Virtualization and the Cloud

Chapter 7

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Requirements for Virtualization

Hypervisors should score well in three dimensions:

1.Safety: hypervisor should have full control of virtualized resources.

2.Fidelity: behavior of a program on a virtual machine should be identical to same program running on bare hardware.

3.Efficiency: much of code in virtual machine should run without intervention by hypervisor.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Type 1 and Type 2 Hypervisors (1)

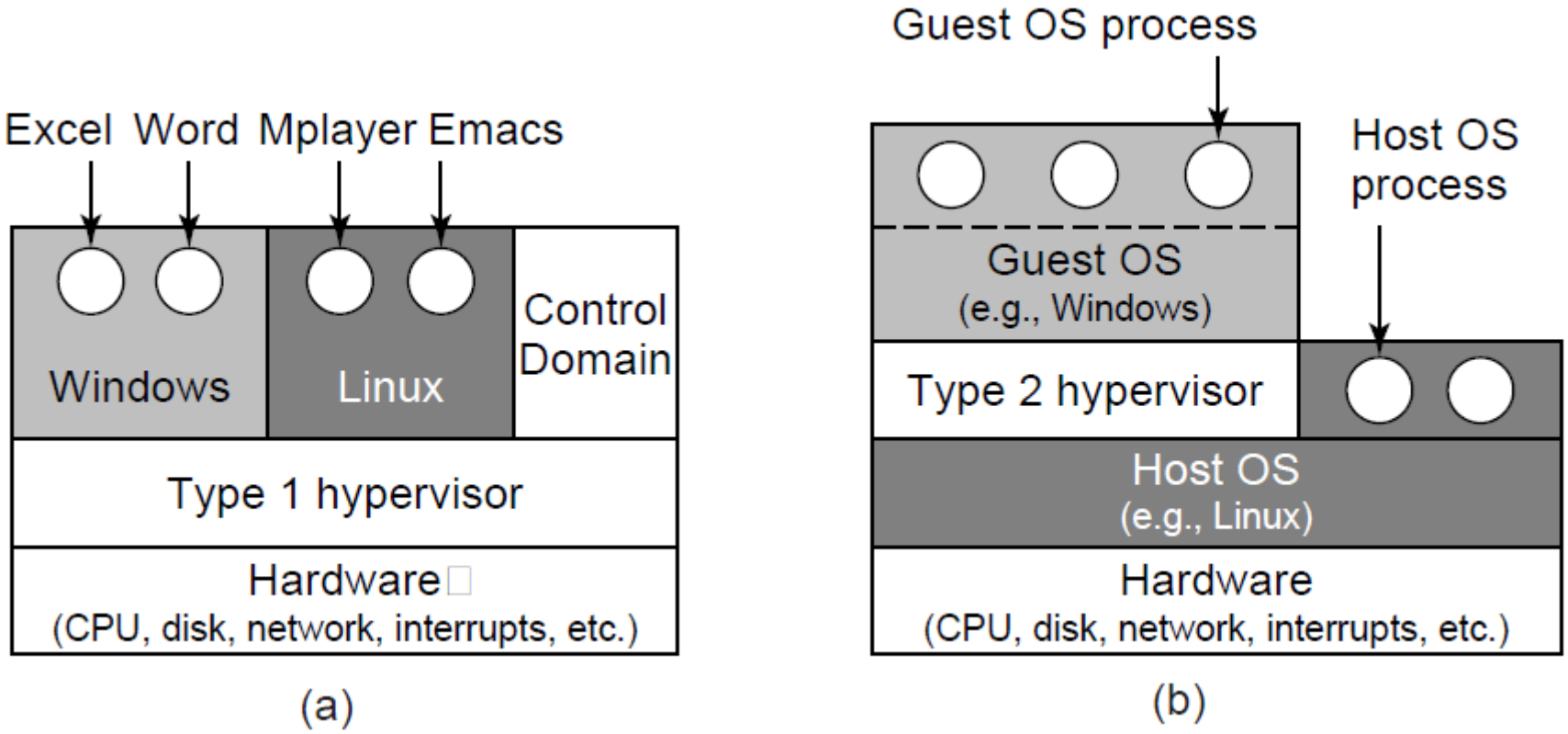


Figure 7-1. Location of type 1 and type 2 hypervisors.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Type 1 and Type 2 Hypervisors (2)

Virtualizaton method	Type 1 hypervisor	Type 2 hypervisor
Virtualization without HW support	ESX Server 1.0	VMware Workstation 1
Paravirtualization	Xen 1.0	
Virtualization with HW support	vSphere, Xen, Hyper-V	VMware Fusion, KVM, Parallels
Process virtualization		Wine

