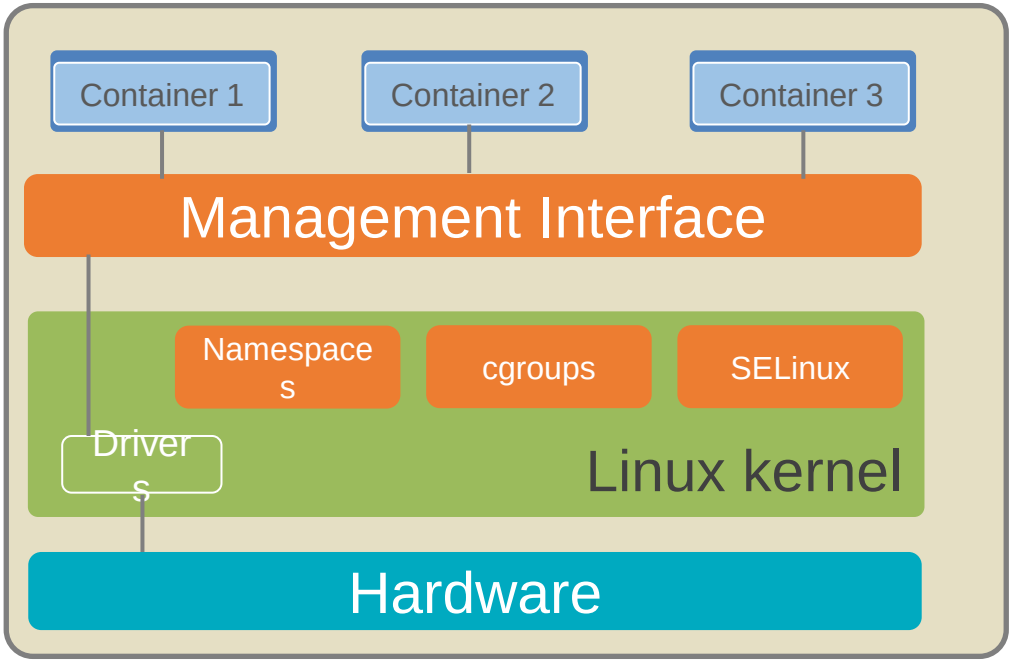
Docker – Containers

Containers

- Containers are operating system level virtualization
  - Allows for multiple isolated user space instances called containers
  - They share a single kernel
  - Can be added or removed at any time
- Containers consist of a self contained Linux file system
  - Can be from any Linux distribution which is compatible with the host kernel
  - Usually contain a single application such as a server
- Operating system level virtualization is lightweight
  - Is often used in Cloud Computing

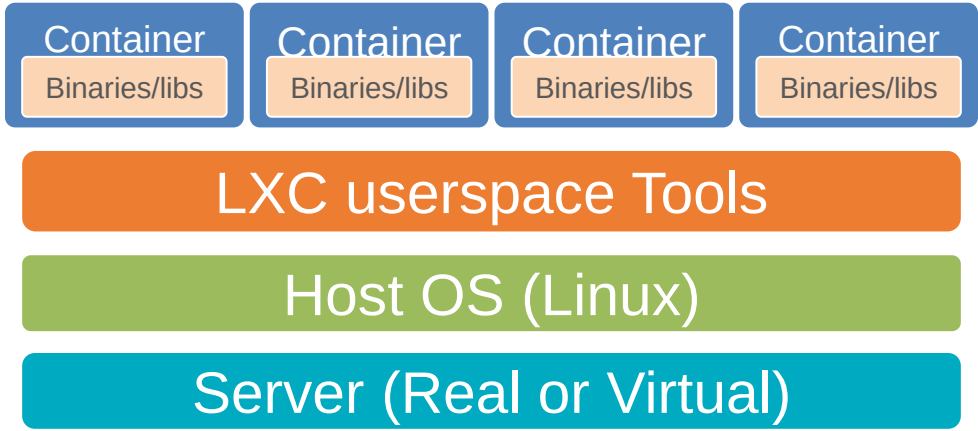
Container Implementation

- Operating system level virtualization uses a set of tools
  - A virtualization subsystem
  - A cgroup hierarchy for each container
  - The container is mounted into the filesystem
- A program inside the container is executed
  - Using chroot to restrict it to the container file system
  - The cgroup constrains use of resources and isolates the container from the rest of the system



