Deploying a TODO app on Kubernetes

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Group 3

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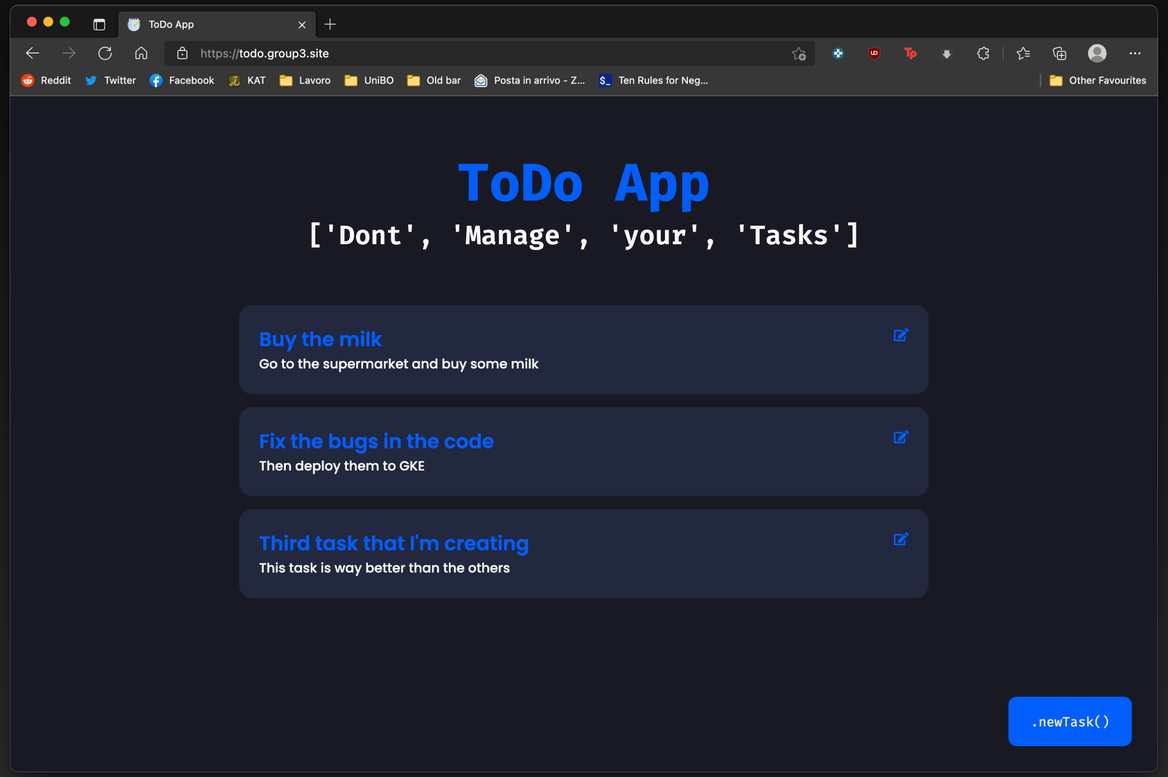
Architecture

The TODO app

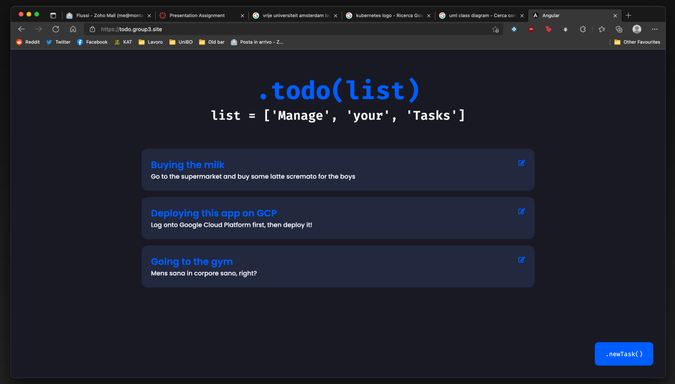
CRUD, made elegant.

- **TODO** app allowing simple **C**reate, **R**ead, **U**pdate, **D**elete operations
- Frontend built in **Angular**, reading data from the API
- API built in **Python** with **Flask**
- **MySQL** database, implemented on **MariaDB**



What's needed?

Building the app from scratch



Angular frontend

Served through

NGINX

MariaDB

Retrieving data from the API

Saving data to

Flask

web development, one drop at a time

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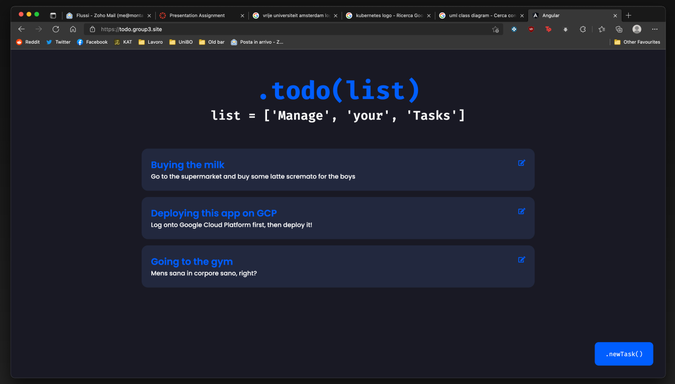
Containerization

Abstracting from the host



Angular frontend

Served through

NGINX

To containerize the frontend, we just need to:

- build the Angular project, getting HTML+CSS+JS
- Instantiate an *nginx* container
- Copy the files into the container

This is done with a simple Dockerfile:

```
FROM node:latest as build
WORKDIR /usr/local/app
COPY ./ /usr/local/app/
RUN npm install
RUN npm run build

FROM nginx:latest
COPY --from=build
/usr/local/app/dist/angular
/usr/share/nginx/html
EXPOSE 80
```

Containerization

Abstracting from the host

To containerize the API, we can use the *python:alpine* image

- Install the requirements
- Expose the correct port
- Launch the API script

```
FROM python:3.9-alpine3.15

WORKDIR /usr/src/app

RUN apk update \
    && apk add --virtual build-deps gcc python3-dev musl-dev \
    && apk add --no-cache mariadb-dev
COPY requirements.txt ./
RUN pip install --upgrade pip \
&& pip install --no-cache-dir -r requirements.txt

COPY . .
EXPOSE 5500
CMD [ "python", "./app.py" ]
```

