AWS EC2 & IAM

CS516 – Cloud Computing

Computer Science Department

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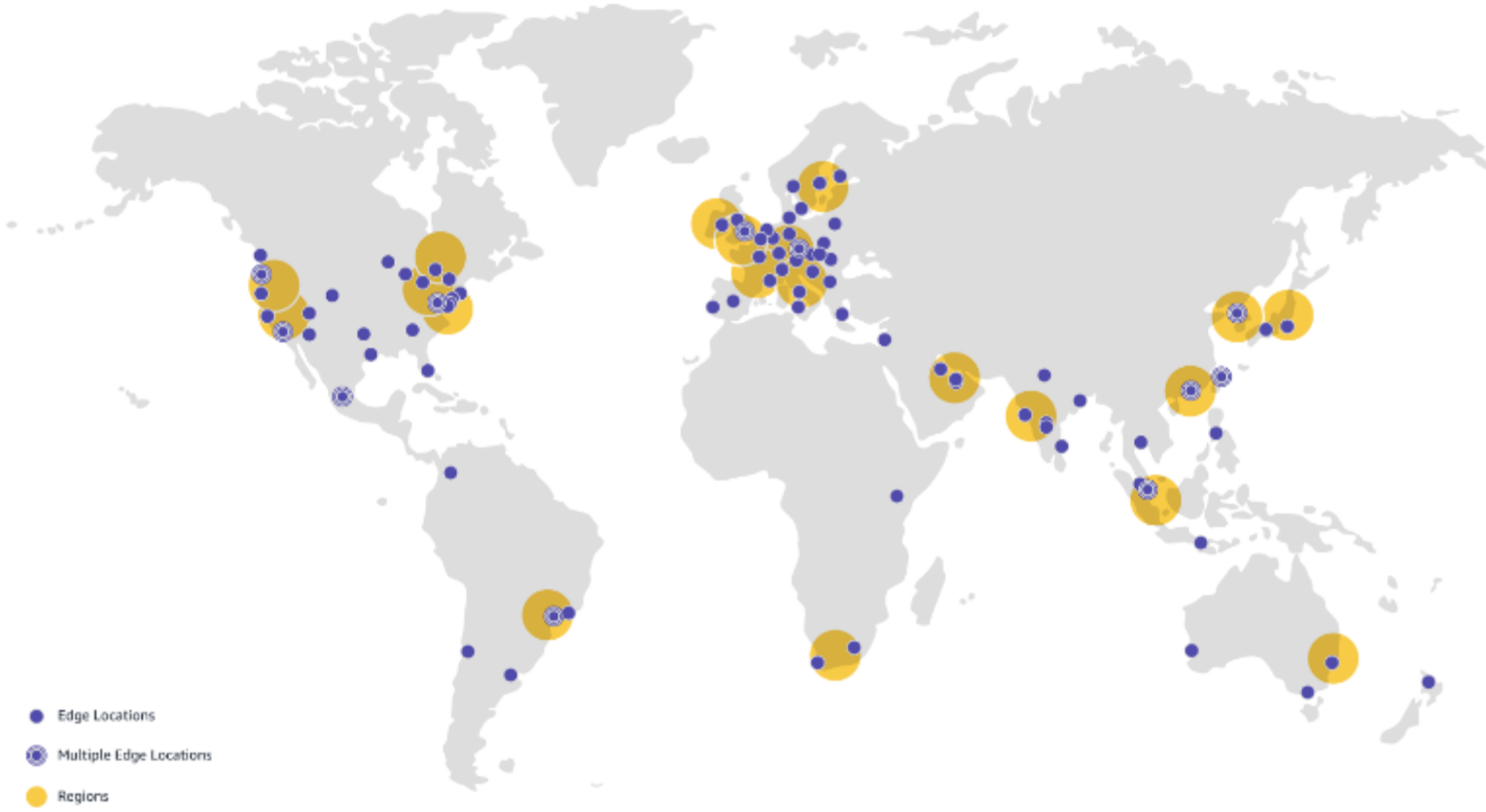
Main points

- The big picture – High level architecture of the AWS Cloud. Concepts include
  - Physical – AZs, edge servers
  - Logical – regions, VPC, subnets, and IP addresses.
- Virtual machine (EC2) – Its components such as AMI, EBS, Snapshots, SG.
- Identity access management (IAM) – users, roles, permissions, and STS assume role.

AWS Global Infrastructure Map

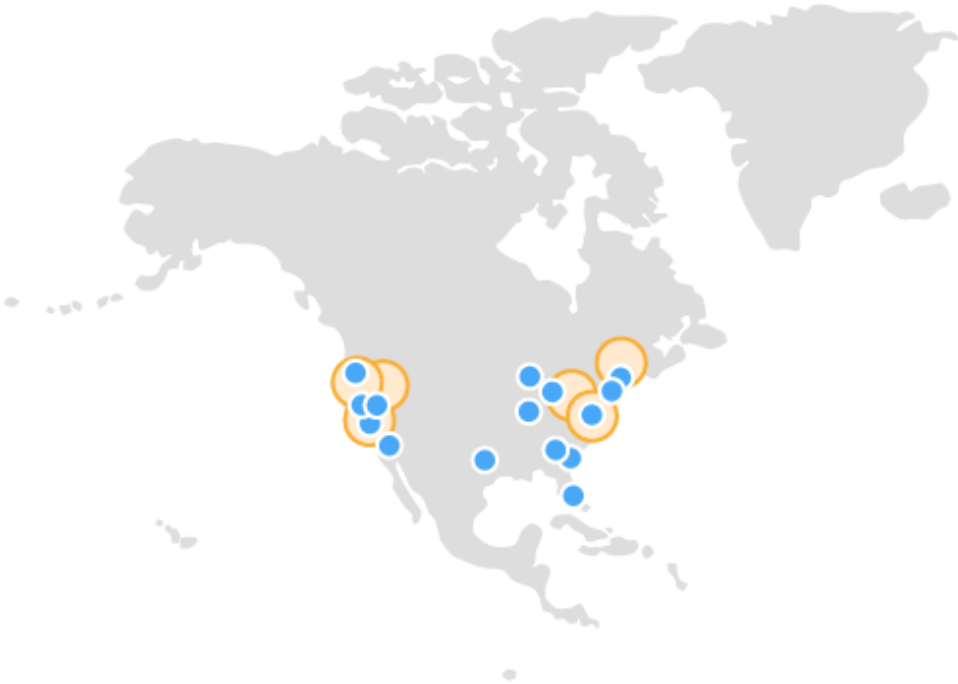


Read more about: AWS Global Infrastructure and AWS Global Accelerator features

AWS Global Infrastructure

Regions (Logical) - A physical location around the world where AWS ***clusters*** data centers. Usually comprised of multiple data centers.

Availability Zones (Physical) - Geographical isolated data centers within a region.



Regions

- Followings vary depending on the region.
  - Service and service feature availability – Check out AWS announcement page to see what services and features are newly added in that region.
  - Limit – See next slide
  - Pricing – The same servers in the US region tent to cost less than the ones in Asia.
- Most services are regional. To build and deploy a global app, you have to deploy the same stack to every region. Most companies target 3 regions in 3 different continents.
- If the region goes down, all apps in that region are down as well. So, architects consider a multi-regional deployment strategy.

Read More about: Regions and Zones

Regions	Transactions per second
•US East (N. Virginia) – The biggest. Global resources live in this region. •US West (Oregon) •Europe (Ireland) – One of 2 major regions in the EU	PutEvents has a soft limit of 10,000 requests per second by default in these Regions.
•US East (Ohio) •Europe (Frankfurt) – One of 2 major regions in the EU	PutEvents has a soft limit of 2,400 requests per second by default in these Regions.
Asia Pacific (Tokyo) – One of 2 major regions in Asia •Asia Pacific (Singapore) – One of 2 major regions in Asia •US West (N. California) •Europe (London) •Asia Pacific (Sydney)	PutEvents has a soft limit of 1,200 requests per second by default in these Regions.
•Canada (Central) •Europe (Paris) •South America (São Paulo) •Asia Pacific (Seoul) •Asia Pacific (Mumbai) •Asia Pacific (Hong Kong) – Not even a region. Most services are not available.	PutEvents has a soft limit of 600 requests per second by default in these Regions.
•AWS GovCloud (US-West) •China (Beijing) •Asia Pacific (Osaka) •Africa (Cape Town)	PutEvents has a soft limit of 400 requests per second by default in these Regions.

AWS Region/AZ

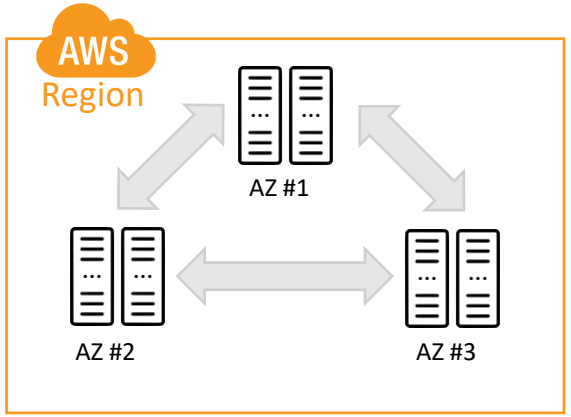
Each Region has multiple, isolated locations known as *Availability Zones*.

Availability Zones provide redundancy for AWS resources in that region, highly available, fault tolerant, and more scalability. AZs have low latency, high-bandwidth network connection, and support near real-time replication between AZs. All traffic is encrypted.

High Availability is creating an architecture in such a way that the system is always available or has the least amount of downtime as possible. If the app is running on 2 or more AZs, it means the app is highly available. Availability is normally expressed in 9's.

- 5 nines uptime means only 5 min downtown is allowed a year
- 4 nines uptime means less than an hour downtown is allowed a year

Fault Tolerant is the ability of your system to withstand failures in one or more of its components and still remain available. Asynchrony and decoupling using SQS increase fault tolerance.

