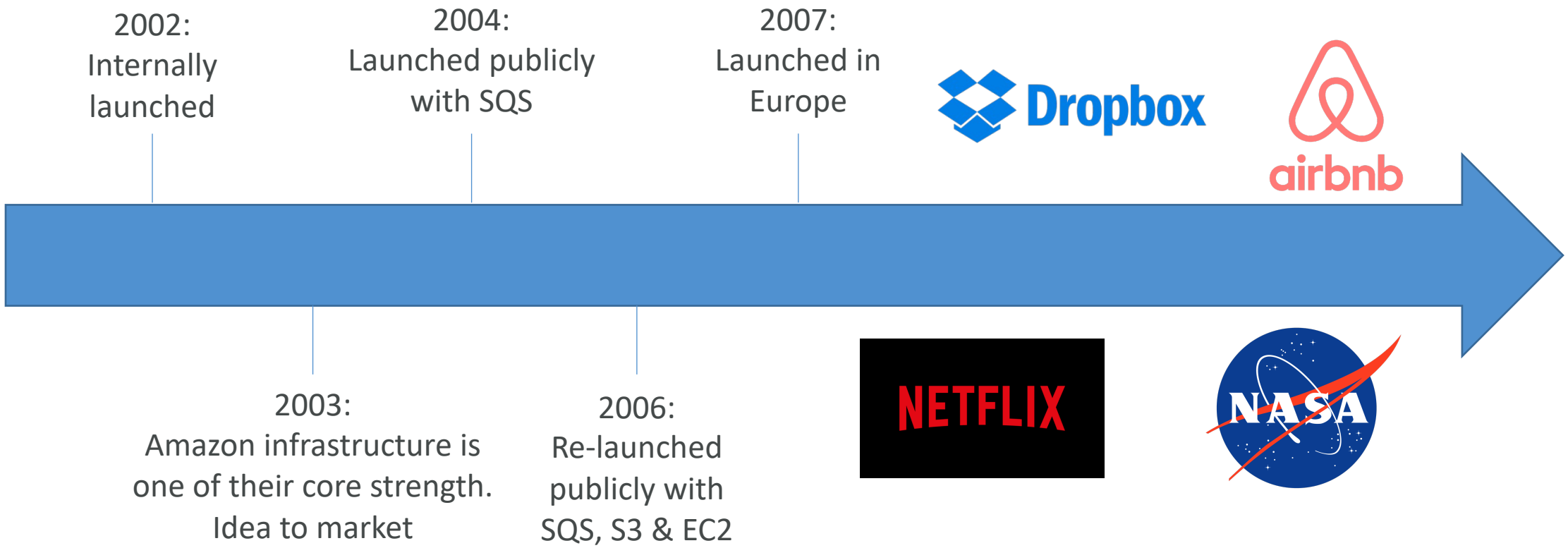
Getting started with AWS

AWS Cloud History



AWS Cloud Number Facts

- In 2019, AWS had $35.02 billion in annual revenue
- AWS accounts for 47% of the market in 2019 (Microsoft is 2nd with 22%)
- Pioneer and Leader of the AWS Cloud Market for the 9th consecutive year
- Over 1,000,000 active users

Gartner Magic Quadrant

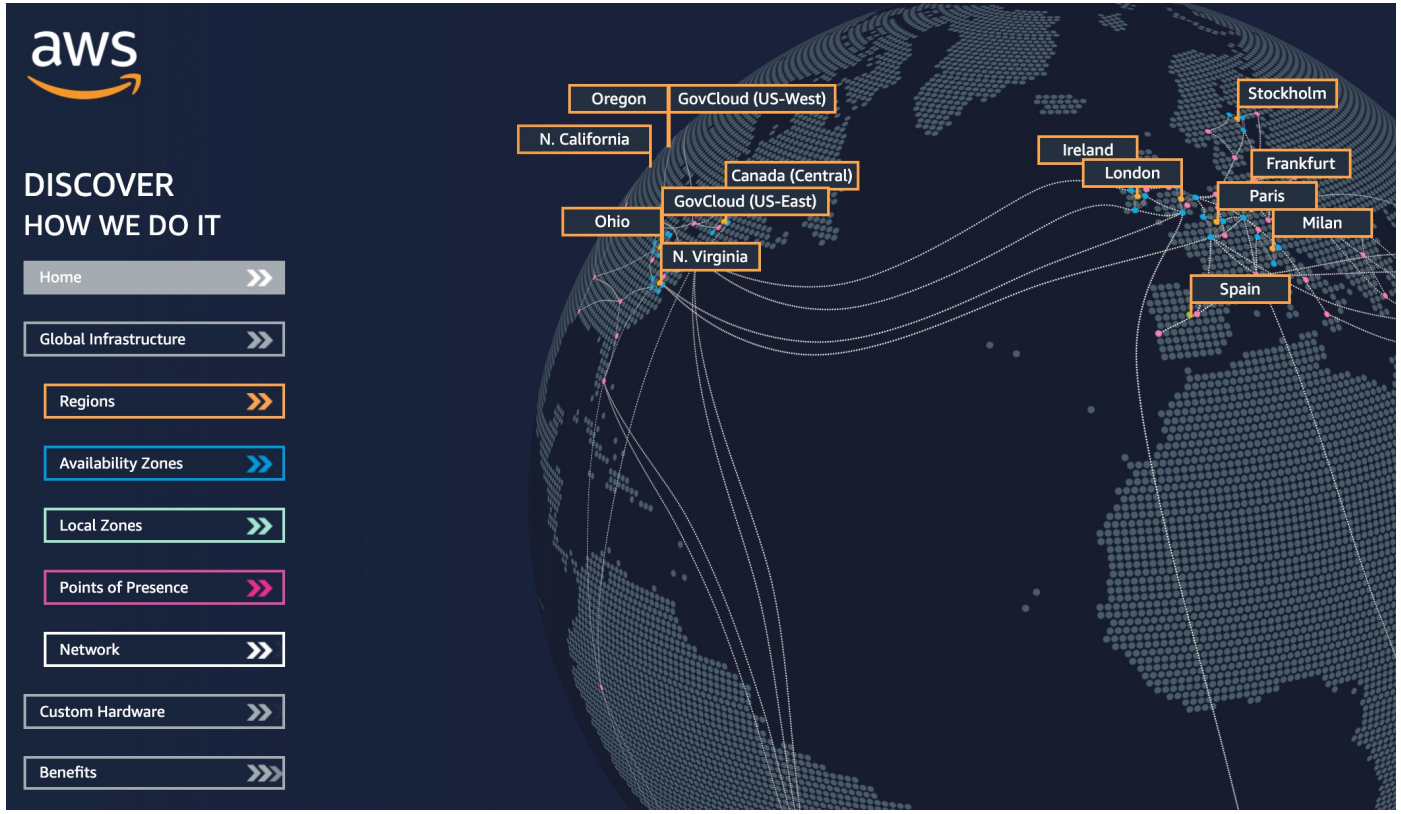
AWS Cloud Use Cases

- AWS enables you to build sophisticated, scalable applications
- Applicable to a diverse set of industries
- Use cases include
  - Enterprise IT, Backup & Storage, Big Data analytics
  - Website hosting, Mobile & Social Apps
  - Gaming

AWS Global Infrastructure

- AWS Regions
- AWS Availability Zones
- AWS Data Centers
- AWS Edge Locations / Points of Presence

- https://infrastructure.aws/



AWS Regions

- AWS has **Regions** all around the world
- Names can be us-east-1, eu-west-3…
- A region is a **cluster of data centers**
- **Most AWS services are region-scoped**

https://aws.amazon.com/about-aws/global-infrastructure/

US East (N. Virginia)	us-east-1
US East (Ohio)	us-east-2
US West (N. California)	us-west-1
US West (Oregon)	us-west-2
Africa (Cape Town)	af-south-1
Asia Pacific (Hong Kong)	ap-east-1
Asia Pacific (Mumbai)	ap-south-1
Asia Pacific (Seoul)	ap-northeast-2
Asia Pacific (Singapore)	ap-southeast-1
Asia Pacific (Sydney)	ap-southeast-2
Asia Pacific (Tokyo)	ap-northeast-1
Canada (Central)	ca-central-1
Europe (Frankfurt)	eu-central-1
Europe (Ireland)	eu-west-1
Europe (London)	eu-west-2
Europe (Paris)	eu-west-3
Europe (Stockholm)	eu-north-1
Middle East (Bahrain)	me-south-1
South America (São Paulo)	sa-east-1

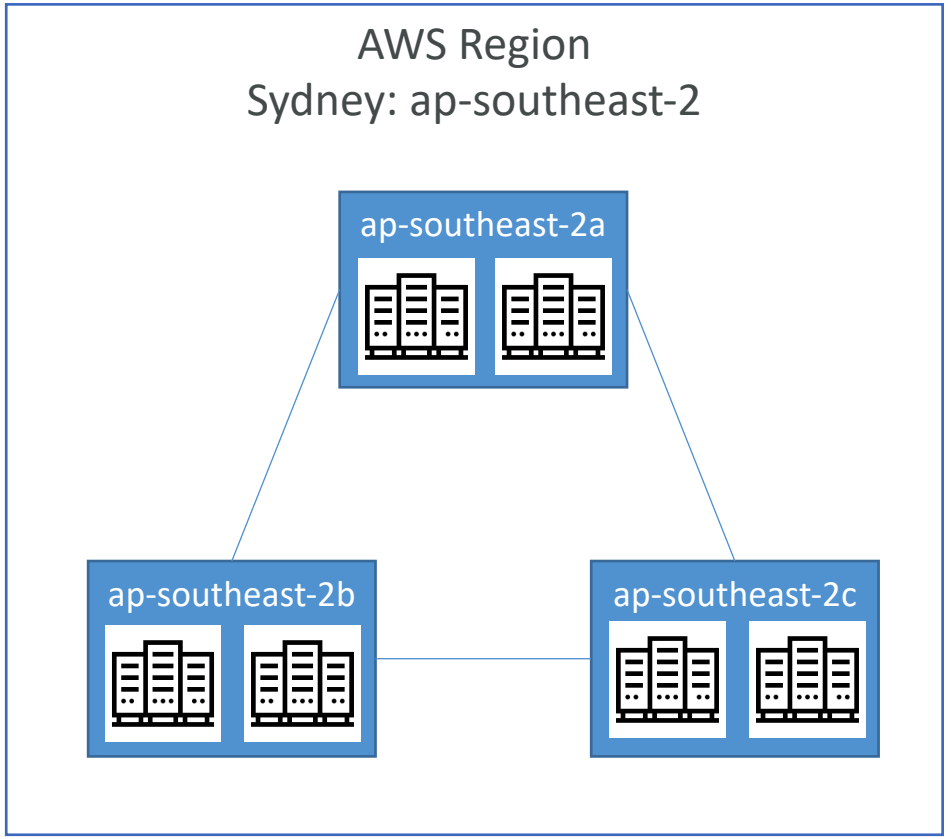
How to choose an AWS Region?

If you need to launch a new application, where should you do it?

- Compliance **with data governance and legal requirements:** data never leaves a region without your explicit permission
- Proximity **to customers:** reduced latency
- Available services **within a Region:** new services and new features aren't available in every Region
- Pricing**:** pricing varies region to region and is transparent in the service pricing page

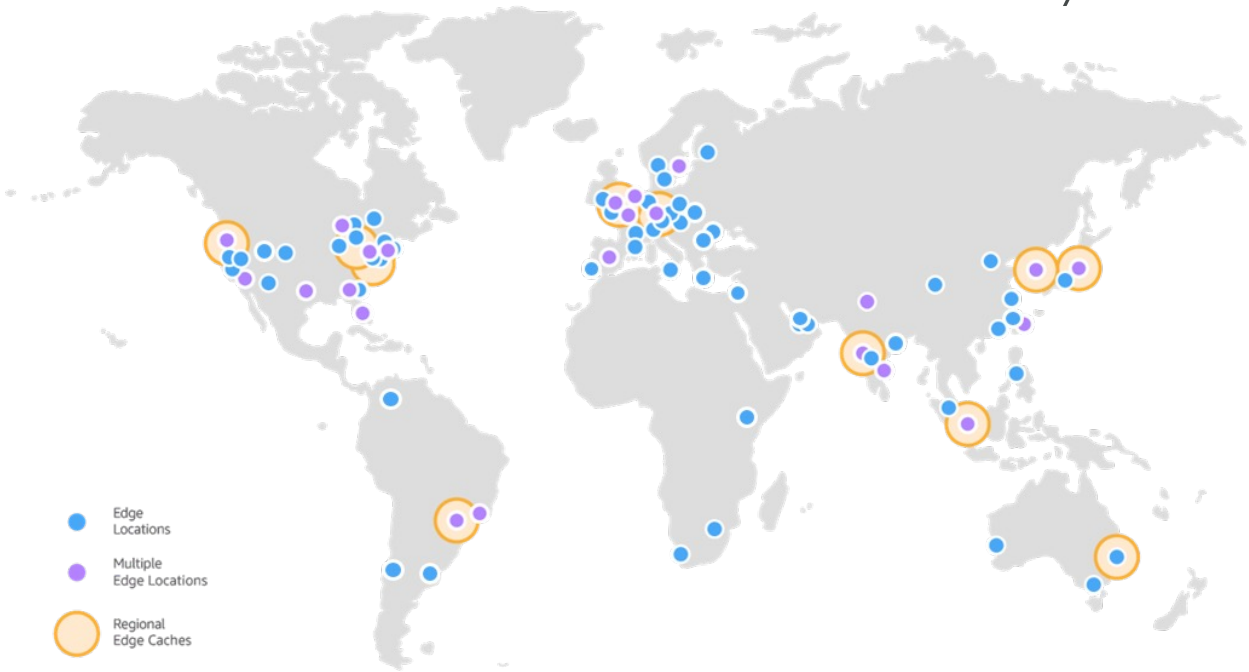
AWS Availability Zones

- Each region has many availability zones (usually 3, min is 3, max is 6). Example:
  - ap-southeast-2a
  - ap-southeast-2b
  - ap-southeast-2c
- Each availability zone (AZ) is one or more discrete data centers with redundant power, networking, and connectivity
- They're separate from each other, so that they're isolated from disasters
- They're connected with high bandwidth, ultra-low latency networking



AWS Points of Presence (Edge Locations)

- Amazon has 216 Points of Presence (205 Edge Locations & 11 Regional Caches) in 84 cities across 42 countries
- Content is delivered to end users with lower latency

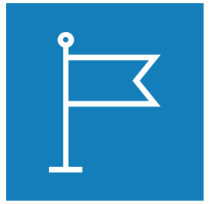


https://aws.amazon.com/cloudfront/features/

Tour of the AWS Console

- AWS has Global Services:
  - Identity and Access Management (IAM)
  - Route 53 (DNS service)
  - CloudFront (Content Delivery Network)
  - WAF (Web Application Firewall)

- Most AWS services are Region-scoped:
  - Amazon EC2 (Infrastructure as a Service)
  - Elastic Beanstalk (Platform as a Service)
  - Lambda (Function as a Service)
  - Rekognition (Software as a Service)

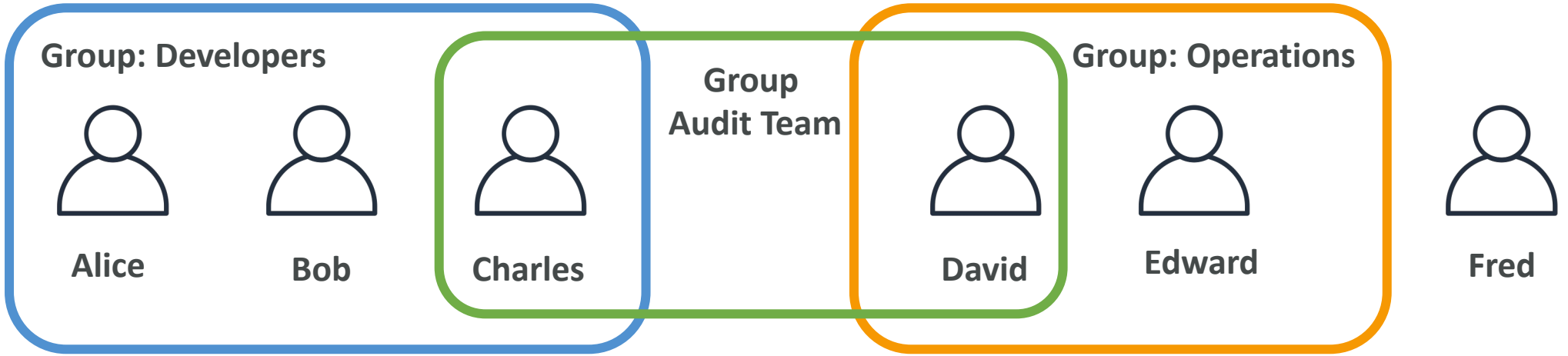


- Region Table: https://aws.amazon.com/about-aws/global-infrastructure/regional-product-services

IAM Section

IAM: Users & Groups

- IAM = Identity and Access Management, **Global** service
- **Root account** created by default, shouldn't be used or shared
- **Users** are people within your organization, and can be grouped
- **Groups** only contain users, not other groups
- Users don't have to belong to a group, and user can belong to multiple groups

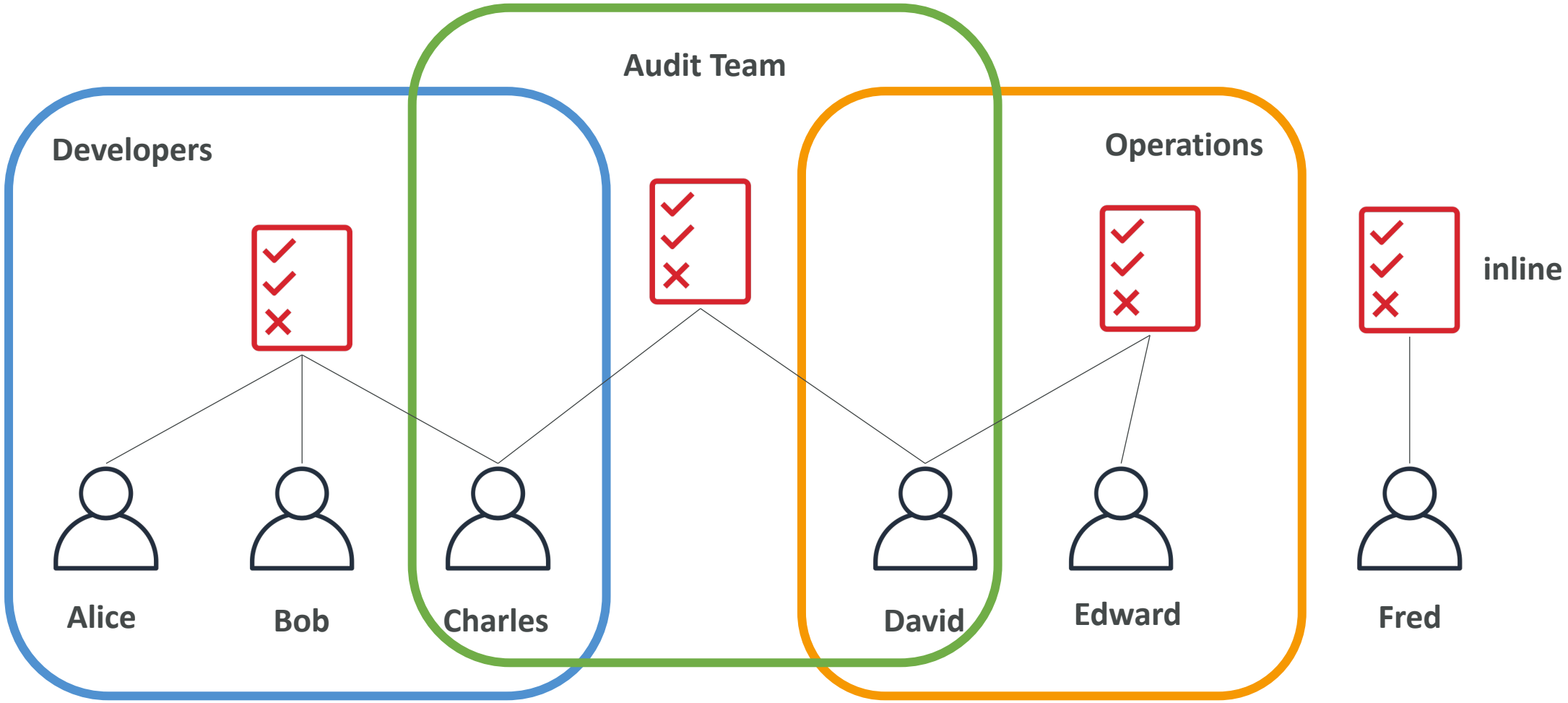


IAM: Permissions

- **Users or Groups** can be assigned JSON documents called policies
- These policies define the **permissions** of the users
- In AWS you apply the **least privilege principle**: don't give more permissions than a user needs

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": "ec2:Describe*",
            "Resource": "*"
        },
        {
            "Effect": "Allow",
            "Action": "elasticloadbalancing:Describe*",
            "Resource": "*"
        },
        {
            "Effect": "Allow",
            "Action": [
                "cloudwatch:ListMetrics",
                "cloudwatch:GetMetricStatistics",
                "cloudwatch:Describe*"
            ],
            "Resource": "*"
        }
    ]
}
```

IAM Policies inheritance



IAM Policies Structure

- Consists of
  - **Version:** policy language version, always include "2012-10-17"
  - **Id:** an identifier for the policy (optional)
  - **Statement:** one or more individual statements (required)
- Statements consists of
  - **Sid:** an identifier for the statement (optional)
  - **Effect:** whether the statement allows or denies access (Allow, Deny)
  - **Principal:** account/user/role to which this policy applied to
  - **Action:** list of actions this policy allows or denies
  - **Resource:** list of resources to which the actions applied to
  - **Condition:** conditions for when this policy is in effect (optional)

