NoHype: Virtualized Cloud Infrastructure without the Virtualization

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Virtualized Cloud Infrastructure

- Run virtual machines on a hosted infrastructure

amazon web services™

the rackspace cloud

GOGRID Control in the Cloud™

Windows Azure

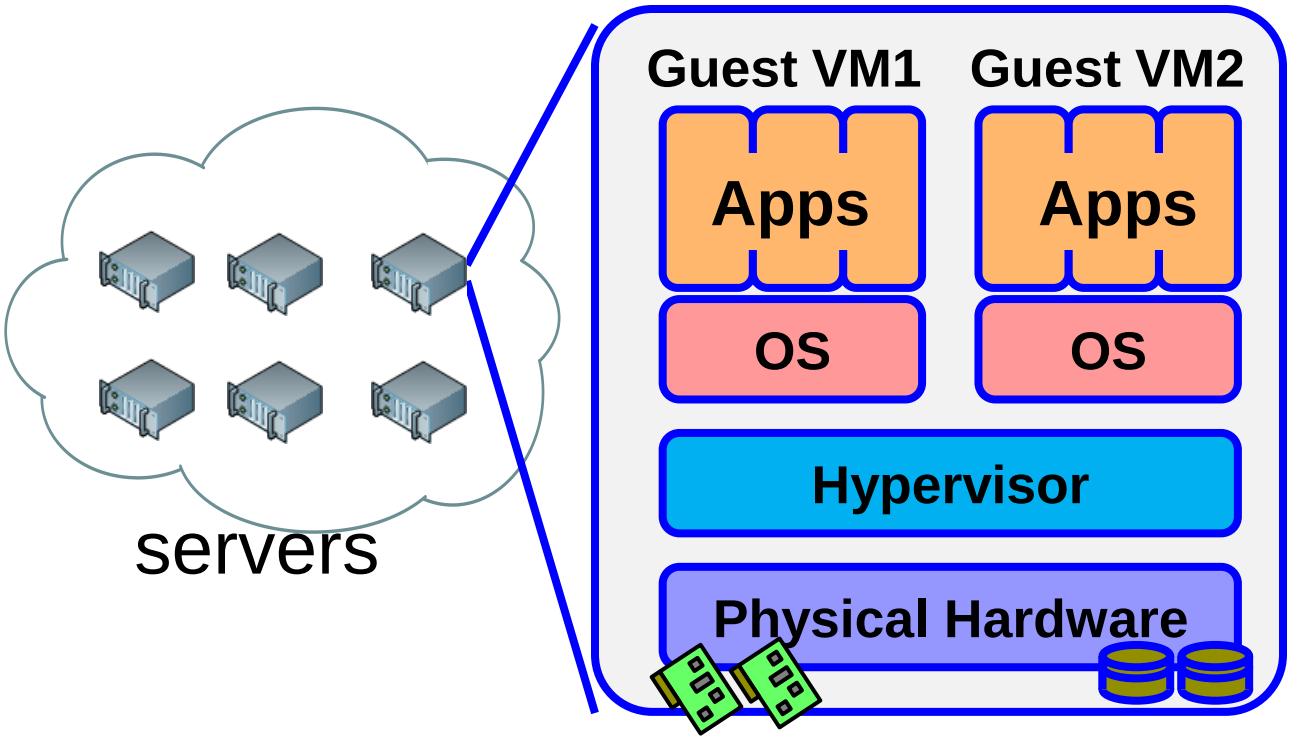
iland CLOUD INFRASTRUCTURE

3tera®

- Benefits…
  - Economies of scale
  - Dynamically scale (pay for what you use)

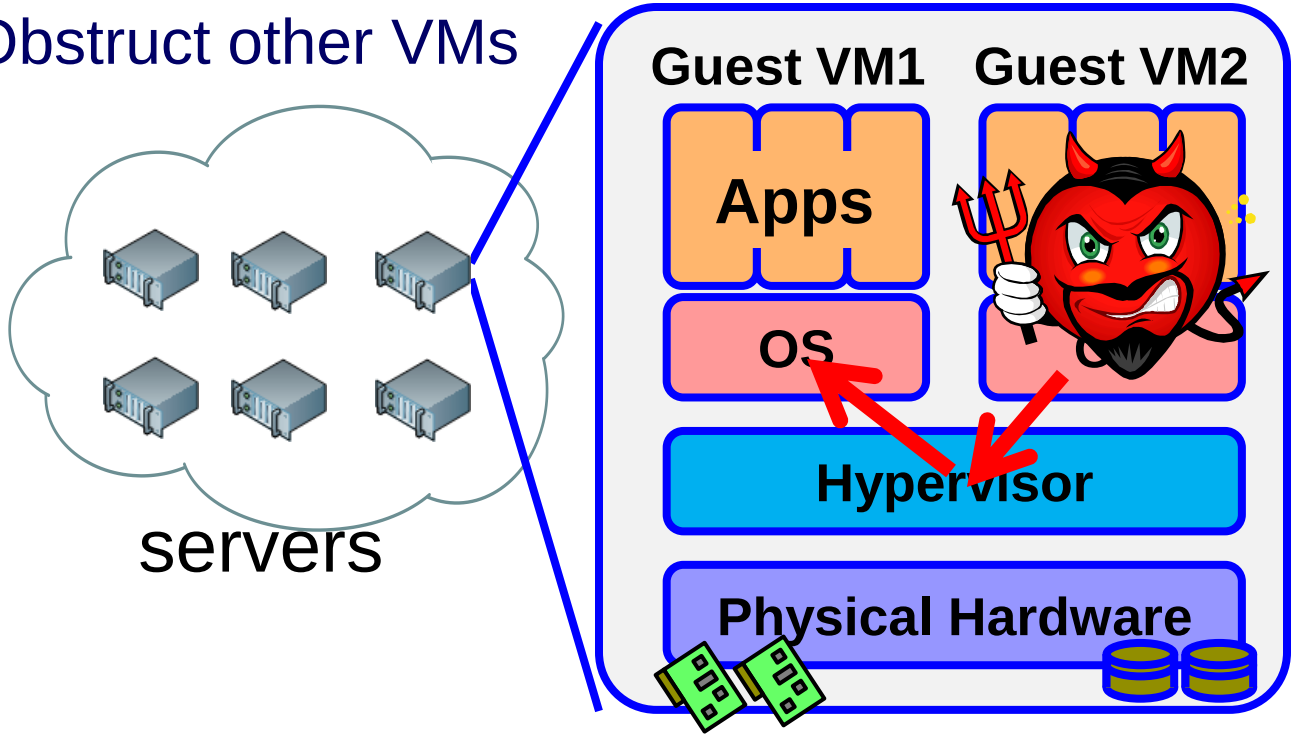
Without the Virtualization

- Virtualization used to share servers
  - Software layer running under each virtual machine



Without the Virtualization

- Virtualization used to share servers
  - Software layer running under each virtual machine
- Malicious software can run on the same server
  - Attack hypervisor
  - Access/Obstruct other VMs



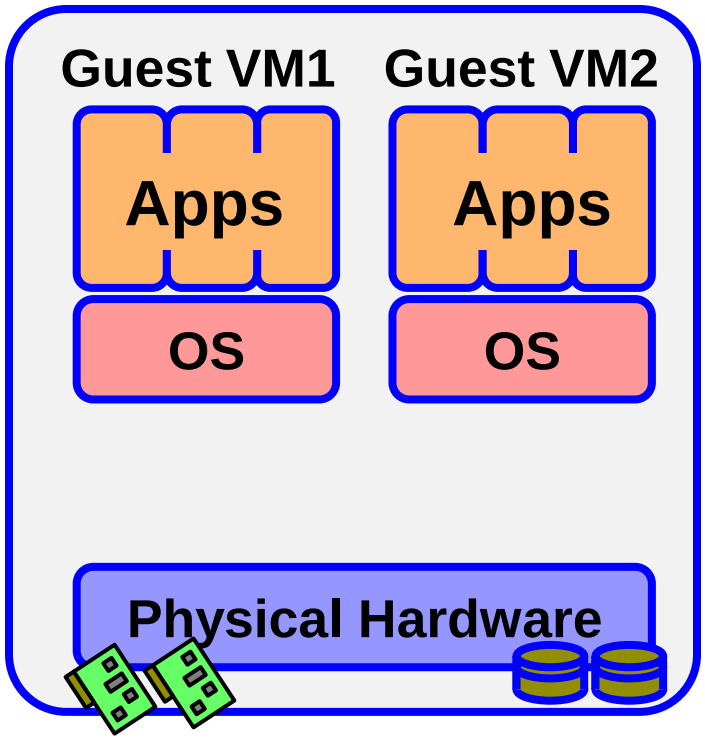
Are these vulnerabilities imagined?