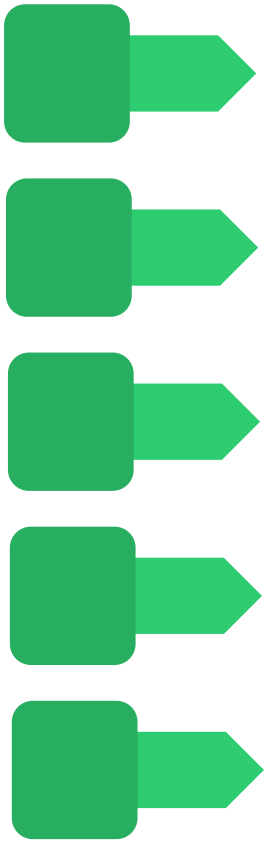
Operating System Level Virtualization

- Operating system level virtualization is where an operating system kernel can support multiple isolated user space instances
  - Instances are called containers or jails
  - There is little overhead as the kernel implements the containers
- There are numerous implementations
  - chroot has been available in UNIX since 1982
  - FreeBSD jail
  - Linux Containers (LXC) command line tools using Linux cgroups
  - LXD a container hypervisor built on LXC
  - Docker is a suite of tools for creating and managing containers



Docker

- Docker is a very light-weight software container and containerization platform
- Docker containers provide a way to run software in isolation
- What does a Docker Container contain and provide?
    - Initially – only a base Linux operating system
    - A boundary or a “jail” to contain running software
    - Like a good jail, there are no unauthorized entries or exits
    - A Docker Image is the foundation for any particular Docker container
- What is outside of Docker?
    - Other Docker containers
    - The operating system, kernel
    - Any other operating software



- Docker was originally a Linux application
- It uses the kernel container functionality
- It requires a 64 bit installation using a kernel version 3.10 or later
- Docker runs on many popular Linux distributions
- It is available as RPM, APT, or binary versions

- Docker runs natively on OS X
- DMG install application running in user space
- Is built on the xhyve hypervisor
- Requires a 2010 or newer Mac with Intel MMU and EPT support
- Requires OS X 10.10.3 Yosemite or newer
- Requires at least 4GB of RAM

Docker for Windows

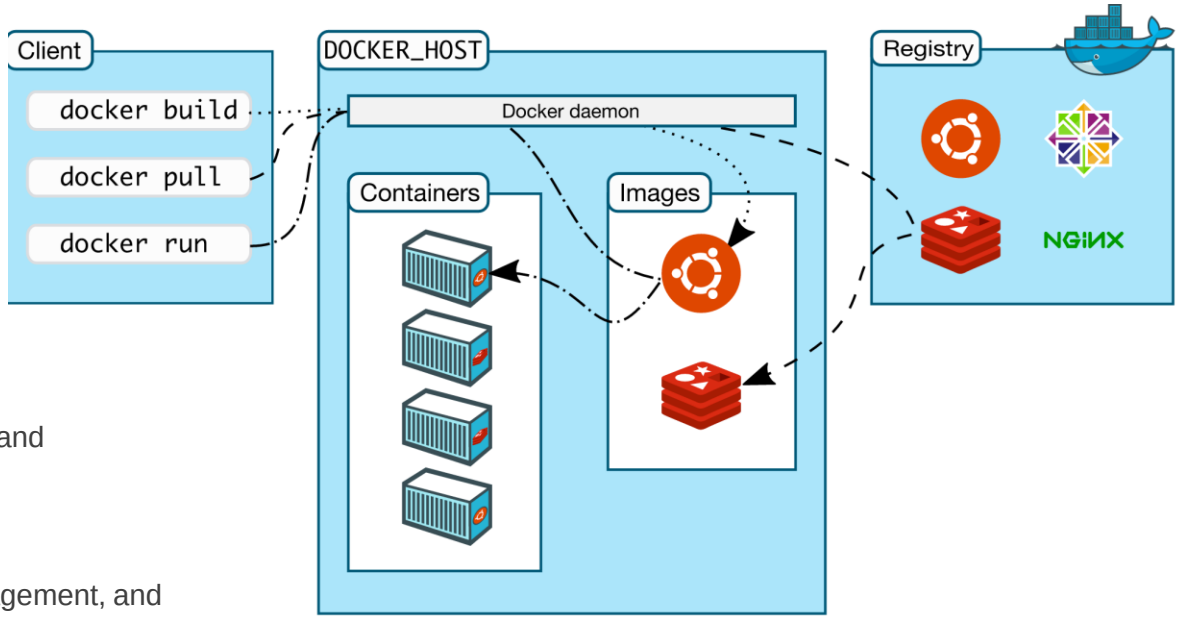
- Docker runs natively on Windows
- Requires later versions of Windows 10 Pro or Enterprise
- Docker requires the Hyper-V package
- This is Microsoft's hypervisor for Windows
- It virtualizes the Docker environment and Linux kernel spec
- Docker can't run alongside VirtualBox VMs

