# Scalable Low-Latency Indexes for a Key-Value Store


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# Thesis

A key value store can support

**strongly consistent secondary indexes**

while operating at **low latency** and **large scale**.

# Summary of Results

- **Scalable Low-latency Indexes for a Key-value Store: SLIK**
  - Enables multiple secondary keys for each object
  - Allows lookups and range queries on these keys
- **Key design features:**
  - **Scalability** using independent partitioning
  - **Strong consistency** using an ordered write approach
- **Implemented in RAMCloud**
- **Performance:**
  - Linear throughput increase with increasing number of partitions
  - 11-13 µs indexed reads
  - 29-37 µs durable writes/overwrites of objects with one indexed attribute
  - Latency approx. 2x non-indexed reads and writes

# Talk Outline

- **Motivation**
- Design
- Performance
- Related Work
- Summary

# Motivation

Traditional RDBMs

MySQL

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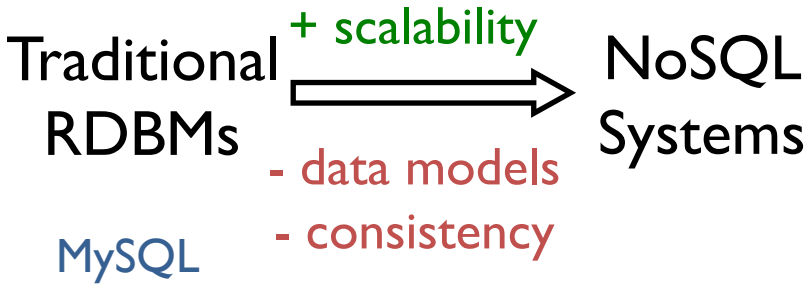
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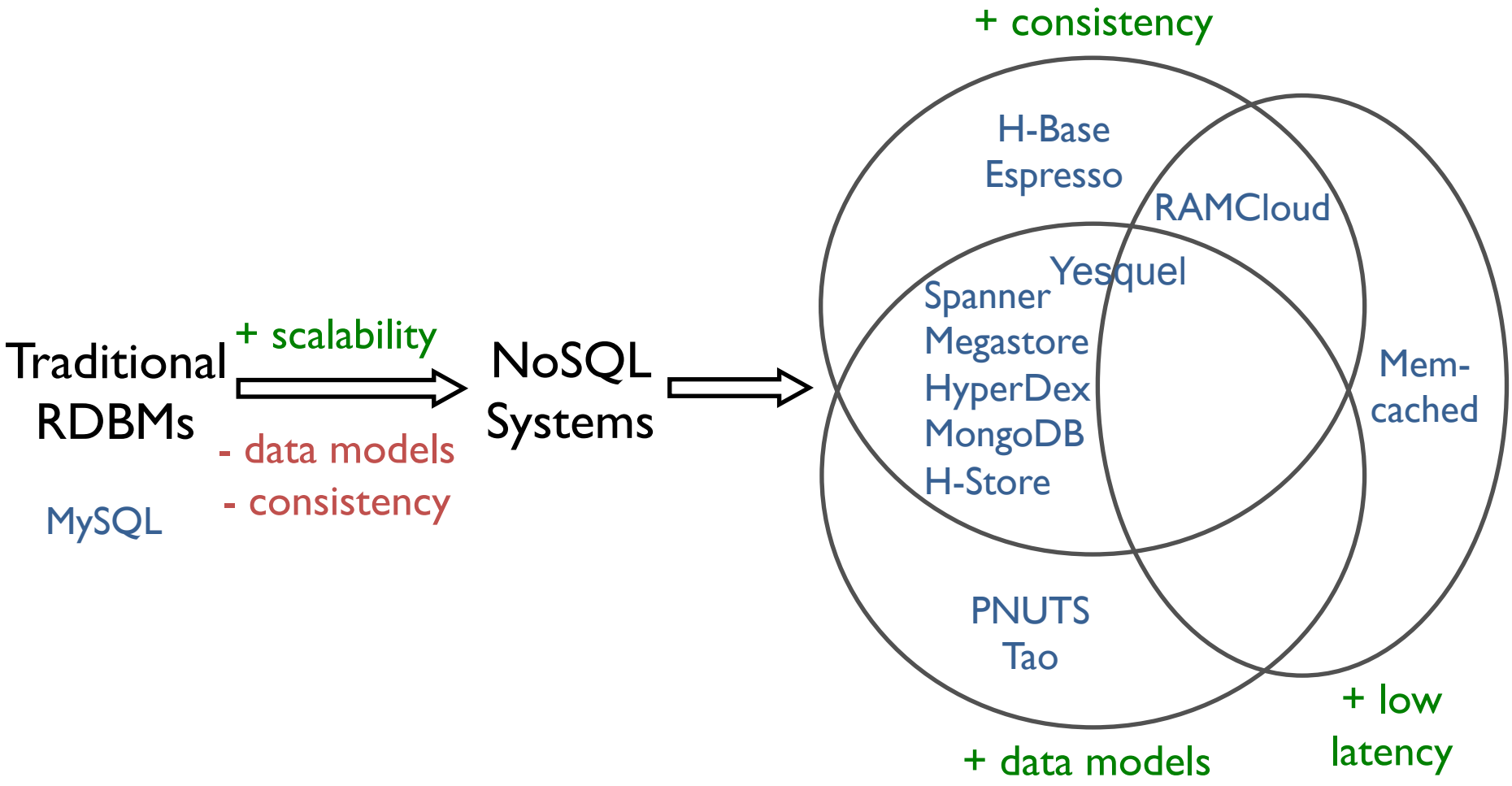
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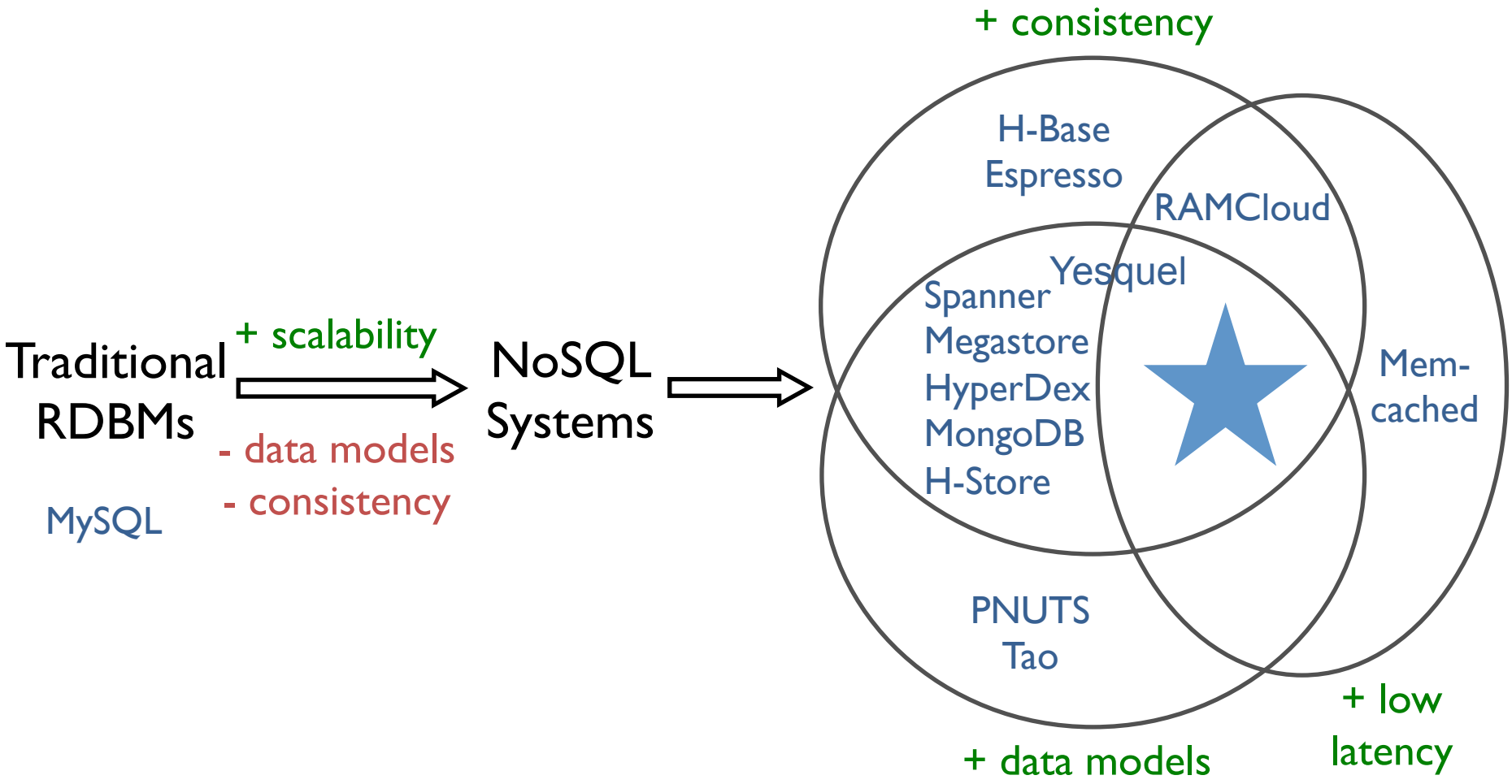
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- **Data model**
- **Scalability**
- **Strong consistency**
- **Storage**
- **Durability**
- **Availability**

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- **Scalability**
  - Nearly constant low latency irrespective of the server span
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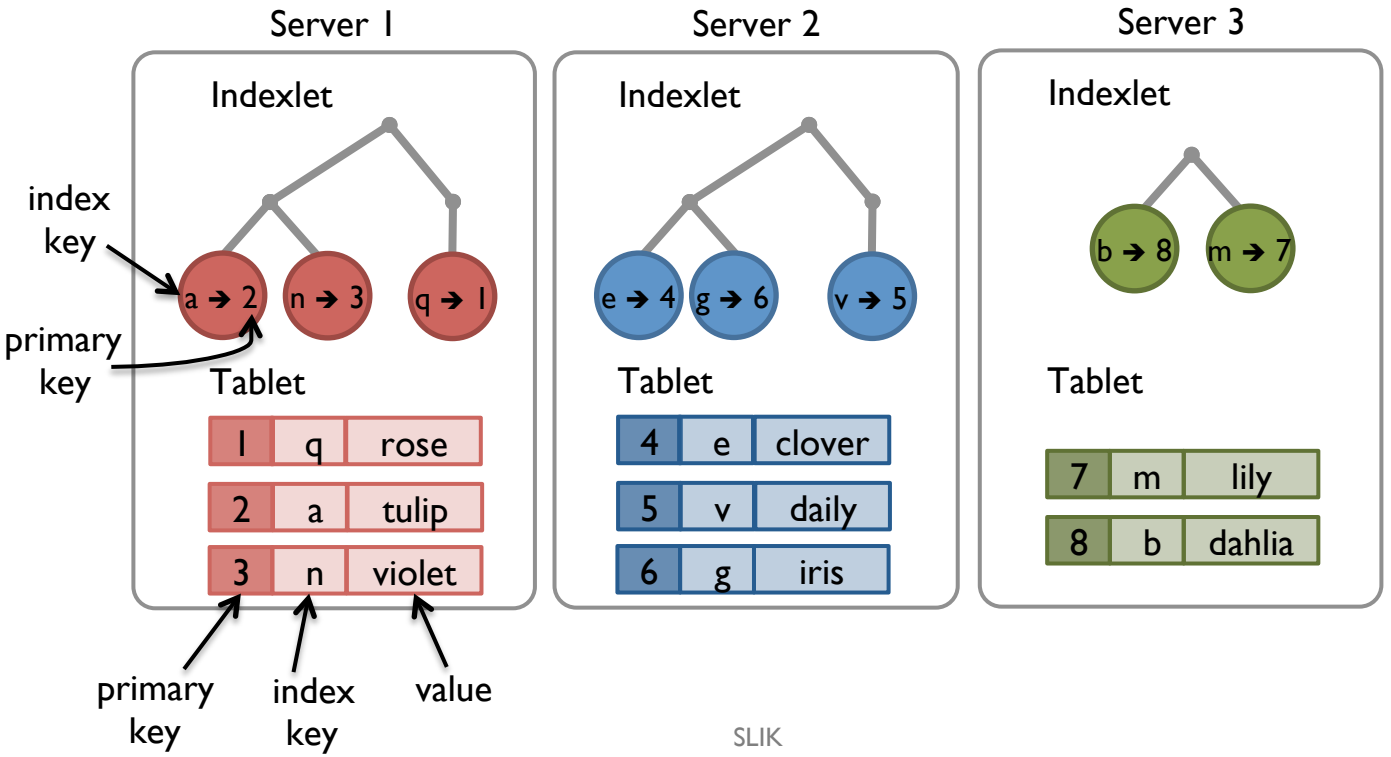
# Index Partitioning: Colocation

- Colocate index entries and objects
- One of the keys used to partition the objects and indexes



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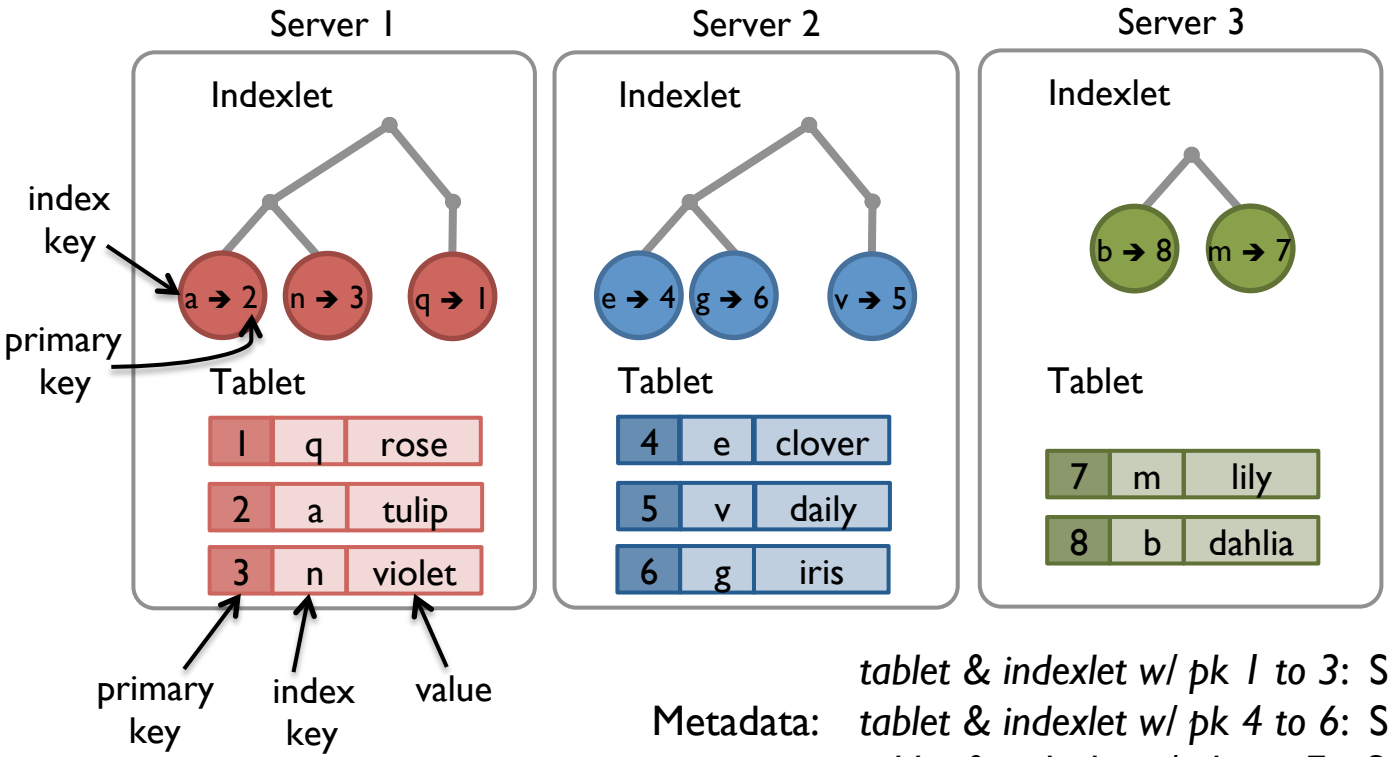
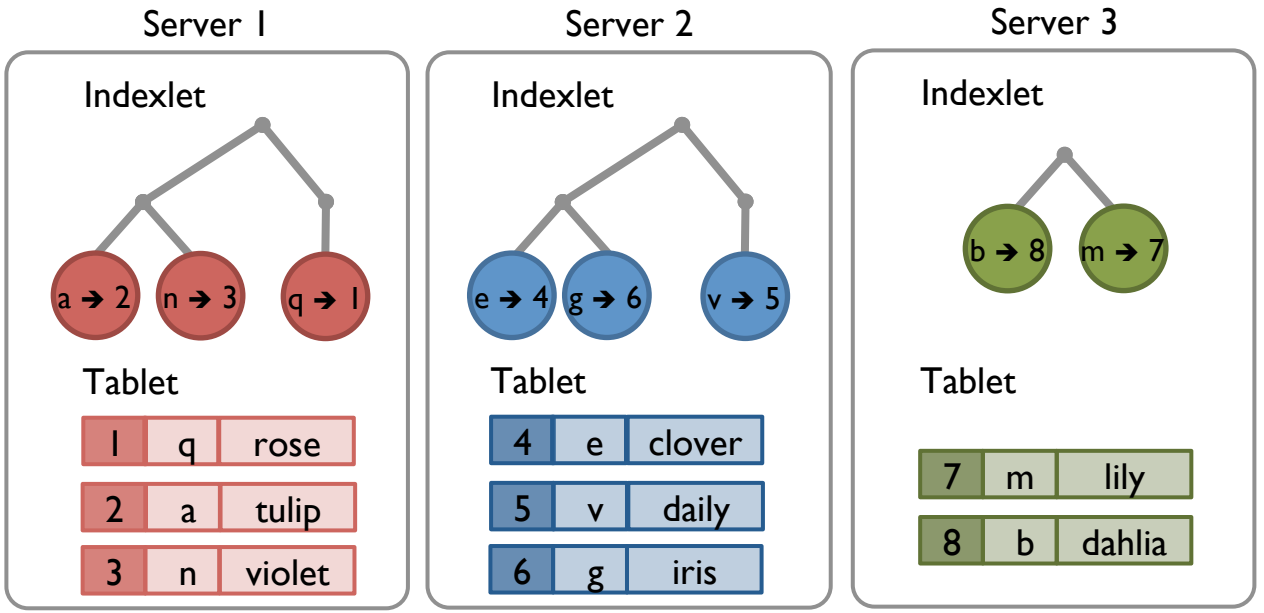
- One of the keys used to partition the objects and indexes
- No association between index partitions and index key ranges




