ECE590-03
Enterprise Storage Architecture

Fall 2016

Virtualized Environments

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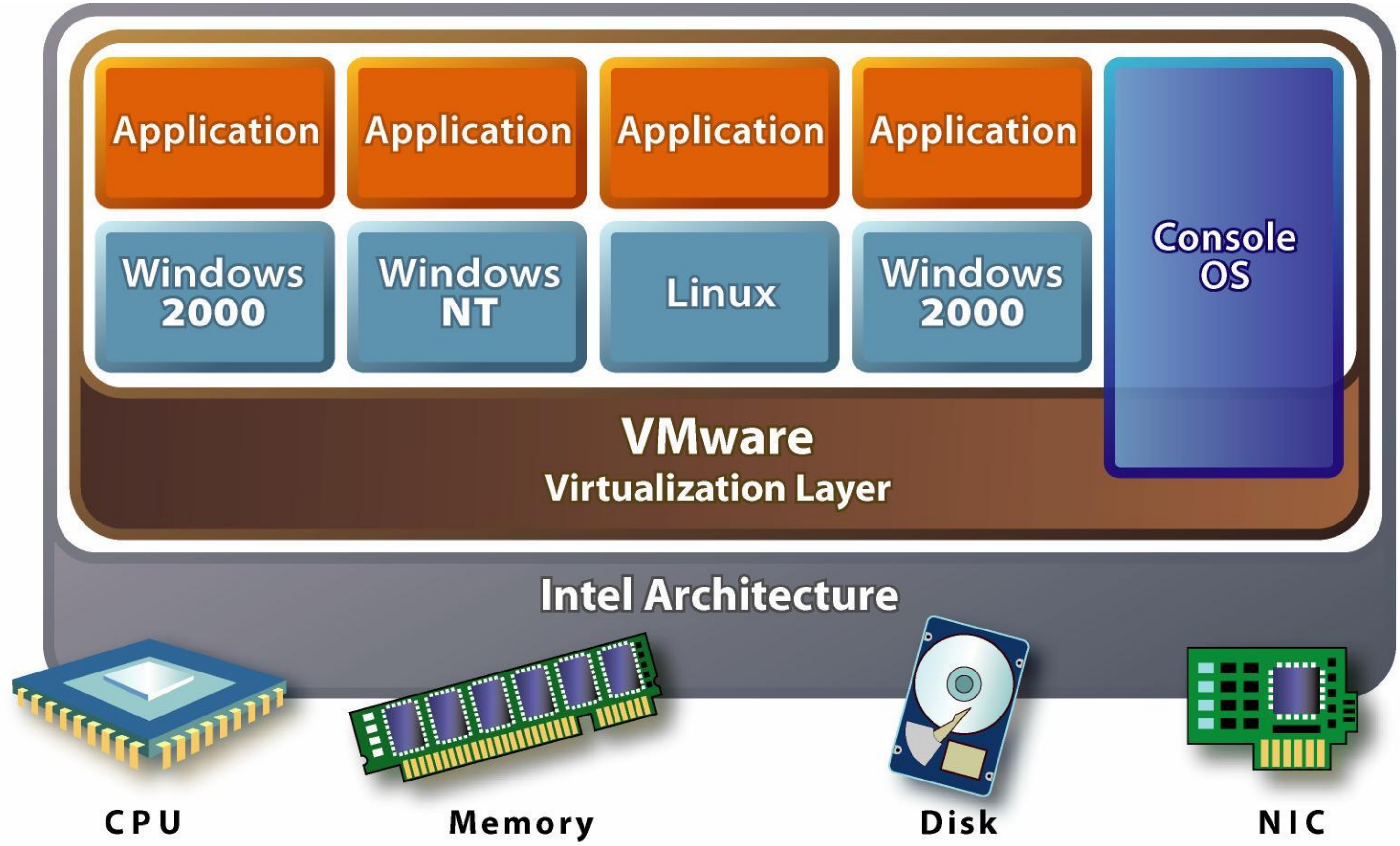
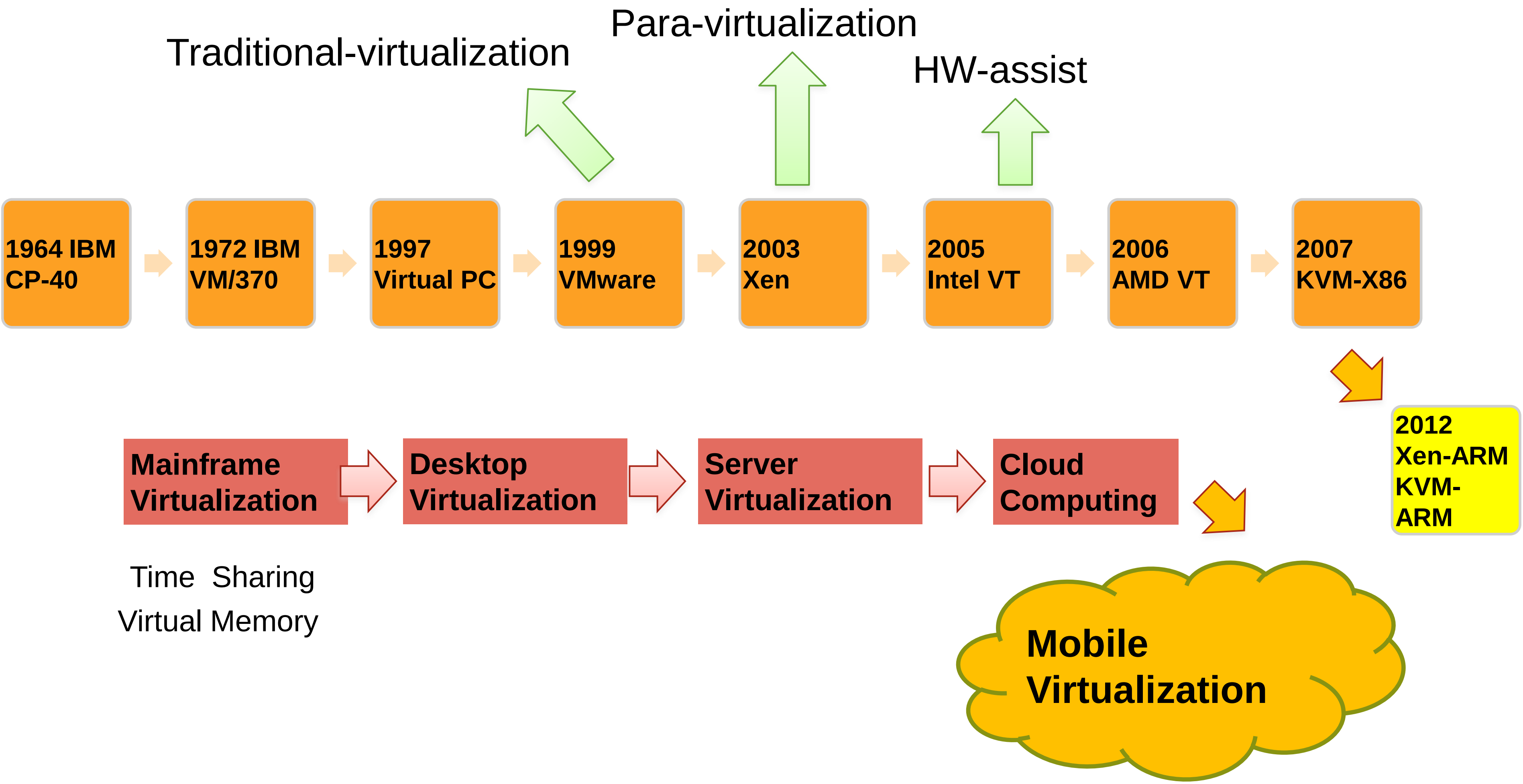
Server virtualization

