# Middleware Architectures 2

## Lecture 2: Cloud Architectures

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# Overview

- Introduction
- Cloud Architecture
- Infrastructure as a Service

# Terminology

- Cloud computing
- *aaS
- DevOps
- Cloud Native, Microservices
- Serverless

# What is a Cloud?

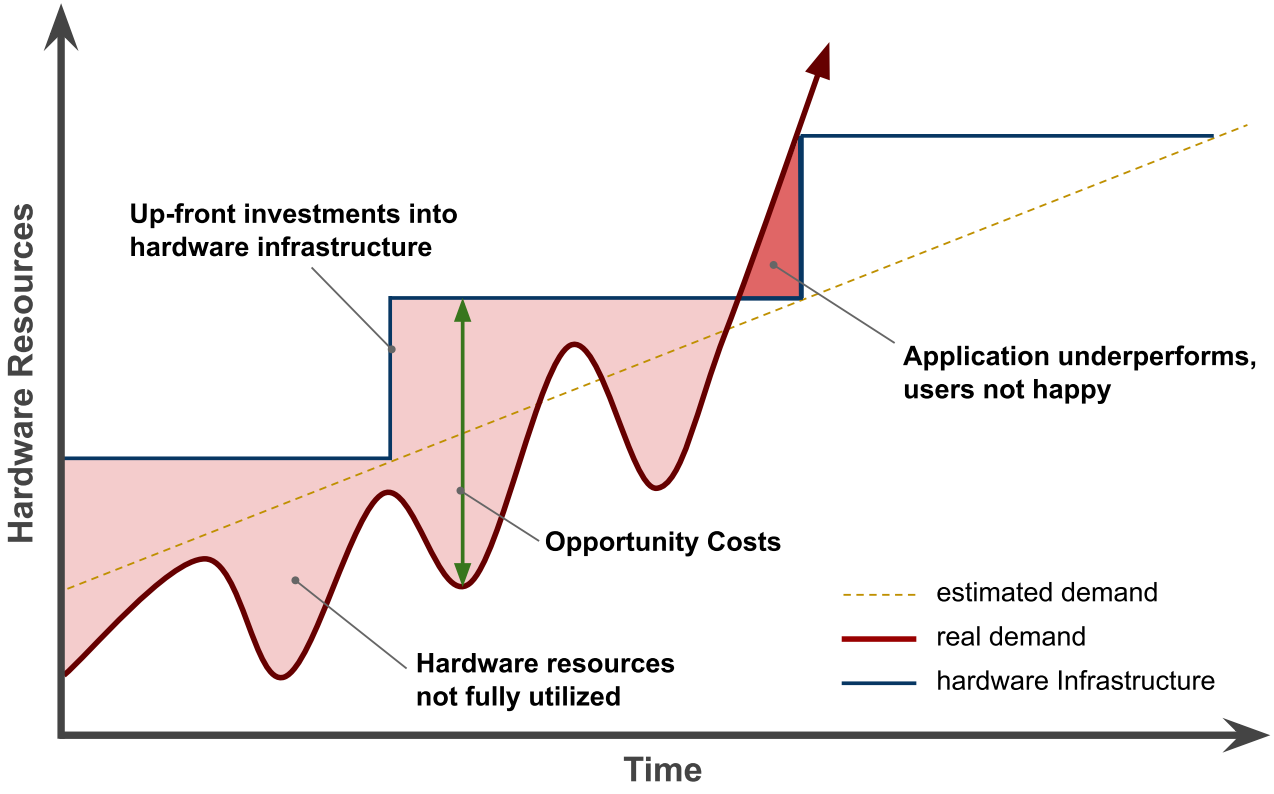
- A different way of thinking
  - *Got your grand mum's savings under your pillow?*
    *→ probably not, you better have them in your bank*
  - *Data is your major asset*
  - *you better have them in a "bank" too*
  - *Someone can abuse your data?*
  - *banks bankrupt too, sometimes – it is a risk you take*
  - *there is a market and a competition*
- Outsourcing of application infrastructure
  - *Reliability and availability*
  - *Low costs – pay-per-use*
  - *Elasticity – can dynamically grow with your apps*
  - *CAPEX vs. OPEX*

# What is a Cloud?

- Any app you access over the web?
- A datacenter?
  - *Offers virtualization*
  - *Any company having a datacenter wants to move to*
- Cloud provider should also offer services, such as:
  - *scalability, storage*
  - *Possible to configure programmatically*
    - → *integration to enterprise administration processes*
    - → *usually REST interface*

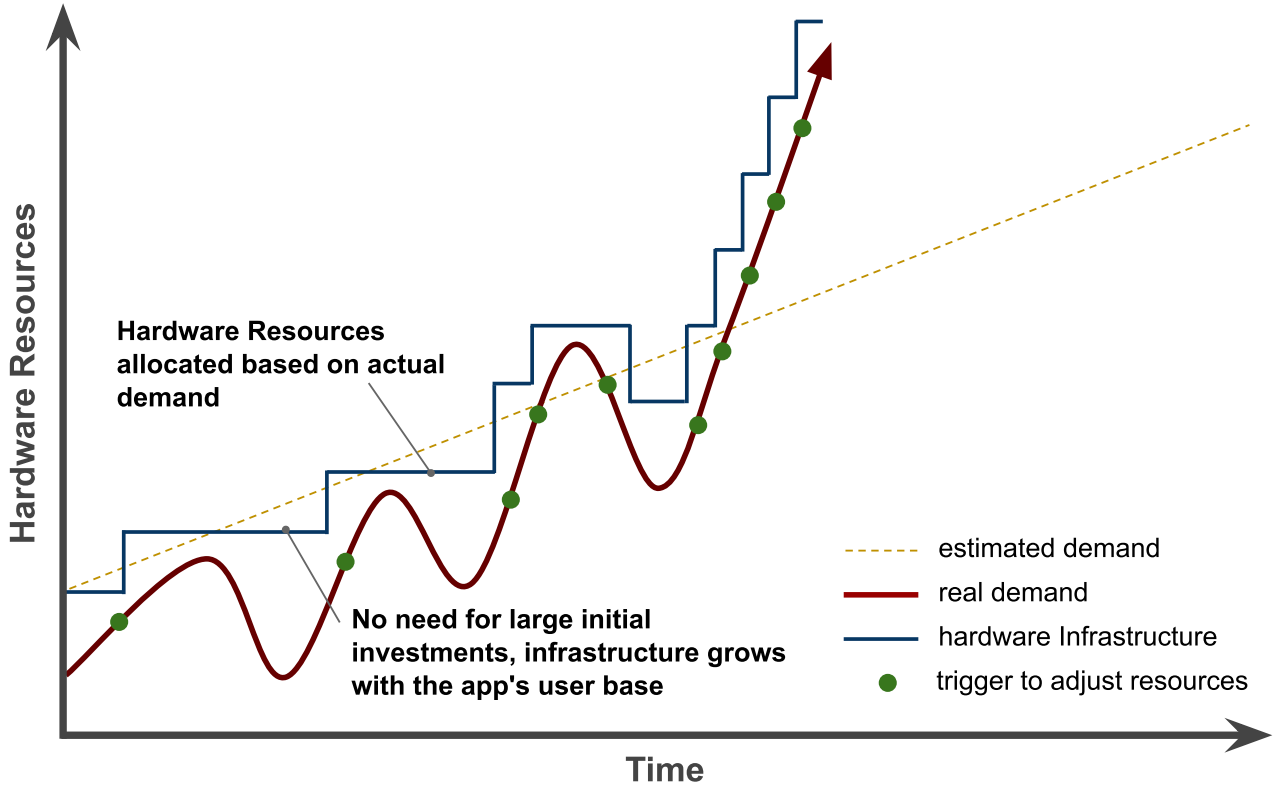
# Traditional Solution to Infrastructure

