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Badger: Fast Key-Value DB in Go

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Dgraph Labs

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- Fast, Distributed graph database.
- Sparse data sets.
- Lots of relationships.

https://dgraph.io

What is Badger?

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- Badger is an embedded key-value database, written in Go.
- Licensed under Apache 2.0.

```
go get github.com/dgraph-io/badger/...
```

Current Status

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- Closing v2.0.
- Close to 3500 Github starts.
- 42 contributors.
- Used by Dgraph, Go-IPFS, 0-stor, Sandglass.

Serving 300TB (and growing) at Usenet E

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Basic Operations

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Set a key-value

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```
func set() error {
    fmt.Println("\nRunning SET")
    return db.Update(func(txn *badger.Txn) error {
        if err := txn.Set([]byte("foo"), []byte("bar")); err != nil {
            return err
        }
        fmt.Println("Set foo to bar")
        return nil
    })
}
```

Get a key-value

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```
func get() error {
    fmt.Println("\nRunning GET")
    return db.View(func(txn *badger.Txn) error {
        item, err := txn.Get([]byte("foo")) // handle err
        if err != nil {
            return err
        }
        val, err := item.Value() // handle err
        if err != nil {
            return err
        }
        fmt.Printf("The value is: %s\n", val)
        return nil
    })
}
```

Iterate key-values

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```
func iterate() error {
    fmt.Println("\nRunning ITERATE")
    return db.View(func(txn *badger.Txn) error {
        opts := badger.DefaultIteratorOptions
        it := txn.NewIterator(opts)
        defer it.Close()

        for it.Rewind(); it.Valid(); it.Next() {
            k := it.Item().Key()
            v, err := it.Item().Value() // handle err
            if err != nil {
                return err
            }
            fmt.Printf("key=%s, value=%s\n", k, v)
        }
        return nil
    })
}
```

Run the code

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```
func main() {
    opt := badger.DefaultOptions
    opt.Dir = "/tmp/db"
    opt.ValueDir = opt.Dir
    var err error
    db, err = badger.Open(opt)
    if err != nil {
        panic(err)
    }
    defer db.Close()
    fmt.Println("DB opened")
    set()
    get()
    iterate()
    fmt.Println("DB done")
}
```

Run

Badger != replacement for Go map

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Motivation and Outcome

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Cgo is not Go

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Some people, when confronted with a problem, think
“I know, I’ll use cgo.”

Now they have two problems.

->Cgo is not Go, Dave Cheney

RocksDB

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- Great write throughput.
- Okay read throughput.

Cons:

- Required Cgo.

BoltDB

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- Pure Go.
- Great read throughput.

Cons:

- Bad write throughput.

Why build it?

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- Go native key-value DB for Dgraph.
- No compromise in read-write performance.
- Avoid Cgo.

What did we spend?

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- Spent a few months.
- Built with <1 full-time gopher.
- Aka, the power of Go!

What did we gain?

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- A faster key-value DB for Go.
- Ability to run Go profilers all the way down to disk.
- Clean Go code (no C).

Launch Reception

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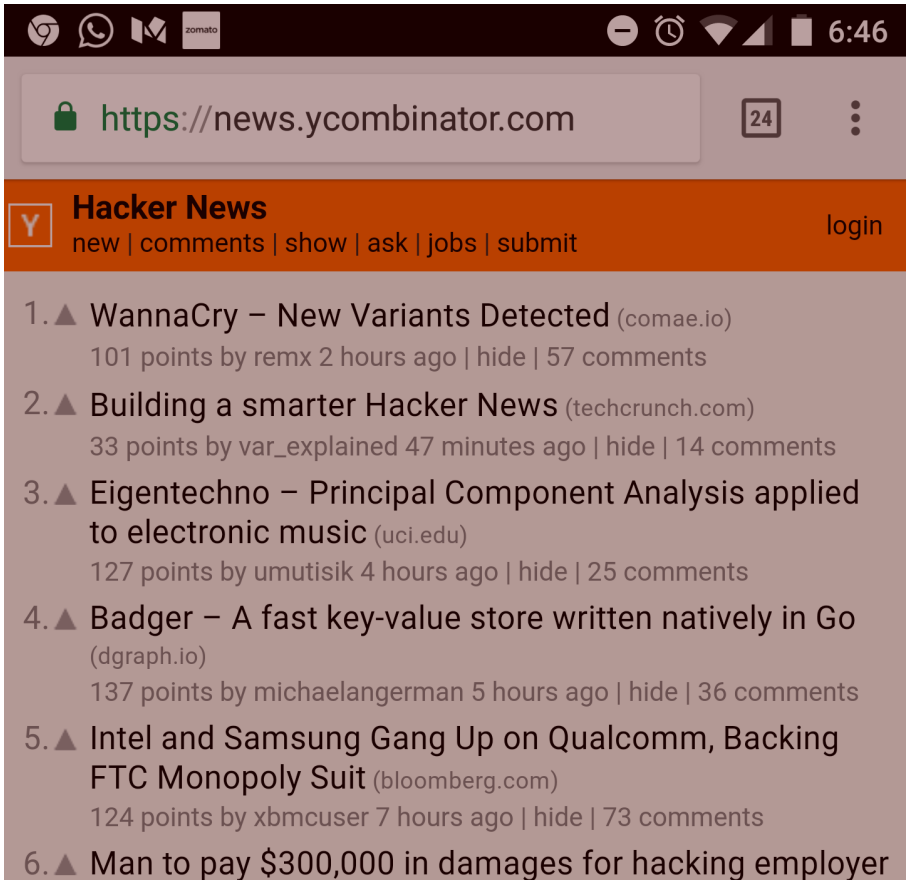
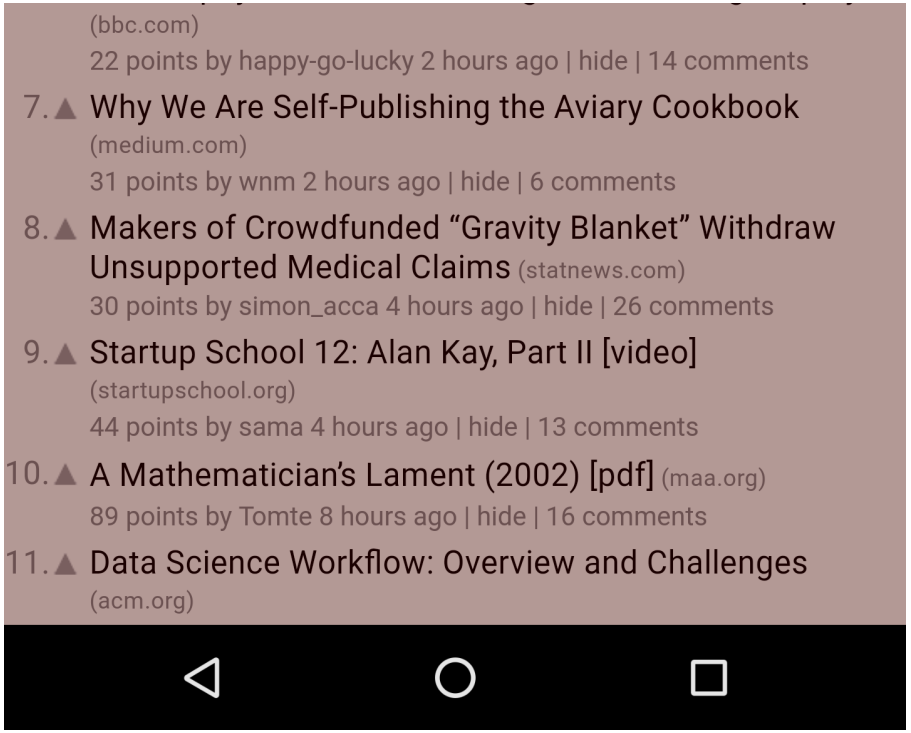
- Within 12 hours of blog post release
- First page of HN for a day.
- 355 points, 96 comments.
- 1250 Github stars in 4 days.




(bbc.com)
22 points by happy-go-lucky 2 hours ago | hide | 14 comments
7. ▲ Why We Are Self-Publishing the Aviary Cookbook
(medium.com)
31 points by wnm 2 hours ago | hide | 6 comments
8. ▲ Makers of Crowdfunded “Gravity Blanket” Withdraw Unsupported Medical Claims (statnews.com)
30 points by simon_acca 4 hours ago | hide | 26 comments
9. ▲ Startup School 12: Alan Kay, Part II [video]
(startupschool.org)
44 points by sama 4 hours ago | hide | 13 comments
10. ▲ A Mathematician’s Lament (2002) [pdf] (maa.org)
89 points by Tomte 8 hours ago | hide | 16 comments
11. ▲ Data Science Workflow: Overview and Challenges
(acm.org)

Recruiters loved it!

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- Got 3 different emails from 3 different recruiters...

Recruiters loved it!

- For jobs in the same company.

