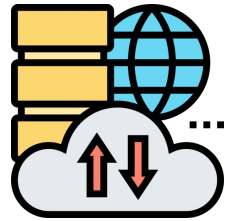
COEN 241
Introduction to Cloud Computing

Lecture 2 - Virtualization



Lecture 1 Recap

- Cloud Computing Primer
- Course Overview
  - Course Objectives
  - Course Structure
  - TODOs
  - Logistics
  - Instructor Information
- Readings
  - Recommended: CCSA 1.1 - 1.3
  - Optional: CCSA 1.5 - 1.15

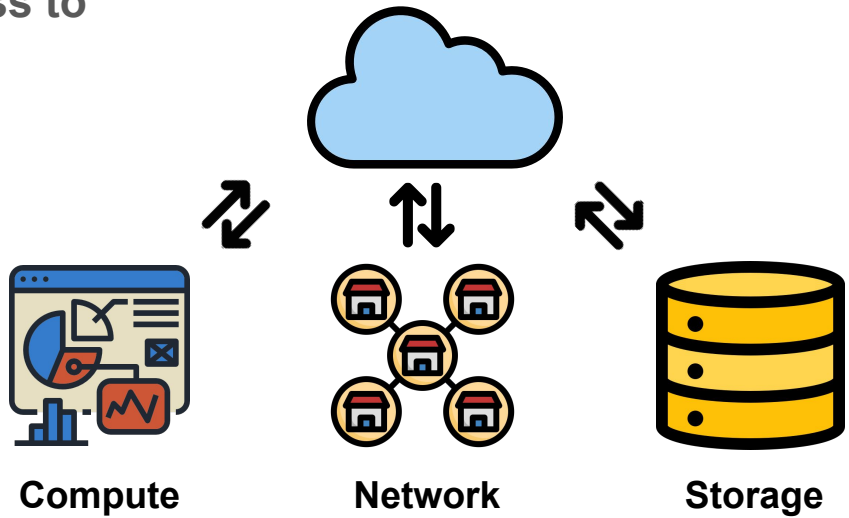
What is Cloud Computing?

Cloud computing is a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources (e.g., server, network, storage & applications) that can be rapidly provisioned and released with minimal management effort or service provider interaction.*

* NIST(The National Institute of Standards and Technology)

What is Cloud Computing?

On demand access to



over the internet

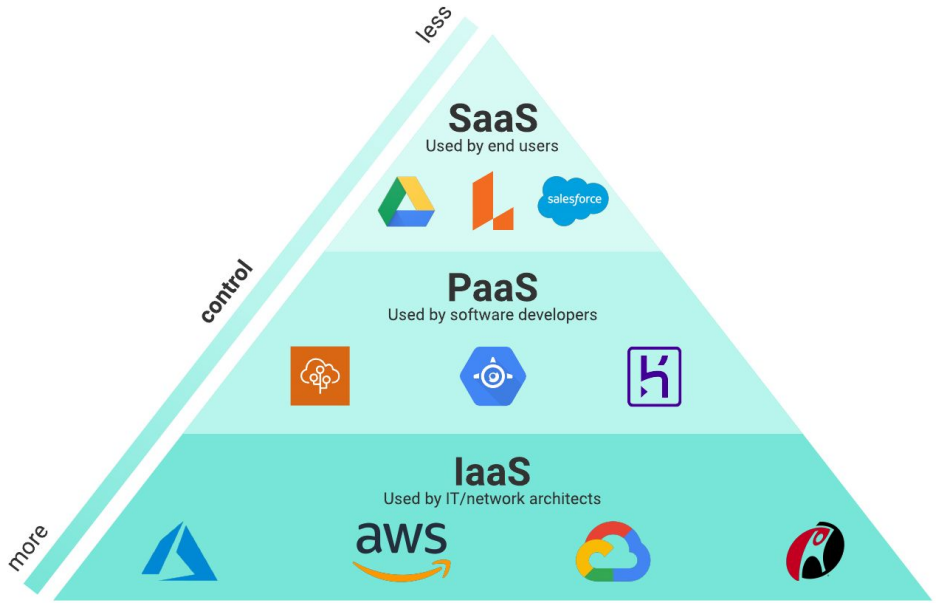
Cloud Computing Enables:

- The illusion of “Ubiquitous” & infinite “Shared Pool” of computing resources available “On-Demand”.
  - Eliminates the need to plan far ahead for provisioning.
- Rapidly and automatically provisioned computing resources.
- Minimal hardware / infrastructure management with increased reliability.

Cloud Computing Enables:

- Access to need-based performance.
- The elimination of an up-front commitment by Cloud users.
  - Allows companies to start small and expand only when needed.
- The ability to pay for use of computing resources on a short-term basis as needed (e.g., processors by the hour and storage by the day)
  - Rewards freeing resources when they are no longer useful.

