Cloud Operations, FS2022

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1 Introduction

CI/CD	Deployment environment, provides name and url for monitoring
Ansible	Installation and configuration of applications
Terraform	Provisioning of infrastructure
Kubernetes	Configuration + application: Deployment, scaling, managing workloads
Helm	Package- and Lifecycle Manager for K8s
Kustomize	Overlaying declarative specifications on top of existing K8s Manifests
Prometheus	Monitoring K8s Infrastructure and applications for reliability
Service Mesh	Traffic Management, Security, Observability and Service Discovery
GitOps	Everything as code, declarative system operation definition, control loop

1.1 DevOps

Figure 1: DevOps Cycle

The DevOps pipeline focuses on Continuous Integration / Continuous Deployment. It applies a systems thinking and avoids too much focus on only one piece of the workflow.

It values feedback, automated and personal to keep production healthy. Monitoring is an important type of automated feedback.

Learning and continued experimentation lead to constantly improved systems and workflows.

1.1.1 Plan

Add objectives and requirements to the **backlog**, feedback from end users and operations team. Add backlog **tasks to sprints**. Track and plan activities using **board and project management tools**.

1.1.2 Code

Code from all developers gets integrated into a **central source code repository**.

1.1.3 Build

Continuous Integration pipeline is invoked every time code is pushed into the central repository. Includes **automated unit and integration tests**. Only after successful build and test, code can be reviewed and merged.

1.1.4 Test

Automated deployment of code into a testing environment. Tests executed include **load, accessibility, performace and end-to-end testing**. Manual work like **user acceptance testing** also usually happens at this stage.

1.1.5 Release

Tag a snapshot of the code with a **semantic versioning number**. Changes, features, breaking changes and deprecated features are documented. Release can include artifacts such as **binaries** and **packages**.

1.1.6 Deploy

Installs release into **production environment**. Can be automated or manual.

1.1.7 Operate

Infrastructure and Operations team ensure **smooth operation of the product**. **Scaling infrastructure** to meet demands.

Issues in infrastructure can be troubleshooted and resolved. **Document issues** for next planning stages.

1.1.8 Monitor

Collect data on usage, performance, errors and more. Data collected is used for next iteration of DevOps cycle.

1.2 Automated DevOps with GitLab CI

Using GitLab CI pipeline, code can be built, tested and deployed automatically on every change. Tasks are defined in .gitlab-ci.yml file kept together with the code repository.

2 CI/CD

2.1 Automated application deployment

2.1.1 Declaring deployment enviroments

Environments in CI definitions describe where code gets deployed. It can be linked to a kubernetes cluster and usually defines a name and url for monitoring the overall application state.

Monitoring a deployment in GitLab requires installation and configuration of Prometheus.

2.1.2 Kubernetes application ressources

Docker Image Tag can be built by combining GitLab variables:

`$CI_REGISTRY_IMAGE:$CI_COMMIT_SHORT_SHA`

To apply a kubernetes yaml manifest during CI/CD Pipeline, use the following script line:

```
cat k8s.yaml | envsubst | kubectl apply -f -
```

Inside the kubernetes yaml manifest, the image can be specified using a variable such as "${DOCKER_IMAGE_TAG}"

2.1.3 Deploying an application to Kubernetes

Kubernetes Cluster needs to be configured as deployment destination in GitLab repository. For this, an agent must be installed inside the cluster. This agent can then be used to communicate through a NAT, access cluster API endpoints in real time, push information about events as well as enable a cache of kubernetes objects.

With a GitOps workflow, kubernetes manifests are kept inside GitLab, and on every change to the repository manifests, the agent inside the cluster automatically updates resources accordingly. This is considered pull-based, because the cluster agent actively pulls from the repository.

The classical CI/CD workflow pushes new configuration from the GitLab repository to the claster using GitLab CI script commands on the kubernetes API.

Environment scope defines which environments are automatically assigned to this cluster when created.

2.1.4 Deploying tokens and pulling secrets

How does the kubernetes cluster access information inside our gitlab repository? Creating a deploy token we can provide the kubernetes cluster with authentication credentials to pull images from the GitLab container registry. read_registry access should be enough.

