Master Thesis Defence: High Availability in Lifecycle Management of Cloud-Native Network Functions

A Near-Zero Downtime Database Version Change Prototype

Ziheng Zhang [1,2] ***Examiner*: Mihhail Matskin** [1]

***Supervisor*: Aleksandar Igic** [2] **Natalino Romio** [2] **Amirhossein Layegh Kheirabadi** [1]

[1]KTH Royal Institute of Technology, [2]Ericsson AB

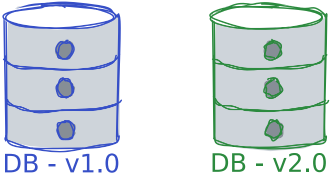
Overview

1. Backgound
2. Deployment Strategy
3. Detailed Implementation
4. Demonstration
5. Conclusion
6. Future Work

Background (1/4)

Our Goal:

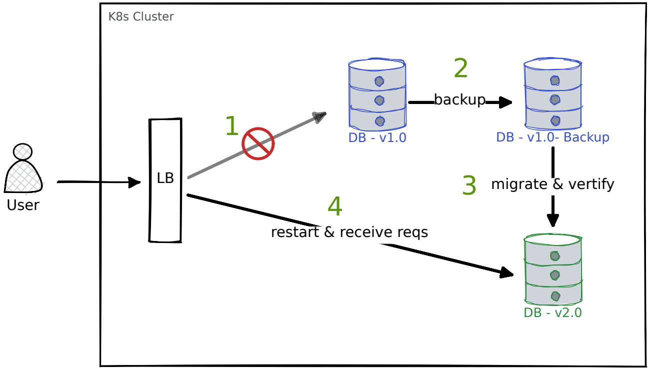
- Perform database version change
- Minimise the downtime
- Automate the procedure to reduce manual intervention
- Transparent to the clients



Background (2/4)

Conventional strategy:

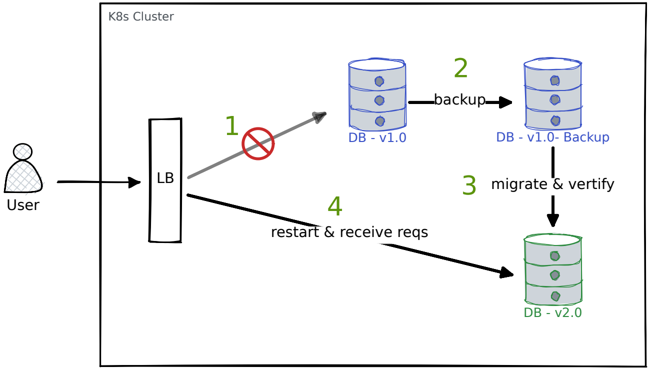
- Suspend the service
- Suspend all user requests
- Backup and migrate
- Verify data consistency
- Restart the service
- Receive requests



Background (2/4)

Conventional strategy:

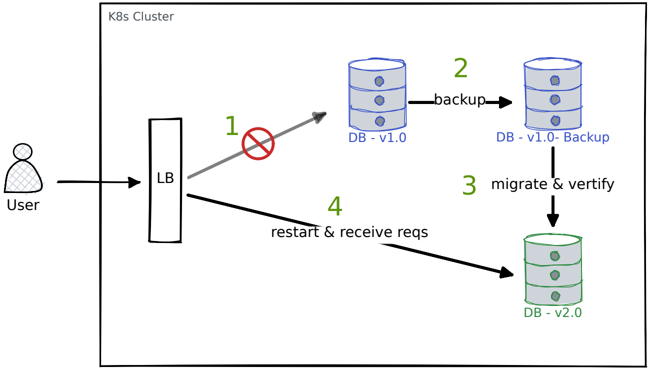
- Suspend the service
- Suspend all user requests
- Backup and migrate
- Verify data consistency
- Restart the service
- Receive requests



Background (2/4)

Conventional strategy:

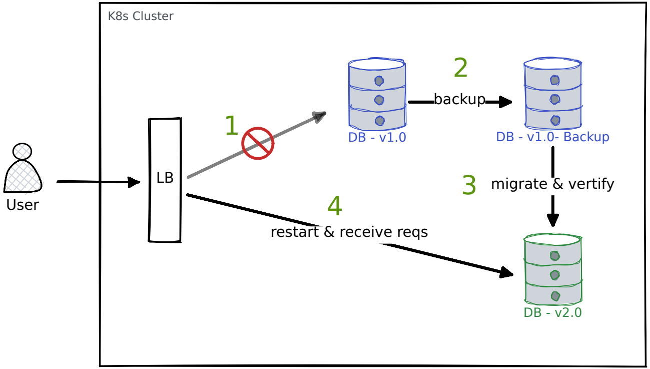
- Suspend the service
- Suspend all user requests
- Backup and migrate
- Verify data consistency
- Restart the service
- Receive requests



Background (2/4)

Conventional strategy:

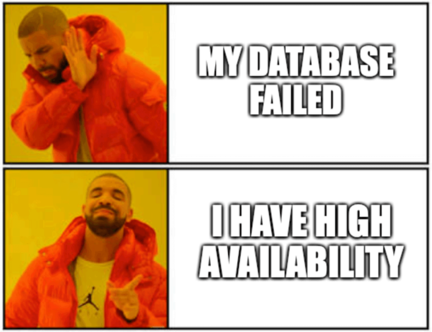
- Suspend the service
- Suspend all user requests
- Backup and migrate
- Verify data consistency
- Restart the service
- Receive requests



Background (3/4)

Limitations of Conventional Strategy:

- Require downtime
- Significant downtime affects high availability
- **Five-nines goal** $(99.999\%$ high availability)
- Too many human interventions



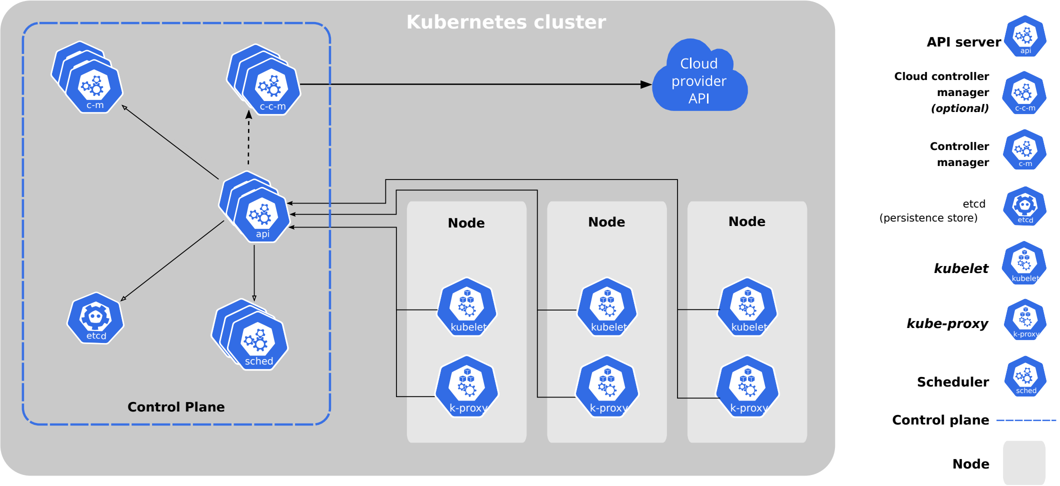
Background (4/4)

Kubernetes (K8s) & K8s Operator:

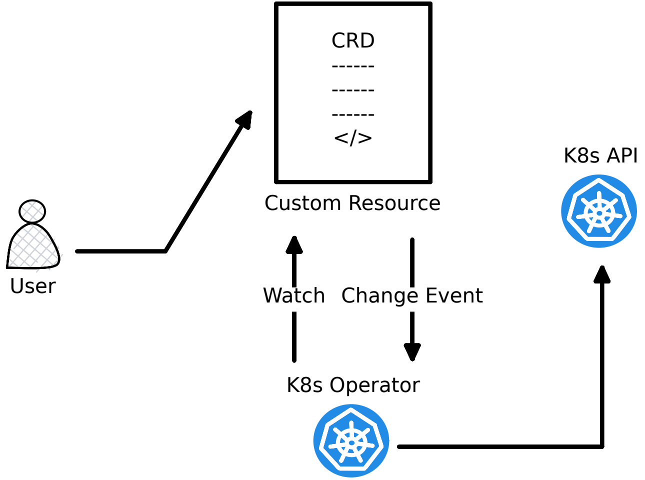
- Extends Kubernetes API for application-specific management.
- Combines custom resources (desired state) and custom controllers (logic).
- Automates deployment, scaling, and management of stateful applications.
- Encapsulates operational knowledge and best practices.
- Reduces manual intervention and enhances reliability.

