Introduction to
Cloud Computing and Virtualization

By

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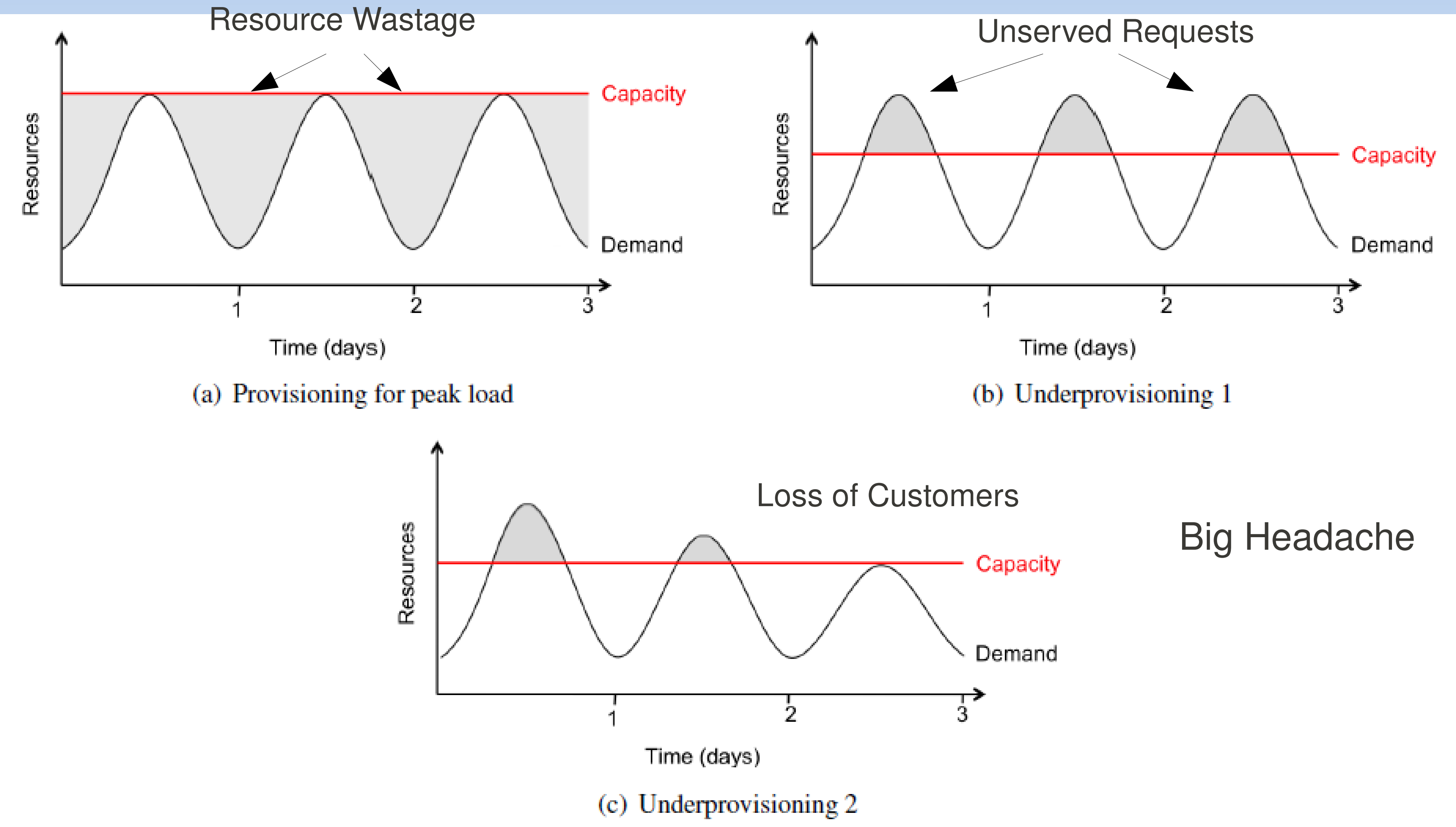
Talk Layout

- **Cloud Computing**
  - Need
  - Features
  - Feasibility
- **Virtualization of Machines**
  - What is it
  - Implementation techniques
  - Benefits
- **XEN's internals**
  - Domains
  - CPU Sharing
  - HyperCall
  - Memory Sharing
  - IO Sharing
- **Conclusion**

Resource Provisioning – Company's/Customer's View



Resource Wastage

(a) Provisioning for peak load

Unserved Requests

(b) Underprovisioning 1

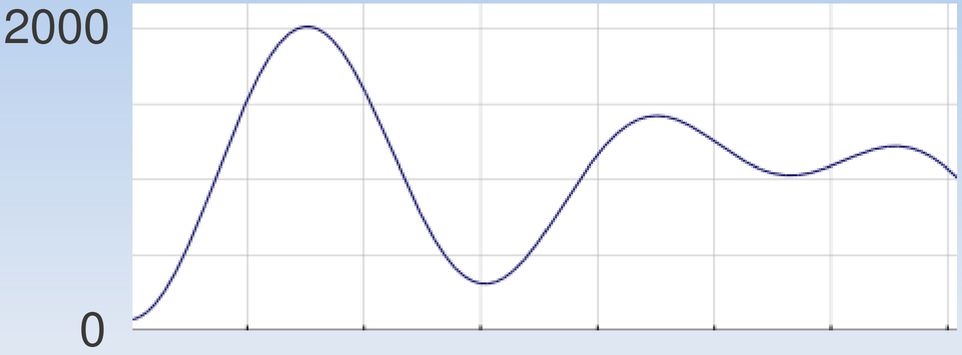
Loss of Customers

Big Headache

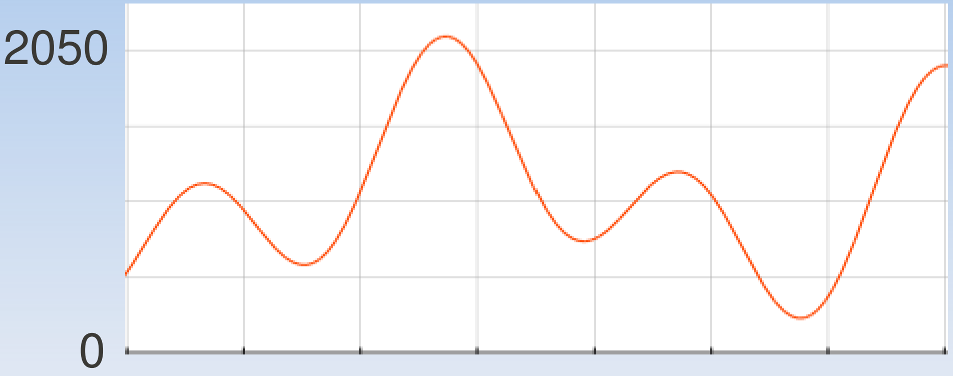
(c) Underprovisioning 2

Image source [1]

