BSc in Computer Engineering
CMP4103
Computer Systems and Network Security

Lecture 5(c)

Containers with Docker lab

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1. Install Docker on Debian GNU/Linux

1.1 Prepare Debian GNU/Linux

Before starting it is essential that it is a 64-bit version of Debian GNU/Linux. Docker does not work with 32-bit machines.

Install Debian GNU/Linux 64-bit and update.

```
$ sudo apt-get update
$ sudo apt-get dist-upgrade
```

Confirm Debian version and Kernel. Debian version 8.5 codename "Jessie". The **amd64** indicates the kernel is 64-bit.

```
$ uname -rv
3.16.0-4-amd64 #1 SMP Debian 3.16.7-ckt25-2+deb8u3 (2016-07-02)

$ cat /etc/debian_version
8.5
```

Setup APT to work with the https method, and that CA certificates are installed.

```
$ sudo apt-get install apt-transport-https ca-certificates
```

1.1.1 IP Forwarding

For Docker containers to access the public networks of the host it is necessary for the host to have IP forwarding enabled. Check the current status as follows; **1** means enables and **0** means disabled.

```
$ cat /proc/sys/net/ipv4/ip_forward
0
```

If it is disabled as shown then change the value to 1 as follows.

```
$ echo 1 | sudo tee /proc/sys/net/ipv4/ip_forward
[sudo] password for debian:
1
```

To make the change permanent it is necessary to adjust the following line in the **/etc/sysctl.conf** file.

```
$ cat /etc/sysctl.conf | grep ip_forward
#net.ipv4.ip_forward=1

$ sudo sed -i.bak 's/#net.ipv4.ip_forward=1/net.ipv4.ip_forward=1/'
/etc/sysctl.conf

$ cat /etc/sysctl.conf | grep ip_forward
net.ipv4.ip_forward=1
```

Now restart the networking service.

```
$ sudo systemctl restart networking.service
```

1.2 Prepare for Docker install

Add the Docker GNU Privacy Guard (GPG) key.

```
$ sudo apt-key adv --keyserver hkp://p80.pool.sks-keyservers.net:80
--recv-keys 58118E89F3A912897C070ADBF76221572C52609D

gpg: requesting key 2C52609D from hkp server p80.pool.sks-
keyservers.net
gpg: key 2C52609D: public key "Docker Release Tool (releasedocker)
<docker@docker.com>" imported
 gpg: Total number processed: 1
 gpg:               imported: 1  (RSA: 1)
```

Add the Docker deb source to the Debian sources and update the APT package index to reflect the change.

```
$ echo 'deb https://apt.dockerproject.org/repo debian-jessie main'
| sudo tee --append /etc/apt/sources.list.d/docker.list

$ sudo apt-get update
```

1.3 Install, start and test the Docker Engine

Install the Docker engine. This will also install the Docker client which permits access to the engine from the shell with the command **docker**.

```
$ sudo apt-get install docker-engine
```

Run the Docker engine and confirm it is running.

```
$ sudo systemctl start docker.service

$ sudo systemctl | grep docker.service
docker.service  loaded active running  Docker Application Container Engine
```

Confirm that the Docker engine is working. Docker has a **hello-world** image. The **docker run** command looks for the image locally, not finding it the on-line library at the Docker Hub is accessed, downloading the image, created a container for that image and runs an executable to print back to the terminal that all is well. The container then terminates.

```
$ sudo docker run hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
c04b14da8d14: Pull complete
Digest: sha256:0256e8a36e2070f7bf2d0b0763dbabdd67798512411de4cdcf9431a1feb60fd9
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working correctly.
  To generate this message, Docker took the following steps:
 1. The Docker client contacted the Docker daemon.
 2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
 3. The Docker daemon created a new container from that image which runs the
    executable that produces the output you are currently reading.
 4. The Docker daemon streamed that output to the Docker client, which sent it
    to your terminal.

To try something more ambitious, you can run an Ubuntu container with:
 $ docker run -it ubuntu bash

Share images, automate workflows, and more with a free Docker Hub account:
 https://hub.docker.com

For more examples and ideas, visit:
 https://docs.docker.com/engine/userguide/
```

1.4 Docker group

During the install a **docker** group is created. Add the user to that group and now the Docker client can run without **sudo** privilidges.

```
$ cat /etc/group | grep docker
docker:x:999:

$ sudo usermod -a -G docker ${USER}

$ cat /etc/group | grep docker
docker:x:999:debian

$ docker run hello-world
```

