pgBackRest magic you'll wish you knew sooner

data egret

Your remote PostgreSQL DBA team

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Stefan Fercot

- PostgreSQL Expert **@Data Egret**
  - PostgreSQL consulting, support, and training
- pgBackRest contributor and advocate
- Also known as pgstef
- https://pgstef.github.io


What is pgBackRest?

- Reliable backup and restore tool for PostgreSQL
- Supports local and remote operation (via SSH or TLS)
- Parallel and asynchronous operations
- Works with S3, Azure, GCS, NFS, and other storage backends
- Multiple compression methods (`gz` , `bz2` , `lz4` , `zst`)
- Supports client-side encryption (`aes-256-cbc`)

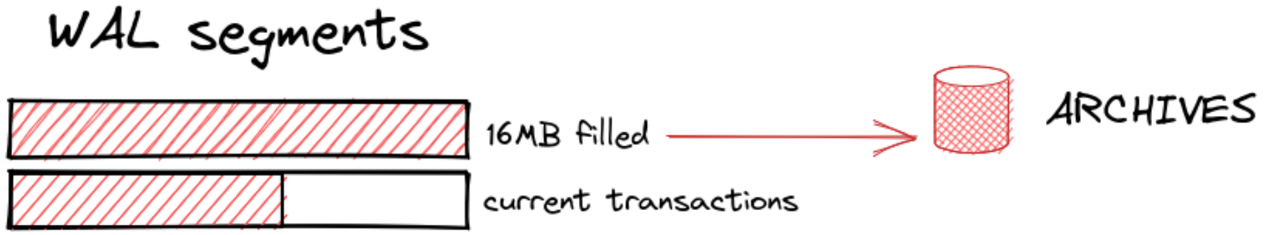
pgBackRest: faster WAL archiving, safer restores

- Archiving mechanics
- Restore scenarios

Archiving: the happy path and the traps

- `archive_command` vs `pg_receivewal` (not supported)
- How can we make archiving faster?
- What can go wrong?

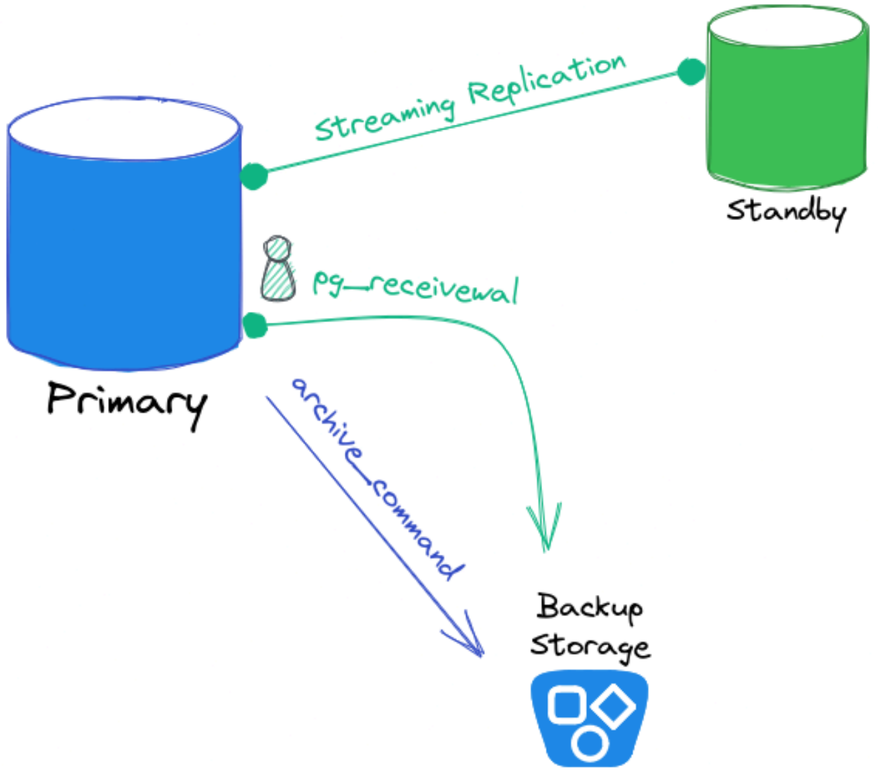
WAL archiving process



`.partial` WAL file

- Usually < 16MB
- `pg_receivewal` behaves like a standby without data files
- `.partial` is pushed by the standby server at promotion time

