One-Sided RDMA-Conscious Extendible Hashing for Disaggregated Memory

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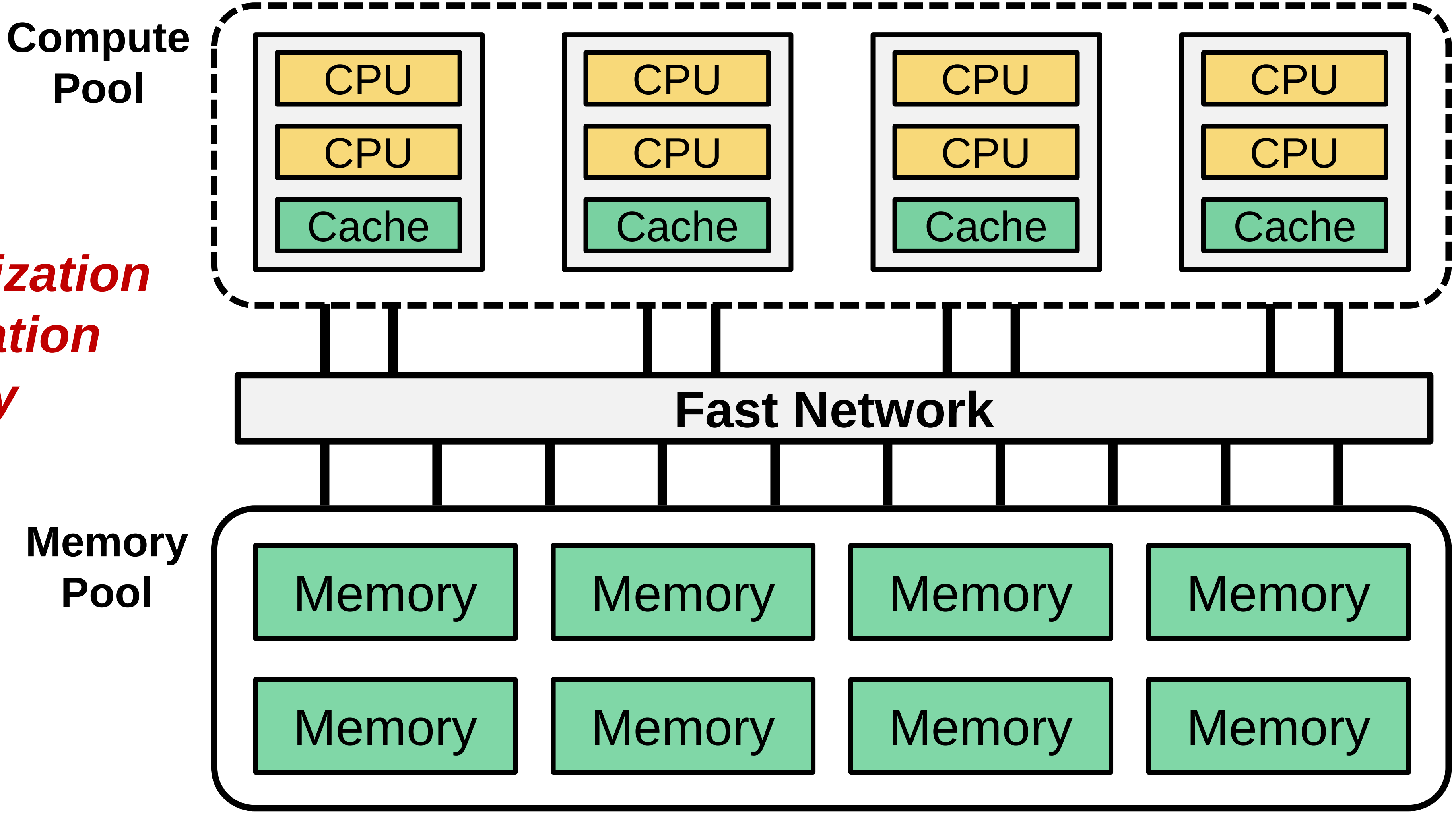
USENIX Annual Technical Conference (ATC), 2021

Disaggregated Memory

Resource Utilization
Failure Isolation
Elasticity



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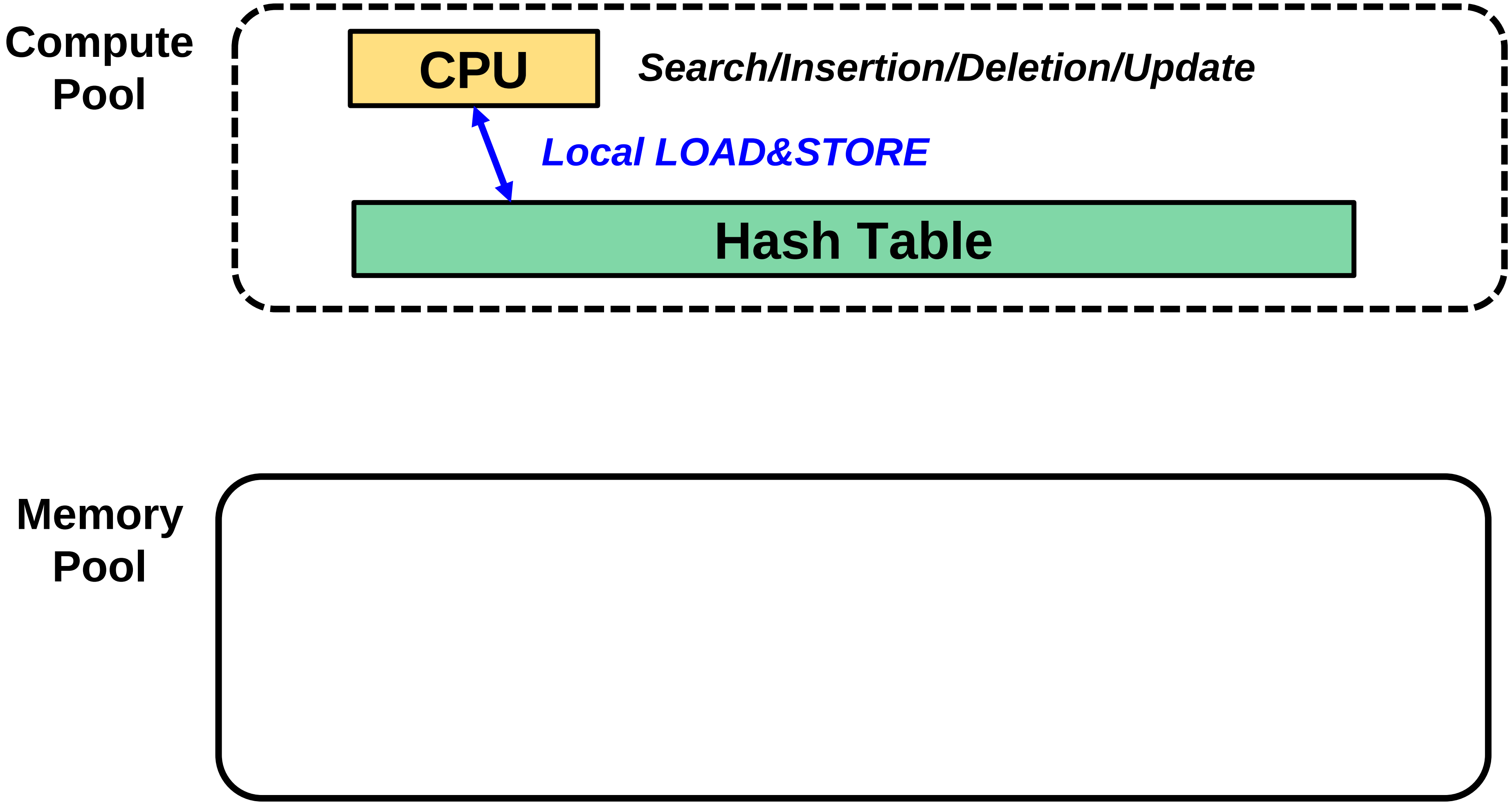
Hashing Indexes in Local Memory

Hashing Indexes in Disaggregated Memory



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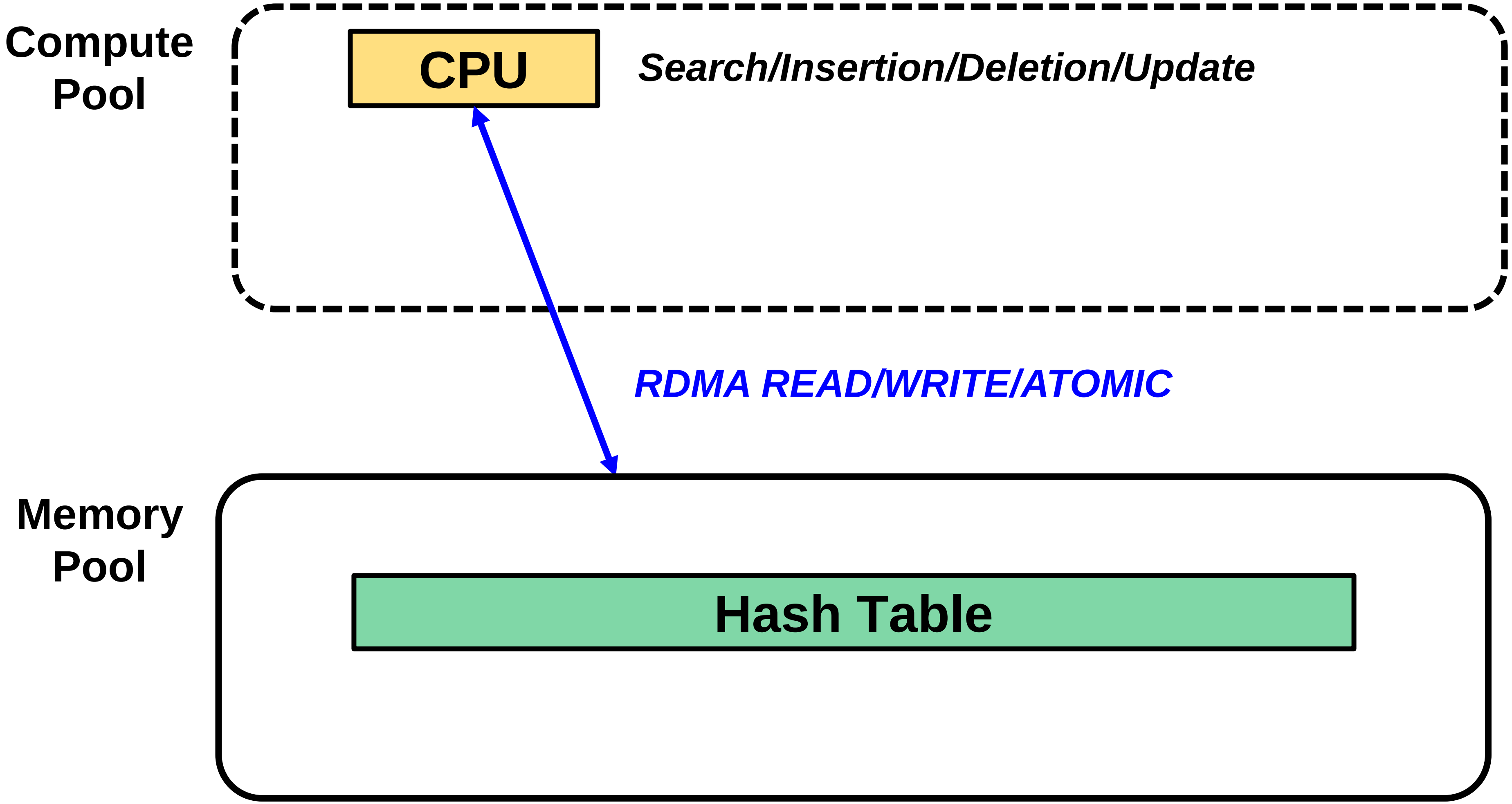
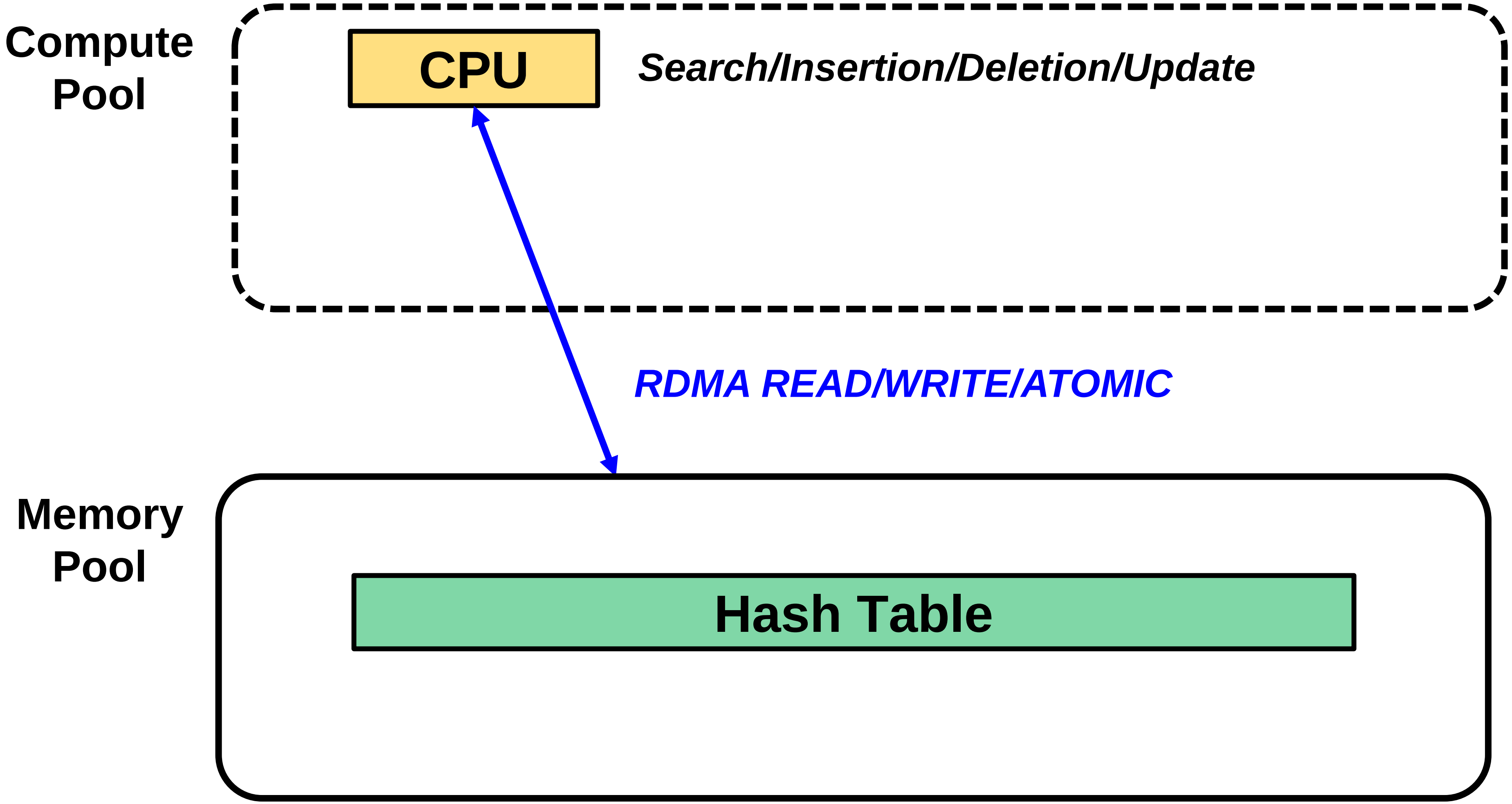
Hashing Indexes in Disaggregated Memory



