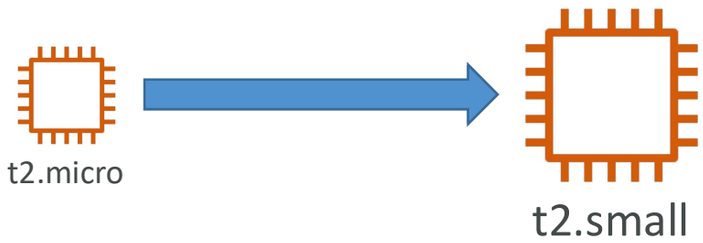
AWS Certified SysOps Administrator Associate Course

SOA-C02

EC2 for SysOps

Rocking EC2 from a SysOps perspective

EC2 Changing Instance Type

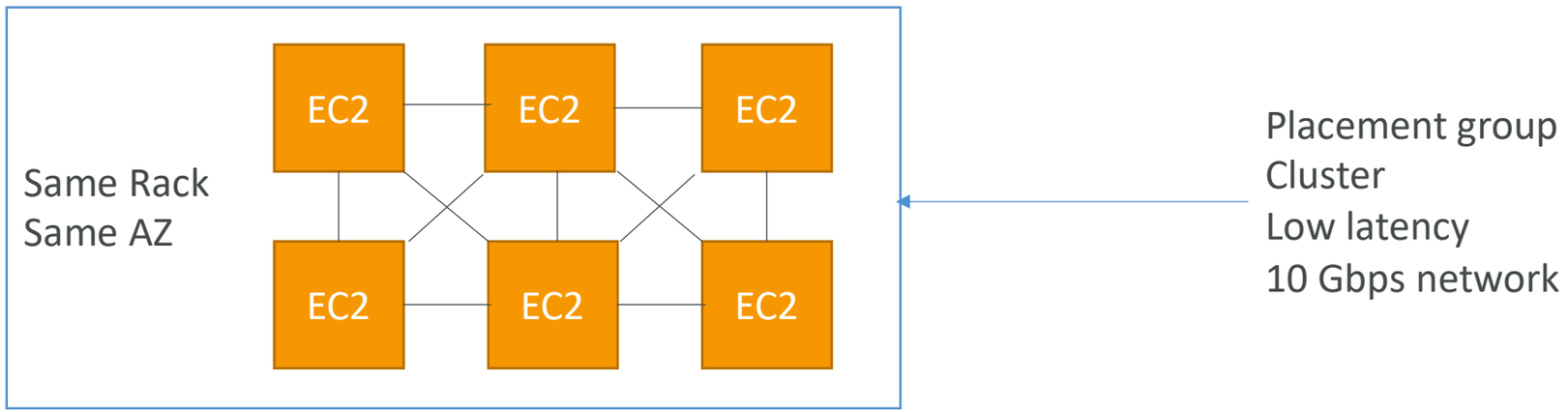


- This only works for EBS backed instances
- Stop the instance
- Instance Settings => Change Instance Type
- Start Instance