Design

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Two common Trees

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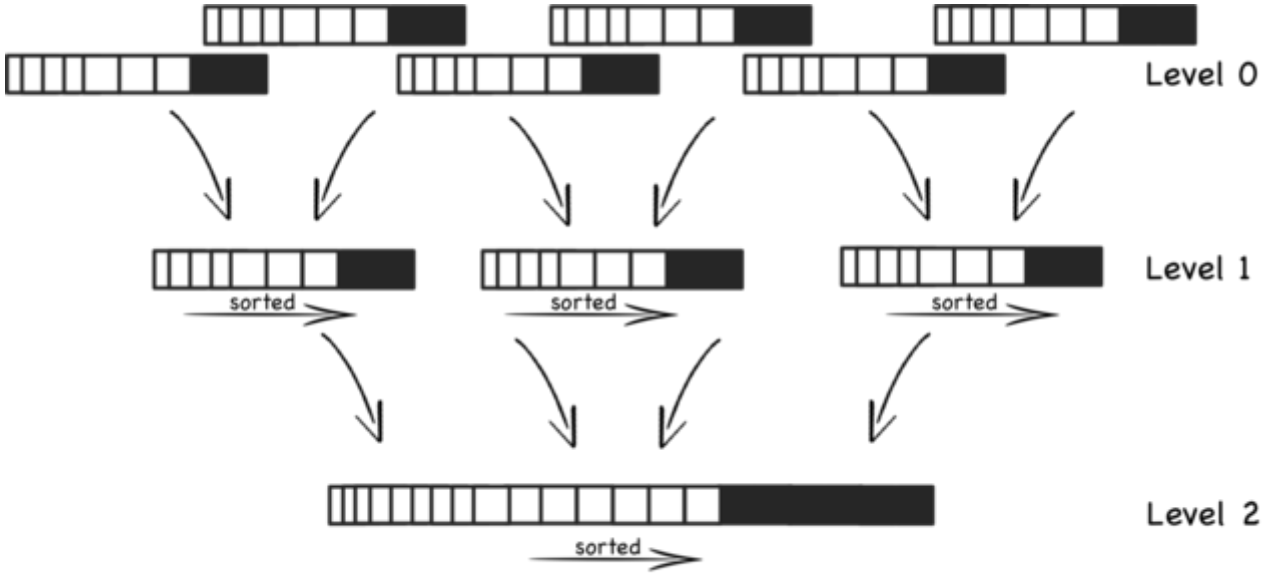
- LSM trees
- B+ trees

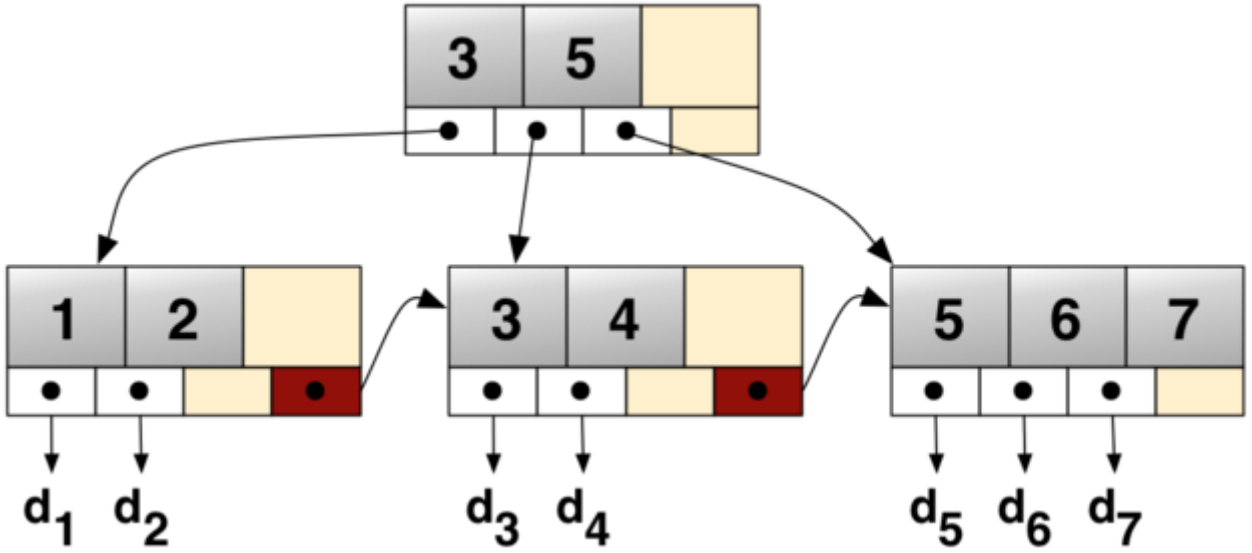
LSM Trees



Compaction continues creating fewer, larger and larger files

- More levels
- High write throughput
- High read latency
- Example: RocksDB

B+ Trees



- Fewer levels
- Low write throughput
- Low read latency
- Example: BoltDB

Badger is based on LSM trees.

