2026 Winter RocksDB Study
2nd week

Dayeon Wee, Yongmin Lee

http://sslab.dankook.ac.kr/, https://sslab.dankook.ac.kr/~choijm

Presentation by Dayeon Wee

wida10@dankook.ac.kr

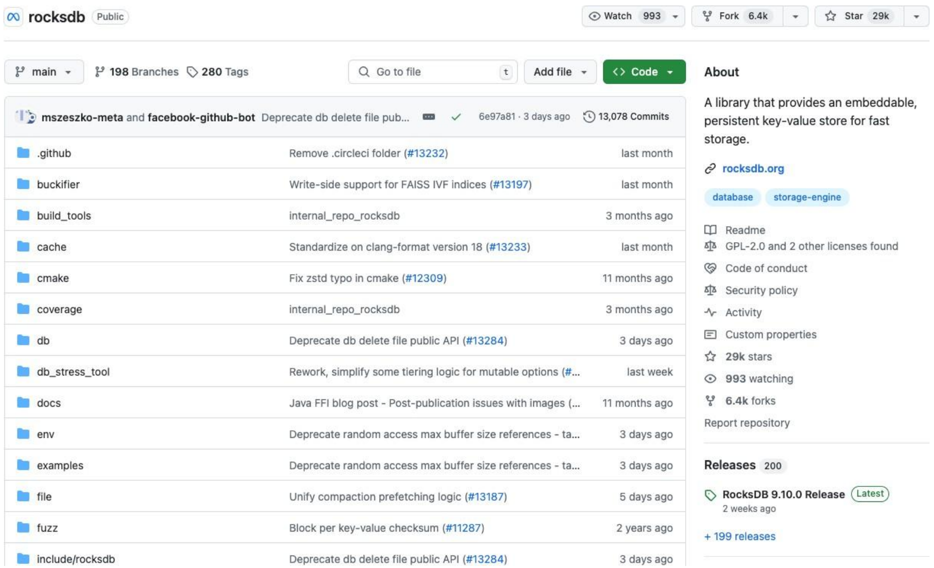
단국대학교 DANKOOK UNIVERSITY

Dankook University System Software Laboratory

Contents

RocksDB Summary

- What is RocksDB
  - ✓ 1) Famous KV Store of Facebook (Meta), derived from LevelDB
  - ✓ 2) A persistent storage engine that supports key/value interface
  - ✓ 3) LSM (Log Structured Merge)-Tree based (for SSD)
  - ✓ 4) Embedded (C++ library) and open source
  - ✓ 5) Support various algorithms, configurations, tools and debugging facilities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main · 198 Branches · 280 Tags · Go to file · Add file · Code

mszeszko-meta and facebook-github-bot Deprecate db delete file pub... 6e97a81 · 3 days ago · 13,078 Commits

.github	Remove .circleci folder (#13232)	last month
buckifier	Write-side support for FAISS IVF indices (#13197)	last month
build_tools	internal_repo_rocksdb	3 months ago
cache	Standardize on clang-format version 18 (#13233)	last month
cmake	Fix zstd typo in cmake (#12309)	11 months ago
coverage	internal_repo_rocksdb	3 months ago
db	Deprecate db delete file public API (#13284)	3 days ago
db_stress_tool	Rework, simplify some tiering logic for mutable options (#...	last week
docs	Java FFI blog post - Post-publication issues with images (...	11 months ago
env	Deprecate random access max buffer size references - ta...	3 days ago
examples	Deprecate random access max buffer size references - ta...	3 days ago
file	Unify compaction prefetching logic (#13187)	5 days ago
fuzz	Block per key-value checksum (#11287)	2 years ago
include/rocksdb	Deprecate db delete file public API (#13284)	3 days ago

About

A library that provides an embeddable, persistent key-value store for fast storage.

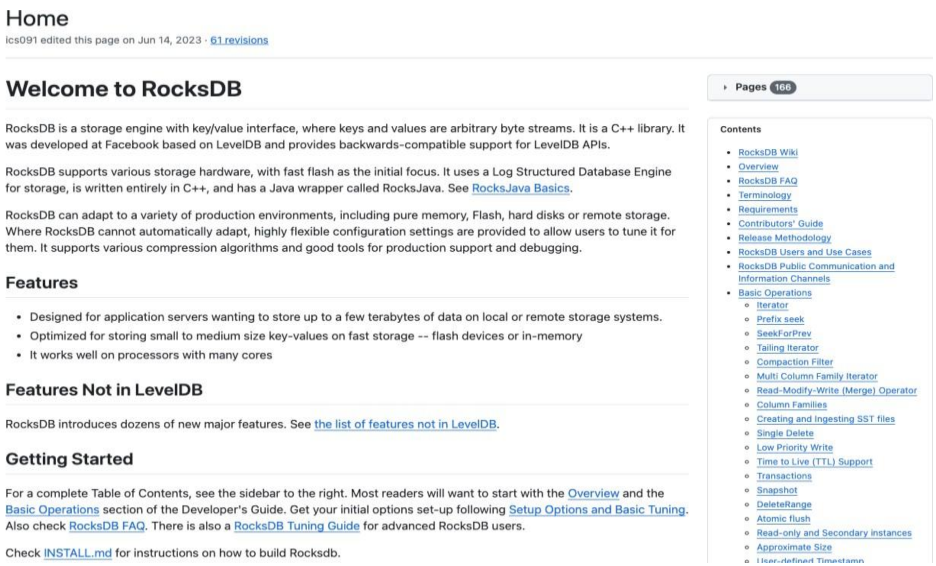
rocksdb.org

database · storage-engine

Readme
GPL-2.0 and 2 other licenses found
Code of conduct
Security policy
Activity
Custom properties
29k stars
993 watching
6.4k forks
Report repository

Releases 200

RocksDB 9.10.0 Release Latest
2 weeks ago
+ 199 releases


Home

ics091 edited this page on Jun 14, 2023 · 61 revisions

Welcome to RocksDB

RocksDB is a storage engine with key/value interface, where keys and values are arbitrary byte streams. It is a C++ library. It was developed at Facebook based on LevelDB and provides backwards-compatible support for LevelDB APIs.

RocksDB supports various storage hardware, with fast flash as the initial focus. It uses a Log Structured Database Engine for storage, is written entirely in C++, and has a Java wrapper called RocksJava. See RocksJava Basics.

RocksDB can adapt to a variety of production environments, including pure memory, Flash, hard disks or remote storage. Where RocksDB cannot automatically adapt, highly flexible configuration settings are provided to allow users to tune it for them. It supports various compression algorithms and good tools for production support and debugging.

Features

- Designed for application servers wanting to store up to a few terabytes of data on local or remote storage systems.
- Optimized for storing small to medium size key-values on fast storage -- flash devices or in-memory
- It works well on processors with many cores

Features Not in LevelDB

RocksDB introduces dozens of new major features. See the list of features not in LevelDB.

