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Database Benchmarking
An unexpected Journey

Dirk Krautschick

PG Dev Day Prague 29.01.2025

#whoami

Dirk Krautschick
Senior Solution Architect

with Aiven since Nov 2023

18 years

DBA, Trainer, Consulting, Sales Engineering

PostgreSQL, Oracle, Kafka, Clickhouse, OpenSearch,...

Married, 2 Junior DBAs

Mountainbike, swimming, movies, music, hifi/home cinema, 8 bit computing

Disclaimer

Inspiration and motivation for trying

I am NOT an deep dive benchmarking guru ...

... just a desperate database guy ...like you!? :-)

Unexceptional Open Source!!!

Everything what looks like advertising won't be meant like such...

...but this time I need to give some brief context of my company

to explain my journey...

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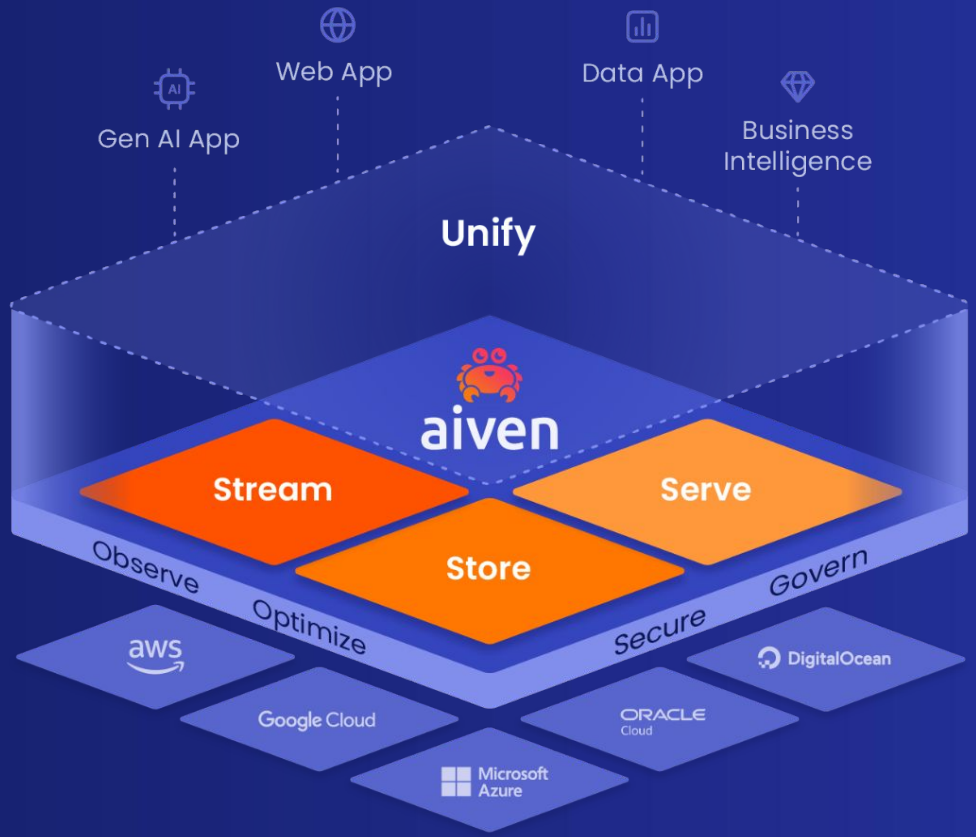
Your Trusted Data & AI Platform

Streaming | Database Optimization | Analytics | Search | Data Warehousing | In-Memory Caching



One cloud data platform

STREAM

Event streaming

Aiven for **Apache Kafka®** and **Kafka® Connect**

Event stream processing

Aiven for **Apache Flink®**

STORE

Relational databases

Aiven for **AlloyDB Omni**

Aiven for **PostgreSQL®**

Aiven for **MySQL**

Key-value database

Aiven for **Valkey**

Aiven for **Dragonfly**

SERVE

Data warehouse

Aiven for **ClickHouse®**

Time series database

Aiven for **Metrics**

Search engine

Aiven for **OpenSearch®**

Data visualization

Aiven for **Grafana®**

UNIFIED PLATFORM

Host

aws

Google Cloud

Microsoft Azure

DigitalOcean

ORACLE Cloud

Bring your own cloud

Deploy

Terraform

Kubernetes

API REST API

CLI Aiven CLI

Aiven Console

Integrate

Datadog

Prometheus

AWS CloudWatch

GCP Monitoring

MongoDB

AWS S3

GCP BigQuery

Couchbase

Snowflake

splunk> Splunk

Sumologic

Debezium

GCP Pub/Sub

GCP Storage

The Request

Can we do a full comparison of the performance of PostgreSQL ...

...everywhere!!!

- Several t-shirt sizes... (“define yourself something what make sense”)
- All major cloud vendors
- PostgreSQL v15, v16, v17,...
- Hyperscaler offerings (AWS RDS, Azure FlexServer, GCP CloudSQL,...)
- “What about things like e.g. AWS Aurora, GCP AlloyDB,...?”

The Request

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...???

Measurement

Well....what does “performance” means in that context?

How to measure that “performance” sustainable and reproducible?

What is the best workload using for those measurements?

Once upon a time....

...somewhere in Mönchengladbach, Germany,

...around 1997-1999,

...during my electronics engineer apprenticeship

“Wer misst, misst Mist!”

Udo Brockers, R.I.P. (* 05.09.1959, + 25.06.2012)

1:1 Translation:

“Who measures, measures manure!”

