Practical Partitioning in Production with Postgres

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EDB

We'll be looking at:

- Intro to Partitioning in PostgreSQL
- Why?
- How?
- Practical Example

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Introduction to Partitioning in PostgreSQL

What is partitioning?

- RDBMS context: division of a table into distinct independent tables
- Horizontal partitioning (by row) – different rows in different tables
- Why?
  - Easier to manage
  - Performance

Partitioning in PostgreSQL

HISTORY

- Has had partitioning for quite some time now… PG 8.1 (2005)
  - Inheritance-based
  - Why haven't I heard of this before?
  - It's not great tbh...
- Declarative Partitioning: PG 10 (2017)
  - Massive improvement

Declarative Partitioning

(PG 10+)

Specification of:

- Partitioning method
- Partition key
  - Column(s) or expression(s)
  - Value determines data routing
- Partition boundaries

By declaring a table (DDL):

```
CREATE TABLE cust (id INT, signup DATE)
PARTITION BY RANGE (signup);

CREATE TABLE cust_2020
PARTITION OF cust FOR VALUES FROM
('2020-01-01') TO ('2021-01-01');
```

- Partitions may be partitioned themselves (sub-partitioning)

Why?

PostgreSQL limits

(Hard limits, hard to reach)

- Database size: unlimited
- Tables per database: 1.4 billion
- Table size: 32 TB
    - Default block size: 8192 bytes
- Rows per table: depends
    - As many as can fit onto 4.2 billion blocks

What partitioning can help with (i)

(Very large tables)

- Disk size limitations
  - You can put partitions on different tablespaces
- Performance
  - Partition pruning
  - Table scans
  - Index scans
  - Hidden pitfalls of very large tables*

What partitioning can help with (ii)

(Very large tables)

- Maintenance
  - Deletions (some filesystems are bad at deleting large numbers of files)
  - **DROP TABLE** cust_2020;
  - **ALTER TABLE** cust **DETACH PARTITION** cust_2020;
- **VACUUM**
  - Bloat
  - Freezing → **xid** wraparound

What partitioning is not

- Magic bullet
  - No substitute for rational database design
- Sharding
  - Not about putting part of the data on different nodes
- Performance tuning
  - Unless you have one of the mentioned issues

How?

Dimensioning

Plan ahead!

- Get your calculator out
  - Data ingestion rate (both rows and size in bytes)
  - Projected increases (e.g. 25 locations projected to be 200 by end of year)
  - Data retention requirements
- Will inform choice of partitioning method and key
- For instance: 1440 measurements/day from each of 1000 sensors – extrapolate per year
- Keep checking if this is valid and be prepared to revise

Partitioning method

Dimensioning usually makes this clearer

- **Range:** For key column(s) e.g. ranges of dates, identifiers, etc.
  - Lower end: inclusive, upper end: exclusive
- **List:** Explicit key values stated for each partition
- **Hash (PG 11+):** If you have a column with values close to unique
  - Define Modulus (& remainder) for number of almost-evenly-sized partitions

Partition Key selection

Choose wisely - know your data!

- Analysis
  - Determine main keys used for retrieval from queries
  - Proper key selection enables **partition pruning**
  - Can use multiple columns for higher granularity (more partitions)
- Desirable
  - High enough cardinality (range of values) for the number of partitions needed
  - A column that doesn't change often, to avoid moving rows among partitions

Sub-partitioning

- Simply put, partitions are partitioned tables themselves. Plan ahead!

```
CREATE TABLE transactions (… , location_code TEXT, tstamp TIMESTAMPTZ)
PARTITION BY RANGE (tstamp);
CREATE TABLE transactions_2021_06
PARTITION OF transactions FOR VALUES FROM ('2021-06-01') TO ('2021-07-01')
PARTITION BY HASH (location_code);
CREATE TABLE transactions_2021_06_p1
PARTITION OF transactions_2021_06 FOR VALUES WITH (MODULUS 4, REMAINDER 0);
```

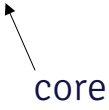
Partitioning by multiple columns

Be careful!

