An overview of PostgreSQL's backup, archiving and replication

What to do, what not to do, where the pitfalls are

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Agenda

• Logical (aka. SQL-) backup
• Binary backup
• PITR & „replication“ with archiving
• Binary streaming replication

• Classic misconceptions and pitfalls
• What you most probably want to do
Some assertions

- You value your data
  - Otherwise you'd not be here ;-)    
- You have (at least) 2 decent servers available
  - ~ same amount of CPU and RAM
  - ECC memory
  - BBU HDD controller / SAN
  - a working UPS
- These should by all means separated as far as possible (and feasible) from each other
- You know your RTO and RPO requirements
Omnipotent natural laws

• Gravity
• Speed of light
• Murphy's law *
  – Disaster does strike
  – Unlike lightning, disaster tends to strike more than once in a row
  – Ask the Gitlab guys!
And keep Einstein in mind

• „Only two things are infinite, the universe and human stupidity, and I'm not sure about the former.“ **
Evolution

- The options and tools evolved over the years
- Nastily, the docs have mostly been amended
- Usually, you want to do it the way that comes last in the docs...
- Which means you're hopefully ready to go after reading ~ 50 pages of A4 in 2 chapters
- You should still read all of it!
The options you had with 7.0

31. Managing a Database
   Creating a Database
   Accessing a Database
   Destroying a Database
   Backup and Restore

32. Troubleshooting
   Postmaster Startup Failures
   Client Connection Problems
   Debugging Messages

33. Database Recovery
34. Regression Test
Sidenote: I especially like this one

Chapter 33. Database Recovery

This section needs to be written. Volunteers?
Logical aka. „SQL-“ backup

• `pg_dump[all]` connects to your DB just as any other client and provides you with a snapshot of your data
  - You can restore the state of the DB at the moment you *initiated* the backup

• Can dump whole clusters (`pg_dumpall`), databases, single tables

• Can provide textual (SQL) representation or custom („proprietary“) format
Textual format of pg_dump

- Plain SQL
- Uses COPY for performance
- Can be used to port DBs....
- Can be read by humans
Custom format of pg_dump

- `pg_dump -Fc`
- Restored using `pg_restore` (into `psql` or straight into a DB)
- Can restore single tables
- Compressed by default
Directory format of pg_dump

- `pg_dump -Fd`
- Can backup (and restore) in parallel (`-j X`)
- Restored using `pg_restore` (into `psql` or straight into a DB)
- Can restore single tables
- Compressed by default
Never forget `pg_dumpall`!

- `pg_dump` reads from **databases**
- So, global objects are not saved!
  - Roles
  - Tablespaces
- So, whenever you `pg_dump`, do a `pg_dumpall --globals-only` along with it!
RTO & RPO of logical backup

• RTO
  – between minutes and days
  – basically depending on size of DB

• RPO
  – your last backup run
  – in the worst case, the one before*!
Pros and cons

+ backup is readable by humans (or can be made so), schema & roles can go to your VCS
+ can be read by newer versions of PG
+ can backup & restore single entities if need be
+ will reveal issues with the „dark corners“ of your DB (when initialised with data checksums)*

- can only backup and thus restore a single point in time
- rather slow
- RPO & RTO... uhm, well
The way beyond pg_dump

- 7.1 added the WAL
- 8.0 added the ability to do
  - On-line backup
  - PITR (no, that's not Pain In The Rear!)
- 9.1 added pg_basebackup
  - „gift-wrapping“ existing backup methods
- 9.2 allowed pg_basebackup to also fetch WAL data
On-line, binary backup

- Erm, we're not there yet ;-)  
- We have to discuss some of Postgres' peculiarities first  
- Everything binary is centered around the WAL...
What the WAL is

- The Write Ahead Log (WAL) is basically the logbook of the DB
- Other DBMS call the equivalent „redolog“
  - some also have an „undolog“, PG doesn’t need that
- Every change is first written to the WAL
- At a CHECKPOINT (which can be spread!), the content is written to the HEAP, usually creating new row versions
WAL (vastly simplified)
The WAL consists of a chain of files, 16MB each ("segments")

Or more like a ring, as WAL segments get renamed and overwritten when feasible

It resides in $PGDATA/pg_xlog (10.0 ff: "pg_wal")

