# Scalable Distributed Inverted List Indexes in Disaggregated Memory

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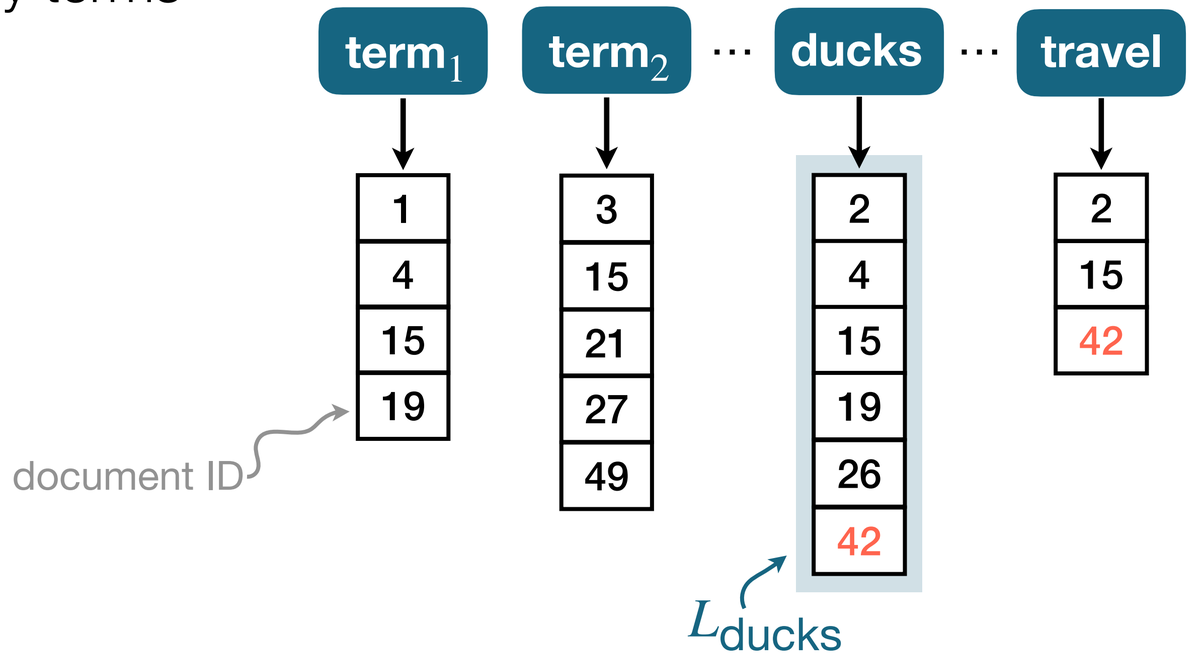
University of Salzburg, Austria
*June 13th, 2024*

# Inverted List Index

A term maps to an *ordered* list of documents that contain this term

**GOAL** Return all documents with common query terms

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- Information retrieval
- Graph analytics
- DB query processing
- Similarity search

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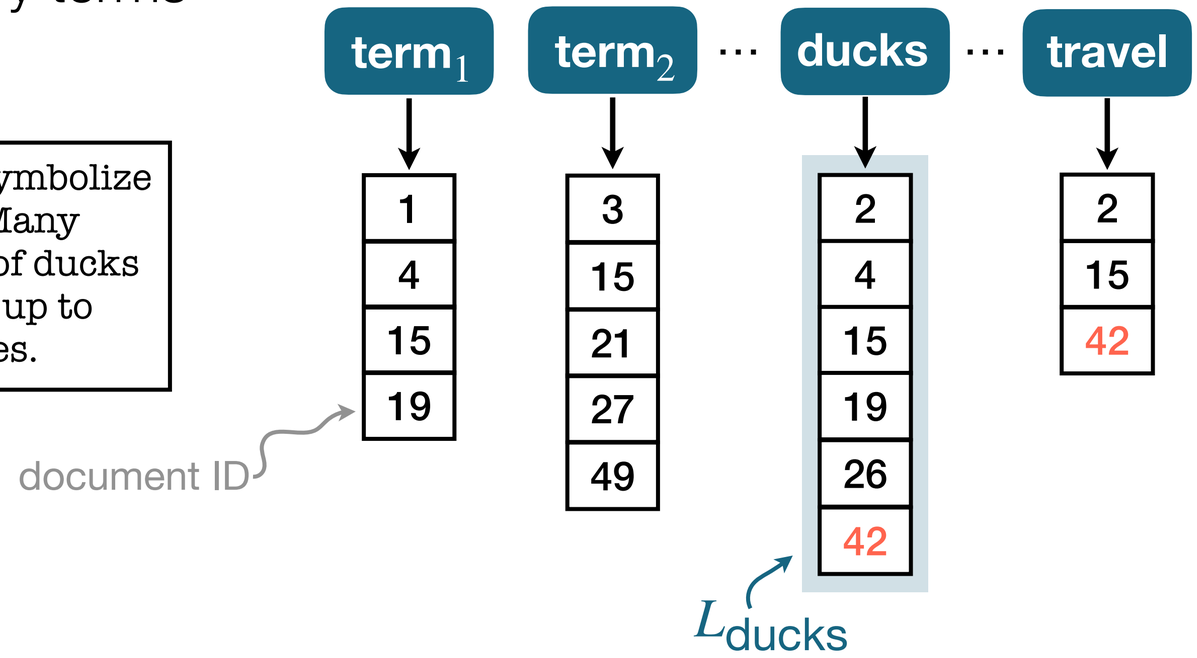
- **INSERT**:
  - For each term in document **D**:
    Append D.id to list $L_{\text{term}}$

**doc**$_{42}$

> **Ducks** symbolize **travel**. Many species of ducks migrate up to 800 miles.

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- **INSERT**:
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    Append D.id to list $L_{\text{term}}$

- **QUERY**:
  - Query terms: **ducks** **travel**
  - Result: $L_{\text{ducks}} \cap L_{\text{travel}} = \{2,15,42\}$

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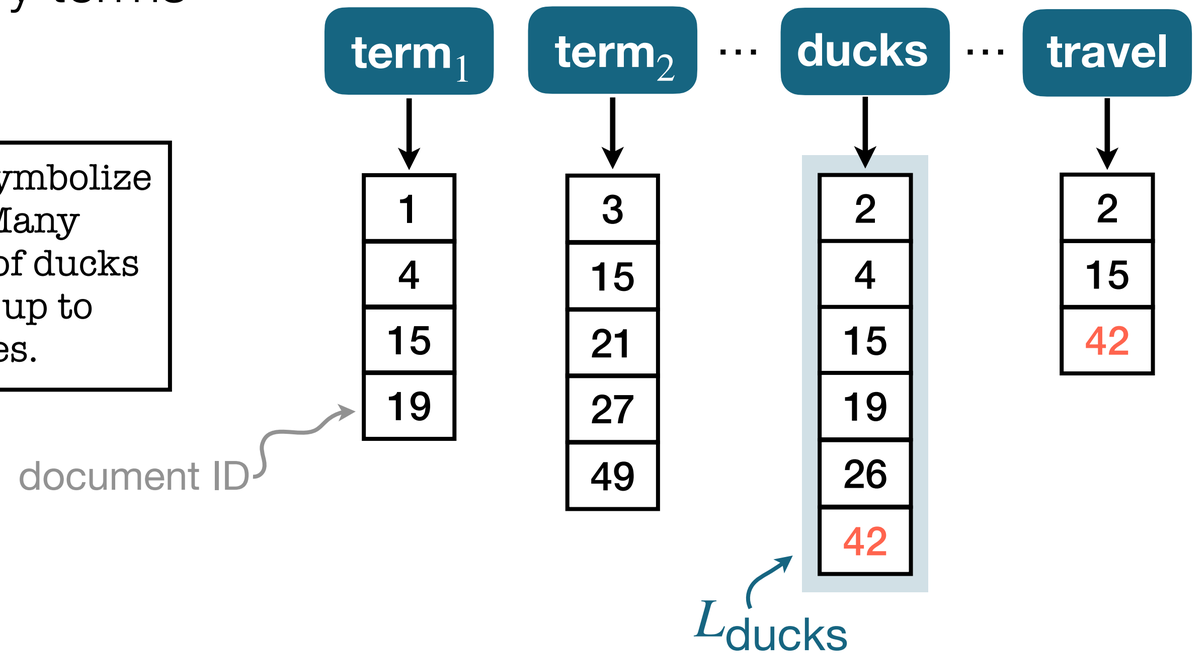


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Two major reasons:

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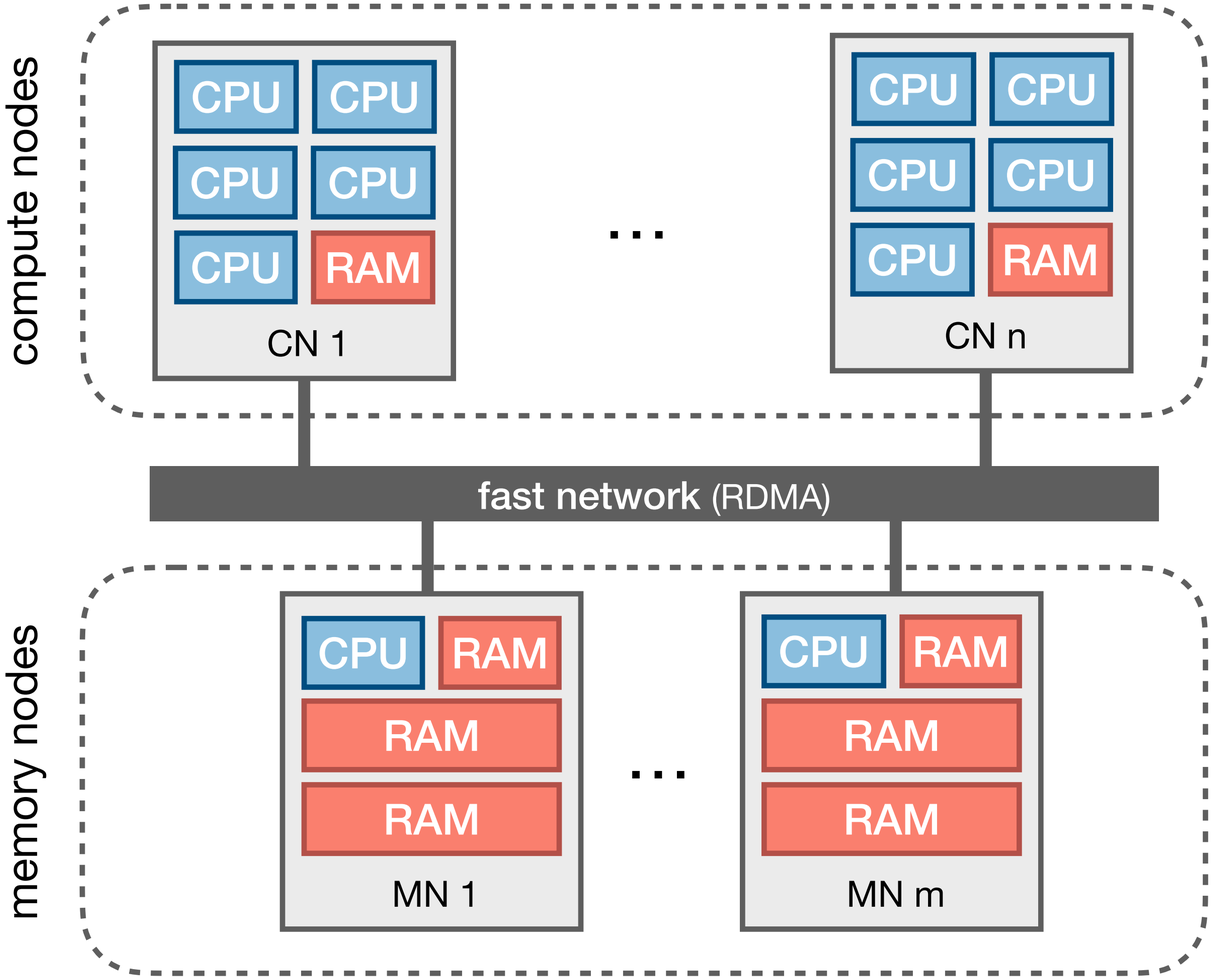
Architecture:

- ⛔ Classic monolithic server architectures underutilize CPU and memory

  CPU and RAM tightly coupled

# Disaggregated Memory (DM)

- High flexibility (elasticity)
- Cost-efficient resource utilization (sustainability)



