# Container Security: What Could Possibly Go Wrong?

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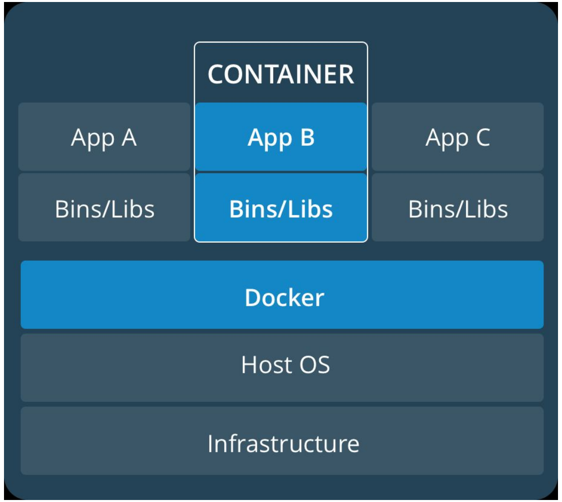
# What is a container?

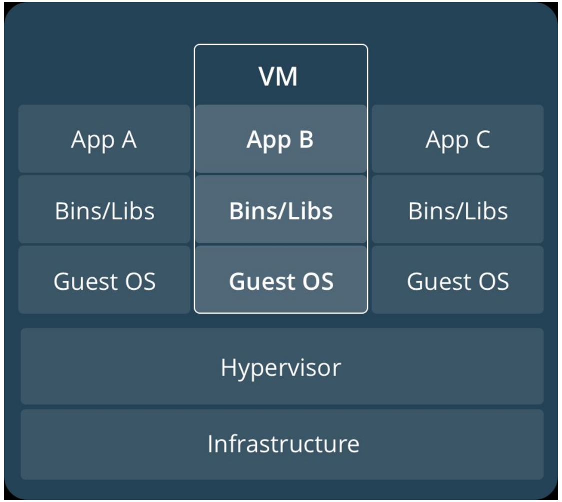
- fundamentally, a container is just **a running process**
- it is **isolated** from the host and from other containers
- each container usually interacts with its **own private filesystem**
- there are different containerization technologies available
  (Docker, LXD, Podman, Singularity, ...)
- in this tutorial, we will focus mainly on Docker

# Containers vs. Virtual Machines

- a container is **an abstraction of the application layer**
  (it runs natively on Linux)

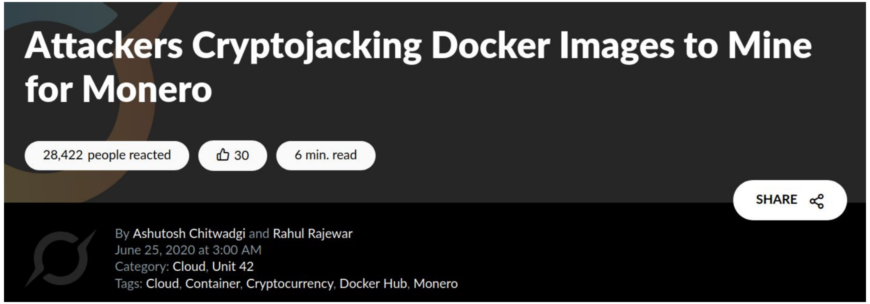



- a virtual machine is **an abstraction of the hardware layer**
  (it runs a full-blown “guest” operating system)



# Threat Landscape

- proper **deployment** and **configuration** requires understanding the technology
- **image management** (integrity and authenticity of the image)
- trust in the **image maintainer** and the **repository operator**
- **malicious images** may be found even in an official registry


Attackers Cryptojacking Docker Images to Mine for Monero

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By Ashutosh Chitwadgi and Rahul Rajewar
June 25, 2020 at 3:00 AM
Category: Cloud, Unit 42
Tags: Cloud, Container, Cryptocurrency, Docker Hub, Monero

*https://unit42.paloaltonetworks.com/cryptojacking-docker-images-for-mining-monero/*

