Introduction

By now, you must have understood

- What containerization is?
- Docker Container basics with commands
- Various docker components
- Docker workflow

Let us have a quick recap of these basics.

Docker Container

Containers are multiple isolated services that are run on a single control host (underlying infrastructure) and they access a single kernel.

Key Benefits

- Improved performance
- portability
- eliminates environmental inconsistencies

Docker is a tool that uses open source Container technology intended to make the process of creating, deploying and running applications easier by using container based virtualization technology.

Docker Components

Docker components include

- *Docker daemon* : *Docker process responsible for managing docker objects*
- *Docker client* : *Communicates with Docker daemon through API calls*
  - *Docker Image* - *Read only template that stores the application and environment*.
  - *Docker Container* - *Runtime instance of a docker image*
  - *Docker File* - *Automates Image construction*
- *Docker registry* - *Public and private repositories to store images*

Docker End-to-End Workflow

Let us quickly look into the steps involved in the docker flow.

- Create a Dockerfile
- Build a Docker Image
- Verify Image

- Push to Registry
- Pull from Registry
- Run Image
- Verify running Container/Service

More on Docker

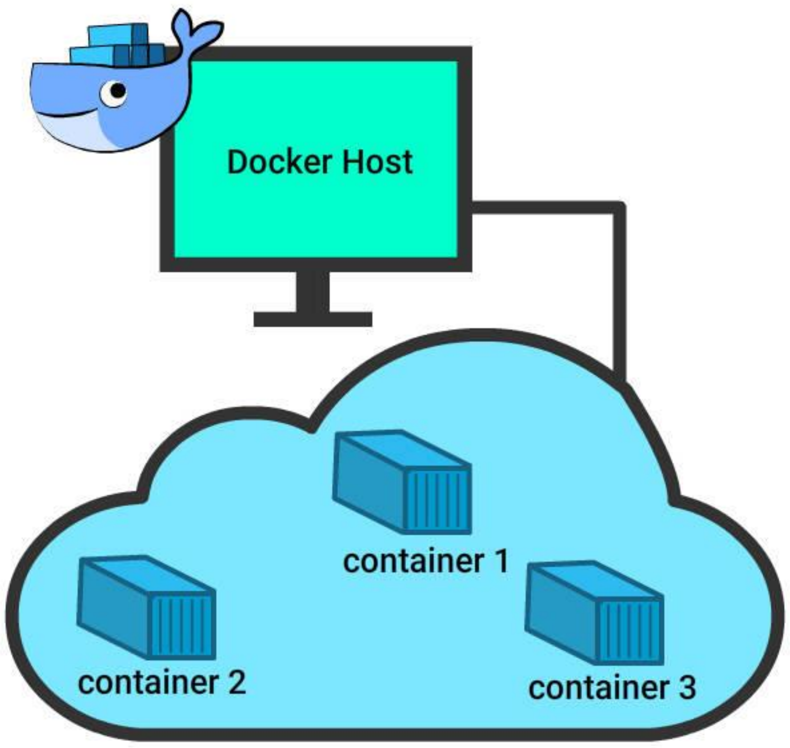
In this course we will continue to learn more about Docker. Following are the aspects of Docker that will be covered.

- Docker Networking
- Docker Storage
- Docker Compose tool
- Docker Security

Docker Network

Docker Network

The concept of networking in Docker comes into picture when working with Docker in a real time scenario at a large scale.

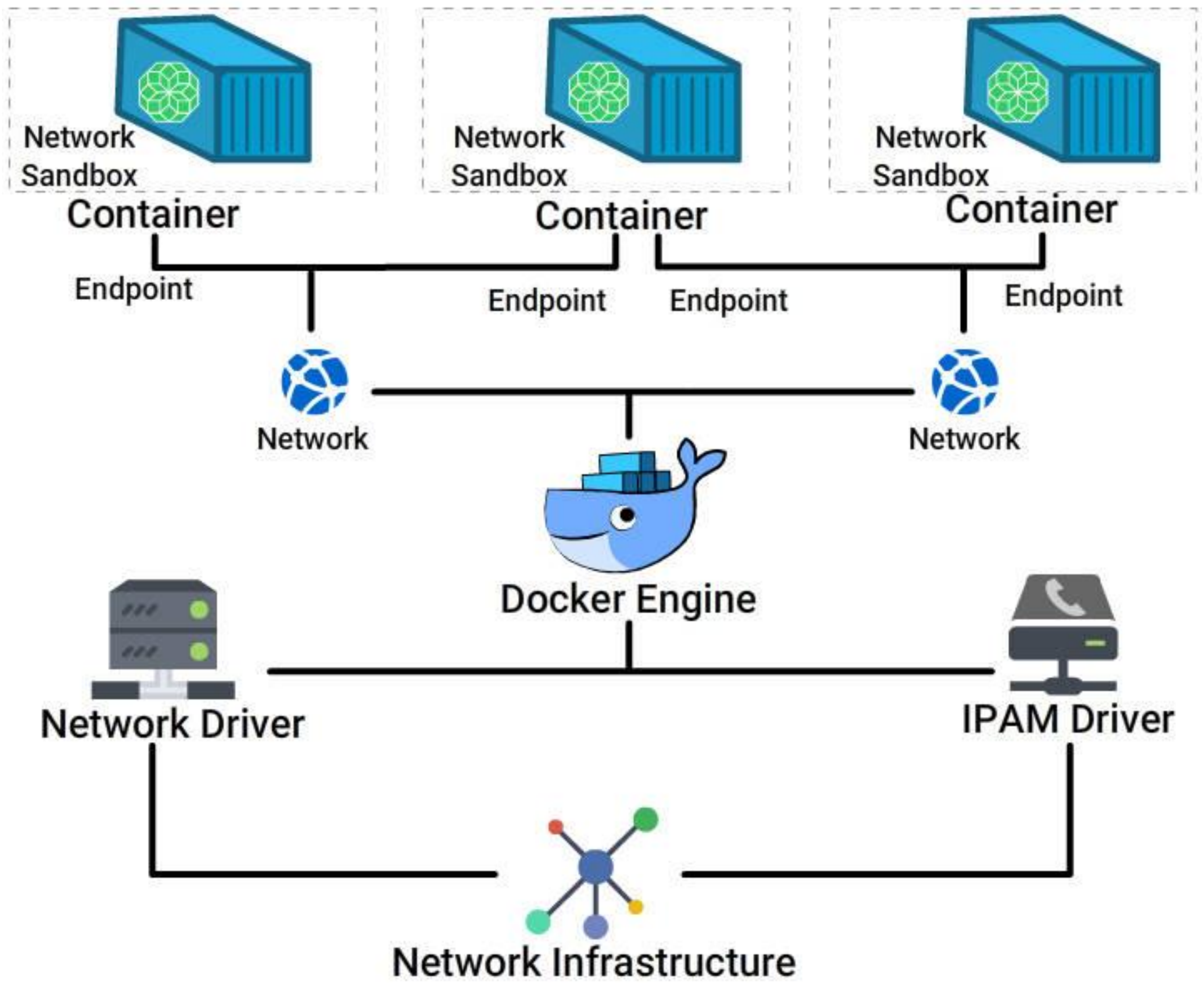


Docker Networking helps us to share data across various containers.

Host and containers in Docker are tied with 1:N relationship, which means one host can command multiple containers.

Container Networking Model

- Container networking model is a standard defined for configuring network interfaces in Linux containers. This was proposed by Docker and later adopted by libnetwork (defines networking for docker) project.
- In this model, a *set of network interfaces* is assembled together to formalize the steps that are required to *provide networking* for containers.
- The *fundamental goal* of this model is to achieve *application portability* across various infrastructures.
- This model not only provides application portability but also utilizes the *advantages of special features and capabilities of the infrastructure*.



This block diagram represents the Container networking model.

Containers are *interconnected* to each other through a network established by connecting the ethernet port of the individual containers to the host system.

Every host system has a *network infrastructure* built in with a network driver and IPAM driver.

Network driver - Device that enables network communication.

IPAM Driver - Provides IP address management services.

CNM core components include

- Sandbox
- Endpoint
- Network

CNM - Components

Sandbox

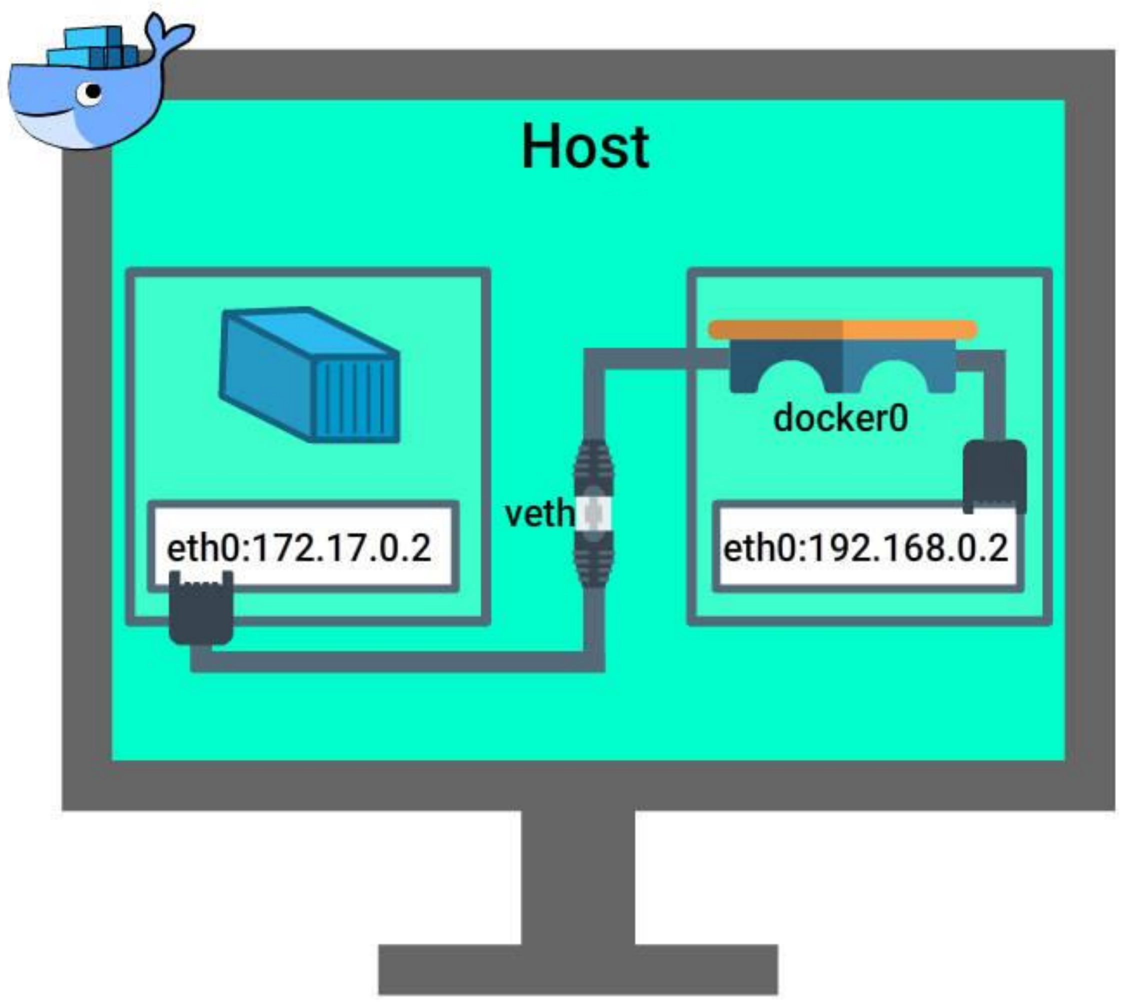
- Includes container's *network stack configuration*
- Manages *container's interfaces, routing table and DNS settings*
- Includes *multiple endpoints from multiple networks*

Endpoint

- Connects *Sandbox to Network*
- Abstracts *Network connection from the application*
- Provides *portability* to connect to different Network drivers

Network

- *Collection of endpoints* that can be connected to each other
- Implementation can be a *Linux bridge, VLAN* etc.



Docker Networking

Refer to the image to understand how docker network is configured on a host machine.

Behind the screens

Docker Networking

- Every *regular host machine* (laptops/ Vm / Cloud machine) has an *ethernet interface* with an IP attached (eg. ip address 10.0.1.1).
- Once you install docker , within the host machine, *Docker creates a bridge*.
- Docker installs scripts that are clever enough to *interpret the networking on the host* and identify a space for its ip configuration.
- When you *start* a container, it *creates a virtual bridge called docker01*.
- *Default inet address* for Docker *172.17.42.1*.

Docker Native Network Drivers

Docker engine had in-built network drivers which are the core component that enables networking in containers.

Below are the different types of network drivers that can be used to configure networking in docker.

Host: Uses host's networking stack.

Bridge: Creates a Linux Bridge on the host which is managed by Docker.

Overlay: Creates an overlay network for multi-host networks.

MACVLAN: Uses MACVLAN brige to connect container interfaces with parent host interface.

None: Container has its own networking stack and completely isolated from the host network.

Network Modes

Various modes for networking is all about how we *manage connections* between containers using the network drivers.

- Bridge mode Networking: The *default network* will be bridge network.

Unless we specify the network option in docker run command, Docker daemon connects the container to this network.

- Host Mode Networking: Add the container to the network stack of the *host*. Container in this mode will not create a new network configuration, where as *share the network config of host*.

--net = host

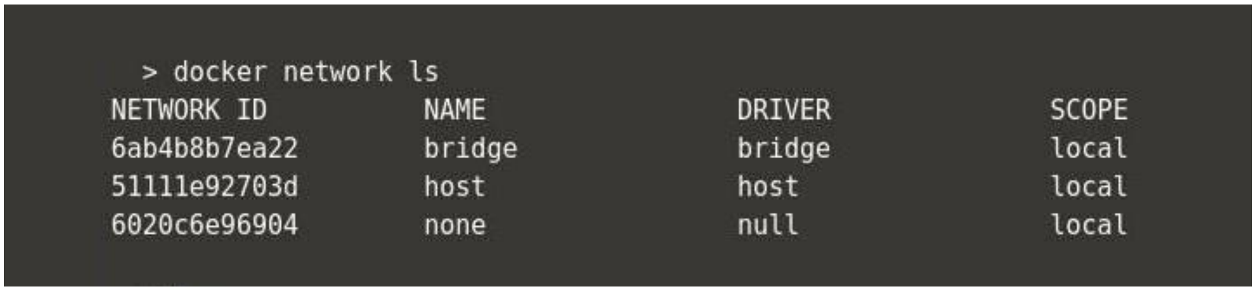
- Container Mode Networking: New container created will have the *same config* as that of the *specified Container*.

--net=container:$comtainer2

- No Networking: Adds container to container network stack. Hence this *lacks connectivity* with the host.

