Pushing the limits on a single machine

A case study on squeezing the most out of a single PostgreSQL instance

By:
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Why single instance?

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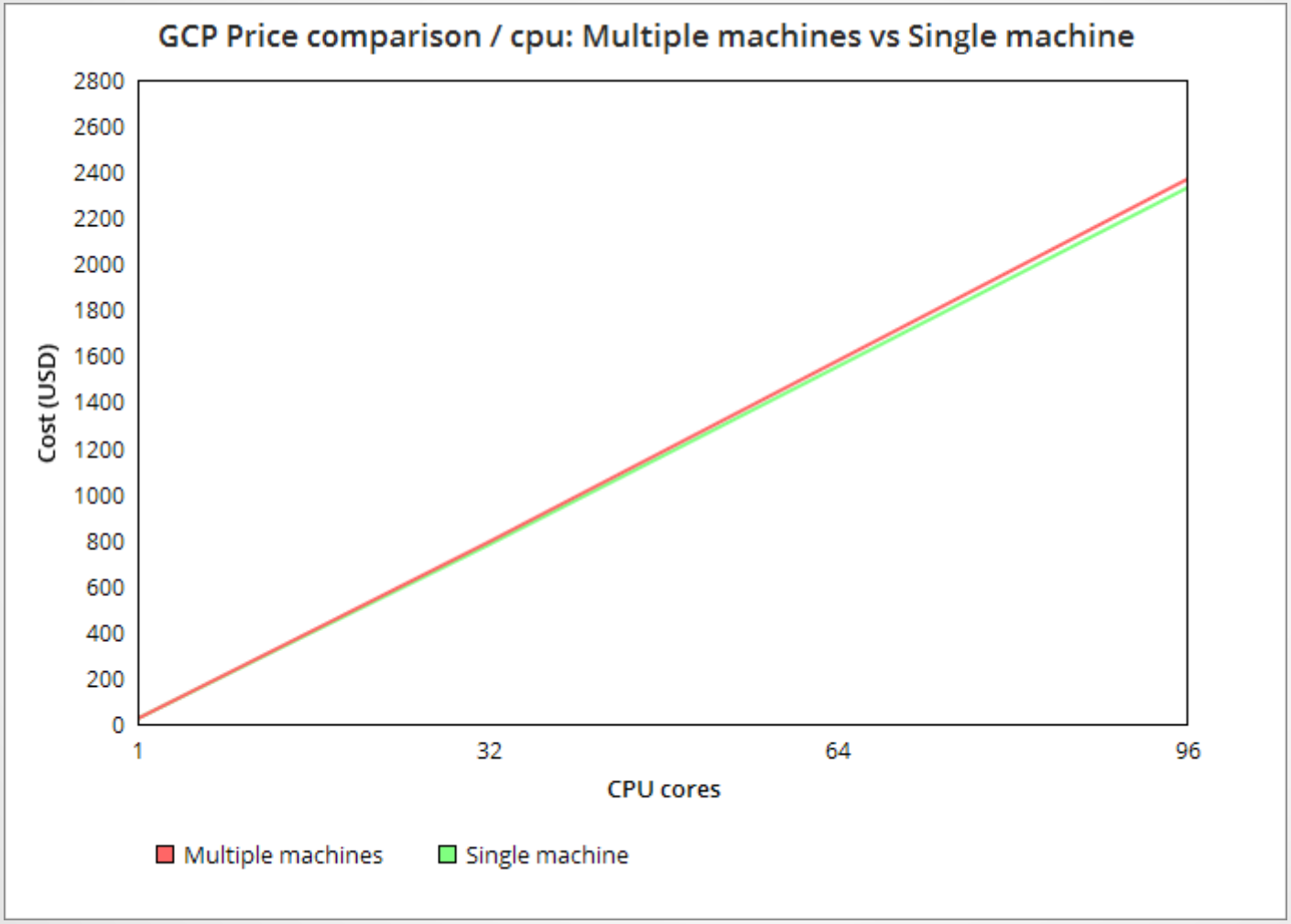

Why single instance?

- Multiple machines have:
  - Higher operational complexity
  - Higher fixed “tax” (OS, monitoring etc)
  - Higher application complexity

About me?

About me?

- 6+ years of building and managing DBs
- Scaling from scratch to 10s of Petabytes
- CTO @ Clarisights
- Apache HBase Committer
- Data Infra @ Facebook and Rocket Fuel

What is Clarisights?

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- A SaaS platform
- Realtime, interactive and contextual reporting
- Targeted to high performance “marketing teams”
- Derives maximum value for medium to large enterprises

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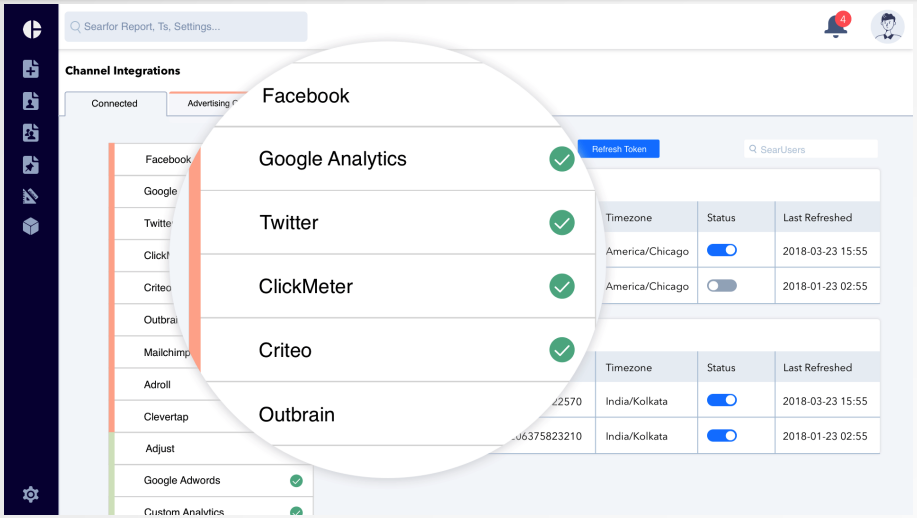
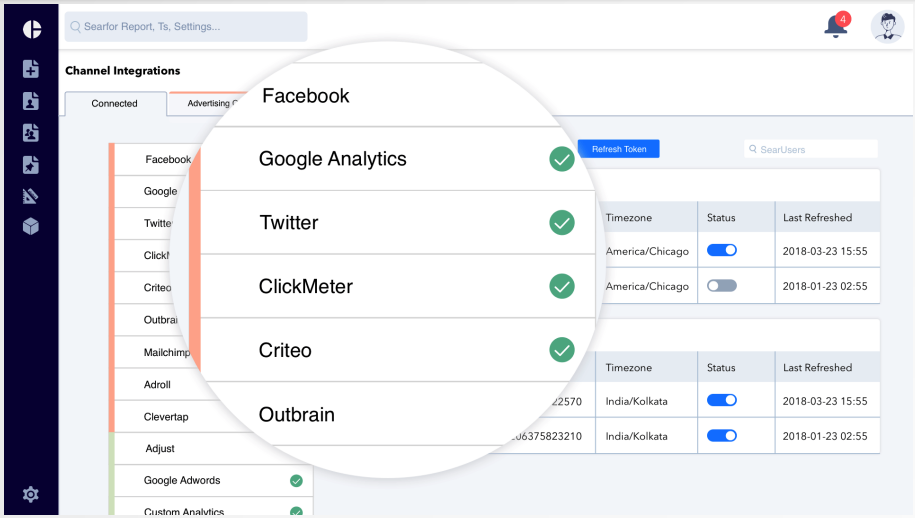
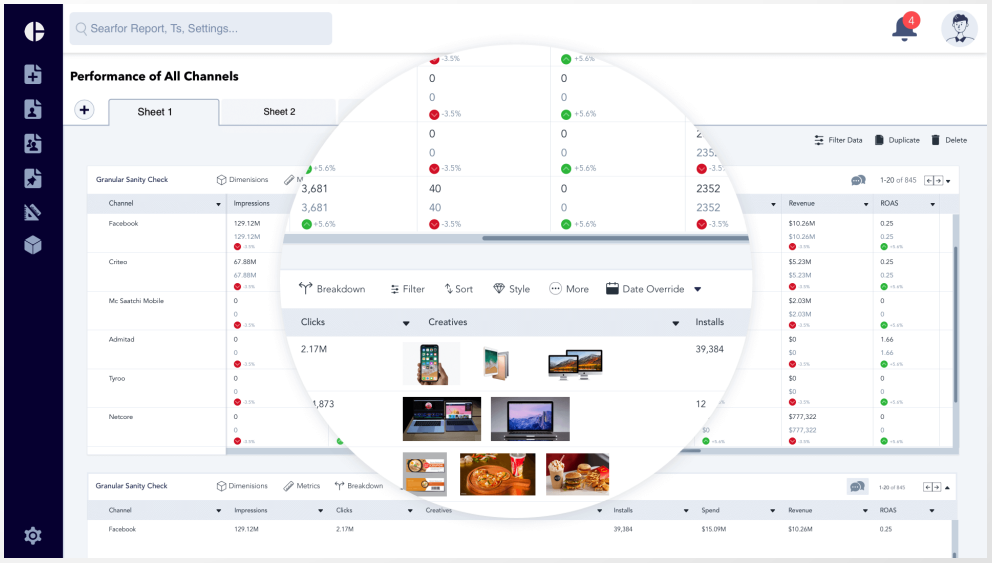
- Targeted to high performance “marketing teams”
- Derives maximum value for medium to large enterprises
- A single vertical solution for 3 problems:
  - API integration
  - Data transformation and enrichment
  - Interactive analytics

