CSCI 447

OPERATING SYSTEMS

CHAPTER 18:VIRTUAL MACHINE

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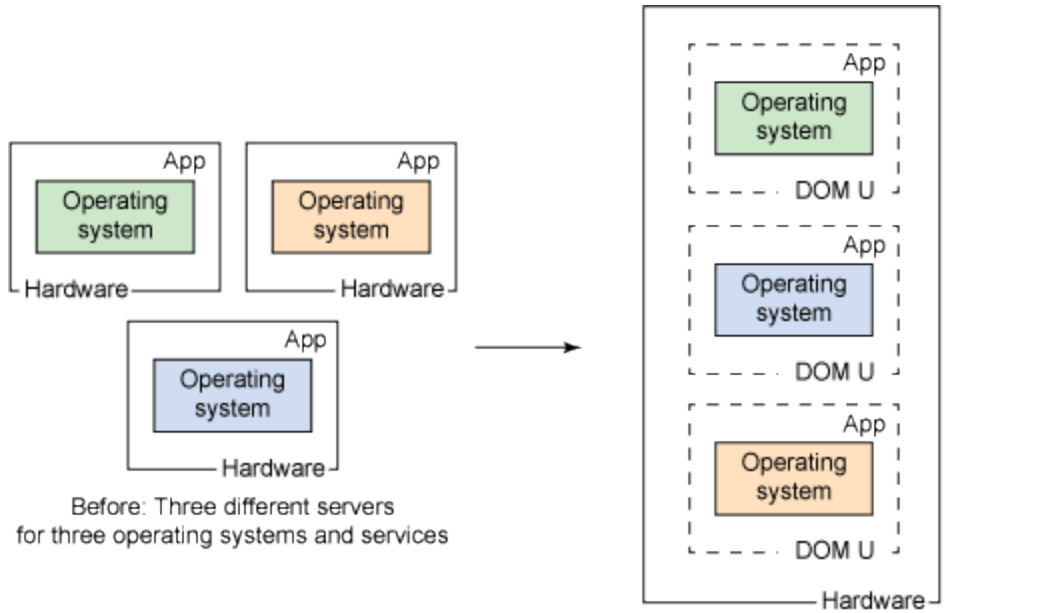

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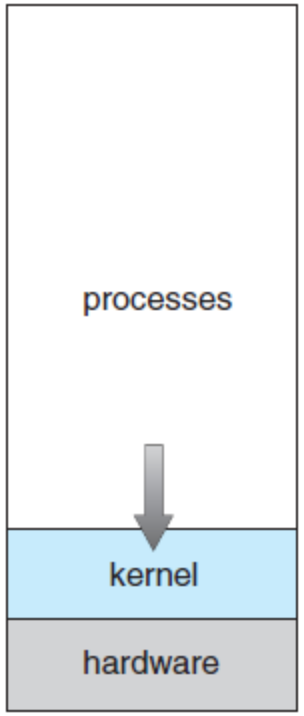

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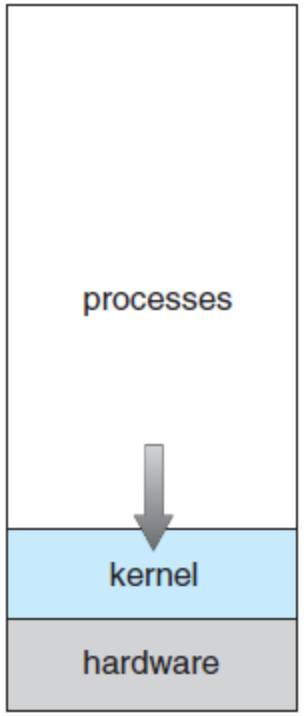

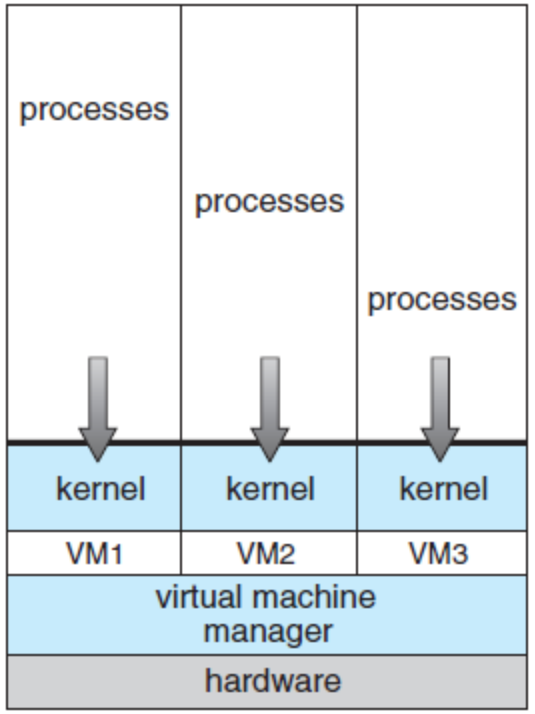

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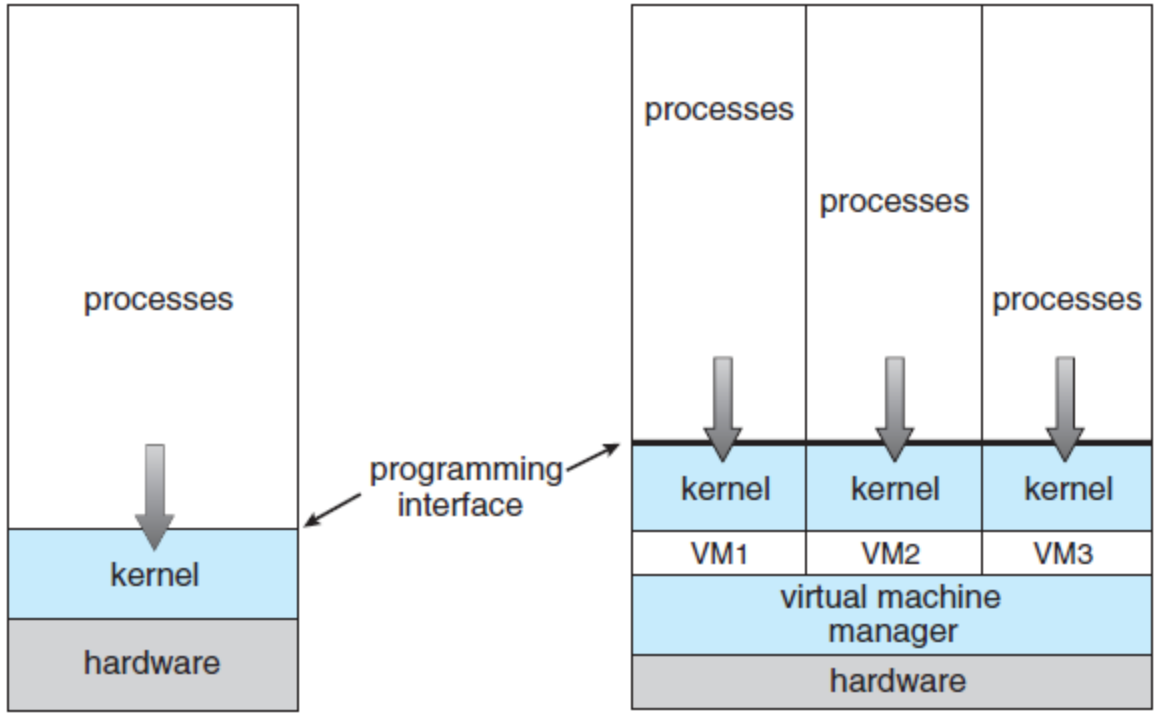

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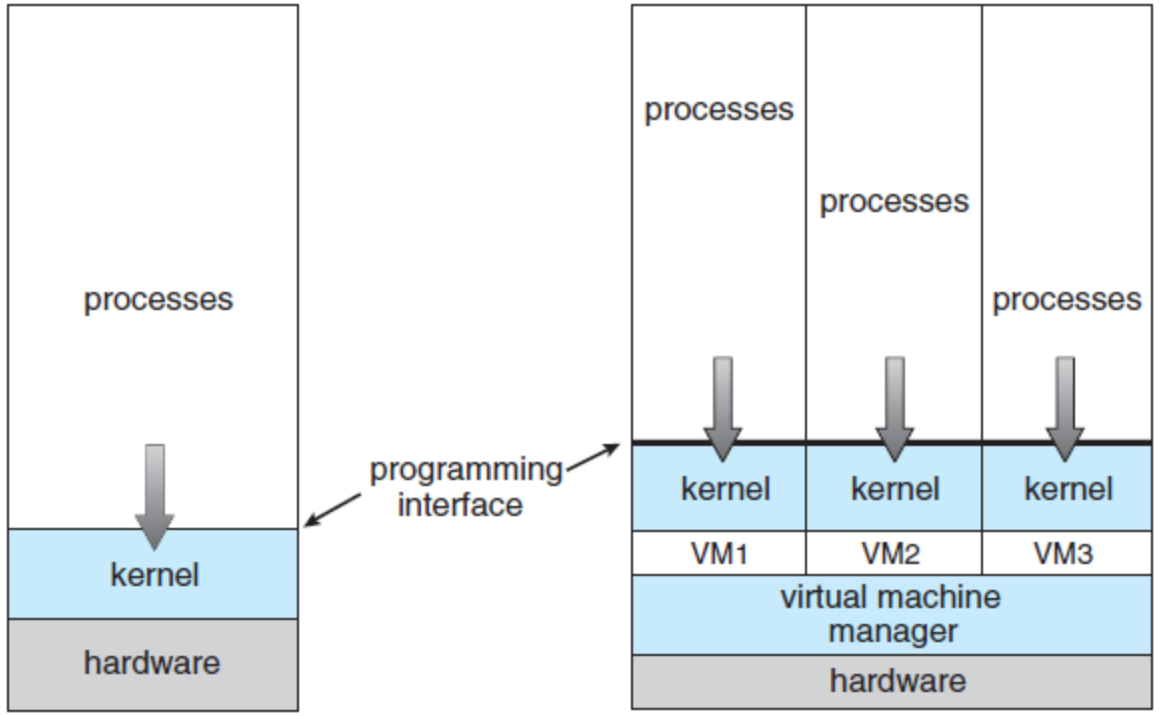

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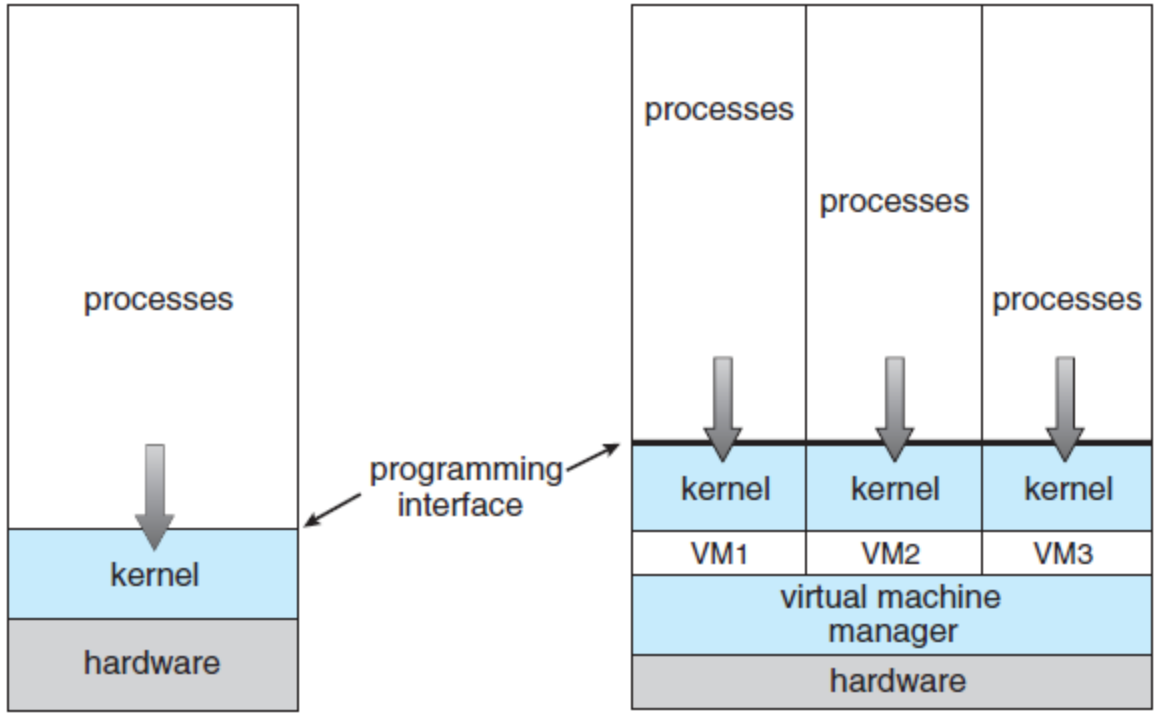

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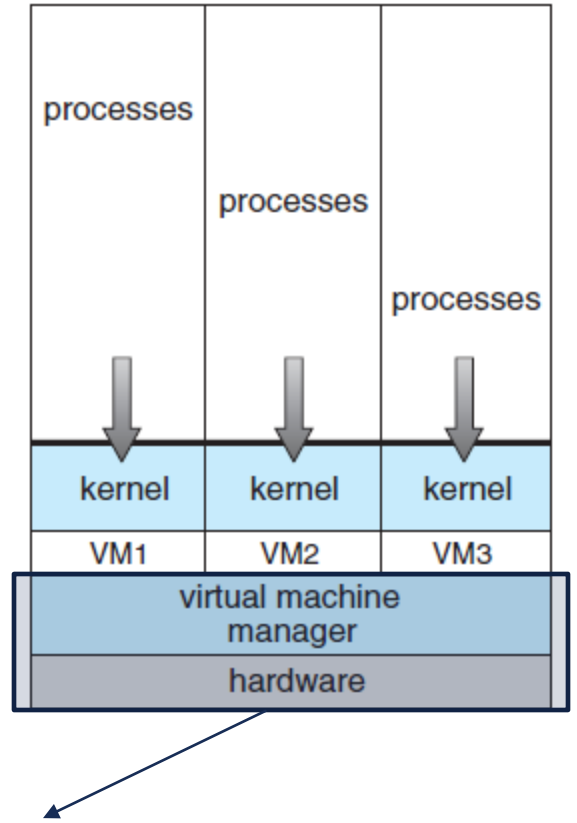
B: Host Machine



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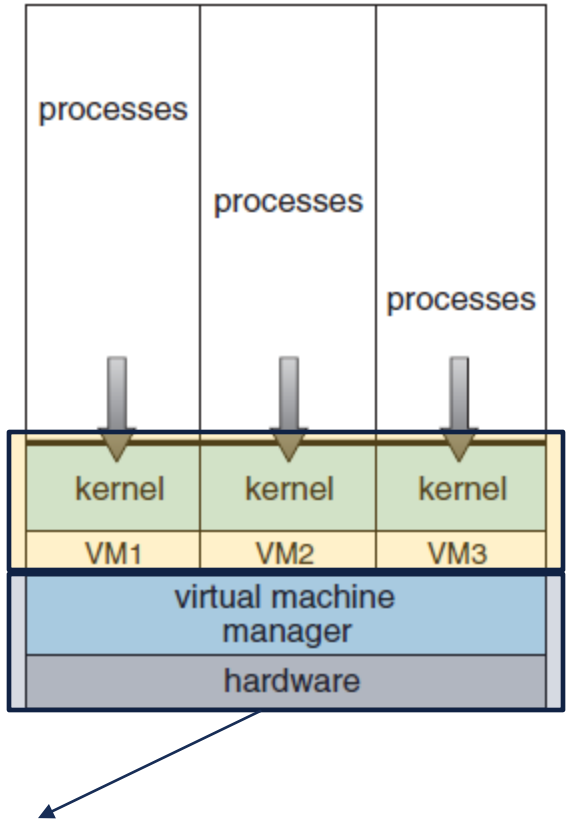

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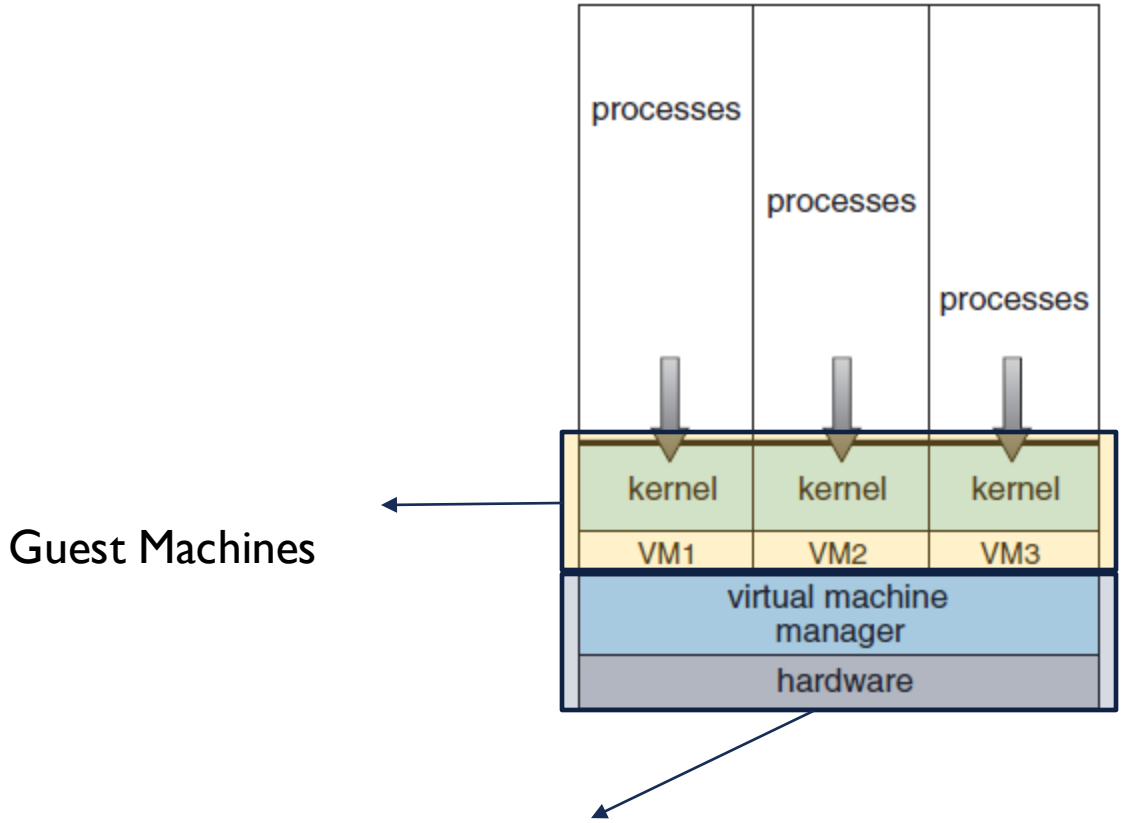

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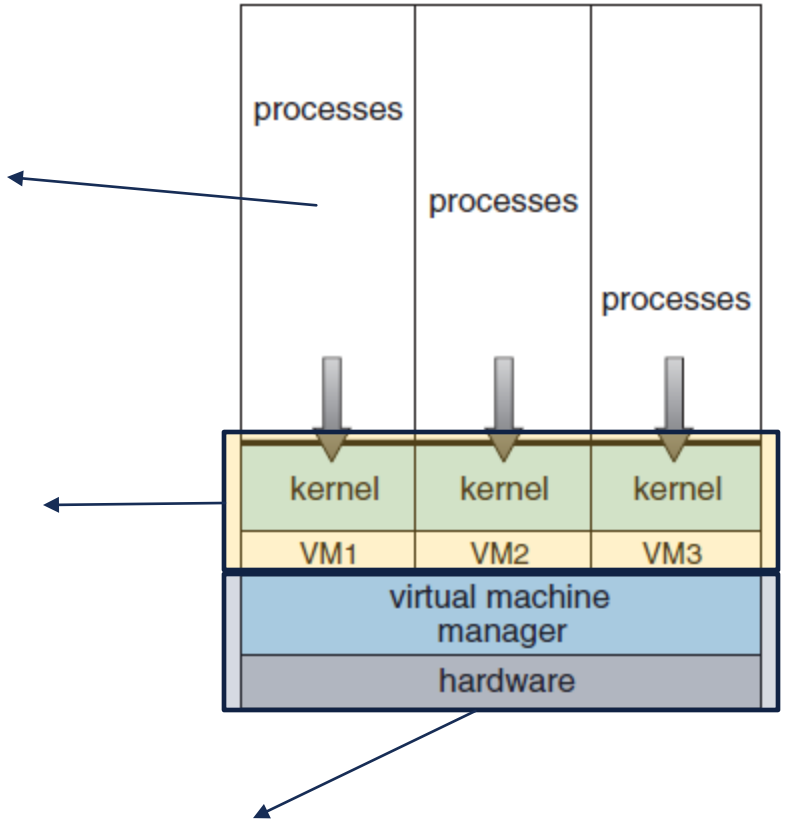

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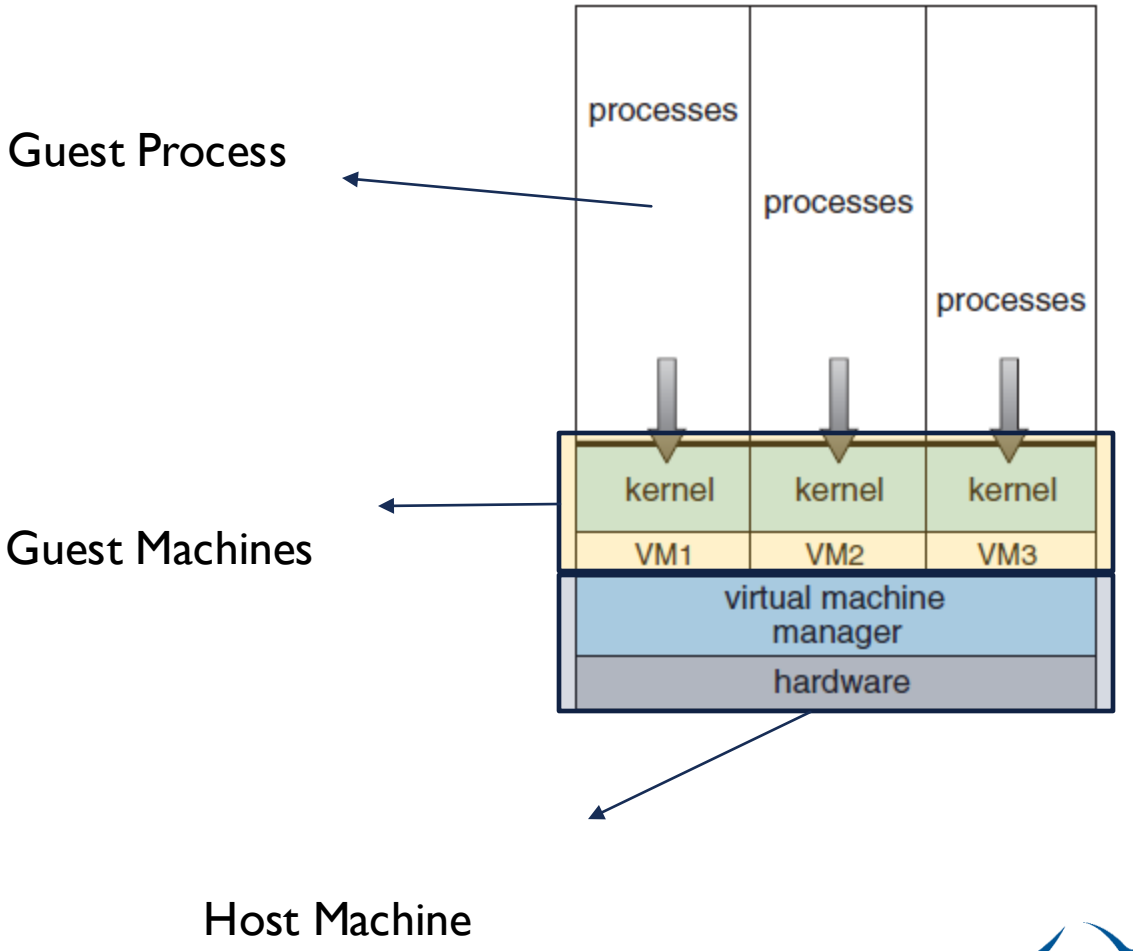

