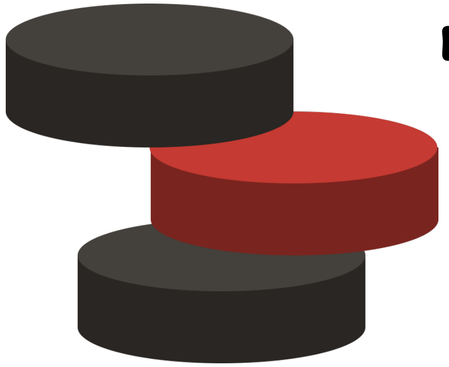
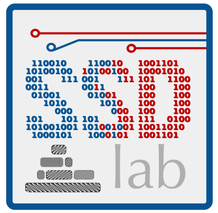


Tectonic: Bridging Synthetic and Real-World Workloads for Key-Value Benchmarking

Alexander H. Ott Shubham Kaushik

James Chen Subhadeep Sarkar



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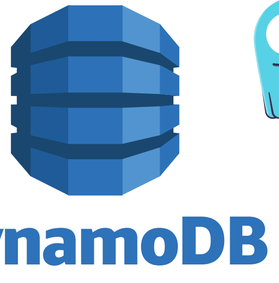
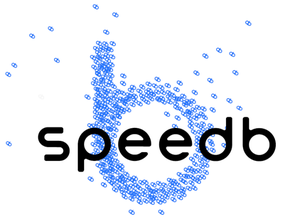
TPC®

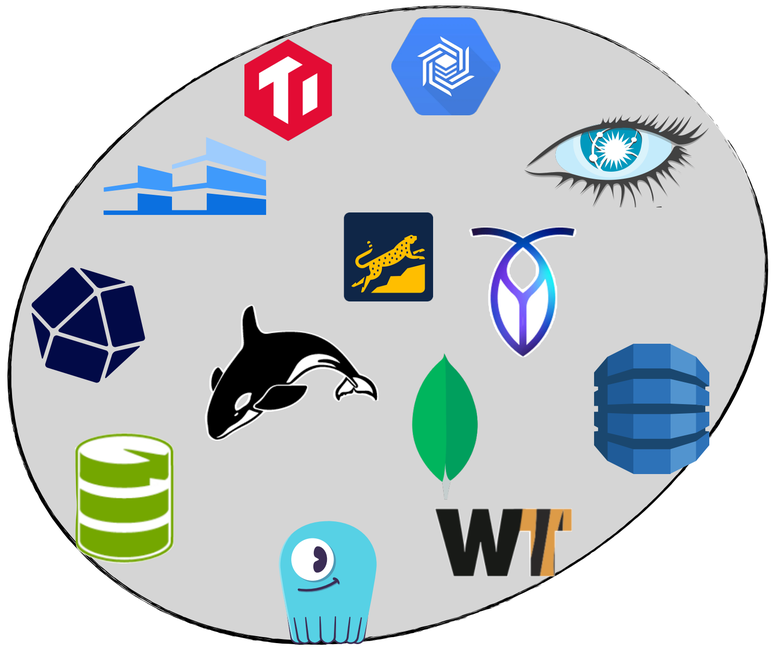
CockroachDB

BigTable

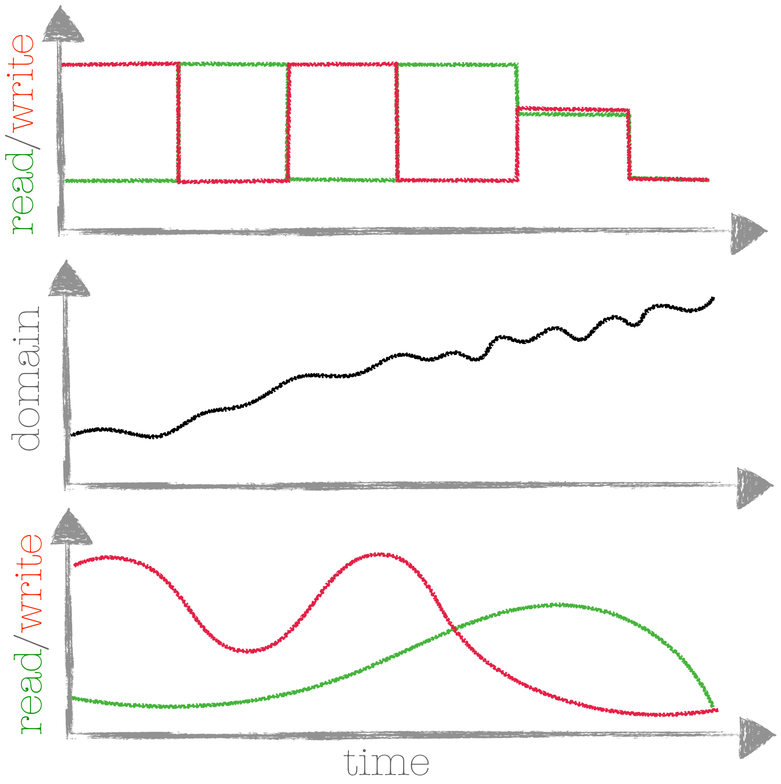
Key-Value Stores







many database vendors
in the playground



several workload scenarios
for every application

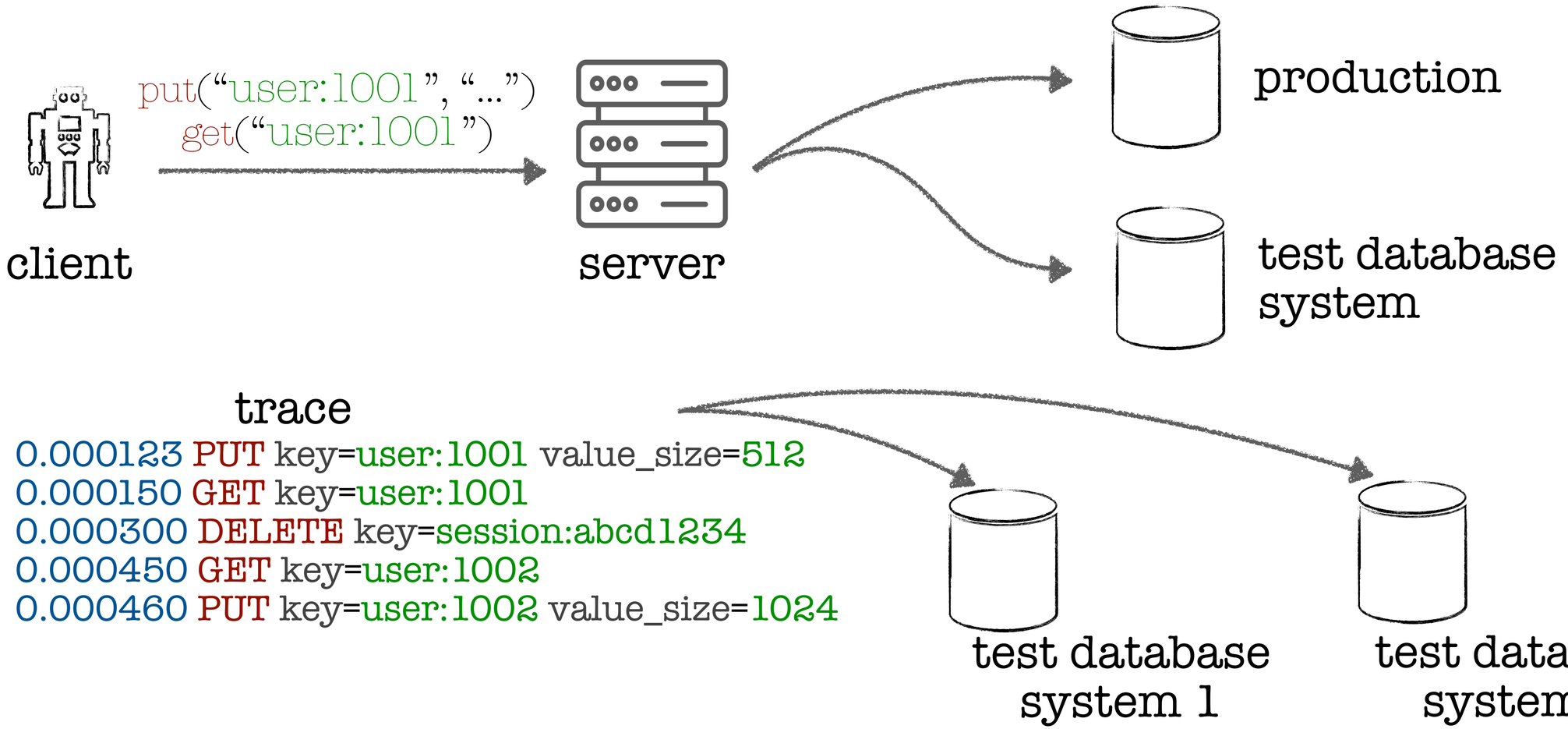
How to **choose** the right database?

How to **tune** a database for specific goals?

How to **compare** database performance?