Metadata:
*tablet & indexlet w/ pk 1 to 3:* S 1
*tablet & indexlet w/ pk 4 to 6:* S 2
*tablet & indexlet w/ pk >= 7:* S 3

# Index Partitioning: Colocation

Client query: objects with index key between m - q



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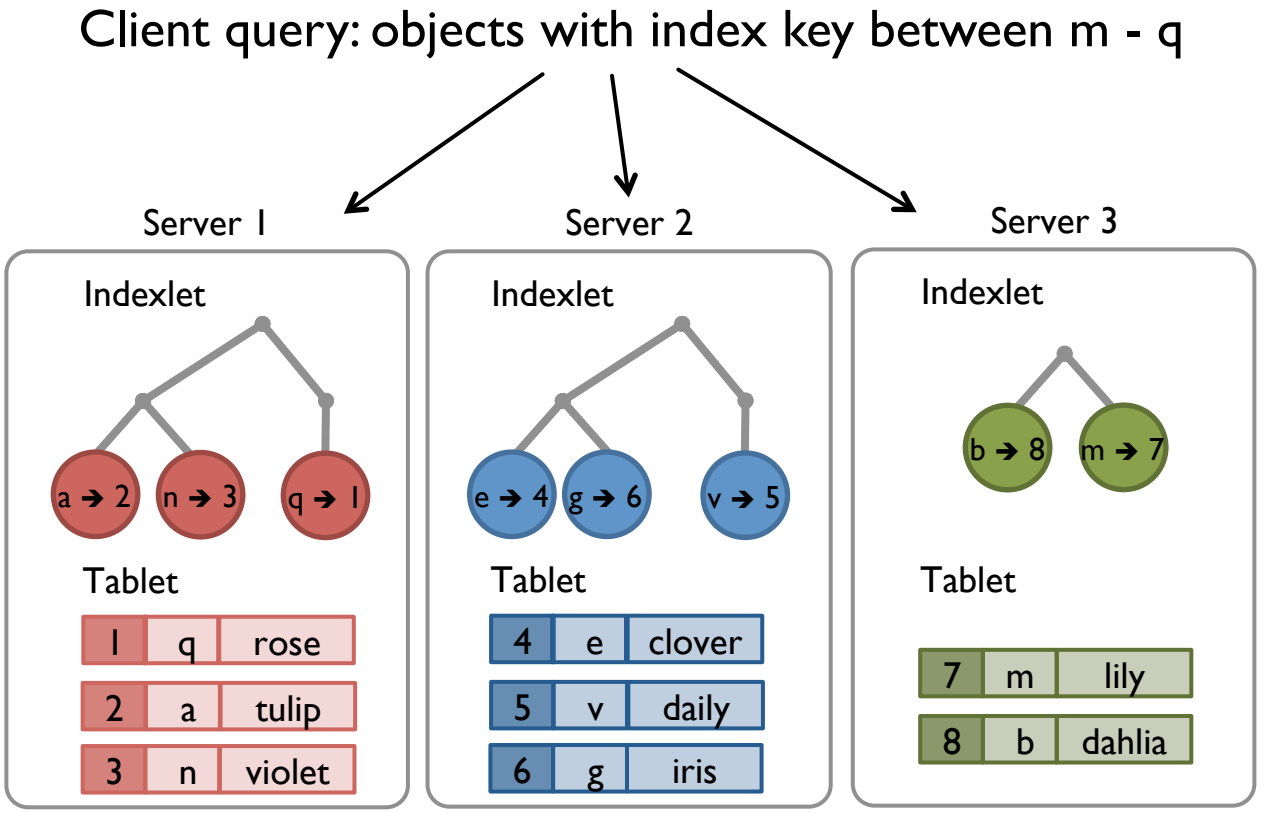

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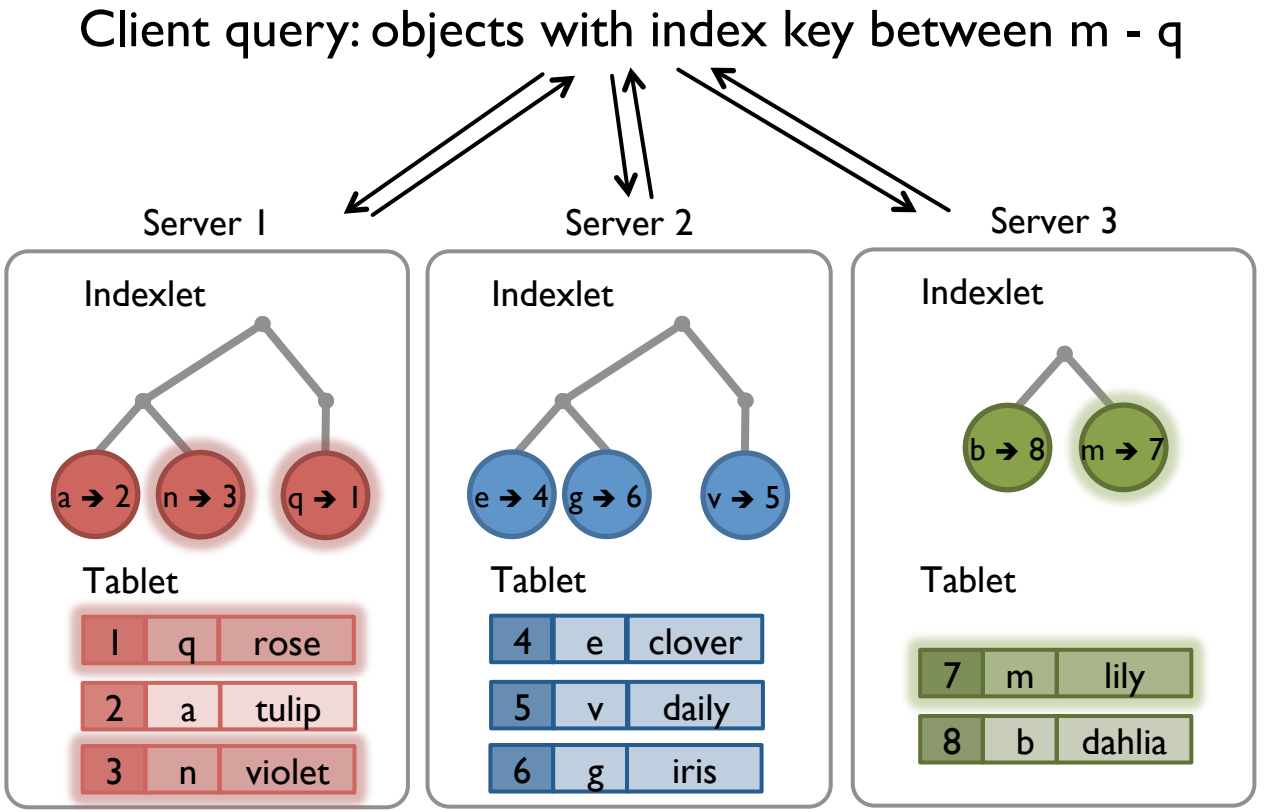

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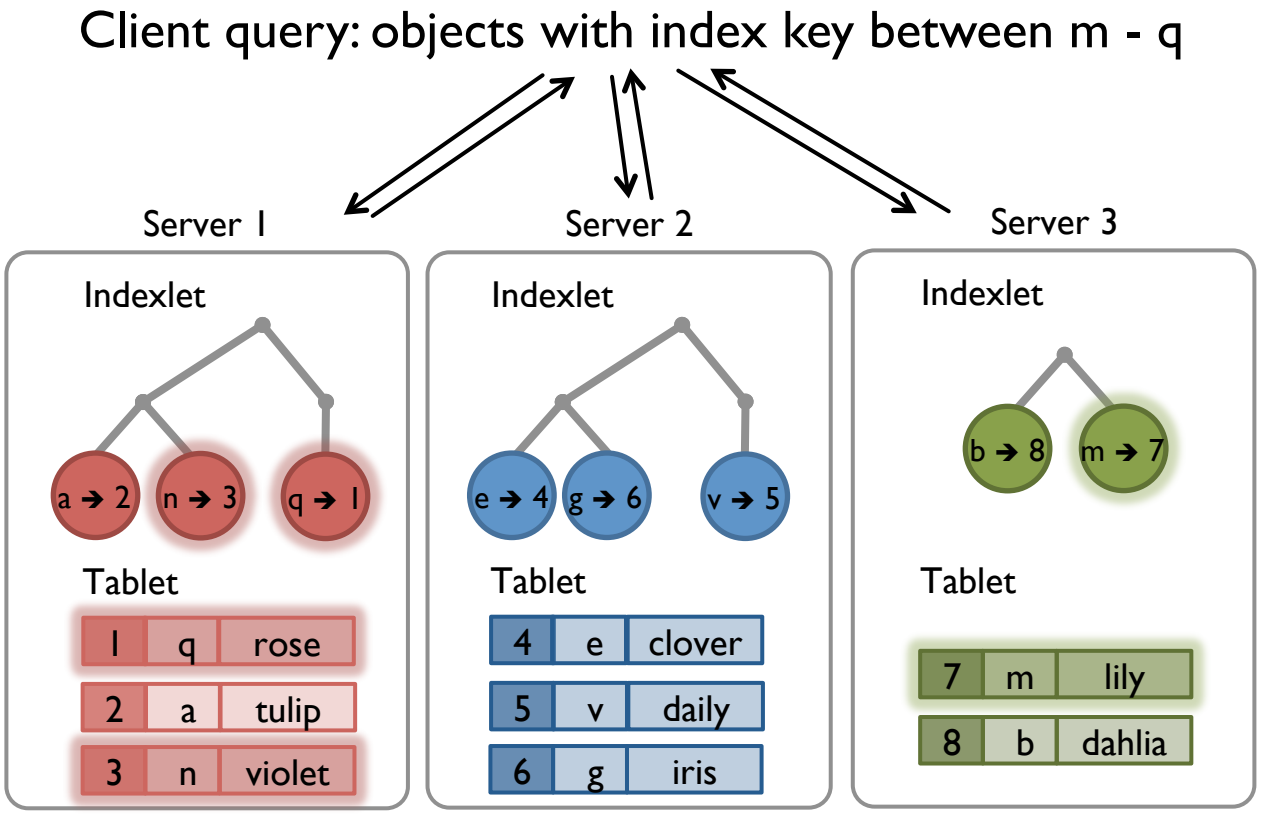
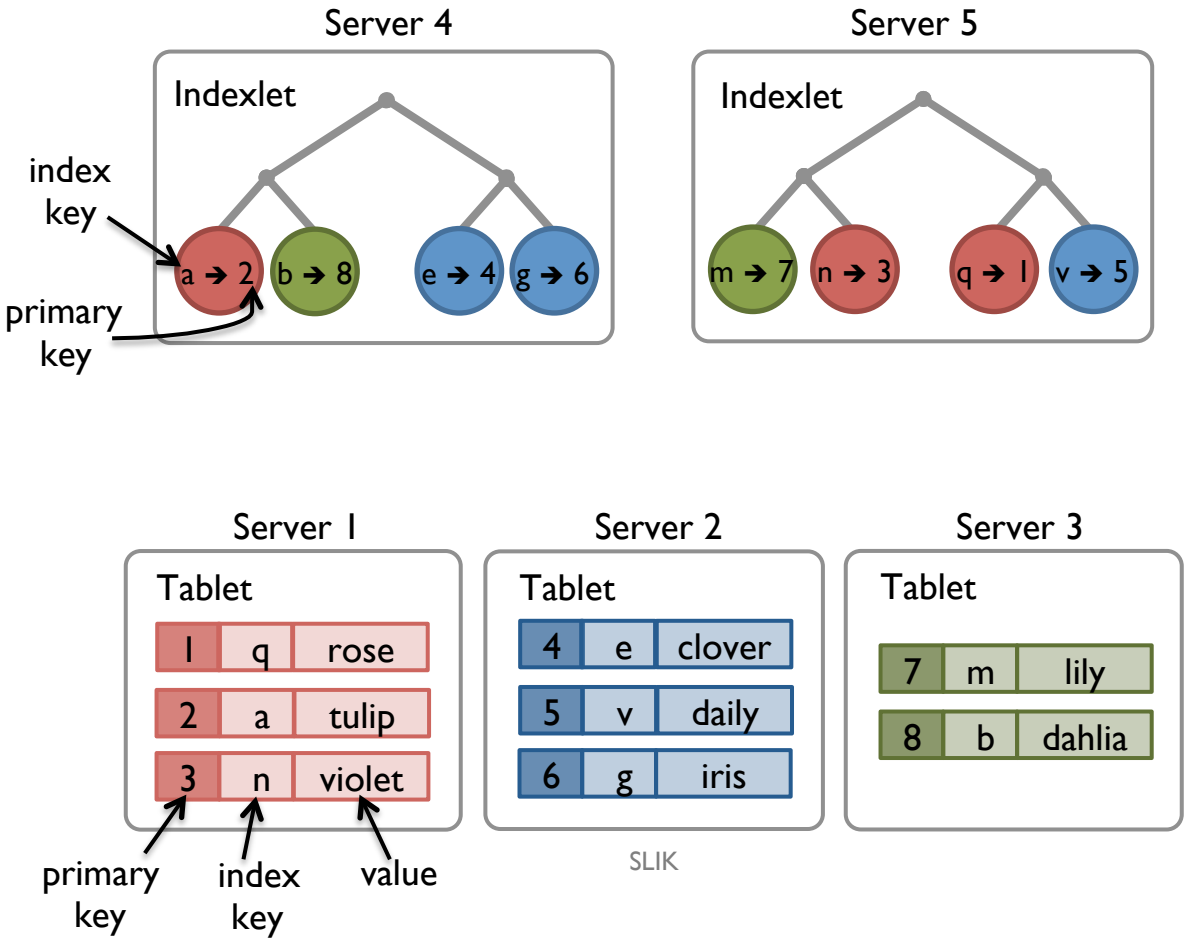



Not Scalable!

