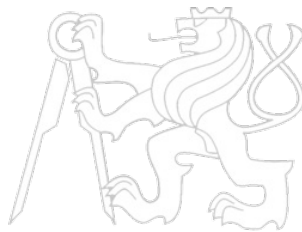


Middleware Architectures 2

Lecture 5: 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?

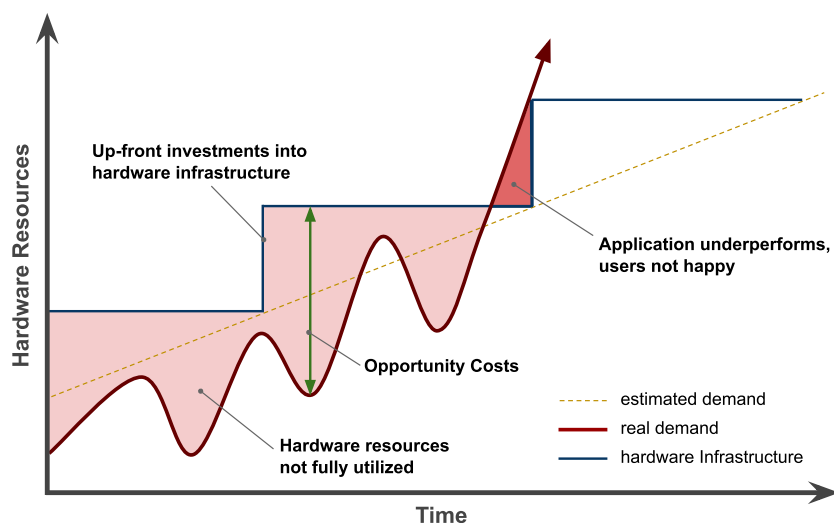
- A different way of thinking
 - *Got your grand mum's savings under your pillow?*
→ *probably not, you better have them in your bank*
 - *Data is your major asset*
 - *you better have them in a "bank" too*
 - *Someone can abuse your data?*
 - *banks bankrupt too, sometimes – it is a risk you take*
 - *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*

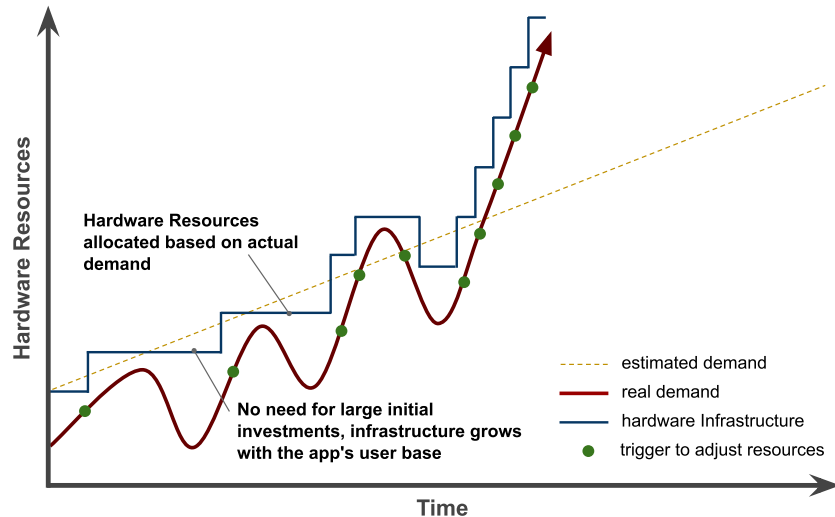
Traditional Solution to Infrastructure

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



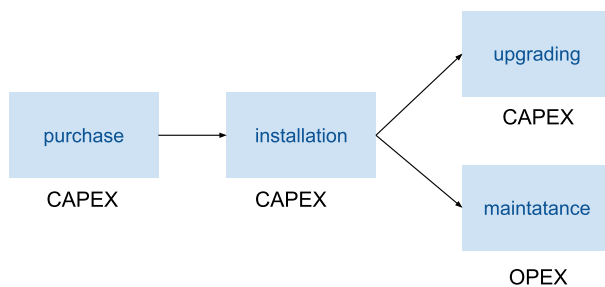
Good Performance – Cloud Solution

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



CAPEX vs. OPEX

- Capital expenditure/capital expense (CAPEX)
 - money to spend to buy, maintain or improve fixed assets
 - buildings, vehicles, 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*
- **Broad network access**
 - *Capabilities are available over the network*
- **Resource pooling**
 - *Provider's computing resources reused by multiple tenants (multitenancy)*
 - *Resources 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*

