PGConf Europe 2024

Are you collecting the right metrics?

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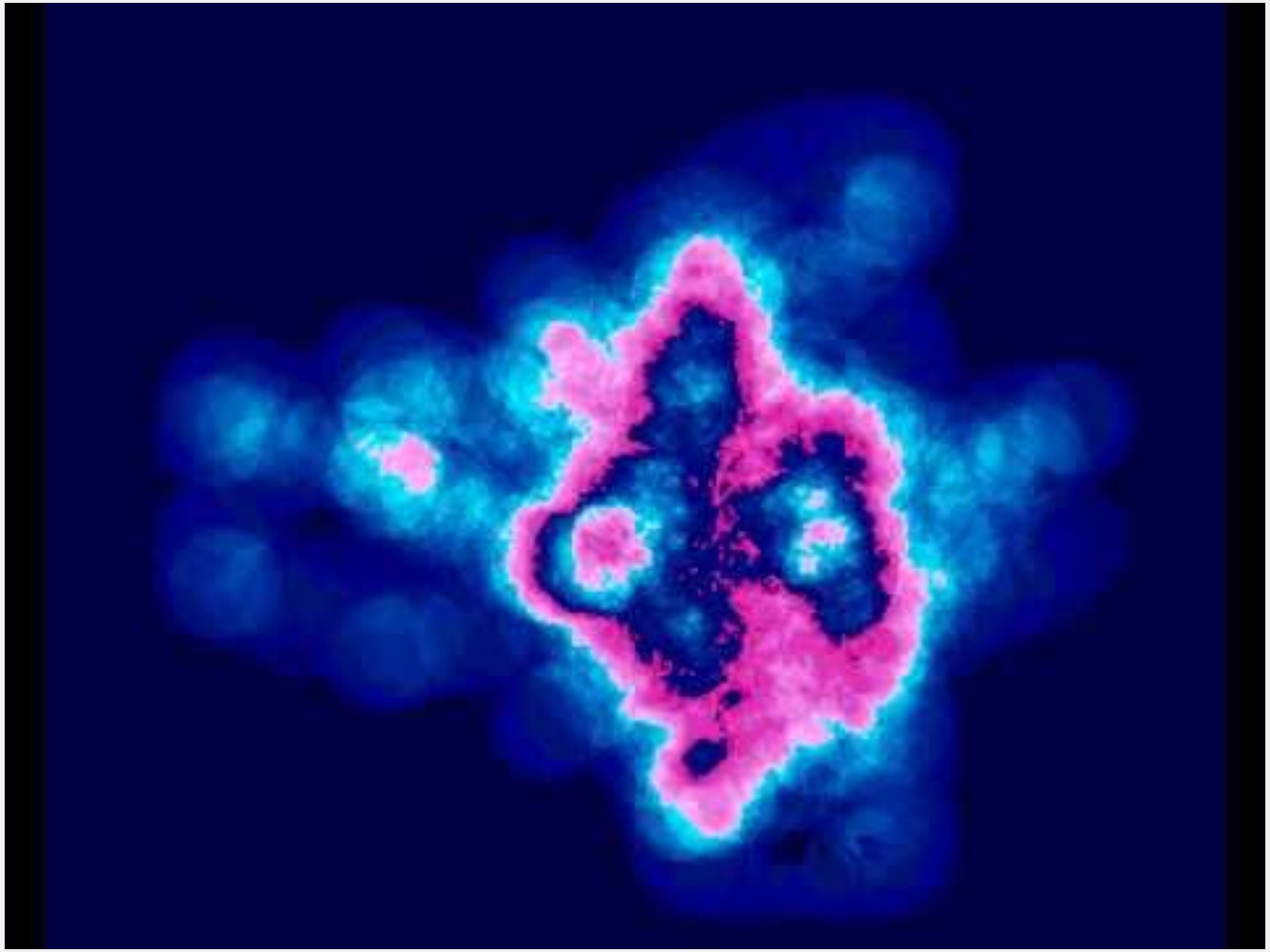
DataBene

Frédéric Delacourt

Demomaker
on Amiga 500



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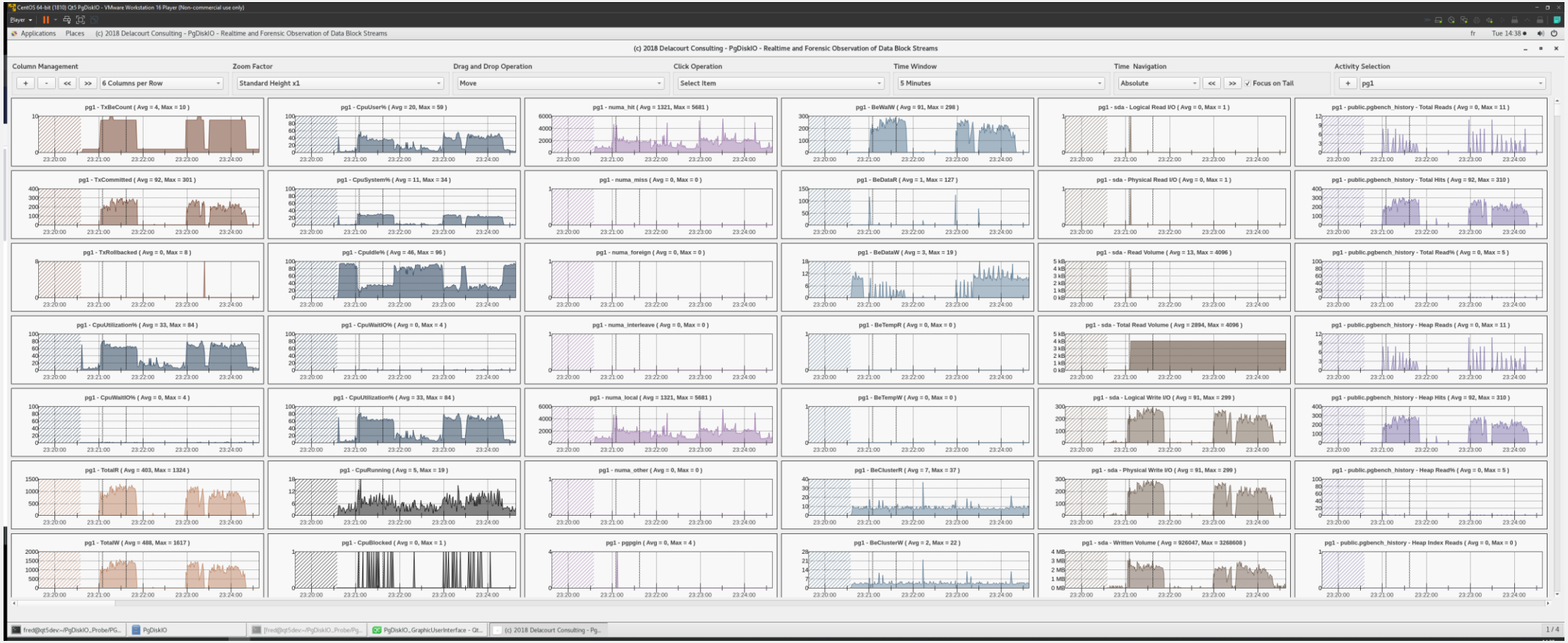
Frédéric Delacourt

Creator of PgDiskIO



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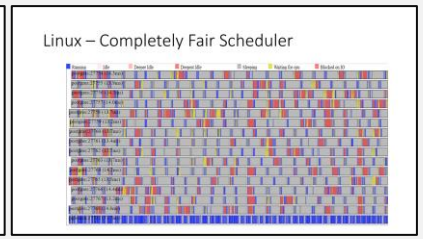
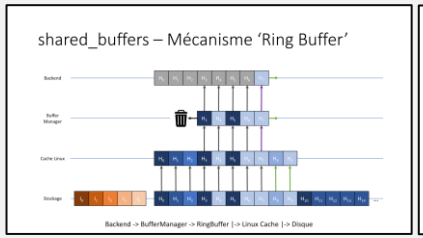
PostgreSQL

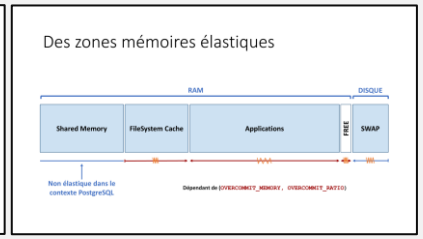
- Sinces 2006 (PostgreSQL 7.2) in the Telecoms
  - Database Architect (+support +dev)

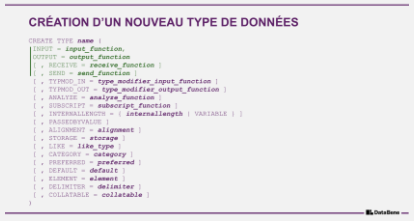
- Since 2017
  - Delacourt Consulting
  - 2ndQuadrant
  - Data Bene
  - Consultant Expert PostgreSQL

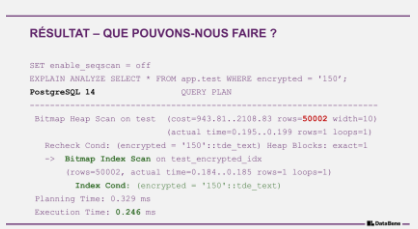
Conferences

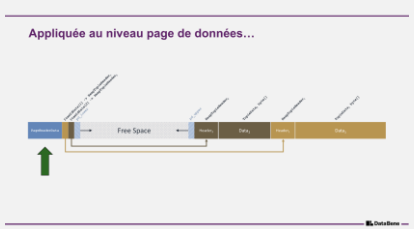


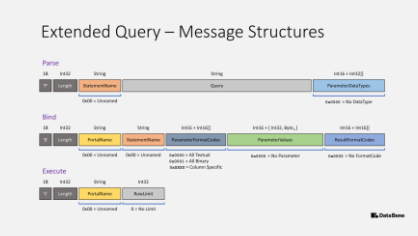


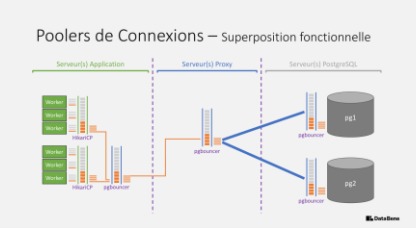


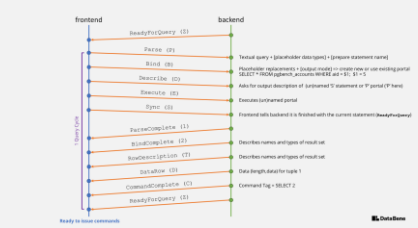


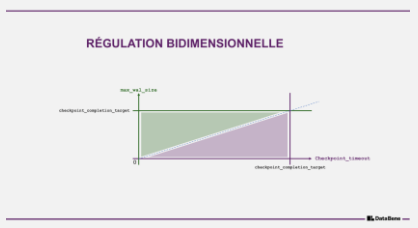


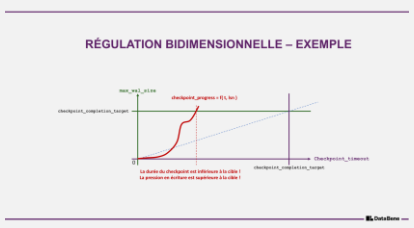












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What about you?

- Who are you?
- How are you related to PostgreSQL?
- What do you expect from this session?

Why collecting metrics?

- Workload Analysis
  - Baseline when the system works fine
  - Allows unexpected pattern detections
- Trends
  - Capacity Planning
- Alerting
  - When things are broken
  - When things are breaking or about to break
- Detail Analyzing
  - Troubleshooting
  - Learning behaviours

PostgreSQL Diagrams

A Graphic Description of PostgreSQL Internals.

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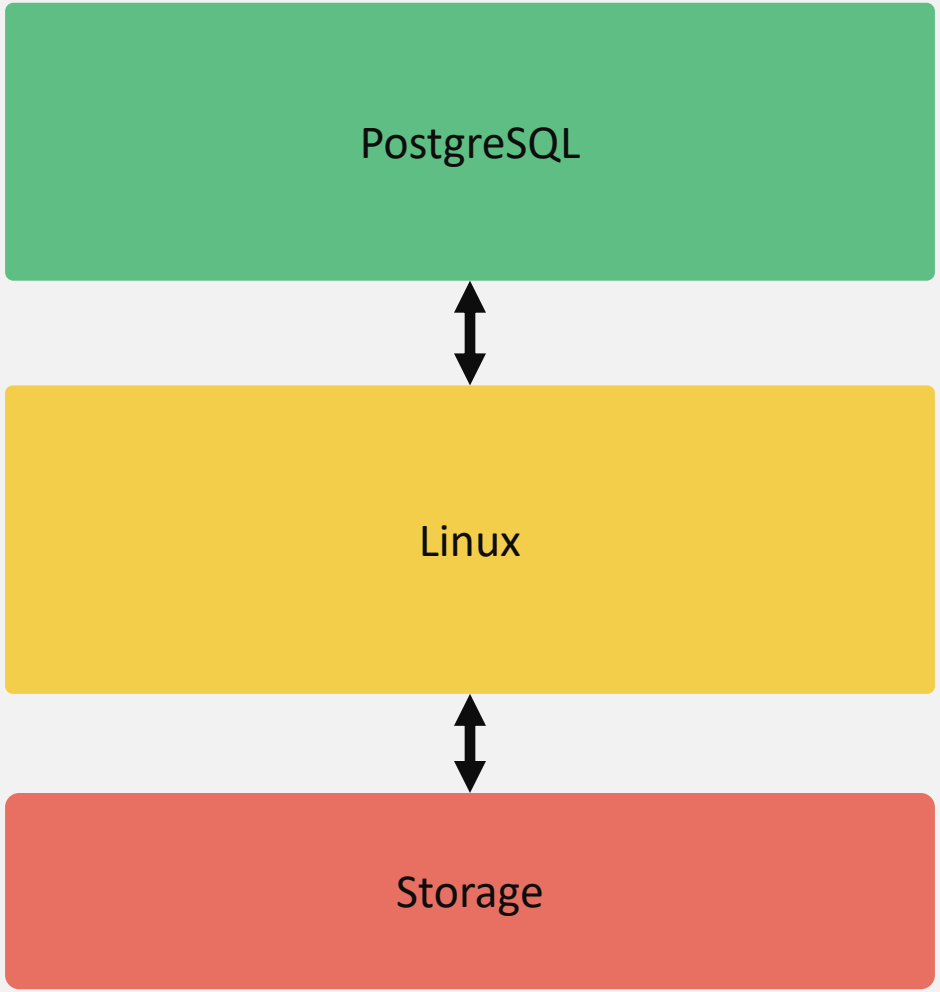
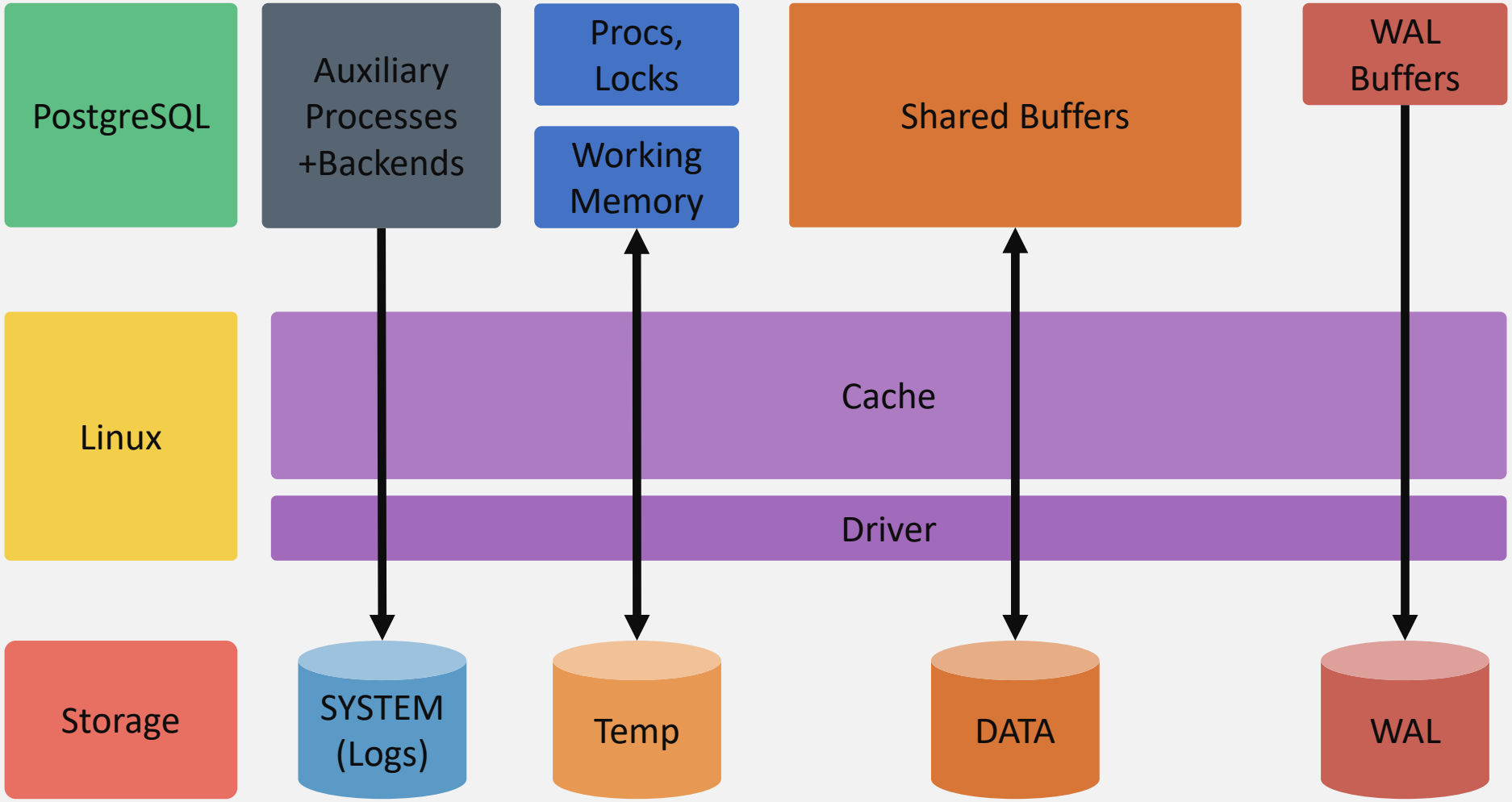
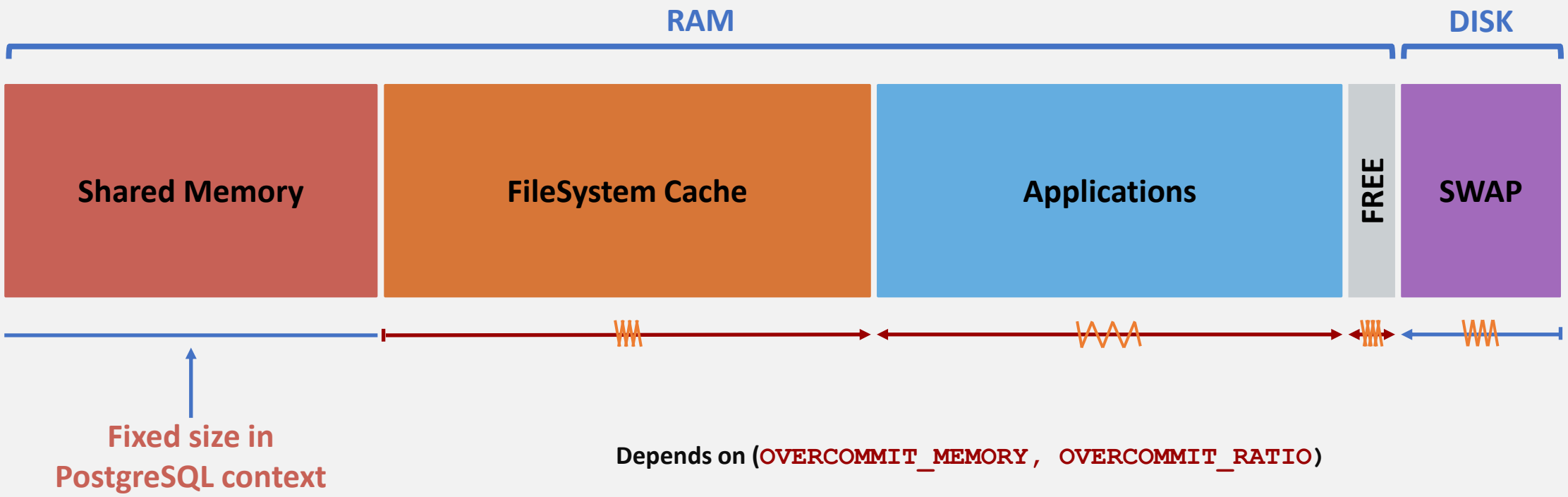

PostgreSQL
Linux
Storage


PostgreSQL
Auxiliary Processes +Backends
Procs, Locks
Working Memory
Shared Buffers
WAL Buffers
Linux
Cache
Driver
Storage
SYSTEM (Logs)
Temp
DATA
WAL

