

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

Project Overview

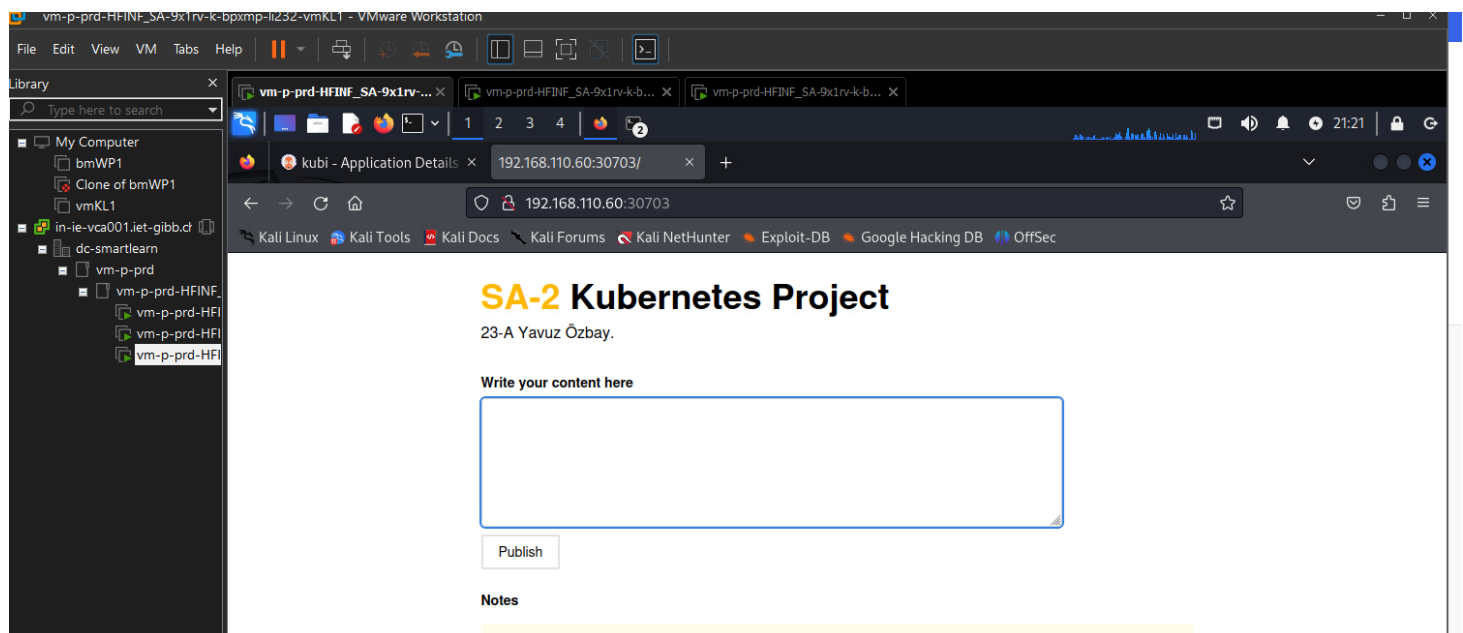
Welcome to the documentation of the System Administration II course at TSBE. This project focuses on the installation and scaling of the expressjs-mongodb-app on a Kubernetes cluster.

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 V 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.

