

SA II Project: Building and Scaling expressjs-mongodb-app on Kubernetes

Project Overview

Welcome to the documentation of the System Administration II course at TSBE. This project focuses on the installation and scaling of the expressjs-mongodb-app on a Kubernetes cluster.

Project Goals

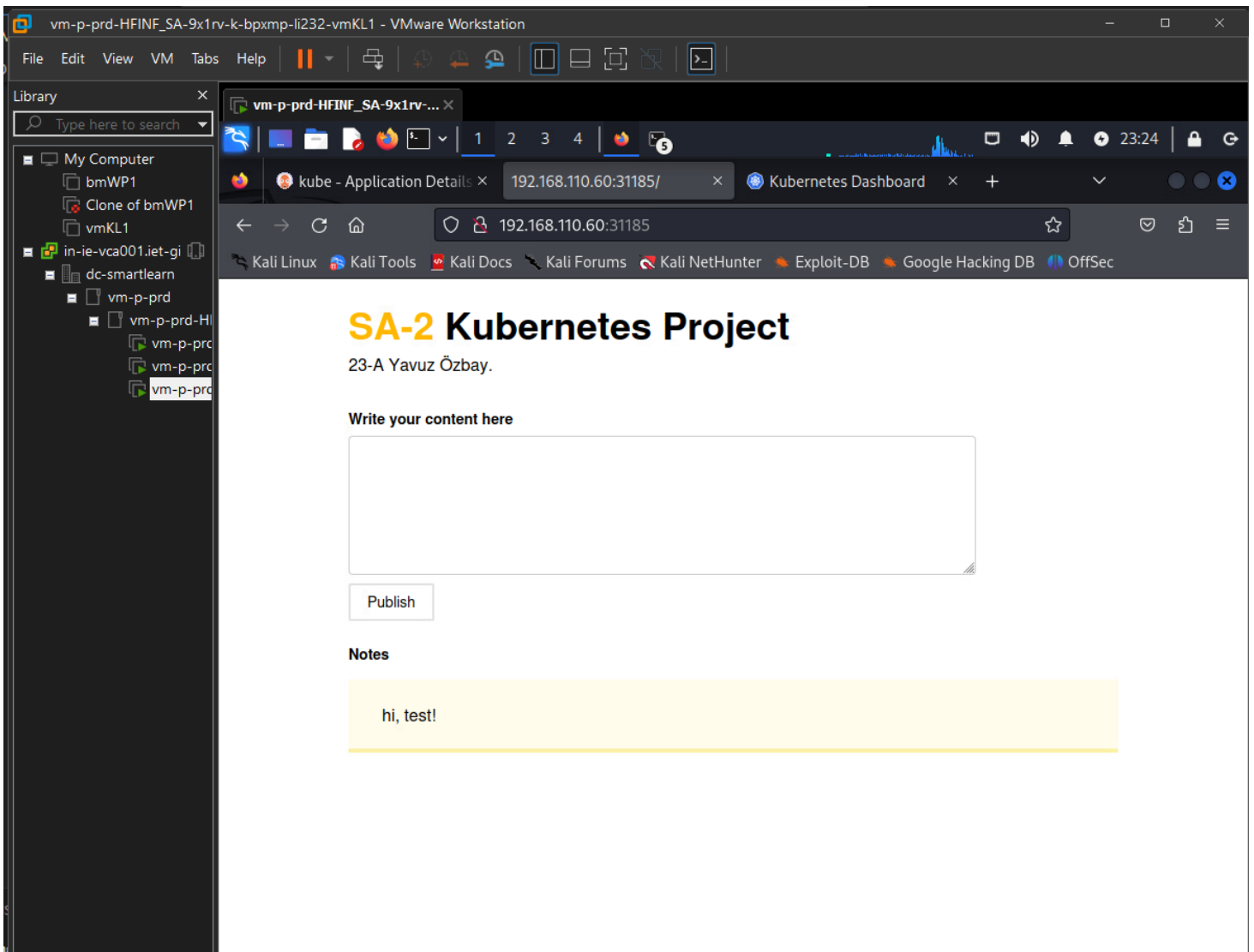
The primary objectives of this project are to set up and configure a Kubernetes cluster with the following key features:

- **Scalability:** to setup Horizontal and Vertical Pod Autoscaling in kubernetes.
- **Persistent Storage:** Implementing containers with persistent storage, specifically for a MongoDB Database.
- **Container Networking:** Establishing effective container networking with port forwarding to enable external access.
- **Security:** Configuring a secure environment to minimize potential security risks.

