EC2: Virtual Machines

What is Amazon EC2?

- **Amazon Elastic Compute Cloud (EC2)** is a scalable compute service that allows users to rent virtual servers in the cloud.
- It provides flexibility to scale compute resources up or down based on demand, offering a cost-effective solution for applications with variable workloads.
- Key features include:
  - **On-Demand Instances**: Pay for compute capacity by the hour or second, with no long-term commitments.
  - **Reserved Instances**: Make a one-time payment for a significant discount on instance usage over a one- or three-year term.

    - **Spot Instances**: Bid for unused EC2 capacity at a potentially lower price, allowing cost savings for flexible workloads.

EC2 Sizing & Configuration Options

- EC2 allows for customized sizing and configurations, which include:
    - **Instance Type**: Selecting the appropriate type based on the application's performance requirements.
    - **Storage Options**: Using Amazon EBS for persistent block storage or instance store for temporary storage.
    - **Networking**: Configuring VPCs, subnets, and security groups to control access and manage traffic.
    - **Elastic Load Balancing**: Distributing incoming traffic across multiple EC2 instances to enhance availability and fault tolerance.
    - **Auto Scaling**: Automatically adjusting the number of instances based on demand, ensuring the application has the necessary resources.

EC2 User Data

- **User data** is a powerful feature for automating the setup of EC2 instances.
- It can be specified at instance launch and is executed on the instance when it first boots.
- bootstrapping means launching commands when a machine starts
- That script is **only run once** at the instance **first start**
- **Common use cases include**:
    - Installing software packages (e.g., `yum install httpd -y` for Apache).
    - Downloading configuration files or scripts from Amazon S3.
    - Configuring system settings and services (e.g., starting an application server).

EC2 Instance Types - Overview

Amazon EC2 offers a variety of instance types, each designed to meet specific application requirements. (https://aws.amazon.com/ec2/instance-types/)

General Purpose Instances

- General purpose instances provide a balanced mix of compute, memory, and network resources.
- They are suitable for a variety of workloads and can handle different application types effectively.
- **Use Cases**:
    - Web servers and applications
    - Small to medium-sized databases
    - Development and testing environments
    - Enterprise applications

Instance Type	vCPUs	Memory (GiB)	Network Performance	Storage
t4g.micro	2	1	Up to 5 Gigabit	EBS only
t3.micro	2	1	Up to 5 Gigabit	EBS only
m5.large	2	8	Up to 10 Gigabit	EBS only

Instance Type	vCPUs	Memory (GiB)	Network Performance	Storage
m5.xlarge	4	16	Up to 10 Gigabit	EBS only

Compute Optimized Instances

- Compute optimized instances are designed for applications that require high-performance processors and are well-suited for compute-intensive workloads.
- **Use Cases**:
  - High-performance web servers
  - Batch processing
  - Data analytics
  - Machine learning inference

Instance Type	vCPUs	Memory (GiB)	Network Performance	Storage
c5.large	2	4	Up to 10 Gigabit	EBS only
c5.xlarge	4	8	Up to 10 Gigabit	EBS only
c5.2xlarge	8	16	Up to 10 Gigabit	EBS only
c5n.9xlarge	36	96	10 Gigabit	EBS only

Memory Optimized Instances

- Memory optimized instances provide high memory bandwidth and are optimized for applications that require large amounts of memory.
- **Use Cases**:
  - High-performance databases (e.g., SAP HANA)
  - In-memory caches (e.g., Redis, Memcached)
  - Real-time big data analytics
  - Data mining applications

Instance Type	vCPUs	Memory (GiB)	Network Performance	Storage
r5.large	2	16	Up to 10 Gigabit	EBS only
r5.xlarge	4	32	Up to 10 Gigabit	EBS only
r5.4xlarge	16	128	Up to 10 Gigabit	EBS only
r5b.12xlarge	48	384	10 Gigabit	EBS only

