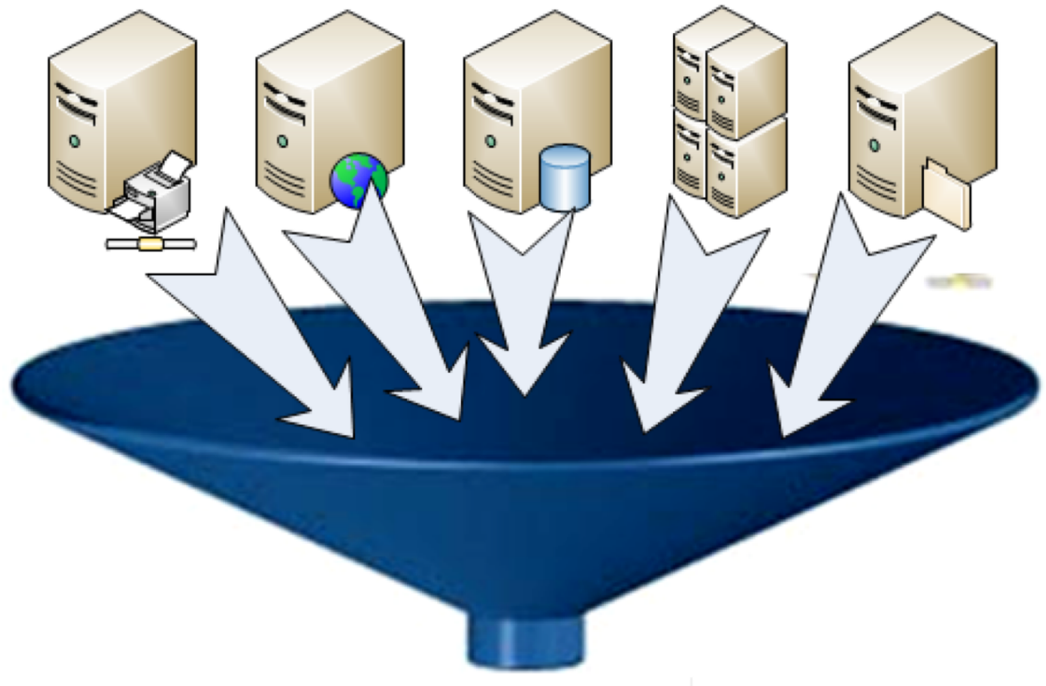
Virtualization

- Technique that allows creating a software-based virtual device or resource that, in practice, is an abstraction provided on top of existing hardware or software resources.

Server Virtualization

- Virtual Machines (VMs)



