Scalable Low-Latency Indexes for a Key-Value Store

Ankita Kejriwal

With Arjun Gopalan, Ashish Gupta, Zhihao Jia, Stephen Yang

and John Ousterhout

PLATFORMLAB

Stanford University

Conjecture

Can a key value store 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**
  - Low-latency, DRAM-based, distributed key-value store
- **Performance:**
  - Scalability: Linear throughput increase with increasing number of partitions
  - Low-latency: 11-13 μs indexed reads, 29-37 μs durable writes/overwrites
  - Latency approximately 2x non-indexed reads and writes

Talk Outline

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

Motivation

Traditional
RDBMs

MySQL

Motivation

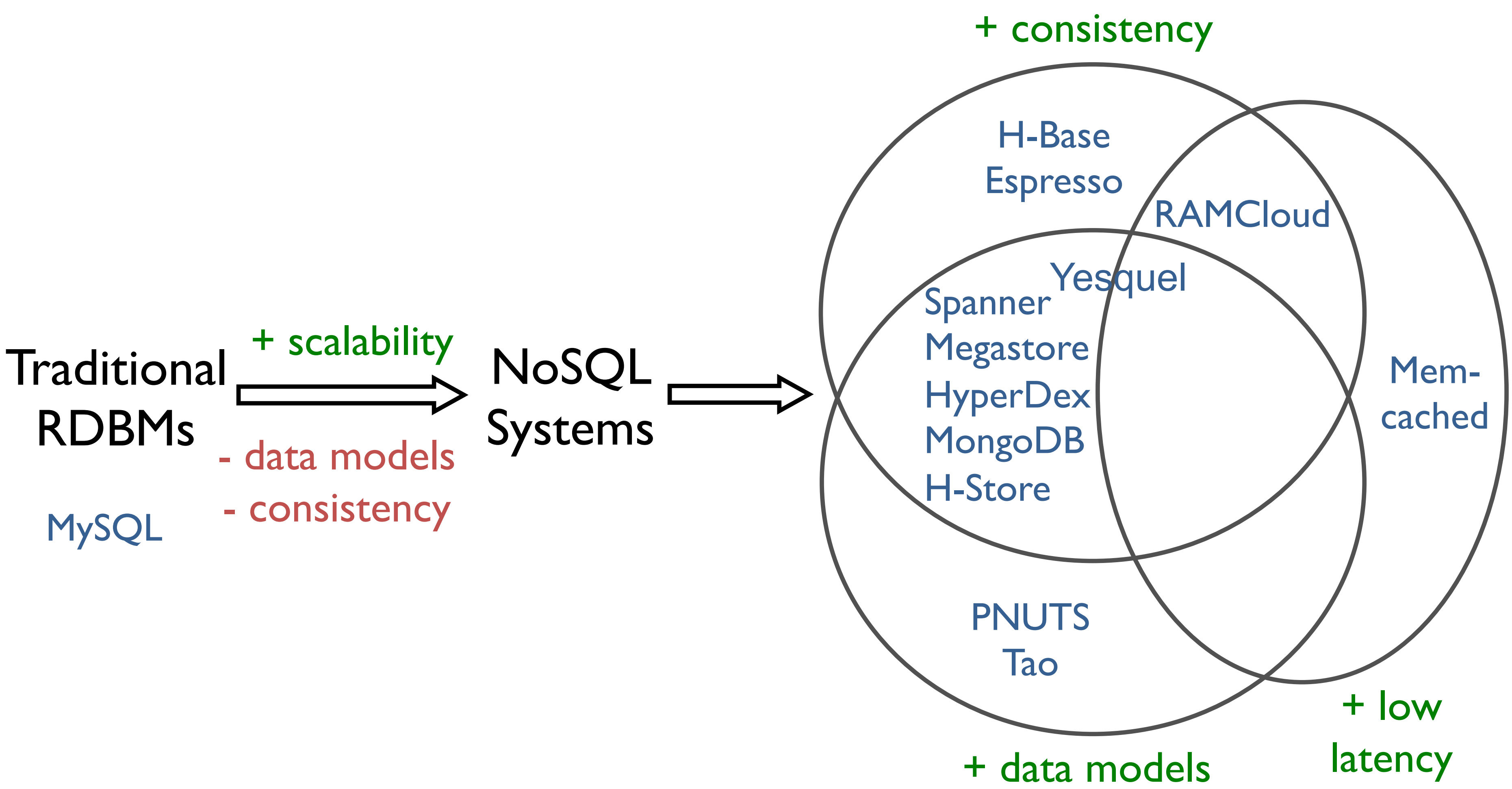
Traditional RDBMs → NoSQL Systems

+ scalability

- data models
- consistency

MySQL

Motivation



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+ scalability
- data models
- consistency
NoSQL Systems
+ consistency
H-Base
Espresso
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Mem-cached
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Tao
+ low latency
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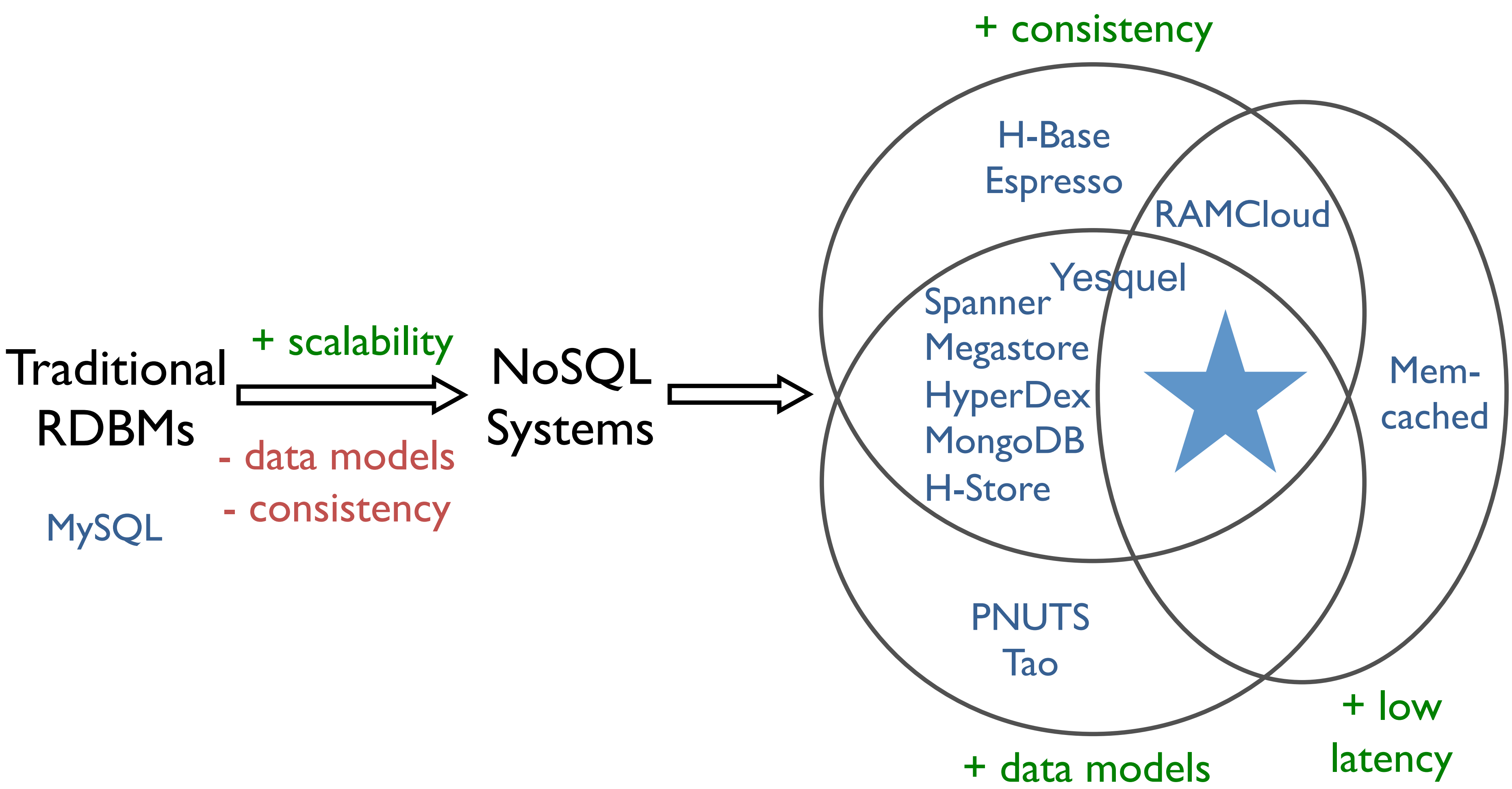

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Design

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

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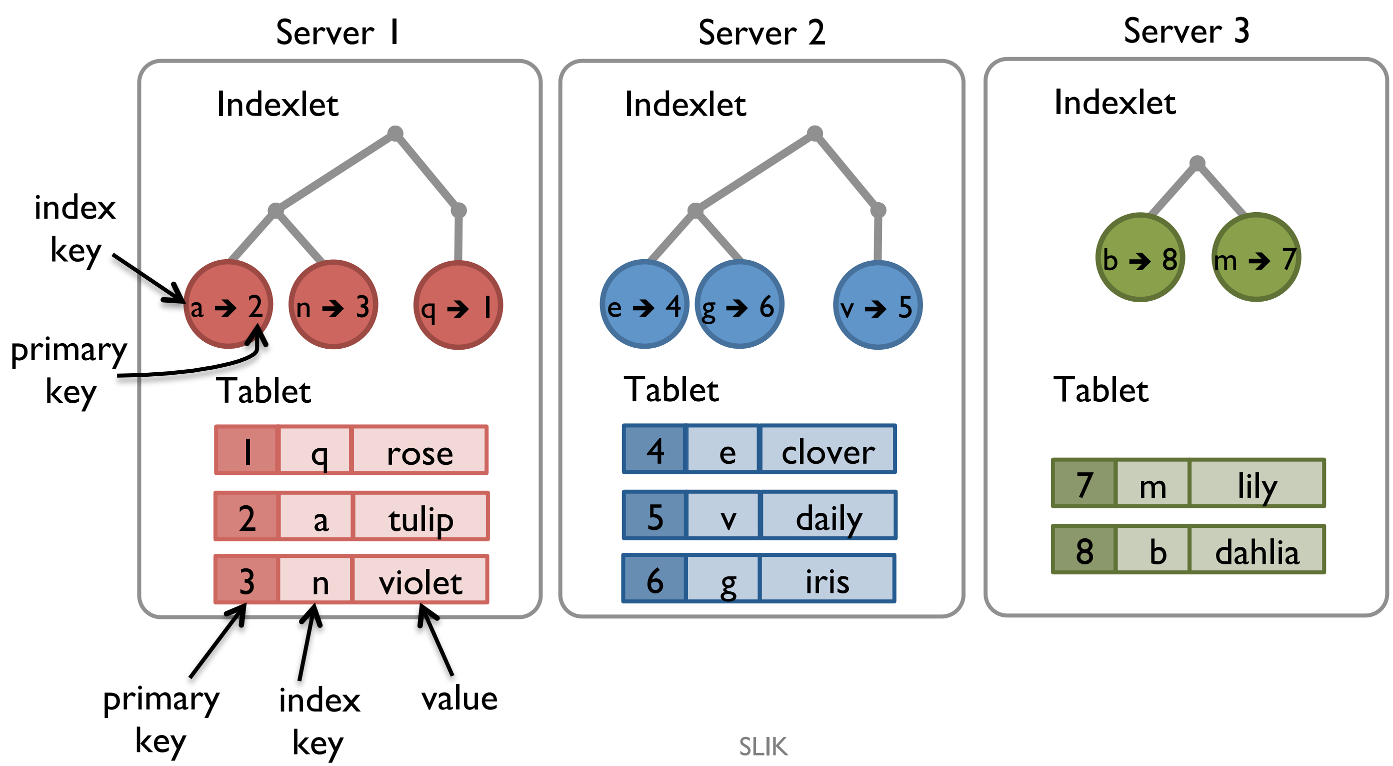
Scalability

- Nearly constant low latency irrespective of the server span
- Linear increase in throughput with the server span

Index Partitioning: Colocation

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



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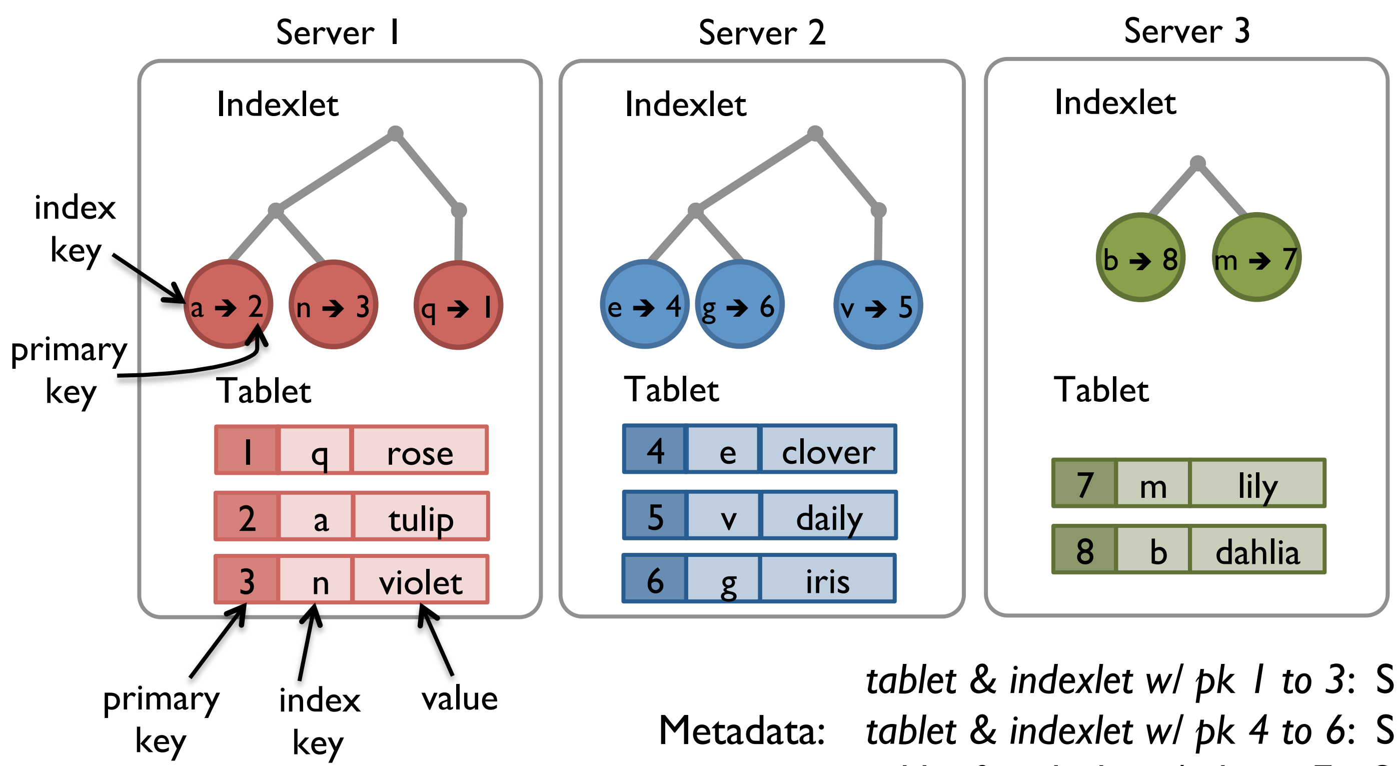
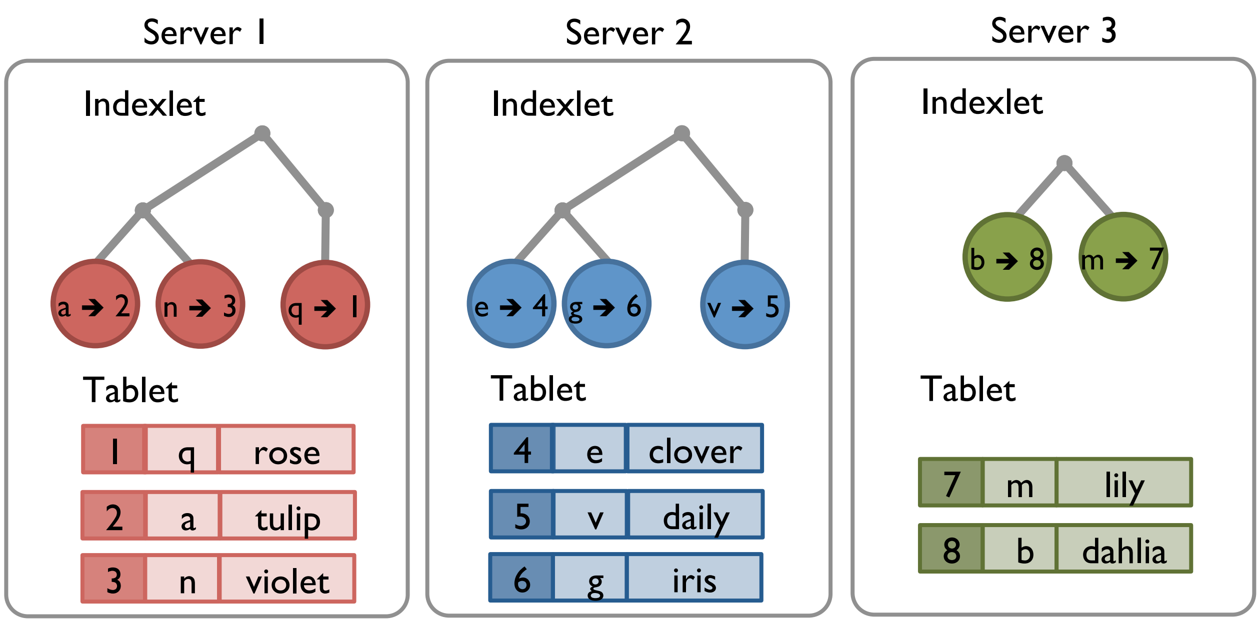
- One of the keys used to partition the objects and indexes
- No association between index partitions and index key ranges



