Intro to Docker

logistics

- Class Hours:
- Start time is 9:30am
- End time is 4:30pm
- Class times may vary slightly for specific classes
- Breaks mid-morning and afternoon (10 minutes)

- Lunch:
- Lunch is 11:45am to 1pm
- Yes, 1 hour and 15 minutes
- Extra time for email, phone calls, or simply a walk.

- Telecommunication:
- Turn off or set electronic devices to vibrate
- Reading or attending to devices can be distracting to other students

- Miscellaneous
- Courseware
- Bathroom

Course Objectives

By the end of the course you will be able to:

- Describe the Docker platform and architecture
- Build, run, and manage Docker containers & images
- Configure container networks
- Maintain data in containers
- Configure a Docker Swarm cluster
- Install Docker on laptop for developer use

Agenda

Day 1:

- What are Containers/What is Docker?
- Interact/Explore Docker Engine and Containers
- Container Networks
- Create Docker Images

Day 2:

- Data Persistence
- Define and Run Multi-Container Applications
- Containers at Scale (Clustering)
  - Docker Swarm
  - Kubernetes
- Capstone Lab + Local Install
- Enterprise Architectures
- Dockerize an Infrastructure (CI/CD and Microservices)

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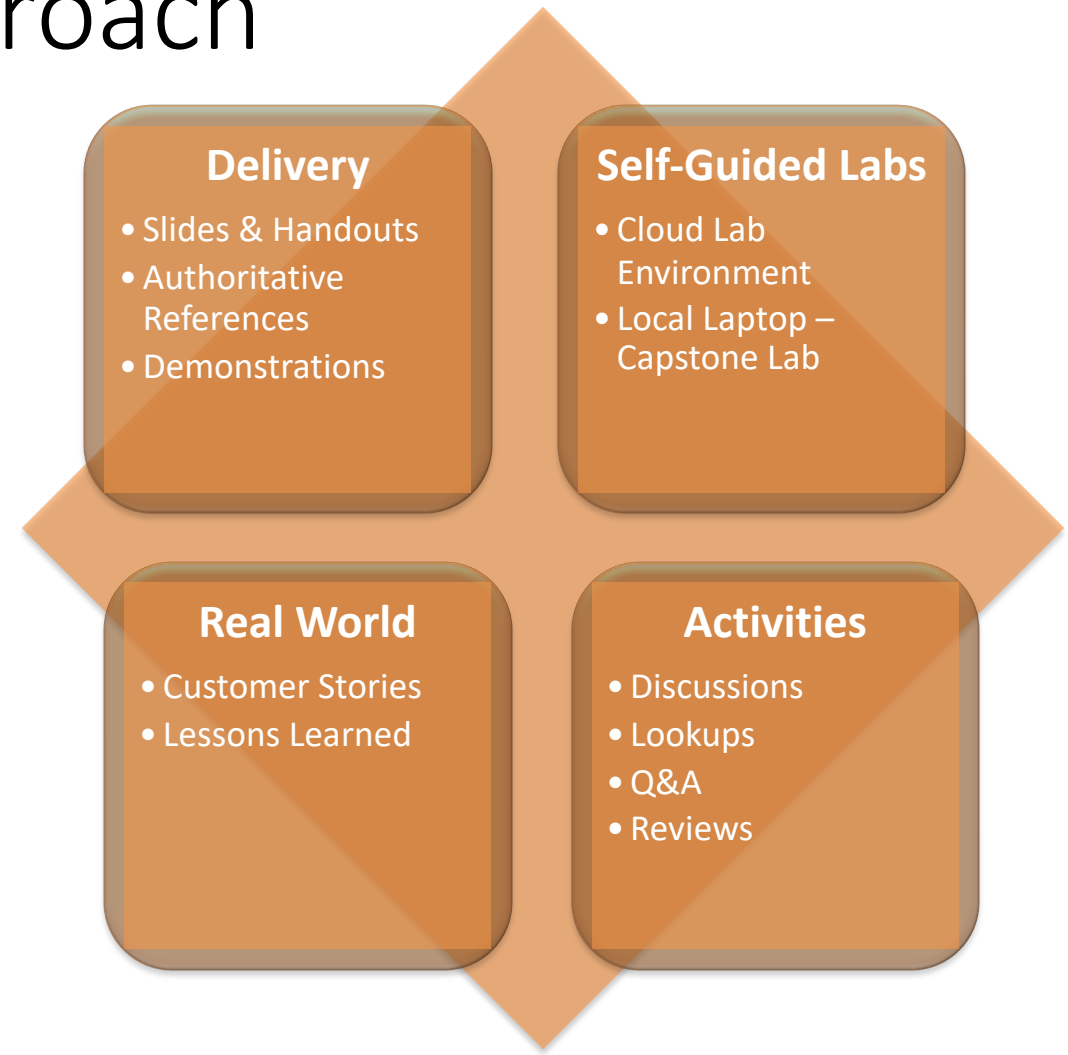
Course Approach



End of Day Office Hours - 1:1 Assistance

The Training Dilemma

Jason Smith

Twitter: @jruels
jason@innovationinsoftware.com

Expertise

- Cloud
- AWS/Azure/Google
- OpenStack
- CICD/Automation
  - Ansible/Chef/Puppet
  - Terraform/Jenkins
- Containers
  - Docker/Kubernetes
  - Microservices

Introductions

- Name
- Job Role
- Which statement best describes your Docker circumstance?
  a. I am ***currently working*** with Docker on a project/initiative
  b. I ***expect to work*** with Docker on a project/initiative in the future
  c. I am ***here to learn*** about Docker outside of any specific work related project/initiative
- Expectations for course (please be specific)

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Lab Environment

Day 1

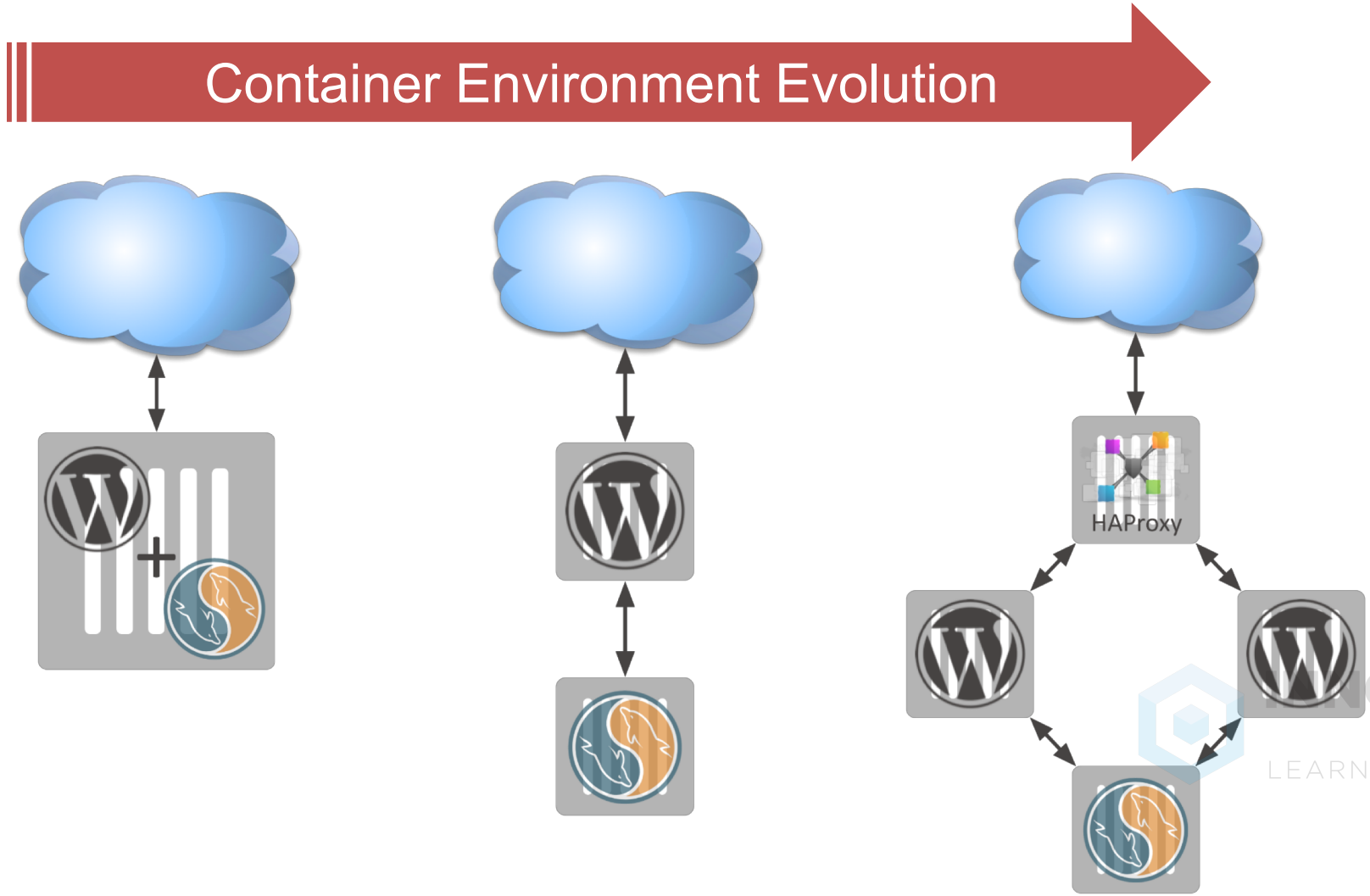
- Cloud Servers

Day 2

- Capstone Lab
- Local laptop

Lab Environment – Reference Application

Lab Environment



Docker Overview

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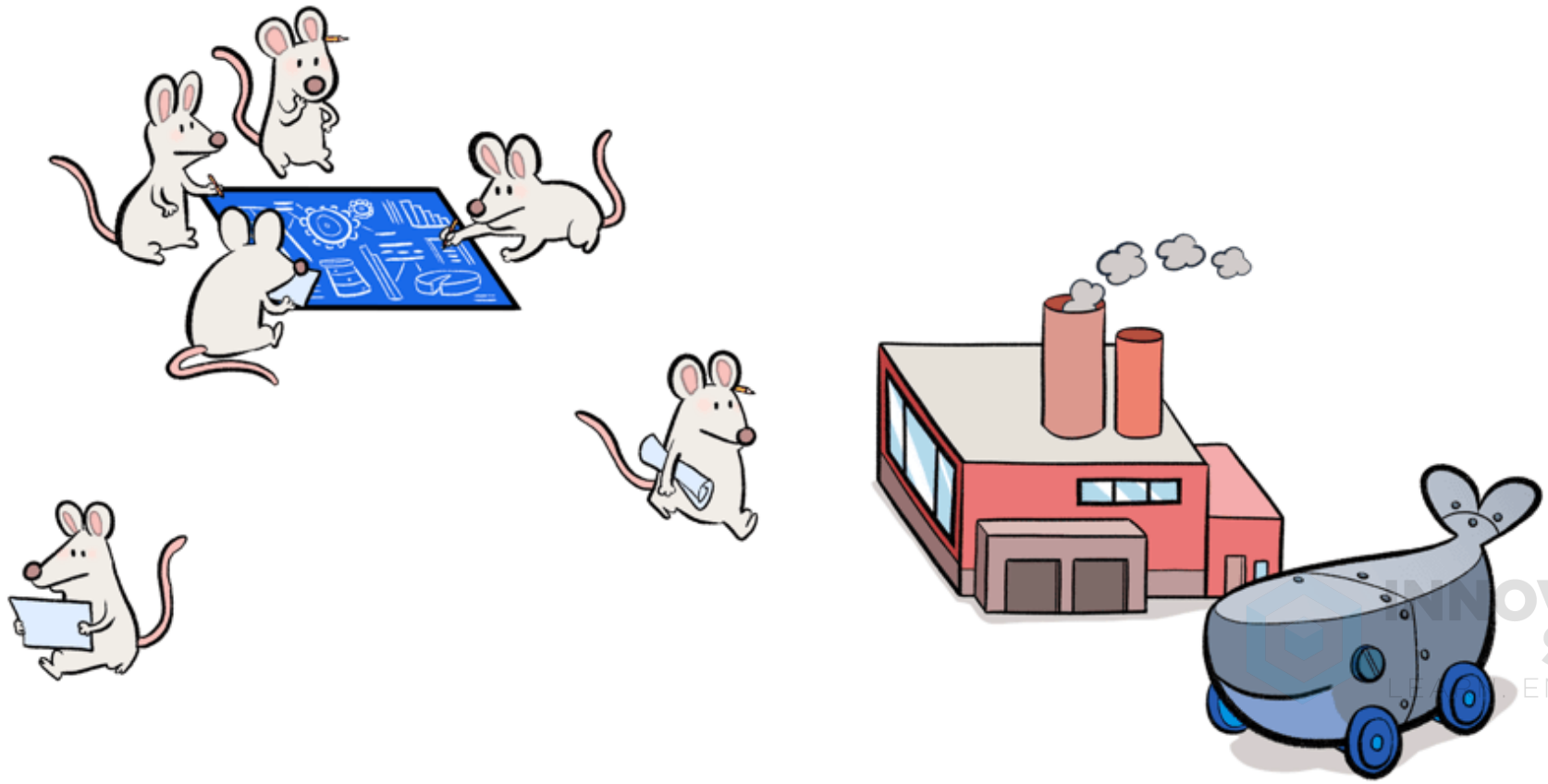
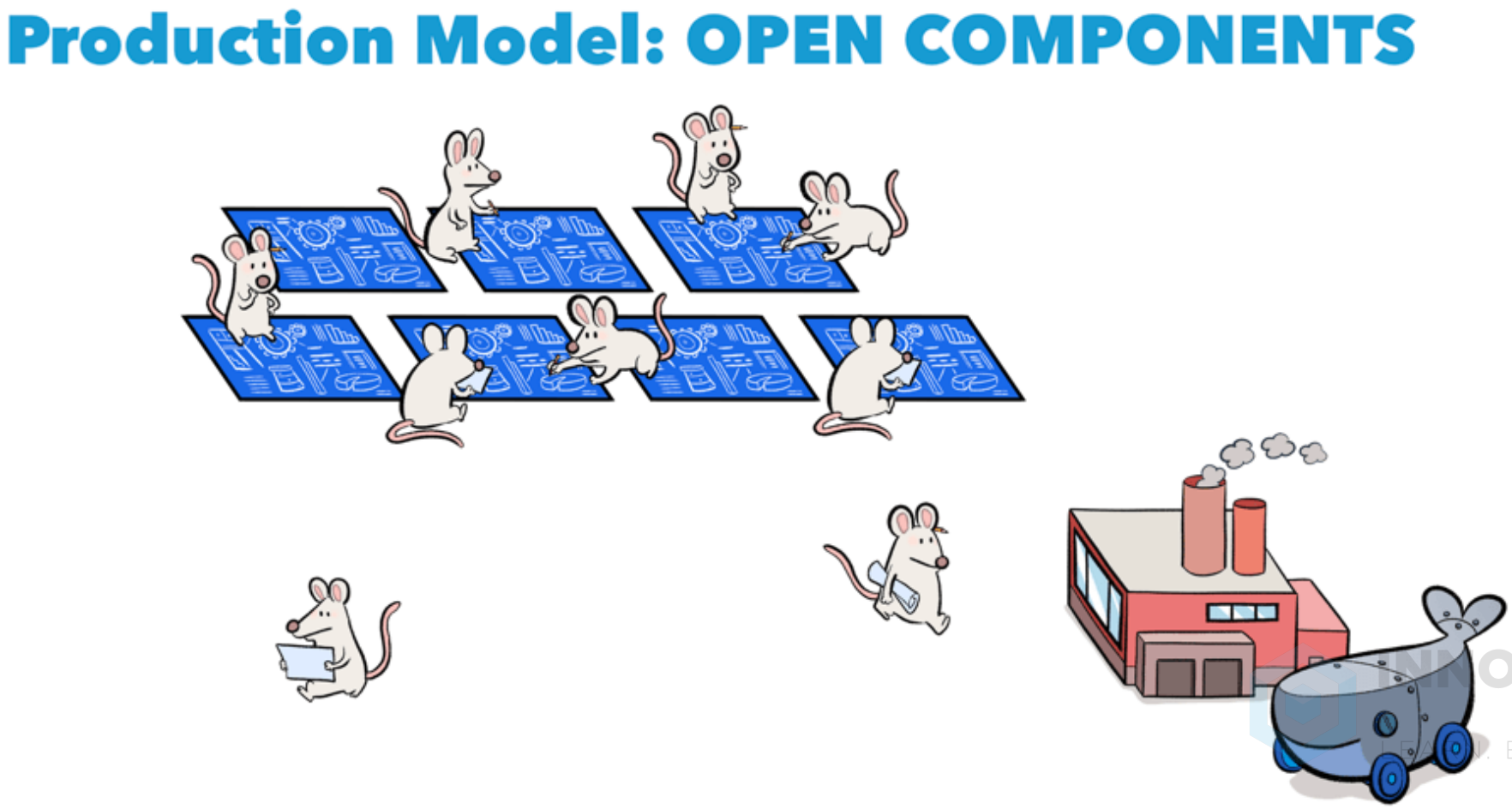
What is Docker?

Production Model: open-source!



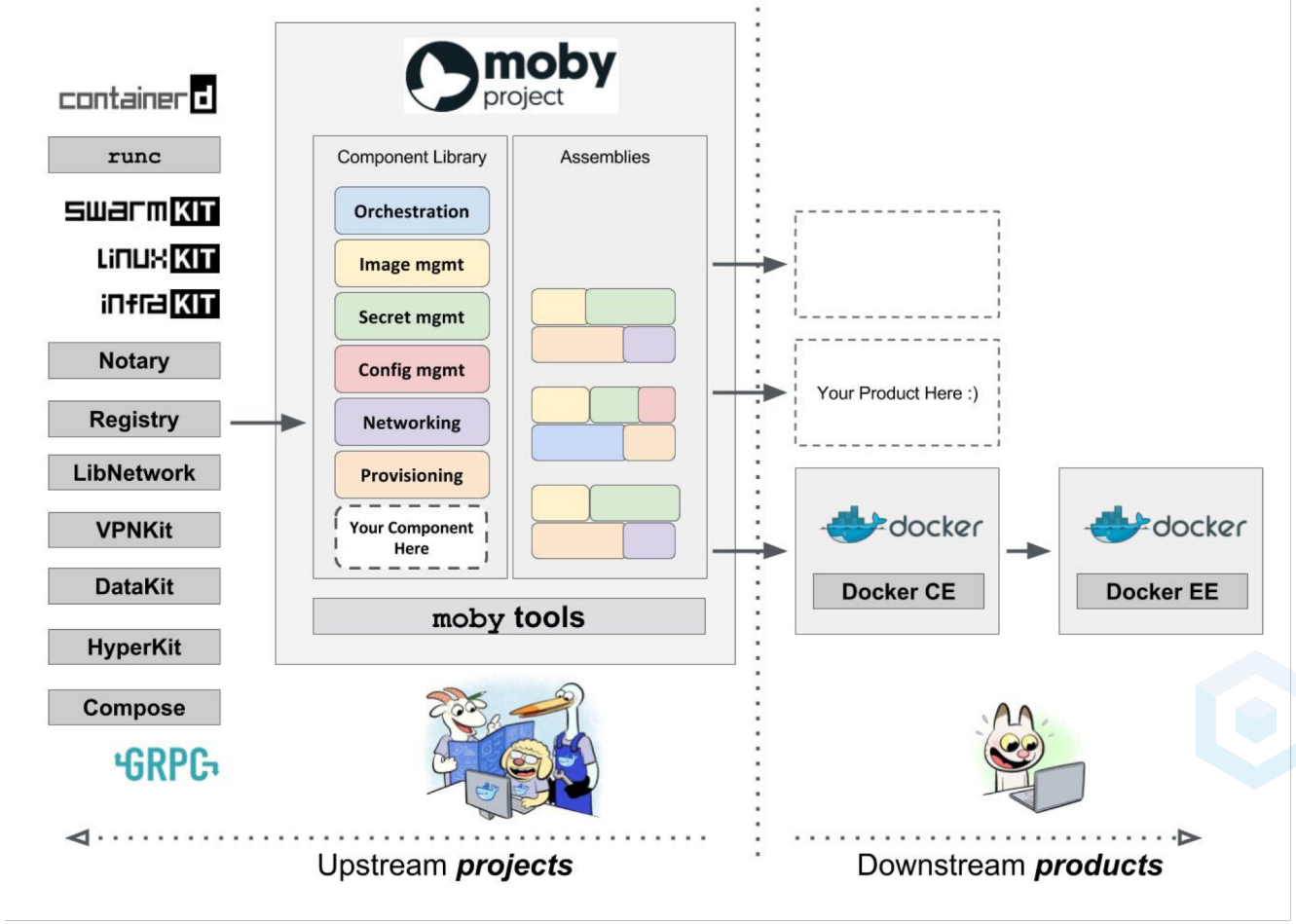
https://mobyproject.org

What is Docker?



https://mobyproject.org

What is Docker?

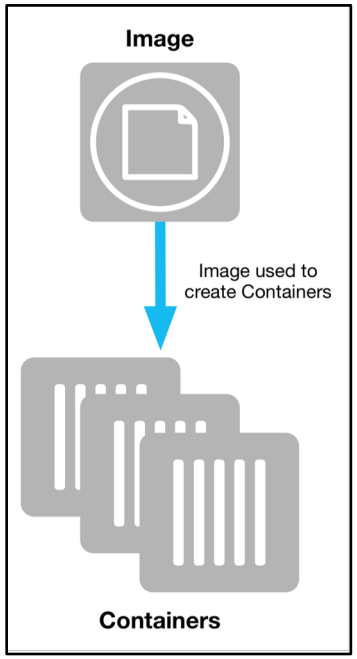


What is Docker?

Docker allows you to package an application with all of its dependencies into a standardized unit for software development.

Terminology

Image



Read only template used to create containers
Built by you or other Docker users
Stored in Docker Hub, Docker Trusted Registry or your own Registry

Terminology

Image

Read only template used to create containers
Built by you or other Docker users
Stored in Docker Hub, Docker Trusted Registry or your own Registry

Container

- Isolated application platform
- Contains everything needed to run your application
- Based on one or more images

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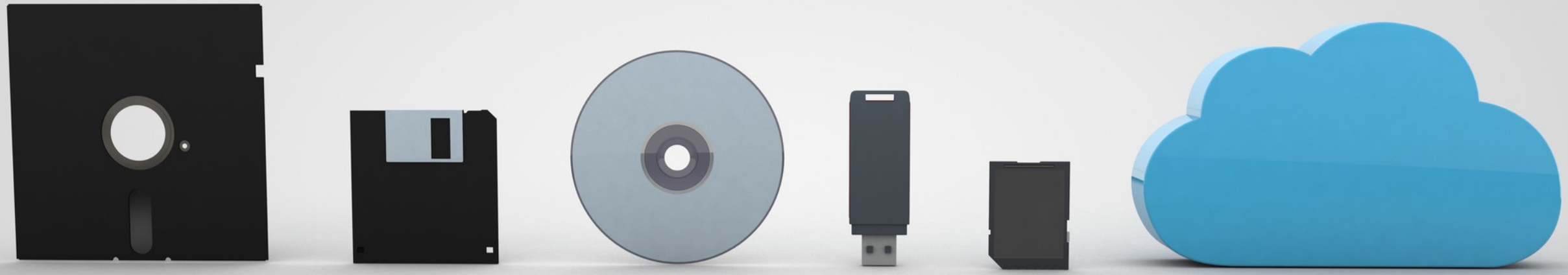
Data Center Evolution



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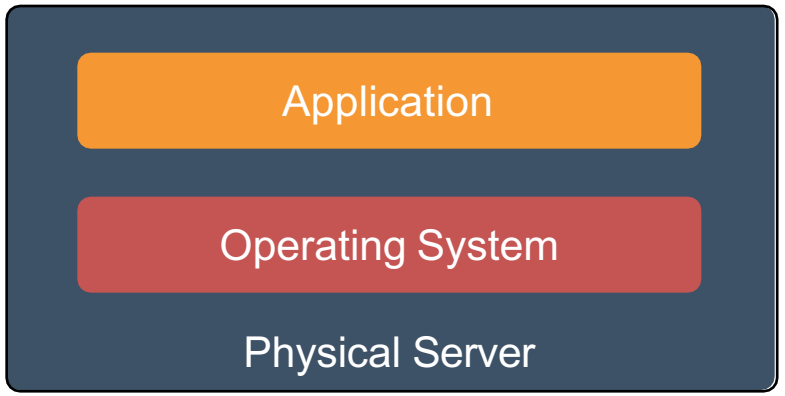
Monolithic

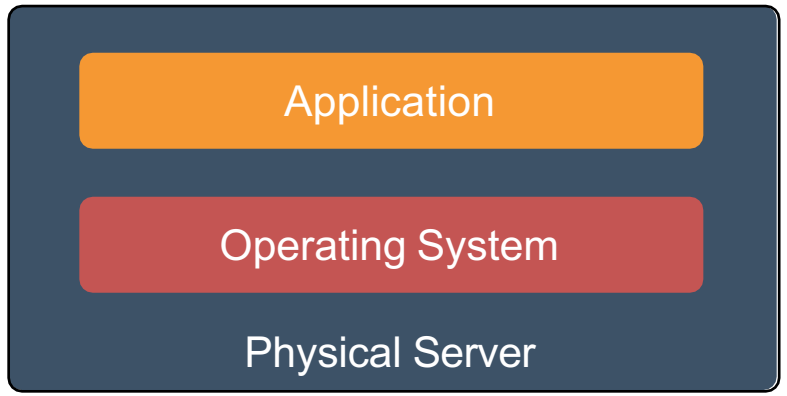
Monolithic Server Architecture



One physical server, one application

Monolithic Server Architecture

Monolithic → Virtualization



One physical server, one application

Problems

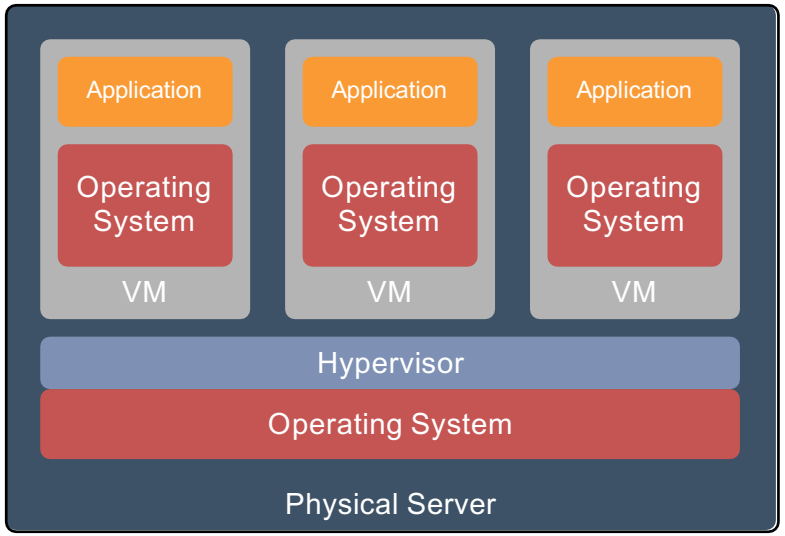
- Slow deployment times
- Cost
- Wasted resources
- Difficult to scale
- Difficult to migrate

Virtualized

docker

Virtualized Infrastructure

Monolithic → Virtualization



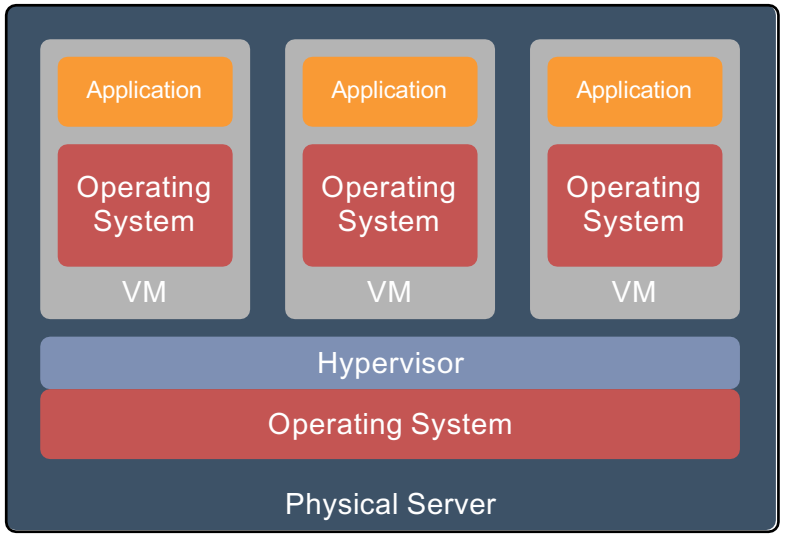
One physical server, multiple applications

Discussion

What are some of the advantages and disadvantages of Virtual Machines?

Virtualized Infrastructure - Advantages

Monolithic → Virtualization



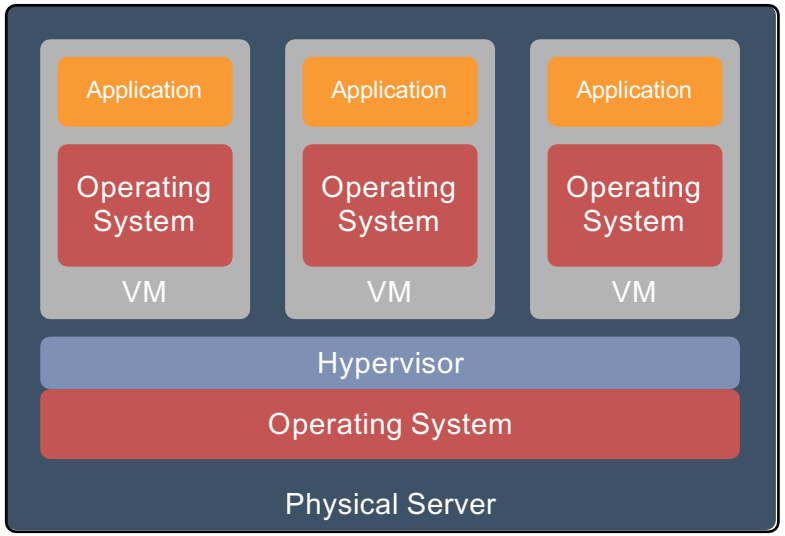
One physical server, multiple applications

Advantages

- Better resource pooling
- Easier to Scale
- Enables Cloud/IaaS
  - Rapid elasticity
  - Pay as you go model

Virtualized Infrastructure - Limitations

Monolithic → **Virtualization** → Containers

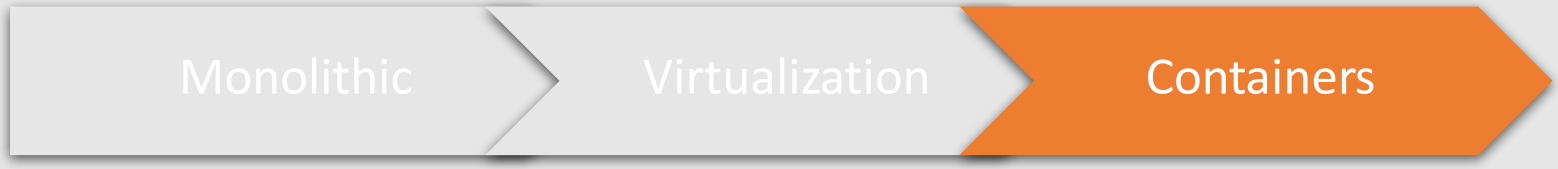


One physical server, multiple applications

Limitations

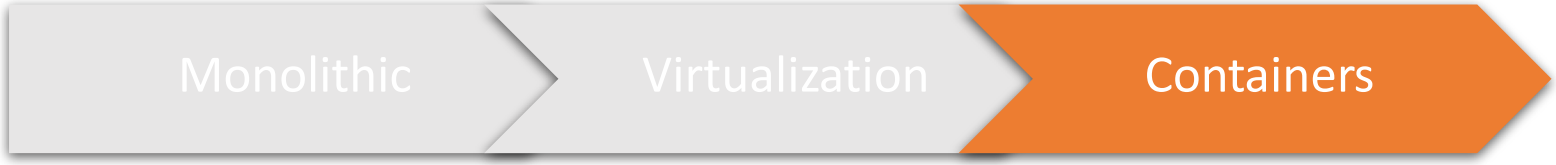
- Each VM requires:
  - CPU allocation
  - Storage
  - RAM
  - Guest Operating System
- More VMs, more wasted resources
- Application portability not guaranteed

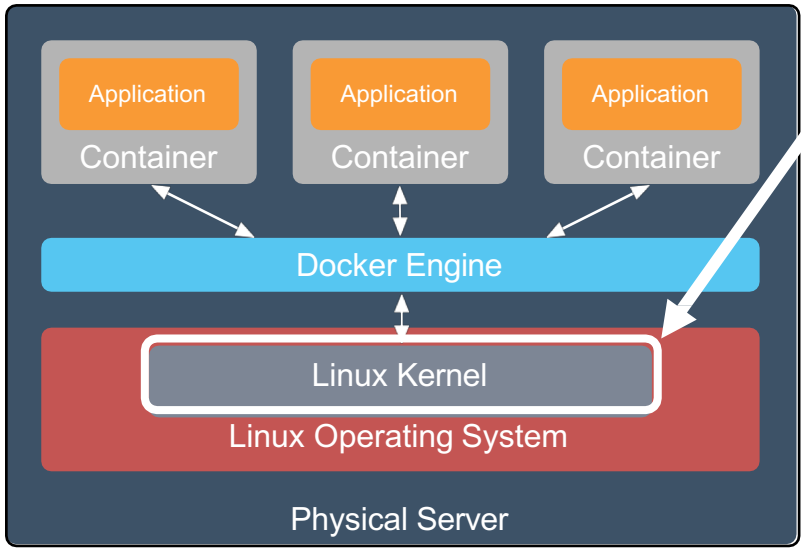
Containers



docker

Containers

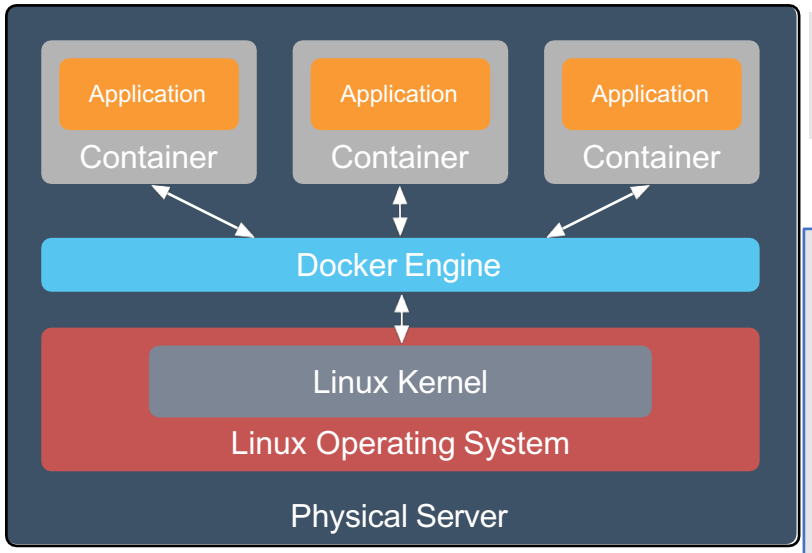




Shared kernel on the host to run multiple guest applications

Containers - Advantages

Monolithic → Virtualization → **Containers**



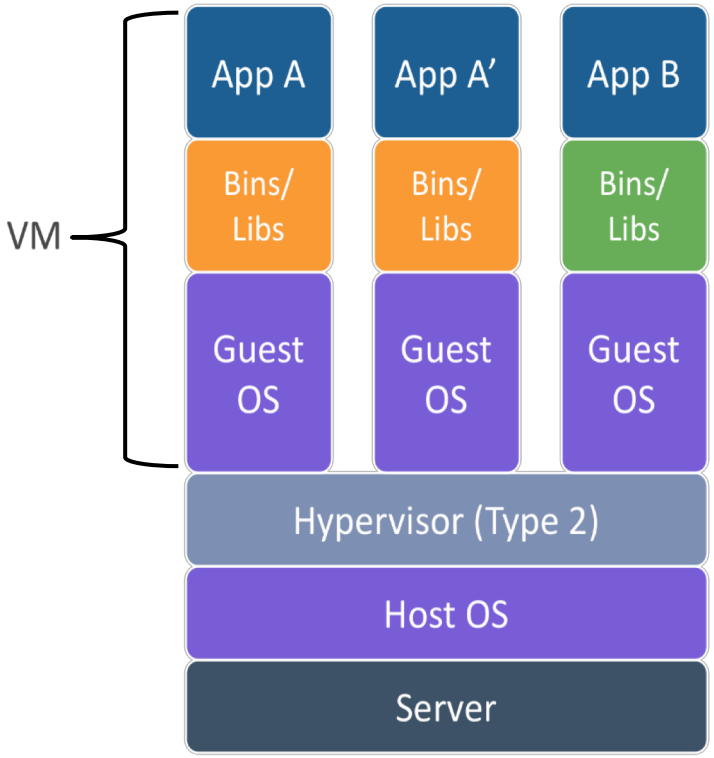
Shared kernel on the host to run multiple guest applications

Advantages over VMs

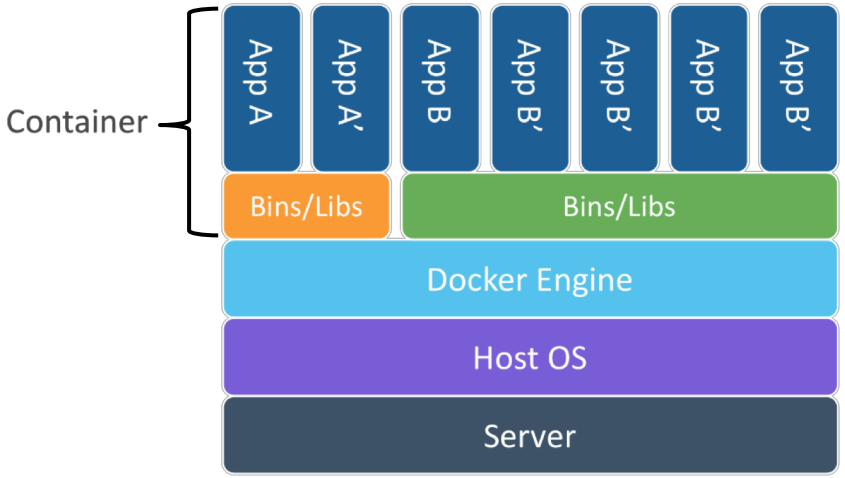
- Containers are more lightweight
- No need to install a guest Operating System
- Less CPU, RAM, storage overhead
- More containers per machine
- Greater portability

Virtual Machines vs. Containers

VMs



Containers



- Shared Operating System
  - OS Kernel abstraction
- All application dependencies contained w/in the container

Container – Concept of Operations

Container based virtualization

Uses the kernel on the host operating system to run multiple guest instances

- Each guest instance is a container
- Each container has its own
  - Root filesystem
  - Processes
  - Memory
  - Devices
  - Network Ports

Container based virtualization

High Level – Lightweight VM

- Own:
  - Process Space
  - Network Interface

- Can:
  - Run cmds as root
  - Have its own /sbin/init (different from host)

Container based virtualization

High Level – Lightweight VM

- Own:
  - Process Space
  - Network Interface
- Can:
  - Run cmds as root
  - Have its own /sbin/init (different from host)

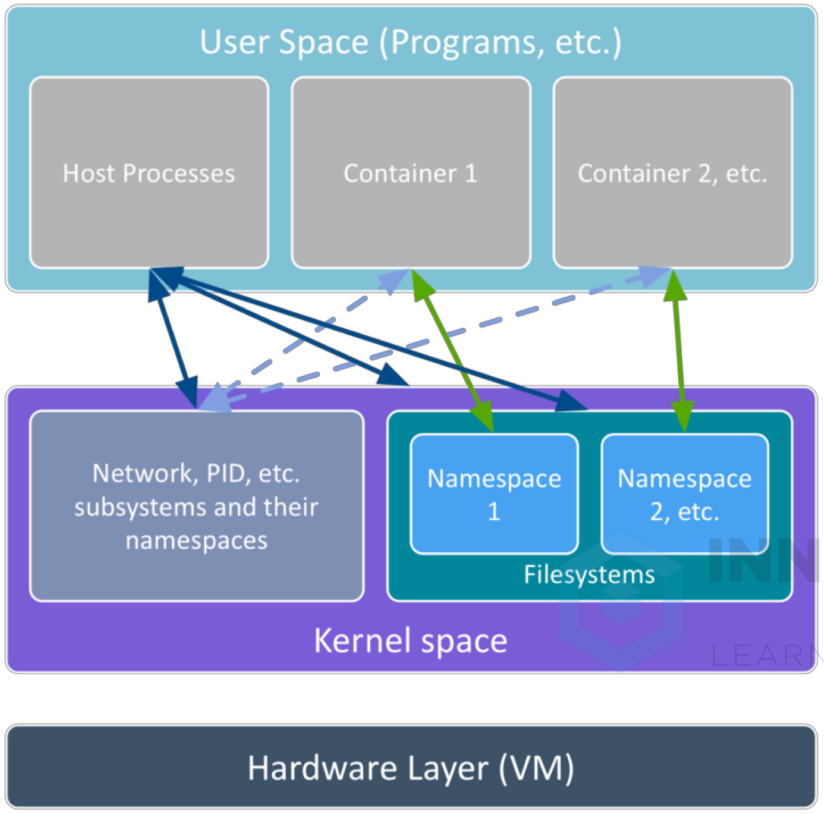
Low Level – chroot expanded

- Container = isolated processes
- Share kernel with host
- No device emulation

Isolation with Namespaces

Namespaces - Limits what a container can see (and therefore use)

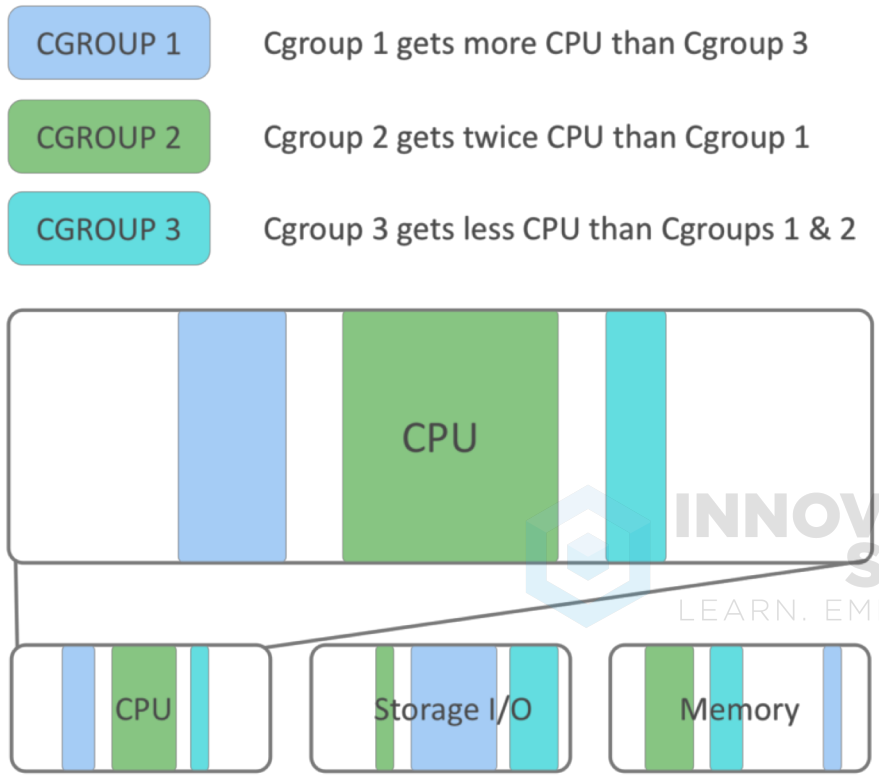
- Namespace wrap a global system resource in an abstraction layer
- Processes running in that namespace think they have their own, isolated resource
- Isolation includes:
  - Network stack
  - Process space
  - Filesystem mount points
  - etc.



