CSI3670
Virtualization

Erik Fredericks (fredericks@oakland.edu)

A Day in the IT Life - 101

% The IT Crowd

https://www.youtube.com/watch?v=C2Ph8zwpNyI

https://www.youtube.com/watch?v=NUNEZ9-4v_E

https://www.youtube.com/watch?v=PtXtIivRRKQ

Short In-Class Work (in your groups)

Assume you're taking over the IT Sysadmin role at a relatively new company

You have servers for:

Development/Production, Email, File Sharing, Database hosting

Event logging, Backup servers

What would you virtualize and **why**

Overview

Virtualization

Technologies

- Xen
- Microsoft Hyper-V

Virtualization

Run multiple machines / operating systems on a **single** system

Independently and concurrently

Multiple users each log into their own VM

(Sound familiar?)

Why Virtualization?

Consider an enterprise data center

Always need more servers

And more

And **more**

Easier to virtualize workstations/servers

But Why Virtualization?

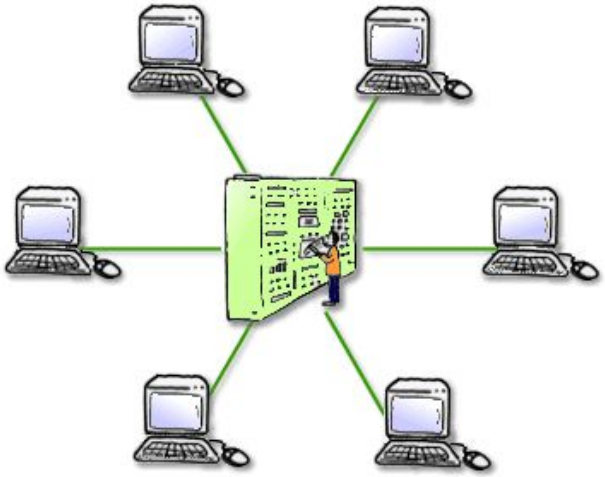
Cost-effective

Less hardware to deal with

Easy to configure

Easy to deploy

History



Implementations have changed over the years

Big Blue (IBM) -- 1960’s

Time-sharing concepts on mainframes

Dormant until cost/manageability made…cost-effective and manageable in the 80’s

VMWare credited for revitalizing virtualization

Terms

Basics

Operating systems generally assume that they are in control

Ha ha. Hahaha. Ha…

But why? What happens if two operating systems try to use the same hardware?

Virtualization then…

Virtualizes hardware!

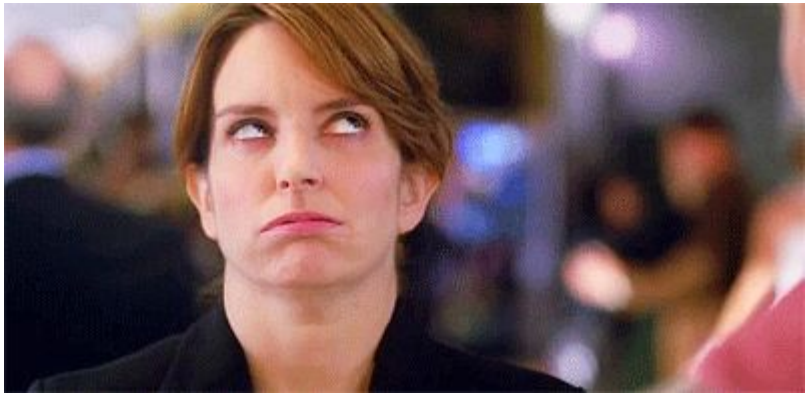
“Abstraction of computing resources”

