SEP 09 – 11, 2025
CONTAINER days CONFERENCE

Revisiting the Outbox Pattern in Go

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About me

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C → Java → Kotlin → Go

Author of pgx-outbox library

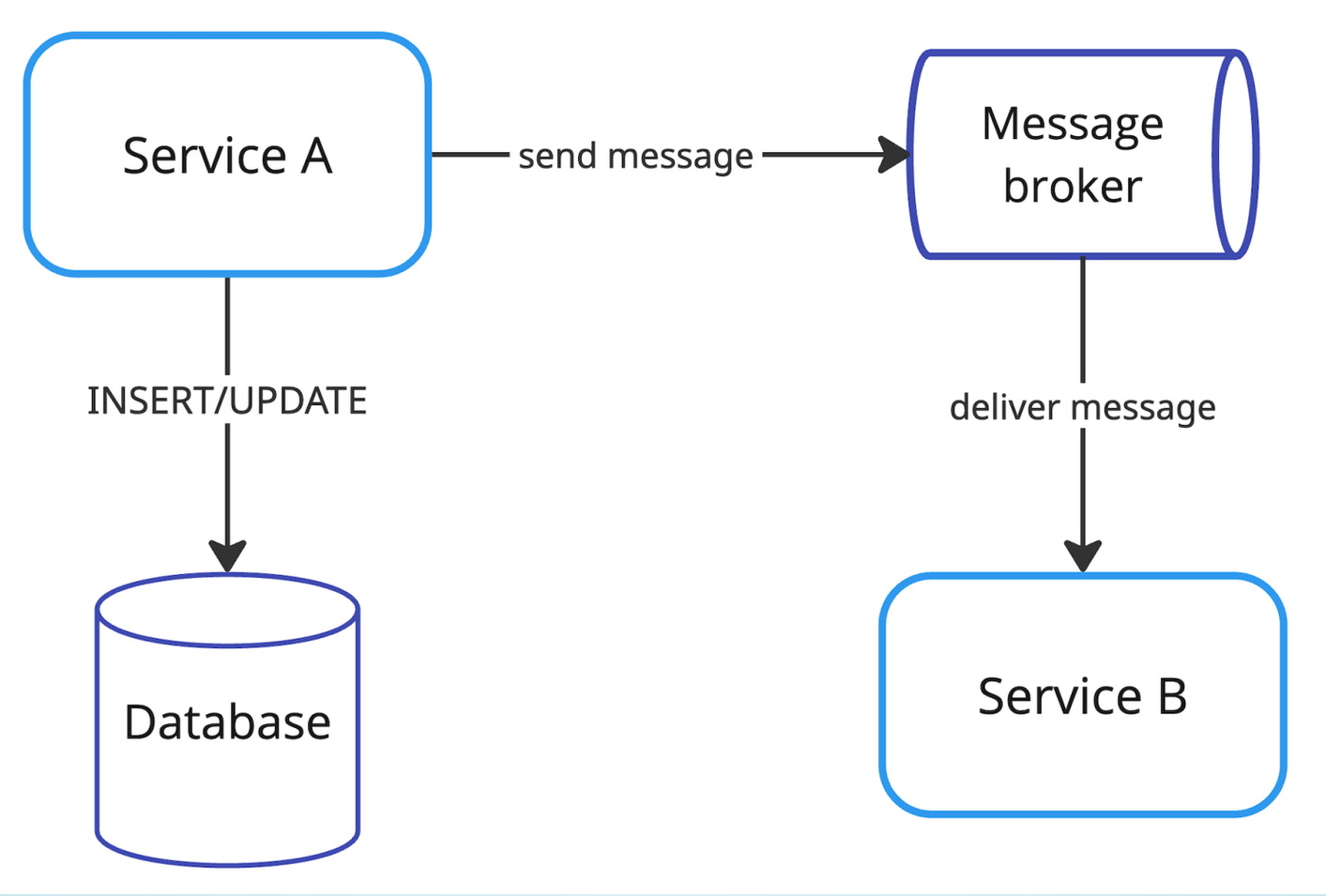
Talk inspirations

- Revisiting the Outbox Pattern

  article by Gunnar Morling