* Yaml files, images, express js-mongodb-app codes, dockerfile are in the main Project file. You can also check out this Kubernetes project on my github repo. -->

<https://github.com/yavuzoz/k8s-expressjs-mongodb-app/tree/main>

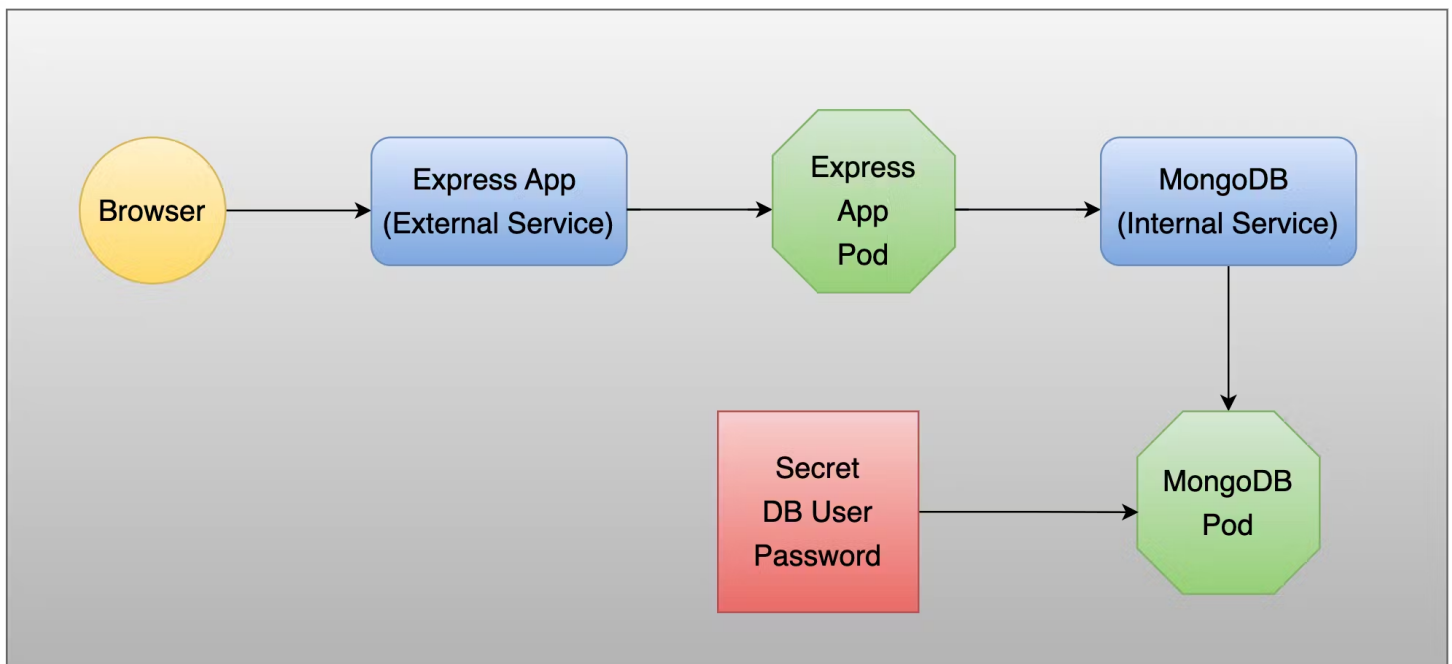
Project Display



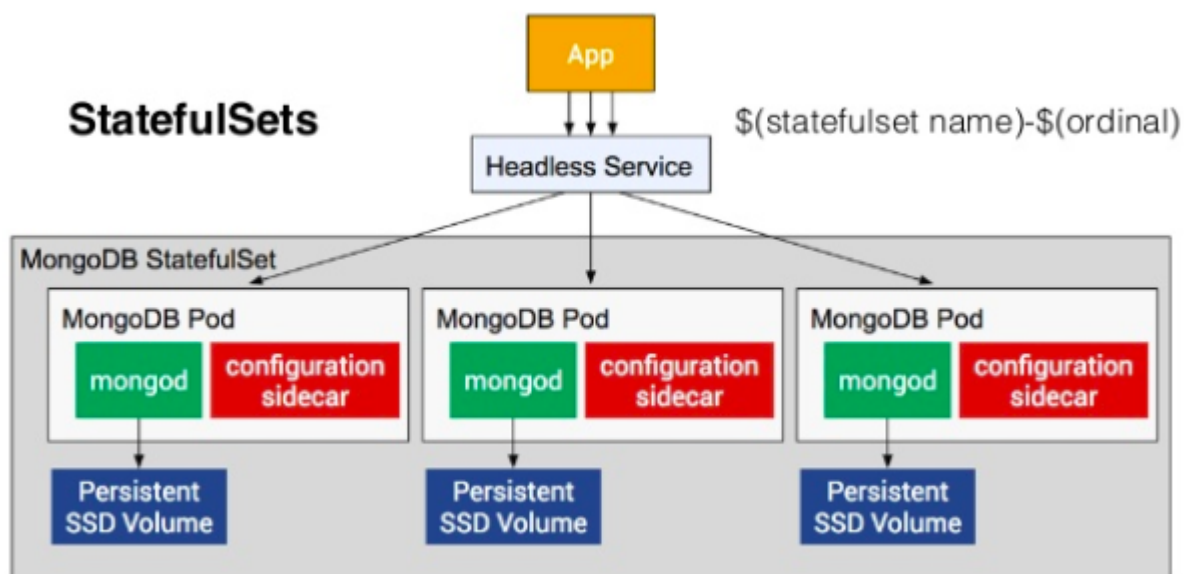
This application is a note-taking system developed using Express.js and MongoDB. It enables users to create and share textual notes through a web interface and has been Dockerized and the Docker image is available on [Docker Hub](#).

```
docker pull yavuzozbay/nodeserver:2.0.0
```

Browser Request Flow through the K8s components



MongoDB with StatefulSets on this Project



Platform & Limitations

The following virtual platform is hosted by the school to execute the project:

vmKL1

The vmKL1 is the management machine used to set up, administer, and access the Kubernetes cluster.

VM Specs:

- OS: Kali GNU/Linux
- Kernel: Linux 6.5.0-kali3-amd64
- CPU: 2 vCPUs
- RAM: 16 GB
- Storage: /dev/sda 35 GB
- Network: Access to vmLM1 & Internet
- IP: 192.168.110.70

Installed Software:

- vscode

vmLM1

The vmLM1 is the Kubernetes host itself. It will act as Control Plane (Master Node) & Data Plane (Worker Node).

VM Specs:

- OS: Ubuntu 22.04.3 LTS
- Kernel: Linux
- CPU: 4 vCPUs
- RAM: 12 GB
- Storage: /dev/sda 16 GB
- Network: Access to vmKL1 & Internet
- IP: 192.168.110.60

Installed Software:

- minikube version: v1.32.0
- Docker version 24.0.5

The container network is set up in a way that only necessary communication is allowed. UFW is active and configured. Open ports to the Kubernetes Node (vmLM1):

- 22/TCP -> SSH
- 443/TCP -> Kubernetes API
- 30703/TCP -> express-mongodb-app
- 8001/TCP -> Kubernetes Dashboard
- 31185/TCP -> Argocd (optional)

As far as the container network goes, only pods that need external access are configured with NodePort. All other pods are configured with Cluster IP for Kubernetes internal-only communication.

