Reaching 1 billion rows / second

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Who we are

Cybertec

- We are a PostgreSQL support company
- Clients around the globe
- What we do:
  - PostgreSQL 24x7 support
  - Training
  - Consulting
  - Geodata
  - Scaling

Reaching a milestone

Goal

- Processing 1 billion rows / second
- Show a path to even more scalability
- Silence the “scalability” discussion at some point
- See where the limitations are
- Do it WITHOUT commercial tools, warehousing tools, etc.

A word of caution

- The goal is NOT to scale EVERY query to 1 billion rows / second
- This is attempt to show a path to enlightenment for “vanilla” PostgreSQL

Traditional PostgreSQL limitations

- Traditionally:
  - We could only use 1 CPU core per query
  - Scaling was possible by running more than one query at a time
  - Usually hard to do
- Single core performance is limited

PL/Proxy: The traditional way to do it

- PL/Proxy is a stored procedure language to scale out to shards.
- Worked nicely for OLTP workloads
- Somewhat usable for analytics
  - A LOT of manual work

PL/Proxy: An example

- A function written in PL/Proxy
  - Use input values to calculate shards
- Downside:
  - A lot of manual work
  - Not really transparent to the application

```
SELECT func('hs@cybertec.at');
```

The 1 billion row challenge

Coming up with a data structure

- We tried to keep that simple:

```
node=# \d t_demo
            Table "public.t_demo"
 Column |  Type   | Collation | Nullable |
--------+---------+-----------+----------+
 id     | serial  |           | not null |
 grp    | integer |           |          |
 data   | real    |           |          |
Indexes:
    "idx_id" btree (id)
```

The query


```
SELECT   grp, count(data)
FROM     t_demo
GROUP BY 1;
```

Performance hint

- Yes, this is a small table
- If you can scale in a linear way, it makes no difference
  - Just add boxes

Single server performance

Tweaking a simple server

- The main questions are:
  - How much can we expect from a single server?
  - How well does it scale with many CPUs?
  - How far can we get?

PostgreSQL parallelism

- Parallel queries have been added in PostgreSQL 9.6
  - It can do a lot
  - It is by far not feature complete yet
- Number of workers will be determined by the PostgreSQL optimizer
  - We do not want that
  - We want ALL cores to be at work

Parallelism in PostgreSQL 10.0

- A lot more features are there
- Many queries can be improved
- There is still some work to do

Adjusting CPU core usage

- Usually the number of processes per scan is derived from the size of the table

```
test=# SHOW min_parallel_relation_size ;
 min_parallel_relation_size
----------------------------
 8MB
(1 row)
```

- One process is added if the tablesize triples

Overruling the planner

- We could never have enough data to make PostgreSQL go for 16 or 32 cores.
- Even if the value is set to a couple of kilobytes.
- The default mechanism can be overruled:

```
test=# ALTER TABLE t_demo
    SET (parallel_workers = 32);
ALTER TABLE
```