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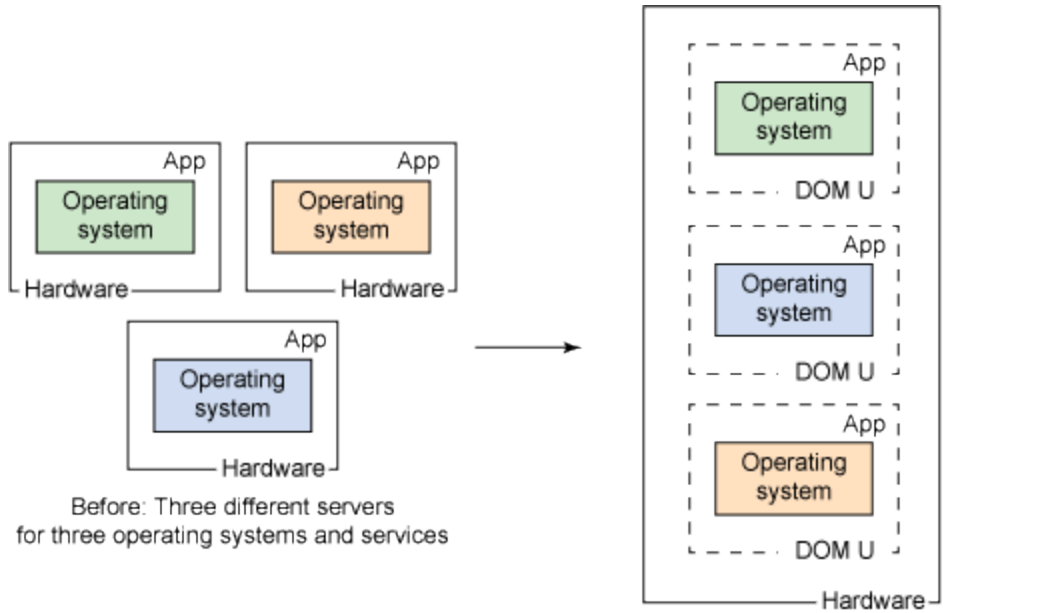

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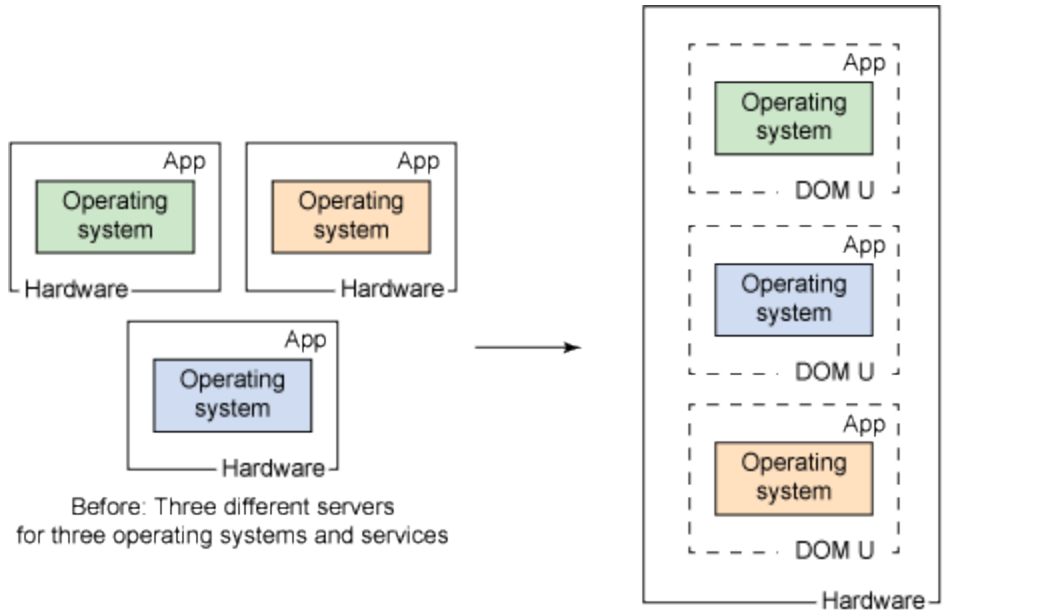

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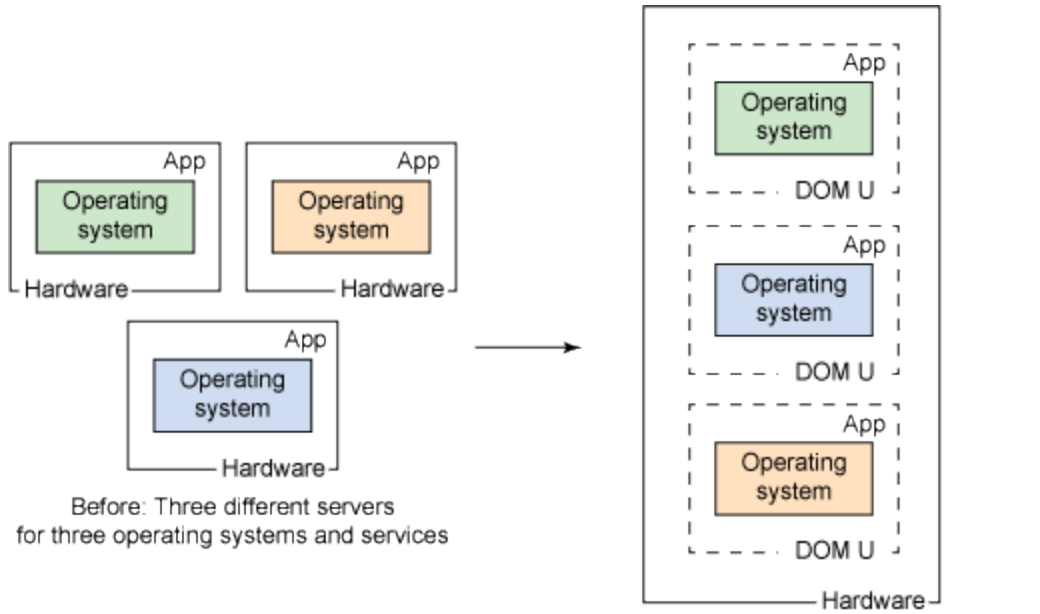

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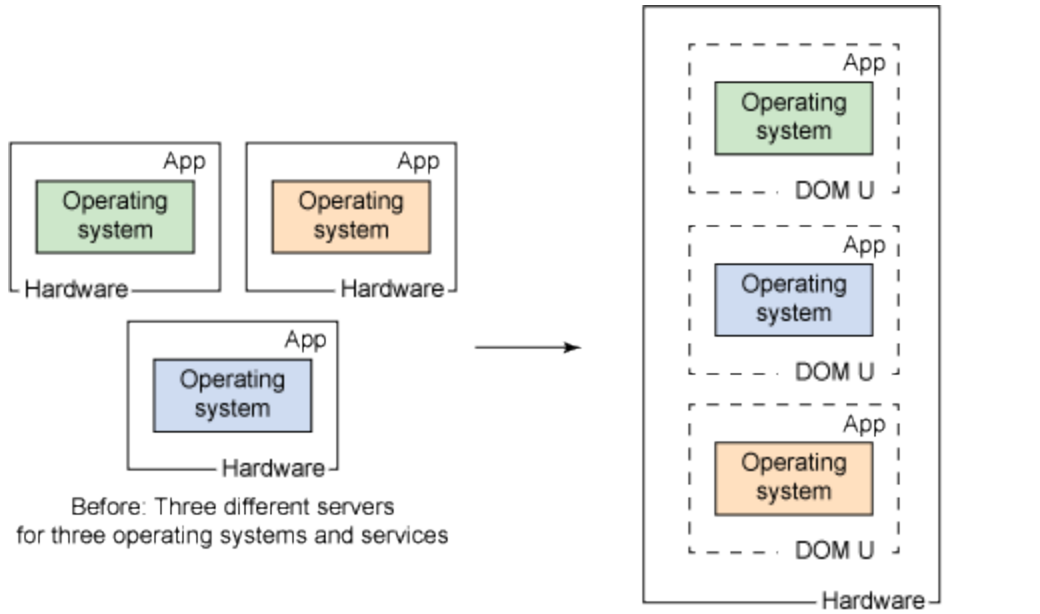

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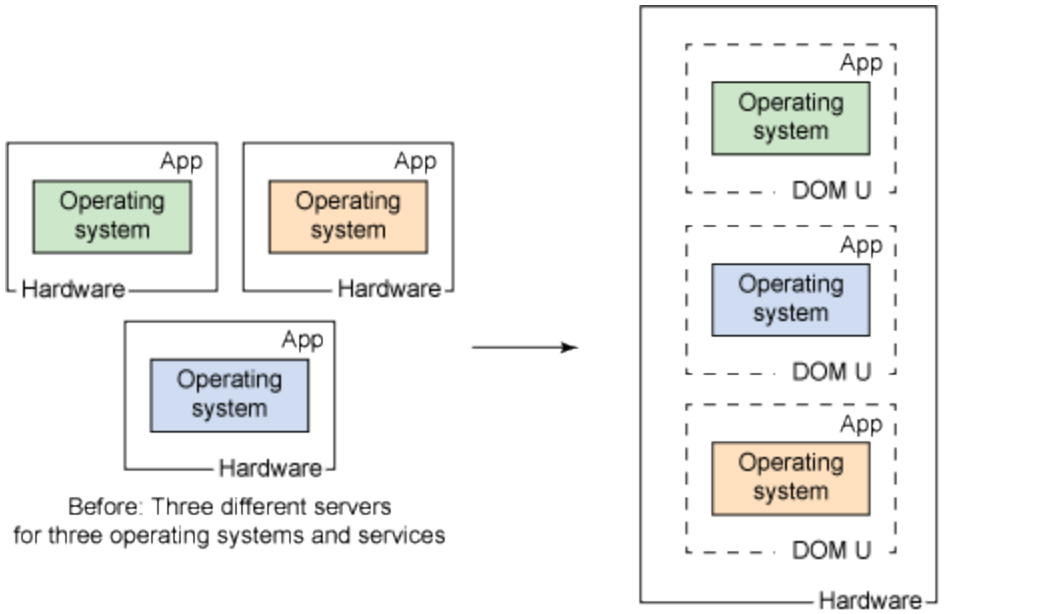
- Why tracks? Faster access, you don't want two OS sharing the same track.



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- In 1990s, general purpose processors became fast enough to support virtualization.
  - **Xen** and **VMware** created technologies, still used today
  - Virtualization has expanded to many OSes, CPUs, VMMs

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- **Cloud computing**
  - Using APIs, programs tell cloud infrastructure (servers, networking, storage) to create new guests, VMs, virtual desktops.
  - More of a "product" of virtual machines.

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- **Performance**. Programs running within that environment show only minor performance decreases.
- **Safety**. The VMM is in complete control of system resources. Guest can only control resources through the VMM.

HYPERVISORS TYPES

- Type 0, I and 2

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  - A HW feature implemented by firmware
  - Each guest has dedicated hardware.
  - OS needs nothing special, VMM is in firmware
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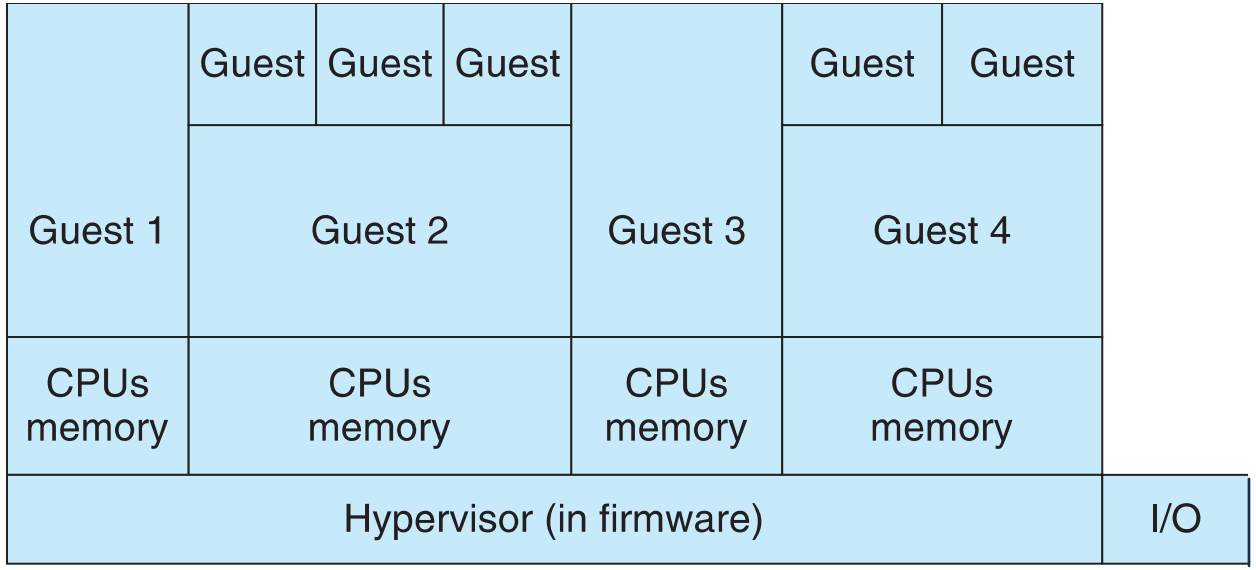

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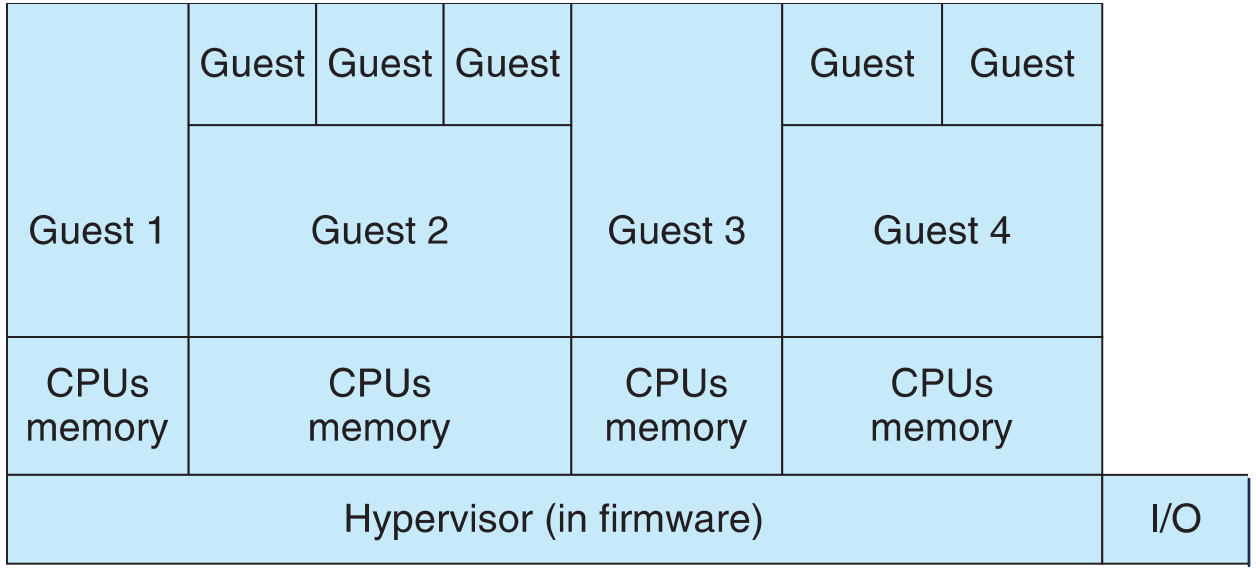

Status as a "Hypervisor" is questionable, since there is no real, virtualization. Each "guest" has its own hardware.

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- Type 1:
- Special purpose operating systems that run natively on HW

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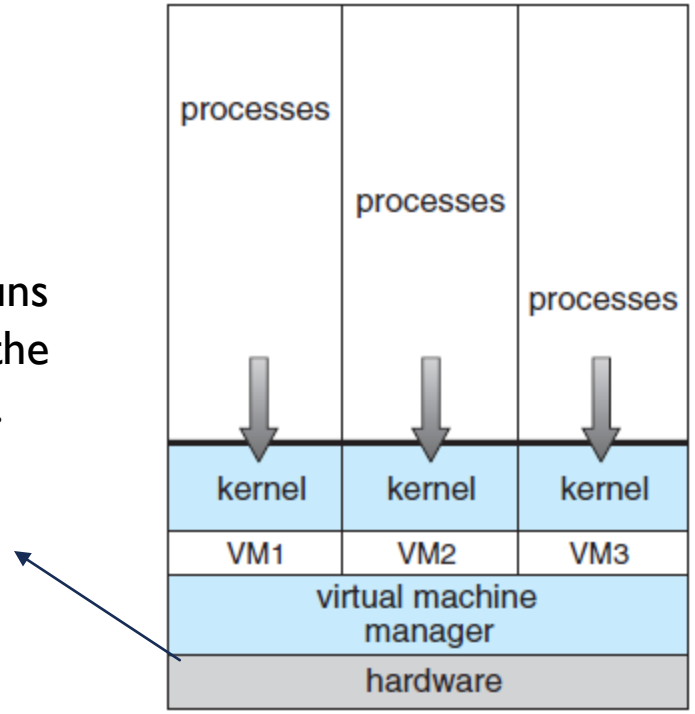

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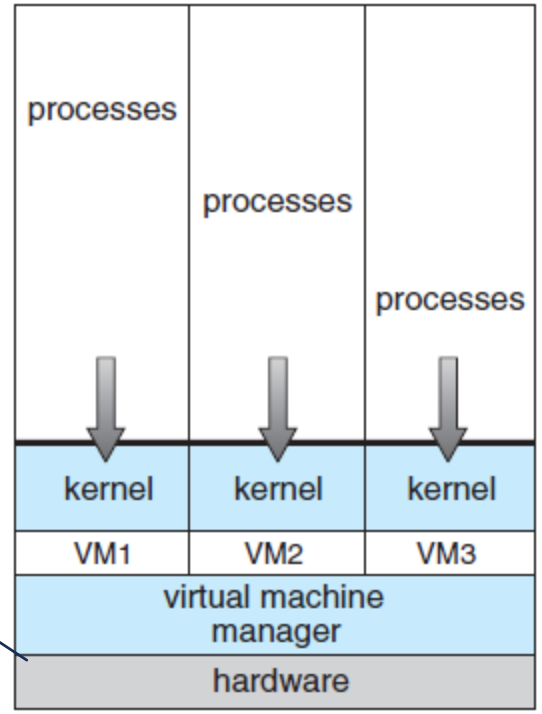

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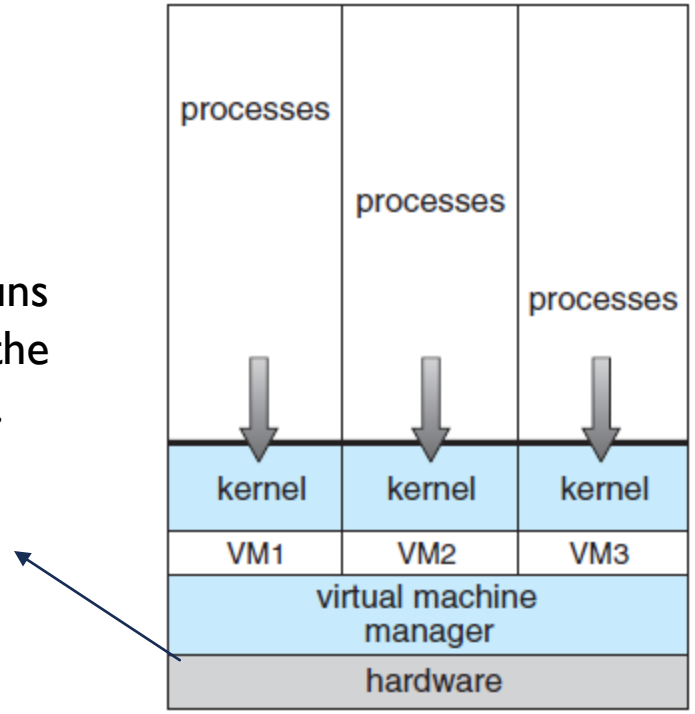

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- More complex to implement
  - Implement device drivers for host HW because no other component can
  - Also provide other traditional OS services like CPU and memory management

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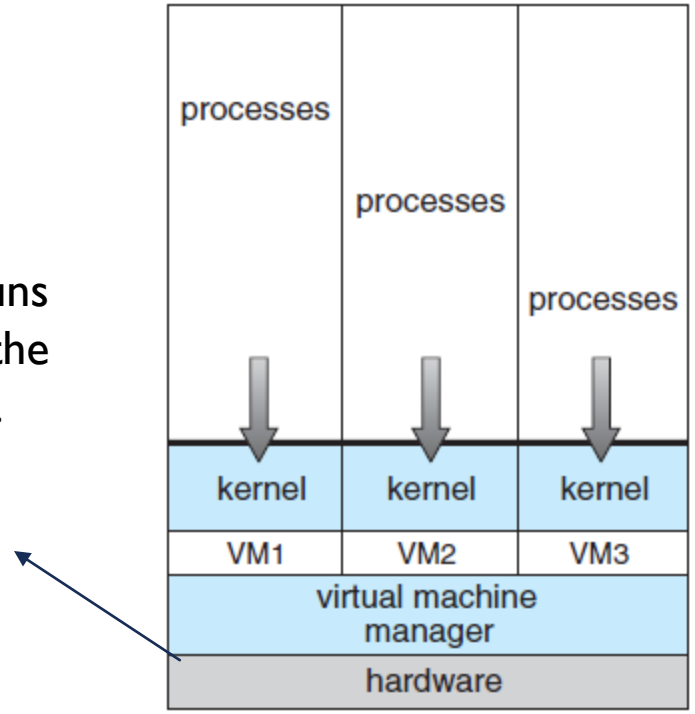

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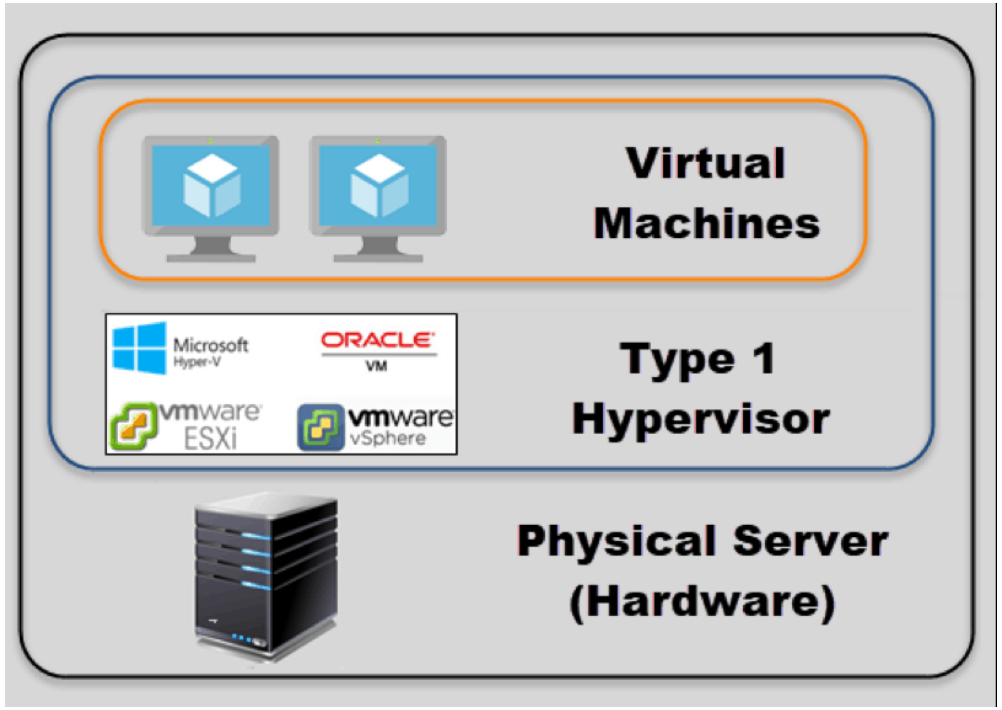