- Personal experience

Dual write problem



Dual write problem

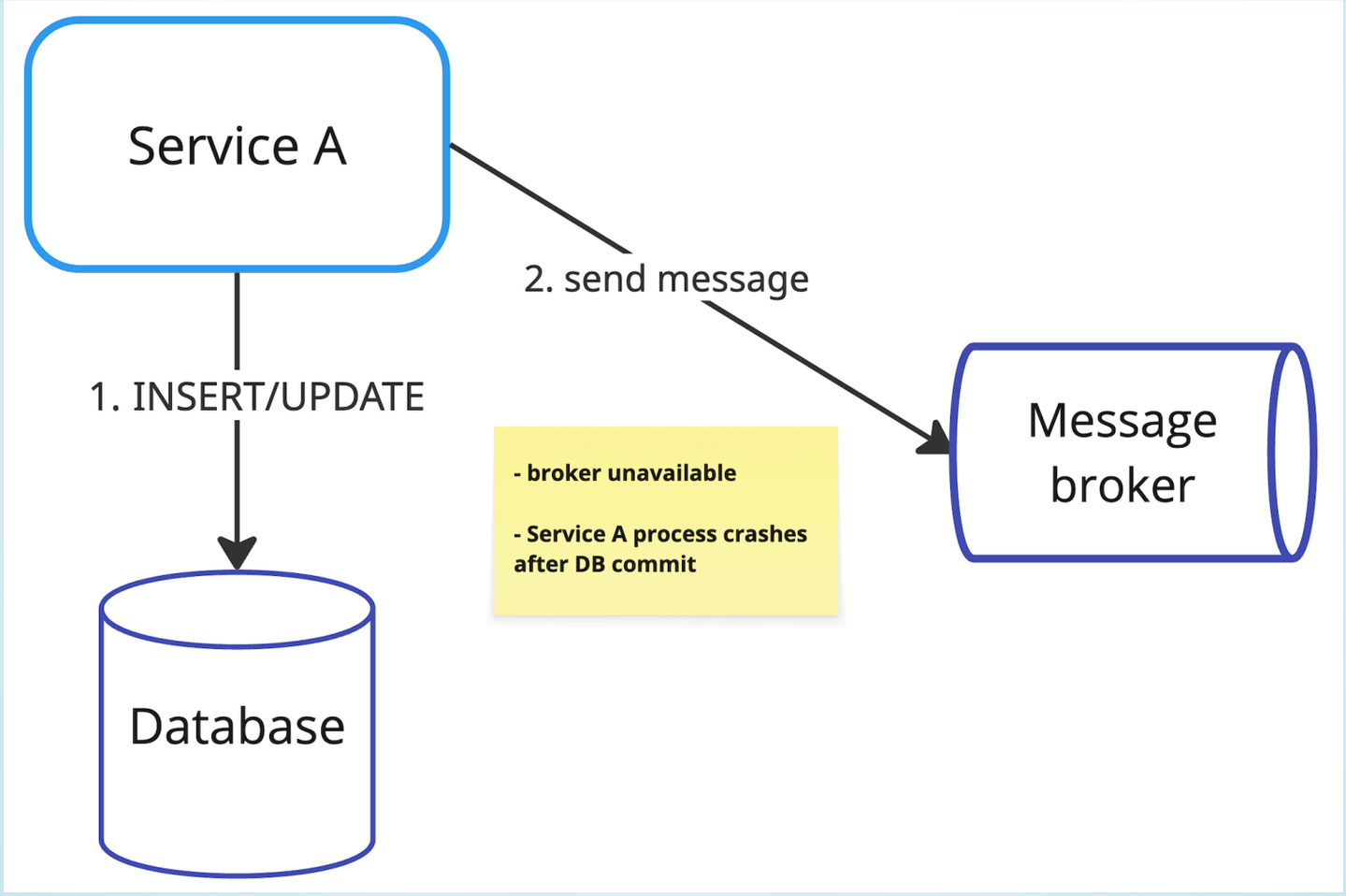
Service A writes to DB and message broker

Inconsistent system state if any of writes fails

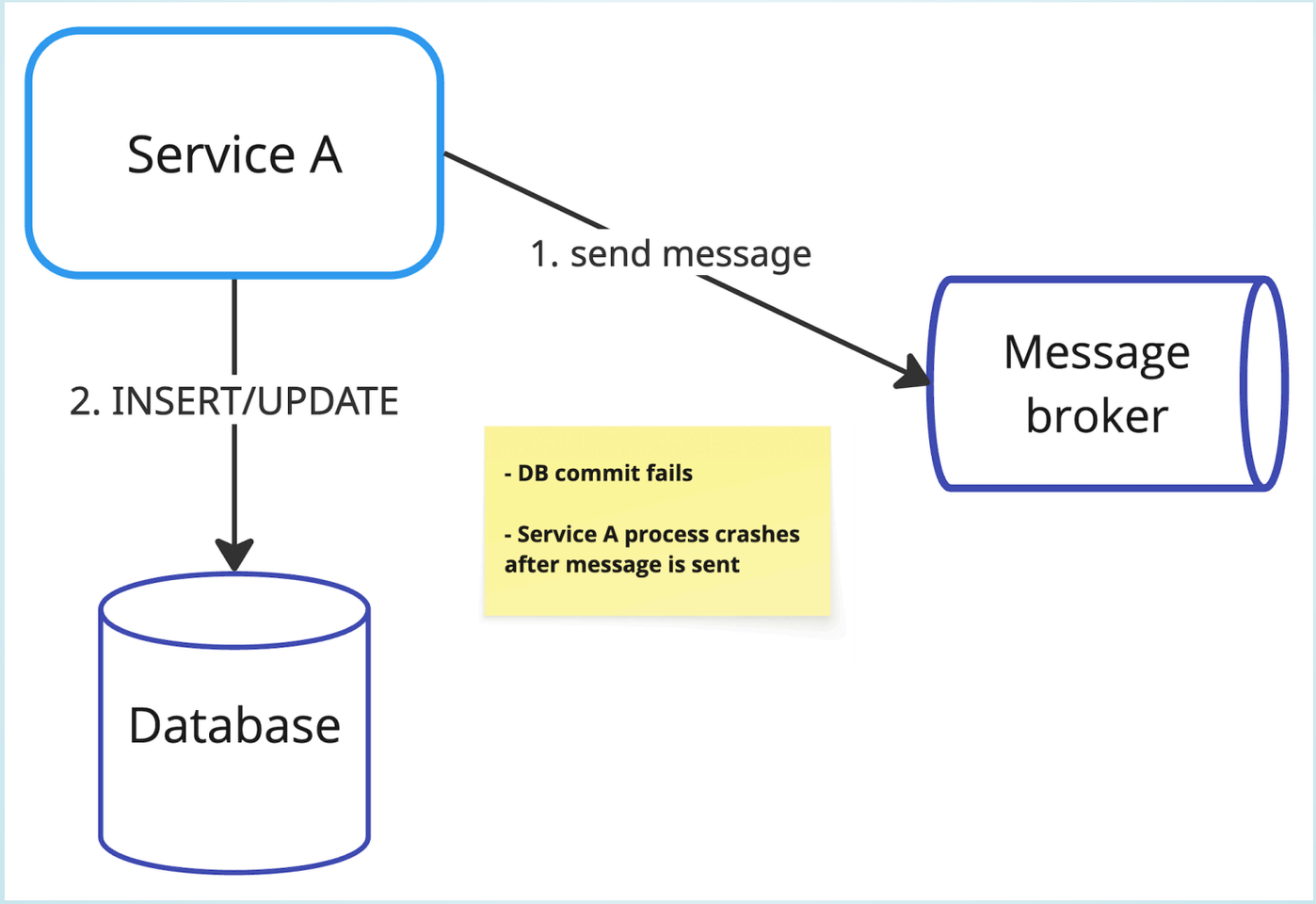
Naive approaches

- Write to DB first, then send to broker
- Send to broker first, then write to DB
- Send to broker within DB tx before commit