- Traditional hardware model
  - *Up-front hardware investments*
  - *Hardware not optimally utilized*



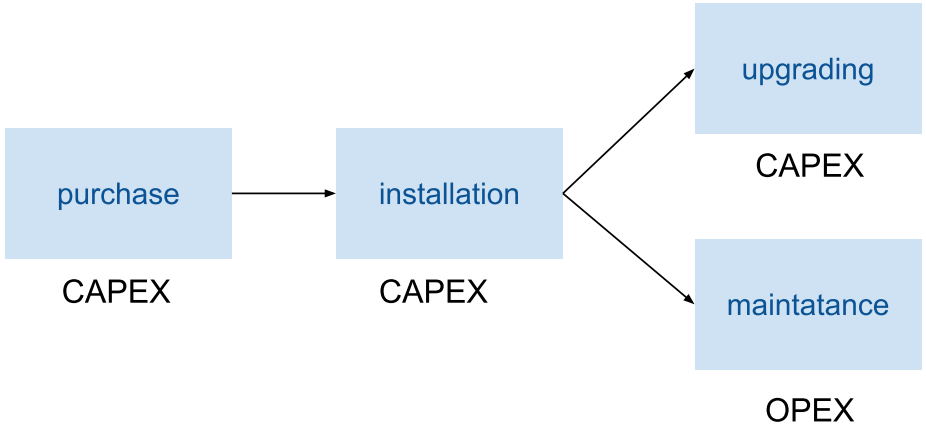
# Good Performance – Cloud Solution

- Cloud Computing model
  - *No up-front hardware investments*
  - *Hardware optimally utilized*



# CAPEX vs. OPEX

- Captial expenditure/capital expense (CAPEX)
  - *money to spend to buy, maintain or improve fixed assets*
    *→ buildings, vehicels, equipment or land*
  - *have impact on costs vs. profit and tax*




- Operational expenditure (OPEX)
  - *ongoing costs for running a product, business, or systems*
  - *OPEX are entirely tax-deductible*
- Cloud lets you trade CAPEX for OPEX
  - *No investments in data centers and infrastructures*
  - *You pay only when you consume resources*

# Cloud Computing Concepts

- **On-demand and self-service**
  - *Resources are provisioned as they are requested and when they are required*
  - *No human interaction, automatic*
- **Board network access**
  - *Capabilities are available over the network*
- **Resource pooling**
  - *Provider's computing resources reused by multiple tenants (multitenancy)*
  - *Resourcces are dynamically assigned/re-assigned according to demand*
  - *Computing resources: CPU, memory, storage, network*
- **Scalability and elasticity**
  - *Infrastructure may grow and shrink according to needs*
  - *Automatic or manual*
- **Measured service**
  - *Resource usage can be monitored, controlled and reported*
- **Pay-per-use**
  - *Consumers only pay for resources when they use them*

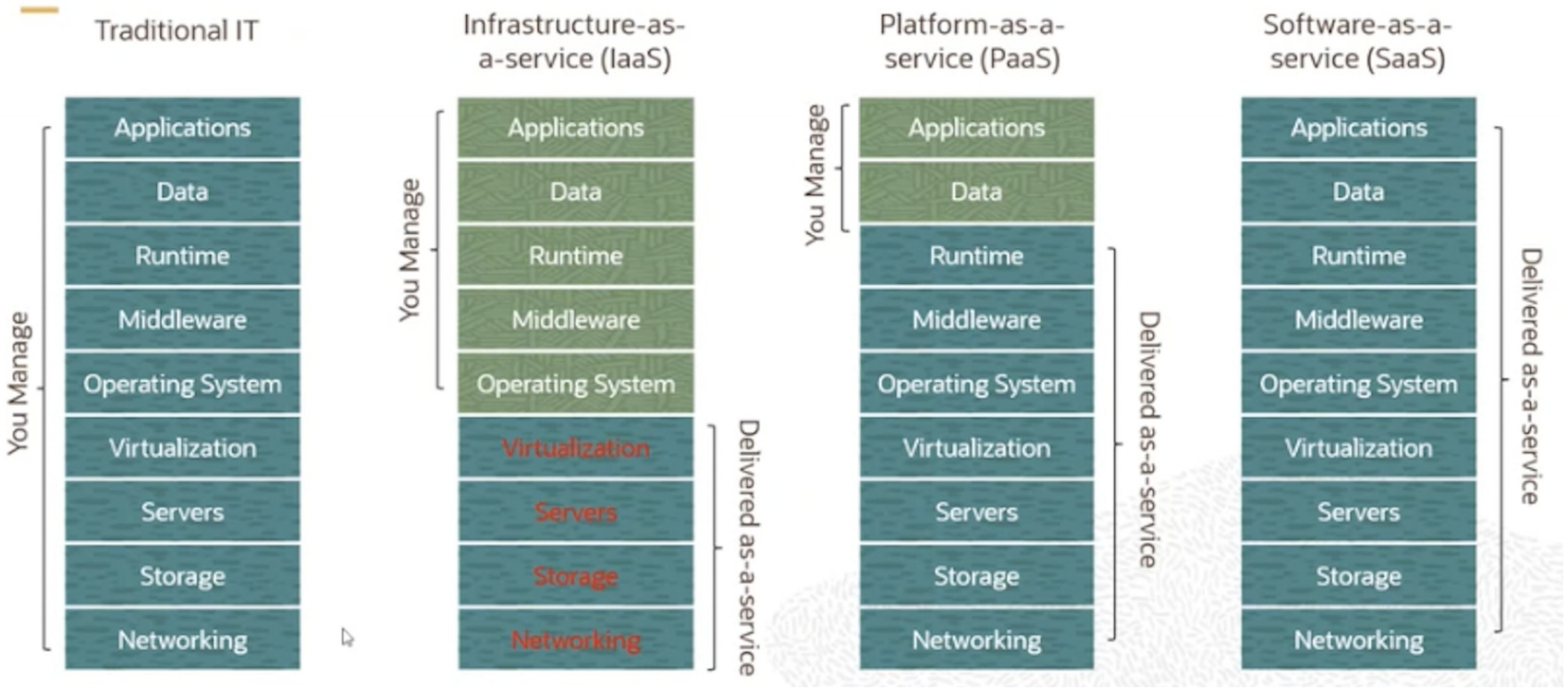
# Cloud Computing Concepts (Cont.)