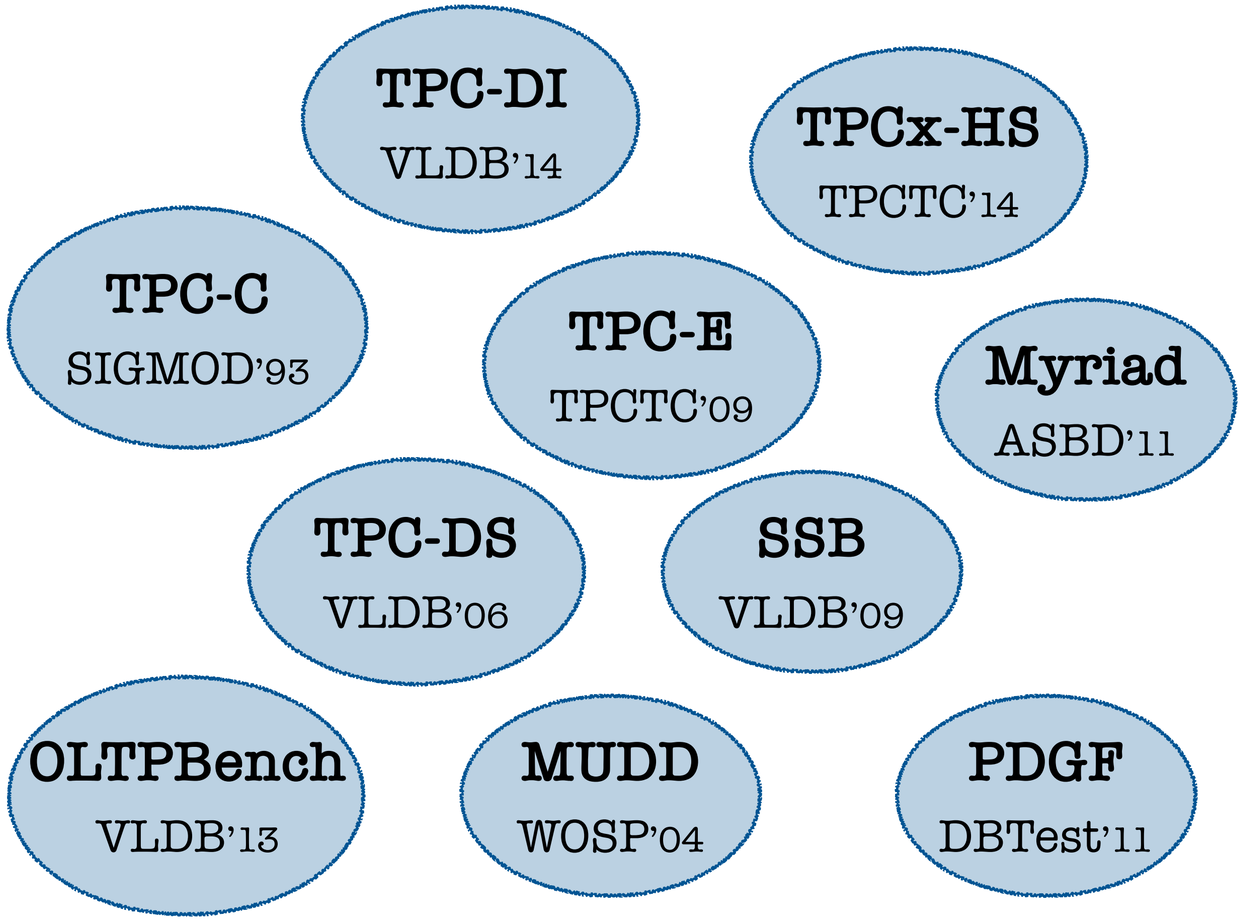
Benchmark databases

Shadow Testing & Trace Replays

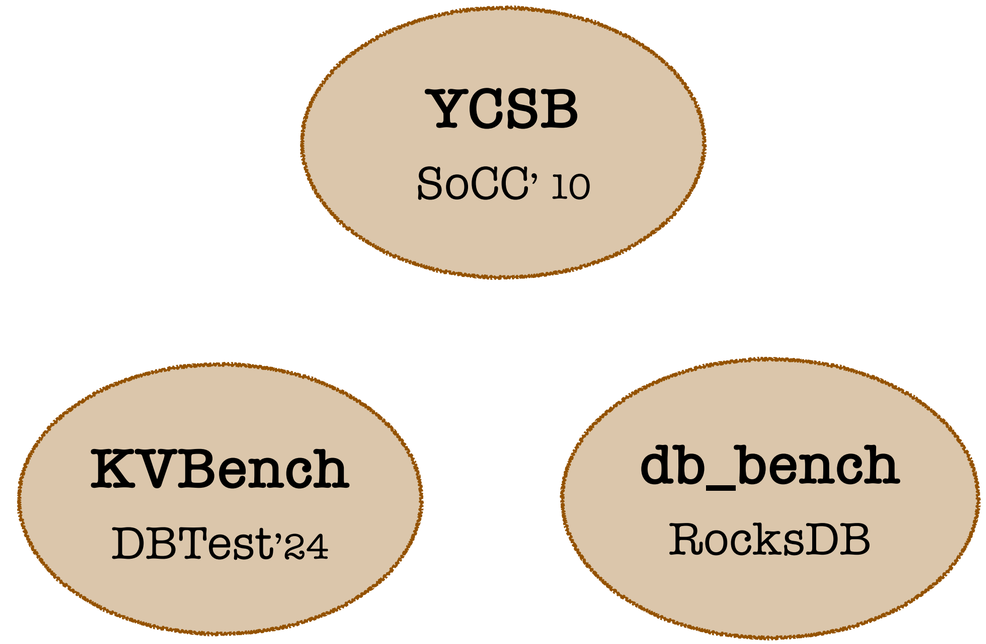


What if we **don't have access** to production **data** or **traces**?