Example (1)


Streaming Replication
Standby
pg_receivewal
Primary
archive_command
Backup
Storage

Example (2)

```
archive_command = 'gzip < %p > /shared/archives/%f.gz'
```

```
pg_receivewal -D /shared/receivewal --compress=gzip -v
```

```
/usr/pgsql-18/bin/pgbench -i -s 65
```

Example (3)

```
$ ps -o pid,cmd fx
    PID CMD
   5461 /usr/pgsql-18/bin/postgres -D /var/lib/pgsql/18/data/
   ...
   5537  \_ postgres: walsender ... streaming 0/34E74D38
   5590  \_ postgres: walsender ... streaming 0/34E74D38
```

```
$ ls /shared/archives
...
000000010000000000000033.gz
```

```
$ ls /shared/receivewal
...
000000010000000000000033.gz
000000010000000000000034.gz.partial
```

Example (4)

```
$ psql -c "SELECT pg_promote();"
```

```
$ ls /shared/archives/
...
000000010000000000000034.partial.gz
00000002.history.gz
```

`pg_receivewal` still points to the old primary!

Timelines and `.history` files

A correct restore — PITR or not — always involves a timeline switch.

- When archive recovery completes or a standby is promoted -> new timeline
  - encoded in WAL segment file names
  - identifies the WAL record series generated after that recovery
  - recorded in `.history` files

Faster archiving?

- Compression types
- Compression level
- Async archiving

Compression types

- File compression types supported (`compress-type`):
  - `bz2` - bzip2
  - `gz` - gzip (default)
  - `lz4`
  - `zst` - Zstandard

Compression level

- When `compress-level` is not specified:
  - defaults to values based on `compress-type`
    - `bz2`: 9
    - `gz`: 6
    - `lz4`: 1
    - `zst`: 3

Async archiving

- With `archive-async=y`:
  - temporary data (acknowledgments) stored in `spool-path`
  - early archiving with `process-max` workers

Example (1) - initial state

```
SELECT application_name, sent_lsn, write_lsn, flush_lsn FROM pg_stat_replication;
 application_name |  sent_lsn  | write_lsn  | flush_lsn
------------------+------------+------------+------------
 walreceiver      | 0/34E74D38 | 0/34E74D38 | 0/34E74D38
 pg_receivewal    | 0/34E74D38 | 0/34E74D38 | 0/34000000
(2 rows)
```

```
SELECT last_archived_wal FROM pg_stat_archiver;
    last_archived_wal
--------------------------
 000000010000000000000033
(1 row)
```

Example (2) - archiving too slow

```
/usr/pgsql-18/bin/pgbench -n -P 1 -T 60 -j 2 -c 50
```

```
SELECT application_name, sent_lsn, write_lsn, flush_lsn FROM pg_stat_replication;
 application_name |  sent_lsn   | write_lsn   | flush_lsn
------------------+-------------+-------------+-------------
 walreceiver      | 0/67F3CE30 | 0/67F33830 | 0/67F0D558
 pg_receivewal    | 0/67F3CE30 | 0/62780B38 | 0/62000000
(2 rows)
```

```
SELECT last_archived_wal FROM pg_stat_archiver;
    last_archived_wal
--------------------------
 000000010000000000000048
(1 row)
```

Example (3) - final state

```
SELECT application_name, sent_lsn, write_lsn, flush_lsn FROM pg_stat_replication;
 application_name |  sent_lsn   | write_lsn   | flush_lsn
------------------+-------------+-------------+-------------
 walreceiver      | 0/A82E1770 | 0/A82E1770 | 0/A82E1770
 pg_receivewal    | 0/A82E1770 | 0/A82E1770 | 0/A8000000
(2 rows)
```

```
SELECT last_archived_wal FROM pg_stat_archiver;
    last_archived_wal
--------------------------
 000000010000000000000A7
(1 row)
```

Example (4) - improvements

```
process-max=2
archive-async=y
compress-type=zst
```

```
/usr/pgsql-18/bin/pgbench -n -P 1 -T 60 -j 2 -c 50
```

```
SELECT application_name, sent_lsn, write_lsn, flush_lsn FROM pg_stat_replication;
 application_name |  sent_lsn   | write_lsn   | flush_lsn
------------------+-------------+-------------+------------
 walreceiver      | 0/C9B5F610 | 0/C9B5F610 | 0/C9B5AE00
 pg_receivewal    | 0/C9B5F610 | 0/BE8D22E0 | 0/BE000000
(2 rows)
```

```
SELECT last_archived_wal FROM pg_stat_archiver;
    last_archived_wal
--------------------------
 000000010000000000000C7
(1 row)
```