These credentials must be saved as environment variables inside the GitLab repository and can then be used to create a kubernetes secret inside the CI script. This kubernetes secret is used as "ImagePullSecret" inside the manifest to create resources.

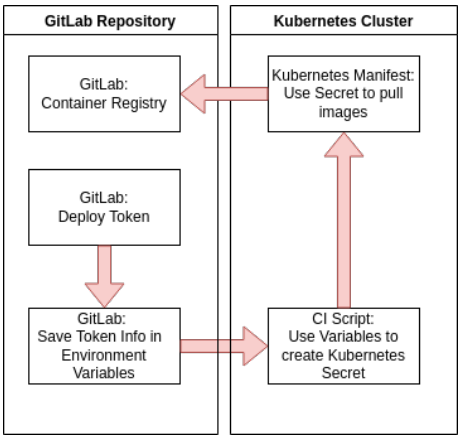


Figure 2: Cluster Authentication

2.1.5 Dynamic environments and review apps

Defining job environment variables inside the CI Script allows us to use the same k8s file for different branches, referencing different applications

- DEPLOY_SUFFIX
- DEPLOY_HOST

```
kind: Service
apiVersion: v1
metadata:
  name: todo-${DEPLOY_SUFFIX}
spec:
  selector:
    app: todo-${DEPLOY_SUFFIX}
  type: NodePort
  ports:
  - protocol: TCP
    port: 80
    targetPort: 5000
---
```

Figure 3: Using environment variables defined in CI-Job

Review Apps can be created automatically when pushing to any non-production branch. CI_COMMIT_REF_SLUG creates a valid k8s name from the branch name. A new environment in GitLab is created automatically.

Figure 4: Automatically creating review apps for branches

2.2 Application Quality and Monitoring

Integration and functional testing can be supported either using review apps or defining instances of containers as services. This makes the service available to the main container built inside the CI job.

2.2.1 Analyzing code quality

Separate jobs that check code quality inside the build pipeline provide results either as reports in merge requests or as separate job artifacts. Code Quality jobs usually run parallel with the other test jobs to reduce overall pipeline time.

Gitlab provides an image specifically for code quality which creates JSON reports – comparing results to previous ones automatically is not a free feature in GitLab.

2.2.2 Dynamic application security testing – DAST

Usually occurs after the deploy stage. Creates a JSON report and compares it with the last one to check for any differences to the reports from previous merges. Not a free feature.

2.2.3 Application monitoring with Prometheus

2.3 Custom CI Infrastructure

2.3.1 Runners

3 Terraform

3.1 Basics

Infrastructure reqirements for deploying applications include VMs, security, network access, firewall rules, availability and maintainability.

Terraform is responsible for deploying and maintaining infrastructure. It supports infrastructure providers such as AWS, Microsoft Azure, Google Cloud and many more via provider plugins.

These plugins convert the terraform calls into something that can communicate with the client SDK of the cloud provider.

Terraform commands are written in Hashicorp Configuration Language HCL which

- is simple, easy to learn
- has in-built type system
- supports for-loops, dynamic blocks, contitionals and string interpolation

The terraform language consists of blocks, arguments (assigning values to a name) and expressions.

```
resource "aws_vpc" "main" {
  cidr_block = var.base_cidr_block
}

<BLOCK TYPE> "<BLOCK LABEL>" "<BLOCK LABEL>" {
  # Block body
  <IDENTIFIER> = <EXPRESSION> # Argument
}
```

A Terraform configuration is a complete document in the Terraform language that tells Terraform how to manage a given collection of infrastructure. A configuration can consist of multiple files and directories.

3.2 Components

version.tf – describes which terraform version and which providers are required
provider.tf – contains access keys, etc.

main.tf – contains actual infrastructure descriptions

terraform init – initializes working directory with specified provider selections, etc.
terraform plan – calculate the changes based on declarations and state, display what would be executed
terraform apply – run the deployment, create, update or delete resources as needed
terraform destroy – remove all resources defined in terraform configuration files

.tfstate – current state information. is used for terraform plan command.

3.3 Resource referencing

<ResourceType>.<Name> represents a managed resource of the given type and name.

VAR.<Name> is the value of an input variable oof the given name.

3.4 Outputs

3.5 Data

3.6 State file sharing

The state file *terraform.tfstate* kept for every environment is best stored in a central location when working in a team. Remote storage providers enable locking of the state file for every operation, in case several users apply modifications at the same time.