Placement Groups

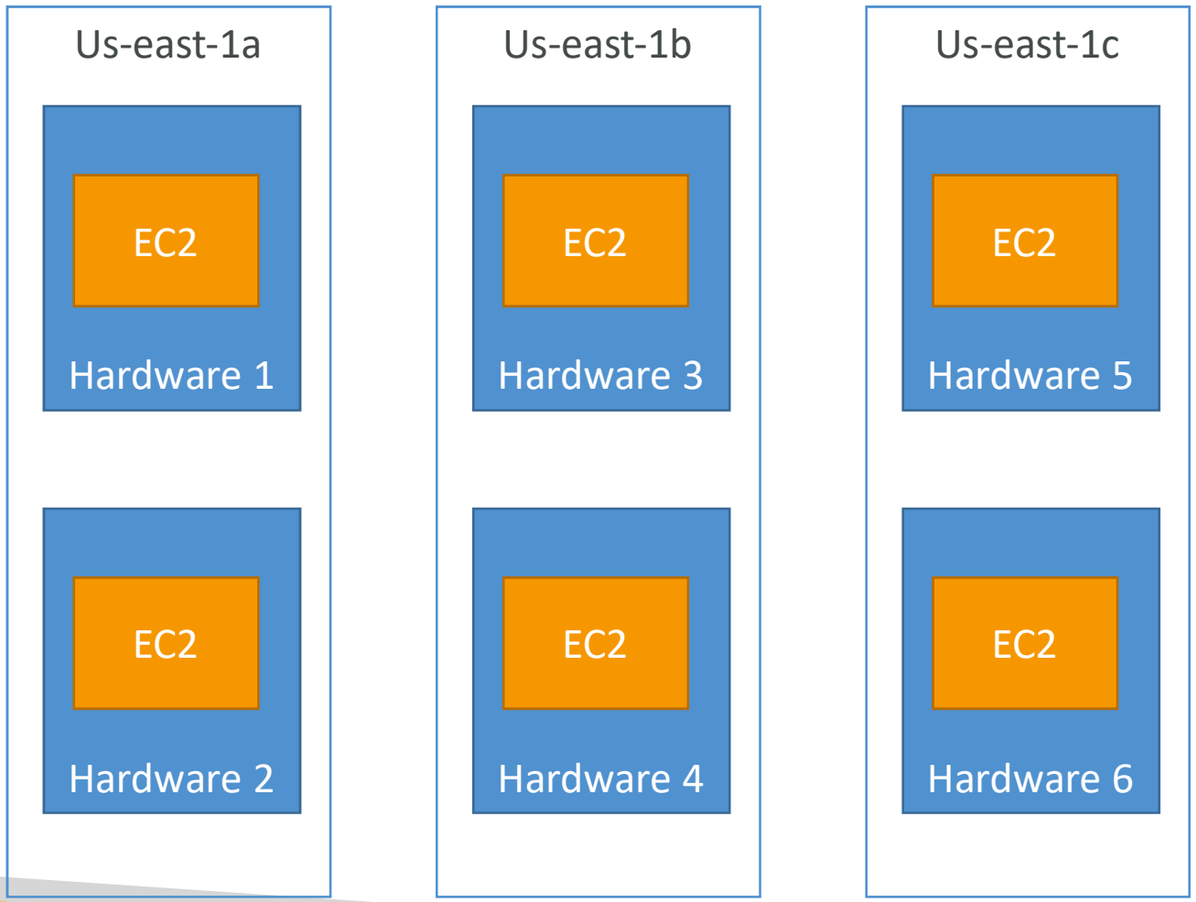
- Sometimes you want control over the EC2 Instance placement strategy
- That strategy can be defined using placement groups
- When you create a placement group, you specify one of the following strategies for the group:
  - *Cluster*—clusters instances into a low-latency group in a single Availability Zone
  - *Spread*—spreads instances across underlying hardware (max 7 instances per group per AZ) – critical applications
  - *Partition*—spreads instances across many different partitions (which rely on different sets of racks) within an AZ. Scales to 100s of EC2 instances per group (Hadoop, Cassandra, Kafka)

Placement Groups
Cluster



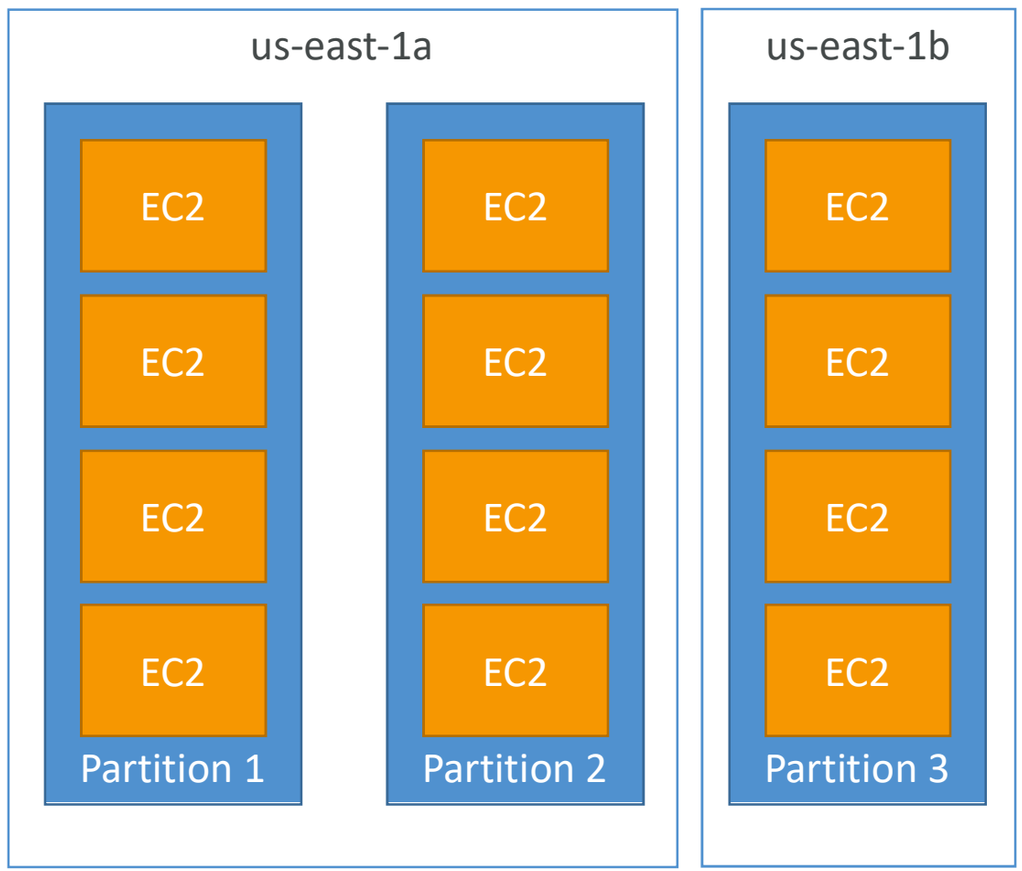
- Pros: Great network (10 Gbps bandwidth between instances with Enhanced Networking enabled - recommended)
- Cons: If the rack fails, all instances fails at the same time
- Use case:
  - Big Data job that needs to complete fast
  - Application that needs extremely low latency and high network throughput

