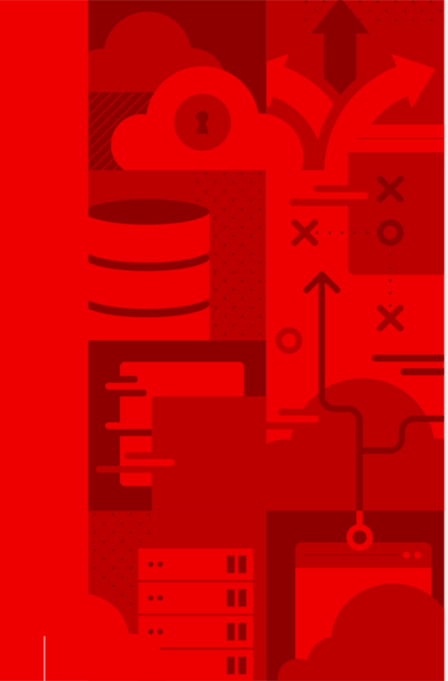


Calculating the future

How to model PostgreSQL performance

Dmitrii Dolgov

11-04-2024

- ➔ Why is it relevant for you?
- ➔ Back of the envelope calculations
- ➔ Approximation
- ➔ Simulation

Why bother?

Benchmarking instead?

Benchmarking instead?

➔ Resource intensive

Benchmarking instead?

- ➔ Resource intensive
- ➔ Hard to get full coverage

Benchmarking instead?

- ➔ Resource intensive
- ➔ Hard to get full coverage
- ➔ Requires cross validation

Benchmarking instead?

- ➔ Resource intensive
- ➔ Hard to get full coverage
- ➔ Requires cross validation

Enhance benchmarking!

It’s easy

It’s easy

➔ just bump max_wal_size?

It’s easy

- ➔ just bump max_wal_size?
- ➔ just increase shared_buffers?

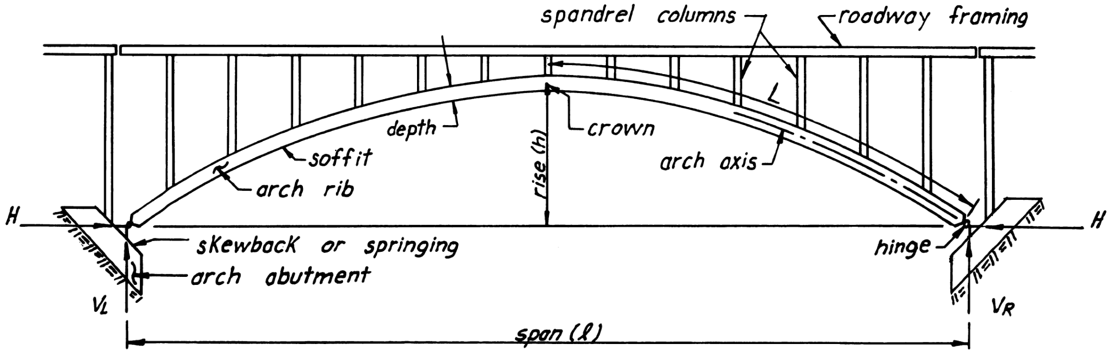
It’s easy

- ➔ just bump max_wal_size?
- ➔ just increase shared_buffers?
- ➔ just configure autovacuum?