Using performance analytic skills?

One idea was using regular performance analysis

Investigating same load on test targets

Relying on existing metric sources (pg_stat_statements, pg_wait_sampling,...etc.)

Creating profiling reports with PG_PROFILE with comparing option

https://www.youtube.com/watch?v=I57TNi6Y728

But again, which workload?

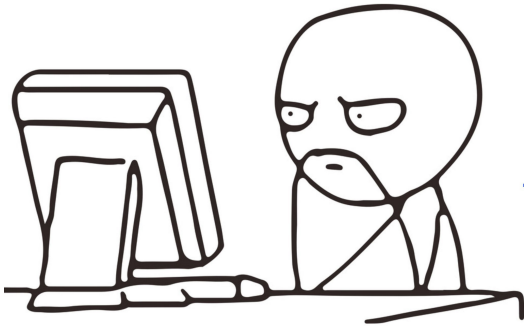
How to measure ideally?

What do we want?

- Absolute results
- Comparing results
- What are the metrics?

How do we want to measure at all?

- Use case specific measurements
- Application based measurements
- Generic measurements



Let’s introduce… pgbench

pgbench

In contrib with PostgreSQL v7.0

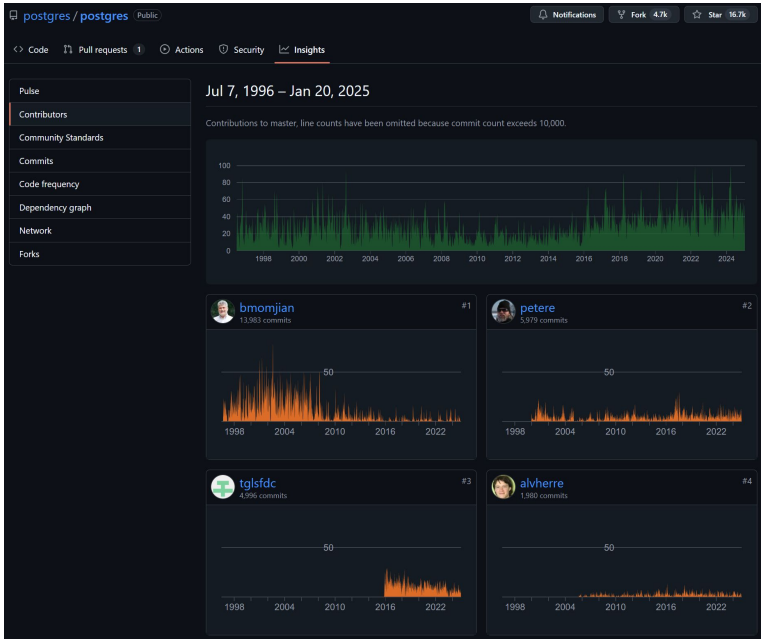
With PostgreSQL at least since 8.2

PostgreSQL License

https://github.com/postgres/postgres/tree/master/src/bin/pgbench

Actual Release v17.2 (Nov 2024)

C-based



Let’s introduce… pgbench

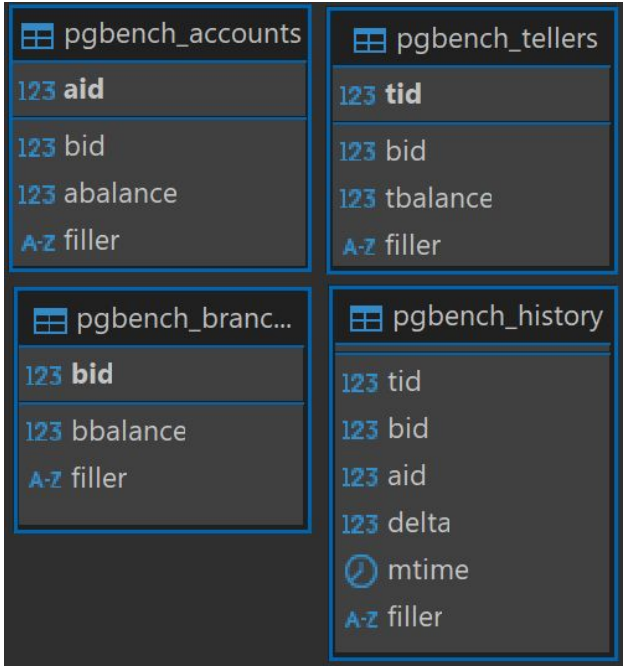
Methodology

So called “TPC-B sort of” based scenario!?

5 select, update and insert command per transaction

4 Tables with the amount or rows (scale factor 1)

```
table                    # of rows
---------------------------------
pgbench_branches         1
pgbench_tellers          10
pgbench_accounts         100000
pgbench_history          0
```



pgbench - An easy quick start...

Installation

…please….if you don't already have PostgreSQL somewhere…?

GET POSTGRESQL!!!!!!!!!!111eleven

https://www.postgresql.org/download/

pgbench - An easy quick start...

Initialization of pgbench

```
# $PGHOME/bin/pgbench -i

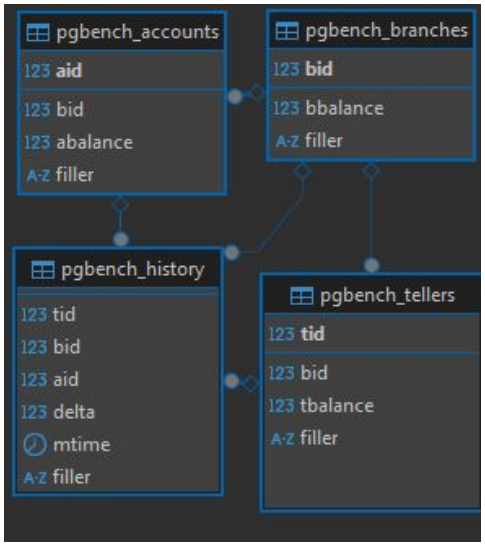
      (if necessary, connection parameters like usual)
```

Consider some parameters....

foreign keys (`--foreign-keys`)

scale factor (`--scale, -s`)

partitioning (`--partition-method, -partitions`)



pgbench - An easy quick start...

