PgQ

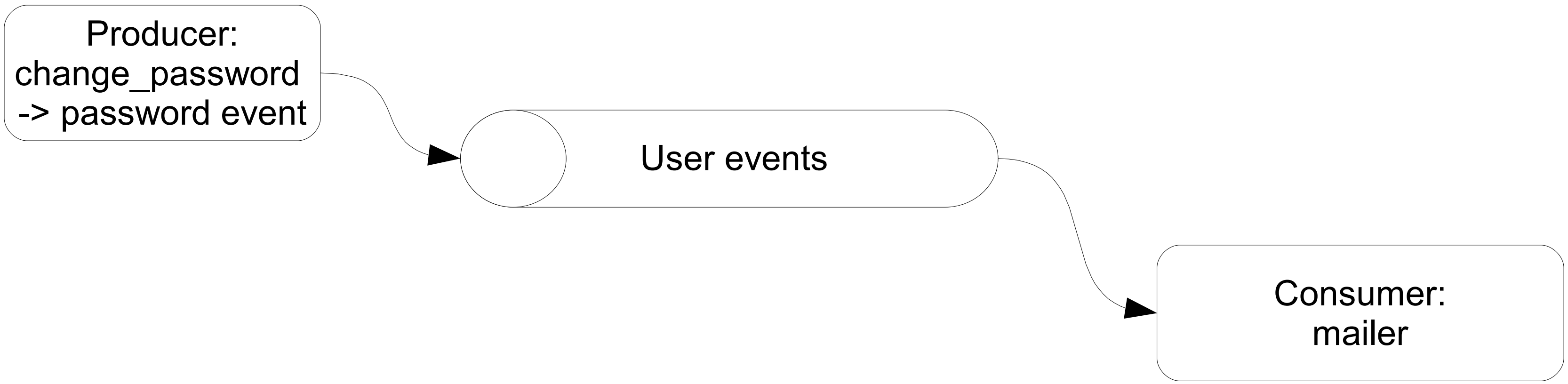
Generic high-performance queue
for PostgreSQL

Agenda

- Introduction to queuing
- Problems with standard SQL
- Solution by exporting MVCC info
- PgQ architecture and API
- Use-cases
- Future

Queue properties

- Data is created during ordinary transactions
- But we want to process it later
- After it is processed, its useless



Queue goals

- High-throughput
  - No locking during writing / reading
  - Parallel writes
  - Batched reads
- Low-latency
  - Data available in reasonably short time
- Robust
  - Returns all events
  - Repeatable reads

Implementing a queue with standard SQL

Standard SQL - row-by-row

- Reading process:
  - Select first unprocessed row
  - Update it as in-progress
  - Later update it as done or delete.
- High-throughput – NO
- Low-latency – YES
- Robust - YES

Standard SQL – SELECT with LIMIT

- Reading process:
  - Select several unprocessed rows with LIMIT
  - Later delete all of them.
- High-throughput – YES
- Low-latency – YES
- Robust - NO

Standard SQL – rotated tables

- Reading process:
  - Rename current event table
  - Create new empty event table
  - Read renamed table
- High-throughput – YES
- Low-latency – NO
- Robust - YES

Standard SQL – group by nr / date

- Reading process:
  - Request block of events for reading
  - Read them
  - Tag the block of events as done
- High-throughput – YES
- Low-latency – YES
- Robust - NO

No good way to implement queue with standard SQL

Postgres-specific solution, ideas

- Vadim Mikheev (rserv)
    - We can export internal Postgres visibility info (trancaction id / snapshot).
- Jan Wieck (Slony-I)
    - If we have 2 snapshots, we can query events that happened between them.
    - “Agreeable order” - order taken from sequence in AFTER trigger

Postgres-specific solution, PgQ improvements

- Optimized querying that tolerates long transactions
- Optimized rotation, the time when query is ran on both old and new table is minimal (long tx problem)
- 64-bit stable external transaction Ids
- Simple architecture – pull-only readers
- Queue component is generic

