Docker Fundamentals

Enrico RUSSO
Università di Genova

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CYBERSECURITY NATIONAL LABORATORY

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Goal

- Present the difference between virtualized and container Deployment
- Present basic usage and command of Docker and Docker Compose

Prerequisites

- Lecture:
  - *NS_0.1 – Network Fundamentals*

Outline

- Docker images and containers
- Docker networking
- Docker compose

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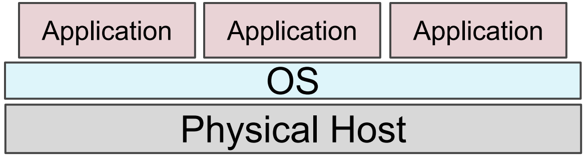
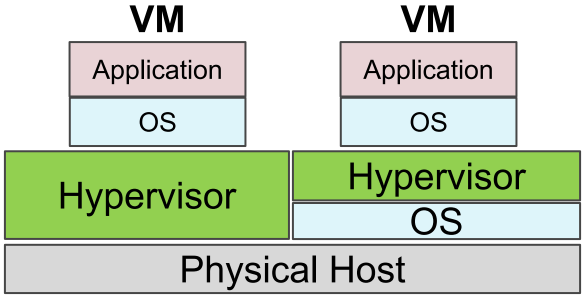
- Docker networking
- Docker compose

Traditional vs Virtualized Deployment





- Physical Hosts run an Operating System (e.g., Windows or Linux).
- Multiple applications run on the shared OS.

- A special software, i.e., the **Hypervisor**, provides Virtual Machines.
- Examples of such technologies are *Virtualbox*[1] or *Linux KVM*[2].
- VM is a full machine running all the components, including its own Operating System, on top of the virtualized hardware

[1]https://www.virtualbox.org/

[2]https://www.linux-kvm.org

Traditional vs Virtualized Deployment

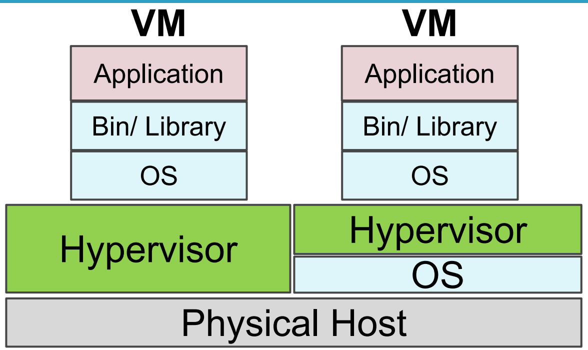
Traditional Deployment

- No way to define resource boundaries for applications.
- Isolating applications requires running them on different physical servers (expensive and resources could be underutilized).

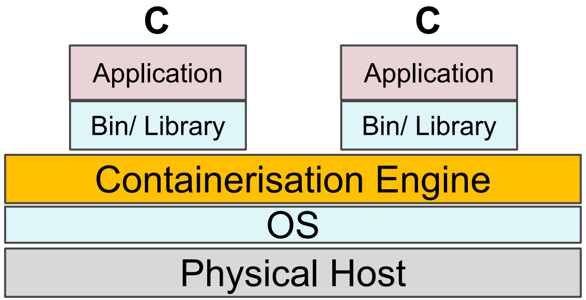
Virtualized Deployment

- Virtualization allows:
  - applications to be isolated between VMs
  - better utilization of resources in a physical server
  - better scalability.

Virtualized vs Container Deployment



- Virtual hardware
  - Each VM has an OS and Application
  - Share hardware resource from the Physical Host



- Virtual Operating Systems
  - Isolated environments, namely **containers**, sharing the same *real* operating system
  - Containers run from a distinct image that provides all files (Bin/, Library) necessary to support them
  - Examples of such technologies is *Docker*[1].

[1] https://www.docker.com/

Virtualized vs Container Deployment

Virtualized Deployment

- Heavyweight: each VM relies on a full copy of an Operating System.
- Provides full isolation.
- Best suited for when you have applications that need to run on *different* Operating System flavors.

Container Deployment

- Lightweight: sharing OS resources significantly reduces the overhead required for running containers.
- Provides a (relaxed) process-level isolation.
- Best suited for when you have applications that need to run over a *single* Operating System kernel.

