Upgrades Don’t Have To Hurt

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pgday.at 2025

Hello

About me

What This Talk Is About

- Why PostgreSQL requires an upgrade process.
- Methods for upgrading the database.
- What problems you can run into.
- Which tools are available.

What This Talk Is Not About

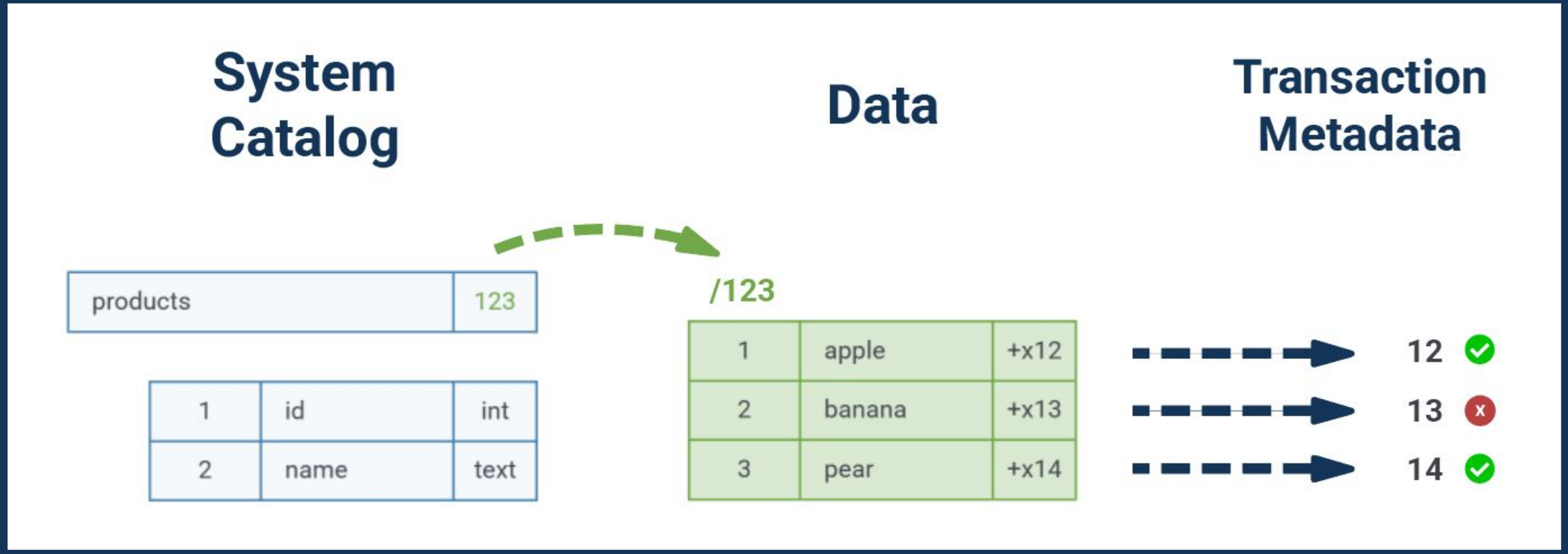
- We are talking about major version upgrades - this means feature releases.
- Bugfix releases just need a restart.
- You should be applying these as part of standard operations.

This Is About Self Managed Databases

- Typically don’t have access to do it yourself.
- DBaaS providers handle upgrade automation for you.
- Sometimes they do it well, sometimes less so.
- Very similar things happen behind the curtain.

Why Do We Need To Upgrade?

How PostgreSQL Stores Data



More Details

See this blogpost for more in-depth discussion:

Why PostgreSQL major version upgrades are hard by Peter Eisentraut

The Bad Old Days

Export And Import

- pg_dump interprets old catalog into SQL statements.
- New version creates system catalogs from SQL statements.
- Data is transferred using COPY.
- Indexes and constraints are added.

How Much Downtime Do You Need?!