--net=none

Network Drivers & Scope

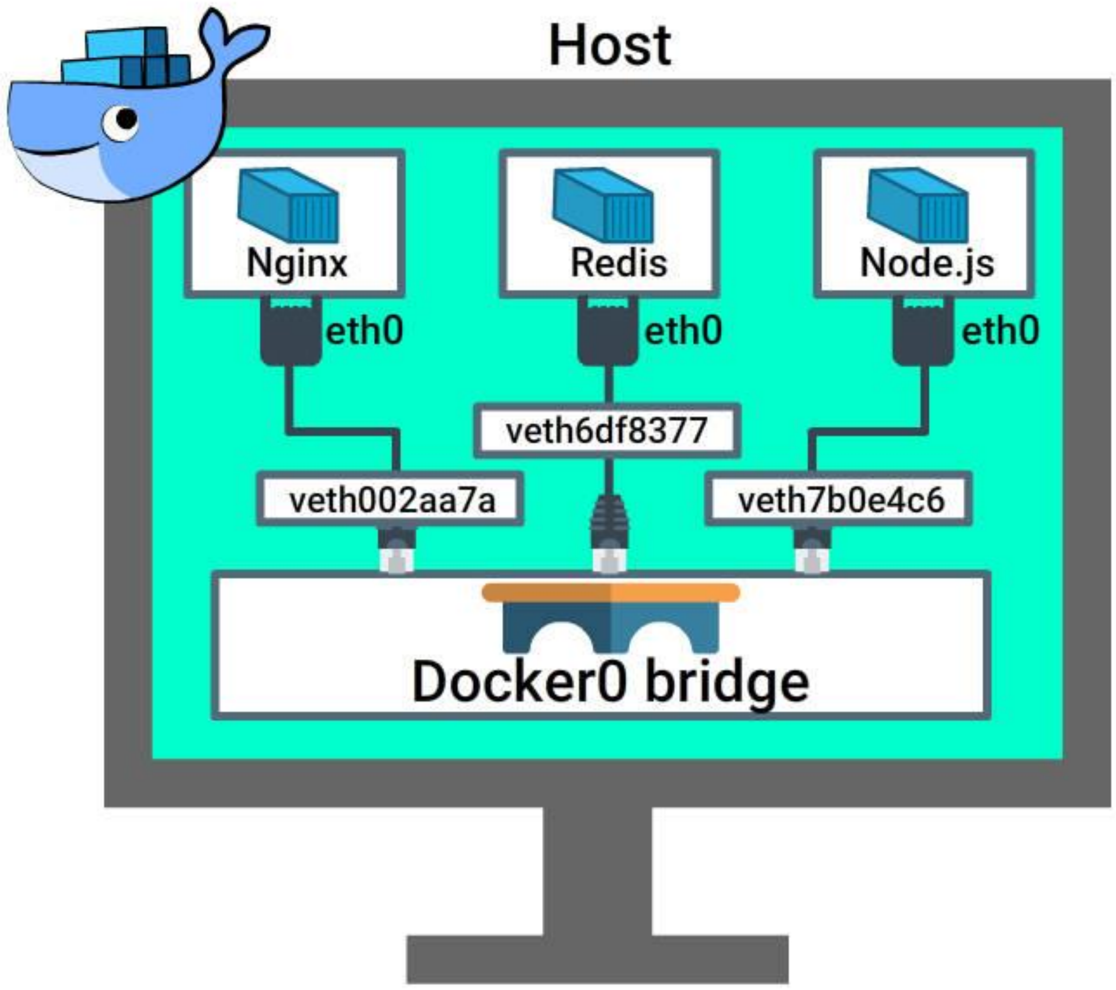


```
  > docker network ls
NETWORK ID          NAME                DRIVER              SCOPE
6ab4b8b7ea22        bridge              bridge              local
51111e92703d        host                host                local
6020c6e96904        none                null                local
```

On Docker installation, there are 3 networks that are automatically created.

This can be listed using command

```
docker network ls
```



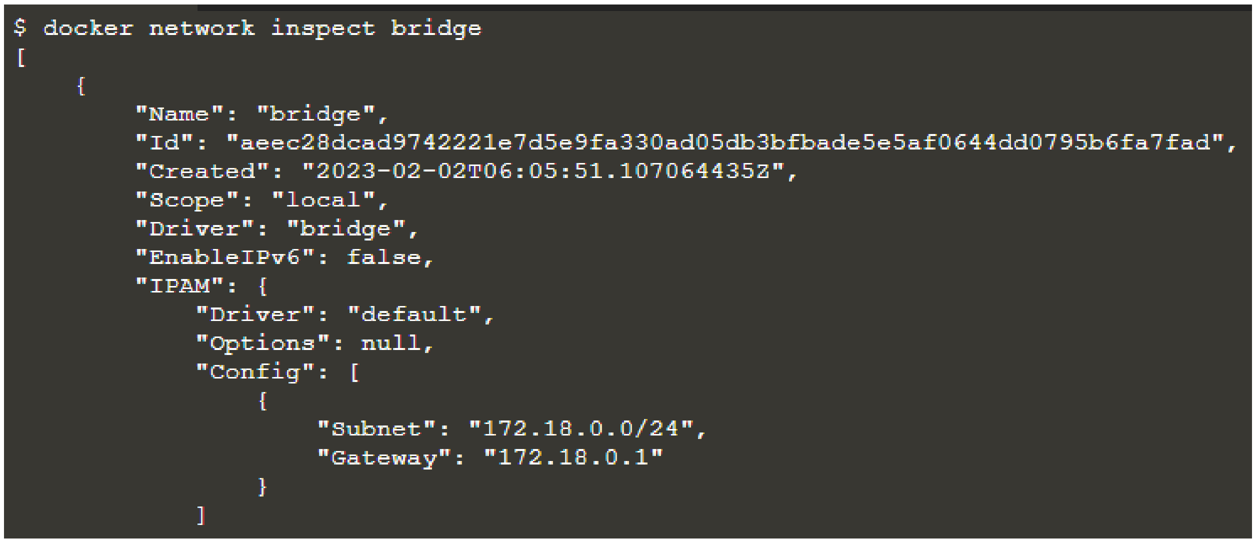
This default network is *available in all docker hosts*. While creating containers, by default they get mapped to this bridge if you do not specify a different one.

Lets run *docker inspect* command to know more on this network.

docker network inspect bridge

This command lists

- Details on the *configured bridge network*
- *Containers running* in the network



```
$ docker network inspect bridge
[
    {
        "Name": "bridge",
        "Id": "aeec28dcad9742221e7d5e9fa330ad05db3bfbade5e5af0644dd0795b6fa7fad",
        "Created": "2023-02-02T06:05:51.107064435Z",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": null,
            "Config": [
                {
                    "Subnet": "172.18.0.0/24",
                    "Gateway": "172.18.0.1"
                }
            ]
```

Bridge Network (Contd1...)

Create couple of containers using the below command.

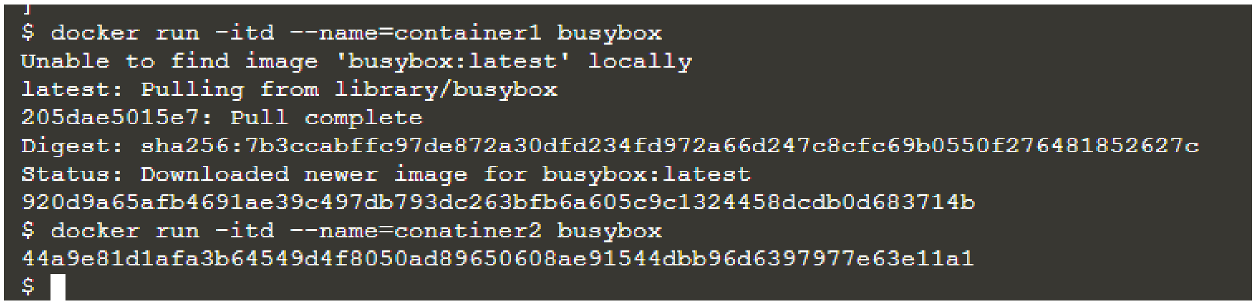
docker run -itd --name=container1 busybox

docker run -itd --name=container2 busybox

--detach , -d	Run container in background and print container ID
--interactive , -i	Keep STDIN open even if not attached
--tty , -t	Allocate a pseudo-TTY

The -t (or --tty) flag tells Docker to allocate a virtual terminal session within the container. This is commonly used with the -i (or --interactive) option, which keeps STDIN open even if running in detached mode (more about that later)

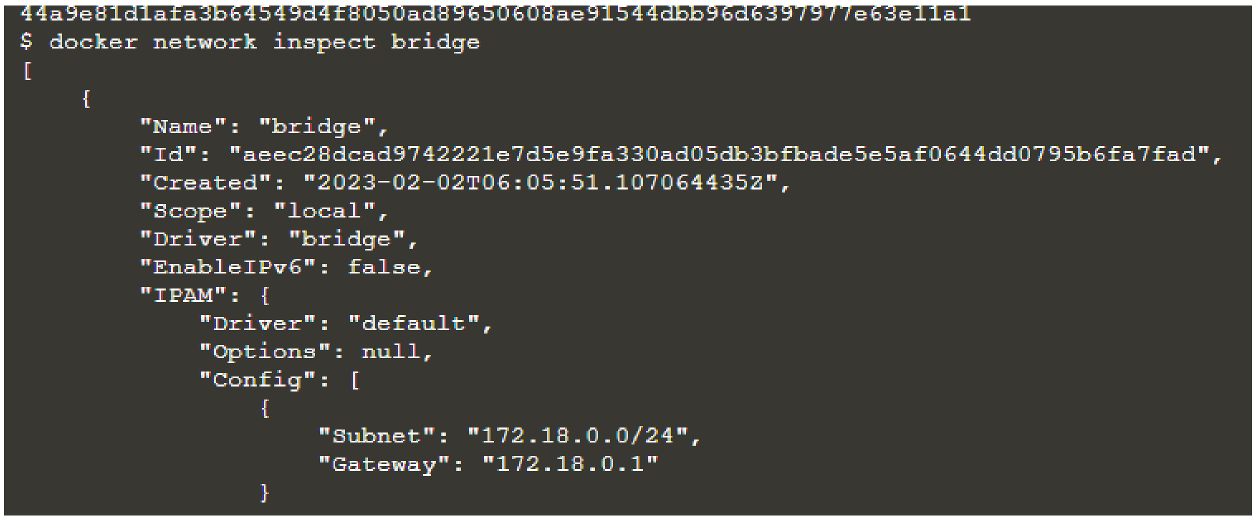
Now we have 2 containers running in the default bridge network.



```
$ docker run -itd --name=container1 busybox
Unable to find image 'busybox:latest' locally
latest: Pulling from library/busybox
205dae5015e7: Pull complete
Digest: sha256:7b3ccabffc97de872a30dfd234fd972a66d247c8cfc69b0550f276481852627c
Status: Downloaded newer image for busybox:latest
920d9a65afb4691ae39c497db793dc263bfb6a605c9c1324458dcdb0d683714b
$ docker run -itd --name=conatiner2 busybox
44a9e81d1afa3b64549d4f8050ad89650608ae91544dbb96d6397977e63e11a1
$
```

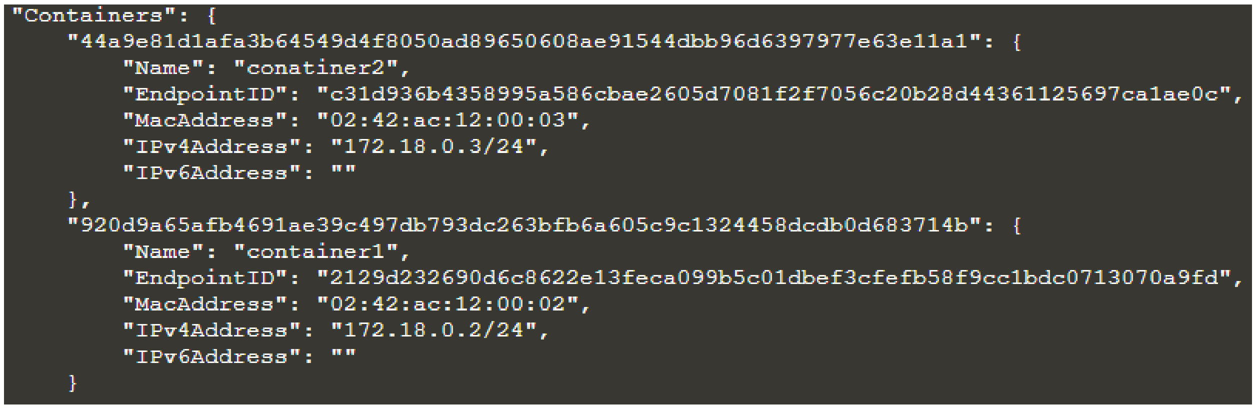
Lets run docker inspect command.

docker network inspect bridge



```
44a9e81d1afa3b64549d4f8050ad89650608ae91544dbb96d6397977e63e11a1
$ docker network inspect bridge
[
    {
        "Name": "bridge",
        "Id": "aeec28dcad9742221e7d5e9fa330ad05db3bfbade5e5af0644dd0795b6fa7fad",
        "Created": "2023-02-02T06:05:51.107064435Z",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": null,
            "Config": [
                {
                    "Subnet": "172.18.0.0/24",
                    "Gateway": "172.18.0.1"
                }
```

Now we can see these containers listed under this bridge network.

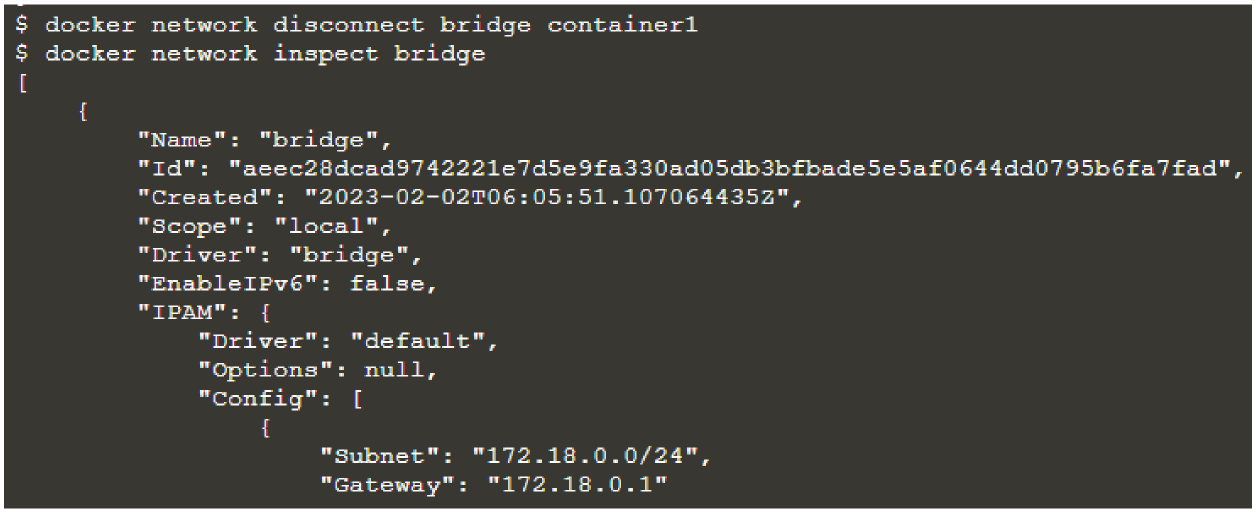


```
"Containers": {
    "44a9e81d1afa3b64549d4f8050ad89650608ae91544dbb96d6397977e63e11a1": {
        "Name": "conatiner2",
        "EndpointID": "c31d936b4358995a586cbae2605d7081f2f7056c20b28d44361125697ca1ae0c",
        "MacAddress": "02:42:ac:12:00:03",
        "IPv4Address": "172.18.0.3/24",
        "IPv6Address": ""
    },
    "920d9a65afb4691ae39c497db793dc263bfb6a605c9c1324458dcdb0d683714b": {
        "Name": "container1",
        "EndpointID": "2129d232690d6c8622e13feca099b5c01dbef3cfefb58f9cc1bdc0713070a9fd",
        "MacAddress": "02:42:ac:12:00:02",
        "IPv4Address": "172.18.0.2/24",
        "IPv6Address": ""
    }
```

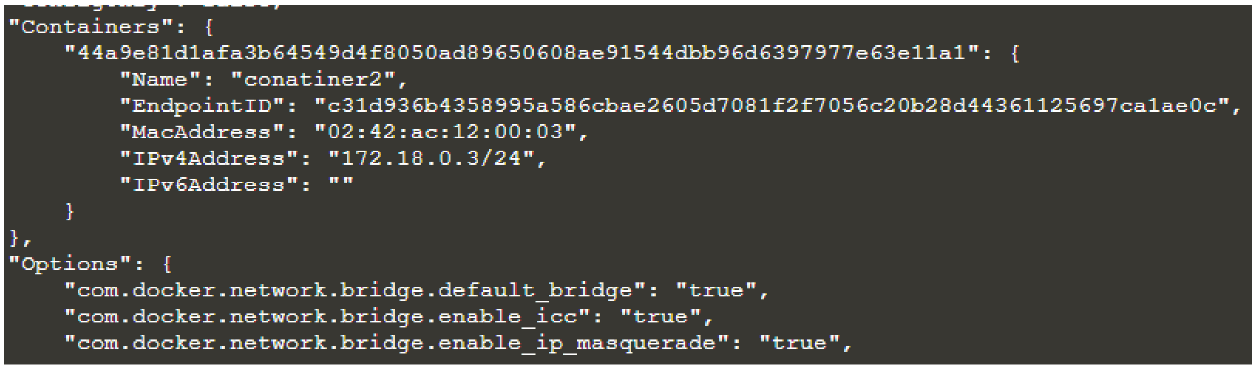
Bridge Network (Contd 2...)