Full Virtualization

Currently accepted as the norm

OS is “unaware” that it is virtualized

- Thinks its hardware is real

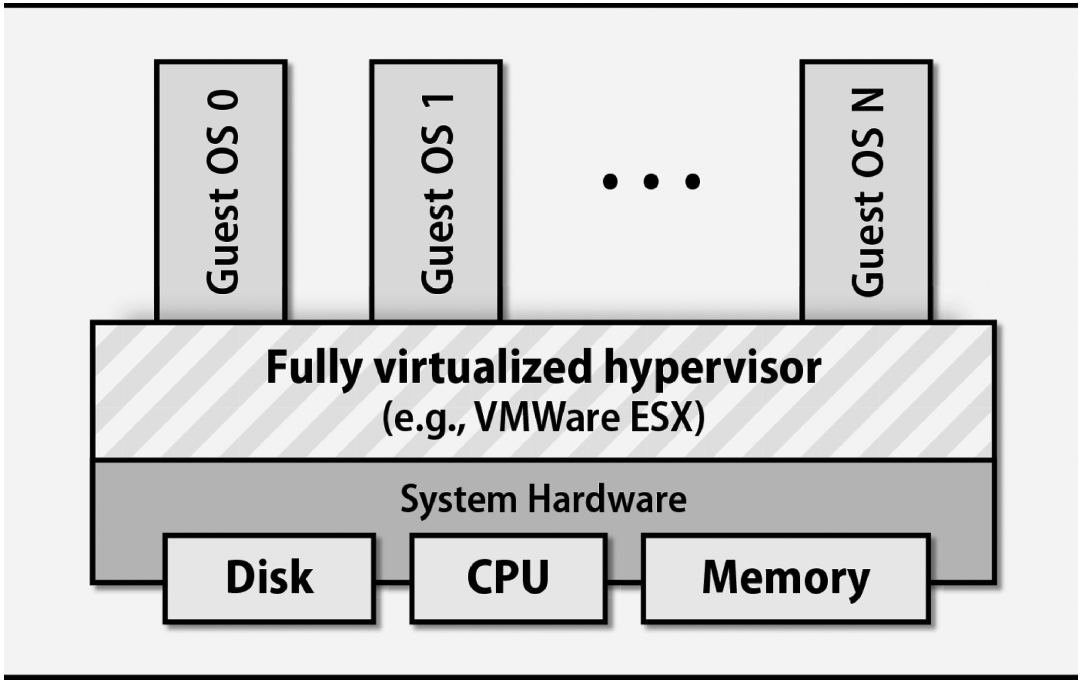


Hypervisor installed between VM and real hardware

- Hypervisor: virtual machine monitor

Full Virtualization

VMWare ESX is an example (what runs on the OU server)



Full Virtualization

Also called “bare-metal” hypervisors

- Control physical hardware
- Hypervisor provides layer of emulation
- OS thinks it is making calls to real hardware
- Currently, most secure approach
  - Any and all calls are intercepted by hypervisor
  - What happens in the VM stays in the VM

Paravirtualization

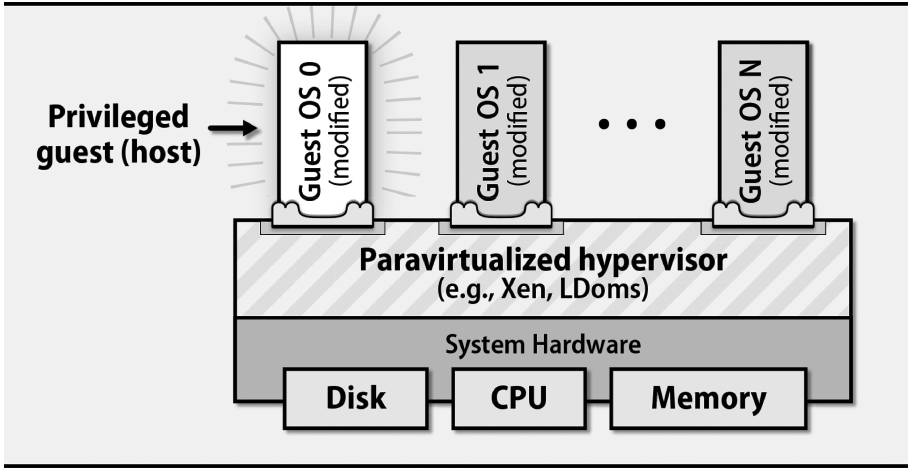
Used by Xen (open source virtualization)

- Also called OS-assisted virtualization

OS kernel must be modified to support hypercalls

- Translation of particular CPU instructions (critical kernel instructions)
- User applications run on guest OS as normal
- Hypervisor still used

Paravirtualization



Translation layer

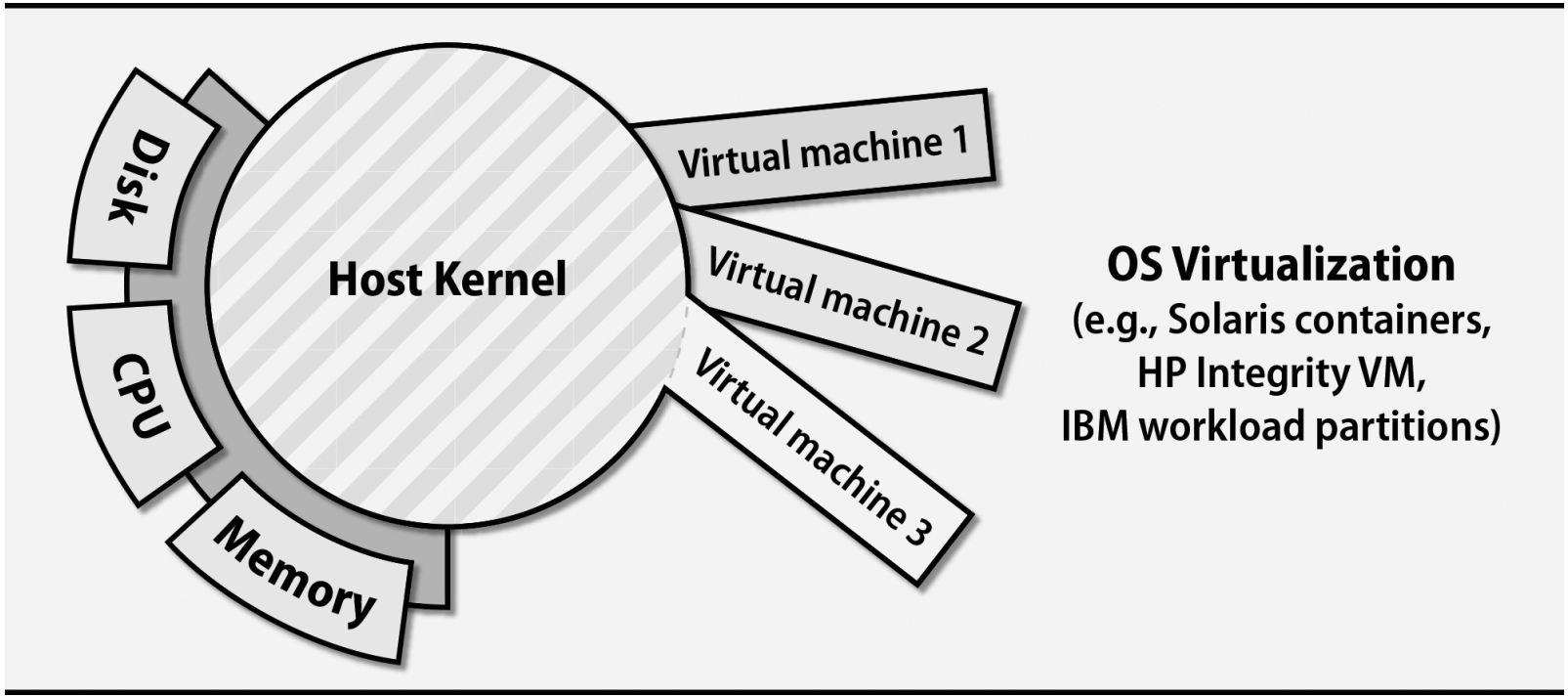
- Less overhead than full virtualization
- Guest OS modification can be a pain
- Easier to modify kernel than to do full virtualization
- (Windows XP and beyond can be installed)
- Privileged guest (dom0): accesses real hardware for other guests

