Amirkabir University of Technology
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Cloud Computing

Introduction to virtualization

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Why Virtualization?

- As the scale of a system and the size of its users grows, it becomes very challenging to manage its recourses.
- Resource management issues:
  - Provision for peak demands ➡ **overprovisioning**
  - **Heterogeneity** of hardware and software
  - Machine failures
- Virtualization is a basic enabler of Cloud Computing, it simplifies the **management of physical resources.**

Virtualization Applications

- For example, the state of a virtual machine (VM) running under a virtual machine manager (VMM) **can be saved** and migrated to another server to balance the load.

- Virtualization allows users to operate in environments they are familiar with, rather than forcing them to specific ones.

Virtualization

- Virtualization techs have a long trail in the history of computer science.

- **Virtualization** is often **synonymous** with **hardware virtualization**

- Plays a fundamental role in efficiently delivering **Infrastructure-as-a-Service (IaaS)** solutions for cloud computing**.**

- Virtualization **abstracts the underlying resources**, **simplifies their use**, **isolates users from one another**, and **supports replication** which increases the elasticity of a system

Virtualization (cont.)

- In many flavors by providing Virtual Environments (VE) at the:
  - Operating system level
  - Programming language level
  - Application level

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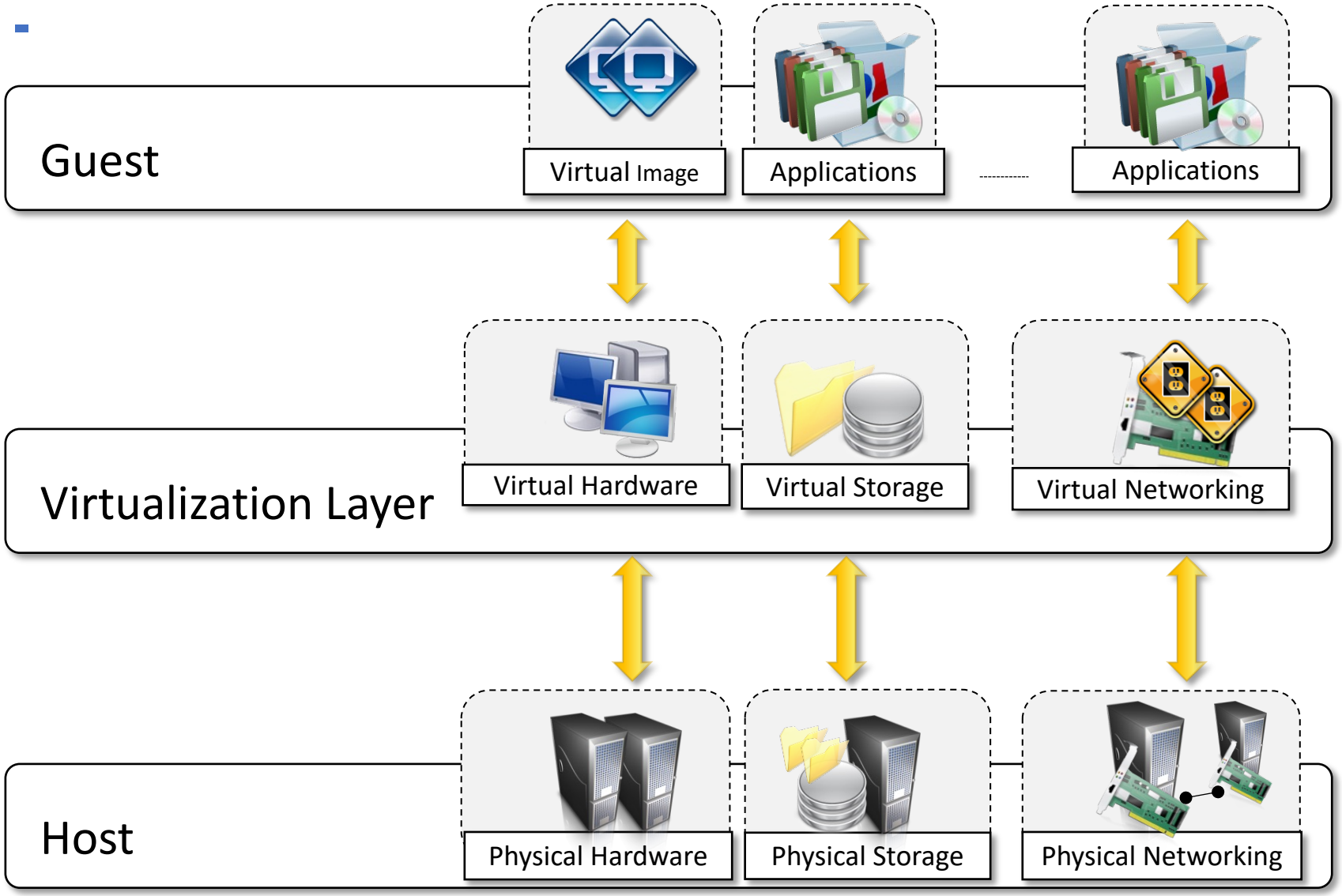
- Virtualization technologies provide a VE for not only **executing applications** but also for **storage**, **memory**, and **networking**.