Placement Groups Spread



- Pros:
  - Can span across Availability Zones (AZ)
  - Reduced risk is simultaneous failure
  - EC2 Instances are on different physical hardware
- Cons:
  - Limited to 7 instances per AZ per placement group
- Use case:
  - Application that needs to maximize high availability
  - Critical Applications where each instance must be isolated from failure from each other

Placements Groups Partition



- Up to 7 partitions per AZ
- Can span across multiple AZs in the same region
- Up to 100s of EC2 instances
- The instances in a partition do not share racks with the instances in the other partitions
- A partition failure can affect many EC2 but won't affect other partitions
- EC2 instances get access to the partition information as metadata
- Use cases: HDFS, HBase, Cassandra, Kafka

Termination Protection

- **Enable termination protection**:
  To protect against accidental termination in AWS Console or CLI

- Exam Tip:
  - We have an instance where shutdown behavior = terminate and enable terminate protection is ticked
  - We shutdown the instance from the OS, what will happen ?

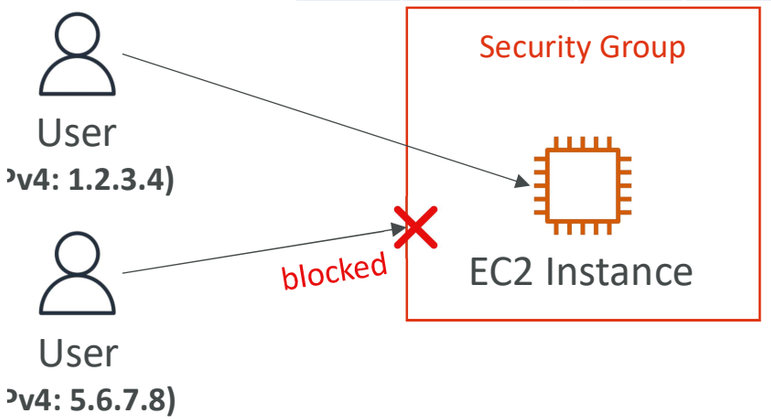
  - The instance will still be terminated!