2. The Docker client

With the Docker client access is granted through the **docker** command. Use the **--version** and **--help** switches to see the version as well as the full list of commands available to interact with the Docker engine. As well as the **--version** switch there is also a **version** command which gives significantly more detail.

```
$ docker --version
Docker version 1.12.0, build 8eab29e

$ docker --help
Usage: docker [OPTIONS] COMMAND [arg...]
       docker [ --help | -v | --version ]

$ docker version
Client:
 Version:      1.12.0
 API version:  1.24
 Go version:   go1.6.3
 Git commit:   8eab29e
 Built:        Thu Jul 28 21:40:59 2016
 OS/Arch:      linux/amd64

Server:
 Version:      1.12.0
 API version:  1.24
 Go version:   go1.6.3
 Git commit:   8eab29e
 Built:        Thu Jul 28 21:40:59 2016
 OS/Arch:      linux/amd64
```

3. Running a webserver container

Create a **docker** directory and switch to it. Build a webpage in this directory.

```
$ mkdir docker

$ echo '<html><p>This is the container index file</p></html>' >
~/docker/index.html

$ cat ~/docker/index.html
<html><p>This is the container index file</p></html>
```

Pull down the **httpd** image from Docker hub. Confirm it is there.

```
$ docker pull httpd
Using default tag: latest
latest: Pulling from library/httpd
 Digest:
 sha256:619b6136504fcaed0d1e1f9fac57cf69eedd174f98889d5b727598ca658d0bfc
Status: Downloaded newer image for httpd:latest

$ docker images
REPOSITORY     TAG       IMAGE ID       CREATED        SIZE
httpd          2.4       462fca6e7913   5 days ago     195.4 MB
hello-world    latest    c54a2cc56cbb   4 weeks ago    1.848 kB
```

3.1 Create a Docker container

The **docker create** command can be used to create a container. The **httpd** at the end is the image name to be used. The container ID is returned.

- **--name <string>** Assign a name to the container
- **--publish <value>** Publish a container's port(s) to the host, See **Docker Networking**.
- **--volume <value>** Bind mount a volume, mounts /**home**/**debian**/**docker** on the host to /usr/local/apache2/htdocs/ on the Docker container. See **Mounting a Data Volumes**.

```
$ docker create --name apache1 --publish 80:80 --volume
/home/debian/docker:/usr/local/apache2/htdocs/ httpd
238194b35479db39b9659e828f15b6791e57e0a1d11572785cdd63a64de9a531

$ docker ps -a
CONTAINER ID  IMAGE  COMMAND             CREATED         STATUS   PORTS    NAMES
238194b35479  httpd   “httpd-foreground" 11 seconds ago  Created           apache1
```

To start the container use the command **docker start**.

```
$ docker start 238194b35479
238194b35479
```

View the container with the **docker ps -l** command. Note the container ID only shows the first 12 characters.

```
$ docker ps -a
CONTAINER ID  IMAGE   COMMAND             CREATED            STATUS          PORTS
NAMES
238194b35479  httpd   "httpd-foreground"  About a minute ago Up 52 seconds
0.0.0.0:80->80/tcp   apache1
```

3.2 Run a Docker container

Before proceeding remove the container just created.

```
$ docker stop 238194b35479
238194b35479

$ docker rm 238194b35479
238194b35479
```

An alternative to the two step **docker create** and **docker start**, is to run the container directly with the **docker run** command and the **--detach** option. This command is designed to build and then run a command in a new container, though running the command is optional. Again the container ID is returned.

- **--detach** Run container in background and print container ID

```
 $ docker run --name apache1 --detach --publish 80:80 --volume
 ~/docker/:/usr/local/apache2/htdocs/ httpd
5d067fd94bdb42057ed4bf54fcb1c29f990398f2a6367258c26f4677109e47d
```

Viewing the container with the **docker ps -l** command is the same as using the **docker create** and **docker start** commands.

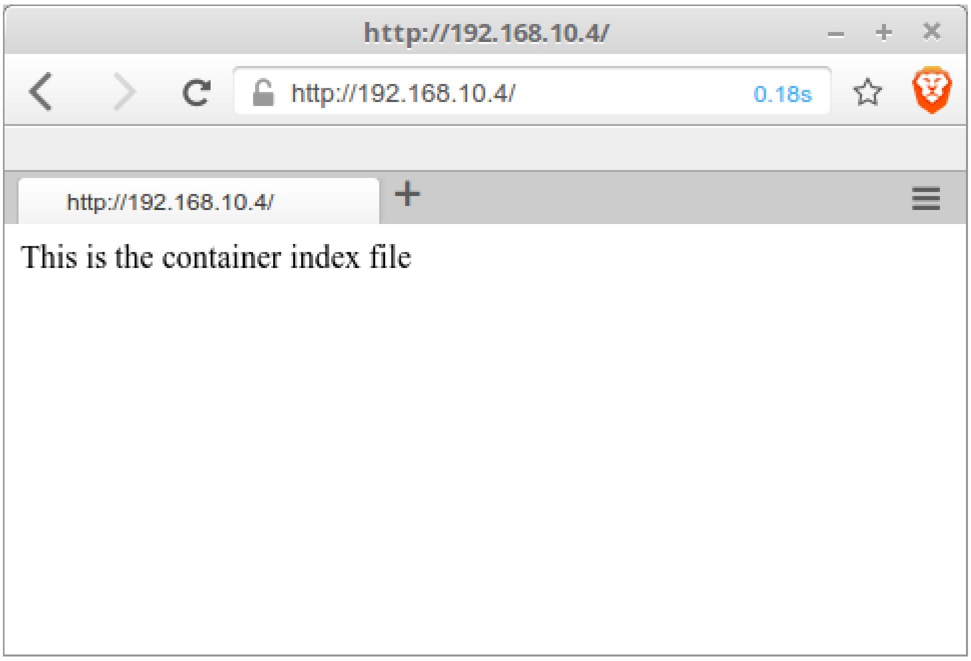
```
$ docker ps -l
CONTAINER ID   IMAGE   COMMAND             CREATED        STATUS        PORTS
NAMES
5d067fd94bdb   httpd   "httpd-foreground"  3 minutes ago  Up 3 minutes  0.0.0.0:80-
>80/tcp  apache1
```