Clarisights



Clarisights





Data engg challenge @ Clarisights

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- Aggregate timeseries data for each Ad/Keyword etc
- 100s of dynamic user defined dimensions
  - Across different sources
  - E.g “City” can be defined for both FB and Google
  - Data enrichment after ingest: Historical updates to dimensions
- Reports (facts) with wide rows (10k+ metrics)
- Historical updates to facts
- High dimensional analytics on “mutating” data

Data engg challenge @ Clarisights

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  - 5 billion+ updates per day
  - 400 billion+ of reads per day
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  - *Still ongoing research in industry*

Problem with HTAP: RUM conjecture

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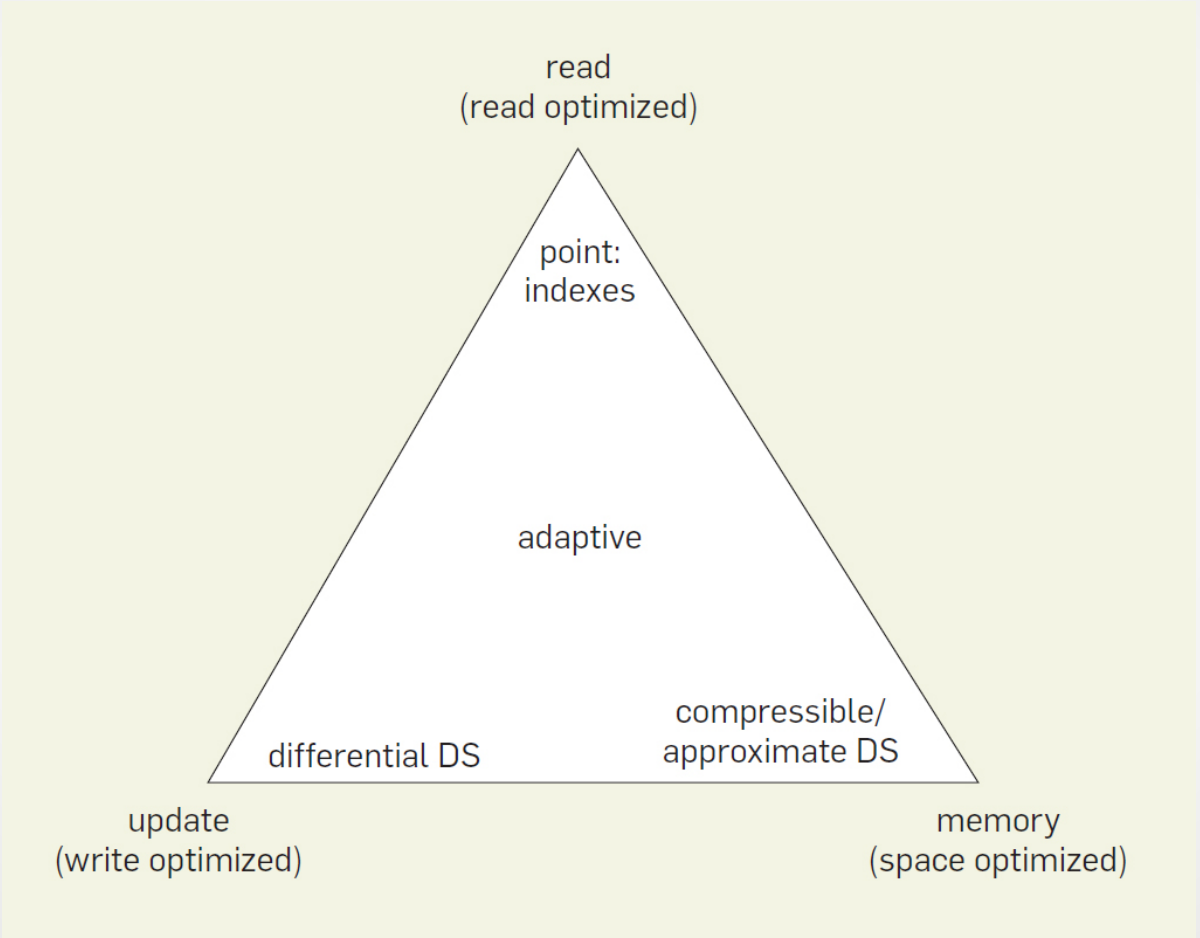

Two systems

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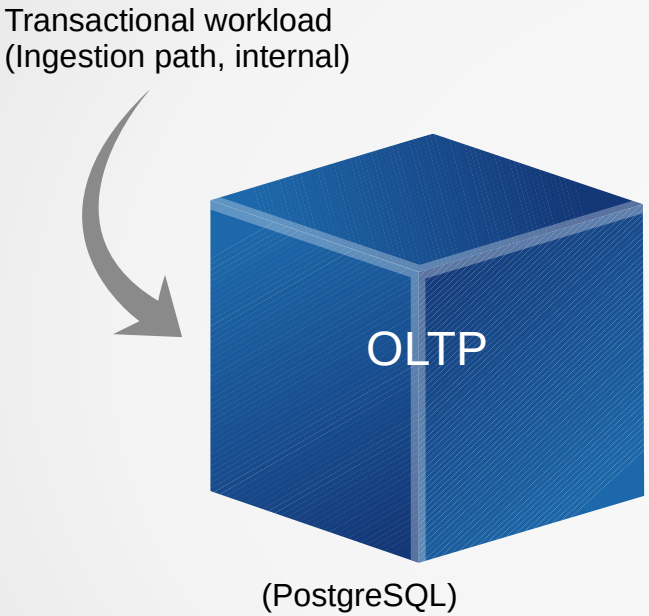
Transactional workload
(Ingestion path, internal)
OLTP
(PostgreSQL)