SSH vs. EC2 Instance Connect

Connect using SSH

Inbound Rules

Type	Protocol	Port	Source
SSH	TCP	22	1.2.3.4/32

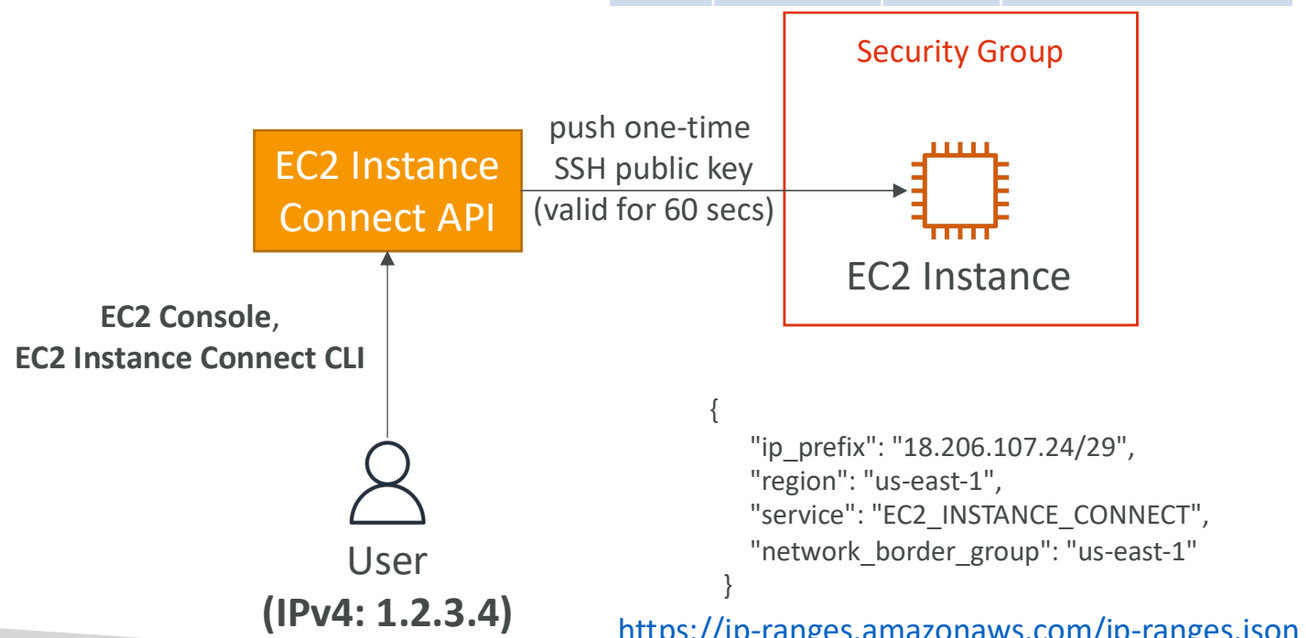


Connect using EC2 Instance Connect

Inbound Rules

Type	Protocol	Port	Source
SSH	TCP	22	18.206.107.24/29

Allows AWS IP Range




```
{
    "ip_prefix": "18.206.107.24/29",
    "region": "us-east-1",
    "service": "EC2_INSTANCE_CONNECT",
    "network_border_group": "us-east-1"
}
```


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

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 Spot Instance Requests

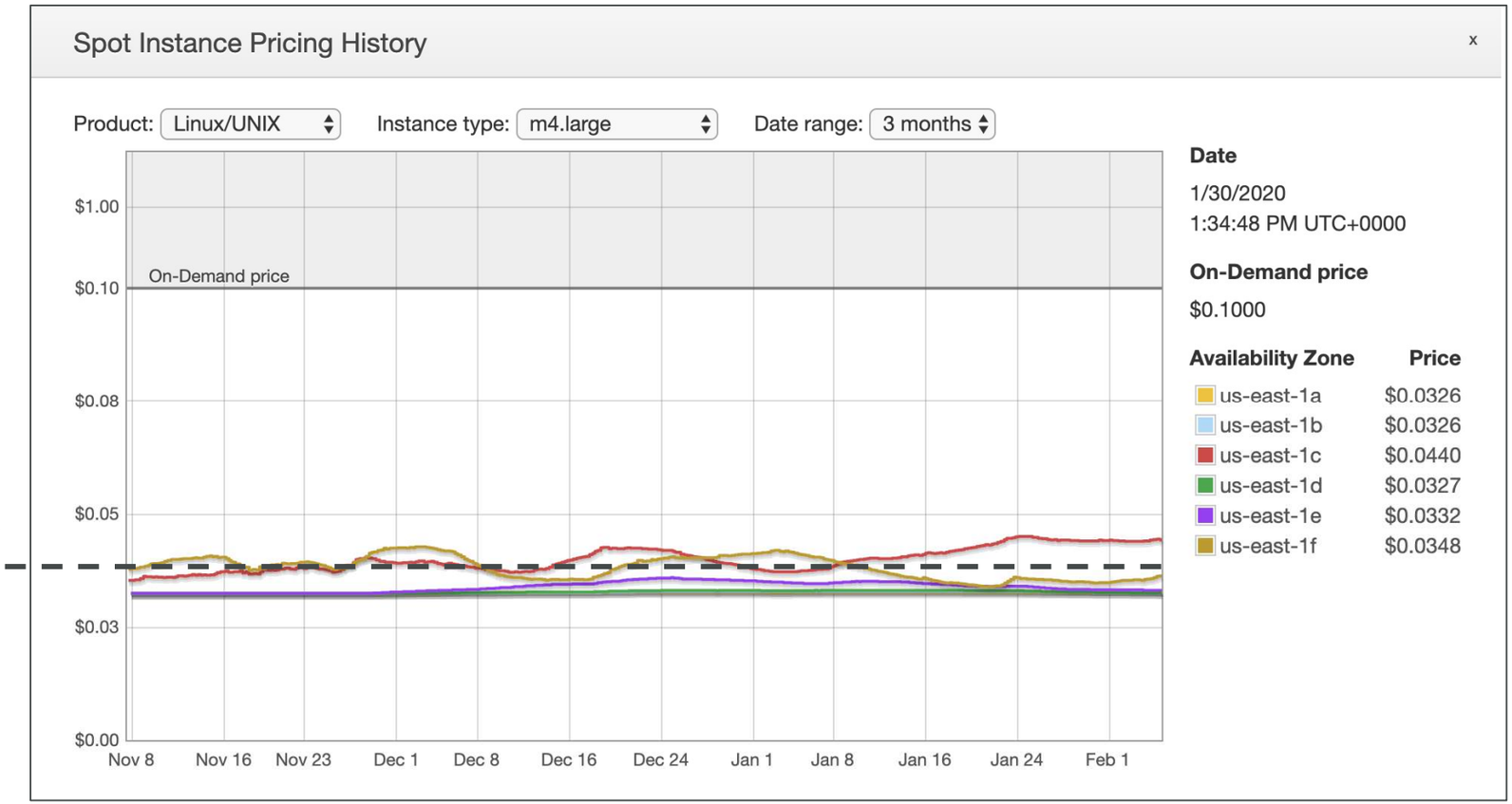
- Can get a discount of up to 90% compared to On-demand

