# Cloud Computing Applications and Services
(Aplicações e Serviços de Computação em Nuvem)

## Virtualization
Part I

University of Minho
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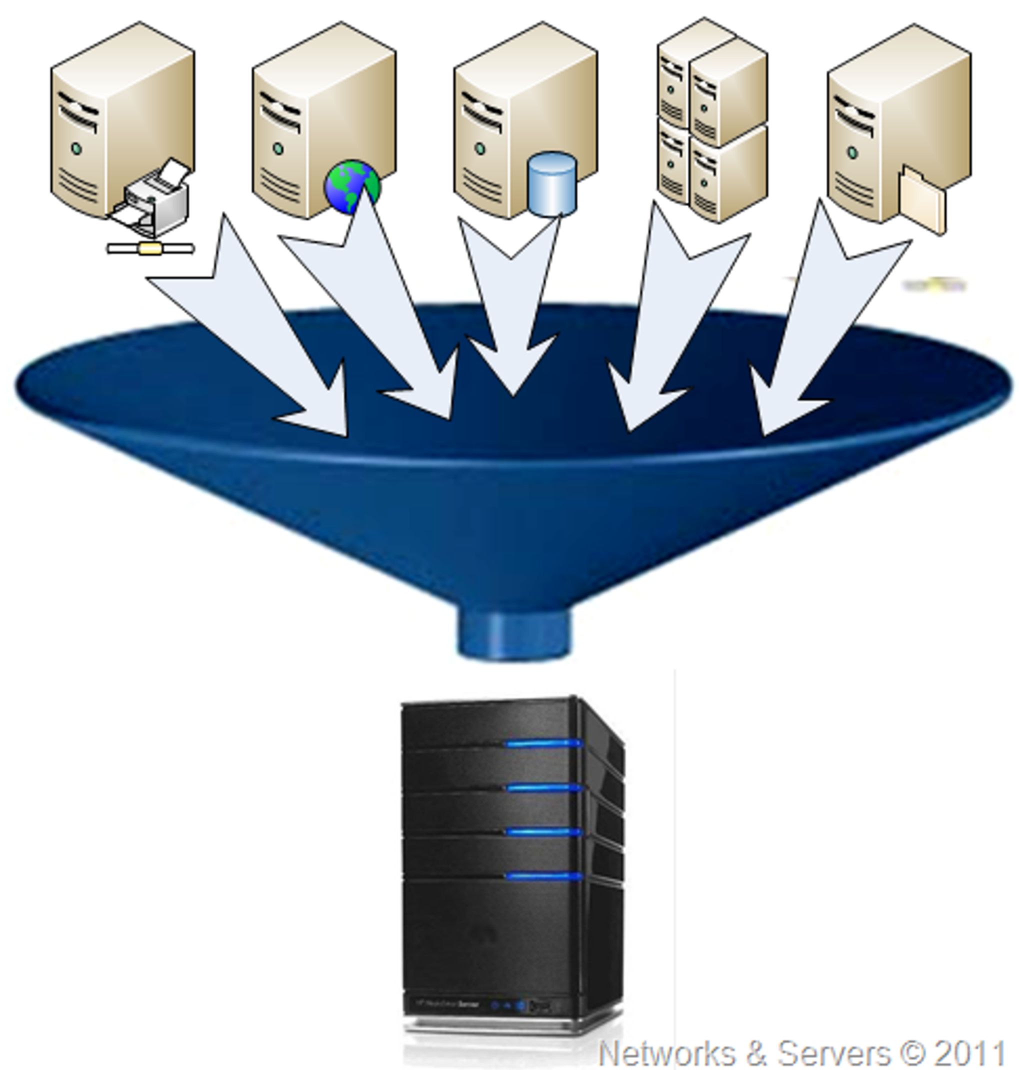
# Virtualization

- 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)



# Other Examples

- Virtual Networks
- Virtual Memory
- Logical Storage Volumes
- ...

