Cloud and Machine Learning

CSCI-GA.3033-085

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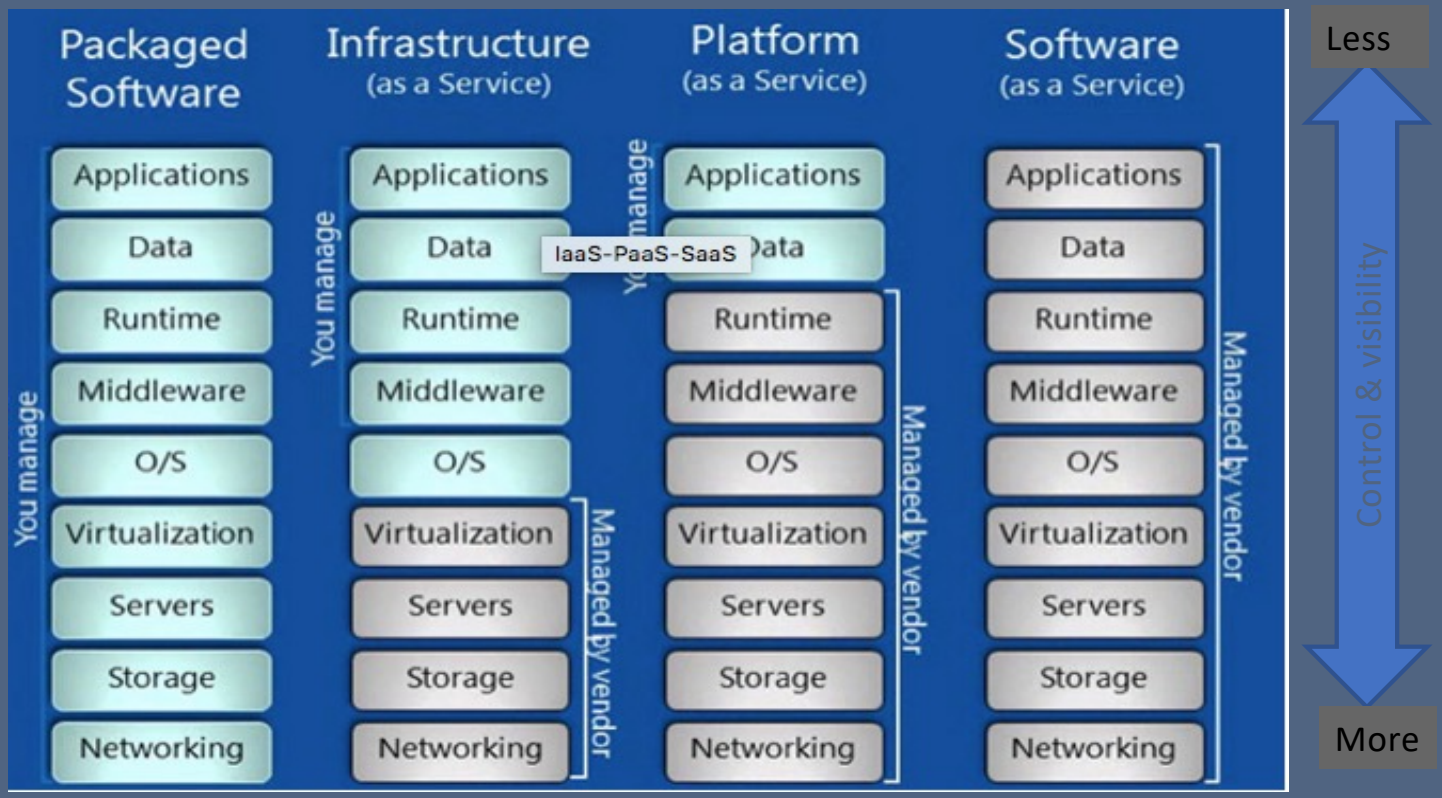
Agenda

- Public Cloud Architecture Components
- Cloud Key Tech: Virtualization and Virtual Machine
- Hands on create and use VM on your laptop

Cloud computing essential elements

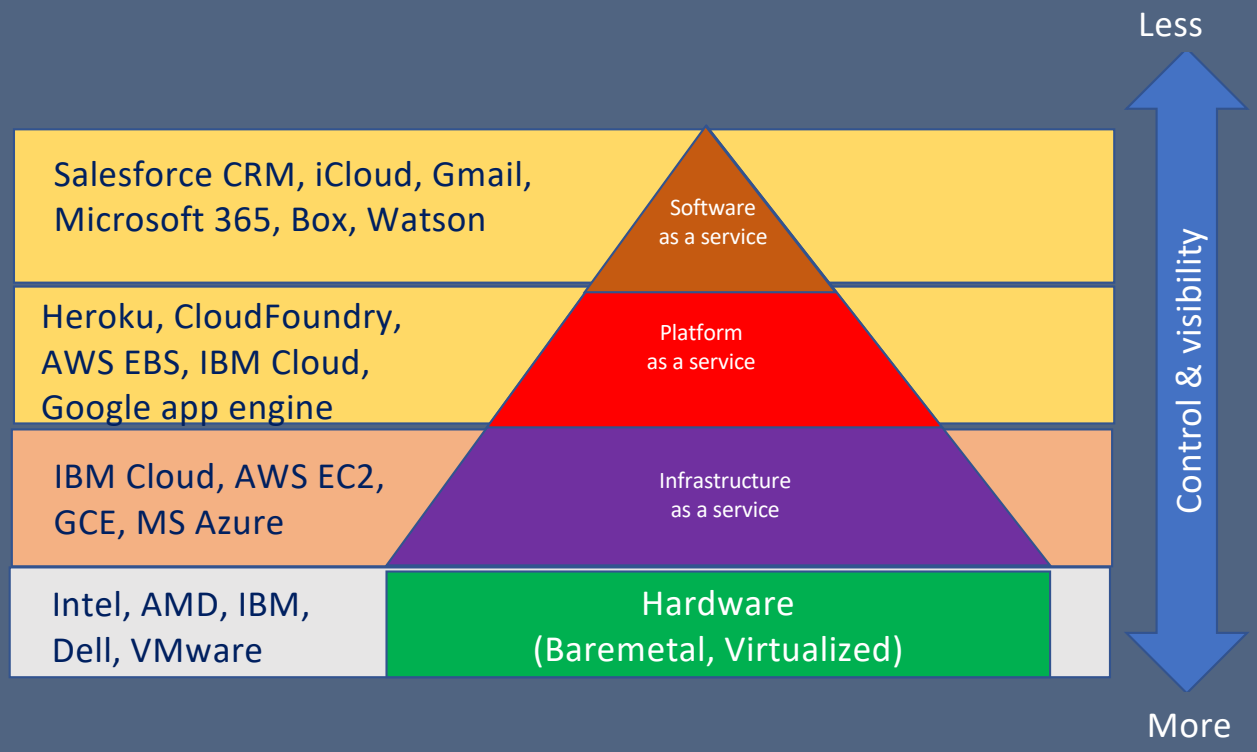
- *On-demand self-service*
- *Broad network access*
- *Resource pooling*
- *Rapid elasticity*
- *Measured service*

Layers of Cloud Computing

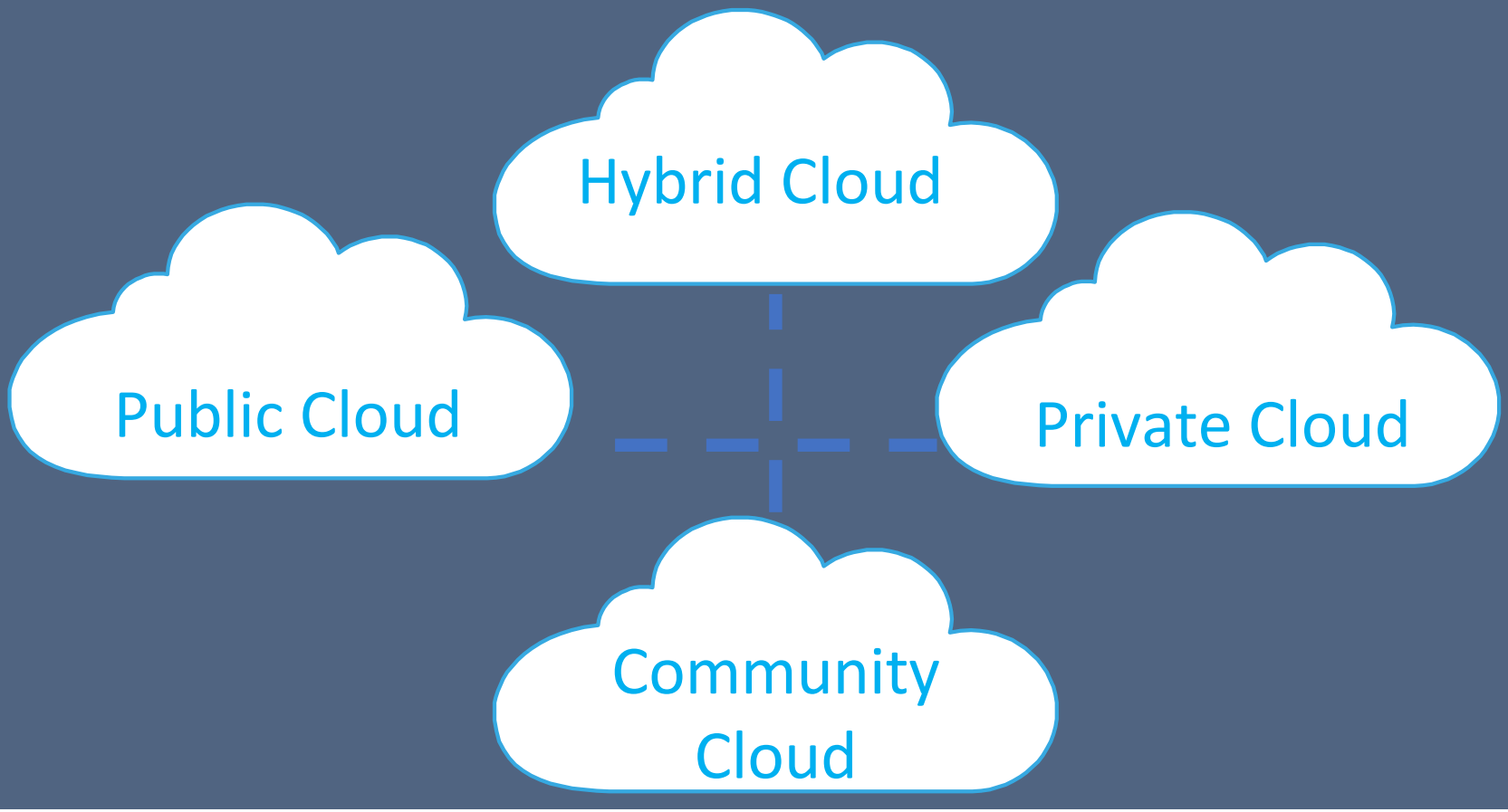


Source: https://venturebeat.com/2011/11/14/cloud-iaas-paas-saas/

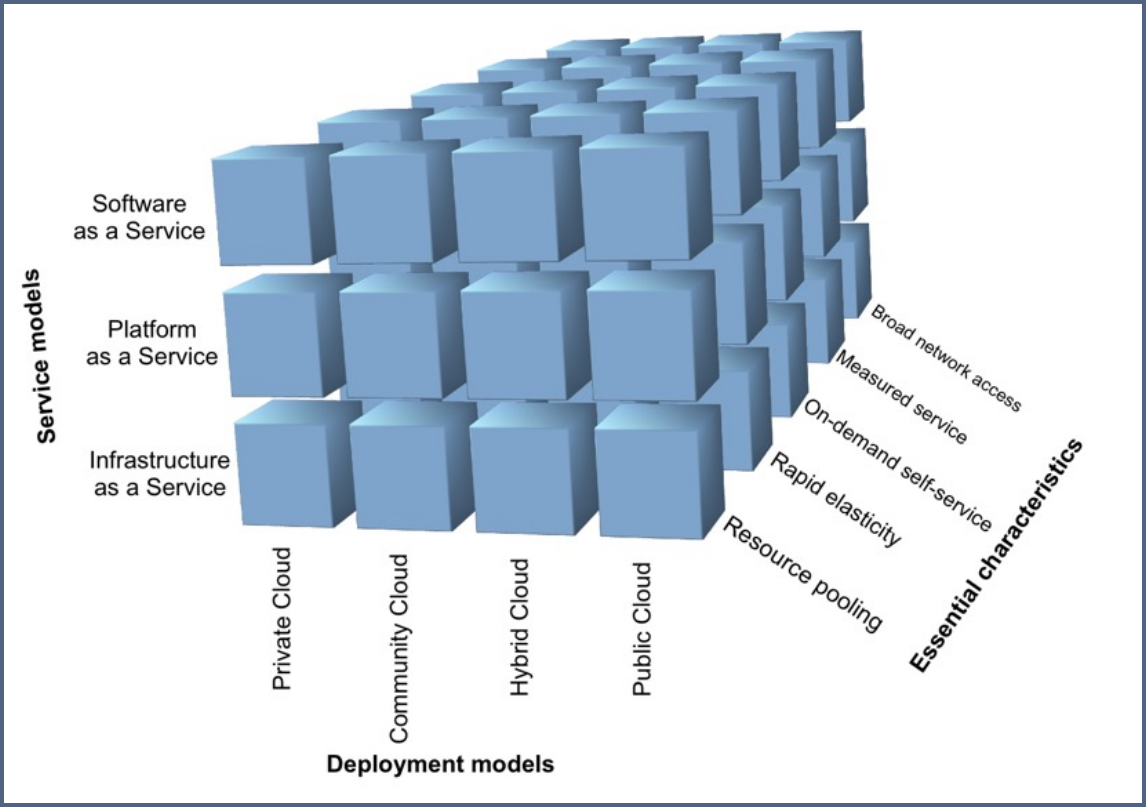
Cloud Computing Models: IaaS, PaaS, SaaS