Docker images and containers

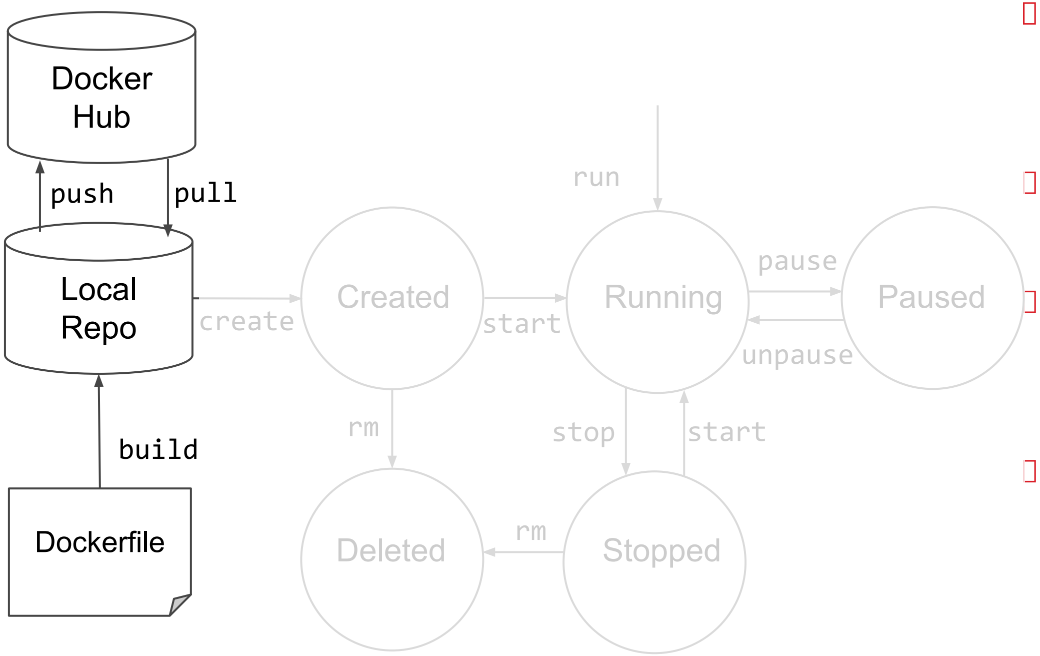
Image

- **Immutable** template for containers
- Includes everything needed to run an application
  - code, runtime, system tools, system libraries, and settings

Container

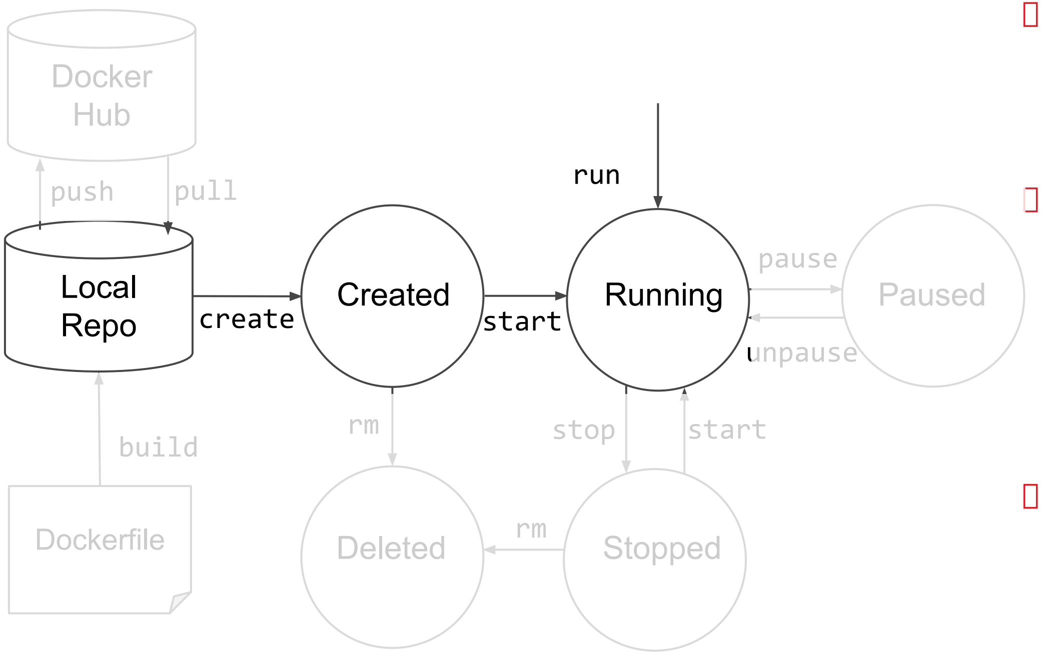
- An instance of an image
- Add a **new writable layer** on top of the underlying image
  - all changes made to the running container (e.g., writing new files or modifying existing files) are written to this writable container layer

