Containers 101

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Containers 101 Agenda

- What is a Container?
  - Containers vs Virtual Machines
- Where are Container Technologies used today?
- Container Technologies
- Docker/OCI vs Linux Containers (LXC)
- Docker/OCI Overview
- Orchestration Overview

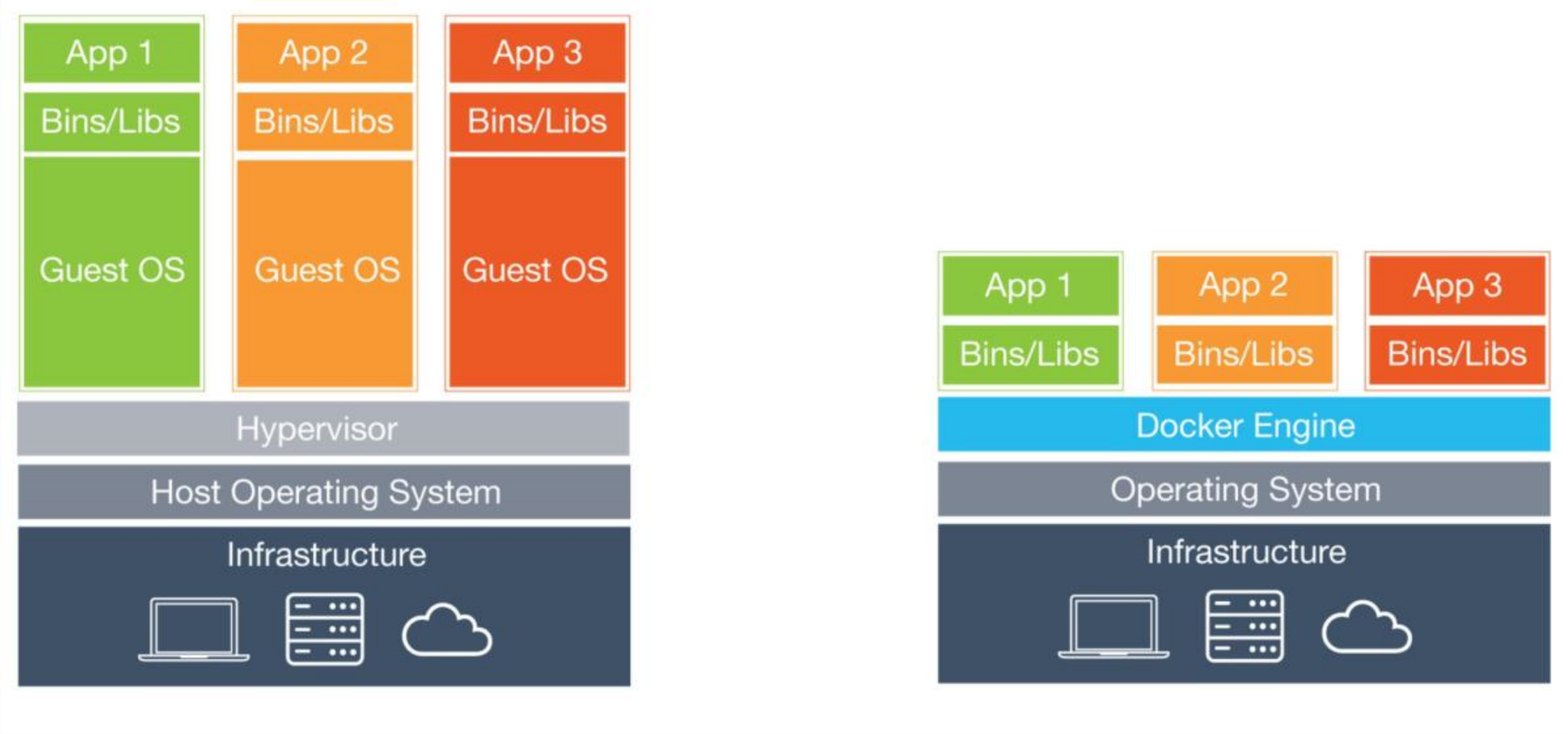
Where are Container Technologies used Today?

- Docker/OCI Containers
- Linux Containers (LXC)
- Snaps/Flatpaks
- FireJail
- The dreaded Google Chrome
- Kubernetes, Amazon ECS etc.

What is a Container

- Sandbox for a process
- Uses technologies built-in to the Linux Kernel

Containers vs Virtual Machines



Three Little Pigs by Dan Walsh

Once upon a time there were Three Little Pigs, who had different types of homes to choose from...