# Usual Best Practice

- especially proper **vulnerability/patch management**
- it is often kernel-related and therefore requiring reboot
- updates **not always** available
- **extremely important** (couple of vulns over the past few years)
- out of scope for today

**Let’s move to Docker itself….**

# Docker Terminology

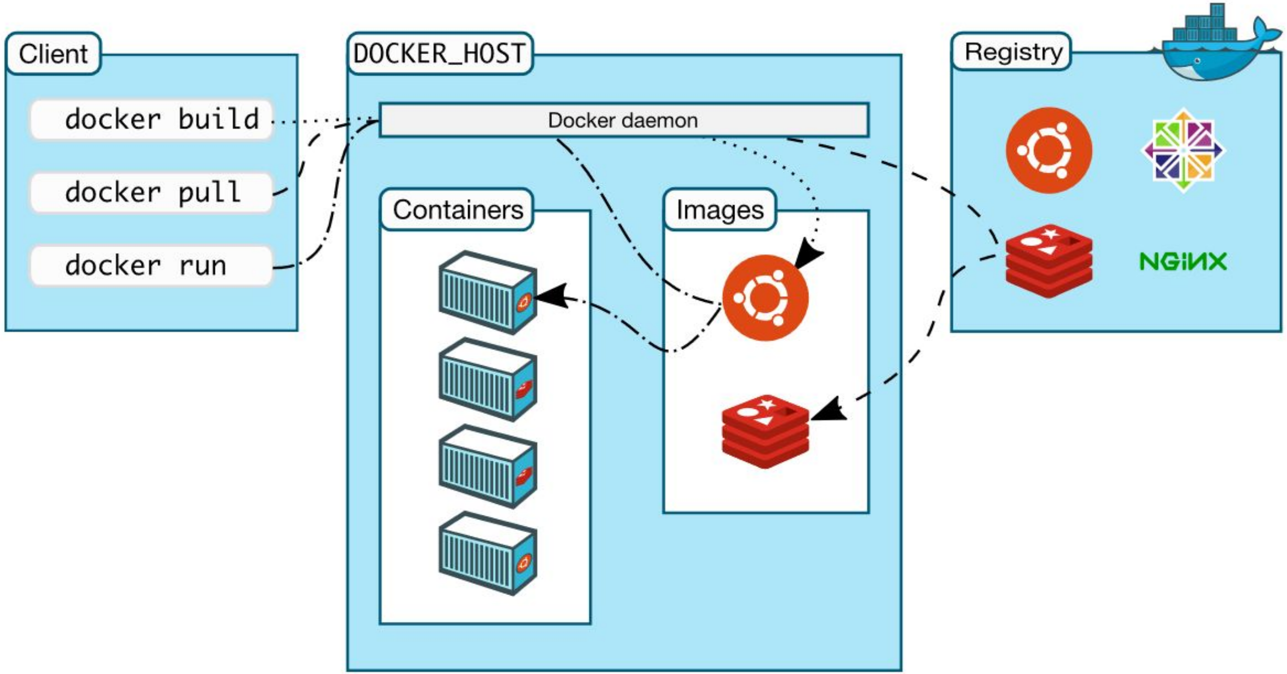
- **Docker container image** - a lightweight, standalone, executable package of software that includes everything needed to run an application
  *(code, runtime, system tools, system libraries and settings)*

- an image is usually pulled from a **registry** to a host machine
  *(e.g.* ***DockerHub*** *- something like a Google Play store, Apple store, etc.)*

- **Docker container** - an instance of an image

- a host machine runs the **container engine** (**Docker Daemon**)

# Docker Architecture



# Docker Container Creation

- the image is opened up and the **filesystem** of that image is copied into a **temporary archive** on the host
- Docker filesystem is a **stacked file system** of individual layers stacked on “mount”
- the ‘/’ root directory of the container is **mounted and available** on the host