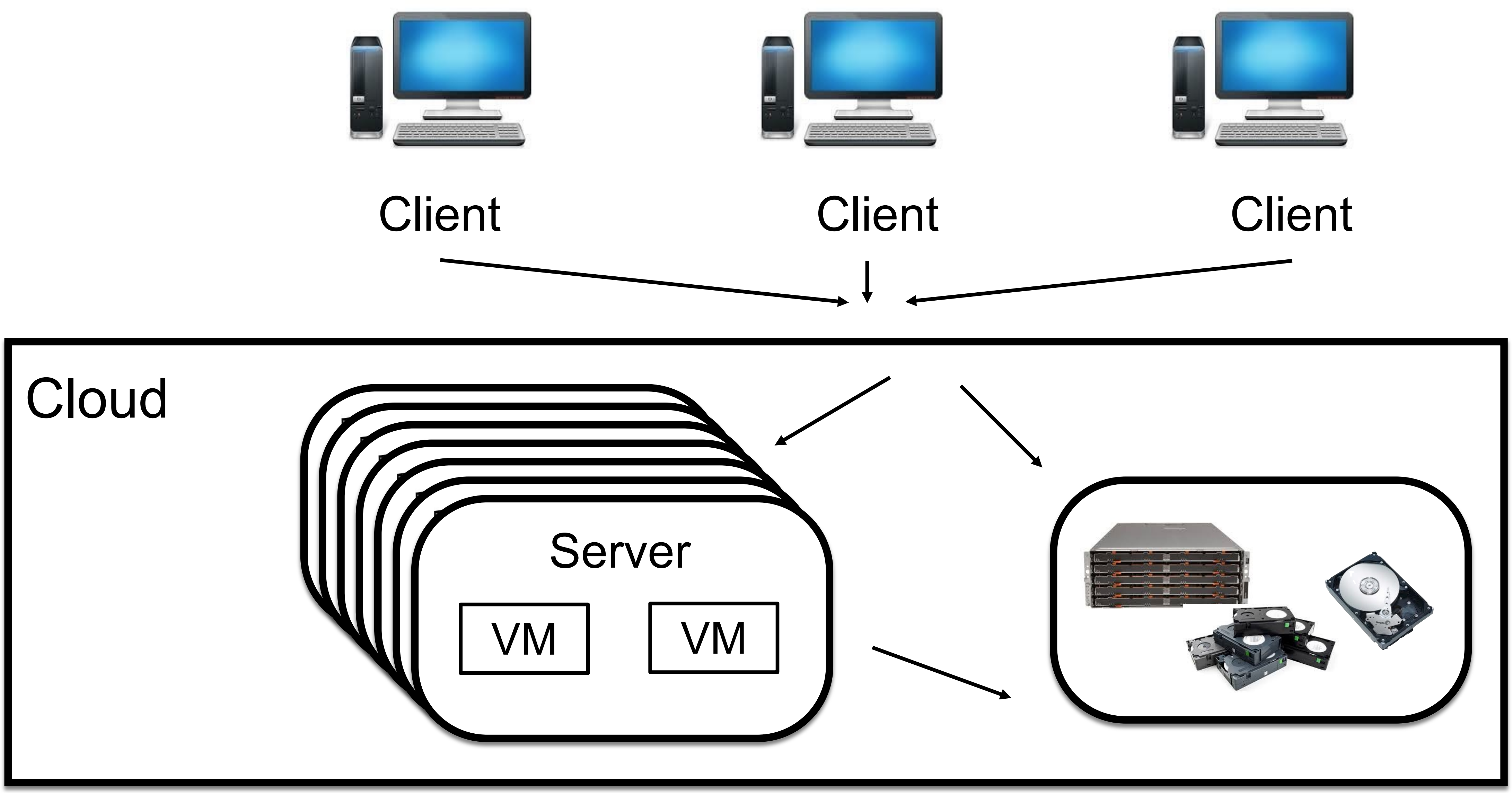
# Virtualization in Practice

## Virtual Desktop Infrastructures (VDIs)

Examples: VMWare Horizon 7, Amazon WorkSpaces

# Virtualization in Practice

## Simplified Cloud Deployment




Examples: Amazon EC2, Google Compute Engine, ...