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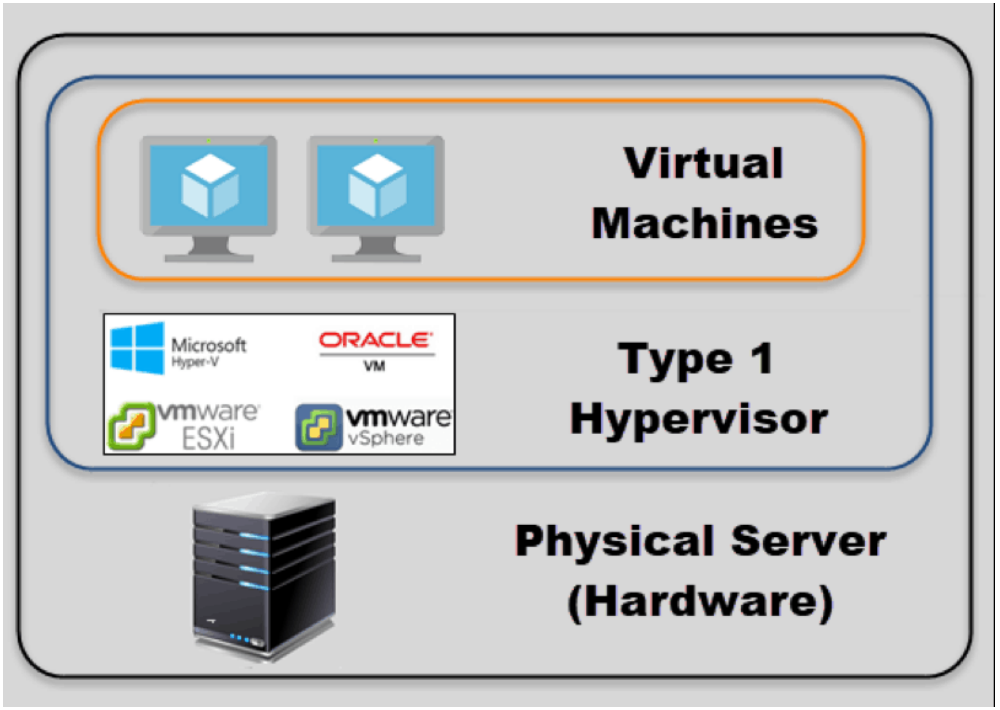

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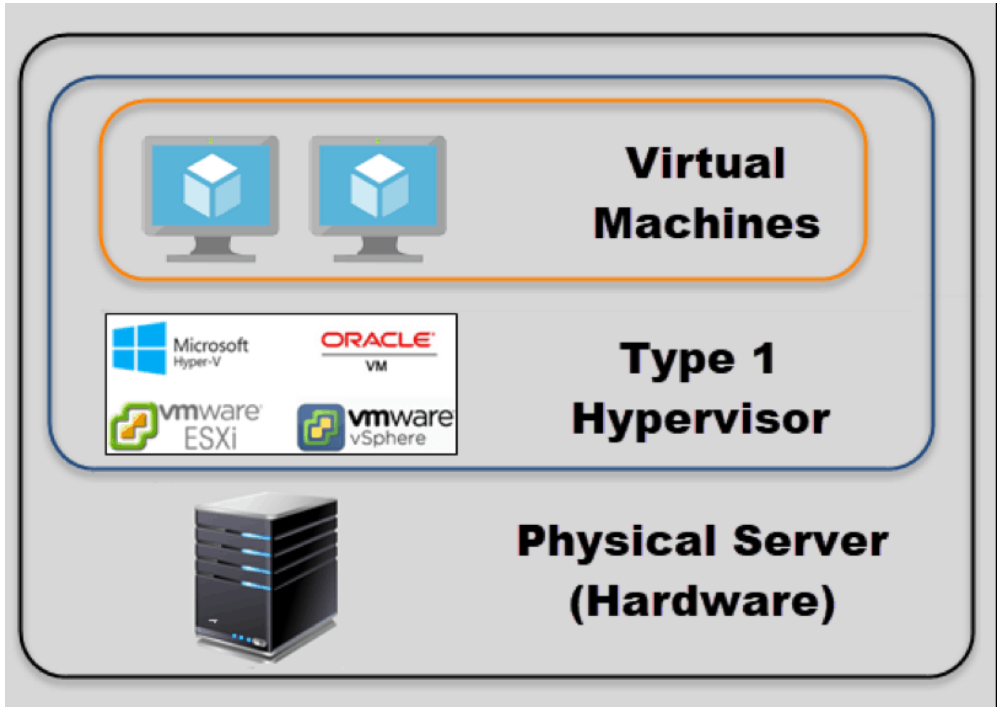

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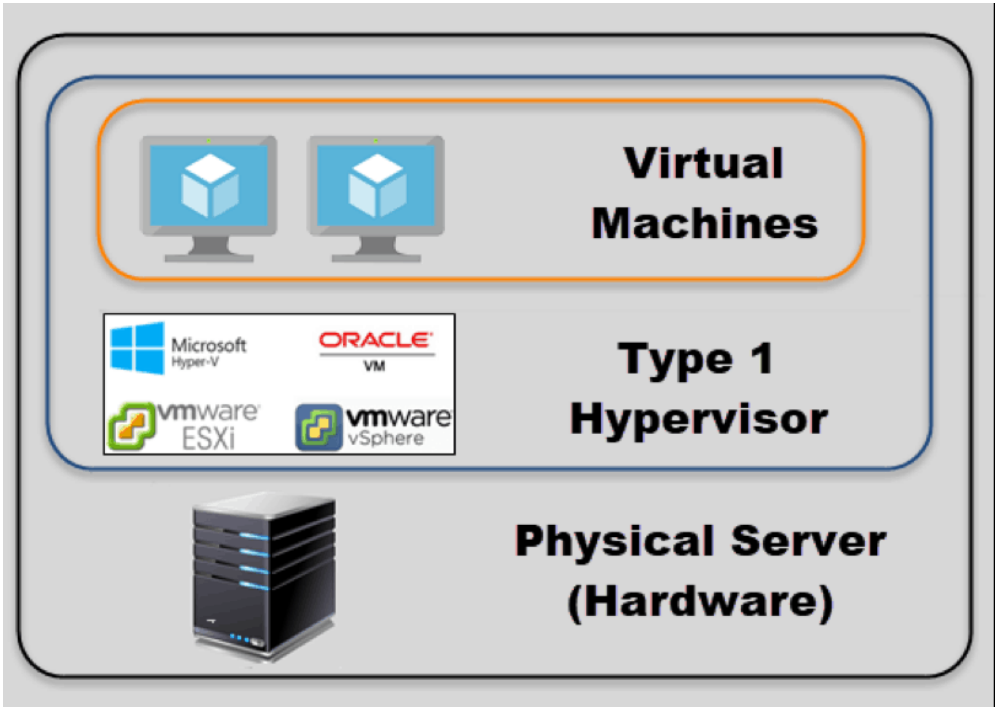

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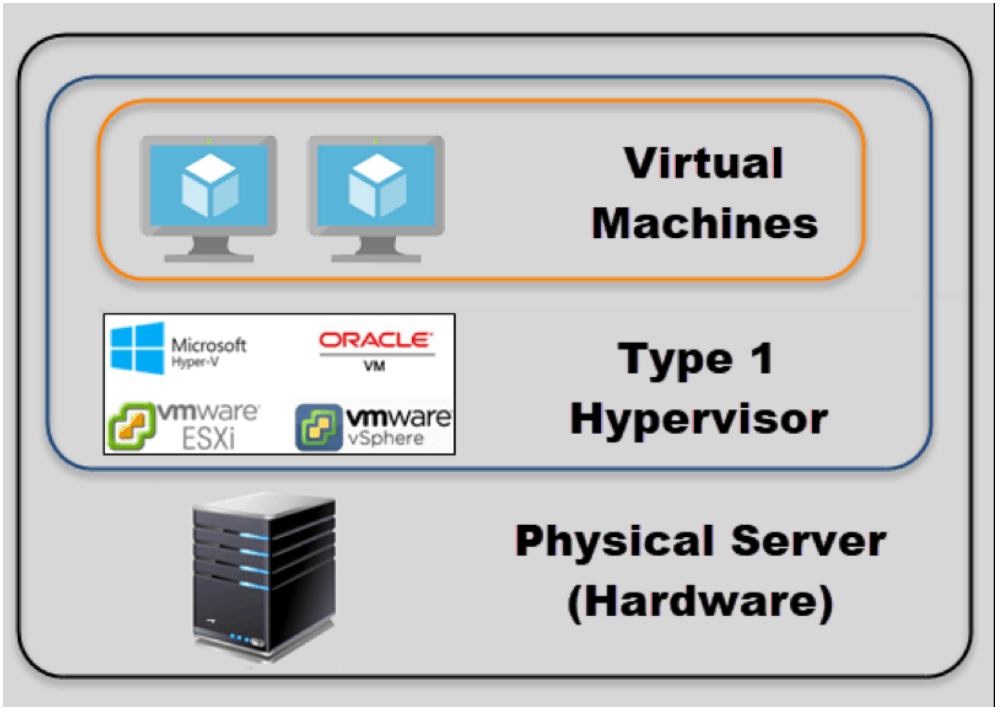

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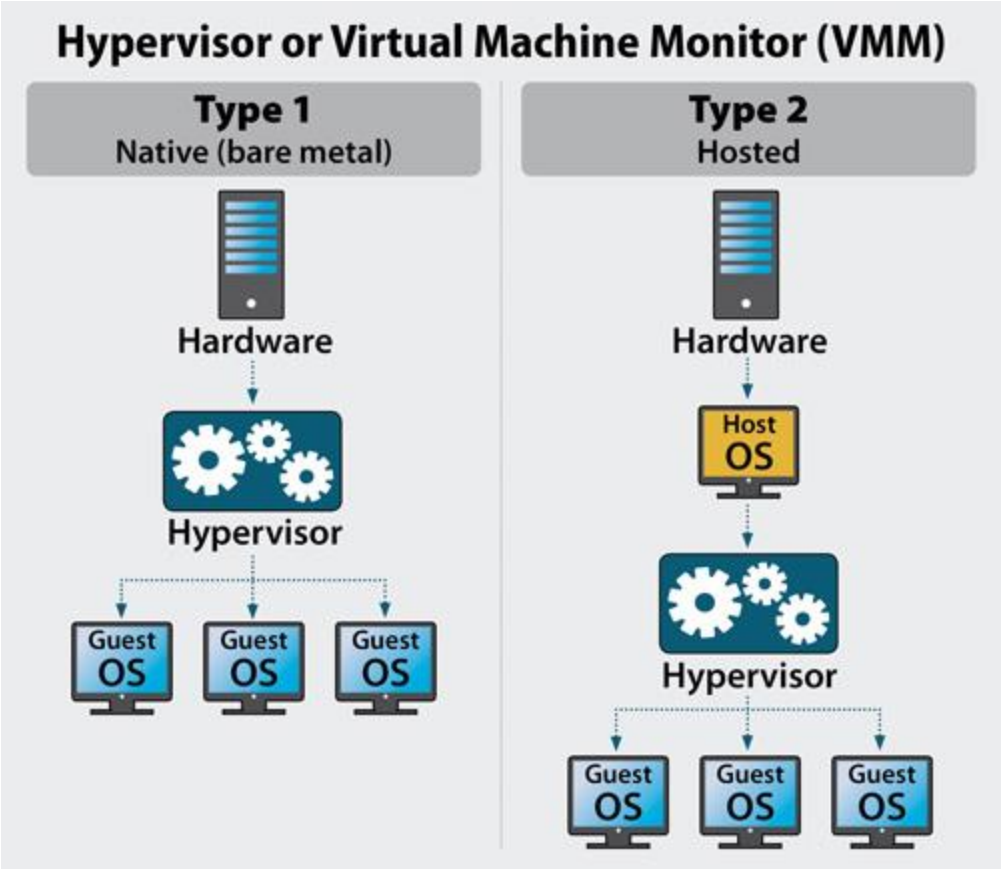

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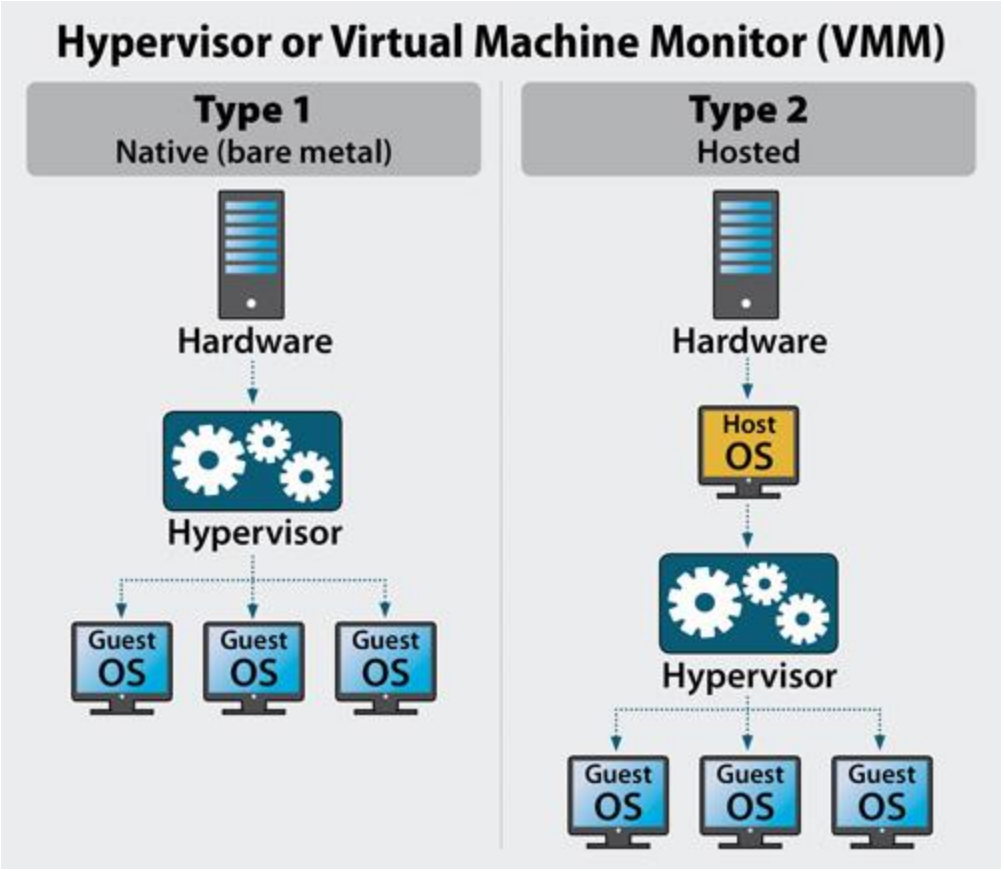

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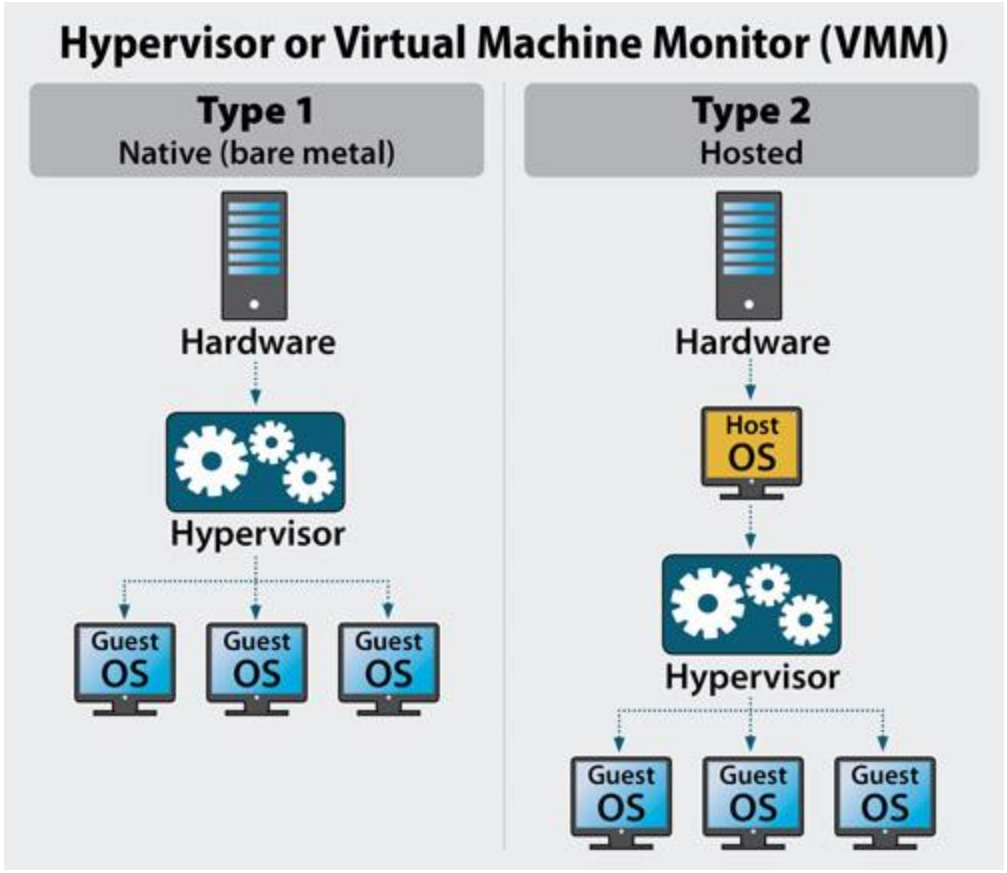

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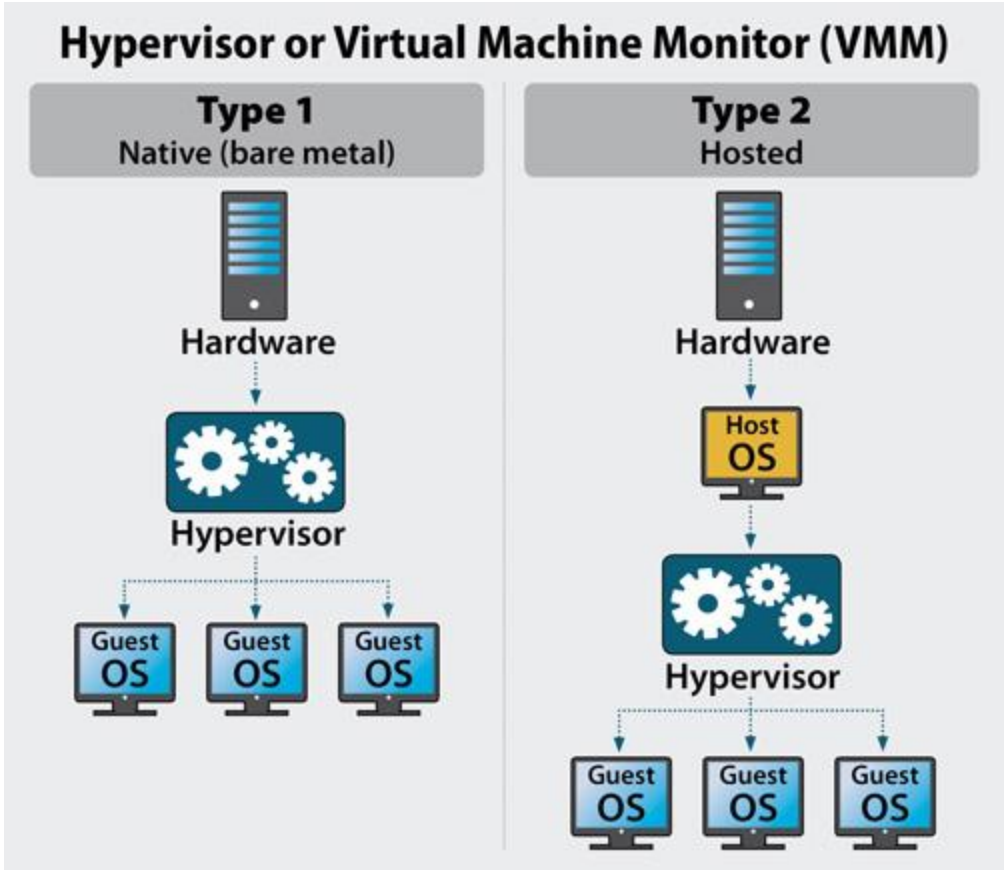
  - Require no changes to host OS, can use on most computers.



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- **VMware Workstation Pro / VMware Fusion**.
  - VMware Workstation Pro is a type 2 hypervisor for Windows OS.
  - It is full of advanced features and has seamless integration with vSphere. This allows you to move your apps between desktop and cloud environments.

VM IMPLEMENTATION

Let's look at some implementation challenges.

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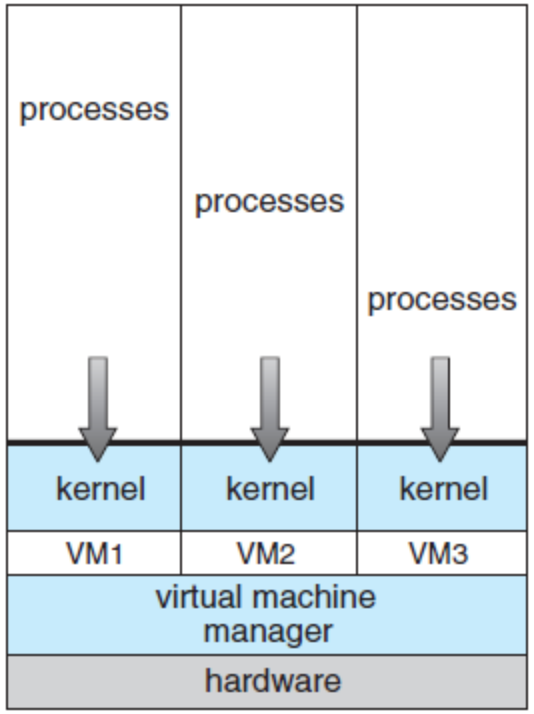
Q: How is user/kernel mode implemented in VMs?



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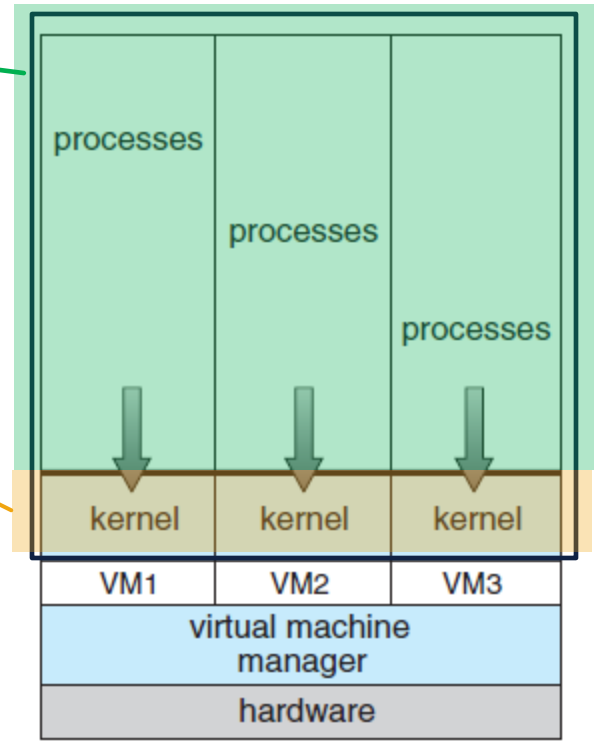
User Mode in eyes of Guest Machine

Kernel Mode in eyes of Guest Machine



VM IMPLEMENTATION

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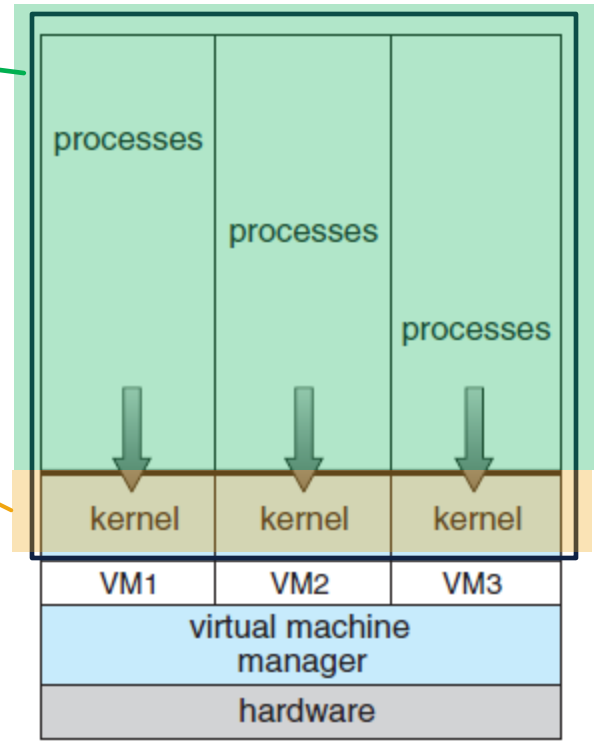
From the VM (Guest machine) perspective, the code can be in user mode or kernel mode.