OS Virtualization

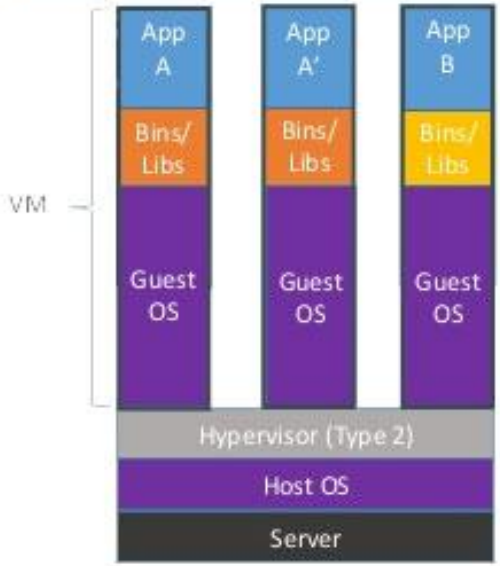
And now for something completely different…

- Operating systems not virtualized but…
- Application environments are!
  - No translation/virtualization layer
  - All environments reference the same kernel/hardware
  - Single kernel shared…cannot install multiple OSs

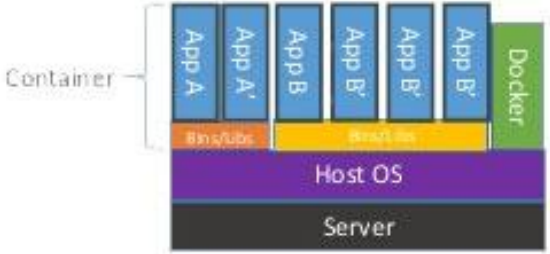
OS Virtualization



Containers vs. VMs



Containers are isolated, but share OS and, where appropriate, bins/libraries



docker

Native Virtualization

AMD/Intel competing to offer virtualization at the chip (CPU) level

Virtualization assembly instructions included

No translation layer required

Intel-VT / AMD-V

Cloud Computing

Computing power as a service

(Or, software as a service -- ahem)

Generally priced on an hourly basis, or per unit of data used

Also, a way to run server farms!

No hardware (that you own) required

No maintenance or knowledge of infrastructure

Cloud Computing

Generally comes with a software interface for managing

- Amazon EC2 (Elastic Compute)
- Microsoft Azure
- Google Cloud

An Aside -- HPC

High-performance computing

- Effectively, a computing cluster
- Managing many, many, many processors
  - For example, 1000+ cores
  - Or...many, many server blades

https://icer.msu.edu/dashboard

HPC

Things to consider:

Space for server racks

HVAC for handling heat overload

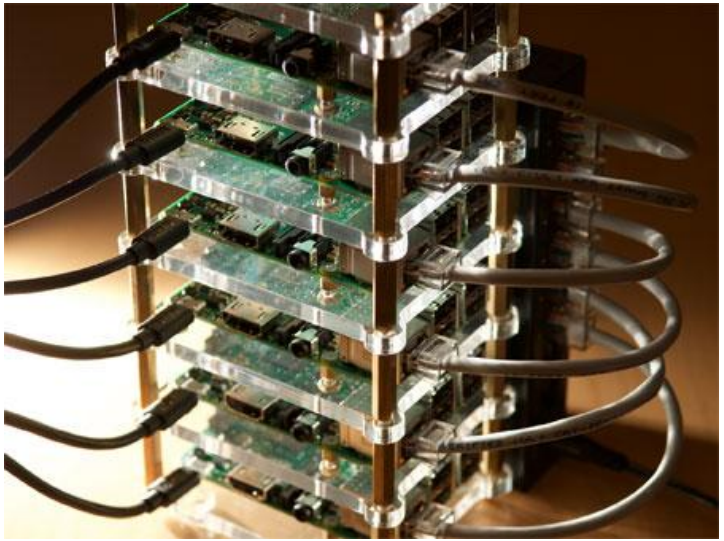
(This is a real issue --- the HPC at MSU would have heat issues roughly once a semester several years ago)