# Index Partitioning: Independent

- Partition each index and table independently
- Partition each index according to sort order for that index



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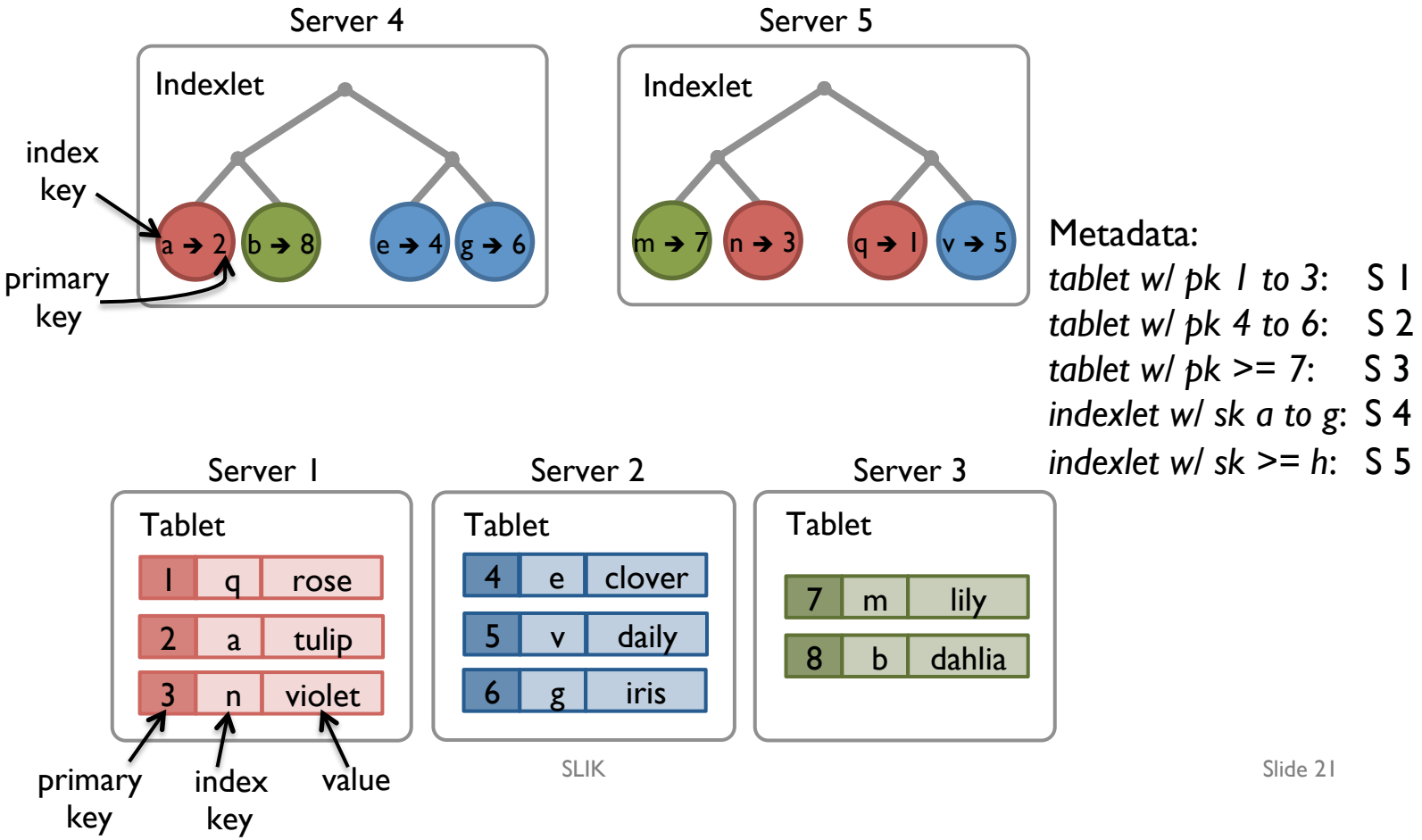

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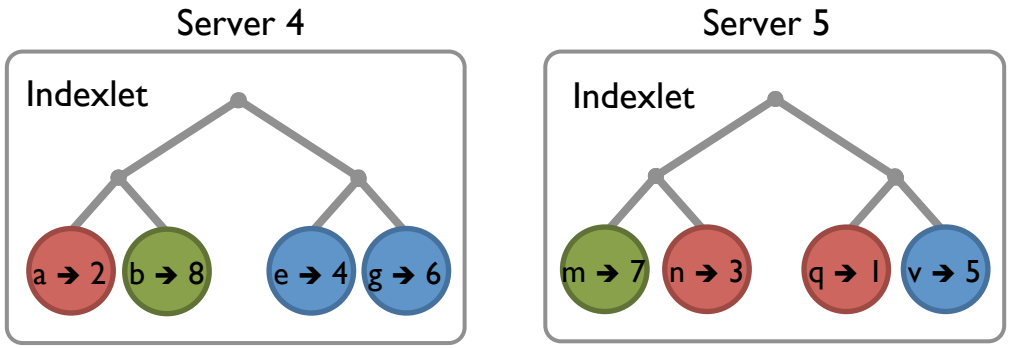


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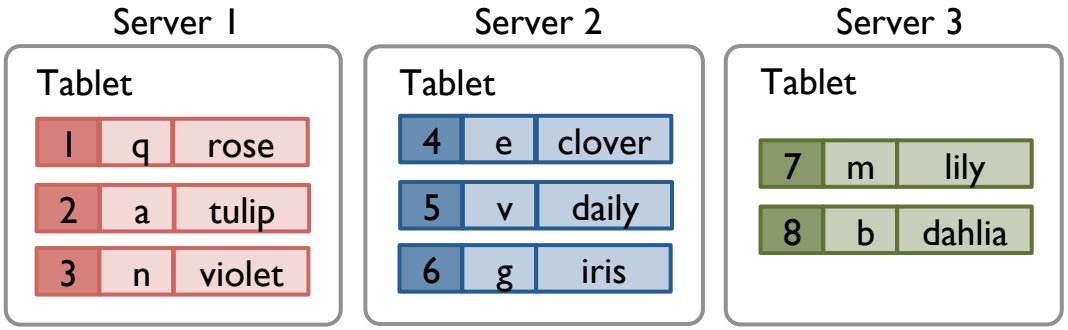

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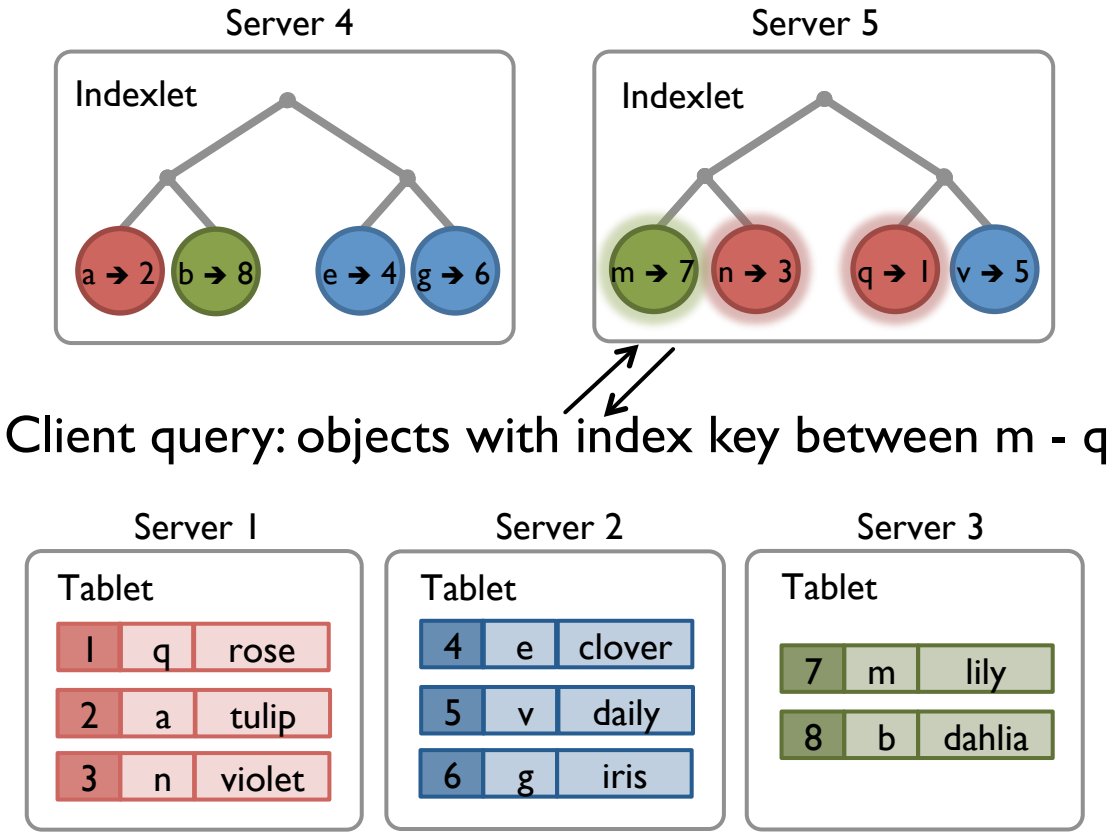

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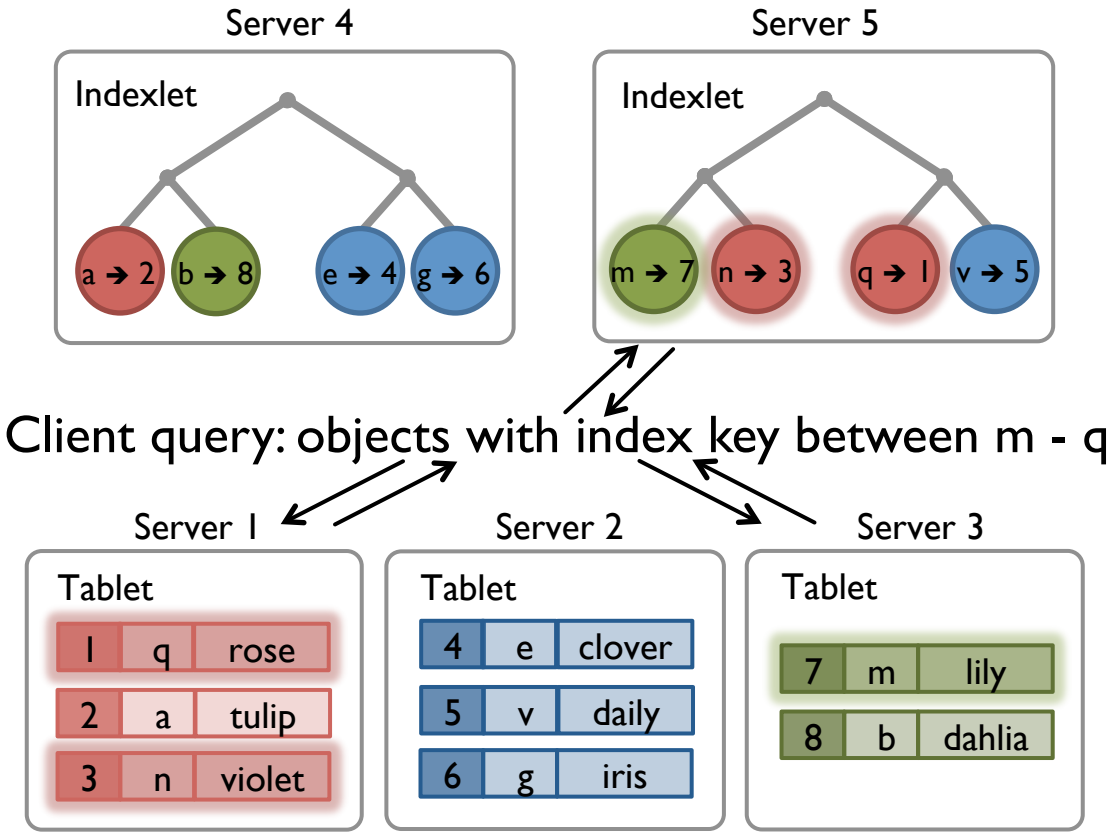