Getting Started

For a complete Table of Contents, see the sidebar to the right. Most readers will want to start with the Overview and the Basic Operations section of the Developer's Guide. Get your initial options set-up following Setup Options and Basic Tuning. Also check RocksDB FAQ. There is also a RocksDB Tuning Guide for advanced RocksDB users.

Check INSTALL.md for instructions on how to build Rocksdb.

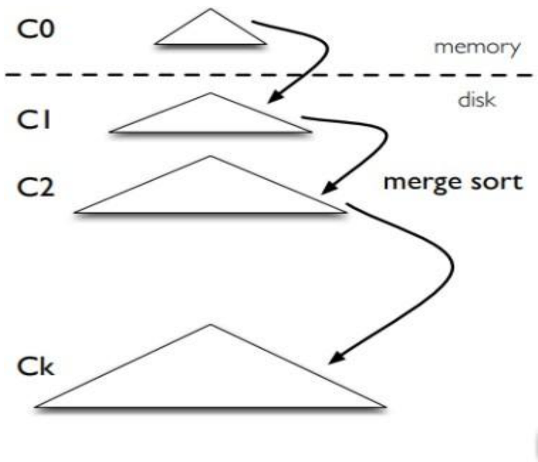
Pages 166

Contents

source: rocksdb github and rocksdb wiki

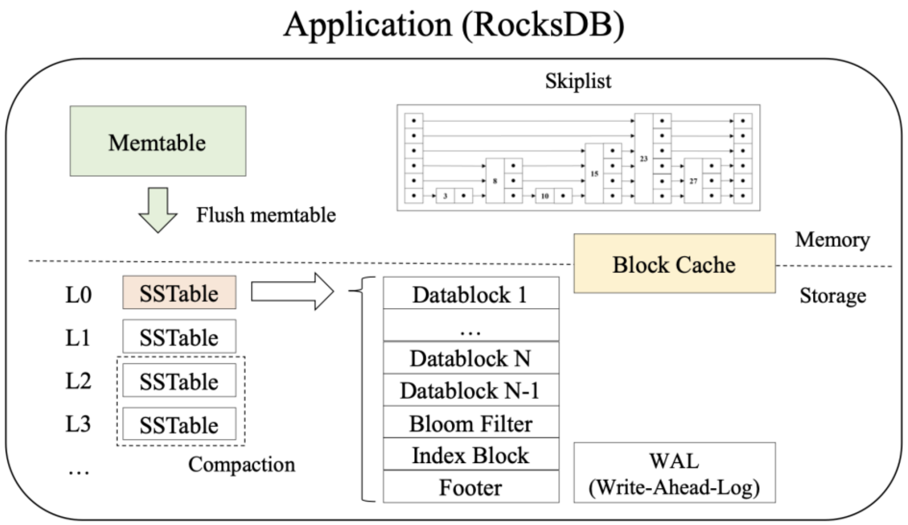
RocksDB Summary

- RocksDB Summary
  - ✓ Based on LSM (Log-Structured Merge)-tree
    - Layerd: C0, C1, …, Ck (exponentially increasing)
  - ✓ Real Implementation: Memtable, SSTable
    - Memtable in memory, SSTable in storage (multiple levels: L0, L1, …, Lk)
  - ✓ Interface: put, get, range scan, delete
  - ✓ Put flow
    - WAL → Memtable → Immutable Memtable → Flush → Compaction (condition)



(a) LSM-tree

source: Wisckey, FAST 2016



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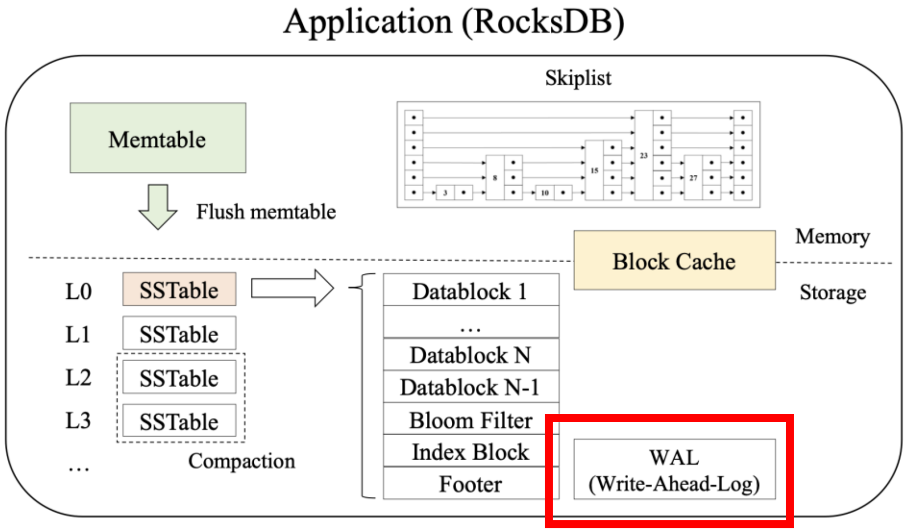

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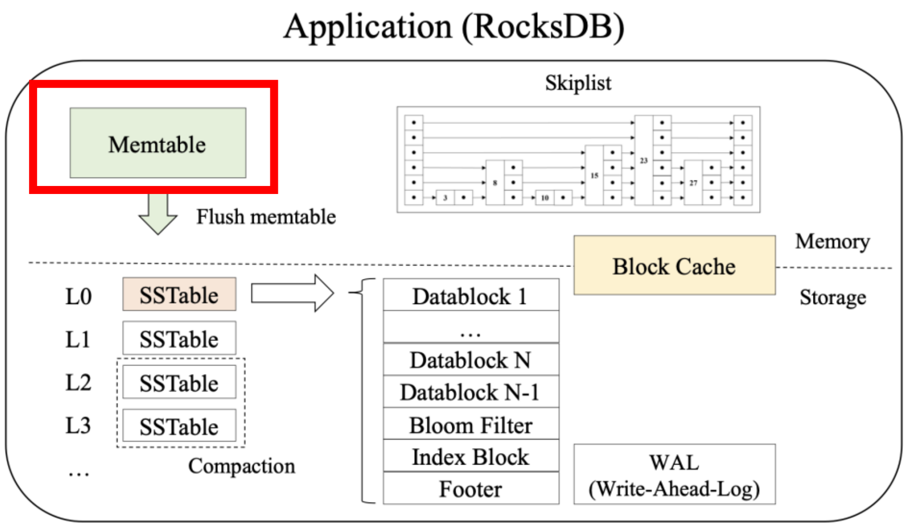

