CloudNativePG 101

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<3 OSS

<3 Coding
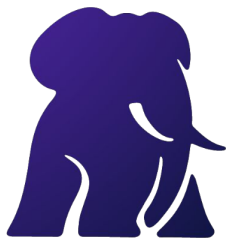
🎵 Playing sax

<3 Paola and Maria

Survey

CloudNativePG

- **CloudNativePG** is a CNCF Sandbox project. It is an open-source operator designed to manage **PostgreSQL** workloads on any supported **Kubernetes** cluster

- It defines a new K8s resource called **Cluster**, representing a PostgreSQL cluster made up of a single primary and an optional number of replicas

Kubernetes (K8s)

Kubernetes

- **Orchestrator** (runs and manages containerized applications on a cluster)

- Higher-level abstractions of workloads

- **Declarative** over imperative.

  Via controller pattern, Kubernetes aligns the current state (of any applied resource) to the desired one

Kubernetes - Sample object

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: nginx-deployment
spec:
  selector:
    matchLabels:
      app: nginx
  replicas: 2 # tells deployment to run 2 pods matching the template
  template:
    metadata:
      labels:
        app: nginx
    spec:
      containers:
      - name: nginx
        image: nginx:1.14.2
        ports:
        - containerPort: 80
```
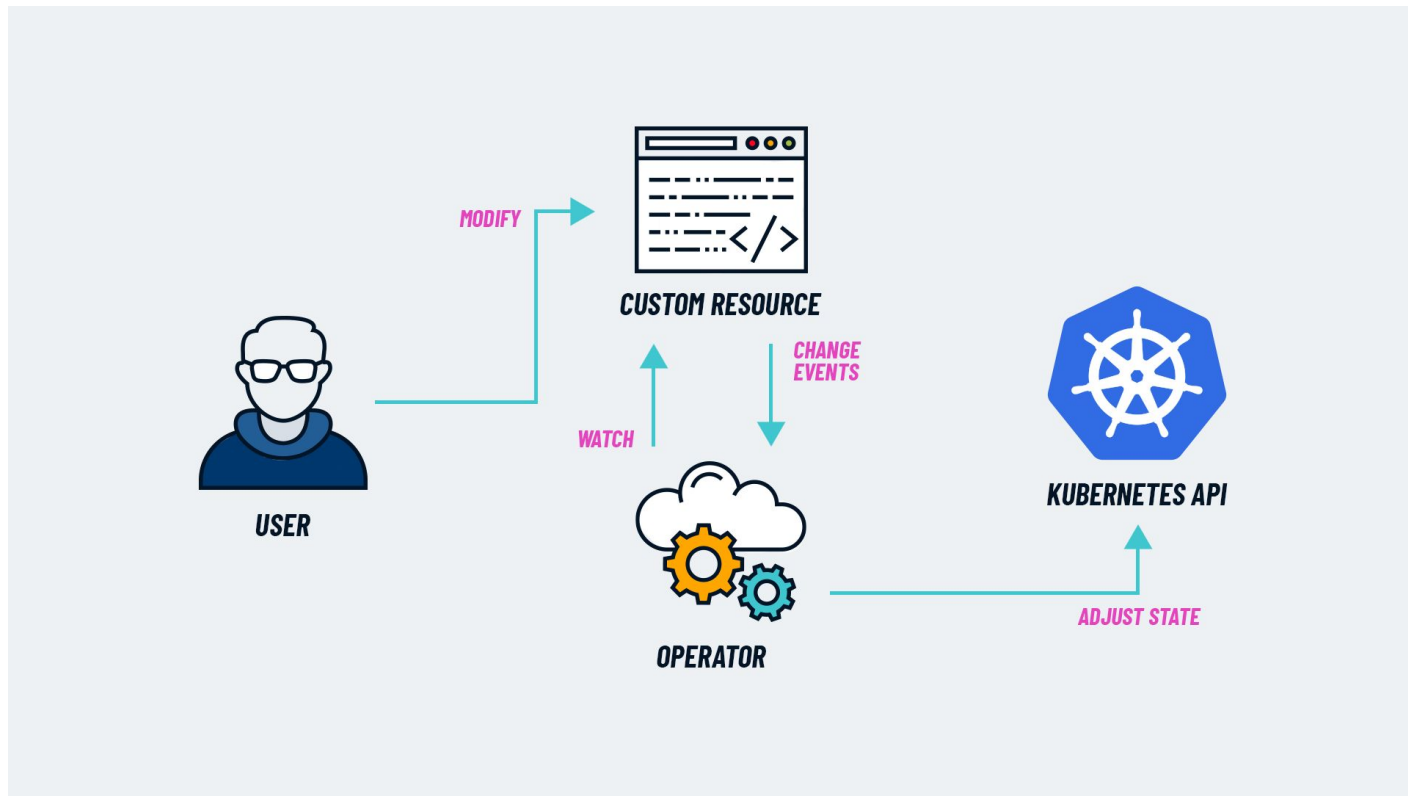
Cloud Native Applications

- Small loosely coupled services (microservices)

- Introduce a set of principles and a culture shift paradigm for **devops** and **CI/CD** approach
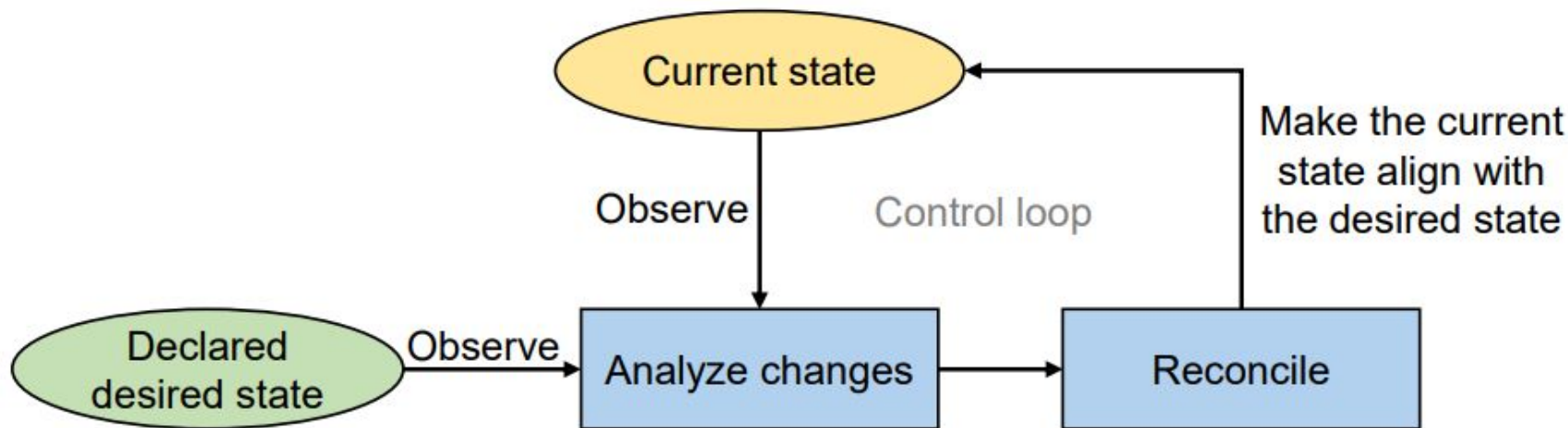
Kubernetes operators

Kubernetes Operator
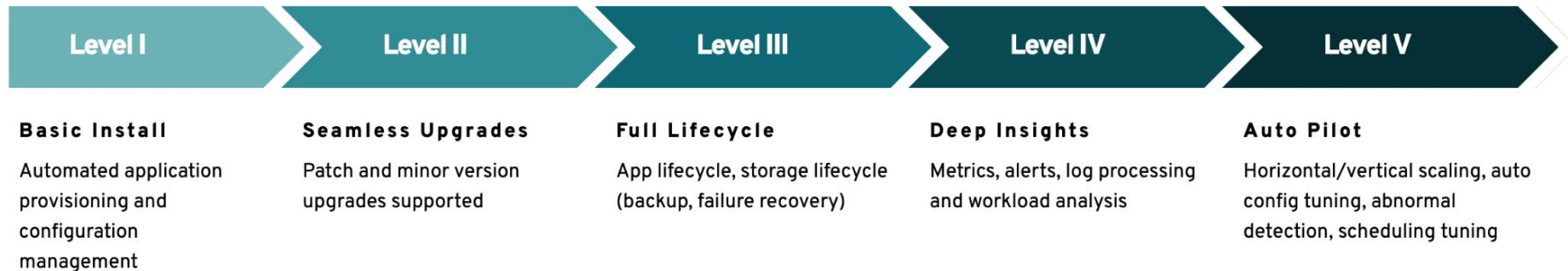
Kubernetes Operator - In a nutshell

- Software extensions to Kubernetes

- Use of **custom resources** to manage applications and their components

- Operators follow Kubernetes principles, notably the control loop

- Operators implement and automate common Day-1 (installation, configuration, etc) and Day-2 (re-configuration, update, backup, failover, restore, etc.) activities

- Via operators, you can stop treating an application as a collection of primitives like Pods, Deployments, Services or ConfigMaps, but instead as a single object that only exposes the knobs that make sense for the application

Kubernetes Operator - Control loop

Picture from "An Empirical Study on Kubernetes Operator Bugs" by Gu - Xao -Wei