Exercise 1 : Install Docker on Linux & Windows

- Use Installation document to install docker on Linux Ubuntu and Windows 10

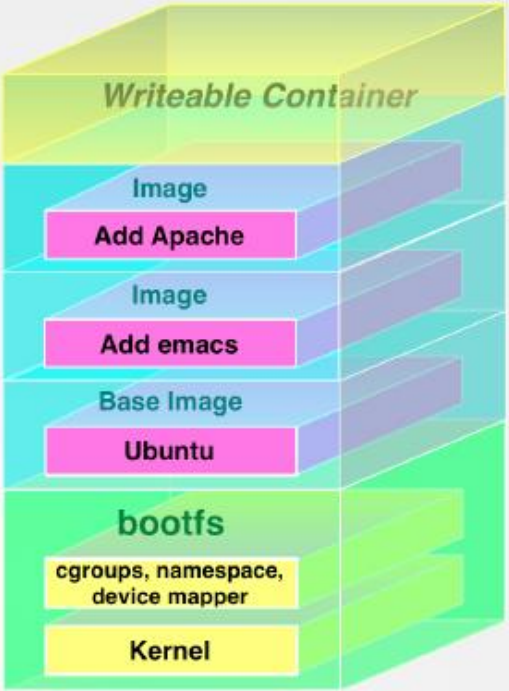
Docker Architecture

- Docker uses a client-server architecture
- Client
  - Is the primary user interface which communicates using a REST API
  - Over HTTP
  - Over local Unix socket
- Server
  - Is the Docker daemon
  - Responsible for building, running, and distributing containers
- Registry
  - Responsible for the storage, management, and delivery of Docker Images
    - Docker Hub
    - Private
    - Other vendors



Docker Images & Containers

- Docker images are read-only templates
  - Foundation is a simplified version of the Linux operating system
  - Changes to foundation, such as application installations added to the Image
  - Images are the templates or build commands for Docker
- Docker containers are running environments
  - Has OS, environment, program, network, etc.
  - Runs (probably one) application
  - All required software contained in image
  - Can have boot-up configuration
  - They can be run, started, stopped, and deleted



Docker Images

- Docker images are built in layers
  - Each layer is a file system
  - The layers are combined in a union file system to make a single image
  - Images are the build component of Docker
- Images start from a base image
  - Foundation is usually a specifically prepared Linux operating system
    - Custom base images can also be created
  - Docker Image are then built by adding layers:
    - Interactively
    - Defined in a directive file called a “Docker File”