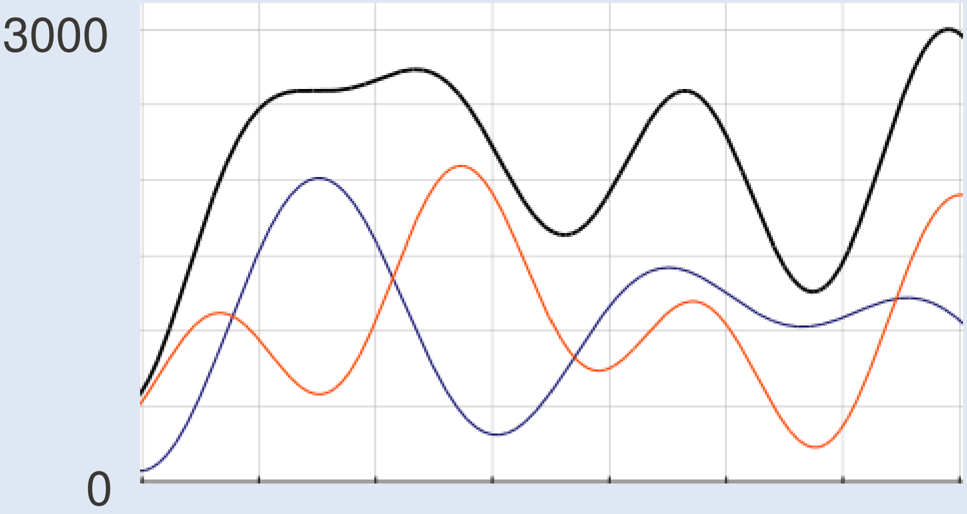
Resource Provisioning – DataCenter/Cloud Provider's View



Company - BLUE



Company - RED



Cloud Provider

Charge for 4050 machines, Work with 3000

Good Business

Computing as a service or utility.

Cloud Computing

scale your infrastructure **on demand** within minutes or even seconds, instead of days or weeks, thereby **avoiding under-utilization (idle servers) and over-utilization**

a broad array of web-based services aimed at allowing users to obtain a wide range of functional capabilities on a '**pay-as-you-go**' basis

Cloud computing really is accessing resources and services needed to perform functions with **dynamically changing needs**. ... The cloud is a **virtualization of resources that maintains and manages itself.**

- On-demand service : User not worried about maintenance and setup issues etc.
- Networked Shared Resources : Large capacity distributed/multiplexed over several users
- Flexible Provisioning : Dynamically scale resources
- Fine-grained metering : pay-as-you-use model

Source : Internet

What is required

By Cloud Provider

- Fast scalability – Quick addition and removal of servers
- Service to customers should not be denied.
- SLA should not be Violated
- Efficient Resource Utilization

Constraints with physical machines

- High Provisioning time.
- Lower Resource Utilization.
- Space, Power, Cooling.
- Low fault tolerance
- Less Isolation - misbehaving application can affect all others.
- High downtime.

What is Virtualization

Wikipedia says “Virtualization, in computing, is the creation of a virtual (rather than actual) version of something, such as a hardware platform, operating system, a storage device or network resources”

- Concept is not new.

  Multi Programming – Each Process thinks it has complete control on all of the resources.

  - Virtual Memory
  - CPU Sharing

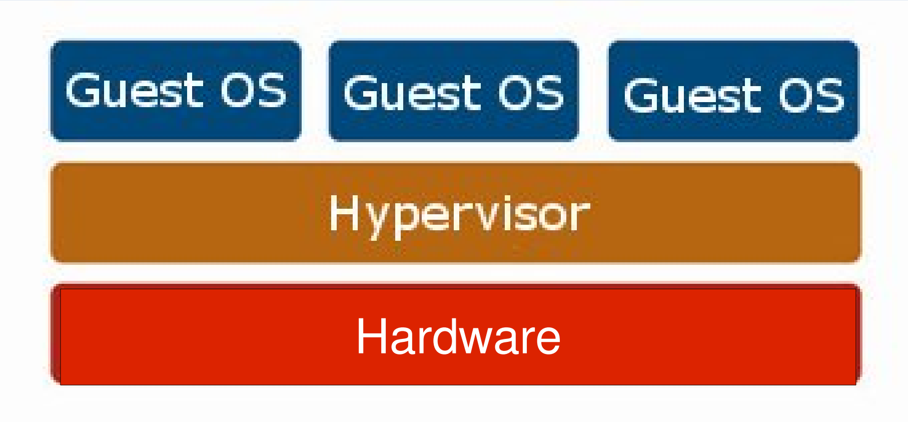
Similarities and Differences with Multiprogramming

- Multi Programming
  - CPU is shared among processes
  - Memory is shared using Page Tables.
  - Process knows it is being managed- uses system calls.

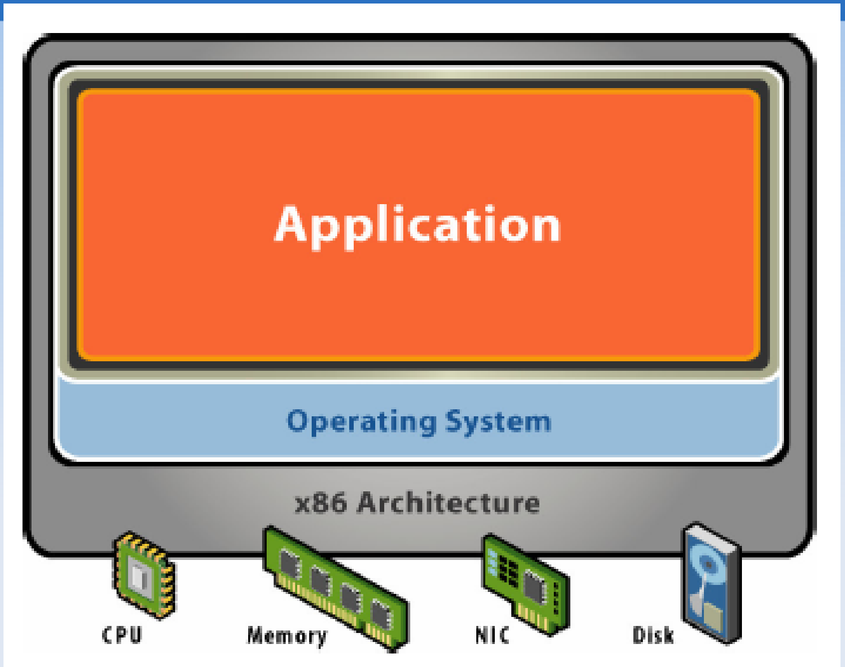
- Virtualization
  - CPU is shared among OSs.
  - Memory is shared using more level of indirections. Multiple Page tables.
  - OS may or may not know that it is being managed.

