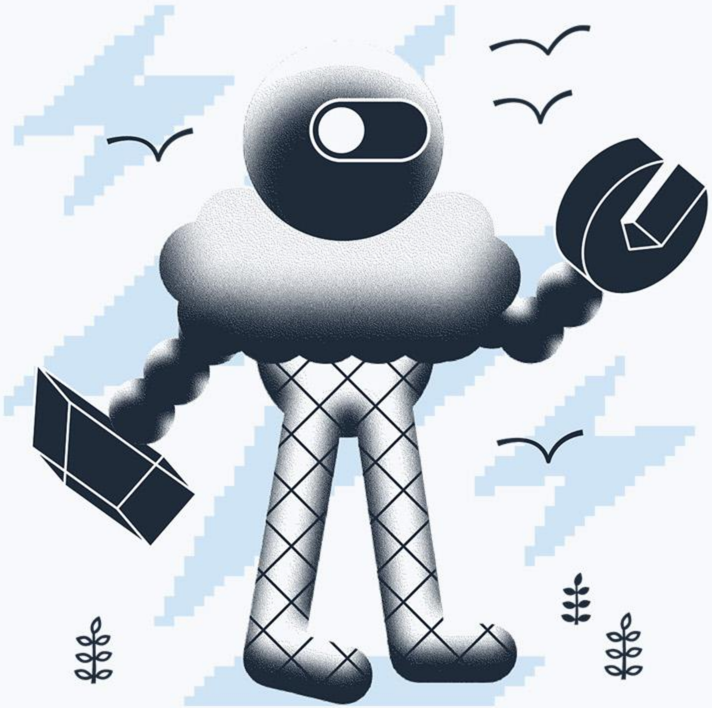
3fs

Containers: A Peek Under the Hood



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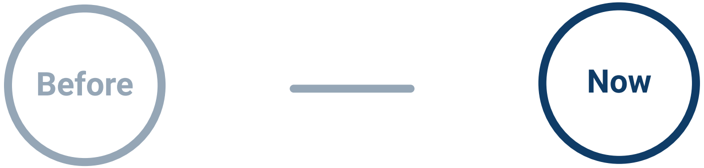
13 APRIL 2024

A little bit about myself



Before

Now

R&D engineer

@ https://www.arctur.si/

Backend software engineer

@ https://www.3fs.cloud

How did I get here?

- I've been actively working with containers for over 7 years.
- For much of that time, I didn't really understand what was happening under the hood. Tools like Docker and Kubernetes really do a good job at hiding the complexity.
- My interest in security made me dig deeper, leading to a realization: you can't protect what you're unaware of.

What is a container?

Let's google it

Docker

“A container is a standard unit of software that packages up code and all its dependencies so the application runs quickly and reliably from one computing environment to another.”

Google Cloud

“Containers are lightweight packages of software that contain all of the necessary elements to run in any environment.”

