Making Sense of PostgreSQL Logical Replication

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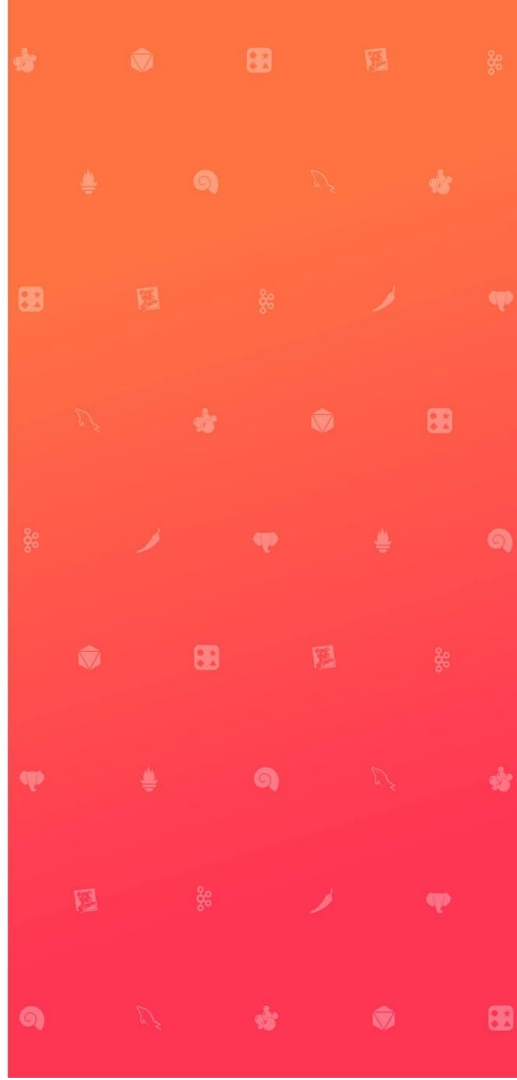
Agenda

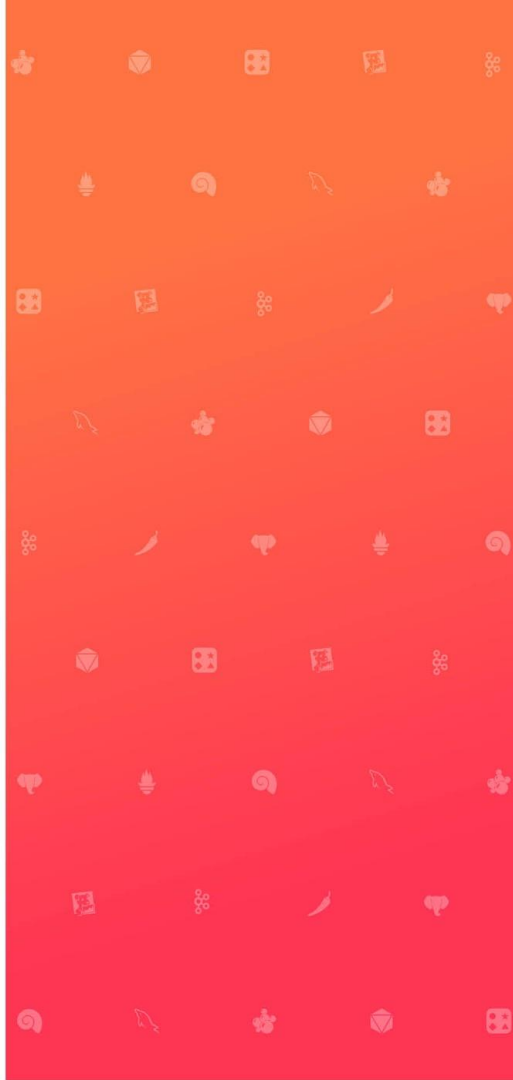
- Background about replication in PostgreSQL
- What is PostgreSQL Logical Replication
- Use cases for logical replication
- CLI example
- Pitfalls and gotchas of Logical Replication
- A quick glance at pg-migrate



Background about replication in PostgreSQL

Postgres Replication can be ...