Cloud Computing Deployment models

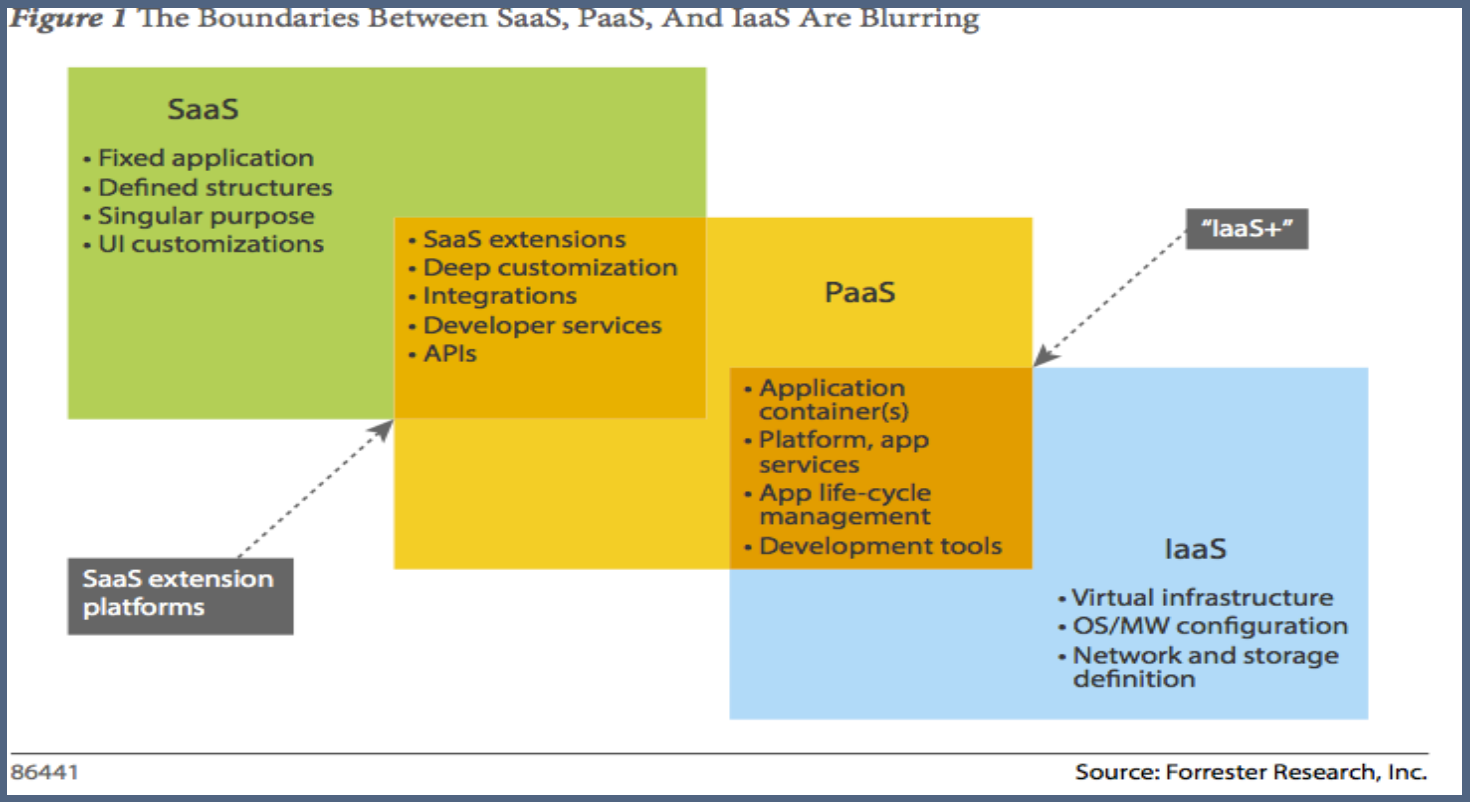


NIST Cloud Definition: in a picture



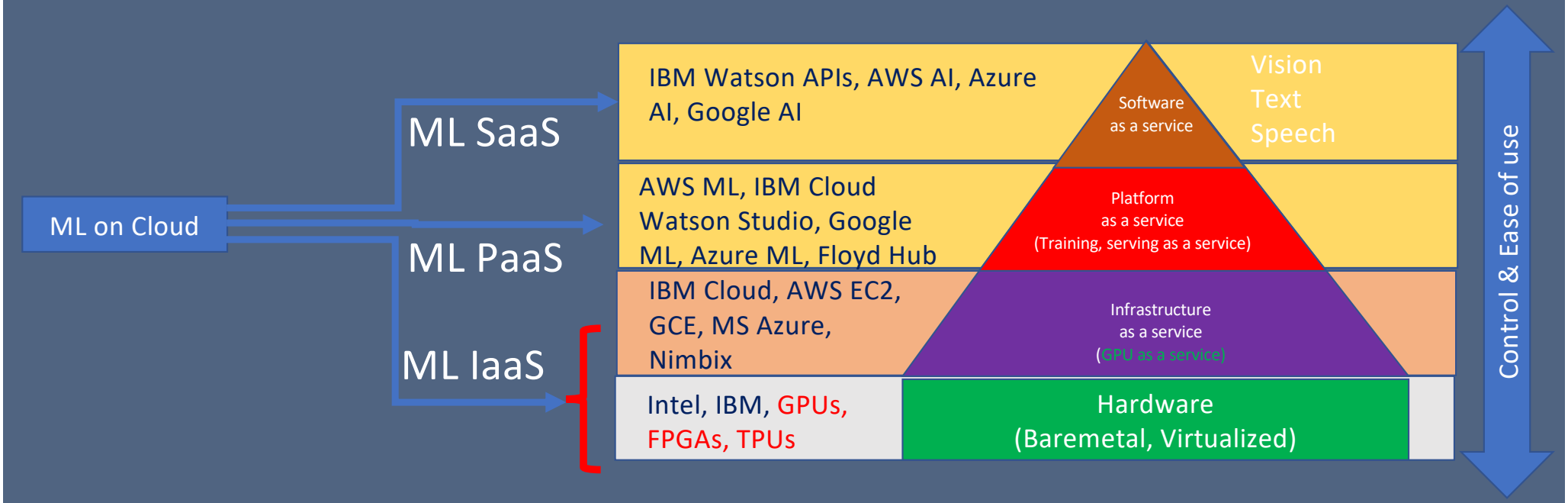
http://cdn.katescomment.com/wordpress/wp-content/uploads/2010/02/CloudCube1.png

Cloud Variations



http://www.forrester.com/pimages/rws/reprints/document/86441/oid/1-MNNSJD

Machine learning on cloud



Homework material (submit a short report)

- Access IBM, Google and Amazon cloud
- Pick one similar service among IaaS, PaaS, and SaaS services from each of the 3 vendors, study them
- Write a report describing each of the services and compare them
- Sample comparison points: usability, capability, performance (e.g., time to create the service)
- Report can be up to 2 pages, it must have 10 items in total (3 clouds, 3 services each and a final comparison section)
  - Technical writing practice (including references, title, author, intro.) is appreciated.
- Must follow NYU Policy on plagiarism
  - A free plagiarism checker you can use: https://plagiarismdetector.net/

Home setup and preview of next class

- Your NYU Net-ID allows you to access Google cloud. Give it a try and let us know if you have issues.
  - NYU Google Cloud accesses
  - Alternatively, get access to Google Cloud free tier services at here.
- AWS has a collection of free tier services.
  - Best to sign up AWS Educate follow this page. It has a list of free services.

Cloud computing benefits

- Cloud enables new business models
- Time to deploy services
- Cost control and ability to scale on-demand
- CapEx to OpeEx
- Business agility
- Simplified usage model
- Resource efficiency

Cloud concerns

- Data, data, data
- Security
- Regulation
- Cost
- Service Level Agreements (SLA’s)
- Loss of control
- Business continuity

This is a list of **data breaches**, using data compiled from various sources, including press reports, government news releases, and mainstream news articles. The list includes those involving the theft or compromise of 30,000 or more records, although many smaller breaches occur continually. Breaches of large organizations where the number of records is still unknown are also listed. In addition, the various methods used in the breaches are listed, with hacking being the most common.

Most reported breaches are in North America, at least in part because of North America's relatively strict disclosure laws. It is estimated that the average cost of a data breach will be over $150 million by 2020, with the global annual cost forecast to be $2.1 trillion.[1][2] As a result of data breaches, it is estimated that in first half of 2018 alone, about 4.5 billion records were exposed.[3] In 2019, a collection of 2.7 billion identity records, consisting of 774 million unique email addresses and 21 million unique passwords, was posted on the web for sale.[4]

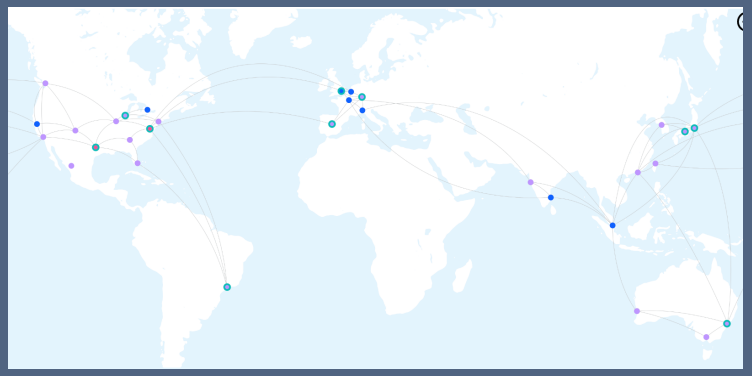
Entity	Year	Records	Organization type	Method	Sources
Iberdrola	2022	1,300,000	energy	poor security	[200]
International Committee of the Red Cross	2022	515,000	humanitarian	unknown	[204][205][206]
Morinaga Confectionery	2022	1,648,922	online shopping	ransomware hacked	[250]
Twitter	2022	5,400,000	tech	hacked	[308]
50 companies and government institutions	2022	6,400,000	various	poor security	[411] [412]
IKEA	2022	95,000	retail	accidentally published	[413]
Ancestry.com	2021	300,000	web	poor security	[23]
Ankle & Foot Center of Tampa Bay, Inc.	2021	156,000	healthcare	hacked	[25]
Apple, Inc./BlueToad	2021	12,367,232	tech, retail	accidentally published	[32]
Apple	2021	275,000	tech	hacked	[33]
Apple Health Medicaid	2021	91,000	healthcare	poor security	[34]
Atraf	2021	unknown	dating	hacked	[38]
CyberServe	2021	1,107,034	hosting provider	hacked	[98][99]
Dedalus	2021	500,000	health	poor security	[103]
Health Service Executive	2021	unknown	healthcare	unknown	[187]
Microsoft Exchange servers	2021	unknown	software	zero-day vulnerabilities	[241]
NEC Networks, LLC	2021	1,600,000	healthcare	hacked	[255]
T-Mobile	2021	45,000,000	telecom	hacked	[341]
Twitch	2021	unknown	tech	hacked/misconfiguration	[348]
500px	2020	14,870,304	social networking	hacked	[7]
Accendo Insurance Co.	2020	175,350	healthcare	poor security	[8][9]
Animal Jam	2020	46,000,000	gaming	hacked	[24]
Betsson Group	2020	unknown	gambling	unknown	[54]
Capcom	2020	350,000	game	hacked	[70]
CheckPeople	2020	56,000,000	background check	unknown	[80]
Clearview AI	2020	unknown (client list)	information technology	hacked	[87][88][89]
FireEye	2020	Unknown	Information Security	hacked	[154][155][156]

https://en.wikipedia.org/wiki/List_of_data_breaches

Public cloud locations (Jan. 2024)

AWS (33 regions, 105 zones)

GCE (39 regions, 118 zones)

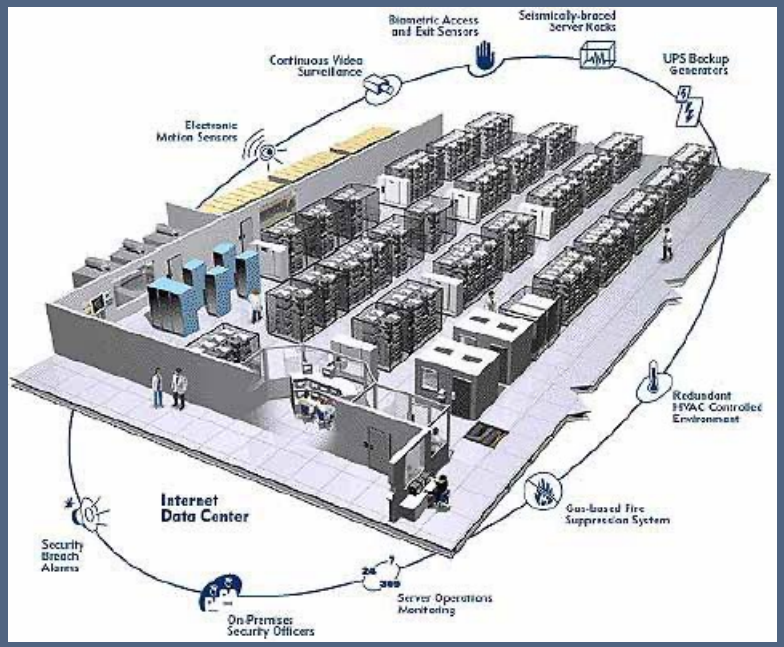


IBM
https://www.ibm.com/cloud/data-centers

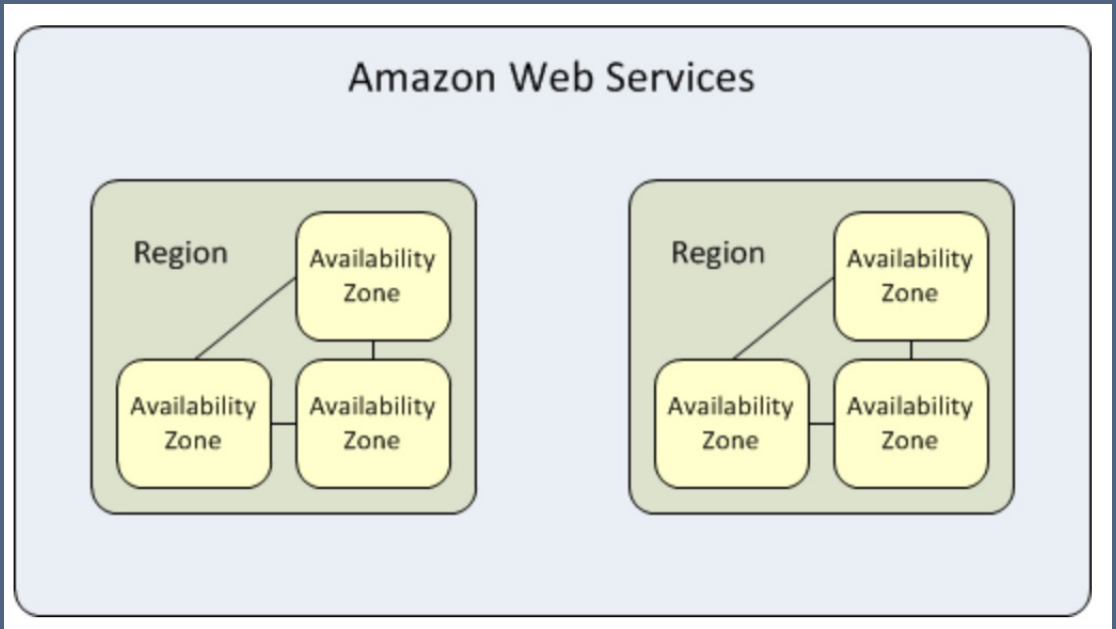
AZURE
https://azure.microsoft.com/en-us/global-infrastructure/)
https://datacenterlocations.com/microsoft-azure/

What are data centers?

https://www.youtube.com/watch?v=XZmGGAbHqa0
https://www.youtube.com/watch?v=Y8Rgje94iI0



Cloud region is a basic concept for all public clouds



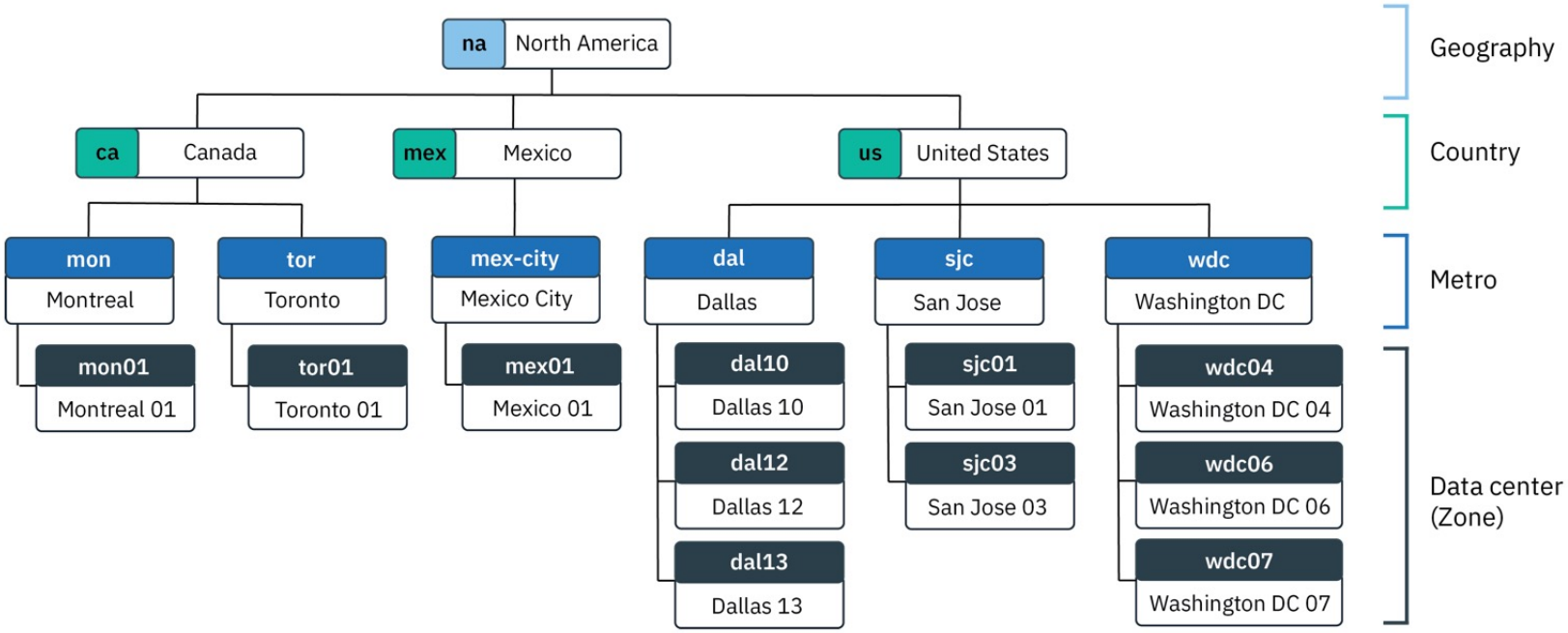
- Physically distant
- Independent power supply
- Independent cooling and backup generators
- Dedicated networking
- Low latency network connection between zones
- Best practice: distribute application in a region

3 or more data centers within a region but isolated from each other
Typically: 0-20 miles apart

IBM Cloud Locations (2024)

How locations are organized

The following image is used as an example to explain how IBM Cloud Kubernetes Service locations are organized.



https://cloud.ibm.com/docs/containers?topic=containers-regions-and-zones

IBM Cloud Locations for VPC (2024)