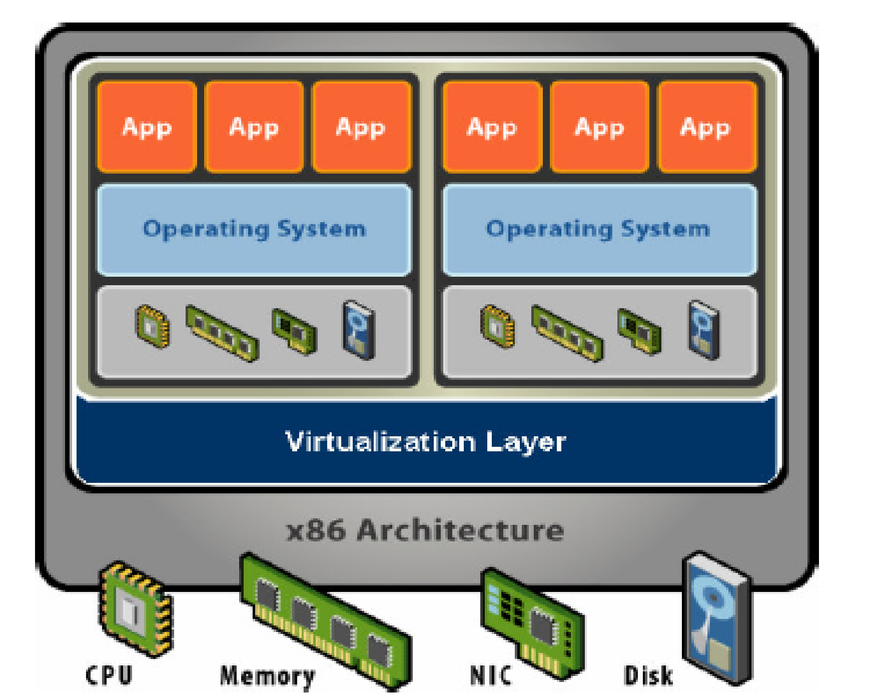
Virtualization Architecture

- OS assumes complete control of the underlying hardware.
- Virtualization architecture provides this illusion through a hypervisor/VMM.
- Hypervisor/VMM is a software layer which:
  - Allows multiple Guest OS (Virtual Machines) to run simultaneously on a single physical host
  - Provides hardware abstraction to the running Guest OSs and efficiently multiplexes underlying hardware resources.



Physical vs. Virtual Machine





- Single OS
- h/w + s/w tightly coupled
- Application crashes affect all
- Resource under-utilization

- Machine view to OS is independent of hardware
- Multiple OS (isolated apps)
- Safely multiplex resources across VMs

image source: vmware.com

Types of Virtual Machines

- **Process view of machine**
  - memory, user-level instr., system calls for OS functions
  - OS interface to hardware defines view of process
  - **Process VM**
  - e.g. Java, .Net, Emulators

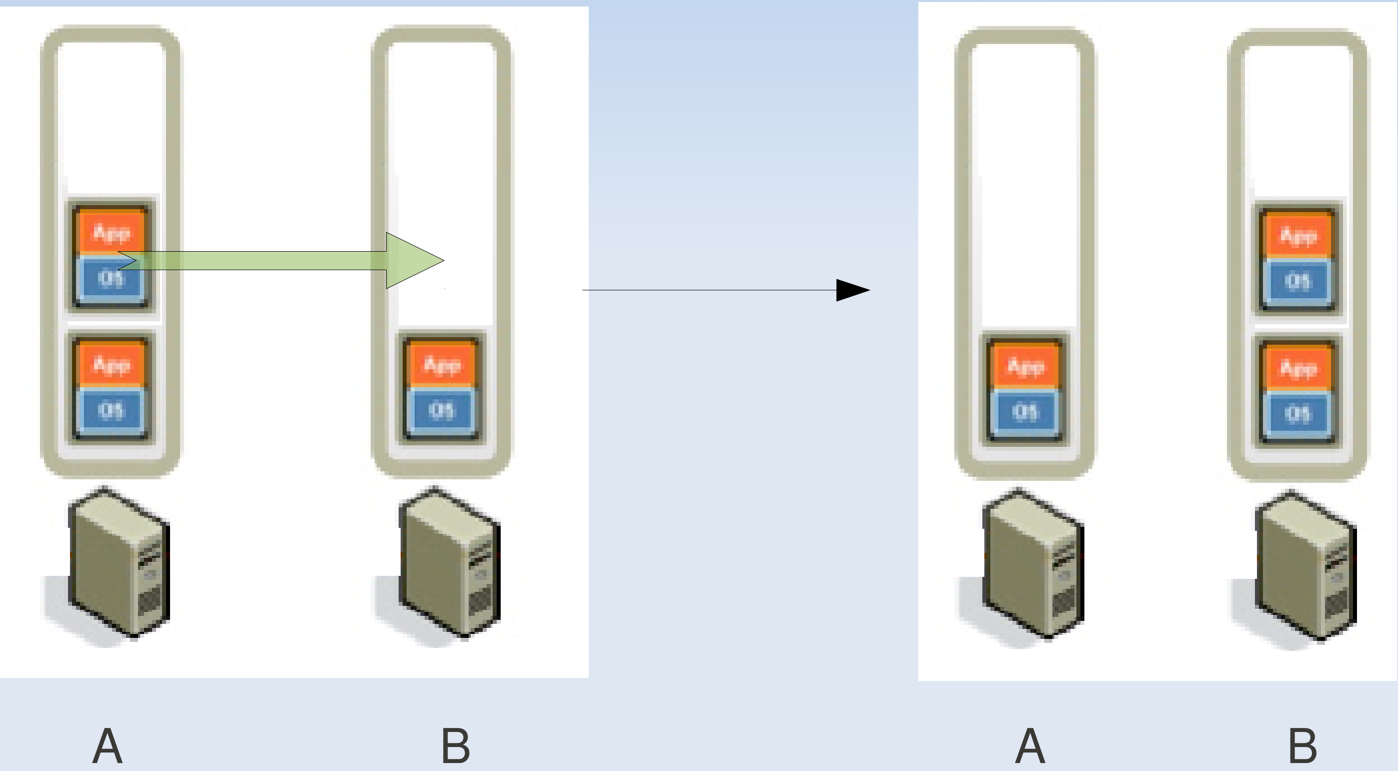
- **System view of machine**
  - environment to support multiple processes
  - sharing resources
  - hardware characteristics defines system view
  - **System VM**
  - e.g.,Xen, kvm, VMware, VirtualBox, UMLinux