Multiple VMs in One Machine



Adapted from "Virtualization Techniques" by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

History of Virtualization



Traditional-virtualization

Para-virtualization

HW-assist

1964 IBM CP-40

1972 IBM VM/370

1997 Virtual PC

1999 VMware

2003 Xen

2005 Intel VT

2006 AMD VT

2007 KVM-X86

2012 Xen-ARM KVM-ARM

Mainframe Virtualization

Desktop Virtualization

Server Virtualization

Cloud Computing

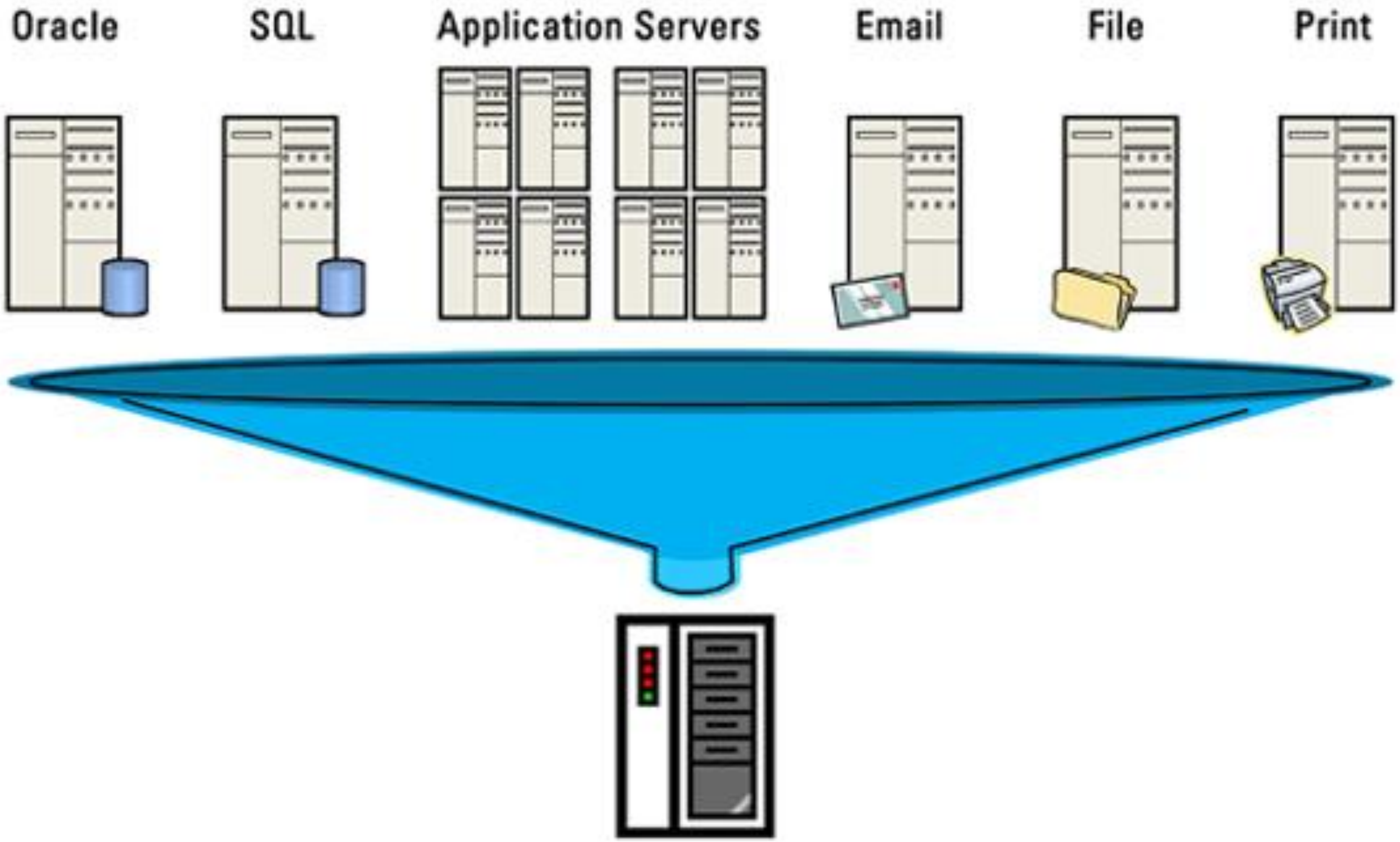
Mobile Virtualization

Time Sharing

Virtual Memory

Adapted from “Virtualization Techniques” by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Example: Server Virtualization



http://www.energystar.gov/index.cfm?c=power_mgt.datacenter_efficiency_virtualization

Adapted from “Virtualization Techniques” by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Benefits of Server Virtualization

- Virtualization can reduce data center energy expenses by 10%–40%
  - Each physical machine has power overhead, so reducing boxes → reducing power
- Virtualization also improves scalability, reduces downtime, and enables faster deployments.
  - Shared storage means VMs can run on any host → easy failover
  - VM snapshots → faster recovery
  - VM cloning → faster deployment
- Reduce the data center footprint
  - Fewer machines

Adapted from “Virtualization Techniques” by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Virtualization Techniques

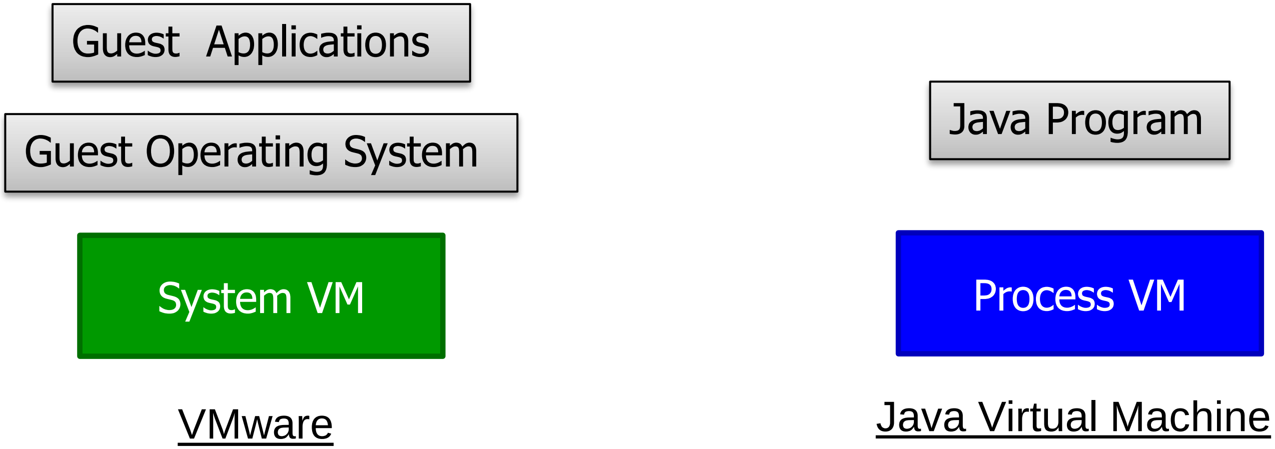
- System Virtualization
  - CPU Virtualization
  - Memory Virtualization
  - I/O Virtualization
  - Hardware Support for Virtualization, e.g. Intel VT
- Storage Virtualization
  - LVM
  - RAID
- Network Virtualization
  - VLANs
  - Software Defined Network

Adapted from “Virtualization Techniques” by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Types of Virtual Machine

- A virtual machine (VM) is a software implementation of a machine that executes programs like a physical machine. Virtual machines are separated into two major classifications:
  - A system virtual machine
    - Which provides a complete system platform which supports the execution of a complete operating system (OS)
  - A process virtual machine
    - Which is designed to run a single program, which means that it supports a single process.