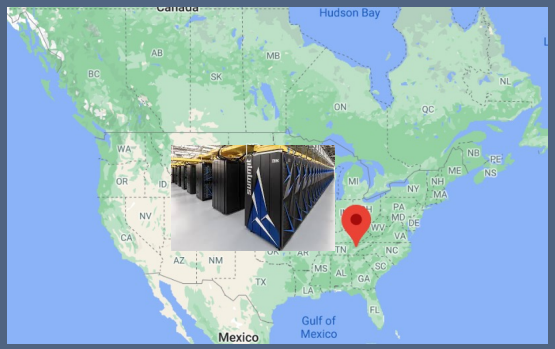
Geography	Country	Metro	Region	Zone	Location
Asia Pacific	Australia	Sydney	au-syd	au-syd-1 au-syd-2 au-syd-3	Sydney 1 Sydney 2 Sydney 3
Asia Pacific	Japan	Osaka	jp-osa	jp-osa-1 jp-osa-2 jp-osa-3	Osaka 1 Osaka 2 Osaka 3
Asia Pacific	Japan	Tokyo	jp-tok	jp-tok-1 jp-tok-2 jp-tok-3	Tokyo 1 Tokyo 2 Tokyo 3
Europe	Germany	Frankfurt	eu-de	eu-de-1 eu-de-2 eu-de-3	Frankfurt 1 Frankfurt 2 Frankfurt 3
Europe	United Kingdom	London	eu-gb	eu-gb-1 eu-gb-2 eu-gb-3	London 1 London 2 London 3
North America	Canada	† Toronto	ca-tor	ca-tor-1 ca-tor-2 ca-tor-3	Toronto 1 Toronto 2 Toronto 3
North America	United States	Dallas	us-south	us-south-1 us-south-2 us-south-3	Dallas 1 Dallas 2 Dallas 3
North America	United States	Washington DC	us-east	us-east-1 us-east-2 us-east-3	Washington DC 1 Washington DC 2 Washington DC 3
South America	Brazil	† São Paulo	br-sao	br-sao-1 br-sao-2 br-sao-3	São Paulo 1 São Paulo 2 São Paulo 3

https://cloud.ibm.com/docs/containers?topic=containers-regions-and-zones

Inside cloud data centers

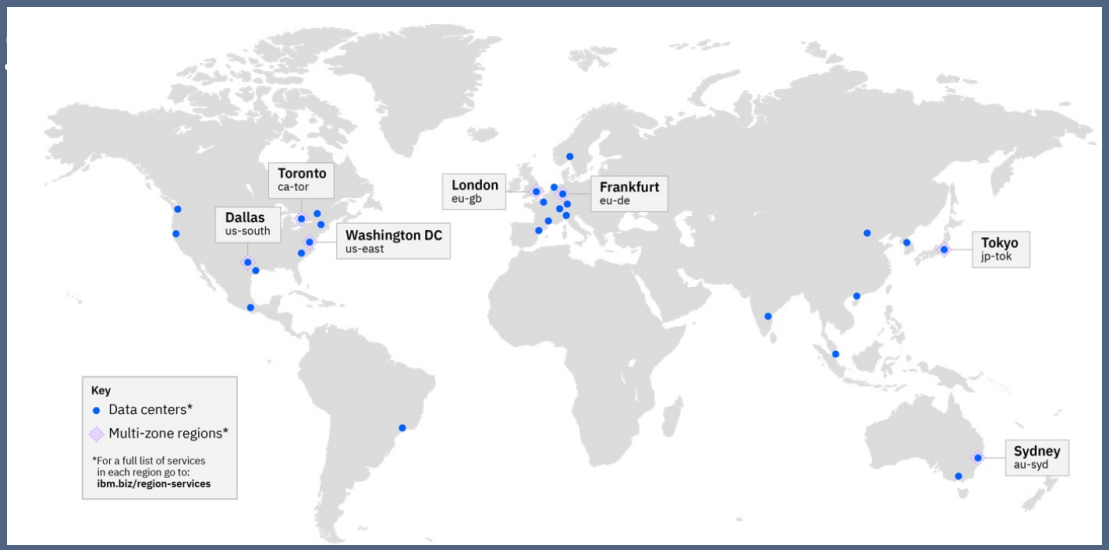
- IBM Cloud: https://www.youtube.com/watch?v=HkIJTyjE4zo
- Google: https://www.youtube.com/watch?v=XZmGGAbHqa0
- Facebook: https://www.youtube.com/watch?v=4A_A-CmrqpQ
- Azure: Microsoft reveals its MASSIVE data center (Full Tour) – YouTube
- Azure architecture: https://www.youtube.com/watch?v=v990MJXuj8Q
- AWS: https://www.youtube.com/watch?v=94PO2-TL4Vs

HPC vs Cloud Location

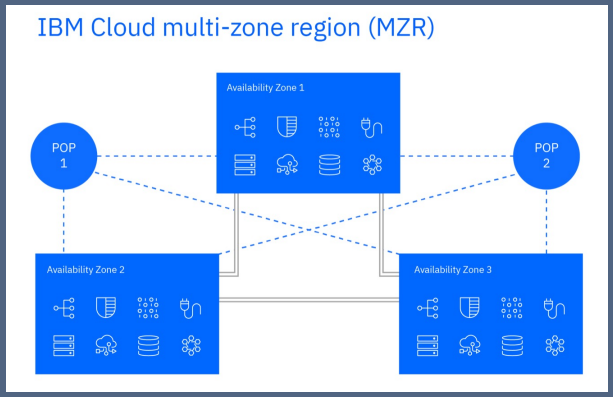


[Summit]

IBM Public Cloud Locations



IBM Public Cloud in a region



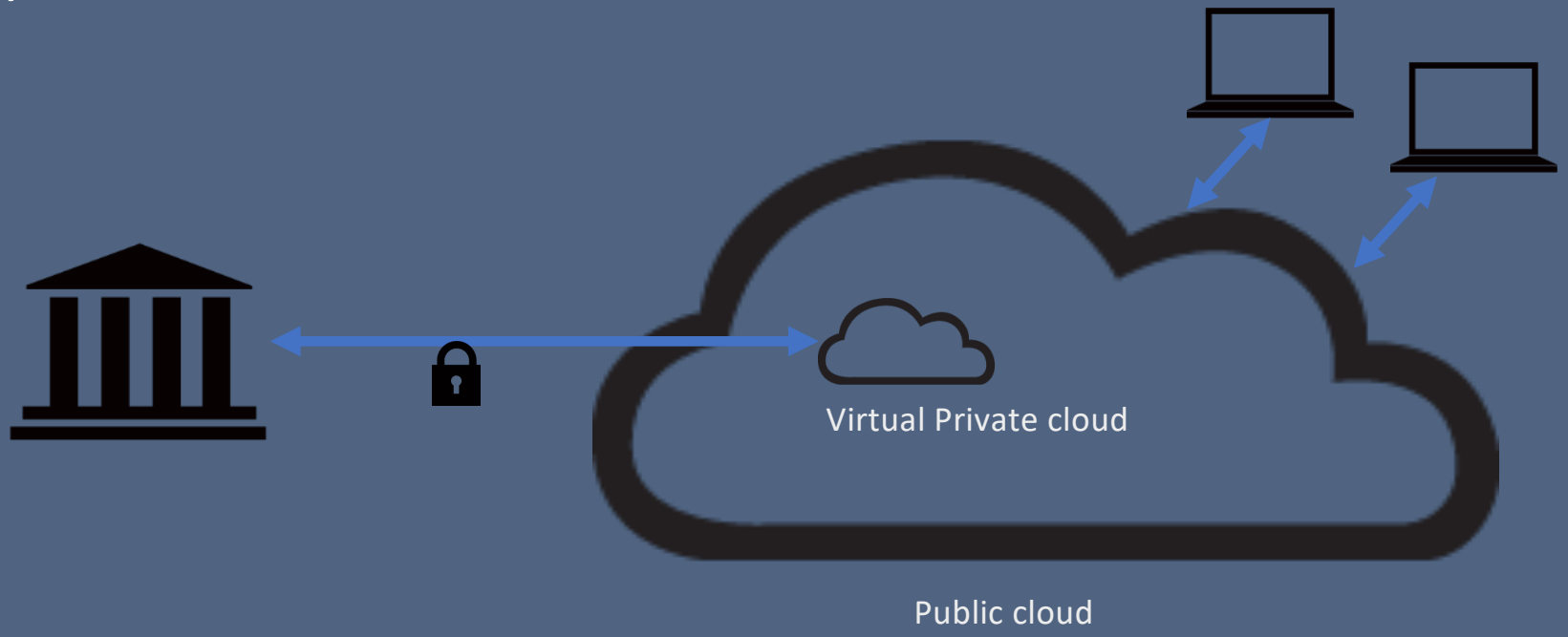
Public Cloud Summary

- Public clouds are geographically distributed computing resources
- Public clouds provide better qualities of service for some workloads (MPI, Gaming)
- Public cloud resources are provided in locations with multiple closely connected data centers called regions
- AWS, GCE, Azure, IBM, and Oracle are among top cloud providers in the US

Key questions to consider for public clouds

- How does public isolate users/organizations from each other?
- How do businesses use public cloud resources?
- What are key differences between on-prem systems and public clouds?

Virtual private cloud

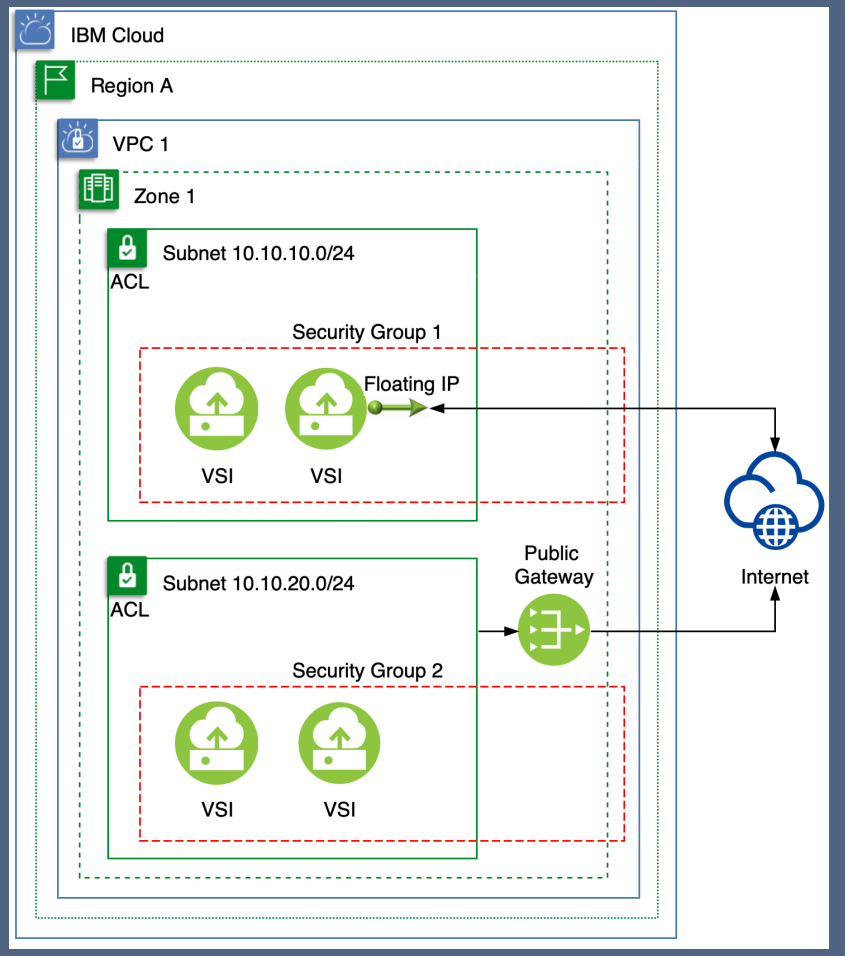


- VPC is a secure, isolated cloud inside a public cloud
- Public clouds provide multiple virtual private clouds (multi-tenancy)

Virtual private cloud concepts

Region

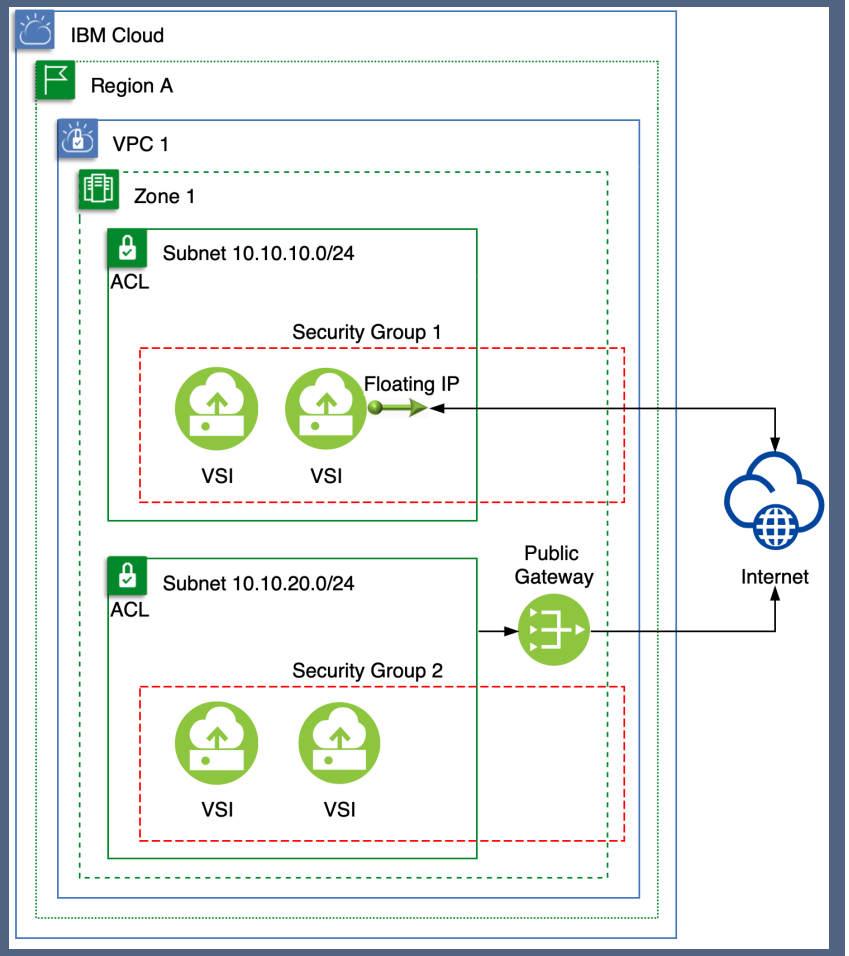
A region is an abstraction that is related to the geographic area in which a VPC is deployed. VPC can span multiple zones in a region.



Virtual private cloud concepts

Zone

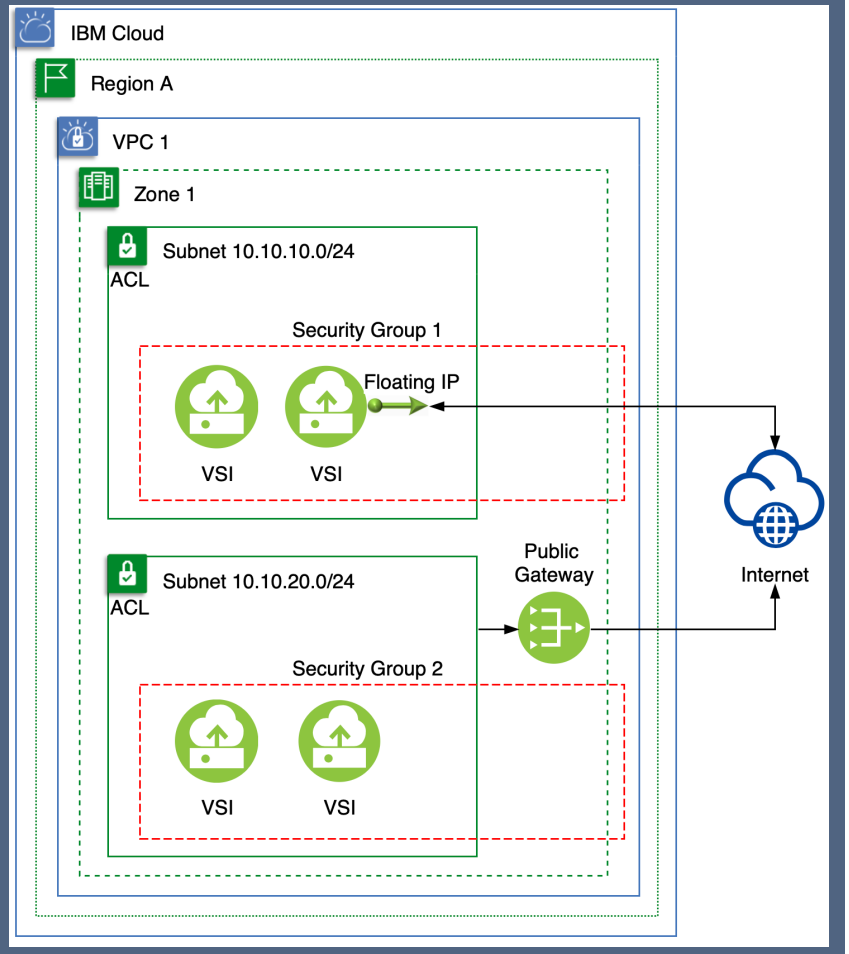
A zone is an abstraction that refers to the physical data center that hosts the compute, network, and storage resources, as well as the related cooling and power, which provides services and applications. Zones are isolated from each other.