List the port mappings for the container with the **docker port** command.

```
$ docker port 5d067fd94bdb
80/tcp -> 0.0.0.0:80
```

Confirm the webpage is visible with a GNU/Linux shell browser or browse to the host IP Address.

```
$ curl localhost
<html><p>This is the container index file</p></html>
```



This is the container index file

Illustration 1: Browser to container webpage

3.3 Stopping and killing the container

The **docker stop** command stops the container. It can be restarted with the **docker restart** command. To remove the container simply use the **docker rm** command.

```
$ docker stop 5d067fd94bdb
5d067fd94bdb

$ docker rm 5d067fd94bdb
5d067fd94bdb

$ docker ps
CONTAINER ID   IMAGE    COMMAND      CREATED    STATUS       PORTS     NAMES
```

While the container has been removed, the image remains.

```
$ docker images
REPOSITORY     TAG      IMAGE ID       CREATED       SIZE
httpd          2.4      462fca6e7913   5 days ago    195.4 MB
hello-world    latest   c54a2cc56cbb   4 weeks ago   1.848 kB
```

3.4 Removing images

To remove the image use the **docker rmi** command.

```
  $ docker rmi --force 462fca6e7913
  Untagged: httpd:2.4
 Untagged:
httpd@sha256:619b6136504fcaed0d1e1f9fac57cf69eedd174f98889d5b727598ca658d0bfc
 Deleted: sha256:462fca6e7913e7758cbc2b476e61b78670bc9ab2573aeb3f6b22dcd15af32f15
```

```
  $ docker rmi --force c54a2cc56cbb
 Untagged: hello-world:latest
                                             Untagged:                      hello-
world@sha256:0256e8a36e2070f7bf2d0b0763dbabdd67798512411de4cdcf9431a1feb60fd9
 Deleted: sha256:c54a2cc56cbb2f04003c1cd4507e118af7c0d340fe7e2720f70976c4b75237dc
```

```
  $ docker images
  REPOSITORY      TAG        IMAGE ID        CREATED         SIZE
```

4. Building an container

Lets build an OS container from an image. Looking for Ubuntu images on Docker Hub.

```
  $ docker search ubuntu
 NAME                              DESCRIPTION                                     STARS     OFFICIAL   AUTOMATED
 ubuntu                            Ubuntu is a Debian-based Linux operating s...   4397      [OK]
 ubuntu-upstart                    Upstart is an event-based replacement for ...   65        [OK]
 rastasheep/ubuntu-sshd            Dockerized SSH service, built on top of of...   30                   [OK]
 torusware/speedus-ubuntu          Always updated official Ubuntu docker imag...   26                   [OK]
 ubuntu-debootstrap                debootstrap --variant=minbase --components...   25        [OK]
 nickistre/ubuntu-lamp             LAMP server on Ubuntu                           8                    [OK]
 nuagebec/ubuntu                   Simple always updated Ubuntu docker images...   6                    [OK]
 nickistre/ubuntu-lamp-wordpress   LAMP on Ubuntu with wp-cli installed            6                    [OK]
 nimmis/ubuntu                     This is a docker images different LTS vers...   5                    [OK]
 maxexcloo/ubuntu                  Docker base image built on Ubuntu with Sup...   2                    [OK]
 admiringworm/ubuntu               Base ubuntu images based on the official u...   1                    [OK]
 darksheer/ubuntu                  Base Ubuntu Image -- Updated hourly             1                    [OK]
 jordi/ubuntu                      Ubuntu Base Image                               1                    [OK]
 life360/ubuntu                    Ubuntu is a Debian-based Linux operating s...   0                    [OK]
 datenbetrieb/ubuntu               custom flavor of the official ubuntu base ...   0                    [OK]
 lynxtp/ubuntu                     https://github.com/lynxtp/docker-ubuntu         0                    [OK]
 esycat/ubuntu                     Ubuntu LTS                                      0                    [OK]
 widerplan/ubuntu                  Our basic Ubuntu images.                        0                    [OK]
 smartentry/ubuntu                 ubuntu with smartentry                          0                    [OK]
 croscon/ubuntu                    Crosconized Ubuntu                              0                    [OK]
 webhippie/ubuntu                  Docker images for ubuntu                        0                    [OK]
 teamrock/ubuntu                   TeamRock's Ubuntu image configured with AW...   0                    [OK]
 ustclug/ubuntu                    ubuntu image for docker with USTC mirror        0                    [OK]
 konstruktoid/ubuntu               Ubuntu base image                               0                    [OK]
 dorapro/ubuntu                    ubuntu image                                    0                    [OK]
```