- Physical
  - Physical Streaming Replication
  - WAL Log Shipping
- Logical
  - Logical Streaming Replication
- Trigger based
  - Slony
- Physical and logical replication are based on WAL, as are most online backup solutions, PITR



Write Ahead Logs

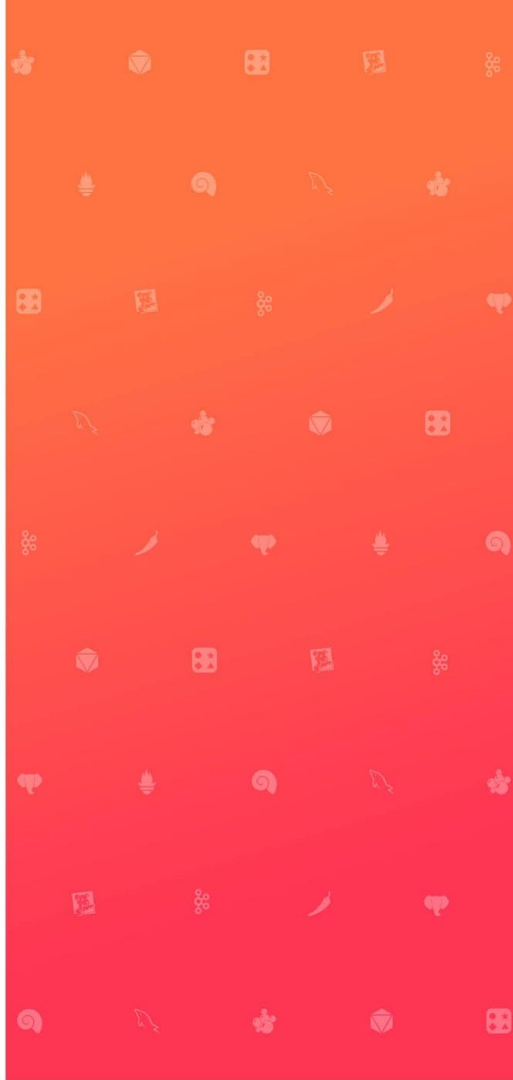
- WAL logs are binary log files, or REDO logs, used in most relational database systems
- A WAL log file consists of several WAL records
- Any transaction performed on a database is first written as a WAL record, only then written to the tables' data files
- Safeguards against data corruption with partial writes (eg power failure)
- Can be replayed from a checkpoint to restore to a current or previous state (PITR)

WAL levels

- The amount of information written to WAL files is controlled by the **wal_level** setting -
- **minimal** - faster, skips some bulk operations, not enough information to reconstruct the data from a base backup - no replication/archiving
- **replica** (default) - allows for physical replication, archiving
- **logical** - the same data as replica, plus the information needed for logical replication

Physical replication

- Before PG 10, built-in replication always happened using physical replication
- Based on WAL (Write Ahead Logs), block level changes sent to the replicas
- The replica is a bit-by-bit copy of the master, the whole database and all changes are always replicated
- Used for High-Availability and read scaling



WAL log shipping - warm standby

- A form of physical replication
- First method of replication in PG (ver 8.2 in 2006)
- WAL files are transferred to an archive with **archive_command** (eg. cp, s3cmd, gsutil cp)
- The log files are sent and processed once the WAL file is filled with enough records
- The replica processes these WAL files
- No synchronous replication
- Supported by eg. PgBarman, WAL-E, pghoard

Streaming Replication

- Introduced in PostgreSQL 9.0 (September 2010)
- Allows the replica to stay more up to date vs the log shipping
- This is because WAL records are sent directly to the replica (vs waiting for the WAL file to fill with enough records)
- Allows for synchronous replication (since 9.1)
- The records are sent directly over the network by the master's wal_sender to the replica's wal_receiver
- Can be used alongside log shipping

Physical replication recap

- Used for HA and read scaling
- The replica is always a bit-by-bit copy of the master
- Everything is replicated
- The replica is always read-only
- The replica has to have the same Postgres version as the master
- The replica has to be on the same HW architecture as the master

What is PostgreSQL's Logical Replication?

