Assignment Project Exam Help

Operating Systems and Concurrency

https://powcoder.com

Lecture 23: Virtualisation and the Cloud I

G52OSC

Add WeChat powcoder

Geert De Maere and Isaac Triguero
{Geert.DeMaere,Isaac.Triguero}@Nottingham.ac.uk

University Of Nottingham
United Kingdom

2018

Goals for Today

Overview

Assignment Project Exam Help

- What is virtualisation?
https://powcoder.com
- Approaches to virtualisation
- What do we need to virtualise?

Add WeChat powcoder

Virtualisation
Context

Assignment Project Exam Help

- Consider a company that has an e-mail server, a web server, an FTP server, etc.

https://powcoder.com

- All these servers usually run on separate machines because of the load and/or primarily **reliability**.
- Sysadmins simply do not trust the OS to run forever with no failure. In separate machines, if one of these servers fail, at least the other ones are not affected.

Add WeChat powcoder

- Is this a good policy?

Figure: A cluster of computing nodes

Virtualisation

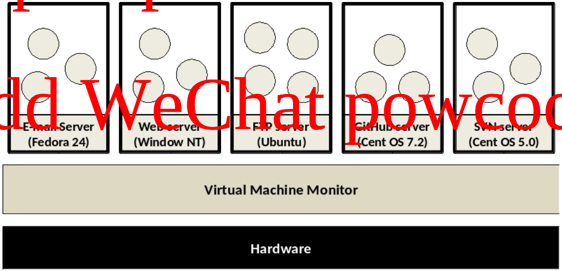
Basic idea

Fundamental idea: Virtual Machines

Assignment Project Exam Help

- **Abstract hardware** of a single computer into several **different execution environments**. An old idea, actually, from 60s and 70s.
- Similar to layered approach, but layer creates virtual system (**virtual machine**, or VM) on which operation systems or applications can run several components.

https://powcoder.com



Add WeChat powcoder

Figure: Virtualisation scheme

Virtualisation

Basic idea: motivation

Assignment Project Exam Help

- A failure in a particular VM does not result in bringing down any others.
- Of course, a failure at the server level would result in an even more catastrophic situation.
- Nevertheless, **most service outages** do not come from faulty hardware, but **due to unreliable software** (especially OSs).

https://powcoder.com

Add WeChat powcoder

Virtualisation
Basic idea

Assignment Project Exam Help

- We have already seen that an OS virtualises (Why?):
  - Virtual memory
  - Virtual file systems

https://powcoder.com

- However, a VM virtualises **an entire physical machine**:
  - Providing the illusion that software has full control over the hardware.
  - As implication you can run multiple instances of an OS (or different OS) on the same physical machine.

Add WeChat powcoder

Virtualisation
Components

Assignment Project Exam Help

- **Host** - underlying hardware system
- Virtual machine manager (VMM) or **hypervisor** - creates and runs virtual machines by providing an interface that is identical to the host (Except in the case of paravirtualization)
- **Guest** - process provided with virtual copy of the host (Usually an operating system)

https://powcoder.com

Add WeChat powcoder

Virtualisation

Main properties

Assignment Project Exam Help

- **Isolation**: each VM is independent, so failures do not affect the host.
- **Encapsulation**: state can be captured into a file.
  - Check pointing, migration. It is easier than migrating processes. We merely have to move the memory image that contains OS tables.
- **Interposition**: All guest actions go through the monitor (VMM), which can inspect, modify, deny operations.
- Fewer physical machines saves money on hardware and electricity.
- Run legacy applications.

https://powcoder.com

Add WeChat powcoder

Virtualisation

Requirements for Virtualisation

Assignment Project Exam Help

- **Safety**: the hypervisor should have full control of the virtualised resources (Resources sharing).

https://powcoder.com

- **Fidelity**: the behaviour of a program on a VM should be identical to that of the same program running on bare hardware. What if we run privileged instructions? (Virtualisation Technology (VT) - Hardware support).
- **Efficiency**: much of the code in the VM should run without intervention by the hypervisor (Overheads). For instance, with VMware:
  - CPU-intensive apps: 2-10% overhead
  - I/O intensive apps: 25-60% overhead

Add WeChat powcoder

Virtualisation

Approaches to Virtualisation

Assignment Project Exam Help

So this is just **like Java**, right?