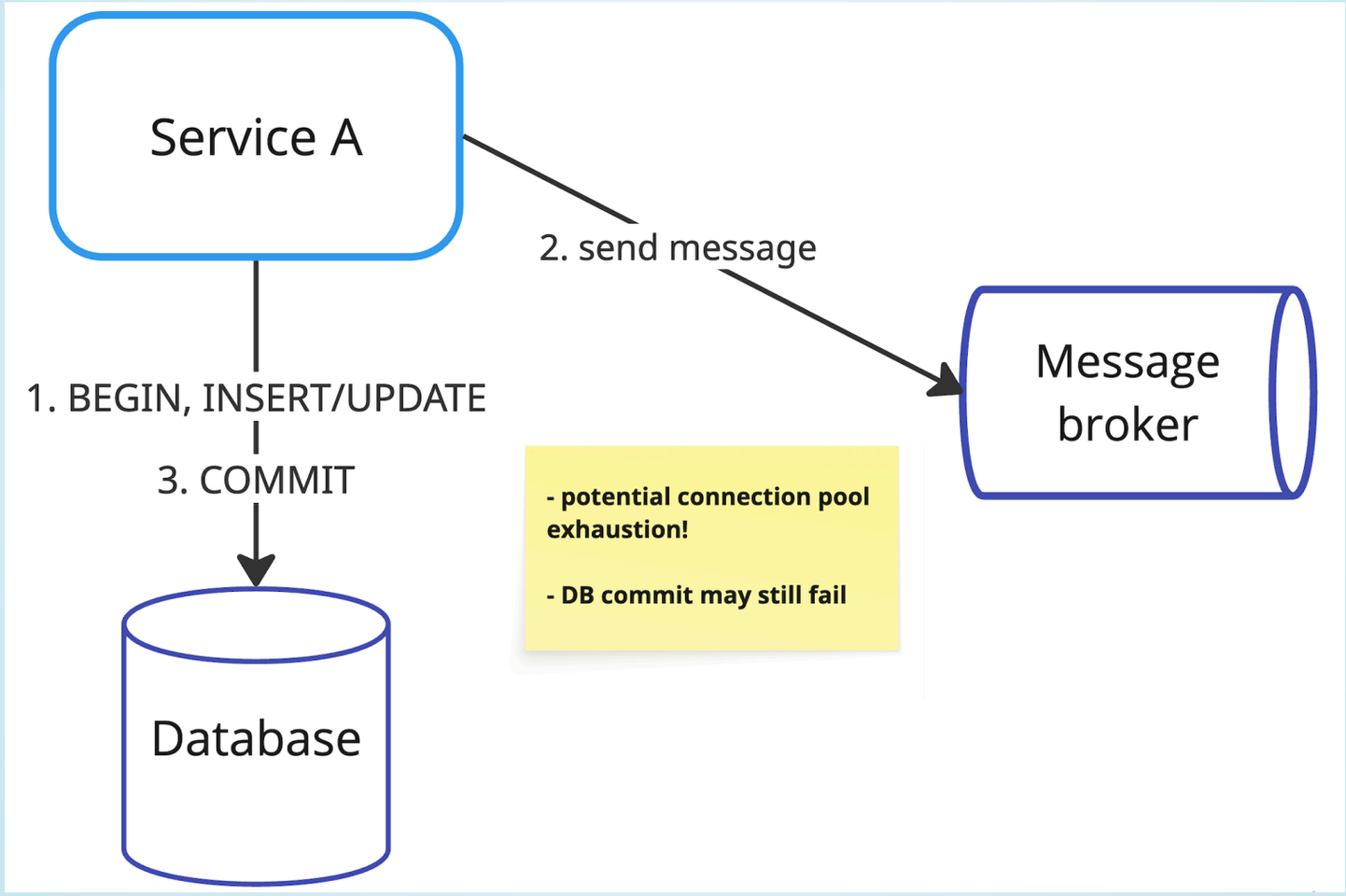
Database first



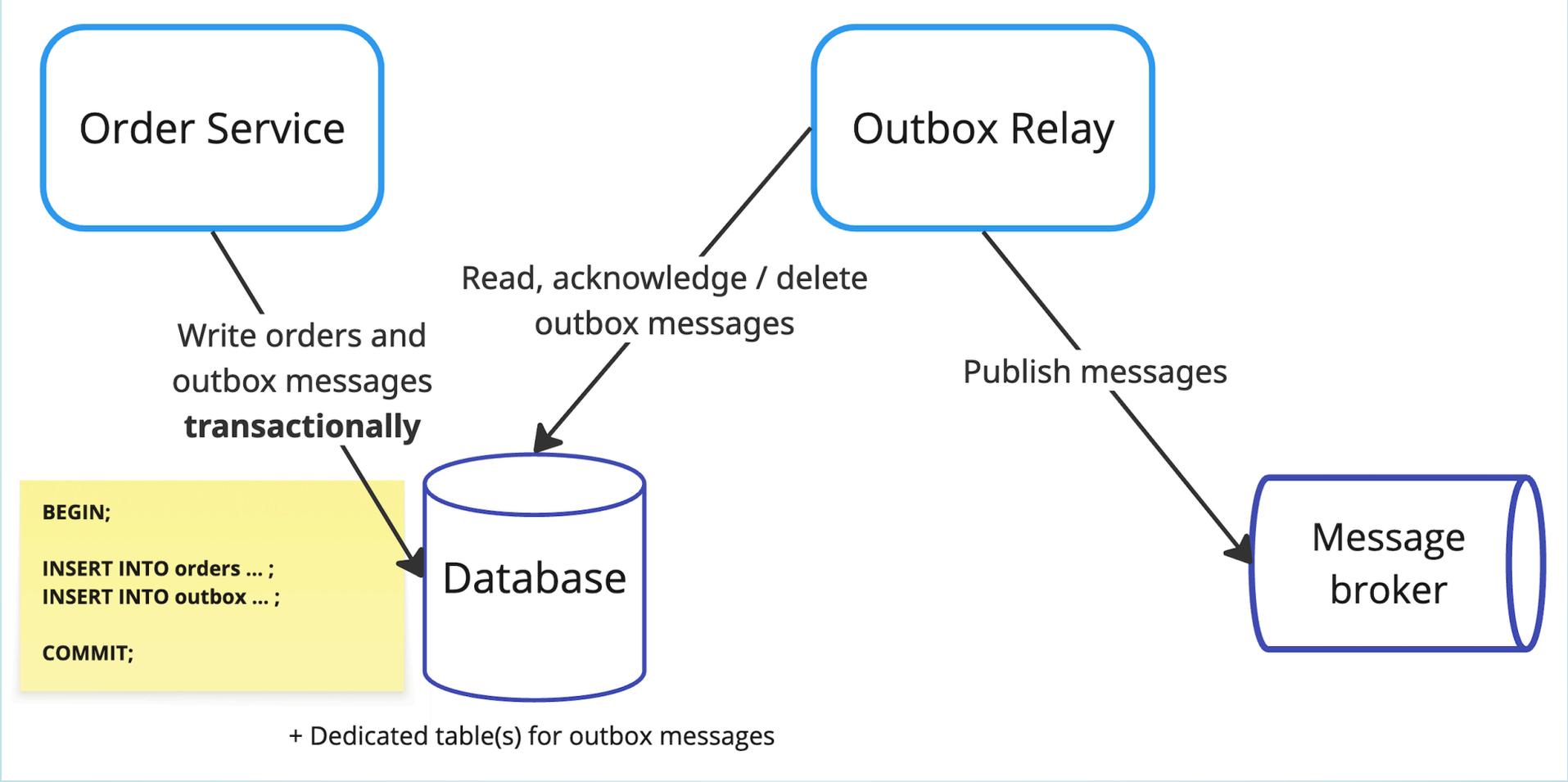
Broker first



Send inside DB tx



Transactional outbox pattern



Outbox table example

```
CREATE TABLE outbox (
    id           BIGINT PRIMARY KEY GENERATED ALWAYS AS IDENTITY,
    payload      JSONB                                  NOT NULL,
    created_at   TIMESTAMP DEFAULT CURRENT_TIMESTAMP NOT NULL,
    -- additional metadata: event type, domain object type and id, topic
);
```

Outbox pattern pros

one of solutions to dual write problem

\+ *Atomicity* between orders and outbox messages

\+ At least once delivery to message broker

