YDB

PGConf India

Sharded and Distributed Are Not the Same: What You Must Know When PostgreSQL Is Not Enough

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About myself

- YDB developer
- Amateur speaker
- Outside YDB I enjoy spending time with my family, aerial photography, and reading

Rumors about YDB and YugabyteDB

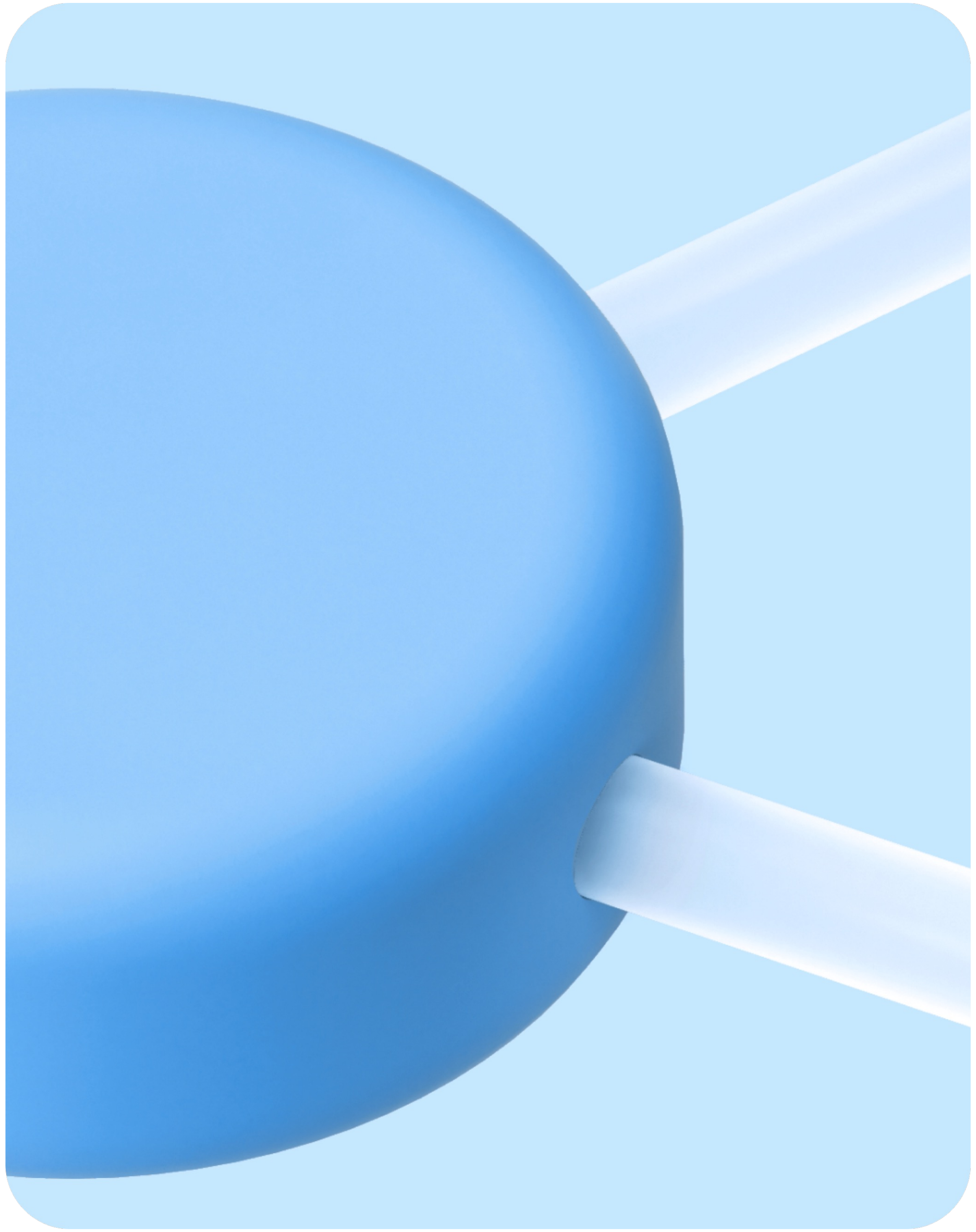
- Many believe that YDB and YugabyteDB are the same thing
- Others say we once had a bar fight

The truth

- YDB and YugabyteDB are **different** distributed DBMSs
- We enjoy discussing topics related to benchmarking and distributed systems