Workload Generators / Benchmarks



relational



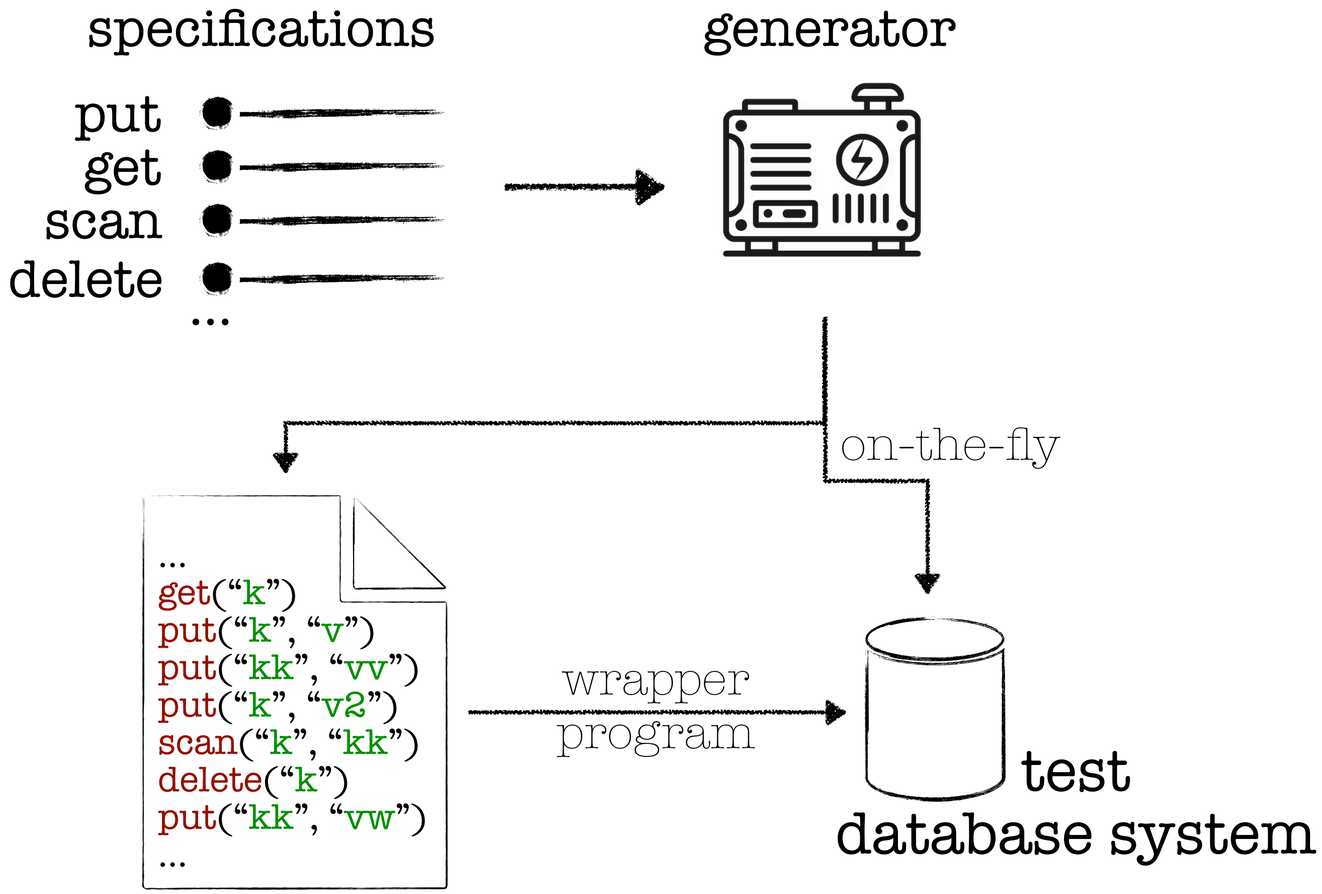
non-relational

Workload Generators / Benchmarks

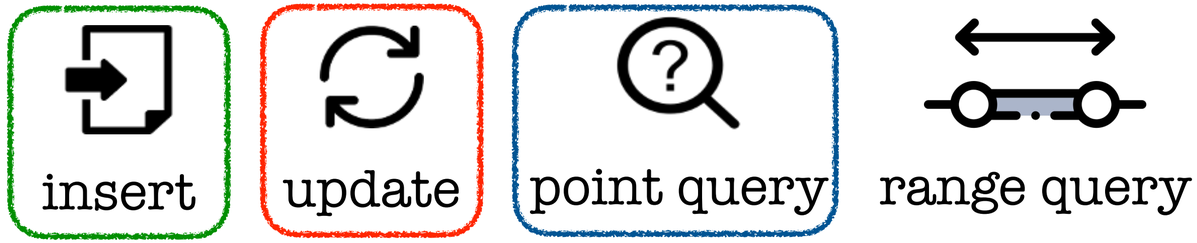
YCSB
SoCC'10

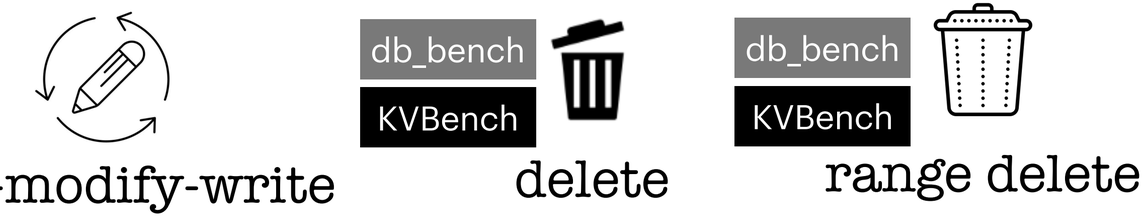
KVBench
DBTest'24

db_bench
RocksDB



Workload Generators: **Features**





read-modify-write

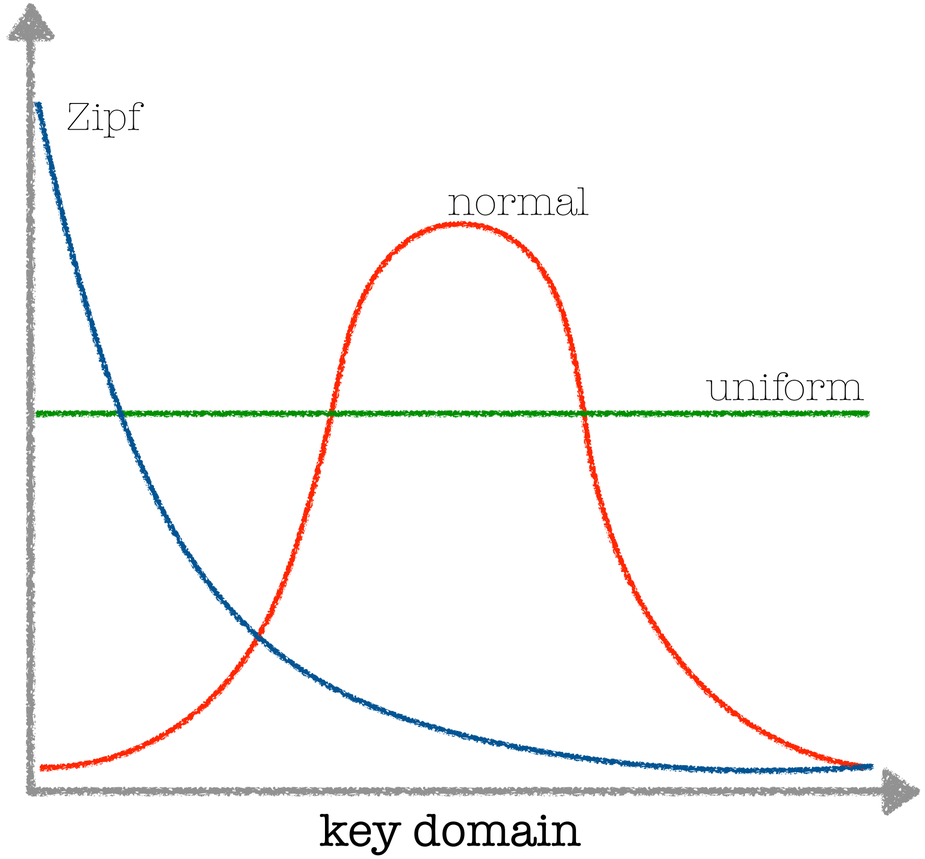
delete

range delete

empty
point query

empty
point delete

supports **different operations**

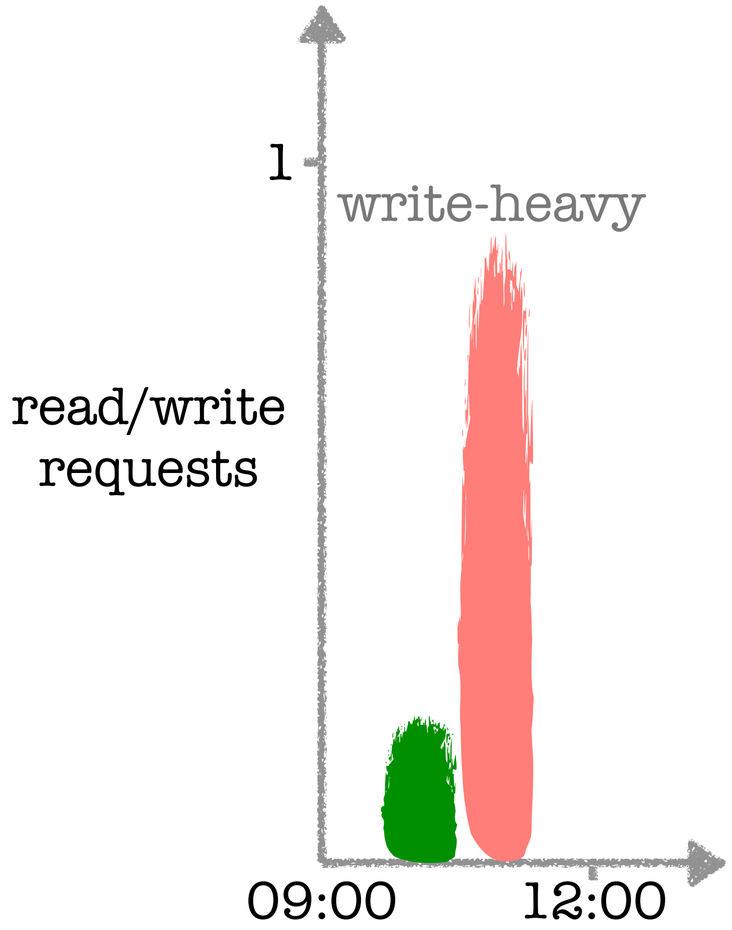


offers **flexible distribution**

Limitations of the SoA

shifting workloads

nearly sorted workloads

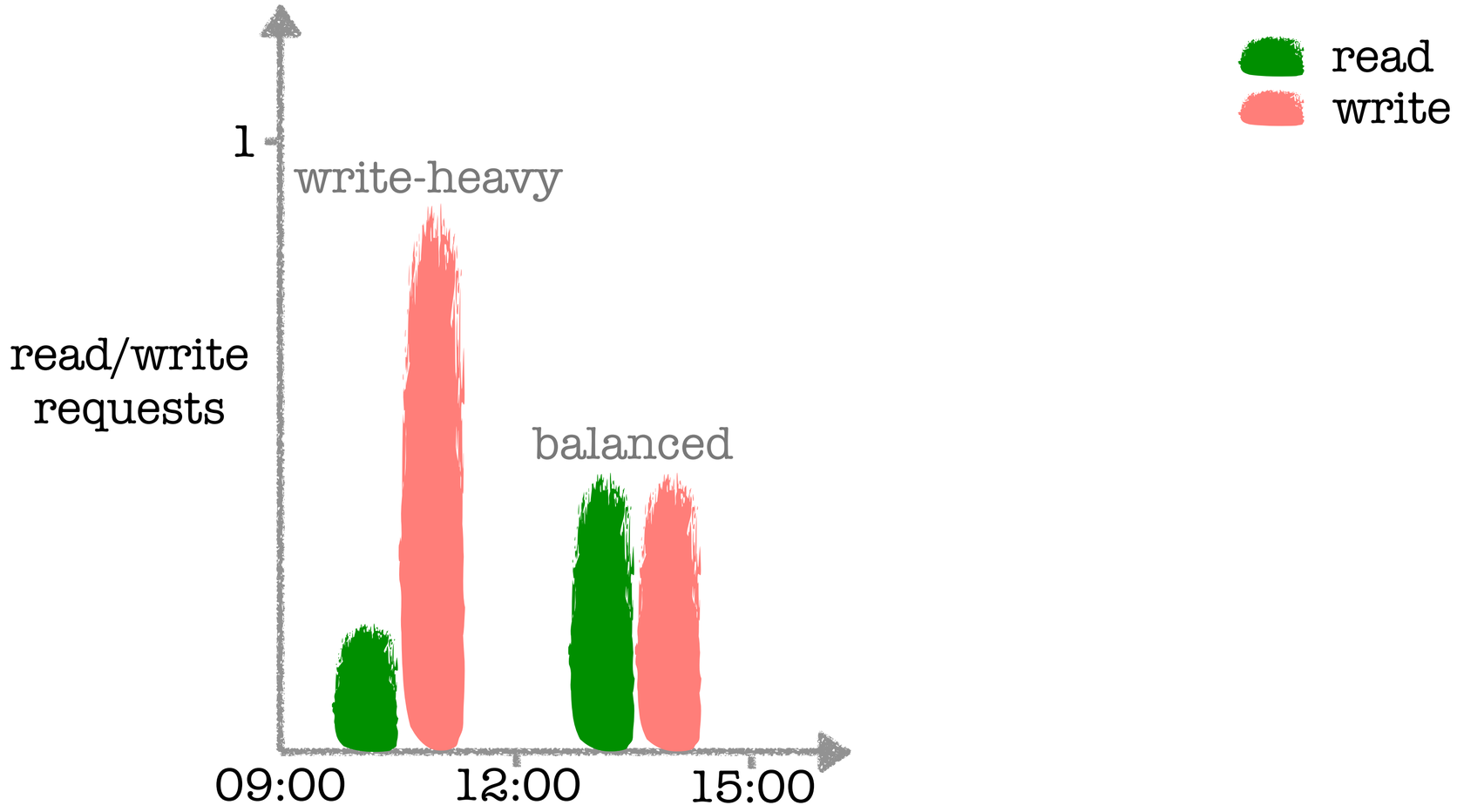