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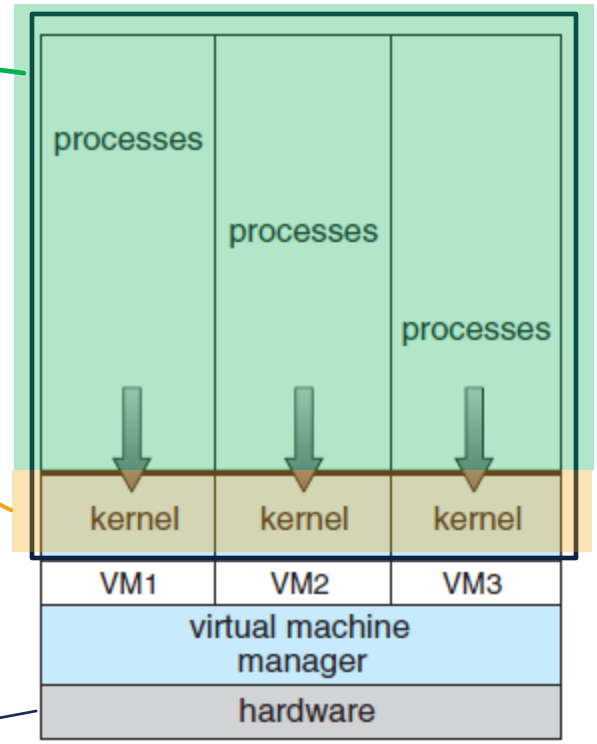

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VM IMPLEMENTATION

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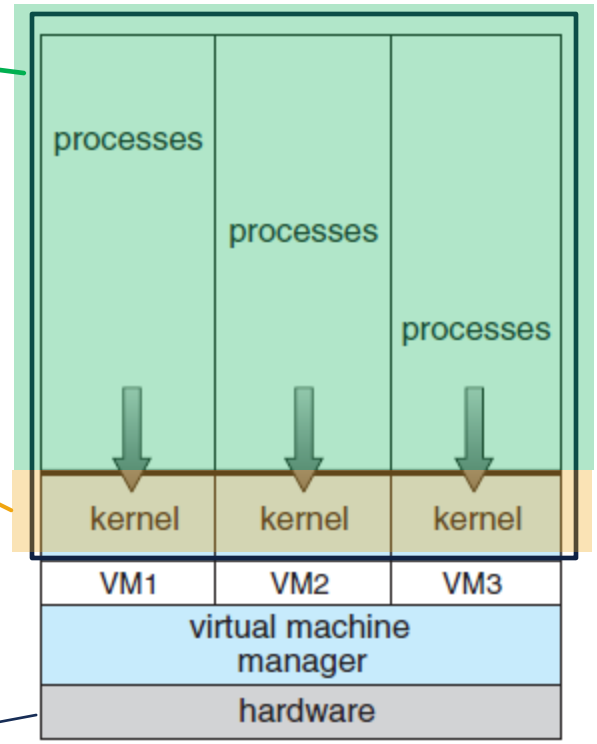
This is 'virtual' kernel mode, not real kernel mode.

Kernel Mode in eyes of Guest Machine



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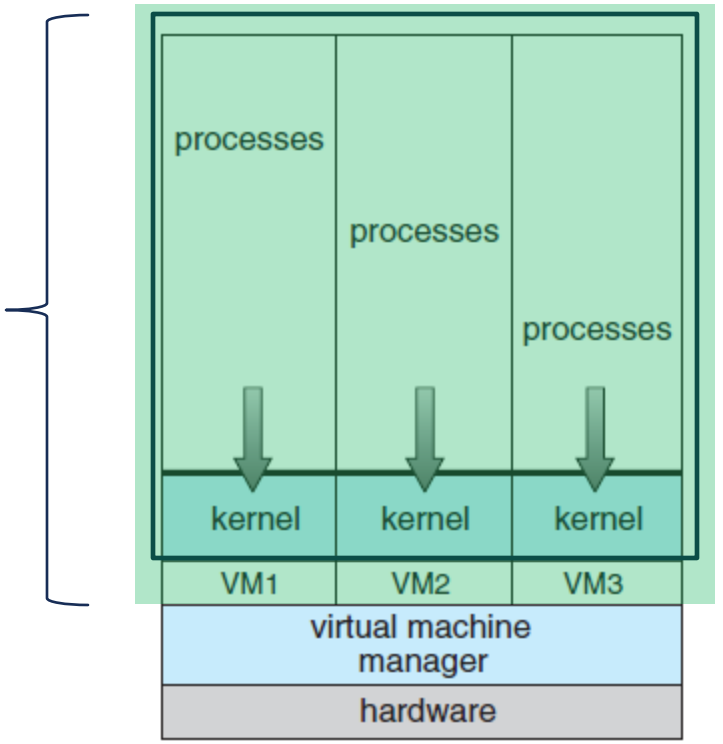

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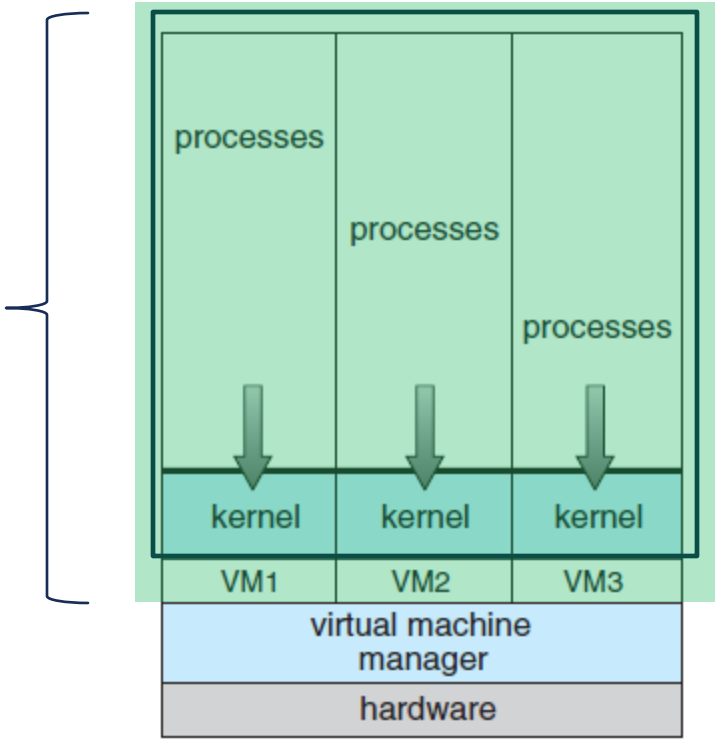

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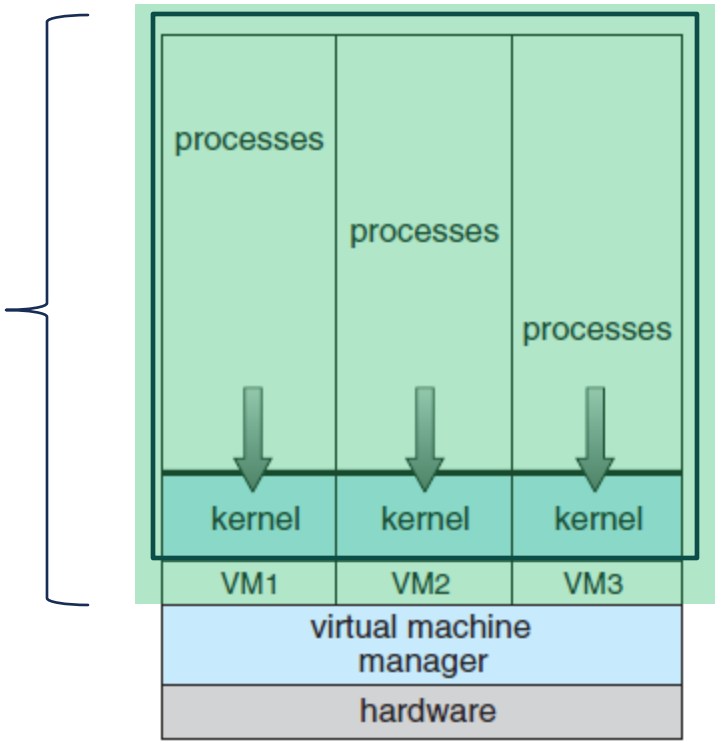

Q: Does the VM need access to kernel mode?

Emulation vs. Virtualization

- Machine Emulation: Guest machine run on a simulated processor; entirely done in software.

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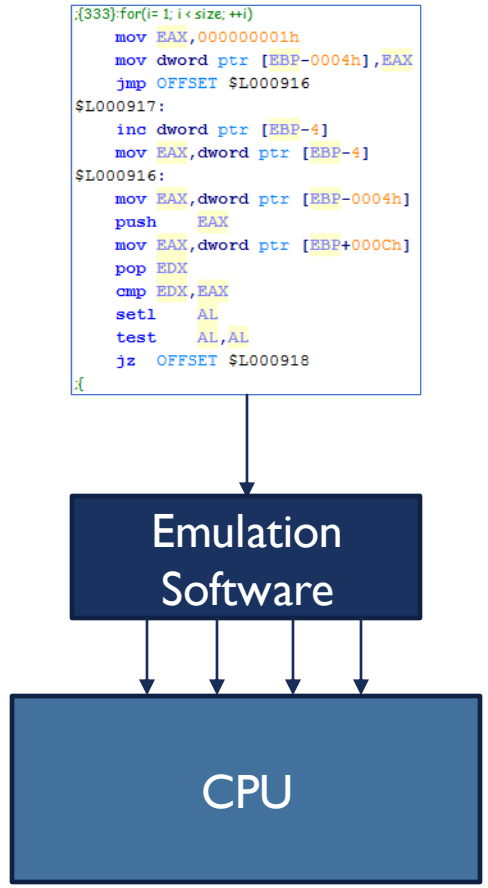

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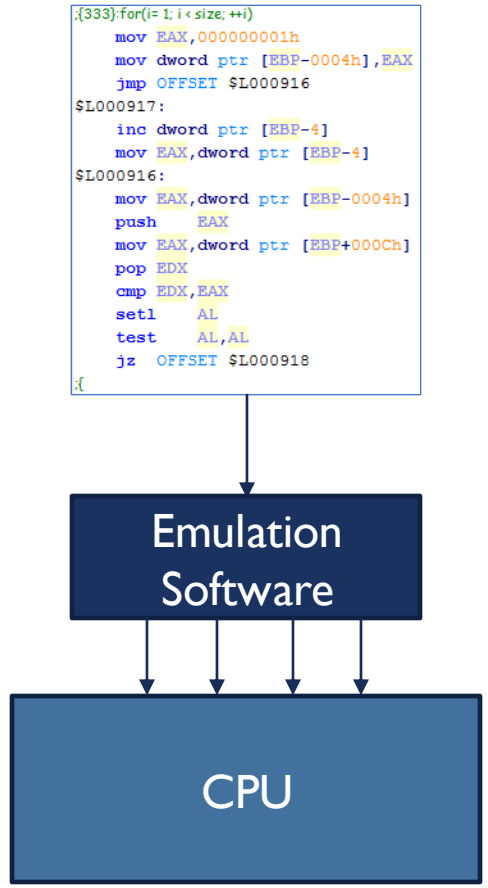

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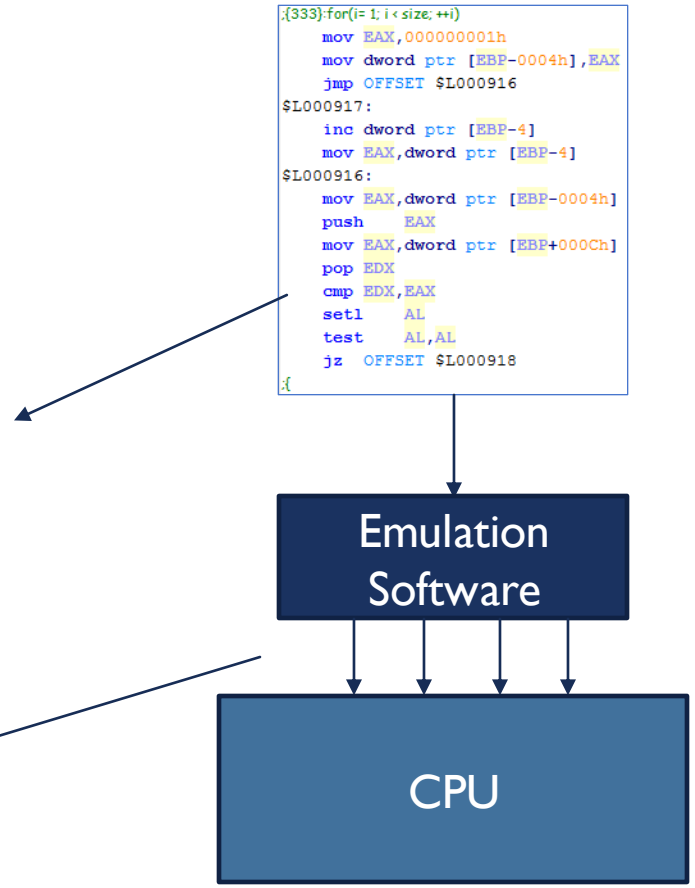

What reaches the CPU is an entirely different code.

VIRTUALIZATION

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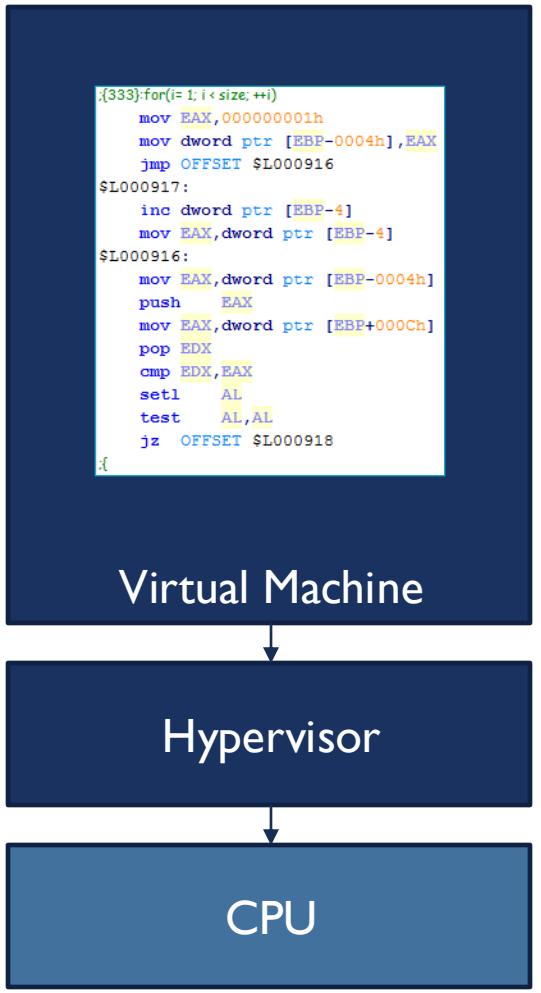

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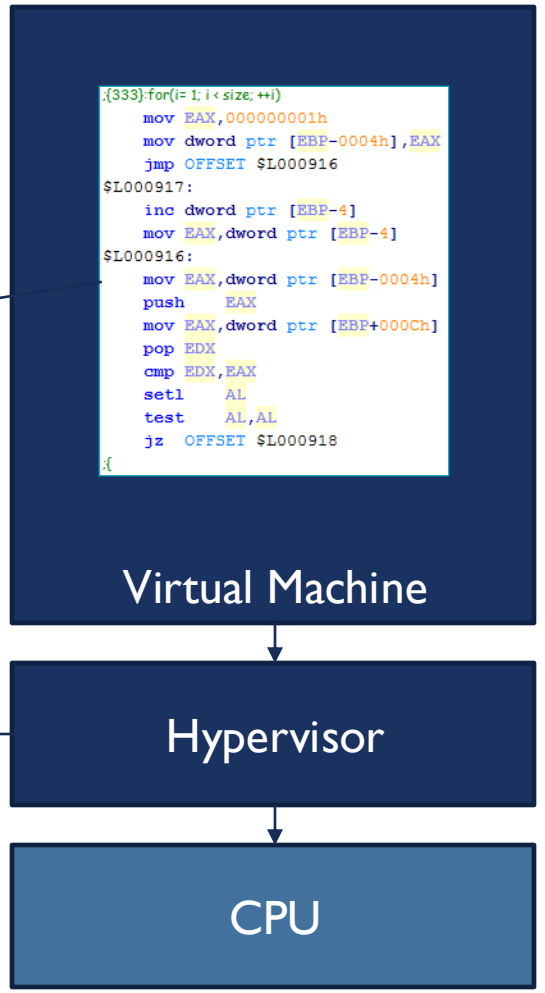

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So how does relate to whether we need kernel mode in virtual machines?

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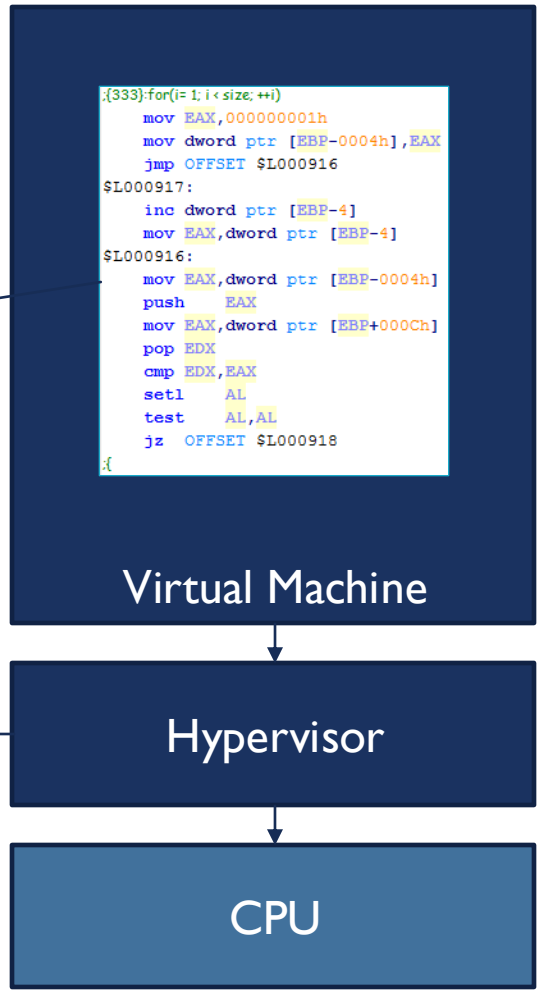

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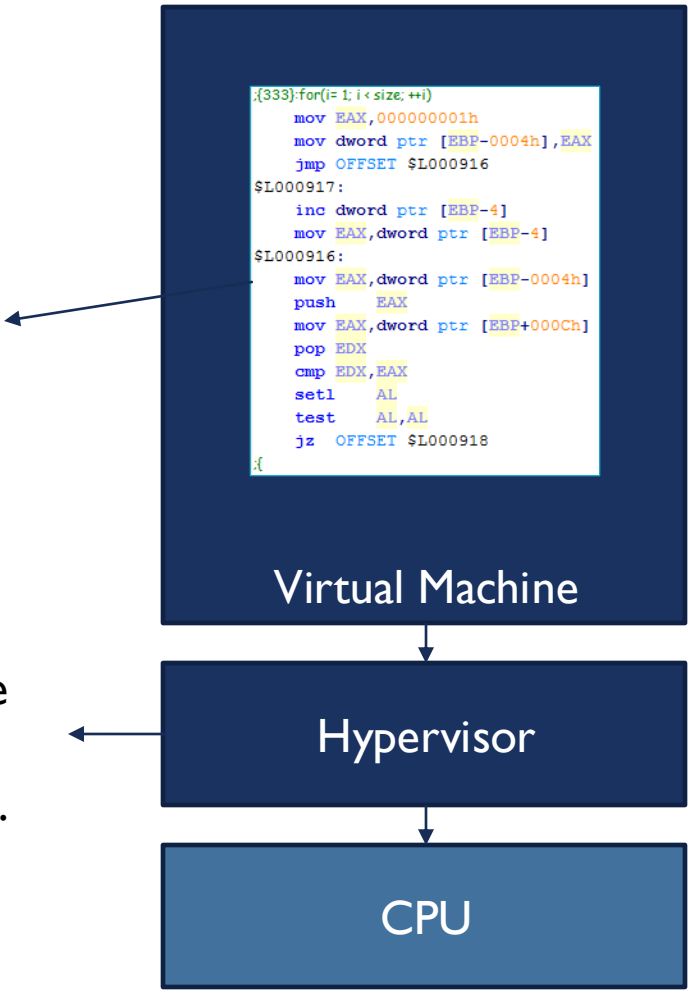

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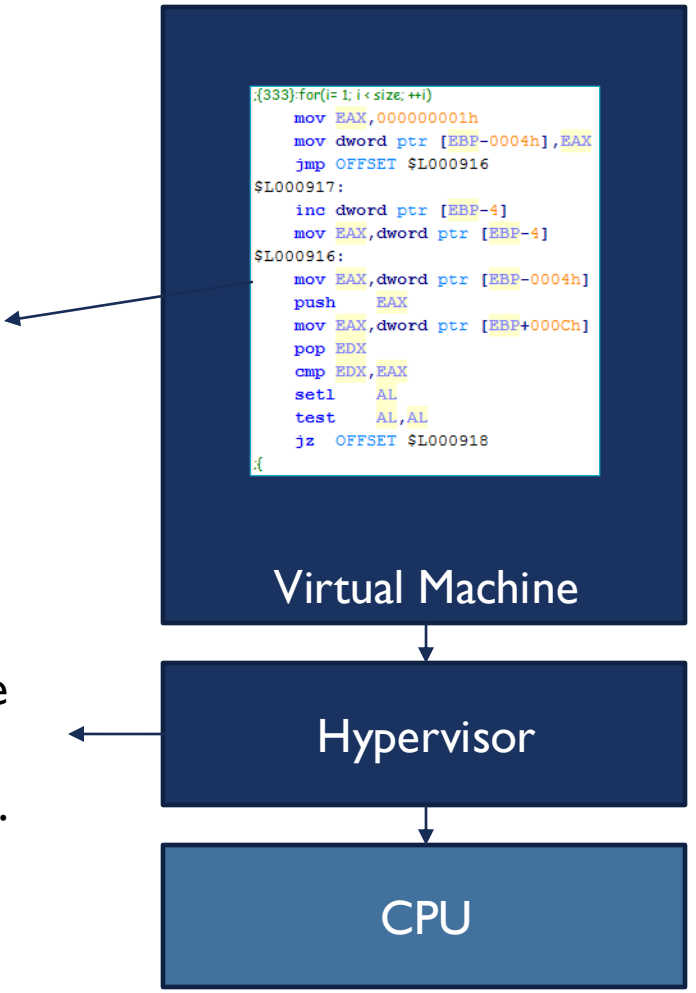
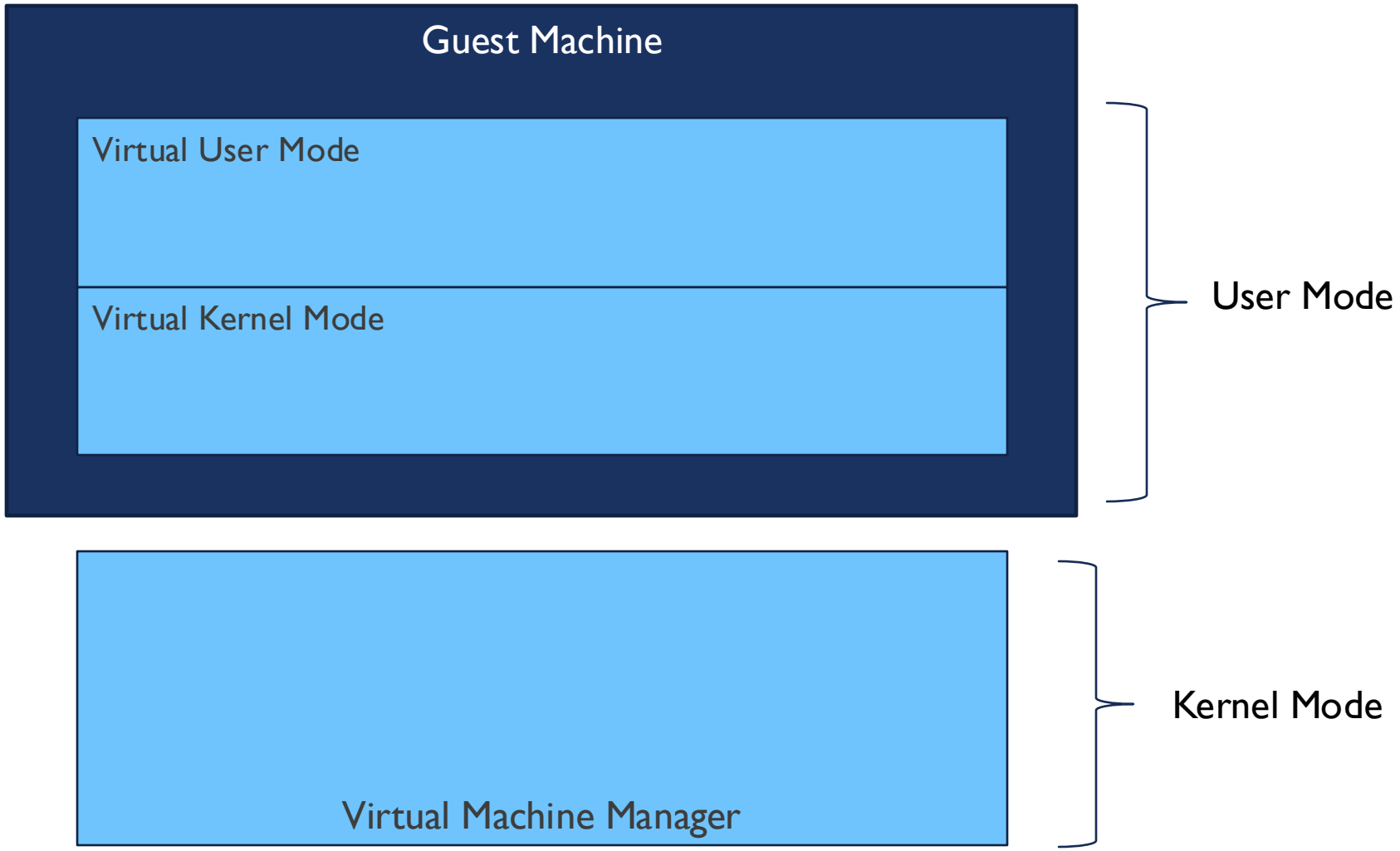
Q: How to handle kernel mode instruction for the virtual machine?