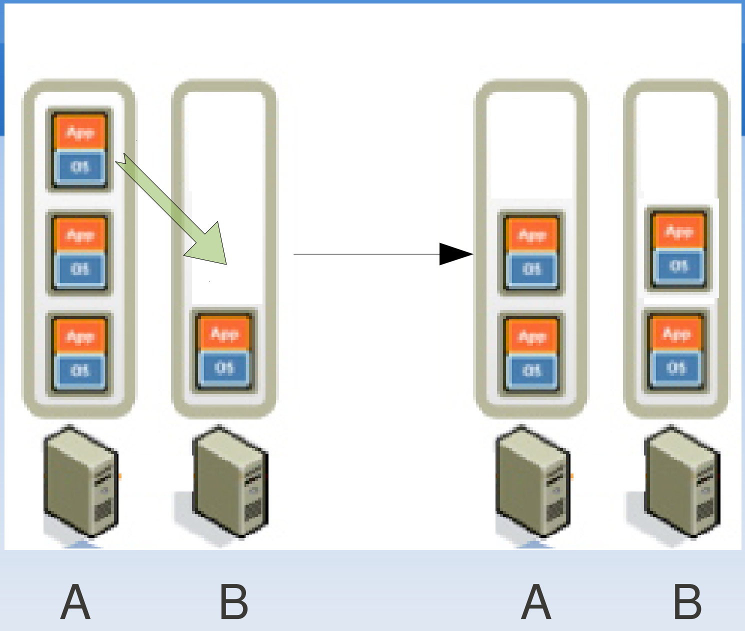
Source [3]

Benefits of using Virtual Machines

- Instant provisioning - fast scalability
- Live Migration is possible
- Load balancing and consolidation in a Data Center is possible.
- Low downtime for maintenance
- Virtual hardware supports legacy operating systems efficiently
- Security and fault isolation

VM Migration



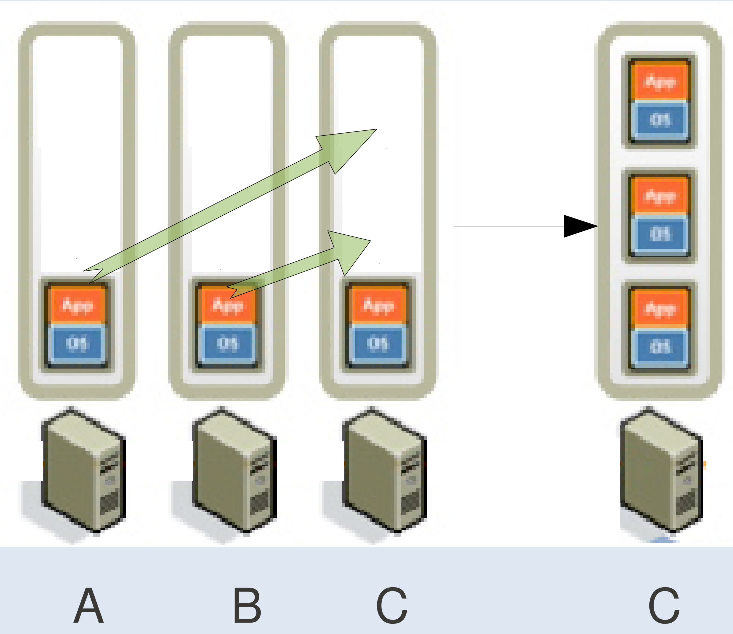


Load Balancing

- Better Response time

Consolidation

-Reduces number of Physical Machine requirement



Importance of Virtualization in Cloud Computing

- Cloud can exist without Virtualization, although it will be difficult and inefficient.
- Cloud makes notion of “Pay for what you use”, “infinite availability- use as much you want”.
- These notions are practical only if we have
  - lot of flexibility
  - efficiency in the back-end.
- This efficiency is readily available in Virtualized Environments and Machines.

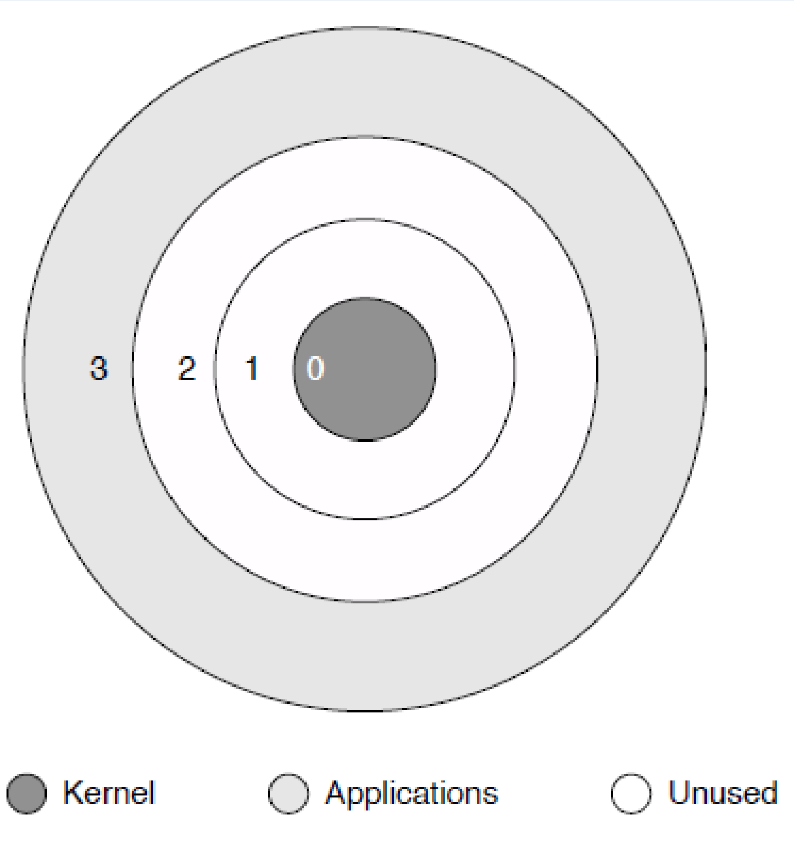
Requirement for Virtualizability

Popek and Goldberg mentioned a set of requirements that must be met in their 1974 paper.

- They divided instructions into three categories:
  - Privileged instructions: execute in a privileged mode, but will trap otherwise.
  - Control sensitive instructions: attempt to change the config of resources
  - Behavior sensitive instructions: are those that behave in a different way depending on the config of resources
- They said that all sensitive instructions must also be privileged instructions.
- Hypervisor must be able to intercept any instructions that changes the state of the machine in a way that impacts other processes.