Memory Zones



PostgreSQL Architecture

Memory – Process - Storage

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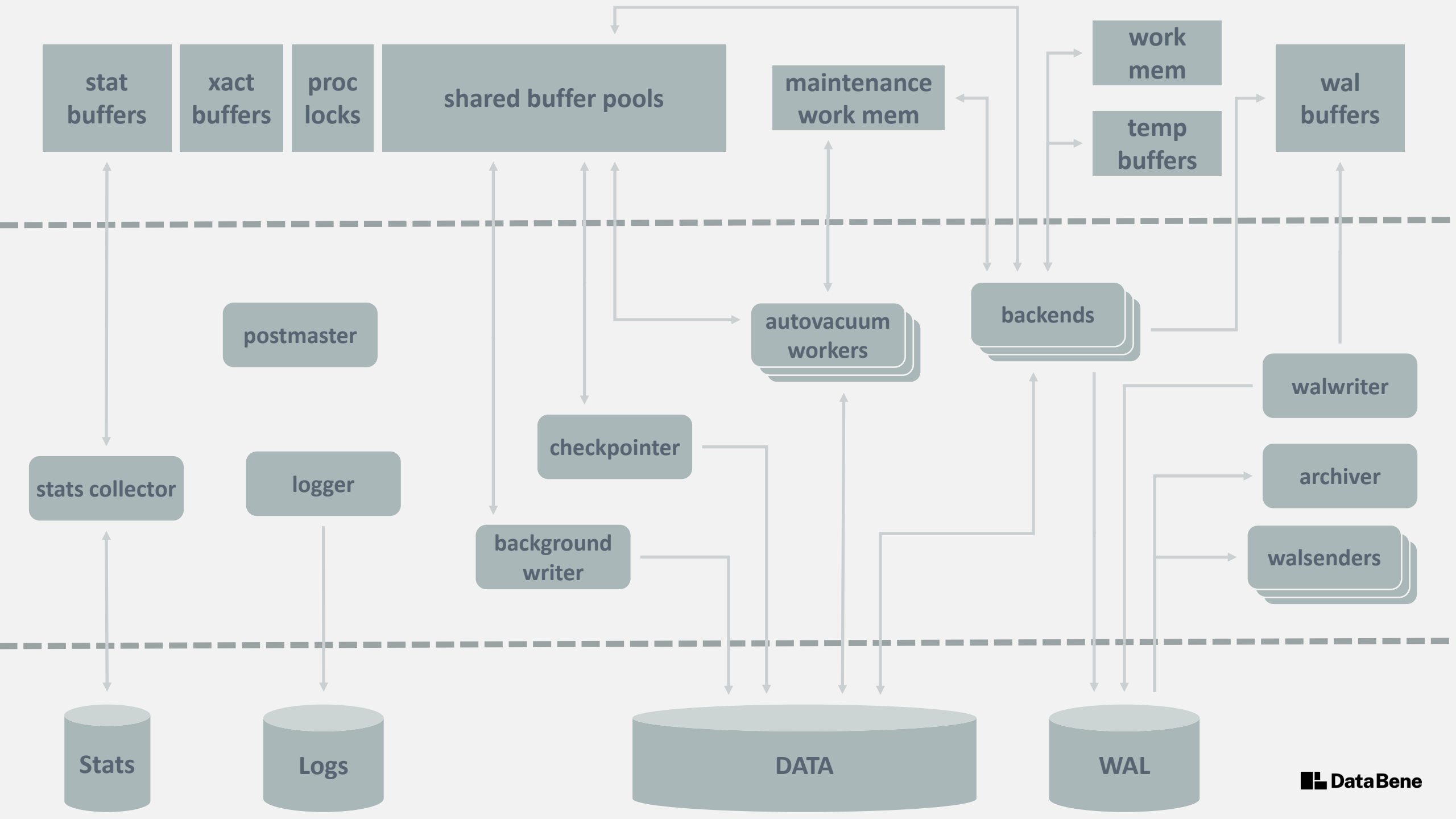
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shared buffer pools
maintenance work mem
work mem
temp buffers
wal buffers
postmaster
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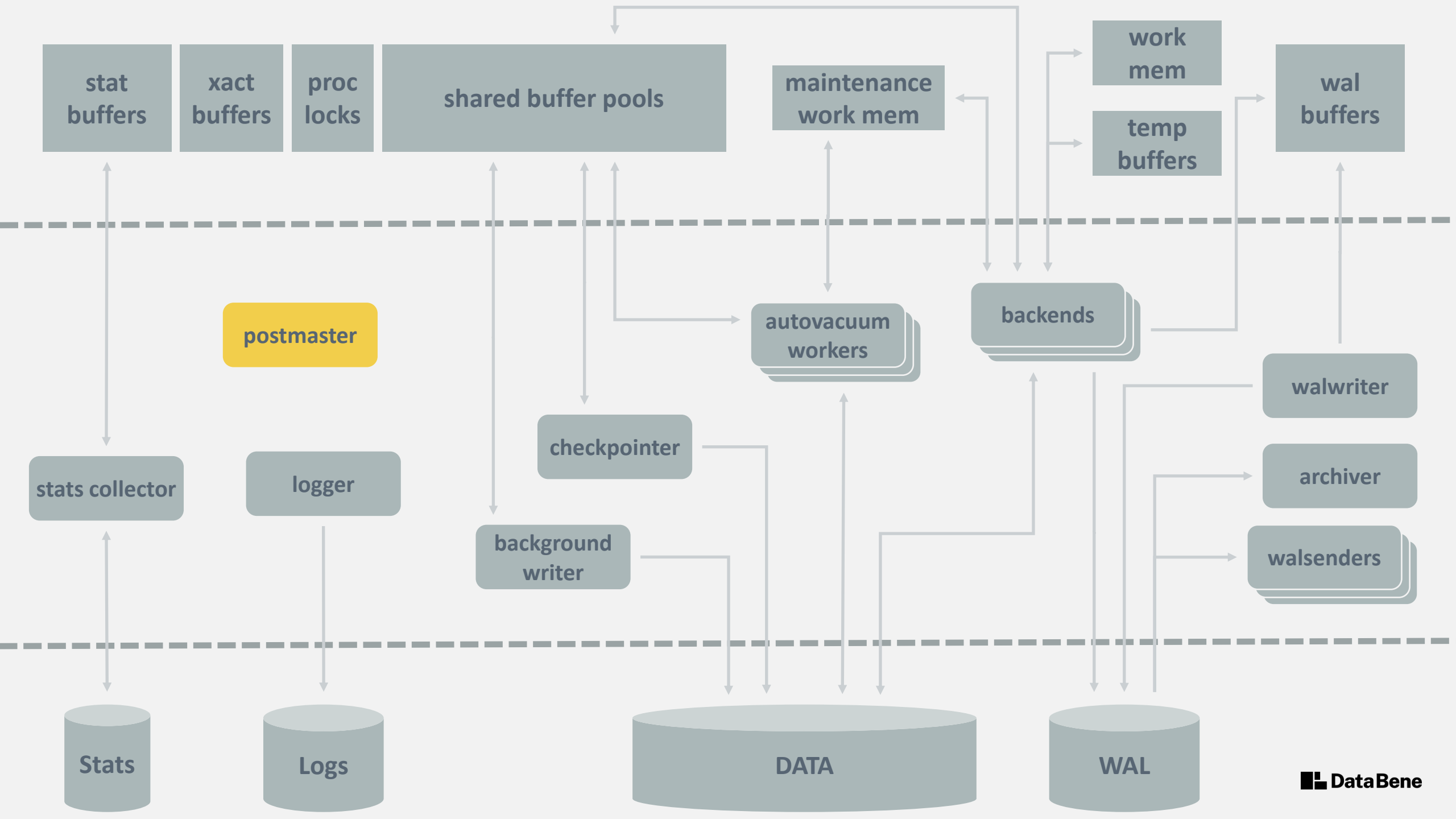
backends
walwriter
checkpointer
stats collector
logger
archiver
background writer
walsenders
Stats
Logs
DATA
WAL
DataBene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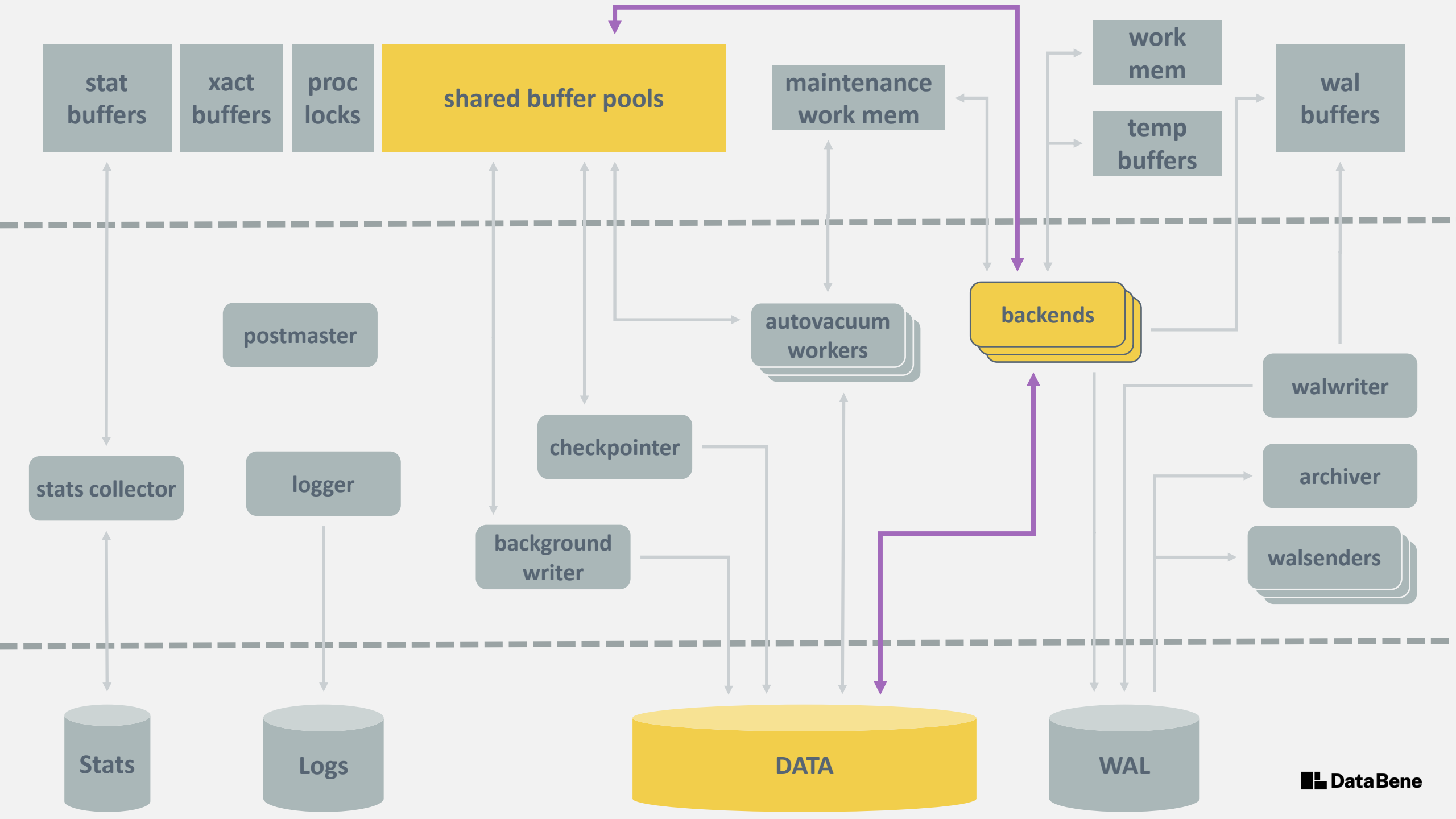
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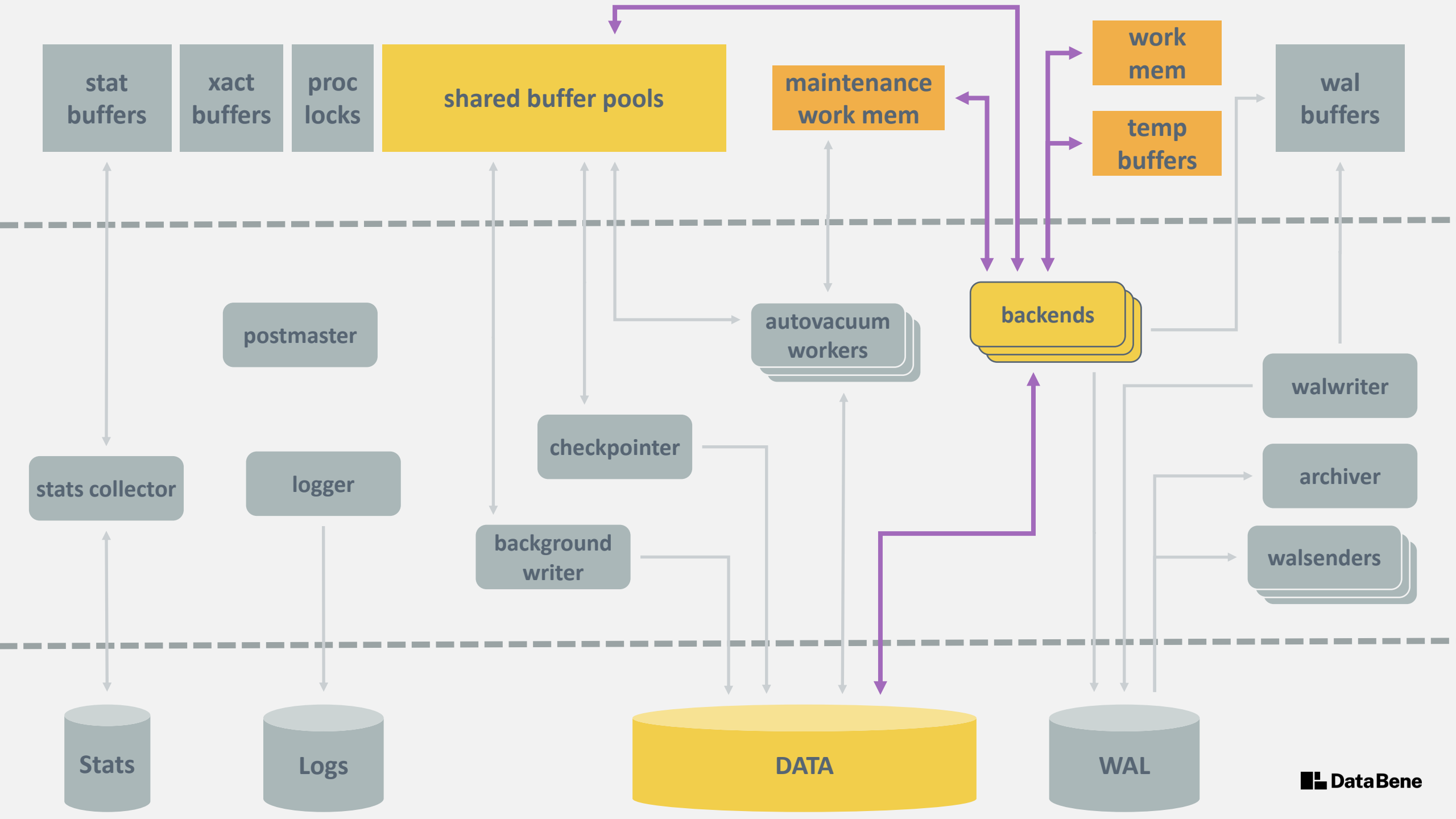
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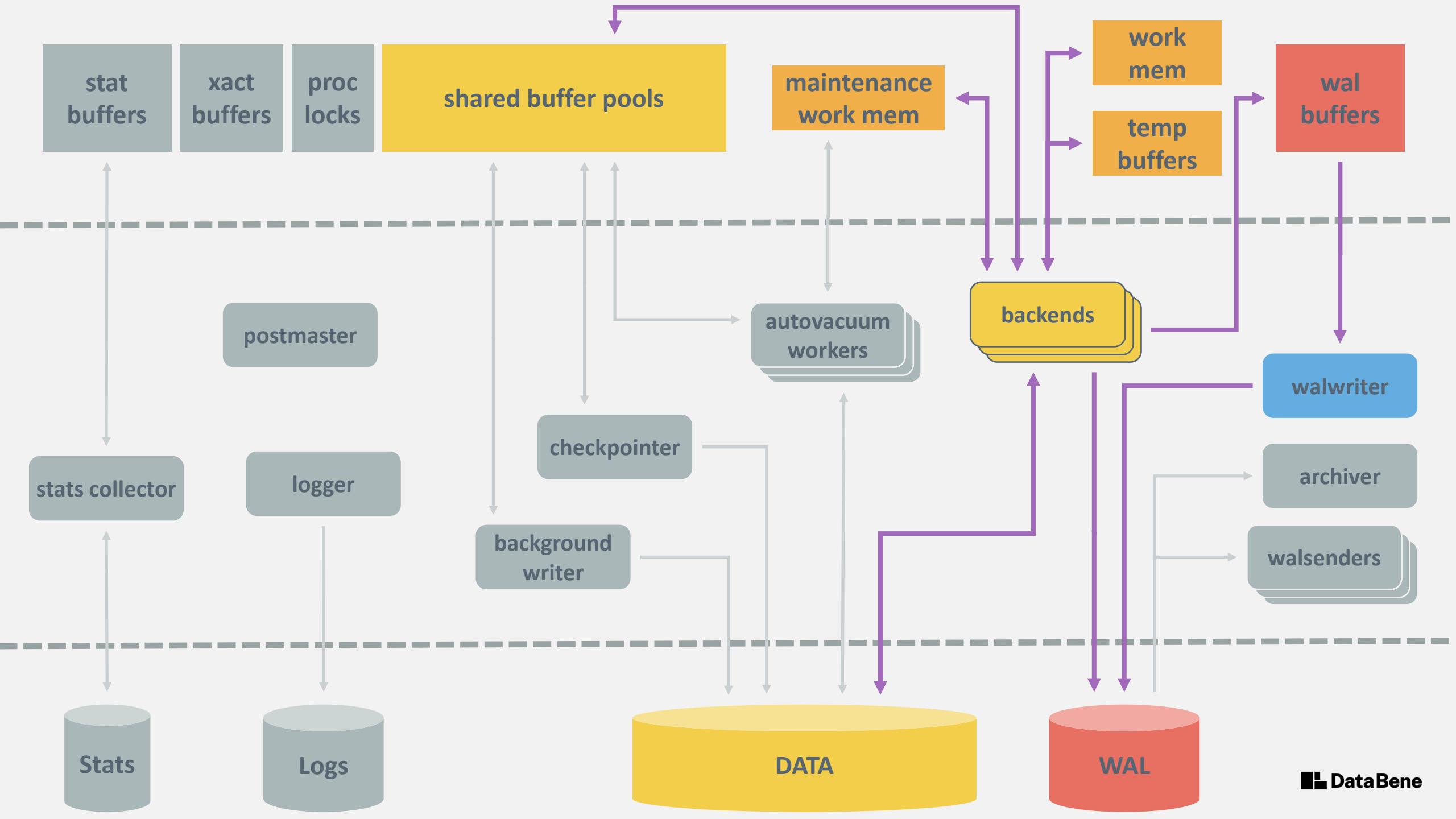