- **CREATE TABLE** transactions (… , location_code **TEXT**, tstamp **TIMESTAMPTZ**) **PARTITION BY RANGE** (tstamp, location_code);
- **CREATE TABLE** transactions_2021_06_a **PARTITION OF** transactions **FOR VALUES FROM** ('2021-06-01', 'AAA') **TO** ('2021-07-01', 'AZZ');
- **CREATE TABLE** transactions_2021_06_b **PARTITION OF** transactions **FOR VALUES FROM** ('2021-06-01', 'BAA') **TO** ('2021-07-01', 'BZZ');
  ERROR: partition "transactions_2021_06_b" would overlap partition "transactions_2021_06_a"

- Because tstamp '2021-06-01' can only go in the first partition!

What Postgres does not do

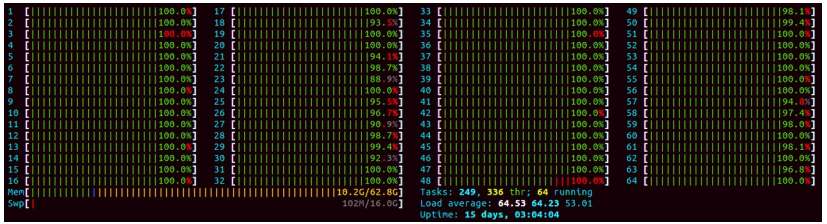


- Automatic creation of partitions
  - Create in advance
  - Use a cronjob
- Imperative merging/splitting of partitions
  - Move rows manually
- Sharding to different nodes
  - You may have to configure FDW manually

Practical Example

Partitioning a live production system

- Is your table too large to handle?
- Can partitioning help?
- What if it's in constant use?



The situation

Huge 20 TB table

- OLTP workload, transactions keep flowing in
  - Table keeps increasing in size
- VACUUM never ends
  - Has been running for a full month already…
- Queries are getting slower
  - Not just because of sheer number of rows…

* Hidden performance pitfall (i)

For VERY large tables

- Postgres has 1GB **segment size**
  - Can only be changed at compilation time
  - 20 TB table = 20000 segments (files on disk)
- Why is this a problem?
  - **md.c** →

```
/*-------------------------------------------------------------------------
 *
 * md.c
 *        This code manages relations that reside on magnetic disk.
 *
 * Or at least, that was what the Berkeley folk had in mind when they named
 * this file.  In reality, what this code provides is an interface from
 * the smgr API to Unix-like filesystem APIs, so it will work with any type
 * of device for which the operating system provides filesystem support.
 * It doesn't matter whether the bits are on spinning rust or some other
 * storage technology.
 *
 * Portions Copyright (c) 1996-2016, PostgreSQL Global Development Group
 * Portions Copyright (c) 1994, Regents of the University of California
 *
 *
 * IDENTIFICATION
 *        src/backend/storage/smgr/md.c
 *
 *-------------------------------------------------------------------------
 */
#include "postgres.h"

```

* Hidden performance pitfall (ii)

```
1973  /*
1974   * Get number of blocks present in a single disk file
1975   */
1976  static BlockNumber
1977  _mdnblocks(SMgrRelation reln, ForkNumber forknum, MdfdVec *seg)
1978  {
1979          off_t           len;
1980
1981          len = FileSeek(seg->mdfd_vfd, 0L, SEEK_END);
1982          if (len < 0)
1983                  ereport(ERROR,
1984                                  (errcode_for_file_access(),
1985                                   errmsg("could not seek to end of file \"%s\": %m",
1986                                                  FilePathName(seg->mdfd_vfd))));
1987          /* note that this calculation will ignore any partial block at EOF */
1988          return (BlockNumber) (len / BLCKSZ);
1989  }
```

- This loops 20000 times every time you want to access a table page
  - Linked list of segments
- Code from PG 9.6
- It has been heavily optimised recently (caching, etc).
- Still needs to run a lot of times

So what do we do?

Next steps

- Need to partition the huge table
  - Dimensioning
  - Partition method
  - Partition key
- Make sure we're on the latest version (PG 13)
  - Get latest features & performance enhancements

What is our table like?