Privilege Rings

- Memory page has a 2 bit code which is checked by CPU before executing the instruction.
- If privilege level is insufficient the CPU does not executes the instruction.



0 – Highest Privilege

VM Implementation Techniques

1. Binary Translation
2. Paravirtualization
3. Hardware Supported Virtualization

1. Binary Translation

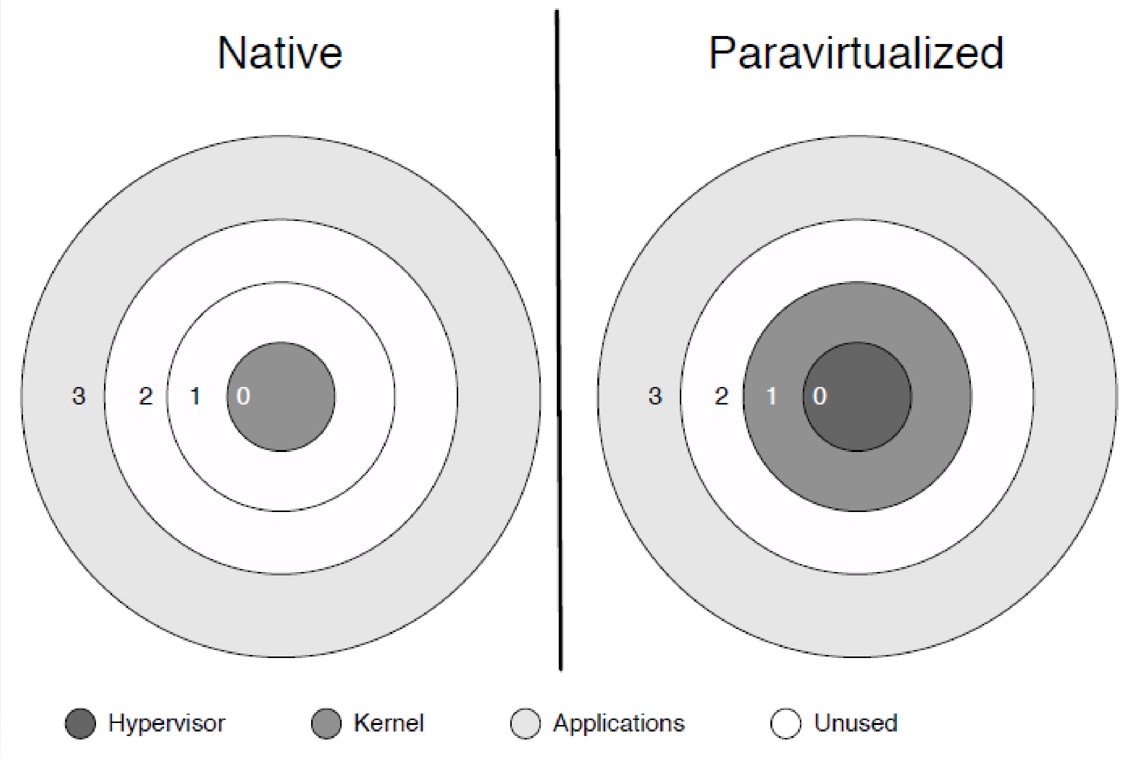
Used in VMWare

- Binary image of OS is manipulated at the runtime.
- Privileged instructions are rewritten to point to their emulated versions.
- Performance from this approach is not ideal, particularly when doing anything I/O intensive.
- Caching of the locations of unsafe instructions can speed Up

2. Paravirtualization

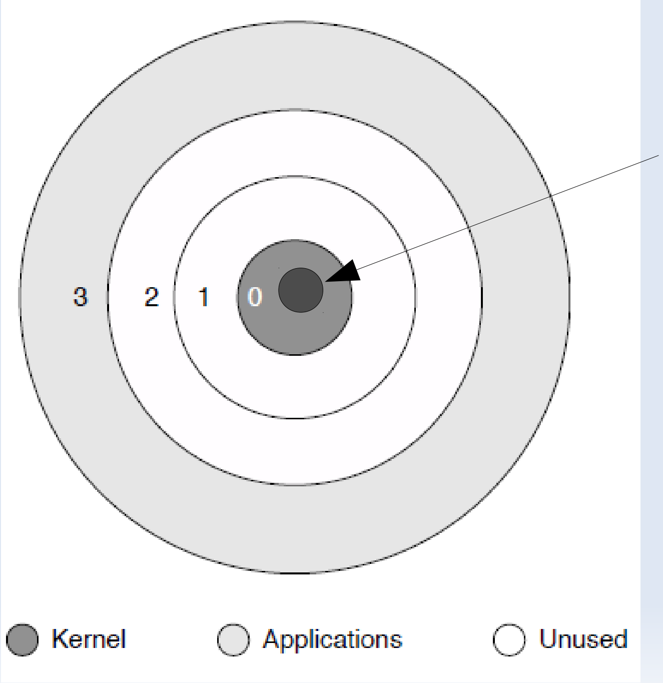
Used in XEN

- Make OS aware of underlying Virtualization env.
- OS's code is manipulated.
- Important system calls are changed to point to the implementation provided by the VMM.



3. HW Supported Virtualization

- Added new instructions which makes Virtualization considerably easier for x86.
  - Intel – IVT(Intel Virtualization Technology)
  - AMD – introduced AMD-V
- OS stays in its original privilege level 0.
- Attempts to access the hardware directly are caught and passed to VMM.
- In other words a new privilege ring is setup for the VMM.



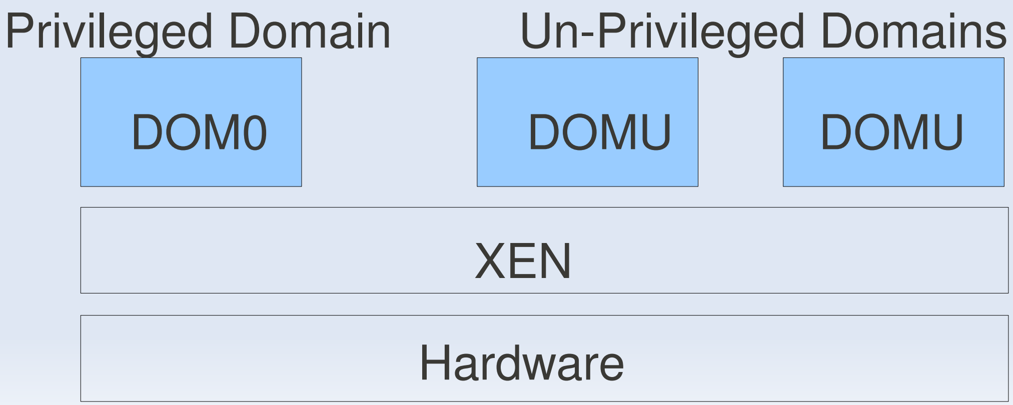
“-1” ring of VMM

XEN

- XEN Domains
- CPU Sharing
- Hyper Calls
- Memory Sharing
- IO Sharing
- XEN Split Driver Technique
- IO Ring