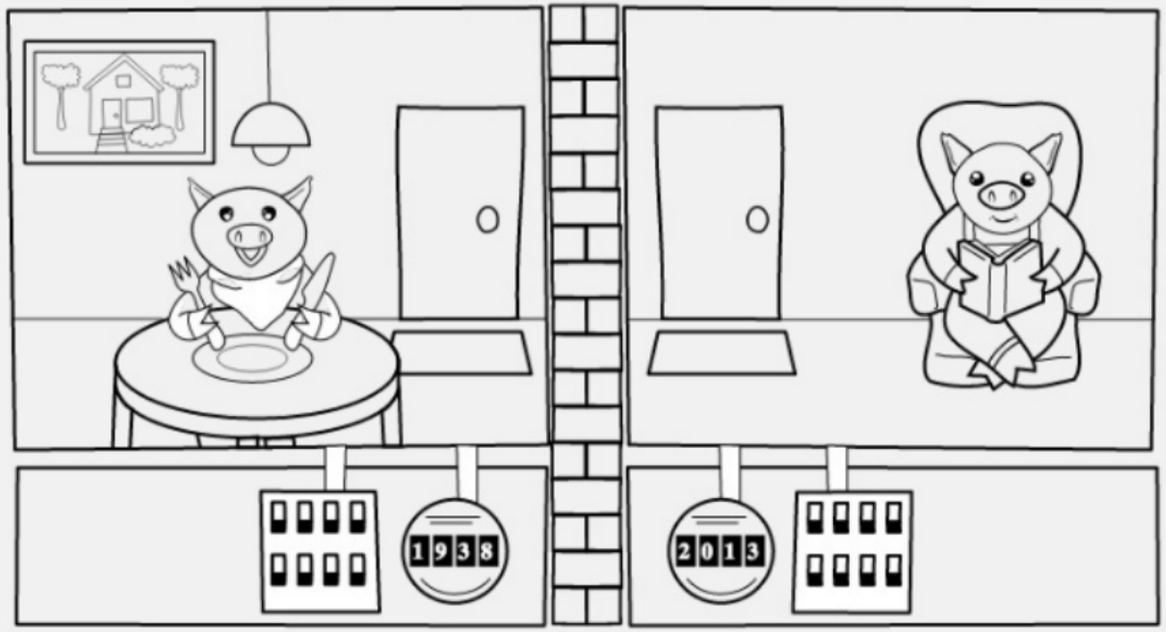
Standalone Homes

Separate Physical Machines

If one house is broken into, the rest remain secure...a lot more maintenance though!

Duplex Home

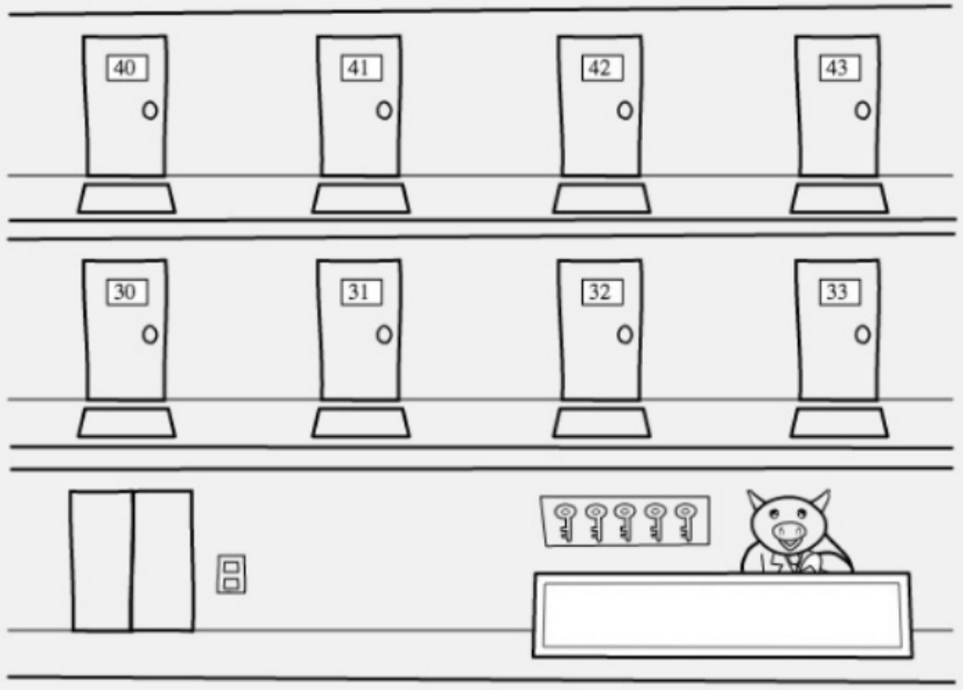
Virtual Machines



Hypervisor, sVirt and the host kernel provide separating..but still cost of maintaining separate OSes