The refresh operation synchronizes the state file with the actual status of the managed infrastructure and maps object IDs to the resource instances defined inside terraform configuration.

3.7 Modules for Code Reuse

Modules are containers for multiple resources that are used together. A module consists of a collection of *.tf* and / or *.tf.json* files kept together in a directory. The root module is usually the main folder of the terraform resources.

4 Ansible

Focus in ansible is writing configuration as code that can easily be pushed out to managed devices, reducing or eliminating the need to manually configure single devices. There is no client installation needed on the endpoints.

Alternatives to ansible include Puppet, Chef and SaltStack. Based on python and extensible via modules, ansible has about 65% market share.

4.1 Basics and Setup

Ansible is usually installed on a control node, e.g. an operators workstation. Inventory, code and playbooks can then be managed and shared through version control systems. Connections to assets that should be configured are initiated for every task that is run, using the ssh protocol for Linux and winrm for Windows devices..

To run tasks, the following is required on an operators machine:

- Python installation
- Ansible installation
- `/etc/hosts` for dns resolution
- ansible.cfg for configuration (default in `/etc/ansible/ansible.cfg`) used for default settings including privilege and remote user, "fallback" for settings that aren't provided at a more specific level
- inventory file (default in `/etc/ansible/hosts`)
  to identify all managed hosts, can be dynamic using central inventory software or static file with host lists

On the managed devices:

- Python installation
- Dedicated ansible user account with ssh / sudo access, typically key-based

4.2 Ad-Hoc Commands and Modules

Executing a single module on some hosts in the inventory can be done by command line:

```
ansible
   -i <inventory file> all
   -m <module name>
   -a <module argument>
   -u <username>
```

`-k` *(ask for password)* Running the same task a second time, ansible recognizes if changes had to be done or the command did not have any effect.

Modules to avoid: *command, shell, raw* because there is no idempotency. Ansible cannot determine, if the configuration is already there or has to be applied. If a simple command is run (like useradd), instead of recognizing the "ok state" (user already exists, do nothing) ansible returns the actual error the command outputs. They should only be used as a last resort, if there is no appropriate ansible module available.

4.3 Playbooks

A playbook contains multiple tasks that are run in order. Errors in one task will cause the whole play to fail.

Each playbook is written in yaml. It consists of several p

4.3.1 Facts and Variables

4.3.2 Working with Conditionals

5 Kubernetes Object Management

The imperative approach would start single pods or services using pods from the command line:

"Create new application pod!"

The declarative approach applies configure files to update the current state:

"I want a deployment with 5 application pods.."

General commands to use for different kinds of resources:

`kubectl get` *`pods`*
: display basic information about a resource type

`kubectl describe` *`pod`* `pod-name`
: get detailed information about a specific resource entity

`kubectl get` *`pods`* `-o wide`
: display more information

`kubectl get` *`pod`* `pod-name -o yaml`
: display config of a running entity in yaml format

`kubectl explain` *`pod.spec`*

```
luzia@ubuntu-srv01:~$ kubectl explain pod.spec
KIND:     Pod
VERSION:  v1

RESOURCE: spec <Object>

DESCRIPTION:
     Specification of the desired behavior of the pod. More info:
     https://git.k8s.io/community/contributors/devel/sig-architecture/api-conventions.md#spec-and-status

     PodSpec is a description of a pod.

FIELDS:
   activeDeadlineSeconds        <integer>
     Optional duration in seconds the pod may be active on the node relative to
     StartTime before the system will actively try to mark it failed and kill
     associated containers. Value must be a positive integer.

   affinity     <Object>
     If specified, the pod's scheduling constraints

   automountServiceAccountToken <boolean>
     AutomountServiceAccountToken indicates whether a service account token
     should be automatically mounted.

   containers   <[]Object> -required-
     List of containers belonging to the pod. Containers cannot currently be
     added or removed. There must be at least one container in a Pod. Cannot be
     updated.

   dnsConfig    <Object>
     Specifies the DNS parameters of a pod. Parameters specified here will be
     merged to the generated DNS configuration based on DNSPolicy.
```

Figure 5: Detailed Spec Information for Resource Types

5.1 Pods and Containers

A pod is an abstraction of a server. It usually runs one container performing some service, as well as sidecar containers performing additional networking

or logging tasks like monitoring or service mesh functionality.