# Advantages

## **Heterogeneity**

- Virtual resources can be provided on top of different physical (hardware) resources
- A virtual resource can support different applications / services while resorting to the same physical hardware (e.g., VMs with different Operating Systems)

# Advantages

## **Transparency**

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

# Advantages

## Isolation

- Virtual resources are isolated, from each other, in terms of
  - Security
  - Performance
    (actually, it depends on the virtualized resource!)
  - 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
  - E.g., ease of migration and backup of VMs

# Disadvantages

## **Performance**

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

# Disadvantages

## **Overprovisioning**

- Deploying more virtualized resources than the physically available ones 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), the security of all virtualized resources may be compromised

# Disadvantages

## **Dependability**

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

# Virtual Machines

- Changing an application / service to run on different Operating Systems (OSs) is a costly and hard task
- VMs allow running different OSs on top of the same physical server (resource consolidation)

# Virtual Machines

## Context

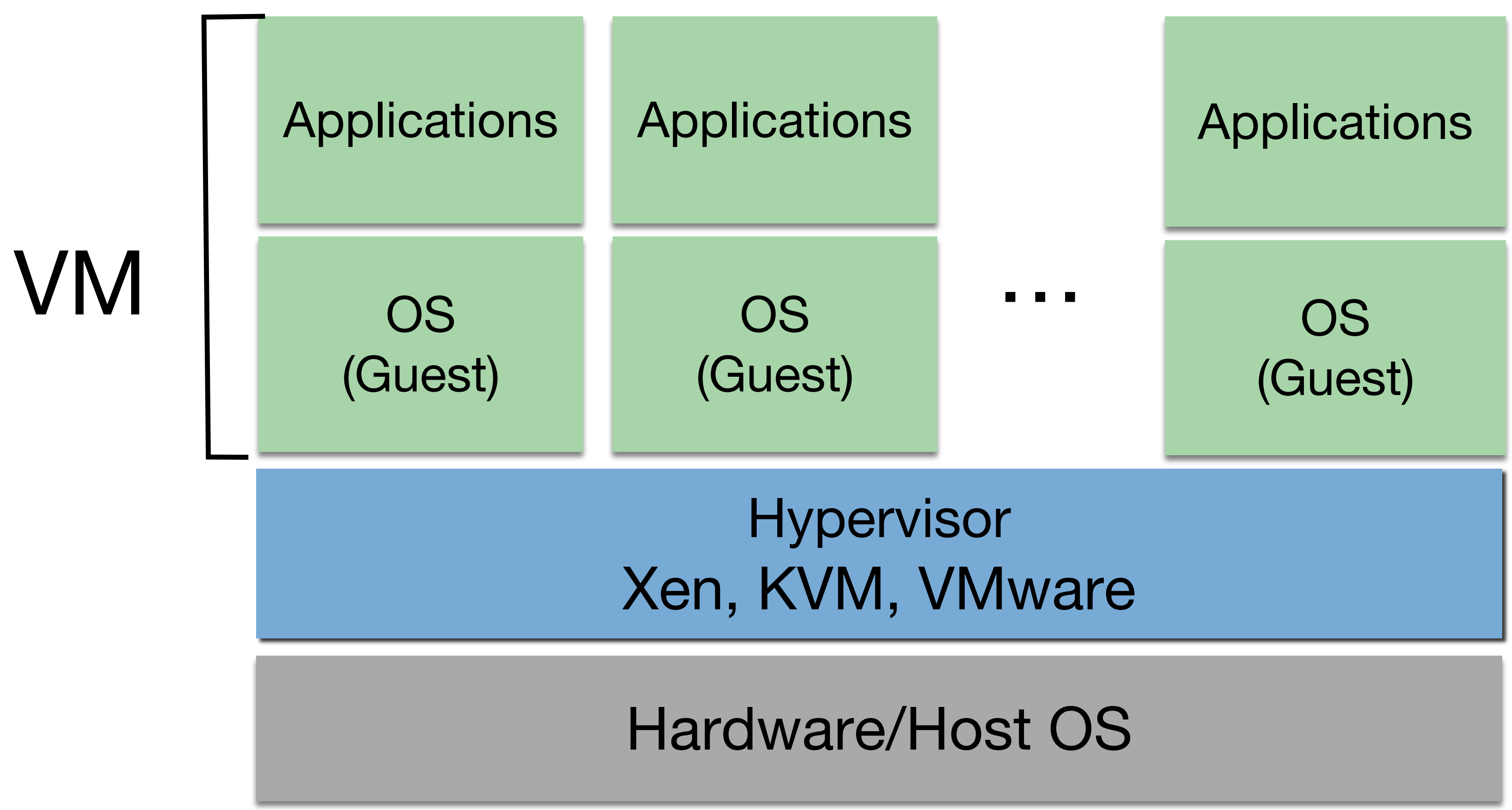
- IBM mainframe systems (from about 45 years ago) allowed applications to use isolated portions of a given system's resources
- Virtualization became mainstream in the early 2000's with the X86 server architecture due to
  - Under-utilized resources
  - Infrastructure costs

