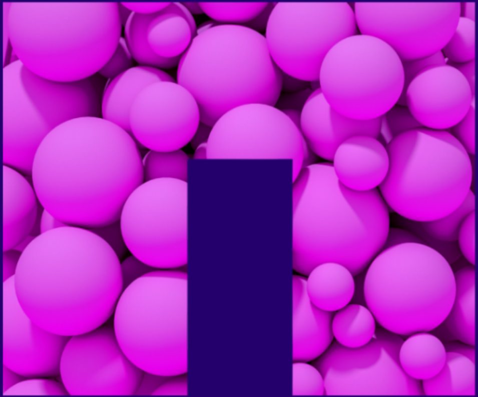
NetApp

PATRONI DEPLOYMENT PATTERNS



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NetApp Open Source Services

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Patroni Overview

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

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
- REST-API for status, health checks and configuration changes, `patronictl` CLI
- Multi-DC deployments
- Flexible replication modes - physical, logical, cascading, synchronous, quorum commit, log shipping
- Prometheus metrics
- Citus support
- Integration with pgBackRest/Barman/WAL-E backup solutions
- Optional HAProxy integration for master/replica service endpoints
- Optional `vip-manager` integration for VIP service endpoint management

Patroni Overview

History

- 2015/03: First Compose Governor commit
- 2015/04: First Zalando commit
- 2015/07: Zalando forks Governor as Patroni
- 2016/03: Last real Compose Governor commit
- 2016/07: Patroni 1.0 release
  - Dynamic DCS configuration
- 2020/09: Patroni 2.0 release
  - etcd V3 API, pure RAFT
- 2021/07: Patroni 2.1 release
  - Failover logical slots

Patroni Overview

History

- 2023/01: Patroni 3.0 release
  - Failsafe mode
  - Citus support
- 2023/08: Patroni 3.1 release
- 2023/10: Patroni 3.2 release
  - Failover priority
- 2023/08: Patroni 3.3 release
  - Log-shipping standbys
- 2024/06: Patroni project moved to its own organization at `https://github.com/patroni/patroni`
- 2024/08: Patroni 4.0 Release
  - Quorum-based failover
  - Removal of `master` term in favor of `primary` or `leader`

Patroni Overview

History

- 2024/10: Still no logo

Patroni Overview

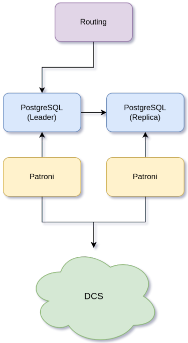
Deployment Options

- 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 PG 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
  - `https://apt.postgresql.org`, `https://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

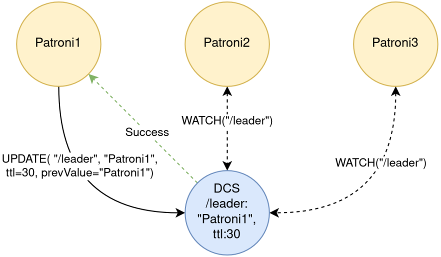
- TTL
  - Time in seconds a DCS key is valid after update
- Loop Wait
  - Time in seconds between DCS updates
- Retry Timeout
  - Time in seconds that is waited (twice) in case DCS is not reachable

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

- Minimal values: `ttl=20, loop_wait=2, retry_timeout=3`
- `ttl >= loop_wait + 2 * retry_timeout`