Major components of a virtualized environment

- **Guest**
  - The system component that interacts with the virtualization layer rather than with the host, as would normally happen.
- **Host**
  - The original env. where the guest is supposed to be managed.
- **Virtualization layer**
  - Recreate the same or a different env. where the guest will operate.

Major components of a virtualized environment (cont.)



Taxonomy of Virtualization Techniques

- **Execution Virtualization**
  - **Hardware Level**
  - **Operating System Level**
  - Programming Language Level
- Network Virtualization
- Storage Virtualization
- Desktop Virtualization
- …

Execution Virtualization

- *Emulation of an execution environment (**env.**)*

- ***The env.** is **separate** from the one hosting the virtualization layer*.

- Providing support for the execution of programs, such as:
  - An operating system
  - A binary specification of a program compiled against an abstract machine model
  - An application.

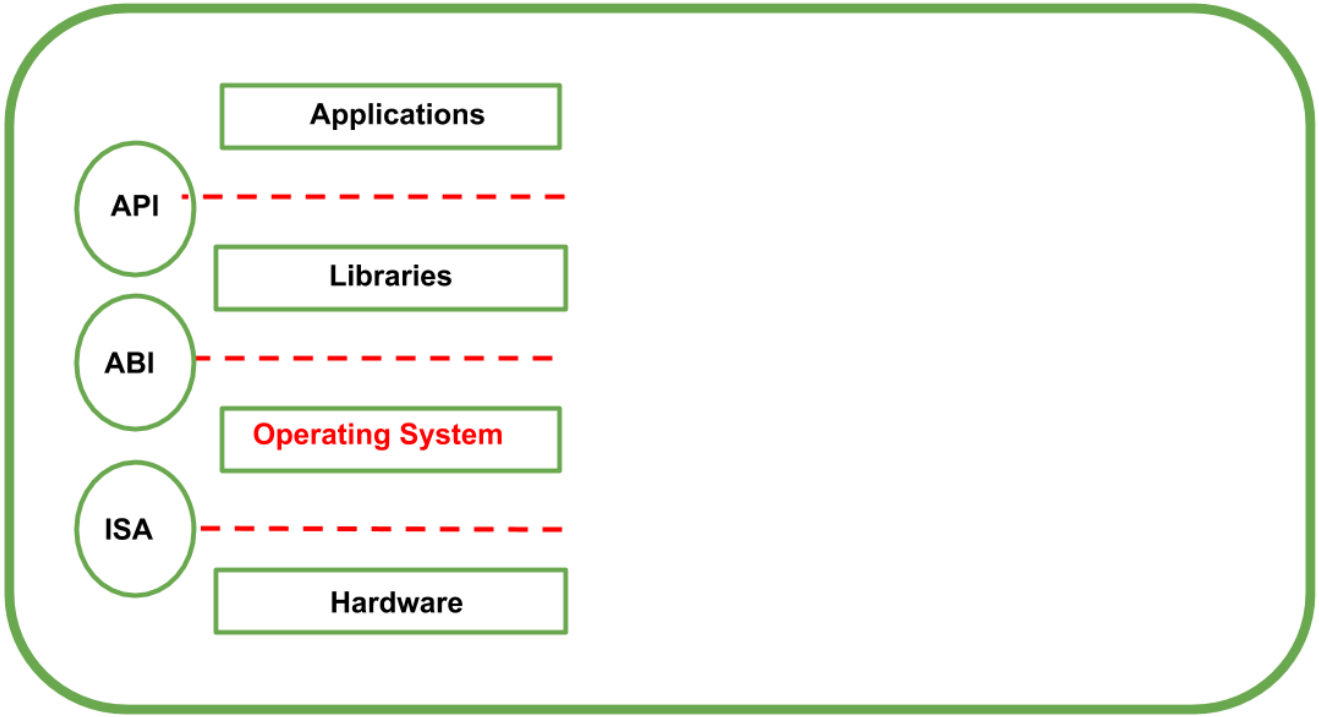
Machine Reference Model