Isolation with Control group (Cgroups)

Cgroups - Limits what a container can use

- Resource metering and limiting
  - CPU
  - MEM
  - Block/IO
  - Network
- Device node (/dev/*) access control



Container Use Cases

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DevOps

Developers

Focus on applications inside the container

Operations

Focus on orchestrating and maintaining containers in production

Container Use Cases

Development

- Allows the ability to define the entire project configuration and tear-down/recreate it easily
- Supports multiple versions of application simultaneously

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Test Environments

- Same container that developers run is the container that runs in test lab and production – includes all dependencies
- Well formed API allows for automated building and testing of new containers

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Container Use Cases

Development

- Allows the ability to define the entire project configuration and tear-down/recreate it easily
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Micro-Services

- Design applications as suites of services, each written in the best language for the task
- Better resource allocation
- One container per microservice vs. one VM per microservice
- Can define all interdependencies of services with templates

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The Docker Platform Components

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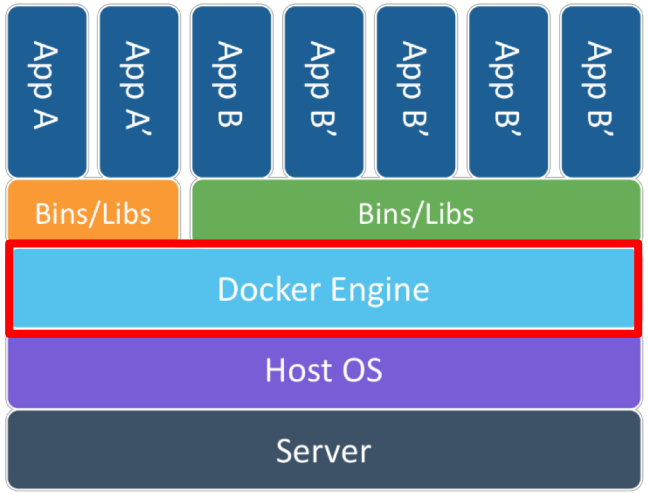
Docker Engine

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

*Lightweight runtime program to **build, ship, and run Docker containers***

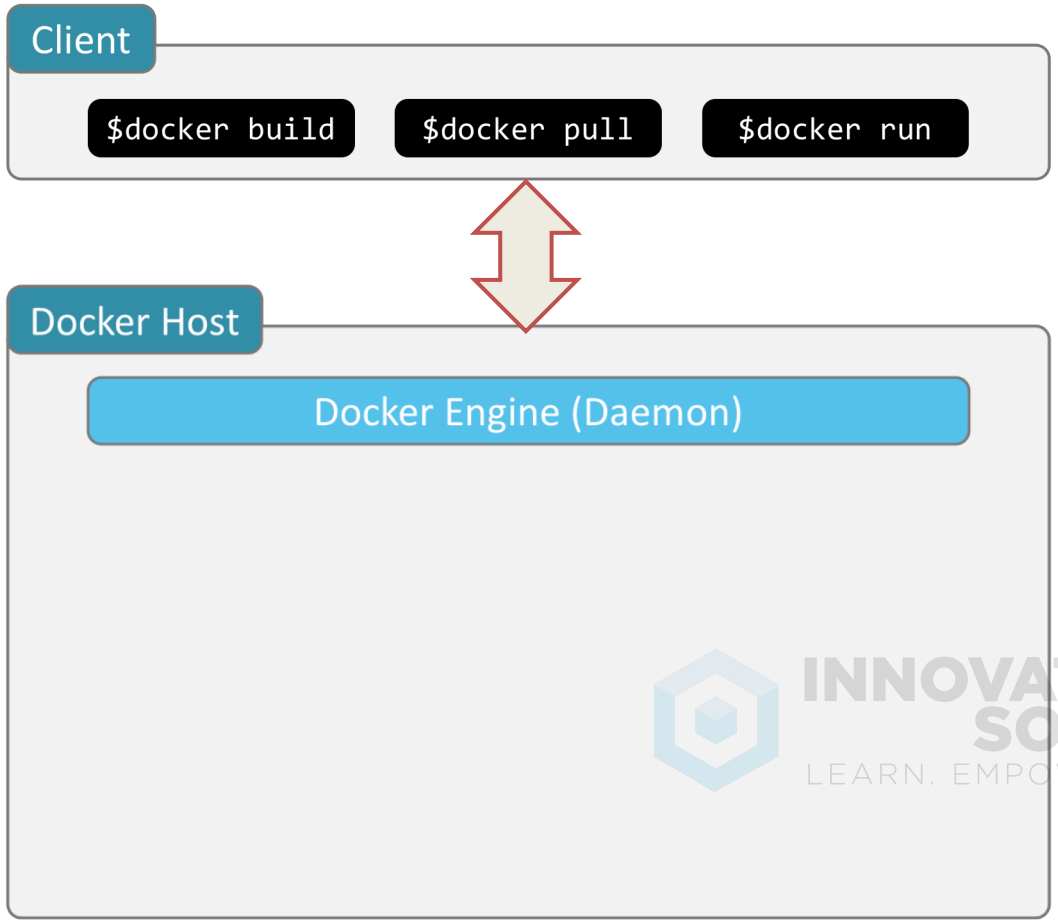
- Also known as **Docker Daemon**
- Uses Linux Kernel namespaces and control groups
  - **Linux Kernel (>= 3.10)**
- Namespaces provide an isolated workspace



Docker Engine

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

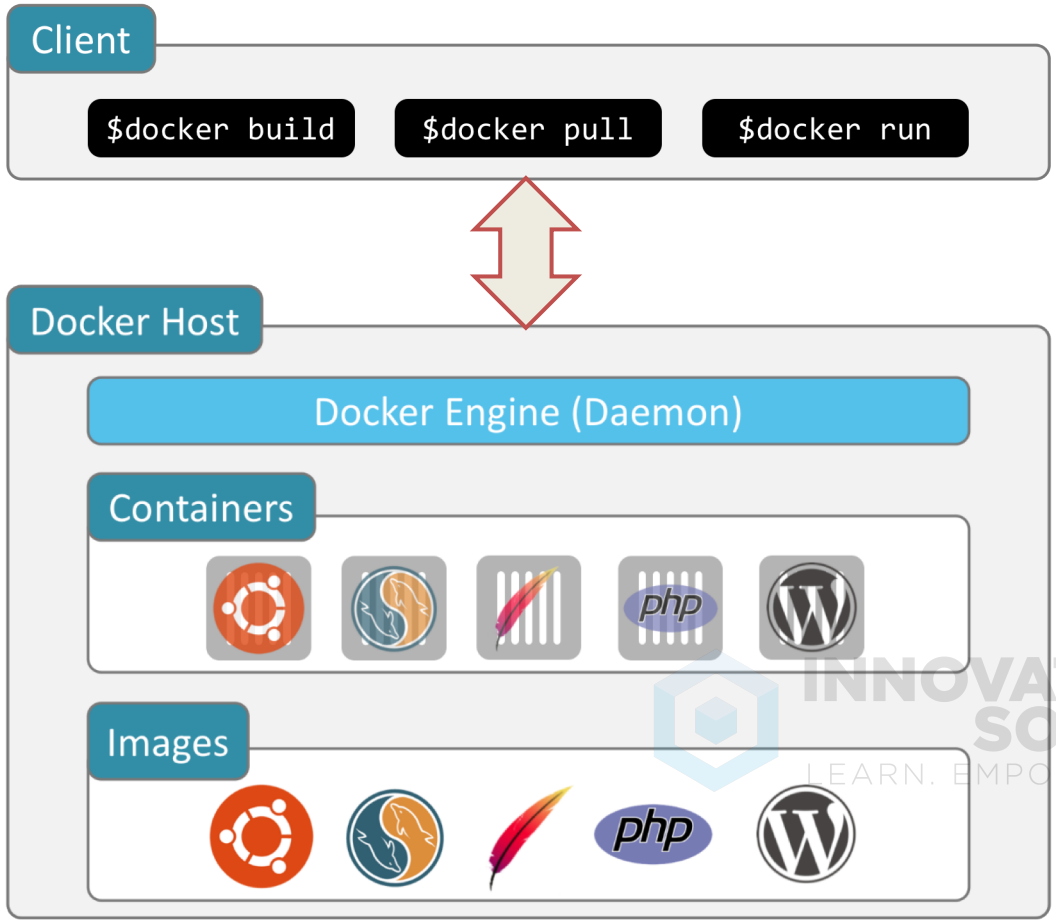
- The Docker Client is the `docker` binary
  - Primary interface to the Docker Host
- Accepts commands and communicates with the Docker Engine (Daemon)



Docker Engine

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

- Lives on a Docker host
- Creates and manages containers on the host



Docker Registry

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

Image Storage & Retrieval System

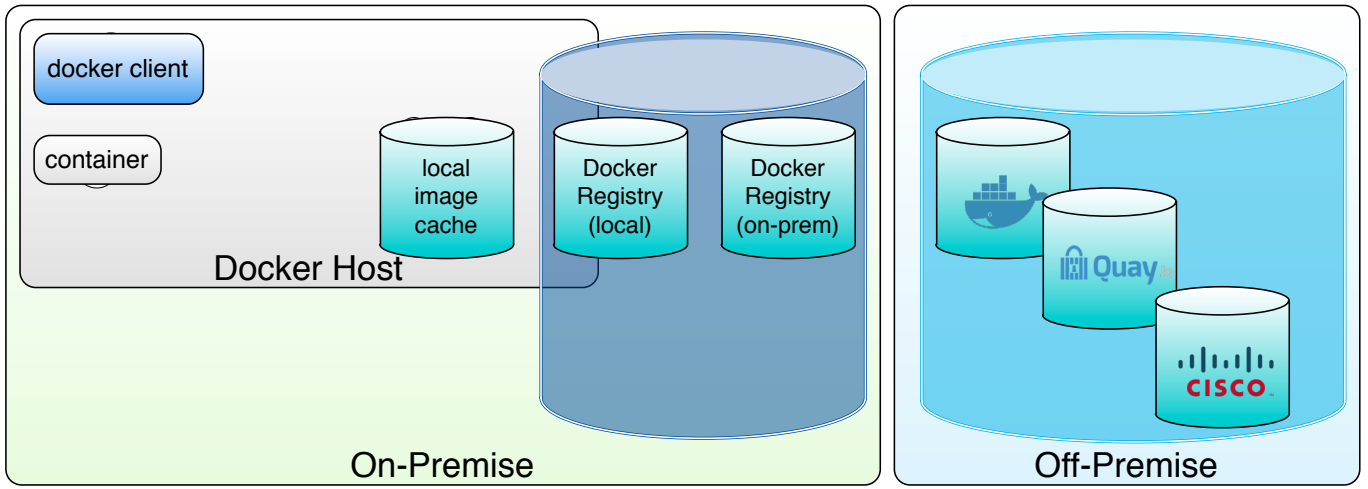
- Docker Engine **Pushes** Images to a Registry
- Version Control
- Docker Engine **Pulls** Images to Run

Docker Registry

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

Types of Docker Registries

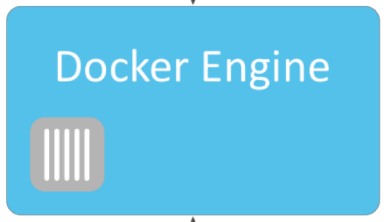
- Local Docker Registry
  (On Docker Host)
- Remote Docker Registry
  (On-Premise/Off-Premise)
- Docker Hub
  (Off-Premise)



Docker Engine and Registry

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

Manage & Monitor



Push/Pull

Docker Engine:

- **Pushes** Images to a Registry
- **Pulls** Images to Run

Docker Registry

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm

The registry and engine both present APIs

- All of Docker's functionality will utilize these APIs

- RESTFUL API
- Commands presented with Docker's CLI tools can also be used with curl and other tools

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Docker Compose

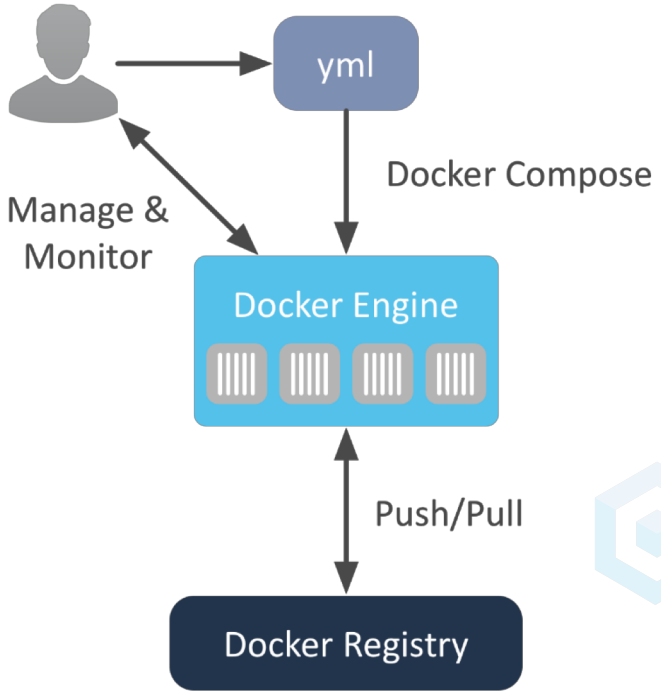
Docker Engine | *Docker Registry* | **Docker Compose** | Docker Swarm

Tool to create and manage multi-container applications

- Applications defined in a single file:

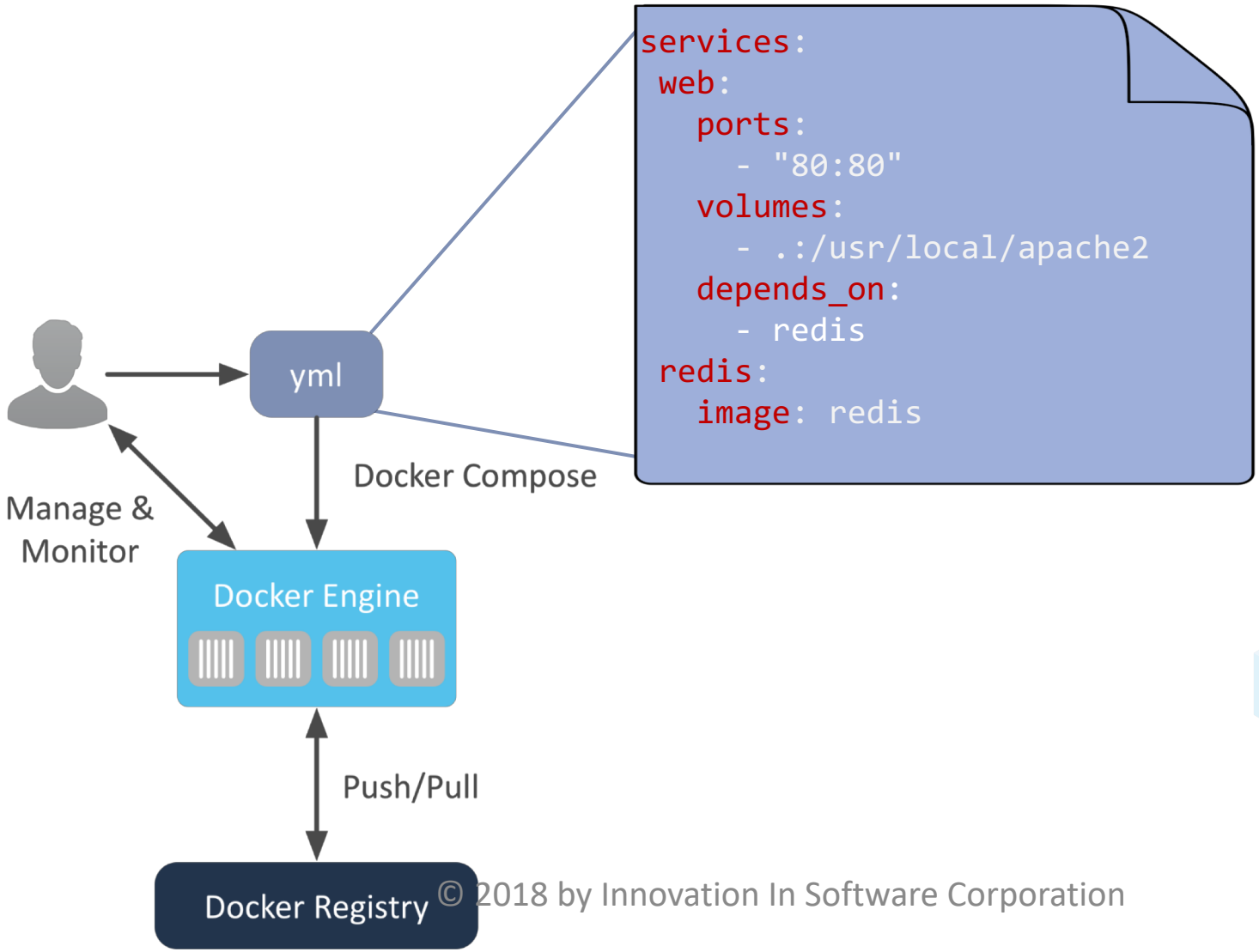
  docker-compose.yml

- Transforms applications into individual containers that are linked together
- Compose will start all containers in a single command



Docker Compose

Docker Engine | *Docker Registry* | **Docker Compose** | Docker Swarm

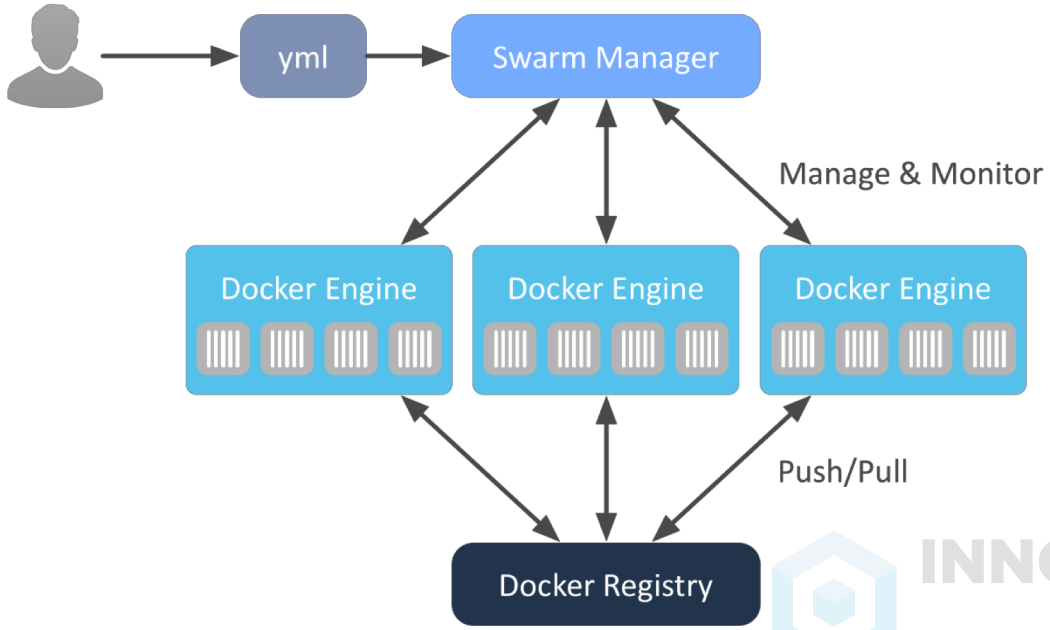


Docker Swarm

Docker Engine | *Docker Registry* | Docker Compose | **Docker Swarm**

Clusters Docker hosts and schedules containers

- Native Clustering for Docker
  - Turn a pool of Docker hosts into a single, virtual host
  - Serves the standard Docker API



Docker Engine Installation

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Docker Engine Installation

Docker for Linux

- Most Mature
- Fully Native
- Requires kernel 3.10 or later

http://www.docker.com/products/overview#/install_the_platform

Docker Engine Installation

Docker for Linux

- Most Mature
- Fully Native
- Requires kernel 3.10 or later

Docker for Mac

- Virtual Linux Using hyperkit
- Intended for desktop use

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Docker Engine Installation

Docker for Linux	*Docker for Mac*	*Docker for Win*
• Most Mature • Fully Native • Requires kernel 3.10 or later	• Virtual Linux Using hyperkit • Intended for desktop use	• Virtual Linux Using Hyper-V • Intended for desktop use

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Docker Engine Installation

Docker for Linux	*Docker for Mac*	*Docker for Win*
• Most Mature • Fully Native • Requires kernel 3.10 or later	• Virtual Linux Using hyperkit • Intended for desktop use	• Virtual Linux Using Hyper-V • Intended for desktop/sever use

Docker Toolbox

- Legacy Windows & Mac Installer
- Broader OS Version Support
- Requires VirtualBox

http://www.docker.com/products/overview#/install_the_platform

Docker Resources

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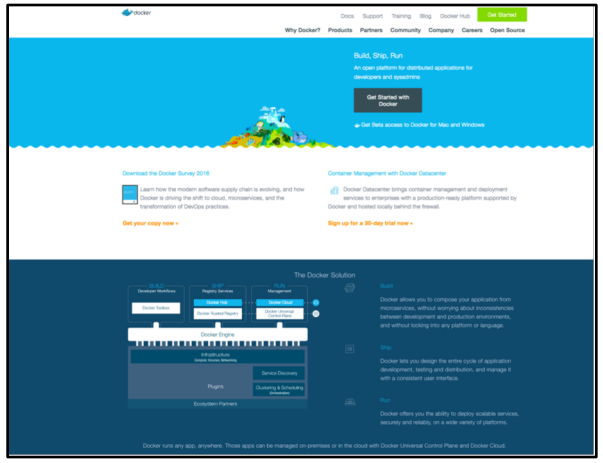
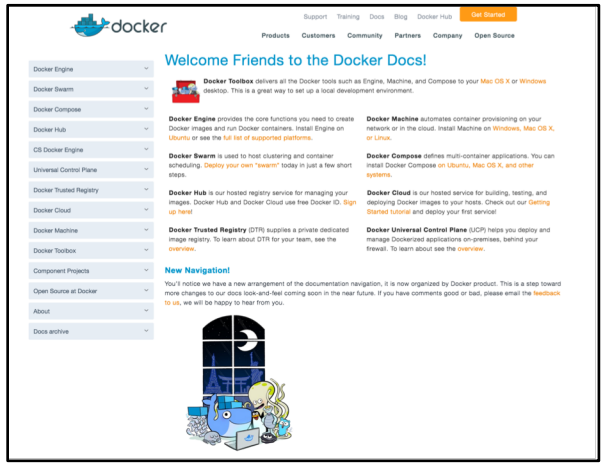
Docker Resources



Homepage

https://www.docker.com



Documentation

https://docs.docker.com

Freenode IRC

#docker

Stack Overflow

stackoverflow.com

Forums

forums.docker.com

Twitter

@docker

Slack

dockercommunity.slack.com

Summary, Review, & Q&A

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Summary

- Docker Overview
- Data Center Evolution
- Container – Concept of Operations
- Container Use Cases
- Docker Platform Components
- Docker Engine Installation
- Resources

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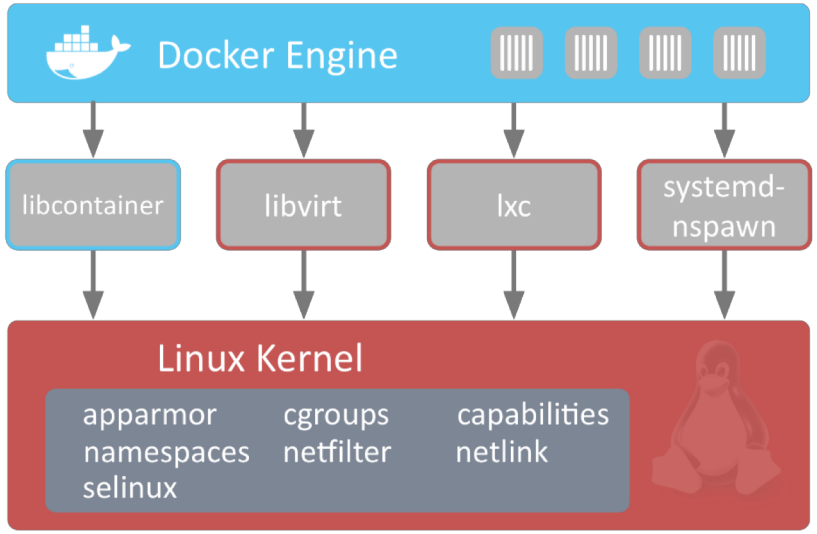
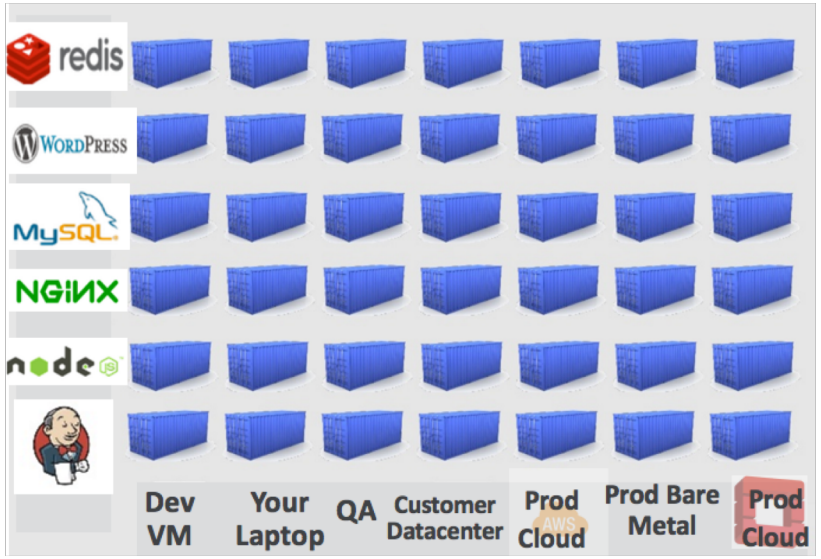
Containers Summary

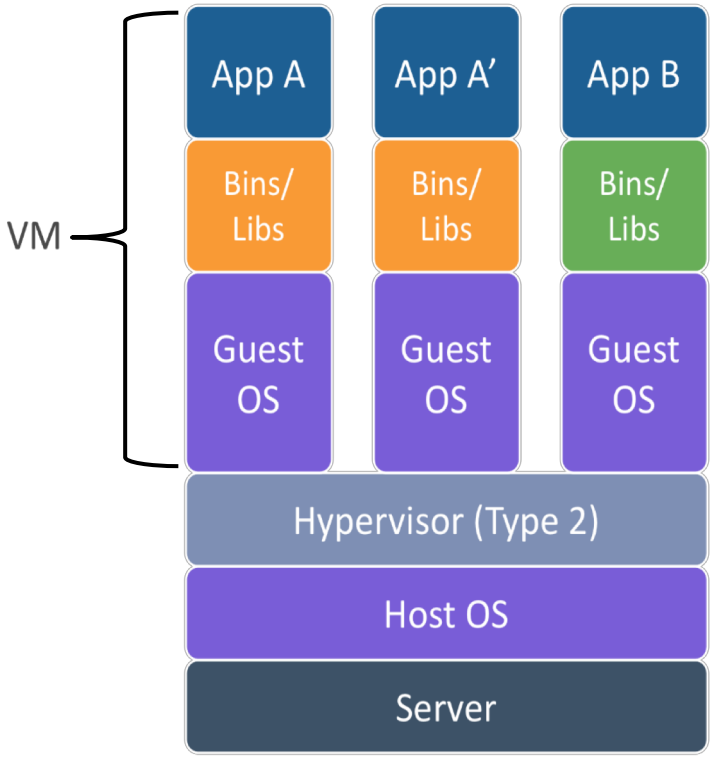




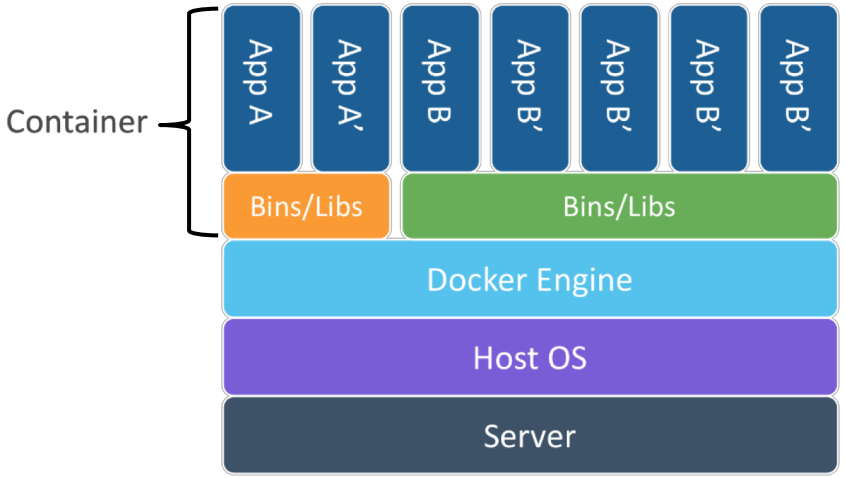
- Powered by Linux Kernel
- Lightweight
  - Make use of Host OS
  - Does not rely on hypervisor
- Isolation
  - All dependencies self contained
  - Applications as a collection of services
- Portability
- Interoperability

Virtual Machines vs. Containers

VMs



Containers



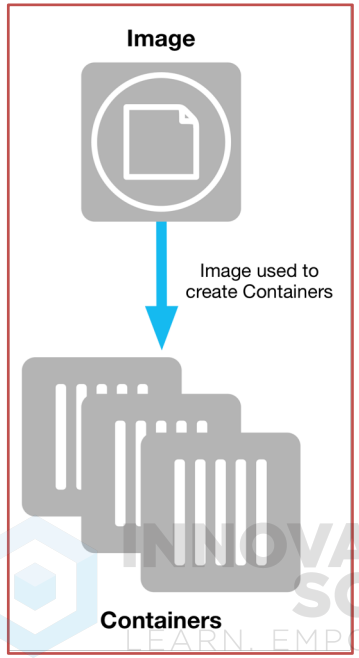
- Shared Operating System
  - OS Kernel abstraction
- All application dependencies contained w/in the container

Review

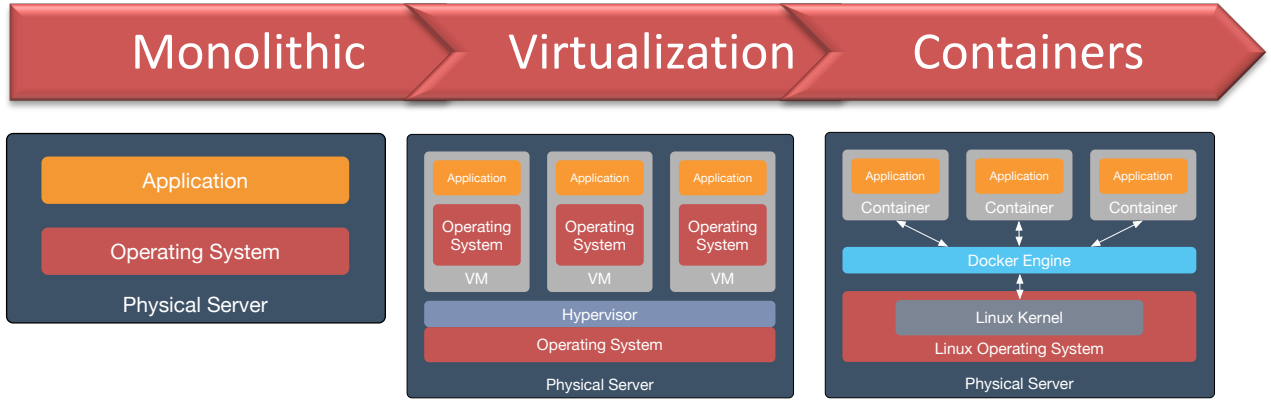
- Docker Overview
- Data Center Evolution
- Container – Concept of Operations
- Container Use Cases
- Docker Platform Components

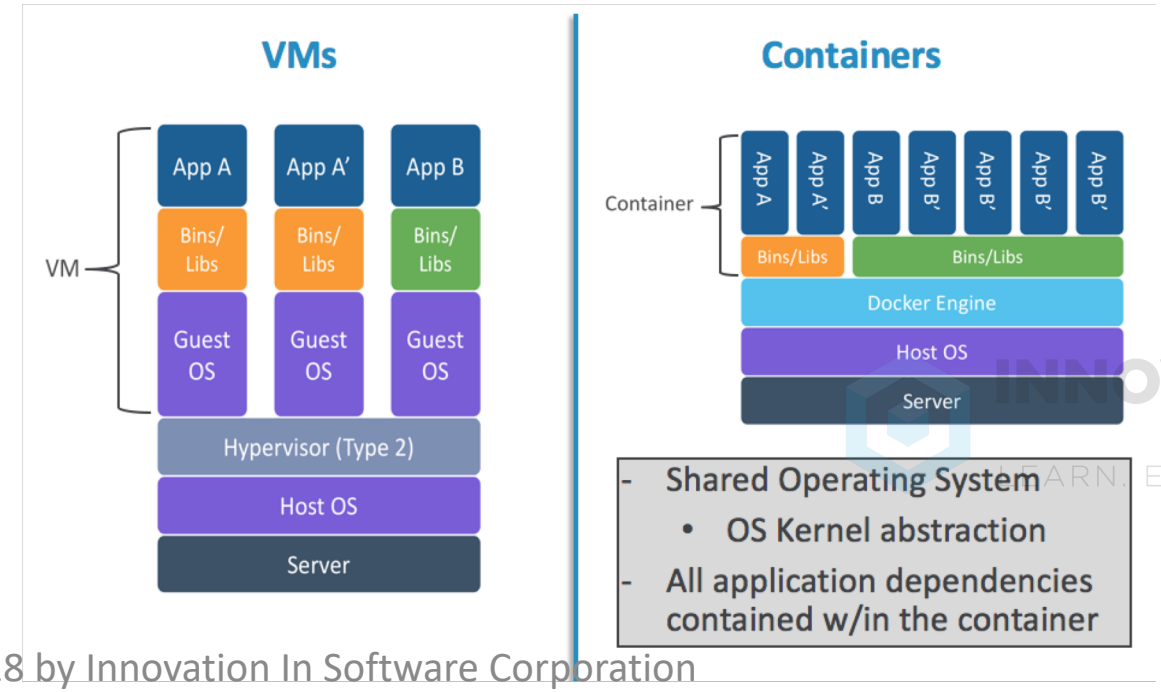
Docker allows you to package an application with all of its dependencies into a standardized unit for software development

Image	Read only template used to create containers Built by you or other Docker users Stored in Docker Hub, Docker Trusted Registry or your own Registry
Container	▪ Isolated application platform ▪ Contains everything needed to run your application ▪ Based on one or more images



- Docker Overview
- Data Center Evolution
- Container – Concept of Operations
- Container Use Cases
- Docker Platform Components





- Docker Overview
- Data Center Evolution
- Container – Concept of Operations
- Container Use Cases
- Docker Platform Components

Container Based Virtualization

Uses the kernel on the host operating system to run multiple guest instances

- Each guest instance is a container
- Each container has its own
  - Root filesystem
  - Processes
  - Memory
  - Devices
  - Network Ports

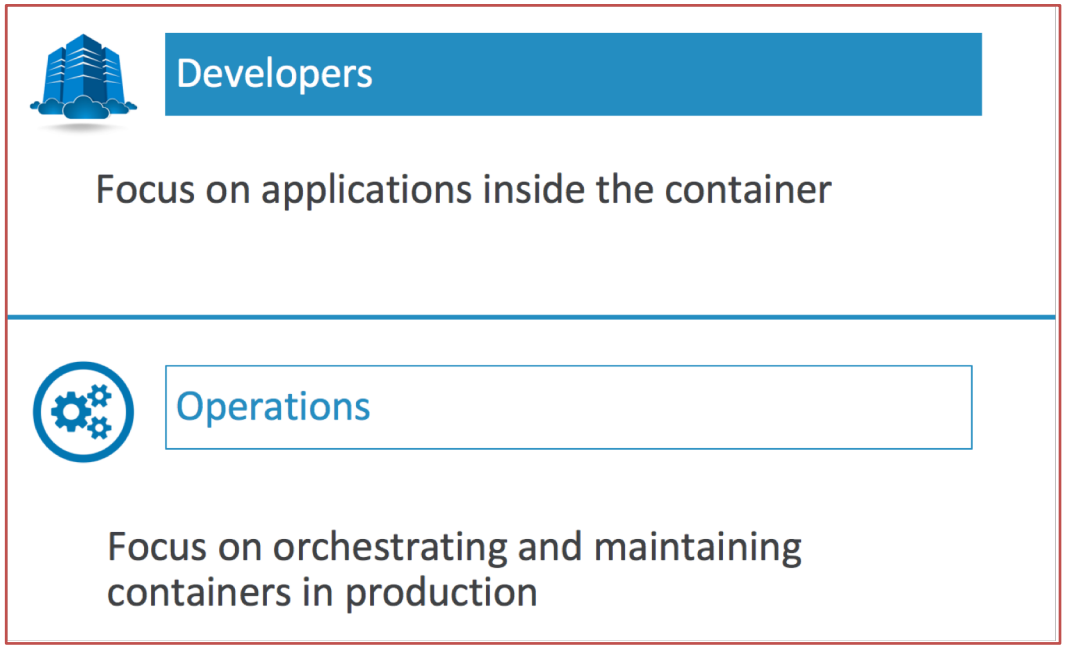
High Level – Lightweight VM

- Own:
  - Process Space
  - Network Interface
- Can:
  - Run cmds as root
  - Have its own /sbin/init (different from host)

Low Level – chroot expanded

- Container = isolated processes
- Share kernel with host
- No device emulation

- Docker Overview
- Data Center Evolution
- Container – Concept of Operations
- Container Use Cases
- Docker Platform Components

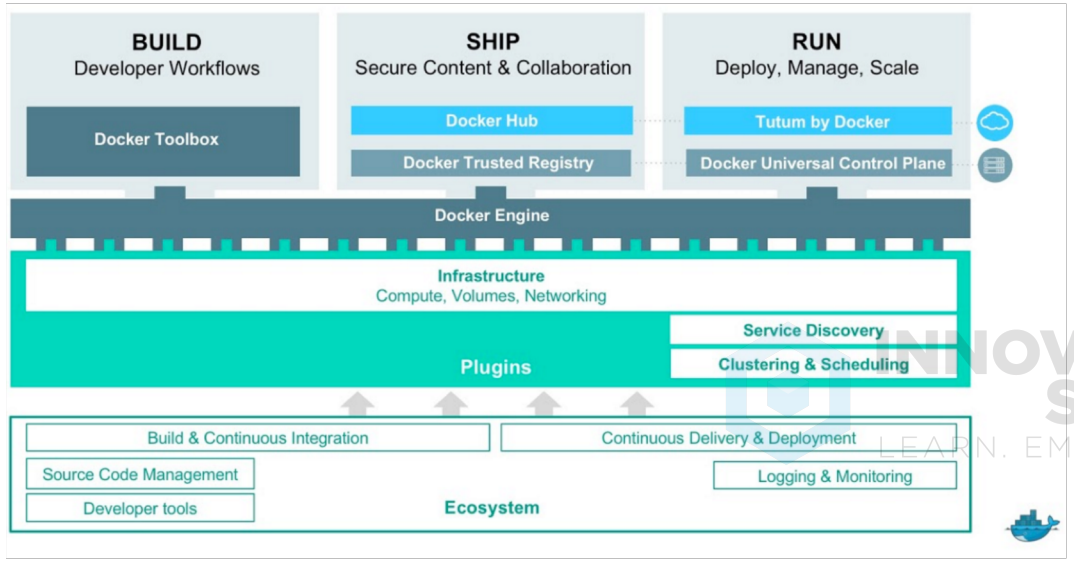


- Docker Overview
- Data Center Evolution
- Container – Concept of Operations

Container Use Cases

- Docker Platform Components

Docker Engine | *Docker Registry* | Docker Compose | Docker Swarm



Interact with Docker Engine

Agenda

- Log into Lab Environment
- Create a Docker Hub Account
- Search for Existing Docker Images
- Run a Container
- Monitor Docker with Native Tools
- Monitor Docker with 3rd Party Tools
- Start, Stop, and Remove Containers

Log into the Lab Environment

Lab Environment (Mac Users)

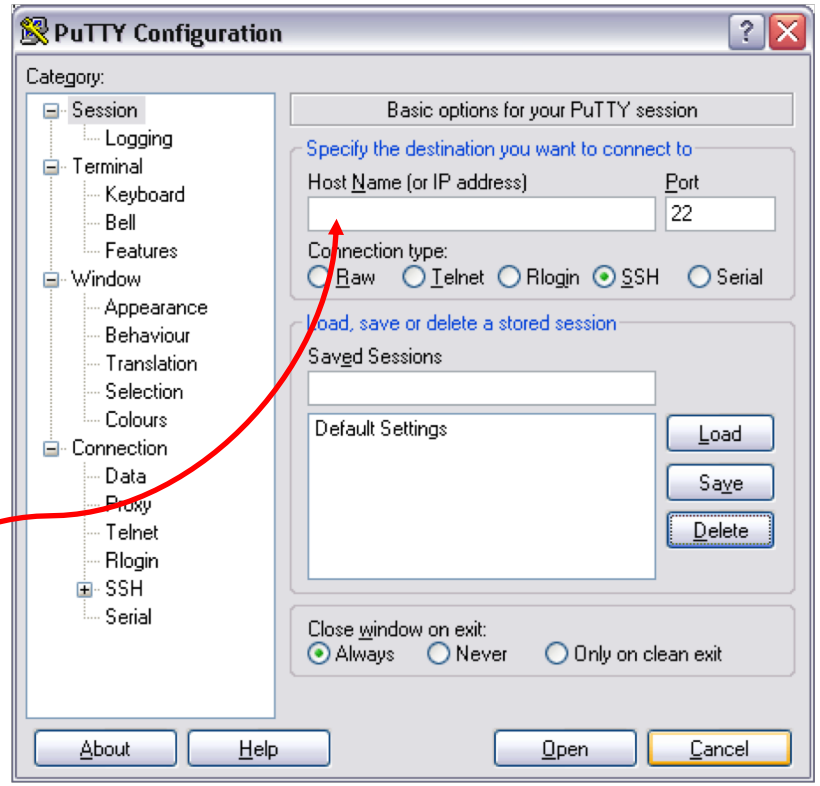
1. Set permissions on the SSH key:

```
$ chmod 400 docker.pem
```

2. Connect to the Docker host using the IP address provided in the lab guide

```
$ ssh –i “/path/to/docker.pem” ubuntu@IPADDRESS
```

Lab Environment (PC Users)

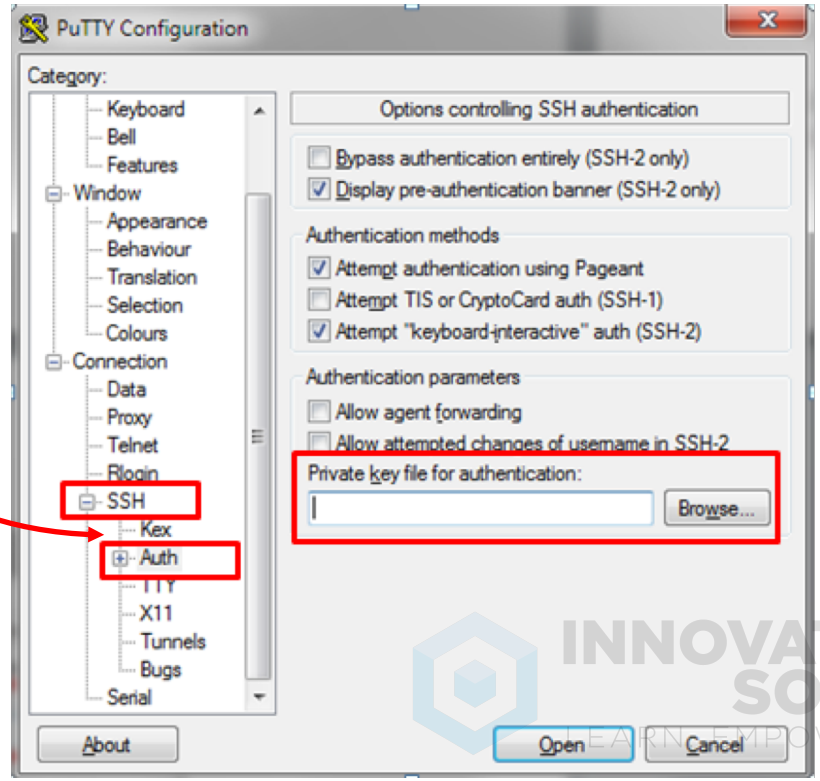


1. Enter the hostname as:

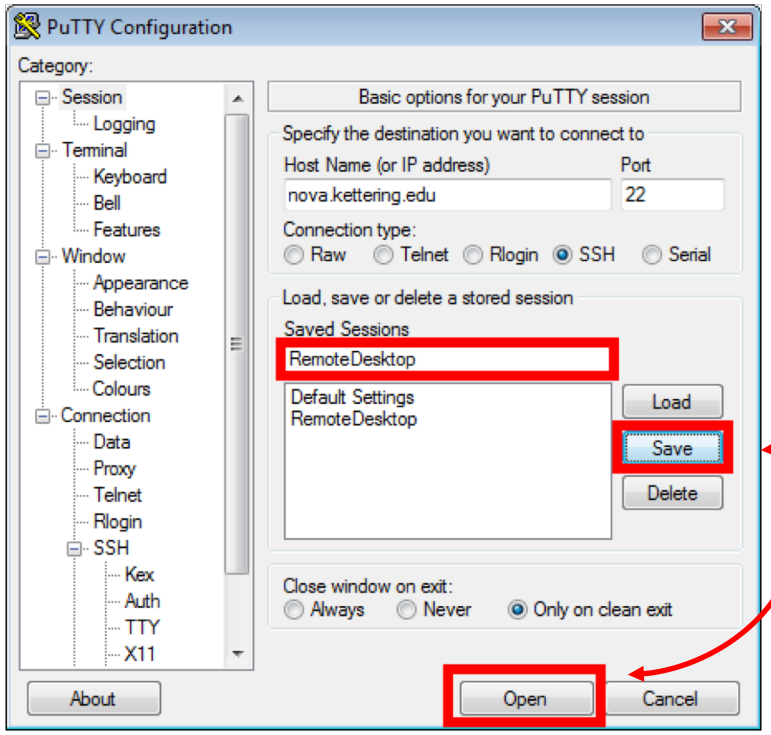
```
ubuntu@IPADDRESS
```

Lab Environment (PC Users)

1. Expand “Connection/SSH/Auth”
   - Specify the ”docker.ppk” file provided



Lab Environment (PC Users)



3. Return to “Session” (top of the tree)
   - Choose a name for the session
   - Click the save button
   - Select “Open” to connect to the lab

Create a Docker Hub Account

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Create a Docker Hub Account

1. Navigate to: **http://hub.docker.com**

2. Select an ID & Password
   - This is YOUR PERSONAL account

3. Confirm Your Email Address

Search for Existing Docker Images

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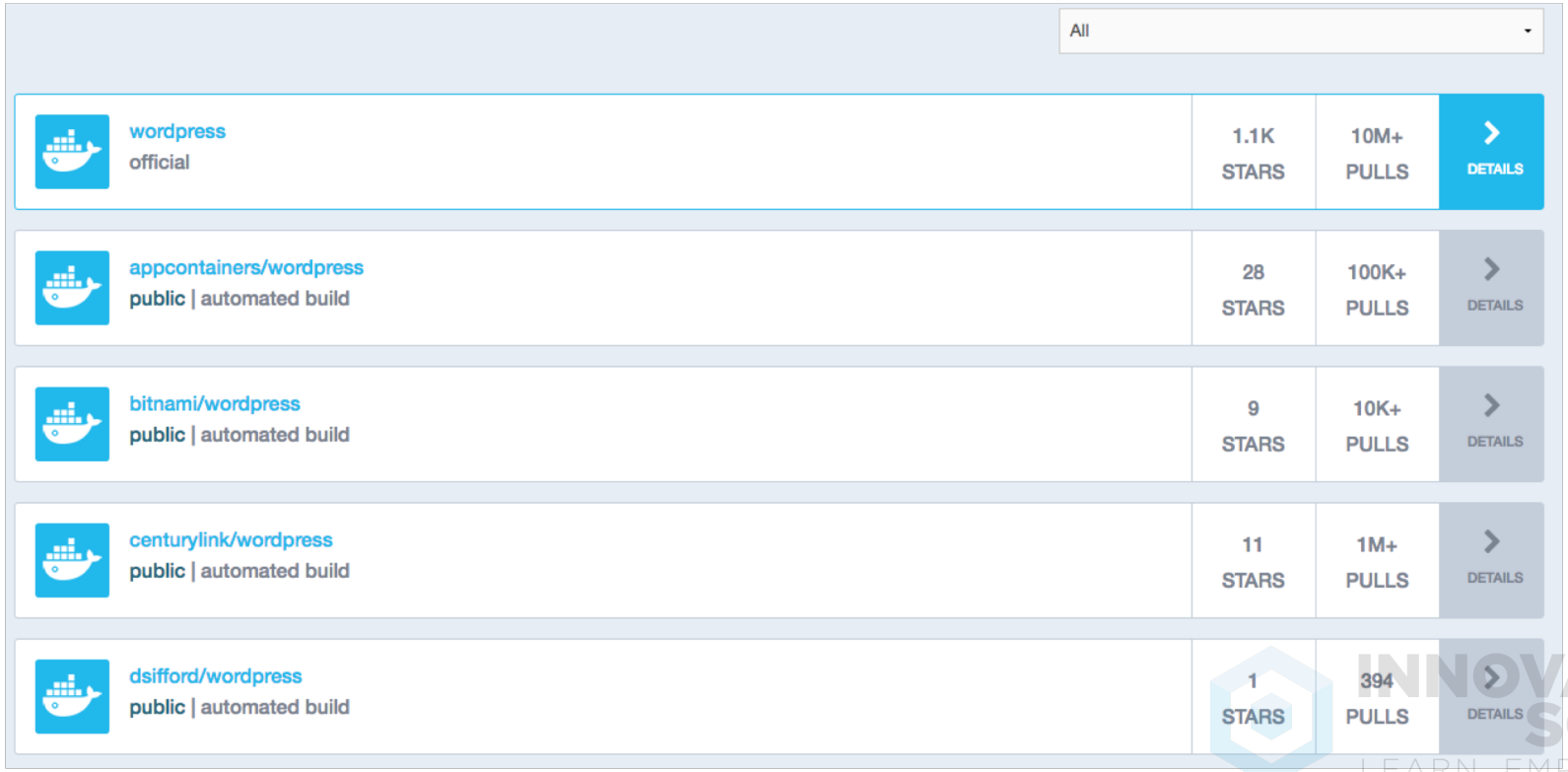
Search Docker Hub