Challenge 1: Hash Collision



Challenge 1: Many remote reads&writes for handling hash collisions

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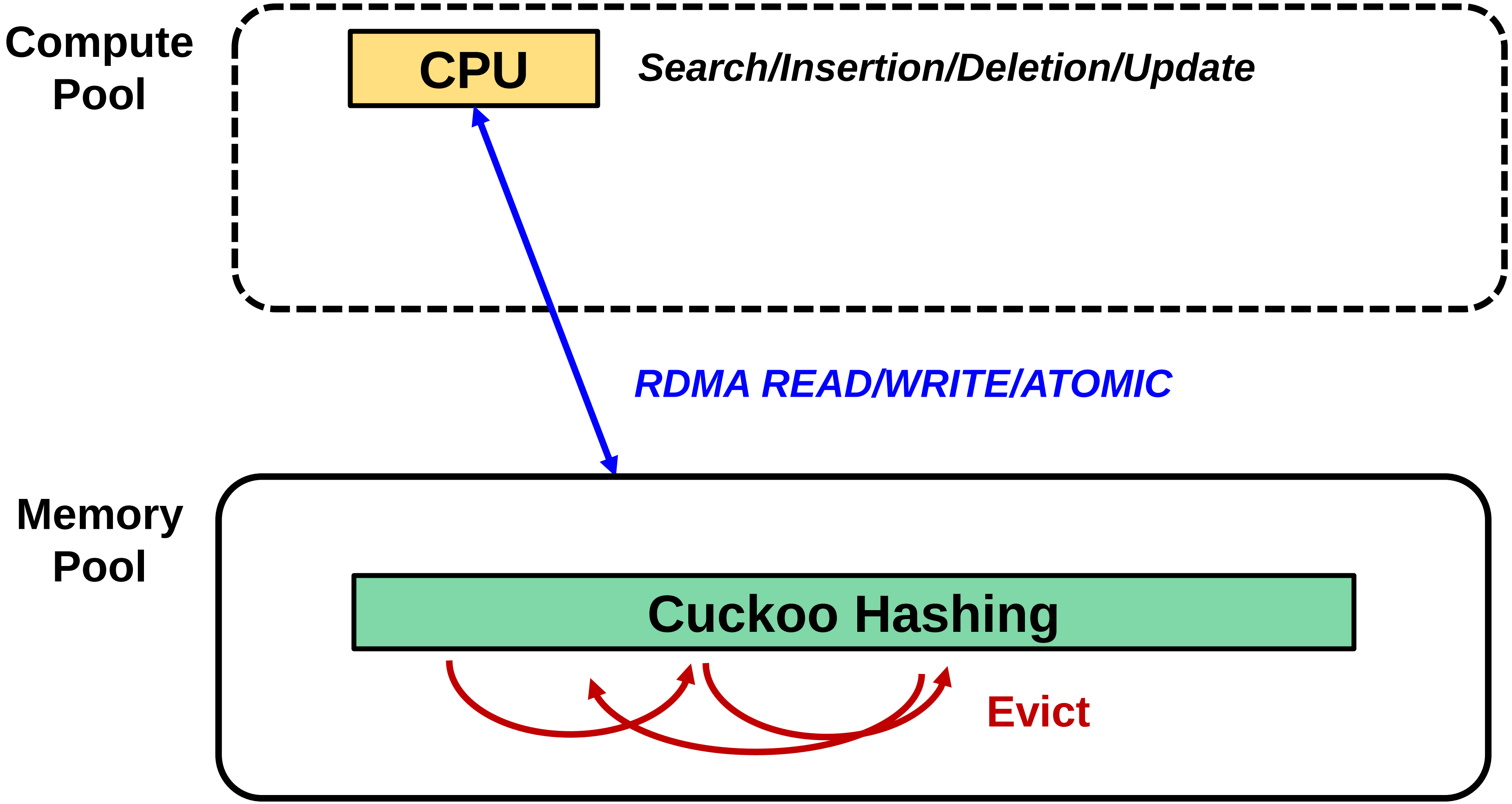

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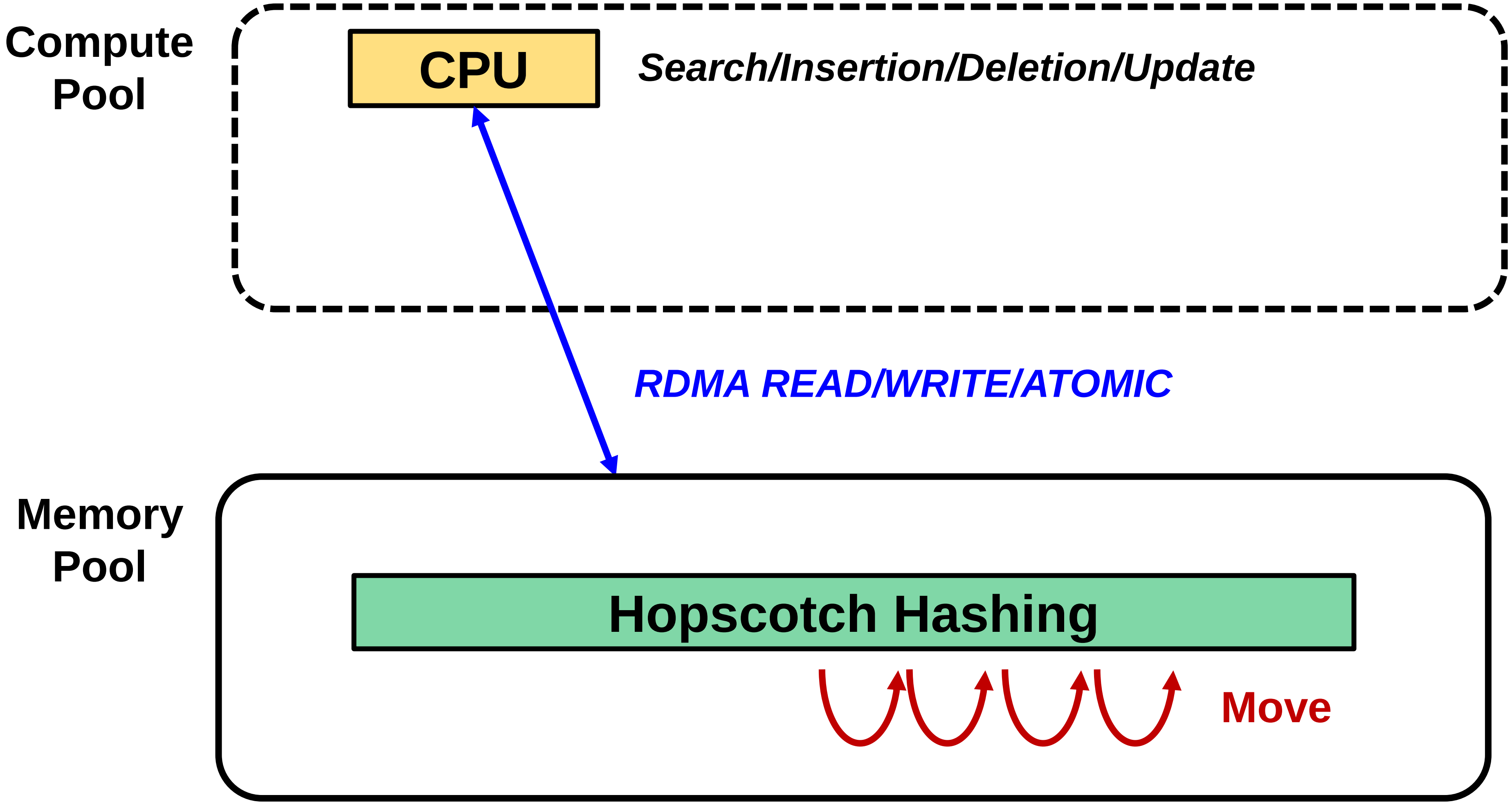