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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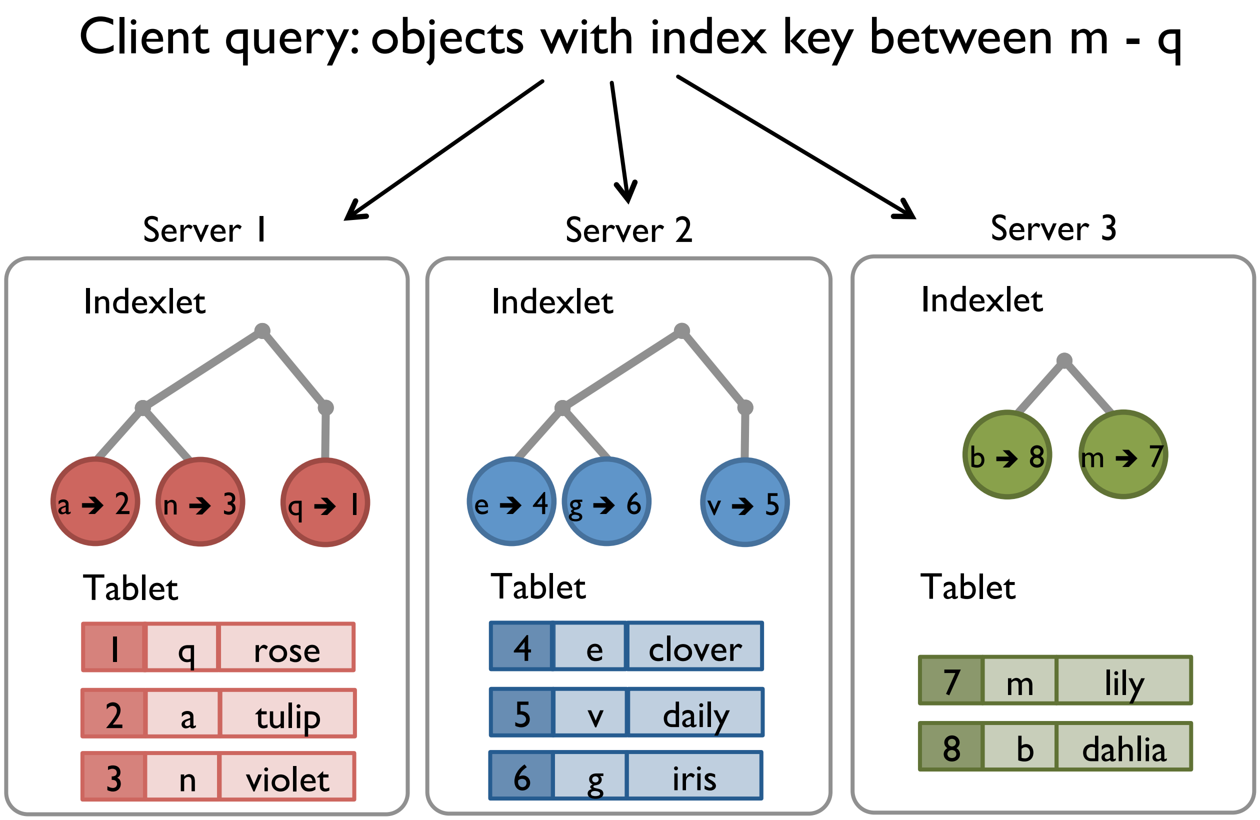

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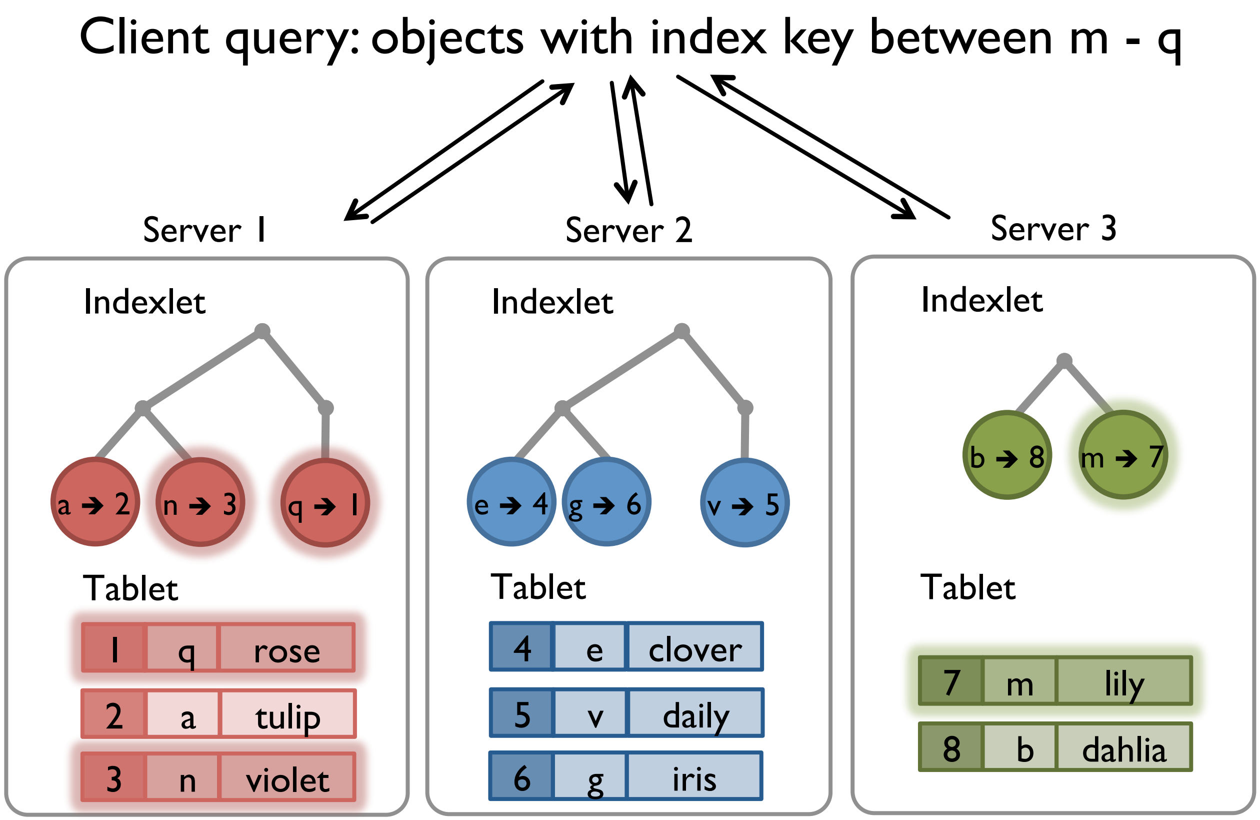

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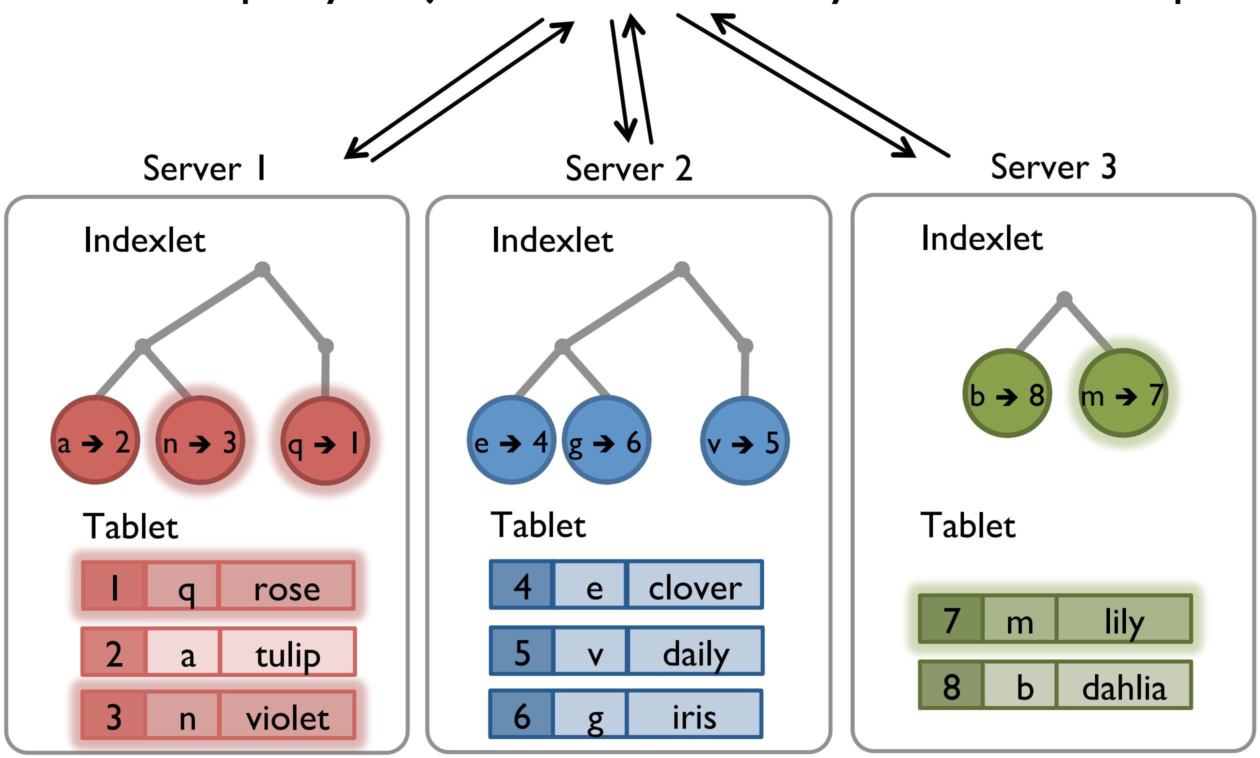
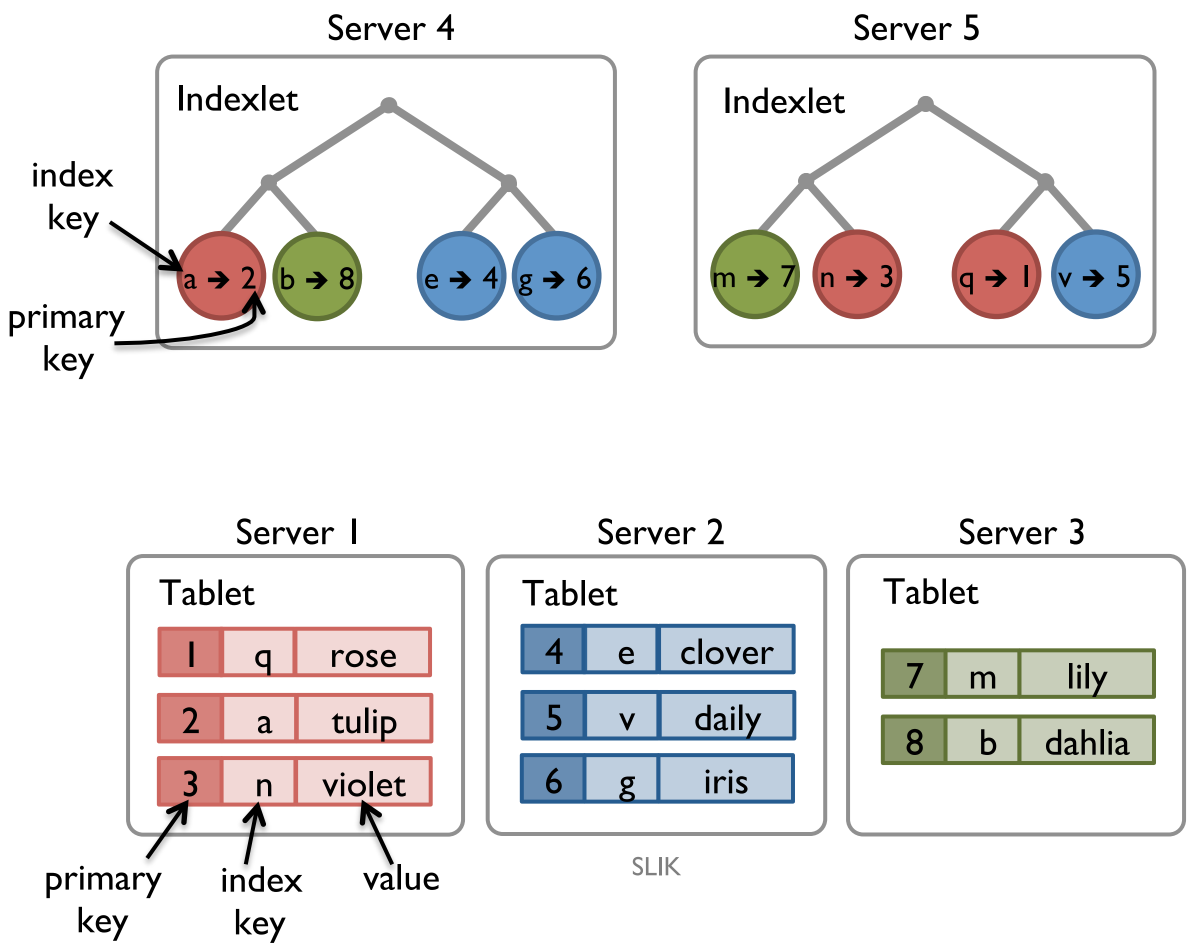


Not Scalable!