Cloud Service Models



Cloud Deployment Models

Agenda for Today

- HW 0 Preview & Project Overview
- Multitenancy
- Virtualizations
- Readings
  - Recommended: CCSA 2.1-2.2
  - Optional:
    - http://www.firmcodes.com/memory-thrashing-in-operating-system/
    - https://www.ibm.com/cloud/learn/virtualization-a-complete-guide

HW 0 Preview

- Provided to give you some background context of Linux shell & git
- Keep the Shell tutorial for your reference
- Just need to submit short answers on Camino

Project TODO Overview

- Form Teams by 9/28
- Project Proposal / Midterm Review by 10/5
  - Brief description of the goal, motivation, technologies you will use, etc.
  - More details soon
- Project Presentation (last two classes of the quarter)
  - 20 minutes of presentation + demo
  - You will get a signup sheet after forming the groups
- Final Project (due finals week)
  - Conference style paper 6~8 pages

Multitenancy

Cloud Computing Enables:

- The illusion of “Ubiquitous” & infinite **“Shared Pool”** of computing resources available “On-Demand”.
  - Eliminates the need to plan far ahead for provisioning.
- Rapidly and automatically provisioned computing resources.
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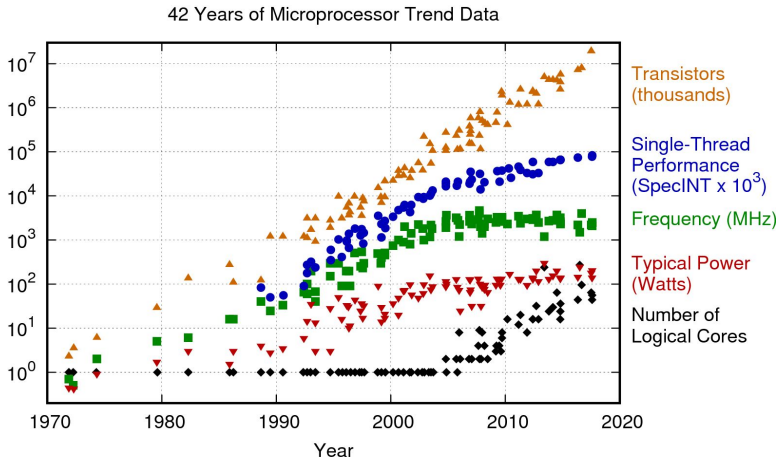
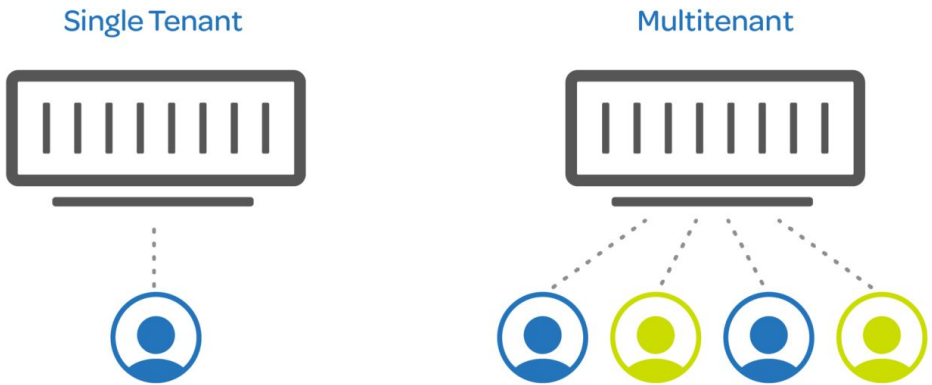
The Need for a “Shared Pool”

- CPUs are getting more powerful (Higher speed, More cores)
- Often times, a single user does not fully utilize a single machine
  - Both in processing power and time
  - Average utilization is < 20%
- Often more cost efficient to “split” a large machine than having many small machines (due to fixed cost in wiring, networking and management)



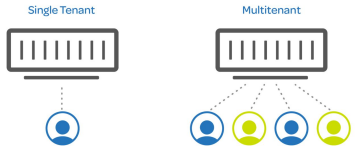
Multitenancy

- Definition: An architecture where multiple users share a single (software or hardware) resource



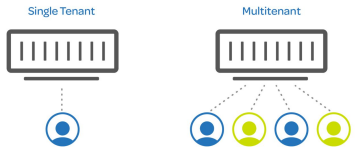
Multitenancy

- Benefits
  - Cost efficient
  - Easier to monitor and manage
  - Easily scalable
- Drawbacks
  - Generally more complex architecture
  - Security and isolation
  - Allocation



How to Enable Multitenancy?

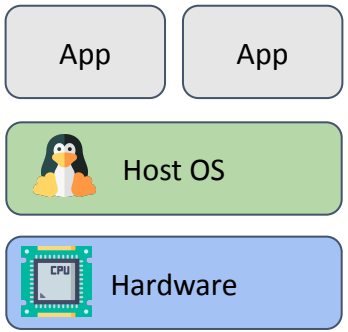
- Definition: Using **software** to create an abstraction layer over the **hardware** that allows the hardware elements of a single computer—processors, memory, storage and more—to be divided into **multiple virtual elements**.
- Virtualization!



Virtualization

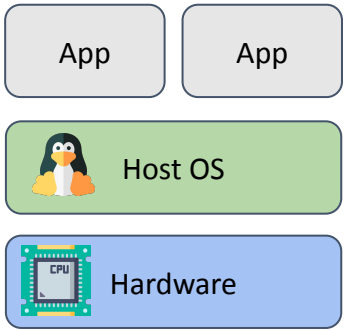
Why can’t we just have multiple processes?

- Can’t we just run separate processes for user?
  - We have multi-core systems now
  - Simple to manage
  - OS is now smart enough!