Run the benchmark

```
# $PGHOME/bin/pgbench

      (if necessary, connection parameters like usual)
```

Consider some parameters....

time or transactions (`--time, ––transactions`)
clients (`--client`)
threads (`--jobs`)
custom scripts
...
https://www.postgresql.org/docs/current/pgbench.html

pgbench - Example script

```
#!/bin/bash
# redirect stdout/stderr to a file
DATE=$(date +"%Y%m%d%H%M")
exec >benchrun$DATE.log 2>&1

SCALE=100
CLIENT_CNT=50
BENCH_TIME=300
THREADS=10

echo "pgbench -i -s $SCALE"
echo "pgbench -c $CLIENT_CNT -j $THREADS -P 60 -r -T $BENCH_TIME "
echo "------------------------------------------------------------"
echo $(date -u)
echo "------------------------- INIT -------------------------------"
pgbench -i -s $SCALE "postgres://<USER>:<PASSWORD>@<HOST>:<PORT>/<DATABASE>"
echo $(date -u)
echo "------------------------- PGBENCH  ---------------------------"
pgbench -c $CLIENT_CNT -j $THREADS -P 60 -r -T $BENCH_TIME "postgres://<USER>:<PASSWORD>@<HOST>:<PORT>/<DATABASE>"
echo $(date -u)
```

pgbench - The result explained

```
------------------------ INIT ------------------------------
dropping old tables...
creating tables...
generating data (client-side)...
vacuuming...
creating primary keys...
done in 649.74 s (  drop tables 0.00 s,
                    create tables 0.01 s,
                    client-side generate 478.74 s,
                    vacuum 0.87 s,
                    primary keys 170.13 s).
```

pgbench - The result explained

```
------------------------ PGBENCH  --------------------------
pgbench (17.2)
starting vacuum...end.
transaction type: <builtin: TPC-B (sort of)>
scaling factor: 2500
query mode: simple
number of clients: 32
number of threads: 2
maximum number of tries: 1
duration: 300 s
number of transactions actually processed: 922031
number of failed transactions: 0 (0.000%)
latency average = 10.389 ms
latency stddev = 91.565 ms
initial connection time = 360.173 ms
…
```

pgbench - The result explained

```
…
tps = 3076.984799 (without initial connection time)
statement latencies in milliseconds and failures:
         0.000           0  \set aid random(1, 100000 * :scale)
         0.000           0  \set bid random(1, 1 * :scale)
         0.000           0  \set tid random(1, 10 * :scale)
         0.000           0  \set delta random(-5000, 5000)
         0.353           0  BEGIN;
         7.374           0  UPDATE pgbench_accounts SET abalance = abalance + …
         0.517           0  SELECT abalance FROM pgbench_accounts WHERE aid = :aid;
         0.605           0  UPDATE pgbench_tellers SET tbalance = tbalance + …
         0.557           0  UPDATE pgbench_branches SET bbalance = bbalance + …
         0.569           0  INSERT INTO pgbench_history (tid, bid, aid, delta, …
         0.406           0  END;
```

pgbench - Demo

DEMO

Benefits and limitations of pgbench

It’s just there, it’s easy, it works!

Quick example load for testing, with many ***(often unused!)*** options

Missing tooling and utilization

What about

- Other specific workloads?
- OLAP/Analytics?
- Other database engines?

The wise elders of benchmarking...

Brief History of DB benchmarking…

1985 Debit/Credit (Jim Gray)
"A Measure of Transaction Processing Power"
https://infolab.usc.edu/csci599/Fall2008/papers/c-2a.pdf
First database benchmark approach

1988 Transaction Processing Performance Council (TPC) was founded
https://www.tpc.org

2000 PostgreSQL 7 (with pgbench in contrib)

2006 PostgreSQL 8.2 (with pgbench included)

2003 HammerDB 1.0

What the heck is that TPC???

Transaction Processing Performance Council

https://www.tpc.org

Non-profit corporation since 1988

Definition of industry standards for benchmarking

- 1989 TPC-A (Debit/Credit) and **1990 TPC-B** (DB version of TPC-A)
- 1992 TPC-C
- 1999 TPC-H
- Several replacements

https://www.tpc.org/information/about/history5.asp

TPC…ok, nice….but…?