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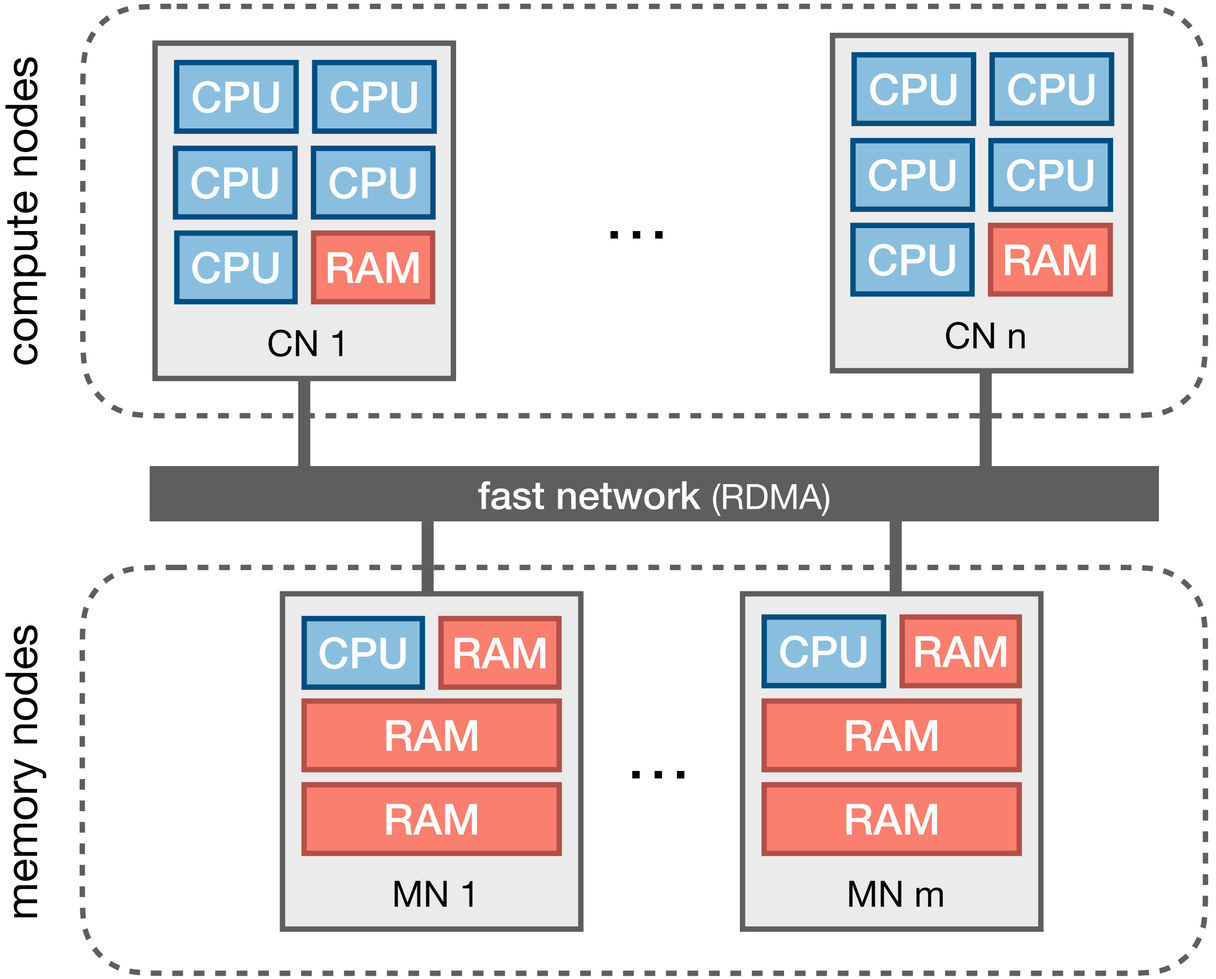

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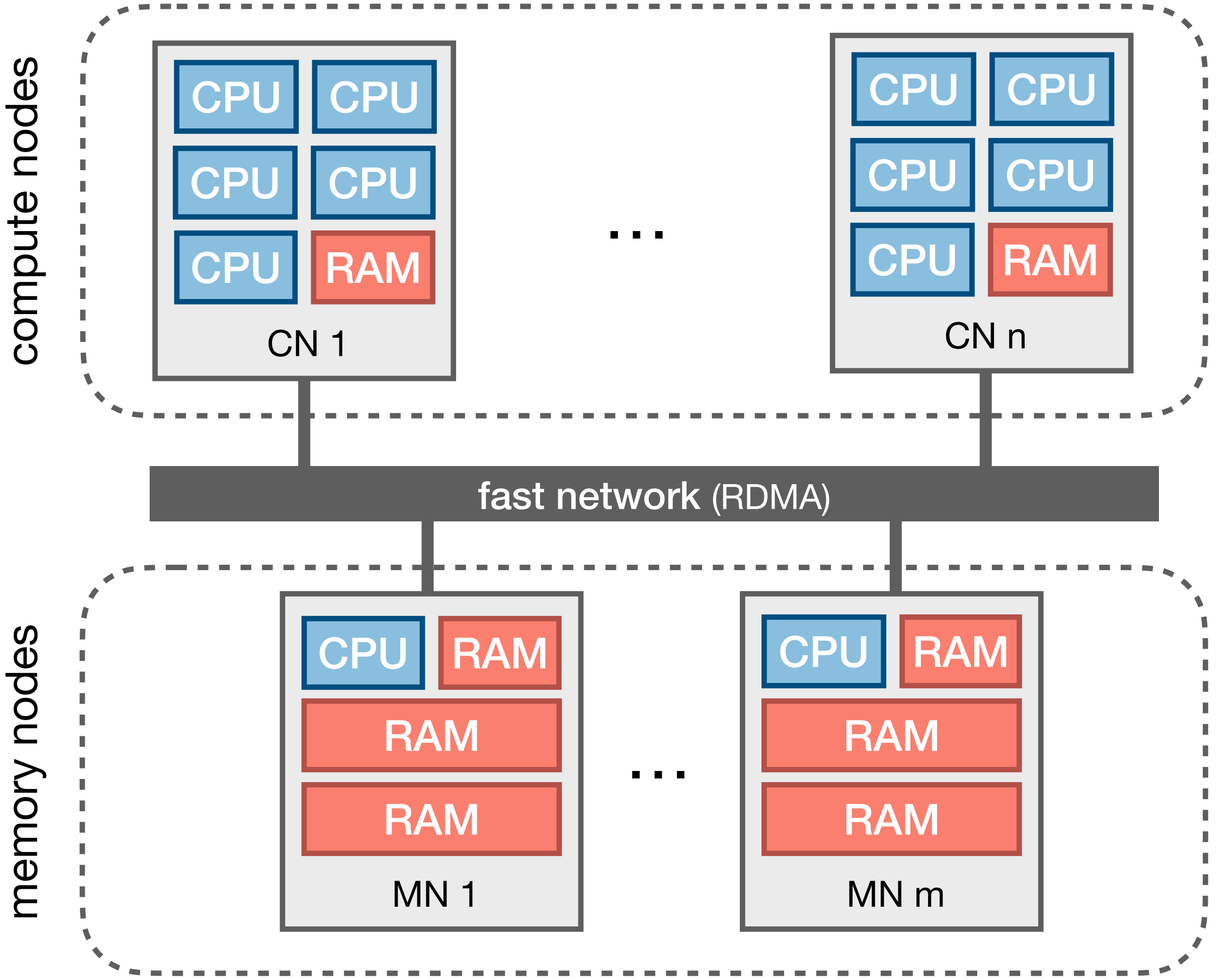
**RDMA**

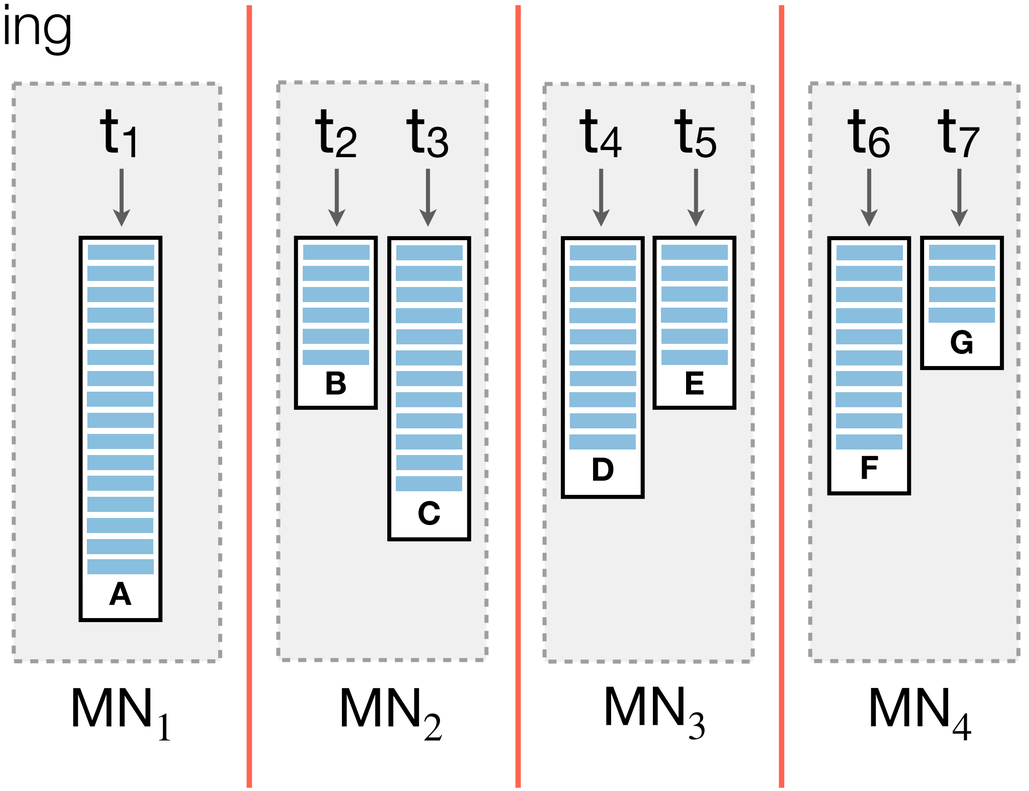
- Fully bypasses the remote CPU
- Low latency (single digit $\mu s$)



# Traditional Distribution Schemes

# Method 1: VERTICAL Partitioning

- Distribute complete lists across MNs using load balancing



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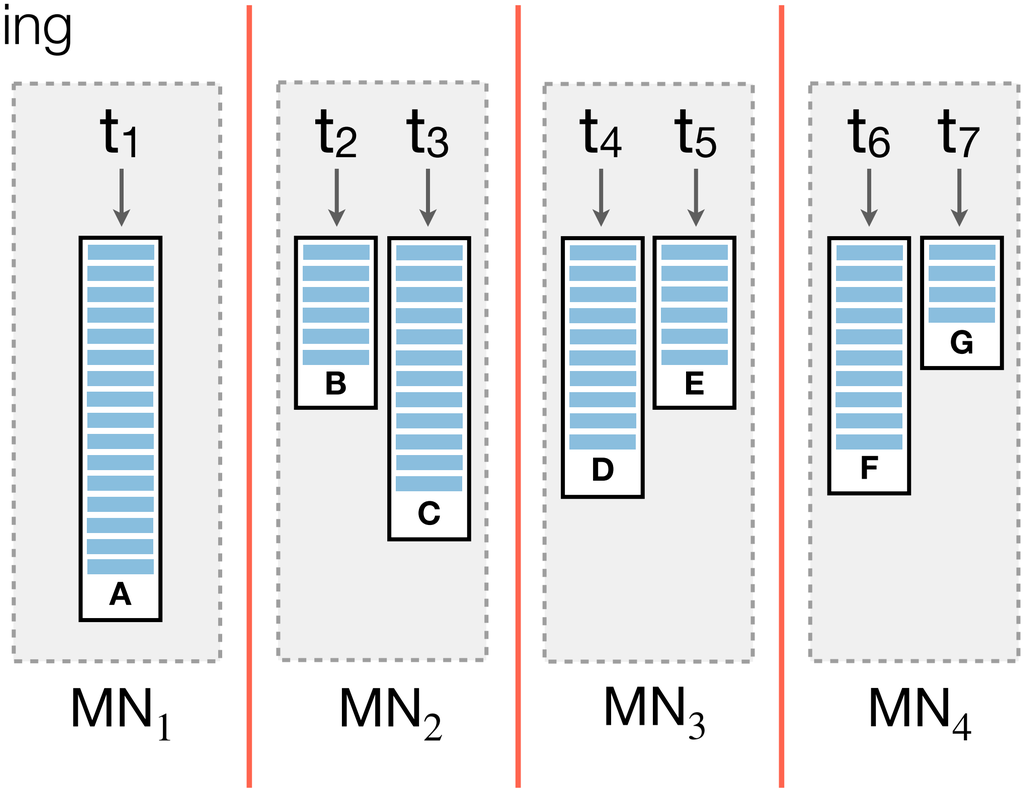