Kubernetes Operator - Capability levels

Level I	Level II	Level III	Level IV	Level V
Basic Install	**Seamless Upgrades**	**Full Lifecycle**	**Deep Insights**	**Auto Pilot**
Automated application provisioning and configuration management	Patch and minor version upgrades supported	App lifecycle, storage lifecycle (backup, failure recovery)	Metrics, alerts, log processing and workload analysis	Horizontal/vertical scaling, auto config tuning, abnormal detection, scheduling tuning

Kubernetes Operator - List of existing operators

Kubernetes Operator - Write your own one

- **SDK** for the major languages

- Custom kubernetes **controllers**

- Design declarative **APIs** for operators

- Usually interact/control a custom object (Custom Resource Definitions (**CRD**))

Kubernetes Operator - Kubebuilder Architecture
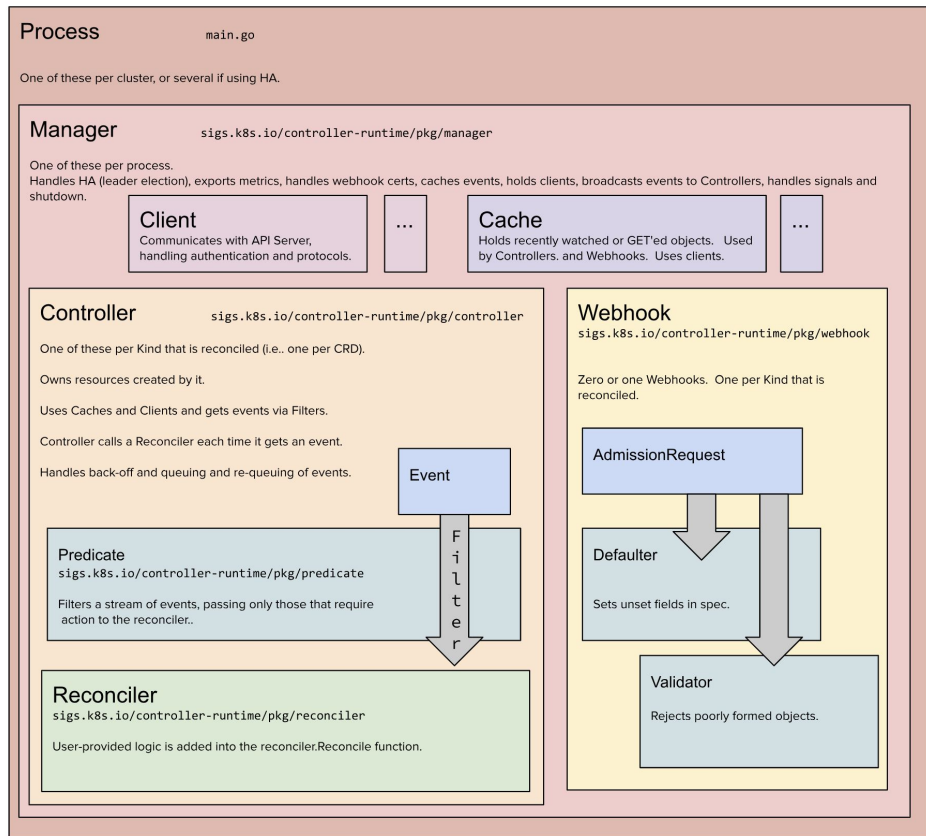
Link to Github repo of **KubeBuilder**

https://github.com/kubernetes-sigs/kubebuilder

Bring Kubernetes to Postgres, bring Postgres to Kubernetes!
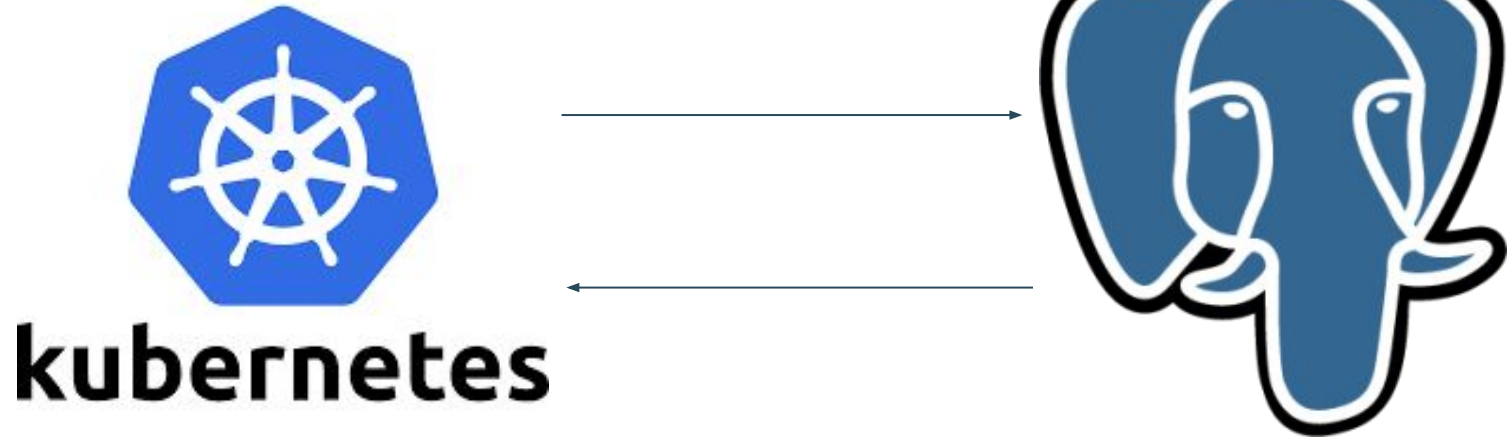
Deep into CloudNativePG

CloudNativePG - Cluster CRD example

