Operating-system-level virtualization and Containers

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Isolation

- Isolation
  - Limiting what/who a process/application can see.
  - Limiting who can see a process/application
- Two extremes
  - Traditional Process
  - System Virtual Machines

Traditional Processes

- Each process gets its own
  - Virtual memory
  - One or more virtual CPUs (threads)
  - Access to OS services via system calls
- All co-located processes can see/share a lot (in an OS-controlled manner)
  - File system, storage, network, and pretty much all I/O devices
  - Other processes
    - For Inter-process communication

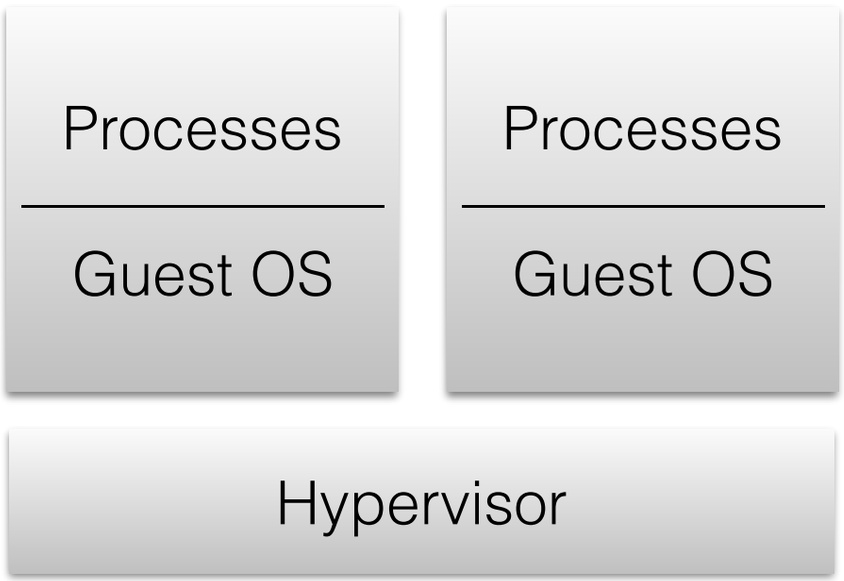
System Virtual Machines

- Co-related processes grouped into VMs
- Each VM has its own
    - Guest OS
    - Guest physical memory (“virtualized” view of memory seen by guest OS)
    - One or more virtual CPUs
    - Virtual I/O devices: virtual disk, virtual network
- Ideally: Co-located VMs don’t see/share ANYTHING

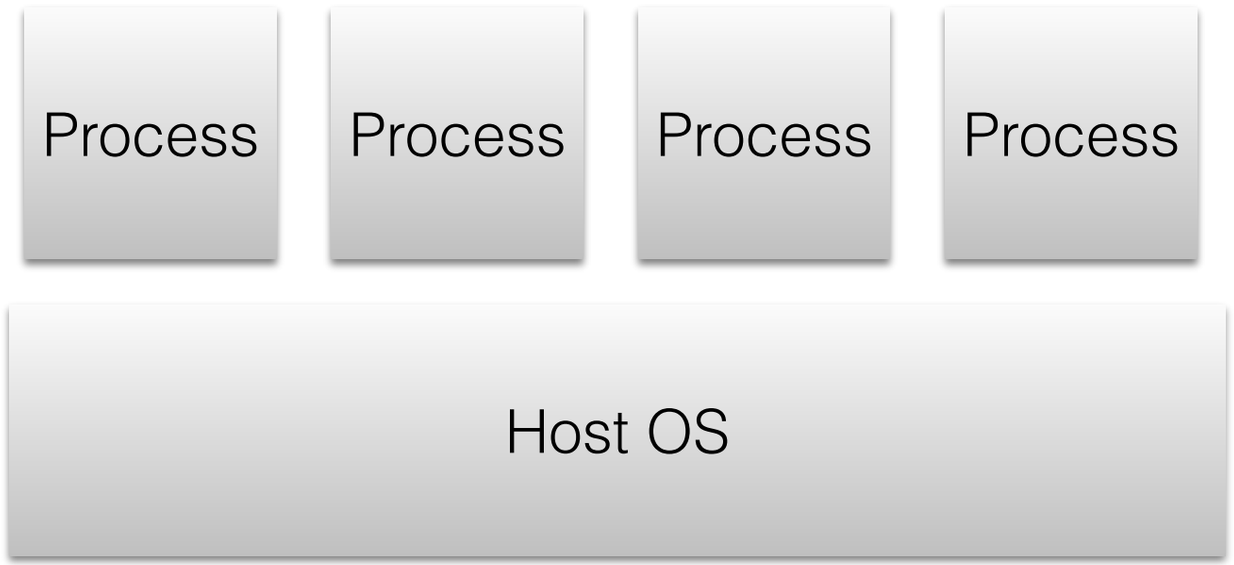
What level to isolate?