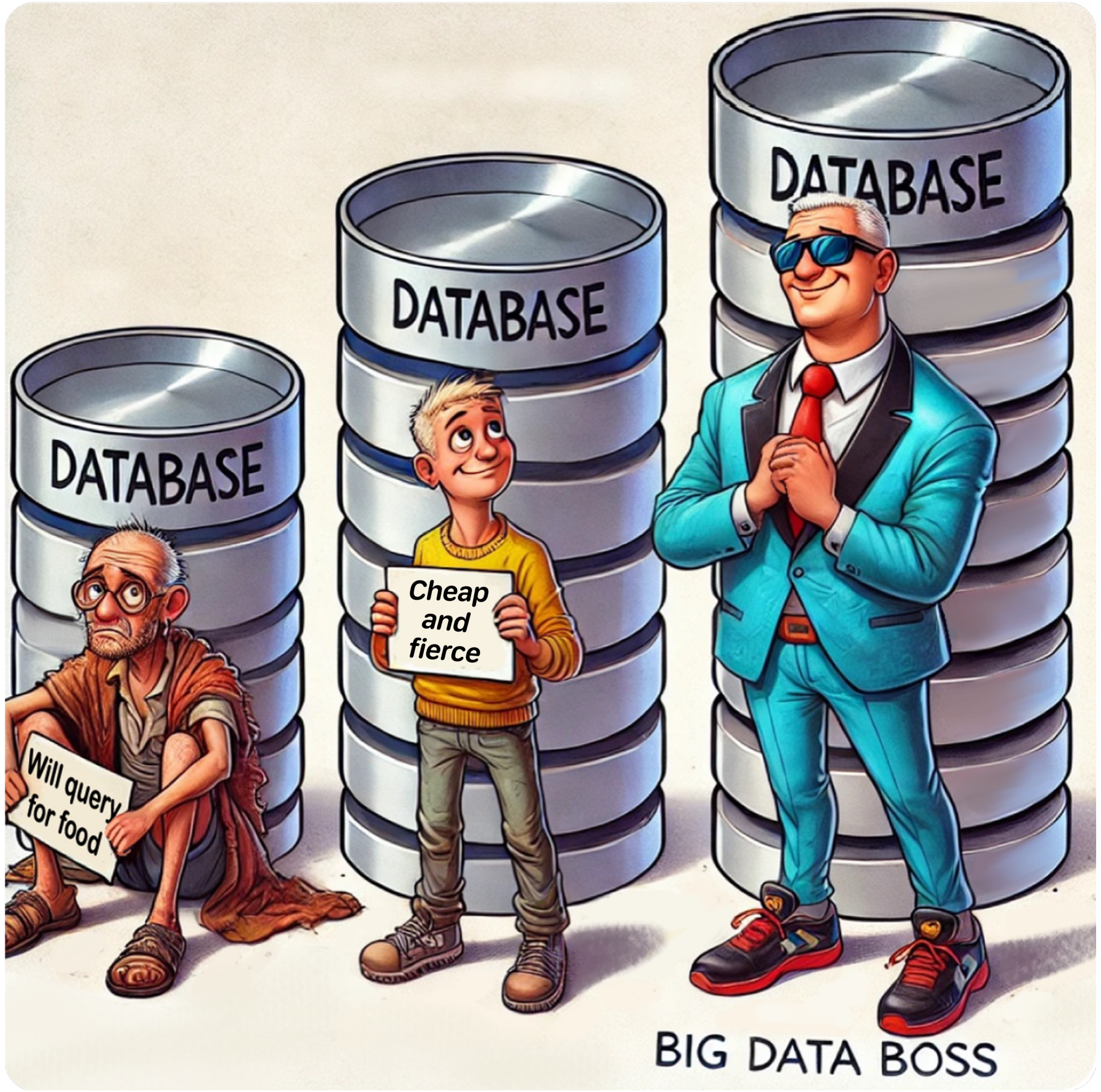
DBMS types and sharding a monolith

01



DBMS usage evolution

1. **No synchronous replication**: it's OK to lose data
2. **Monolith DBMS like PostgreSQL**: scalability is limited
3. **Sharded or Distributed DBMS:** many users and large-scale project
4. **Distributed DBMS:** consistent global snapshot, on-the-fly scaling at any time



It’s not just about performance

- Availability
- Durability

All of this implies replication

And efficiency of resource utilization depends on whether we use replicas for query processing or not

What we will talk about today

1

We will discuss myths related to sharding, wide/distributed transactions, and two-phase commit

2

In case of multi-shard transactions Citus-like solutions are not ACID and do not provide the same guarantees as PostgreSQL

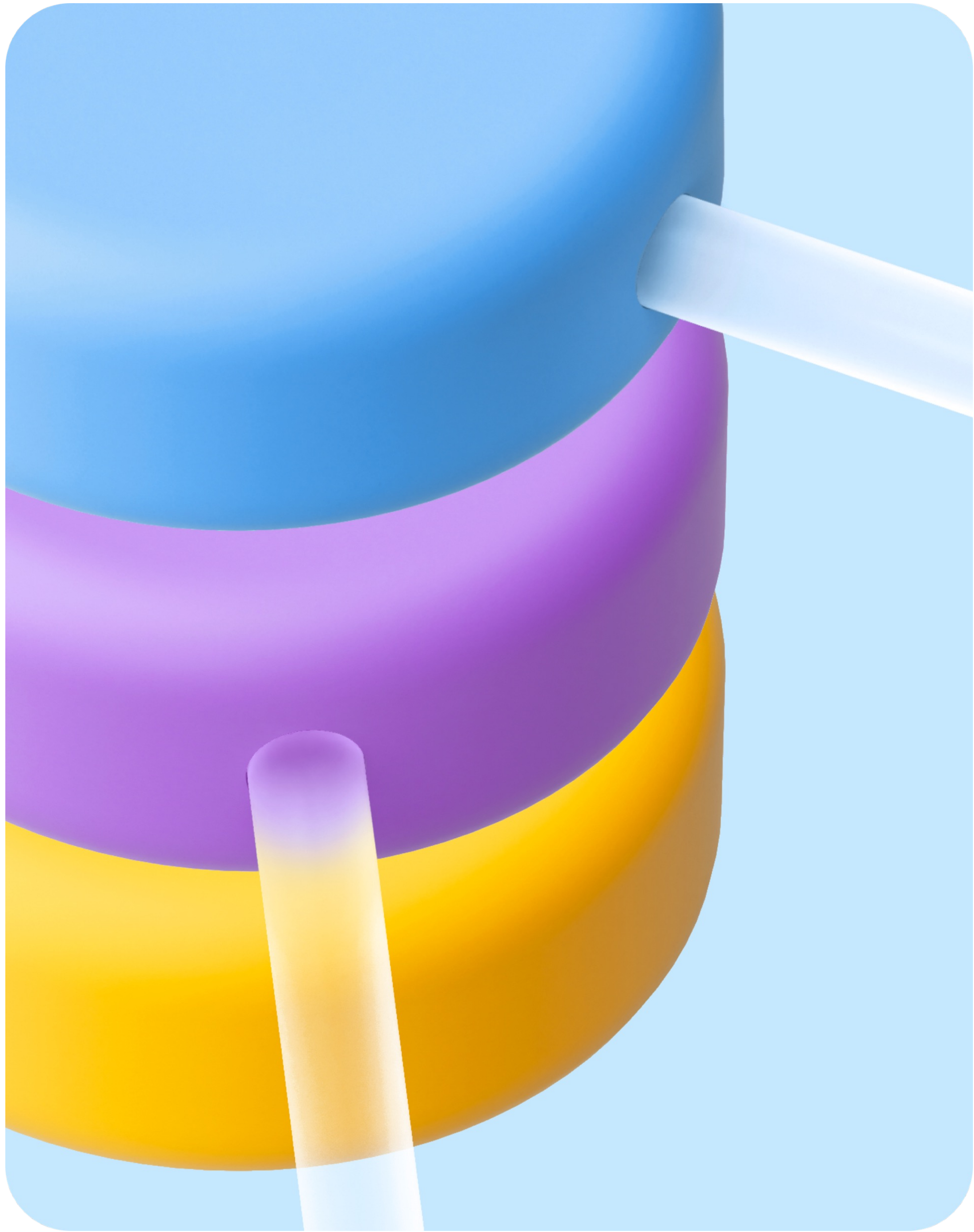
3

Using TPC-C as an example, we will show that PostgreSQL is highly efficient, but synchronous replication might limit vertical scaling