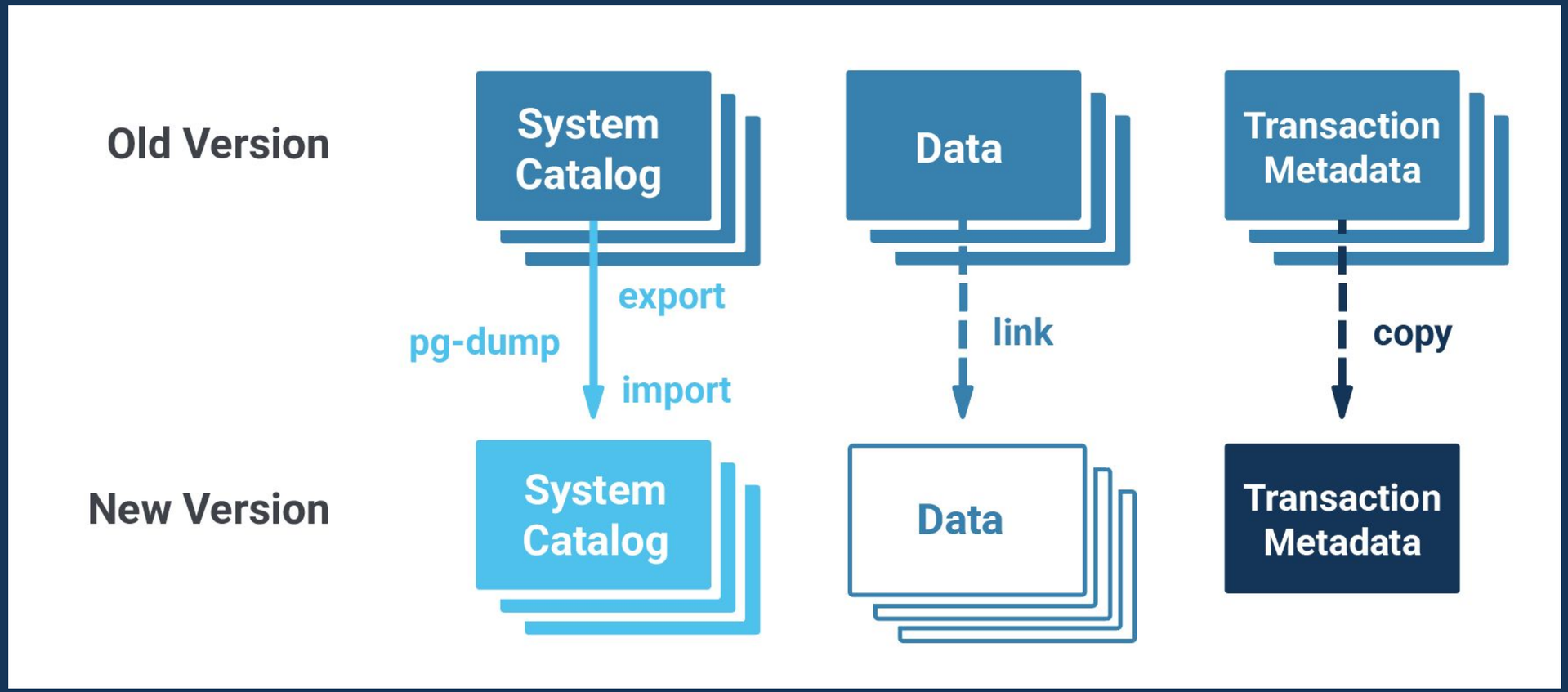
- Hours or days for large databases.
- Application writes must be disabled.
- Maybe acceptable for small databases that are not needed 24/7.

There Must Be A Better Way

- The actual data format doesn’t really change.
  - Rows are rows.
  - Integers are integers.
  - Strings are strings.
- Can we make use of this?

The pg_upgrade Way

Transferring



Database Memory Transplantation

ISO 27001
CERTIFIED

Copy Based Transfer

- Reads and writes all of the data files.
- Double disk space needed temporarily.