```
{
    "Version": "2012-10-17",
    "Id": "S3-Account-Permissions",
    "Statement": [
        {
            "Sid": "1",
            "Effect": "Allow",
            "Principal": {
                "AWS": ["arn:aws:iam::123456789012:root"]
            },
            "Action": [
                "s3:GetObject",
                "s3:PutObject"
            ],
            "Resource": ["arn:aws:s3:::mybucket/*"]
        }
    ]
}
```

IAM – Password Policy

- Strong passwords = higher security for your account
- In AWS, you can setup a password policy:
  - Set a minimum password length
  - Require specific character types:
    - including uppercase letters
    - lowercase letters
    - numbers
    - non-alphanumeric characters
  - Allow all IAM users to change their own passwords
  - Require users to change their password after some time (password expiration)
  - Prevent password re-use

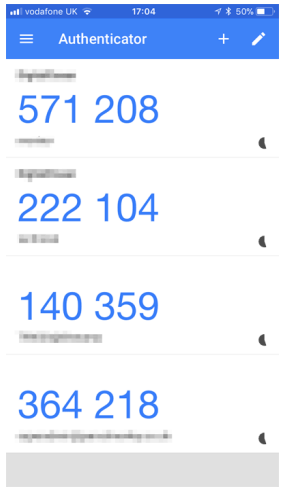
Multi Factor Authentication - MFA

- Users have access to your account and can possibly change configurations or delete resources in your AWS account
- You want to protect your Root Accounts and IAM users
- MFA = password *you know* + security device *you own*

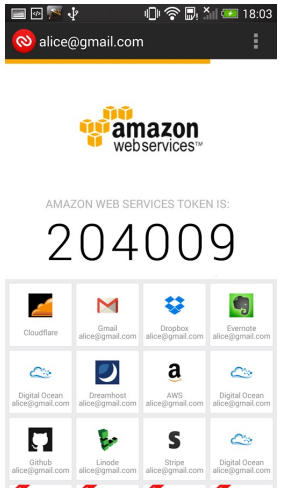
- Main benefit of MFA:
  if a password is stolen or hacked, the account is not compromised

MFA devices options in AWS

Virtual MFA device



Google Authenticator
(phone only)



Authy
(multi-device)

Support for multiple tokens on a single device.

Universal 2nd Factor (U2F) Security Key

YubiKey by Yubico (3rd party)

Support for multiple root and IAM users using a single security key

MFA devices options in AWS

Hardware Key Fob MFA Device

Provided by Gemalto (3rd party)

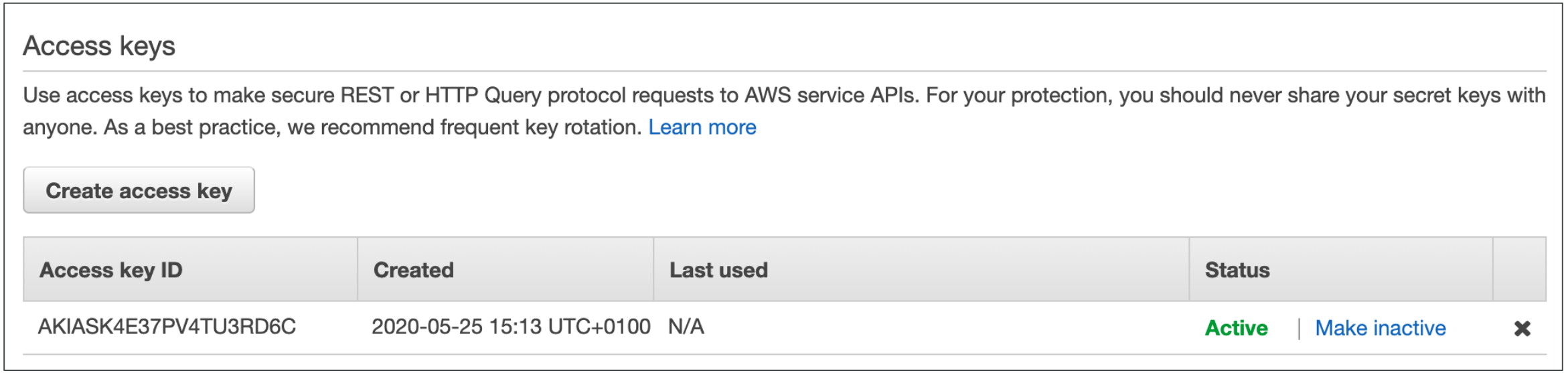
Hardware Key Fob MFA Device for AWS GovCloud (US)

Provided by SurePassID (3rd party)

How can users access AWS ?

- To access AWS, you have three options:
  - **AWS Management Console** (protected by password + MFA)
  - **AWS Command Line Interface (CLI):** protected by access keys
  - **AWS Software Developer Kit (SDK)** - for code: protected by access keys
- Access Keys are generated through the AWS Console
- Users manage their own access keys
- Access Keys are secret, just like a password. Don't share them
- Access Key ID ~= username
- Secret Access Key ~= password

Example (Fake) Access Keys



Access keys

Use access keys to make secure REST or HTTP Query protocol requests to AWS service APIs. For your protection, you should never share your secret keys with anyone. As a best practice, we recommend frequent key rotation. Learn more

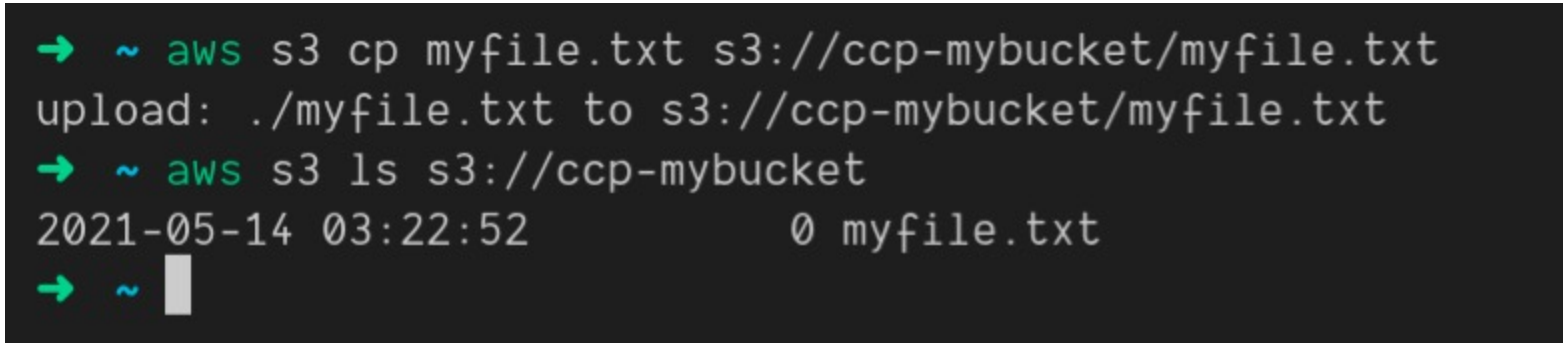
Create access key

Access key ID	Created	Last used	Status	
AKIASK4E37PV4TU3RD6C	2020-05-25 15:13 UTC+0100	N/A	Active | Make inactive	✖

- Access key ID: AKIASK4E37PV4983d6C
- Secret Access Key: AZPN3zojWozWCndIjhB0Unh8239a1bzbzO5fqqkZq
- Remember: don't share your access keys

What's the AWS CLI?

- A tool that enables you to interact with AWS services using commands in your command-line shell
- Direct access to the public APIs of AWS services
- You can develop scripts to manage your resources
- It's open-source https://github.com/aws/aws-cli
- Alternative to using AWS Management Console

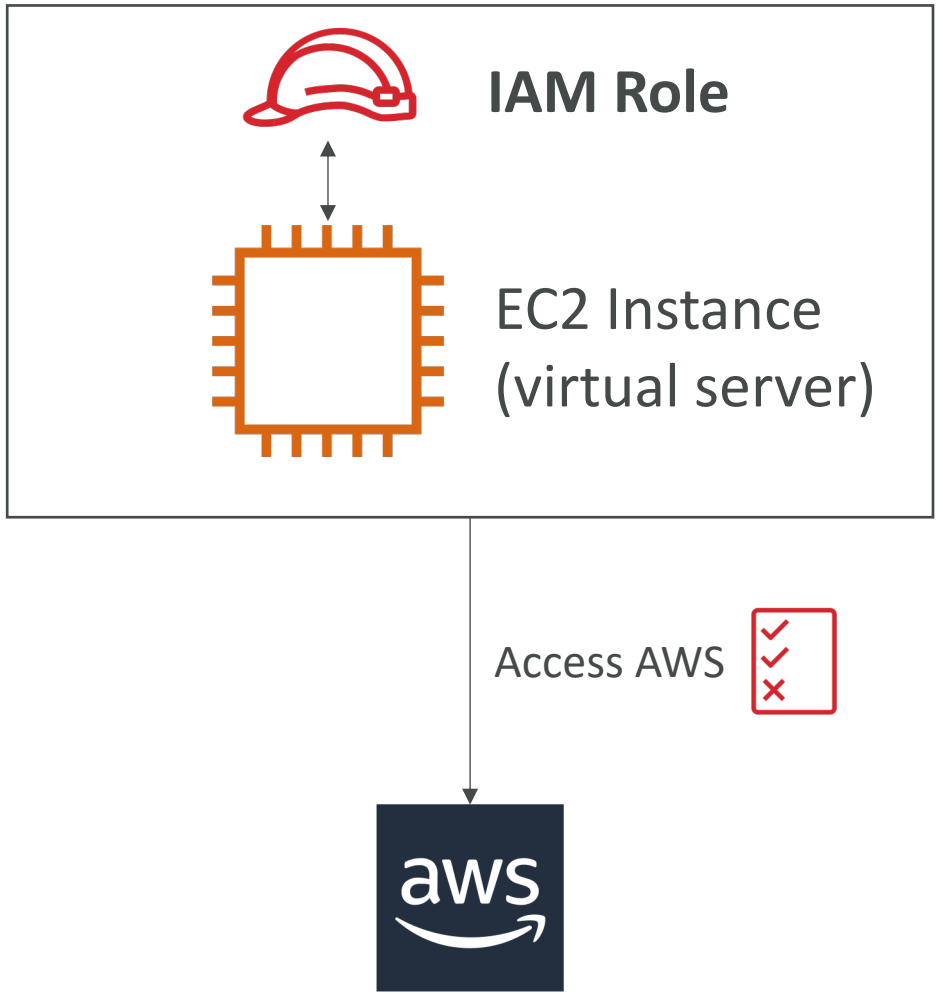


What's the AWS SDK?

- AWS Software Development Kit (AWS SDK)
- Language-specific APIs (set of libraries)
- Enables you to access and manage AWS services programmatically
- Embedded within your application
- Supports
  - SDKs (JavaScript, Python, PHP, .NET, Ruby, Java, Go, Node.js, C++)
  - Mobile SDKs (Android, iOS, …)
  - IoT Device SDKs (Embedded C, Arduino, …)
- Example: AWS CLI is built on AWS SDK for Python

IAM Roles for Services

- Some AWS service will need to perform actions on your behalf
- To do so, we will assign **permissions** to AWS services with **IAM Roles**
- Common roles:
  - EC2 Instance Roles
  - Lambda Function Roles
  - Roles for CloudFormation



IAM Security Tools

- IAM Credentials Report (account-level)
  - a report that lists all your account's users and the status of their various credentials

- IAM Access Advisor (user-level)
  - Access advisor shows the service permissions granted to a user and when those services were last accessed.
  - You can use this information to revise your policies.

IAM Guidelines & Best Practices

- Don't use the root account except for AWS account setup
- One physical user = One AWS **user**
- **Assign users to groups** and assign permissions to groups
- Create a **strong password policy**
- Use and enforce the use of **Multi Factor Authentication (MFA)**
- Create and use **Roles** for giving permissions to AWS services
- Use Access Keys for Programmatic Access (CLI / SDK)
- Audit permissions of your account with the IAM Credentials Report
- **Never share IAM users & Access Keys**

Shared Responsibility Model for IAM

- Infrastructure (global network security)
- Configuration and vulnerability analysis
- Compliance validation

You

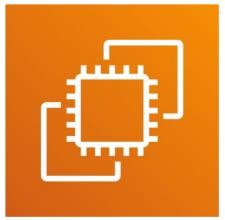
- Users, Groups, Roles, Policies management and monitoring
- Enable MFA on all accounts
- Rotate all your keys often
- Use IAM tools to apply appropriate permissions
- Analyze access patterns & review permissions

IAM Section – Summary

- **Users:** mapped to a physical user, has a password for AWS Console
- **Groups:** contains users only
- **Policies:** JSON document that outlines permissions for users or groups
- **Roles:** for EC2 instances or AWS services
- **Security:** MFA + Password Policy
- **Access Keys:** access AWS using the CLI or SDK
- **Audit:** IAM Credential Reports & IAM Access Advisor

EC2 Basics

Amazon EC2



- EC2 is one of the most popular of AWS' offering
- EC2 = Elastic Compute Cloud = Infrastructure as a Service
- It mainly consists in the capability of :
  - Renting virtual machines (EC2)
  - Storing data on virtual drives (EBS)
  - Distributing load across machines (ELB)
  - Scaling the services using an auto-scaling group (ASG)

- Knowing EC2 is fundamental to understand how the Cloud works

EC2 sizing & configuration options

- Operating System (**OS**): Linux, Windows or Mac OS
- How much compute power & cores (**CPU**)
- How much random-access memory (**RAM**)
- How much storage space:
  - Network-attached (**EBS & EFS**)
  - hardware (**EC2 Instance Store**)
- Network card: speed of the card, Public IP address
- Firewall rules: **security group**
- Bootstrap script (configure at first launch): EC2 User Data

EC2 User Data

- It is possible to bootstrap our instances using an EC2 User data script.
- bootstrapping means launching commands when a machine starts
- That script is only run once at the instance first start
- EC2 user data is used to automate boot tasks such as:
  - Installing updates
  - Installing software
  - Downloading common files from the internet
  - Anything you can think of
- The EC2 User Data Script runs with the root user

Hands-On:
Launching an EC2 Instance running Linux

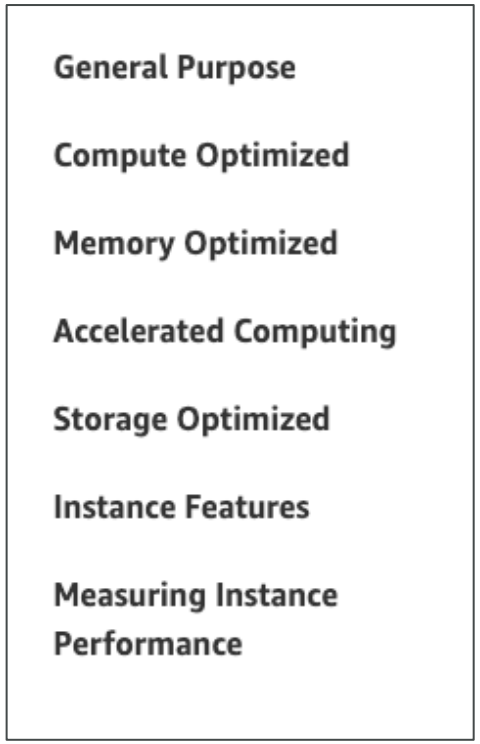
- We'll be launching our first virtual server using the AWS Console
- We'll get a first high-level approach to the various parameters
- We'll see that our web server is launched using EC2 user data
- We'll learn how to start / stop / terminate our instance.

EC2 Instance Types - Overview

- You can use different types of EC2 instances that are optimised for different use cases (https://aws.amazon.com/ec2/instance-types/)
- AWS has the following naming convention:

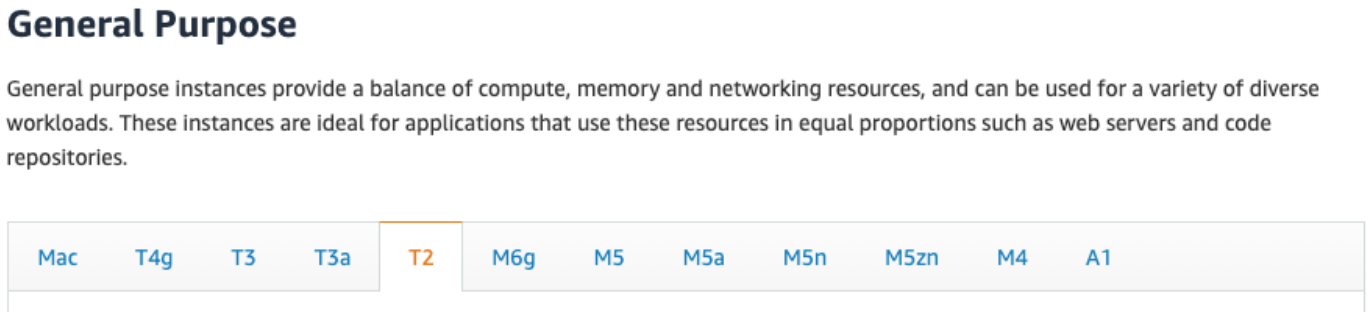
m5.2xlarge

- m: instance class
- 5: generation (AWS improves them over time)
- 2xlarge: size within the instance class



EC2 Instance Types – General Purpose

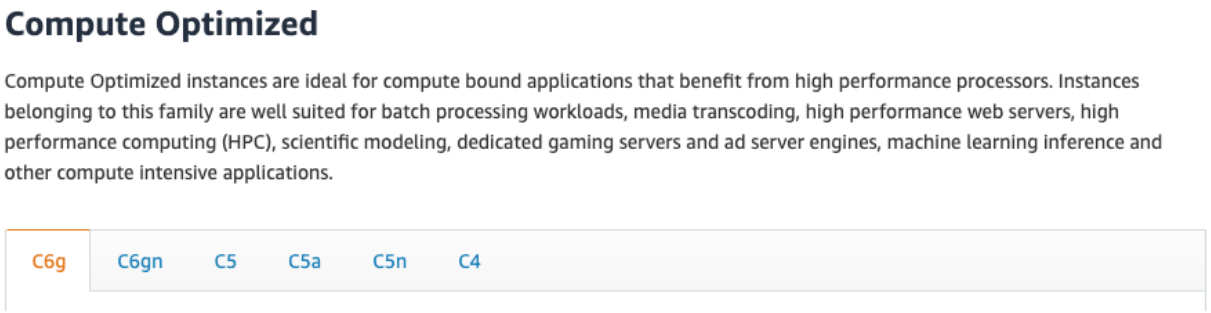
- Great for a diversity of workloads such as web servers or code repositories
- Balance between:
  - Compute
  - Memory
  - Networking
- In the course, we will be using the t2.micro which is a General Purpose EC2 instance



** this list will evolve over time, please check the AWS website for the latest information*

EC2 Instance Types – Compute Optimized

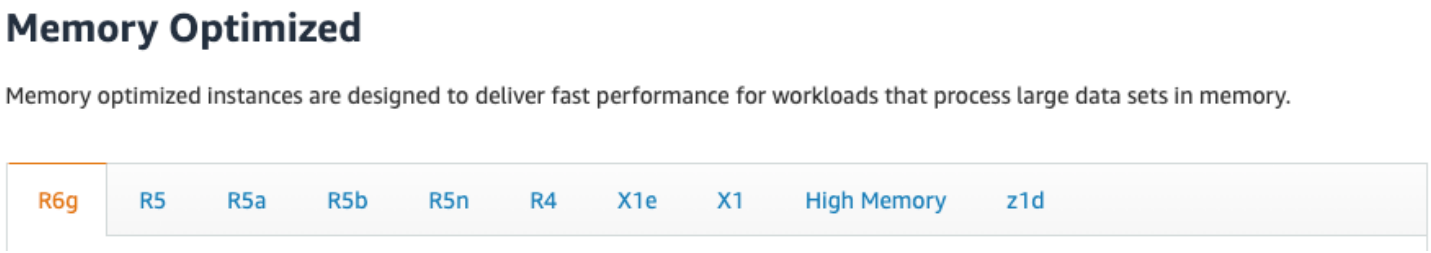
- Great for compute-intensive tasks that require high performance processors:
  - Batch processing workloads
  - Media transcoding
  - High performance web servers
  - High performance computing (HPC)
  - Scientific modeling & machine learning
  - Dedicated gaming servers



** this list will evolve over time, please check the AWS website for the latest information*

EC2 Instance Types – Memory Optimized

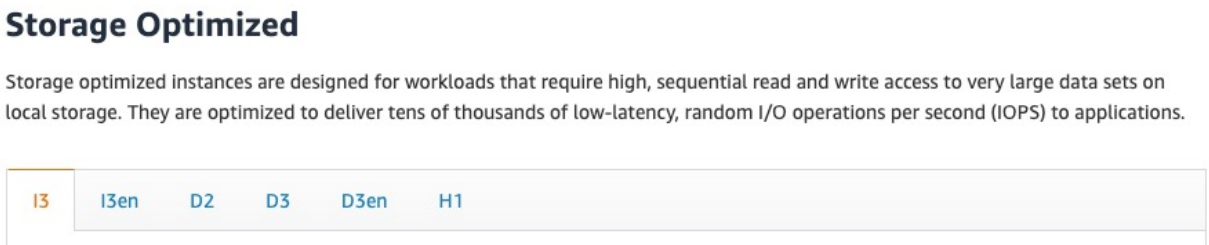
- Fast performance for workloads that process large data sets in memory
- Use cases:
  - High performance, relational/non-relational databases
  - Distributed web scale cache stores
  - In-memory databases optimized for BI (business intelligence)
  - Applications performing real-time processing of big unstructured data



** this list will evolve over time, please check the AWS website for the latest information*

EC2 Instance Types – Storage Optimized

- Great for storage-intensive tasks that require high, sequential read and write access to large data sets on local storage
- Use cases:
  - High frequency online transaction processing (OLTP) systems
  - Relational & NoSQL databases
  - Cache for in-memory databases (for example, Redis)
  - Data warehousing applications
  - Distributed file systems



** this list will evolve over time, please check the AWS website for the latest information*

EC2 Instance Types: example

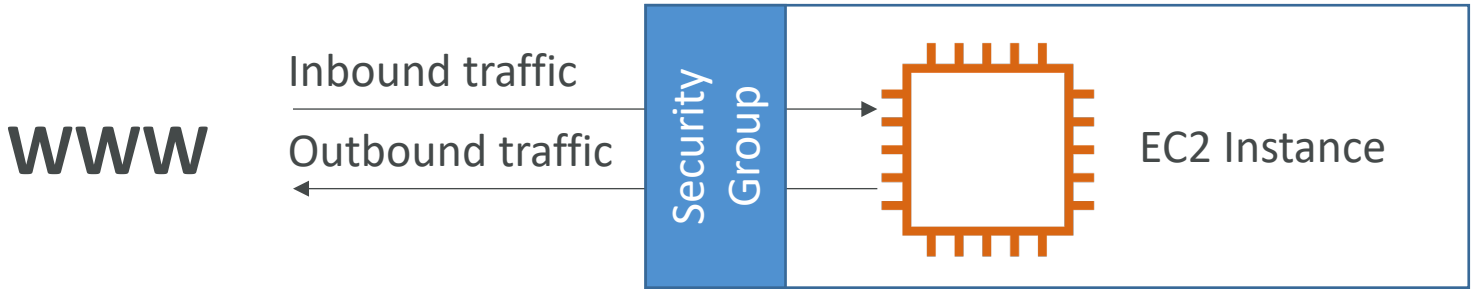
Instance	vCPU	Mem (GiB)	Storage	Network Performance	EBS Bandwidth (Mbps)
t2.micro	1	1	EBS-Only	Low to Moderate	
t2.xlarge	4	16	EBS-Only	Moderate	
c5d.4xlarge	16	32	1 x 400 NVMe SSD	Up to 10 Gbps	4,750
r5.16xlarge	64	512	EBS Only	20 Gbps	13,600
m5.8xlarge	32	128	EBS Only	10 Gbps	6,800

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

Great website: https://instances.vantage.sh

Introduction to Security Groups

- Security Groups are the fundamental of network security in AWS
- They control how traffic is allowed into or out of our EC2 Instances.



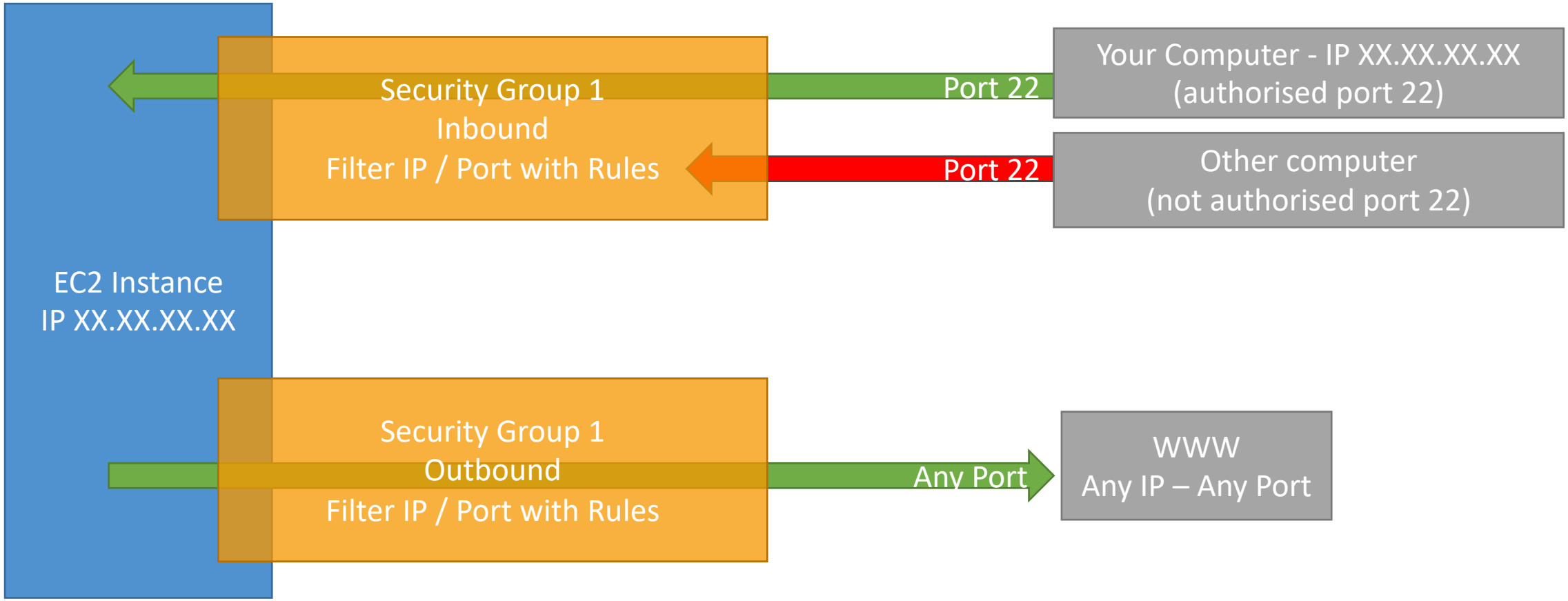
- Security groups only contain allow rules
- Security groups rules can reference by IP or by security group

Security Groups Deeper Dive

- Security groups are acting as a "firewall" on EC2 instances
- They regulate:
  - Access to Ports
  - Authorised IP ranges – IPv4 and IPv6
  - Control of inbound network (from other to the instance)
  - Control of outbound network (from the instance to other)

Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	0.0.0.0/0	test http page
SSH	TCP	22	122.149.196.85/32	
Custom TCP Rule	TCP	4567	0.0.0.0/0	java app

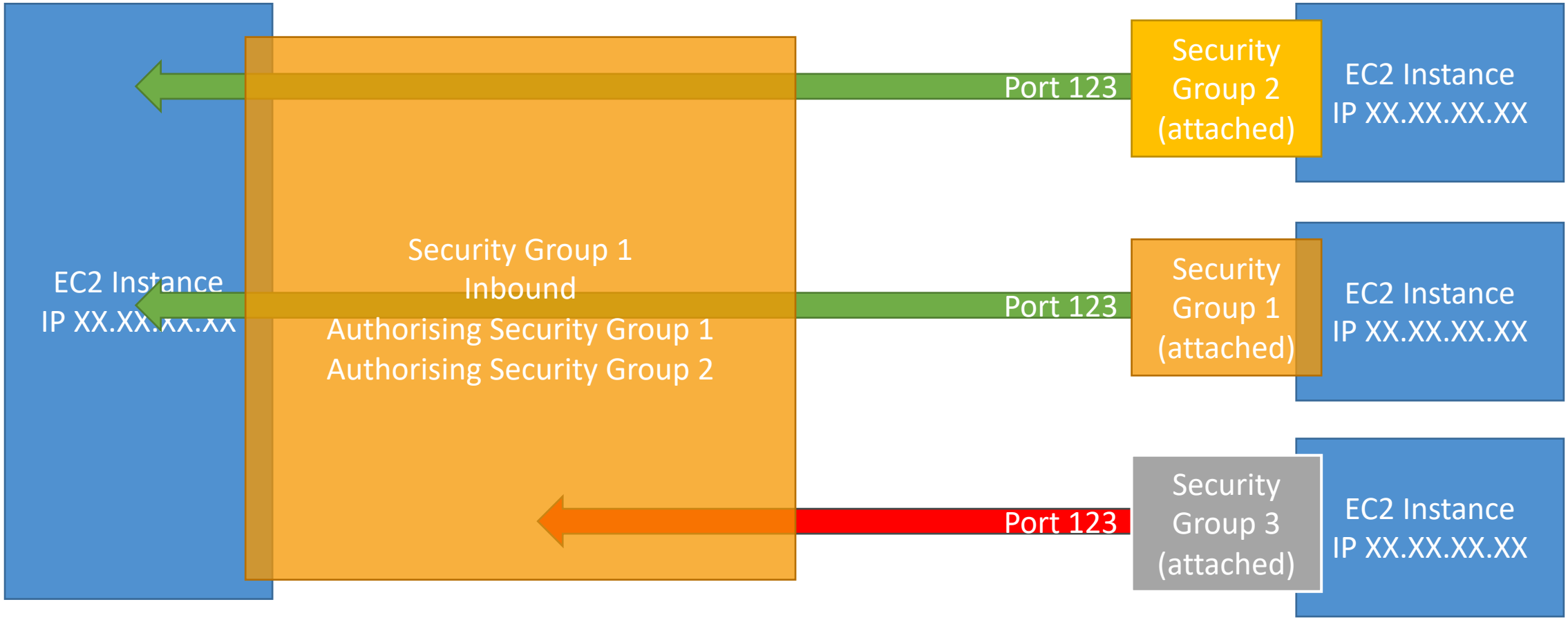
Security Groups Diagram



Security Groups
Good to know

- Can be attached to multiple instances
- Locked down to a region / VPC combination
- Does live "outside" the EC2 – if traffic is blocked the EC2 instance won't see it
- It's good to maintain one separate security group for SSH access
- If your application is not accessible (time out), then it's a security group issue
- If your application gives a "connection refused" error, then it's an application error or it's not launched
- All inbound traffic is blocked by default
- All outbound traffic is authorised by default

Referencing other security groups Diagram



Classic Ports to know

- 22 = SSH (Secure Shell) - log into a Linux instance
- 21 = FTP (File Transfer Protocol) – upload files into a file share
- 22 = SFTP (Secure File Transfer Protocol) – upload files using SSH
- 80 = HTTP – access unsecured websites
- 443 = HTTPS – access secured websites
- 3389 = RDP (Remote Desktop Protocol) – log into a Windows instance

SSH Summary Table

	SSH	Putty	EC2 Instance Connect
Mac	✓		✓
Linux	✓		✓
Windows < 10		✓	✓
Windows >= 10	✓	✓	✓

Which Lectures to watch

- **Mac / Linux:**
  - SSH on Mac/Linux lecture
- **Windows:**
  - Putty Lecture
  - **If Windows 10:** SSH on Windows 10 lecture
- **All:**
  - EC2 Instance Connect lecture

SSH troubleshooting

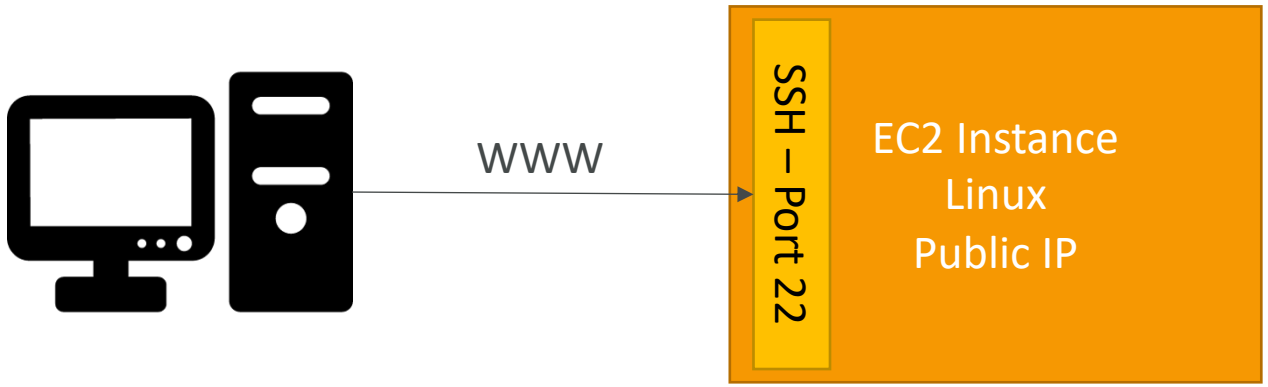
- Students have the most problems with SSH

- If things don't work…
  1. Re-watch the lecture. You may have missed something
  2. Read the troubleshooting guide
  3. Try EC2 Instance Connect

- If one method works (SSH, Putty or EC2 Instance Connect) you're good
- If no method works, that's okay, the course won't use SSH much

How to SSH into your EC2 Instance
Linux / Mac OS X

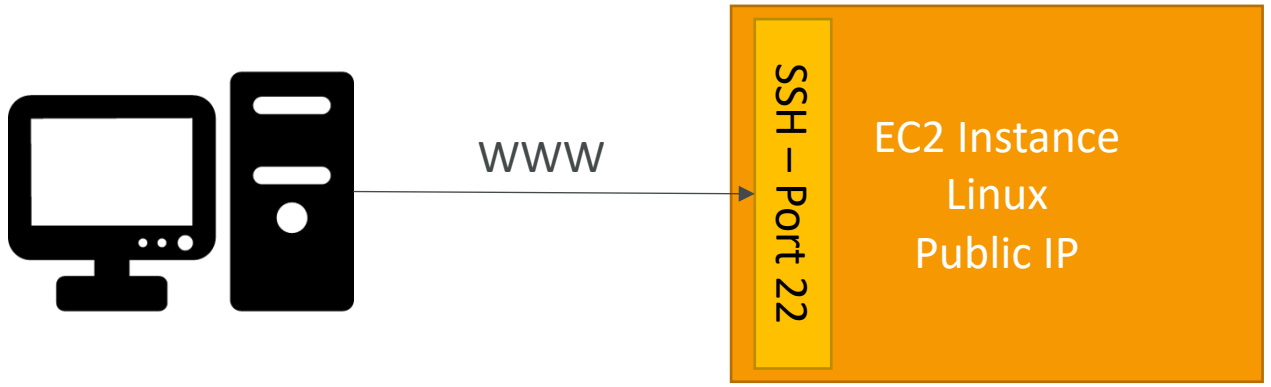
- We'll learn how to SSH into your EC2 instance using Linux / Mac
- SSH is one of the most important function. It allows you to control a remote machine, all using the command line.



- We will see how we can configure OpenSSH ~/.ssh/config to facilitate the SSH into our EC2 instances

How to SSH into your EC2 Instance
Windows

- We'll learn how to SSH into your EC2 instance using Windows
- SSH is one of the most important function. It allows you to control a remote machine, all using the command line.



- We will configure all the required parameters necessary for doing SSH on Windows using the free tool Putty.

EC2 Instance Connect

- Connect to your EC2 instance within your browser
- No need to use your key file that was downloaded
- The "magic" is that a temporary key is uploaded onto EC2 by AWS

- Works only out-of-the-box with Amazon Linux 2

- Need to make sure the port 22 is still opened!

EC2 Instances Purchasing Options

- **On-Demand Instances** – short workload, predictable pricing, pay by second
- **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, cheap, can lose instances (less reliable)
- **Dedicated Hosts** – book an entire physical server, control instance placement
- **Dedicated Instances** – no other customers will share your hardware
- **Capacity Reservations** – reserve capacity in a specific AZ for any duration

EC2 On Demand

- 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

EC2 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

Note: the % discounts are different from the video as AWS change them over time – the exact numbers are not needed for the exam. This is just for illustrative purposes ☺

EC2 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)

EC2 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**

EC2 Dedicated Hosts

- A physical server with EC2 instance capacity fully dedicated to your use
- Allows you 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

EC2 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)

Characteristic	Dedicated Instances	Dedicated Hosts
Enables the use of dedicated physical servers	X	X
Per instance billing (subject to a $2 per region fee)	X	
Per host billing		X
Visibility of sockets, cores, host ID		X
Affinity between a host and instance		X
Targeted instance placement		X
Automatic instance placement	X	X
Add capacity using an allocation request		X

EC2 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

Which purchasing option is right for me?

- **On demand:** coming and staying in resort whenever we like, we pay the full price
- **Reserved:** like planning ahead and if we plan to stay for a long time, we may get a good discount.
- **Savings Plans:** pay a certain amount per hour for certain period and stay in any room type (e.g., King, Suite, Sea View, …)
- **Spot instances:** the hotel allows people to bid for the empty rooms and the highest bidder keeps the rooms. You can get kicked out at any time
- **Dedicated Hosts:** We book an entire building of the resort
- **Capacity Reservations:** you book a room for a period with full price even you don't stay in it

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

Price Type	Price (per hour)
On-Demand	$0.10
Spot Instance (Spot Price)	$0.038 - $0.039 (up to 61% off)
Reserved Instance (1 year)	$0.062 (No Upfront) - $0.058 (All Upfront)
Reserved Instance (3 years)	$0.043 (No Upfront) - $0.037 (All Upfront)
EC2 Savings Plan (1 year)	$0.062 (No Upfront) - $0.058 (All Upfront)
Reserved **Convertible** Instance (1 year)	$0.071 (No Upfront) - $0.066 (All Upfront)
Dedicated Host	On-Demand Price
Dedicated Host Reservation	Up to 70% off
Capacity Reservations	On-Demand Price

EC2 Instance Storage Section

What's an EBS Volume?

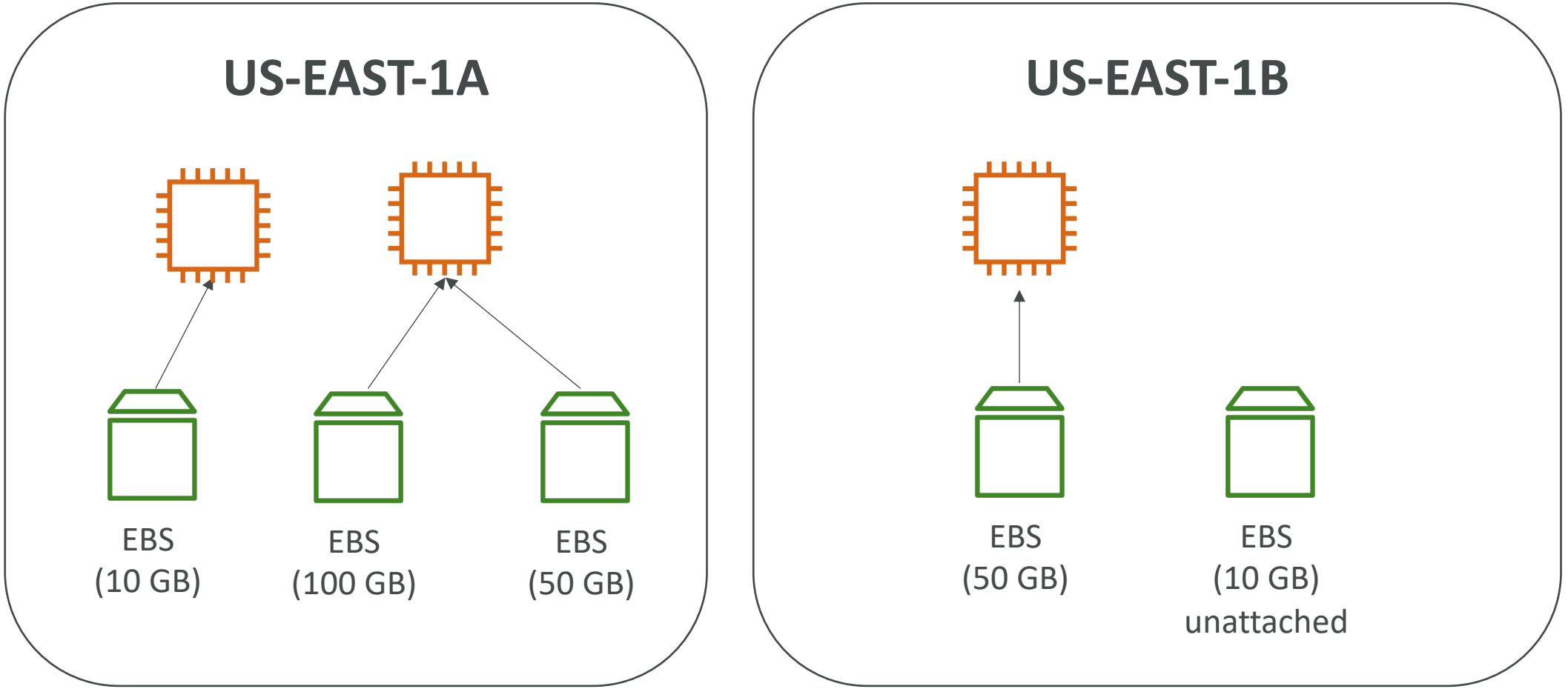
- An EBS (Elastic Block Store) Volume is a network drive you can attach to your instances while they run
- It allows your instances to persist data, even after their termination
- **They can only be mounted to one instance at a time** (at the CCP level)
- They are bound to **a specific availability zone**

- Analogy: Think of them as a "network USB stick"
- Free tier: 30 GB of free EBS storage of type General Purpose (SSD) or Magnetic per month

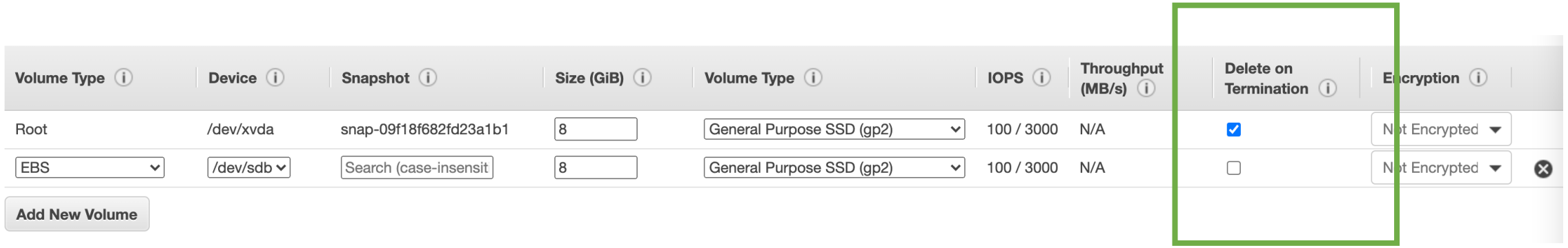
EBS Volume

- It's a network drive (i.e. not a physical drive)
  - It uses the network to communicate the instance, which means there might be a bit of latency
  - It can be detached from an EC2 instance and attached to another one quickly
- It's locked to an Availability Zone (AZ)
  - An EBS Volume in us-east-1a cannot be attached to us-east-1b
  - To move a volume across, you first need to snapshot it
- Have a provisioned capacity (size in GBs, and IOPS)
  - You get billed for all the provisioned capacity
  - You can increase the capacity of the drive over time

EBS Volume - Example



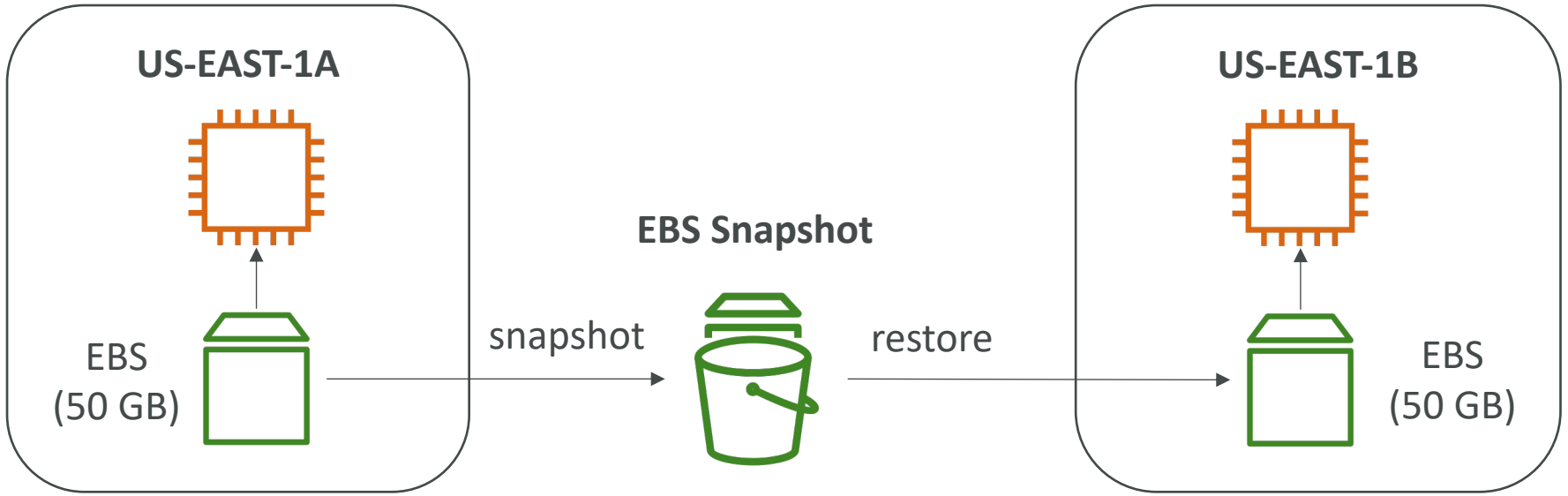
EBS – Delete on Termination attribute



- Controls the EBS behaviour when an EC2 instance terminates
  - By default, the root EBS volume is deleted (attribute enabled)
  - By default, any other attached EBS volume is not deleted (attribute disabled)
- This can be controlled by the AWS console / AWS CLI
- Use case: preserve root volume when instance is terminated

EBS Snapshots

- Make a backup (snapshot) of your EBS volume at a point in time
- Not necessary to detach volume to do snapshot, but recommended
- Can copy snapshots across AZ or Region

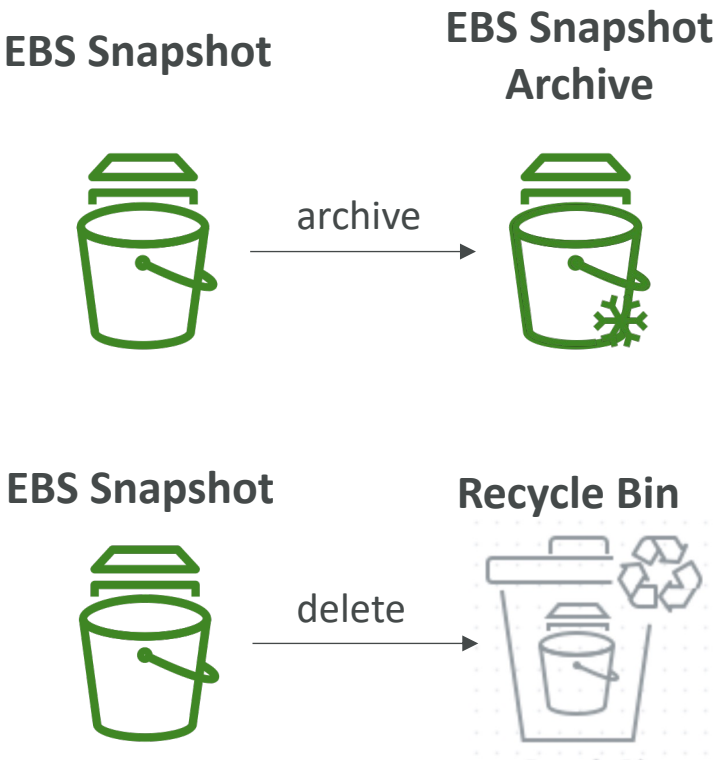


EBS Snapshots Features

- EBS Snapshot Archive
  - Move a Snapshot to an "archive tier" that is 75% cheaper
  - Takes within 24 to 72 hours for restoring the archive

- Recycle Bin for EBS Snapshots
  - Setup rules to retain deleted snapshots so you can recover them after an accidental deletion
  - Specify retention (from 1 day to 1 year)

- Fast Snapshot Restore (FSR)
  - Force full initialization of snapshot to have no latency on the first use ($$$)

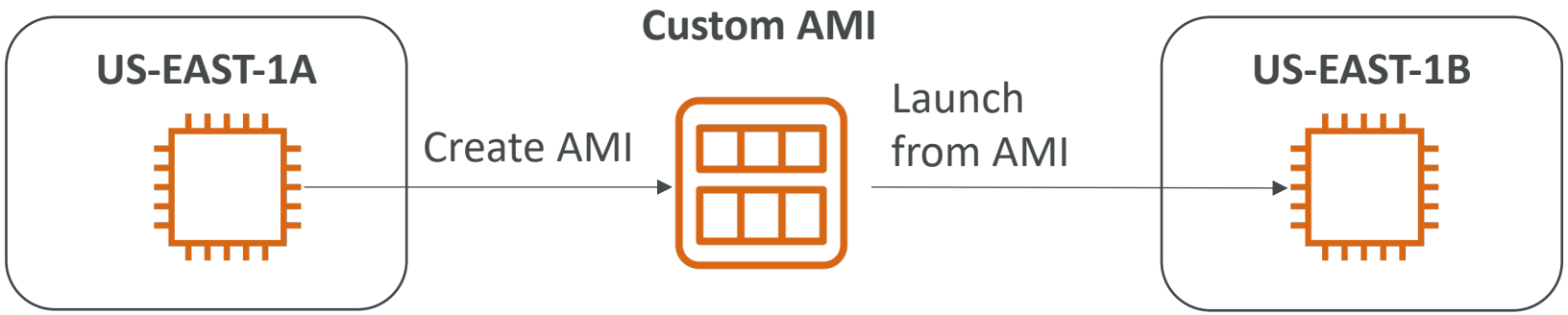


AMI Overview

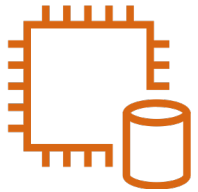
- AMI = Amazon Machine Image
- AMI are a **customization** of an EC2 instance
  - You add your own software, configuration, operating system, monitoring…
  - Faster boot / configuration time because all your software is pre-packaged
- AMI are built for a **specific region** (and can be copied across regions)
- You can launch EC2 instances from:
  - **A Public AMI:** AWS provided
  - **Your own AMI:** you make and maintain them yourself
  - **An AWS Marketplace AMI:** an AMI someone else made (and potentially sells)

AMI Process (from an EC2 instance)

- Start an EC2 instance and customize it
- Stop the instance (for data integrity)
- Build an AMI – this will also create EBS snapshots
- Launch instances from other AMIs



EC2 Instance Store



- EBS volumes are **network drives** with good but "limited" performance
- If you need a high-performance hardware disk, use EC2 Instance Store

- Better I/O performance
- EC2 Instance Store lose their storage if they're stopped (ephemeral)
- Good for buffer / cache / scratch data / temporary content
- Risk of data loss if hardware fails
- Backups and Replication are your responsibility

Local EC2 Instance Store

Very high IOPS

Instance Size	100% Random Read IOPS	Write IOPS
i3.large *	100,125	35,000
i3.xlarge *	206,250	70,000
i3.2xlarge	412,500	180,000
i3.4xlarge	825,000	360,000
i3.8xlarge	1.65 million	720,000
i3.16xlarge	3.3 million	1.4 million
i3.metal	3.3 million	1.4 million
i3en.large *	42,500	32,500
i3en.xlarge *	85,000	65,000
i3en.2xlarge *	170,000	130,000
i3en.3xlarge	250,000	200,000
i3en.6xlarge	500,000	400,000
i3en.12xlarge	1 million	800,000
i3en.24xlarge	2 million	1.6 million
i3en.metal	2 million	1.6 million

EBS Volume Types

- EBS Volumes come in 6 types
  - gp2 / gp3 (SSD): General purpose SSD volume that balances price and performance for a wide variety of workloads
  - io1 / io2 (SSD): Highest-performance SSD volume for mission-critical low-latency or high-throughput workloads
  - st1 (HDD): Low cost HDD volume designed for frequently accessed, throughput-intensive workloads
  - sc1 (HDD): Lowest cost HDD volume designed for less frequently accessed workloads

- EBS Volumes are characterized in Size | Throughput | IOPS (I/O Ops Per Sec)
- When in doubt always consult the AWS documentation – it's good!
- Only gp2/gp3 and io1/io2 can be used as boot volumes

EBS Volume Types Use cases

General Purpose SSD

- Cost effective storage, low-latency
- System boot volumes, Virtual desktops, Development and test environments
- 1 GiB - 16 TiB
- gp3:
  - Baseline of 3,000 IOPS and throughput of 125 MiB/s
  - Can increase IOPS up to 16,000 and throughput up to 1000 MiB/s independently
- gp2:
  - Small gp2 volumes can burst IOPS to 3,000
  - Size of the volume and IOPS are linked, max IOPS is 16,000
  - 3 IOPS per GB, means at 5,334 GB we are at the max IOPS

EBS Volume Types Use cases

Provisioned IOPS (PIOPS) SSD

- Critical business applications with sustained IOPS performance
- Or applications that need more than 16,000 IOPS
- Great for **databases workloads** (sensitive to storage perf and consistency)
- io1/io2 (4 GiB - 16 TiB):
  - Max PIOPS: 64,000 for Nitro EC2 instances & 32,000 for other
  - Can increase PIOPS independently from storage size
  - io2 have more durability and more IOPS per GiB (at the same price as io1)
- io2 Block Express (4 GiB – 64 TiB):
  - Sub-millisecond latency
  - Max PIOPS: 256,000 with an IOPS:GiB ratio of 1,000:1
- Supports EBS Multi-attach

EBS Volume Types Use cases

Hard Disk Drives (HDD)

- Cannot be a boot volume
- 125 GiB to 16 TiB
- Throughput Optimized HDD (st1)
  - Big Data, Data Warehouses, Log Processing
  - **Max throughput** 500 MiB/s – max IOPS 500
- Cold HDD (sc1):
  - For data that is infrequently accessed
  - Scenarios where lowest cost is important
  - **Max throughput** 250 MiB/s – max IOPS 250

EBS – Volume Types Summary

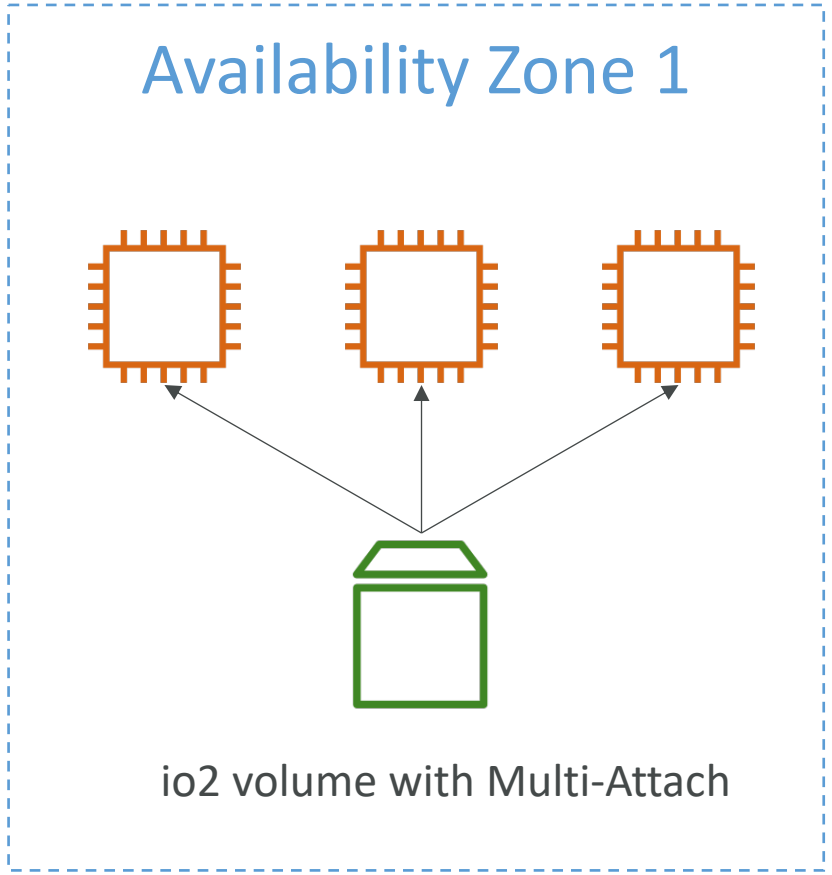
	General Purpose SSD		Provisioned IOPS SSD		
Volume type	gp3	gp2	io2 Block Express ‡	io2	io1
Durability	99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)	99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)	99.999% durability (0.001% annual failure rate)		99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)
Use cases	• Low-latency interactive apps • Development and test environments		Workloads that require sub-millisecond latency, and sustained IOPS performance or more than 64,000 IOPS or 1,000 MiB/s of throughput	• Workloads that require sustained IOPS performance or more than 16,000 IOPS • I/O-intensive database workloads	
Volume size	1 GiB - 16 TiB		4 GiB - 64 TiB	4 GiB - 16 TiB	
Max IOPS per volume (16 KiB I/O)	16,000		256,000	64,000 †	

	Throughput Optimized HDD	Cold HDD
Volume type	st1	sc1
Durability	99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)	99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)
Use cases	• Big data • Data warehouses • Log processing	• Throughput-oriented storage for data that is infrequently accessed • Scenarios where the lowest storage cost is important
Volume size	125 GiB - 16 TiB	125 GiB - 16 TiB
Max IOPS per volume (1 MiB I/O)	500	250
Max throughput per volume	500 MiB/s	250 MiB/s
Amazon EBS Multi-attach	Not supported	Not supported
Boot volume	Not supported	Not supported

https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/ebs-volume-types.html#solid-state-drives

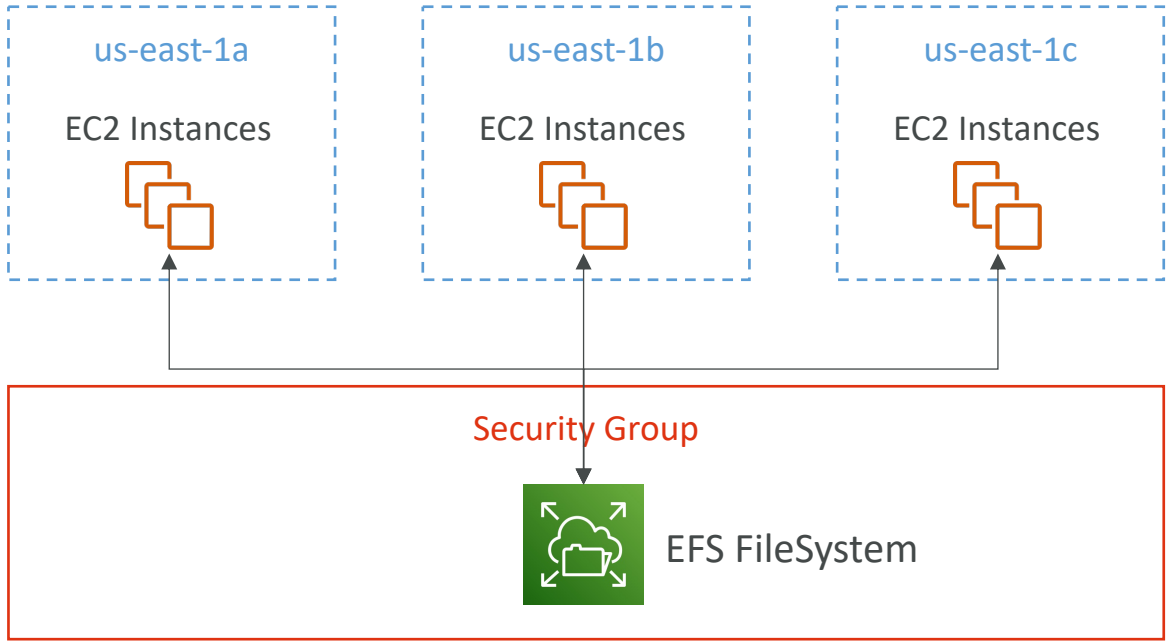
EBS Multi-Attach – io1/io2 family

- Attach the same EBS volume to multiple EC2 instances in the same AZ
- Each instance has full read & write permissions to the high-performance volume
- Use case:
  - Achieve **higher application availability** in clustered Linux applications (ex: Teradata)
  - Applications must manage concurrent write operations
- **Up to 16 EC2 Instances at a time**
- Must use a file system that's cluster-aware (not XFS, EX4, etc…)



EFS – Elastic File System

- Managed NFS (network file system) that can be mounted on many EC2
- EFS works with EC2 instances in multi-AZ
- Highly available, scalable, expensive (3x gp2), pay per use



EFS – Elastic File System

- Use cases: content management, web serving, data sharing, Wordpress
- Uses NFSv4.1 protocol
- Uses security group to control access to EFS
- **Compatible with Linux based AMI (not Windows)**
- Encryption at rest using KMS

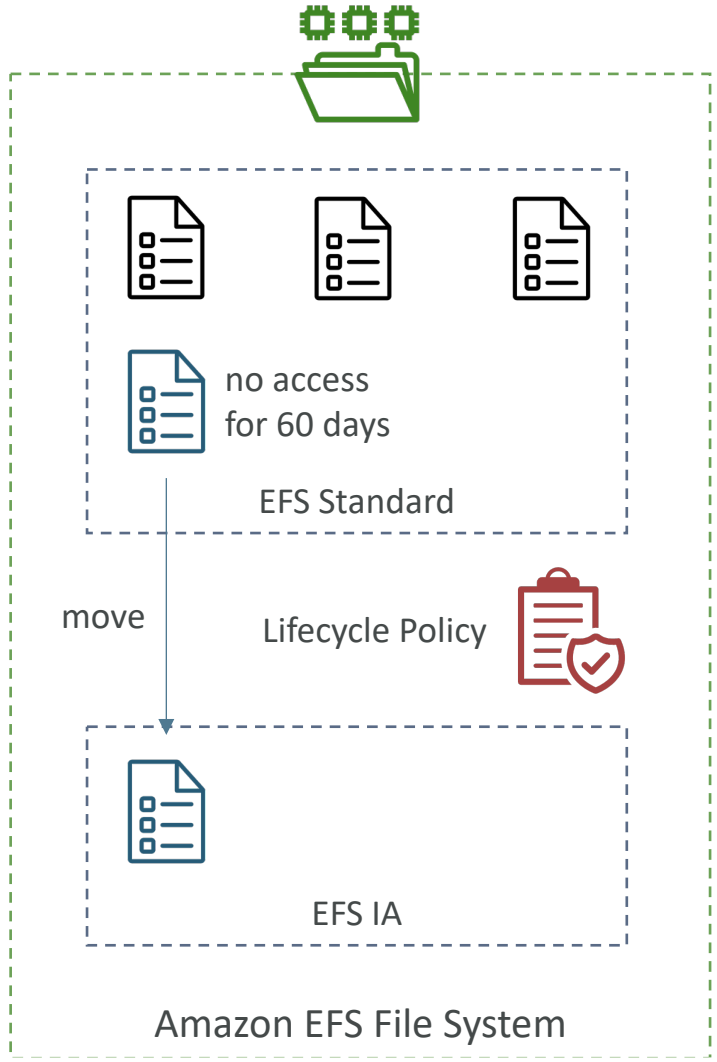
- POSIX file system (~Linux) that has a standard file API
- File system scales automatically, pay-per-use, no capacity planning!

EFS – Performance & Storage Classes

- EFS Scale
  - 1000s of concurrent NFS clients, 10 GB+ /s throughput
  - Grow to Petabyte-scale network file system, automatically
- Performance mode (set at EFS creation time)
  - General purpose (default): latency-sensitive use cases (web server, CMS, etc…)
  - Max I/O – higher latency, throughput, highly parallel (big data, media processing)
- Throughput mode
  - Bursting (1 TB = 50MiB/s + burst of up to 100MiB/s)
  - Provisioned: set your throughput regardless of storage size, ex: 1 GiB/s for 1 TB storage

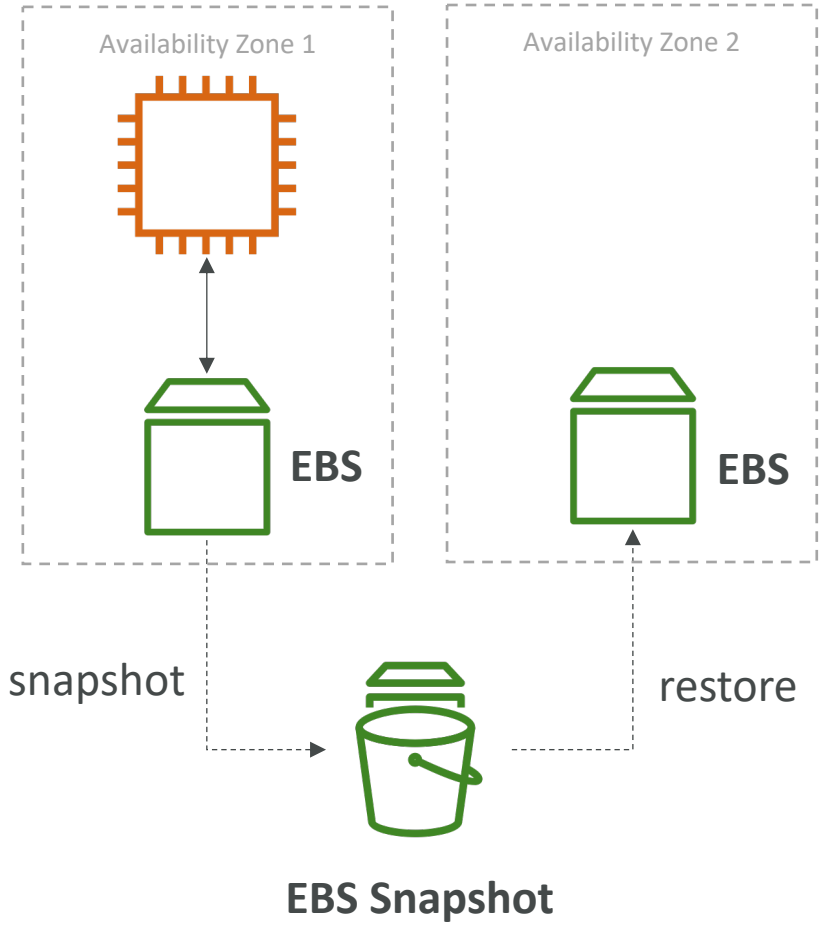
EFS – Storage Classes

- Storage Tiers (lifecycle management feature – move file after N days)
  - Standard: for frequently accessed files
  - Infrequent access (EFS-IA): cost to retrieve files, lower price to store. Enable EFS-IA with a Lifecycle Policy
- Availability and durability
  - Standard: Multi-AZ, great for prod
  - One Zone: One AZ, great for dev, backup enabled by default, compatible with IA (EFS One Zone-IA)
- Over 90% in cost savings



EBS vs EFS – Elastic Block Storage

- EBS volumes…
  - one instance (except multi-attach io1/io2)
  - are locked at the Availability Zone (AZ) level
  - gp2: IO increases if the disk size increases
  - io1: can increase IO independently
- To migrate an EBS volume across AZ
  - Take a snapshot
  - Restore the snapshot to another AZ
  - EBS backups use IO and you shouldn't run them while your application is handling a lot of traffic
- Root EBS Volumes of instances get terminated by default if the EC2 instance gets terminated. (you can disable that)

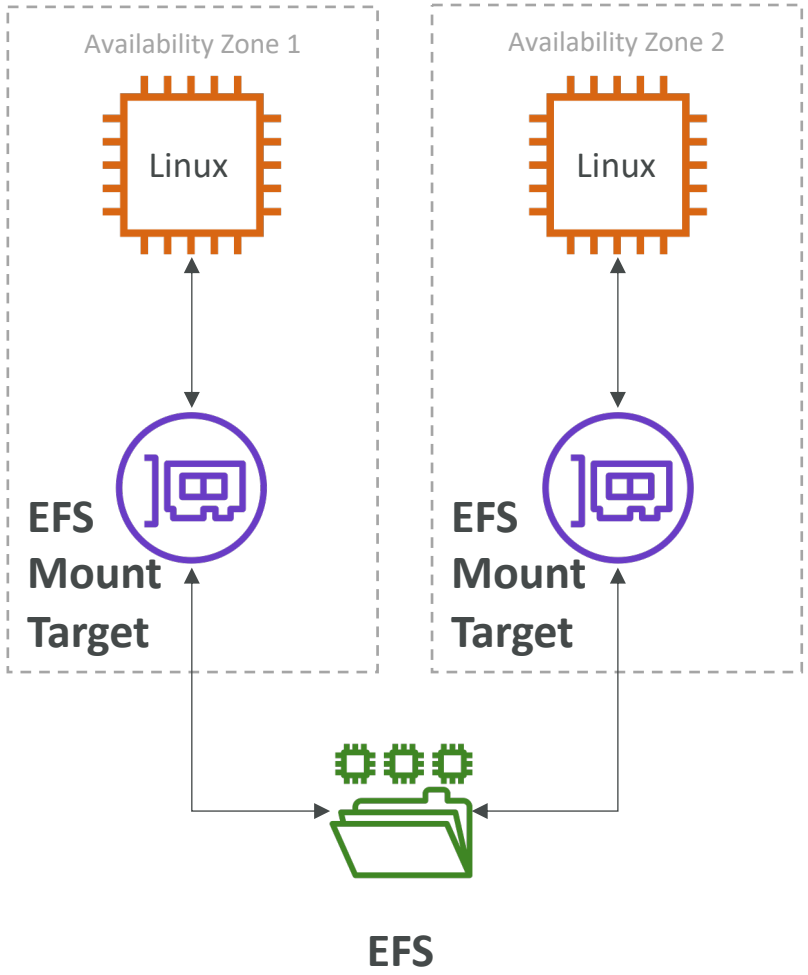


EBS vs EFS – Elastic File System

- Mounting 100s of instances across AZ
- EFS share website files (WordPress)
- Only for Linux Instances (POSIX)

- EFS has a higher price point than EBS
- Can leverage EFS-IA for cost savings

- Remember: EFS vs EBS vs Instance Store



AWS Fundamentals – Part II

Load Balancing, Auto Scaling Groups and EBS Volumes

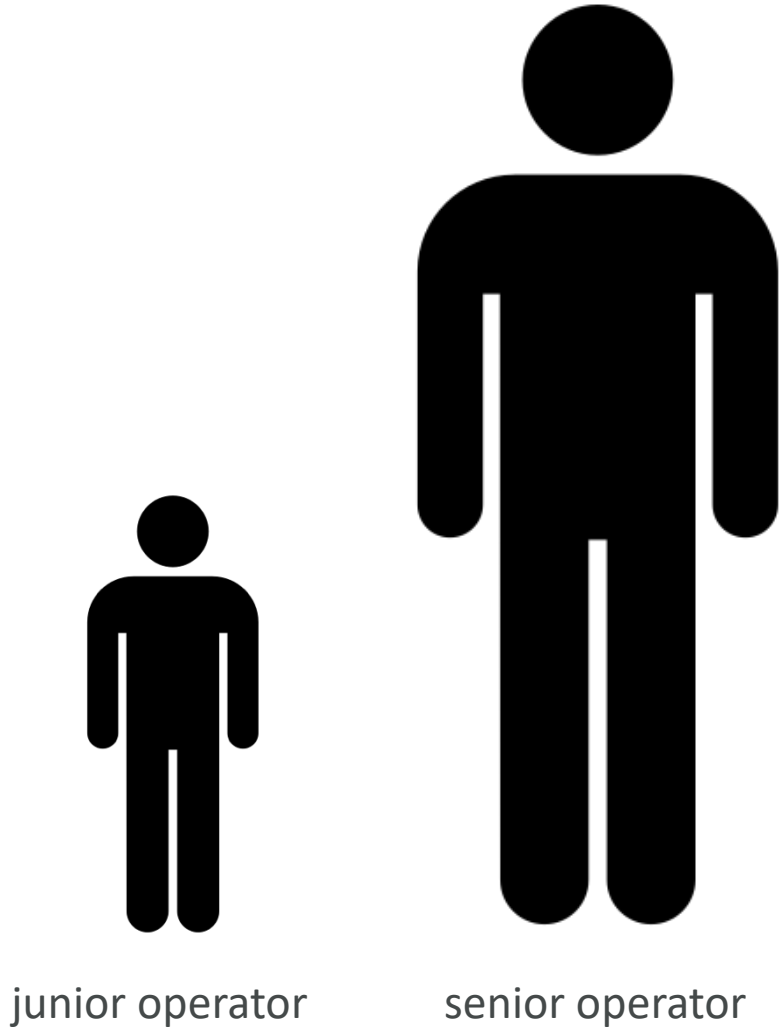
Scalability & High Availability

- Scalability means that an application / system can handle greater loads by adapting.
- There are two kinds of scalability:
  - Vertical Scalability
  - Horizontal Scalability (= elasticity)
- **Scalability is linked but different to High Availability**

- Let's deep dive into the distinction, using a call center as an example

Vertical Scalability

- Vertically scalability means increasing the size of the instance
- For example, your application runs on a t2.micro
- Scaling that application vertically means running it on a t2.large
- Vertical scalability is very common for non distributed systems, such as a database.
- RDS, ElastiCache are services that can scale vertically.
- There's usually a limit to how much you can vertically scale (hardware limit)

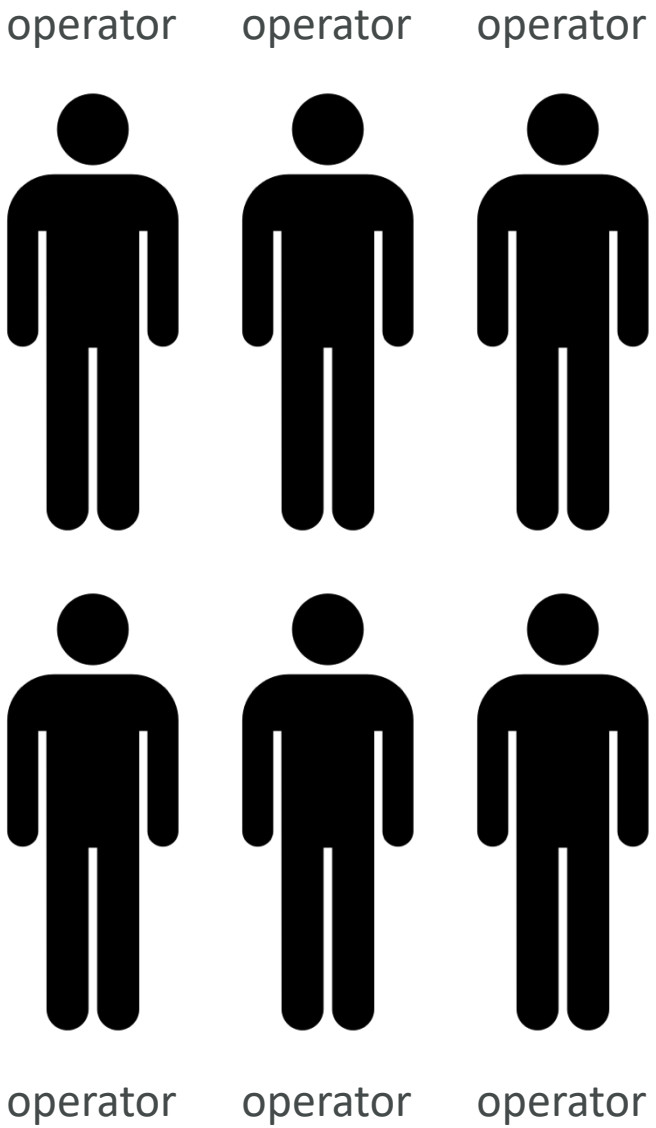


Horizontal Scalability

- Horizontal Scalability means increasing the number of instances / systems for your application

- Horizontal scaling implies distributed systems.
- This is very common for web applications / modern applications

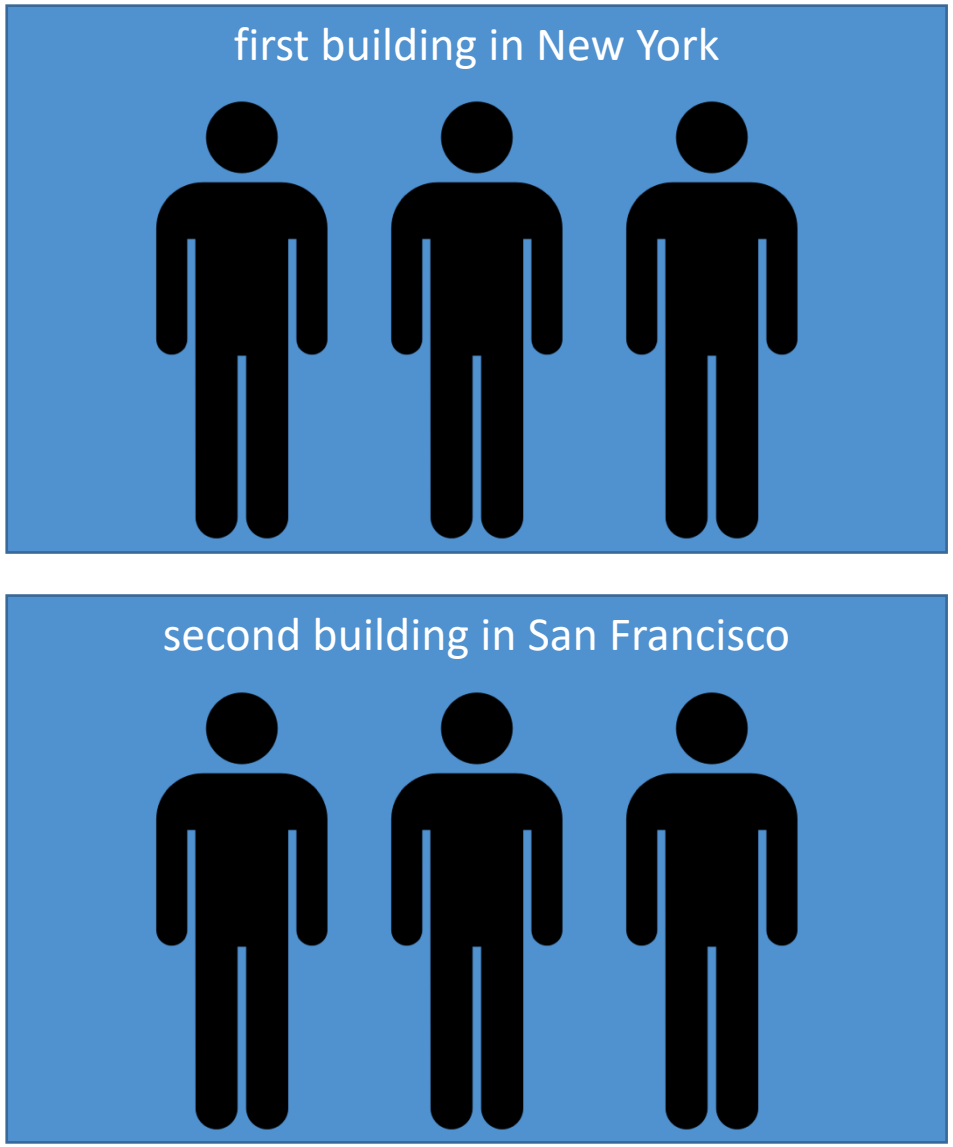
- It's easy to horizontally scale thanks the cloud offerings such as Amazon EC2



High Availability

- High Availability usually goes hand in hand with horizontal scaling
- High availability means running your application / system in at least 2 data centers (== Availability Zones)
- The goal of high availability is to survive a data center loss

- The high availability can be passive (for RDS Multi AZ for example)
- The high availability can be active (for horizontal scaling)

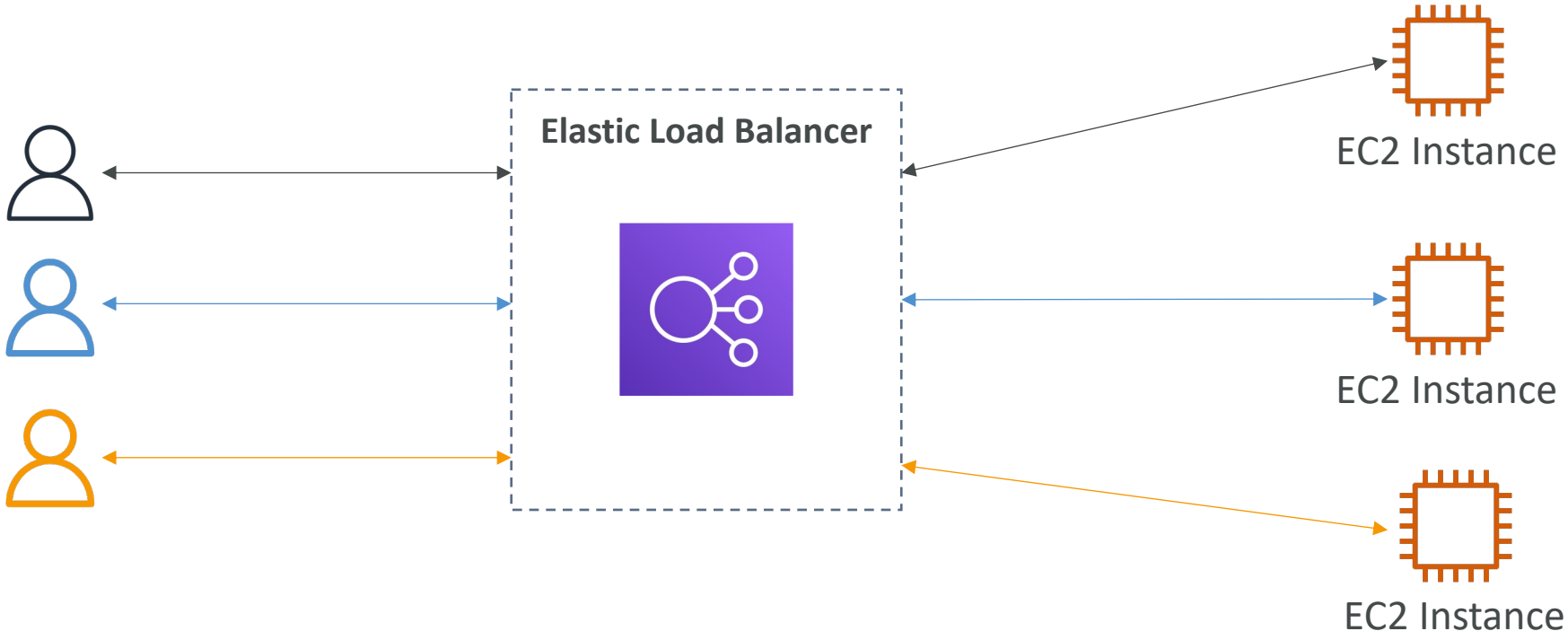


High Availability & Scalability For EC2

- Vertical Scaling: Increase instance size (= scale up / down)
  - From: t2.nano - 0.5G of RAM, 1 vCPU
  - To: u-12tb1.metal – 12.3 TB of RAM, 448 vCPUs
- Horizontal Scaling: Increase number of instances (= scale out / in)
  - Auto Scaling Group
  - Load Balancer
- High Availability: Run instances for the same application across multi AZ
  - Auto Scaling Group multi AZ
  - Load Balancer multi AZ

What is load balancing?

- Load Balances are servers that forward traffic to multiple servers (e.g., EC2 instances) downstream



Why use a load balancer?

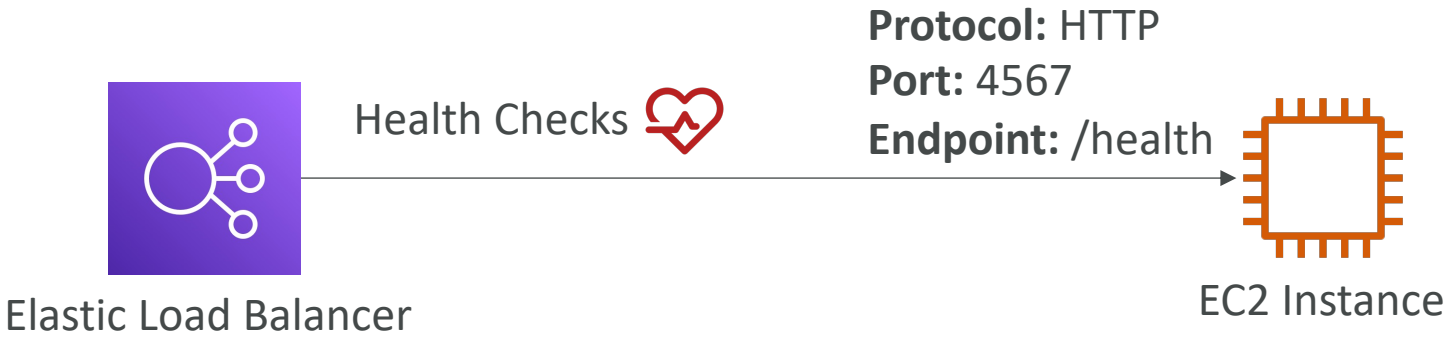
- Spread load across multiple downstream instances
- Expose a single point of access (DNS) to your application
- Seamlessly handle failures of downstream instances
- Do regular health checks to your instances
- Provide SSL termination (HTTPS) for your websites
- Enforce stickiness with cookies
- High availability across zones
- Separate public traffic from private traffic

Why use an Elastic Load Balancer?

- An Elastic Load Balancer is a managed load balancer
  - AWS guarantees that it will be working
  - AWS takes care of upgrades, maintenance, high availability
  - AWS provides only a few configuration knobs
- It costs less to setup your own load balancer but it will be a lot more effort on your end
- It is integrated with many AWS offerings / services
  - EC2, EC2 Auto Scaling Groups, Amazon ECS
  - AWS Certificate Manager (ACM), CloudWatch
  - Route 53, AWS WAF, AWS Global Accelerator

Health Checks

- Health Checks are crucial for Load Balancers
- They enable the load balancer to know if instances it forwards traffic to are available to reply to requests
- The health check is done on a port and a route (/health is common)
- If the response is not 200 (OK), then the instance is unhealthy

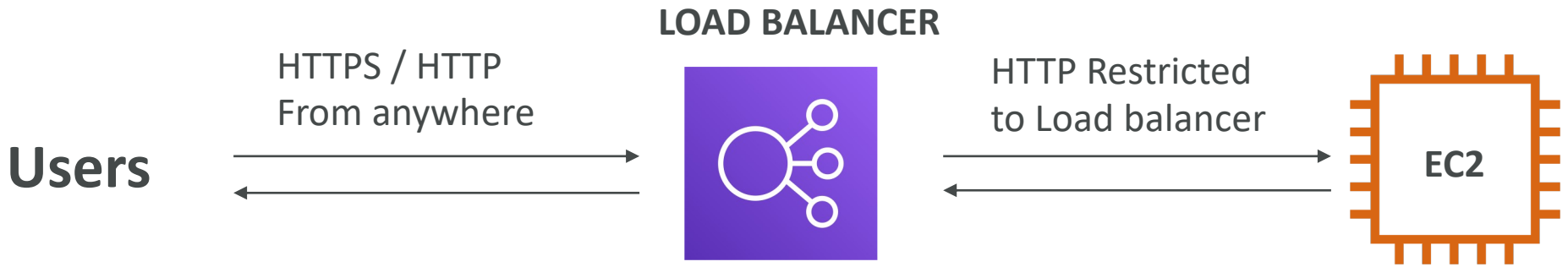


Types of load balancer on AWS

- AWS has 4 kinds of managed Load Balancers
- Classic Load Balancer (v1 - old generation) – 2009 – CLB
  - HTTP, HTTPS, TCP, SSL (secure TCP)
- Application Load Balancer (v2 - new generation) – 2016 – ALB
  - HTTP, HTTPS, WebSocket
- Network Load Balancer (v2 - new generation) – 2017 – NLB
  - TCP, TLS (secure TCP), UDP
- Gateway Load Balancer – 2020 – GWLB
  - Operates at layer 3 (Network layer) – IP Protocol

- Overall, it is recommended to use the newer generation load balancers as they provide more features
- Some load balancers can be setup as internal (private) or external (public) ELBs

Load Balancer Security Groups



Load Balancer Security Group:

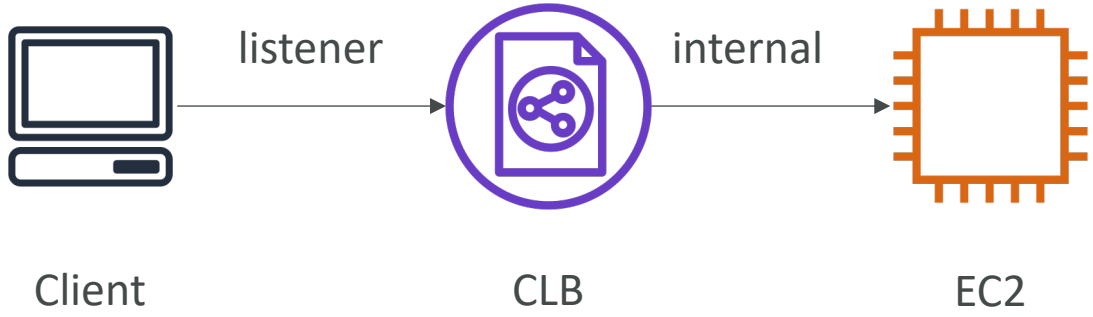
Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	0.0.0.0/0	Allow HTTP from an...
HTTPS	TCP	443	0.0.0.0/0	Allow HTTPS from a...

Application Security Group: Allow traffic only from Load Balancer

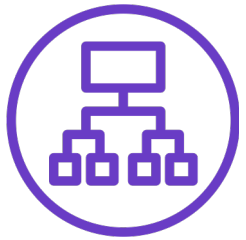
Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	sg-054b5ff5ea02f2b6e (load-b	Allow Traffic only...

