Containers, Dockers, and Kubernetes

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These slides and audio/video recordings of this class lecture are at:
http://www.cse.wustl.edu/~jain/cse570-18/

Overview

1. What is a Container and Why?
2. How Docker helps using containers
3. Docker Commands
4. Orchestration: Swarms and Kubernetes
5. Docker Networking and Security

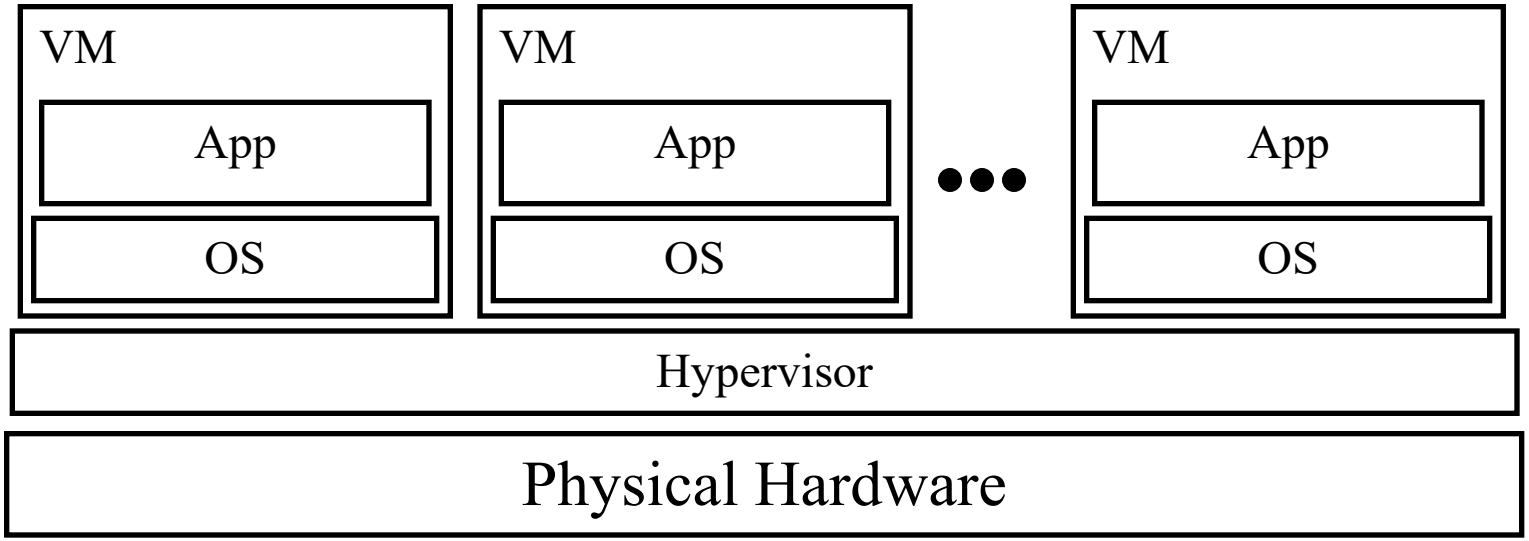
Key Reference: N. Poulton, "Docker Deep Dive," Oct 2017, ISBN: 9781521822807 (Not a Safari Book)

Advantages of Virtualization

- Minimize hardware costs (CapEx)
  Multiple virtual servers on one physical hardware
- Easily move VMs to other data centers
  - Provide disaster recovery. Hardware maintenance.
  - Follow the sun (active users) or follow the moon (cheap power)
- Consolidate idle workloads. Usage is bursty and asynchronous.
  Increase device utilization
- Conserve power
  Free up unused physical resources
- Easier automation (Lower OpEx)
  Simplified provisioning/administration of hardware and software
- Scalability and Flexibility: Multiple operating systems

Ref: http://en.wikipedia.org/wiki/Platform_virtualization
Ref: K. Hess, A. Newman, "Practical Virtualization Solutions: Virtualization from the Trenches," Prentice Hall, 2009, ISBN:0137142978