Docker Hub

Docker Search

http://hub.docker.com

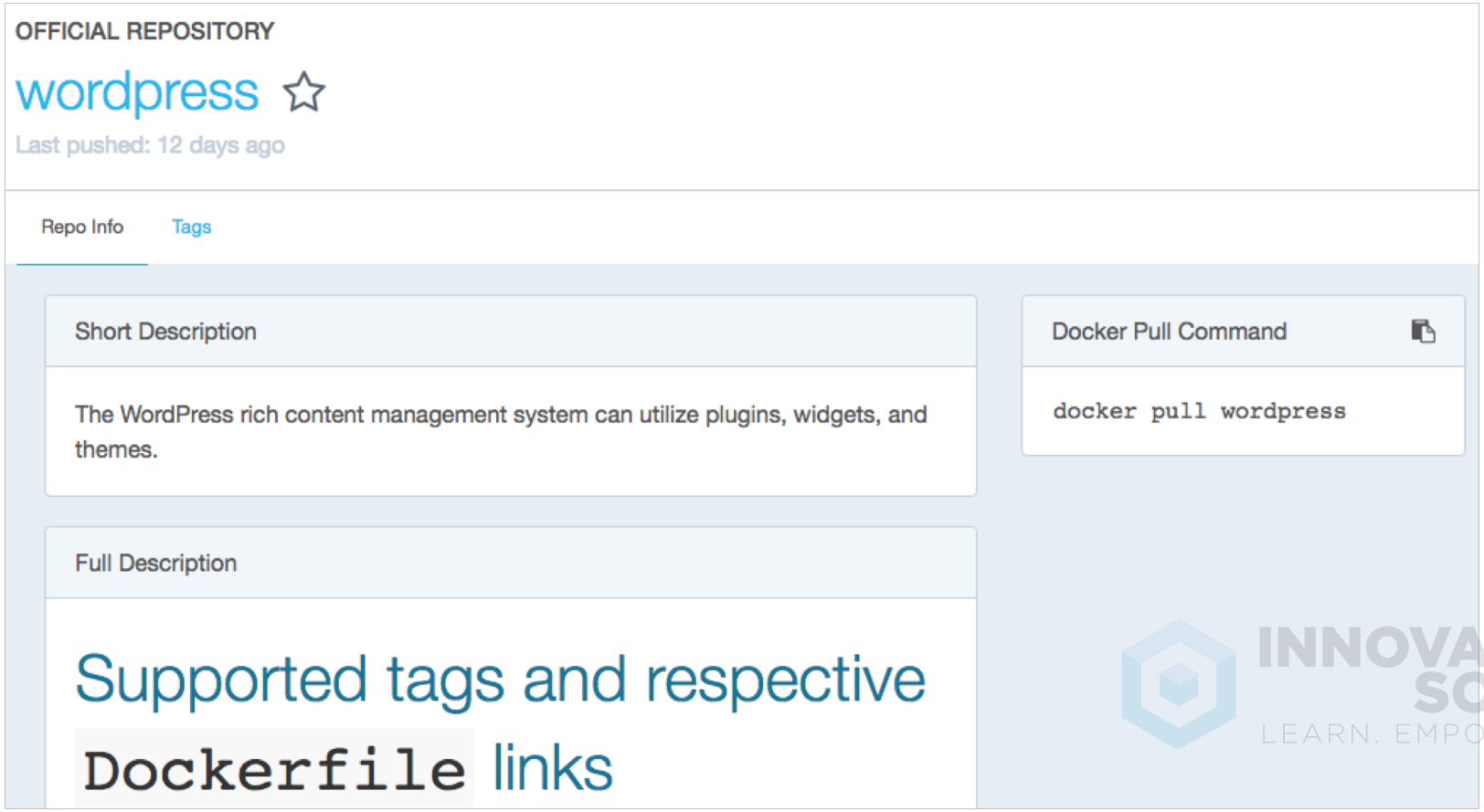


Search Docker Hub

Docker Hub

Docker Search

http://hub.docker.com



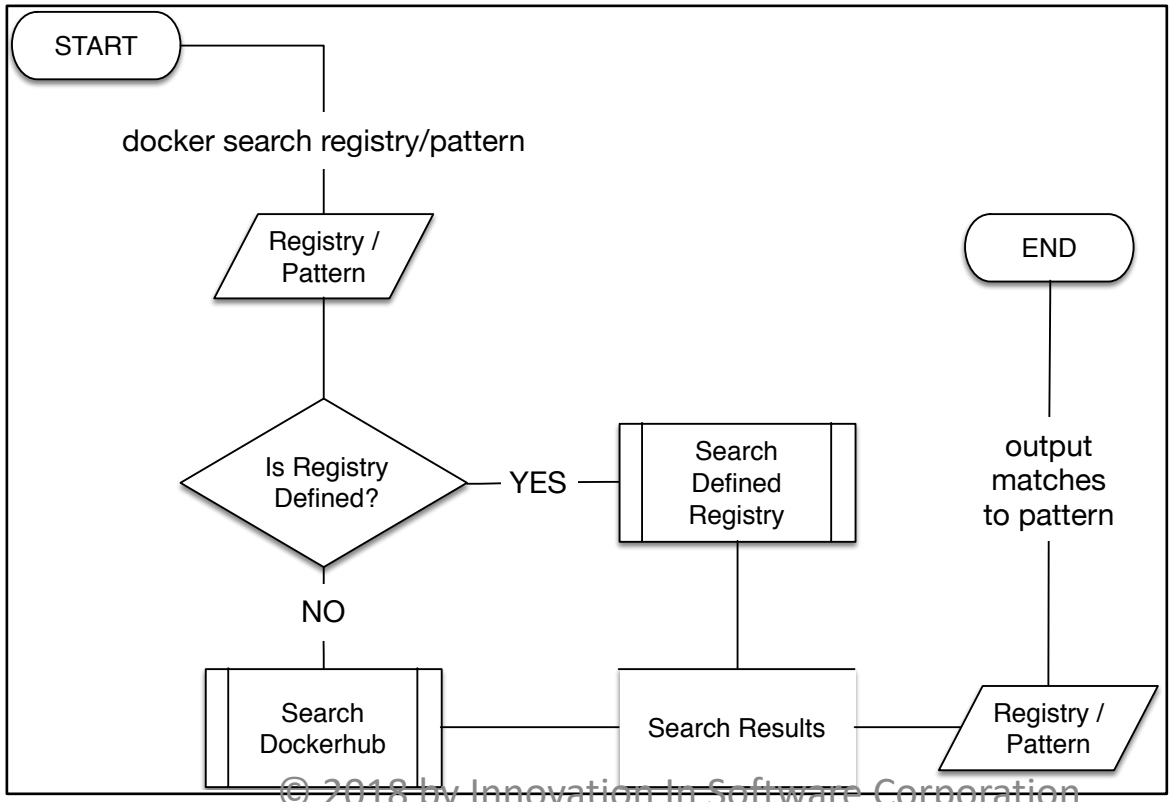
Docker Search (Command-Line)

Docker Hub

Docker Search

```
$ docker search repository/pattern
```

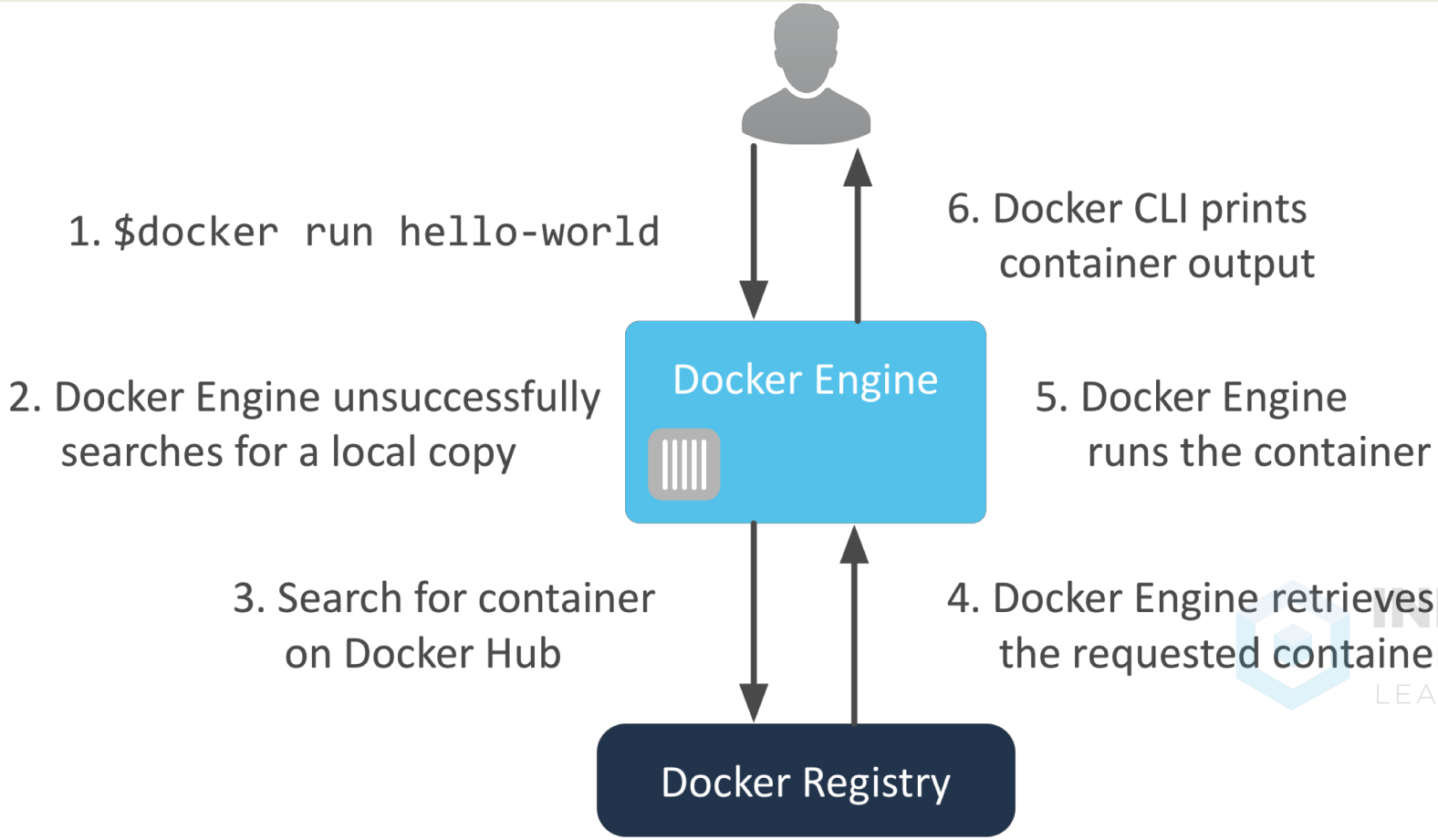
```
$ docker search wordpress
$ docker search quay.io/wordpress
$ docker pull <image_name>
```



Run a Container

Container Review

What does running a container require?



Run a Container

In your Lab Environment, execute the following command: `$ docker run hello-world`

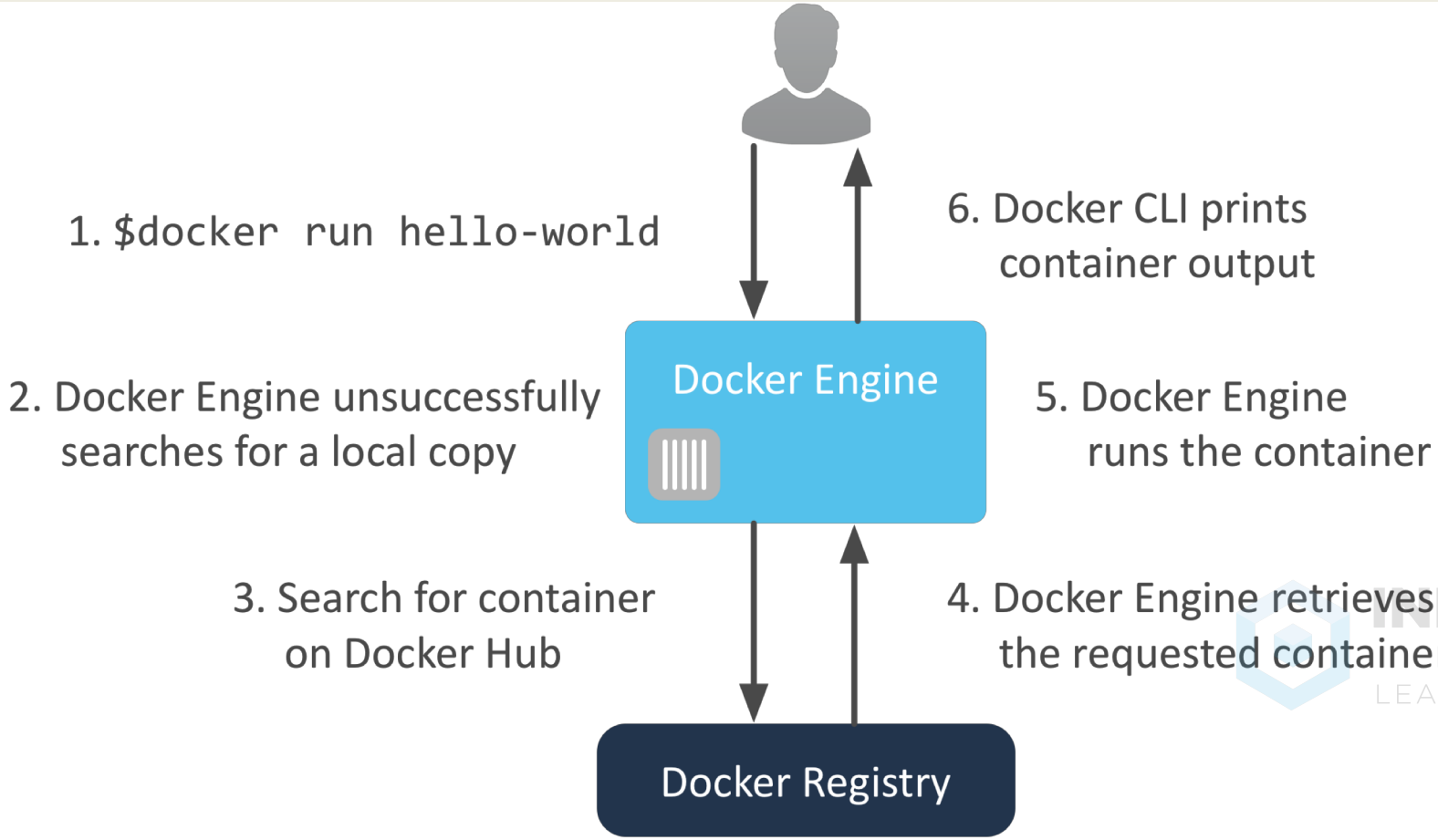
The container will run and display the following:

```
Unable to find image 'hello-world:latest' locally
latest: Pulling from library/hello-world
ad01a741289f: Pull complete
Digest:
sha256:af451bc5c4d6e87b64303f707f7bd98debd7fd3175a676c08f4bf46cb48813d4
Status: Downloaded newer image for hello-world:latest

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

Run a Container

What just happened?



Run a Container

Containers can accept additional arguments

In your Lab Environment, execute the following command:

```
$ docker run docker/whalesay \
          cowsay ’Go Docker’
```

The container will run and display the following:

```
Unable to find image 'docker/whalesay:latest' locally
latest: Pulling from docker/whalesay

e190868d63f8: Pull complete
909cd34c6fd7: Pull complete
0b9bfabab7c1: Pull complete
a3ed95caeb02: Pull complete
00bf65475aba: Pull complete
c57b6bcc83e3: Pull complete
8978f6879e2f: Pull complete
8eed3712d2cf: Pull complete
Digest:
sha256:178598e51a26abbc958b8a2e48825c90bc22e641de3d31e18aaf55f3258ba93b
Status: Downloaded newer image for docker/whalesay:latest
```

Run a Container

docker run also accepts additional arguments

In your Lab Environment, execute the following command:

```
$ docker run -d docker/whalesay \
          cowsay ’Detached’
```

The container will run and display the following:

```
3fa9d2d4f5ad3169d2e763f7ef48436c15ca4f8749a044e3017e6cb96cc60a2d
```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Run a Container

What just happened?

```
$ docker run -d docker/whalesay \
         cowsay ’Detached’
```

Run a Container

```
$ docker run -d docker/whalesay \
          cowsay 'Detached'
```

The *–d [detach]* flag instructs the Docker Engine to run the container in the background.

```
docker run –help

Usage:  docker run [OPTIONS] IMAGE [COMMAND] [ARG...]
Run a command in a new container

Options:
-d, --detach            Run container in background and print container ID
```

Run a Container

Why Run a Container in the Background?

Discussion

Why Run a Container in the Background?

- Containers that do not require interaction can be started and left to run in their own process

Monitor Docker – Native Tools

Native Monitoring Tools

These following tools provide real-time metrics on a container or a set of containers.

`docker ps <switch>`

- list containers

`docker logs <container>`

- displays console output of the container

`docker top <container>`

- lists all the processes running in a container

`docker stats <container>`

- streams real time stats of containers

`docker inspect <container>`

- displays detailed container configuration

Docker ps (list containers)

Show running Docker containers

```
$ docker ps

CONTAINER ID        IMAGE                          COMMAND
ece82d202fd6        grafana/grafana:2.0.2          "/usr/sbin/grafana-se“
2be9d338d8e4        google/cadvisor                "/usr/bin/cadvisor -s"
ffa57323dad8        tutum/influxdb:0.8.8           "/run.sh"
```

Show Docker containers id

```
$ docker ps -q
ece82d202fd6
2be9d338d8e4
ffa57323dad8
c5817eea595e
```

Show all Docker containers

```
$ docker ps –a

CONTAINER ID        IMAGE                          COMMAND
ece82d202fd6        grafana/grafana:2.0.2          "/usr/sbin/grafana-se“
2be9d338d8e4        google/cadvisor                "/usr/bin/cadvisor -s"
ffa57323dad8        tutum/influxdb:0.8.8           "/run.sh"
c5817eea595e        nginx/nginx-php                "/usr/local/bin/run"
```

Docker ps (list containers)

In your Lab Environment, execute the following command:

```
$ docker ps
```

The command will display the output:

```
CONTAINER ID   IMAGE   COMMAND   CREATED   STATUS   PORTS   NAMES
```

This is expected since we have no running containers…

Docker ps (list containers)

What about all containers?

In your Lab Environment, execute the following command:

```
$ docker ps -a
```

The command will display output similar to:

```
CONTAINER ID      IMAGE               COMMAND                  CREATED             STATUS                      PORTS      NAMES
f774f8618226      hello-world         "/hello"                 7 seconds ago       Exited (0) 6 seconds ago               timely_terapin
3fa9d2d4f5ad      docker/whalesay     "cowsay 'Go Docker'"     50 minutes ago      Exited (0) 50 minutes ago              ecstatic_feynman
8f5e737d15bf      docker/whalesay     "cowsay 'Detached'"      About an hour ago   Exited (0) 59 minutes ago              happy_leavitt
```

The process we executed in these containers finished, so the containers exited

Make note (copy) a CONTAINER ID

Docker logs <container>

Display the Console Output of a Container

```
$ docker logs f774f8618226

Hello from Docker!
This message shows that your installation appears to be working correctly.
To generate this message, Docker took the following steps:
 1. The Docker client contacted the Docker daemon.
 2. The Docker daemon pulled the "hello-world" image from the Docker Hub.
 3. The Docker daemon created a new container from that image which runs the
    executable that produces the output you are currently reading.
 4. The Docker daemon streamed that output to the Docker client, which sent it
    to your terminal.
To try something more ambitious, you can run an Ubuntu container with:
 $ docker run -it ubuntu bash
Share images, automate workflows, and more with a free Docker Hub account:
 https://hub.docker.com
For more examples and ideas, visit:
 https://docs.docker.com/engine/userguide/
```

Docker logs <container>

Try it!

In your Lab Environment, execute the following command:

```
$ docker logs <container_id>
```

The command will display the output:

Docker top <container>

Running the **`docker top`** command on all host container

- Flags used with regular top can be used **`–aux -faux`**

```
$ docker top –help
Usage:  docker top [OPTIONS] CONTAINER [ps OPTIONS]
Display the running processes of a container
--help=false       Print usage
```

Docker top <container>

Try it!

In your Lab Environment, execute the following command:

```
$ docker run -d busybox top
```

This will pull and run the latest build of busybox and run the ‘top’ command.

Once the container has started, the console will display the Container ID:

```
7ed45bb572d0886686c5d9ac7484094716cf0c581087d6499193a799a3ed6345
```

Docker top <container>

Now that we have a running container:
In your Lab Environment, execute the following command:

```
$ docker top <container_id>
```

The console will display the running process in the container:

```
PID                 USER                TIME                COMMAND
3372                root                0:03                top
```

Docker stats <container>

docker stats command

```
$ docker stats --help
Usage:  docker stats [OPTIONS] CONTAINER [CONTAINER...]
Display a live stream of container(s) resource usage statistics
--help=false         Print usage
--no-stream=false    Disable streaming stats and only pull the first
result
```

docker stats command on a single container

```
$ docker stats <container_id>

CONTAINER           CPU %               MEM USAGE / LIMIT
cdfd04b5aeef        0.15%               29.52 MB / 2.098 GB

MEM %               NET I/O             BLOCK I/O
1.41%               6.684 kB / 648 B    0 B / 49.15 kB
```

Docker stats <container>

Try it!

In your Lab Environment, execute the following command:

```
$ docker stats <container_id>
```

The console will display the real-time stats of the container:

```
CONTAINER
CPU %               MEM USAGE / LIMIT     MEM %               NET I/O
BLOCK I/O           PIDS
7ed45bb572d0886686c5d9ac7484094716cf0c581087d6499193a799a3ed6345
0.25%               147 MiB / 1.954 GiB   7.35%               648 B /
648 B       0 B / 0 B           24
```

Docker inspect <container>

docker inspect command

```
$ docker inspect --help
Usage:    docker inspect [OPTIONS] CONTAINER|IMAGE|TASK
Return low-level information on a container, image or task
  -f, --format       Format the output using the given go template
  --help             Print usage
  -s, --size         Display total file sizes if the type is container
  --type             Return JSON for specified type, (e.g image, container or task)
```

docker inspect command on a single container

```
$ docker inspect 506fe8cf11bb
[
    {
        "Id": "506fe8cf11bbbb74bf9db26f6561f218ec437cc2b8267d214affb31493e4c251",
        "Created": "2016-07-11T15:51:34.148392848Z",
```

Docker inspect <container>

Try it!

In your Lab Environment, execute the following command:

```
$ docker inspect <container_id>
```

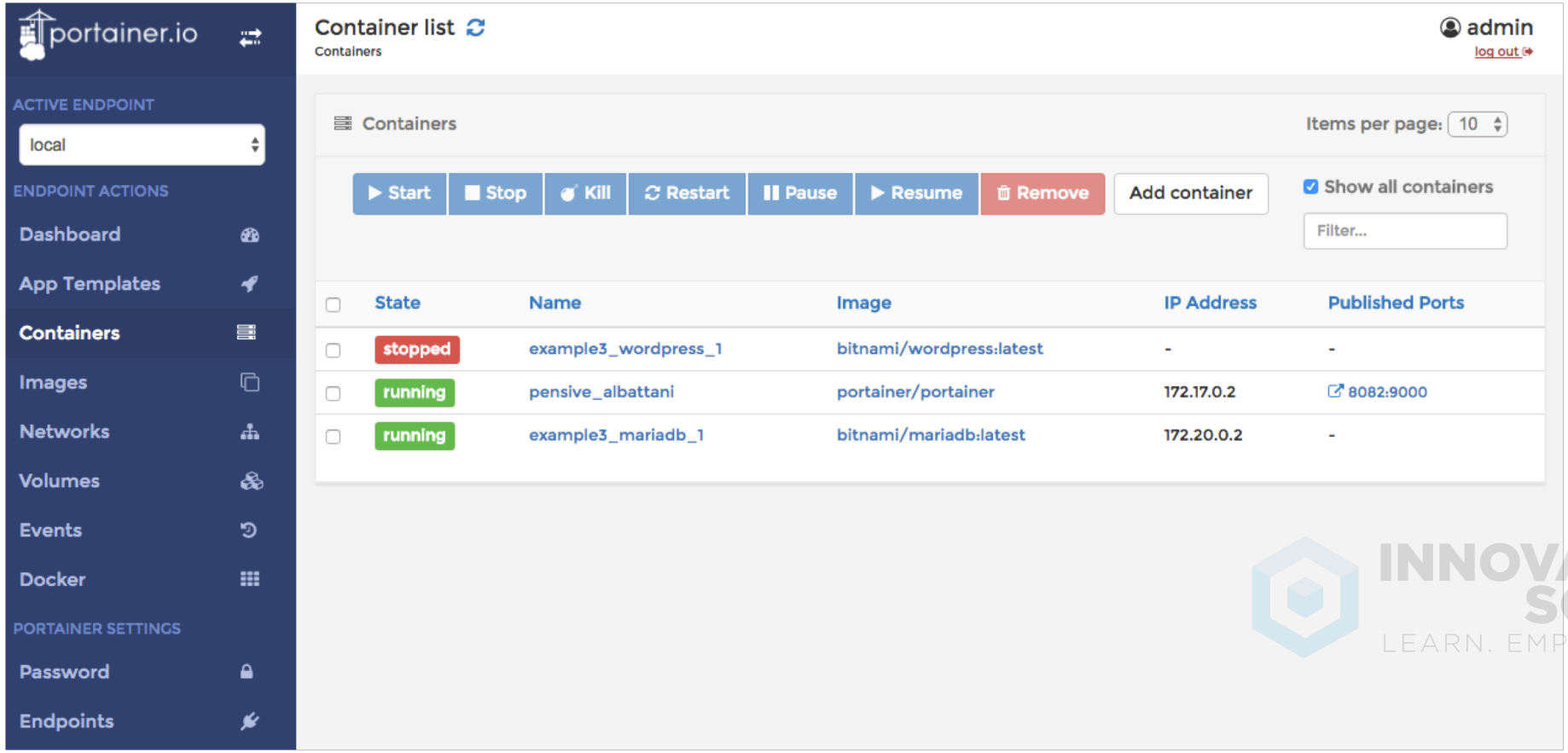
The console will display the configuration details of the container

```
[
    {
        "Id":
"8404dd7fcb18ba49e6d839bf87ce877297566cfac6ca9a6f0c93846e2bf5e366",
        "Created": "2016-09-09T14:46:28.911819016Z",
        "Path": "top",
```

Monitor Docker – 3rd Party Tools

Portainer

Portainer (formerly DockerUI) provides a web interface for the Docker Remote API



https://github.com/portainer/portainer

Portainer

Try it!

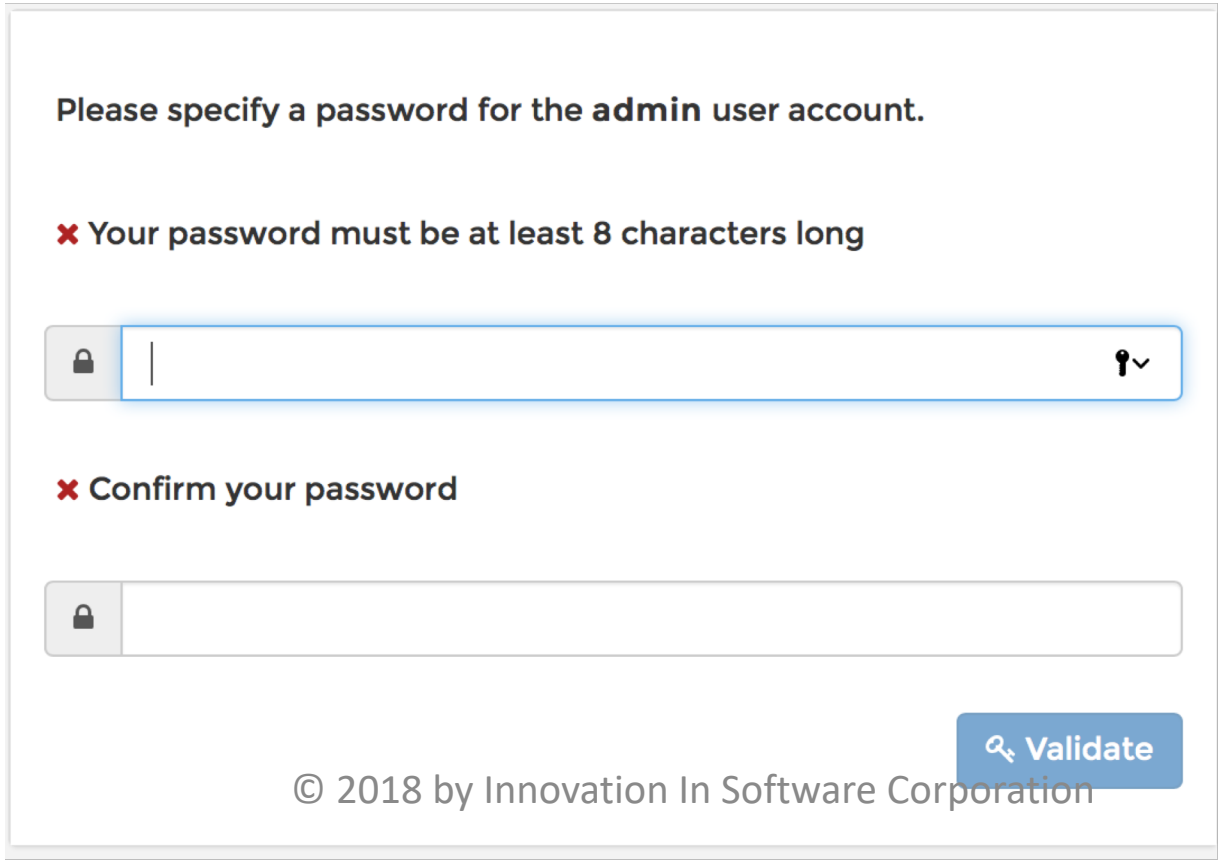
In your Lab Environment, execute the following command:

```
$ docker run -d -p 8082:9000 --privileged -v
/var/run/docker.sock:/var/run/docker.sock portainer/portainer
```

In your lab guide, locate the IP address of your Master host

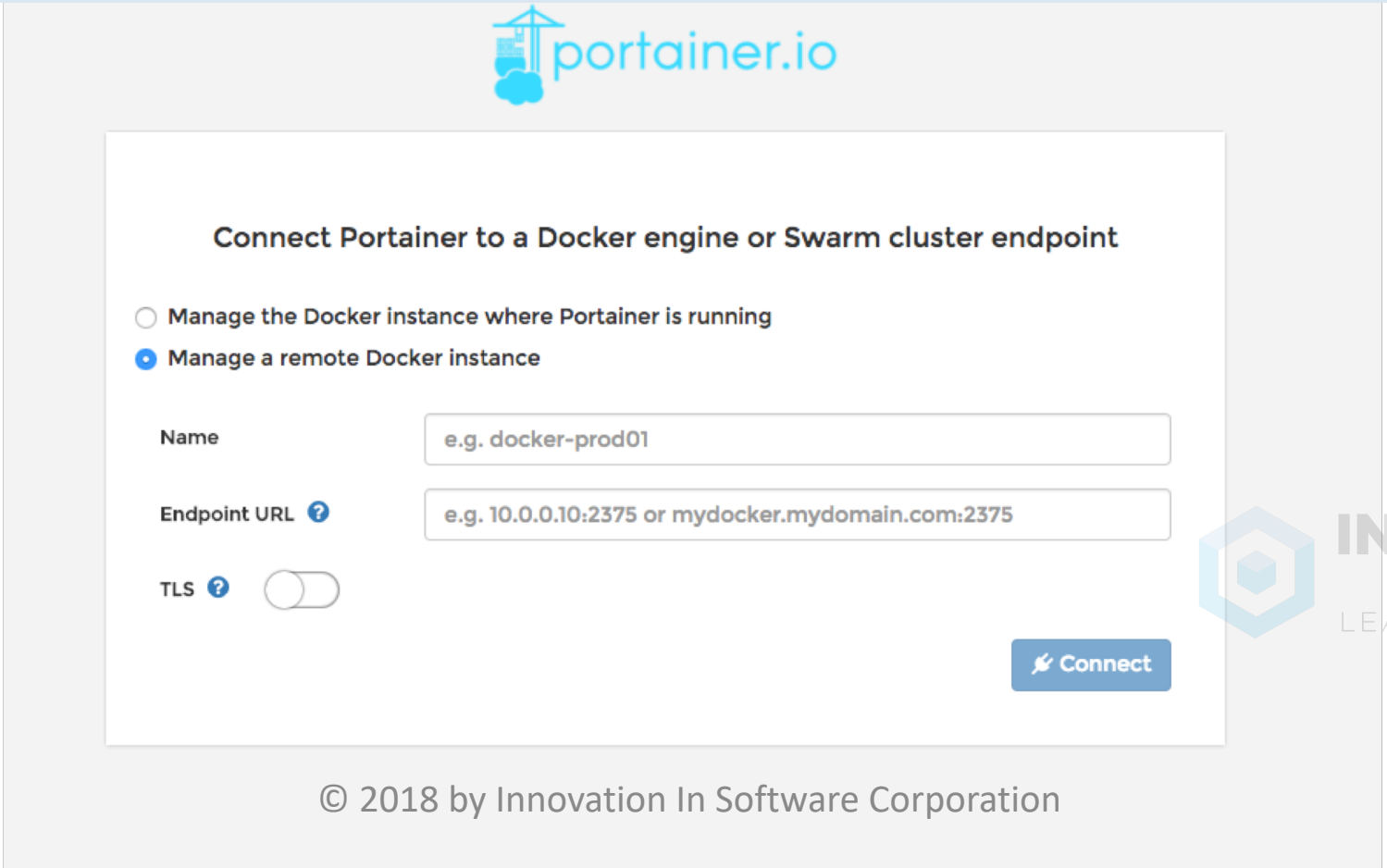
Portainer

Open a Web Browser, and set Admin password using the IP address and port: **http://*<IPADDRESS>*:8082/**



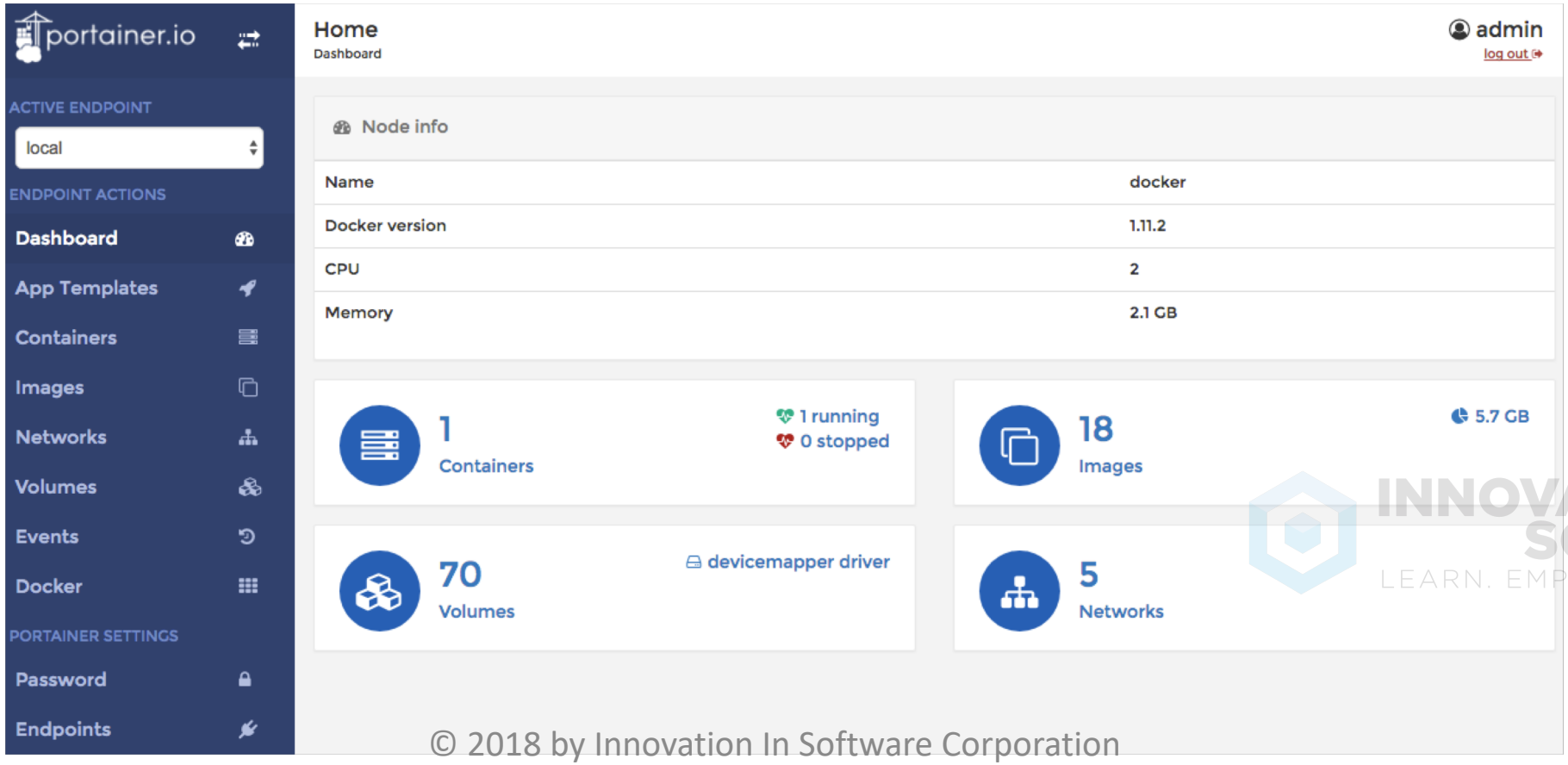
Portainer

Choose: **Manage the Docker instance where Portainer is running**



Portainer

Click around Portainer



Google cAdvisor

cAdvisor (Container Advisor) provides container users an understanding of the resource usage and performance characteristics of their running containers.

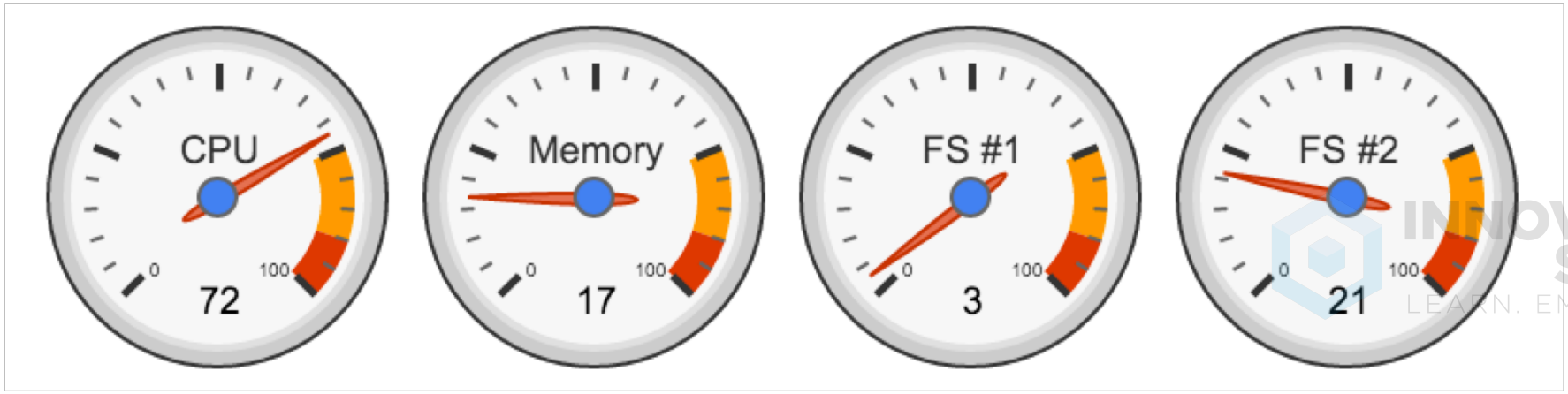
- Analyzes resource usage and performance characteristics of running containers
- cAdvisor can be run in several ways:
  - installed locally on the Docker host
  - run as a privileged container

https://github.com/google/cadvisor

Google cAdvisor

cAdvisor provides:

- A real-time, easy to read dashboard overview of the host running docker containers
- An overview for usage of:
  - CPU
  - Memory
  - Filesystem



cAdvisor Pros and Cons

cAdvisor Pros

- Real-time visibility into docker hosts
- Easy to read quick glance dashboard
- Presents metrics for use by other applications

cAdvisor Cons

- Provides only 60 seconds of history
- Unable to customize queries
- No alerting mechanism
- Provides visibility into host its installed on

cAdvisor Pros and Cons

cAdvisor Pros

- Real-time visibility into docker hosts
- Easy to read quick glance dashboard
- Presents metrics for use by other applications

cAdvisor Cons

- Provides only 60 seconds of history
- Unable to customize queries
- No alerting mechanism
- Provides visibility into host its installed on

Discussion

How can these tools be used together to find a troublesome container?

Start, Stop & Remove Containers

Manage Containers

The following tools allow management of containers

`docker stop <container>`

- Stop a container

`docker start <container>`

- Start a container

`docker rm <container>`

- Remove a container

docker stop <container>

Stop a Docker container

```
$ docker stop --help

Usage:  docker stop [OPTIONS] CONTAINER [CONTAINER...]


Stop one or more running containers


Options:
      --help       Print usage
  -t, --time int   Seconds to wait for stop before killing it (default
10)
```

docker stop <container>

Try it!

In your Lab Environment, execute the following command:

```
$ docker stop <container_id>
```

This will stop the container. The console will acknowledge with the Container ID

```
7ed45bb572d0
```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docker start <container>

Start a Docker container

```
$ docker start --help

Usage:  docker start [OPTIONS] CONTAINER [CONTAINER...]


Start one or more stopped containers


Options:
  -a, --attach               Attach STDOUT/STDERR and forward signals
      --detach-keys string   Override the key sequence for detaching a
container
      --help                 Print usage
  -i, --interactive          Attach container's STDIN
```

docker start <container>

Try it!
In your Lab Environment, execute the following command:

```
$ docker start <container_id>
```

This will start the container.

The console will acknowledge with the Container ID.

```
7ed45bb572d0
```

docker rm <container>

Remove a Docker container

```
$ docker rm --help

Usage:  docker rm [OPTIONS] CONTAINER [CONTAINER...]


Remove one or more containers


Options:
  -f, --force     Force the removal of a running container (uses
SIGKILL)
      --help      Print usage
  -l, --link      Remove the specified link
  -v, --volumes   Remove the volumes associated with the container
```

docker rm <container>

Try it!
In your Lab Environment, execute the following command:

```
$ docker rm <container_id>
```

This will remove the container.

The console will acknowledge with the Container ID.

```
7ed45bb572d0
```

But what if I wanted to delete ALL containers?
In your Lab Environment, execute the following command:

```
$ docker rm $(docker ps -a -q)
```

This will remove the container. The console will acknowledge with all the Container IDs.