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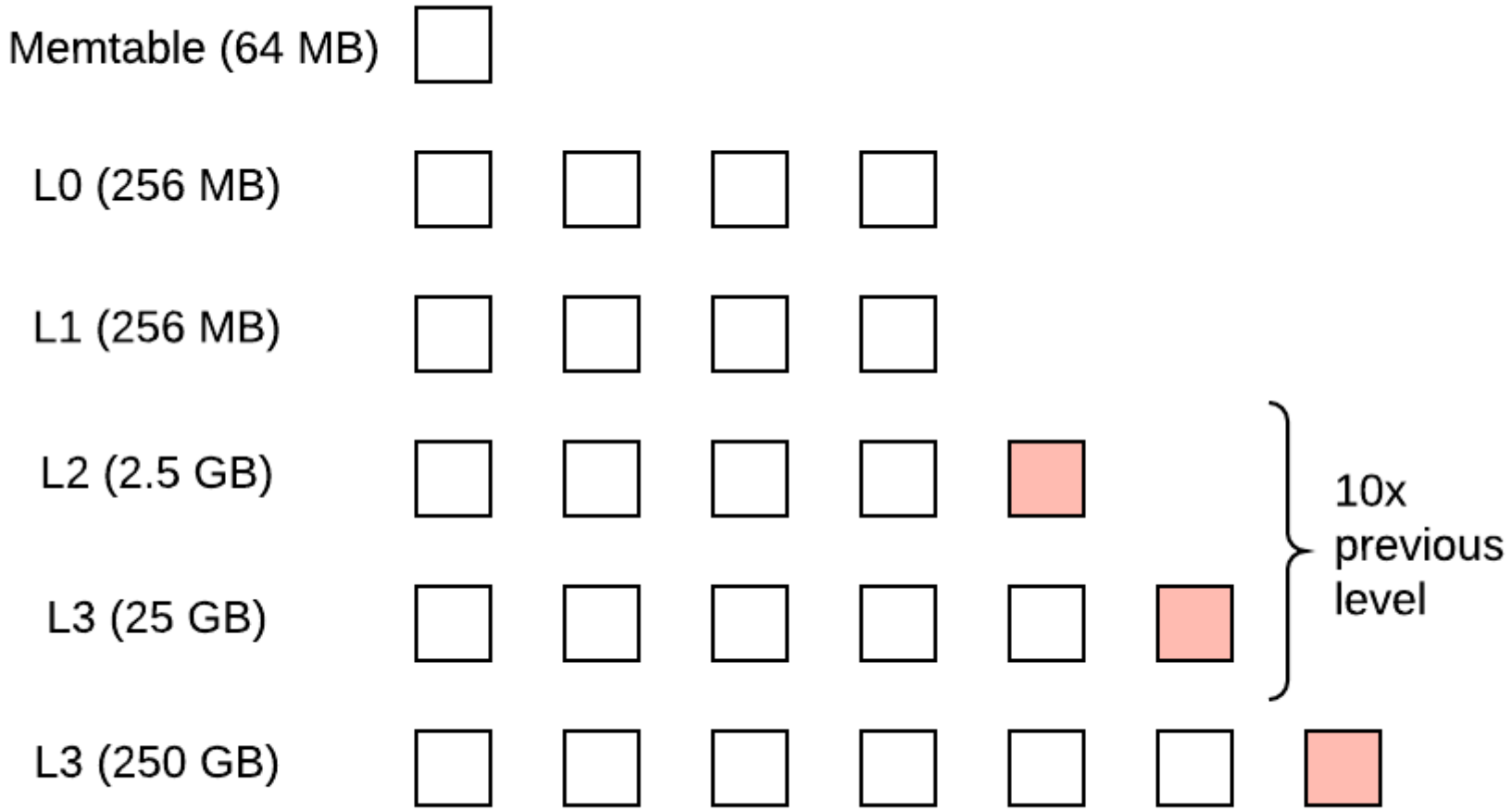
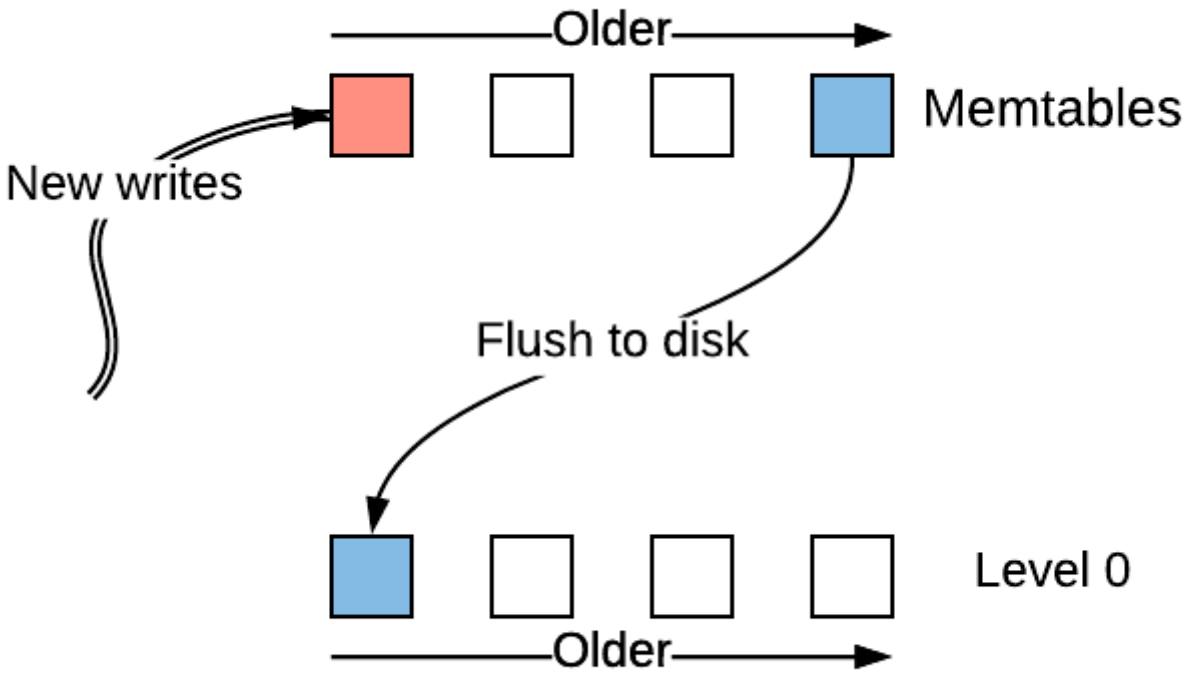
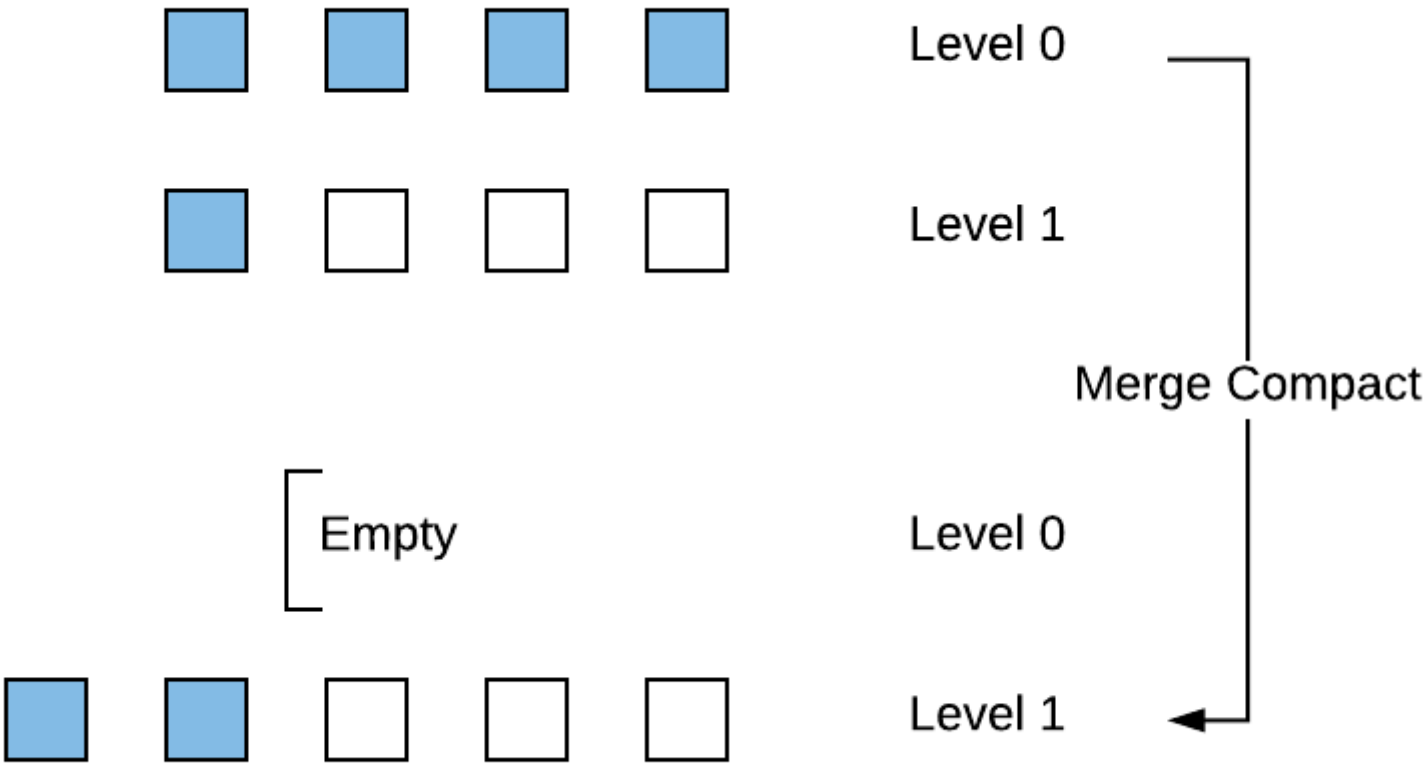
LSM Trees


Memtable (64 MB)
L0 (256 MB)
L1 (256 MB)
L2 (2.5 GB)
L3 (25 GB)
L3 (250 GB)
10x
previous
level

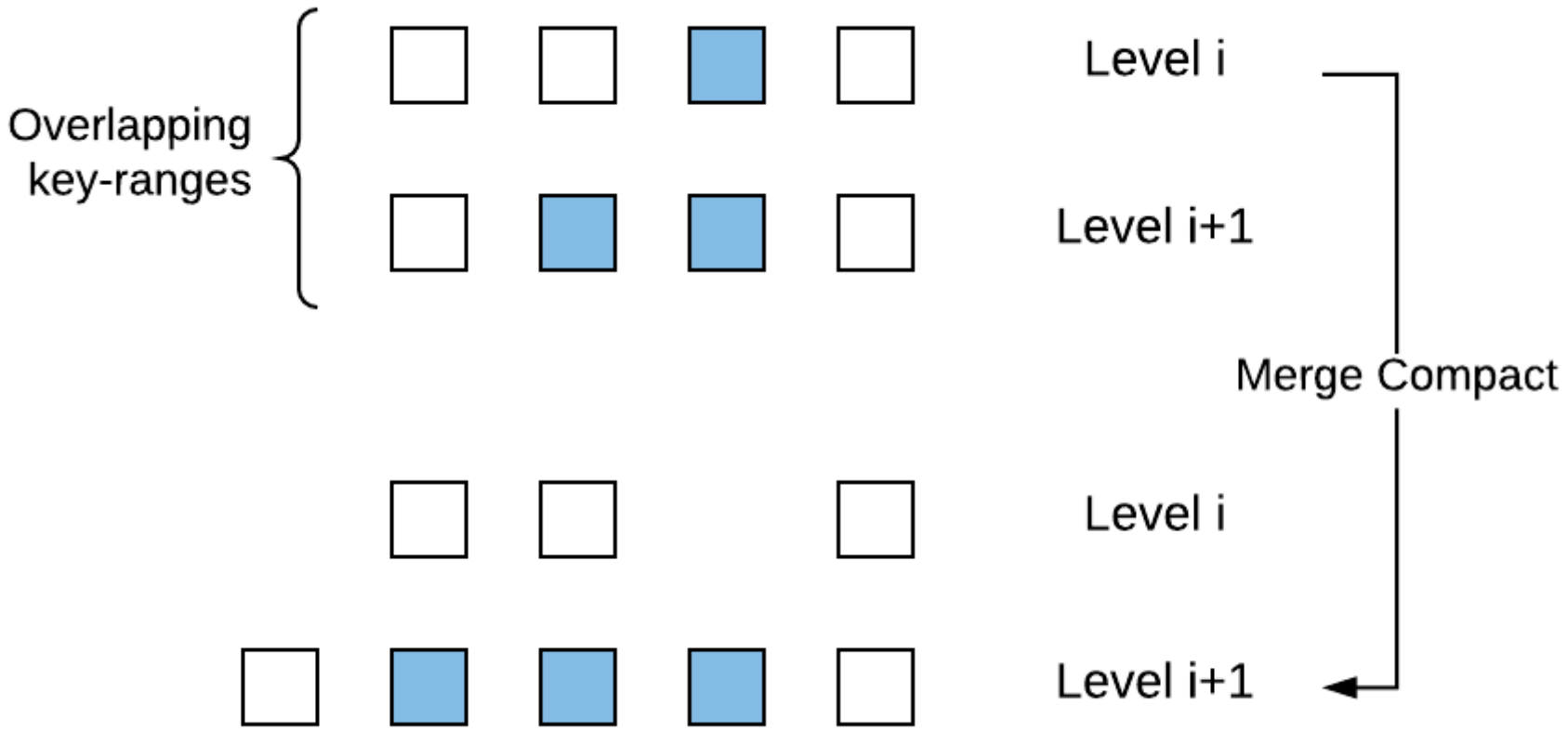
Writes in LSM trees: Memtable to L0



Writes in LSM trees: L0 to L1



Writes in LSM trees: Li to Li+1



What makes Badger unique?