Disconnect from the bridge network

docker network disconnect bridge container1



```
$ docker network disconnect bridge container1
$ docker network inspect bridge
[
    {
        "Name": "bridge",
        "Id": "aeec28dcad9742221e7d5e9fa330ad05db3bfbade5e5af0644dd0795b6fa7fad",
        "Created": "2023-02-02T06:05:51.107064435Z",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": null,
            "Config": [
                {
                    "Subnet": "172.18.0.0/24",
                    "Gateway": "172.18.0.1"
```



```
"Containers": {
    "44a9e81d1afa3b64549d4f8050ad89650608ae91544dbb96d6397977e63e11a1": {
        "Name": "conatiner2",
        "EndpointID": "c31d936b4358995a586cbae2605d7081f2f7056c20b28d44361125697ca1ae0c",
        "MacAddress": "02:42:ac:12:00:03",
        "IPv4Address": "172.18.0.3/24",
        "IPv6Address": ""
    }
},
"Options": {
    "com.docker.network.bridge.default_bridge": "true",
    "com.docker.network.bridge.enable_icc": "true",
    "com.docker.network.bridge.enable_ip_masquerade": "true",
```

User Defined Network

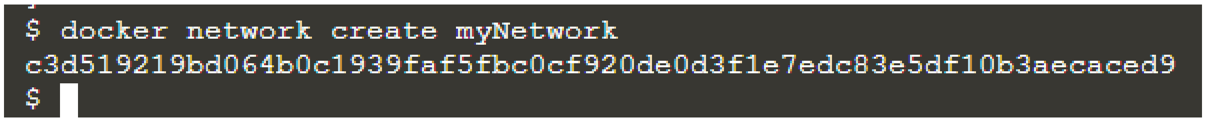
Users can create 2 kinds of network

- *Bridge network*
- *Overlay network*

Docker command to create a *Bridge network*

docker network create <<network name>>

e.g. docker network create myNetwork

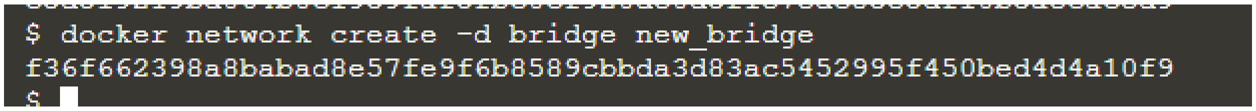


```
$ docker network create myNetwork
c3d519219bd064b0c1939faf5fbc0cf920de0d3f1e7edc83e5df10b3aecaced9
$
```

Create a User Defined Network

Lets create our new bridge network and learn how to connect containers to the network.

Step 1:

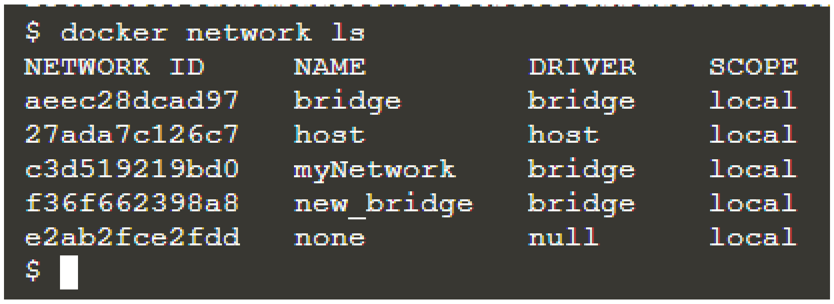


```
$ docker network create -d bridge new_bridge
f36f662398a8babad8e57fe9f6b8589cbbda3d83ac5452995f450bed4d4a10f9
$
```

-d --> to specify the driver type (in this case its is bridge network)

Step 2:

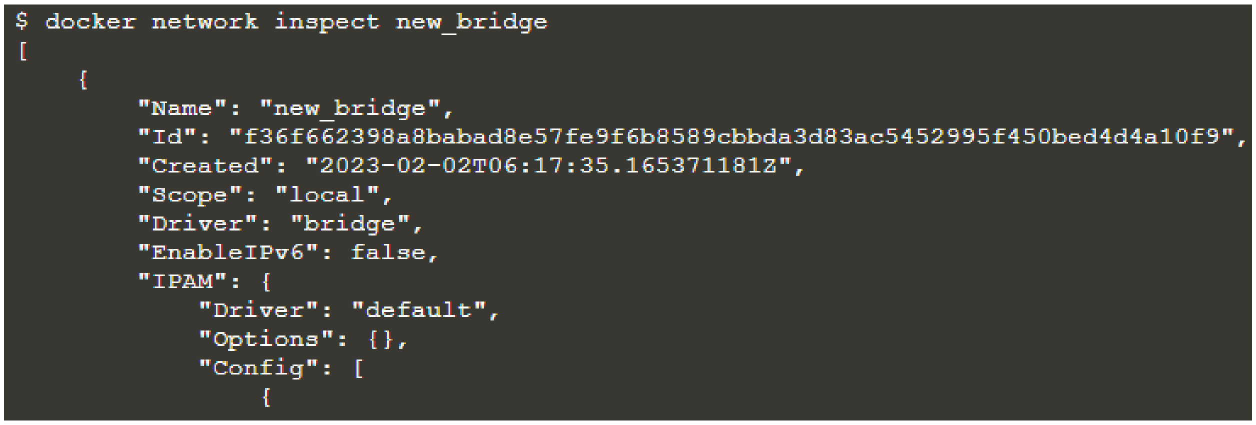
Verify if the new network is created



```
$ docker network ls
NETWORK ID     NAME          DRIVER    SCOPE
aeec28dcad97   bridge        bridge    local
27ada7c126c7   host          host      local
c3d519219bd0   myNetwork     bridge    local
f36f662398a8   new_bridge    bridge    local
e2ab2fce2fdd   none          null      local
$
```

This command will list the new bridge along with the other default bridges.

Run the below command to inspect the new network created.



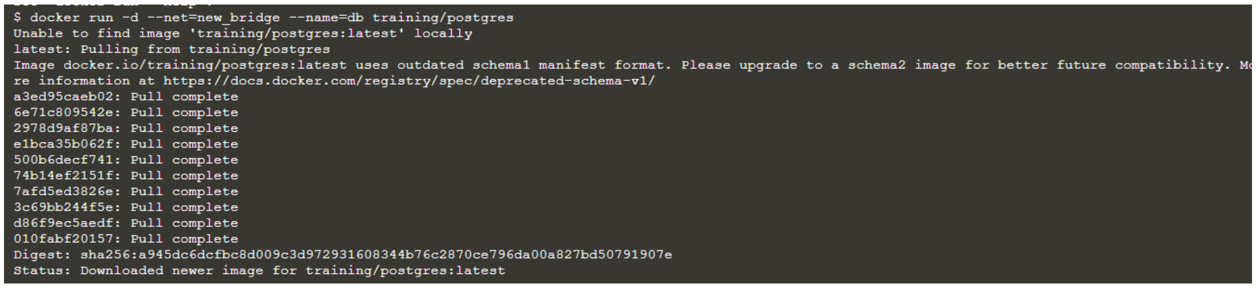
```
$ docker network inspect new_bridge
[
    {
        "Name": "new_bridge",
        "Id": "f36f662398a8babad8e57fe9f6b8589cbbda3d83ac5452995f450bed4d4a10f9",
        "Created": "2023-02-02T06:17:35.165371181Z",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": {},
            "Config": [
                {
```

Create a User Defined Network (Contd 1...)

Step 3:

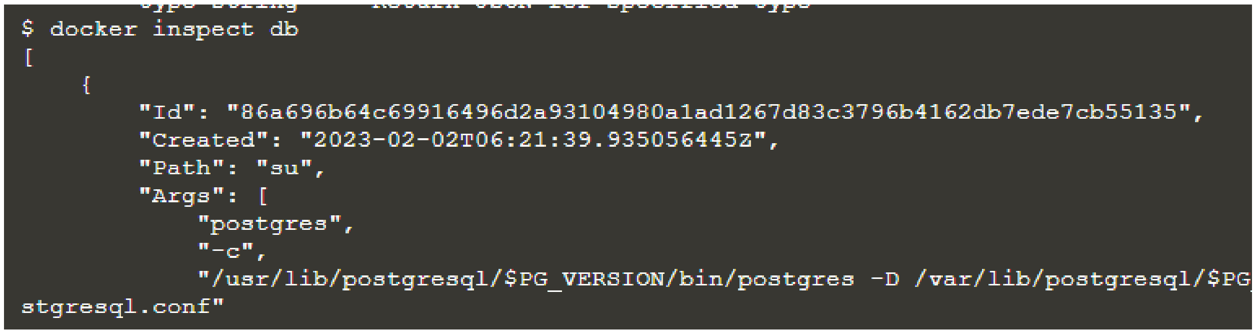
Add container to the network

Lets create a new container using image training/postgres to run a PostgreSQL db and tag this to the new network created.



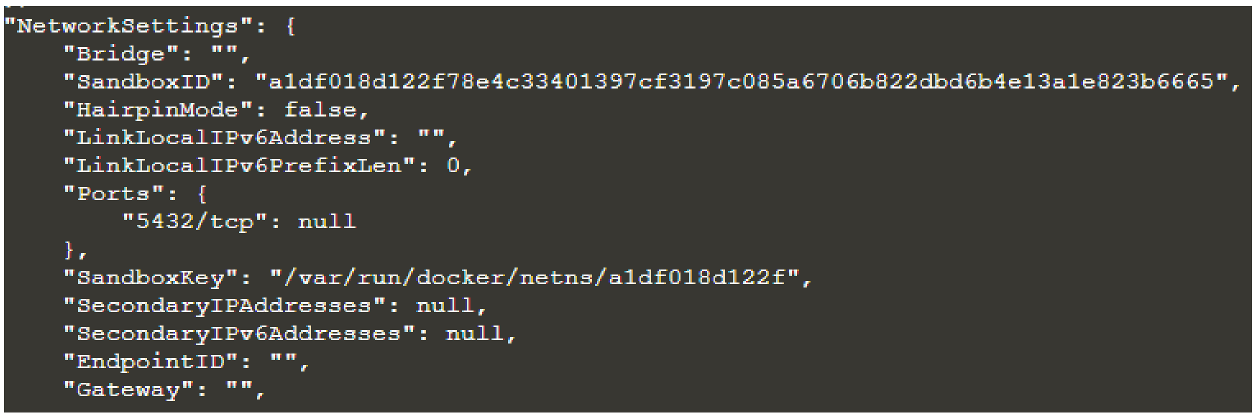
```
$ docker run -d --net=new_bridge --name=db training/postgres
Unable to find image 'training/postgres:latest' locally
latest: Pulling from training/postgres
Image docker.io/training/postgres:latest uses outdated schema1 manifest format. Please upgrade to a schema2 image for better future compatibility. Mo
re information at https://docs.docker.com/registry/spec/deprecated-schema-v1/
a3ed95caeb02: Pull complete
6e71c809542e: Pull complete
2978d9af87ba: Pull complete
e1bca35b062f: Pull complete
500b6decf741: Pull complete
74b14ef2151f: Pull complete
7afd5ed3826e: Pull complete
3c69bb244f5e: Pull complete
d86f9ec5aedf: Pull complete
010fabf20157: Pull complete
Digest: sha256:a945dc6dcfbc8d009c3d972931608344b76c2870ce796da00a827bd50791907e
Status: Downloaded newer image for training/postgres:latest
```

Step 4: Verify if its connected to the new network.

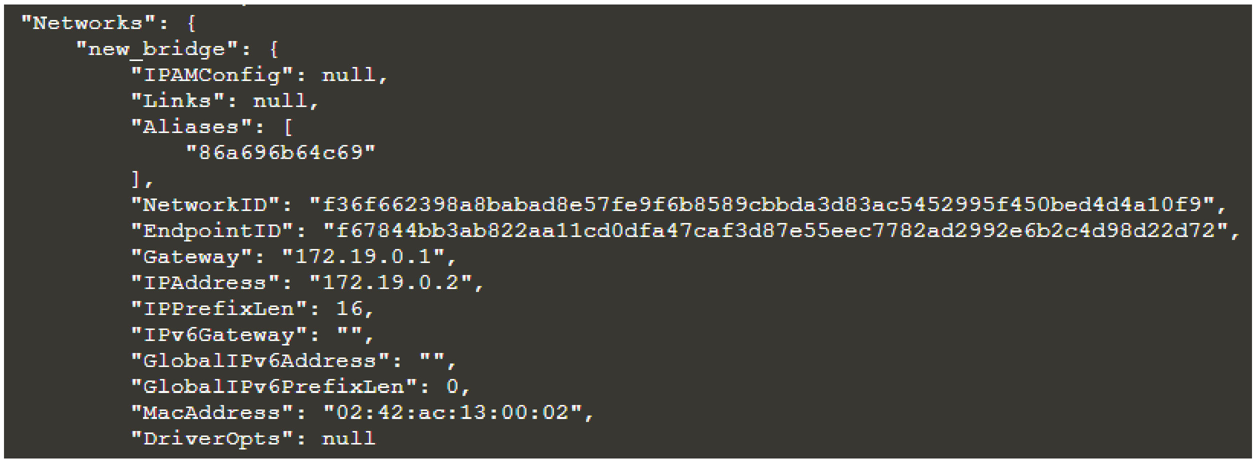


```
$ docker inspect db
[
    {
        "Id": "86a696b64c69916496d2a93104980a1ad1267d83c3796b4162db7ede7cb55135",
        "Created": "2023-02-02T06:21:39.935056445Z",
        "Path": "su",
        "Args": [
            "postgres",
            "-c",
            "/usr/lib/postgresql/$PG_VERSION/bin/postgres -D /var/lib/postgresql/$PG
stgresql.conf"
```

Under network setting we need network details .

