Log-Based CRDT for Edge Applications

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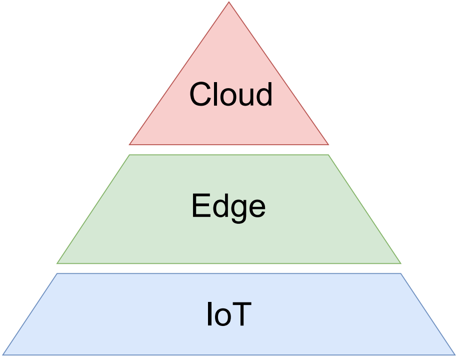
University of California, Santa Barbara

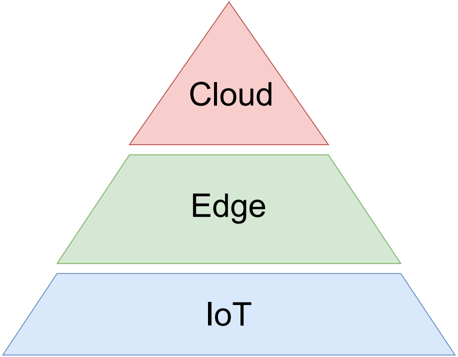
September 27, 2022

UCSB

Multi-Tiered Cloud Architecture



Multi-Tiered Cloud Architecture

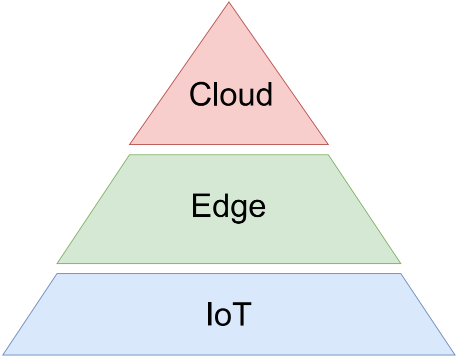


heterogeneity

unstable network connectivity

unreliable power source

Multi-Tiered Cloud Architecture



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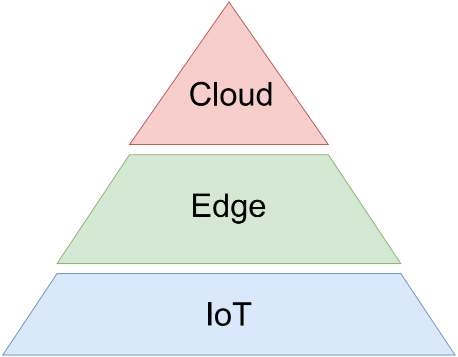
seamless integration of data throughout all layers
require *minimization/avoidance of coordination*:

Multi-Tiered Cloud Architecture



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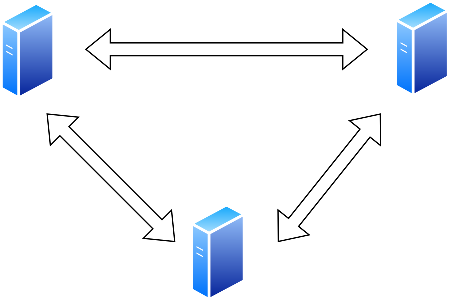
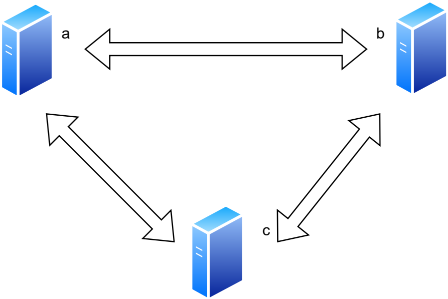
Conflict-Free Replicated Data Types **CRDTs**

Conflict-Free Replicated Data Type (CRDT)



shared data type

Conflict-Free Replicated Data Type (CRDT)



shared data type

allows concurrent update

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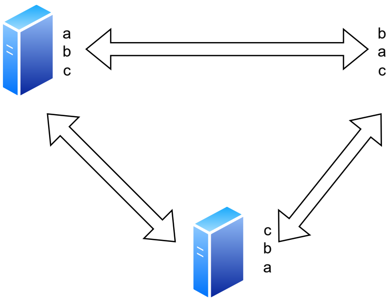

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allows concurrent update

strong eventual consistency

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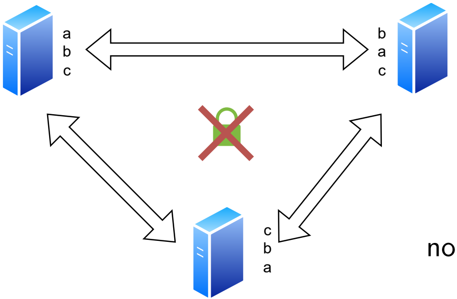

shared data type

allows concurrent update

strong eventual consistency

no complex coordination overhead

Why Another type of CRDT?