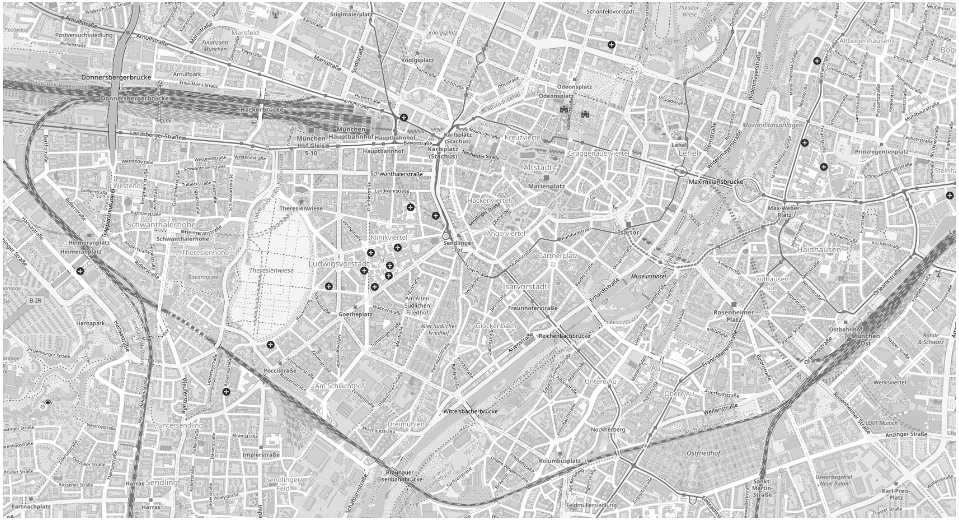
It’s easy

- ➔ just bump max_wal_size?
- ➔ just increase shared_buffers?
- ➔ just configure autovacuum?

Well...



Douglas A. Nettleton, John S. Torkelson Department of Transportation, Federal Highway Administration, Office of Engineering, Bridge Division


Donnersbergerbrücke
München Hauptbahnhof
Karlsplatz (Stachus)
Altstadt
Marienplatz
Theresienwiese
Ludwigsvorstadt
Isarvorstadt
Haidhausen
Lehel
Maximiliansbrücke
Odeonsplatz
Schwanthalerhöhe
Westend
Sendlinger Tor
Gärtnerplatz
Glockenbach
Untere Au
Obere Au
Ostfriedhof
Ostbahnhof München Ost
Rosenheimer Platz
Untersendling
Harras Sendling
Hansapark
Goetheplatz
Klinikviertel
Angerviertel
Hackenviertel
Graggenauer Viertel
Kreuzviertel
Marsfeld
Altbogenhausen
Prinzregentenplatz
Max-Weber-Platz
Werksviertel
Isartor

OSM

Target of the experiment

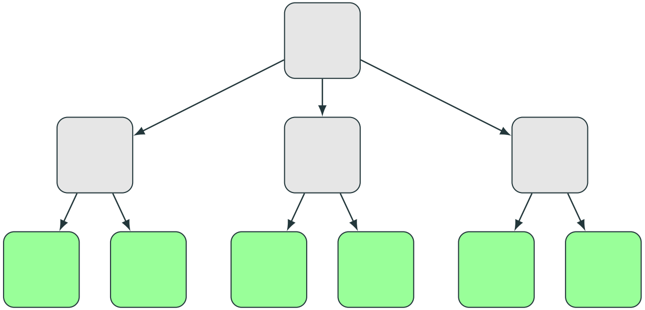
```sql
create table test(a int);
create index on test(a);
create table test(a int);
create index on test(a);
```

