VoliMap

Optimizing Key-Value Store Performance by Leveraging User-Space Page Tables

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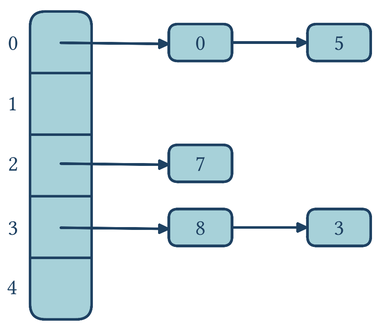
Problematic: Key-Value Store

Hashmap



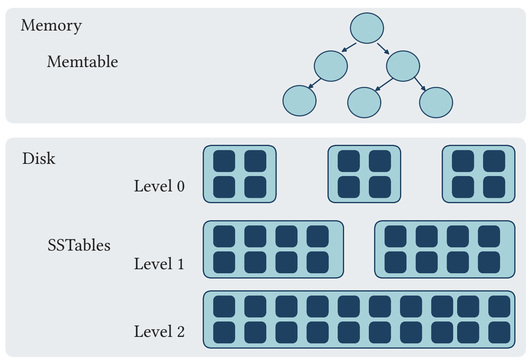
Hash table with separate chaining

Hash table with open addressing (linear probing)

✓ Constant time $O(1)$ for basic operations
✗ Costly global resizing (requires full lock)
✗ No range query support

Treemap

B+-tree

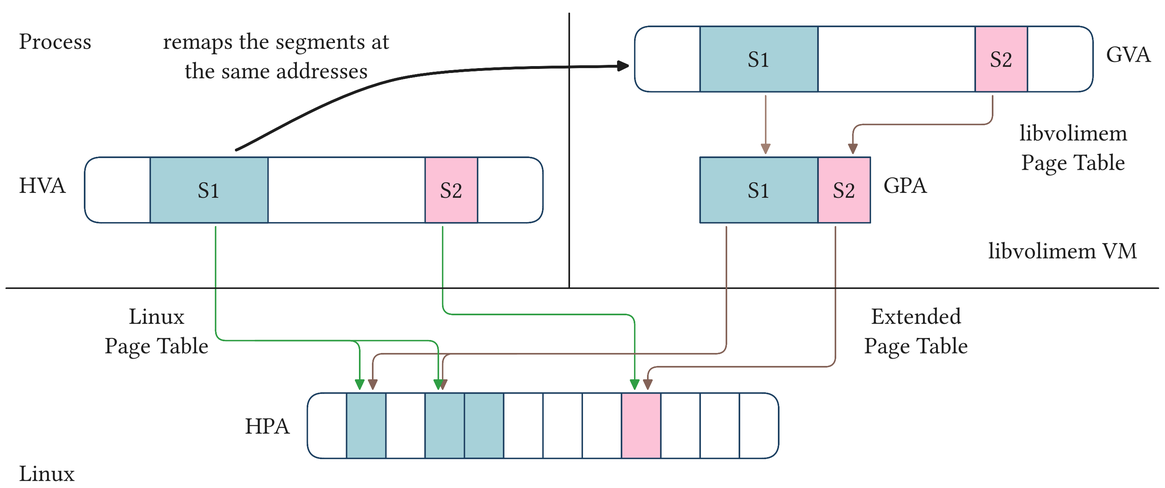


Log-Structured Merge-tree (LSM-tree)

✗ $O(\log n)$ complexity for basic operations
✓ No global resizing (fine-grained subtree locking)
✓ Range query support

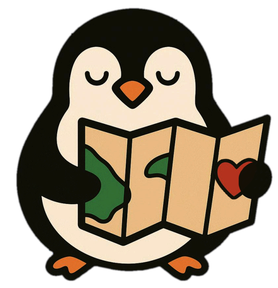
Implementation: VoliMem

- Library that transforms any process into a lightweight virtual machine
- Leverages virtualization to expose the page table to user space
- Fast fault processing inside VM
- VMs do not run an operating system



Design: VoliMap

Objective

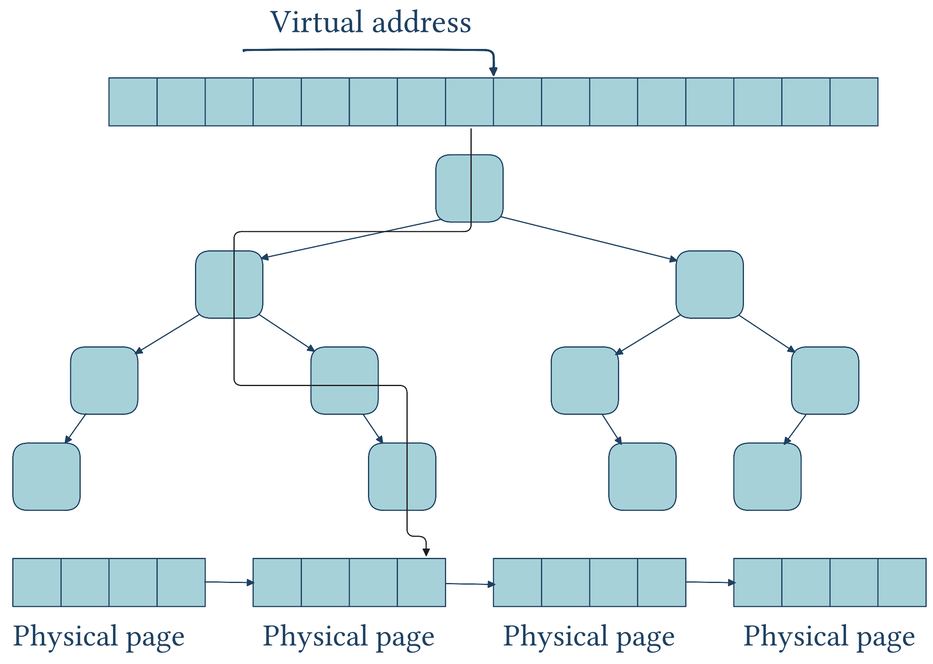


	Hashmap	Treemap	VoliMap
Put	O(1)	O(log n)	O(1)
Get	O(1)	O(log n)	O(1)
Remove	O(1)	O(log n)	O(1)
Range query	Not supported	supported	supported
Global resize	needed	Not needed	Not needed
Memory usage	Inefficient	Efficient	Efficient

Average Complexity of Operations

Idea

- Access data through a large array in virtual address space
- Array indexing triggers page table traversal to reach actual data
- Leverages hardware MMU for efficient Page Table traversal



- Uses a contiguous array of nodes in memory, each node = 16 bytes (integer + pointer).
- Hash function: index = key % hashmap_size ⟶ helps range queries by keeping related keys nearby.
- Collision handling: linear probing within the same virtual page.
- Buckets: multiple virtual pages mapped to a single physical page to reduce memory usage.
- Supports insertion, update, lookup, and deletion with atomic operations (CMPXCHG16B).

Current state

We are implementing a prototype of VoliMap supporting insertion, lookup, update, and deletion.

We will then focus on adding efficient range query support by exploiting page table traversal while preserving concurrency guarantees.

We also plan to evaluate Volimap against state-of-the-art key-value storess.

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