It holds daily transaction totals for each point of sales

- Dimensioning
  - One partition per month will be about 30GB of data, so acceptable size
- Method, Key
  - Candidate key is transaction date, which we can partition by range
  - Check that there are no data errors (e.g. dates in the future when they shouldn't be)
- Partition sizes don't have to be equal
  - We can partition older, less often accessed data by year

Problems

What things you cannot do in production

- Lock the table totally (**ACCESS EXCLUSIVE**) or prevent writes
  - People will start yelling, and they will be right
- Cause excessive load on the system (e.g. I/O) or cause excessive disk space usage
  - Can’t copy whole 20 TB table into empty partitioned table
  - See above about yelling
- Present an inconsistent or incomplete view of the data

The plan

Take it step by step

- Rename the huge table and its indices
- Create an empty partitioned table with the old huge table's name
- Create the required indices on the new partitioned table
  - They will be created automatically for each new partition
- Create first new partition for new incoming data
- Attach the old table as a partition of the new table so it can be used normally*
- Move data out of the old table incrementally at our own pace

Rename the huge table and its indices

```
-- Do this all in one transaction
BEGIN;

ALTER TABLE dailytotals RENAME TO dailytotals_legacy;

ALTER INDEX dailytotals_batchid RENAME TO dailytotals_legacy_batchid;

ALTER INDEX ...
...
```

Create empty partitioned table & indices

```
CREATE TABLE dailytotals (
        totalid         BIGINT      NOT NULL DEFAULT nextval('dailytotals_totalid_seq')
 ,      totaldate       DATE        NOT NULL
 ,      totalsum        BIGINT
        …
 ,      batchid         BIGINT      NOT NULL
)
PARTITION BY RANGE (totaldate);

CREATE INDEX dailytotals_batchid ON dailytotals (batchid);
…
```

Create partition for new incoming data

```
CREATE TABLE dailytotals_202106
PARTITION OF dailytotals
FOR VALUES FROM ('2021-06-01') TO ('2021-07-01');
```

Attach old table as a partition (i)

```
DO $$
DECLARE earliest DATE;
DECLARE latest DATE;
BEGIN

-- Set boundaries
SELECT min(totaldate) INTO earliest FROM dailytotals_legacy;
latest := '2021-06-01'::DATE;
```

Attach old table as a partition (ii)

```
-- HACK HACK HACK (only because we know and trust our data)
ALTER TABLE dailytotals_legacy
ADD CONSTRAINT dailytotals_legacy_totaldate
CHECK (totaldate >= earliest AND totaldate < latest)
NOT VALID;

-- You should not touch pg_catalog directly
UPDATE pg_constraint
SET convalidated = true
WHERE conname = 'dailytotals_legacy_totaldate';
```

Attach old table as a partition (iii)

```
ALTER TABLE dailytotals
ATTACH PARTITION dailytotals_legacy
FOR VALUES FROM (earliest) TO (latest);

END;
$$ LANGUAGE PLPGSQL;
COMMIT;
```

Move data from old table at our own pace

- For instance, during quiet hours for the system, in scheduled batch jobs, etc.

```
WITH rows AS (
        DELETE FROM dailytotals_legacy d
        WHERE (totaldate >= '2020-01-01' AND totaldate < '2021-01-01')
        RETURNING d.* )
INSERT INTO dailytotals SELECT * FROM rows;
```

- In the same transaction: **DETACH** the old table, perform the move, re**ATTACH** with changed boundaries. Rinse and repeat!
- Make sure the target partition exists!

Partitioning improvements

Make sure you're on the latest release so you have them!

- **PG11: DEFAULT** partition, **UPDATE** on partition key, **HASH** method, PKs, FKs, Indexes, Triggers
- **PG12:** Performance (pruning, **COPY**), FK references for partitioned tables, ordered scans
- **PG13:** Logical replication for partitioned tables, improved performance (**JOIN**s, pruning)

- (Soon) **PG14**: **REINDEX CONCURRENTLY**, **DETACH CONCURRENTLY**, faster **UPDATE**/**DELETE**

To conclude...

- Know your data!
- Upgrade – be on the latest release!
- Partition before you get in deep water!

- Find me on Twitter: @vyruss