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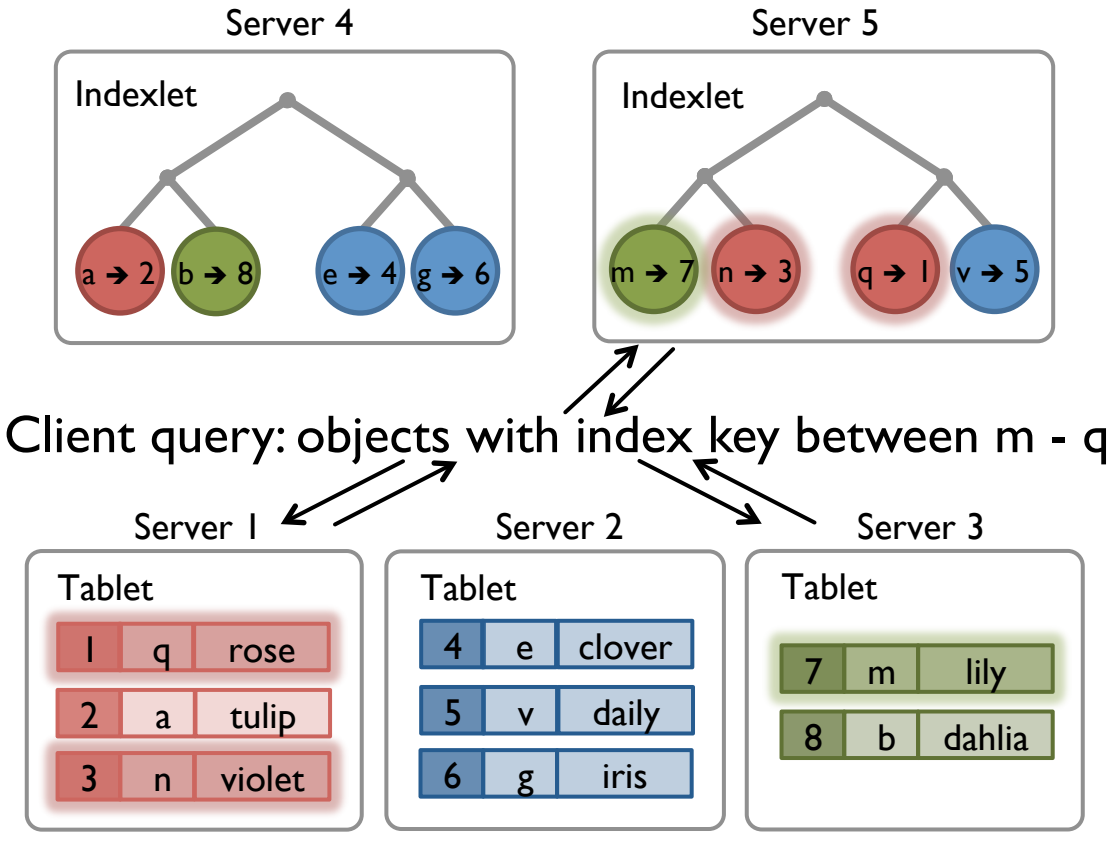
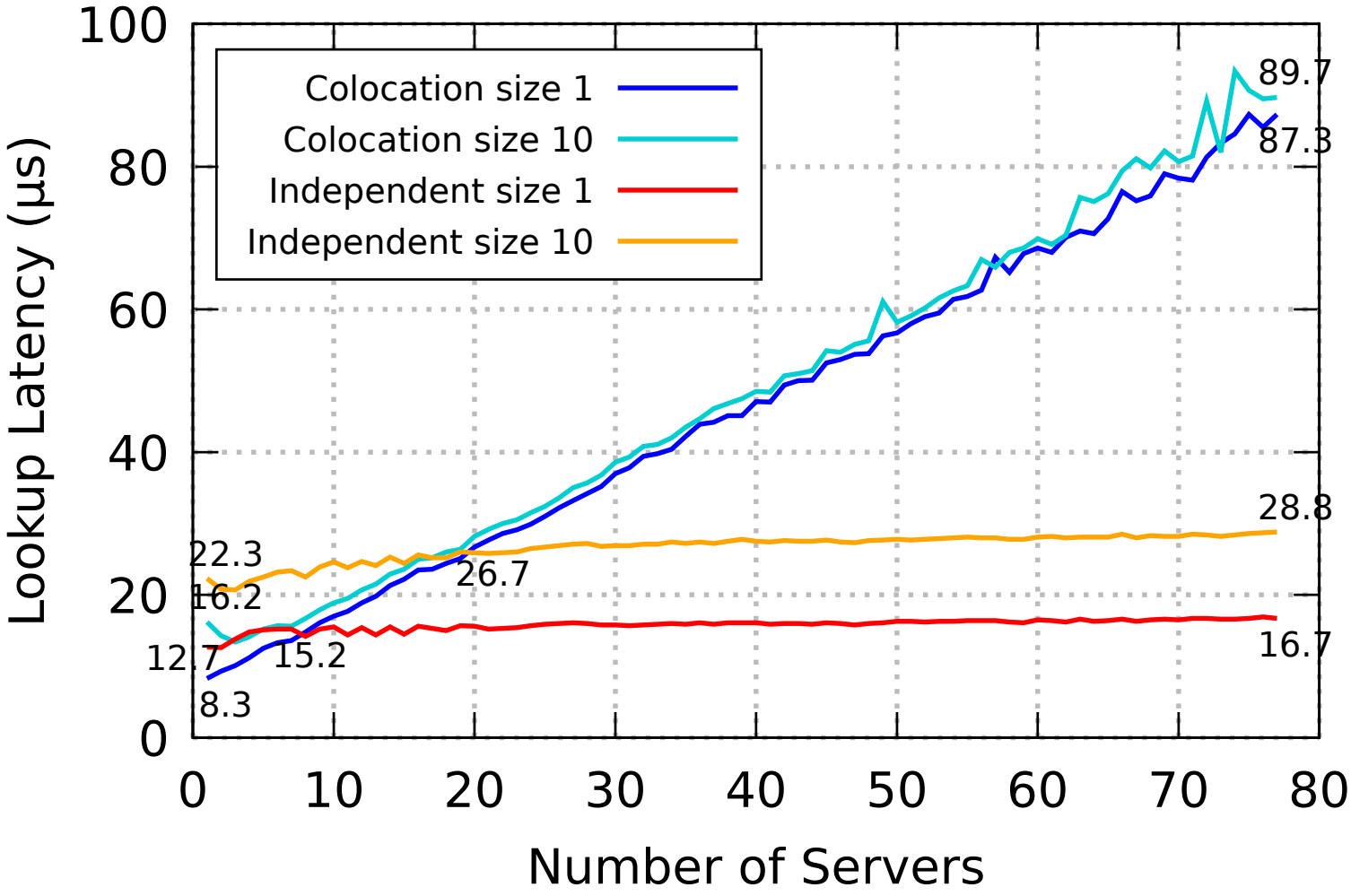



Scalable!

# Index Partitioning: Lookup Latency



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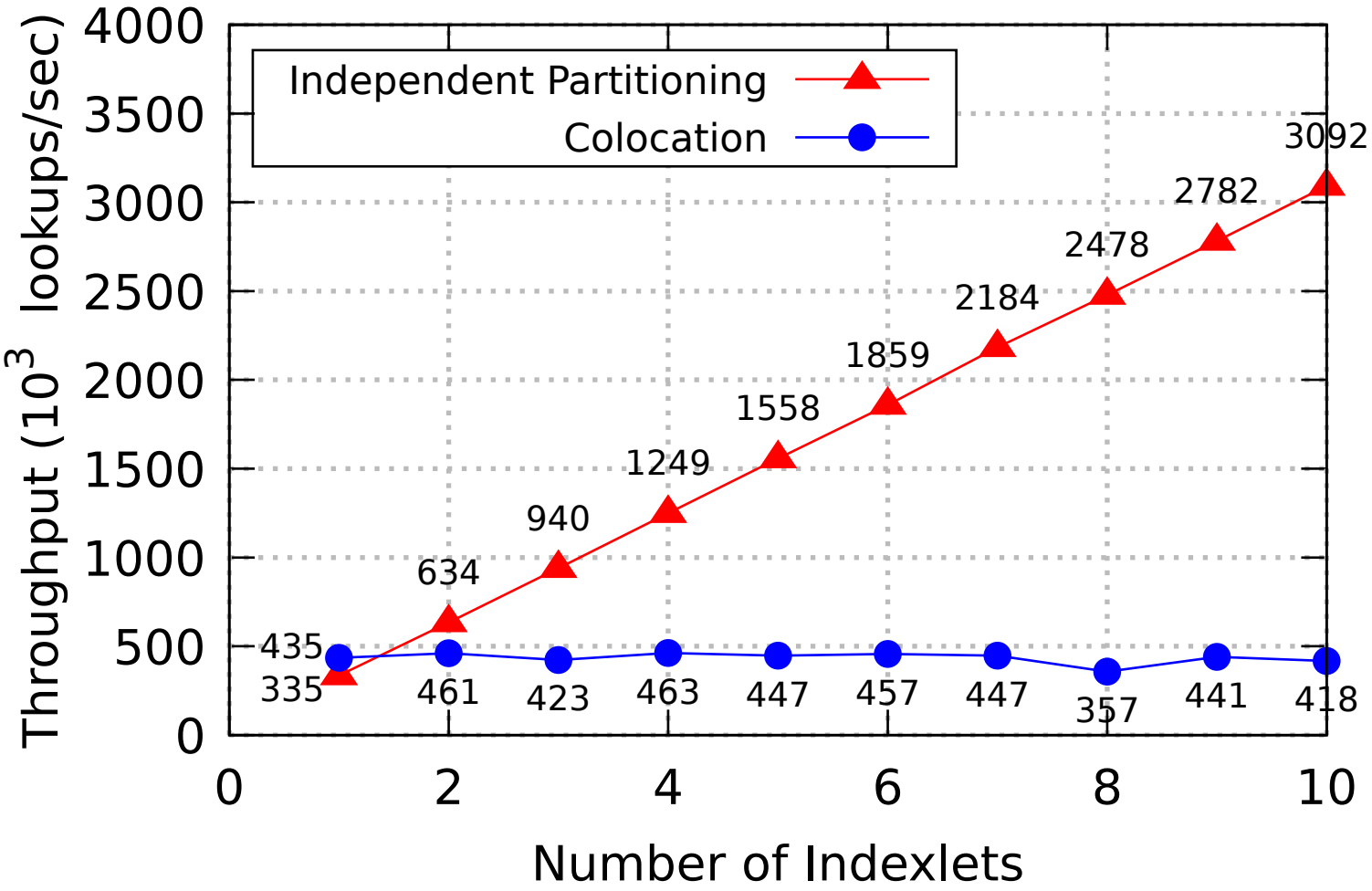

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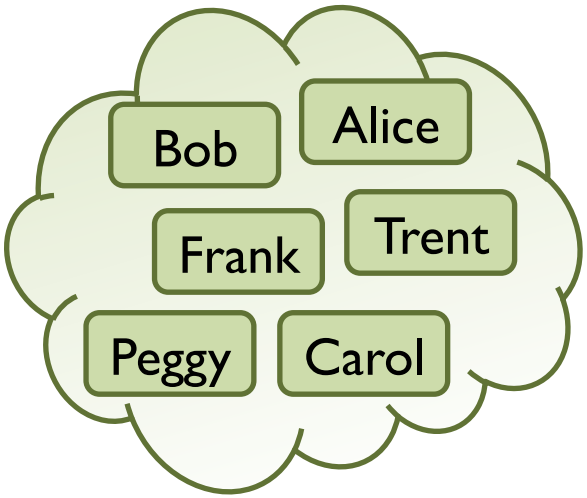

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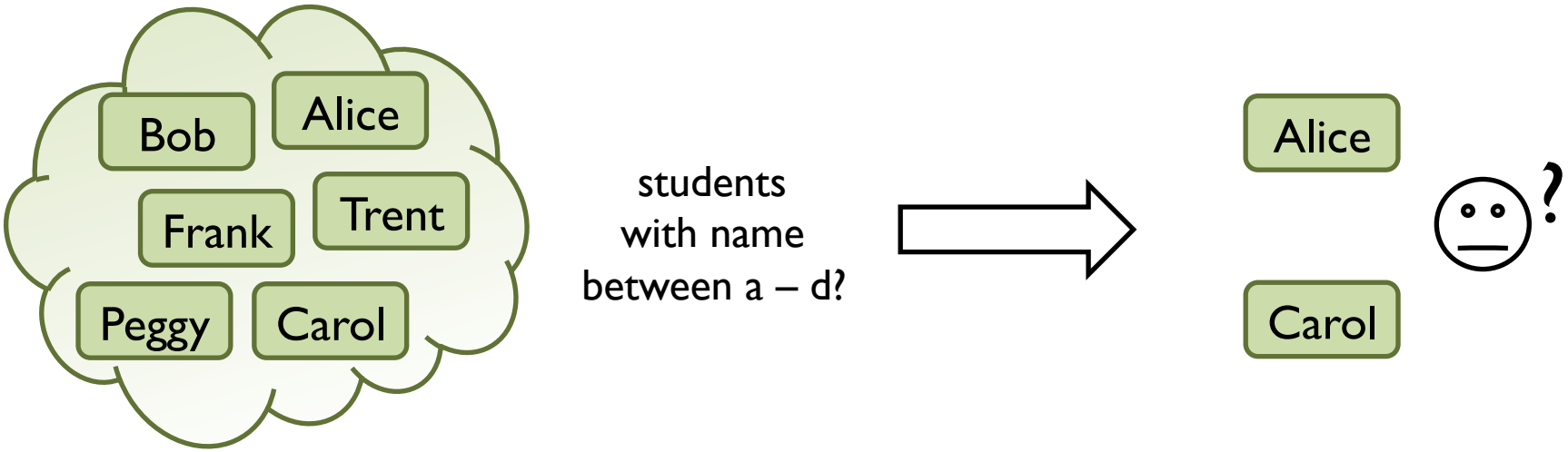

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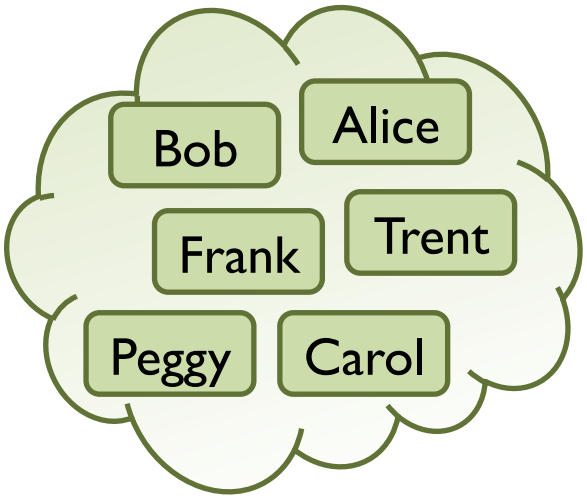

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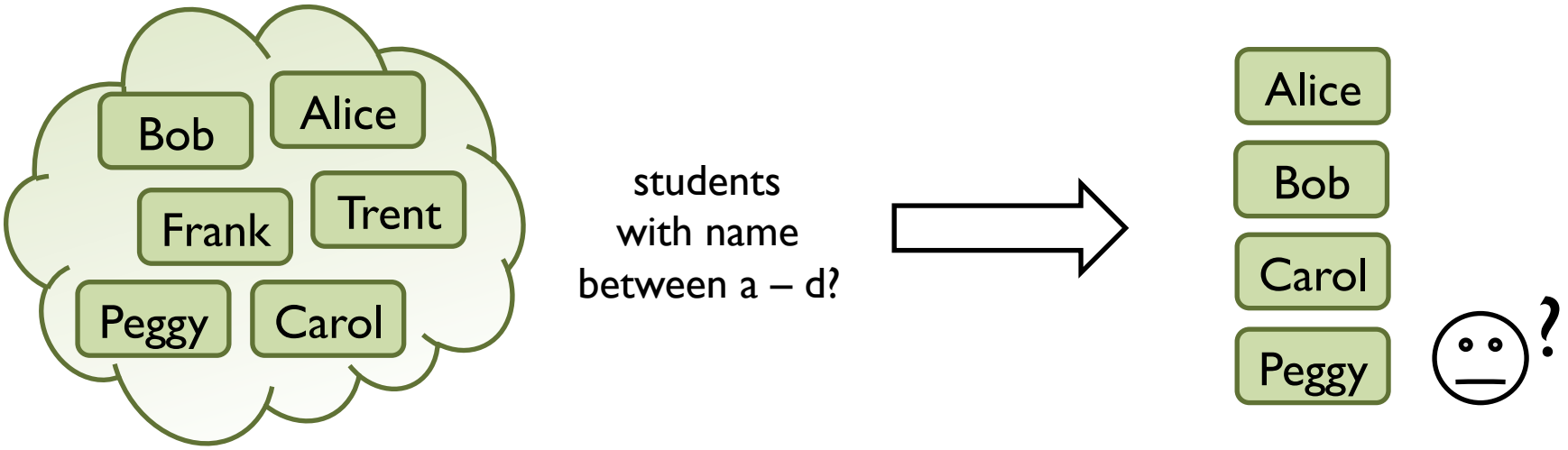

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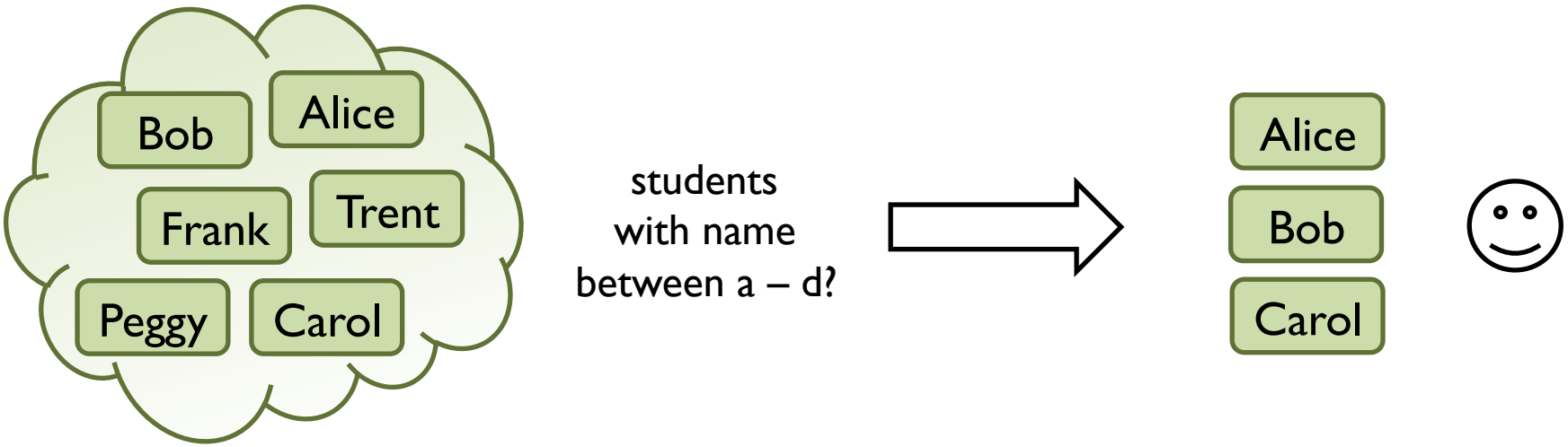