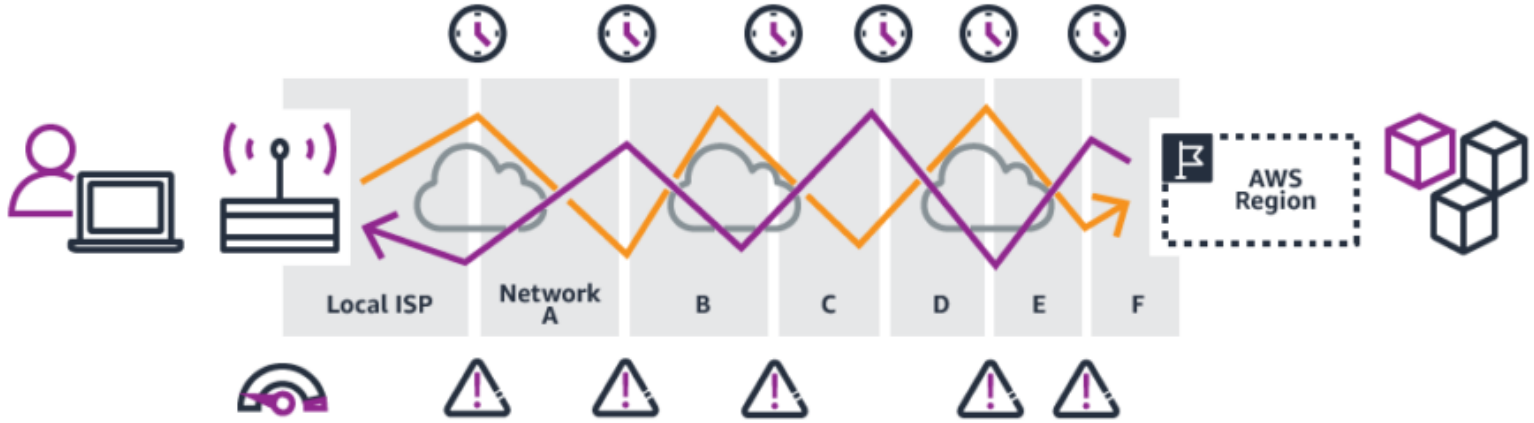


Edge servers

AWS has servers in 247+ countries. Those servers are not many in that area to form an AZ or a region. Those servers are called **edge servers**. Edge servers play the following roles:

- AWS Global Accelerator takes advantage of edge servers and routes requests efficiently in the AWS network without bouncing on the internet.
- CloudFront caches your static contents all over the world on edge servers.
- You can run small code on Lambda@Edge which is a feature of CloudFront.

AWS Global Accelerator is a networking service that improves the availability and performance of the applications that you offer to your global users. (Source: aws.amazon.com) Before:



After:

AWS Accelerator is taking advantage of edge servers to improve performance.
[Building a global app with AWS Global Accelerator]

VPC

Virtual Private Cloud (VPC)

VPC is an isolated virtual network where non-public AWS resources run. You have complete control over your networking such as the selection of your own local **IP** address range, the creation of **subnets**, and other networking components. Local IP address is a reusable IPv4 in the local home, company, on-premise, and cloud network such as 192.168.0.1, 10.0.0.0, etc.

In other words, VPC is simply how you manage networking in the cloud. VPC is not that hard. It is very similar to traditional networking. One who has networking experience can learn VPC easily. VPC is mostly managed by a networking guy or the DevOps team. You just need to know what it is as a software developer. This is known is “T-shaped” team.

There are 2 types of AWS resources:

1. Public – It is just like a third-party API that you can call directly such as S3, DynamoDB, SNS, SQS, and so on (FaaS services). If valid authorization tokens are present, the API call is a success.
2. Non-public – You must launch those resources in VPC so that it gets an IP address so others can connect to it. It includes EC2, RDS, Load Balancers, and so on (IaaS and PaaS services).

Subnets

A subnet is a sub-section of a network. Generally, it includes all the computers in a specific location like zip code for addressing houses.

A VPC includes many subnets. A subnet is associated with an AZ.

There are 2 types of subnets:

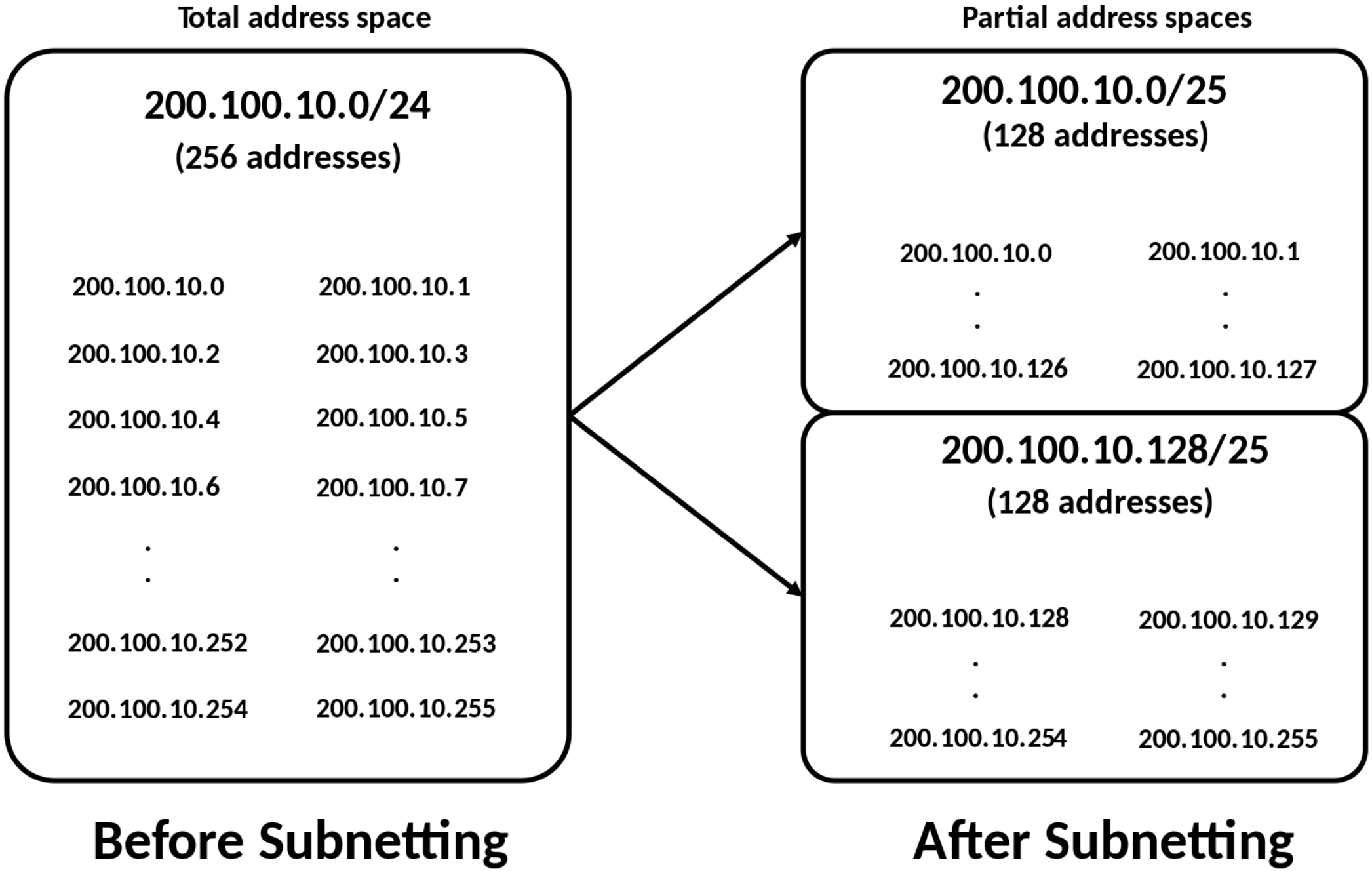
- Anyone can access to resources in **public** subnet directly from the internet.
- A **private** subnet is a safe environment where you can run back-end servers and databases securely. The internet (outsiders) cannot directly access resources in private subnet. The only way to access private resources is through the other resource in the public subnet. All resources in VPC talk to one another using private IPs even if they all have public IPs.