Our focus



Adapted from "Virtualization Techniques" by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

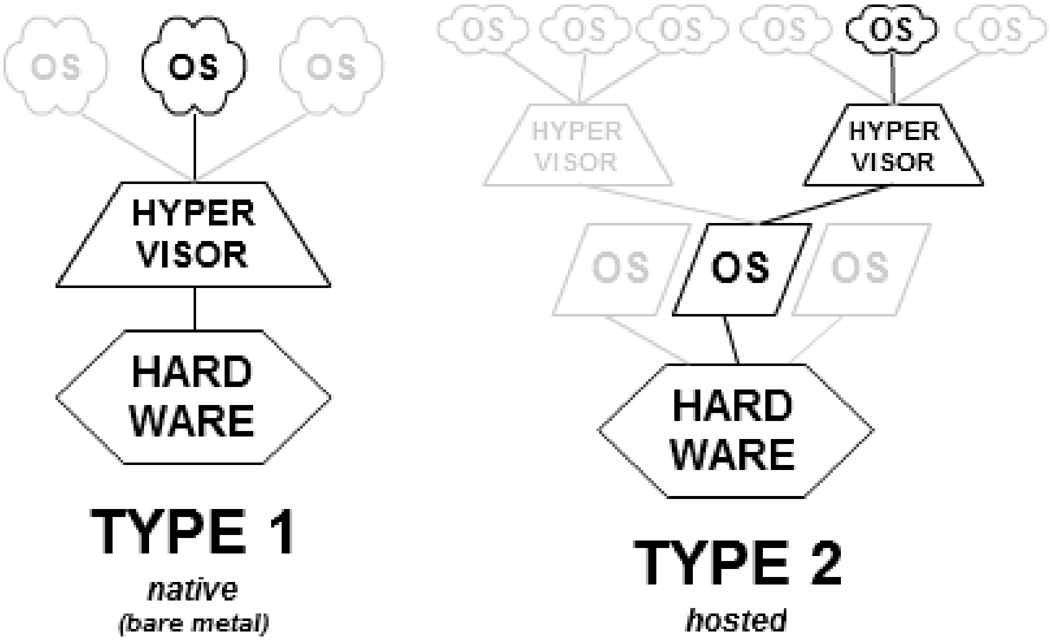
System Virtual Machine

- System virtual machine is controlled by a hypervisor or VMM (Virtual Machine Monitor)
- A hypervisor or VMM is a software to provide a hardware emulation interface including CPU, memory, I/O by multiplexing host resources

Adapted from “Virtualization Techniques” by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Two Types of Hypervisor

- In their 1974 article "Formal Requirements for Virtualizable Third Generation Architectures" Gerald J. Popek and Robert P. Goldberg classified two types of hypervisor:
  - Type 1 hypervisor : bare metal type
  - Type 2 hypervisor : hosted type



http://en.wikipedia.org/wiki/Hypervisor

Adapted from "Virtualization Techniques" by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Purpose of Hypervisor

- CPU Virtualization
  - Handle all sensitive instructions by emulation
- Memory Virtualization
  - Allocate guest physical memory
  - Translate guest virtual address to host virtual address
- I/O Virtualization
  - Emulate I/O devices for guest
  - Ex: Keyboard, UART, Storage and Network

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Implementations of Hypervisor

- Full Virtualization
  - A wholly emulated virtual machine makes guest operating system binary can be executed directly without modifying guest source code
  - For efficiency, it can benefit from hardware-assisted virtualization
- Para-Virtualization
  - Hypercalls are defined and used in a guest operating system to make a virtual machine abstraction
- Pre-Virtualization
  - By compiling technique, guest operating system binary or source could be compiled for virtualization

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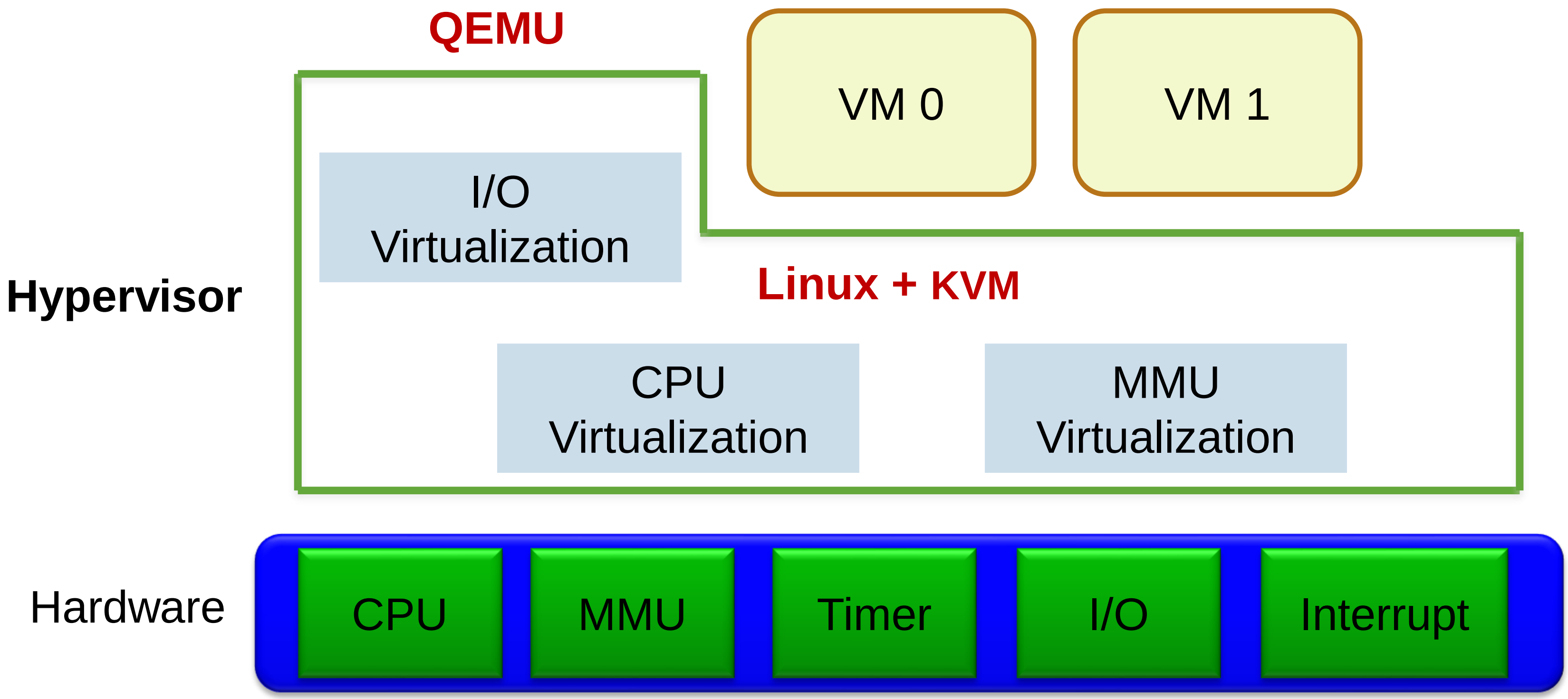
Hypervisor Case: KVM



