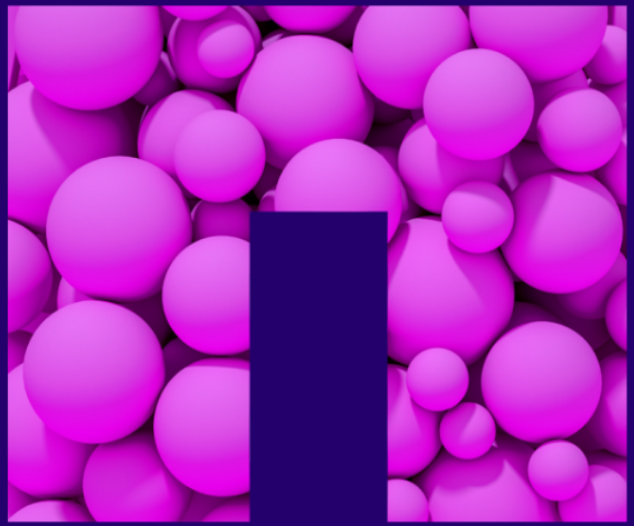
NetApp

PATRONI DEPLOYMENT PATTERNS



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NetApp Open Source Services
PGConf.EU 2024

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

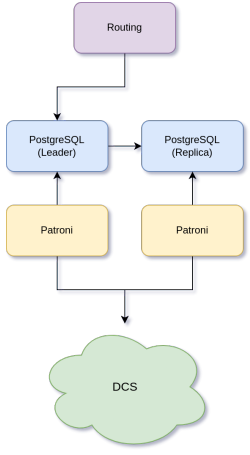
Deployment Options

- 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

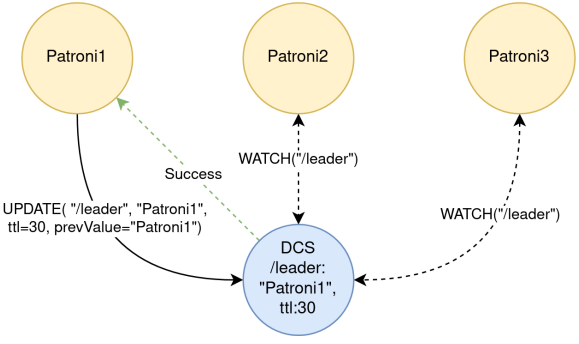
- TTL
  - Time in seconds a DCS key is valid after update
- Loop Wait
  - Time in seconds between DCS updates
- Retry Timeout
  - Time in seconds that is waited (twice) in case DCS is not reachable

