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Test your containers with the Docker Desktop one-node cluster

Test Lab

The built-in single-node Kubernetes cluster included with Docker Desktop is a handy tool for testing your container. By Artur Skura

Docker makes it easy for developers to deploy applications and ensure that the local development environment is reasonably close to the staging and production environments. Remember the times you found a great app only to discover the installation instructions extended over several pages and involved configuring the database, populating tables, installing many packages

and corresponding libraries – and then because of a tiny glitch in the docs, things didn't work as expected? Thanks to Docker, these days are mostly over. You can develop your app and test it locally and then deploy it to the testing and production environments with few or no changes. But Docker itself is not enough. Modern apps rarely consist

of just one container. If you have more than one container, you need a way to organize them that is transparent to your users. In other words, you need a container orchestration platform. The unquestioned leader in orchestration is Kubernetes (K8s for short). It is easy to get started with Kubernetes if you have Docker Desktop installed. Simply go to *Settings | Kubernetes* and select *Enable Kubernetes* (**Figure 1**). Enabling Kubernetes from Docker Desktop gets you a one-node cluster suitable for local testing and experiments.

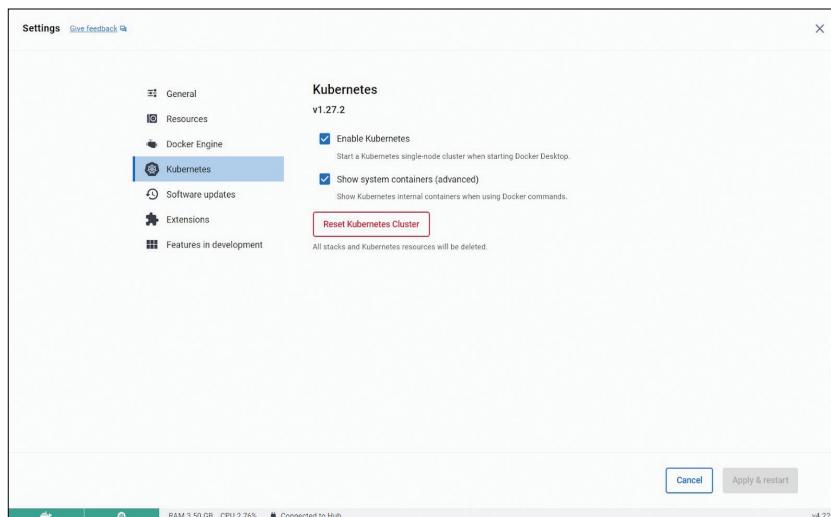


Figure 1: Enabling Kubernetes in Docker Desktop.

Listing 1: my-app/nginx/nginx.conf

```

01 events {
02     worker_connections 1024;
03 }
04 http {
05     server {
06         listen 80;
07         location / {
08             proxy_pass http://webapp:5000;
09         }
10     }
11 }
```

Single-node clusters are quite useful for testing, and the single-node Kubernetes cluster bundled with Docker Desktop is pre-configured and ready to use. Along with this single-node cluster (called “Kubernetes server” in Docker docs), Docker Desktop also includes the `kubectl` command-line tool (called “Kubernetes client”). Because `kubectl` is already set up to work with the cluster, you can start issuing commands straight away without additional configuration.

About Kubernetes

Many people say they would like to start learning Kubernetes, but they somehow get stuck at the first phase, that is, the installation. The problem is, administering a Kubernetes cluster and developing software that runs on it are two different tasks that are often handled by different teams. Installing, upgrading, and managing the cluster is usually done by the Ops or DevOps team, whereas the development is usually done by developers. Using a single-node cluster, developers can take the first steps with verifying that the containerized application works in Kubernetes before passing it on to Ops for further implementation.

Do I Need cri-dockerd?

Kubernetes was built around the Docker Engine container runtime, and the early versions of Kubernetes were fully compatible with Docker Engine. Docker Engine is a full-featured runtime with many features for supporting end users and developers – and even a system for integrating third-party extensions. In many cases, developers don't need all the functionality provided by Docker Engine and just want a much simpler runtime. Kubernetes implemented the Container Runtime Interface (CRI) in 2016 as a universal interface to support other container runtimes. Docker contributed the code for a simpler, more elementary container runtime called containerd, which is compatible with CRI. Containerd is now maintained by the Cloud Native Computing Foundation.