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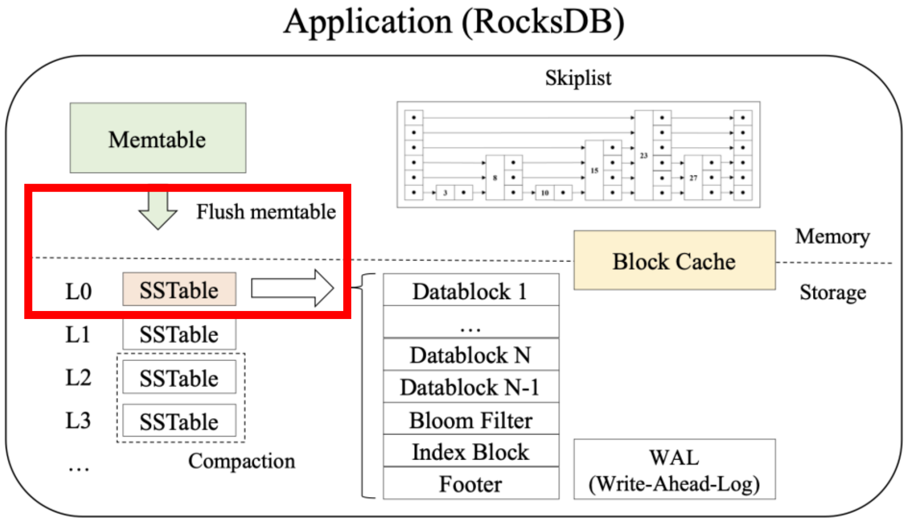

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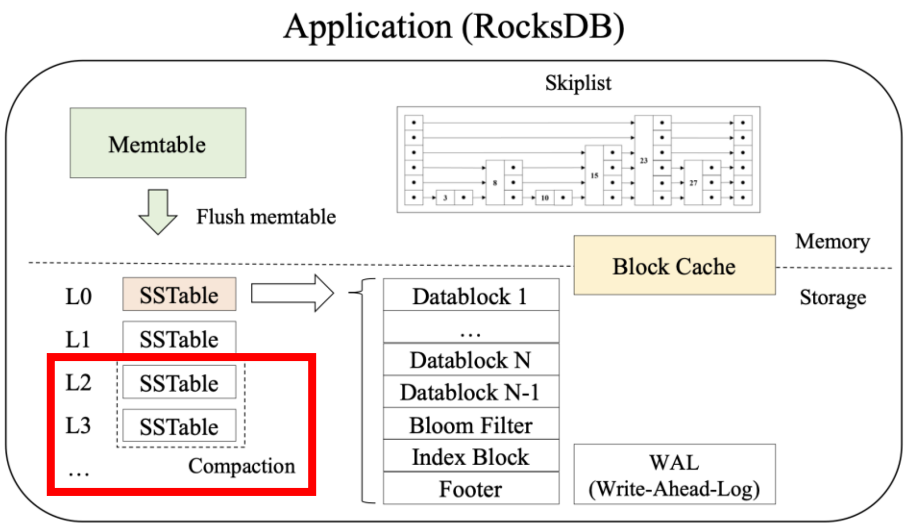
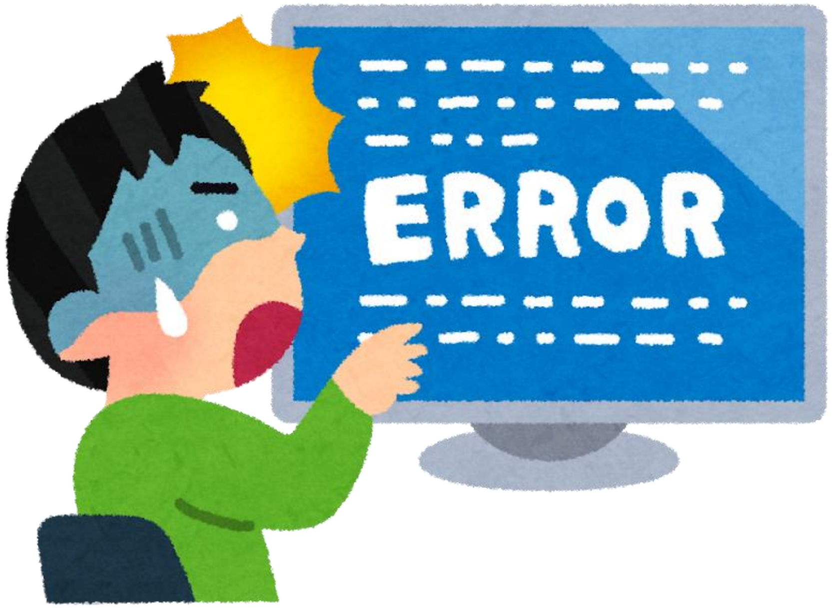


RocksDB Write (Put, Flush, Compaction)

- Put interface (WAL)
  - ✓ Write-Ahead-Log: Do before write memtable
    - Crucial components of RocksDB that ensures data durability and recoverability

Computer Crashed !



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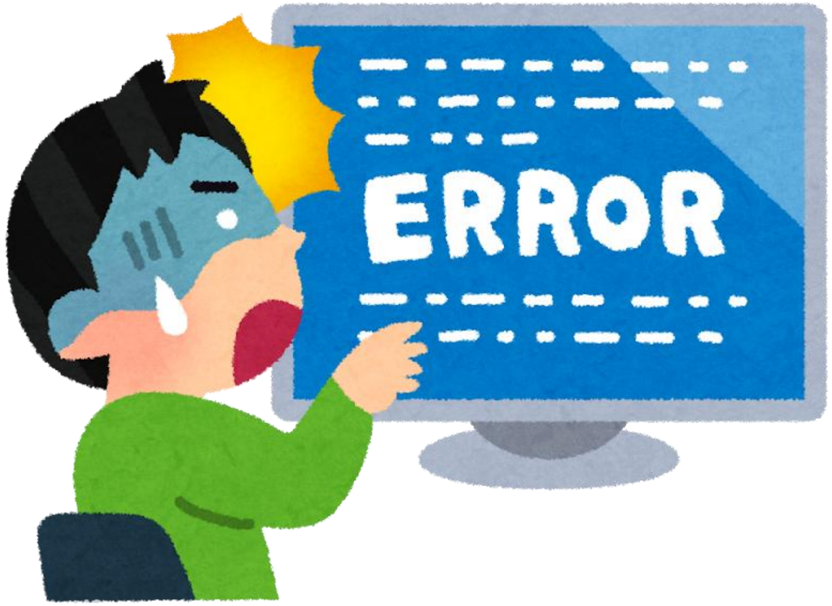
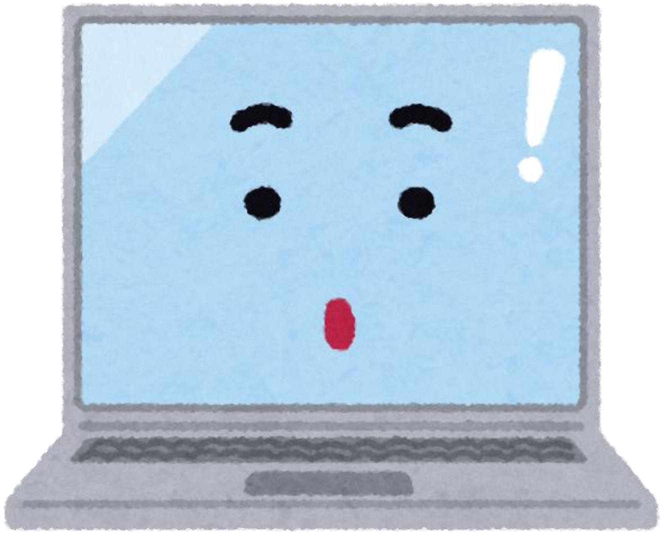


Ah! WAL !!