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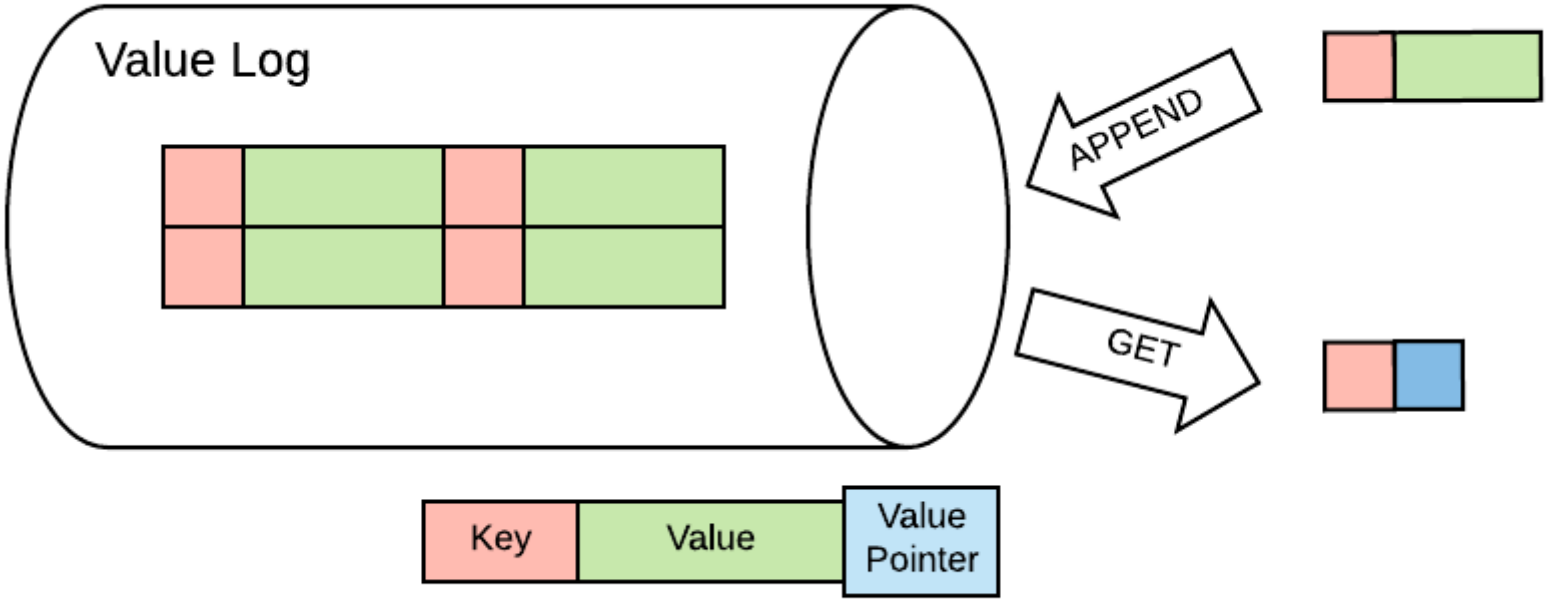
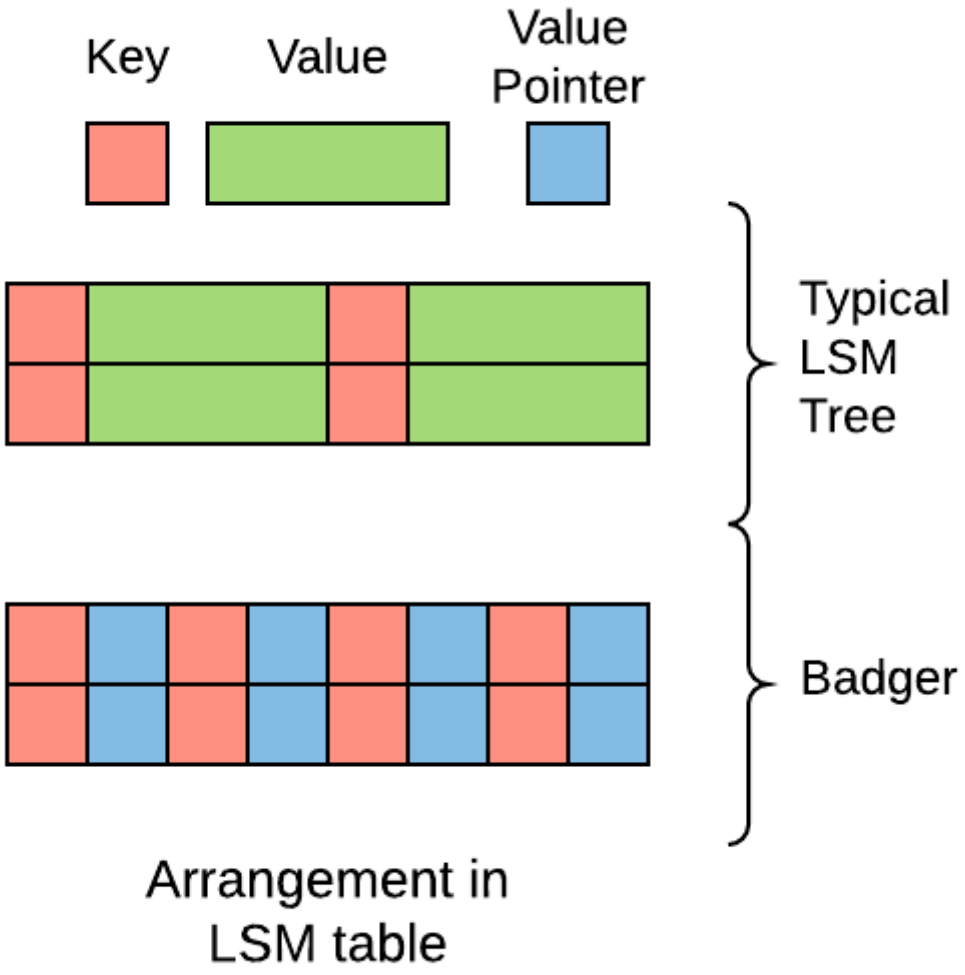
- Based on WiscKey paper by Uni Wisconsin-Madison.
- Separates keys from values.
- Stores keys in LSM tree.
- Stores value in value log.

Write to Value Log



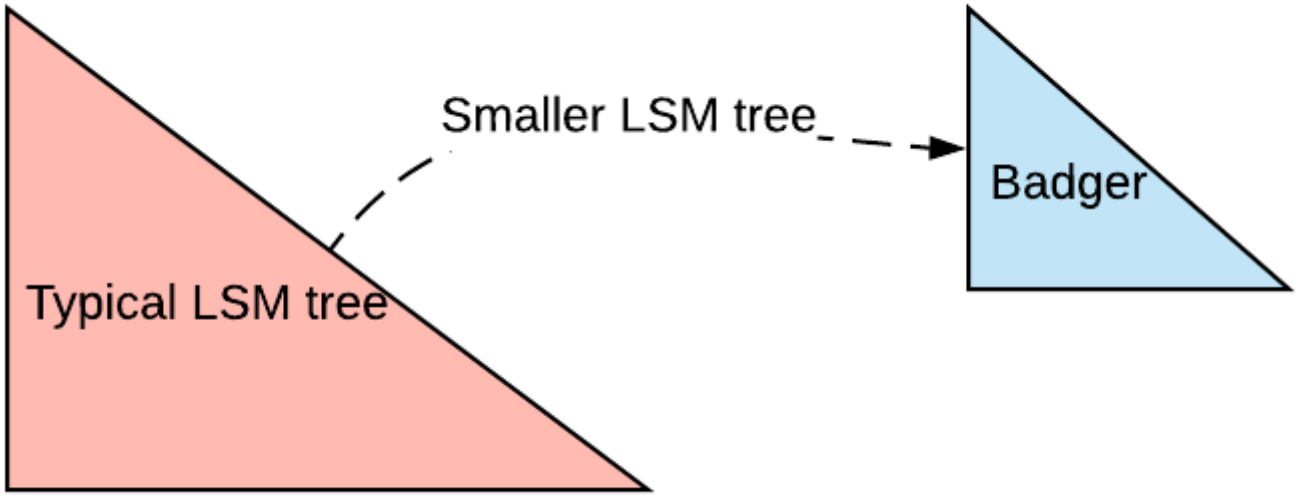
- Write value, get pointer.