- CPU and memory virtualization is handled in the Linux Kernel Space
- I/O virtualization is handled in the Linux User Space by QEMU
- It's a type 2 virtual machine
- It's a full virtualization implementation

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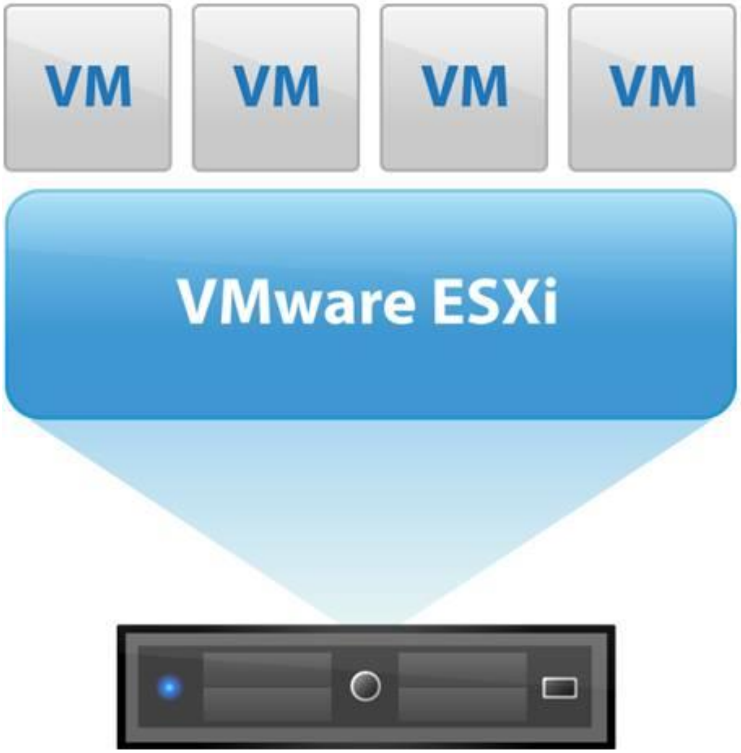
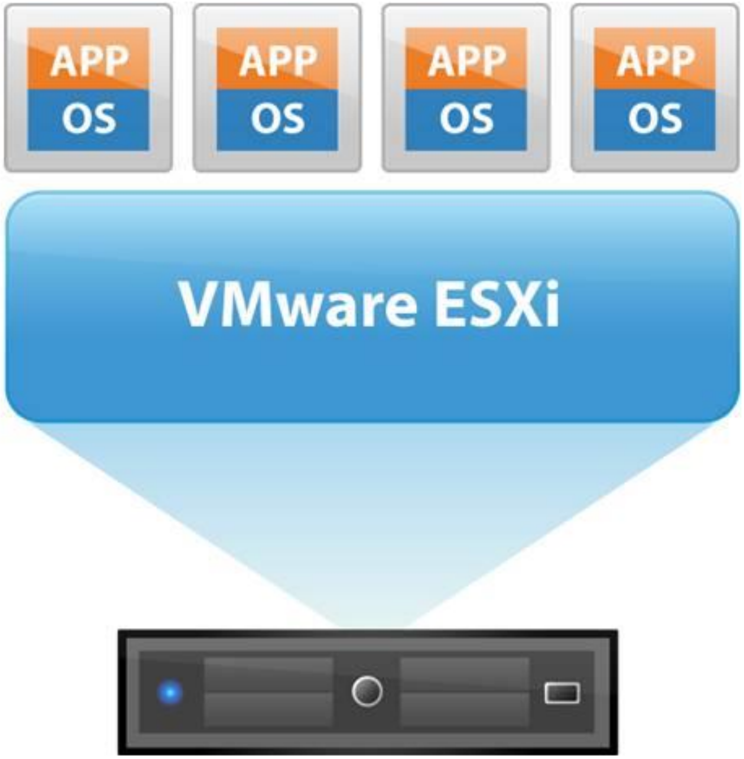
Hypervisor Case: VMware ESXi



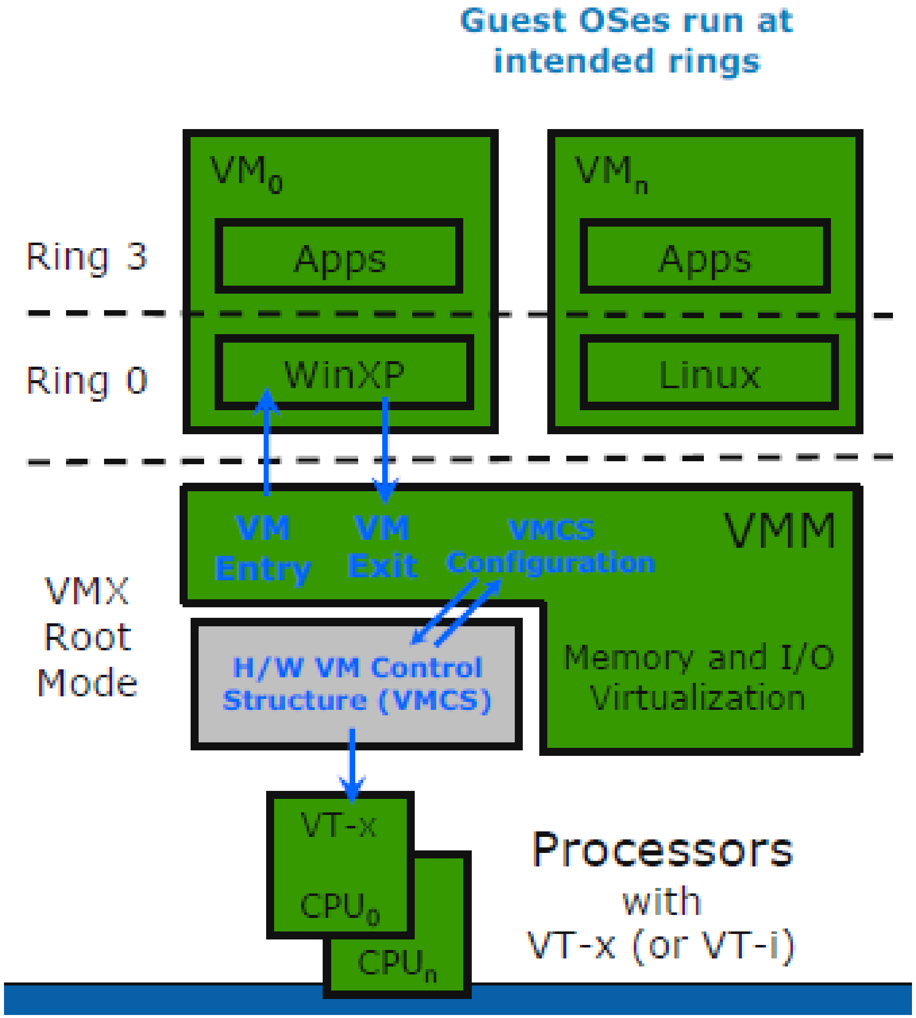


- Without hardware assist, sensitive instructions are dynamically rewritten; with hardware assist, hardware helps trap sensitive instructions to VMM
- It's a type 1 virtual machine
- It's a full virtualization implementation