Red Hat

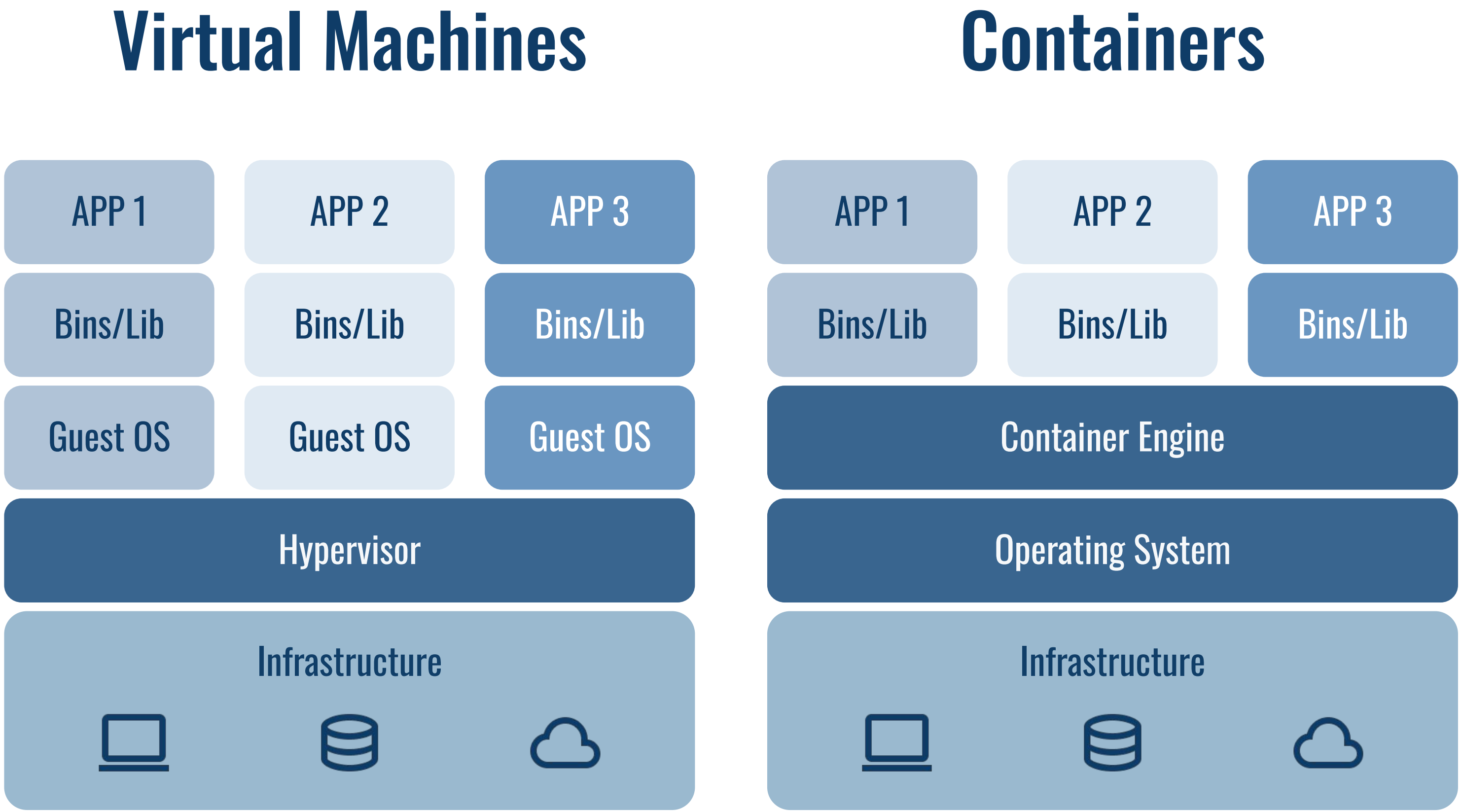
“Containers are technologies that allow the packaging and isolation of applications with their entire runtime environment—all of the files necessary to run.”

Probably most heard answer?

“ Oh you mean docker? It is something like a Virtual Machine but lightweight.”

Truth?

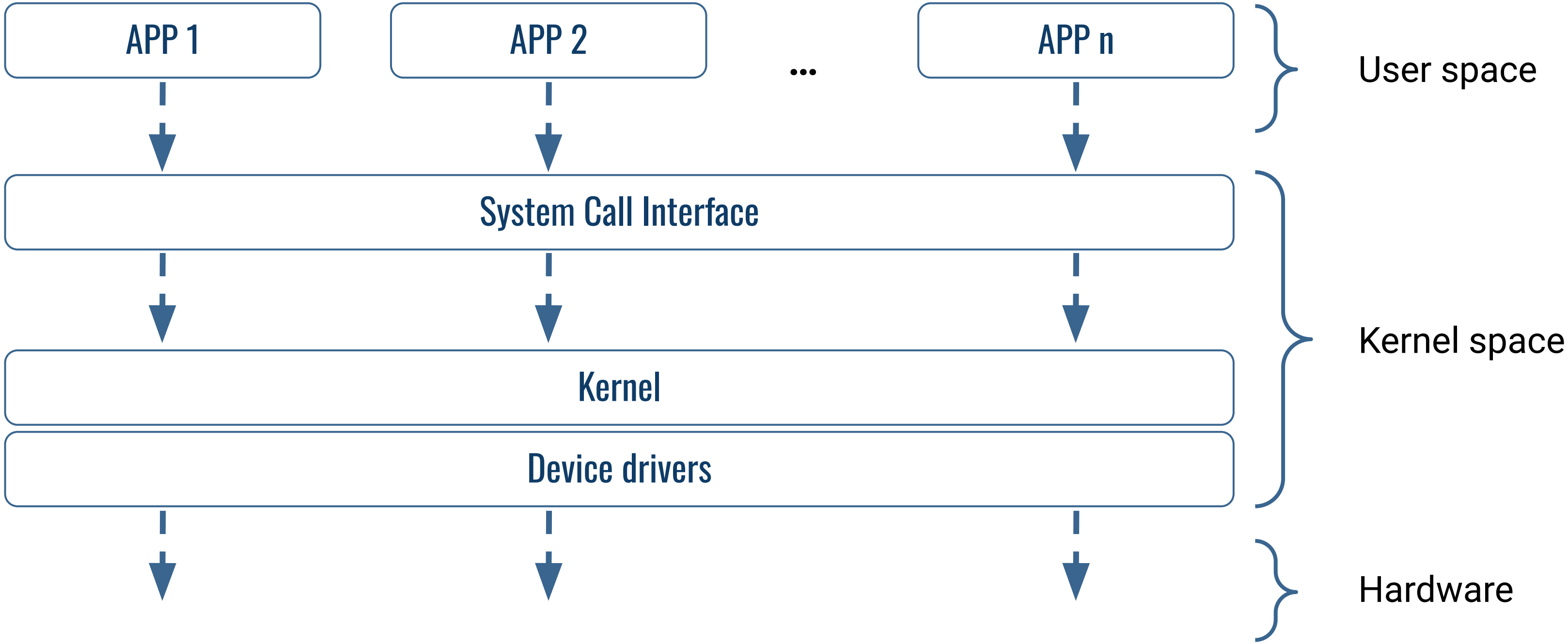
- They are **just processes**, just like any other application that runs directly on the host
- The major difference between containers and VMs is that containers **share host kernel** while VMs virtualize hardware and run multiple guest operating systems on a single physical machine.