CRDT

does not support non-commutative operation

Op-based CRDTs require exactly-once causal delivery

State-based CRDTs require data type-specific merge

Why Another type of CRDT?

our work: Log-Structured CRDT (**LSCRDT**)

CRDT	Log-Structured CRDT (LSCRDT)
does not support non-commutative operation	supports non-commutative operation
Op-based CRDTs require exactly-once causal delivery	no special delivery requirement
State-based CRDTs require data type-specific merge	generic merge step

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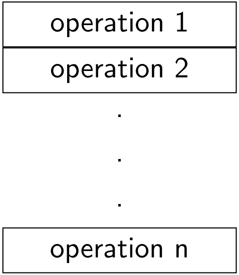
State-based CRDTs require data type-specific merge	generic merge step

additional LSCRDT features: **operation reversal** and **versioning**

Data Types Using Logs

log of operations (OpLog)



operation 1

operation 2

.

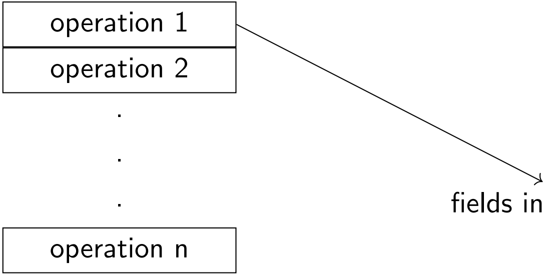
.

.

operation n

Data Types Using Logs

log of operations (OpLog)



operation 1

operation 2

.

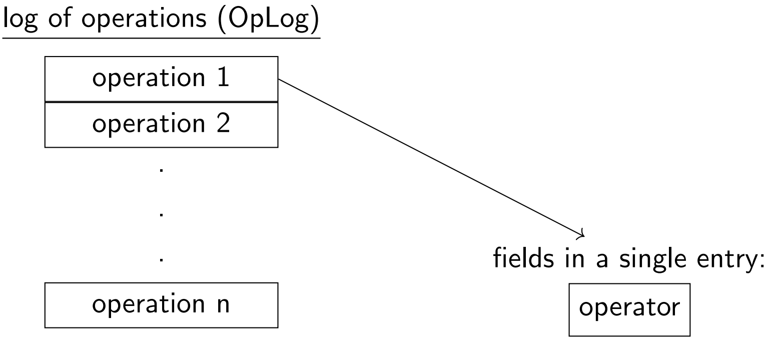
.

.

operation n

fields in a single entry:

Data Types Using Logs



log of operations (OpLog)

operation 1

operation 2

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operation n

fields in a single entry:

operator

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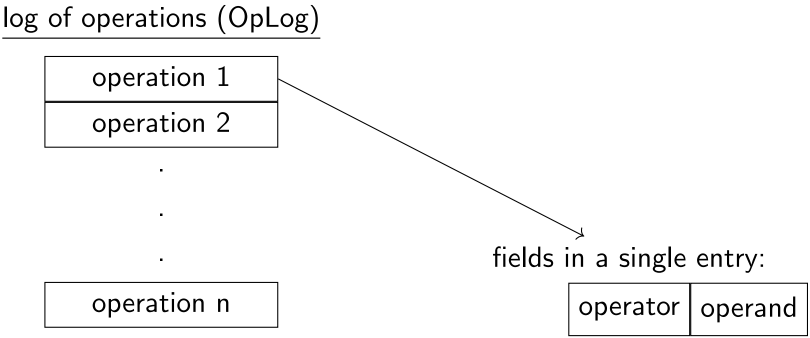

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operand

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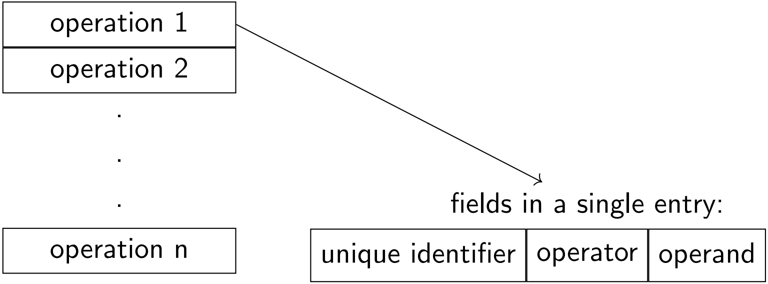