- Service Models (aka Cloud Layers)
  - *IaaS – Infrastructure as a Service*
  - *PaaS – Platform as a Service, Serverless*
    - → *MWaaS, DBaaS, ...*
    - → *FaaS*
  - *SaaS – Software as a Service*
- Deployment Models
  - *Public Cloud*
  - *Private Cloud*
  - *Hybrid Cloud*

# Overview

- Introduction
- Cloud Architecture
  - *Service Models*
  - *Multitenancy*
- Infrastructure as a Service

# Service Models



# IaaS: Infrastructure as a Service

- Usage
  - *Predefined shapes of compute instances (e.g. micro, small, large, extra-large)*
    *→ for example: RedHat 7.8, 613 MB of memory, 1 TB block storage*
  - *Pay-per-use – pay for resources you use (time or amount)*
    *→ no up-front costs*
- IaaS Services Examples
  - *Load balancer*
  - *Autoscaling*
  - *Connectivity with on-premise network*
  - *Resource monitoring*
- IaaS providers
  - *Amazon EC2, GoGrid, Rackspace, OpenNebula, Google Cloud, Oracle OCI, ...*

# PaaS: Platform as a Service

- Usage
  - *Choose software platform, e.g., JEE, .NET, Python, etc.*
  - *Pay-per-use – pay for the resources you use; no up-front costs*
  - *Cloud native, microservices, containers*
- PaaS features
  - *Serverless*
  - *Auto Scalling and Load balancing*
  - *Local development environment*
  - *Administration API*
- PaaS providers
  - *Google App Engine – first PaaS service*
  - *Today, mostly Kubernetes, Google, Heroku, Azure, AWS, Oracle*

# SaaS: Software as a Service

- Software delivery model for applications hosted in the cloud
  - *typically software for end-users*
  - *services accessed using a web browser*
  - *provides API for programmatic access*
- SaaS characteristics
  - *Typically build on top of IaaS or PaaS*
  - *Configurable and customizable modern Web applications*
  - *Usually basic version for free, need to pay for "pro" version*
  - *Global availability - any computer, any device*
  - *Easy management - automatic and fast updates*
  - *Pay-per-use – pay for the time you use*
- SaaS providers
  - *Google Apps, Salesforce, ...*

# Overview

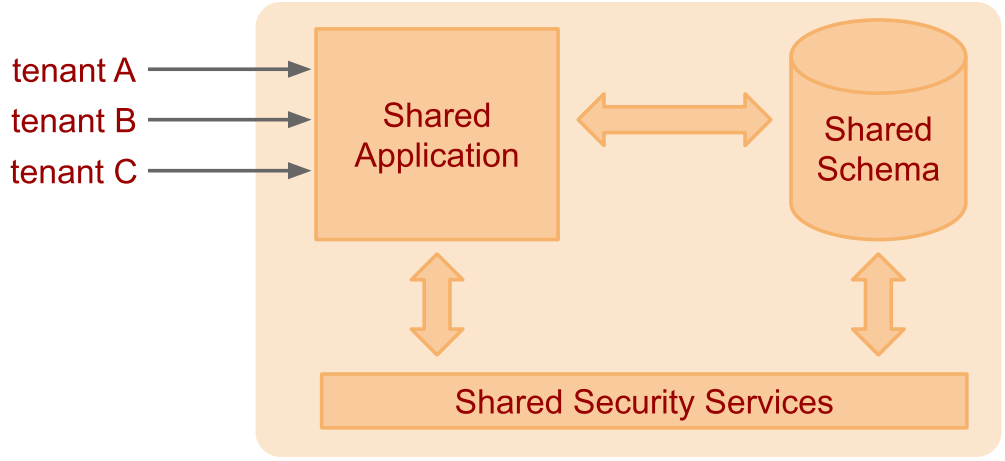
- Introduction
- Cloud Architecture
  - *Service Models*
  - *Multitenancy*
- Infrastructure as a Service

# Multitenancy

- Architectural approach where resources are shared between multiple tenants or consumers
- Implications
  - *Centralization of infrastructure in locations with lower costs*
  - *Peak-load capacity increases*
  - *Utilisation and efficiency improvements for systems that are not well utilised*
- Sharing options
  - *Shared Everything*
  - *Shared Infrastructure*
    - → *Virtual Machines*
    - → *OS "virtualization"*