Virtual Machines
APP 1
APP 2
APP 3
Bins/Lib
Bins/Lib
Bins/Lib
Guest OS
Guest OS
Guest OS
Hypervisor
Infrastructure
Containers
APP 1
APP 2
APP 3
Bins/Lib
Bins/Lib
Bins/Lib
Container Engine
Operating System
Infrastructure

Why does shared kernel matter?

- Userspace applications cannot directly access the system's hardware resources or perform low-level operations.
- They must make **system calls** to the kernel to request access to these resources.
- **System calls** are requests made by user-space applications to the kernel to perform privileged operations on their behalf, such as reading from or writing to files, creating or terminating processes, establishing connections and managing memory.

Why does the shared kernel matter?



APP 1

APP 2

...

APP n

User space

System Call Interface

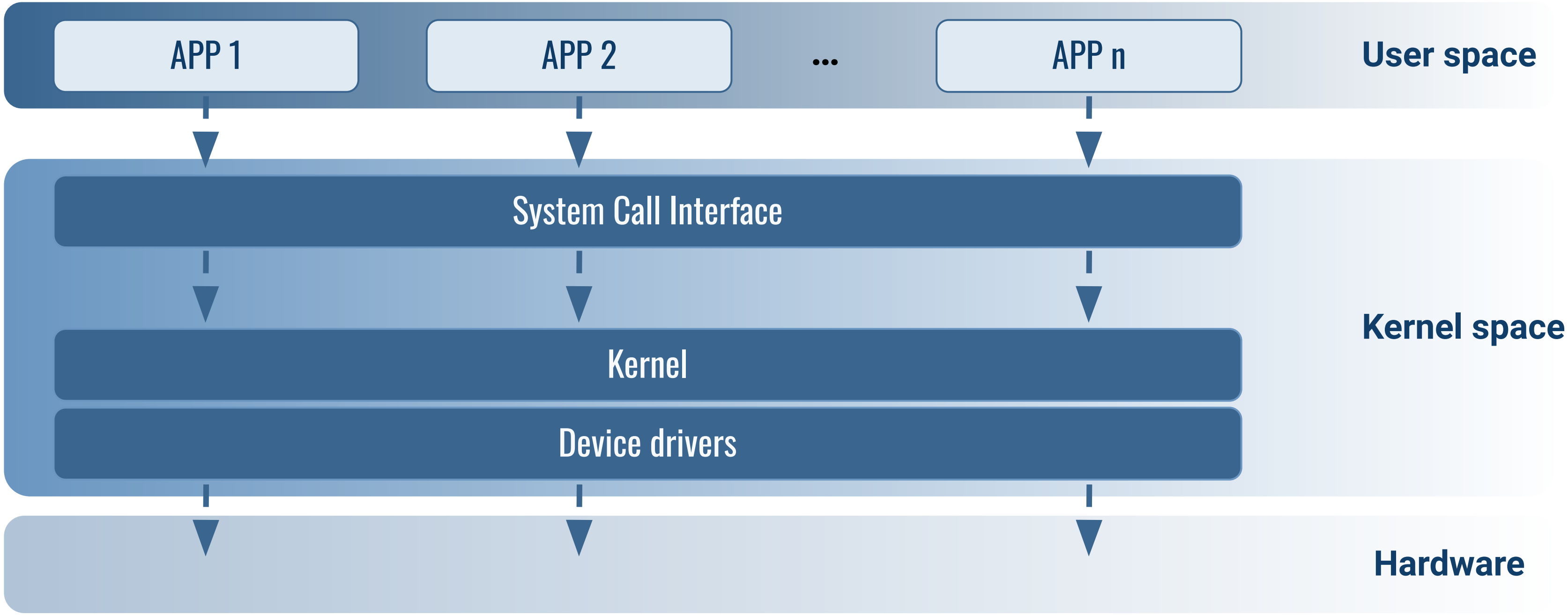
Kernel

Device drivers

Kernel space

Hardware

Why does the shared kernel matter?



DEMO

It is just a process.

What makes a process a container?