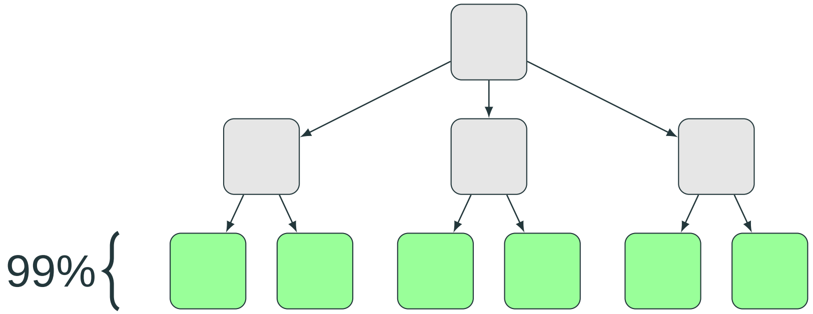
Back of the envelope calculations

Assuming we know the schema,

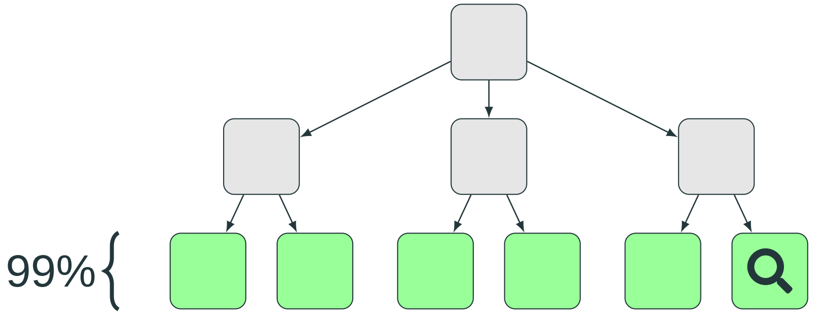
how to approximate space usage?

```sql
create table test(a int);
create index on test(a);
create table test(a int);
create index on test(a)
    with (fillfactor = 100);
```