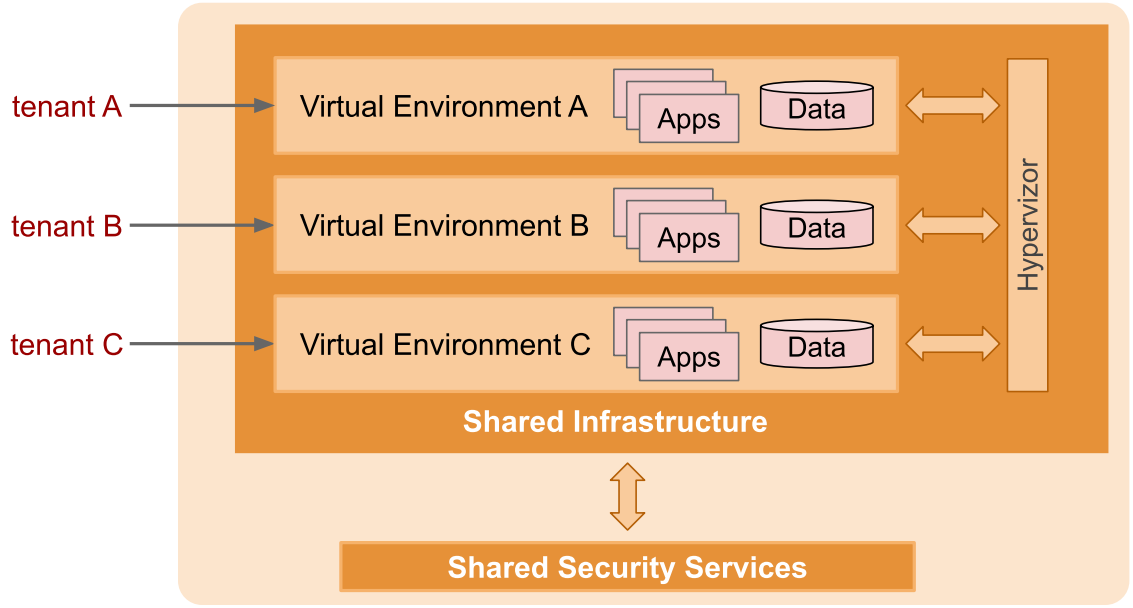
# Shared Everything

- Resources are shared between all tenants or consumers
  - *tenant: a service consumer*
- Common for the SaaS model
- The application should provide tenant isolation
- Data for multiple tenants is stored in the same database tables



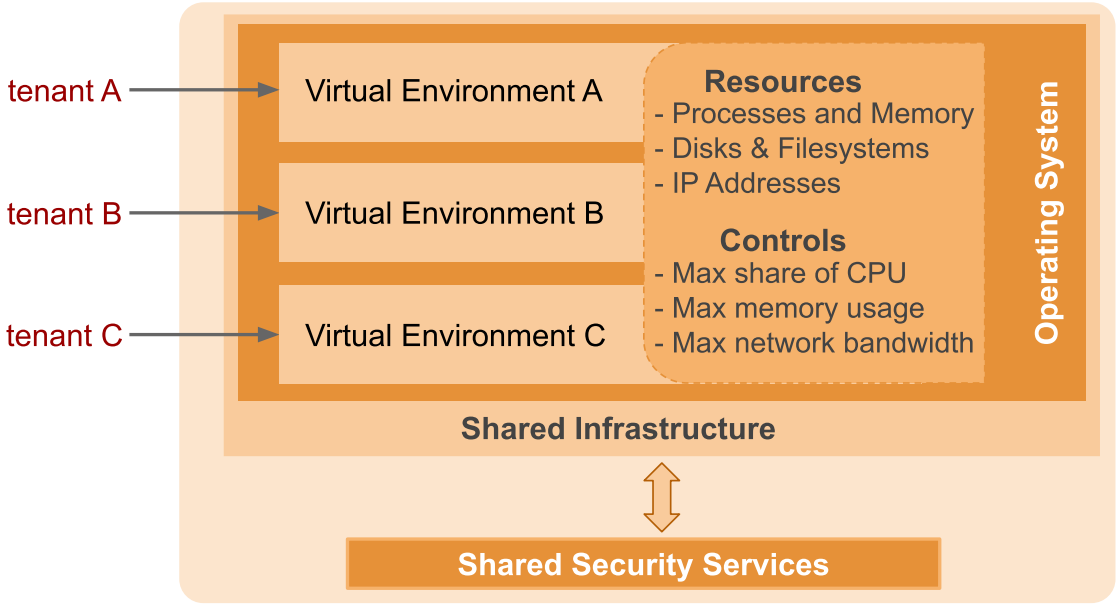
# Shared Infrastructure: Virtual Machines

- Infrastructure shared via virtual machines
  - *each tenant has its own virtual environment*
  - *Isolation provided by hypervisor*
    - *→ hypervisor: virtual machine manager, runs virtual machines*
  - *Resource contention depends on VM capability and configuration*
  - *Adds an additional layer and processes to run and manage*



# Shared Infrastructure: OS Virtualization

- Infrastructure shared via OS Virtualization
  - *Each tenant has its own processing zone*
  - *Isolation provided by the operating system*
  - *Resource contention depends on zone configuration*
  - *No VMs to run and manage, no abstraction layer between app & OS*