Virtual private cloud concepts

Subnet

Each subnet consists of a specified IP address range (CIDR block). Subnets are bound to a single zone and cannot span multiple zones or regions. Subnets within the VPC offer private connectivity; they can talk to each other over a private link through the implicit router. Setting up routes is not necessary.



Virtual private cloud concepts

Public Gateway

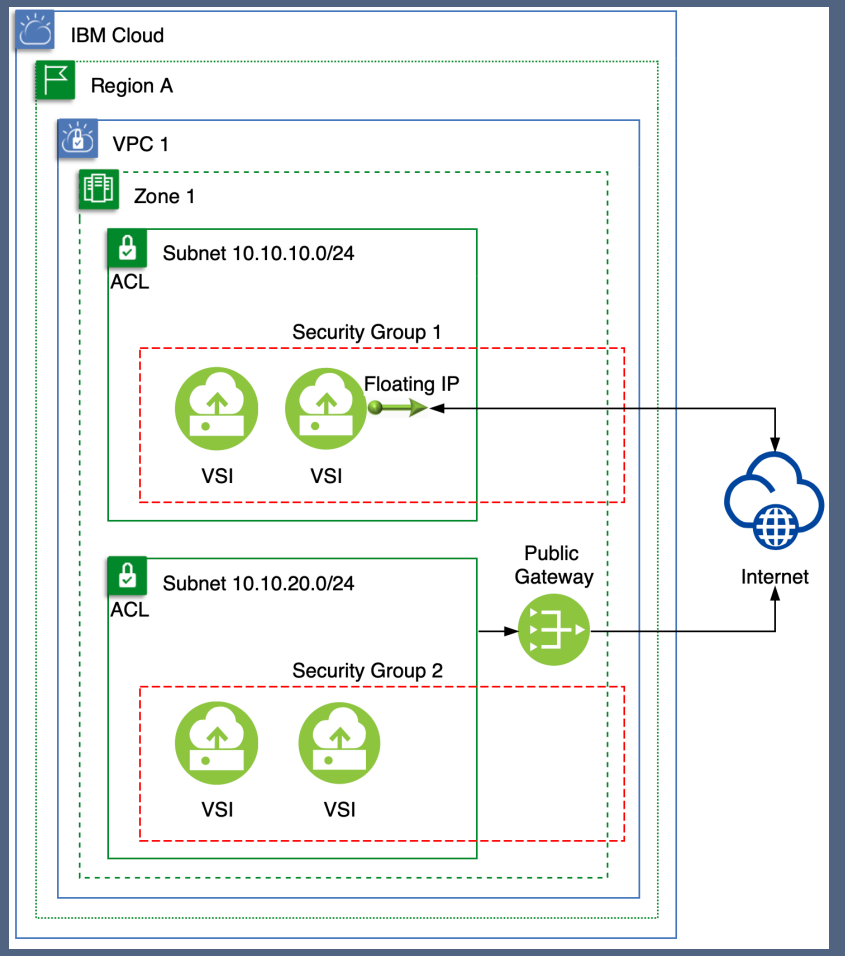
A Public Gateway enables a subnet and all its attached virtual server instances to connect to the internet.

Floating IP

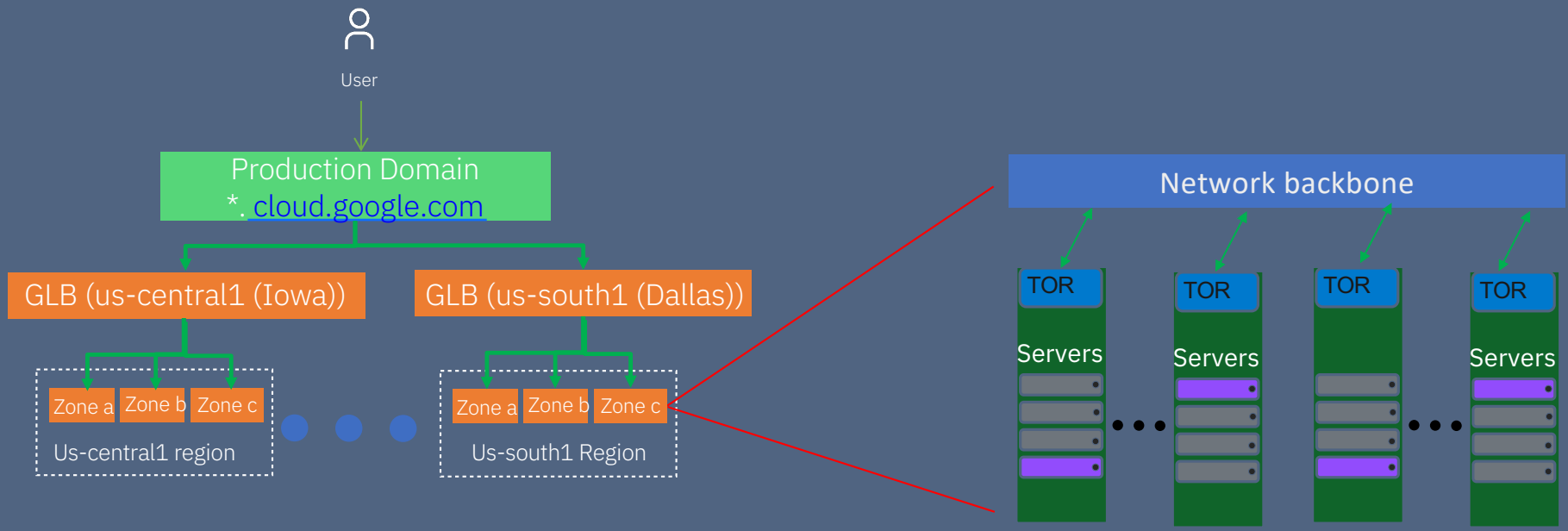
Floating IP addresses are IP addresses that are provided by the system and are reachable from the public internet.

Security Groups (SG)

Set of rules to filter traffic to an instance.



VM creation flow



GLB – Global load balancer
TOR: Top of the Rack Switch

Simulation, Emulation, Virtualization

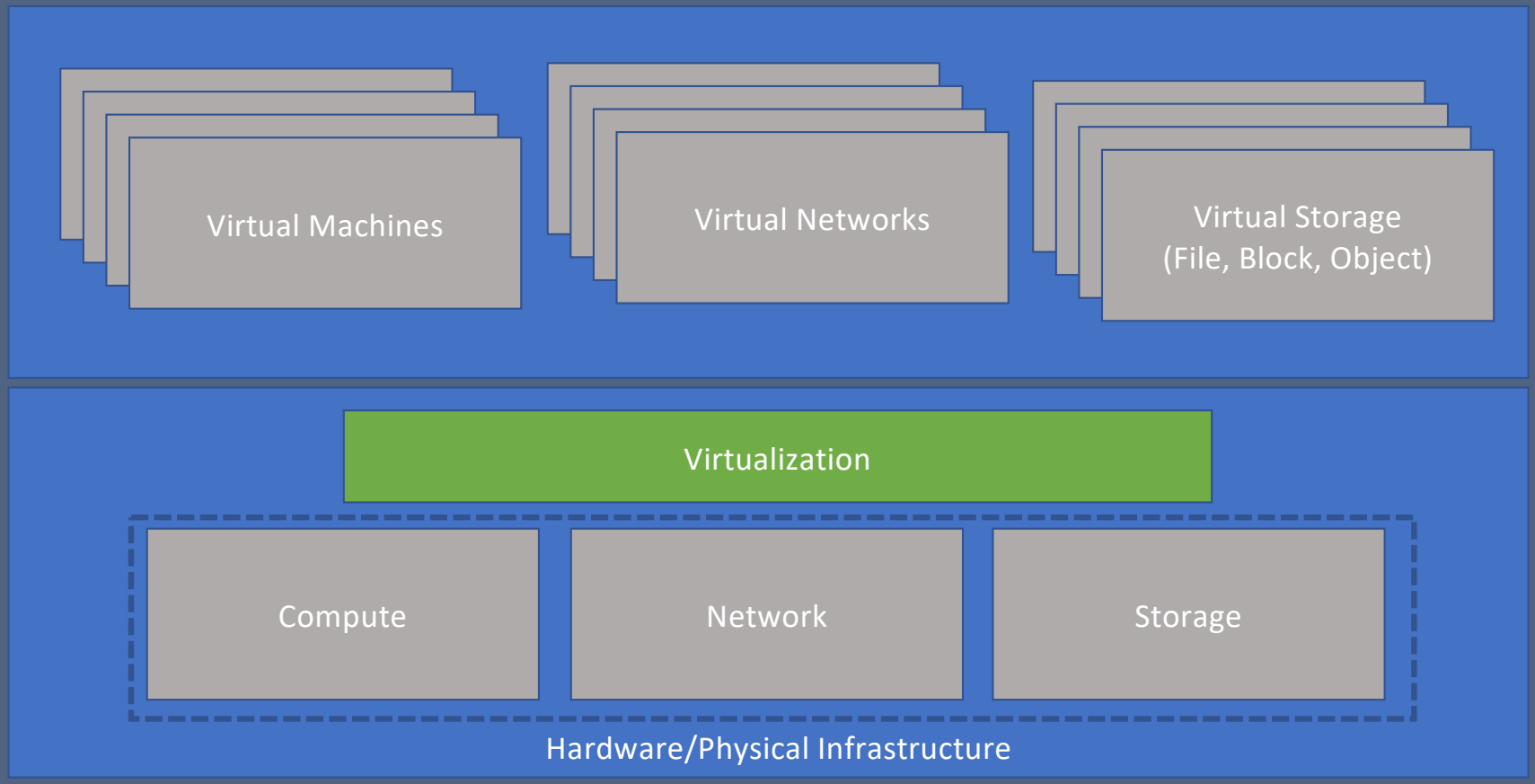
- Simulation: A computer software or a device that can mimic a system .
- Emulation: In computing, it enables one machine (named **Host**) to function like other systems (named **Guest**). It is relatively inexpensive, easily accessible but with significant performance overhead.
- Virtualization: A single (physical) resource is divided into many **"virtual"** resources to allow sharing.

What is virtualization?

- Virtualization is to create an illusion of some actual things, such as servers, network,….
- Often used in the partition of resources to satisfy multiple requests without the awareness of requesters.
  - CPU virtualization: time sharing + context switch
  - Memory virtualization: virtual memory
  - Network cable virtualization: packet switch vs. circuit switch

Slide credit: Che-Rung Lee

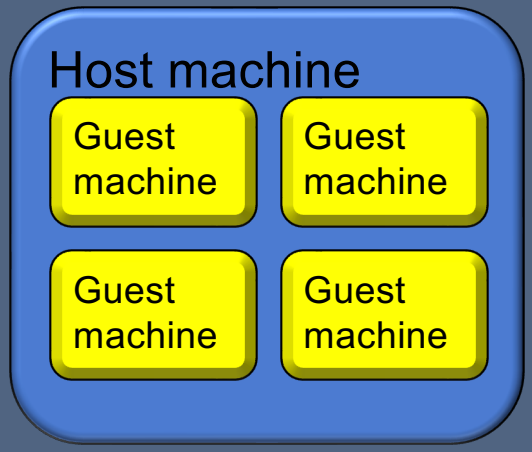
Cloud Architecture in a Zone



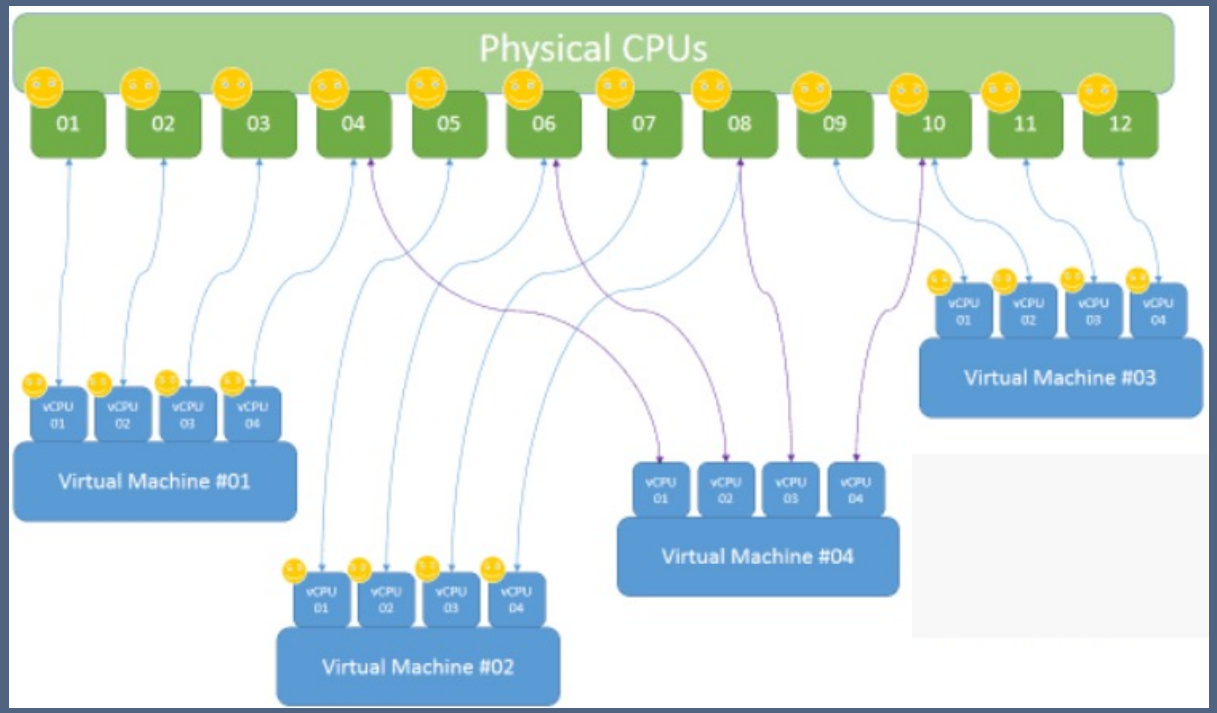
What is a virtual machine?

- A virtual machine (VM) is a software implementation of a machine (i.e., a computer) that executes programs like a physical machine.