More keys per table

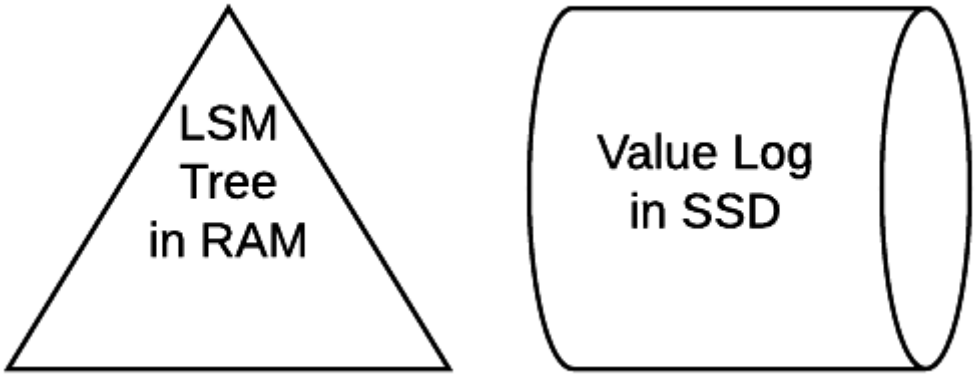


Arrangement in LSM table

Smaller LSM tree



Typical Badger setup



Advantages of smaller LSM tree

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- Can be kept in RAM.
- Low read amplification (fewer lookups).
- Low write amplification (fewer compactions).
- $\propto$ Number of keys.

Usenet Express

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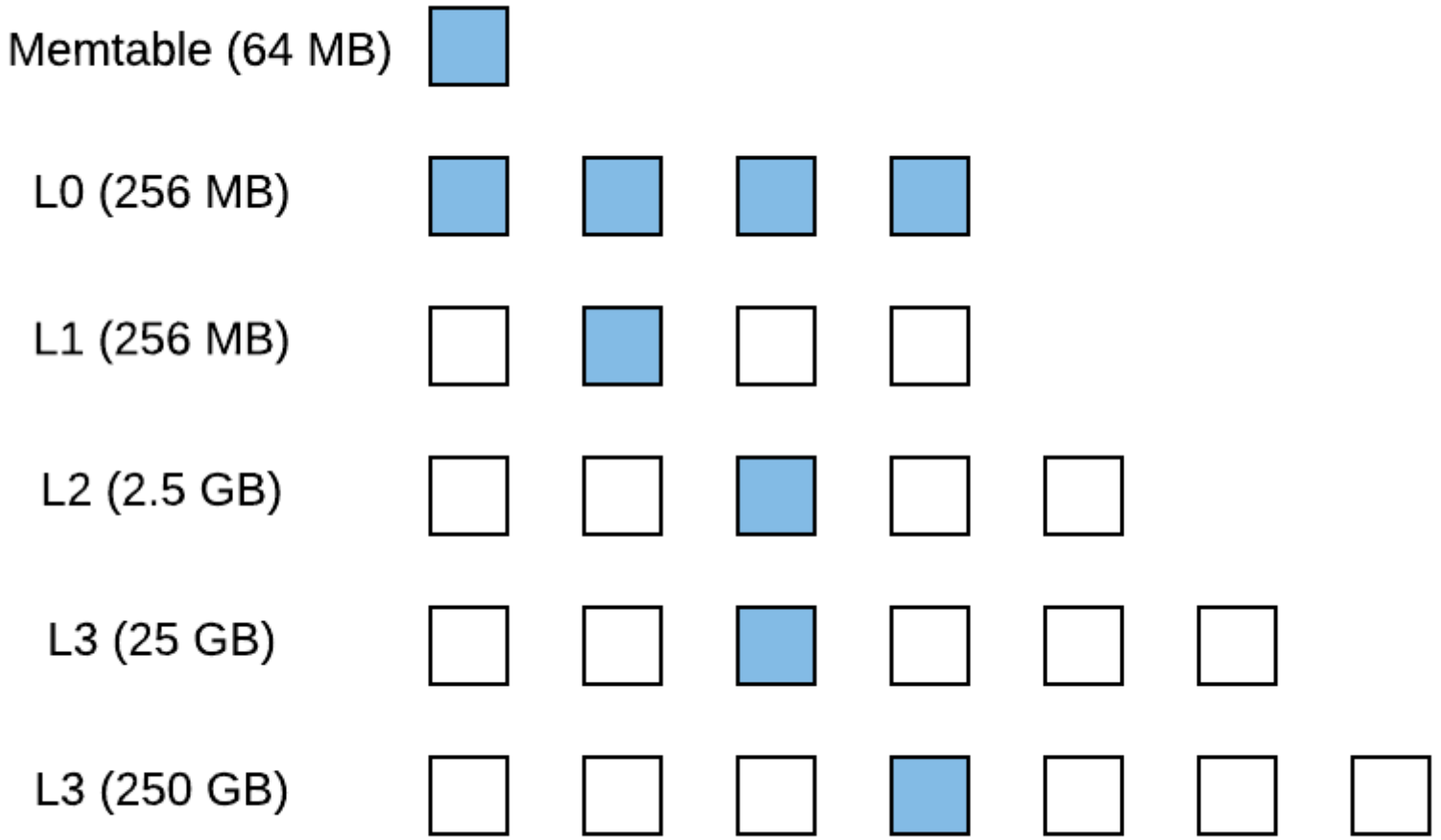
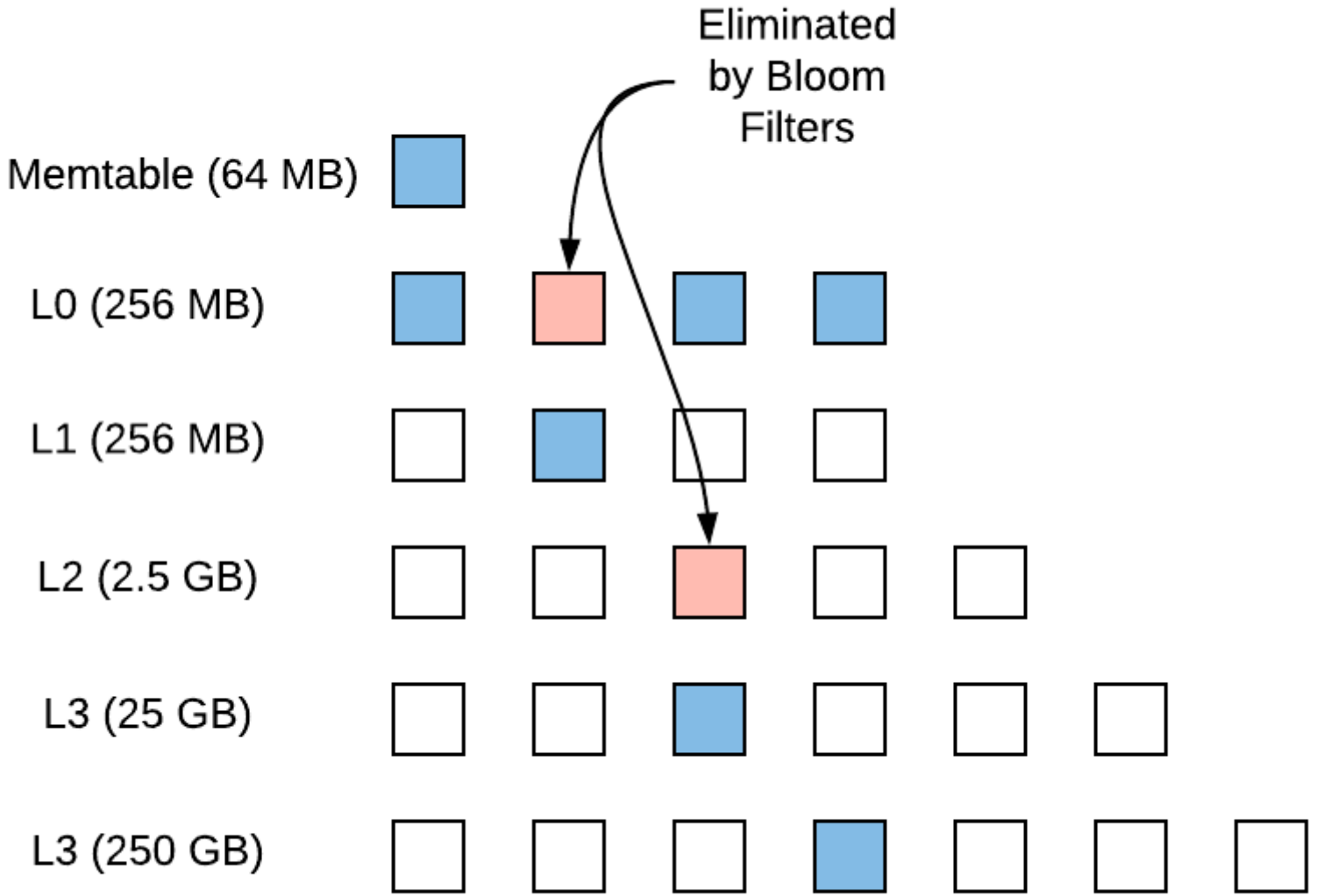
- Hundreds of terabytes of data.
- Few gigabytes of LSM tree.