RocksDB Write (Put, Flush, Compaction)

- Put interface (WAL)
  - ✓ Write-Ahead-Log: Do before write memtable
    - Crucial components of RocksDB that ensures data durability and recoverability
  - ✓ Employs sequential disk writes and Crash recovery
  - ✓ A set of records where each record consists of CRC, size, type and payload
  - ✓ Options (on/off, configurable)

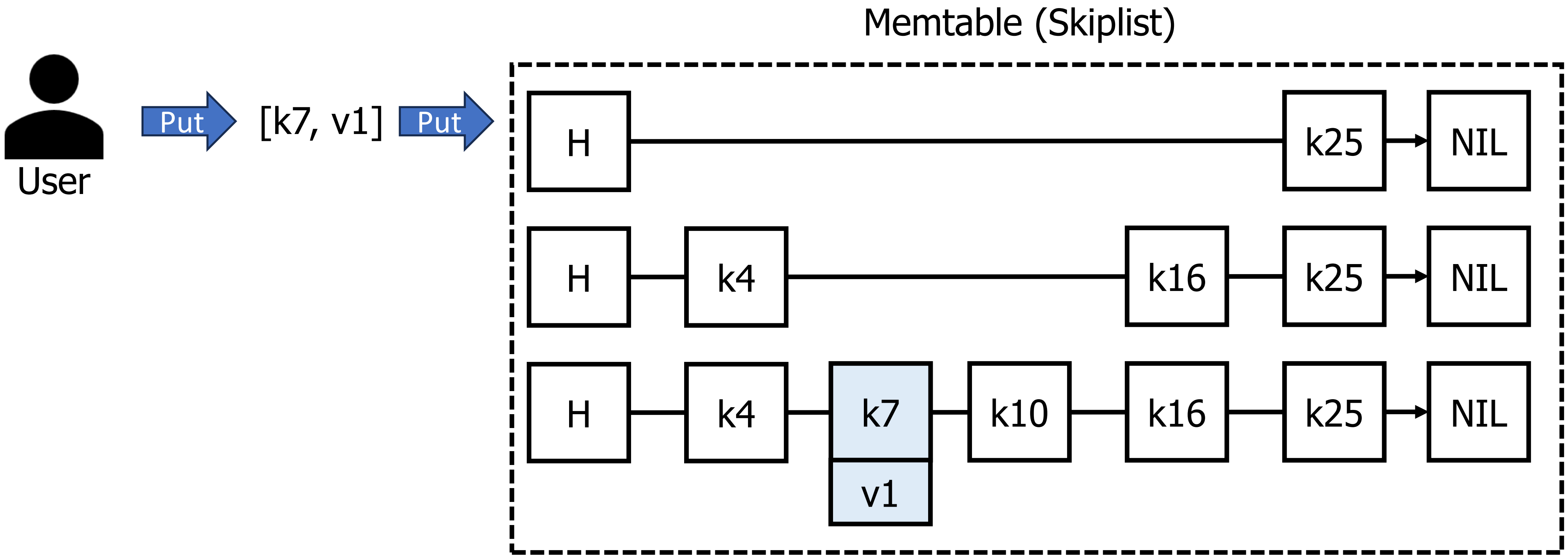
```
+---------+-----------+-----------+--- ... ---+
|CRC (4B) | Size (2B) | Type (1B) | Payload   |
+---------+-----------+-----------+--- ... ---+

CRC = 32bit hash computed over the payload using CRC
Size = Length of the payload data
Type = Type of record
       (kZeroType, kFullType, kFirstType, kLastType, kMiddleType )
       The type is used to group a bunch of records together to represent
       blocks that are larger than kBlockSize
Payload = Byte stream as long as specified by the payload size
```

WAL format

source: rocksdb github wiki

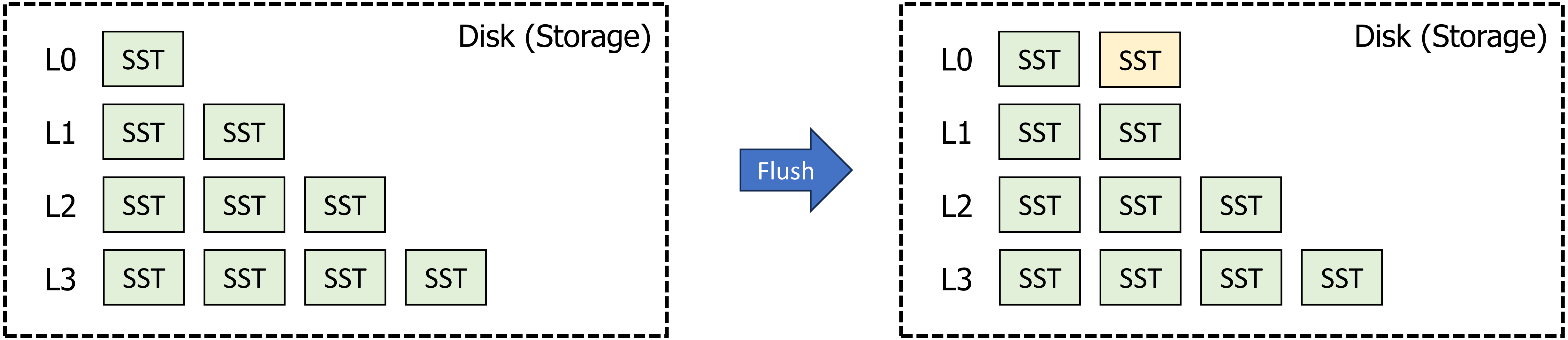
RocksDB Write (Put, Flush, Compaction)

- Put interface (memtable)
  - ✓ Further separate into **mutable** and **immutable**
  - ✓ Data structure: skiplist (or hashtable, hashskiplist …)
  - ✓ Managing data in a **sorted** state
  - ✓ Default size (64MB, configurable)