Retrieving data from the API

Flask

web development,
one drop at a time

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Containerization

Abstracting from the host

To containerize the DB, we can use the *mariadb:10.3.5* image

- Setting the parameters for DB name, user, password
- Exposing the 3306 port

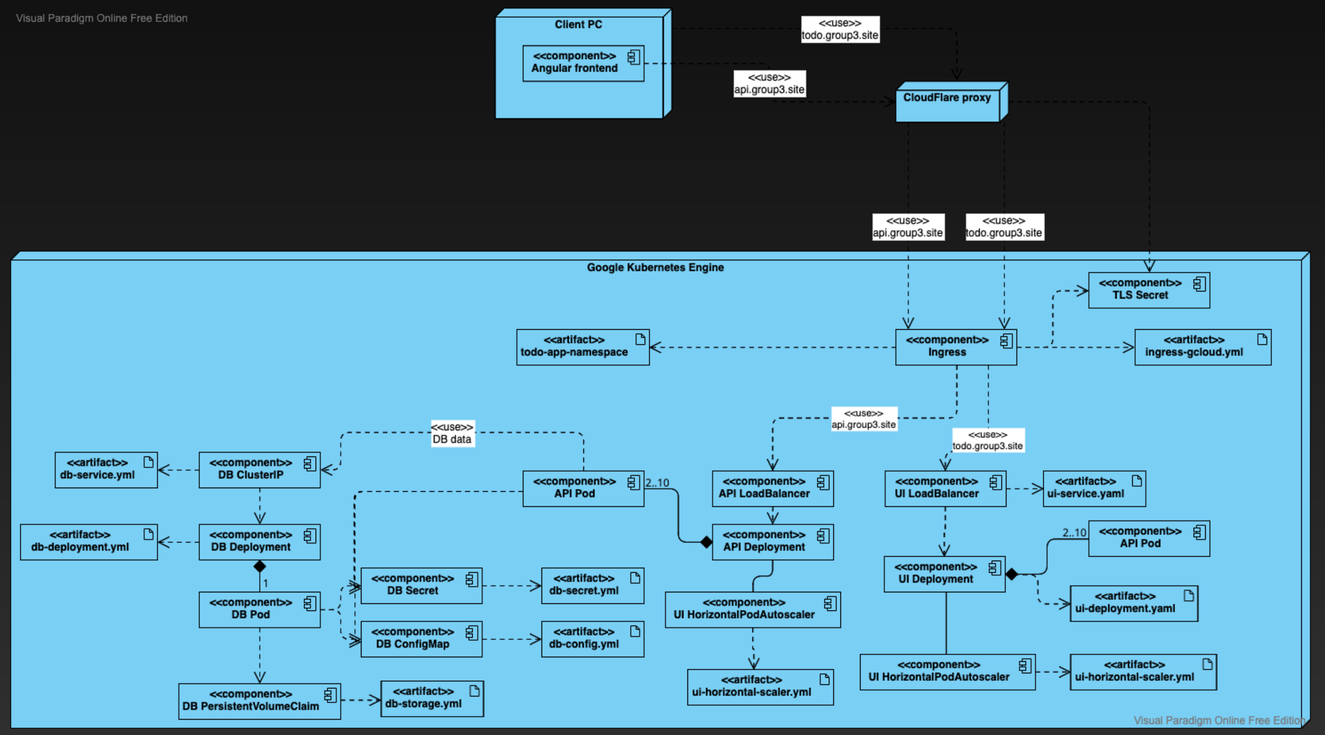
```
FROM mariadb:10.3.5

RUN apt-get update & apt-get upgrade -y

ENV MYSQL_USER=todo \
    MYSQL_PASSWORD=password \
    MYSQL_DATABASE=todo \
    MYSQL_ROOT_PASSWORD=mypass

EXPOSE 3306
```

Saving data to

Bringing it to Kubernetes

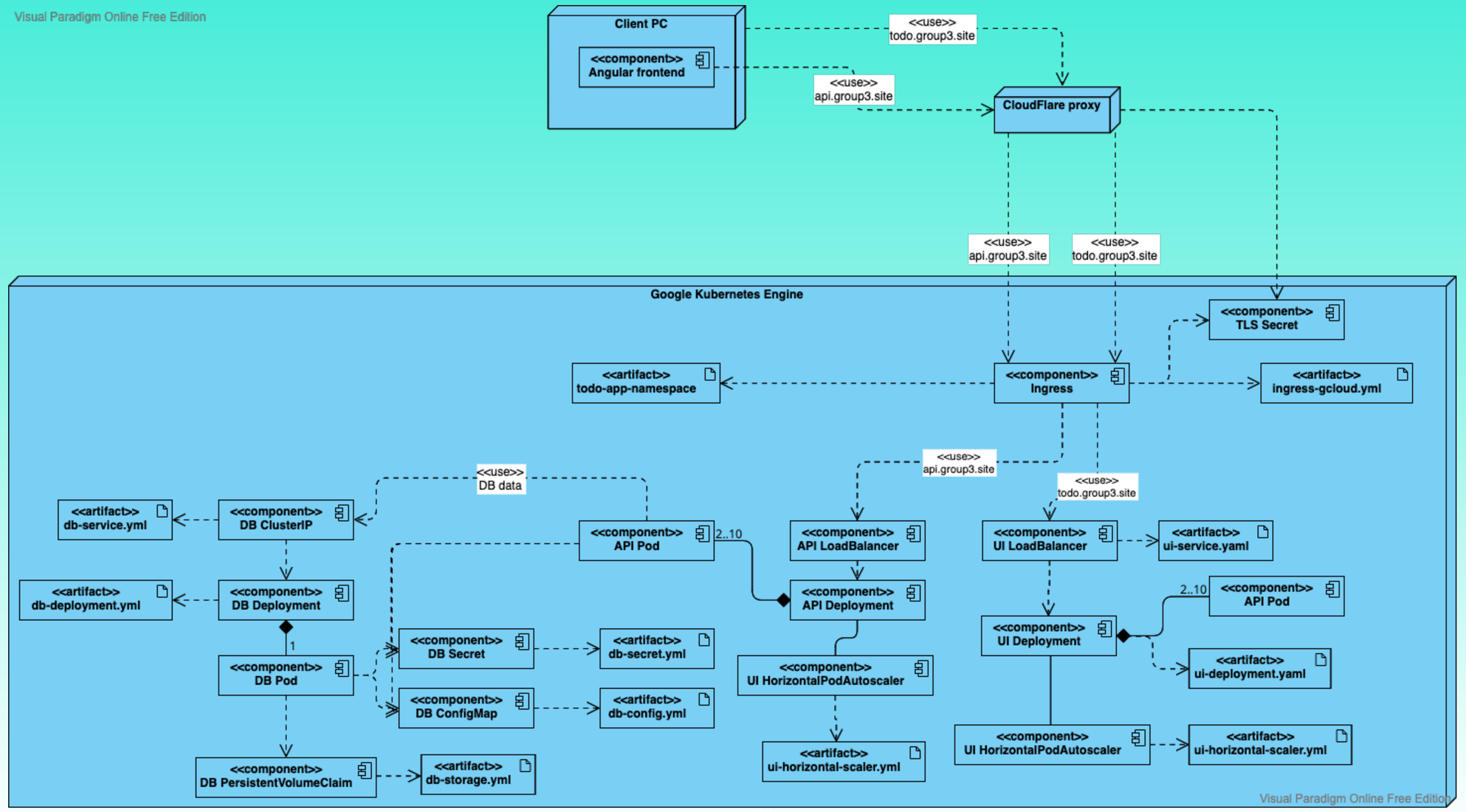
Containers have to be orchestrated!

- **Kubernetes** allows us to manage the orchestration of containers easily
- We will need to define different components: deployments, services, volumes, configs and secrets.
- The deployment will then have to **horizontally scale** when needed



Bringing it to Kubernetes

Containers have to be orchestrated!



Deployments

Containers have to be orchestrated!