More details to the following two slides.

Background (4/4)

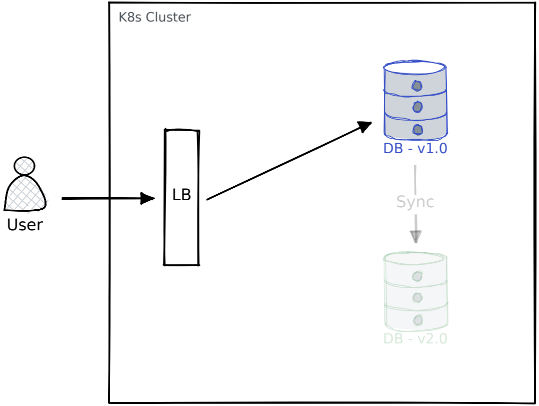


Background (4/4)



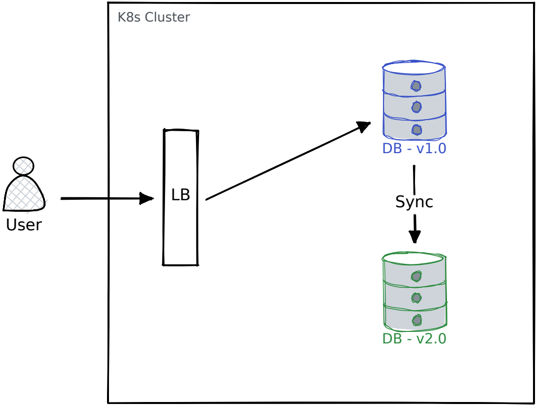
Blue-Green Deployment (1/4)

- The initial state of the cluster. Only a *Master* node.



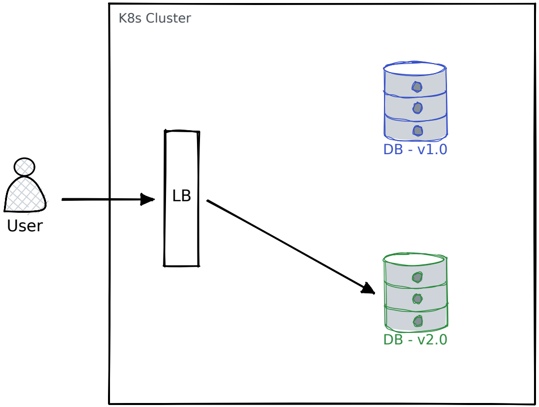
Blue-Green Deployment (2/4)

- Create the DB with the new version (the *Follower*) and start the sync.



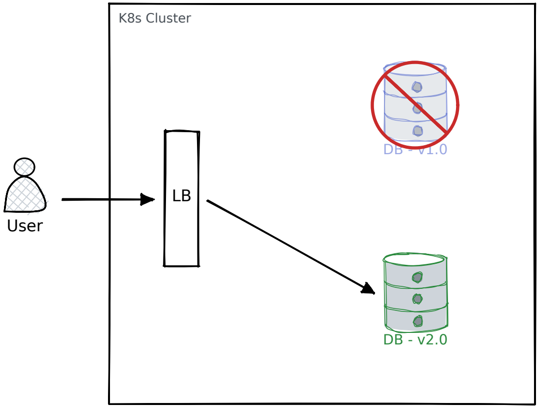
Blue-Green Deployment (3/4)

- Change the data flow from the *Master* to the *Follower*.



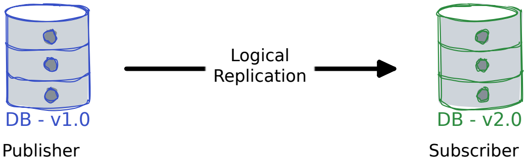
Blue-Green Deployment (4/4)

- Delete *the master* DB (Optional).



How To Achieve Synchronization? (1/3)

- Logical Replication.