4

Distributed DBMSs are more efficient than commonly believed

Myths and misconceptions



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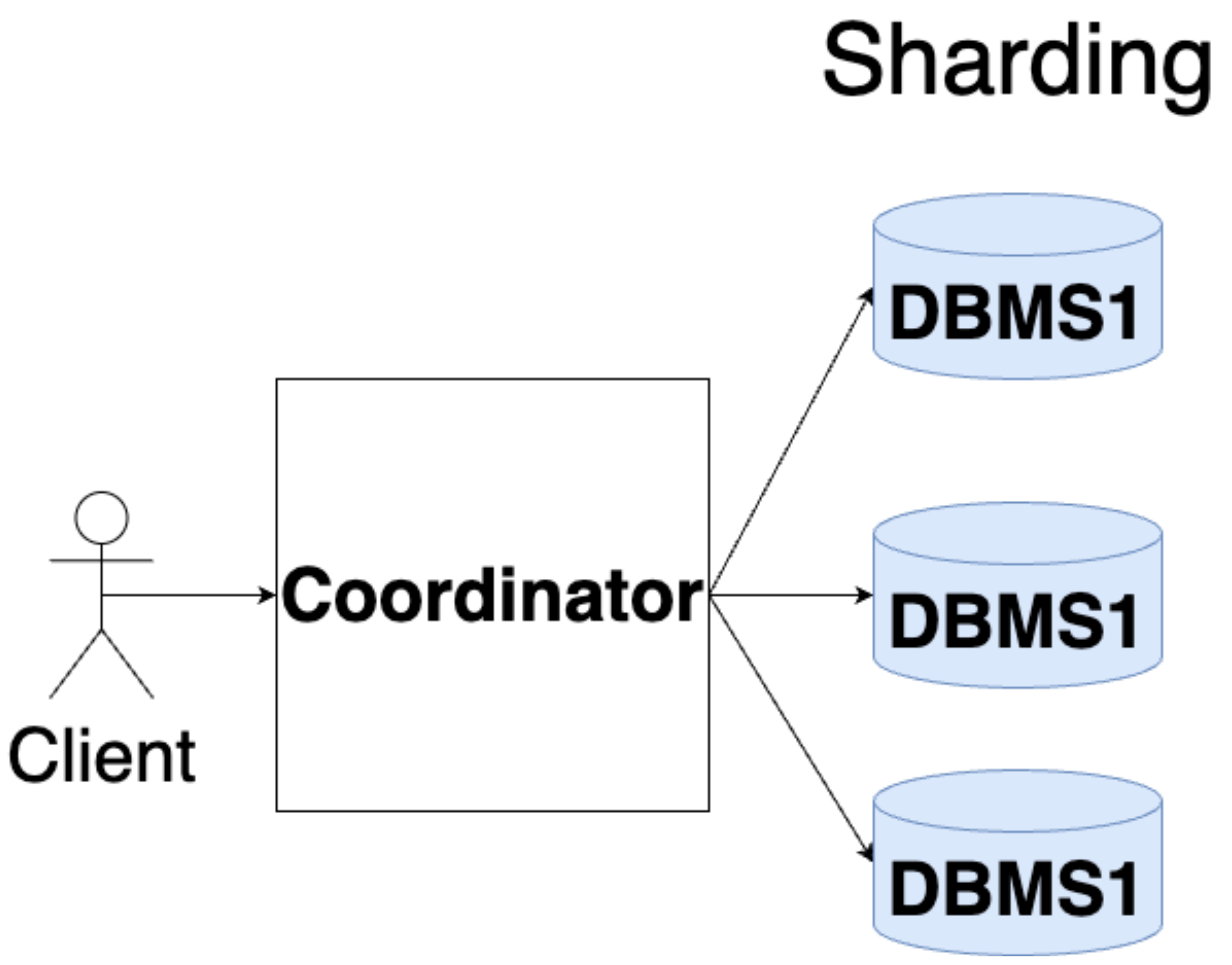
Monolith sharding

1. Instead of a single DBMS, we have N DBMSs, managed by a coordinator (routing layer).
2. Single-shard and multi-shard (wide) transactions.
3. Shards are visible to the user, as single-shard and multi-shard transactions have different guarantees.



All your transactions need is ACID

- **A**tomicity
- **C**onsistency
- **I**solation
- **D**urability

Isolation levels

Serializable — the default level in SQL standard, CockroachDB and YDB. Anomalies are impossible.

Weaker isolation levels (anomalies are possible [1]):

- repeatable read (snapshot isolation)
- read committed — the default in PostgreSQL
- read uncommitted

Isolation levels: practical considerations

Serializable

DBMS is the one who takes care about A-C-**I**-D.

Weaker isolation levels

Application developer is responsible for transaction isolation.

Isolation levels: Citus is not ACID

Wide transactions in Citus are not isolated!*

“Multi-node transactions in Citus provide atomicity, consistency, and durability guarantees, but do not provide distributed snapshot isolation guarantees. A concurrent multi-node query could obtain a local MVCC snapshot before commit on one node, and after commit on another”

[2] Citus: Distributed PostgreSQL for Data-Intensive Applications

** however, not everybody needs it. It depends on your app.*

When the balance is incorrect

```sql
-- Transfer 100 from Alice to Bob

BEGIN ISOLATION LEVEL REPEATABLE
READ;

UPDATE accounts
SET balance = balance - 100
WHERE name = 'Alice';

UPDATE accounts
SET balance = balance + 100
WHERE name = 'Bob';

COMMIT;
```

```sql
-- Calc the total balance

BEGIN ISOLATION LEVEL
REPEATABLE READ;

SELECT SUM(balance)
AS total_balance
FROM accounts;

COMMIT;
```

What about Atomicity?

1

Atomic commit does not provide atomic visibility. «Atomic» means «all or nothing»

2

Some suggest calling this property **Abortability** rather than Atomicity

3

Two-phase commit (2PC) achieves Abortability, but not atomic visibility

4

2PC does not implement distributed transactions [3]

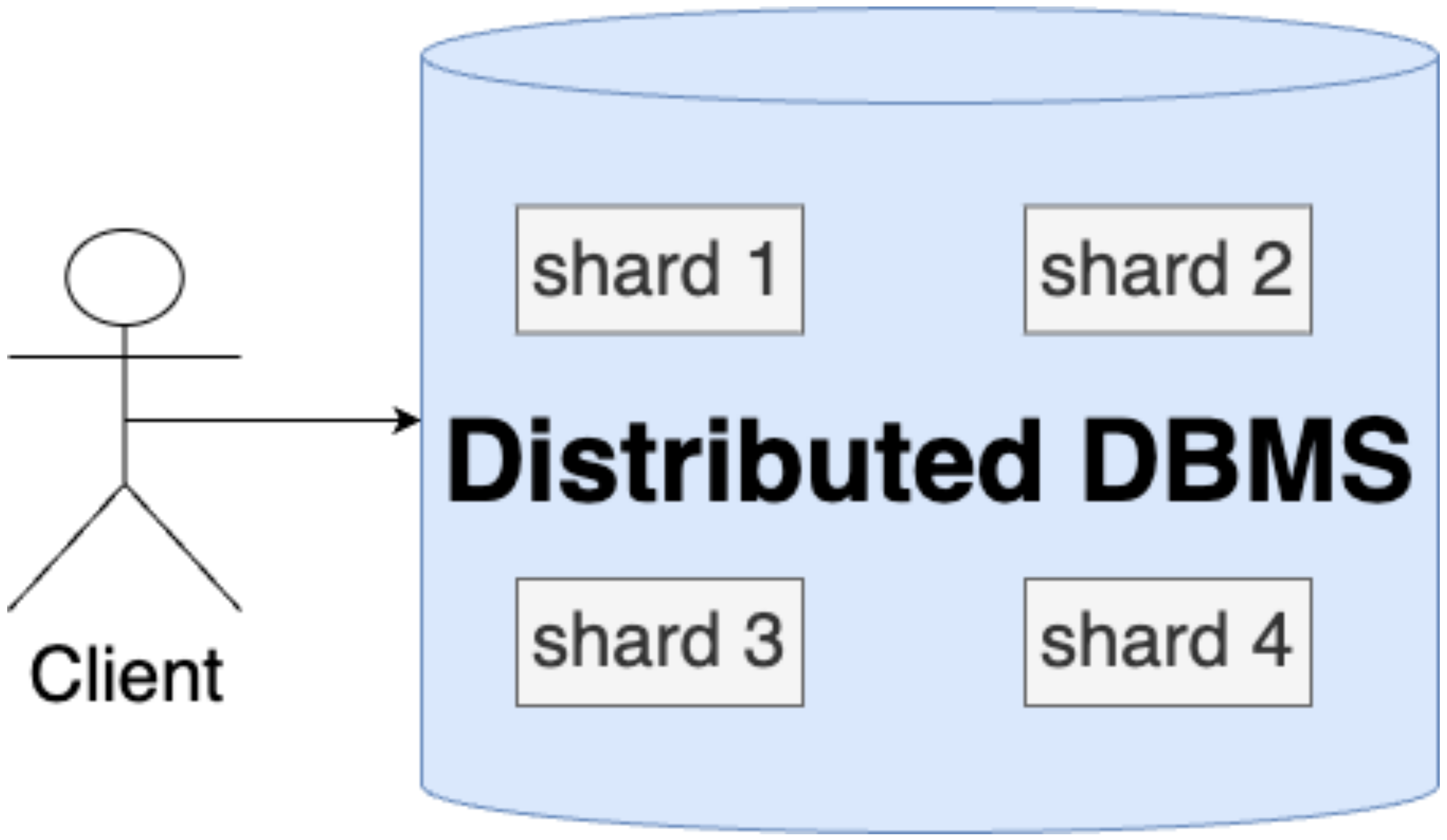
Sharding in a distributed DBMS

1

Shard is just an implementation detail of a DBMS

2

For the user, there is no difference between a monolithic and a distributed DBMS: the same guarantees for any transactions



Are wide transactions really that expensive? Theory.