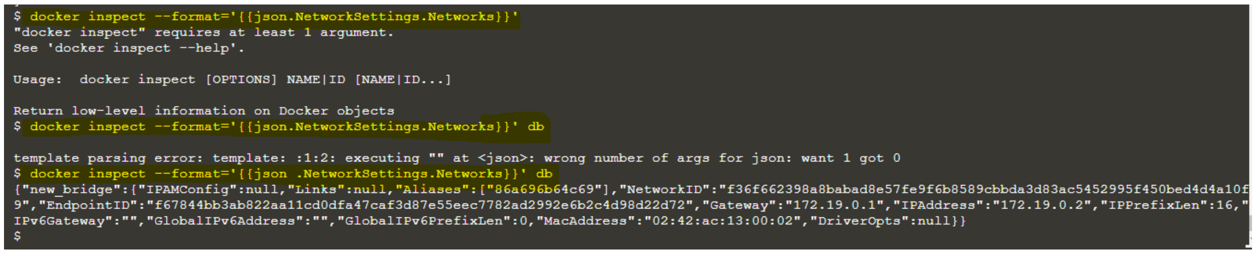


```
"NetworkSettings": {
    "Bridge": "",
    "SandboxID": "a1df018d122f78e4c33401397cf3197c085a6706b822dbd6b4e13a1e823b6665",
    "HairpinMode": false,
    "LinkLocalIPv6Address": "",
    "LinkLocalIPv6PrefixLen": 0,
    "Ports": {
        "5432/tcp": null
    },
    "SandboxKey": "/var/run/docker/netns/a1df018d122f",
    "SecondaryIPAddresses": null,
    "SecondaryIPv6Addresses": null,
    "EndpointID": "",
    "Gateway": "",
```



```
 "Networks": {
     "new_bridge": {
         "IPAMConfig": null,
         "Links": null,
         "Aliases": [
             "86a696b64c69"
         ],
         "NetworkID": "f36f662398a8babad8e57fe9f6b8589cbbda3d83ac5452995f450bed4d4a10f9",
         "EndpointID": "f67844bb3ab822aa11cd0dfa47caf3d87e55eec7782ad2992e6b2c4d98d22d72",
         "Gateway": "172.19.0.1",
         "IPAddress": "172.19.0.2",
         "IPPrefixLen": 16,
         "IPv6Gateway": "",
         "GlobalIPv6Address": "",
         "GlobalIPv6PrefixLen": 0,
         "MacAddress": "02:42:ac:13:00:02",
         "DriverOpts": null
```

Run the below command to get the network details on where this container is connected.



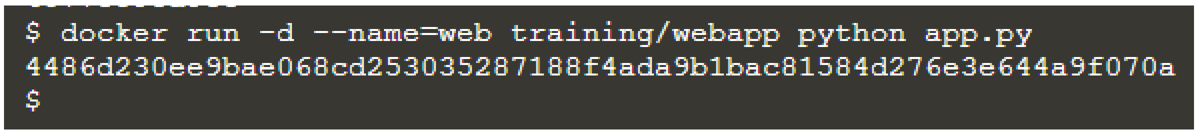
```
$ docker inspect --format='{{json.NetworkSettings.Networks}}'
"docker inspect" requires at least 1 argument.
See 'docker inspect --help'.

Usage:  docker inspect [OPTIONS] NAME|ID [NAME|ID...]

Return low-level information on Docker objects
$ docker inspect --format='{{json.NetworkSettings.Networks}}' db

template parsing error: template: :1:2: executing "" at <json>: wrong number of args for json: want 1 got 0
$ docker inspect --format='{{json .NetworkSettings.Networks}}' db
{"new_bridge":{"IPAMConfig":null,"Links":null,"Aliases":["86a696b64c69"],"NetworkID":"f36f662398a8babad8e57fe9f6b8589cbbda3d83ac5452995f450bed4d4a10f
9","EndpointID":"f67844bb3ab822aa11cd0dfa47caf3d87e55eec7782ad2992e6b2c4d98d22d72","Gateway":"172.19.0.1","IPAddress":"172.19.0.2","IPPrefixLen":16,"
IPv6Gateway":"","GlobalIPv6Address":"","GlobalIPv6PrefixLen":0,"MacAddress":"02:42:ac:13:00:02","DriverOpts":null}}
$
```

Create a User Defined Network (Contd 2...)

Step 5:

Lets run the python web app using image training/webapp without specifying any network settings.

This connects the container to the default bridge network.



```
$ docker run -d --name=web training/webapp python app.py
4486d230ee9bae068cd253035287188f4ada9b1bac81584d276e3e644a9f070a
$
```

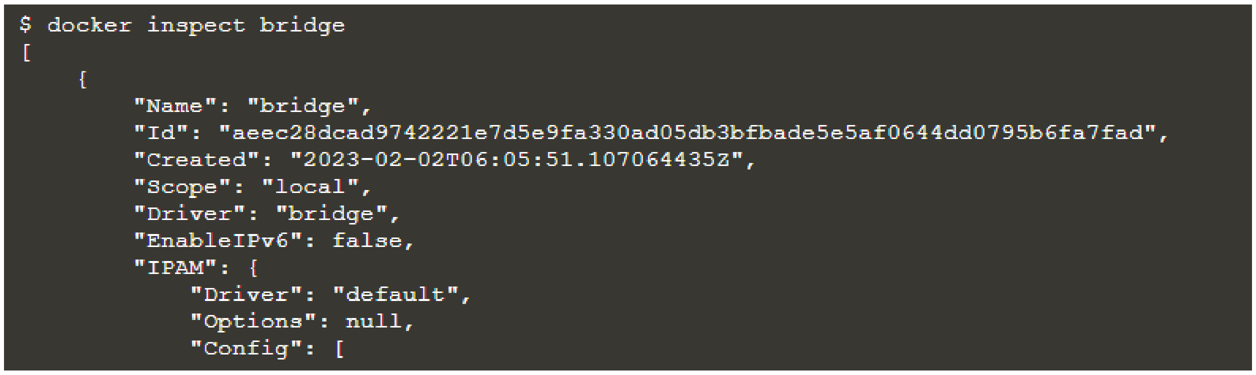
We can also specify command to run along with docker run command .

Step 6:

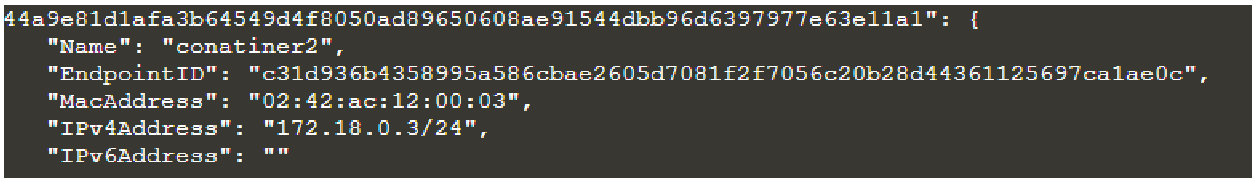
Verify if the web app container is connected to the default bridge network.

We can use ‘range’ to iterate over an array, The ‘range’ must end with {{end}}.

IP address of default bridge network .

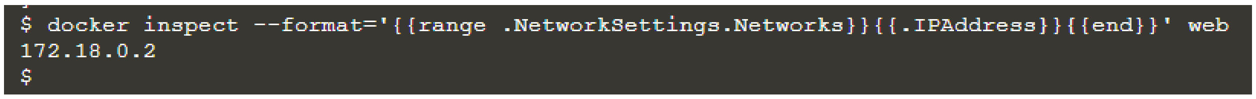


```
$ docker inspect bridge
[
    {
        "Name": "bridge",
        "Id": "aeec28dcad9742221e7d5e9fa330ad05db3bfbade5e5af0644dd0795b6fa7fad",
        "Created": "2023-02-02T06:05:51.107064435Z",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": null,
            "Config": [
```

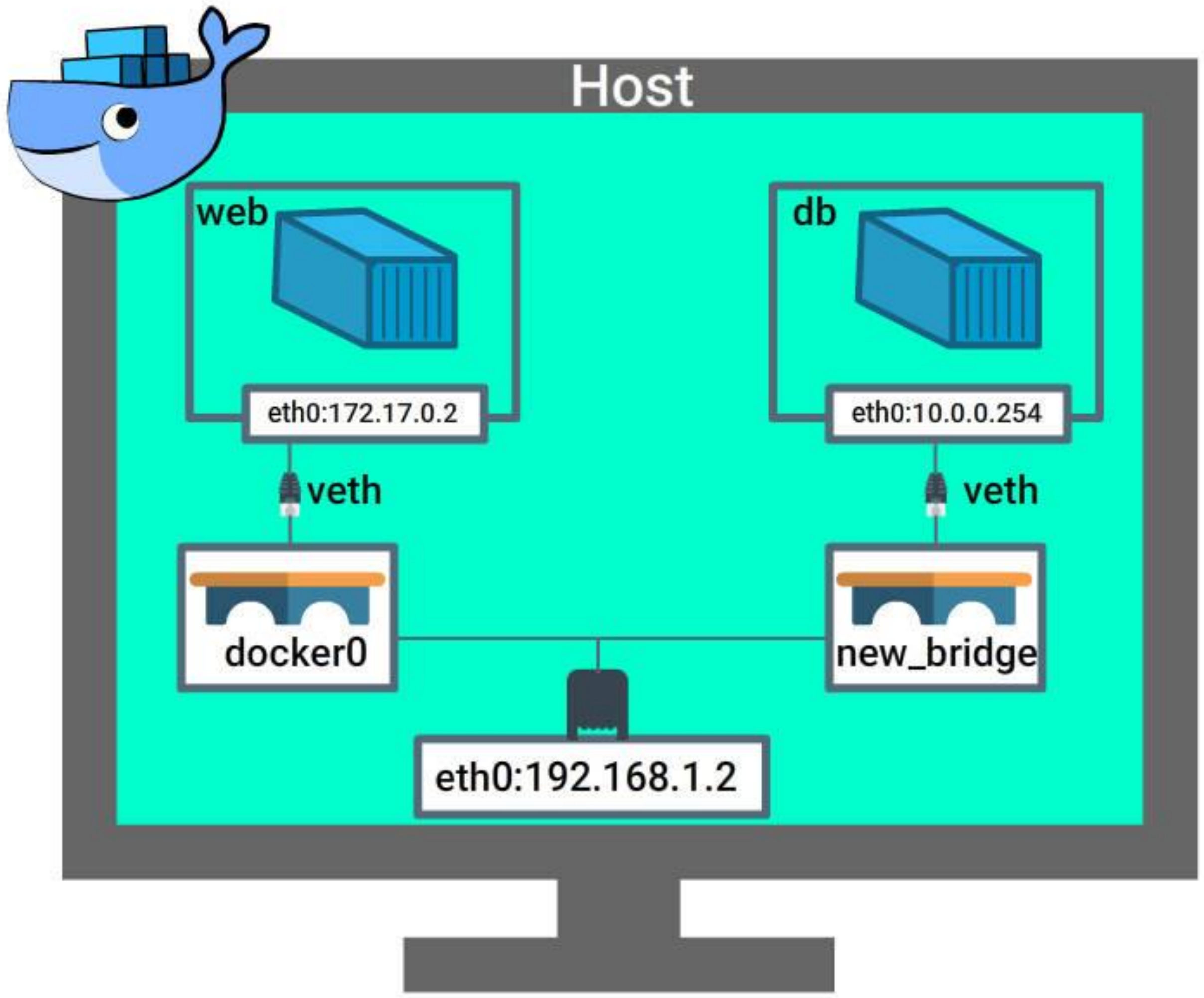


```
44a9e81d1afa3b64549d4f8050ad89650608ae91544dbb96d6397977e63e11a1": {
   "Name": "conatiner2",
   "EndpointID": "c31d936b4358995a586cbae2605d7081f2f7056c20b28d44361125697ca1ae0c",
   "MacAddress": "02:42:ac:12:00:03",
   "IPv4Address": "172.18.0.3/24",
   "IPv6Address": ""
```

Ip address of web containers network is also same , this suggests that web container is using default network .



```
$ docker inspect --format='{{range .NetworkSettings.Networks}}{{.IPAddress}}{{end}}' web
172.18.0.2
$
```



Create a User Defined Network (Contd 4...)

Step 7:

Check Connectivity between containers.

Lets try to ping the web app container from the db container using the below command.

```
docker exec -it db bash
```

Now lets enter the ping command in the db running container.

```
ping 172.17.0.2
```

Note: ip address should be as that of the web app container. Refer to Step 6 to get the ip address.

Press CTRL-C to end this ping and you will find that the ping command failed. This is because the web app and the db container is not connected to the same network.

Create a User Defined Network (Contd 5...)

Step 8:

Connect web container to new_bridge.

You can open an additional terminal in Katacoda playground. Let's execute the below commands in this new terminal.

Let's now connect web container new_bridge network.

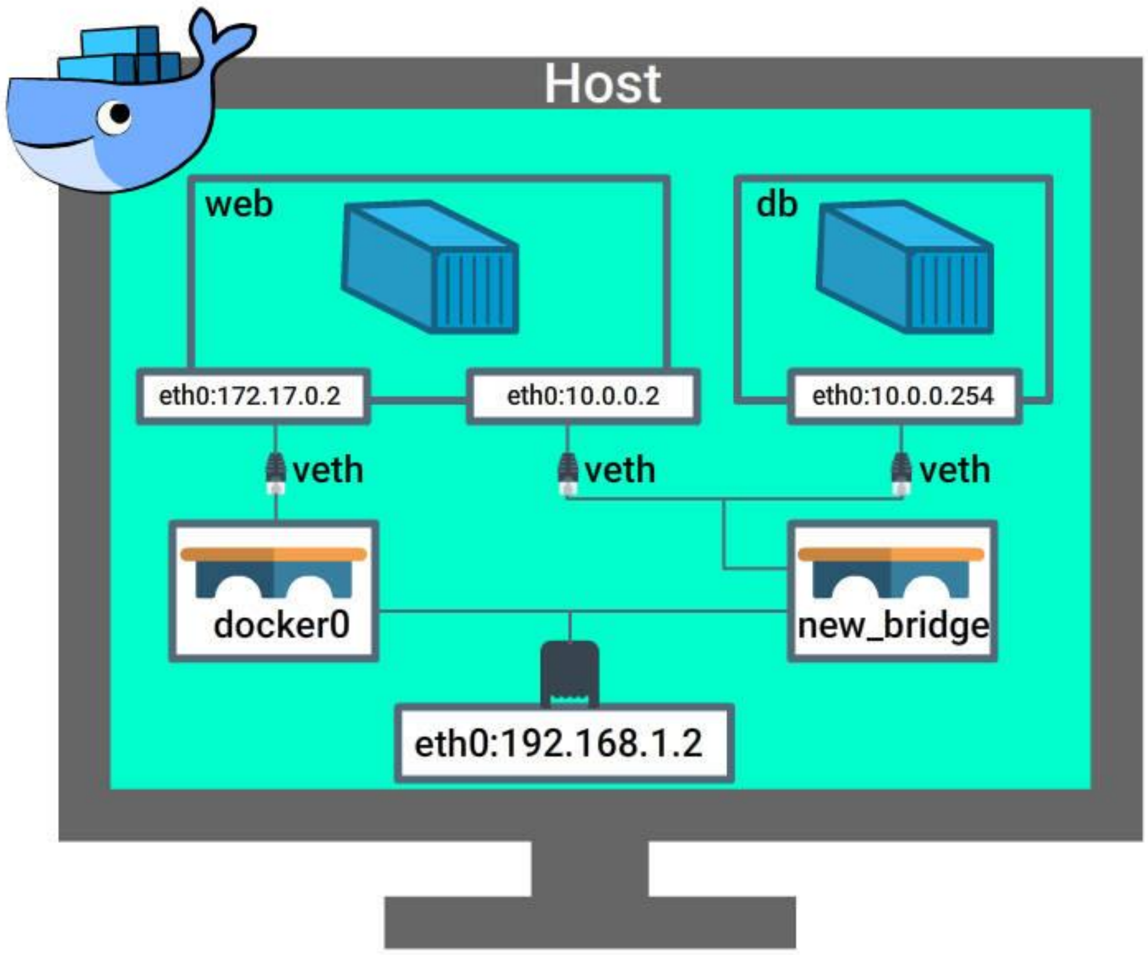
```
docker network connect new_bridge web
```

Step 9:

Repeat Step 7 commands to ping web container from db container. Get the ipaddress by running below command again. This time you will find 2 ipaddress, the second one is for the connectivity with the new_bridge.

```
docker inspect --format='{{json .NetworkSettings.Networks.new_bridge}}'  web
```

This ping command is successful now since we have established connectivity between 2 containers.