read
write

Limitations of the SoA

shifting workloads

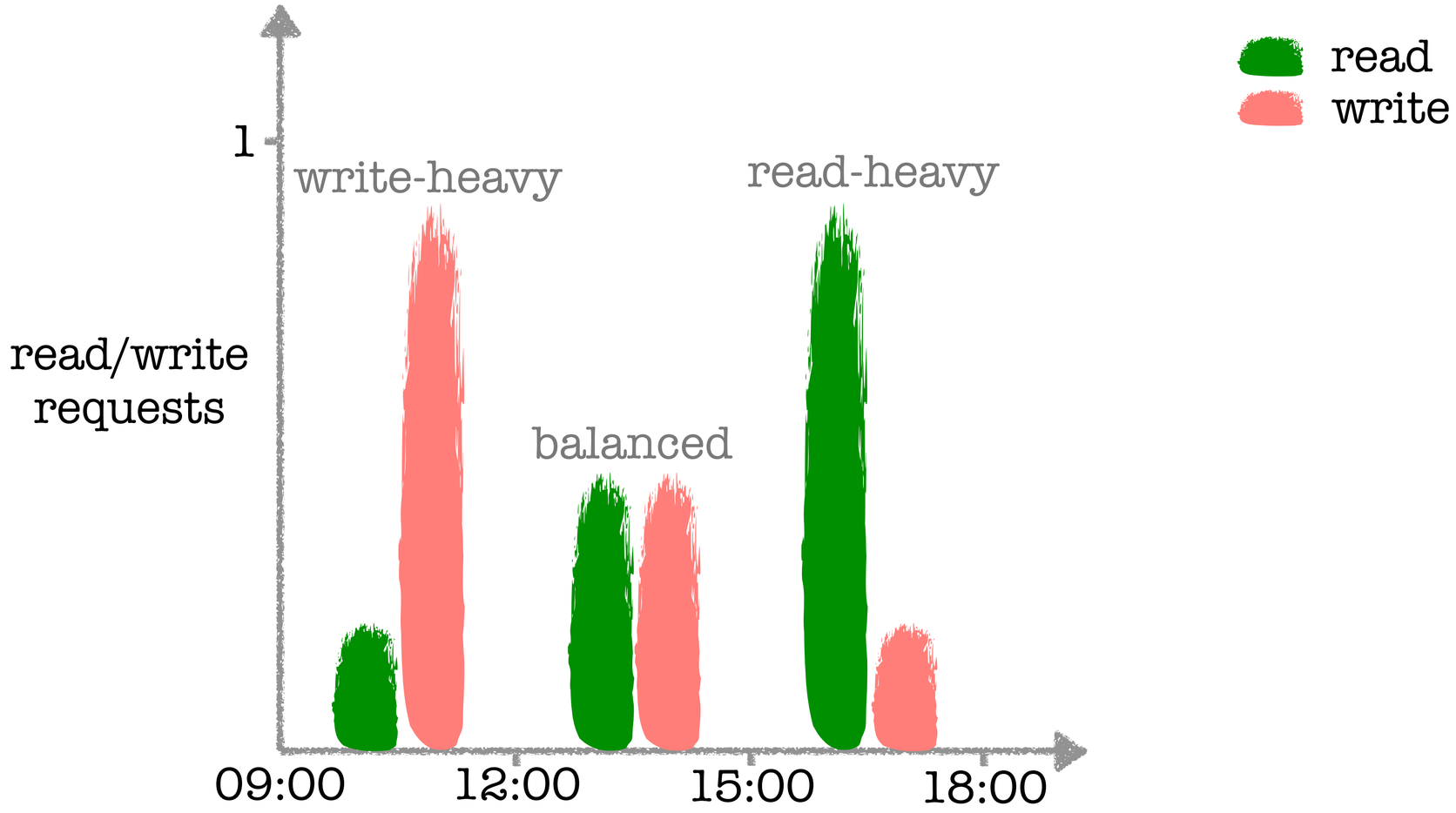
nearly sorted workloads



Limitations of the SoA

shifting workloads

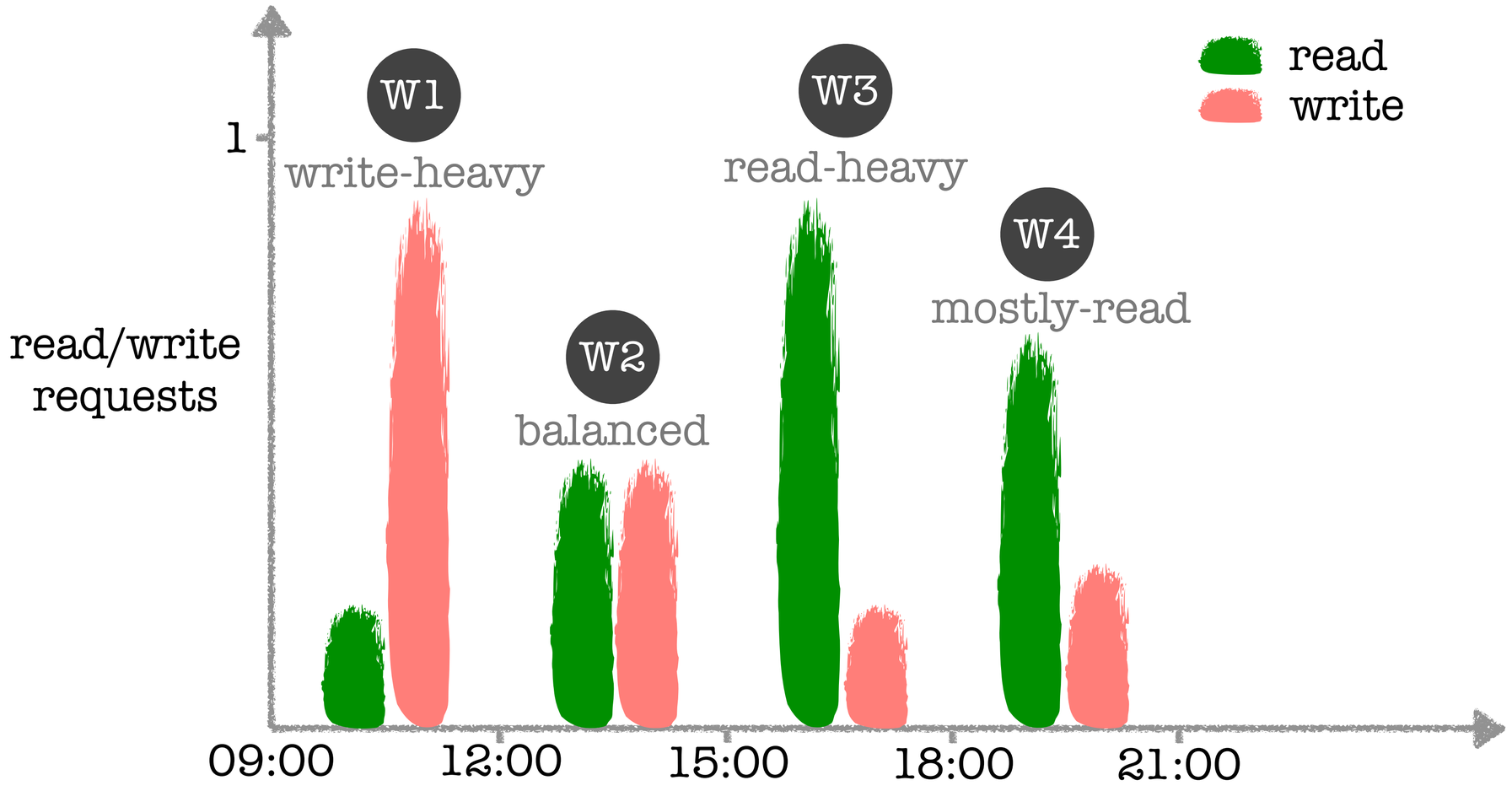
nearly sorted workloads



Limitations of the SoA

shifting workloads

nearly sorted workloads



How can we generate such shifting workloads?

Limitations of the SoA

write-heavy W1

balanced W2

read-heavy W3

mostly-read W4

YCSB/KVBench

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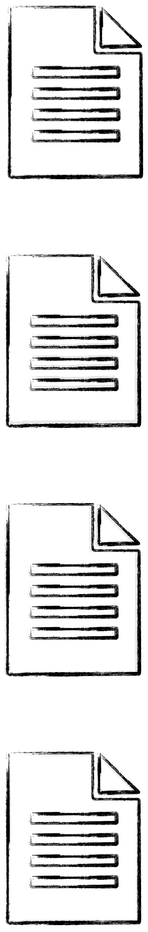
Limitations of the SoA

write-heavy W1

balanced W2

read-heavy W3

mostly-read W4