# Overview

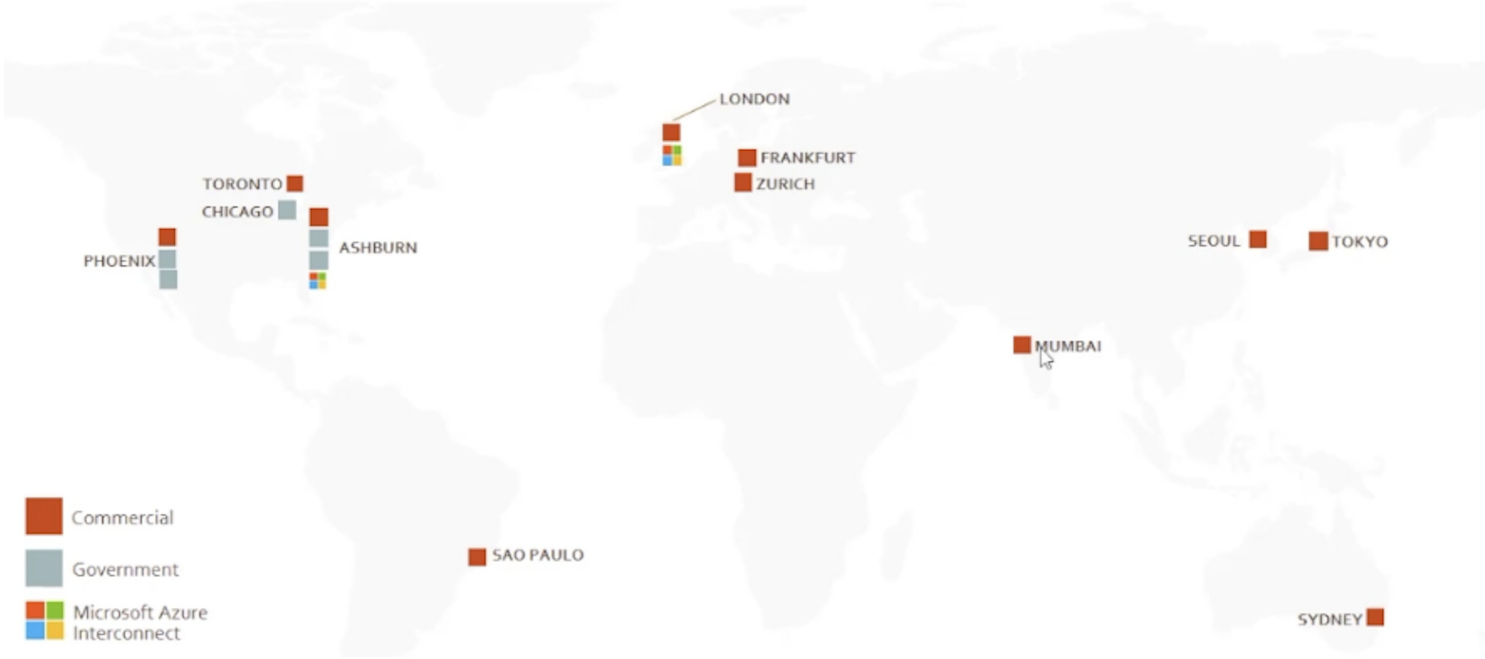
- Introduction
- Cloud Architecture
- Infrastructure as a Service
  - *Networking*
  - *Compute*
  - *Storage*
  - *Infrastructure as Code*

# Overview

- Infrastructure = environment where your app is running
- Tenancy = your "space" in the cloud
- What you need
  - *Servers (compute instances) to run your app in a location (region)*
  - *Connectivity*
    - → *Private network for intra-communication*
    - → *Public network for internet communication*
    - → *Firewall (security) rules*
    - → *Route tables*
  - *Storage*
    - → *Operating system*
    - → *Your app data*
  - *Identity Management*
    - → *Who and how can access and control your tenancy*
  - *Monitoring, Logging, Auditing*

# Region

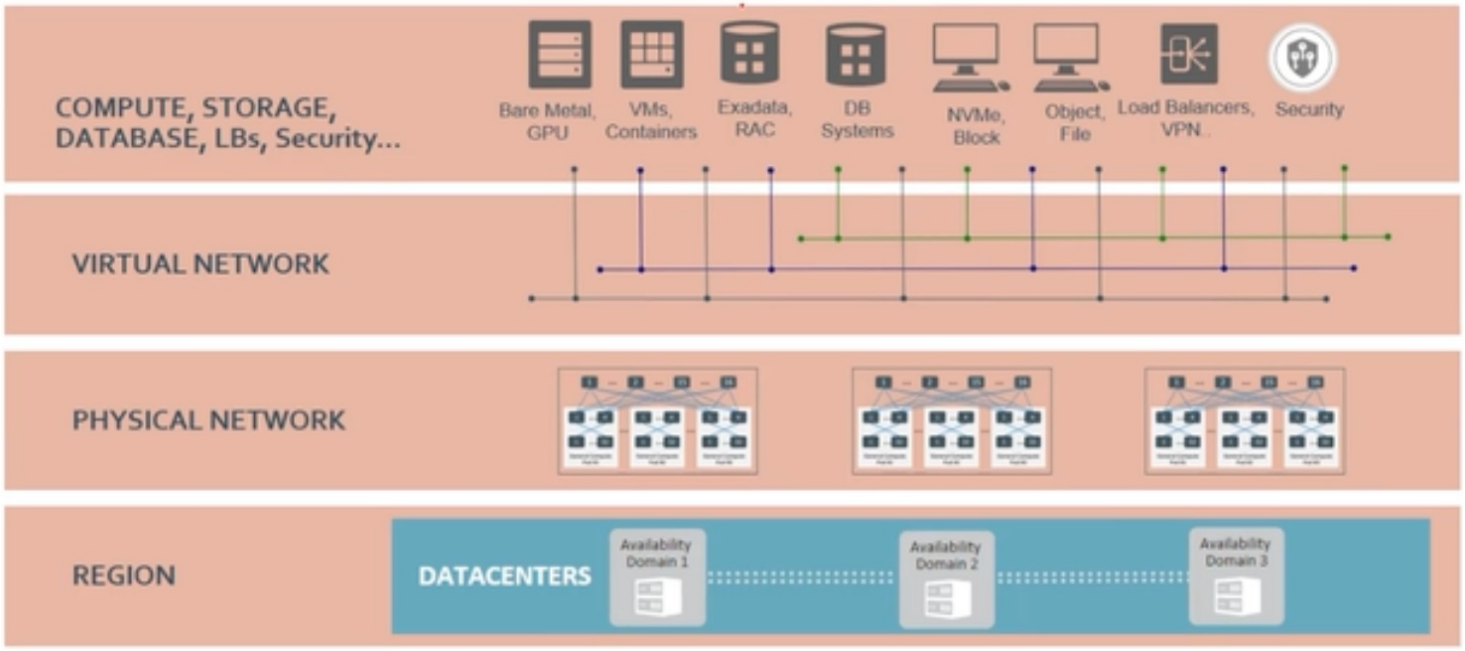
- Region = location on a planet where cloud data centers are located




- Why location matters...
  - *Latency - your users should be close to your app*
  - *Regulations - your data should be stored in EU*
  - *Connectivity to external providers*
    - *→ Such as other cloud vendors*