Large company/vendor driven

Expensive and provided reports not relevant anymore

But…

- “Fair use” for research possible
- Workload examples are adapted and/or established
- Easy to use

Well, what other gear do we have?

sysbench

https://github.com/akopytov/sysbench

oltpbench (now BenchBase)

https://github.com/oltpbenchmark/oltpbench https://github.com/cmu-db/benchbase

pgbench-tools (soon “pgbent”)

https://github.com/gregs1104/pgbench-tools

YCSB (Yahoo! Cloud Serving Benchmark)

https://github.com/brianfrankcooper/YCSB

Let’s introduce… HammerDB

HammerDB

Hosted by the TPC-Council

Steve Shaw to be mentioned

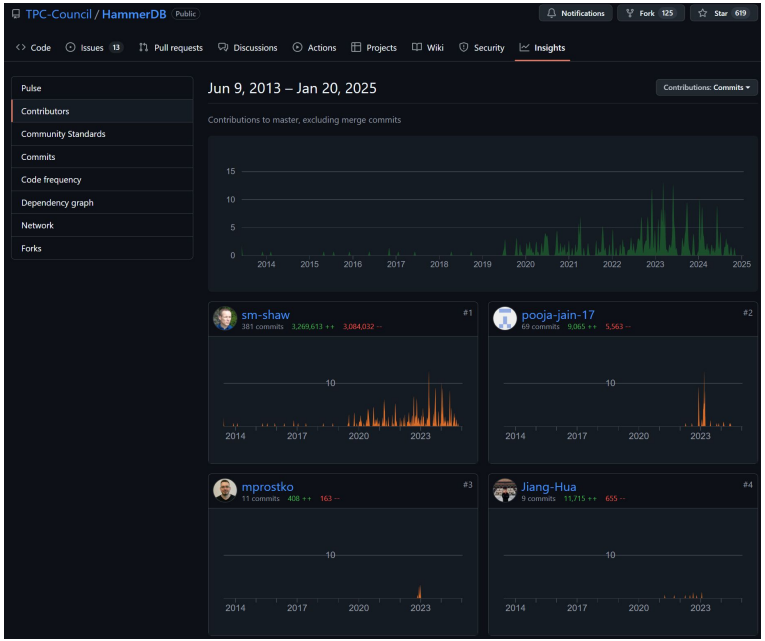
GNU License 3

https://github.com/TPC-Council/HammerDB

Release v1.0.0 (July 2003)

Actual Release v4.12 (Oct 2024)

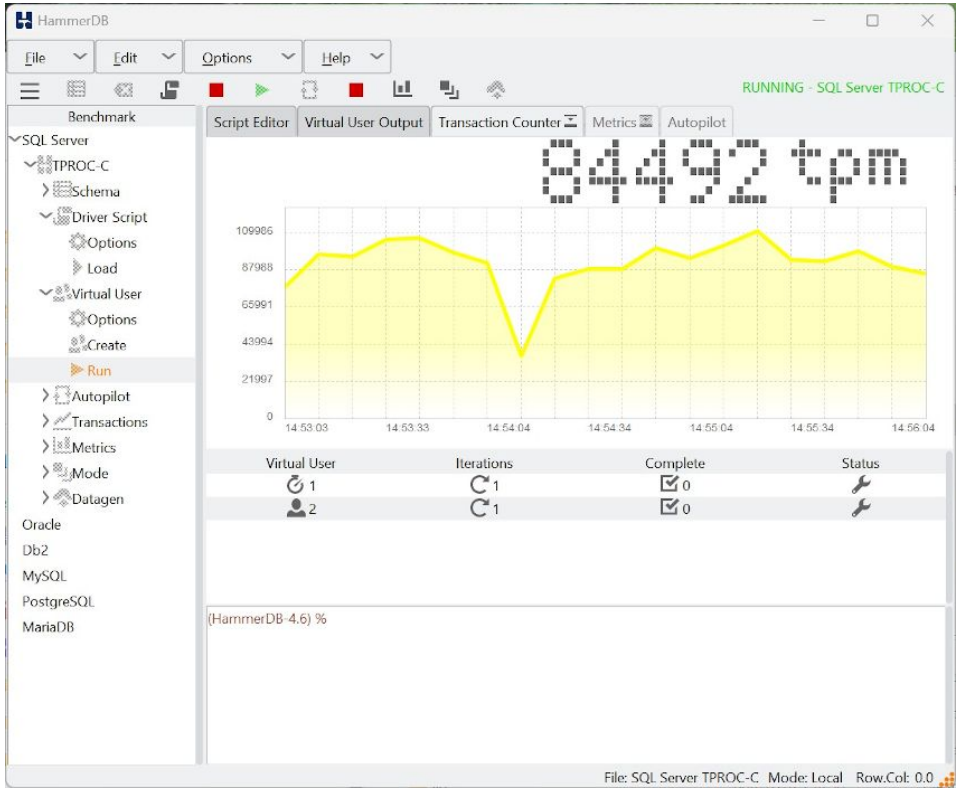
Tcl based



Let’s introduce… HammerDB

Databases

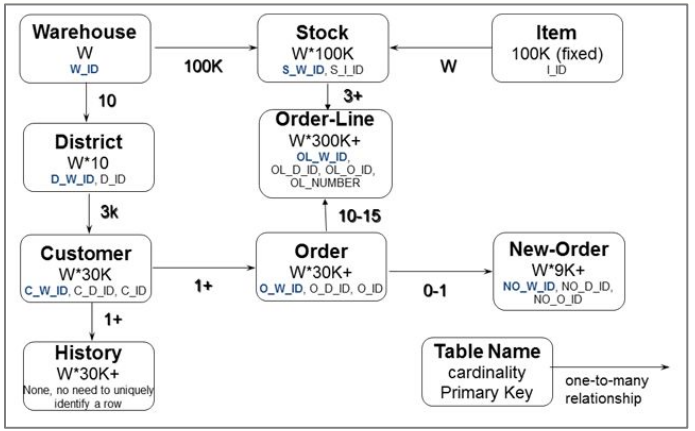
- **PostgreSQL**
- Oracle
- SQL Server
- DB2
- MySQL
- MariaDb