- Consider ***different levels*** of the computing stack

- We need A reference model that defines ***the interfaces between the levels of abstractions, which hide implementation details.***

- Virtualization techniques ***replace*** one of the layers ***and intercept the calls*** that are directed toward it.

Machine Reference Model (cont.)



ISA: Instruction Set Architecture

ABI: Application Binary Interface

API: Application Programming Interface

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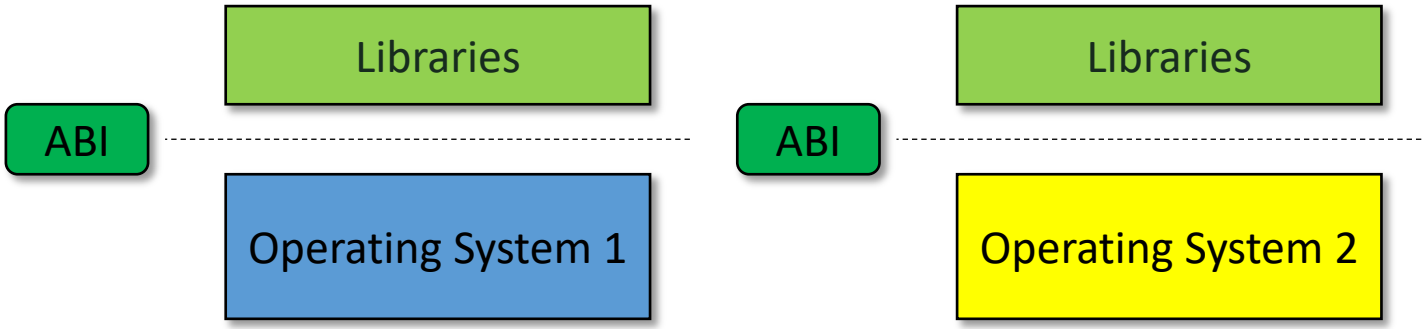
Execution Virtualization

Machine Reference Model (cont.)

- **ISA** is an interface between software and hardware.
- **ABI** allows the ensemble consisting of the application and the library modules to access the hardware; the ABI does not include privileged system instructions, instead it invokes system calls.
- **API** defines the set of instructions the hardware was designed to execute and gives the application access to the ISA; it includes high-level language library calls which often invoke system calls

Machine Reference Model (cont.)