- **Deployments** are workload resources allowing us to make sure our containers are always working as they should
  - The **DB** deployment specifies which ConfigMaps to use for the env, which image to use, which volumes and secrets.
  - The **API** deployment specifies the container and the same ConfigMaps that are used for the DB, in order to connect to it
  - The **UI** deployment sets up an nginx container on port 80

```yaml
apiVersion: apps/v1
kind: Deployment
metadata:
  name: db-deployment
  namespace: todo-app
spec:
[...]
      - name: todo-db
        image: mariadb:10.3.5
        imagePullPolicy: "IfNotPresent"
        ports:
        - containerPort: 3306
        env:
        - name: MYSQL_USER
          valueFrom:
            configMapKeyRef:
              name: db-config
              key: MYSQL_USER
[...]
        volumeMounts:
        - name: data
          mountPath: /var/lib/mysql
      volumes:
      - name: data
        persistentVolumeClaim:
          claimName: mariadb-pv-claim
```

Services

Exposing our software

- **Services** define logical sets of pods and allow us to access them
  - The **DB** service creates a *ClusterIP*, allowing us to reach the DB at a given IP:port
  - The **API** service creates a Load Balancer that equally distributes the requests across the available pods
  - The **UI** service creates a LoadBalancer as the API one

```yaml
apiVersion: v1
kind: Service
metadata:
  name: api-loadbalancer
  namespace: todo-app
spec:
  type: LoadBalancer
  ports:
    - port: 5050
      targetPort: 5500
  selector:
    app: api
```

ConfigMaps

Saving parameters

- **ConfigMaps** allow us to save environment variables and configuration parameters
  - The **DB** config contains the MySQL users, DB name and hostname
  - The **API** service is linked to the same config.

```yaml
apiVersion: v1
kind: ConfigMap
metadata:
  name: db-config
  namespace: todo-app
  labels:
    app: todo-db
data:
  MYSQL_HOST: todo-db
  MYSQL_USER: todo
  MYSQL_DATABASE: todo
```

Secrets

Saving confidential data

- **Secrets** contain base64 encrypted data, as passwords and TLS keys
  - The **DB** password is saved in a secret
  - The **TLS** keys are saved in special secrets

```yaml
apiVersion: v1
kind: Secret
metadata:
  name: db-secret
  namespace: todo-app
type: Opaque
data:
  MYSQL_ROOT_PASSWORD: bXlwYXNzCg==
  MYSQL_PASSWORD: cGFzc3dvcmQ
```

Volumes

Maintaining the data

- **Volumes** allow us to save data to a persistent volume, that doesn't disappear with the pod
  - The **DB** needs a persistent volume, obtained through a **PersistentVolumeClaim** that is dynamically managed by Kubernetes

```
~/Vrije/Lab/Containerization/todo-app  main ● ?   ✔ 10556  18:38:18
$ kubectl get sc standard -n todo-app
NAME                 PROVISIONER            RECLAIMPOLICY   VOLUMEBINDINGMODE   ALLOWVOLUMEEXPANSION   AGE
standard (default)   kubernetes.io/gce-pd   Delete          Immediate           true                   5d3h

~/Vrije/Lab/Containerization/todo-app  main ● ?   ✔ 10557  18:38:35
$ kubectl get pv -n todo-app
NAME                                       CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS   CLAIM                  STORAGECLASS
pvc-5fffdf43-88cd-4582-a3b0-b7ab48513e09   5Gi        RWO            Delete           Bound    todo-app/db-pv-claim   standard
```

```yaml
apiVersion: v1
kind: PersistentVolumeClaim
metadata:
  name: db-pv-claim
  namespace: todo-app
spec:
  accessModes:
  - ReadWriteOnce
  resources:
    requests:
      storage: 5Gi
```

Ingress

Managing HTTP access

- **Ingress** is an external component providing TLS support and name-based virtual hosting
- Using Ingress, we can use **subdomains** for the APIs and the frontend, without having to use different ports

```yaml
apiVersion: networking.k8s.io/v1
kind: Ingress
metadata:
  name: todo-app-ingress
  namespace: todo-app
spec:
  tls:
  - hosts:
    - api.group3.site
    secretName: api-cloudflare-tls
  - hosts:
    - todo.group3.site
    secretName: ui-cloudflare-tls
  rules:
    - host: api.group3.site
      http:
        paths:
        - path: /
          pathType: Prefix
          backend:
            service:
              name: api-loadbalancer
              port:
                number: 5050
    - host: todo.group3.site
      http:
        paths:
        - path: /
          pathType: Prefix
          backend:
            service:
              name: ui-loadbalancer
              port:
                number: 5051
```

Prerequisites

Google Kubernetes Engine

Deploying to the cloud

Our cluster's IP

34.107.151.112

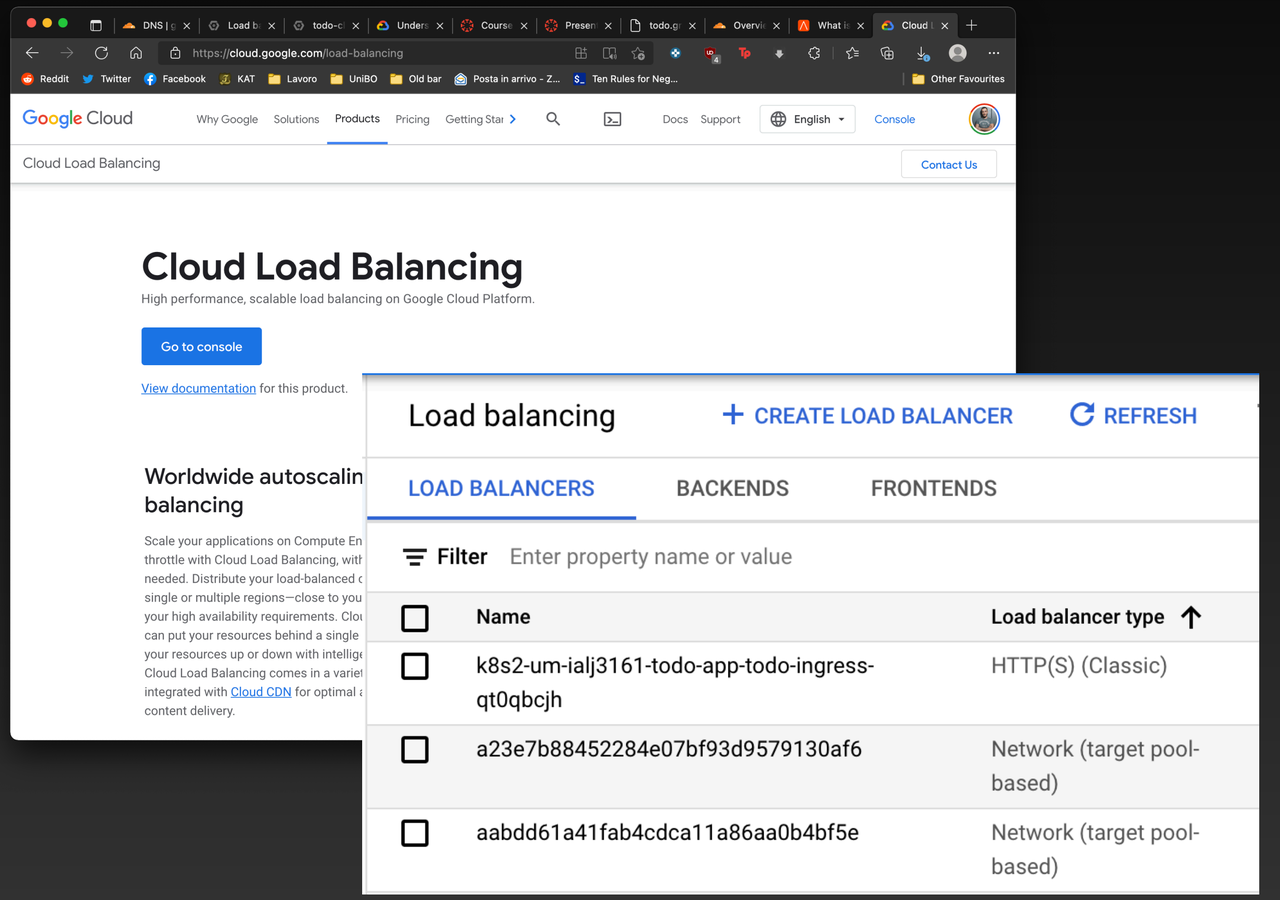
- GKE allows us to deploy the application in Google's cloud servers
- We picked the **Eemshaven, NL**, datacenter as the latency is minimal
- The cluster is deployed on **3 nodes**

Nome ↑	Stato	CPU richiesta	CPU allocabile	Memoria richiesta	Memoria allocabile
gke-todo-cluster-default-pool-62352e64-fh1h	Ready	851 mCPU	940 mCPU	588.25 MB	2.96 GB
gke-todo-cluster-default-pool-62352e64-tqtz	Ready	363 mCPU	940 mCPU	341.35 MB	2.96 GB
gke-todo-cluster-default-pool-62352e64-wivc	Ready	803 mCPU	940 mCPU	446.69 MB	2.96 GB

LoadBalancer

Distributing the requests.