Create Network

Command to *create new bridge network*.

```
docker network create <<network name>>
```

e.g docker network create myNetwork

Connect Container to Network

```
docker network connect <<network name>> <<Container name>>
```

e.g. Create a container busybox and connect this to myNetwork.

```
docker run -itd --name=container1 busybox

docker network connect myNetwork container1
```

List all Networks

```
docker network ls
```

Inspect a Network

We can inspect a network to list the configuration and containers connected to using command

```
docker network inspect <<network name>>

docker network inspect myNetwork
```

Disconnect a container from a Network

docker network disconnect <<network name>> <<container name>>

e.g.

docker network disconnect isolated_nw container5

Remove network

Command to remove unused network

docker network rm <<network name>>

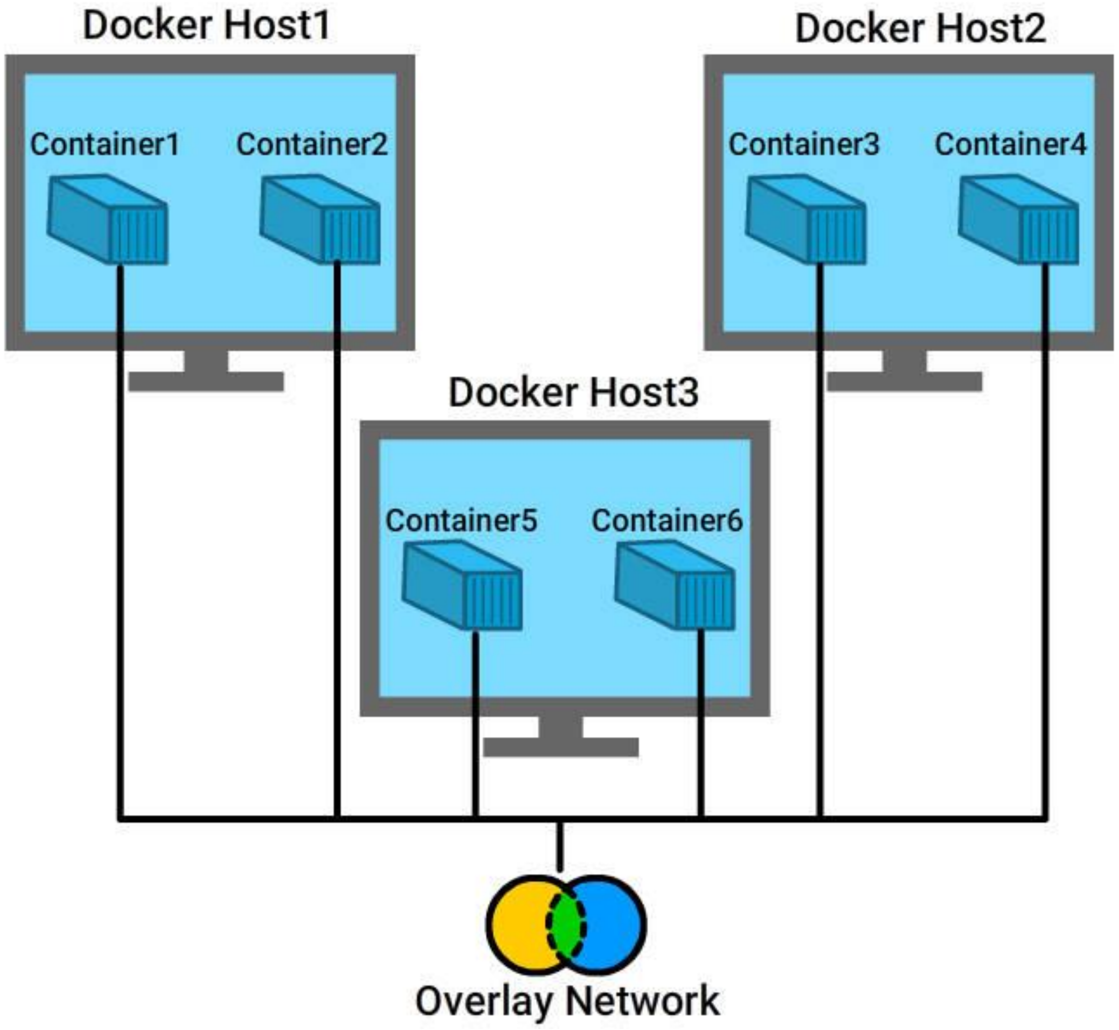
e.g. docker network rm Mynetwork

Multi-Host Networking

Docker Engine provides *out-of-the-box* support to *multi-host networking* using *overlay network driver*.

A *bridge network* is used when we run a relatively *small network* on a *single host*.

An *overlay network* is used when we have a significantly *larger network* involving *multiple host*.



Refer to the Overlay network block diagram. This network connects multiple containers from different hosts.

Overlay Network

There are 2 ways of creating an overlay network.

- Overlay networking with an *external key-value store*
- Overlay networking in *swarm mode*

Overlay networking with an external key-value store

We need a valid key-value store service to create a Overlay network.

Before creating a network in this way, you must install and configure your chosen key-value store service.

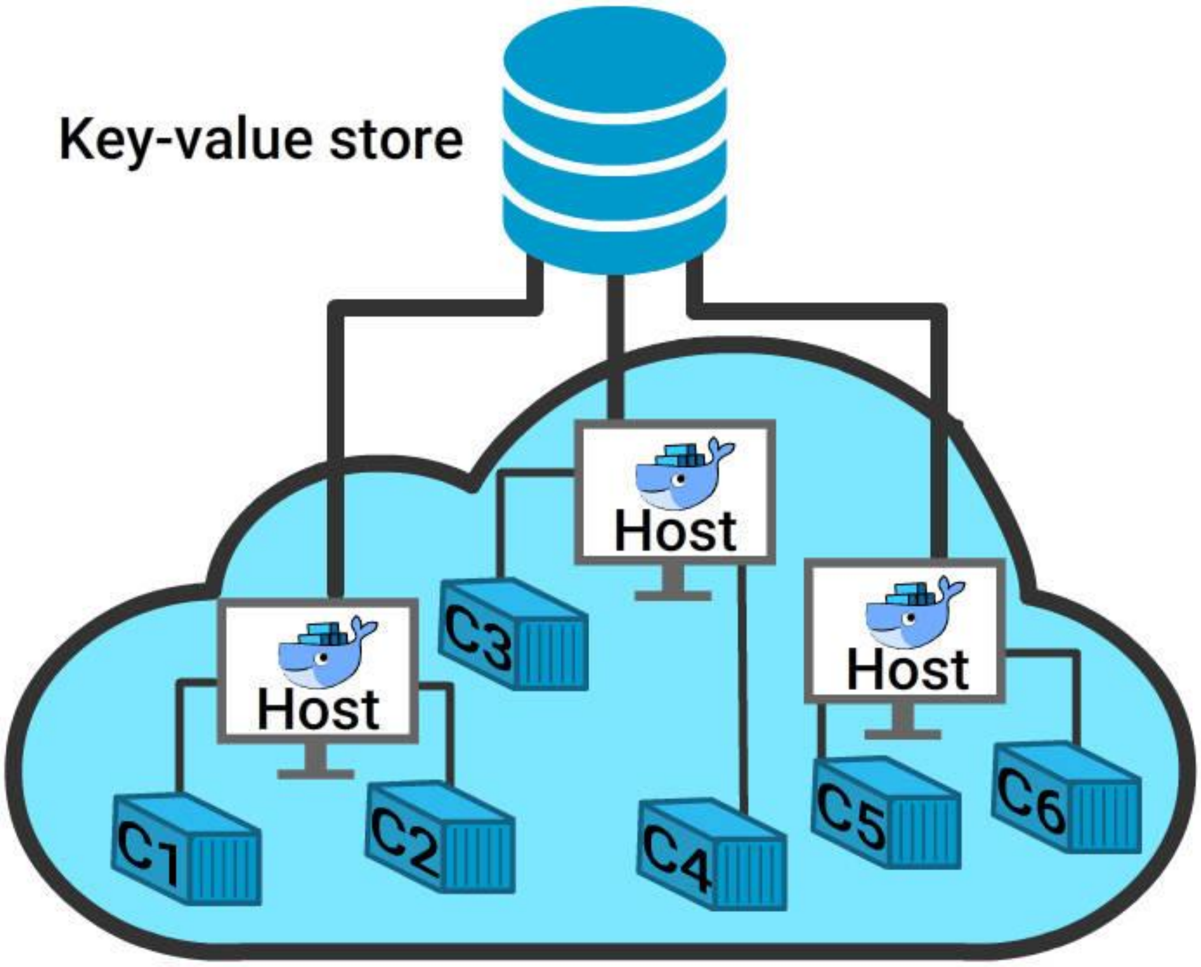
Pre-requisites:

A key-value store (Docker supports Consul, Etcd, and ZooKeeper)

A cluster of hosts that connects to key-value store

Host with Docker Engine configured properly

Host within cluster must have a unique hostname because key-value store uses host name to identify cluster members



In this block diagram, containers from various host systems communicate through key-value store.

Overlay networks in swarm mode

What is Swarm?

A ***swarm*** is a cluster of ***Docker engines, or nodes***, where you deploy services.

The ***cluster management*** and ***orchestration*** features embedded in the Docker Engine are built using ***SwarmKit***.

Docker engines participating in a cluster are running in ***swarm mode***.

Source: docker.com

You can initialize a swarm or join an already existing swarm.

Overlay Network in Swarm Mode

The swarm nodes exchange overlay network information using a ***gossip protocol***.

By default the nodes ***encrypt and authenticate*** information they exchange via gossip using the ***AES algorithm in GCM mode***.

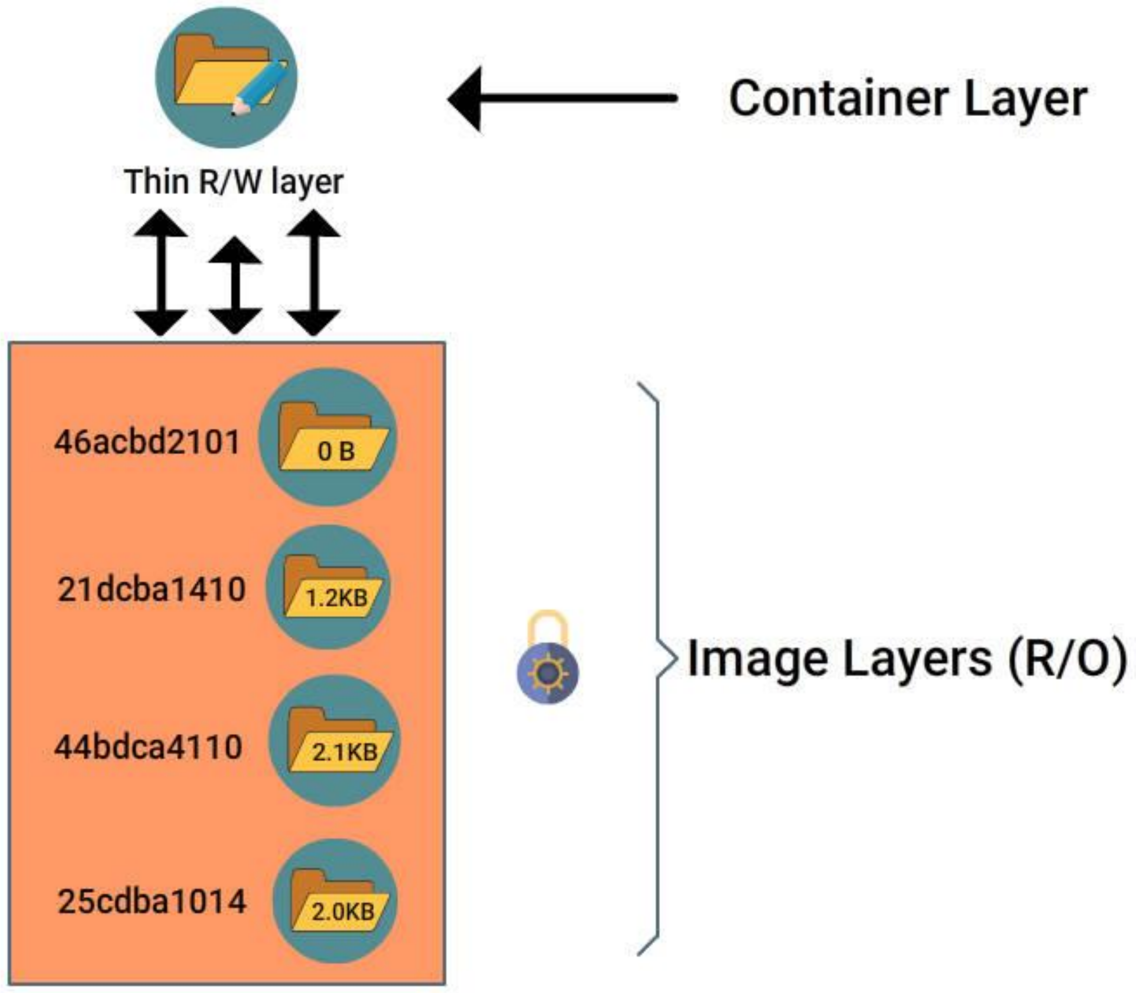
Manager nodes in the swarm rotate the key used to encrypt gossip data every 12 hours.

How Images are stored ?

Let's assume that we pull ***nginx image*** using docker pull command as below.

docker pull nginx

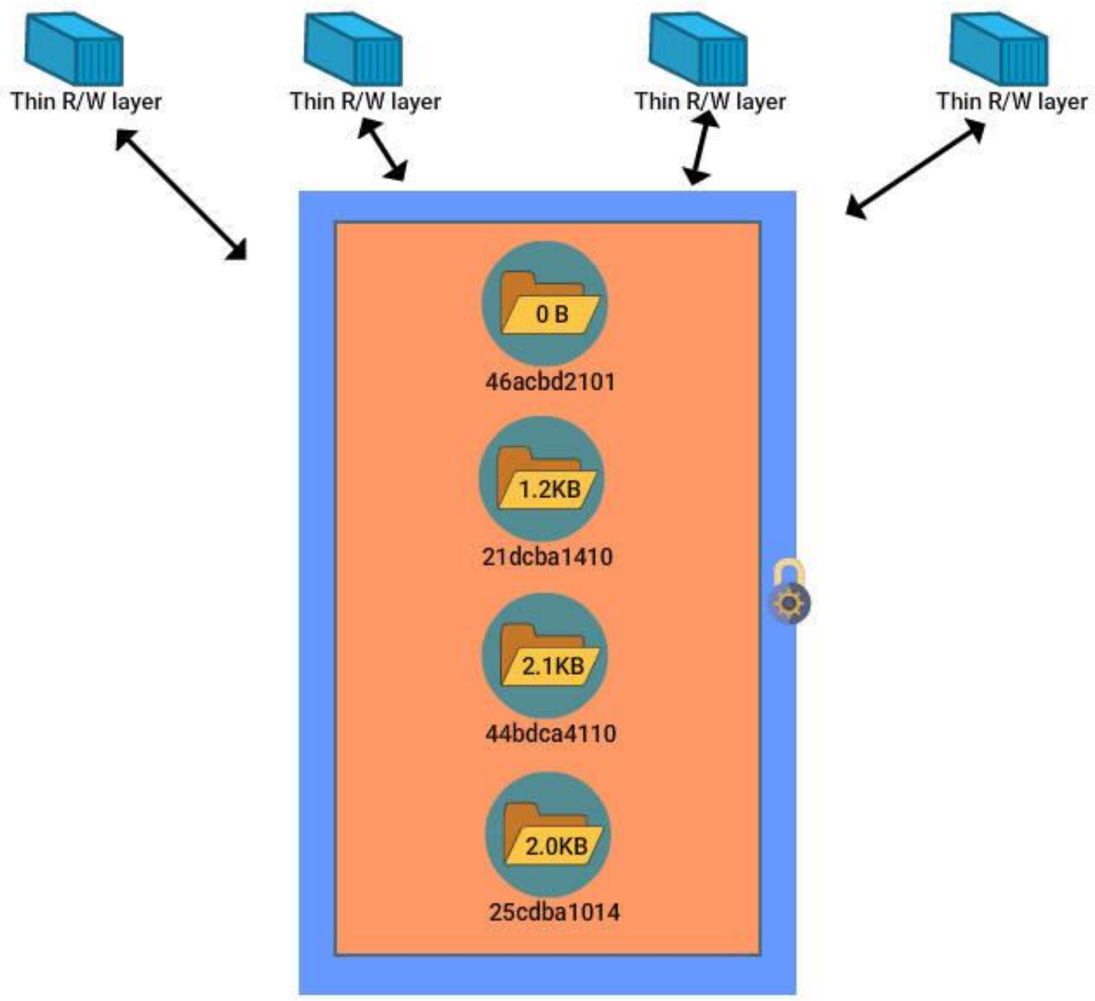
Docker will download this image from the docker hub to host directory which is managed by docker engine running in the host machine.