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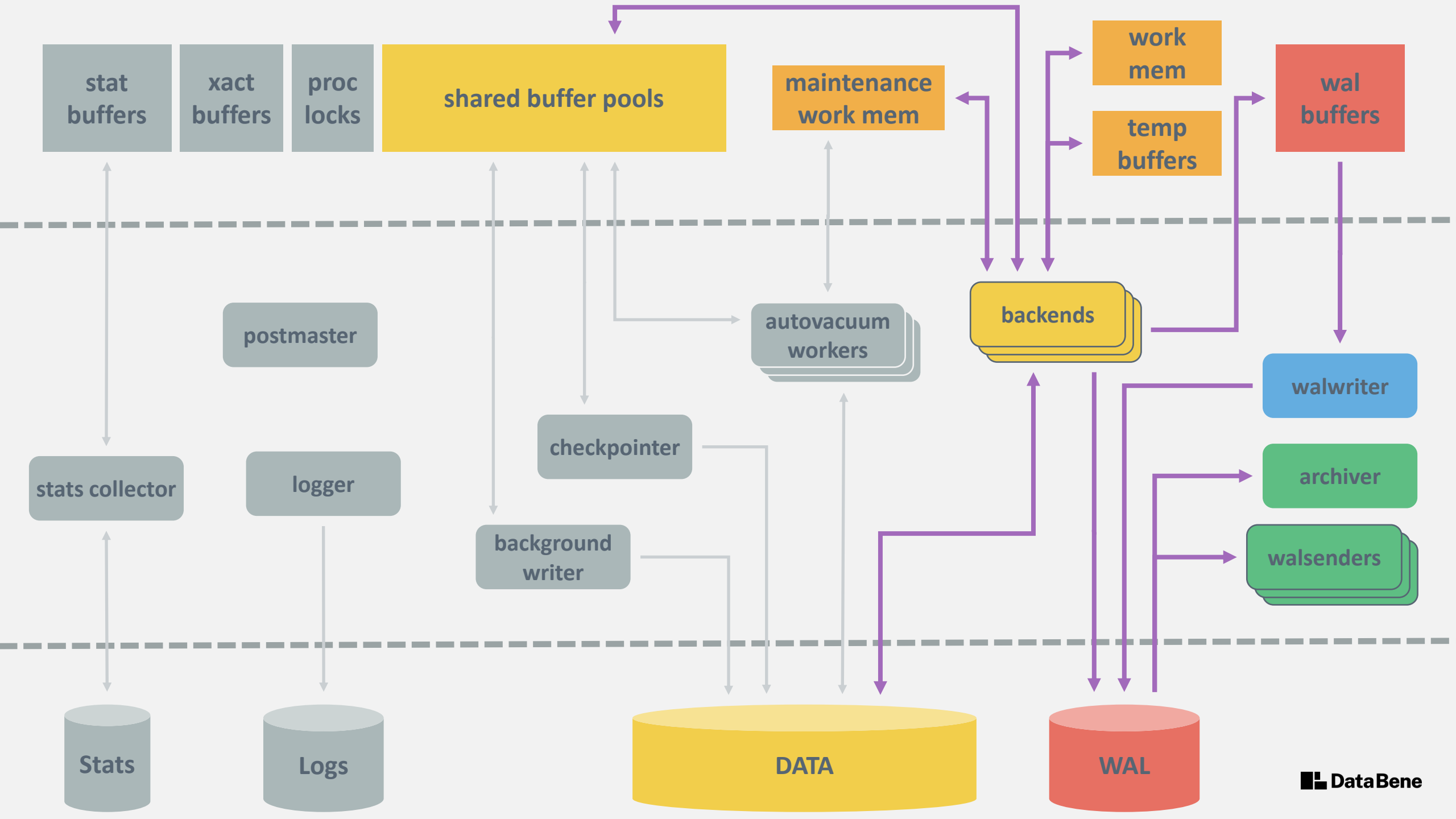
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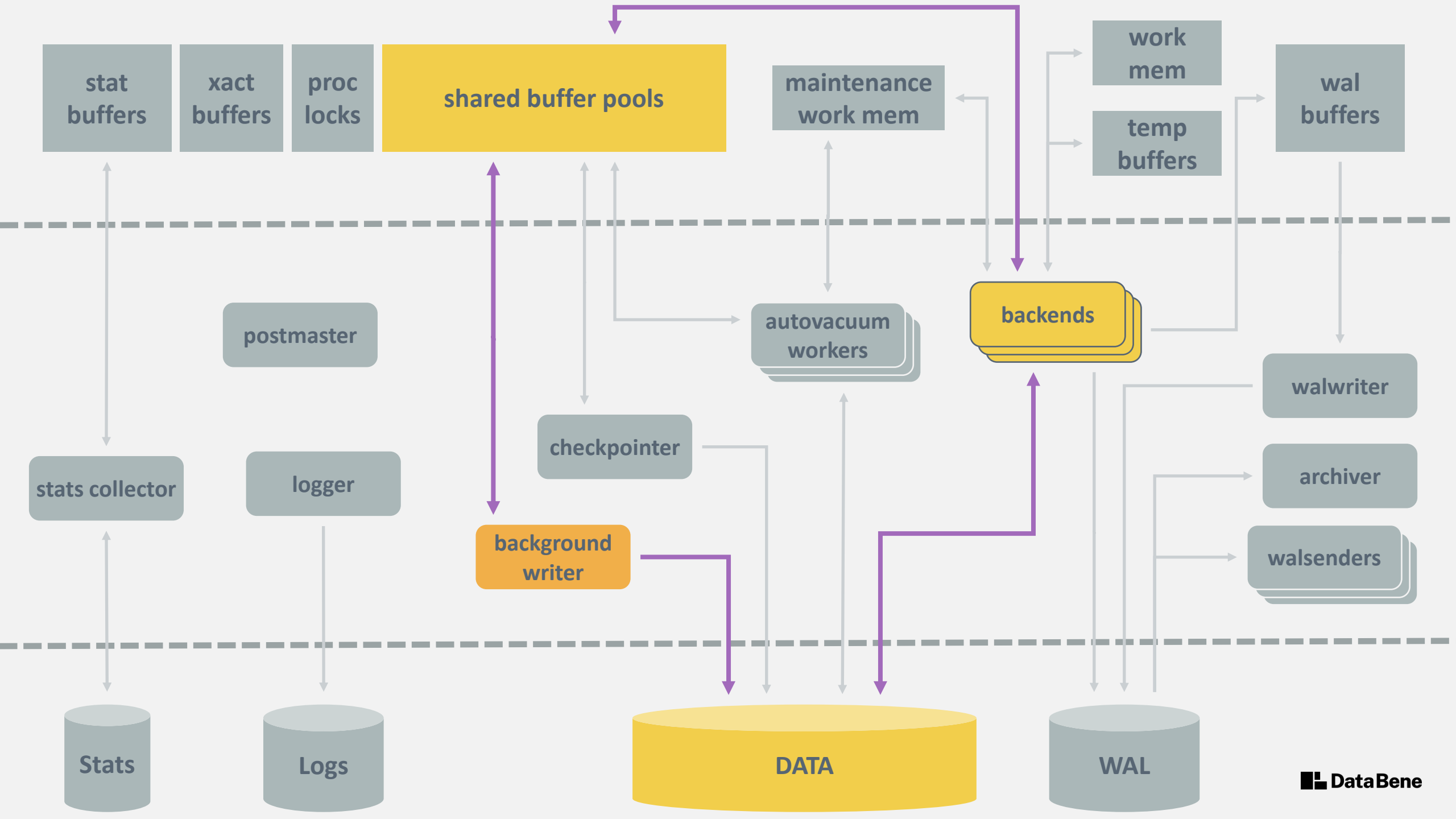
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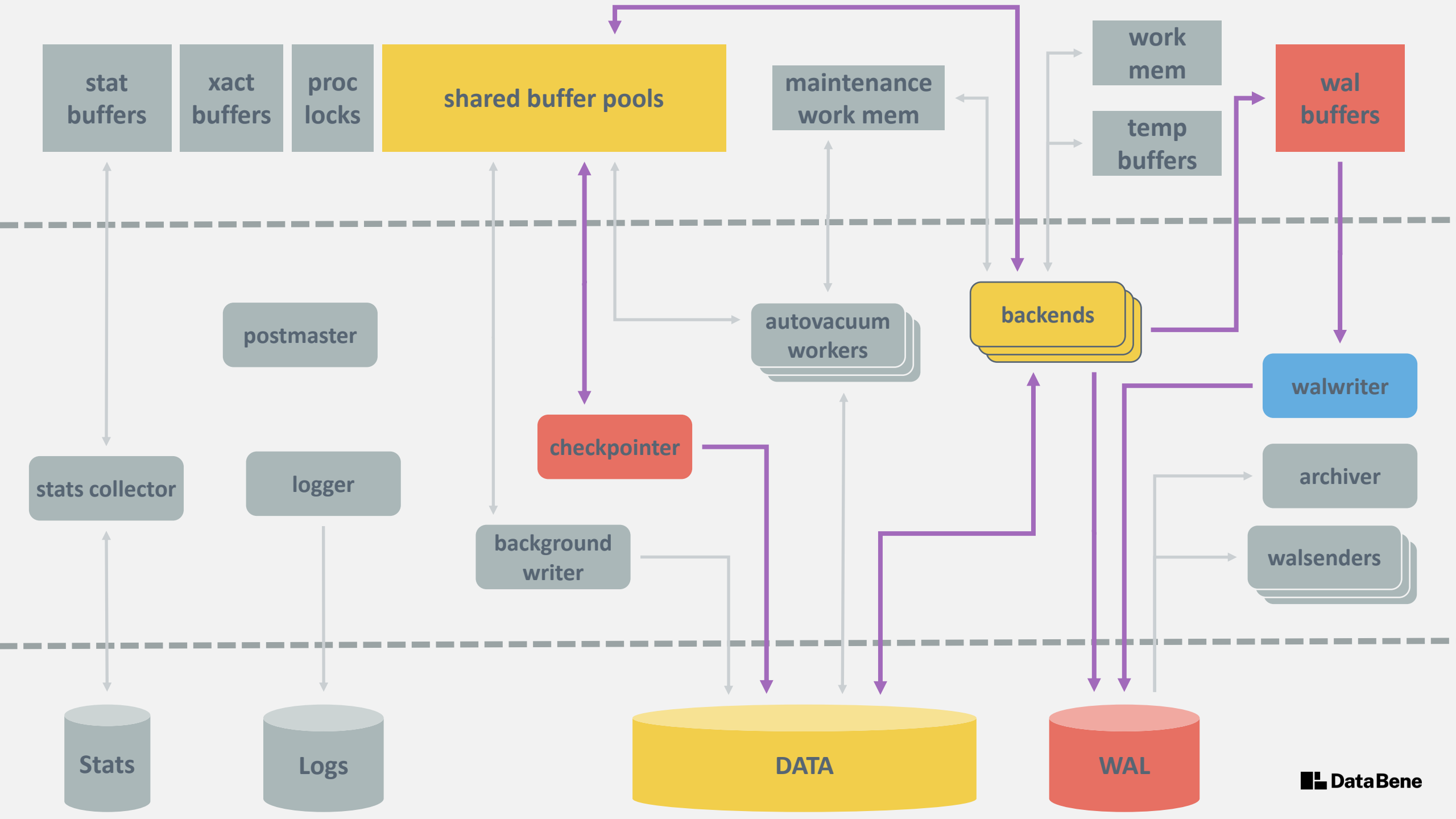
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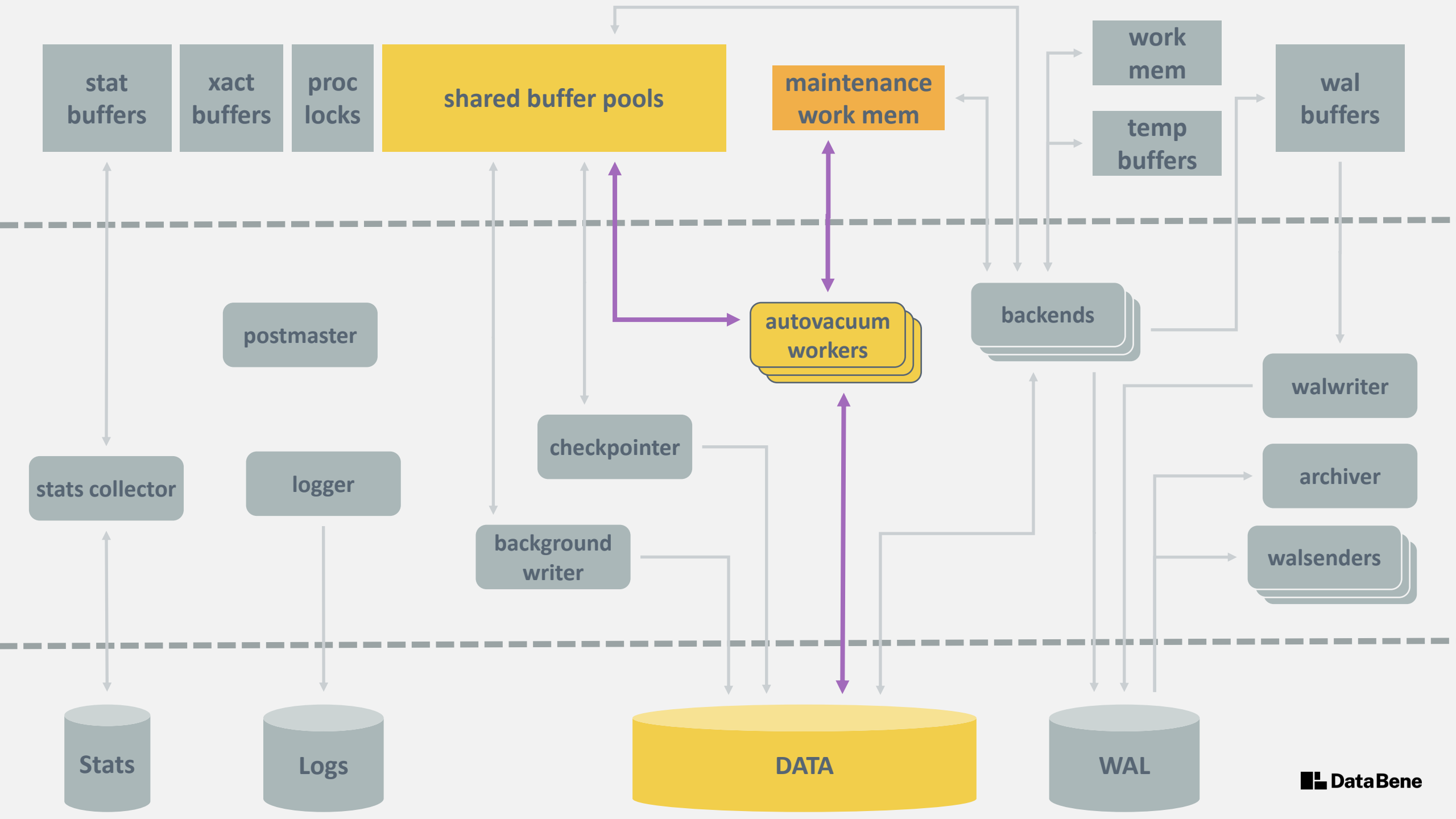
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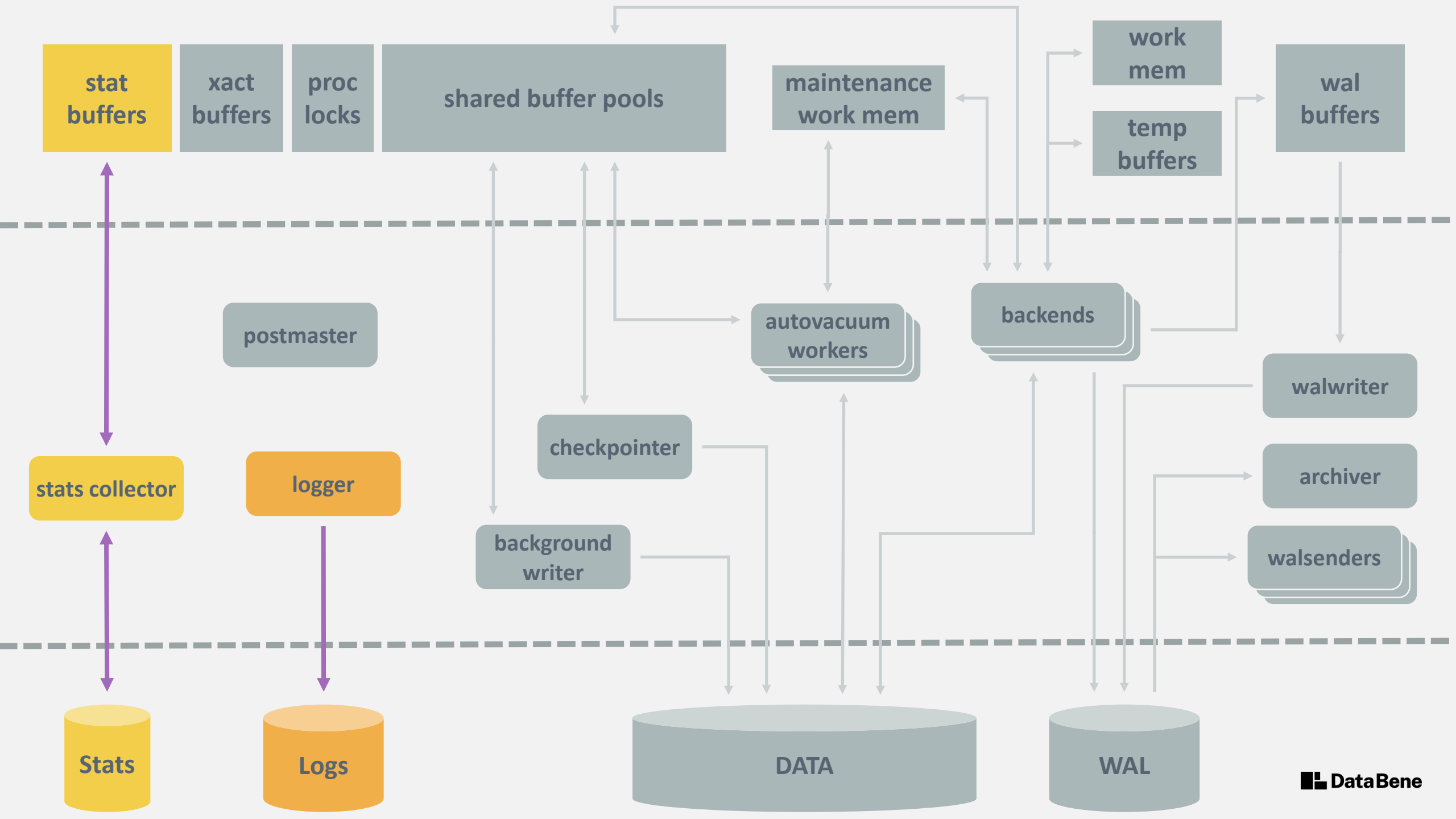
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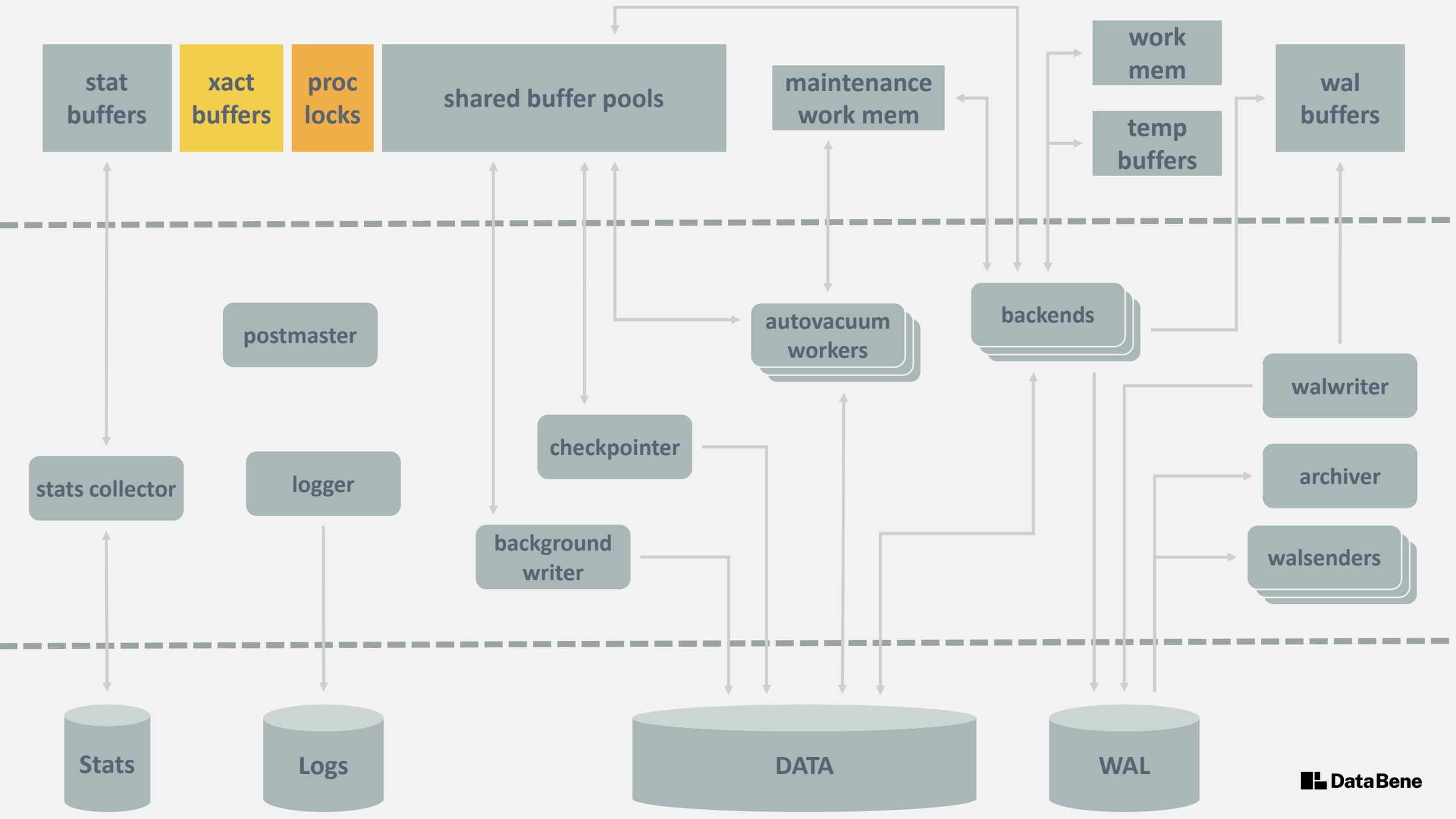
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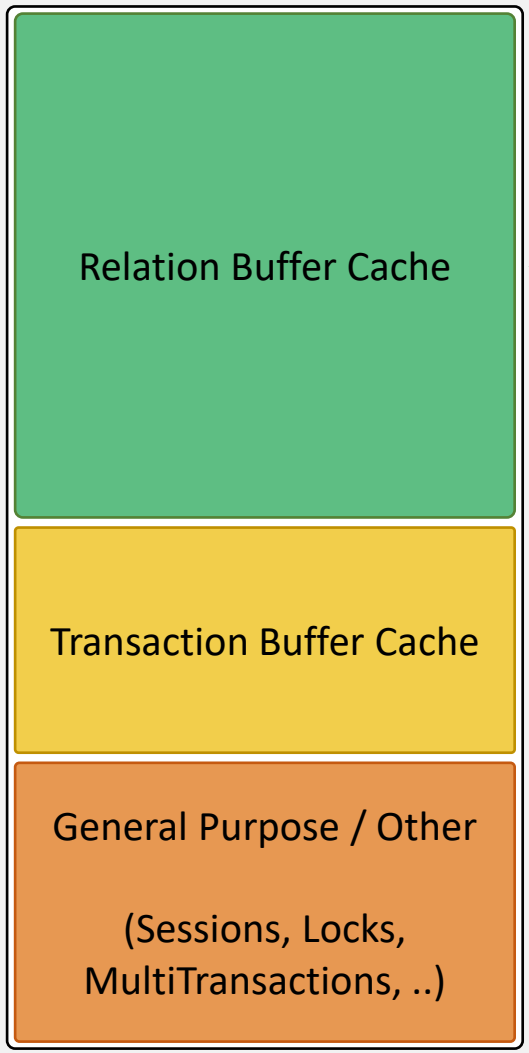
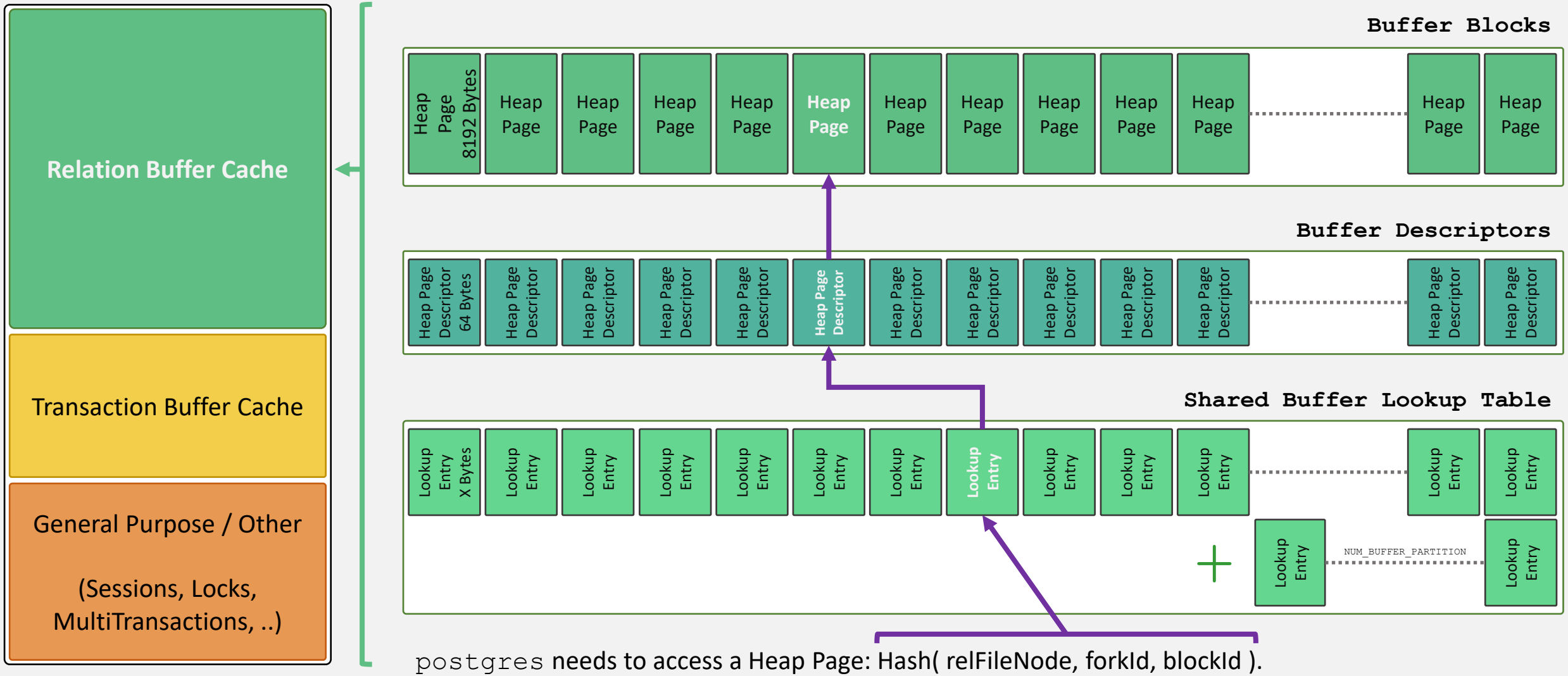
Shared Buffers