operation 1

operation 2

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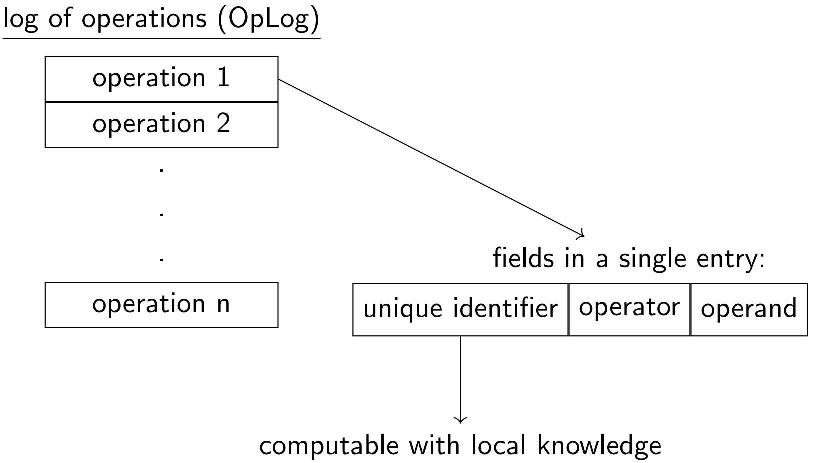
fields in a single entry:

unique identifier | operator | operand

Data Types Using Logs



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fields in a single entry:

unique identifier	operator	operand

computable with local knowledge

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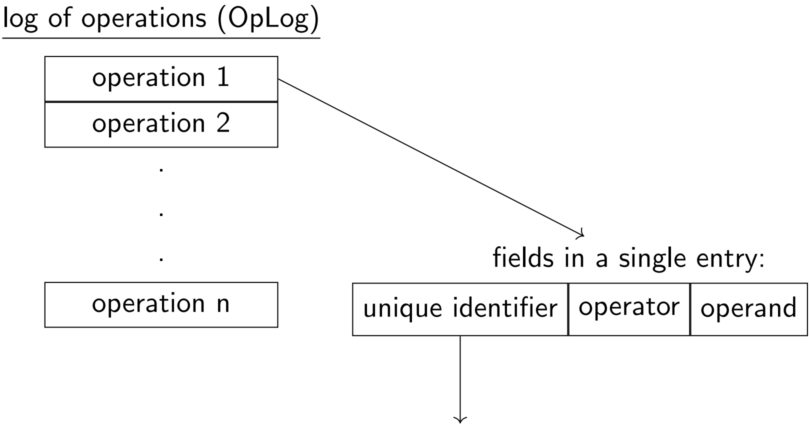

log of operations (OpLog)

operation 1

operation 2

.

.

.

operation n

fields in a single entry:

unique identifier	operator	operand

computable with local knowledge

version stamps (Lamport timestamps):

counter (one plus highest value) + replica ID

LSCRDT Registers

Replica A OpLog

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1	1A	assign	10

LSCRDT Registers

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1	1A	assign	10
2	2A	assign	5

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1	1A	assign	10
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		⋮	
9	9A	assign	7

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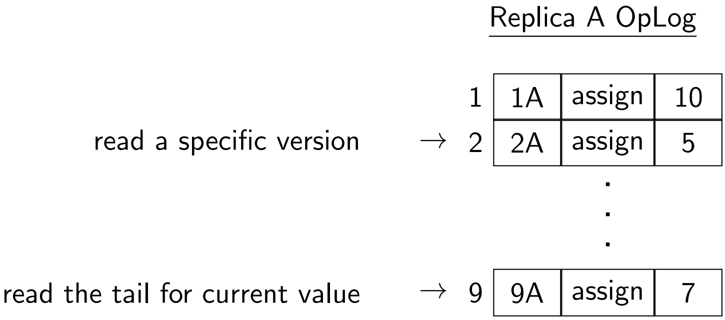
	1	1A	assign	10
	2	2A	assign	5
			⋮	
read the tail for current value →	9	9A	assign	7

LSCRDT Registers

Replica A OpLog

		1	1A	assign	10
read a specific version	→	2	2A	assign	5
				⋮	
read the tail for current value	→	9	9A	assign	7

LSCRDT Registers



Replica A OpLog

read a specific version → 2

read the tail for current value → 9

1	1A	assign	10
2	2A	assign	5
		⋮	
9	9A	assign	7

Optimization: maintain a map from version stamp to sequence number

LSCRDT Counters

Replica A OpLog

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1	1A	inc	10
2	2A	dec	5
3	3A	dec	3