YCSB/KVBench

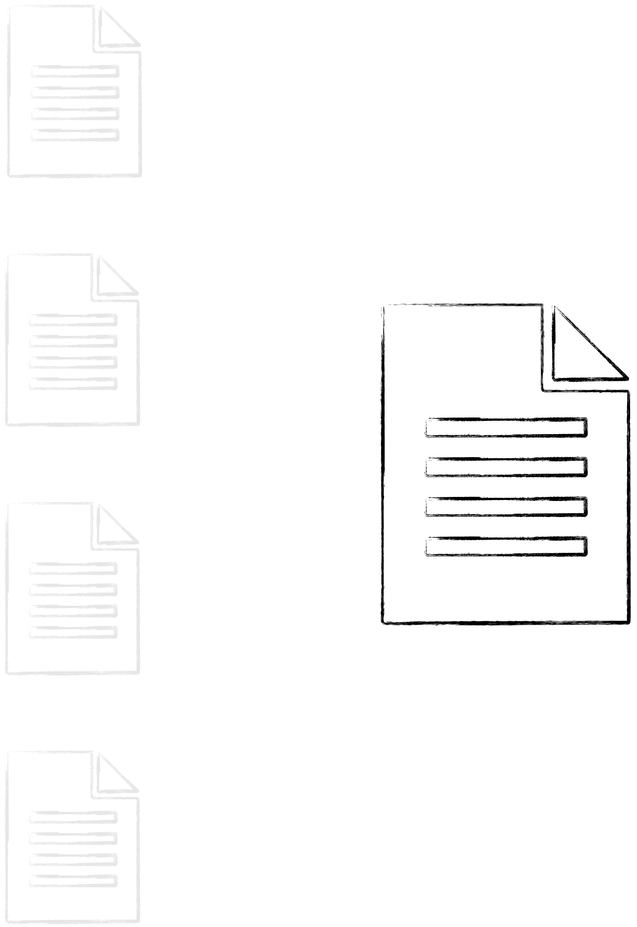
Limitations of the SoA

write-heavy W1

balanced W2

read-heavy W3

mostly-read W4



YCSB/KVBench

⚠ always human/script in the loop

⚠ each workload is agnostic to the others

⚠ hard to mimic the real-world worklaods

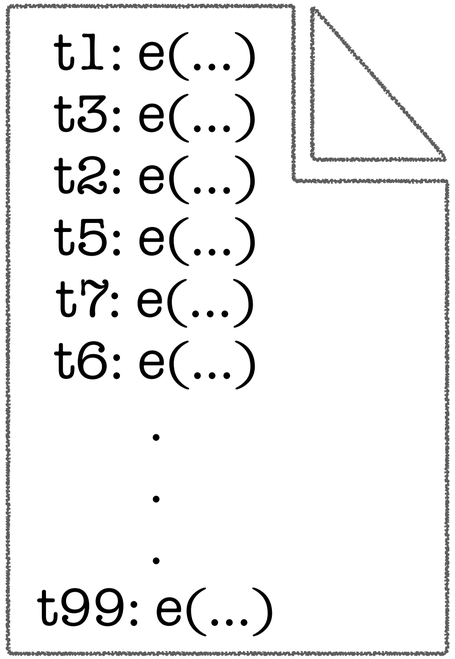
Limitations of the SoA

shifting workloads

nearly sorted workloads

data warehouse (TPC-H)

stock market trading



nearly sorted

YCSB/KVBench **does not support** nearly-sorted data generation

lab

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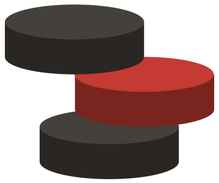
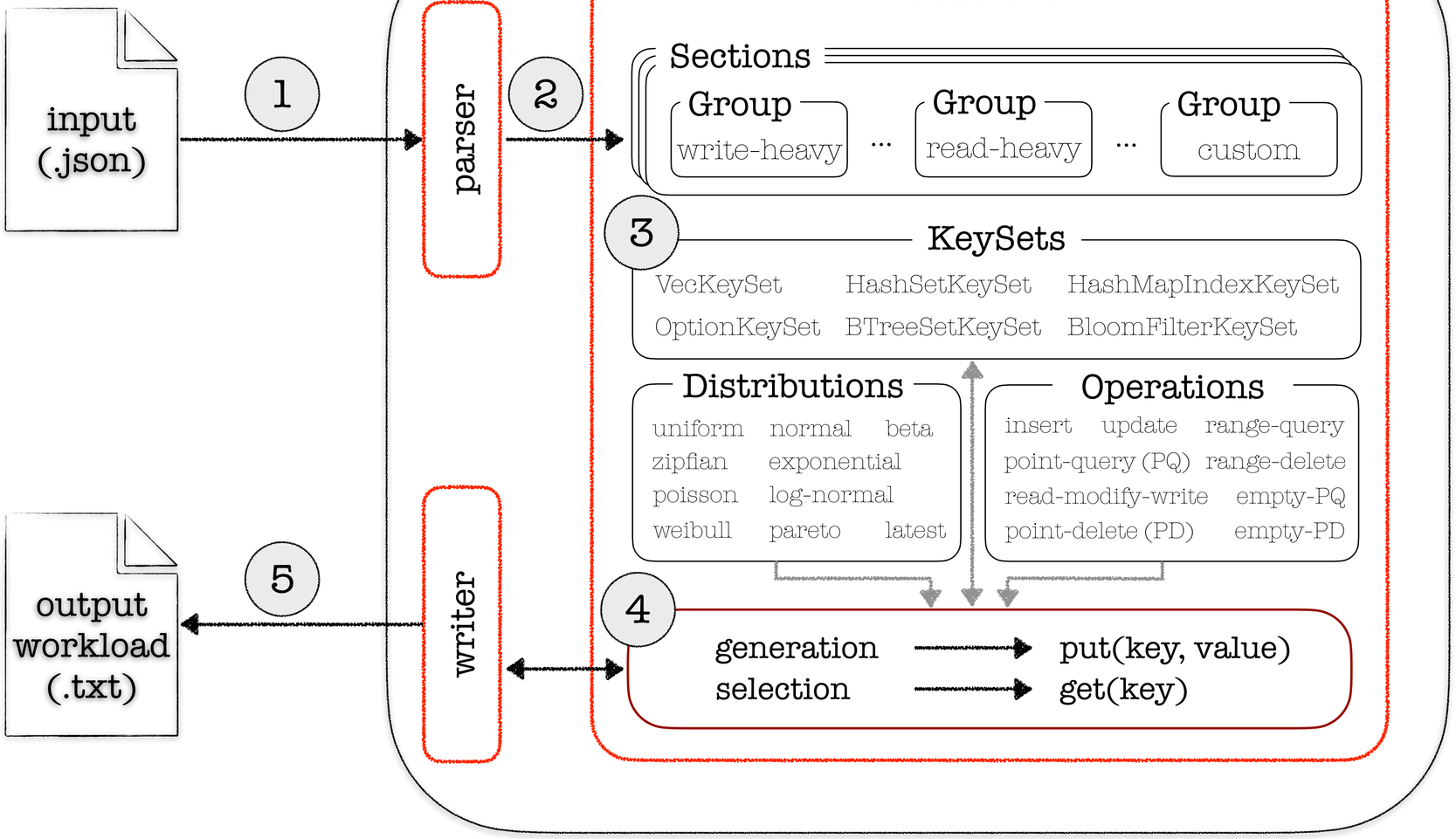