Adapted from "Virtualization Techniques" by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Intel VT-x

- New CPU Operating Mode
  - VMX Root Operation
  - Non-Root Operation
- New Transitions
  - VM entry to Guest
  - VM exit to VMM
- VM Control Structure
  - Configured by VMM software


Guest OSes run at intended rings
Ring 3
Ring 0
VMX Root Mode
VM0
Apps
WinXP
VMn
Apps
Linux
VM Entry
VM Exit
VMCS Configuration
VMM
H/W VM Control Structure (VMCS)
Memory and I/O Virtualization
VT-x
CPU0
CPUn
Processors with VT-x (or VT-i)

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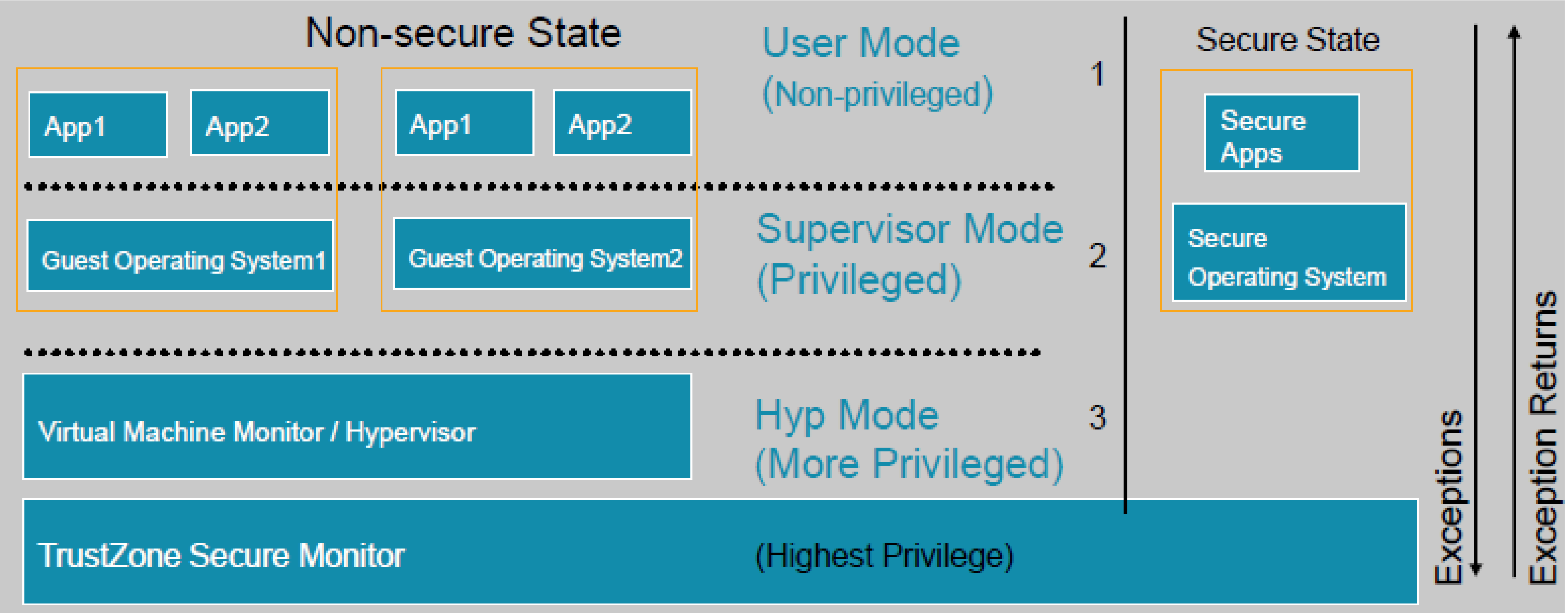
ARM Virtualization Extension



- Secure world supports a single virtual machine
- New Non-secure level of privilege to hold Hypervisor
  - Hypervisor mode applies to normal world
  - Hyp Mode is used by the Hypervisor
  - Guest OS given same kernel/user privilege structure as for a non virtualized environment
- Monitor mode controls transition between worlds

Adapted from “Virtualization Techniques” by Dr. Yeh-Ching Chung, National Tsing Hua University, Taiwan.

Storage virtualization

Storage virtualization

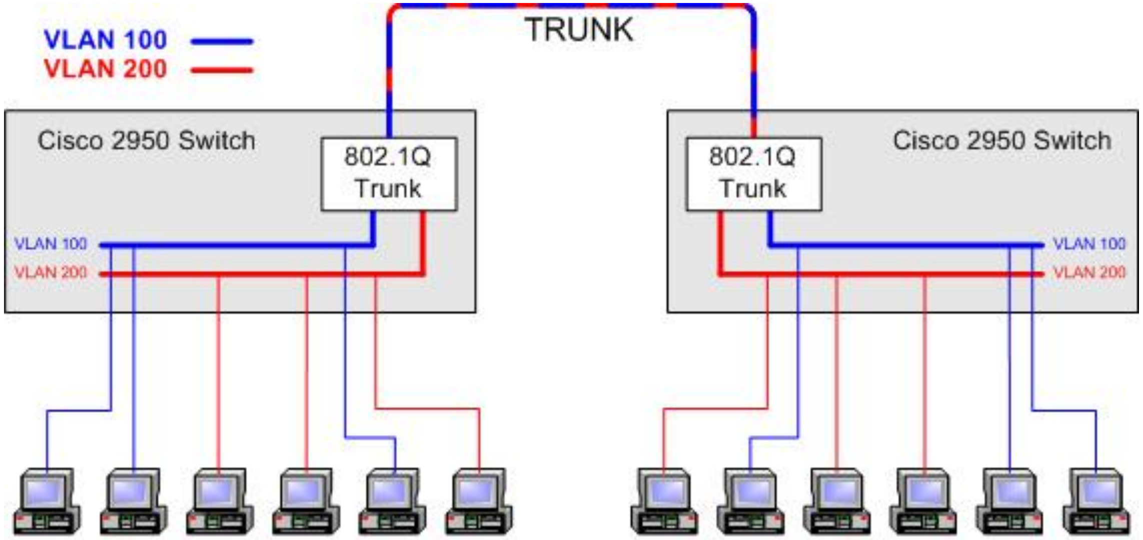
- It’s all the stuff we’ve covered so far:
  - RAID, file systems, etc.