LSCRDT Counters

Replica A OpLog

1	1A	inc	10	10
2	2A	dec	5	5
3	3A	dec	3	2

Maintain extra column per entry for cumulative sum

LSCRDT Sets

Replica A OpLog

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1	1A	add	10
2	2A	add	5
3	3A	add	3
4	4A	rem	5

LSCRDT Sets

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1	1A	add	10
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Replica A Checkpoint

1	3A	{10, 5, 3}

Maintain checkpoint entry at a specific interval

Replication Overview

OpLog(A)

OpLog(B)

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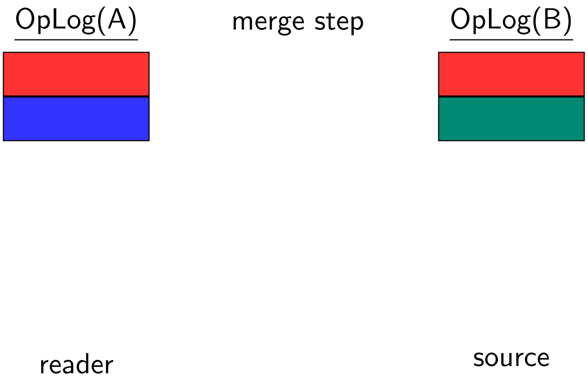


OpLog(A)

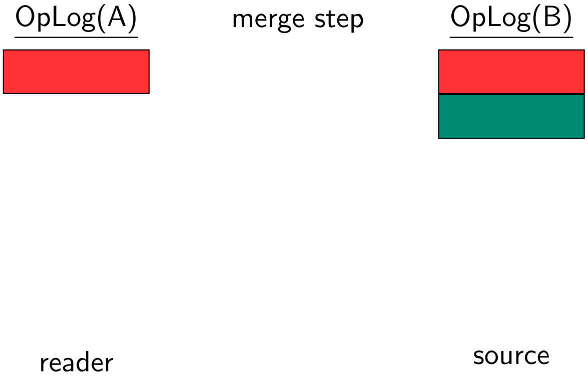
merge step

OpLog(B)

reader

source

Replication Overview



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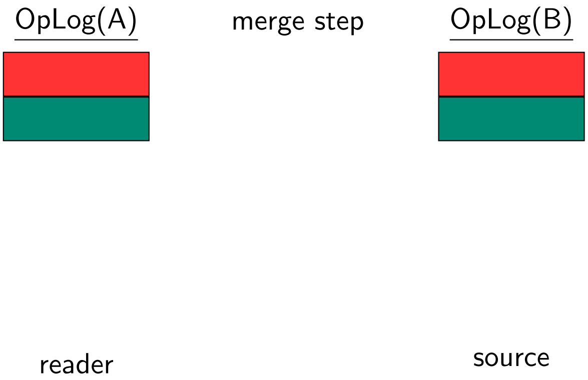

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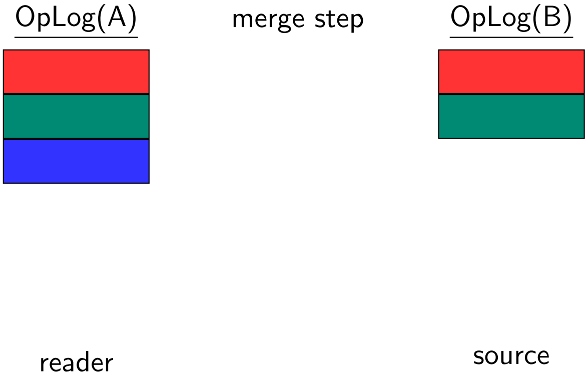

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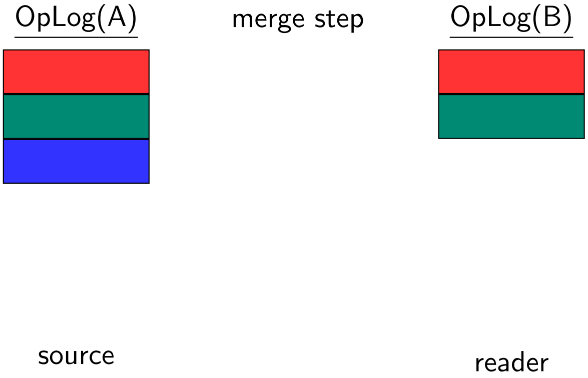