Apartment Building

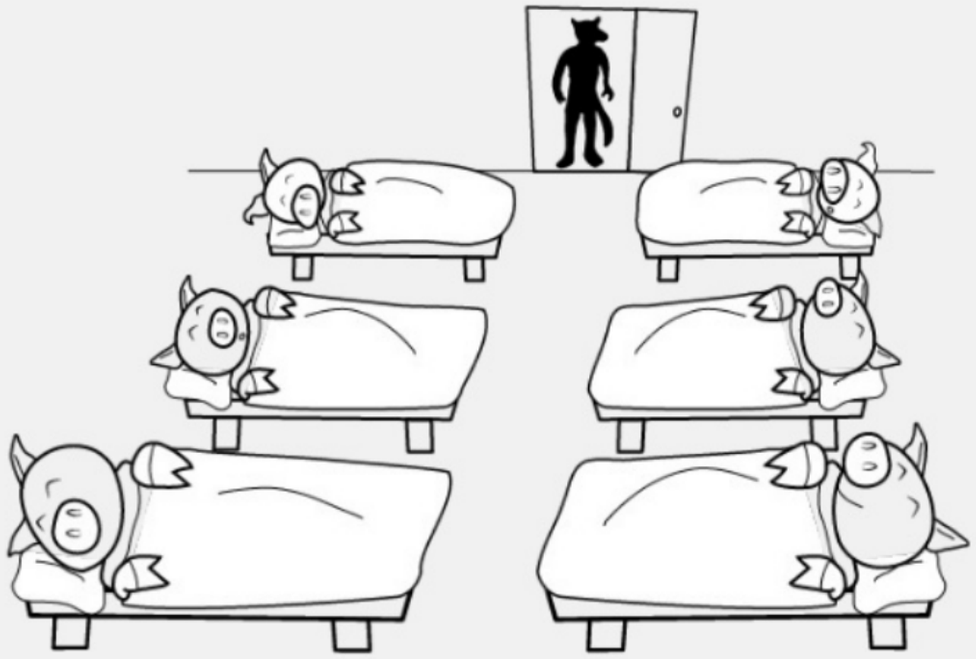
Containers



Excellent sharing of services, lower cost of maintenance and decent separation

Hostel

Services on the same machine



Limited isolation between services, better if you have SELinux

Park Bench

setenforce 0

Don't let this be you...

Pigs in Apartment Building

The best combination

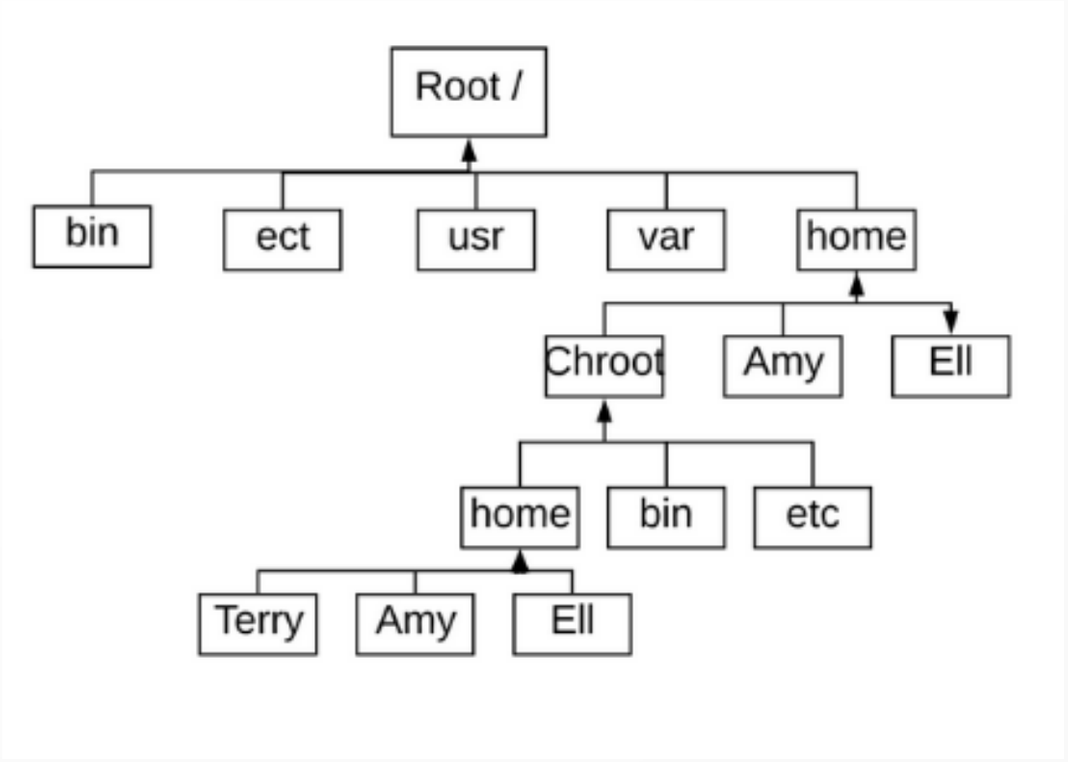
Best combination of resource sharing, ease of maintenance & security.