HPC

Other issues

- Configuring such a large service
  - Usually need an **admin** node and a lot of **compute** nodes
    - Each requires an operating system, partitions, IP address, etc.
      - Can automate this process
  - Need to coordinate **jobs**
    - Jobs get distributed over compute nodes for quicker processing
    - Effectively a massively-parallel computational engine

HPC Examples



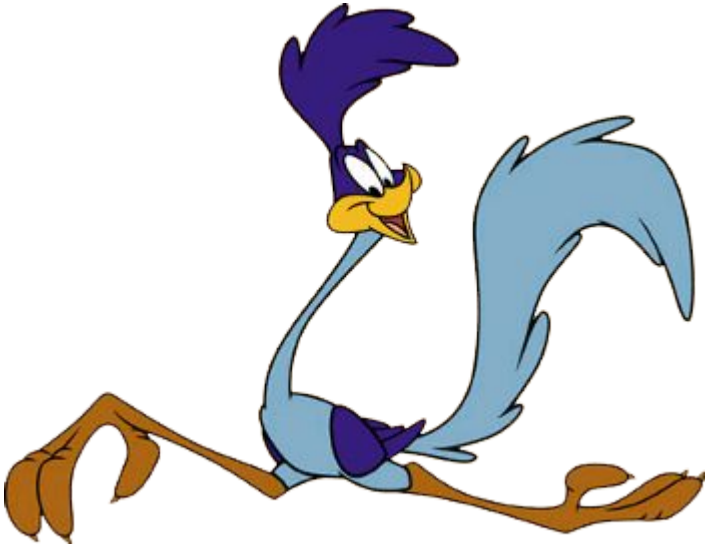
Virtualization Benefits

Cost savings

Reduced energy use

Simplified business continuity

Greater technical agility



Benefits ➜ Cost

Major factor in **ALL** IT projects

- Not only in terms of hardware
- Cooling requirements (HVAC)
- Electricity requirements
- Support / maintenance fees

Benefit ➜ Continuity

Survive physical/logical crises

- **Minimal impact** to normal business operations

Disaster recovery

- Virtual server can simply be...migrated to new server
- Backup scheme becomes even more important!

Benefit ➜ Continuity

All those scripts you know how to write?

Even more important now

Servers **fully** scriptable ➜ they’re completely virtual!

Boot, shutdown, reboot, migration

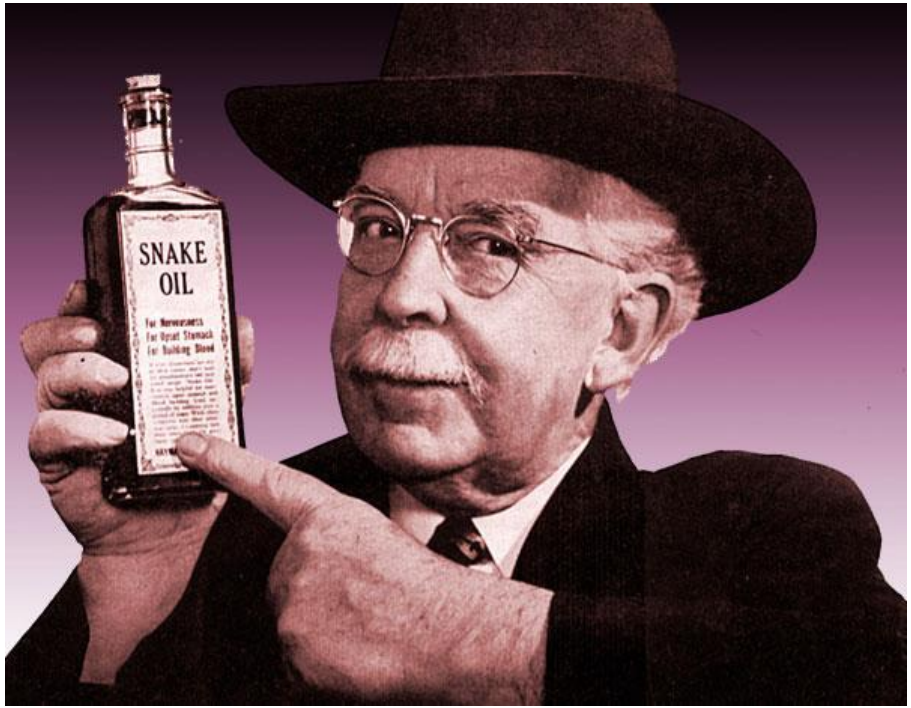
All **cron**-able

Have legacy hardware to deal with?

