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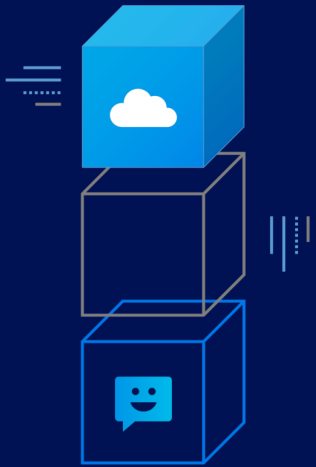
# Patroni Deployment Patterns



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SCaLE 21x, 2024-03-14

# Introduction

- High-Availability is complicated
  - False positive failovers can reduce availability
- In-Core Postgres only provides replication primitives
  - Streaming replication, asynchronous or synchronous
  - Standby cloning
  - Hot standby
  - Promoting standbys to primaries
  - Rewinding outdated former primaries to new standbys
- Automatic failover requires external support/implementations
  - Failover/switchover orchestration
  - Leader election
  - Split-brain avoidance
  - Quorum enforcement
  - Fencing of faulty nodes
  - Service failover

# Introduction

## Prior Art

- Pacemaker / Postgres Automatic Failover (PAF)
  - Uses corosync for node inter-communication
  - Relies on STONITH for split-brain avoidance
  - PAF provides improved resource agent
  - Switchovers non-trivial, timeouts difficult to tune
  - Storage switchover possible
- repmgr
  - Good solution for manual management of replication
  - `repmgrd` provides automatic failover
  - Originally not intended for this, somewhat brittle
  - Upstream commitment unclear
- pg_auto_failover
  - Relatively new project, by Citus/Microsoft (now independent)
  - Thorough state-machine, monitor node
  - Future roadmap unclear, feature-complete?

# Patroni Overview

# Patroni Overview

- Cloud-Native project/template for PostgreSQL high availability
- Based on Compose Governor (`https://github.com/compose/governor`)
- Written in Python
- MIT Licence (similar to Postgres licence)
- Project run by Zalando (`https://github.com/zalando/patroni`)
  - Current project co-maintainer works at Zalando
  - Project founder / project co-maintainer now works at Microsoft
  - Project co-founder / former co-maintainer now works at Timescale

# Patroni Overview

## Major Features

- Agent, configures instances and replication, enables switchover (Bot-Pattern)
- Uses a distributed configuration store (DCS) for leader election and split-brain avoidance
- Offers a REST-API for status, health checks and configuration changes
- Prometheus metrics
- Citus support
- Optional HAProxy integration for master/replica service endpoints
  - HTTP check REST-API on `/master` and `/replica`, respectively
- Optional vip-manager for VIP service endpoint management
  - Checks status of local node in DCS and (de-)configures VIP accordingly

# Patroni Overview

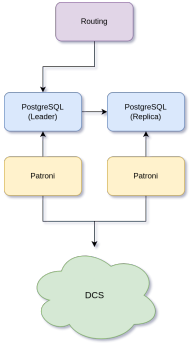
## Deployment Options

- Containers
  - Spilo, `https://github.com/zalando/spilo`
  - Crunchy Container Suite, `https://github.com/CrunchyData/crunchy-containers`
  - CYBERTEC-pg-container, `https://github.com/cybertec-postgresql/CYBERTEC-pg-container`
- Kubernetes Operators
  - Zalando Operator, `https://github.com/zalando/postgres-operator`
  - Cybertec Operator, `https://github.com/cybertec-postgresql/CYBERTEC-pg-operator`
  - Crunchy PGO Postgres Operator, `https://github.com/CrunchyData/postgres-operator`
  - Percona Operator for PostgreSQL, `https://github.com/percona/percona-postgresql-operator`
  - OnGres StackGres, `https://github.com/ongres/stackgres`
- Bare-Metal
  - Python `pip3 install patroni[etcd]`
- Linux distribution packages
  - <apt.postgresql.org>, <yum.postgresql.org>
  - `https://www.credativ.de/en/blog/howtos/integrating-patroni-into-debian/`