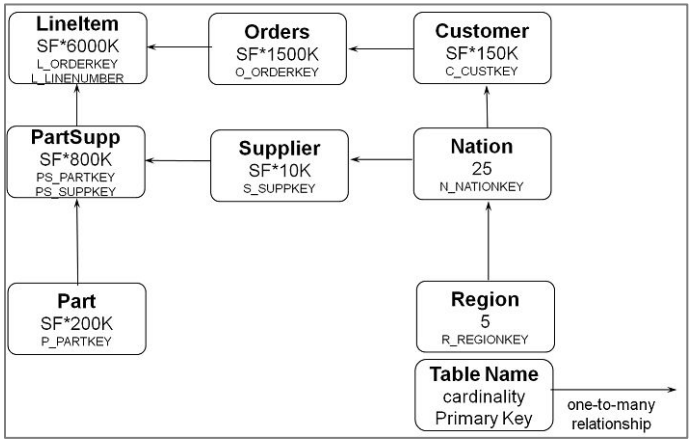


Let’s introduce… HammerDB

Workloads

- TPROC-C
  - Based on TPC-C
  - classic OLTP
- TPROC-H
  - Based on TPC-H
  - Analytics





Let’s introduce… HammerDB

Warehouses

- like scaling factor in pgbench
- 1 wh = 100,000 items, 10 sales districts with 3000 customers each
- 5 warehouses are around 510 MByte (TPC-C)

Virtual Users

- like clients/transactions part like pgbench

HammerDB - An easy quick start…

Installation

https://www.hammerdb.com/download.html

```
# wget https://github.com/TPC-Council/HammerDB/releases/download/v4.12/HammerDB-4.12-Linux.tar.gz

# tar -xzf HammerDB-4.12-Linux.tar.g
```

Yeah….thats it!

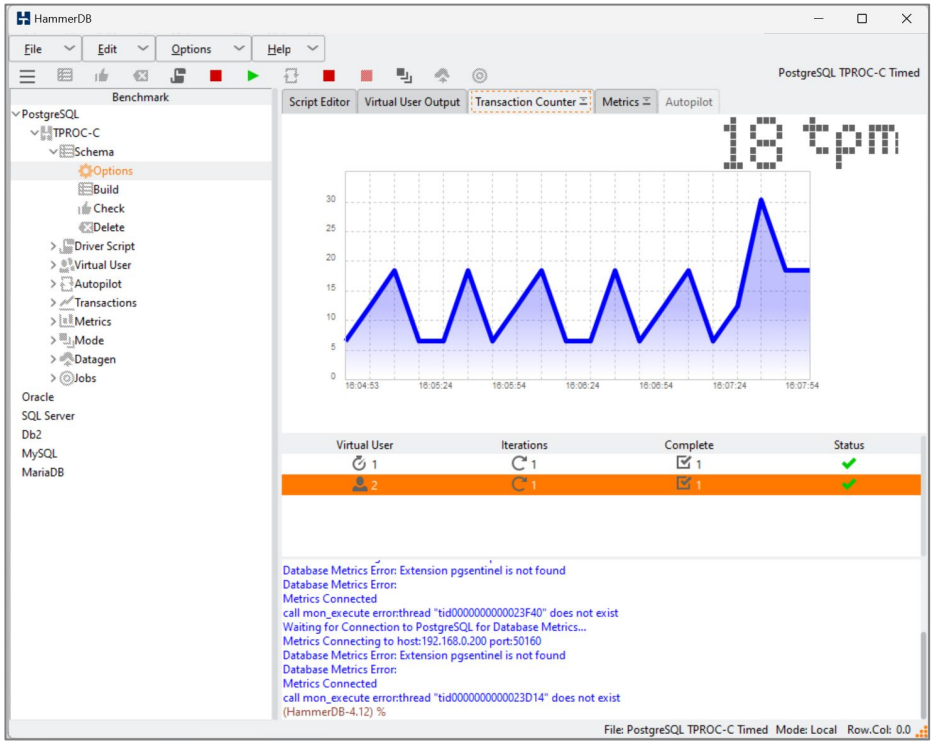
HammerDB - An easy quick start...

There is a GUI

Same on all OS

Easy to start with

But not that intuitive :-)



HammerDB - An easy quick start...

There is a command line as well...

```
~/HammerDB-4.12 []# ./hammerdbcli
    HammerDB CLI v4.12
    Copyright (C) 2003-2024 Steve Shaw
    Type "help" for a list of commands
    Initialized new Jobs on-disk database /tmp/hammer.DB
    hammerdb> librarycheck
```

HammerDB - An easy quick start...

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    HammerDB CLI v4.12
    Copyright (C) 2003-2024 Steve Shaw
    Type "help" for a list of commands
    Initialized new Jobs on-disk database /tmp/hammer.DB
    hammerdb> librarycheck
    Checking database library for Oracle
    Error: failed to load Oratcl - can't read "env(ORACLE_HOME)"
    …
    Checking database library for PostgreSQL
    Success ... loaded library Pgtcl for PostgreSQL
    Checking database library for MariaDB
    …
    hammerdb>
```

HammerDB

DEMO

HammerDB - An easy quick start...

Definition of the database type...

```
hammerdb> dbset db pg
Database set to PostgreSQL
```

Definition of the workload...

```
hammerdb> dbset bm TPC-C
Benchmark set to TPC-C for PostgreSQL
```

HammerDB - An easy quick start…

```
hammerdb> print dict
Dictionary Settings for PostgreSQL
connection {
 pg_host     = localhost
 pg_port     = 5432
 pg_sslmode = prefer
}
tpcc        {
 pg_count_ware        = 1
 pg_num_vu            = 1
 pg_superuser         = postgres
 pg_superuserpass     = postgres
 pg_defaultdbase      = postgres
 pg_user              = tpcc
 pg_pass              = tpcc
 pg_dbase             = tpcc
 …
}
```

HammerDB - An easy quick start...

Setting of the parameters...