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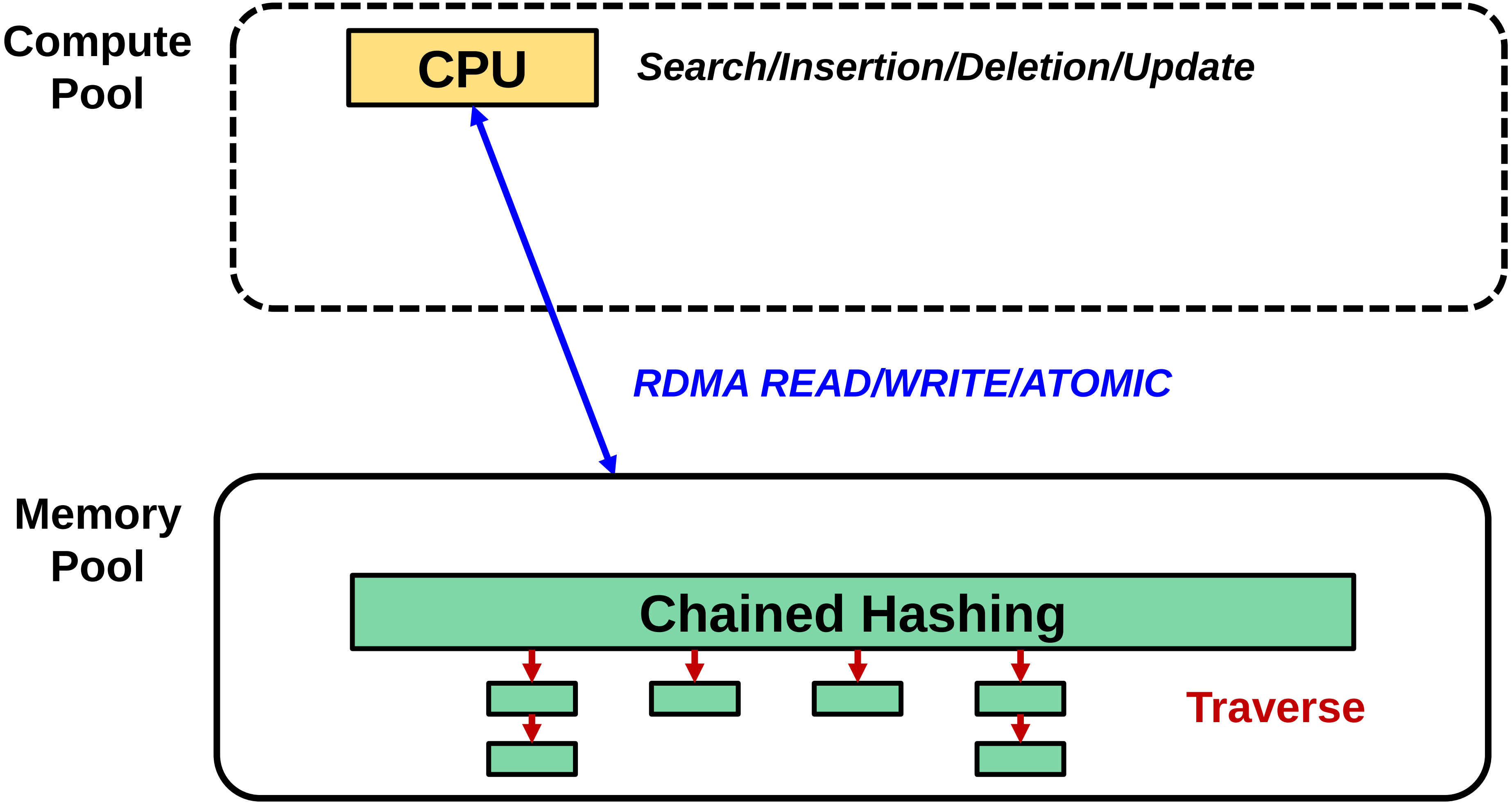
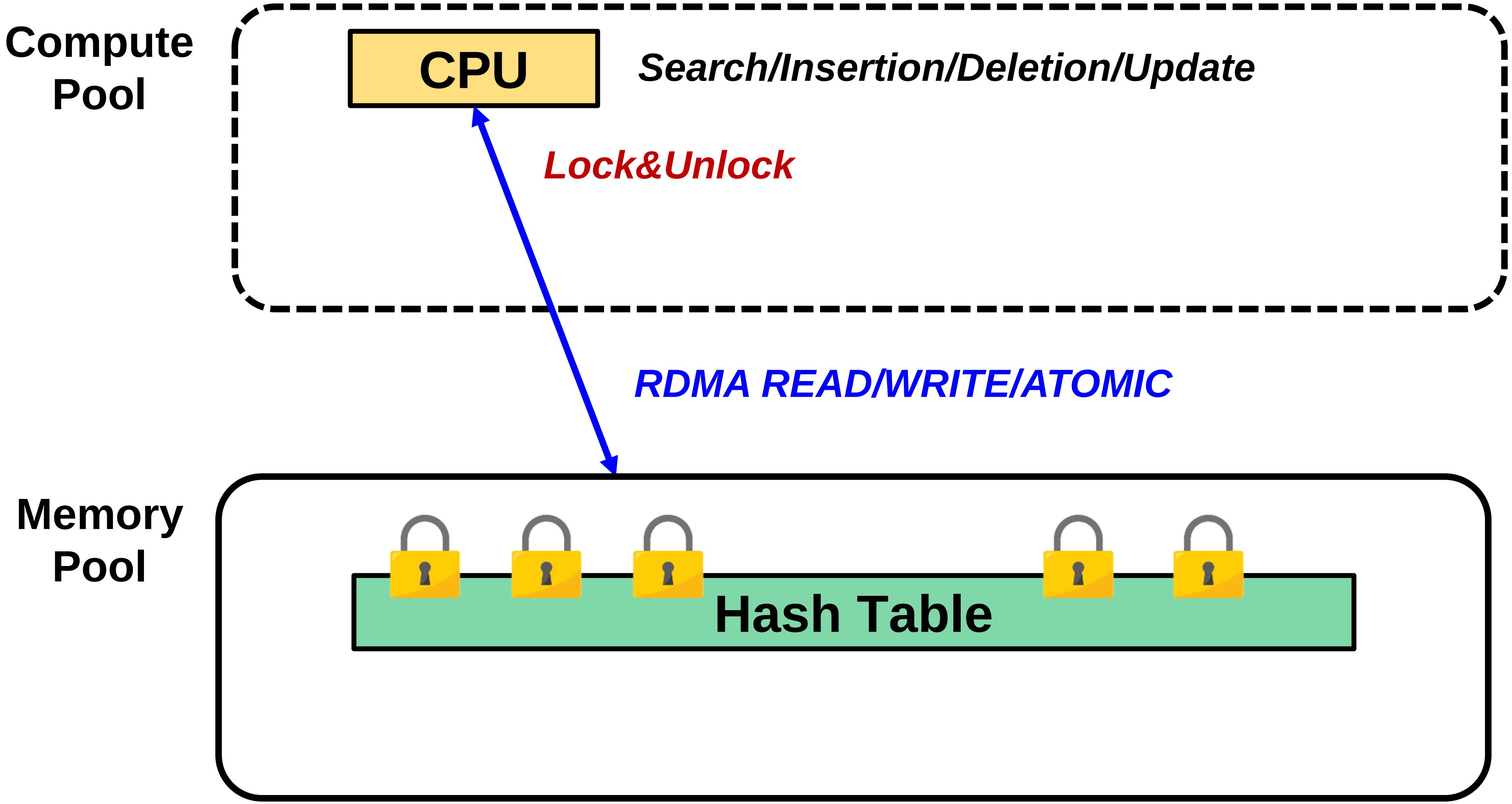


Challenge 1: Many remote reads&writes for handling hash collisions

Challenge 2: Concurrency Control



Challenge 2: Locking has high overhead

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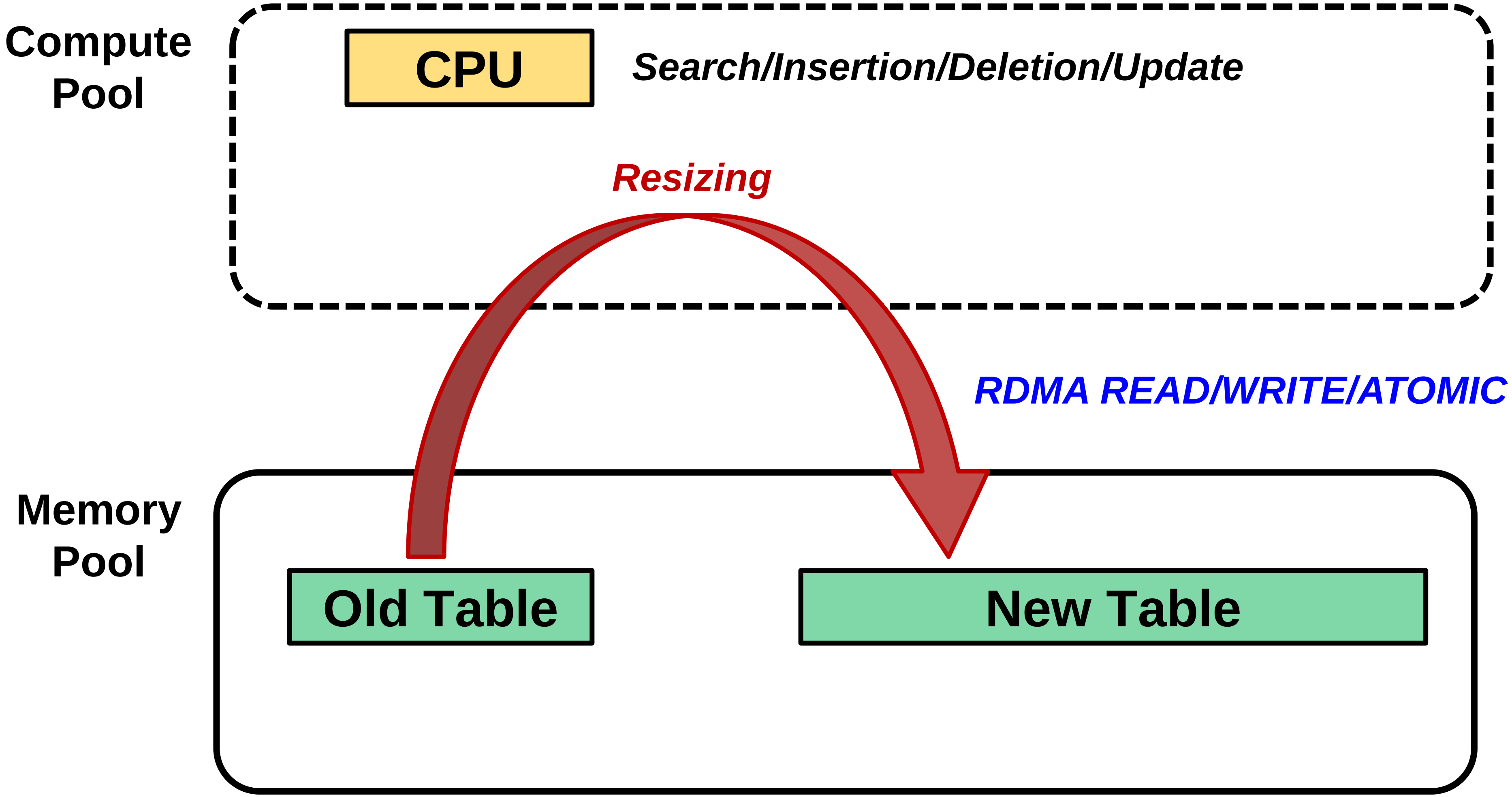
Challenge 3: Remote Resizing