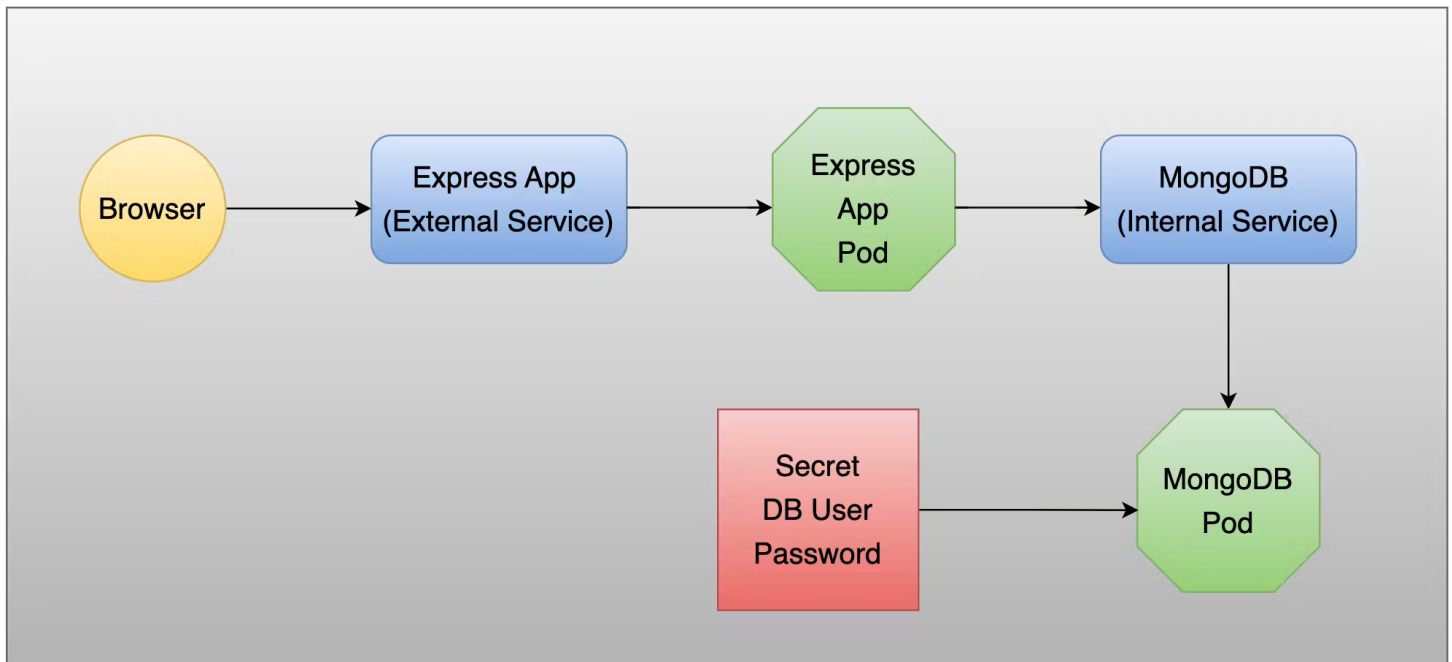
Project Display



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

 mongoDB-architectur

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

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

# 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 nodejs-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
```

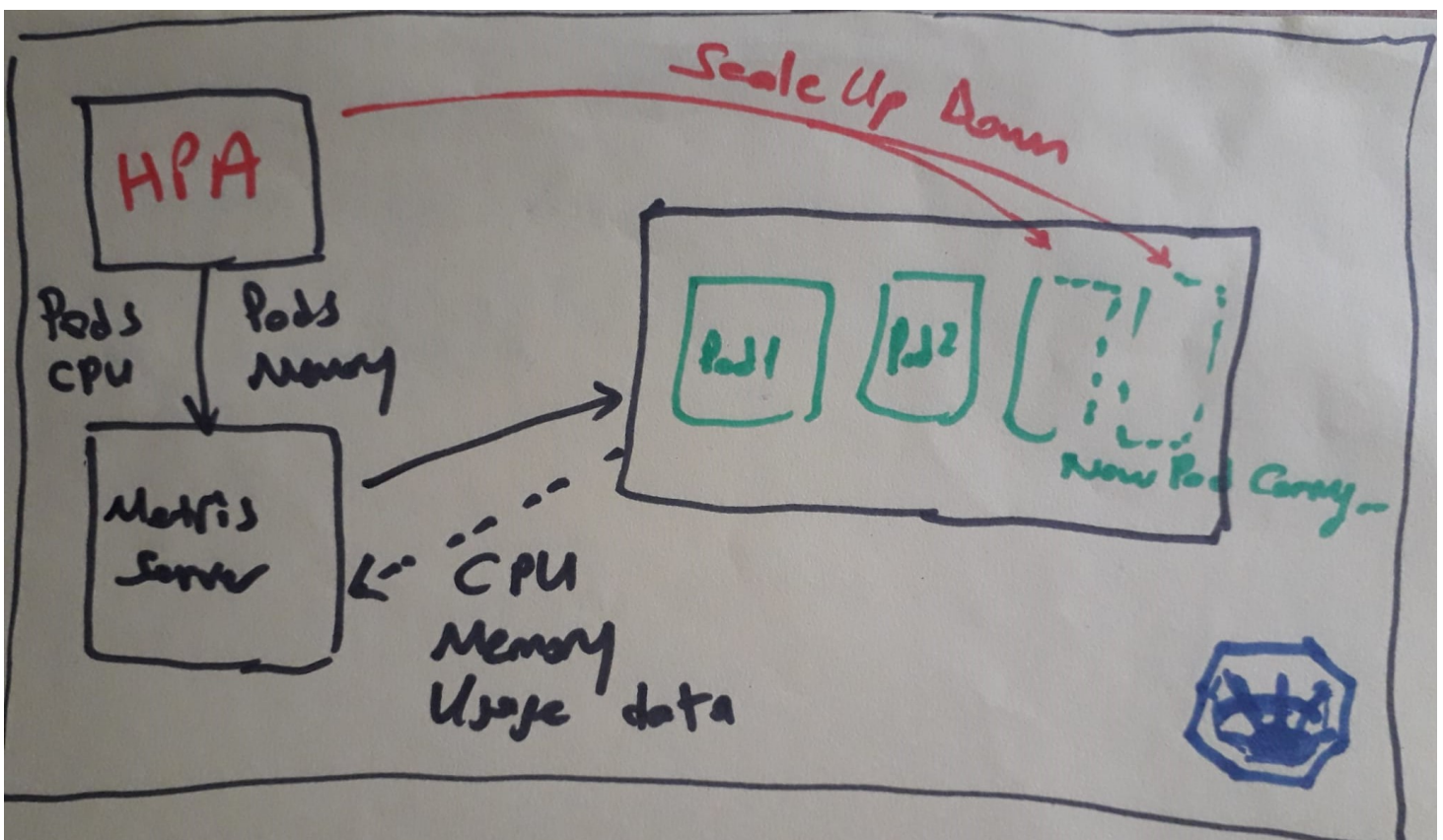
```
# apply project yaml files
kubectl apply -f mongo-config.yaml
kubectl apply -f mongo.yaml
kubectl apply -f mongo-hpa.yaml
kubectl apply -f server.yaml
kubectl apply -f server-hpa.yaml
```

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

# Start dashboard
minikube dashboard
```

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
```

output:

NAME	REFERENCE	TARGETS	MINPODS	MAXPODS	REPLICAS	AGE
server-hpa	Deployment/server	<unknown>/50%	1	10	0	13s

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.

Simulating load on the deployment pods


```
hey -c 2 -n 1 -z 5m http://<external-ip>:<port>/compute
```

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

 **kubernetes**

default

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Running: 1

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Name	Images	Labels	Pods	Created
server	yavuzozbay/nodeserver:2.0.0	-	1 / 1	a.mil

Pods

Name	Images	Labels	Node	Status	Restarts	CPU Usage (cores)	Memory Usage (bytes)
server-68c5768597-f9br4	yavuzozbay/node server:2.0.0	app: server pod-template-hash: 68c5768597	minikube	Running	0	97.00m	29.55Mi
mongo-0	mongo:6.0.2-focal	app: mongo apps.kubernetes.io/pod-index: 0 controller-revision-hash: mongo-744f99bf6b	minikube	Running	0	166.00m	184.84Mi

Replica Sets

Name	Images	Labels	Pods	Created
server-68c5768597	yavuzozbay/nodeserver:2.0.0	app: server	1 / 1	a.mil

With HTTP Requests

kubernetes

default

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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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Name	Images	Labels	Pods	Created
server	yavuzozbay/nodese	-	4 / 1	.19.minutes ago

Pods

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

Replica Sets

Name	Images	Labels	Pods	Created
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