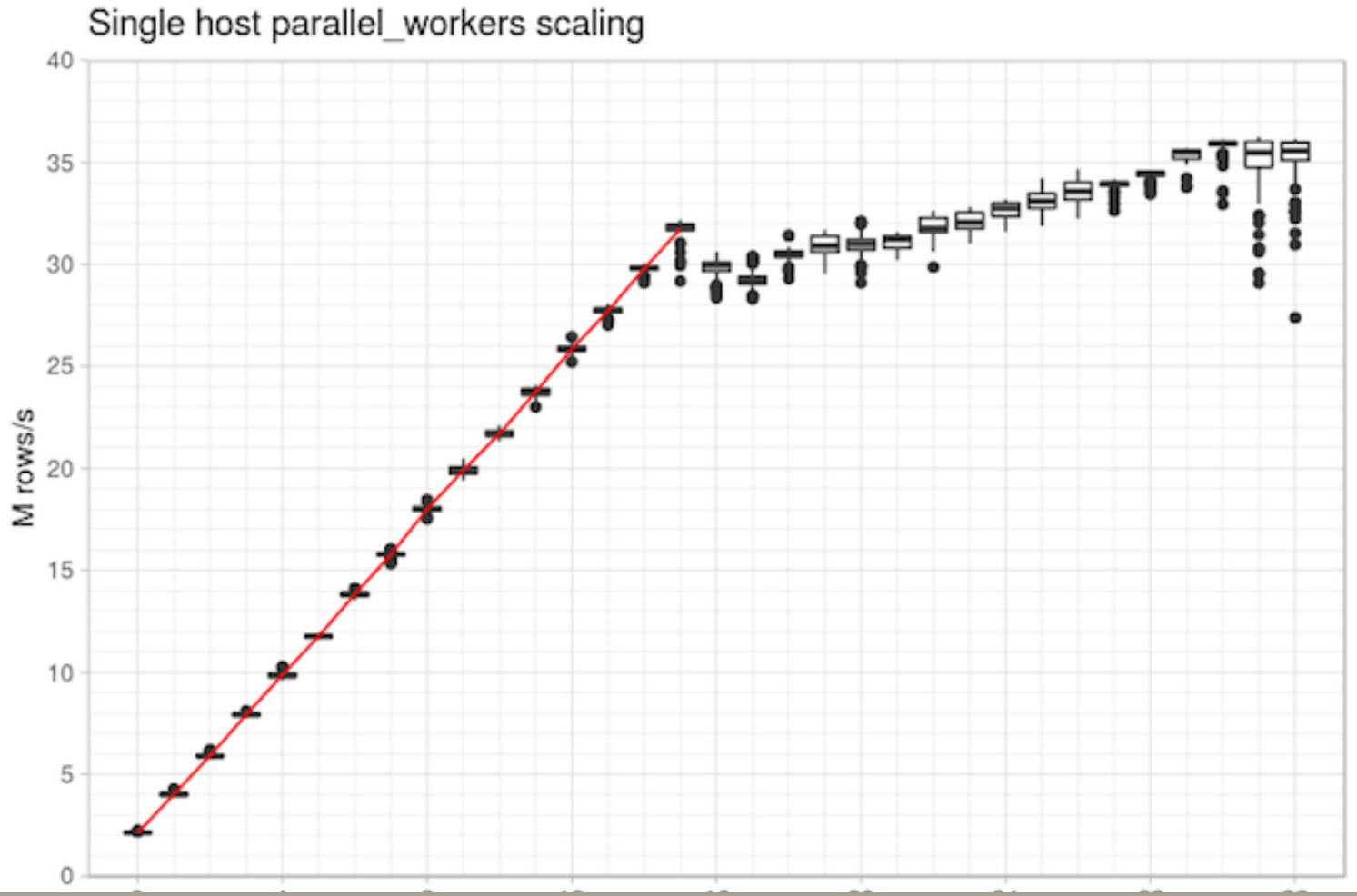
Making full use of cores

- How well does PostgreSQL scale on a single box?
- For the next test we assume that I/O is not an issue
  - If I/O does not keep up, CPU does not make a difference
  - Make sure that data can be read fast enough.
- Observation: 1 SSD might not be enough to feed a modern Intel chip

Some simple math

- 1 SSD: 500 MB / sec (roughly)
- 1 TB of data = 2000 seconds = 33 minutes
- Scaling to countless disks and cores is necessary anyway

Single node scalability (1)



Single node scalability (2)

- We used a 16 core box here
- As you can see, the query scales up nicely
- Beyond 16 cores hyperthreading kicks in
  - We managed to gain around 18%

Single node scalability (3)

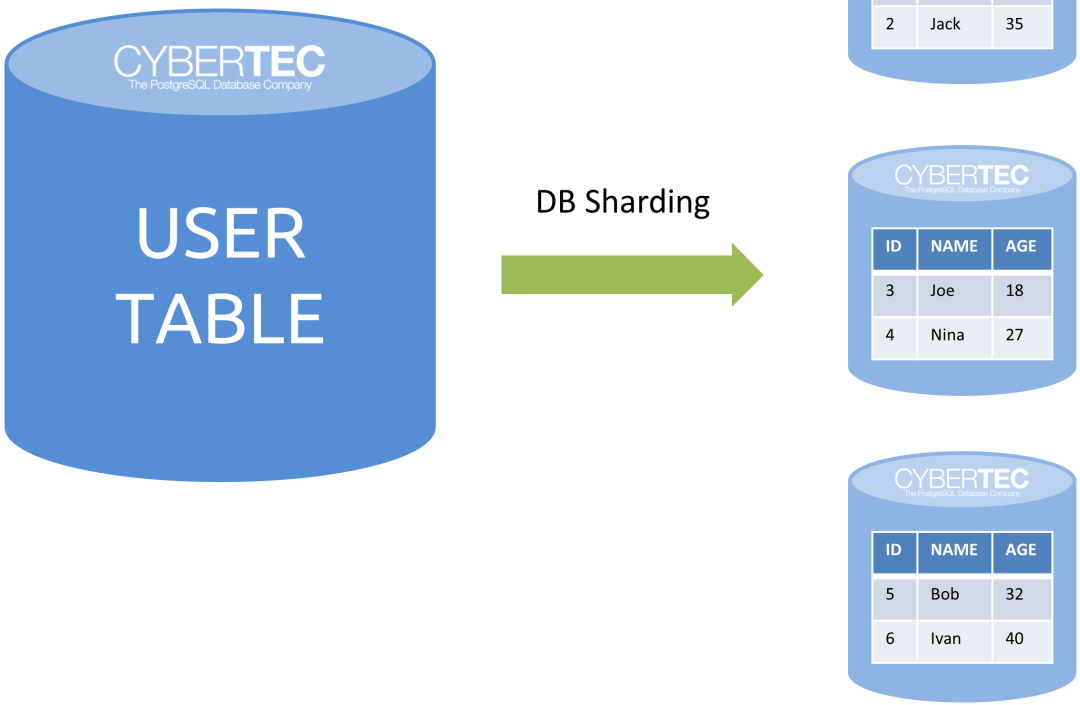
- On a single Google VM we could reach close to 40 million rows / second
- For many workloads this is already more than enough
- Rows / sec will of course depend on type of query