TRAP AND EMULATE



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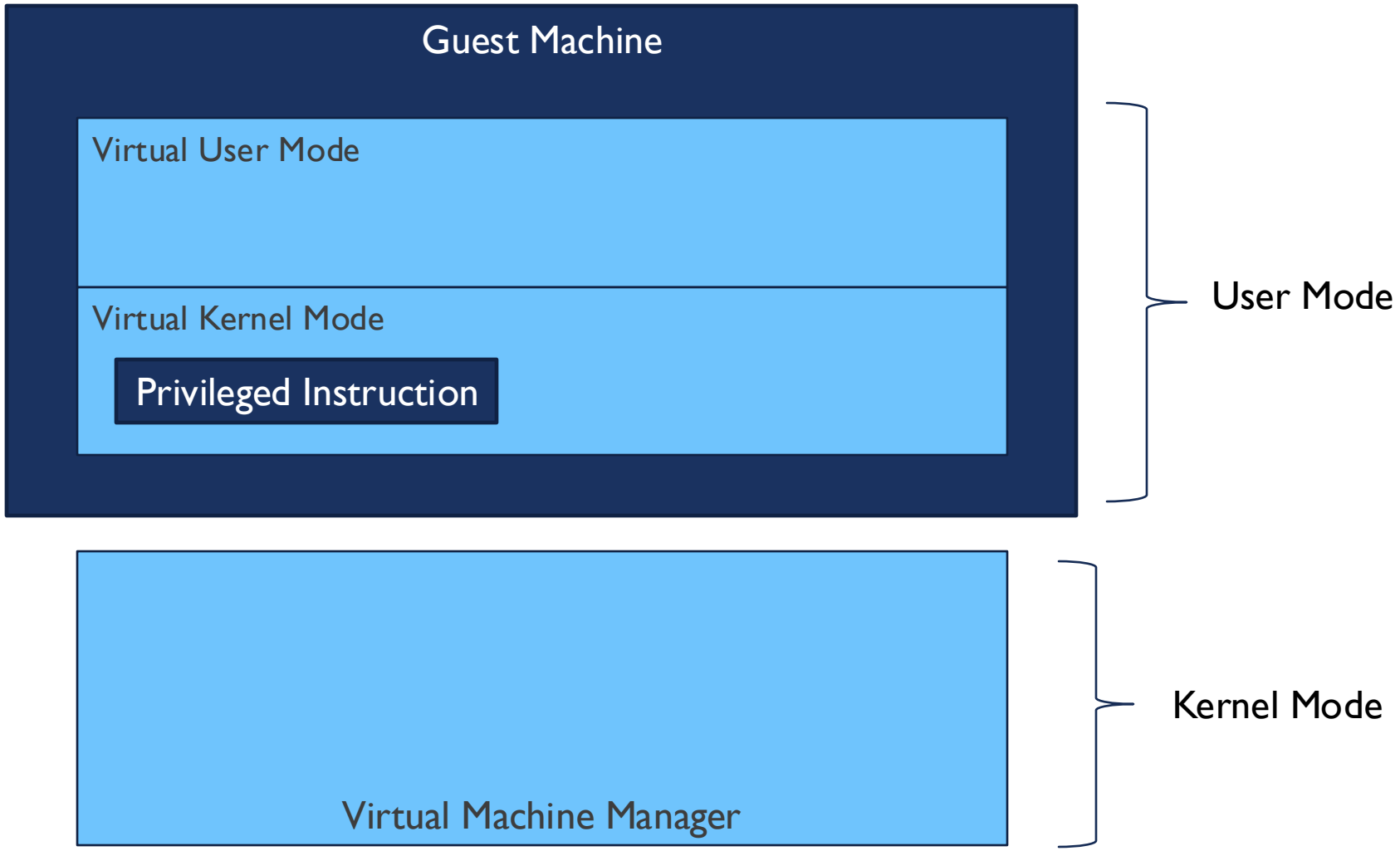

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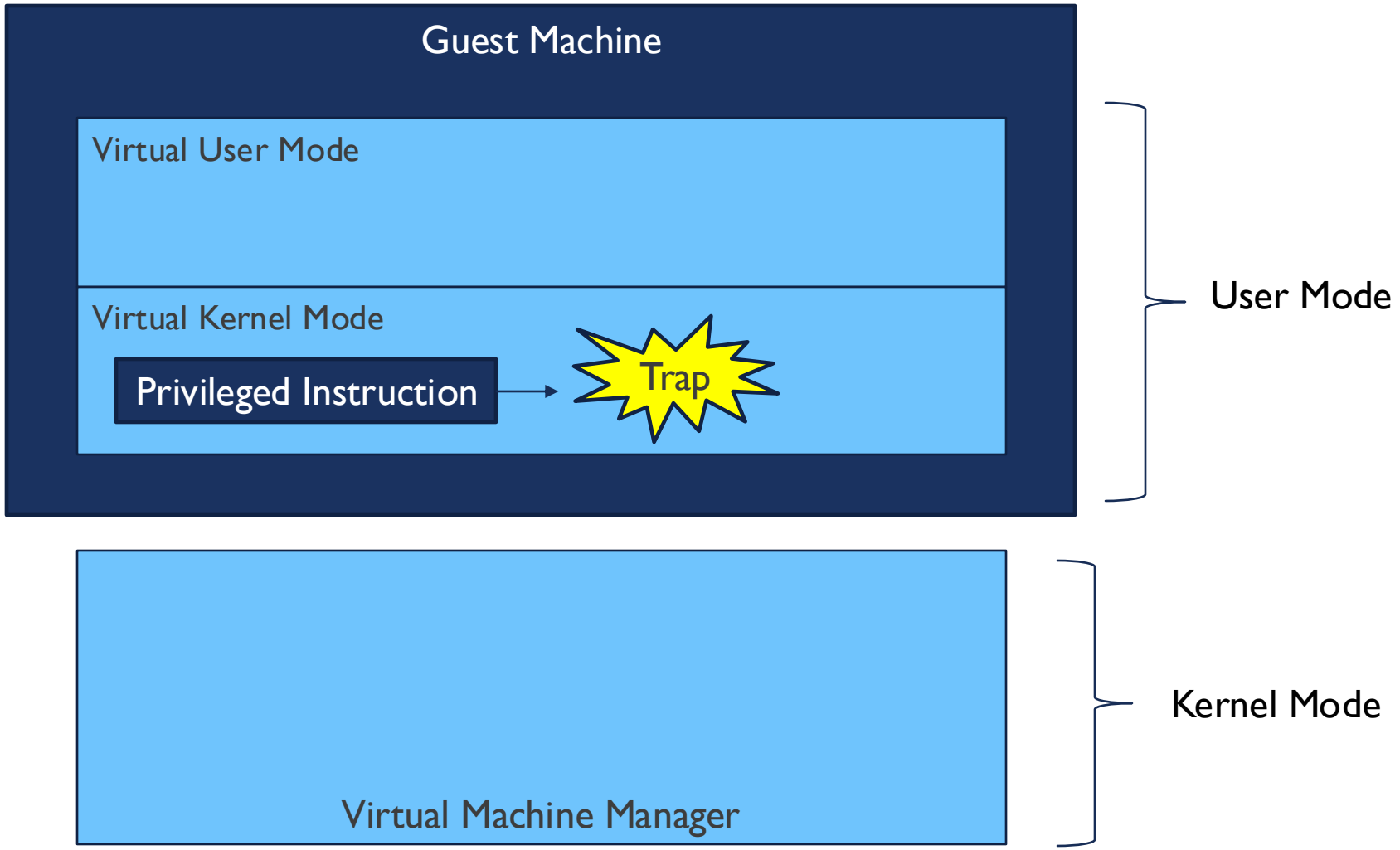

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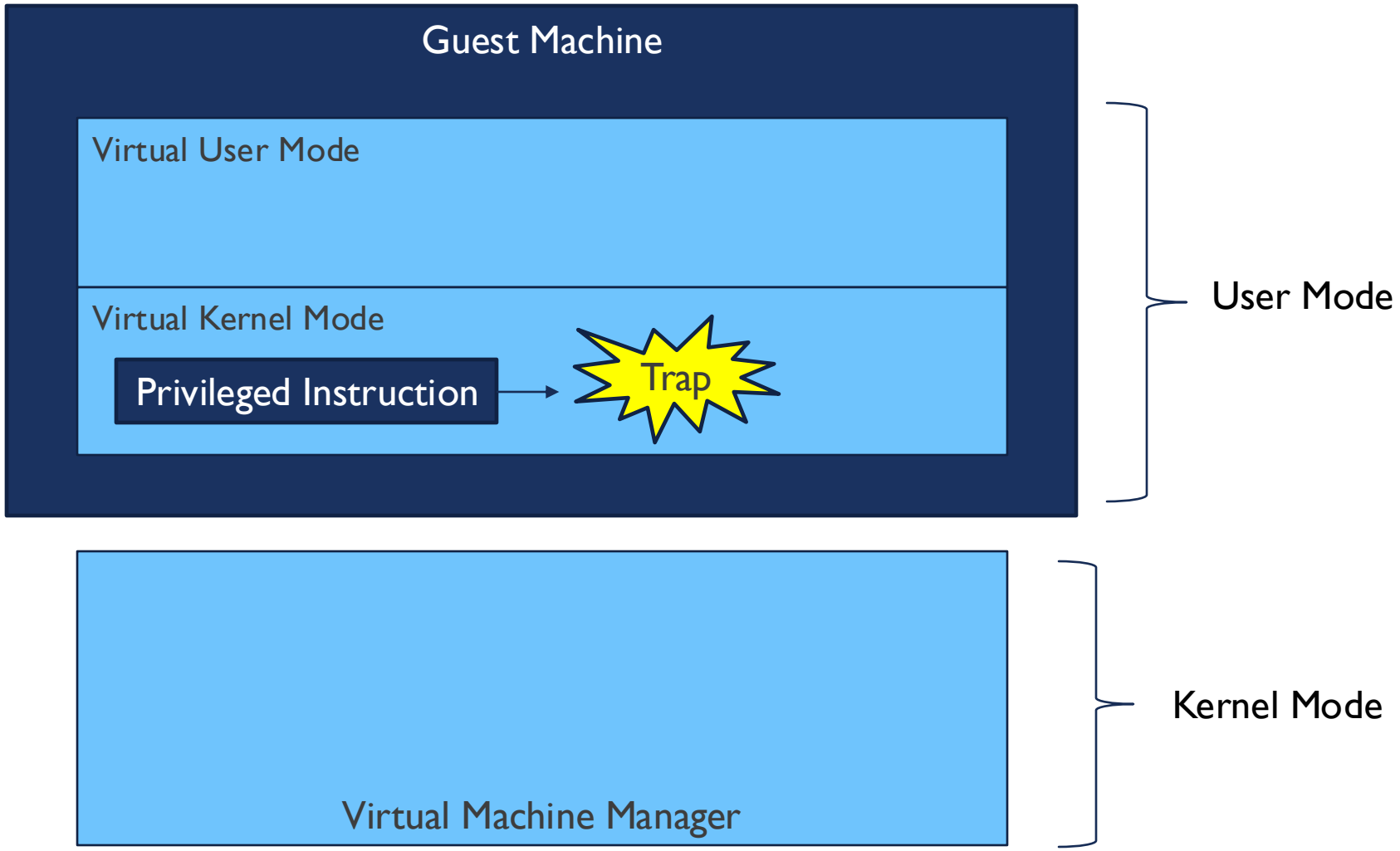

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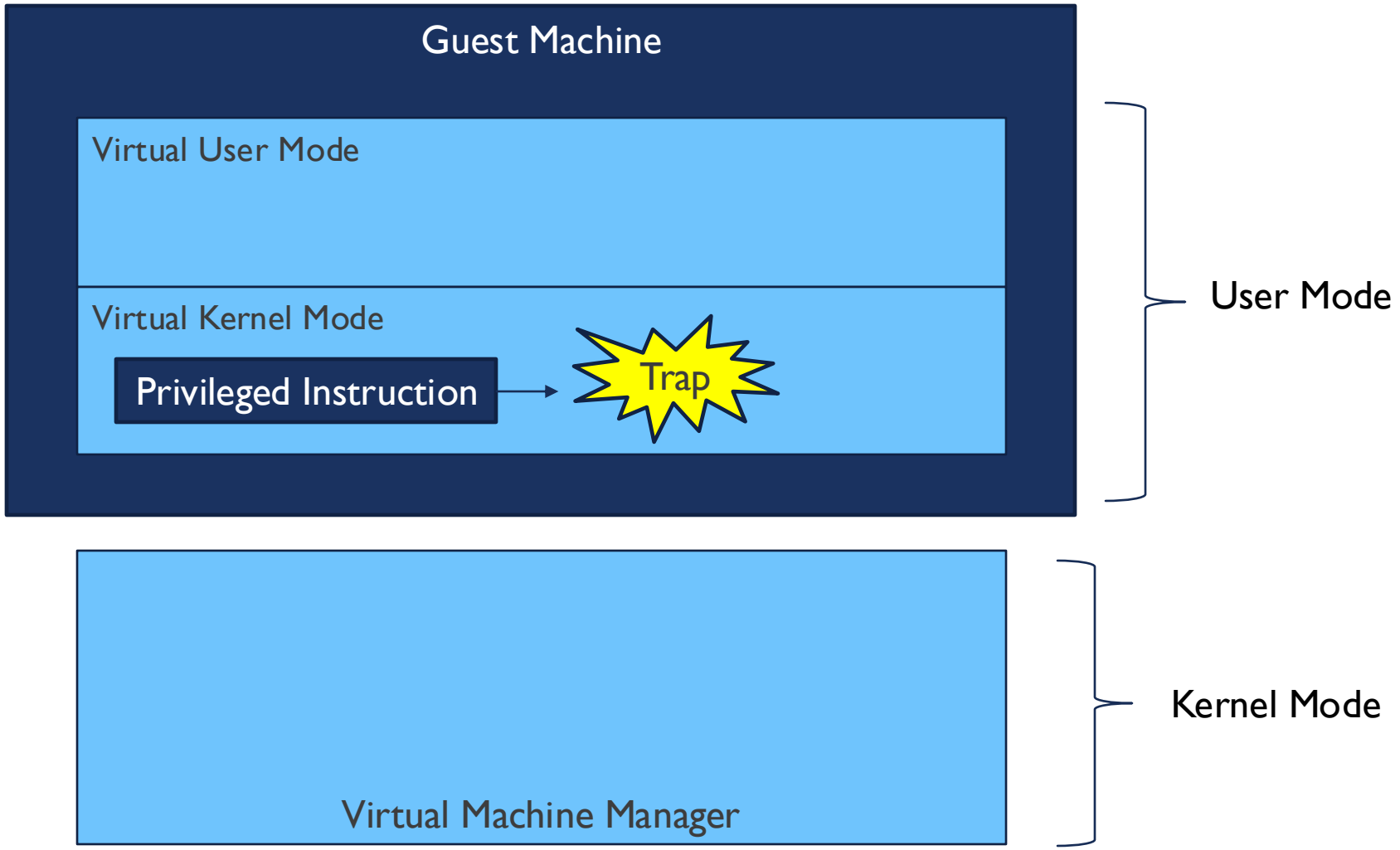

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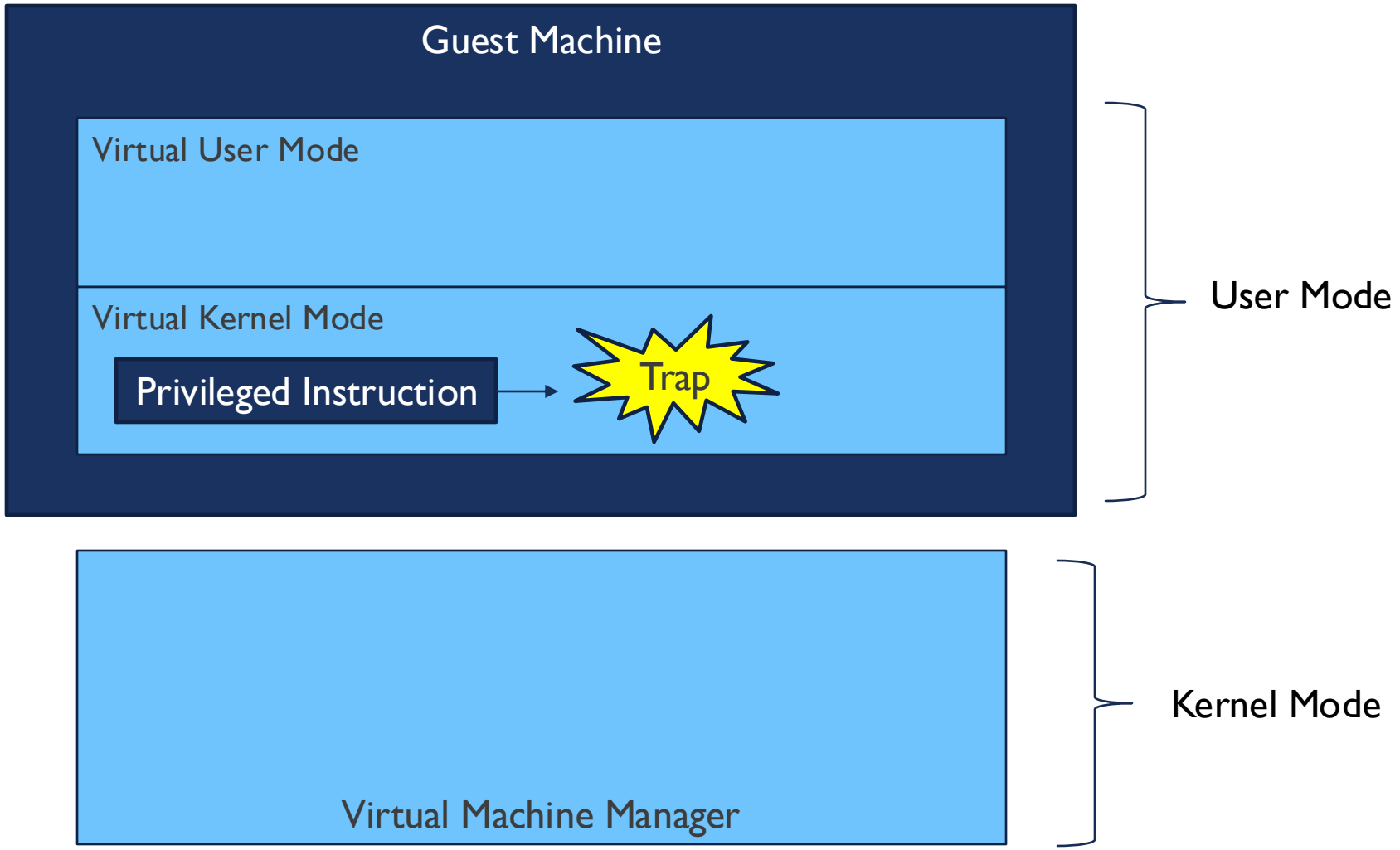
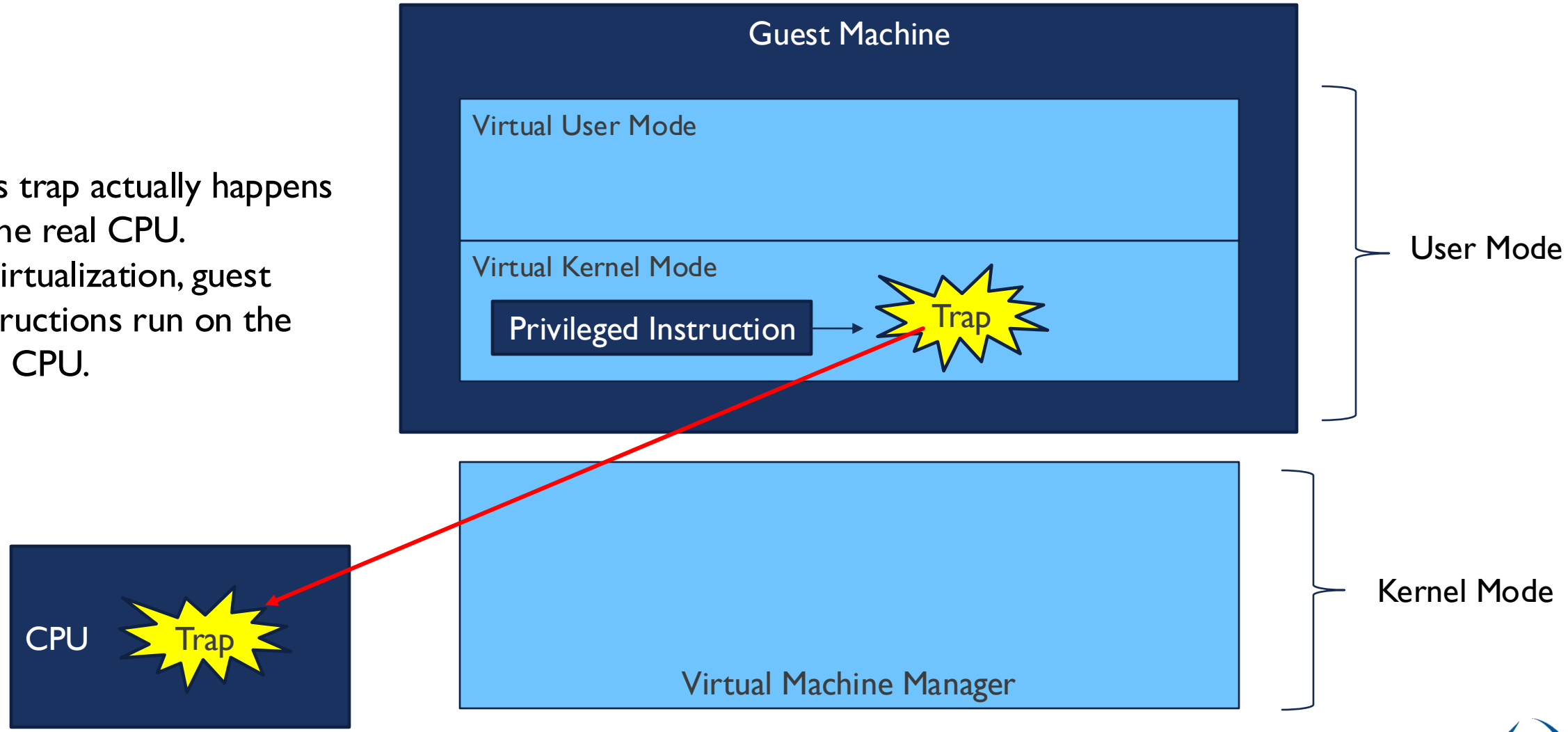


TRAP AND EMULATE

- This trap actually happens in the real CPU.
- In virtualization, guest instructions run on the real CPU.