And what added value it brings vs Physical Replication

Logical replication

- Logical Replication was first introduced in PostgreSQL 10 (Oct 2017)
- A method of replicating data objects and their changes based on a replication identity (usually a primary key)
- Uses a publish / subscribe model
  - Subscribers subscribe to one or more publications on a publisher node
  - Subscribers can re-publish data to further subscribers

What this means in practise

- Processes the WAL records and decodes them to logical changes
- Instead of having a record of what bytes change in a datafile - we now know what rows change in what tables
- The changes are applied on the replica as logical INSERT, UPDATE, DELETE (and since PG 11, TRUNCATE) changes in transactional order
- We can filter changes based on their type, or the tables they affect

How it works - Pub / Sub

- A publication is defined on the master
  - Applied to one or more tables
  - Can filter based on change types
- A subscription is defined on the replica server
  - The subscriber can also publish to further subscribers
- When a subscription is created it copies a snapshot of the published tables, then changes on the publisher are sent to the subscriber in real-time

Replication identity

- Replication is done based on a “Replication Identity”
  - In practice this is usually the primary key
  - Can be any unique index
  - Finally it can be set to “FULL” which makes the whole row the key

Replica writability

- Unlike with streaming replication, the replica is writable
- Does not imply multi-master
  - Bi-directional replication is not supported
- The destination table schema can differ from the source, but needs to exist
  - Can have more columns
  - Column order doesn’t matter
  - The changes need to be able to go through

Logical replication use cases

Replication of a subset of a database

- If you wish, you can choose to replicate only certain tables from a database
  - Not possible in streaming replication
- This is more economic and performant
- The replica table is writable
  - You can add indexes, views
  - Can add columns
  - The replica's security definition can be different

Database consolidation

- Replicating select tables from several databases to a single database
- Great for analytics
- The replica can have different security definitions - you can allow wider access on the consolidated DB

Online migration

- Online database migration
- Essentially -
  - Start replication
  - Wait for replication to finish
  - Point your clients at the destination
- No master promotion involved
- Possibility to upgrade PG major versions

Replicating between different types of clusters

- Logical replication is possible between different versions* of Postgres
- Allows for replication between different platforms:
  - Windows to Linux
  - x86 to ARM

CLI example

Simple replication of one table

Set wal_level to logical

- Enable wal_level = logical on both the *source* and *destination* databases
- Restart the clusters for changes to take effect

```
$ ALTER SYSTEM SET wal_level = logical;

$ show wal_level;
 wal_level
-----------
 logical
(1 row)
```

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Create some example data

- Create a source database
- In it create a table called test_table and add some test values

```
postgres=# CREATE DATABASE source;
postgres=# \c source

source=# CREATE TABLE test_table (id INT);
CREATE TABLE
source=# INSERT INTO test_table VALUES (1), (2);
INSERT 0 2
```

Create a publication

- On the source cluster, create a publication for test_table

```
source=# CREATE PUBLICATION pub1 FOR TABLE test_table;
CREATE PUBLICATION
```

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Now on to the destination DB

- We need to have the schema defined on the destination, here we do it by hand, but you could use eg. pg_dump --schema-only

```
postgres=# \c destination
You are now connected to database "destination" as user
"postgres".

destination=# CREATE TABLE test_table (id INT);
CREATE TABLE
```

Create a subscription

- Now we create a subscription on the destination
- Make sure that you can reach the source postgresql server port from the destination

```
destination=# CREATE SUBSCRIPTION sub1
  CONNECTION 'host=192.168.122.33 port=5432 dbname=source'
  PUBLICATION pub1;
NOTICE:  created replication slot"sub1" on publisher
CREATE SUBSCRIPTION
```

Replication is now running!

- You can check the contents of the destination table and you should now find the test data there

```
destination=# SELECT * FROM test_table;
 id
----
  1
  2
(2 rows)
```

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Replication status

- Check the status of a replication from pg_stat_subscription and pg_replication_slots

```
source=# SELECT confirmed_flush_lsn, pg_current_wal_lsn(),
  (pg_current_wal_lsn() - confirmed_flush_lsn)AS lsn_distance
  FROM pg_catalog.pg_replication_slots
       WHERE slot_name = 'sub1';
 confirmed_flush_lsn | pg_current_wal_lsn | lsn_distance
---------------------+--------------------+--------------
 0/167B708           | 0/167B708          |            0
(1 row)
```

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Cleaning up

- If you are doing a migration you will want to stop the replication
- Remember to clean up unused replication slots

```
destination=# DROP SUBSCRIPTION sub1;
NOTICE:  dropped replication slot"sub1" on publisher
DROP SUBSCRIPTION
```

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Logical replication towards Aiven PostgreSQL