Problems of Virtualization



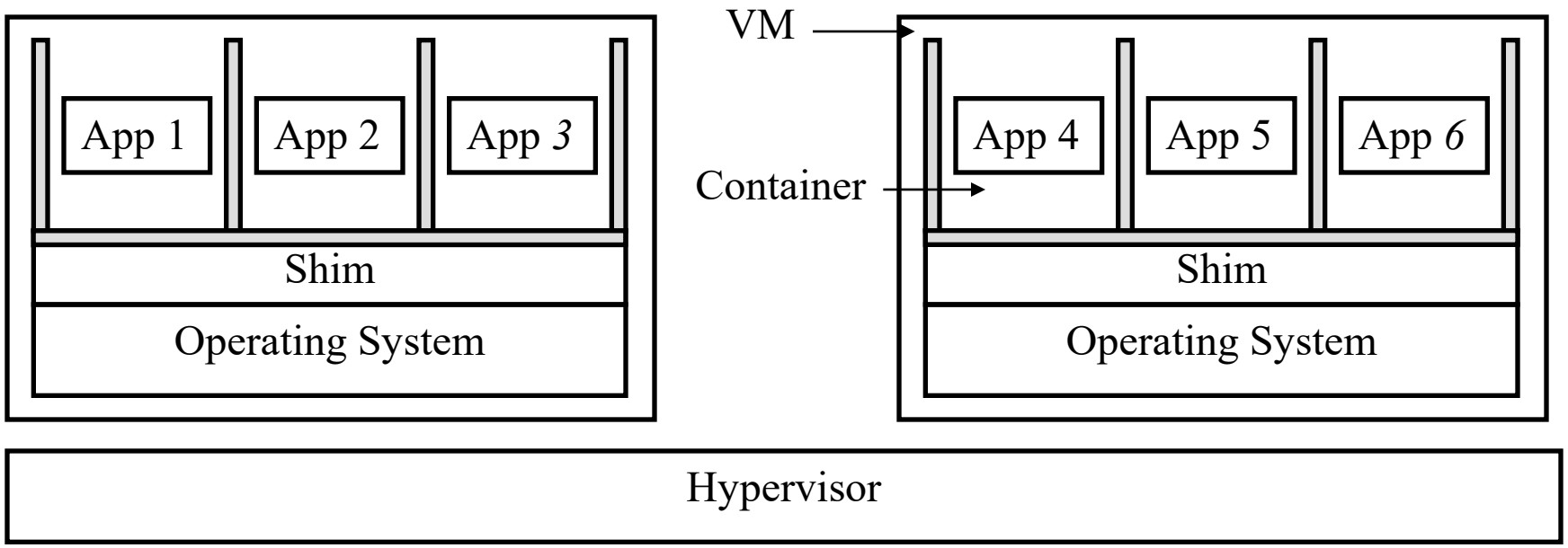
- Each VM requires an operating system (OS)
  - Each OS requires a license ⇒ CapEx
  - Each OS has its own compute and storage overhead
  - Needs maintenance, updates ⇒ OpEx
  - VM Tax = added CapEx + OpEx

Solution: Containers

- Run many apps in the same virtual machine
  - These apps share the OS and its overhead
  - But these apps can't interfere with each other
  - Can't access each other's resources without explicit permission
  - Like apartments in a complex

  $\Rightarrow$ Containers

Containers



- Multiple containers run on one operating system on a virtual/physical machine
- All containers share the operating system ⇒ CapEx and OpEx
- Containers are isolated ⇒ cannot interfere with each other
  - Own file system/data, own networking ⇒ Portable

Containers (Cont)

- Containers have all the good properties of VMs
  - Come complete with all files and data that you need to run
  - Multiple copies can be run on the same machine or different machine ⇒ Scalable
  - Same image can run on a personal machine, in a data center or in a cloud
  - Operating system resources can be restricted or unrestricted as designed at container build time
  - Isolation: For example, "Show Process" (ps on Linux) command in a container will show only the processes in the container
  - Can be stopped. Saved and moved to another machine or for later run

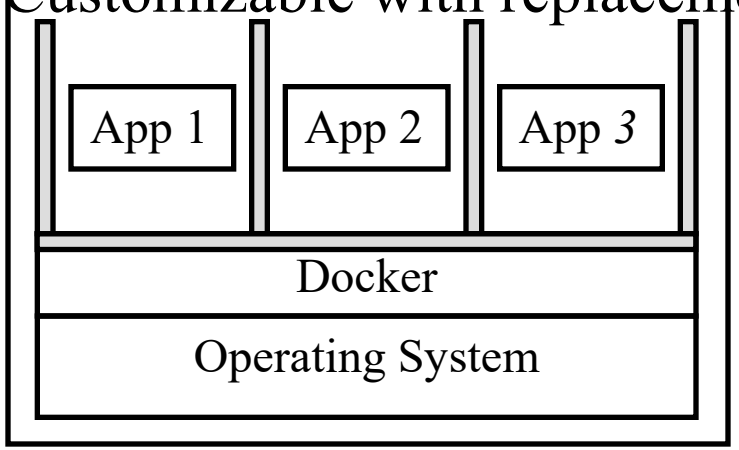
VM vs. Containers

Criteria	VM	Containers
Image Size	3X	X
Boot Time	>10s	~1s
Computer Overhead	>10%	<5%
Disk I/O Overhead	>50%	Negligible
Isolation	Good	Fair
Security	Low-Medium	Medium-High
OS Flexibility	Excellent	Poor
Management	Excellent	Evolving
Impact on Legacy application	Low-Medium	High

