DEMYSTIFYING DOCKER

PRASHANTH

CLOUD PLATFORM, SAP

AGENDA

- Linux Internals
  - Processes
  - Memory & Storage
- How does OS help in achieving
  - Resource control
  - Isolation
  - Security
- Docker
  - Overview
  - Usage

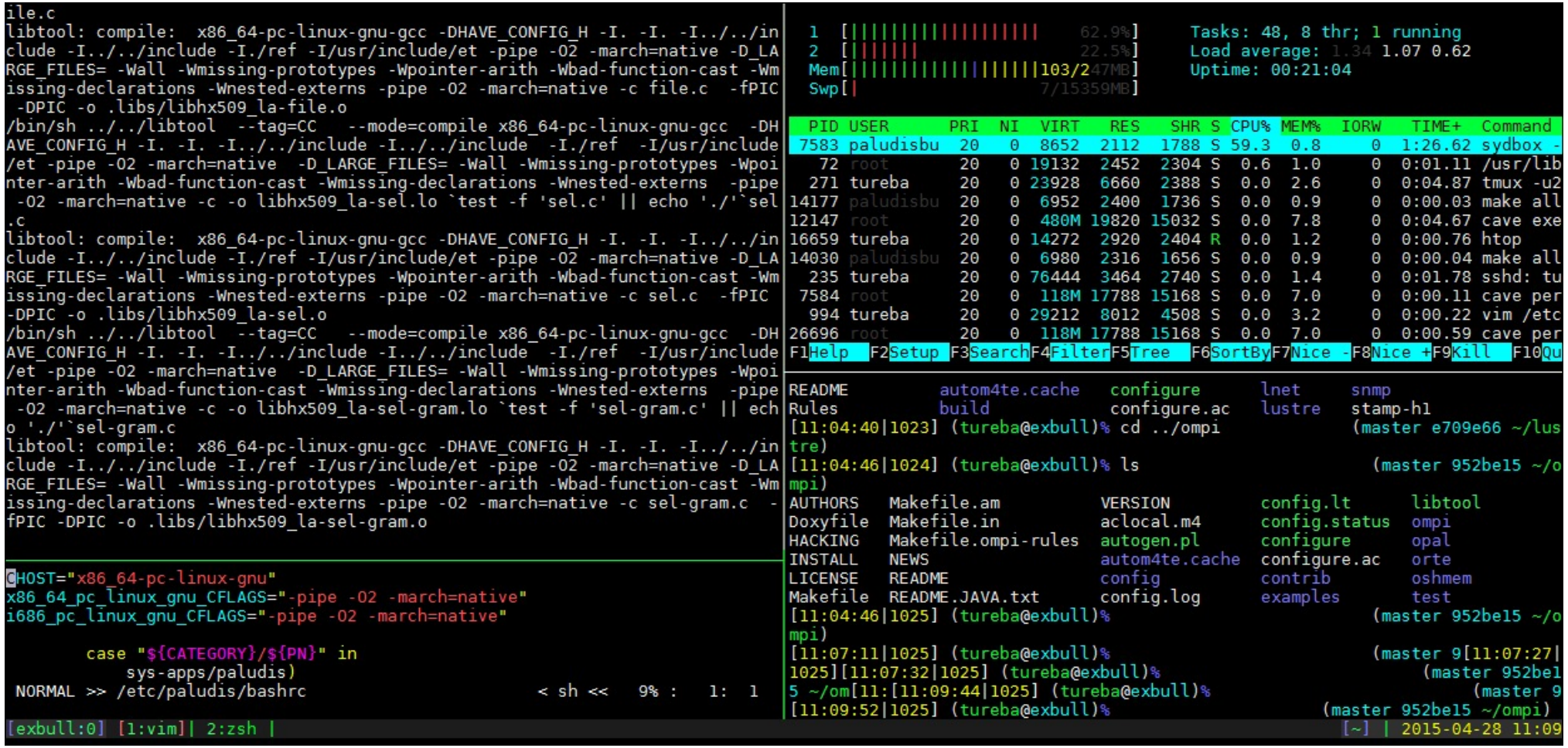


Fig: Terminal

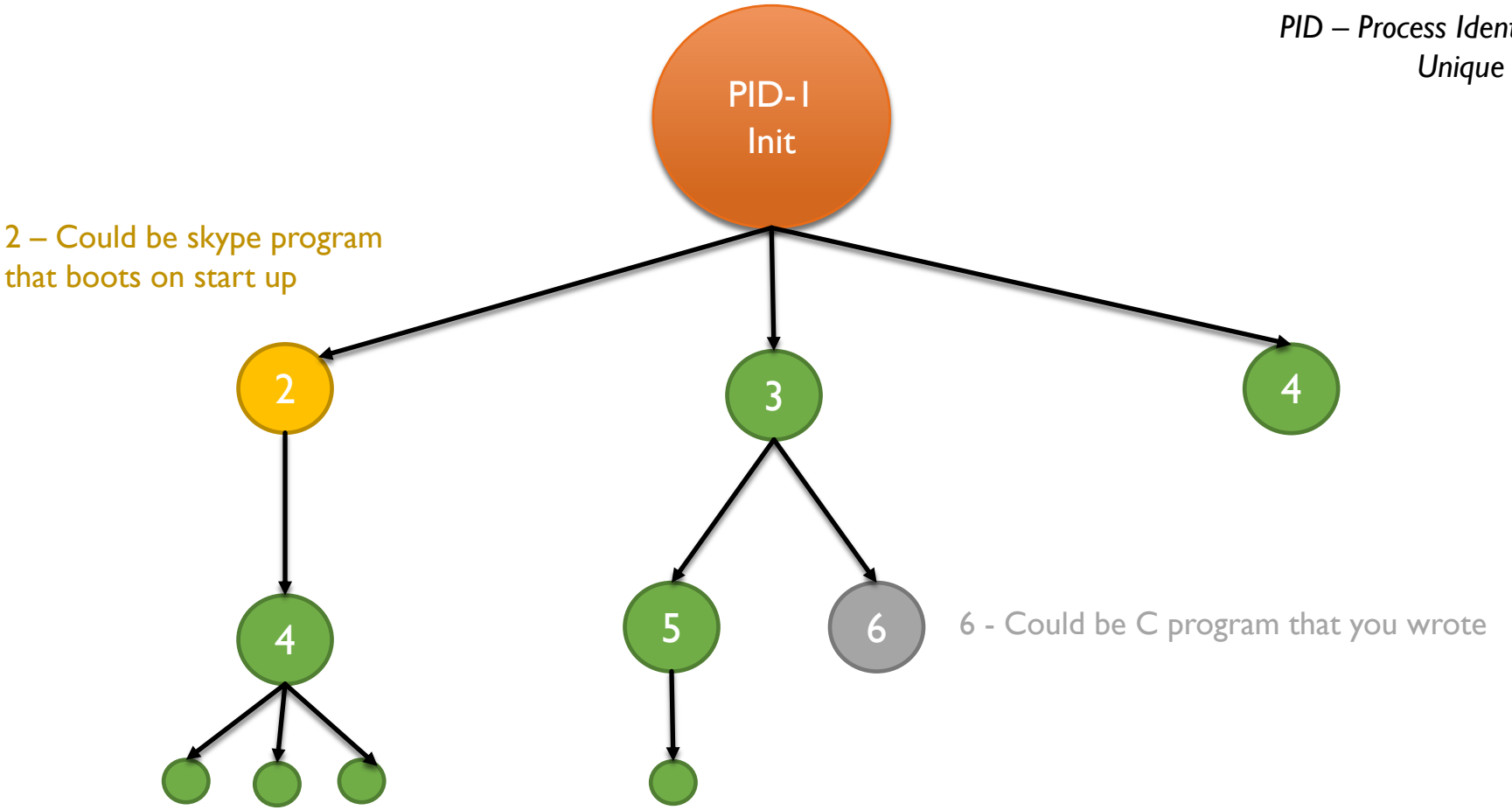
LINUX (OS) INTERNALS

PROCESS

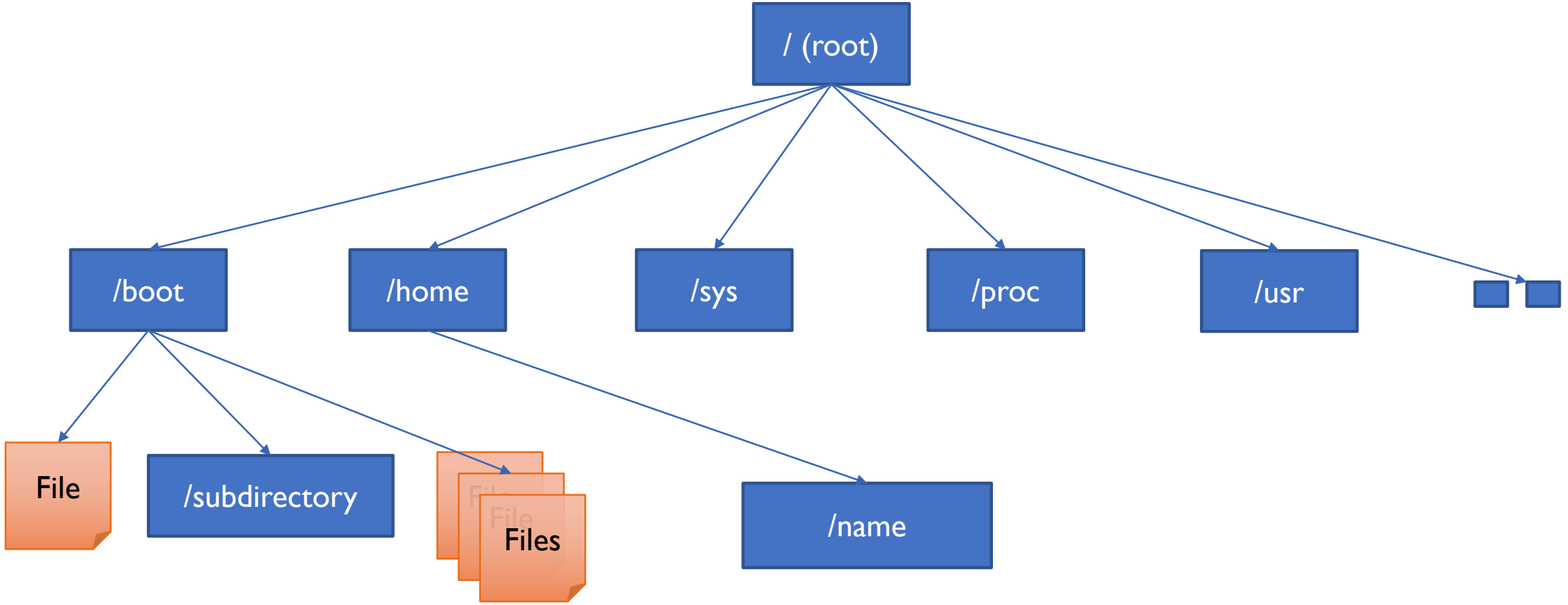