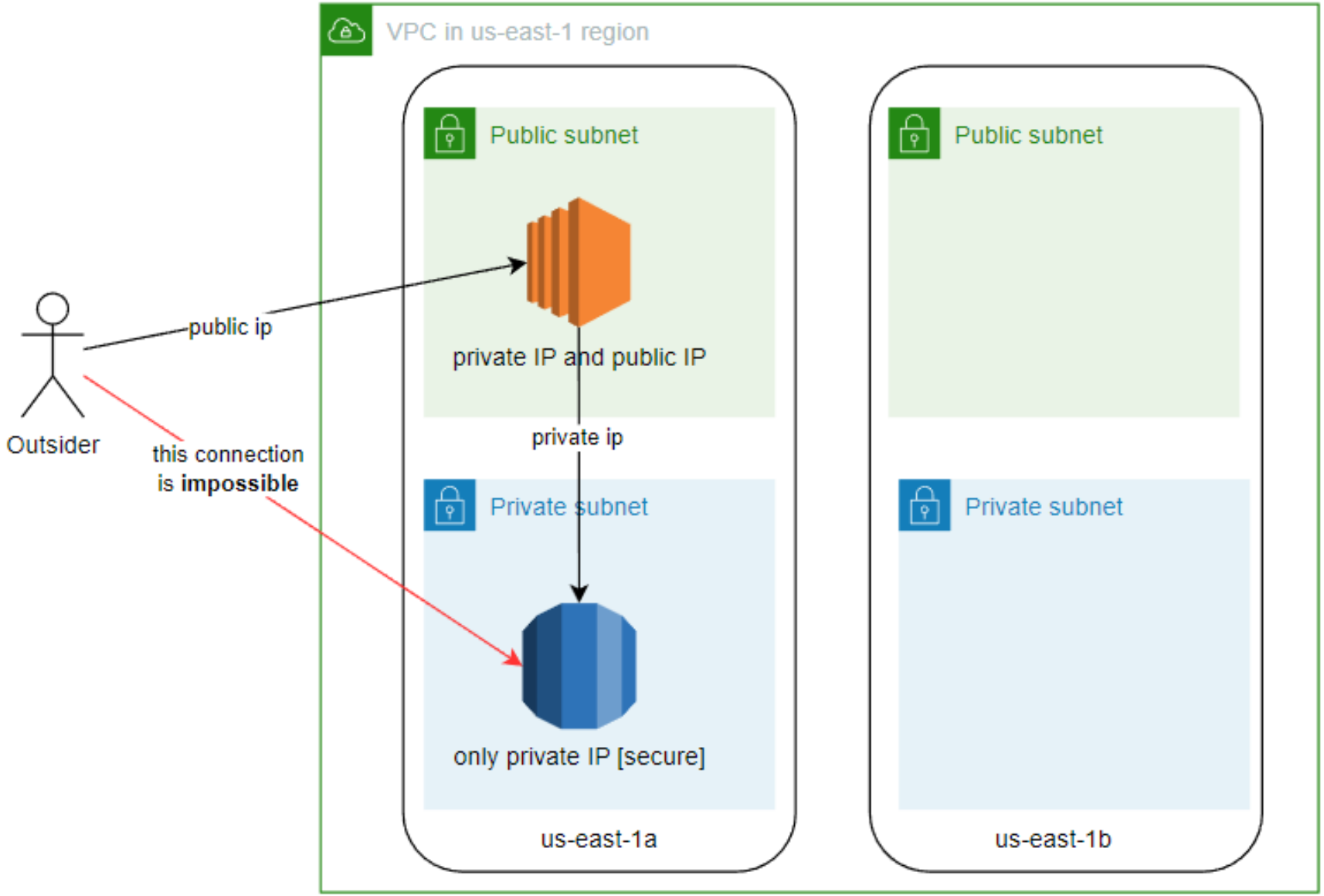
Subnets are written in CIDR format.

Read more about Subnets

CIDR ranges for the private network

CIDR	Starting and ending IPs	Total number of hosts
10.0.0.0/8	10.0.0.0 – 10.255.255.255	16,777,216
172.16.0.0/12	172.16.0.0 – 172.31.255.255	1,048,576
192.168.0.0/16	192.168.0.0 – 192.168.255.255	65,536


Total address space
200.100.10.0/24
(256 addresses)
200.100.10.0
200.100.10.1
200.100.10.2
200.100.10.3
200.100.10.4
200.100.10.5
200.100.10.6
200.100.10.7
200.100.10.252
200.100.10.253
200.100.10.254
200.100.10.255
Partial address spaces
200.100.10.0/25
(128 addresses)
200.100.10.0
200.100.10.1
200.100.10.126
200.100.10.127
200.100.10.128/25
(128 addresses)
200.100.10.128
200.100.10.129
200.100.10.254
200.100.10.255
Before Subnetting
After Subnetting


VPC in us-east-1 region
Public subnet
Public subnet
private IP and public IP
public ip
Outsider
this connection
is impossible
private ip
Private subnet
Private subnet
only private IP [secure]
us-east-1a
us-east-1b

VPC Security Layers

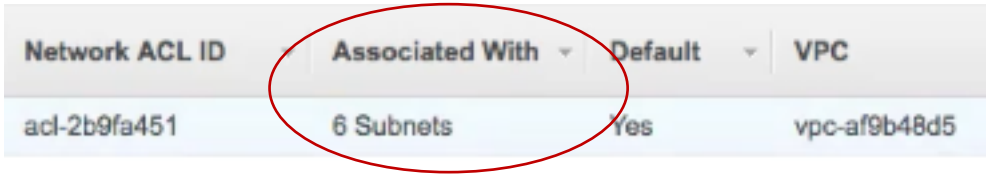
The VPC has 2 layers of security:

- Security Groups (SG) is a firewall on a resource level.
- Network Access Control Lists (NACL) is a firewall on a subnet layer. In one subnet, there are many resources.

To access your resource in the VPC, you must allow access on both layers. People don’t normally touch the NACL whereas the SG is the most important concept like IAM that developers work daily basis. If the resource is not responding, most likely, it is an issue with your SG that doesn’t allow incoming access.

Network Access Control Lists - NACL

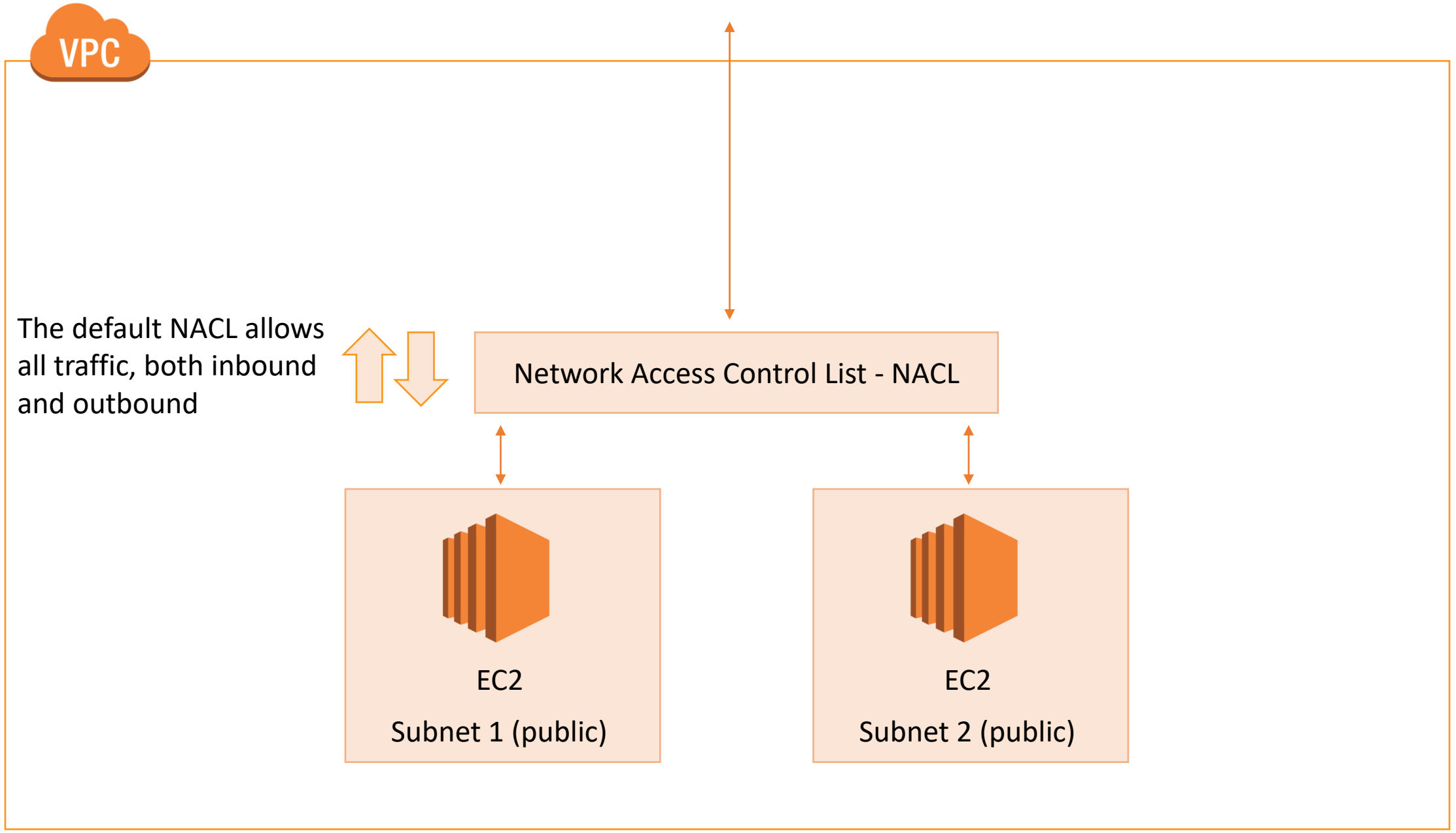
NACL acts as a firewall for controlling traffic in and out of one or more subnets. Your default VPC already has an NACL in place and is associated with all default subnets.



Network ACL ID	Associated With	Default	VPC
acl-2b9fa451	6 Subnets	Yes	vpc-af9b48d5

To access an EC2 instance from the internet, the request must pass the NACL security layer. If there is a rule that denies the request on the way, you cannot access the instance. Once it passed the NACL layer, then the request also has to pass Security Groups (SG) layer associated with the instance.

Read more about Network ACLs


VPC
The default NACL allows all traffic, both inbound and outbound
Network Access Control List - NACL
EC2
Subnet 1 (public)
EC2
Subnet 2 (public)

NACL Rules

- The default NACL allows all traffic to the default subnets.
- Rules are evaluated from lowest to highest based on rule #. The first rule found that applies to the traffic type is immediately applied, regardless of any rules that come after it.
- The NACL allows or denies traffic from entering a subnet. Once inside the subnet, other AWS resources may have additional security layers (security groups).