Classic Load Balancers (v1)

- Supports TCP (Layer 4), HTTP & HTTPS (Layer 7)
- Health checks are TCP or HTTP based
- Fixed hostname XXX.region.elb.amazonaws.com



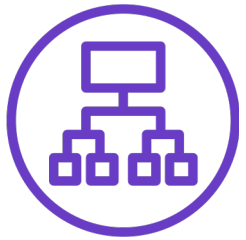
Application Load Balancer (v2)



- Application load balancers is Layer 7 (HTTP)

- Load balancing to multiple HTTP applications across machines (target groups)
- Load balancing to multiple applications on the same machine (ex: containers)
- Support for HTTP/2 and WebSocket
- Support redirects (from HTTP to HTTPS for example)

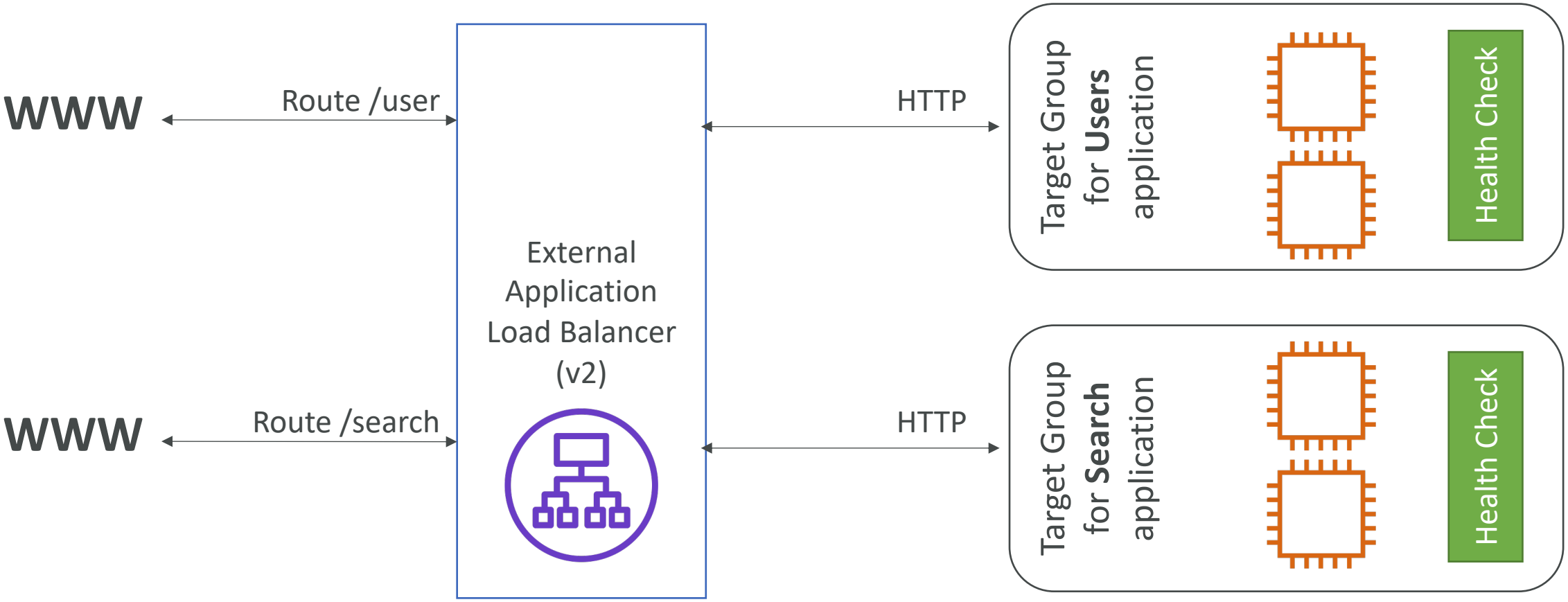
Application Load Balancer (v2)



- Routing tables to different target groups:
  - Routing based on path in URL (example.com/users & example.com/posts)
  - Routing based on hostname in URL (one.example.com & other.example.com)
  - Routing based on Query String, Headers (example.com/users?id=123&order=false)

- ALB are a great fit for micro services & container-based application (example: Docker & Amazon ECS)
- Has a port mapping feature to redirect to a dynamic port in ECS
- In comparison, we'd need multiple Classic Load Balancer per application

Application Load Balancer (v2)
HTTP Based Traffic

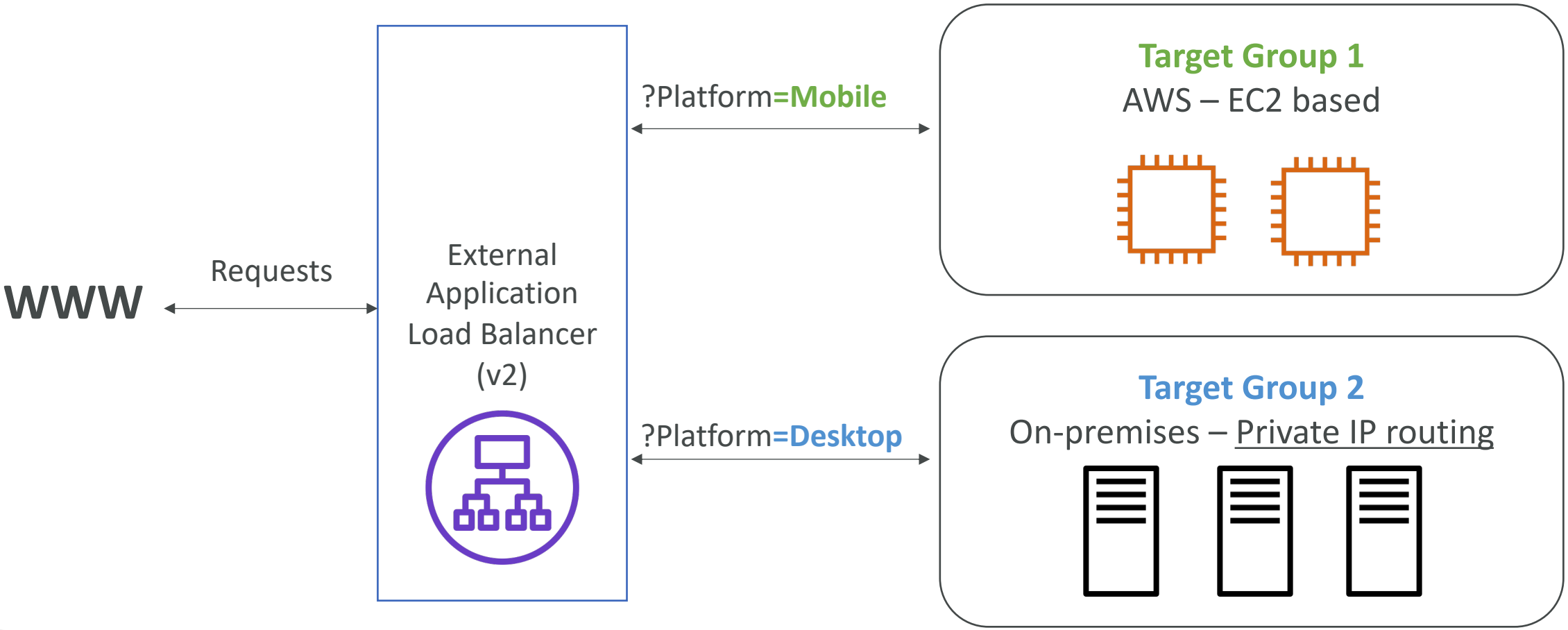


Application Load Balancer (v2) Target Groups

- EC2 instances (can be managed by an Auto Scaling Group) – HTTP
- ECS tasks (managed by ECS itself) – HTTP
- Lambda functions – HTTP request is translated into a JSON event
- IP Addresses – must be private IPs

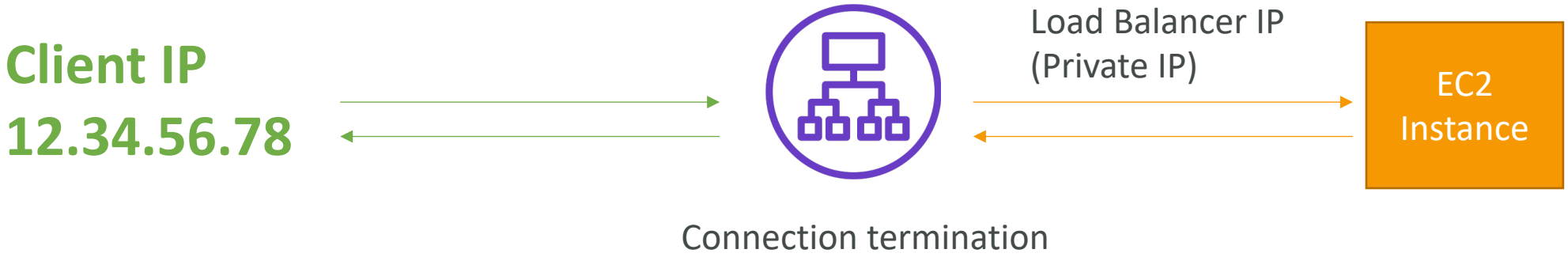
- ALB can route to multiple target groups
- Health checks are at the target group level

Application Load Balancer (v2) Query Strings/Parameters Routing

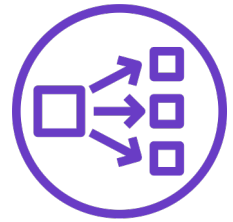


Application Load Balancer (v2)
Good to Know

- Fixed hostname (XXX.region.elb.amazonaws.com)
- The application servers don't see the IP of the client directly
  - The true IP of the client is inserted in the header **X-Forwarded-For**
  - We can also get Port (X-Forwarded-Port) and proto (X-Forwarded-Proto)



Network Load Balancer (v2)

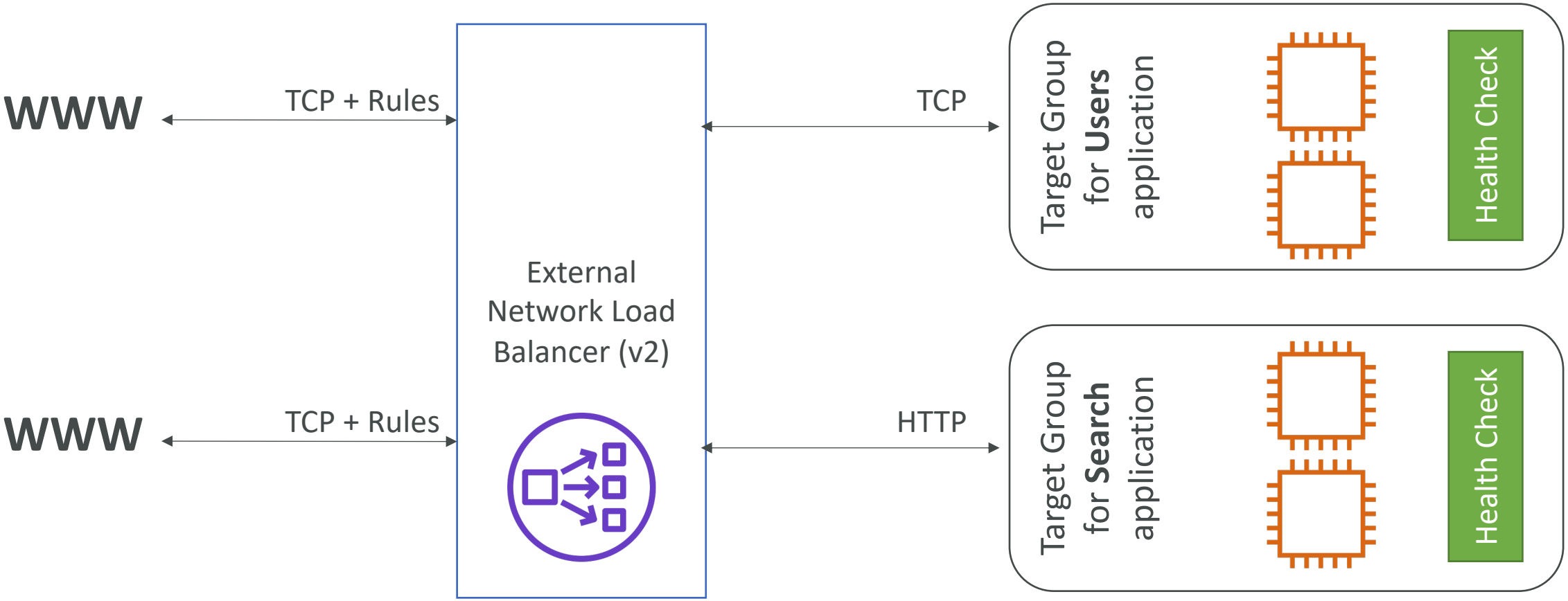


- Network load balancers (Layer 4) allow to:
  - **Forward TCP & UDP traffic to your instances**
  - Handle millions of request per seconds
  - Less latency ~100 ms (vs 400 ms for ALB)

- **NLB has one static IP per AZ, and supports assigning Elastic IP** (helpful for whitelisting specific IP)

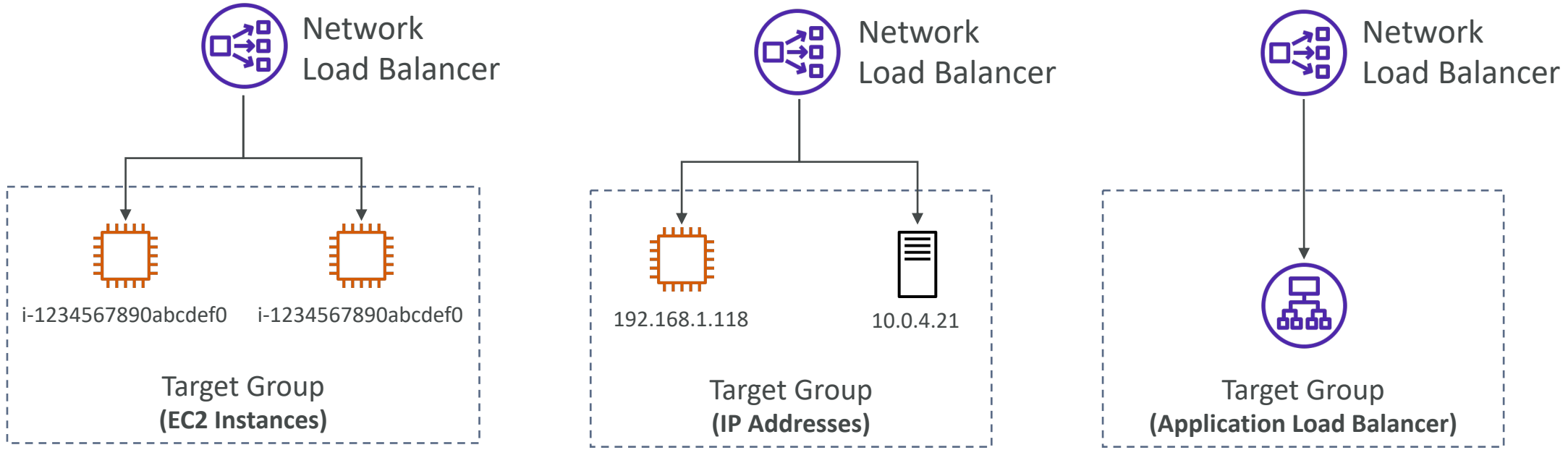
- NLB are used for extreme performance, TCP or UDP traffic
- Not included in the AWS free tier

Network Load Balancer (v2)
TCP (Layer 4) Based Traffic



Network Load Balancer – Target Groups

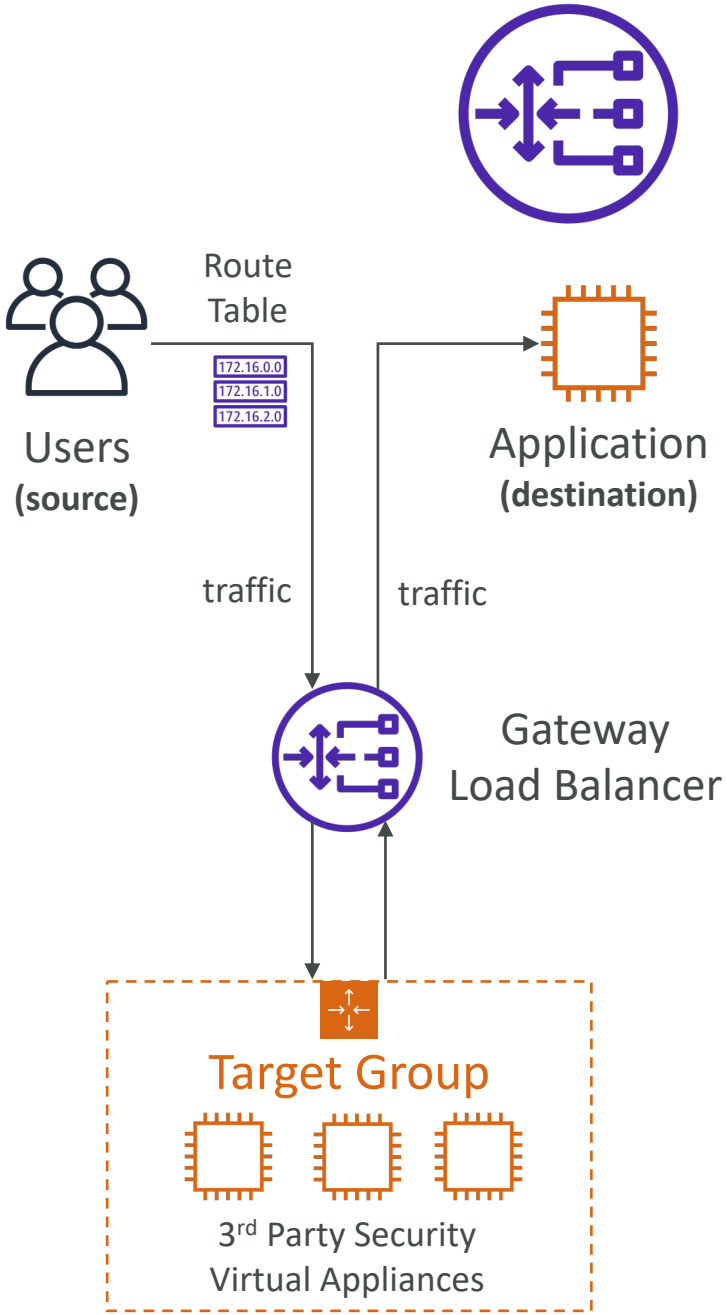
- EC2 instances
- IP Addresses – must be private IPs
- Application Load Balancer
- Health Checks support the TCP, HTTP and HTTPS Protocols



Gateway Load Balancer

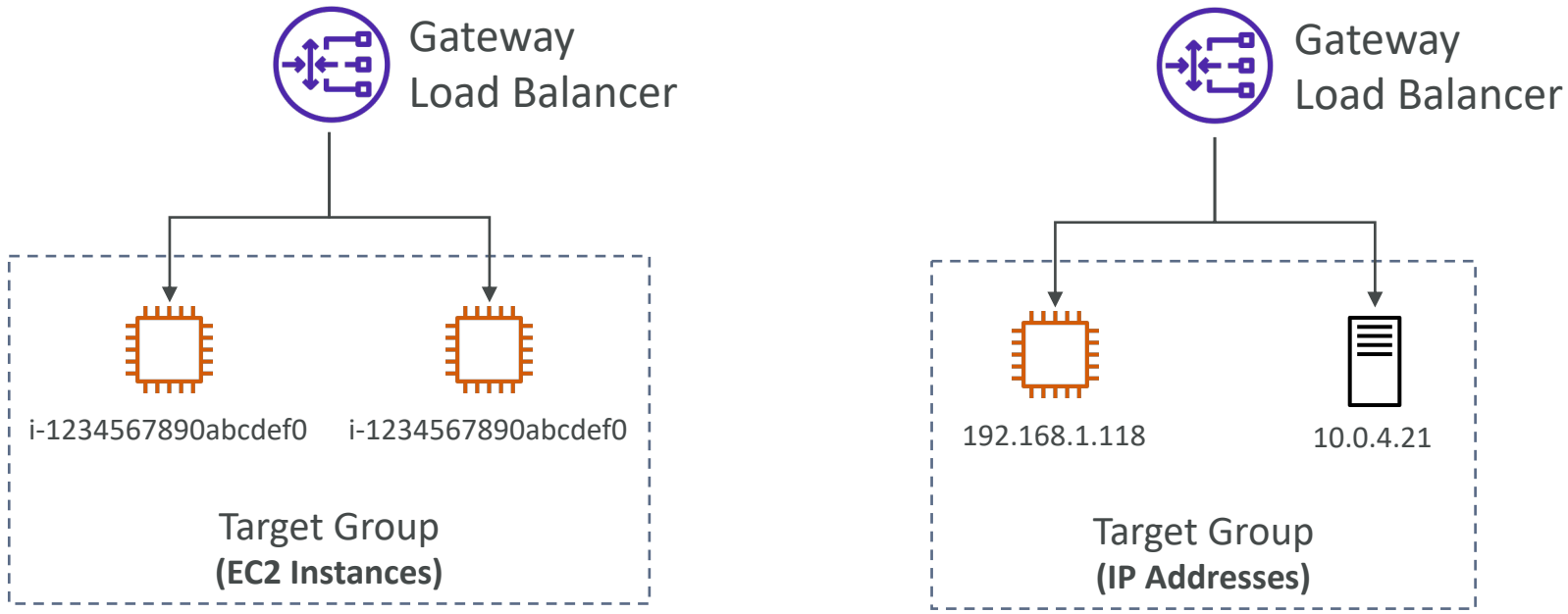
- Deploy, scale, and manage a fleet of 3rd party network virtual appliances in AWS
- Example: Firewalls, Intrusion Detection and Prevention Systems, Deep Packet Inspection Systems, payload manipulation, …

- Operates at Layer 3 (Network Layer) – IP Packets
- Combines the following functions:
  - **Transparent Network Gateway** – single entry/exit for all traffic
  - **Load Balancer** – distributes traffic to your virtual appliances
- Uses the **GENEVE** protocol on port **6081**



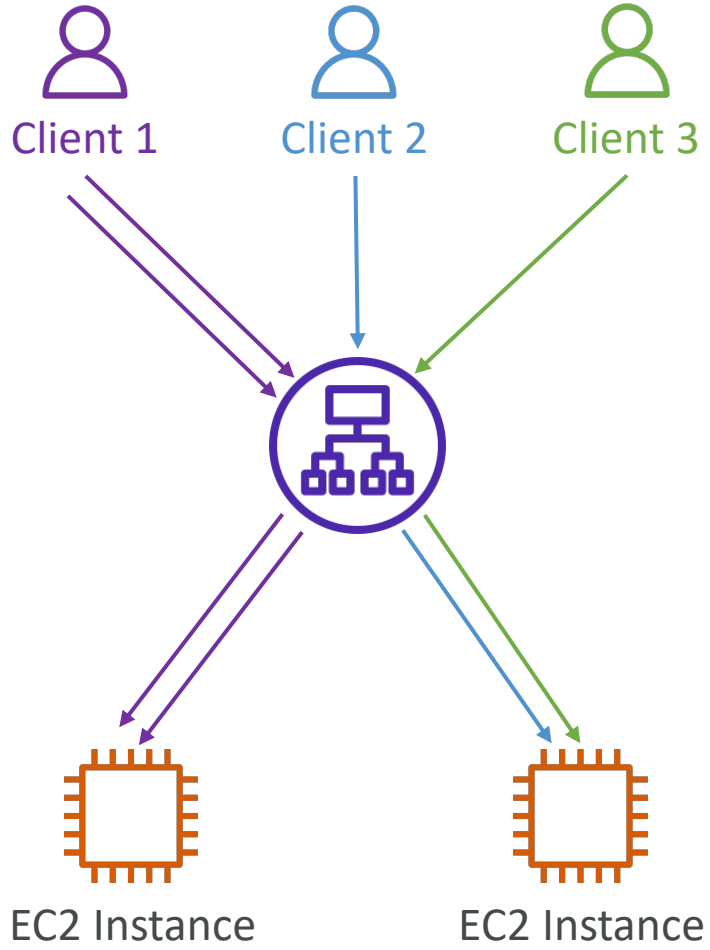
Gateway Load Balancer – Target Groups

- EC2 instances
- IP Addresses – must be private IPs



Sticky Sessions (Session Affinity)

- It is possible to implement stickiness so that the same client is always redirected to the same instance behind a load balancer
- This works for Classic Load Balancers & Application Load Balancers
- The "cookie" used for stickiness has an expiration date you control
- Use case: make sure the user doesn't lose his session data
- Enabling stickiness may bring imbalance to the load over the backend EC2 instances



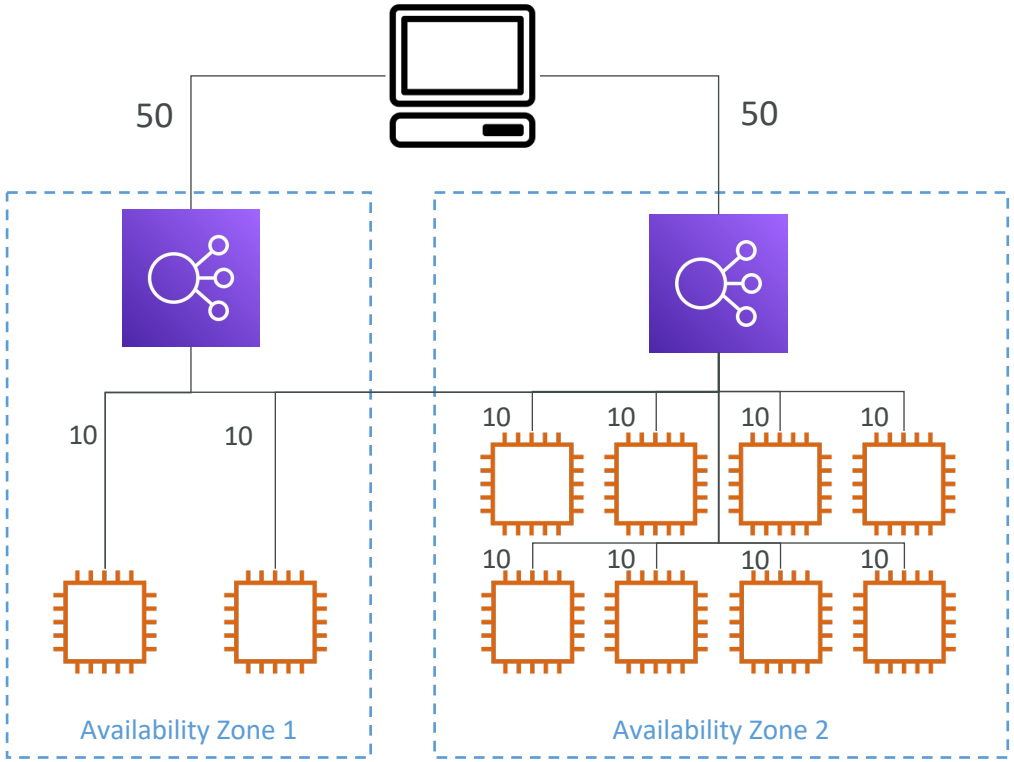
Sticky Sessions – Cookie Names

- Application-based Cookies
  - Custom cookie
    - Generated by the target
    - Can include any custom attributes required by the application
    - Cookie name must be specified individually for each target group
    - Don't use **AWSALB**, **AWSALBAPP**, or **AWSALBTG** (reserved for use by the ELB)
  - Application cookie
    - Generated by the load balancer
    - Cookie name is **AWSALBAPP**
- Duration-based Cookies
  - Cookie generated by the load balancer
  - Cookie name is **AWSALB** for ALB, **AWSELB** for CLB

Cross-Zone Load Balancing

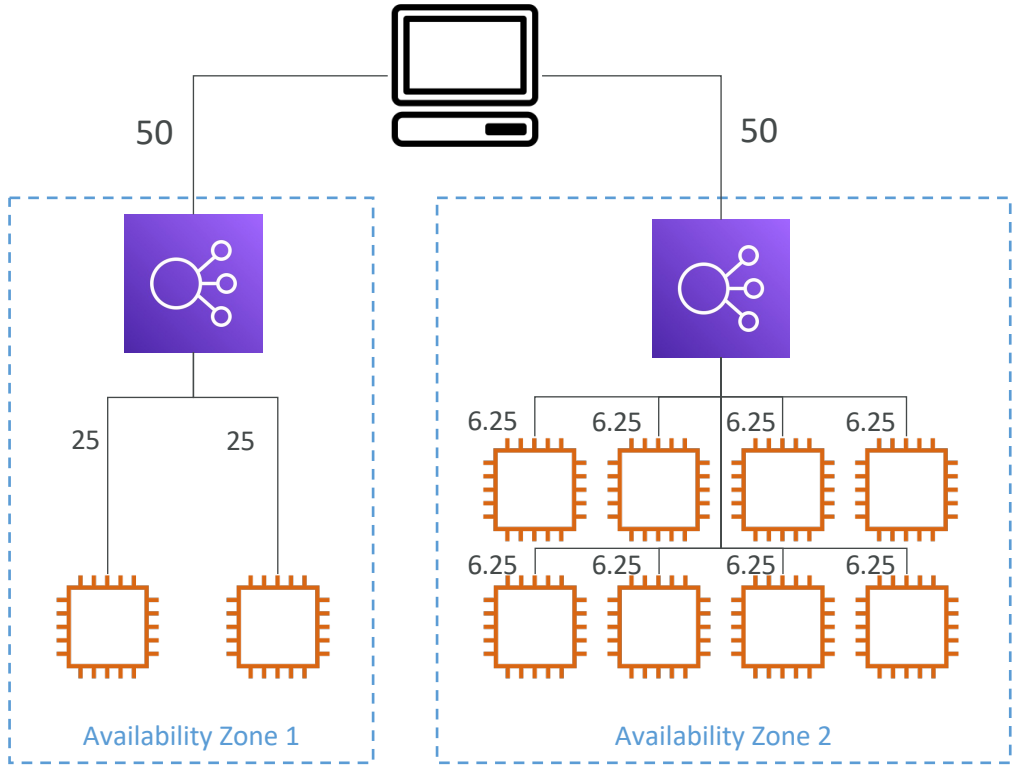
With Cross Zone Load Balancing:

each load balancer instance distributes evenly across all registered instances in all AZ



Without Cross Zone Load Balancing:

Requests are distributed in the instances of the node of the Elastic Load Balancer



Cross-Zone Load Balancing

- Application Load Balancer
  - Enabled by default (can be disabled at the Target Group level)
  - No charges for inter AZ data
- Network Load Balancer & Gateway Load Balancer
  - Disabled by default
  - You pay charges ($) for inter AZ data if enabled
- Classic Load Balancer
  - Disabled by default
  - No charges for inter AZ data if enabled

SSL/TLS - Basics

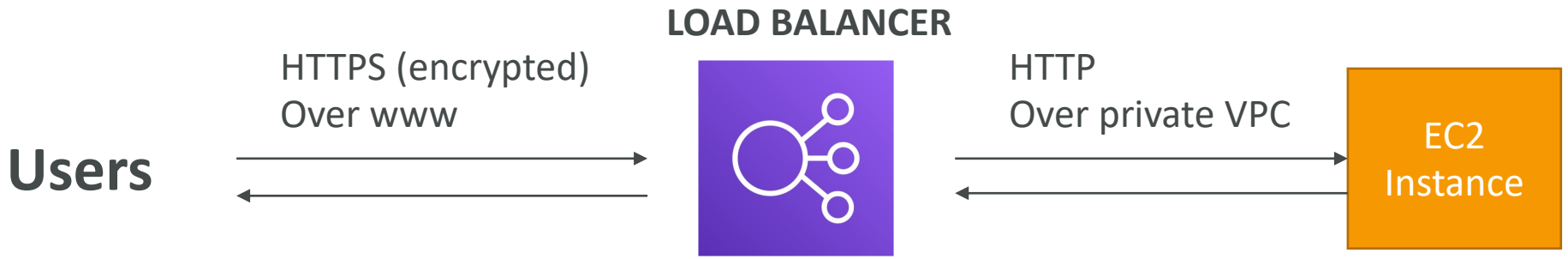
- An SSL Certificate allows traffic between your clients and your load balancer to be encrypted in transit (in-flight encryption)

- **SSL** refers to Secure Sockets Layer, used to encrypt connections
- **TLS** refers to Transport Layer Security, which is a newer version
- Nowadays, **TLS certificates are mainly used**, but people still refer as SSL

- Public SSL certificates are issued by Certificate Authorities (CA)
- Comodo, Symantec, GoDaddy, GlobalSign, Digicert, Letsencrypt, etc…

- SSL certificates have an expiration date (you set) and must be renewed

Load Balancer - SSL Certificates



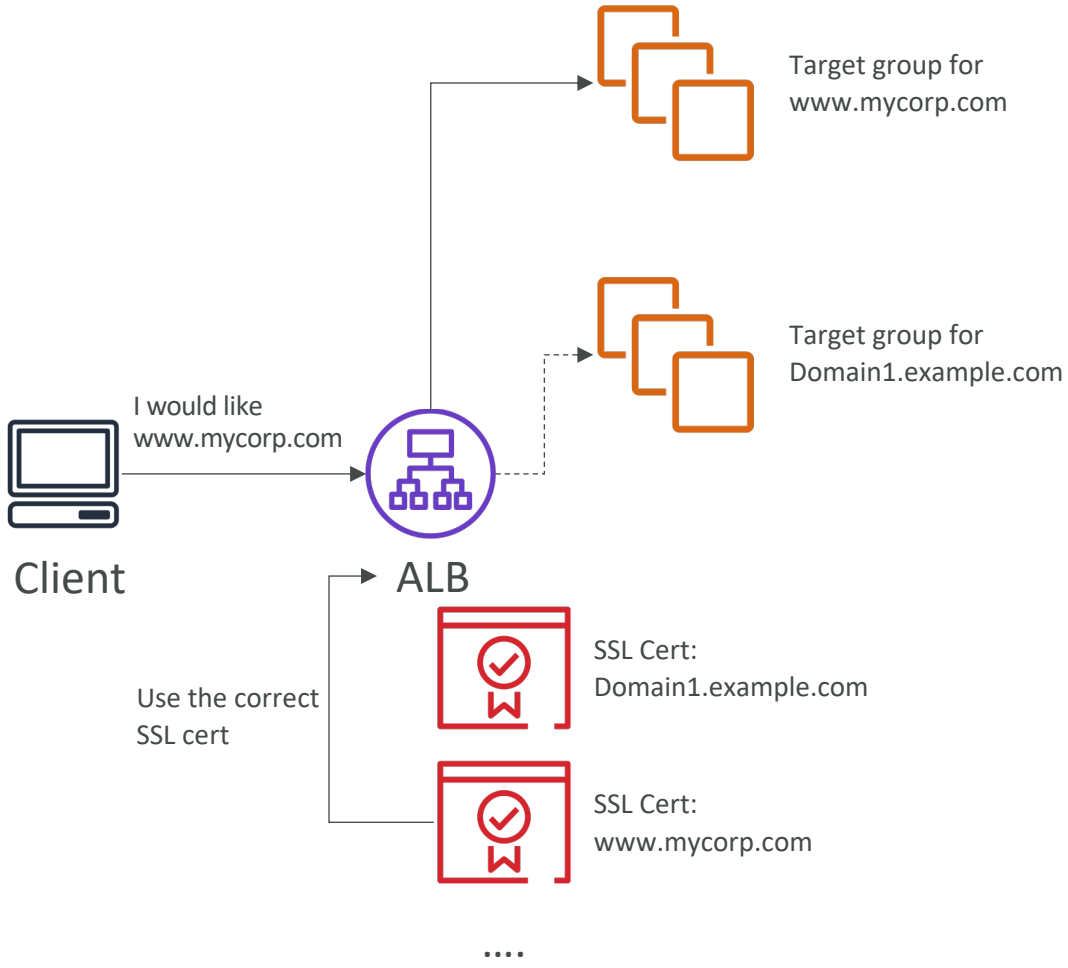
- The load balancer uses an X.509 certificate (SSL/TLS server certificate)
- You can manage certificates using ACM (AWS Certificate Manager)
- You can create upload your own certificates alternatively
- HTTPS listener:
  - You must specify a default certificate
  - You can add an optional list of certs to support multiple domains
  - Clients can use SNI (Server Name Indication) to specify the hostname they reach
  - Ability to specify a security policy to support older versions of SSL / TLS (legacy clients)

SSL – Server Name Indication (SNI)

- SNI solves the problem of loading **multiple SSL certificates onto one web server** (to serve multiple websites)
- It's a "newer" protocol, and requires the client to **indicate** the hostname of the target server in the initial SSL handshake
- The server will then find the correct certificate, or return the default one

Note:

- Only works for ALB & NLB (newer generation), CloudFront
- Does not work for CLB (older gen)



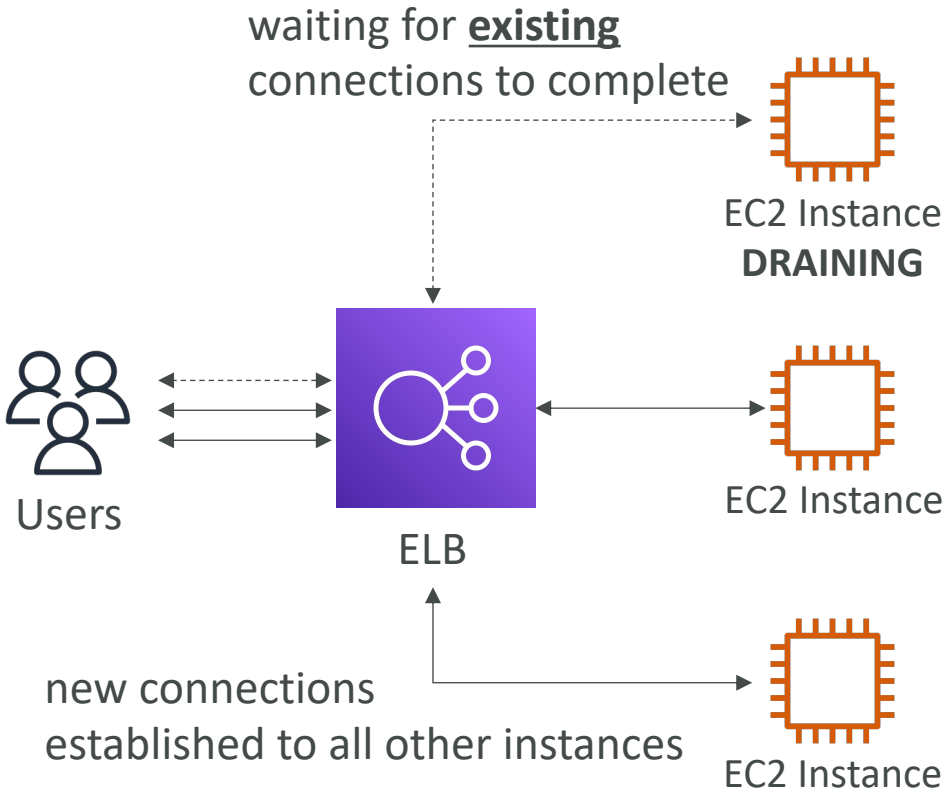
Elastic Load Balancers – SSL Certificates

- Classic Load Balancer (v1)
  - Support only one SSL certificate
  - Must use multiple CLB for multiple hostname with multiple SSL certificates
- Application Load Balancer (v2)
  - Supports multiple listeners with multiple SSL certificates
  - Uses Server Name Indication (SNI) to make it work
- Network Load Balancer (v2)
  - Supports multiple listeners with multiple SSL certificates
  - Uses Server Name Indication (SNI) to make it work

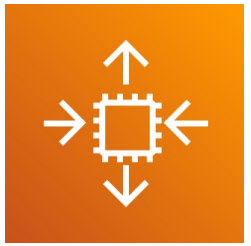
Connection Draining

- Feature naming
  - Connection Draining – for CLB
  - Deregistration Delay – for ALB & NLB

- Time to complete "in-flight requests" while the instance is de-registering or unhealthy
- Stops sending new requests to the EC2 instance which is de-registering
- Between 1 to 3600 seconds (default: 300 seconds)
- Can be disabled (set value to 0)
- Set to a low value if your requests are short



What's an Auto Scaling Group?

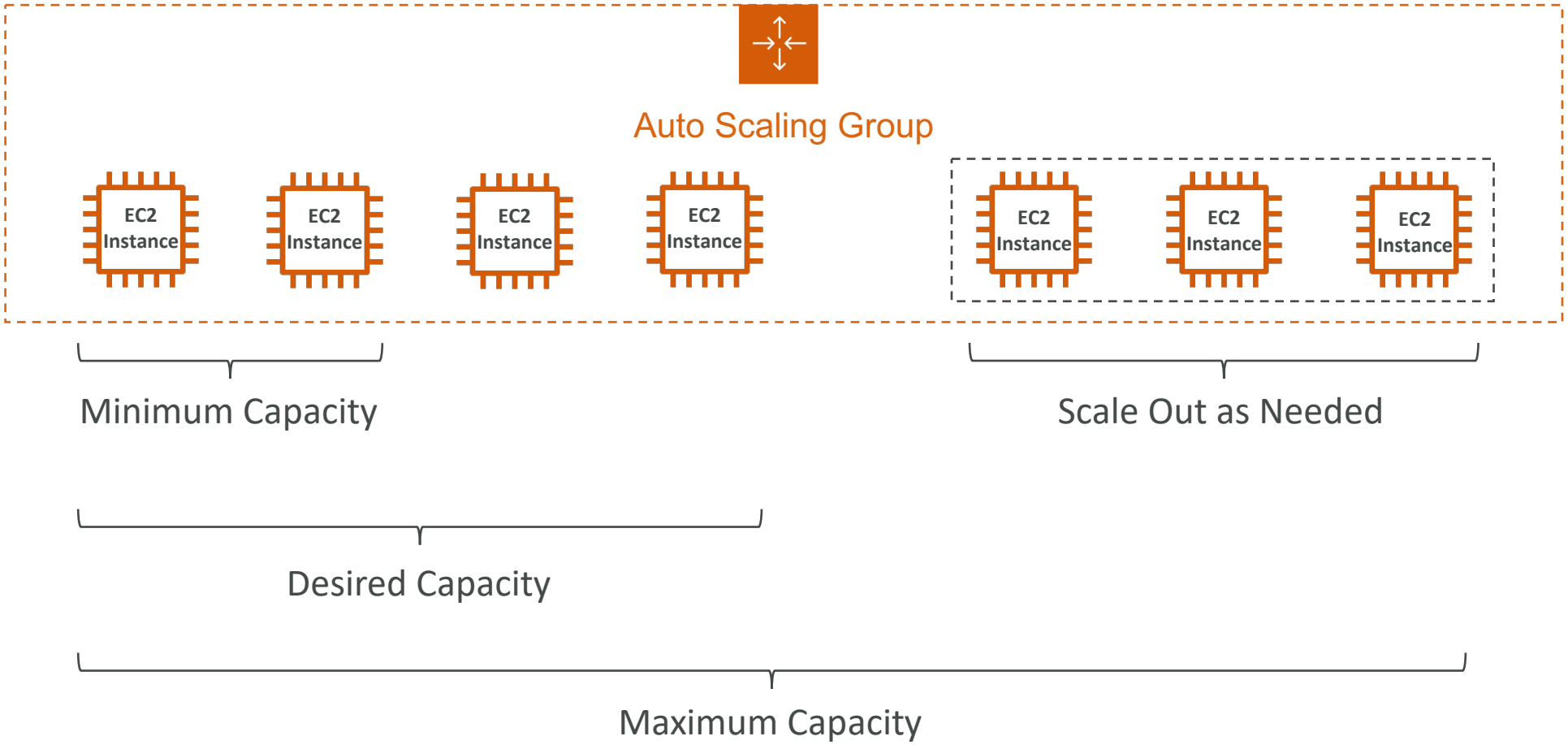


- In real-life, the load on your websites and application can change
- In the cloud, you can create and get rid of servers very quickly

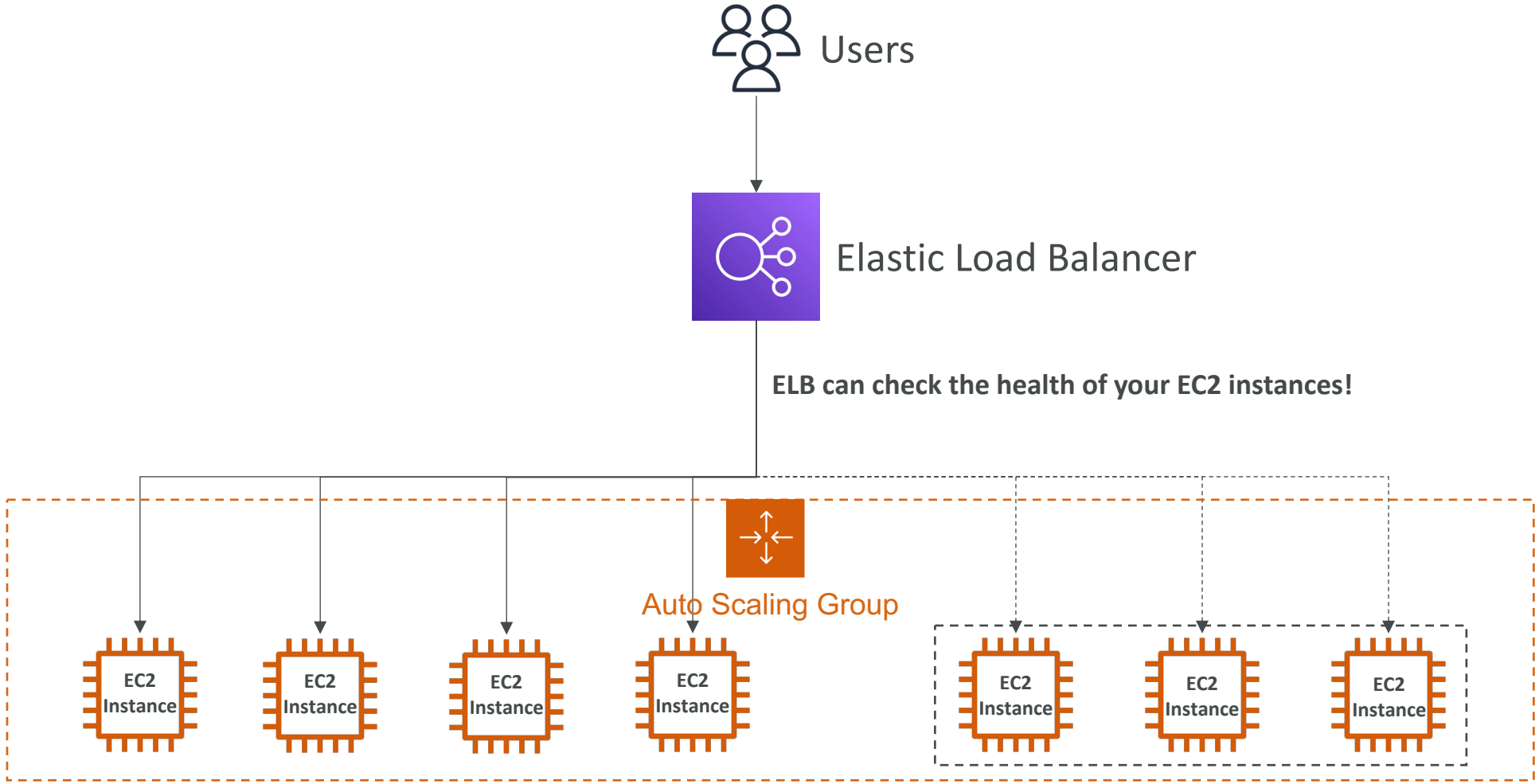
- The goal of an Auto Scaling Group (ASG) is to:
  - Scale out (add EC2 instances) to match an increased load
  - Scale in (remove EC2 instances) to match a decreased load
  - Ensure we have a minimum and a maximum number of EC2 instances running
  - Automatically register new instances to a load balancer
  - Re-create an EC2 instance in case a previous one is terminated (ex: if unhealthy)

- ASG are free (you only pay for the underlying EC2 instances)

Auto Scaling Group in AWS

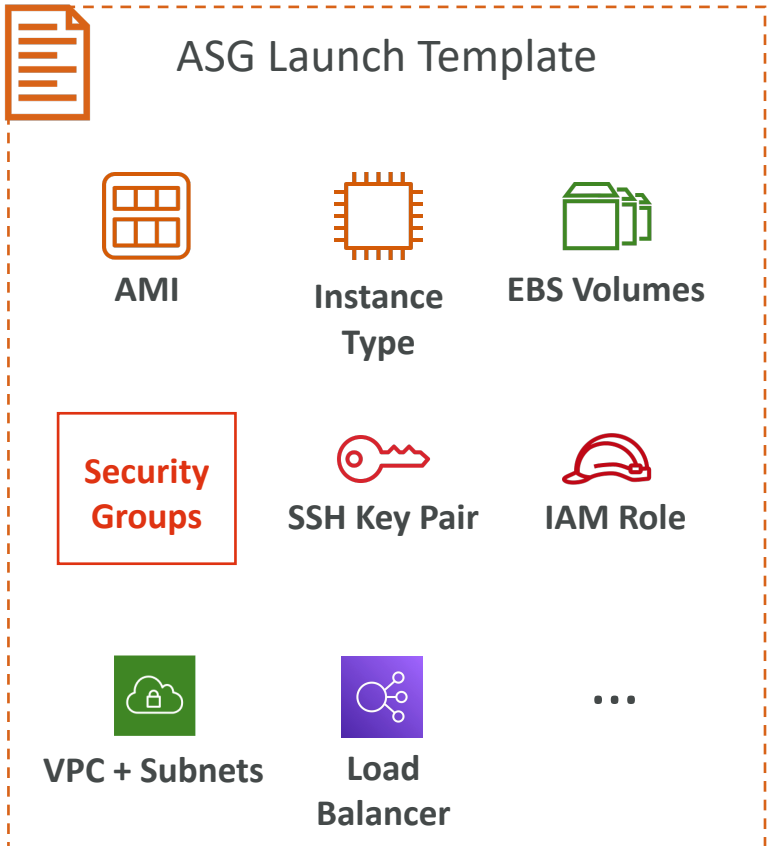


Auto Scaling Group in AWS With Load Balancer



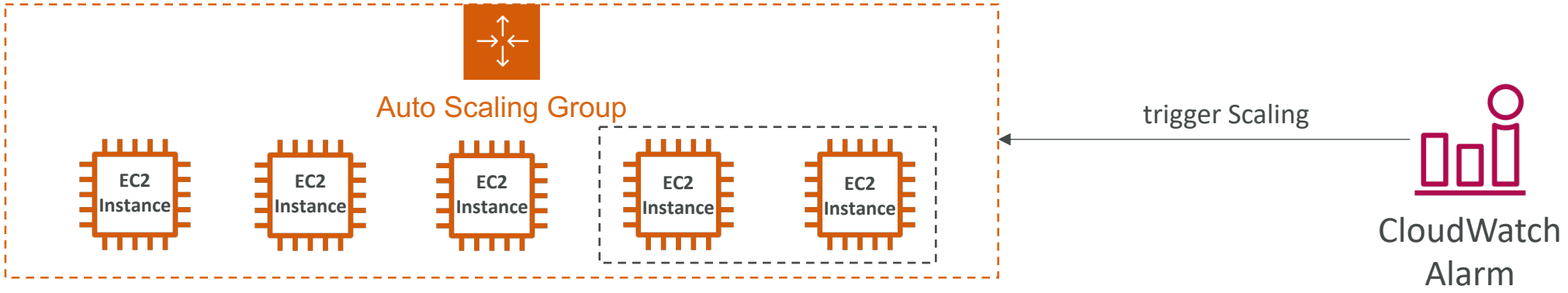
Auto Scaling Group Attributes

- A **Launch Template** (older "Launch Configurations" are deprecated)
  - AMI + Instance Type
  - EC2 User Data
  - EBS Volumes
  - Security Groups
  - SSH Key Pair
  - IAM Roles for your EC2 Instances
  - Network + Subnets Information
  - Load Balancer Information
- Min Size / Max Size / Initial Capacity
- Scaling Policies



Auto Scaling - CloudWatch Alarms & Scaling

- It is possible to scale an ASG based on CloudWatch alarms
- An alarm monitors a metric (such as **Average CPU**, or a **custom metric**)
- Metrics such as Average CPU are computed for the overall ASG instances
- Based on the alarm:
  - We can create scale-out policies (increase the number of instances)
  - We can create scale-in policies (decrease the number of instances)

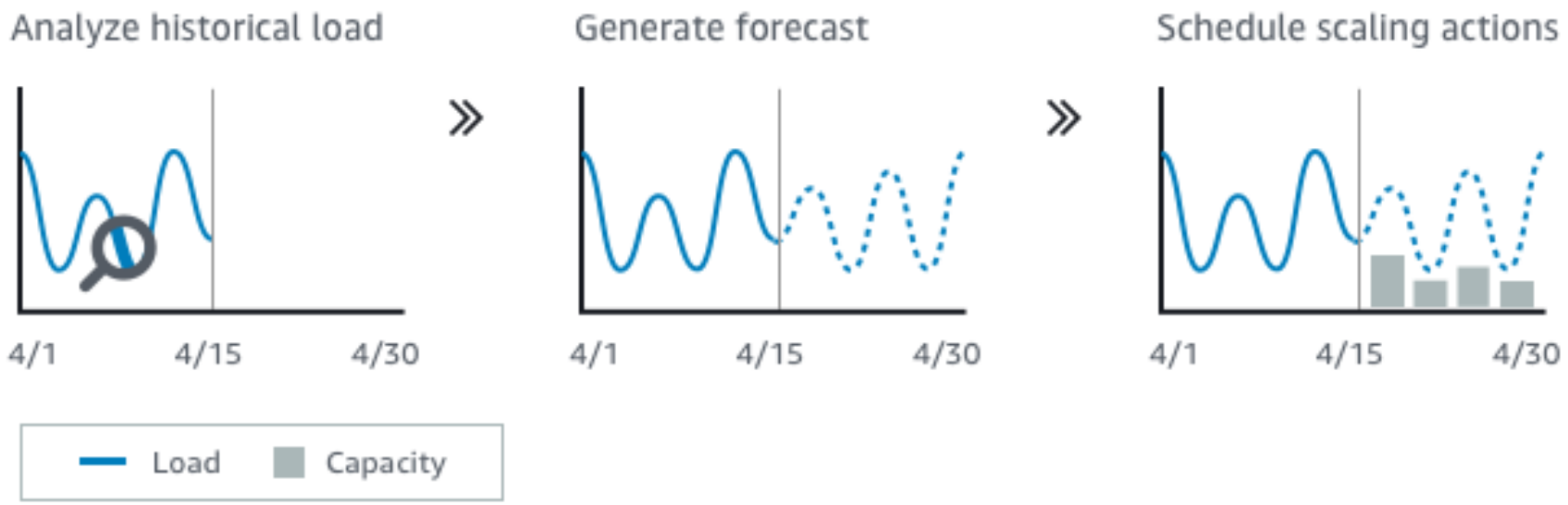


Auto Scaling Groups – Dynamic Scaling Policies

- Target Tracking Scaling
  - Most simple and easy to set-up
  - Example: I want the average ASG CPU to stay at around 40%
- Simple / Step Scaling
  - When a CloudWatch alarm is triggered (example CPU > 70%), then add 2 units
  - When a CloudWatch alarm is triggered (example CPU < 30%), then remove 1
- Scheduled Actions
  - Anticipate a scaling based on known usage patterns
  - Example: increase the min capacity to 10 at 5 pm on Fridays

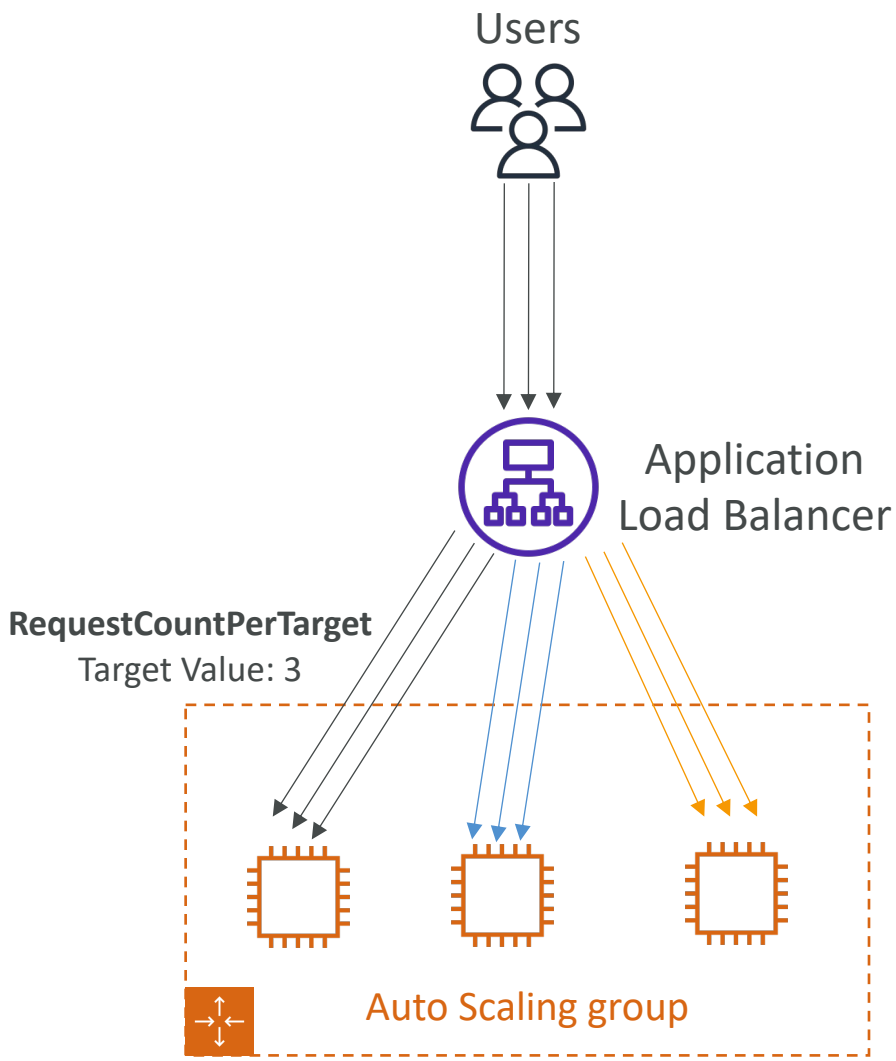
Auto Scaling Groups – Predictive Scaling

- **Predictive scaling:** continuously forecast load and schedule scaling ahead



Good metrics to scale on

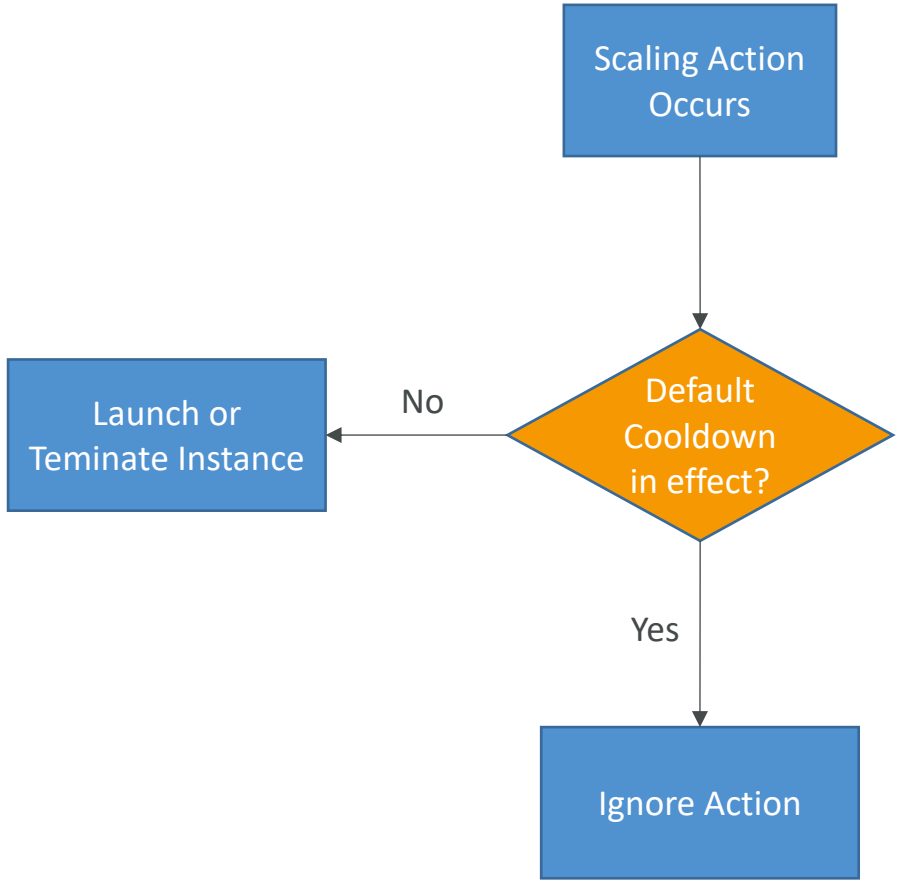
- **CPUUtilization**: Average CPU utilization across your instances
- **RequestCountPerTarget**: to make sure the number of requests per EC2 instances is stable
- **Average Network In / Out** (if you're application is network bound)