Figure 7-2. Examples of the various combinations of virtualization type and hypervisor. Type 1 hypervisors always run on the bare metal whereas type 2 hypervisors use the services of an existing host operating system.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Techniques for Efficient Virtualization

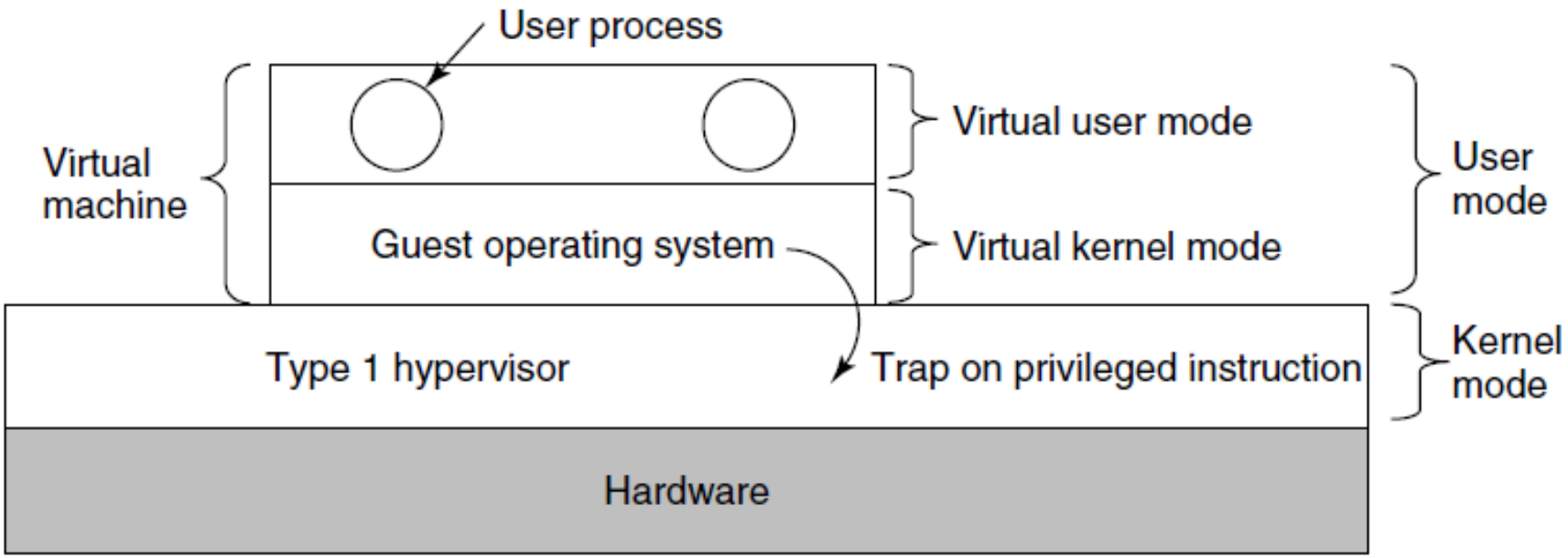


Figure 7-3. When the operating system in a virtual machine executes a kernel only instruction, it traps to the hypervisor if virtualization technology is present.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Virtualizing the Unvirtualizable