- **Isolation**
  Processes should run independently, unaware of other processes or the host system.

- **Encapsulation**
  Wraps everything an application needs to run (including dependencies and libraries) into a single package.

- **Resource restriction**
  Controls and limits the amount of CPU, memory, and disk resources that each container can use.

What makes a process a container?

Isolation

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Namespaces

Isolation

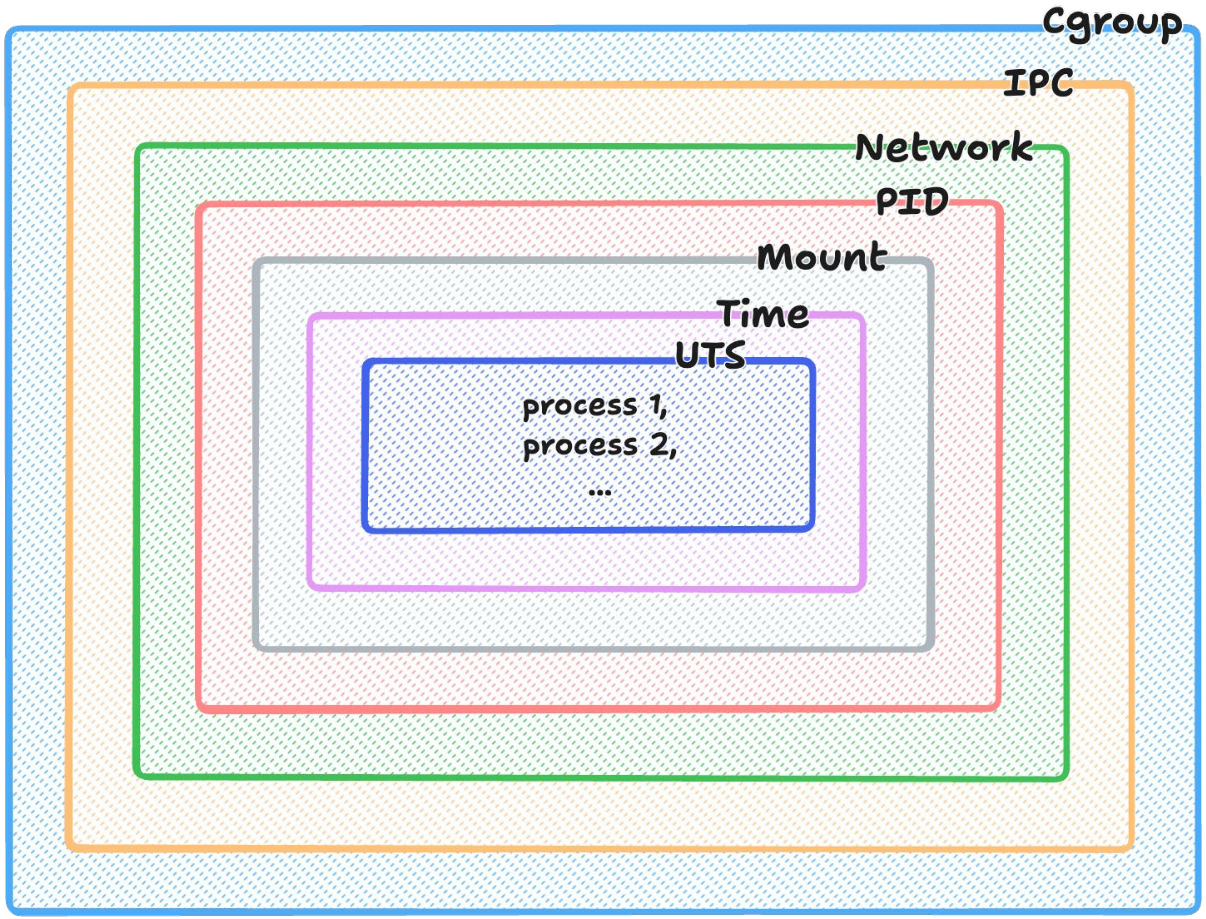
Namespaces

- Allow a process to have its own isolated instance of global resources (e.g., process IDs, network interfaces).
- They limit the potential impact of malicious processes.
- Changes to the system resource are visible to other processes that are members of the namespace, but are invisible to other processes.

Types

- Control Groups (Cgroups)
- Inter Process Communication (IPC)
- Network
- Mount
- Process ID (PID)
- Time
- User
- Unix Time Sharing (UTS)

Default namespace layout



Cgroup

IPC

Network

PID

Mount

Time

UTS

process 1,
process 2,
...