Tectonic



Section

represents one phase of a workload

Group

a set of interleaved operations that executes in a section

KeySet

a data structure that helps in generating operations more optimally

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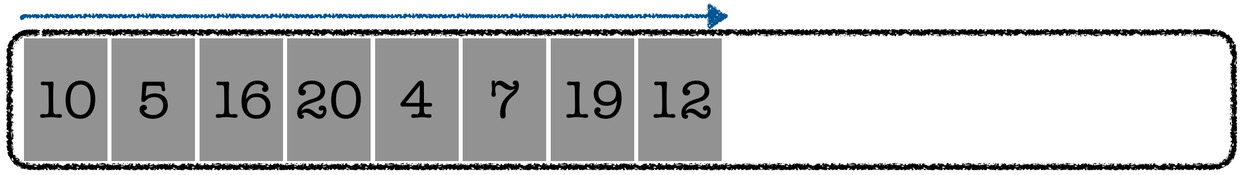
Tectonic: **Features**

advanced operations

- inserts vs updates
- empty vs non-empty
- range delete

KeySet
(vector)



vector (unsorted)

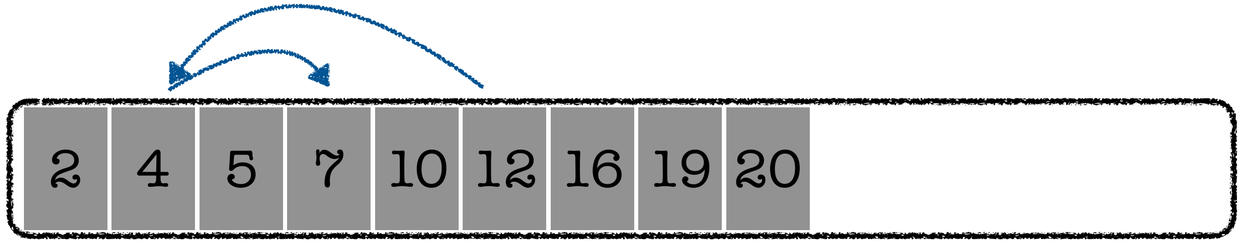
✗ Inserts

Tectonic: **Features**

advanced operations

- inserts vs updates
- empty vs non-empty
- range delete

KeySet
(vector)



vector (unsorted)

- ✗ Inserts

vector (sorted)

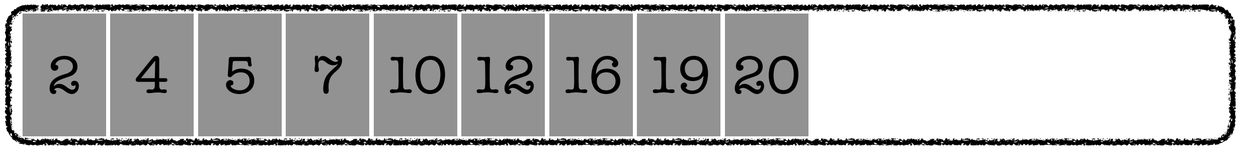
- ✗ Inserts
- — Updates + point queries

Tectonic: **Features**

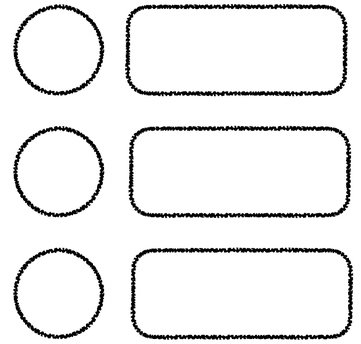
advanced operations

- inserts vs updates
- empty vs non-empty
- range delete

KeySet
(vector)



KeySet
(hash table)



vector (unsorted)

✗ Inserts

vector (sorted)

✗ Inserts

— Updates + point queries

hash set

✓ Inserts

✗ Updates + point queries

What is the **appropriate data structure?**

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Tectonic: Features - **KeySet**

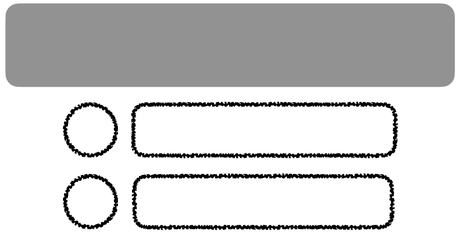
VecKeySet

- ✓ blind inserts
- ✓ updates
- ✓ point queries
- ✓ range queries
- ✗ empty queries
- ✗ deletes

BloomFilterKeySet

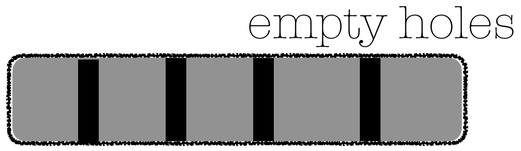
- ✓ empty deletes
- ✓ empty queries
- ✓ unique inserts
- ✗ non-empty deletes

HashMapIndexKeySet



- ✓ non-empty deletes
- ✗ range queries
- ✗ updates

OptionKeySet

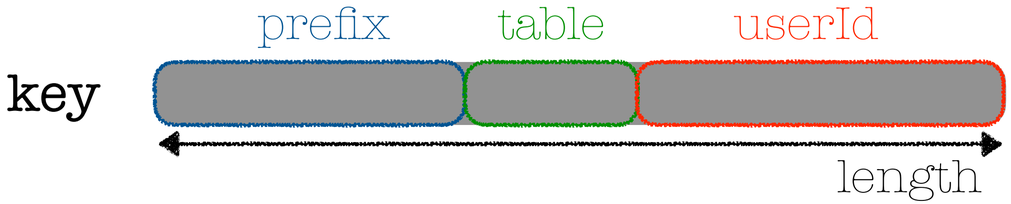


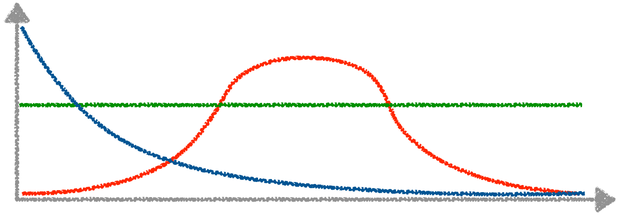
- ✓ non-empty deletes
- ✓ range deletes
- ✓ updates
- ✓ range queries

Tectonic: **Features**

dynamic properties

- prefix-based keys
- different distribution
- varied key-value lengths
- varied range op selectivity





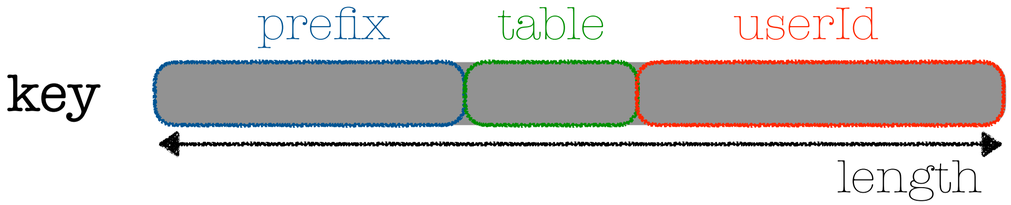
range selectivity

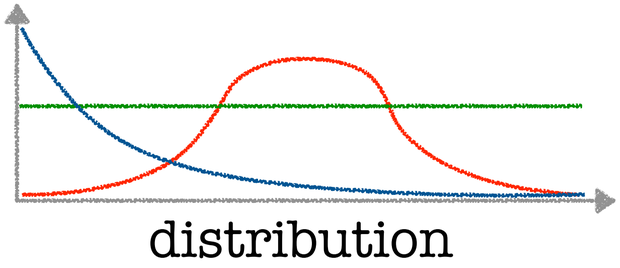
* key/value length

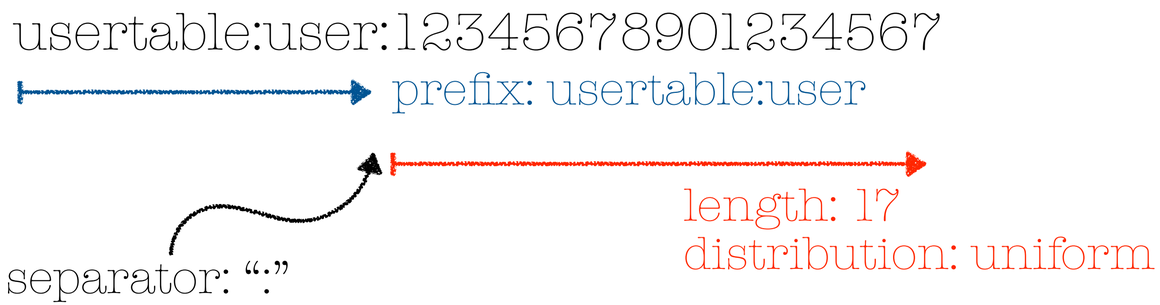
Tectonic: **Features**

dynamic properties

- prefix-based keys
- different distribution
- varied key-value lengths
- varied range op selectivity








```
"segmented": {
 "separator": ":",
 "segments": [
   "usertable:user",
   {
    "uniform": {
     "len": 17,
     "character_set": "numeric"
    }
   }
 ]
}
```