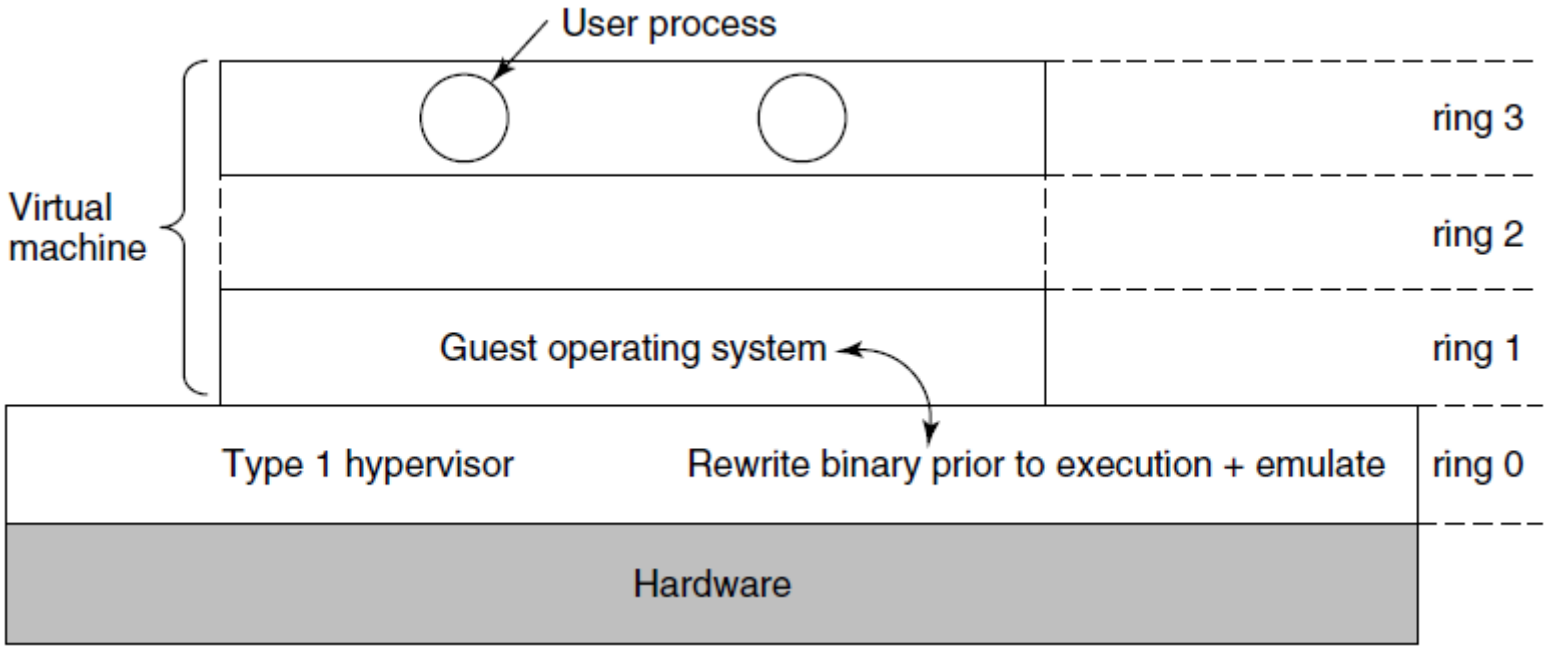


Figure 7-4. The binary translates rewrites the guest operating system running in ring 1, while the hypervisor runs in ring 0

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Are Hypervisors Microkernels Done Right? (1)