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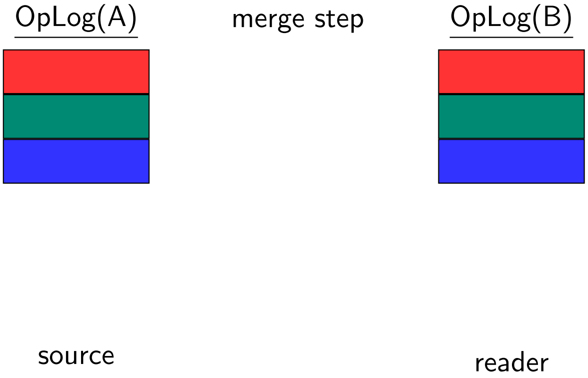

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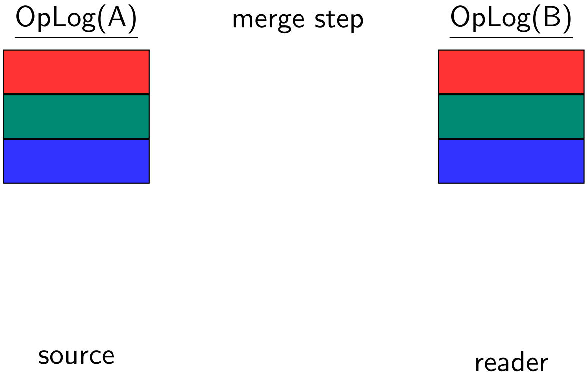

OpLog(A)

merge step

OpLog(B)

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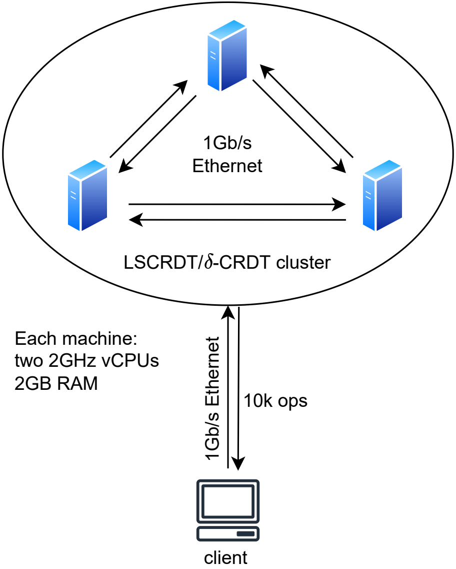
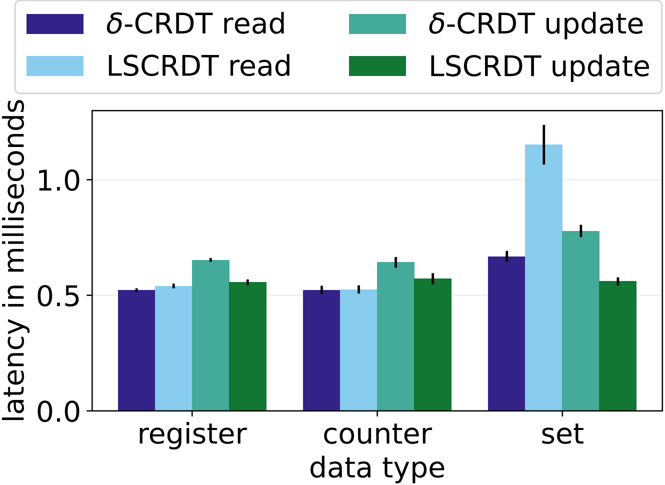
reader

both replicas have **same operations** in the **same order** – convergence!

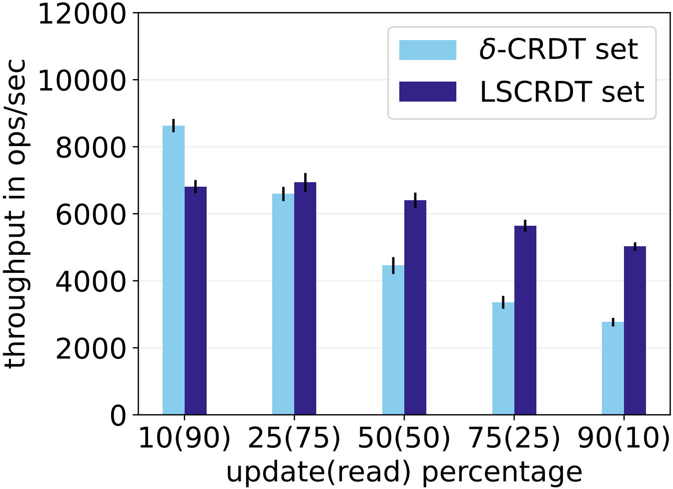
Experimental Setup



Single Node Latency



Throughput for Set



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