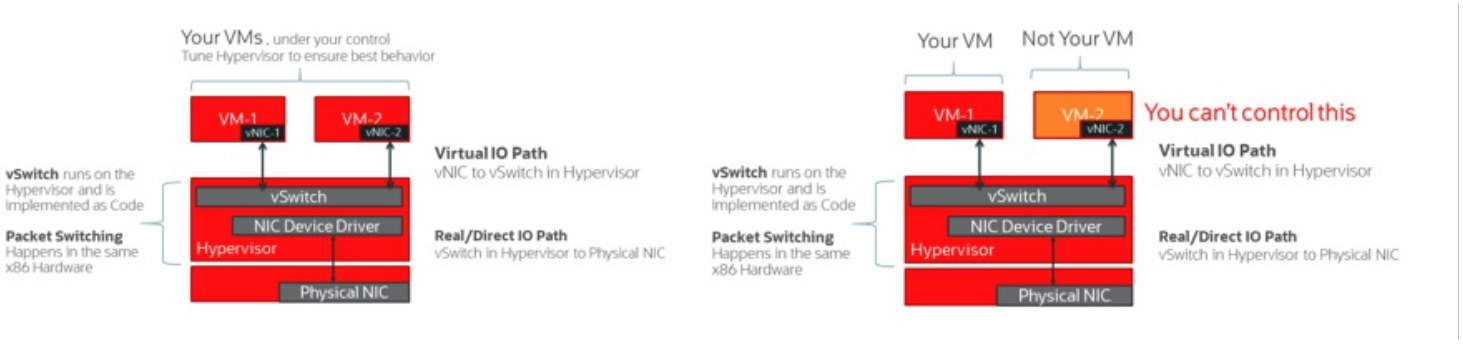
# Datacenters

- Datacenter (aka Availability Domain – AD)
  - *Computing resources in a location within a region*
  - *One or more datacenters exsit in a region*
    - → *They are completely de-correlated, independent*
    - → *They have separated power supply, do not share underlying infrastructure*
    - → *If one DC fails, the other one is up and running*

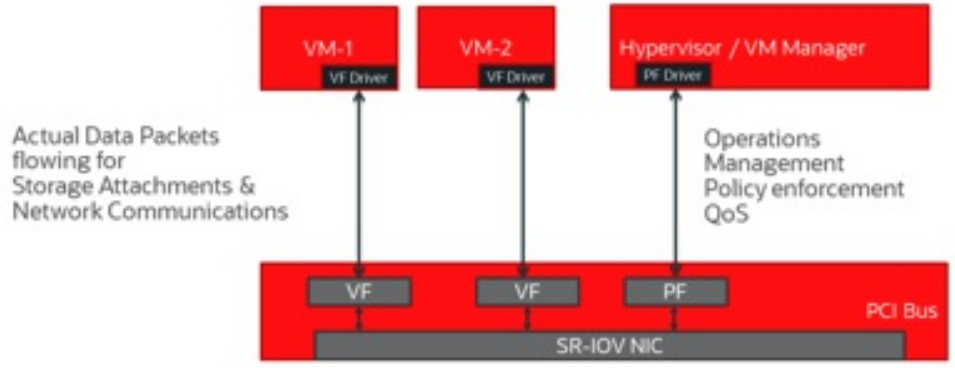


# Off-box Network Virtualization

- Gen 1.0 Cloud, inefficient Resource Sharing
  - *On-Premise virtualization to share resources amongst multiple tenants in the cloud.*




- Gen 2.0 Cloud
  - *Smart-NIC accelerated SR-IOV (Single Root I/O Virtualization)*
    - *→ Networking is a specialized function, needs hardware/sillicon to accelerate it*



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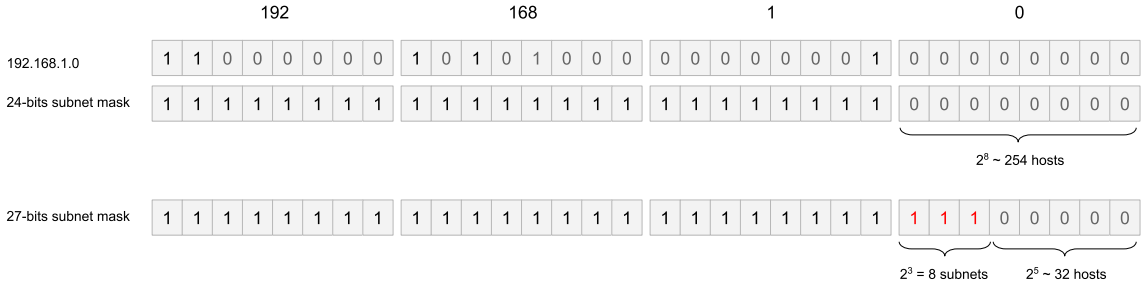
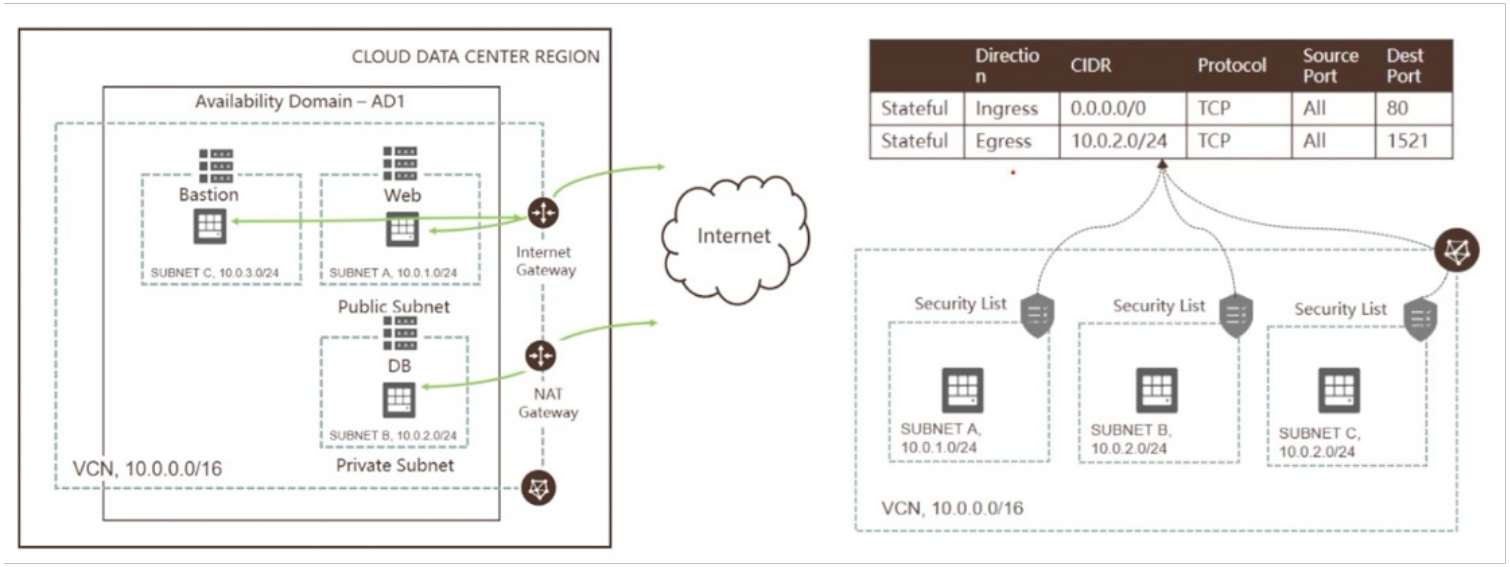
# Virtual Cloud Network