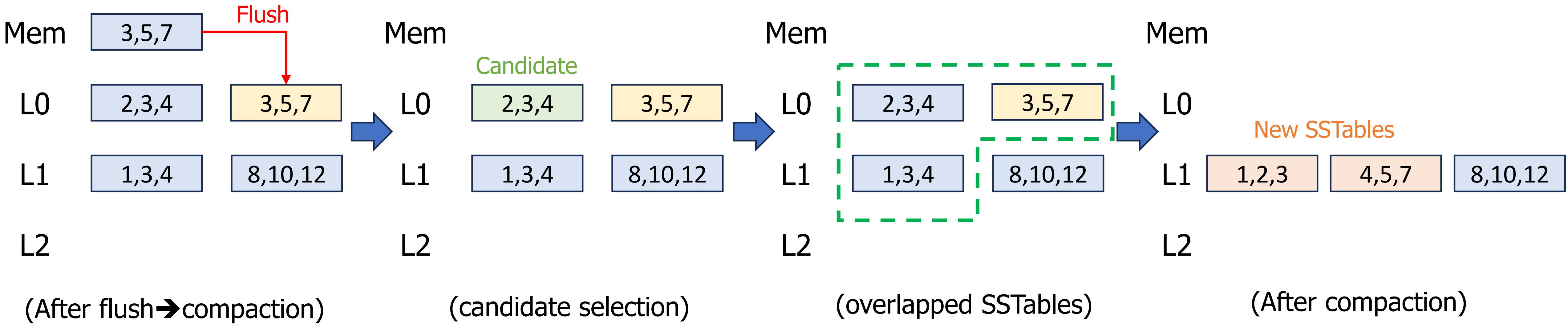
RocksDB Write (Put, Flush, Compaction)

- Put interface (Flush)
  - ✓ Flush: Writing data from the in-memory Memtable to persistent SSTable files on disk
    - SSTable (Sorted String Table)
  - ✓ Triggering the flush
    - Memory limit reached (64MB) → Memtable to Immutable memtable → Stored data in Level 0
  - ✓ Occur in the background



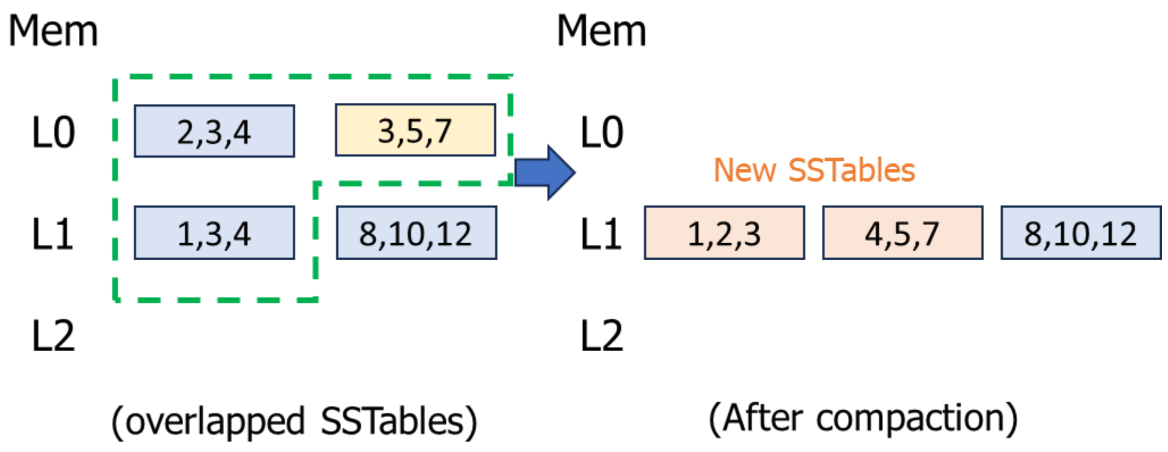
RocksDB Write (Put, Flush, Compaction)

- Put interface (Compaction)
  - ✓ Compaction procedure
    - 1) Select candidate (FIFO, Least overlapped, …)
    - 2) Read overlapped SSTables from current and next level
    - 3) Do **merge sort**
    - 4) Write new SSTables to the next level



RocksDB Write (Put, Flush, Compaction)

- Put interface (Compaction)
  - ✓ Compaction effect
    - 1) Remove old data (reclaim)
    - 2) Sort keys at L1, L2, … (fast lookup)
  - ✓ Trigger
    - When a level exceeds its maximum size (except L0)
  - ✓ Compaction cost
    - Read/Write SSTables from/into storage ➔ **Heavy operation**
    - Cause **amplification**
  - ✓ Amplification
    - An undesirable phenomenon where the actual amount of operations/space are more than intended
  - ✓ Types
    - 1) WAF (Write Amplification Factor) = actual writes/intended writes
    - 2) SAF (Space Amplification Factor) = actual used space/required space
    - 3) RAF (Read Amplification Factor) = actual reads/intended reads



RocksDB Read (Get, Bloom filter)

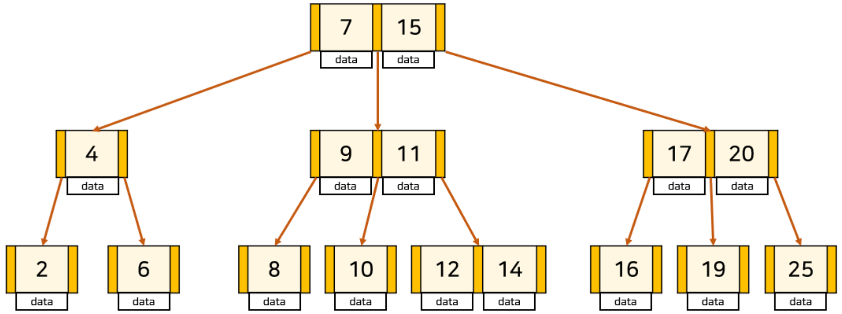
- What is lookup (query)?
  - ✓ Two types
    - 1) Point lookup (single query): get a value related to a given key
    - 2) Range lookup (scan): get values related to a range of keys
  - ✓ How to: various data structures (e.g. array, list, sorted, hash, …)
    - 1) linear search (O(N)), 2) binary search (O(logN)), 3) hash (O(1))
    - Tradeoffs: search speed, update overhead, scan overhead, …