- Terminology :
  - Host machine
  - Guest machine

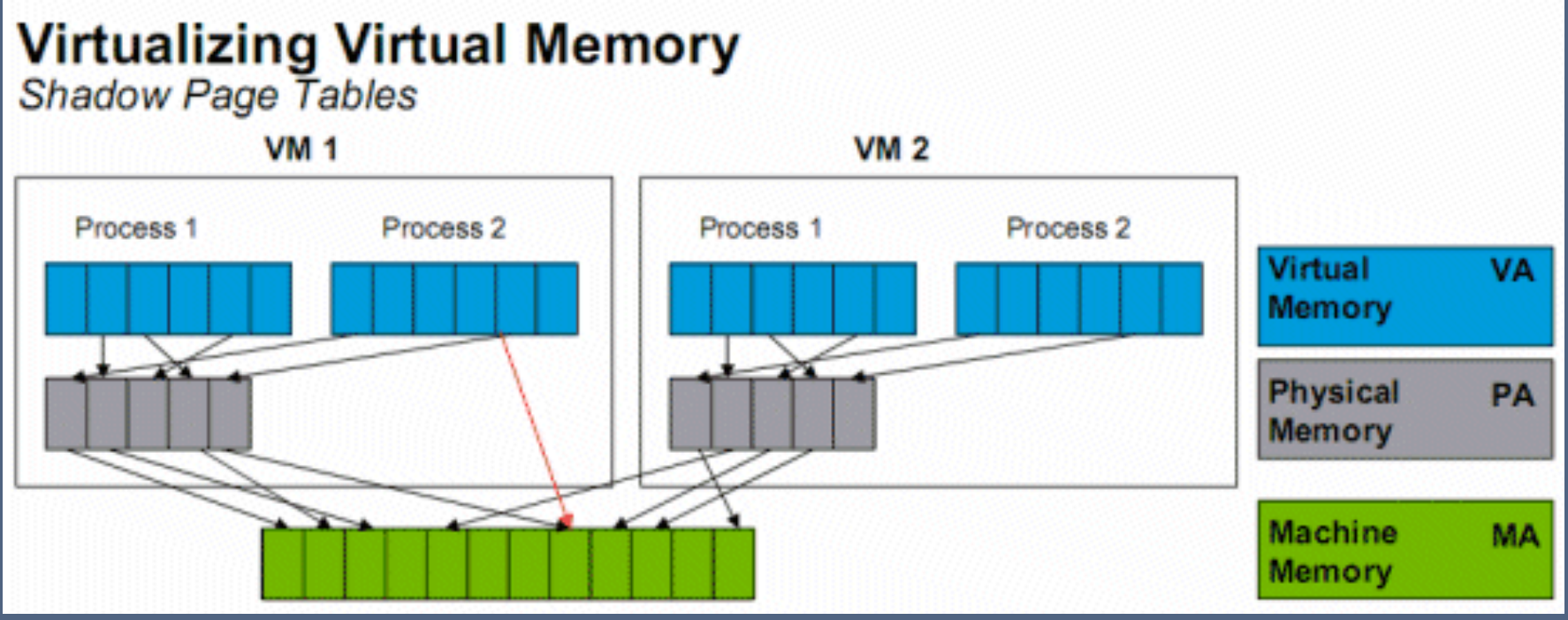


CPU/Processor virtualization



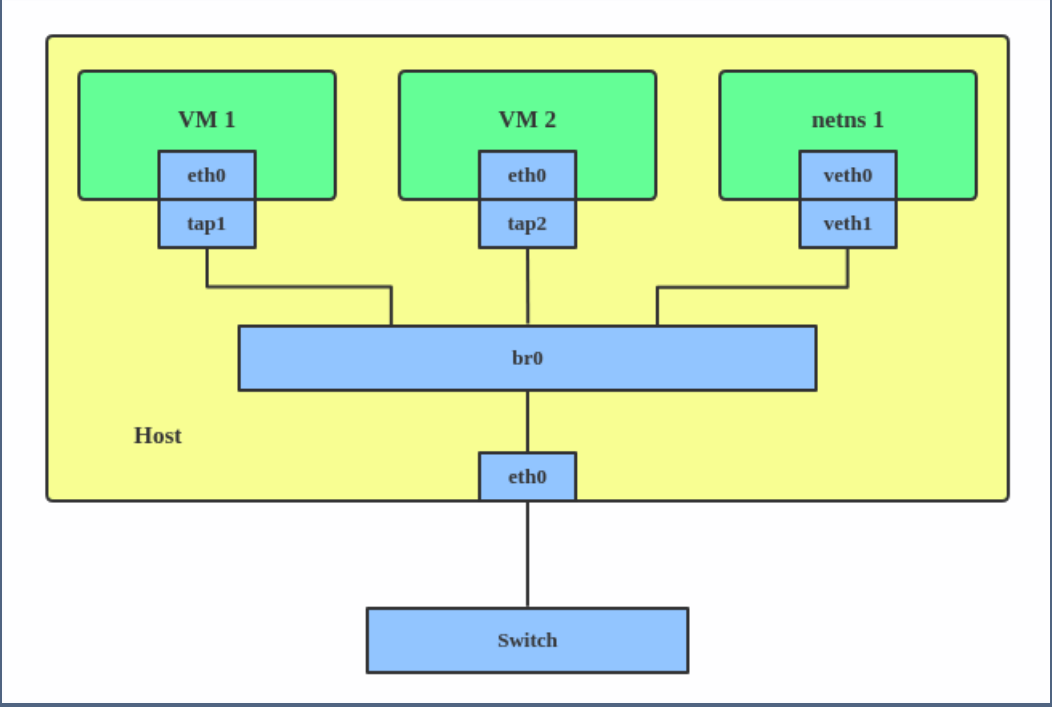
https://www.flackbox.com/virtual-processor-scheduling-how-vmware-and-microsoft-hypervisors-work-at-the-cpu-level

VM memory virtualization (partitioned)



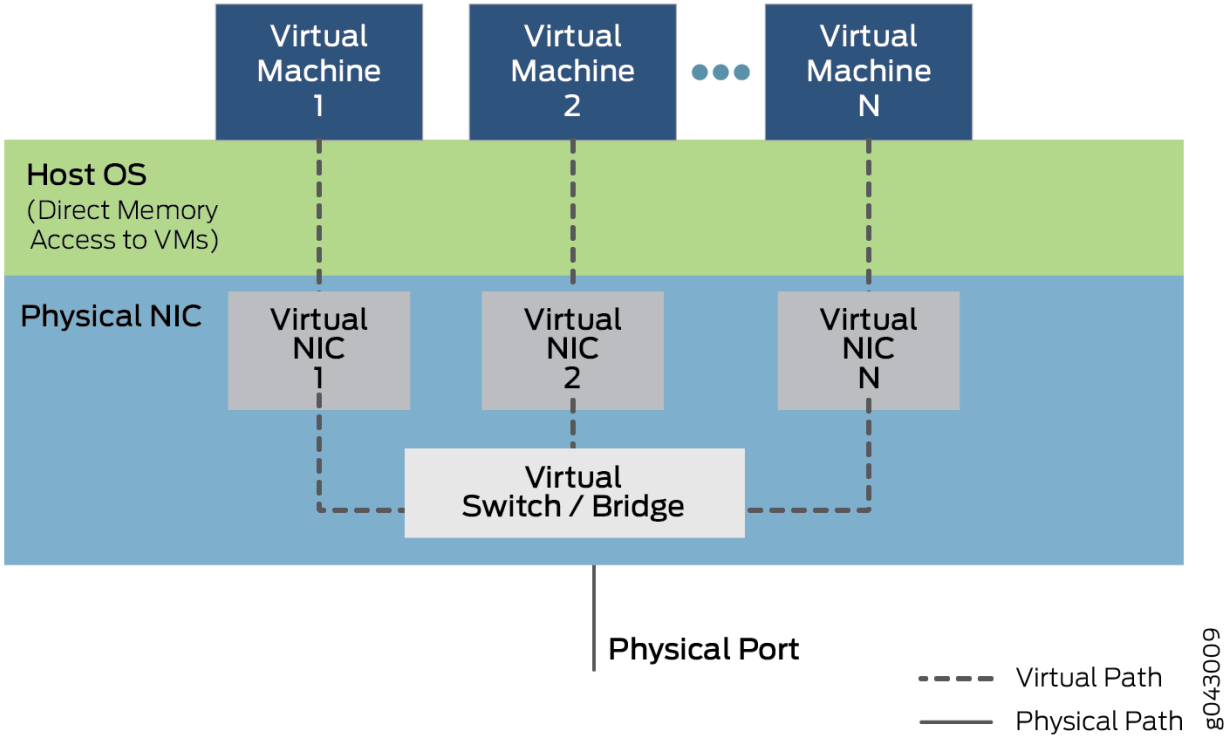
https://www.anandtech.com/show/2480/10

Linux Virtual Networking



https://developers.redhat.com/blog/2018/10/22/introduction-to-linux-interfaces-for-virtual-networking#bridge

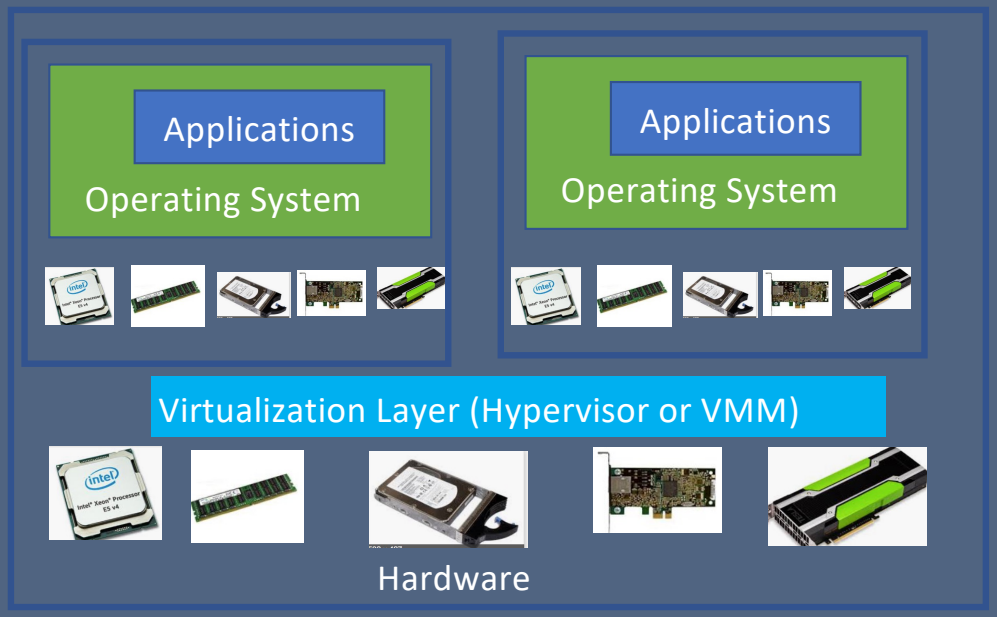
SR-IOV



https://www.juniper.net/documentation/en_US/junos/topics/concept/disaggregated-junos-sr-iov.html

Physical vs virtual machines

Baremetal or Non-virtualized system



Virtualized system

Issues of virtualization

- Hardware sharing
  - On a physical resources, many virtual ones can share the same hardware as they owe it alone.
- Performance
  - The performance of virtualized resource can be close to the physical ones.
- Migration
  - Virtual machines can be migrated from one physical machine to another physical machine.
  - Life migration: migration without interrupting the program executions on virtual machines.

Slide credit: Che-Rung Lee

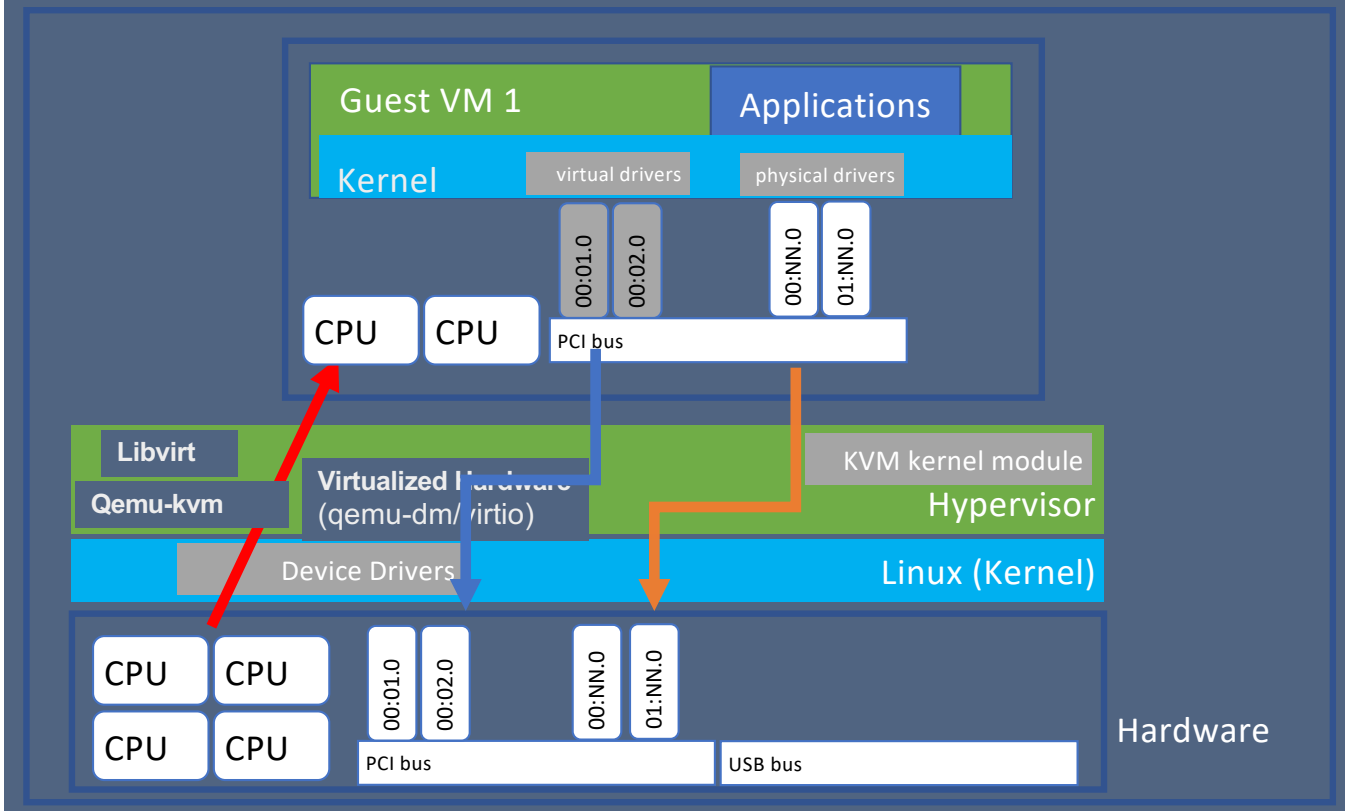
Hypervisor

- A **hypervisor** (or **virtual machine monitor**, **VMM**, **virtualizer**) is a system software that creates, runs, and manages virtual machines.
  - The hypervisor is the supervisor of the supervisors.
  - The term dates to circa 1970.

Virtualization method

- A real computer system contains hardware and software, which includes OS and applications.
- For a virtual machine, the hardware part needs to be realized by software
- To support multiple VMs, the virtualized hardware can be shared.

KVM (kernel virtual machine) virtualized hardware



Three methods of virtualization:

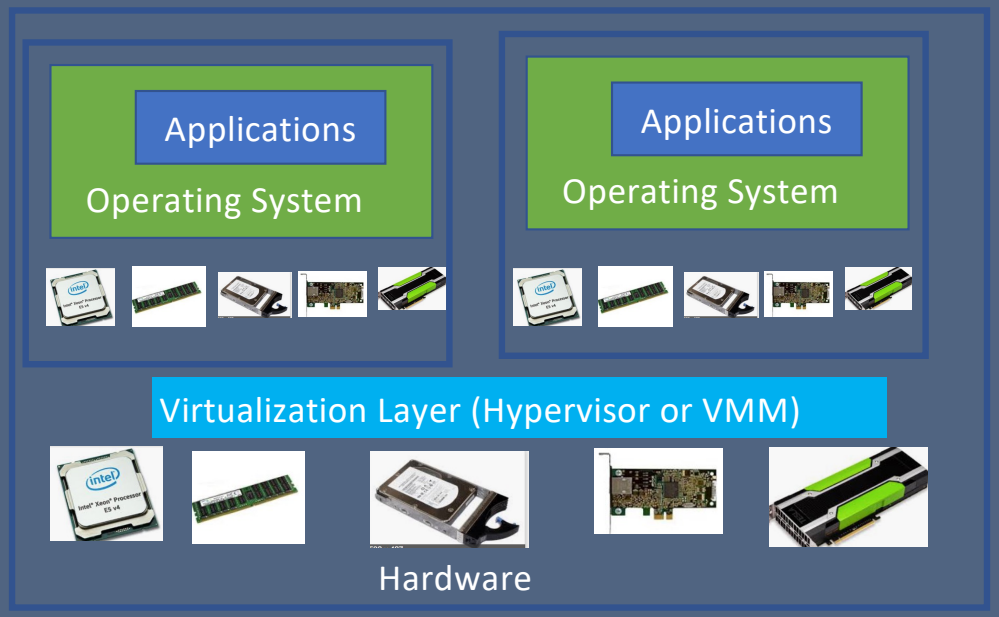
1. PCI Virtualization
2. PCI device passthrough
3. PCI virtual function passthrough

Storage: 1, 2, 3 (future)

Network: 1, 2, 3 (future)