- VCN = a private network in a **single region** in which your instances reside
- A a single and contigous IPV4 CIDR block of your choice
  - *CIDR (classless inter-domain routing) notation*
  - *IP address:*
    - → *network prefix (the most significant bits) and*
    - → *interfaces on the network (least significant bits) ~ network hosts*
  - *Example:* `192.168.1.0/24`
    - → *IP range:* `192.168.1.0` - `192.168.1.255`
- You further create subnets on a VCN to organize your instances
  - *The subnets must be "within" the VCN, they can span across ADs*
  - *Example: using* `27` *bits for a subnet mask allow for 8 subnets*
    - → `192.168.1.0/27`, `192.168.1.32/27`, `192.168.1.64/27`, ...
    - → *Each subnet can have 32 hosts*



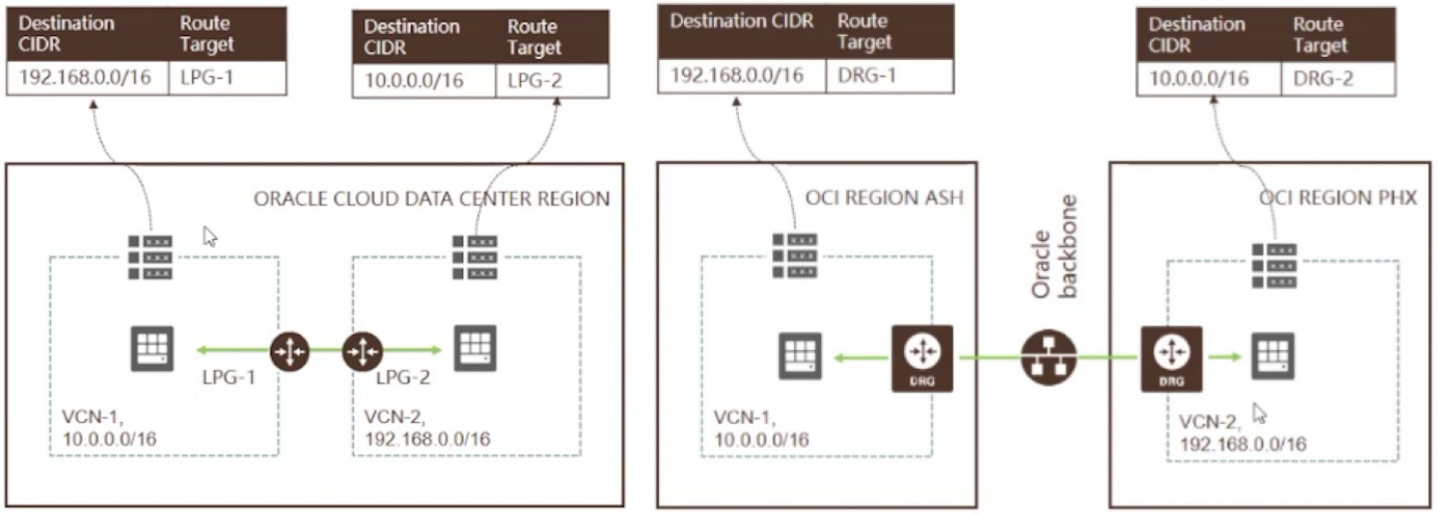
# VCN Routing and Security

- Private and Public subnets
  - *Public can communicate in/out from/to Internet*
  - *Internet traffic routed to public subnet*
  - *Private can be completely isolated or communicate to Internet only*
- Route tables
  - *Required to route across subnets and in/out from the Internet*
- Security
  - *Control access to/from the subnet*



# Peering

- Local Peering
  - *Connecting two VCNs in a region*
- Remote Peering
  - *Connecting two VCNs across regions*
- Connectivity with on-premise datacenter
  - *Fast connection needs to be in place*
  - *Secure VPN needs to be established*



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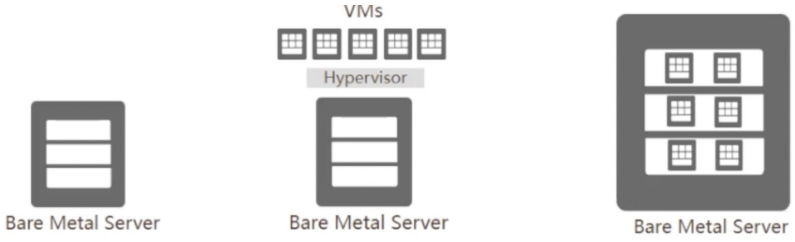
# Compute Instances

- Shape = amount of memory and CPU an instance is using
  - *There are classes of shapes that you can choose from*
  - *Standard and HPC/GPU shapes*
- Virtual Machine (VM) – multi-tenant model
  - *A hypervisor to virtualize the underlying Bare Metal server into smaller VMs*
- Bare Metal (BM) – single-tenant model
  - *Direct hardware access, full bare metal server*
  - *Types of workloads: performance intensive, require a specific hypervisor*
- Dedicated VM Hosts (DVM) – single-tenant model
  - *VM instances running on dedicated single-tenant servers*
  - *Not shared with other customers*




- States: start, stop, reboot, terminate
  - *Billing pauses in STOP state but depends on shape*