Query: $\{t_1, t_2, t_5\}$

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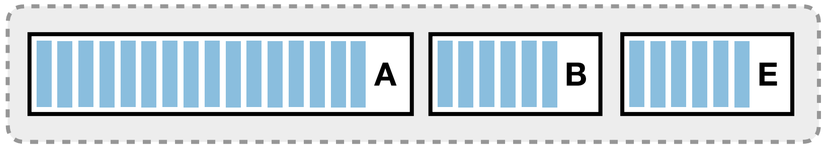

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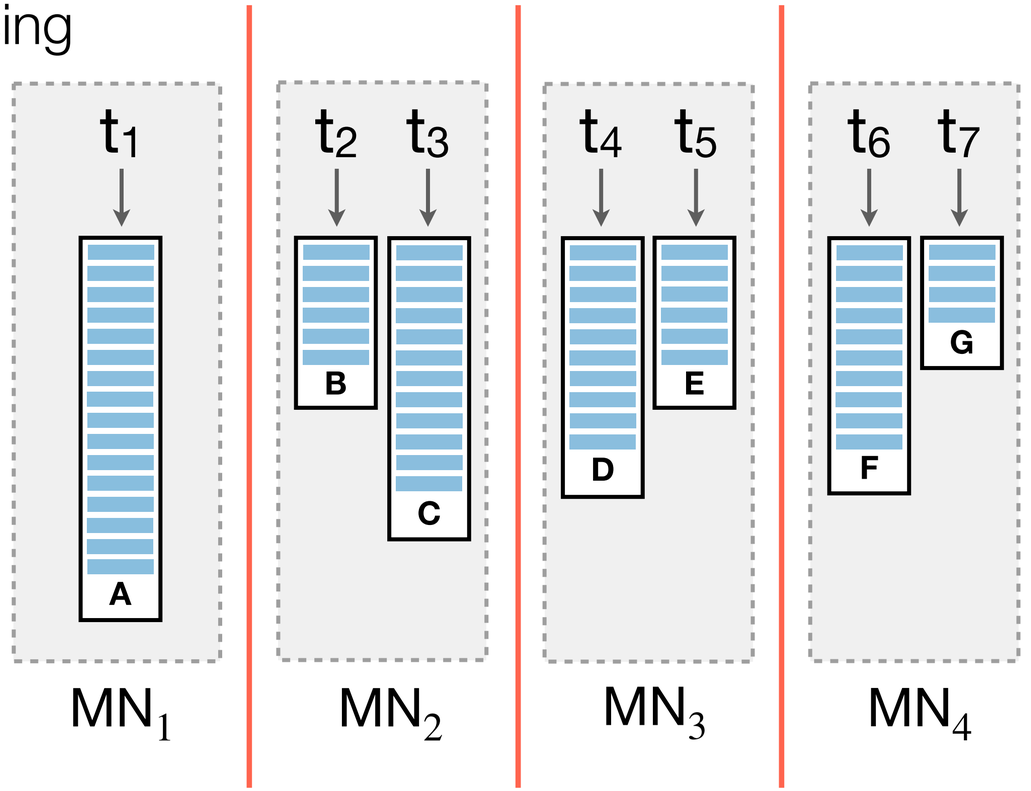


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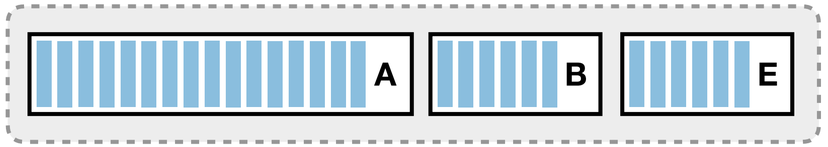

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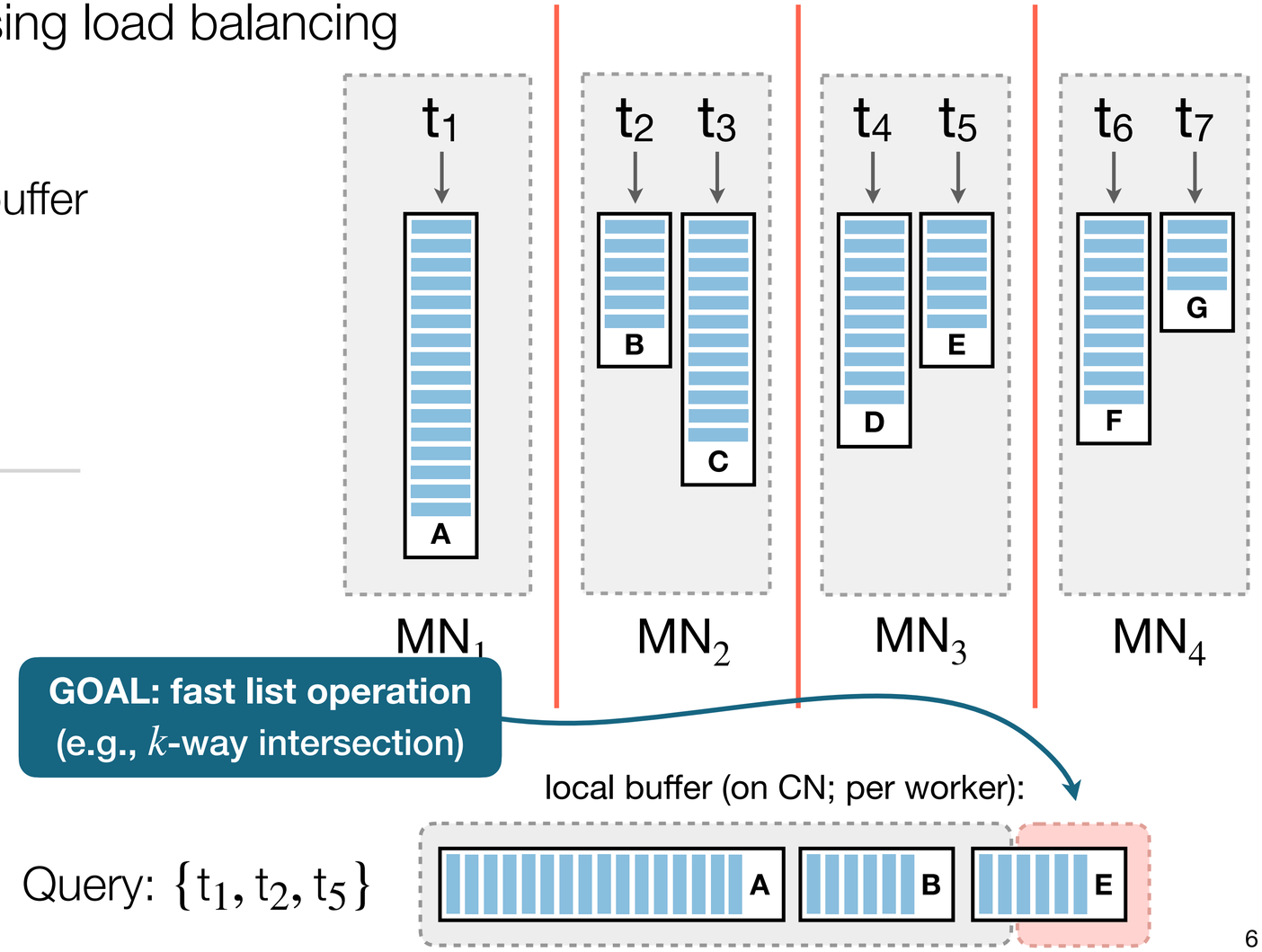

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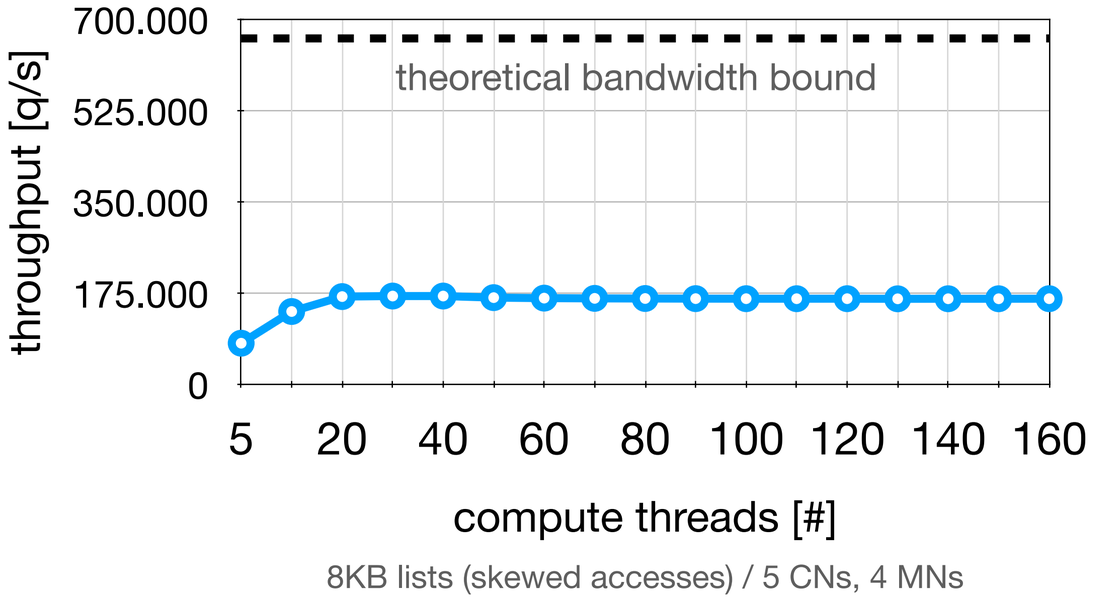


8KB lists (skewed accesses) / 5 CNs, 4 MNs

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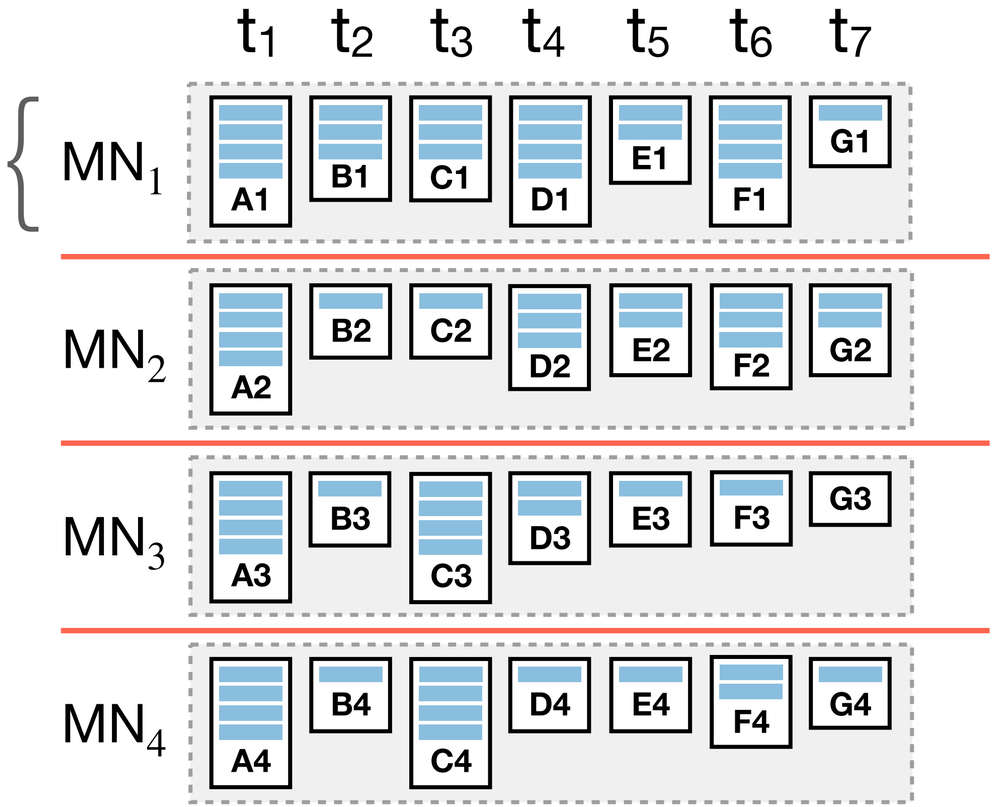