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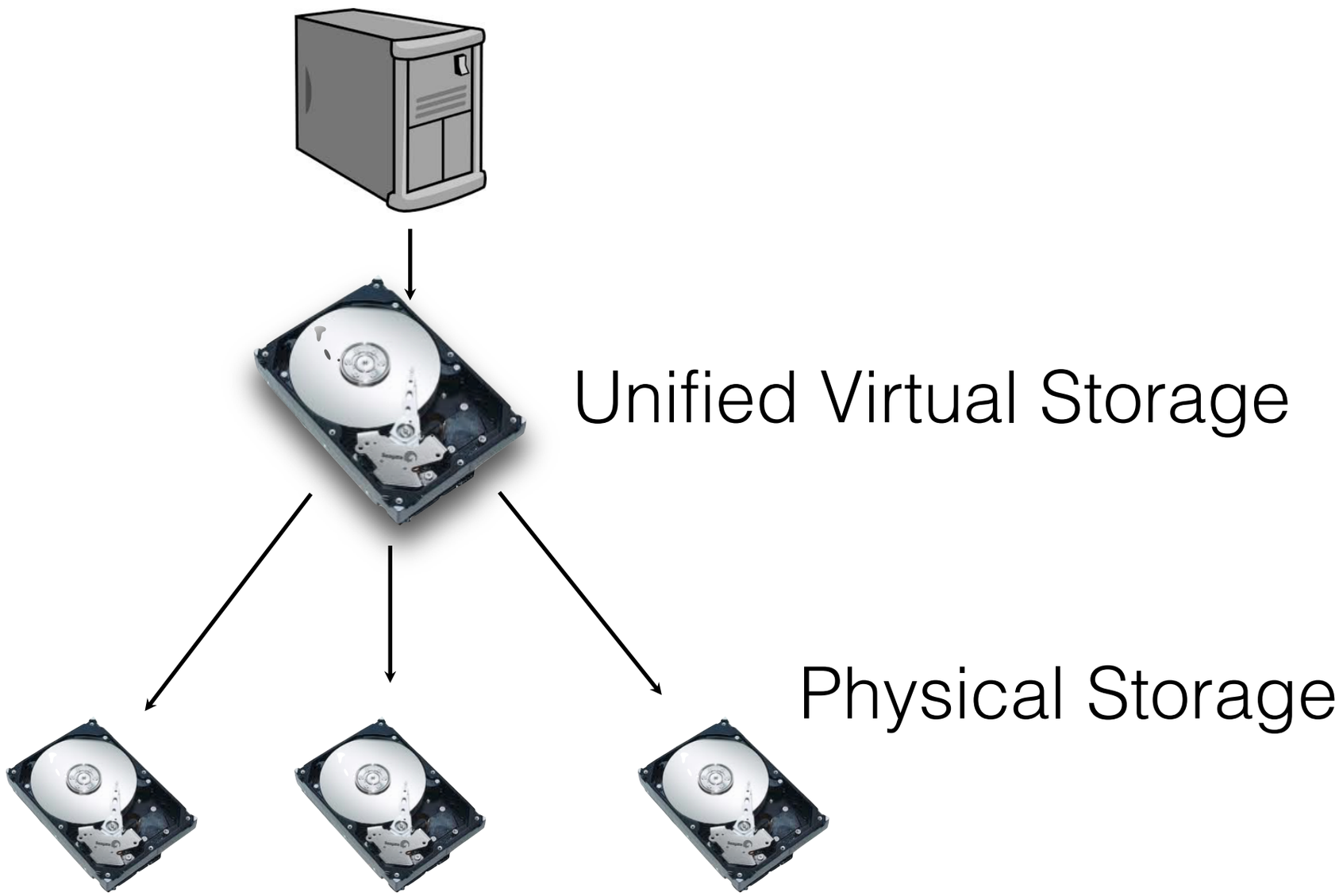
Storage Virtualization

- Disk partitioning

Storage Virtualization

- Distributed storage



Other Examples

- Network devices
- Random Access Memory
- Containers
- …

Virtualization in Practice

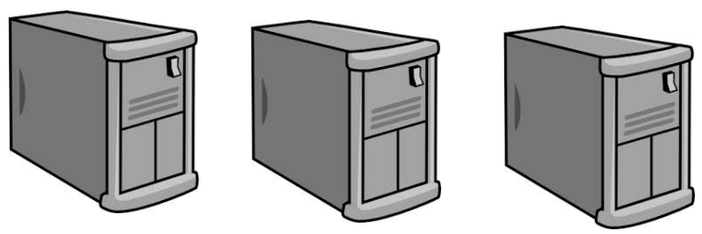
Virtual Desktop Infrastructures (VDIs)

- VMWare Horizon 7
- Amazon WorkSpaces

Virtualization in Practice

Storage Virtualization (Software-Defined Storage)