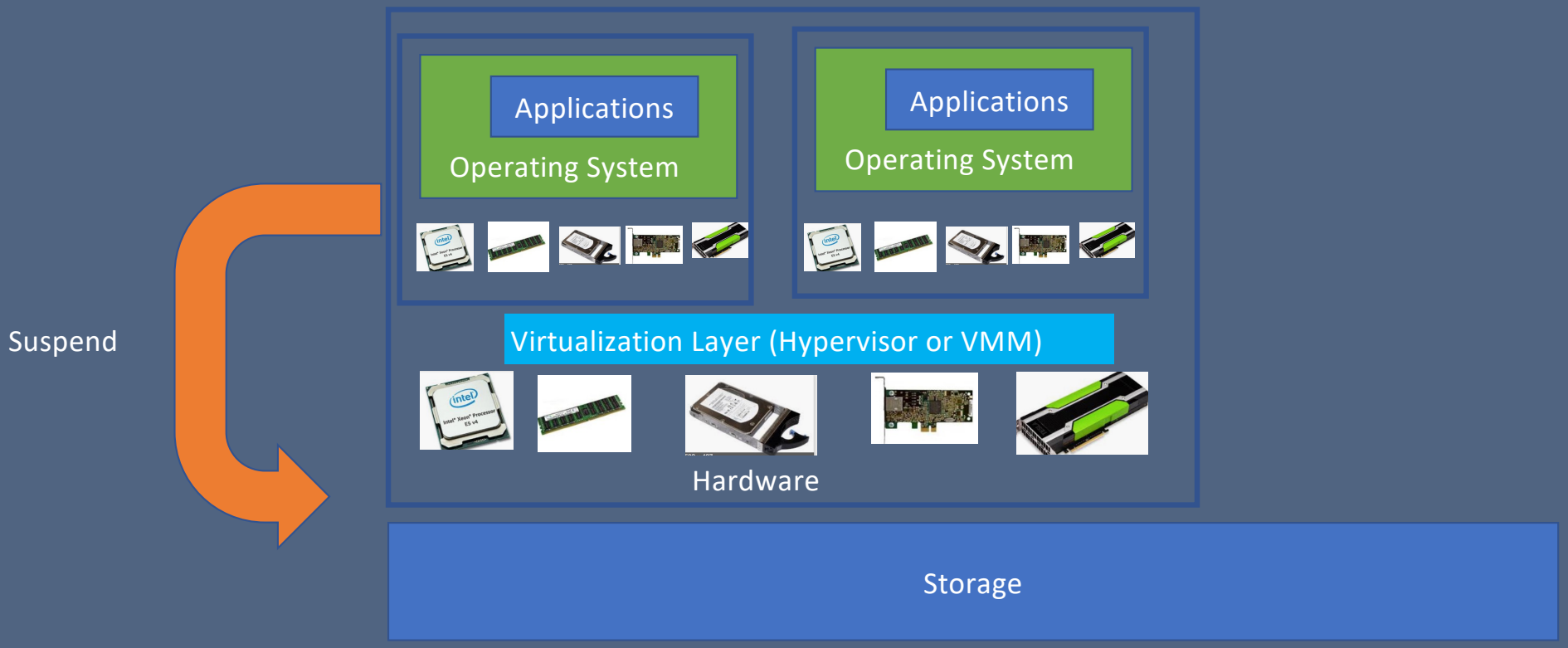
GPUs: 2, 3 (future)

Virtual machine operations: Multiplexing



The Reincarnation of Virtual Machines – Mendel Rosenblum

Virtual machine operations: Suspend



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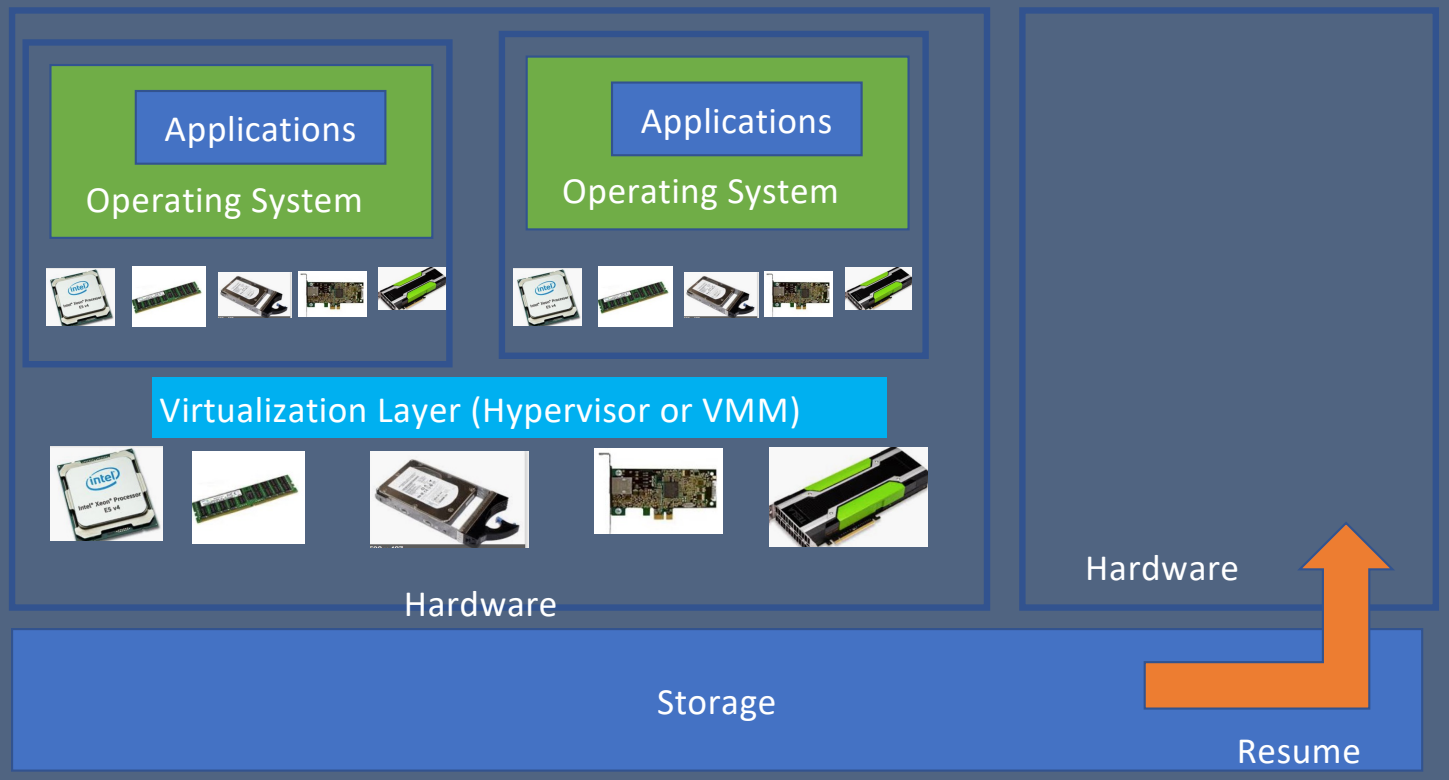
Virtual machine operations: Resume



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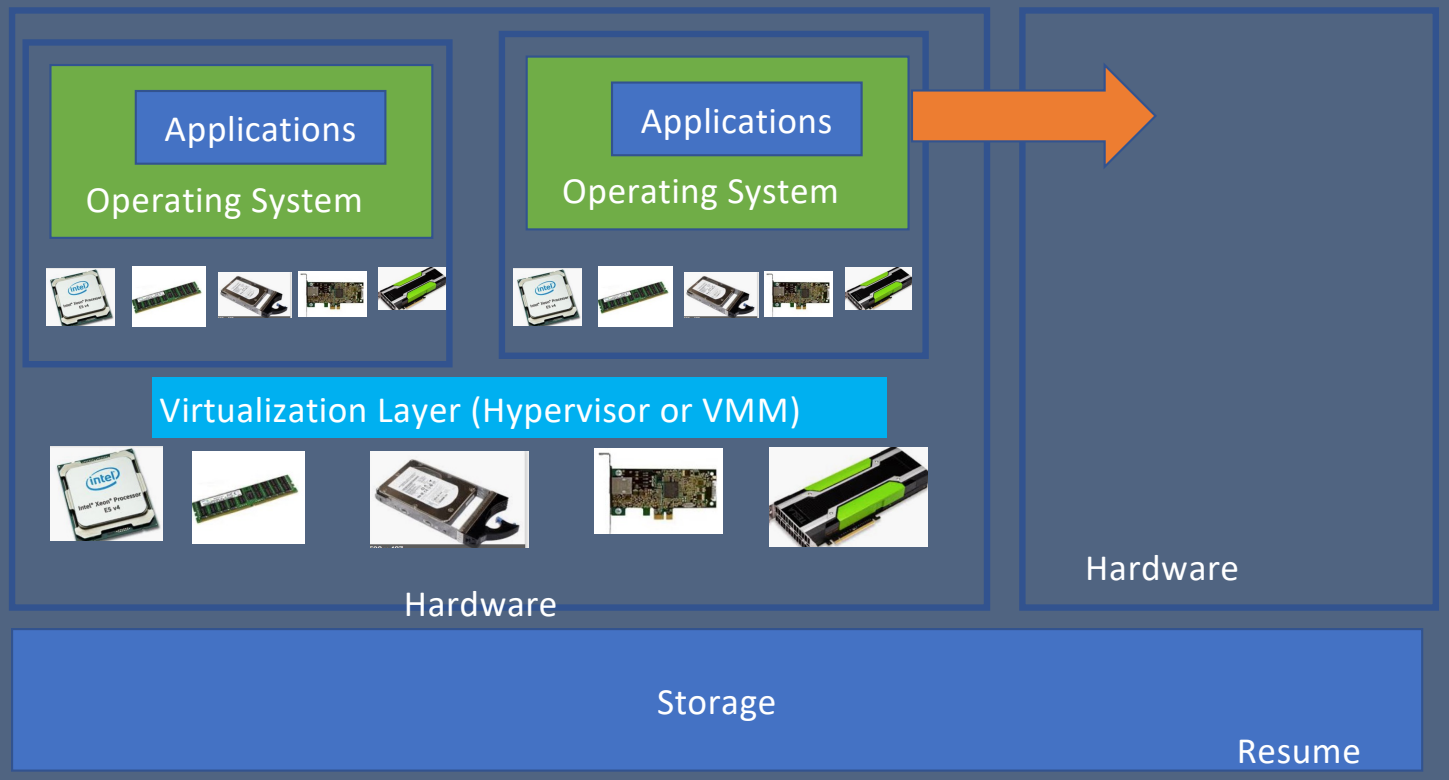
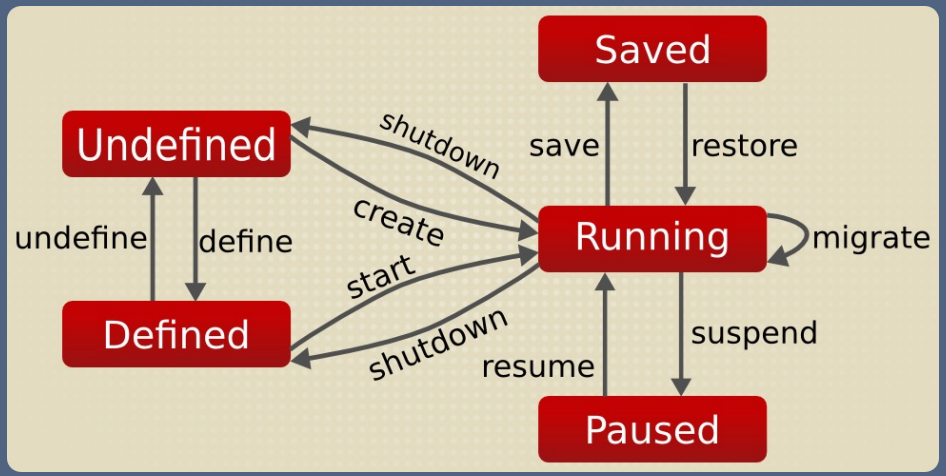
Virtual machine operations: Live Migration



The Reincarnation of Virtual Machines – Mendel Rosenblum

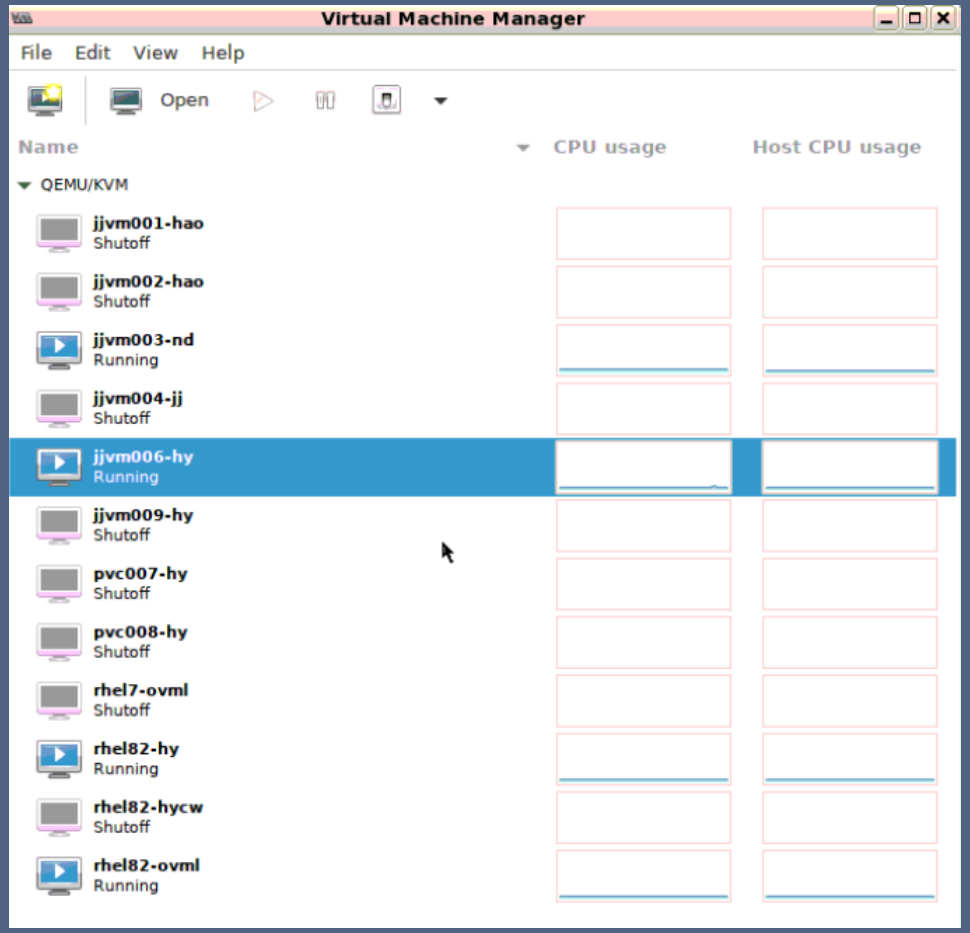
OS-level Virtualization Key Words

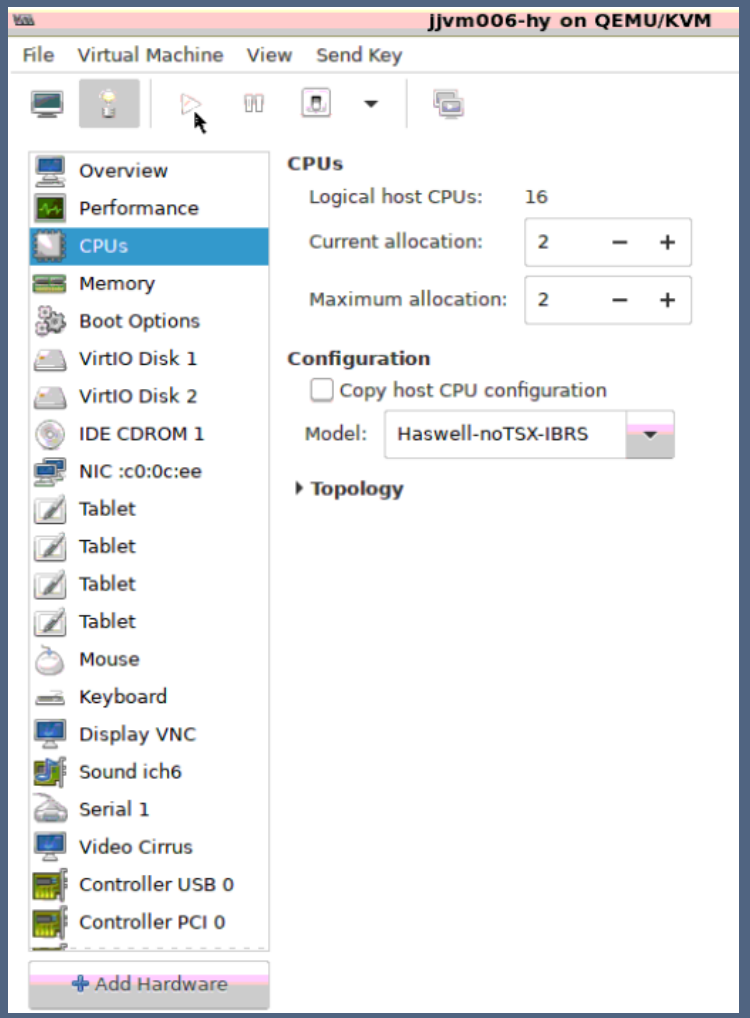
- Hypervisors: KVM/QEMU, libvirt/virsh/virt-manager, (Hyper-V, VirtualBox, VMWare ESX, Xen, LPAR)
- Network virtualization: SDN, NFV, OVS, DPDK, SRIOV, Cloud-native network function
- Hardware assisted virtualization: VT-x, ADM-V, second level address translation (SLAT)



