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CDC for a brave new world

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Speaker

- Aiven co-founder
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- PostgreSQL user for the last 18 years

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CDC Definition

In databases, Change Data Capture (CDC) is a set of software design patterns used to determine (and track) the data that has changed so that action can be taken using the changed data.

- Wikipedia

CDC - The Why

- Data's journey through your company's systems usually just starts with its initial storing
- Real-time change information stream - as it happens
- No need to do bulk updates anymore with all their assorted errors
- Much more efficient, way fewer resources required since only delta is transferred

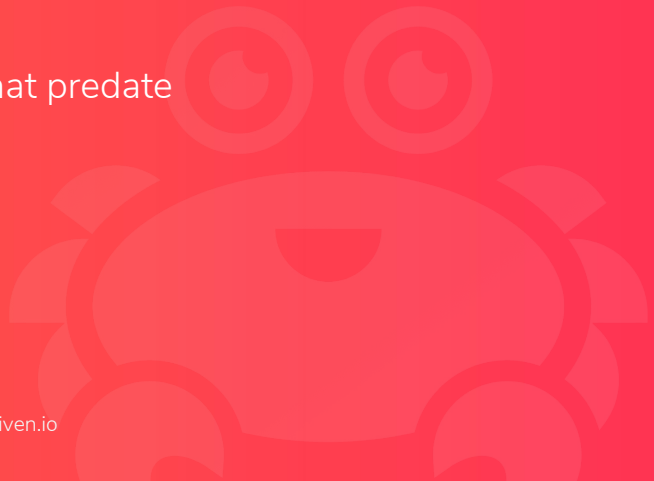
Foreword on examples

```
CREATE TABLE source_table (
    id SERIAL PRIMARY KEY,
    important_data text NOT NULL,
    create_time TIMESTAMPTZ NOT NULL DEFAULT clock_timestamp(),
    update_time TIMESTAMPTZ NOT NULL DEFAULT clock_timestamp(),
    updated BOOLEAN NOT NULL DEFAULT FALSE
);

ALTER TABLE source_table REPLICA IDENTITY FULL;


INSERT INTO source_table (important_data)
    VALUES ('first bit of very important analytics data');

INSERT INTO source_table (important_data)
       VALUES ('second bit of very important analytics data');
```

CDC - in the age of the Dinosaur

<Imagine a dinosaurs roaming freely through an idyllic landscape>

We're now talking about prehistoric times that predate the early 2000's



CDC - In the age of the Dinosaur

- Nightly database dump of some or all tables often done with pg_dump
- ETL from multiple databases to a single system
- Batch based
- Maybe using some proprietary ETL
- PostgreSQL COPY command made this less onerous

CDC - In the age of the Dinosaur

- Timestamp / sequence / status column based approach
- Add a column updated_timestamp to your table which you then read afterwards to try to find changed rows
- Same thing by having an updated boolean column in your table
- Possible limitations for noticing deletes or updates in naive implementations
- Confluent's Kafka JDBC connector works like this

CDC - In the age of the Dinosaur

```
SELECT * FROM source_table
      WHERE id >= 0
       ORDER BY id ASC LIMIT 1;

SELECT * FROM source_table
      WHERE timestamp >= y
      ORDER BY timestamp ASC LIMIT 1;

SELECT * FROM source_table
       WHERE updated IS FALSE
      ORDER BY id ASC LIMIT 1;
```

CDC - In the age of the Dinosaur

```
SELECT * FROM source_table
      WHERE updated IS FALSE
      ORDER BY id LIMIT 1;
UPDATE source_table SET updated = 't'

WHERE id = (SELECT id FROM source_table
      WHERE updated IS FALSE
      ORDER BY id ASC LIMIT 1)
      RETURNING *;
```

CDC - Trigger based approaches

You create change tables that contain the INSERTed UPDATEd or DELETEd rows

- Slony, PGQ (Londiste) and plenty of homespun solutions
- Allows all DML (INSERTs, UPDATEs, DELETEs) to be extracted
- Bad performance as in doubles all writes done to the database
- Doesn’t handle DDL (ALTER TABLE etc) gracefully

CDC - Trigger based approaches continued

- CREATE TRIGGER store_changes AFTER UPDATE, INSERT, DELETE ON source_table FOR EACH ROW EXECUTE PROCEDURE store_change();
- And then the trigger just INSERTs the contents of the change to a change table with the information stating whether it was an INSERT, UPDATE or DELETE
- The change table contents are read and applied from start to finish in some other database

CDC - Advent of a new age

<Imagine something very modern>

PG's built-in logical decoding saga started with
the release of 9.4 at the end of '14

CDC - Logical decoding - What is it?