- A program in execution is a process
- Examples
  - C program that you execute
  - Linux/Unix terminal commands that you run – ls, pwd, cd etc.

PROCESS MANAGEMENT OVERVIEW

PID – Process Identification
Unique ID attached to a process



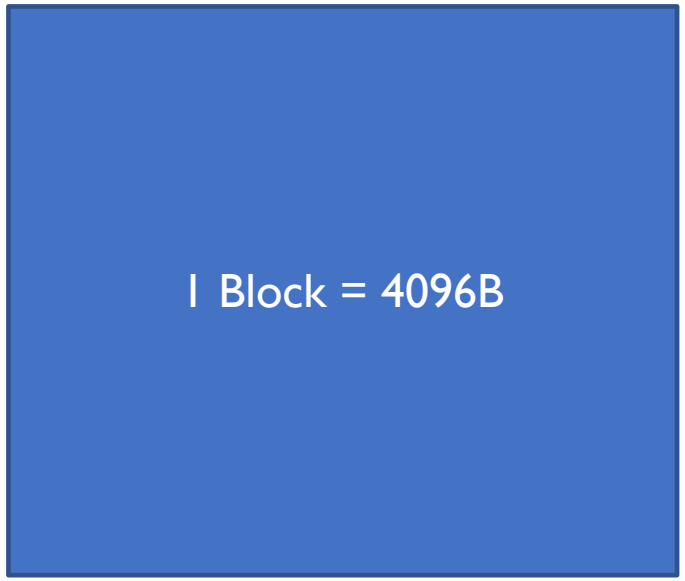
FILE SYSTEMS (FS)



DATA STORAGE IN COMPUTERS

Character – 1B
Then, this corresponds to

0 + 64 + 32 + 0 + 8 + 0 + 2 + 0 = 106 = 'j'