Pull the most popular image **ubuntu** and create a container for it.

```
$ docker pull ubuntu
Using default tag: latest
latest: Pulling from library/ubuntu
43db9dbdcb30: Pull complete
2dc64e8f8d4f: Pull complete
670a583e1b50: Pull complete
183b0bfcd10e: Pull complete
Digest: sha256:c6674c44c6439673bf56536c1a15916639c47ea04c3d6296c5df938add67b54b
Status: Downloaded newer image for ubuntu:latest
```

```
$ docker images
REPOSITORY     TAG          IMAGE ID           CREATED             SIZE
ubuntu         latest       42118e3df429       11 days ago         124.8 MB
```

```
$ docker run --name ubuntu --detach --tty --interactive ubuntu
49b5bb9e9b5b51592285db846cfa8512076ecfa00cdd8165e22d5a5bf6125673
```

- **--interactive** Keep STDIN open even if not attached
- **--tty** Allocate a pseudo-TTY

Use the **docker attach** command to connect to the Ubuntu container.

```
$ docker attach 49b5bb9e9b5b
root@49b5bb9e9b5b:/# cat /etc/issue
Ubuntu 16.04 LTS \n \l
```

4.1 Install applications in container

For demonstration purposes two containers, one with an **Ubuntu** image and the second with **Debian** will be launched. An **iperf** server will run on the **Ubuntu** image and a client on the **Debian** image and a bandwidth will be performed between them.

4.1.1 Ubuntu image

Before progressing further it is imperative that APT is updated. IProute2 or IPERF is not installed on the image so must be added.

```
root@49b5bb9e9b5b:/# apt-get update
root@49b5bb9e9b5b:/# apt-get install iproute2
root@49b5bb9e9b5b:/# apt-get install iperf
```

Check the IP address assigned to this container and run the IPERF server.

```
root@49b5bb9e9b5b:/# ip addr | grep 'inet '| grep eth0
    inet 172.17.0.2/16 scope global eth0

root@49b5bb9e9b5b:/# iperf -s
------------------------------------------------------------
Server listening on TCP port 5001
TCP window size: 85.3 KByte (default)
------------------------------------------------------------
```

4.1.2 Debian image

Like for the Ubuntu image update the APT repositories and install IPERF, IProute2 is already installed in the image.

```
root@17ff9e52b582:/# apt-get update
root@17ff9e52b582:/# apt-get install iperf
```

Test the link to the Ubuntu image.

```
root@17ff9e52b582:/# iperf -c 172.17.0.2
------------------------------------------------------------
Client connecting to 172.17.0.2, TCP port 5001
TCP window size:  340 KByte (default)
------------------------------------------------------------
[  3] local 172.17.0.4 port 35337 connected with 172.17.0.2 port 5001
[ ID] Interval       Transfer     Bandwidth
[  3]  0.0-10.0 sec  28.1 GBytes  24.2 Gbits/sec
```

4.2 Create a new image after making changes

A new image can be created from a container in which changes were made. Here a new Ubuntu container called **ubuntu-iperf** is created.

```
$ docker commit --author "Diarmuid O'Briain" --message "My new
Ubuntu Template" 49b5bb9e9b5b diarmuid/ubuntu-iperf
sha256:afe36be87a540f8e39e25b9a4bdde383fb125dbbe8b24492d70c443773b1e02f
```

```
$ docker images
REPOSITORY              TAG         IMAGE ID            CREATED             SIZE
diarmuid/ubuntu-iperf   latest      afe36be87a54        27 seconds ago      124.8 MB
debian                  latest      17ff9e52b582        6 days ago          125.1 MB
ubuntu                  latest      49b5bb9e9b5b        12 days ago         124.8 MB
```