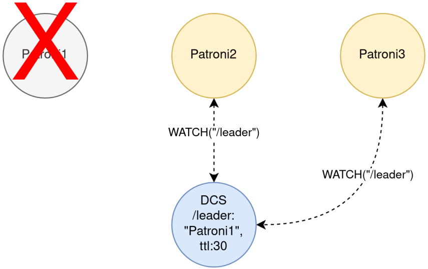
Leader Race

Leader Updates Leader Key



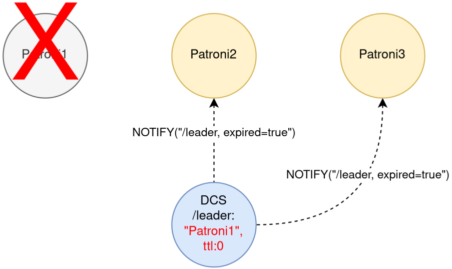
Leader Race

Leader Goes Down



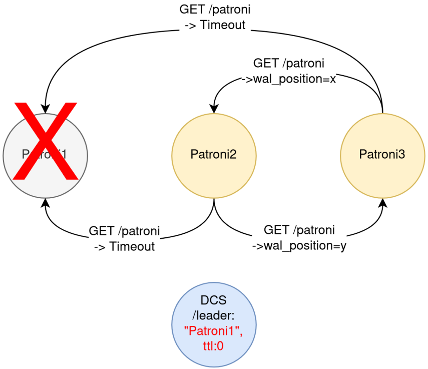
Leader Race

Leader Key Expires


Patroni1
Patroni2
Patroni3
NOTIFY("/leader, expired=true")
NOTIFY("/leader, expired=true")
DCS
/leader:
"Patroni1",
ttl:0

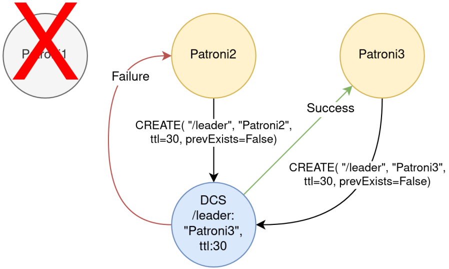
Leader Race

Followers Query Old Leader and Other Nodes



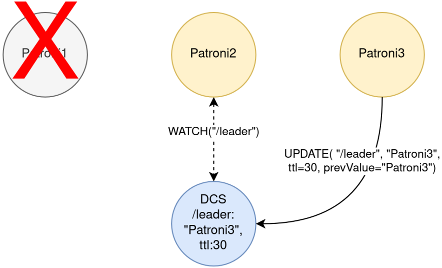
Leader Race

Followers Race to Acquire Leader Key


Patroni1
Patroni2
Patroni3
Failure
CREATE("/leader", "Patroni2", ttl=30, prevExists=False)
Success
CREATE("/leader", "Patroni3", ttl=30, prevExists=False)
DCS /leader: "Patroni3", ttl:30

Leader Race

New Leader Elected

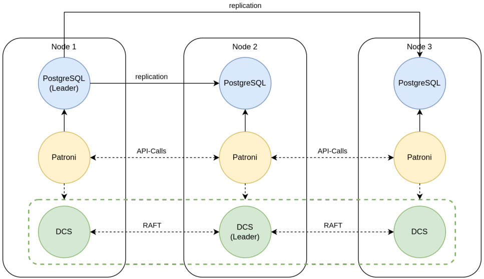

Patroni1
Patroni2
Patroni3
WATCH("/leader")
UPDATE("/leader", "Patroni3", ttl=30, prevValue="Patroni3")
DCS /leader: "Patroni3", ttl:30

DEPLOYMENT TOPOLOGIES

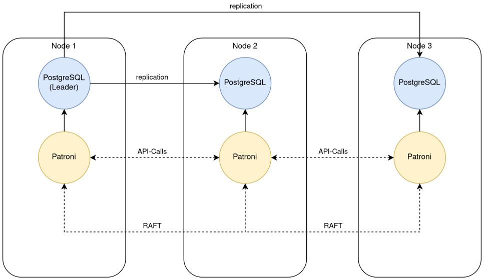
Deployment Topologies

- 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)