- No, a Java VM is very different from the physical machine that runs it.
- A hardware-level VM reflects underlying processor architecture

https://powcoder.com

Like a simulator or **emulator** that can run old Nintendo games?

- Not exactly, they emulate the behaviour of different hardware architectures
- Simulators generally have very high overhead
- A hardware-level VM utilises the **underlying physical processor directly**

Add WeChat powcoder

Virtualisation

Approaches to Virtualisation

Assignment Project Exam Help

- **Full virtualisation**: It tries to trick the guest into believing that it has the entire system.
- **Paravirtualisation**: VM does not simulate hardware. It offers a set of *hypercalls* which allows the guest to send explicit requests to the hypervisor (as a system call offers kernel services to applications).
- **Process-level virtualisation**: The aim is to simply allow a process that was written for a different OS to run. For instance, Wine in Linux to run Windows applications, Cygwin to run Linux shell on Windows.

https://powcoder.com

Add WeChat powcoder

Virtual Machine Managers

Types of Hypervisors

There are two main types of VMMs:

Assignment Project Exam Help

- **Natives (Type 1)**: Technically, it is like an OS, since it is the only program running in the most privileged mode. Its job is to support multiple copies of the actual hardware.

https://powcoder.com

- **Hosted (Type 2)**: It relies on a OS to allocate and schedule resources, very much like a regular process.

Add WeChat powcoder

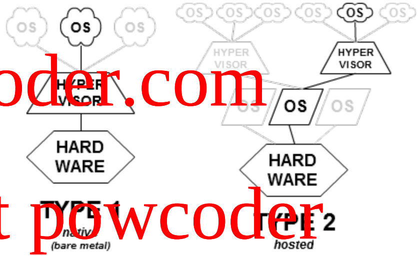


Figure: Types of Hypervisor (Wikipedia)

Both VMMs act as real hardware.

VMMs

Native Virtual Machines (Type 1 Hypervisors)

Assignment Project Exam Help

- Hypervisor installs directly on hardware.
- The hypervisor is the real kernel.
- (Unmodified) **OS runs in user mode**.
  - It seems to be in kernel model: **virtual kernel mode**.
  - Privileged instructions need to be processed by the Hypervisor.
  - Hardware VT technology will be necessary.
- Acknowledged as preferred architecture for high-end servers.
- Paravirtualisation-based VMs are typically based on type 1 hypervisors.

https://powcoder.com

Add WeChat powcoder

Examples: VMware ESX Server, Xen, Microsoft Viridian (2008)

VMMs

Hosted Virtual Machines (Type 2 Hypervisors)

Assignment Project Exam Help

- Installs and runs VMs as **an application on an existing OS**.
- Relies on host scheduling. Therefore, it may not be suitable for intensive VM workloads.
- I/O path is slow because it requires world switch.
- Process-level virtualisation will rely on type 2 hypervisors. It needs an OS.

https://powcoder.com

Examples: VMware Player/Workstation/Server, Microsoft Virtual PC/Server, Parallels Desktop

Add WeChat powcoder

What do we need to virtualise?

Assignment Project Exam Help

A hypervisor **must virtualise**:

- Privileged instructions (Exceptions and interruptions)
- CPU
- Memory
- I/O devices

https://powcoder.com

Are we then duplicating OS functionality on a VMM?

- Approaches will be **similar** to what we did with OSs.
- A bit **simpler** in functionality and implementing a different abstraction: Hardware interface vs. OS interface.

Add WeChat powcoder

What do we need to virtualise?

