TCSS 562: Software Engineering for Cloud Computing
Fall 2018
http://faculty.washington.edu/wlloyd/courses/tcss562

School of Engineering and Technology
University of Washington – Tacoma

Tutorial 7 – Docker Tutorial

Disclaimer: Subject to updates as corrections are found
Version 0.10

The purpose of tutorial #7 is to provide an introduction to Docker, cgroups, and resource isolation with containers. This tutorial should be completed using a Ubuntu system. Any of the following should be sufficient: a Ubuntu system (e.g. laptop), a Ubuntu Virtual Box, or an EC2 instance with Ubuntu. The system must have at least 2 CPU cores, and access to at least 4 GB of memory.

For the tutorial, answer the questions as best as possible based on the observations of performing the tests/activities as described. Submit answers as a PDF file in Canvas. Use Google Docs, or Microsoft Word to create a PDF file.

Task 1 – Working with Docker, creating a Dockerfile

To start, log into your Ubuntu machine. If using an EC2 instance, a multi-core VM such as a c4.large/m4.large or better is recommended. EC2 instances should be created as spot instances, unless wanting to "pause" the instance, then an on-demand instance is required. (minimum of 10 cents/hour)

Install Docker on Ubuntu

Highlight the commands, and copy-and-paste to the VM:

```
curl -fsSL https://download.docker.com/linux/ubuntu/gpg | sudo apt-key add -

sudo add-apt-repository "deb [arch=amd64] https://download.docker.com/linux/ubuntu
$(lsb_release -cs) stable"

# refresh sources
sudo apt update

# install packages
apt-cache policy docker-ce

sudo apt-get install -y docker-ce

#verify that docker is running
sudo systemctl status docker
```

The "Docker Application Container Engine" should show as running.

When working with Docker directly on your local VM, we will preface docker commands with "sudo", so the commands run as the superuser.

Create a docker image for testing

The “Docker Hub” is a public repository of docker images. Many public images are provided which include installations of many different software packages.
The “sudo docker search” command enables searching the repository to look for images.

Let’s start by downloading the “ubuntu” docker container image:
Note that docker commands are prefaced as “sudo”.
They must be run as superuser.

```
sudo docker pull ubuntu
```

Verify that the image was downloaded by viewing local images:

```
sudo docker images –a
```

Next, make a local directory to store files which describe a new docker image.

```
mkdir docker_test
cd docker_test
```

Using a text editor such as vi, vim, pico, or nano, edit the file “Dockerfile” to describe a new Docker image based on ubuntu:

```
nano Dockerfile
```

```
# Test Dockerfile contents:
FROM ubuntu
RUN apt-get update
RUN apt-get install -y stress-ng
RUN apt-get install -y sysbench
COPY entrypoint_test.sh /
ENTRYPOINT ["/entrypoint_test.sh"]
CMD ["6000"]
```

Next, create a script called “entrypoint_test.sh” under your docker_test directory as follows:

```
#!/bin/bash
# test daemon - runs container continually as a task...
# Exits task and container when sleep time expires.
sleep=$1
echo "daemon up...  sleep_for=$1"
sleep $sleep
exit
```

You’ll need to change permissions on this file.
Give the owner execute permission:

```
chmod u+x entrypoint_test.sh
```

Next, build the docker container:

```
sudo docker build -t stressng .
```

Check that the docker image was build locally:

```
sudo docker images
```

Next launch the container as follows:

```
sudo docker run -d --rm stressng
```

Check that the container is up

```
sudo docker ps -a
```

Next, run the bash shell interactively as a second process inside this container:
Find the container-id from the docker ps command.

```
sudo docker exec -it <container-ID> bash
```

Next, open a second ssh terminal to your Ubuntu machine.
Navigate to the directory as follows:

```
cd /sys/fs/cgroup/cpuacct/docker
```

Under the docker directory, find the unique identifier for your container.
This matches the first several characters of the container ID as seen using docker ps -a.
Navigate to this directory:

```
cd <container-ID-long>
```

Next, watch the “cpuacct.usage” file:

```
watch -n .5 cat cpuacct.usage
```

The cpu utilization is shown in nano seconds.
Move the decimal 9 places to the left to convert to CPU seconds.

QUESTION 1. Without running any test, how much CPU time has been spent in seconds, since this container was created?

Task 2 – Using Cgroups to monitor resource utilization

Print out the initial CPU utilization value:

```
cat cpuacct.usage
```

Next, run the stress-ng command:

```
stress-ng --cpu 2 --cpu-method fft --cpu-ops 5000
```

Next, print out the updated current CPU utilization value:

```
cat cpuacct.usage
```

QUESTION 2. After running the test, what is the present CPU utilization value in seconds?