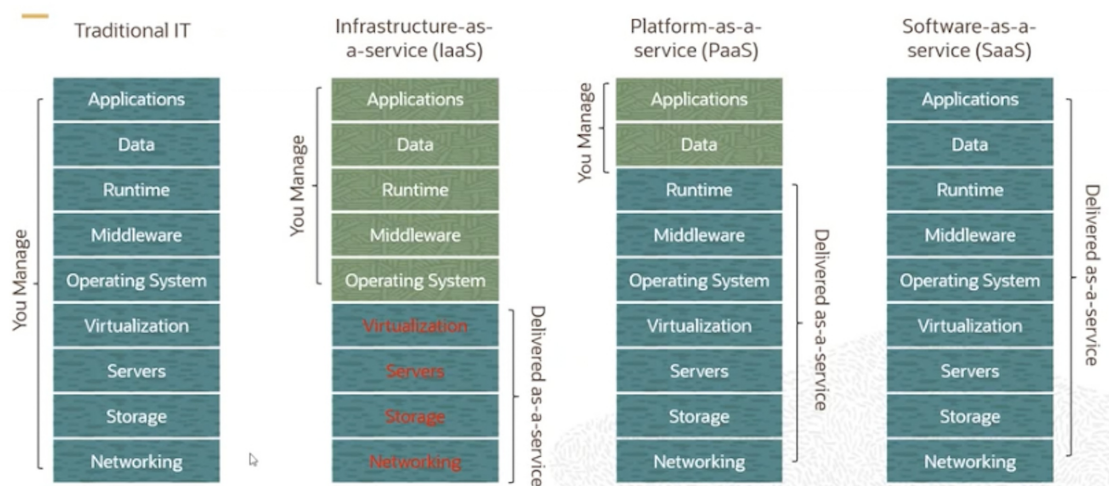
Cloud Computing Concepts (Cont.)

- **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

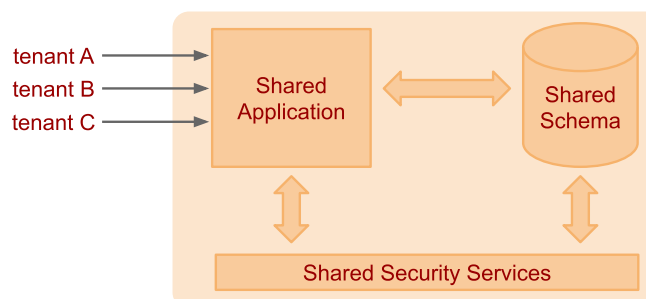
- Introduction
- Cloud Architecture
 - *Service Models*
 - *Multitenancy*
- Infrastructure as a Service