Data Structure	Time Complexity								Space Complexity
	Average				Worst				Worst
	Access	Search	Insertion	Deletion	Access	Search	Insertion	Deletion	
Array	Θ(1)	Θ(n)	Θ(n)	Θ(n)	O(1)	O(n)	O(n)	O(n)	O(n)
Stack	Θ(n)	Θ(n)	Θ(1)	Θ(1)	O(n)	O(n)	O(1)	O(1)	O(n)
Queue	Θ(n)	Θ(n)	Θ(1)	Θ(1)	O(n)	O(n)	O(1)	O(1)	O(n)
Singly-Linked List	Θ(n)	Θ(n)	Θ(1)	Θ(1)	O(n)	O(n)	O(1)	O(1)	O(n)
Doubly-Linked List	Θ(n)	Θ(n)	Θ(1)	Θ(1)	O(n)	O(n)	O(1)	O(1)	O(n)
Skip List	Θ(log(n))	Θ(log(n))	Θ(log(n))	Θ(log(n))	O(n)	O(n)	O(n)	O(n)	O(n log(n))
Hash Table	N/A	Θ(1)	Θ(1)	Θ(1)	N/A	O(n)	O(n)	O(n)	O(n)
Binary Search Tree	Θ(log(n))	Θ(log(n))	Θ(log(n))	Θ(log(n))	O(n)	O(n)	O(n)	O(n)	O(n)
Cartesian Tree	N/A	Θ(log(n))	Θ(log(n))	Θ(log(n))	N/A	O(n)	O(n)	O(n)	O(n)
B-Tree	Θ(log(n))	Θ(log(n))	Θ(log(n))	Θ(log(n))	O(log(n))	O(log(n))	O(log(n))	O(log(n))	O(n)
Red-Black Tree	Θ(log(n))	Θ(log(n))	Θ(log(n))	Θ(log(n))	O(log(n))	O(log(n))	O(log(n))	O(log(n))	O(n)
Splay Tree	N/A	Θ(log(n))	Θ(log(n))	Θ(log(n))	N/A	O(log(n))	O(log(n))	O(log(n))	O(n)
AVL Tree	Θ(log(n))	Θ(log(n))	Θ(log(n))	Θ(log(n))	O(log(n))	O(log(n))	O(log(n))	O(log(n))	O(n)
KD Tree	Θ(log(n))	Θ(log(n))	Θ(log(n))	Θ(log(n))	O(n)	O(n)	O(n)	O(n)	O(n)

source: https://www.digitalvidya.com/blog/data-structures-and-algorithms-in-python/

RocksDB Read (Get, Bloom filter)

- How to materialize lookup in DB?
  - ✓ In traditional RDB (e.g. InnoDB)
    - Make use of B-tree (or B+tree)
    - B-tree: generalized binary tree that has multiple children (n-ary tree)
    - B+tree: all KV are stored in leaves, all leaves are linked for scan
    - Good for lookup, Bad for update due to tree reconstruction

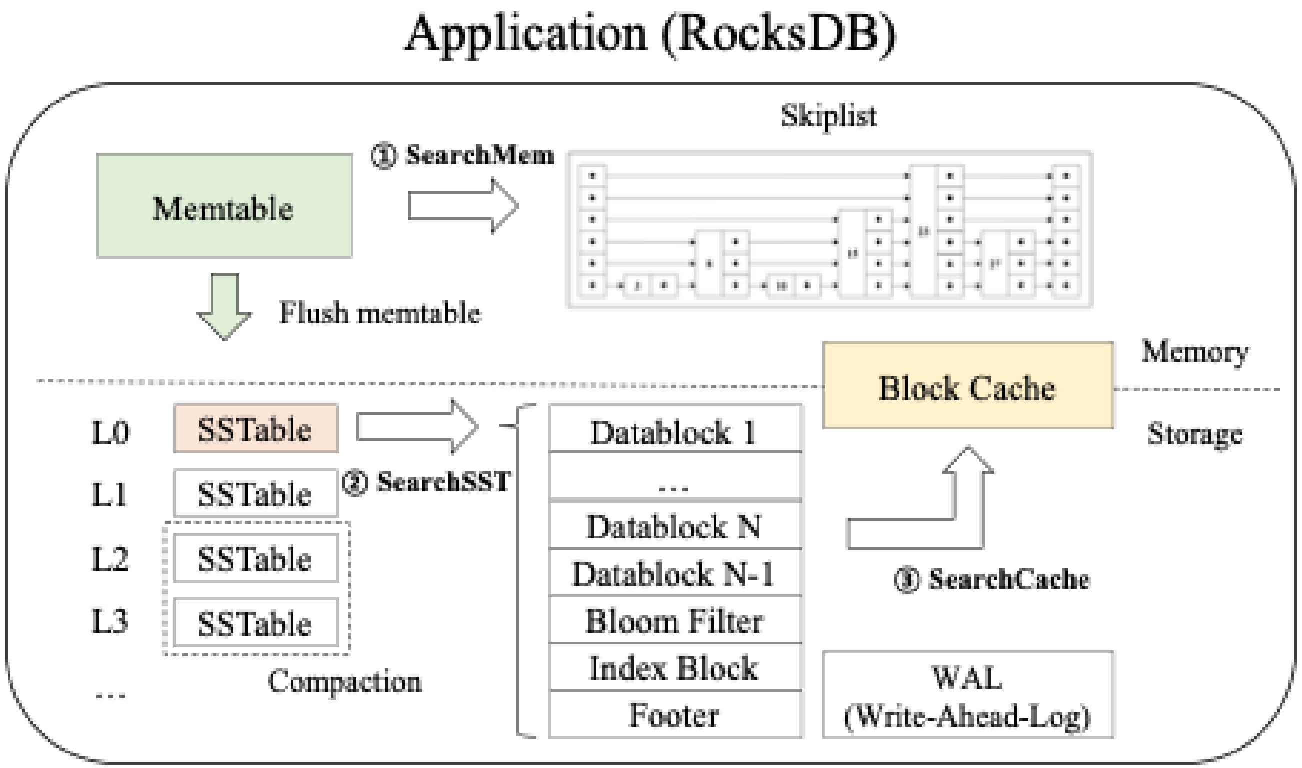


B-tree

  - ✓ RocksDB
    - Make use of LSM-tree, a write-optimized data structure
    - Employ B+tree for lookup may deteriorate its original merit
    - Utilize its own data structures for lookup purpose including **Skiplist**, Index block and Bloom filter