Inbound

Rule #	Type	Protocol	Port Range	Source	Allow / Deny
100	ALL Traffic	ALL	ALL	0.0.0.0/0	ALLOW
*	ALL Traffic	ALL	ALL	0.0.0.0/0	DENY

All traffic is allowed

Inbound

Rule #	Type	Protocol	Port Range	Source	Allow / Deny
90	SSH (22)	TCP (6)	22	0.0.0.0/0	DENY
100	SSH (22)	TCP (6)	22	0.0.0.0/0	ALLOW
*	ALL Traffic	ALL	ALL	0.0.0.0/0	DENY

All traffic is denied

Only Allow HTTP

Inbound

Rule #	Type	Protocol	Port Range	Source	Allow / Deny
100	HTTP (80)	TCP (6)	80	0.0.0.0/0	ALLOW
*	ALL Traffic	ALL	ALL	0.0.0.0/0	DENY

Deny everything and only allow HTTP

Outbound

Rule #	Type	Protocol	Port Range	Destination	Allow / Den
100	HTTP (80)	TCP (6)	1024-65535	0.0.0.0/0	ALLOW
*	ALL Traffic	ALL	ALL	0.0.0.0/0	DENY

Allow HTTP response

Notes

- The outbound traffic will use ephemeral ports 1024-65535 for the return web traffic and not port 80. Because the client computer is receiving the response on one of these ephemeral ports.
- An ephemeral port is a short-lived transport protocol port for Internet Protocol (IP) communications.

Security Groups (SG)

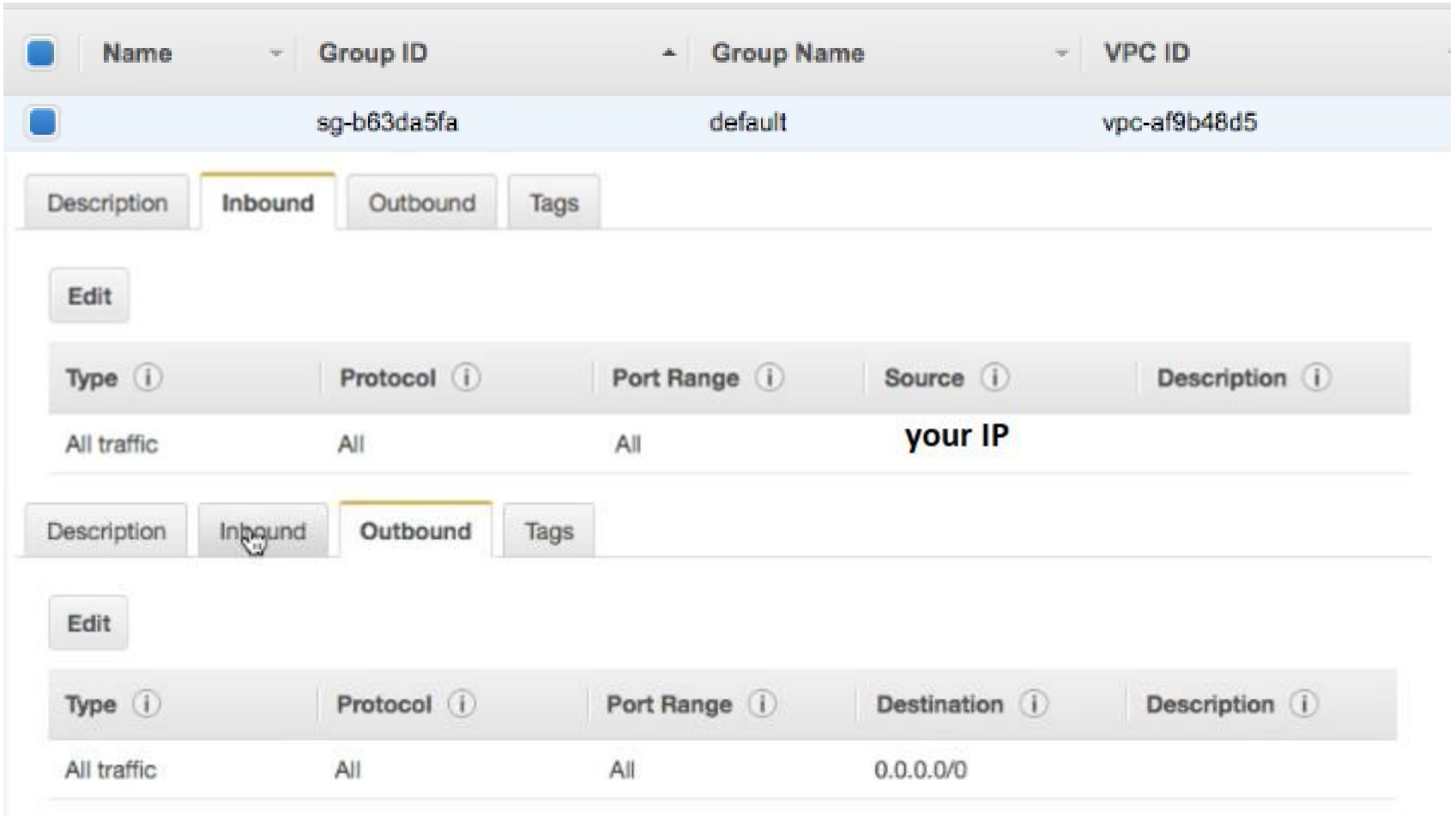
Security groups are found on the **instance level**. They act as a **virtual firewall** that controls the traffic for one or more instances.

You add rules to security groups to **allow traffic** to (or from) its associated resource. By default, there is no inbound, which means everything is denied. You cannot write a deny rule like the NACL.

You can attach multiple SGs to an instance. All the rules from the security groups that are associated with the instance are evaluated.

Read more: Security Groups

Inbound/Outbound Rules



NACL

Inbound Outbound

Security Group

EC2 Instance

NACL	Security Group
NACL can be understood as the firewall or protection for the **subnet**.	Security group can be understood as a firewall to protect EC2 **instances**.
These are **stateless**, meaning any change applied to an incoming rule isn't automatically applied to an outgoing rule. Example: If a request comes through port 80, it should be explicitly indicated that its outgoing response would be the same port 80.	These are **stateful**, which means any changes which are applied to an incoming rule is automatically applied to a rule which is outgoing. Example: If the incoming port of a request is 80, the outgoing response of that request is also 80 (it is opened automatically) by default.
NACL supports **allow** and **deny** rules. Denial of rules can be explicitly mentioned, so that when the layer sees a specific IP address, it blocks connecting to it.	SG supports **only allow rules**, and the default behavior is denial of all.
In case of NACL, the rules are applied in the order of their priority, wherein priority is indicated by the number the rule is assigned. This means every rule is evaluated based on the priority it has.	In case of a security group, all the rules are applied to an instance.

EC2

AWS Elastic Cloud Compute (EC2)

EC2 is a web service that provides resizable compute capacity in the cloud. It is designed to make web-scale cloud computing easier for developers.

Basically, a virtual computer, very similar to the desktop or laptop you use at home, and commonly referred to as an **instance**.

You can use Amazon EC2 to launch as many or as few virtual servers as you need, configure security and networking, and manage storage.

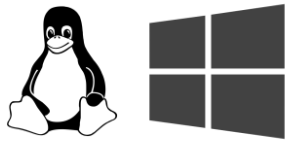
Amazon EC2 autoscaling enables you to scale in or out to handle changes in requirements or spikes in popularity, reducing your need to forecast traffic.

Read more: Amazon EC2

Computer and EC2 Instance

Computer

EC2 Instance

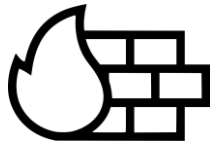


Operating System
AMIs
(Linux or Windows)

CPU & RAM
Instance Type

Hard Drive
EBS

Network Adapter
ENI



Firewall
Security Groups

Amazon Machine Image - AMI

Preconfigured and required to launch an EC2 instance that includes an operating system, software packages, and other required settings.

Amazon Machine Image (AMI) provides the information required to launch an instance. You specify an AMI when you launch an instance.

In class, I have limited time to demonstrate all components of EC2. You can practice all at home if you are dedicated. Always highly encourage you to play with the AWS console, read descriptions and experiment with all the things you see on the AWS EC2 console. Similarly, be bold and play with all services. You have a free account.

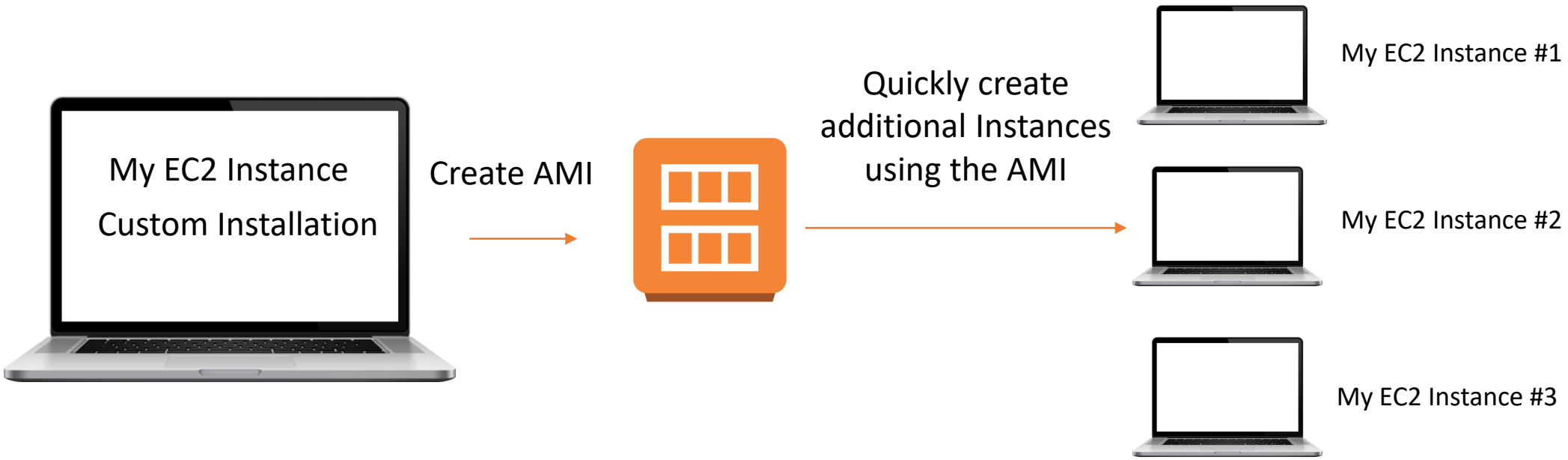
Read more: AMI

Custom AMI

Assume that you need to run your app in hundreds of servers. It is not possible to configure every single server one by one. Instead, you can create a custom AMI and use it on as many servers as you want.