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

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

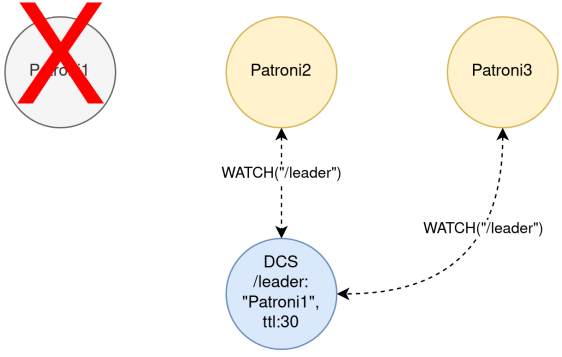
Leader Race

Leader Updates Leader Key



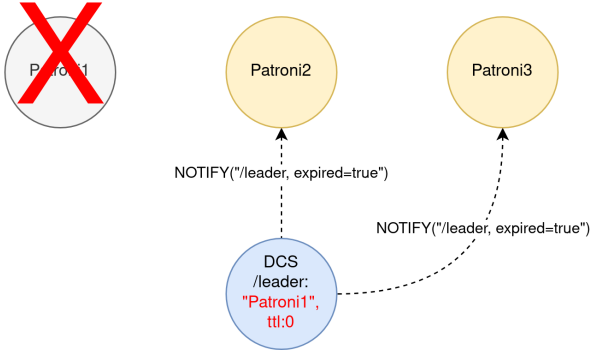
Leader Race

Leader Goes Down



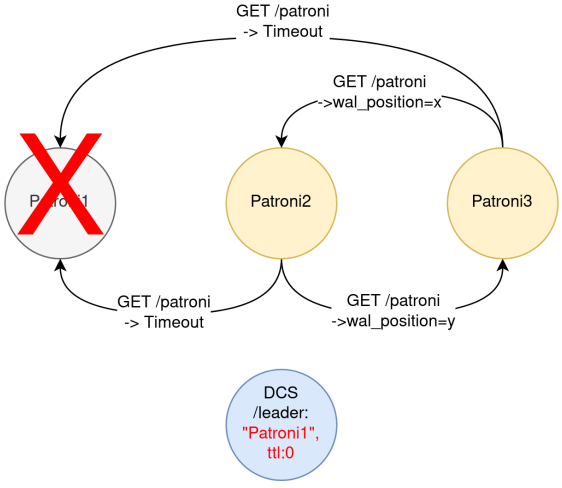
Leader Race

Leader Key Expires



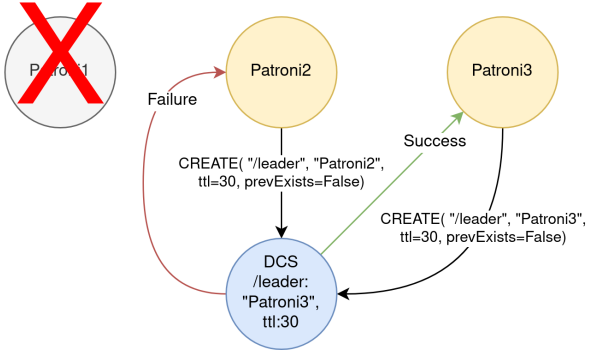
Leader Race

Followers Query Old Leader and Other Nodes



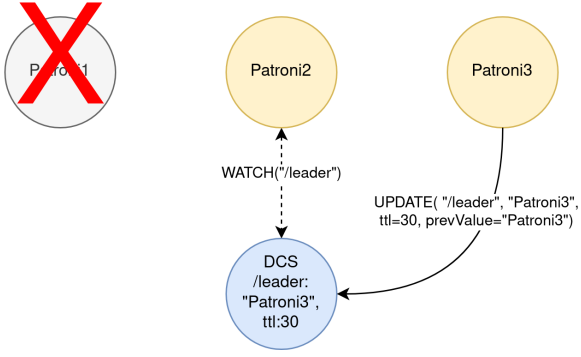
Leader Race

Followers Race to Acquire Leader Key



Leader Race

New Leader Elected

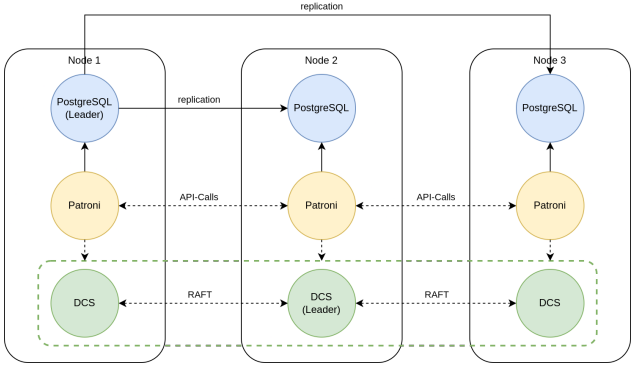


DEPLOYMENT TOPOLOGIES

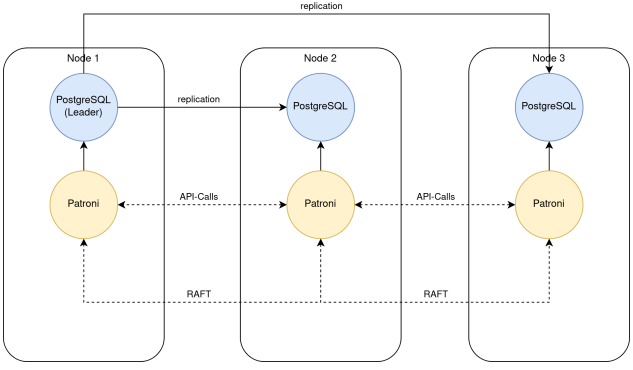
Deployment Topologies

- 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)