- No headlines… doesn't mean it's not real
  - Not enticing enough to hackers yet? (small market size, lack of confidential data)
- Virtualization layer huge and growing
  - 100 Thousand lines of code in hypervisor
  - 1 Million lines in privileged virtual machine
- Derived from existing operating systems
  - Which have security holes

NoHype

- NoHype removes the hypervisor
  - There's nothing to attack
  - Complete systems solution
  - Still retains the needs of a virtualized cloud infrastructure

No hypervisor →



Virtualization in the Cloud

- Why does a cloud infrastructure use virtualization?
  - To support dynamically starting/stopping VMs
  - To allow servers to be shared (multi-tenancy)
- Do not need full power of modern hypervisors
  - Emulating diverse (potentially older) hardware
  - Maximizing server consolidation

Roles of the Hypervisor

- Isolating/Emulating resources
  - CPU: Scheduling virtual machines
  - Memory: Managing memory
  - I/O: Emulating I/O devices
- Networking
- Managing virtual machines

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Push to side

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Push to HW / Pre-allocation

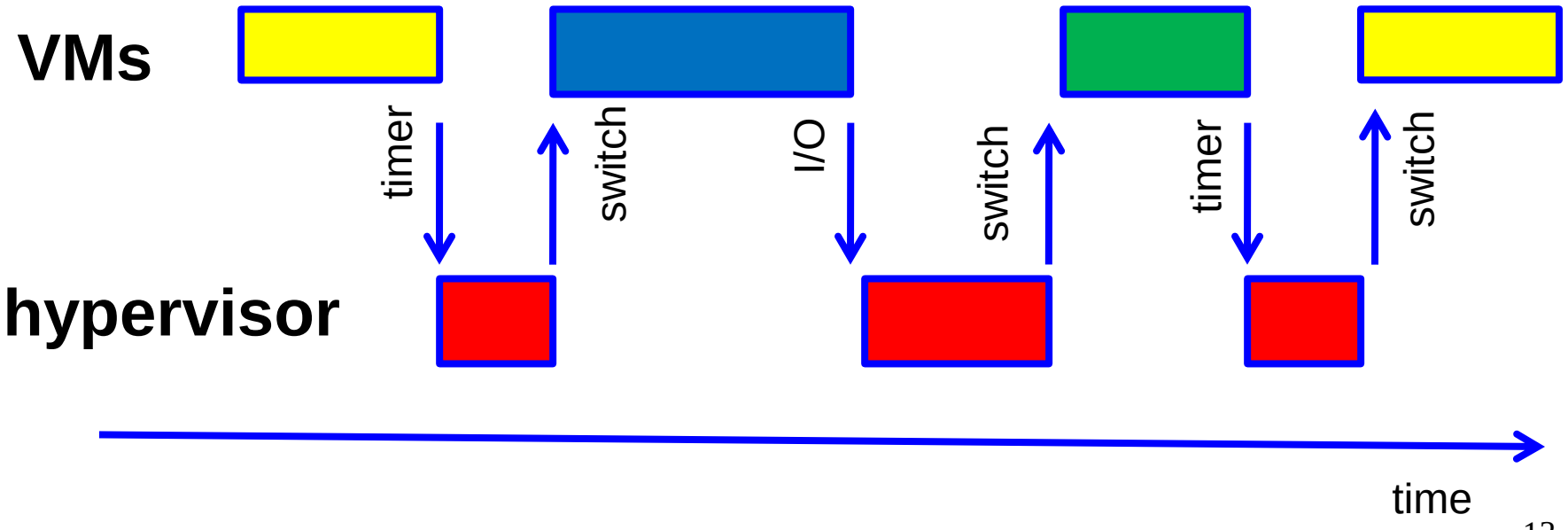
Remove

Push to side

NoHype has a double meaning… “no hype”

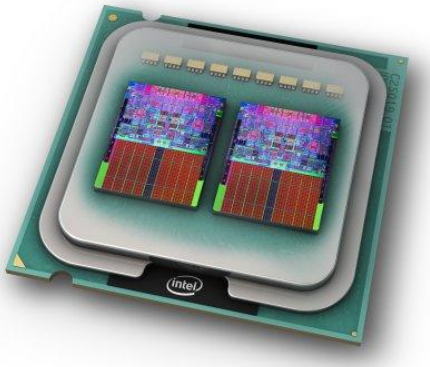
Scheduling Virtual Machines

- Scheduler called each time hypervisor runs (periodically, I/O events, etc.)
  - Chooses what to run next on given core
  - Balances load across cores



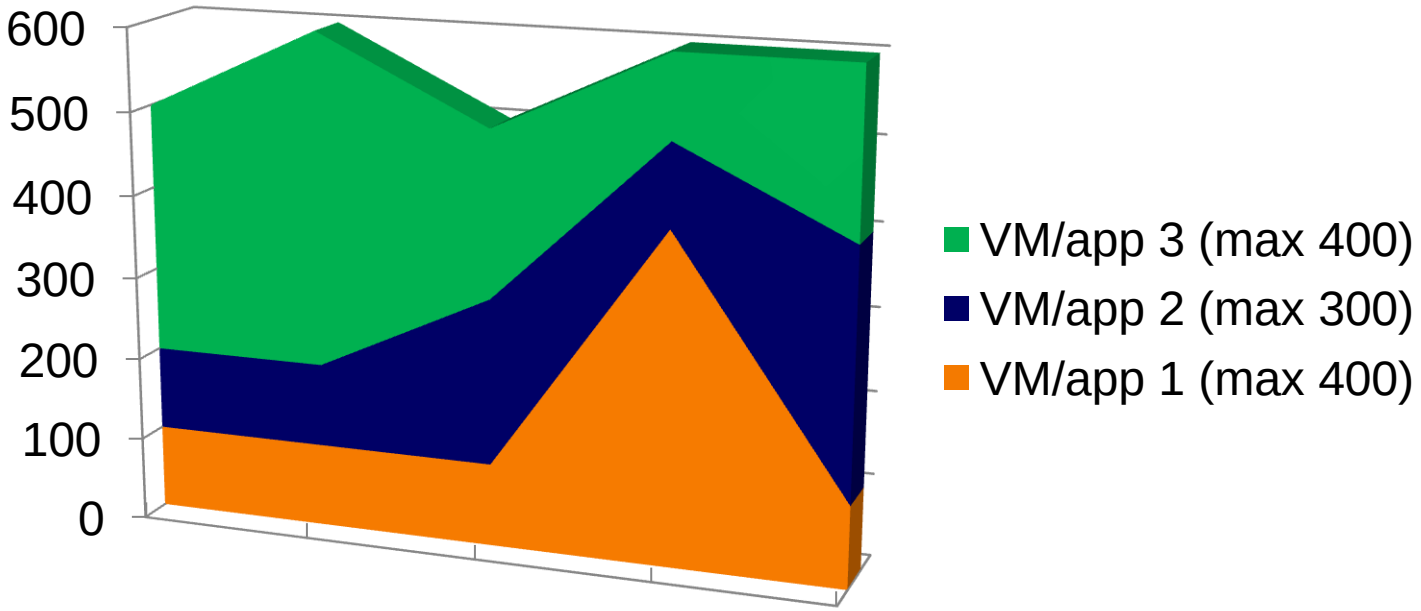
Dedicate a core to a single VM

- Ride the multi-core trend
  - 1 core on 128-core device is ~0.8% of the processor
- Cloud computing is pay-per-use
  - During high demand, spawn more VMs
  - During low demand, kill some VMs
  - Customer maximizing each VMs work, which minimizes opportunity for over-subscription



Managing Memory

- Goal: system-wide optimal usage
  - i.e., maximize server consolidation



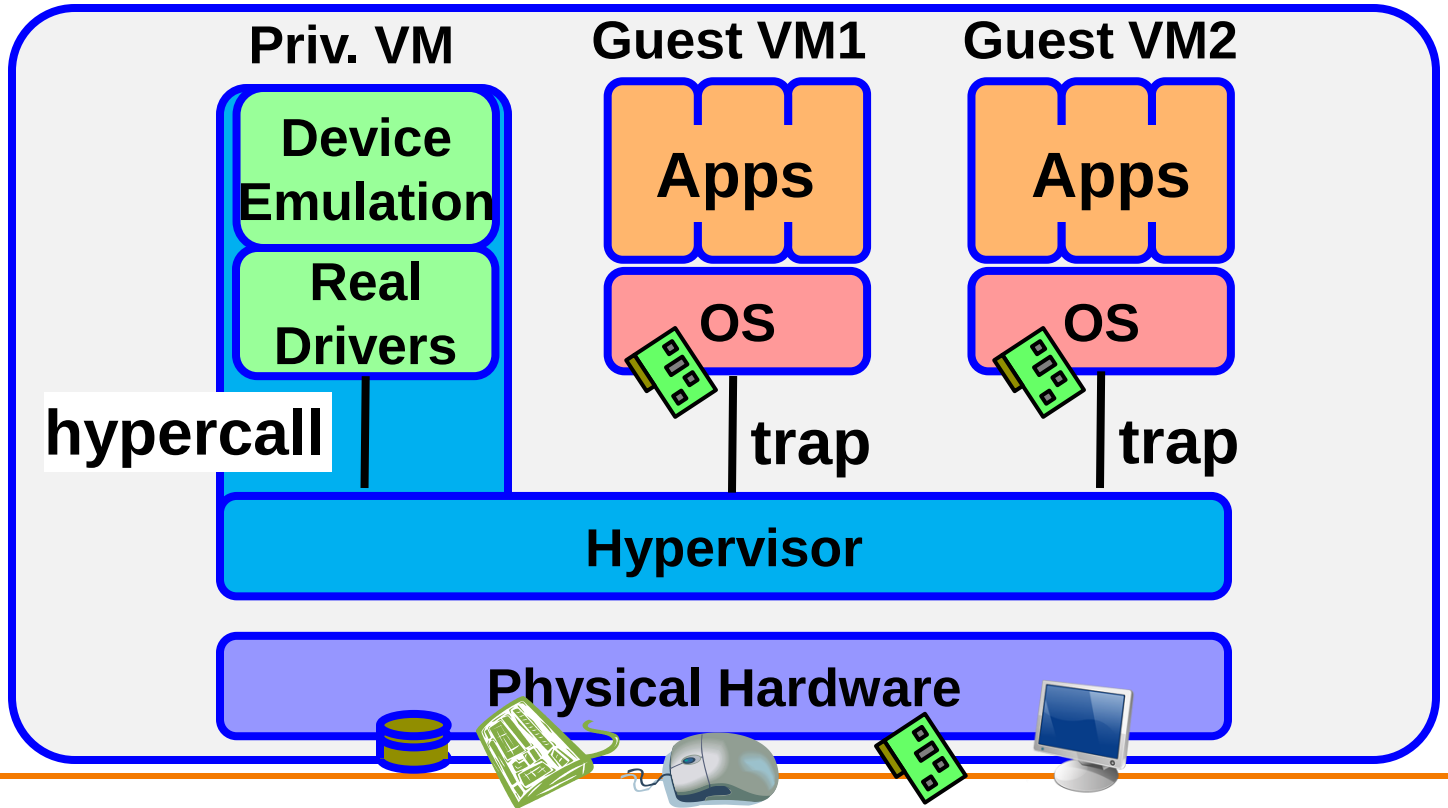
- Hypervisor controls allocation of physical memory