Why can't we just have multiple processes?

- Hard to control resource contention
  - Need fine grained resource management for each process
- Hard to manage dependencies
  - All the users must be compatible with the shared OS
- Hard to guarantee performance!
  - Memory Thrashing
  - Unfair I/O access

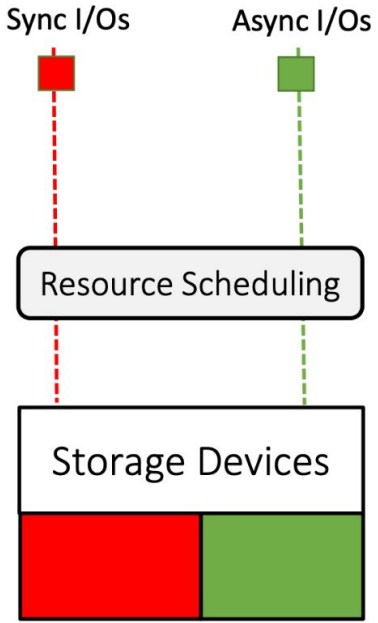


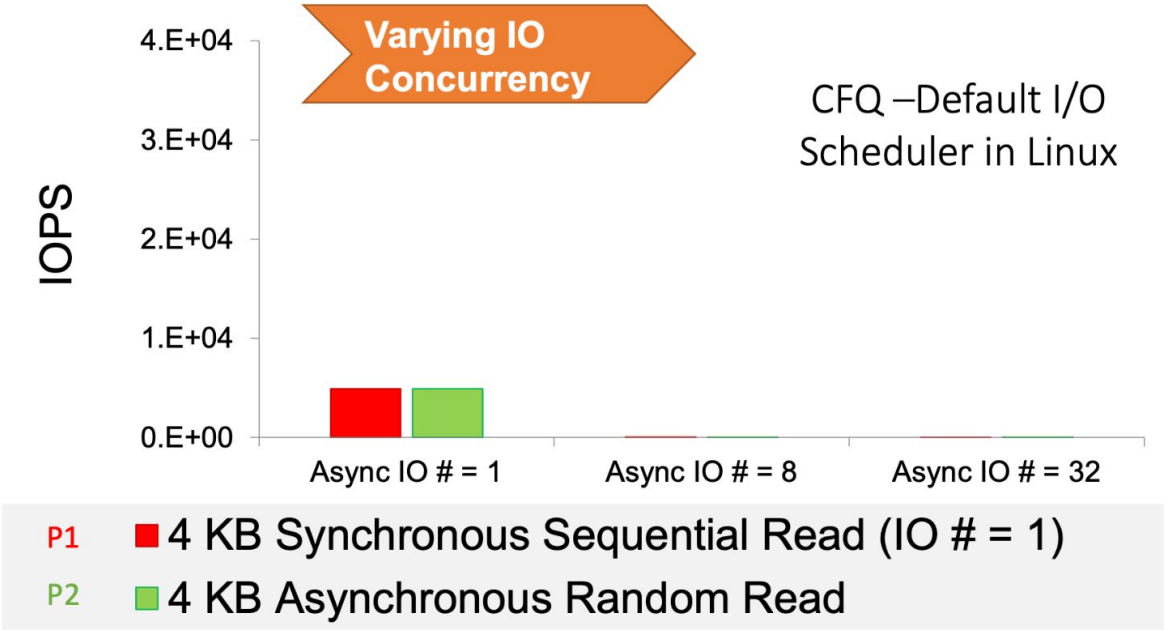
Exercise: Memory Sharing

```
int main() {
        int i;
        char *p[2048];

        for(i=0;i<2048;i++) {
                p[i]=malloc(1024000); // allocate 1 MB
                memset(p[i],'\0',1024000); // set as 0s
        }

        while(1) {
                if (i>=2048)
                        i = 0;
                memset(p[i],'\0',1024000);
                i++;
        }
}
```

- What does this program do?
- What would happen if we run 10 processes with the same code given on the right?
- What happens if we have machines with following amounts of RAM?
  - 2GB
  - 10GB
  - 20GB

