EE379K Enterprise Network Security Lab 2 Report

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Part 3 - Orchestration

3a - Orchestration with Kubernetes

Docker applications

Running the simple PHP and MySQL server example with

```
$ docker-compose up
```

sets up both the web-service and SQL DB are on localhost. The web-service can be accessed through `localhost:8000`, which maps internally to port 80 inside the container. Additionally, the web-service uses port 3306 to access the SQL DB, while port 8082 is exposed to the host. The contents seen on the homepage, `http://localhost:8000`, is due to `src/index.php`.
By going into `docker-compose.yml` and changing the port mapping from `8000:80` to `9000:80`, as shown in Figure 1, the web-server can now be accessed at `http://localhost:9000`, since this changed what port is exposed to the host machine and maps it to the internal port.

```yaml
version: '2'
services:
  mysql:
        image: mysql:8.0
        container_name: mysql8-service
        command: --default-authentication-plugin=mysql_native_password
        volumes:
          - .:/application
        restart: always
        environment:
          - MYSQL_ROOT_PASSWORD=.sweetpwd.
          - MYSQL_DATABASE=my_db
          - MYSQL_USER=db_user
          - MYSQL_PASSWORD=.mypwd
        ports:
          - "8082:3306"
  website:
    container_name: php72
    build:
      context: ./
    ports:
      - 9000:80
```

Figure 1: Changing port mapping inside docker-compose.yml

Kubernetes

After tagging and pushing the web-service image to the microk8s registry, then the following commands are used to run the web-application in kubernetes:

```
$ microk8s.kubectl apply -f webserver.yaml
$ microk8s.kubectl apply -f webserver-svc.yaml
$ microk8s.kubectl apply -f mysql.yaml
$ microk8s.kubectl apply -f mysql-svc.yaml
```

Then, the different namespaces, shown in Figure 2 and Figure 3, are seen under the `NAMESPACE` column in each of the outputs of the following commands:

```
$ microk8s.kubectl get pods --all-namespaces
$ microk8s.kubectl get services --all-namespaces
```

For example, the `default` namespace refers to the default namespace for objects without any specified namespace. Additionally, Kubernetes creates the `kube-system` namespace, and it includes pods and services like the dashboard. [1]

```
class@class-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get pods --all-namespaces
NAMESPACE            NAME                                         READY   STATUS    RESTARTS   AGE
container-registry   registry-d7d7c8bc9-xg7wk                     1/1     Running   0          4h34m
default              mysql-5c6d57fc45-zw6fk                       1/1     Running   0          4h30m
default              webserver-77b46fb75f-j7pwh                   1/1     Running   0          4h31m
default              webserver-77b46fb75f-snj6h                   1/1     Running   0          4h31m
default              webserver-77b46fb75f-v8fbm                   1/1     Running   0          4h31m
kube-system          coredns-9b8997588-c2nq4                      1/1     Running   0          4h34m
kube-system          dashboard-metrics-scraper-566cddb686-cvt7r   1/1     Running   0          4h33m
kube-system          heapster-v1.5.2-5c58f64f8b-9vqgv             4/4     Running   1          4h33m
kube-system          hostpath-provisioner-7b9cb5cdb4-2fhr9        1/1     Running   0          4h34m
kube-system          kubernetes-dashboard-678b7d865c-t8qfm        1/1     Running   0          4h33m
kube-system          monitoring-influxdb-grafana-v4-6d599df6bf-pnc4r   2/2   Running   0        4h33m
```

Figure 2: Output of microk8s.kubectl get pods –all-namespaces

```
class@class-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get services --all-namespaces
NAMESPACE            NAME                        TYPE           CLUSTER-IP       EXTERNAL-IP   PORT(S)                  AGE
container-registry   registry                    NodePort       10.152.183.253   <none>        5000:32000/TCP           4h34m
default              kubernetes                  ClusterIP      10.152.183.1     <none>        443/TCP                  4h39m
default              mysql8-service              NodePort       10.152.183.195   <none>        3306:30765/TCP           4h30m
default              web-service                 LoadBalancer   10.152.183.210   <pending>     80:31670/TCP             4h31m
kube-system          dashboard-metrics-scraper   ClusterIP      10.152.183.250   <none>        8000/TCP                 4h33m
kube-system          heapster                    ClusterIP      10.152.183.228   <none>        80/TCP                   4h33m
kube-system          kube-dns                    ClusterIP      10.152.183.10    <none>        53/UDP,53/TCP,9153/TCP   4h34m
kube-system          kubernetes-dashboard        NodePort       10.152.183.68    <none>        443:32388/TCP            4h33m
kube-system          monitoring-grafana          ClusterIP      10.152.183.139   <none>        80/TCP                   4h33m
kube-system          monitoring-influxdb         ClusterIP      10.152.183.52    <none>        8083/TCP,8086/TCP        4h33m
```