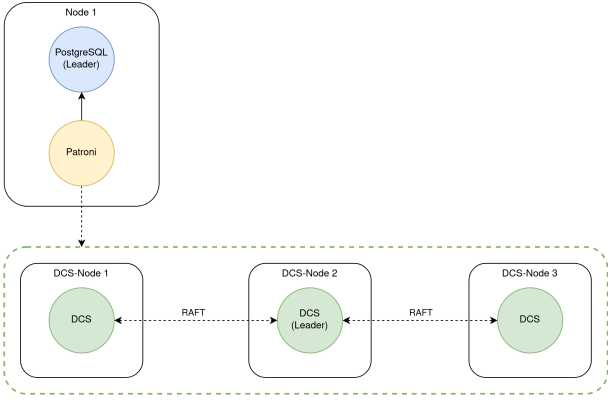
3 Nodes, Local DCS



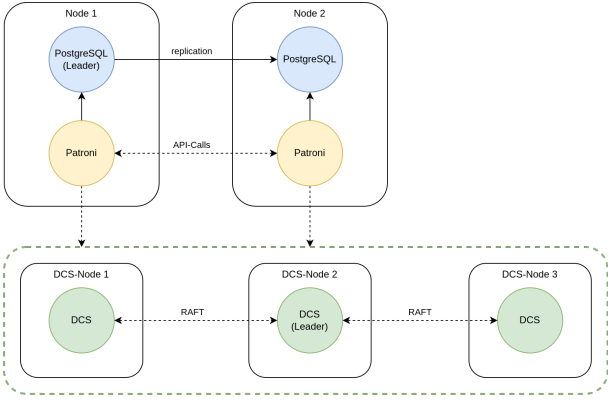
3 Nodes, Internal DCS



1 Node, Standalone DCS

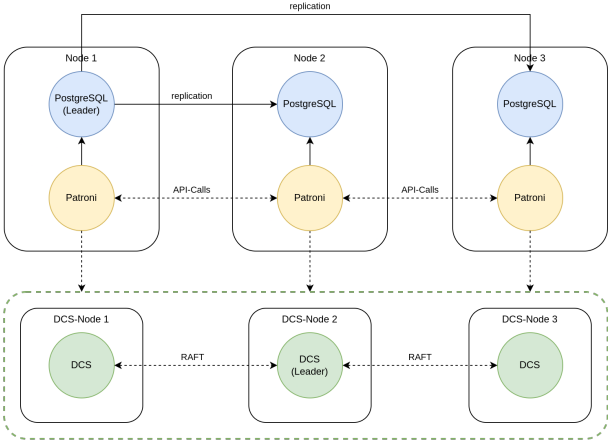


2 Nodes, Standalone DCS

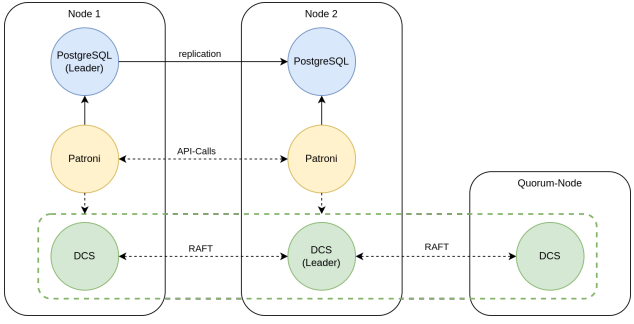


3 Nodes, Standalone DCS

"normales Deployment"



2 Nodes + Quorum-Node, Local DCS



PATRONI OPERATION CONCEPTS

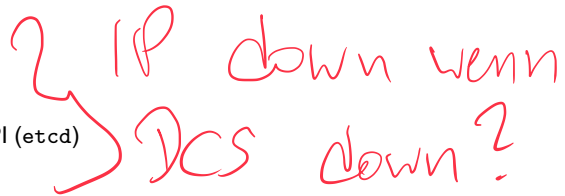
patronictl

- 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`

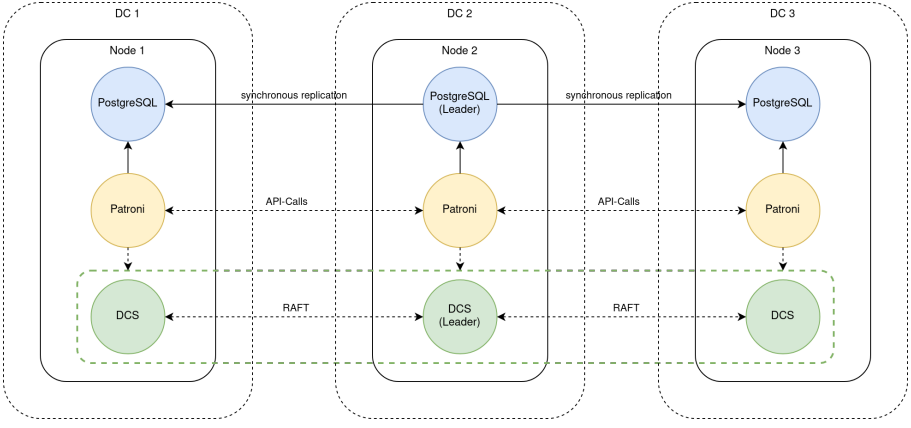
Multi-Datacenter Deployments

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

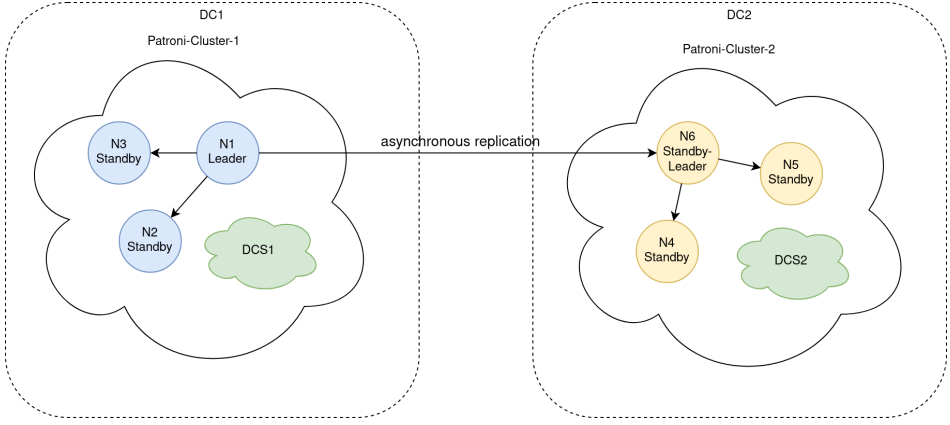
- Patroni provides Standby-Cluster functionality
  - Secondary DC has own DCS cluster
  - Standby-Cluster leader replicates from primary cluster

```
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