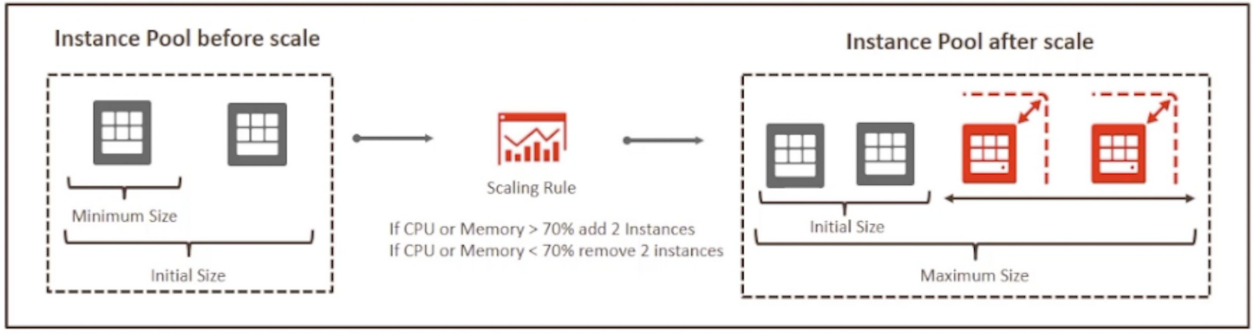
# Image

- Image
  - *A template of a virtual hard drive with OS*
  - *Other software, libraries, configurations, etc.*
- Stored on a boot volume
- Base images are provided
  - *CentOS, Ubuntu, Windows Server, Oracle Linux, RedHat, etc.*
  - *Some may require licence costs*
- Custom images
  - *You can create a custom image from the base image*
  - *Specific packages, libraries or custom configuiration*
  - *You store the image in the object storage*

# Autoscaling

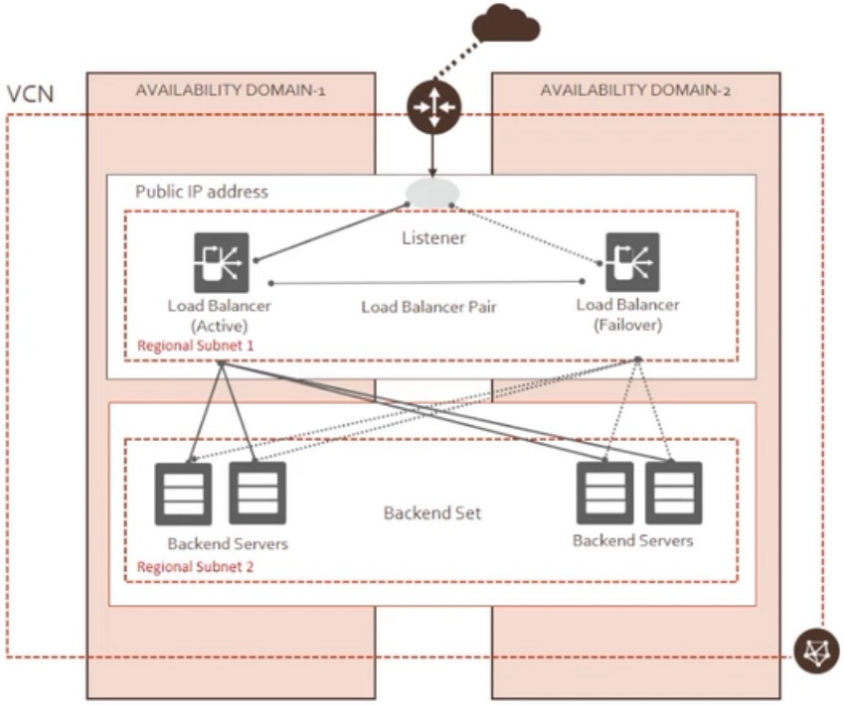
- Instance configuration
  - *OS image, metadata, shape, vNICs, storage, subnets*
  - *Apply configuration to multiple instances at the same time*
    - *→ You can manage them all together (start, stop, terminate)*


- Autoscaling
  - *Automatically adjust a number of compute instances in an instance pool*
  - *Control using performance metrics such CPU or memory utilization*
  - *cooldown period – time between scale in and scale out (e.g. 300 seconds)*



# Load Balancer

- Managed service
  - *Health check – checks health status of backends (TCP, HTTP)*
  - *Algorithm – round-robin, IP hash, least connections*
- Supports protocols
  - *TCP, HTTP 1.1, HTTP/2, WebSocket, SSL termination, end-to-end SSL*
  - *Supports sticky sessions (sessions persistence)*
- High Availability
  - *Primary and stand-by LB*
  - *Each LB is in different AD*
  - *Failover uses floating IP*



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# Object Storage

- Types of data to store
  - *Storage for unstructured data (images, media files, logs, backups)*
  - *Data managed as objects, provides API using HTTP verbs*
- Namespace
  - *Logical entity that serves as top-level container for all bueckts and objects*
  - *Each tenancy is provided one unique namespace*
- Bucket
  - *A logical container for storing objects*
  - *Bucket names must be unique within tenancy*
  - *Hot bucket – standard, can be accessed immediatelly*
  - *Cold bucket – rarely accessed data, need to be restored*
    - → *Minimum retention, such as 90 days*
    - → *Time to First Byte (TTFB) is in hours, e.g. 4 hours*
- Object and metadata
  - *data managed as objects regardless data type*
- Example object URL path:

```
/n/<namespace>/b/<bucket>/o/<object_name>
```

# Block Storage

- Local NVMe SSD device
  - *Locally attached device, provided by some shapes, 200K IOPS - 1M IOPS*
  - *Workloads that require high storage performance*
  - *usually no RAID, snapshots, backups*
- Block volumes
  - *Reside in storage servers*
  - *NVMe SSD based, up to 35K IOPS*
  - *Data stored on block volumes beyond the lifespan of compute instance*
  - *Multiple replicas across multiple storage servers*
- File Storage
  - *Network file server (NFS)*
  - *Client mounts a **mount target** (NFS endpoint) and an **export path***
  - *Example*

```
sudo mount 10.0.0.6/example1/path /mnt/mountpointA
```

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# Overview

- Definition
  - *Application envs (in a cloud) managed via definition files*
  - *Version control, team development, scripting, etc.*
- Major Technologies
  - ***Configuration Management Tools***
    - → *install and manage software on machines that already exist*
    - → *Examples: Ansible, Chef, Puppet*
  - ***Abstraction of cloud infrastructure***
    - → *Terraform*

# Terraform

- Higher-level abstraction of the datacenter and associated services
- Supports many service providers
  - *Google, Microsoft, Oracle, AWS*
- Steps
  1. *Description of resources in Hashicorp Configuration Language (HCL)*
     - *instances, networks, firewall rules, routing tables, etc.*
  2. *Terraform generates execution plan to reach the desired state*
  3. *Terraform executes the plan to reach the desired state; can generate incremental execution plan*