Manual Setup Guide

vmKL1

```
# Update the System
sudo apt update -y
sudo apt upgrade -y
```

vmLM1

```
# Port forward , Enable & open necessary ports on the server firewall
sudo ufw allow 22/tcp
sudo ufw allow 443/tcp
sudo ufw allow 80
sudo ufw allow 8001 # for minikube dashboard
sudo ufw allow 30703 # for express-mongodb-app
sudo ufw allow 31185 # for ArgoCD (optional)
sudo ufw enable
```

Enable SSH Access

Port 22

```
# Restart sshd
sudo systemctl restart sshd
```

```
# Update the System
sudo apt update -y
sudo apt upgrade -y
```

```
# Install Docker
sudo apt install docker.io
docker --version # Check Docker version
```

```
# Download Minikube
curl -LO https://storage.googleapis.com/minikube/releases/latest/minikube-linux-amd64
sudo install minikube-linux-amd64 /usr/local/bin/minikube
minikube version # Check Minikube version
```

```
# Install Kubectl
sudo snap install kubectl --classic
kubectl version # Check Kubectl version

# Start Minikube with Docker driver
minikube start --driver=docker
sudo usermod -aG docker $USER && newgrp docker
minikube node add --worker
kubectl label node <node_name> node-role.kubernetes.io/worker=worker
kubectl get nodes
```

```
# Update local apt cache
sudo apt update
```

```
# Create a namespace for the app
kubectl create namespace expressjs-mongodb-app
```

```
# Create a project folder for deployment
mkdir ~/kube
cd kube
```

```
# create project yaml files
sudo nano mongo-config.yaml
sudo nano mongo.yaml
sudo nano mongo-hpa.yaml
sudo nano server.yaml
sudo nano server-hpa.yaml
```

```
# apply project yaml files
kubectl apply -f mongo-config.yaml
kubectl apply -f mongo.yaml
kubectl apply -f mongo-hpa.yaml
kubectl apply -f server.yaml
kubectl apply -f server-hpa.yaml
```

or Easy to Apply, you can automaticly with ArgoCD tool all yaml files to apply (optional)

```
# create argocd
kubectl create namespace argocd
kubectl apply -n argocd -f https://raw.githubusercontent.com/argoproj/argo-cd/stable/manifests/:
```

Argocd server LoadBalancer to external service

```
kubectl patch svc argocd-server -n argocd -p '{"spec": {"type": "LoadBalancer"}}'
```

Argocd server NodePort to external service

```
kubectl patch svc argocd-server -n argocd -p '{"spec": {"type": "NodePort"}}'
```

ArgoCD password to take(username : admin)

```
kubectl -n argocd get secret argocd-initial-admin-secret -o jsonpath="{.data.password}" | base64
```