Pre-allocate Memory

- In cloud computing: charged per unit
  - e.g., VM with 2GB memory
- Pre-allocate a fixed amount of memory
  - Memory is fixed and guaranteed
  - Guest VM manages its own physical memory (deciding what pages to swap to disk)
- Processor support for enforcing:
  - allocation and bus utilization

Emulate I/O Devices

- Guest sees virtual devices
  - Access to a device's memory range traps to hypervisor
  - Hypervisor handles interrupts
  - Privileged VM emulates devices and performs I/O



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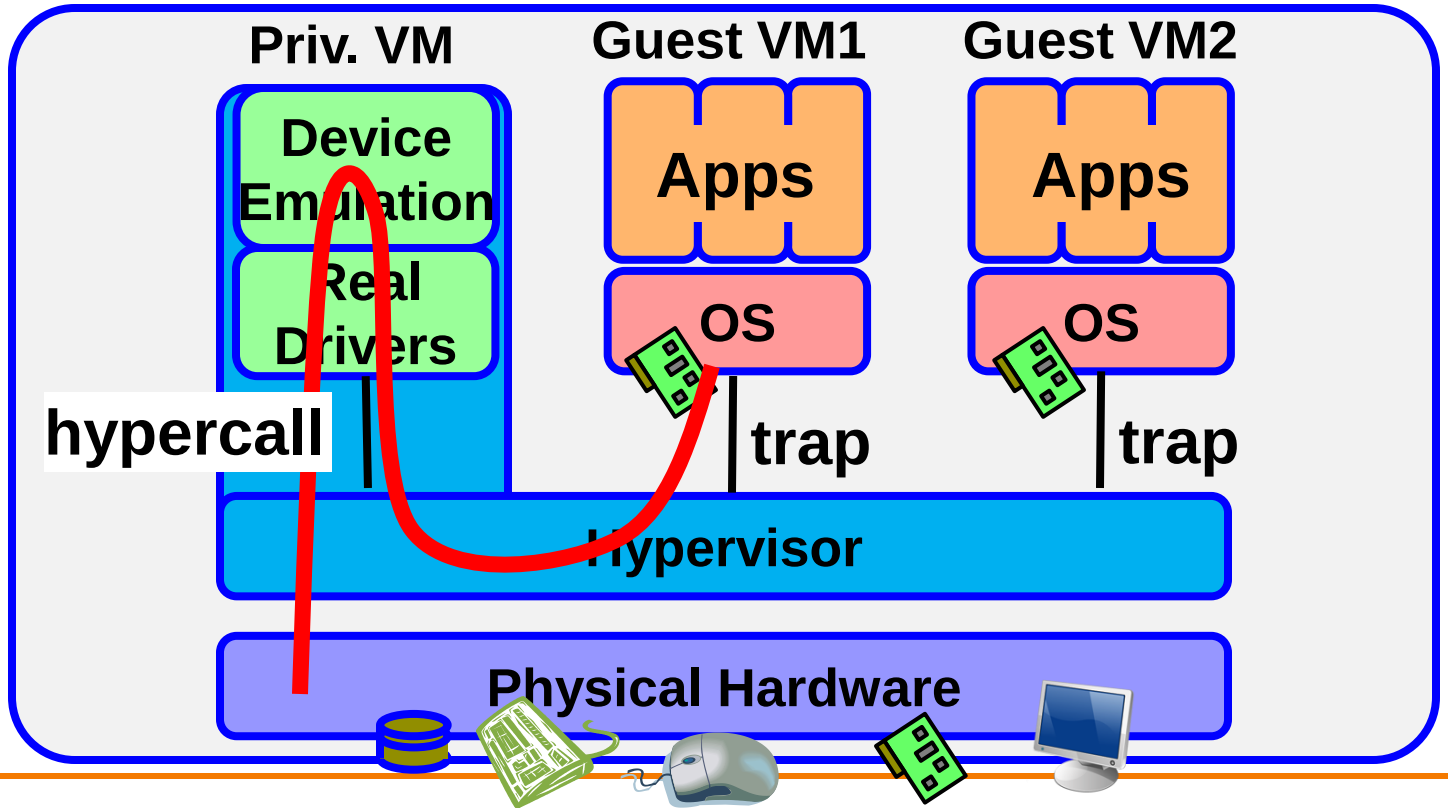
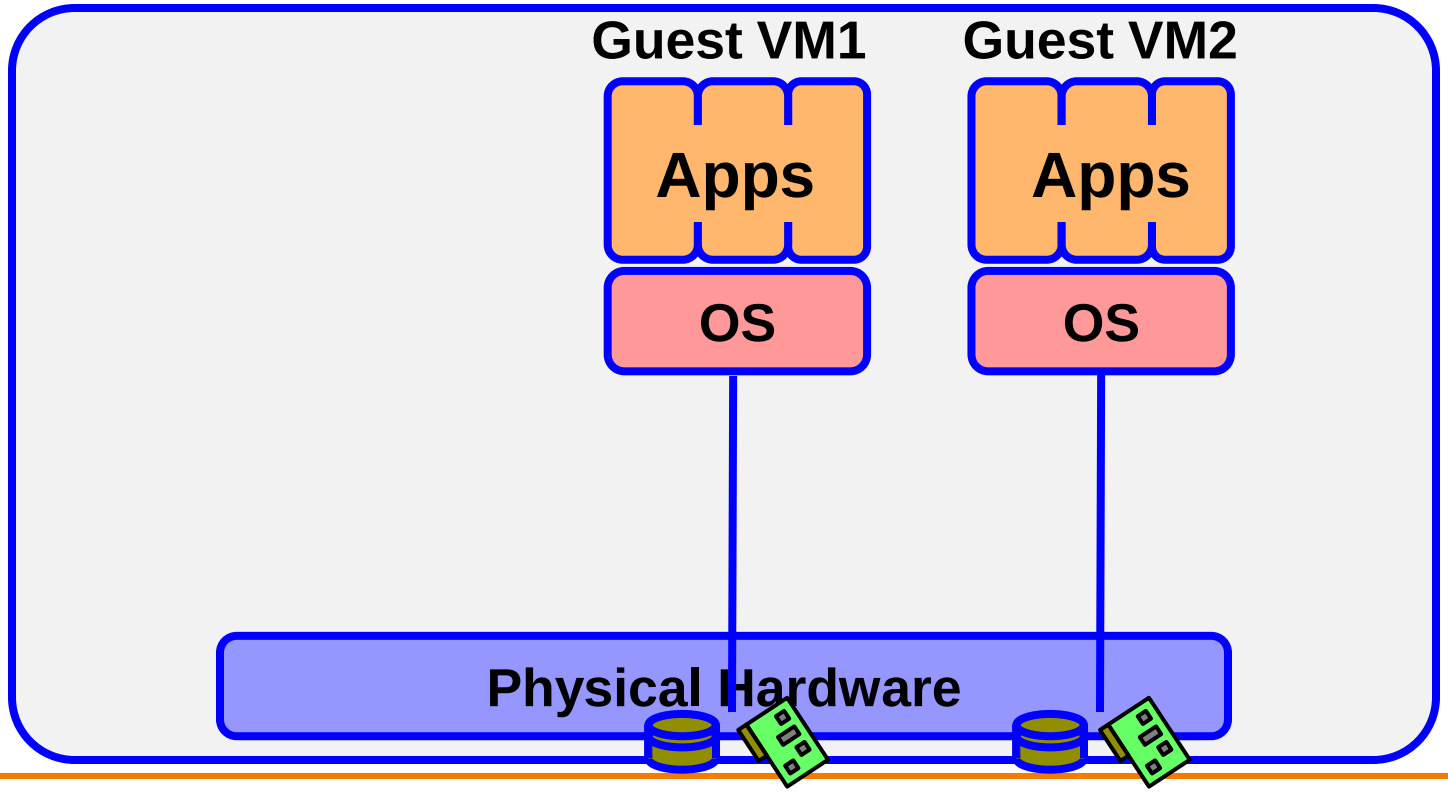


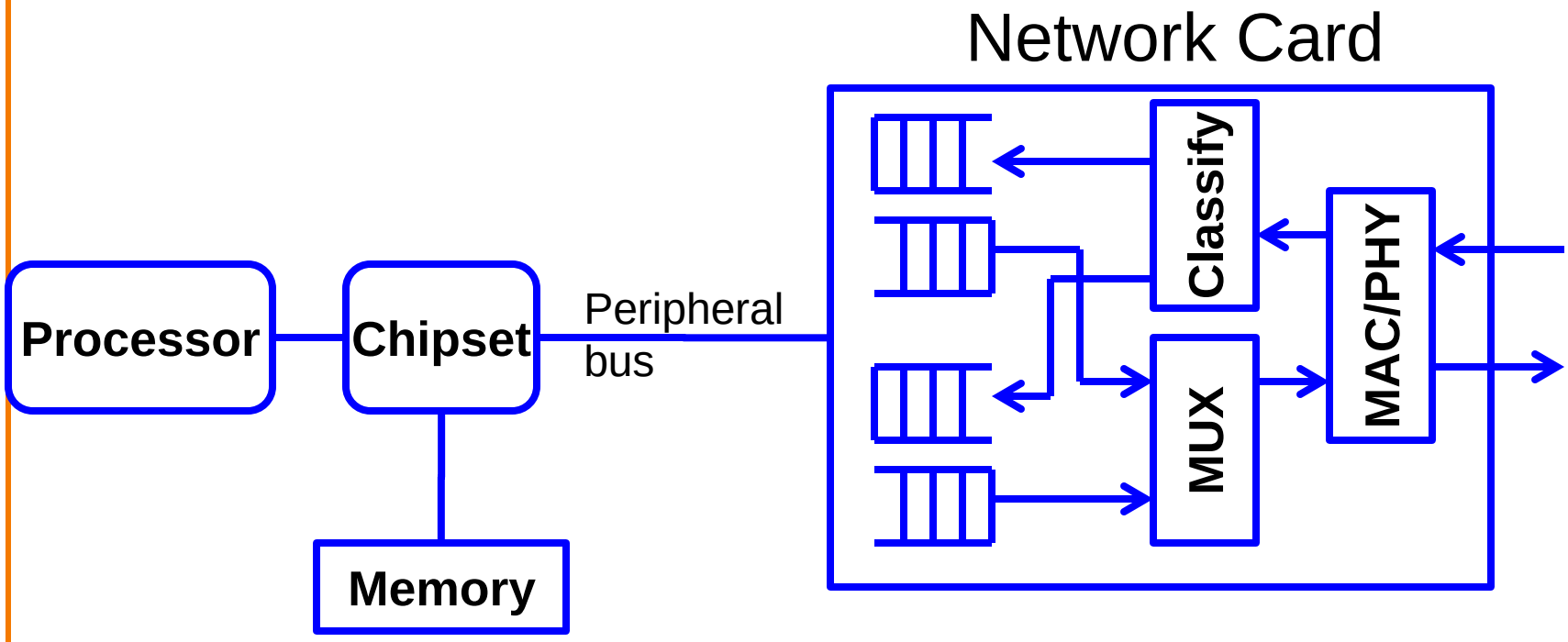
Dedicate Devices to a VM

- In cloud computing, only networking and storage
- Static memory partitioning for enforcing access
  - Processor (for to device), IOMMU (for from device)