Link Mode

- Metadata only operation.
- Enabled by pg_upgrade --link option.
- Source and target must be on the same filesystem.
- Must not touch old version after new version has been started!
- On some filesystems (XFS/Btrfs) --clone and --copy-file-range can do copy on write.

Swap Mode

- New in PostgreSQL 18
- pg_upgrade --swap --sync-method=fsync
- Moves the whole data directory over and injects new system catalog.
- Helps when there are thousands of table and index segments.

Statistics

- Table statistics are not transferred.
- An analysis process had to be run to recalculate statistics.
- Danger of terrible query plans before this.
- Phased to get some rough estimates quickly.
  - Danger: per column statistics can make even the rough estimates take very long.
- Fixed in version 18!

Large Objects Are Bad

- Large objects get transferred by export-import.
- Transferring can take a very long time.
- Prior to version 17, a very large number could break the upgrade.

No pg_downgrade

- New version will use incompatible data formats.
- Backup only helps so much - will lose everything since the backup.
- Test first!

Sanity Check

- pg_upgrade --check is able to catch some errors.
- Runs quickly and with old version still running.
- Run it before the main upgrade process starts.

Upgrading Replicas

- Streaming replication only works with the same major version.
- Replicas must be byte-by-byte identical copies.
- Upgrade process is not deterministic.
- Trying to run pg_upgrade on a replica will result in failure or corruption.

The Brute Force Way

- Recreate replica from a fresh backup.
- Takes quite a bit of time.
- Reduced redundancy while replica reinitialization is underway.

The Hacky Way

- The old version data directory is identical before the upgrade if the replica was caught up. (check LSN!)
- rsync can transfer hard links.
- A special rsync command can copy over system catalogs and redo the hard links on replica.
  - See pg_upgrade documentation.
- Must happen before primary is started, otherwise silent data corruption.
- Unlogged tables will get transferred too.
  - Workaround: truncate before the upgrade.

pg_ugprade Summary

- Not many extra resources needed.
- Usually fast enough.
  - Typically takes from seconds to a few minutes.
- Bad cases can take hours.
- Replica handling is messy.
- One way street.

Logical Replication Upgrades

Online Export And Import

- Logical replication is effectively an export-import, but with changes replicated.
- Works between different PostgreSQL major versions.
- Initial synchronization still takes a long time.

The Big Picture

1. Set up logical replication to target version.
2. Wait for a suitable time.
3. Stop application traffic to source version.
4. Transfer non-replicated objects and wait for catch-up.
5. Point application at target version.

Not Burning Any Bridges

- To retain capability to go backwards, set up reverse replication during switchover.
- With origin=none option this could be set up ahead of time.