```
> batcat cloudnative-pg/docs/src/samples/cluster-example.yaml

       File: cloudnative-pg/docs/src/samples/cluster-example.yaml

   1   apiVersion: postgresql.cnpg.io/v1
   2   kind: Cluster
   3   metadata:
   4     name: cluster-example
   5   spec:
   6     instances: 3
   7
   8     storage:
   9       size: 1Gi
```

CloudNativePG - Suggested architecture
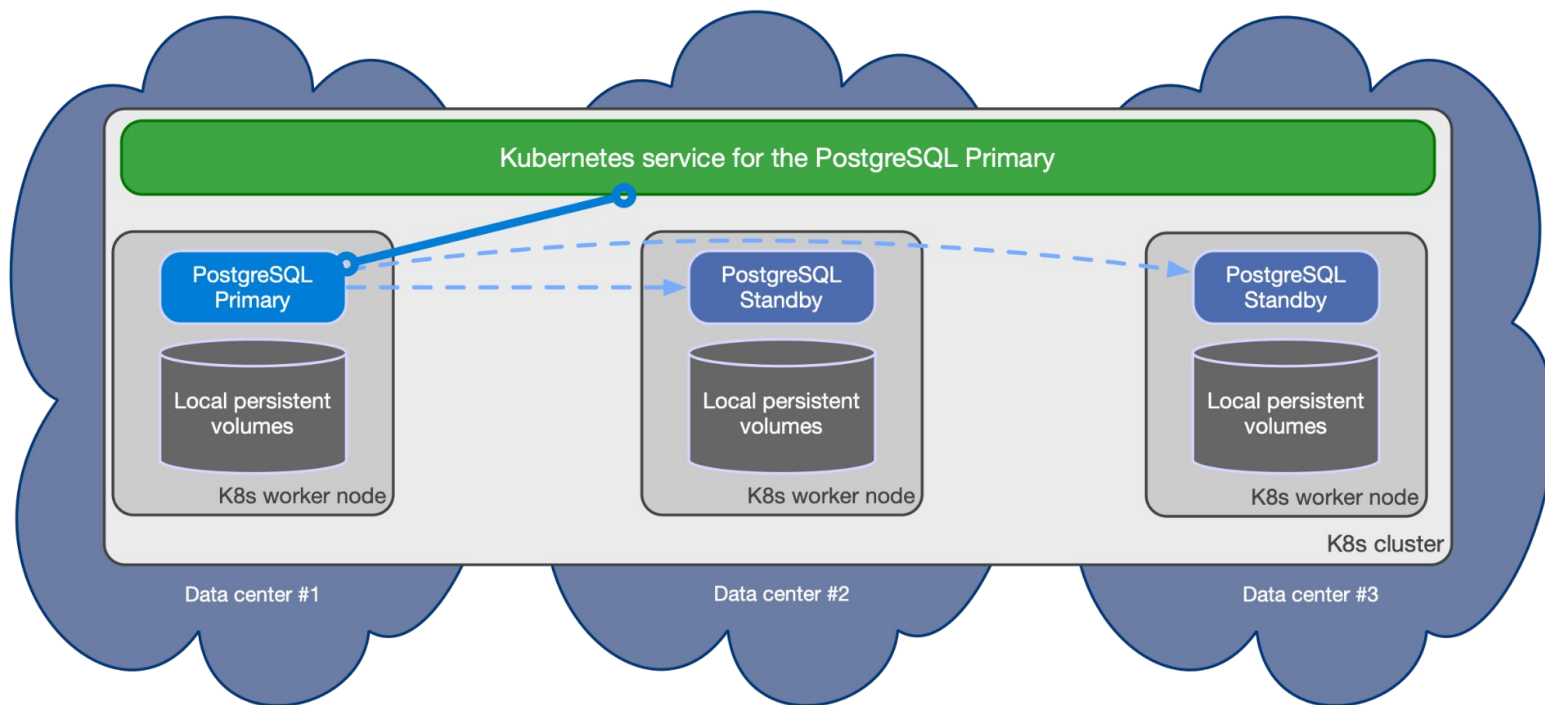
CloudNativePG - PVC management

- **No Statefulsets**

- **The operator manages directly PersistentVolumeClaims**:
    - It creates a PVC for each PostgreSQL instance, with the goal of storing the PGDATA
    - It then mounts it into each pod

- **CSI** for PVCs allows
    - **Volume Snapshot** backup and restore
    - Online resize
    - PVC cloning

CloudNativePG - Main features

- Direct integration with K8s Api Server for self healing

- High Availability capability

- Planned switchover

- Scale up/down capabilities

- Definition of an arbitrary number of instances, rw and ro services

- Declarative management of PostgreSQL configuration