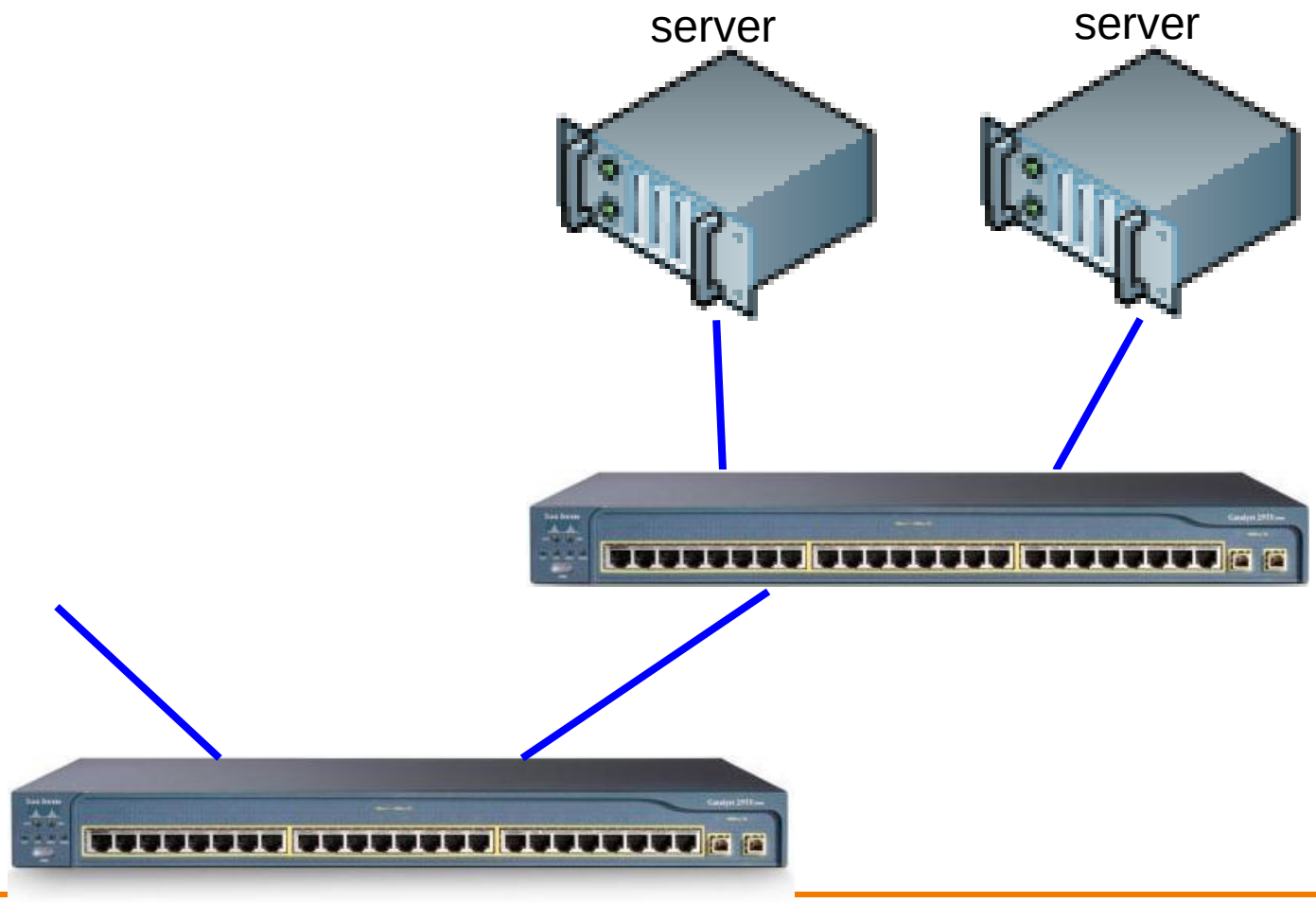
Virtualize the Devices

- Per-VM physical device doesn't scale
- Multiple queues on device
  - Multiple memory ranges mapping to different queues



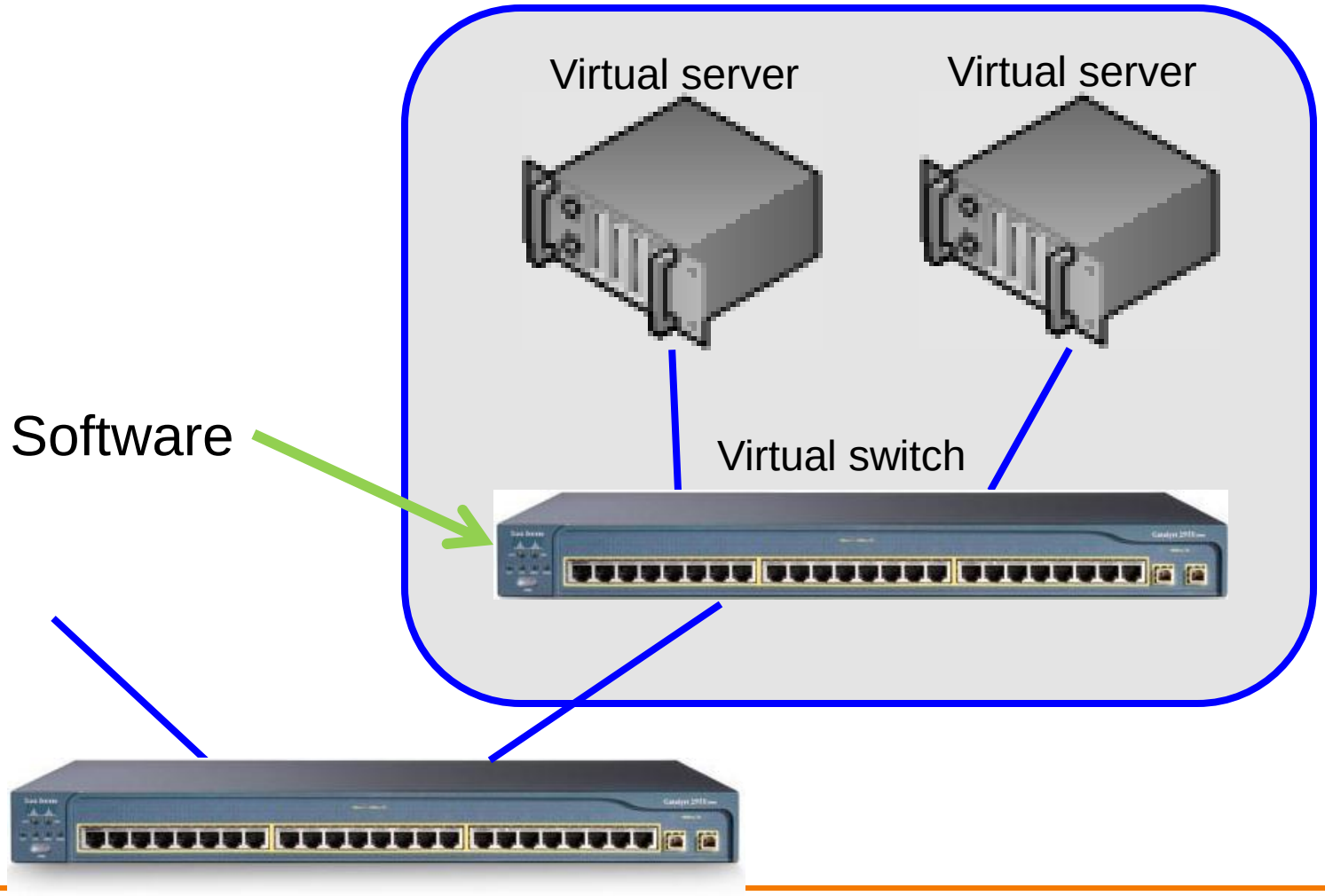
Networking

- Ethernet switches connect servers



Networking (in virtualized server)