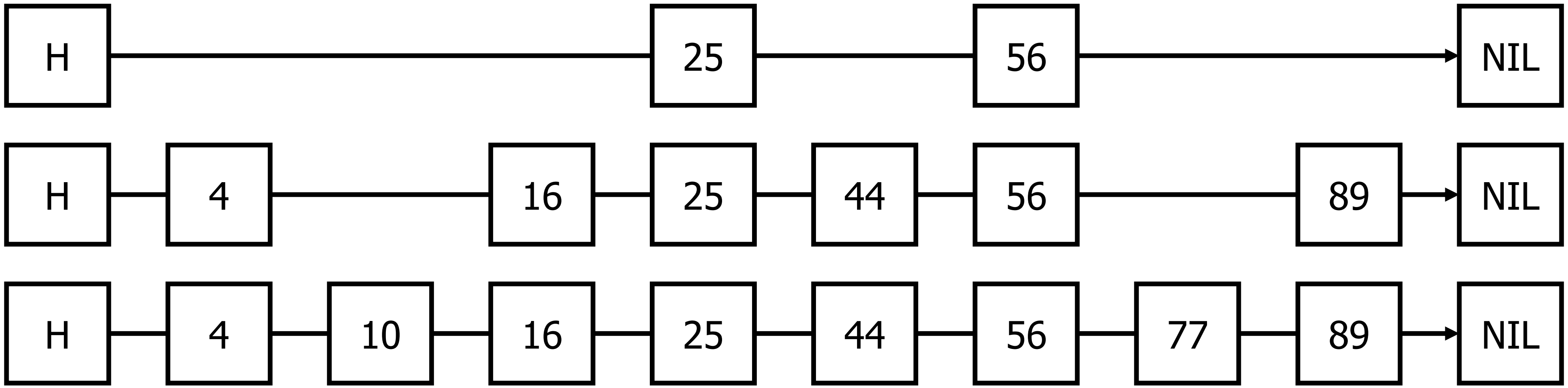
RocksDB Read (Get, Bloom filter)

- RocksDB lookup: Overview
  - ✓ Lookup procedure
    - 1) Memtable and Immutable memtable
    - 2) SSTables (from L0 to Lmax)



RocksDB Read (Get, Bloom filter)

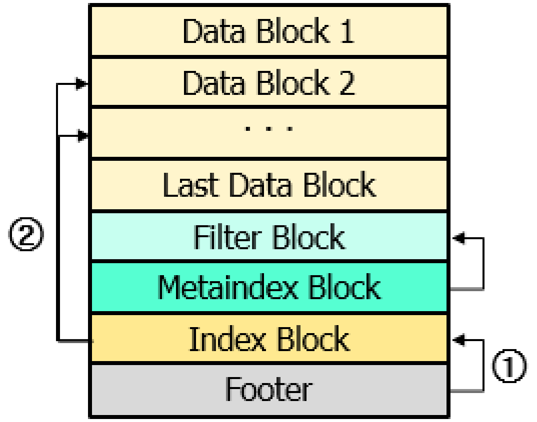
- Get interface (Memtable)
  - ✓ KV pairs in memory, managed by Skiplist
    - Skiplist: a data structure with a set of sorted linked lists
    - All keys appears in the last list
    - Some keys also appear in the upper list (for fast search)
    - Good for both lookup and scan (O(logN))
    - Useful in multithreaded system architectures



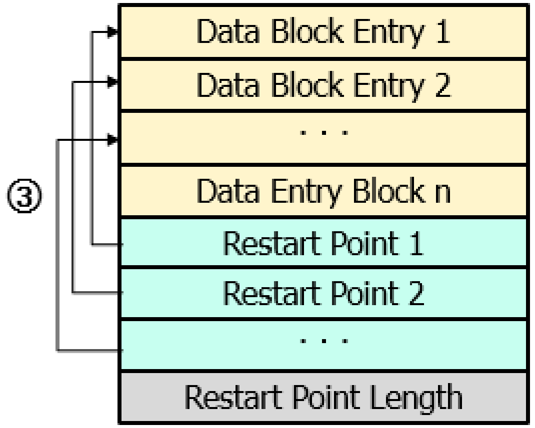
Skiplist Structure

RocksDB Read (Get, Bloom filter)

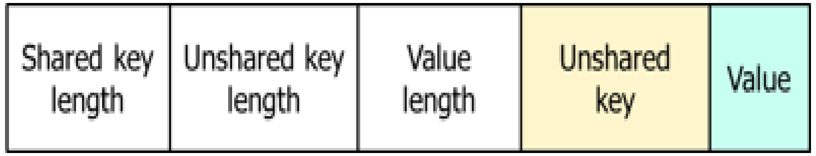
- Get interface (SSTable)
  - ✓ KV pairs in storage, managed as a file
  - ✓ Issue: SSTable is large (default 64MB)
    - Assume 1KB KV ➔ 64,000 pairs in a file
    - A file is divided into multiple disk blocks
  - ✓ Solution: well-defined SSTable format
    - 1) SSTable is divided into data blocks
    - 2) Each KV is searched using index (Binary search)
    - 3) Filter block (**Bloom filter**)
    - 4) Other meta blocks (e.g. compressions)
    - 5) Metaindex: one entry for every meta blocks
    - 6) Footer: pointers for metaindex & index blocks



(SSTable format)



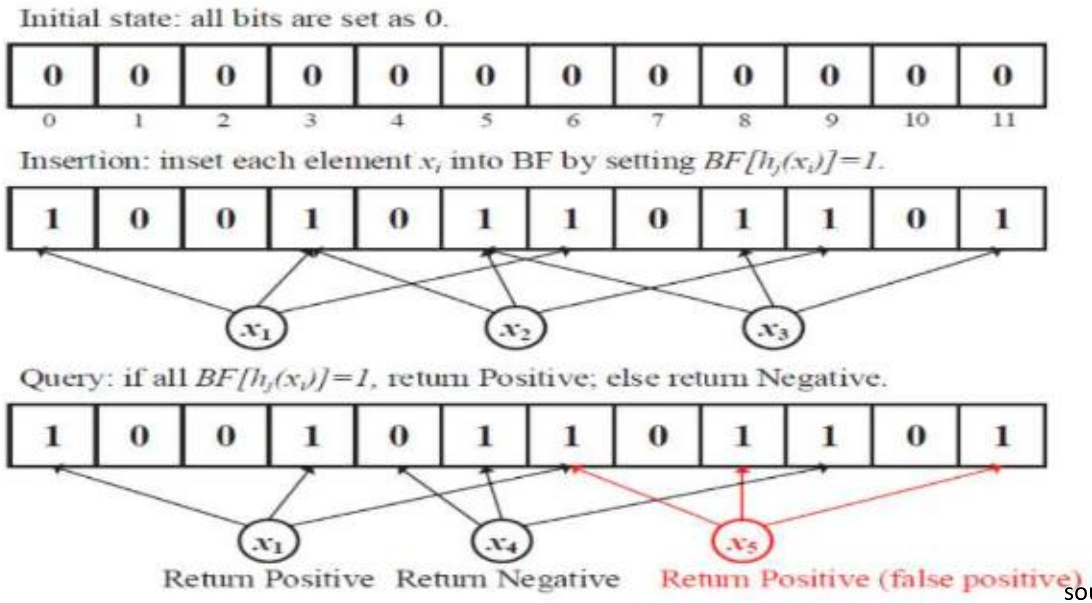
(Data block format)