```
1028e737f3ab
b72a77b7a22f
f774f8618226
3fa9d2d4f5ad
8f5e737d15bf
```


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Use with Caution

Summary, Review & QA

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Summary

- Log into Lab Environment
- Create a Docker Hub Account
- Search for Existing Docker Images
- Run a Container
- Monitor Docker with Native Tools
- Monitor Docker with 3rd Party Tools
- Start, Stop, and Remove Containers

Review

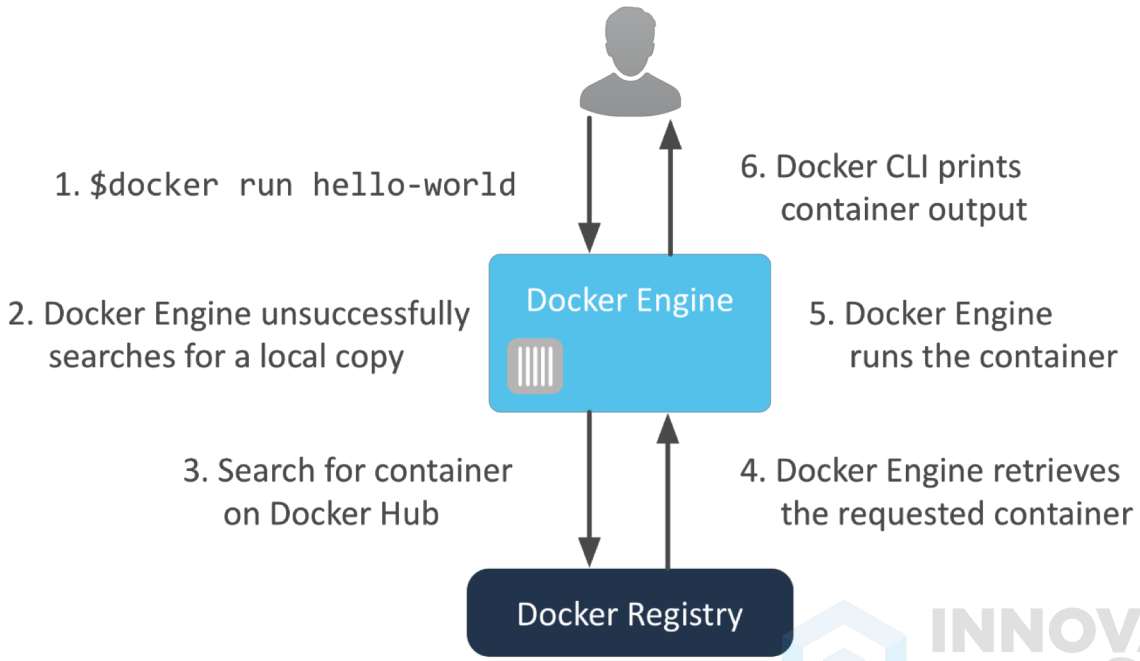
Run a Container

Monitor Docker Containers Using Native Tools

Monitor Docker Containers Using 3rd Party Tools

Start, Stop, and Remove Containers

```
$ docker run hello-world
```



Review

Run a Container

Monitor Docker Containers Using Native Tools

Monitor Docker Containers Using 3rd Party Tools

Start, Stop, and Remove Containers

- **`docker ps <switch>`**
  - list containers
- **`docker logs <container>`**
  - displays console output of the container
- **`docker top <container>`**
  - lists all the processes running in a container
- **`docker stats <container>`**
  - streams real time stats of containers
- **`docker inspect <container>`**
  - displays detailed container configuration

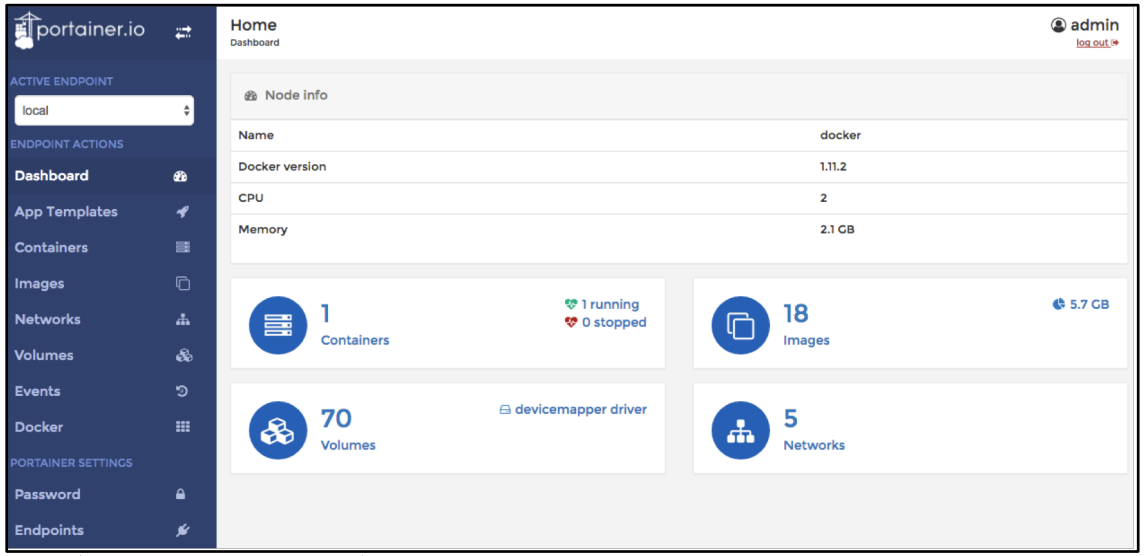
Review

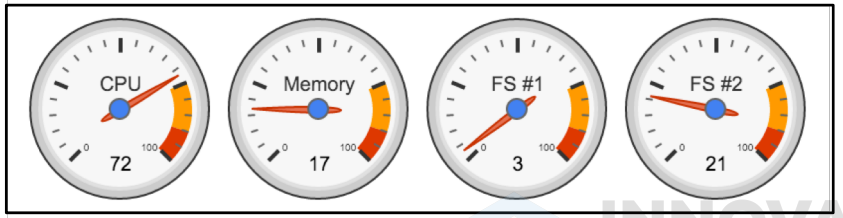
Run a Container

Monitor Docker Containers Using Native Tools

Monitor Docker Containers Using 3rd Party Tools

Start, Stop, and Remove Containers





Review

Run a Container
Monitor Docker Containers Using Native Tools
Monitor Docker Containers Using 3rd Party Tools
Start, Stop, and Remove Containers

- **`docker stop <container>`**
  - Stop a container
- **`docker start <container>`**
  - Start a container
- **`docker rm <container>`**
  - Remove a container

Docker Images

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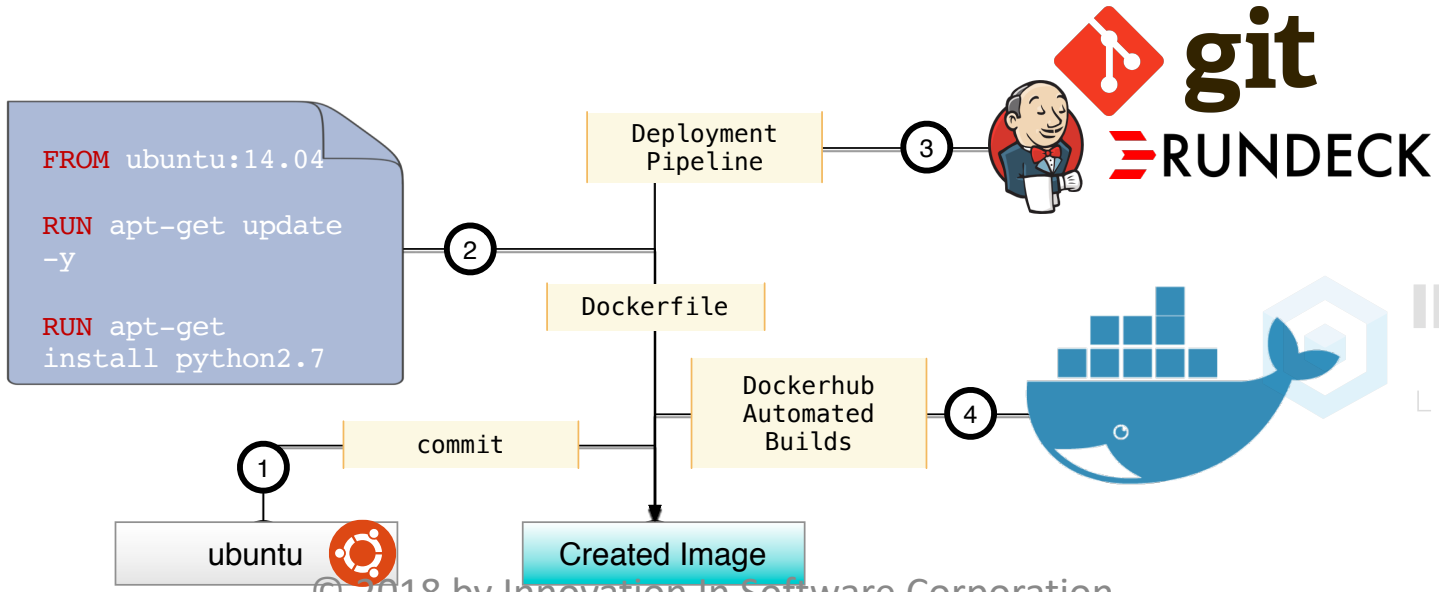
Agenda

- Anatomy of Docker Image
- The Union File System
- Build Images with Dockerfile
- Build Images with docker build
- Commits on Containers
- Docker Image Metadata
- Docker Image Flow

Methods to Create an Image

Images can be created from:

1. The command-line
2. An image from a Dockerfile
3. An image from a deployment pipeline
4. An image from Docker automated builds



Anatomy of Docker Image

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Docker Image Terminology

Image

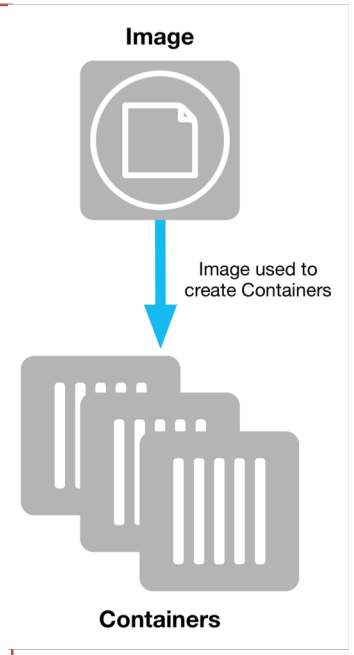
Union Filesystem

Dockerfile

Container

Hierarchy of files, with meta-data for how to create/run a container

- Read only template used to create containers
- Can be exported or modified to new images
- Created manually or through automated processes
- Stored in a Registry (Docker Hub, Docker Trusted Registry, etc.)



Docker Image Terminology

Image

Union Filesystem

Dockerfile

Container

UnionFS – Used by Docker to layer images

- Not a distributed File System

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Docker Image Terminology

Image

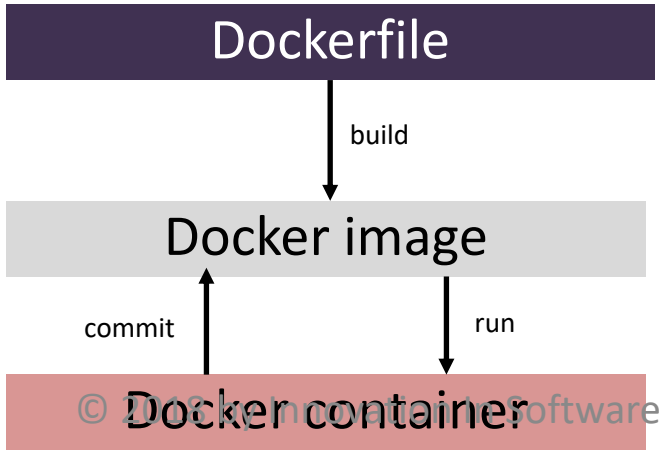
Union Filesystem

Dockerfile

Container

Configuration File (script) for creating images. Defines:

- Existing image to be the starting point
- Set of instructions to augment that image (each of which results in a new layer of the file system)
- Meta-data such as ports exposed
- The command to execute when the image is run



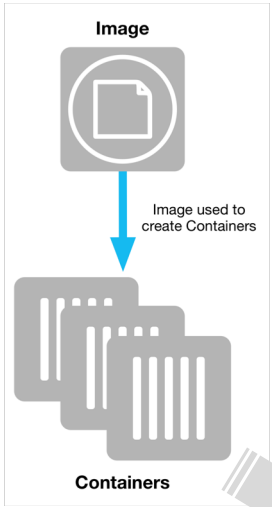
Docker Image Terminology

Image

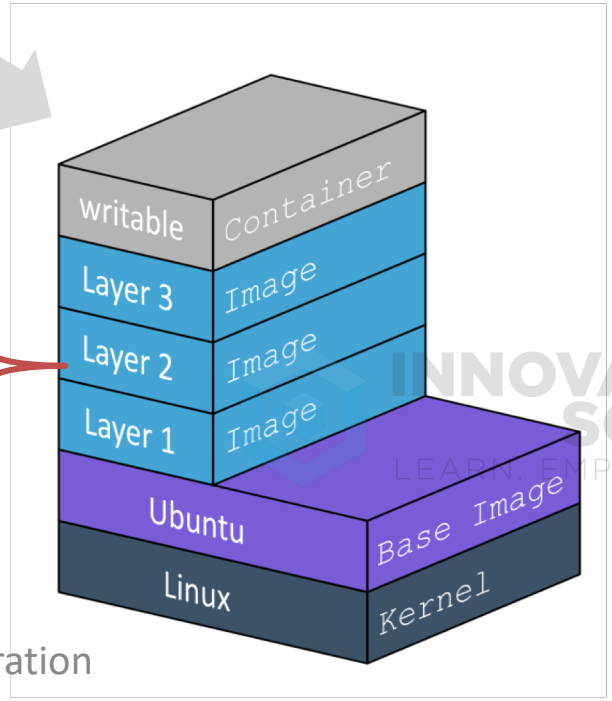
Union Filesystem

Dockerfile

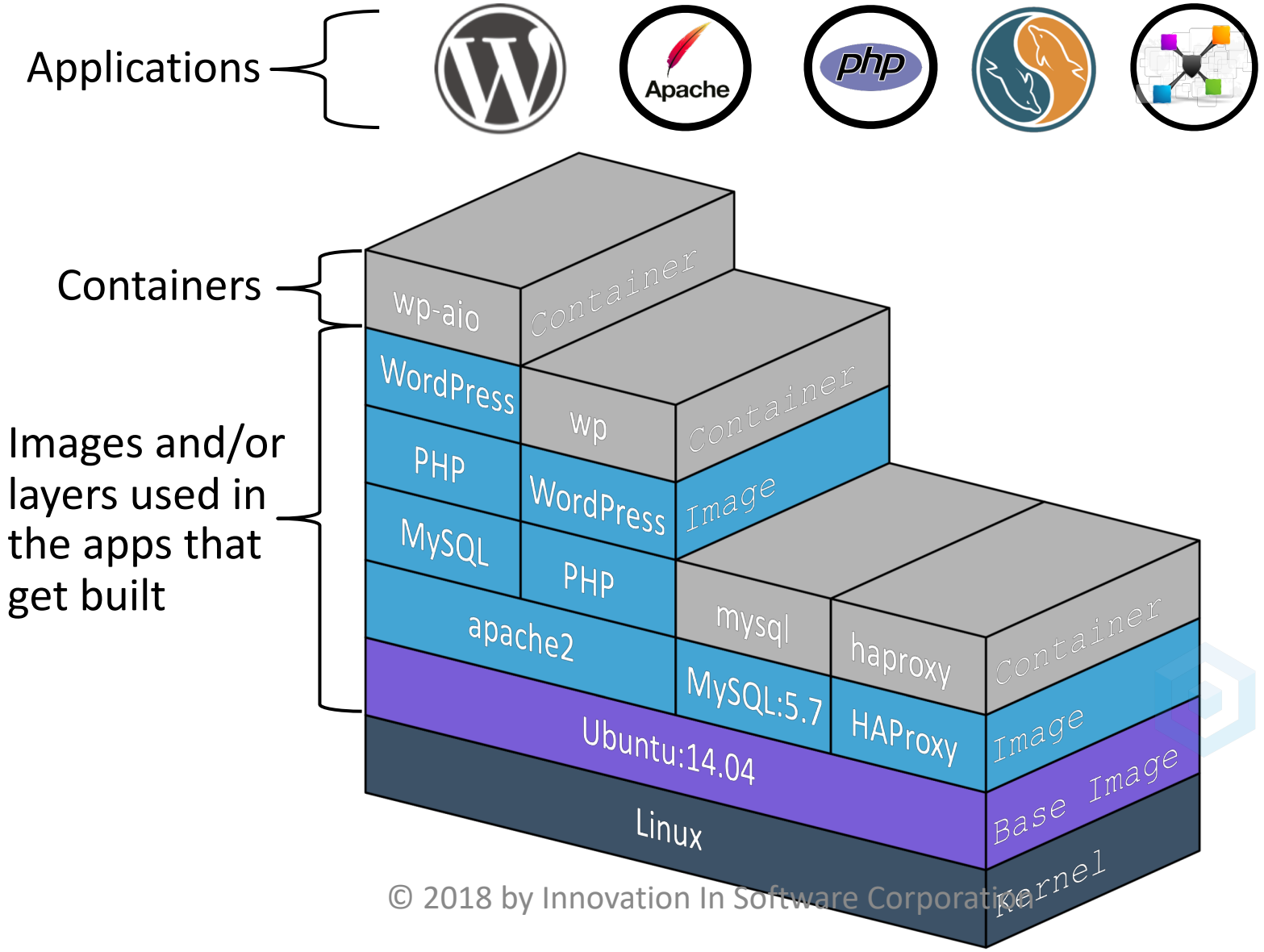
Container



Runtime instance of an image plus a read/write layer



Applications, Containers, and Images



Union Files System

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Image/Container Interactions

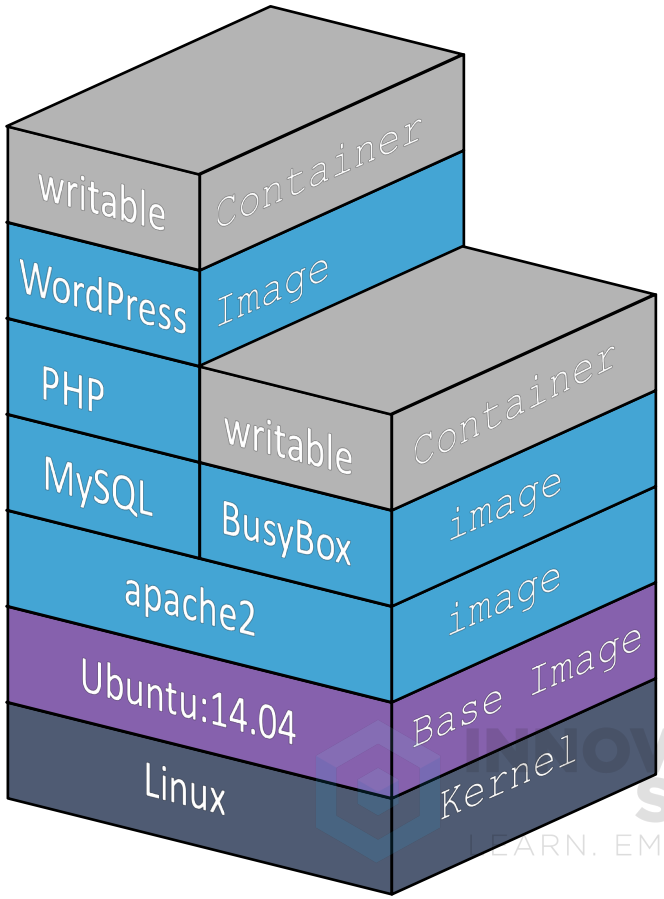
Pull an image from a Docker Registry

Run a container from an image

Add a file to a running container – Example, the image requires an additional file called index.html

Change to a running container – Example, the image requires an update of the index.php file

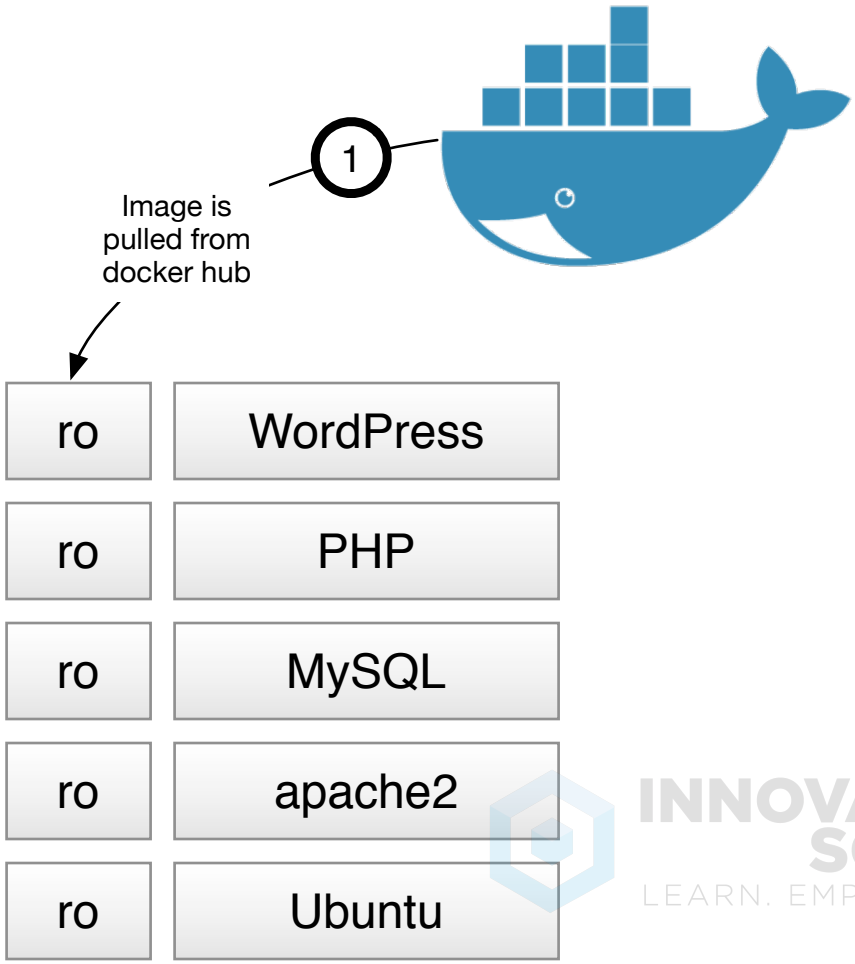
Delete files from a running container – All containers share the same host kernel



Pull the WordPress AIO

The WordPress All-In-One image is pulled from Docker Hub

```
$docker inspect wordpress-aio
```



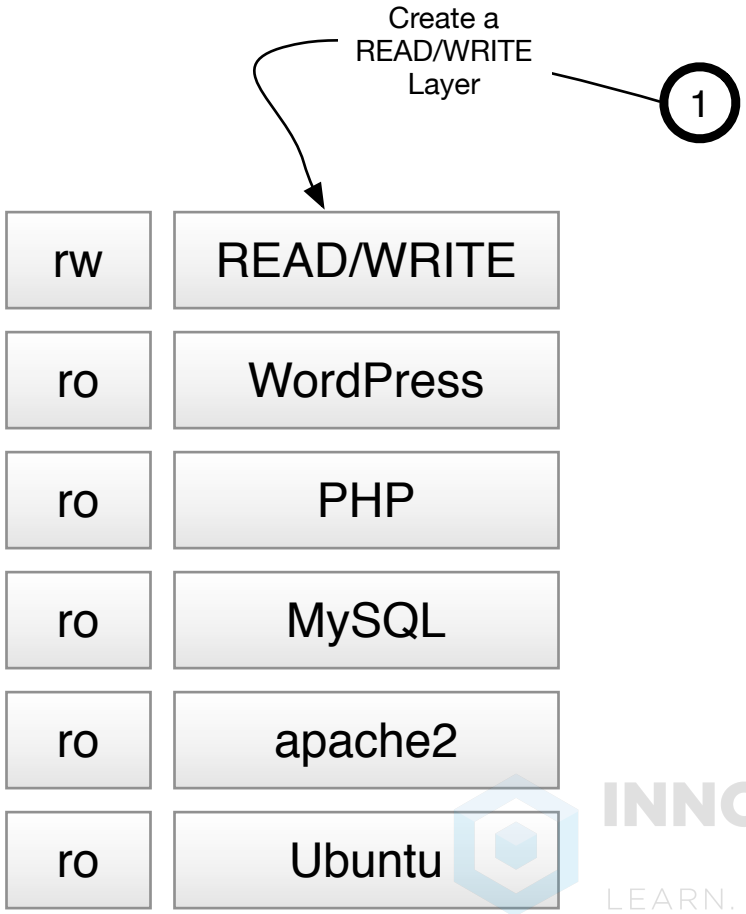
Docker images are:

- Pulled or created
- Stored in a local image repo
- READ-ONLY
- The basis of all containers

Run the WordPress AIO

A container is made from the previously pulled WordPress AIO image

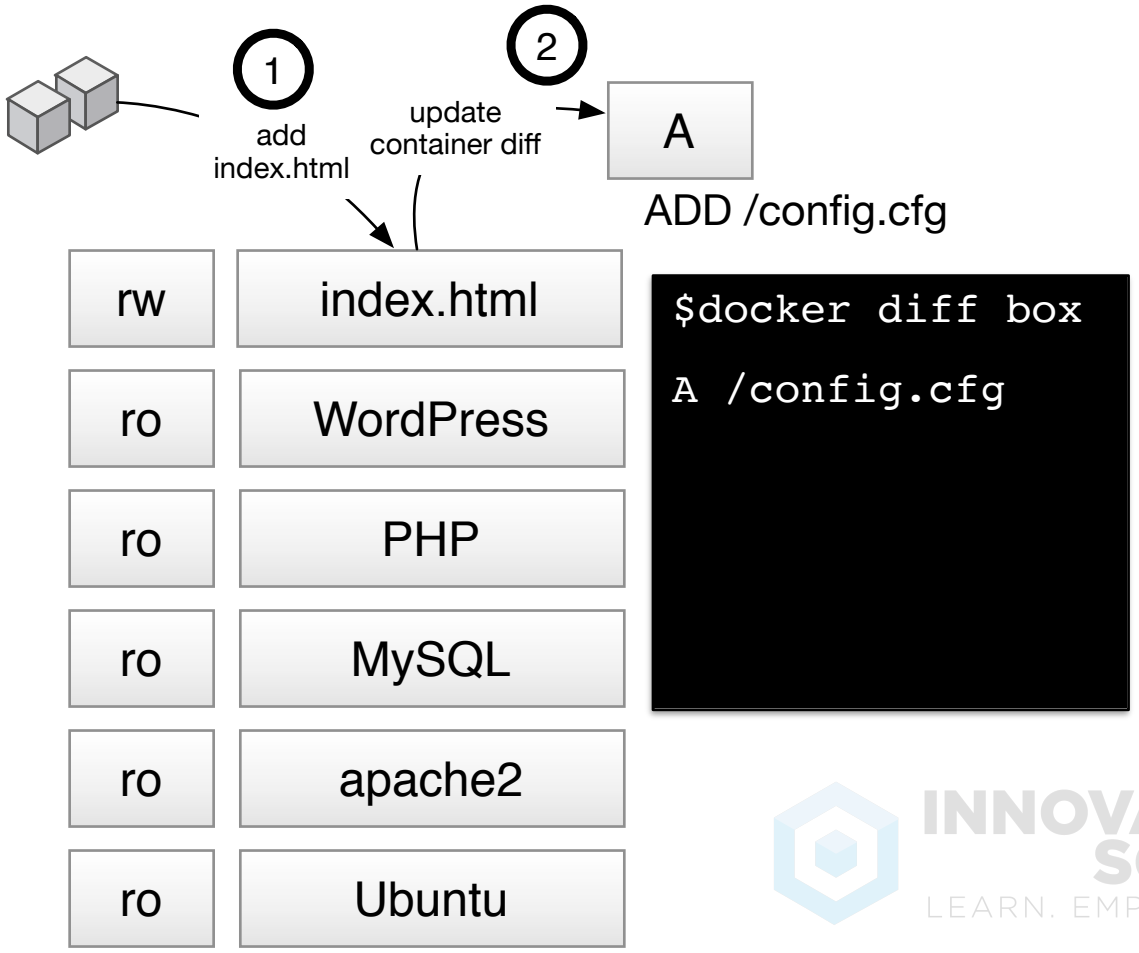
1. `$docker run wordpress-aio`
2. Container created
3. READ/WRITE layer created
4. All **ADD**, **CHANGE**, **DELETE** are committed to the READ/WRITE Layer



Add a file to WordPress AIO

Index.html is **created** on the WordPress container

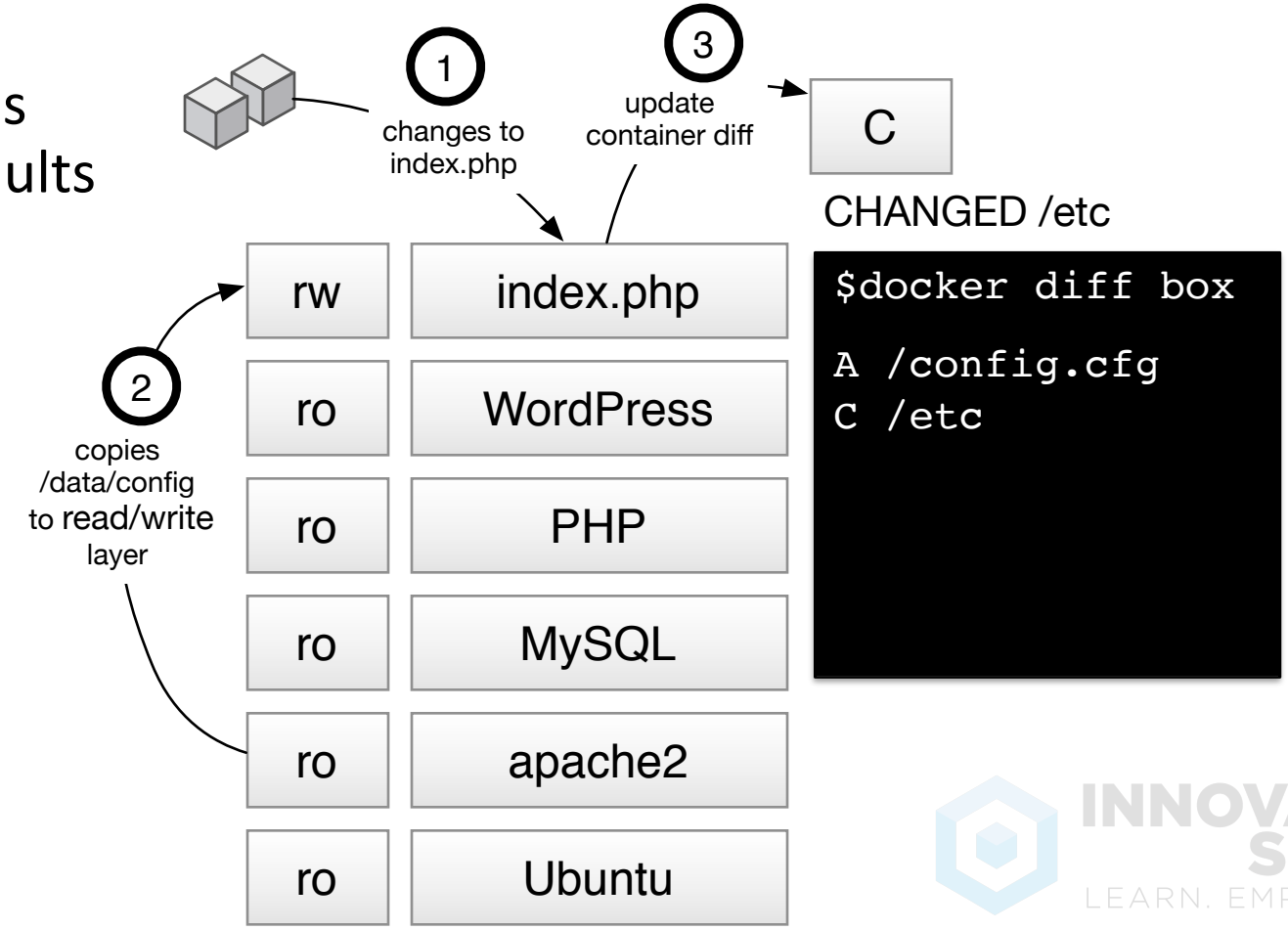
1. A file named index.html is created
2. The created file is written to the READ/WRITE layer



Change a file in WordPress AIO

The index.php file is **updated** from defaults

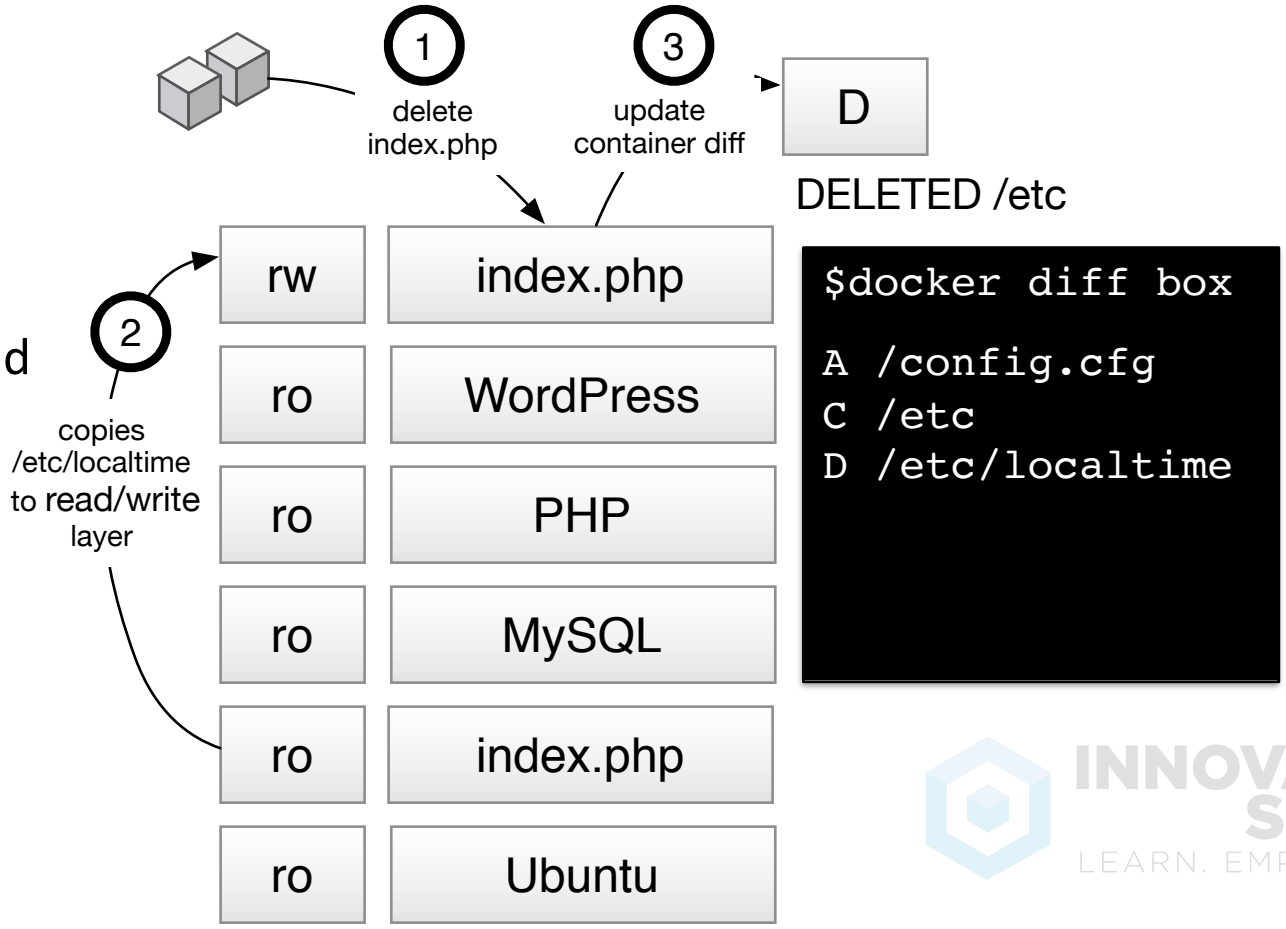
1. The file is edited
2. copies the file from READ-ONLY layer to READ/WRITE layer
3. update diff



Delete a file on WordPress AIO

The index.php file is **deleted**

1. The file is deleted
2. copy data from READ-ONLY layer to READ/WRITE layer and marked as DELETED
3. update diff



UnionFS ADD, CHANGE, DELETE

- **ADD** – Add the data blocks to the READ/WRITE layer
- **CHANGE –** Copies the data blocks from the READ ONLY layer to the READ/WRITE layer and makes changes. Writes are committed to the READ/WRITE layer
- **DELETE** – Copies the data blocks from the READ ONLY layers to the READ/WRITE layer and makes it as DELETED

Copy-On-Write

- Only when changes are made to the R/W UnionFS is data written
- Sometimes referred to as “Change Block Tracking” or “Copy-On-Change”

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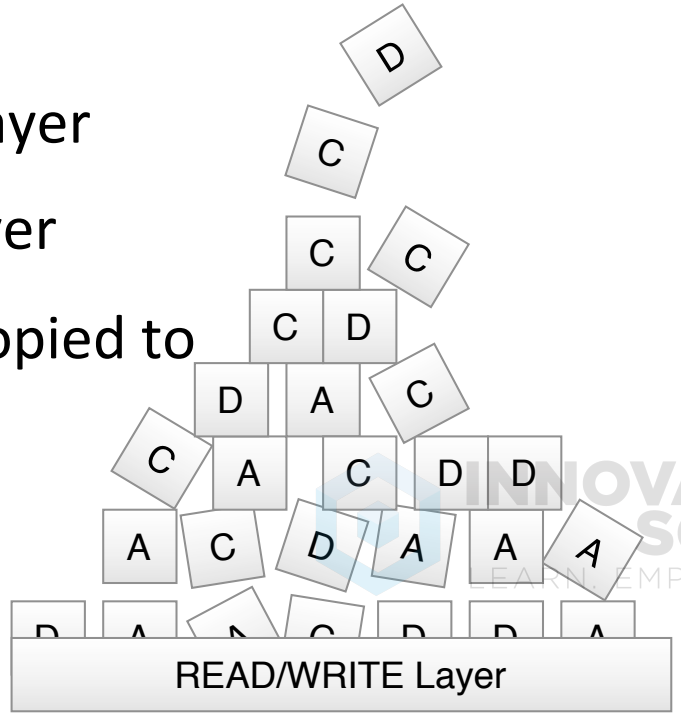
Key Takeaways

- **Images** are:
  - Highly portable and readily available
  - Reusable for many deployments
- **ADD** – ADD DATA to READ/WRITE Layer
- **CHANGE –** ADD DATA to READ/WRITE Layer
- **DELETE –** ADD DATA to READ/WRITE Layer
- **ALL** ADDs, CHANGEs, and DELETEs are copied to the READ/WRITE Layer



Images Lab: Task 1

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Build Docker Images (Dockerfile)

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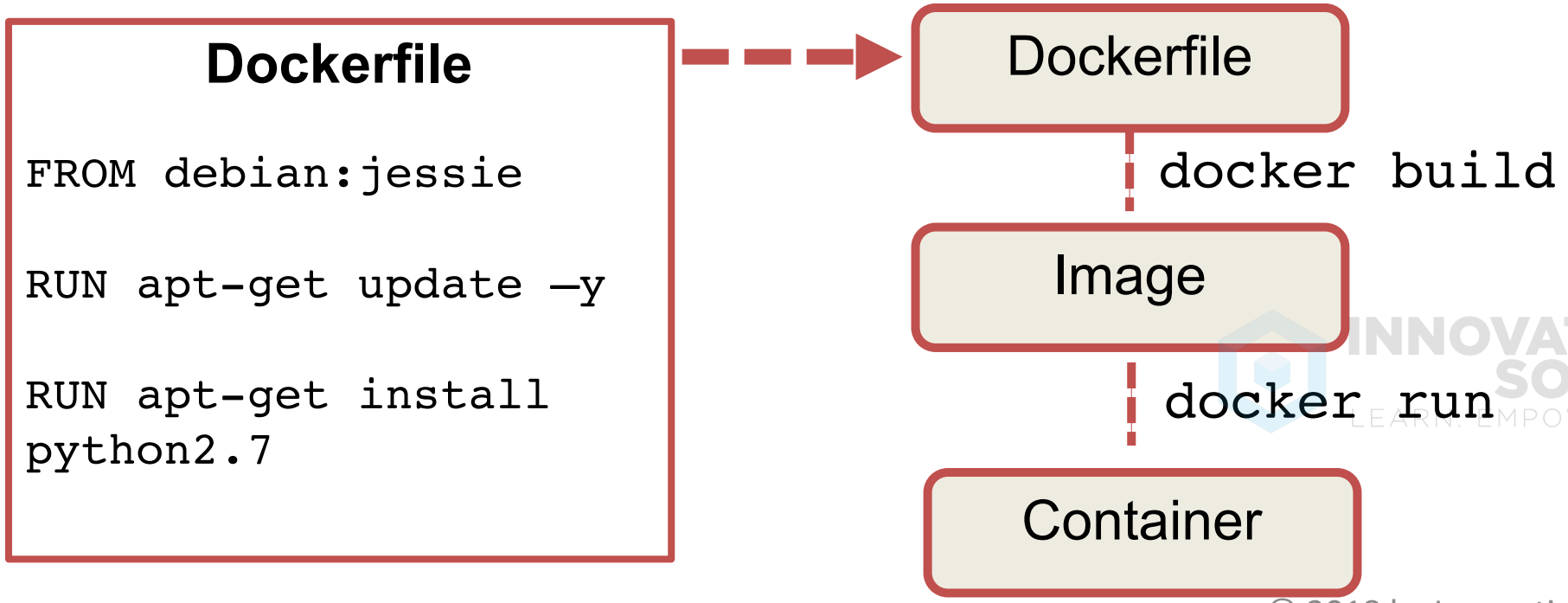
Dockerfile

Docker can build images automatically by reading the instructions from a **Dockerfile**

E.g. dockerfile that installs python 2.7 on top of debian jessie image



Dockerfile Syntax

Dockerfiles have an easily readable format

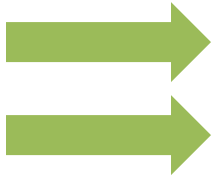
comments
INSTRUCTIONS
arguments

```
#My first Dockerfile
FROM ubuntu:16.04
RUN apt-get update
```

Lines starting with the “#” are comments
Comments can be placed anywhere
Comments help tell others what is intended

Dockerfile Syntax

```
# comments
INSTRUCTIONS
arguments
```



```
#My first Dockerfile
FROM ubuntu:16.04
RUN apt-get update
```

INSTRUCTIONS should be CAPITALIZED

INSTRUCTIONS are run during image build

The first INSTRUCTION is always FROM

Dockerfile Syntax

comments

INSTRUCTIONS

arguments

```
#My first Dockerfile
FROM ubuntu:16.04
RUN apt-get update
```

`arguments` are what gets fed to the builder

`arguments` can be run sequentially in the same `INSTRUCTION` with an escape

Escape Parser Directive

- form # directive=value
- Parser directives are optional, and affect the way in which subsequ lines in a Dockerfile are handled
- Windows uses “\” for directories

```
# escape=`
FROM microsoft/windowsservercode
SHELL [“powershell”,”-command”]
RUN New-Item -ItemType Directory `
    C:\Example
ADD Execute-MyCmdlet.psl c:\example
```

Escape Parser Directive

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FROM microsoft/windowsservercode
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ADD Execute-MyCmdlet.psl c:\example
```

Escape Parser Directive

- This prevents Docker from worrying about “/” as escapes
- An # escape=` Parser Directive is used

```
# escape=`
FROM microsoft/windowsservercode
SHELL [“powershell”,”-command”]
RUN New-Item -ItemType Directory `
    C:\Example
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```

Escape Parser Directive

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- An # escape=` Parser Directive is used

```
# escape=`
FROM microsoft/windowsservercode
SHELL [“powershell”,”-command”]
RUN New-Item -ItemType Directory `
    C:\Example
ADD Execute-MyCmdlet.psl c:\example
```

Dockerfile Example

- Dockerfile takes the latest mongo image
- Updates it
- Installs an entrypoint script to streamline execution

```
FROM mongo:latest
RUN apt-get update && apt-get install -y dos2unix
EXPOSE 27017
COPY docker-entrypoint-init.sh /entrypoint-init.sh
RUN dos2unix /entrypoint-init.sh && \
  apt-get --purge remove -y dos2unix && \
  rm -rf /var/lib/apt/lists/*
RUN chmod ugo+x /entrypoint-init.sh
ENTRYPOINT ["/entrypoint-init.sh"]
CMD ["mongod"]
```

Dockerfile Instructions

Command	Description
#	Comment line
MAINTAINER	Provides name and contact info of image creator
FROM	Tells Docker which base image to build on top of (e.g. centos7)
COPY	Copies a file or directory from the build host into the build container
RUN	Runs a shell command inside the build container
CMD	Provides a default command for the container to run. May be overridden or changed
ADD	Copies new files, directories or remote file URLs
LABEL	Adds metadata to an image

source: https://docs.docker.com/v1.8/reference/builder/

Dockerfile Instructions

Command	Description
VOLUME	Exposes any database storage area, configuration storage, or files/folders created by your Docker container
USER	Change to a non-root user
WORKDIR	Sets the working directory for any RUN, CMD, ENTRYPOINT, COPY or ADD instruction
ONBUILD	Executes after the current Dockerfile build completes. ONBUILD executes in any child image derived FROM the current image
EXPOSE	Informs Docker that the container will listen on the specified network ports at runtime
ENTRYPOINT	Allows you to configure a container that will run as an executable
ENV	Sets the environment variable <key> to the value

source: https://docs.docker.com/v1.8/reference/builder/

Copy vs Add

Functionally similar – serve the same purpose

COPY

- Only supports basic copying of local files into container
  - Does not extract compressed files
- When using multiple dockerfile steps that use different file contexts, copy individually

ADD

- Additional features
  - Local-only tar extraction
  - Remote URL support
- Using ADD to fetch remote url packages increases image sizes

ADD – Not Recommended

```
ADD http://example.com/big.tar.xz /usr/src/things/
RUN tar -xJf /usr/src/things/big.tar.xz -C
/usr/src/things
RUN make -C /usr/src/things all
```

- Image size matters
- Using `ADD` to fetch packages from remote URLs INCREASES images sizes
  - Not recommended
- Use `curl` or `wget`
  - Gain ability to delete the files you no longer need after they've been extracted
  - Reduces unnecessary layers in your image

Best Practice: Use Curl

```
RUN mkdir -p /usr/src/things \
&& curl -SL http://example.com/big.tar.xz \   | tar
-xJC /usr/src/things \
&& make -C /usr/src/things all
```

- Use `curl` instead of `ADD`
  - Allows for cleaning up the tar file after it's been extracted and application installed

Image/Container Interactions

Pull an image from a Docker Registry
Run a container from an image
Add a file to a running container

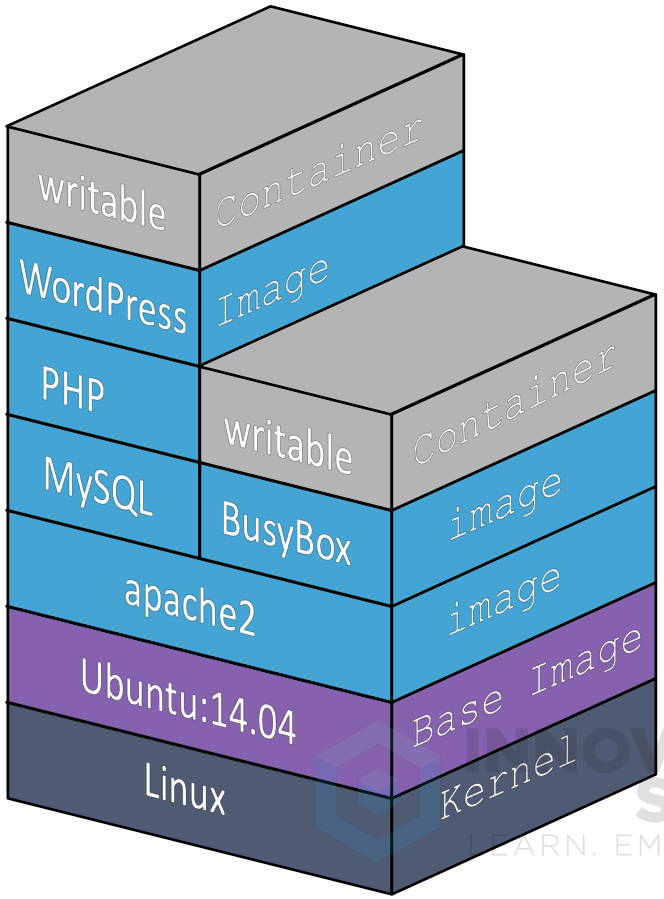
Example: The image requires an additional file called index.html

Change to a running container

Example: The image requires an update of the index.php file

Delete files from a running container

All containers share the same host kernel



More Complex Dockerfile