Client Client Client



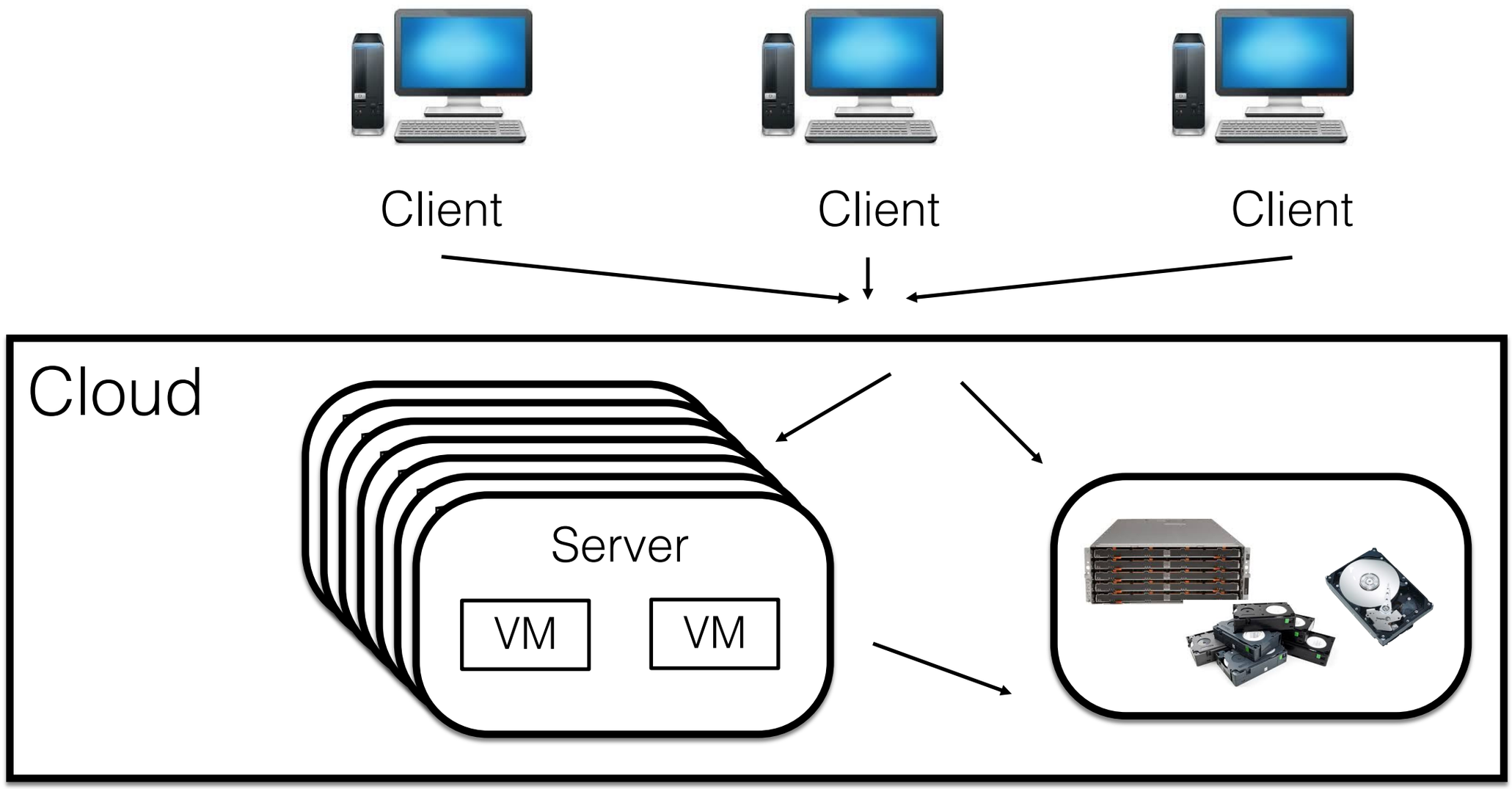
Server Server Server

Logical Devices

- Amazon S3, Glacier
- EMC ViPR

Virtualization in Practice

Simplified Cloud deployment



- Amazon EC2, EBS

Advantages

Heterogeneity

- Virtual resources can be provided on top of different/multiple physical (hardware) resources

- A virtual resource can support different applications/operating systems while resorting to the same physical hardware (e.g., VMs)

Advantages

Transparency

- User interaction with virtual resources is similar to the interaction with a physical one

Advantages

Isolation

- Virtual resources are fully isolated from the underlying hardware/software in terms of:
  - Security
  - Performance
  - Failures (including OS/data corruption)

Advantages

Resource Optimization

- Physical resources can be leveraged to support more clients/applications
- Server Consolidation
- Lower Costs

Advantages

Simplified Management

- Managing a virtual resource is simpler than managing bare-metal resources.