Ref: M. K. Weldon "The Future X Network: A Bell Labs Perspective," CRC Press, 2016, 476 pp., ISBN:9781498779142

Docker

- Provides the isolation among containers
- Helps them share the OS
- Docker = Dock worker ⇒ Manage containers
- Developed initially by Docker.com
- Downloadable for Linux, Windows, and Mac from Docker.com
- ~~Customizable with replacem~~ent modules from others



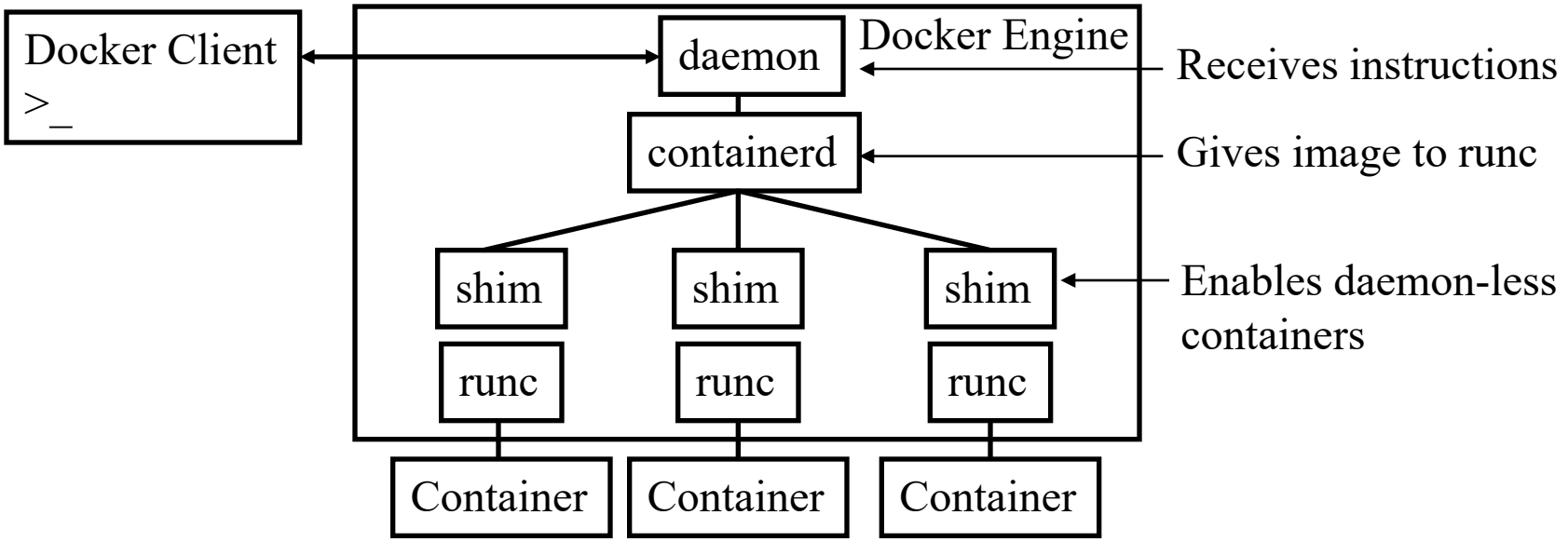
Docker

- Docker Engine: Runtime
- Two Editions:
  - Community Edition (CE): Free for experimentation
  - Enterprise Edition (EE): For deployment with paid support
- Written in "Go" programming language from Google
- Now open source project under mobyproject.org
  https://github.com/moby/moby
- Download the community edition and explore

Ref: https://golang.org/

Docker Engine Components

- daemon: API and other features
- containderd: Execution logic. Responsible for container lifecycle. Start, stop, pause, unpause, delete containers.
- runc: A lightweight runtime CLI
- shim: runc exists after creating the container.
  shim keeps the container running. Keep stdin/stdout open.