- Only thing to add: **volume management**
  - Concatenate multiple block devices together (including RAID devices)
  - Decouples resulting block device from a single RAID topology
  - Example: Linux Logical Volume Manager (LVM)

Network virtualization

VLANs

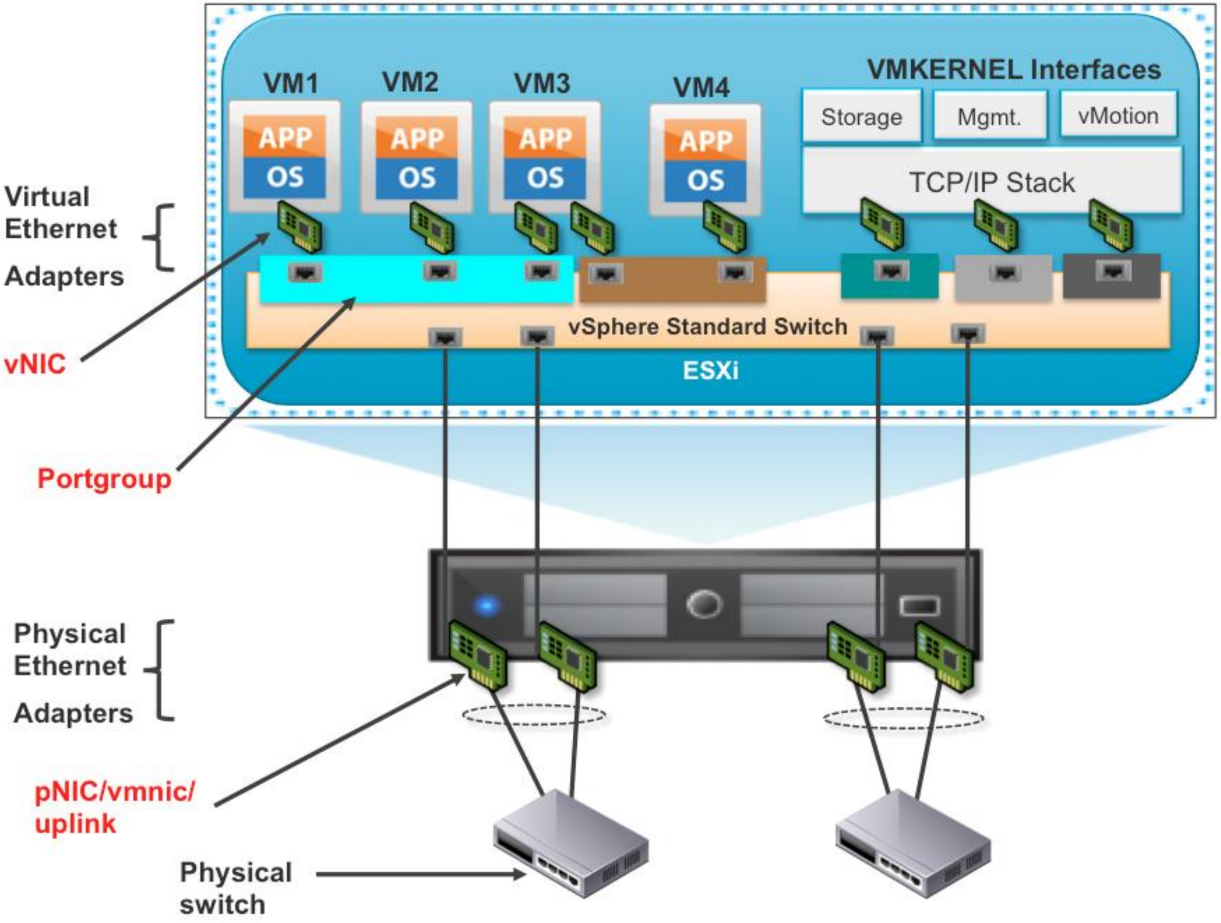
- Logically separate network
- Switch ports can be:
  - **Access ports:** can only see one VLAN, aren't aware of VLAN concept
  - **Trunk ports:** end point includes a VLAN tag in packet header to indicate which VLAN it wants to talk to; interprets such headers on incoming packets



http://www.examcollection.com/certification-training/ccnp-configure-and-verify-vlans-and-trunking.html

VLANs and System Virtualization

- Virtual switches provide virtual access ports
- Hypervisor’s physical NICS are trunk ports for uplink



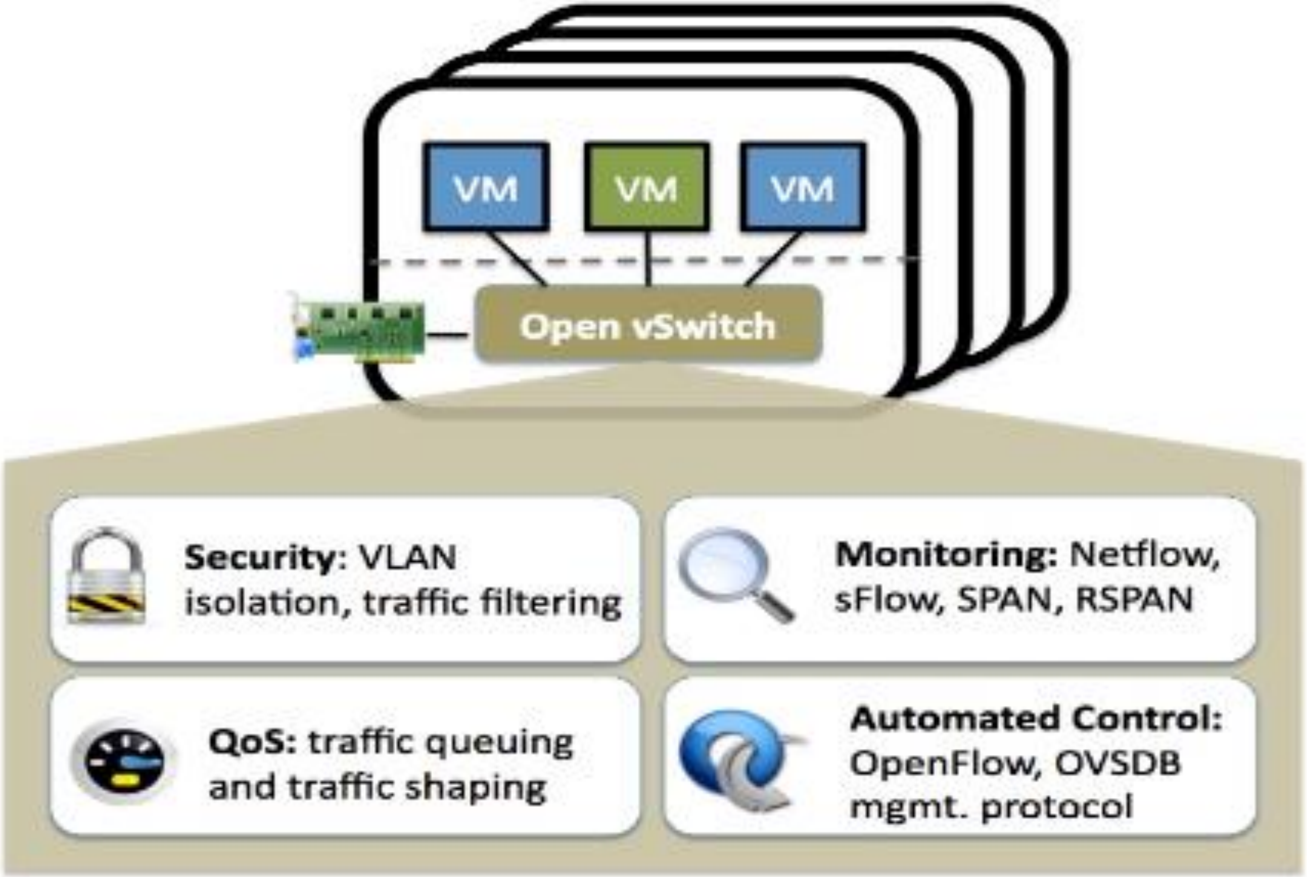
http://blogs.vmware.com/vsphere/2013/01/network-troubleshooting-using-esxcli-5-1.html

Software Defined Networking

- **“Software Defined Networking” (SDN)**: Overused and abused buzzword
- Just means “the network config is done in software”.
- Often translates to “connect everything with fat cables, split up traffic and configure network in software”.