- High Availability

- Dynamic Load Balancing

  - E.g., VMs Live Migration/Snapshots

Disadvantages

Performance

- The abstraction of resources often includes a performance penalty
  - CPU, Network, I/O

Disadvantages

Overprovisioning

- Deploying more virtualised resources than needed may lead to performance degradation

Disadvantages

Security

- If isolation is not properly addressed or, a malicious user/sysadmin has access to the physical resources (e.g., server), security may be compromised

Disadvantages

Dependability

- The failure of physical resource may result in the failure of multiple virtual ones.

Disadvantages

Learning Curve

- Administrators need to understand and manage a new paradigm

- In some virtualization techniques, applications must be rewritten or need additional configuration to be deployable

Virtual Machines

- Changing an application to run on different Operating Systems is a costly and hard task

- VMs allow running different operating systems on top of the same physical server

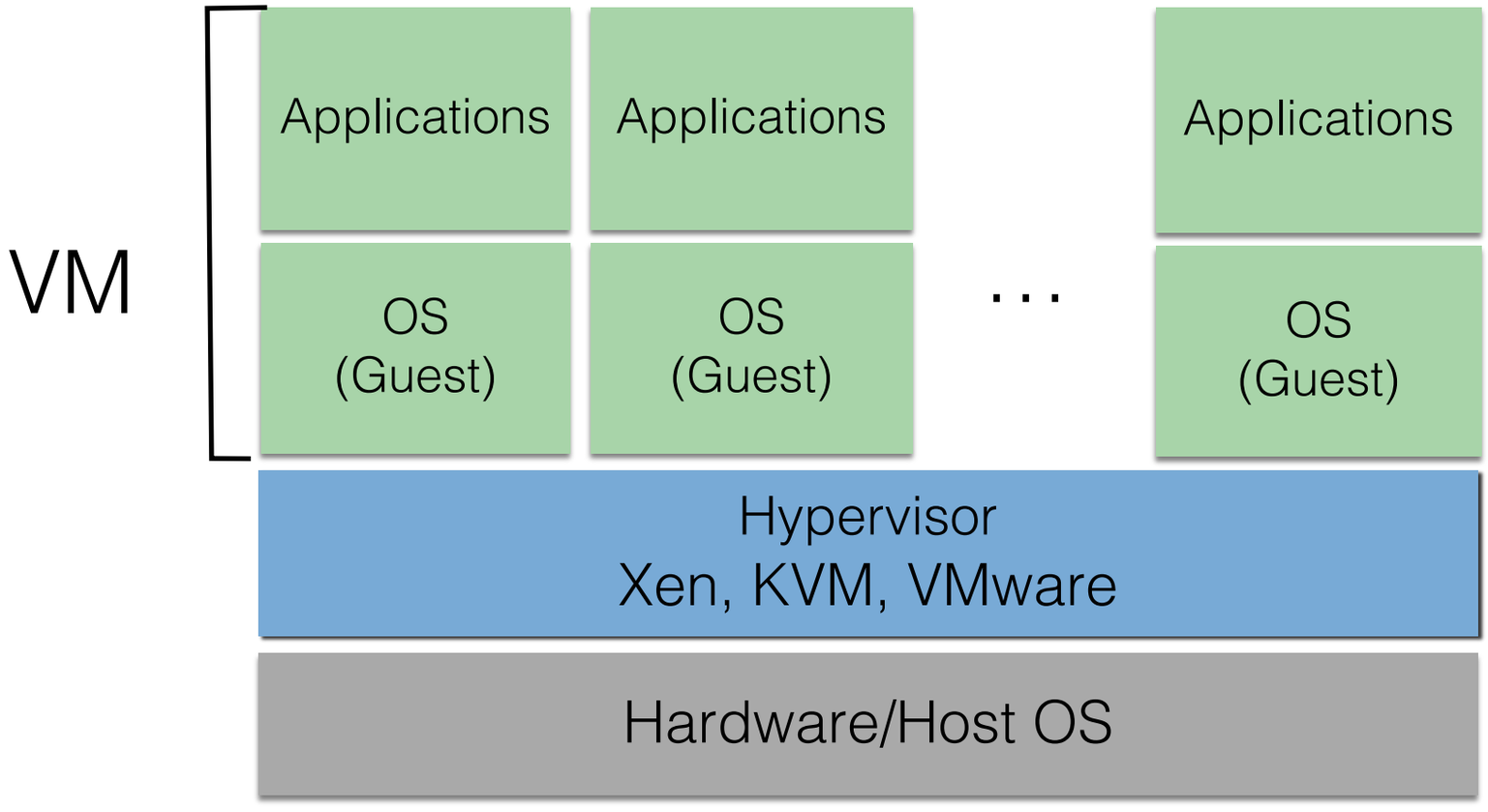
Virtual Machines

(context)

- IBM mainframe systems (from about 45 years ago) allowed applications to use isolated portions of a system's resources
- Virtualization became mainstream in the early 2000's with the X86 server architecture due to:
  - Under-utilised resources
  - Infrastructure costs