Storage Optimized Instances

- Storage optimized instances are designed for applications that require high, sequential read and write access to large datasets.
- **Use Cases**:
  - Data warehousing applications
  - Hadoop distributed computing

- High-frequency trading applications
- NoSQL databases (e.g., Cassandra)

Instance Type	vCPUs	Memory (GiB)	Network Performance	Storage
i3.large	2	15	Up to 10 Gigabit	1 x 475 GB NVMe SSD
i3.xlarge	4	30	Up to 10 Gigabit	1 x 950 GB NVMe SSD
i3.2xlarge	8	61	Up to 10 Gigabit	1 x 1.9 TB NVMe SSD
d2.8xlarge	36	244	Up to 10 Gigabit	12 x 2 TB HDD

EC2 Instance Types: Example

Here's a quick overview of some example instance types in each category, along with their characteristics:

Instance Type	vCPUs	Memory (GiB)	Storage	Use Case
t3.micro	2	1	EBS only	General-purpose applications with burstable performance; suitable for low-traffic web servers or development environments.
c5.large	2	4	EBS only	Compute-intensive applications like gaming, web servers, and machine learning inference.
m5.xlarge	4	16	EBS only	Balanced workloads, such as small databases and caching fleets. Ideal for web applications.
r5.xlarge	4	32	EBS only	Memory-intensive applications such as databases, in-memory caches, and analytics workloads.
i3.2xlarge	8	61	1 x 2.5 TB NVMe SSD	Storage-intensive applications like NoSQL databases, data warehousing, and big data analytics.
p3.2xlarge	8	61	EBS only	GPU-accelerated computing for machine learning, high-performance computing (HPC), and graphics-intensive applications.

t2.micro is part of the AWS free tier (up to 750 hours per month)

Introduction to Security Groups

- **Security Groups** are **virtual firewalls** that control inbound and outbound traffic to Amazon EC2 instances.
- They act at the instance level, not the subnet level, and provide a way to manage access to resources within a VPC (Virtual Private Cloud).
- Security groups can be associated with multiple instances and can be modified at any time, allowing for flexible management of network access.

- **Key Features**:
  - By default, all inbound traffic is denied, and all outbound traffic is allowed.
  - You can specify rules based on protocol (TCP, UDP, ICMP), port number, and source IP address or CIDR block.