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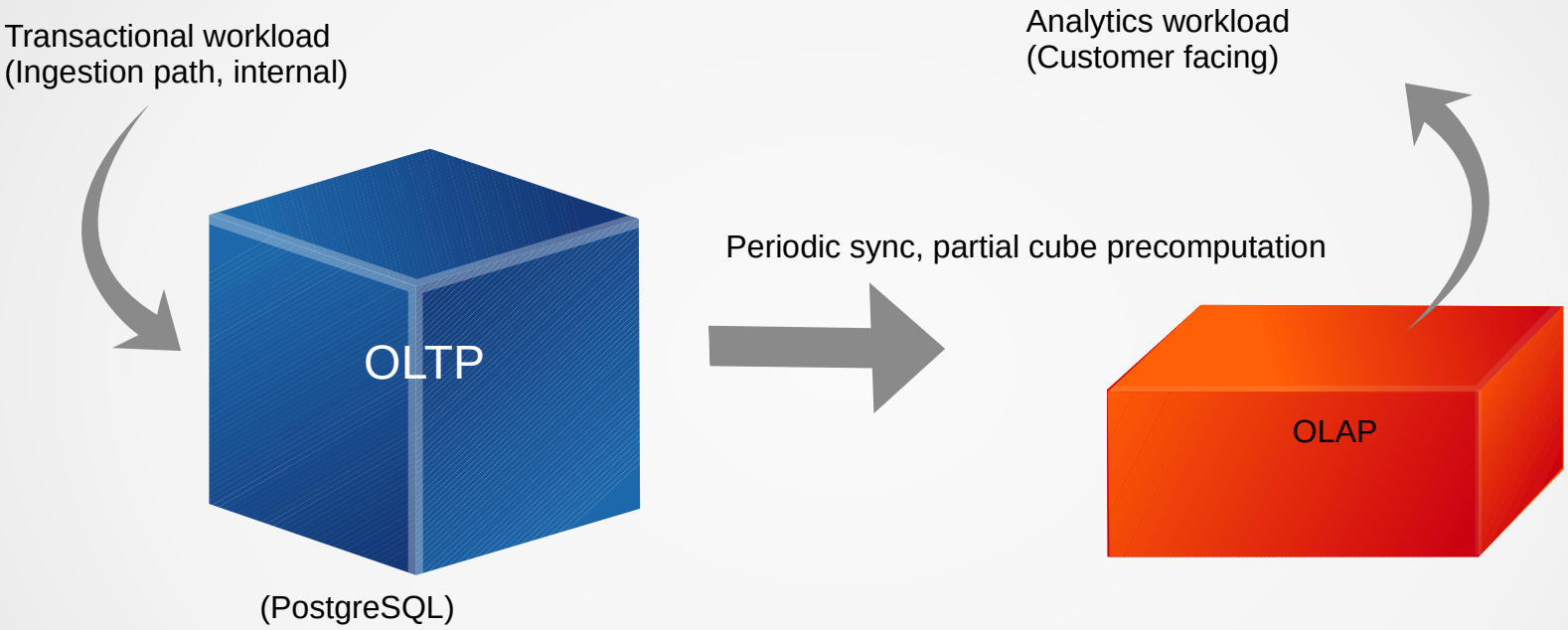
Transactional workload
(Ingestion path, internal)
OLTP
(PostgreSQL)
Periodic sync, partial cube precomputation
Analytics workload
(Customer facing)
OLAP

General approach to scaling

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- Scaling PostgreSQL as a service
  - Config/Systems tuning
  - Intelligent data storage layout

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  - Config/Systems tuning
  - Intelligent data storage layout
- RUM aware access patterns

Optimizing for throughput

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- Write latency is harder to optimize in PostgreSQL
  - Synchronous access patterns from client
  - Backed by asynchronous design of server
  - Design is more throughput driven than latency
- Read latency and throughput can both be optimized

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- Write latency is harder to optimize in PostgreSQL
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  - Backed by asynchronous design of server
  - Design is more throughput driven than latency
- Read latency and throughput can both be optimized
- Our use case is throughput driven

Optimizing for throughput: Concurrency

Approach

- Latency is not a problem
- Throw massive number of clients
- 10k+ clients connected simultaneously per instance

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Problems

- Memory overhead for connections
- 1 GB allocation limit in PostgreSQL ~ 10K max connections

Concurrency: PGBouncer for the save

- Session, Transaction and Statement pooling modes

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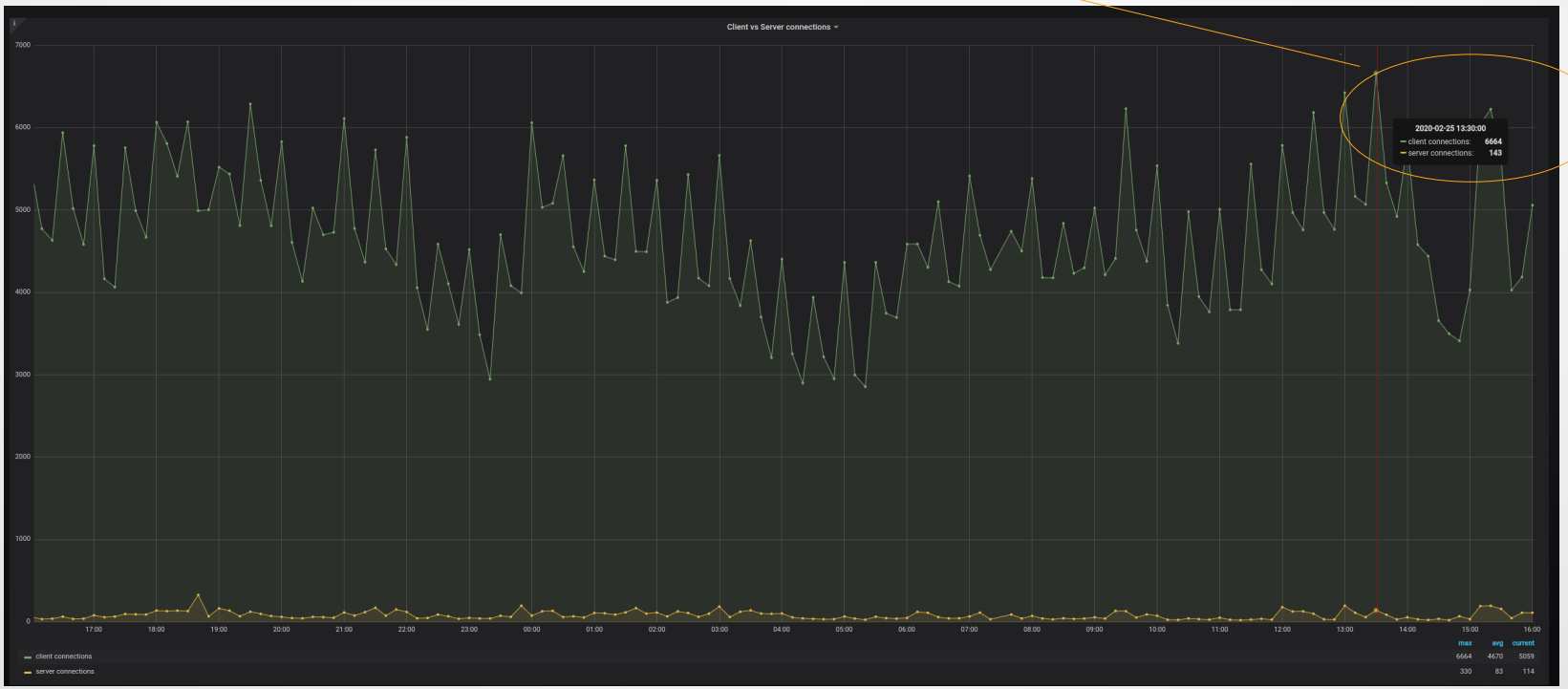
- Session, Transaction and Statement pooling modes
- Transaction pooling mode provides good enough protection