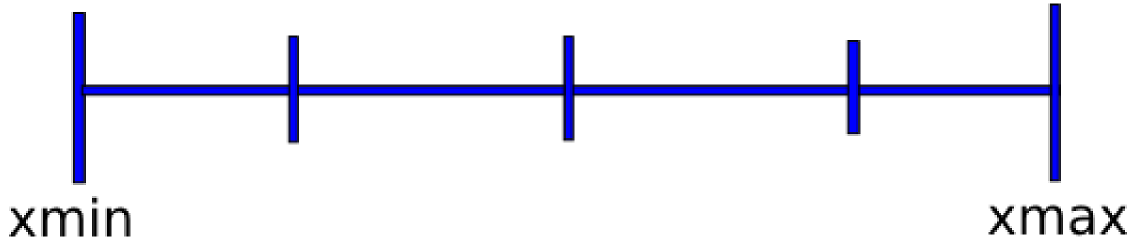
Postgres-spacific solution, MVCC basics

- Transaction IDs (txid) are assigned sequentially
- Transactions can be open variable amount of time, their operations should be invisible for that time
- Snapshot represents point in time – it divides txids into visible ones and invisible ones

Postgres-specific solution, details

- Event log table:
    - (ev_txid, ev_data)
- Tick table where snapshots are stored
    - (tick_id, tick_snapshot)
- Result:
    - High-performance – YES
    - Low-latency – YES
    - Robust - YES

Postgres-specific solution – Snapshot basics



- Xmin – lowest transaction ID in progress
- Xmax – first unassigned transaction ID
- Xip – list of transaction Ids in progress
- `txid_visible_in_snapshot(txid, snap) =`

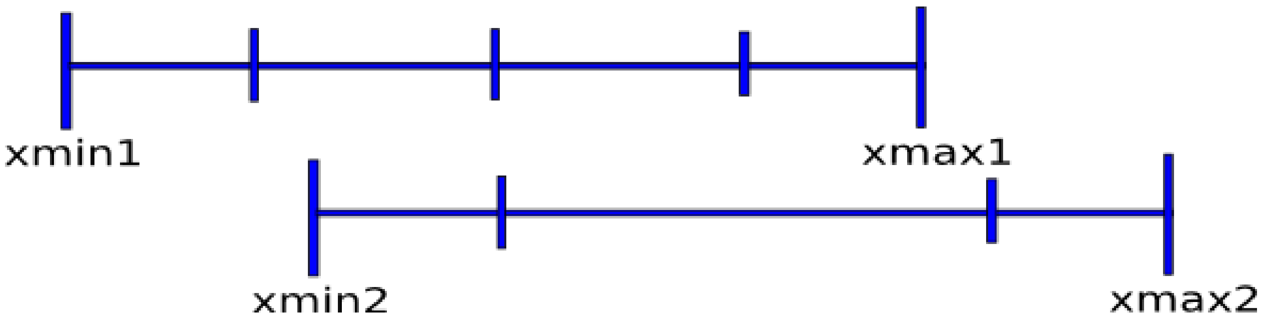
```
txid < snap.xmin OR
( txid < snap.xmax AND
  txid NOT IN (snap.xip) )
```

Postgres-specific solution – Core API

- Current transaction details:
  - `txid_current(): int8`
  - `txid_current_snapshot(): txid_snapshot`
- Snapshot components:
  - `txid_snapshot_xmin(snap): int8`
  - `txid_snapshot_xmax(snap): int8`
  - `txid_snapshot_xip(snap):  SETOF int8`
- Visibility check:
  - `txid_visible_in_snapshot(txid, snap): bool`