Structure – Usage – Processing



- Stored Objects
  - Tables, Indexes, Materialized Views
  - Free Space Map and Visibility Map.
- Used by Processes
  - `postgres`, `writer`, `checkpointer`.
- Modifications (INSERT, UPDATE, DELETE)
  - Are always done in the cache (`postgres`),
  - Written on Disk later (`checkpointer`, `writer`, `postgres`).


Relation Buffer Cache
Transaction Buffer Cache
General Purpose / Other
(Sessions, Locks, MultiTransactions, ..)
Buffer Blocks
Heap Page 8192 Bytes
Heap Page
Buffer Descriptors
Heap Page Descriptor 64 Bytes
Heap Page Descriptor
Shared Buffer Lookup Table
Lookup Entry X Bytes
Lookup Entry
NUM_BUFFER_PARTITION
postgres needs to access a Heap Page: Hash(relFileNode, forkId, blockId).

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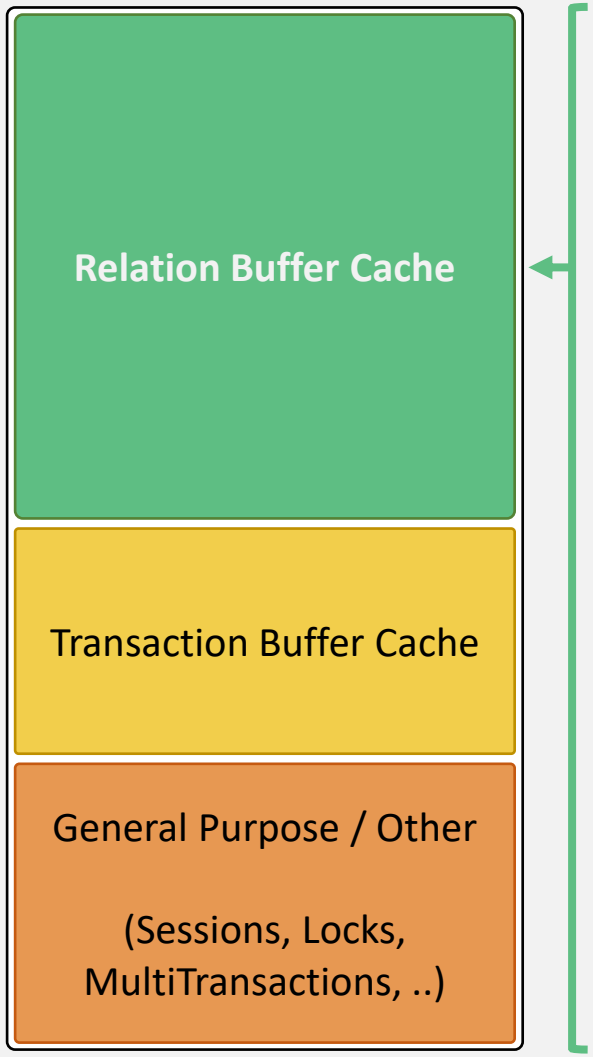
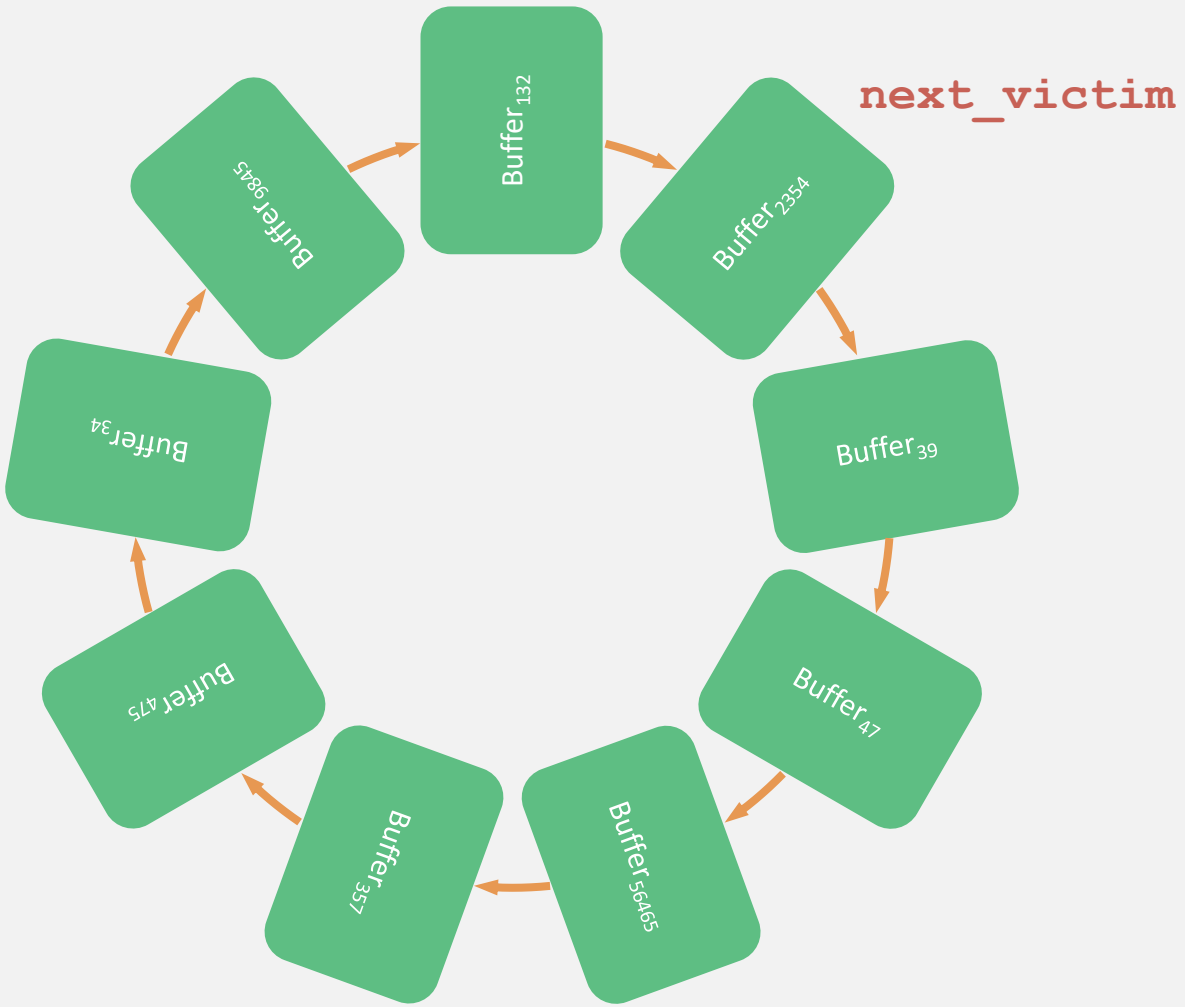

Relation Buffer Cache
Transaction Buffer Cache
General Purpose / Other
(Sessions, Locks, MultiTransactions, ..)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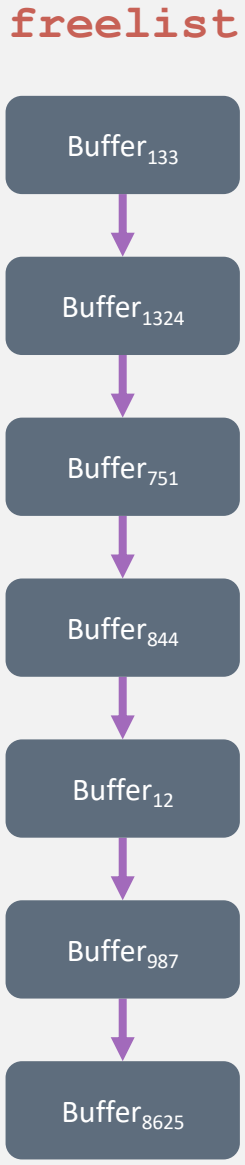
Buffer2354
Buffer39
Buffer47
Buffer56465
Buffer357
Buffer475
Buffer34
Buffer9845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Buffer1324
Buffer751
Buffer844
Buffer12
Buffer987
Buffer8625

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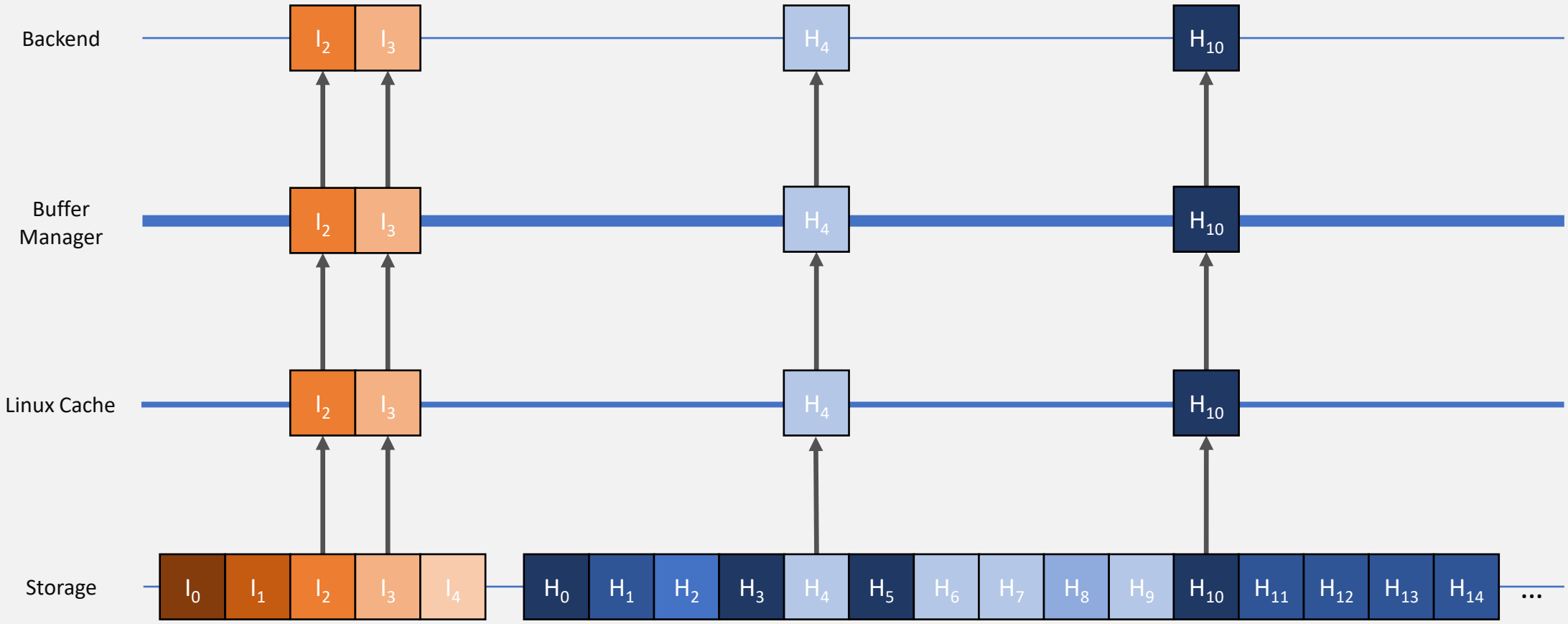
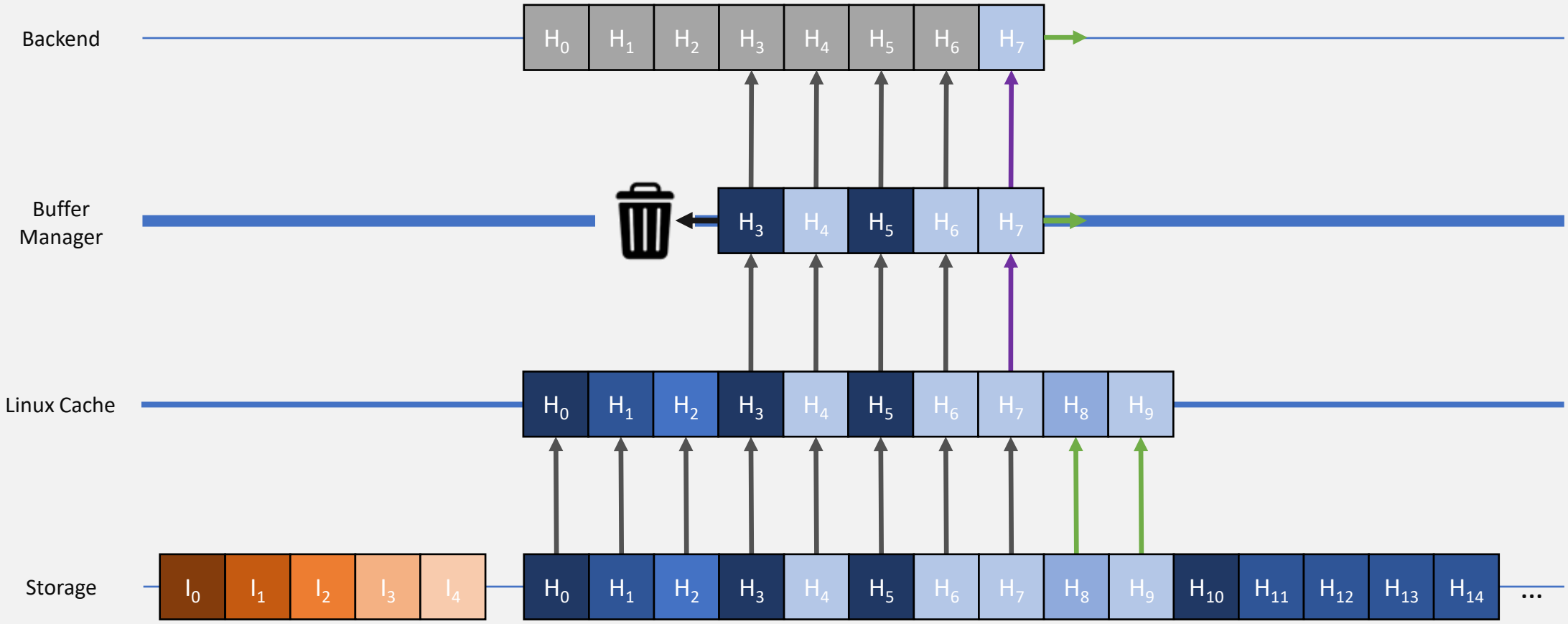


Backend -> BufferManager -> BufferPool |-> Linux Cache |-> Storage



Backend -> BufferManager -> RingBuffer |-> Linux Cache |-> Storage

Index Level Statistics

pg_catalog.pg_stat_[all|sys|user]_indexes

Column	Type
relid	oid
indexrelid	oid
schemaname	**name**
relname	**name**
indexrelname	**name**
idx_scan	bigint
last_idx_scan	timestamp with time zone
idx_tup_read	bigint
idx_tup_fetch	bigint

pg_catalog.pg_stat_[all|sys|user]_indexes

Column	Type
relid	oid
indexrelid	oid
schemaname	name
relname	name
indexrelname	name
idx_scan	**bigint**
last_idx_scan	**timestamp with time zone**
idx_tup_read	bigint
idx_tup_fetch	bigint

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$rate_{idx\_scan} = \frac{\Delta idx\_scan}{\Delta T}$$

Old event when $last\_idx_{scan} \leq now() - k\Delta T; k \in [0.5\,;3[$

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pg_catalog.pg_stat_[all|sys|user]_indexes

Column	Type
relid	oid
indexrelid	oid
schemaname	name
relname	name
indexrelname	name
idx_scan	bigint
last_idx_scan	timestamp with time zone
idx_tup_read	**bigint**
idx_tup_fetch	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

- idx_tup_read is the number of returned entries by the index scan
- idx_tup_fetch is the number of entries which produced reads in heap
- idx_tup_fetch ≤ idx_tup_read

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pg_catalog.pg_stat_[all|sys|user]_indexes

Column	Type
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indexrelid	oid
schemaname	name
relname	name
indexrelname	name
idx_scan	**bigint**
last_idx_scan	timestamp with time zone
idx_tup_read	**bigint**
idx_tup_fetch	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$ratio_{fetch} = \frac{\Delta idx\_tup\_fetch}{\Delta idx\_tup\_read}$$ (index_onlyscan)

$$\text{avg}_{index\_by\_scan} = \frac{\Delta idx\_tup\_read}{\Delta idx\_scan}$$ (for watch/baseline)

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pg_catalog.pg_statio_[all|sys|user]_indexes

Column	Type
relid	oid
indexrelid	oid
schemaname	name
relname	name
indexrelname	name
idx_blks_read	**bigint**
idx_blks_hit	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$\mathbf{cache_{idx\_hit}} = \frac{\Delta idx\_bkls\_hit}{\Delta idx\_bkls\_hit + \Delta idx\_bkls\_read} \geq \mathbf{0.98}$$

$$\mathbf{cache_{idx\_miss}} = \frac{\Delta idx\_blks\_read}{\Delta idx\_blks\_hit + \Delta idx\_blks\_read}$$

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Table Level Statistics

pg_catalog.pg_stat_[all|sys|user]_tables

Column	Type
relid	oid
schemaname	**name**
relname	**name**
seq_scan	bigint
last_seq_scan	timestamp with time zone
seq_tup_read	bigint
idx_scan	bigint
last_idx_scan	timestamp with time zone
idx_tup_fetch	bigint
n_tup_ins	bigint
n_tup_upd	bigint
n_tup_del	bigint
n_tup_hot_upd	bigint
n_tup_newpage_upd	bigint