ArgoCD services list

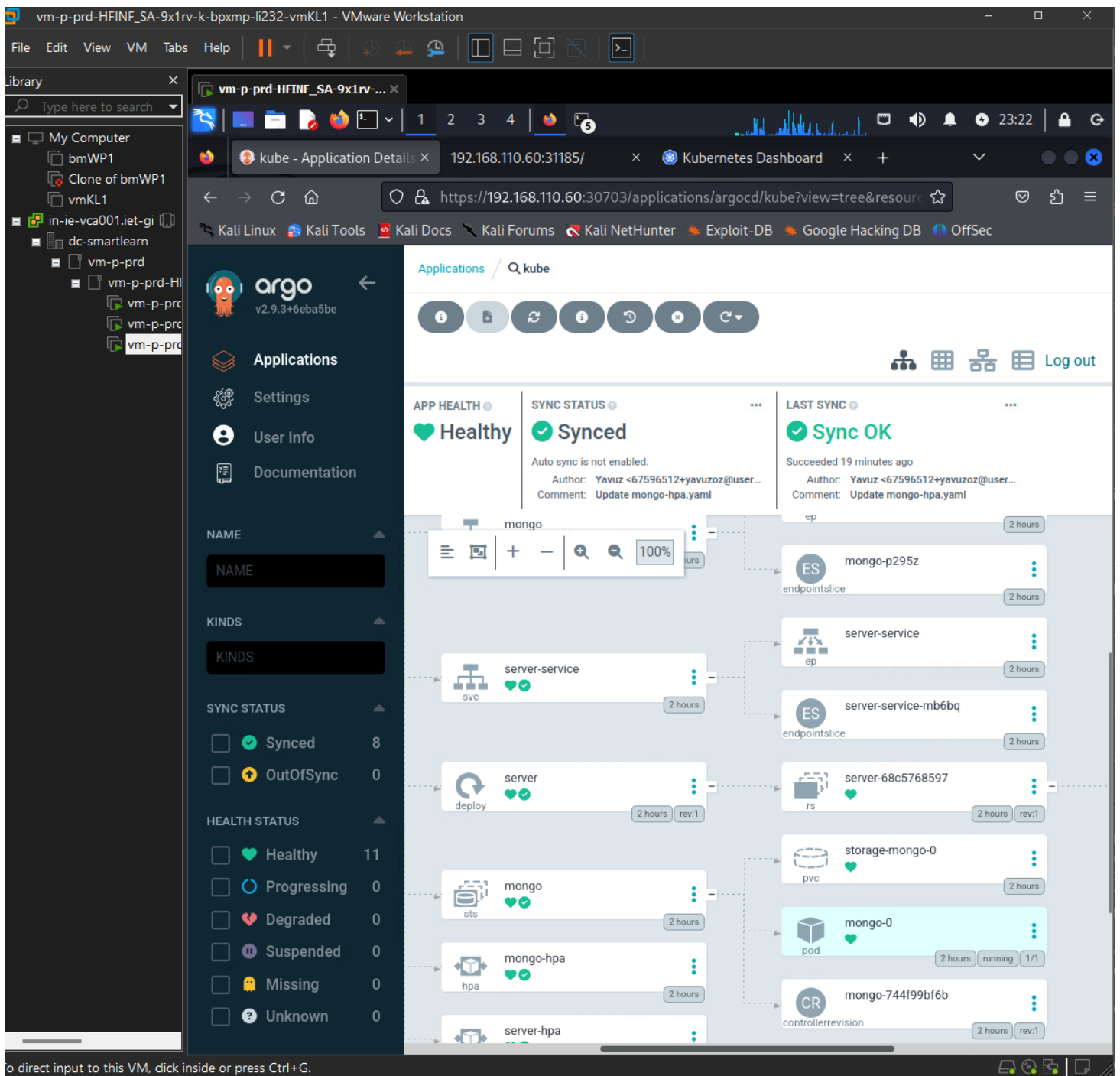
```
kubectl get services -n argocd
```

output:

argocd-server LoadBalancer 10.105.157.43 80:32033/TCP,443:32743/TCP

ArgoCD server Port forwarding

```
sudo socat TCP-LISTEN:31185,fork TCP:192.168.49.2:32743
```



```
kubectl get service
```

```
kubectl get pods
```

output service:

```
NAME TYPE CLUSTER-IP EXTERNAL-IP PORT(S) AGE
```

```
kubernetes ClusterIP 10.96.0.1 443/TCP 18m
```

```
mongo ClusterIP 10.103.129.64 27017/TCP 34s
```

```
server-service NodePort 10.99.192.106 80:30285/TCP 34s
```


output pods:

| NAME | READY | STATUS | RESTARTS | AGE |
|------|-------|--------|----------|-----|
|------|-------|--------|----------|-----|

| | | | | |
|---------|-----|---------|---|------|
| mongo-0 | 1/1 | Running | 0 | 110m |
|---------|-----|---------|---|------|