- Software Ethernet switches connect VMs



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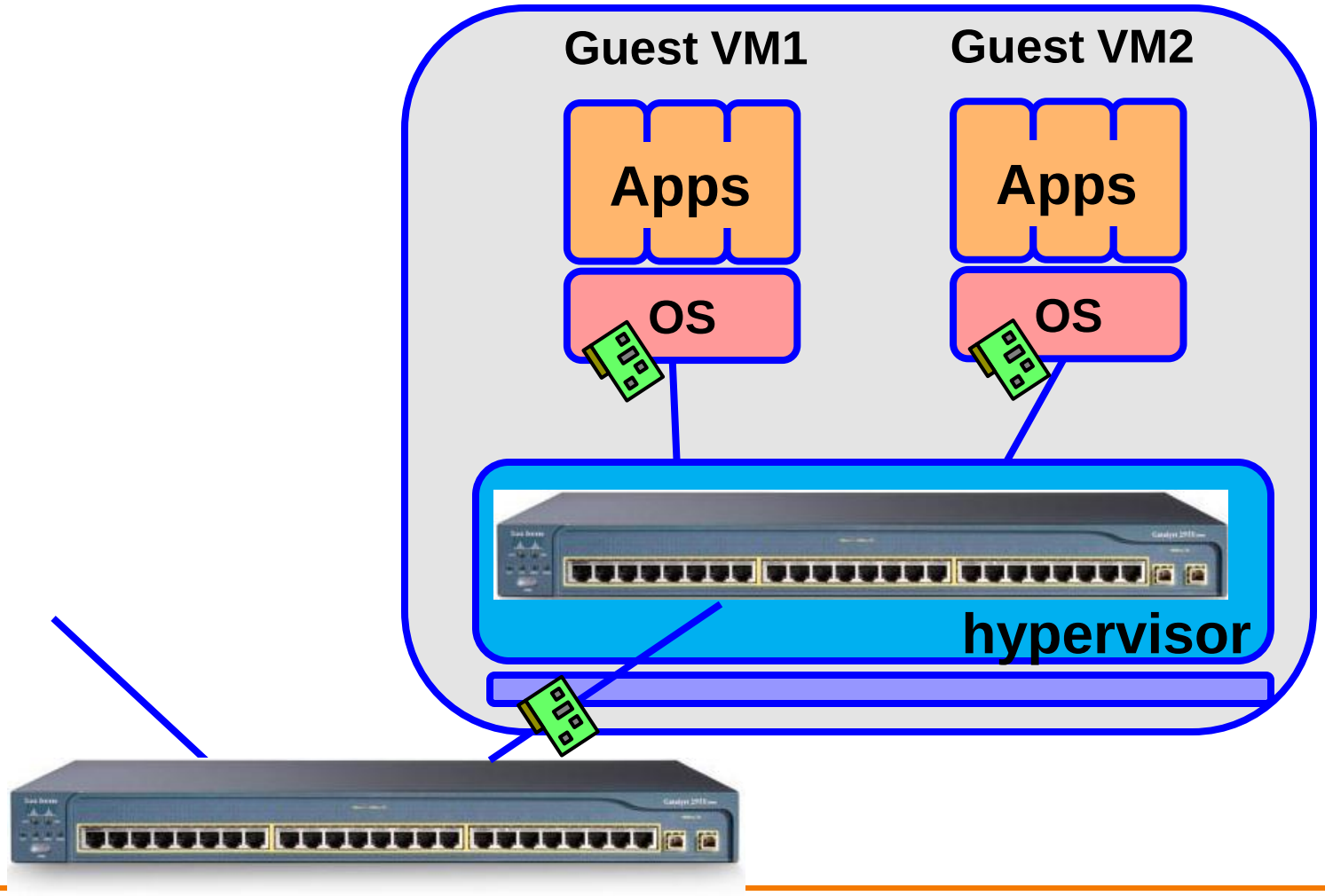

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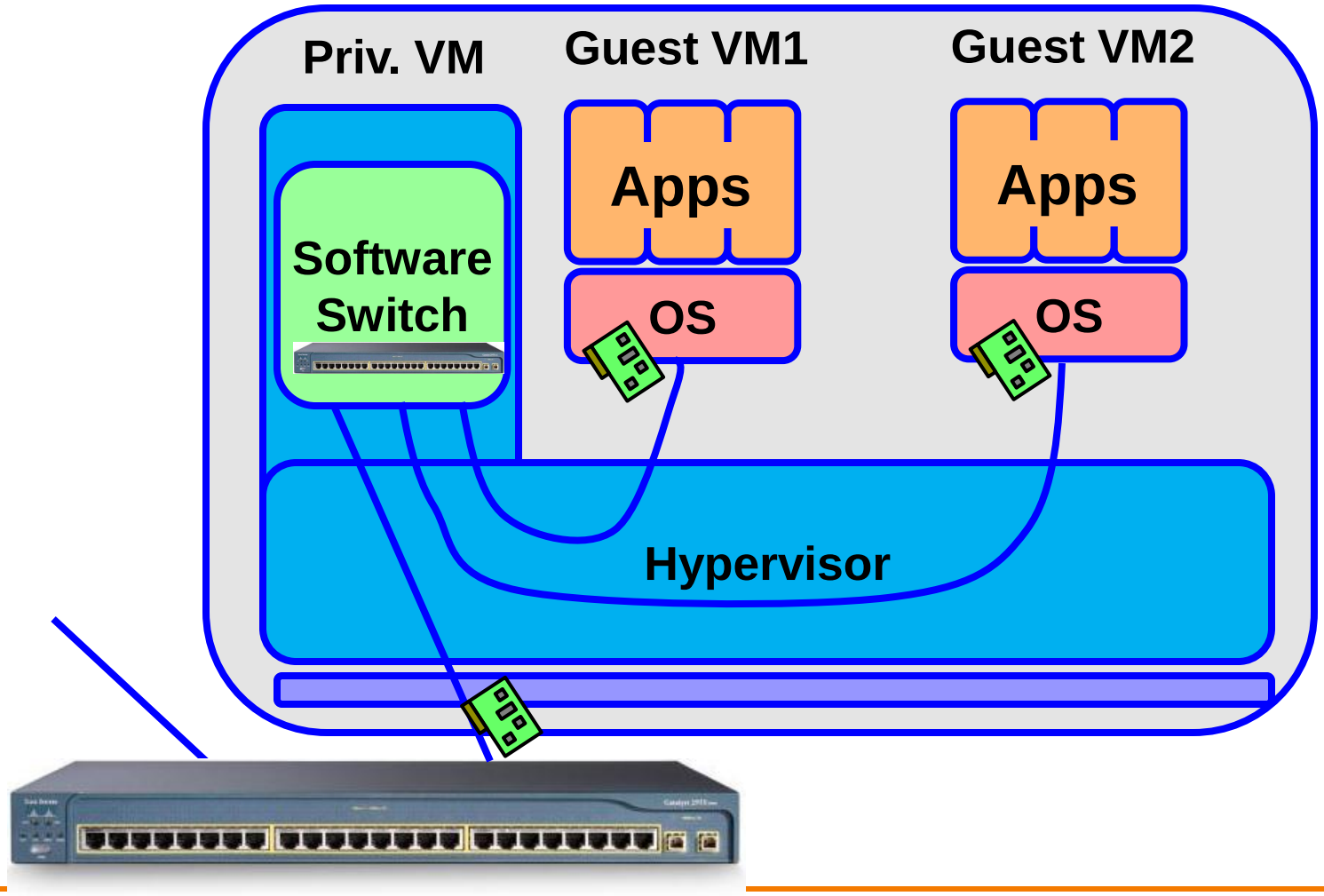
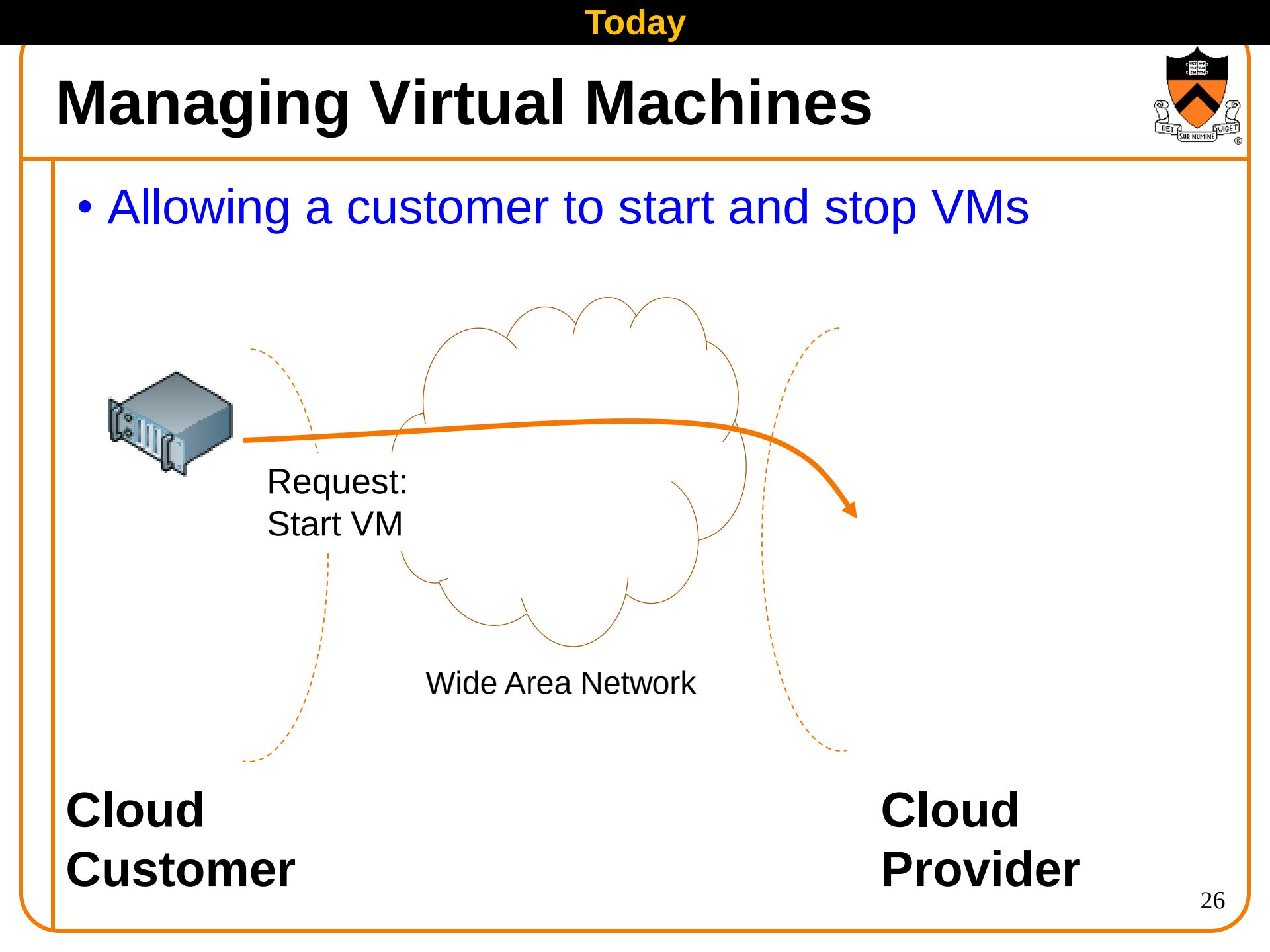