- **Any custom metric** (that you push using CloudWatch)



Auto Scaling Groups - Scaling Cooldowns

- After a scaling activity happens, you are in the **cooldown period (default 300 seconds)**
- During the cooldown period, the ASG will not launch or terminate additional instances (to allow for metrics to stabilize)

- Advice: Use a ready-to-use AMI to reduce configuration time in order to be serving request fasters and reduce the cooldown period



AWS Fundamentals – Part III

RDS, Aurora & ElastiCache

Amazon RDS Overview

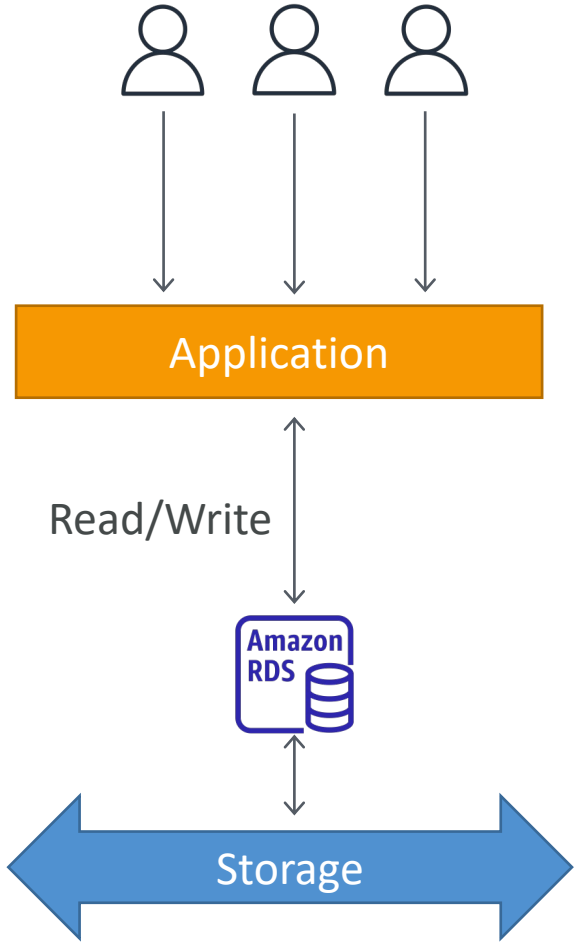
- RDS stands for Relational Database Service
- It's a managed DB service for DB use SQL as a query language.
- It allows you to create databases in the cloud that are managed by AWS
  - Postgres
  - MySQL
  - MariaDB
  - Oracle
  - Microsoft SQL Server
  - Aurora (AWS Proprietary database)

Advantage over using RDS versus deploying DB on EC2

- RDS is a managed service:
  - Automated provisioning, OS patching
  - Continuous backups and restore to specific timestamp (Point in Time Restore)!
  - Monitoring dashboards
  - Read replicas for improved read performance
  - Multi AZ setup for DR (Disaster Recovery)
  - Maintenance windows for upgrades
  - Scaling capability (vertical and horizontal)
  - Storage backed by EBS (gp2 or io1)
- BUT you can't SSH into your instances

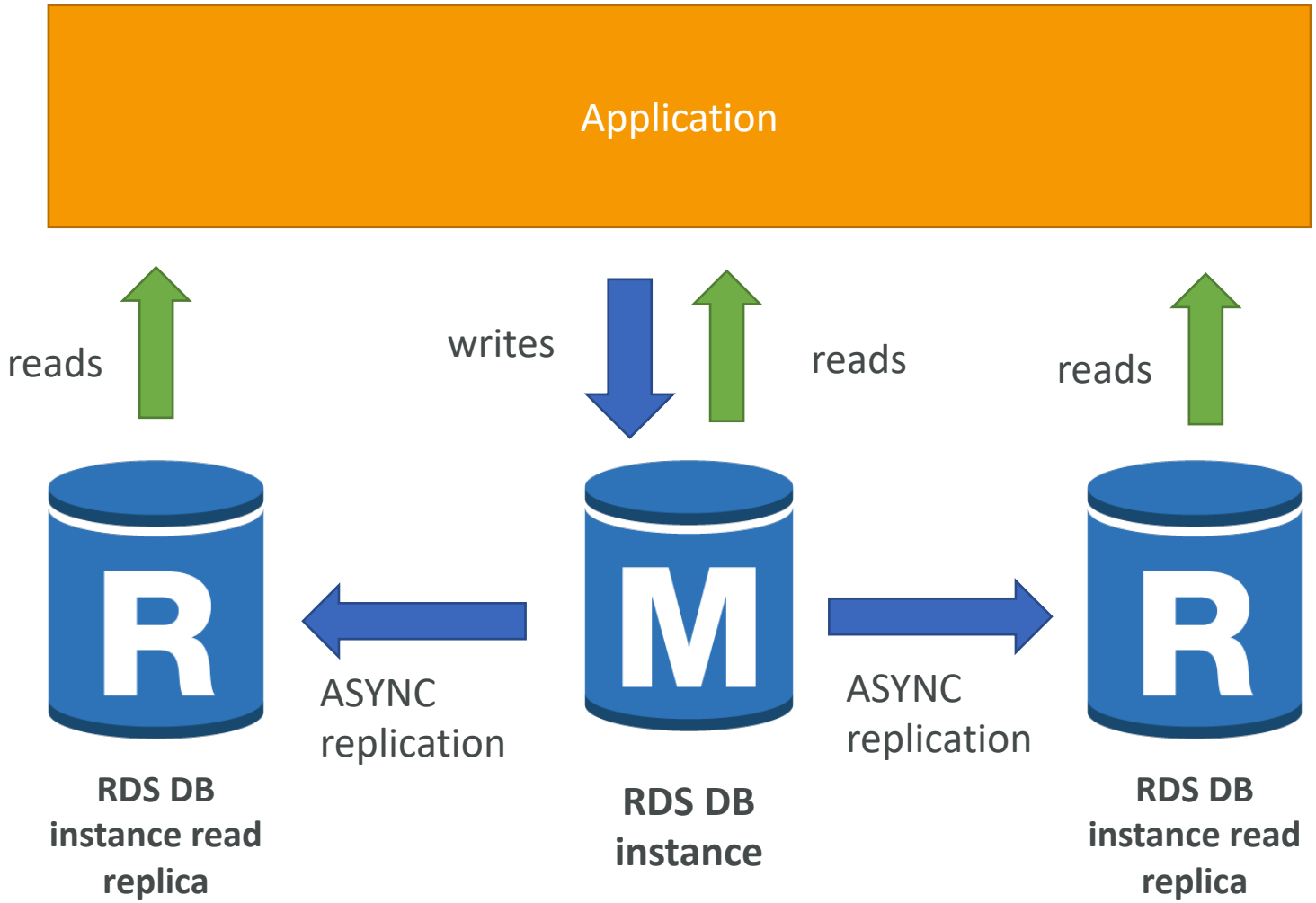
RDS – Storage Auto Scaling

- Helps you increase storage on your RDS DB instance dynamically
- When RDS detects you are running out of free database storage, it scales automatically
- Avoid manually scaling your database storage
- You have to set **Maximum Storage Threshold** (maximum limit for DB storage)
- Automatically modify storage if:
  - Free storage is less than 10% of allocated storage
  - Low-storage lasts at least 5 minutes
  - 6 hours have passed since last modification
- Useful for applications with **unpredictable workloads**
- Supports all RDS database engines (MariaDB, MySQL, PostgreSQL, SQL Server, Oracle)



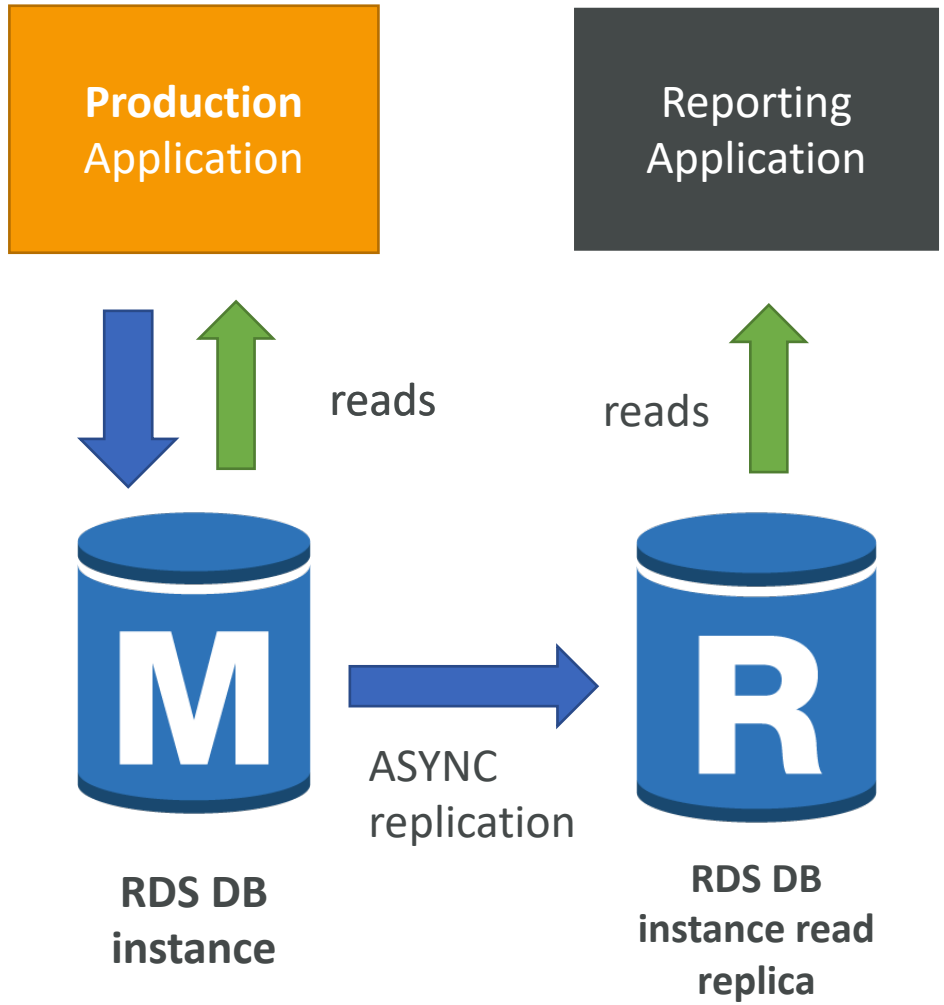
RDS Read Replicas for read scalability

- Up to 5 Read Replicas
- Within AZ, Cross AZ or Cross Region
- Replication is **ASYNC**, so reads are eventually consistent
- Replicas can be promoted to their own DB
- Applications must update the connection string to leverage read replicas



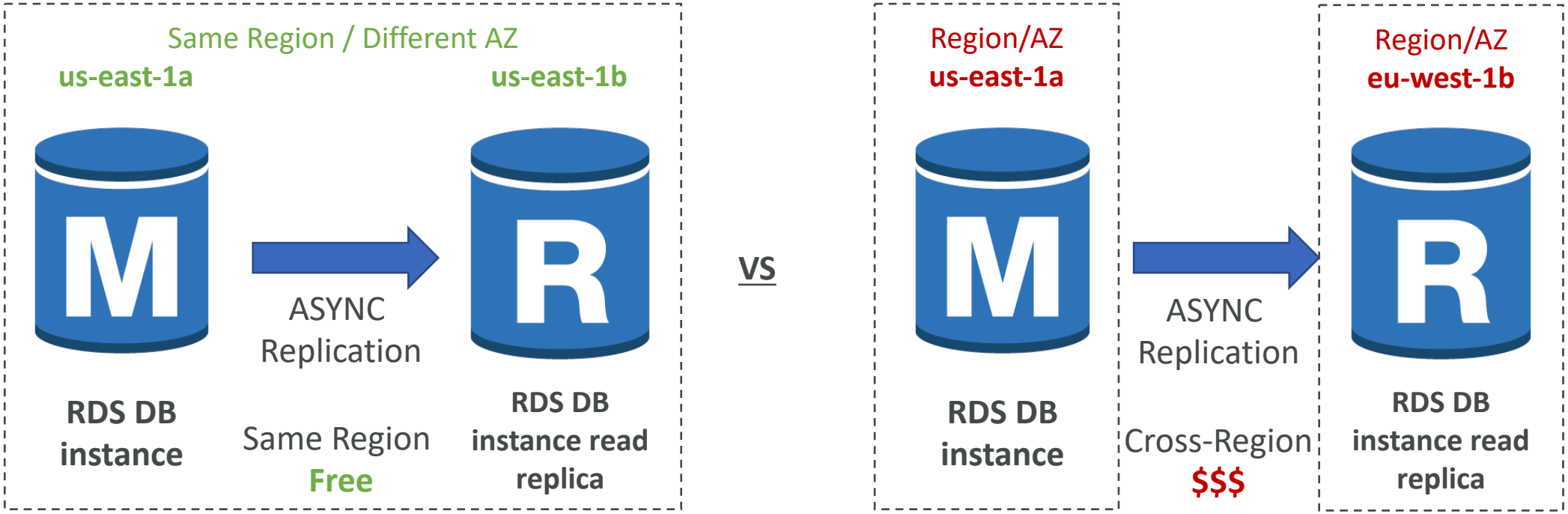
RDS Read Replicas – Use Cases

- You have a production database that is taking on normal load
- You want to run a reporting application to run some analytics
- You create a Read Replica to run the new workload there
- The production application is unaffected
- Read replicas are used for SELECT (=read) only kind of statements (not INSERT, UPDATE, DELETE)



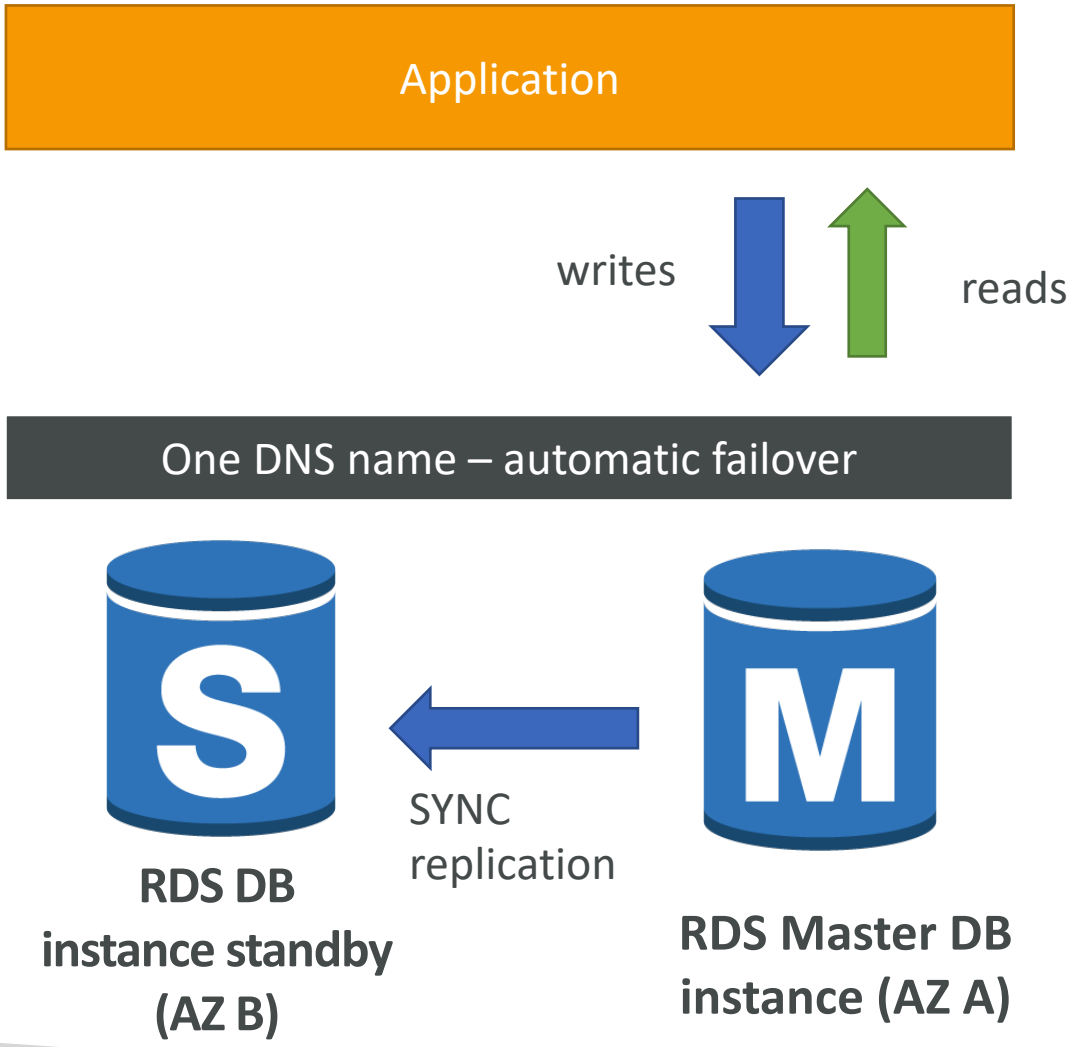
RDS Read Replicas – Network Cost

- In AWS there's a network cost when data goes from one AZ to another
- For RDS Read Replicas within the same region, you don't pay that fee



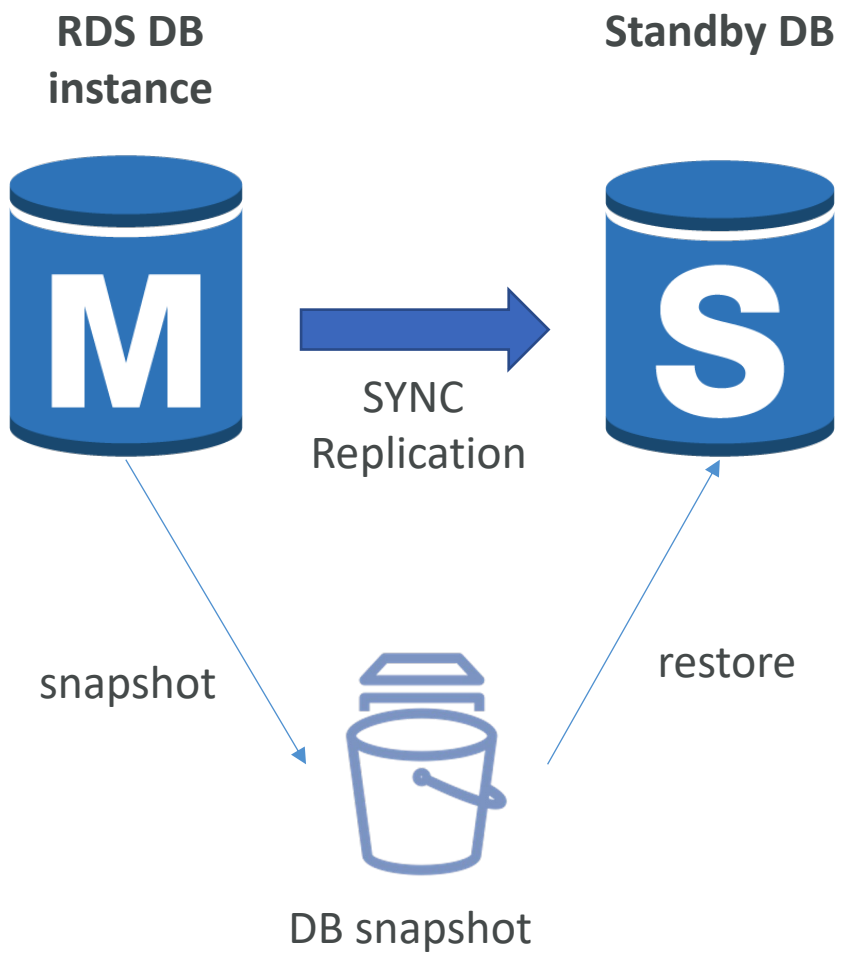
RDS Multi AZ (Disaster Recovery)

- **SYNC** replication
- One DNS name – automatic app failover to standby
- Increase **availability**
- Failover in case of loss of AZ, loss of network, instance or storage failure
- No manual intervention in apps
- Not used for scaling
- Multi-AZ replication is free
- Note: The Read Replicas be setup as Multi AZ for Disaster Recovery (DR)



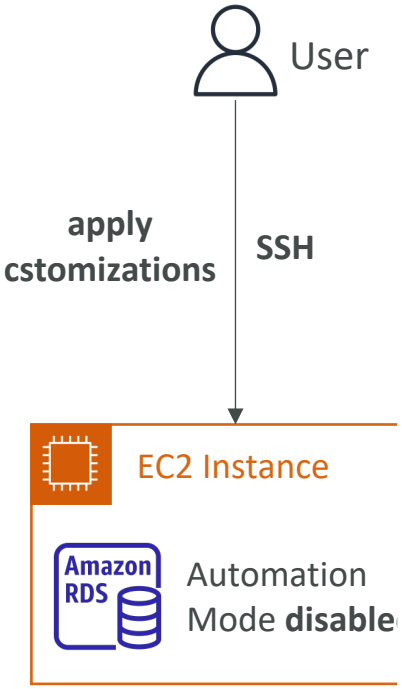
RDS – From Single-AZ to Multi-AZ

- Zero downtime operation (no need to stop the DB)
- Just click on "modify" for the database
- The following happens internally:
  - A snapshot is taken
  - A new DB is restored from the snapshot in a new AZ
  - Synchronization is established between the two databases



RDS Custom

- Managed Oracle and Microsoft SQL Server Database with OS and database customization
- RDS: Automates setup, operation, and scaling of database in AWS
- Custom: access to the underlying database and OS so you can
  - Configure settings
  - Install patches
  - Enable native features
  - Access the underlying EC2 Instance using SSH or SSM Session Manager
- De-activate Automation Mode to perform your customization, better to take a DB snapshot before
- RDS vs. RDS Custom
  - RDS: entire database and the OS to be managed by AWS
  - RDS Custom: full admin access to the underlying OS and the database

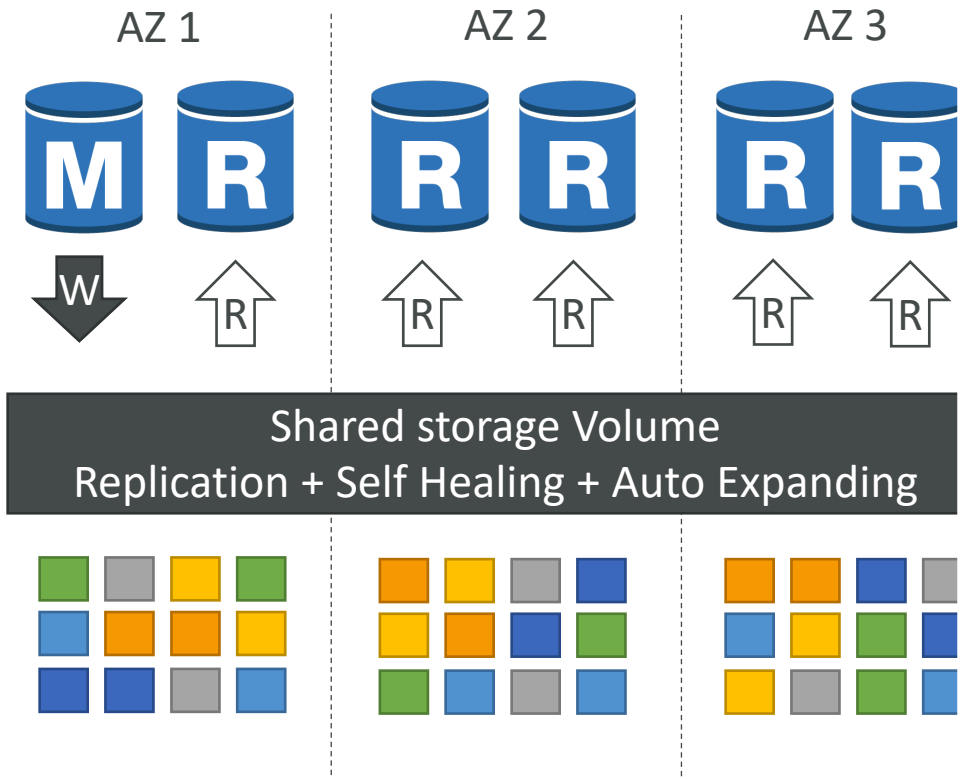


Amazon Aurora

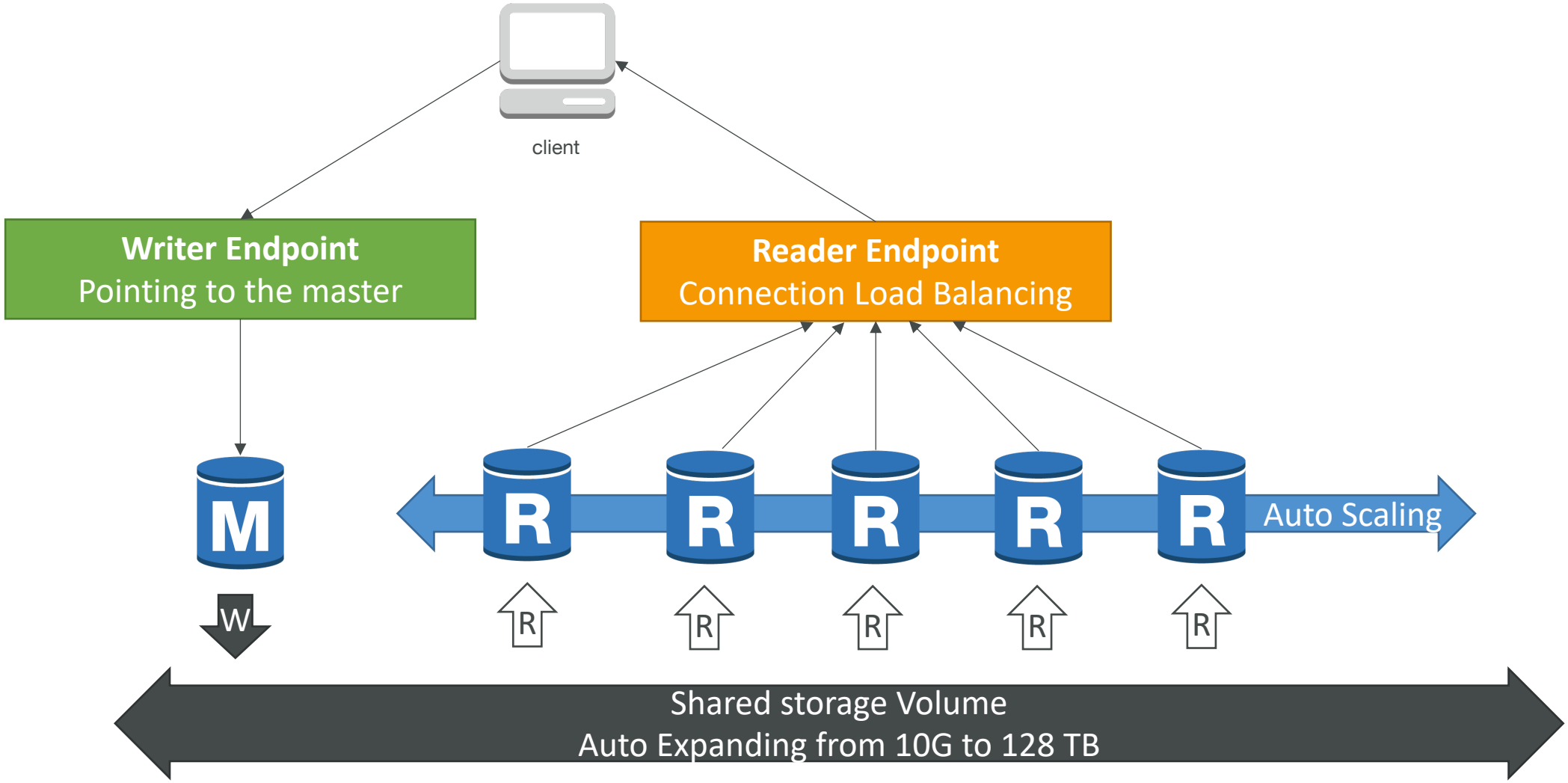
- Aurora is a proprietary technology from AWS (not open sourced)
- Postgres and MySQL are both supported as Aurora DB (that means your drivers will work as if Aurora was a Postgres or MySQL database)
- Aurora is "AWS cloud optimized" and claims 5x performance improvement over MySQL on RDS, over 3x the performance of Postgres on RDS
- Aurora storage automatically grows in increments of 10GB, up to 128 TB.
- Aurora can have 15 replicas while MySQL has 5, and the replication process is faster (sub 10 ms replica lag)
- Failover in Aurora is instantaneous. It's HA (High Availability) native.
- Aurora costs more than RDS (20% more) – but is more efficient

Aurora High Availability and Read Scaling

- 6 copies of your data across 3 AZ:
  - 4 copies out of 6 needed for writes
  - 3 copies out of 6 need for reads
  - Self healing with peer-to-peer replication
  - Storage is striped across 100s of volumes
- One Aurora Instance takes writes (master)
- Automated failover for master in less than 30 seconds
- Master + up to 15 Aurora Read Replicas serve reads
- Support for Cross Region Replication



Aurora DB Cluster



Features of Aurora

- Automatic fail-over
- Backup and Recovery
- Isolation and security
- Industry compliance
- Push-button scaling
- Automated Patching with Zero Downtime
- Advanced Monitoring
- Routine Maintenance
- Backtrack: restore data at any point of time without using backups

RDS & Aurora Security

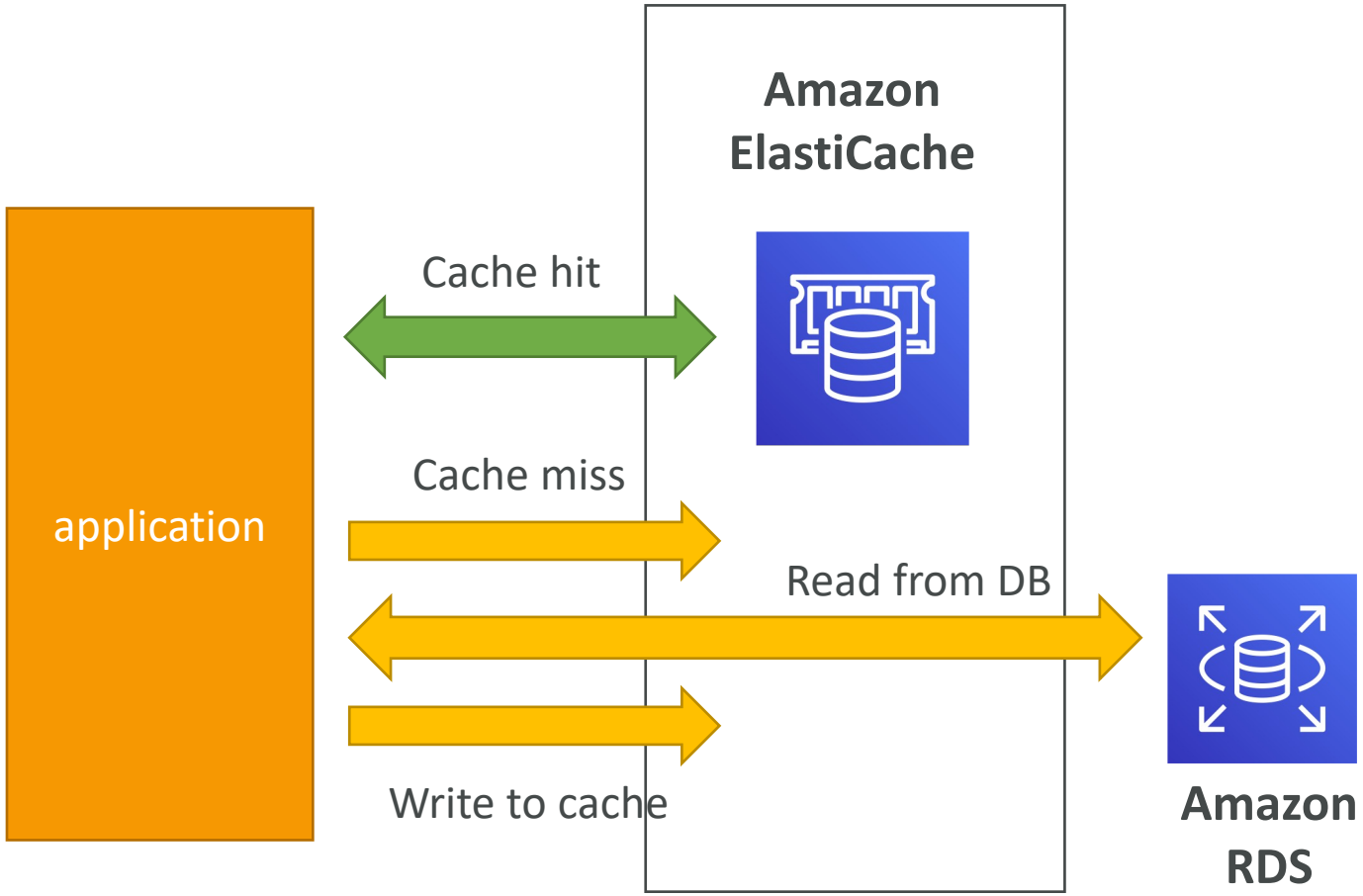
- At-rest encryption:
  - Database master & replicas encryption using AWS KMS – must be defined as launch time
  - If the master is not encrypted, the read replicas cannot be encrypted
  - To encrypt an un-encrypted database, go through a DB snapshot & restore as encrypted
- In-flight encryption: TLS-ready by default, use the AWS TLS root certificates client-side
- IAM Authentication: IAM roles to connect to your database (instead of username/pw)
- Security Groups: Control Network access to your RDS / Aurora DB
- No SSH available except on RDS Custom
- Audit Logs can be enabled and sent to CloudWatch Logs for longer retention

Amazon ElastiCache Overview

- The same way RDS is to get managed Relational Databases…
- ElastiCache is to get managed Redis or Memcached
- Caches are in-memory databases with really high performance, low latency
- Helps reduce load off of databases for read intensive workloads
- Helps make your application stateless
- AWS takes care of OS maintenance / patching, optimizations, setup, configuration, monitoring, failure recovery and backups
- Using ElastiCache involves heavy application code changes

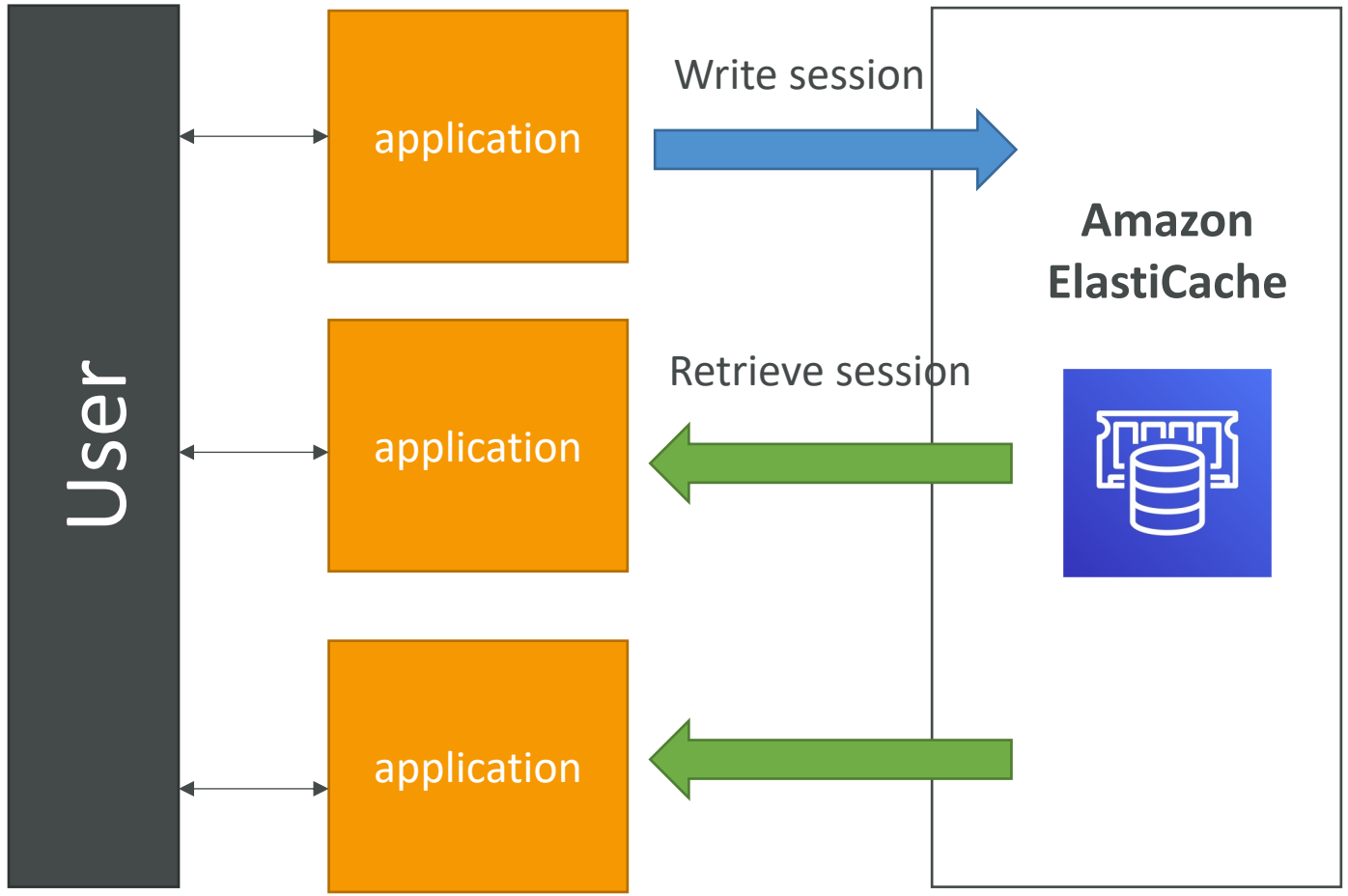
ElastiCache
Solution Architecture - DB Cache

- Applications queries ElastiCache, if not available, get from RDS and store in ElastiCache.
- Helps relieve load in RDS
- Cache must have an invalidation strategy to make sure only the most current data is used in there.



ElastiCache
Solution Architecture – User Session Store

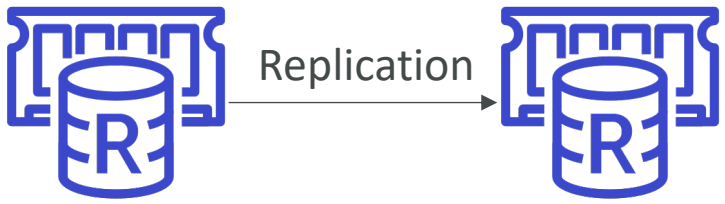
- User logs into any of the application
- The application writes the session data into ElastiCache
- The user hits another instance of our application
- The instance retrieves the data and the user is already logged in



ElastiCache – Redis vs Memcached

REDIS

- **Multi AZ** with Auto-Failover
- **Read Replicas** to scale reads and have **high availability**
- Data Durability using AOF persistence
- **Backup and restore features**

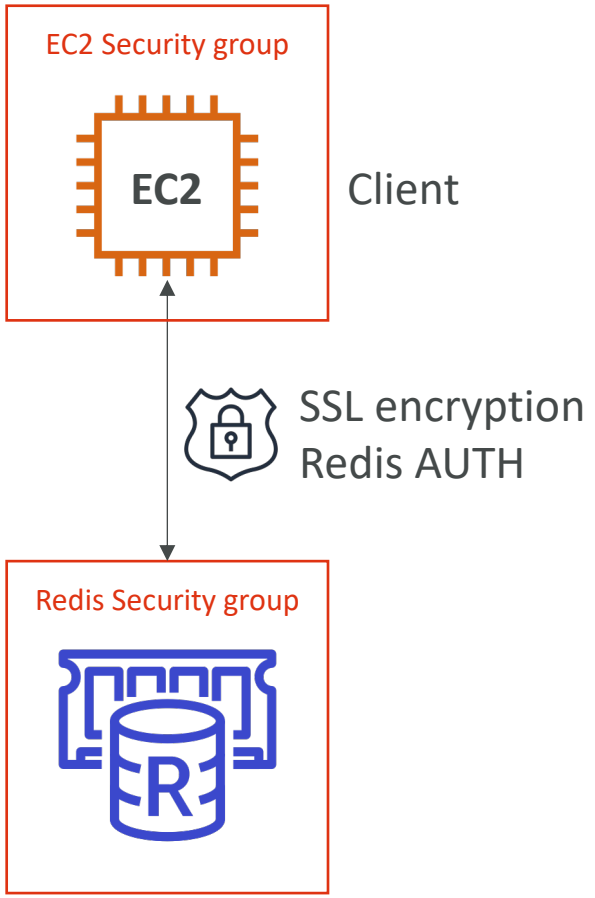


MEMCACHED

- Multi-node for partitioning of data (sharding)
- **No high availability (replication)**
- **Non persistent**
- **No backup and restore**
- Multi-threaded architecture

ElastiCache – Cache Security

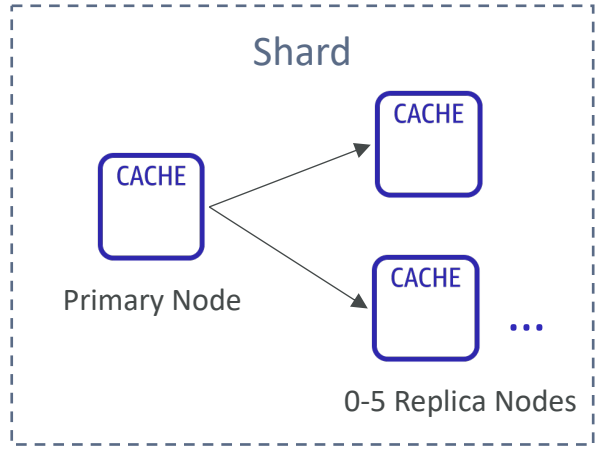
- All caches in ElastiCache:
  - Do not support IAM authentication
  - IAM policies on ElastiCache are only used for AWS API-level security
- Redis AUTH
  - You can set a "password/token" when you create a Redis cluster
  - This is an extra level of security for your cache (on top of security groups)
  - Support SSL in flight encryption
- Memcached
  - Supports SASL-based authentication (advanced)



ElastiCache Replication: Cluster Mode Disabled

- One primary node, up to 5 replicas
- Asynchronous Replication
- The primary node is used for read/write
- The other nodes are read-only
- **One shard, all nodes have all the data**
- Guard against data loss if node failure
- Multi-AZ enabled by default for failover
- Helpful to scale read performance

Redis (cluster mode disabled) Cluster with Replication

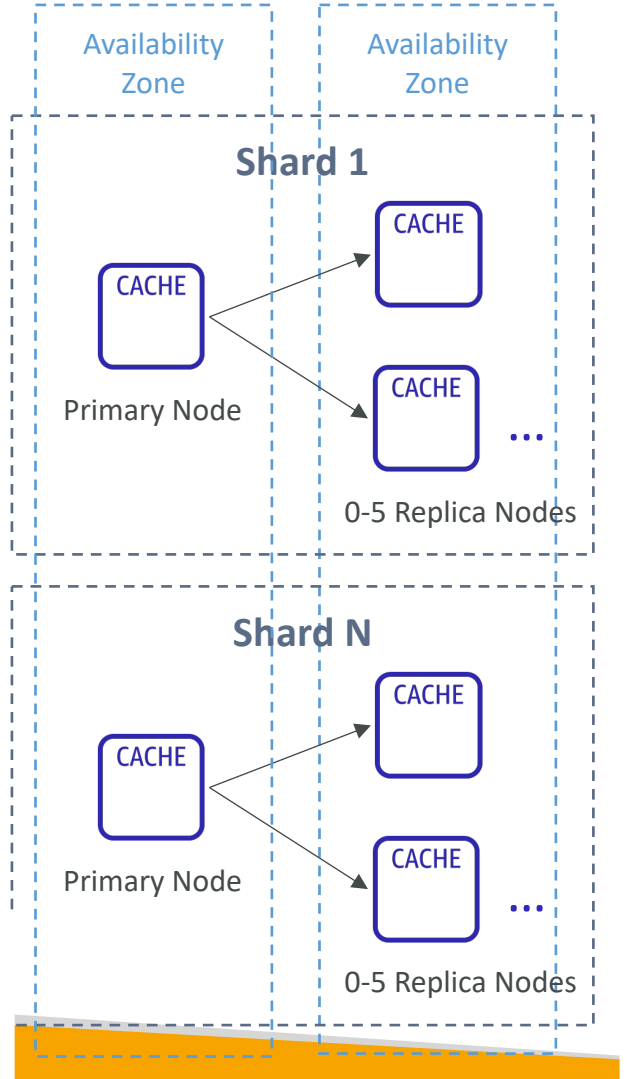


ElastiCache Replication: Cluster Mode Enabled

- Data is partitioned across shards (helpful to scale writes)
- Each shard has a primary and up to 5 replica nodes (same concept as before)
- Multi-AZ capability

- Up to 500 nodes per cluster:
  - 500 shards with single master
  - 250 shards with 1 master and 1 replica
  - …
  - 83 shards with one master and 5 replicas

Redis (cluster mode enabled) Cluster with Replication



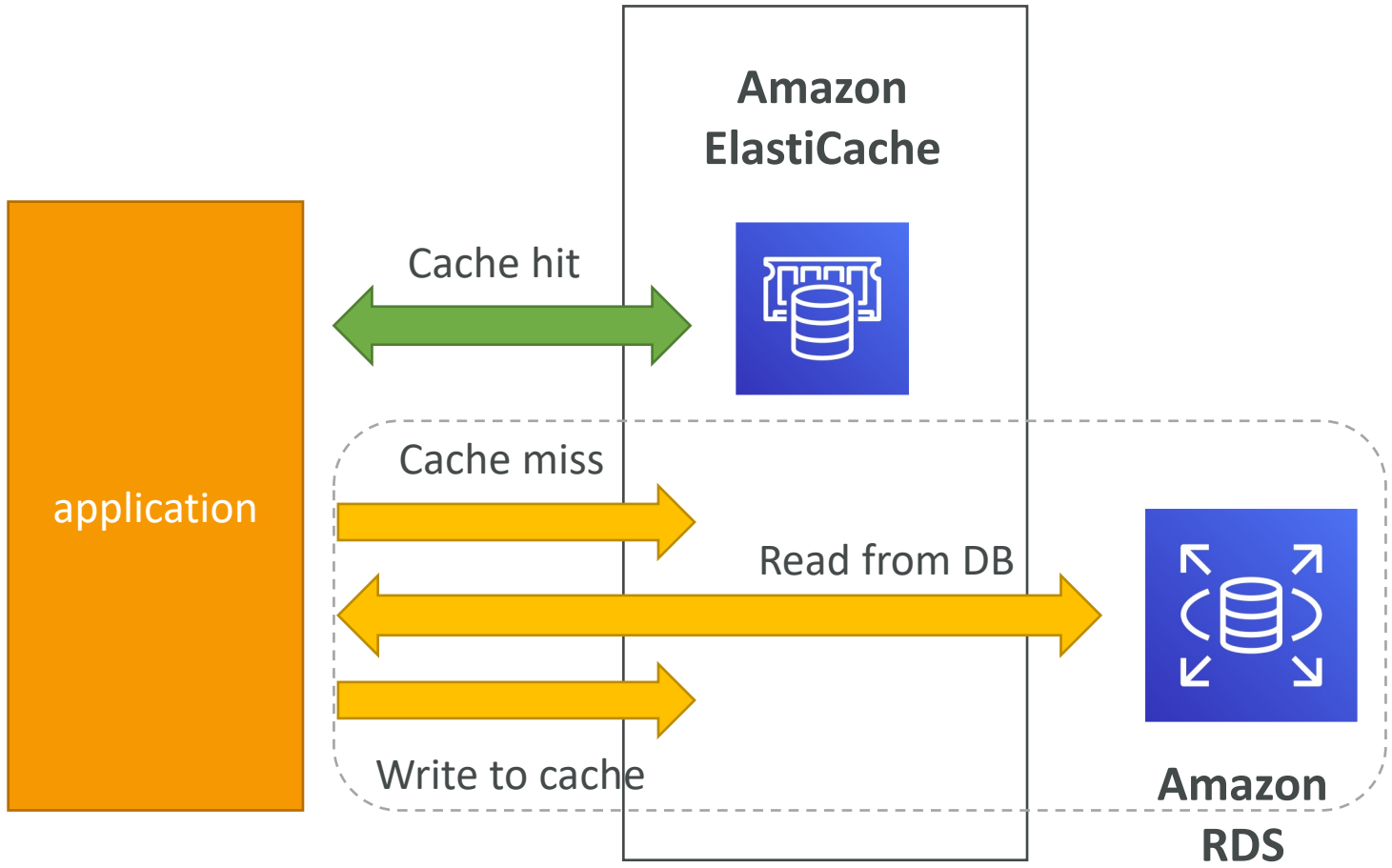
Caching Implementation Considerations

- Read more at: https://aws.amazon.com/caching/implementation-considerations/

- **Is it safe to cache data?** Data may be out of date, eventually consistent
- **Is caching effective for that data?**
  - Pattern: data changing slowly, few keys are frequently needed
  - Anti patterns: data changing rapidly, all large key space frequently needed
- **Is data structured well for caching?**
  - example: key value caching, or caching of aggregations results

- Which caching design pattern is the most appropriate?

Lazy Loading / Cache-Aside / Lazy Population



- Pros
  - Only requested data is cached (the cache isn't filled up with unused data)
  - Node failures are not fatal (just increased latency to warm the cache)
- Cons
  - Cache miss penalty that results in 3 round trips, noticeable delay for that request
  - Stale data: data can be updated in the database and outdated in the cache

Lazy Loading / Cache-Aside / Lazy Population Python Pseudocode

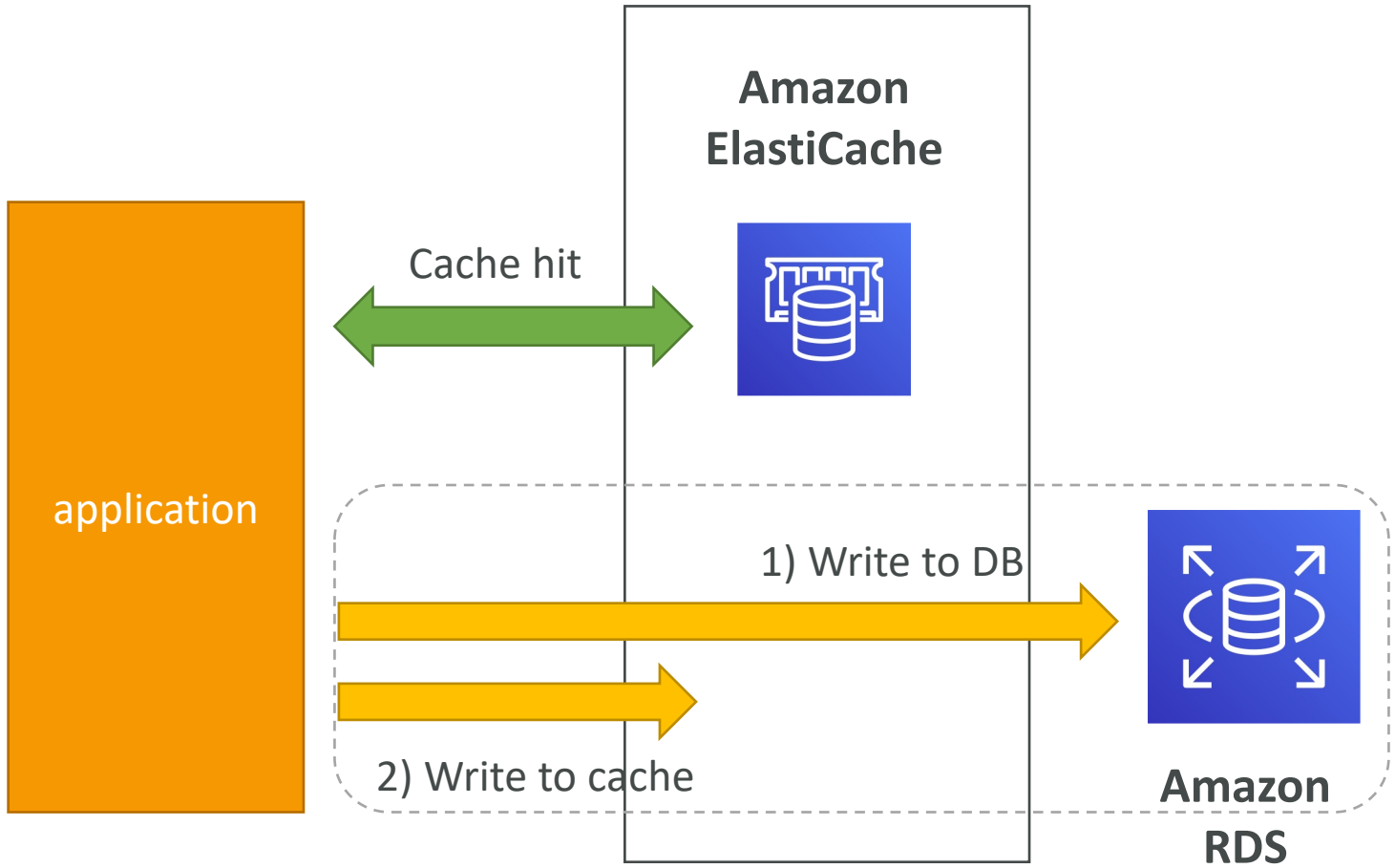
```python
# Python