Exercise: Unfairness of I/O Resource Sharing



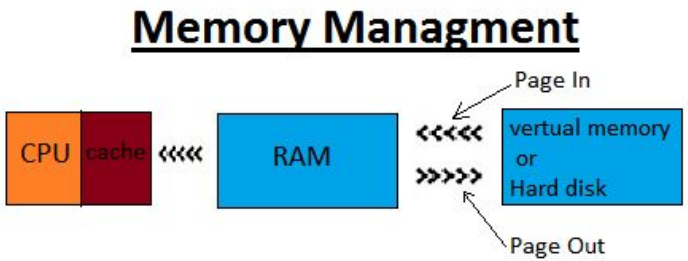


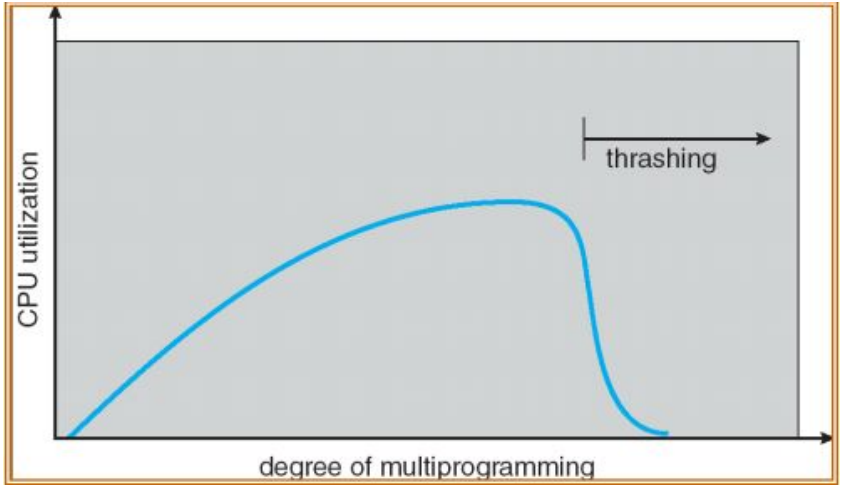
Exercise: Unfairness of I/O Resource Sharing

- What happens if we increase the number of asynchronous IOs to 4?
- What happens if we increase the number of asynchronous IOs to 32?

Memory Thrashing

- Memory thrashing is a problem that arises when the memory being accessed is much more than the physical memory.
  - Unpredictive contention
  - Any solution?





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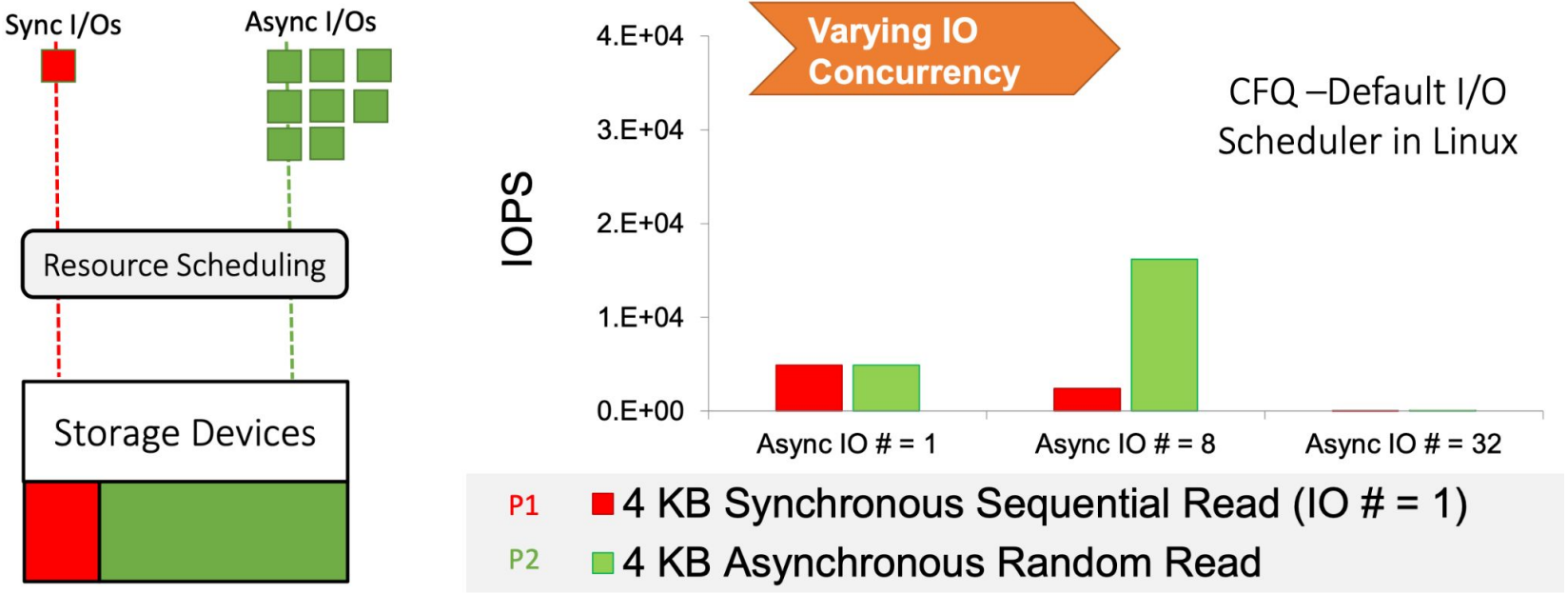
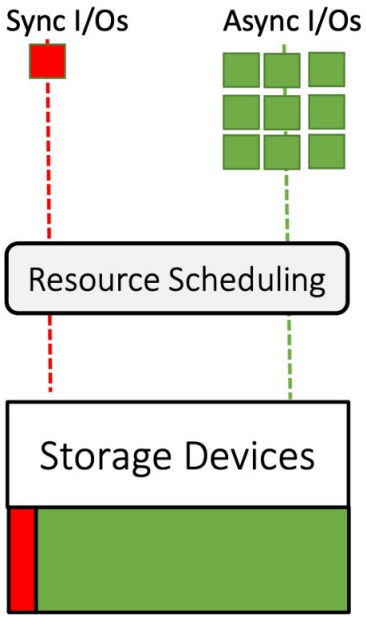
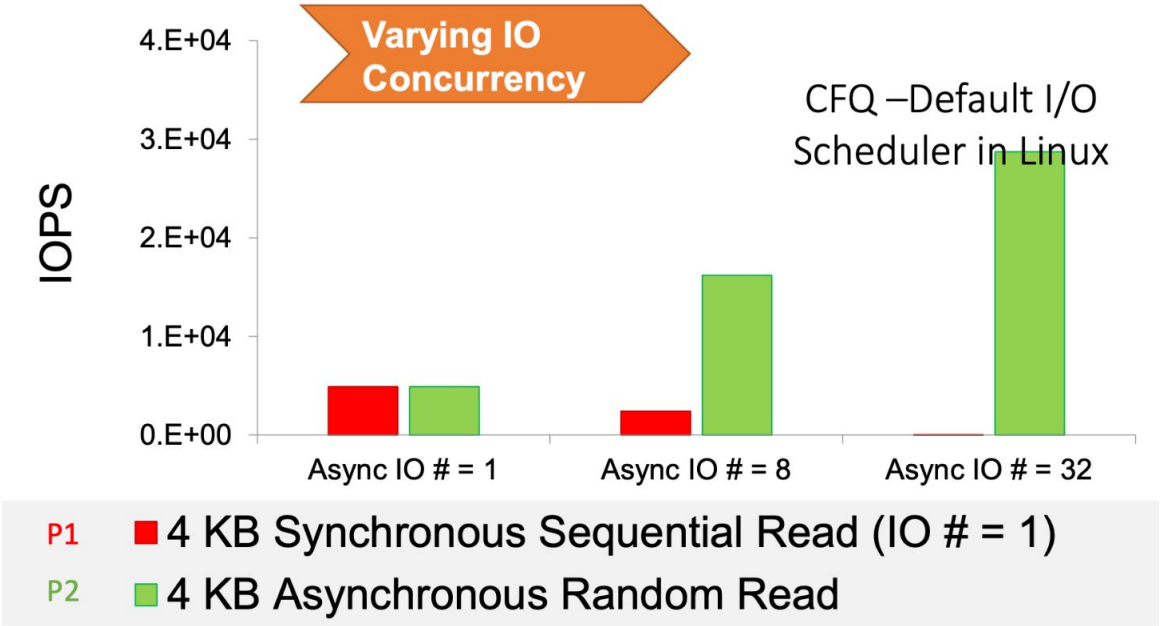
Example: Unfairness of I/O Resource Sharing