Column	Type
n_live_tup	bigint
n_dead_tup	bigint
n_mod_since_analyze	bigint
n_ins_since_vacuum	bigint
last_vacuum	timestamp with time zone
last_autovacuum	timestamp with time zone
last_analyze	timestamp with time zone
last_autoanalyze	timestamp with time zone
vacuum_count	bigint
autovacuum_count	bigint
analyze_count	bigint
autoanalyze_count	bigint

pg_catalog.pg_stat_[all|sys|user]_tables

Column	Type
relid	oid
schemaname	name
relname	name
seq_scan	**bigint**
last_seq_scan	**timestamp with time zone**
seq_tup_read	**bigint**
idx_scan	bigint
last_idx_scan	timestamp with time zone
idx_tup_fetch	bigint

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$\text{avg}_{tuples\_by\_scan} = \frac{\Delta seq\_tup\_read}{\Delta seq\_scan}$$ (for watch/baseline)

Old event when $last\_ * \_scan \leq now() - k\Delta T; k \in [0.5\,;3[$

DataBene

pg_catalog.pg_stat_[all|sys|user]_tables

Column	Type
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schemaname	name
relname	name
seq_scan	bigint
last_seq_scan	timestamp with time zone
seq_tup_read	bigint
idx_scan	**bigint**
last_idx_scan	**timestamp with time zone**
idx_tup_fetch	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$\text{avg}_{tuples\_by\_scan} = \frac{\Delta idx\_tup\_fetch}{\Delta idx\_scan}$$ (for watch/baseline)

Old event when $last\_ * \_scan \leq now() - k\Delta T; k \in [0.5\,;3[$

DataBene

pg_catalog.pg_stat_[all|sys|user]_tables

Column	Type
relid	oid
schemaname	name
relname	name
n_tup_ins	**bigint**
n_tup_upd	**bigint**
n_tup_del	**bigint**
n_tup_hot_upd	**bigint**
n_tup_newpage_upd	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$ratio_{hot} = \frac{\Delta n\_tup\_hot\_upd}{\Delta n\_tup\_upd}$$

$$ratio_{newpage} = \frac{\Delta n\_tup\_newpage\_upd}{\Delta n\_tup\_upd}$$

$$ratio_{rw} = \frac{\Delta seq\_tup\_read + \Delta idx\_tup\_fetch}{\Delta n\_tup\_ins + \Delta n\_tup\_upd + \Delta n\_tup\_del}$$

DataBene

pg_catalog.pg_stat_[all|sys|user]_tables

Column	Type
relid	oid
schemaname	name
relname	name
n_mod_since_analyze	**bigint**
!last_analyze	**timestamp with time zone**
!last_autoanalyze	**timestamp with time zone**
analyze_count	bigint
autoanalyze_count	bigint

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

Make sure table received (auto)ANALYZE

$$n\_mod\_since\_analyze \geq analyze\_threshold + analyze\_scale\_factor * pg\_class.reltuples$$

DataBene

pg_catalog.pg_stat_[all|sys|user]_tables

Column	Type
relid	oid
schemaname	name
relname	name
n_live_tup	**bigint**
n_dead_tup	**bigint**
n_ins_since_vacuum	**bigint**
!last_vacuum	**timestamp with time zone**
!last_autovacuum	**timestamp with time zone**
vacuum_count	bigint
autovacuum_count	bigint

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

Make sure table received (auto)VACUUM

$$n\_ins\_since\_vacuum \geq vacuum\_insert\_threshold + vacuum\_insert\_scale\_factor * pg\_class.reltuples$$
$$n\_dead\_tup \geq vacuum\_threshold + vacuum\_scale\_factor * pg\_class.reltuples$$

DataBene

pg_catalog.pg_statio_[all|sys|user]_tables

Column	Type
relid	oid
schemaname	name
relname	name
heap_blks_read	**bigint**
heap_blks_hit	**bigint**
idx_blks_read	**bigint**
idx_blks_hit	**bigint**
toast_blks_read	**bigint**
toast_blks_hit	**bigint**
tidx_blks_read	**bigint**
tidx_blks_hit	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 15\, mins)$$

$$cache_{hit} = \frac{\Delta x\_hit}{\Delta x\_hit + \Delta x\_read}$$

$$cache_{miss} = \frac{\Delta x\_read}{\Delta x\_hit + \Delta x\_read}$$

DataBene

Database Level Statistics

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
numbackends	integer
xact_commit	bigint
xact_rollback	bigint
blks_read	bigint
blks_hit	bigint
tup_returned	bigint
tup_fetched	bigint
tup_inserted	bigint
tup_updated	bigint
tup_deleted	bigint
conflicts	bigint
temp_files	bigint
temp_bytes	bigint

Column	Type
deadlocks	bigint
checksum_failures	bigint
checksum_last_failure	timestamp with time zone
blk_read_time	double precision
blk_write_time	double precision
session_time	double precision
active_time	double precision
idle_in_transaction_time	double precision
sessions	bigint
sessions_abandoned	bigint
sessions_fatal	bigint
sessions_killed	bigint
stats_reset	timestamp with time zone

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	**oid**
datname	**name**

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
numbackends	**integer**

The number of currently connected backends to this database!

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
stats_reset	**timestamp with time zone**

The cumulated statistic counters started accumulating since **stats_reset**.

pg_catalog.pg_stat_database

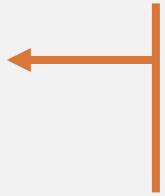
Column	Type
datid	oid
datname	name
xact_commit	**bigint**
xact_rollback	bigint

Number of COMMITTED transactions since **stats_reset**.

SELECT are accounted!

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	**bigint**
xact_rollback	bigint



$$tps_{committed} = \frac{\Delta xact\_commit}{\Delta T}$$

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	**bigint**
xact_rollback	bigint

$$tps_{committed} = \frac{\Delta xact\_commit}{\Delta T}$$

Should we alert when $tps_{committed}$ is outside upper and lower boundaries?

- **Absolute boundaries**
- **$\leq 0.5x$ *or* $\geq 2x$ window averaged**
- **Compared to expected timely activity**

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	**bigint**
xact_rollback	bigint

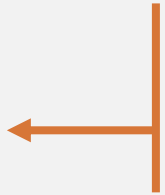
$$tps_{committed} = \frac{\Delta xact\_commit}{\Delta T}$$

Should we up/down-scale the system?

DataBene

pg_catalog.pg_stat_database

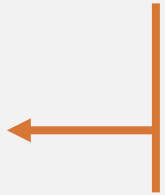
Column	Type
datid	oid
datname	name
xact_commit	bigint
xact_rollback	**bigint**



Should be kept as low as possible!

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	bigint
xact_rollback	**bigint**

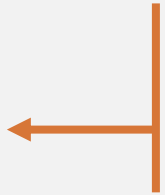


Too much rollbacks means:

- concurrency issues (or bad design)
- producing dead tuples!

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	bigint
xact_rollback	**bigint**



$$tps_{rollacked} = \frac{\Delta xact\_rollback}{\Delta T}$$

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	**bigint**
xact_rollback	**bigint**

$$tps_{committed} = \frac{\Delta xact\_commit}{\Delta T}$$

$$tps_{rollacked} = \frac{\Delta xact\_rollback}{\Delta T}$$

$$\text{ratio}_{rollacked} = \frac{\Delta xact\_rollback}{\Delta xact\_committed}$$

Should we alert when $\text{ratio}_{rollbacked}$ is higher than a threshold?

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
xact_commit	**bigint**
xact_rollback	**bigint**

$$tps_{committed} = \frac{\Delta xact\_commit}{\Delta T}$$

$$tps_{rollacked} = \frac{\Delta xact\_rollback}{\Delta T}$$

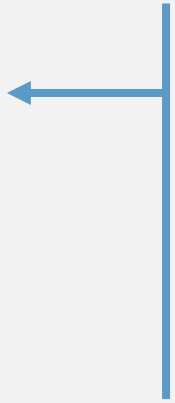
$$\text{ratio}_{rollacked} = \frac{\Delta xact\_rollback}{\Delta xact\_committed}$$

You just degraded performance and power efficiency by $\text{ratio}_{\text{rollbacked}}$ of your PostgreSQL server over the last observed period.

DataBene

pg_catalog.pg_stat_database

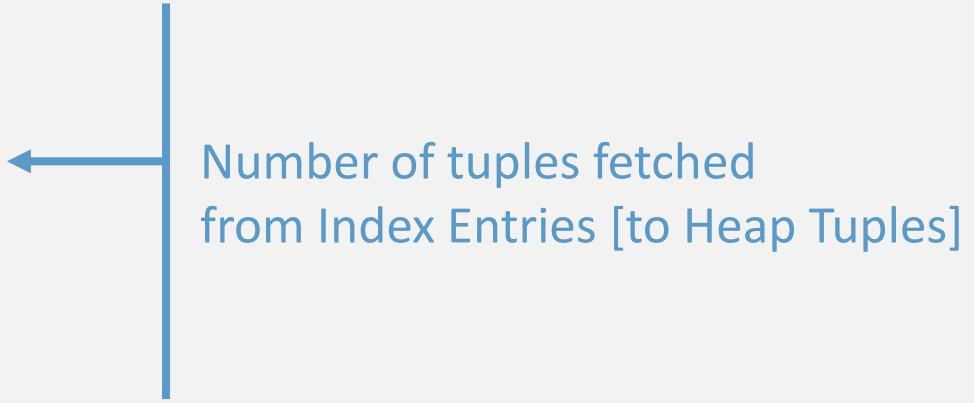
Column	Type
datid	oid
datname	name
tup_returned	**bigint**
tup_fetched	bigint
tup_inserted	bigint
tup_updated	bigint
tup_deleted	bigint



Number of visible tuples manipulated in SELECT, UPDATE, DELETE, VACUUM… excluding INSERT

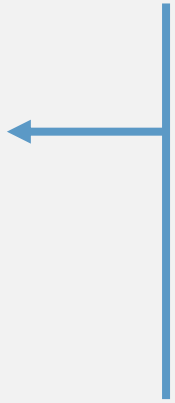
pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
tup_returned	bigint
tup_fetched	**bigint**
tup_inserted	bigint
tup_updated	bigint
tup_deleted	bigint



pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
tup_returned	**bigint**
tup_fetched	**bigint**
tup_inserted	bigint
tup_updated	bigint
tup_deleted	bigint



$$\text{index\_scan}\_ratio = \frac{\Delta tup\_fetched}{\Delta tup\_returned}$$

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
tup_returned	bigint
tup_fetched	bigint
tup_inserted	**bigint**
tup_updated	**bigint**
tup_deleted	**bigint**

Data Manipulation Language
- INSERT
- UPDATE
- DELETE

Produce dead tuples (no tracking at db level)
- INSERT + ROLLBACK | UPDATE + ROLLBACK
- UPDATE + COMMIT | DELETE + COMMIT

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
tup_returned	**bigint**
tup_fetched	**bigint**
tup_inserted	**bigint**
tup_updated	**bigint**
tup_deleted	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T}$$

$$rate_{DML} = \frac{\Delta inserted + \Delta updated + \Delta deleted}{\Delta T}$$

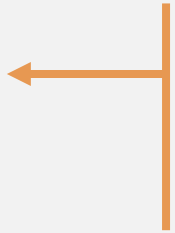
$$ratio_{rw} = \frac{rate_{tup\ returned}}{\bar{rate}_{DML}}$$

Do you find it useful?

DataBene

pg_catalog.pg_stat_database

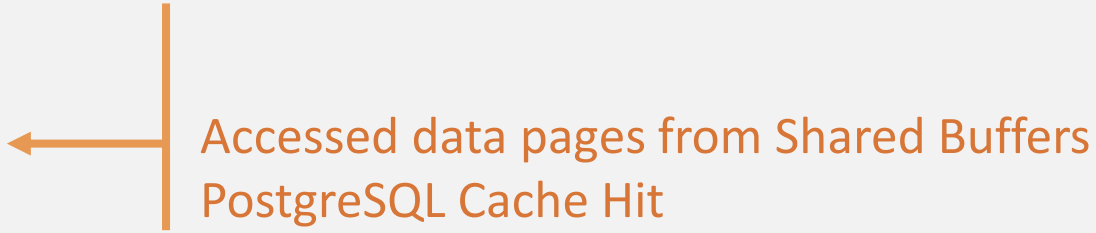
Column	Type
datid	oid
datname	name
blks_read	**bigint**
blks_hit	bigint
temp_files	bigint
temp_bytes	bigint
blk_read_time	double precision
blk_write_time	double precision



Missed data pages from Shared Buffers
PostgreSQL Cache Miss

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
blks_read	bigint
blks_hit	**bigint**
temp_files	bigint
temp_bytes	bigint
blk_read_time	double precision
blk_write_time	double precision



pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
blks_read	**bigint**
blks_hit	**bigint**
temp_files	bigint
temp_bytes	bigint
blk_read_time	double precision
blk_write_time	double precision

$$rate_x = \frac{\Delta x}{\Delta T}$$

$$cache_{hit} = \frac{\Delta blks\_hit}{\Delta blk\_hit + \Delta blks\_read}$$

$$cache_{miss} = \frac{\Delta blks\_read}{\Delta blk\_hit + \Delta blks\_read}$$

- **Usually $cache_{hit} < 0.7$ is correlated with performance issues.**
- **Low $cache_{hit}$ ratio is expected when workload consists in accessing uniform distributed tuples over large tables.**

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
blks_read	bigint
blks_hit	bigint
temp_files	**bigint**
temp_bytes	**bigint**
blk_read_time	double precision
blk_write_time	double precision

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \; \Delta T \in (5, 15, 30, 60\ mins, 1\ day)$$

$$avg_{filesize} = \frac{\Delta temp\_bytes}{\Delta temp\_files}$$ <- not that usefull

More information in log files (pid<->temp_files)

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
blks_read	bigint
blks_hit	bigint
temp_files	bigint
temp_bytes	bigint
blk_read_time	**double precision**
blk_write_time	**double precision**

$rate_x = \frac{\Delta x}{\Delta T}$; for which ΔT?

To be compared with what ?
Useful or useless ?

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
deadlocks	**bigint**
conflicts	bigint
checksum_failures	bigint
checksum_last_failure	timestamp with time zone

$rate_x = \frac{\Delta x}{\Delta T}$; $\Delta T \in (60\ mins, 1\ day)$?

Catches bugs not performance issues
Use log content!

Alert on detection!

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
deadlocks	bigint
conflicts	**bigint**
checksum_failures	bigint
checksum_last_failure	timestamp with time zone

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (30s, 1 - 60\, mins, 1\, day)?$$

Number of cancelled queries due to conflicts with recovery (standby only)

DataBene

pg_catalog.pg_stat_database_conflicts

Column	Type
datid	oid
datname	name
confl_tablespace	**bigint**
confl_lock	**bigint**
confl_snapshot	**bigint**
confl_bufferpin	**bigint**
confl_deadlock	**bigint**
confl_active_logicalslot	**bigint**

Only on Standby

$rate_x = \frac{\Delta x}{\Delta T}$; $\Delta T \in (30s, 1 - 60\ mins, 1\ day)$?

Causes of cancelled queries due to conflicts with recovery

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
deadlocks	bigint
conflicts	bigint
checksum_failures	**bigint**
checksum_last_failure	**timestamp with time zone**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1 - 60\, mins)$$

ALERT!!!
Be proactive on this, check regularly.

DataBene

pg_catalog.pg_stat_database

Column	Type
datid	oid
datname	name
session_time	**double precision**
active_time	**double precision**
idle_in_transaction_time	**double precision**
sessions	**bigint**
sessions_abandoned	**bigint**
sessions_fatal	**bigint**
sessions_killed	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (5 - 60\, mins, 1\, day)$$

Updated on « **pg_stat_activity.state_change** »

$$ratio_{active} = \frac{\Delta active\_time}{\Delta session\_time}$$

$$rate_{idle\_trans} = \frac{\Delta idle\_in\_transaction\_time}{\Delta session\_time}$$

DataBene

Cluster Level Statistics

Standalone

pg_catalog.pg_stat_io

Column	Type
backend_type	text
object	text
context	text
reads	bigint
read_time	double precision
writes	bigint
write_time	double precision
writebacks	bigint
writeback_time	double precision
extends	bigint
extend_time	double precision
op_bytes	bigint
hits	bigint
evictions	bigint
reuses	bigint
fsyncs	bigint
fsync_time	double precision
stats_reset	timestamp with time zone

pg_catalog.pg_stat_io

Column	Type
backend_type	**text**
stats_reset	**timestamp with time zone**

- autovacuum launcher,
- autovacuum worker,
- logical replication launcher,
- logical replication worker,
- client backend,
- parallel worker,
- background writer,
- checkpointer,
- archiver,
- standalone backend,
- startup,
- walreceiver,
- walsender,
- walwriter
- walsummarizer

pg_catalog.pg_stat_io

Column	Type
backend_type	text
object	**text**
context	**text**

- relation
- temp relation

- normal
- vacuum
- bulkread
- bulkwrite
- temporary relation

pg_catalog.pg_stat_io

Column	Type
backend_type	text
object	text
context	text
op_bytes	**bigint**

IO Operation Size (BLOCKSIZE = 8192)

pg_catalog.pg_stat_io

Column	Type
backend_type	text
object	text
context	text
reads	**bigint**
writes	**bigint**
writebacks	**bigint**
writeback_time	**double precision**
extends	**bigint**
extend_time	**double precision**
hits	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1s - 15\,mins)$$

$$\text{cache}_{\text{hit\_ratio}} = \frac{\Delta hits}{\Delta hits + \Delta reads}$$

$$\text{cache}_{\text{pending\_writes}} = \Delta\text{writes} - \Delta writebacks$$

$$\text{avg}_{\text{writeback\_time}} = \frac{\Delta writeback\_time}{\Delta writebacks}$$

$$\text{avg}_{\text{extend\_time}} = \frac{\Delta extend\_time}{\Delta extends}$$

DataBene

pg_catalog.pg_stat_io

Column	Type
backend_type	text
object	text
context	text
evictions	**bigint**
reuses	**bigint**
fsyncs	**bigint**
fsync_time	**double precision**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \in (1s - 15\,mins)$$

reuses is related to BAS Ring Buffers

$$\text{avg}_{\text{fsync\_time}} = \frac{\Delta fsync\_time}{\Delta fsyncs} \leq \sim 100ms$$

DataBene

pg_catalog.pg_stat_wal

Column	Type
wal_records	bigint
wal_fpi	bigint
wal_bytes	numeric
wal_buffers_full	bigint
wal_write	bigint
wal_sync	bigint
wal_write_time	double precision
wal_sync_time	double precision
stats_reset	timestamp with time zone

pg_catalog.pg_stat_wal

Column	Type
wal_records	bigint
wal_fpi	bigint
wal_bytes	numeric
wal_buffers_full	bigint
wal_write	bigint
wal_write_time	double precision
wal_sync	bigint
wal_sync_time	double precision
stats_reset	timestamp with time zone

$$rate_x = \frac{\Delta x}{\Delta T}\ ; \Delta T\ \in (\mathbf{1s} - 5\ mins)$$

$$\Delta \text{Volume}_{\text{fpi}} = \Delta \text{wal\_fpi} * wal\_block\_size$$

$$\Delta \text{Volume}_{\text{rec}} = \Delta \text{wal\_bytes} - \Delta Volumefpi$$

$$\text{avg}_{\text{wal\_write}} = \frac{\Delta wal\_write\_time}{\Delta wal\_write}$$

$$\text{avg}_{\text{wal\_sync}} = \frac{\Delta wal\_sync\_time}{\Delta wal\_sync} \leq 100\mu s \text{ (pg\_test\_sync)}$$

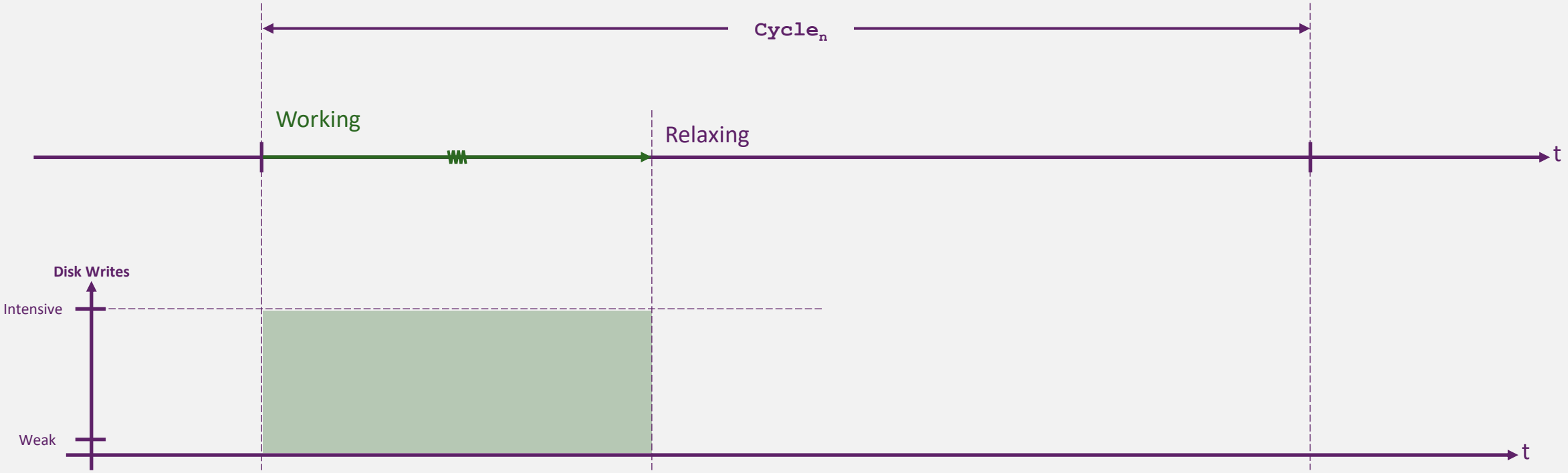
$$\text{ratio}_{\text{fullwrite}} = \frac{\Delta wal\_buffer\_full * wal\_buffers * wal\_block\_size}{\Delta wal\_bytes}$$