Outbox pattern cons

- Message publication delay
- Extra code or deployment unit
- Consumer might need to deduplicate
- Increased database load

Reading from outbox

id	payload	created_…	broker	topic
91	{"id": "f20ea629	2025-08-17 14:10…	sns	topic1
90	{"id": "3669a2c5	2025-08-17 14:10…	sns	topic1

- Periodic polling
- Log-based change data capture (CDC)

Periodic polling

- SELECT (with LIMIT)
- Options to mark published:
  a. DELETE by ids
  b. UPDATE *published_at* by ids
  c. Store latest id in a separate table

Go libs with polling

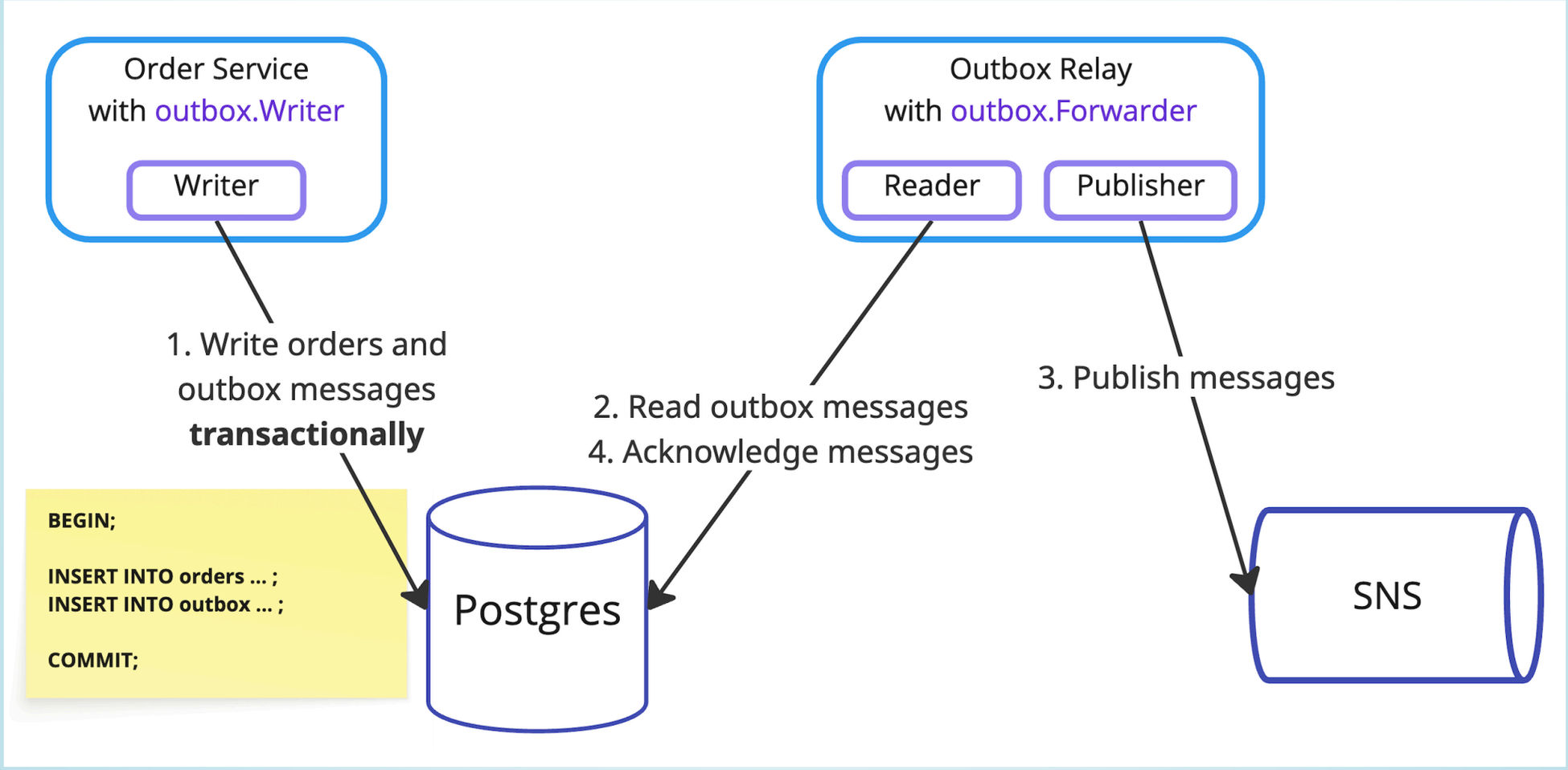
- Watermill-SQL
- pgx-outbox
- go-outbox, - outboxer