A pod is the minimal entity managed by Kubernetes. Typically only started within a deployment to ensure fault-tolerance.

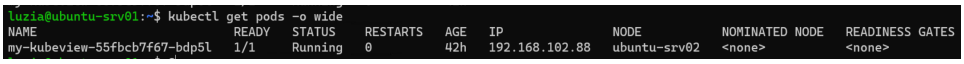


Figure 6: Get Pod Information

Configure pods with the following metadata

```
apiVersion:
kind:
metadata:
spec:
```

Connecting to a pod for further inspection:

`kubectl exec -it` *`pod-name -- command`*

5.1.1 Sidecar Container

Runs services like monitoring that are able to directly access the main container inside a pod.

5.1.2 Init Container

Container which is started to complete a job before the pods main container starts. If this job fails, the main container is not started.

5.2 Namespaces

A namespace implements linux kernel level resource isolation. Can be used to strictly separate between customer resources.

Set current namespace:

`kubectl config set-context --current --namespace==`*`name`*

5.3 Resource Limitations

By default, pods use as much resources as they need. Resource limits can be defined inside the pod specifications.

5.4 Deployments

Adds additional features to single pod deployments, like scalability and update strategies.

Deployments create and manage ReplicaSets to ensure a stable set of identical pods running at any given time.

Check deployment rollout status using the following command:

Figure 7: Pod Resource Limits

`kubectl rollout status deployment/`*`deployment-name`*

5.5 Rolling Update Strategies

Applying changes in deployments means changing the number of pods, or even changing every pod to a newer version. Exactly how this is done can be defined using Rolling Update Strategies.

Recent transactions can be viewed, or the last change can be undone with the following commands:

```
kubectl rollout history
kubectl rollout undo
```

Default Update strategies:

Recreate: Kill all pods and create new ones. Leads to temporary unavailability.

RollingUpdate: updates one pod at a time to guarantee application availability. This behavior can be specified further with Rolling Update Options.

maxUnavailable: limit the number of pods that can be upgraded at the same time

maxSurge: limit the number of pods that can run on top of the specified number to guarantee availability

5.6 Pod Access Options

5.6.1 Service

An API resource that is used to expose a logical set of pods. A service applies round-robin load-balancing to forward traffic to specific pods. To determine which pods are targeted, a label is used as selector. Pods are