Containerd works for many common scenarios today, but some users still prefer the more robust Docker Engine, with its user interface

Kubernetes is a complex beast, and it might be confusing to present its architecture in detail, so I'll focus on the essentials. For starters, it's enough to remember two concepts: nodes and pods. Nodes normally correspond to virtual (or, less often, bare metal) machines on which pods are running. Pods, on the other hand, correspond to sets of containers, and they are running in nodes. One node can contain several pods. One pod cannot run on more than one node – instead, you create replicas of the pod using so-called *deployments*. A typical Kubernetes cluster has several nodes with one or more pods running on each node. When one node fails, the pods that had been running on it are considered lost and are scheduled by the cluster to run on other, healthy nodes. All this happens automatically when you use a deployment. Kubernetes is therefore a self-healing platform for running containerized apps. Even on the basis of this simplified description, you can understand why Kubernetes took the world by storm.

A Multi-Container Example

A simple example will show how easy it is to test your Docker containers using Docker Desktop's single-node

features and support for extensions. Because Docker Engine was developed before CRI, it does not fit directly with the CRI interface. Kubernetes implemented a temporary adapter called dockershim to support Docker Engine on CRI-based Kubernetes installations. Dockershim was deprecated in Kubernetes 1.20 and removed in version 1.24. A new adapter called cri-dockerd now provides “fully conformant compatibility between Docker Engine and the Kubernetes system.” If you are running Kubernetes 1.24 or newer with containerd, you won't have to worry about compatibility. However, if you want to continue to use the Docker Engine runtime, you might have to replace dockershim with the cri-dockerd adapter. Cri-dockerd is included with Docker Desktop, so you won't need to worry about cri-dockerd to access Docker Desktop's single-node Kubernetes cluster.

Kubernetes cluster. I will create a `docker-compose.yml` file that sets up a web application stack consisting of an Nginx reverse proxy, a Python Flask web application, and a Redis database. In the root directory of your project (let's call it `my-app`), create

Listing 2: my-app/nginx/Dockerfile

```
01 FROM nginx:alpine
02 COPY nginx.conf /etc/nginx/nginx.conf
```

Listing 3: my-app/webapp/app.py

```
01 from flask import Flask
02 import redis
03 import os
04
05 app = Flask(__name__)
06 redis_host = os.getenv("REDIS_HOST", "localhost")
07 r = redis.Redis(host=redis_host, port=6379, decode_
    responses=True)
08
09 @app.route('/')
10 def hello():
11     count = r.incr('counter')
12     return f'Hello, you have visited {count} times.'
13
14 if __name__ == '__main__':
15     app.run(host="0.0.0.0", port=5000)
```

Listing 4: my-app/webapp/Dockerfile

```
01 FROM python:3.11
02 WORKDIR /app
03 COPY .
04 RUN pip install Flask redis
05 CMD ["python", "app.py"]
```

Listing 5: my-app/docker-compose.yml

```
01 services:
02   nginx:
03     build: ./nginx
04     ports:
05       - "8080:80"
06     depends_on:
07       - webapp
08   webapp:
09     build: ./webapp
10     environment:
11       - REDIS_HOST=redis
12     depends_on:
13       - redis
14   redis:
15     image: "redis:alpine"
16     volumes:
17       - redis-data:/data
18
19 volumes:
20   redis-data:
```

```
[+] Running 7/7
✓ redis 6 layers [||||||]    0B/0B      Pulled
  ✓ 7264a8db6415 Pull complete
  ✓ a28817da73be Pull complete
  ✓ 536ccaaebaffb Pull complete
  ✓ f54d1871dea6 Pull complete
  ✓ 4d190b4b6472 Pull complete
  ✓ 33fcc9c965f Pull complete
[+] Building 19.9s (5/9)
=> [webapp internal] load .dockerrcignore
=> [webapp internal] load build definition from Dockerfile
=> [webapp internal] transferring dockerfile: 133B
=> [webapp internal] load metadata for docker.io/library/python:3.8
=> [webapp auth] library/python:pull token for registry-1.docker.io
=> [webapp internal] FROM docker.io/library/python:3.8@sha256:28f1561fe0279d606b8543d8e2cd54abb7ec58ad4bbc19a065db1229cf3aa27
=> => resolve docker.io/library/python:3.8@sha256:28f1561fe0279d606b8543d8e2cd54abb7ec58ad4bbc19a065db1229cf3aa27
=> => sha256:d31b0195c5f04dc78eca9d73bd223fc36a29f54ee888bc4e0615b5839e692 24.03MB / 24.03MB
=> => sha256:9b1fd34c308b75e7edb20c2fd09a9862697f302ef9ae357e521ef3c04d5534e3f 64.11MB / 64.11MB
=> => sha256:8902fdff6d89ebfb04c37179f3bd802af491cd46ce0246aac21e76e57fdcc7 7.56KB / 7.56KB
=> => sha256:de4cac68b6165c40cf6fb830417948c31be03a968e233e55ee40221553a5e570 49.56MB / 49.56MB
=> => sha256:2f1561fe0279d606b8543d8e2cd54abb7ec58ad4bbc19a065db1229cf3aa27 1.86KB / 1.86KB
=> => sha256:c3ac277836cfed64b092c9e58f6295ac79f6091e7aa602c505e7c887c6b6f513 2.01KB / 2.01KB
=> => sha256:c4854bca8d79db59368a84d2fd3e783620647fe0b01433lc7fd2bd8526e5b 85.98MB / 211.03MB
=> => sha256:9c9b1d31279a02d1f5c2eb72e9ca9830b128840470843e09761a45d7bebbe6e 6.39MB / 6.39MB
=> => extracting sha256:de4cac68b6165c40cf6fb830417948c31be03a968e233e55ee40221553a5e570
=> => sha256:d80126e05932093abbaeb9c31482da66a59f7904ca4967def0a54e756d53 17.28MB / 17.28MB
=> => sha256:4f372691895ada3e85a9eb181ad24df319a56cbd1a54949a012a5a0c40de3 245B / 245B
=> => sha256:47c0268b48e9672b440eb5c3bf3f98196336ca02bcc0a1c7ccc06466b99bb3f0 2.85MB / 2.85MB
[+] [webapp internal] load build context
=> => transferring context: 538B