- Support for local PV with PVC templates

- Backup on VolumeSnapshot and object stores

- Major PG upgrade

- kubectl plugin for cluster management

- Declarative tablespaces, databases, publications and subscriptions

- CNPG-I: define your own plugin!

CloudNativePG - Deployment across Kubernetes clusters

Distributed PostgreSQL topology with **replica clusters** enables multi-cluster deployments in private, public, hybrid, and multi-cloud contexts.

A replica cluster is a separate **Cluster** resource that is in continuous recovery, replicating from another source, either via WAL or streaming replication.
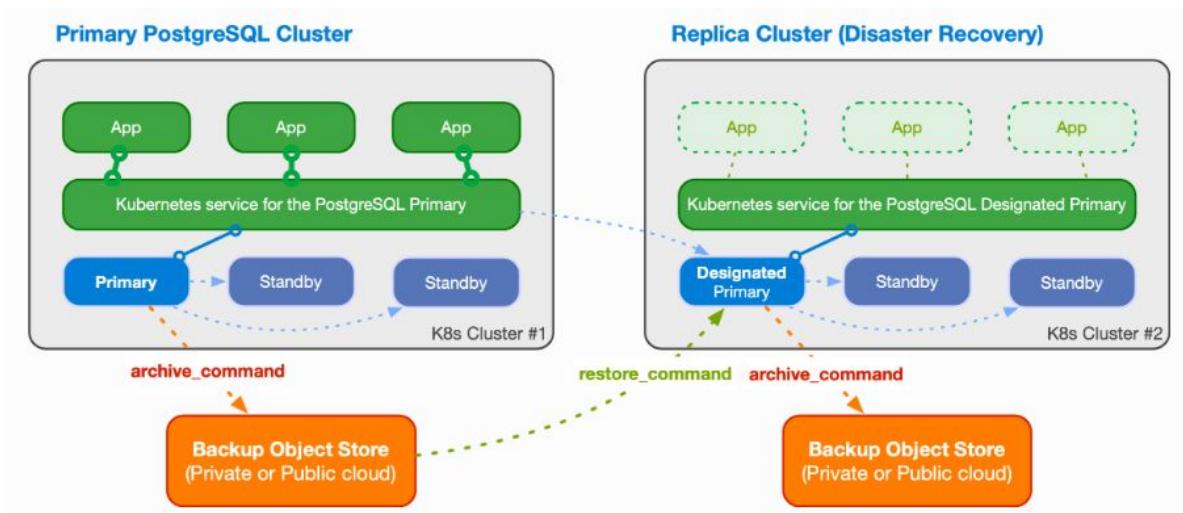
CloudNativePG - Connection pooling

CloudNativePG provides native support for connection pooling with PGBouncer, through the **Pooler** CRD.

A pooler is a deployment of PgBouncer pods that sits between your application and a PostgreSQL service. It creates a separate, scalable, configurable, and highly available database access layer.
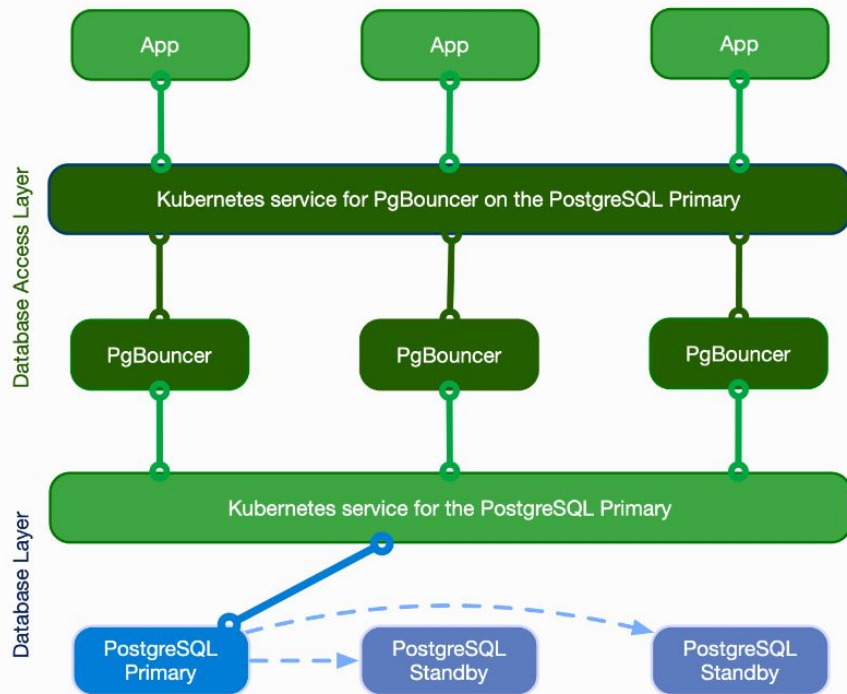
CloudNativePG - Installation