  /var/lib/docker/overlay2/51415bc9cd3ab2c47d218a897516ea2bf0545595fadf4a167ed5cfd3230a5f99/

- changes to the directory **are visible** from both sides
- when the container is removed, any changes to its state **disappear** unless “committed” via **dockerd**

# Docker Container Processes

- the container engine manages the process tree **natively** on the kernel
- to provide application sandboxing, Docker uses Linux **namespaces** and **cgroups**
- when you start a container with *docker run*, Docker creates **a set of namespaces** and **control groups**

# Namespaces

- Docker Engine uses the following namespaces on Linux
  - **PID namespace** for process isolation
  - **NET namespace** for managing/separating network interfaces
  - **IPC namespace** for separating inter-process communication
  - **MNT namespace** for managing/separating filesystem mount points
  - **UTS namespace** for isolating kernel and version identifiers

    (mainly to set the hostname and domainname visible to the process)
  - **User ID** (user) namespace for privilege isolation
- user namespace **must be enabled** on purpose, it is **not** used by default

# PID namespace

- allows to establish **separate process trees**
- the complete picture still **visible** from the **host** (outside the namespace)

```
 1029  ?        Ssl    7:48    /usr/bin/containerd
28834 ?         Sl     0:00    \_ containerd-shim -namespace moby  .........
28851 pts/0     Ss     0:00    \_ bash
28899 pts/0     S+     0:00    \_ dash
```

```
root# docker run --rm -it debian/ps bash
root@3146c2faec9b:/# dash
# ps af

 PID   TTY     STAT  TIME    COMMAND
   1   pts/0   Ss    0:00    bash
   6   pts/0   S     0:00    dash
   7   pts/0   R+    0:00    \_ ps af
```

# User ID (user) Namespace

- enables **different uid/gid** structures **visible** to the **kernel**
- **mapping** between uids in the namespace and “global” uids is **needed**
- by default, **root in the container is root in the host** !

**global (host) id’s**

- 0
- 1
- ....
- 1000
- 1001
- ...
- 100000
- 100001

**id’s in the namespace**

- 0
- 1

# Cgroups I.

- short for **control groups**
- they allow Docker Engine to **share available system resources**
- they implement **resource limiting** for different resources (CPU, disk I/O, etc.)
- they help to ensure that a single container **cannot** bring the system down
- cgroups are organized in a (tree) **hierarchy** for a given cgroup type

# Cgroups II.

- a process (thread, task) **may be assigned** one cgroup
    - example of memory control (top level):
    - three children: web browsing (20 %), crypto mining (60 %), others (20 %)
- access via the /sys pseudo-filesystem is the simplest

  /sys/fs/cgroup/memory/ (top level)

  /sys/fs/cgroup/memory/web (specific cgroup)

# Linux Kernel Capabilities

- capabilities turn the binary “root/non-root” dichotomy into a **fine-grained access control system**
- by default, Docker starts containers with **a restricted set of capabilities**
- Docker supports the **addition** and **removal** of capabilities
- additional capabilities extends the utility but has security implications, too
- a container started with **--privileged flag** obtains **all** capabilities
- running **without --privileged** doesn’t mean the container doesn’t have root privileges!

# I am root. Or not?

- multiple levels of root privileges, from an unprivileged root user:
  - if user namespace is **enabled**, root inside a container has no root privileges outside in the host system
  - **by default**, root in a container has some privileges
    - but these are restricted by the **default set of capabilities**
  - we can **explicitly** add **extra capabilities** to our root in a container
  - with the **--privileged flag**, we have full root rights granted

root

```
root# docker run --rm -it debian/ip bash
root@b523a39fcc48:/# iptables -L -n
iptables: Permission denied (you must be root).
root@b523a39fcc48:/#
```

root

```
root# docker run --rm -it --cap-add=NET_ADMIN debian/ip bash
root@361c51aa11b0:/# iptables -L -n
Chain INPUT (policy ACCEPT)
target     prot opt source               destination

Chain FORWARD (policy ACCEPT)
target     prot opt source               destination

Chain OUTPUT (policy ACCEPT)
target     prot opt source               destination
root@361c51aa11b0:/#
```