1

Transaction execution time is typically expressed in terms of the number of consecutive RTTs (Round Trip Time) and the number of I/O operations

2

NVMe disks — I/O can be neglected

- Postgres: 1 RTT (replication)
- Sharded Postgres: 3 RTT where 1 RTT (replication) + 2 RTT (2PC)
- YDB: 4.5 RTT + 0.5 ms plan/batch [4]

Transaction time, ms (lower is better)
35
30
25
20
15
10
5
0
0.5 1 1.5 2 2.5 3 3.5 4 4.5 5 5.5 6 6.5 7
RTT, ms
Replicated Postgres (1 RTT)
Sharded Postgres (3 RTT)
YDB (4.5 RTT + 0.5 ms)

Are wide transactions really that expensive? A practical perspective.

1

In a single availability zone installation, the difference is only a few milliseconds

2

In a multi-availability zone installation, the difference can be up to 10 ms

But distributed transactions are still below 50 ms

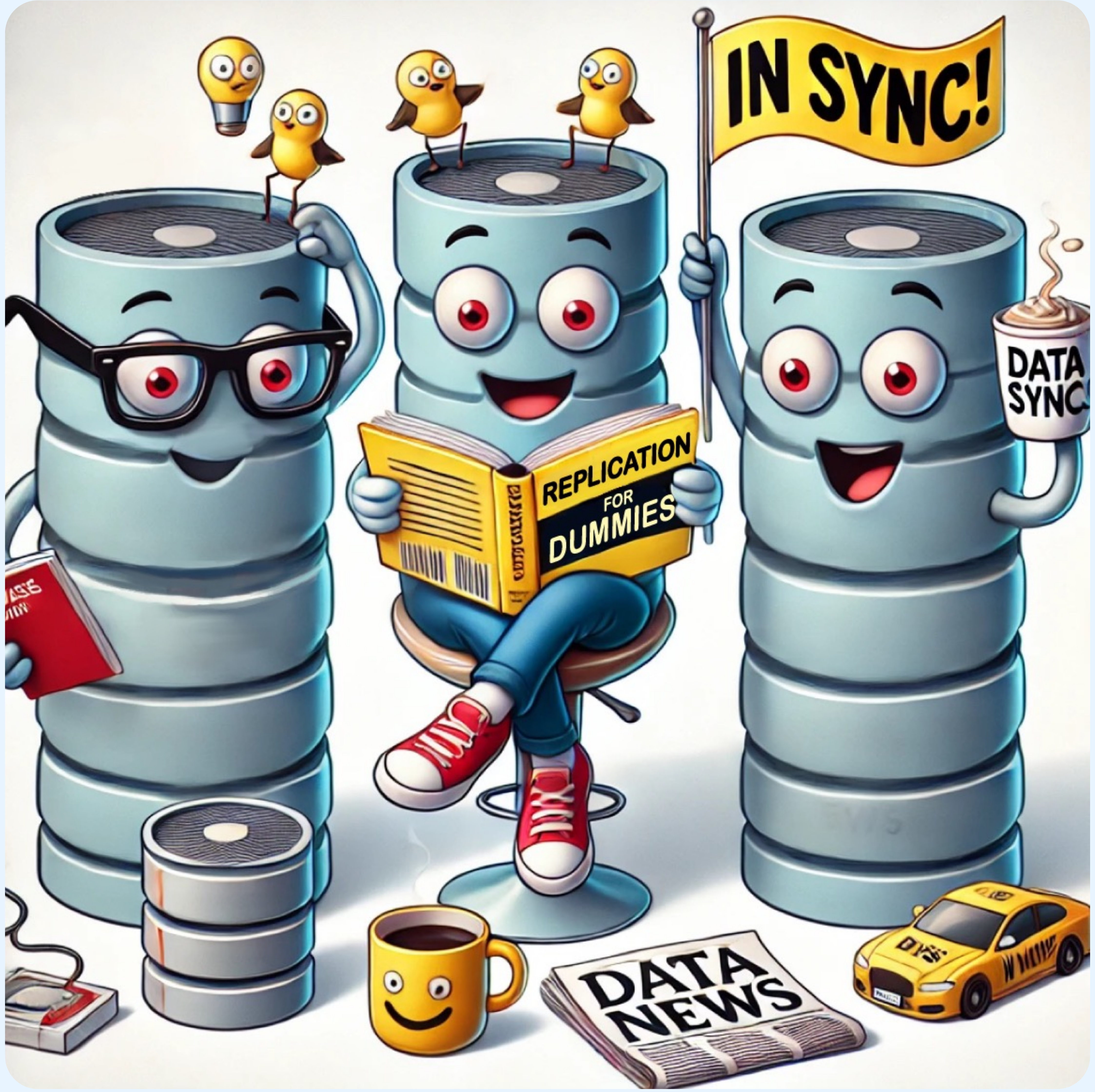
3

In a multi region cluster, the difference can be significant. In this case if your workload allows, pure sharding might be better