```

Figure 2: Building images with Docker Compose.

```
[+] Running 5/5
✓ Network my-app_default      Created
✓ Volume "my-app_redis-data"  Created
✓ Container my-app-redis-1    Created
✓ Container my-app-webapp-1   Created
✓ Container my-app-nginx-1    Created
Attaching to my-app-nginx-1, my-app-redis-1, my-app-webapp-1
my-app-redis-1  | 1:C 27 Aug 2023 11:23:47.622 * o000o000o000o Redis is starting o000o000o000o
my-app-redis-1  | 1:C 27 Aug 2023 11:23:47.622 * Redis version=7.2.0, bits=64, commit=00000000, modified=0, pid=1, just started
my-app-redis-1  | 1:C 27 Aug 2023 11:23:47.622 # Warning: no config file specified, using the default config. In order to specify a config file use redis-server /path/to/redis.conf
my-app-redis-1  | 1:M 27 Aug 2023 11:23:47.623 * monotonic clock: POSIX clock_gettime
my-app-redis-1  | 1:M 27 Aug 2023 11:23:47.625 * Running mode=standalone, port=6379.
my-app-redis-1  | 1:M 27 Aug 2023 11:23:47.626 * Server initialized
my-app-redis-1  | 1:M 27 Aug 2023 11:23:47.626 * Ready to accept connections tcp
my-app-webapp-1 | * Serving Flask app 'app'
my-app-webapp-1 | * Debug mode: off
my-app-webapp-1 | WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
my-app-webapp-1 | * Running on all addresses (0.0.0.0)
my-app-webapp-1 | * Running on http://127.0.0.1:5000
my-app-webapp-1 | * Running on http://172.19.0.3:5000
my-app-webapp-1 | Press CTRL+C to quit
my-app-nginx-1  | /docker-entrypoint.sh: /docker-entrypoint.d/ is not empty, will attempt to perform configuration
my-app-nginx-1  | /docker-entrypoint.sh: Looking for shell scripts in /docker-entrypoint.d/
my-app-nginx-1  | /docker-entrypoint.sh: Launching /docker-entrypoint.d/10-listen-on-ipv6-by-default.sh
my-app-nginx-1  | 10-listen-on-ipv6-by-default.sh: info: Getting the checksum of /etc/nginx/conf.d/default.conf
my-app-nginx-1  | 10-listen-on-ipv6-by-default.sh: info: Enabled listen on IPv6 in /etc/nginx/conf.d/default.conf
my-app-nginx-1  | /docker-entrypoint.sh: Sourcing /docker-entrypoint.d/15-local-resolvers.envsh
my-app-nginx-1  | /docker-entrypoint.sh: Launching /docker-entrypoint.d/20-envsubst-on-templates.sh
my-app-nginx-1  | /docker-entrypoint.sh: Launching /docker-entrypoint.d/30-tune-worker-processes.sh
my-app-nginx-1  | /docker-entrypoint.sh: Configuration complete; ready for start up
```

Figure 3: Running containers with Docker Compose

two folders: `nginx` and `webapp`. The `nginx` directory will contain a Nginx configuration file `nginx.conf` ([Listing 1](#)) with a Dockerfile ([Listing 2](#)); the `webapp` directory will contain a Flask app `app.py` ([Listing 3](#)) and the corresponding Dockerfile ([Listing 4](#)). In this way, I will build two images: one containing the Flask app and another with Nginx. The user will connect to a Nginx instance, which will communicate with the Flask app. The app, in turn, will use the Redis in-memory storage tool as a simple store for counting users' visits.