Goetz Graefe. ”Modern B-Tree Techniques.” Foundations and Trends in Databases 3.4 (2010) 203-402



Goetz Graefe. ”Modern B-Tree Techniques.” Foundations and Trends in Databases 3.4 (2010) 203-402

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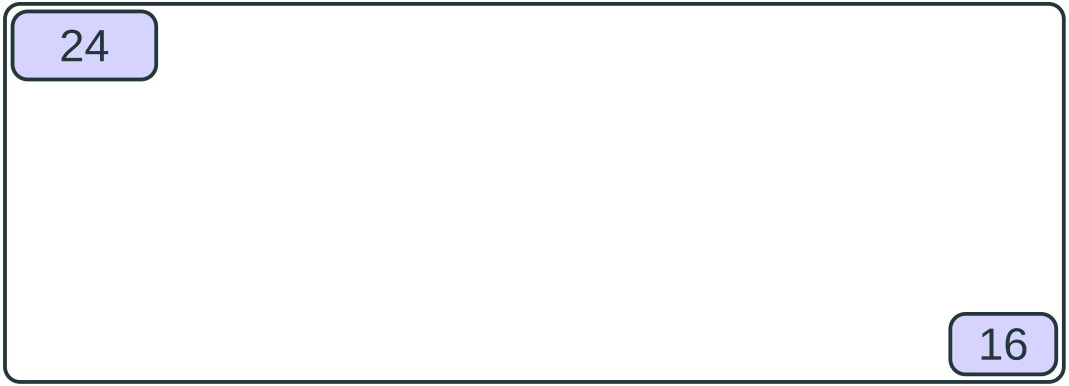
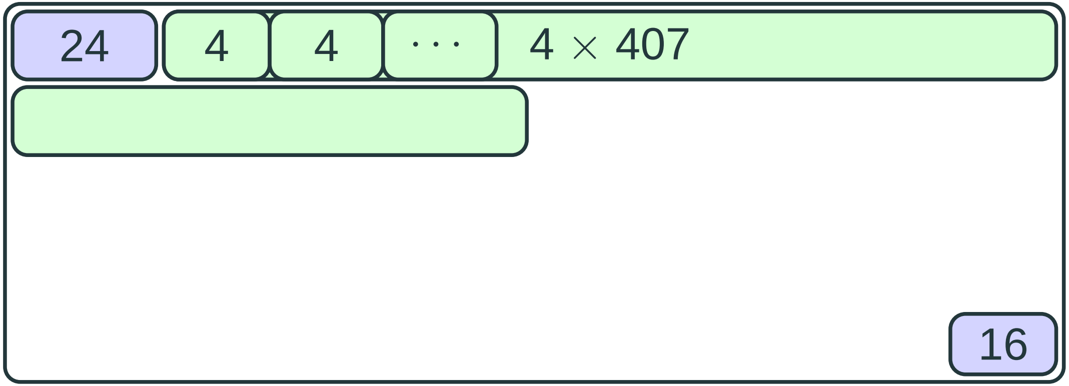
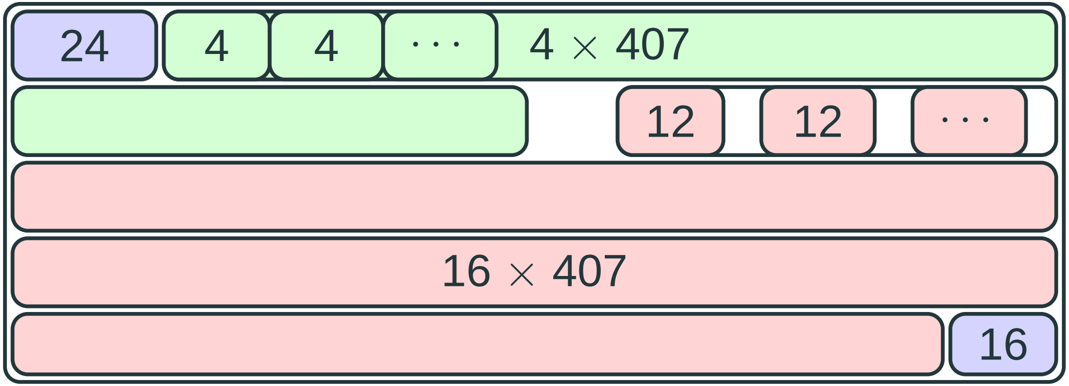
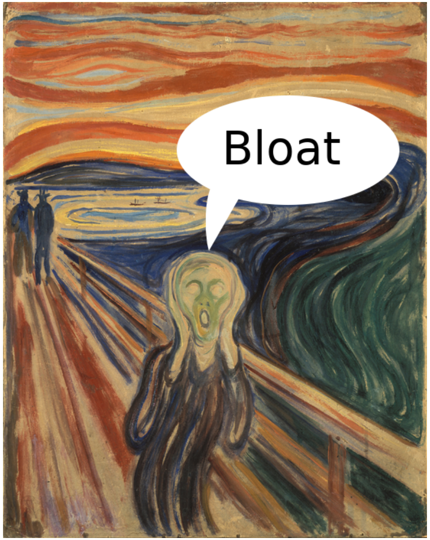