# Patroni Architecture

# Patroni Architecture Overview

- Distributed Configuration Store (DCS)
  - Key-value store of cluster configuration
  - Single source of truth
- Patroni Service
  - Manages local PostgreSQL node
  - REST API (monitoring/management)
- PostgreSQL
  - Streaming replication between nodes
- Routing
  - Via middleware (proxy/pooler)
  - Via virtual IP
  - Via client-based failover



# Distributed Configuration Store

- RAFT consensus algorithm
- Distributed key-value store
- Key changes done via atomic CAS (compare and swap) operations
- Automatically expiring keys (TTL, watches)
- Implementations:
  - etcd (v2/v3)
  - Consul
  - Zookeeper
  - Kubernetes API
  - PySyncObj (deprecated)

# Split-Brain Avoidance

- Realised through quorum via DCS
- Primary periodically updates the leader key in DCS with a TTL
- Replicas watch validity of leader key
- Leader race initiated when leader key expires
- Fencing of problematic nodes
  - Primary demotes itself to standby when DCS is not reachable, failsafe mode is not active and leader key expires
  - Watchdog device can shutdown nodes in case they no longer react

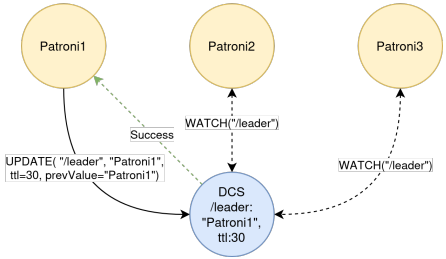
# Patroni Loops/Timeouts

- TTL
  - Time in seconds a DCS key is valid after update
- Loop Wait
  - Time in seconds between DCS updates
- Retry Timeout
  - Time in seconds that is waited (twice) in case DCS is not reachable

```
ttl: 30
loop_wait: 10
retry_timeout: 10
```