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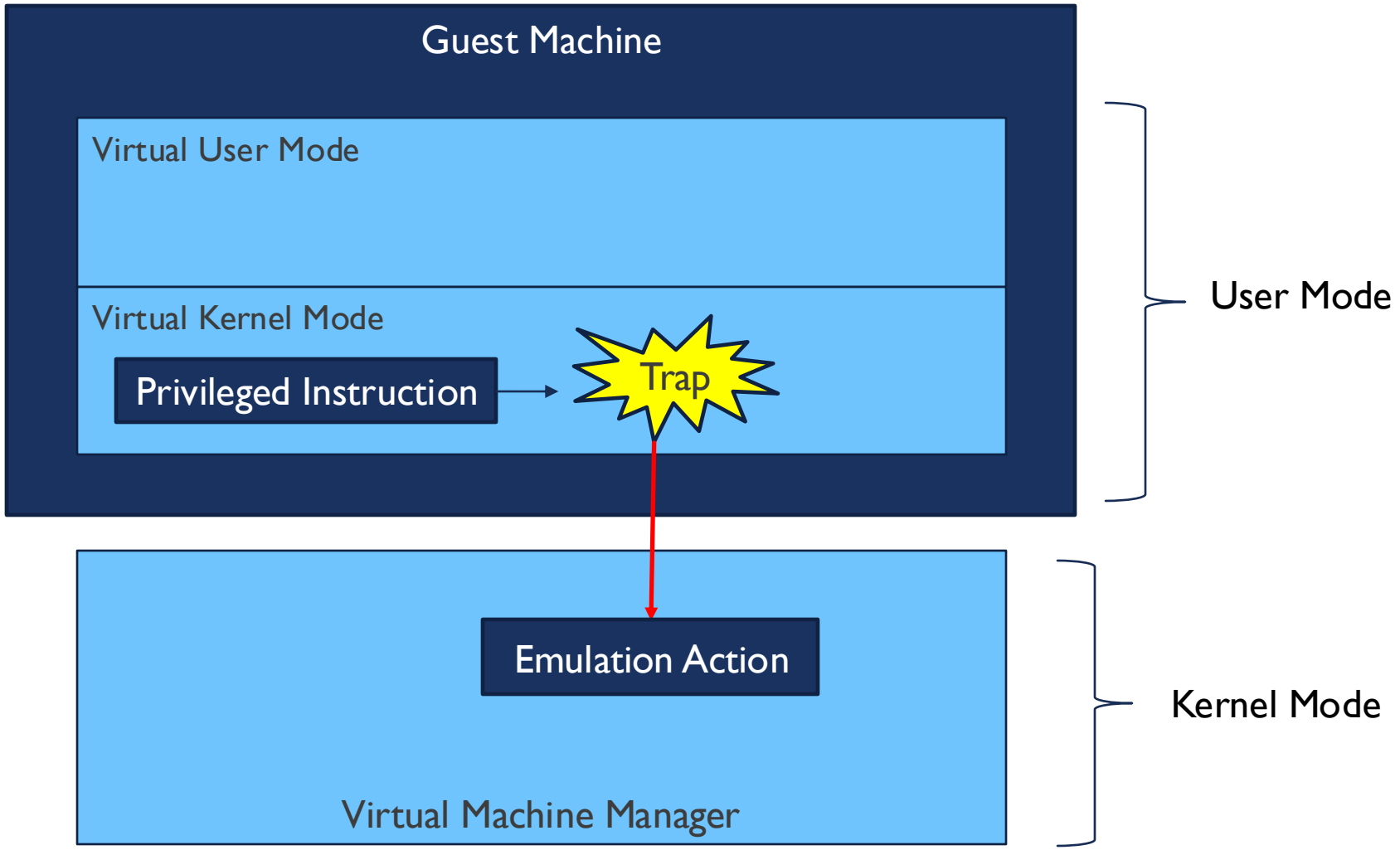

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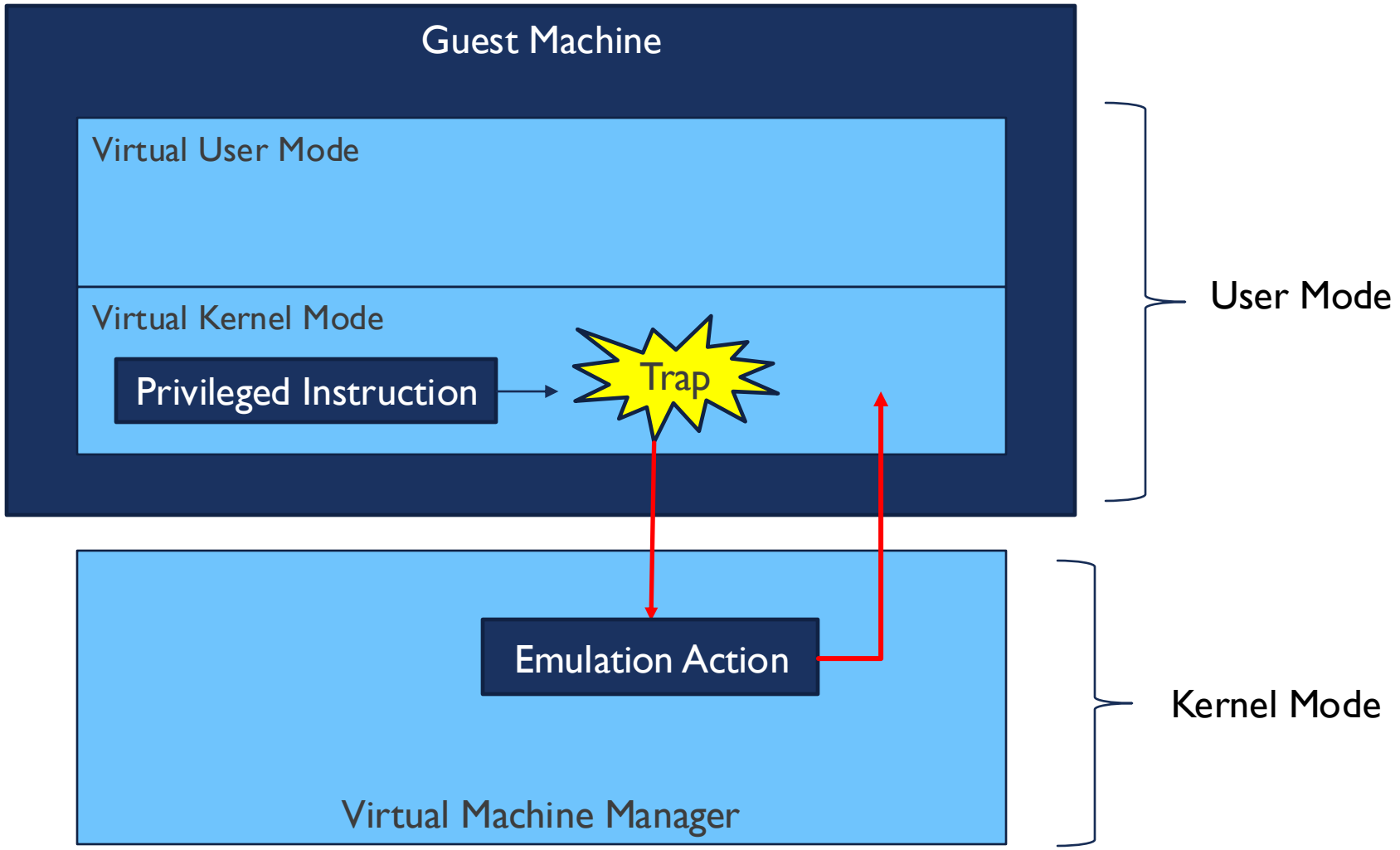

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- The VMM then resumes the guest machine program.

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`popf` can execute both in kernel or user but behaves differently in each mode.

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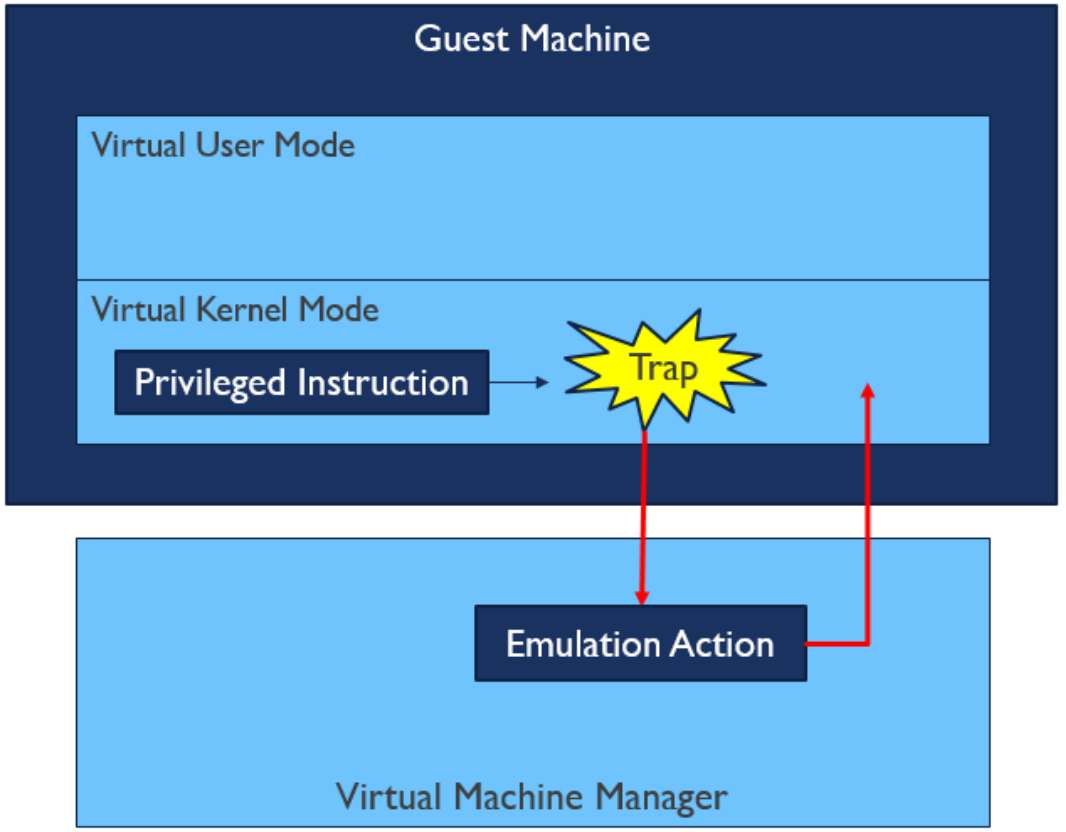

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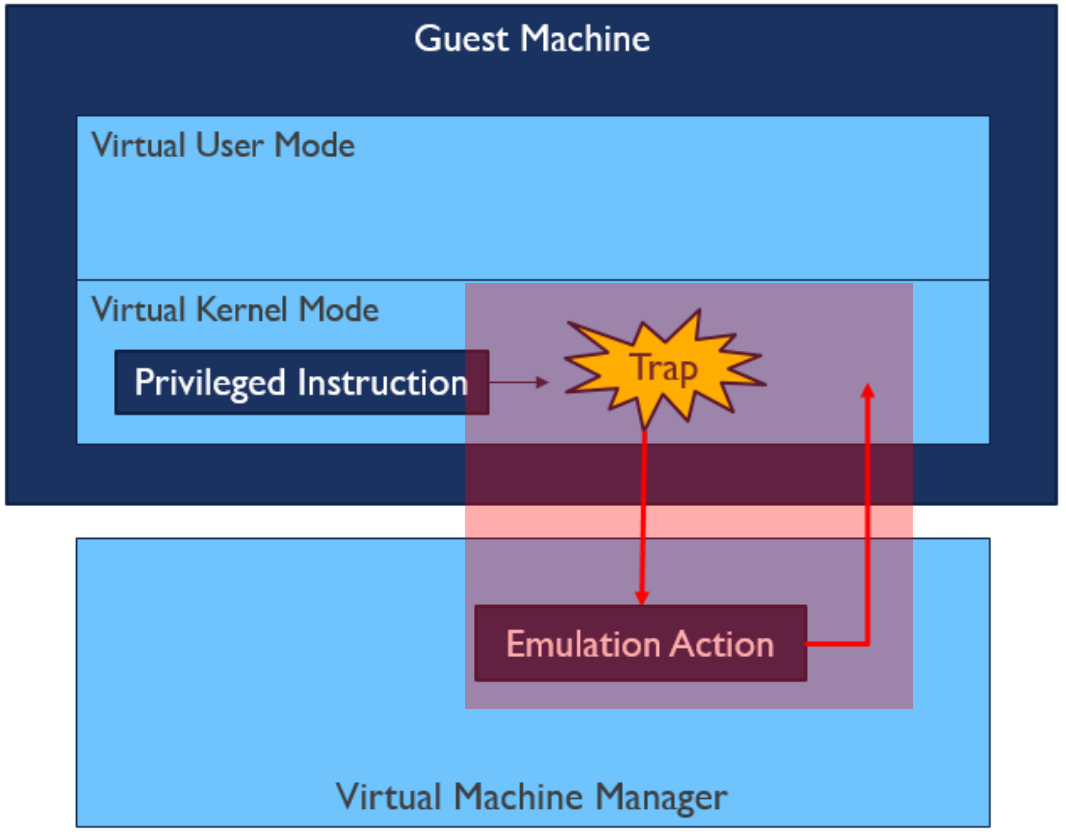

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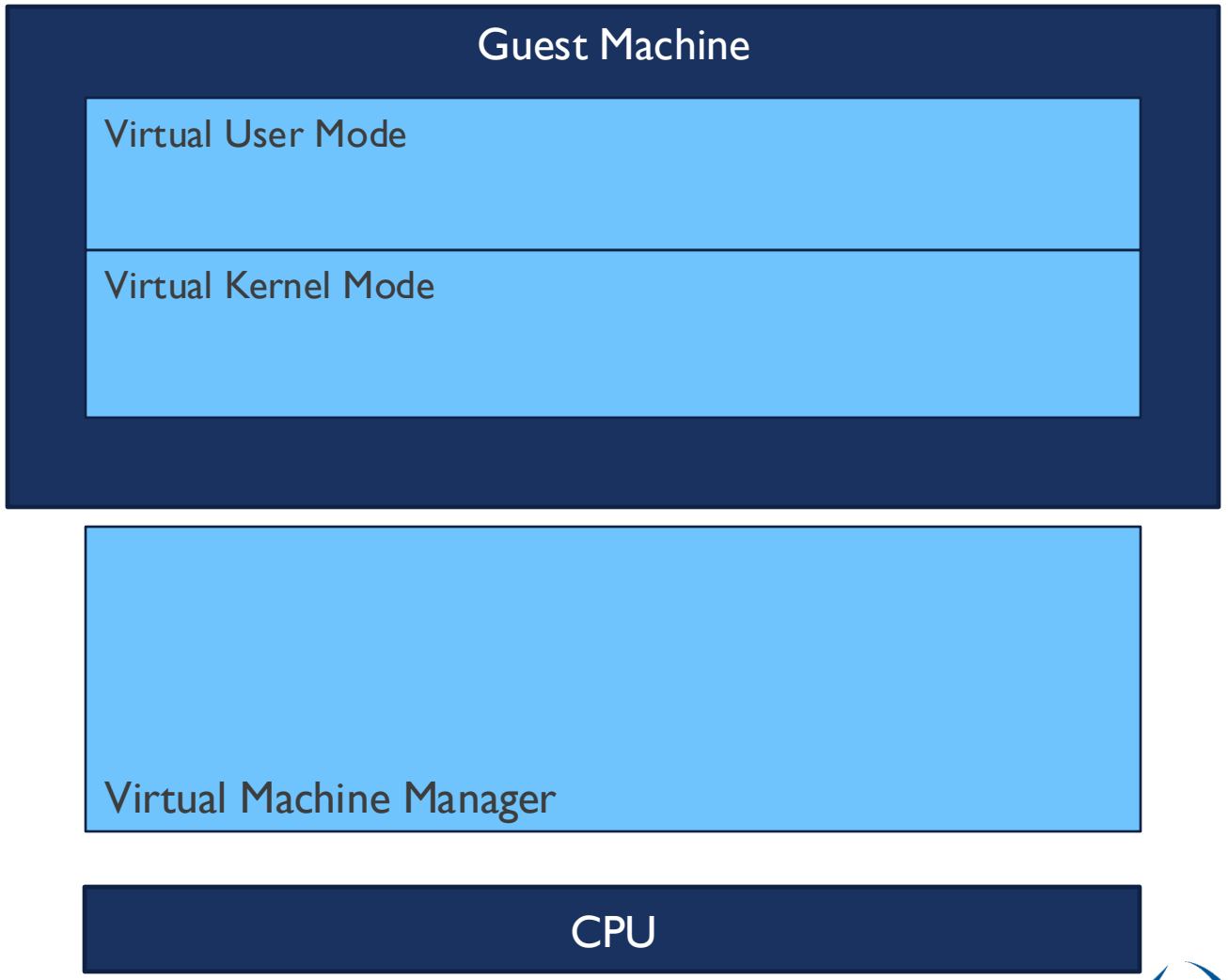

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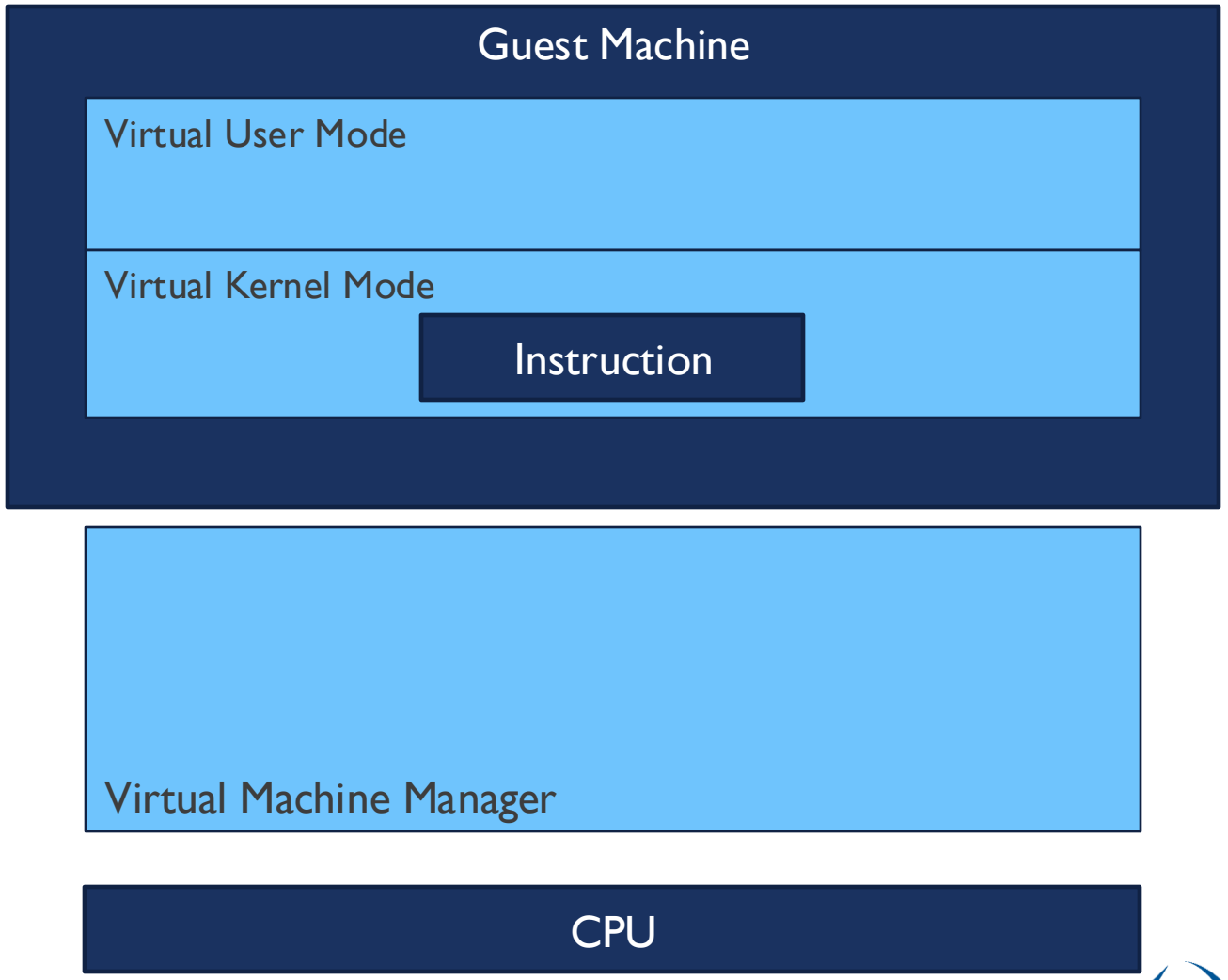

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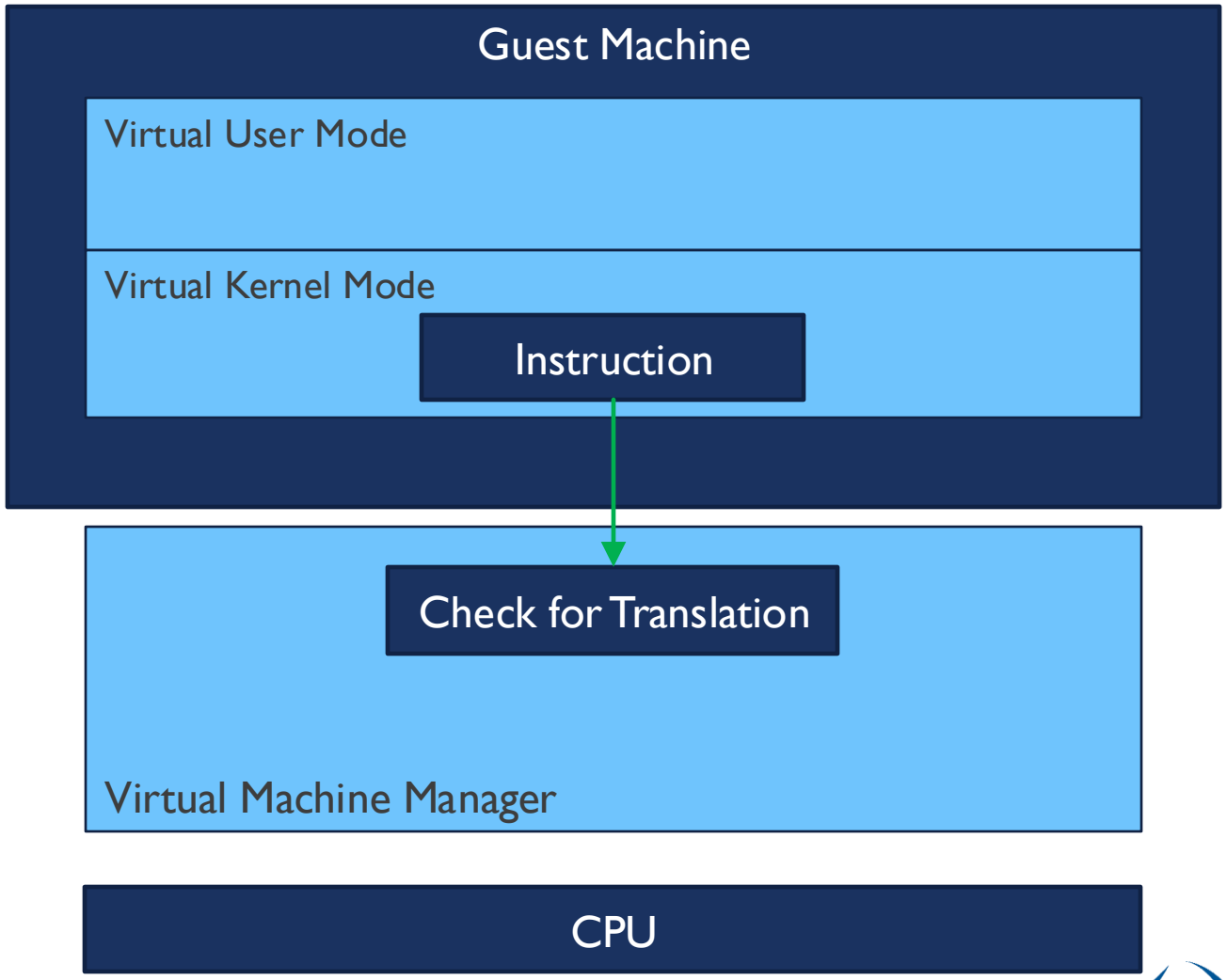