def get_user(user_id):
    # Check the cache
    record = cache.get(user_id)

    if record is None:
        # Run a DB query
        record = db.query("select * from users where id = ?", user_id)
        # Populate the cache
        cache.set(user_id, record)
        return record
    else:
        return record

# App code
user = get_user(17)
```

Write Through – Add or Update cache when database is updated



- Pros:
  - Data in cache is never stale, **reads are quick**
  - **Write penalty** vs Read penalty (each write requires 2 calls)
- Cons:
  - Missing Data until it is added / updated in the DB. Mitigation is to implement Lazy Loading strategy as well
  - Cache churn – a lot of the data will never be read

Write-Through Python Pseudocode

```python
# Python

def save_user(user_id, values):

    # Save to DB

    record = db.query("update users ... where id = ?", user_id, values)

    # Push into cache

    cache.set(user_id, record)

    return record

# App code

user = save_user(17, {"name": "Nate Dogg"})
```

Cache Evictions and Time-to-live (TTL)

- Cache eviction can occur in three ways:
  - You delete the item explicitly in the cache
  - Item is evicted because the memory is full and it's not recently used (LRU)
  - You set an item **time-to-live (or TTL)**
- TTL are helpful for any kind of data:
  - Leaderboards
  - Comments
  - Activity streams
- TTL can range from few seconds to hours or days

- If too many evictions happen due to memory, you should scale up or out

Final words of wisdom

- Lazy Loading / Cache aside is easy to implement and works for many situations as a foundation, especially on the read side
- Write-through is usually combined with Lazy Loading as targeted for the queries or workloads that benefit from this optimization
- Setting a TTL is usually not a bad idea, except when you're using Write-through. Set it to a sensible value for your application
- Only cache the data that makes sense (user profiles, blogs, etc…)

- *Quote: There are only two hard things in Computer Science: cache invalidation and naming things*

Route 53 Section

What is DNS?

- Domain Name System which translates the human friendly hostnames into the machine IP addresses
- www.google.com => 172.217.18.36
- DNS is the backbone of the Internet
- DNS uses hierarchical naming structure

.com

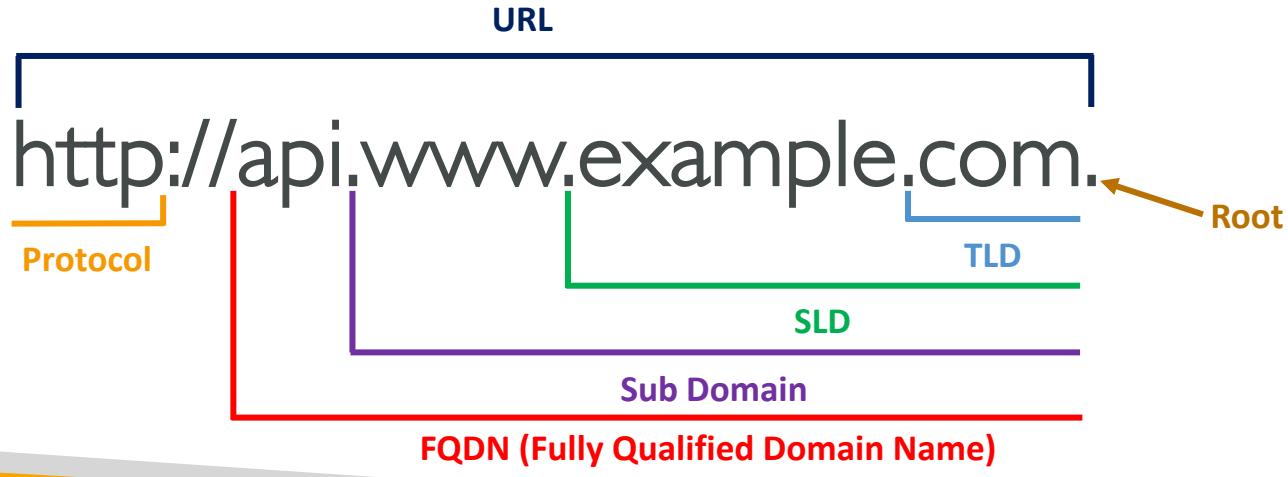
example.com

www.example.com

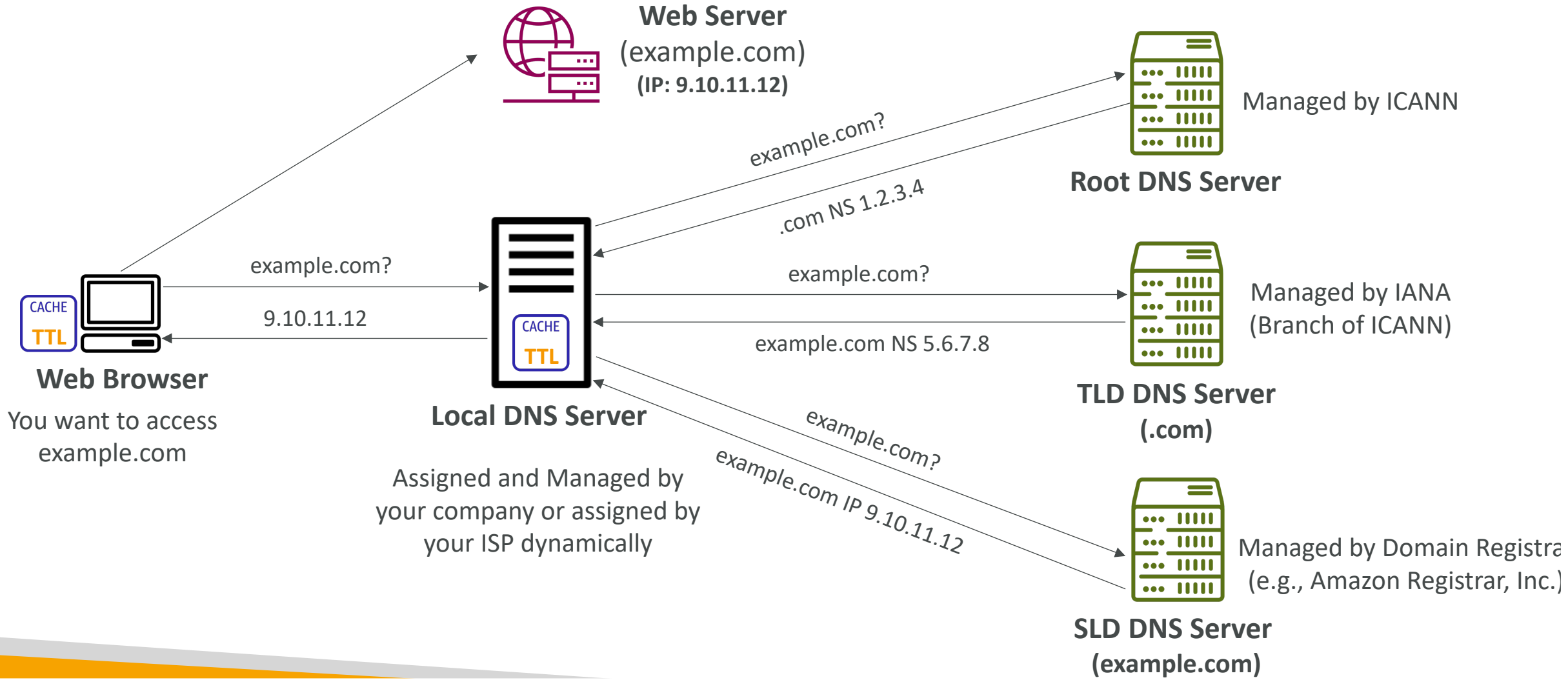
api.example.com

DNS Terminologies

- **Domain Registrar:** Amazon Route 53, GoDaddy, …
- **DNS Records:** A, AAAA, CNAME, NS, …
- **Zone File:** contains DNS records
- **Name Server:** resolves DNS queries (Authoritative or Non-Authoritative)
- **Top Level Domain (TLD):** .com, .us, .in, .gov, .org, …
- **Second Level Domain (SLD):** amazon.com, google.com, …

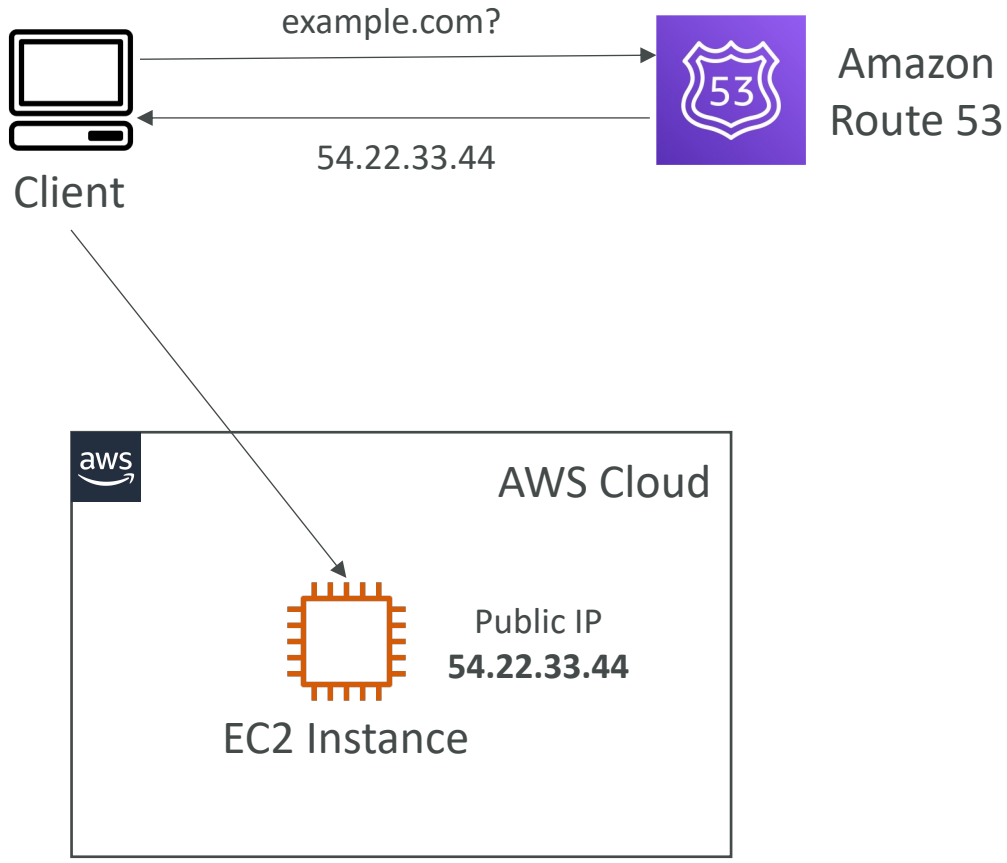


How DNS Works



Amazon Route 53

- A highly available, scalable, fully managed and *Authoritative* DNS
  - Authoritative = the customer (you) can update the DNS records
- Route 53 is also a Domain Registrar
- Ability to check the health of your resources
- The only AWS service which provides 100% availability SLA
- Why Route 53? 53 is a reference to the traditional DNS port



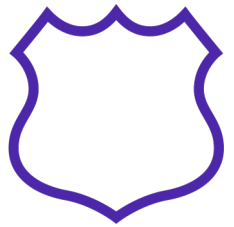
Route 53 – Records

- How you want to route traffic for a domain
- Each record contains:
  - **Domain/subdomain Name** – e.g., example.com
  - **Record Type** – e.g., A or AAAA
  - **Value** – e.g., 12.34.56.78
  - **Routing Policy** – how Route 53 responds to queries
  - **TTL** – amount of time the record cached at DNS Resolvers
- Route 53 supports the following DNS record types:
  - (must know) A / AAAA / CNAME / NS
  - (advanced) CAA / DS / MX / NAPTR / PTR / SOA / TXT / SPF / SRV

Route 53 – Record Types

- A – maps a hostname to IPv4
- AAAA – maps a hostname to IPv6
- CNAME – maps a hostname to another hostname
  - The target is a domain name which must have an A or AAAA record
  - Can't create a CNAME record for the top node of a DNS namespace (Zone Apex)
  - Example: you can't create for example.com, but you can create for www.example.com
- NS – Name Servers for the Hosted Zone
  - Control how traffic is routed for a domain

Route 53 – Hosted Zones



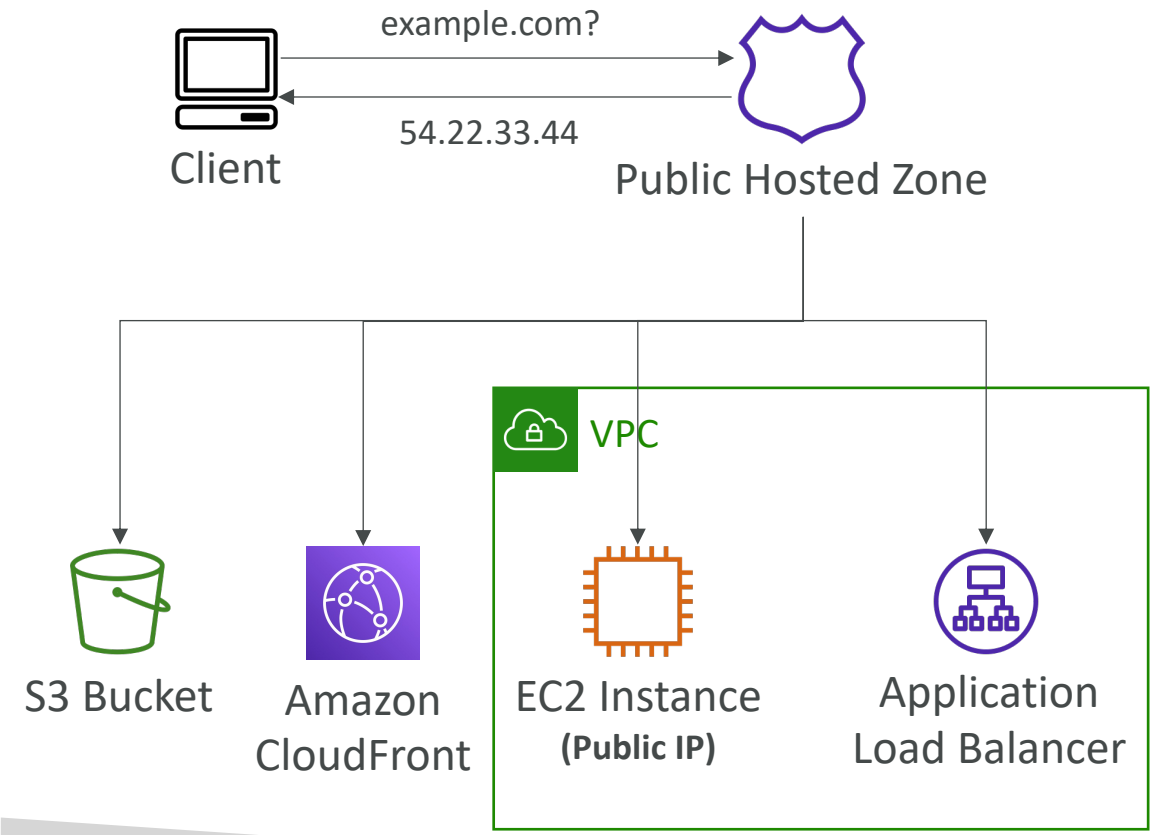
- A container for records that define how to route traffic to a domain and its subdomains

- **Public Hosted Zones** – contains records that specify how to route traffic on the Internet (public domain names)
  application1.mypublicdomain.com
- **Private Hosted Zones** – contain records that specify how you route traffic within one or more VPCs (private domain names)
  application1.company.internal

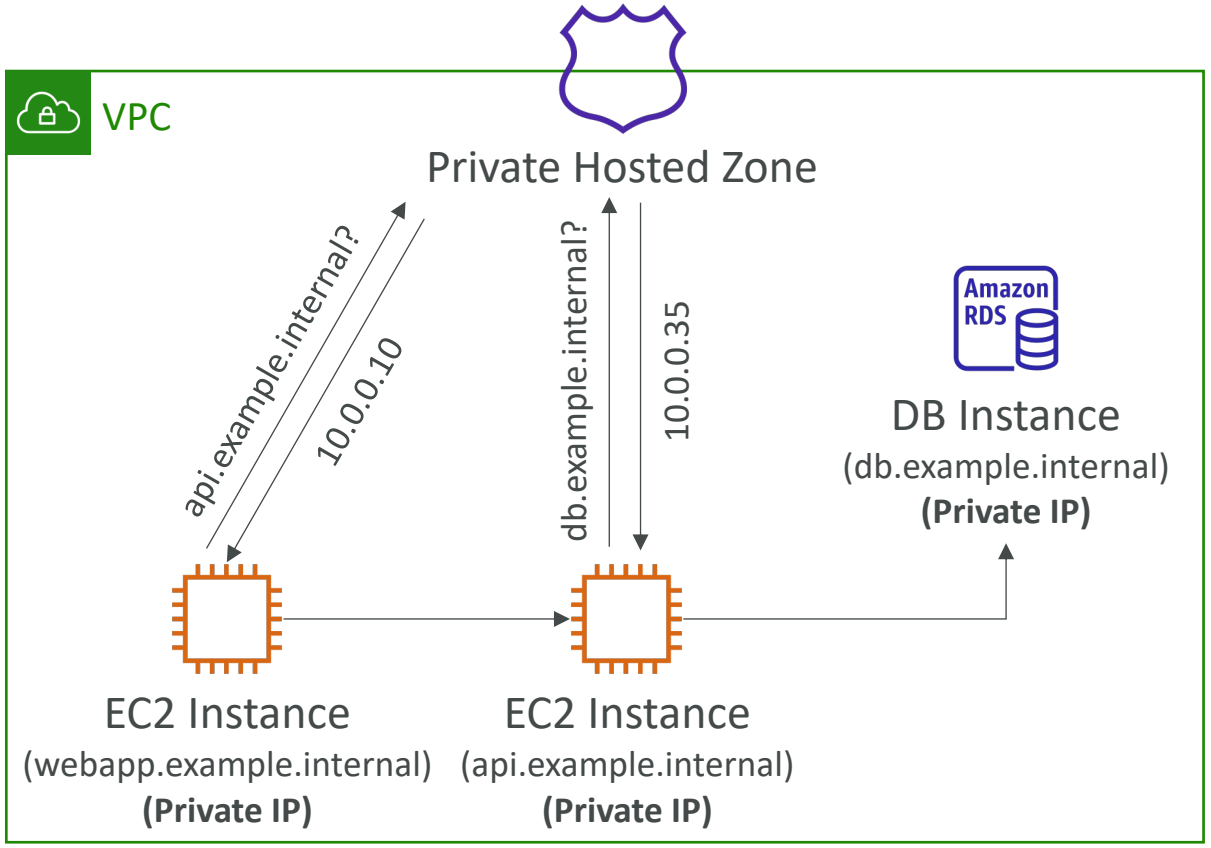
- You pay $0.50 per month per hosted zone

Route 53 – Public vs. Private Hosted Zones

Public Hosted Zone

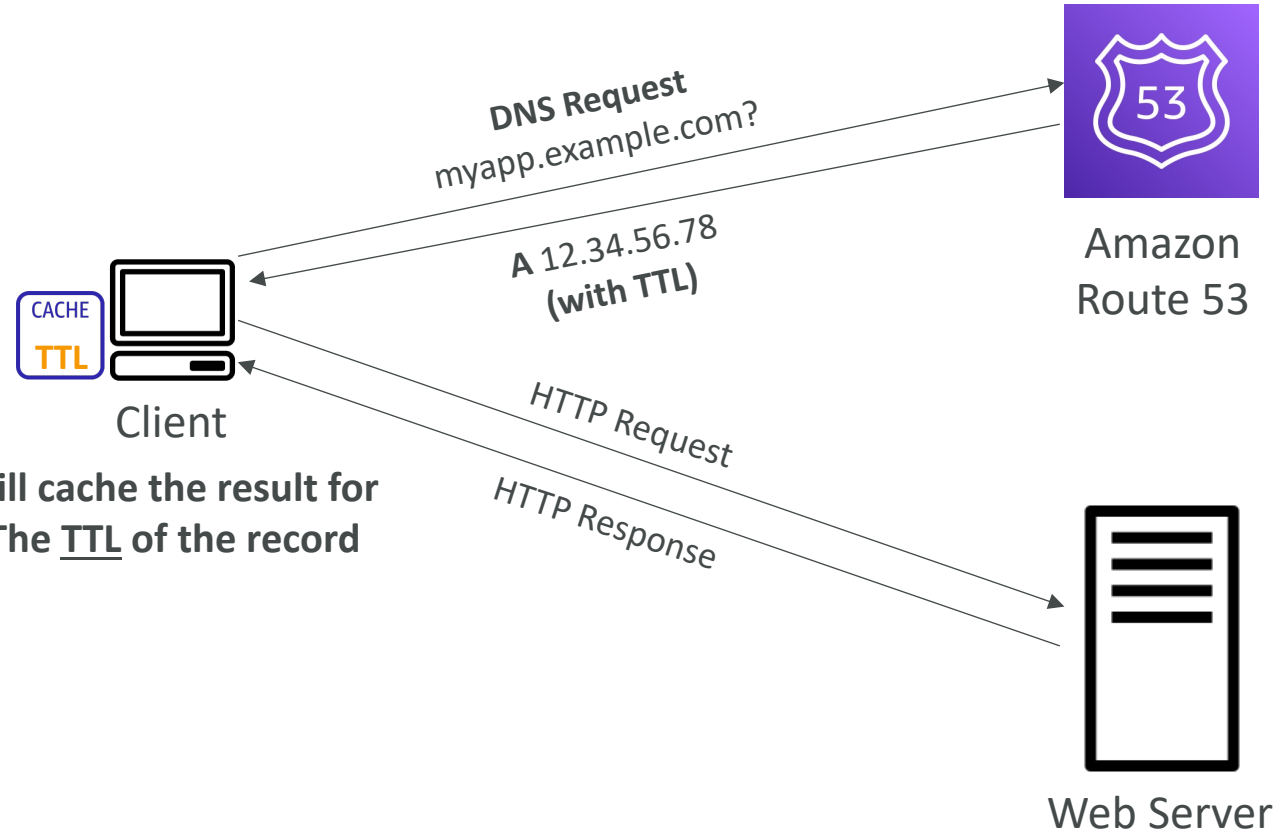


Private Hosted Zone



Route 53 – Records TTL (Time To Live)

- High TTL – e.g., 24 hr
  - Less traffic on Route 53
  - Possibly outdated records
- Low TTL – e.g., 60 sec.
  - More traffic on Route 53 ($$)
  - Records are outdated for less time
  - Easy to change records
- Except for Alias records, TTL is mandatory for each DNS record



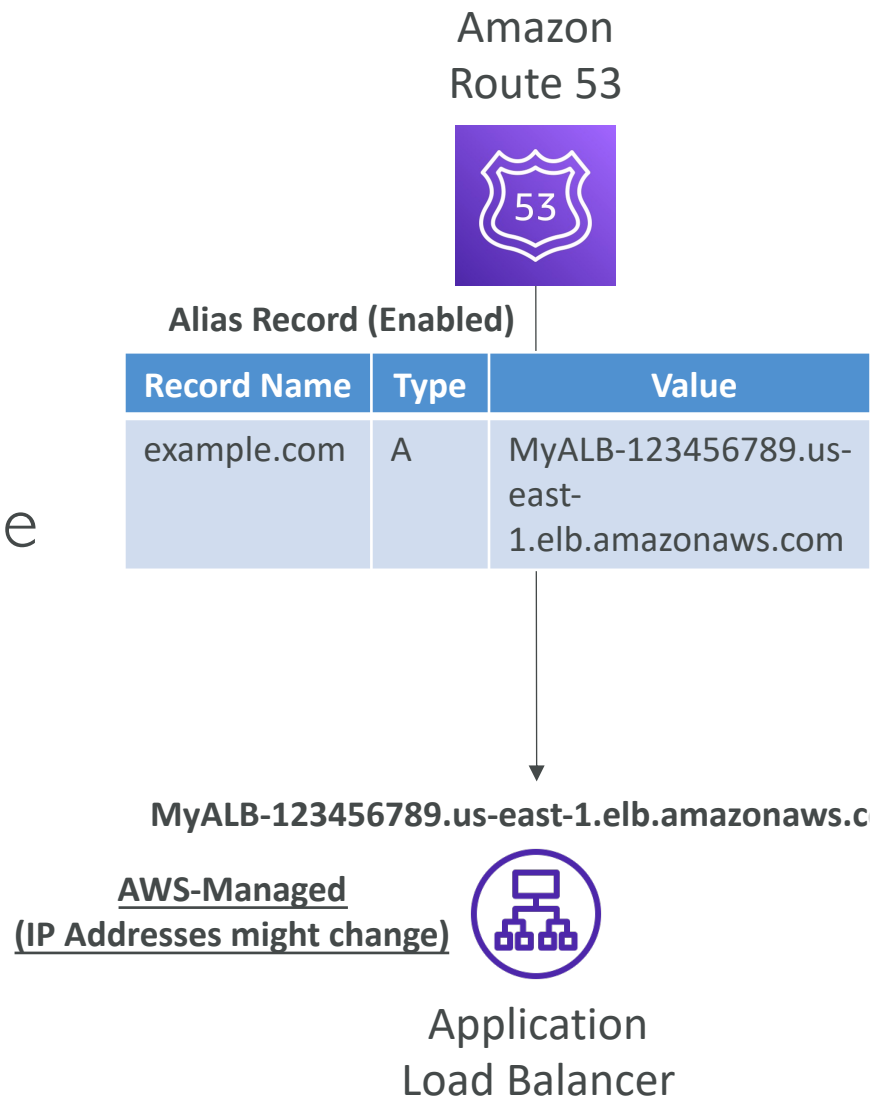
CNAME vs Alias

- AWS Resources (Load Balancer, CloudFront...) expose an AWS hostname:
  - lb1-1234.us-east-2.elb.amazonaws.com and you want myapp.mydomain.com

- CNAME:
  - Points a hostname to any other hostname. (app.mydomain.com => blabla.anything.com)
  - ONLY FOR NON ROOT DOMAIN (aka. something.mydomain.com)
- Alias:
  - Points a hostname to an AWS Resource (app.mydomain.com => blabla.amazonaws.com)
  - Works for ROOT DOMAIN and NON ROOT DOMAIN (aka mydomain.com)
  - Free of charge
  - Native health check

Route 53 – Alias Records

- Maps a hostname to an AWS resource
- An extension to DNS functionality
- Automatically recognizes changes in the resource's IP addresses
- Unlike CNAME, it can be used for the top node of a DNS namespace (Zone Apex), e.g.: example.com
- Alias Record is always of type A/AAAA for AWS resources (IPv4 / IPv6)