Replication

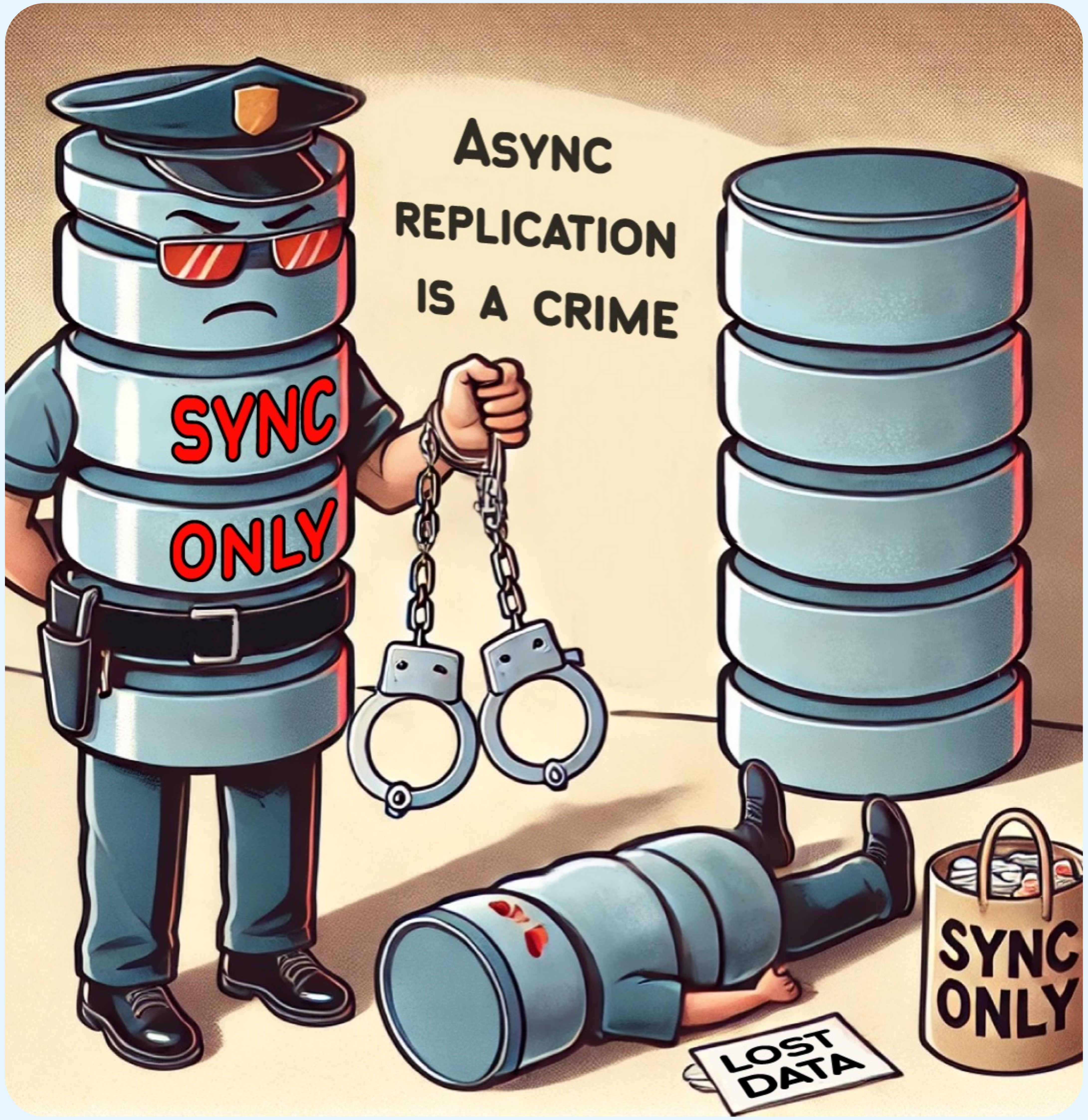
How Many Standby Replicas Are Enough?

It depends on your fault tolerance model, but **three replicas is a good minimum number** (leader and two standby replicas)



Async replication in the absence of Sync replication

- risk of data loss
- stale reads and anomalies
- combination of synchronous and asynchronous replication only with a larger number of replicas



Replicas utilization in a monolith (1)

1 The leader uses **X CPU cores** for processing, while there are three servers in the cluster, each with X cores and **3X cores in total**.

The replicas remain idle

2 We want to tolerate the failure of one server. The original **X cores** load could be distributed between two servers left, using **X/2 cores** on each

3 Also, if replicas are used, you could have 3 servers with **X/2 cores each** and **less RAM**

4 This usually helps reduce latency

Replicas utilization in a monolith (2)

1 With two replicas, the 'idle time' is 66.6% — the same poor number as utilization at 99.9%

2 If the server has only 16–32 cores, it's not that expensive

3 But what if the server has 64-128 cores and many NVMe disks?

Replication in both sharded and distributed DBMS's

1

Replicas and leaders are distributed across all hosts: **66.6%** hardware utilization VS. **33.3%** in a monolith DBMS.

2

Thanks to sharding, we have many small replication threads, which scale better

Remember that

1 Citus works great with single-shard transactions. In a multi-region installations it might outperform distributed DBMSs.

2 Citus is not PostgreSQL: it provides different guarantees for single- and multishard transactions.

3 Citus is not a distributed DBMS: isolation of multi-shard transactions is just read committed.

4 Don’t be afraid of YugabyteDB, CocrkoachDB and YDB: distributed transactions are not that expensive when you have a fast network.

But when is PostgreSQL not enough?

1

We took TPC-C – a very popular OLTP benchmark, 3 powerful servers, and found the limit when PostgreSQL fails to handle it

2

We evaluated the performance of distributed DBMSs compared to PostgreSQL in such a small installation

TPC-C results

03

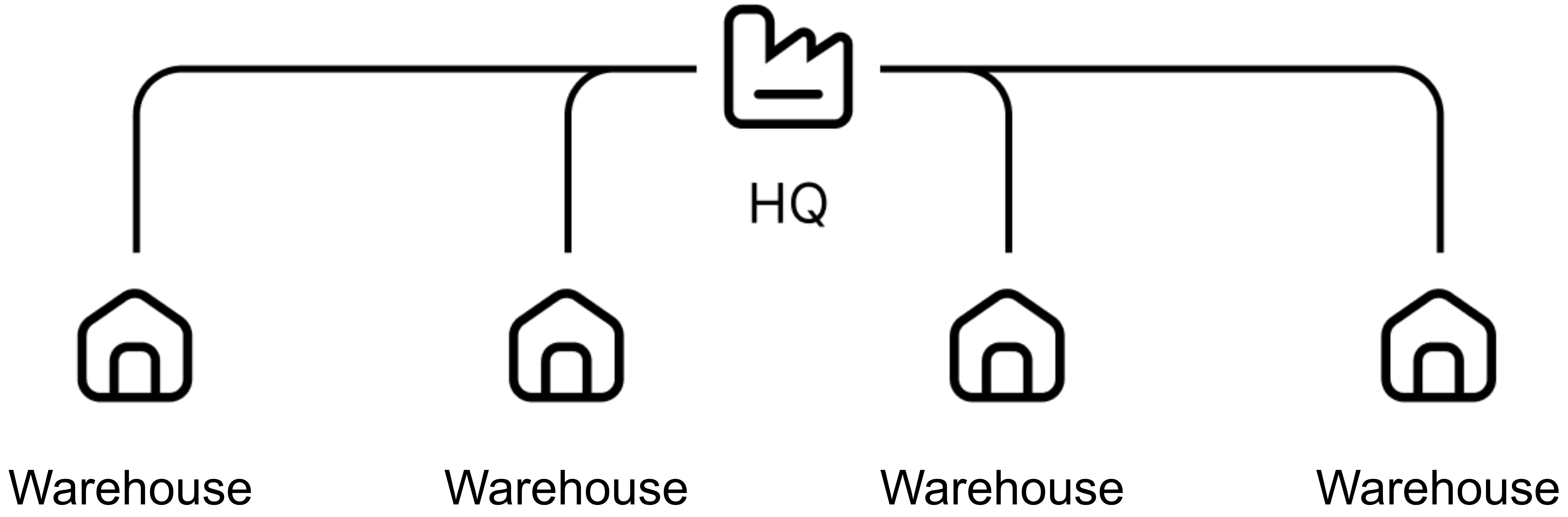
TPC-C

Since 1992

«The only objective comparison for evaluating OLTP performance» — CockroachDB

YugabyteDB and TiDB also stated that TPC-C is the most objective performance measurement of OLTP systems