- Kubernetes doesn't offer an implementation for the LoadBalancer object
- **MetalLB** is an implementation for bare-metal Kubernetes clusters, used for MicroK8s (used in the first stages of the project)
- Google Kubernetes Engine uses Google's **Cloud Load Balancer**, an efficient implementation
- The load balancers are **automatically instantiated** when a Service (type: LoadBalancer) is added



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Ingress and TLS

Managing HTTP requests and SSL

- Installing Ingress is instant on MicroK8s (microk8s enable ingress) but it can be done from manifests too
- **The TLS** configuration requires a TLS certificate, either self-signed or made by a certificate authority
- Self-signed certificates generate **errors on most browsers**, so they're not an option
- **CloudFlare** offers the possibility of a double encryption: from the server to CloudFlare proxy, from the proxy to the final user
- This requires using an **origin CA certificate** with Ingress

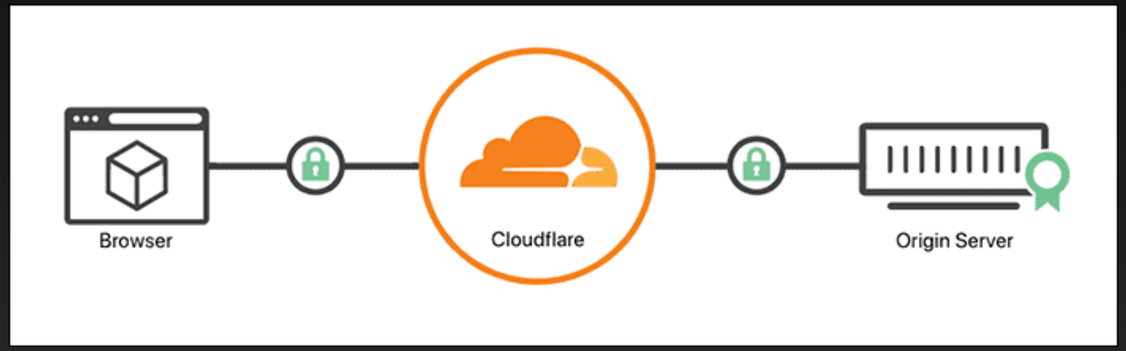
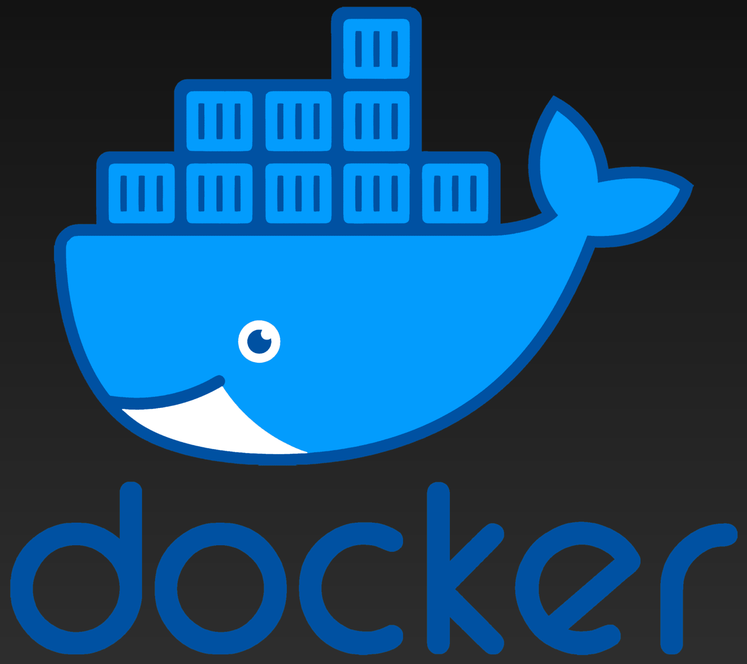


Image registry

Providing images to Kubernetes

- By default, Kubernetes pulls images from Docker Hub
- Google Kubernetes Engine provides an image registry through the **Container Registry** service
- After activating the API, it's sufficient to build and push images:

```
gcloud builds submit –tag gcr.io/todo-app-339413/todo-db:v1.0
```



Network policies

Providing images to Kubernetes

- By default, Kubernetes pods **accept traffic** from any source in the Cluster
- This is not a safe behaviour: we'd like to **isolate the pods** that don't need connections
- The DB will only be accessible by the API
- The API and the UI have to be **publicly accessible**
- In order for Network Policies to be effective, the correct option has to be enabled when creating the GKE cluster

```yaml
apiVersion: networking.k8s.io/v1
kind: NetworkPolicy
metadata:
  name: api-db-egress-network-policy
  namespace: todo-app
spec:
  podSelector:
    matchLabels:
      app: api
  egress:
  - to:
    - podSelector:
        matchLabels:
          app: db
    ports:
      - port: 3306
        protocol: TCP
  policyTypes:
  - Egress
```

Role Based Access Control

Setting up accounts and user roles

- Using **RBAC**, we can set up roles and accounts with **limited permissions** to the cluster
- We defined a **PodReader** role to allow maintainers to check the cluster pods' status
- This role has then been bound to two **Google accounts** that can manage the cluster