- You can't set the TTL

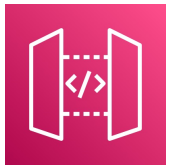


Route 53 – Alias Records Targets

- Elastic Load Balancers
- CloudFront Distributions
- API Gateway
- Elastic Beanstalk environments
- S3 Websites
- VPC Interface Endpoints
- Global Accelerator accelerator
- Route 53 record in the same hosted zone

Elastic Load Balancer

Amazon CloudFront



Amazon API Gateway

Elastic Beanstalk

S3 Websites

VPC Interface Endpoints

Global Accelerator

Route 53 Record
(same Hosted Zone)

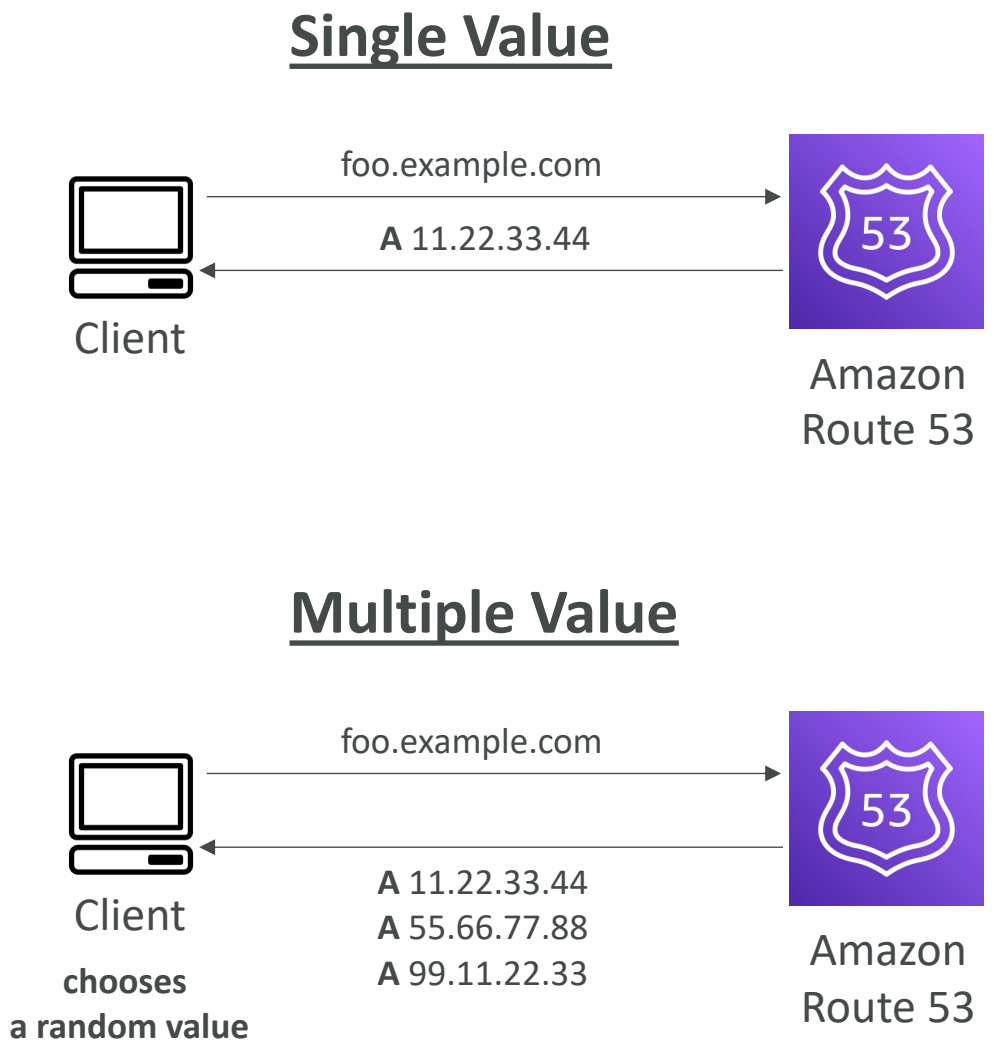
- You cannot set an ALIAS record for an EC2 DNS name

Route 53 – Routing Policies

- Define how Route 53 responds to DNS queries
- Don't get confused by the word *"Routing"*
  - It's not the same as Load balancer routing which routes the traffic
  - DNS does not route any traffic, it only responds to the DNS queries
- Route 53 Supports the following Routing Policies
  - Simple
  - Weighted
  - Failover
  - Latency based
  - Geolocation
  - Multi-Value Answer
  - Geoproximity (using Route 53 Traffic Flow feature)

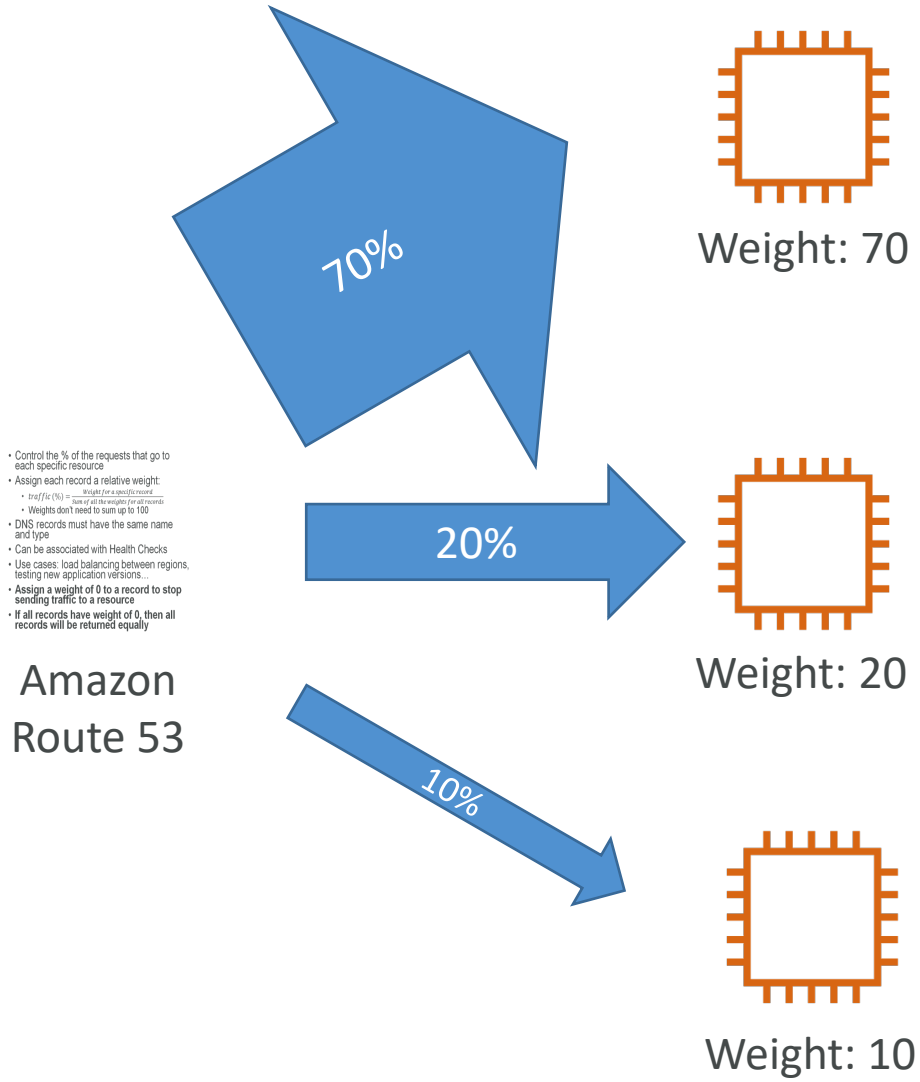
Routing Policies – Simple

- Typically, route traffic to a single resource
- Can specify multiple values in the same record
- **If multiple values are returned, a random one is chosen by the client**
- When Alias enabled, specify only one AWS resource
- Can't be associated with Health Checks



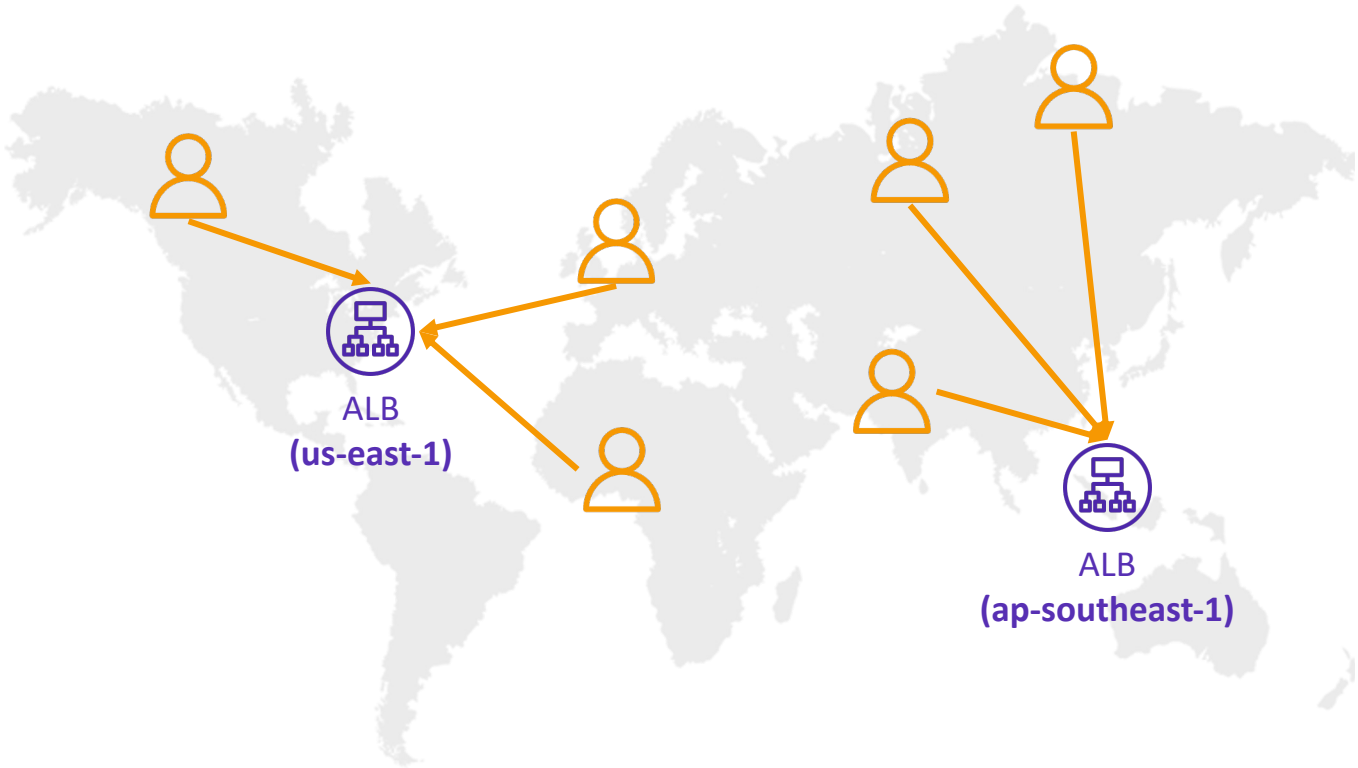
Routing Policies – Weighted

- Control the % of the requests that go to each specific resource
- Assign each record a relative weight:
  - $traffic\ (\%) = \frac{Weight\ for\ a\ specific\ record}{Sum\ of\ all\ the\ weights\ for\ all\ records}$
  - Weights don't need to sum up to 100
- DNS records must have the same name and type
- Can be associated with Health Checks
- Use cases: load balancing between regions, testing new application versions…
- Assign a weight of 0 to a record to stop sending traffic to a resource
- If all records have weight of 0, then all records will be returned equally



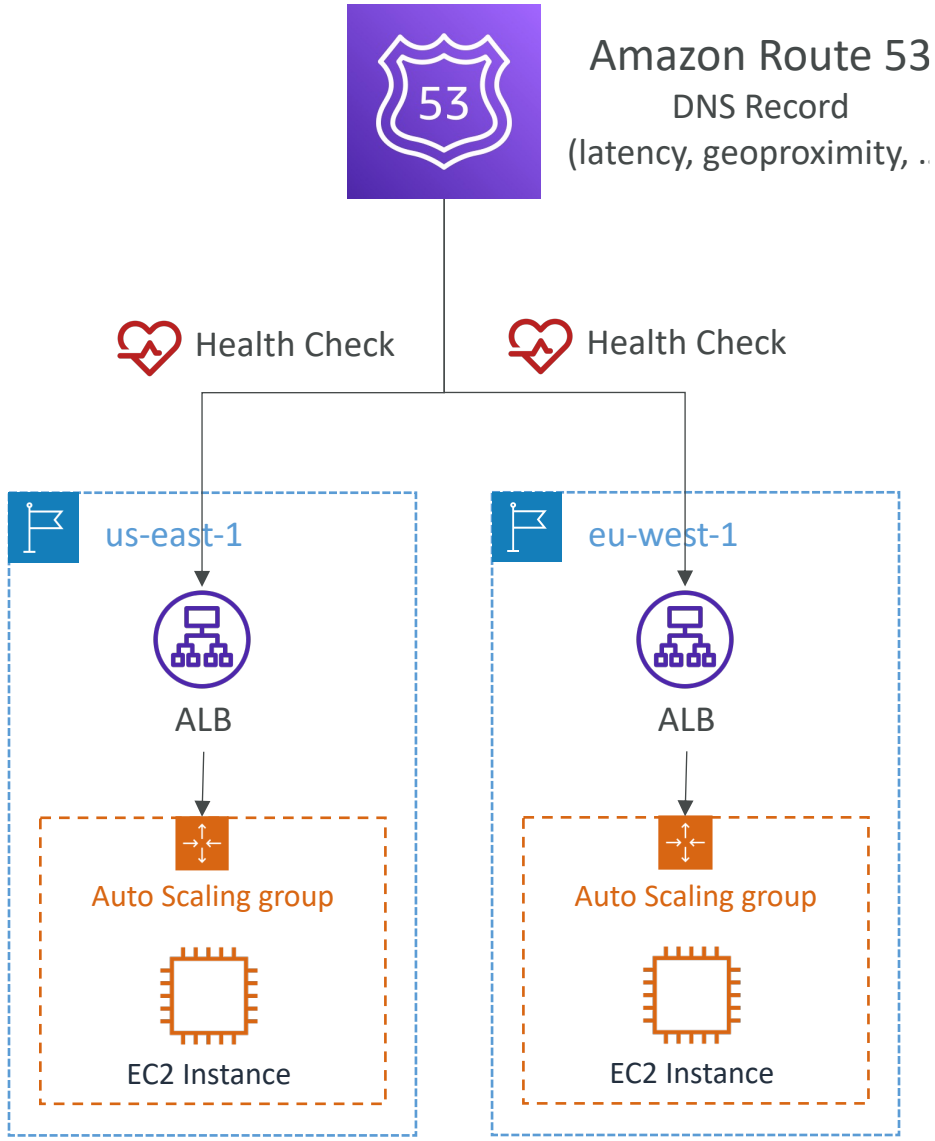
Routing Policies – Latency-based

- Redirect to the resource that has the least latency close to us
- Super helpful when latency for users is a priority
- **Latency is based on traffic between users and AWS Regions**
- Germany users may be directed to the US (if that's the lowest latency)
- Can be associated with Health Checks (has a failover capability)



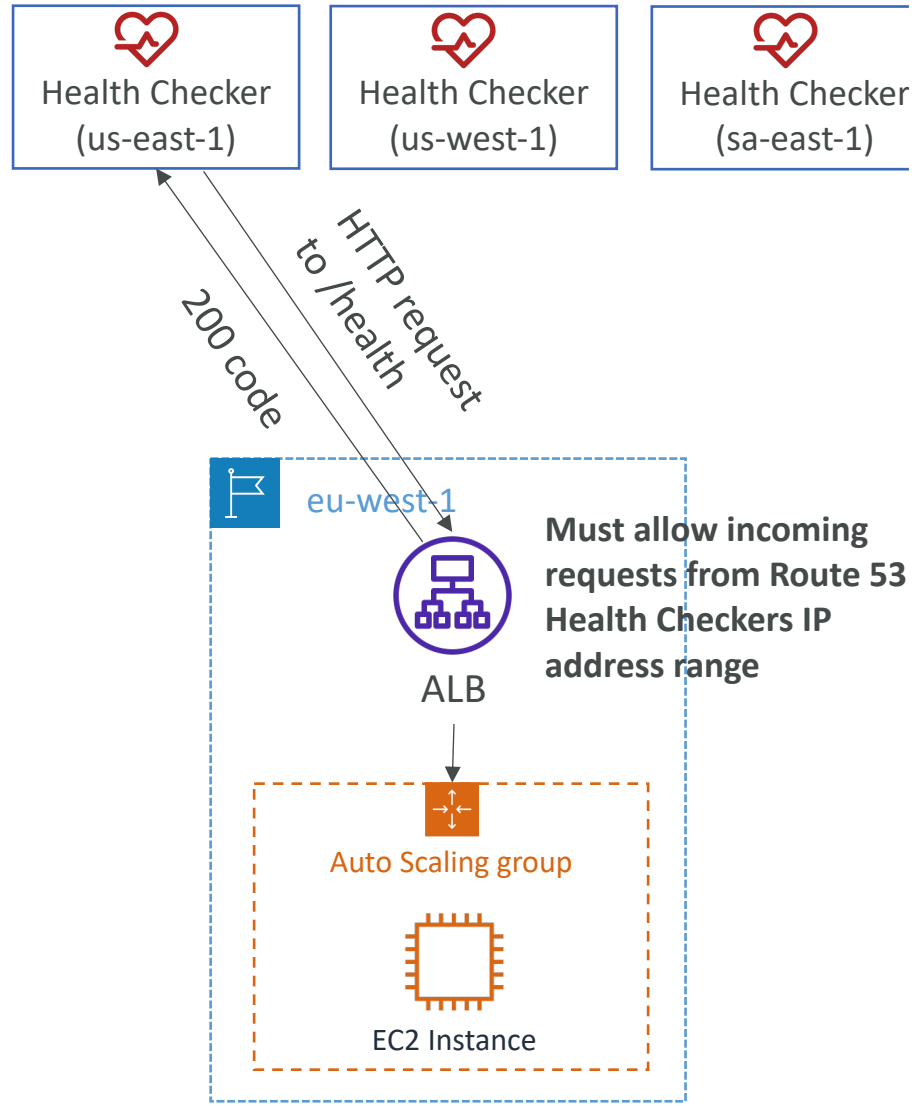
Route 53 – Health Checks

- HTTP Health Checks are only for **public resources**
- Health Check => Automated DNS Failover:
  1. Health checks that monitor an endpoint (application, server, other AWS resource)
  2. Health checks that monitor other health checks (Calculated Health Checks)
  3. Health checks that monitor CloudWatch Alarms (full control !!) – e.g., throttles of DynamoDB, alarms on RDS, custom metrics, … (helpful for private resources)
- Health Checks are integrated with CW metrics



Health Checks – Monitor an Endpoint

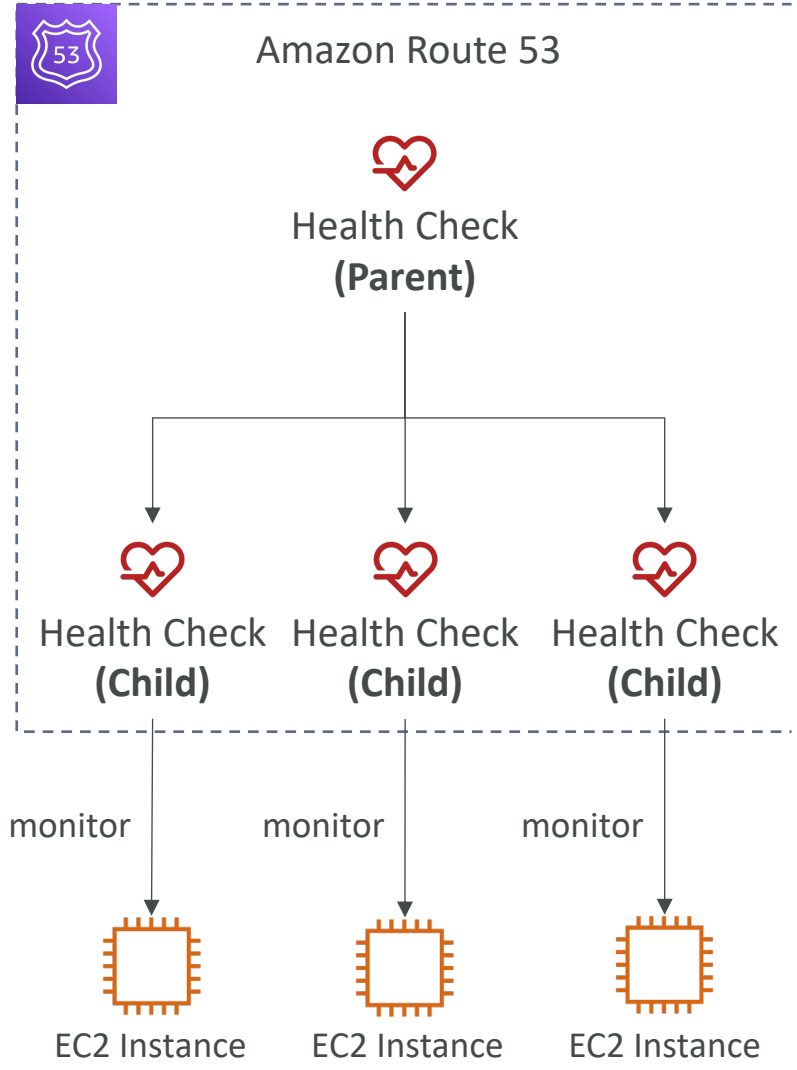
- About 15 global health checkers will check the endpoint health
  - Healthy/Unhealthy Threshold – 3 (default)
  - Interval – 30 sec (can set to 10 sec – higher cost)
  - Supported protocol: HTTP, HTTPS and TCP
  - If > 18% of health checkers report the endpoint is healthy, Route 53 considers it **Healthy**. Otherwise, it's **Unhealthy**
  - Ability to choose which locations you want Route 53 to use
- Health Checks pass only when the endpoint responds with the 2xx and 3xx status codes
- Health Checks can be setup to pass / fail based on the text in the first **5120 bytes** of the response
- Configure you router/firewall to allow incoming requests from Route 53 Health Checkers



https://ip-ranges.amazonaws.com/ip-ranges.json

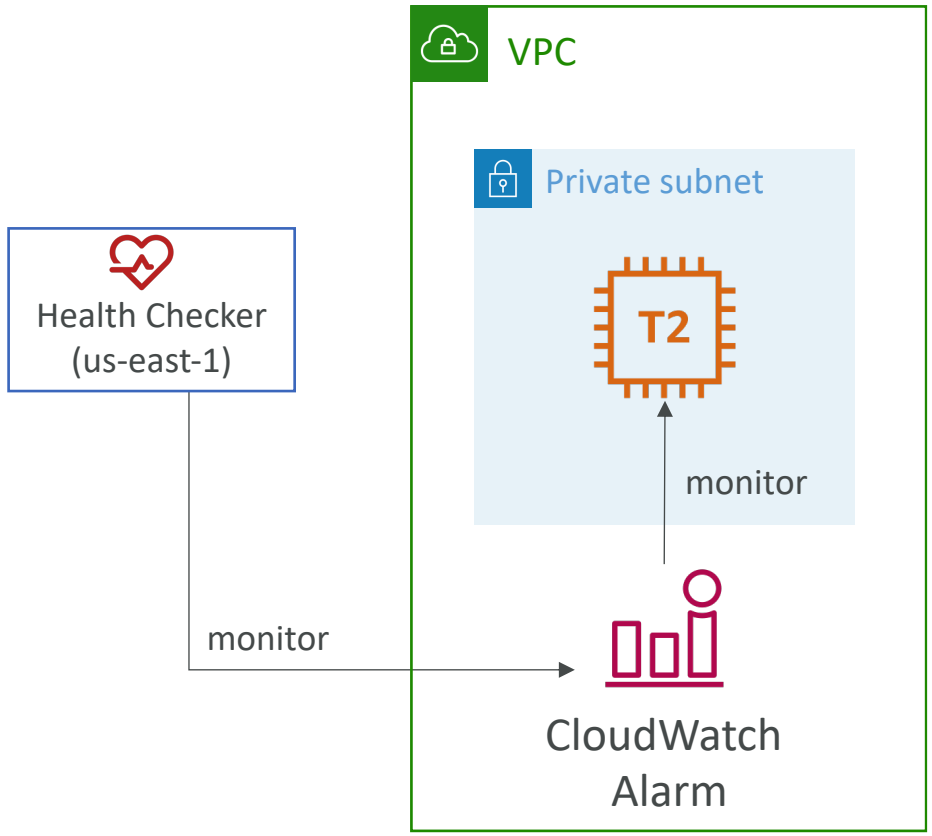
Route 53 – Calculated Health Checks

- Combine the results of multiple Health Checks into a single Health Check
- You can use **OR**, **AND**, or **NOT**
- Can monitor up to 256 Child Health Checks
- Specify how many of the health checks need to pass to make the parent pass
- Usage: perform maintenance to your website without causing all health checks to fail

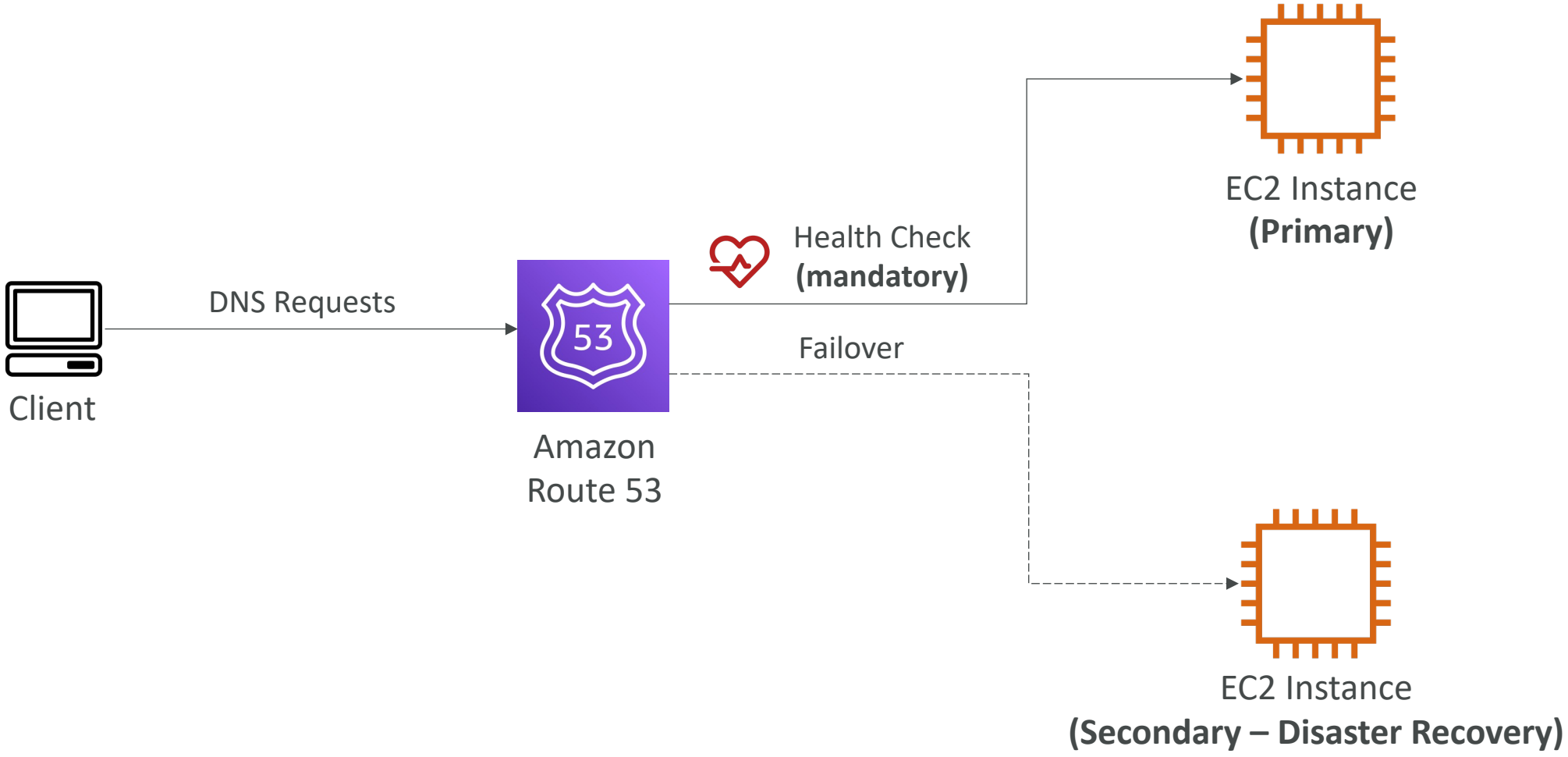


Health Checks – Private Hosted Zones

- Route 53 health checkers are outside the VPC
- They can't access **private** endpoints (private VPC or on-premises resource)
- You can create a **CloudWatch Metric** and associate a **CloudWatch Alarm**, then create a Health Check that checks the alarm itself

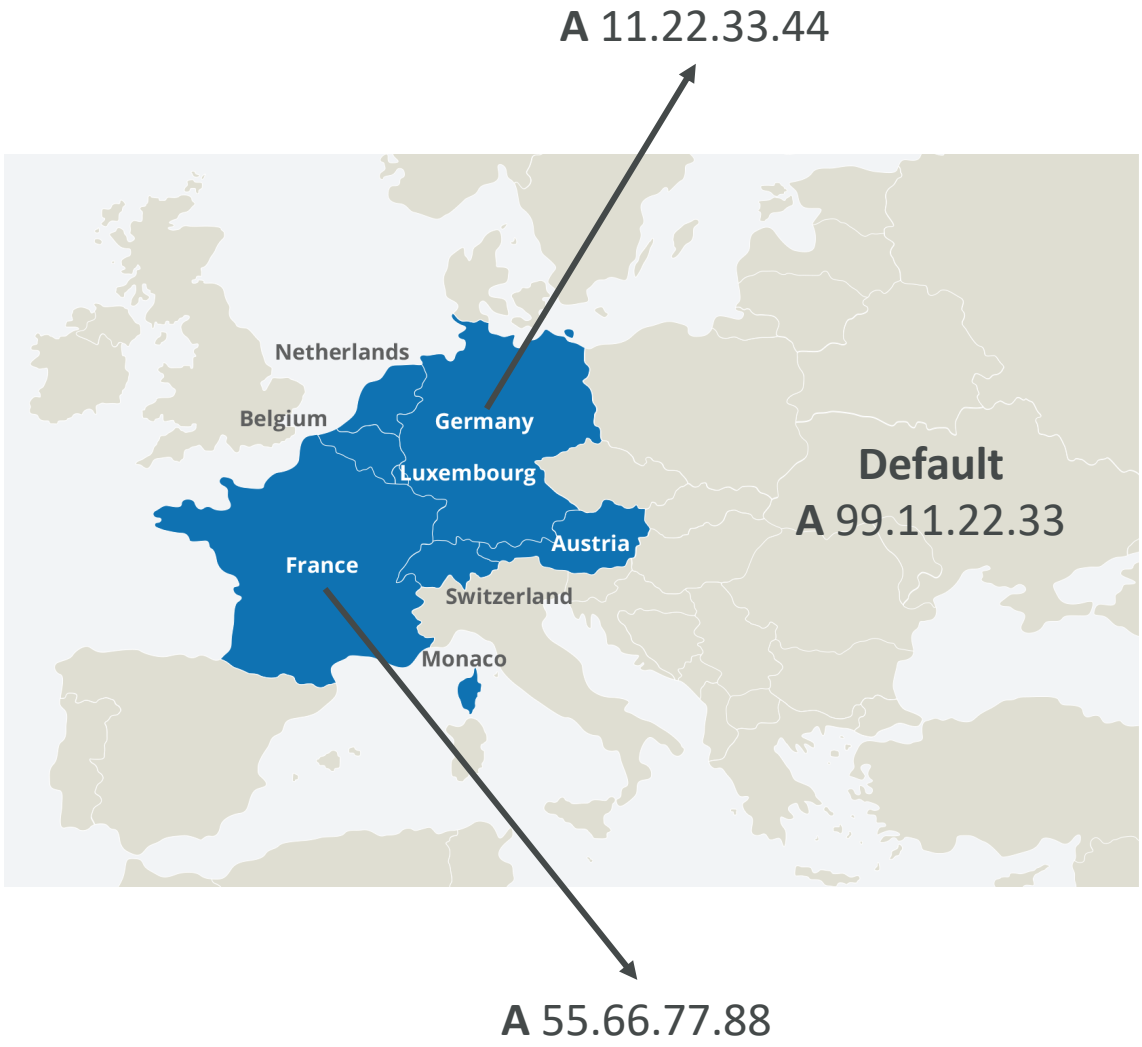


Routing Policies – Failover (Active-Passive)



Routing Policies – Geolocation

- Different from Latency-based!
- **This routing is based on user location**
- Specify location by Continent, Country or by US State (if there's overlapping, most precise location selected)
- Should create a **"Default"** record (in case there's no match on location)
- Use cases: website localization, restrict content distribution, load balancing, …
- Can be associated with Health Checks

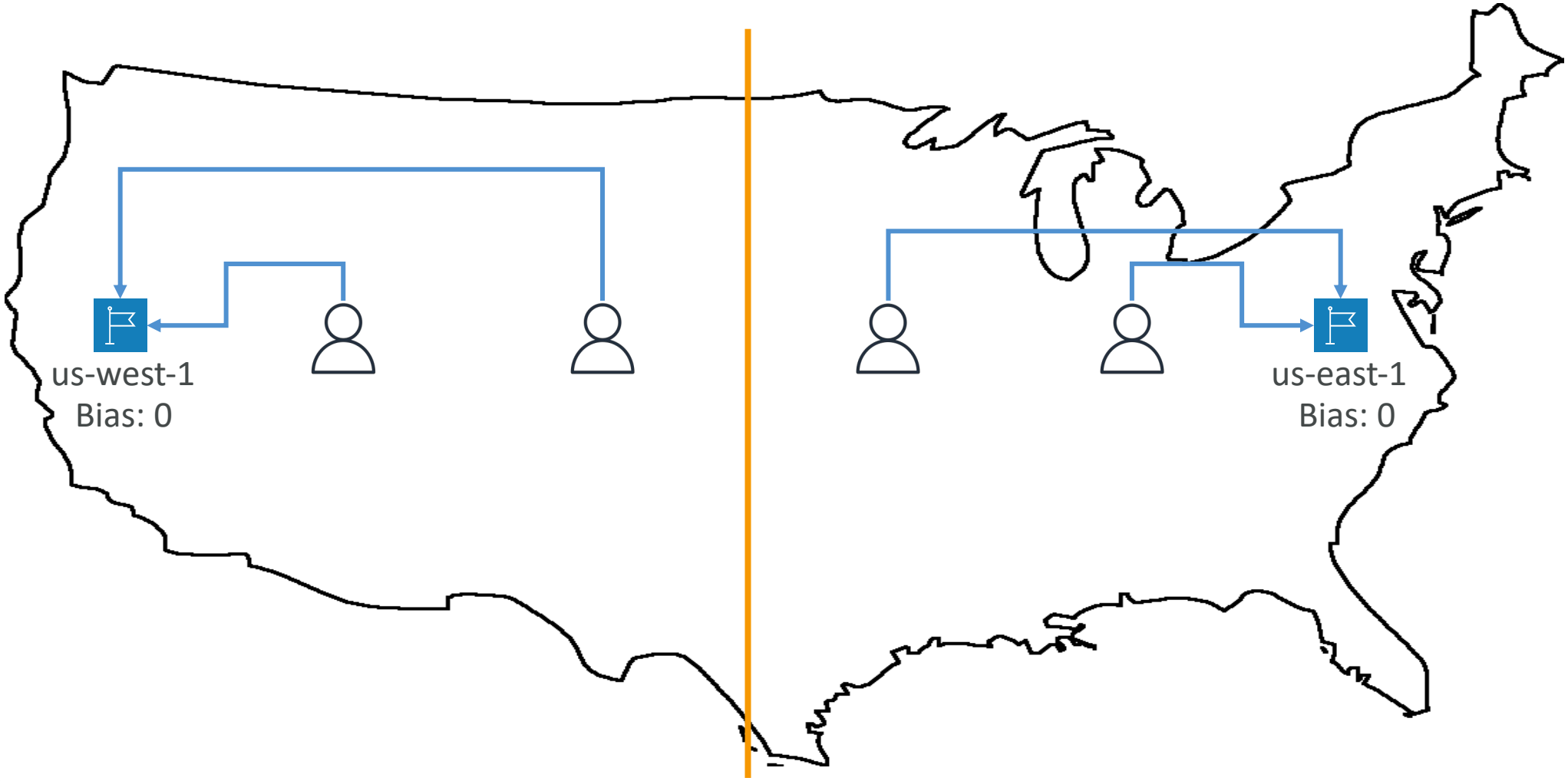


Routing Policies – Geoproximity

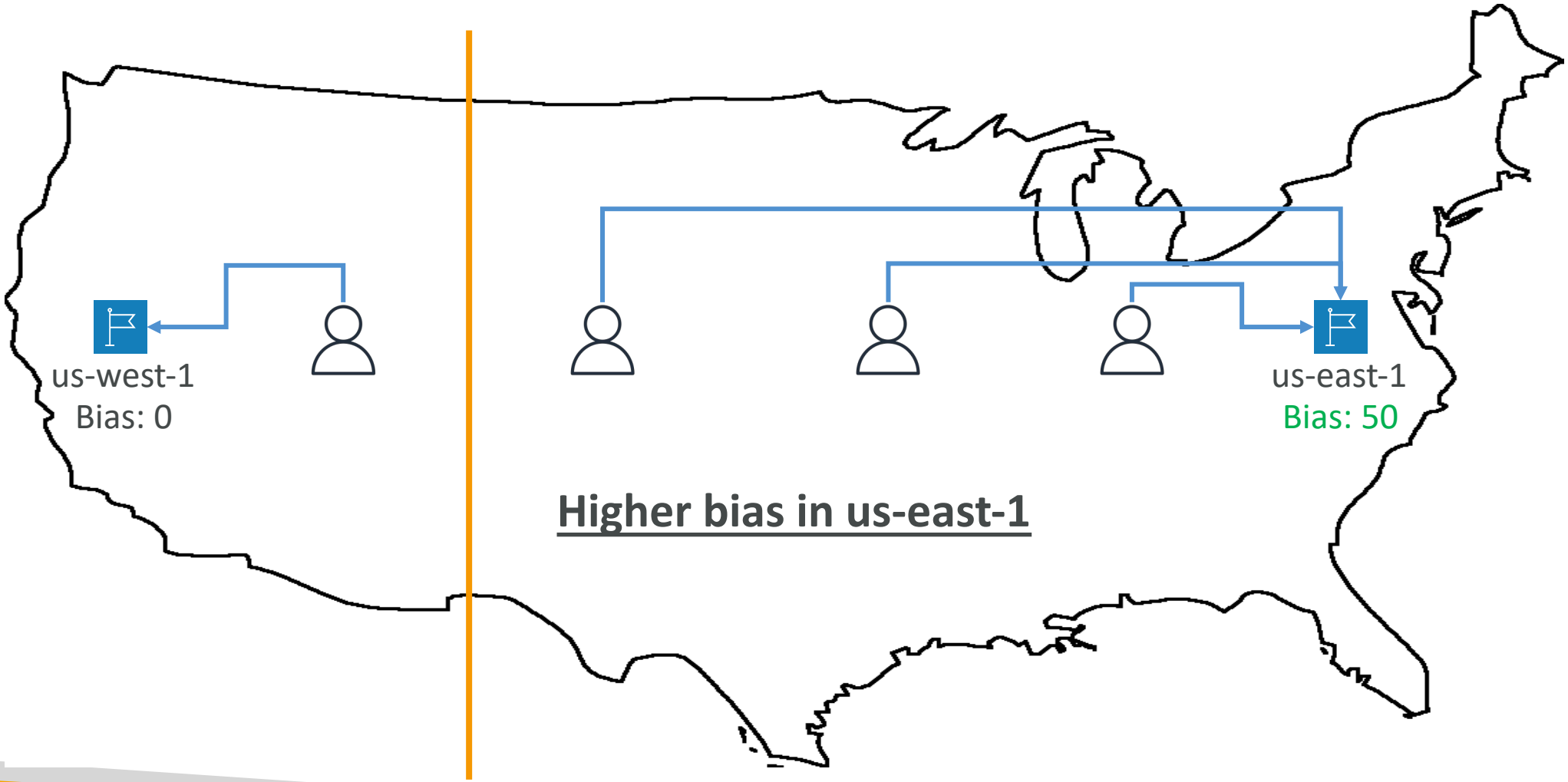
- Route traffic to your resources based on the geographic location of users and resources
- Ability **to shift more traffic to resources based** on the defined **bias**
- To change the size of the geographic region, specify **bias** values:
  - To expand (1 to 99) – more traffic to the resource
  - To shrink (-1 to -99) – less traffic to the resource

- Resources can be:
  - AWS resources (specify AWS region)
  - Non-AWS resources (specify Latitude and Longitude)
- You must use Route 53 **Traffic Flow** to use this feature

Routing Policies – Geoproximity



Routing Policies – Geoproximity



Route 53 – Traffic flow

- Simplify the process of creating and maintaining records in large and complex configurations
- Visual editor to manage complex routing decision trees
- Configurations can be saved as **Traffic Flow Policy**
  - Can be applied to different Route 53 Hosted Zones (different domain names)
  - Supports versioning