```
# Dockerfile to build CartRT container images
# Based on Ubuntu
FROM 889199535989.dkr.ecr.us-east-1.amazonaws.com/java/java8:1.8.0_25
# File Author / Maintainer
MAINTAINER TicketsRus commerceapi-
ticketsrus@LNEAllAccess.onmicrosoft.com
# Make directory on CoreOS for tomcat, download and un-tar the tomcat
installable
RUN mkdir -p /opt/tomcat && \
   cd /opt && \
   curl -s -L -o - 'http://supergsego.com/apache/tomcat/tomcat-
7/v7.0.72/bin/apache-tomcat-7.0.72.tar.gz' | tar -C /opt/tomcat -zxf -
# Getting jamon dependencies
RUN cd /opt/tomcat/apache-tomcat-7.0.72/lib && curl -O
http://git.tm.tmcs/corch-hollywood-dev/cart-
runtime/raw/master/shoppingcart-service-
main/src/main/assembly/etc/default/tomcat/lib/jamon-2.73.jar
RUN cd /opt/tomcat/apache-tomcat-7.0.72/lib && curl -O
http://git.tm.tmcs/corch-hollywood-dev/cart-
runtime/raw/master/shoppingcart-service-
main/src/main/assembly/etc/default/tomcat/lib/jamontomcat-2.73.jar
RUN cd /opt/tomcat/apache-tomcat-7.0.72/webapps && curl -O
http://git.tm.tmcs/corch-hollywood-dev/cart-
runtime/raw/master/shoppingcart-service-
main/src/main/assembly/etc/default/tomcat/webapps/jamon.war
```

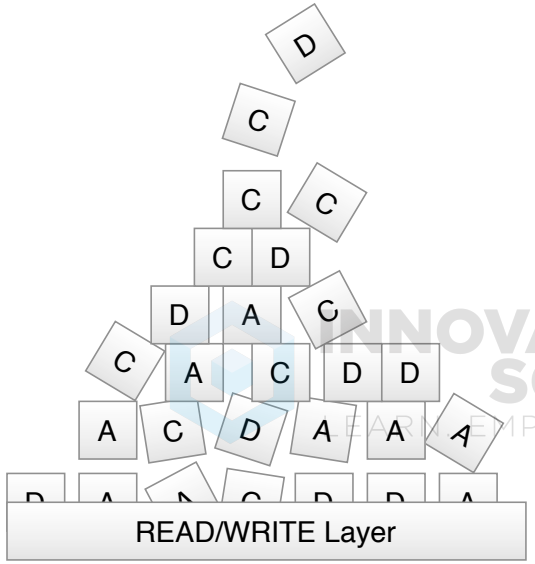
Use of &&

```
# Dockerfile to build CartRT container images
# Based on Ubuntu
FROM 889199535989.dkr.ecr.us-east-1.amazonaws.com/java/java8:1.8.0_25
# File Author / Maintainer
MAINTAINER TicketsRus comme eapi-
ticketsrus@LNEAllAccess.onm crosoft.com
# Make directory on CoreOS or tomcat, download and un-tar the tomcat
installable
RUN mkdir -p /opt/tomcat && \
   cd /opt && \
   curl -s -L -o - 'http://supergsego.com/apache/tomcat/tomcat-
7/v7.0.72/bin/apache-tomcat-7.0.72.tar.gz' | tar -C /opt/tomcat -zxf -
# Getting jamon dependencies
RUN cd /opt/tomcat/apache-tomcat-7.0.72/lib && curl -O
http://git.tm.tmcs/corch-hollywood-dev/cart-
runtime/raw/master/shoppingcart-service-
main/src/main/assembly/etc/default/tomcat/lib/jamon-2.73.jar
RUN cd /opt/tomcat/apache-tomcat-7.0.72/lib && curl -O
http://git.tm.tmcs/corch-hollywood-dev/cart-
runtime/raw/master/shoppingcart-service-
main/src/main/assembly/etc/default/tomcat/lib/jamontomcat-2.73.jar
RUN cd /opt/tomcat/apache-tomcat-7.0.72/webapps && curl -O
http://git.tm.tmcs/corch-hollywood-dev/cart-
runtime/raw/master/shoppingcart-service-
main/src/main/assembly/etc/default/tomcat/webapps/jamon.war
```

Key Takeaways

Docker Images are:

- Highly portable and readily available
- Is a defined state of software
- Reusable for many deployments



Build Docker Images (Docker build)

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Build a Docker Image (Dockerfile)

The `docker build` command is used to ”bake” an image

- Uses Dockerfile
- Most common flag is `–t` which names the image and (optionally) tags it

`build` flags	Description
-- pull	Pull new version of the image
-m, --memory	Memory limit
--no-cache	Do not use cache when building the image
-q, --quiet	Suppress the verbose output generated by the containers

Build a Docker Image (Dockerfile)

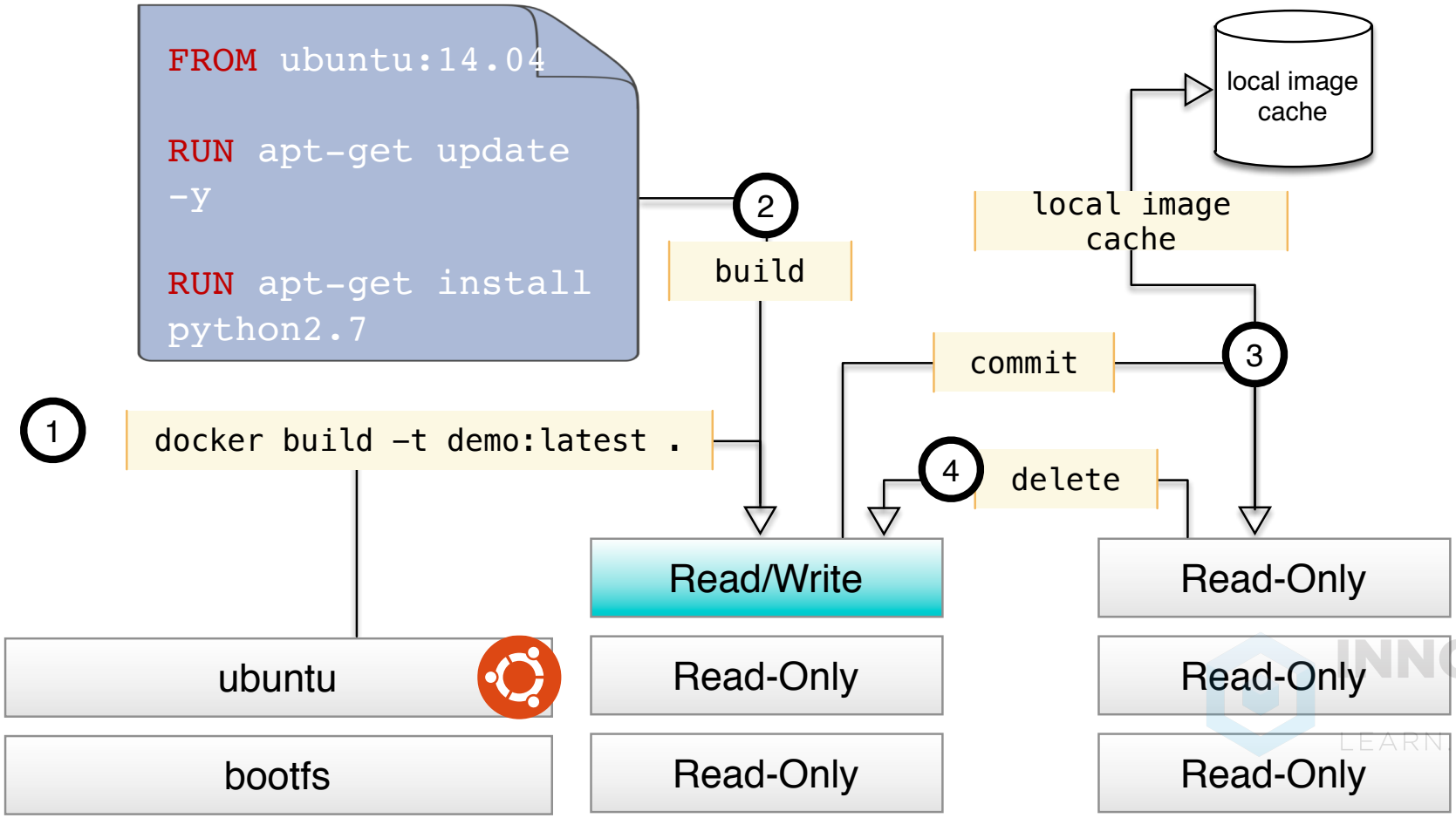

Image Tags

Version tags simplify image identification and tracking

- Common - especially with base operating systems (i.e. ubuntu:14.04)
- Allows iteration on known good versions of images, as well as enable us to know exactly what version of our image we are running
- Use multiple tags on an image for easy handling of version for dev, test, etc.
  - Ex. myimage:dev, myimage:1.1, myimage:latest

Image Lab: Task 2

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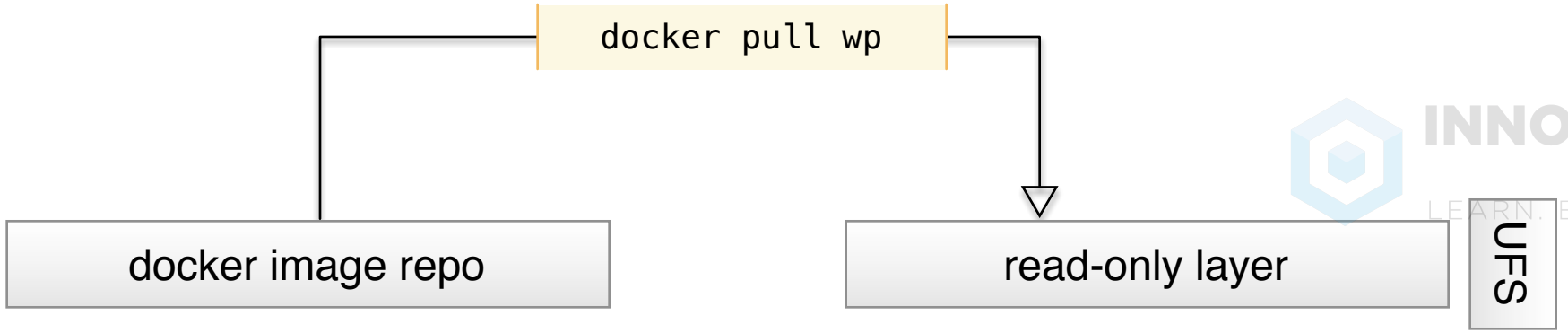
Commits on Containers

Union Filesystem

docker pull– The image is pulled from a Docker registry

```
$ docker image pull <image>
```

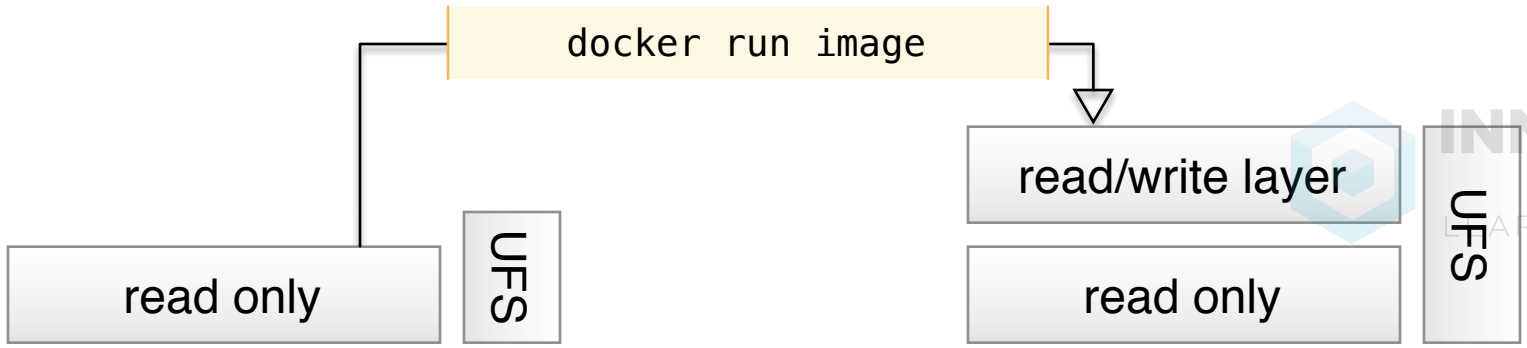


Union Filesystem

RUN – Creates a read/write layer for the container to use

ADDS, CHANGES, DELETES are written to the read/write layer, the COPY ON WRITE layer.

```
$ docker container run --options <image>
```



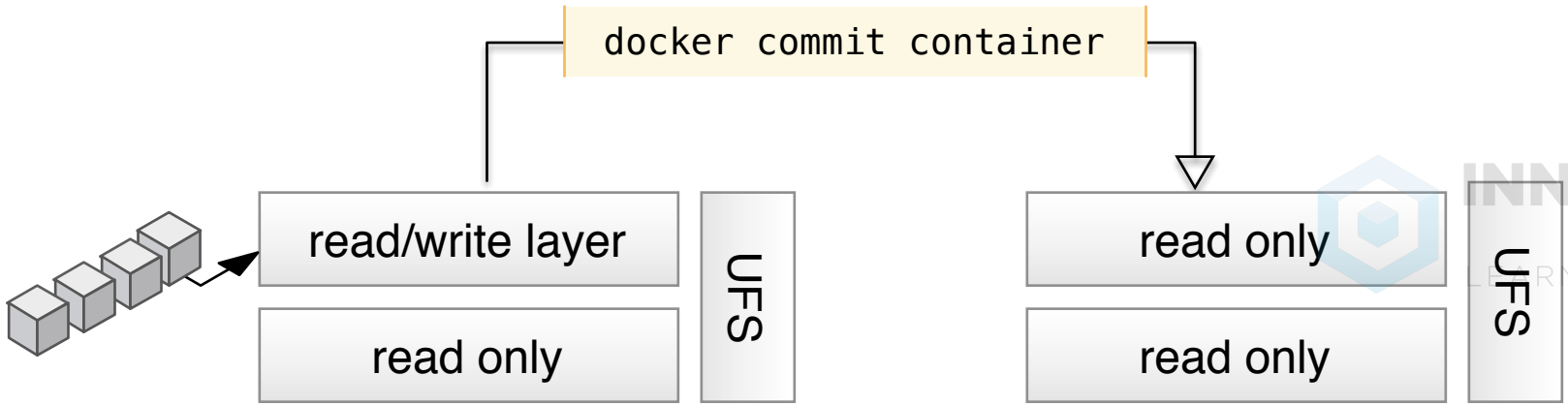
Union Filesystem

Container is committed

- When a container is committed, the READ/WRITE layer becomes a READ ONLY layer

```
docker commit -m “comment” -a “author” demo
author/demo:new
```

```
$ docker commit -m “comment” -a “author” wp <repo>/wp:tag
```



Union Filesystem

A Container run from the newly created image

- The UFS READ/WRITE READ-ONLY process starts again
- A new READ/WRITE layer is created
- Only when changes are made to to R/W UnionFS is data written

```
$ docker container run --options <repo>/wp:tag
```

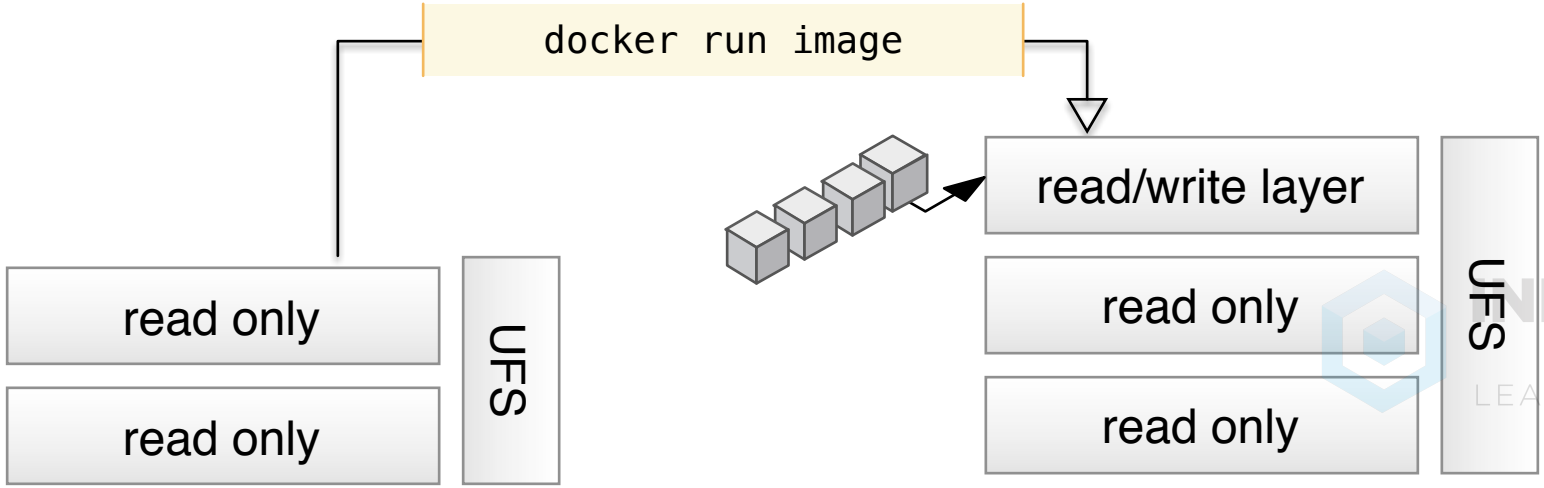
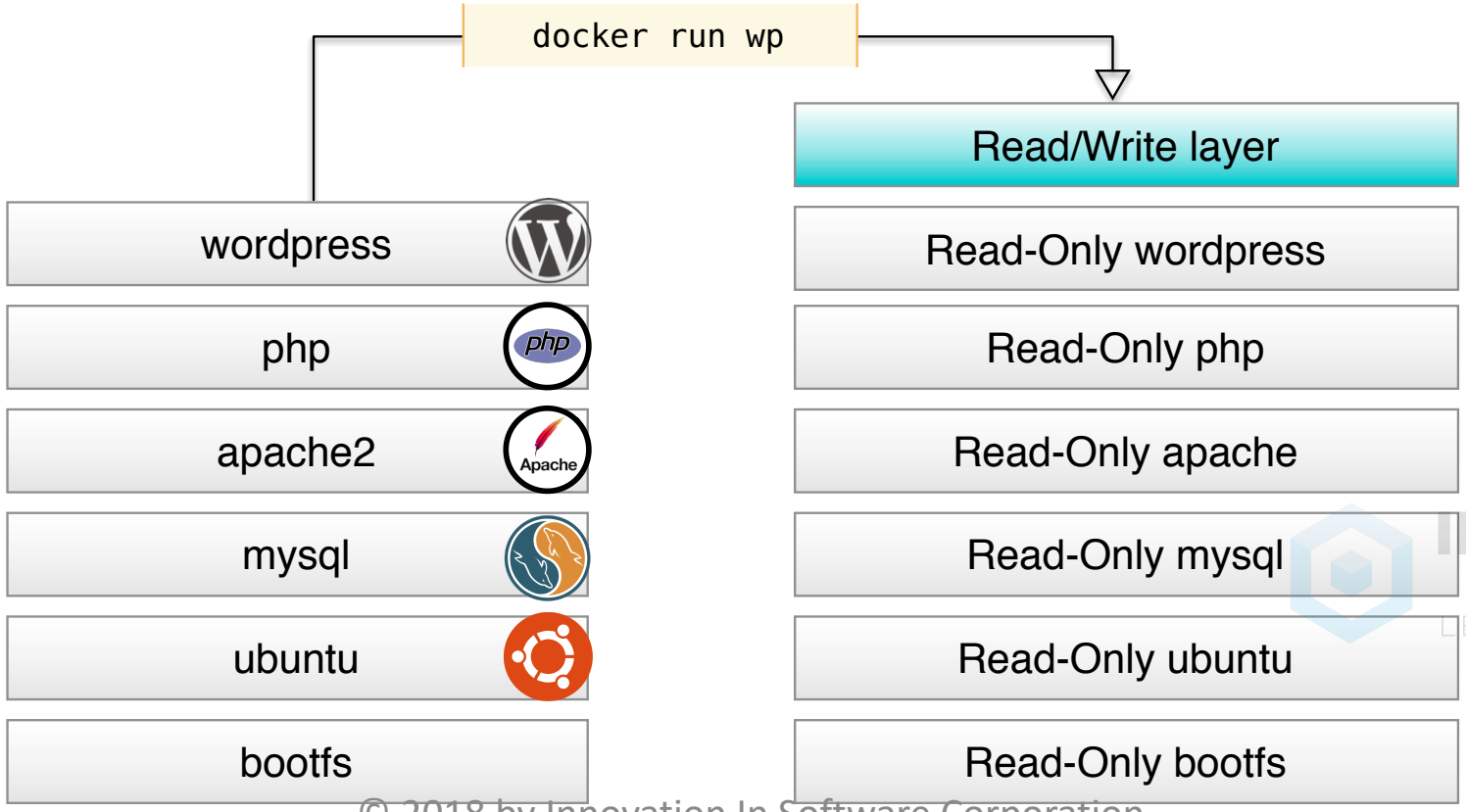


Image layers are shared by containers

Containers use the same image layers

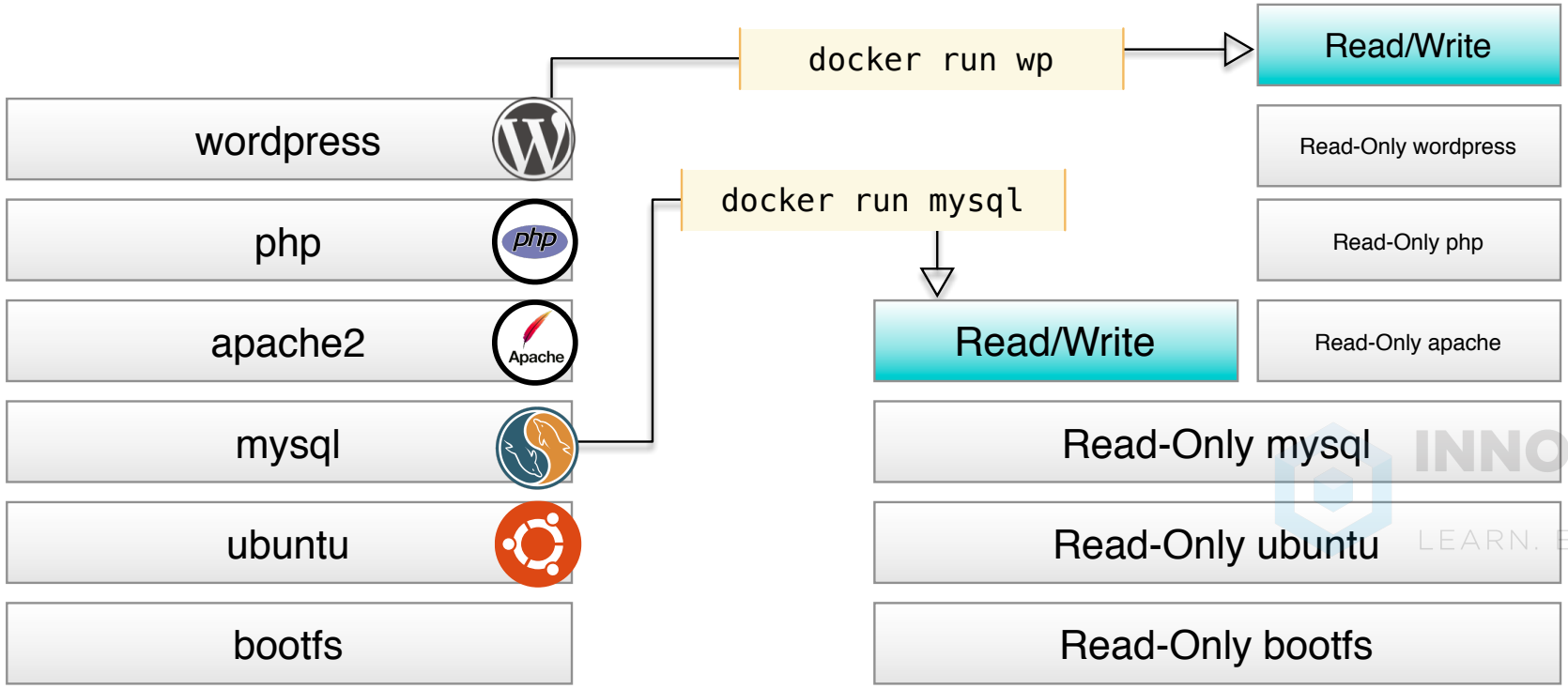
- A WordPress container is deployed, read/write layer is created



Read-Only layers are shared

Containers use the same image layers

- A WordPress container is deployed, read/write layer is created
- A MySQL container is deployed, read/write layer is created
- Read/Only layers that are common are used by both containers



Docker Image Metadata

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Image Metadata

What is it? – Image metadata describes the image through the use of key value pairs.

- **docker image inspect <id>**
  - Queries the Docker Engine, a json formatted output is returned

```
$ docker image inspect <image>
```

```
        "Id“=
         "RepoTags“=
         "RepoDigests“=
         "Parent“=
         "Comment“=
         "Created“=
         "Container“=
         "ContainerConfig"
```

Adding custom Image Metadata

```
FROM ubuntu:14.04
LABEL vendor=ACME
RUN apt-get update
RUN apt-get install
apache2 -y
```

- **LABEL** – Use LABEL in the Dockerfile to add custom metadata to images
- **{{.Config.Labels}}** – the location in the JSON of the custom entries
- **Image Size** – Two LABEL entries will result in two layers being created

```
"Labels": {
                "com.example.release-date": "2015-02-12",
                "com.example.version": "0.0.1-beta",
                "com.example.version.is-beta": "",
                "com.example.version.is-production": "",
                "vendor": "ACME Incorporated"
```

Adding Image Metadata

- Individual **LABEL** entries carry the same negative impact as **ADD**
- Using a single **LABEL** with \ break for each line reduces the image size

```
FROM ubuntu:14.04
LABEL vendor=ACME\ Incorporated \
      com.example.is-beta= \
      com.example.is-production="" \
      com.example.version="0.0.1-beta" \
      com.example.release-date="2015-02-12”

RUN apt-get update
RUN apt-get install apache2 -y
```

Why use custom Image Metadata

- **Communication** – Communicates what the image is used for
- **Groups** – Can be used to group containers

```
$ docker images --filter "label=vendor=ACME"
```

- **Guidelines for custom metadata**
  - Keys should only consist of lower-cased alphanumeric characters, dots, and dashes [a-z0-9-.]
  - Keys should start and end with an alpha numeric character
  - Keys may not contain consecutive dots or dashes
  - Keys without namespaces (dots) are reserved for CLI use
  - Guidelines are not enforced by Docker

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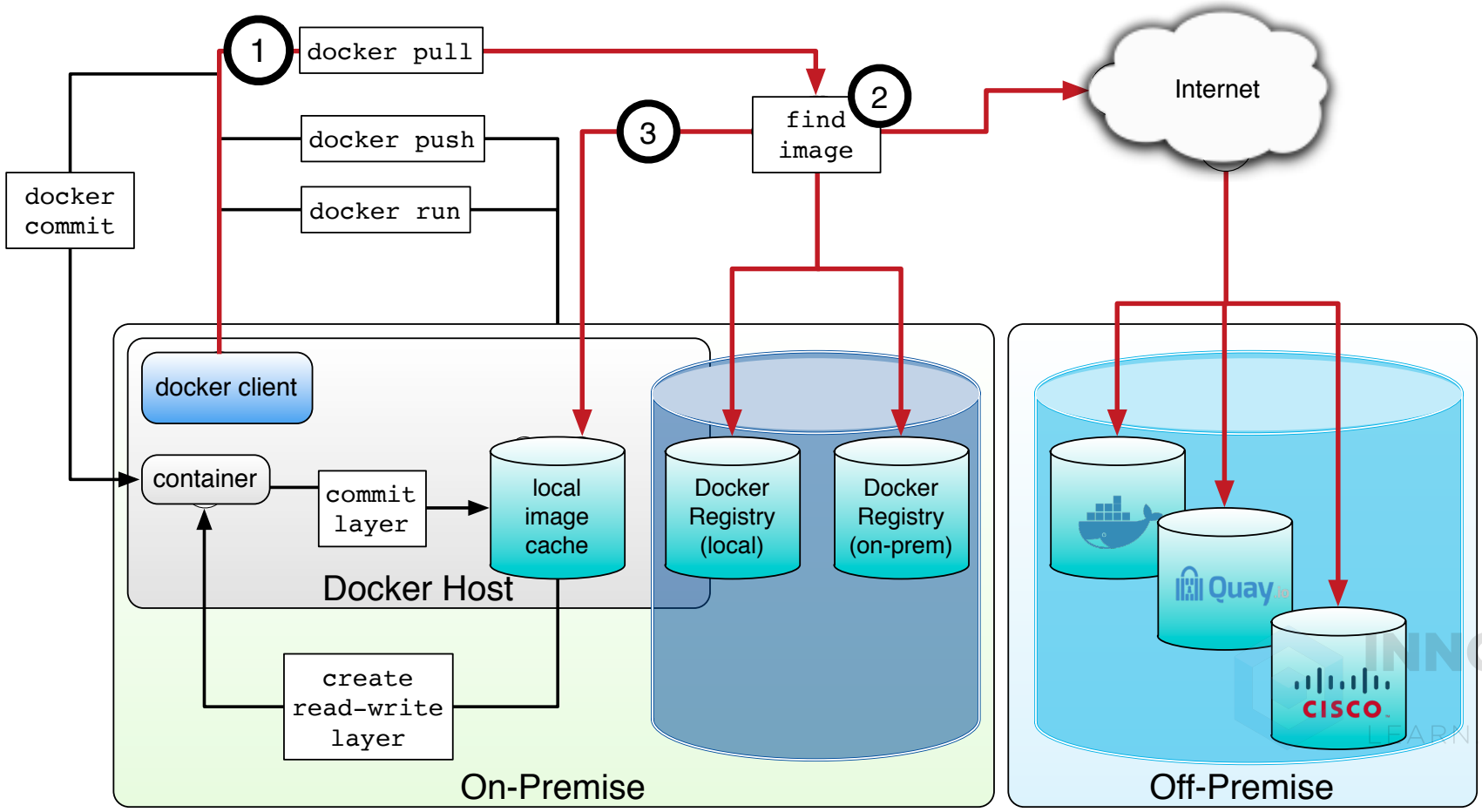
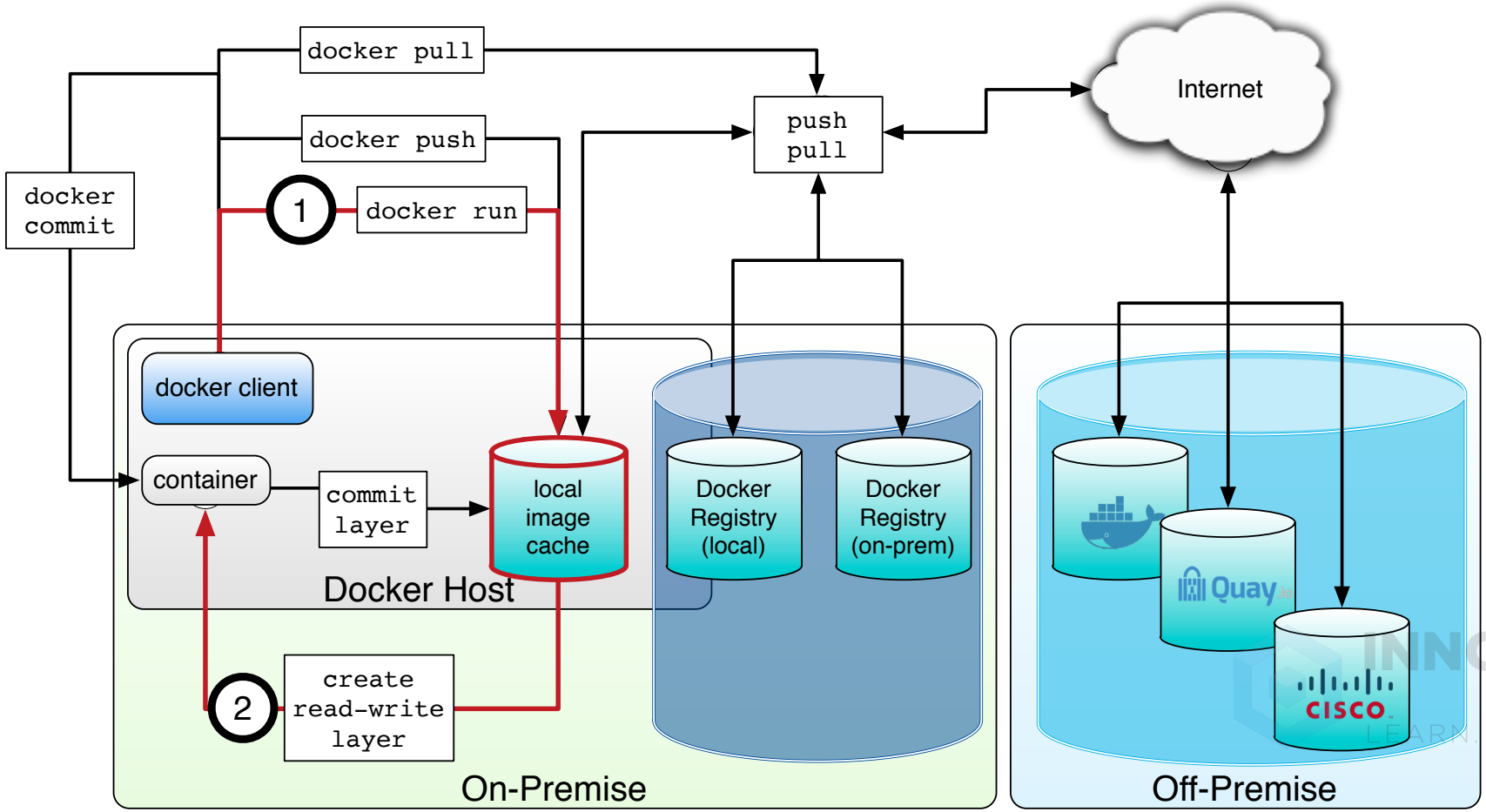
Docker Images Flow (Review)

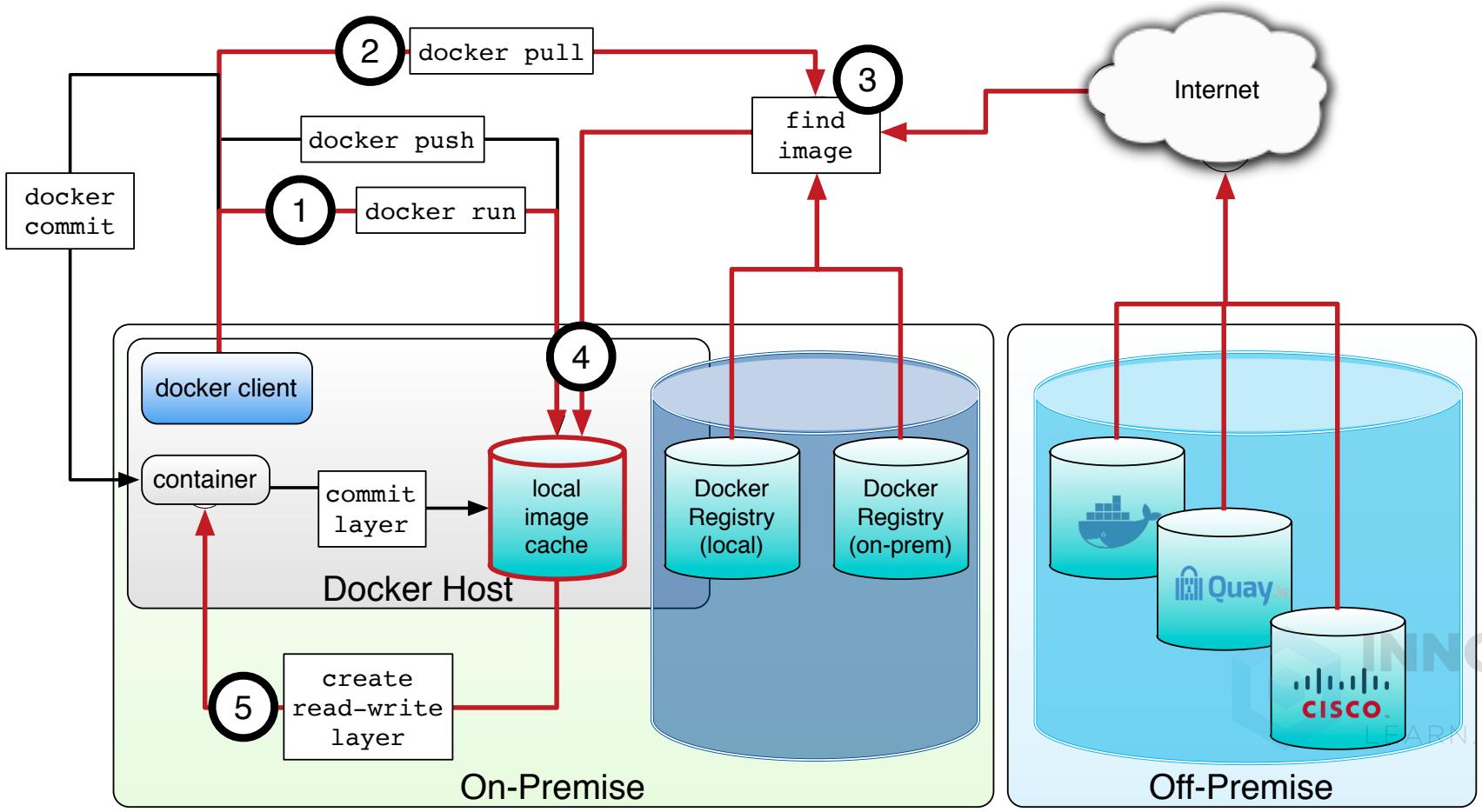
Docker Pull



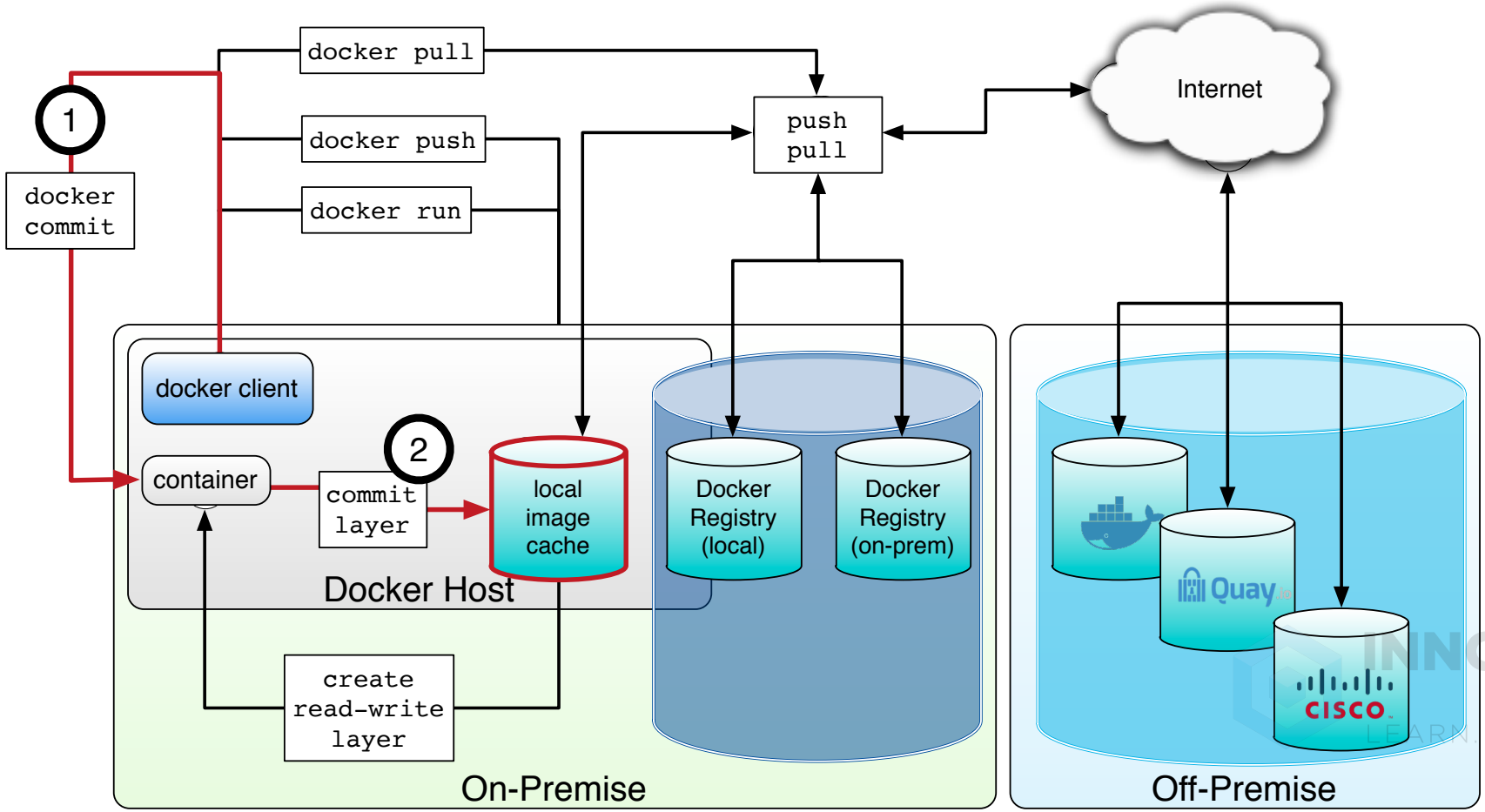
Docker Run



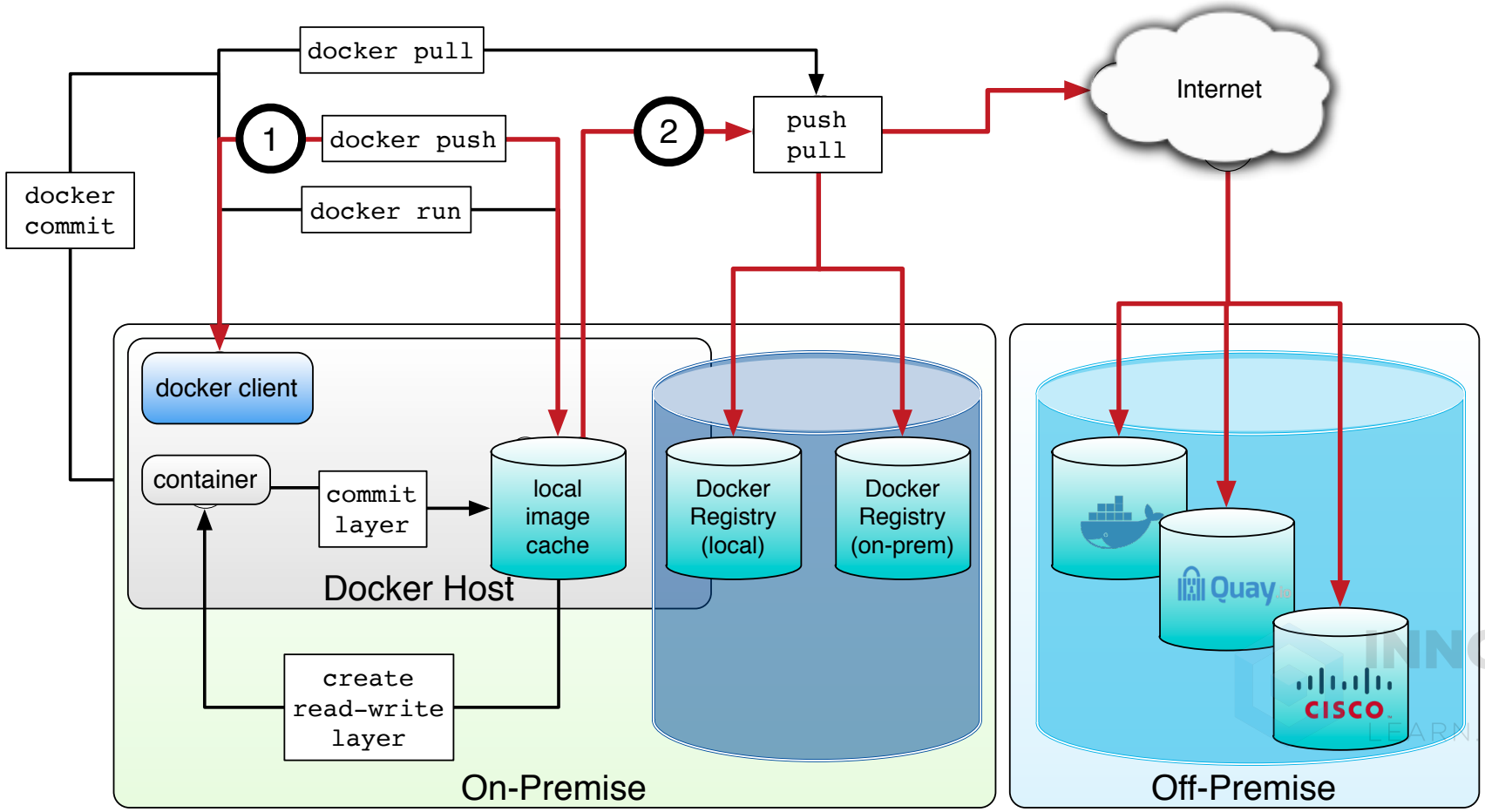
Docker Run (Image not in cache)



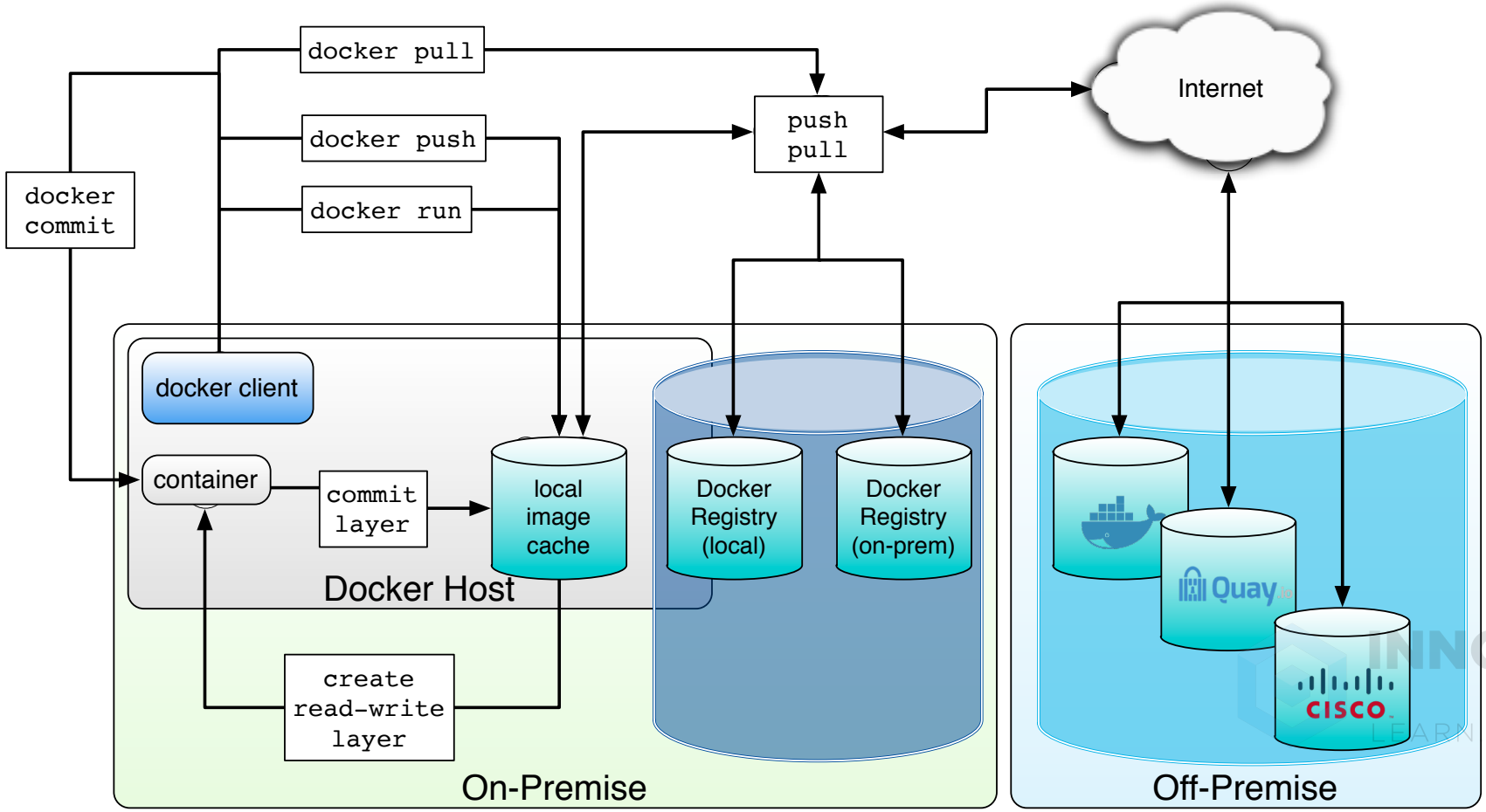
Docker Commit



Docker Push



Docker Flow



Images Lab: Task 3

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Summary, Review & QA

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Summary

- Anatomy of Docker Image
- The Union File System
- Build Images with Dockerfile
- Build Images with docker build
- Commits on Containers
- Docker Image Metadata
- Docker Image Flow

Review

- Anatomy of Images
- The Union Filesystem
- Build Docker Images with dockerfile
- Build Docker Images with a docker build
- Commits on Containers
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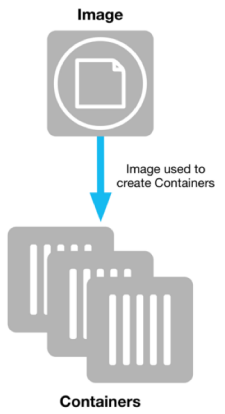
- Docker Image Flow

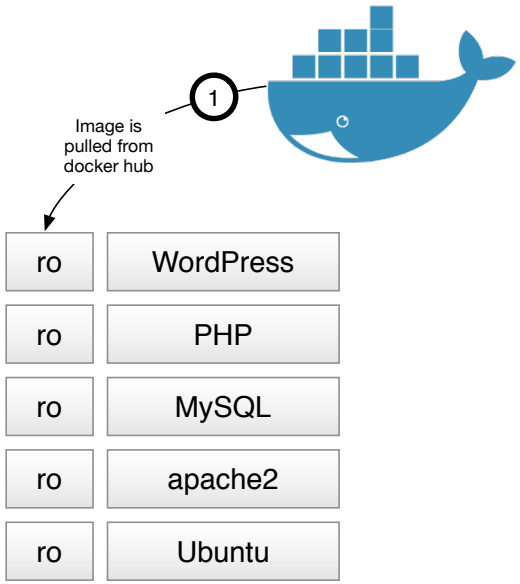
Hierarchy of files, with meta-data for how to create/run a container

- Read only template used to create containers
- Can be exported or modified to new images
- Created manually or through automated processes
- Stored in a Registry (Docker Hub, Docker Trusted Registry, etc.)



Review

- Anatomy of Images
- The Union Filesystem
- Build Docker Images with dockerfile
- Build Docker Images with a docker build
- Commits on Containers
- Docker Image Metadata
- Docker Image Flow



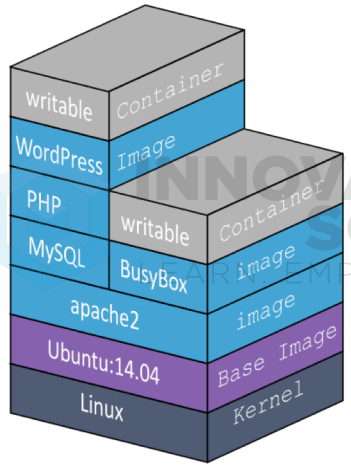
Pull an image from a Docker Registry

Run a container from an image

Add a file to a running container – Example, the image requires an additional file called index.html

Change to a running container – Example, the image requires an update of the index.php file

Delete files from a running container – All containers share the same host kernel



Review

- Anatomy of Images
- The Union Filesystem
- Build Docker Images with dockerfile
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- Commits on Containers
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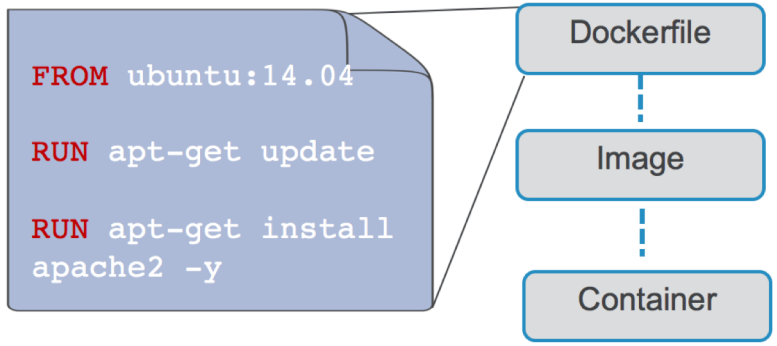
- Docker Image Flow

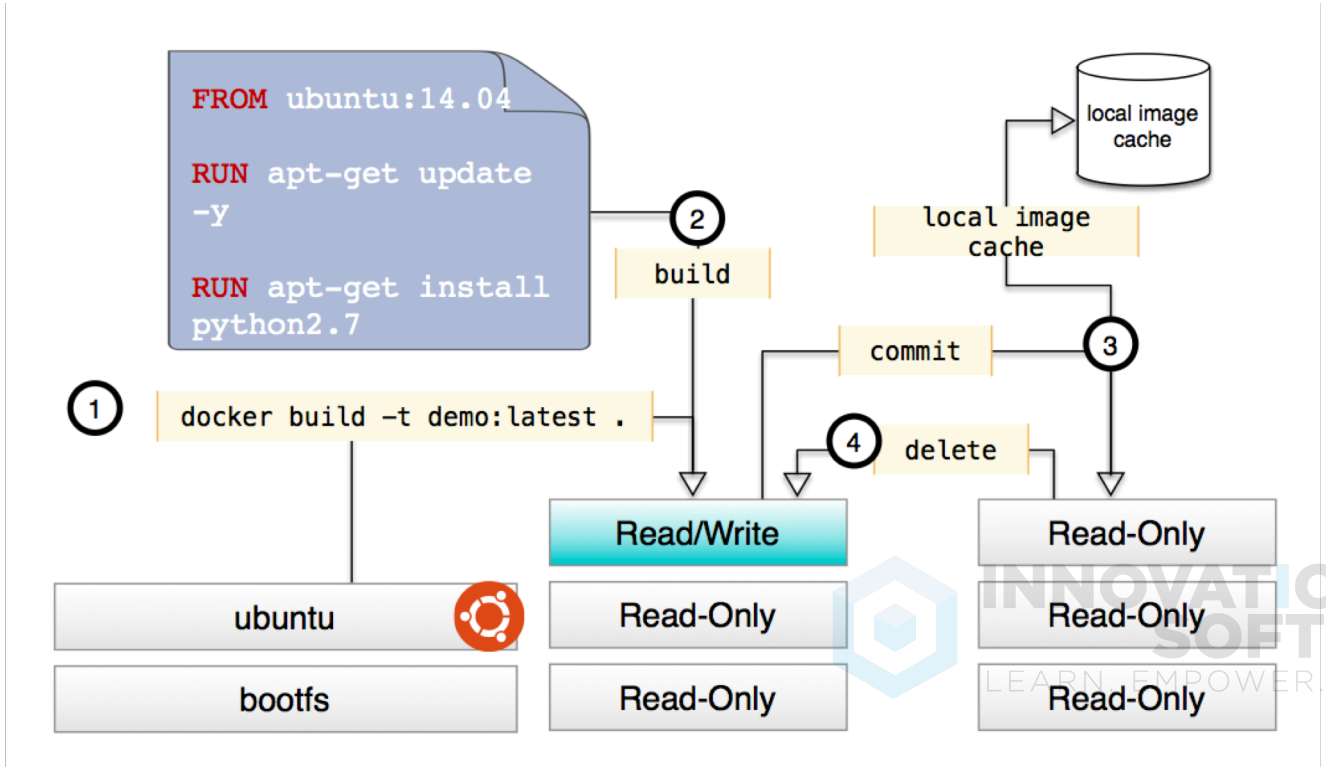


dockerfile that takes ubuntu:14.04 image and installs apache2 on top of the ubuntu:14.04 image.

Command	Description
#	A simple comment.
MAINTAINER	Provides name and contact info of of image creator
FROM	Tells Docker which base image to build on top of (i.e. centos:7)
COPY	Copies a file or directory from the build host into the build container
RUN	Runs a shell command inside the build container
CMD	Provides a default command for the container to run. May be overridden, changed, etc.
ADD	The ADD instruction copies new files, directories or remote file URLs
LABEL	The LABEL instruction adds metadata to an image

Review

- Anatomy of Images
- The Union Filesystem
- Build Docker Images with dockerfile
- Build Docker Images with a docker build
- Commits on Containers
- Docker Image Metadata
- Docker Image Flow



Review

- Anatomy of Images
- The Union Filesystem
- Build Docker Images with dockerfile
- Build Docker Images with a docker build
- Commits on Containers
- Docker Image Metadata
- Docker Image Flow