What's a Container Made of

- Chroot
- Linux Namespaces
- Cgroups
- Linux Capabilities
- SECCOMP

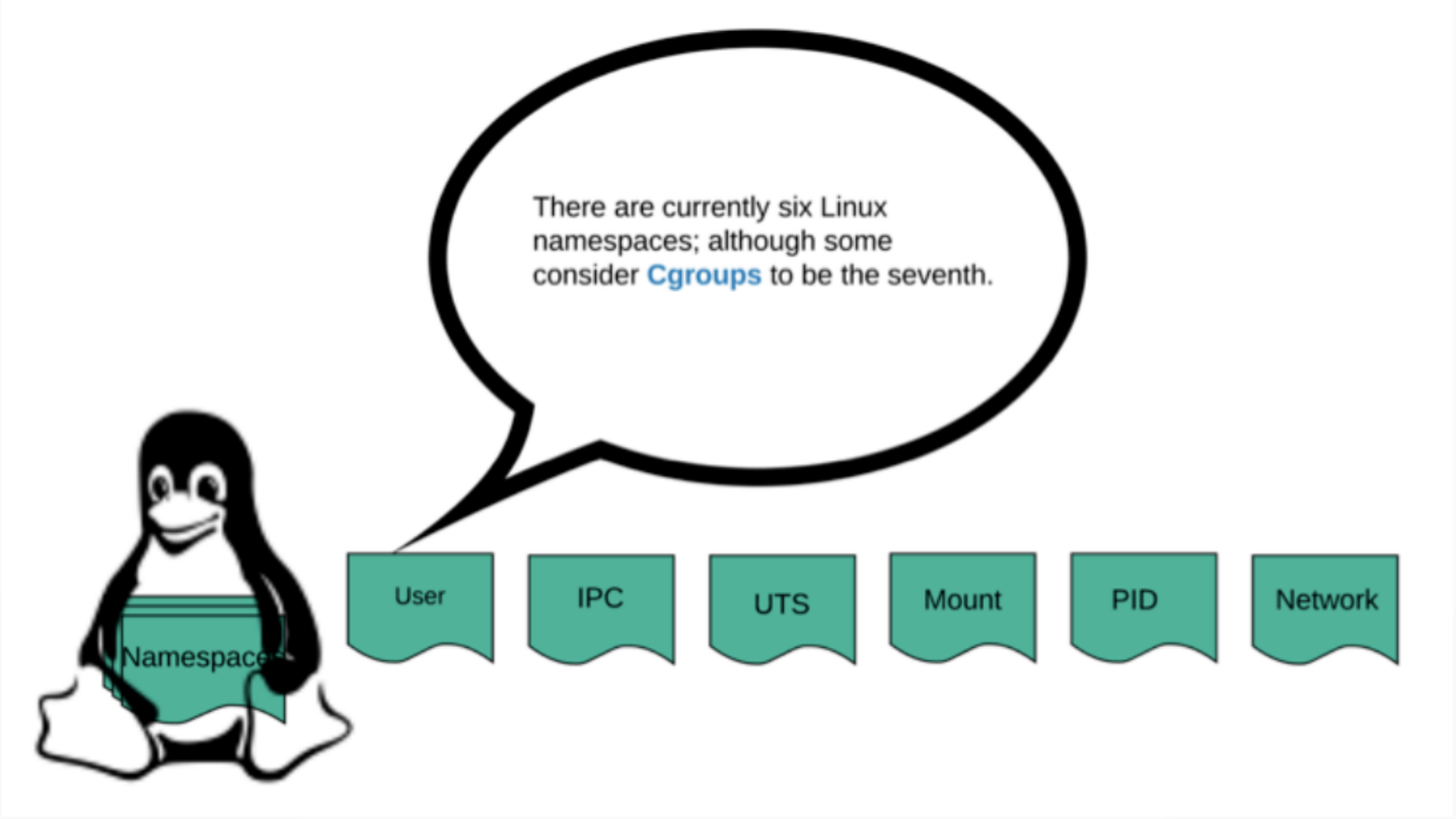
Chroot

- Chroot = Change root
  - Changes the apparent root directory.
  - A new “root” directory becomes the root directory for both the current and running processes and all of the children processes.
  - A new “root” directory is known as a jailed directory or “Chroot jail”.
  - Chroot must be run as privileged user.