```
hammerdb> diset connection pg_host 192.168.0.200
Changed connection:pg_host from localhost to 192.168.0.200 for PostgreSQL

hammerdb> diset connection pg_port 50178
Changed connection:pg_port from 5432 to 50178 for PostgreSQL

hammerdb> diset tpcc pg_num_vu 5
Changed tpcc:pg_num_vu from 1 to 5 for PostgreSQL

hammerdb> diset tpcc pg_count_ware 10
Changed tpcc:pg_count_ware from 1 to 10 for PostgreSQL
…
```

HammerDB - An easy quick start...

Creating the schema...

```
hammerdb> buildschema
Script cleared
Building 10 Warehouses with 6 Virtual Users, 5 active + 1 Monitor VU(dict value
pg_num_vu is set to 5)
Ready to create a 10 Warehouse PostgreSQL TPROC-C schema
in host 192.168.0.200:50178 sslmode PREFER under user TPCC in database TPCC?
Enter yes or no: replied yes
Vuser 1 created - WAIT IDLE
Vuser 2 created - WAIT IDLE
...
Vuser 1:GATHERING SCHEMA STATISTICS
Vuser 1:TPCC SCHEMA COMPLETE
Vuser 1:FINISHED SUCCESS
ALL VIRTUAL USERS COMPLETE
Schema Build jobid=6795743D62C903E243831353
hammerdb>
```

HammerDB - An easy quick start...

Let's roll...