Figure 3: Output of microk8s.kubectl get services –all-namespaces

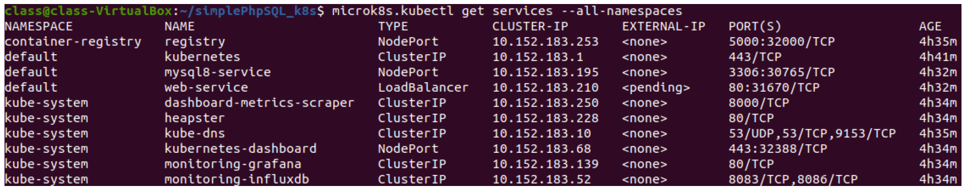
In the `webserver.yaml` file, there are specifications on how many instances of each application to deploy under `spec/replicas`:

```
apiVersion: apps/v1
kind: Deployment
...
spec:
  replicas: 3
...
```

This value can be changed to change the number of instances of web-servers. For example, if it was changed to 2, then the output of the `microk8s.kubectl get` commands would be the following:

```
class@class-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get pods --all-namespaces
NAMESPACE            NAME                                         READY   STATUS    RESTARTS   AGE
container-registry   registry-d7d7c8bc9-xg7wk                     1/1     Running   0          4h35m
default              mysql-5c6d57fc45-zw6fk                       1/1     Running   0          4h32m
default              webserver-77b46fb75f-j7pwh                   1/1     Running   0          4h33m
default              webserver-77b46fb75f-v8fbm                   1/1     Running   0          4h33m
kube-system          coredns-9b8997588-c2nq4                      1/1     Running   0          4h35m
kube-system          dashboard-metrics-scraper-566cddb686-cvt7r   1/1     Running   0          4h34m
kube-system          heapster-v1.5.2-5c58f64f8b-9vqgv             4/4     Running   1          4h34m
kube-system          hostpath-provisioner-7b9cb5cdb4-2fhr9        1/1     Running   0          4h35m
kube-system          kubernetes-dashboard-678b7d865c-t8qfm        1/1     Running   0          4h34m
kube-system          monitoring-influxdb-grafana-v4-6d599df6bf-pnc4r   2/2   Running   0        4h34m
```

Figure 4: New output of microk8s.kubectl get pods –all-namespaces



```
class@class-VirtualBox:~/simplePhpSQL_k8s$ microk8s.kubectl get services --all-namespaces
NAMESPACE            NAME                        TYPE           CLUSTER-IP       EXTERNAL-IP   PORT(S)                   AGE
container-registry   registry                    NodePort       10.152.183.253   <none>        5000:32000/TCP            4h35m
default              kubernetes                  ClusterIP      10.152.183.1     <none>        443/TCP                   4h41m
default              mysql8-service              NodePort       10.152.183.195   <none>        3306:30765/TCP            4h32m
default              web-service                 LoadBalancer   10.152.183.210   <pending>     80:31670/TCP              4h32m
kube-system          dashboard-metrics-scraper   ClusterIP      10.152.183.250   <none>        8000/TCP                  4h34m
kube-system          heapster                    ClusterIP      10.152.183.228   <none>        80/TCP                    4h34m
kube-system          kube-dns                    ClusterIP      10.152.183.10    <none>        53/UDP,53/TCP,9153/TCP    4h35m
kube-system          kubernetes-dashboard        NodePort       10.152.183.68    <none>        443:32388/TCP             4h34m
kube-system          monitoring-grafana          ClusterIP      10.152.183.139   <none>        80/TCP                    4h34m
kube-system          monitoring-influxdb         ClusterIP      10.152.183.52    <none>        8083/TCP,8086/TCP         4h34m
```

Figure 5: New output of microk8s.kubectl get services –all-namespaces

RBAC

For Role Based Access Control, first a service account and role need to be created and then bound together. Then, the following command can be used to set up and run the Kubernetes Dashboard:

```
$ microk8s.kubectl -n kube-system
    edit service kubernetes-dashboard
```