Virtualize it!

Practicality (or...the downsides)

Not a **panacea**



Transitioning to Virtual

This requires careful planning and foresight

Even more so than just buying a server!

Why?

[Suggested] Things to not Virtualize (Leave as Hardware)

Resource-intensive servers

- Backup servers / log hosts

High-bandwidth applications

- Intrusion detection systems

Busy database systems (I/O bound)

Anything with **hardware-based** copyright protection (e.g., dongles)

[Suggested] Things to Virtualize

Web-servers that “face” the internet

Stand-alone application servers

- Minimally used

Developer systems

- Version control / Build servers

Testing hosts and/or staging environments

Core infrastructure

- DHCP, DNS, LDAP, SSH gateways, time servers, etc.

Major Players

Xen

Microsoft Hyper-V

VMWare

Also KVM (Kernel-based Virtual Machine, not Keyboard,Video,Mouse)

HP-UX, IBM AIX, and others

Xen

Open-source hypervisor project

- http://xenproject.org/

Linux-based Type-1 hypervisor

- Guest operating systems called “domains”
- Domain 0 (dom0) controls hypervisor

Xen

Supports **two** primary types of virtualization:

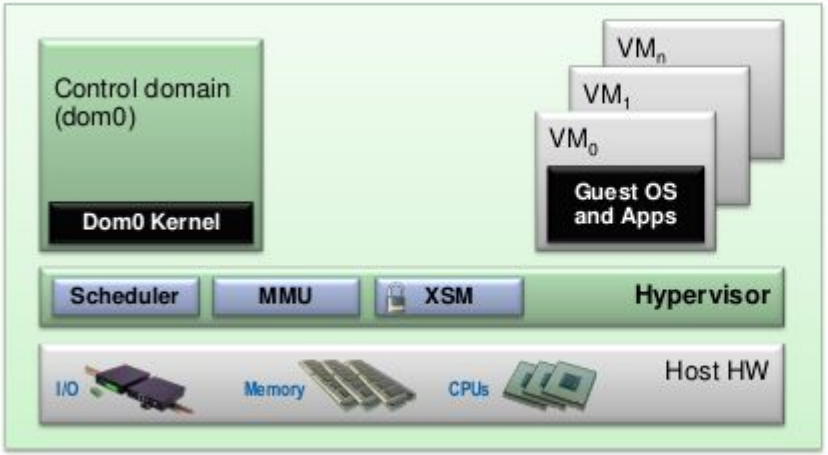
Para-virtualization

- Modified/enlightened guest operating systems
- “Aware of virtualization”
- Don’t require emulated hardware

Hardware virtual machine (HVM)

- “Full virtualization”
- Everything is emulated
- Much more overhead

Xen



Trusted Computing Base

Control Domain aka Dom0

- Dom0 kernel with drivers

Guest Domains

- Your apps

Xen Migration

Domain migration

- Move a domX from one physical host to another
  - Live migration ➔ moves without any loss in service
  - “Magical trick”
    - SSH sessions preserved, HTTP connections not lost, etc.

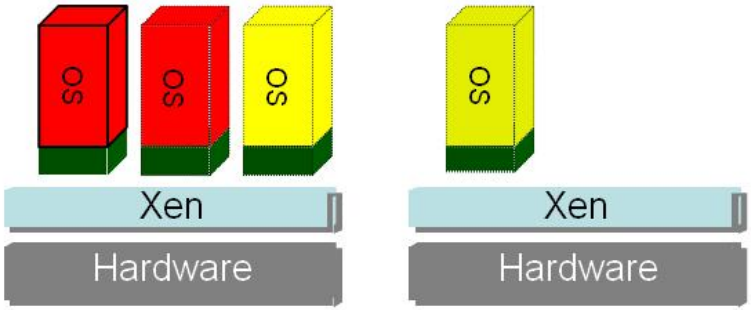
Xen Migration

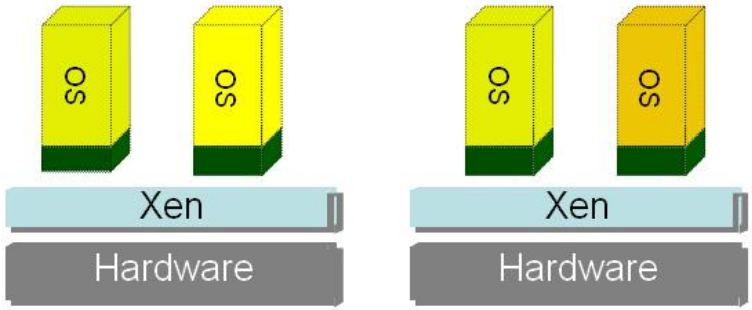
Storage must be shared

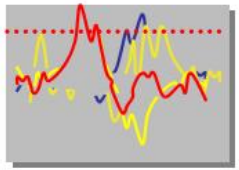
- Disk image files must be accessible by both hosts

Must be on the same IP subnet

- IP and MAC preserved
- Network hardware “discovers” new location after IP traffic starts moving again



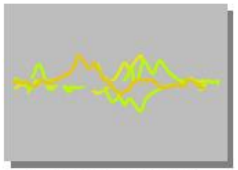




Load before

Goal driven, policy based relocation

QoSPolicyA<..>
QoSPolicyB<..>
QoSPolicyC<..>
QoSPolicyD<..>



Load after

Xen Demo

$ ./demo_not_found.sh

Error: demo not available

Hyper-V

Uses a hypervisor as well (x64-based, no 32-bit!)