Custom AMIs contain all configurations, dependencies, and environments required to run your app.

Understanding AMI



Instance Types

The Instance Type determines the underlying hardware such as CPU, GPU, RAM, network and disk read/write capacity.

Each instance type offers different compute, memory, and storage, graphic capabilities and is grouped into instance families based on these capabilities.

NVIDIA instances have a GPU (accelerated computing) that works best for ML since a GPU provides high parallel and simultaneous computing.

The same service price varies depending on the region. For example, the same instance in the USA costs higher than the one in Japan.

With EC2 (IaaS), you have more control such as dictating the underlying hardware. Whereas in Lambda (FaaS) and ECS (Container as a Service), you can not control it.

Read more: Instance Types

General-purpose and memory-optimized instance type

General-purpose instances provide a balance of compute, memory, and networking resources. It can be used for web servers and code repositories. General-purpose instance types start with **T** and **M**.

Memory-optimized instances are good for applications that process large amounts of data in memory such as caching. Memory-optimized instance types start with **R** and **X**.

Compute-optimized instance type

Compute-optimized instances are ideal for compute-bound applications that benefit from high-performance processors. It is good for batch processing workloads, media transcoding, high-performance web servers, high-performance computing (**HPC**), scientific modeling, dedicated gaming servers, ad server engines, machine learning inference, and other compute-intensive applications. Compute-optimized instance types start with **C**.

Accelerated computing instance type

Accelerated computing instances use hardware accelerators (GPUs) or co-processors to perform functions such as floating point number calculations, graphics processing, or data pattern matching.

Both accelerated computing and compute-optimized instance types provide high computing power. But the way how they provide the computing power is different. Accelerated computing instances have GPUs which are accelerators whereas the compute-optimized ones have good high-performance processors. Accelerated computing instance types start with **P** and **G**.

Storage-optimized instance type

Storage-optimized instances are designed for workloads that require high, sequential read and write access to very large data sets on local storage. They are optimized to deliver tens of thousands of low-latency, random I/O operations per second (IOPS) to applications. Storage-optimized instance types start with **I** and **D**.

Do not configure EC2 as a database! Instead, use Relation Database Service which provides instance types designated for databases.

Elastic Block Storage - EBS

EBS is a storage volume for an EC2 instance. It provides block level storage volumes for use with EC2 instances.

EBS volumes are **highly available and reliable** storage volumes that can be attached to any running instance that is **in the same Availability Zone**

=

EBS volumes that are attached to an EC2 instance are exposed as storage volumes that persist **independently** from the life of the instance. It charges independently.

Read more: [Amazon EBS Volumes]

Input/Output Operations Per Second - IOPS

IOPS is the amount of data that can be written to or retrieved from EBS per second.

The operations are measured in KiB, and the underlying drive technology determines the maximum amount of data that a volume type counts as a single IO.

More IOPS means better volume performance (faster R/W speeds).

More expensive. Recommended for production environment.

Types of EBS volumes

- **Provisioned IOPS** – The fastest and most expensive where you can specify IOPS. Good for production servers.
- **General Purpose** – It provides a moderate amount of speed. You can not specify IOPS. The IOPS depends on the volume size. Good for development environment servers.
- **HDD and Magnetic** – The cheapest option and slow. It is good when storing large amounts of data and archiving and you don’t need much performance.

Create Additional Volume

Amazon Elastic File System (Amazon EFS)

It is an elastic file system that lets you share file data without provisioning or managing storage.

Amazon EFS is designed to provide massively parallel **shared** access to thousands of Amazon EC2 instances.

Amazon EFS is well suited to support a broad spectrum of use cases from home directories to business-critical applications.

You need to set an Security Group that allows access from a fleet of EC2 instances on the EFS volume.

Read more: Amazon EFS

Block vs File vs Object storages

File storage stores data as a single piece of information **in a folder** to help organize it among other data. Our laptops.

Block storage takes a file apart **into singular blocks** of data and then stores these blocks as separate pieces of data. Complex but fast. Used in servers.

Object storage **is a flat structure** in which files are spread out among hardware. Unlimited scaling. The cloud.

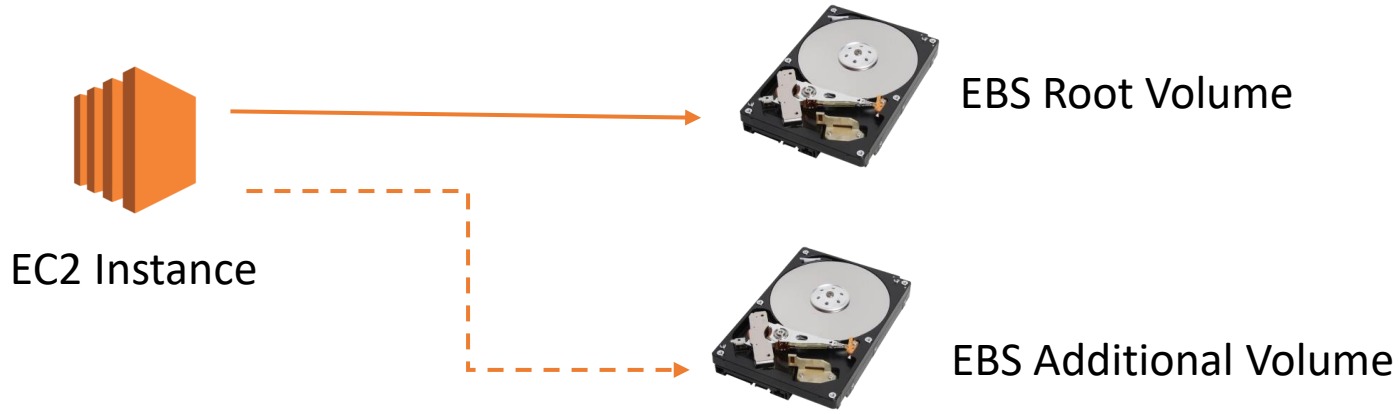
Read more: File storage, block storage, or object storage?

Root vs. Additional EBS Volumes

Every EC2 instance must have a **root volume** that the AMI is restored.

You can add **additional EBS Volumes** to an instance at any time. Any additional volume can be attached or detached from the instance at any time.

Additional EBS volumes are NOT deleted (the default) and you still pay when the instance is terminated whereas the root volume gets deleted when the instance is terminated.

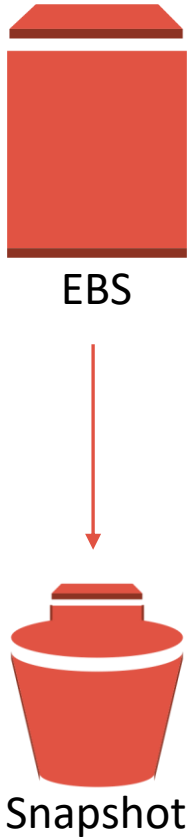


Snapshots

A snapshot is an **image** of an EBS volume that can be stored as an **incremental backup** of the volume or used to create a duplicate.

A snapshot is not an active EBS volume. You cannot attach or detach a snapshot to an EC2 instance.

To restore a snapshot, you need to create a new EBS volume using the snapshot as its template.



AMI vs Snapshots

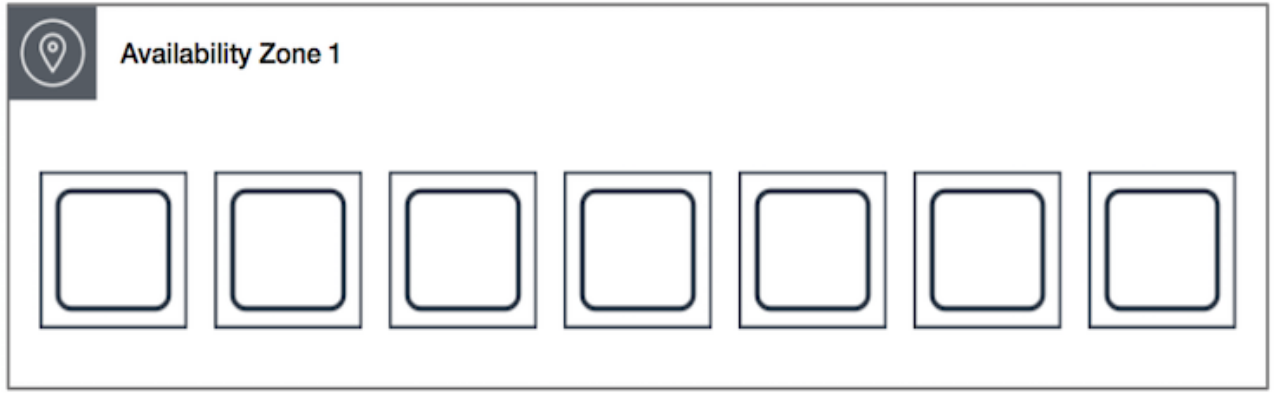
AMI	**EBS Snapshot**
An entire EC2 instance definition that includes all EBS snapshots plus some metadata like kernel, AMI name, description, block device mappings, and more.	Backup of a single volume.
Could be used to deploy your applications on different machines easily.	You need to recover and mount a snapshot to an EC2 instance.