- Define **max spot price** and get the instance while **current spot price < max**
  - The hourly spot price varies based on offer and capacity
  - If the current spot price > your max price you can choose to **stop** or **terminate** your instance with a 2 minutes grace period.
- Other strategy: **Spot Block**
  - "block" spot instance during a specified time frame (1 to 6 hours) without interruptions
  - In rare situations, the instance may be reclaimed

- **Used for batch jobs, data analysis, or workloads that are resilient to failures.**
- **Not great for critical jobs or databases**

EC2 Spot Instances Pricing

User-defined max price



https://console.aws.amazon.com/ec2sp/v1/spot/home?region=us-east-1#

Burstable Instances (T2/T3)

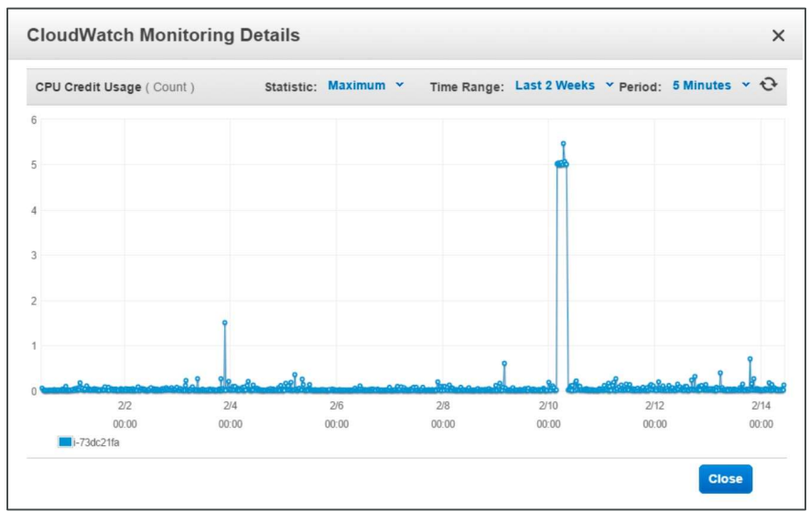
- AWS has the concept of burstable instances (T2/T3 machines)

- Burst means that overall, the instance has OK CPU performance.
- When the machine needs to process something unexpected (a spike in load for example), it can burst, and CPU can be VERY good.
- If the machine bursts, it utilizes "burst credits"
- If all the credits are gone, the CPU becomes BAD
- If the machine stops bursting, credits are accumulated over time

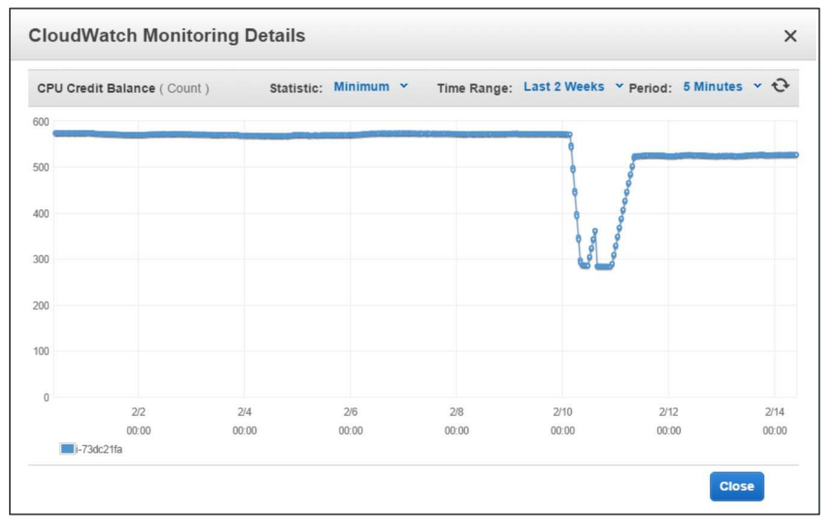
Burstable Instances (T2/T3)

- Burstable instances can be amazing to handle unexpected traffic and getting the insurance that it will be handled correctly
- If your instance consistently runs low on credit, you need to move to a different kind of non-burstable instance