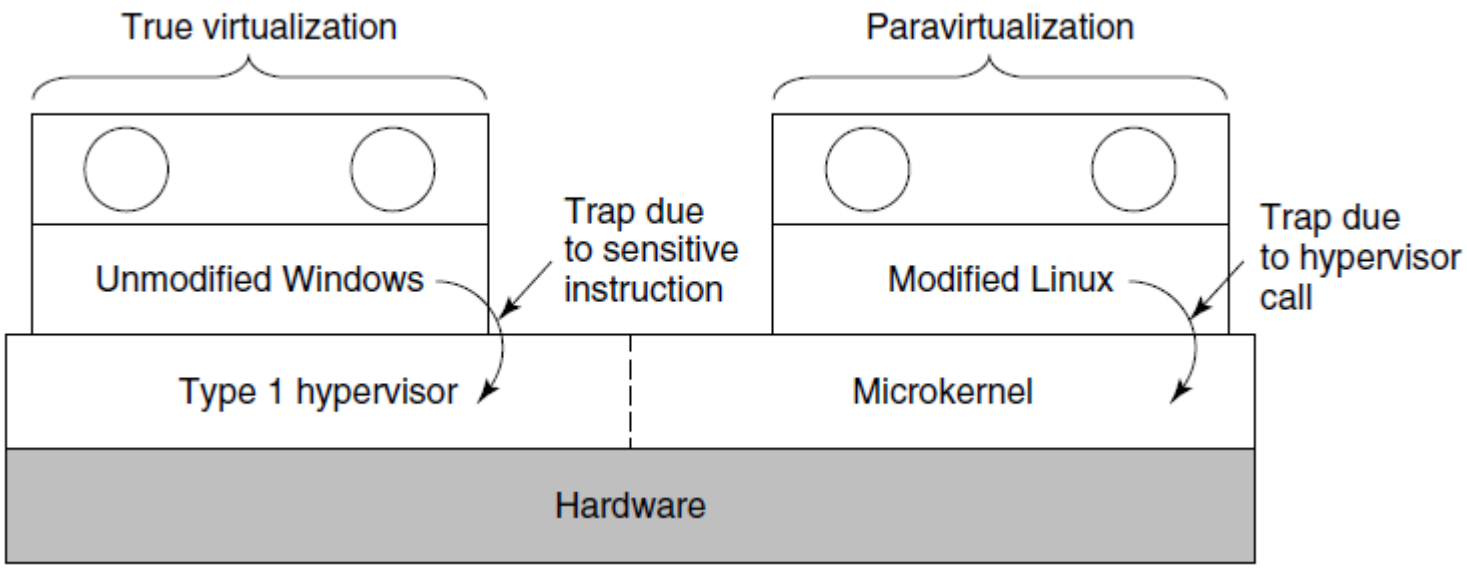


Figure 7-5. True virtualization and paravirtualization

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Are Hypervisors Microkernels Done Right?

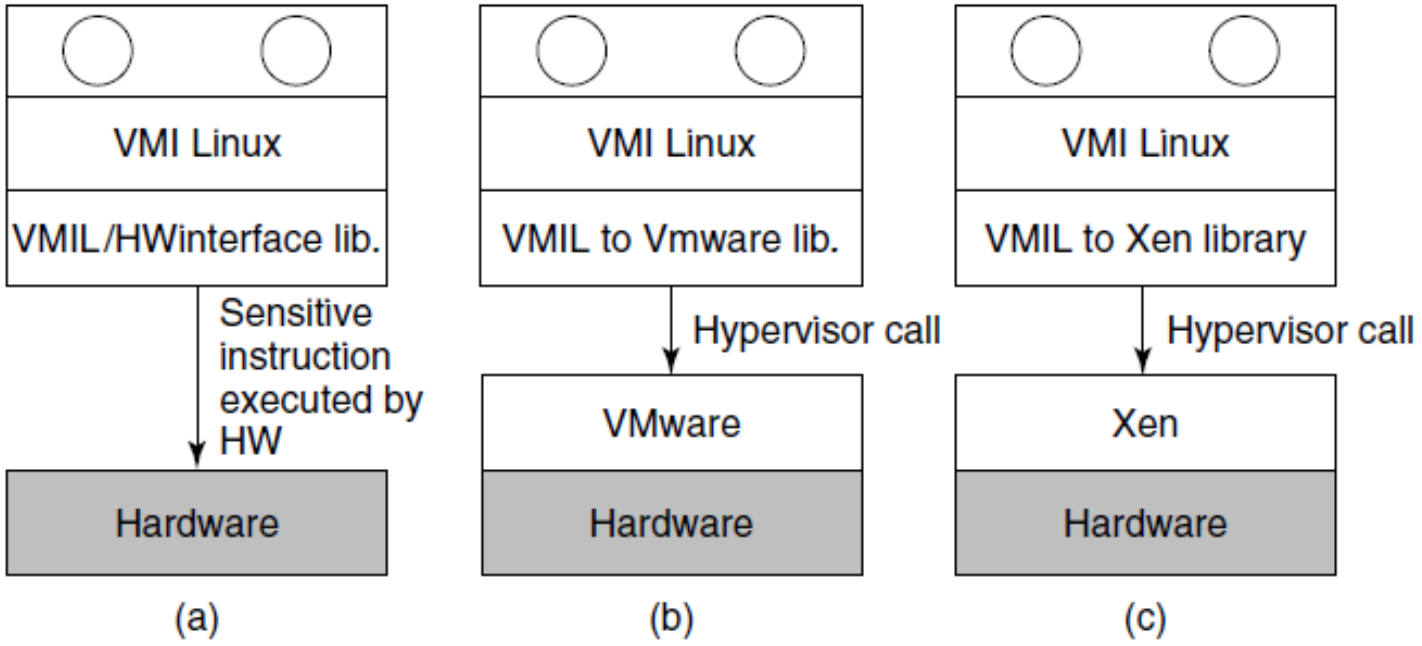


Figure 7-6. VMI Linux running on (a) the bare hardware (b) VMware (c) Xen.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Hardware Support For Nested Page Tables