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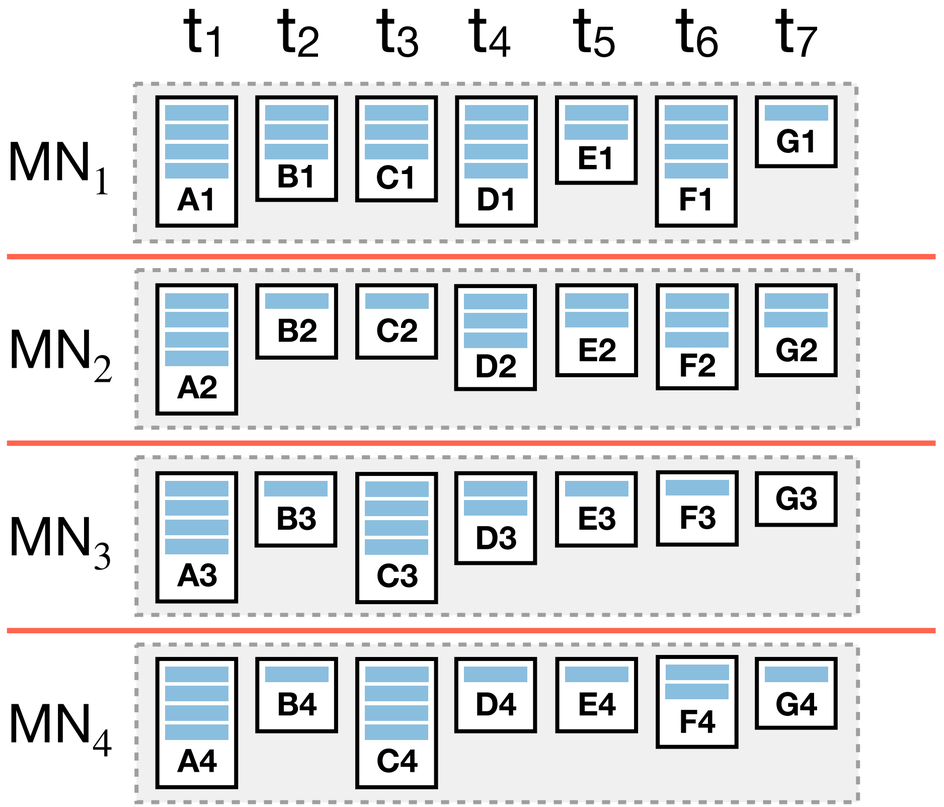


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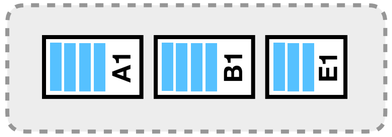

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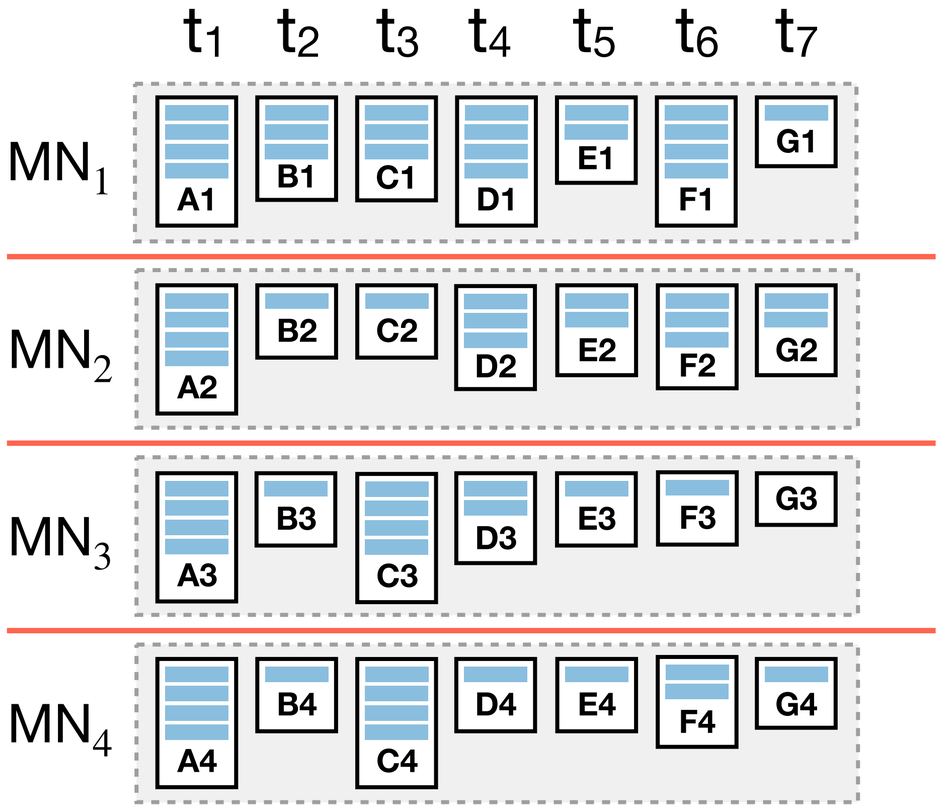


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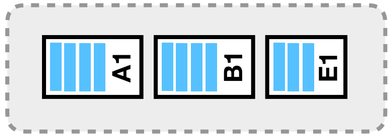

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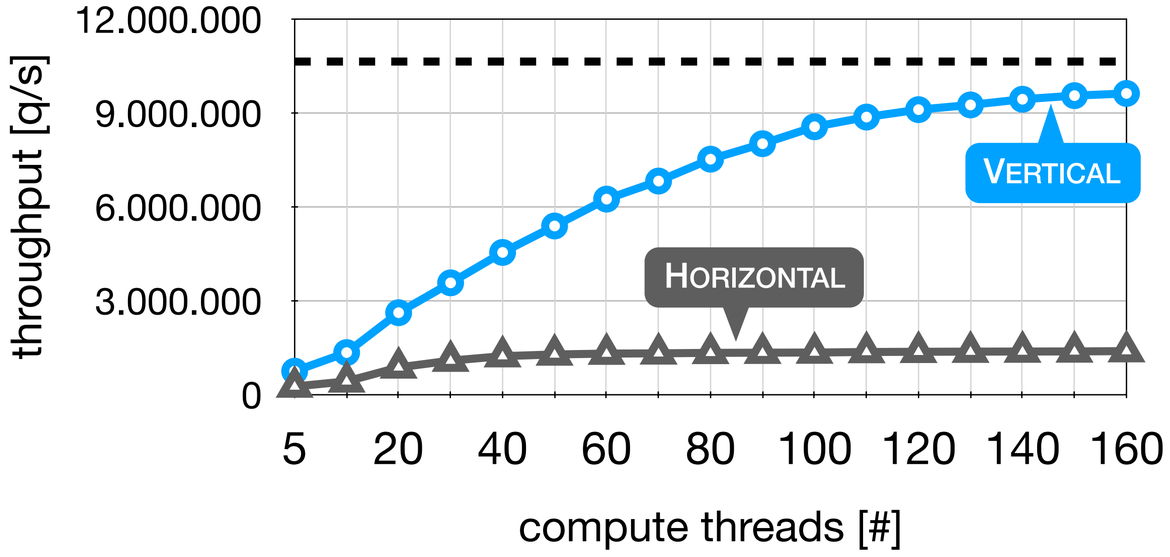


512B lists (uniform accesses) / 5 CNs, 4 MNs

# Block-based Scheme for Inverted Lists in DM

# Block-based Partitioning

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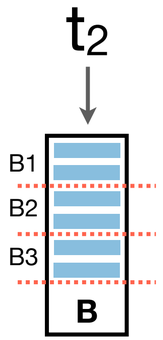

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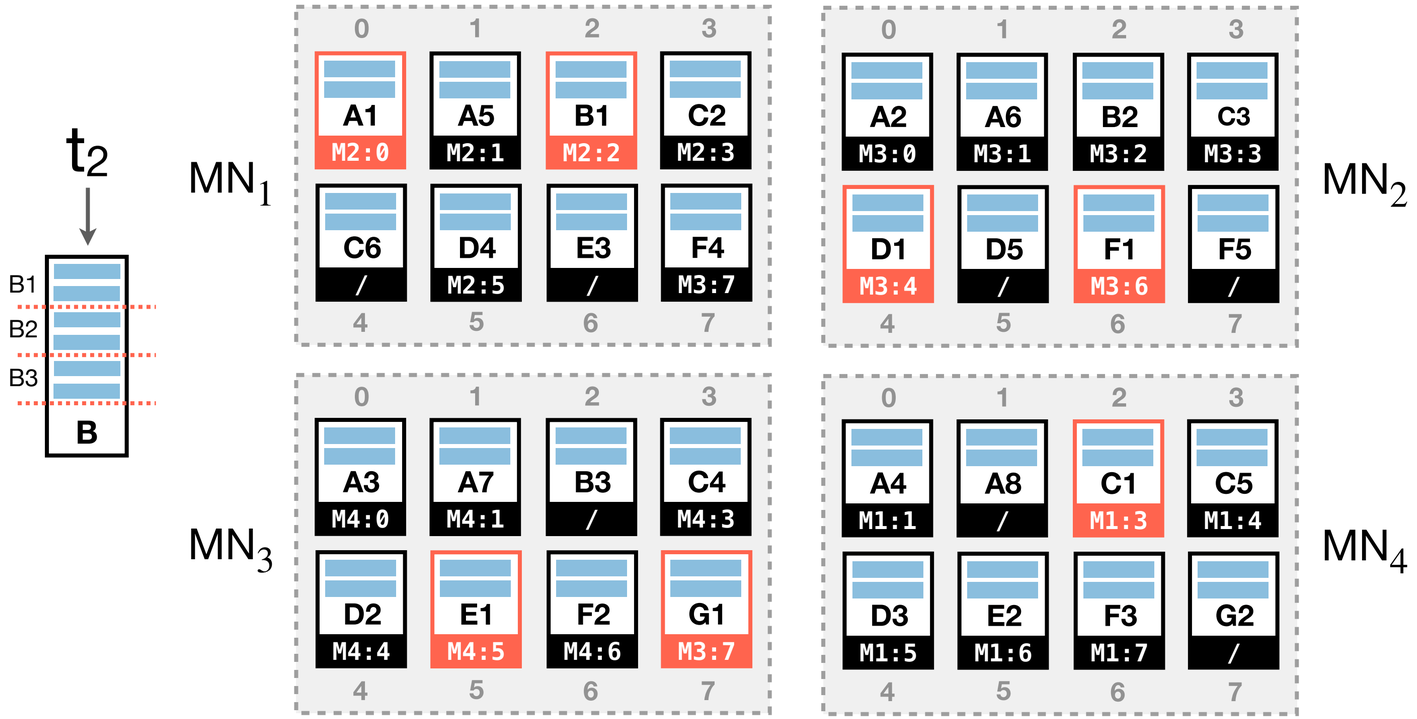

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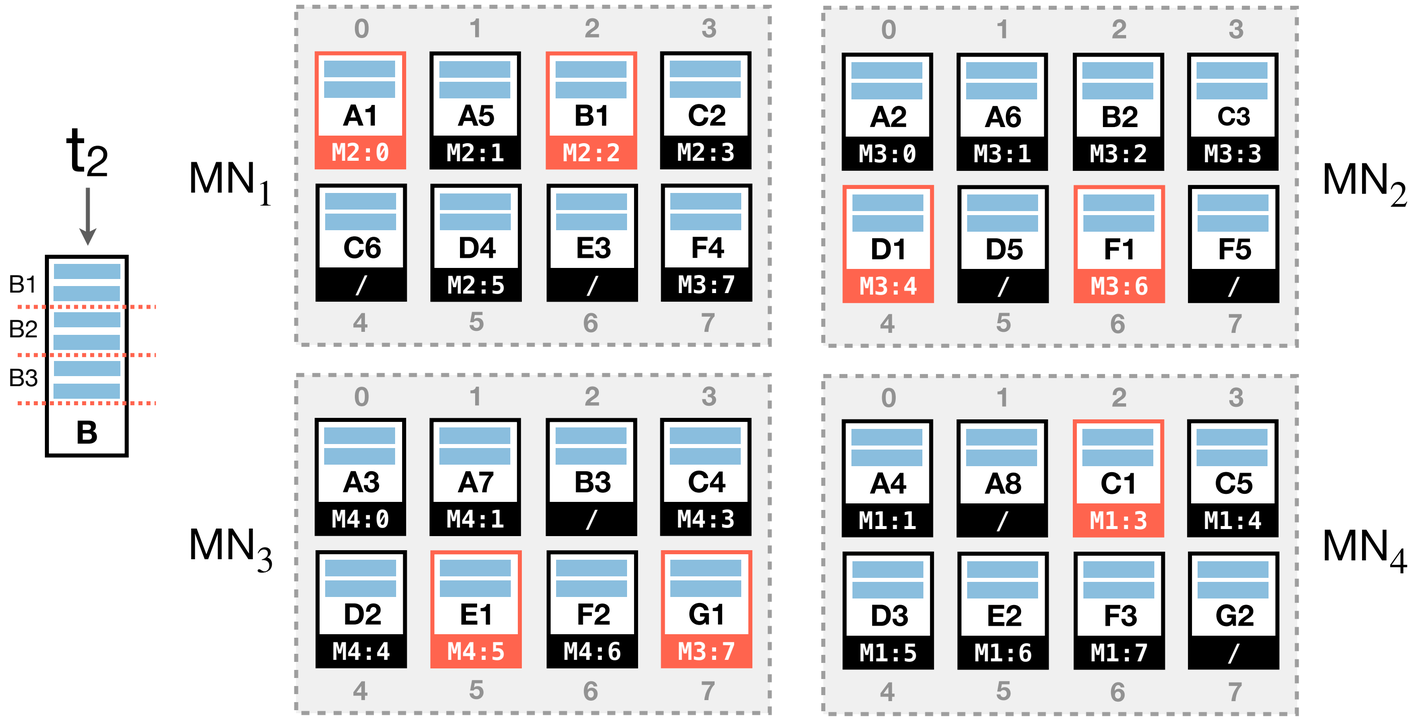