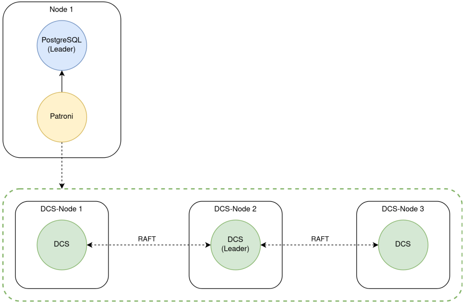
3 Nodes, Local DCS



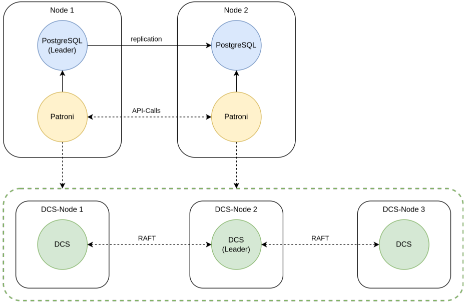
3 Nodes, Internal DCS



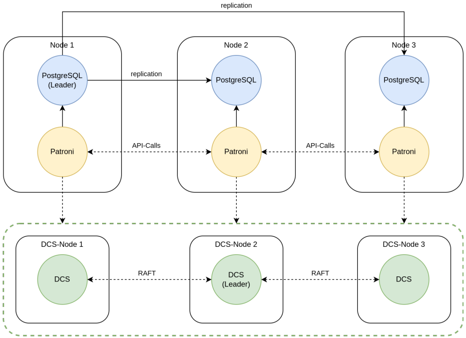
1 Node, Standalone DCS



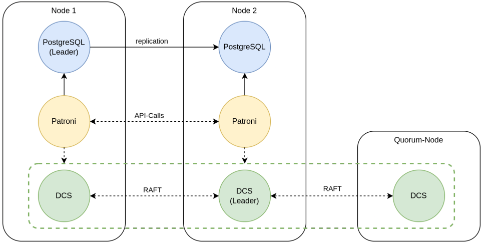
2 Nodes, Standalone DCS



3 Nodes, Standalone DCS



2 Nodes + Quorum-Node, Local DCS



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
- `failover_priority: int` - prefer node during leader election (if otherwise eligible)
- `nostream: true/false` - node uses archive recovery instead of streaming replication

Replication Modes

- Patroni uses asynchronous physical replication by default
- Synchronous replication is possible
- Three different synchronous replication modes
  - `synchronous_mode: true`
  - `synchronous_mode_strict: true`
  - `synchronous_mode: quorum`
- Parameter `synchronous_node_count` determines number of sync standbys
  - `synchronous_node_count: 2 -> 2 (pg2,pg3)`
- In quorum commit mode all eligible standbys are sync standbys
  - `synchronous_node_count` determines number of standbys that need to ack
  - `synchronous_node_count: 1 -> ANY 1 (pg2,pg3)`

Replication Slot Management

- Physical slots automatically created for Patroni nodes unless `use_slots: false` is set
- Further slots can be configured under `slots:` and `ignore_slots:`

```
slots:
  pg1_l1:
    type: logical
    plugin: test_decoding
  dc2:
    type: physical
ignore_slots:
  - name: pg1_l2
    type: logical
```

- Physical slots for cluster nodes are retained for `member_slots_ttl` (default 30min) after node goes away
- Logical replication / change data capture 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
```

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`

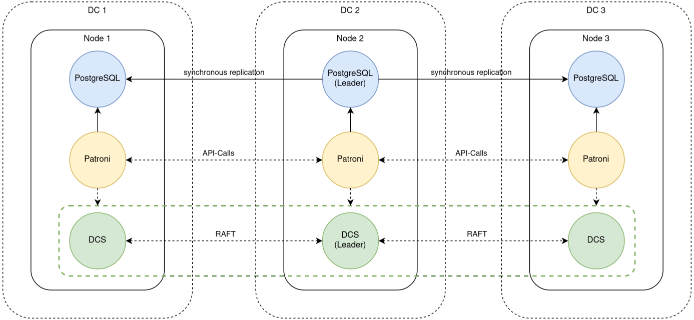
Multi-Datacenter Deployments

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

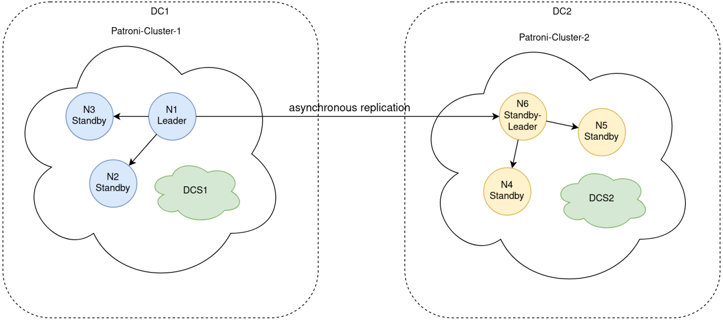
- Patroni provides Standby-Cluster functionality
  - Secondary DC has own DCS cluster
  - Standby-Cluster leader replicates from primary cluster

```
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 configuration
- 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

THANK YOU

NetApp