Docker Images have a series of in-build layers within. All the subsequent layers except for the last one is ***read- only***.

When we create a container from the image built, a ***new layer*** which is writable is added on top. This is called ***container layer***.

Changes done on the running container gets stored in the ***thin writable layer***.



The underlying image layer is shared between containers whereas the thin writable layer is separate for every individual containers.

Storage drivers manage the contents of the image layers as well as the thin writable container layer.

Storage drivers supported for Ubuntu systems are

- aufs
- devicemapper
- overlay2
- overlay
- zfs

Let's run the following command in Katacoda Docker playground to view the Storage driver used.

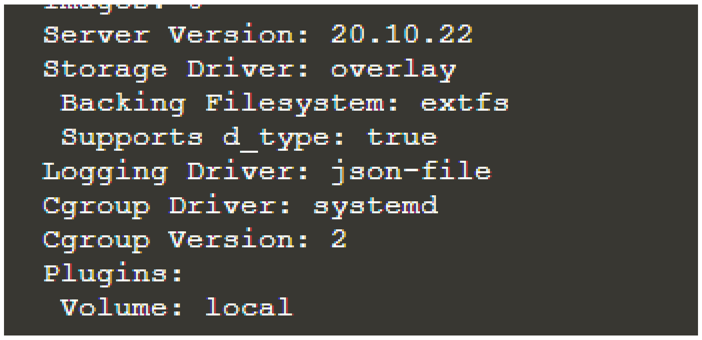
docker info

Let's consider only the below set of information in the terminal output to understand the current storage driver configured.

Server Version: 1.13.1

Storage Driver: overlay

Backing Filesystem: extfs



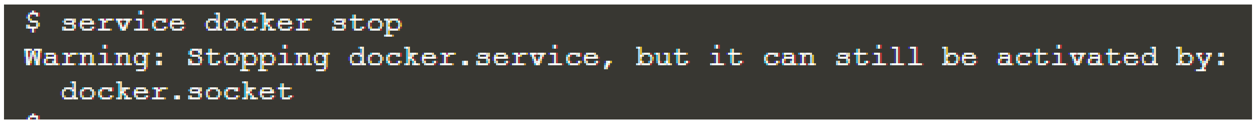
```
 Server Version: 20.10.22
 Storage Driver: overlay
  Backing Filesystem: extfs
  Supports d_type: true
 Logging Driver: json-file
 Cgroup Driver: systemd
 Cgroup Version: 2
 Plugins:
  Volume: local
```

Modify Storage Driver

Current Storage driver configured can be modified as below.

Step:1

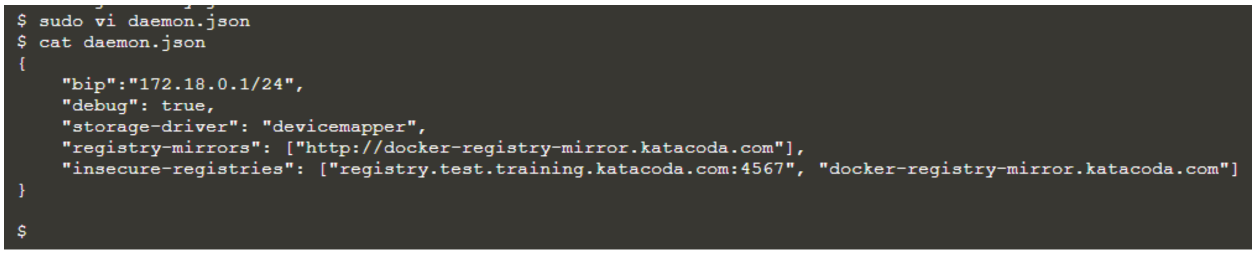
Stop the docker service.



```
$ service docker stop
Warning: Stopping docker.service, but it can still be activated by:
  docker.socket
```

Step 2:

In a Ubuntu machine, add the following to daemon.json file in /etc/docker/ directory to modify the driver to 'devicemapper'

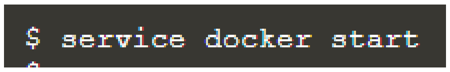


```
$ sudo vi daemon.json
$ cat daemon.json
{
    "bip":"172.18.0.1/24",
    "debug": true,
    "storage-driver": "devicemapper",
    "registry-mirrors": ["http://docker-registry-mirror.katacoda.com"],
    "insecure-registries": ["registry.test.training.katacoda.com:4567", "docker-registry-mirror.katacoda.com"]
}

$
```

Modify Storage Driver (Contd...)

Step 3:

Once you add it, restart docker service using command



```
$ service docker start
```

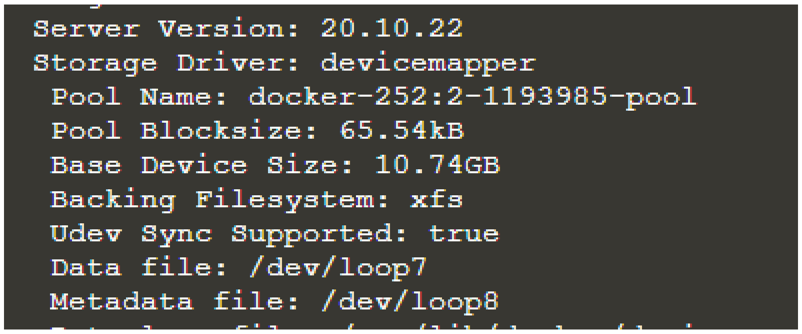
Note:

This cannot be tried out in Katacoda playground since this requires a root access.

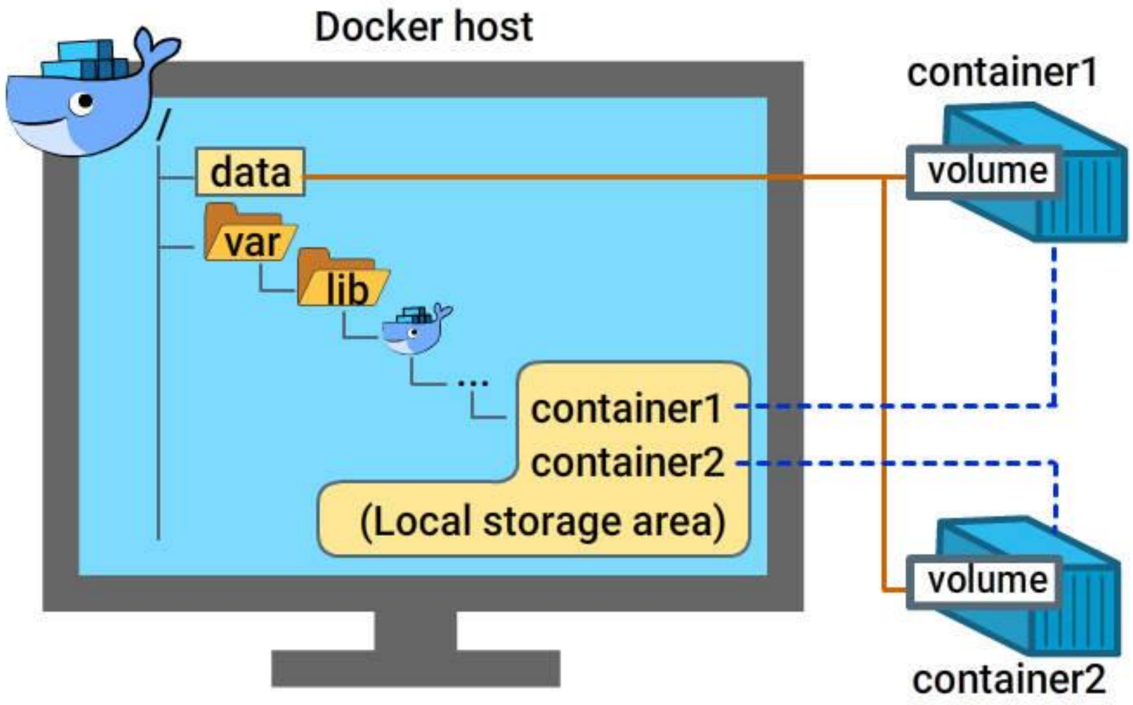
Step 4:

You can verify using command

```
docker info
```



```
Server Version: 20.10.22
Storage Driver: devicemapper
 Pool Name: docker-252:2-1193985-pool
 Pool Blocksize: 65.54kB
 Base Device Size: 10.74GB
 Backing Filesystem: xfs
 Udev Sync Supported: true
 Data file: /dev/loop7
 Metadata file: /dev/loop8
```



Docker Volumes are directories that ***store data outside of the container's filesystem*** in the host machine.

Data stored on Volumes are ***reusable and are shareable*** even when the ***container is stopped***.

Data in the volumes can be ***reused*** by the same service on redeployment, or ***shared*** with other services.

In Docker Cloud, you can define one or more data volumes for a service.

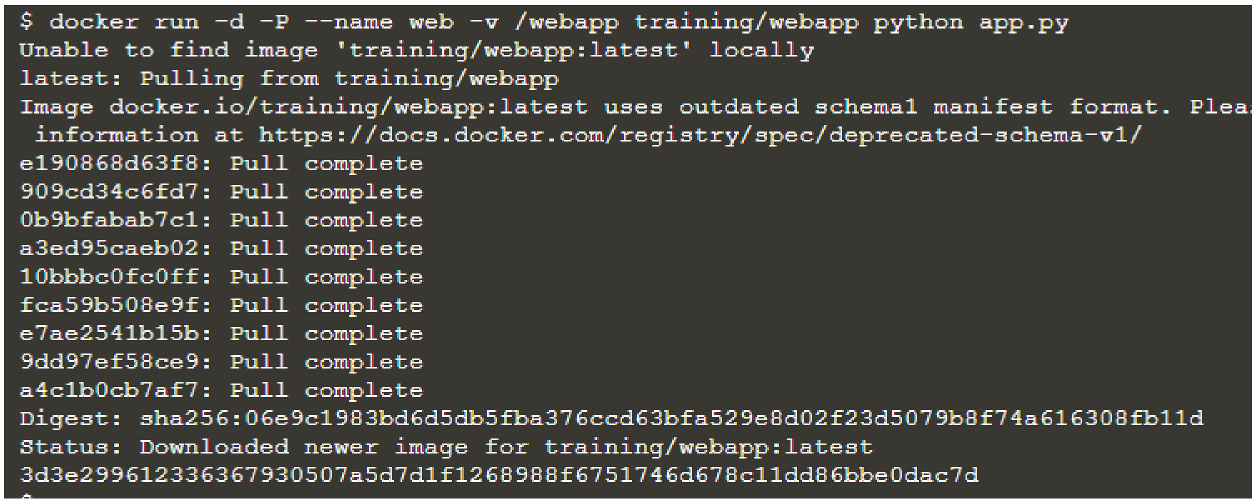
Containers directly ***read and write*** data on to the volumes.

Storage drivers do not have any control on the data volumes.

Docker Volumes - Commands

Add a Data Volume:

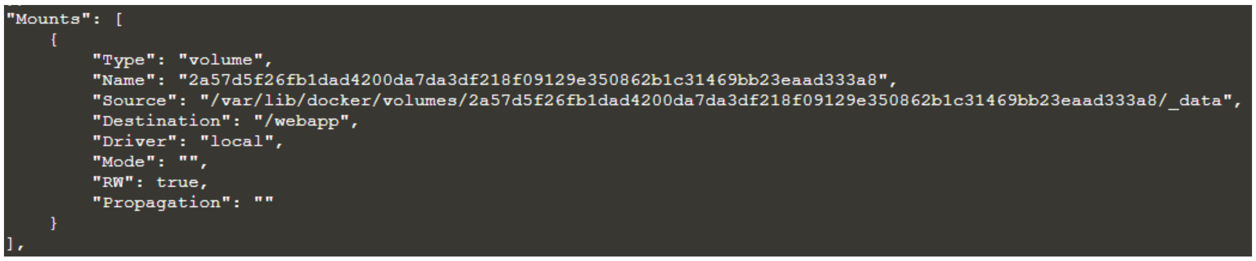
Note: You can add ***one or more volumes*** to a ***single container***



```
$ docker run -d -P --name web -v /webapp training/webapp python app.py
Unable to find image 'training/webapp:latest' locally
latest: Pulling from training/webapp
Image docker.io/training/webapp:latest uses outdated schema1 manifest format. Plea
 information at https://docs.docker.com/registry/spec/deprecated-schema-v1/
e190868d63f8: Pull complete
909cd34c6fd7: Pull complete
0b9bfabab7c1: Pull complete
a3ed95caeb02: Pull complete
10bbbc0fc0ff: Pull complete
fca59b508e9f: Pull complete
e7ae2541b15b: Pull complete
9dd97ef58ce9: Pull complete
a4c1b0cb7af7: Pull complete
Digest: sha256:06e9c1983bd6d5db5fba376ccd63bfa529e8d02f23d5079b8f74a616308fb11d
Status: Downloaded newer image for training/webapp:latest
3d3e29961233636793O507a5d7d1f1268988f6751746d678c11dd86bbe0dac7d
```

Locate a volume:

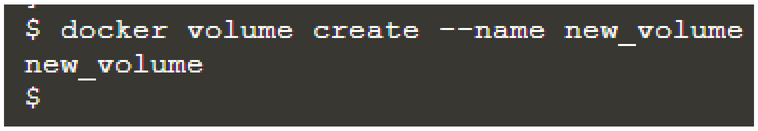
```
docker inspect web
```



```
"Mounts": [
    {
        "Type": "volume",
        "Name": "2a57d5f26fb1dad4200da7da3df218f09129e350862b1c31469bb23eaad333a8",
        "Source": "/var/lib/docker/volumes/2a57d5f26fb1dad4200da7da3df218f09129e350862b1c31469bb23eaad333a8/_data",
        "Destination": "/webapp",
        "Driver": "local",
        "Mode": "",
        "RW": true,
        "Propagation": ""
    }
],
```

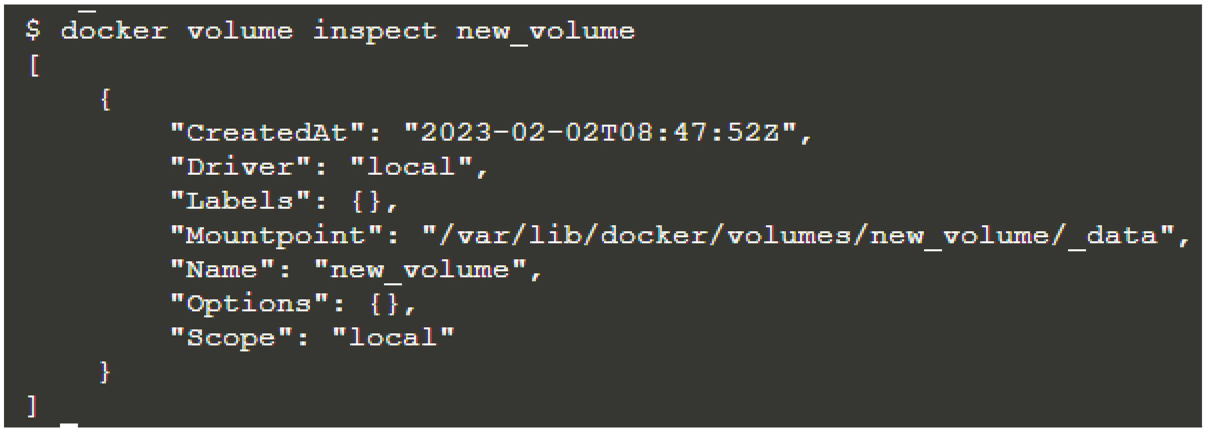
Mounts section of the output trace displays the source and destination as well as Read/write mode if enabled or not.