```
hammerdb> vurun
Script loaded, Type "print script" to view
Vuser 1 created MONITOR - WAIT IDLE
Vuser 2 created - WAIT IDLE
2 Virtual Users Created with Monitor VU
Vuser 1:RUNNING
Vuser 1:DBVersion:17.2
Vuser 1:Beginning rampup time of 2 minutes
Vuser 2:RUNNING
…
Vuser 1:TEST RESULT : System achieved 20622 NOPM from 47596 PostgreSQL TPM
Vuser 1:FINISHED SUCCESS
Vuser 2:FINISHED SUCCESS
ALL VIRTUAL USERS COMPLETE
Benchmark Run jobid=6796AD8E62CA03E253833373
hammerdb>
```

About HammerDB results

NOPM (New orders per minute)

- How fast are you going
- Close relation to official tpmC

TPM (Transactions per minute)

- How hard your engine is working

Comparison performance

- NOPM can be compared between engines
- TPM can only be compared across the same engine
- TPM useful engineering metric to compare statistics

Back to my initial task…

Starting with pgbench

- because it was just there and established! :-)

All scenarios

- T-shirt size
- Cloud vendor

Long run (60 min), short run (5 min)

My approach with pgbench

A “good enough” compute instance (VM)

- each cloud vendor
- same region/availability zone
- Preventing latency

All DBs with defaults

Scripted (based on the example) sequenced set of pgbench runs

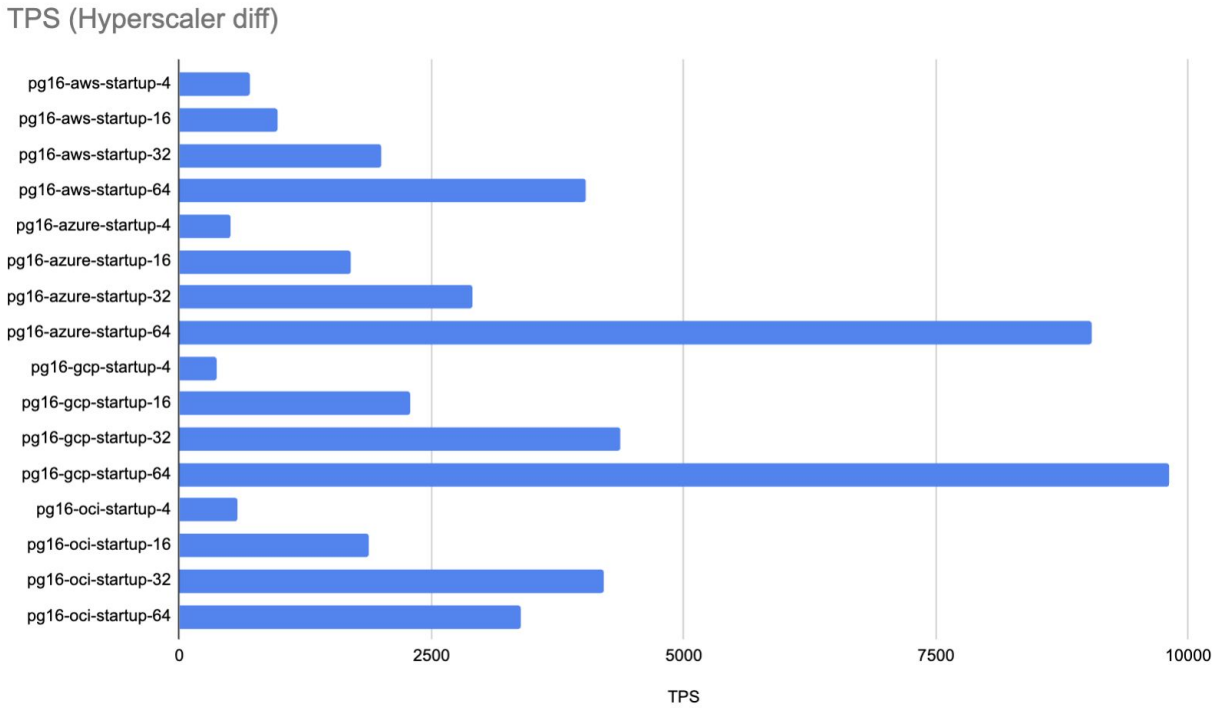
To prevent abnormalities, >3 runs checking average result

Rough scale increase for t-shirt sizes (*4, *16, *32, *64)

- Scale (500, 1500, 2500 and 4500)
- Client count (4, 16, 32 and 64)

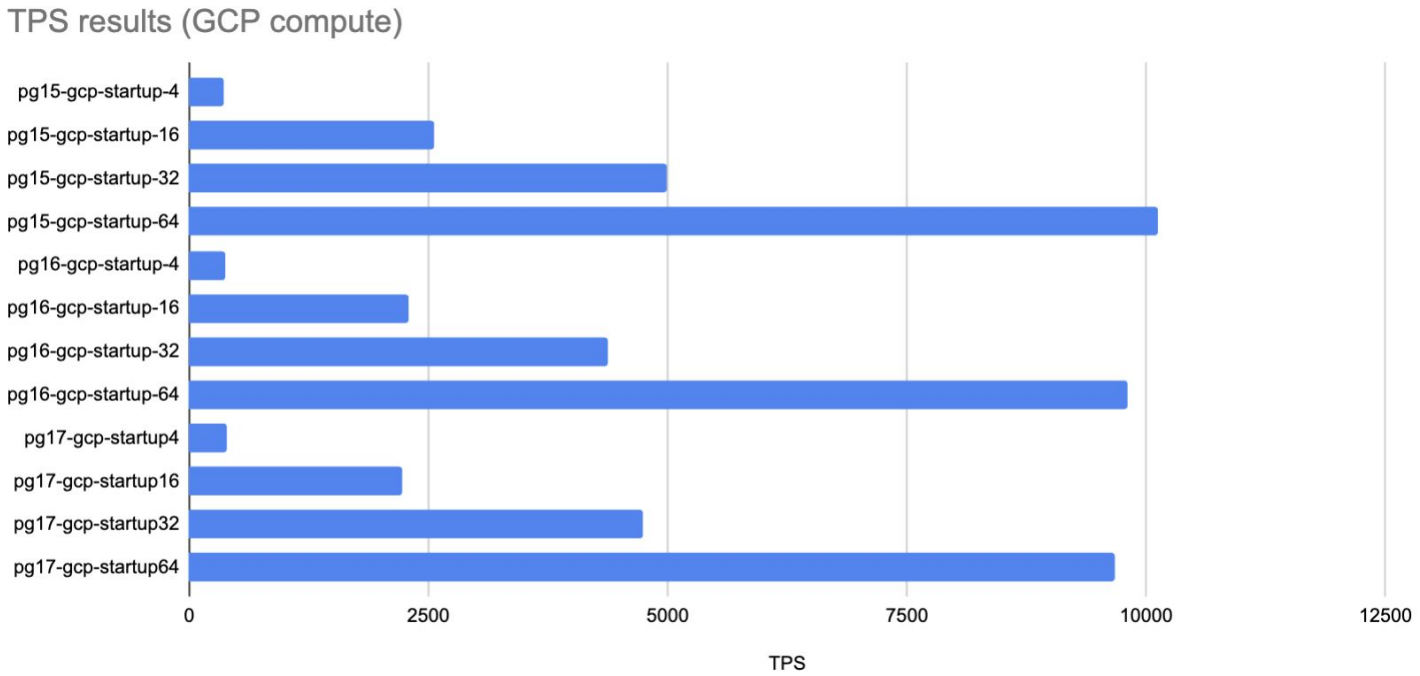
Some findings from me…

Huge differences between hyperscalers (compute instances)



Some findings from me...

Differences between PostgreSQL versions (15, 16, 17)



My next steps…

More research, long term results

Consolidating the results, creating blog post at Aiven

Switch to HammerDB

- Analytical workload integration (e.g. to challenge AlloyDB Omni)