general purpose queues: - River, etc

pgx-outbox

- Strong focus on *Postgres* and *pgx* driver
- Implements *Message*, *Writer*, *Forwarder*
- UPDATE approach to mark published messages
- Inspired by Watermill Forwarder

pgx-outbox architecture



Outbox Writer

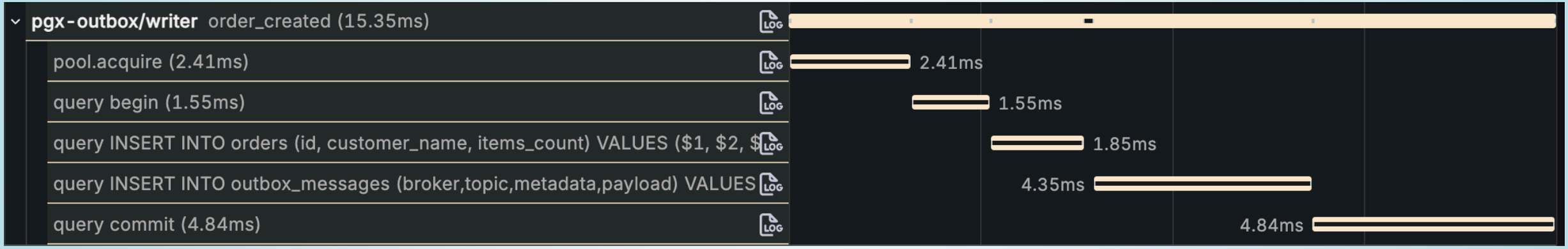
```
type Writer interface {

    // supports both pgx.Tx and stdlib *sql.Tx
    Write(ctx, tx Tx, message Message) (int64, error)

    // pgx transaction only to invoke SendBatch and Prepare methods
    WriteBatch(ctx, tx pgx.Tx, messages []Message) ([]int64, error)

}
```

Tracing with otelpgx



Polling cons

- Low publication delay vs polling too often
- Risk of starving other workloads under high traffic
- UPDATE and DELETE create dead tuples (MVCC)
- Autovacuum settings might need tuning

Log-based CDC

Write-Ahead Log (WAL) in Postgres

\+ Lower publication delay (tens of ms)

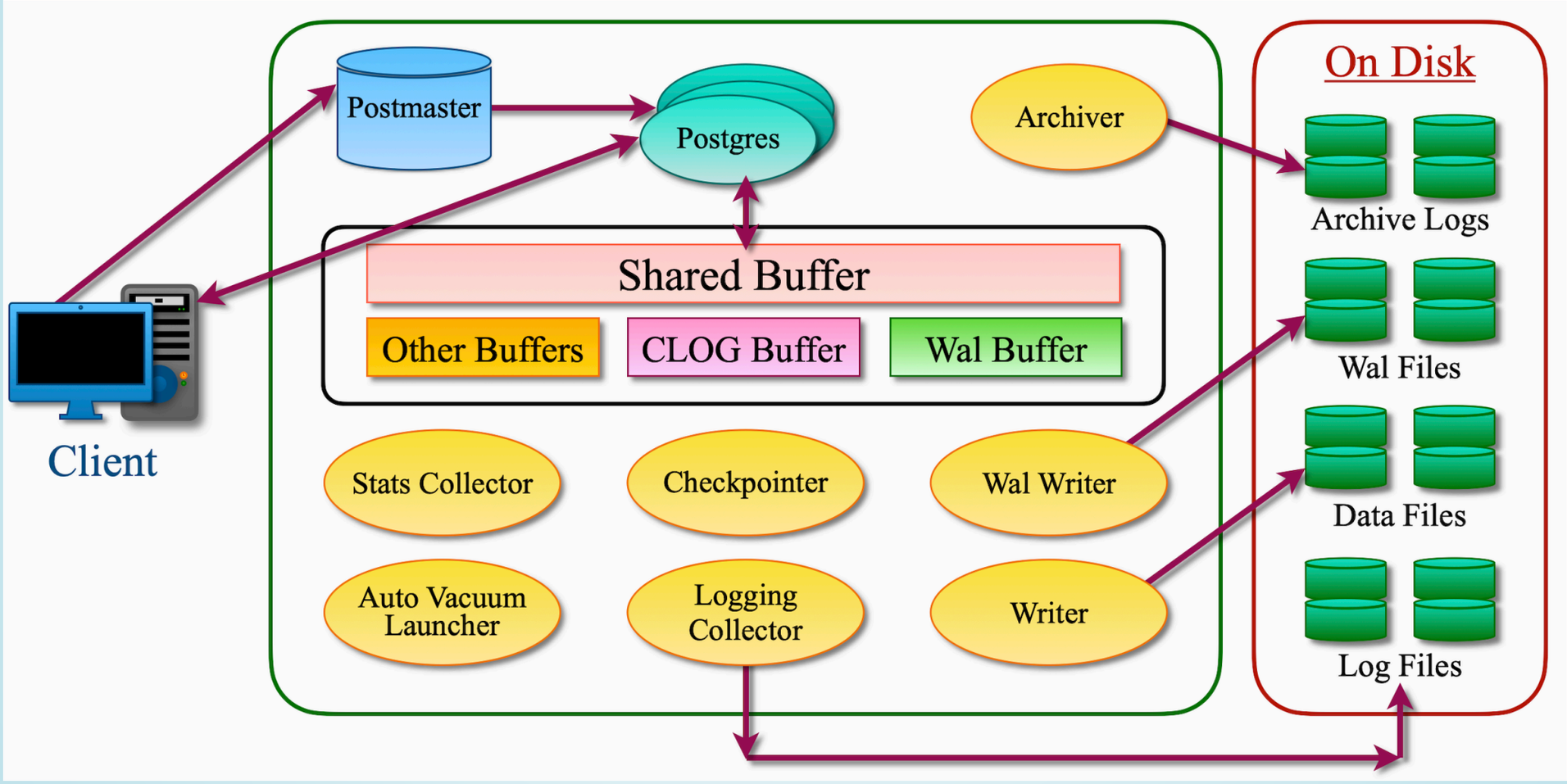
\+ Reduced DB load: avoids polling, dead tuples