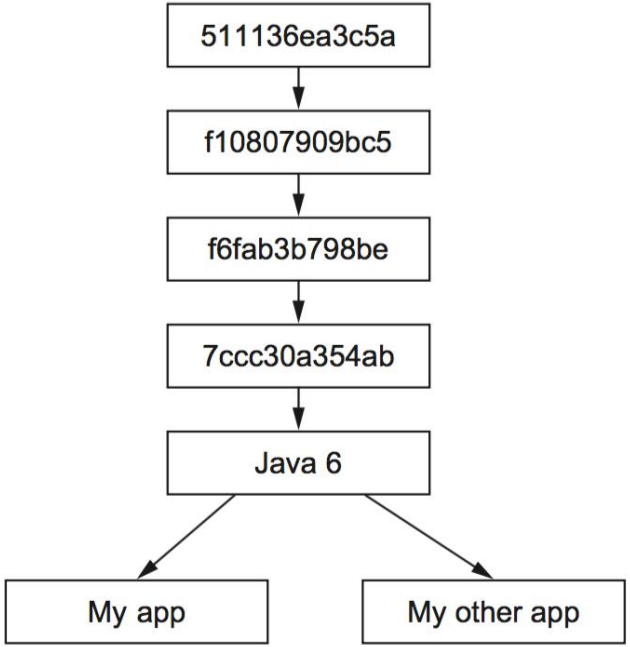


Figure 3.7 The full lineage of the two Docker images used in section 3.3.1

Running Containers

- The docker `run` command starts a container based on a named Docker Image
  - Docker first looks for a local copy of the image
    - If it does not exist it is pulled from a Docker Registry
      - The default Registry is the Docker Hub Registry
  - A new container is created using the file system from the image
  - A read-write layer is added to the top of the file system
  - A network interface is created and an IP address is assigned from a pool
  - Standard input, output, and error streams are connected
  - A specified application is executed
- Docker container appears as a child of the daemon process, ms are connected

Pulling & Running Containers

- A Docker Image must be located on the local computer
  - It may have been created locally
  - It may have been pulled from a Registry
  - It may be missing
- The `pull` command insures that the specified image is on the local computer
  - It will transfer all constituent layers of the image as separate transfers
- The `run` command creates and initiates a container based on the image
  - The example runs the latest CentOS image
  - It runs the command `command`

```
docker pull centos:latest
```

```
docker run centos:latest whoami
docker run centos:latest pwd
docker run centos:latest date
```

To use a container interactively requires switches to the run command

- -i or --interactive keeps STDIN open
- -t or --tty allocates a pseudo TTY

```
docker run –i –t centos:latest /bin/bash
```

Listing Running Containers

- Running containers can be listed using the ps command
  - Note that the container has been given a name
- The stats command shows running container resource usage, use ^C to exit

```
docker ps
docker stats
```

Containers can be explicitly named using the --name switch

- By default, Docker makes up a comical name such as hungry_lumiere
- Most commands will accept either the name or the ID of the container
- Note: The `ps` command accepts a switch `-a` for all containers

```
docker run –it –-name centosC1 centos:latest /bin/bash
docker stop centos
docker rm centos
```

Attaching to Running Container

- Attaching to a container attaches to the contained process's STDIN, STDOUT, and STDERR
  - You can attach with either the container ID or its name
  - Several command prompts can attach to the same container process
  - All tty sessions see the same input and outputs
  - The container ID is obtained using ps
- You can detach from a container and leave it running using ^p ^q

On first terminal:

```
docker run –it –-name centosC1 centos:latest /bin/bash
> date
```

On second terminal:

```
docker attach centosC1
> date
```

Containers can be stopped using the stop command

- It has an optional –t or --time parameter which defaults to 10 seconds
- The main process, PID=1, is sent a SIGTERM
- After the timeout interval, it is sent a SIGKILL

```
docker stop centos
```

Pausing Containers

- Docker containers may be paused
  - Use the `pause` command
  - All container processes are suspended as a group
  - It does not use the SIGSTOP, SIGCONT mechanism as processes can see the signals
  - It uses the cgroups freezer mechanism where all processes in a cgroup and its children are suspended without the processes being aware
- Process can be resumes using the unpause command

On first terminal:

```
docker run –it –-name centosC1 centos:latest /bin/bash
```

On second terminal:

```
docker pause centosC1
> date
```

On second terminal:

```
docker unpause centosC1
```

- Once a container is stopped, it is still available
  - The ps –a command shows all containers
- A stopped container can be started with the start command
  - The –i or --interactive switch connects STDIN
  - The –a or attach switch attaches STDIN and STDERR

```
docker ps -a
docker start -ai centosC1      OR
Docker restart centosC1
```

Docker containers can be removed with the rm command

- The –f or --force switch causes running containers to be force stopped for removal
- The ps –aq command shows all containers IDs to enable all to be removed

```
docker rm centosC1
docker rm $(docker ps -aq)
```

- Containers can be run in the background
  - Use the run command with the –d or --detach switch
- Signals can be sent using the kill command
  - The default signal is SIGTERM

```
docker run –d –-name webserver nginx
docker kill webserver
```