- Examples:
  - Open vSwitch (for KVM/Xen environments)
  - Cisco Nexus 1000V (virtual vSwitch)

Open vSwitch


VM
VM
VM
Open vSwitch
Security: VLAN isolation, traffic filtering
Monitoring: Netflow, sFlow, SPAN, RSPAN
QoS: traffic queuing and traffic shaping
Automated Control: OpenFlow, OVSDB mgmt. protocol

- When it comes to virtualization, open vSwitch is attractive because it provides the ability for **a single controller to manage your virtual network across all your servers**.

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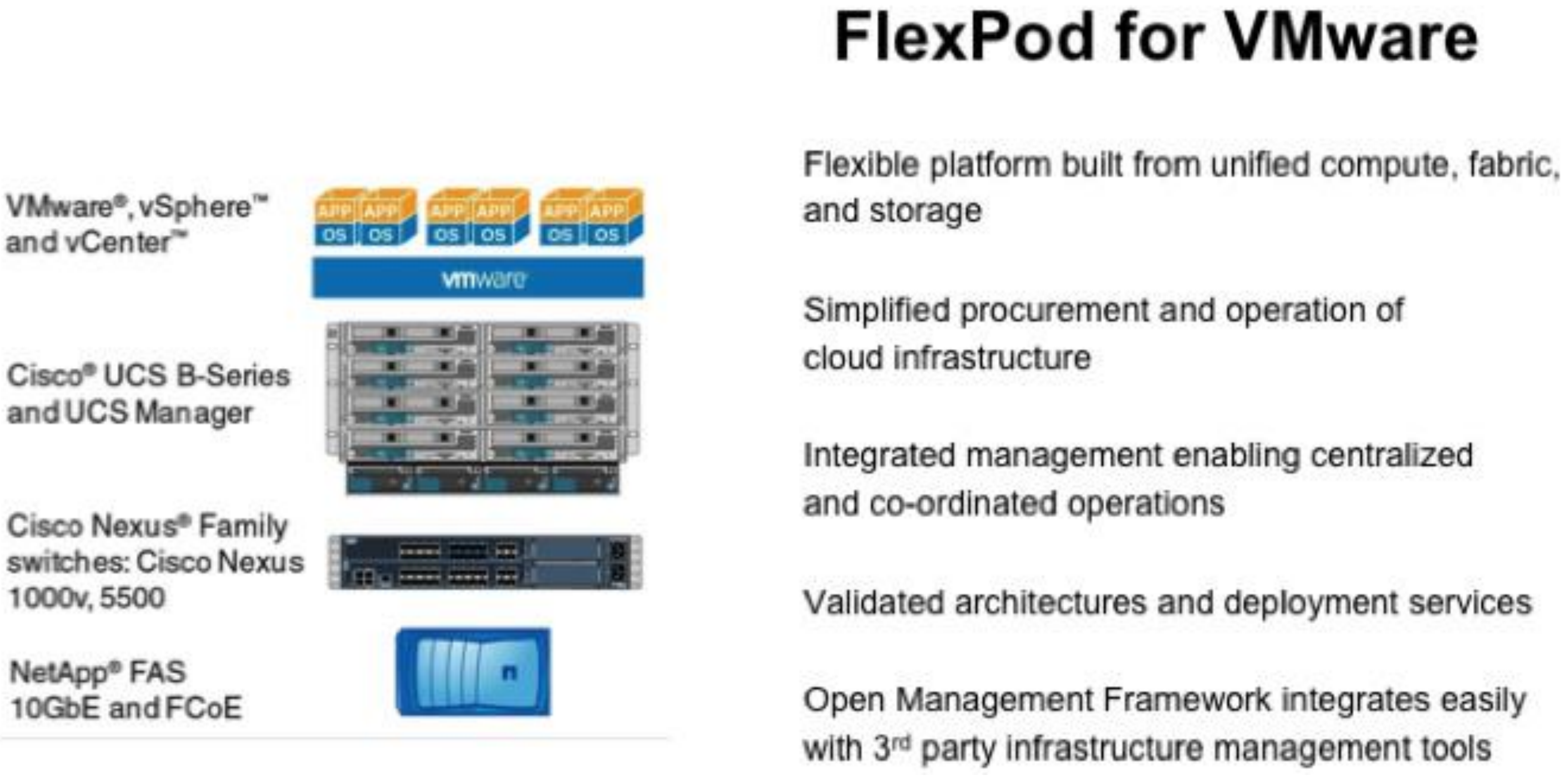
Putting it all together

“FlexPod for VMware”: VMware on Cisco+NetApp



FlexPod for VMware

VMware®, vSphere™ and vCenter™

Cisco® UCS B-Series and UCS Manager

Cisco Nexus® Family switches: Cisco Nexus 1000v, 5500

NetApp® FAS 10GbE and FCoE

Flexible platform built from unified compute, fabric, and storage

Simplified procurement and operation of cloud infrastructure

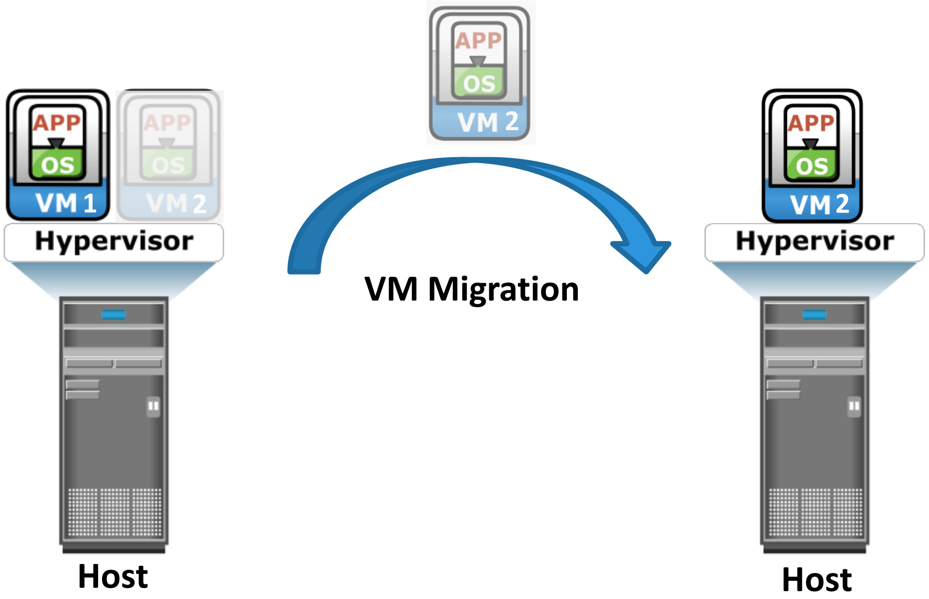
Integrated management enabling centralized and co-ordinated operations