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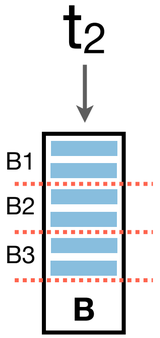


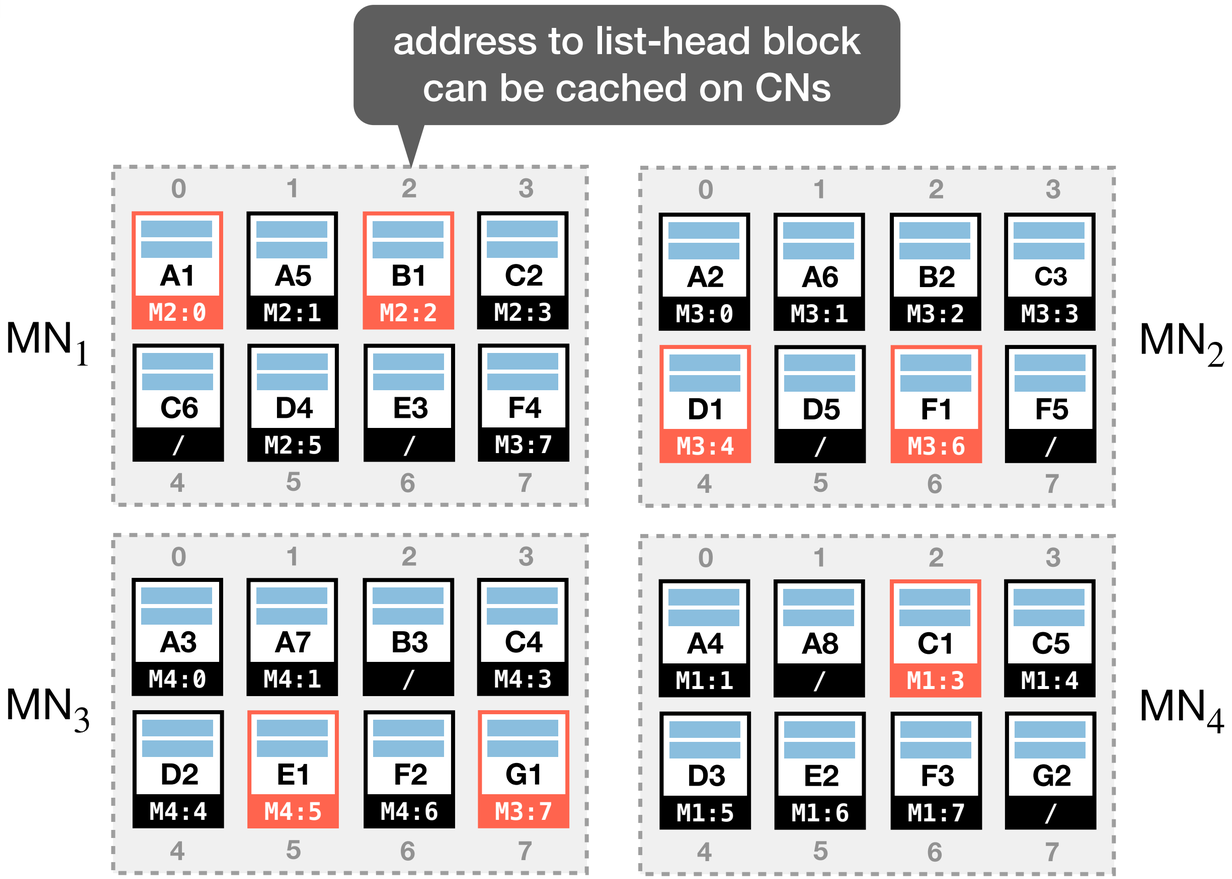

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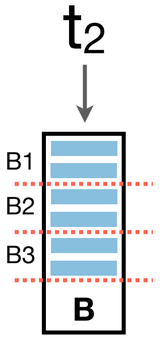


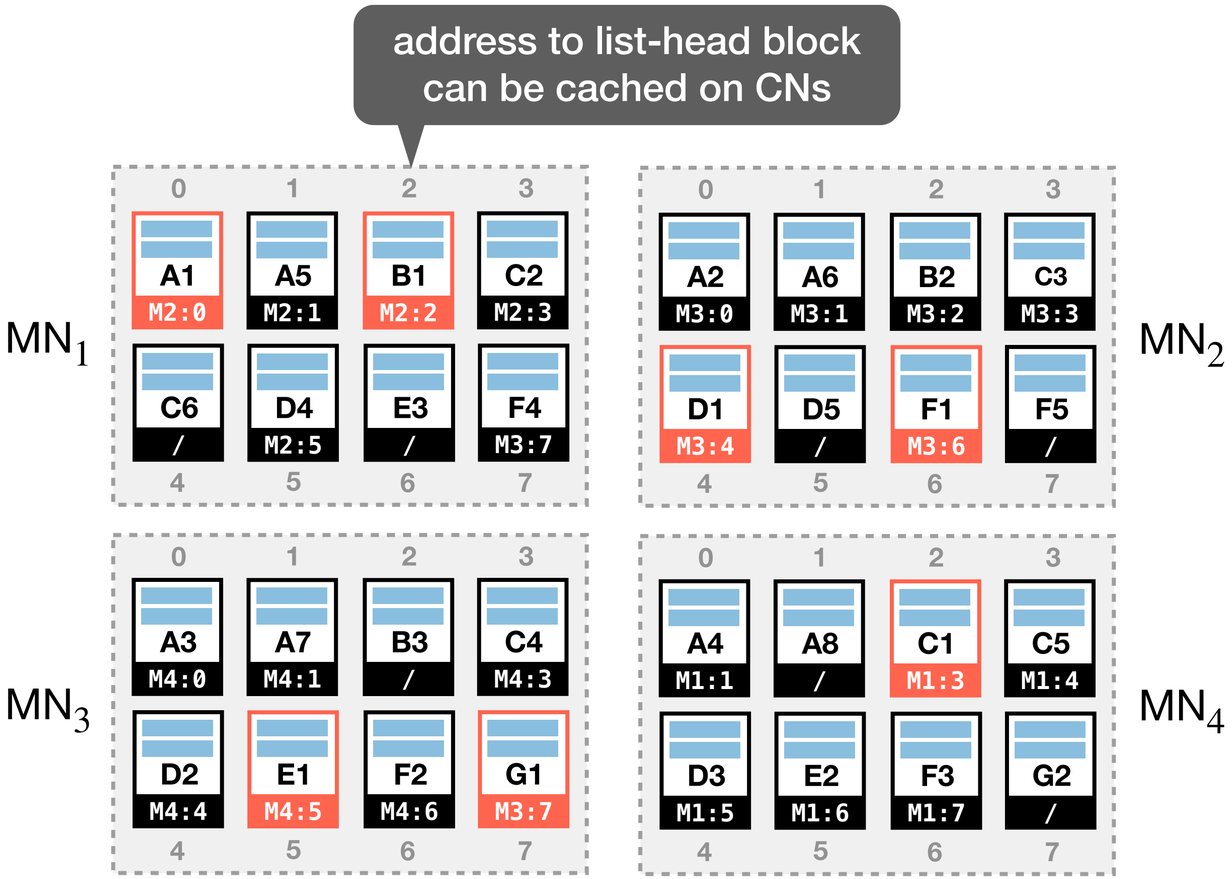


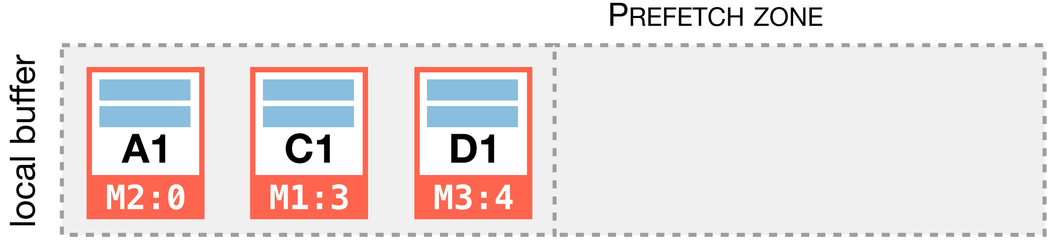

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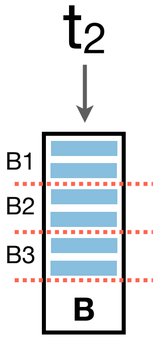


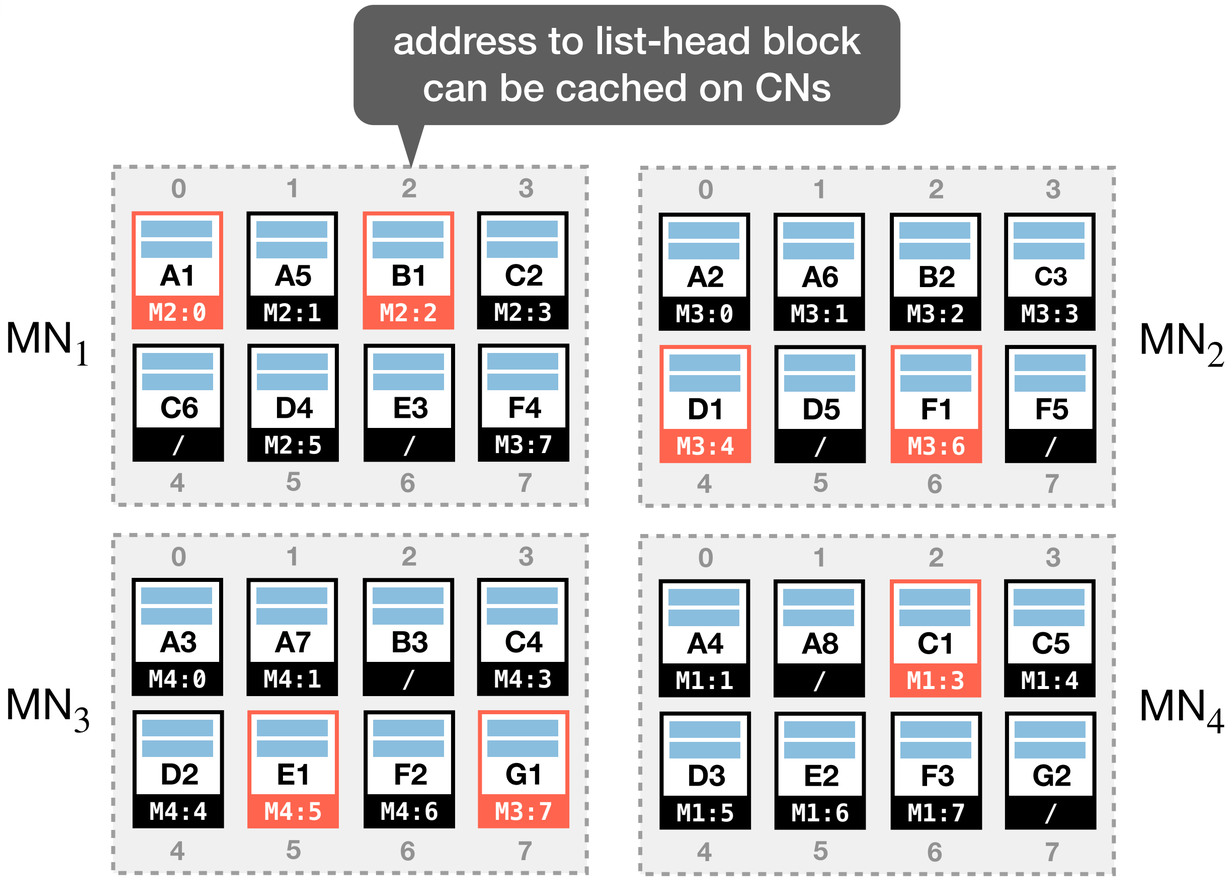


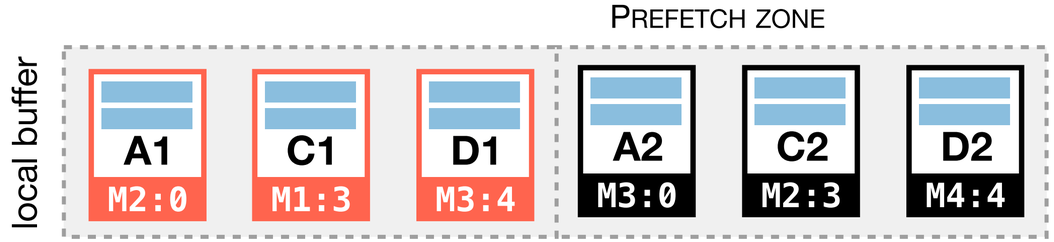

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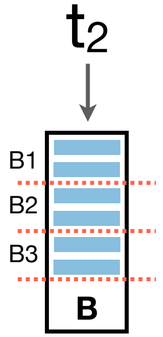