Chroot Demo

Linux Namespaces

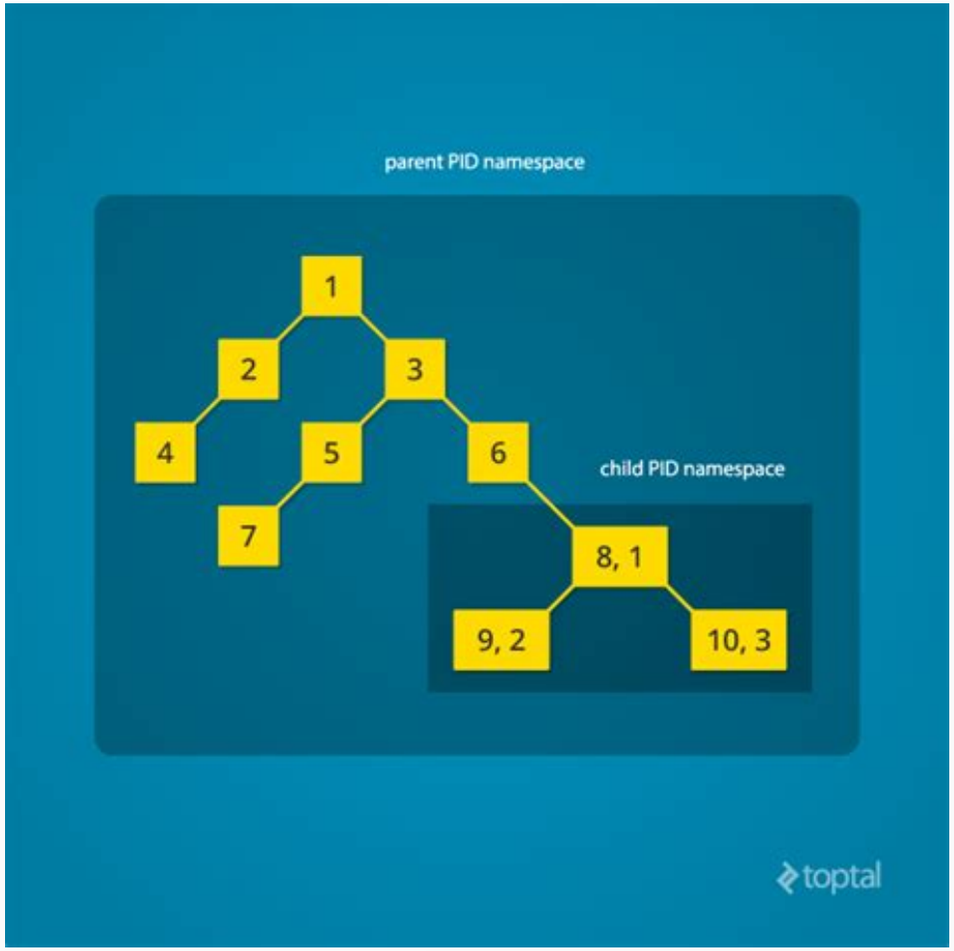


Linux Namespace

- User
  - Maps non-root user ID on the host to root user ID in the namespace
  - Can map non existent user ID on the host (i.e. ID above 65000)
- IPC – Interprocess communication
- UTS – different host and domain names
- Mount
  - Isolates the mount table
  - Mount / Unmount operations isolated to the namespace
- PID – Process IDs
- Network
  - Virtualize the network stack
  - Each namespace can have it’s own virtual or physical network interface, resources and firewall rules.

PID Namespace

- Allows a container its own isolated instances of global resources
  - I.E. PID namespace can only see processes running in the container