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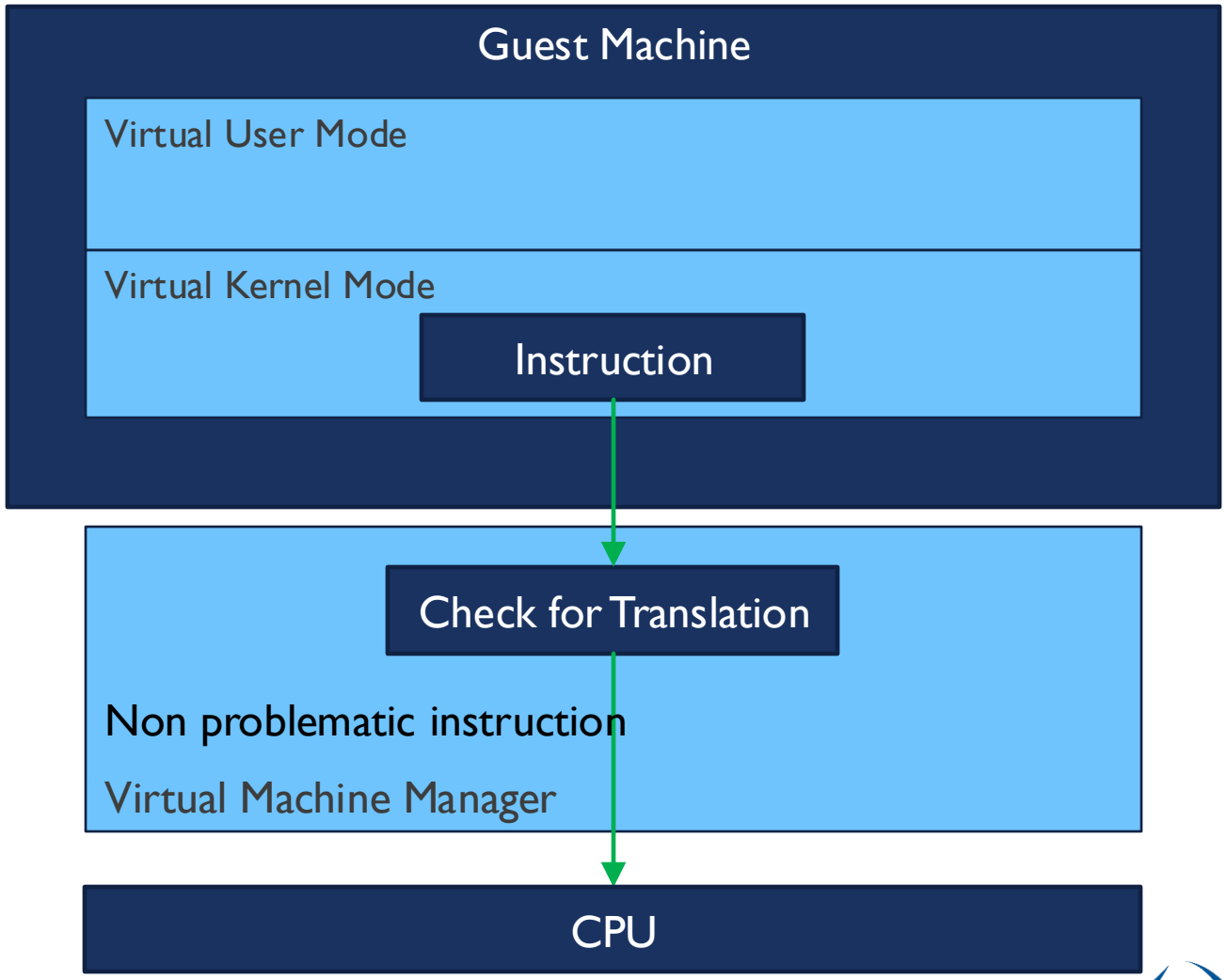

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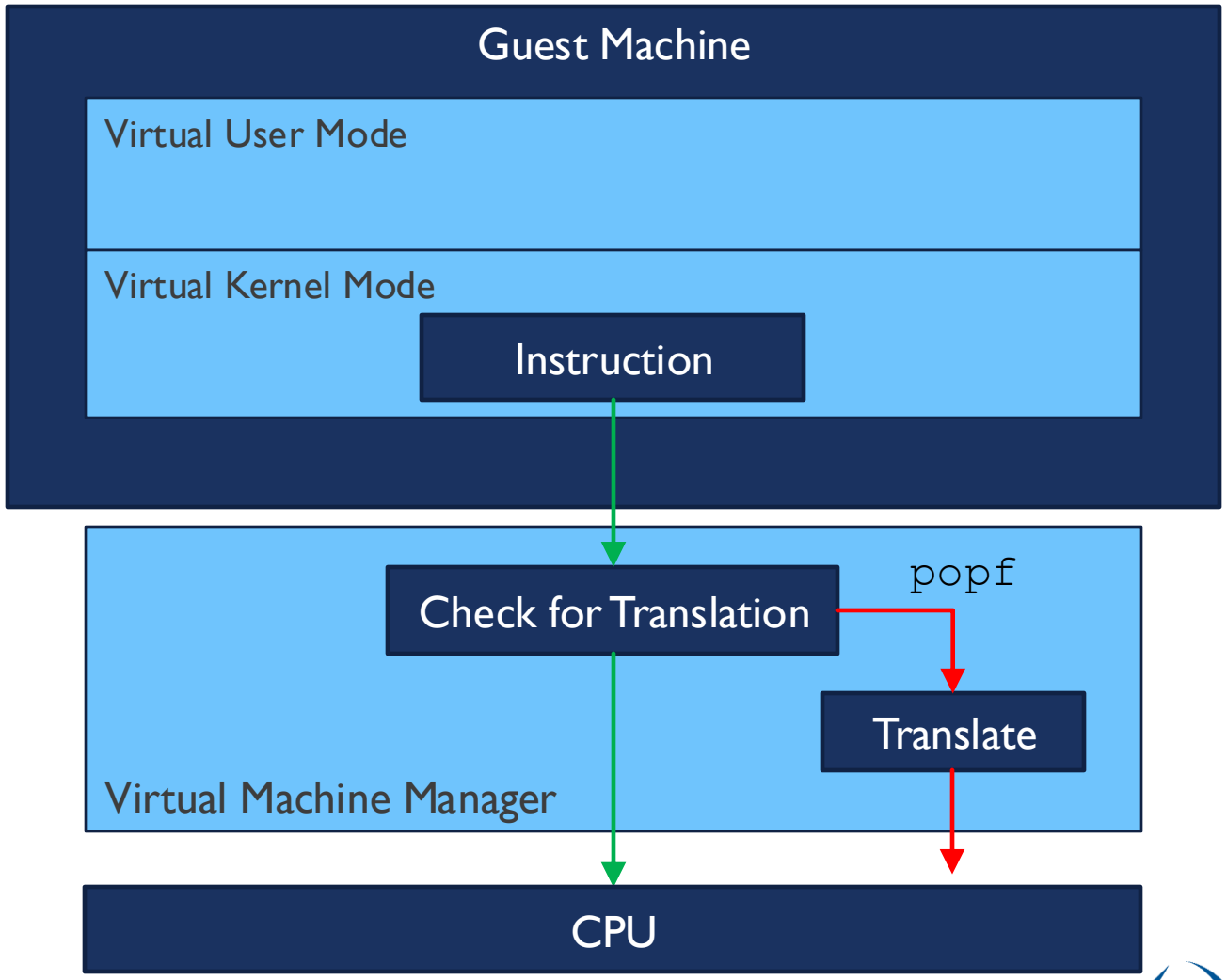

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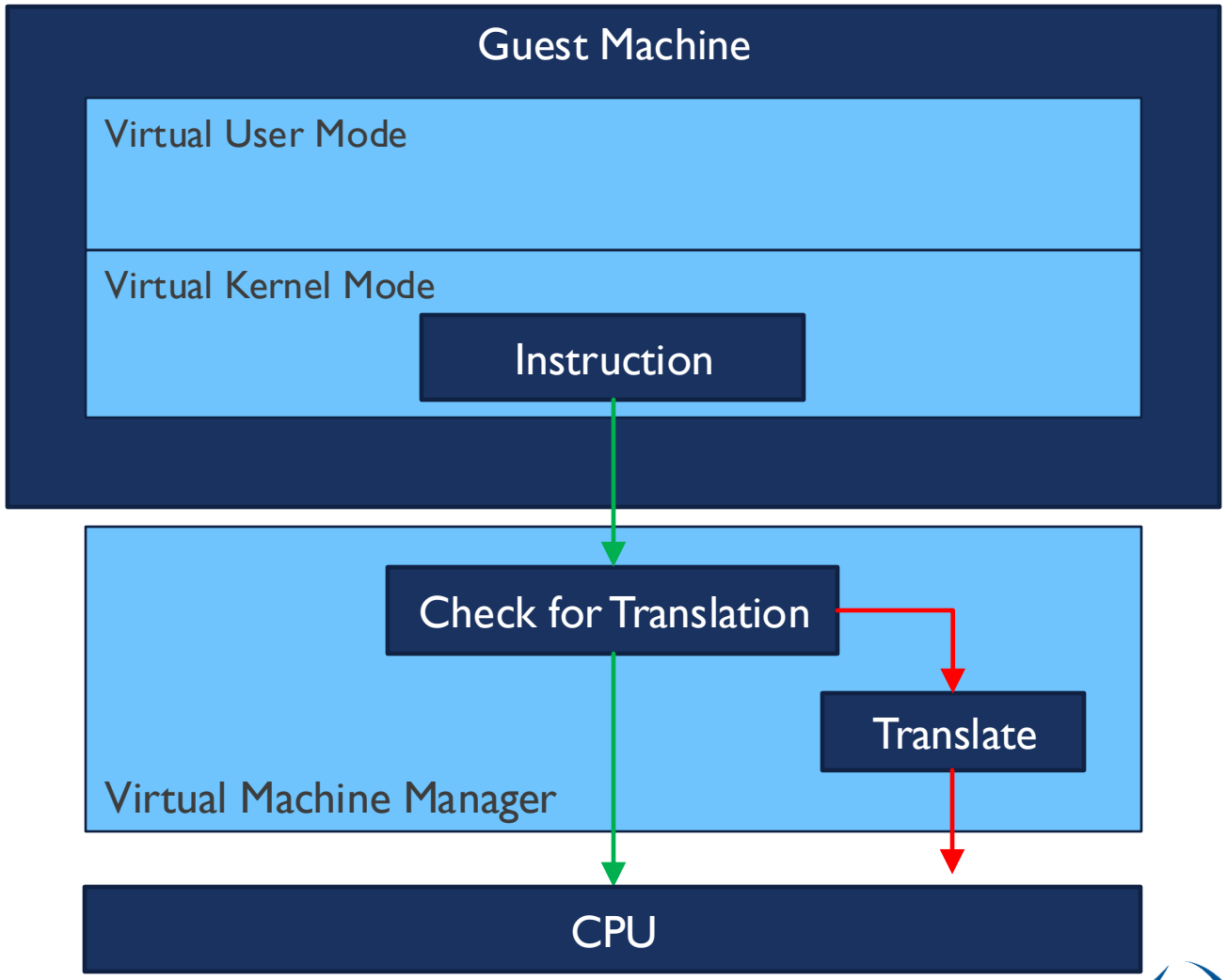
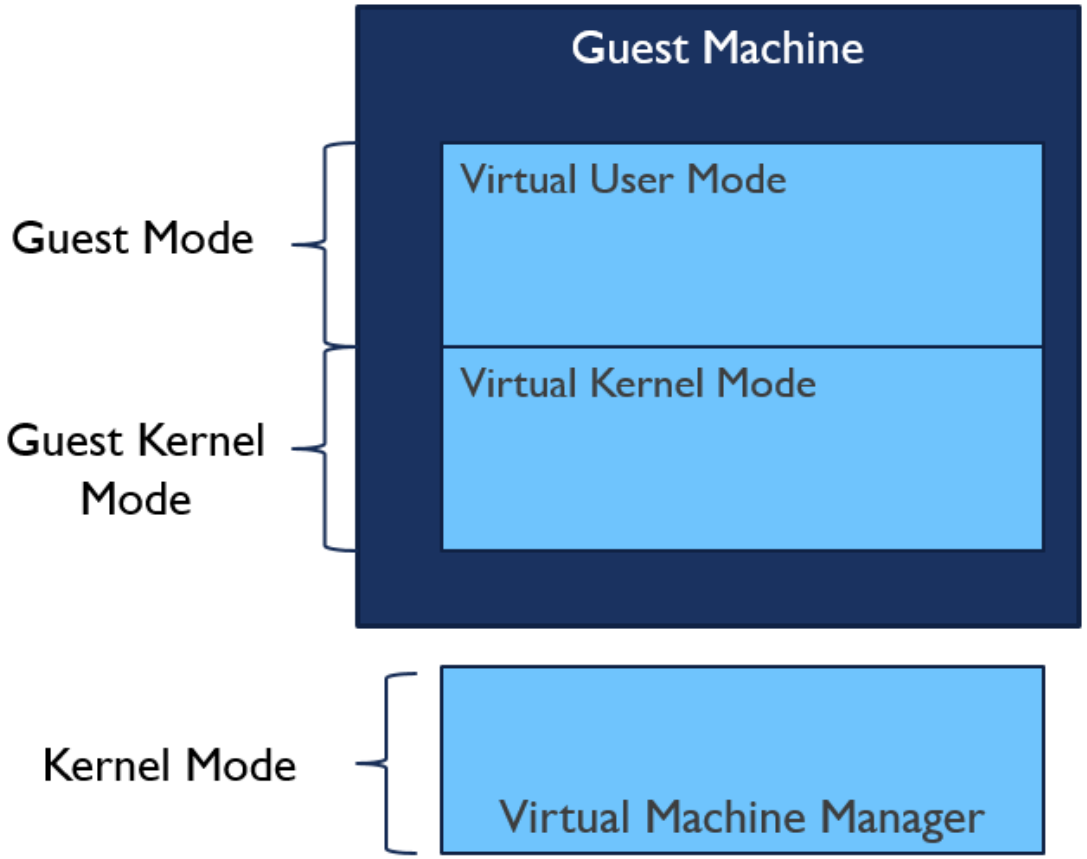


HARDWARE SUPPORT

- All virtualization needs some HW support
- More support -> more feature rich, stable, better performance of guests
- Intel added new **VT-x** instructions in 2005 and AMD the **AMD-V** instructions in 2006
  - CPUs with these instructions remove need for binary translation
  - Generally define more CPU modes – "guest" and "host"
- HW support for Nested Page Tables, DMA, interrupts as well over time



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- Can't use unmodified OS.
- Every OS must be modified before running on the virtual machine.

- With the advanced hardware support for virtualization … Para virtualization is no longer needed.
- Hardware-accelerated virtualization now shows similar performance: no need to modify OS anymore.
- Still used in some specialized system.

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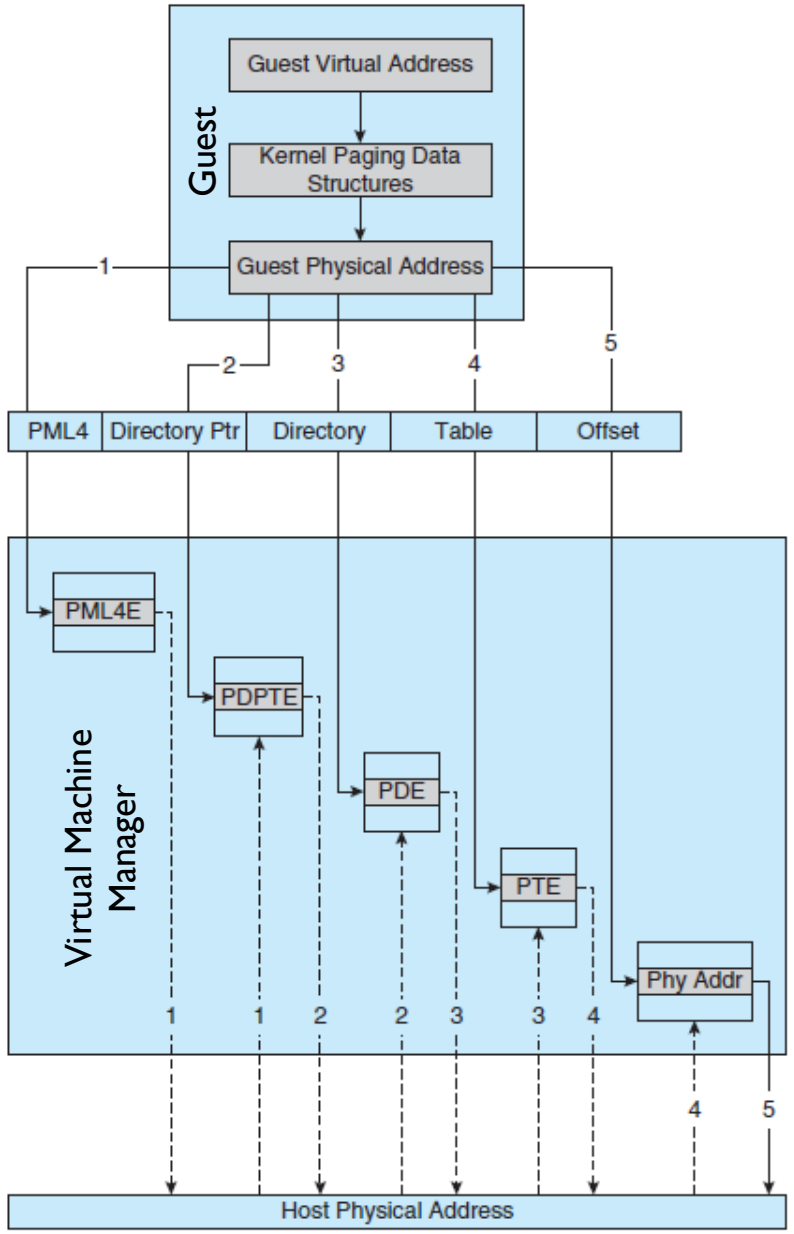

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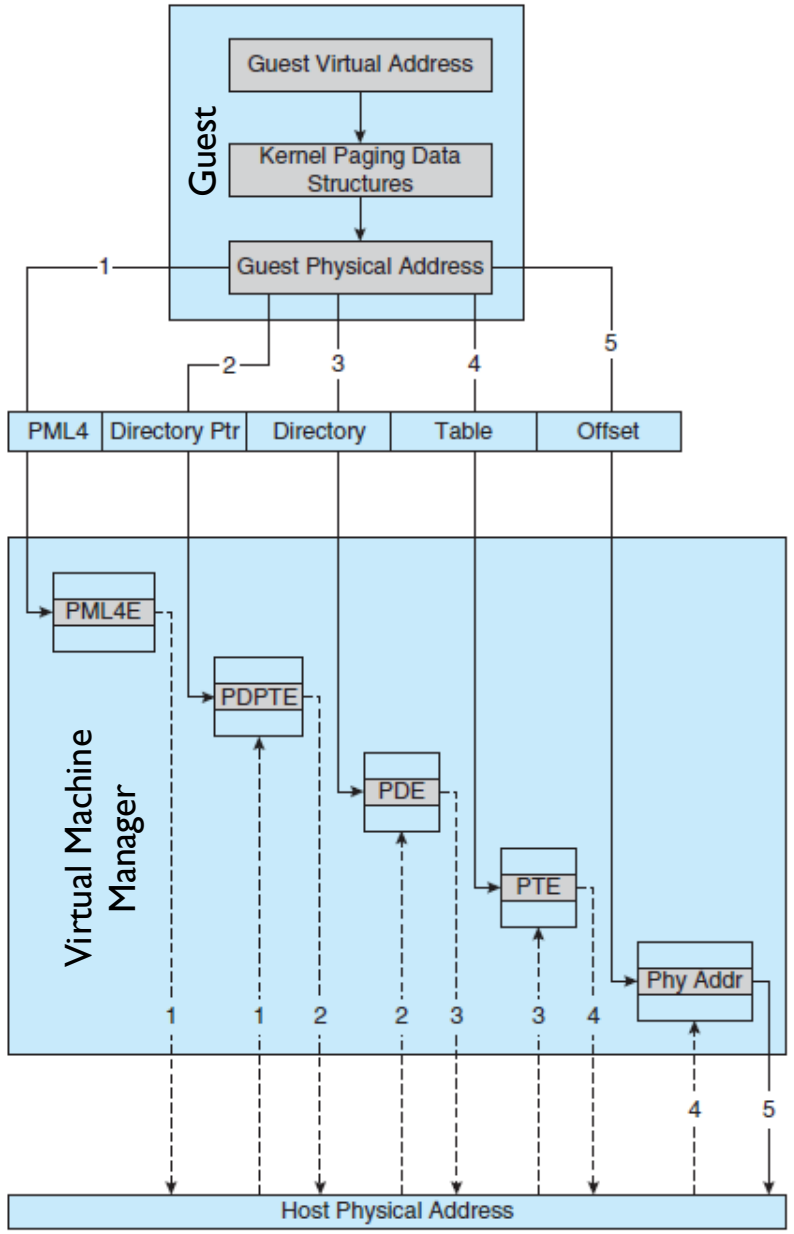

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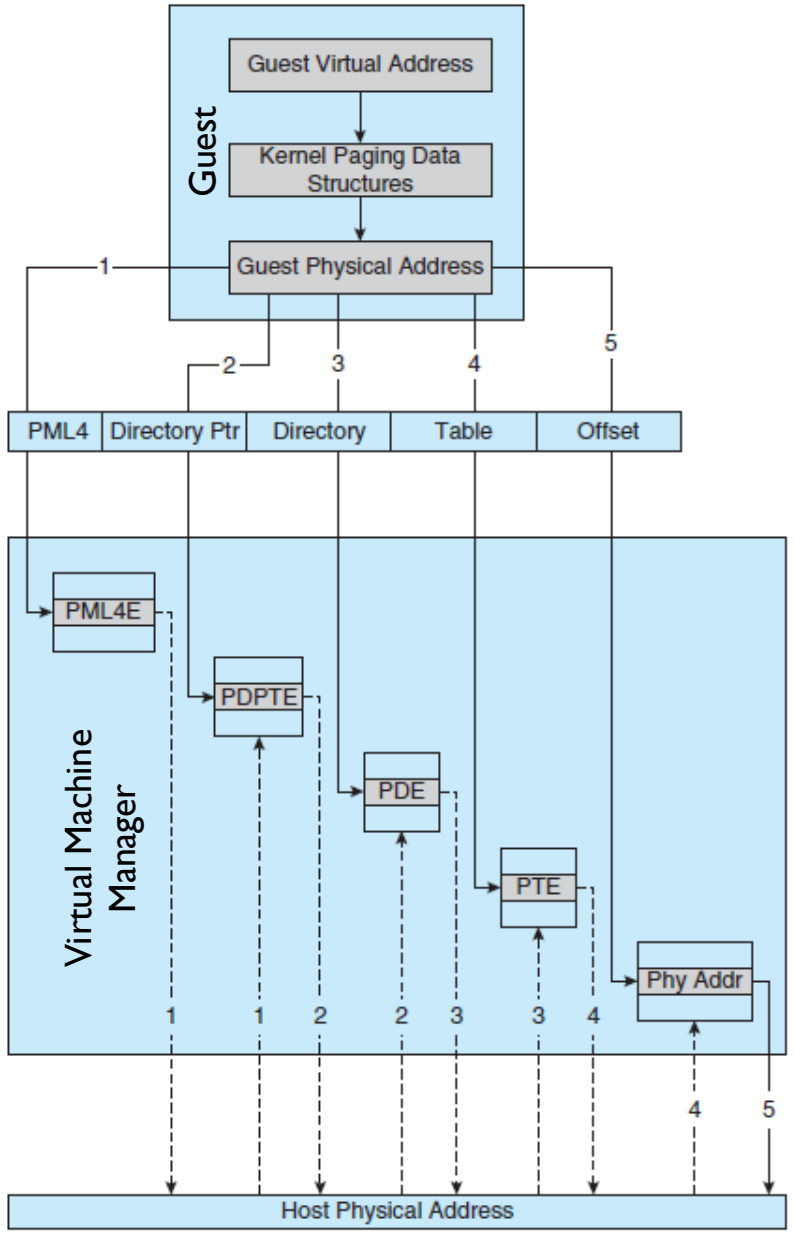
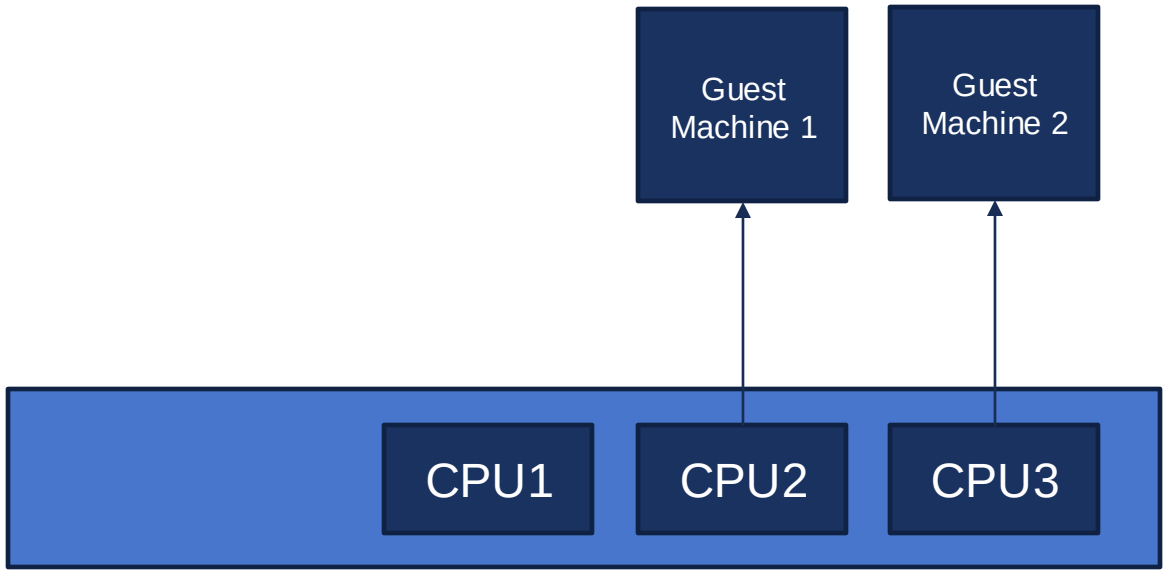
Why is it needed?
The guest doesn't have access to physical memory.