Create a Volume:



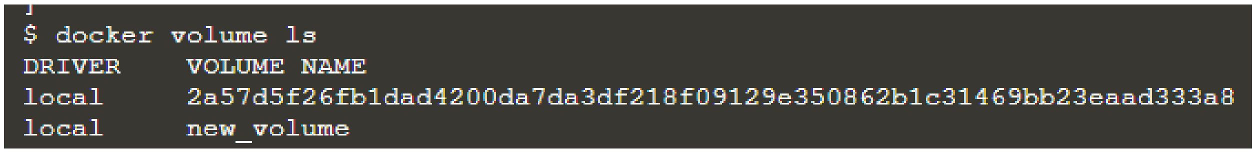
```
$ docker volume create --name new_volume
new_volume
$
```

Display detailed information on Volumes:



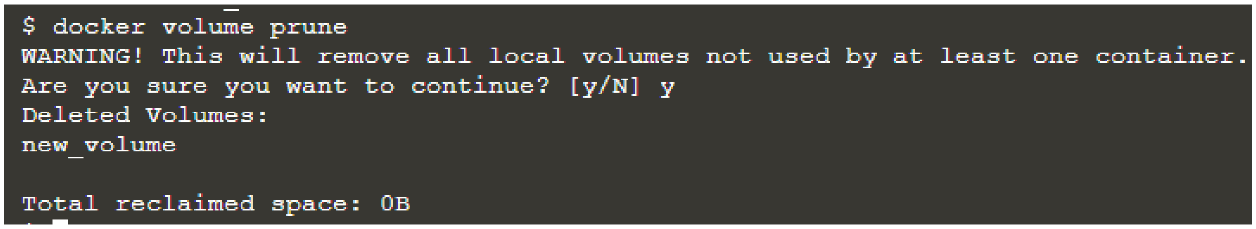
```
$ docker volume inspect new_volume
[
    {
        "CreatedAt": "2023-02-02T08:47:52Z",
        "Driver": "local",
        "Labels": {},
        "Mountpoint": "/var/lib/docker/volumes/new_volume/_data",
        "Name": "new_volume",
        "Options": {},
        "Scope": "local"
    }
]
```

List volumes:



```
$ docker volume ls
DRIVER    VOLUME NAME
local     2a57d5f26fb1dad4200da7da3df218f09129e350862b1c31469bb23eaad333a8
local     new_volume
```

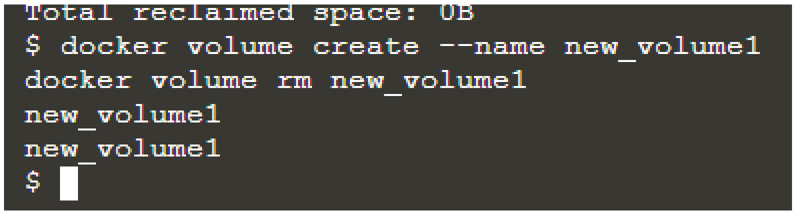
Remove unused volumes



```
$ docker volume prune
WARNING! This will remove all local volumes not used by at least one container.
Are you sure you want to continue? [y/N] y
Deleted Volumes:
new_volume

Total reclaimed space: 0B
```

This will remove 'new_volume'.

Remove one or more volumes

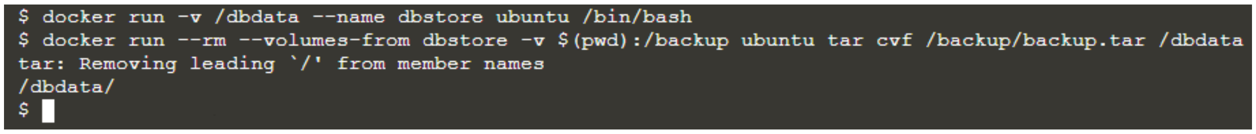


```
Total reclaimed space: 0B
$ docker volume create --name new_volume1
docker volume rm new_volume1
new_volume1
new_volume1
$
```

Backup/ Restore/ Migrate Data Volumes

Command to Back up Volumes:

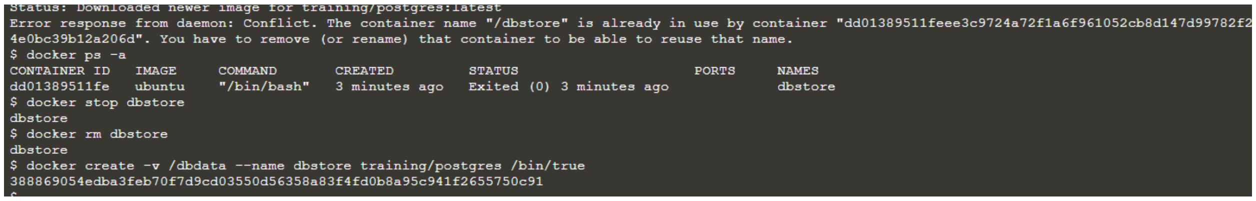
```
docker run --rm --volumes-from dbstore -v $(pwd):/backup ubuntu tar cvf /back
up/backup.tar /dbdata
```



```
$ docker run -v /dbdata --name dbstore ubuntu /bin/bash
$ docker run --rm --volumes-from dbstore -v $(pwd):/backup ubuntu tar cvf /backup/backup.tar /dbdata
tar: Removing leading `/' from member names
/dbdata/
$ 
```

Create and Mount Data Volume Container

Data Volume Container is created to share persistent data between containers.



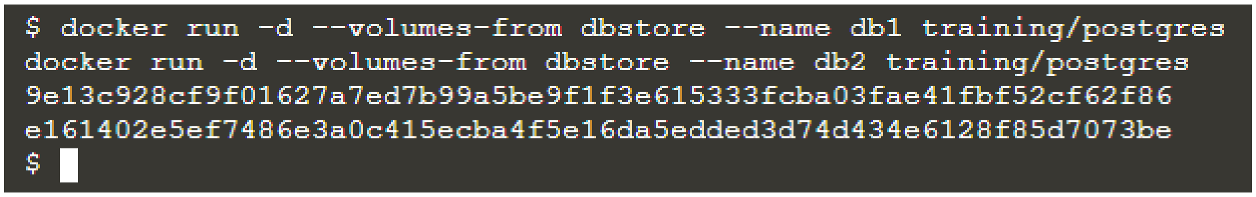
```
Status: Downloaded newer image for training/postgres:latest
Error response from daemon: Conflict. The container name "/dbstore" is already in use by container "dd01389511feee3c9724a72f1a6f961052cb8d147d99782f2
4e0bc39b12a206d". You have to remove (or rename) that container to be able to reuse that name.
$ docker ps -a
CONTAINER ID   IMAGE     COMMAND       CREATED         STATUS                       PORTS     NAMES
dd01389511fe   ubuntu    "/bin/bash"   3 minutes ago   Exited (0) 3 minutes ago             dbstore
$ docker stop dbstore
dbstore
$ docker rm dbstore
dbstore
$ docker create -v /dbdata --name dbstore training/postgres /bin/true
388869054edba3feb70f7d9cd03550d56358a83f4fd0b8a95c941f2655750c91
```

Here we have mounted a volume '/dbdata' using image 'training/postgres'.

Command to mount '/dbdata' volume to other containers using '--volumes-from' keyword.

docker run -d --volumes-from dbstore --name db1 training/postgres

docker run -d --volumes-from dbstore --name db2 training/postgres



```
$ docker run -d --volumes-from dbstore --name db1 training/postgres
docker run -d --volumes-from dbstore --name db2 training/postgres
9e13c928cf9f01627a7ed7b99a5be9f1f3e615333fcba03fae41fbf52cf62f86
e161402e5ef7486e3a0c415ecba4f5e16da5edded3d74d434e6128f85d7073be
$ 
```

Docker Volumes - Points to remember

- Data volumes can be ***reused*** and ***shared*** amongst containers
- Data volume changes are ***independent*** of the image update
- Even when containers are ***deleted***, data volumes ***persist***
- Data volumes get ***initialized*** when we ***create a container***

Below mentioned types can be mounted as a Data volume.

- ***Host directory***
- ***Shared storage volume***
- ***Host file***

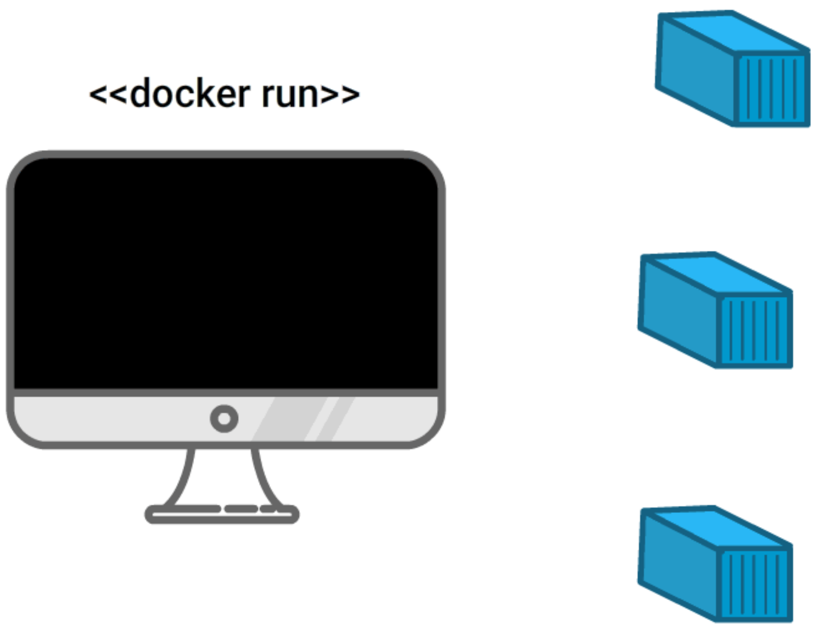
Docker Compose

Docker Compose is a tool used to ***define and run applications*** containing ***multiple containers***.

Why ***docker Compose***?

When an application is built to have ***many services/containers*** , its difficult to manage them separately. Every container will have its own ***dockerfile*** and to ***bring it up*** individual ***run commands*** are to be executed. Whereas with Docker compose, we can bring ***all services up with a single command***.

Docker Compose



Docker compose simplifies the process to run services on a real time large scale applications.

Installing Docker Compose

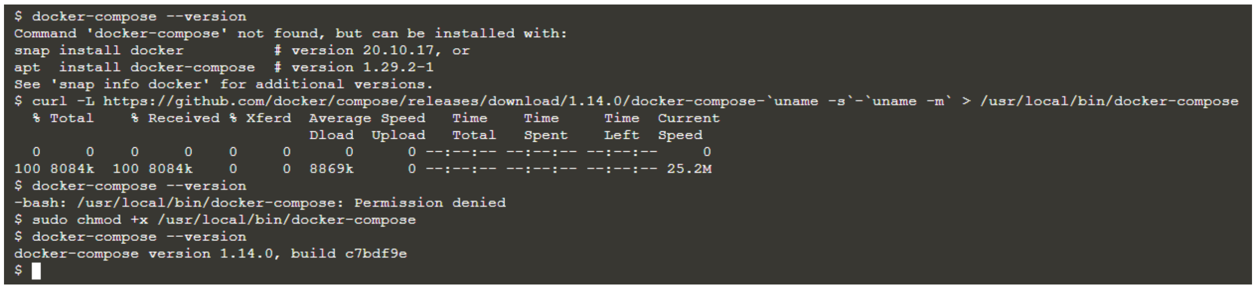
Installation on Ubuntu:

Docker compose version : 1.14.0

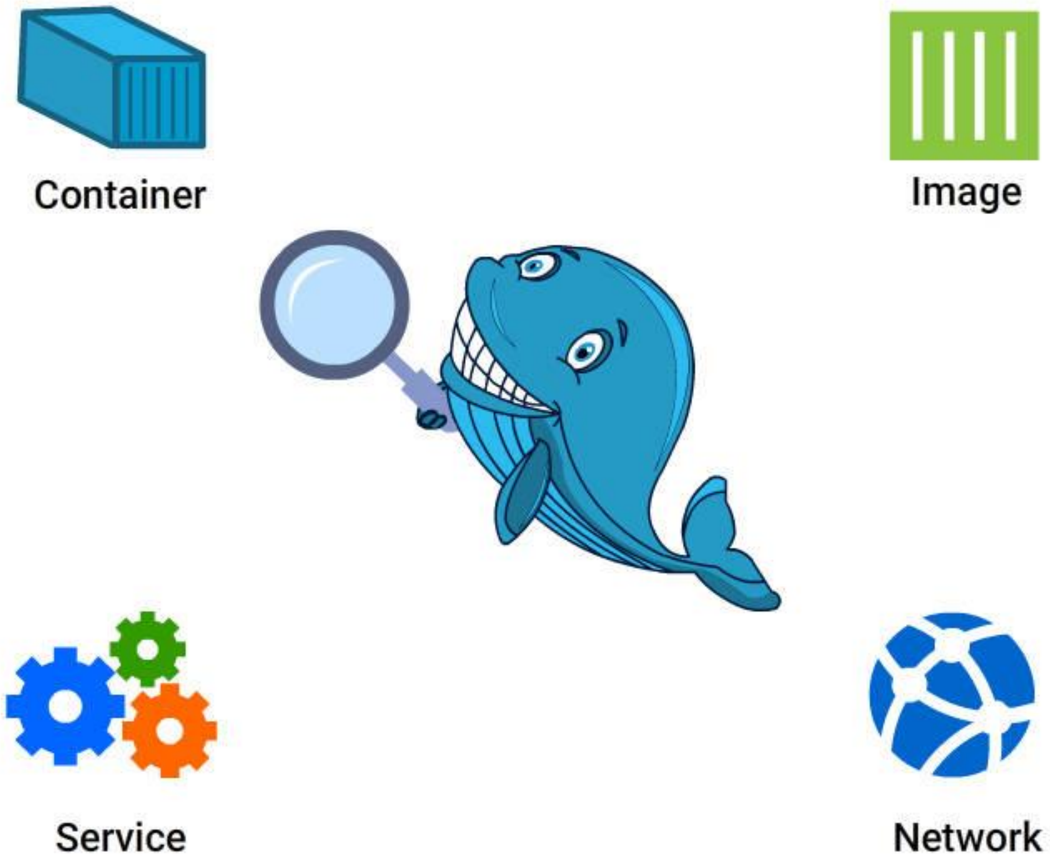
Run the following command as ***super user*** (Run sudo -i command to execute as super user)

Applying ***executable permission*** to binary.