QUESTION 3. What is the difference in CPU time in seconds that transpired for running the test? *(subtract the two values)*

The output of stress-ng reports the runtime in seconds.
This is considered “wall clock time”.

What is the difference between the reported runtime and the CPU time as measured by the linux cgroup cpuacct ?

Before proceeding, try repeating the test, and explore various system metrics that are available under the **/sys/fs/cgroup/** directory. You may also explore running different stress-ng tests.

For help in stress-ng, see:
http://manpages.ubuntu.com/manpages/artful/man1/stress-ng.1.html
https://wiki.ubuntu.com/Kernel/Reference/stress-ng
https://www.cyberciti.biz/faq/stress-test-linux-unix-server-with-stress-ng/

Task 3 – Persisting Docker Images to “Docker Hub” image repository

Docker images are stored in “Docker Hub”. Docker Hub can be compared to “GitHub”. Where “GitHub” provides a repository for tracking changes to source code for one project, “DockerHub” provides a repository for tracking changes to a Docker container image. Just like GitHub, with DockerHub there are public and private repositories. DockerHub repositories are used to collect versions of a single image. These version can be tagged with names for quick retrieval. Free DockerHub accounts are limited to only one private repository of images, but they can have unlimited public repositories. So if wanting to maintain more the one private Docker image, it is necessary to upgrade beyond the basic DockerHub account.

To get started, you’ll need to create an account on DockerHub.
Using a web browser, navigate to:

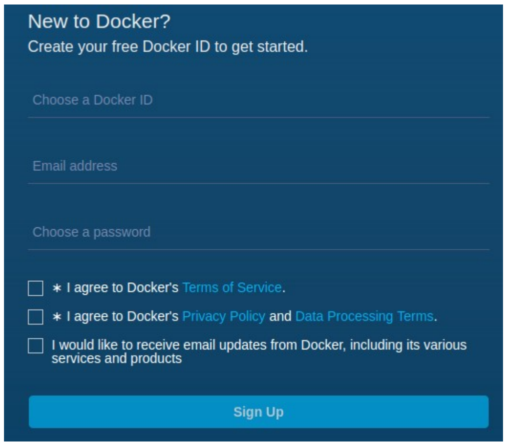
https://hub.docker.com/

Next, create an account by completing the form:

Please note your account information (username, email, password) for future use.

Once creating an account, using the GUI, create a new repository:

Click on the “New Repository” button:


New to Docker?
Create your free Docker ID to get started.

Choose a Docker ID

Email address

Choose a password

☐ ∗ I agree to Docker's Terms of Service.
☐ ∗ I agree to Docker's Privacy Policy and Data Processing Terms.
☐ I would like to receive email updates from Docker, including its various services and products

Give the repository a name.
Enter Name: tcss562

Choose to make the repository either public or private.
Then press the **[CREATE]** button.

Now, log into your DockerHub account from the command line:

```
sudo docker login –u <USERNAME>
```

Inspect your IMAGE ID for your stressng Docker image

```
sudo docker images –a
```

Using the IMAGE ID, tag this image for adding into your DockerHub repository

```
sudo docker tag <IMAGE ID> <Docker Hub USERNAME>/tcss562:latest
```

Now commit the image to your public repository

```
sudo docker push <Docker Hub USERNAME>/tcss562
```

Now manually delete both the stressng image and the tagged image that you just committed to the DockerHub repository.

To remove the images, you'll need to make sure the container has exited.
To kill the container, find it's ID using: sudo docker ps -a
Then kill the container using: sudo docker kill <container-id>

Now remove all traces of the stressng image from your system

```
sudo docker rmi stressng
sudo docker rmi <Docker Hub USERNAME>/tcss562
```

Now using the DockerHub search command, look for the tcss562 repository

```
sudo docker search tcss562
```

You may see other students repositories here if they create public repositories.

Go ahead and PULL your pushed docker image, put preface the command with the Linux "time" command to record how long it takes.

```
time sudo docker pull <Docker Hub USERNAME>/tcss562
```

Now, purge this image:

```
sudo docker rmi <Docker Hub USERNAME>/tcss562
```

Next, rebuild your stressng container, but time how long it takes:

```
time sudo docker build -t stressng .
```

QUESTION 4. Is it faster to pull the docker image from DockerHub or rebuild the image from scratch locally? Please list the times for pulling vs. building.