Understanding logs

- `archive-push` console output goes into the PostgreSQL logs

```
P00   INFO: archive-push command begin 2.58.0: [pg_wal/0000000100000000000000C6] ...
P00   INFO: pushed WAL file '0000000100000000000000C6' to the archive asynchronously
P00   INFO: archive-push command end: completed successfully (639ms)
P00   INFO: archive-push command begin 2.58.0: [pg_wal/0000000100000000000000C7] ...
P00   INFO: pushed WAL file '0000000100000000000000C7' to the archive asynchronously
P00   INFO: archive-push command end: completed successfully (20ms)
```

- `demo-archive-push-async.log`

```
P00   INFO: archive-push:async command begin 2.58.0: [/var/lib/pgsql/18/data/pg_wal] ...
P00   INFO: push 2 WAL file(s) to archive: 0000000100000000000000C6...0000000100000000000000C7
P02 DETAIL: pushed WAL file '0000000100000000000000C7' to the archive
P01 DETAIL: pushed WAL file '0000000100000000000000C6' to the archive
P00   INFO: archive-push:async command end: completed successfully (554ms)
```

Async high-level implementation details

- Create the spool `out` path if it does not already exist
- Read `.ready` files from `archive_status`
- Remove `.ok` files that are not in the ready list
- Return `.ready` files that are not in the `.ok` list
- Create the parallel executor and run jobs
- On success:
  - log success
  - write the status file

What can go wrong with archiving?

> *Things can get worse… and they will!*

WAL segments piling up…

An error prevents PostgreSQL from removing/recycling WAL files!

```
$ ls data/pg_wal/archive_status |grep .ready
...
000000010000000020000001B.ready
000000010000000020000001C.ready
000000010000000020000001D.ready
000000010000000020000001E.ready
```

Archiving queue

- `archive-push-queue-max`
  - maximum size of the PostgreSQL archive queue
  - prevents WAL storage from filling up until PostgreSQL stops…
  - …but can create **missing archives**!
- **Monitor** archiving to ensure it keeps working

A very realistic failure chain

- NFS/S3/… hiccup -> archive queue fills
- `archive-push-queue-max` reached
- PostgreSQL continues -> WAL is recycled
- Backup exists…
- …but PITR fails due to missing WAL
  - a new backup is needed!

Log error example without `archive-async`

```
P00   INFO: archive-push command begin 2.58.0: [pg_wal/000000010000000010000000E0] ...
P00   WARN: dropped WAL file '000000010000000010000000E0' because archive queue exceeded 128MB
P00   INFO: archive-push command end: completed successfully (8ms)
P00   INFO: archive-push command begin 2.58.0: [pg_wal/000000010000000010000000E1] ...
P00  ERROR: [103]: unable to find a valid repository:
...
P00   INFO: archive-push command end: aborted with exception [103]
LOG:  archive command failed with exit code 103
```

Side effect

```
$ ls data/pg_wal/archive_status |grep .ready

000000010000000100000E1.ready
000000010000000100000E2.ready
000000010000000100000E3.ready
000000010000000100000E4.ready
000000010000000100000E5.ready
000000010000000100000E6.ready
000000010000000100000E7.ready
000000010000000100000E8.ready
```

- 8 x 16MB <= 128MB
- Only the oldest WAL file gets purged

Log error example with `archive-async`

```
P00   WARN: dropped WAL file '000000010000000200000001' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000002' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000003' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000004' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000005' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000006' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000007' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000008' because archive queue exceeded 128MB
P00   WARN: dropped WAL file '000000010000000200000009' because archive queue exceeded 128MB

P00   INFO: archive-push command begin 2.58.0: [pg_wal/00000001000000020000000A] ...
P00  ERROR: [103]: unable to find a valid repository:
...
P00   INFO: archive-push command end: aborted with exception [103]
LOG:  archive command failed with exit code 103
```

Side effect

```
$ ls data/pg_wal/archive_status |grep .ready

000000010000000200000000A.ready
000000010000000200000000B.ready
```

- The entire 128MB waiting queue gets purged

Restore: pgBackRest + PostgreSQL

pgBackRest handles the restore;
PostgreSQL handles the recovery!