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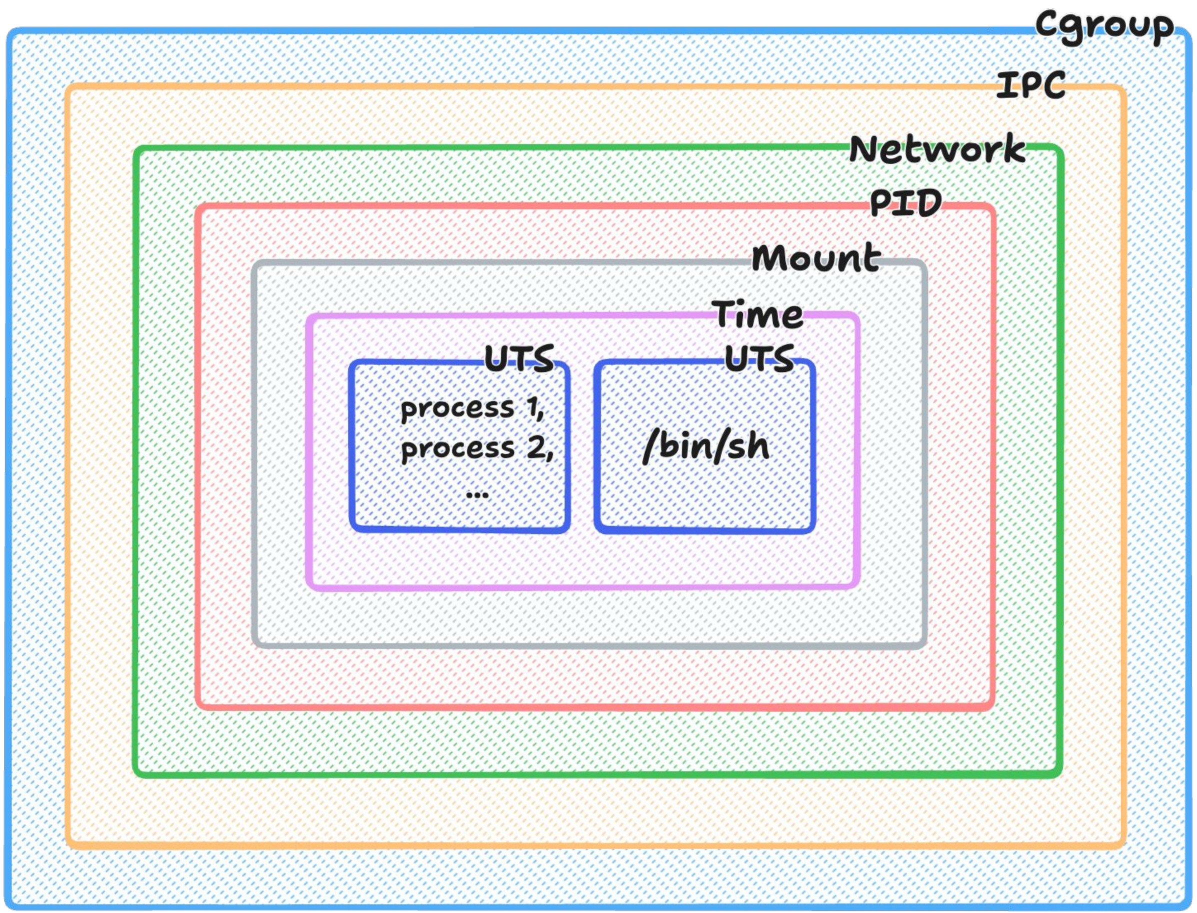
What we want to do in demo