Server conns: 163
Client conns: 6664



Transaction Pooling: What do we lose?

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- Session specific features:
  - Prepared statements
  - Cursors with Hold
  - Advisory locks (Rails migrations)

Scaling reads: OLAP Sync

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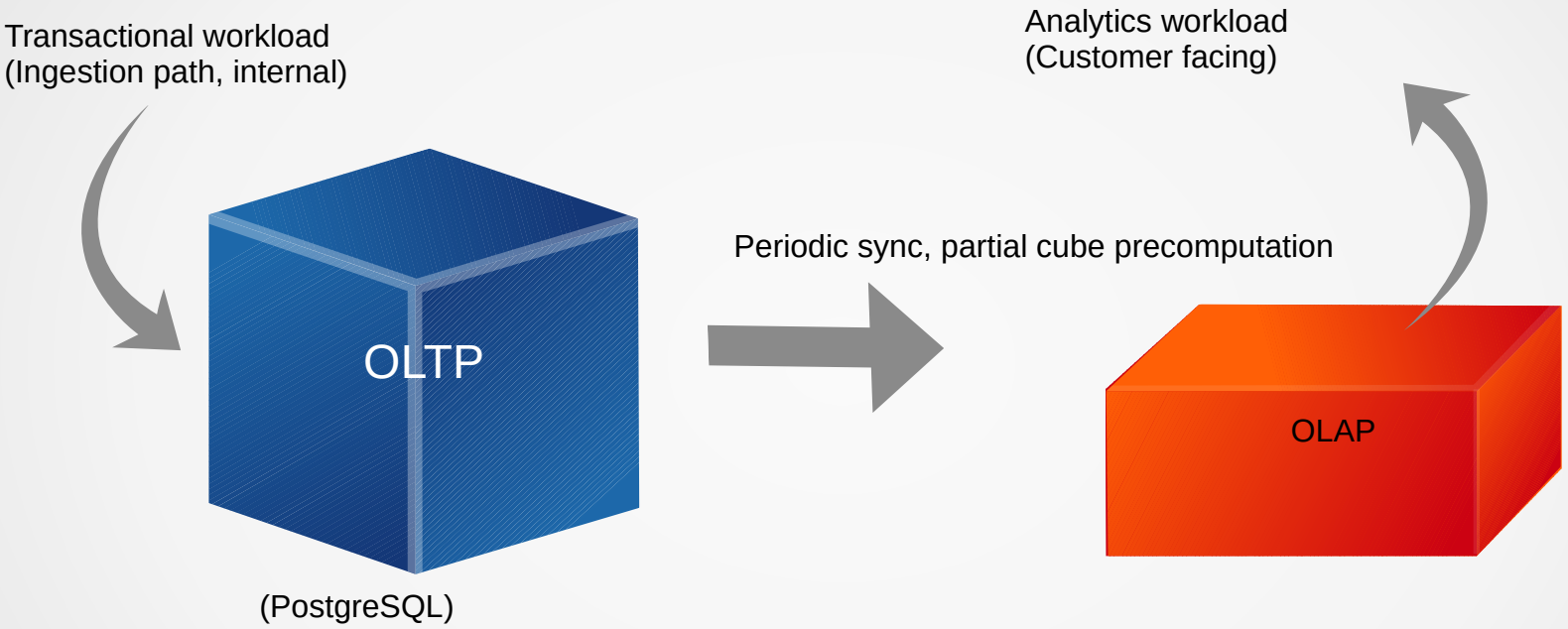

OLAP sync: precomputation

- Queries over several days worth of data.
- Queries involving aggregations:

```
select sum(installs)::bigint as aj_installs,
sum(sessions)::bigint as aj_sessions, .....,
to_char(date_trunc('YYYY-MM-DD',
timestamp_utc::timestamp at time zone 'UTC')) as day
from adjust_revenues
where account_id = 1
group by internal_id, day
```

OLAP sync: Batch reads

- Need to read in batches of 1000 results

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  Initial approach

- Rails Active Record *find_in_batches*

  select sum(installs)::bigint as aj_installs, ...
  group by account_id, internal_id, day ***ORDER BY id ASC OFFSET 1001 LIMIT 1000***

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  Initial approach

- Rails Active Record *find_in_batches*

  select sum(installs)::bigint as aj_installs, ...
  group by account_id, internal_id, day ***ORDER BY id ASC OFFSET 1001 LIMIT 1000***

- Too much redundant work
  - Filter supported by indexes
  - But still need to do group by and order by

OLAP sync: Removing redundant work

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First optimization: Use cursors

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  - Memory overhead
  - Impacts other operations

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Second optimization: Use cursors with hold

- Session specific feature
- Does not work with transaction pooling

OLAP sync: Removing redundant work

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Third optimization: Materialized views

- Do not automatically refresh
- Need to clean up old data from the view: expensive

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Fourth optimization: Temporary tables

- We got it right this time

OLAP sync: Removing redundant work

Third optimization: Materialized views

- Do not automatically refresh
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Fourth optimization: Temporary tables

- We got it right this time
- Did we?

OLAP sync: Temporary tables

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- Replication stopped working
- Temporary tables' writes are also logged to WAL
- Too many writes to the WAL
  - Replication can't run fast enough to keep up

OLAP sync: Final solution

- Normal PostgreSQL tables
- Unlogged tables
  - Not written to WAL
  - No need to replicate or recreate
- Important: Separate tablespace and disk

Unlogged tables: What did we lose?