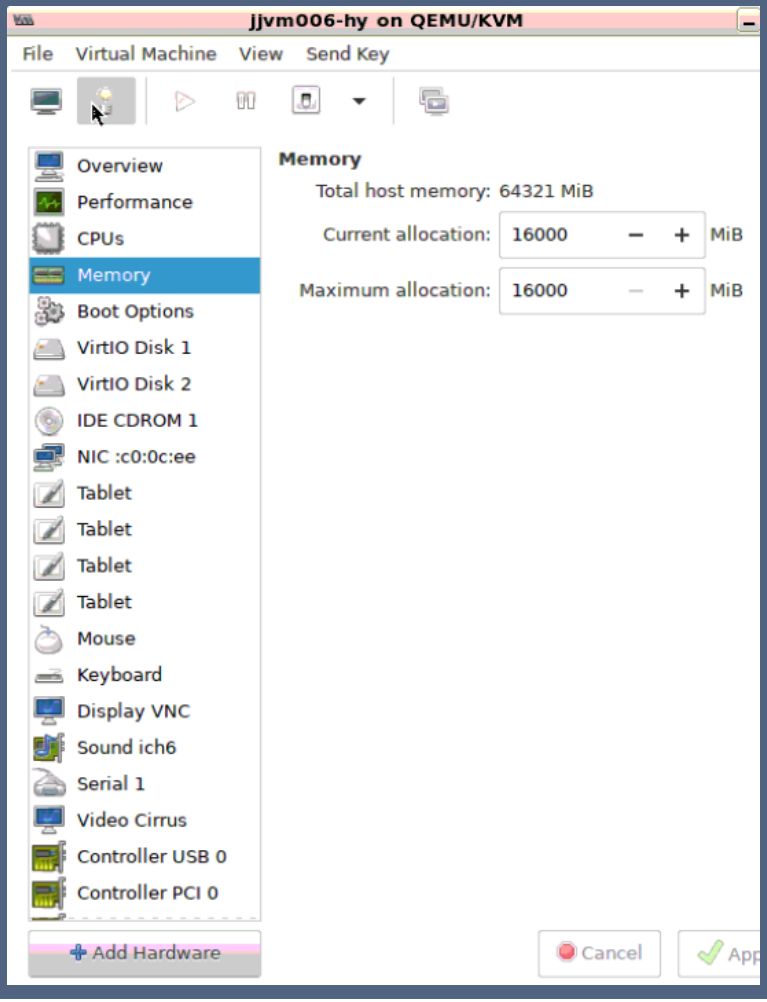
https://wiki.libvirt.org/page/VM_lifecycle

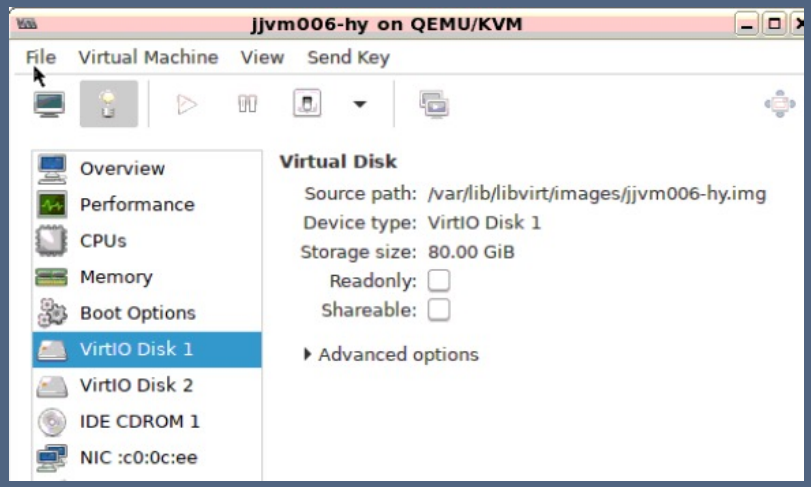
Linux virt-manager Example

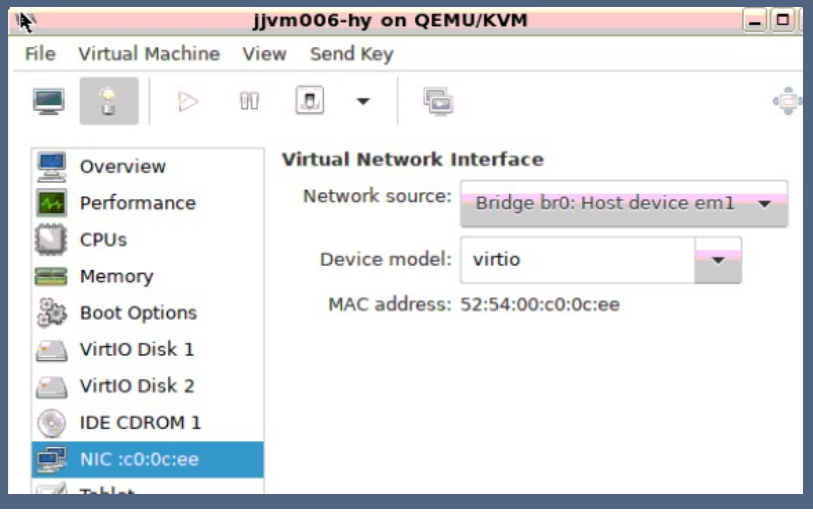




Linux virt-manager Example

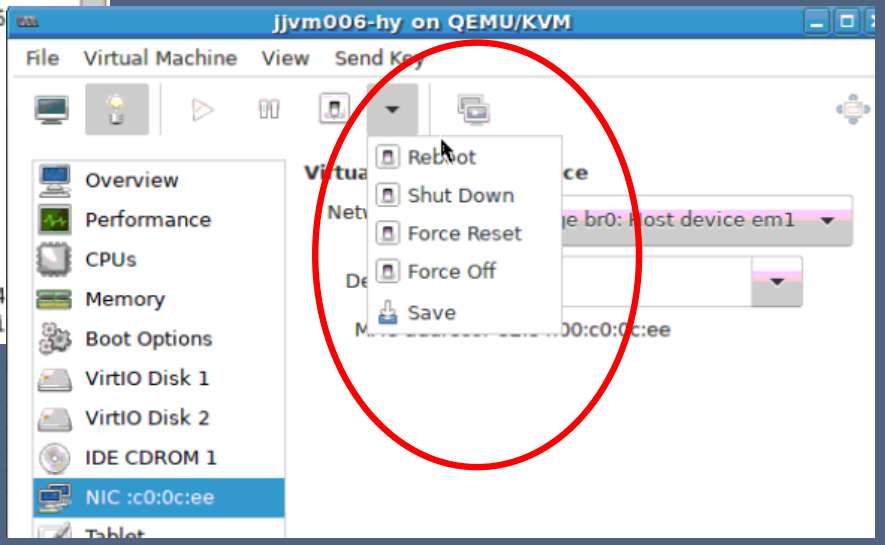




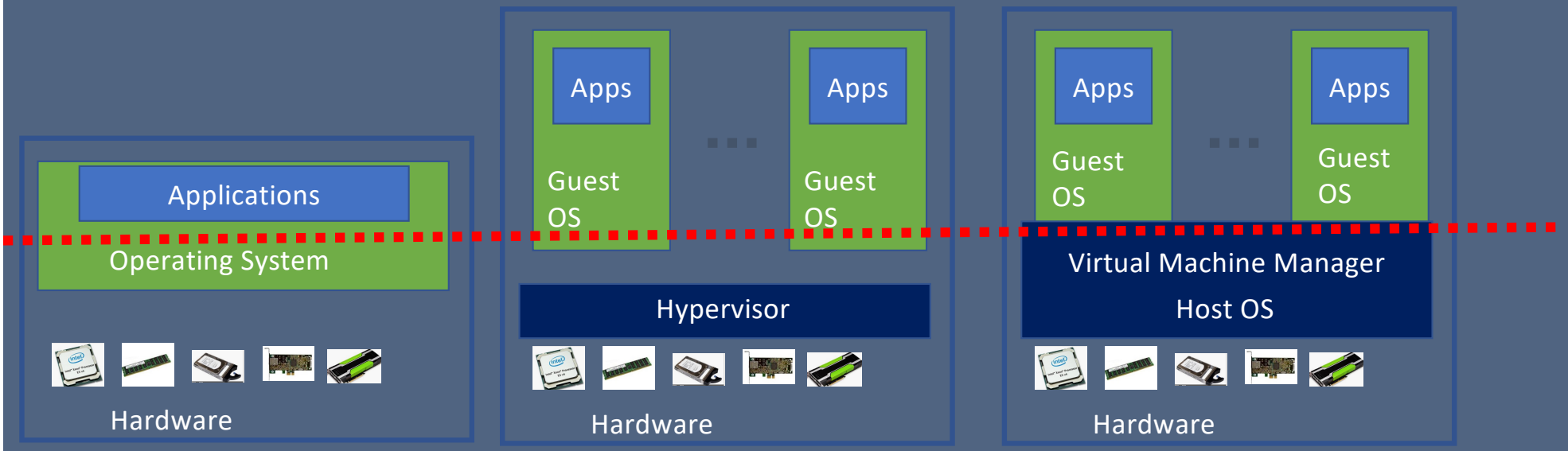


Linux virt-manager Example

```
                :/var/lib/libvirt/images$ sudo ls -l
total 1486820712
-rw------- 1 root         root  21478375424 Oct 27  2020 generic.qcow2
-rw------- 1 root         root  85899345920 Sep  2 11:22 jjvm001-hao.img
-rw------- 1 libvirt-qemu kvm   85899345920 Dec  1  2019 jjvm002-hao.img
-rw------- 1 libvirt-qemu kvm  107374182400 Sep 16 12:53 jjvm003-nd.img
-rw------- 1 libvirt-qemu kvm   85899345920 Feb 15  2021 jjvm004-jj.img
-rw------- 1 libvirt-qemu kvm   85899345920 Sep 16 13:00 jjvm006-hy.img
-rw------- 1 libvirt-qemu kvm  214781394944 Sep  3  2020 jjvm006-hy.qcow2
-rw------- 1 root         root  85899345920 Sep  2  2020 jjvm009-hy.img
-rw------- 1 root         root 214748364800 Aug 31  2018 pvc007-hy.img
-rw------- 1 root         root 171798691840 Feb 15  2021 pvc008-hy.img
-rw-r----- 1 libvirt-qemu kvm    4043309056 Mar 31  2016 RHEL-7.2-20151030.0-Server-x86_64-dvd1
.iso
-rw-rw---- 1 libvirt-qemu kvm    3793747968 Mar 29  2017 RHEL-7.3-20161019.0-Server-x86_6
.iso
-rw------- 1 root         root 107390828544 Feb 15  2021 rhel7-ovml-1.qcow2
-rw------- 1 root         root 274920112128 Feb 15  2021 rhel82-hycw.qcow2
-rw------- 1 libvirt-qemu kvm  274920112128 Sep 16 13:04 rhel82-hy.qcow2
-rw------- 1 libvirt-qemu kvm  214781394944 Sep 16 13:04 rhel82-ovml.qcow2
-rw-rw-r-- 1 libvirt-qemu kvm    8436842496 Sep  2  2020 rhel-8.2-x86_64-dvd.iso
-rw-rw-r-- 1 libvirt-qemu kvm    4497342464 Feb 12  2019 rhel-server-7.6-x86_64-dvd.iso
-rw-r--r-- 1 libvirt-qemu kvm     601882624 Mar  9  2016 ubuntu-14.04.3-server-amd64.iso
-rw-r----- 1 libvirt-qemu kvm     699400192 Nov  3  2016 ubuntu-16.04.1-server-amd64.iso
-rw-rw-r-- 1 libvirt-qemu kvm     889192448 Oct  4  2019 ubuntu-18.04.3-live-server-amd64
-rw-rw-r-- 1 libvirt-qemu kvm    1046083584 Feb 15  2021 ubuntu-20.10-live-server-amd64.i
```



Different VM architectures



Baremetal or Non-virtualized system

Native VM using Hypervisor (e.g. PowerVM)

Hosted VM using VMM (e.g. KVM)

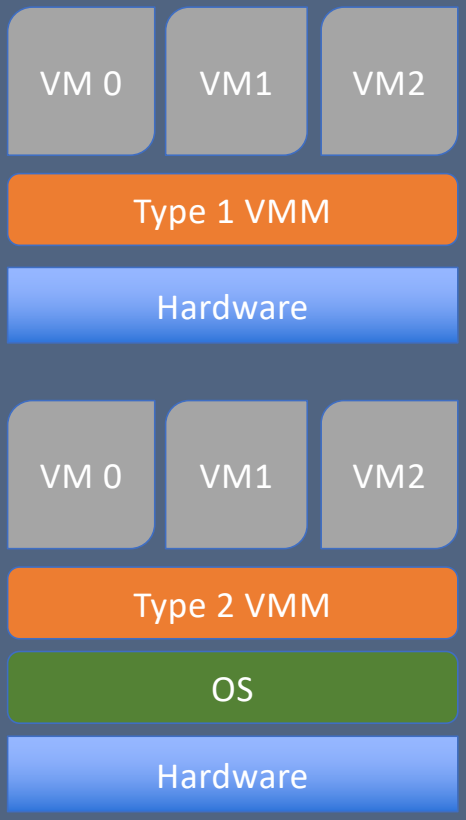
Popular Hypervisors and VMM

Hypervisor/VMM	Host CPU	Host OS	Guest OS	Comments
XEN	X86	NetBSD, Linux	Linux, Windows, BSD, Solaris	Native Hypervisor from Cambridge
KVM	X86, POWER, S390	Linux	Linux, Windows	Native/Para
POWER KVM	POWER	Linux	Linux, AIX, IBM i	Paravirtauliation
POWER VM	POWER	POWER VM Firmware	Linux, AIX, IBM i	Native
Hyper V	X86	Windows	Windows, Linux, FreeBSD	Native
VMWare ESXi	X86	Custom code	Linux, Windows, many	Native
VirtualBox	X86	Any host OS	Windows, Linux, Darwin	Paravirtauliation

Additional info: https://en.wikipedia.org/wiki/Comparison_of_platform_virtualization_software

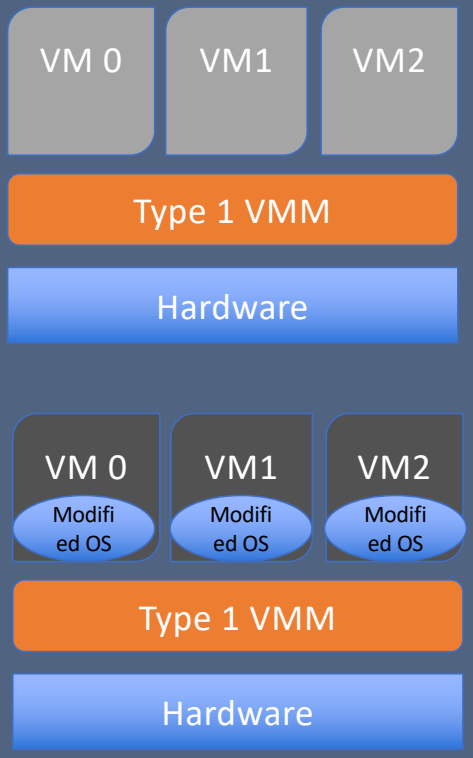
Types of VMMs

- Type 1 – Bare metal
  - VMMs run directly on the host's hardware as a hardware control. (OS)
  - Ex: Xen
- Type 2 – Hosted VMM
  - VMMs are software applications running within a conventional operating system.
  - Ex: KVM