XEN Domains

- Xen runs guests in environments known as domains which encapsulate a complete running virtual environment
- There are two types pf Domains:
  - DomU -
    - the “U” stands for unprivileged.
    - Guest OSs run in this domain.
  - Dom0
    - has elevated privileges
    - Provides device drivers
    - Provides tools/mechanisms to configure Virtualization environment



Privileged Domain

Un-Privileged Domains

DOM0

DOMU

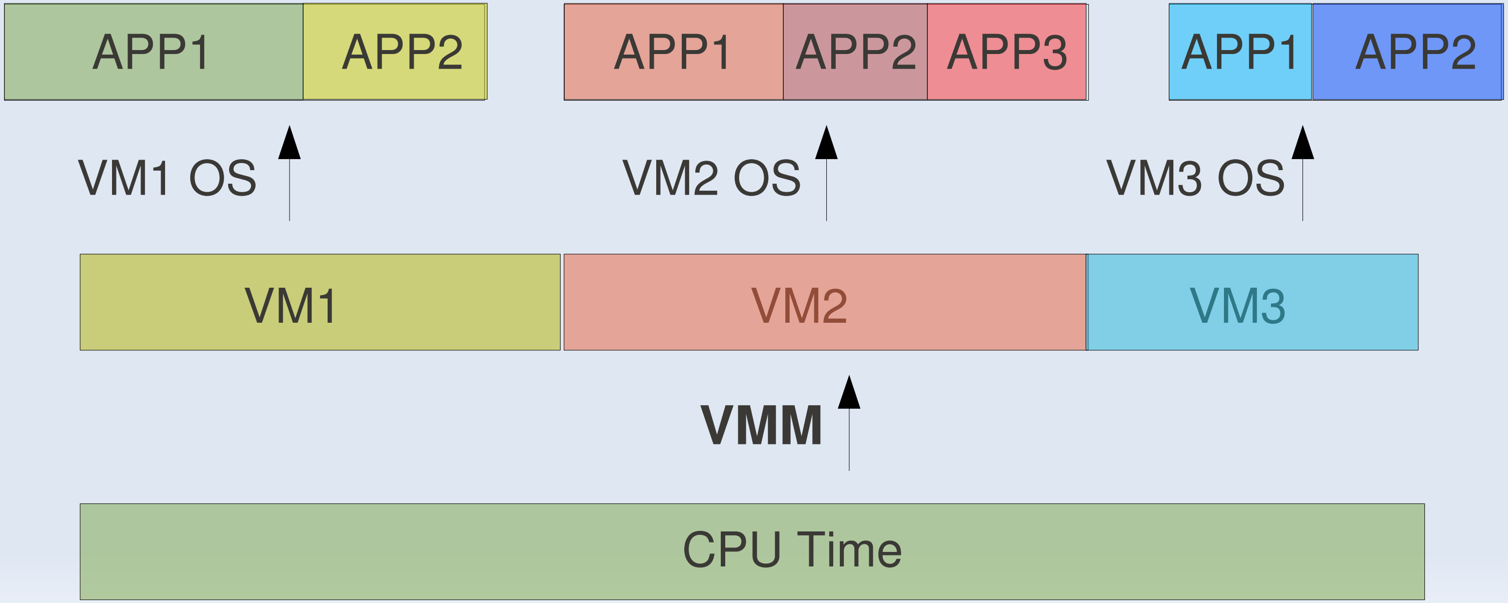
DOMU

XEN