- PostgreSQL can keep track of all the changes happening in a database
- Decodes WAL to desired output format
- Multiple logical decoding output plugins exist
- Very performant, low-overhead solution for CDC
- Avoids the multiple write problem with triggers by using the WAL that PG was going to write anyway

CDC - Logical decoding - What can it do?

- Track all DML (INSERT, UPDATE, DELETE) changes
- Unit of Change is a row of data that's already committed
- Allows reading only the wanted subset of changes
- Use cases include auditing, CDC, replication and many more
- Logical replication connections supported in multiple PostgreSQL drivers (JDBC, Python psycopg2)

CDC - Logical decoding - What can’t it do?

- Replicate DDL
- Possible to set up event triggers that write to a table and then have your replication system run the DDL based on it
- Depending on output plugin some data types not supported
- Failovers not handled gracefully as replication slots exist only on master nodes
- Changes tracked are limited to a single logical DB

CDC - Logical decoding - How to set it up

postgresql.conf:

```
wal_level=logical
max_replication_slots = 10 # At least one
max_wal_sender = 10  # At least one

$ CREATE ROLE foo REPLICATION LOGIN;
```

Before PG 10 also needs changes to pg_hba.conf

CDC - wal2json

- Author: Euler Taveira de Oliveira
- Decodes logical changes into JSON format
- Datatype limitations (JSON doesn't natively support everything)
- Supported by multiple DBaaS vendors (Aiven, AWS RDS, https://github.com/eulerto/wal2json)
- Supported by Debezium 0.7.x+

CDC - approach - pg_recvlogical

- Writes data in the defined output format
- Receive all logical changes and write them to a file
- Advantage of this is simplicity, great for simple use cases
- Downside is that there's just a single receiver of the data that writes it into a simple file
- If you lose that single file you've lost the change

CDC - pg_recvlogical wal2json usage

```
$ /usr/pgsql-10/bin/pg_recvlogical -d "host=localhost user=valtha"
--create-slot --start --slot pgconfus --plugin wal2json -v --file -
{"change":[{
    "kind":"insert",
    "schema":"public",
    "table":"source_table",
    "columnnames":[
        "id","important_data","create_time","update_time","updated"],
    "columntypes":[
        "integer","text","timestamp with time zone","timestamp with time
zone","boolean"],
    "columnvalues":[
       1,"first bit of very important analytics data","2018-03-15
02:35:22.476475+02","2018-03-15 02:35:22.476476+02",false]
}]}
```

CDC - approach - read changes within an application

- Receive all logical changes and directly receive them in an application
- Really easy to transform the data further
- Acting on the data, e.g. sending an email, is trivial
- Downside is that there's just a single receiver of the data

CDC - pg_recvlogical wal2json usage

```
slot_name = "pgconfus"
log_conn = psycopg2.connect(dsn,
    connection_factory=LogicalReplicationConnection)
log_cursor = log_conn.cursor()
log_cursor.create_replication_slot(slot_name,
    slot_type=REPLICATION_LOGICAL, output_plugin="wal2json")
log_cursor.start_replication(slot_name=slot_name,
    slot_type=REPLICATION_LOGICAL)


# Insert data in autocommit mode and wait for the replication message
cursor.execute("INSERT INTO source_table (important_data) VALUES ('first bit
of very important analytics data')")
time.sleep(1)
print("Payload: {}".format(log_cursor.read_message().payload))
```

CDC - approach - streaming platform

- Receive all logical changes and write them to a distributed system
- Change data is immediately replicated n times
- Allows multiple readers for the same data and easy-post processing of it
- Upside is that it makes very complex processing possible
- Downside is the (much) increased complexity
- Many larger organizations love this

Apache Kafka foreword

- Distributed streaming platform
- Supports publish/subscribe behavior
- Data spread into topics which are further split into partitions
- Data consists of a binary value, timestamp and an optional key
- AWS Kinesis and Google Pub/Sub are close cousins (https://kafka.apache.org/)

Apache Kafka foreword continued

- All data organized into topics and further on into partitions
- Data within a partition is guaranteed to keep order
- Messages can optionally have a key used for choosing the partition and to only keep the last value for that key within a topic
- If data is unkeyed it has a retention policy attached to it that prunes it based on time or data size
- Allows writing once and consuming the same data by same or other readers multiple times

CDC - Why Apache Kafka

- Apache Kafka is meant for streaming data
- Huge ecosystem of tools to handle data streams
- Reliable
- Scalable
- Natural “message bus” for data from different databases