The key part that glues everything together is the `docker-compose.yml` file.

(Listing 5). It defines three services and one volume. You might ask why three services since we only prepared two Dockerfiles? The two Dockerfiles are custom images, whereas the Redis image is a standard image (redis:alpine) without any modifications, so you don't even need to create a Dockerfile for it – you can instead use the ready-made image directly

with the image directive. Docker Compose makes it easy to start and build the whole infrastructure:

```
docker compose up --build
```

This command will first build the three Docker images (**Figure 2**) and then run the resulting containers (**Figure 3**) in the correct order: As you will notice in



Figure 4: The Flask app correctly counting user visits.

`docker-compose.yml`, the `redis` service, even though defined last, needs to run first because `webapp` depends on it, whereas `nginx` has to start last because it depends on `webapp` already running. The Flask app should be available on `localhost:8080` and working as intended (**Figure 4**). (By the way, you might notice that I am using `docker compose`, a new command integrated with Docker Desktop, called Compose V2, instead of the legacy Compose V1 command `docker-compose`. Unless you have a good reason to use V1, you should always use V2 as V1 is not receiving updates.) As a side note, if you are planning on using the Docker Engine runtime with Kubernetes, see the sidebar entitled “Do I Need cri-dockerd?”

Migrating to Kubernetes

This brings me to the main topic: How do I migrate the preceding example to Kubernetes? Because the app is already containerized, the migration should be very easy. In real life, DevOps engineers need to deal with legacy apps written for a monolithic architecture.

Although this architecture is not inherently bad, if you want to leverage the power of containers, it becomes an obstacle. Some organizations go to the other extreme and rewrite everything using microservices, which might not be the optimal choice in all cases. What you need are logical components that you can develop and deploy fairly independently and that will still work together well.

The Docker Compose file defined three services, so I need one Kubernetes Service file for each (**Listings 6-8**). In addition, I also need to create a deployment file for each (**Listings 9-11**) and a

ConfigMap resource for Nginx (**Listing 12**). Deployments define, among other things, what containers and volumes should run and how many of replicas should be created. A ConfigMap is another type of resource used for configuration. Kubernetes will not build images. You need to have them already built and pass them to deployments as arguments of the `image` directive. In the case of Redis, I am not modifying the official image and can use it directly.

With Nginx, things get a bit more complex because I need to adapt the default configuration. Fortunately, I don't have to modify the image this time and can use another Kubernetes resource: ConfigMap. ConfigMap will allow me to manage the configuration independently

of the actual Nginx container. This approach has many advantages. For example, I can reconfigure Nginx dynamically, and Kubernetes will

Listing 8: my-k8s-app/redis-service.yaml

```
01 apiVersion: v1
02 kind: Service
03 metadata:
04   name: redis
05 spec:
06   ports:
07     - port: 6379
08   selector:
09     app: redis
```

Listing 9: my-k8s-app/nginx-deployment.yaml

```
01 apiVersion: apps/v1
02 kind: Deployment
03 metadata:
04   name: nginx
05 spec:
06   replicas: 1
07   selector:
08     matchLabels:
09       app: nginx
10   template:
11     metadata:
12       labels:
13         app: nginx
14     spec:
15       containers:
16         - name: nginx
17           image: nginx:alpine
18           ports:
19             - containerPort: 80
20           volumeMounts:
21             - name: nginx-config
22               mountPath: /etc/nginx/nginx.conf
23               subPath: nginx.conf
24           volumes:
25             - name: nginx-config
26               configMap:
27                 name: nginx-config
```

Listing 6: my-k8s-app/nginx-service.yaml

```
01 apiVersion: v1
02 kind: Service
03 metadata:
04   name: nginx
05 spec:
06   ports:
07     - port: 8080
08   targetPort: 80
09   selector:
10     app: nginx
```

Listing 7: my-k8s-app/webapp-service.yaml

```
01 apiVersion: v1
02 kind: Service
03 metadata:
04   name: webapp
05 spec:
06   ports:
07     - port: 5000
08   selector:
09     app: webapp
```