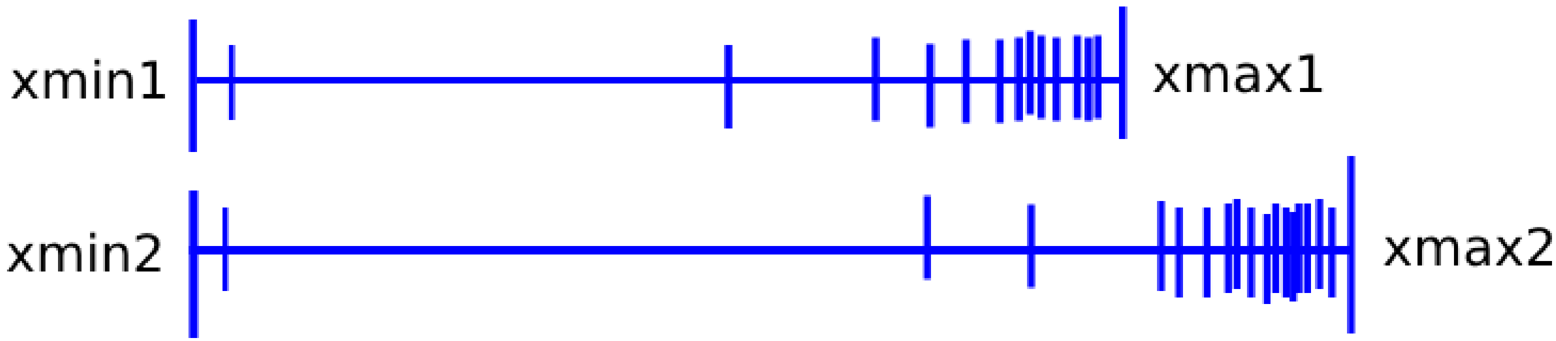
Query between snapshots

Query between snapshots – Simple version



- Snapshot 1 – xmin1, xmax2, xip1
- Snapshot 2 – xmin2, xmax2, xip2
- ```
  SELECT * FROM queue
   WHERE ev_txid BETWEEN xmin1 AND xmax2
     AND NOT is_visible(ev_txid, snap1)
     AND is_visible(ev_txid, snap2)
  ```
- Index scan between xmin1 and xmax2
  ```

Query between snapshots – optimized version



- Query must be done in 2 parts – range scan and list of explicit ids
- ```
  SELECT * FROM queue
   WHERE ( ev_txid IN (xip1) OR
           ( ev_txid BETWEEN xmax1 AND xmax2) )
     AND NOT is_visible(ev_txid, snap1)
     AND is_visible(ev_txid, snap2)
  ```
  ```

Query between snapshots – more optimizations

- More optimizations
  - Pick txids that were actually committed
  - Decrease explicit list by accumulating nearby ones into range scan
- Final notes:
  - The values must be substituted literally into final query, Postgres is not able to plan parametrized query.
  - PgQ itself uses UNION ALL instead OR. But OR seems to work at least on 8,3.

Query between snapshots – helper function

- All complexity can be put into helper function
  - ```
    SELECT range_start, range_end, explicit_list
    FROM txid_query_helper(snap1, snap2);
    ```
- This results in query:
  - ```
    SELECT * FROM queue
     WHERE ev_txid IN (explicit_list) OR
      ( ev_txid BETWEEN range_start AND range_end
        AND NOT is_visible(ev_txid, snap1)
        AND is_visible(ev_txid, snap2) )
    ```

There is PgQ.

PgQ architecture

- Ticker (pgqadm.py -d config.ini ticker)
  - Inserts ticks – per-queue snapshots
  - Vacuum tables
  - Rotates tables
  - Re-inserts retry events
- Event Producers
  - pgq.insert_event()
  - pgq.sqltriga() / pgq.logutriga()
- Event Consumers
  - Need to register
  - Poll for batches

PgQ event structure

```
CREATE TABLE pgq.event (
  ev_id    int8 NOT NULL,
  ev_txid int8 NOT NULL DEFAULT txid_current(),
  ev_time timestamptz NOT NULL DEFAULT now(),
  -- rest are user fields --
  ev_type text,    -- what to expect from ev_data
  ev_data text,    -- main data, urlenc, xml, json
  ev_extra1 text, -- metadata
  ev_extra2 text, -- metadata
  ev_extra3 text, -- metadata
  ev_extra4 text  -- metadata
);
CREATE INDEX txid_idx ON pgq.event (ev_txid);
```

PgQ ticker

- Reads event id sequence for each queue.
- If new events have appeared, then inserts tick if:
  - Configurable amount of events have appeared
    `ticker_max_count (500)`
  - Configurable amount of time has passed from last tick
    `ticker_max_lag (3 sec)`
- If no events in the queue, creates tick if some time has passed.
  - `ticker_idle_period (60 sec)`
- Configuring from command line:
  - `pgqadm.py ticker.ini config my_queue ticker_max_count=100`

PgQ API: event insertion

- Single event insertion:
  - `pgq.insert_event(queue, ev_type, ev_data): int8`
- Bulk insertion, in single transaction:
  - `pgq.current_event_table(queue): text`
- Inserting with triggers:
  - `pgq.sqltriga(queue, ...) - partial SQL format`
  - `pgq.logutriga(queue, ...) - urlencoded format`