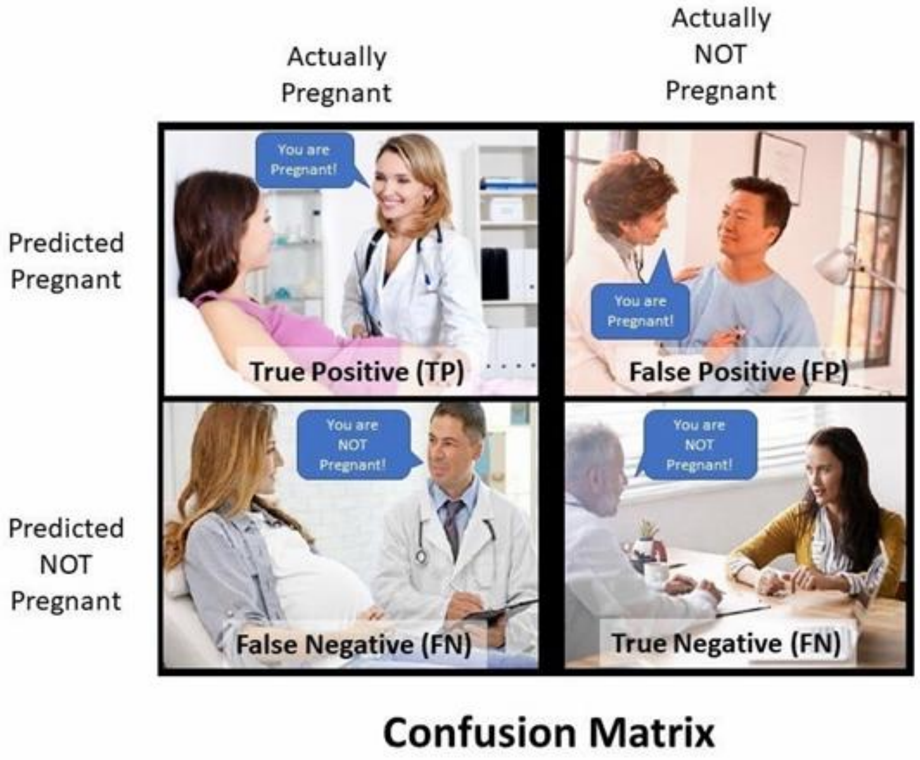


(Data block entry format)

RocksDB Read (Get, Bloom filter)

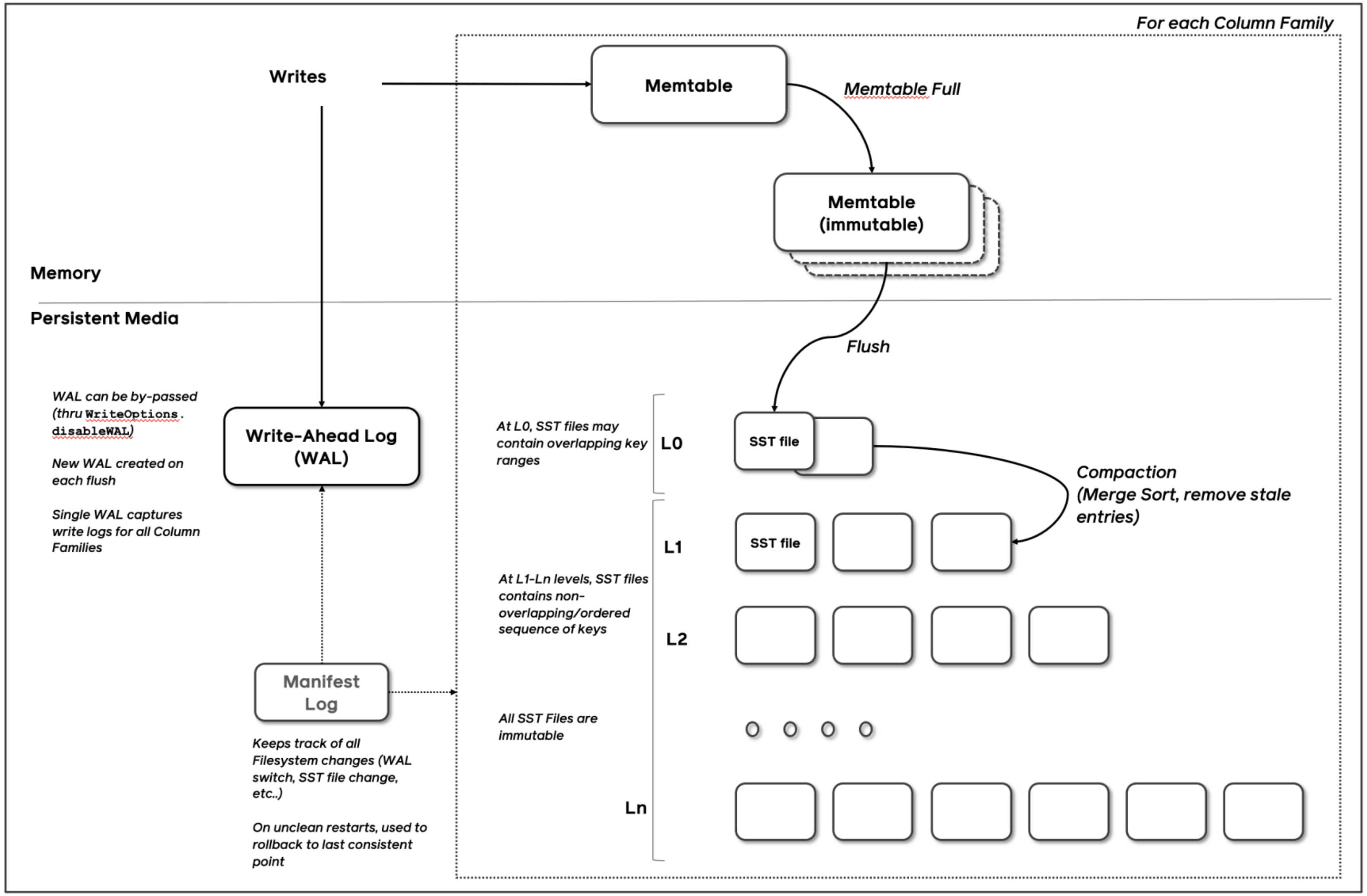
- Get interface (Bloom filter)
  - ✓ Used to reduce the read amplification (unnecessary read)
    - Only know the key range of each SSTable
  - ✓ Bloom filter: a data structure for identifying membership
    - Based on bits and multiple hashes
    - Good property: No false negative
    - Issue: can yield false positive ➔ tradeoffs between bits and rate (1% false positive rate with 9.9 bits per key, from RocksDB wiki)





source: https://devopedia.org/bloom-filter

RocksDB Wrap up



source: https://github.com/facebook/rocksdb/wiki/RocksDB-Overview

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Thank You
Q & A ?

Presentation by Dayeon Wee

wida10@dankook.ac.kr