- Operating systems can still be 32-bit though

Not available in all server editions!

- Standard ➜ 2 VMs
- Datacenter ➜ Unlimited

Windows Server 2012 R2 Hyper-V Component Architecture

You can get the free mobile app at: http://gettag.mobi

You can get the free Windows 8 app, Server Proconcepts, from the Windows Store

Live Migration

More information...

Improved Live Migration

Windows Server 2012 R2 takes full advantage of your hardware to reduce the time required to live migrate your virtual machines. It is now faster and easier to manage and maintain and your private cloud infrastructure. When maintenance or upgrades are required on your server running Hyper-V, live migration enables you to quickly migrate your virtual machines. This reduces the time it takes to monitor lengthy migration operations.You can also quickly and efficiently balance your virtual machine workloads.

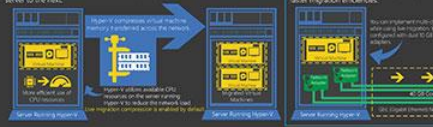
In Windows Server 2012 R2, live migration provides three options to reduce the time required to live migrate your virtual machines. You can choose to use memory compression. Alternatively you can choose to use Remote Direct Memory Access (RDMA) functionality (which requires RDMA-enabled adapters) or multichannel network adapters.

These live migration options can support your private cloud infrastructure by:

- Increasing the efficiency of live migration when your hardware resources are constrained (memory compression).
- Increasing the scalability of live migration when your hardware resources are not constrained (multi-channel and RDMA-enabled network adapters).

Faster Live Migration (less than 10 GB)

In environments where hardware and networking resources are constrained, live migration delivers performance improvements for migrating virtual machines by compressing the memory data before sending it across the network. This utilizes spare CPU capacity available in the server running Hyper-V. Hyper-V closely monitors the CPU requirements of the virtual machine and only consumes an appropriate amount of CPU resources to quickly move virtual machines from one server to the next.

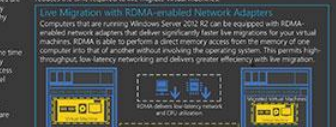


Faster Live Migration (greater than 10 GB)

In environments where networking resources are not constrained, you can configure live migration to use multi-channel network adapters or RDMA-enabled network adapters, which reduces the time required to live migrate virtual machines.

Live Migration with RDMA-enabled Network Adapters

Computers that are running Windows Server 2012 R2 can be equipped with RDMA-enabled network adapters that deliver significantly faster live migrations for your virtual machines. RDMA is able to perform a direct memory access from the memory of one computer into that of another without involving the operating system. This permits high-throughput, low-latency networking and delivers greater efficiency with live migration.



Live Migration with Multi-Channel Network Adapters

Windows Server 2012 R2 servers running multi-channel network adapters installed can perform faster live migrations for your virtual machines. Large virtual machines can be migrated simultaneously, utilizing multiple network adapters and hence achieving faster migration efficiencies.

Upgrading Your Private Cloud

More information...

Live Migration

Hyper-V live migration in Windows Server 2012 R2 updates live migration with new capabilities that enable you to easily upgrade and manage your private cloud. You can now live migrate your virtual machines from Windows Server 2012 to Windows Server 2012 R2 in a simple, automated process that delivers zero downtime for your virtual machines.

You can now easily upgrade your private cloud infrastructure, which eliminates impact to your virtual machine workloads and helps you avoid the cost and inconvenience associated with unwanted downtime. Live migration delivers a more robust and automated upgrade path for large-scale environments and makes it easy to adjust to a faster upgrade cadence as different versions of Windows Server are released. It also makes it easier for you to manage and deliver on your service level agreements.

Simple Live Migration

Live Migration Without Shared Storage

Live Migration with Failover Clusters

Live Migration with SMB Shared Storage

In-Place Upgrades

In Windows Server 2012 R2, in-place upgrades are easier than before. Hyper-V now supports restoring virtual machines from a saved state created on Windows Server 2012 in Windows Server 2012 R2. You simply save your virtual machine state prior to upgrading your host computer, upgrade the host, and then restore the virtual machine. The ability to save and restore virtual machine states across different releases is supported across all Hyper-V features—including import/export, backup and restore, in-place upgrades and checkpoints (snapshots). This can significantly reduce the downtime associated with release upgrades.

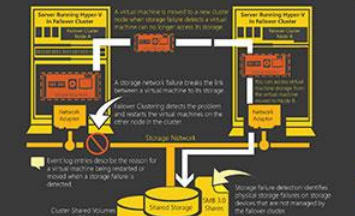
Hyper-V and Failover Clustering

More information...