BLOCKS STORE DATA ON HARD DISKS

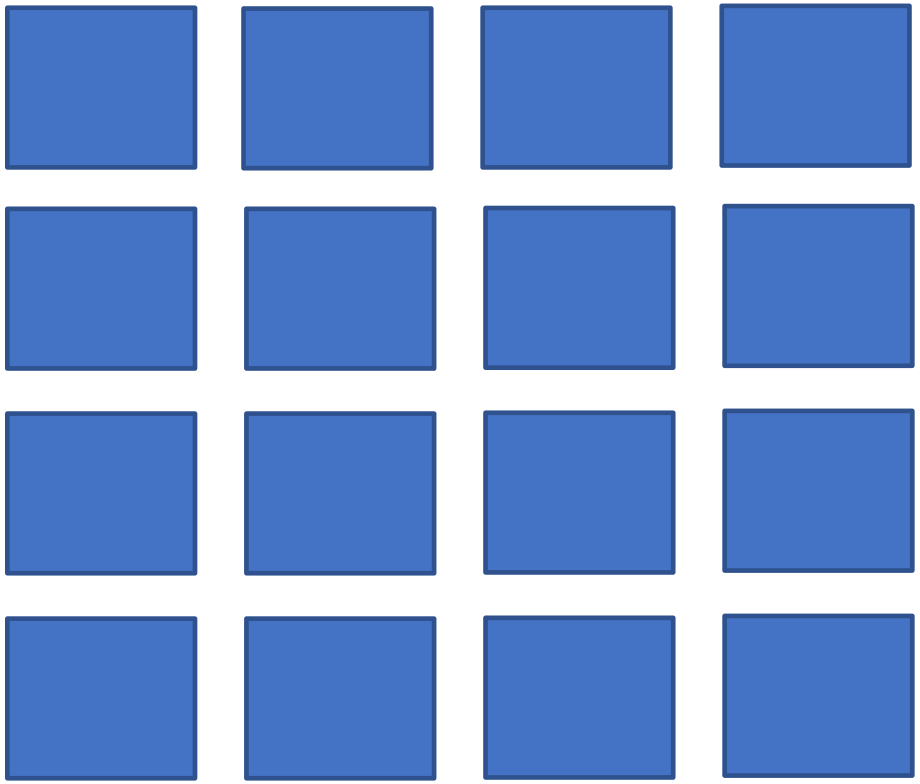


Fig: Hard disk containing 16 blocks of data visualizing the data present

OS MAPPING OF BLOCKS TO FS

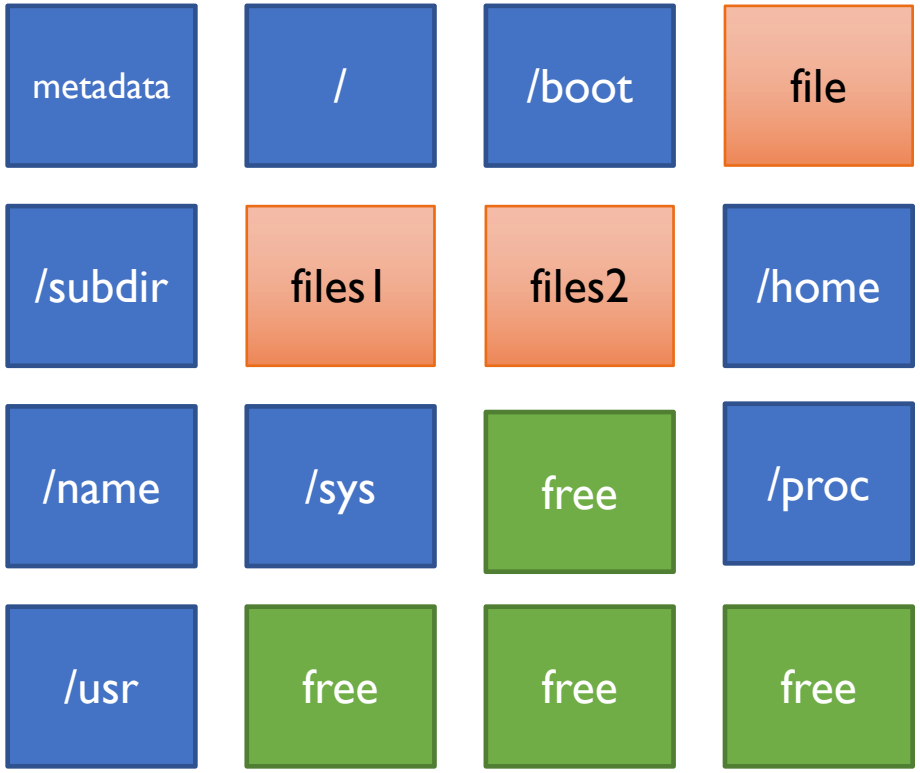


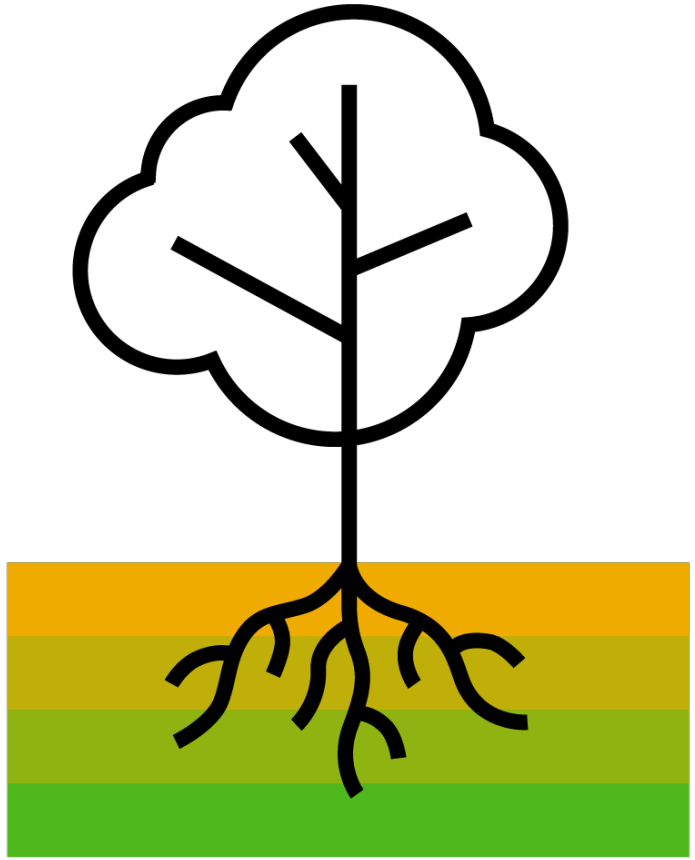
Fig: Hard disk containing 16 blocks of data visualizing the data present

FILE SYSTEM

In simple words,

File systems are a way to represent the data blocks present on a disk by the OS

ROOT V/S NON-ROOT USERS



CAREER OPTIONS?

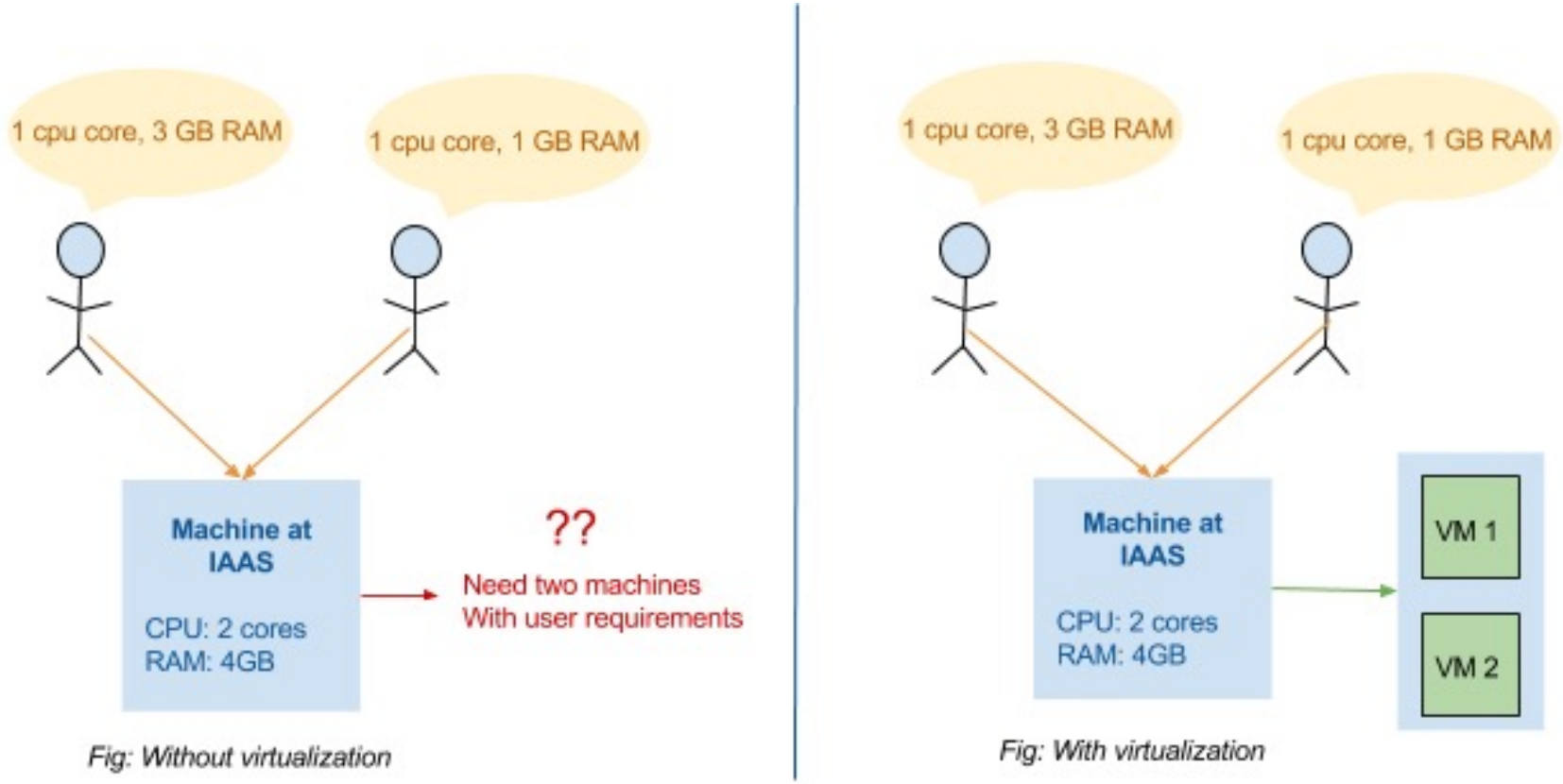
WHAT IS THE PROBLEM THEN?