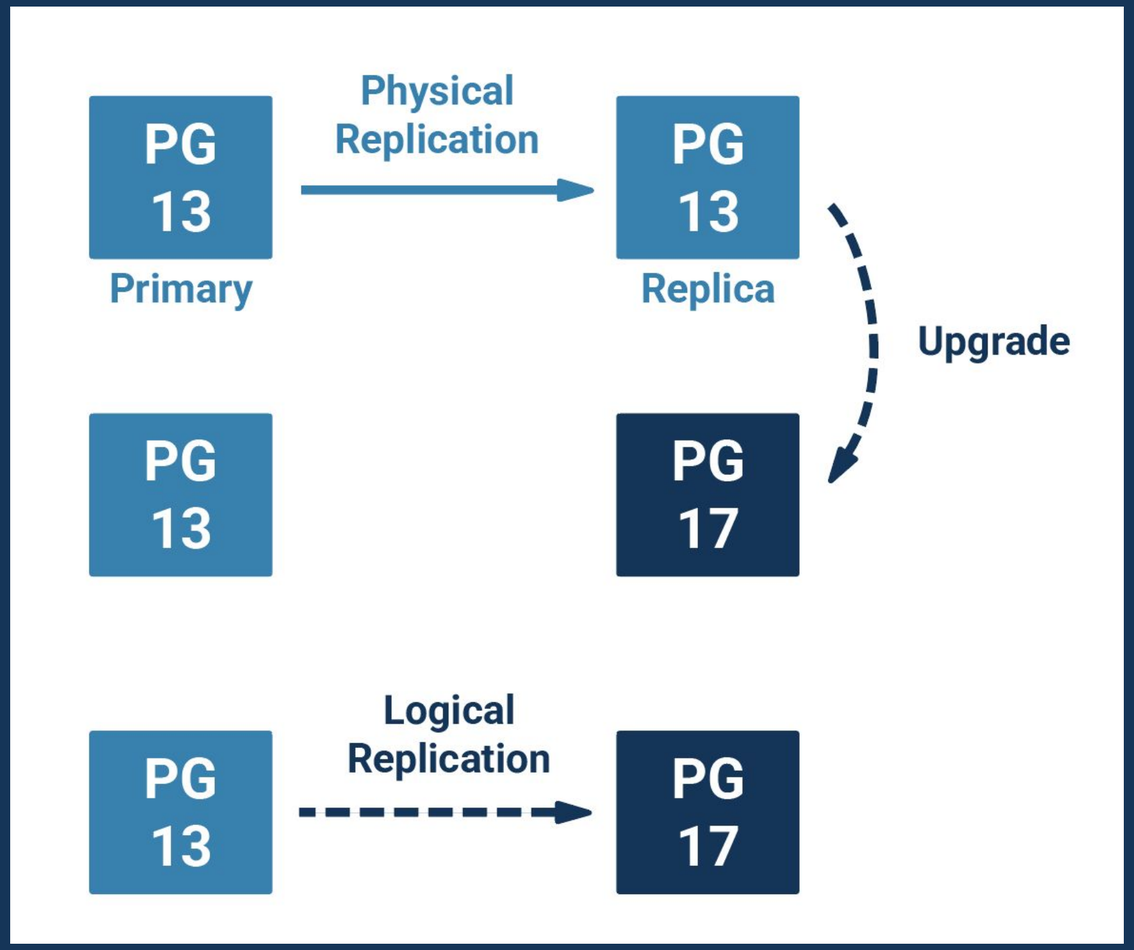
Quiescing The Application

- Many ways to do this.
- pgbouncer and the PAUSE feature can make this easy.

Speeding Up The Replication Setup

- Export and import of huge databases can take way too long.
- Use a streaming replica as a basis.
- Promote and upgrade the replica.
- Set up logical replication to start where physical replication left off.
- Implemented as pg_createsubscriber in version 17

Converting Physical Replica To Logical



Schema Changes Are Not Replicated

- Need to manually apply schema changes in target.
- Typically easier to not change the schema during upgrade process.
- This schema freeze can be enforced using an event trigger.

Sequences

- Sequence values are not incremented with logical replication.
- A quick solution is to sync them during switchover:

```
1| SELECT format('SELECT setval(''%I.%I'', %s);',
2| schemaname, sequencename, last_value)
3| FROM pg_sequences WHERE last_value IS NOT NULL;
```

Other Non-Replicated Objects

- Materialized view contents need to be refreshed on target.
- Large objects are not replicated.
- Unlogged tables will be empty.
- Replication slots for CDC need manual syncing.

Throughput Issues

- One apply worker per subscription doing the work of many backends.
- At best 20k updates/s per apply worker.
- Can split up tables between multiple subscriptions.

Logical Upgrade In A Nutshell

- Unavailability for writes measured in seconds.
  - Can be made to look externally as a small latency spike.
- Need a new server, or sacrifice a streaming replica during the upgrade.
- More moving pieces to manage.
- Very large databases require extreme care.

Things To Worry About

Application Compatibility

- PostgreSQL tries to not break applications unnecessarily.
- Sometimes things do change or deprecated features get dropped.
- Application developers should review release notes of the major version(s)
- Test!

Application Compatibility Examples

- 18: Unlogged partitioned tables are now an error, partitions still fine.
- 17: Functions used in indexes and materialized views must specify search path explicitly.
- 16: plpgsql cursor names are dynamically generated to avoid conflicts.
- 15: Only database owner can create objects public schema by default.
- 14: Custom array functions may need to be dropped and recreated after upgrade.