Virtual Machines

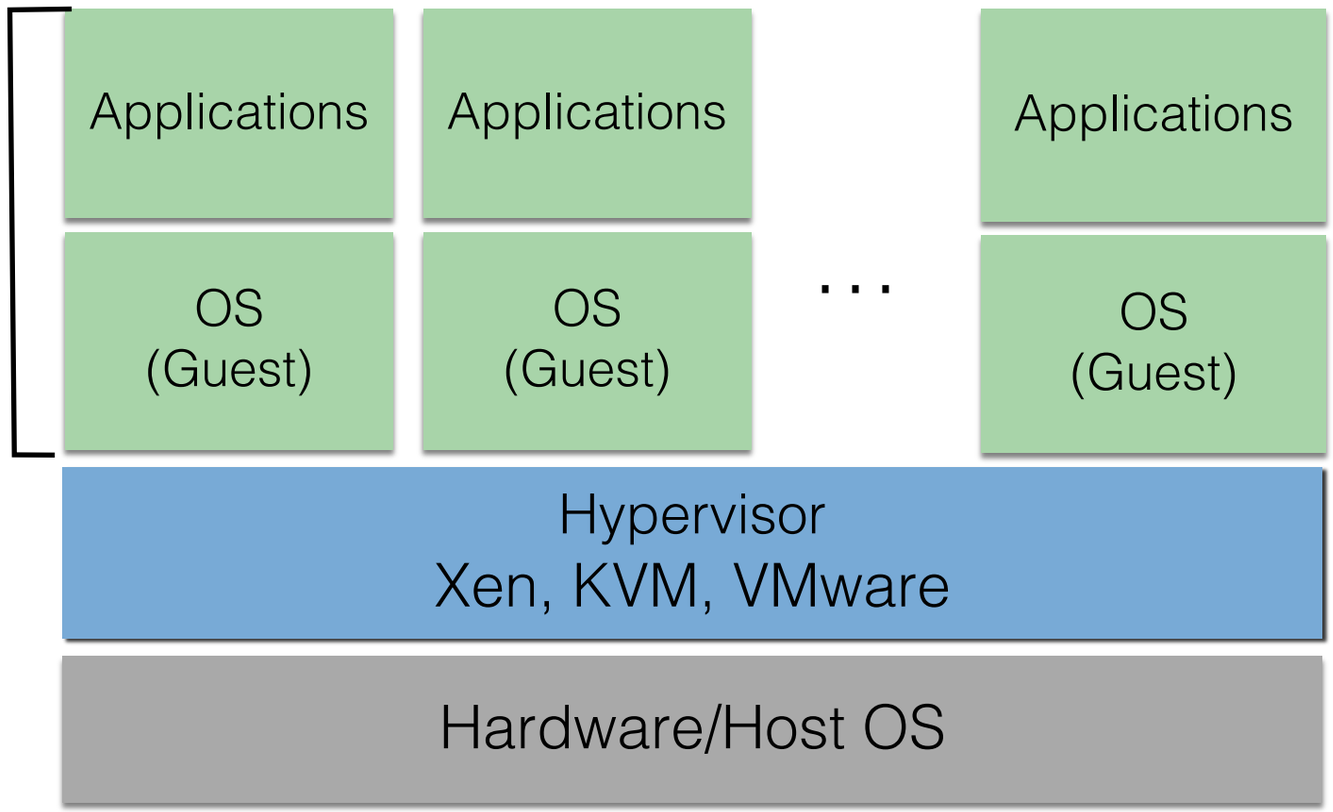
Architecture



Virtual Machines

Architecture

- Operations are intercepted by the Hypervisor and executed on the physical hardware
  - RAM
  - Disk
  - CPU
  - Network
  - ...



Virtual Machines

Hypervisor

Hypervisor
Xen, KVM, VMware

- Controls the low-level interaction between VMs and the underlying host OS/hardware
  - access to shared disk, network, CPU, and RAM resources

Virtual Machines

Storage

- Each VM allocates a specific chunk of the host's storage capacity

- The storage system must handle multiple writers/readers efficiently

- Thin-provisioning (e.g., sparse allocation, copy-on-write)

Virtual Machines

CPU

- Time slicing - processing requests are sliced up and shared across the VMs
- Similar to running multiple processes in a physical host
- Overcommitting vCPUs may lead to poor performance

Virtual Machines

Network

- VMs share network bandwidth (similarly to storage)
- Each VM can be configured with a different network setup

Virtual Machines

Network

- Host-only
    - Shares the host networking namespace. The VM only has access to the host
- Nat
    - Masks network activity as if it is done by the Host (single network identity). The VM has access to external resources
- Bridge
    - Uses the hypervisor to assign a specific IP to the VM (DHCP must be enabled in the network). The VM is seen as another node in the physical network

Virtual Machines

RAM

- VMs share RAM (similarly to storage)

- It is possible to perform memory reclamation across VMs deployed in the same host

Virtualization Modes

- Modern virtualization is hardware-assisted and does not require traditional (emulation) software virtualization

- Better performance closer to the native one

Virtualization Modes

Paravirtualization

- Requires hooks/modifications at the VM (guest) OS