- There is a help article about logical replication towards Aiven PostgreSQL with more examples
- The article also explains how to use the aiven-extras on the Aiven side for access to the superuser

Logical replication Pitfalls and gotchas

Things to keep in mind when using logical replication

Does not support DDL changes

- Logical replication does not support schema changes
- In DB migrations you will typically copy the schema first, then start replication
- You are also able to change the schema by hand
  - Eg. when adding a column, you can add it to the replica, then the master

Schema change example workaround

- Pause replication
- Migrate destination
- Migrate source
- New tables need to be added separately to the publication with ALTER PUBLICATION
- Refresh the subscription
- Resume replication

Sequences can be tricky

- Start values of sequences aren't transparently replicated
- A write to the destination can cause sequence collisions
- Workarounds include
  - Using non-overlapping ranges for auto-increments
  - Using external sources for the values (etcd, ZooKeeper)

No primary key?

- Logical replication needs a replication identity
- Usually a primary key - if it doesn't exist:
  - Use another unique index of the table
  - Use the full row as the replication identity
  - Or add a primary key to the table

Material about the previous cases

- A great article about the DDL changes, sequences, replication identity issues with example workarounds at PGDash

Large objects

- Postgres objects of type “large object” (BLOB) can’t be replicated
- Instead of using large objects you can reference objects on object store or network storage (GCS, S3, NFS, EFS)
- For smaller data, you can store the data in the tables themselves

Partitioned tables

- Partitioned tables are not currently (<= PG 12) fully supported
- You can however replicate the child tables by replicating them explicitly
- Partition hierarchies need to be the same
- Support for logical replication in partitioned tables coming in Postgres 13

Extensions

- Be careful with extensions when using Logical Replication - version mismatches or missing extensions can cause problems
- Require whitelisting (eg. pgextwlist) or superuser-like access to enable
- Some extensions don’t work with logical replication
    - eg. TimescaleDB is not supported

Superuser access

- Some of the operations, eg publishing ALL TABLES require superuser privileges
  - Not a problem when you have superuser access
  - More of an issue on managed platforms
- Aiven addresses this through the open source “aiven-extras” extension
- AWS RDS has a custom rds_replication role which allows for replication
- GCP CloudSQL and Heroku PG don’t support logical replication at all

aiven-db-migrate

An open source migration toolkit in the works

aiven-db-migrate

- An Aiven built open source tool in Python 3.5+ for migrating databases
- Currently in development, first release will target PostgreSQL
- Plans to expand to cover also other DBs eg. MySQL
- Not restricted to Aiven products, can also be used for migrations between non-Aiven DBs

aiven-db-migrate - PostgreSQL

- Supports logical replication
- Does sanity checking on the source and target
  - Versions compatibility
  - Extensions
  - Permissions
- Also supports pg_dump as a fallback
- Supports aiven-extras for admin level out of the box (easy migrations to Aiven)

aiven-db-migrate - PostgreSQL

- To be integrated to the Aiven platform for migrations
- Under active development - more switches and functionality to be added
- To be open sourced as a standalone tool
  - Once released - contributions are always appreciated
- Blog post will follow

aiven-db-migrate - example

```
$ pg_migrate

--source
"postgres://postgres:xxxx@noisedata-public.aaaaa.eu-west-1.rds.amazonaws.com:5432"

--target
"postgres://avnadmin:xxx@noisedata-sandbox.aivencloud.com:12691/defaultdb?sslmode=require"

--wait-until-replication-in-sync
```

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Final words

Final words

- Logical Replication allows for lots of use cases and a variety of new setups
  - Partial replication
  - Multiple sources to one target
  - Replication between versions
  - Online upgrades and migrations
- It also involves a lot of moving parts so always plan and test your migrations as well as possible

Thank you for your time!

Q & A

Questions?

Links

- “Postgres 12 Documentation : Logical Replication“
  https://www.postgresql.org/docs/12/logical-replication.html
- https://pgdash.io/blog/postgres-replication-gotchas.html
- “Partitioned tables can now be replicated …”
  https://amitlan.com/writing/pg/partition-logical-replication/
- “Aiven-extras extension” https://github.com/aiven/aiven-extras
- “Using logical replication to replicate tables, or a whole database to Aiven PostgreSQL”
  https://help.aiven.io/en/articles/2464717-postgresql-logical-replication