Network Namespace Demo

Cgroups – Control Groups

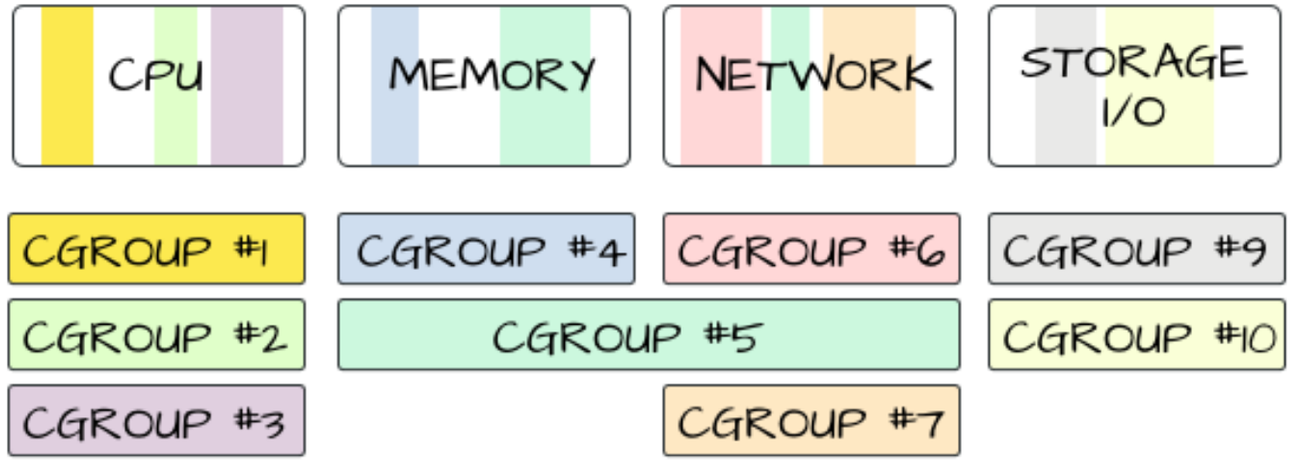
- Limits the usage of resources to the container/process
  - Number of CPU cores
  - % of CPU usage
  - Amount of memory
- Control which device nodes can be created within a namespace
  - i.e. /dev/console, /dev/tty, /dev/random used by kernel and by default not available to containers
- Access in /sys/fs/cgroup

Cgroups – Control Groups

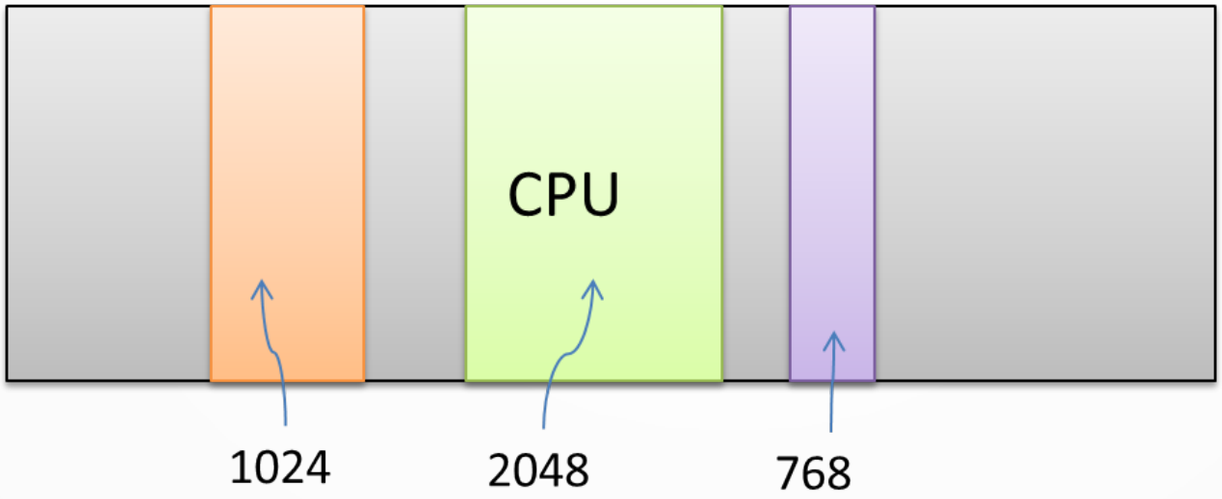
Docker Grounds up: Resource Isolation

Cgroups : Isolation and accounting

- cpu
- memory
- block i/o
- devices
- network
- numa
- freezer



Cgroups – Control Groups



Cgroup #1	Cgroup #1 gets more CPU than Cgroup #3
Cgroup #2	Cgroup #2 gets twice CPU than Cgroup #1
Cgroup #3	Cgroup #3 gets less CPU than both other Cgroups

Linux Capabilities

- Linux root privileges broken down into 32 capabilities
- Capabilities can be disabled per container.
- Two capabilities always dropped:
  - CAP_NET_ADMIN: capability to configure network (i.e. ip routes, firewall rules, etc.)
  - CAP_SYS_ADMIN: catch all capability, used to control mounts

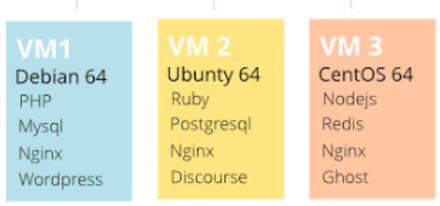
SECCOP

- Containers can interact with kernel system calls (syscalls)
  - i.e. bind, accept, fork
- SECCOMP limits the number of syscalls a container can access
- Docker disables around 44 of 300+ system calls with default aptions
  - i.e. mount, settimeofday