lab

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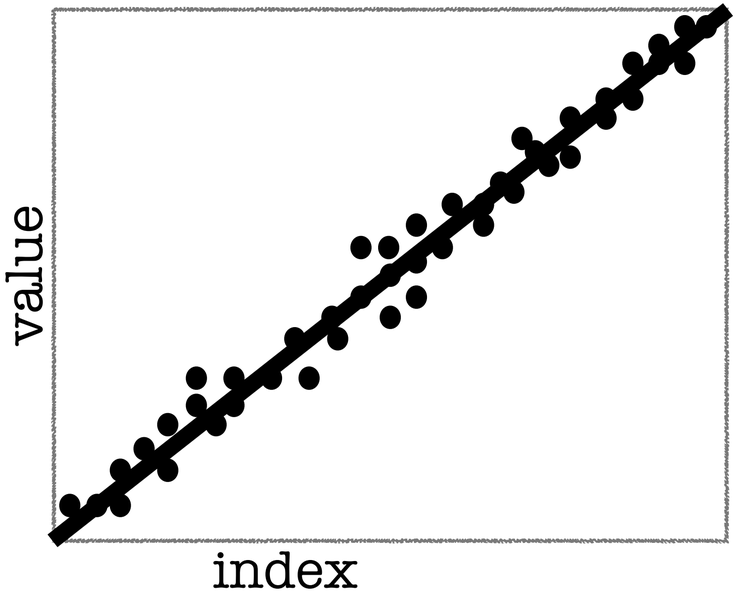
Tectonic: **Features**

Ben-Moshe et al., “Detecting and exploiting...” (EDBT/ICDT ’11)

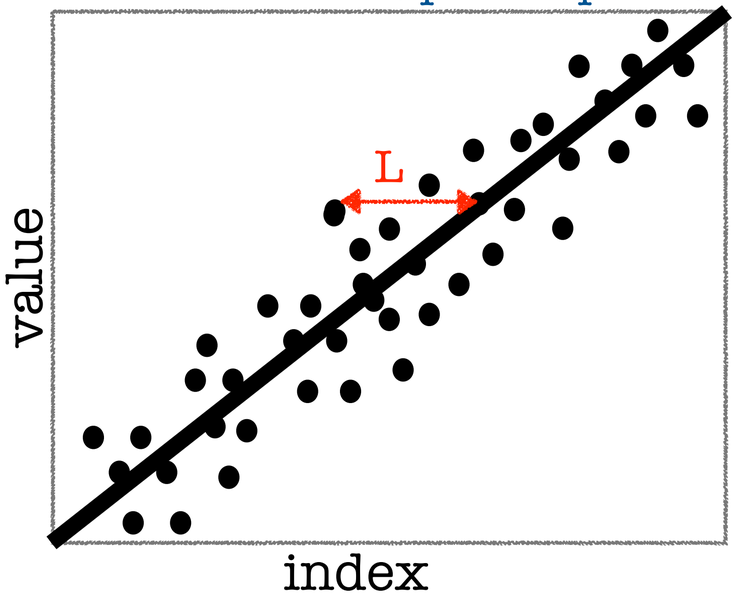
Raman et al., “BoDS” (TPCTC’22)

● fully sorted workloads ● nearly sorted workloads




```
“sorted”: {
 “k”: 10000,
 “l”: {
  “uniform”: { “min”: 0, “max”: 10 }
 }
}
```

K: count of displaced points




```
“sorted”: {
 “k”: 10000,
 “l”: {
  “uniform”: { “min”: 0, “max”: 1000 }
 }
}
```

Tectonic: **Features**

SHIFT

shifting workloads

● generates a shifting workload

mimic the stock exchange workload

Tectonic **Demo**

Monday

Phase 1: open market

Group 1

```
"sorted": {
  "k": 1000,
  "l": {...}
   }
},
"inserts": {
  "op_count": 1M,
  "key": {...},
  "val": {
    "uniform": { "len": 64 }
   }
 },
"point_queries": {
  "op_count": 100K
}
```

Phase 2: close market

Group 2

```
"point_queries": {
  "op_count": 1M,
  "selection": {
    "beta": {
      "alpha": 0.5,
      "beta": 1.2
    }
  }
}
```

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Tectonic **Demo**

Section A — Monday

Group 1

```
"sorted": {
   "k": 1000,
   "l": {...}
    }
}
```

```
"inserts": {
   "op_count": 1M,
   "key": {...},
   "val": {
      "uniform": { "len": 64 }
    }
 },
```

```
"point_queries": {
   "op_count": 100K
}
```

Group 2

```
"point_queries": {
  "op_count": 1M,
  "selection": {
     "beta": {
        "alpha": 0.5,
        "beta": 1.2
      }
   }
}
```

Section B — Tuesday

Group 1

```
"sorted": {
   "k": 1000,
   "l": {...}
    }
}
```

```
"inserts": {
   "op_count": 1M,
   "key": {...},
   "val": {
      "uniform": { "len": 64 }
    }
 },
```

```
"point_queries": {
   "op_count": 90K
}
```

Group 2

```
"point_queries": {
  "op_count": 1.1M,
  "selection": {
     "beta": {
        "alpha": 0.7,
        "beta": 2.1
      }
   }
}
```

lab

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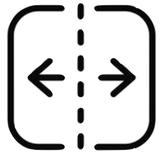
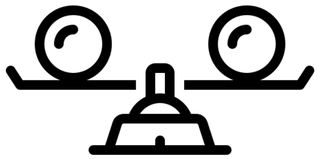
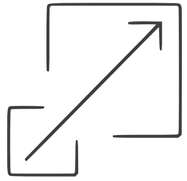
Experimental Setup



How **efficiently Tectonic mimic** SoA benchmarks?



Can Tectonic generate **similar patterns** in the database?



How **scalable is Tectonic** while offering better performance?

Chameleon

ubuntu

Intel(R) Xeon(R) Gold 6240R CPU
2.40GHz cores
192GB RAM
240GB SSD

lab

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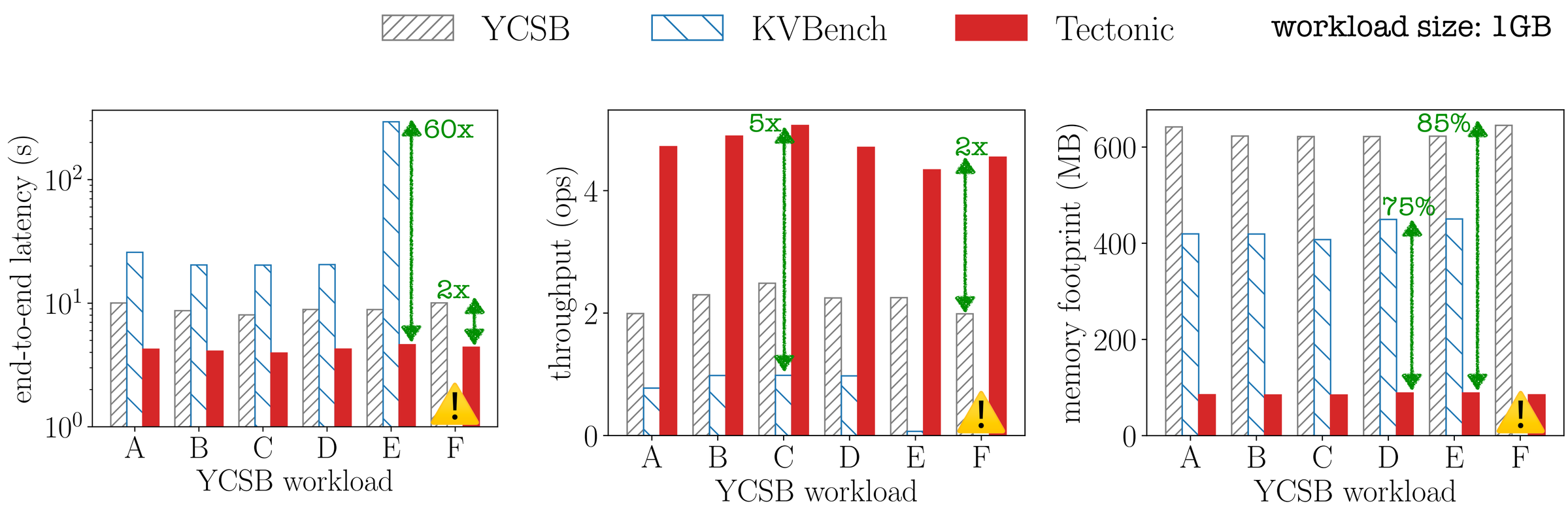
How **efficiently Tectonic mimic** SoA benchmarks?