Verify by running version command.



```
$ docker-compose --version
Command 'docker-compose' not found, but can be installed with:
snap install docker          # version 20.10.17, or
apt  install docker-compose  # version 1.29.2-1
See 'snap info docker' for additional versions.
$ curl -L https://github.com/docker/compose/releases/download/1.14.0/docker-compose-`uname -s`-`uname -m` > /usr/local/bin/docker-compose
  % Total    % Received % Xferd  Average Speed   Time    Time     Time  Current
                                 Dload  Upload   Total   Spent    Left  Speed
  0     0    0     0    0     0      0      0 --:--:-- --:--:-- --:--:--     0
100 8084k  100 8084k    0     0  8869k      0 --:--:-- --:--:-- --:--:-- 25.2M
$ docker-compose --version
-bash: /usr/local/bin/docker-compose: Permission denied
$ sudo chmod +x /usr/local/bin/docker-compose
$ docker-compose --version
docker-compose version 1.14.0, build c7bdf9e
$ █
```



This docker command is used to display ***low-level information*** on docker objects such as ***Images, Containers, volume, network, node, service, and task***.

These objects can be identified by either ***object name or ID***.

The default output will be a ***JSON array***.

```
docker inspect [--help] [-f|--format[=FORMAT]] [-s|--size] [--type] NAME|ID [
NAME|ID...]
```

--help: prints usage statement

-f, --format="" :Format the output using the given Go template

-s, --size : Display total file sizes if the type is container

--type: container|image|network|node|service|task|volume

Return JSON for specified type, permissible values are "image", "container",

"network", "node", "service", "task", and "volume"

Let's ***pull*** an image from ***docker hub*** and run ***Inspect*** command.

```
docker pull tomcat
```

Docker inspect command to display the ***information on the Image***.

```
docker inspect tomcat
```

When there is a ***name conflict*** with the image name and the corresponding container name lets add the ***type option*** and specify the object as ***image or container***.

```
docker inspect --type=image tomcat
```

We already have a Tomcat image pulled from docker hub. Let's run the same Image as below.

```
docker run -d --name tomcatContainer tomcat
```

Let's now run ***docker inspect*** command on the ***new container*** created.

```
docker inspect tomcatContainer
```

Display Size information on a container

docker inspect -s tomcatContainer

Highlighted below the ***size section*** of the output.

    "SizeRw": 37433,

```
    "SizeRootFs": 292398179
```

Formatting Docker Inspect Output

Let's understand more on formatting looking into the below example.

Display ***IP address*** of Container instance

```
docker inspect --format='{{range .NetworkSettings.Networks}}{{.IPAddress}}{{end}}' tomcatContainer
```

Display ***MAC address*** of the container

```
docker inspect --format='{{range .NetworkSettings.Networks}}{{.MacAddress}}{{end}}' tomcatContainer
```

Display ***log path*** of the container

```
docker inspect --format='{{.LogPath}}' tomcatContainer
```

Display ***Image name*** of the container

```
docker inspect --format='{{.Config.Image}}' tomcatContainer
```

Display a ***subsection in JSON format***

```
docker inspect --format='{{json .Config}}' tomcatContainer
```

Docker Security

Creating services using docker is ***gaining traction*** when compared to the ***virtual machine set up.***

To use ***services effectively and securely***, We need to be aware of ***potential threats and security issues*** to docker.

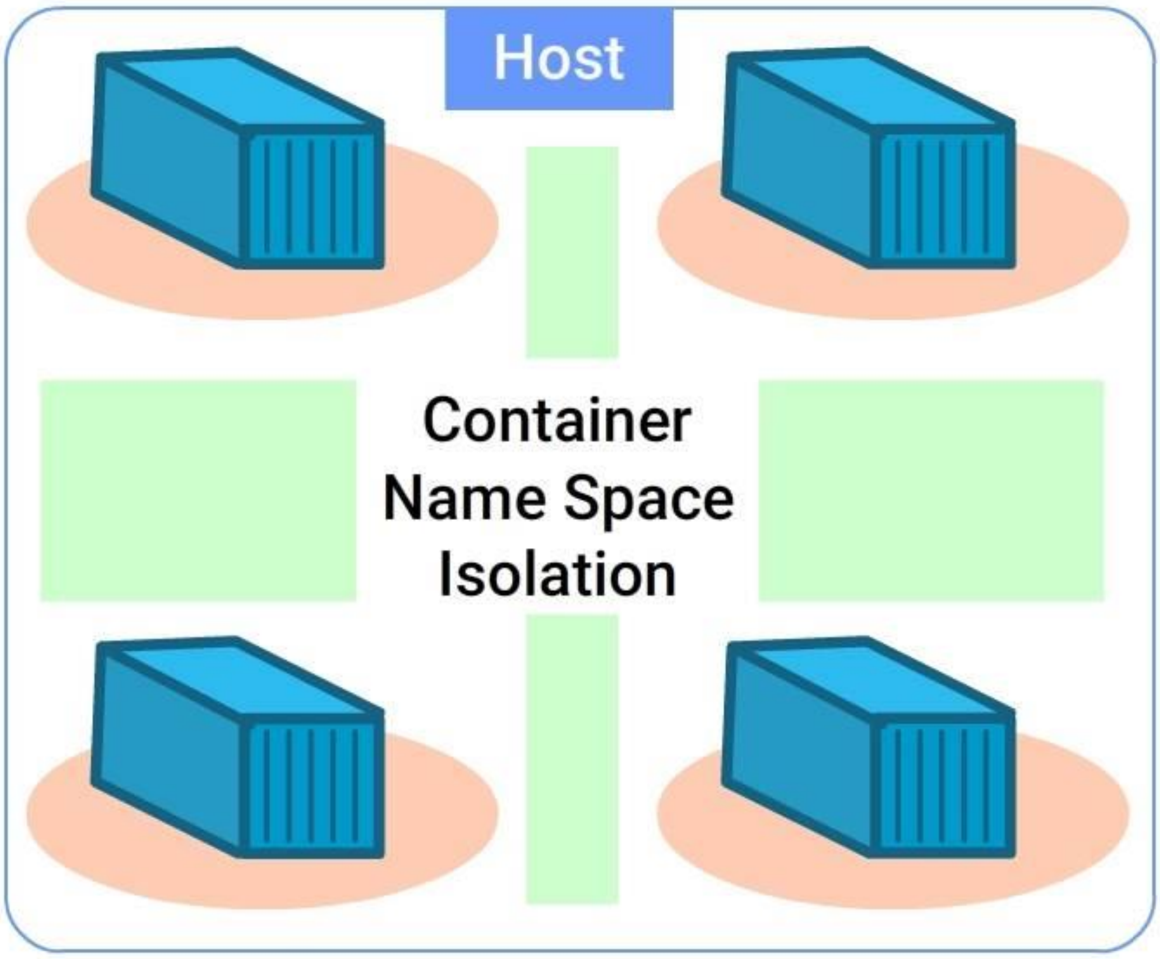
Let's look into few of the security issues.

- ***Risk of privilege escalation via containers.***

For example, if an attacker gets inside a ***containerized app***, it becomes easy to gain ***root access*** to the ***host system***.

- A potential attack on ***one container*** can compromise data or resources used by a ***different container***. This can happen even without root access.
- ***Simple DoS attacks*** where one container gets all available ***system resources*** which stop other containers from functioning properly.
- ***Pulling insecure or invalidated images*** from the public repository.

Container Isolation - Kernel Namespaces



LXC containers are similar to ***Docker Containers*** and hence the ***security features*** remain similar.

Docker creates a ***namespace and control groups*** for the container when it is started.

Namespace provide a ***isolation*** between containers running on the same host machine.

Every container owns an ***individual network stack***. Containers interact with rest others as if they interact with ***external hosts***. Every container is like a ***physical machine*** connected to rest through a ***common Ethernet switch***.

Control groups are responsible for ***accounting and limiting of resources***.

They ensure that all containers receive ***fair share of available resources*** (CPU, memory and disk space)

Prevent Container based Dos attacks (Denial of Service). i.e. it ensures that one container cannot exhaust all the resources available which might bring the whole system down.

Control groups are responsible for ***accounting and limiting of resources***.

They ensure that all containers receive ***fair share of available resources*** (CPU, memory and disk space)

Prevent Container based Dos attacks (Denial of Service). i.e. it ensures that one container cannot exhaust all the resources available which might bring the whole system down.

Docker Daemon Attack

Only trusted users should be given access to control the docker daemon since this user will have ***root privilege to the host*** system to run docker daemon.

Also, Docker gives the ***flexibility to share files/ directories*** between the ***host system and the container***.

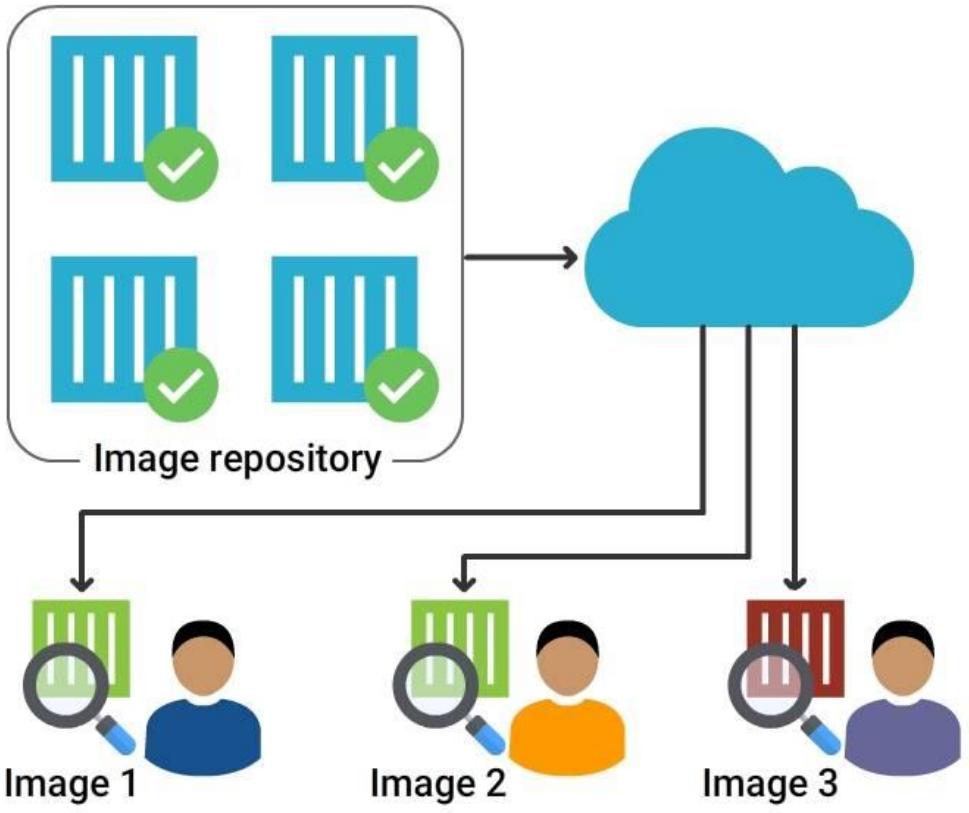
By this way, a ***running container*** can directly ***access the host directory*** and modify the files.

Docker Daemon Attack (Contd...)

Parameter checking is very important when we use the web server to ***provision containers*** since ***malicious users*** can easily create ***arbitrary containers***.

Rest API endpoint was modified to use ***UNIX socket instead of TCP socket*** since the TCP sockets are prone to ***cross site forgery attacks***.

When we expose the ***REST API over HTTP***, we should ensure that we have ***enough security*** using client stunnel, SSL certificates, HTTPS and certificates.



Securing Images

Poisoned images cause a ***serious problem*** since the attacker can take control over the complete host system as well as the data.

With Docker 1.3.2, images are extracted in ***chrooted subprocess***. This is a major step towards ***privilege separation***.

With Docker 1.10.0, ***cryptographic checksums*** of their Image contents are used to store and access them. This prevents the attacker from ***colliding with the existing images***.

Linux Kernel Capabilities

Bunch of processes listed below needs ***root access*** on Linux system to run. But the ***infrastructure around the container*** takes care of almost all of these tasks.

- SSH
- Cron
- Log Management
- Hardware Management
- Network Management

Containers do ***not need root privileges*** in most of the cases. Hence containers will have a ***limited*** root privilege rather than the complete root access.

Linux Kernel Capabilities

Docker follows a ***whitelist approach*** by allowing only the capabilities listed.

Docker also supports ***addition and removal of capabilities***. With the reduction in capabilities, docker becomes more secure and with the addition of capabilities, it becomes less secure.

Docker Features - User Namespace

With Docker 1.10, ***User Namespaces*** are supported by the Docker daemon.

User Namespaces allows users to work on ***daemon commands*** on containers with ***root access*** but ***without root privilege on the host***.

The container root user is ***mapped*** to another non uid-0 outside the container. This will ***reduce the risk of Container breakout***.

Why User Namespace?

Let consider the below ***example***.

User 100 in container 1 is mapped to User 501 outside the container.

User 150 in container 2 is mapped to User 502 outside the container.

This is something similar to ***network port mapping***. This mapping is done to enable the administrator to ***set privilege*** to the users. Admin can set uid 0 (root) to a user inside container 1 without giving root access to the host system.

Secure Docker

To summarize,

- Add ***-u flag*** to Docker run command while ***starting a container*** to run as a ***normal user*** instead of ***root user***
- Remove ***SUID flags*** from container images to make ***privilege escalation*** attack ***harder***
- Add ***Docker Control groups*** and configure them to set limits on ***resource usage*** for a container
- Add ***user namespace*** in Docker to create an isolation between the containers as well as the container and the host

Secure Docker (Contd...)

Use only trusted images or images from official source from Docker repository

Use software for static analysis of vulnerabilities in application containers e.g.Clair

Apart from the capabilities, leverage systems like TOMOYO, AppArmor, SELinux, GRSEC, etc. with docker

Other Security features

Apart from the capabilities, systems like ***TOMOYO, AppArmor, SELinux, GRSEC,*** etc. can be leveraged with docker.

Running a kernel with ***GRSEC and PAX***, will add more ***security*** at both ***compile and run time***.

Security model templates that work with docker can be used.

For e.g. ***AppArmor and Red Hat*** offers ***SELinux*** policies for Docker. These provide ***additional security*** on top of capabilities.

Users can themselves define policies with their access control mechanism.

Avoid ***storing data*** in containers.

Use ***Volumes*** to store data if needed, since a container can be ***stopped*** or application running can be ***re-version-ed***.

Avoid ***creating large images*** which is difficult to manage across ***multiple containers***.

Always create ***multi-layered Image***.

It is easier to ***manage and distribute*** across multiple containers.

Always use ***Dockerfile*** to create an image.

This process is ***reproducible*** and changes to this file can be ***tracked*** through any version control.

Tag images with correct version.

Avoid generic tags like ***'Latest'*** to the image.

Always run ***one process per containers***.

This will be easier to ***manage, trouble shoot issues*** and update processes individually.

Use ***Environment variables*** to store credentials.

Do not ***store directly*** in the image.

Run processes with ***non-root user id***.

Communicate between containers using ***environmental variables***.

Do not use ***IP address***, since it ***changes*** for every container restart.

Keep ***Container interactions minimal***.

Do not accept any connection on exposed ports through any network interface.

Use tools to ***monitor and identify vulnerabilities*** in images.

Wherever feasible, Run containers in Read -only mode.

Do not install ***unnecessary packages***.

This improves ***performance and reduces complexity***.