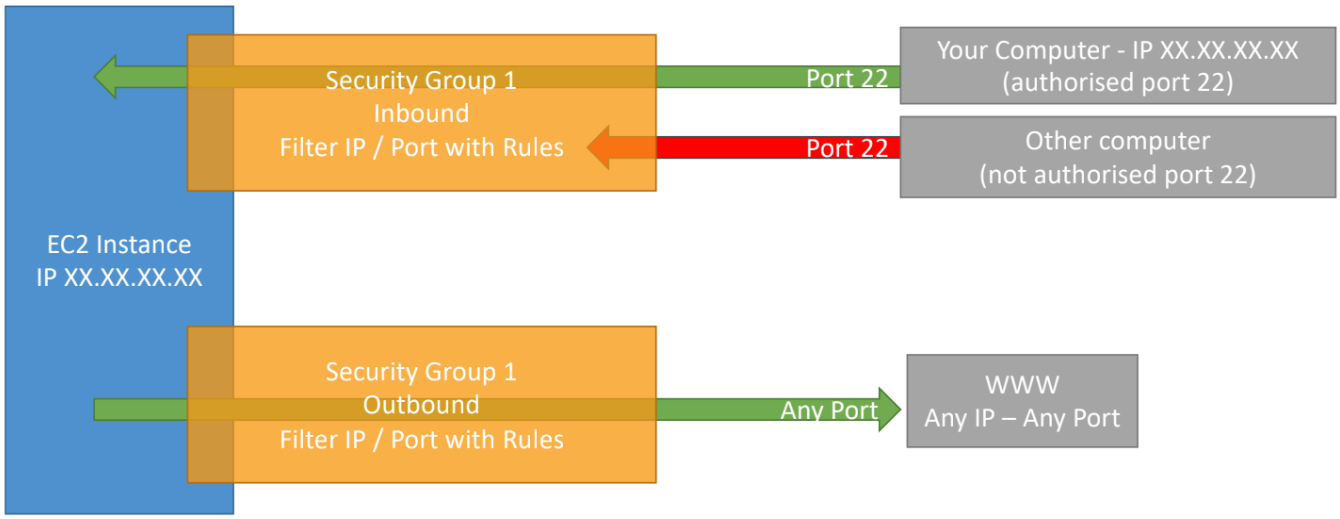
Common Use Cases

- Restricting access to an application server (allowing only specific IPs).
- Allowing traffic from specific ports (e.g., HTTP/HTTPS).
- Isolating database instances from public access.

Deeper Dive

- **Inbound Rules**: Define the traffic allowed into your instances.
- **Outbound Rules**: Define the traffic allowed out from your instances.
- Each rule includes:
  - **Type**: The protocol used (e.g., HTTP, SSH).
  - **Protocol**: The protocol number (TCP = 6, UDP = 17).
  - **Port Range**: The port(s) affected by the rule.
  - **Source/Destination**: The IP address or CIDR range from which traffic is allowed.

Security Groups Diagram



Examples of Security Group Rules

Rule Type	Protocol	Port Range	Source/Destination
Inbound Rule	TCP	22	203.0.113.0/24 (SSH Access)
Inbound Rule	TCP	80	0.0.0.0/0 (HTTP Access)
Outbound Rule	All Traffic	All	0.0.0.0/0

Good to Know

- **Limits**: Each security group can have up to 60 inbound and 60 outbound rules by default (this limit can be increased by requesting through AWS Support).
- **Default Security Group**: When you create a VPC, a default security group is automatically created, which allows all outbound traffic and denies all inbound traffic by default.
- **Multiple Security Groups**: You can assign multiple security groups to a single EC2 instance, enabling fine-grained control over traffic.
- **Security Best Practices**:
  - Apply the principle of least privilege (only allow necessary traffic).
  - Regularly review and audit security group rules.
  - Use descriptive names and tags for easy management.

Classic Ports to Know

Port Number	Protocol	Service	Description
20	TCP	FTP (Data Transfer)	Used for transferring files over FTP.
21	TCP	FTP (Control)	Used for controlling file transfer sessions.
22	TCP	SSH	Secure Shell for secure logins and command execution.
80	TCP	HTTP	Hypertext Transfer Protocol for web traffic.
443	TCP	HTTPS	Secure HTTP for secure web traffic.
3389	TCP	RDP	Used for Remote Desktop Protocol, allowing users to connect to and control remote Windows machines.

EC2 Instance Launch Types

- **On Demand Instances**: short workload, predictable pricing
- **Reserved**: (1 & 3 years)
  - **Reserved Instances**: long workloads
  - **Convertible Reserved Instances**: long workloads with flexible instances
- **Savings Plans** (1 & 3 years): commitment to an amount of usage, long workload
- **Spot Instances**: short workloads, for cheap, can lose instances
- **Dedicated Instances**: no other customers will share your hardware
- **Dedicated Hosts**: book an entire physical server, control instance placement
- **Capacity Reservations**: reserve capacity in a specific AZ for any duration

On Demand Instance

- Pay for what you use:
  - Linux or Windows - billing per second, after the first minute
  - All other operating systems - billing per hour
- Has the highest cost but no upfront payment
- No long-term commitment

- Recommended for **short-term** and **un-interrupted workloads**, where you can't predict how the application will behave