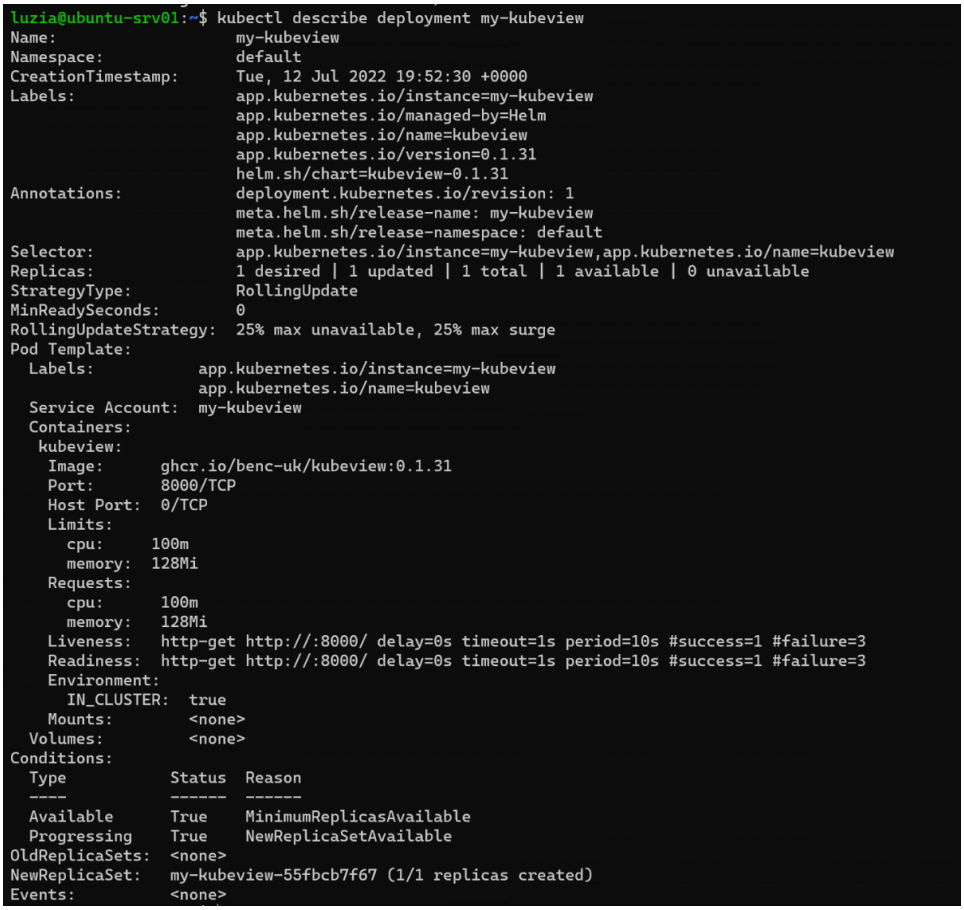


Figure 8: Deployment details

continuously scanned for this label to decide if they should be included in the service.

Services are independent from deployments. All they see is pods with labels, so they can also be used to load-balance between different deployments.

Kube-proxy opens ports on the Cluster IP address for a service and redirects traffic to a pod that matches the specification.

Different Service Types include:

- ClusterIP (default): exposes service on an *internal* cluster IP address
- NodePort: Allocates a specific port on the node IP, forwarding traffic to a cluster IP address.
- LoadBalancer: *only implemented in public cloud*
- ExternalName: *used in migration*

Create services using the commands

`kubectl expose deployment` *`name`* `--port=`*`80`*

or

`kubectl create service --port .`

This exposes a deployment, allocating its pods as service endpoint.

Different port types exist:

- targetPort: The port on the container, that the actual application exposes and the service addresses.
- port: The port on which the **service** is accessible.
- nodePort: What is **exposed externally** in the nodePort service type.

5.6.2 Ingress

Provides external access to internal Kubernetes cluster resources, as well as load balancing using an ingress controller (nginx, haproxy, traefik, ...).

It uses selector labels to connect to pods that are used as a service endpoint.

It can be configured to do the following:

- Give externally reachable URLs to services
- Terminate SSL/TLS connections
- Offer name-based virtual hosting
- Load balance traffic

```
luzia@ubuntu-srv01:~$ kubectl create ingress nginxsvc-ingress  --rule="/=grafana:3000" --namespace=monitoring
ingress.networking.k8s.io/nginxsvc-ingress created
luzia@ubuntu-srv01:~$ kubectl describe ingress nginxsvc-ingress --namespace=monitoring
Name:             nginxsvc-ingress
Labels:           <none>
Namespace:        monitoring
Address:
Ingress Class:    <none>
Default backend:  <default>
Rules:
  Host        Path  Backends
  ----        ----  --------
  *
              /   grafana:3000 (192.168.102.83:3000)
Annotations:  <none>
Events:       <none>
```

5.7 Scheduling

Kube-Scheduler: Matches pods to nodes, is needed to run kubernetes. Labels can be used to influence scheduling (nodeName, nodeSelector, affinity/antiAffinity, taints)

Filtering: Nodes need to meet the resources needed to run the pods.

PodFitsHostPort, PodFitsResources, PodMatchNodeSelector, CheckNodeDiskPressure, CheckVolumeBinding
Scoring: Ranking after filtering is applied: SelectorSpreadPriority, LeastRequestedPriority, NodeAffinityPriority
NodeSelector: Label as Key=Value, can be used in yaml as key: value
NodeName: Specify a node host specifically
Affinity:
nodeAffinity: like nodeSelector, uses labels. Type: required / preferred
podAffinity: required/preferred (+ weight)

5.8 Taints and Tolerations

5.9 Storage

5.10 ConfigMaps

5.11 Secrets

5.12 Probes

6 Service Mesh

6.1 Microservice Principles

The modern architecture of microservices focuses on the following aspects of operation.