Task 4 – Using Docker to constrain resource allocation

Next, exit the ssh session.

Now, assign the cpu-shares of the docker container:

```
sudo docker update --cpu-shares="128" <container-id>
```

Repeat the stress test:

```
stress-ng --cpu 2 --cpu-method fft --cpu-ops 5000
```

QUESTION 5. What happens to the runtime of the test?

For question 4, based on the documentation, describe what we are seeing with respect to the runtime of stressng after assigning cpu-shares:
https://docs.docker.com/config/containers/resource_constraints/#cpu

Next, reset the CPU shares to the default

```
sudo docker update --cpu-shares="1024" <container-id>
```

And then assign the containers “cpus”

```
sudo docker update –cpus=".5" <container-id>
```

Now, print out the cpuacct.usage before the test:

```
cat cpuacct.usage
```

Now, in the second window, repeat the stress test and observe the run time:

```
stress-ng --cpu 2 --cpu-method fft --cpu-ops 5000
```

Obtain the end cpu usage, and calculate the differences:

```
cat cpuacct.usage
```

QUESTION 6. What was the CPU utilization for the test? How did it vary from our previous measurement? What could explain the behavior we are seeing ?

Next, reset the CPU allocation for the container:

```
sudo docker update --cpus="2" <container-id>
```

Task 3 – Test CPU Isolation with Docker

Now, in a second terminal window, create a second instance of the same container.

Launch the container as follows:

```
sudo docker run -d --rm stressng
```

Check that the new container is up, and check for the new ID:

```
sudo docker ps -a
```

Now, let's test CPU isolation of containizeration.

Assuming you're on a two-core system, first limit the CPU alllocation to 1 core for each of the two containers.

Find the container IDs using the docker ps -a command.

And assign the CPU allocation for both containers:

```
sudo docker update --cpus="1" <container-id-A>
sudo docker update --cpus="1" <container-id-B>
```

Next, run a bash shell interactively on the second container:
Use the container-id from the docker ps command above.

```
sudo docker exec -it <container-ID> bash
```

In two separate terminals, for each of the containers, type the command, but DO NOT hit enter yet:

```
stress-ng --cpu 2 --cpu-method fft --cpu-ops 5000
```

First, run one container alone to measure the stand-alone performance of the command.

Next, prepare to run the command in both commands in parllel.
This requires submitting commands to both containers as close as possible in time so their execution overlaps as much as possible.

QUESTION 7. What is the performance difference when running the command standalone vs. running two instances at the same time with CPU allocation has been set to 1?

If container isolation is "perfect" for sharing the CPU, then performance should essentially be the same.

Task 4 – Test memory Isolation with Docker

Next, let's try a memory stress test to test for how well the Docker containers provide isolation from concurrent memory operations on the host.

In one of the terminals, run the sysbench command to stress memory.

```
sysbench --test=memory --memory-block-size=1M --memory-total-size=100G --num-threads=1 run
```

At the conclusion, look for the memory throughput value.

This is right below the “Total operations”, and the throughput is shown in “MiB/sec”. This represents the amount of memory that was transferred per second.

Now, stage this command to performance the memory stress test on two containers at the same time. Recall these two containers should have had their CPU’s limited using the setting: --cpus=”1”

Run the command at the same time in two containers:

```
sysbench --test=memory --memory-block-size=1M --memory-total-size=100G --num-threads=1 run
```

If memory isolation is “perfect” for sharing the memory subsystem of the host, then performance should essentially be the same.

QUESTION 8. What is the memory throughput values (MiB/sec) for both containers A and B?

QUESTION 9. What is the average memory latency (in ms) for both containers A and B?

QUESTION 10. How did the memory throughput and memory latency change when comparing the standalone (1 container) test values with the concurrent container test?

QUESTION 11. From the test results, do the docker containers appear to provide?
(a) Better memory isolation
(b) Better CPU isolation

QUESTION 12. Provide a plausible explanation for Question #11.

Task 5 – Cleanup

At the end of the tutorial, if using EC2, you may want to create an image of your virtual machine with Docker. If you haven’t already, reimaging your server VM will allow it to be restored with minimal effort and setup in the future.

After reimaging, be sure to **TERMINATE** all EC2 instances. Failing to do so, could result in loss of AWS credits or AWS charges to a credit card.

You may also want to purge old duplicate snapshots, when you’ve created more than one image of an EBS-backed instance. It may not be worthwhile to keep old copies around when new images supersede them.