- Hardware is expressed in terms of ISA
  - ISA for processor, registers, memory and the interrupt management.
- ABI separates the OS layer from the application and libraries
  - System Calls defined
  - Enables portability of various applications and libraries across OS which employ the same ABI

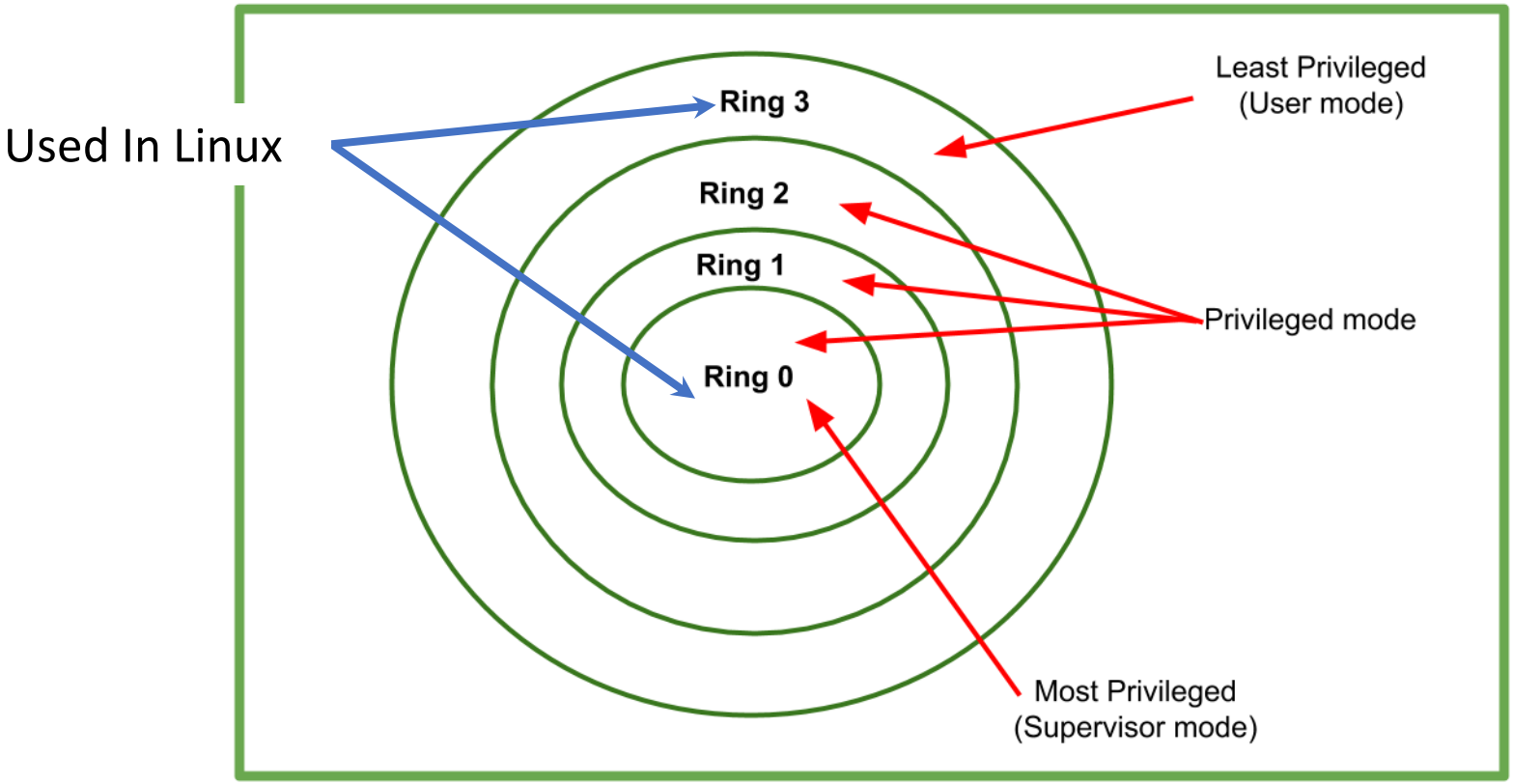


Instruction Set

- **Non-privileged** instructions
  - Can be used without interfering with other tasks.
  - They do not access shared resources.
  - All the floating, fixed-point, and arithmetic instructions.
- **Privileged** instructions
  - Executed under specific restrictions
  - Behavior-sensitive instructions that operate on the I/O.
  - Control-sensitive instructions that alter the state of the CPU registers.

Multi-class of privileged instructions

- A hierarchy of privileges in the form of ring-based security:
  - Ring 0, Ring 1, Ring 2, and Ring 3.