How To Achieve Synchronization? (2/3)

In the *Master* node,

- Configure the PostgreSQL settings
  - $ set `wal_level=logical` in `postgresql.conf`
- Create a publication
  - `$ create publication [pub_name] for all tables`
- Export the schema.
  - `$ pg_dump -U [usr_name] -t [table_name] [db_name] > [file.sql]`

How To Achieve Synchronization? (2/3)

In the *Master* node,

- Configure the PostgreSQL settings
  - $ set `wal_level=logical` in `postgresql.conf`
- Create a publication
  - `$ create publication [pub_name] for all tables`
- Export the schema.
  - `$ pg_dump -U [usr_name] -t [table_name] [db_name] > [file.sql]`

How To Achieve Synchronization? (2/3)

In the *Master* node,

- Configure the PostgreSQL settings
  - $ set `wal_level=logical` in `postgresql.conf`
- Create a publication
  - $ `create publication [pub_name] for all tables`
- Export the schema.
  - $ `pg_dump -U [usr_name] -t [table_name] [db_name] > [file.sql]`

How To Achieve Synchronization? (3/3)

In the *Follower* node,

- Sync the schema in the *Master* node.

```
$ psql -U [usr_name] -h [Master_IP] -p [port] \
  -d [db_name] -f [file.sql]
```

- Create the subscription.

```
$ create subscription [sub_name] connection \
  'dbname=[db_name] host=[Master_IP] user=[usr_name] \
  password=[pwd] port=[port]' publication [pub_name]
```

How To Achieve Synchronization? (3/3)

In the *Follower* node,

- Sync the schema in the *Master* node.

```
$ psql -U [usr_name] -h [Master_IP] -p [port] \
  -d [db_name] -f [file.sql]
```

- Create the subscription.

```
$ create subscription [sub_name] connection \
  'dbname=[db_name] host=[Master_IP] user=[usr_name] \
  password=[pwd] port=[port]' publication [pub_name]
```

When will Synchronization end? (1/2)

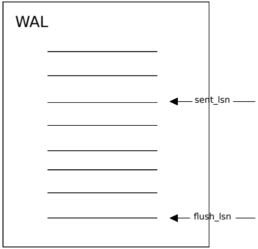
In PostgreSQL, `pg_stat_replication` view provides the replication info.

- `sent_lsn`

  represents the latest WAL position sent by the *Master* to the *Follower*.
- `pg_current_wal_flush_lsn`

  returns the latest WAL position that has been flushed to disk on the *Master* node.
- `pg_wal_lsn_diff(lsn1, lsn2)`

  returns the byte difference between two WAL positions.



When will Synchronization end? (1/2)

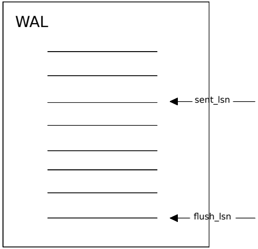
In PostgreSQL, `pg_stat_replication` view provides the replication info.

- `sent_lsn`

  represents the latest WAL position sent by the *Master* to the *Follower*.
- `pg_current_wal_flush_lsn`

  returns the latest WAL position that has been flushed to disk on the *Master* node.
- `pg_wal_lsn_diff(lsn1, lsn2)`

  returns the byte difference between two WAL positions.



When will Synchronization end? (1/2)

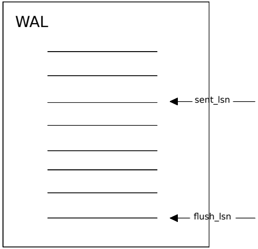
In PostgreSQL, `pg_stat_replication` view provides the replication info.

- `sent_lsn`

  represents the latest WAL position sent by the *Master* to the *Follower*.
- `pg_current_wal_flush_lsn`

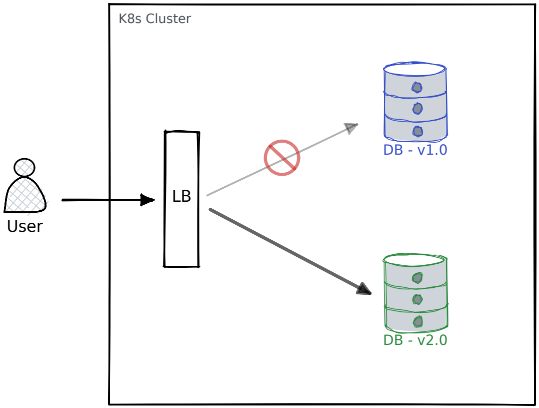
  returns the latest WAL position that has been flushed to disk on the *Master* node.
- `pg_wal_lsn_diff(lsn1, lsn2)`

  returns the byte difference between two WAL positions.



