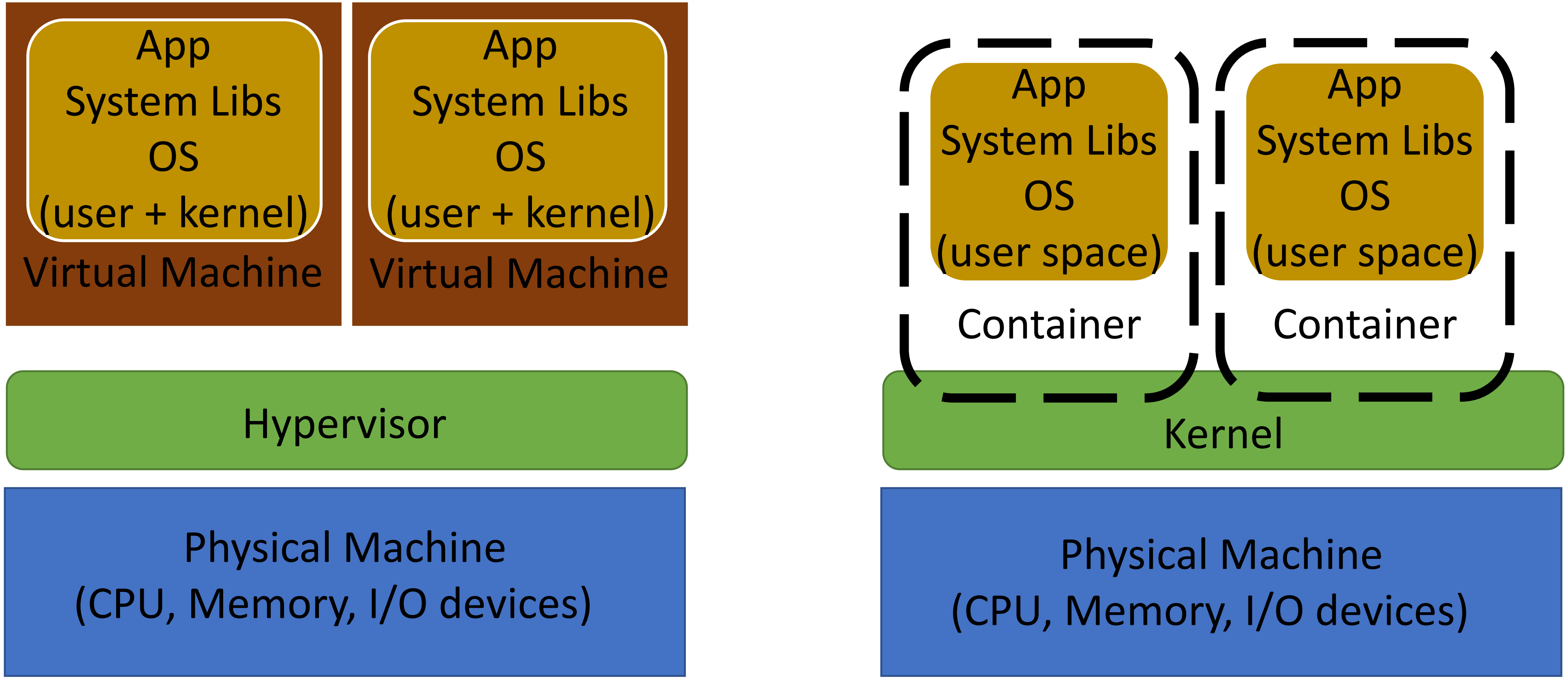
Linux kernel infrastructure for Containers

Srivatsa S. Bhat
VMware
srivatsa@csail.mit.edu

University of Washington
20 Feb 2018

Virtual Machines vs Containers



What is a container?

Containers:

- Provide a virtual Operating System environment
- Are processes with enhanced grouping and isolation
- Share an underlying kernel
- Don’t need special hardware support (eg: VT-x etc)

Building blocks of containers

- Namespaces
- Control Groups (cgroups)
- And the rest of the traditional OS abstraction (processes, files, networking, IPC, users etc)

Namespaces

What is a namespace?

- A collection of names identifying objects/entities
- A technique to partition a global resource into smaller scope.

Namespaces in the Linux kernel:

- UTS namespace
- mnt namespace
- PID namespace
- User namespace
- Network namespace
- IPC namespace

Namespace API

- **clone(function, stack, CLONE_NEW*, args);**
  - UTS namespace - CLONE_NEWUTS
  - mnt namespace - CLONE_NEWNS
  - PID namespace - CLONE_NEWPID
  - User namespace - CLONE_NEWUSER
  - Network namespace - CLONE_NEWNET
  - IPC namespace - CLONE_NEWIPC
- **setns(fd, nstype); fd refers to one of /proc/PID/ns/***
- **unshare(flags);**

UTS namespace

Abstracts:

- sethostname()
- setdomainname()
- uname()

mnt namespace

Abstracts:

- mount points
- File system hierarchy

Features:

- Supports shared subtrees via mount-event propagation
  - MS_SHARED
  - MS_PRIVATE
  - MS_SLAVE
  - MS_UNBINDABLE

PID namespace

Abstracts:

- Process ID numbers

Features:

- Hierarchical
- Special semantics for the ‘init’ process in each PID namespace
    - Reaping orphan tasks
    - Restrictions on sending signals to the init process

User namespace

Abstracts:

- User IDs, Group IDs and Capabilities

Features:

- Hierarchical
- Unprivileged process can create user namespaces
  - Gets full capabilities in new user namespace
  - Root privileges inside namespace; unprivileged outside.
- UID/GID mappings defined using :
  - /proc/PID/uid_map
  - /proc/PID/gid_map
- Used in conjunction with other namespaces

Other namespaces

Network namespace:

- Abstracts network devices, IP addresses, port numbers etc.
- Eg:
  - ip netns add mynetns
  - ip netns exec mynetns <command>
  - ip netns delete mynetns

IPC namespace:

- Abstracts Sys V IPC (shared memory etc), POSIX message queues

Control groups

Cgroups provide resource control for various system resources

- Eg: CPU time, memory consumption, I/O bandwidth etc.

/sys/fs/cgroup:

- cpuset
- cpu,cpuacct
- blkio
- memory
- …

- Cgroups are mostly orthogonal to namespaces
  - Resource limits can be applied to any group(s) of processes
- Offers flexibility in applying resource limits on containers

Putting it all together

Docker

- Dockerfile – used to build container images
- Container images – layered using copy-on-write filesystem overlay
- Container registries – reusable container image layers

Kubernetes

- Provides container orchestration and management
- Microservices – a new paradigm to deploy containerized apps

Containers in the cloud

- Containers as a service, as opposed to virtual machines

Tip: Check out the **contain** tool, a bare-bones container runtime:

https://github.com/vmware/photon/tree/master/tools/src/contain