# Docker Daemon

- running containers (and applications) with Docker implies running the Docker daemon
- to control it, it requires **root privileges**, or **docker group membership**
- only **trusted users** should be allowed to control your Docker daemon
- it allows you to share a directory between the Docker host and a guest container
- e.g. we can start a container where the /host directory is the / directory on your host

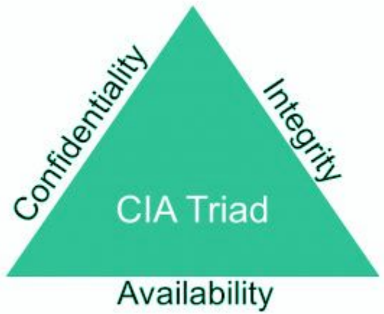
# Docker API

- an **API** for interacting with the **Docker daemon**
- **by default**, the Docker daemon listens for Docker API requests at a unix domain socket created at **/var/run/docker.sock**
- with -H it is possible to make the Docker daemon listen on a specific IP and port
- you **could** set it to 0.0.0.0:2375 or a specific host IP to give access to everybody
- Docker API requests go, by default, to the **Docker daemon of the host**

# Docker vs. chroot command

- a container **isn't instantiated by the user** but the Docker daemon!
- anyone who's allowed to communicate with the Docker daemon **can manage containers**
- that includes using any **configuration parameters**
- they can play with binding/mounting files/directories
- or decide which user id will be used in the container
    - including root (unlike eg. chroot) !

# Escaping




- a **very general** term
- it does not necessarily mean **controlling the host system**
- **data access** (according to the C.I.A triad):
  - reading violating C.
  - modifying violating I.
- **executing** code **outside** the container (assigned cgroups and namely namespaces)

# Escaping from/using Containers

- Methods:
  - Get access off the barriers (e.g. mounting filesystem while making a docker)
  - Inject a “hook” that is invoked by another party in the system
    - crontab rule, a kernel “notifier” running command on certain events
      - must run outside the container - APIs (e.g. inotify) won’t help

# Examples of Docker-related incidents

- **unprotected access** to Docker daemon over the Internet
  - revealed by common Internet scans
  - instantiation of malicious containers used for dDoS activities
- **stolen credentials** providing access to the Docker daemon
  - used to deploy a container set up in a way allowing breaking the isolation
  - the attackers escaped to the host system
  - an deployed crypto-mining software and misused the resources

# Other kernel security features

- it is possible to **enhance Docker security** with systems like TOMOYO, AppArmor, SELinux, etc.
- you can also run the kernel with GRSEC and PAX
- all these extra security features require **extra effort**
- some of them are **only for containers** and not for the Docker daemon
- as of Docker 1.10 User Namespaces are **supported directly** by the Docker daemon

# Cheat Sheets

# Docker Cheat Sheet I.

*start a new container from an image*
docker run IMAGE

*start a new container from an image with a command*
docker run IMAGE command

*start a new container in background*
docker run -d IMAGE

*start a new container and map a local directory into the container*
docker run -v HOSTDIR:TARGETDIR IMAGE

# Docker Cheat Sheet II.

*show a list of running containers*
docker ps

*show a list of all containers*
docker ps -a

*delete a container*
docker rm CONTAINER

*start a shell inside a running container*
docker exec -it CONTAINER EXECUTABLE

*stop a running container*
docker stop CONTAINER

*start a stopped container*
docker start CONTAINER

*download an image*
docker pull IMAGE

# Practical Part

# Cyber Range KYPO

- platform to organize and control cyber exercise, mostly CTF-like events
- set of services on the top of OpenStack cloud, providing separated *sandboxes*
  - machines are instantiated as VMs, connected using isolated network
- web portal mediating access to the environment and guiding participants through levels
  - description, tasks, hints
  - levels are linked using flags
- scoreboard and monitoring of progress for organizers
- platform is open-source, actively maintained by Masaryk University
  - https://kypo.muni.cz/