1. Deployment Independence
2. Oranized by business capability
3. Products not Projects
4. API Focused
5. Smart endpoints and dumb pipes
6. Decentralized governance
7. Decentralized data management
8. Infrastructure Automation (IaC)
9. Design for failure
10. Evolutionary design

Figure 9: Traditional Service Architecture

6.2 Service Mesh

A service mesh is a dedicated and configurable infrastructure layer that handles the communication between services without having to change the code in a microservice architecture.

Instead of every service implementing important functionality themselves, a proxy is deployed to intercept network traffic to each container inside a pod.

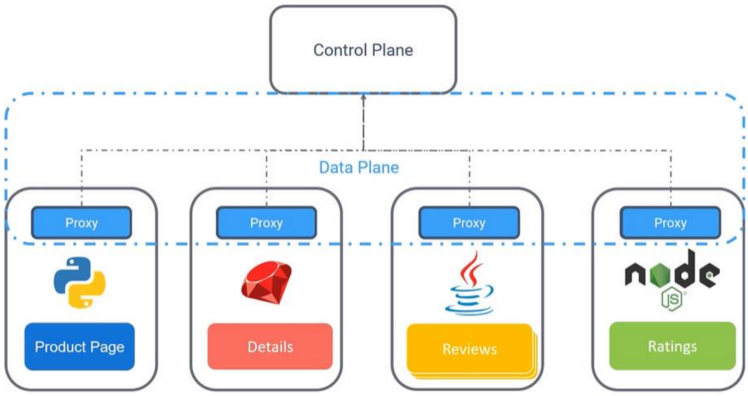


Figure 10: Service Mesh Architecture

Service Mesh is responsible for Traffic Management, Security, Observability and Service Discovery inside each microservice. This is done by embedding capabilities via sidecar containers directly into kubernetes pods.

6.3 The Istio Approach

Grafana	Visualization of metrics collected by Prometheus
Istio Ingress Gateway	Envoy Proxy which serves as an entry point for the service mesh
Istiod	Backbone of the Istio control plane, configures sidecar proxies
Jaeger	Provides tracing functionality for traffic inside the service mesh
Kiali	Istio dashboard
Prometheus	Collects monitoring information from sidecar proxies

6.4 Canary Deployment

Canary deployments are used to test a new version of a microservice in production. To do so, the new version gets deployed, but only a small percentage of traffic gets sent to it. If no problems occur and no customers complain, the traffic rate to the new version gets increased.

6.5 Virtual Services

Inside a VirtualService configuration file, a set of traffic routing rules can be defined that should be applied when a host is addressed. Each routing rule defines matching criteria for traffic of a specific protocol.

If traffic is matched, it is sent to a named destination service or a specific subset / version of it. This can be used for load balancing and different deployment strategies.

6.6 Jaeger Spans and Traces

A trace represents a single request through the service mesh which gets handled by the services. Each unit of work inside a trace is called a span. Spans can be requests to other services, for example.

7 GitOps

The concept of GitOps enforces using Git as *single source of truth defining the application state.*

Instead of different people using *kubectl create / apply* or *helm install / upgrade* commands from their own laptops, the whole configuration of a kubernetes cluster is kept inside a (separate!) Git repository.

This brings the known advantages of a version control system to Continuous Delivery for Kubernetes Clusters:

- **Versioned and immutable**
- **Declarative** definitions of apps, environments and configurations
- **Automated and repeatable**, less opportunity for errors
- Code review for changes
- Tracking of who did what
- Rollback via Git
- Whole infrastructure can be recreated from source control

Separating the git repository holding kubernetes manifests and the actual application code provides more simplicity when updating some deployment information.

No build and test pipeline will be triggered without any change to the actual code. Git history will be cleaner. Application may be distributed over several git repositories. Separation of access is possible.