Challenge 3: Moving items from the old table to the new table

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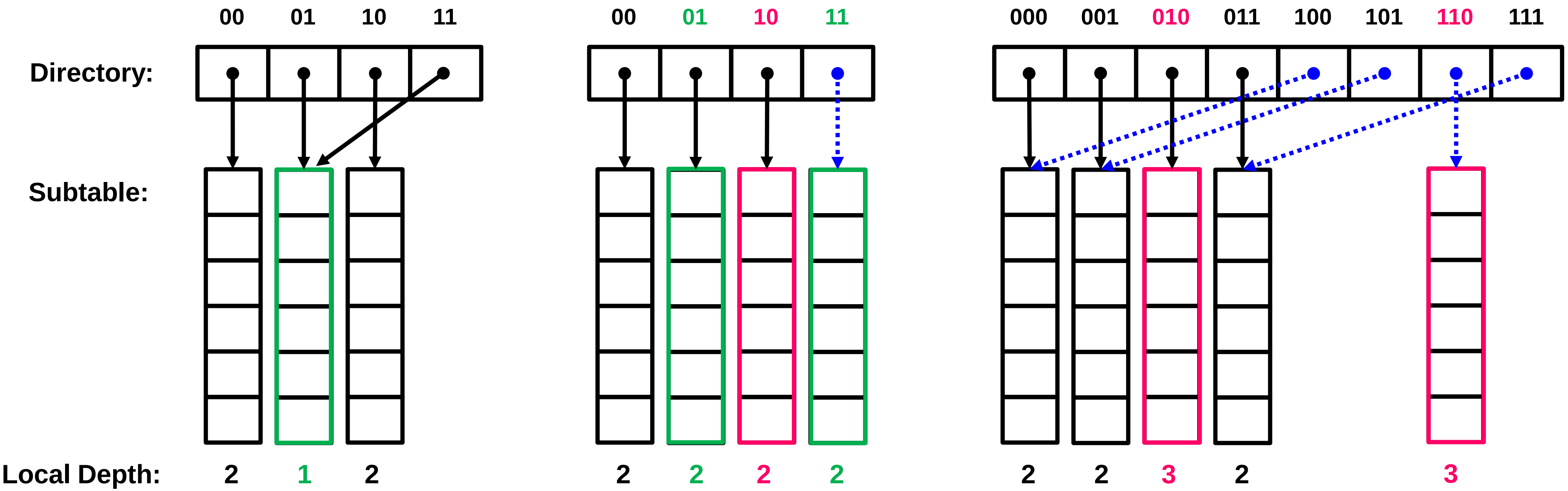
Challenge 3: Extendible Resizing



(a) A hash table (global depth = 2)

(b) Subtable resizing (global depth = 2)

(c) Directory resizing (global depth = 3)

- Challenge of using extendible resizing in disaggregated memory
  - One extra RDMA for accessing the directory

Challenge Summary

1. **Many remote reads&writes for handling hash collisions**
   - Cuckoo hashing, hopscotch hashing, chained hashing

2. **Concurrency control for remote access**
   - One RDMA RTT for locking or unlocking

3. **Tricky remote resizing of hash tables**
   - One extra RDMA RTT for accessing the directory

RDMA-Conscious Extendible (RACE) Hashing

1. **Many remote reads&writes for handling hash collisions**
   - Cuckoo hashing, hopscotch hashing, chained hashing
   - ***Solution**: One-sided RDMA-conscious table structure*

2. **Concurrency control for remote access**
   - One RDMA RTT for locking or unlocking
   - ***Solution**: Lock-free remote concurrency control*

3. **Tricky remote resizing of hash tables**
   - One extra RDMA RTT for accessing the directory
   - ***Solution**: Extendible remote resizing with stale-read caching*

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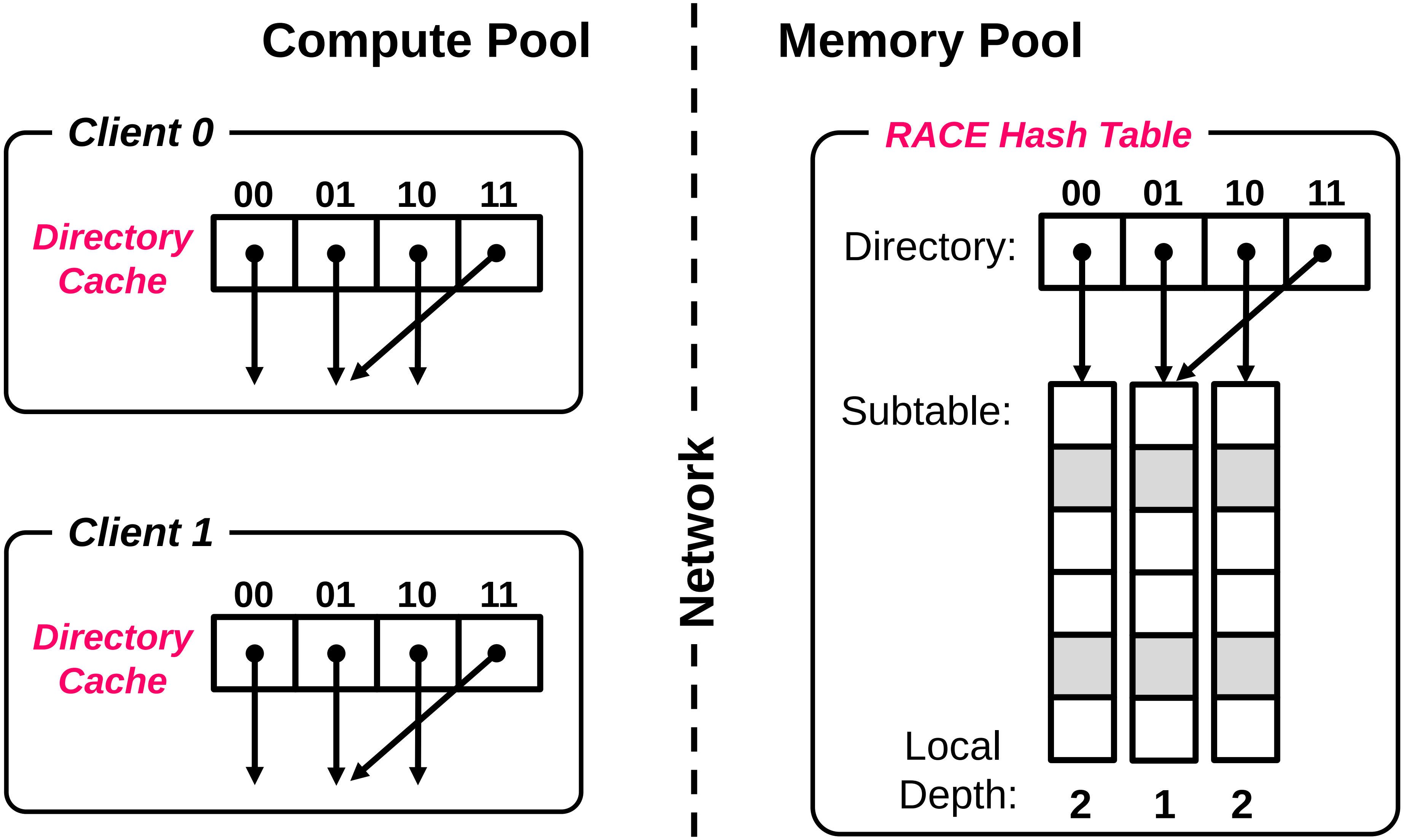
Architectural Overview



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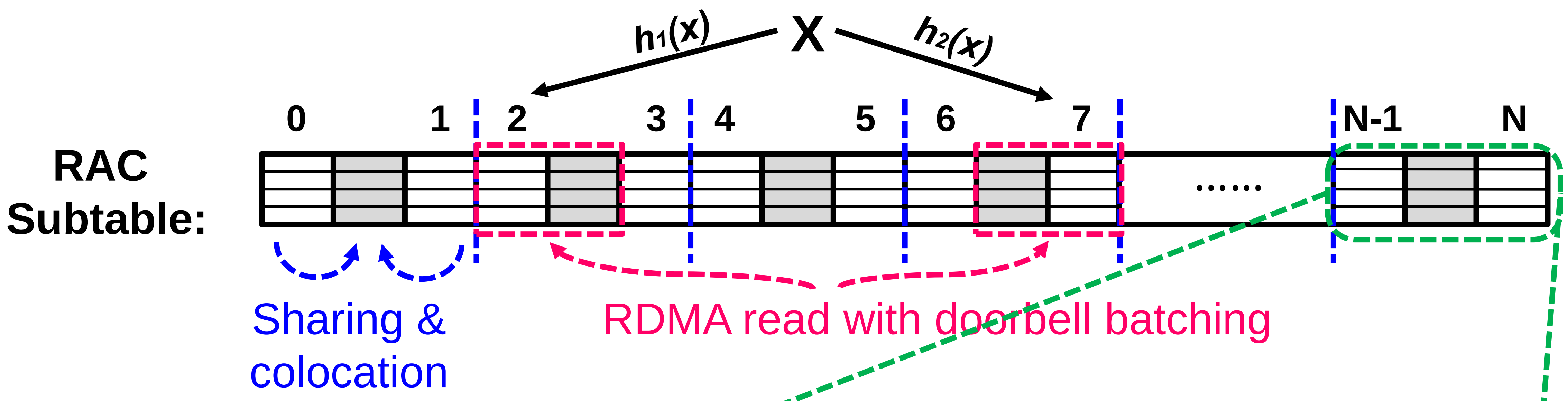
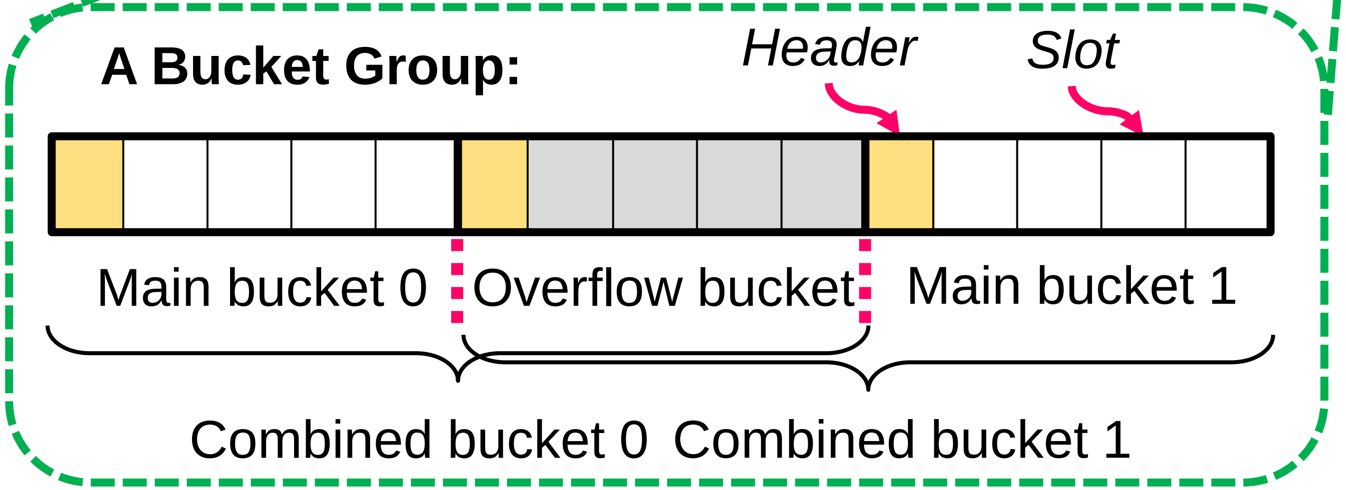
One-sided RDMA-Conscious (RAC) Subtable