\+ Events emitted in exact commit order

Write-Ahead Log

- append-only **binary** log of all **row**-level changes
- written before data files, ensures crash recovery
- changes grouped per transaction in commit order
- exists in shared buffer, flushed to on-disk files

Postgres process and memory architecture



https://www.cloudduggu.com/postgresql/architecture/

Transactions example

TX1	START TRANSACTION	0/AC90FD
TX1	INSERT INTO t1 VALUES ...	0/AC9102
TX2	START TRANSACTION	0/AC9110
TX2	INSERT INTO t1 VALUES ...	0/AC912F
TX2	UPDATE t1 SET ...	0/AC9134
TX3	START TRANSACTION	0/AC9140
TX3	INSERT INTO t1 VALUES ...	0/AC914A
TX1	UPDATE t1 SET ...	0/AC9153
TX2	DELETE FROM t1 WHERE ...	0/AC9155
TX3	UPDATE t1 SET ...	0/AC915D
TX2	ROLLBACK	0/AC9160
TX3	DELETE FROM t1 WHERE ...	0/AC9168
TX3	COMMIT	0/AC916A
TX1	DELETE FROM t1 WHERE ...	0/AC9170
TX1	COMMIT	0/AC9179

https://www.dolthub.com/blog/2024-03-08-postgres-logical-replication/

Corresponding WAL

0/AC9140	BEGIN	TX3
0/AC914A	INSERT t1 tuple [...]	TX3
0/AC914F	INSERT t1 tuple [...]	TX3
0/AC915D	UPDATE t1 old [...] new [...]	TX3
0/AC9160	UPDATE t1 old [...] new [...]	TX3
0/AC9164	UPDATE t1 old [...] new [...]	TX3
0/AC9168	DELETE t1 tuple [...]	TX3
0/AC916A	COMMIT	TX3
0/AC9179	BEGIN	TX1
0/AC9102	INSERT t1 tuple [...]	TX1
0/AC9153	UPDATE t1 old [...] new [...]	TX1
0/AC9170	DELETE t1 tuple [...]	TX1
0/AC9176	DELETE t1 tuple [...]	TX1
0/AC9179	COMMIT	TX1

https://www.dolthub.com/blog/2024-03-08-postgres-logical-replication/

Reading from WAL

Logical replication protocol in Postgres

- Debezium (Server)
- *jackc/pglogrepl*
- PeerDB

Debezium

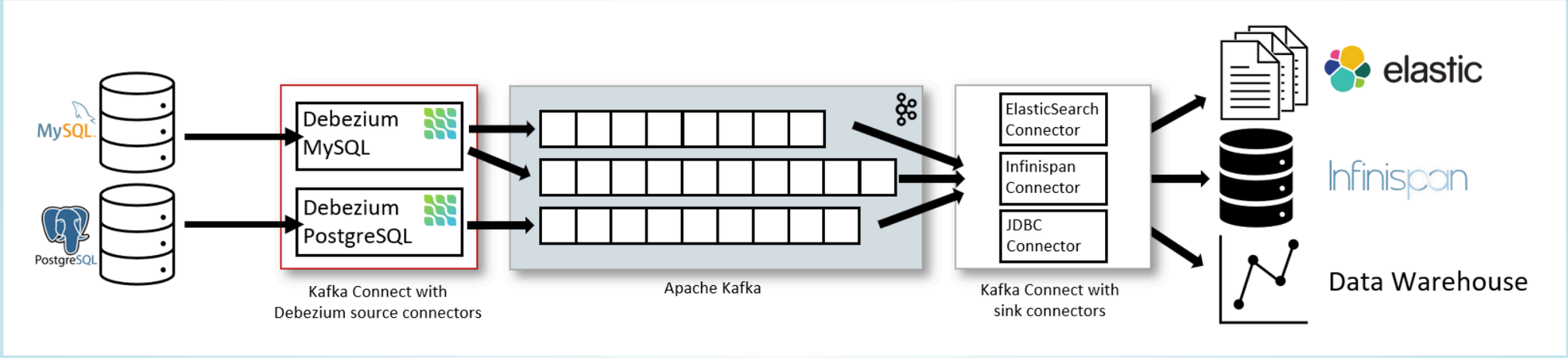
Connectors for Kafka Connect or standalone Server