DEMO

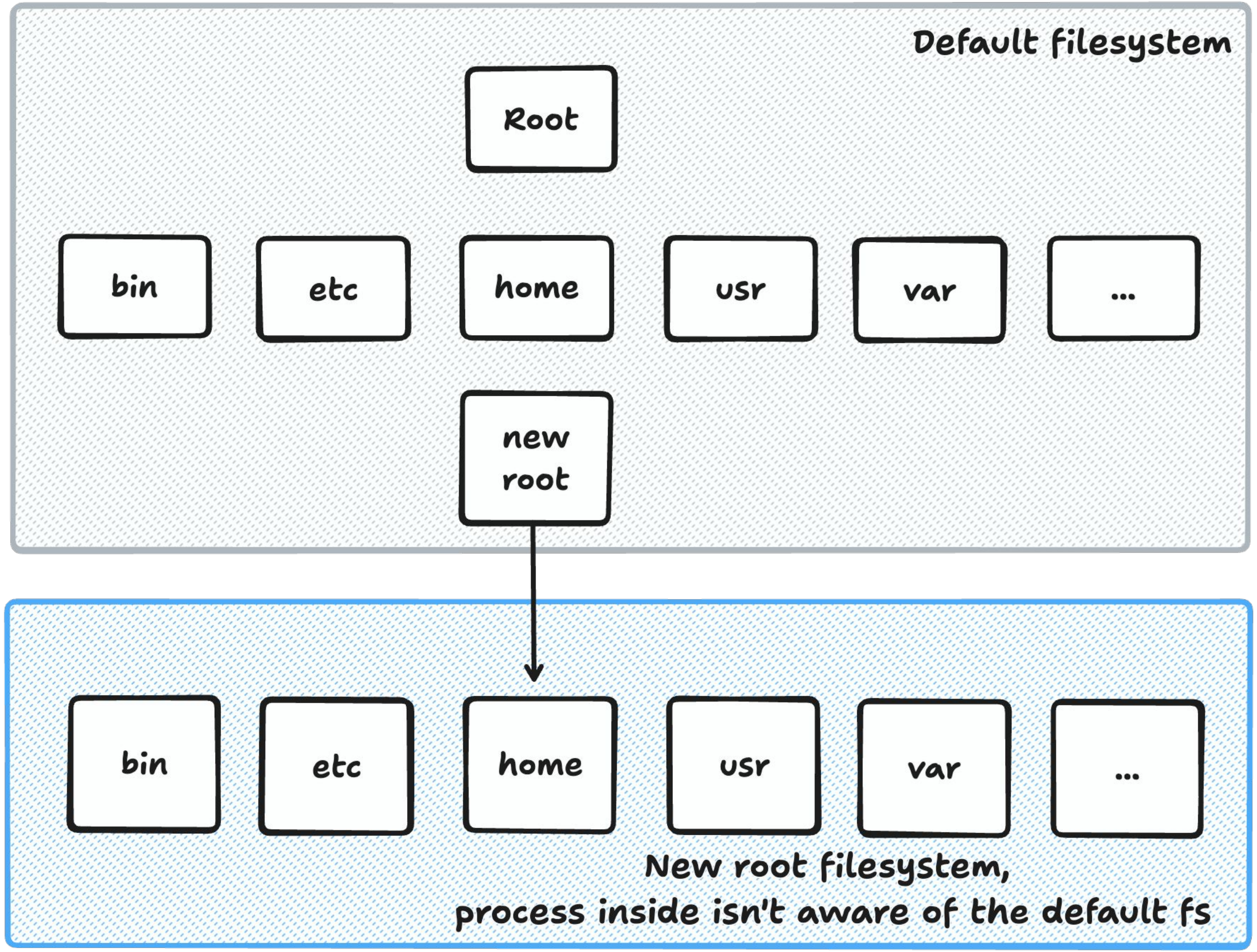
- Unix Time Sharing namespace
- Process ID namespace

Chroot

Encapsulation

Chroot

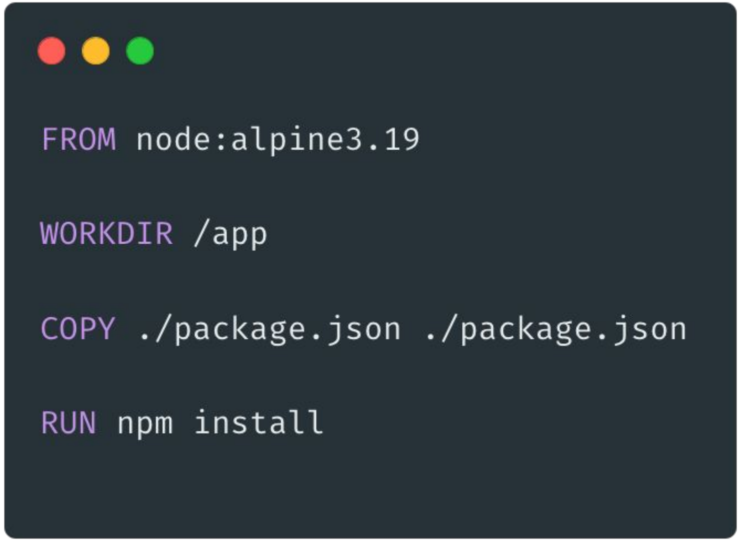
- Used to run command or interactive shell with a new root directory.


Default filesystem
Root
bin
etc
home
usr
var
...
new root
bin
etc
home
usr
var
...
New root filesystem,
process inside isn't aware of the default fs

DEMO

- Chroot

Docker image layering

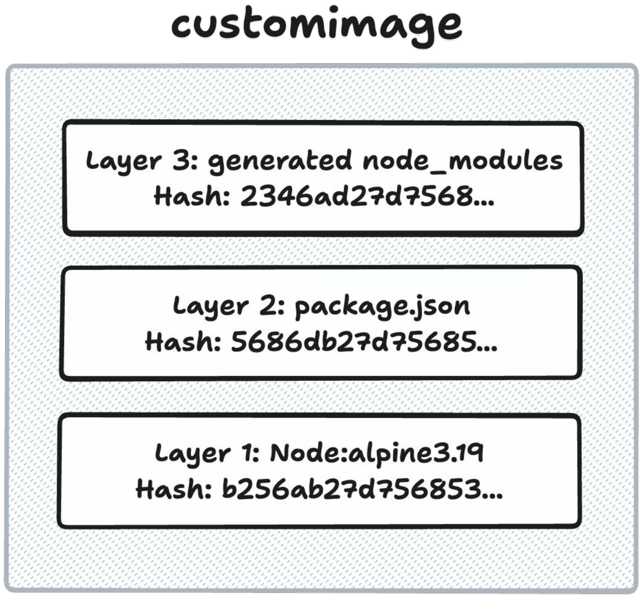


```
FROM node:alpine3.19

WORKDIR /app

COPY ./package.json ./package.json

RUN npm install
```