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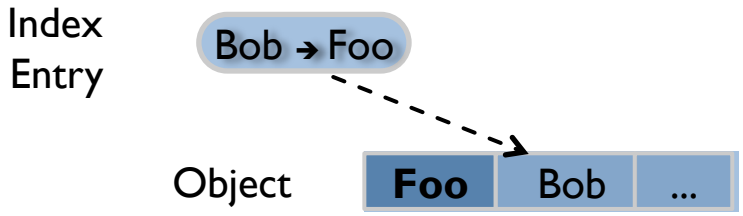

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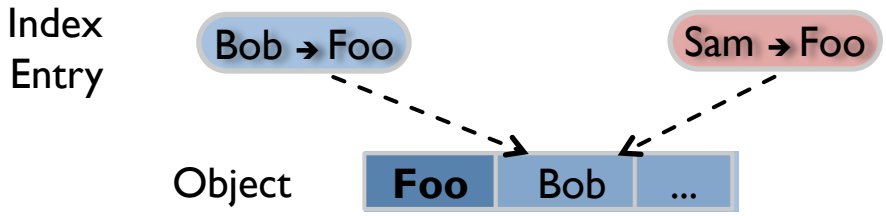


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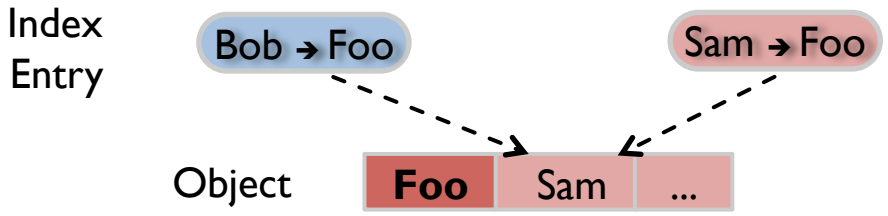


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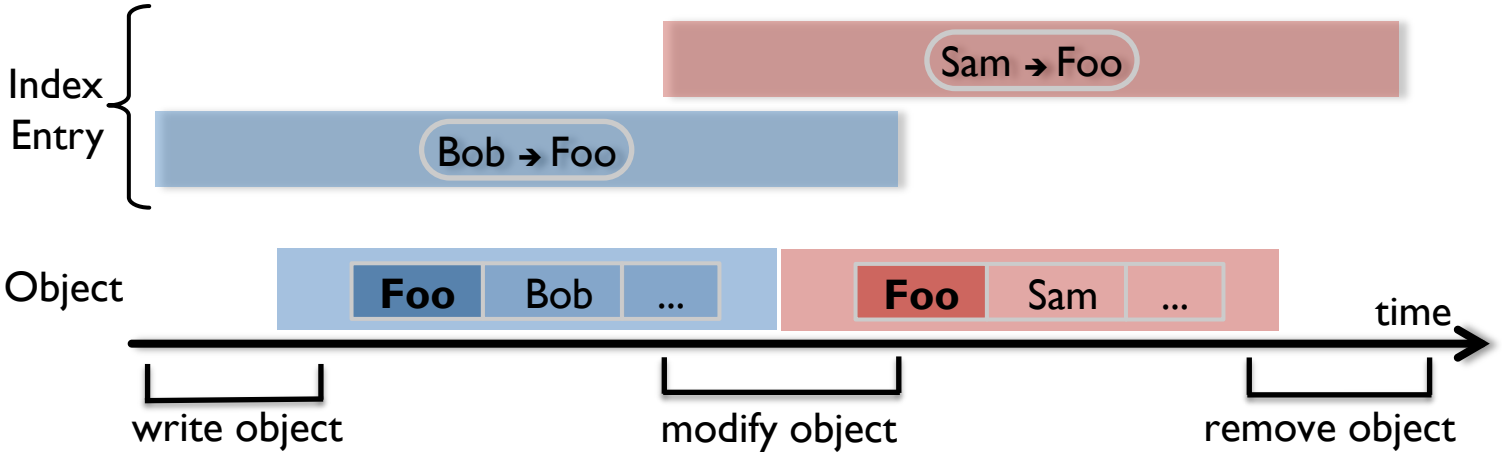

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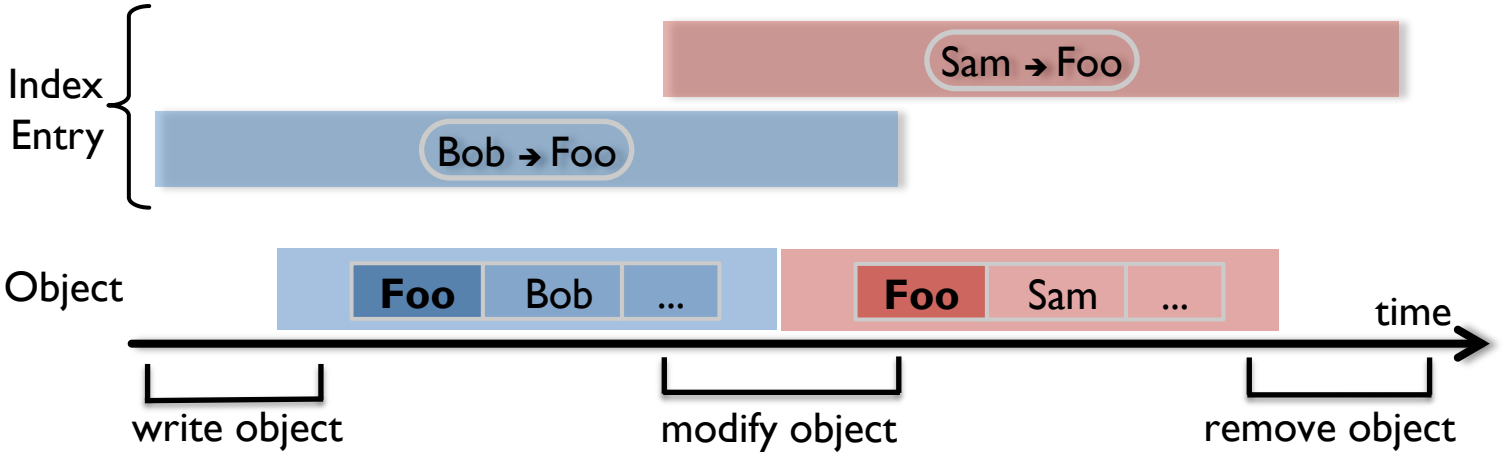

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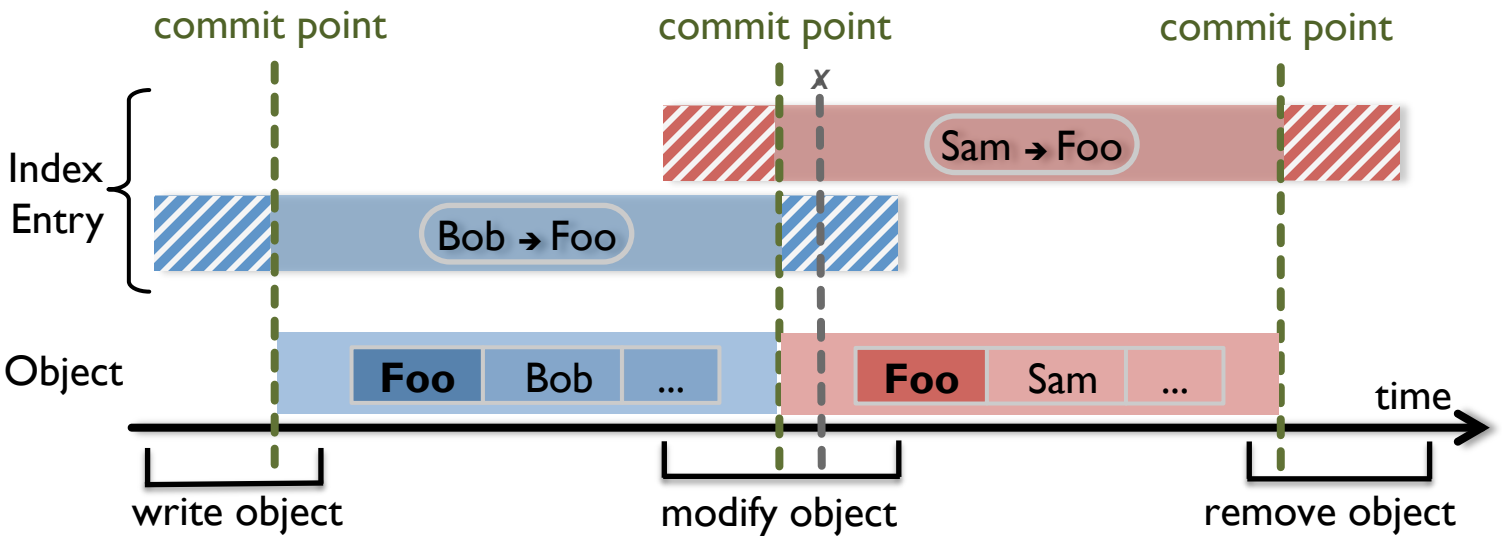

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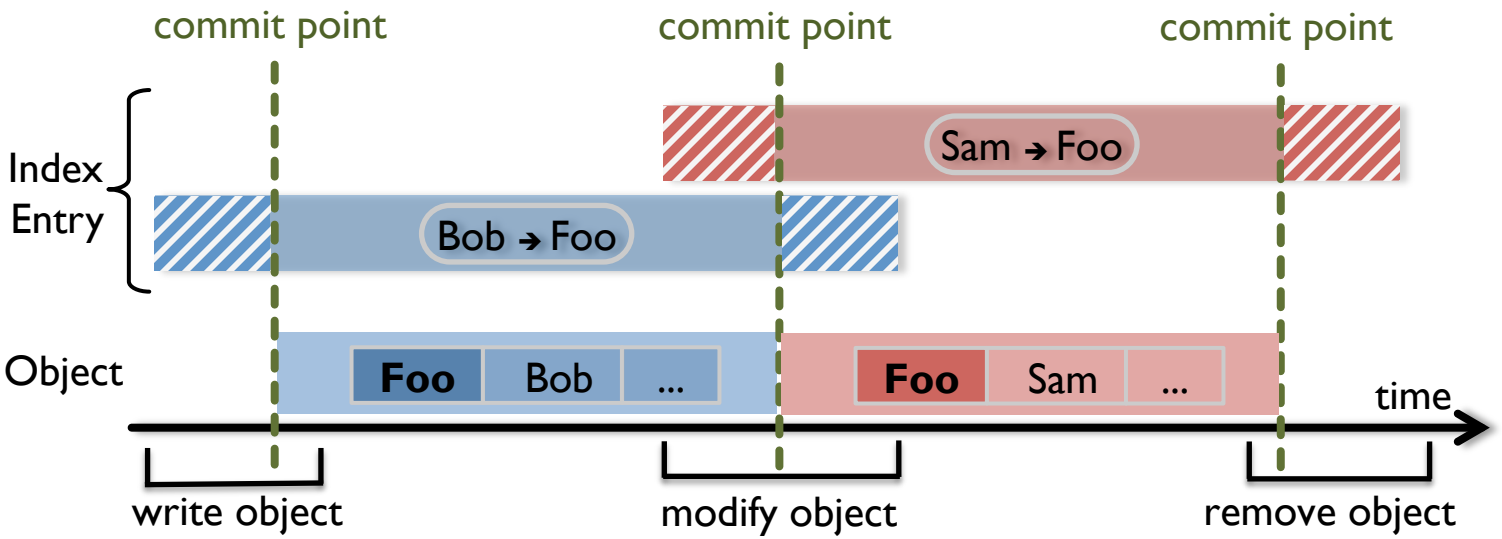

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  - Solution: Use independent partitioning
  - But: indexed object writes: distributed operations
  - Potential consistency issues between indexes and objects
- **Strong consistency**
  - With minimal performance overheads
  - Solution: Ordered write approach + treat indexes as hints

# Talk Outline

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- Related Work
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# Performance: Questions

- Does SLIK provide low latency?
- Does SLIK provide scalability?
- How does the performance of indexing with SLIK compare to other state-of-the-art systems?

# Performance: Systems for Comparison

- **H-Store:**
  - Main memory database
  - Data (and indexes) partitioned based on specified attribute
  - Many parameters for tuning
    - Got assistance from developers to tune for each test
    - Examples: txn_incoming_delay, partitioning column
- **HyperDex:**
  - Spaces containing objects
  - Data (and indexes) partitioned using hyperspace hashing
  - Each index contains all object data
  - Designed to use disk for storage

# Hardware

| | |
|---|---|
| CPU | Xeon X3470 (4x2.93 GHz cores, 3.6 GHz Turbo) |
| RAM | 24 GB DDR3 at 800 MHz |
| Flash | 2x Crucial M4 SSDs |
| Disks | CT128M4SSD2 (128 GB) |
| NIC | Mellanox ConnectX-2 InfiniBand HCA |
| Switch | Mellanox SX6036 (4X FDR) |

# Latency

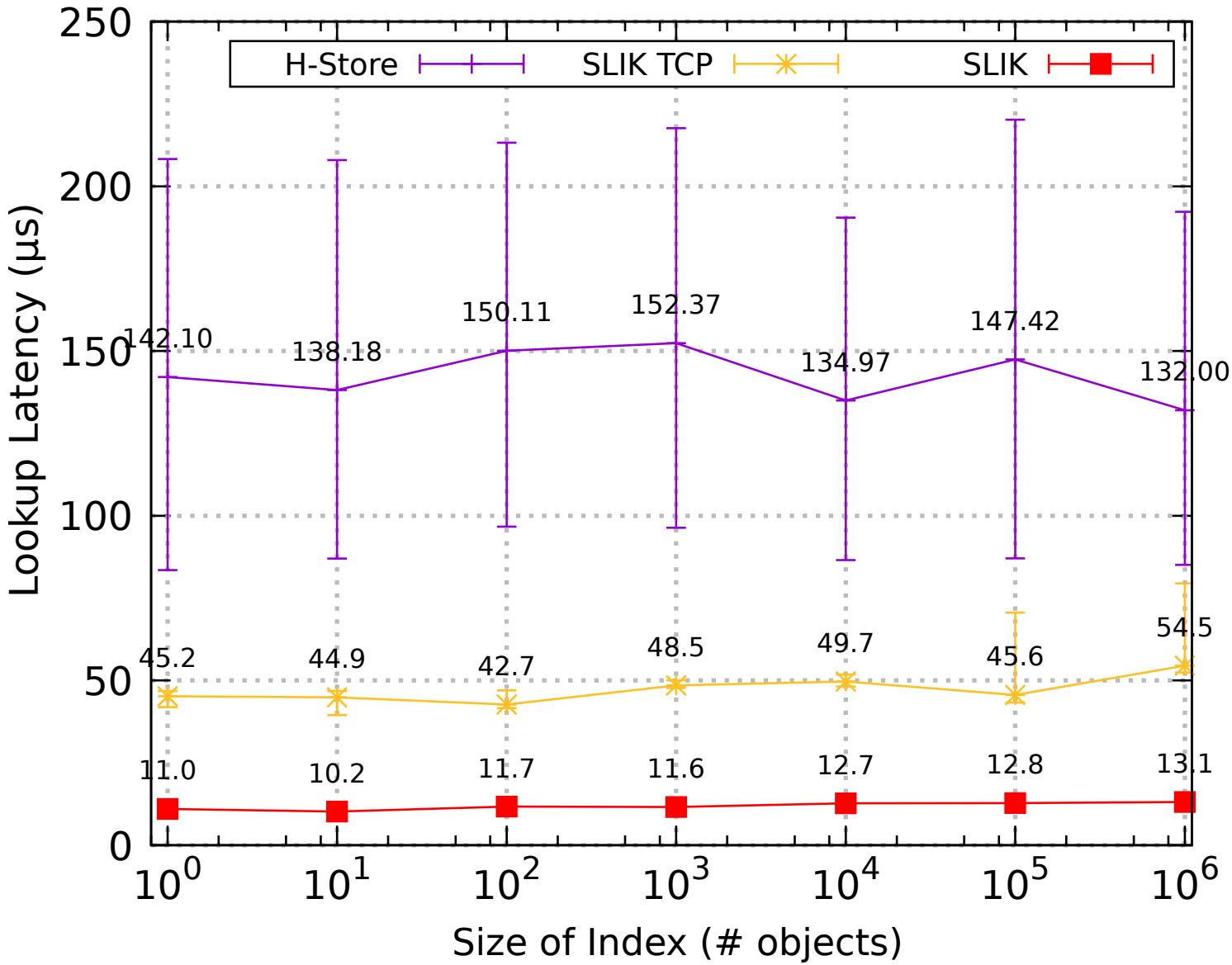
**Experiments**:

1. Lookups: table with single secondary index
2. Overwrites: table with single secondary index
3. Overwrites: varying number of secondary indexes

**Configuration**:

- Single client
- Single partition for table and (each) index
- Object: 30 B pk, 30 B sk, 100 B value
- SLIK: Three-way replication to durable backups
- H-Store: No replication, durability disabled, single server

# Lookup Latency



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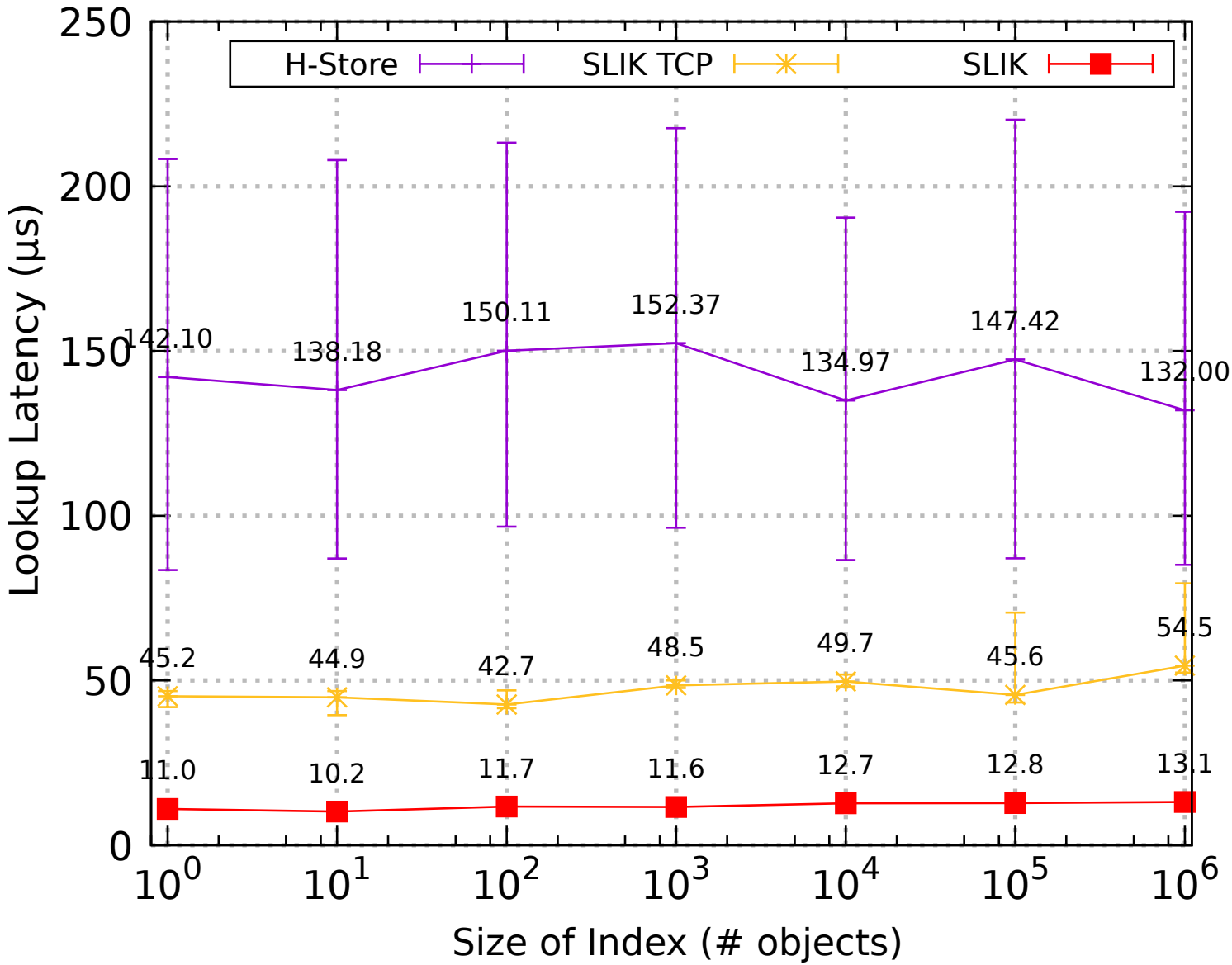
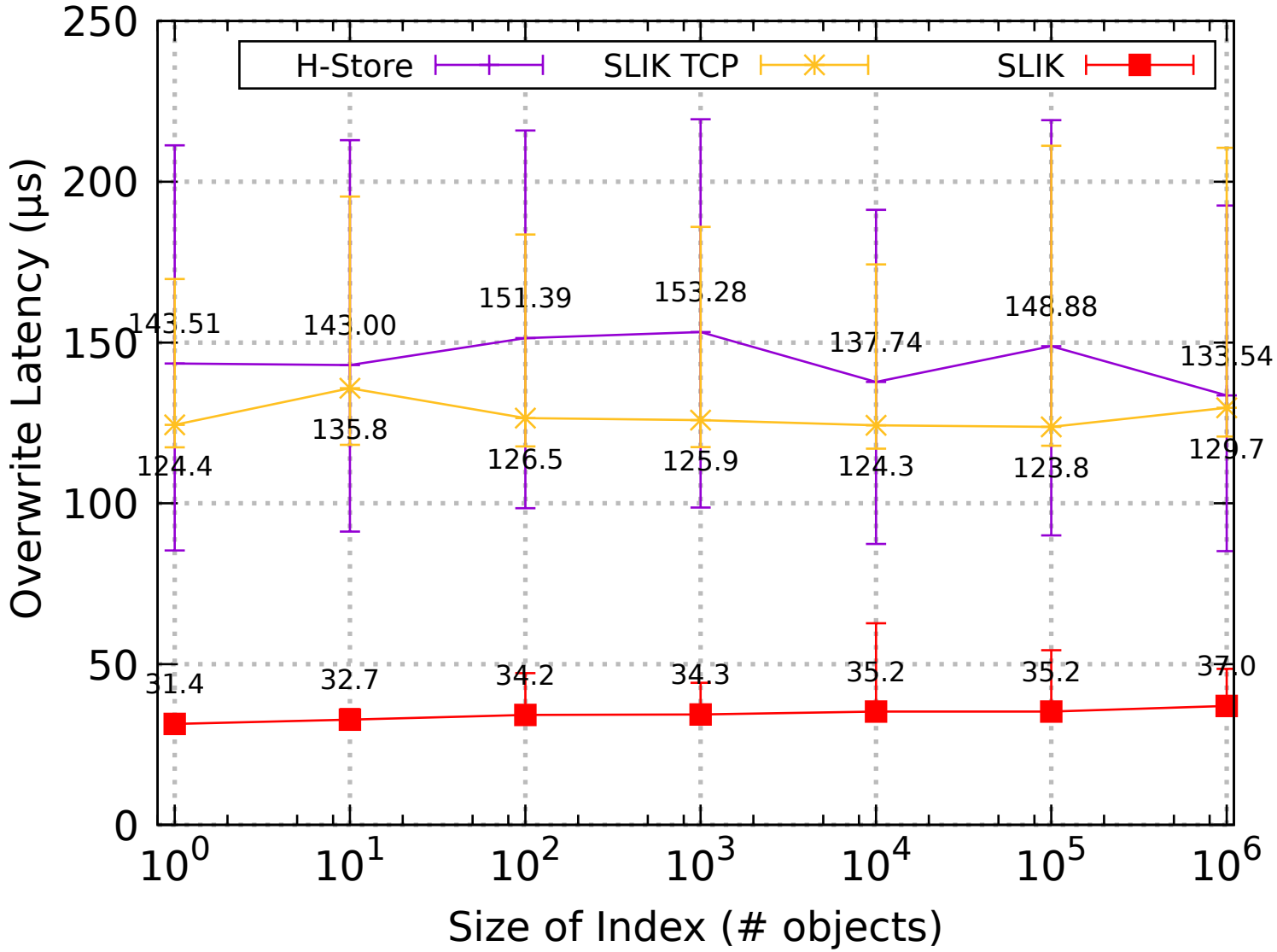


# Overwrite Latency



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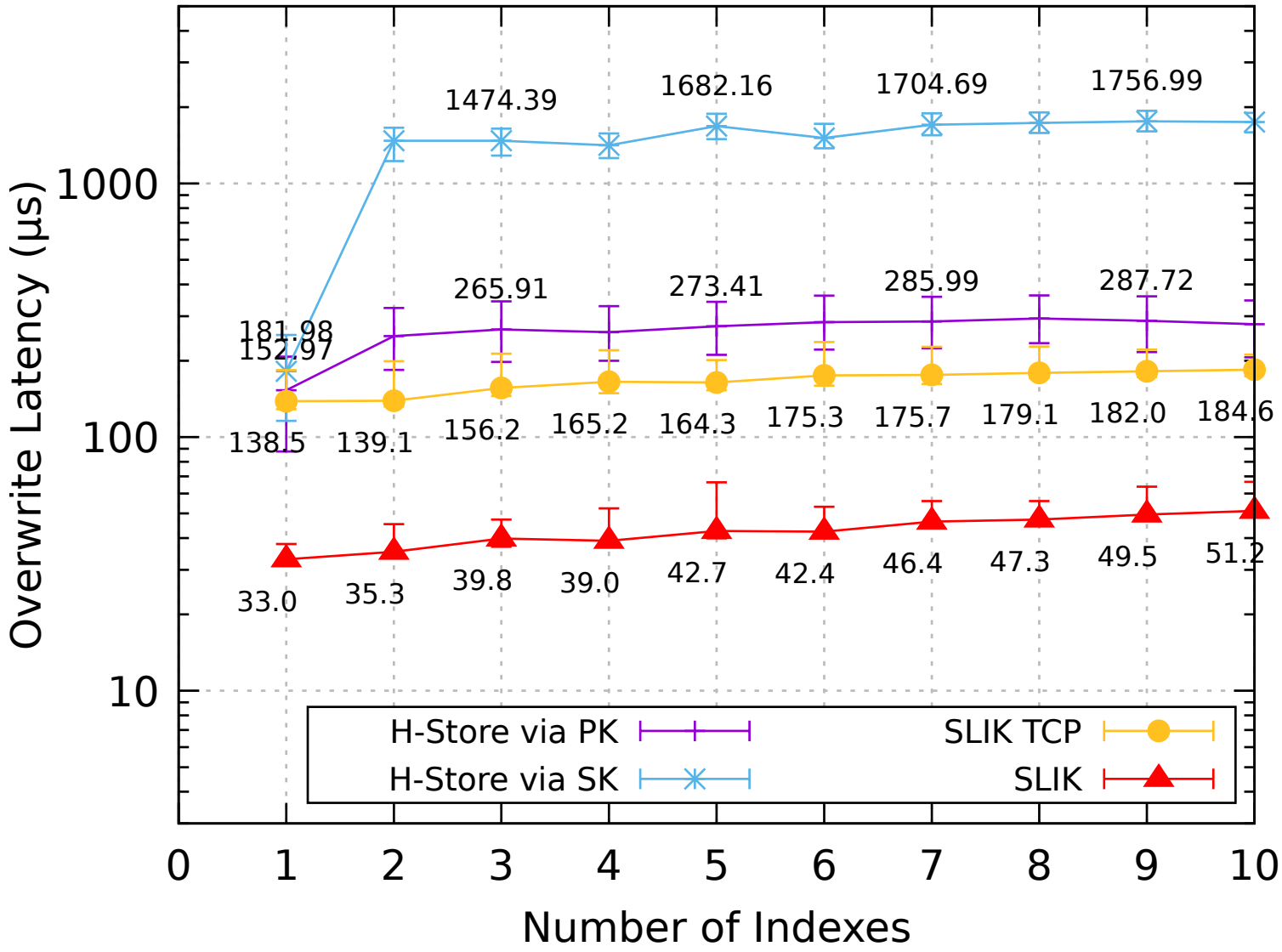

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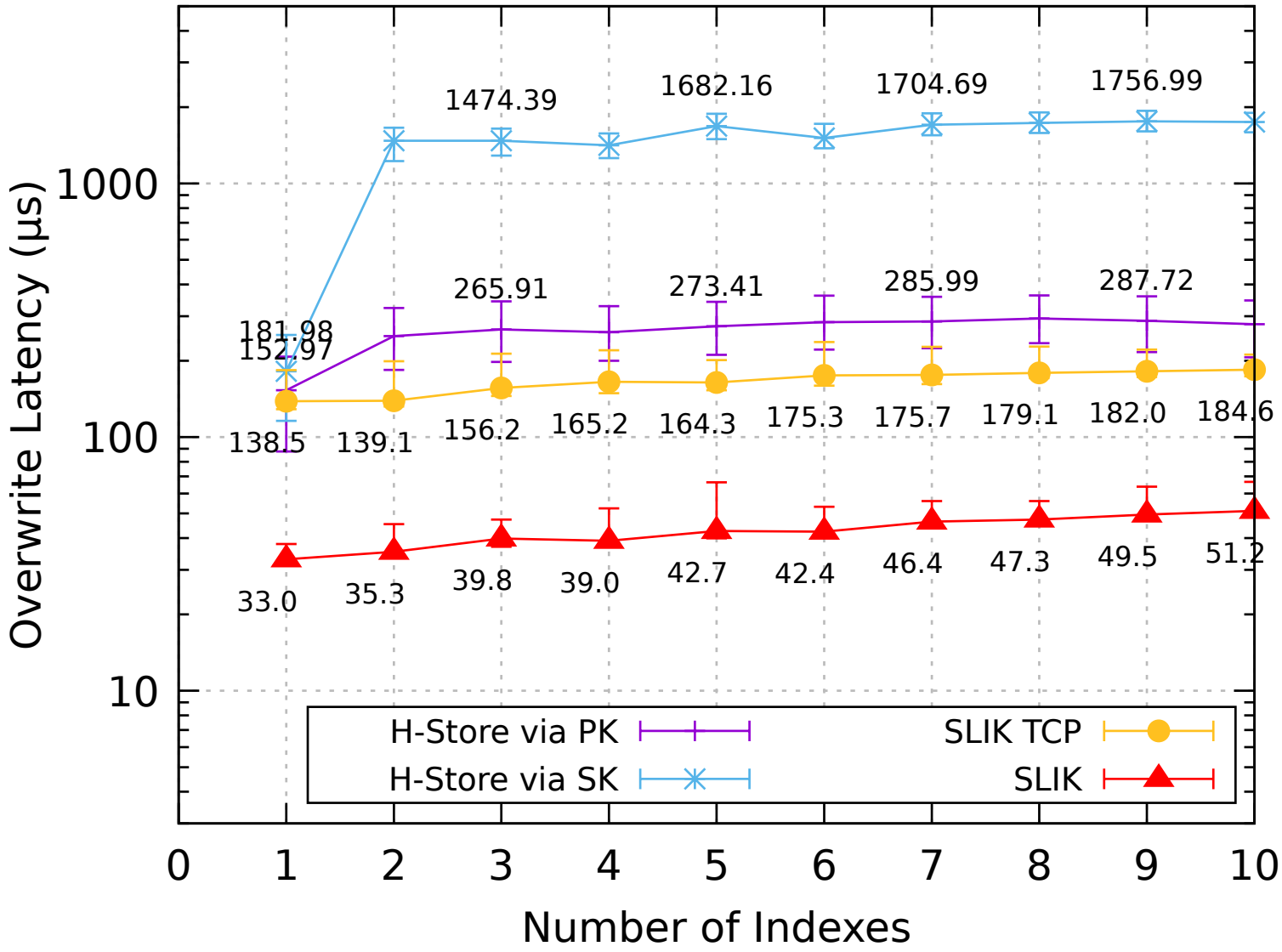