Index Partitioning: Independent

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



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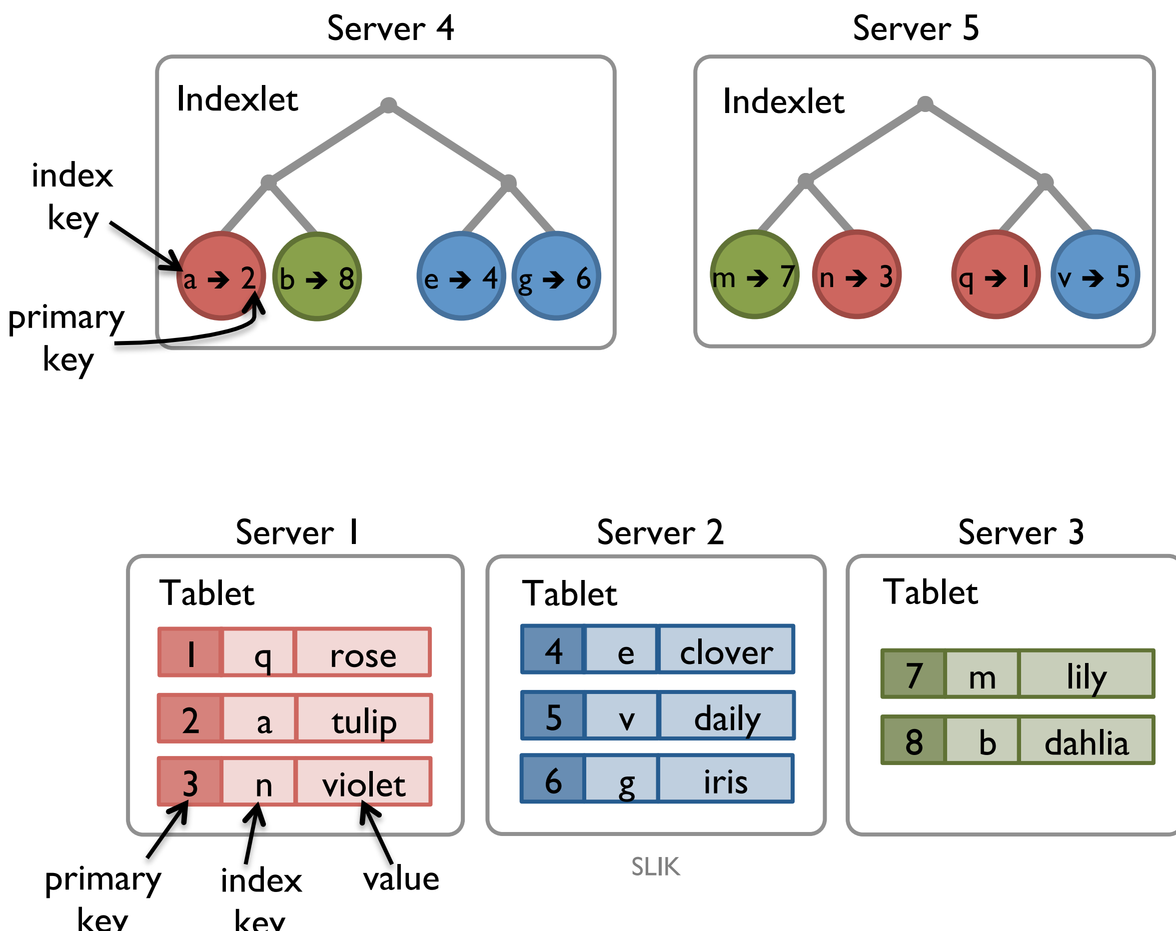

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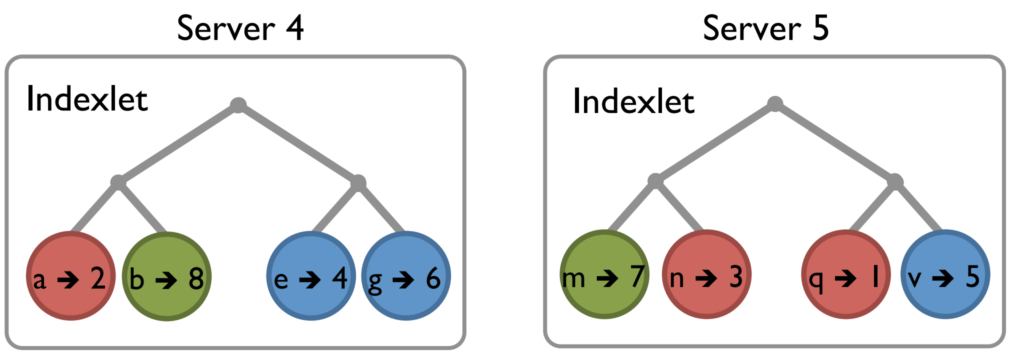

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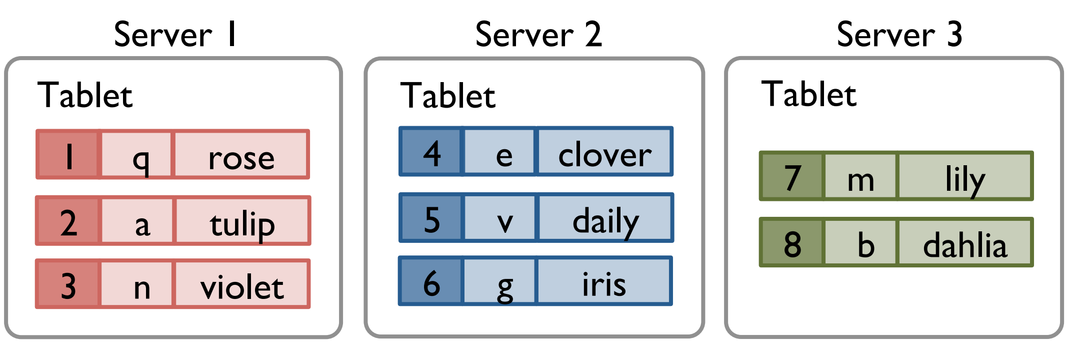

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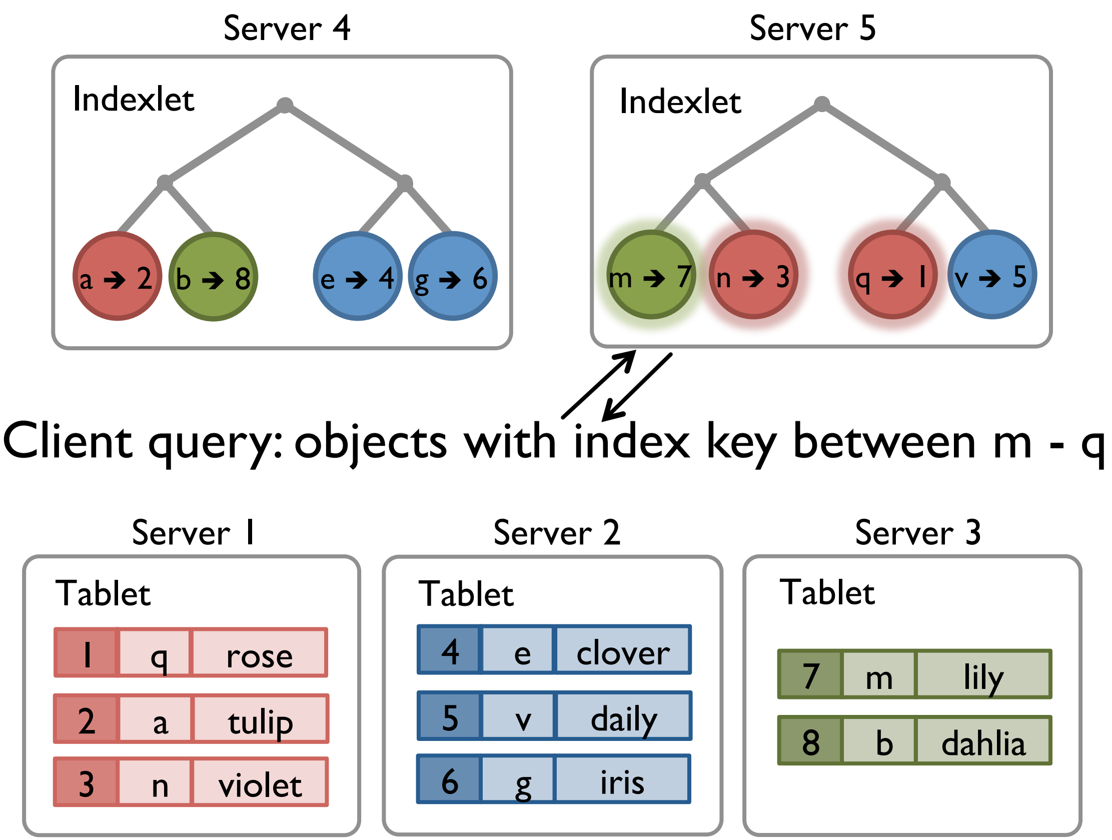

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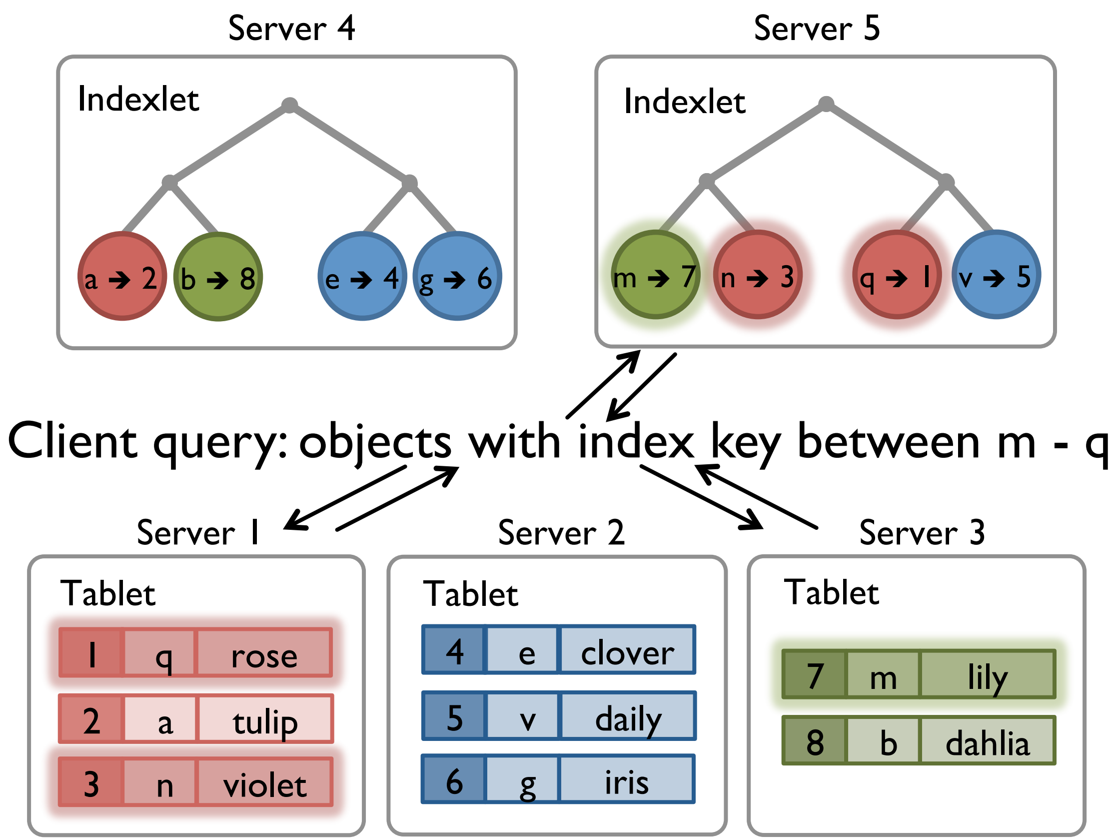

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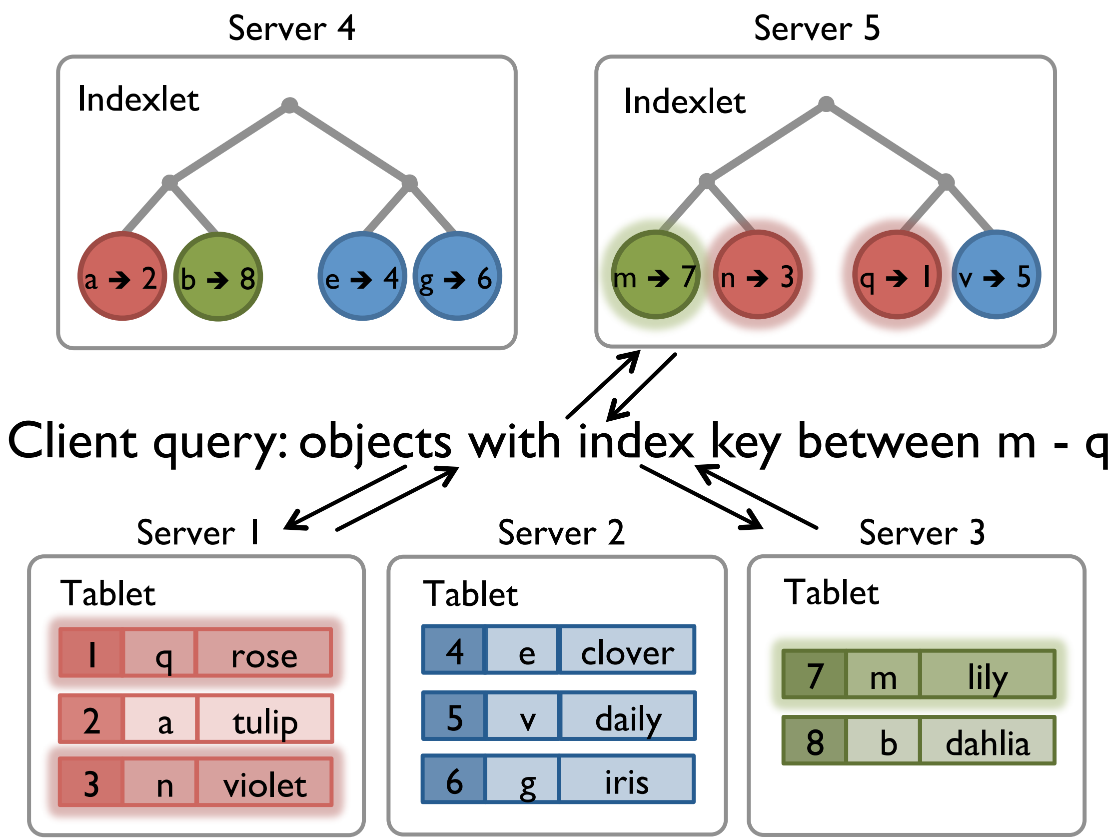

Scalable!