- Costly operations are performed directly on the native host instead of the virtual environment (e.g., disk and network I/O)
- E.g., Xen and VMware

Virtualization Modes

Paravirtualization

- Advantages
  - Better performance
- Disadvantages
  - Guest OS must be modified
  - Maintainability of the modified kernel

Virtualization Modes

Full Virtualization

- VM OS is unmodified and presented with a simulated hardware interface (emulator)

- The hypervisor emulates all hardware devices on the virtual environment

- These emulated devices are used to build a virtual machine

- E.g., Xen, VirtualBox and KVM (QEMU)

Virtualization Modes

Full Virtualization

- Advantages
  - No modifications to the guest OS (full isolation)
  - Higher range of supported OS flavors, easier migration/portability of VMs
- Disadvantages
  - All operations must be processed by two layers (VM and hypervisor)
  - Lower I/O and CPU performance

Virtualization Types

Type 1 - bare metal hypervisor

- Does not require host OS, deployed directly on the hardware
- “Small operating system”
- Better performance
- It usually requires virtualization support at the hardware level
- E.g., Vmware ESX

Virtualization Types

Type 2 - hosted hypervisor

- Deployed on top of the host's OS
- Host OS is not dedicated for the VMs
- Worst performance
- E.g., VirtualBox
- KVM and Xen present an hybrid solution

VMs Deployment

- Configuration File
  - Number of CPUs
  - RAM and Storage space
  - I/O devices it has access to (virtual disks/network)
- OS image must be copied to the virtual disk

Virtual Machine Deployment

- Templates can be used to provision VMs in a easier way with the appropriate provisioning tools
- E.g., Vagrant
  - Command-line interface
  - Vagrantfile (Ruby syntax)

Virtual Machine Migration

- Types
  - Live Migration
  - Offline Migration
- Purpose:
  - Load Balancing (Geographical, Load, etc)
  - Host Maintenance