Docker Images

- Docker has a number of base images on Docker Hub
  - Including many versions of Linux distributions
  - The image centos:latest will be used as a base
- Application images are created by adding layers to a base image
  - It can be done manually from a container running a shell
  - It can be automated using Docker's build process
- The Docker search facility can be used to search for images on Docker Hub

Listing and Removing Images

- Images can be listed using the images command
- Images can be deleted using the rmi command

```
docker images
docker rmi centos-git
```

The CentOS base image is cut down

- It doesn't have the which or ifconfig commands
- We can install these from the command line using yum

```
docker run -it --name centosC1 centos:latest
yum install -y which
yum install -y net-tools
exit
```

Building Image Interactively

- Any changes made interactively are only in the container
  - The diff command can be used to see which files have been changed
- The changed container can be committed to create an image
- The image can then be run
  - The run --rm option deletes the container on exit

```
docker run –it --name centosC1 centos:latest
yum install –y which
yum install –y net-tools
exit

docker diff centosC1
docker commit centosC1 centos-net
docker rm centosC1
docker run --rm –it --name centosC2 centos-net
```

The images can be inspected to see the layers

- The inspect command returns a JSON array by default
- It can be used on images and containers
- The –s or –-size switch gives the size of a container
- The –f or –format switch can be used to extract the JSON fields

```
docker inspect centos-net
```

Automating Docker Image Build

- Docker image creation can be automated
- Create a directory containing all the files required for the build
- Add a file called Dockerfile which defines the build process
- The directory becomes the build context
- Each command in the build file creates a layer of the image
- A new container is created at each stage

- Dockerfile contains build directives
  - FROM defines the starting image
  - MAINTAINER defines the email address of the builder

```
FROM centos:latest
MAINTAINER phill@totaleclipse.eu
```

- The Dockerfile SHELL command defines the default shell to use
  - It must be specified in JSON form
  - The default for Linux and windows are shown
  - It takes the form SHELL ["executable", "parameters"]

```
SHELL ["/bin/sh", "-c"]
SHELL ["cmd", "/S", "/C"]
```

COPY

- The Dockerfile COPY command copies files into the container
  - The source files or directories must be in the build context
  - The source files can contain UNIX shell wildcards ? * []
  - Destination directories must end in a / and will get created if they don't exist

```
COPY jdk*.rpm /tmp/
```

ADD

- The Dockerfile ADD command copies files and remote file URLs into the container
  - The source files or directories must be in the build context or remote URLs
  - The source files can contain UNIX shell wildcards ? * []
  - Destination directories must end in a / and will get created if they don't exist
  - Local source files in tar or compressed tar format get unpacked

```
ADD apache-maven*.tar.gz /opt/
```

- The Dockerfile RUN command executes a Linux command
  - Multiple commands can be separated with a ; - needed for cd
  - Commands shouldn't block for input – commands have a –y switch which answers yes to all questions

```
RUN yum install -y which
RUN rpm -i /tmp/*rpm
RUN cd /opt; ln -s apache-maven* maven
```

ENV

The Dockerfile ENV command sets environment variables in the image.

```
ENV JAVA_HOME=/usr/java/latest
ENV PATH=/usr/local/sbin:/usr/local/bin:/usr/sbin:/usr/bin:/sbin:/bin:/opt/maven/bin
```

EXPOSE

Exposes the port at which the container application will be made available

```
EXPOSE 22
```

COMMAND

The Dockerfile CMD command sets the default application.

```
CMD /bin/bash
```

- The build process requires a directory
  - All of the directory contents are transferred to the daemon
  - It must contain a Dockerfile build script
  - Images should be tagged image-name:version
  - A temporary container is created for each command in the build

```
docker build –t centos-java:latest .
```

Exercise 2 : Automate Build of Docker Image

- Use document to build Jtrac image and run a container using it

- A major issue using Docker is getting the correct versions of images
  - Docker uses registries to distribute images
  - Registries can be hosted or you can have a private version
- Considerations about registries:
  - Performance, rollout frequency, and number of images
  - Security issues, including access control and digitally signing images