5. Dockerfile

Dockerfile can be used to build new images. The Dockerfile is a set of instructions on how the image should be built. First, create a directory and a Dockerfile. The Dockerfile specifies the base image with the **FROM** instruction and a series of **RUN** instructions contain the commands that need to be run on top of the image.

```
$ mkdir ~/docker/Debian
$ cat <<EOM>> ~/docker/Debian/Dockerfile
> # Training Debian GNU/Linux Dockerfile
> FROM debian
> MAINTAINER Diarmuid O'Briain <diarmuid@debmain.org>
> RUN apt-get update
> RUN apt-get install -y iperf
> EOM

$ cat ~/docker/Debian/Dockerfile
# Training Debian GNU/Linux Dockerfile
FROM debian
MAINTAINER Diarmuid O'Briain <diarmuid@debmain.org>
RUN apt-get update
RUN apt-get install -y iperf
```

The image is then build with a tag to identify who the image belongs to, the repository and an identity tag to differentiate the image from others. The path at the end points to the **Dockerfile**.

```
$ docker build --tag diarmuid/debian-iperf:v2 ~/docker/Debian
Sending build context to Docker daemon 2.048 kB
Step 1 : FROM debian
 ---> 1b01529cc499
Step 2 : MAINTAINER Diarmuid O'Briain <diarmuid@debmain.org>
 ---> Using cache
 ---> 21137da1564d
Step 3 : RUN apt-get update
 ---> Using cache
 ---> 6834b99be7ee
Step 4 : RUN apt-get install -y iperf
 ---> Using cache
 ---> 9f41db1a1140
Successfully built 9f41db1a1140

$ docker images
REPOSITORY              TAG       IMAGE ID       CREATED          SIZE
diarmuid/debian-iperf   v2        9f41db1a1140   20 minutes ago   135.3 MB
debian                  latest    1b01529cc499   5 days ago       125.1 MB
ubuntu                  latest    42118e3df429   11 days ago      124.8 MB
```

6. Exiting Containers

Exiting a container will put it in an **Exited** state.

```
root@1b01529cc499:/# exit
exit

$ docker ps -l
CONTAINER ID  IMAGE    COMMAND      CREATED        STATUS                    PORTS   NAMES
1b01529cc499  debian   "/bin/bash"  7 minutes ago  Exited (130) 7 seconds ago  deb1
```

The container can be restarted with the **docker start** command and then reattached to it with the **docker attach** command.

```
$ docker start 1b01529cc499
1b01529cc499

$ docker ps -l
CONTAINER ID   IMAGE      COMMAND         CREATED        STATUS         PORTS   NAMES
1b01529cc499   debian     "/bin/bash"     9 minutes ago  Up 4 seconds           deb1

$ docker attach 1b01529cc499
```

It is possible to leave the container without it exiting, leave it running using the keystrokes CTRL-P + CTRL-Q. To reattached with the running container again use the **docker attach** command.

```
root@1b01529cc499:/# [CTRL+P+Q]

$ docker ps -l
CONTAINER ID   IMAGE      COMMAND         CREATED        STATUS         PORTS   NAMES
1b01529cc499   debian     "/bin/bash"     9 minutes ago  Up 27 seconds          deb1
```

6.1 Tidying up exited containers

When working with Docker for some time the list of exited containers becomes unweildy. They can be removed with the **docker rm** command individually or in bulk by extracting the list of Container ID's and passing them to the **docker rm** command with the aid of **xargs**.

```
$ docker ps -a
CONTAINER ID  IMAGE          COMMAND                  CREATED            STATUS
PORTS     NAMES
22dc3a2d3127  debian         "/bin/bash"              16 hours ago       Exited
(0) 11 hours ago            debian9
3df4ba2755c9  6834b99be7ee   "/bin/sh -c 'apt-get "   17 hours ago       Exited
(0) 17 hours ago            jolly_gates
e36246464720  debian         "/bin/bash"              17 hours ago       Exited
(0) 16 hours ago            debian4
17ff9e52b582  debian         "/bin/bash"              18 hours ago       Exited
(0) 17 hours ago            debian3
d9e5b671cca8  debian         "/bin/bash"              18 hours ago       Exited
(0) 16 hours ago            debian2
d4caadada7f4  ubuntu         "/bin/bash"              18 hours ago       Exited
(0) 16 hours ago            ubuntu2
87a36da02033  ubuntu         "/bin/bash"              18 hours ago       Exited
(0) 18 hours ago            ubuntu
64581def7fb2  462fca6e7913   "httpd-foreground"       20 hours ago       Exited
(0) 20 hours ago            my-apache-app
f8af6e0cc47d  c54a2cc56cbb   "/hello"                 21 hours ago       Exited
(0) 21 hours ago            dreamy_spence
87f7a903c63b  c54a2cc56cbb   "/hello"                 21 hours ago       Exited
(0) 21 hours ago            prickly_wilson

$ docker rm 22dc3a2d3127
22dc3a2d3127


$ docker ps -a | grep Exit | cut -d ' ' -f 1 | xargs docker rm
3df4ba2755c9
e36246464720
17ff9e52b582
d9e5b671cca8
d4caadada7f4
87a36da02033
64581def7fb2
f8af6e0cc47d
87f7a903c63b

$ docker ps -a
CONTAINER ID  IMAGE    COMMAND       CREATED          STATUS         PORTS     NAMES
```