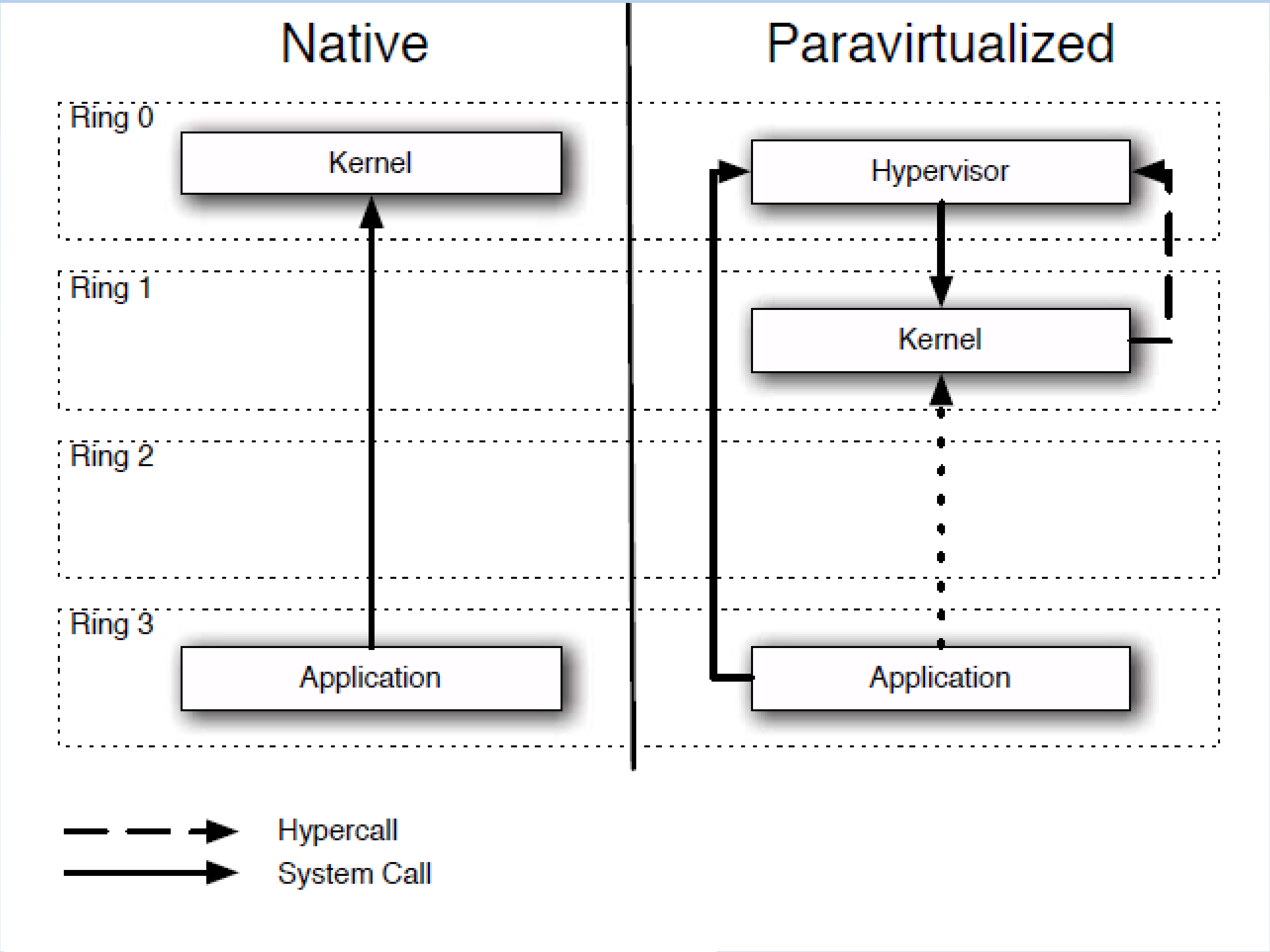
Hardware

CPU Sharing

- VMM or Hypervisor provides a virtual view of CPU to VMs.
- In multi processing, CPU is alloted to the different processes in form of time slices by the OS.
- Similarly VMM or Hypervisor allots CPU to different VMs.

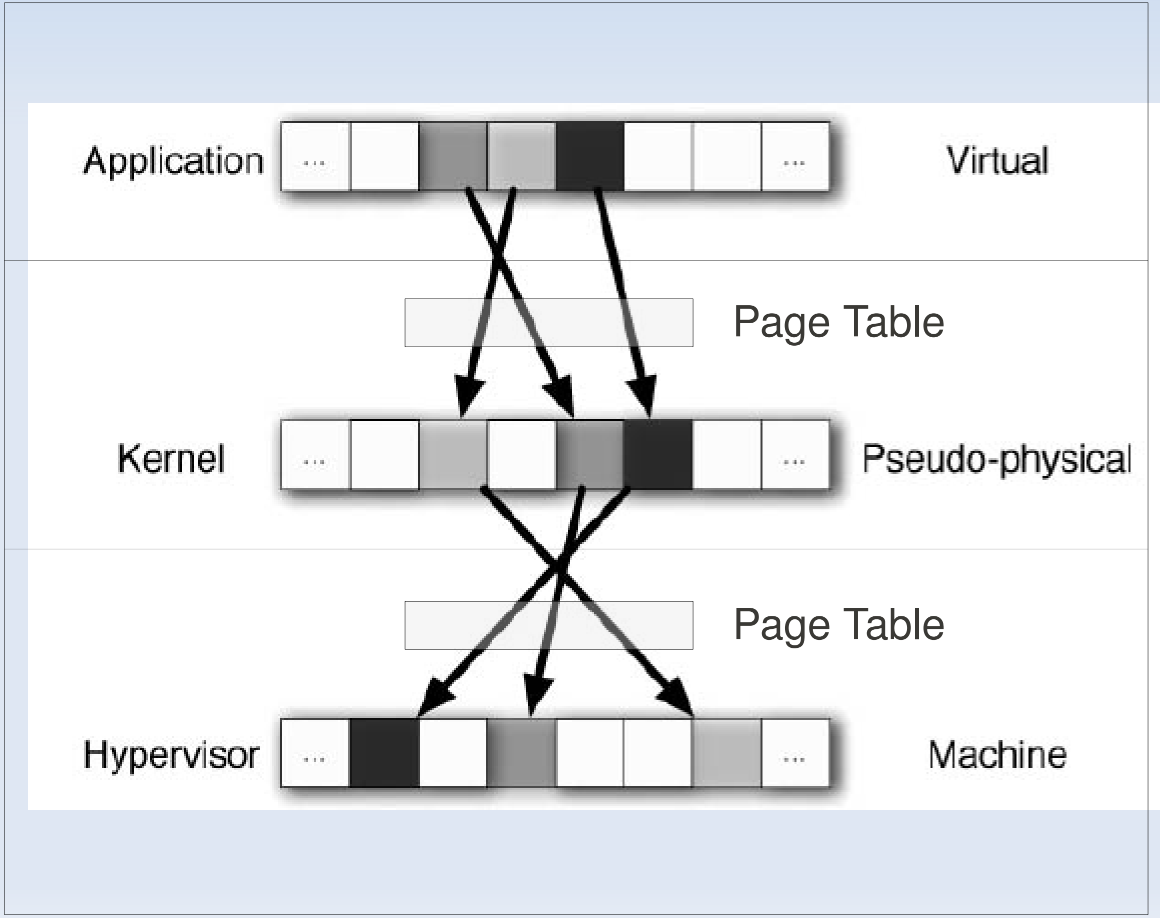


XEN Hypercall



Memory Sharing

- In Multiprogramming there is a single level of indirection maintained by Kernel.
- In case of Virtual Machines there is one more level of indirection maintained by VMM