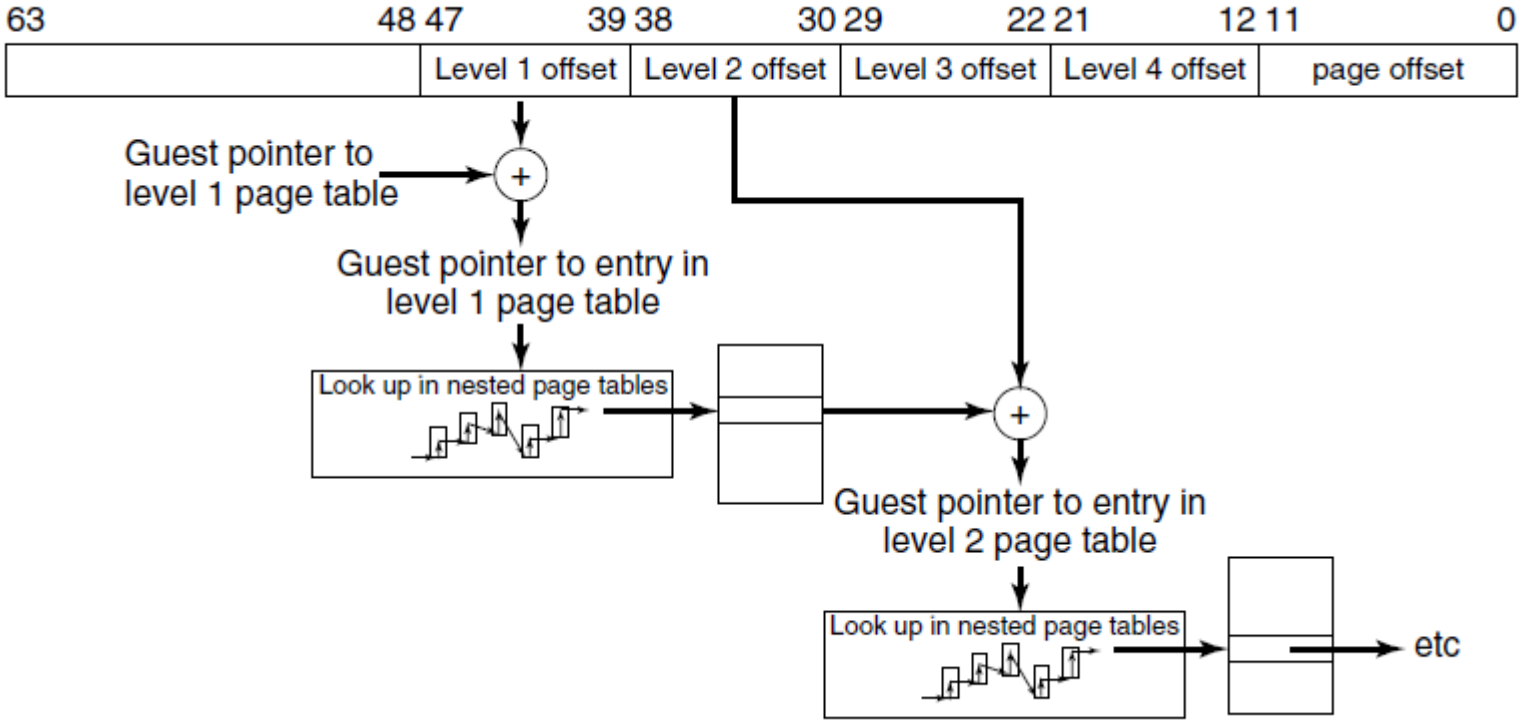


Figure 7-7. Extended/nested page tables are walked every time a guest physical address is accessed—including the accesses for each level of the guest's page tables.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Clouds

National Institute of Standards and Technology defines characteristics of “cloud”

1. On-demand self-service
2. Broad network access
3. Resource pooling
4. Rapid elasticity
5. Measured service

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Challenges in Bringing Virtualization to the x86 (1)

Core attributes of a virtual machine to x86-based target platform:

1. Compatibility
2. Performance
3. Isolation

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Challenges in Bringing Virtualization to the x86 (2)

Major Challenges:

1. The x86 architecture was not virtualizable
2. The x86 architecture was of daunting complexity
3. x86 machines had diverse peripherals
4. Need for a simple user experience

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Virtualizing the x86 Architecture (1)