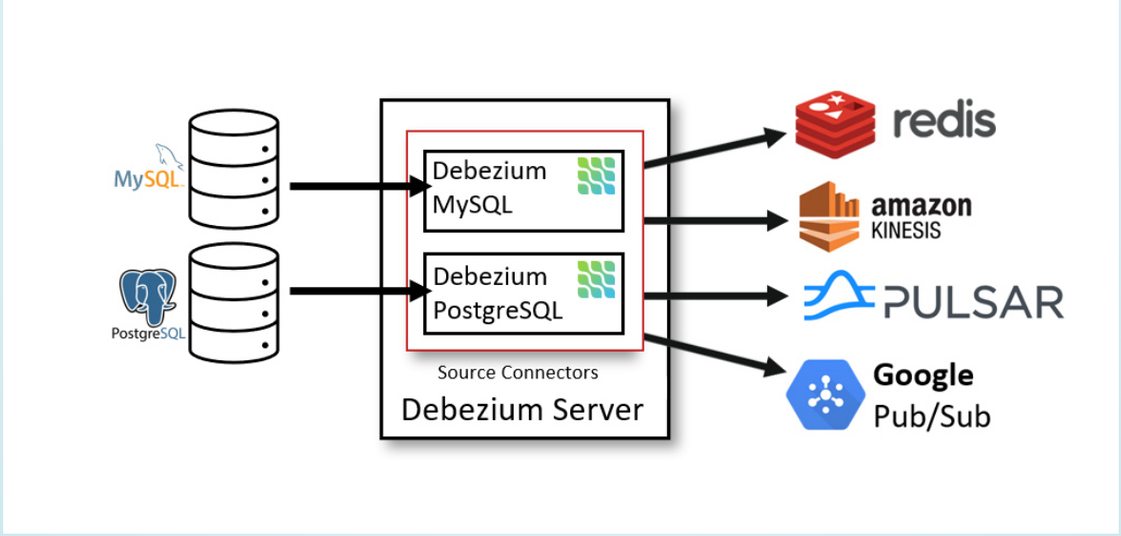
Consumes DB events and can send to sinks

Very mature, started in 2015 by Red Hat

Open source, written in **Java**

Debezium architectures





https://debezium.io/documentation/reference/stable/architecture.html

Server config example

```
# Source: Postgres
debezium.source.connector.class=io.debezium...PostgresConnector
debezium.source.database.{*}=
debezium.source.plugin.name=pgoutput
debezium.source.publication.name=debezium_publication
debezium.source.slot.name=debezium_slot
debezium.source.table.include.list=public.outbox_messages

# Sink: HTTP
debezium.sink.type=http
debezium.sink.http.url=http://http-listener:8080

# Output format & single message transformation (SMT)
debezium.format.{key,value}=json
debezium.transforms=unwrap
```

Outbox event router

- Implemented as Kafka Connect SMT
  - Suggests outbox table schema:

id, aggregateid, aggregatetype, type, payload

- Routes to Kafka topic based on *aggregatetype*
  - Uses *aggregateid* as message key

Debezium + Go

- Kubernetes CRD + Operator for CDC
- Operator creates single-pod Deployment
- Pod is powered by Debezium,

captures outbox inserts in *source* DB,

publishes to message broker sink

jackc/pglogrepl

decodes logical replication messages

includes a basic example

400 stars, 200 users

same author as *pgx* driver

not so active development

Concepts

Publication

Replication slot

Decoding plugin

Log sequence number (LSN)

Publication

Definition of tables and CDC operations to be published to consumers

```sql
CREATE PUBLICATION pub1 FOR TABLE t1, t2;
-- ALL TABLES
-- WITH (publish = 'insert, update', 'delete', 'truncate');

SELECT * FROM pg_publication;
```

```go
query := "CREATE PUBLICATION pub1 FOR TABLE t1, t2"

result := conn.Exec(ctx, query) // low level *pgconn.PgConn
defer result.Close()

_, err := result.ReadAll()
```

Replication slot

Named position in WAL to track a replication consumer progress

```
SELECT pg_create_logical_replication_slot('slot', 'pgoutput');

SELECT * FROM pg_replication_slots;
```

```
pglogrepl.CreateReplicationSlot(ctx, conn, "slot", "pgoutput")
```

Decoding plugins

pgoutput - built-in, default

test_decoding - built-in, only for testing

wal2json - 3rd party, produces JSON

decoderbufs, pglogical

pgoutput arguments

```
pluginArguments := []string{
    "proto_version '2'", // versions 3 and 4 are not supported by the lib
    fmt.Sprintf("publication_names '%s'", "pub1"),
    "messages 'false'",  // pg_logical_emit_message() is not used
    "streaming 'false'", // receive only committed transactions
}
```

Starting replication

LSN is a unique 64-bit address in WAL, e.g. 0/AC90FD

```
START_REPLICATION SLOT slot LOGICAL 0/AC90FD -- LSN where to start
   ("proto_version" '2',
   "publication_names" 'pub1',
   "messages" 'false',
   "streaming" 'false');
```

```
sysIdent, err := pglogrepl.IdentifySystem(ctx, conn)

pglogrepl.StartReplication(ctx, conn, "slot", sysIdent.XLogPos,
   pglogrepl.StartReplicationOptions{PluginArgs: pluginArguments})
```

Message loop

```
for {
    var rawMsg pgproto3.BackendMessage
    rawMsg, err := conn.ReceiveMessage(ctx)

    switch msg.Data[0] {
    // XLog is historical name for WAL
    case pglogrepl.XLogDataByteID: // 'w'
        err = handleXLogData(msg.Data[1:]) // actual data

    case pglogrepl.PrimaryKeepaliveMessageByteID: // 'k'
        err = handlePrimaryKeepalive(msg.Data[1:])
    }
}
```