- Processes share too much
  - Great performance but
  - Not isolated enough
- System VMs are too heavy
  - Great Isolation
  - But too heavy due to separate guest OS per VM
- Operating-system-level virtualization
  - Multiple isolated user-spaces
  - Share one kernel.

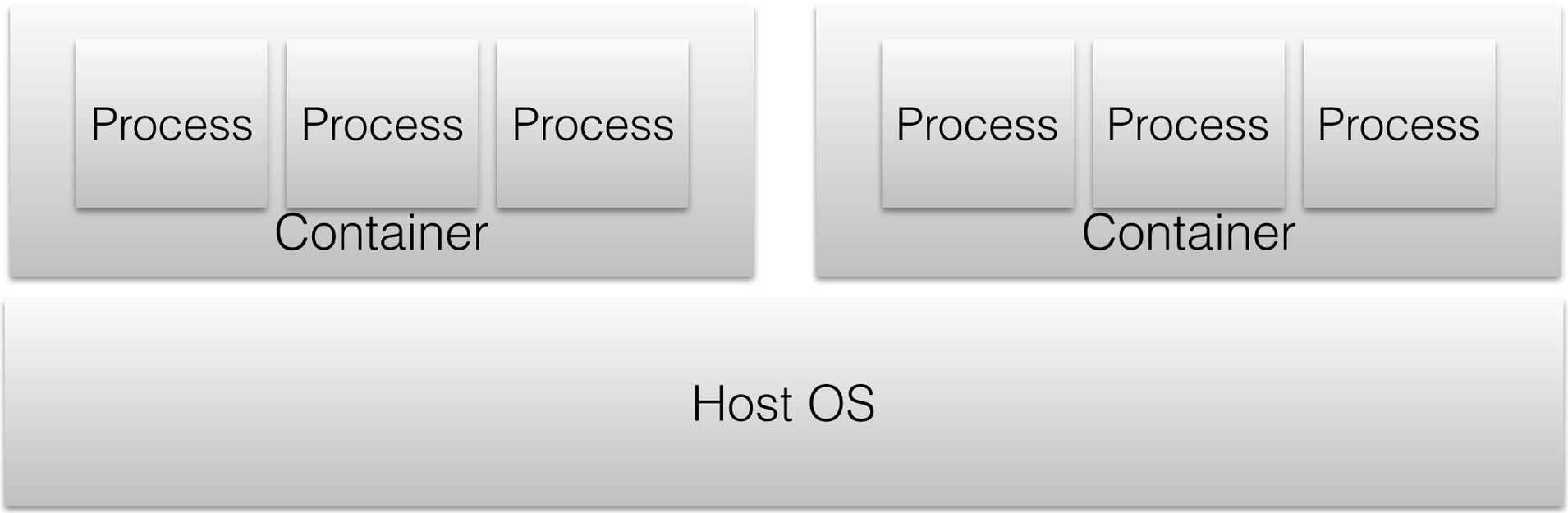
Containers



Traditional VMs



Traditional Processes



Containers

- Take traditional processes and restrict what they can see and who can see them

Chroot jail

- Change root directory for the calling process and its children to a given path
- $ chroot NEWROOT
- OR
- chroot(path)
- “This call changes an ingredient in the pathname resolution process and does nothing else.” — man chroot
- Not secure. Lots of ways to escape chroot jail.

FreeBSD Jails

- Build upon chroot to compartmentalize the files and other resources
- Jails protects rest of the system from the jailed process
    - Not the other way around!
- Virtualized resources
    - file system,
    - the set of users, including own root account.
    - networking subsystem
- Again: Jail escapes are possible!

Linux Namespaces

- “A namespace wraps a global system resource in an abstraction that makes it appear to the processes within the namespace that they have their own isolated instance of the global resource.” - from “$ man namespaces”
- PID Namespace
    - Limit the set of processes that can be see each other.
- IPC namespace
    - Limit the set of processes which are allowed to communicate with each other
- Filesystem namespace
    - Limit which part of filesystem is seen by a process group
- Network namespace
    - Unique IP address host name, domain name, etc for a group of processes
- User Namespace
    - User and Group IDs

Cgroups (Control Groups)

- Beancounter i.e., performs resource accounting for groups of processes

- Allows administrator to set soft/hard limits on things like memory usage, network bandwidth, CPU usage etc.

- Typically used alongside with Linux namespaces

Single System Image

- Extend the notion of namespaces to multiple physical machines
- Multiple machines look like one (or more) namespace(s)
  - PID namespace
  - IPC Namespace
  - Filesystem namespace
- Process migration
  - Allows moving processes from one machine to another without changing its namespace.
- Examples: MOSIX, OpenSSI, Kerrighed