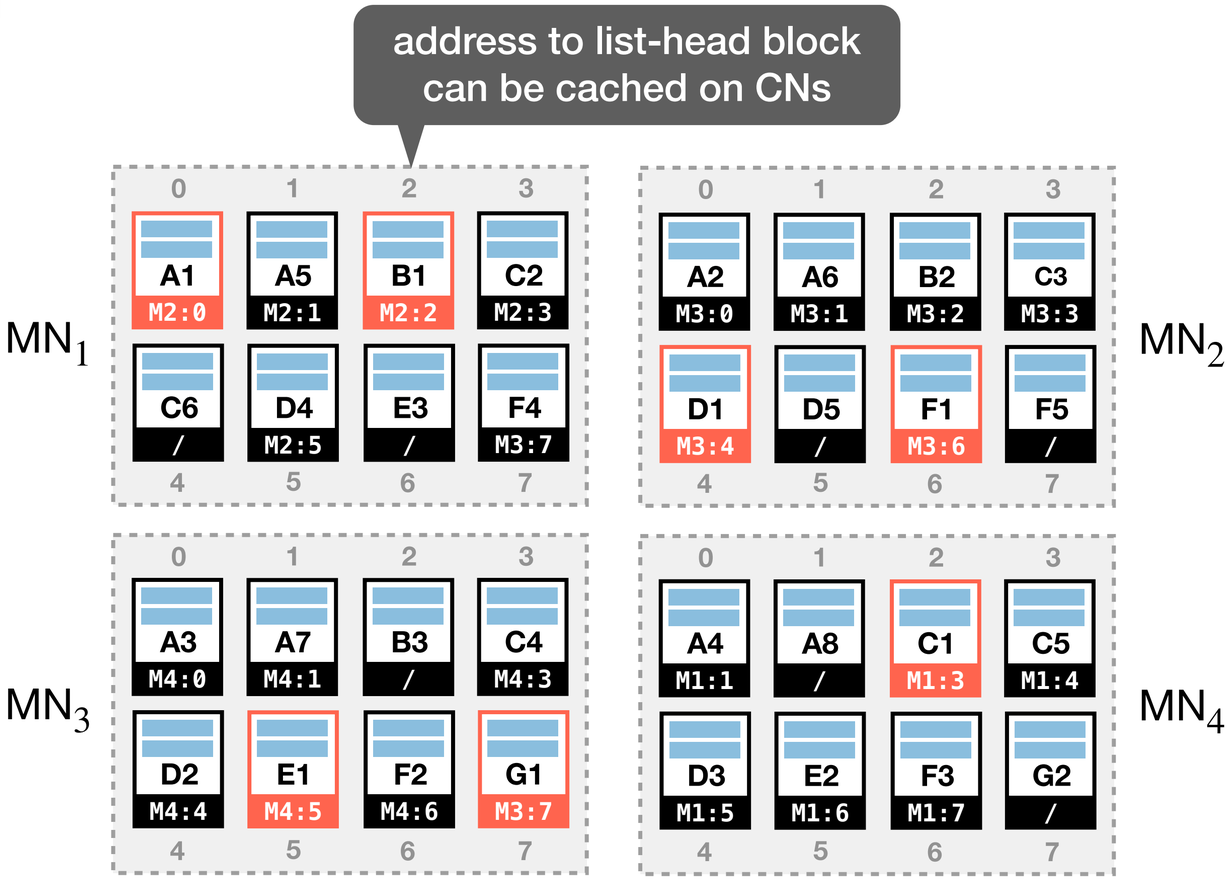


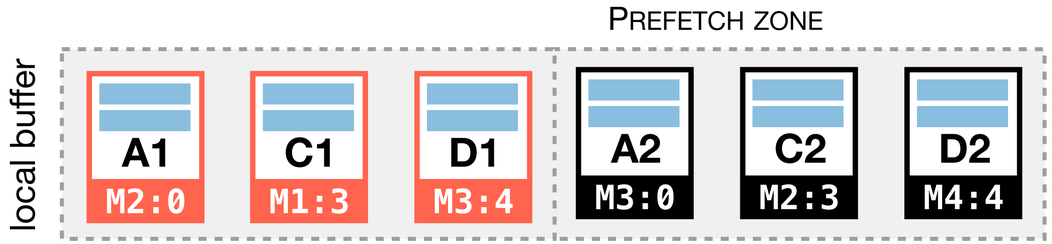

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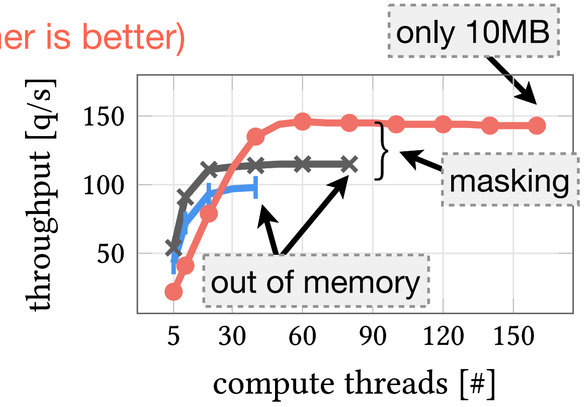
**C4** — **Network Roundtrips**

Number of roundtrips is minimal for very small lists
(otherwise, latency is masked with list operation)

# Scalability Experiments

(higher is better)

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(information retrieval)

average query size: 6


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- Block size: 1KB

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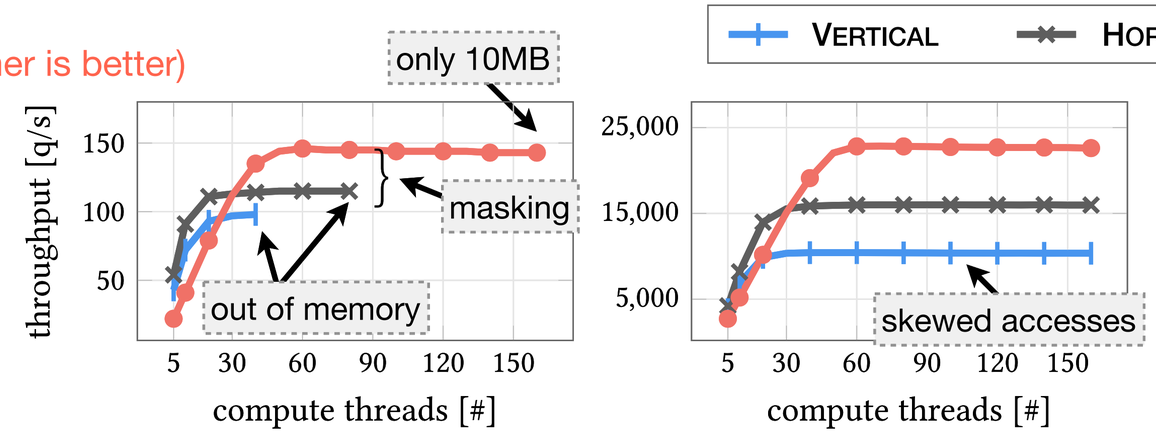


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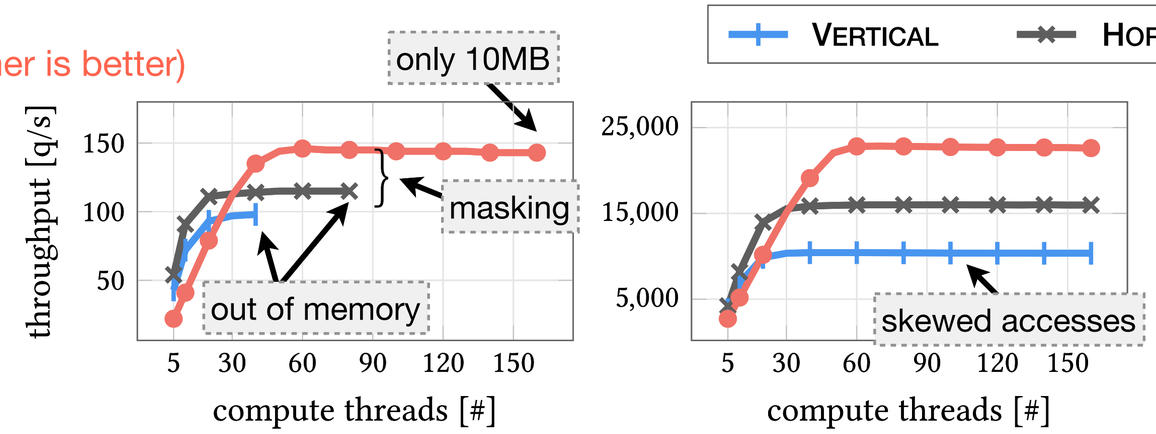


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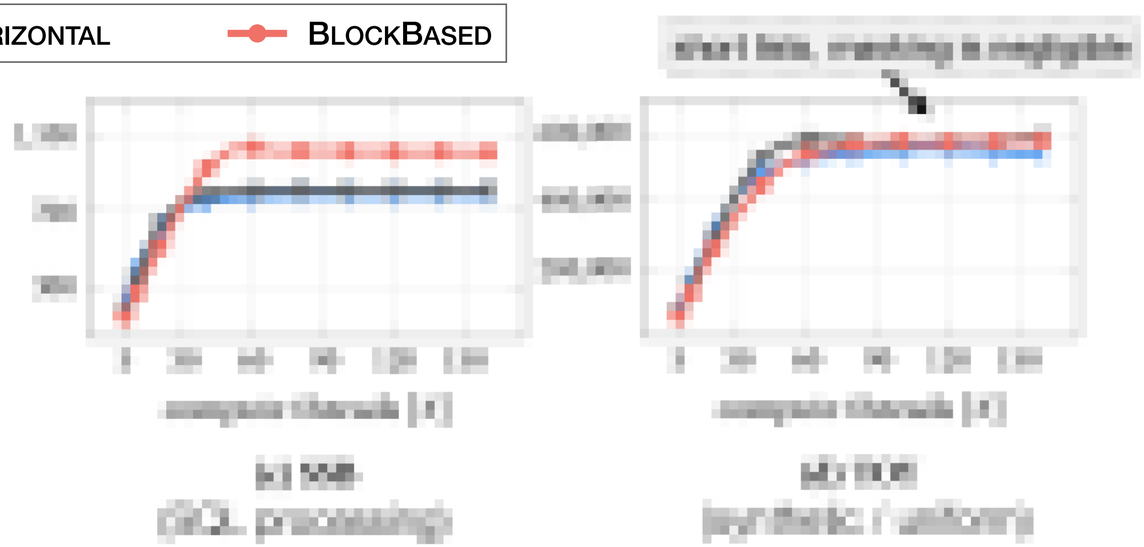

