

(Linux) Containers introduction

WASA: Web and Software Architecture

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Containers

Virtualization technologies

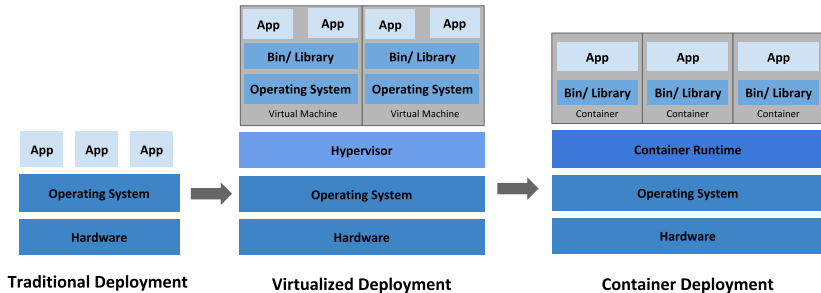


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Standard deployment:

- Processes aware of other processes
 - they can interact each other (POSIX signals, shared mem)
- They share kernel, libraries, filesystem, hardware
- Little to no constraints, limited "supervision" (restart-on-crash, etc.)

Virtualization:

- World divided in two roles:
 - host is the O.S. running on real hardware
 - guest is the O.S. running in the virtual machine
- Guest machine instructions are executed/translated by the hypervisor
- Direct hardware access not needed
 - guests have "virtual hardware" devices
 - but it might be granted if needed
- VMs are isolated: crashes, security incidents, etc. in guests are not affecting other guests

Containers

Containers:

- World is still divided in:
 - host is the O.S. running on real hardware
 - containerized process(es) is the process(es) running in a container
- A container is a set of restrictions placed on **syscall**
 - A container may have one or more processes
- Containerized processes runs on the same kernel of the host
- Restricted environment
 - Filesystem is not shared by default
 - processes cannot interact by default
 - other restrictions are in place
- Less isolation than the VM:

a problem in a containers is not affecting other containers

Linux containers

In general, many operating systems supports containers in various shapes:

- chroot in most UNIXes (since 1982!)
- FreeBSD jails (2000)
- Solaris Containers/Zones (2000)
- LXC on Linux (2005)
- Docker/Podman on GNU/Linux (2013), Windows and recently FreeBSD
 - macOS is not in this list!
- Other technologies: LXD, vServer, OpenVZ, Virtuozzo, etc.

Linux containers

In Linux, containers are built over **cgroups** (v2 currently). cgroups were designed by Google in 2006, and published in 2008.

They provide:

- Resource limitings
 - limits on CPUs, RAM, filesystem, I/O
- Prioritization
 - some processes may have priority
- Accounting
 - resource usage measurements (e.g., billing, issue detection)
- Lifecycle control
 - restart on crash, checkpoint, schedule, etc.

Linux containers

cgroups are responsible for resource management. It makes sense, to grant some daemon exclusive access to this functionality to avoid lots of problems.

systemd-nspawn

If your sound card can do hardware mixing, and your Linux device driver supports this feature, then multiple programs can access your sound card at the same time and you hear them all simultaneously!

PulseAudio does software mixing. Without hardware or software mixing, only one program can access the sound card; as a result, you cannot have Audacious AND VLC put out sound at the same time!
JACK daemon does the same but targets professional audio editors.

DRM manages the GPU
KMS manages the display controller (CRTC) The display controller usually sits on the die of the GPU, and communicates with the monitor, e.g. changes the resolution or the refresh rate.

David Herman split DRM and KMS, then added "render nodes" to the DRM.

X.Org doesn't need to be root any longer, but it's still wise (technically necessary?) to grant it exclusive access to the KMS.

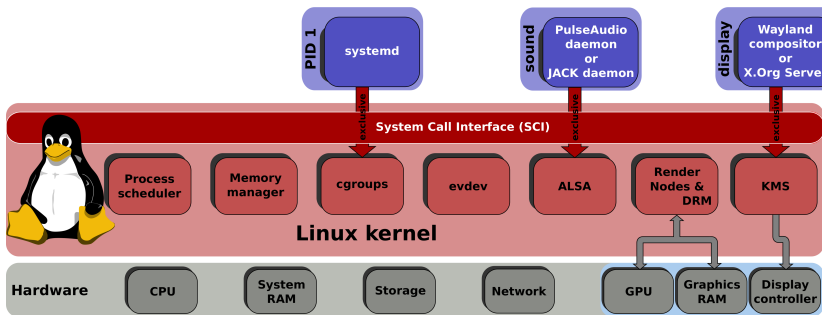


Image courtesy of Wikipedia author ScotXW - CC BY 4.0

Namespace isolation

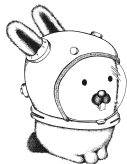
Each container runs in namespaces. A namespace may contain one or more containers.

