iMesh 2D on-chip network)

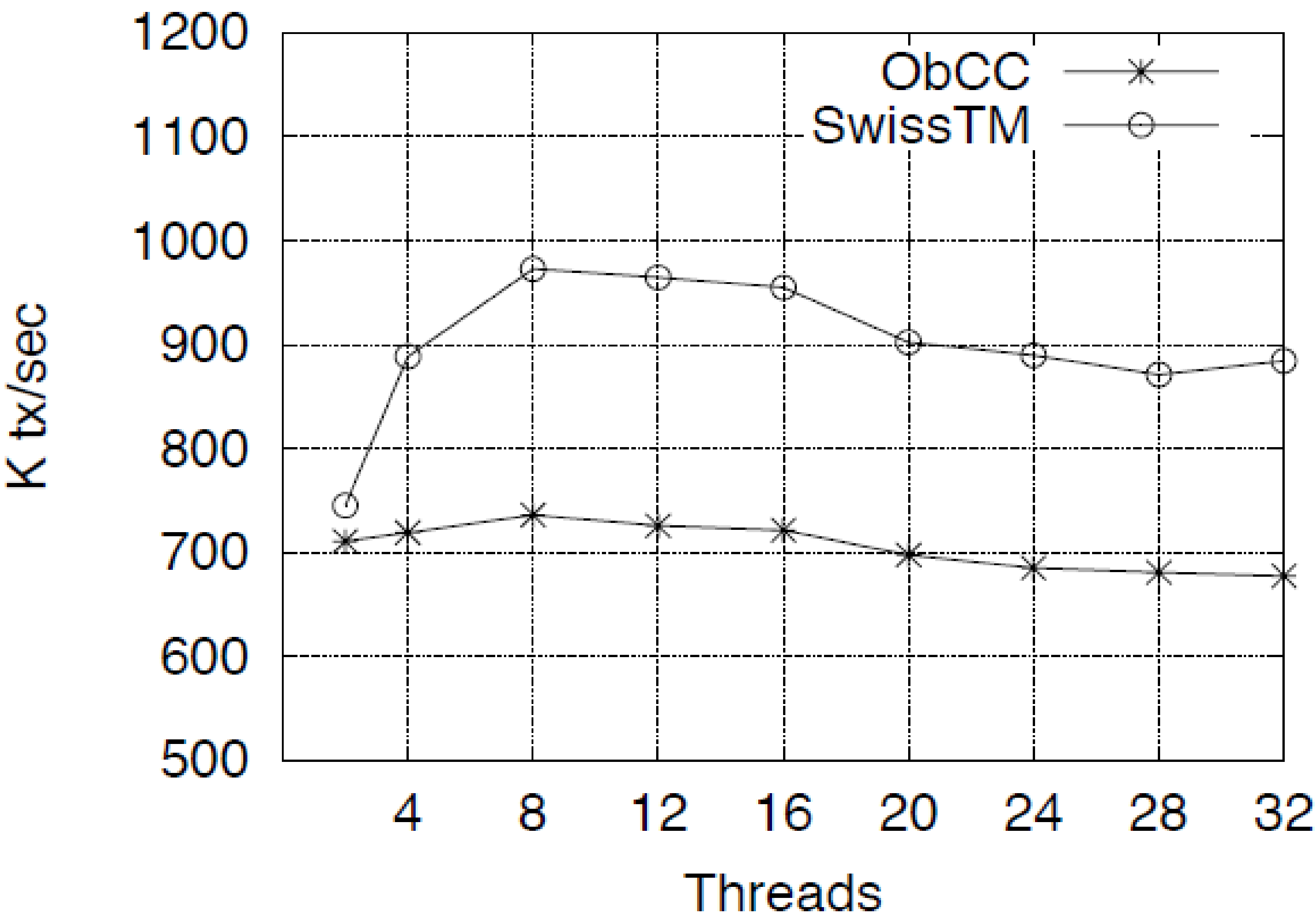
Evaluation: Network Layer

- Good performance for small number of replicas (4-8)