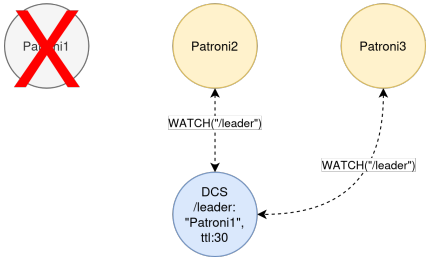
# Leader Race

## Leader Updates Leader Key



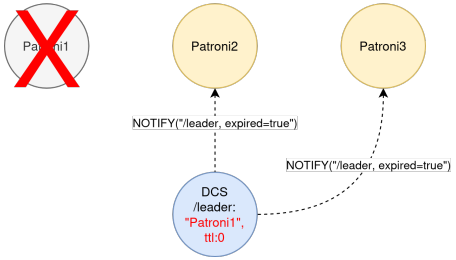
# Leader Race

## Leader Goes Down



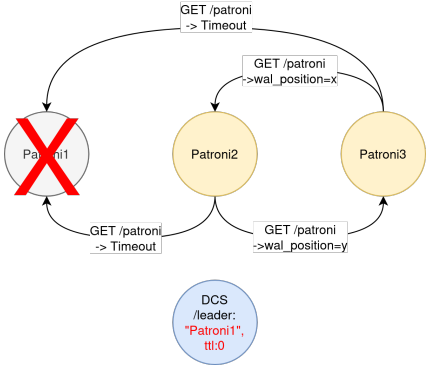
# Leader Race

## Leader Key Expires



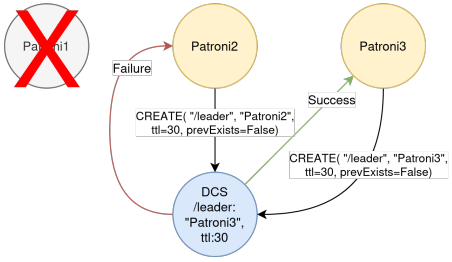
# Leader Race

## Followers Query Old Leader and Other Nodes



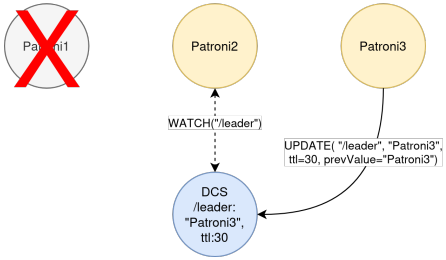
# Leader Race

## Followers Race to Acquire Leader Key



# Leader Race

## New Leader Elected



# Patroni Operation Concepts

# patronictl

- Command-Line tool to manage Patroni / Patroni clusters
- Talks to Patroni's REST API
- Can start/stop nodes, initiate switchovers, planned restarts
- Cluster configuration changes (`show-config`, `edit-config`)
- Maintenance Mode (`pause`, `resume`)

```
root@pg1:~# patronictl list
+ Cluster: pg-test (7346325357177231574) ---+----+-----------+
| Member | Host       | Role    | State     | TL | Lag in MB |
+--------+------------+---------+-----------+----+-----------+
| pg1    | 10.0.3.236 | Leader  | running   |  1 |           |
| pg2    | 10.0.3.31  | Replica | streaming |  1 |         0 |
| pg3    | 10.0.3.238 | Replica | streaming |  1 |         0 |
+--------+------------+---------+-----------+----+-----------+
```

# Client Failover

- If a switch/failover occurs, clients need to connect to new leader
- HAProxy
  - Can use REST API http response codes for health checks
  - `https://www.credativ.de/en/blog/postgresql/moodle-postgresql-load-balancing-with-haproxy-and-patroni/`
- vip-manager
  - Polls DCS for state of local node and (de)configures VIP
  - Supports only etcd and consul
  - `vip-manager-2.x` supports etcd V3 API (`etcd3`), `vip-manager-1.x` supports etcd V2 API (`etcd`)
- Client-based failover
  - libpq `host=pg1,pg2,pg3 target_session_attrs=primary`
  - pgJDBC `jdbc:postgresql://pg1,pg2,pg3?targetServerType=primary`

# Configuration Tags

Tags determine behaviour of individual nodes

- `nofailover: true/false` - failover/switchover is disabled, node is never promoted to leader
- `noloadbalance: true/false` - `/replica` endpoint always returns 503
- `clonefrom: true/false` - node is used for cloning of new standbys in favor of cluster leader
- `nosync: true/false` - node never becomes a synchronous standby
- `replicatefrom: node_name` - node to (cascadingly) replicate from

# Replication Modes

- Patroni uses asynchronous physical replication by default
- Synchronous replication is possible
- Two different synchronous replication modes
  - `synchronous_mode: true`
  - `synchronous_mode_strict: true`
  - `synchronous_node_count: n`
- Cascading replication possible via `replicatefrom` tag
- Logical replication / change data capture including switch/failover support
  - Logical replication slots need to be registered with Patroni
  - Slot management and replication position advancement
  - Integration with `pg_failover_slots` pending

# Replica Creation Options

- Default replica creation via `pg_basebackup`
- Other replica creation methods can be specified via `create_replica_methods`
- Allows replica creation from backups

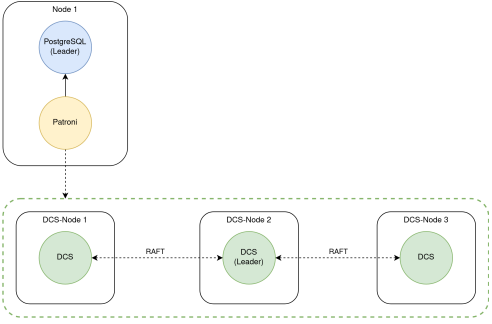
```
create_replica_methods:
- pgbackrest
pgbackrest:
  command: /usr/bin/pgbackrest --stanza={{ stanza }} --delta restore
  keep_data: true
  no_params: true
recovery_conf:
  restore_command: /usr/bin/pgbackrest --stanza={{ stanza }} archive-get %f %p
```

# Deployment Topologies

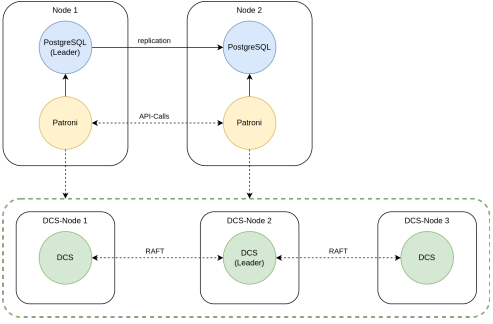
# Deployment Topologies

- 1-N Patroni/Postgres nodes
  - 1-node Patroni setups to leverage integrated configuration/administration
  - 2-node Patroni setups minimal requirement for high-availability
  - 3-node Patroni setups typical
- M>2 DCS nodes required to avoid single point of failure (SPOF)
- Number of DCS nodes should be odd (M=3,5,7…)
- DCS Deployment topologies:
  - DCS operated on same hosts as Patroni and PostgreSQL
  - DCS operated as stand-alone Cluster
  - DCS locally with PySyncObj RAFT (deprecated)