Reserved Instances

- Up to 72% discount compared to On-demand
- You reserve a specific instance attributes (Instance Type, Region, Tenancy, OS)
- Reservation Period – 1 year (+discount) or 3 years (+++discount)
- Payment Options – No Upfront (+), Partial Upfront (++), All Upfront (+++)
- Reserved Instance's Scope – Regional or Zonal (reserve capacity in an AZ)
- Recommended for steady-state usage applications (think database)
- You can buy and sell in the Reserved Instance Marketplace
- Convertible Reserved Instance
    - Can change the EC2 instance type, instance family, OS, scope and tenancy
    - Up to 66% discount

Savings Plans

- Get a discount based on long-term usage (up to 72% - same as RIs)
- Commit to a certain type of usage ($10/hour for 1 or 3 years)
- Usage beyond EC2 Savings Plans is billed at the On-Demand price
- Locked to a specific instance family & AWS region (e.g., M5 in us-east-1)
- Flexible across:
    - Instance Size (e.g., m5.xlarge, m5.2xlarge)
    - OS (e.g., Linux, Windows)
    - Tenancy (Host, Dedicated, Default)

Spot Instances

- Can get a discount of up to 90% compared to On-demand
- Instances that you can "lose" at any point of time if your max price is less than the current spot price
- The MOST cost-efficient instances in AWS
- Useful for workloads that are resilient to failure
    - Batch jobs
    - Data analysis
    - Image processing
    - Any distributed workloads
    - Workloads with a flexible start and end time
- Not suitable for critical jobs or databases

Dedicated Hosts

- A physical server with EC2 instance capacity fully dedicated to your use
- Allows you to address compliance requirements and use your existing server- bound software licenses (per-socket, per-core, pe—VM software licenses)
- Purchasing Options:
    - On-demand – pay per second for active Dedicated Host
    - Reserved - 1 or 3 years (No Upfront, Partial Upfront, All Upfront)
- The most expensive option
- Useful for software that have complicated licensing model (BYOL – Bring Your Own License)
- Or for companies that have strong regulatory or compliance needs

Dedicated Instances

- Instances run on hardware that's dedicated to you
- May share hardware with other instances in same account
- No control over instance placement (can move hardware after Stop / Start)

Capacity Reservations

- Reserve On-Demand instances capacity in a specific AZ for any duration
- You always have access to EC2 capacity when you need it
- No time commitment (create/cancel anytime), no billing discounts
- Combine with Regional Reserved Instances and Savings Plans to benefit from billing discounts
- You're charged at On-Demand rate whether you run instances or not
- Suitable for short-term, uninterrupted workloads that needs to be in a specific AZ

EC2 Instance Launch Types Comparison

Launch Type	Cost Structure	Payment Options	Commitment	Use Case	Flexibility
On-Demand Instances	- Linux/Windows: per second after the first minute - Other OS: billed per hour	No upfront payment	No long-term commitment	Short-term and unpredictable workloads	High flexibility; can start/stop anytime
Reserved Instances	Up to 72% discount compared to On-Demand	- No Upfront - Partial Upfront - All Upfront	1 year or 3 years	Steady-state applications (e.g., databases)	Reserved capacity in a specific region or AZ

Launch Type	Cost Structure	Payment Options	Commitment	Use Case	Flexibility
Savings Plans	Up to 72% discount based on long-term usage	Commit to a certain usage amount	1 year or 3 years	Applications with predictable usage patterns	Flexible across instance size, OS, and tenancy
Spot Instances	Discount up to 90% compared to On-Demand	Pay the Spot price	No commitment required	Cost-sensitive, resilient workloads (e.g., batch jobs)	Instances can be terminated anytime if spot price exceeds your max price
Dedicated Hosts	Most expensive; pay per second for active host	- On-Demand - Reserved (1 or 3 years)	Long-term commitment possible	Compliance-heavy applications or complex licensing models	Full control over server; ideal for BYOL scenarios
Dedicated Instances	Higher than shared instances; not the most expensive	On-Demand pricing	No long-term commitment	Workloads needing dedicated hardware but can share resources	Limited control over instance placement
Capacity Reservations	Billed at On-Demand rates regardless of instance running	No upfront payment	No time commitment	Ensures EC2 capacity availability in a specific AZ	Can create/cancel anytime; no discounts on billing

Which purchasing option is right for my use case?