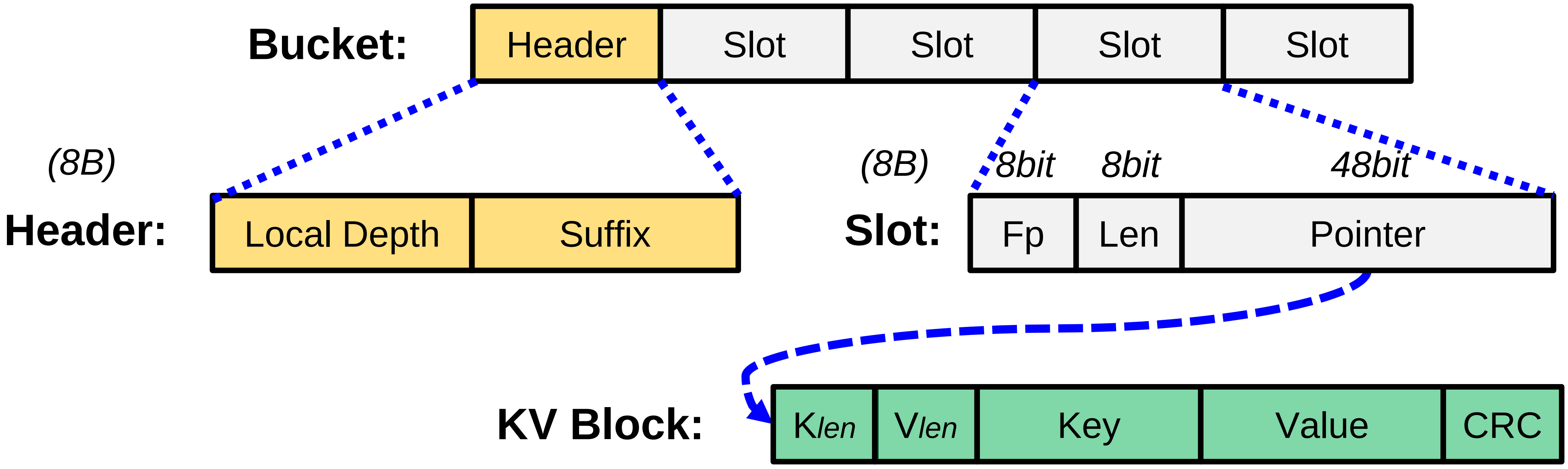


- **Design decisions**
  - **Associativity**
  - **Two choices**
  - **Overflow colocation**
- **Strengths**
  - **RDMA-search friendly**
  - **RDMA-IDU friendly**
  - **High memory efficiency**



Lock-free Remote Concurrency Control

- Bucket Structure: supporting the RDMA CAS



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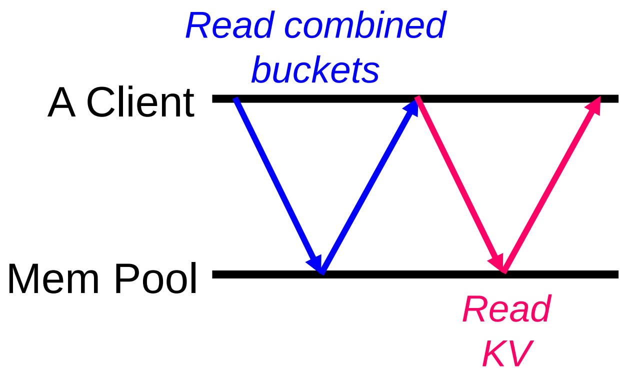
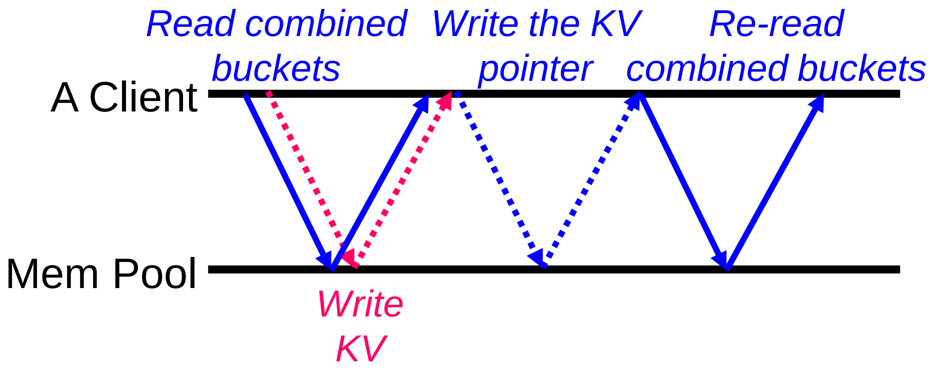
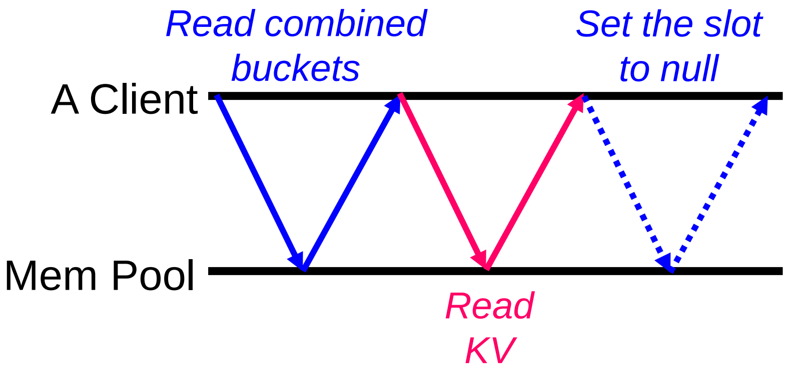
Lock-free Remote Concurrency Control



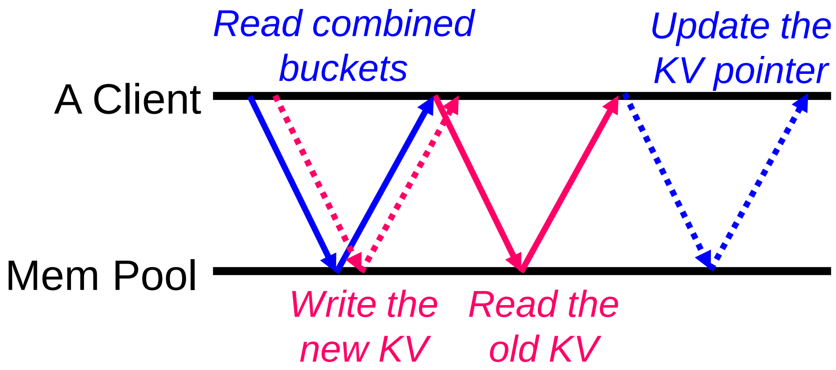
(a) Search



(b) Insertion

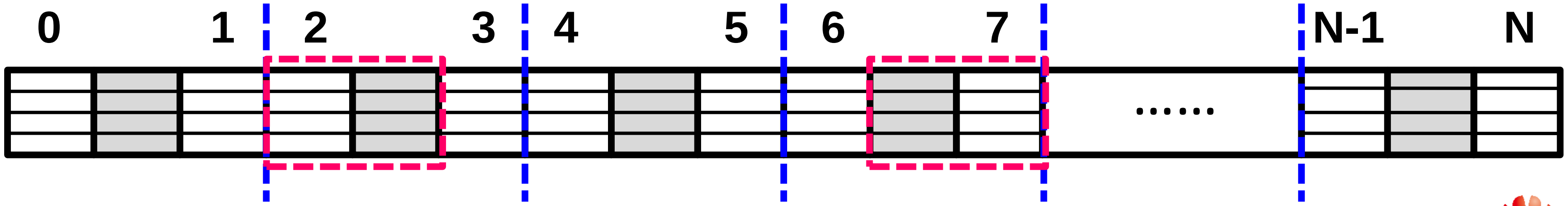


(c) Deletion



(d) Update

RAC Subtable:



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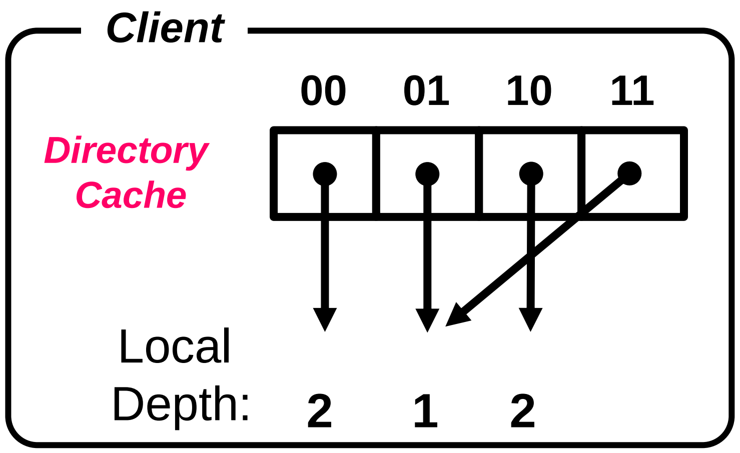
Extendible Remote Resizing

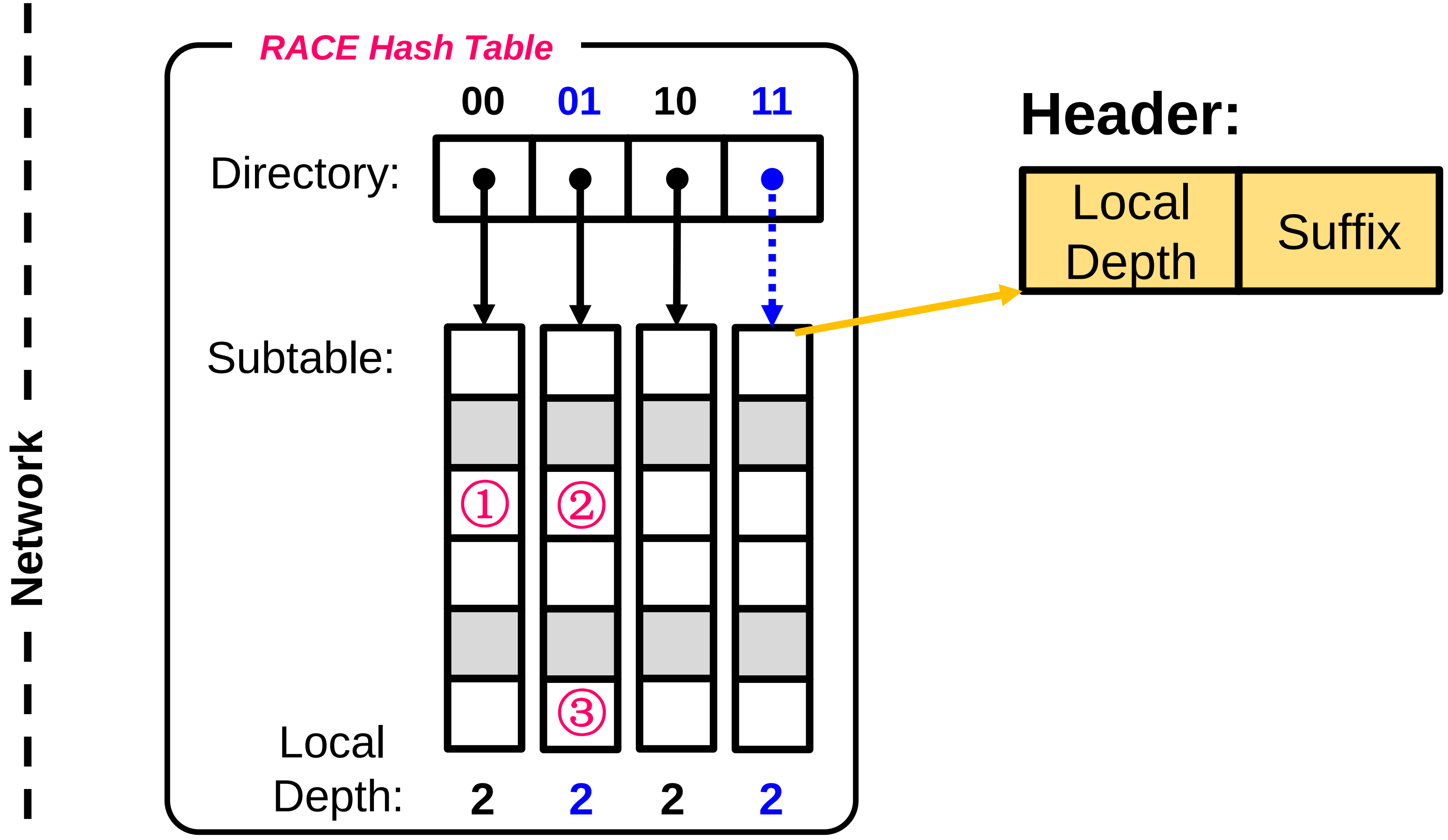
- Client Directory Cache with Stale Reads