GETTING YOUR ATTENTION

- Today's talk will be applicable to many domains in CS
  - Cloud computing
  - HPC and Big Data
  - Support for heavy compute in ML
  - Application development

- **Hot topic** in virtualization (cloud) and app development

RECAP OF HARDWARE VIRTUALIZATION



Virtual machines (VMs) helps partitioning of resources

ISSUES WITH HYPERVISOR BASED VIRTUALIZATION

- Memory for each VM's OS
- Start up latency
- Dual control loop
- Complete emulation of hardware stack

Result:
Bad cost-benefit ratios = customers are overpricing services offer by cloud providers

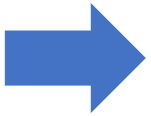
WHAT DO WE REALLY WANT?

PROCESS GROUPS ON WHICH SOME SORT OF RESTRICTIONS COULD BE IMPOSED

MACHINE (HOST) SETUP

Conventional host setup

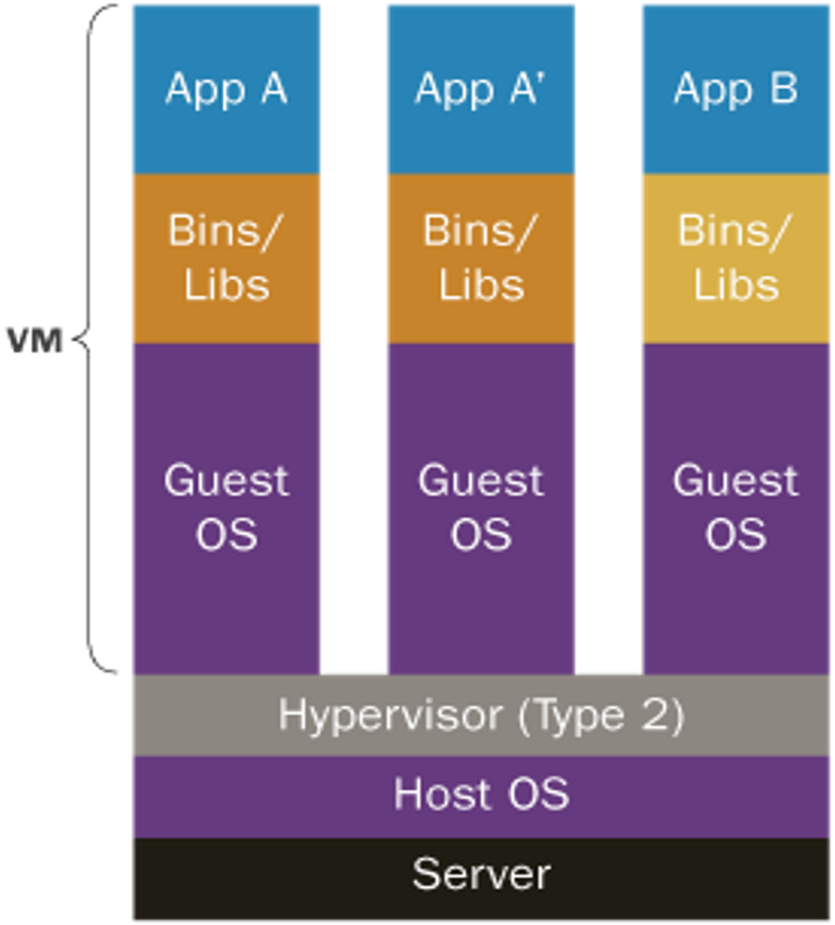
- All processes running on a host are visible to each other
- Cannot have control over resources utilized by a process / process group
- There are only two modes of privileges in the system,
  1. Privileged (Root)
  2. Non-privileged

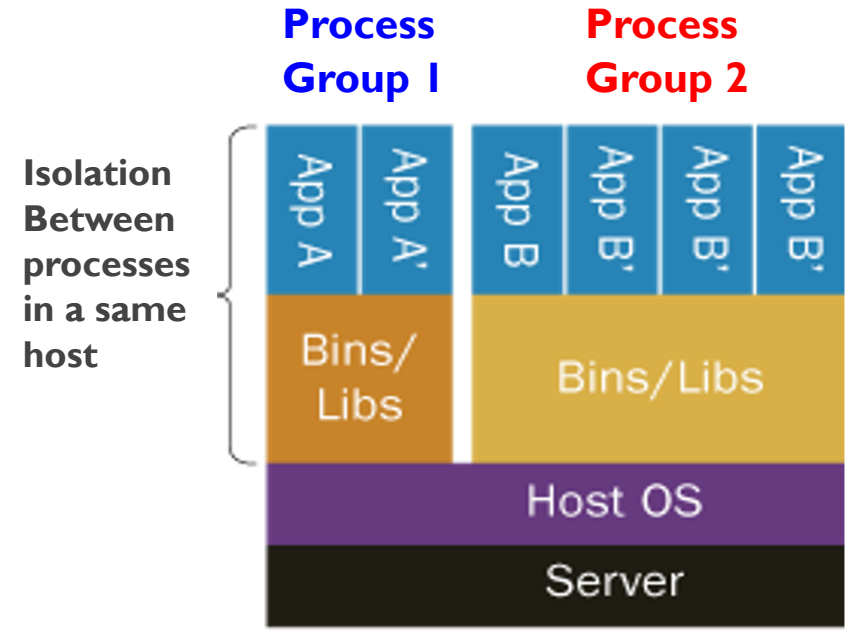


Desired host setup

- Process groups must be able to run in **isolation from each other**
- Have **control over resources** utilized by a process / process group
- **Access control -** Assign different levels of privileges to a process group with more classes of privileges

VMS VERSUS OUR DESIRED SETUP





Reference: [1]

HOW TO INCORPORATE RESOURCE CONTROL, ISOLATION AND ACCOUNTING USING NATIVE SETUP?