- Need to cleanup the tables
- Need to adjust monitoring scripts, automated workflows
- pg_class fragmentation

Scaling reads: Indexing “impactful” queries

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  - Problem: Targetted only towards slow queries

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  - Dexter, PGHero
  - Problem: Targetted only towards slow queries
- Attempt 2: Using application sampling profiler to pinpoint bottlenecks
  - Problem: Higher turnaround time to pinpoint PG queries of interest

Scaling reads: Finding “impactful” queries

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- Approach 3: Sampling profiler on *pg_stat_activity*

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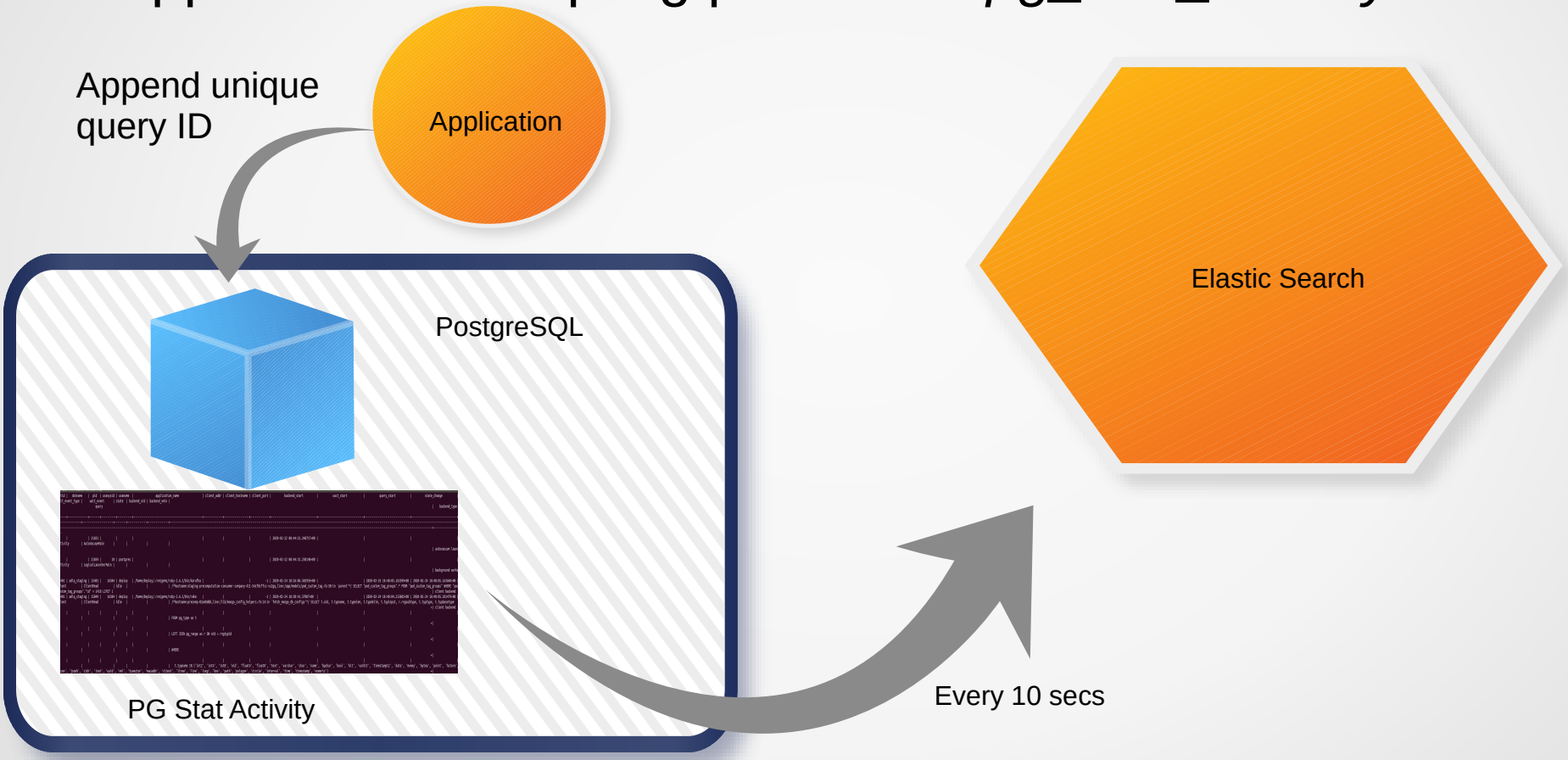
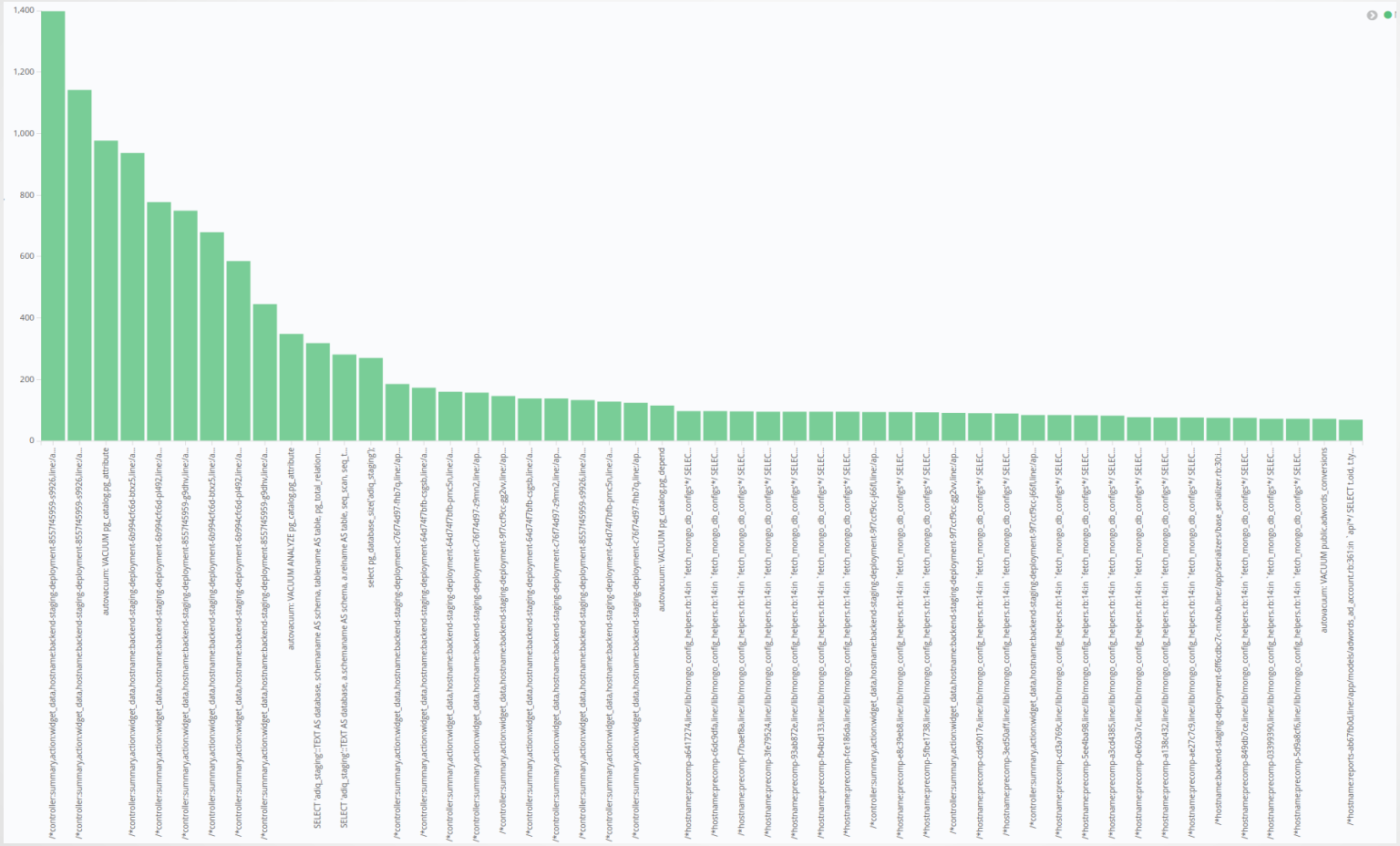


Scaling reads: Finding “impactful” queries

Fig: Count of queries by ID



No. of times query was active (Last X minutes)