Docker/OCI vs Linux Containers/LXC

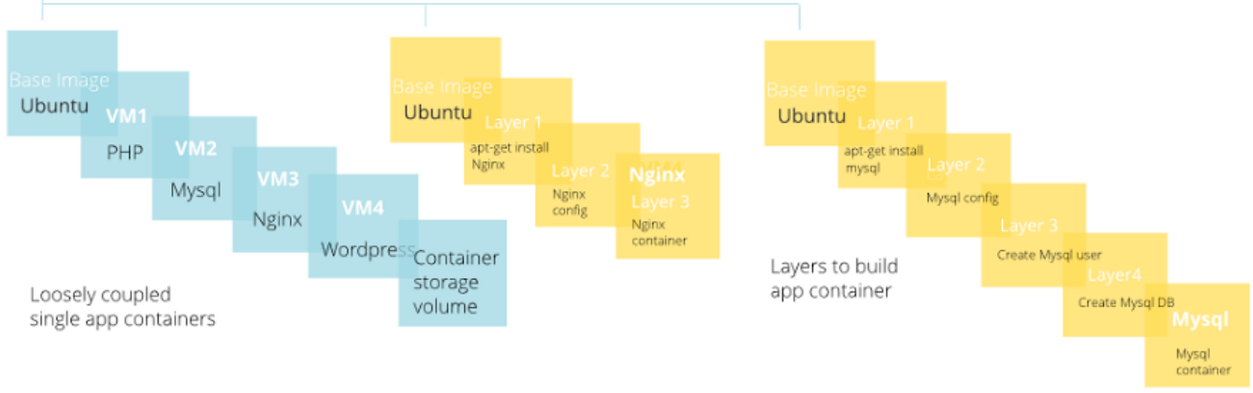
Key differences between LXC and Docker

LXC



- Filesystem neutral
- Containers are like VMs with a fully functional OS
- Data can be saved in a container or outside
- Build loosely coupled or composite stacks

Docker



- Containers are made up of read only layers via AUFS/Devicemapper
- Containers are designed to support a single applicaton.
- Instances are ephemeral, persistent data is stored in bind mounts to host or data volume containers

Benefits of Docker/OCI Containers

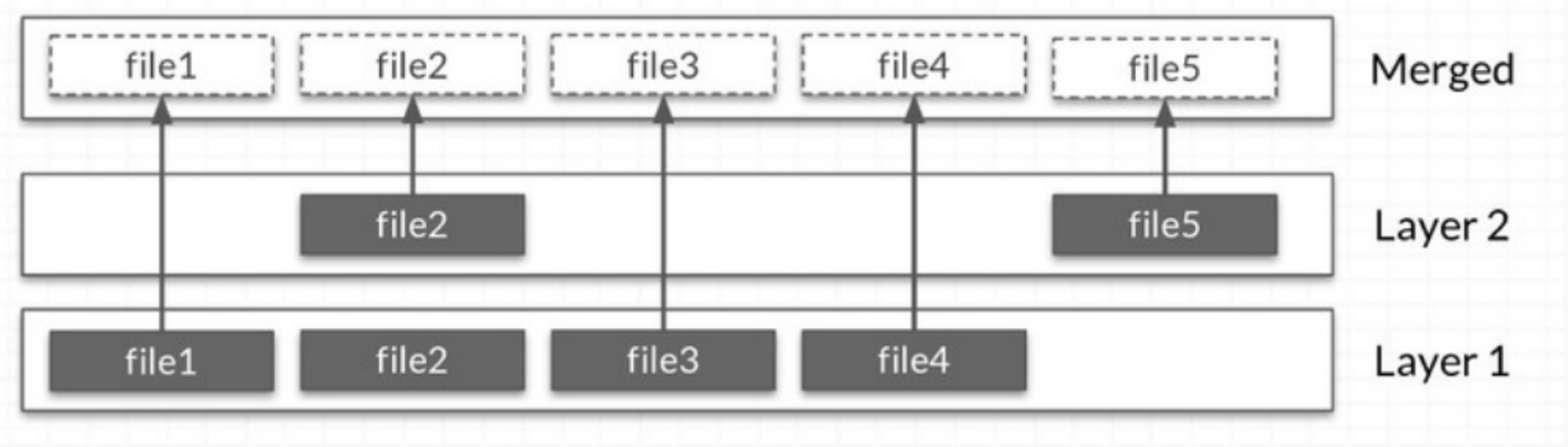
- Portable Deployment Across Machines
- App Centric
  - Sometimes referred to application containers vs machine containers
- Automatic Build
- Versioning
- Component re-use
- Sharing