```
$ docker pull <image>
```

```
   $ docker run --options <image>
```

```
$ docker commit -a "comment" -a
"author" wp <repo>/wp:tag
```

```
$ docker run --options
<repo>/wp:tag
```

Review

- Anatomy of Images
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- Build Docker Images with dockerfile
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- Commits on Containers
- Docker Image Metadata
- Docker Image Flow

What is it? – Image metadata describes the image through the use of key value pairs.

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  - Queries the Docker Engine, a json formatted output is returned

```
$ docker inspect <image>
```

```
"Id"=
"RepoTags"=
"RepoDigests"=
"Parent"=
"Comment"=
"Created"=
"Container"=
"ContainerConfig"
```

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$ docker images --filter "label=vendor=ACME"
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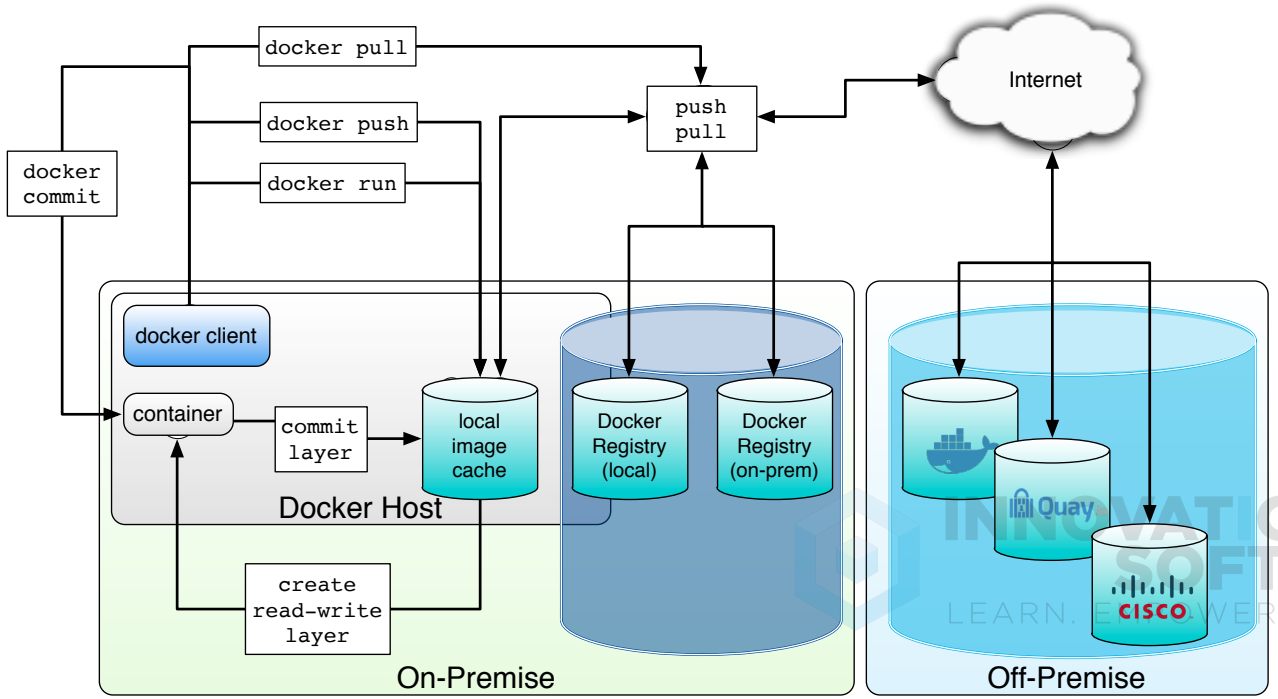
Review

- Anatomy of Images
- The Union FileSystem
- Build Docker Images with dockerfile
- Build Docker Images with a docker build
- Commits on Containers
- Docker Image Metadata
- Docker Image Flow



Docker Networking

Agenda

- Docker Networking Overview & Architecture
- Container Network Deployment Methods
- Expose Service ports
- Port Mapping Containers
- Links Containers
- User Traffic Flow
- Add Networks to Docker Bridge

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Docker Networking Overview

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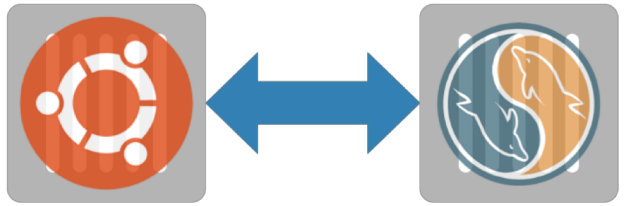
Docker Networking Overview

Docker Engine provides network access for containers that need:

- Other Containers



Docker Networking Overview

Docker Engine provides network access for containers that need:

- Other Containers
- Networks

Docker Networking Overview

Docker Engine provides network access for containers that need:

- Other Containers
- Networks

Accomplished through:

1. IP Address Management (IPAM)
2. Service Port exposure
3. Manual Port Mapping
4. Dynamic Port Mapping

Docker Networking Architecture

Network Interfaces

Docker Container

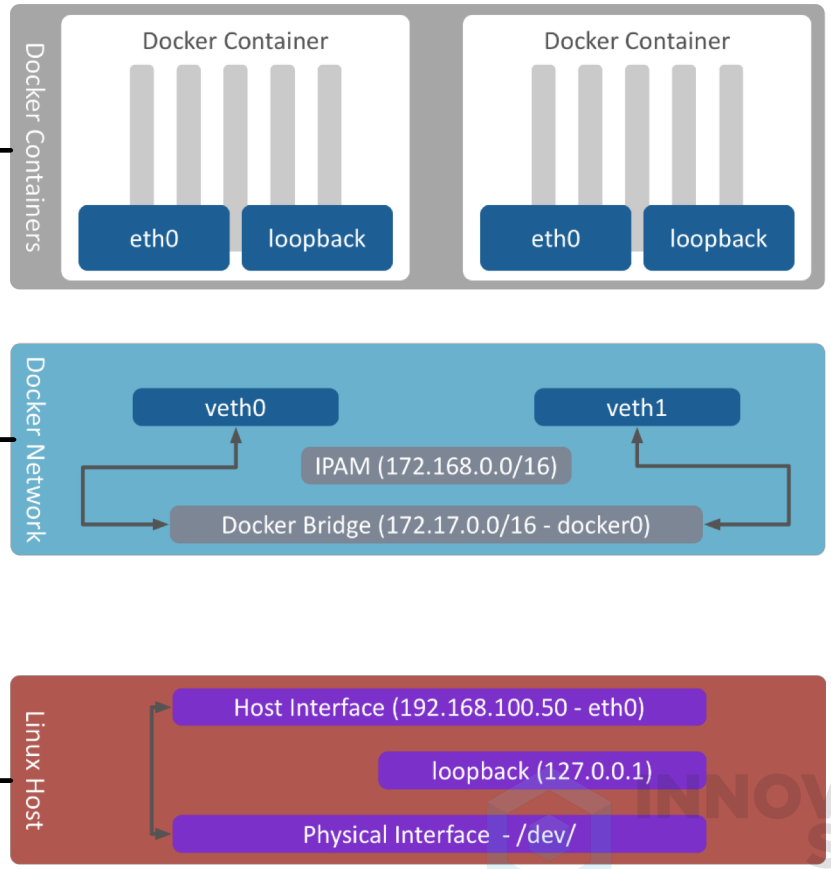
- eth0 Interface
- Loopback Interface

Docker Network

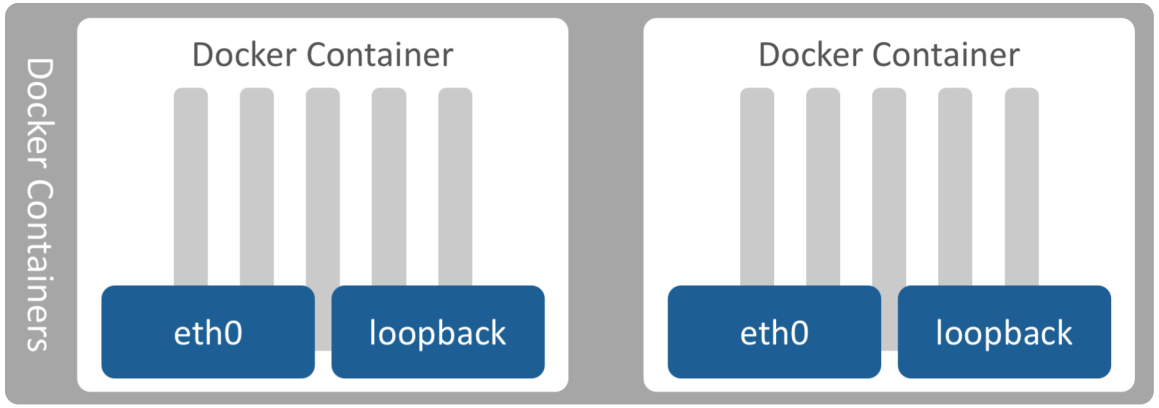
- Docker Bridge
- IP Address Management

Linux Host Network

- Host Interfaces
- Host Loopback Interface
- Physical Interfaces



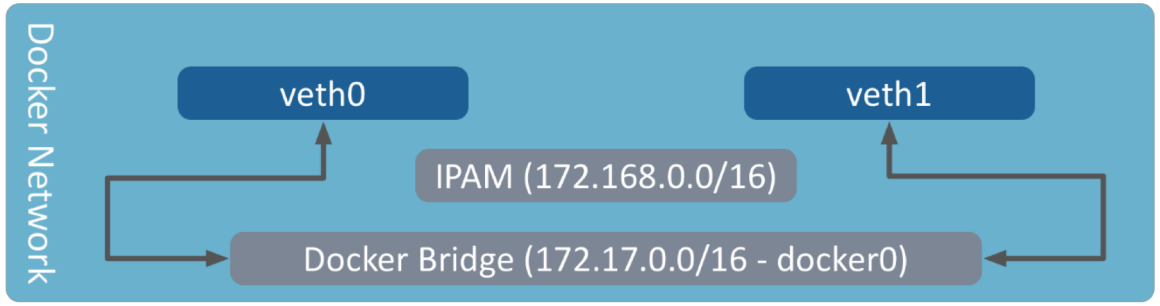
Docker Container



Docker Container

- **Loopback Interface** - used for internal communication
- **eth0 Interface** - used for external communication
- Container TCP Port Exposure

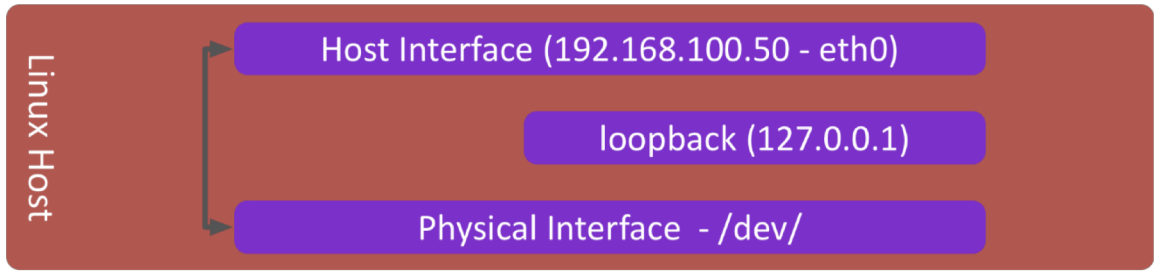
Docker Container



Docker Network

- **Docker Bridge** (e.g. docker0) - the bridge which manages traffic between Docker Engine and the Linux Host
- **veth Interfaces** - interfaces on the bridge to the containers
- **IP Address Management** - assigns IP addresses to container that require them
- Container to Host TCP Port Mapping

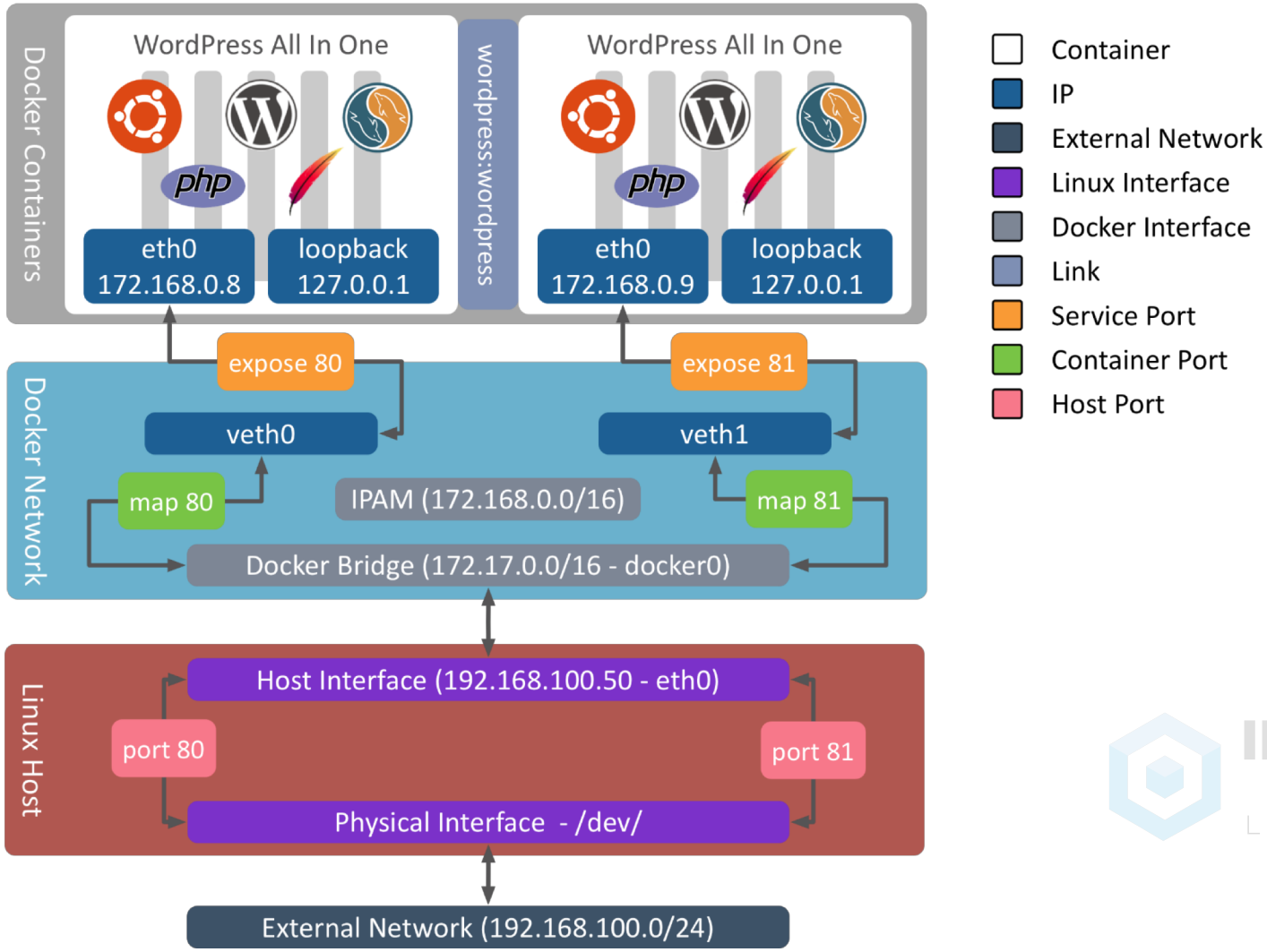
Docker Container



Linux Host Network

- **Host Loopback Interface** - host internal communication
- **Host Interfaces** - internal and external communication
- **Physical Interfaces** - sends/receives external communication to/from the outside world
- Linux Host TCP Ports

Docker Networking Architecture



Container Network Deployment Methods

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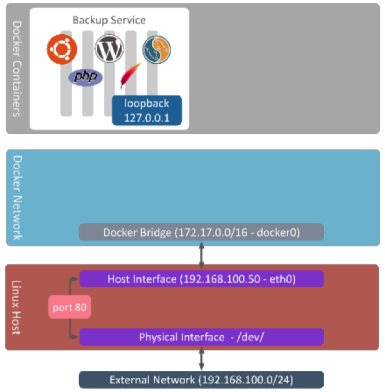
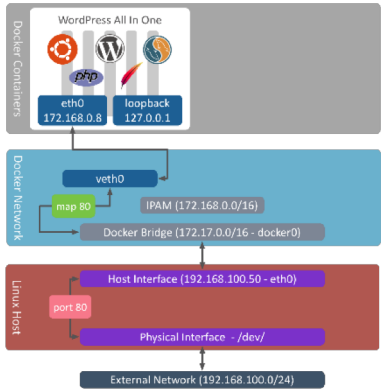
Container Network Models

Isolated Container Method



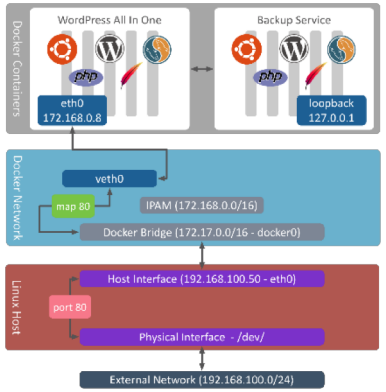
- Seldom used
- Provides the most security
- Has zero access to network resources
- Has no eth0 but has a loopback

Bridged Container Method



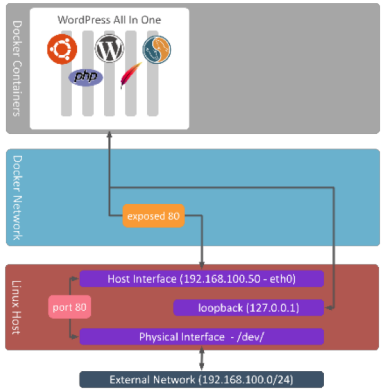
- Most commonly used
- Has limited access to network resources
- Has an eth0 and a loopback

Shared Container Method



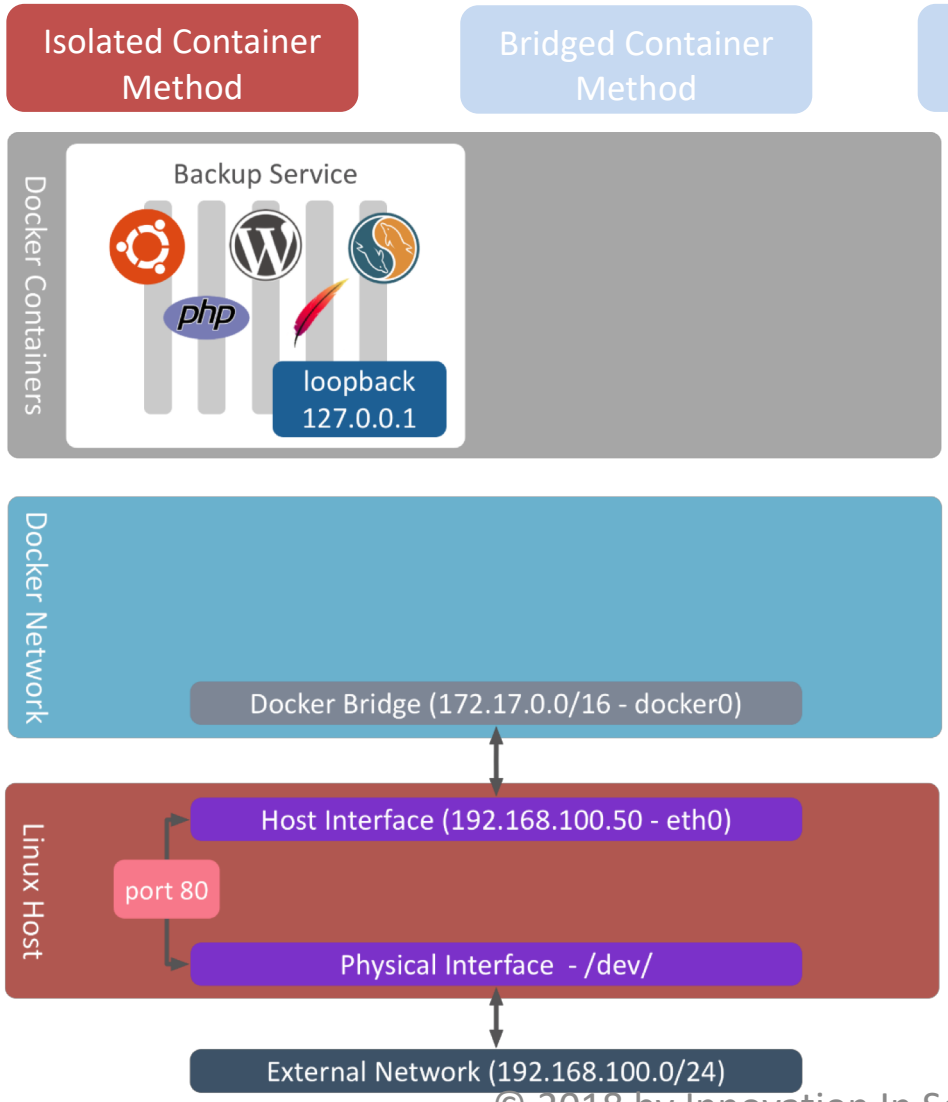
- Least used
- Has limited and no access to network resources
- Each container has either a loopback or eth0

Open Container Method



- Used as a last resort and with caution
- Unrestricted access to host network
- Uses host network and loopback

Isolated Container Method



Container has:

- No network access to the outside OR other containers
- A loopback
- Access to storage resources but not NAS/iSCSI
- e.g. Backup, Bigdata analytics, Batch jobs

Demo – Isolated Container Method

Deploy a container using --net none flag

Run“ip addr”

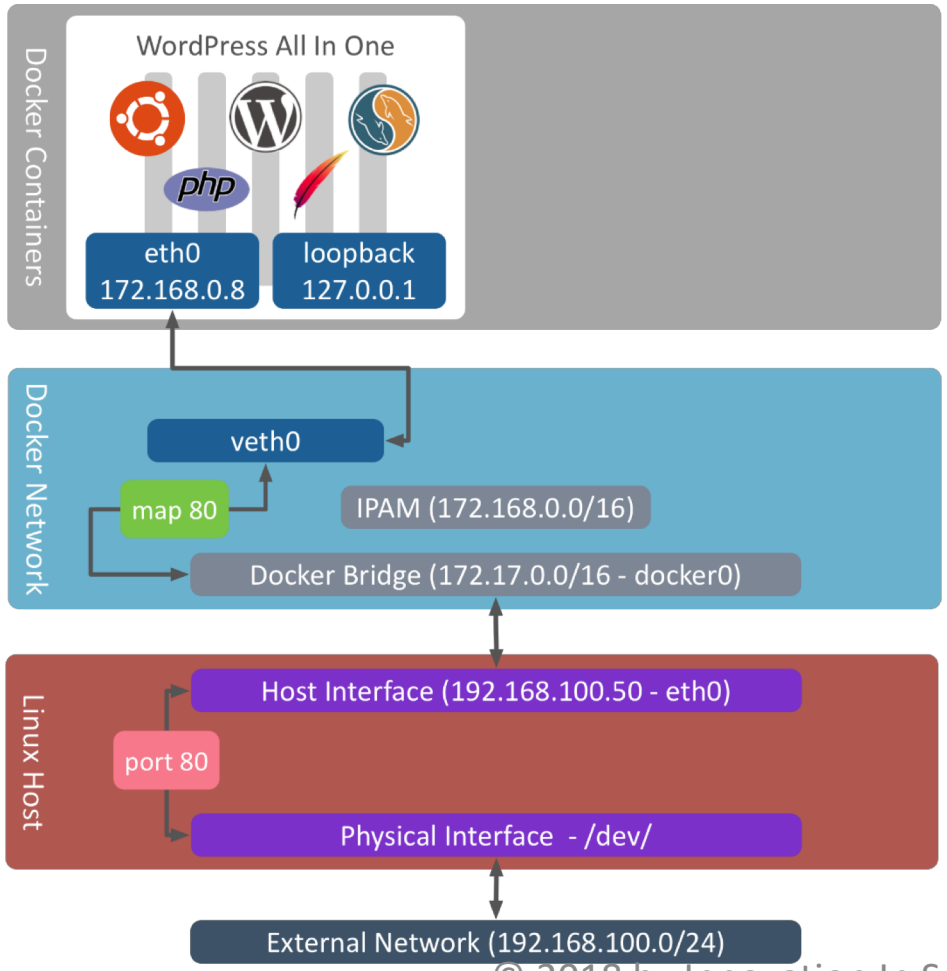
Deploy a container using --net none flag

Run “ping -w 2 8.8.8.8”

No network connectivity

Bridged Container Method (Default)

Isolated Container Method | **Bridged Container Method** | Shared Container Method | Open Container Method



Container has:

- Network access to the outside and other containers
- IP address is assigned by IPAM services (dhcp default)
- A loopback
- Access to storage resources
- e.g. Most application workloads (web servers, load balancing, database servers)

Demo – Bridged Container Method

Deploy a container using --net bridge

Review “ip addr” output

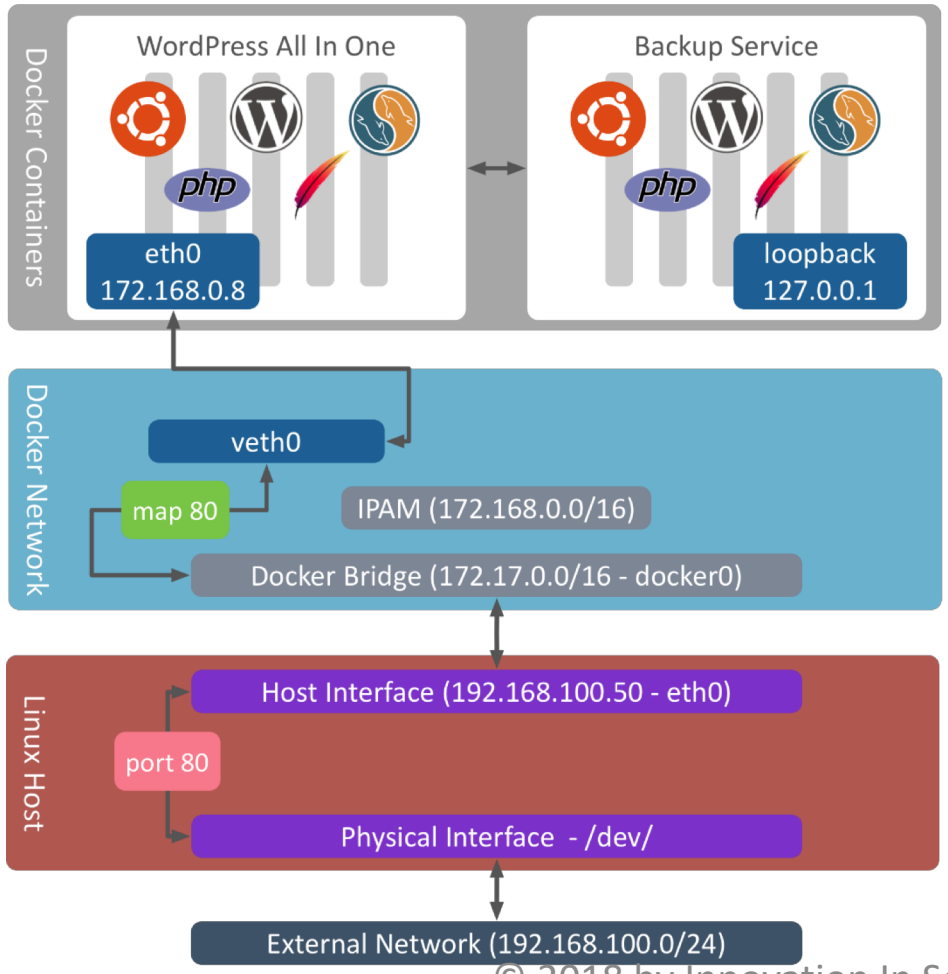
Deploy a container using no --net flag (default)

Review “ip addr” output

Deploy a container and run “ping -w 2 8.8.8.8”

Shared Container Method

Isolated Container Method | Bridged Container Method | **Shared Container Method** | Open Container Method



Container One has:

- Access to bridge network through eth0
- Uses Container B's loopback

Container Two has:

- A loopback network
- Uses Container A's eth0 to access network
- Example: "Black Box" processes

Demo – Shared Container Method

Deploy container to default bridge

Deploy second container using shared

Review container ifconfig

Review bridge network metadata

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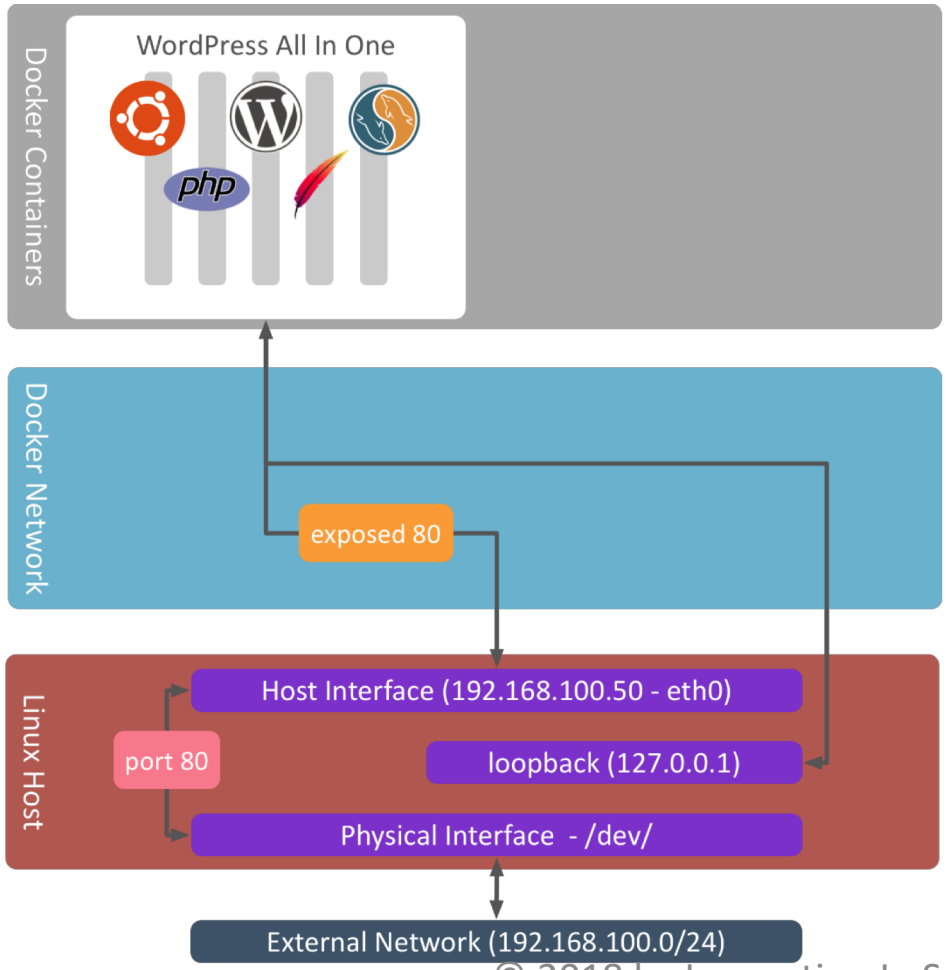
Open Container Method

Isolated Container Method | Bridged Container Method | Shared Container Method | **Open Container Method**



Container:

- Has no:
  - Ethernet interface (eth0)
  - Loopback interface (lo)
- Uses
  - Linux Host's network and loopback interfaces
  - Access the outside network through the host's network.
  - Example: Packet Capture

Demo – Open Container Method

Deploy a container using --net host

Review “ip addr” output

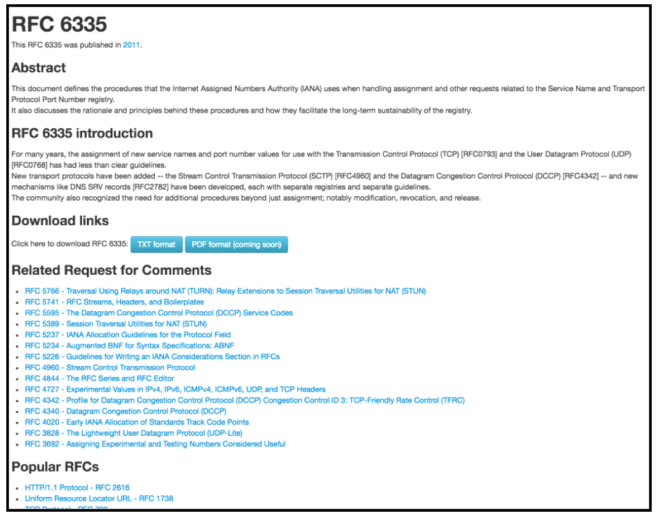
Deploy a container using --net host

Review “ping -w 2 8.8.8.8”

Service Ports

Service Ports

Service names and ports are used to distinguish between different services. Many are **defined in RFC6335**



RFC 6335

This RFC 6335 was published in 2011.

Abstract

This document defines the procedures that the Internet Assigned Numbers Authority (IANA) uses when handling assignment and other requests related to the Service Name and Transport Protocol Port Number registry.
It also discusses the rationale and principles behind these procedures and how they facilitate the long-term sustainability of the registry.

RFC 6335 introduction

For many years, the assignment of new service names and port number values for use with the Transmission Control Protocol (TCP) [RFC0793] and the User Datagram Protocol (UDP) [RFC0768] has had less than clear guidelines.
New transport protocols have been added -- the Stream Control Transmission Protocol (SCTP) [RFC4960] and the Datagram Congestion Control Protocol (DCCP) [RFC4342] -- and new mechanisms like DNS SRV records [RFC2782] have been developed, each with separate registries and separate guidelines.
The community also recognized the need for additional procedures beyond just assignment; notably modification, revocation, and release.

Download links

Click here to download RFC 6335: TXT format | PDF format (coming soon)

Related Request for Comments

- RFC 5766 - Traversal Using Relays around NAT (TURN): Relay Extensions to Session Traversal Utilities for NAT (STUN)
- RFC 5741 - RFC Streams, Headers, and Boilerplates
- RFC 5595 - The Datagram Congestion Control Protocol (DCCP) Service Codes
- RFC 5389 - Session Traversal Utilities for NAT (STUN)
- RFC 5237 - IANA Allocation Guidelines for the Protocol Field
- RFC 5234 - Augmented BNF for Syntax Specifications: ABNF
- RFC 5226 - Guidelines for Writing an IANA Considerations Section in RFCs
- RFC 4960 - Stream Control Transmission Protocol
- RFC 4844 - The RFC Series and RFC Editor
- RFC 4727 - Experimental Values in IPv4, IPv6, ICMPv4, ICMPv6, UDP, and TCP Headers
- RFC 4342 - Profile for Datagram Congestion Control Protocol (DCCP) Congestion Control ID 3: TCP-Friendly Rate Control (TFRC)
- RFC 4340 - Datagram Congestion Control Protocol (DCCP)
- RFC 4020 - Early IANA Allocation of Standards Track Code Points
- RFC 3828 - The Lightweight User Datagram Protocol (UDP-Lite)
- RFC 3692 - Assigning Experimental and Testing Numbers Considered Useful

Popular RFCs

- HTTP/1.1 Protocol - RFC 2616
- Uniform Resource Locator URL - RFC 1738

- Some Common Service Ports:
  - FTP TCP Port 21
  - SSH TCP Port 22
  - HTTP Web Server TCP Port 80
  - HTTP SSL Web Server TCP Port 443
  - LDAP TCP Port 389

Service Ports and Applications

Common TCP Service and Application Ports:

Service	Service Port
FTP	21
SSH	22
HTTP	80
Apache	80
LDAP	389
HTTPS	443
MariaDB	3306
MySQL	3307
redis	6379
tomcat	8080

Expose Service Ports

Expose Service Ports

Docker Engine provides a mechanism to expose required service ports

- Exposure is by port, not service name
- Service port exposure is required for communication with the container
- Service ports are exposed:
  - Docker Container creation
  - Docker Image creation

Expose Service Ports

Common TCP Service Ports:

Service	Service Port	Exposed Port
FTP	21	21
SSH	22	22
HTTP	80	80
Apache	80	80
LDAP	389	389
HTTPS	443	443
MariaDB	3306	3306
MySQL	3307	3307
redis	6379	6379
tomcat	8080	8080

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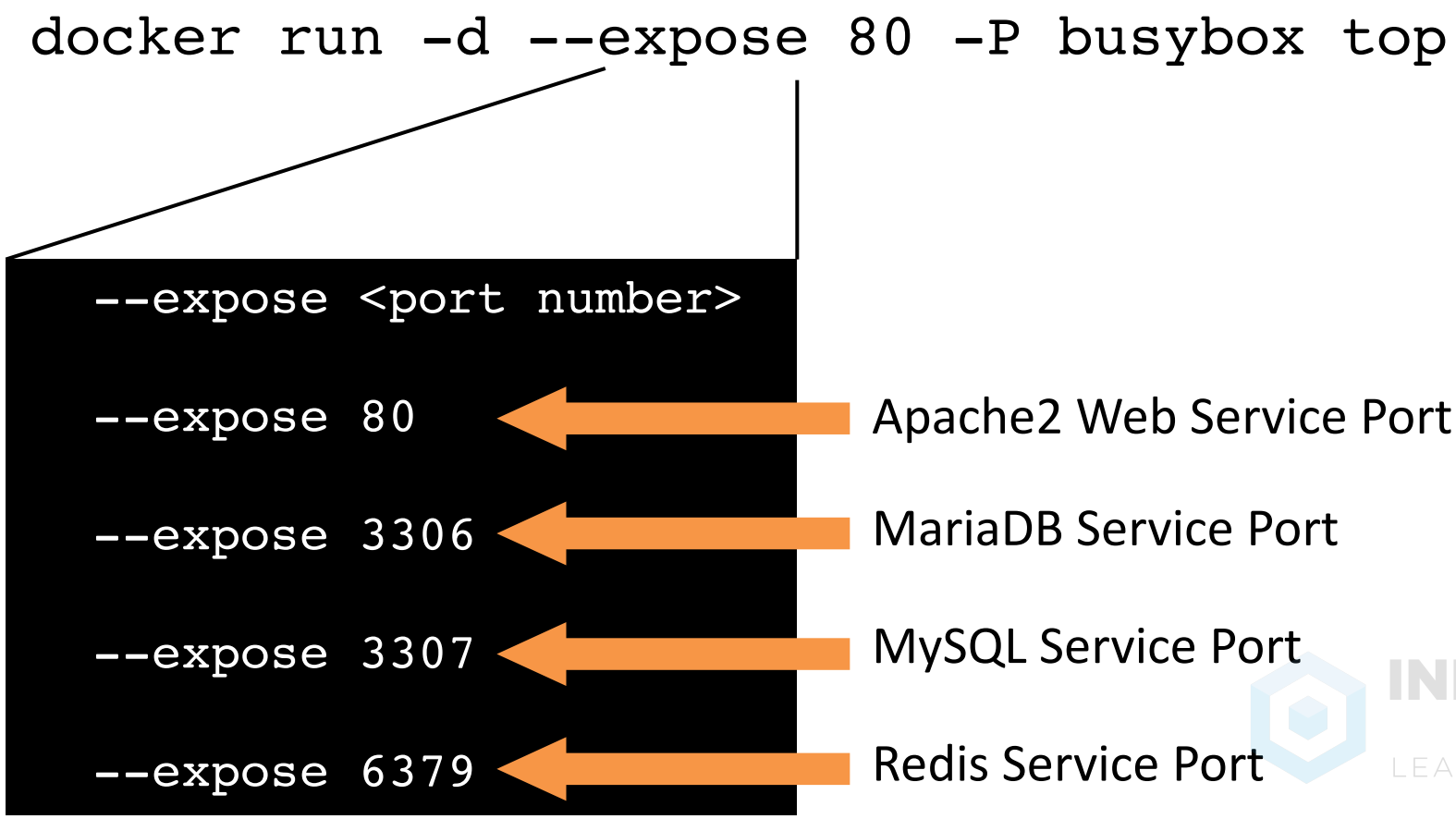
Map Ports on a Bridged Container



Demo – Expose a Service Port

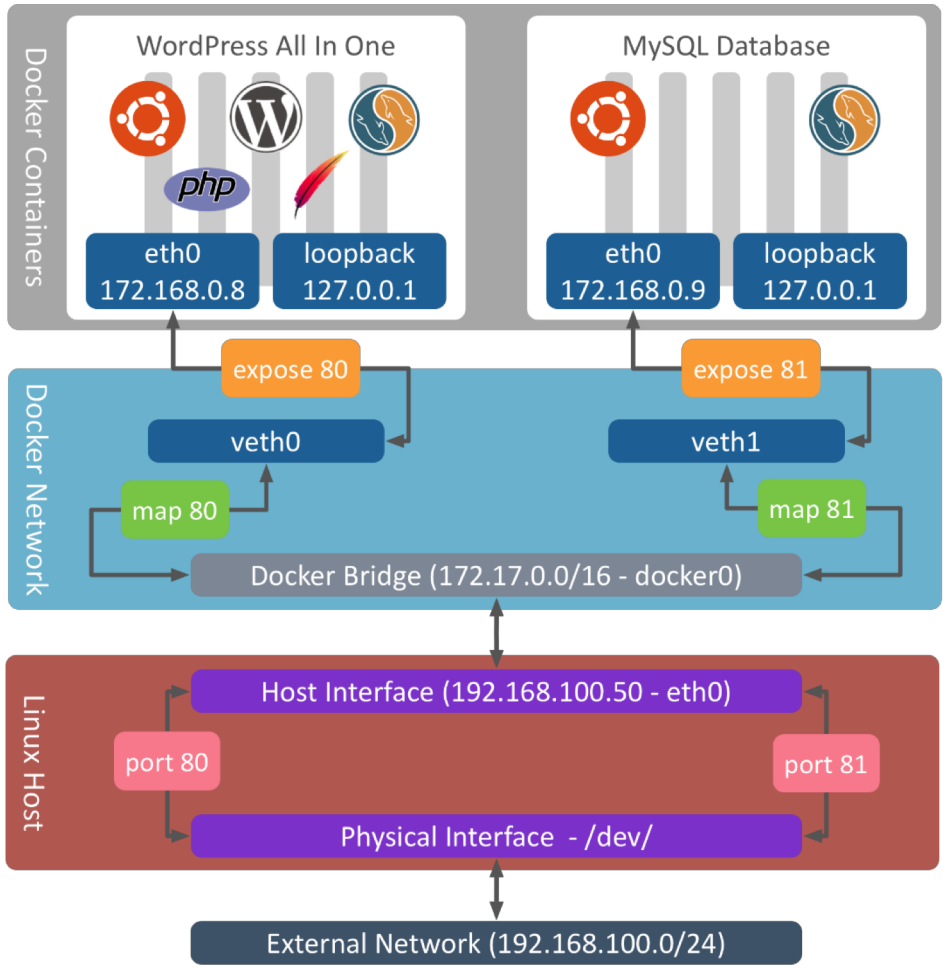
Create a Docker container using --expose flag

Run Docker port command

Run Docker inspect to validate port is exposed

Stop and remove container

Expose Container Service Ports



Container:

- Service ports are defined
- Service ports are exposed from the container
- Ports are not accessible outside Docker network

Port Mapping Containers

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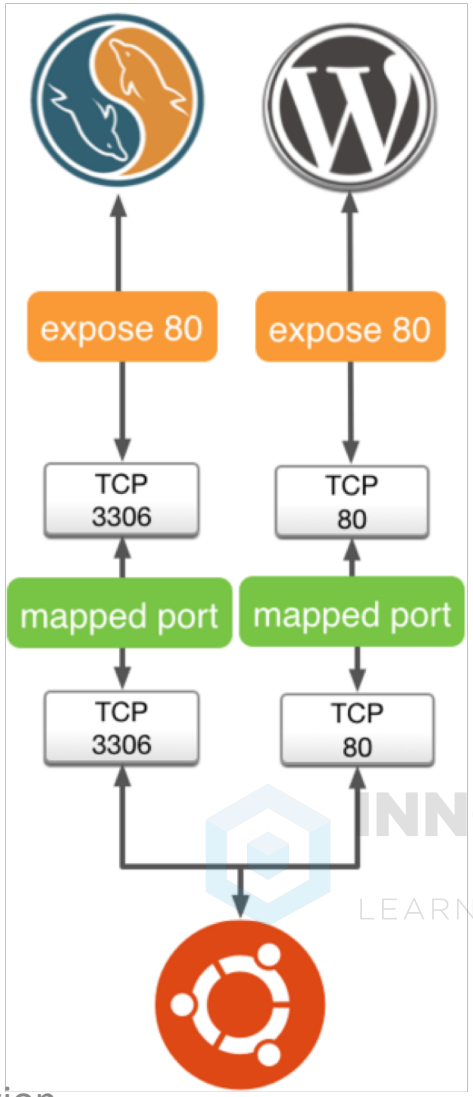
Map Exposed Service Ports

Docker provides a mechanism to map exposed service ports

- TCP ports can be mapped:
  - Dynamically
  - On all host interfaces
  - On user defined ports and interfaces
- Exposed service ports are only mapped during container creation:
  - Docker Container creation



Expose Service Ports

Common Service Ports:

Service	Service Port	Expose port	Mapped Port	Host Port
Apache2	80	80	80	33731
HTTPD	80	80	80	33732
LDAP	389	389	389	33733
MariaDB	3306	3306	3306	33734
MySQL	3307	3307	3307	33735
redis	6379	6379	6379	33736

Docker provides a mechanism to:

- map exposed service ports → mapped service ports → host TCP ports

- Note the two service ports using TCP Port 80

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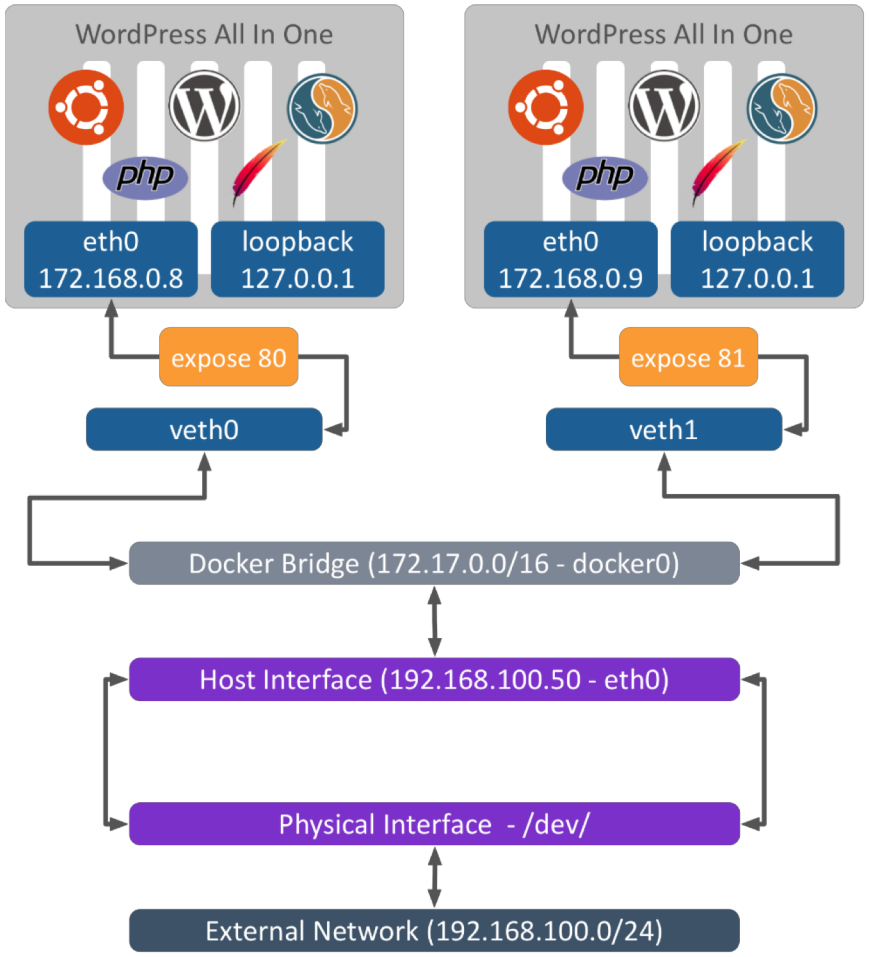
WordPress Service Ports

WordPress AIO Service Ports:

Service	Service Port	Exposed Port	Mapped Port	Host Port
WPAIO01	80	80	80	33731
WPAIO02	80	80	80	33732
WPAIO03	80	80	80	33733
WPAIO04	80	80	80	33734
WPAIO05	80	80	80	33735
WPAIO06	80	80	80	33736

The above table depicts how a single Linux Host can host up six WordPress AIO(s) on container port 80, using dynamically assigned ports on the Linux Host

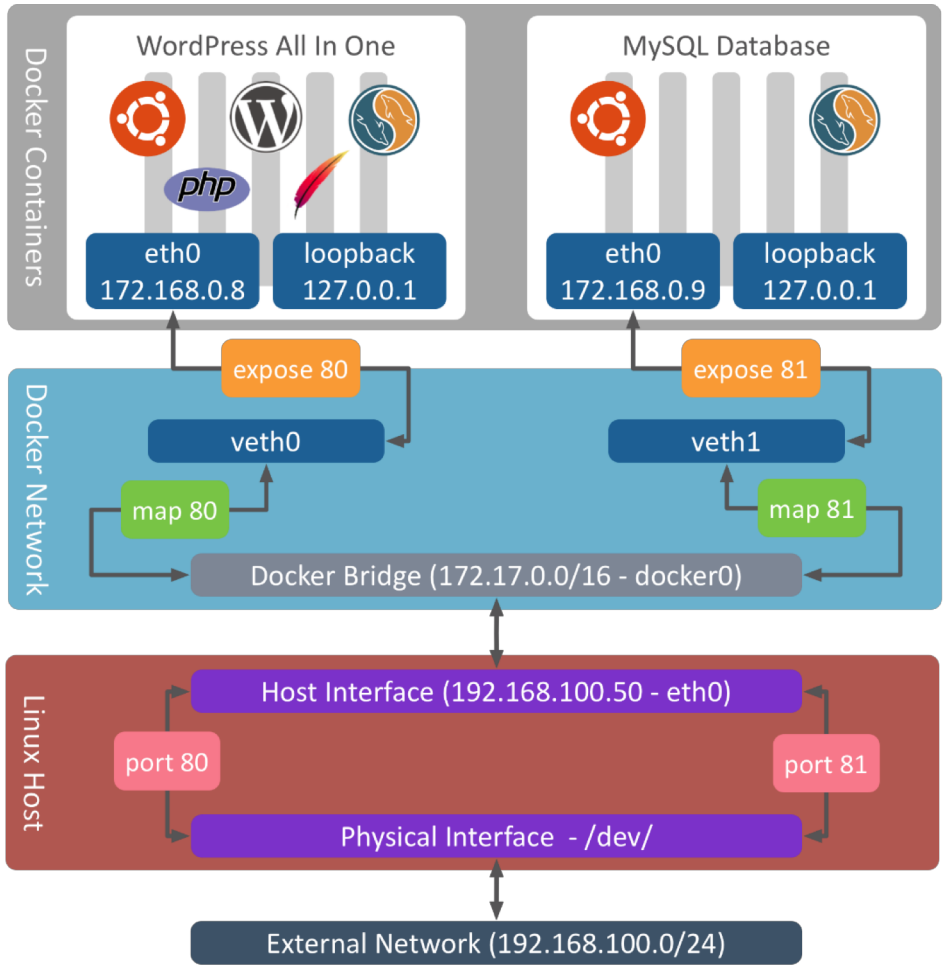
Expose Container Service Ports



Container:

- Service ports are defined
- Service ports are exposed from the container
- Ports are not accessible

Map Container Service Ports



Container:

- Service Ports are known
- Ports are exposed from the container
- Host ports are mapped to container ports for accessibility

Demo – Container Service Ports

Create a Docker container using --expose flag and the -P flag

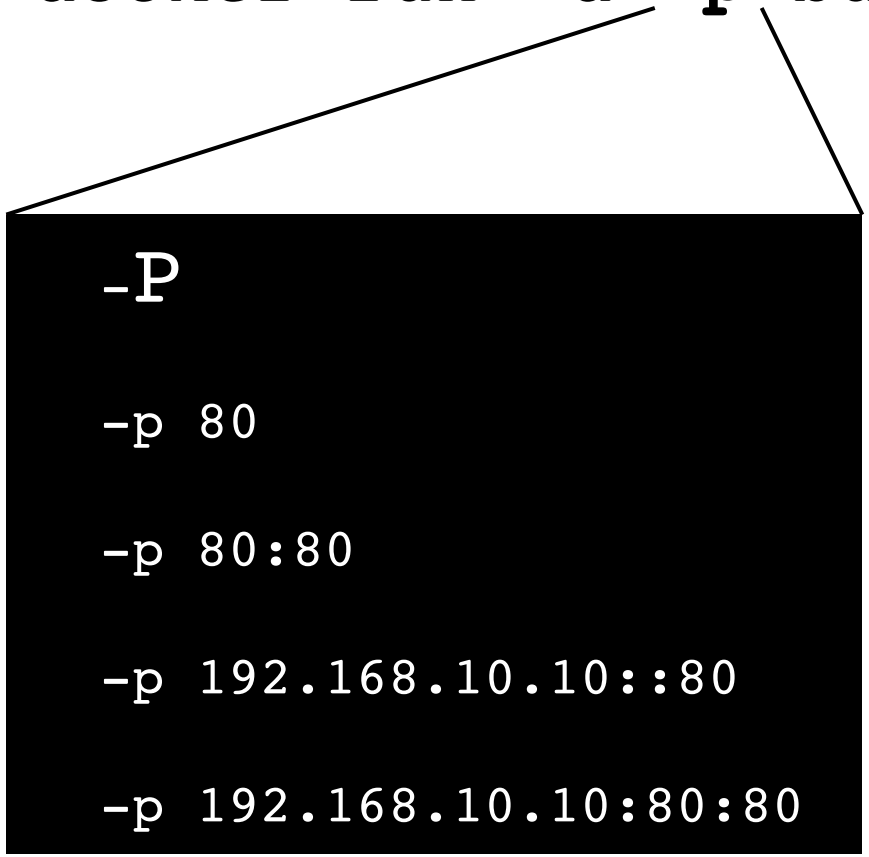
Run Docker port command to validate port is mapped to all interfaces (0.0.0.0)

Run Docker inspect to validate port is exposed

Stop and remove container

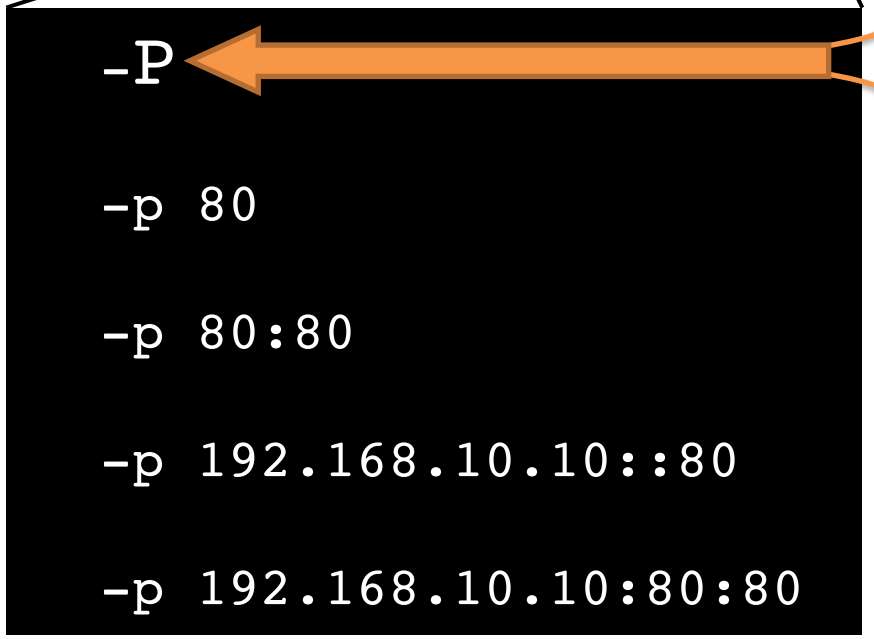
Map Ports on a Bridged Container