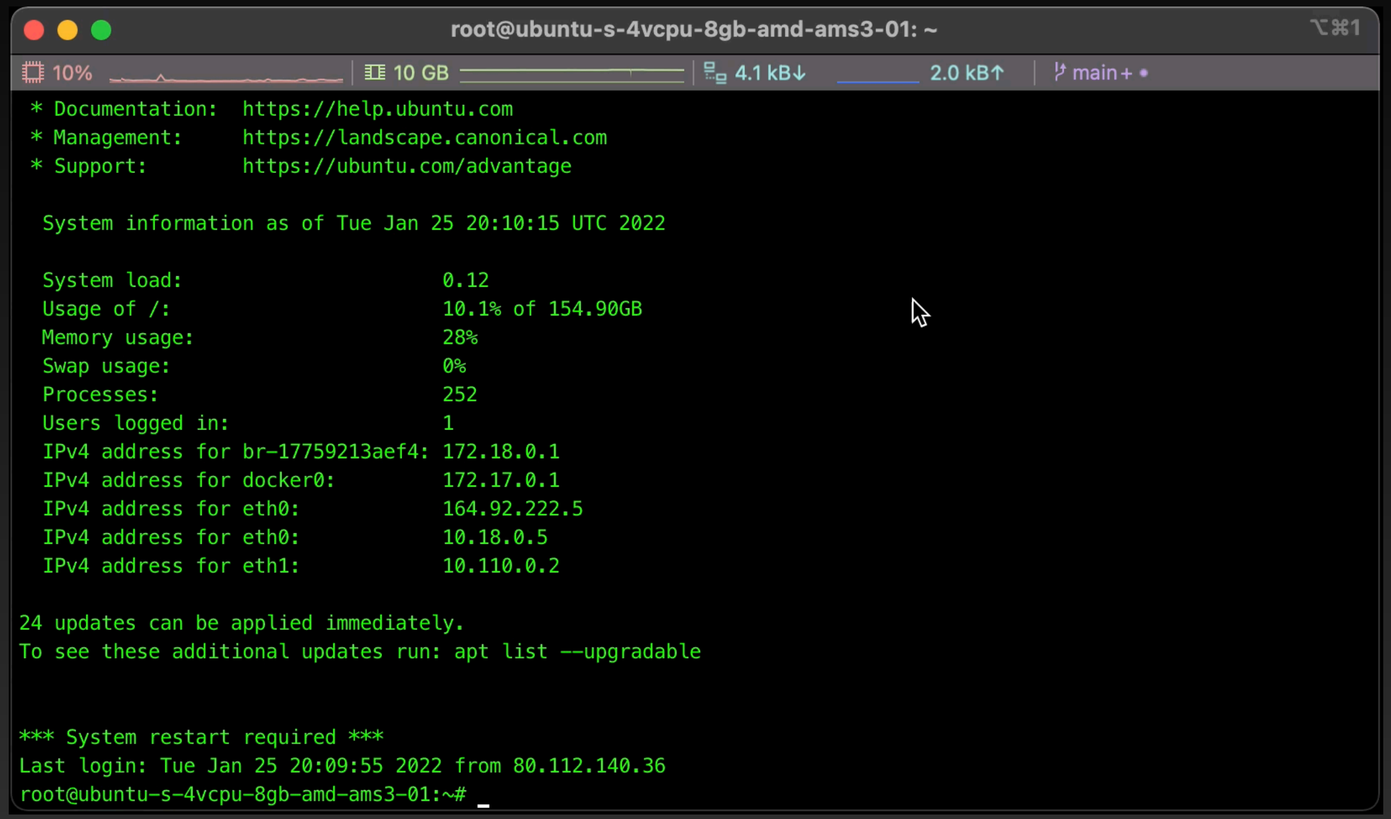
```
~/Vrije/Lab/Containerization/todo-app  main ● ?
$ kubectl auth can-i delete pods -n todo-app --as sim.montali@gmail.com
no

~/Vrije/Lab/Containerization/todo-app  main ● ?
$ kubectl auth can-i list pods -n todo-app --as sim.montali@gmail.com
yes
```

```yaml
apiVersion: rbac.authorization.k8s.io/v1
kind: RoleBinding
metadata:
  name: admin-pods-reader
  namespace: todo-app
subjects:
- kind: User
  name: b.bozorgi92@gmail.com
  namespace: todo-app
- kind: User
  name: sim.montali@gmail.com
  namespace: todo-app
roleRef:
  kind: Role
  name: pod-reader
  apiGroup: rbac.authorization.k8s.io
```

Container build and first deployment, scaling, uninstallation

Building the images

Generating the Docker images



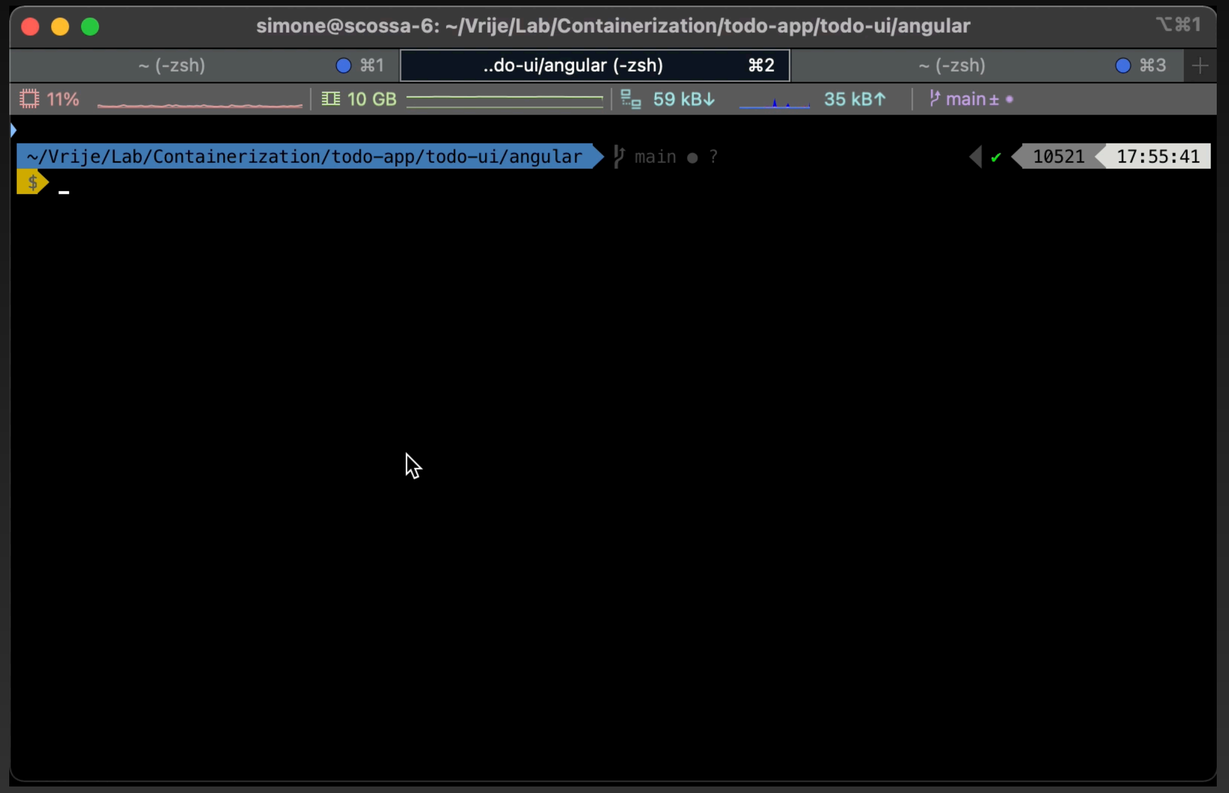
First, clone the project git repository

```
git clone git@github.com:ThreeLittleBirdsContainerized/todo-app.git
```

Building the images

Generating the Docker images

After creating a Google Kubernetes Engine cluster and activating the APIs we need,