PgQ API: insert complex event with pure SQL

- ```
  CREATE TABLE queue.some_event (col1, col2);
  CREATE TRIGGER some_trg
      BEFORE INSERT ON queue.some_event
      FOR EACH ROW EXECUTE PROCEDURE
      pgq.logutriga('dstqueue', 'SKIP');
  ```
- Plain insert works:
  - ```
    INSERT INTO queue.some_event(col1, col2)
    VALUES ('value1', 'value2');
    ```
- Type safety, default values, sequences, constraints!
- Several tables can insert into same queue.

PgQ API: reading events

- Registering
  - `pgq.register_consumer(queue, consumer)`
  - `pgq.unregister_consumer(queue, consumer)`
- Reading
  - `pgq.next_batch(queue, consumer): int8`
  - `pgq.get_batch_events(batch_id): SETOF record`
  - `pgq.finish_batch(batch_id)`

Remote event tracking

- Async operation allows coordinating work between several database.
- Occasionally data itself allows tracking:
  - eg. Delete order.
- If not then explicit tracking is needed.
- pgq_ext module.
- Tracking can happen in multiple databases.

Tracking events

- Per-event overhead
- Need to avoid accumulating
- pgq_ext solution
  - `pgq_ext.is_event_done(consumer, batch_id, ev_id)`
  - `pgq_ext.set_event_done(consumer, batch_id, ev_id)`
- If batch changes, deletes old events
- Eg. email sender, plproxy.

Tracking batches

- Minimal per-event overhead
- Requires that all batch is processed in one TX
  - `pgq_ext.is_batch_done(consumer, batch_id)`
  - `pgq_ext.set_batch_done(consumer, batch_id)`
- Eg. replication, most of the Skytools partitioning script.

Use-case: row counter for count(*) speedup

```
import pgq
class RowCounter(pgq.Consumer):
    def process_batch(self, db, batch_id, ev_list):
        tbl = self.cf.get('table_name'); delta = 0
        for ev in ev_list:
            if   ev.type == 'I' and ev.extra1 == tbl: delta += 1
            elif ev.type == 'D' and ev.extra1 == tbl: delta -= 1
            ev.tag_done()
        q = 'select update_stats(%s, %s)'
        db.cursor().execute(q, [tbl, delta])
RowCounter('row_counter', 'db', sys.argv[1:]).start()
```

```
[row_counter]
db = ...
pgq_queue_name = ...
table_name = ...
job_name = ...
logfile = ...
pidfile = ...
```

Use-case: copy queue to different database

```
import pgq
class QueueMover(pgq.RemoteConsumer):
  def process_remote_batch(self, db, batch_id, ev_list, dst_db):
    # prepare data
    rows = []
    for ev in ev_list:
      rows.append([ev.type, ev.data, ev.time])
      ev.tag_done()

    # insert data
    fields = ['ev_type', 'ev_data', 'ev_time']
    curs = dst_db.cursor()
    dst_queue = self.cf.get('dst_queue_name')
    pgq.bulk_insert_events(curs, rows, fields, dst_queue)

script = QueueMover('queue_mover', 'src_db', 'dst_db', sys.argv[1:])
script.start()
```

Use-case: email sender

- Non-transactional, so need to track event-by-event
- Needs to commit at each event

Use-case: replication (Londiste)

- Per-batch tracking on remote side
- COPY as a parallel consumer
  - Register, then start COPY
  - If COPY finishes, applies events from queue for that table
  - Then gives it over to main consumer
- Example session:

```
$ ed replic.ini; ed ticker.ini
$ londiste.py replic.ini provider install
$ londiste.py replic.ini subscriber install
$ pgqadm.py -d ticker.ini ticker
$ londiste.py -d replic.ini replay
$ londiste.py replic.ini provider add table1 table2 ...
$ londiste.py replic.ini subscriber add table1 table2 ...
```

Future: cascaded queues

- The goal is to have exact copy of queue in several nodes so reader can freely switch between them.
- Exact means tick_id + events. For simplicity the txids and snapshots are not carried over.
- To allow consumers to randomly switch between nodes, the global horizon is kept. Each node has main worker that sends its lowest tick_id to provider. Worker on master node send global lowest tick_id to queue, where each worker can see it.
- Such design allows workers to care only about 2 node.
- Fancy stuff: merging of plproxy partitions.

Questions?

PgQ queue info table

```
create table pgq.queue (
        queue_id                    serial,
        queue_name                  text        not null,

        queue_ntables               integer     not null default 3,
        queue_cur_table             integer     not null default 0,
        queue_rotation_period       interval    not null default '2 hours',

        queue_ticker_max_count      integer     not null default 500,
        queue_ticker_max_lag        interval    not null default '3 seconds',
        queue_ticker_idle_period    interval    not null default '1 minute',

        queue_data_pfx              text        not null,
        queue_event_seq             text        not null,
        queue_tick_seq              text        not null,
);
```