Placement groups

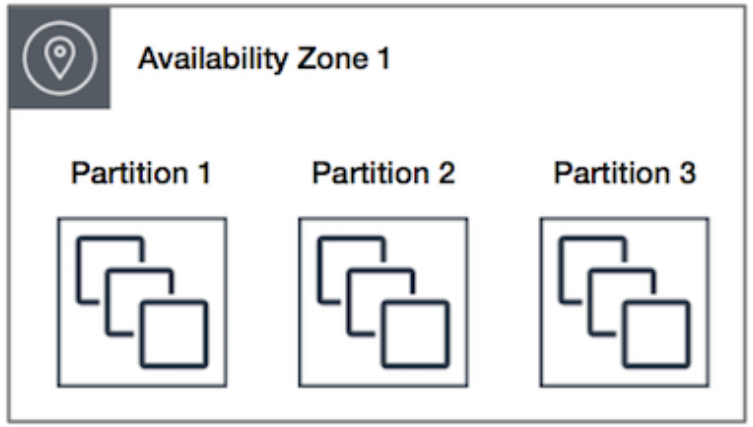
A placement group is a logical grouping of instances within a single AZ that benefit from low network latency and high network throughput.

Cluster – Packs instances close together. *Low latency and high performance*.
Partition – Spreads instances across logical partitions. Partitions don't share the underlying hardware. Large distributed and replicated workloads such as Hadoop, Cassandra, and Kafka.
Spread – Places a small group of instances across distinct underlying hardware to *reduce correlated failure.*

Spread



Cluster



Partition

IP Addressing

An IP address is the EC2 instance address on the network.

Private IP Address:

EC2 instance receives the private IP from the subnet.

All EC2 instances (all devices in the network) have a private IP address.

Private IP addresses allow instances to communicate with resources in the same network.

Public IP address:

All EC2 Instances can be launched with or without a public IP address.

Public IP addresses are required for the instance to communicate with the Internet.

Read more: IP Addressing

Elastic IP

Elastic IP is static public IP.

When you stop and then start an EC2 instance, it may change its public IP. If you need to have a fixed public IP for your instance, you need an Elastic IP.

- An Elastic IP is a public IPv4 IP you own.
- You can attach it to one instance at a time.
- By default, you can have 5 elastic IPs in AWS.
- It charges when you are NOT using it. When used, it is free.

EC2 Instance Options - On-Demand

On-demand purchasing allows you to choose any instance type you like and provision/terminate it at any time (on-demand).

The most expensive purchasing option.

You are only charged when it is running (billed by the hour).

Read more: EC2 pricing

EC2 Instance Options - Reserved

Reserved purchasing allows you to purchase an instance for a set time period of 1 or 3 years.

This allows for a significant price discount over using on-demand.

You can select to pay upfront, partial upfront, or no upfront.

Once you buy a reserved instance, you own it for the selected time period and are responsible for the entire price - regardless of how often you use it.

About 20% savings with a one-year term and 30% savings with a three-year term.

EC2 Instance Options - Spot

Cheapest but not reliable.

Amazon sells unused instances for short amounts of time at a substantial discount.

Spot pricing is a way for you to bid on an instance type, then only pay for and use that instance when the spot price is equal to or below your bid price. Spot prices fluctuate based on supply and demand.

A provisioned instance automatically terminates when the spot price is greater than your bid price.

You can use Spot instances along with other types of instances in your cluster or a fleet of servers for a fault-tolerant application. So, you save a lot.

IAM

IAM

IAM Policies are **permissions** that you can assigned to any User (Person), Group (Person), and Roles (Service).

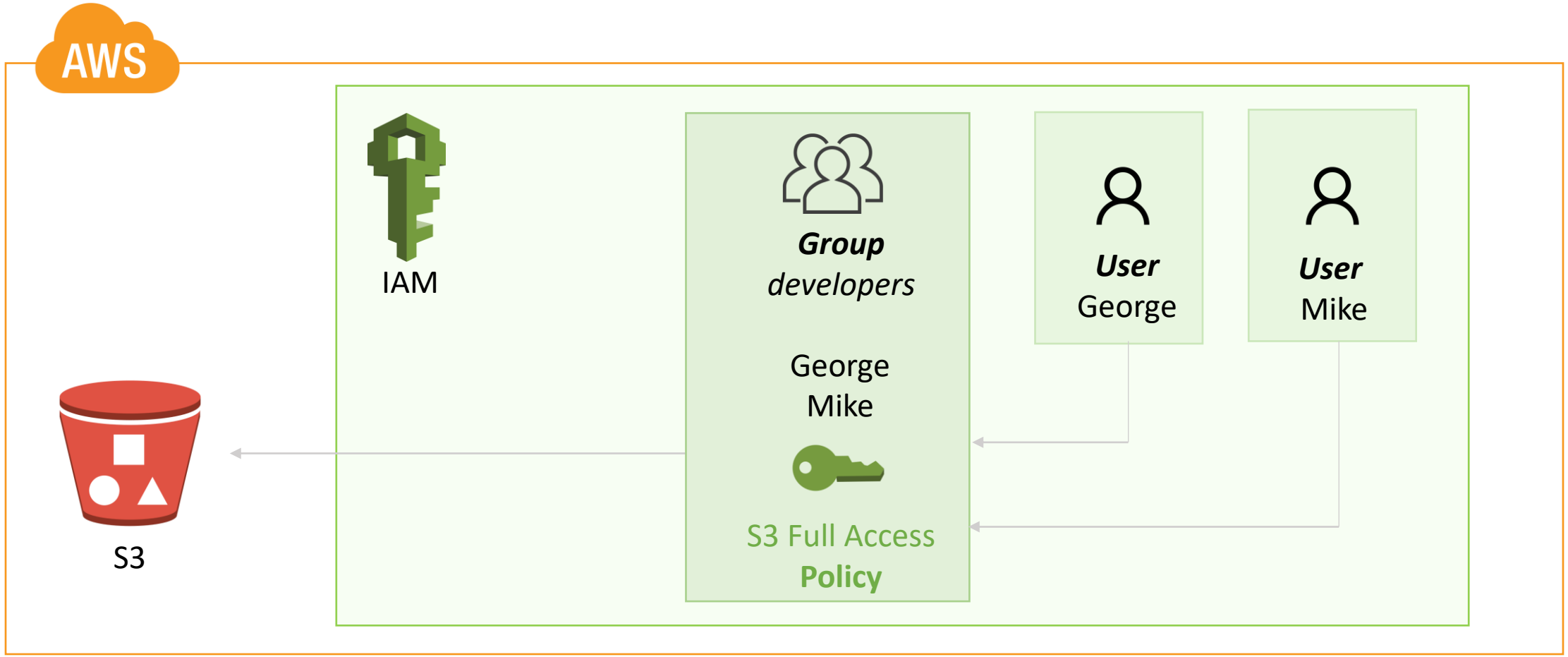
We don't attach an IAM Policy to a Service directly, instead, we would need to use a **Role**. Inside the role, we define IAM policies and associate that role with the resources (service).

There are 2 types of IAM policies:

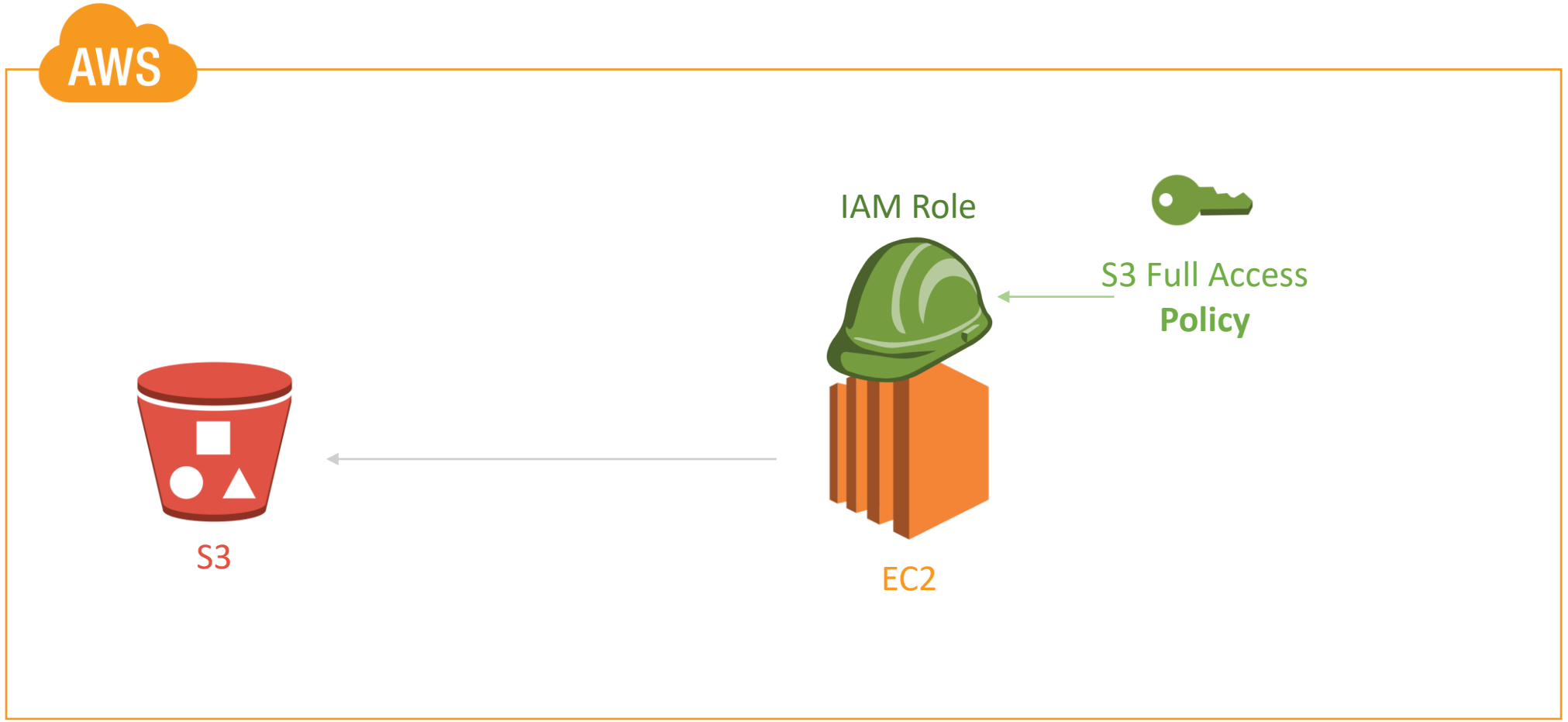
- **AWS managed** - It is fine for POC. You shouldn’t use it. The best practice is to write your own user-managed policies.
- **User managed** - recommended, always used in real life or production.