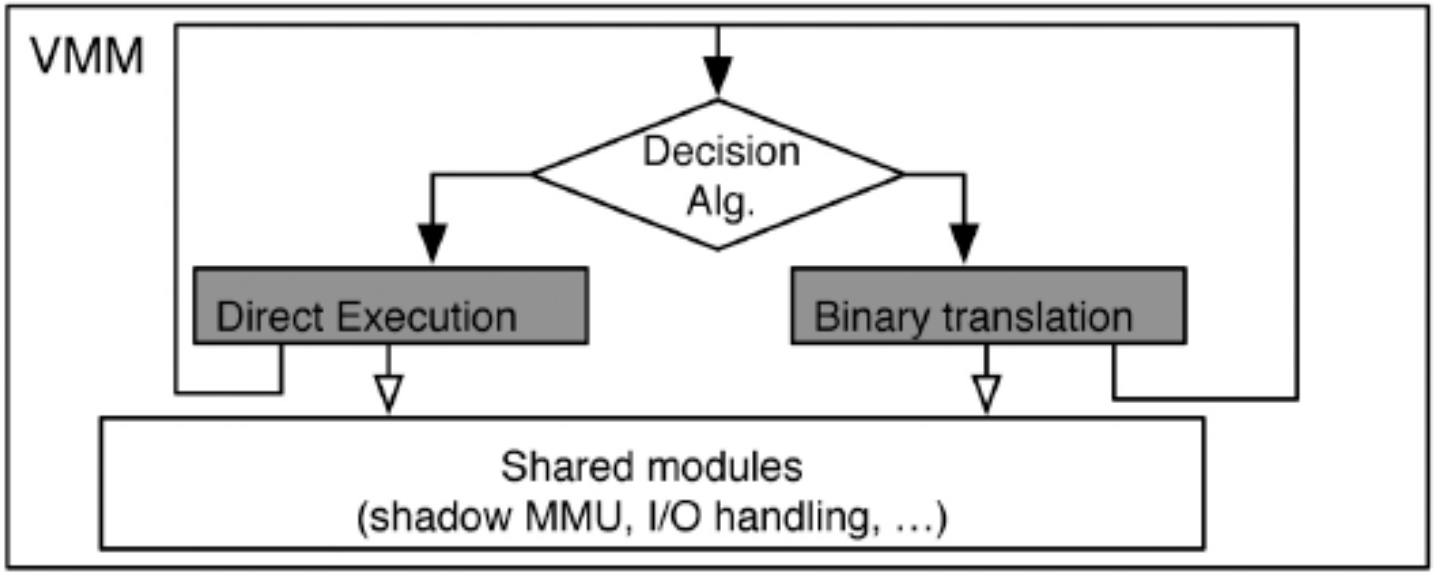


Figure 7-8. High-level components of the VMware virtual machine monitor (in the absence of hardware support).

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Virtualizing the x86 Architecture (2)

Binary translation must be used if any of the following is true:

1. Virtual machine is currently running in kernel mode
2. Virtual machine can disable interrupts and issue I/O instruction
3. Virtual machine is currently running in real mode

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Virtual Hardware Platform (1)

	Virtual Hardware (front end)	*Back end*
Multiplexed	1 virtual x86 CPU, with the same instruction set extensions as the un-derlying hardware CUP	Scheduled by the host operating system on either a uniprocessor or multiprocessor host
	Up to 512 MB of contiguous DRAM	Allocated and managed by the host OS (page-by-page)

Figure 7-9 Virtual hardware configuration options of the early VMware Workstation, ca. 2000.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Virtual Hardware Platform (2)

Emulated	PCI Bus	Fully emulated compliant PCI bus
	4x IDE disks 7x Buslogic SCSI Disks	Virtual disks (stored as files) or direct access to a given raw device
	1x IDE CD-ROM	ISO image or emulated access to the real CD-ROM
	2x 1.44 MB floppy drives	Physical floppy or floppy image
	1x VMware graphics card with VGA and SVGA support	Ran in a window and in full-screen mode. SVGA required VMware SVGA guest driver
	2x serial ports COM1 and COM2	Connect to host serial port or a file
	1x printer (LPT)	Can connect to host LPT port
	1x keyboard (104-key)	Fully emulated; keycode events are generated when they are received by the VMware application
	1x PS-2 mouse	Same as keyboard
	3x AMD Lance Ethernet cards	Bridge mode and host-only modes
	1x Soundblaster	Fully emulated

Figure 7-9 Virtual hardware configuration options of the early VMware Workstation, ca. 2000.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Role of the Host Operating System (1)