DataBene

Background Writer

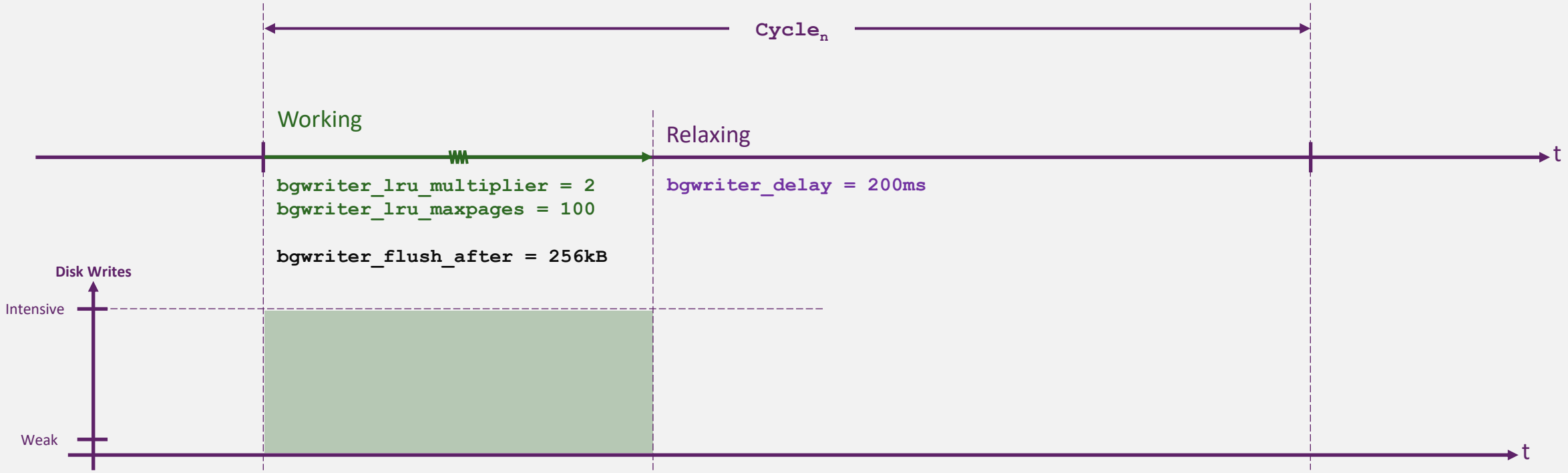
Structure – Usage – Processing

ACTIVITY and IO PRESSURE



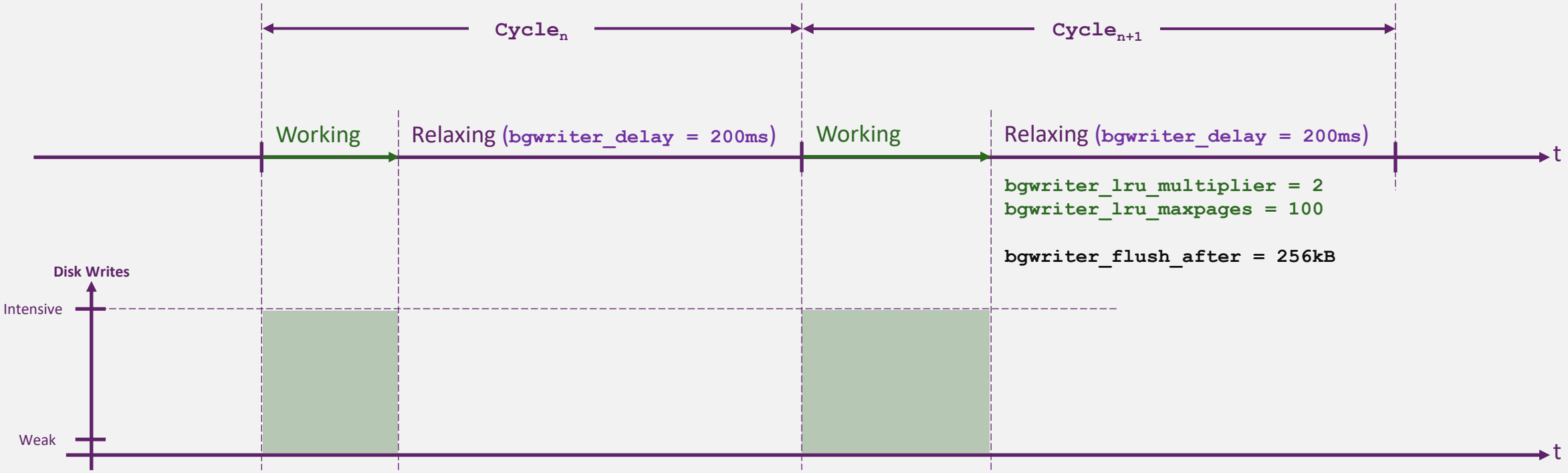
DataBene

ACTIVITY and IO PRESSURE



DataBene

ACTIVITY and IO PRESSURE



DataBene

pg_catalog.pg_stat_bgwriter

Column (**pg16**)	Type
checkpoints_timed	bigint
checkpoints_req	bigint
checkpoint_write_time	double precision
checkpoint_sync_time	double precision
buffers_checkpoint	bigint
buffers_clean	bigint
maxwritten_clean	bigint
buffers_backend	**bigint**
buffers_backend_fsync	**bigint**
buffers_alloc	**bigint**
stats_reset	timestamp with time zone

Column (**pg17**)	Type
buffers_clean	**bigint**
maxwritten_clean	**bigint**
buffers_alloc	**bigint**
stats_reset	**timestamp with time zone**

Column (**pg17**)	Type
num_timed	**bigint**
num_requested	**bigint**
restartpoints_timed	**bigint**
restartpoints_req	**bigint**
restartpoints_done	**bigint**
write_time	**double precision**
sync_time	**double precision**
buffers_written	**bigint**
stats_reset	**timestamp with time zone**

DataBene

pg_catalog.pg_stat_bgwriter

Column	Type
buffers_clean	**bigint**
maxwritten_clean	**bigint**
buffers_alloc	bigint
stats_reset	timestamp with time zone

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \; \in (\mathbf{1s} - 15\, mins)$$

- $maxwritten\_clean \times \boldsymbol{bgwriter\_lru\_maxpages} \leq buffers\_clean$
- pg16
  - Minimize pg_stat_bgwriter.backend_buffers
- Pg17
  - Minimize pg_stat_io.evictions for « client backend »

Checkpoint(er)

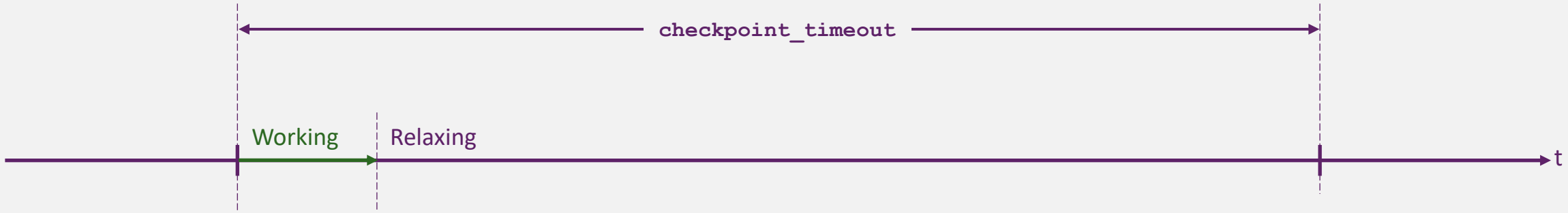
Understanding Performance Key Points

CHECKPOINT KEY CONCEPTS

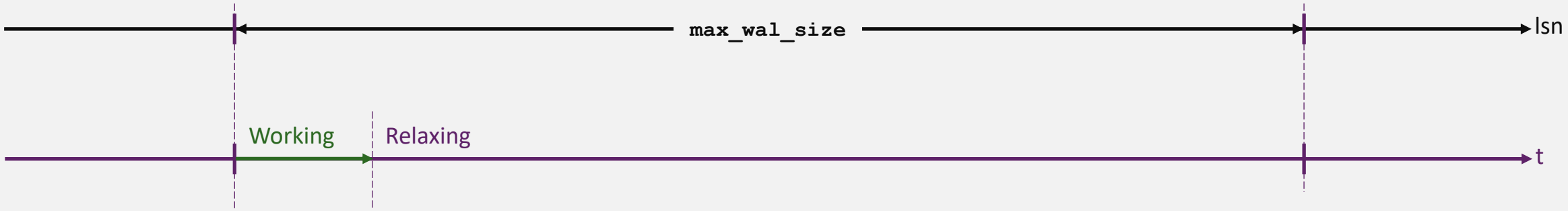
checkpoint_timeout - max_wal_size - checkpoint_completion_target
checkpoint_warning - min_wal_size - checkpoint_flush_after

CHECKPOINT TRIGGERING

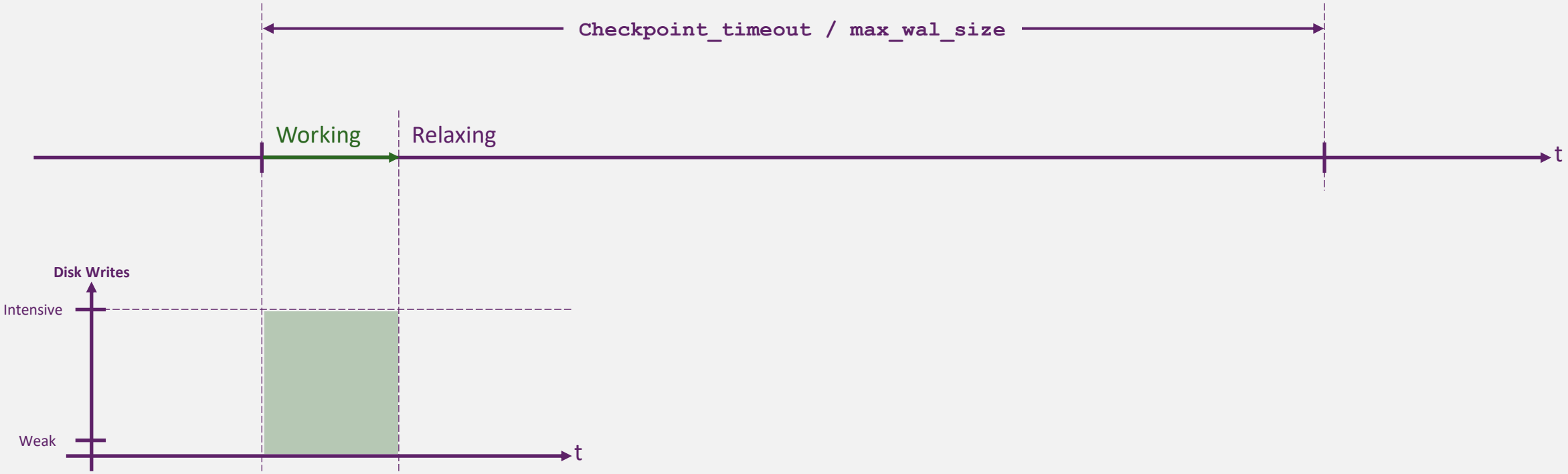
TEMPORAL TRIGGERING



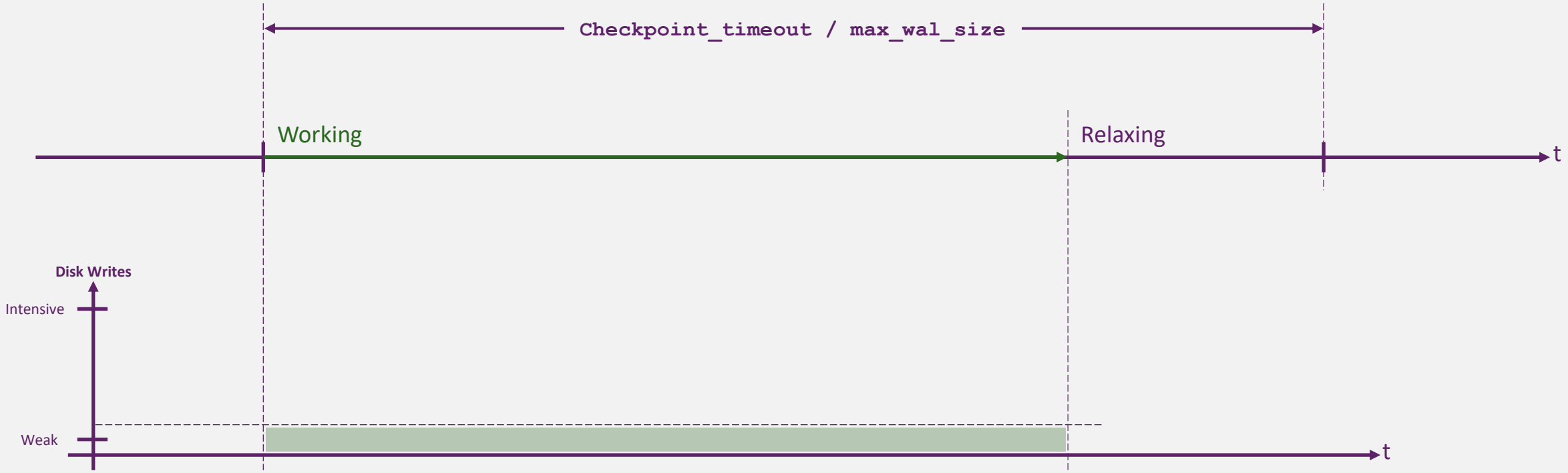
SPATIAL TRIGGERING



IO PRESSURE (intensive)



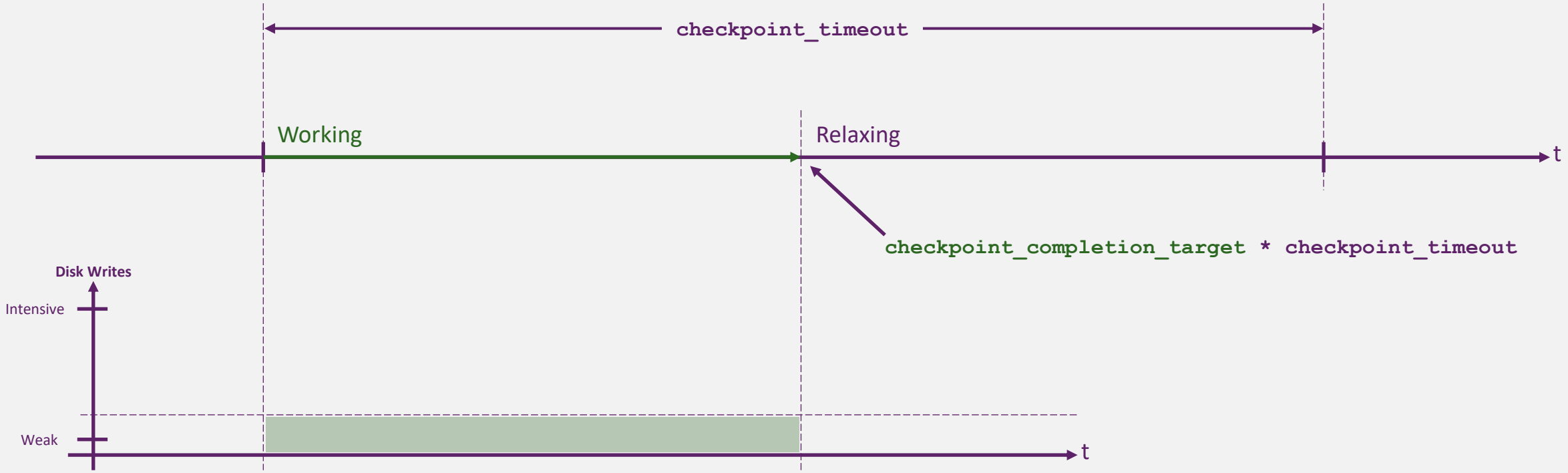
IO PRESSURE (spread)



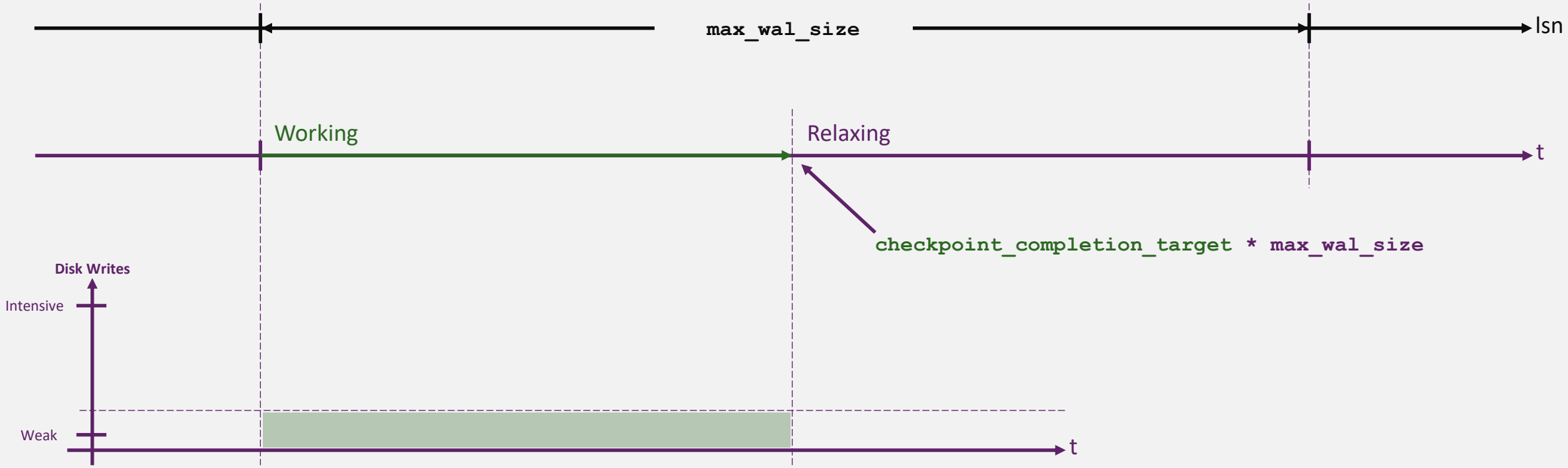
DataBene

IO PRESSURE SPREADING FEEDBACK LOOP

TEMPORAL SPREADING FEEDBACK LOOP



SPATIAL SPREADING FEEDBACK LOOP



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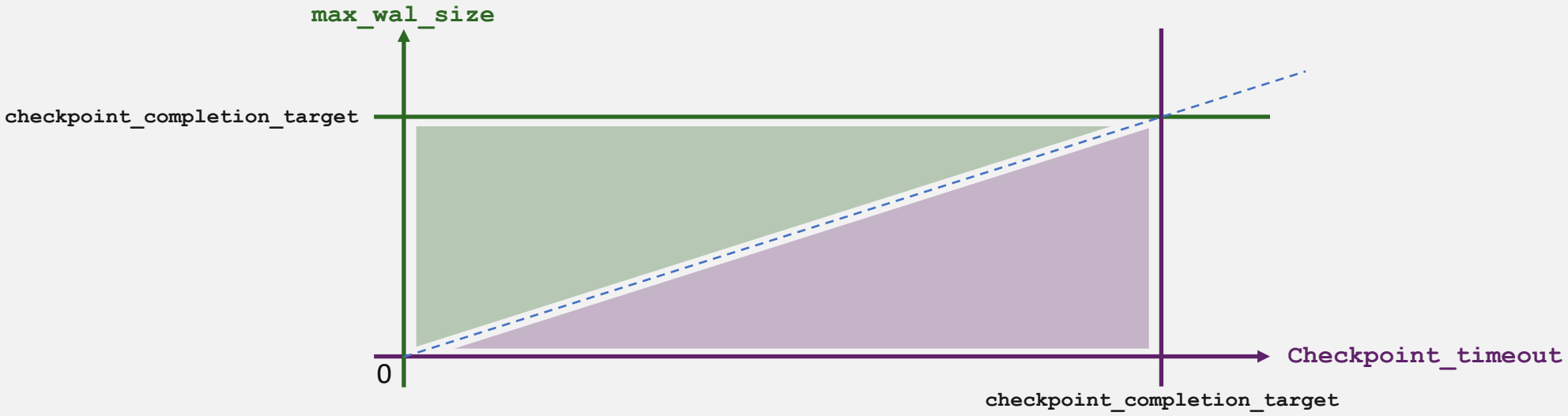
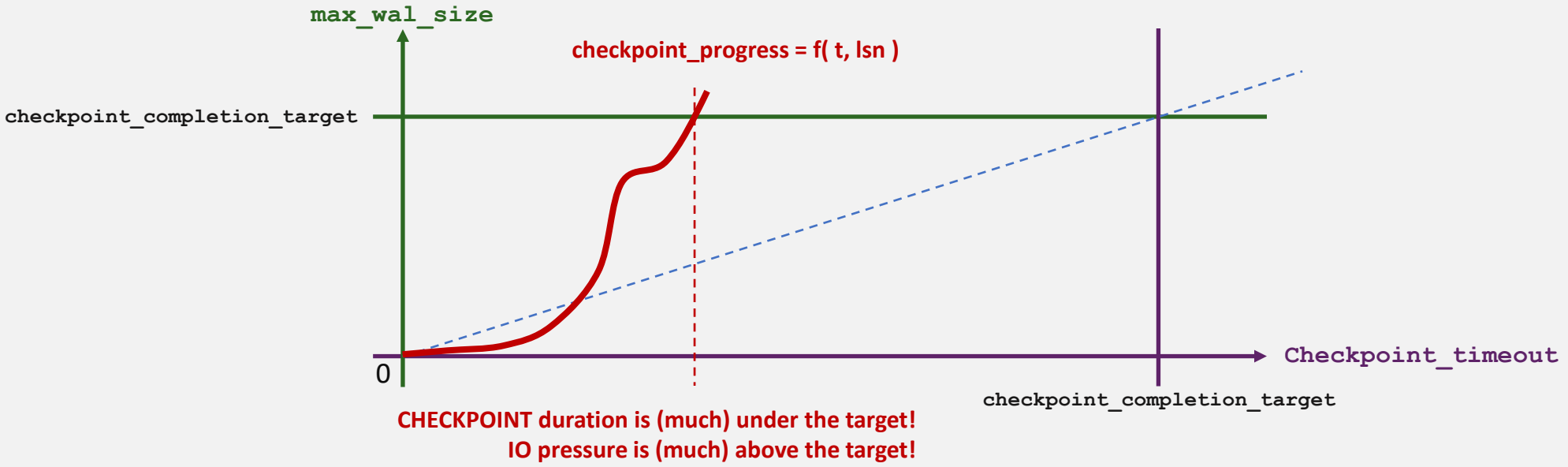
FEEDBACK LOOP

```
while num_processed < num_to_scan

   WriteDirtyPageToDisk()
   num_processed++

   checkpoint_progress = num_processed / num_to_scan
   checkpoint_progress = checkpoint_progress * checkpoint_completion_target

   wal_progress = (current LSN - start LSN) / max_wal_size
   if checkpoint_progress < wal_progress then continue

   time_progress = (now - start_time) / checkpoint_timeout
   if checkpoint_progress < time_progress then continue

   sleep( CheckpointWriteDelay = 100ms )
```