DB Compute instance verification and comparison

Digging deeper and more specific PG parameter comparison

Automatism, Scripting improvements

Collaboration with companies like benchant

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Database Benchmarking
The Desolation of the Hyperscalers

Dirk Krautschick

Coming soon ... maybe at PGconf.EU???

So, what are the takeaways?

Choose your tooling wisely

- Effort vs. goals?

Always think about Udo! :-)

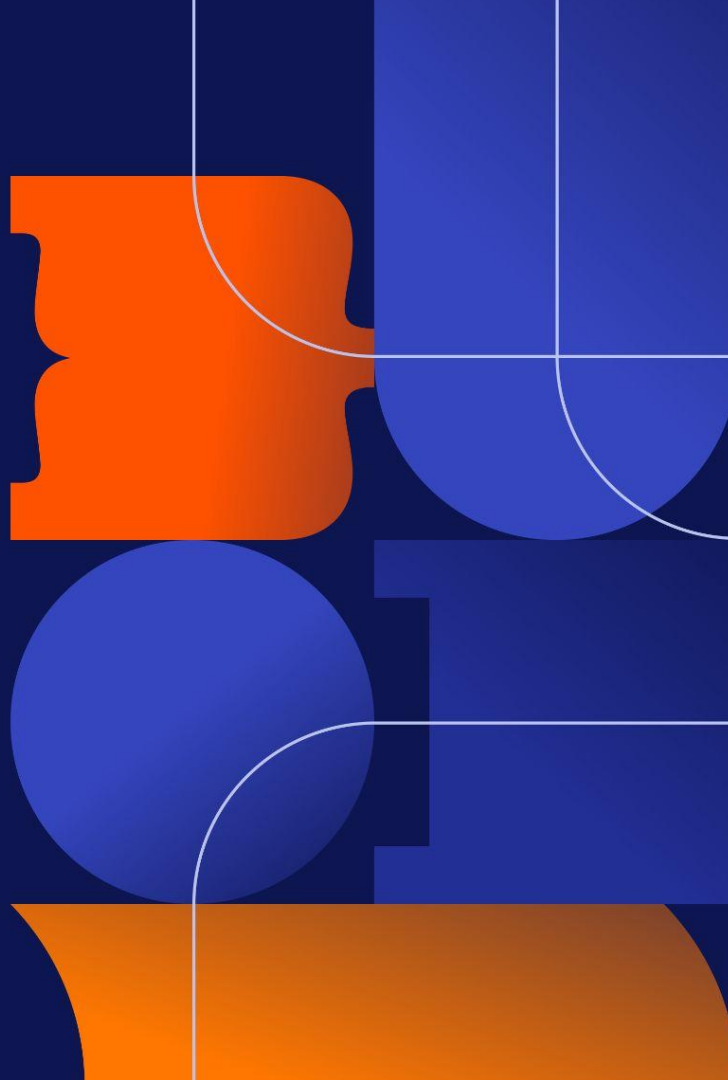
- Measuring is not difficult
- Context, comparison and structure is key

Define your objectives, metrics and foundations clearly

Take care of reproduction...and DO reproductions

Questions?

Please do ask or
catch me outside!



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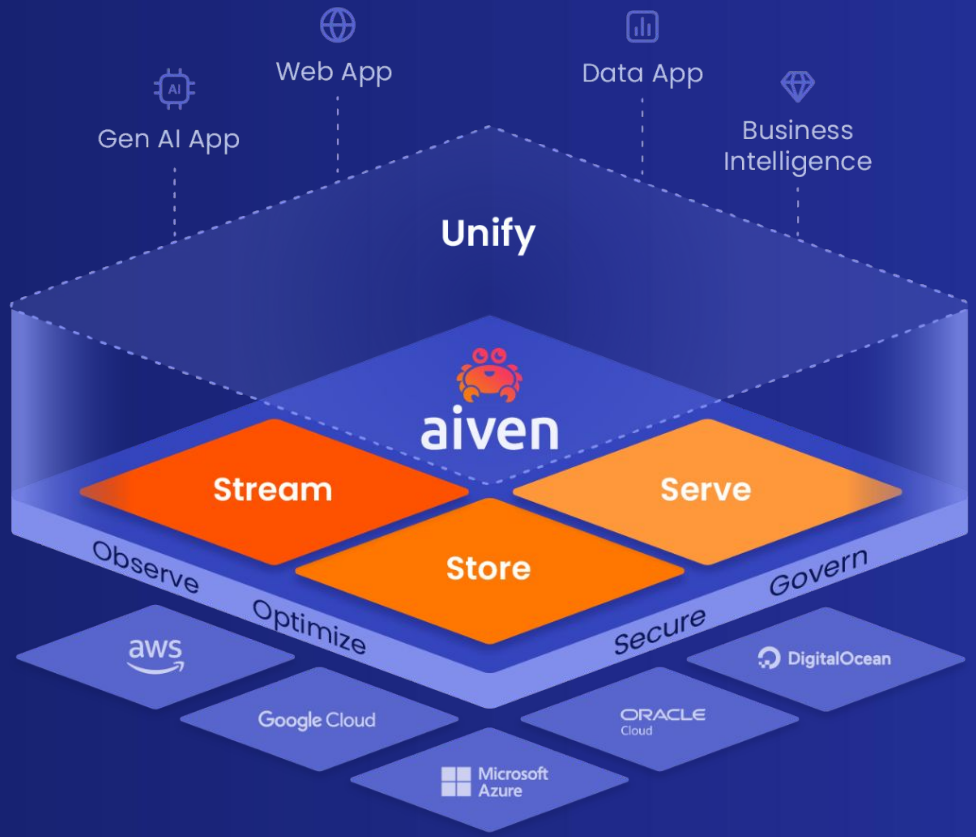

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Aiven for **MySQL**

Key-value database

Aiven for **Valkey**

Aiven for **Dragonfly**

SERVE

Data warehouse

Aiven for **ClickHouse®**

Time series database

Aiven for **Metrics**

Search engine

Aiven for **OpenSearch®**

Data visualization

Aiven for **Grafana®**

UNIFIED PLATFORM

Host

aws

Google Cloud

Microsoft Azure

DigitalOcean

ORACLE Cloud

Bring your own cloud

Deploy

Terraform

Kubernetes

API REST API

CLI Aiven CLI

Aiven Console

Integrate

Datadog

Prometheus

AWS CloudWatch

GCP Monitoring

MongoDB

AWS S3

GCP BigQuery

Couchbase

Snowflake

splunk> Splunk

Sumologic

Debezium

GCP Pub/Sub

GCP Storage

Customers


okta


snyk


DOORDASH


priceline


fiverr.


Norauto


DECATHLON


GTL


ACTIVISION
BLIZZARD


MIRAKL


GOV.UK


goto financial


spare


Schibsted


TOYOTA


paf


CONRAD


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ometria


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