Credit usage



Credit balance



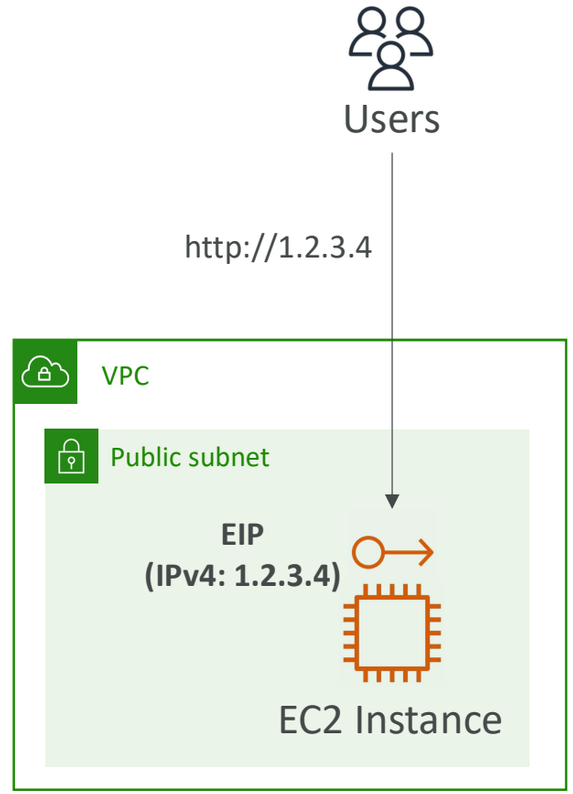
CPU Credits

Instance type	Launch credits	vCPUs	CPU credits earned per hour	Maximum earned CPU credit balance	vCPUs	Baseline performance (% CPU utilization)
t2.nano	30	1	3	72	1	5%
t2.micro	30	1	6	144	1	10%
t2.small	30	1	12	288	1	20%
t2.medium	60	2	24	576	2	40% (of 200% max)*
t2.large	60	2	36	864	2	60% (of 200% max)*
t2.xlarge	120	4	54	1296	4	90% (of 400% max)*
t2.2xlarge	240	8	81	1944	8	135% (of 800% max)*

Elastic IPs

- When you stop and then start an EC2 instance, it changes its public IP
- If you need to have a fixed public IP, you need an Elastic IP
- An Elastic IP is a public IPv4 you own as long as you don't delete it
- You can attach it to one instance at a time
- You can remap it across instances

- You don't pay for the Elastic IP if it's attached to a server
- You pay for the Elastic IP if it's not attached to a server



Elastic IPs

- With an Elastic IP address, you can mask the failure of an instance or software by rapidly remapping the address to another instance in your account.

- You can only have 5 Elastic IP in your account (you can ask AWS to increase that).

- How you can avoid using Elastic IP:
  - Always think if other alternatives are available to you
  - You could use a random public IP and register a DNS name to it
  - Or use a Load Balancer with a static hostname

CloudWatch Metrics for EC2

- AWS Provided metrics (AWS pushes them):
  - Basic Monitoring (default): metrics are collected at a 5 minute internal
  - Detailed Monitoring (paid): metrics are collected at a 1 minute interval
  - Includes CPU, Network, Disk and Status Check Metrics

- Custom metric (yours to push):
  - Basic Resolution: 1 minute resolution
  - High Resolution: all the way to 1 second resolution
  - Include RAM, application level metrics
  - Make sure the IAM permissions on the EC2 instance role are correct !

EC2 included metrics

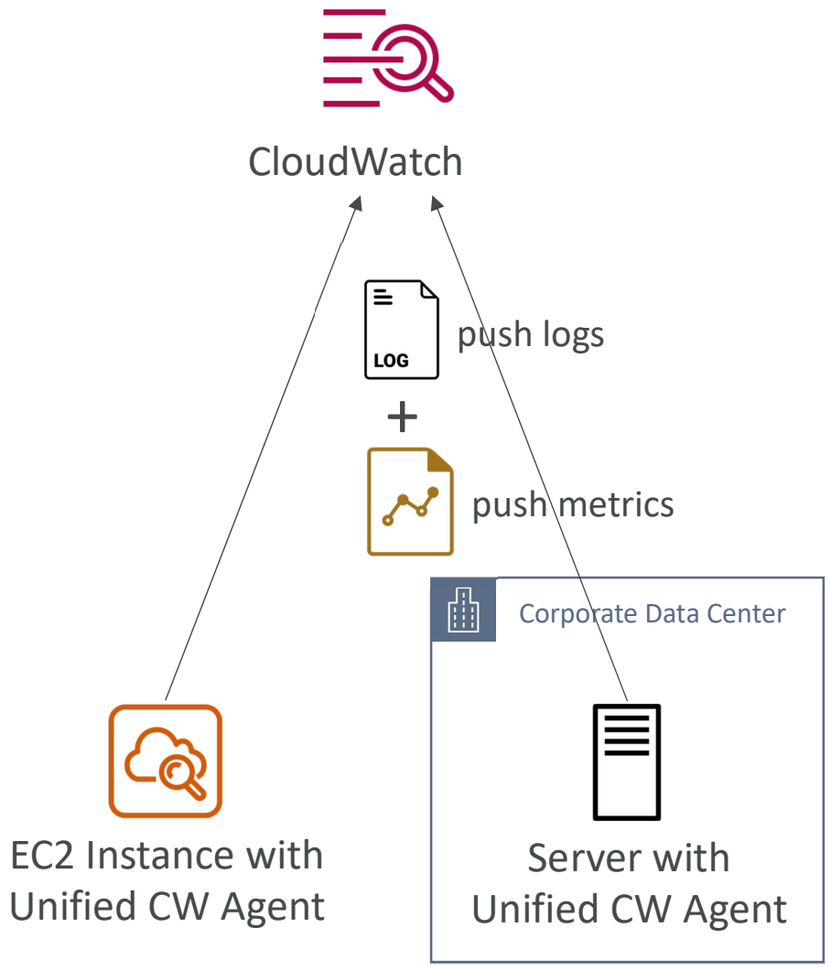
- CPU: CPU Utilization + Credit Usage / Balance
- Network: Network In / Out
- Status Check:
  - Instance status = check the EC2 VM
  - System status = check the underlying hardware
- Disk: Read / Write for Ops / Bytes (only for instance store)