Validated architectures and deployment services

Open Management Framework integrates easily with 3rd party infrastructure management tools

http://community.netapp.com/t5/Tech-OnTap-Articles/Running-Microsoft-Apps-on-FlexPod-for-VMware/ta-p/84887

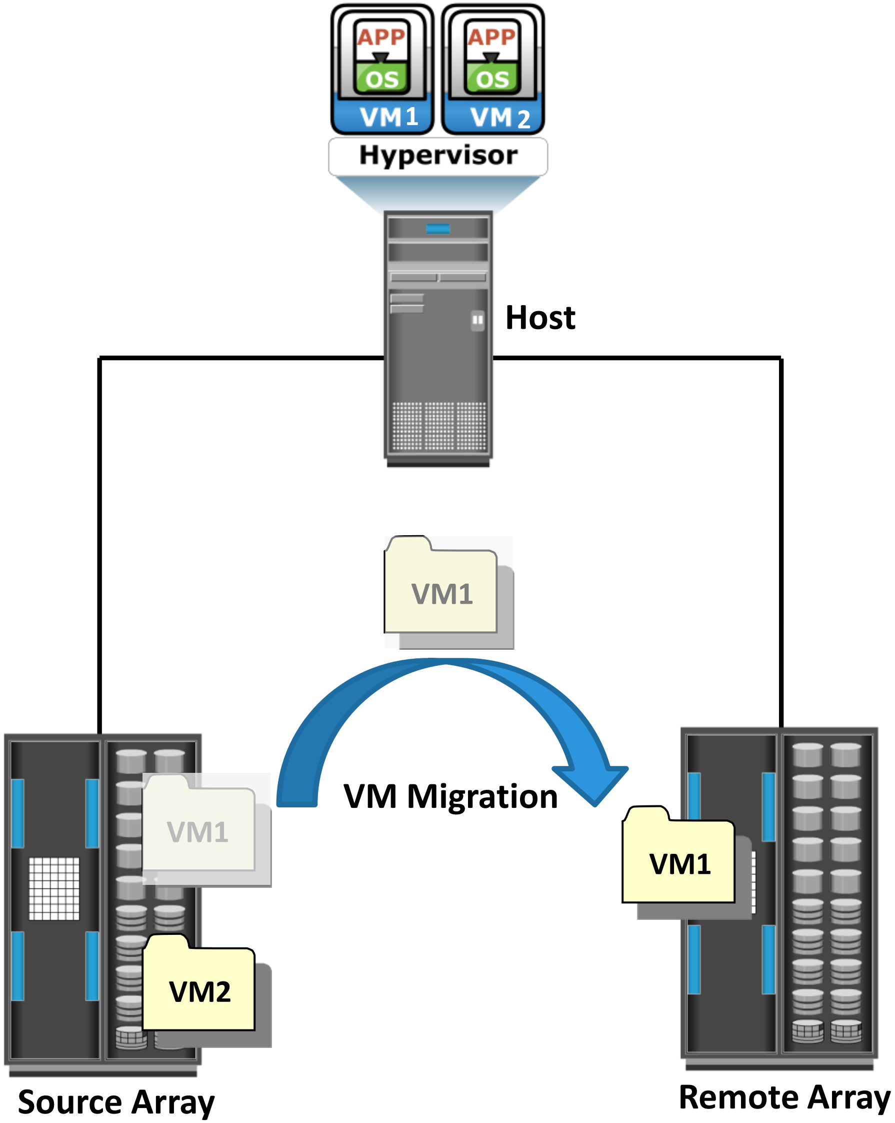
VM Migration: Hypervisor-to-Hypervisor



- Active state of a VM is moved from one hypervisor to another
  - Copies the contents of virtual machine memory from the source hypervisor to the target
- This technique requires source and target hypervisor access to the same storage

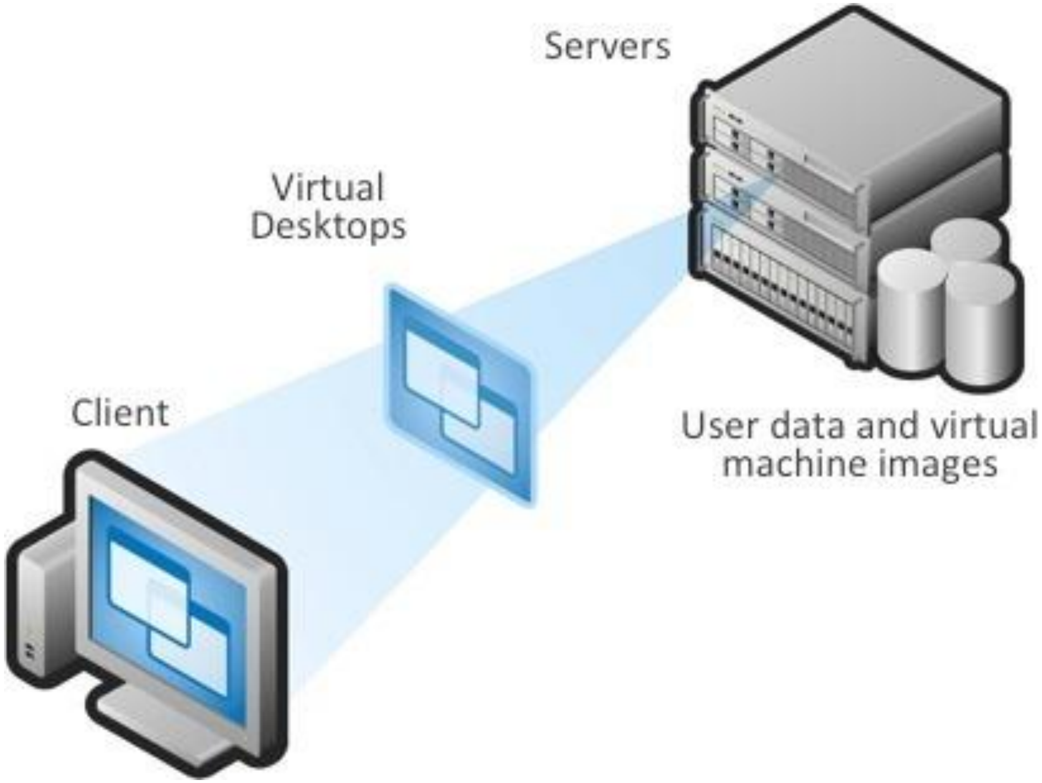
VM Migration: Array-to-Array

- VM files are moved from source array to remote array
- Can move VMs across dissimilar storage arrays
- Balances storage utilization by redistributing VMs to different storage arrays



Common use case:
Virtual Desktop Infrastructure (VDI)

Virtual Desktop Infrastructure (VDI)



- Virtual desktop Infrastructure (VDI) is a desktop-centric service that hosts users desktop environments on remote servers, which are accessed over a network using a remote display protocol.

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VDI

- User’s physical machine is just a “thin client”; just shows remote desktop of VM
  - User does all work in VM
  - VM can be monitored and managed much easier than physical laptop

- Example: NetApp’s Virtual Engineering Desktop and “Dome” architecture for intellectual property security
  - Engineering VLAN separated from internet