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"*

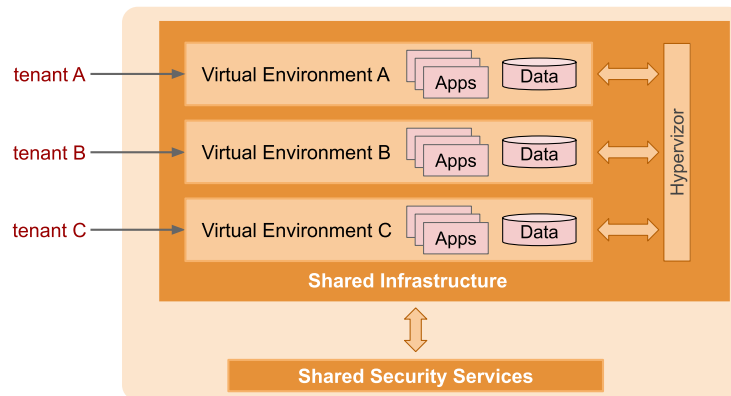
Shared Everything

- 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



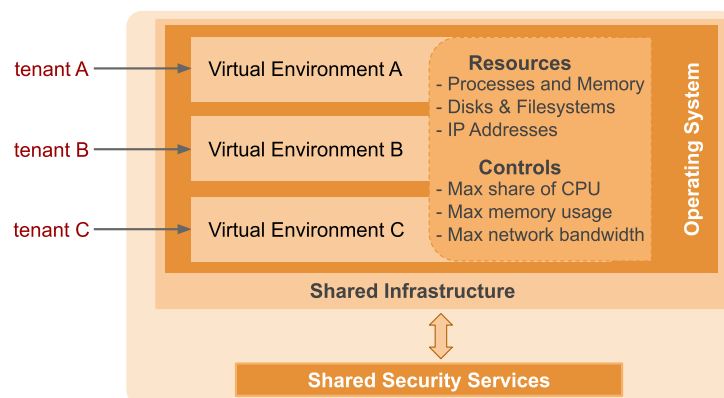
Shared Infrastructure: Virtual Machines

- 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

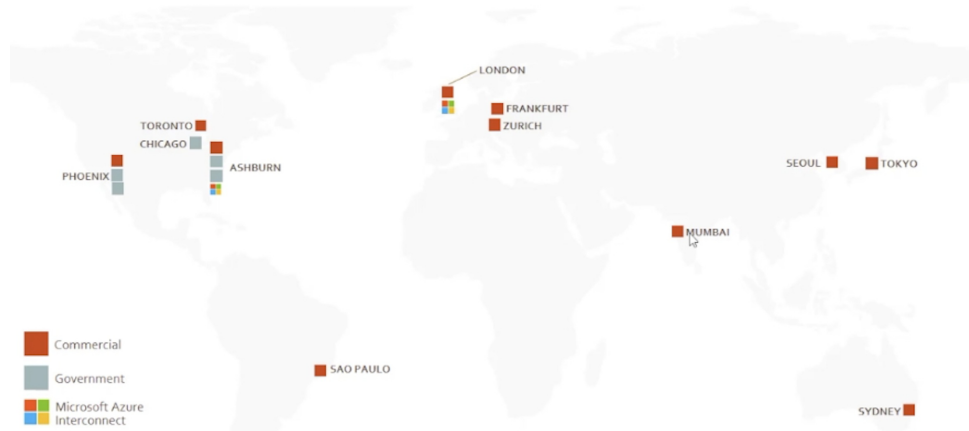
- Introduction
- Cloud Architecture
- **Infrastructure as a Service**
 - *Networking*
 - *Compute*
 - *Storage*
 - *Infrastructure as Code*

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

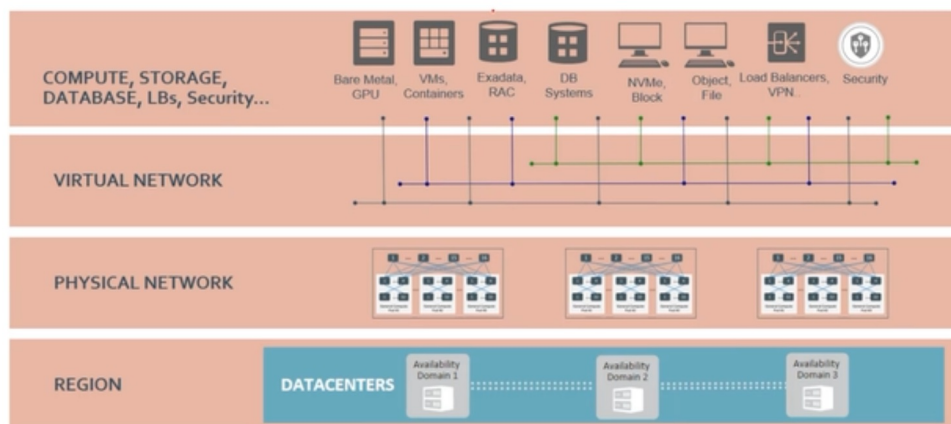
- Region = location on a planet where cloud data centers are located



- 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 exist 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

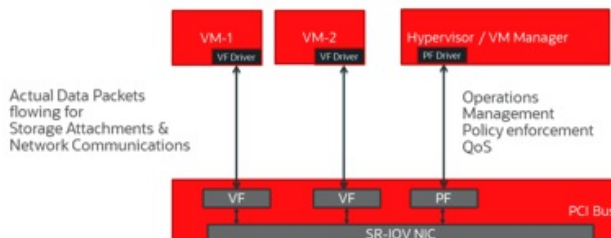


Off-box Network Virtualization

- 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/silicon to accelerate it*