- RAM is NOT included in the AWS EC2 metrics

Unified CloudWatch Agent

- For virtual servers (EC2 instances, on-premises servers, …)
- Collect additional system-level metrics such as RAM, processes, used disk space, etc.
- Collect logs to send to CloudWatch Logs
  - No logs from inside your EC2 instance will be sent to CloudWatch Logs without using an agent
- Centralized configuration using SSM Parameter Store
- Make sure IAM permissions are correct

- Default namespace for metrics collected by the Unified CloudWatch agent is **CWAgent** (can be configured/changed)



EC2 Hibernate

- We know we can stop, terminate instances
  - **Stop** – s the data on disk (EBS) is kept intact in the next start
  - **Terminate** – any EBS volumes (root) also set-up to be destroyed is lost

- On start, the following happens:
  - First start: the OS boots & the EC2 User Data script is run
  - Following starts: the OS boots up
  - Then your application starts, caches get warmed up, and that can take time!

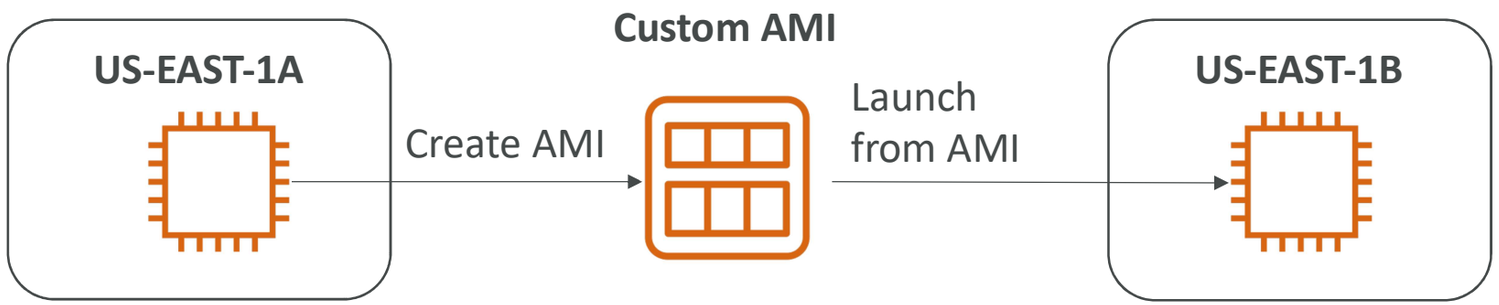
AMI

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)

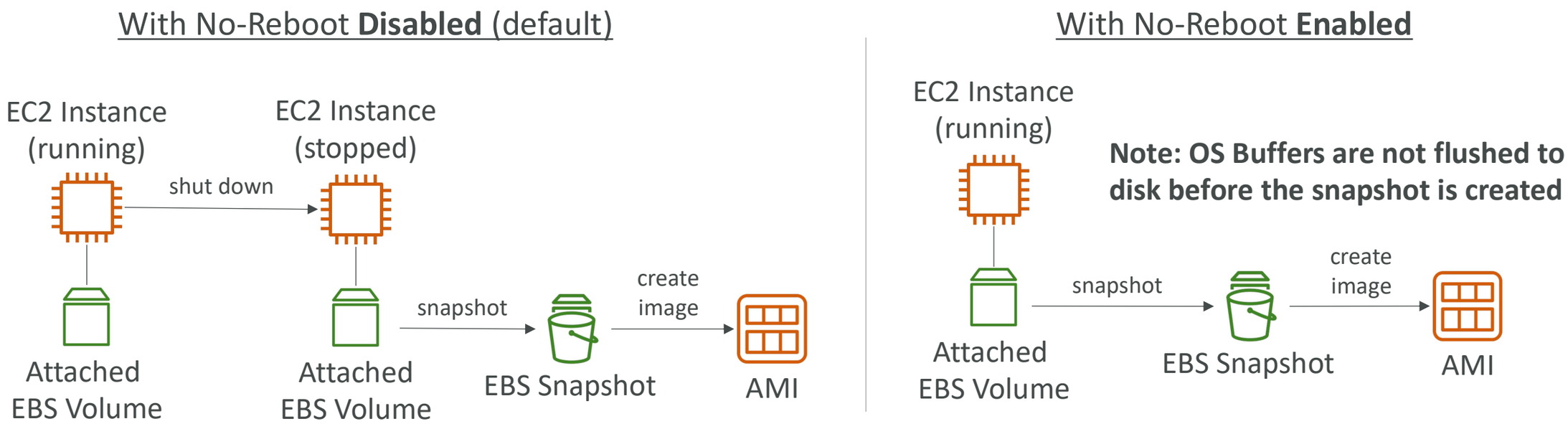
AMI Process (from an EC2 instance)