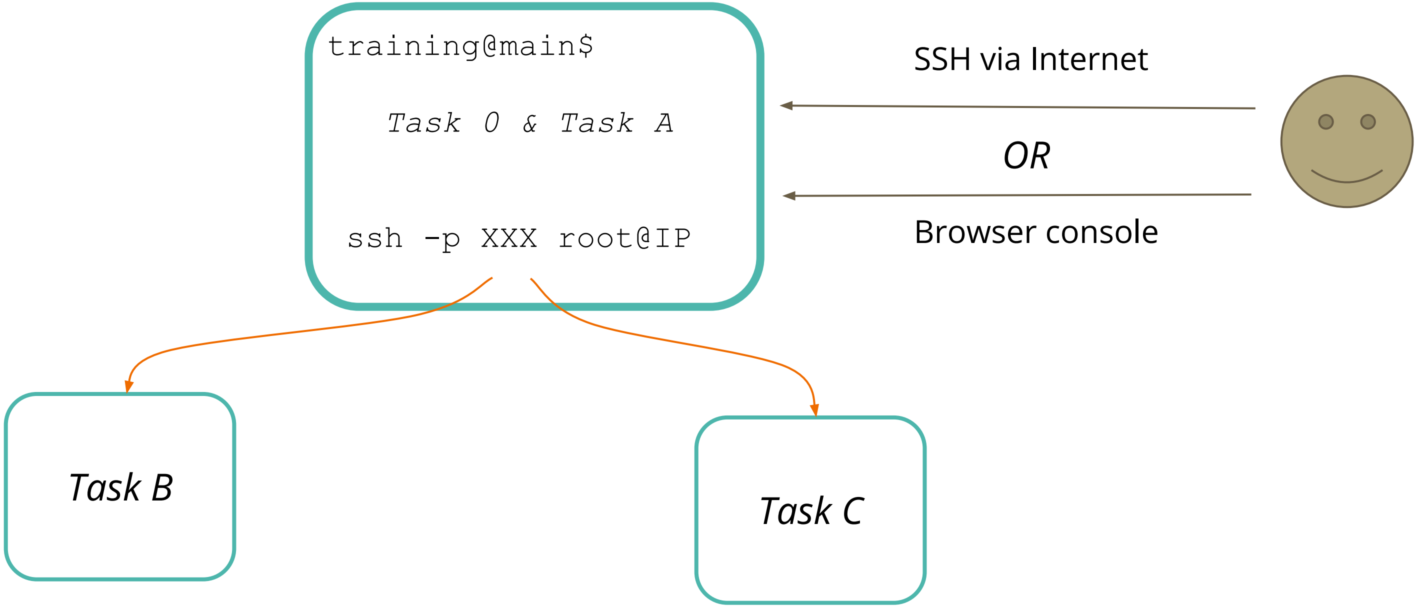
# How To Get Started

- “book” your account at
  - https://docs.google.com/spreadsheets/d/1gs2DPeYRO1gAdQS78D721GX5BAIrlG_WUKciKT1ua6Y/

- log in portal https://isgc.crp.kypo.muni.cz using the booked credentials
  - you will start off the intro page
  - 16 “levels” in total (inc. intro etc.), each level contains
    - description
    - hints
    - specification of the flag
  - once you determine the flag, submit it to get to the next level

- interaction with VMs via either
  - embedded console (see the topology, click the “main” node (right mouse button) and open the console
  - directly using SSH (but ignore the “Get SSH Access”)

# Topology



training@main$
Task 0 & Task A
ssh -p XXX root@IP
SSH via Internet
OR
Browser console
Task B
Task C

# Thank you for your attention.

Please be so kind and fill in our short questionnaire:

https://forms.gle/7kpR5gdE3L3bom8m6