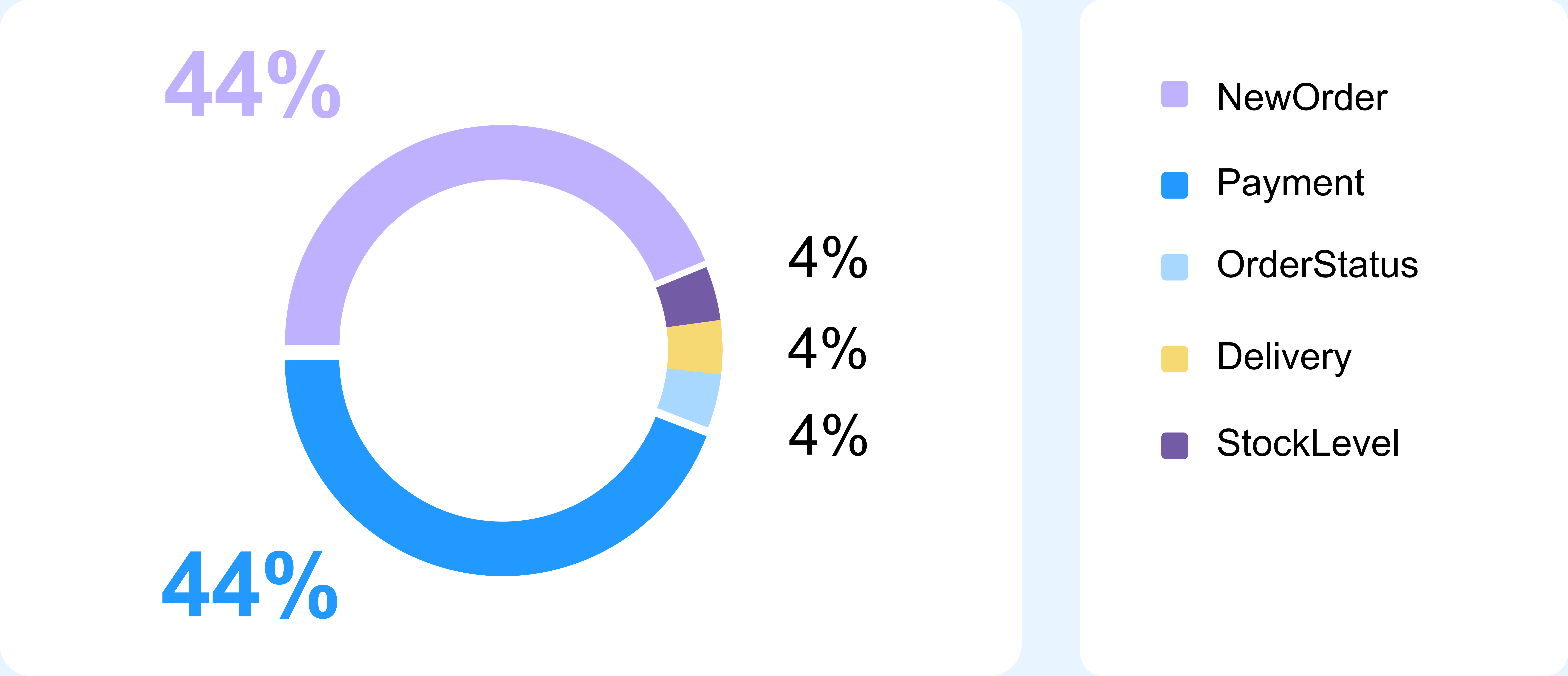
Simulates an e-commerce organization



TPC-C logic

- Number of warehouses is a parameter
- Each warehouse (around 100 MB of data) serves 10 districts
- Each district has a terminal
- Customers use a terminal for orders and payments
- Sometimes customers check the order status
- Delivery is handled by database as well
- Warehouses rarely make inventorization

TPC-C transactions



TPC-C transactions

Serializable level of isolation (repeatable read in Postgres is enough)

1.9:1 read-to-write ratio

Multi-step (interactive)

tpmC integral metric: benchmark measures the number of New Order transactions per minute

CMU Benchbase

- Multi-DBMS SQL Benchmarking Framework via JDBC
- Developed by Carnegie Mellon under Andy Pavlo's supervision
- It's easy to add new DBMS and benchmarks

- The only well known TPC-C implementation
- YugabyteDB uses Benchbase fork
- We had to fork too (with a goal to upstream the YDB support)

Client-side requirements for 15 000 warehouses

150K

OS threads

600 GB

RAM

To test YDB running on 3 servers, we used 5 servers to run the benchmark (each 128 cores and 512 GB RAM)

Scaling out

- DBMS with 9, 15, 30, 60, 81 servers
- YDB, CockroachDB, YugabyteDB

$10,000

Single run in AWS

Multiple runs are usually required

Our fork and upstream

- github.com/ydb-platform/tpcc and github.com/ydb-platform/tpcc-postgres
- We plan to upstream the improvements
- We adapted TPC-C to Java virtual threads, which can lead to deadlocks in other benchmarks supported by Benchbase

[5] How we switched to Java 21 virtual threads and got a deadlock in TPC-C for PostgreSQL

Tuning PostgreSQL

04

Setup: 3 bare metal servers, single DC

128 logical CPU cores

Two Intel Xeon Gold 6338 CPU @ 2.00GHz, hyper-threading is turned on

512 GB

RAM

4 NVMe disks

RAID0 for PostgreSQL

Transparent hugepages (huge pages for PostgreSQL)

Ubuntu 20.04.3 LTS

DBMS should survive a single server failure

PostgreSQL has two sync replicas

CockroachDB and YDB use replication factor 3

In PostgreSQL, everything is configurable!