7. Mounting a Data Volumes

You can add a data volume to a container using the **--volume** option during the **docker run** command. Multiple mounts can be created simply by using multiple **--volume** options. To demonstrate create a directory ~/**docker**/**Ubuntu2**/ with a file in it.

```
$ mkdir ~/docker/Ubuntu2

$ echo "This is a sample text file" >> ~/docker/Ubuntu2/sampleFile.txt

$ cat  ~/docker/Ubuntu2/sampleFile.txt
This is a sample text file
```

When using the **docker run** command add a mount point /**opt**/**Ubuntu2** in the container mounted to the directory created on the host.

```
$ docker run --name Ubuntu2 --detach --tty --interactive --volume
~/docker/Ubuntu2:/opt/Ubuntu2 ubuntu
```

Attach to the container and confirm access to the file on the host.

```
$ docker attach 9277c3802f4e

root@9277c3802f4e:~# cat /opt/Ubuntu2/sampleFile.txt
This is a sample text file
```

Mounting a Data Volume as read only by adding **:ro** at the end of the **--volume** string.

```
$ docker run --name Ubuntu2 --detach --tty --interactive --volume
~/docker/Ubuntu2:/opt/Ubuntu2:ro ubuntu
```

8. Docker networking

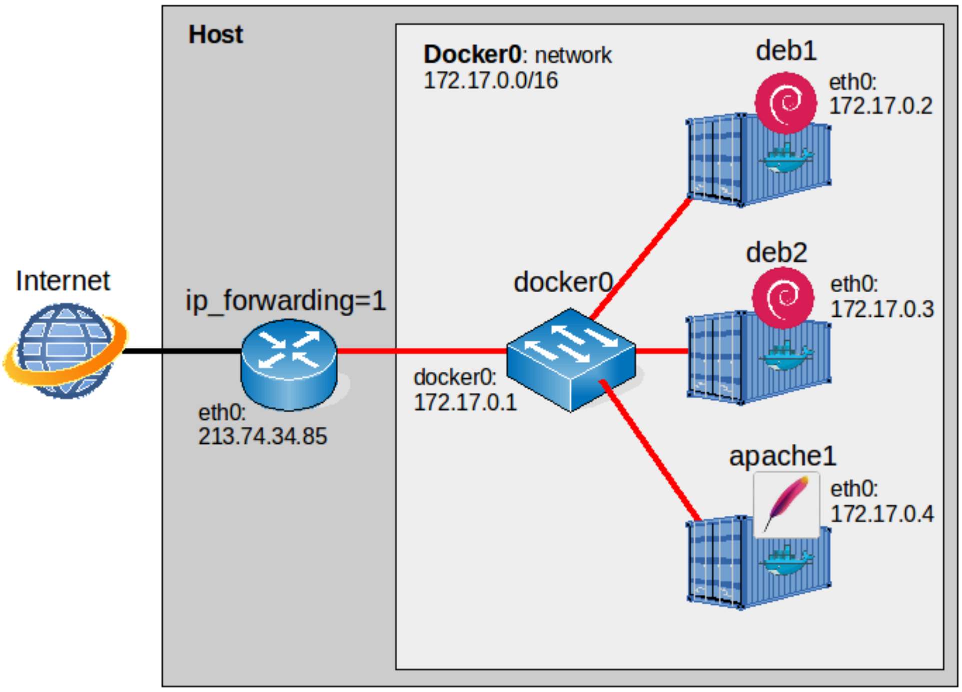


Illustration 2: Docker networking

Before starting this section, there are two containers running in two shells on the host.

```
$ docker run --name deb1 --detach --tty --interactive debian
539e0844b2a7485442eaf1c73e4ea228df3dda5cfd8d52295122a7d47795d172

$ docker run --name deb2 --detach --tty --interactive debian
f8cd2f240023da32d2357e3197fd38755b7fb0bb609ce6469276a477b2964746

$ docker ps -a
CONTAINER ID  IMAGE    COMMAND       CREATED          STATUS          PORTS     NAMES
f8cd2f240023  debian   "/bin/bash"   12 seconds ago   Up 12 seconds             deb2
539e0844b2a7  debian   "/bin/bash"   30 minutes ago   Up 22 minutes             deb1
```