```
kubectl apply —server-side -f \
https://raw.githubusercontent.com/cloudnative-pg/cloudnative-pg/main/releases/cnpg-1.24.1.yaml
```

Refer to the CloudNativePG documentation for Helm Chart and
Operator Lifecycle Manager (OLM), directly from OperatorHub.io

CloudNativePG - Operand images

- The PostgreSQL operand **container images** are available for all PGDG supported versions of PostgreSQL, across multiple architectures, directly from the postgres-containers project's GitHub Container Registry.

- Daily jobs ensure that CVEs in the entire stack are promptly addressed

- Additionally, the community provides images for the PostGIS extension

- Check this blog article, if you want create your own **custom** container image.

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CloudNativePG - Observability

- CloudnativePG exposes native **Prometheus** exporters. Some are already defined, but you can extend them and add new ones

- All logs are in stdout

  and in **JSON** format

- CNPG plugin **status** command

CloudNativePG - Kubectl Plugin

CloudnativePG provides a **plugin** for kubectl to manage a cluster in Kubernetes


```
> ./kubectl-cnpg --help
A plugin to manage your CloudNativePG clusters

Usage:
  kubectl cnpg [command]

Operator-level administration
  install      CloudNativePG installation-related commands

Troubleshooting
  logs         Logging utilities
  report       Report on the operator or a cluster for troubleshooting