MODIFY THE HOST TO SUPPORT SUCH FEATURES

KERNEL'S MAPPING OF FEATURES

- Resource control and accounting → **Control Groups (cgroups)**
  - Memory - 4GB, CPU - 2 cores to process group 1
- Isolated environment → **Namespaces**
  - Processes in process group 1 must not be able to view processes in process group 2
- Access control → **Capabilities**
  - Process with PID:x must not be able to shutdown/reboot the system

DEEP DRIVE OF THESE LINUX FEATURES

CONTROL GROUPS (C-GROUPS)

CGROUPS

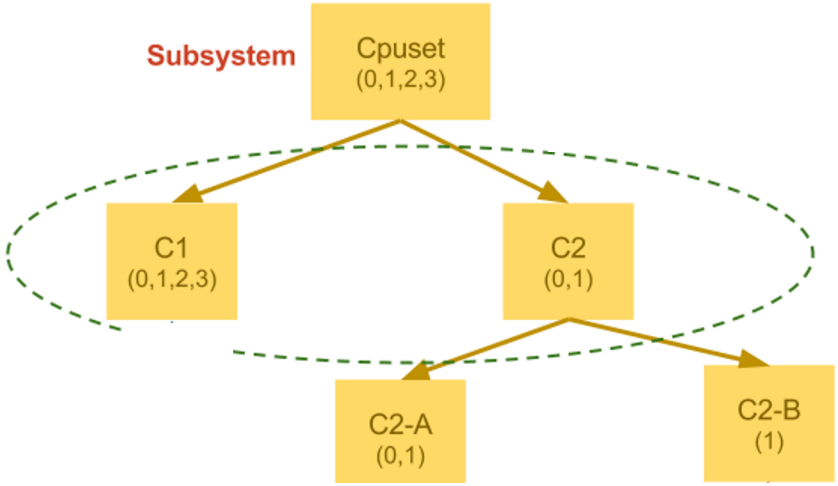
- **Linux resource controller** for each resource
- 12 different subsystems – CPU, memory, network, blkio etc.
- Perform **Accounting**
- Enforcing resource **Restriction**
- Follows hierarchy
- User space API – pseudo file-system

SITUATION

You have 5 processes (PIDs 1-5)

- **Process Group 1 (PG 1)**
  - PIDs: 1,2
  - 4 CPUs, 4GB RAM, 2x Disk access rate
- **Process Group 2 (PG 2)**
  - PIDs: 3, 4, 5
  - 1 CPU, 4GB RAM, 1x Disk access rate

WORKING OF CPUSET SUBSYSTEM

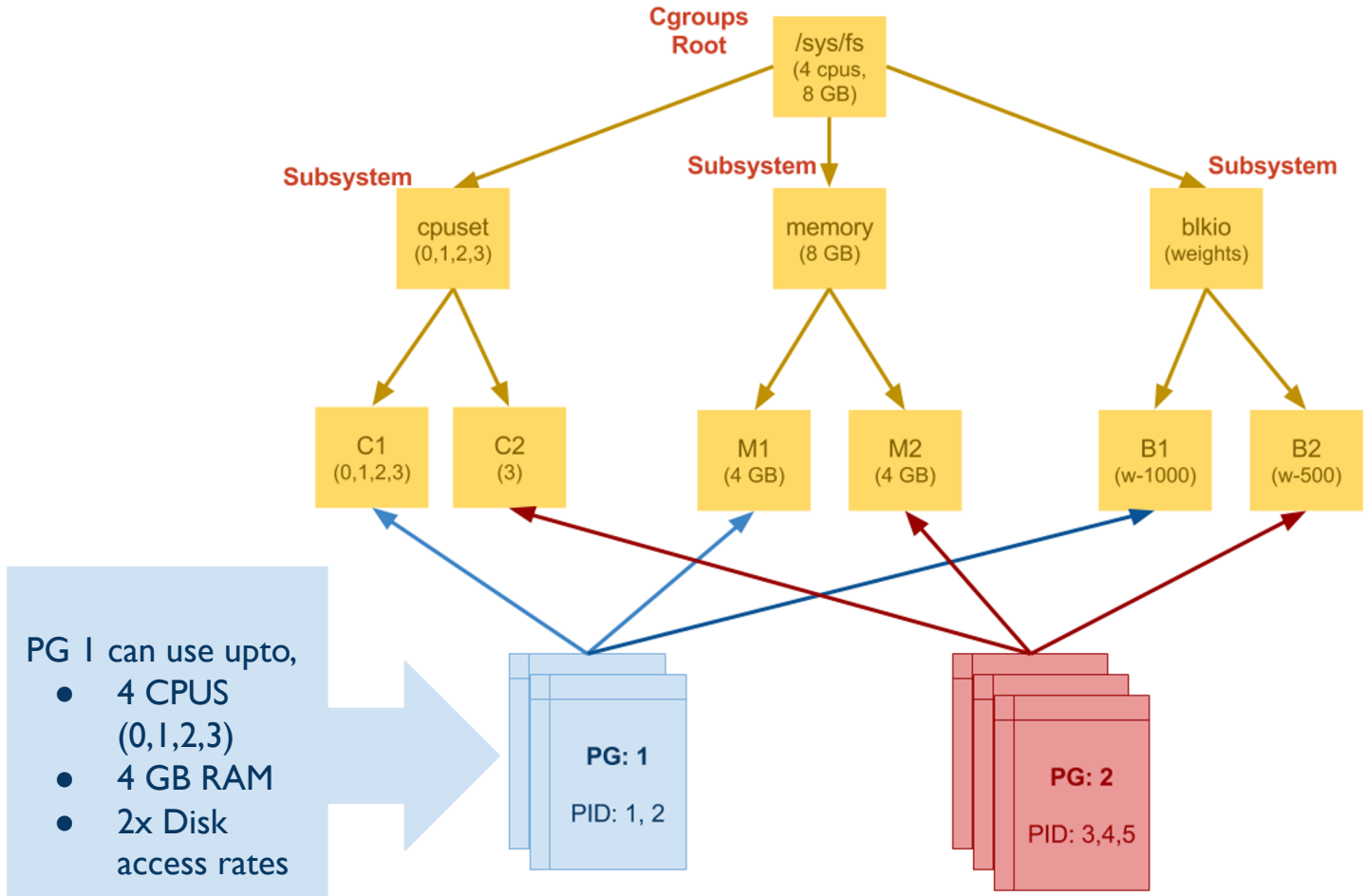


PG 1 can use upto,

- 4 CPUS (0,1,2,3)

CPUSET Subsystem: Allows pinning of processes to CPU cores

WORKING OF 3 SUBSYSTEM TOGETHER



PG 1 can use upto,

- 4 CPUS (0,1,2,3)
- 4 GB RAM
- 2x Disk access rates

Multiple Subsystems: Attach a process to one node in each subsystem

NAMESPACES

NAMESPACES

- **Isolated system views**, 6 namespaces, Each namespaces has multiple isolated environments

- Each container is attached to 1 isolated namespace in all 6 types (similar to cgroups)
  1. Mount – Each container its own view of system files
  2. PID – Container processes are isolated from other container processes
  3. Network – Only aware of its network resources
  4. IPC – IPC communication local to container
  5. UTS – Hostnames and domain names can be different
  6. User – Users in each container are local

- API – passing flags to clone(), unshare() system call

SITUATION

- A situation where you have N processes, and you wish to isolate them from other processes in the system in such a way that,
  - Our processes must not be able to see/interact with other processes in the system
  - We have our own range of PIDs for our processes