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- Solution: Use independent partitioning
- But: indexed object writes: distributed operations
- Potential consistency issues between indexes and objects

Design

- Data model
- **Scalability**
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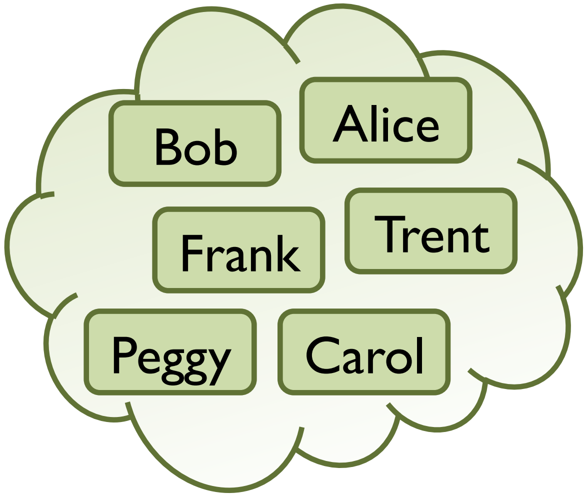

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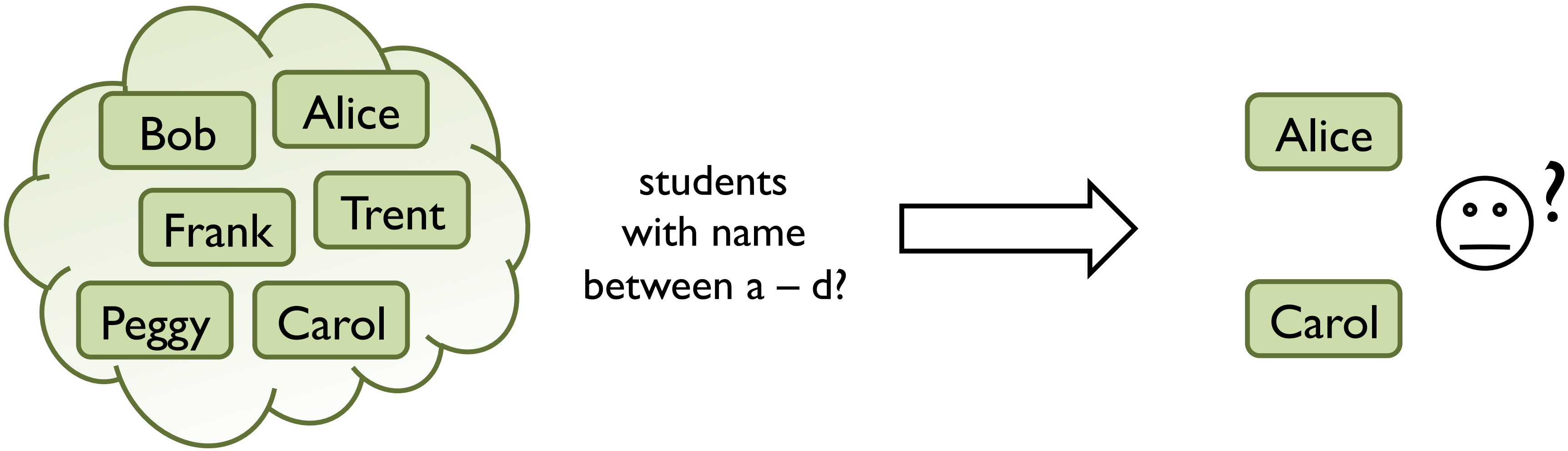

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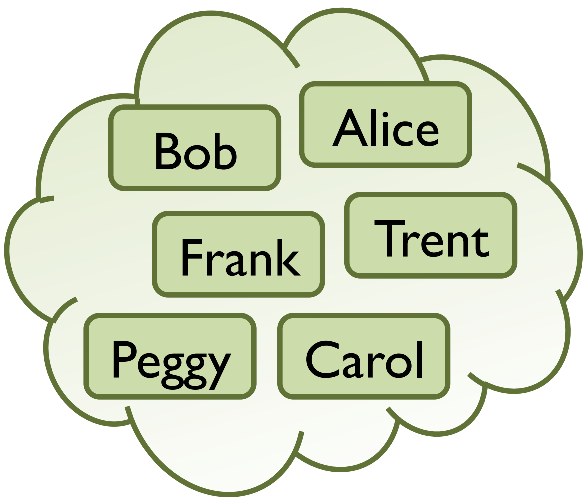

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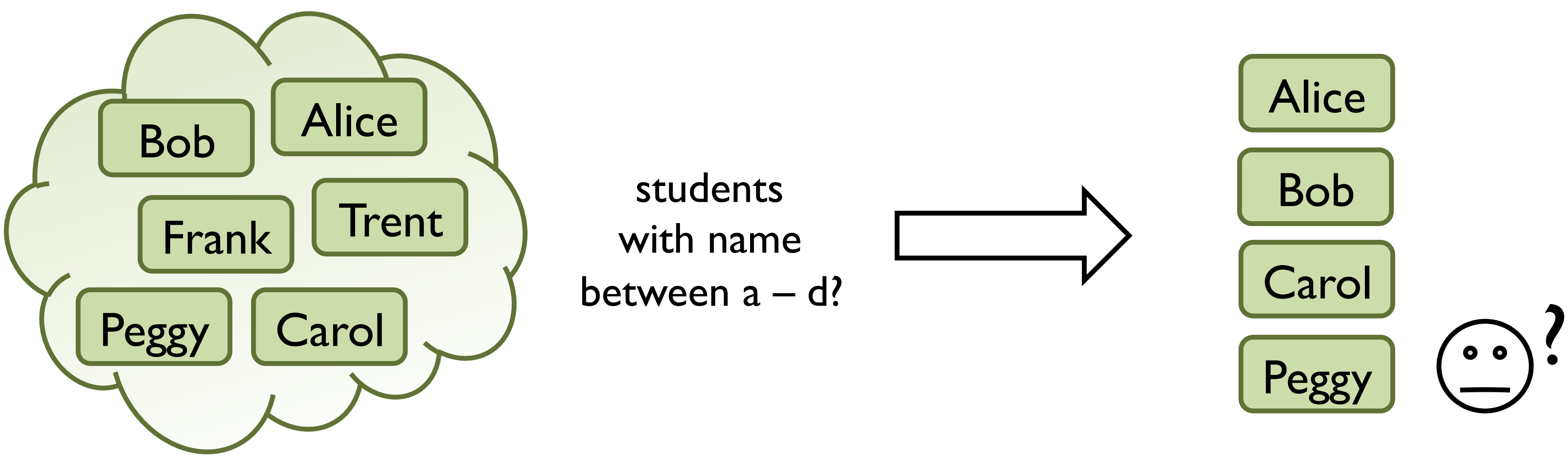

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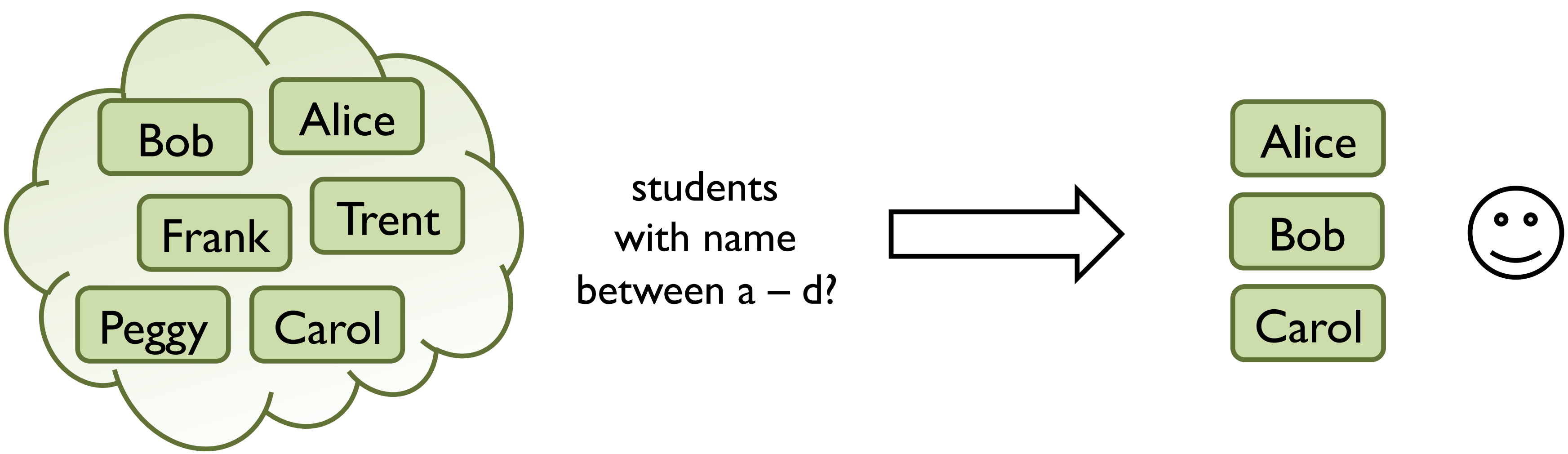

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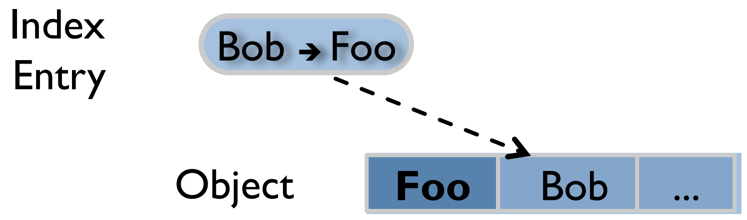

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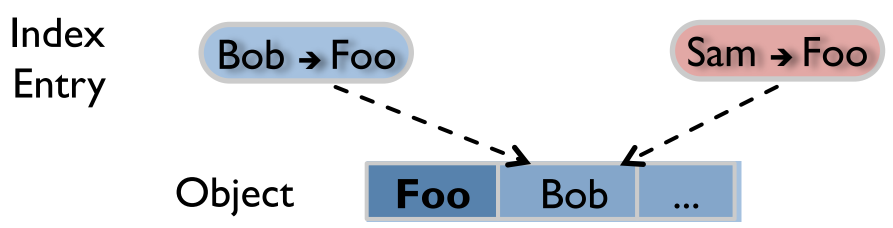

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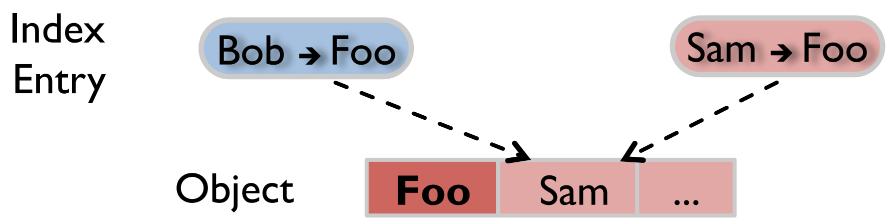

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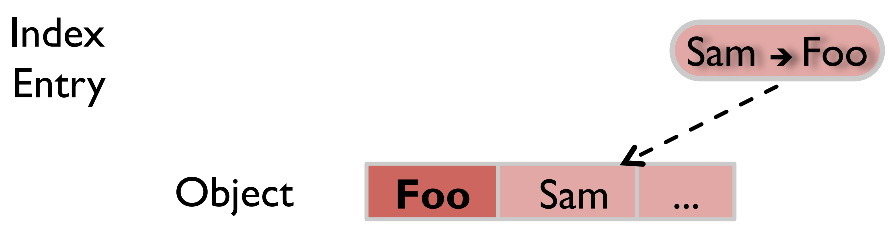

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2. Modify object
3. Remove old index entry

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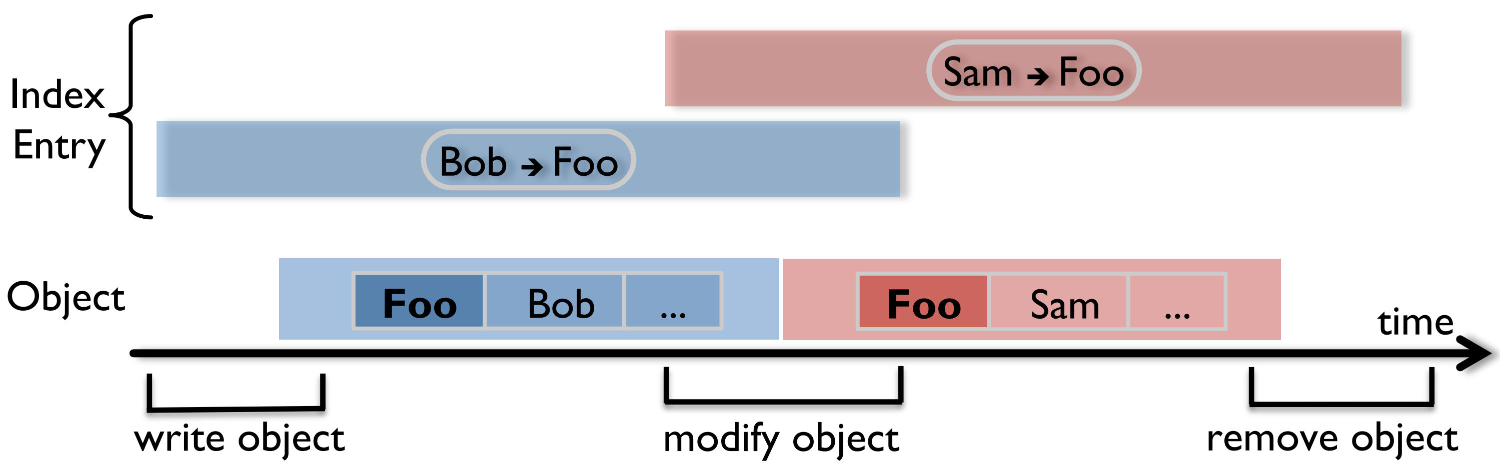

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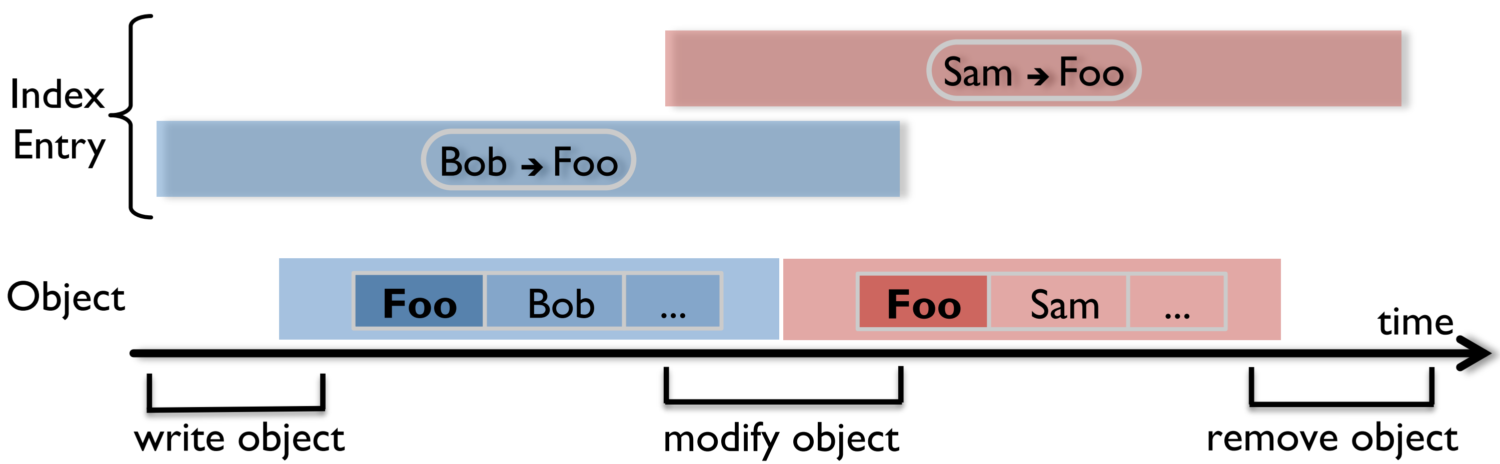