When will Synchronization end? (2/2)

When Synchronization is finished, change the dataflow from the *Master* to the *Follower*.



Custom Resource Definition (CRD) (1/3)

What is Custom Resource Definition (CRD)?

- Extends the Kubernetes API with custom resources.
- Allows for application-specific customization.
- Simplifies the integration of custom logic.
- Enables creation, modification, and management of custom objects.
- Eliminates the need for direct changes to the core Kubernetes codebase.

Custom Resource Definition (CRD) (2/3)

Service in K8s:

```
apiVersion: v1
kind: Service
metadata:
  name: postgres-master
spec:
  selector:
    app: postgres-master
  ports:
    - name: postgres-master
    port: 5432
    targetPort: 5432
  type: LoadBalancer
```

CRD in K8s:

```
apiVersion: pgupgrade.zzh.domain/v1
kind: PgUpgrade
metadata:
  ...
spec:
  # my desired state in cluster
  image: postgres:15
  dbname: mydatabase
  subname: zzhsub1
  pubname: zzhpub1
  olddbhost: "10.244.1.76"
  ...
```

Custom Resource Definition (CRD) (3/3)

```
- image:  postgres:15 # version of db
- dbname:  mydatabase # db name that we need to sync with
- subname:  zzhsub1   # subscription name
- pubname:  zzhpub1   # publication name
- olddbhost:  "10.244.1.76" # IP address of the Master node
- olddbport:  "5432" # port of the Master node
- finishsync:  false # whether the sync is finished
- killdeployments:  pg-delete-test # delete the master node
```

Custom Resource Definition (CRD) (3/3)

```
- image:  postgres:15 # version of db
- dbname:  mydatabase # db name that we need to sync with
- subname:  zzhsub1   # subscription name
- pubname:  zzhpub1   # publication name
- olddbhost:  "10.244.1.76" # IP address of the Master node
- olddbport:  "5432" # port of the Master node
- finishsync:  false # whether the sync is finished
- killdeployments:  pg-delete-test # delete the master node
```

Custom Resource Definition (CRD) (3/3)

```
- image:  postgres:15 # version of db
- dbname:  mydatabase # db name that we need to sync with
- subname:  zzhsub1   # subscription name
- pubname:  zzhpub1   # publication name
- olddbhost:  "10.244.1.76" # IP address of the Master node
- olddbport:  "5432" # port of the Master node
- finishsync:  false # whether the sync is finished
- killdeployments:  pg-delete-test # delete the master node
```

Custom Resource Definition (CRD) (3/3)

```
- image:  postgres:15 # version of db
- dbname:  mydatabase # db name that we need to sync with
- subname:  zzhsub1   # subscription name
- pubname:  zzhpub1   # publication name
- olddbhost:  "10.244.1.76" # IP address of the Master node
- olddbport:  "5432" # port of the Master node
- finishsync:  false # whether the sync is finished
- killdeployments:  pg-delete-test # delete the master node
```

Custom Resource Definition (CRD) (3/3)

```
- image: postgres:15 # version of db
- dbname: mydatabase # db name that we need to sync with
- subname: zzhsub1   # subscription name
- pubname: zzhpub1   # publication name
- olddbhost: "10.244.1.76" # IP address of the Master node
- olddbport: "5432" # port of the Master node
- finishsync: false # whether the sync is finished
- killdeployments: pg-delete-test # delete the master node
```

Implementation

Detailed implementation can be found here:

- zzheng2020/Master-Thesis
- zzheng2020/pgoperator

Demonstration

Demo Video

Conclusion

In this project, we

- Successfully implemented a prototype for near-zero downtime database version upgrades.
- Requires only one database restart (if the configuration is pre-set, no restart is needed).
- Automates the process, reducing manual intervention.
- Achieves high availability for the database system in the Kubernetes cluster.

Future Work

Future work could include:

- Integrating it into PostgreSQL Operator.
- Enhancing automation and error handling.
- Developing a user-friendly interface.
- Evaluating security and compliance.

The End