Docker Registry Service

- A registry is a service used to manage and distribute images
- It is based on a description
- Registries manage Docker images stored in repositories
- Repositories are collections of related images
    - Different versions of an application
    - All images have the name of the repository with a tag name to distinguish between images

- Docker Hub is the default registry
  - It has a root namespace for official images
  - Root images include versions of supported Linux distributions
  - For example the nginx images can be addressed in different ways

```
hub.docker.com/_/nginx:1.9
nginx:1.9
```

Labels

- Labels are used to uniquely identify images
  - Labels look like URIs
  - Components separated by /
- Label components:
  - Registry FQDN
  - Namespace _ is for Docker Hub, r is for user
  - User or organization name
  - Repository name: tag
    - A tag is either a version number or a descriptive label

```
https://hub.docker.com/r/databliss/netkernel-se/
```

URI = Uniform Resource Identifier
FQDN = Fully Qualified Domain Name

Other Docker Registries

Docker Hub is not the only Docker registry.

- Google Container Registry
  - Part of the Google Cloud Platform, good for access control and security
- Amazon EC2 Container Service
  - Part of Amazon AWS
- Quay
  - Has free and pay for plans
- Private Registry

- First it is necessary to log into the registry
  - You will be prompted for a password
  - The credentials will be stored in ~/.docker/config.json
  - The password is stored as a hash

```
docker login --username=user
```

- Images need to have the same name as the repository
  - Create a container from an image
  - Commit the image to the Docker Hub registry name
  - Alternatively, create a new tag for the image
- Images can then be pushed into the repository
  - It can take a while as all layers are pushed

```
docker create --name java centos-java
docker commit java phill/question:java-1.0
docker push phill/question
```

- Image tags can be viewed on the Docker Hub web site
- Images are retrieved
    - By using the docker pull command

```
docker pull phill/question:java-1.0
```

Deleting Images

- Images can be deleted from the command line
- Docker Hub doesn't allow images to be deleted at present
    - Can only delete the entire repository from the Settings menu

```
docker rmi phill/question:java-1.0
```

- Private registries are a good solution for the following cases:
  - Provide a local image cache to speed up image loading
  - Allow teams to share images locally
  - Store images specific to a project lifecycle stage, development, and UAT
  - Guarantee that the registry will be available for as long as required

- The easiest way to create a private registry is to use a prebuilt Docker container
    - Docker Hub has a number of registry images including the official one
- The registry images can be pulled from Docker Hub

```
docker pull registry:2
```

- The registry image can now be run as a container
  - It needs to be run as a daemon container
  - The –p option exposes the container's ports as local ports
  - It usually uses port 5000

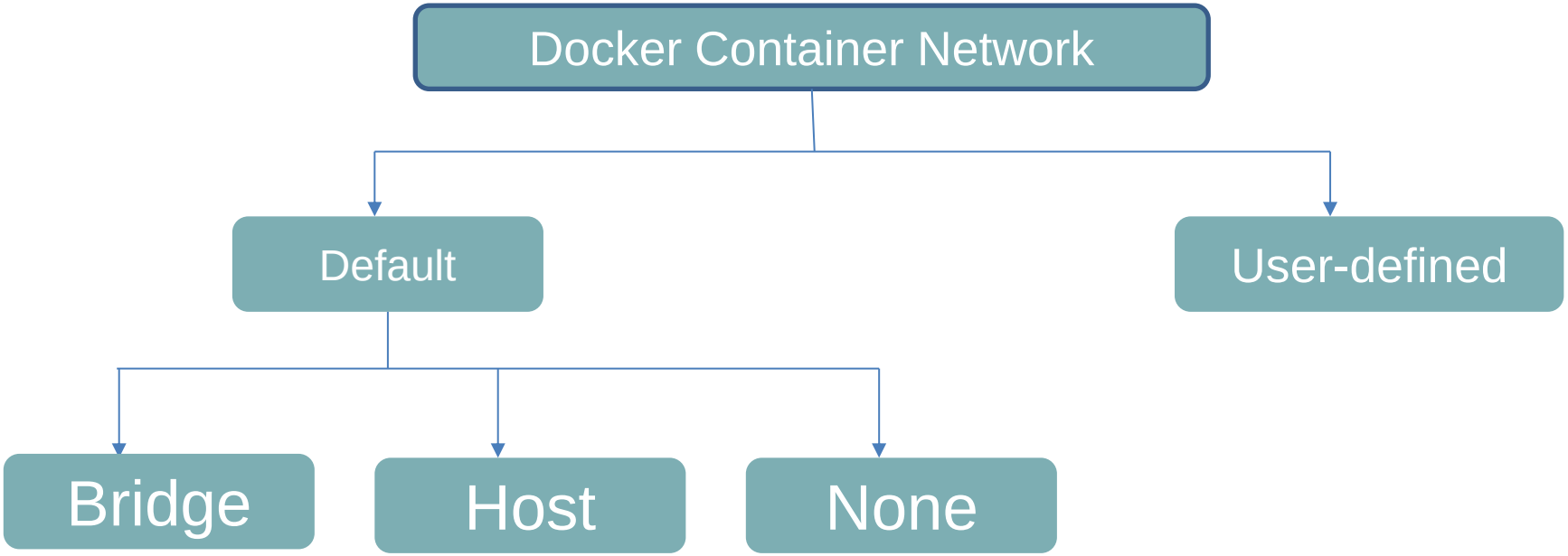
```
docker run -d -p 5000:5000 --name registry registry
```