Read More about: IAM Policies

AWS IAM Group



AWS IAM Role

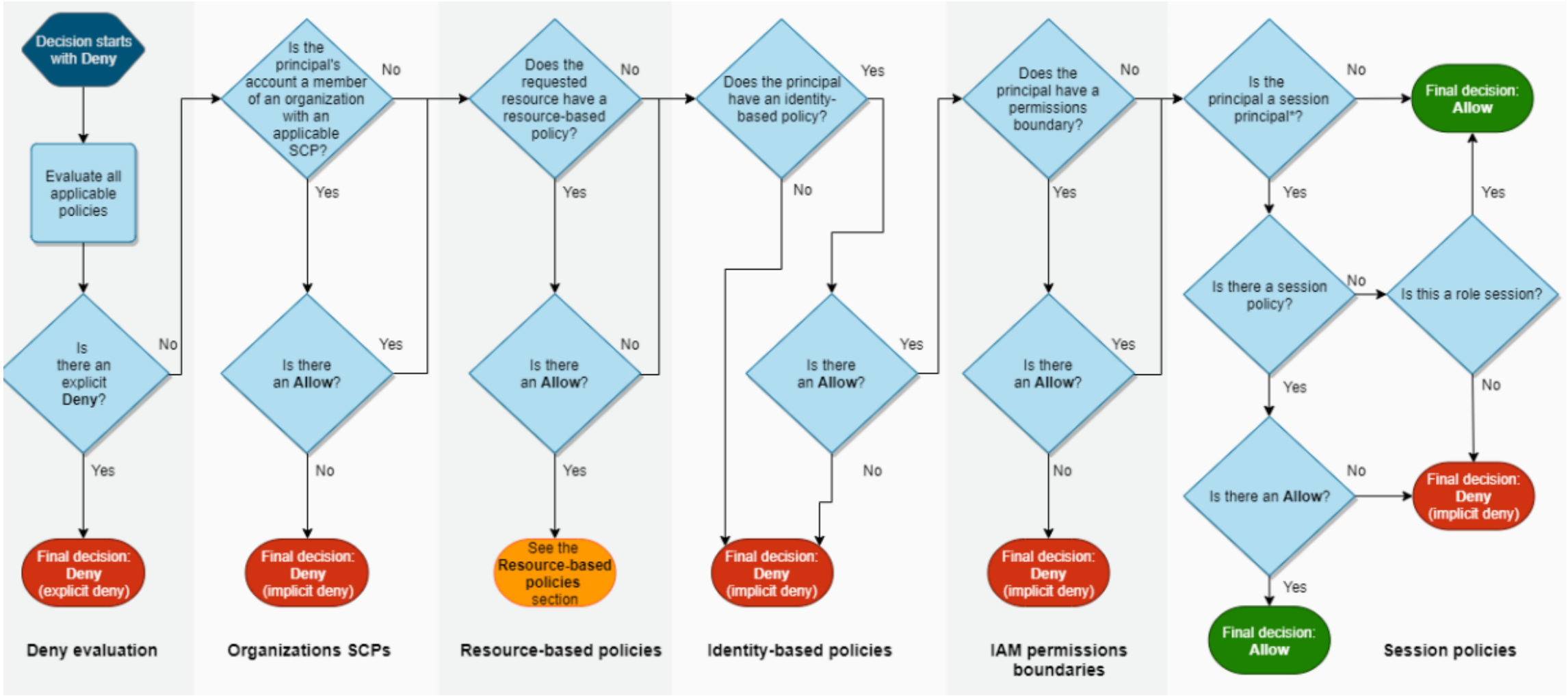


Two ways to allow/deny access in IAM

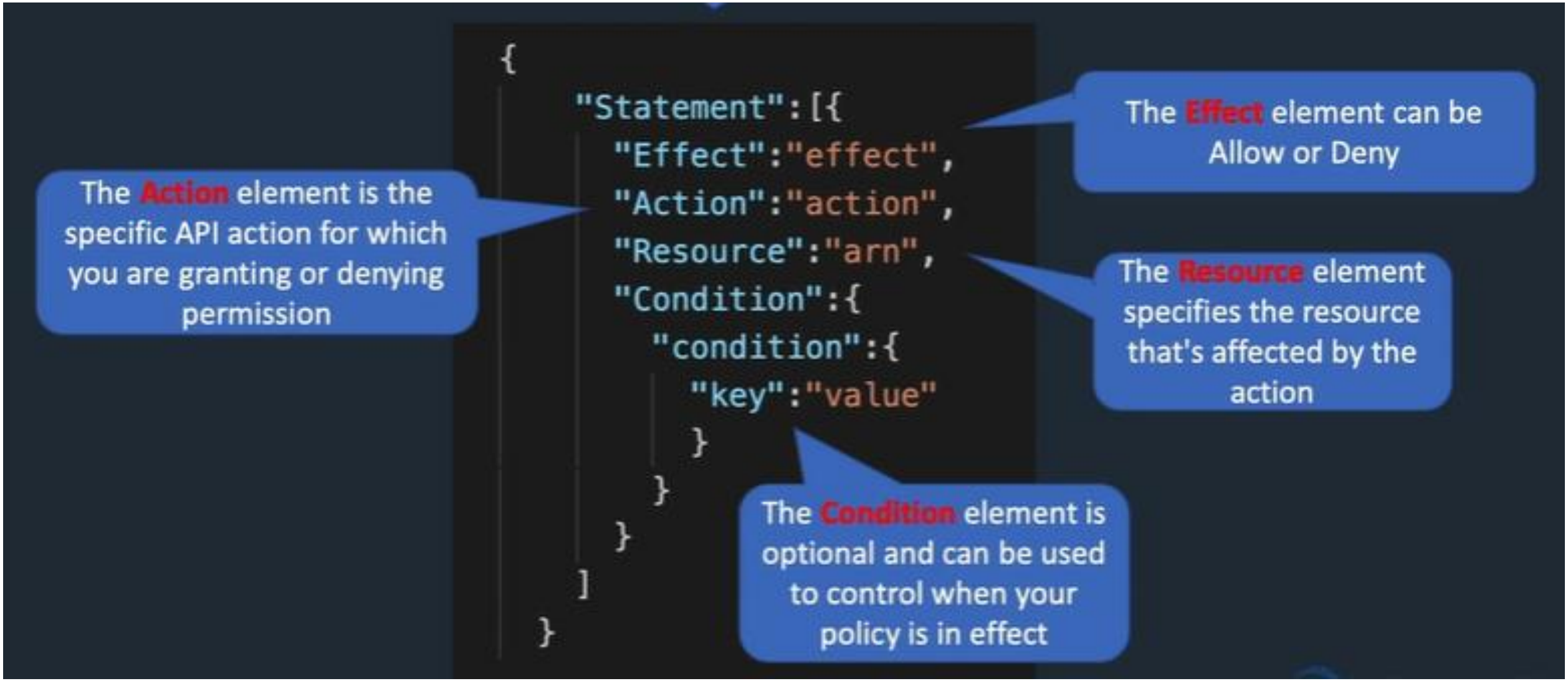
1. **Identity-based** policies – Attach policies to IAM identities (users, groups, or roles) as we talked about in the previous 3 slides.
2. **Resource-based** policies – Attach inline policies to resources (such as S3, SQS, SNS) directly. Resource-based policies have a **principal** tag that defines who can the actions defined.

Which one will win if there are identity and resource-based policies, one of them allows and the other one denies?

1. Deny policies always win.
2. The resource-based policies take precedence over identity-based policies.



IAM Policy structure



IAM JSON policy elements: Condition

The Condition element (or Condition block) lets you specify conditions for when a policy is in effect.
In the Condition element, you build expressions in which you use condition operators (equal, less than, etc.) to match the condition keys and values in the policy against keys and values in the request context.
Learn more: IAM JSON policy elements: Condition

```
"Condition" : { "{condition-operator}" : { "{condition-key}" : "{condition-value}" }}
```

```
"Condition" : { "StringEqualsIgnoreCase" : { "aws:username" : "johndoe" }}
```

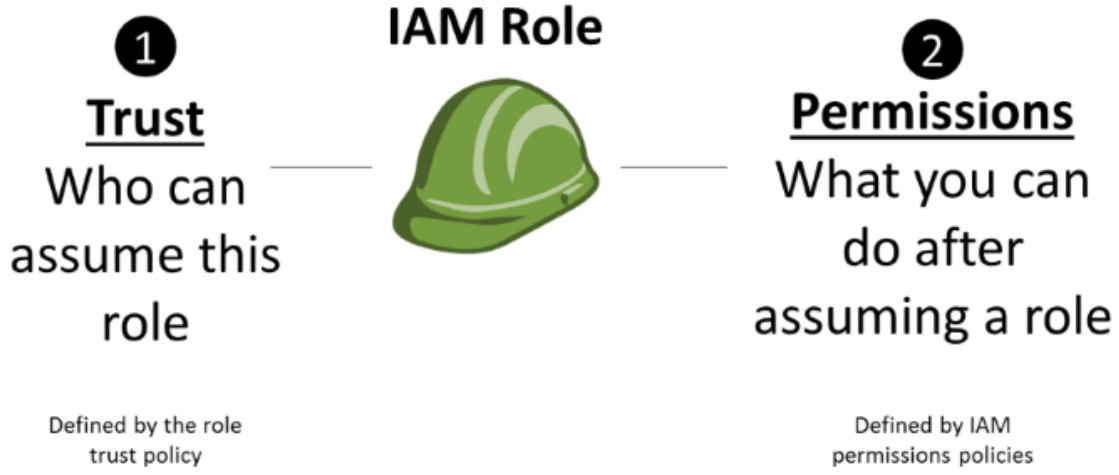
```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": [
                "rds:DescribeDBInstances",
                "rds:DescribeDBClusters",
                "rds:DescribeGlobalClusters"
            ],
            "Resource": "*"
        },

        {
            "Effect": "Allow",
            "Action": [
                "rds:RebootDBInstance",
                "rds:StartDBInstance",
                "rds:StopDBInstance"
            ],
            "Resource": "*",
            "Condition": {
                "StringEquals": {
                    "aws:PrincipalTag/Department": "DBAdmins",
                    "rds:db-tag/Environment": "Production"
                }
            }
        }
    ]
}
```