Tectonic is up to **60x faster** than KVBench and **2x faster** than YCSB

Tectonic is **5x more efficient** than KVBench and **2x** than YCSB

Tectonic **uses 75% to 85% less memory** than state-of-the-art

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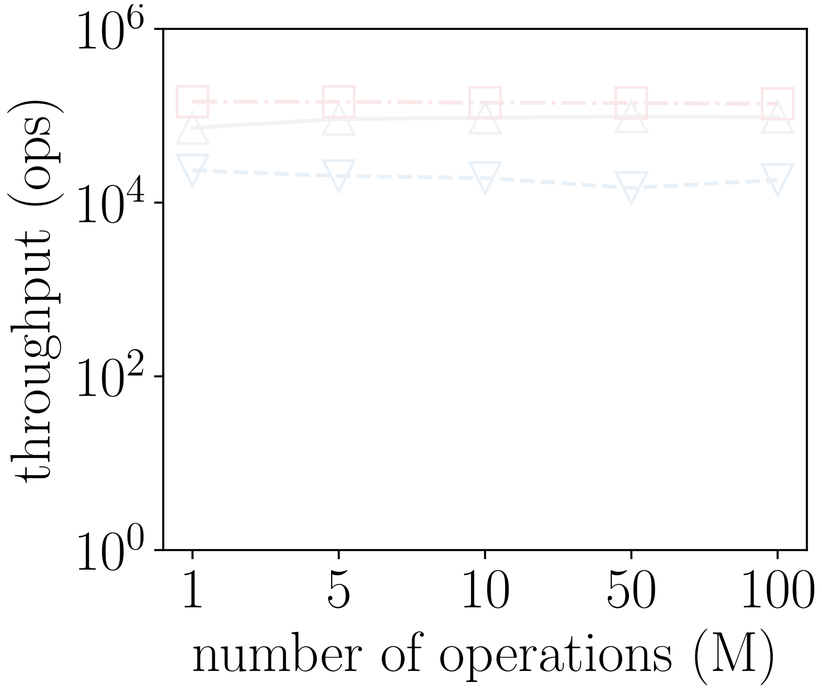
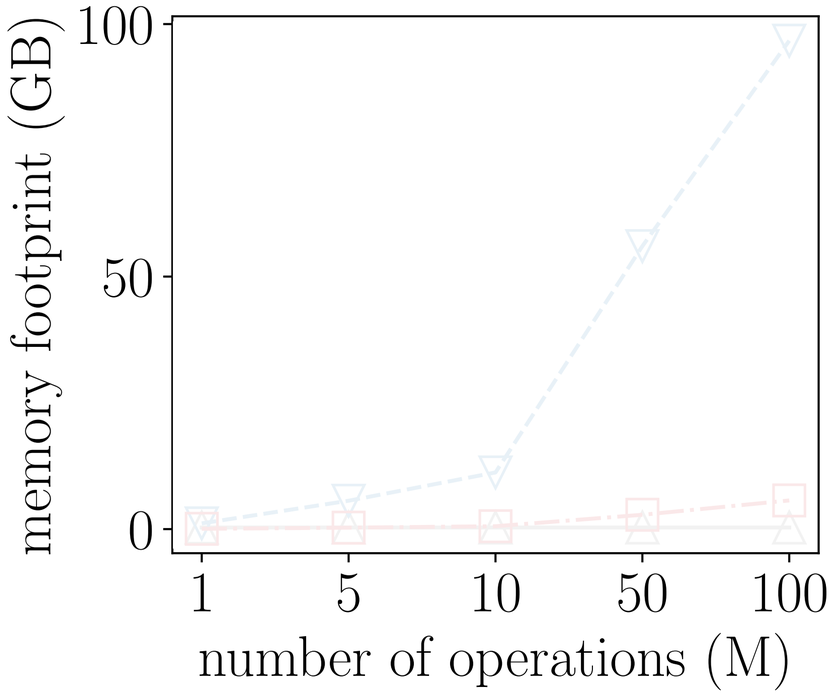
How **scalable is Tectonic?**

w/l: 50% inserts followed by interleaved 40% inserts, 5% update, and 5% point queries

YCSB KVBench Tectonic entry size: 1KB



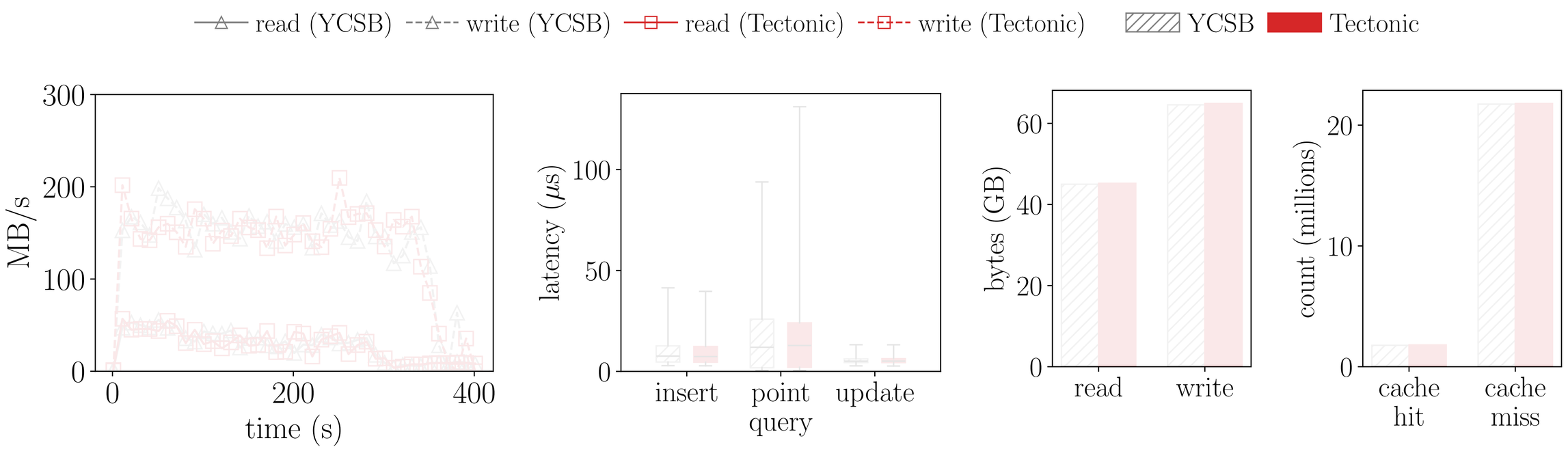
Tectonic is **scalable and offers better throughput** with an increasing number of operations



Tectonic **offers better memory usage**, unlike KVBench, with an increasing number of operations

Can Tectonic generate **similar patterns**?

workload: preload DB with 10M inserts, then runs 5M updates interleaved with 5M point queries



the read and write patterns are similar

different operations' latencies are the same

same amount of bytes read and written; cache hits and misses are similar

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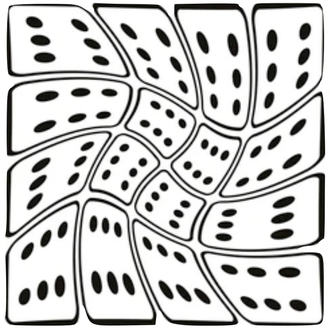
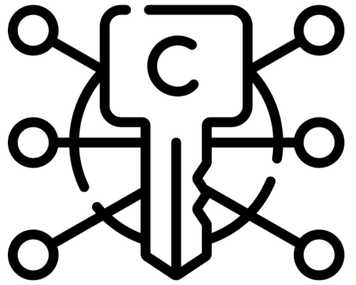
Conclusion



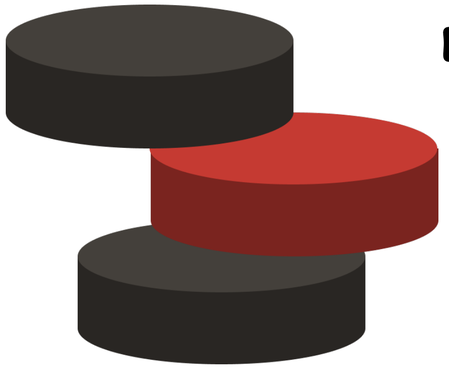
supports **realistic workloads**, including **shifting and dynamic patterns**



composite key generation; several **operations** with **different distributions**

capable of generating **fully** as well as **nearly-sorted workloads**

offers up to **2x better throughput** than SoA; up to **84 % lower memory footprint**



Tectonic: Bridging Synthetic and Real-World Workloads for Key-Value Benchmarking

Thank You!

Questions?

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