- The registry is identified by hostname:port
  - For example localhost:5000
  - Images need to be named with the registry prefix
  - For example, localhost:5000/alpine
  - The image can then be pushed into the registry or pulled from it

```
docker pull alpine
docker tag alpine:latest localhost:5000/alpine:latest
docker push localhost:5000/alpine
```

Exercise 3 : Building Private Docker Registry

- Use document to build private docker registry and push images to it


Docker Container Network
Default
User-defined
Bridge
Host
None

Docker Container Networks - Default

- Docker creates three networks by default, which can't be removed
- The none network is local to the container – it has localhost
- The host network gives the container the same network as the host
- The bridge network is the default
  - A docker0 or bridge0 virtual interface is created on the host

```
$ docker network ls

NETWORK ID      NAME                DRIVER                  SCOPE
9d6a9ab487ba    bridge              bridge                  local
c7956146a031    host                host                    local
115642b21a91    none                null                    local
```

Default – Bridge Network

- The bridge network creates a subnet and a subnet mask.

```
$ docker network inspect bridge
[ {
        "Name": "bridge",
        "Id":
"9d6a9ab487ba1d00715bfa60833a9cf5daa564d9a02918424ca3d38e26b2b5f8",
        "Scope": "local",
        "Driver": "bridge",
        "EnableIPv6": false,
        "IPAM": {
            "Driver": "default",
            "Options": null,
            "Config": [
                {
                    "Subnet": "172.17.0.0/16",
                    "Gateway": "172.17.0.1"
                }
            ]},
```

Default – Bridge Network

- The bridge network assigns MAC and IP addresses to each container

```
$ docker network inspect bridge
...
       "Containers": {
            "eb6dc24ff73fff0da60e98b02aa28e76f92f316aeed73f774ef7b3b0220b5b69": {
                "Name": "centos",
                "EndpointID":
"5b4437f5c54b0923f4558ecc01f9326fafa0fbb4d1f8564131d6dac9bd47e0de",
                "MacAddress": "02:42:ac:11:00:02",
                "IPv4Address": "172.17.0.2/16",
                "IPv6Address": ""
            }
        },
```

- The bridge network supplies a /etc/hosts file for each container

```
127.0.0.1       localhost
::1     localhost ip6-localhost ip6-loopback
fe00::0         ip6-localnet
ff00::0         ip6-mcastprefix
ff02::1         ip6-allnodes
ff02::2         ip6-allrouters
172.17.0.2      eb6dc24ff73f
```