Cluster administration
  destroy      Destroy the instance named [cluster]-[node] or [node] with the associated PVC
  fencing      Fencing related commands
  hibernate    Hibernation related commands
  maintenance  Sets or removes maintenance mode from clusters
  promote      Promote the pod named [cluster]-[node] or [node] to primary
  reload       Reload a cluster
  restart      Restart a cluster or a single instance in a cluster

Database administration
  backup       Request an on-demand backup for a PostgreSQL Cluster
  certificate  Create a client certificate to connect to PostgreSQL using TLS and Certificate authentication
  publication  Logical publication management commands
  snapshot     DEPRECATED (use `backup -m volumeSnapshot` instead)
  status       Get the status of a PostgreSQL cluster
  subscription Logical subscription management commands

Miscellaneous
  fio          Creates a fio deployment, pvc and configmap
  pgadmin4     Creates a pgAdmin deployment
  pgbench      Creates a pgbench job
  psql         Start a psql session targeting a CloudNativePG cluster

Additional Commands:
  completion   Generate the autocompletion script for the specified shell
  help         Help about any command
  version      Prints version, commit sha and date of the build
```

CloudNativePG - What I personally love

- Massive suite of e2e running in CI/CD pipelines

- Exhaustive documentation

- CNPG team members

- Community enthusiasm

The picture shows some of the
maintainers running a demo
at the Project Pavillion of
KubeCon Eu London 2025

CloudNativePG - Product

- CloudNativePG is **production ready**!

- We proudly reached around 5.8K Github stars in less than 3 years and about 4K commits

- CloudNativePG became the de facto standard to deploy **PostgreSQL in Kubernetes**

- Community is very active inside the Slack workspace

- CloudNativePG has been accepted into the **CNCF Sandbox**

CloudNativePG - License

CloudNativePG has been originally created **EDB**

CloudNativePG is 100% **open source** and community-driven

All components are available under the Apache 2 license on Github

CloudNativePG - Adopters

- **Google Cloud**
  https://cloud.google.com/kubernetes-engine/docs/tutorials/stateful-workloads/cloudnativepg

- **Microsoft Azure**
  https://learn.microsoft.com/en-us/azure/aks/postgresql-ha-overview

- **IBM**

- **EDB**

  EDB CloudNativePG Cluster, EDB CloudNativePG Global Cluster, EDB Postgres AI Cloud Service (DBaaS)

  Full list here

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CloudNativePG - End users

- **EDB**

- **Hitachi**

- **Akamai Technologies**

- **Tembo**

- **CNDI**

    Full list at https://cloudnative-pg.io/end_users

CloudNativePG - Beyond the operator

CloudNativePG project contains a plenty of interesting repositories:

- Helm charts

- CNPG-I

- Grafana dashboards

- PostGIS Containers

- Ciclops

CloudNativePG - Useful links

Website: https://cloudnative-pg.io/

CloudNativePG is on LinkedIn, GitHub, cncf.io/sandbox-projects/ , but also on

- **Slack https://cloud-native.slack.com/archives/C08MAUJ7NPM**
- **Twitter https://twitter.com/CloudNativePg**
- **Mastodon https://mastodon.social/@CloudNativePG**
- **Bluesky https://bsky.app/profile/cloudnativepg.bsky.social**

CloudNativePG - Resources

- CloudNativePG website and GitHub project

- CloudNativePG Recipes on Gabriele Bartolini's blog

- CloudNativePG maintainers and contributors are active on Data On Kubernetes community

- Latest KubeCon talks mentions CloudNativePG, eg.
  - "We tested and compared 6 Database Operators. The results are in!"
  - "Kubernetes on Multisites - A Story About Stateful App, Hybrid Clouds and High Availability"

- CNCF blog article "Cloud Neutral Postgres Databases with Kubernetes and CloudNativePG"

DoK Community

Join the Community

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Demo

- Describe the demo environment
- Apply and analyze Cluster CRD
- Hands into PostgreSQL
- CNPG plugin usage
- Failover
- Declarative Database CRD

If we have time:
- Major PG offline upgrade
- Metrics

If we run out of time and you are interested, let's chat in the hallway!

Thanks!

Get in touch with me on
- **#cloudnativepg-dev on CNCF Slack**
- **LinkedIn**
- **gabriele.quaresima@enterprisedb.com**