Handling data

- Insert messages
- Relation messages
- Status updates:

write, flush, apply positions

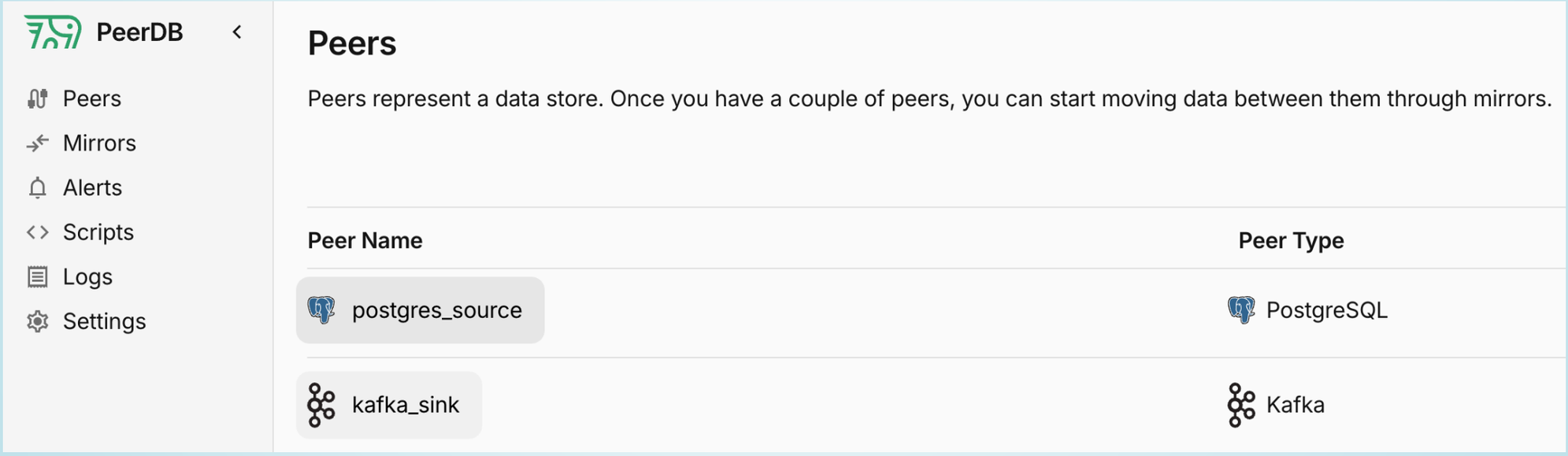
Logical replication is hard !

PeerDB

- efficient data streaming from DBs
- written in Go (and Rust)
- uses *Temporal* orchestration engine
- open-source, Elastic License 2.0 (ELv2)
- acquired by ClickHouse, integrated to ClickPipes

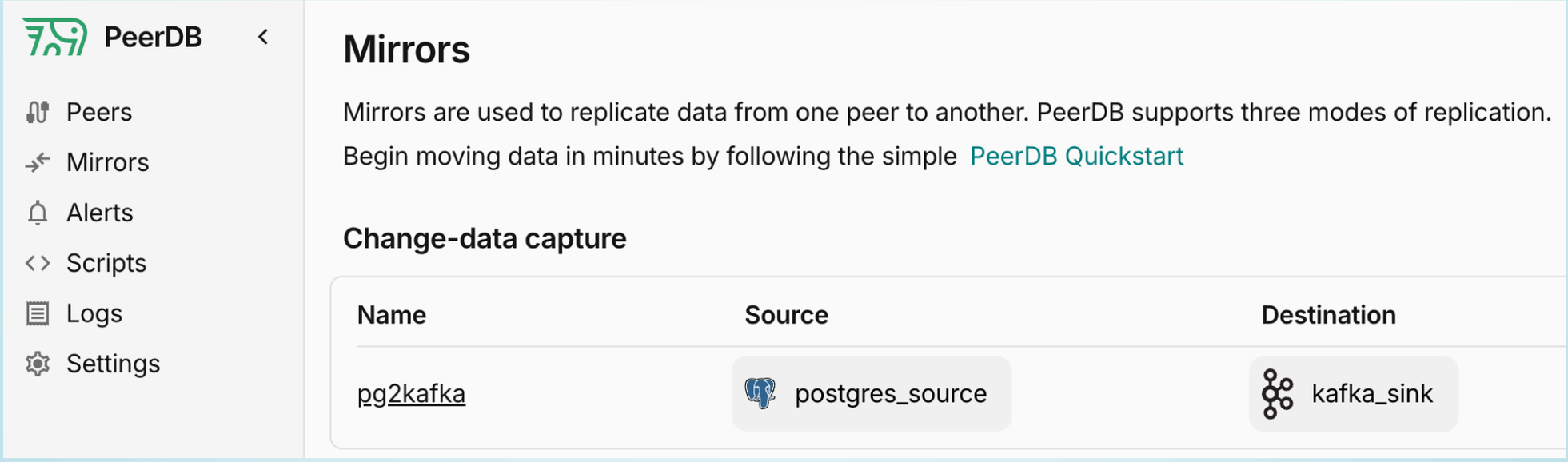
Peers

connection definition to a data source/sink



Mirrors

replication flow that continuously syncs data



Message example

- Lua script for single message transformation
  - *gofakeit* to generate fake data


```
{
    "id": 2508,
    "metadata": {
        "span_id": "45ead39608ffc918",
        "trace_id": "ac146df6aa060e043ea390e3756565df"
    },
    "payload": {
        "created_at": "2025-09-03T19:14:55.365722Z",
        "customer_name": "Nickolas Stanton",
        "event_type": "order_created",
        "id": "bd009799-000d-4944-b914-9fe49041b55d",
        "items_count": 9,
        "quote": "\"Cronut yr tote bag tote bag small batch roof.\"
    },
    "created_at": "2025-09-03T19:14:55.365722Z"
}
```

Replication pitfalls

WAL **bloat** can fill storage,

if replication slot is inactive or not advancing

due to bugs in replication clients or Postgres.

Takeaways

- Avoid microservices if not needed
- Low traffic → *Watermill-SQL, pgx-outbox*
- High traffic → *Debezium, PeerDB*

Thank you!

PeerDB-io/peerdb

jackc/pglogrepl

nikolayk812/pgx-outbox