Storage Failure Detection for Virtual Machines

Windows Server has always allowed you to cluster your virtual machines using storage managed by the failover cluster. If a storage failure was detected, the failover cluster responded in an appropriate manner and ensured that your virtual machine maintained access to its storage. In Windows Server 2012 R2, Hyper-V and Failover Clustering have been enhanced to detect physical storage failures on storage devices that are not managed by the failover cluster (for example, SMB 3.0 shares).

Storage failure detection can detect the failure of a virtual machine boot disk or any secondary data disk associated with the virtual machine. If such an event occurs, Failover Clustering ensures that the virtual machine is relocated and restarted on another node in the cluster. This eliminates situations where unmanaged storage failures would not be detected and where virtual machines resources may become unavailable. For example, a SQL data store failing on a secondary drive is now detected.

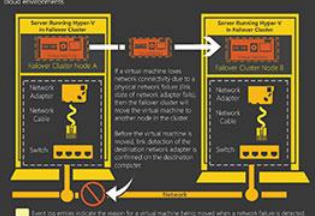


Storage failure detection supports VHD and VHDX file formats, differencing disks, virtual hard disks connected to IDE controllers, virtual hard disks connected to SCSI controllers, virtual machine checkpoints (snapshots), and virtual machines using storage and network resource pools.

Network Failure Detection for Virtual Machines

In previous releases, Failover Clustering has monitored and managed network connectivity among cluster nodes, and between clients and cluster nodes. It detects problems with a network adapter or other network device and takes appropriate action to ensure connectivity is uninterrupted. In Windows Server 2012 R2, Hyper-V and Failover Clustering have been enhanced to detect network connectivity issues for virtual machines. If the physical network assigned to the virtual machine suffers a failure—such as a faulty switch port, network adapter, or a disconnected network cable—then the failover cluster moves the virtual machine to another node in the failover cluster in order to restore network connectivity.

You can use network failure detection to monitor the health of a physical cluster node as well as the health of the virtual machine and ensure that you can provide a robust environment to host private cloud environments.



Network failure detection works with any virtual machine. It supports legacy and software-based network adapters, SR-IOV-enabled network adapters, virtual machine checkpoints, storage or network resource pools, and advanced networking features enabled on your network adapters.

Hyper-V Storage

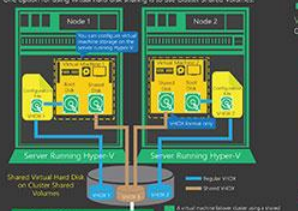
More information...

Hyper-V with Virtual Hard Disk Sharing

Windows Server 2012 R2 enables you to share a virtual hard disk file (VHDX format), which provides shared storage for a virtual machine failover cluster (also known as a guest cluster). By making shared storage available to virtual machines, you can can easily use a virtual machine failover cluster to protect your application services (for example, SQL or file server services) running inside your virtual machines.

Virtual Machine Clustering Using Cluster Shared Volumes

One option for using virtual hard disk sharing is to use Cluster Shared Volumes.



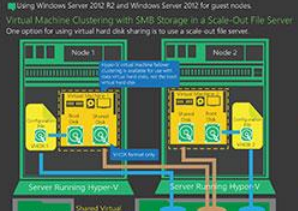
Supported Scenarios for Virtual Hard Disk Sharing

Supported scenarios include:

- Fast virtual hard disk sharing using SMB Direct and SMB Multichannel.
- Migrating shared virtual hard disks using live migration.
- Saving and restoring virtual machines.
- Protecting against the failure of a guest node. Hyper-V host, or file server node.
- Using Windows Server 2012 R2 for file server nodes and Hyper-V hosts.
- Using Windows Server 2012 R2 and Windows Server 2012 for guest nodes.

Virtual Machine Clustering with SMB Storage in a Scale-Out File Server

One option for using virtual hard disk sharing is to use a scale-out file server.



Storage Quality of Service

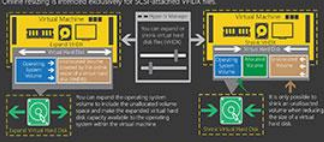
Hyper-V in Windows Server 2012 R2 includes the ability to set certain Quality of Service (QoS) parameters for storage on a virtual machine.

Storage QoS provides storage performance isolation in a multi-tenant environment and mechanisms to notify you when the storage I/O performance does not meet the defined threshold to efficiently run your virtual machine workloads.

Online Virtual Hard Disk Resizing

Windows Server 2012 R2 enhances your capability to manage virtual machine storage resources. You can increase or decrease the size of a virtual hard disk while the virtual machine is still running.

Online resizing is intended exclusively for SCSI-attached VHDX files.



Session Modes

More information...

The Hyper-V Virtual Machine Connection tool (VMConnect) provides you access to the desktop or console environment of running virtual machines. Windows Server 2012 R2 and Windows 8.1 introduce a new enhanced session mode to connect to virtual machines. Basic mode connections are supported.

Basic Mode

Basic session mode provides a basic console view for the virtual machine, which allows you to send mouse and keyboard information and to view the graphics displayed by the virtual machine. This is analogous to plugging in a monitor to a physical computer.