IAM role

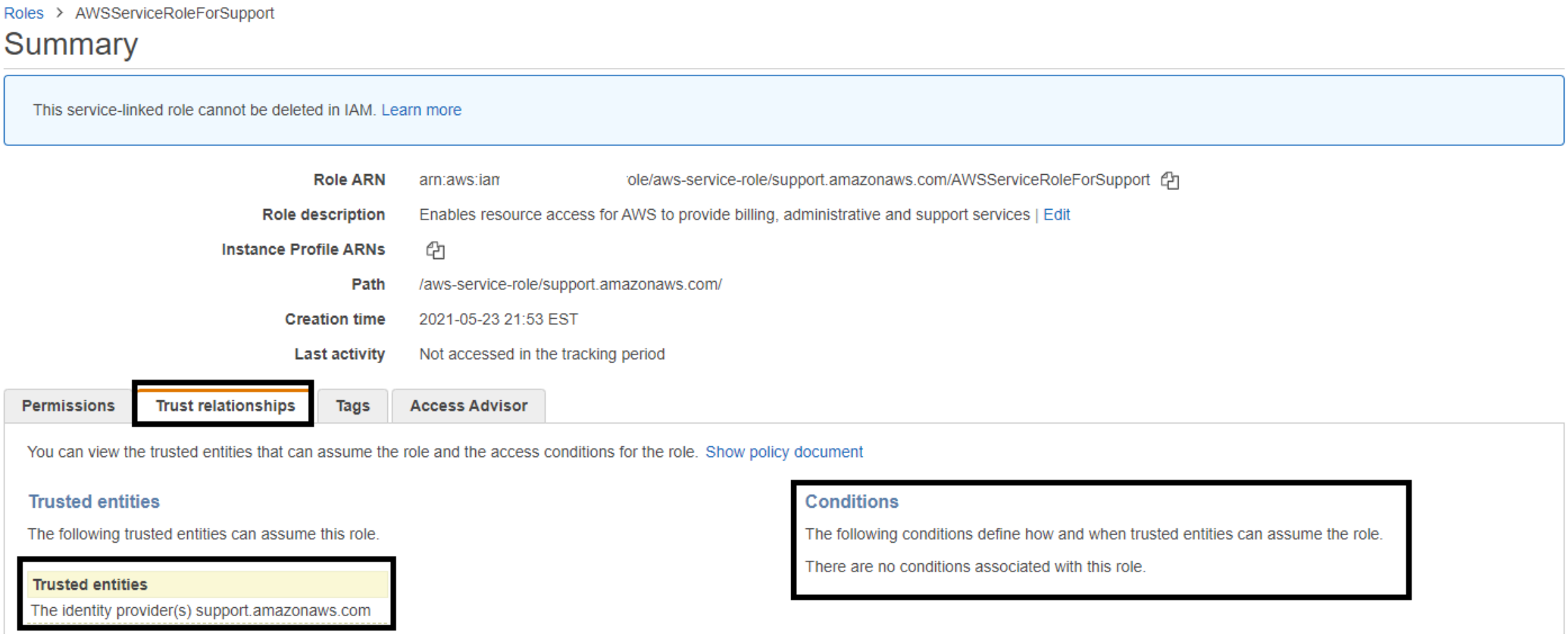
IAM role is similar to IAM user but you assign that to a resource, not a developer. There is a trust policy that defines which service can assume (use) that role. An IAM user and role have one thing in common, permission policies.

When the service in the trust policy assumes the role, AWS STS (Security Token Service) returns **temporary** tokens (access key id, secret access key, and **session token**), and those tokens are rotated automatically.



Trust relationships in AWS console

In this example, support.amazonaws.com (AWS's support team member) can assume the AWSServiceRoleForSupport role in my account. There are no conditions. If you check the permission policies, then you will find what AWS support can do in your account.



AWS Security Token Service (AWS STS)

Under the hood, tokens are generated and used to access AWS services. STS is a web service that enables you to request **temporary** credentials for IAM role.

The temporary credentials consist of:

1. **Access key ID** - Access keys are long-term credentials for an IAM user. Like username.
2. **Secret access key** - Like password.
3. **Session token** - Validates temporary credentials.
4. **Duration** - defines how long the temporary credentials lasts. Most cases 12 hours. 15-min is min. You will not see these in the permanent tokens for users.

STS - AssumeRole

The underlying service makes an implicit “AssumeRole” call to STS on behalf of the resource and fetch the temporary tokens. It all happens under the hood. For instance, when fetching images from S3 in EC2, EC2 makes the AssumeRole call to STS, then receives the token and provides the token to S3. You don’t have to manually rotate it. The rotation is done by AWS.

IAM User vs Role

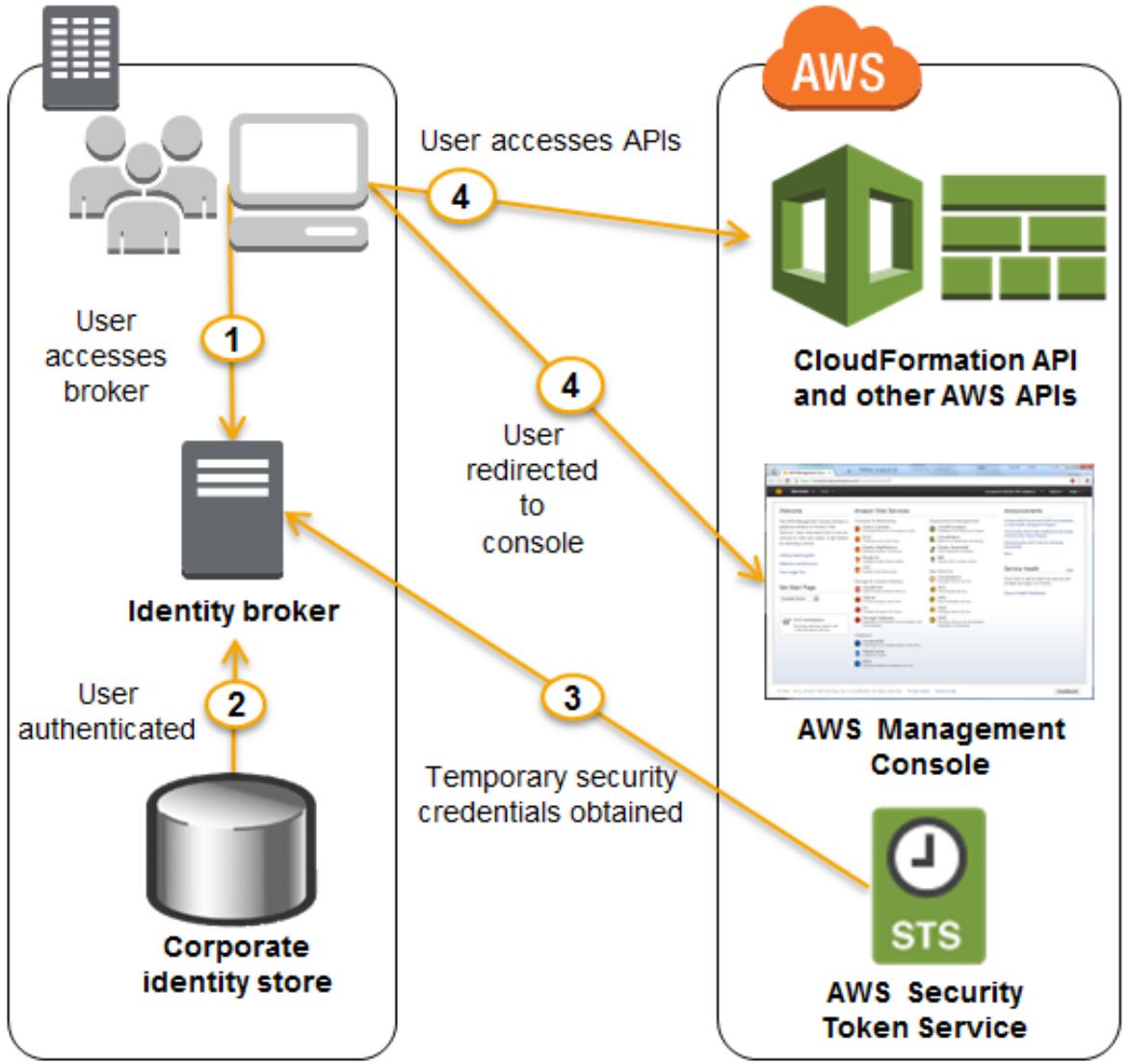
IAM User	**IAM Role**
IAM entity assigned to a **person**.	IAM entity assigned to a **service**. It has a trust policy that specifies what services can use the role.
Tokens are permanent. It is on you to rotate that regularly.	**Tokens are temporary**. Tokens are generated by AWS STS. It has an extra token “aws_session_token”.

Identity federation

Identity federation grants external identities secure access to resources in your AWS account. These external identities can come from your corporate identity provider such as Microsoft Active Directory.

Federated users (external identities) are users you manage outside of AWS in your corporate directory, but to whom you grant access to your AWS account using **temporary security credentials** (Role and STS).

Federated users and temporary security credentials STS



IAM Summary

IAM is about:

1. allow/deny
2. what actions?
3. on which resources?
4. who?
5. condition (optional)