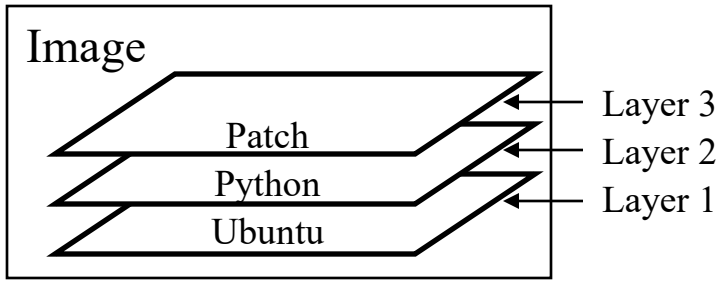
Ref: N. Poulton, "Docker Deep Dive," Oct 2017, ISBN: 9781521822807 (Not a Safari Book)

Image Registries

- Containers are built from images and can be saves as images
- Images are stored in registries
  - Local registry on the same host
  - Docker Hub Registry: Globally shared
  - Private registry on Docker.com
- Any component not found in the local registry is downloaded from specified location
- Official Docker Registry: Images vetted by Docker
- Unofficial Registry: Images not vetted (Use with care)
- Each image has several tags, e.g., v2, latest, …
- Each image is identified by its 256-bit hash

Layers

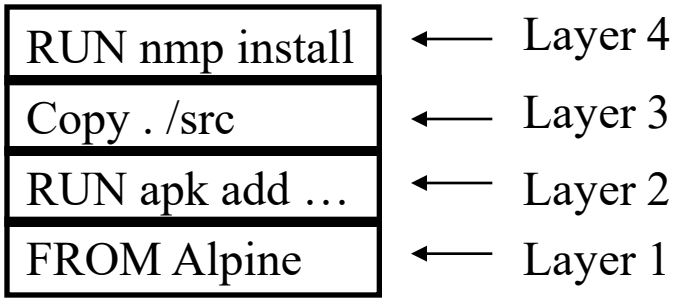
- Each image has many layers
- Image is built layer by layer
- Layers in an image can be inspected by Docker commands
- Each layer has its own 256-bit hash
- For example:
  - Ubuntu OS is installed, then
  - Python package is installed, then
  - a security patch to the Python is installed
- Layers can be shared among many containers



Building Container Images

- Create a **Dockerfile** that describes the application, its dependencies, and how to run it

FROM Alpine	← Start with Alpine Linux
LABEL maintainer="xx@gmail.com"	← Who wrote this container
RUN apk add –update nodejs nodejs –npm	← Use apk package to install nodejs
COPY . /src	← Copy the app files from build context
WORKDIR /src	← Set working directory
RUN nmp install	← Install application dependencies
EXPOSE 8080	← Open TCP Port 8080
ENTRYPOINT ["node", "./app.js"]	← Main application to run



Note: WORKDIR, EXPOSE, ENTRYPOINT result in tags. Others in Layers.

Docker Commands

- **docker container run**: Run the specified image
- **docker container ls**: list running containers
- **docker container exec**: run a new process inside a container
- **docker container stop**: Stop a container
- **docker container start**: Start a stopped container
- **docker container rm**: Delete a container
- **docker container inspect**: Show information about a container

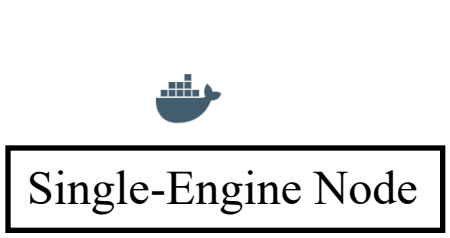
Open Container Initiative (OCI)

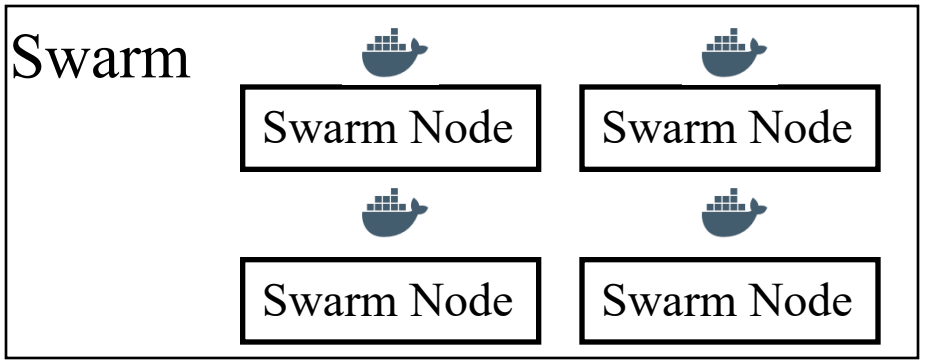
- A company called CoreOS defined alternative image format and container runtime API's
- Led to formation of OCI under Linux Foundation to govern container standards
  - OCI Image spec
  - OCI Runtime spec
- Everyone including Docker is now moving to OCI