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Scaling writes: Write amplification

- PostgreSQL is not “optimized” for point updates
- Any update is a Copy-on-Write (CoW) operation
  - PostgreSQL deals only in pages (8KB)
- The CoW happens with a delay

Scaling writes: Delayed write amplification

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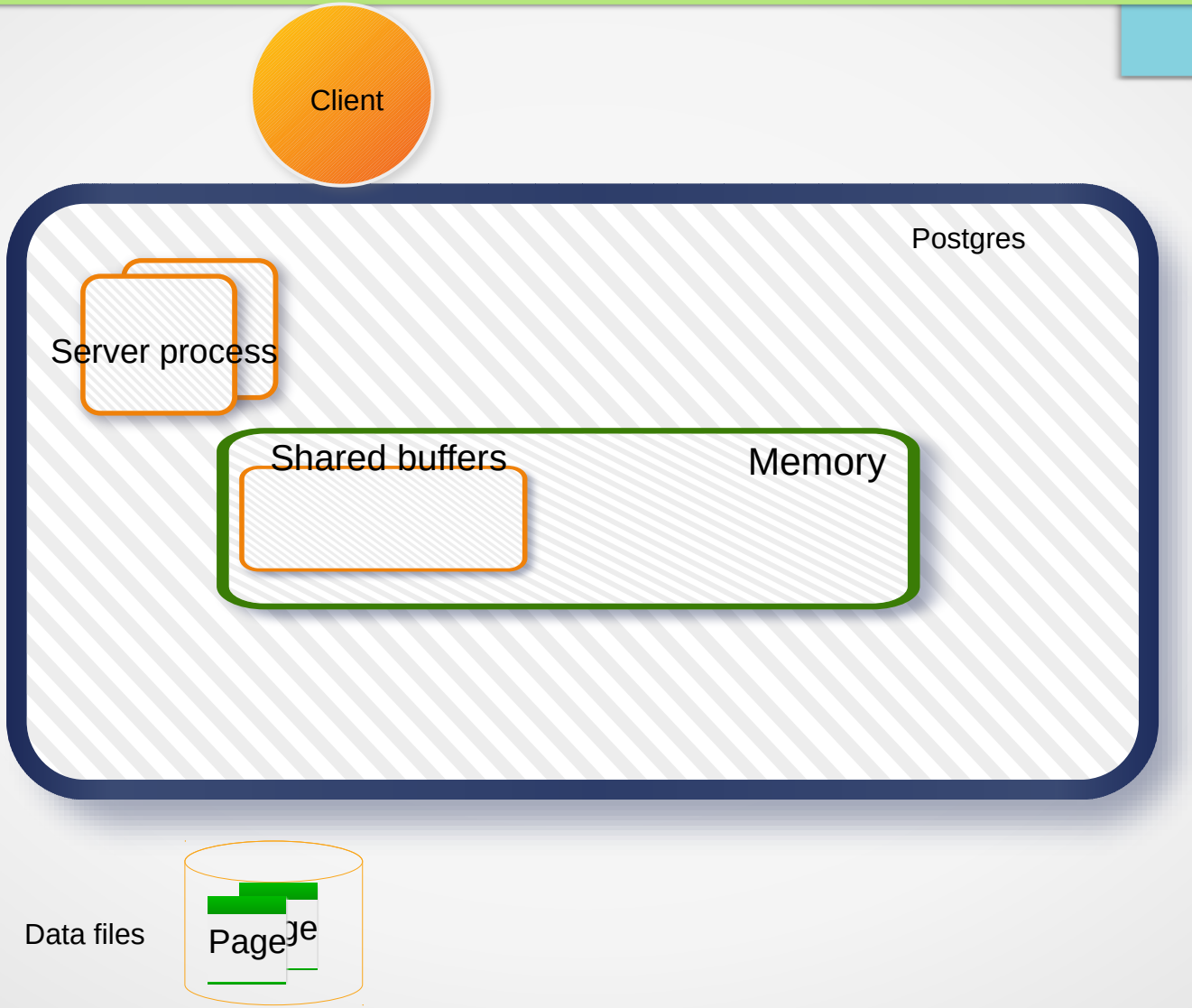
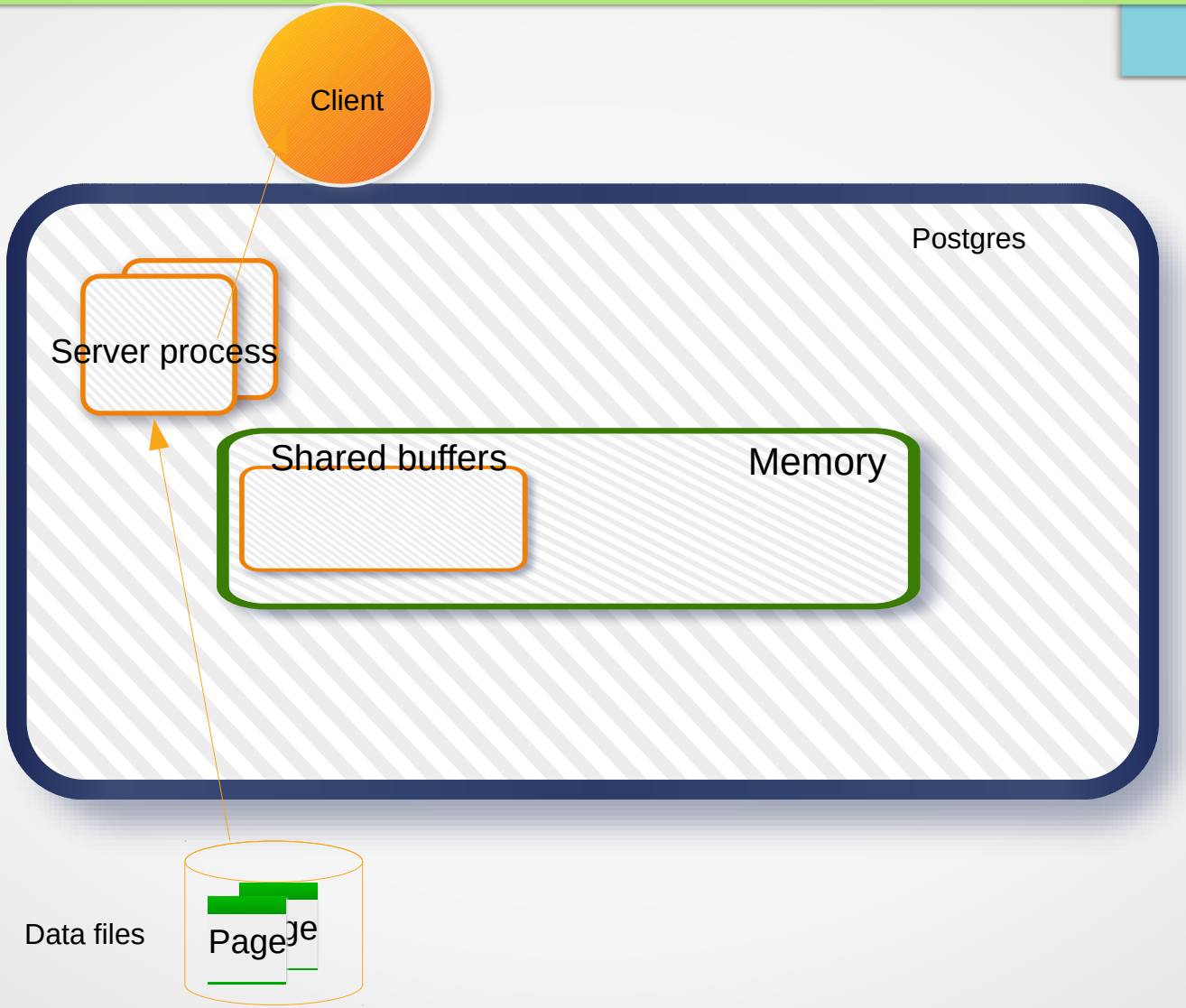
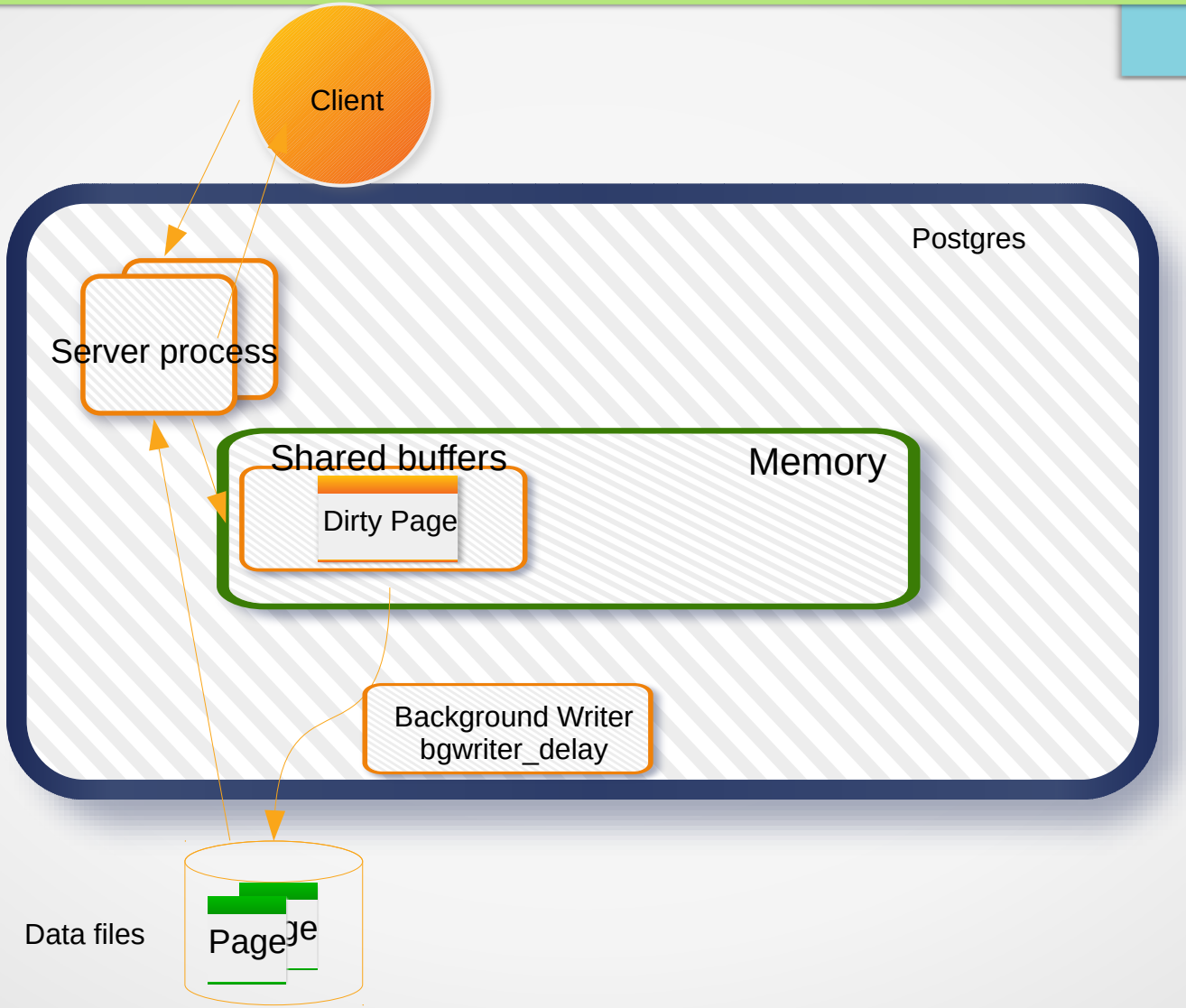