The size is determined by wal_min_size and wal_max_size (default: 1GB/2GB)

These are SOFT limits!
The archiver

- WAL segments are written by the „wal writer“ process
- WAL segments are read and applied to the HEAP by the „checkpoint“ process
- In between, they are handed to the archiver process
  - when `archive_mode != 'off'`
  - which is almost certainly what you want!
Binary snapshot

- Prepare your database:
  - `pg_start_backup()`
- Get a snapshot
  - We'll discuss the options later!
- „Release“ the HEAP again
  - `pg_stop_backup()`
Master DB

snapshot

1:1 copy of PGDATA
Ok, anything more that I need?

• Oh yes!

• All the WAL segments since the pg_start_backup()!

• Hopefully, they are still there, eh?
  - If you wrote a lot of data into your DB after pg_start_backup(), they might have been recycled already!*
Master DB

archive_command

1:1 copy of PGDATA
WAL segments
Copy to new PGDATA

Provide via "restore_command"
in recovery.conf
(e.g. cp, scp, rsync, ...)

1:1 copy of PGDATA

WAL segments
RTO & RPO

• RTO
  – between minutes & days
  – depending on size & activity during backup

• RPO
  – the end of your backup
  – or the end of the one before!*
Pros and cons

+ 1:1 copy of your DB
+ rather failsafe
+ rather fast
+ RTO fine

- can only back up and thus restore a single point in time
- can only back up and thus restore whole DB clusters
- RPO... still, uhm, well
Options to get that snapshot

- LVM / filesystem snapshot
- rsync
- pg_basebackup
Options to get that snapshot

- LVM-/filesystem-snapshot
- rsyne
- pg_basebackup
Options to get the WAL segments

- archive_command (postgresql.conf)
- pg_basebackup
  - With --xlog-method=[fetch|stream]
  - -X [s|f]

USE BOTH!
Why use both?

- Actually, get used to both
- When you have a WAL archive anyway, you can (probably) rely on that
- But `pg_basebackup` with `-X` is also handy to clone new slaves (we'll get there)
Master DB

archive_command

1:1 copy of PGDATA
WAL segments
WAL archive
Why do I want to have a WAL archive?

- The WAL segments, together with the snapshot of your HEAP, allow you to restore your database to any point in time
  - e.g., the moment right before you forgot the WHERE in your „DELETE FROM customers“ statement ;-) **

- That‘s Point In Time Recovery („PITR“)

- Obviously, you need two things for that:
  - a binary snapshot of your HEAP
  - all WAL segments between your snapshot and your mistake
Can also replay WALs from the archive continuously: „warm standby“

Copy to new PGDATA

Provide via „restore.conf“ in recovery.conf (e.g. cp, scp, rsync, …)

Master DB

1:1 copy of PGDATA

WAL archive

Restore Target
RTO & RPO

- **RTO**
  - minutes to hours (cold standby)
  - seconds (warm standby)

- **RPO**
  - your last archived WAL segment

- warm standby = „poor man's replication“
Binary streaming replication

- Binary streaming is like a warm standby server as seen before
- But the WAL segments get sent over the network directly
- Transactions are replayed immediately
  - i.e., „ASAP“
Let's talk about options!

- Streaming replication can be synchronous or asynchronous
  - choose per transaction!
  - choose between remote_write & remote_apply
- *can* use replication slots
- *can* be cascaded
- slaves *can* serve RO queries
  - you *can* take your backup from a slave (
- Streaming slave can be delayed (so you can still press the big red button) **
Sync replication pitfalls

• You can now have N sync slaves
• Make sure you always have N+1 slaves in total
  – If you go to N-1, your DB will still work
  – but not finish any transactions before you get back to N!
  *
• Network latency / roundtrip time becomes an issue!
  – so choose wisely (you can!) which transactions should by sync
  – and where to put your sync slave
Pros and cons

+ 1:1 copy of your DB, online
+ Reliable & battle proven
+ RTO & RPO very good
+ very flexible

- works on whole DB clusters only
- implications on network connection loss
So, with replication,...

- I don't need the WAL archive anymore, right?

R U effing kidding me?!?
We need to talk...