8.1 docker0

When Docker is installed on the host it adds a bridge, **docker0** for the containers as part of the installation. Docker adds a free range of IP addresses from the RFC 1918 for IPv4, and RFC 4193 IPv6 to the bridge to be used for containers. When a new container is added Docker selects a free IP address from the range and assigns it to the container's eth0 interface and the **docker0** IP address as the default gateway. Using the **docker0** IP address and the subnet Docker manipulates the hosts filtering and NAT tables to ensure that containers have access to the public network on the hosts physical interface. This bridge can be viewed by the hosts **brctl show** command. Also on show are the two interfaces which were added for each of the containers created.

```
$ sudo brctl show
[sudo] password for debian:
bridge name     bridge id               STP enabled     interfaces
docker0         8000.0242e243f55b       no              veth2957c1c
                                                        veth46911d0
```

Docker connects containers to the **docker0** bridge by default. On the host, this bridge can be seen to be the master for the container interfaces **veth2957c1c** and **veth46911d0** confirming what was shown with the **brctl show** command. The bridge also has an IP address associated with it 172.17.0.1/16.

```
$ ip addr list
  1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default
      link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
      inet 127.0.0.1/8 scope host lo
         valid_lft forever preferred_lft forever
      inet6 ::1/128 scope host
         valid_lft forever preferred_lft forever
  2: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc pfifo_fast state UP
      group default qlen 1000
      link/ether 08:00:27:c8:30:2c brd ff:ff:ff:ff:ff:ff
      inet 192.168.10.4/24 brd 192.168.10.255 scope global eth0
         valid_lft forever preferred_lft forever
      inet6 fe80::a00:27ff:fec8:302c/64 scope link
         valid_lft forever preferred_lft forever
  3: docker0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP
      group default
      link/ether 02:42:e2:43:f5:5b brd ff:ff:ff:ff:ff:ff
      inet 172.17.0.1/16 scope global docker0
         valid_lft forever preferred_lft forever
      inet6 fe80::42:e2ff:fe43:f55b/64 scope link
         valid_lft forever preferred_lft forever
  7: veth2957c1c: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue master
      docker0 state UP group default
      link/ether 26:80:9e:ae:d5:7b brd ff:ff:ff:ff:ff:ff
      inet6 fe80::2480:9eff:feae:d57b/64 scope link
         valid_lft forever preferred_lft forever
  9: veth46911d0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue master
      docker0 state UP group default
      link/ether 3e:6d:d2:2c:2f:96 brd ff:ff:ff:ff:ff:ff
      inet6 fe80::3c6d:d2ff:fe2c:2f96/64 scope link
         valid_lft forever preferred_lft forever
```

With the **docker network** commands it is possible to inspect this **docker0** bridge further. Using the command **docker network inspect bridge** it can be seen that the network **172.17.0.0/16** has been assigned to containers, with the **docker0** IP Address 172.17.0.1 as the gateway. It is also possible to see the IP addresses assigned to the individual containers. In the options section IP masquerade **ip_masquerade** or Network Address Translation (NAT) is enabled to insure the containers can access the network on the host physical network.

```
$ docker network ls
NETWORK ID          NAME                DRIVER              SCOPE
5e4b1f069bba        bridge              bridge              local
24e4301c2c59        host                host                local
1b9f6273f6eb        none                null                local

$ docker network inspect 5e4b1f069bba
[
    {
        "Name": "bridge",
        "Id": "5e4b1f069bbacb39a30854d45dbd85cafc537b1bcc42ab6dc568a00b6cf5911e",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": null,
            "Config": [
                {
                    "Subnet": "172.17.0.0/16",
                    "Gateway": "172.17.0.1"
                }
            ]
        },
        "Internal": false,
        "Containers": {
            "539e0844b2a7485442eaf1c73e4ea228df3dda5cfd8d52295122a7d47795d172": {
                "Name": "deb1",
                "EndpointID": "6aeccd20f2ae892721e1c6b9bc0af6d2842eb0c18f430bcb0e594c34fa706af2",
                "MacAddress": "02:42:ac:11:00:02",
                "IPv4Address": "172.17.0.2/16",
                "IPv6Address": ""
            },
            "f8cd2f240023da32d2357e3197fd38755b7fb0bb609ce6469276a477b2964746": {
                "Name": "deb2",
                "EndpointID": "4f1fc9094995aac5e369364625a90dd11465a56c079b80413d29a888676767e3",
                "MacAddress": "02:42:ac:11:00:03",
                "IPv4Address": "172.17.0.3/16",
                "IPv6Address": ""
            }
        },
        "Options": {
            "com.docker.network.bridge.default_bridge": "true",
            "com.docker.network.bridge.enable_icc": "true",
            "com.docker.network.bridge.enable_ip_masquerade": "true",
            "com.docker.network.bridge.host_binding_ipv4": "0.0.0.0",
            "com.docker.network.bridge.name": "docker0",
            "com.docker.network.driver.mtu": "1500"
        },
        "Labels": {}
    }
]
```