Docker container lifecycle



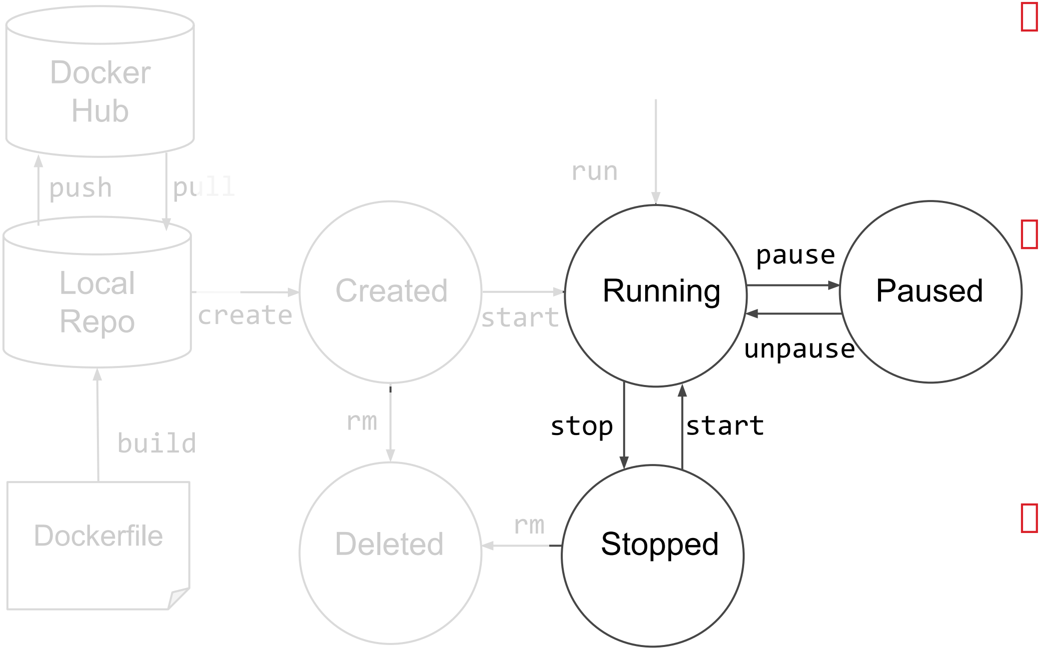
- Docker images can be pulled from a central repository (Docker Hub)
- Pulled images are saved in a local repository
- Custom images can be created and saved starting from a specific configuration file (Dockerfile)
- Custom images can be pulled to the central repository

Docker container lifecycle



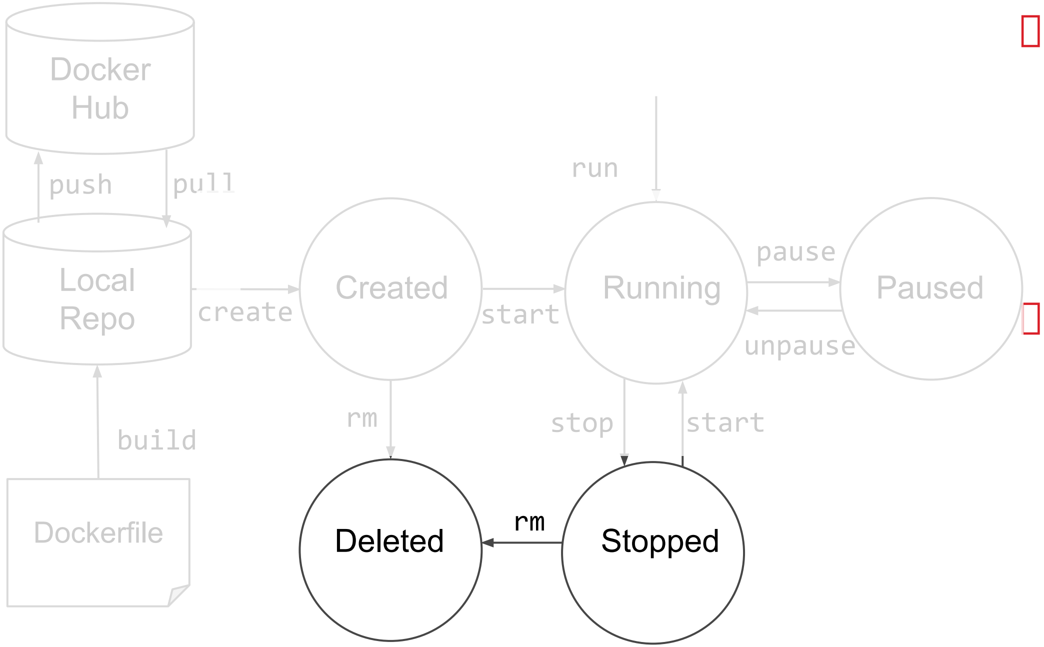
- A saved image can be used for creating a container (a writeable layer is added)
- Starting a container means running a default command contained in the image, namely the entrypoint (can be overridden)
- A container can be created and started using a single run command