8192 / 1668



8192 / 8180



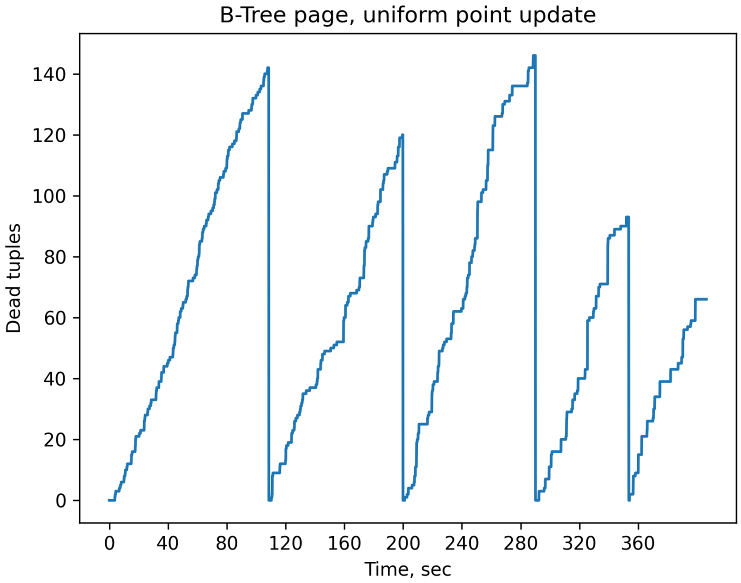


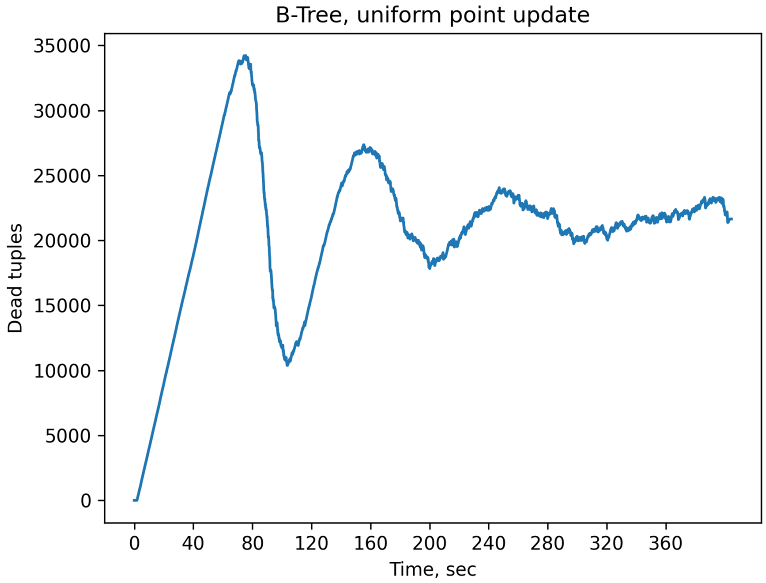
Edvard Munch – The Scream (about a bloated index)

Assuming we know the workload, how to approximate bloat?

```
-- -M prepared --rate=max-rate
\set aid random(0, N)
\set bid random(0, N)

-- a pre-populated table
update test set a = :aid
    where a = :bid;
```


B-Tree page, uniform point update
Dead tuples
0
20
40
60
80
100
120
140
Time, sec
0
40
80
120
160
200
240
280
320
360


B-Tree, uniform point update
Dead tuples
35000
30000
25000
20000
15000
10000
5000
0
0
40
80
120
160
200
240
280
320
360
Time, sec

Portrait de l'artiste sous les traits d'un moqueur

Approximation

Assuming we know the workload, how to approximate amount of IO?

```
create table test(a int);
create index on test(a)
    with (fillfactor = 100);
```

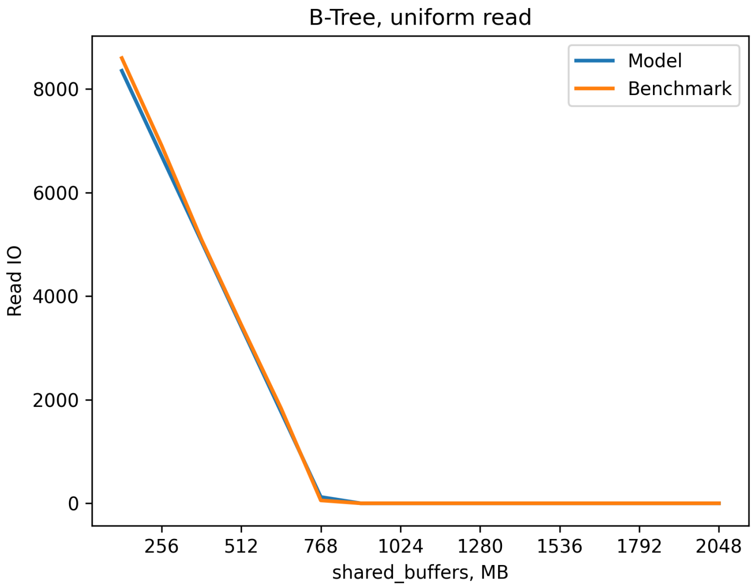
```
create unlogged table test(a int);
create index on test(a)
    with (fillfactor = 100);
```

```
create unlogged table test(a int);
create index on test(a)
    with (fillfactor = 100);

# autovacuum = off
# *_flush_after = 0
# etc
```