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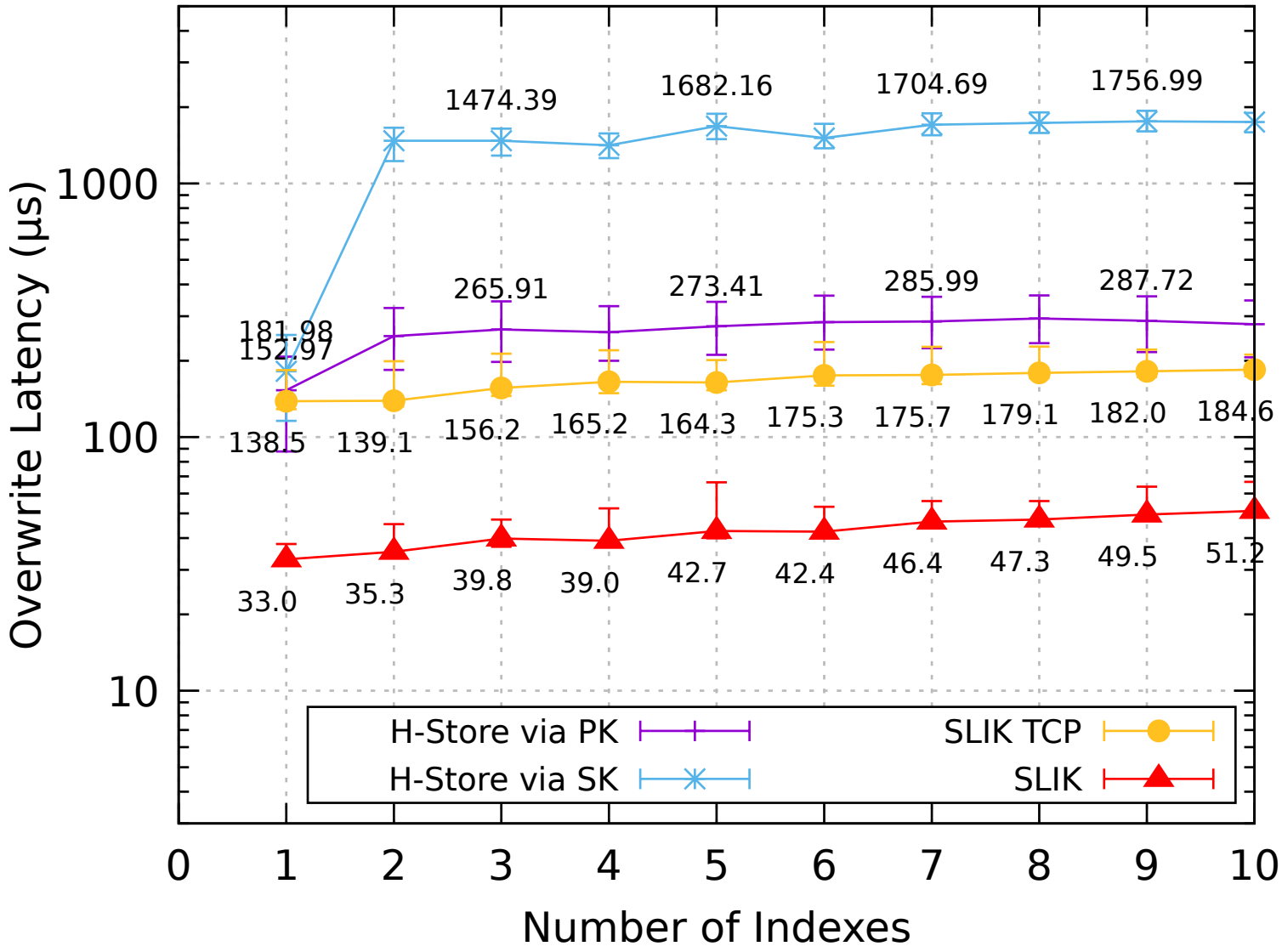


# Scalability

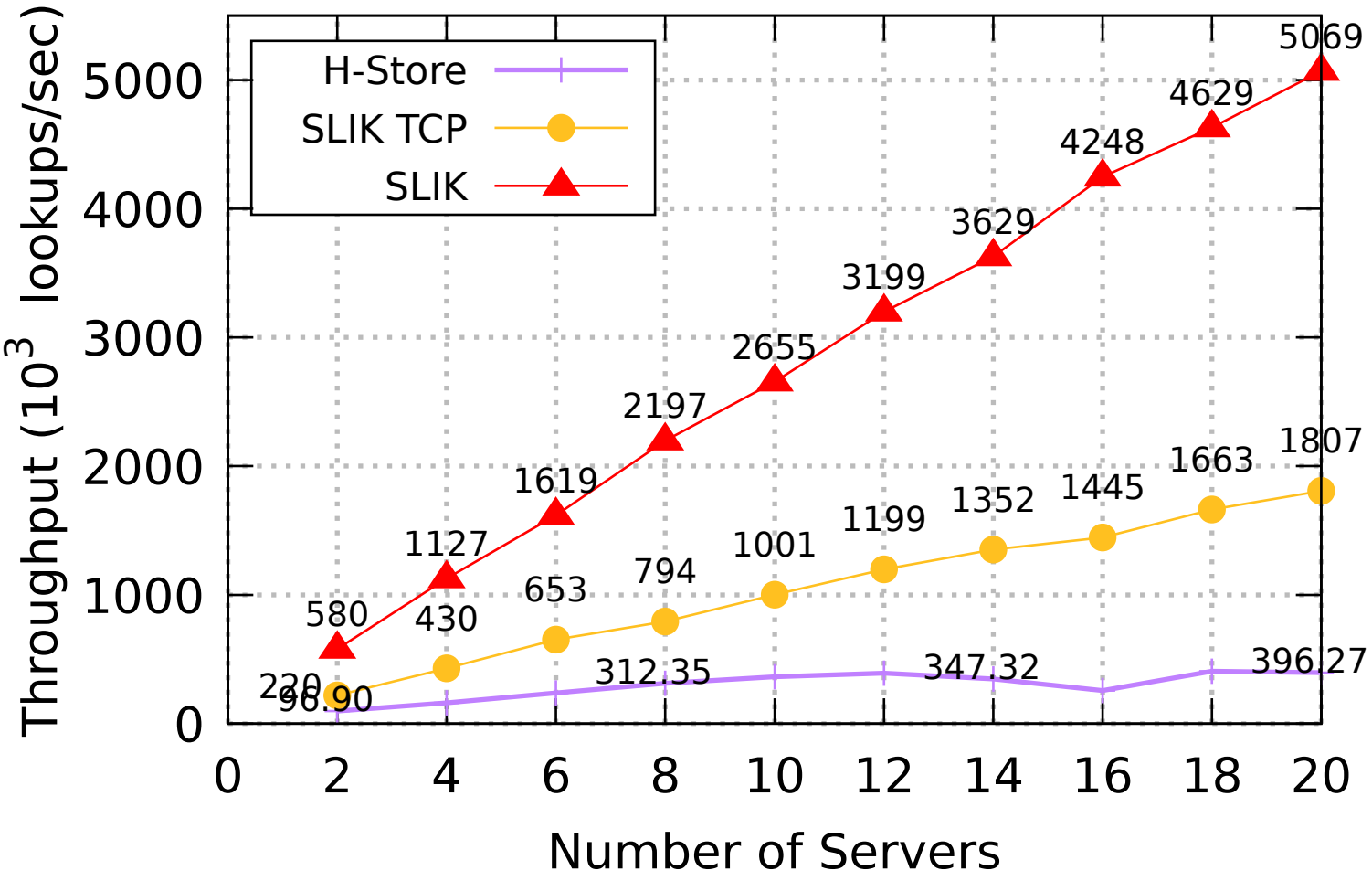
**Experiments**:

1. Lookup throughput with increasing number of partitions
2. Lookup latency with increasing number of partitions

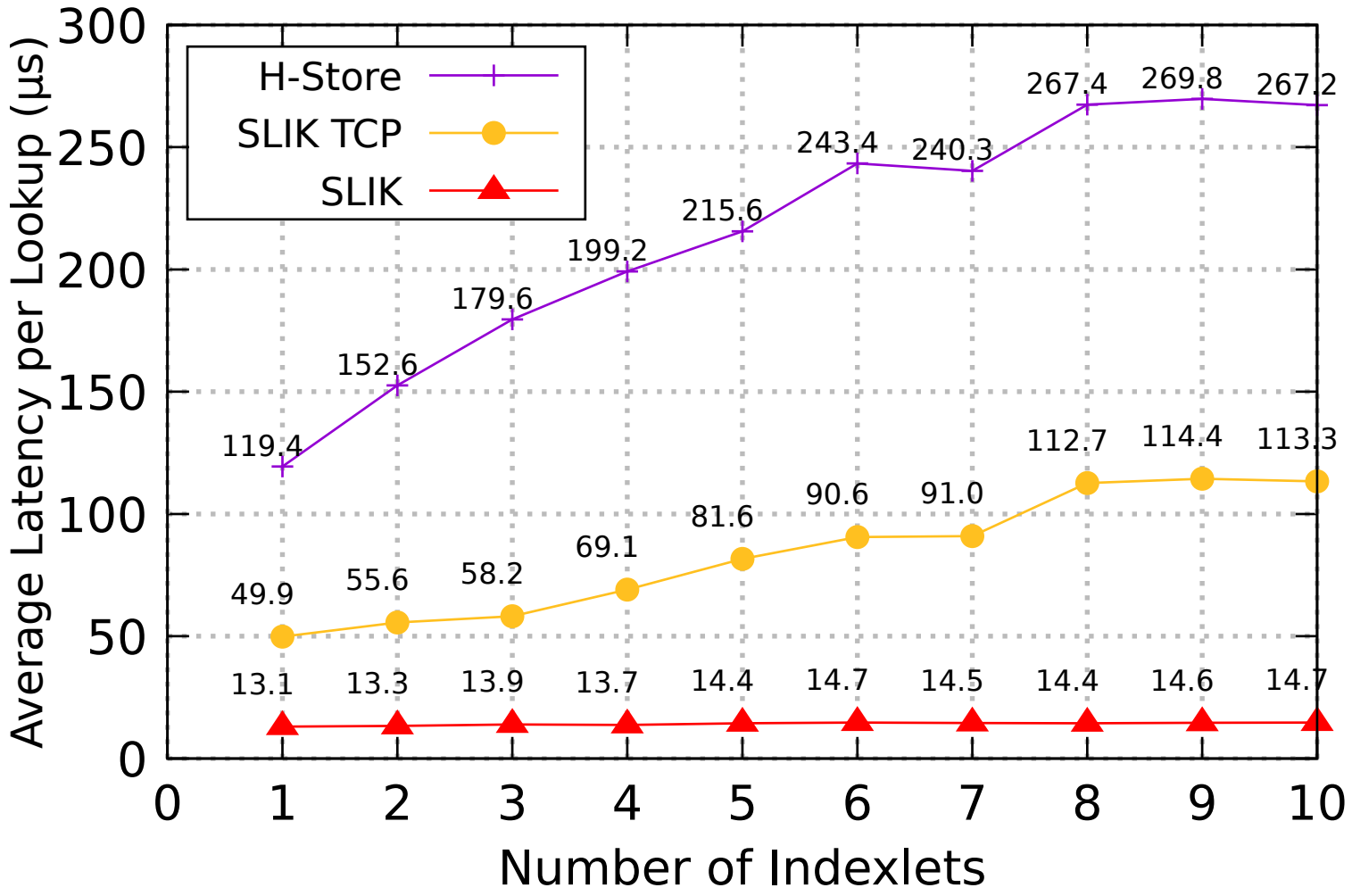
**Configuration**:

- Single table with one secondary index
- Table and index partitioned across servers
- Object: 30 B pk, 30 B sk, 100 B value
- Throughput experiment: Loaded system
- Latency experiment: Unloaded system

# Scalability: Lookup Throughput



# Scalability: Lookup Latency



# Talk Outline

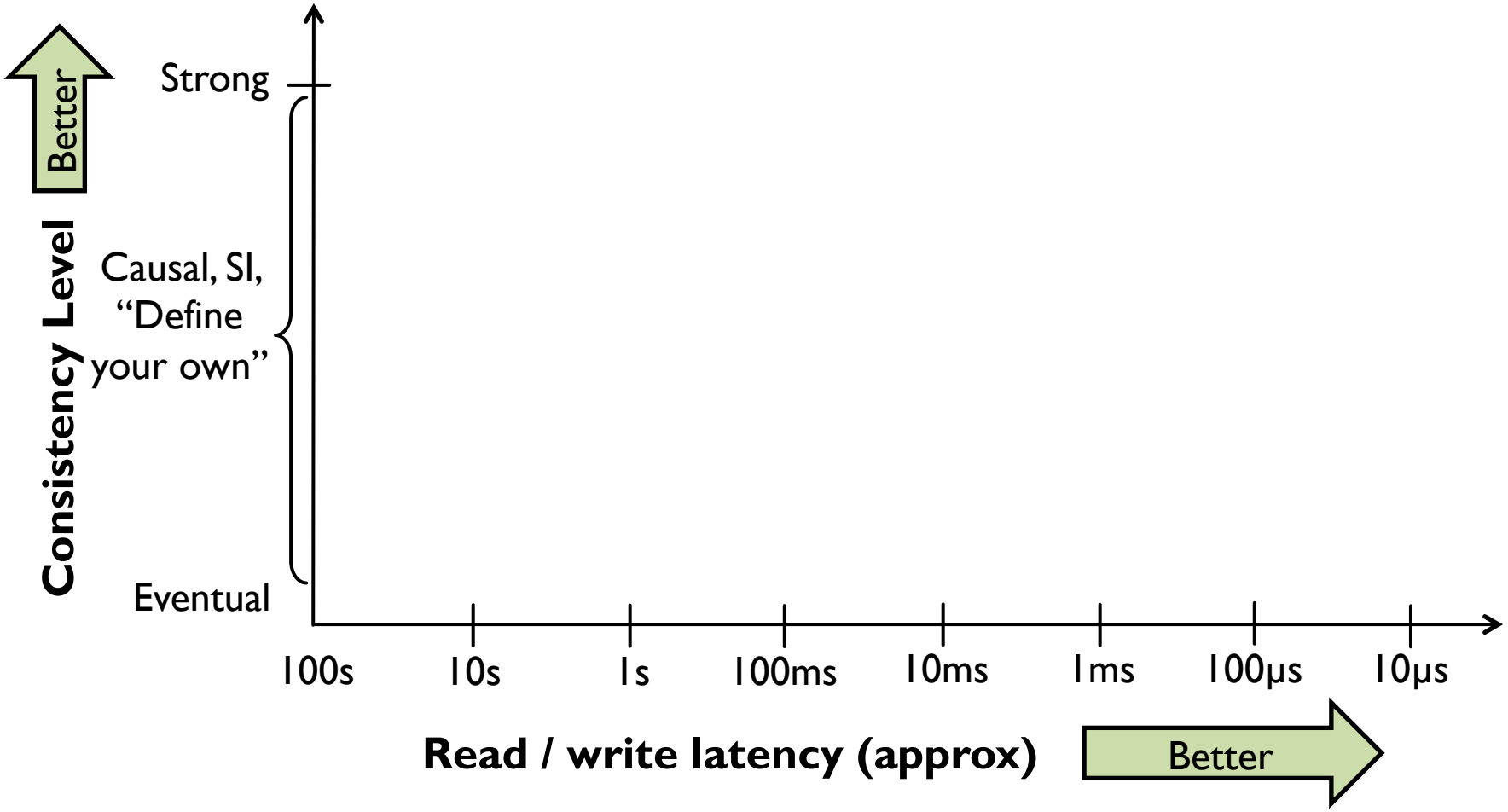
- Motivation
- Design
- Performance
- **Related Work**
- Summary