Evaluation: Concurrency Control

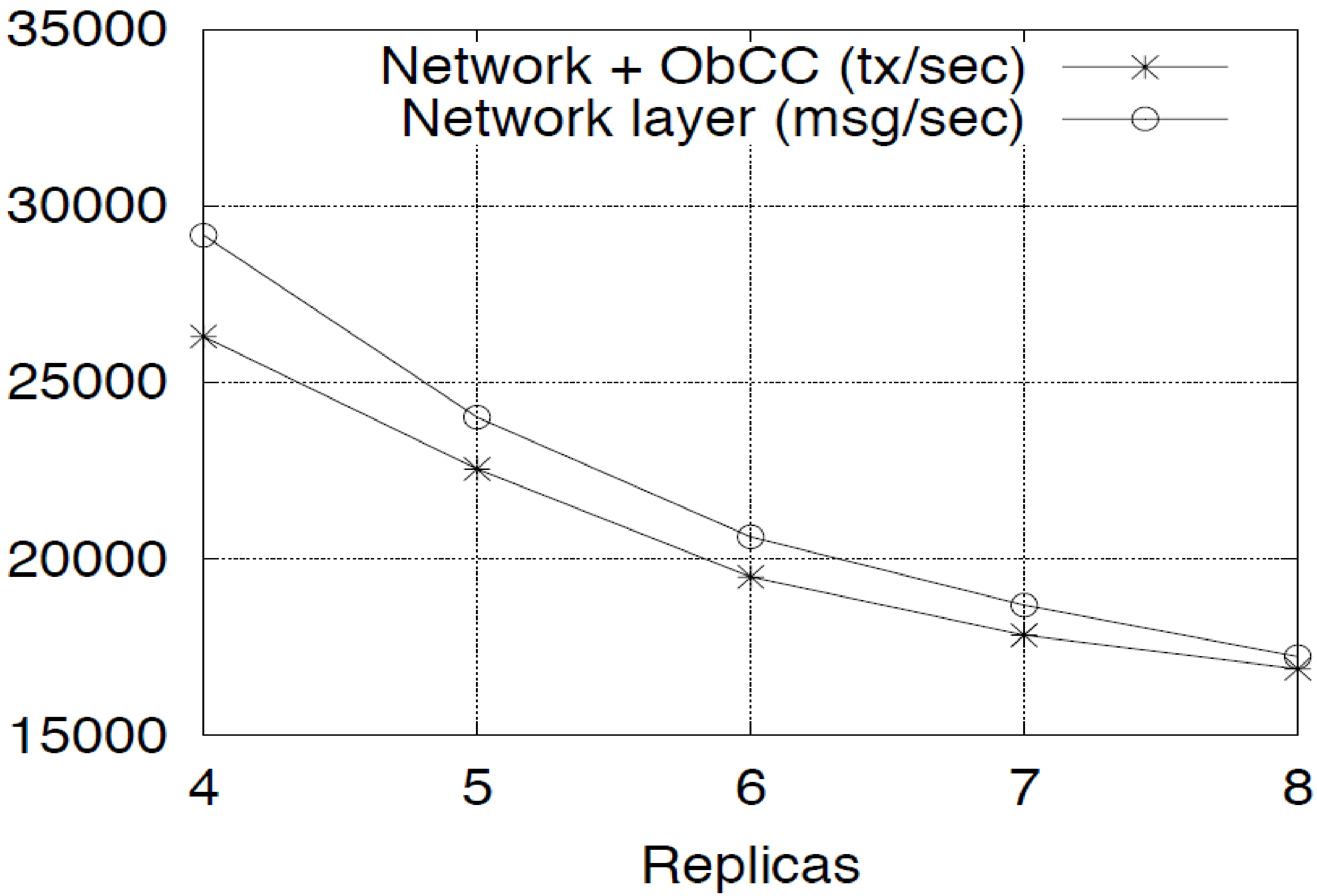
- Overhead of ordered commit is about 25%



Hash-Set

Evaluation: Integration

- System performance is bound by network performance
- Limited gap



Hash-Set

Conclusion

- Active replication is a good candidate for solving soft-errors
  - Fully masks errors
  - Reasonable overhead

- Future Work:
  - Optimizing System components
    - Reducing network layer overhead
    - Increase requests execution concurrency
  - Trying different architectures
    - Message-passing vs. shared-bus

Questions

Thank you!