Plan Changes

- New version has new and better ways to execute queries.
- Flip side: planner has new and more interesting ways to generate bad plans.
- Always a risk, but a higher risk during upgrades.
- Test!
- Have pg_stat_statements, auto_explain and pg_hint_plan ready to fix issues that weren’t caught.

Using pg_hint_plan To Fix Stuff At Runtime

- Example: terrible plan because join between orders and order_events was severely underestimated.

```
1| INSERT INTO hint_plan.hints(query_id, application_name, hints)
2| VALUES (1234567890, '', 'Rows(orders order_events *1000)');
```

Schema Compatibility

- Is the schema pg_dump restorable in the new version?
- May need to get rid of dropped features.
- System catalog references cause issues.
  - Drop and recreate usually enough.
  - pg_monitor role might be an alternative.
- Test!

Extensions

- Need to have in use extensions installed for the new version.
- Some extensions have specific compatibility limitations.
  - PostGIS
  - Timescale
  - May need to upgrade extension before PostgreSQL upgrade.
  - May need to upgrade in several steps.
- Some extensions may need to be dropped and recreated.
- If extension version is updated, need to upgrade the schema:
  - ALTER EXTENSION xyz UPDATE
- Test!

Configuration

- Configuration variables get added and removed between versions.
  - wal_keep_segments -> wal_keep_size in 13
  - Removal of stats_temp_directory in 15
- Some tweaks to configuration may be needed.
- why-upgrade.depesz.com can give you a list.
- Patroni handles per version config customization.

OS Upgrades

- For OS release upgrades you have to be careful about locales.
- If glibc version changes, text indexes may become corrupted and need to be rebuilt.
- glibc 2.28 is especially problematic.
  - EL7 -> EL8+
  - Debian 9 -> 10+
  - Ubuntu 18.04 -> 18.10+
- For more details, see Locale data changes in PostgreSQL wiki.

Automation

Always Automate

- Any manual step introduces a place where a mistake can be made.
- Makes sure testing matches what happens in production.
- Reduces the amount of downtime needed.
- Check as much as you can ahead of time.
- Fail early if anything looks wrong.
- Have a way to roll back or roll forwards from points of failure.

pg_upgradecluster

- Script for single command upgrade.
- Comes with postgresql-common.
- Run pg_upgrade like this:

```
1| pg_upgradecluster --method=upgrade --link 13 main
```

- Does initdb and adapts config files.
- No tablespaces handling.
- Can’t use the rsync trick for replicas.

Spilo

- PostgreSQL container intended to run in and outside of Kubernetes.
- Has a scripted approach to handle major version upgrade.
  - Runs various pre-flight checks.
  - Coordinates shutdown across replicas.
  - Does pg_upgrade --link and then the magic rsync to replicas.
  - Updates extensions and statistics.
  - Cleanup and new backup.
- Handles integration with Patroni.
- Single command to upgrade.

Kubernetes Operators

- Zalando postgres-operator uses Spilo.
- CloudNativePG can run pg_upgrade, but handles replicas using a full copy.
- Crunchy operator runs pg_upgrade as a separate container, requires multiple steps.
- Logical replication also works, but no significant help from any operator.

Future Work

Patroni

- Work underway to port Spilo upgrade process to Patroni.
- Hooks for handling special extensions.
- Goal: patronictl upgrade --version=18

pg_upgrade

- The rsync approach is not very nice.
- pg_upgrade could output a package file to convert up to date replicas to new version.
- On an idea level so far.

Summary

Upgrades That Work

- Test upgrade in development and staging environments.
- Test application on upgraded version.
- Script the whole process.
- Test the scripts.
- Have a backup available.
- Run the upgrade script.
- Initiate a new backup.

Which Option To Use

Can you afford a few minutes of maintenance window per year?

- If yes, just go with pg_uprade.
- If no, you need to invest the time.

“ ”

If it hurts,
do it more often.

Martin Fowler

Thank You

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