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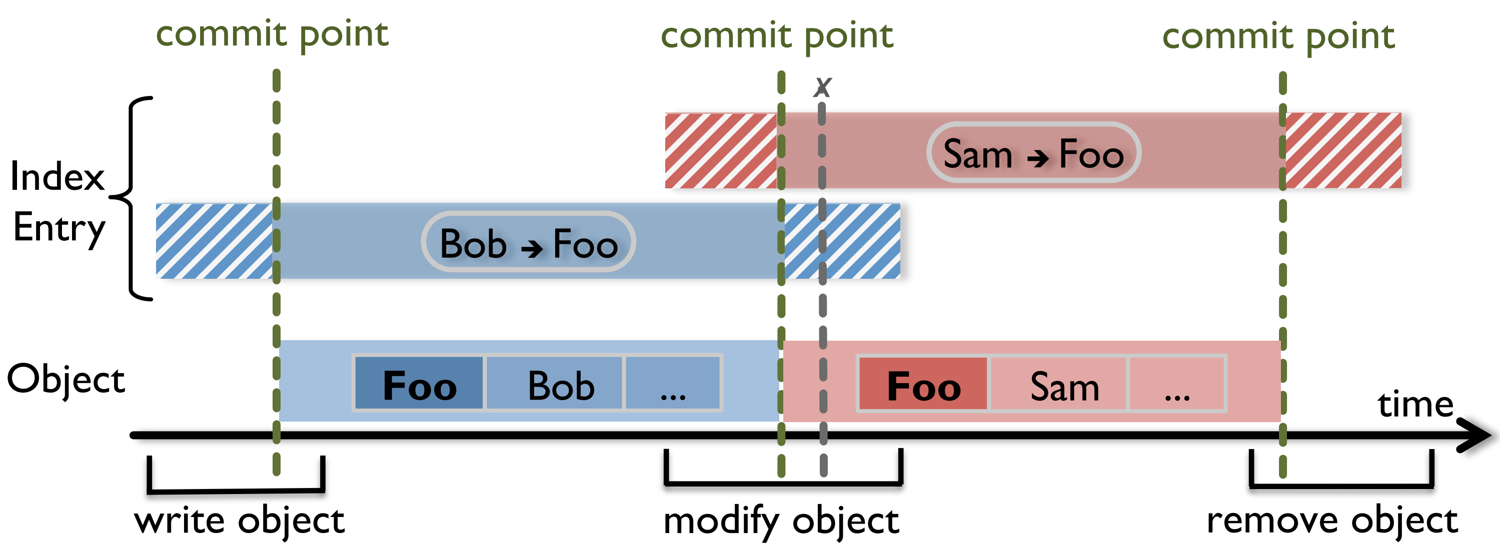

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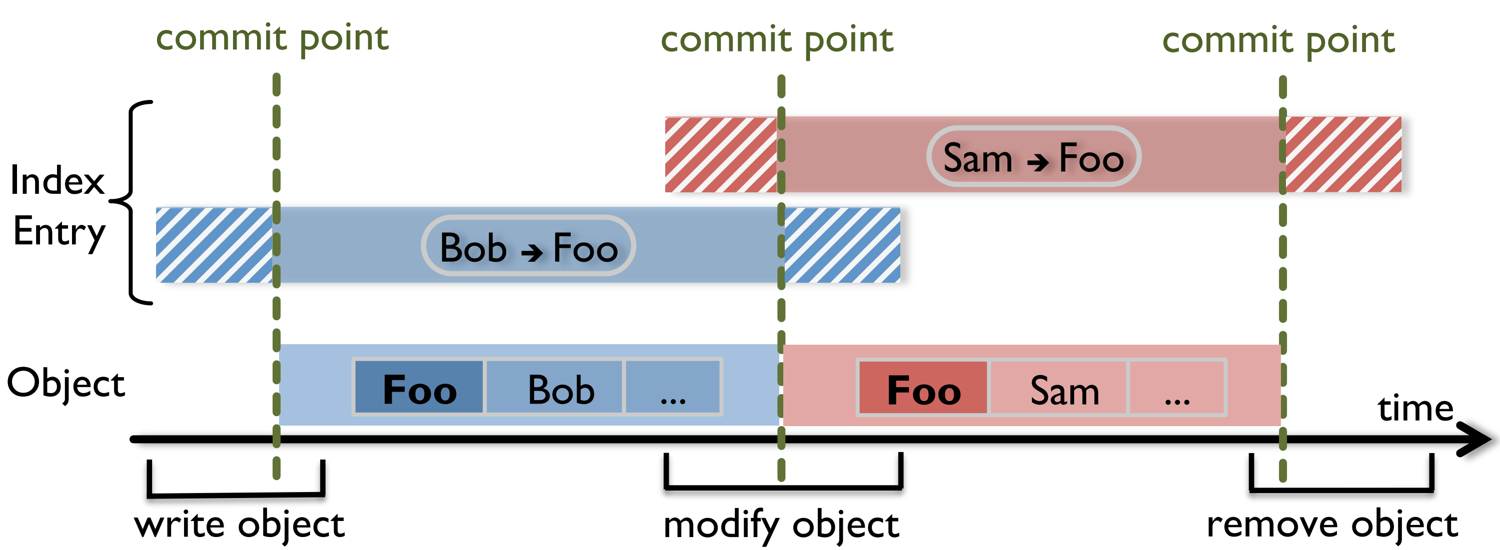

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Performance: Questions

- 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 Disks	2x Crucial M4 SSDs CT128M4SSD2 (128 GB)
NIC	Mellanox ConnectX-2 InfiniBand HCA
Switch	Mellanox SX6036 (4X FDR)

Latency

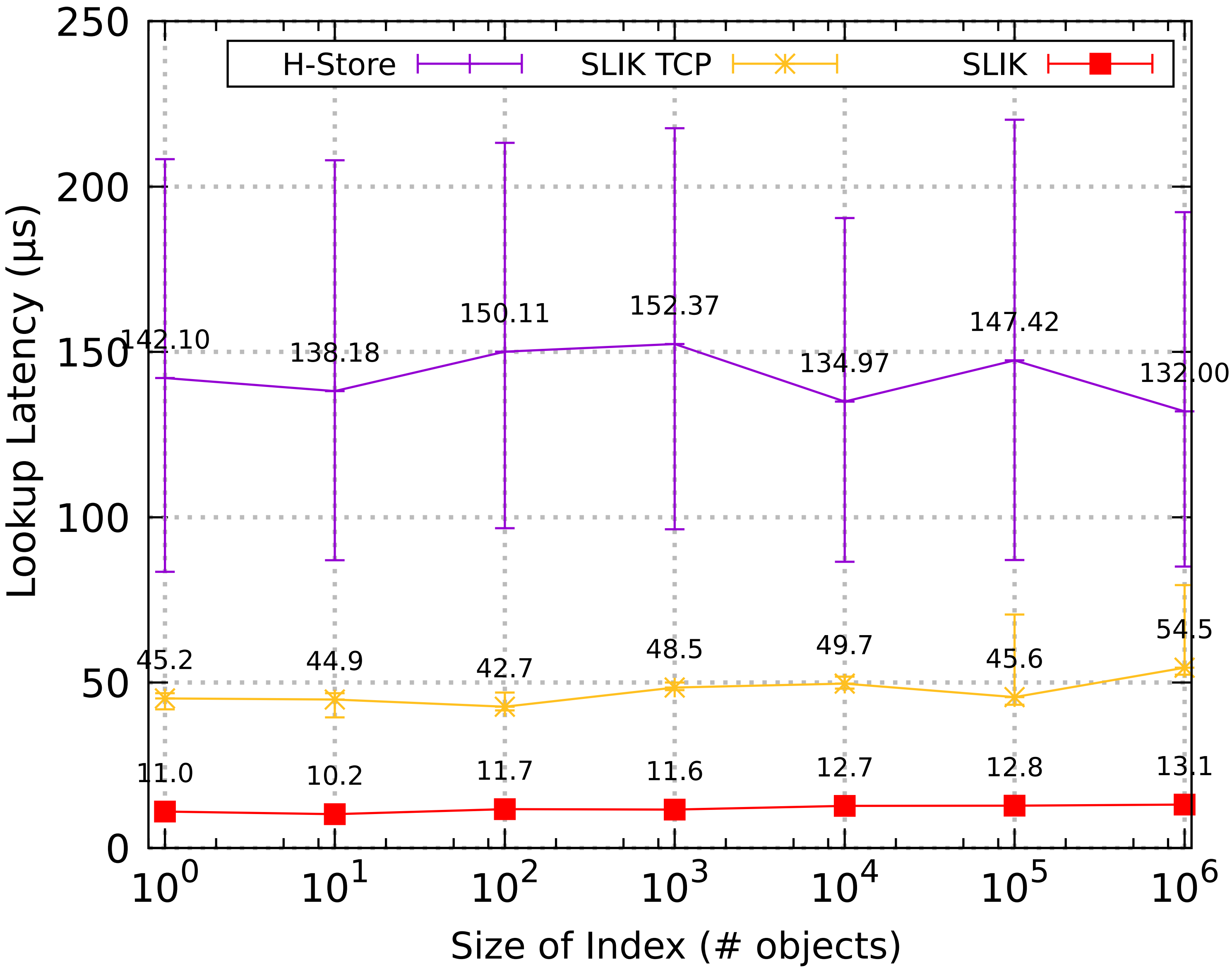
Experiments:

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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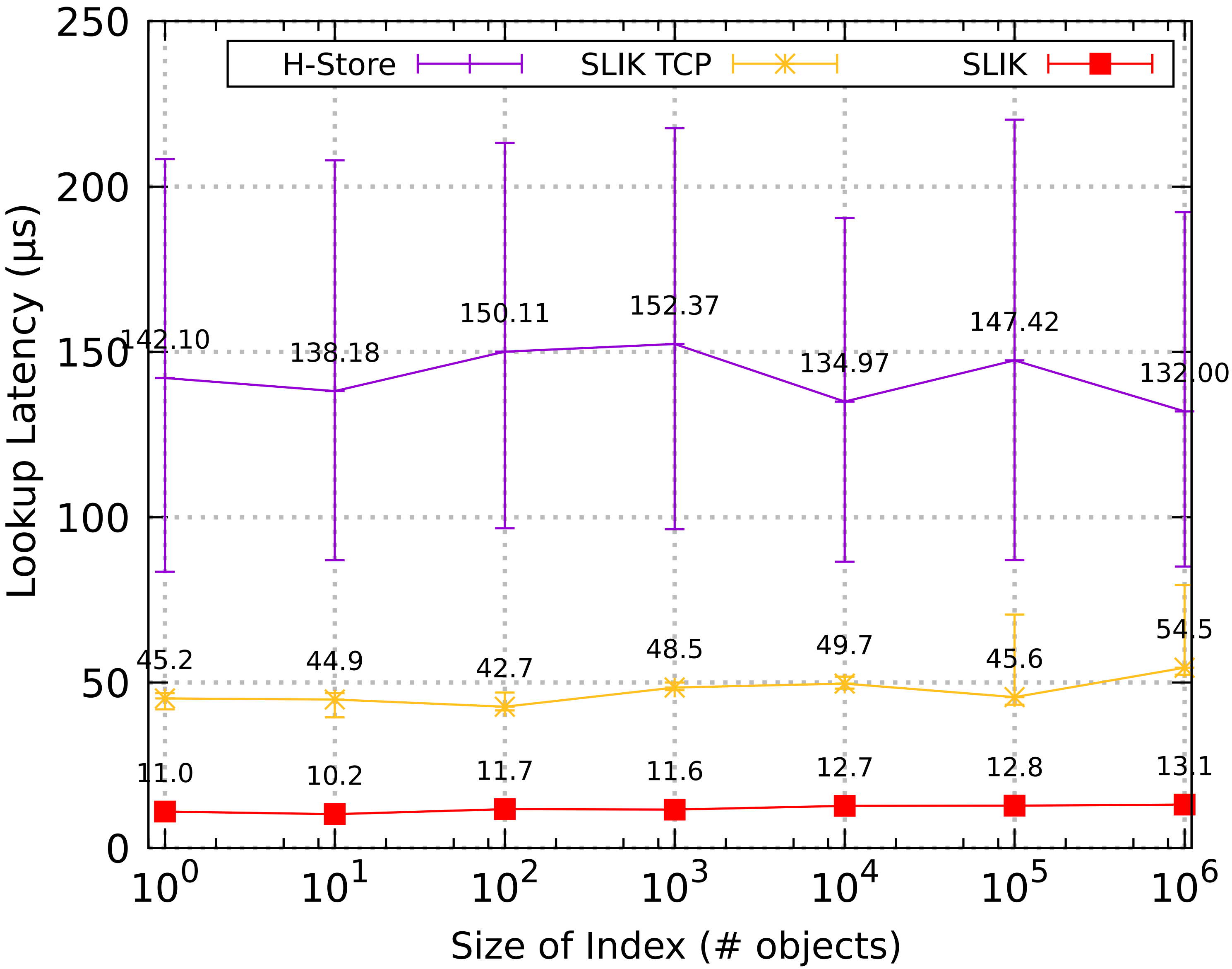
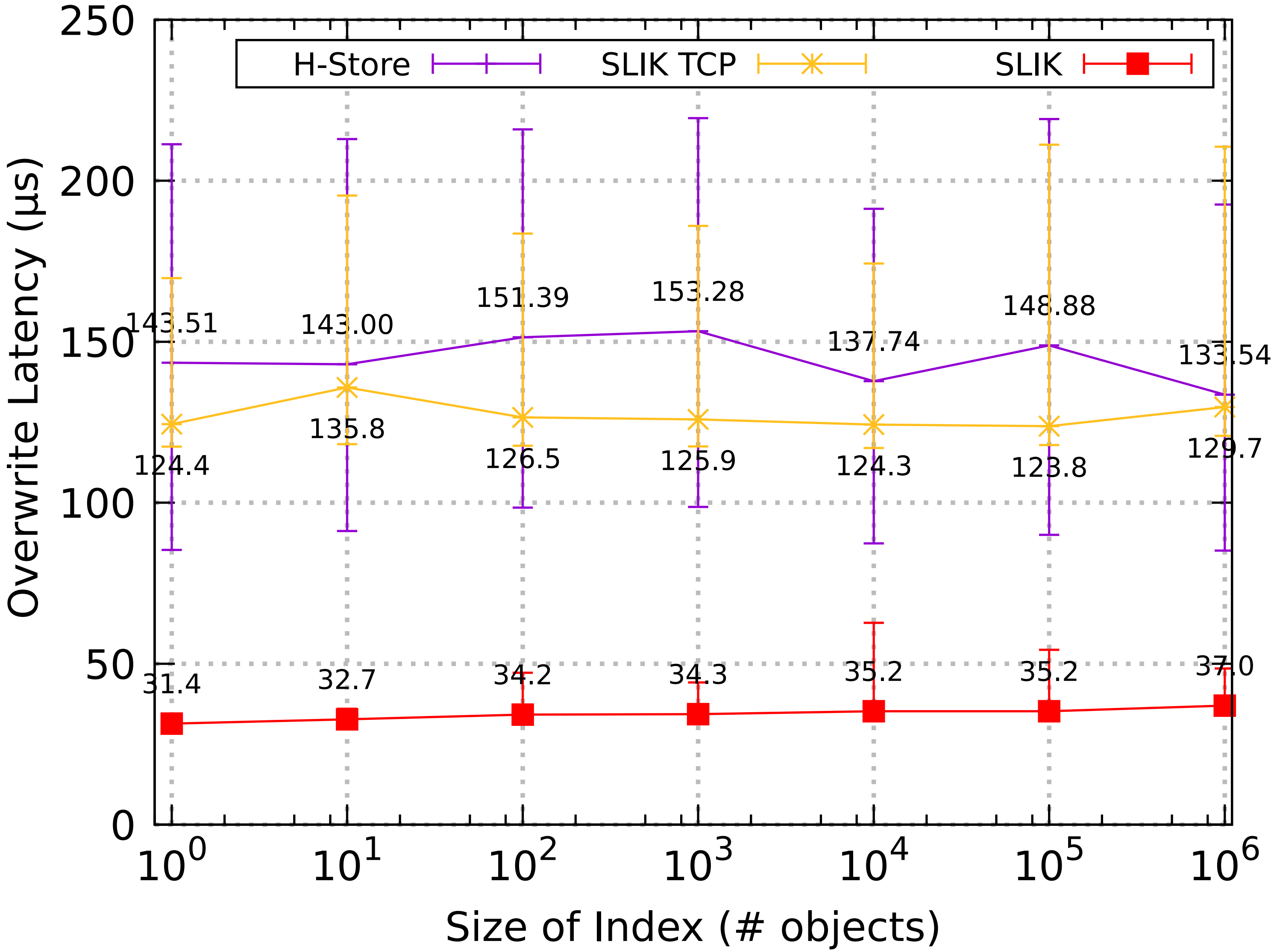