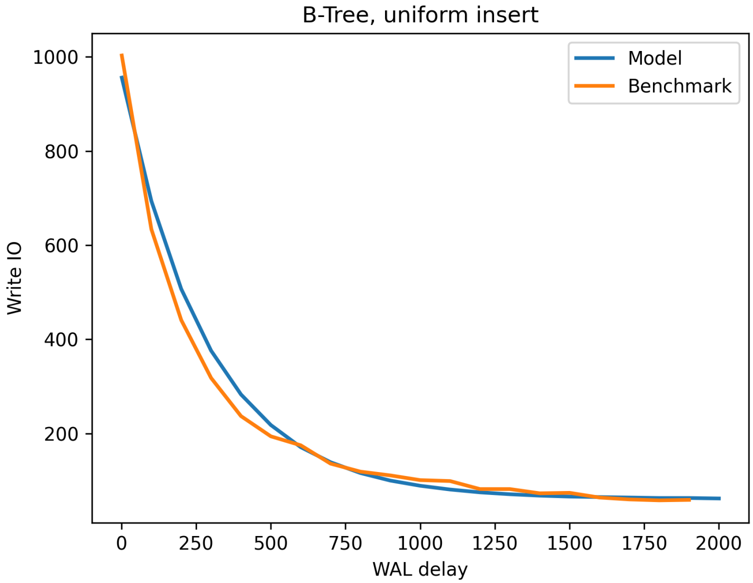
```
-- -M prepared --rate=max-rate
\set aid random(0, N)

-- a pre-populated table
select * from test where a = :aid;
```


B-Tree, uniform read
Model
Benchmark
Read IO
8000
6000
4000
2000
0
256
512
768
1024
1280
1536
1792
2048
shared_buffers, MB

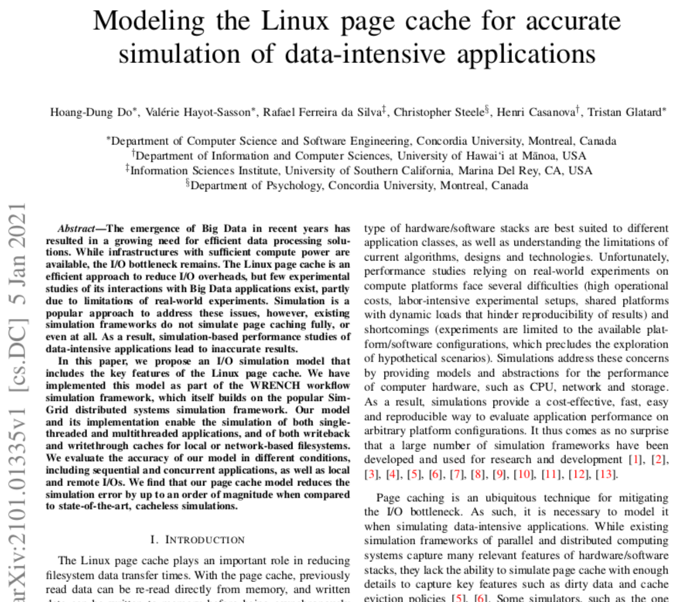
```
-- -M prepared --rate=max-rate
\set aid random(0, N)

-- an empty table
insert into test values(:aid);
```


B-Tree, uniform insert
Model
Benchmark
Write IO
1000
800
600
400
200
0
250
500
750
1000
1250
1500
1750
2000
WAL delay

$$IO = Q \cdot M_{press} \sum_{l=1}^{L} \frac{N_l}{N} + Q_w \cdot W_g + \frac{Q_w}{I}$$

$$IO = \overbrace{Q \cdot M_{press} \sum_{l=1}^{L} \frac{N_l}{N}}^{\text{Read}} + \underbrace{Q_w \cdot W_g}_{\text{Insert}} + \overbrace{\frac{Q_w}{I}}^{\text{Split}}$$



Modeling the Linux page cache for accurate simulation of data-intensive applications

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*Department of Computer Science and Software Engineering, Concordia University, Montreal, Canada
†Department of Information and Computer Sciences, University of Hawai'i at Mānoa, USA
‡Information Sciences Institute, University of Southern California, Marina Del Rey, CA, USA
§Department of Psychology, Concordia University, Montreal, Canada

***Abstract*—The emergence of Big Data in recent years has resulted in a growing need for efficient data processing solutions. While infrastructures with sufficient compute power are available, the I/O bottleneck remains. The Linux page cache is an efficient approach to reduce I/O overheads, but few experimental studies of its interactions with Big Data applications exist, partly due to limitations of real-world experiments. Simulation is a popular approach to address these issues, however, existing simulation frameworks do not simulate page caching fully, or even at all. As a result, simulation-based performance studies of data-intensive applications lead to inaccurate results.**

In this paper, we propose an I/O simulation model that includes the key features of the Linux page cache. We have implemented this model as part of the WRENCH workflow simulation framework, which itself builds on the popular SimGrid distributed systems simulation framework. Our model and its implementation enable the simulation of both single-threaded and multithreaded applications, and of both writeback and writethrough caches for local or network-based filesystems. We evaluate the accuracy of our model in different conditions, including sequential and concurrent applications, as well as local and remote I/Os. We find that our page cache model reduces the simulation error by up to an order of magnitude when compared to state-of-the-art, cacheless simulations.