Least execution modes

- **Supervisor mode** (master mode or kernel mode)
  - To perform sensitive operations on hardware-level resources.
- **User mode**
  - There are ***restrictions to control*** the machine-level resources.

Least execution modes (cont.)

Invoking the privileged instructions is user mode

hardware interrupts occur and trap the potentially harmful execution of the instruction

What is hypervisor?

- **Conceptually**, the **hypervisor runs above the supervisor mode.**
  - From here the prefix **hyper**- is used.

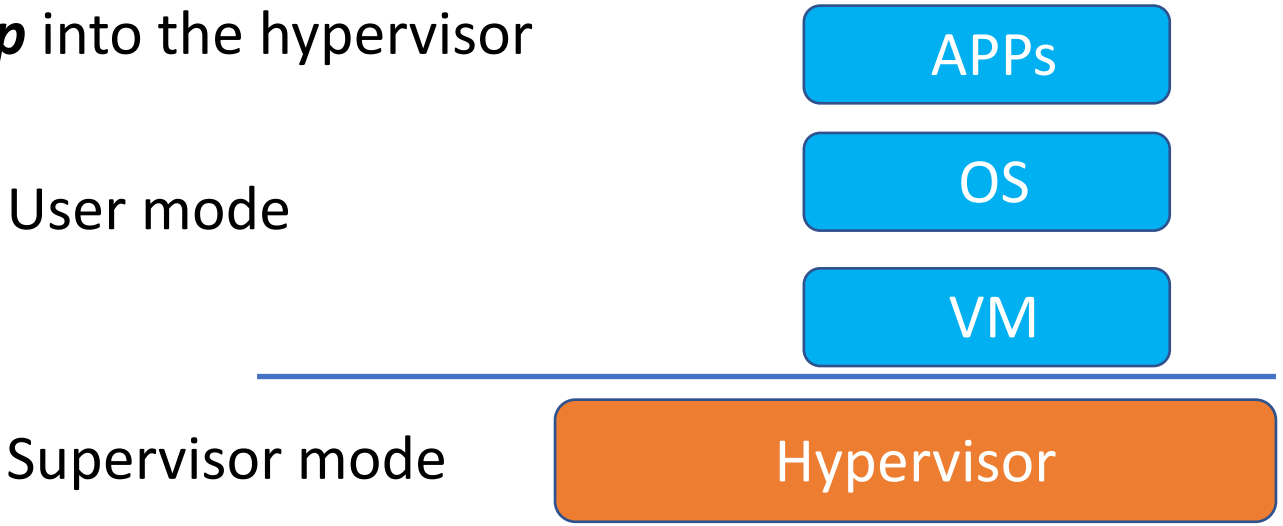
- **In reality, hypervisors are run in supervisor mode.**

- The division between privileged and non-privileged instructions has posed ***challenges*** in designing virtual machine managers.

Historical approach for **efficient** virtualization

- ***Virtual machine & guest Operating System*** are run in ***user mode***
  - ***Direct execution of non-privileged instructions on the hardware***
- ***Hypervisor*** is run in ***supervisor mode***.
- Running sensitive instructions in user mode →

  automatically trap into the hypervisor



Execution Virtualization

A big challenge

- Sensitive instructions ***should only be*** executed in **privileged mode**.

- **Original ISA** lets ***17 sensitive instructions*** to be called in ***user mode***.
- ***Not able to isolate*** multiple operating systems from each other
  - They **can *access the privileged state of the processor and change it.***
- Recent ISA **redesign such instructions as privileged ones**.
  - Intel VT and AMD Pacifica

What is Intel Virtualization Technology (VT)?

- Intel VT is the company's hardware assistance for processors running virtualization platforms.

- On November 13, 2005, Intel released two models of Pentium 4 as the first Intel processors to support VT-x.

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Int VT extensions

- Intel VT-x adds migration, priority and memory handling capabilities.

- Intel VT-d adds virtualization support to Intel chipsets that can assign specific I/O devices to specific virtual machines.

- Intel VT-c brings better virtualization support to I/O devices such as network switches

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