Scaling writes: Delayed write amplification



Scaling writes: Delayed write amplification



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- Make use of the delayed flush
  - Group writes on application side
  - Bulk writes to the same table / partition
  - BG writer writes less dirty pages less often
  - More than 400% gain in write throughput

Scaling writes: Traffic seggregation

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- Optimizing for reducing random iops (reducing iowaits)
- IO schedulers for block devices in Linux are intelligent
  - IO scheduler per block device
  - Merge IO access to similar locations on disk

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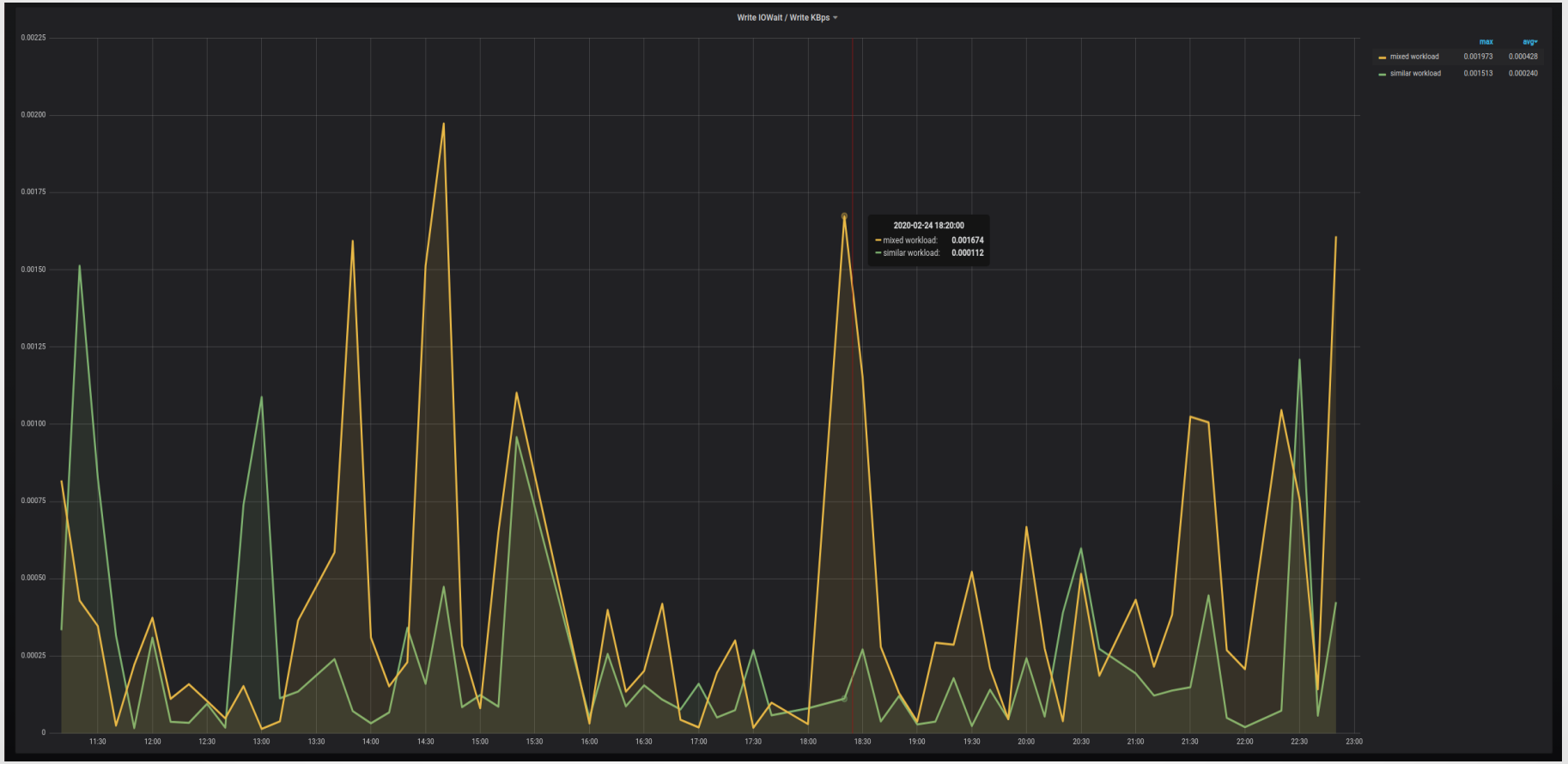
  Approach: Segregate access patterns on disks
- Put data for different types of data sources on different disks
  - Logically different workloads
  - Reducing concurrent writes to different tables on same disk
  - Use tablespaces