Overwrite Latency



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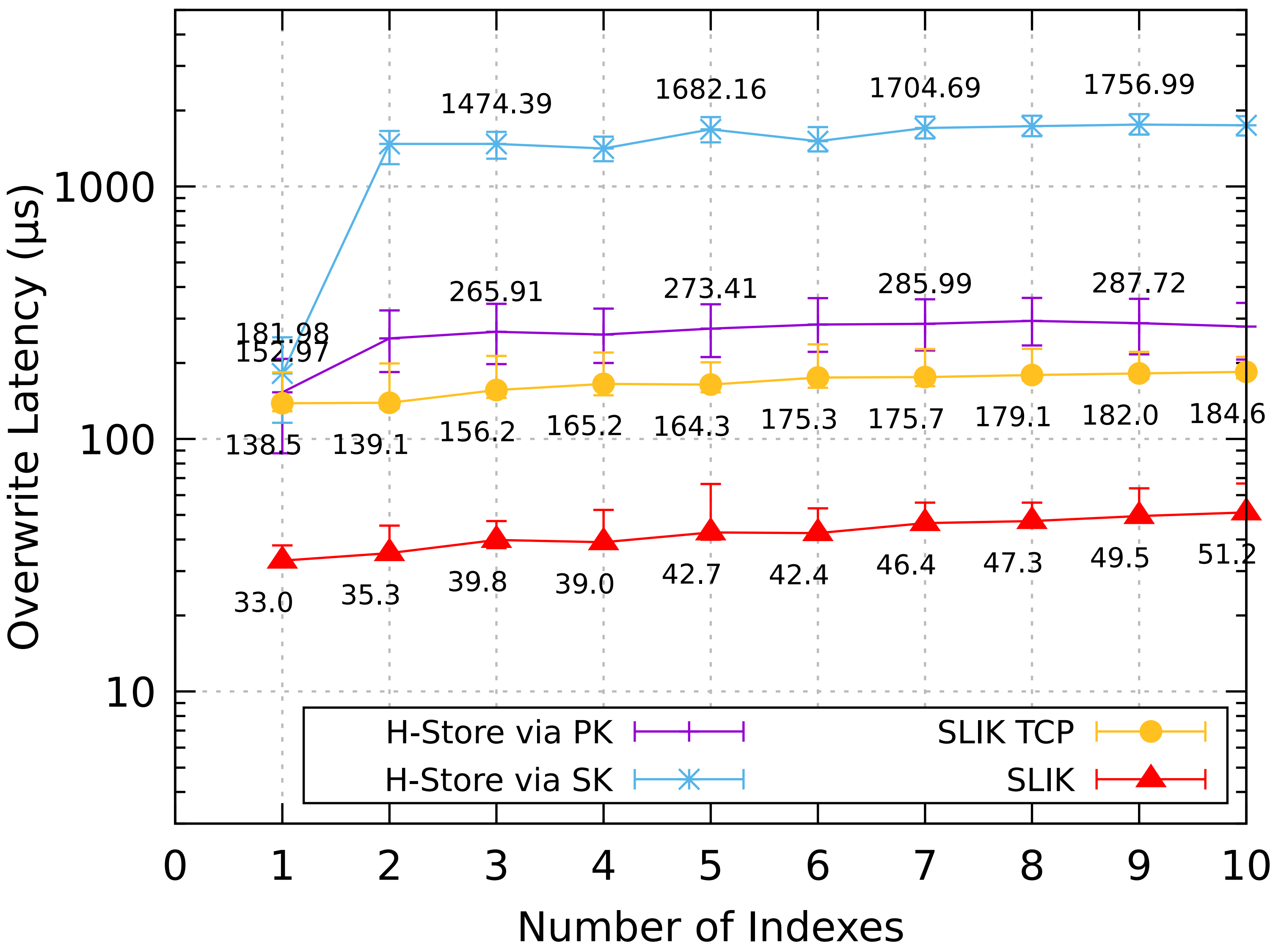

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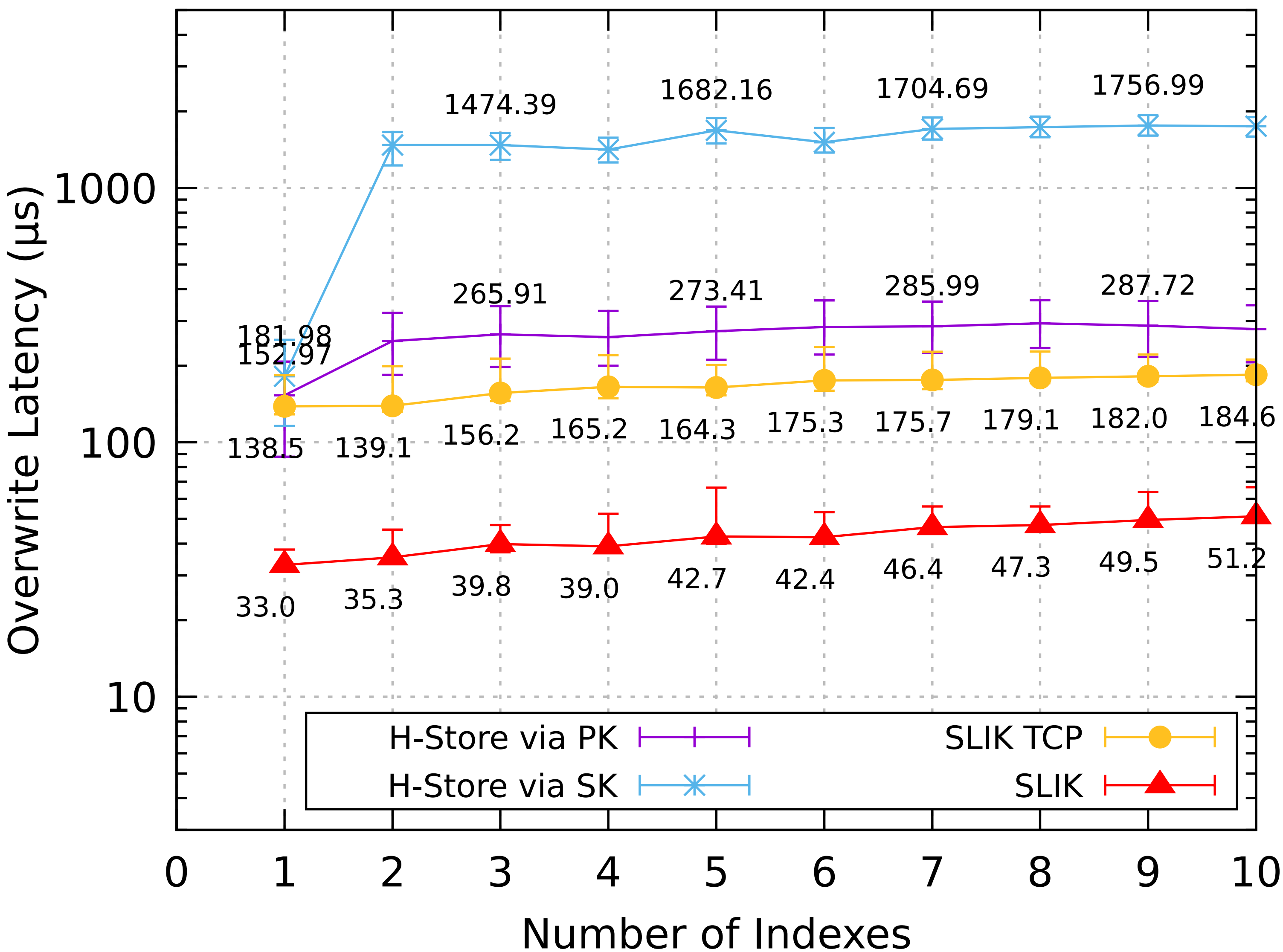

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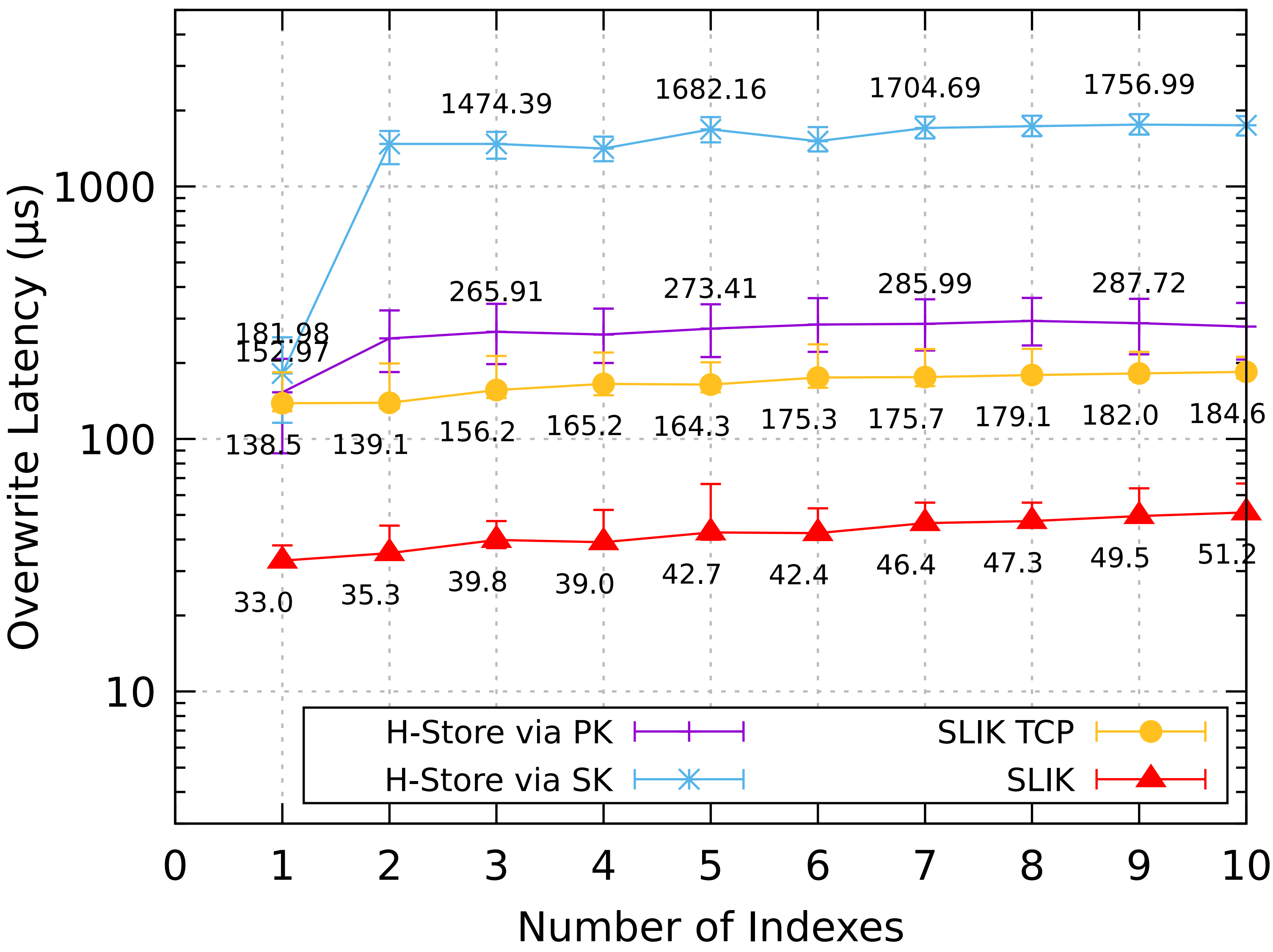


Scalability

Compare: (a) partitioning approaches (b) systems

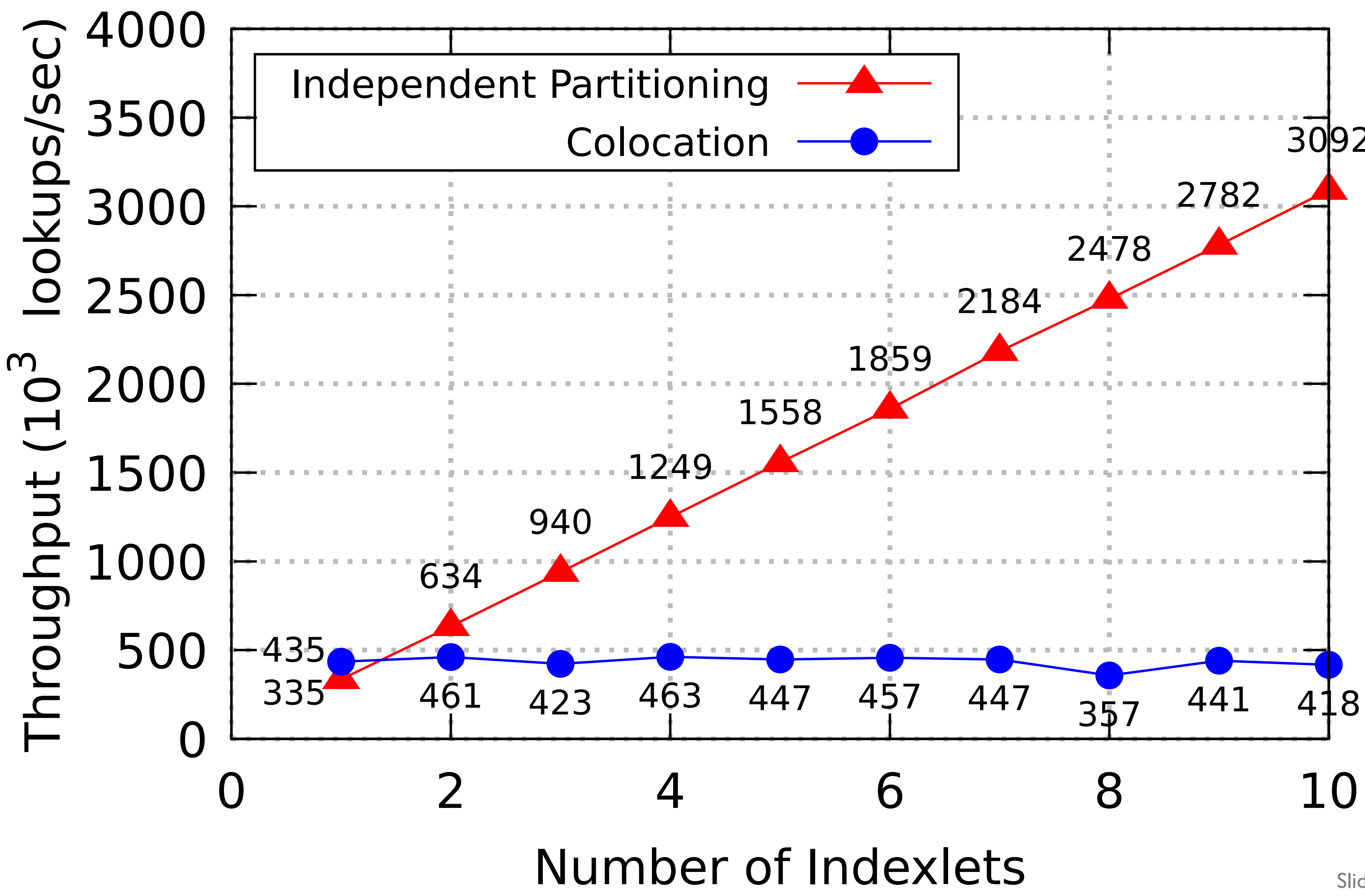
Experiments:

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 experiments: Loaded system
- Latency experiments: Unloaded system

Scalability: Throughput



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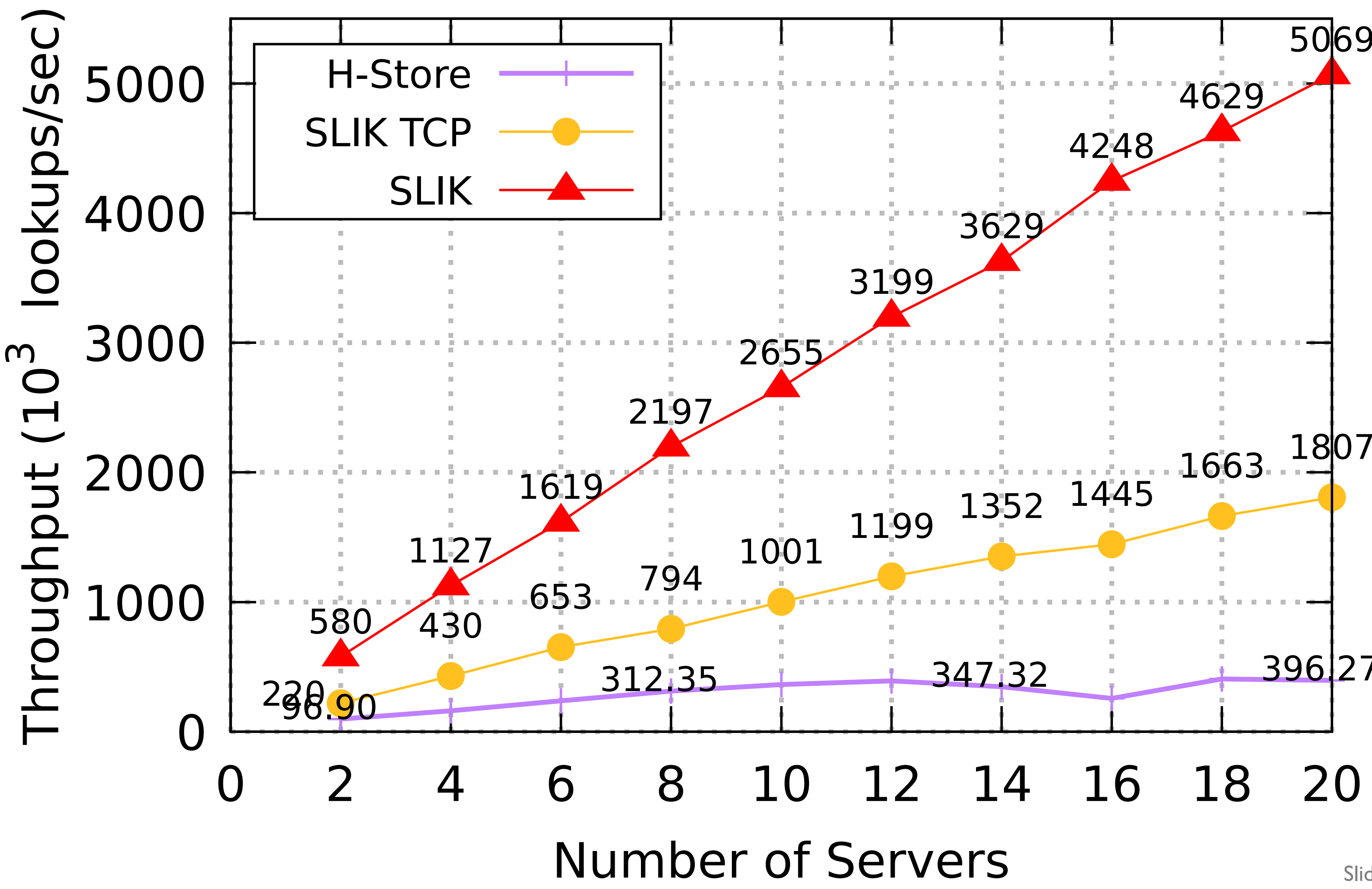

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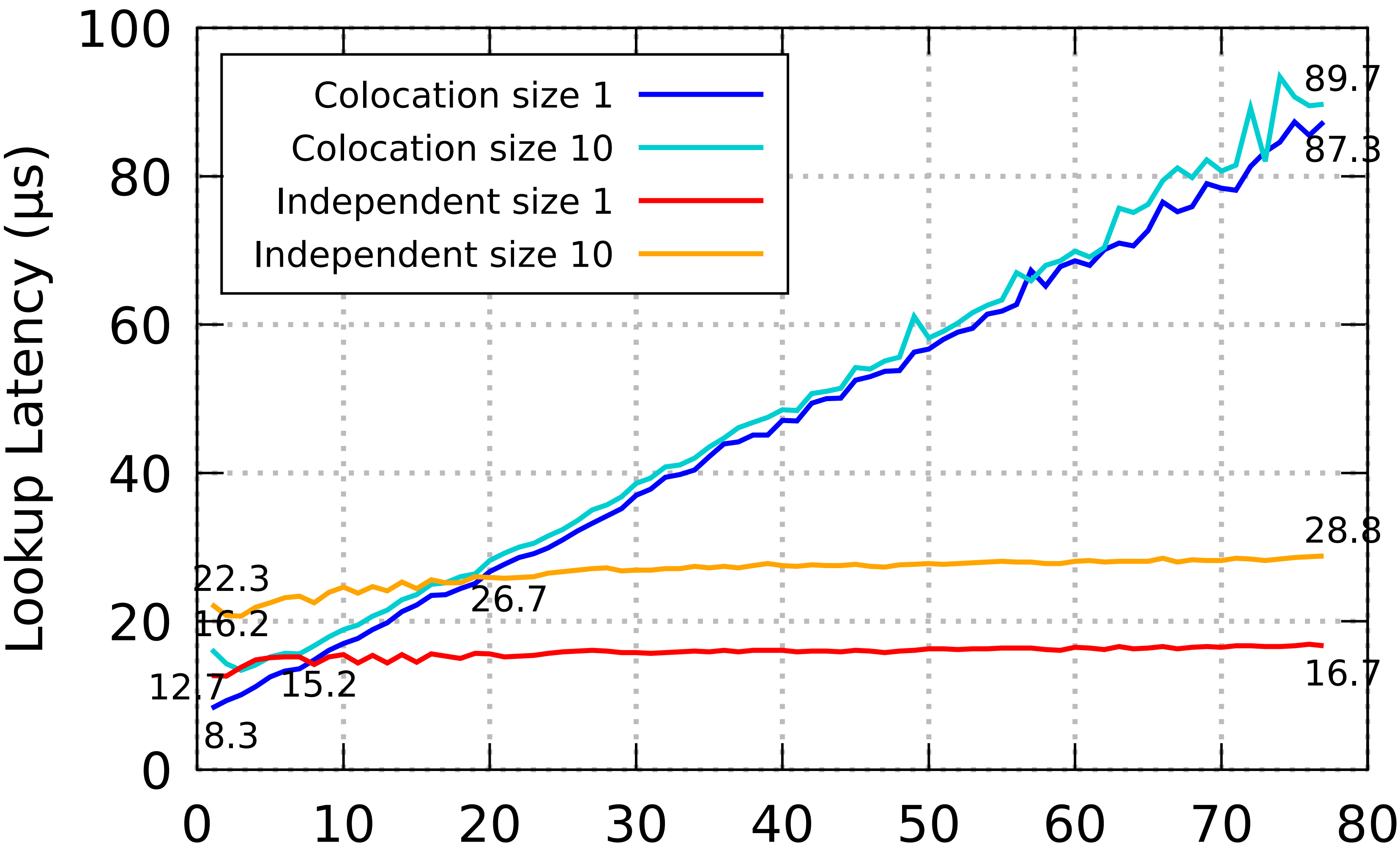

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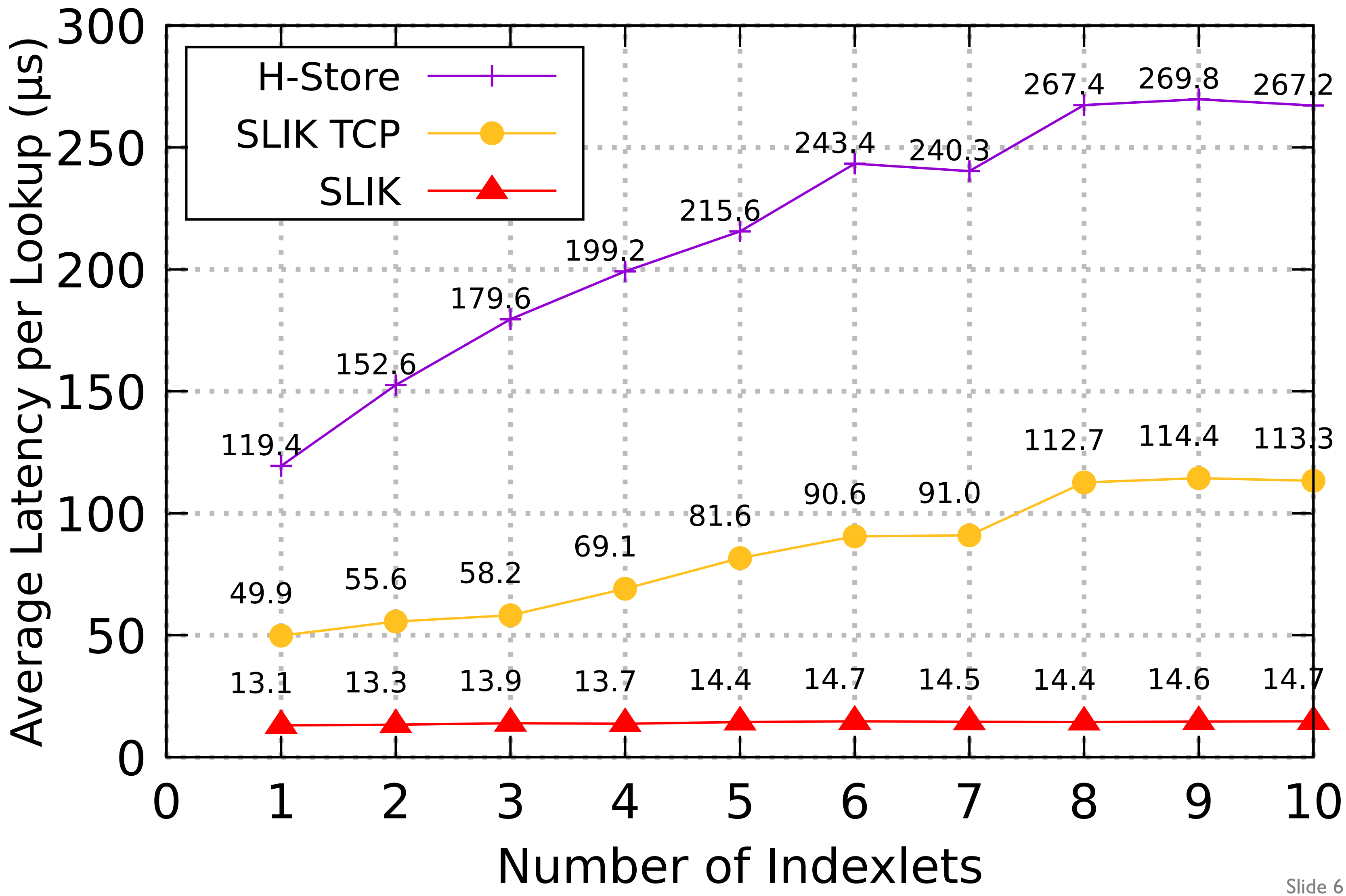

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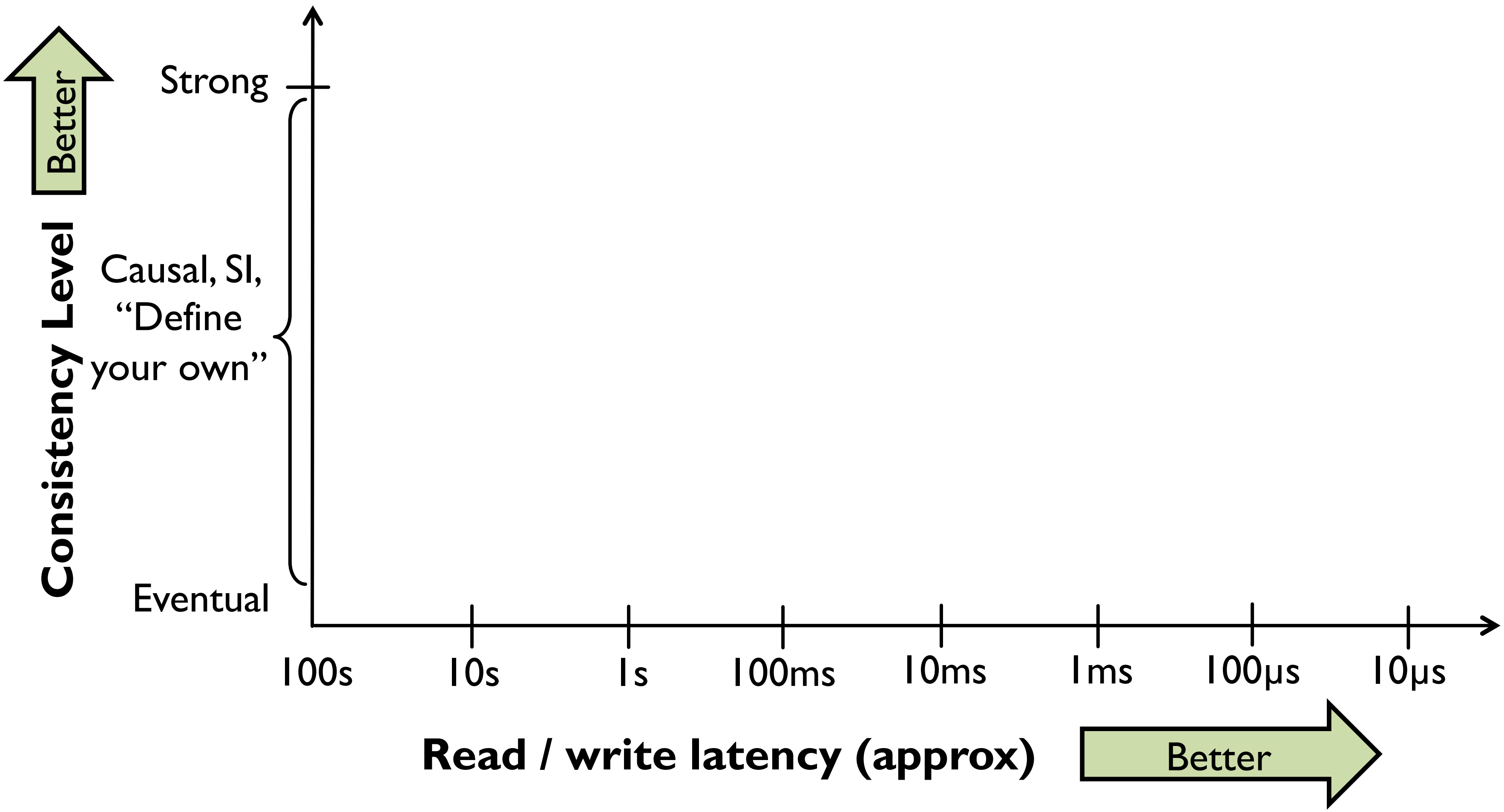
Related Work