Docker container lifecycle



- After executing the entrypoint, the container stops
- A **foreground** process specified as the entrypoint can keep running the container
- A running container can be paused or stopped

Docker container lifecycle



- After a container is stopped, the writeable layer still exists
- Deleting a container permanently removes the associated writable layer

Docker lifecycle example: images

- Pull an image from the central hub
  - docker pull <image>
- Build an image from a Dockerfile
  - docker build -t <image>
- List images saved in the local repository
  - docker images
- Delete an image
  - docker rmi <image>

Docker lifecycle example: containers

- Start a container
  - docker run <image>
- Start a container overriding default entrypoint with <newcmd>
  - docker run --entrypoint <newcmd> <image>
- Execute a command <cmd> (e.g., /bin/bash) in a running container
  - docker exec -it <containerID> <cmd>
- Stop a container
  - docker stop <containerID>
- Remove a container
  - docker rm <containerID>
- List running and stopped containers
  - docker ps –a

Docker volumes

- Volumes can be used to save (persist) data and to share data between containers
- Volume is <u>unrelated</u> to the container layers: deleting a container does not involve deleting an associated volume
- A volume can be:
  - (anonymous/)named: managed internally by Docker itself
  - host: refers to a filesystem location of the host running Docker

Docker volumes: example

- Create a named volume
  - docker volume create volumename
- Run a container using the named volume
  - docker run –v volumename:/path/in/container_filesystem
- Running a container using a host volume
  - docker run –v /path/on/host_filesystem:/path/in/container_filesystem

Dockerfile

- Docker can build custom images automatically by reading the instructions from a Dockerfile
- Dockerfile is a text document that contains all the commands a user could call on the command line to assemble an image
- The *docker build* allows the execution of an automated build of an image starting from a Dockerfile

(Dockerfile reference: https://docs.docker.com/engine/reference/builder/)

Dockerfile example

Command	Description	Example
FROM <image>	Start building from this (base) image	FROM ubuntu
RUN <cmd>	Run the specified command	RUN apt install apache2
COPY <src> <dest>	Copy a file to the image fs	COPY vh.conf /etc/apache2/conf/
CMD ["exec", "param1“, ...]	Configure the default command when container starts	CMD ["apache2", "-D", " FOREGROUND "]

Outline

- Docker images and containers
- Docker networking
- Docker compose

Docker networking

Docker supports different configurations, the two main ones being

- *Bridge* (default)
  - isolated layer 3 networks enabling connected containers to communicate
  - (can) allow the access to external networks masquerading connections with the host network configuration
- *Host*
  - containers use the host network
  - listening ports are exposed to the outside world

Docker networking: published ports

- A container connected to bridges is isolated and does not expose any of its ports to the outside world
- A published port can be made available to services running outside the container
- A published port is mapped to a port on the Docker host

Docker networking: examples

- Create network with a configured subnet and gateway address
  - docker network create --driver bridge <networkname> --subnet=<ip/mask> --gateway=<ip/mask>
- Connect a container to a network
  - docker network connect <networkname> <containerid>
- Run a container and expose a port
  - docker run –h <host-name> -p <internal-port>:<exposed-port> --name <container-name> <image-name>

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Docker compose

Compose is a tool for defining and running multi-container Docker applications

- A single file for providing configurations
- A single set of commands for configuring, building, and running all the containers

Docker compose configuration

- The Compose file (docker-compose.yaml) uses a standard, human-readable syntax, namely YAML* syntax. It defines
  - Services: configuration that is applied to each container (much like passing command-line parameters to *docker run*)
  - Networks (optional): define configuration of networks to be created
  - Volumes (optional): define configuration of volumes to be created

* https://yaml.org/

Docker compose configuration: example


```yaml
services:
 # frontend container
 app:
  # use a custom image
  build:
   # directory containing Dockerfile
   context: ./app
  # image name
  image: custom_image
  # exposed ports (host:container)
  ports:
    - 8080:80
  # a mapped host volume
  volumes:
   -  ./config/config.json:/etc/config.json
  # connected networks (defined in networks..)
  networks:
   ext:
    ipv4_address: 192.168.100.100
   int:
 # backend container
 db:
  # pull an existing image
  image: mariadb
  # a mapped named volume
  volumes:
   - db-content:/var/lib/mysql
  networks:
   int:

volumes:
 db-content:

networks:
 ext:
  driver: bridge
  ipam:
   driver: default
   config:
    - subnet: 192.168.100/24
 int:
  driver: bridge
```

Docker compose: commands example

- (build images and) run services
  - docker-compose up –d
- stop services
  - docker-compose stop
- start services
  - docker-compose start -d
- stop and remove containers and networks
  - docker-compose down
- show logs (entrypoint output)
  - docker-compose logs -f [service_name]

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