- Replication does not replace backup
- And, while we're on it: **
- RAID does not replace backups
- SAN does not replace backups
- „The Cloud“ does not replace backups **
Putting it all together

• You want to have a WAL archive
• You want to have (a) replication slaves
  – maybe more than one
  – maybe a sync one
  – maybe a delayed one
  – maybe cascaded
• RTO: minimal
• RPO:
  – closest possible (sync slave)
  – closest feasible (async slave)
• Protection against human errors (RTO obviously rises...)
• Allow read only queries on slave(s)
Master DB

Stream

Slave DB

1:1 copy of PGDATA

WAL archive

archive_command

restore_command
Pros and cons

+ all of replication
+ all of WAL archive

- major version still has to be the same
Configure postgresql.conf

- `wal_level = replica` # or logical already
- `archive_mode = on` # always to cascade
- `archive_command = /your/archive_script.sh %p %f`
- `max_wal_senders = 10` # or more
- `max_replication_slots = 10` # or more
- `synchronous_commit = local` # for now
- `synchronous_standby_names = '' | <set>`
- `hot_standby = on`
- `log_collector = on`
Set up your WAL archive

• Don't roll your own! **
  – Use pgbarman, pgbackrest, WAL-E, ...
  – Follow their instructions

• Invest the saved time in thinking about redundancy, persistance and data safety

• Your DB server is not a good place to keep your archive **

• Even the same datacenter is a bad choice (unless you mirror)
/your/archive_script.sh

• Only slightly complex functionality will not fit in archive_command
• A script can be changed w/out HUPing the DB
• Purpose of the script: somehow get %p ($1) to your WAL archive as %f ($2)
• rsync is not a bad choice, however:
  – make sure %f does not exist in the archive yet before you start sending
  – call sync remotely (or mount your archive sync) after sending
  – rsync tends to give RCs > 127, filter these
• Make sure it never, ever returns RC=0 w/out having done the job
  – Unless you're still setting everything up
  – „set -e“ etc.
  – Errors will end up in PG's log (as we turned log_collector on)
Let me repeat that

- You are most probably writing into some OS pagecache, and potentially async on top (NFS)!
- Your backup is not safe until it has been flushed to persistent storage in a safe location *
- Your archived WAL segments are not safe until they have been flushed to persistent storage in a safe location *
- You'll probably make some compromises, but keep the implications on the RCO in mind **
Now, activate archiving

- And watch it
- PG will not throw away WAL segments it could not archive
  - your PGDATA can run out of disk space!
- Replication slots have the same implication, so keep that in mind
Now, try a full backup

- Since you're using a tool anyway**, you're hopefully ready to go already (rights, replication permission, preparation, ...)

- E.g., do
  - barman backup all
Doing your first slave

- Add a „replication“ line to your master's `pg_hba.conf`
- Prepare the new PGDATA
  - e.g. on Debian/Ubuntu do a `pg_createcluster` and `rm -rf` the result (no, really)
  - Make sure the `postgresql.conf` etc. match your master's
- Run
- `pg_basebackup -X stream -h <master> -U <user> -R -D <new_pgddata>`
- Add a `restore_command` to the resulting `recovery.conf`
  - Which gets the segment from your archive
- Start the slave, enjoy, rinse, repeat
Now, start looking for software

• E.g.
  – repmgr
  – PAF
  – pglookout
  – ...

●
  – repmgr
  – PAF
  – pglookout
  – ...

—
In the not so recent past...

- Slony
- Bucardo
- Skytools
Logical replication

• Coming into core with 10.0
• Already available with e.g. pglogical
• If you can afford a few MB extra backup volume, already set
  – `wal_level = logical`
• Allows for e.g.
  – painless, low-downtime version upgrades
  – sharding
  – collecting data from different DBs in a DWH
  – multi-master
  – …
When in core

- Somewhat moving target yet, but will be more like
Famous last words

- Don't reinvent the wheel!
- Test your backup procedure!
- Test your restore procedure!!! **
- Monitor your logs and your lags!
- Make sure your configs are in sync!
- Make sure everybody in your team understands your backup and restore procedures! **
- In case of disaster *
  - keep calm and follow your procedures **
Thank you for your attention!

Thats all Folks!