Docker/OCI: Images

- What is an Image?
  - Fully self-contained “thing” that contains everything an app needs to run
    - Application source code
    - All runtime dependencies, config files, and binaries
  - At the end of the day, it’s basically just a transportable file system
  - Images are Stateless and Immutable!
  - Share images by pushing to a registry
    - Docker Hub is the default Docker registry
    - Many other third-party registries exist
    - Once shared, others can pull the image

Docker/OCI: Image Layers

- Images are composed of layers of filesystem changes
- Each layer can add or remove from the previous layer
- Each layer's filesystem changes are stored as a single tar file
- Joined together layers provide a full filesystem
- Container uses the merged view



Docker/OCI: DockerFile

- Text file that contains a script to create an image
  - Each line creates a layer
  - Chain RUN commands together
- Allows various commands:
  - FROM – specify the parent image
  - COPY – copy files from the host into the image
  - RUN – run a command using binaries inside container (i.e. install)
  - CMD – specify the default command

```
FROM ubuntu
RUN apt-get update
RUN apt-get install -y python python-pip
RUN pip install awscli
RUN apt-get autoremove --purge -y python-pip
```

Verses

```
FROM ubuntu
RUN apt-get update && \
    apt-get install -y python python-pip && \
    pip install awscli && \
    apt-get autoremove --purge -y python-pip && \
    rm -rf /var/lib/apt/lists/*
```

Docker/OCI: Volumes

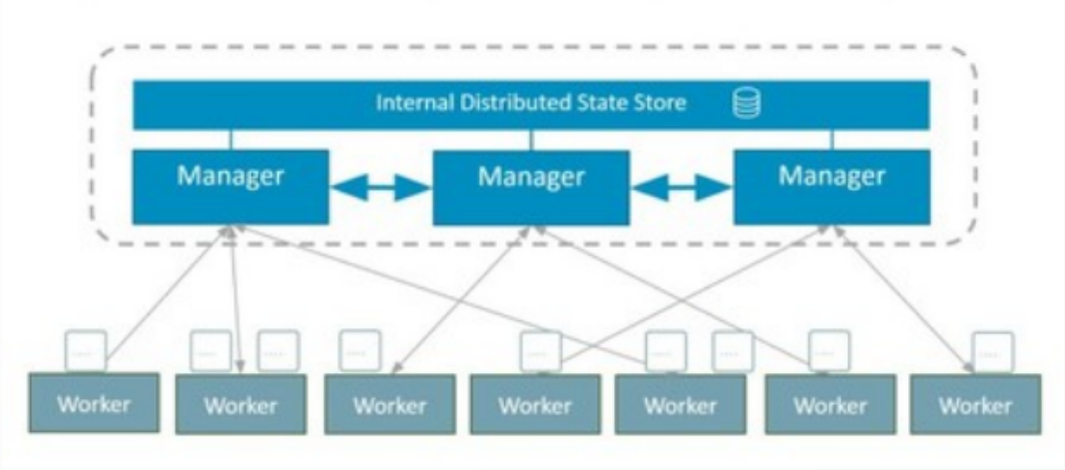
- Volumes provide the ability to persist/supply data in containers
- Bind mount volumes
  - You choose where to persist the data
  - Example: -v /docker-data/mysql:/var/lib/mysql
- Named volumes:
  - Let Docker choose where to persist the data
  - Example: -v mysql-data:/var/lib/mysql
- Issues with user permissions when accessing same files from both host and the container
  - Map a user ID in container to a host user ID

Orchestration Overview

- Provides the ability to manage the running of container workloads, often over a fleet of machines
- As an administrator, you device the expected state, or the desired state
  - Includes service definitions, (images, ports, volumes, etc.), replica counts (how many of each to run), update policies, and more.
- The system then tries to make the actual state reflect the expected state
  - If a container exits, it'll try to restore it. If you change the expected state, it'll try to reconcile it.

Actors in Orchestrators

- Every orchestrator has the concept of two types of nodes
- Managers
  - Serve the brains of the cluster
  - Maintain state & schedule work
  - Sometimes called masters
- Worker nodes
  - Perform the actual work, as instructed by a manager
  - Sometimes called agents or nodes



Different type of Orchestrators

- Docker Swarm
  - Shipped with the Docker Engine
  - Very user friendly and easy to get up and running
  - Satisfies most needs, though not all; theoretically extensible, but takes a little work
- Kubernetes
  - Spun out of the work done within Google and contributed to CNCF
  - Think of it as a toolkit – so not as easy to get setup and running
  - Very configurable and extensible
- Amazon ECS
- Hashicorp – Separate Products for easier management
  - Terraform – Provision and Manage Bare Metal and Virtual Machines
  - Nomad – Provision and Manage Containers and legacy applications
  - Vault – Handle password, secret, and key management
  - Consul – Orchestrate and Manage worker nodes and provide connections to outside world