Processes/containers that runs in the same namespace can share their resources with others.

There are different namespaces:

- Process ID (PID)
- Network
- UTS / hostname
- Mount
- IPC
- User
- Cgroup

Linux namespaces came from Plan 9, which is an experimental operating system from Bell Labs.



Plan 9 was invented by the same group that developed UNIX and many programming languages: B, C, and GO!

OCI containers

Docker (2013) is a set of tool for managing Linux containers, and, lately, Windows containers.



Docker containers have been standardized under OCI (Open Container Initiative), and different implementations exists (e.g., podman).

OCI/Docker glossary

- **Container:** a Linux containers (or Windows containers on Windows)
- **(Container) Image:** an archive with files and configurations for creating a new container
- **Registry:** a forge for sharing/storing container images (e.g., DockerHub)
- **Dockerfile/Containerfile:** a file that specifies how to build a container image
- **(Docker) compose:** a YAML that specifies how to run a container
- **Volume:** an external storage space that is mounted inside the container
 - containers may share a volume
 - volume are persistent

Docker Container are started from an image. The image contains the new "root directory" for the container. **This new root will be ephemeral** (data will be deleted at exit).

Processes cannot access files outside that root. However, docker can be instructed to mount an external volume in a specific path inside the container.

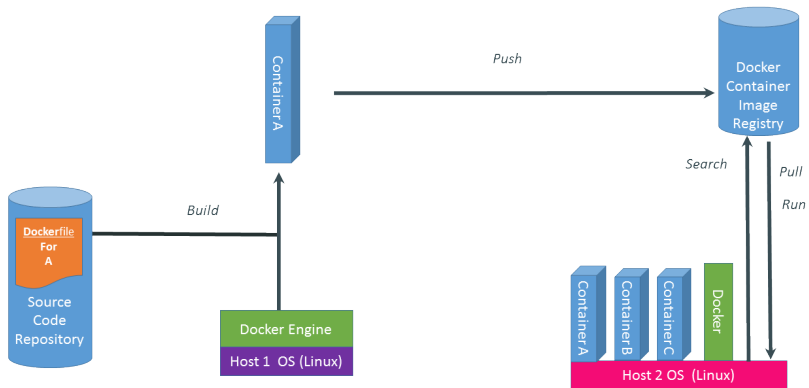
OCI/Docker container images

Container image are built using Dockerfile/Containerfile. The file contains instructions; each instruction creates a layer.

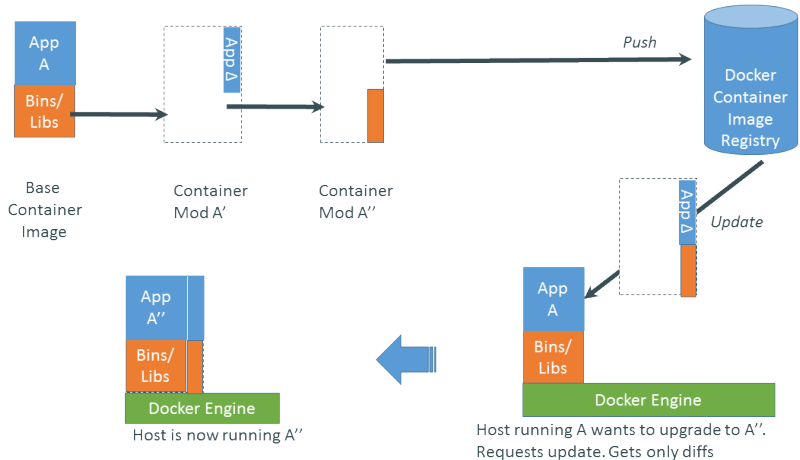
Layers contains the difference since previous layers. They can be cached and reused.

Usually, container images starts from a base image, which contains some tools. E.g., `debian:stable` contains a basic Debian stable system; `python:3` contains a basic Python 3 interpreter (with all dependencies!).

OCI/Docker: flow



OCI/Docker: share layers



Once a container is built, it can run on any Linux platform, regardless of the underlying system (provided that it supports cgroups and other container-related technologies).



Run your first container

To run a container with Docker, you can use a simple command:

```
docker run -it --rm debian:bullseye
```

This command creates a new interactive (flag `-it`) container using the image `debian:bullseye`, and remove the container at exit (flag `--rm`).