| | | | | |
|-------------------------|-----|---------|---|------|
| server-68c5768597-xspgk | 1/1 | Running | 0 | 110m |
|-------------------------|-----|---------|---|------|

```
# Start server service
minikube service server-service
minikube service server-service --url

# server-service port forwarding
sudo socat TCP-LISTEN:30703,fork TCP:192.168.49.2:30285

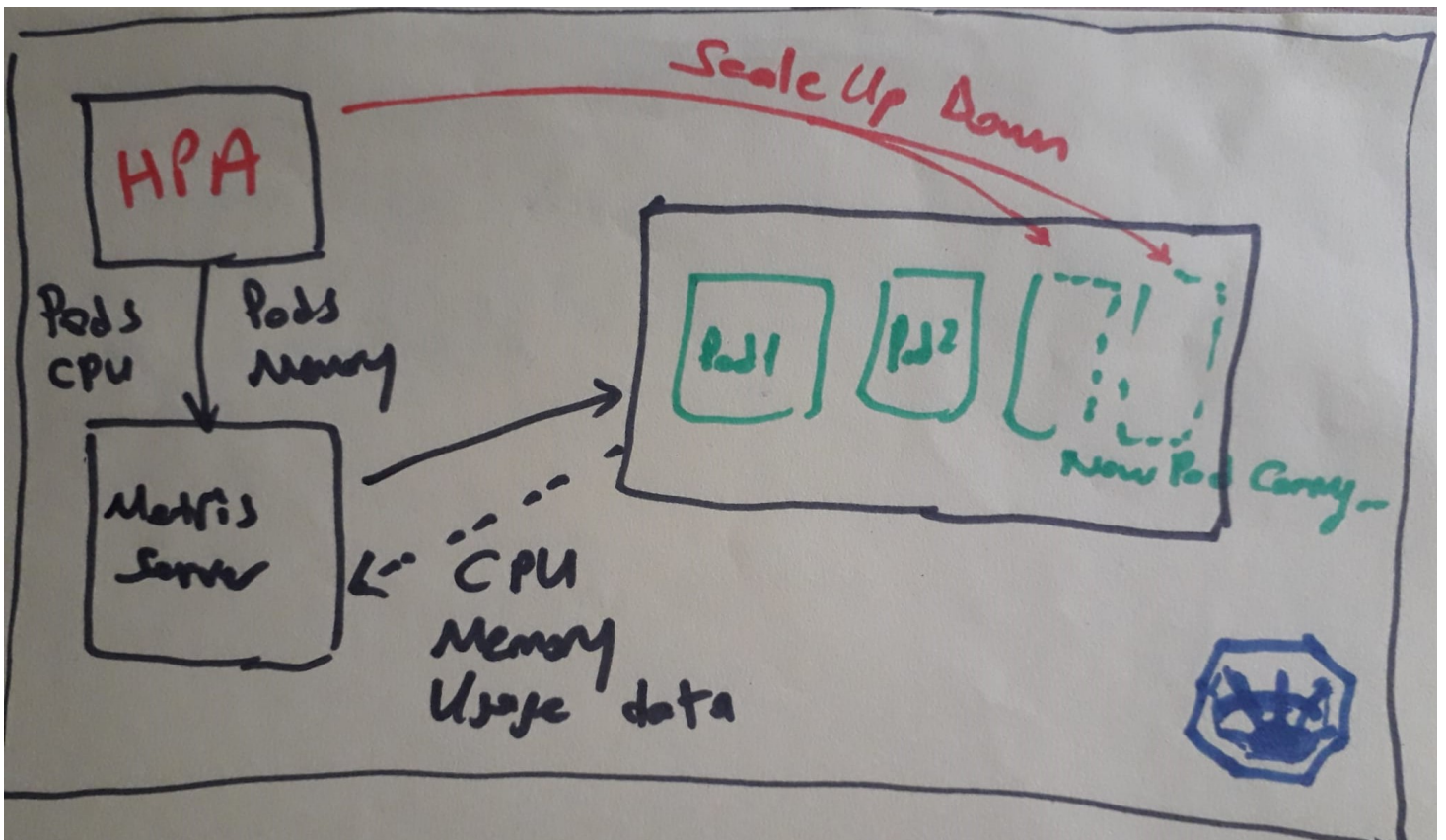
# Start dashboard
minikube dashboard
minikube dashboard --url=true
kubectl proxy --address='0.0.0.0' --disable-filter=true
```

To send some load(http request) to the application i used hey tool

```
# for Testing HPA
sudo apt install hey
```

Setup Horizontal Pod Autoscaling in kubernetes:

Autoscaling is one of the great features of kubernetes allowing us to automatically horizontally scale nodes or pods depending on the demand or load on our web application, it even allows us to do vertical autoscaling in case of pods.



Horizontal Pod Autoscaler(HPA)?

I define my deployment in server.yaml set the number of number replicas like:

```
apiVersion: apps/v1
kind: Deployment
metadata:
  name: server
spec:
  replicas: 1
  selector:
    matchLabels:
      app: server
  template:
    metadata:
      labels:
        app: server
    spec:
      containers:
        - name: server
          image: yavuzozbay/nodeserver:2.0.0
          ports:
            - containerPort: 3000
          env:
            - name: MONGO_URL
              valueFrom:
                configMapKeyRef:
                  name: mongo-config
                  key: MONGO_URL
            imagePullPolicy: Always
      resources:
        requests:
          memory: "128Mi"
          cpu: "100m"
        limits:
          memory: "264Mi"
          cpu: "250m"
```