```
docker run -d -p busybox:latest top
```



Map Ports on a Bridged Container

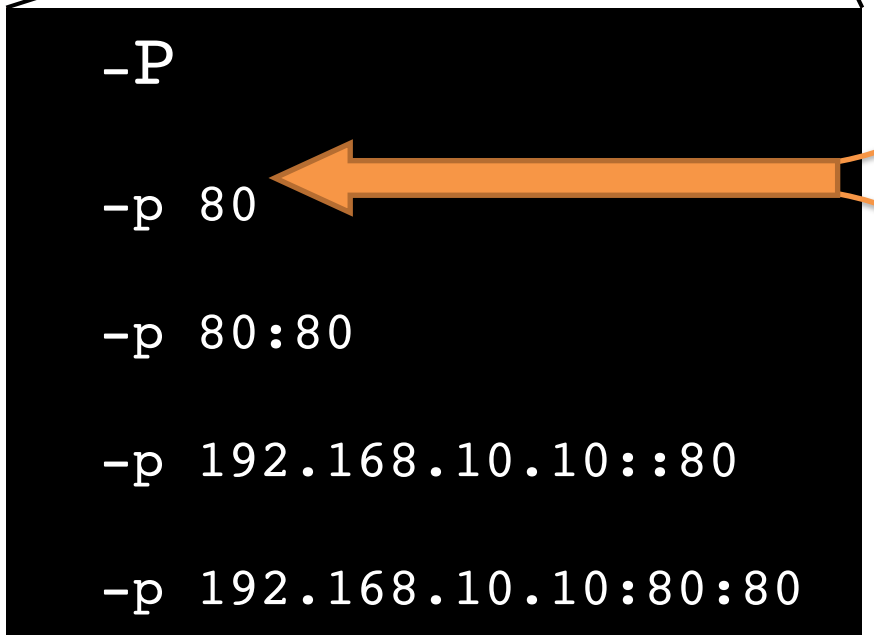
```
docker run -d -p busybox:latest top
```



- Map exposed ports to all host interfaces
- Random host ports
- Ports must be exposed
- Capital **P** not p

Map Ports on a Bridged Container

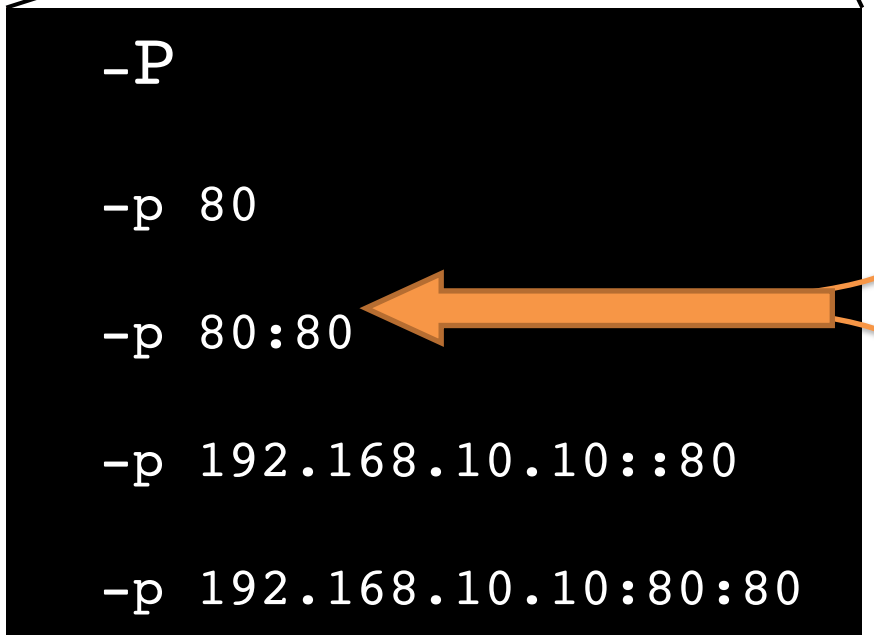
```
docker run -d -p busybox:latest top
```



- Maps container port 80 to random host port on all host interfaces

Map Ports on a Bridged Container

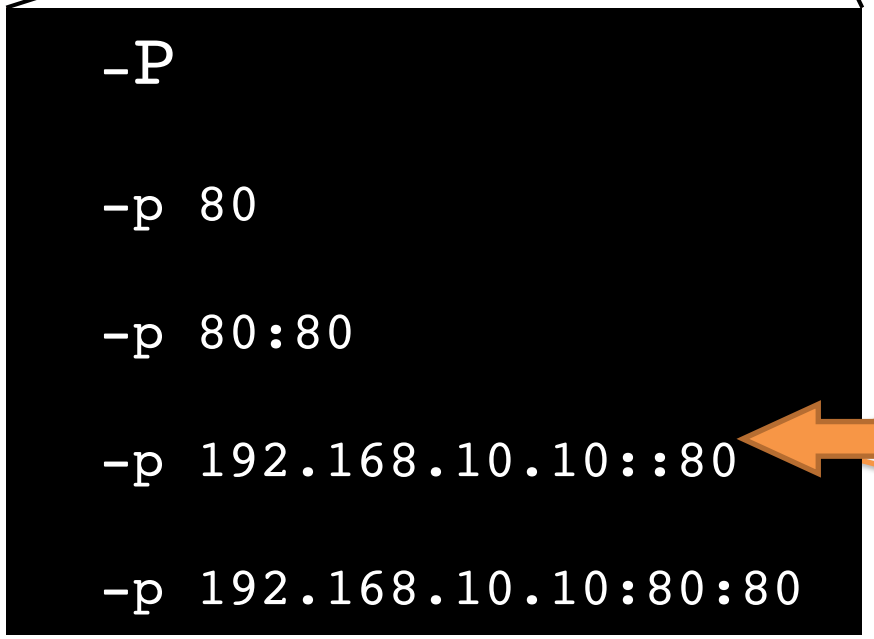
```
docker run -d -p busybox:latest top
```



- Maps container port 80 to host port 80 on all host interfaces

Map Ports on a Bridged Container

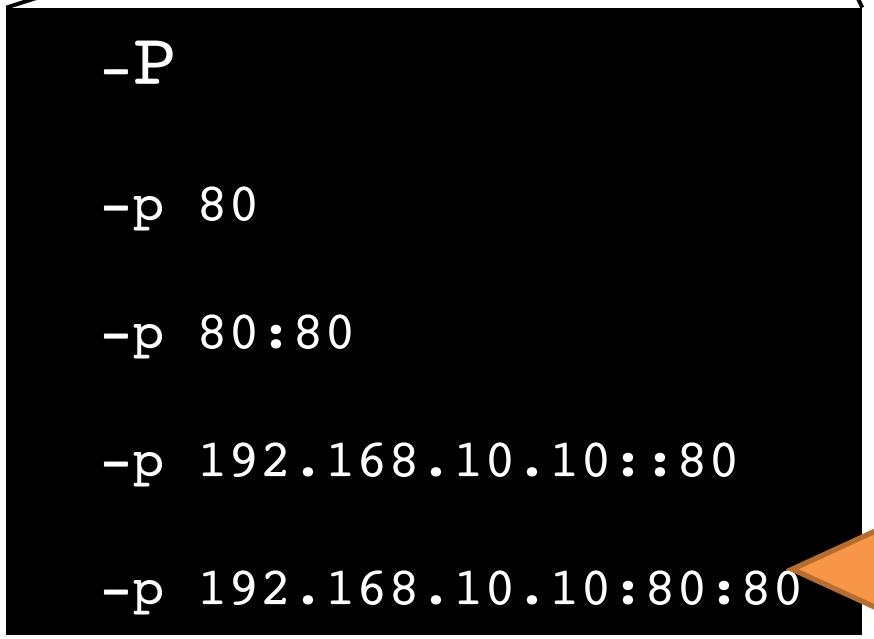
```
docker run -d -p busybox:latest top
```



- Maps container port 80 to random host port on specified host interface

Map Ports on a Bridged Container