Scaling writes: Traffic segregation

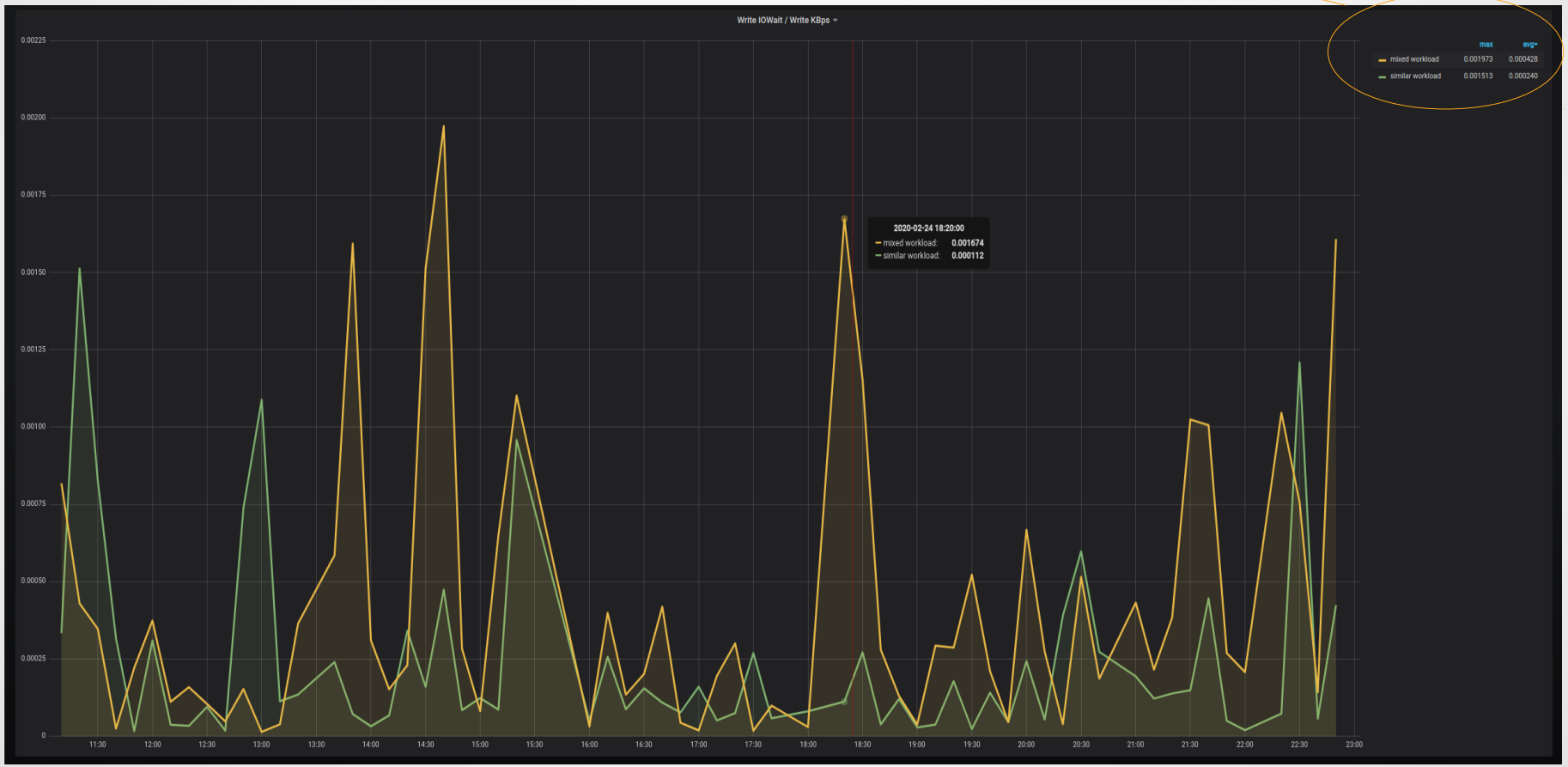
wawait / WkBps



Scaling writes: Traffic segregation

wawait / WkBps

Mixed workload: 0.000428
Similar workload: 0.000240



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Scaling backups

Approach 1

- pg_dump
  - Custom scripts and external parallel tools
  - Too slow, > 1 hour per TB

Scaling backups

Approach 2

- Differential disk snapshots on slave
  - Ability to take consistent snapshot by stopping process
  - Zero impact on master
  - Fast backup and restore < 5 mins per TB
  - Combined with WAL archiving on master for Point in Time Recovery (PITR)

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Approach

- More aggressive autovacuum
  - Lower thresholds
  - Increased number of autovacuum workers
  - *1 GB mem limit is still there*
  - *Affects production workload*

Scaling ops: Indexing

- Larger tables mean
  - Longer time for index creation
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Scaling ops: Partitioning

- Helps across the board
- Autovacuum
  - Smaller tables mean smaller working set
  - 1 GB limit is mitigated
- Indexing
  - Partial indexes for the save
  - Easily drop data / indexes on older partitions

Other knobs to turn

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- Parallel scans
  - PG 9.6+
  - Increased scan throughput
  - *max_parallel_workers, max_parallel_workers_per_gather*

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- Parallel scans
  - PG 9.6+
  - Increased scan throughput
  - *max_parallel_workers, max_parallel_workers_per_gather*
- Understand your block device
  - *seq_page_cost* vs *random_page_cost*
  - Equal for SSDs, vastly different for spinning disks

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- Understand your access pattern
  - Separate tables with different patterns on diff disks
  - Set block device *readahead* for sequential vs random access patterns

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- Understand your access pattern
  - Separate tables with different patterns on diff disks
  - Set block device *readahead* for sequential vs random access patterns
- Understand your filesystem
  - Use XFS
  - Configure *noatime*

Other knobs to turn

- Understand your database
  - PostgreSQL is row oriented
  - Huge read amplification with small number of tables

Questions?

We are hiring

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