customimage

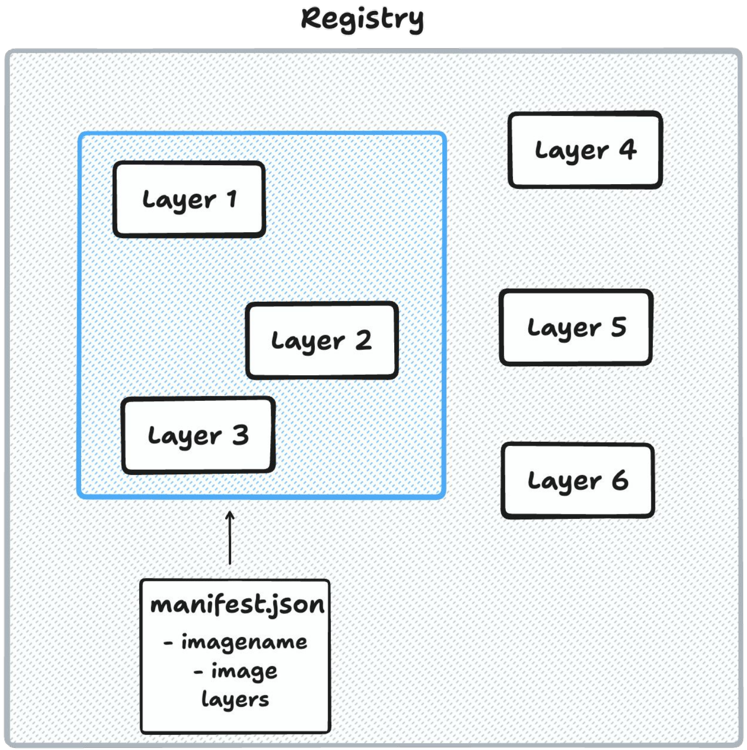
Layer 3: generated node_modules
Hash: 2346ad27d7568...

Layer 2: package.json
Hash: 5686db27d75685...

Layer 1: Node:alpine3.19
Hash: b256ab27d756853...

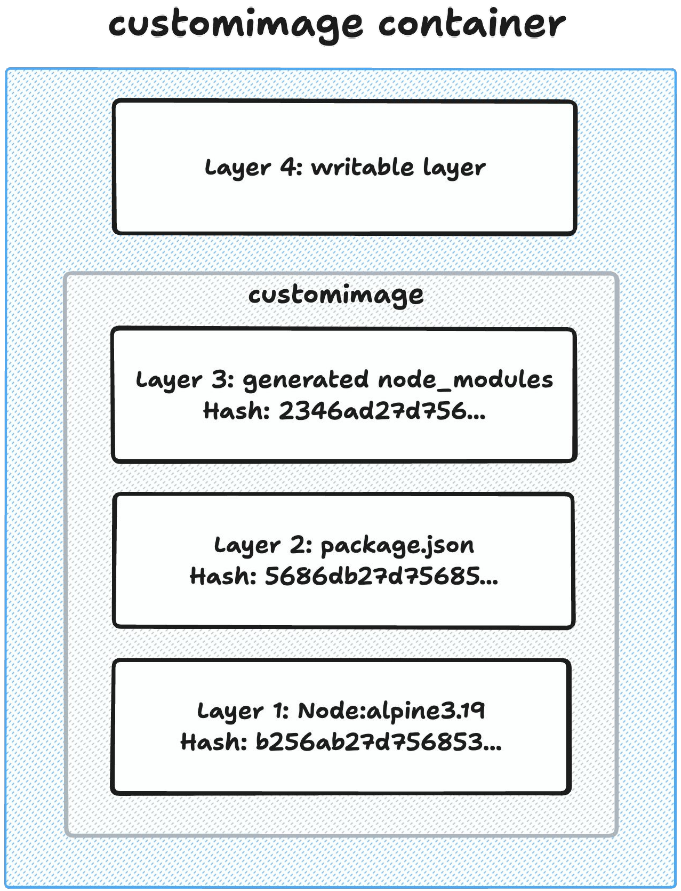
Layers inside container registry

- Layers are independent entities in a Docker registry.
- Manifest.json defines the composition of a Docker image



Once used

- A new writable layer on top of the image's read-only layers is created.
- Allowing for the original image to remain unchanged and reusable.