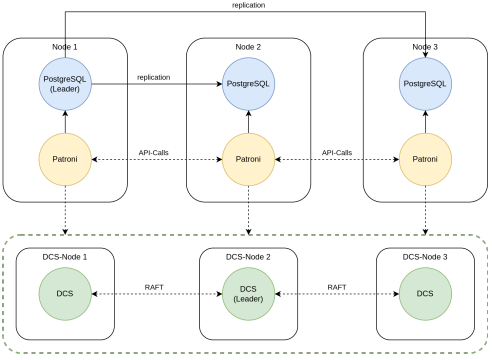
# 1 Node, Standalone DCS



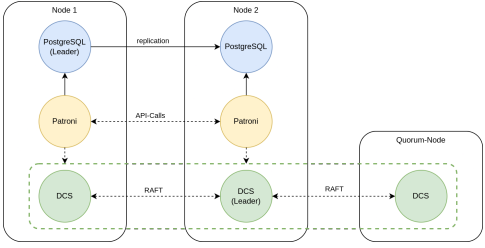
# 2 Nodes, Standalone DCS



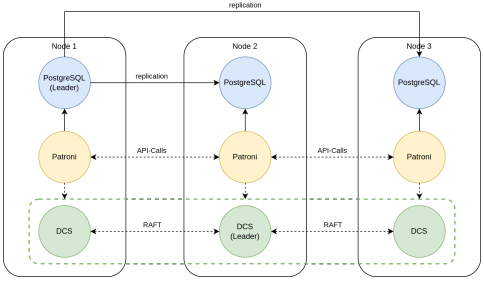
# 3 Nodes, Standalone DCS



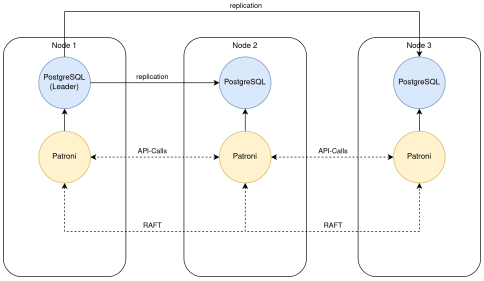
# 2 Nodes + Quorum-Node, Local DCS



# 3 Nodes, Local DCS



# 3 Nodes, Internal DCS



# Multi-Datacenter Deployments

# Multi-Datacenter Deployments

- Multi-region, multi-datacenter (DC), multi-availability zone (AZ)
- Single Patroni cluster stretched over multiple DCs
  - Automatic failover and synchronous replication possible
- Separate Patroni clusters in separate DCs
  - Manual failover and asynchronous replication
- `https://patroni.readthedocs.io/en/latest/ha_multi_dc.html`

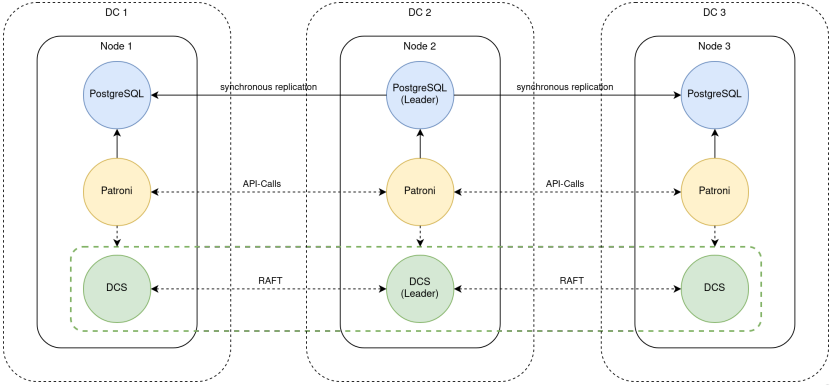
# Multi-Datacenter Deployments

## Single Patroni Cluster

- Stretching a DCS cluster over multiple DCs is discouraged
  - Depending on distance, latency will be a problem
- If multi-DC automatic failover is a requirement, three DCs are needed
- At least one DCS node per DC, one DC can be witness (no Patroni instance)