# Related Work

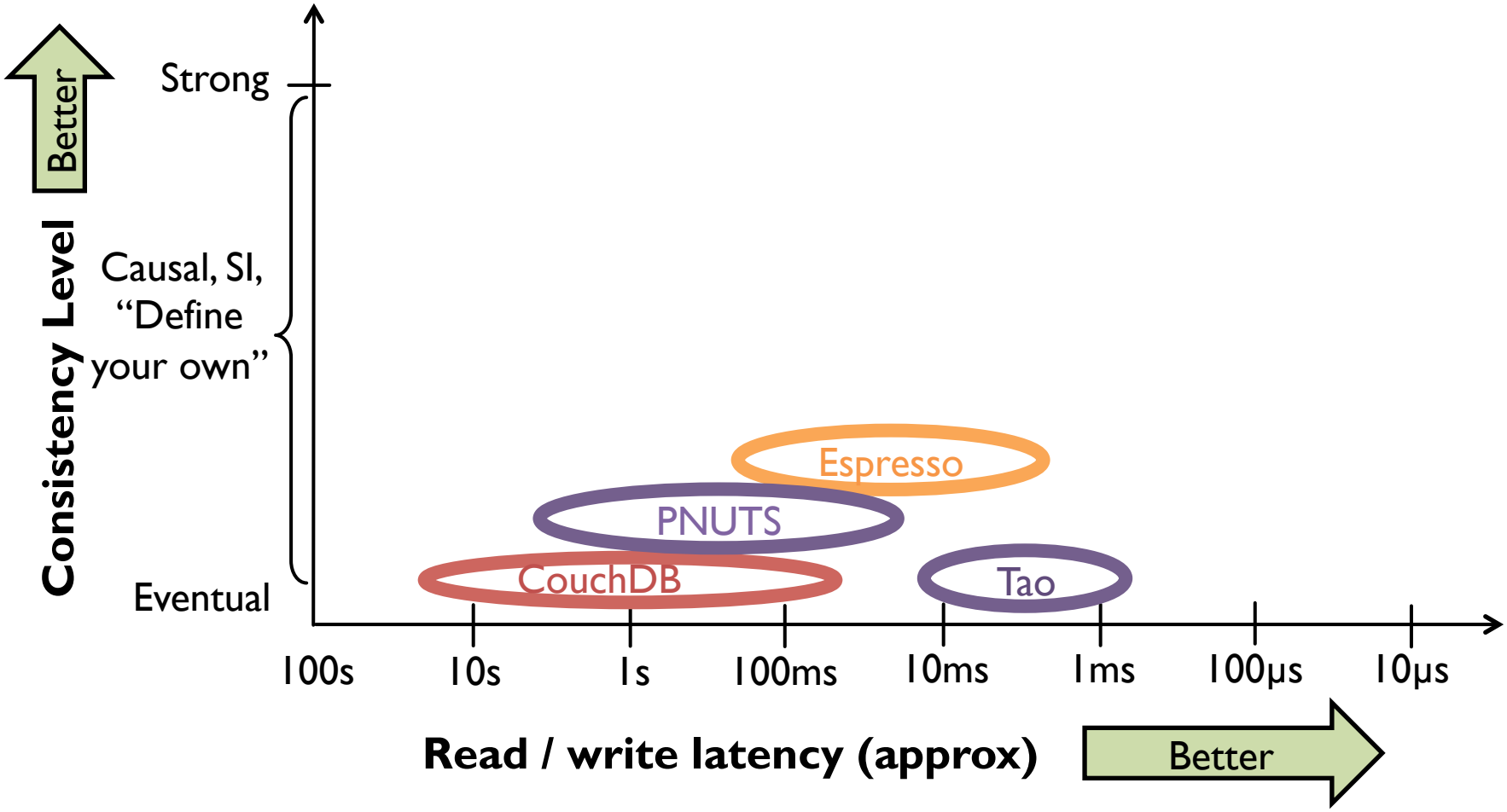
## Data storage system

- **Data model** (spectrum from key-value to relational)
- **Consistency** (spectrum from eventual to strong)
- **Performance**: **latency and/or throughput**

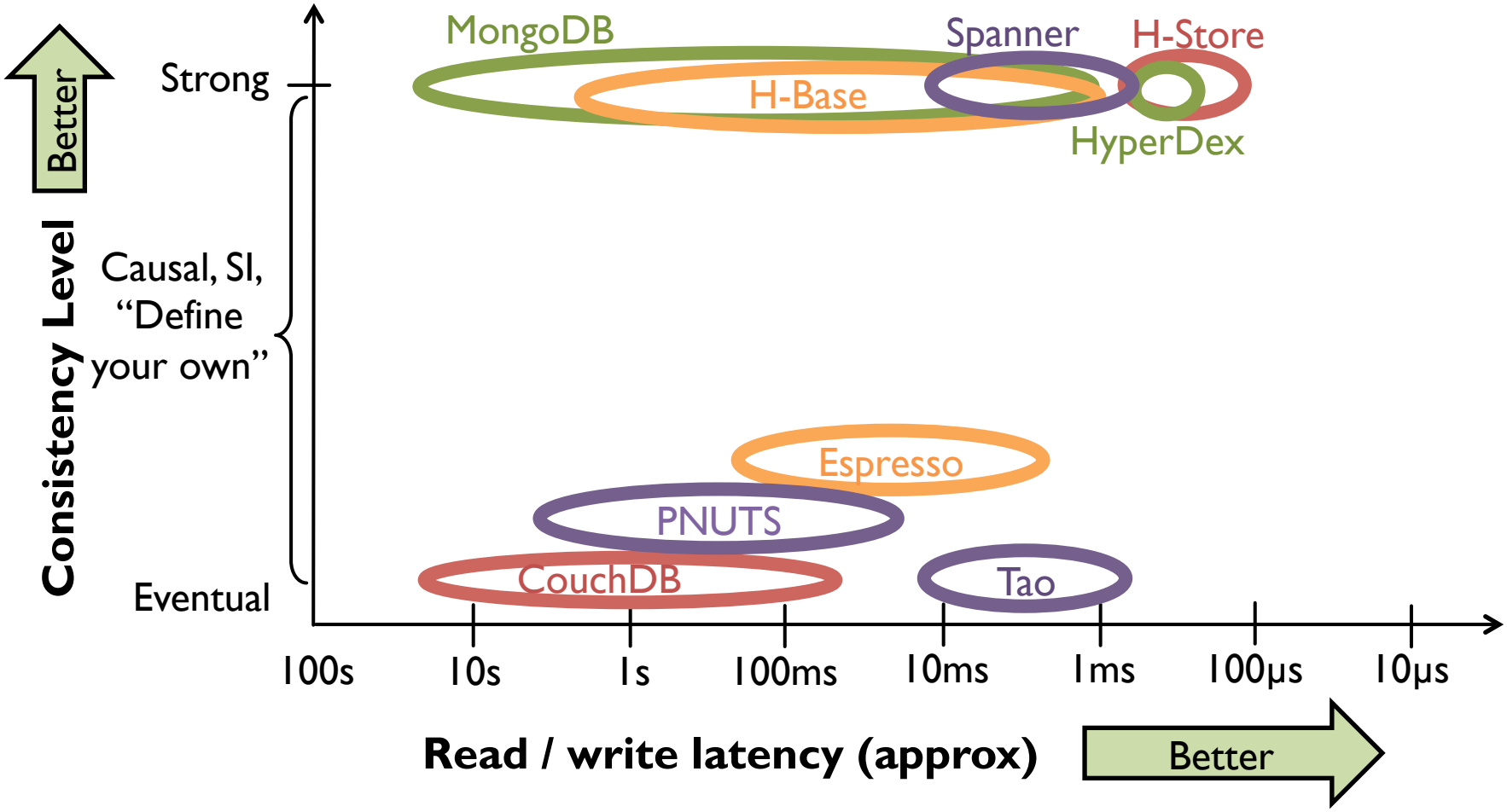
# Current Web Scale Datastores



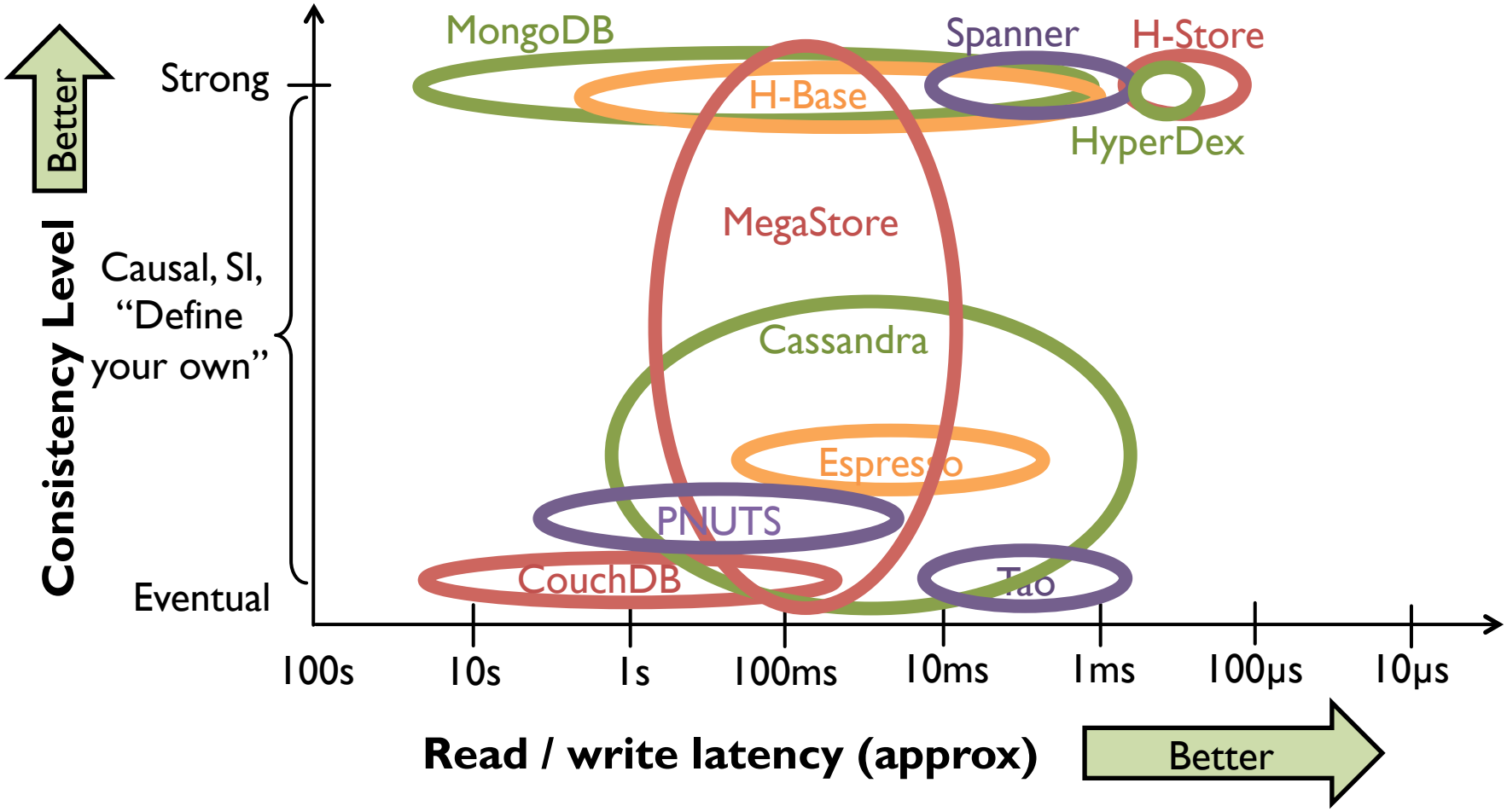
# Current Web Scale Datastores



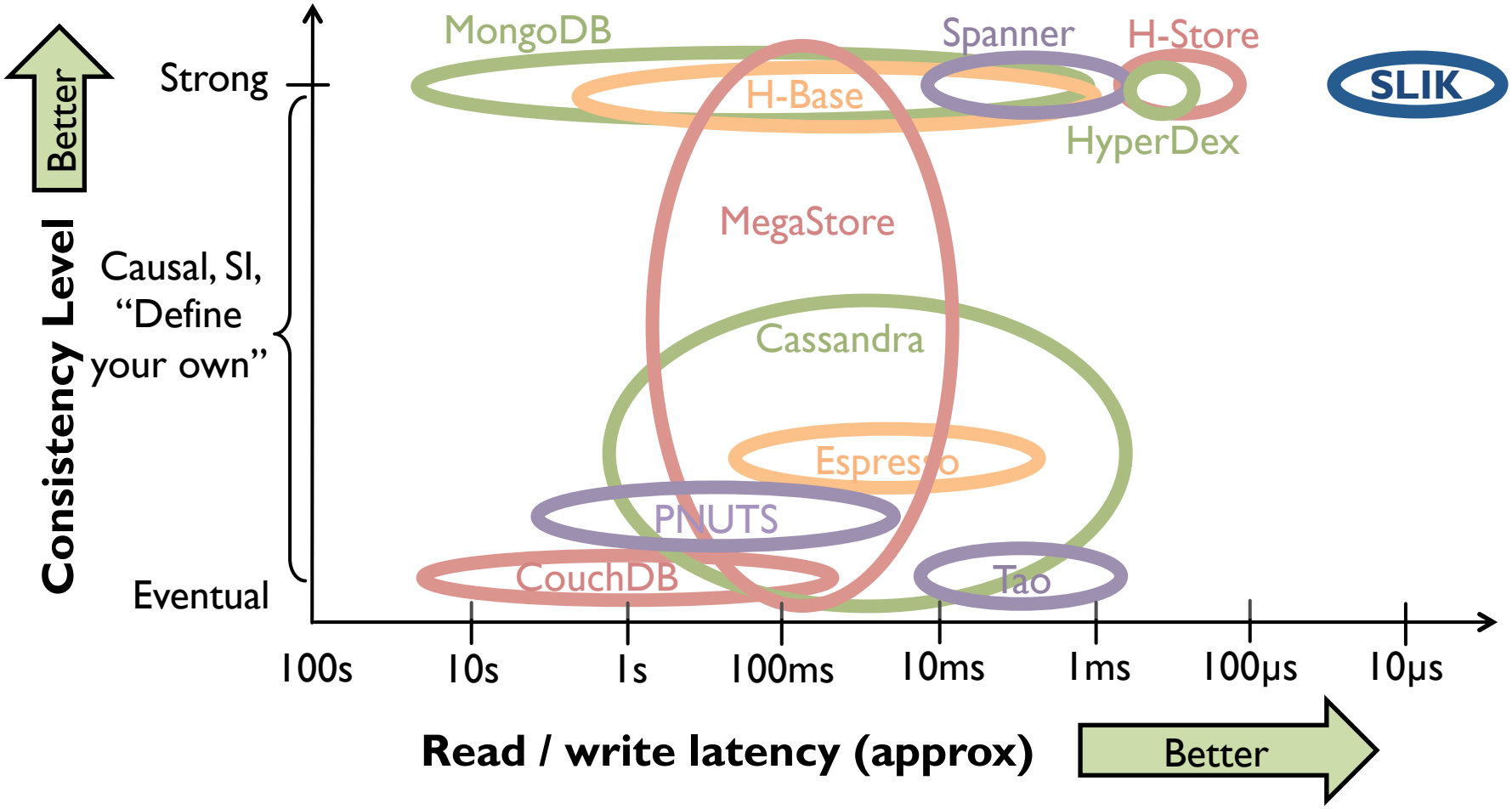
# Current Web Scale Datastores



# Current Web Scale Datastores



# Current Web Scale Datastores



# Talk Outline

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# Summary

By using ordered writes and treating indexes as hints

Lookups and range queries on secondary keys

A key value store can support

**strongly consistent secondary indexes**

while operating at **low latency** and **large scale**.

By using approaches that have minimal overheads we get:
*11-13 µs lookups and*
*30-37 µs (over)writes*

By using independent partitioning we get:
*linear throughput increase and*
*minimal impact on latency as the scale increases*

# Thank you!

Code available free and open source: github.com/PlatformLab/RAMCloud
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PLATFORMLAB

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