The type must be changed to `NodePort` and the exposed port is given under `ports/nodePort`:

```
...
spec:
  clusterIP: 10.152.183.68
  ports:
  - nodePort: 32388 # port num
    port: 443
    protocol: TCP
    targetPort: 8443
  selector:
    k8s-app: kubernetes-dashboard
  sessionAffinity: None
  type: NodePort # change from ClusterIP to NodePort
...
```

Then, once a secret token is obtained, the dashboard can be opened and a list of all the pods in the default namespace can be seen, like in Figure 6. Only these pods are shown because the namespace of the user-sa account is set to default, which is specified in the `sa-role-bind.yaml` file:

```
...
subjects:
- kind: ServiceAccount
```

```
    name: user-sa
    namespace: default
...
```

In order to create another service account that can access just the kube-system namespace, a new service account must be initialized. This can be done by first creating a service account and then making slight modifications to the `user-role.yaml` and `sa-role-bind.yaml` files, as can be seen in `part3/kube-role.yaml` and `part3/kube-sa-role-bind.yaml`, respectively. After creating the new service account, login to the dashboard with the token for the new account and now nothing can be seen in the `default` namespace, but the pods in the `kube-system` namespace are now visible on the dashboard, as shown in Figure 7. The sequence of commands to set this up are as follows:

```
$ microk8s.kubectl create serviceaccount kube-sa --namespace kube-system
$ microk8s.kubectl apply -f kube-role.yaml
$ microk8s.kubectl apply -f kube-sa-role-bind.yaml
```