# Multi-Datacenter Deployments

## Single Patroni Cluster



# Multi-Datacenter Deployments

## Multiple Patroni Clusters

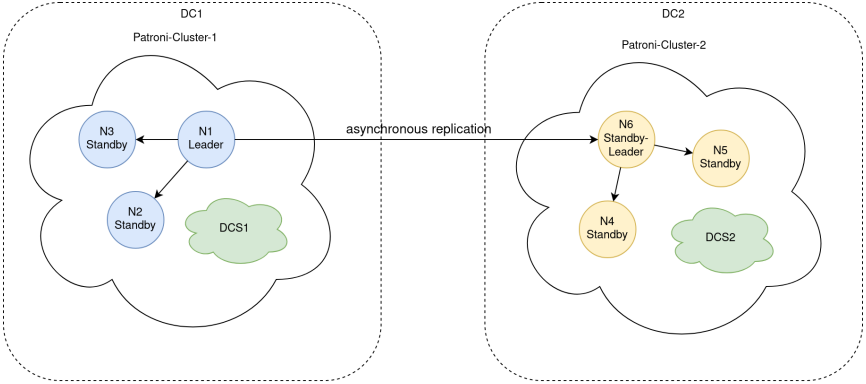
- Patroni provides Standby-Cluster functionality
  - Secondary DC has own DCS cluster
  - Standby-Cluster leader replicates from primary cluster

```
standby_cluster:
  host: dc1-1,dc1-2,dc1-3 # or VIP/service IP
  primary_slot_name: dc2
slots:
  dc1:
    type: physical
  dc2:
    type: physical
```

- Failover manually by removing `standby_cluster` section from config
- Former primary cluster needs to be fenced

# Multi-Datacenter Deployments

## Multiple Patroni Clusters



# DCS Caveats and Considerations

# DCS Caveats and Considerations

- Up until 2.x, Patroni was reliant on DCS being available
- If DCS is not reachable (down, or doing leader election)
  - Patroni assumes network partition
  - Leader is demoted to avoid split-brain

```
2024-02-18 09:59:18,301 ERROR: Request to server http://10.0.3.184:2379 failed:
ReadTimeoutError("HTTPConnectionPool(host='10.0.3.184', port=2379): Read timed out. (r>
[...]
2024-02-18 09:59:24,971 ERROR: Error communicating with DCS
2024-02-18 09:59:24,972 INFO: demoting self because DCS is not accessible and I was a leader
2024-02-18 09:59:24,972 INFO: Demoting self (offline)
```

- etcd in particular requires strict network / I/O latency guarantees
  - Multi-DC latencies usually too high for defaults
  - I/O operations slower than 1s can lead to leader election

# DCS Failsafe Mode

- Patroni 3.0 introduces DCS failsafe mode
- Leader maintains `/failsafe` DCS key, contains list of cluster members
- In case DCS is not available
  - Leader tries to contact all followers
  - In case all followers reply, cluster carries on
  - Otherwise, leader demotes itself
- Configuration: `failsafe_mode: true`
- `https://patroni.readthedocs.io/en/latest/dcs_failsafe_mode.html`

```
2024-02-18 10:18:44,450 ERROR: Error communicating with DCS
2024-02-18 10:18:44,461 INFO: Got response from pg3 http://10.0.3.238:8008/patroni: Accepted
2024-02-18 10:18:44,461 INFO: Got response from pg2 http://10.0.3.31:8008/patroni: Accepted
2024-02-18 10:18:44,463 INFO: continue to run as a leader because failsafe mode is enabled and
                              all members are accessible
```

# etcd Considerations

- etcd is sensitive to resource starvation if run locally on Postgres nodes
  - Dedicated network interface advised
  - Dedicated storage device advised
- etcd can use up the default WAL space if used with Patroni
  - Set `ETCD_AUTO_COMPACTION_RETENTION` environment variable / `--auto-compaction-retention` option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