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



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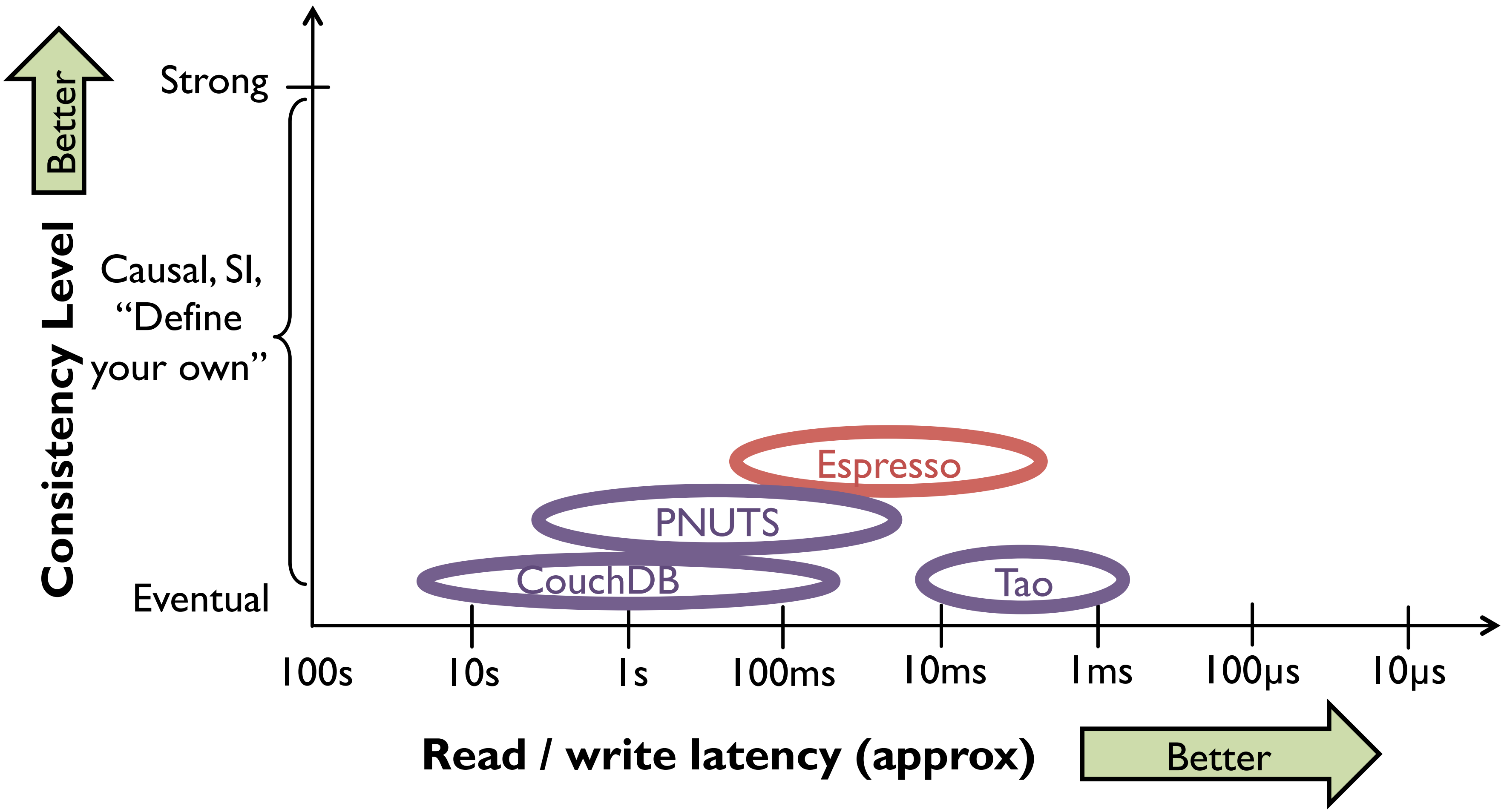

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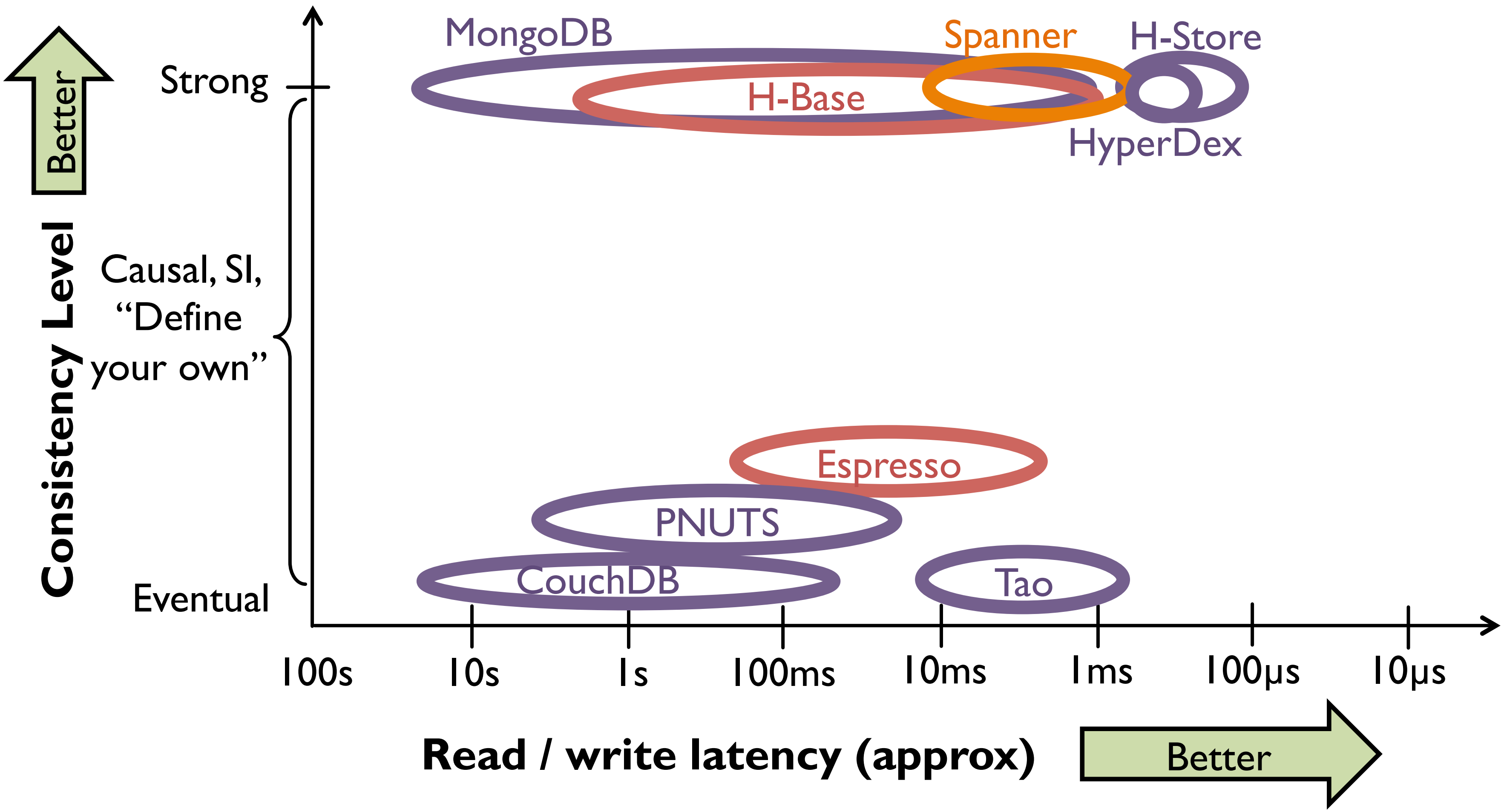

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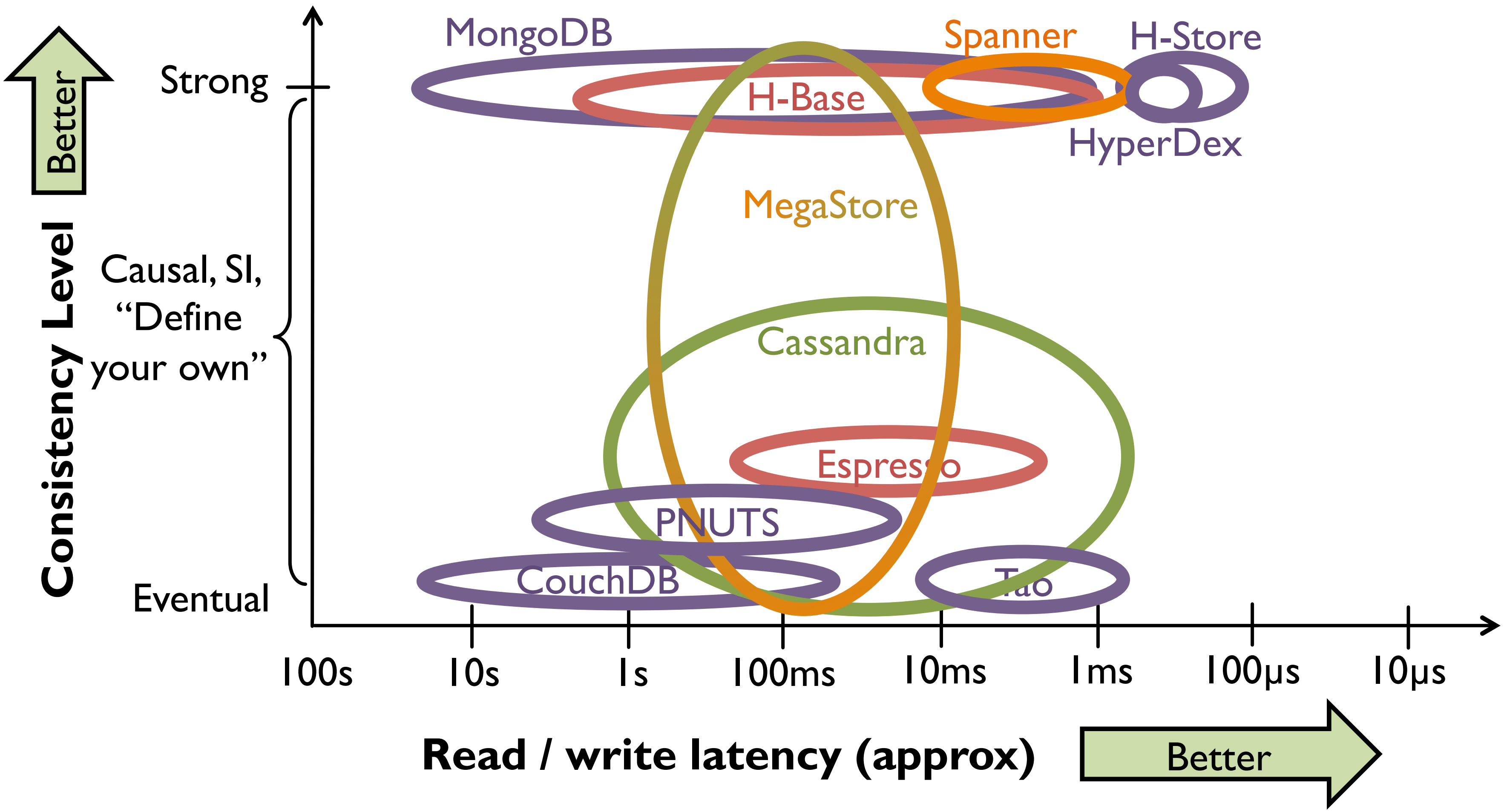

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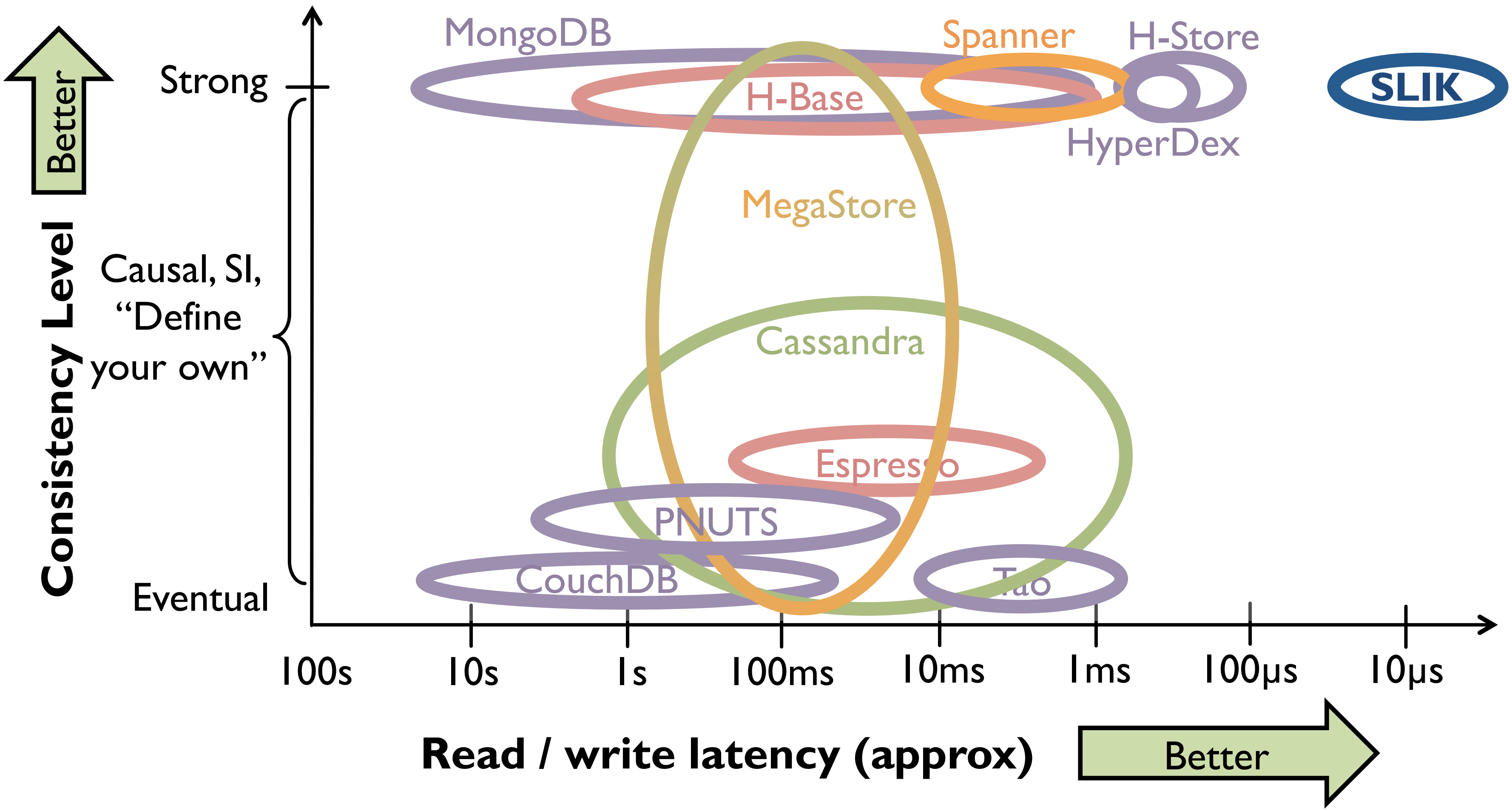

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Conjecture

Can a key value store support

strongly consistent secondary indexes

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

Summary

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**.

Summary

By using ordered writes and treating indexes as hints

Lookups and range queries on secondary keys

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

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
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Summary

By using ordered writes and treating indexes as hints

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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

My papers and other information at: stanford.edu/~ankitak

I can be reached at: ankitak@cs.stanford.edu

PLATFORMLAB Stanford University