BIDIMENSIONNAL FEEDBACK LOOP DIAGRAM



BIDIMENSIONNAL FEEDBACK LOOP – EXAMPLE



pg_catalog.pg_stat_checkpointer

Column	Type
num_timed	bigint
num_requested	bigint
restartpoints_timed	bigint
restartpoints_req	bigint
restartpoints_done	bigint
write_time	**double precision**
sync_time	**double precision**
buffers_written	**bigint**

$$rate_x = \frac{\Delta x}{\Delta T} \; ; \Delta T \; \in (1\ mins)$$

- sync_time must be kept low

$$\Delta sync\_time \leq \sim 100ms$$

- Check IO spreading

$$\text{avg}_{\text{iops}} = \frac{\Delta buffe\_written}{\Delta writte\_time} \leq IOPressure$$

- Check completion_target is respected

$$\frac{avg_w(write\_time)}{checkpoint\_timeout} = checkpoint\_completion\_target$$

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Logging

- Do not forgot to logs some events
  - logging_collector = on
  - log_destination = ‘stderr,csv’ (csv can be injected to a database and then queried)
  - log_temp_files = 1
  - log_lock_waits = on
  - log_line_prefix = ‘%m [%p] %a %u@%d %a’ as a minimum
  - log_checkpoints = on
  - log_autovacuum_min_duration = 60000 (ms)
  - log_min_duration_statement = the value which make sense for you
- Mine your log every day
  - pgbadger can help with that

Hey, I did not cover the following yet:

- pg_stat_slru
- pg_stat_replication
  - SELECT pg_wal_lsn_diff(pg_current_wal_lsn(), sent_lsn) AS sent_lag_bytes from pg_stat_replication;
- pg_class size catalog tables
  - SELECT relname,relpages,pg_size_pretty(8192::bigint*relpages) FROM pg_class WHERE relnamespace= 'pg_catalog'::regnamespace ORDER BY 2 DESC;
- pg_index is not valid (pg_index.indisvalid)
  - select * from pg_index where not indisvalid;
- pg_stat_archiver
  - SELECT now() - COALESCE(last_failed_time, '1970-01-01'::date) <= interval '5 mins' AS recent_failure FROM pg_stat_archiver ;
- pg_stat_activity (wait_event_type, wait_event, state, long running query/snapshot) with pg_locks (granted ?)

Linux

procFS, cgroups, perf

ProcFS - CPU

```
$ cat /proc/stat
#    user     nice    system  idle       iowait irq softirq steal guest guest_nice
cpu  31597599 2158402 9278540 1083188543 1623186 0  303365  0     0     0
cpu0  6700402  488305 2278642  272134488  392242 0   19813  0     0     0
cpu1  7706591  563056 2072923  271348166  413324 0   18152  0     0     0
cpu2  8151274  502605 2405923  270298148  422380 0  173093  0     0     0
cpu3  9039330  604434 2521050  269407739  395239 0   92305  0     0     0
```

$$CPU\ Utilization = \frac{user\ +\ nice\ +\ system\ +\ stealth\ +\ guest}{user\ +\ nice\ +\ system\ +\ stealth\ +\ guest\ +\ idle\ [+\ iowait]} < 0.85$$

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ProcFS - CPU

```
$ cat /proc/stat
…
intr 697368832 48 0 0 0 0 0 0 1 0 0 0 0 0 0 0 0 0 0 6 0 0 0 25 23437850 15669310 2 11670157 0 0 0 … 0 0 0
ctxt 426424223
btime 1726754569
processes 1486375
procs_running 1
procs_blocked 0
#                    TIMER      NET_TX    NET_RX    BLOCK       TASKLET SCHED      HRTIMER RCU
softirq 837985299 6 108387462 15434898 35102963 11475396 0 4390    475399864 48060   192132260
```

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ProcFS - Network

```
$ cat /proc/net/dev
Inter-|   Receive
 face |          bytes  packets errs drop fifo frame compressed multicast
    lo:           19449      119    0    0    0     0          0         0
  eno0:    10296287653 26877099    0    0    0     0          0   1416671
docker0:     684107064 12947192    0    0    0     0          0         0
veth303a4b4: 250762391  3804884    0    0    0     0          0         0
veth37d40dd: 251701833  3817537    0    0    0     0          0         0
veth4c6976c:  33518004   489729    0    0    0     0          0         0
veth75f0dc9: 252377309  3828110    0    0    0     0          0         0
veth49d99b2:  24114346   312563    0    0    0     0          0         0
veth4fd0c00:  23808783   309302    0    0    0     0          0         0
veth2a4269b:  23354884   302527    0    0    0     0          0         0
```

ProcFS - Disk

```
$ cat /proc/diskstats
8 0 sda 1274558 151495 85887753 4817963 9019869 7340199 238013064 28267395 0 24084484 48700750 0 0 0 0 1615784 15615391
8 1 sda1 236 0 11618 368 0 0 0 0 0 660 368 0 0 0 0 0 0
8 2 sda2 437 211 40076 1732 257 114 85912 2763 0 3452 4495 0 0 0 0 0 0
```

ProcFS - Diskstat

```
==  ====================================
 1  major number
 2  minor number
 3  device name
 4  reads completed successfully
 5  reads merged
 6  sectors read
 7  time spent reading (ms)
 8  writes completed
 9  writes merged
10  sectors written
11  time spent writing (ms)
12  I/Os currently in progress
13  time spent doing I/Os (ms)
14  weighted time spent doing I/Os (ms)
==  ====================================
```

Kernel 4.18+ appends four more fields for discard

tracking putting the total at 18:

```
==  ====================================
15  discards completed successfully
16  discards merged
17  sectors discarded
18  time spent discarding
==  ====================================
```

Kernel 5.5+ appends two more fields for flush requests:

```
==  ====================================
19  flush requests completed successfully
20  time spent flushing
==  ====================================
```

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ProcFS – Diskstat – Service Time

$$\frac{\delta[io_{ticks}]}{(\delta[read_{IOs} + read_{merges} + write_{IOs} + write_{merges}])}$$

ServiceTime is given in milliseconds.

Rewritten with field numbers:

$$\frac{\delta[f13]}{(\delta[f4 + f5 + f8 + f9])}$$

ProcFS – Diskstat – Queue Time

$$\frac{\delta[time_{in\_queue}]}{(\delta[read_{IOs} + read_{merges} + write_{IOs} + write_{merges}] + \delta[in\_flight])} - servicetime$$

QueueTime is given in milliseconds.

Rewritten with field numbers:

$$\frac{\delta[f14]}{(\delta[f4 + f5 + f8 + f9] + \delta[f12])} - \frac{\delta[f13]}{(\delta[f4 + f5 + f8 + f9])}$$

cgroups

- cgroups are used everywhere and automatically
- `/sys/fs/cgroup`
  - `blkio`
  - `cpu | cpu,cpuacct | cpuacct | cpuset`
  - `devices`
  - `freezer`
  - `hugetlb | memory`
  - `misc`
  - `net_cls | net_cls,net_prio | net_prio`
  - `perf_event`
  - `pids`
  - `rdma`
  - `systemd`
  - `unified`

CPU consumption of my PostgreSQL service

```
$ cat /sys/fs/cgroup/cpuacct/system.slice/ \
      system-postgresql.slice/cpuacct.usage_all
cpu user system
0 1841620000000 38442320000000
1 700600000000 13517880000000
2 1627472000000 33766160000000
3 1489560000000 30669040000000
```

Unit: 10ms (1/100th s) => direct percent of CPU consumption.

Compute rate as usual $rate_{cpu\%} = \frac{\Delta user + \Delta system}{\Delta T}$

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IODisk comsumption for my docker

```
cat /sys/fs/cgroup/blkio/docker/0f040c…8c7bc0e3\
    /blkio.throttle.io_service_bytes
8:0 Read 3897999360
8:0 Write 2056773632
8:0 Sync 4718170112
8:0 Async 1236602880
8:0 Discard 0
8:0 Total 5954772992
Total 5954772992
```

Perf

- Very interesting tool you have to try at least once.
- Only for troubleshooting because it is kind of manual.
- Usually perf.data file has to be processed on the recorded server.
  - Processing data file can be consuming

Perf – System Probe

```
sudo perf list
```

Gives a lot of available hardware and system metrics!

Perf - Example

```
sudo \
perf stat -e
block:block_rq_*,syscalls:sys_enter_write,syscalls:sys_enter_fsync \
-a -r 5 -- psql -q -p 5434 -U postgres postgres \
-c "drop table if exists x; create table x as select a FROM
generate_series(1,1000000) a;";
```

Perf – Completely Fair Scheduler

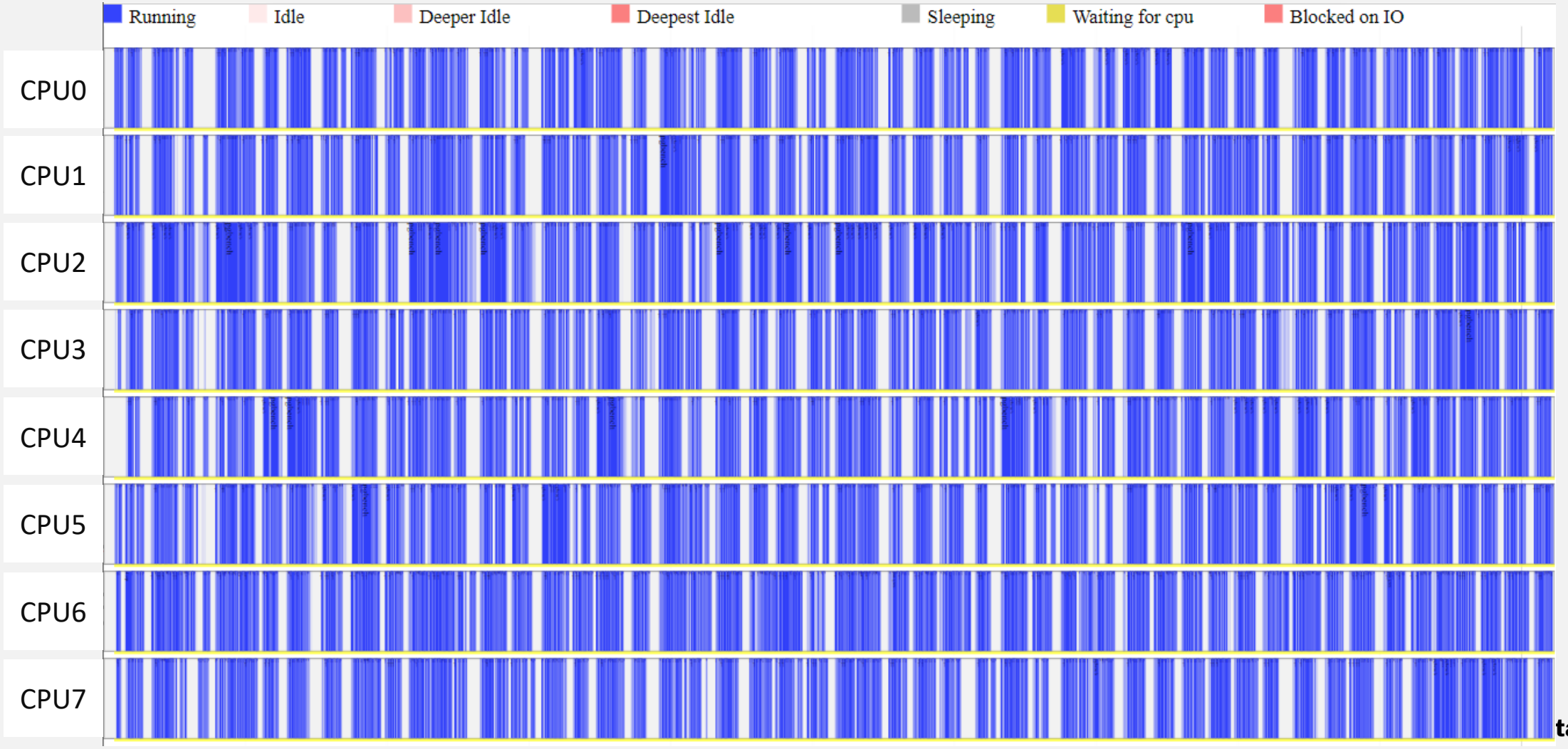
To investigate

```
perf sched record sleep 0.1
perf sched latency -s max
perf sched map
perf timechart
```

[Announce] 'perf sched': Utility to capture, measure and analyze scheduler latencies and behavior

https://lwn.net/Articles/353295/

Linux – Completely Fair Scheduler



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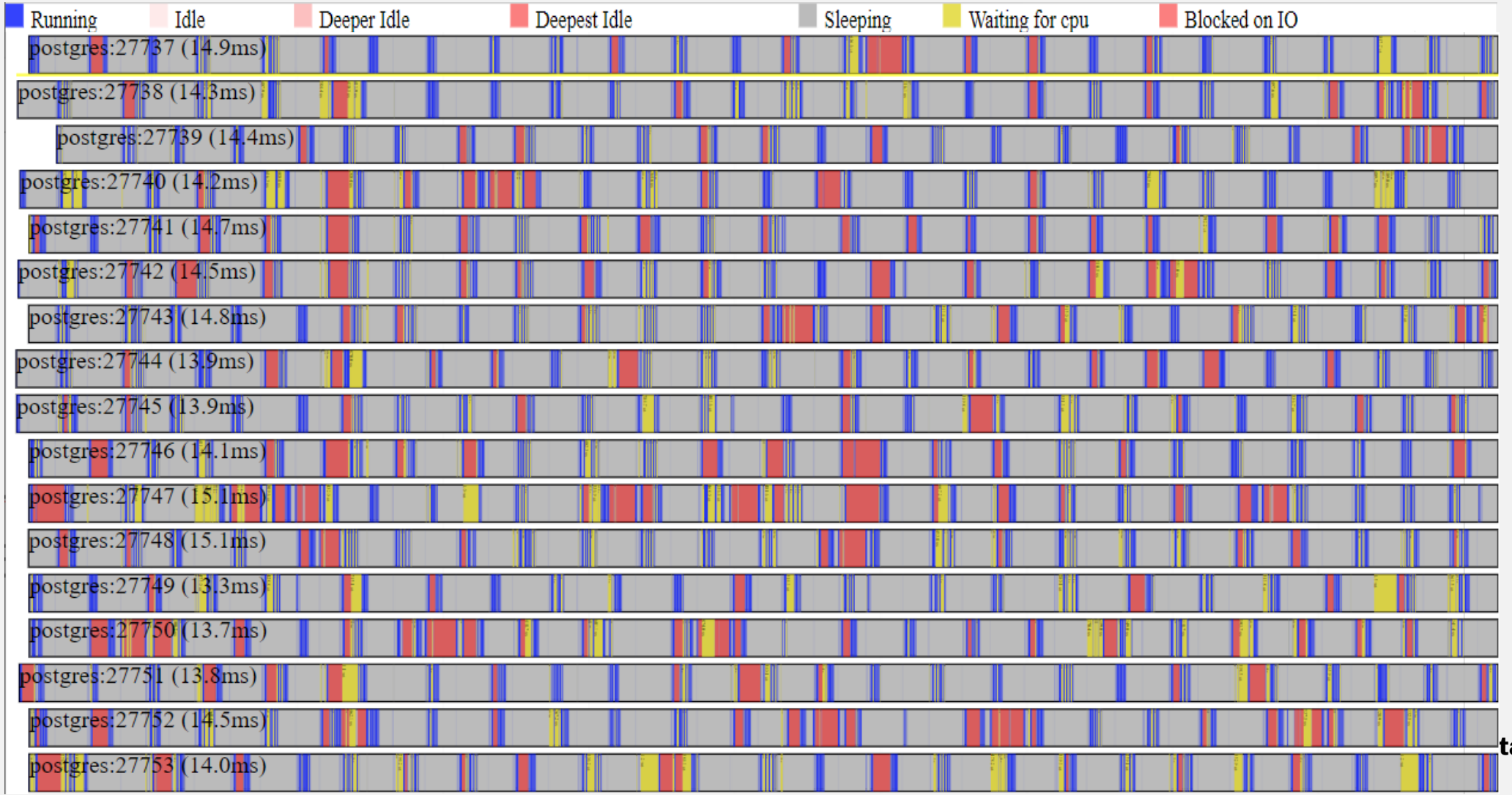
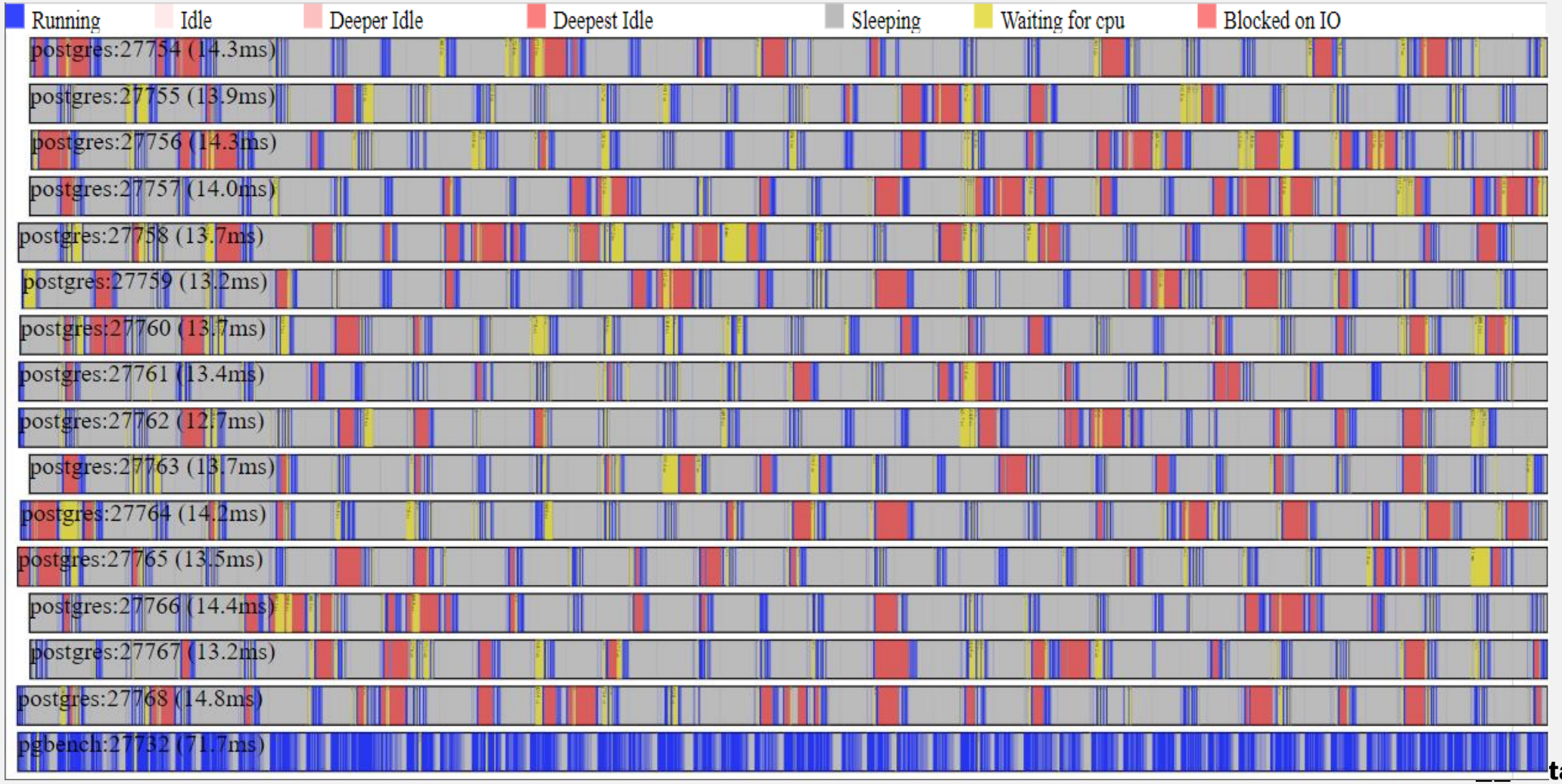
Linux – Completely Fair Scheduler