1

Write-ahead log

2

B-Tree

3

Execution engine

4

Replication

5 I/O

Our approach to tuning

**From fault-intolerant and extremely fast to slower,
but fault-tolerant PostgreSQL**

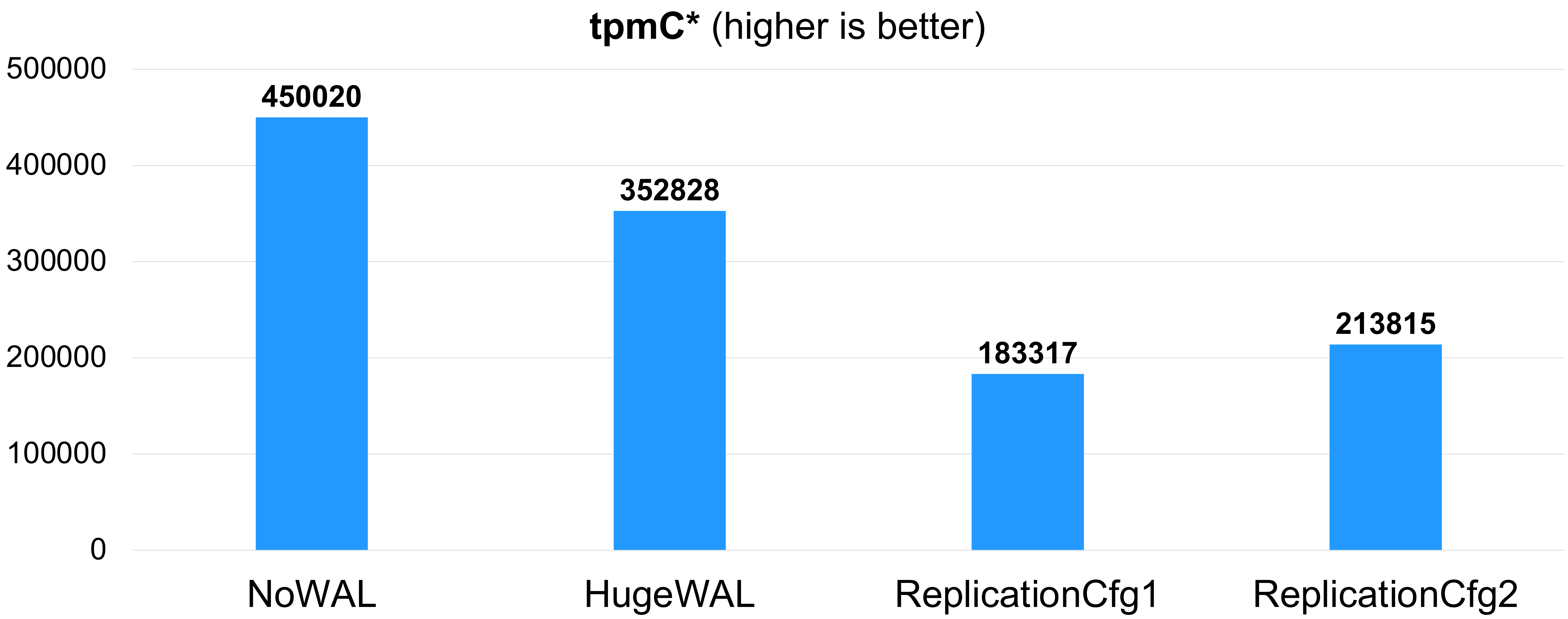
Three NVMe RAID0 — data, One NVMe — WAL:

1. Unlogged tables with replication turned off: **NoWAL**
2. Huge WAL (Recovery time is tens of minutes) with ideal I/O distribution: **HugeWAL**
3. Two sync replicas: **ReplicationCfg1**

Two NVMe RAID0 — data, two NVMe RAID0 — WAL:

4. Two sync replicas with `synchronous_commit = apply`: **ReplicationCfg2**

PostgreSQL configurations evaluation



* *The results are not officially recognized TPC results and are not comparable with other TPC-C test results published on the TPC website.*

Results summary

1 Fault-intolerant **PostgreSQL** is **incredibly fast**

2 With replication, the result is twice as slow, but still good

3 PostgreSQL replicas use only one thread to apply the WAL

4 Synchronous replication in PostgreSQL is a bottleneck and limits vertical scalability

[6] More details on configurations and results.

Is 200K tpmC a lot?

~8 000

interactive transactions per second

~130 000

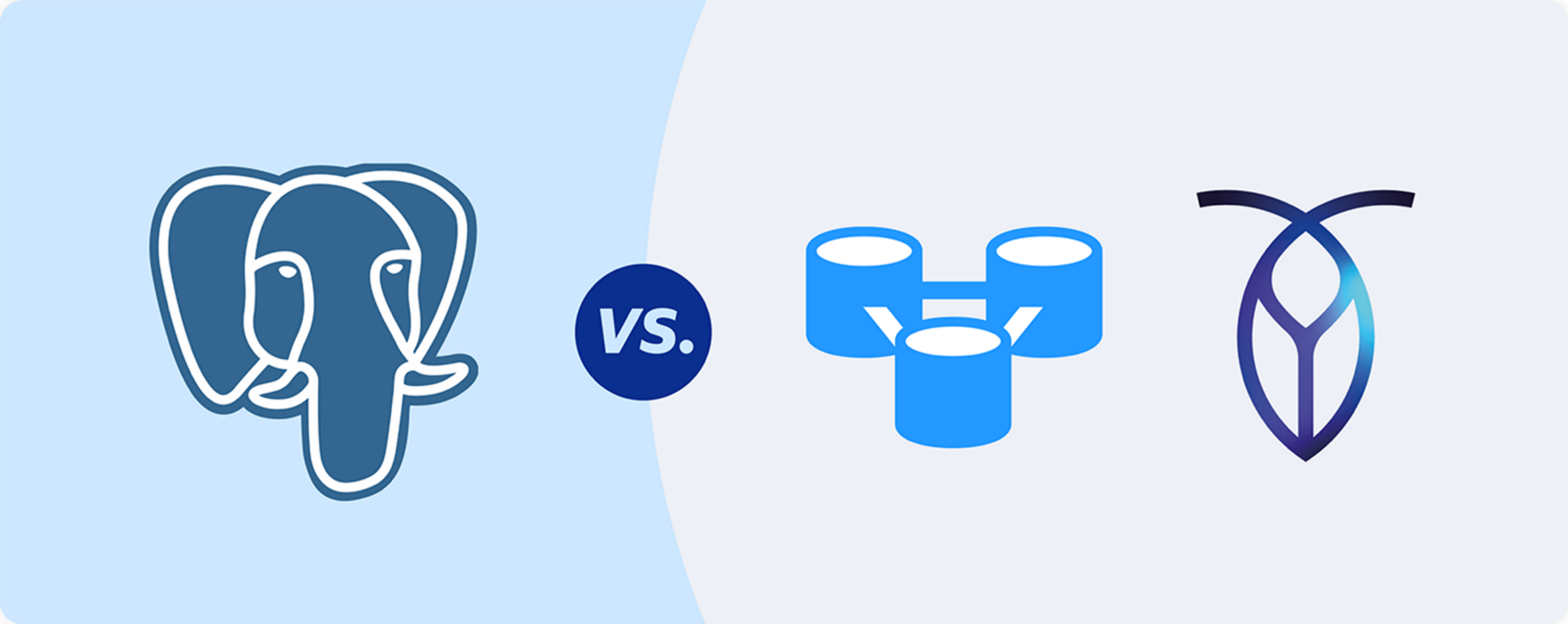
database requests (queries) per second

Leader server:

- WAL write 400 MB/s,
- data write 600 MB/s
- read 700 MB/s
- network consumption 9 Gbit/s
- CPU usage: on average 20 cores (out of 128)

Can distributed DBMSs show comparable results on the same hardware?