With the HPA resource defined we can tune up the number of replicas up and down depending on CPU usage or memory usage.

```
apiVersion: autoscaling/v1
kind: HorizontalPodAutoscaler
metadata:
  name: server-hpa
spec:
  scaleTargetRef:
    apiVersion: apps/v1
    kind: Deployment
    name: server
  minReplicas: 1
  maxReplicas: 10
  targetCPUUtilizationPercentage: 50
```

The main components of the file definition for hpa are:

- `scaleTargetRef.name`- which points to our deployment name.
- `minReplicas` - minimum number of replicas running at all time.
- `maxReplicas` - maximum number of replicas that HPA can scale up to. It sets the upper limit and pods cannot be scaled up more than `maxReplicas` number.
- `targetCPUUtilizationPercentage` - this is the threshold of CPU resource usage on the pod. When the threshold is hit the HPA adds a new pod. We have set it scale if CPU usage crosses 50%.
- `targetCPUUtilizationPercentage`- this is a similar threshold but for memory utilization.

How HPA works?

For hpa to work it needs to have access to metrics like CPU and memory usage of our kubernetes pod component. The metrics are supplied through metrics server which pulls the usage out of the pods. HPA can then query metrics server with the latest usage information about CPU and memory and then scale up according to the values set in our `server-hpa.yaml`.

Installing metrics-server

First we need to install metrics server that will query the pod for CPU and Memory usage. On minikube it can be done by :

```
minikube addons enable metrics-server
```

or for other clusters it can be installed with a `kubectl` deployment command.

This installs a metrics-server inside the `kube-system` namespace and can be checked via:

```
kubectl get pods -n kube-system | grep metrics-server
```

Output:

| | | | | |
|--------------------------------|-----|---------|---|------|
| metrics-server-d9b576748-rr6vb | 1/1 | Running | 2 | 4h5m |
|--------------------------------|-----|---------|---|------|

Setting up HPA

Lets quickly install hpa by just running:

```
kubectl apply -f server-hpa.yaml
```

This will setup the HPA resource to track server app deployment and to check if its setup just run:

```
kubectl get hpa server-hpa
```

| NAME | REFERENCE | TARGETS | MINPODS | MAXPODS | REPLICAS | AGE |
|------------|-------------------|---------|---------|---------|----------|-----|
| server-hpa | Deployment/server | 1%/50% | 1 | 10 | 1 | 49m |

Testing HPA

To test if HPA actually scales the pods, lets try to put some load on our application. In the deployment server.yaml i have also setup some default resource limits on our pods like :

```
resources:
  requests:
    memory: "128Mi"
    cpu: "100m"
  limits:
    memory: "264Mi"
    cpu: "250m"
```

I have added a /compute to the demo nodejs application with some non-blocking nodejs code so that we can call the endpoint multiple times and it ends up simulating a more realistic load situation by doing a heavy calculation.

Test Result :

After we are able to sustain the load for some time the HPA comes into action and increases the pod replica count to our specified number until the load gets back to normal and then brings it down to minimum number.

initial state

The screenshot shows the Kubernetes dashboard interface. The top navigation bar includes the Kubernetes logo, a dropdown menu set to 'default', a search bar, and a notification bell. The left sidebar contains a menu with categories: Workloads (Cron Jobs, Daemon Sets, Deployments, Jobs, Pods, Replica Sets, Replication Controllers, Stateful Sets), Service (Ingresses, Ingress Classes, Services), Config and Storage (Config Maps, Persistent Volume Claims, Secrets, Storage Classes), and Cluster (Cluster Role Bindings, Cluster Roles, Events, Namespaces, Network Policies, Nodes, Persistent Volumes, Role Bindings, Roles).

The main content area displays four sections:

- Replica Sets:** Shows two green circles representing running pods, each labeled 'Running: 1'.
- Stateful Sets:** Shows a single green circle representing a running pod, labeled 'Running: 1'.
- Deployments:** A table with columns: Name, Images, Labels, Pods, and Created. It lists a deployment named 'server' using the image 'yavuzozbay/node:server:2.0.0' with 1 pod running.
- Pods:** A table with columns: Name, Images, Labels, Node, Status, Restarts, CPU Usage (cores), and Memory Usage (bytes). It lists two pods: 'server-68c5768597-f9br4' (Running, 97.00m CPU, 29.55Mi Memory) and 'mongo-0' (Running, 166.00m CPU, 184.84Mi Memory).
- Replica Sets:** A table with columns: Name, Images, Labels, Pods, and Created. It lists a replica set named 'server-68c5768597' using the image 'yavuzozbay/node:server:2.0.0' with 1 pod running.