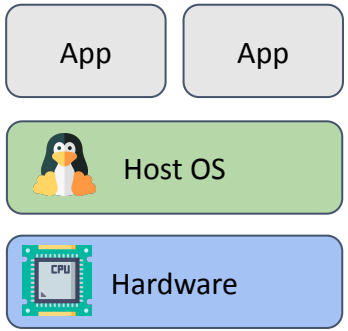
Example: Unfairness of I/O Resource Sharing





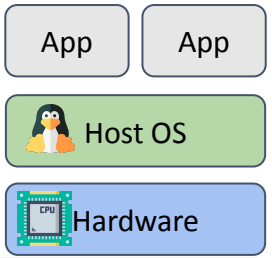
Pros & Cons of Having Multiple Processes

- Pros:
  - Multiple applications (from different users) can run “simultaneously”.
  - Maximize resource utilization
    e.g., multiple processes on a multi-core system
- Cons
  - Contention
  - Dependency/Compatibility Issues
    - The application’s version and the OS version should (strictly) match one another other



Potential Solutions

- Contention
  - Strong regulation, such as limiting (via metering)
  - More advanced resource management: limit, share, and reservation for multiple resources, such as CPU, memory, block I/O, and network
- Dependency/compatibility
  - Provide processes with their own view of the system
  - With their own running environments (i.e., library versions)
- Virtualization!

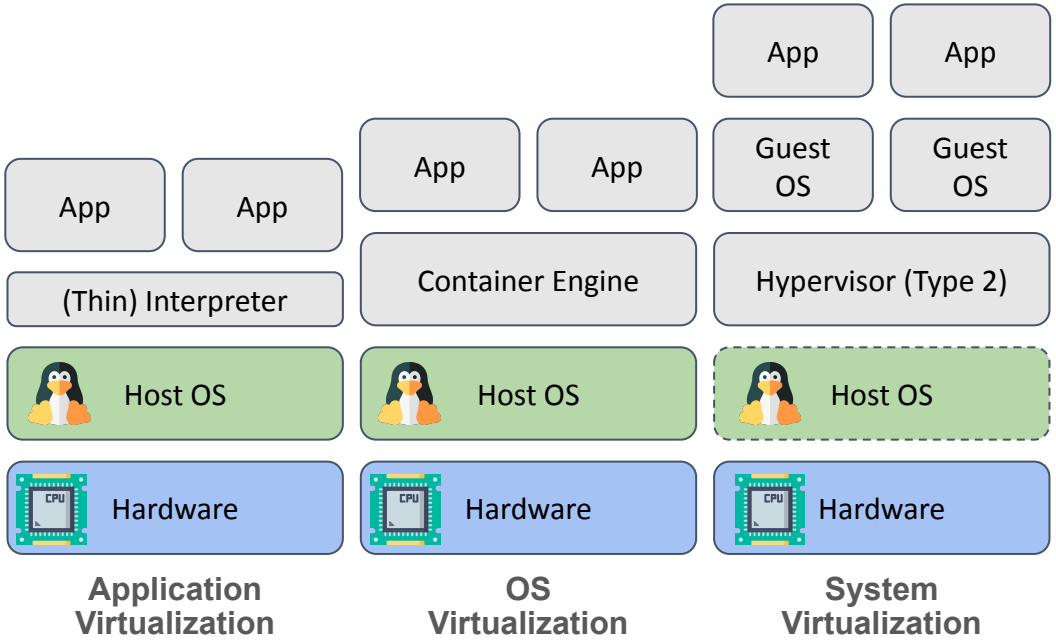


What is Virtualization?