Ref: https://www.opencontainers.org/

Swarm

- Orchestrating thousands of containers
- Swarm: A group of nodes collaborating over a network
- Two modes for Docker hosts:
  - Single Engine Mode: Not participating in a swarm
  - Swarm Mode: Participating in a Swarm
- A service may run on a swarm
- Each swarm has a few managers that dispatch tasks to workers. Managers are also workers (i.e., execute tasks)





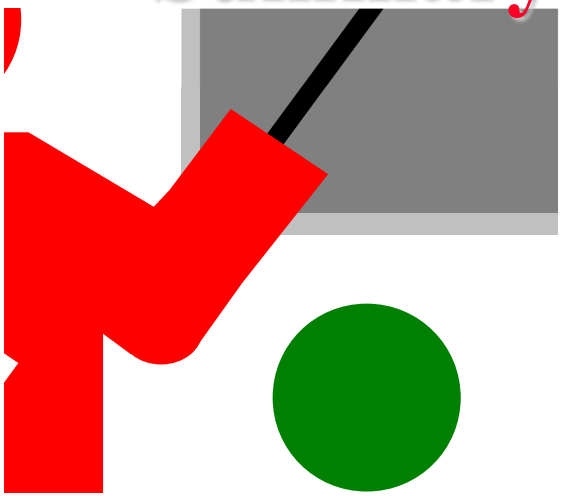
Swarms (Cont)

- The managers select a leader, who really keeps track of the swarm
- Assigns tasks, re-assigns failed worker's tasks, …
- Other mangers just monitor passively and re-elect a leader if leader fails
- Services can be scaled up or down as needed
- Several Docker commands:
  - **docker service** : Manage services
  - **docker swarm**: Manage swarms
  - **docker node**: Manage nodes

Kubernetes

- Open Source Container Orchestration alternative
- Original source released by Google
- Cloud Native Computing Foundation (CNCF) project in Linux Foundation
- Pre-cursor to Swarms
- Facilities similar to Swarms
- A set of related containers is called a "Pod"
  A Pod runs on a single host.
- Swarm is called a "Cluster"

Summary



- Virtual Machines provide scalability, mobility, and cost reduction but need OS which increase resource requirements
- Containers provide isolation on a single OS and are lightweight
- Docker allows managing containers
- Docker Swarm and Kubernetes allow orchestrating a large number of containers
- Docker provides overlay networking and security

Acronyms

- API Application Programming Interface
- CapEx Capital Expenditure
- CE Community Edition
- CLI Command Line Interface
- CNCF Native Computing Foundation
- DCT Docker Content Trust
- EE Enterprise Edition
- ID Identifier
- ISBN International Standard Book Number
- LAN Local Area Network
- OpEx Operational Expenses
- OS Operating System
- TCP Transmission Control Protocol
- VM Virtual Machine

References

- N. Poulton, "Docker Deep Dive," Oct 2017, ISBN: 9781521822807 (Not a Safari Book) **Highly Recommended.**
- Parminder Singh Kocher, "Microservices and Containers, First edition," Addison-Wesley Professional, April 2018, 304 pp., ISBN:978-0-13-459838-3 (Safari Book).
- Russ McKendrick; Pethuru Raj; Jeeva S. Chelladhurai; Vinod Singh, "Docker Bootcamp," Packt Publishing, April 2017, 196 pp., ISBN:978-1-78728-698-6 (Safari Book).
- Russ McKendrick; Scott Gallagher, "Mastering Docker - Second Edition," Packt Publishing, July 2017, 392 pp., ISBN:978-1-78728-024-3 (Safari Book).
- Jeeva S. Chelladhurai; Vinod Singh; Pethuru Raj, "Learning Docker - Second Edition," Packt Publishing, May 2017, 300 pp., ISBN:978-1-78646-292-3 (Safari Book).

Wikipedia Links

- https://en.wikipedia.org/wiki/Docker_(software)
- https://en.wikipedia.org/wiki/Operating-system-level_virtualization
- https://en.wikipedia.org/wiki/Kubernetes
- https://en.wikipedia.org/wiki/Microservices
- https://en.wikipedia.org/wiki/DevOps
- https://en.wikipedia.org/wiki/OpenShift
- https://en.wikipedia.org/wiki/LXC