Moving on to many nodes

The basic system architecture (1)

- We want to shard data to as many nodes as needed
- For the demo: Place 100 million rows on each node
  - We do so to eliminate the I/O bottleneck
  - In case I/O happens we can always compensate using more servers
- Use parallel queries on each shard
- Want this to be a PostgreSQL and not a storage benchmark

The basic system architecture (2)



Testing with two nodes (1)


```
explain SELECT grp, COUNT(data) FROM t_demo GROUP BY 1;
 Finalize HashAggregate
   Group Key: t_demo.grp
   ->  Append
         ->  Foreign Scan  (partial aggregate)
         ->  Foreign Scan  (partial aggregate)
         ->  Partial HashAggregate
               Group Key: t_demo.grp
               ->  Seq Scan on t_demo
```

Testing with two nodes (2)

- Throughput doubles as long as partial results are small
- Planner pushes down stuff nicely
- Linear increases are necessary to scale to 1 billion rows

Preconditions to make it work (1)

- postgres_fdw uses cursors on the remote side
  - cursor_tuple_fraction has to be set to 1 to improve the planning process
  - set fetch_size to a large value
- That is the easy part

Preconditions to make it work (2)

- We have to make sure that all remote database servers work at the same time
- This requires "parallel append and async fetching"
  - All queries are sent to the many nodes in parallel
  - Data can be fetched in parallel
  - We cannot afford to wait for each nodes to complete if we want to scale in a linear way

Preconditions to make it work (3)

- PostgreSQL could not be changed without substantial work being done recently
  - Traditionally joins had to be done BEFORE aggregation
  - This is a showstopper for distributed aggregation because all the data has to be fetched from the remote host before aggregation
- Without this change the test is not possible.

Preconditions to make it work (4)

- Easy tasks:
  - Aggregates have to be implemented to handle partial results coming from shards
  - Code is simple and available as extension
- For the test we implemented a handful of aggregates

Parallel execution on shards is now possible

- Dissect aggregation
- Send partial queries to shards in parallel
- Perform parallel execution on shards
- Add up data on main node

Final results


```
node=# SELECT grp, count(data) FROM t_demo GROUP BY 1;
 grp |    count
-----+-----------
   0 | 320000000
   1 | 320000000
...
   9 | 320000000
(10 rows)
 Planning time: 0.955 ms
 Execution time: 2910.367 ms
```

Hardware used

- We used 32 boxes (16 cores) on Google
- Data was in memory
- Adding more servers is EASY
- Price tag: The staggering amount of EUR 28.14 (for development, testing and running the test)

A look at PostgreSQL 10.0

- A lot more parallelism will be available
  - Many executor nodes will enjoy parallel execution
- PostgreSQL 10.0 will be a giant leap forward

More complex plans

- ROLLUP / CUBE / GROUPING SETS has to wait for 10.0
  - A patch for that has been seen on the mailing list
- Be careful with complex intermediate results
- Avoid sorting of large amounts of data
- Some things are just harder on large data sets

Future ideas: JIT compilation

- JIT will allow us to do the same thing with fewer CPUs
- Will significantly improve throughput
- Some project teams are working on that

Future ideas: “Deeper execution”

- So far only one “stage” of execution is used
- Nothing stops us from building “trees” of servers
  - More complex operations can be done
  - Infrastructure is in place

Future things: Column stores

- Column stores will bring a real boost
- Vectorization can speed up things drastically
- Many commercial vendors already do that
- GPUs may also be useful

Finally

- Any questions?

Contact us

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