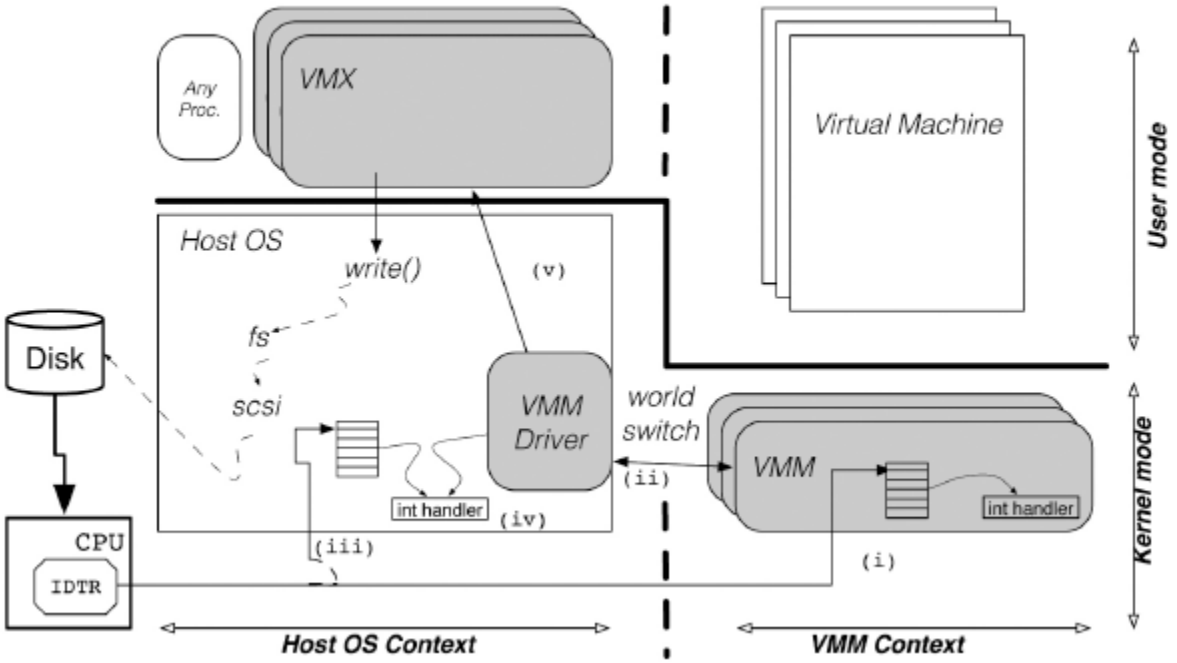


Figure 7-10. The VMware Hosted Architecture and its three components: VMX, VMM driver and VMM.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

Role of the Host Operating System (2)