Linux – Completely Fair Scheduler



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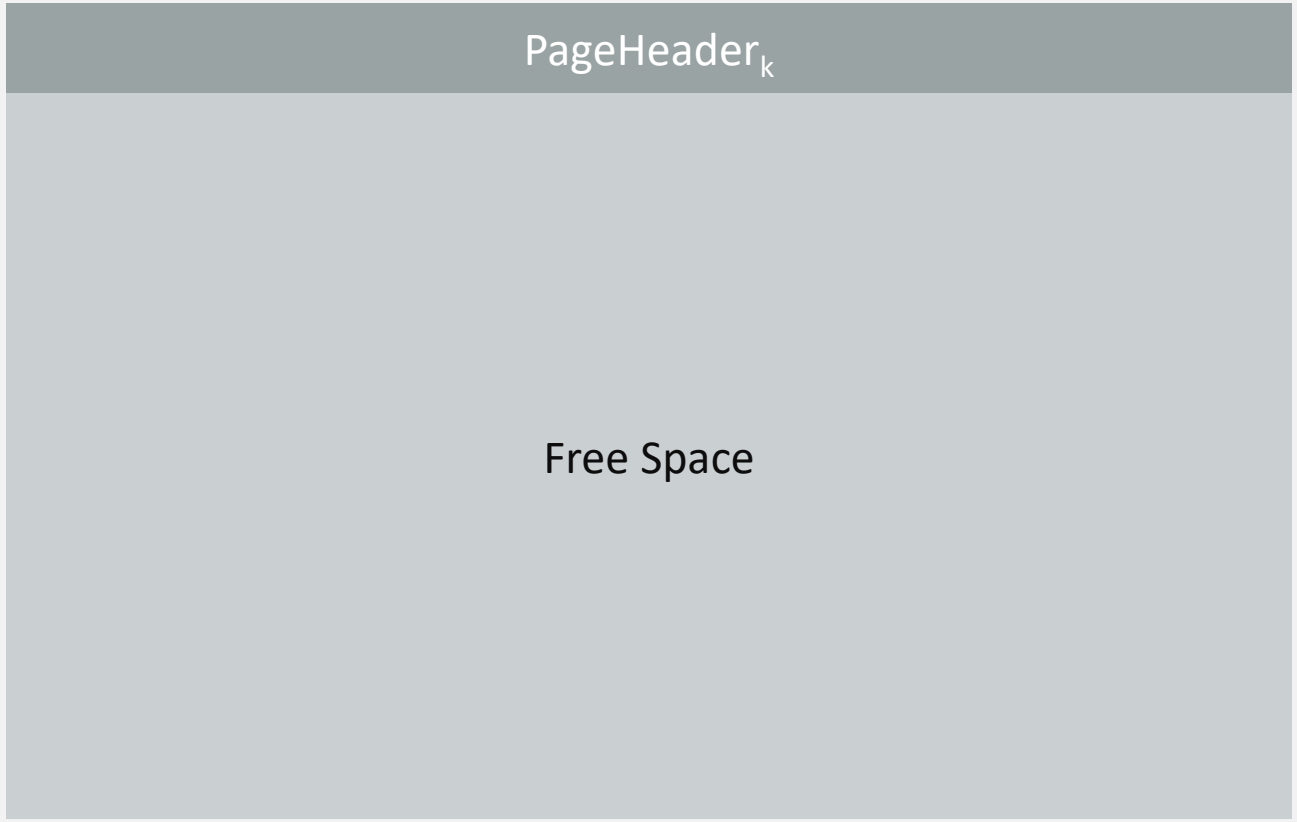
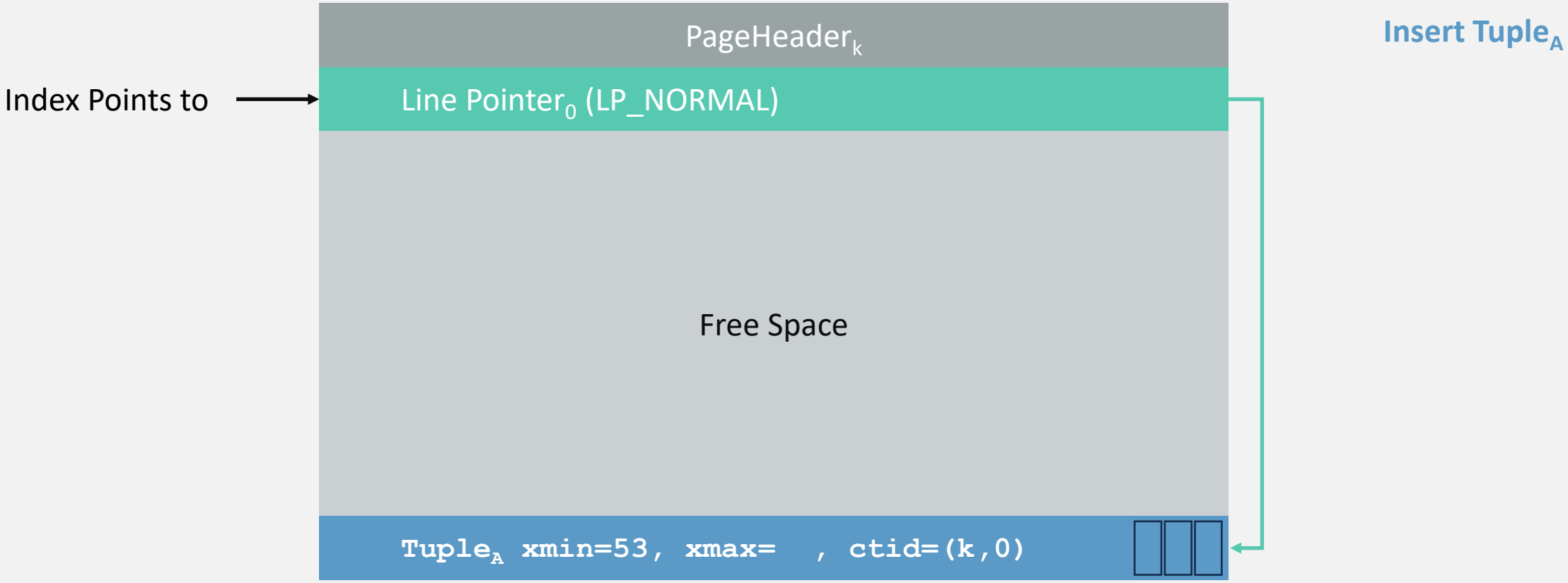
Thank You

Without Heap Only Tuples

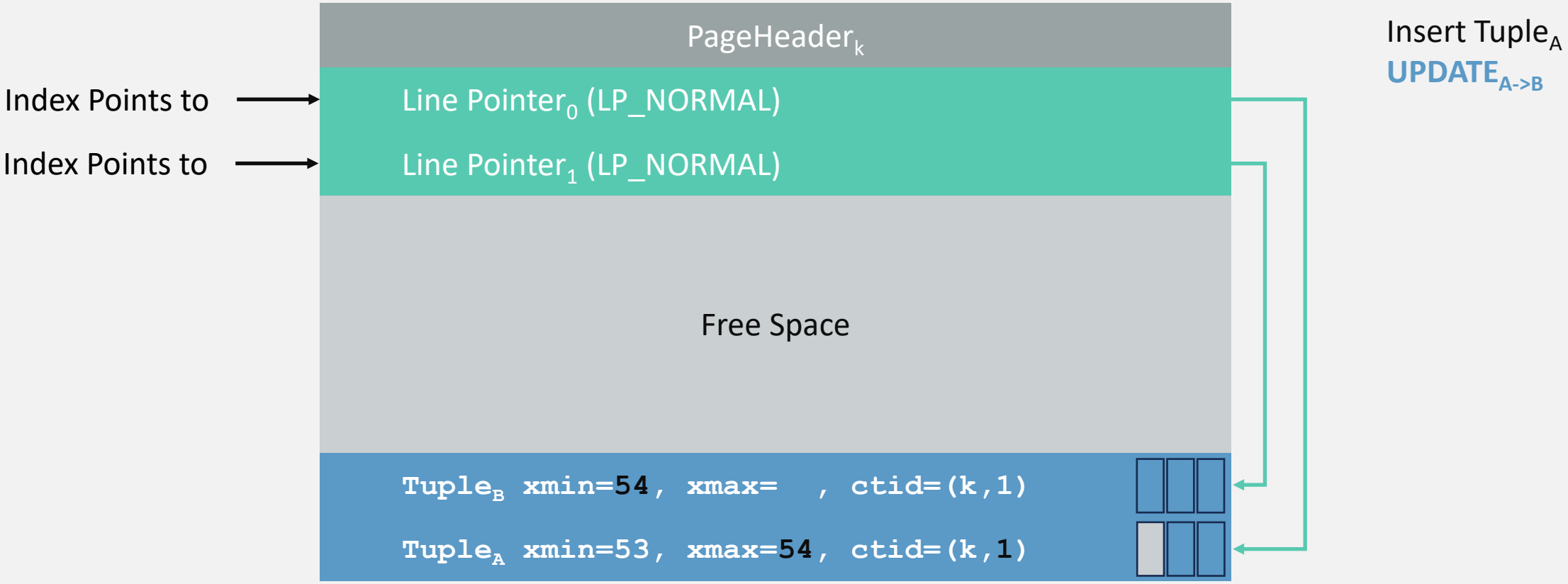
Structure – Usage – Processing


PageHeader$_k$
Free Space



LP_NORMAL | LP_REDIRECT | LP_DEAD | LP_UNUSED | Unvisible

DataBene



LP_NORMAL | LP_REDIRECT | LP_DEAD | LP_UNUSED | Unvisible

DataBene

Heap Only Tuples

Structure – Usage – Processing

LP_NORMAL | LP_REDIRECT | LP_DEAD | LP_UNUSED | Unvisible | HEAP_ONLY_UPDATE | HEAP_ONLY_TUPLE

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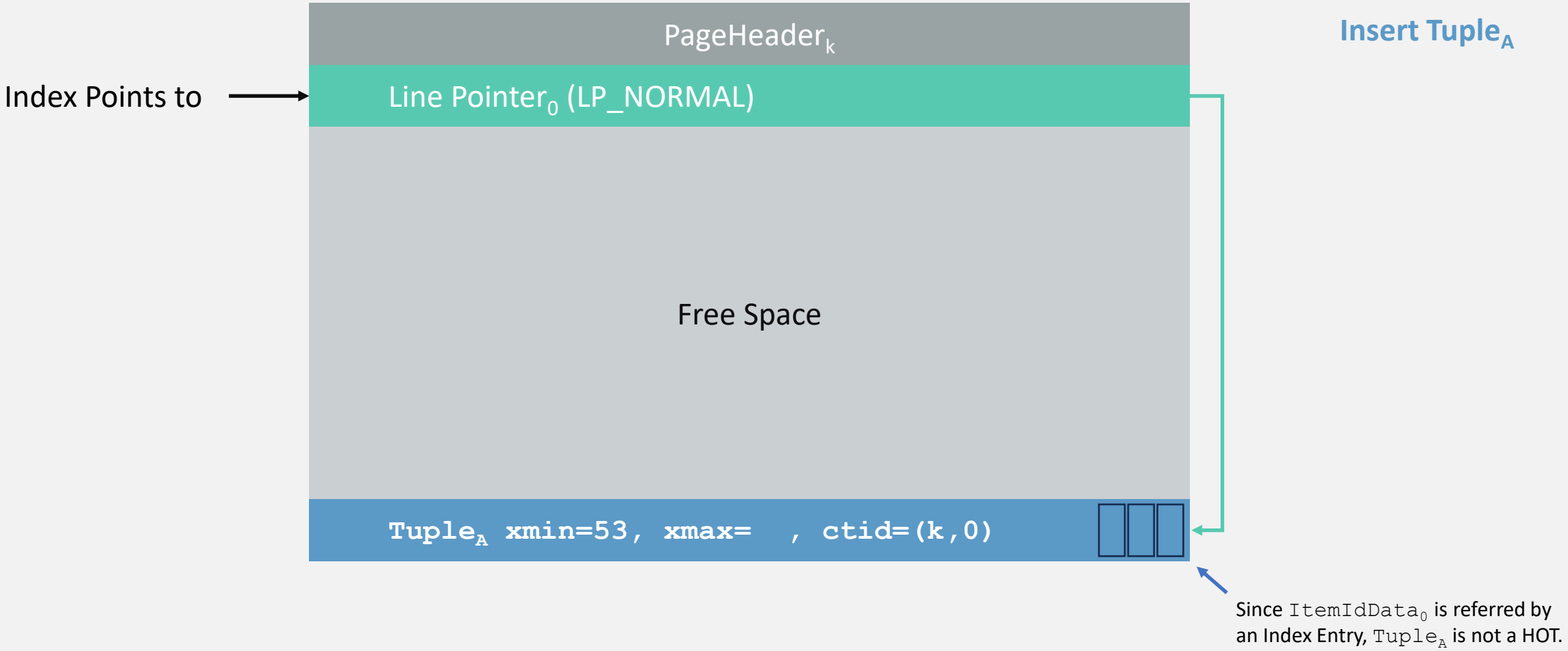
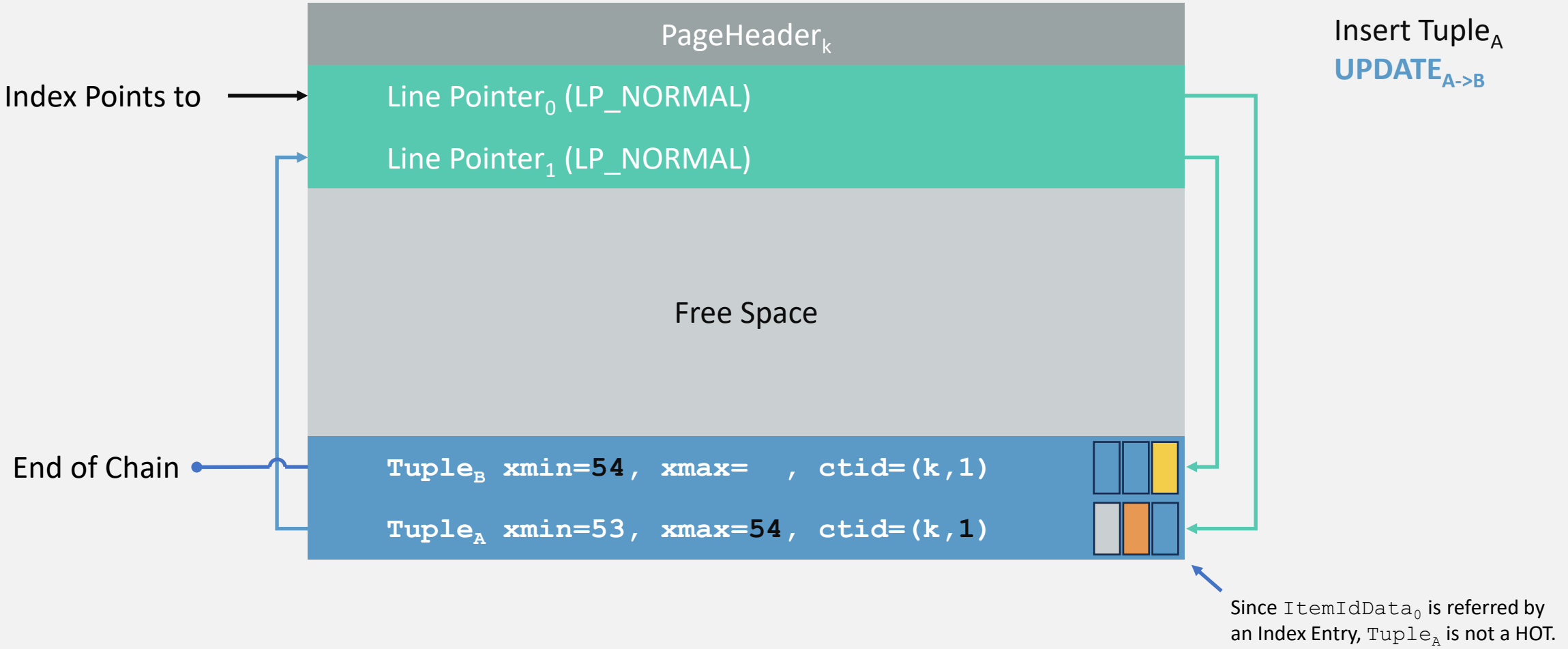


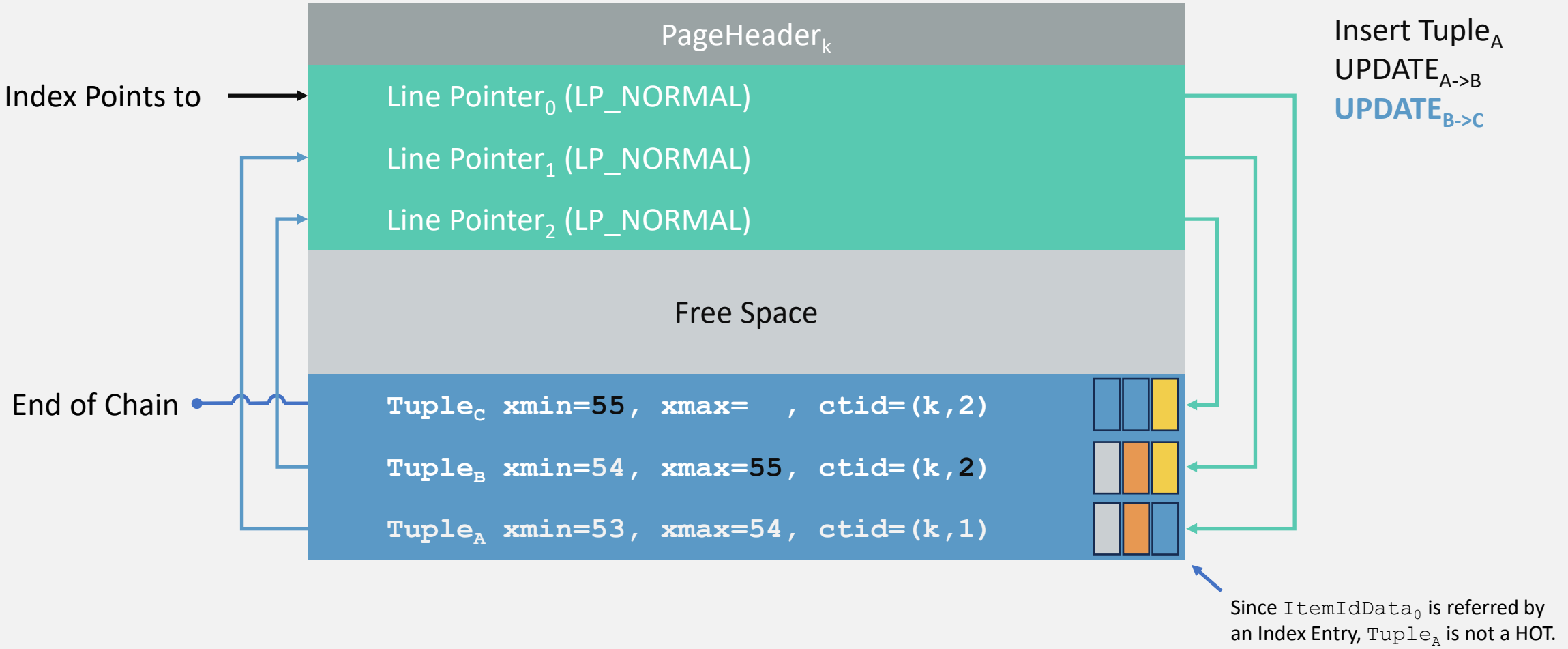
LP_NORMAL | LP_REDIRECT | LP_DEAD | LP_UNUSED | Unvisible | HEAP_ONLY_UPDATE | HEAP_ONLY_TUPLE

DataBene



LP_NORMAL | LP_REDIRECT | LP_DEAD | LP_UNUSED | Unvisible | HEAP_ONLY_UPDATE | HEAP_ONLY_TUPLE

DataBene



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DataBene