Virtualising Privileged Instructions

Assignment Project Exam Help

- It is not safe to let guest kernel run in kernel mode
- So a VM needs two modes: **virtual user mode** and **virtual kernel mode**. Both of which run in real user mode!

https://powcoder.com

- What happens when the guest OS executes an instruction that is allowed only when the CPU really is in kernel mode? (e.g. **map virtual pages to physical pages**)

Add WeChat powcoder

  - Type-1 hypervisors: in CPUs without Virtual Technology (VT), the instruction fails, and the OS crashes.
  - Type-2 hypervisors could work without VT - privileged instructions are emulated (binary translation)

What do we need to virtualise?

Virtualising Privileged Instructions

Assignment Project Exam Help

How does switch from virtual user mode to virtual kernel mode occur?

https://powcoder.com

- Attempting a privileged instruction in user mode causes an error -> trap
- VMM gains control, analyses error, executes operation as attempted by guest
- Returns control to guest in user mode
- Known as **trap-and-emulate**

Add WeChat powcoder

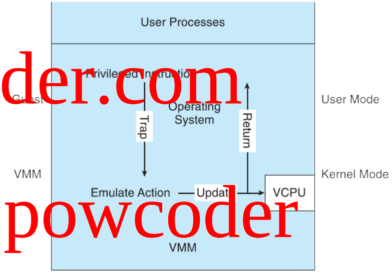


Figure: Trap-and-emulate (Silberschatz)

What do we need to virtualise?

Virtualising the CPU

Assignment Project Exam Help

How do VMMs schedule CPU utilisation when guests believe they have dedicated CPUs?

https://powcoder.com

- VMMs need to **multiplex** VMs on CPU
- But, how can we do that?
  - **Time-slice** the VMs
  - Each VM will timeslice its OS/Applications during its quantum.

Add WeChat powcoder

- For type 1: we will need a relatively simple scheduler (E.g. round robin, work-conserving (give unused quantum to other VMs))

What do we need to virtualise?

Memory

Assignment Project Exam Help

- The hypervisor partitions memory among VMs
    - It **assigns hardware pages to VMs**.
    - It needs to control mappings for isolation.

https://powcoder.com

- In each VM, the OS creates and manages page tables. But **these tables are not used by the MMU**.

Add WeChat powcoder

- For each VM, the hypervisor creates a shadow page table that maps virtual pages used by the VM onto the actual pages the hypervisor gave it.

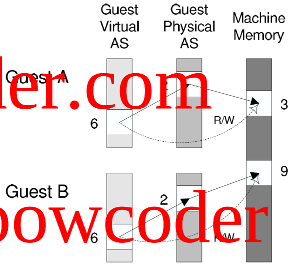


Figure: Shadow Page Tables

What do we need to virtualise?

Virtualising Event and I/O

Assignment Project Exam Help

- Guest OSs cannot interact directly with I/O devices - but the guest OS thinks it "owns" the device (e.g. disk)
- VMM receives interrupts and exceptions
- Type I hypervisors run the drivers.
- Type II hypervisors: Driver knows about VMM and cooperates to pass the buck to a real device driver on the underlying host OS.

https://powcoder.com

Add WeChat powcoder

Summary

Take-Home Message[1]

Assignment Project Exam Help

- Virtualisation benefits.
- Approaches to virtualisation.
- What do we need to virtualise?

https://powcoder.com

Add WeChat powcoder

[1] Tanenbaum Section 7.2, 7.3

Problem
From Tanenbaum

Assignment Project Exam Help

- Why do type 2 hypervisors exist? After all, there is nothing they can do that type 1 hypervisors cannot do and the type 1 hypervisors are generally more efficient as well.

https://powcoder.com

- Can a virtualised OS (e.g. Cent OS 7) use a paging system with virtual memory to manage its own memory? If yes, will this be using TLBs?
- Submit your answers at:
  `https://b.socrative.com/login/student/`
  Room name: G52OSC

Add WeChat powcoder