Let’s talk about `restore` command and recovery targets…

Restore type?

- `--type` (and `--target` to define the target)
  - `default`: end of the WAL archive stream
  - `immediate`: backup consistency point
  - `lsn`: LSN (*Log Sequence Number*), `recovery_target_lsn`
  - `name`: restore point, `recovery_target_name`
  - `xid`: transaction ID, `recovery_target_xid`
  - `time`: timestamp, `recovery_target_time`
  - …

Backup set

- `--set`
  - default: `latest`
  - auto-selected for `time` and `lsn` targets

Timeline

- `--target-timeline`
  - `recovery_target_timeline`
  - default: `latest`
  - useful value: `current`

What happens at the target?

- `--target-action` (`recovery_target_action`)
  - `pause`: pause when the recovery target is reached
  - `promote`: promote the instance and switch to a new timeline
  - `shutdown`: shut down the server

Delta mode: restore into an existing PGDATA

- `--delta` (CLI) or `delta=y` (config)
- Uses checksums to decide what to copy
  - **Restore**: allows restoring into a non-empty data directory
  - **Backup**: uses checksums instead of timestamps

```
Restore or backup using checksums.
During a restore, by default the PostgreSQL data and tablespace directories
are expected to be present but empty. This option performs a delta restore
using checksums.

During a backup, this option will use checksums instead of timestamps to
determine if files will be copied.
```

Delta restore is not incremental backup

- **Delta restore**
  - affects how files are copied during restore
  - allows restoring into a non-empty data directory
  - does **not** change backup format or WAL requirements
- **Incremental backup**
  - affects how backups are created
  - stores only changes since a previous backup
  - requires a dependency chain
  - **not related** to `--delta`
- `--delta` **backup**: uses checksums, not timestamps

Selective restore

- `--db-include`
  - databases not explicitly included are restored as sparse, zeroed files
  - system databases are always restored unless explicitly excluded
    - (`template0`, `template1`, `postgres`)
- `--db-exclude`
  - excluded databases are restored as sparse, zeroed files
  - with `--db-include`, this only applies to system databases

Example (1)

Name	Size
db1	1015 MB
db2	3047 MB

```
db1=# SELECT pg_create_restore_point('dont_fear_demo_effect');
 pg_create_restore_point
-------------------------
 4/91FF5B58
(1 row)

db1=# DELETE FROM pgbench_accounts;
DELETE 6500000
```

Example (2) - restore command

```
$ pgbackrest restore --stanza=demo --type=name --target='dont_fear_demo_effect' --db-include=db1
P00   INFO: restore command begin 2.58.0: ...
P00   INFO: repo1: restore backup set 20260130-105007F, recovery will start at ...
P00   INFO: write updated /var/lib/pgsql/18/data/postgresql.auto.conf
P00   INFO: restore global/pg_control
P00   INFO: restore size = 4GB, file total = 1603
P00   INFO: restore command end: completed successfully

$ cat /var/lib/pgsql/18/data/postgresql.auto.conf
# Recovery settings generated by pgBackRest restore on ...
restore_command = 'pgbackrest --stanza=demo archive-get %f "%p"'
recovery_target_name = 'dont_fear_demo_effect'

$ du -hs /var/lib/pgsql/18/data
1.1G  /var/lib/pgsql/18/data
```

Example (3) - the result

```
db1=# SELECT COUNT(*) FROM pgbench_accounts;
  count
---------
 6500000
(1 row)

db1=# \c db2
connection to server on socket "/run/postgresql/.s.PGSQL.5432" failed:
  FATAL:  relation mapping file "base/16440/pg_filenode.map" contains invalid data

db1=# DROP DATABASE db2; -- corrupted after selective restore
DROP DATABASE
```

Selective restore summary

- Saves disk space and restore time (not recovery time!)
- pgBackRest restore `--db-include` with `--type=immediate` usually works well
- Selective PITR can work; otherwise, if it does not, a regular restore is required
- Selective restore is an optimization, not a guarantee

Asynchronously fetch WAL segments

- With `archive-get` and `archive-async=y`:
  - prefetches up to `archive-get-queue-max` WAL segments to **speed up recovery**
  - uses `process-max` workers
  - stores them in `spool-path`

Conclusion

- Tune your archiving (async, compression, concurrency)
- Monitor backups and archives
- Regularly test restores

Schrödinger's Law of Backups

> *The condition/state of any backup is unknown until a restore is attempted.*

Questions?

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