Compute Pool | **Memory Pool**



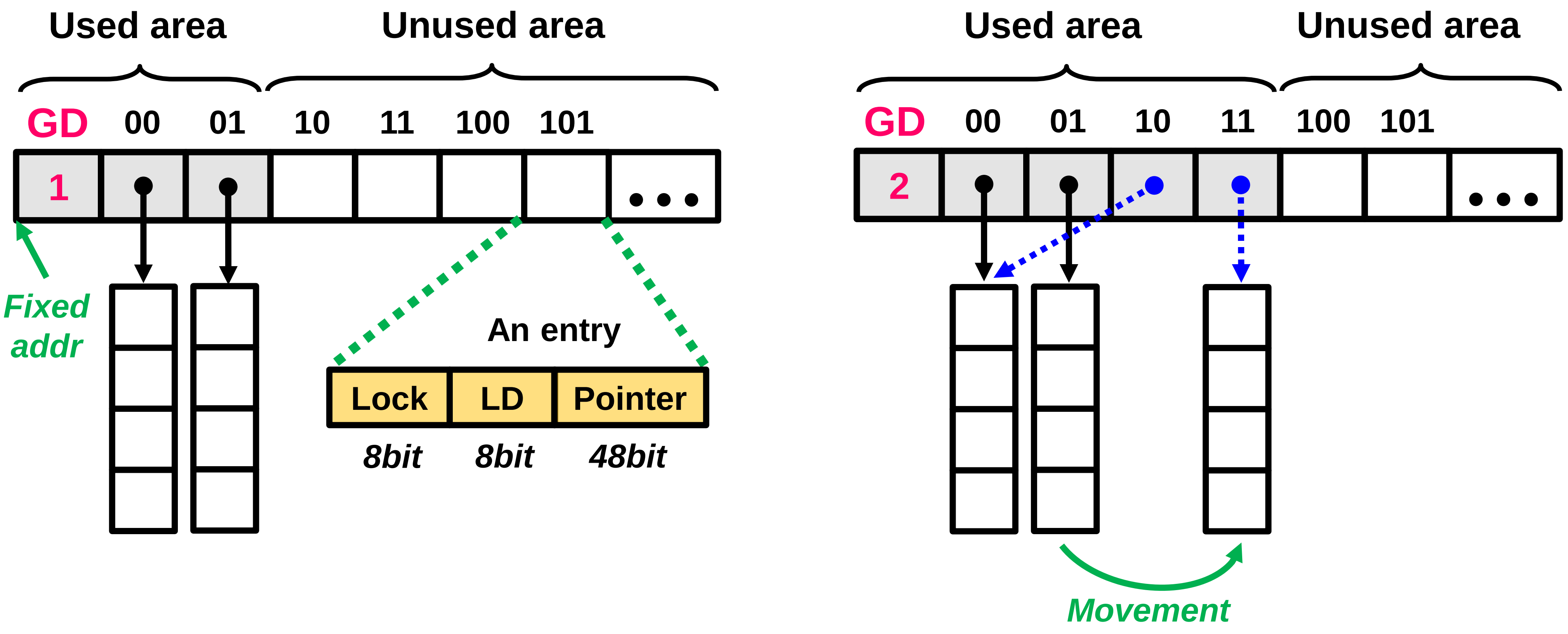
Different cases of stale reads:

	Key	Bucket		Correct?
①	XX00	2	00	Yes
②	XX01	2	01	Yes
③	XX11	2	01	No



Extendible Remote Resizing

- Resize a directory



(a) Before the directory resizing

(b) After the directory resizing

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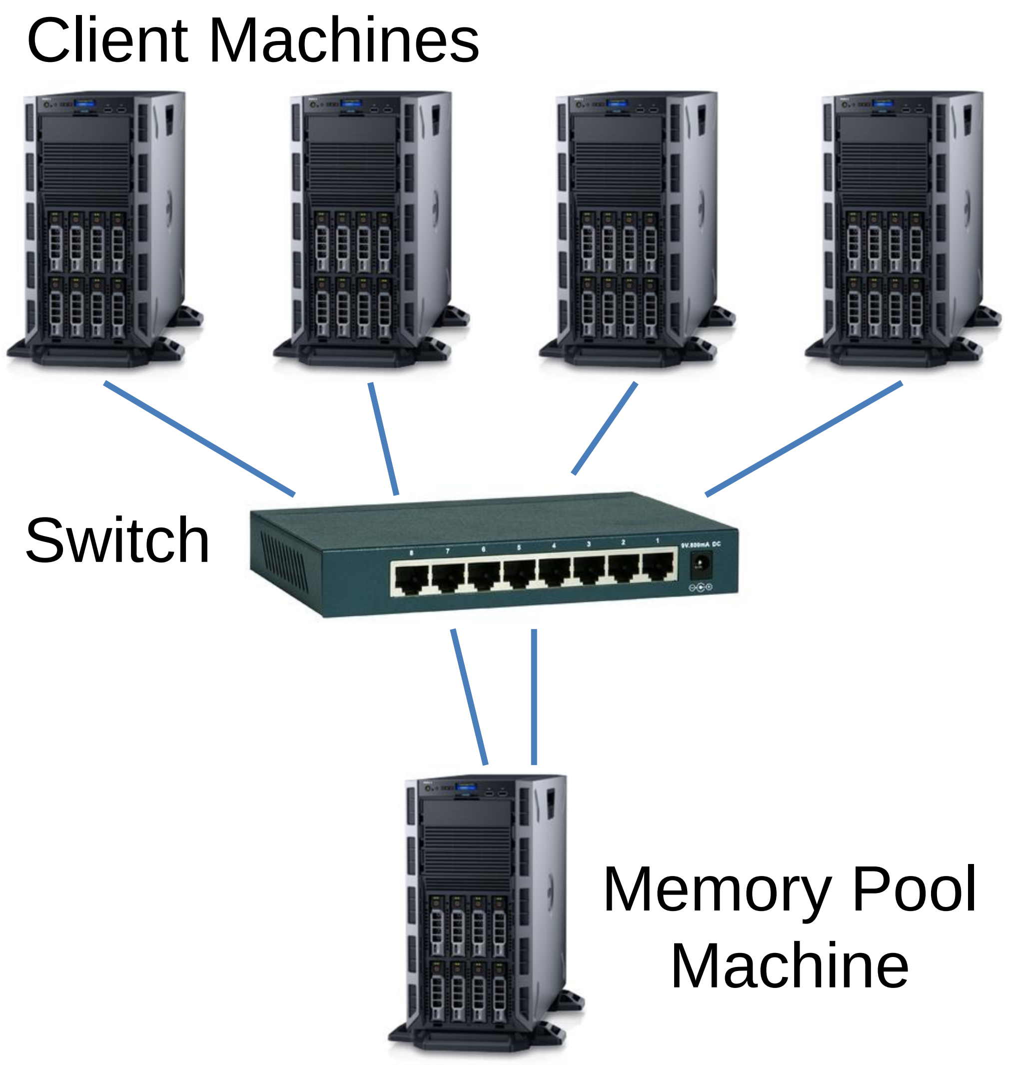
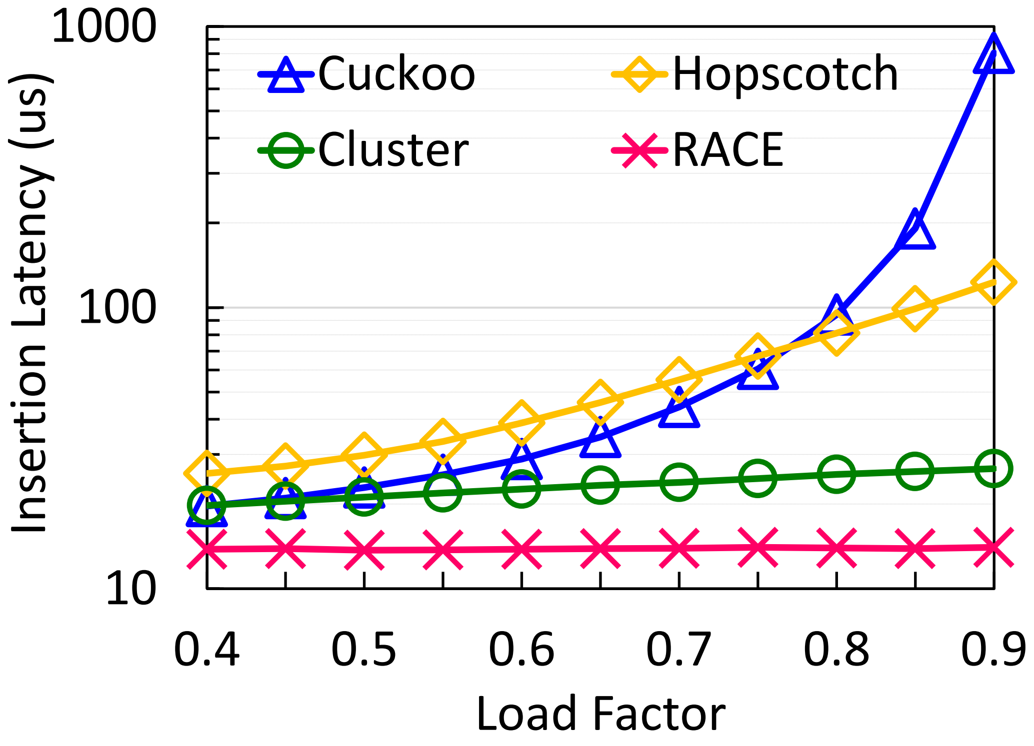
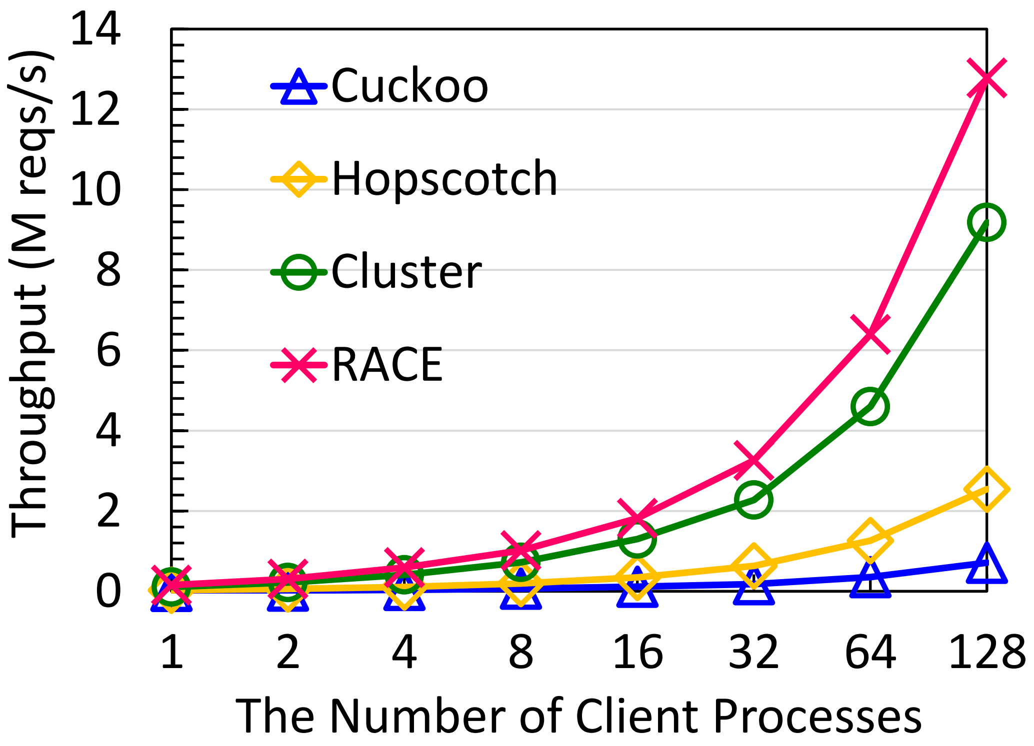
Experimental Setup

- **Testbed**
  - 4 client machines + 1 memory machine
- **Workloads**
  - YCSB, 16B key + 32B value
- **Comparisons**
  - Pilaf cuckoo hashing [ATC'15]
  - FaRM hopscotch hashing [NSDI'14]
  - DrTM cluster hashing [SOSP'15]