Debezium

- Apache Kafka Connect Connector plugin (http://debezium.io/)
- Uses logical replication to replicate a stream of changes to a Kafka topic
- Supports PostgreSQL, MongoDB, MySQL, (Oracle)
- Uses log compaction, only needs to keep the latest value (if you pre-create topics)
- Can run arbitrary transformation code on the data as it's received
- Supports protobuf output plugin or wal2json

Why Debezium

- Gets the data in real-time from PostgreSQL - No more waiting
- Once you get the data to Kafka you can process it whichever way
- Plenty of other Kafka Connect connectors to send it to the next system
- Basis for Kafka centric architectures
- You don’t need to know beforehand who is going to consume the data or why

Debezium gotchas

- Remember to set REPLICA IDENTITY FULL to see UPDATE, DELETE changes
- When PG master failover occurs, PG replication slot disappears
    - Need to recreate state
- If you don’t pre-create topics they use DELETE not COMPACT as cleanup policy
- Limited datatype support
- Unlike documentation says, sslmode param is “require”, not “required”

Debezium example

```
$ curl -H "Content-type:application/json" \
       -X POST https://avnadmin:zqv9z@debezium-demoproject.aivencloud.com:25649/connectors \
       -d '{
 "name": "test_connector",
 "config": {
   "connector.class": "io.debezium.connector.postgresql.PostgresConnector",
   "database.hostname": "debezium-pg-demoproject.aivencloud.com",
   "database.port": "22737",
   "database.user": "avnadmin",
   "database.password": "nqj26a2lni8pi2ax",
   "database.dbname": "defaultdb",
   "database.server.name": "testdb",
   "table.whitelist": "public.source_table",
   "plugin.name": "wal2json",
   "database.sslmode": "require"
 }
}'
```

Debezium example continued

```
$ /opt/kafka/bin/kafka-console-consumer.sh --bootstrap-server
debezium-demoproject.aivencloud.com:26884 --topic testdb.public.source_table
--from-beginning --consumer.config client.properties

{"before":null,"after":{"id":1, "important_data":"first bit of very important
analytics data", "create_time": "2018-04-19T19:03:11.528398Z", "update_time":
"2018-04-19T19:03:11.528398Z","updated":false},
"source":{"version":"0.7.4","name":"testdb","ts_usec":1524164591528773000,
"txId":3573,"lsn":1509950840,"snapshot":null, "last_snapshot_record":null},
"op":"c", "ts_ms":1524164592172}

{"before":null,"after":{"id":2,"important_data":"second bit of very important
analytics data","create_time":"2018-04-19T19:03:11.628889Z","update_time":
"2018-04-19T19:03:11.62889Z","updated":false},
"source":{"version":"0.7.4","name":"testdb","ts_usec":1524164591628982000,
"txId":3574,"lsn":1509951256, "snapshot":null,
"last_snapshot_record":null},"op":"c","ts_ms":1524164592179}
```

CDC - approach - built-in logical replication

- In CDC context usually works best if you just have have the same table in multiple databases
- Doesn’t allow any transforms of the data while in transit
- Commonly used for replicating data to larger data warehouses where analytics is run
- Useful for a lot of other things as well
- Finally built-in!

Logical replication

- With logical replication you can replicate all or a subset of your data
- Replication scope always limited to a single database for a replication connection
- Currently requires superuser privileges or a hassle to set up
- Amazon Database Migration Service (DMS) another common use case (doesn't use built-in PG logical replication)
- Allows no-downtime migrations (in theory)

Logical replication example

```
-- Track only inserts
=# CREATE PUBLICATION cdc_pub FOR TABLE source_table
      WITH (publish='INSERT');
CREATE PUBLICATION

=# CREATE SUBSCRIPTION test_sub CONNECTION
      'host=127.0.0.1 port=5433 dbname=source user=postgres'
      PUBLICATION cdc_pub;
CREATE SUBSCRIPTION
NOTICE:  created replication slot "test_sub" on publisher
```

Logical replication example

```
-- Source database:
source=# INSERT INTO source_table (important_data) VALUES
           ('first bit of important replicated analytics data');

-- Target database:
target=# SELECT * FROM source_table;
```

CDC - Recap

- Logical decoding and replication have revolutionized the way CDC can be done with PostgreSQL
- We're only seeing the very beginnings of its adoption
- Note that logical decoding is not a perfect solution (yet)
- Apache Kafka a natural fit - it is meant for streaming data

Q & A

Time to ask me anything

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Thanks!

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