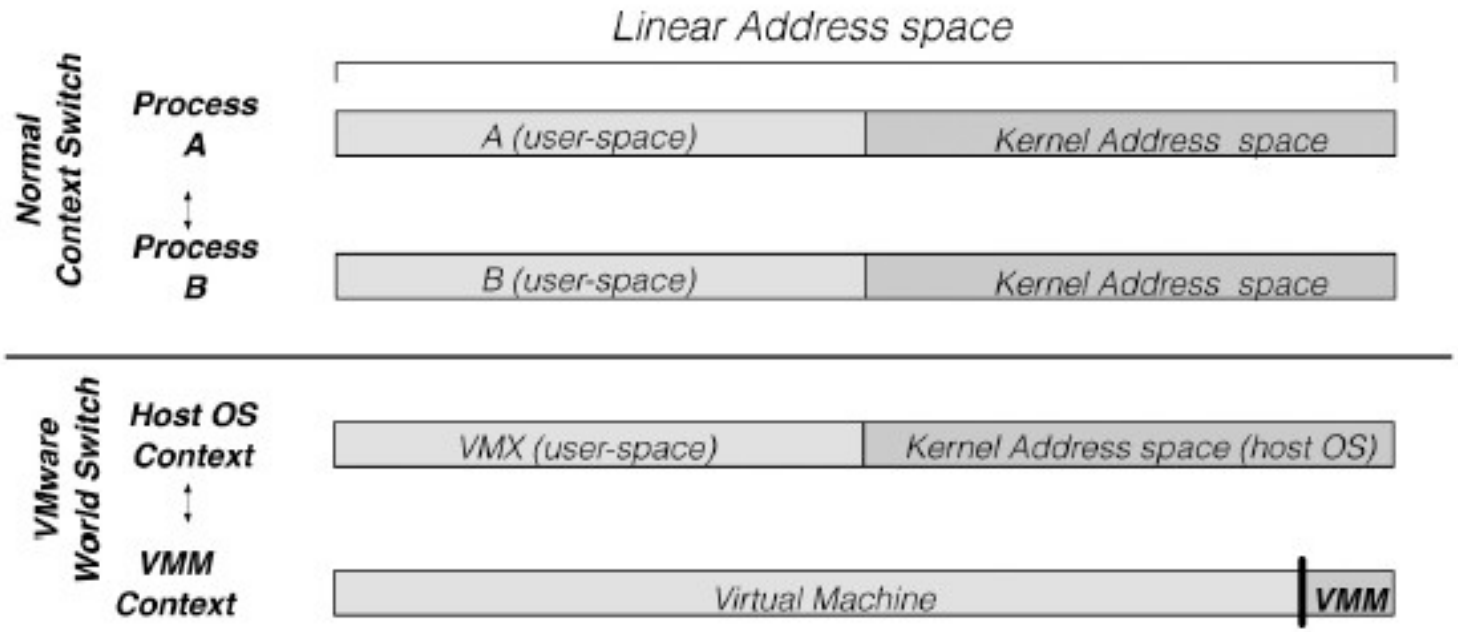


Figure 7-11. Difference between a normal context switch and a world switch.

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

ESX Server: VMware's type-1 Hypervisor (1)

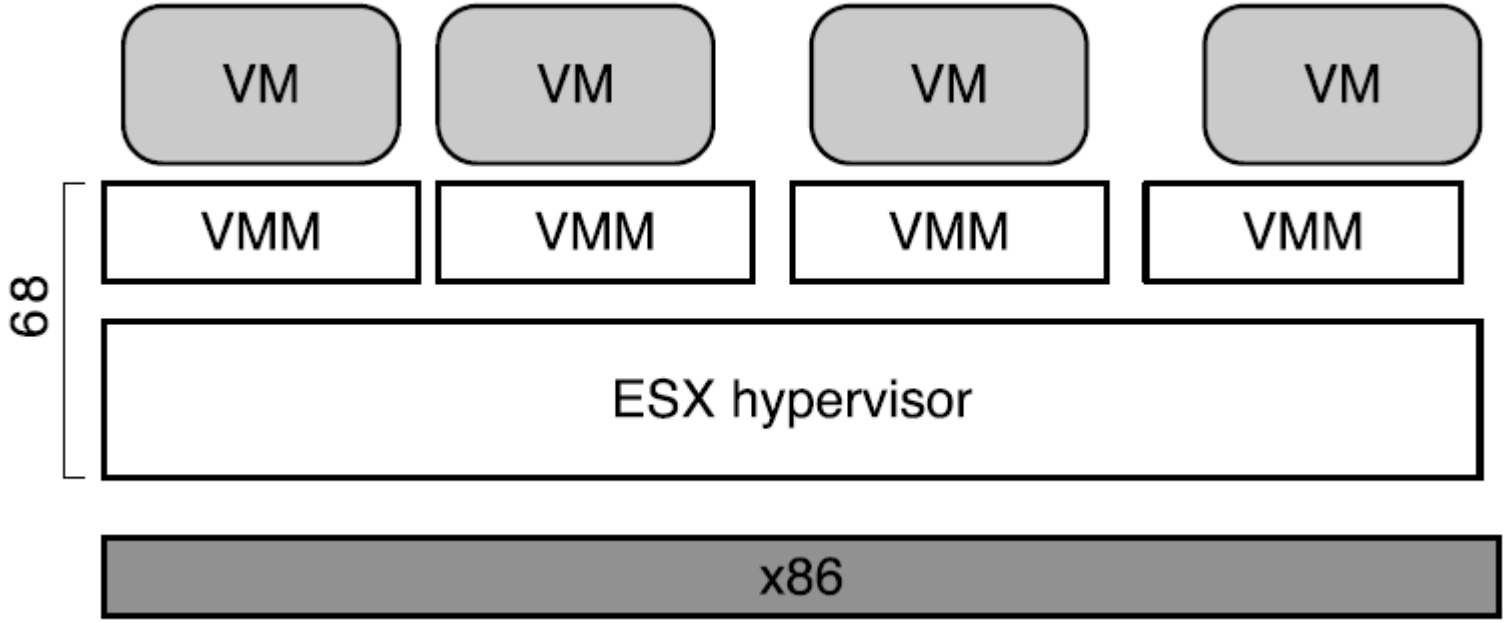


Figure 7-11. ESX Server: VMware's type-1 Hypervisor

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

ESX Server: VMware's type-1 Hypervisor (2)

ESX Server architecture provides substantial benefits

1. CPU scheduler ensures that each virtual machine gets a fair share of the CPU
2. Memory manager is optimized for scalability
3. I/O subsystem is optimized for performance
4. Back ends also typically relied on abstractions provided by host operating system.
5. ESX Server made it easy to introduce new capabilities

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.

End

Chapter 7

Tanenbaum & Bo, Modern Operating Systems:4th ed., (c) 2013 Prentice-Hall, Inc. All rights reserved.