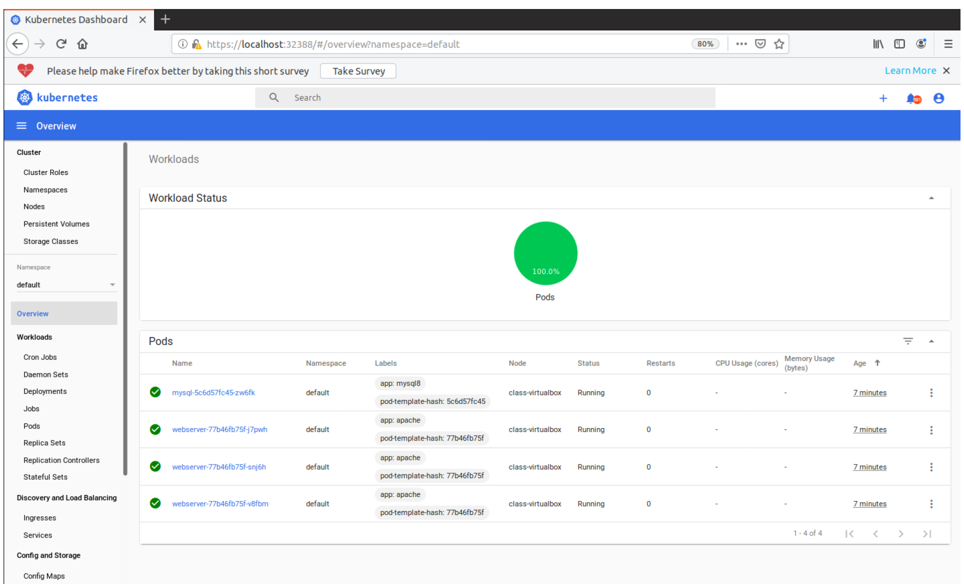


Figure 6: Dashboard view of default namespace visible to user-sa

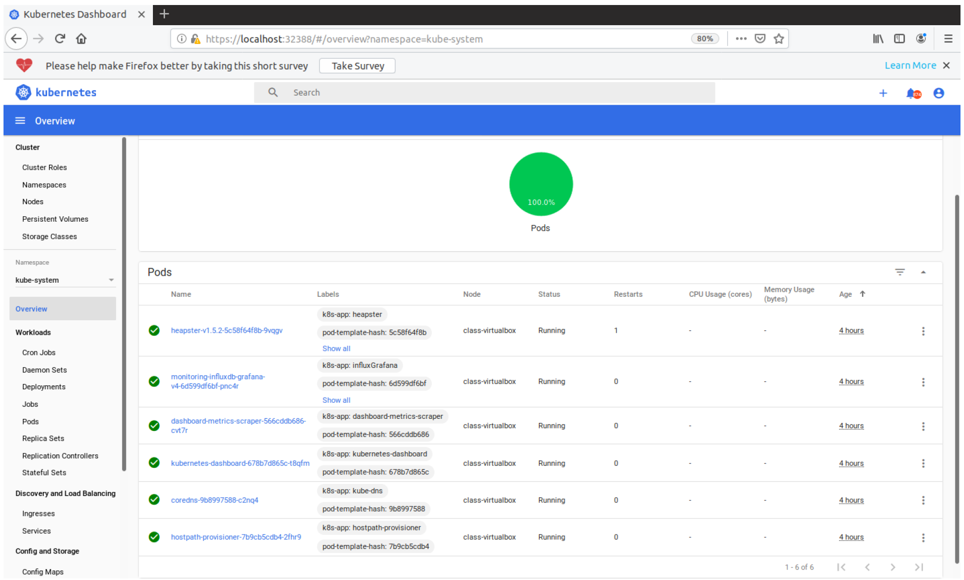


Figure 7: Dashboard view of kube-system namespace visible to kube-sa

3b - Creating a Kubernetes cluster for DVWA

For this part, the Dockerfile for the Damn Vulnerable Web App was to be split into two, one for the database and one for the web-app. The split Dockerfile and main.sh can be seen in `part3/db/` and `part3/dvwa/`. Then, after the images are built, they needed to be deployed to Kubernetes. After creating `part3/mysql.yaml` and `part3/webserver.yaml` by modifying the contents of the corresponding files from the `simplePhpSQL` project. The commands used to do this are:

```
$ docker tag docker-vulnerable-dvwa_website:latest localhost:32000/docker-vulnerable
$ docker push localhost:32000/docker-vulnerable-dvwa_website:k8s
$ docker apply -f mysql.yaml
$ docker apply -f webserver.yaml
```

Then, the pods can be seen in Figure 8 with the resource consumptions as well. One issue is that the webserver could not connect to the database. The following are what is believed to occur regarding the forkbomb injection.

If the script in `part3/b.php` was injected into the web-app, it would crash the pod hosting the web-app since it tries to run the fork bomb. In fact, without setting limits it seems to crash the entire VM. This means that the website is not accessible until Kubernetes successfully restarts it.

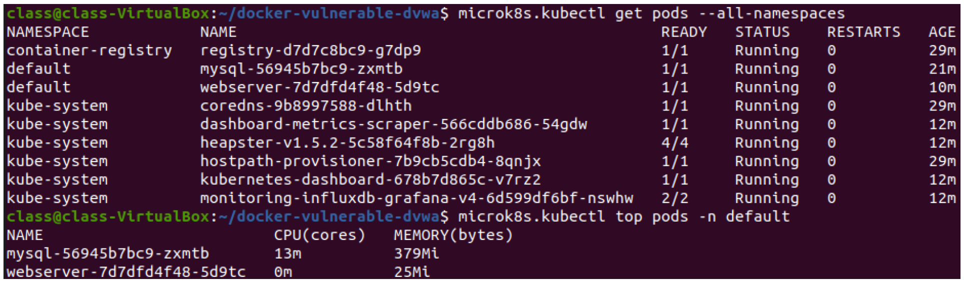


Figure 8: Pods and resource consumption of webserver after deploying the split DVWA

The web-app deployment can also be configured to launch multiple instances by changing the `replicas` value in `part3/webserver.yaml` to a number greater than 1 and redeploying it. Then, if the fork bomb was run now, the application would have greater resiliency to it. In other words, given that resource limitations have been set on the pods, the fork bomb would only take down one of the pods while the others are still functional. Traffic is then redirected to the working pods while the one that has crashed is terminated and brought up again. As a result, the website is still accessible.

One DevOps use case for for Kubernetes is providing resiliency to these kinds of attacks so that it becomes much harder to completely take down the service. Having multiple instances also means that one pod can be upgraded and deployed without having to take down the whole service. Then the pod(s) that haven't been upgraded can be done with little to no downtime. Another usage is that having mutliple instances can better balance heavy loads and make full use of the host's resources.

Conclusion

There were lots of strange issues that were very difficult to troubleshoot, making this lab frustrating and time consuming. It provided a good, hands-on way to explore the material, but it was difficult to figure out exactly how to divide the DVWA into two images and connect them after deploying to Kubernetes. Besides that difficulty with Docker, this lab helped with learning more about Kubernetes.

References

[1] "Kubernetes Concepts - Namespaces," September 2019.