Default – Host Network

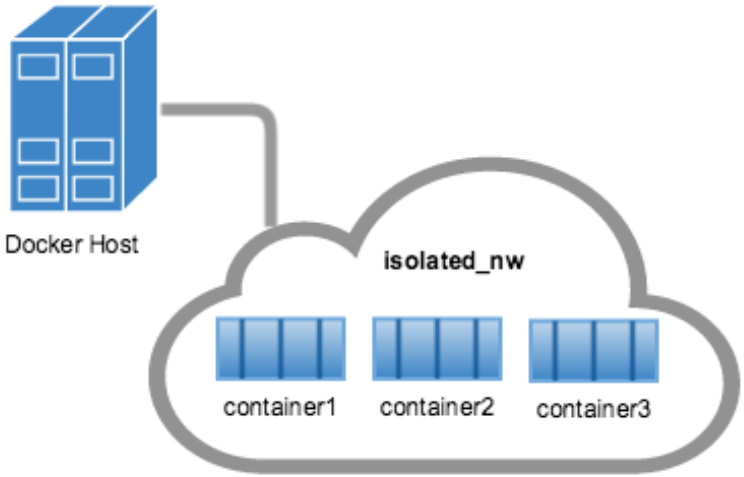
A container attached to a host network has the same network as the host
It has the same network configuration as the host
It is not used much any more

Default – None Network

- A container attached to a none network has no network
- It has only a localhost interface
- It can't communicate with other networked containers
- It is not used much any more

Docker Container Network – User Defined Network

- User defined networks can be created
  - Docker provides drivers including bridge
- Containers can only communicate with other containers on the same network
- Multiple networks can be created
- Containers can be connected to multiple networks
  - Can communicate with any container on any connected network



Creating User Defined Network

- New networks can be created
- The default driver is the bridge network
- A new subnet is created unless addresses are specified

```
$ docker network create isolated_bridge
b58db4ec8887a9187151c46850d69b58276a95d780e7465a24aaffb014f6ad8

$ docker network ls
NETWORK ID          NAME                DRIVER              SCOPE
9d6a9ab487ba        bridge              bridge              local
c7956146a031        host                host                local
db58db4ec888        isolated_bridge     bridge              local
115642b21a91        none                null                local
```

Using networks

- Networks can be specified only when a container is run
- A network can be added to an existing container
  - A new network interface is added
- A network can be disconnected from a container
- A user-defined network can be removed

```
docker run -it --network isolated_bridge --name java centos-java
docker network connect isolated_bridge centos
docker network disconnect isolated_bridge centos
docker network rm isolated_bridge
```

Exercise 4 : Docker networking

- Networking between container on docker network

- Docker Compose is a tool for running multi-container Docker applications
- A configuration file is used to define the services
- All of the services can be run using a single command
- Compose can manage the lifecycle of an application
  - Start, stop, and rebuild services
  - View the status of running services
  - Get the log output of running services
  - Run a command on a service

Installing Compose

- Run this command to download the latest version of Docker Compose:

```
cd ~
sudo curl -L
"https://github.com/docker/compose/releases/download/1.22.0/docker-
compose-$(uname -s)-$(uname -m)" -o /usr/local/bin/docker-compose
```

- Apply executable permissions to the binary:

```
sudo chmod +x /usr/local/bin/docker-compose
```

Compose

- Create a directory for Docker Compose
- Create a YAML file called docker-compose.yml
- The docker-compose command needs to be run from the directory containing the YAML file
- Any number of containers can be specified

```
version: "2"
services:
  sshd:
    build: sshd
    image: centos-sshd:latest
    ports:
      - "2222:22"
```

- First of all create a directory with name of service containing a Dockerfile under Docker Compose folder
- Docker Compose would use this to build image

```
FROM  centos:latest
RUN yum install -y openssh-server
RUN mkdir /var/run/sshd
RUN useradd -c "Student User" -m student
RUN echo "student:student" | chpasswd
RUN ssh-keygen -t rsa -f /etc/ssh/ssh_host_rsa_key -q -N ""
EXPOSE 22
CMD ["/usr/sbin/sshd", "-D"]
```

Run Compose

- Docker Compose has an up option which runs all containers
- The –d option runs it in the background
- The down option terminates all managed containers

```
docker-compose up -d
```

```
ssh -p 2222 student@locahost
```

```
docker-compose down
```

Exercise 5 : Docker Compose

- Use docker compose to run cotnainers

- A single command can be executed on a container
- A new container is started from the image
- The –-rm option removes the container after the command is run
- The –-name option names the new container
- The –p option publishes container ports to the host
- A TTY is allocated unless the –T option is given


Cognixia
A Collabera LEARNING SOLUTIONS COMPANY
THANK YOU
45%