```
docker run -d -p busybox:latest top
```



- Maps container port 80 to host port 80 on host specified host interface

Networking Lab: Task 1

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Link Containers

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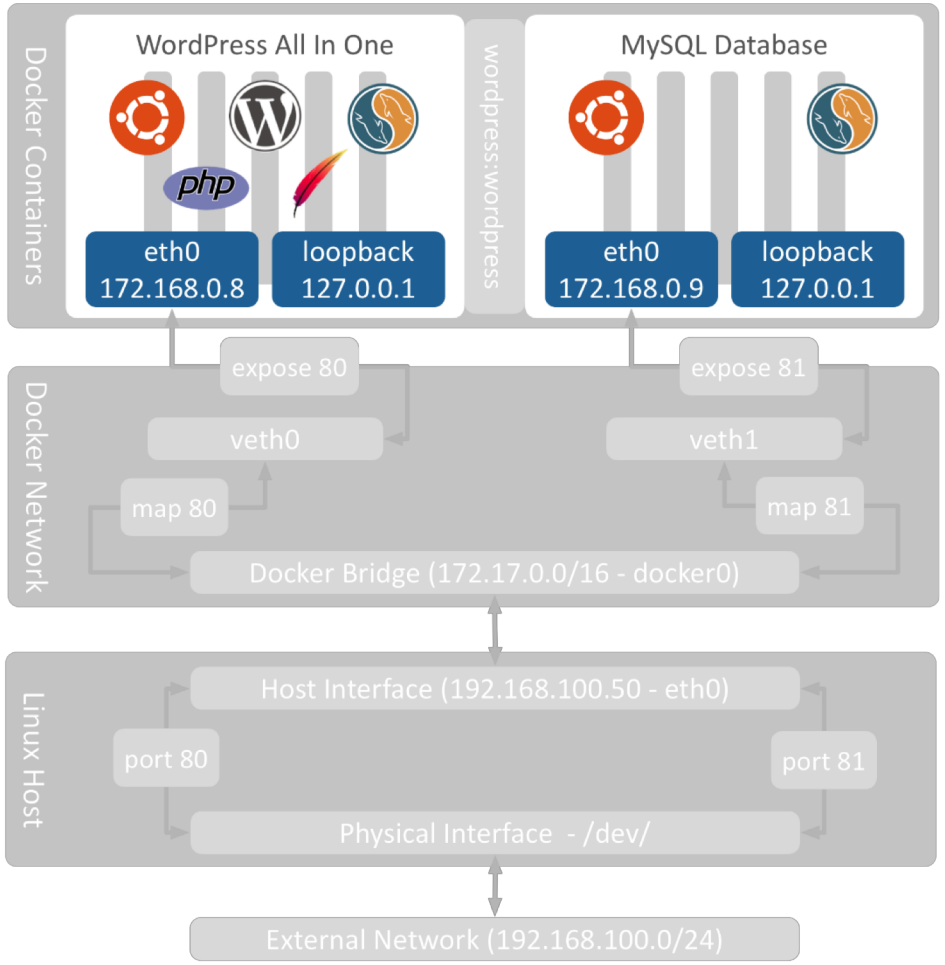
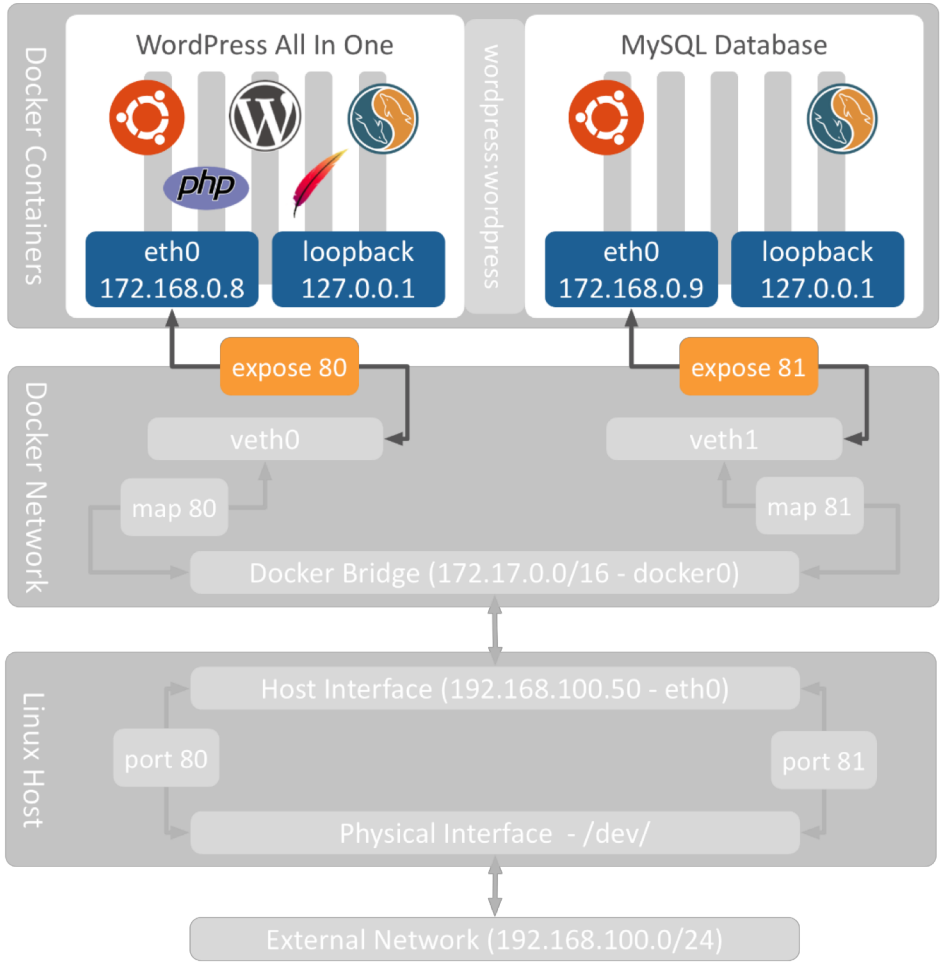
Link containers



Linking:

- Service Ports are known to all containers
- Ports are exposed from the container
- Host ports are mapped to container ports for accessibility
- Linking containers create internal routing rules
- Linking containers uses aliases to connect containers

Link containers



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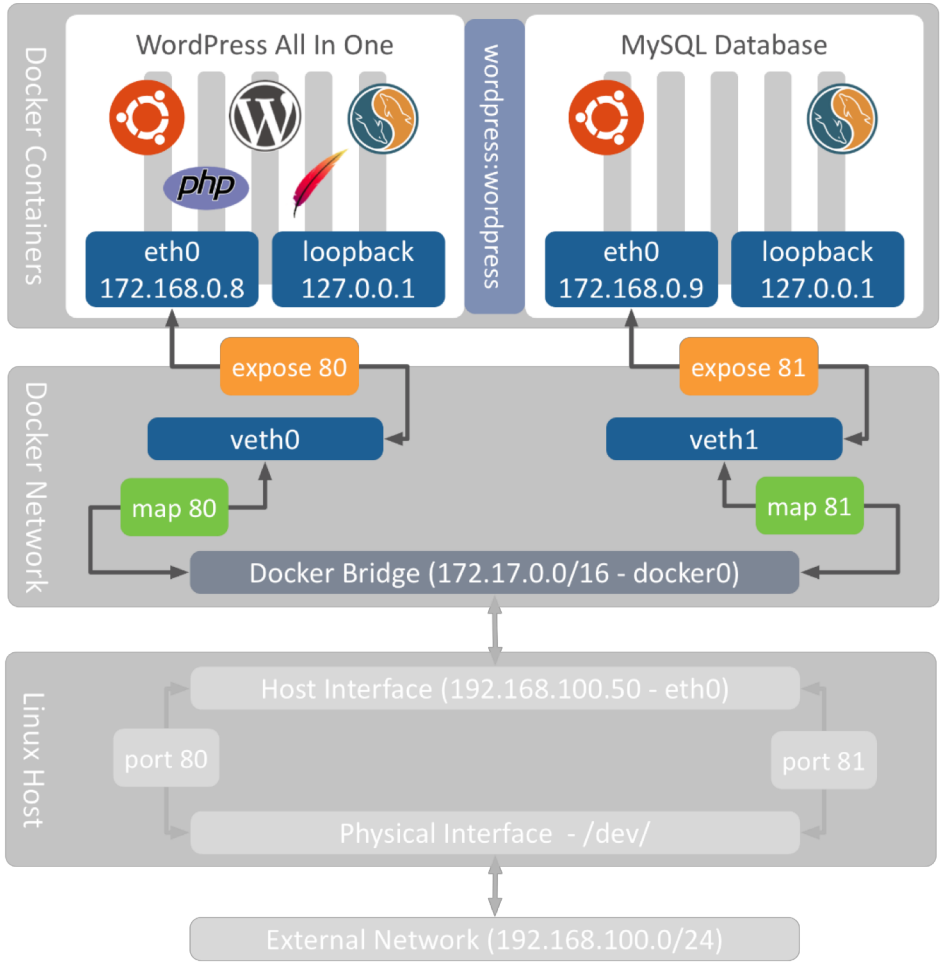

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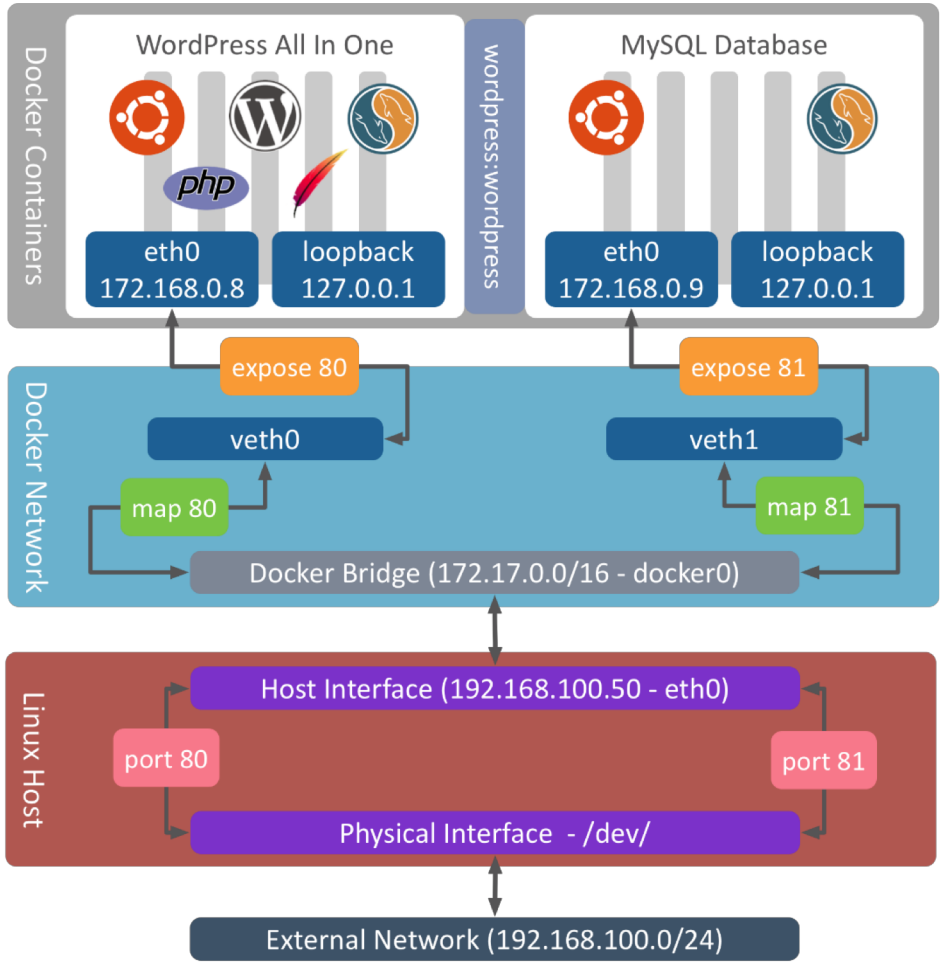

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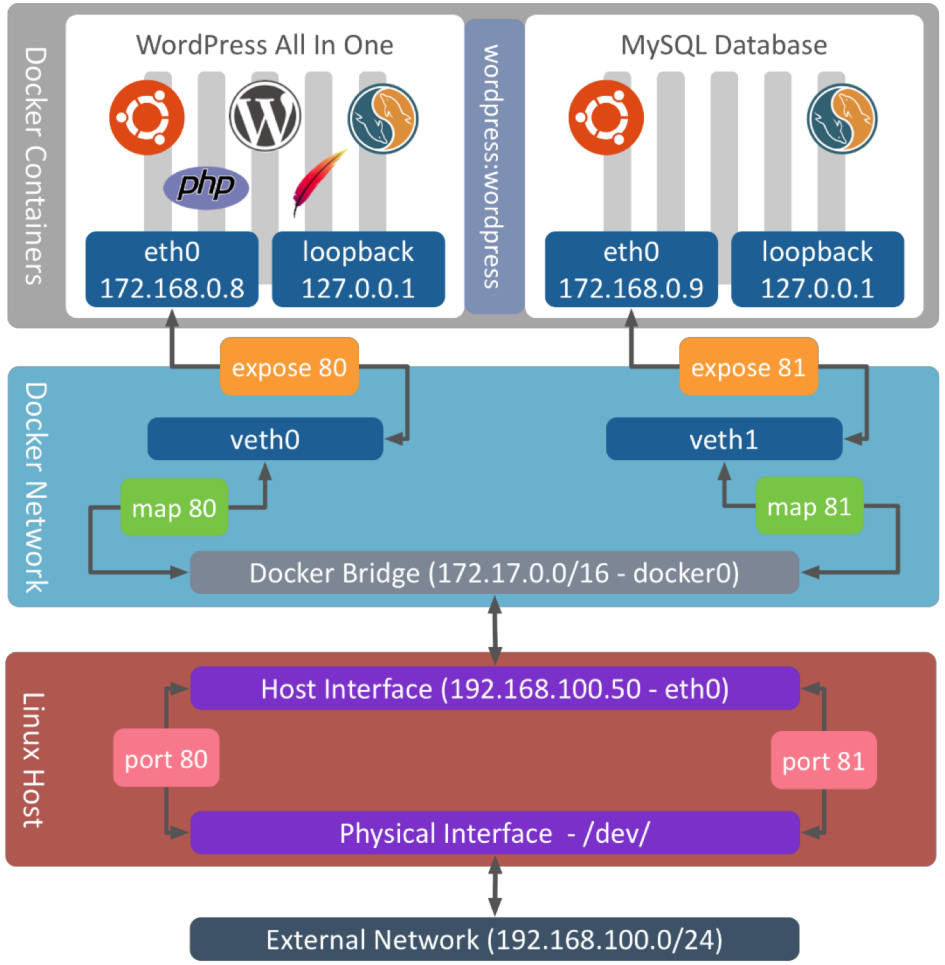

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- Linking containers create internal routing rules
- Linking containers uses aliases to connect containers

User Traffic Flow

User Traffic Flow

- **Applications provide:**
  - Service Ports that need to be exposed
- **Docker Engine provides:**
  - Exposure of required Service Ports
  - Mapping of required Service Ports
- **Linux Host provides:**
  - Internal connectivity between containers
  - Internal connectivity between host and containers
  - External connectivity between containers and users

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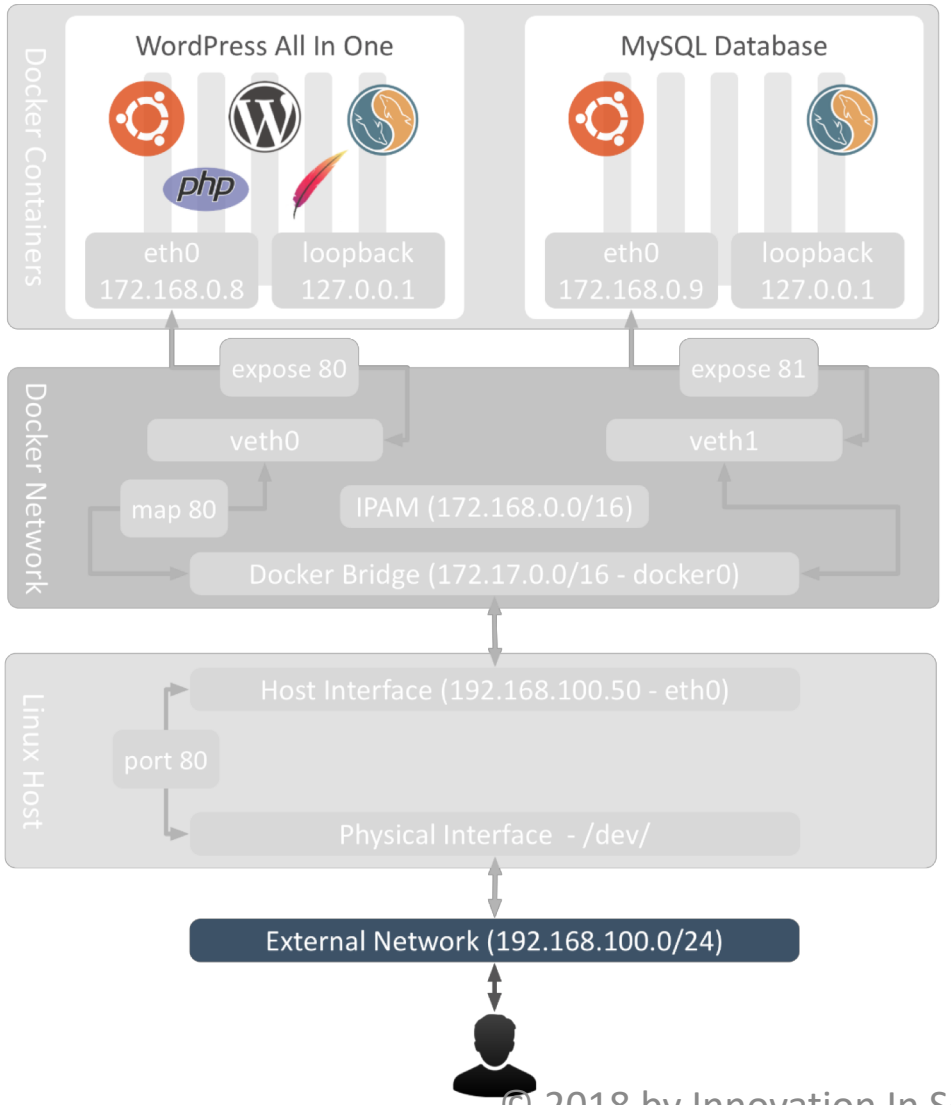
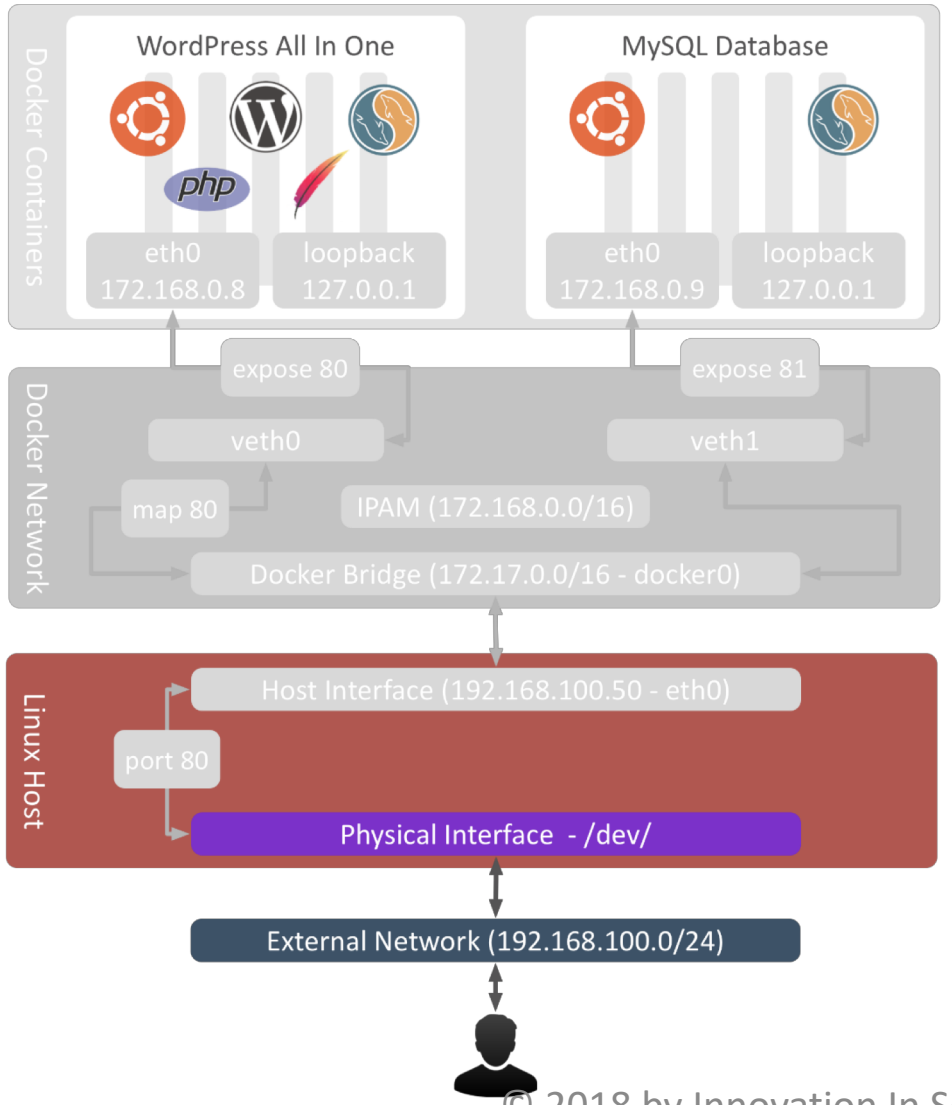
User Traffic Flow



User Traffic:

- Enters from the external network (outside the Docker host)
- Enters the physical interface
- Is passed to the host interface (eth0)
- Is passed to the Docker Bridge
- Is passed to the veth interface
- Is passed to eth0 in the container

User Traffic Flow



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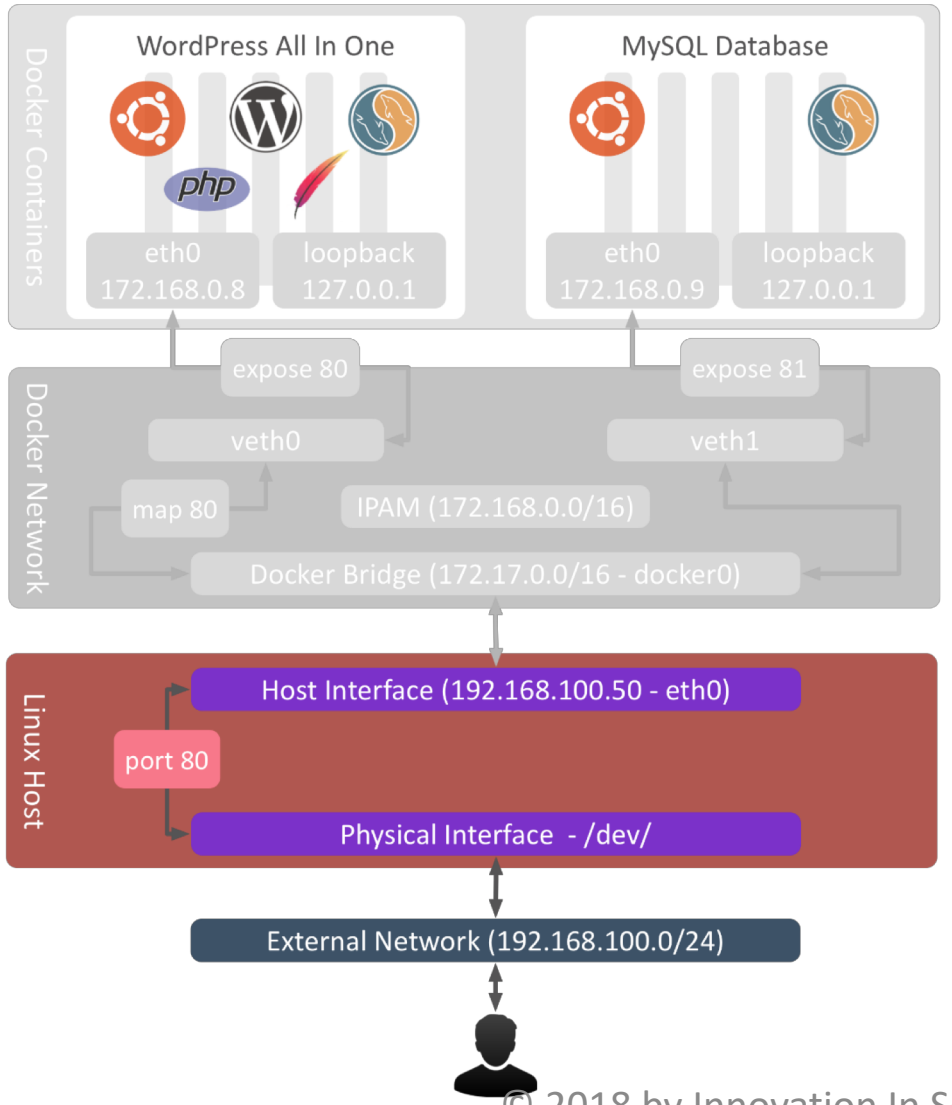

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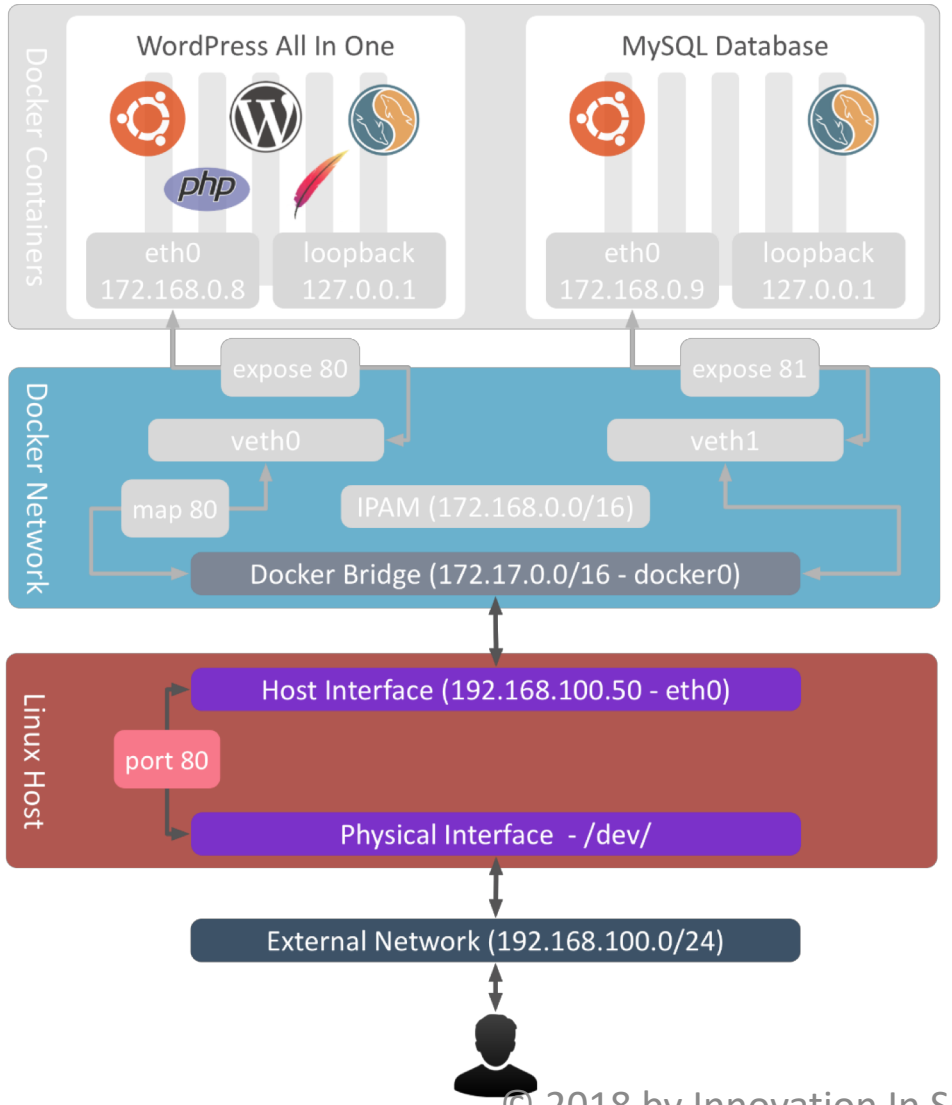

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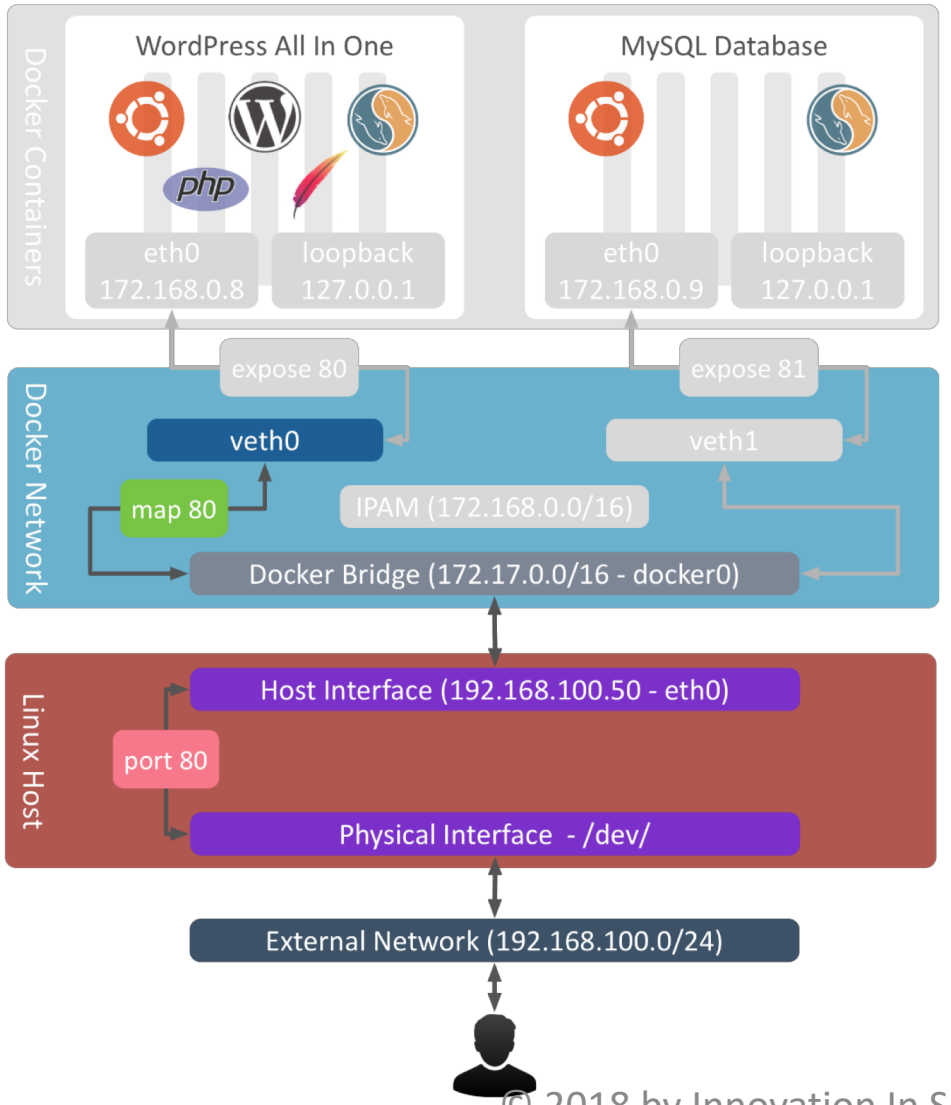

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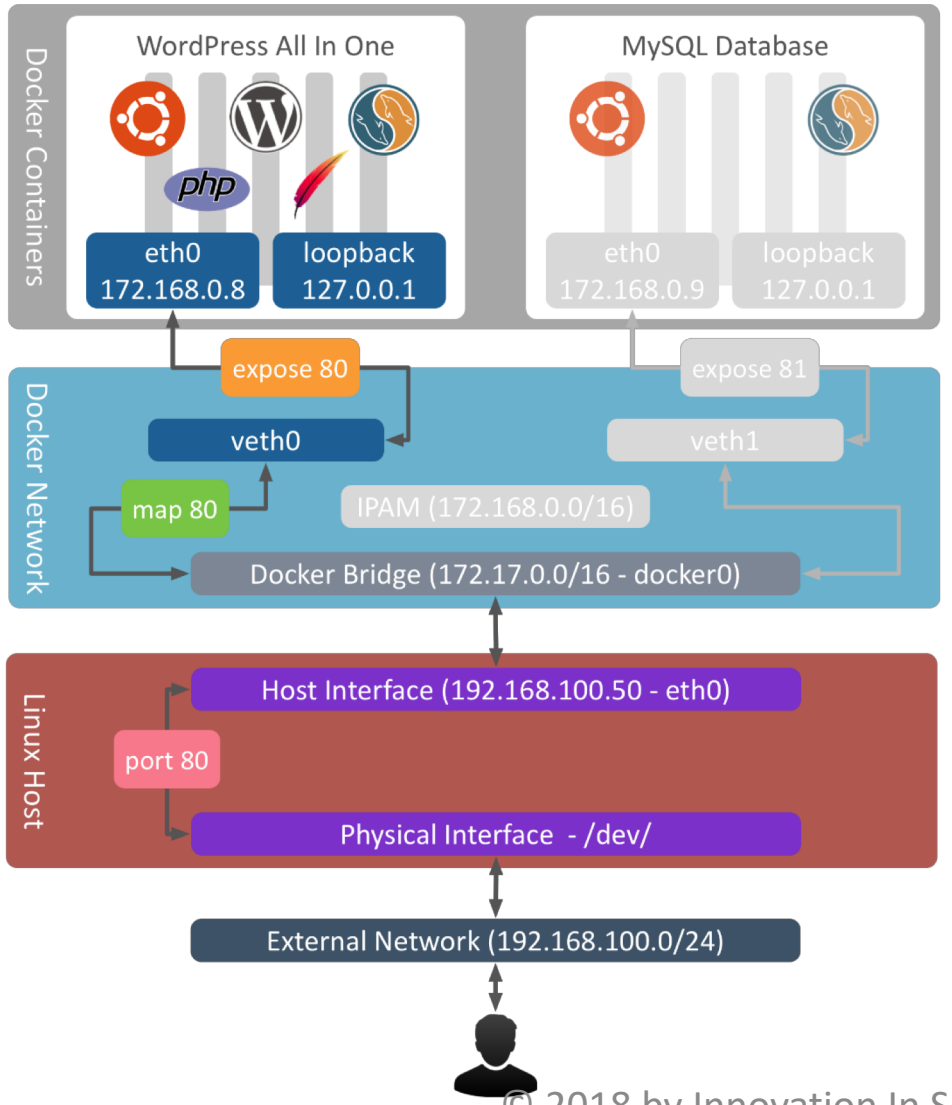

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Add Networks to Docker Bridge

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Add Networks to Docker Bridge

Four types of Networks:

1. **none** (no network access, most secure)
2. **bridge** (limited access to host network, moderately secure)
3. **host** (no restrictions to host networks, least secure)
4. **overlay** (networks with other Docker hosts)

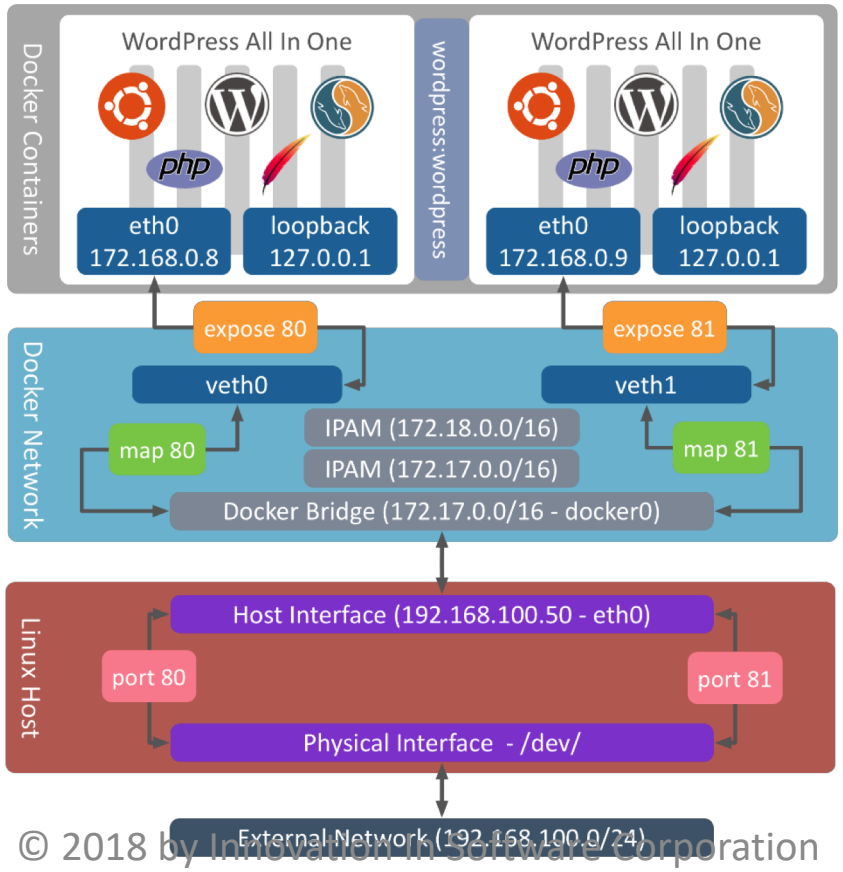
Why use Docker bridge Network segments?

- Use functions of docker bridge to isolate containers from each others by limited **inter-container communication (icc)**
- Provide levels of security in the same docker host

Add Networks to Docker Bridge

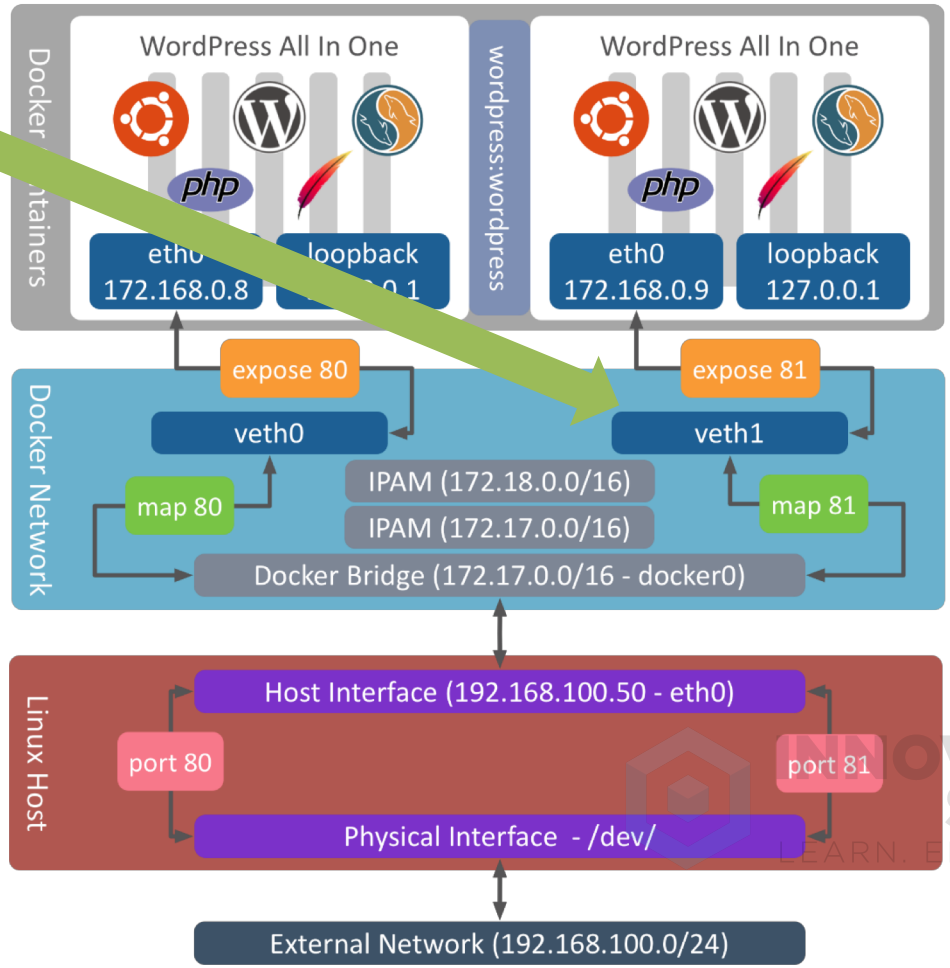
Create additional networks on bridge docker0

```
$ docker network create database --driver bridge
```



Add Networks to Docker Bridge

- Creates a veth interface pair
- Connects one end to docker0 bridge
- Connects other end to container eth0
- Assigns an IP address from docker0 IPAM for network



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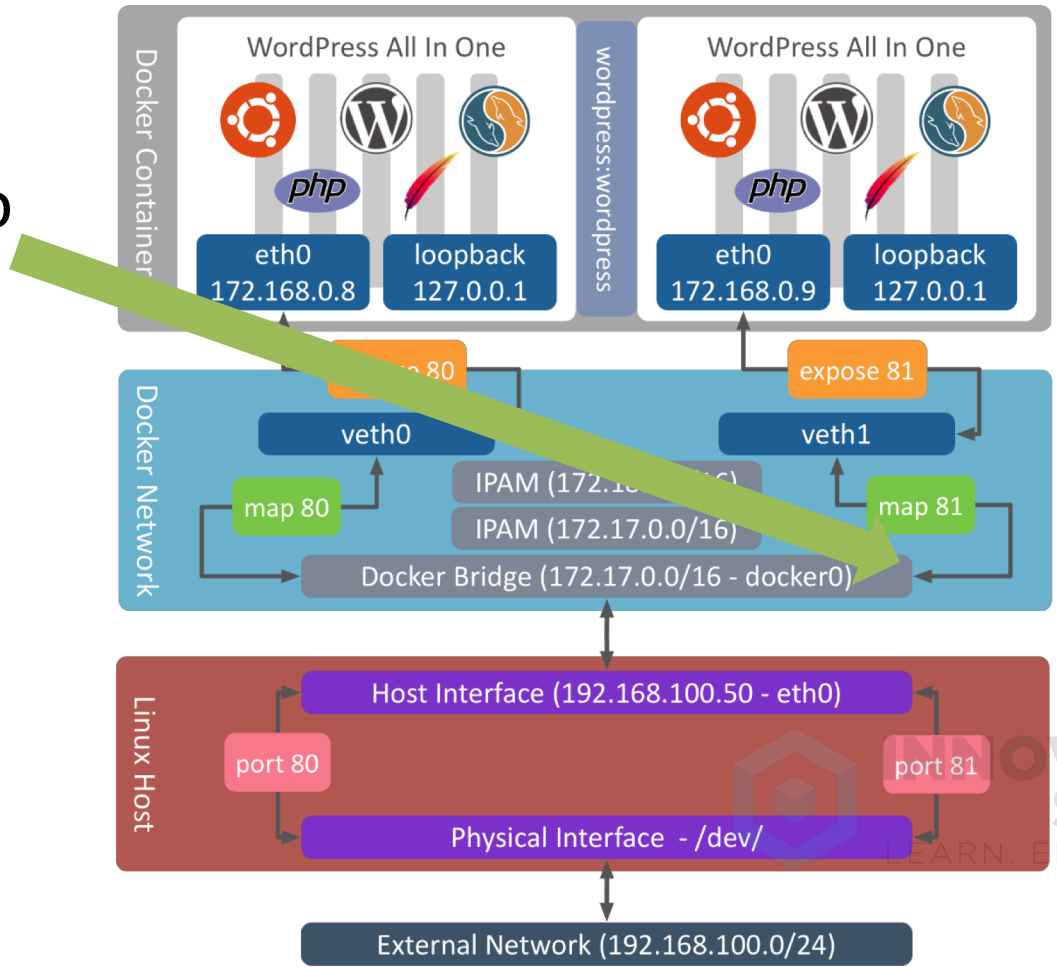

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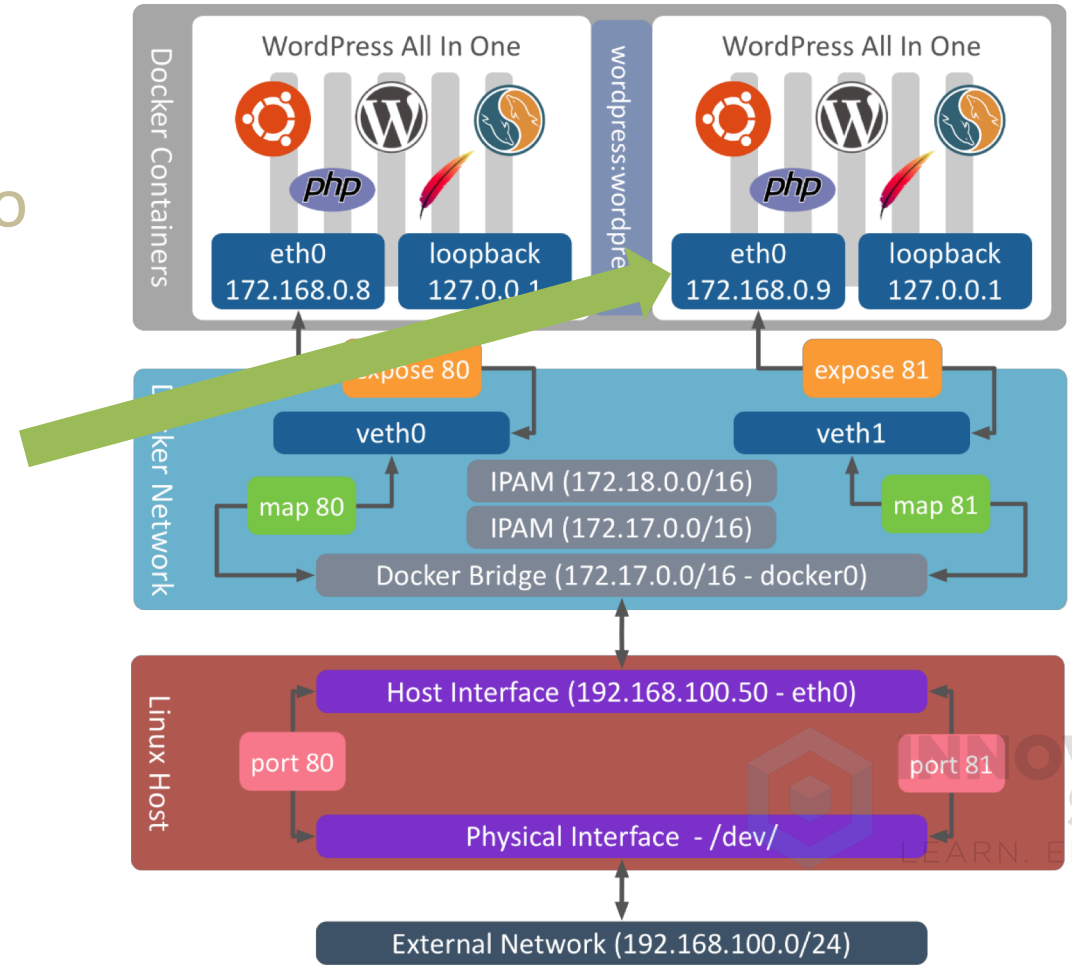

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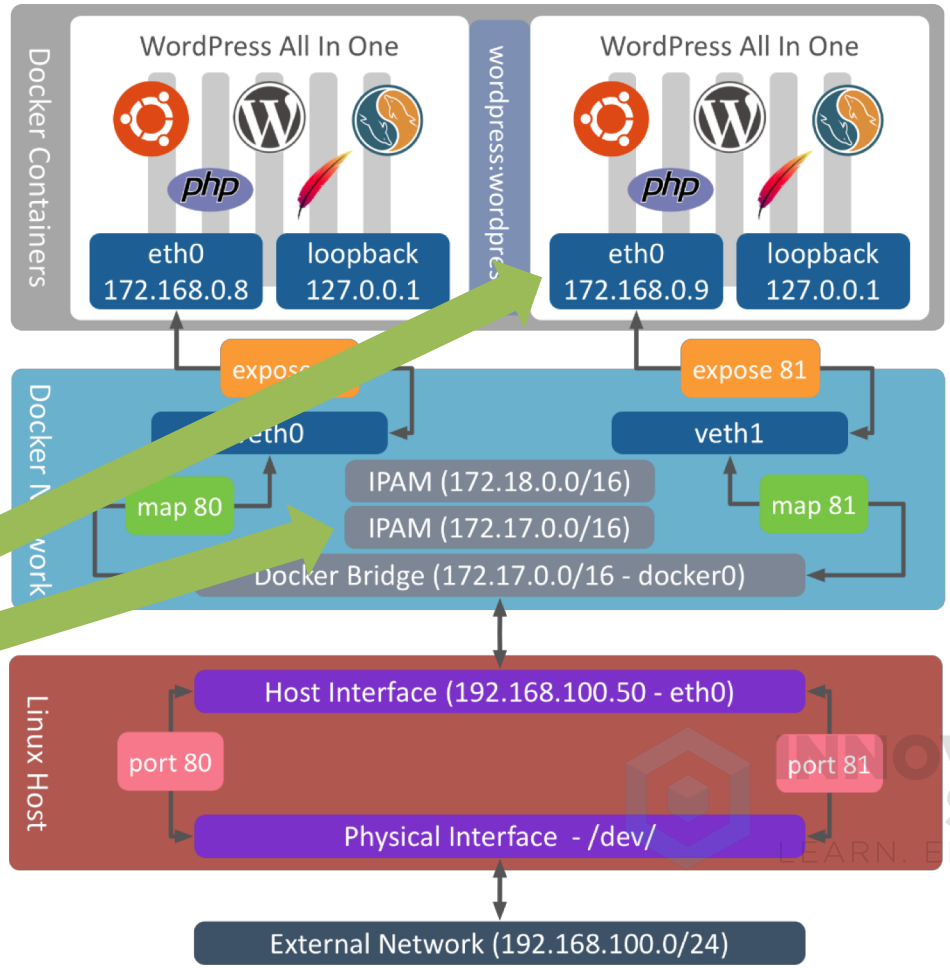

Add Networks to Docker Bridge

Create an additional network on docker0:

- defaults to docker bridge (docker0)

```
$ docker network create database--driver
bridge
```

Network is in `docker network ls` output:

```
$ docker network ls
NETWORK ID          NAME                DRIVER
82cb7fbd657d        bridge              bridge
2e46aa7d66a0        dbase               bridge
957de60d5958        host                host
6b64d7ed1c93        none                null
2c257ae62bcd        wordpress           bridge
```

Add Networks to Docker Bridge

Docker network inspect <network>:

- Provides details on the network

```
$ docker network inspect database
```

- IPAM range, this is the range that the containers are assigned IP Addresses

```
"IPAM": {
            "Driver": "default",
            "Options": {},
            "Config": [
                {
                    "Subnet": "172.19.0.0/16",
                    "Gateway": "172.19.0.1/16"
}
```

Example Using default network

Deploy a demo container (default network):

- network option undefined using “bridge,” the default docker0 network

```
$ docker run -d busybox top
```

- docker inspect formatted for bridge and IPAddress of container.

```
$ docker inspect -f \
{{.NetworkSettings.Networks.bridge.IPAddress}} \
$(docker ps -lq)

172.17.0.5
```

Example using defined network

Deploy a demo container (defined network):

- network option undefined using “bridge,” the default docker0 network

```
$ docker run --network database -d busybox top
```

- docker inspect formatted for bridge and IPAddress of container.

```
$ docker inspect -f \
{{.NetworkSettings.Networks.database.IPAddress}
} \
$(docker ps -lq)

172.19.0.5
```

Docker Network Metadata

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Network Metadata

What is it? – Network metadata describes what the Network is through the use of key value pairs

- **docker network inspect <id>**
  - Queries the Docker Engine, a json formatted output is returned

```
$ docker network inspect <network>
```

```
        “Name“=
         “Id“=
         “Scope“=
         “Driver“=
         “EnableIPv6“=
         “IPAM“=
              “Driver“=
              “Options“=
              “Subnet“=
         "Containers“=
```

Networking Lab: Task 2

Summary, Review & QA

INNOVATION SOFTWARE
LEARN. EMPOWER. INNOVATE.

Review

Overview & Architecture

Network Deployment Methods

Expose Service ports

Port Mapping

Containers

Link Containers

User Traffic Flow

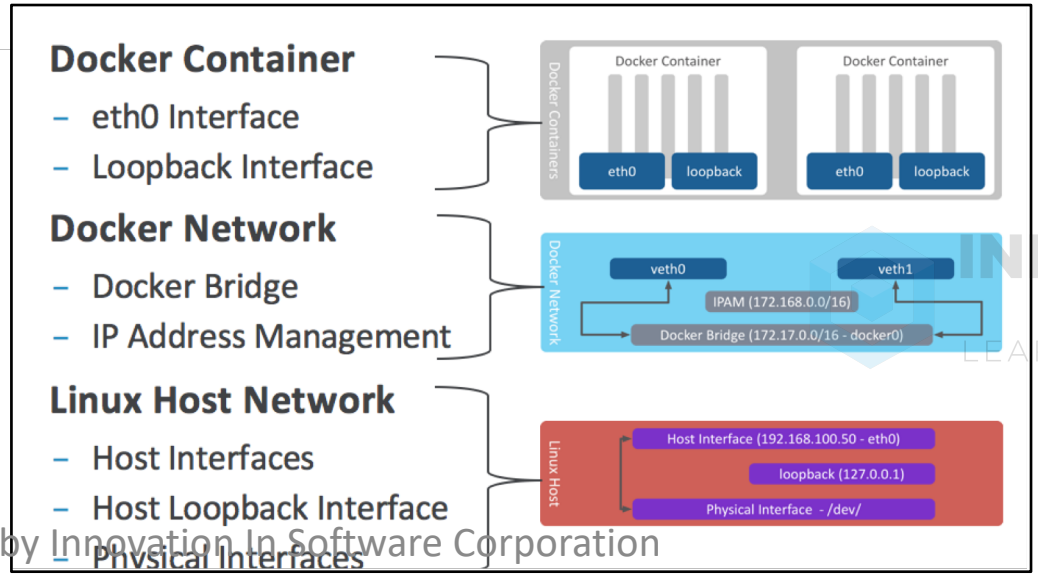
Add Networks to Docker Bridge

Docker Engine provides network access for containers that need:

- Other Containers
- Networks

Accomplished through:

1. IP Address Management (IPAM)
2. Service Port exposure
3. Manual Port Mapping
4. Dynamic Port Mapping



Review

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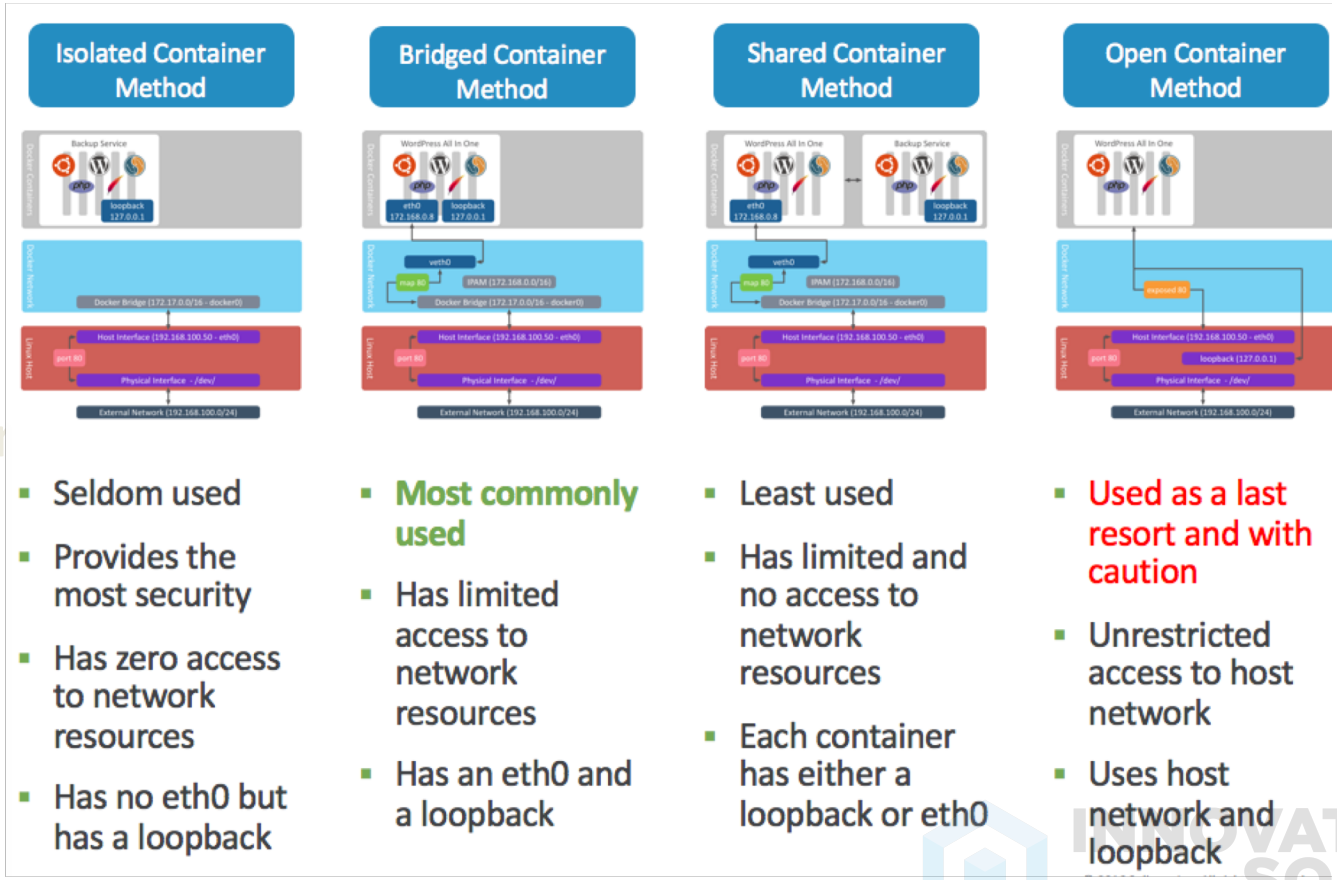
Add Networks to Docker Bridge



Review

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Expose Service ports

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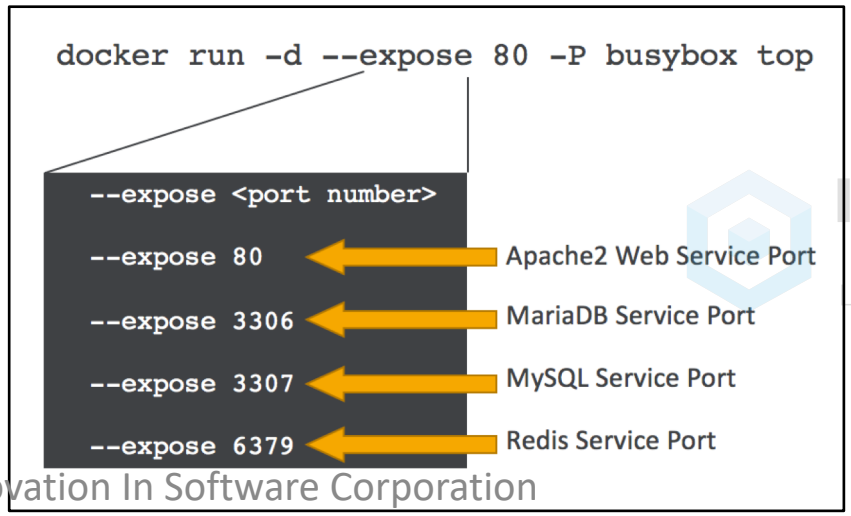
Docker Bridge

Docker Engine provides a mechanism to expose required service ports

- Exposure is by port, not service name
- Service port exposure is required for communication with the container
- Service ports are exposed:
  - Docker Container creation
  - Docker Image creation



Review

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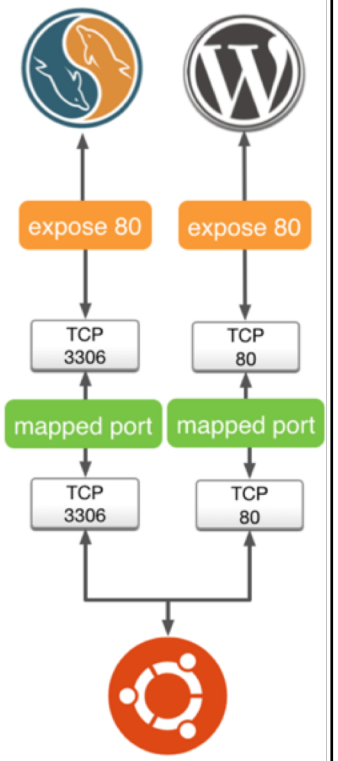
Add Networks to Docker Bridge

Docker provides a mechanism to map exposed service ports

- TCP ports can be mapped:
  - Dynamically
  - On all host interfaces
  - On user defined ports and interfaces
- Exposed service ports are only mapped during container creation:
  - Docker Container creation



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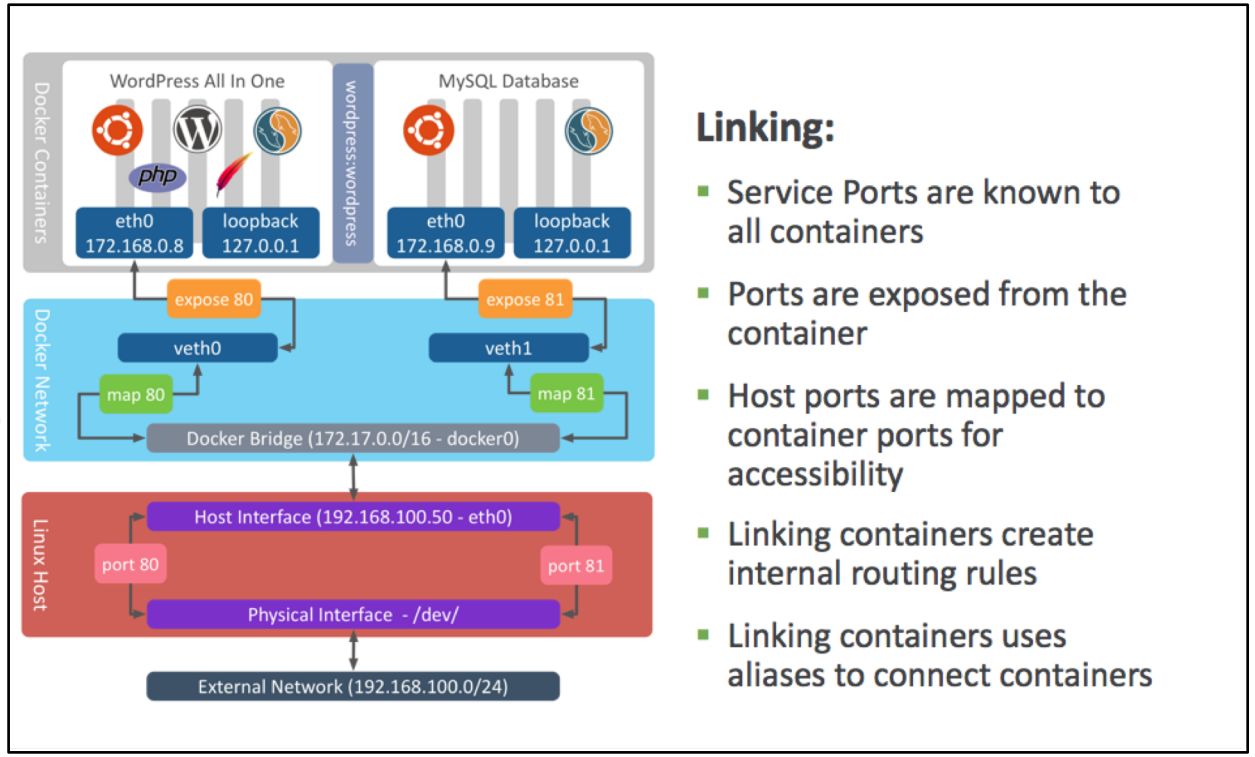

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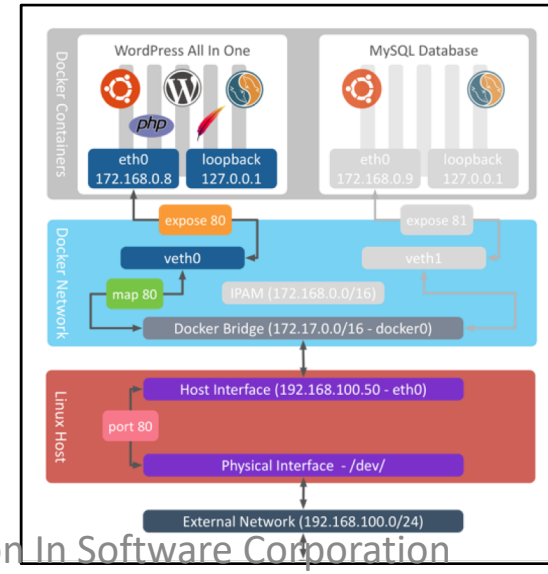
Add Networks to
Docker Bridge

- **Applications provide:**
  - Service Ports that need to be exposed
- **Docker Engine provides:**
  - Exposure of required Service Ports
  - Mapping of required Service Ports
- **Linux Host provides:**
  - Internal connectivity between containers
  - Internal connectivity between host and containers
  - External connectivity between containers and users



User Traffic:

- Enters from the external network (outside the Docker host)
- Enters the physical interface
- Is passed to the host interface (eth0)
- Is passed to the Docker Bridge
- Is passed to the veth interface
- Is passed to eth0 in the container

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Add Networks to Docker Bridge

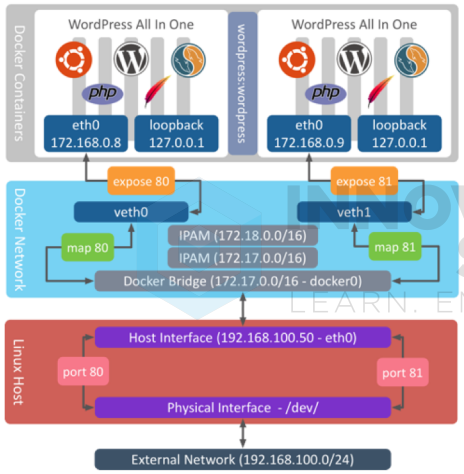
Four types of Networks:

1. **none** (no network access, most secure)
2. **bridge** (limited access to host network, moderately secure)
3. **host** (no restrictions to host networks, least secure)
4. **overlay** (networks with other Docker hosts)

Why use Docker bridge Network segments?

- Use functions of docker bridge to isolate containers from each others by limited **inter-container communication (icc)**
- Provide levels of security in the same docker host

- Creates a veth interface pair
- Connects one end to docker0 bridge
- Connects other end to container eth0
- Assigns an IP address from docker0 IPAM for network



Networking Labs: Task 3 and Task 4