PostgreSQL vs. distributed DBMSs



05

YDB

Open-Source Distributed SQL Database

1. Partial PostgreSQL compatibility [7].

   OLTP, OLAP, Kafka-like topics

   Transactions between topics and tables

2. Strong consistency

3. Clusters with thousands of servers

4. Apache 2.0 license

5. Star ydb-platform on GitHub

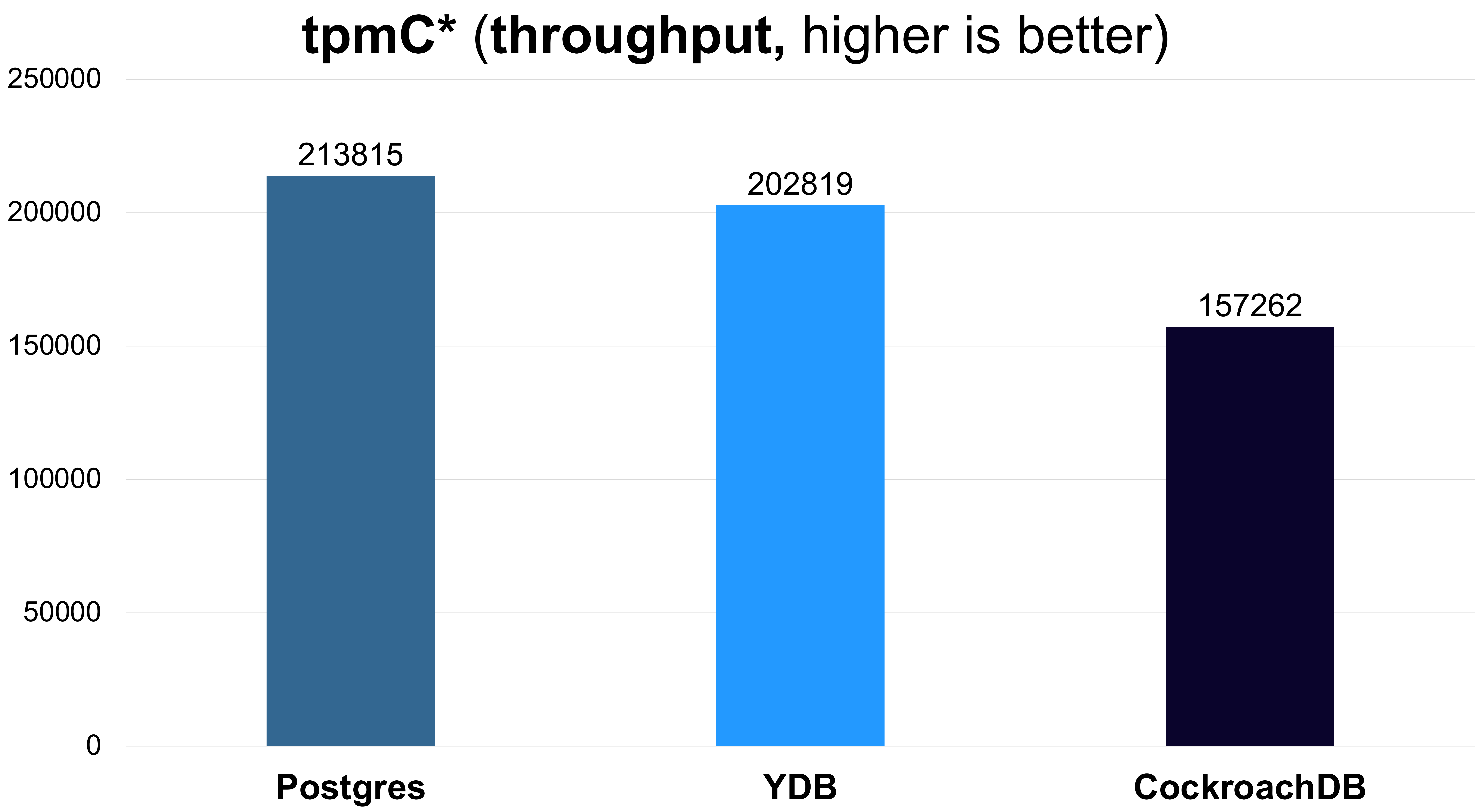
CockroachDB

~~Open-Source~~ Distributed SQL Database

1 Partial PostgreSQL compatibility

OLTP only

2 Strong consistency



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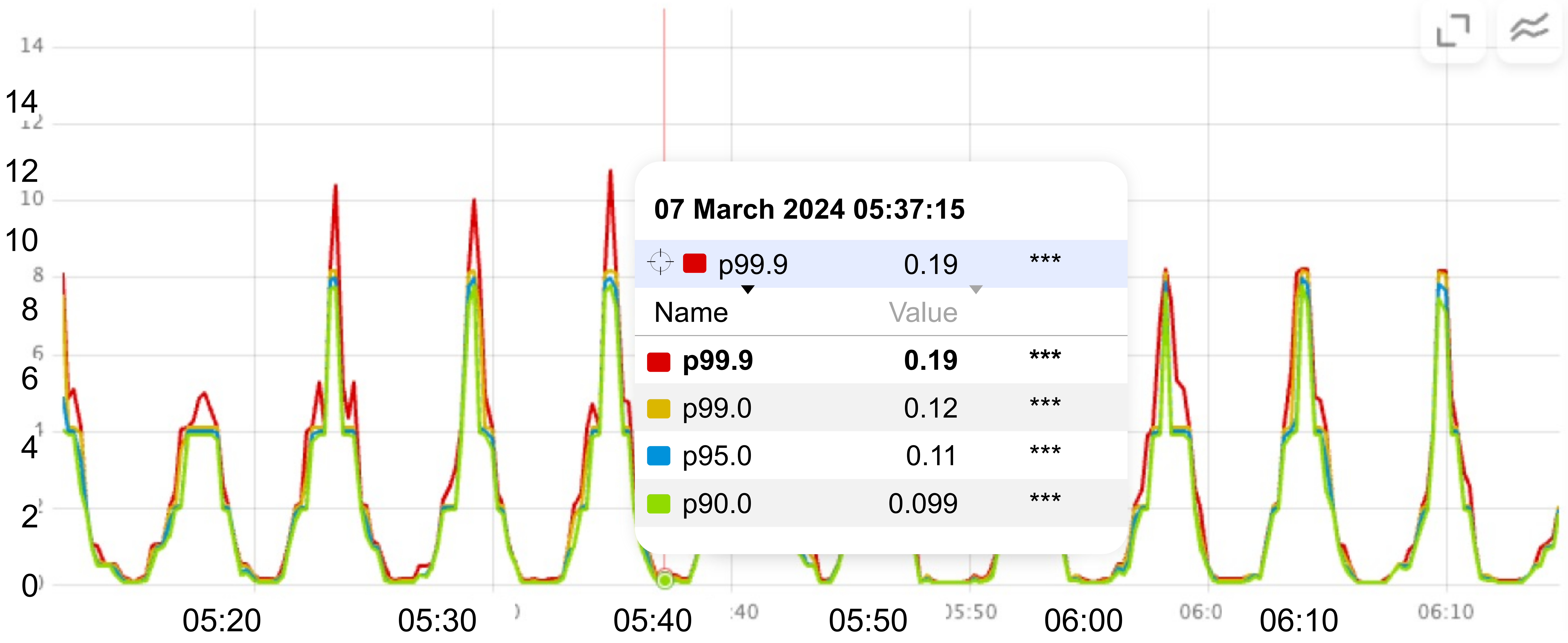
Postgres NewOrder Latencies*, seconds (lower is better)



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NewOrder latency в Postgres

Each peak corresponds to the start of a checkpoint

Sessions are 'hanging' waiting for IPC: SyncRep

This is an architectural issue (only 1 thread for receiving and applying WAL by replicas)

Conclusions

1

PostgreSQL is highly efficient, but:

1. It does not scale horizontally.
2. Synchronous replication limits vertical scaling and it's not always possible to just add more cores and RAM.

2

Citus-like solutions are not ACID-compliant and do not provide the same guarantees as PostgreSQL in case of multi-shard (distributed) transactions.

3

When you need serializable distributed transactions, consider distributed DBMSs: they are more efficient than commonly believed.

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Questions?

Slides and materials

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