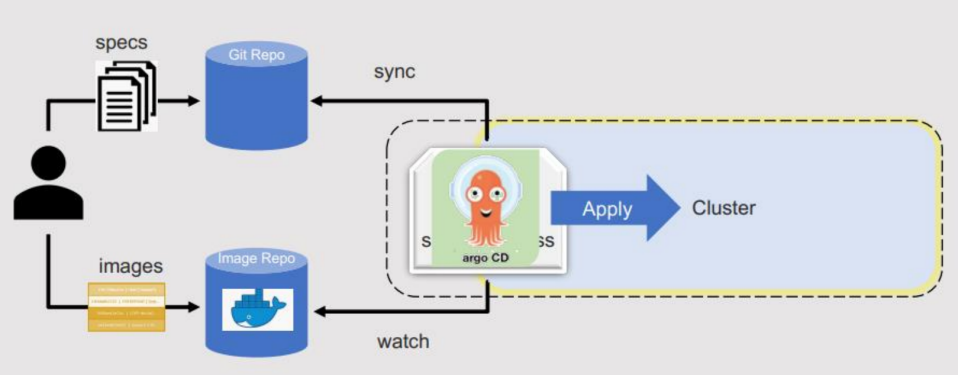
7.1 ArgoCD

Declarative GitOps tool used to deploy applications on Kubernetes.

It is lightweight, easy to configure, built with GitOps Workflow in mind and intended only for Kubernetes.
How does it work?

- Spins up its own controller inside the cluster
- watches for changes in a repository
- compares against resources deployed in the cluster
- synchronizes both states (desired state wins)

Its key concepts are the following:



App/Application	Group of K8s resources defined by a manifest (CRD), used to monitor repository and update cluster
Application source type	Which build tool is used to build the app
Live State	Current state of the application cluster
Target State	Desired state as stored in Git
Sync Status	Is live the same as target?
Sync	Updating app to the target state
Sync operation status	Success/failure state of the sync operation
Refresh	Comparison of Code in Git with live state (.. of Sync Status)
Health Status	Is the app running correctly? Serving Requests?
Configuration Management Tool	Tool to create manifests from files in direcory (Kustomize, Ksonnet)
Configuration Management Plugin	Custom tools ...

7.2 ArgoCD Application

Specifies information such as ArgoCD project, source repo, revision, path, cluster, namespace.

Can be created via command line, Web Interface, Yaml in web, K8s Manifest (CRD).

Can be specified using kustomize, helm, ksonnet, jsonnet, plain yaml, custom configuration management tool set up as plugin to ArgoCD.

`argocd app create, argocd list`

Different app health statuses include

- Progressing
- healthy
- Degraded
- Suspended
- Missing

7.2.1 History and Rollback

ArgoCD keeps track of the various versions deployed and allows you to go back to a previous state. Can be accessed from the graphical user interface.

7.2.2 Manual Sync

- **Prune**: Allow deleting resources that are unexpected, meaning they no longer exist in git.
- **Dry Run**: Preview what an apply operation would do without affecting the cluster
- **Apply only**: Skip pre/post sync hooks
- **Force**: Deletes and re-creates resource(s) when patch encounters conflict after 5 retries

7.2.3 Automated Sync

Only occurs if App Sync Status is *OutOfSync*. Attempts one sync per unique combination of commit hash and parameters of the app – unless *selfHeal* flag is true.

sefHeal attempts to sync after a default timeout of 5 seconds.

7.2.4 ArgoCD Projects

Projects can be a logical group of applications, which supports organization by teams.

Features include restrictions and roles to isolate different teams and the resources available inside a project.

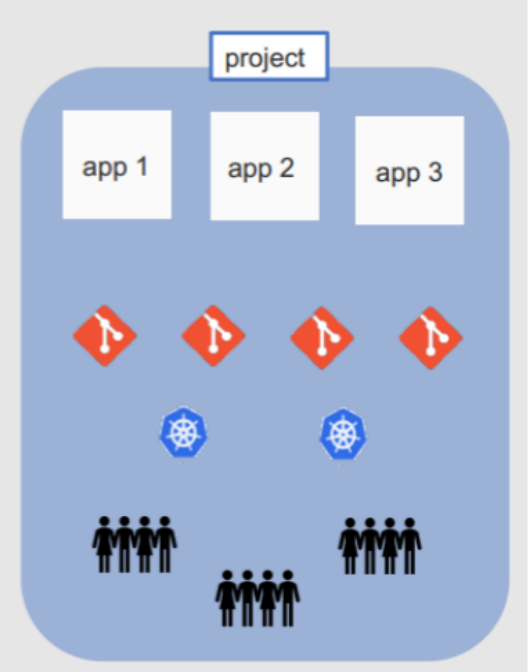


Figure 11: ArgoCD Projects