- **On-Demand Instances**:
  - Staying at a resort whenever we want and paying the full price for each night.
  - Ideal for a startup running a web application with unpredictable traffic spikes.
- **Reserved Instances**:
  - Planning a long vacation in advance, allowing us to get a significant discount for booking ahead.
  - Best for a company operating a database server that requires constant uptime for a year.
- **Savings Plans**:
  - Committing to a set amount per hour for a specified duration while enjoying any room type
  - Suitable for a SaaS provider that anticipates steady usage of compute resources over three years.
- **Spot Instances**:
  - Bidding for available rooms; the highest bidder secures the room, but they can be asked to leave at any moment.

    - Perfect for a research team processing large data sets where jobs can be paused and resumed.
- **Dedicated Hosts**:
    - Renting an entire wing of the resort exclusively for ourselves.
    - Appropriate for a financial institution needing to comply with strict regulatory requirements and using custom software licenses.
- **Dedicated Instances**:
    - Having a private room that's solely ours but sharing some amenities with other guests.
    - Great for a business running non-critical applications that need some level of hardware isolation.
- **Capacity Reservations**:
    - Booking a room for a set period at full price, even if we don’t end up using it.
    - Useful for an enterprise ensuring EC2 capacity for a new product launch in a specific availability zone.

Price Comparison Example – m4.large – us-east-1

Launch Type	Hourly Price	Monthly Price (Approx.)	Notes
On-Demand Instance	$0.096 per hour	$69.12	Pay-as-you-go pricing. Ideal for short-term usage.
Reserved Instances	$0.054 per hour (1-year term)	$39.24	Commit to one year for a significant discount.
Savings Plans	$0.058 per hour (1-year term)	$41.76	Flexible savings plan applicable to any instance type.
Spot Instances	$0.028 per hour (varies with demand)	$20.16	Pricing varies; can be interrupted. Best for flexible workloads.
Dedicated Hosts	$0.12 per hour (per host)	$86.40	Dedicated physical server; pricing per host.
Dedicated Instances	$0.096 per hour	$69.12	Similar to on-demand but on dedicated hardware.
Capacity Reservations	$0.096 per hour	$69.12	Reserved capacity at on-demand pricing.

Shared Responsibility Model for EC2

Responsibility	AWS Responsibilities	User Responsibilities
Infrastructure Security	The security of the underlying infrastructure, including hardware, software, networking, and facilities.	Securing the EC2 instances, including operating systems and applications.
Physical Security	Ensures physical security of data centers where EC2 instances run.	N/A

Responsibility	AWS Responsibilities	User Responsibilities
Network Security	Implements security measures for the network, including firewalls and DDoS protection.	Configuring security groups, network ACLs, and VPC settings.
Data Protection	Provides encryption options for data at rest and in transit.	Managing data encryption and access control.
Access Management	Offers IAM services to manage access to AWS resources.	Configuring IAM users, roles, and policies for access management.
Compliance	Complies with various compliance standards and certifications for infrastructure.	Compliance related to the applications and data hosted on EC2 instances.
Patch Management	Provides a secure and up-to-date infrastructure.	Applying patches and updates to the operating system and applications.

EC2 Section – Summary

- EC2 Instance: AMI (OS) + Instance Size (CPU + RAM) + Storage + security groups + EC2 User Data
- Security Groups: Firewall attached to the EC2 instance
- EC2 User Data: Script launched at the first start of an instance
- SSH: start a terminal into our EC2 Instances (port 22)
- EC2 Instance Role: link to IAM roles
- Purchasing Options: On-Demand, Spot, Reserved (Standard + Convertible + Scheduled), Dedicated Host, Dedicated Instance