Applications use Virtual Addresses

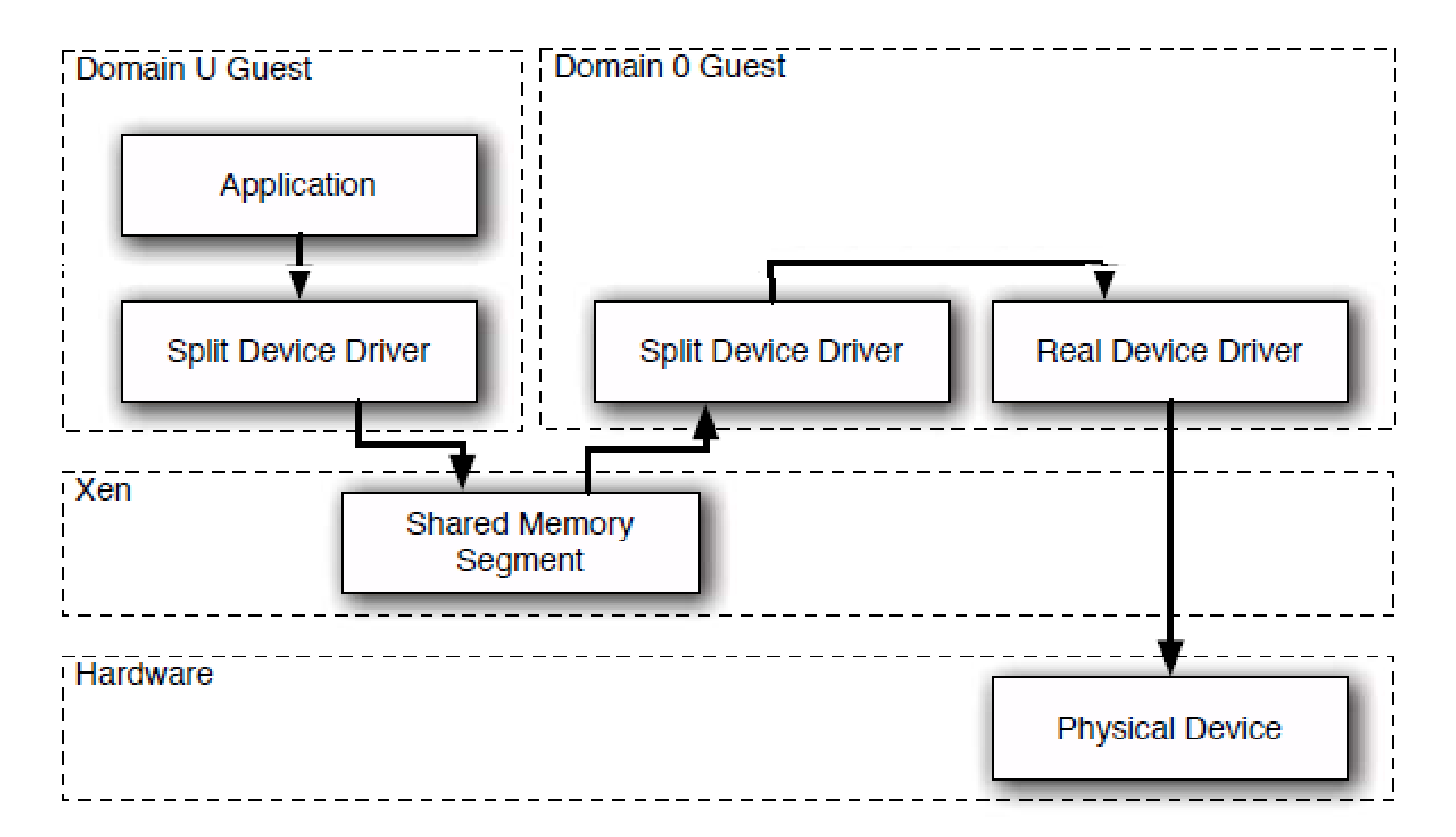
Kernel translates Virtual Addresses to Pseudo-Physical Addresses

Hypervisor translates Pseudo-Physical Addresses to Machine addresses

IO Sharing

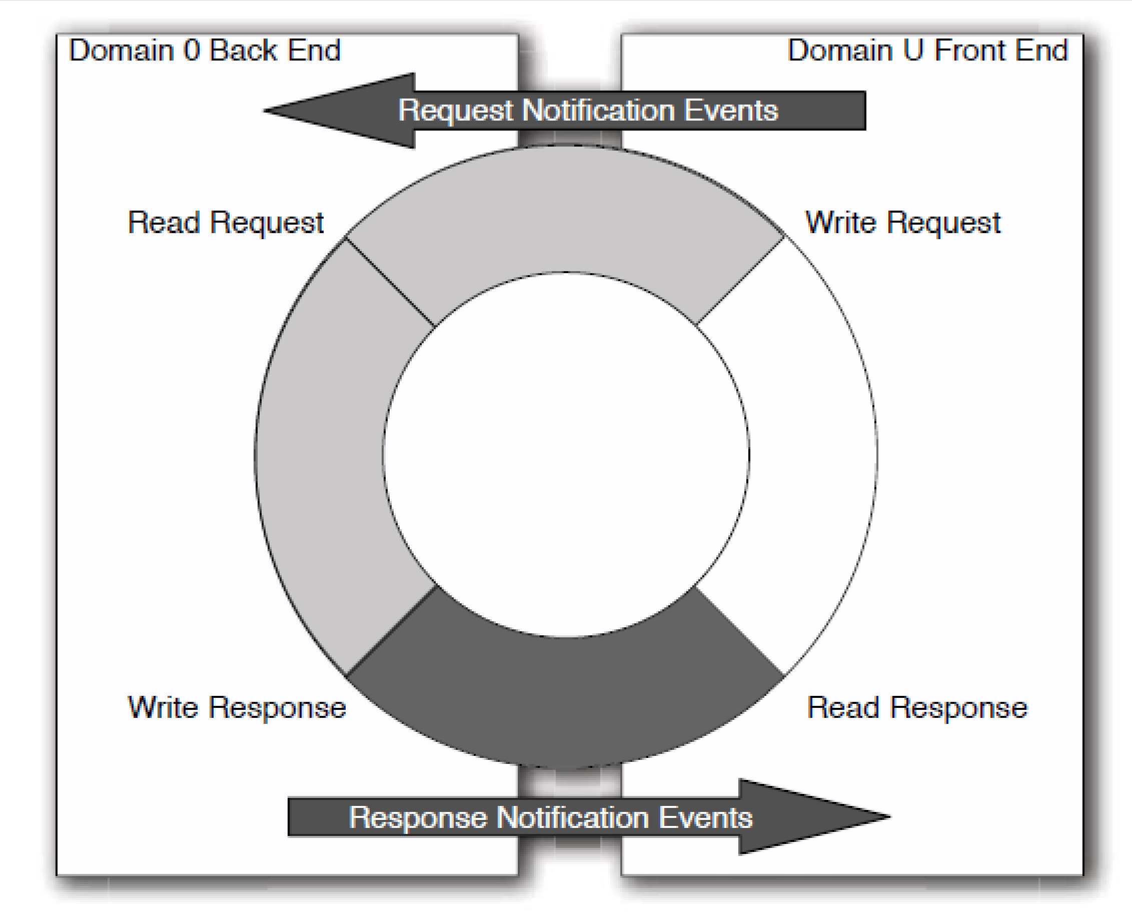
- DMA Problem
  - Device needs to use Physical Memory location.
  - In a virtualized environment, the kernel is running in a hypervisor-provided virtual address space
  - Allowing the guest kernel to convey an arbitrary location to device for writing is a serious security hole
  - Detecting a DMA instruction is nontrivial. Each device defines its own protocol for talking to drivers.
- XEN Follows Split Driver Model: Dom 0 does the IO on behalf of all the other guests.
  - As DOM0 is privileged the IO has no problem

XEN IO Split Device Driver



IO Ring

Shared memory is used with event based synchronization



Conclusions

- Notion of Cloud is possible without Virtualization, but it will be inefficient and inflexible.
- Virtualization is an attempt to manage OS.
- There are many levels and many ways to implement Virtualization.

References

[1] Amburst et al. “Above the Clouds: A Berkeley view of cloud computing”

[2]David Chisnall. “The Definitive Guide to XEN Hypervisor”.

[3] Prof. Purushottam Kulkarni, CSE, IITB, His Presentation.

[4] Vmware “ www.vmware.com”

[5] Wikipedia and Internet.