MORE RESULTS IN THE PAPER

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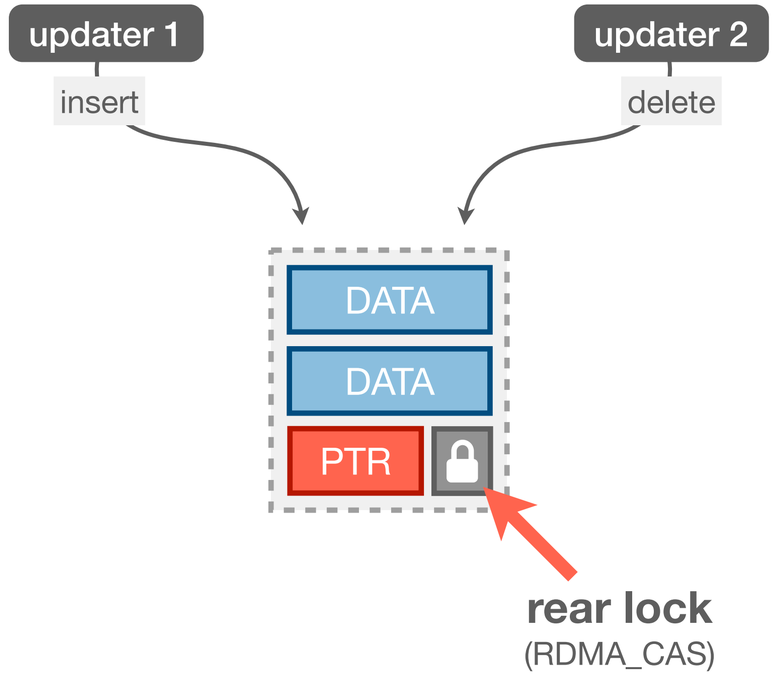

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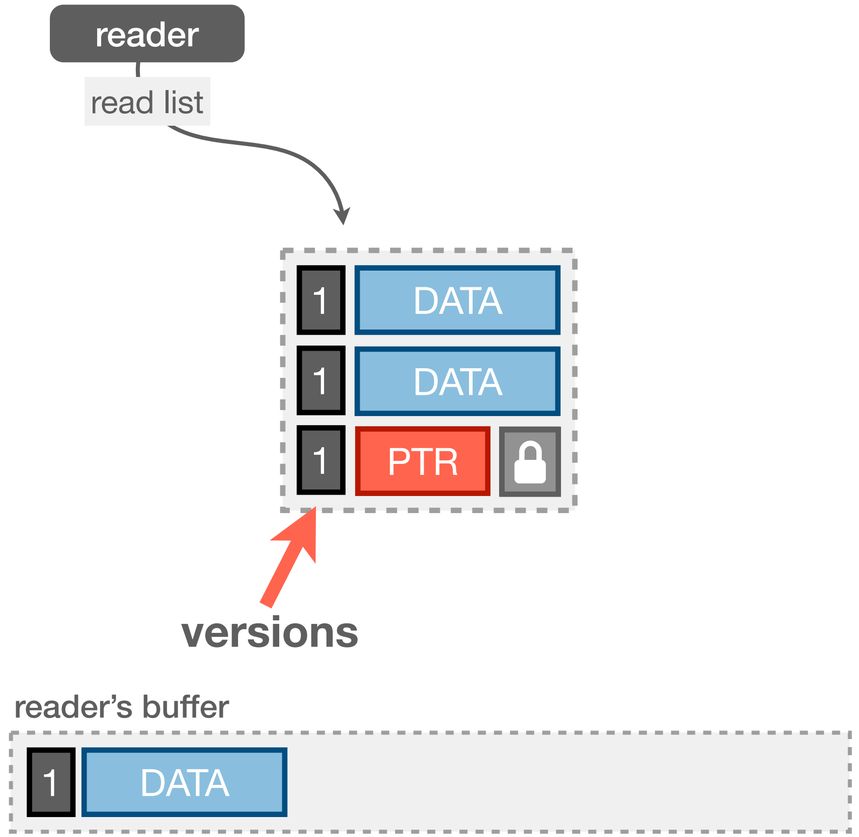

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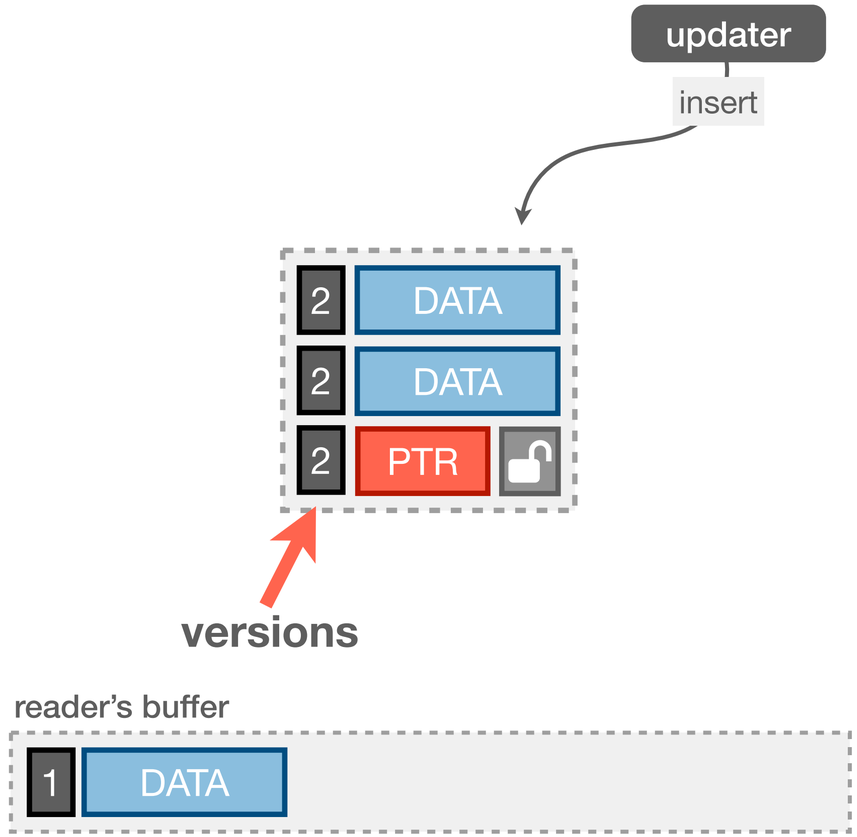

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Protocol for incremental concurrent index updates

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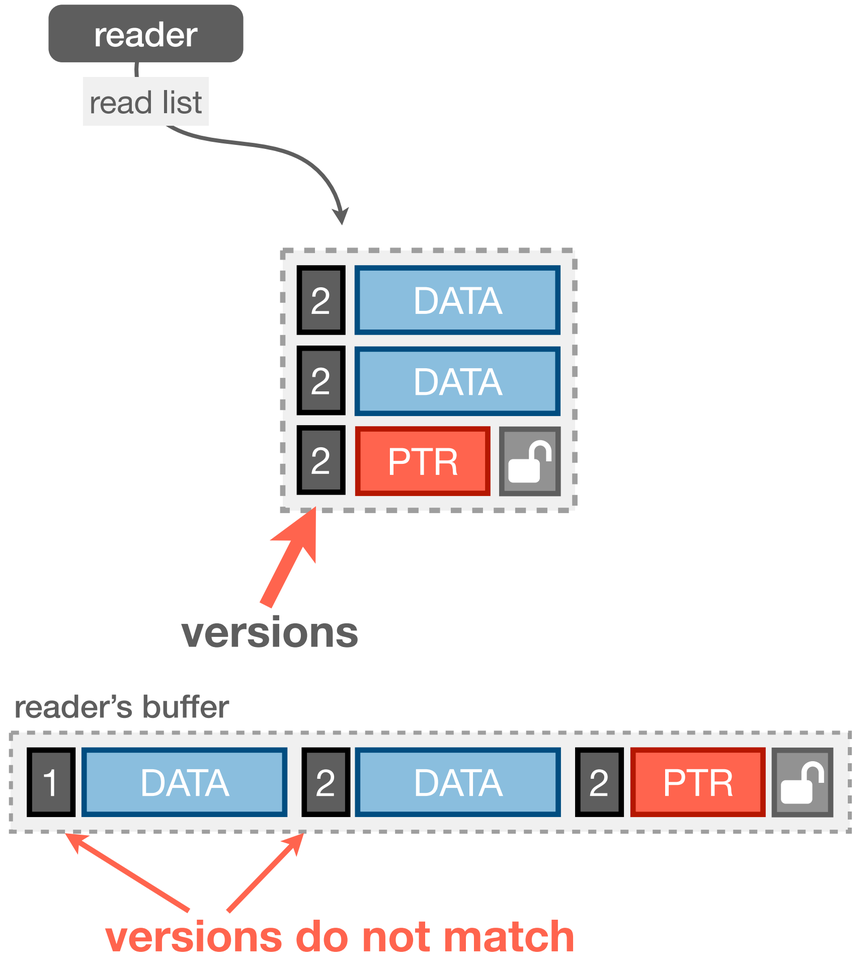

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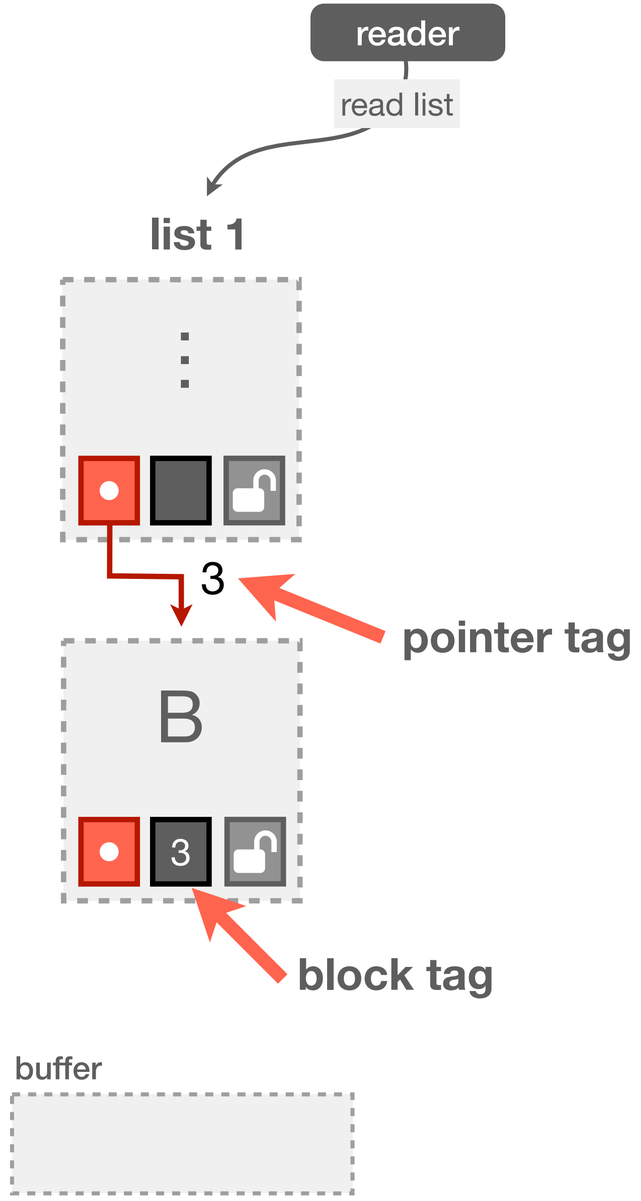

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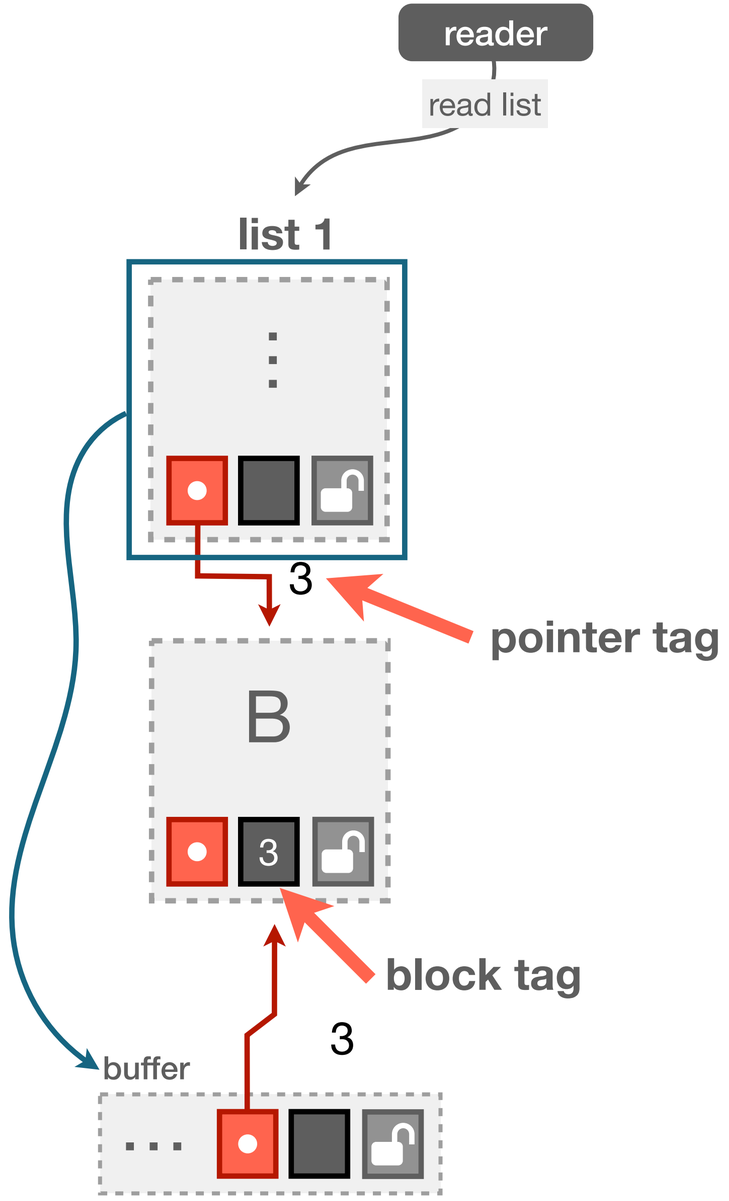