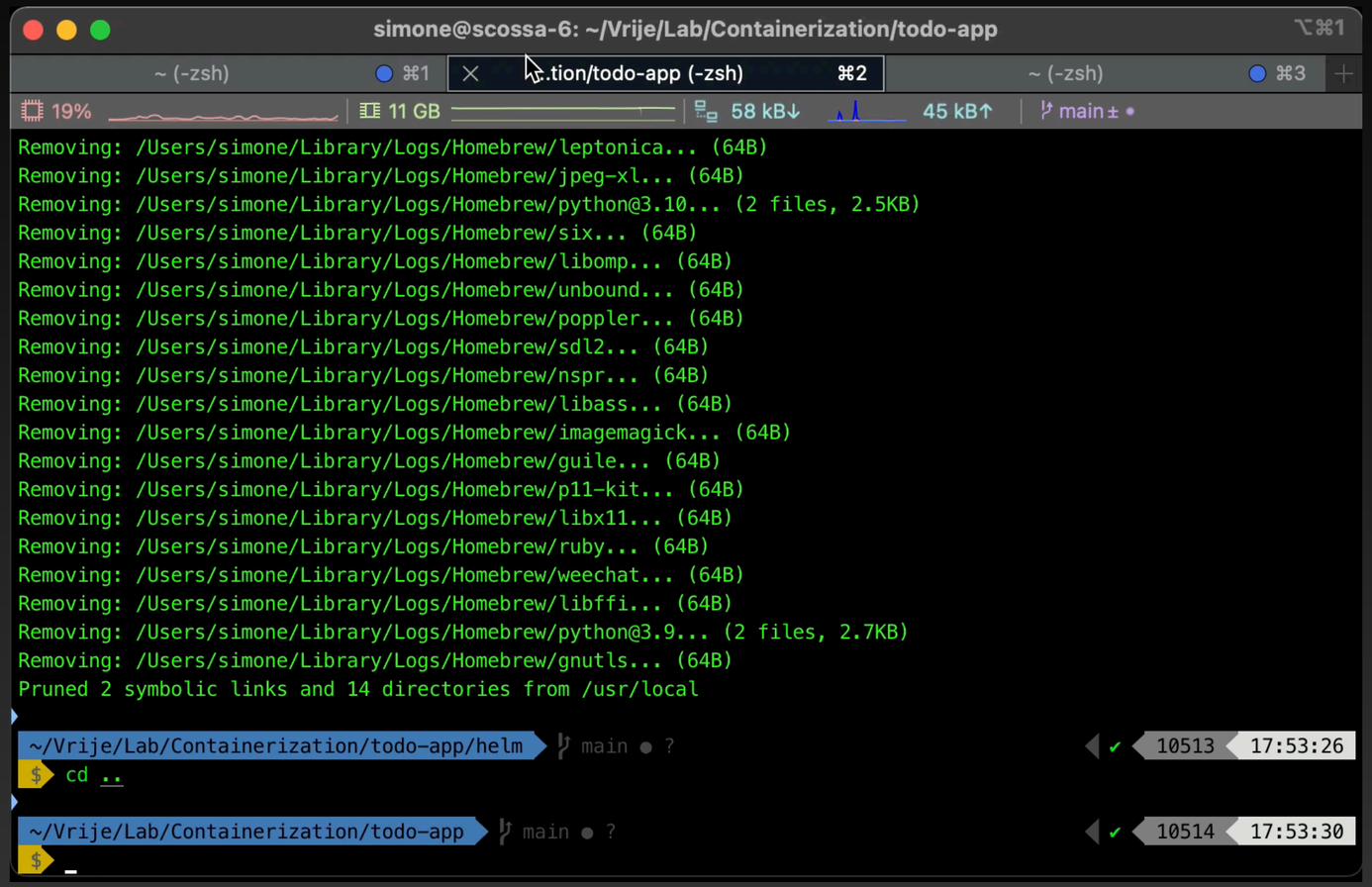


Build the Docker images and push them to GCP

```
gcloud builds submit –tag gcr.io/todo-app-339413/todo-db:v1.0
```

Installing through HELM

Starting up the cluster

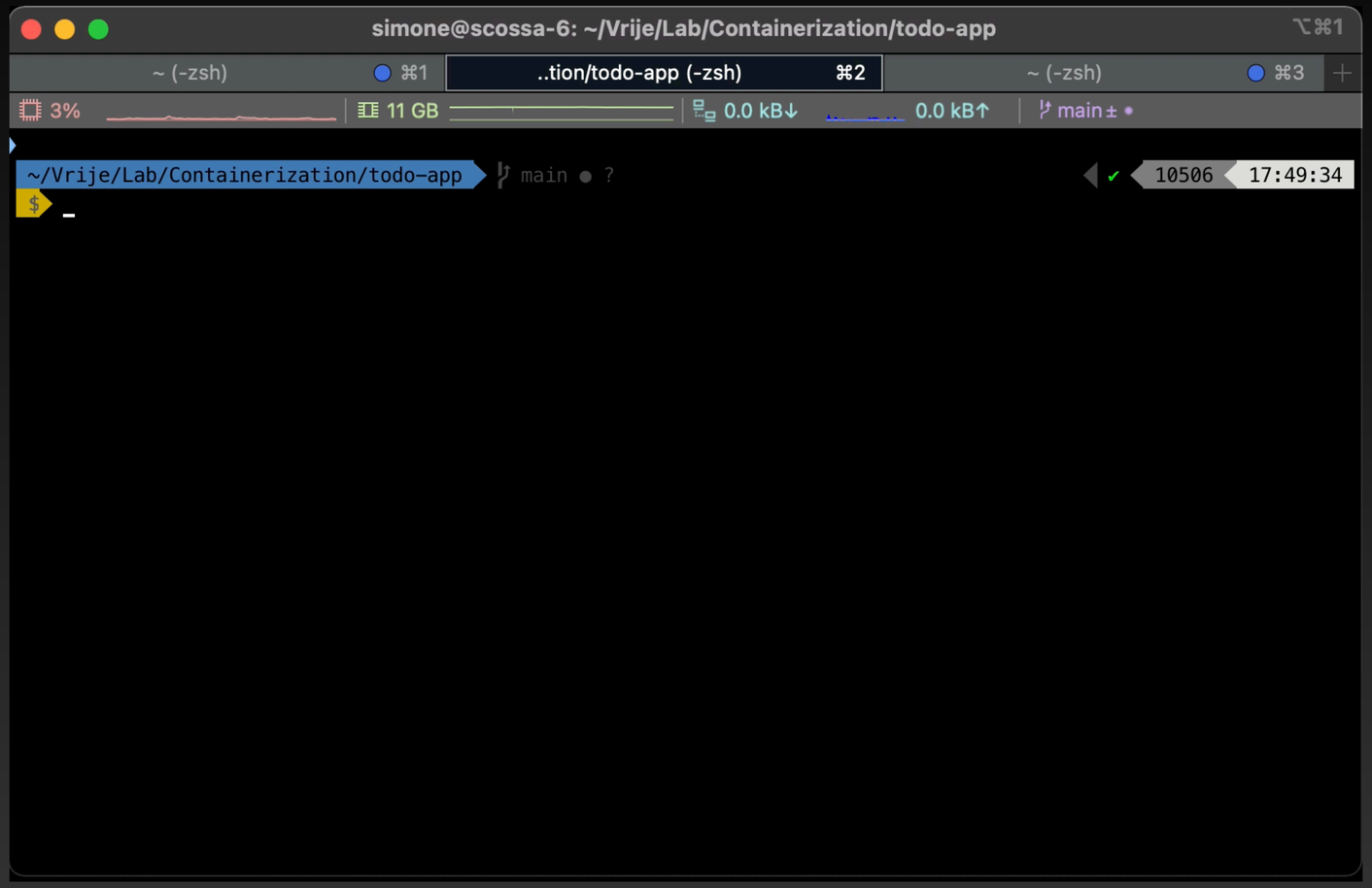


Install everything through HELM

```
helm install helm/todo-app-chart
```

Securing the HTTP requests

TLS certificates are added from CloudFlare for a 2-points encryption



Add the TLS origin certificates from CloudFlare

```
kubectl create secret tls api-cloudflare-tls --cert api.ca --key api.pk -n todo-app
kubectl create secret tls api-cloudflare-tls --cert ui.ca --key ui.pk -n todo-app
```