Do Networking in the Network

- Co-located VMs communicate through software
  - Performance penalty for not co-located VMs
  - Special case in cloud computing
  - Artifact of going through hypervisor anyway
- Instead: utilize hardware switches in the network
  - Modification to support hairpin turnaround

Managing Virtual Machines



- Allowing a customer to start and stop VMs

Cloud Customer

Cloud Provider

Managing Virtual Machines

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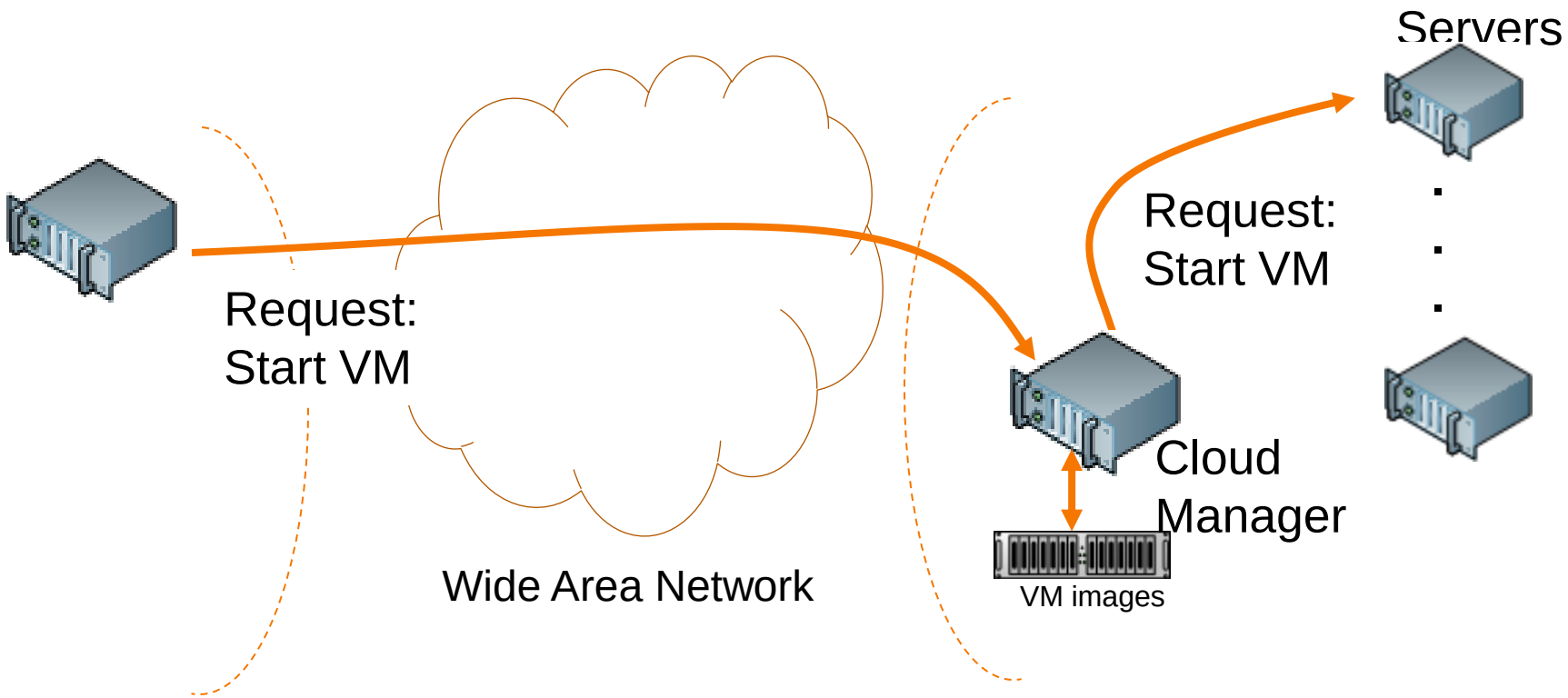
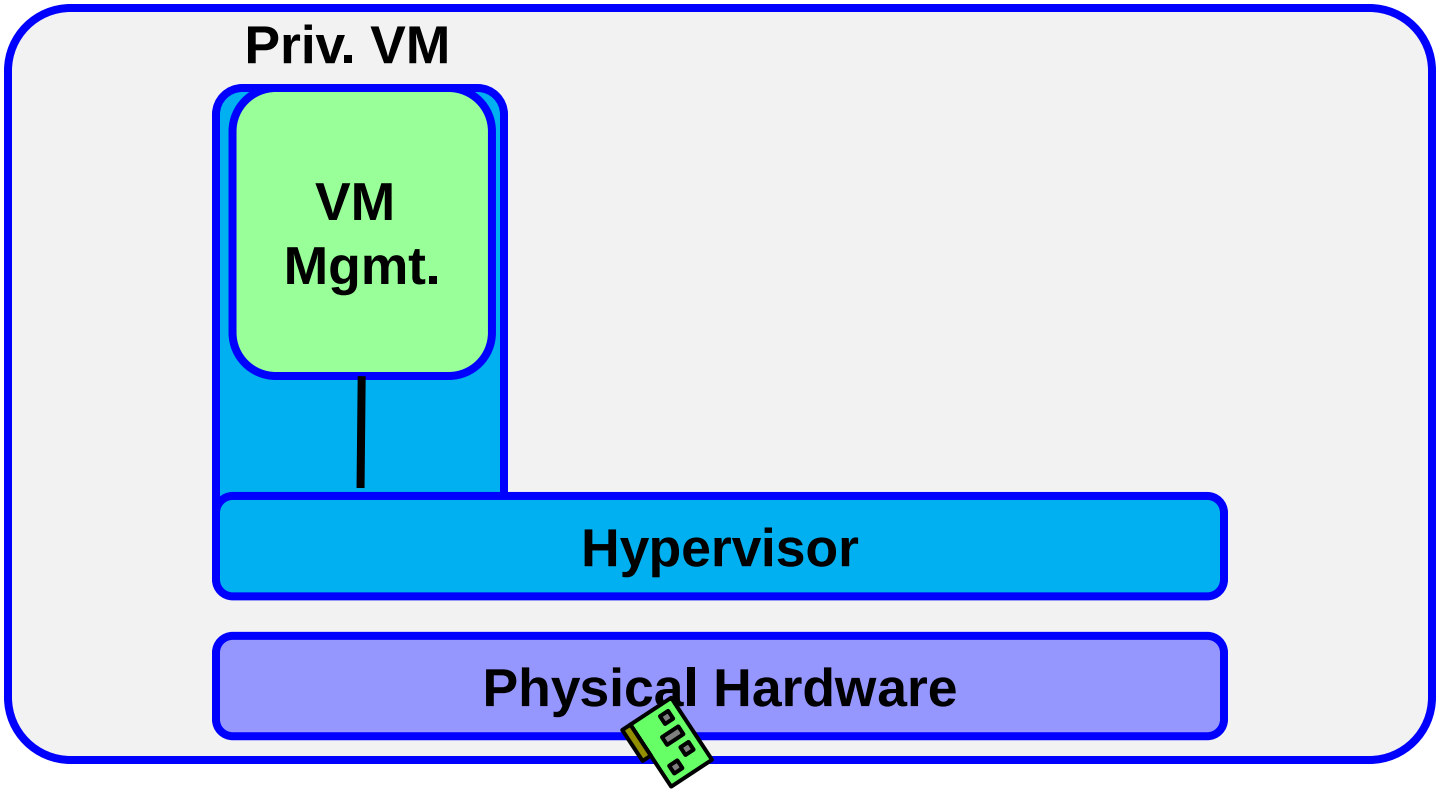