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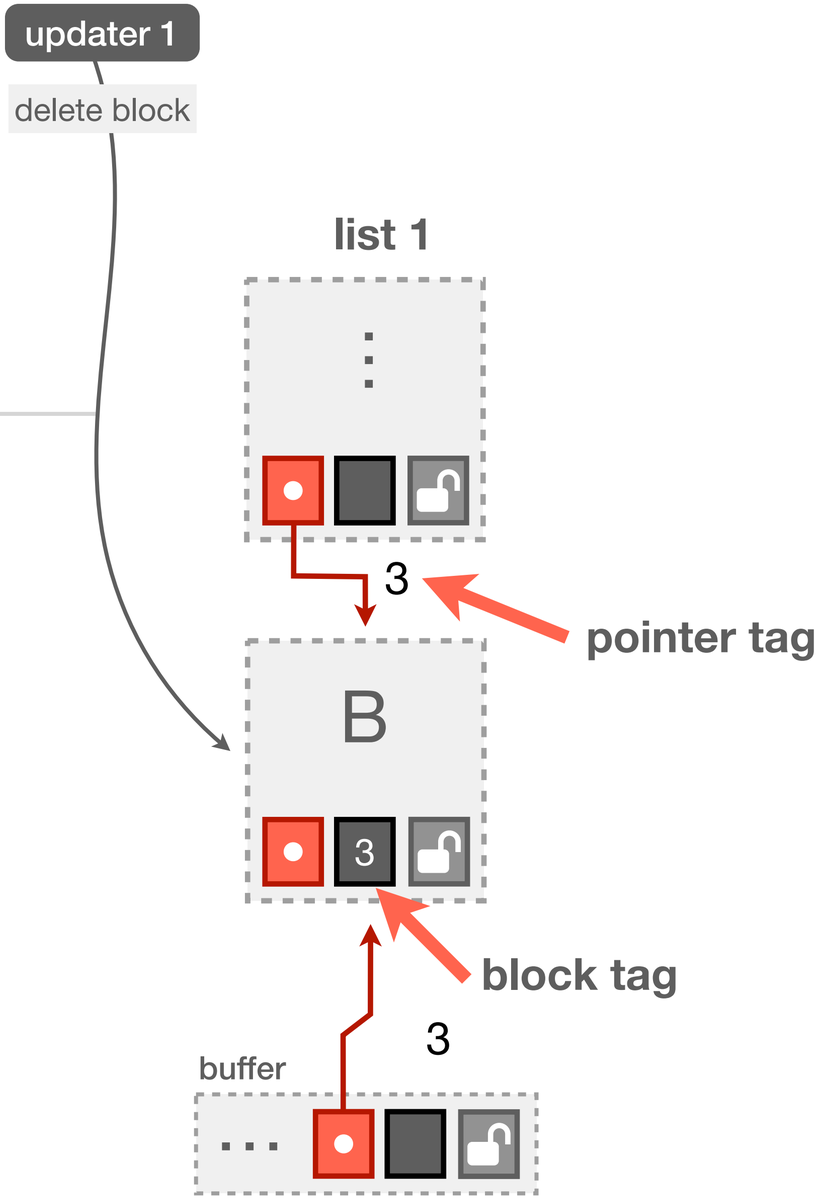

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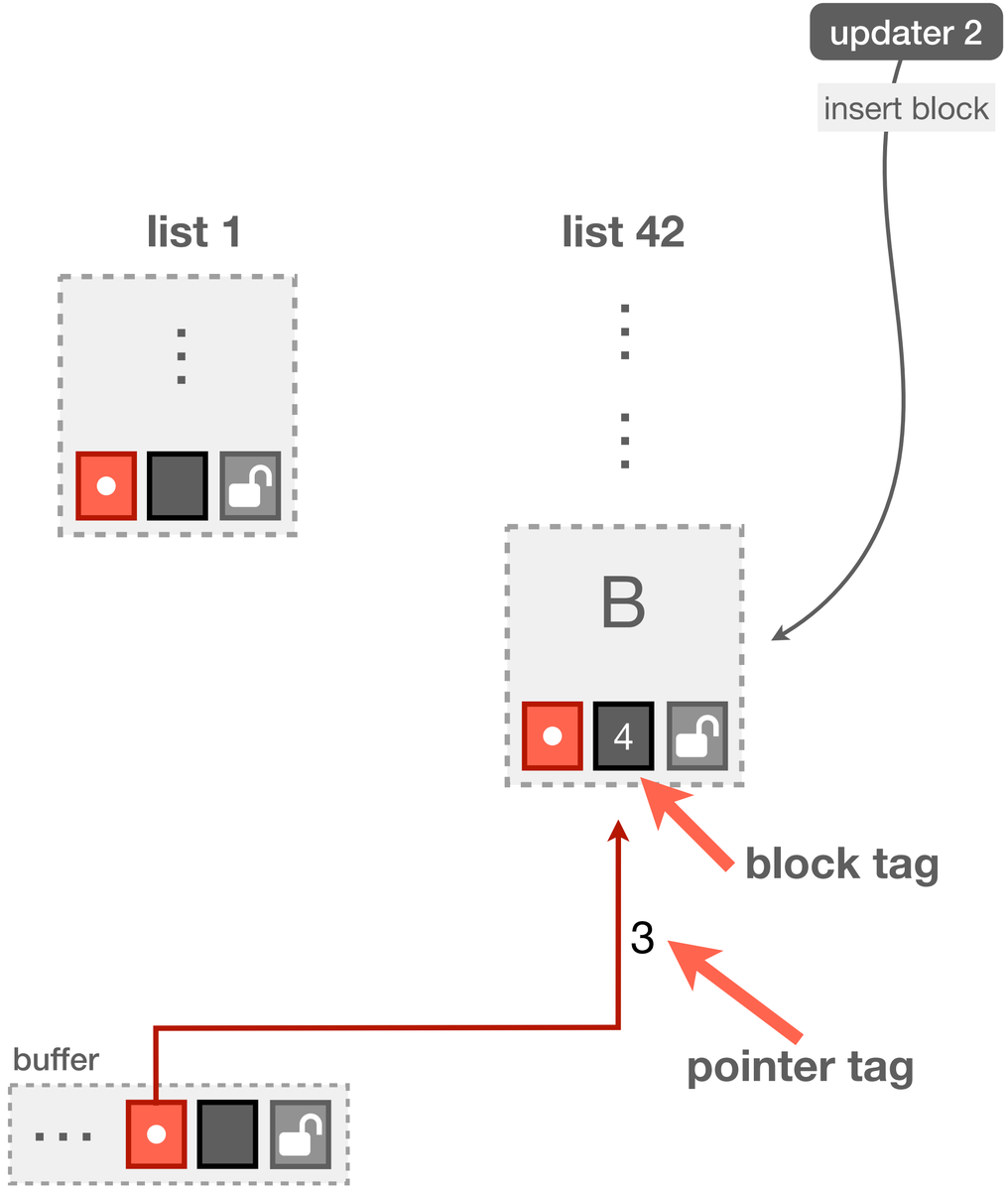

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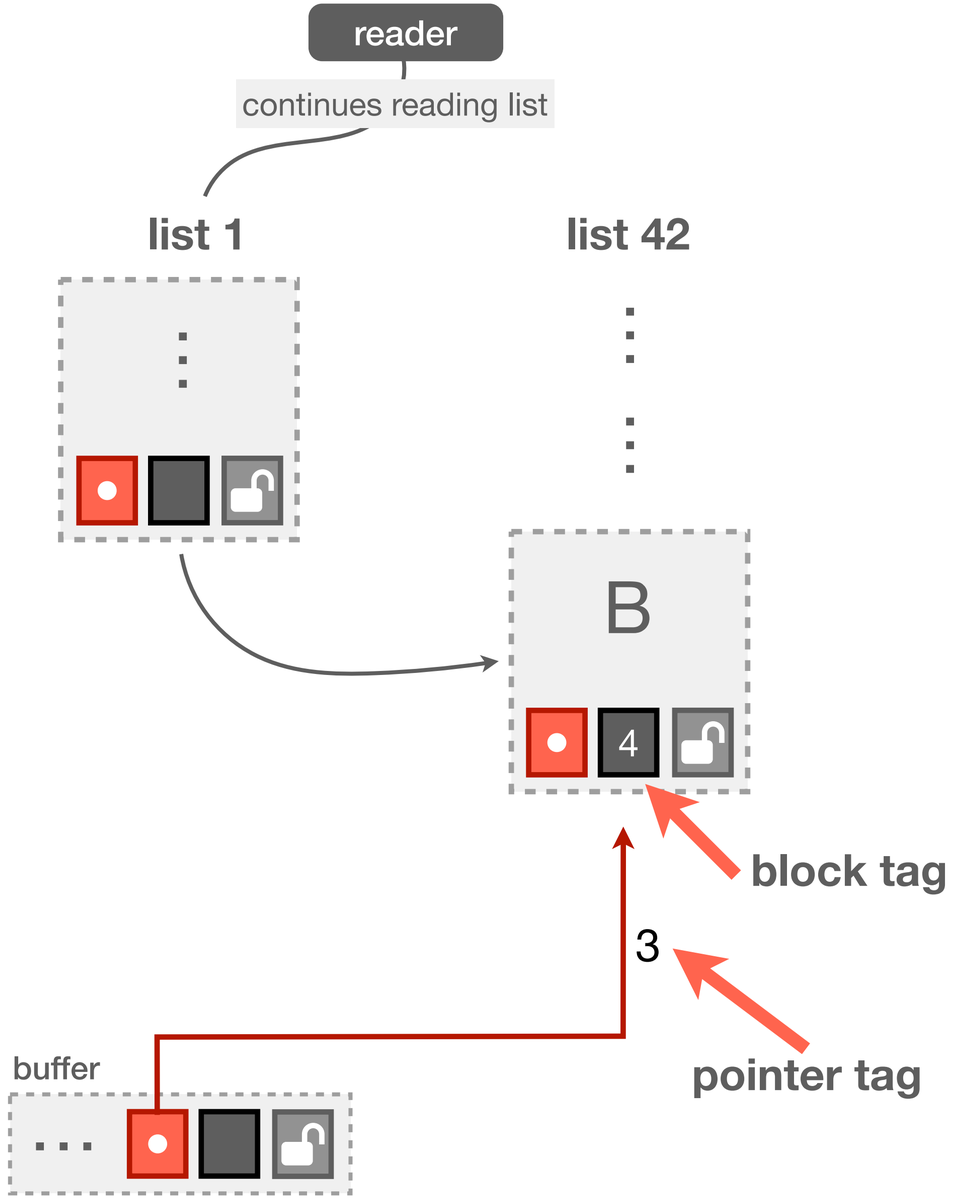

# Conclusion

- Identified key performance bottlenecks of traditional partitioning schemes

not efficient under memory disaggregation

- Proposed a scalable inverted list index design for disaggregated memory
- Developed a protocol to support fast concurrent index updates:
  - Lock-free read queries
  - Fine-grained write locks for updates
- Scalability evaluation on real-world datasets

# Scalable Distributed Inverted List Indexes in Disaggregated Memory

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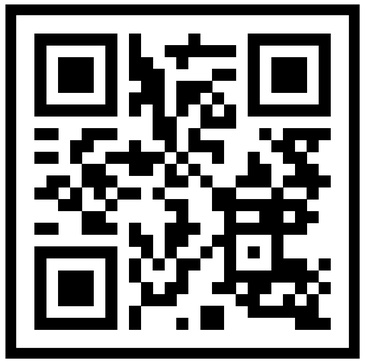
github.com/DatabaseGroup/rdma-inverted-index


link to paper