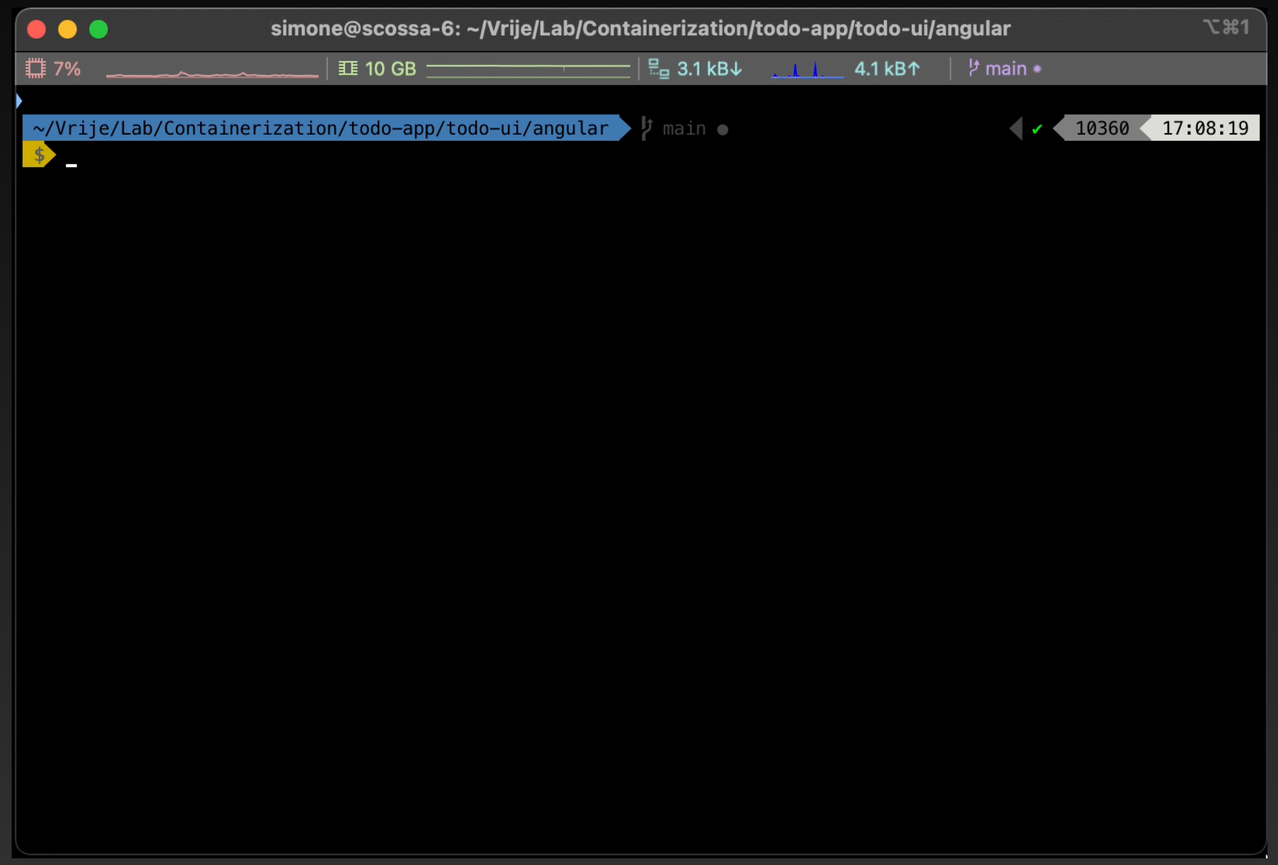
The service is now up and running!

Let’s check the UI

Scaling up the cluster

Horizontally scaling

```yaml
apiVersion: autoscaling/v2beta2
kind: HorizontalPodAutoscaler
metadata:
  name: ui-scaler
  namespace: todo-app
spec:
  scaleTargetRef:
    apiVersion: apps/v1
    kind: Deployment
    name: ui-deployment
  minReplicas: 2
  maxReplicas: 10
  metrics:
  - type: Resource
    resource:
      name: cpu
      target:
        type: Utilization
        averageUtilization: 50
```



Deployments scale automatically, but to do it manually:

```
kubectl scale deployment/api-deployment --replicas=10 -n todo-app
```

Uninstalling

Removing our software

To uninstall the app, it's sufficient to run an uninstall through HELM

```
helm uninstall todo
```

and delete the images:

```
gcloud container images delete gcr.io/todo-app-339413/todo-api
gcloud container images delete gcr.io/todo-app-339413/todo-ui
gcloud container images delete gcr.io/todo-app-339413/todo-db
```

Application upgrade and re-deployment

Deployment rollout

Upgrading the project

- Editing and re-building is easy:
  - Build the images (which builds the Angular project too)

```
gcloud builds submit --tag gcr.io/todo-app-339413/todo-api:v1.2
```

  - And change the image version in the deployment

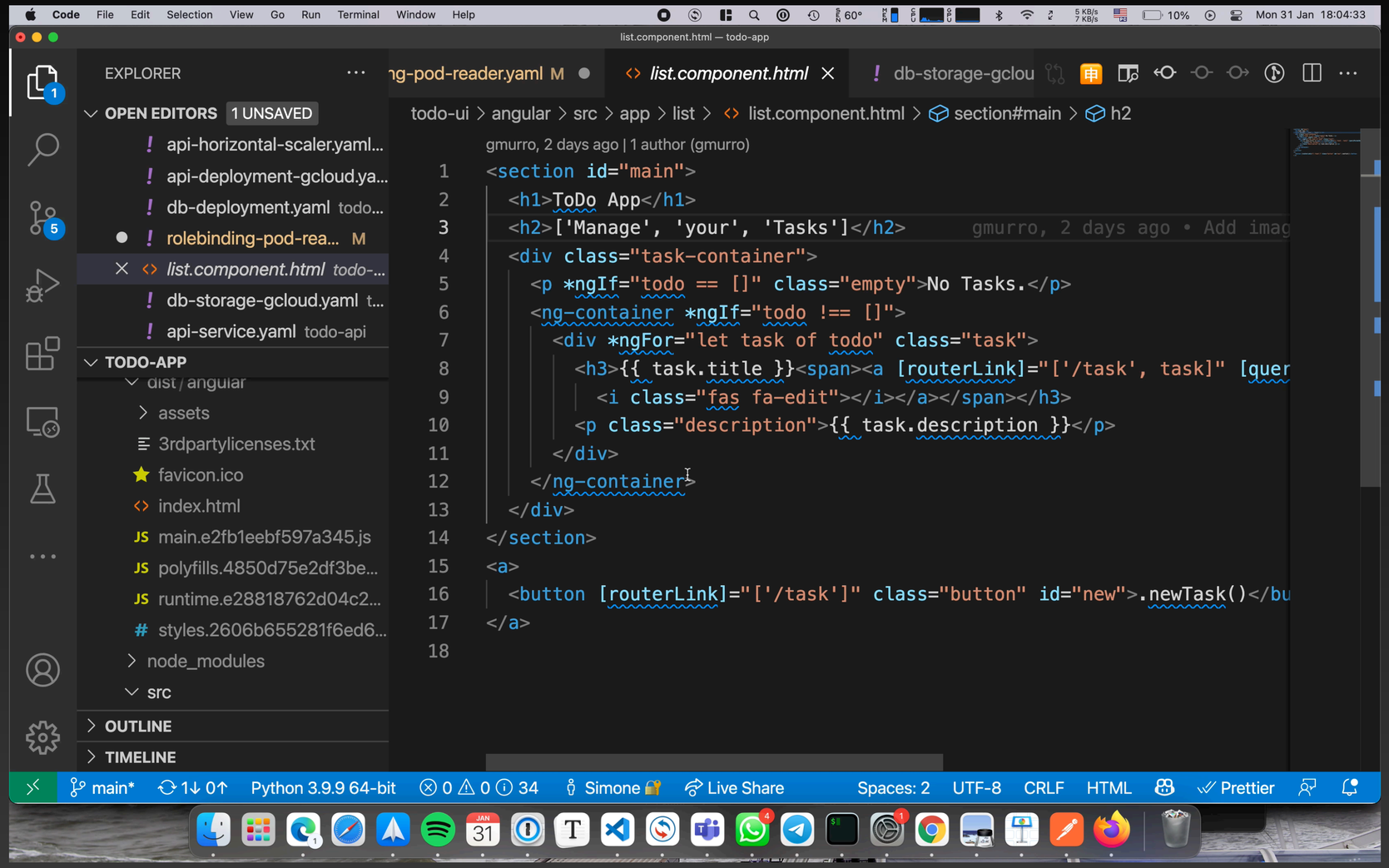
```
kubectl set image deployment/api-deployment todo-api=gcr.io/todo-app-339413/
todo-api:v1.2 -n todo-app
```