# Virtual Machines

## Architecture

- Guest (i.e., VM) OS instructions are intercepted, translated, and executed on physical hardware

- RAM
- Disk
- CPU
- Network
- ...



# Virtual Machines

## Hypervisor

Hypervisor
Xen, KVM, VMware

- Also known as Virtual Machine Monitor (VMM)
- Controls the low-level interaction between VMs and the underlying host OS/hardware
- Provides access to the host's CPU, RAM, disk and network hardware resources

# Virtual Machines

## Host’s CPU

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

# Virtual Machines

## Host’s RAM and Persistent Storage

- Each VM allocates a specific portion of the host’s RAM and persistent storage (e.g., SSD, HDD) capacity
- Storage shared across VMs must handle multiple writers/readers efficiently
- Storage resources can be allocated as required (i.e., thin-provisioning)

# Virtual Machines

## Host’s Network

- VMs share the host’s network bandwidth and can be configured with different network setups
    - **Host-only**: Shares the host’s 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. The VM is seen as another node in the physical network

# Virtualization Modes

## Full Virtualization

- Guest OS is fully abstracted from the underlying host's hardware (e.g., VirtualBox)
- **Advantage:** No modifications to the guest OS means higher range of supported OS flavors, and easier migration/portability of VMs
- **Disadvantage:** guest OS instructions must be translated leading to potentially lower I/O and CPU performance
- Hardware-assisted virtualization leverages **specific hardware** to reduce the performance penalty of instruction translation (e.g., Intel VT-x, AMD-V)

# Virtualization Modes

## Paravirtualization

- Requires hooks/modifications at the guest OS to bypass the translation of costly OS instructions (e.g., Xen)
- **Advantage:** Better CPU and I/O performance as the guest OS communicates directly with the hypervisor (i.e., without translation)
- **Disadvantage:** Guest OS must be modified, which is worst for maintainability and portability

# Virtualization Types

## Type 1 - Bare Metal Hypervisor

- The hypervisor does not require a general-purpose OS at the host server (e.g., VMware ESX)
- The hypervisor is deployed directly on hardware as a “small operating system”
- Better performance but it usually requires specific virtualization support at the hardware level

# Virtualization Types

## Type 2 - Hosted Hypervisor

- The hypervisor is deployed on top of a general-purpose OS (e.g., VirtualBox)
- Worst performance… The OS is not optimized for virtualization purposes
- KVM and Xen present a **hybrid solution** since their hypervisors require installing specific kernel modules on top of general-purpose OSs.

# Further reading


- S. Alapati. **Modern Linux Administration: How to Become a Cutting-edge Linux Administrator**. O'Reilly, 2016

- Paul Barham, Boris Dragovic, Keir Fraser, Steven Hand, Tim Harris, Alex Ho, Rolf Neugebauer, Ian Pratt, and Andrew Warfield. **Xen and the art of virtualization**. SIGOPS Oper. Syst. 2003.

# Questions?