WORKING OF PID NAMESPACES

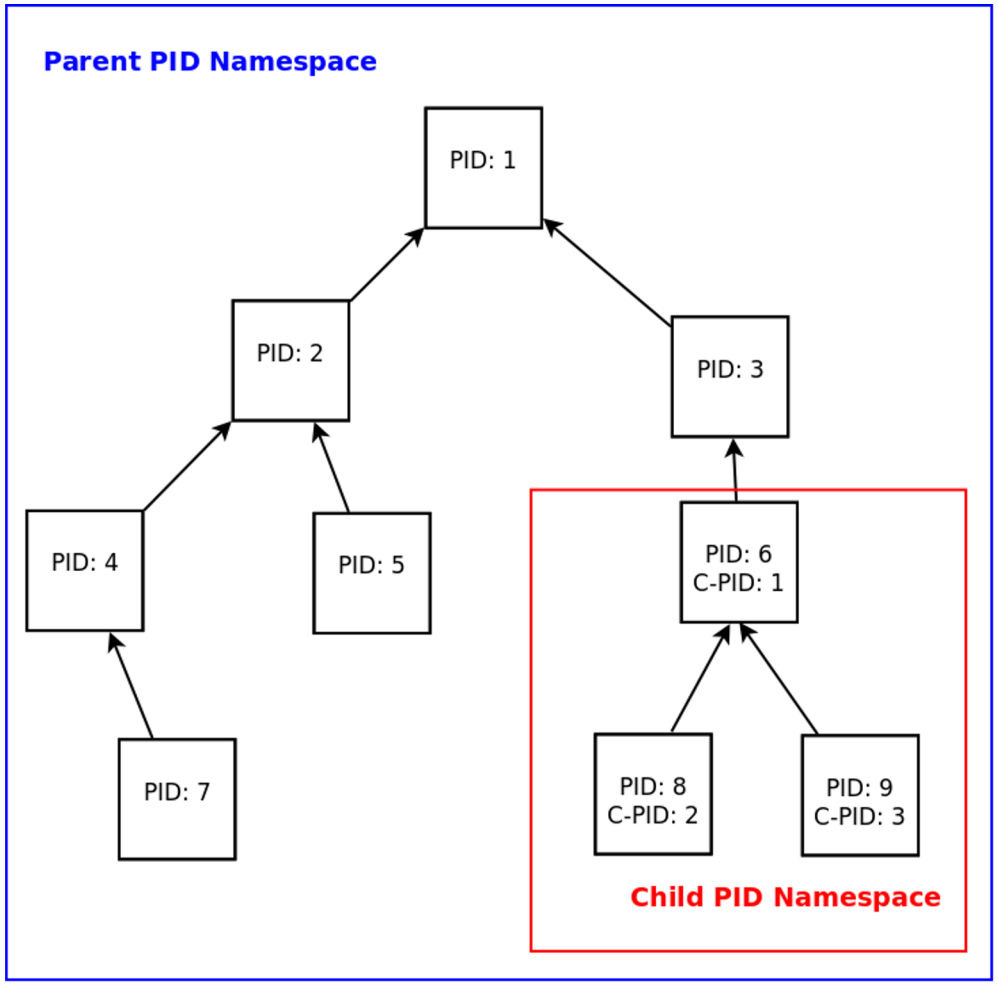


Fig: Example of PID Namespace in which pids 6,8,9 in parent ns map to 1,2,3 in child ns

CAPABILITIES

- Access control model by partitioning root access
- Root privileges are subdivided into up to 128 different privileges for a user
- Examples
  - CAP_SYS_BOOT - Rebooting of system
  - CAP_NET_ADMIN - Network configurations

CONTAINER

- **Containers = cgroups + namespaces + capabilities**
- " Container is a virtual environment that contains a set of processes grouped along with its dependent resources into a single logical OS entity."
- Also known as **OS-Virtualization**

CONTAINER MANAGER

- **Container managers make use of host functionalities to create, manage and delete containers**
- " A lightweight hypervisor that manages the deployment of containers "
- Example - Docker, LXC/LXD, Rocket etc.

VMS VERSUS CONTAINERS

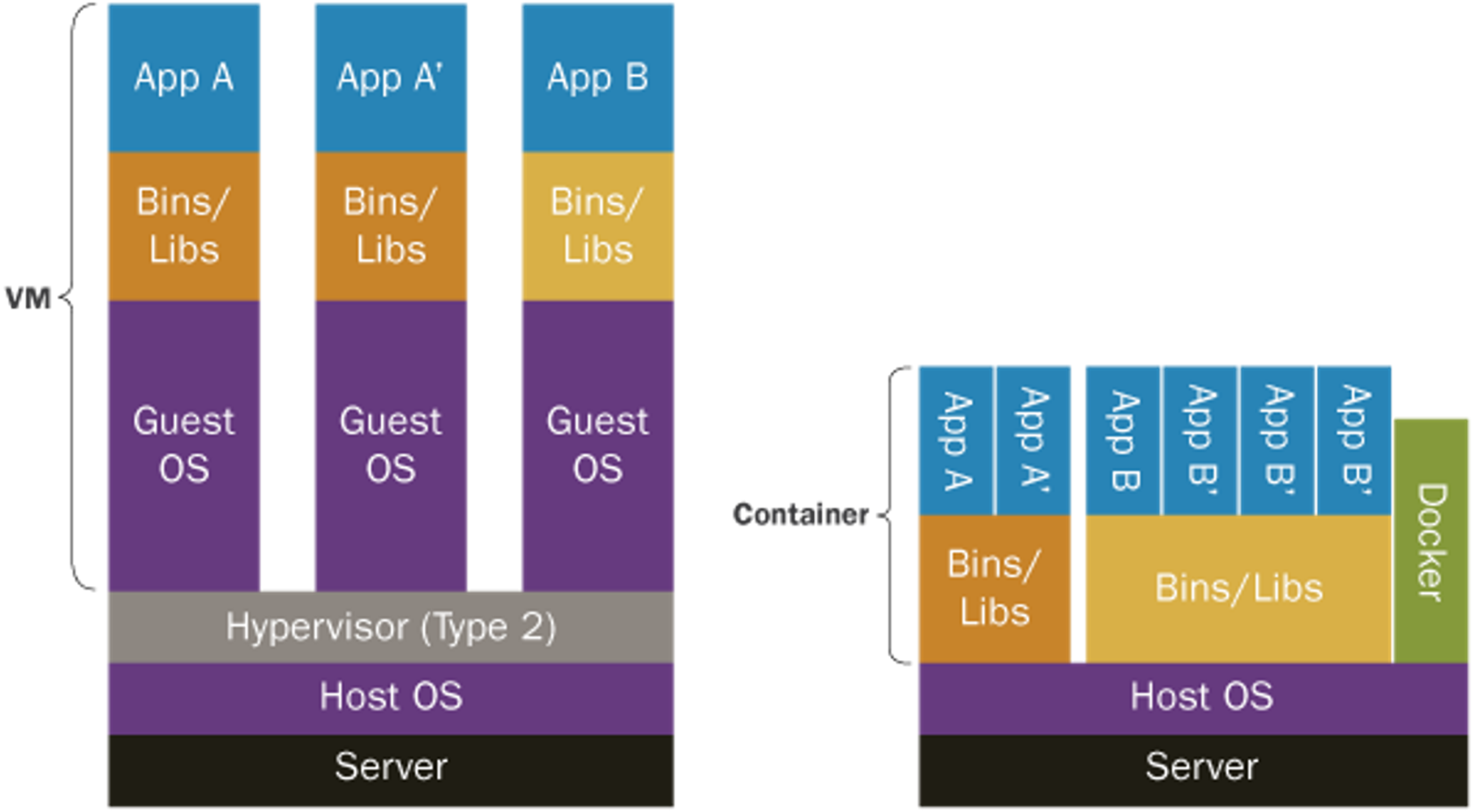


Fig:VMs versus containers

Reference: [1]

HOW DO CONTAINER MANAGERS ADD VALUE WHEN KERNEL ALREADY SUPPORTS CONTAINER EXECUTION ?