  - Or use HELM:

```
helm upgrade todo helm/todo-app-chart
```

Deployment rollout

Upgrading the project



Canary rollout

Upgrading the project

- To perform a canary rollout, we'll serve the new version just to a % of users
  - Build the new image (which builds the Angular project too)

```
gcloud builds submit --tag gcr.io/todo-app-339413/todo-api:v1.3
```

  - Create a new deployment with less Replicas and the new image

```
kubectl apply -f new-api-deployment.yml
```

  - Downscale the old deployment

```
kubectl scale --replicas=9 deploy api-deployment
```

  - Link both deployments to the Service (LoadBalancer)

  - Re-apply the service

```
kubectl apply -f api-service.yml
```

GitHub Actions

Automating the process

- **GitHub Actions** allow us to automatically deploy the updates at each push to the repository
- Defining a YAML configuration that **builds** the Angular code, the **container image** and deploys to GKE
- It's required to get an **access token from GKE** and save it into the GitHub secrets

```yaml
name: Build and Deploy UI to GKE

on:
  push:
    branches:
      - main

env:
  PROJECT_ID: ${{ secrets.GKE_PROJECT }}
  GKE_CLUSTER: todo-cluster    # Add your cluster name here.
  GKE_ZONE: europe-west4-b   # Add your cluster zone here.
  DEPLOYMENT_NAME: ui-deployment # Add your deployment name here.
  IMAGE: todo-ui

jobs:
  setup-build-publish-deploy:
    name: Setup, Build, Publish, and Deploy UI
    runs-on: ubuntu-latest
    environment: production

    steps:
    - name: Checkout
      uses: actions/checkout@v2

    # Setup gcloud CLI
    - uses: google-github-actions/setup-gcloud@94337306dda8180d967a56932ceb4ddcf01edae7
      with:
        service_account_key: ${{ secrets.GKE_SA_KEY }}
        project_id: ${{ secrets.GKE_PROJECT }}

    # Configure Docker to use the gcloud command-line tool as a credential
    # helper for authentication
    - run: |-
        gcloud --quiet auth configure-docker

    # Get the GKE credentials so we can deploy to the cluster
    - uses: google-github-actions/get-gke-credentials@fb08709ba27618c31c09e014e1d8364b02e5042e
      with:
        cluster_name: ${{ env.GKE_CLUSTER }}
        location: ${{ env.GKE_ZONE }}
        credentials: ${{ secrets.GKE_SA_KEY }}

    # Build the Angular project
    - name: Build Angular
      run: |-
        ng build
    # Build the Docker image
    - name: Build
      run: |-
        docker build \
          --tag "gcr.io/$PROJECT_ID/$IMAGE:$GITHUB_SHA" \
          --build-arg GITHUB_SHA="$GITHUB_SHA" \
          --build-arg GITHUB_REF="$GITHUB_REF" \
          .

    # Push the Docker image to Google Container Registry
    - name: Publish
      run: |-
        docker push "gcr.io/$PROJECT_ID/$IMAGE:$GITHUB_SHA"

    # Deploy the Docker image to the GKE cluster
    - name: Deploy
      run: |-
        kubectl apply -f -
        kubectl rollout status deployment/$DEPLOYMENT_NAME
        kubectl get services -o wide
```

Some numbers

How the project was built, one step at a time.

92

Commits

1

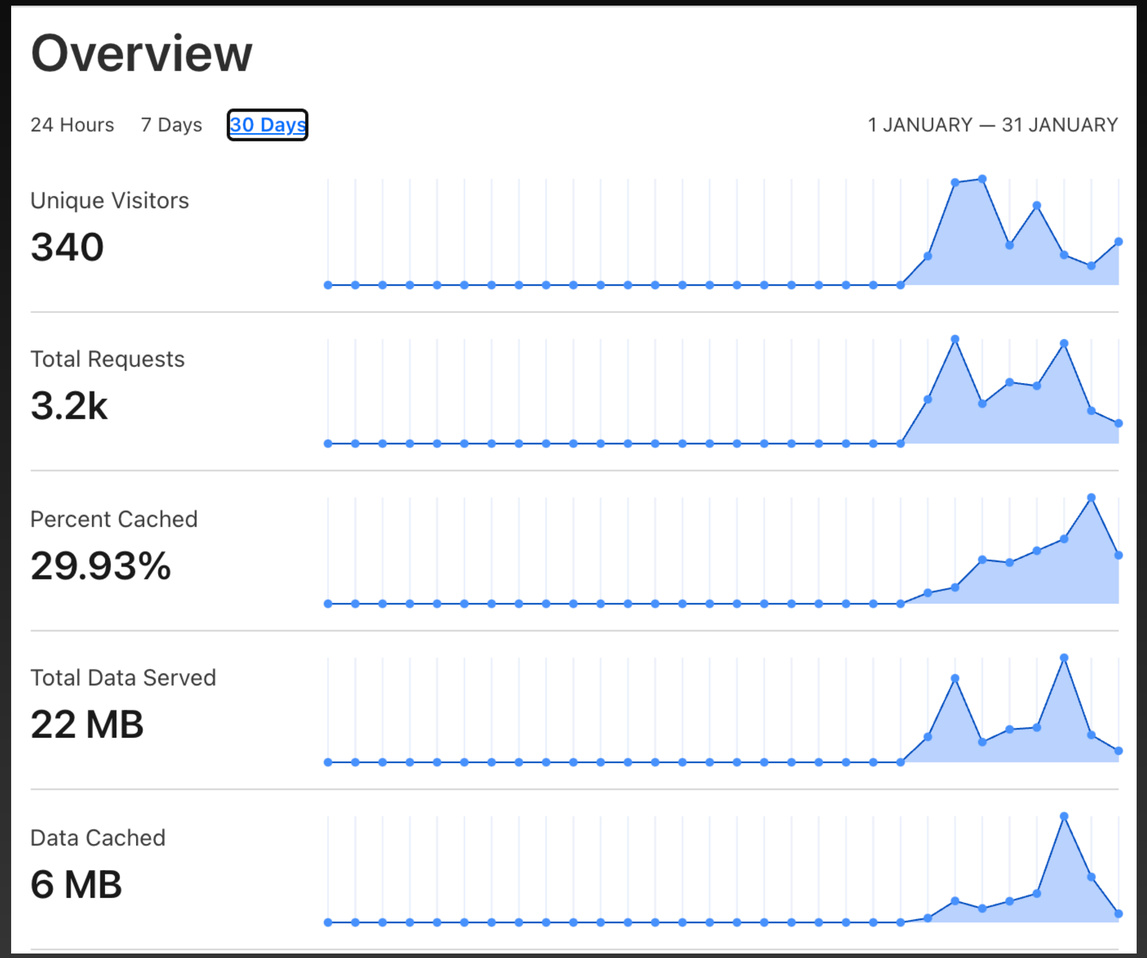
VPS

27

YML artifacts

3100

HTTP(S) requests




Thanks!