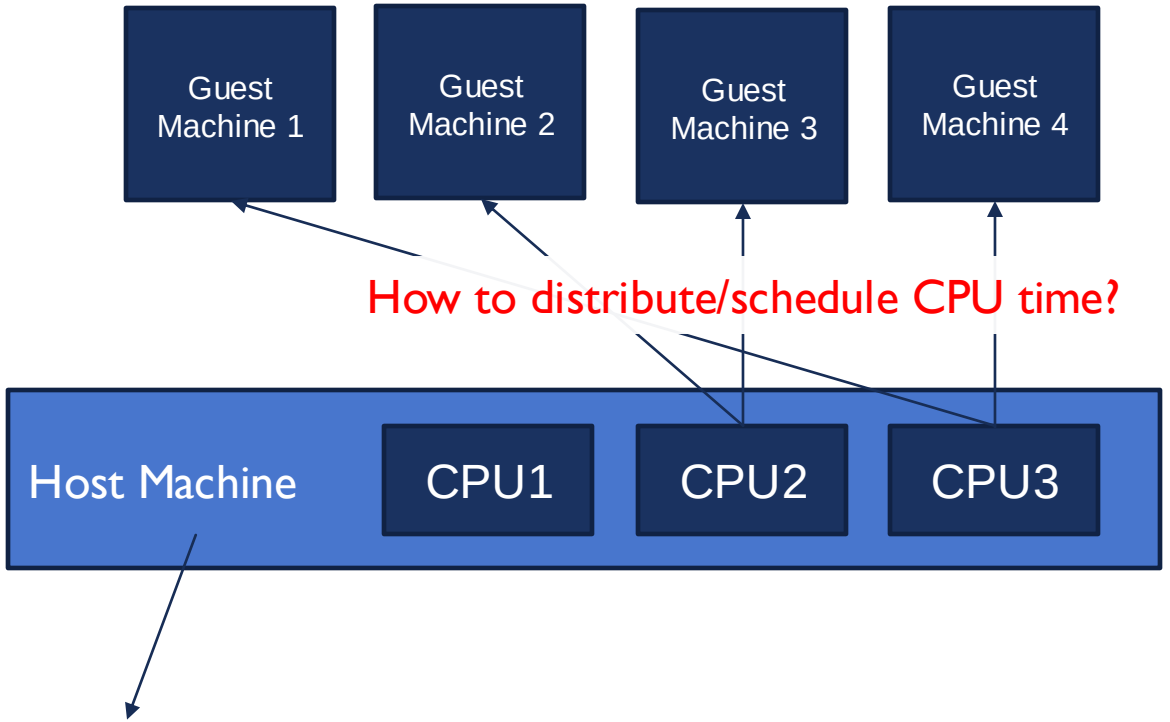
CPU MAPPING

- **How Are CPUs Mapped to virtual Machines?**



CPU MAPPING

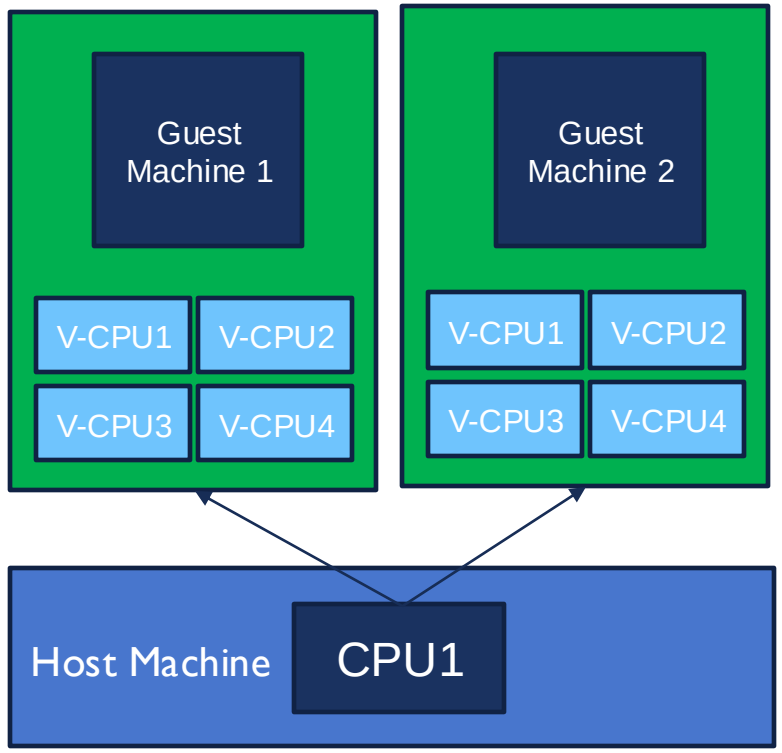
- What if we have too many virtual machines?



Host machine also needs access to CPU for VMM and maybe other applications …

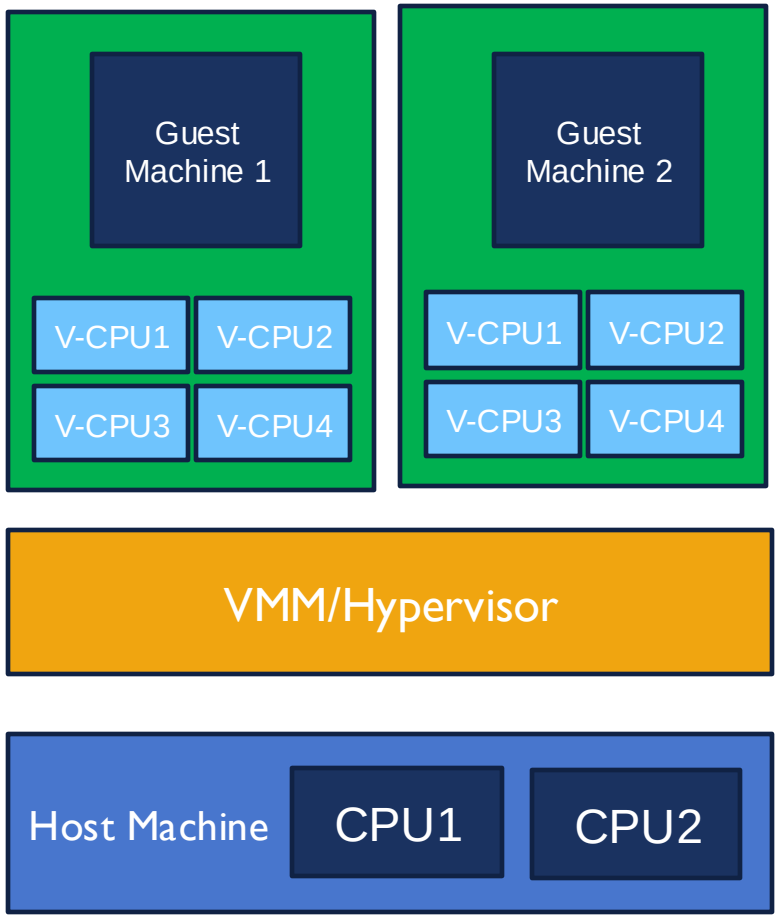
CPU MAPPING

- Sometimes VMs have multicore while the actual system has a single CPU (single core).



CPU MAPPING

- If there are enough CPUs … just assign one to one.
- Assignment does not mean dedicated/exclusive access. It just indicates that Guest Machine 1 code can run only on CPU1.
- CPU1 may run other code as well, like VMM code or some other non-virtualized code.
- Hypervisor does all Guest Machine scheduling.



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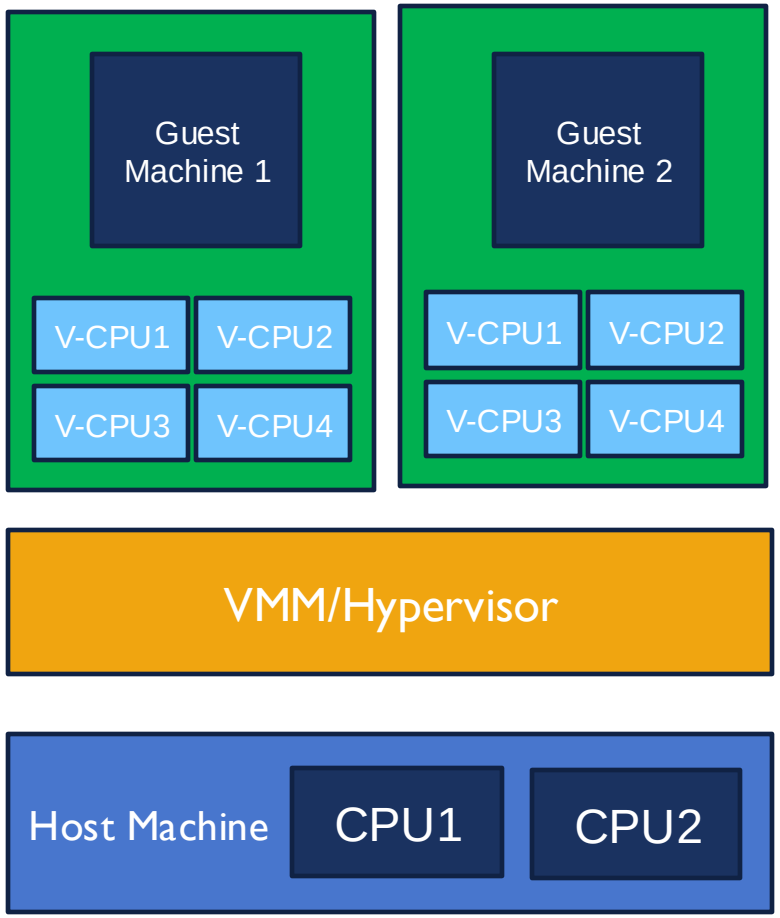
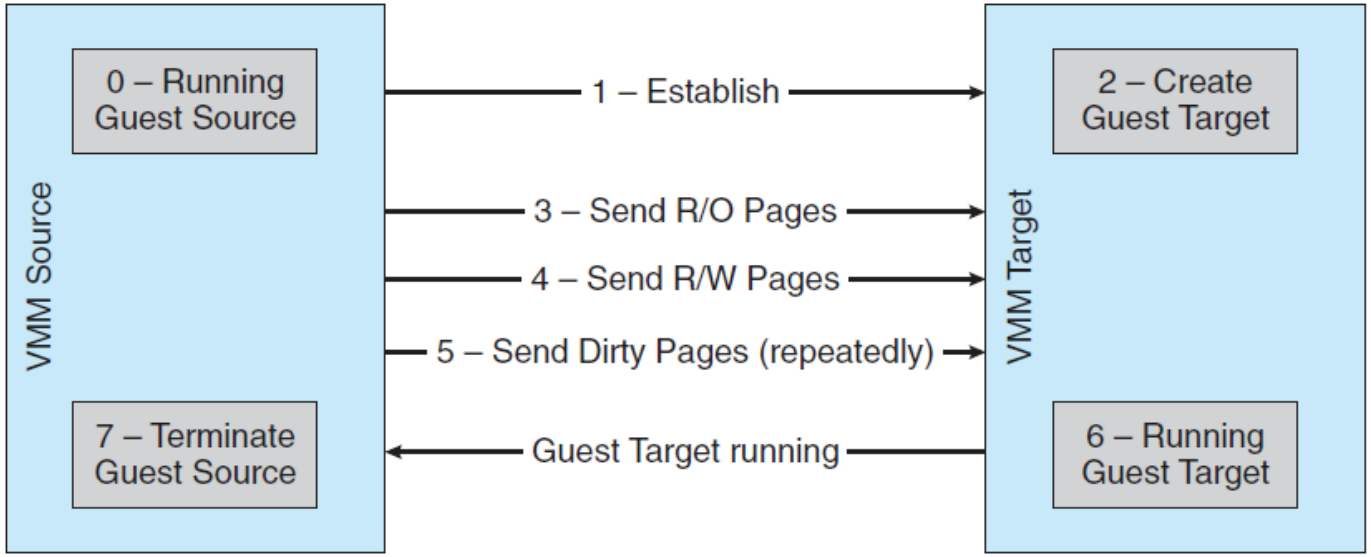
- Assignment does not mean dedicated/exclusive access. It just indicates that Guest Machine 1 code can run only on CPU1.
- CPU1 may run other code as well, like VMM code or some other non-virtualized code.
- Hypervisor does all Guest Machine scheduling.
- Overcommitment: Virtual CPU count exceeds real CPU by a large margin. Causes performance degradation.



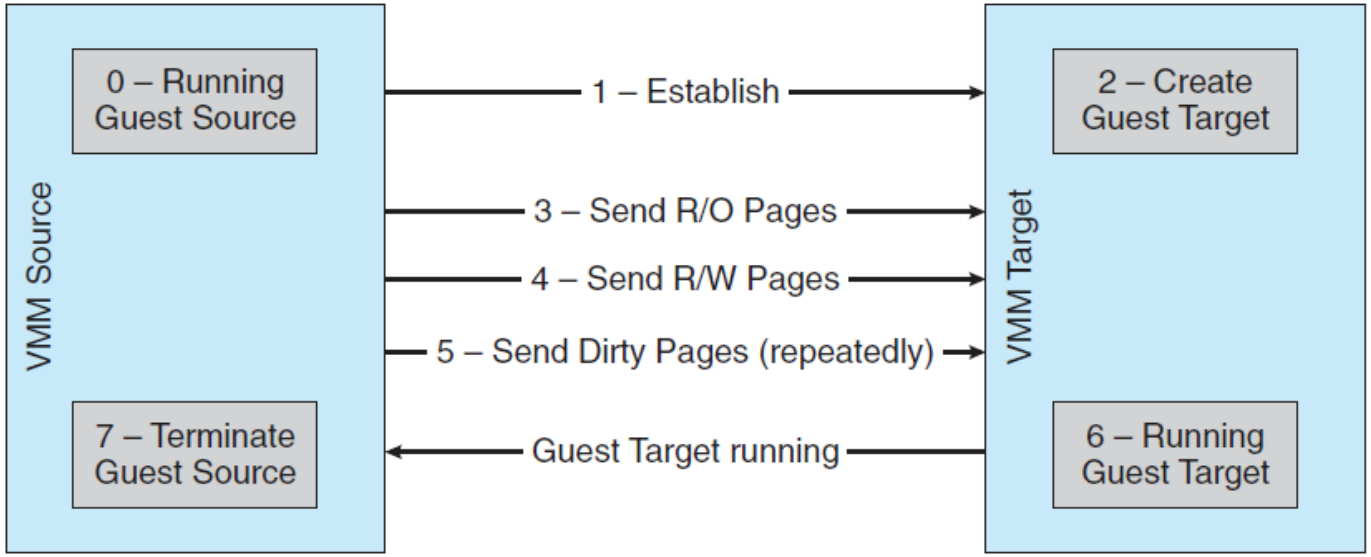
LIVE MIGRATION

- Running guest can be moved between systems, without interrupting user access to the guest or its apps.
- Very useful for resource management, maintenance downtime windows, etc



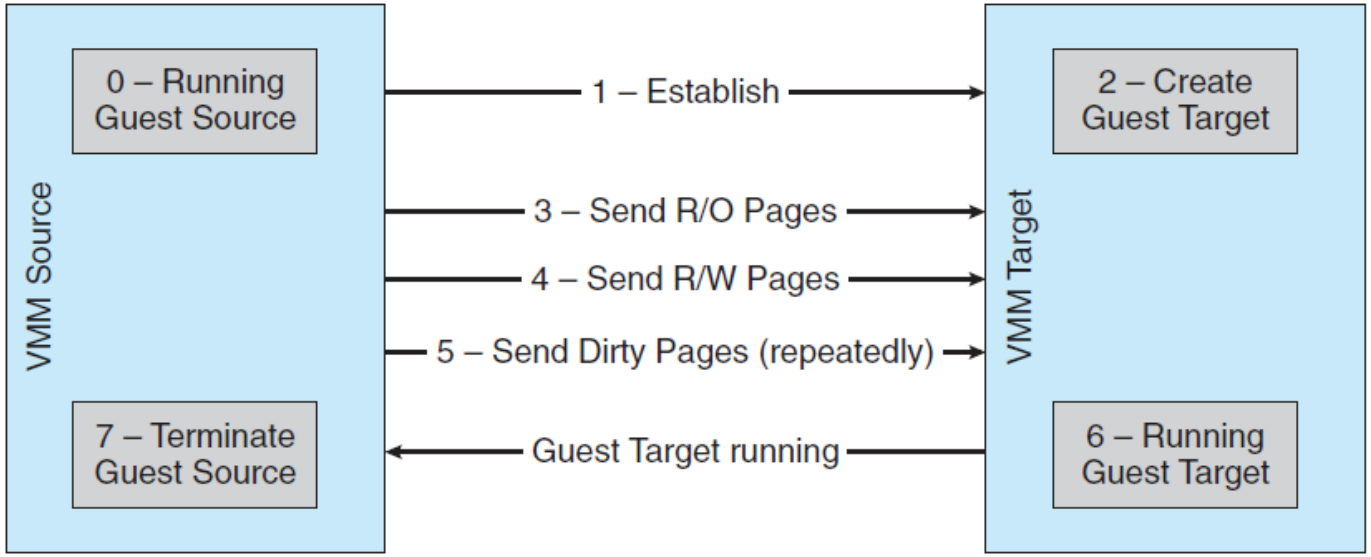
LIVE MIGRATION

1. The source VMM establishes a connection with the target VMM
2. The target creates a new guest by creating a new VCPU, etc
3. The source sends all read-only guest memory pages to the target



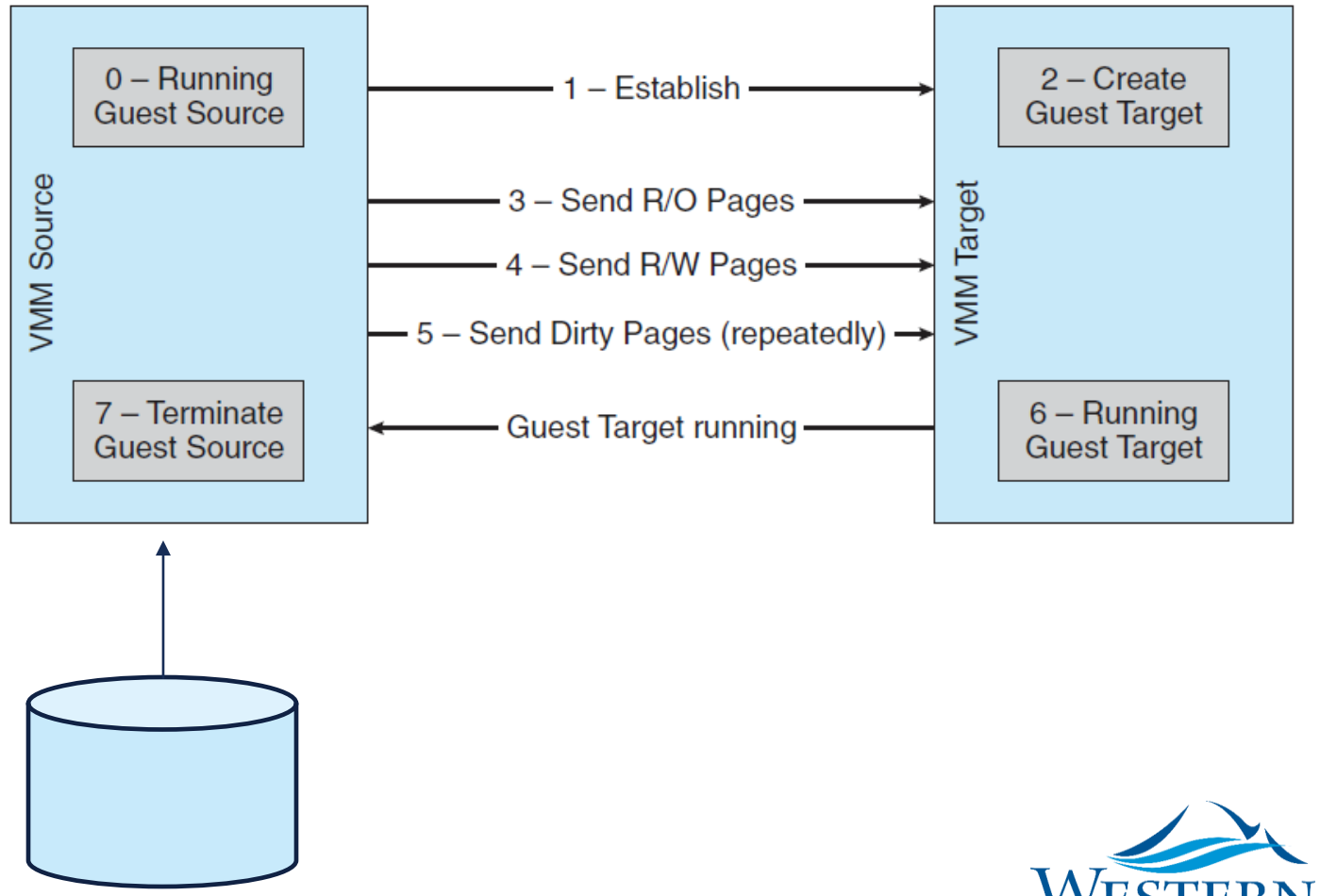
LIVE MIGRATION

4. The source sends all read-write pages to the target, marking them as clean
5. The source repeats step 4, as during that step some pages were probably modified by the guest and are now dirty
6. When cycle of steps 4 and 5 becomes very short, source VMM freezes guest, sends VCPU's final state, sends other state details, sends final dirty pages, and tells target to start running the guest



LIVE MIGRATION

Q: What about the system disk/mass storage?



LIVE MIGRATION

Q: What about the system disk/mass storage?

Disk is simply accessed remotely. Moving cost is too time consuming.