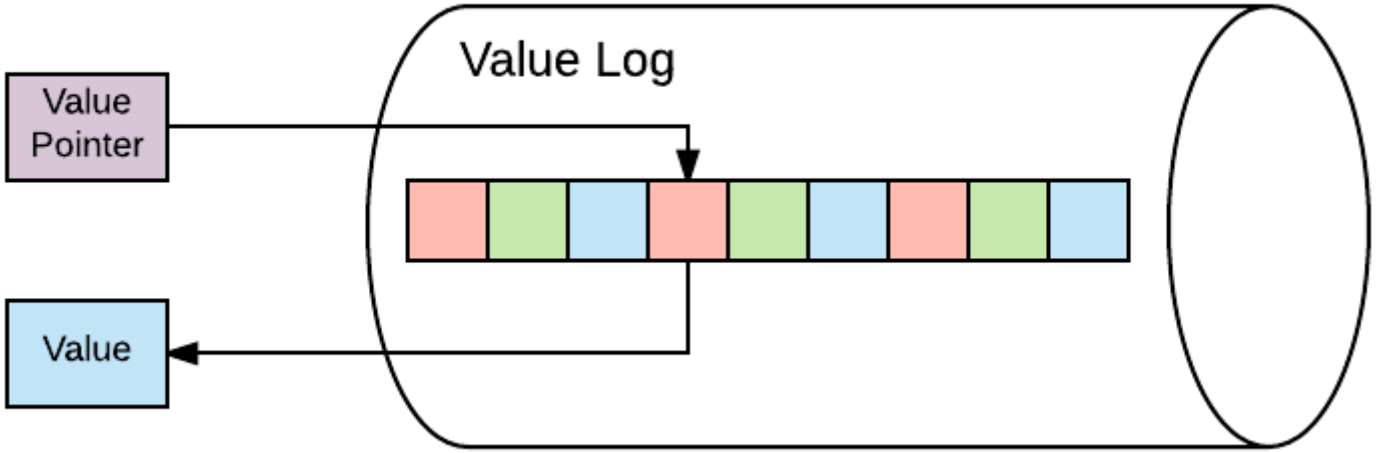
Reads in Badger: LSM tree



Reads in Badger: Bloom Filters



Reads in Badger: Value Log



- Once key found in LSM tree, read from value log.

Badger is FAST-er

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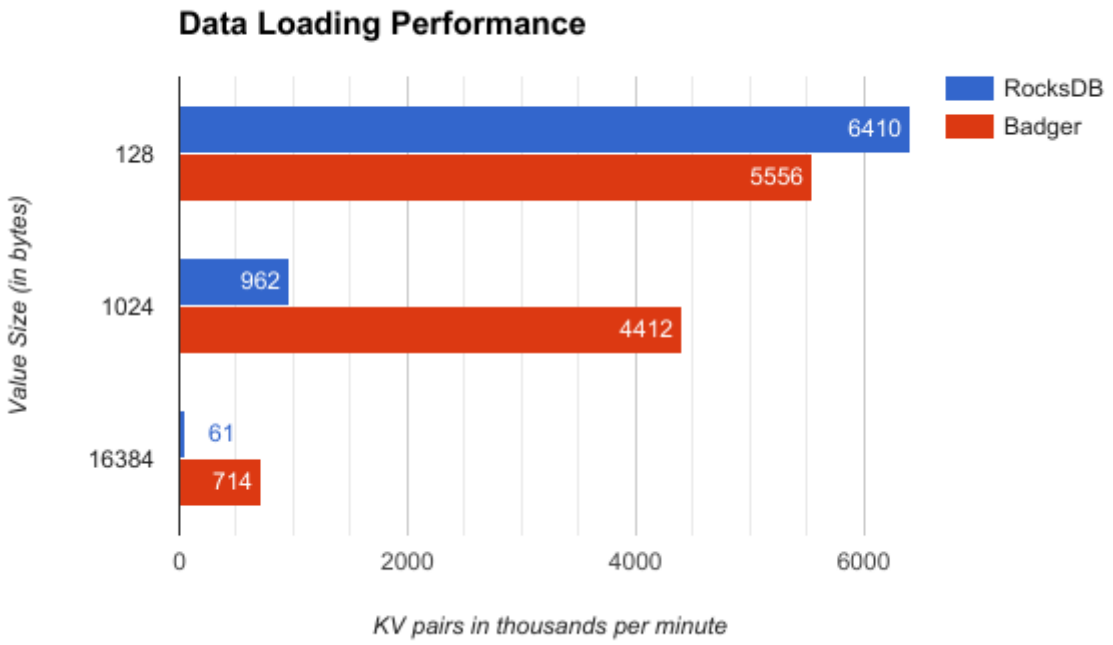
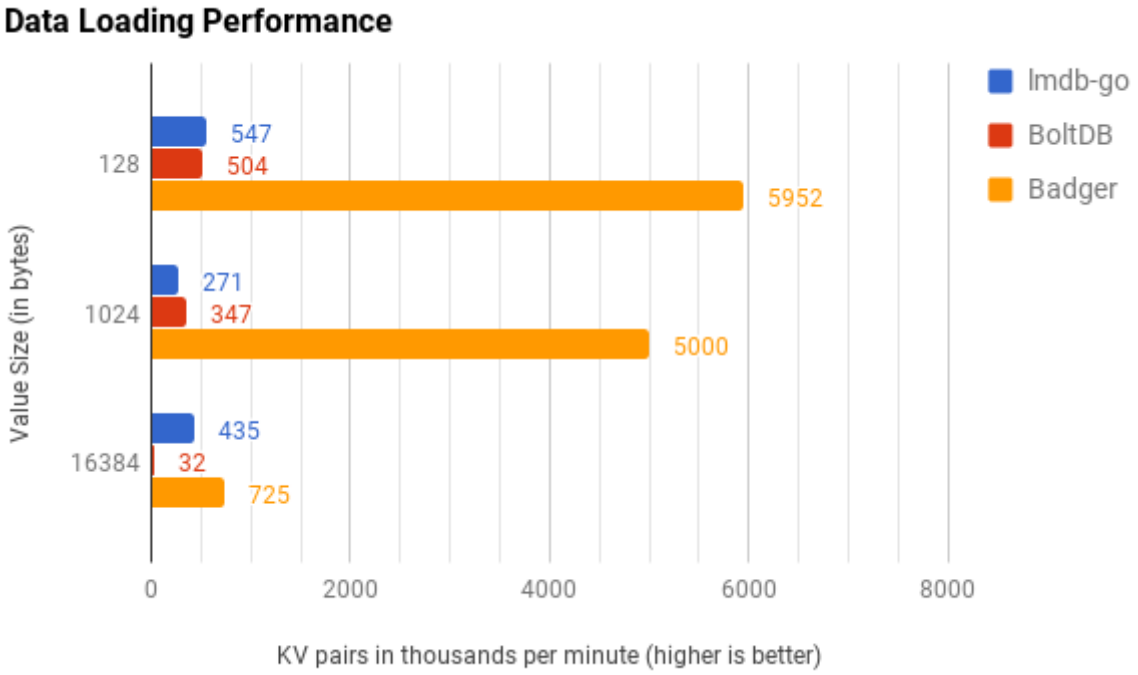
Data Loading: Badger vs Go-RocksDB



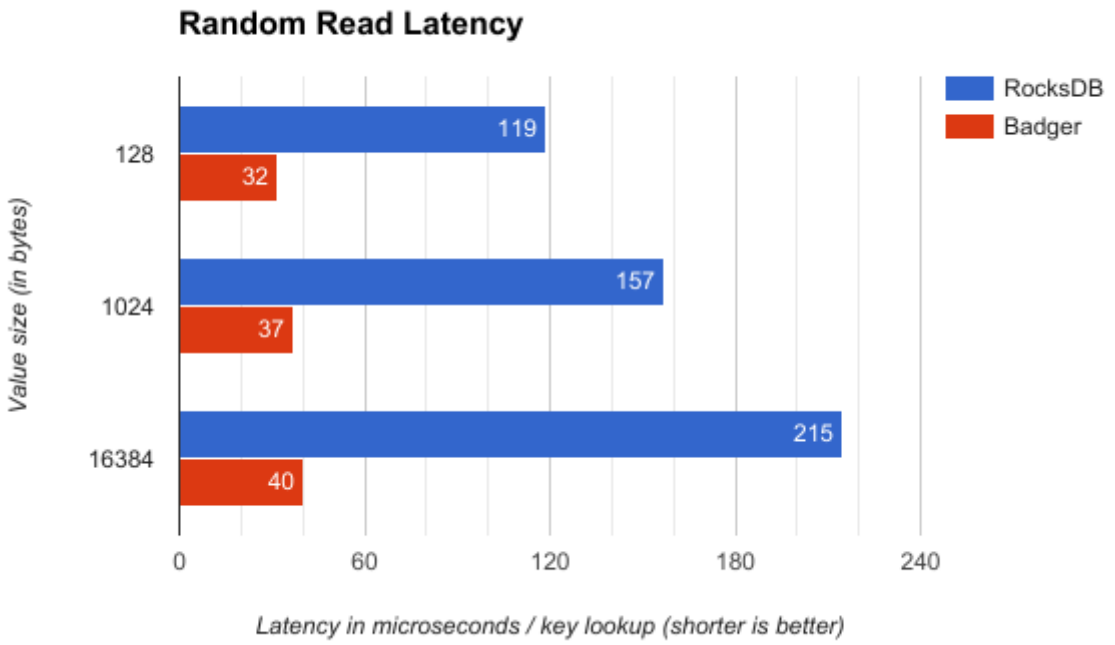
- As value size increases, Badger's becomes 11.7x faster.