DEMO

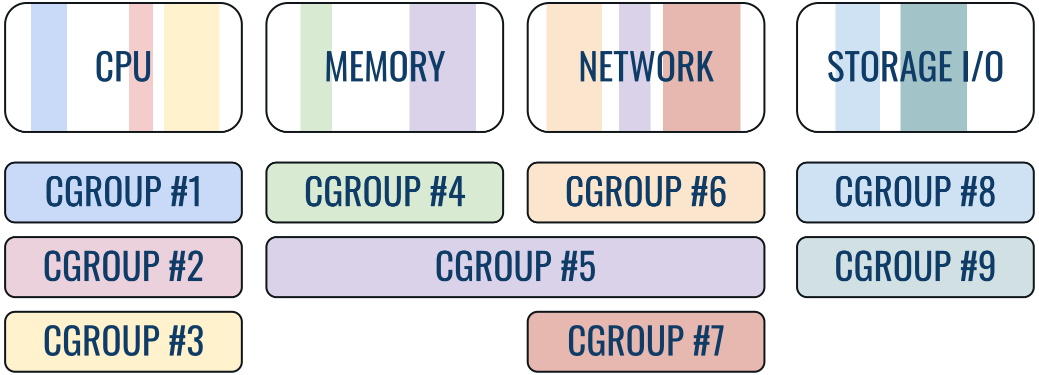
- Docker image inspection

Controls Groups

Resource limitations

Cgroups

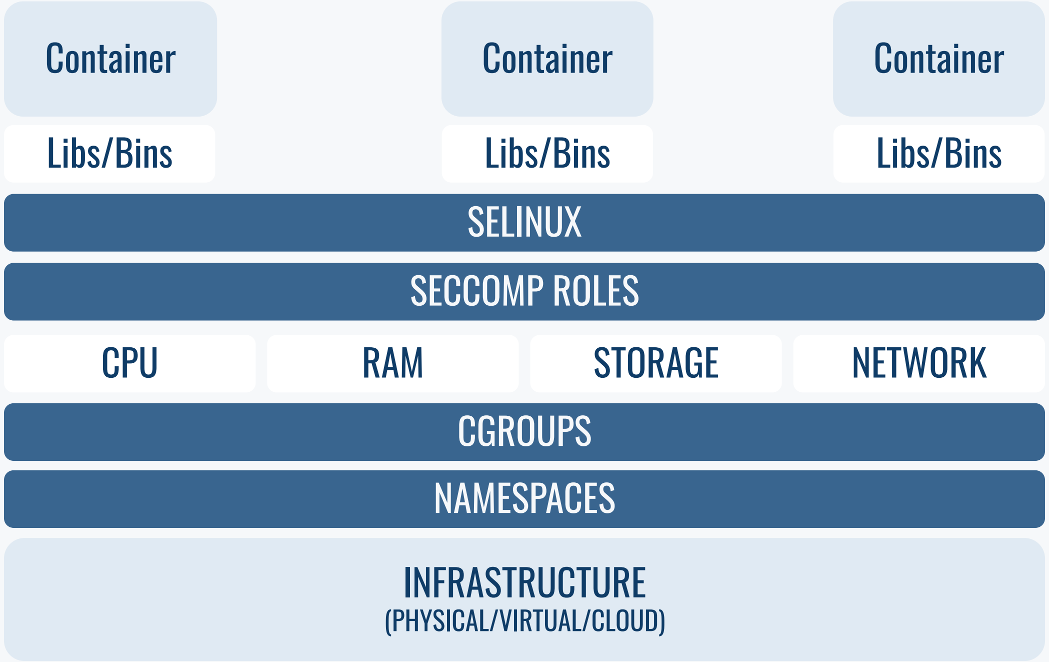
- Allow you to allocate resources (CPU time, system memory, network bandwidth, or combinations of these resources among processes)
- Cgroups are organized hierarchically (child cgroups inherit some of the attributes of their parents)



DEMO

- Cgroups in actions.

Let's put everything together.



Container
Container
Container

Libs/Bins
Libs/Bins
Libs/Bins

SELINUX

SECCOMP ROLES

CPU
RAM
STORAGE
NETWORK

CGROUPS

NAMESPACES

INFRASTRUCTURE
(PHYSICAL/VIRTUAL/CLOUD)

Container escapes

And how to be “safer”

Be careful when using

- **–privileged** flag (124k files on Github)
- **-v /var/run/docker.sock:/var/run/docker.sock** mount (171k files on Github)
- **–cap-add=*** flags (52 files on Github)

DEMO

- Escape from a privileged container.
- Escape out of container with mounted docker.sock.

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QUESTIONS?