Listing 10: my-k8s-app/webapp-deployment.yaml

```
01 apiVersion: apps/v1
02 kind: Deployment
03 metadata:
04   name: webapp
05 spec:
06   replicas: 1
07   selector:
08     matchLabels:
09       app: webapp
10   template:
11     metadata:
12       labels:
13         app: webapp
14       spec:
15         containers:
16           - name: webapp
17             image: YOUR-DOCKER-IMAGE # This needs to be
18             built and pushed, see instructions below
19           env:
20             - name: REDIS_HOST
21               value: "redis"
22           ports:
23             - containerPort: 5000
```

Listing 11: my-k8s-app/redis-deployment.yaml

```

01 apiVersion: apps/v1
02 kind: Deployment
03 metadata:
04   name: redis
05 spec:
06   replicas: 1
07   selector:
08     matchLabels:
09       app: redis
10   template:
11     metadata:
12       labels:
13         app: redis
14     spec:
15       containers:
16         - name: redis
17           image: redis:alpine
18       ports:
19         - containerPort: 6379

```

Listing 12: my-k8s-app/nginx-configmap.yaml

```

01 apiVersion: v1
02 kind: ConfigMap
03 metadata:
04   name: nginx-config
05 data:
06   nginx.conf: |
07     events {
08       worker_connections 1024;
09     }
10
11   http {
12     server {
13       listen 80;
14
15       location /
16         proxy_pass http://webapp:5000;
17     }
18   }
19 }
```

Listing 13: Applying the Configurations

```

kubectl apply -f nginx-configmap.yaml
kubectl apply -f redis-deployment.yaml
kubectl apply -f redis-service.yaml
kubectl apply -f webapp-deployment.yaml
kubectl apply -f webapp-service.yaml
kubectl apply -f nginx-deployment.yaml
kubectl apply -f nginx-service.yaml

```

Listing 14: Viewing the Running Pods

NAME	READY	STATUS	RESTARTS	AGE
nginx-794866d4f-9p5q4	1/1	Running	0	13s
redis-84fd6b8dcc-7vzp7	1/1	Running	0	36s
webapp-b455df999-bn58c	1/1	Running	0	25s

propagate changes to all the pods. Also, I can use the same Nginx container in different environments and only the ConfigMap will change. Versioning also works better with a ConfigMap than with a container.

In the `nginx-deployment.yaml` file ([Listing 9](#)), the ConfigMap is mounted into the Nginx container at the `/etc/nginx/nginx.conf` path. This replaces the default Nginx configuration file with the file defined in the ConfigMap. Using a ConfigMap would make little sense for the Flask app, so I need to build the image first, upload it to a container registry, and then pass its name as `image` in the deployment. In order to do so, I need to first create an account on Docker Hub or another container registry. Then go to the `my-app/webapp` directory used earlier with Docker Compose and build the image, for example, as `flaskapp`:

```
docker build -t flaskapp .
```

Now log in to your registry. For Docker Hub, I will use:

```
docker login --username=your-username
```

The next stage is tagging:

```
docker tag flaskapp:latest YOUR_USERNAME/flaskapp:latest
```

At this point, you can push the image to the registry:

```
docker push YOUR_USERNAME/flaskapp:latest
```

In the two last commands, replace `YOUR_USERNAME` with your actual user name. Now, replace the image: `YOUR-DOCKER-IMAGE` in [Listing 10](#) with `YOUR_USERNAME/flaskapp:latest` so that Kubernetes is able pull your container from the Docker Hub and use it for deployment.

At this point, I am ready to apply all the configurations. I will create the necessary infrastructure and run the containers ([Listing 13](#)). When you run the `kubectl get pods` command, you should see the pods running ([Listing 14](#)).

You can also use the `kubectl get` command to get information on deployments, services, and ConfigMaps. In order to actually use the app, type the following command:

```
kubectl port-forward svc/nginx 8080:8080
```

And, as before, visit `localhost:8080` – you should see the same Flask app as deployed earlier with Docker Compose, the only difference being that now it is running on Kubernetes. Congratulations – you have built and deployed your first application on the local one-node Kubernetes cluster! Now, the magic lies in the fact that you can perform the same sequence of `kubectl apply` commands in the production environment, for example in EKS on AWS, and the app will run exactly as it should. In practice, there are a few differences, such as making the app available to the external world using a load balancer, storing secrets, storage options, and so on, but these are more related to the interaction of Kubernetes with the external environment – the app itself stays the same.

Conclusion

The local Kubernetes cluster distributed with Docker Desktop lets you learn the basics of Kubernetes – creating pods, deployments, services, and ConfigMaps – and also test the deployment locally before pushing it to staging and production environments. ■

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Author

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