NEXT SLIDE

ROLE OF CONTAINER MANAGERS

- Provides **simpler APIs** to manage container deployments
- **Automates deployment** of applications
- Storage  Disk Images
- Provides additional features on top of kernel features,
  - GUI based managers
  - Security features
  - And more.

DISK IMAGES

- New ROOTFS – mount namespace
- Smaller than the normal OS-disk image – **No kernel**
- Disk image **contains application and its dependencies** (libraries and packages)

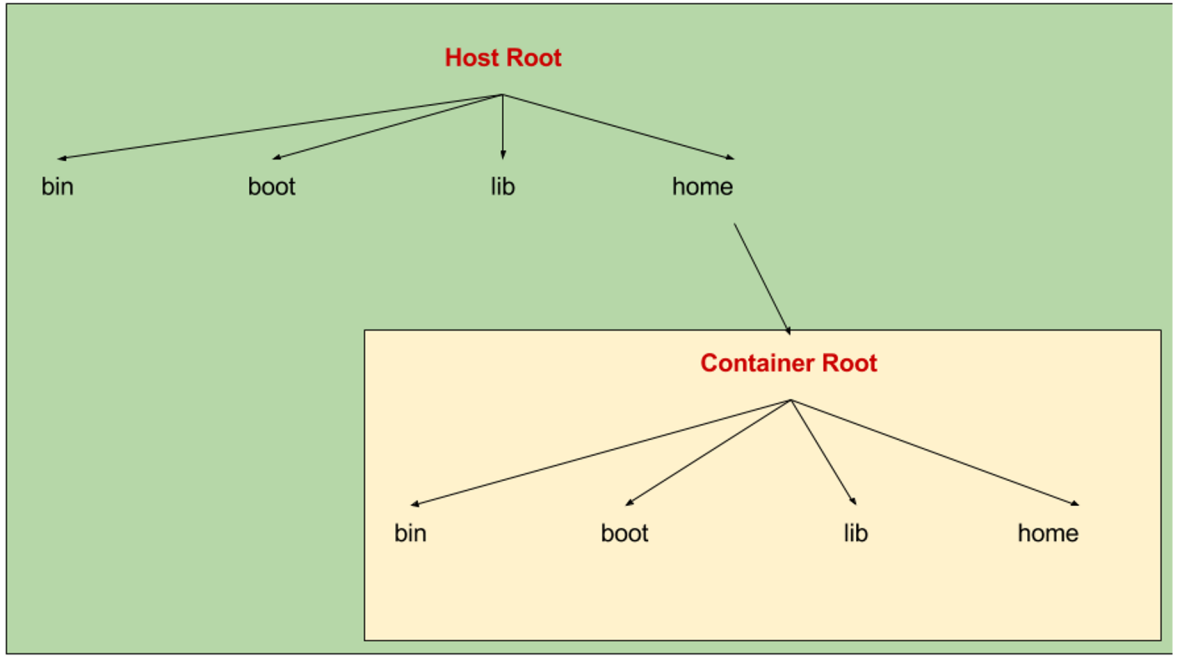


Fig: mount namespace used to mount a new container root

DOCKER

WASN'T THIS TALK ABOUT DOCKER

DOCKER ARCHITECTURE

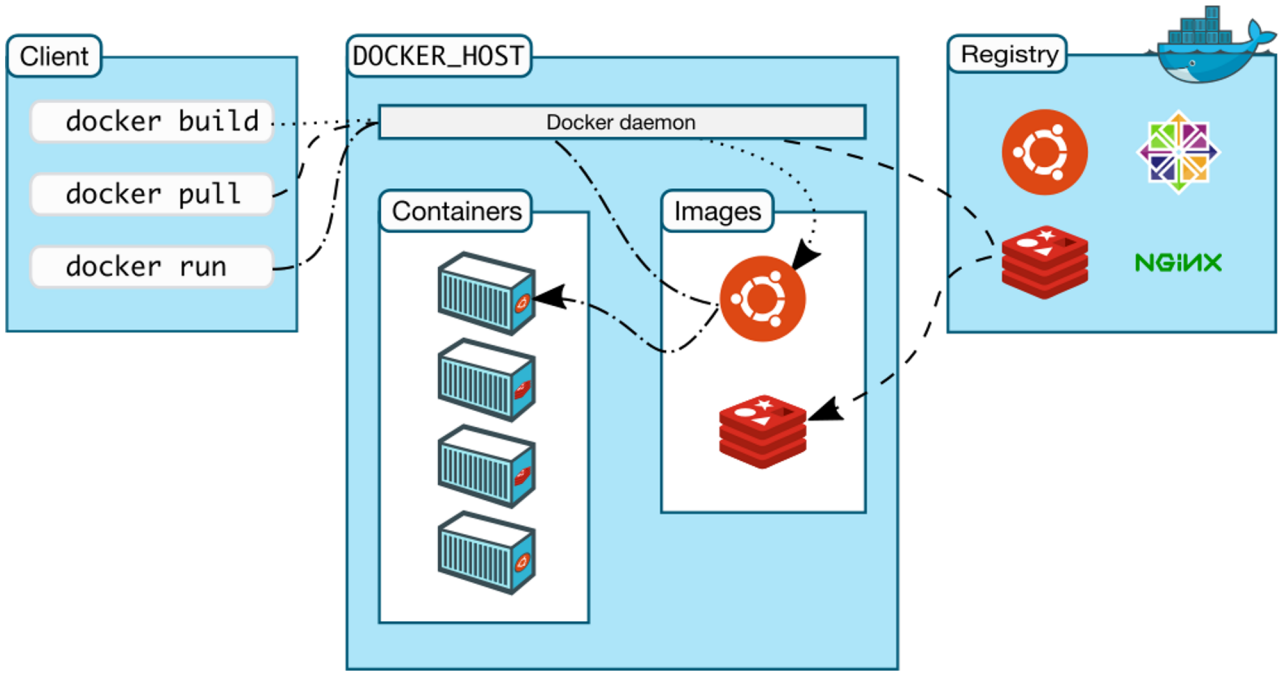


Fig: Docker Architecture, source: [2]

COMPONENTS

1. Client: UI to manage containers
2. Host: Machine
3. Registry: Image store
4. Images: Read-only template
5. Containers: Created from image