With HTTP Requests

Simulating load on the deployment pods

```
hey -c 2 -n 1 -z 5m http://192.168.49.2:30285/compute
```

kubernetes

default

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Cluster Roles

Events

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Network Policies

Nodes

Persistent Volumes

Role Bindings

| Name | Images | Labels | Node | Status | Restarts | CPU Usage (cores) | Memory Usage (bytes) |
|-------------------------|------------------------------|---|----------|---------|----------|-------------------|----------------------|
| server-68c5768597-b2k6c | yavuzozbay/node-server:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Running | 0 | 34.00m | 30.91Mi |
| server-68c5768597-8n4fw | yavuzozbay/node-server:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Running | 0 | 231.00m | 194.98Mi |
| server-68c5768597-k55j8 | yavuzozbay/node-server:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Running | 0 | 37.00m | 26.81Mi |
| server-68c5768597-sqvpp | yavuzozbay/node-server:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Running | 0 | 39.00m | 26.73Mi |
| server-68c5768597-f9br4 | yavuzozbay/node-server:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Running | 2 | 56.00m | 26.90Mi |
| mongo-0 | mongo:6.0.2-focal | app: mongo apps.kubernetes.io/pod-index: 0 controller-revision-hash: mongo-744f99bf6b Show all | minikube | Running | 0 | 18.00m | 213.20Mi |

Replica Sets

| Name | Images | Labels | Pods | Created |
|-------------------|------------------------------|--|-------|---------|
| server-68c5768597 | yavuzozbay/node-server:2.0.0 | app: server pod-template-hash: 68c5768597 | 5 / 5 | 6.m |

Stateful Sets

| Name | Images | Labels | Pods | Created |
|-------|-------------------|--------|-------|---------|
| mongo | mongo:6.0.2-focal | - | 1 / 1 | 6.m |

Once the CPU load flattens down to normal the extra new pods are removed.

kubernetes
default
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🔔

Workloads

Workloads

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Replica Sets

| Name | Images | Labels | Pods | Created ↑ |
|--------|-----------------------|--------|-------|-----------------|
| server | yavuzozbay/node:2.0.0 | - | 4 / 1 | .19.minutes ago |

| Name | Images | Labels | Node | Status | Restarts | CPU Usage (cores) | Memory Usage (bytes) | Created ↑ |
|-------------------------|-----------------------|---|----------|-------------|----------|-------------------|----------------------|----------------|
| server-68c5768597-f5pl9 | yavuzozbay/node:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Terminating | 0 | 1.00m | 27.90Mi | 2.minutes ago |
| server-68c5768597-5crj | yavuzozbay/node:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Terminating | 0 | 1.00m | 153.64Mi | 4.minutes ago |
| server-68c5768597-9sj8j | yavuzozbay/node:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Running | 0 | 1.00m | 26.16Mi | 4.minutes ago |
| server-68c5768597-sqvpp | yavuzozbay/node:2.0.0 | app: server pod-template-hash: 68c5768597 | minikube | Terminating | 1 | 1.00m | 28.59Mi | 14.minutes ago |
| mongo-0 | mongo:6.0.2-focal | app: mongo apps.kubernetes.io/pod-index: 0 controller-revision-hash: mongo-744f99bf6b | minikube | Running | 0 | 12.00m | 219.36Mi | 19.minutes ago |

| Name | Images | Labels | Pods | Created ↑ |
|------|--------|--------|------|-----------|
|------|--------|--------|------|-----------|

Happy Coding! 🚀

Thank you for exploring our Kubernetes project. We hope you find it insightful and useful. If you have any questions, feedback, or ideas for improvement, feel free to reach out. Remember: "Legends never die, they just update !"

Happy coding, and may your Kubernetes journey be smooth and successful!