Insertion





- RACE hashing improves the insertion throughput by 1.4~16.9×

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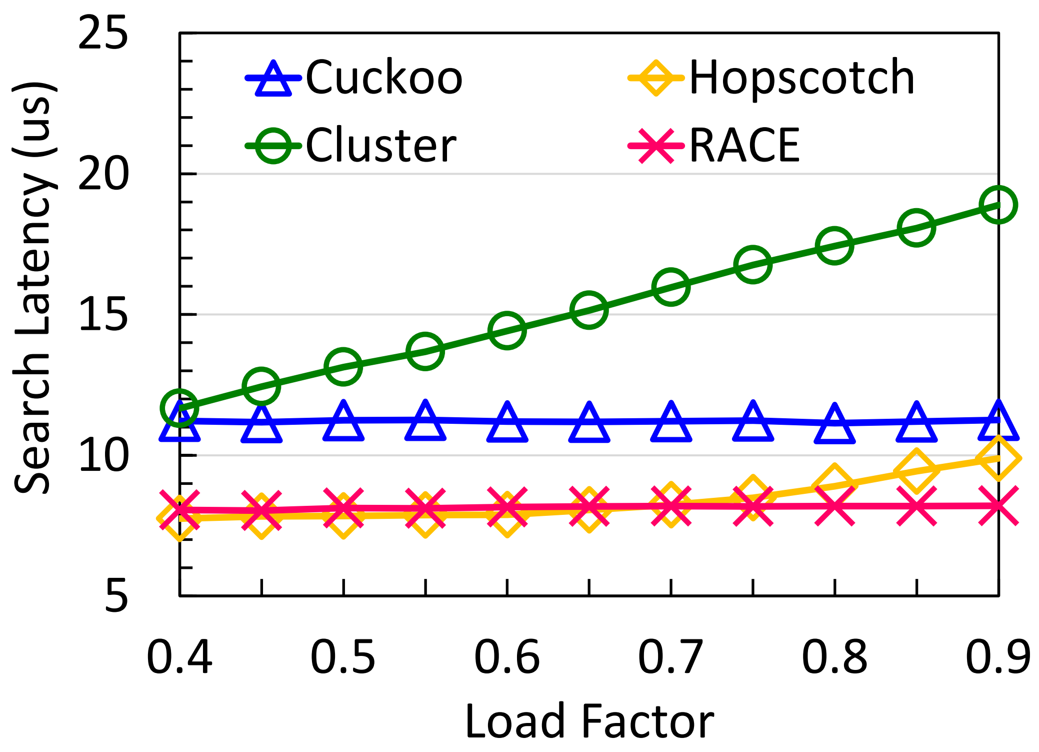
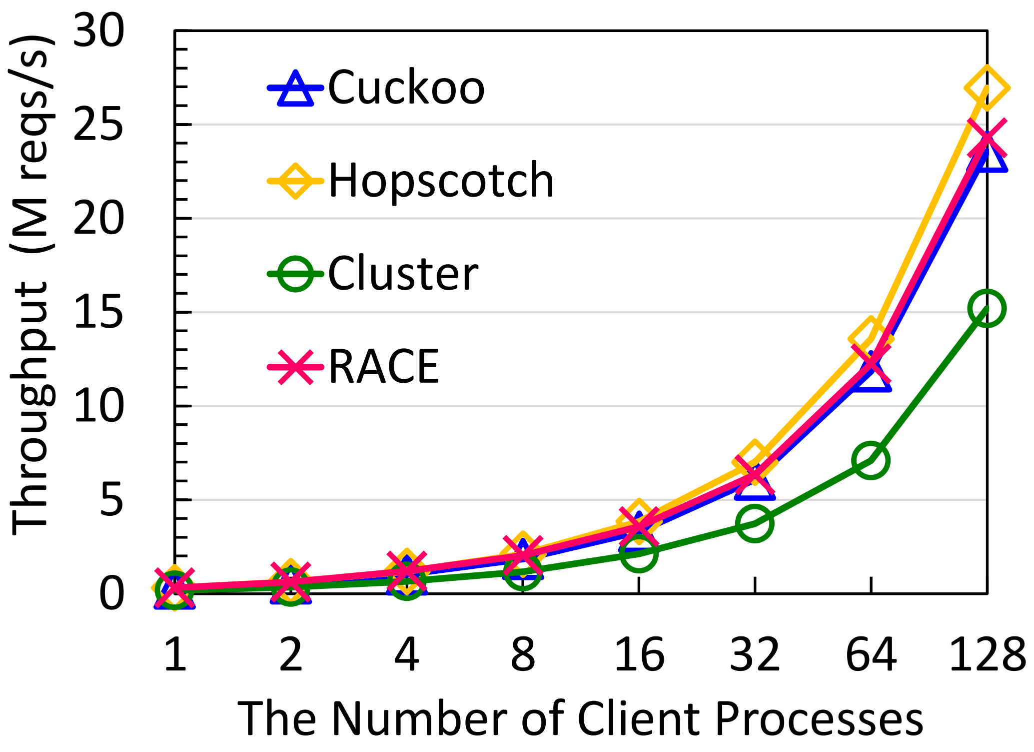
Search

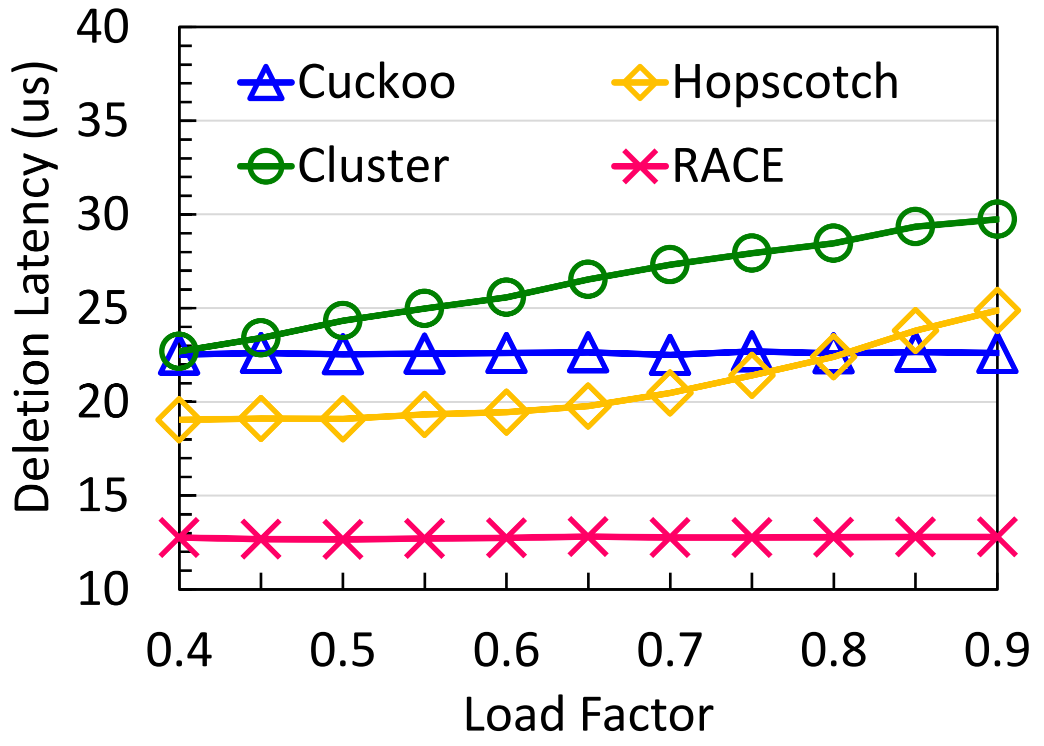


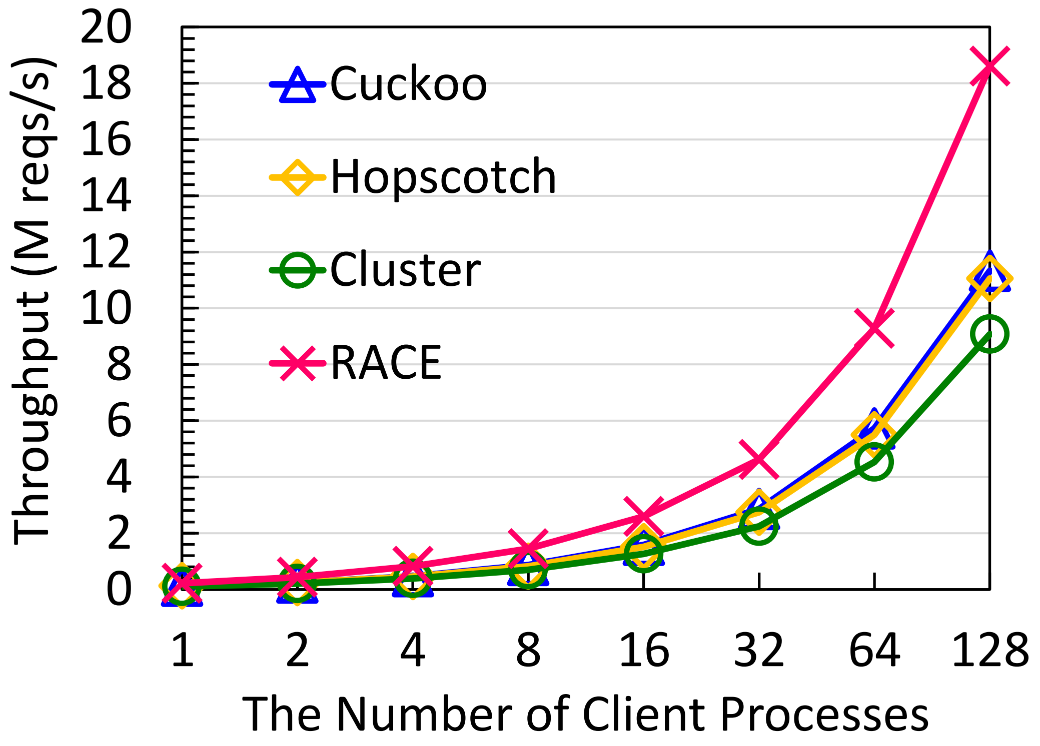
25
20
15
10
5
Search Latency (us)
Cuckoo
Hopscotch
Cluster
RACE
0.4
0.5
0.6
0.7
0.8
0.9
Load Factor



30
25
20
15
10
5
0
Throughput (M reqs/s)
Cuckoo
Hopscotch
Cluster
RACE
1
2
4
8
16
32
64
128
The Number of Client Processes