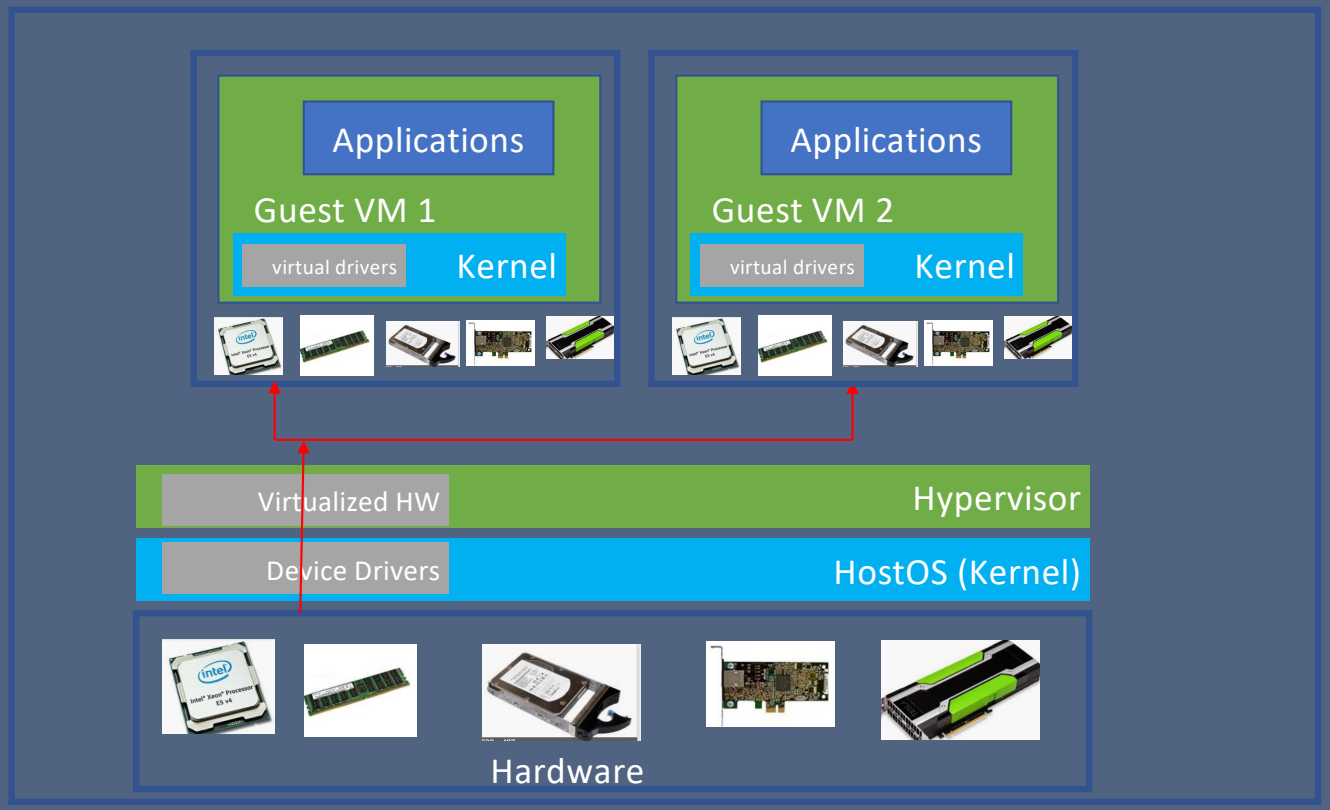


Types of VMMs

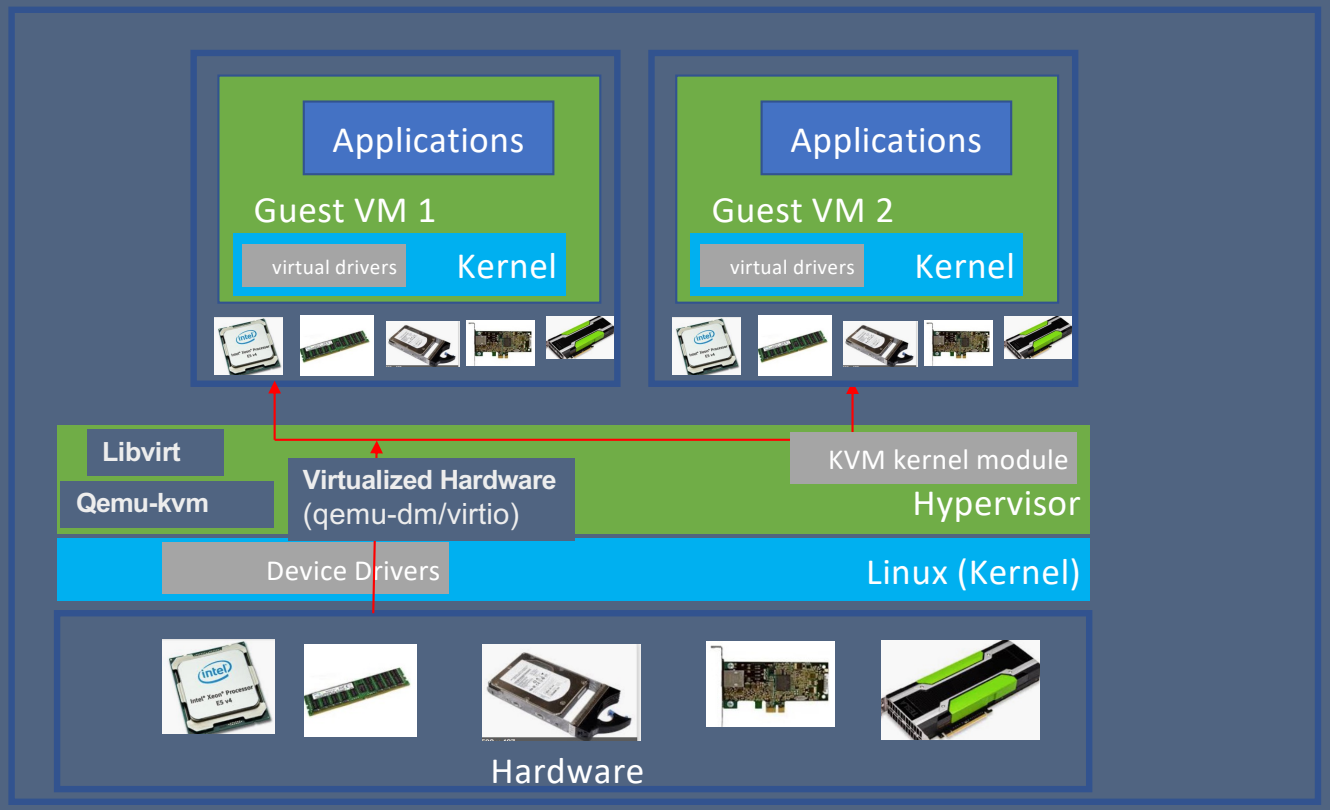
- Full-paravirtualization
  - Guest OS need not change
  - Ex: VM-Ware using binary translation
  - Ex: KVM + QEMU
- Para-virtualization
  - Guest OS needs to be modified
  - Ex: Xen with
  - Ex: KVM + virtio



Traditional virtualization



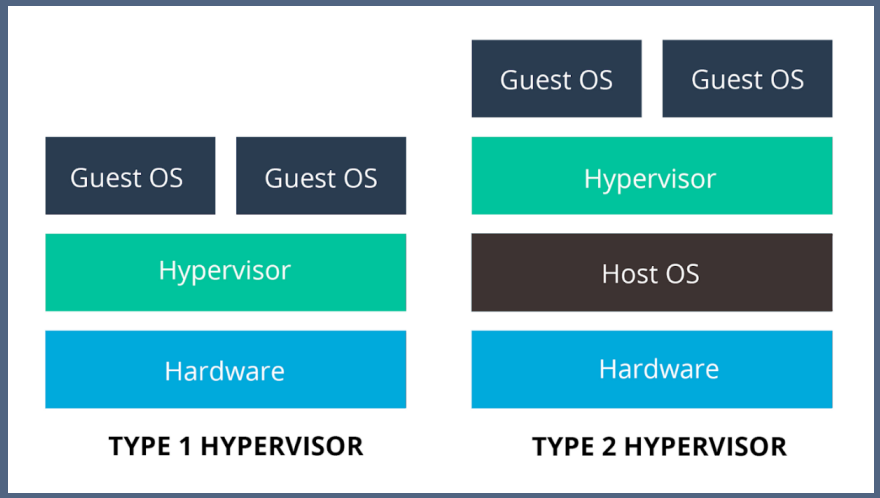
KVM (kernel virtual machine) virtualization



Libvirt: VM Management
Qemu-kvm: Hypervisor mgmt.

Quick Reads on Virtualization

- Type 1 vs Type 2 Hypervisor
  - “KVM is both”

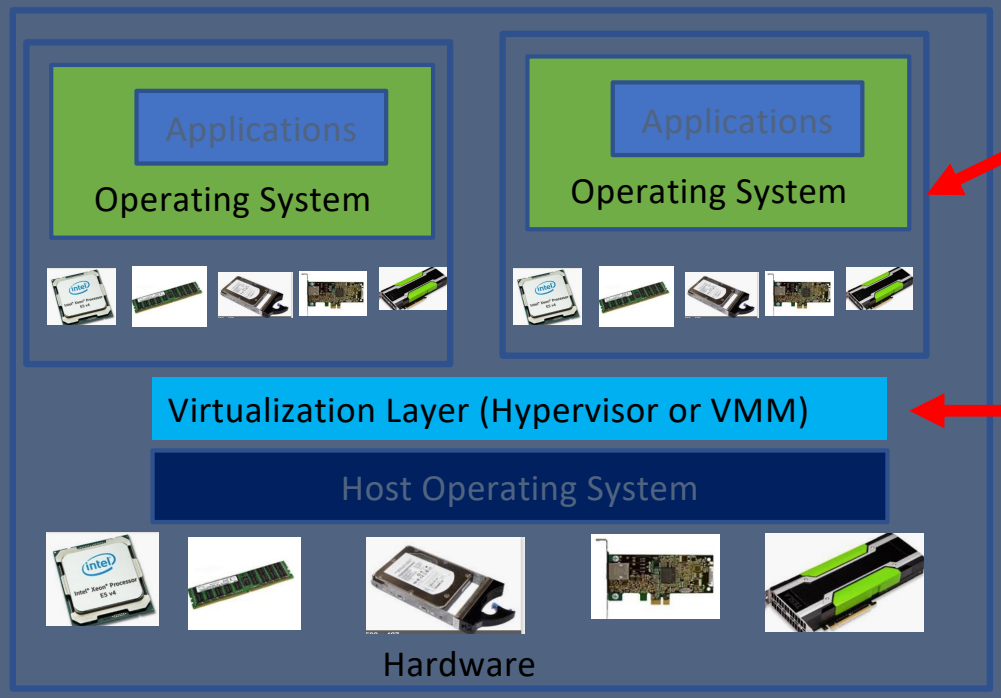


- Top (Type 1) Hypervisors in Enterprise (2021)
- QEMU vs KVM

Hands-On: VM on Laptop

- Virtualization Hands-on: Turn your laptop into a Dev Cloud
  - Create Virtual Machine and access the VM
  - Build a python hello world web app (flask)

Virtual machines



https://linuxconfig.org/virtualization-solutions-on-linux-systems-kvm-and-virtualbox

VirtualBox

- Free hypervisor
  - that runs on Windows, Linux, Mac, Solaris host operating systems and
  - supports a rich collection of guest operating systems
- Similar to Linux virt-manager, Parallels desktop on Mac, VMWare Fusion
- Create re-usable VMs with your own code and customized software stack
- How To Install UBUNTU 20.04 LTS ON VirtualBox in Windows 10 / MacOS
- https://www.virtualbox.org/wiki/Downloads

VAGRANT

- A software tool for building and maintaining portable development environments
- Provisioners: Customize configuration of the environment
  - Chef, Puppet, Ansible, Terraform (Infrastructure as code)
- Providers: Services to setup virtual environments
  - Virtualbox, Vmware, Hyper-v, IBM Cloud, Docker containers, etc
- It supports Docker natively
- Learn more: https://www.vagrantup.com
- Download: https://developer.hashicorp.com/vagrant/downloads

Turn your laptop into a dev cloud

Virtualbox + Vagrant: Window laptop or MacBook-Intel

```
$ vagrant init ubuntu/focal64 # if from scratch
$ git clone  https://github.com/ihchung/ibmcloud.git # if use stocked settings
$ vagrant up --provider virtualbox
$ vagrant ssh
```

Multipass: MacBook-M1 or Windows

1. Install Multipass: `brew install --cask multipass`
2. Check available images: `multipass find`
3. Launch an appropriate Ubuntu image: `multipass launch 20.04`
4. Check if running: `multipass list`
5. Connect to VM: `multipass shell [VM_NAME]`

References:

Install and use multipass

- https://multipass.run/docs/installing-on-macos
- https://multipass.run/docs/windows-tutorial

Launch ubuntu (Linux distro) with multipass

- https://linux.how2shout.com/how-to-install-mutliple-ubuntu-vms-using-multipass-on-ubunut-20-04/

WSL for windows: https://learn.microsoft.com/en-us/windows/wsl/install

Turn your laptop into a dev cloud (Vagrant)

```
$ cd workspace/
$ vagrant init ubuntu/focal64
        A `Vagrantfile` has been placed in this directory. You are now
        ready to `vagrant up` your first virtual environment! Please read
        the comments in the Vagrantfile as well as documentation on
        `vagrantup.com` for more information on using Vagrant.
$ ls
        Vagrantfile
$ vagrant up --provider virtualbox
        Bringing machine 'default' up with 'virtualbox' provider...
        ==> default: Importing base box 'ubuntu/focal64'...
        ...
        ==> default: Forwarding ports...
            default: 22 (guest) => 2222 (host) (adapter 1)
        ==> default: Booting VM...
        ==> default: Waiting for machine to boot. This may take a few minutes...
            default: SSH address: 127.0.0.1:2222
            default: SSH username: vagrant
            default: SSH auth method: private key
        ...
        ==> default: Machine booted and ready!
        ==> default: Checking for guest additions in VM...
        ==> default: Mounting shared folders...
            default: /vagrant => C:/Users/HAOYU/NYU/workspace
$ vagrant ssh
        Welcome to Ubuntu 20.04.5 LTS (GNU/Linux 5.4.0-131-generic x86_64)
        vagrant@ubuntu-focal:~$
```

Turn your laptop into a dev cloud (Mac-M1)

1. Install Multipass: `brew install --cask multipass`
2. Check available images: `multipass find`

```
multipass was successfully installed!
aashkatrivedi@Aashkas-MBP ~ % multipass find
Image                       Aliases           Version          Description
18.04                       bionic            20220131         Ubuntu 18.04 LTS
20.04                       focal,lts         20220207         Ubuntu 20.04 LTS
21.10                       impish            20220201         Ubuntu 21.10
anbox-cloud-appliance                         latest           Anbox Cloud Appliance
charm-dev                                     latest           A development and testing environment for charmers
docker                                        latest           A Docker environment with Portainer and related tools
minikube                                      latest           minikube is local Kubernetes
aashkatrivedi@Aashkas-MBP ~ % multipass launch 18.04
Launched: iridescent-petrel
```

3. Launch an appropriate Ubuntu image: `multipass launch 20.04`
4. Check if running: `multipass list`
5. Connect to VM: `multipass shell [VM_NAME]`

```
aashkatrivedi@Aashkas-MBP ~ % multipass launch 18.04
Launched: iridescent-petrel
aashkatrivedi@Aashkas-MBP ~ % multipass list
Name                    State             IPv4             Image
iridescent-petrel       Running           192.168.64.2     Ubuntu 18.04 LTS
aashkatrivedi@Aashkas-MBP ~ % multipass shell iridescent-petrel
Welcome to Ubuntu 18.04.6 LTS (GNU/Linux 4.15.0-167-generic aarch64)

To run a command as administrator (user "root"), use "sudo <command>".
See "man sudo_root" for details.

ubuntu@iridescent-petrel:~$
```

Run Python flask app in the VM

- Install requirements

```
source venv/bin/activate
cd /vagrant/hello-app; pip3 install -r requirements.txt

# OR reinstall the repo if not mounted
git clone https://github.com/yuhaohaoyu/ibmcloud-fall-2023.git
cd hello-app; pip3 install -r requirements.txt
```

- export PORT=8001
- Run the app: python3 hello.py

```
 * Serving Flask app 'hello'
 * Debug mode: off
WARNING: This is a development server. Do not use it in a production deployment. Use a production WSGI server instead.
 * Running on all addresses (0.0.0.0)
 * Running on http://127.0.0.1:8001
 * Running on http://9.74.12.176:8001
Press CTRL+C to quit
```

- Check the url in the browser running on your laptop: http://127.0.0.1:8001

Run Python flask app in Multipass VM (Mac-M1)

0. Prepare the multipass VM for python

```
sudo apt-get update
sudo dpkg --configure -a
sudo apt-get install -y git curl wget zip tree
sudo apt-get install -y python3-dev python3-pip python3-venv
python3 -m venv venv
source venv/bin/activate
sudo apt-get -y autoremove
```

1. clone github repo:

```
git clone https://github.com/yuhaohaoyu/ibmcloud-fall-2023.git
```

2. install requirements:

```
cd hello-app; pip3 install -r requirements.txt
```

3. Run the app:

```
export PORT=8001
python3 hello.py
```

App running on `http://192.168.64.2:8001/` (Check what terminal says)

```
ubuntu@iridescent-petrel:~/vm_demo/hello-app$ export PORT=8001
ubuntu@iridescent-petrel:~/vm_demo/hello-app$ python3 hello.py
 * Serving Flask app 'hello' (lazy loading)
   WARNING: This is a development server. Do not use it in a production deployment.
 * Running on http://192.168.64.2:8001/ (Press CTRL+C to quit)
192.168.64.1 - - [16/Feb/2022 11:22:08] "GET / HTTP/1.1" 200 -
192.168.64.1 - - [16/Feb/2022 11:22:08] "GET /favicon.ico HTTP/1.1" 404 -
```

3.c

Summary

- We learned how resources are virtualized in the cloud
- We learned about the popular hypervisors and VMMs
- We turned your laptop into a dev cloud
- Run a hello-world application in this VM