- The act of creating a virtual (rather than actual) version of something, including virtual computer hardware platforms, storage devices, and computer network resources.
- Virtualization is about adding a layer for manageability
  - Virtualization support is increasingly being added into various software and hardware

Types of Virtualization

- **Application Virtualization**
  - E.g., JVM, PVM
- **OS Virtualization**
  - Containers
- **System Virtualization**
  - Virtual Machines
- Network Virtualization
- Storage Virtualization
- Many more...

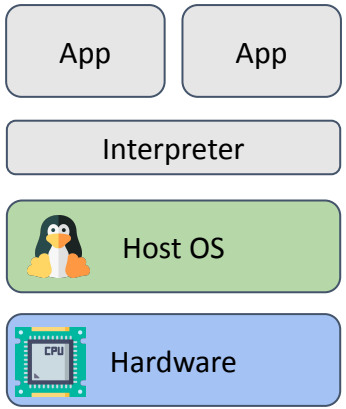


Application Virtualization

- Purpose: Provide a **platform-independent programming environment** that abstracts the underlying hardware or OS and allows a program to execute in the same way on any platform

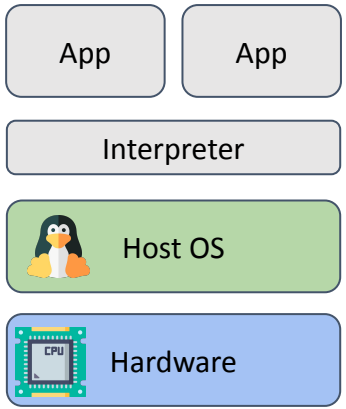
- What is virtualized?
  - Processor
  - System calls
  - Memory management

- Each application is run as a **separate process**
- Examples: Java Virtual Machine



Application Virtualization

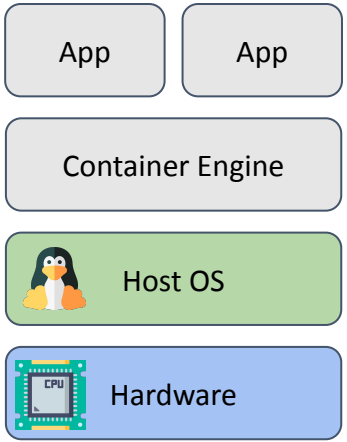
- Benefit
  - Portability
- Drawbacks
  - Language dependent, i.e, not flexible



OS Virtualization

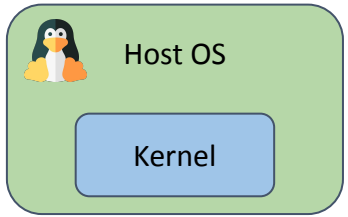
- Virtualizing everything above the Host OS **Kernel**
  - Userspace

- We will revisit this concept!



Digression: What is a Kernel?

- **Operating System** is system program that provides interface between user and computer.
- **Kernel** is the core component of an operating system. It is also a system program and a part of of OS which converts user commands into machine language.

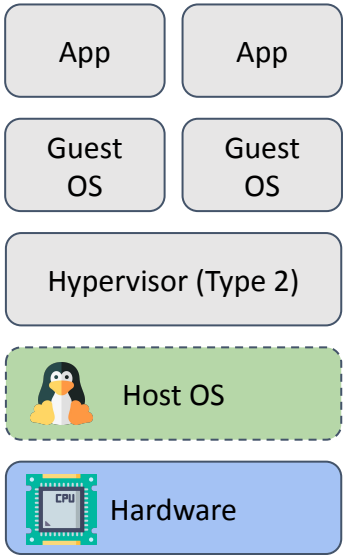


Digression: What is a Kernel?

	KERNEL	OPERATING SYSTEM
Definition	Kernel is part of an OS	Operating System is a system program.
Interface	Kernel is an interface between software and hardware	Operating System is an interface between user and hardware.
Type	Monolithic and Microkernels	Single and Multiprogramming batch system, Distributed, Realtime
Purpose	Manages kernel memory, processes, task and disk	In addition to the responsibilities of Kernel, OS provides added security, UI, window manager and etc.