Deletion





- RACE hashing improves the deletion throughput by 1.7~2.1×

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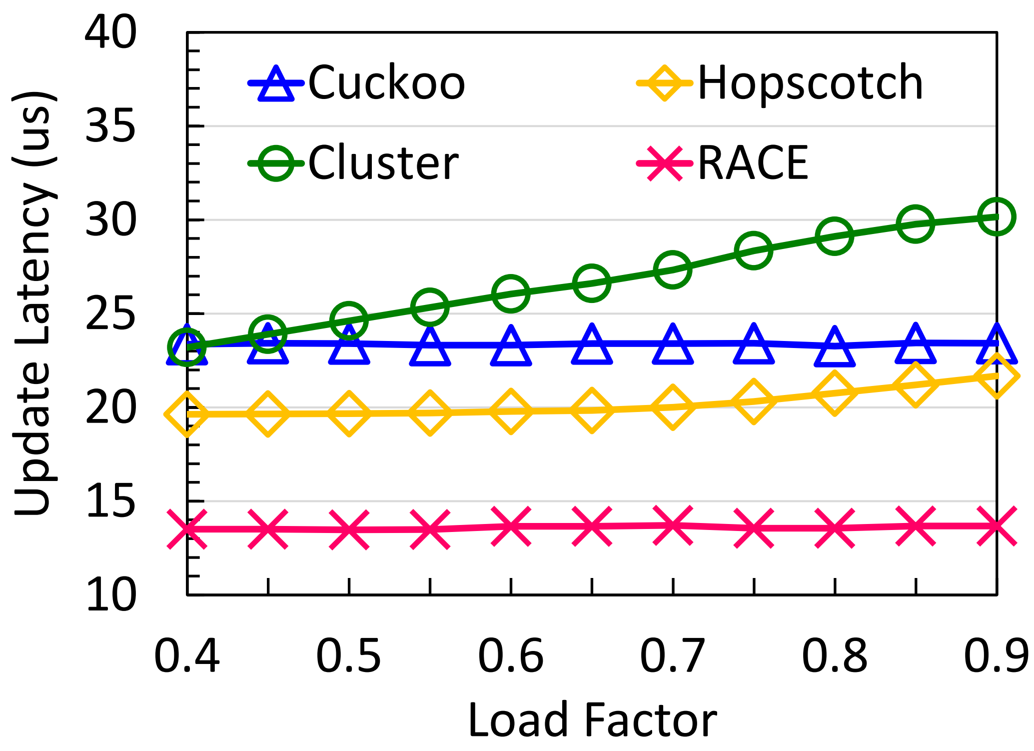
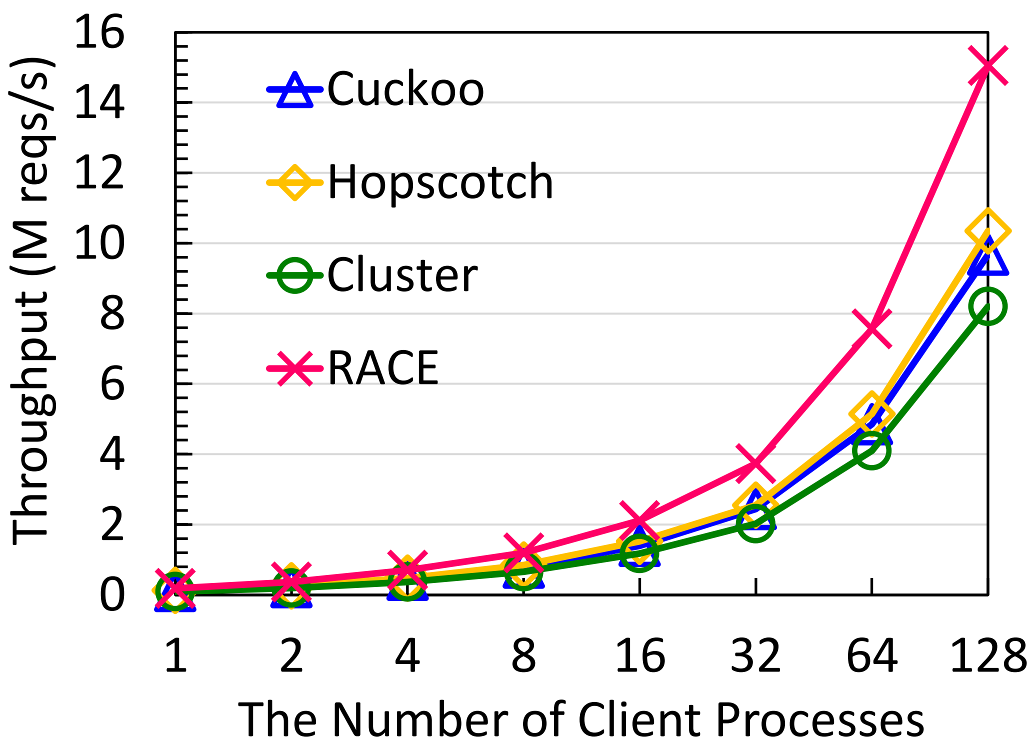
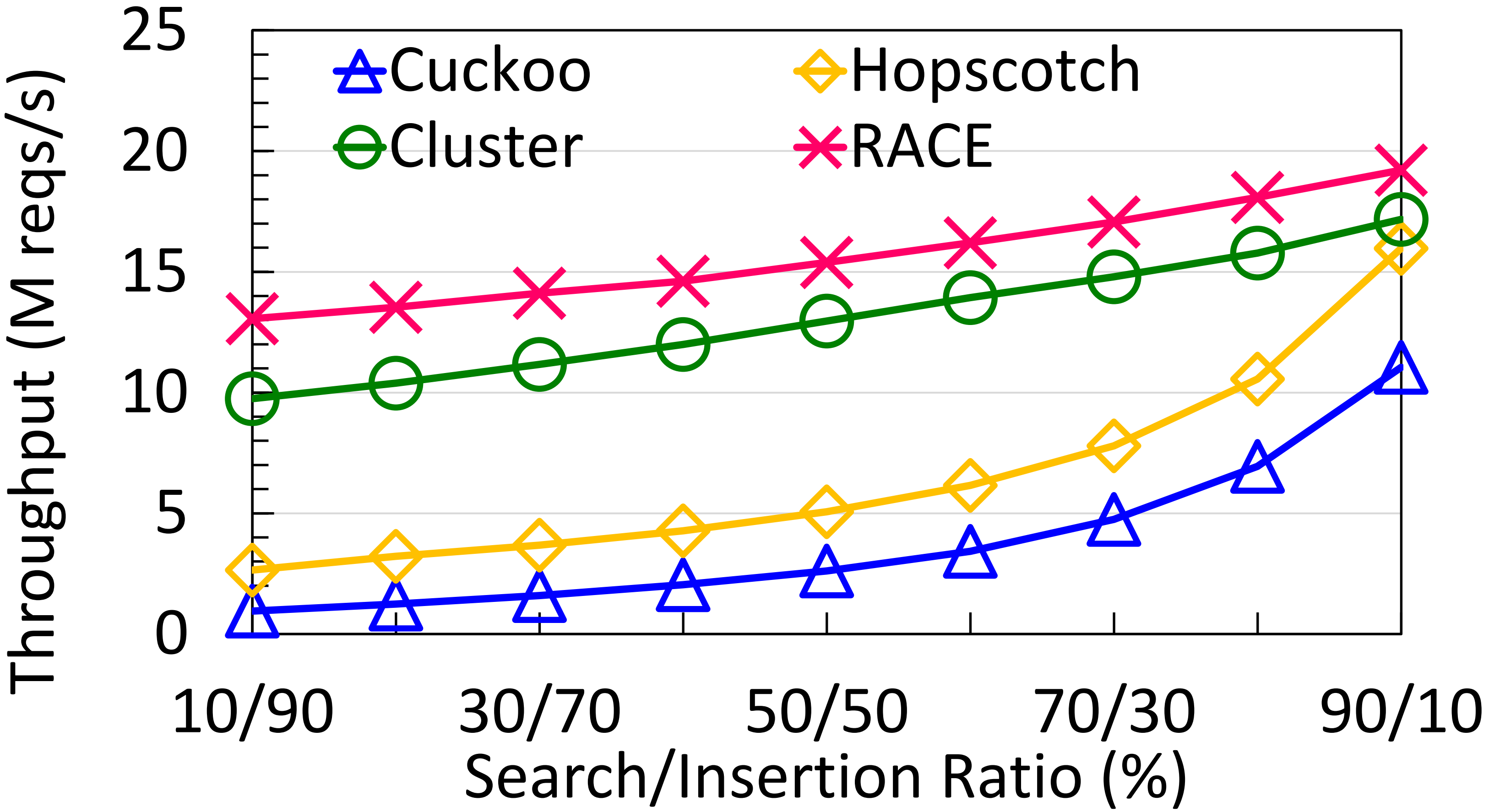
Update





- RACE hashing improves the deletion throughput by 1.5~1.9×

YCSB Hybrid Workloads



- RACE hashing speeds up the YCSB hybrid workloads by 1.4~1.3.7×

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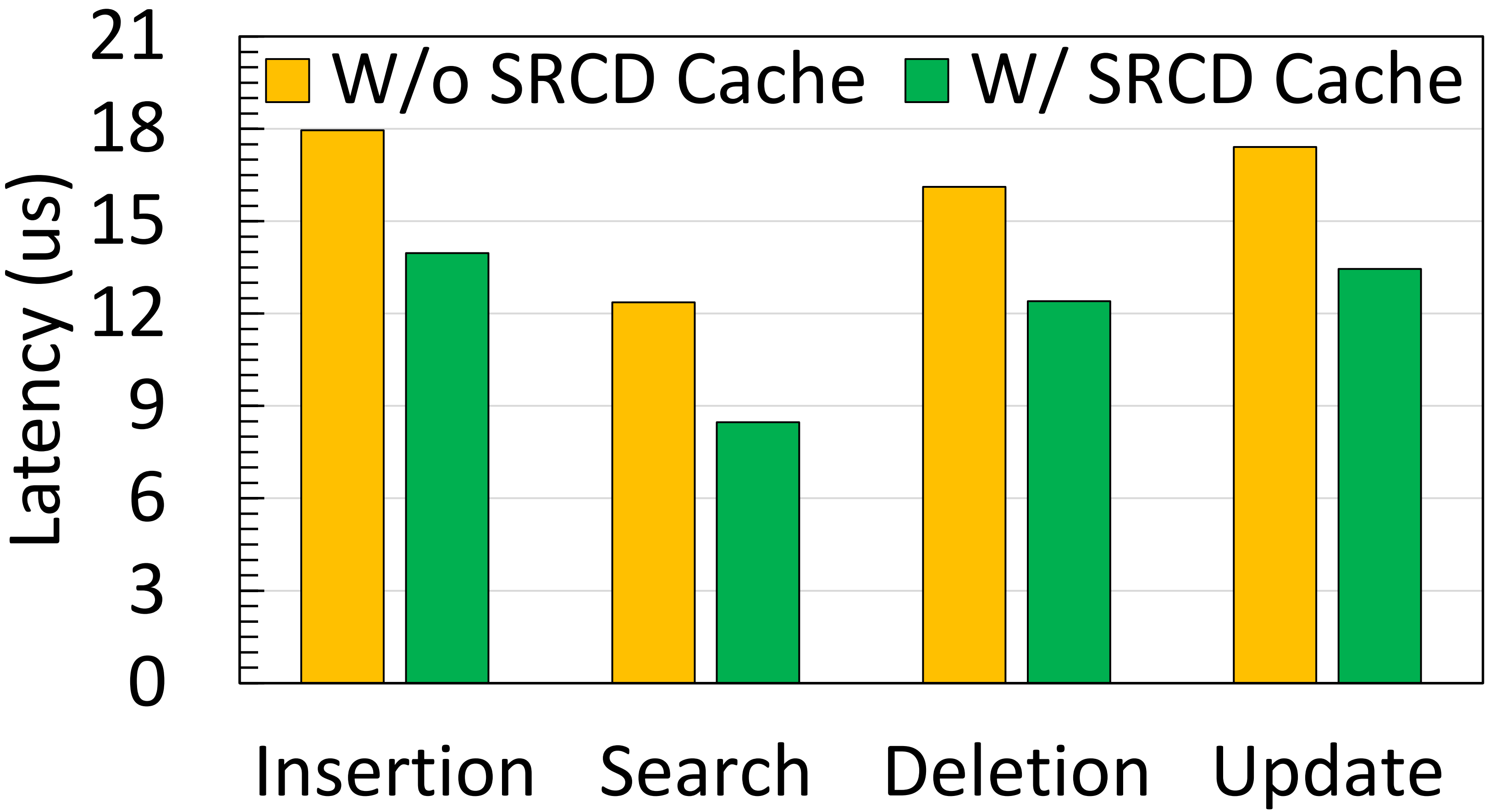
The Stale-read Client Directory (SRCD) Cache



- The SRCD cache reduces the request latency by 23%~32%

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Conclusion

- Traditional distributed in-memory hashing indexes become inefficient in disaggregated memory
  - Many remote access, concurrency access, resizing
- We propose RACE hashing, the first hashing index designed for disaggregated memory
  - One-sided RDMA-conscious table structure
  - Lock-free remote concurrency control
  - Extendible remote resizing
- RACE Hashing outperforms state-of-the-art distributed in-memory hashing indexes by 1.4-13.7× in YCSB hybrid workloads

Thank you! Q&A