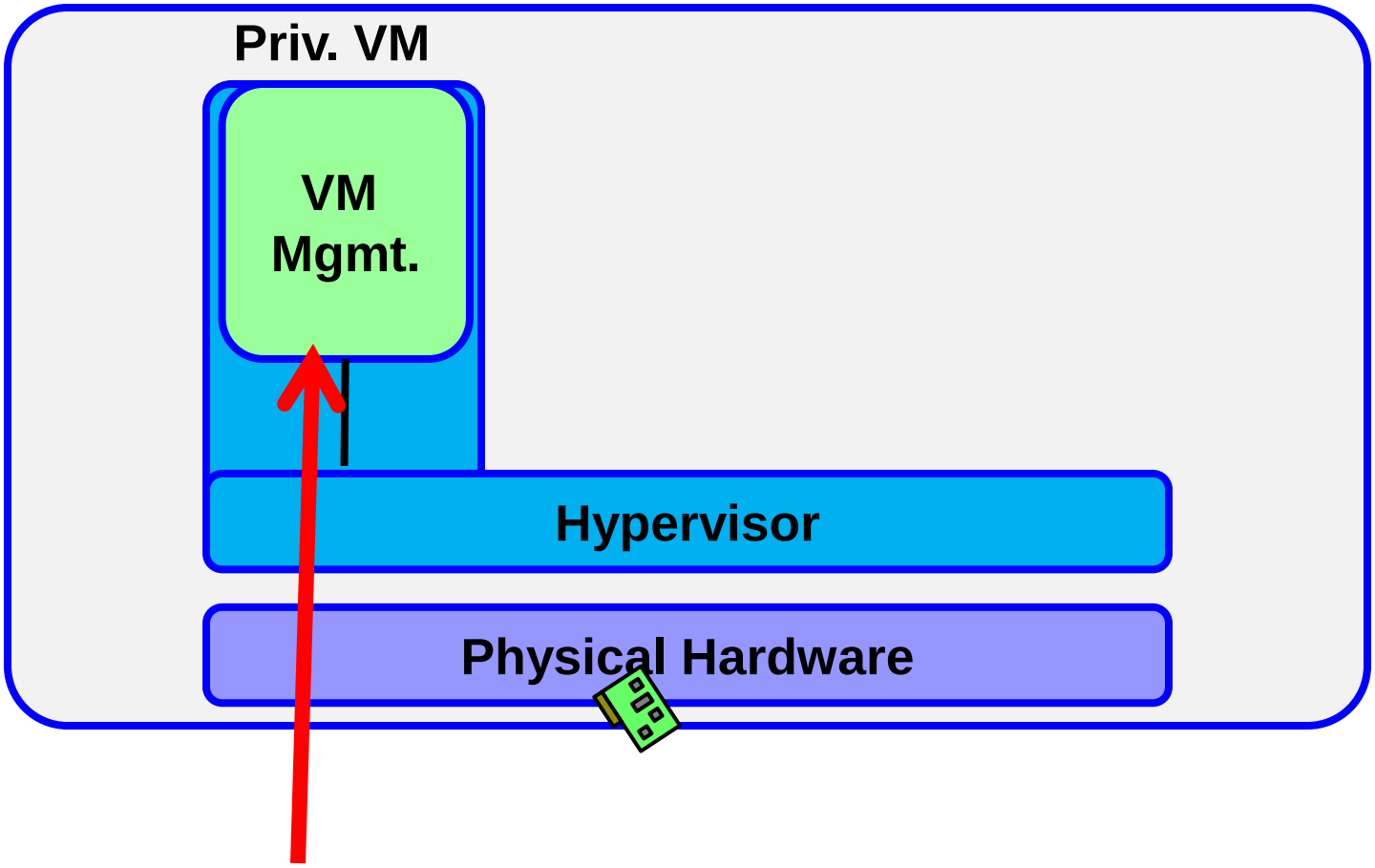
Hypervisor's Role in Management

- Run as application in privileged VM



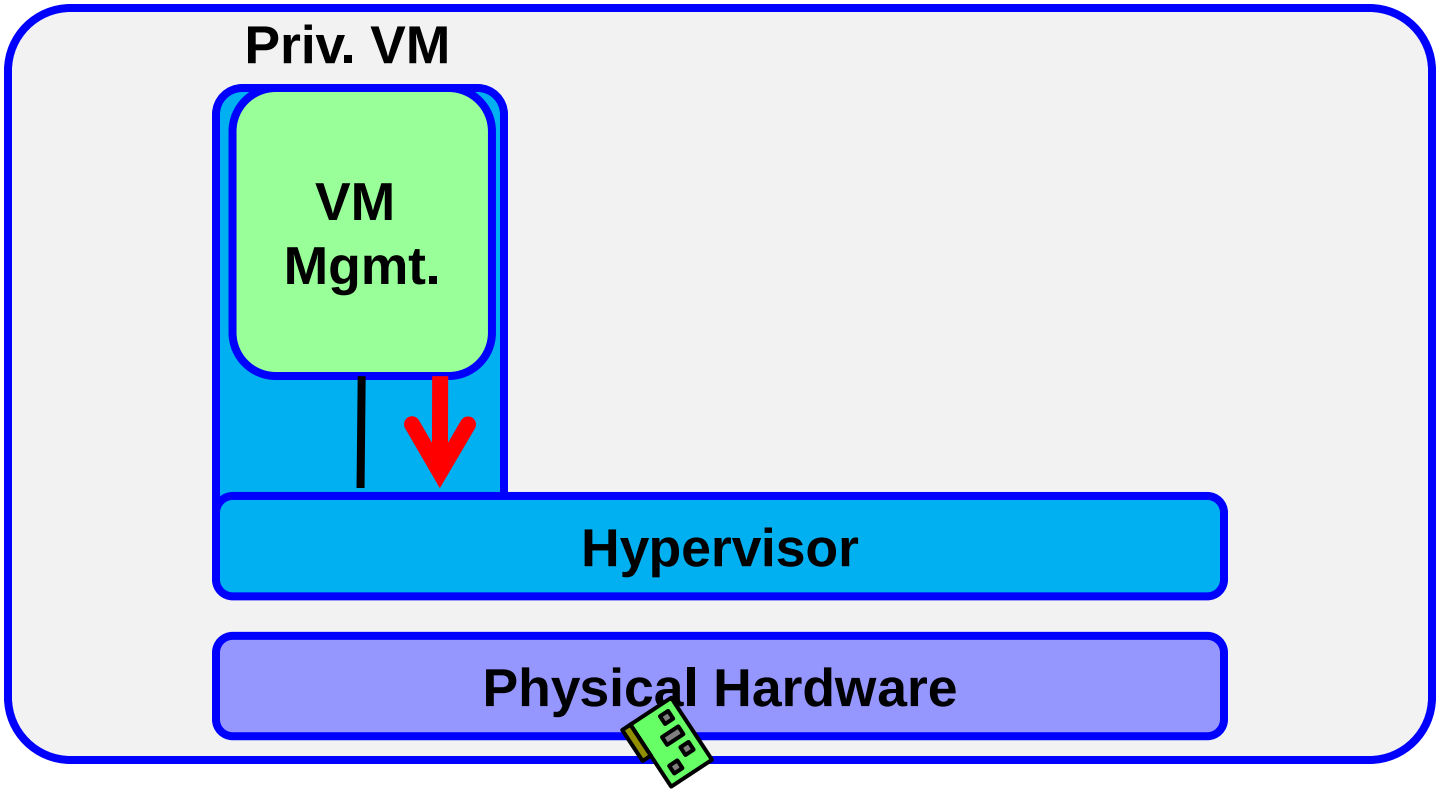
Hypervisor's Role in Management

- Receive request from cloud manager



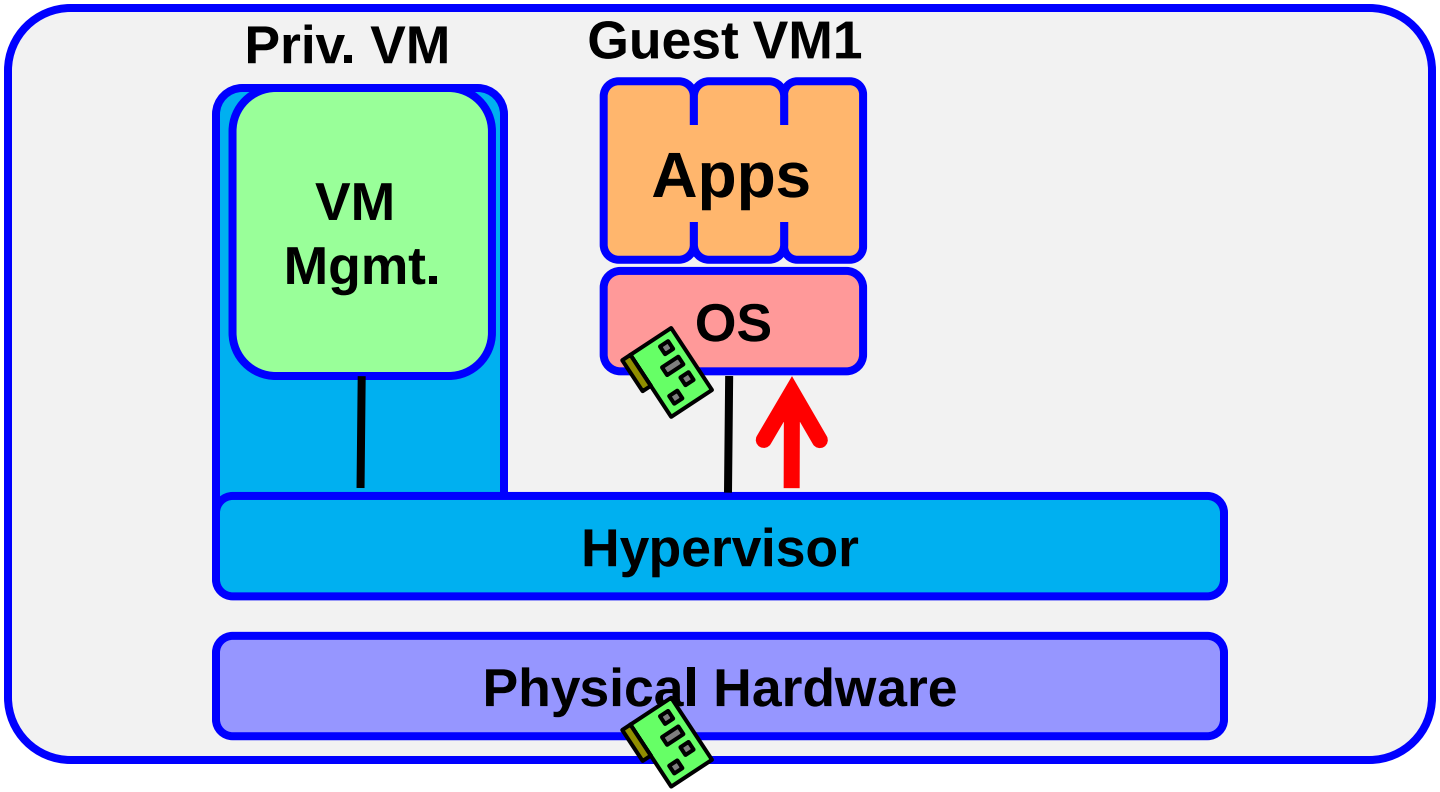
Hypervisor's Role in Management

- Form request to hypervisor



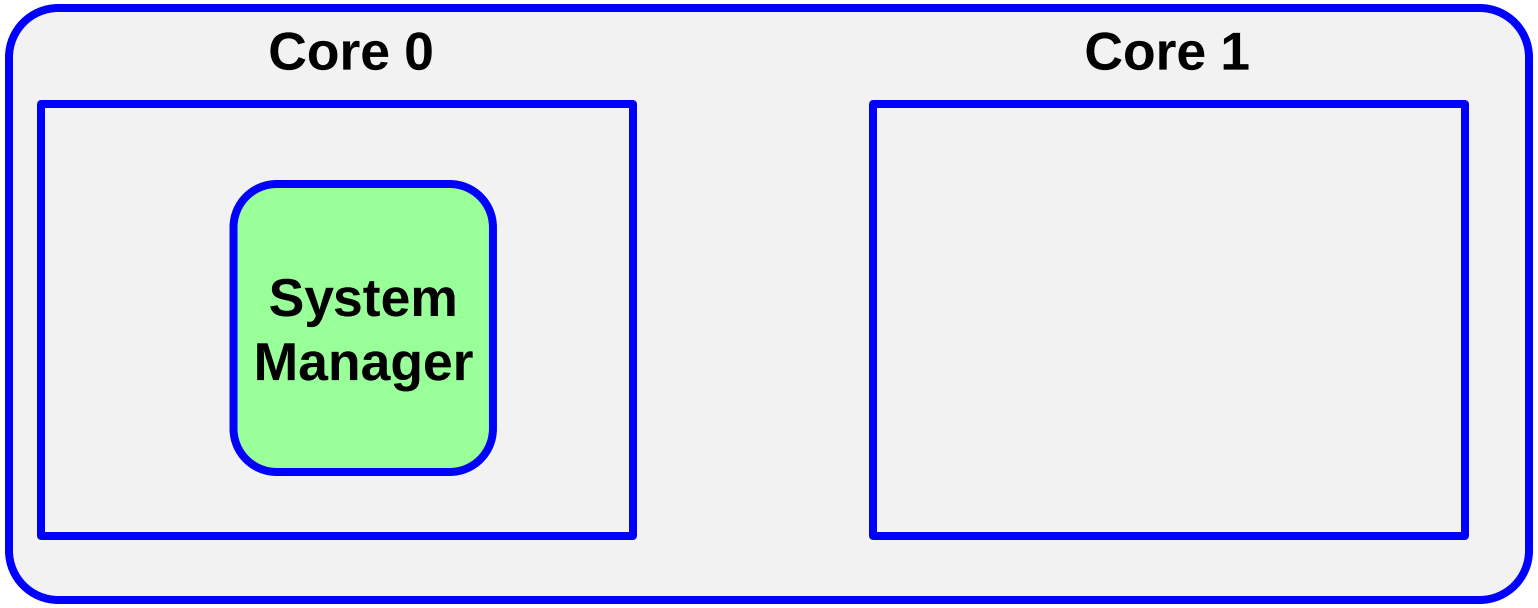
Hypervisor's Role in Management

- Launch VM



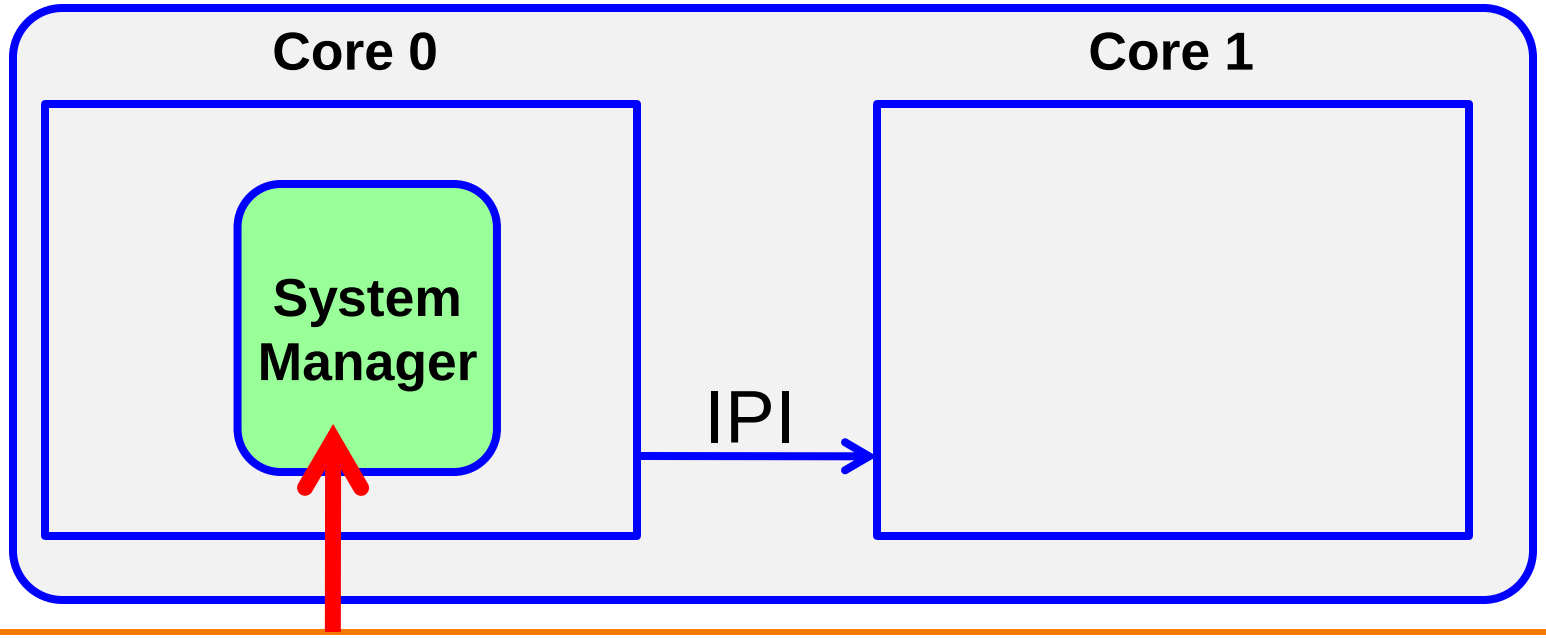
Decouple Management And Operation

- System manager runs on its own core



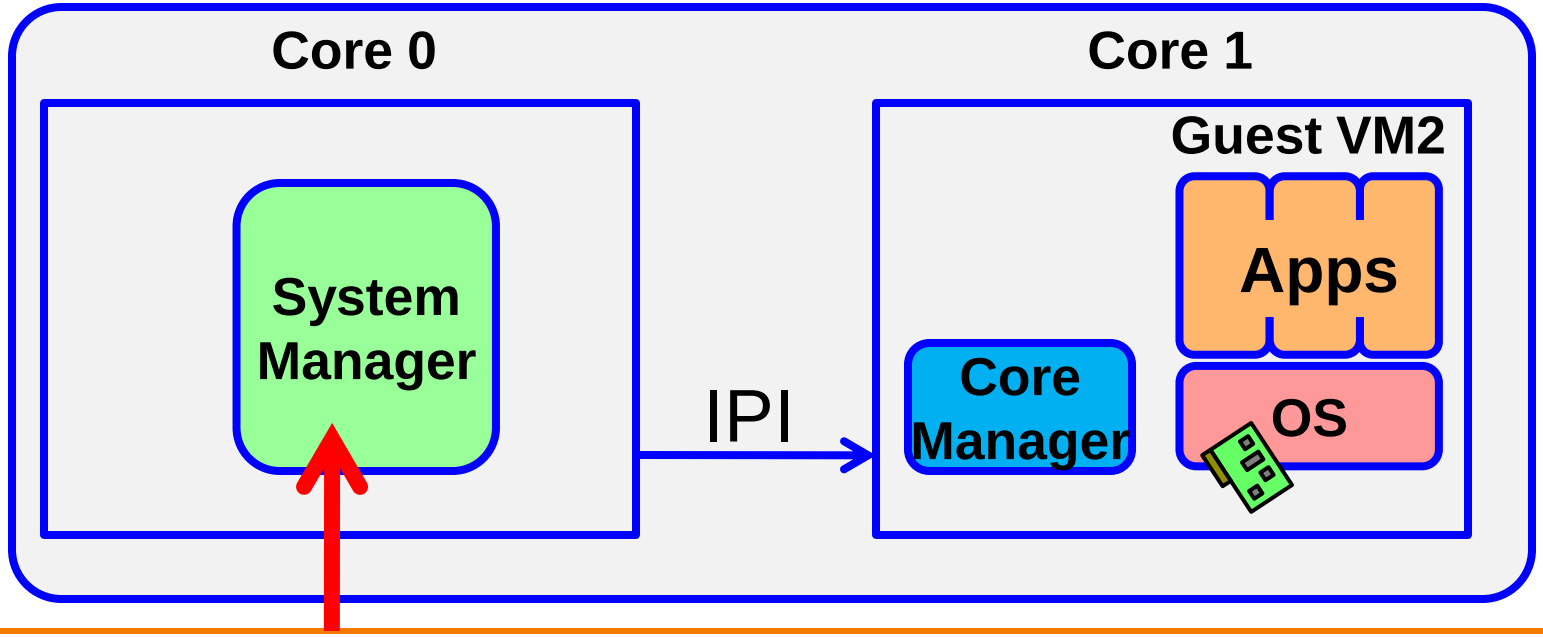
Decouple Management And Operation

- System manager runs on its own core
- Sends an IPI to start/stop a VM



Decouple Management And Operation

- System manager runs on its own core
- Sends an IPI to start/stop a VM
- Core manager sets up core, launches VM
  - Not run again until VM is killed



Removing the Hypervisor Summary

- Scheduling virtual machines
  - One VM per core
- Managing memory
  - Pre-allocate memory with processor support
- Emulating I/O devices
  - Direct access to virtualized devices
- Networking
  - Utilize hardware Ethernet switches
- Managing virtual machines
  - Decouple the management from operation

Security Benefits

- Confidentiality/Integrity of data
- Availability
- Side channels

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Confidentiality/Integrity of Data

Requires access to the data

With hypervisor	NoHype
Registers upon VM exit	No scheduling
Packets sent through software switch	No software switch
Memory accessible by hypervisor	No hypervisor

- System manager can alter memory access rules
  - But, guest VMs do not interact with the system manager

NoHype Double Meaning

- Means no hypervisor, also means "no hype"

- Multi-core processors
  - Available now
- Extended (Nested) Page Tables
  - Available now
- SR-IOV and Directed I/O (VT-d)
  - Network cards now, Storage devices near future
- Virtual Ethernet Port Aggregator (VEPA)
  - Next-generation switches

Conclusions and Future Work

- Trend towards hosted and shared infrastructures
- Significant security issue threatens adoption
- NoHype solves this by removing the hypervisor
- Performance improvement is a side benefit

- Future work:
  - Implement on current hardware
  - Assess needs for future processors

Questions?

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