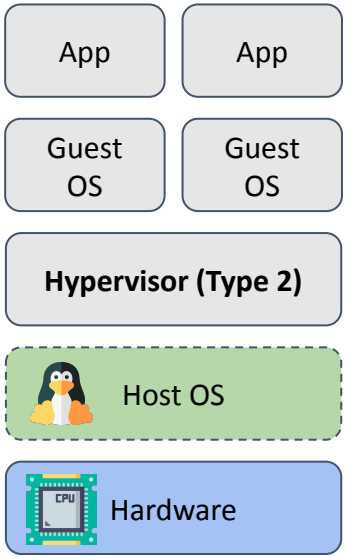
System Virtualization

- What is virtualized?
  - CPU: vCPU
  - vMem
  - virtual network card
  - virtual hard disks
  - Even usb ports and more
- Creates a virtual computer system, called **virtual machine (VM)** consisting of the set of (virtual) hardware, upon which a full (guest) OS runs.
- **Hypervisor** manages the virtual machines



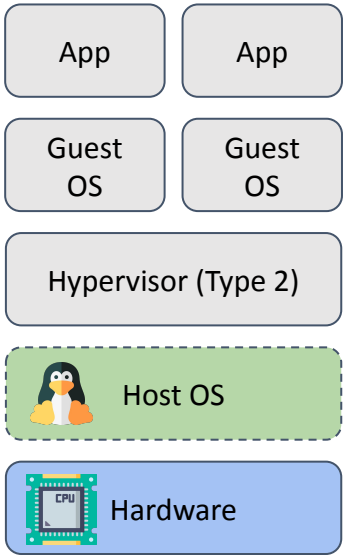
Hypervisor (Virtual Machine Monitor)

- A thin layer of software that's between the hardware and the operating system, virtualizing and managing all hardware resources for VMs
- Examples
  - VMWare
  - **Virtualbox**
  - Parallels
  - QEMU
  - Xen
  - KVM
- We will cover this more next lecture



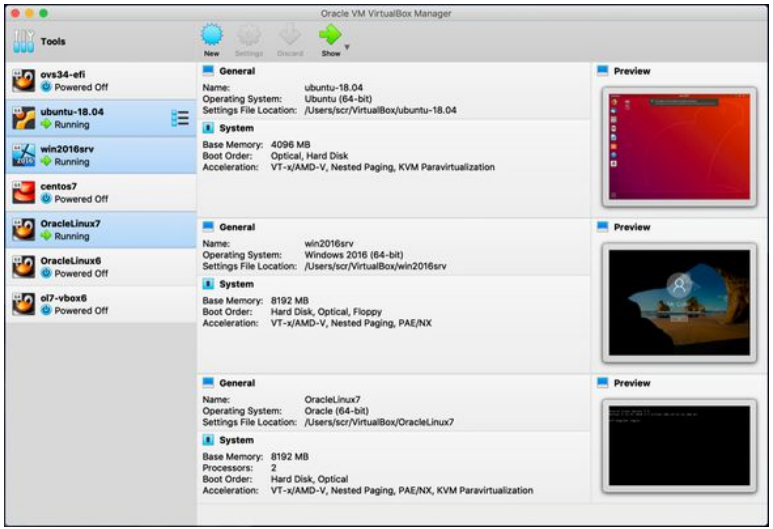
Virtual Machines

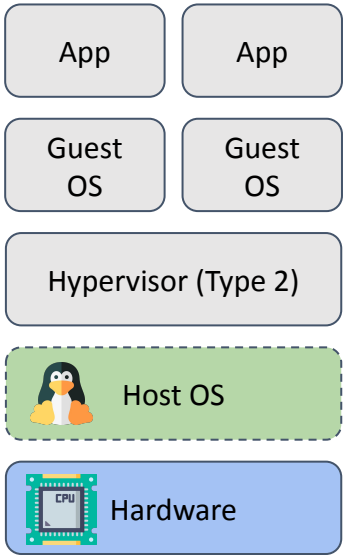
- A fully protected and isolated copy of the underlying physical machine's hardware (i.e., emulated by software)
- Must be configured and created
- Portable and reconfigurable as needed
  - Open Virtualization Format (OVF)
  - Disk image



Virtual Machines

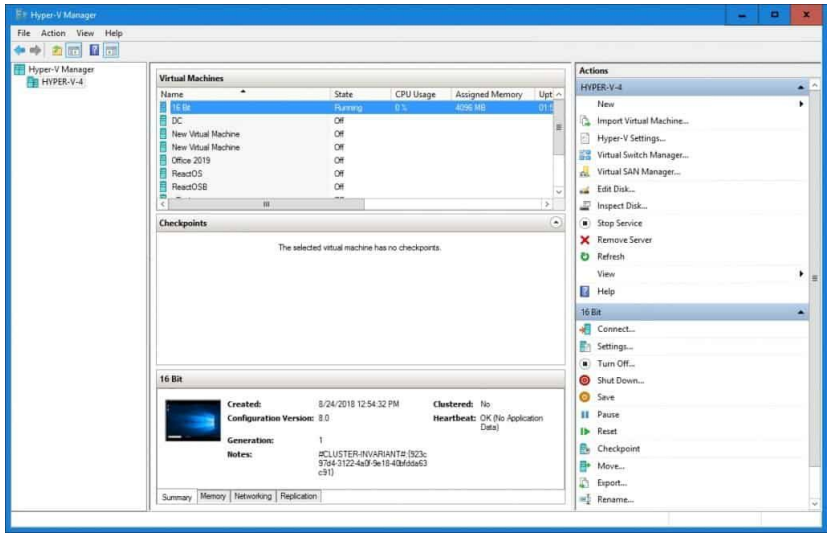
- Example of Virtual Machines
  - Virtual Disk Image file (VDI) for VirtualBox