I. Introduction

The Linux page cache plays an important role in reducing filesystem data transfer times. With the page cache, previously read data can be re-read directly from memory, and written

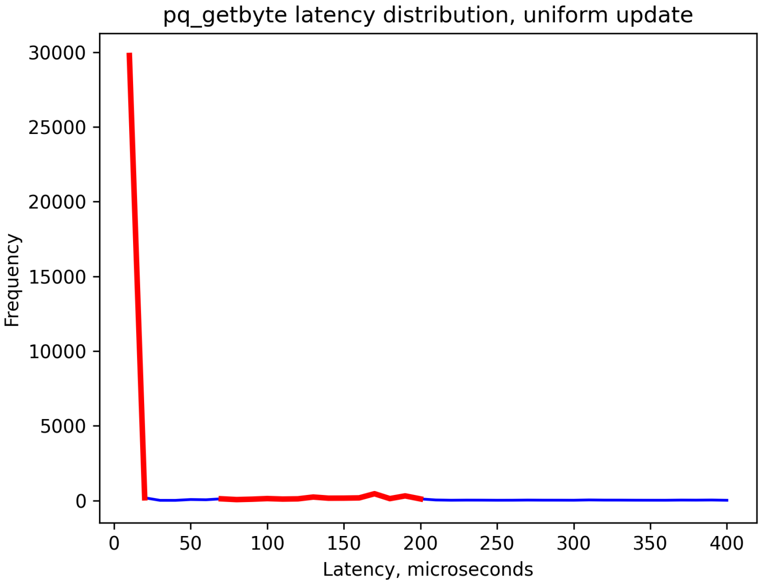
type of hardware/software stacks are best suited to different application classes, as well as understanding the limitations of current algorithms, designs and technologies. Unfortunately, performance studies relying on real-world experiments on compute platforms face several difficulties (high operational costs, labor-intensive experimental setups, shared platforms with dynamic loads that hinder reproducibility of results) and shortcomings (experiments are limited to the available platform/software configurations, which precludes the exploration of hypothetical scenarios). Simulations address these concerns by providing models and abstractions for the performance of computer hardware, such as CPU, network and storage. As a result, simulations provide a cost-effective, fast, easy and reproducible way to evaluate application performance on arbitrary platform configurations. It thus comes as no surprise that a large number of simulation frameworks have been developed and used for research and development [1], [2], [3], [4], [5], [6], [7], [8], [9], [10], [11], [12], [13].

Page caching is an ubiquitous technique for mitigating the I/O bottleneck. As such, it is necessary to model it when simulating data-intensive applications. While existing simulation frameworks of parallel and distributed computing systems capture many relevant features of hardware/software stacks, they lack the ability to simulate page cache with enough details to capture key features such as dirty data and cache eviction policies [5], [6]. Some simulators, such as the one

Simulation

Assuming we know the workload, how to approximate query latency?

```
data Event = PqGetByte TxLatency
           | GetCachedPlan TxLatency
           | BtGetTuple TxLatency
           | BtInsert TxLatency
           | HeapPagePrune TxLatency
           | HeapUpdate TxLatency
           | CommitTx TxLatency
           | SocketFlush TxLatency
```


pq_getbyte latency distribution, uniform update
Frequency
30000
25000
20000
15000
10000
5000
0
0
50
100
150
200
250
300
350
400
Latency, microseconds

Summary

- → Predicting the future is possible!
- → Be aware of limitations
- → Reduce large system to small parts
- → Combine with benchmarking and profiling

Questions?

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ddolgov at redhat dot com