Enhanced Session Mode

In enhanced session mode, VMConnect provides you with a high-fidelity experience when connecting to Hyper-V virtual machines. It delivers the ability to share a clipboard between the client computer and virtual machine—and supports redirected audio, redirected USB, multi-touch, multi-monitor, and the use of smartcards for logon authentication. Enhanced session mode provides similar capabilities to Remote Desktop Services without the need for a network connection to the virtual machine.

- USB device redirection requires that Group Policy is configured on the client computer.
- Enhanced session mode support requires a guest operating system that supports Remote Desktop Services. Device redirection capabilities might differ depending on the operating system running in the virtual machine.
- Remote Desktop Services does not need to be enabled in the guest operating system.

Generation 2 Virtual Machines

More information...

Generation 2 Virtual Machines

Windows Server 2012 R2 introduces a new class of virtual machines that are optimized for virtualization—generation 2 virtual machines. They provide advanced features that deliver significant management, storage and security benefits.

In Windows Server 2012 R2, generation 2 virtual machine hardware removes most of the emulated ("legacy") devices, or replaces them with optimized software-based devices.

Generation 2 virtual machines lay the foundation for advanced virtual machine features, including a reduced attack surface for the platform and faster boot times for virtual machines.

Booting Generation 2 Virtual Machines

Generation 2 virtual machines use a Unified Extensible Firmware Interface (UEFI) and software-based devices when turning on your computer. UEFI is an alternate firmware interface and delivers improved boot time performance and flexibility.

Generation 2 virtual machines provide the following boot capabilities:

Running simultaneous virtual machines on the same server. Windows Server 2012 R2 supports creating and running generation 1 and generation 2 virtual machines on the same server simultaneously. This ensures you can easily migrate virtual machines running on an earlier version of Hyper-V to Windows Server 2012 R2.

Network boot. Generation 2 virtual machines use the optimized virtual network adapter. This eliminates the need for an emulated network adapter. It simplifies the process of booting a virtual machine and decreases problems associated with configuring virtual machine network adapters. IPV4 and IPV6 addressing schemes are supported.

Secure Boot. Generation 2 virtual machines use UEFI firmware, which provides support for Secure Boot. Secure Boot functionality prevents "unauthorized" operating systems and software from loading during the startup process.

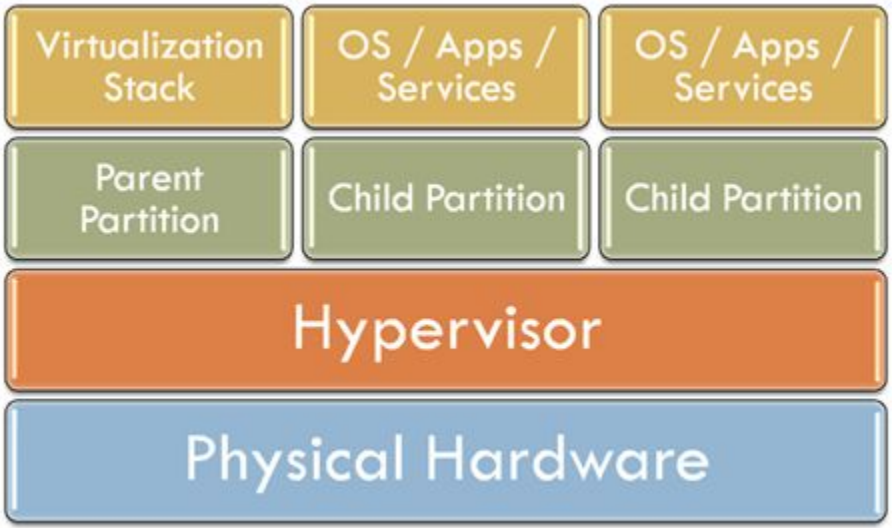
Boot from a SCSI CD/DVD. Generation 2 virtual machines can boot from a SCSI CD/DVD drive using an ISO image file.

Boot from a SCSI-attached virtual hard disk. Using UEFI firmware support, generation 2 virtual machines can boot from SCSI-attached virtual hard disks (VHDX). The VHDX file format supports volumes up to 64 TB.

Understanding Generation 2 Virtual Machines

Author: Martin McClean (Cloud & Enterprise Division) email: virtue@microsoft.com

Simplified View



VMWare

A discussion unto itself (will look at vsphere datacenters)

Hyper-V vs. Xen

Hyper-V technically free

- But requires Windows Server purchase (plus, whichever edition you choose)
- Can run on any hardware

Xen can be free or paid (if you go with Citrix XenServer)

- Requires Intel-VT or AMD-V (CPU virtualization instructions)

Xen tends to be preferred for situations that require high-performance

But…if you’re a Microsoft shop…chances are you’ll go with Hyper-V

Further Reading

VMWare Virtualization Overview

https://www.vmware.com/content/dam/digitalmarketing/vmware/en/pdf/techpaper/VMware_paravirtualization.pdf

Hyper-V vs. VMWare vs. Xen

http://blog.unitedlayer.com/hypervisor-101-vmware-virtualbox-hyper-v-infographic

HPC

http://www.admin-magazine.com/HPC/Articles/real_world_hpc_setting_up_an_hpc_cluster