These IP address assignments can be confirmed first by inspecting the containers and then from within the individual containers.

```
$ docker inspect 539e0844b2a7 | grep '"IPAddress":'
            "IPAddress": "172.17.0.2",
                    "IPAddress": "172.17.0.2",

$ docker inspect f8cd2f240023 | grep '"IPAddress":'
            "IPAddress": "172.17.0.3",
                    "IPAddress": "172.17.0.3",
```

```
root@539e0844b2a7:/# ip addr list
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
6: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP group
    default
    link/ether 02:42:ac:11:00:02 brd ff:ff:ff:ff:ff:ff
    inet 172.17.0.2/16 scope global eth0
       valid_lft forever preferred_lft forever
    inet6 fe80::42:acff:fe11:2/64 scope link
       valid_lft forever preferred_lft forever
```

```
root@f8cd2f240023:/# ip addr list
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
    inet6 ::1/128 scope host
       valid_lft forever preferred_lft forever
8: eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 1500 qdisc noqueue state UP group
    default
    link/ether 02:42:ac:11:00:03 brd ff:ff:ff:ff:ff:ff
    inet 172.17.0.3/16 scope global eth0
       valid_lft forever preferred_lft forever
    inet6 fe80::42:acff:fe11:3/64 scope link
       valid_lft forever preferred_lft forever
```

8.2 IP Tables

Docker manipulates the host packet filtering and NAT masquerade tables. In this case in the POSTROUTING Chain adding a MASQUERADE rule for all protocols from the 172.17.0.0/16 subnet to anywhere allows the containers access to the Internet.

```
 $ sudo iptables --list --ipv4 --table nat
Chain PREROUTING (policy ACCEPT)
target     prot opt source               destination
DOCKER     all  --  anywhere             anywhere           ADDRTYPE match dst-type LOCAL

Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
DOCKER     all  --  anywhere             !loopback/8        ADDRTYPE match dst-type LOCAL

Chain POSTROUTING (policy ACCEPT)
target     prot opt source               destination
MASQUERADE  all  --  172.17.0.0/16  anywhere

Chain DOCKER (2 references)
target     prot opt source               destination
RETURN     all  --  anywhere             anywhere
```

Connectivity can be confirmed between the containers and to the Internet.

```
root@f8cd2f240023:/# ping -c1 172.17.0.2
PING 172.17.0.2 (172.17.0.2): 56 data bytes
64 bytes from 172.17.0.2: icmp_seq=0 ttl=64 time=0.054 ms
--- 172.17.0.2 ping statistics ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max/stddev = 0.054/0.054/0.054/0.000 ms

root@f8cd2f240023:/# ping -c1 8.8.8.8
PING 8.8.8.8 (8.8.8.8): 56 data bytes
64 bytes from 8.8.8.8: icmp_seq=0 ttl=56 time=591.236 ms
--- 8.8.8.8 ping statistics ---
1 packets transmitted, 1 packets received, 0% packet loss
round-trip min/avg/max/stddev = 591.236/591.236/591.236/0.000 ms
```

8.3 Port binding

What of port binding. To consider it recreate the HTTP webserver from earlier, this time make the port on the host **8080**.

```
 $ docker run --name apache1 --detach --publish 8080:80 --volume
 /home/debian/docker:/usr/local/apache2/htdocs/ httpd
11babc86c51664464e73be12b250170ac14d8c77557cf85457c0eb6e7047f12f
```

Now re-review the IPTABLES NAT masquerade table. A Specific entry for Transmission Control Protocol (TCP) traffic received on port 8080 is added to the DOCKER chain as a Destination NAT (DNAT) rule to redirect to the container's port 80.

```
 $ sudo iptables --list --numeric --table nat
Chain PREROUTING (policy ACCEPT)
target     prot opt source           destination
DOCKER     all  --  0.0.0.0/0        0.0.0.0/0            ADDRTYPE match dst-type LOCAL

Chain INPUT (policy ACCEPT)
target     prot opt source           destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source           destination
DOCKER     all  --  0.0.0.0/0        !127.0.0.0/8         ADDRTYPE match dst-type LOCAL

Chain POSTROUTING (policy ACCEPT)
target     prot opt source           destination
MASQUERADE  all  --  172.17.0.0/16   0.0.0.0/0
MASQUERADE  tcp  --  172.17.0.4      172.17.0.4           tcp dpt:80

Chain DOCKER (2 references)
target     prot opt source           destination
RETURN     all  --  0.0.0.0/0        0.0.0.0/0
DNAT       tcp  --  0.0.0.0/0        0.0.0.0/0            tcp dpt:8080 to:172.17.0.4:80
```