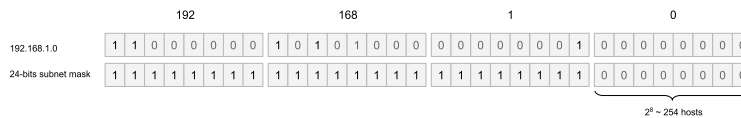


Overview

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

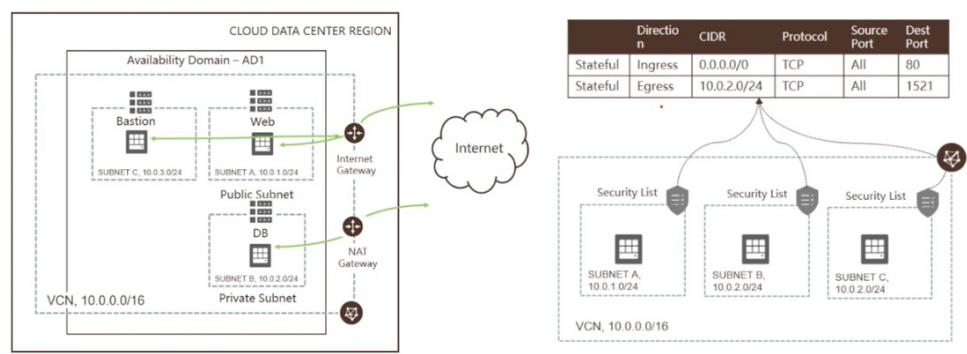
Virtual Cloud Network

- VCN = a private network in a **single region** in which your instances reside
- A single and contiguous 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



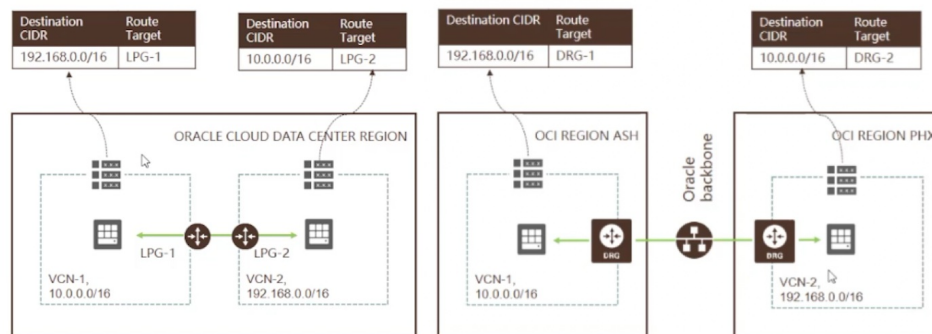
VCN Routing and Security

- 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

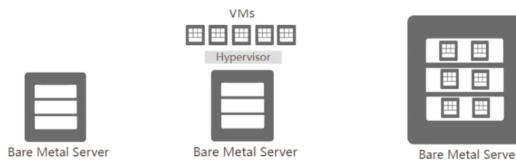


Overview

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

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

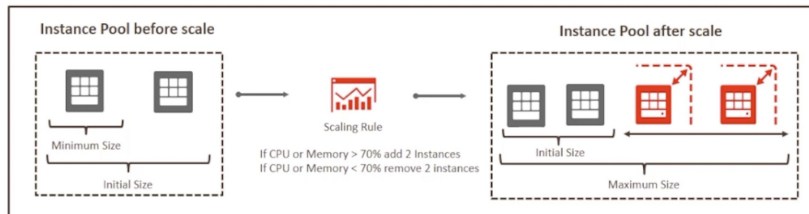
- Image
 - A template of a virtual hard drive with OS
 - Other software, libraries, configurations, etc.
- Stored on a boot volume
- Base images are provided
 - CentOS, Ubuntu, Windows Server, Oracle Linux, RedHat, etc.
 - Some may require licence costs
- Custom images
 - You can create a custom image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

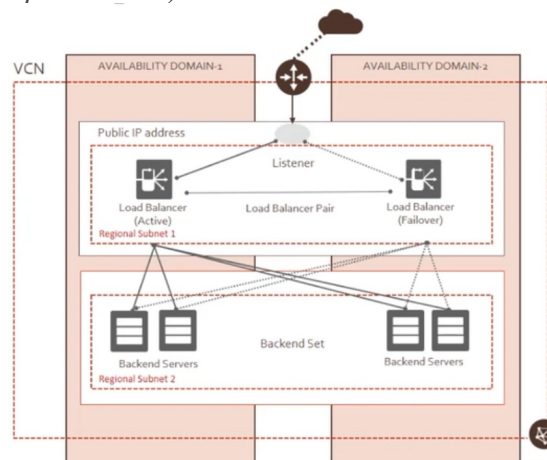


- Autoscaling
 - Automatically adjust a number of compute instances in an instance pool
 - Control using performance metrics such CPU or memory utilization
 - cooldown period – time between scale in and scale out (e.g. 300 seconds)



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



Overview

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 - *Infrastructure as Code*

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 buckets 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 immediately*
 - *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
```

Overview

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

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*