Data Loading: Badger vs BoltDB



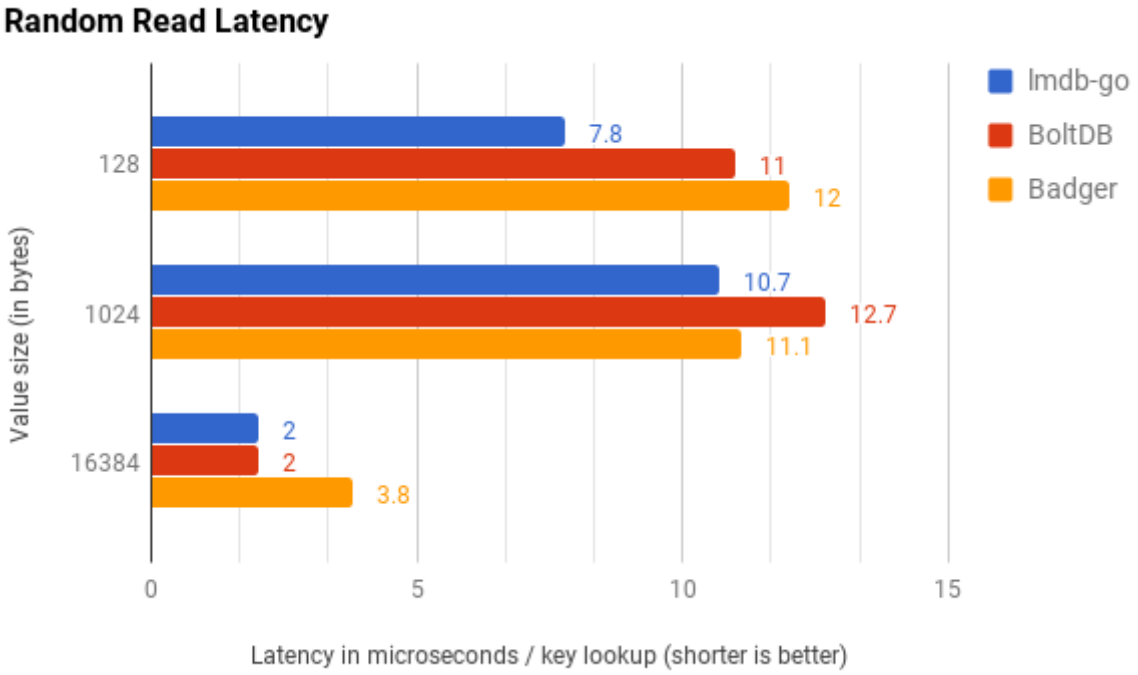
- 11x - 22x faster than BoltDB on all value sizes.

Random Reads: Badger vs Go-RocksDB



- Random Get latency is 3.7x - 5.3x lower than RocksDB.

Random Reads: Badger vs BoltDB



- Random Get latency is slightly better or worse, depending on value size.

Various other benchmarks

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Range iteration latency, etc.

Can be found on https://blog.dgraph.io/

Benchmarking code is open sourced.

github.com/dgraph-io/badger-bench (https://github.com/dgraph-io/badger-bench)

Features

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Concurrent Transactions

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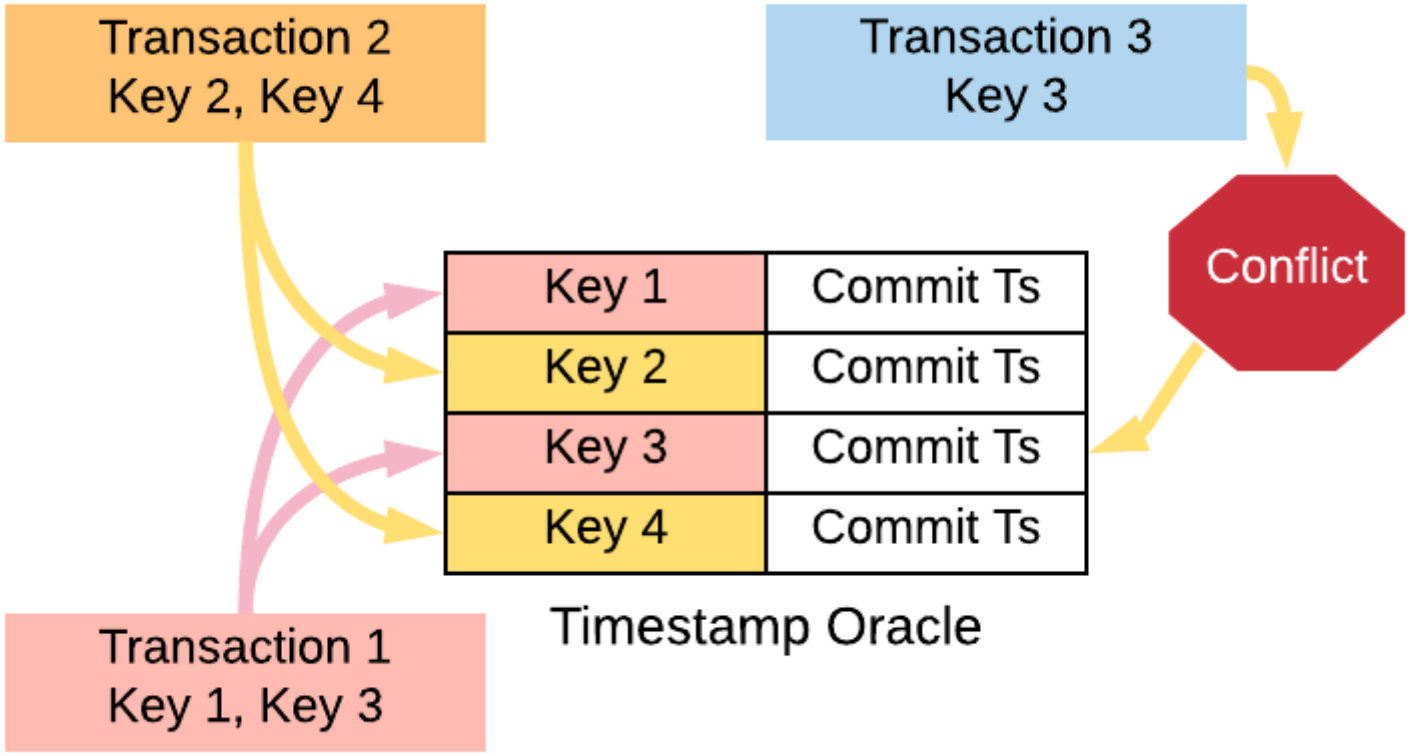
Badger uses Oracle to achieve concurrent lock-free transactions.



Concurrent Writes

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Batch up writes from multiple transactions.

Amortize cost of disk write.

No wait -> Smart Batching.

Smart Batching in Go

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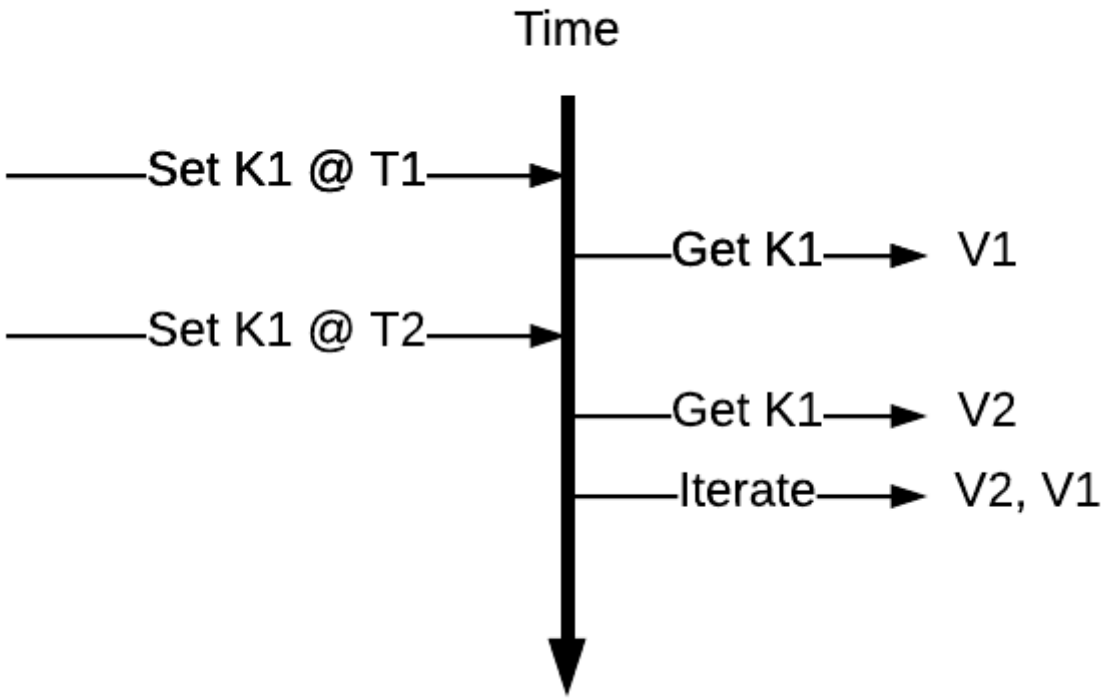
```
reqs := make([]*request, 0, 10)
for {
    var r *request
    select {
    case r = <-db.writeCh:
    case <-lc.HasBeenClosed():
        goto closedCase
    }

    for {
        reqs = append(reqs, r)
        reqLen.Set(int64(len(reqs)))

        select {
        case r = <-db.writeCh:
        case pendingCh <- struct{}{}:
            goto writeCase
        case <-lc.HasBeenClosed():
            goto closedCase
        }
    }
```

```
closedCase:
    close(db.writeCh)
    for r := range db.writeCh {
        reqs = append(reqs, r)
    }

    pendingCh <- struct{}{}
    writeRequests(reqs)
    return

writeCase:
    go writeRequests(reqs)
    reqs = make([]*request, 0, 10)
    reqLen.Set(0)
}
```

Multi Version Concurrency Control



Badger stores multiple versions of the key.