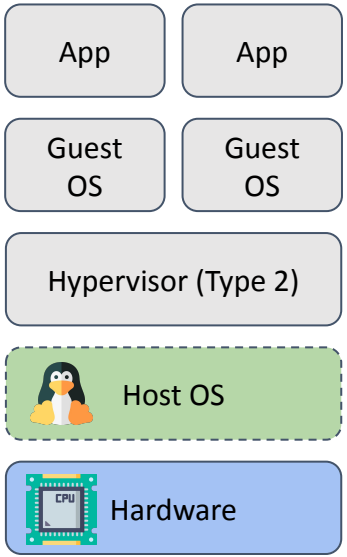




Virtual Machines

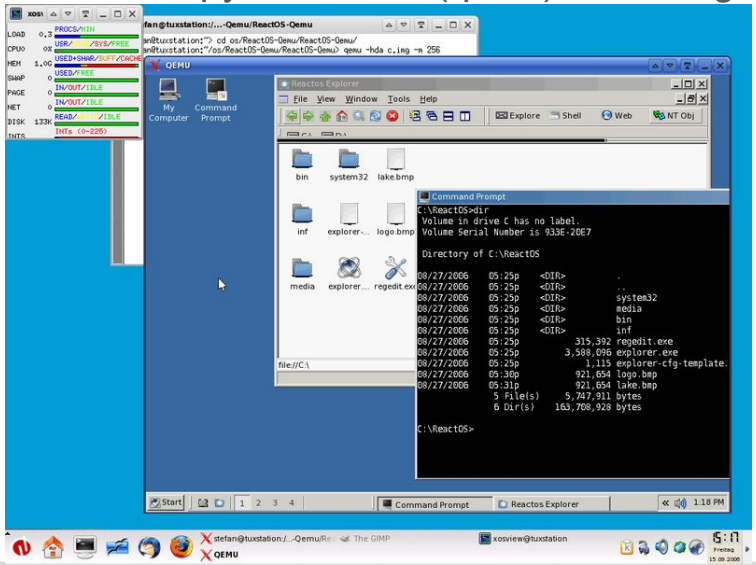
- Example of Virtual Machines
  - Virtual Hard Disk image (VHD) for Hyper-V

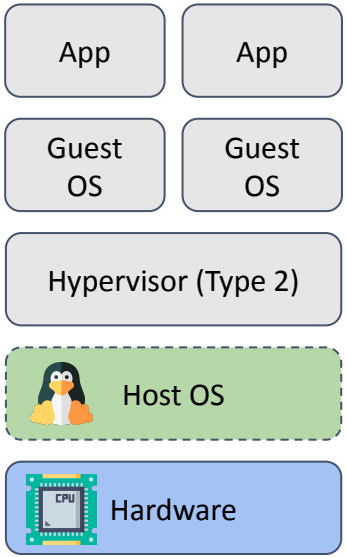




Virtual Machines

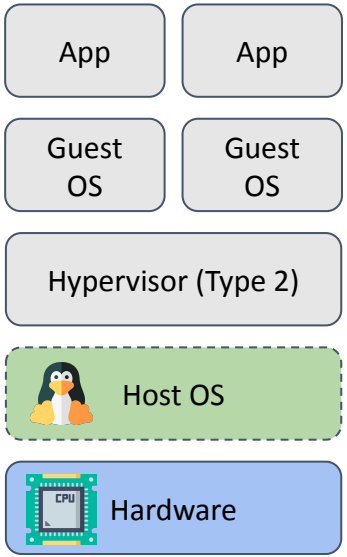
- Example of Virtual Machines
  - “QEMU Copy On Write" (qcow) disk image for QEMU





Pros & Cons of System Virtualization

- Pros
  - Strong isolation (than containers)
  - More levels of protection – VM's kernel and host kernel
  - Full OS
- Cons
  - Performance overhead
  - Large memory & storage footprint
  - More configurations needed



History of System Virtualization

- IBM VM/370 – A VMM for IBM mainframe
  - Multiple OS environments on expensive hardware
  - Desirable when few machine around
- Popular research idea in 1960s and 1970s
  - Entire conferences on virtual machine monitors
  - Hardware/VMM/OS designed together
- Interest died out in the 1980s and 1990s
  - Hardware got much cheaper
  - Operating systems got more powerful (e.g. multi-user)

History of System Virtualization

- Early x86 computers were underpowered
  - Windows 95 with few applications often maxed-out resources
  - Server work left to expensive server-class computers
- PC computing power increased
  - X86 servers began to appear
  - Mostly under-utilized due to no virtualization
- x86 virtualization surged mid-2000s thanks to the Xen hypervisor

History of System Virtualization

- Commercial virtual machines for x86 architecture
  - Connectx VirtualPC (now Microsoft)
  - VMware (1999-)
  - KVM (Linux)
- Research virtual machines for x86 architecture
  - **Xen (SOSP '03)**
  - Plex86
- Now widely used in all public cloud providers!

Agenda for Today

- HW 0 Preview
- Multitenancy
- Virtualizations
- Readings
  - Recommended: CCSA 2.1-2.2
  - Optional:
    - http://www.firmcodes.com/memory-thrashing-in-operating-system/
    - https://www.ibm.com/cloud/learn/virtualization-a-complete-guide

TODOs!

- HW 0
  - On Camino

- Start looking for teams ASAP!

Questions?