DOCKER IMAGE LAYERS

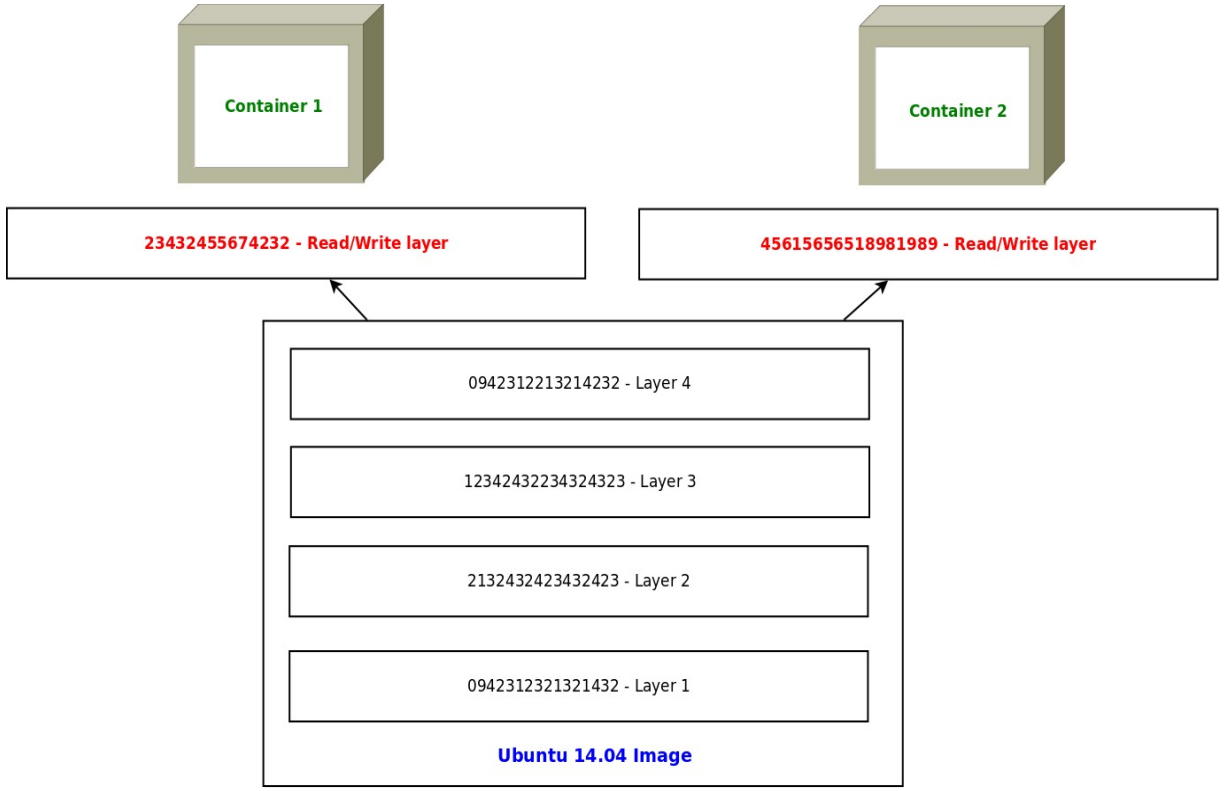
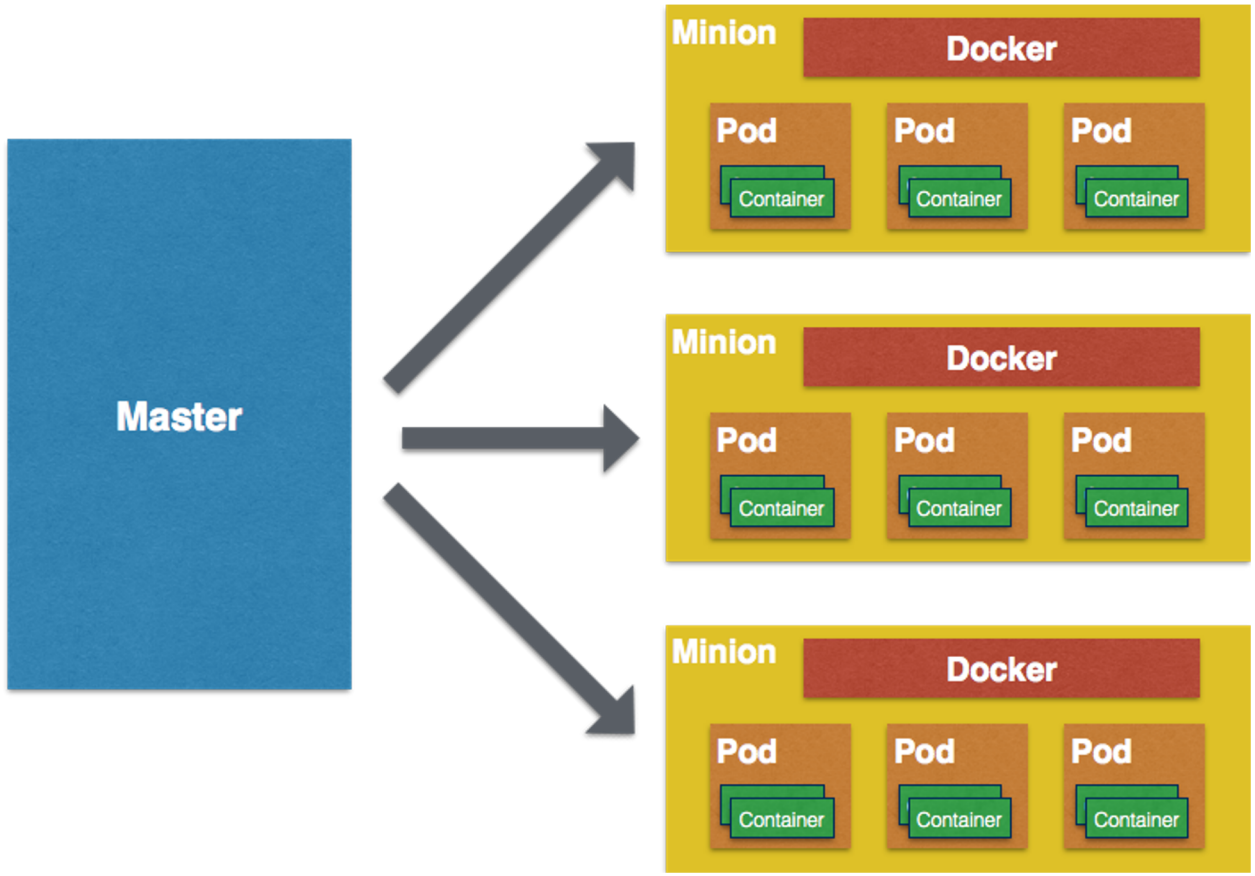


Fig: Docker image layers

- Stackable image layers
- Reuse layers
- Copy-On-Write (CoW)
- Container adds Read-Write layer on image
- Commit makes layer read only

KUBERNETES



- Container **orchestration tool**, originally designed by Google
- Automated Deployment, Management and Scaling **across machines**
- Groups application into logical units – pods
- Minion is machine

Fig: Container orchestration using Kubernetes, source [3]

MERITS AND DEMERITS OF CONTAINERS

MERITS

- Startup latency minimal
- No hardware emulation
- No multiple OS copies
- Overheads - close to native

DEMERITS

- Only base kernel type containers
- Security

VMS VERSUS CONTAINERS

Container better @

- Memory Usage – VM takes 11-60x container's usage
- Disk I/O – VM takes 2x
- CPU utilization – Marginally better
- Startup Latency – VM typically takes about 50-100x

VMs better @

- Network – VM is 1.2x better here
- Live-Migration – Better in VMs
- Support for guest of OS of different kernel
- Security

SUMMARY

- Containers are the new thing in virtualization
- Companies have already investing so heavily here
- Try to learn FOSS projects and contribute to them

CONTACT INFO

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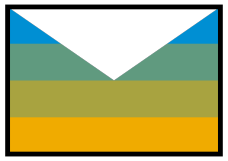

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REFERENCES

1. P. B. Menage, “Adding generic process containers to the linux kernel," in Proceedings of the Linux Symposium , vol. 2, pp. 45{57, Citeseer, 2007.
2. D. Inc., “Docker offical documentation," 2016.
3. http://blog.arungupta.me/wp-content/uploads/2015/01/kubernetes-key-concepts.png