Provides direct access to the versions, via iterate.

Crash Resilience

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LSM Memtables can be lost to crashes.

Can be recovered from value log on restart.

Value Log Garbage Collection

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Why?

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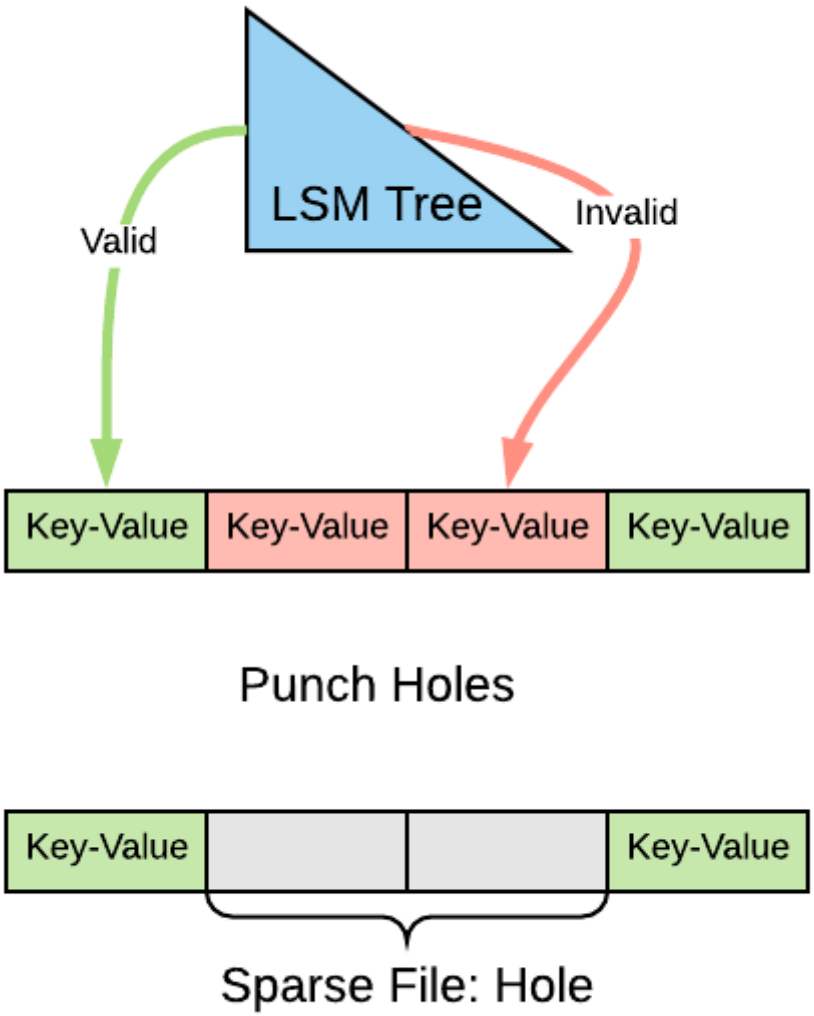
Value log would keep growing with every Set.

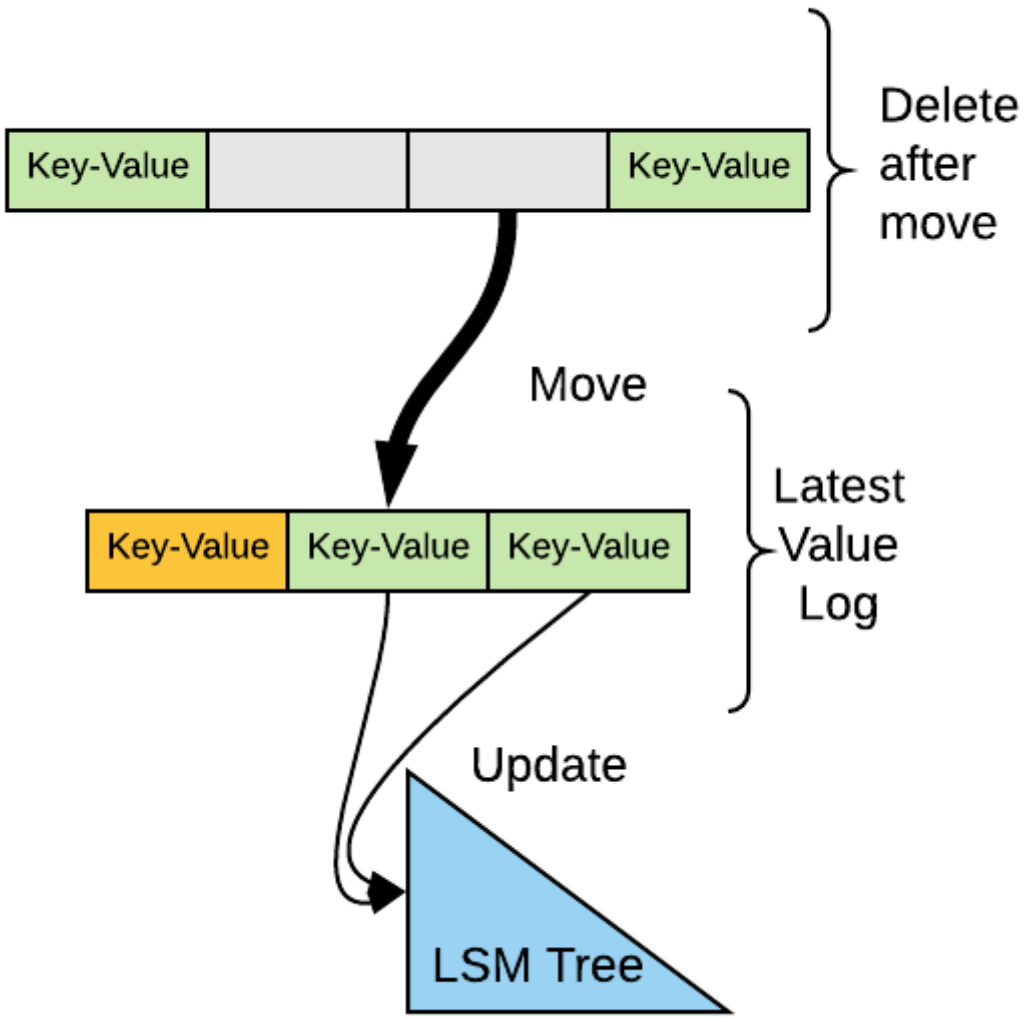
Older versions of keys can be deleted.

Corresponding values can be deleted from value log.

Stage 1: Punch Holes (v2.0 in Linux)



Stage 2: Move entries, Delete log



Dealing with Qu-err-key file systems.

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Would a file delete reclaim space in the f system?

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Delete, no reclaim

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No

```
if err := t.fd.Truncate(0); err != nil {
    // This is very important to let the FS know
    // that the file is deleted.
    return err
}
```

Truncate the file before deleting.

Would closing a file sync its contents to d

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Close, no-sync

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No

```
if err := lf.fd.Sync(); err != nil {
    return errors.Wrapf(err, "Unable to sync value log: %q", lf.path)
}
if err := lf.fd.Close(); err != nil {
    return errors.Wrapf(err, "Unable to close value log: %q", lf.path)
}
```

Explicitly sync file before closing.

Can a new synced file be lost?

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Create, no-found

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Yes

```
f, err := os.Open(dir)
if err != nil {
    return errors.Wrapf(err, "While opening directory: %s.", dir)
}
err = f.Sync()
closeErr := f.Close()
if err != nil {
    return errors.Wrapf(err, "While syncing directory: %s.", dir)
}
return errors.Wrapf(closeErr, "While closing directory: %s.", dir)
```

Sync a directory just like you would sync a file.

Can a crash add garbage data to end of f

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Crash, no-clean

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Yes.

Add checksums to know when to truncate a file.

Who should use Badger?

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Don't use Badger if...

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You no Go! (C++, Java)

You have a single-threaded sequential workload.

You have a small, read-only workload.

All your data can fit in memory easily.

Use Badger if...

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You Go!

You want to avoid Cgo.

You want a performant read-write workload.

You access data concurrently (many goroutines accessing data).

You need 3-dimensional access.

Future Work

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Encryption at rest.

Others? (tell us what you need)

Work on Badger and Dgraph. Come join us!

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github.com/dgraph-io/badger (https://github.com/dgraph-io/badger)

github.com/dgraph-io/dgraph (https://github.com/dgraph-io/dgraph)

Careers at Dgraph (https://dgraph.io/about.html)

Talk to us on Wechat

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Thank you

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