- 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

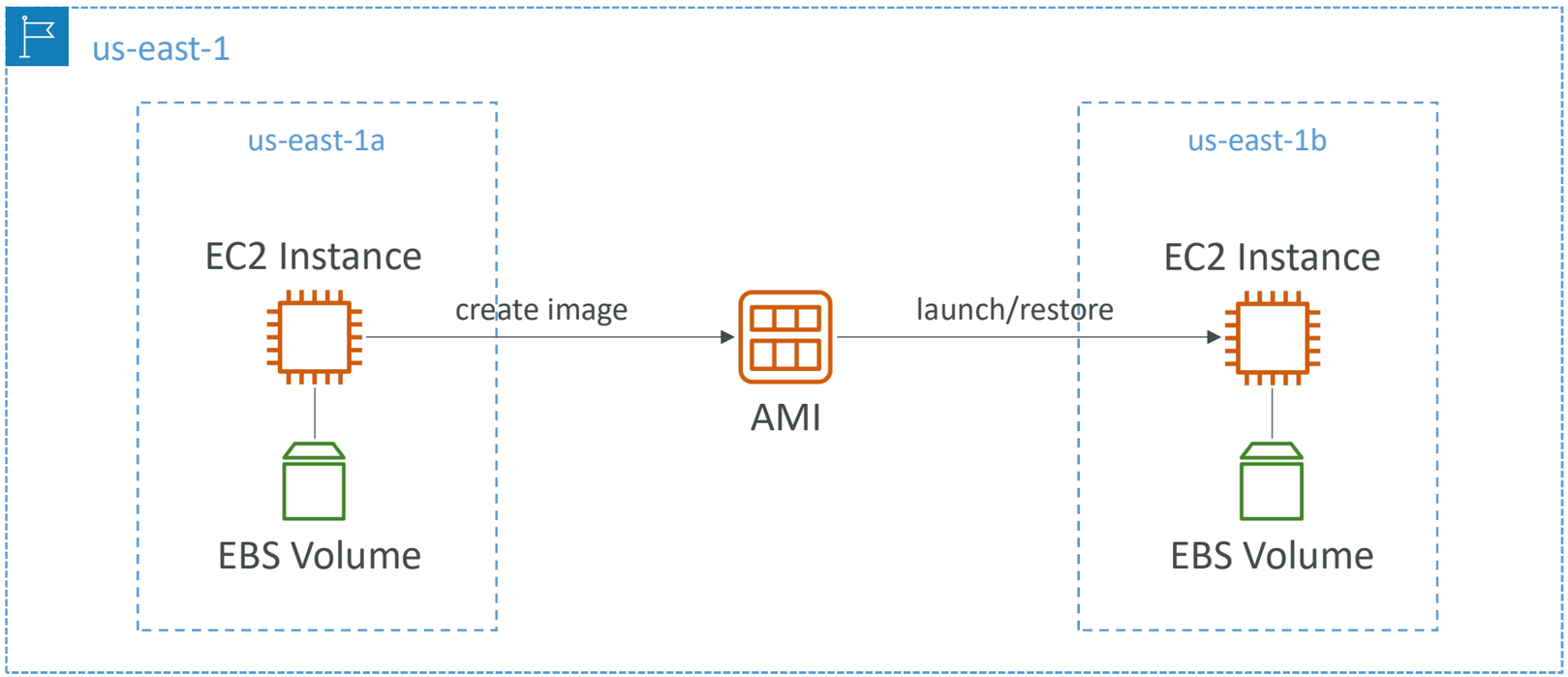


AMI No-Reboot Option

- Enables you to create an AMI without shutting down your instance
- By default, it's not selected (AWS will shut down the instance before creating an AMI to maintain the file system integrity)

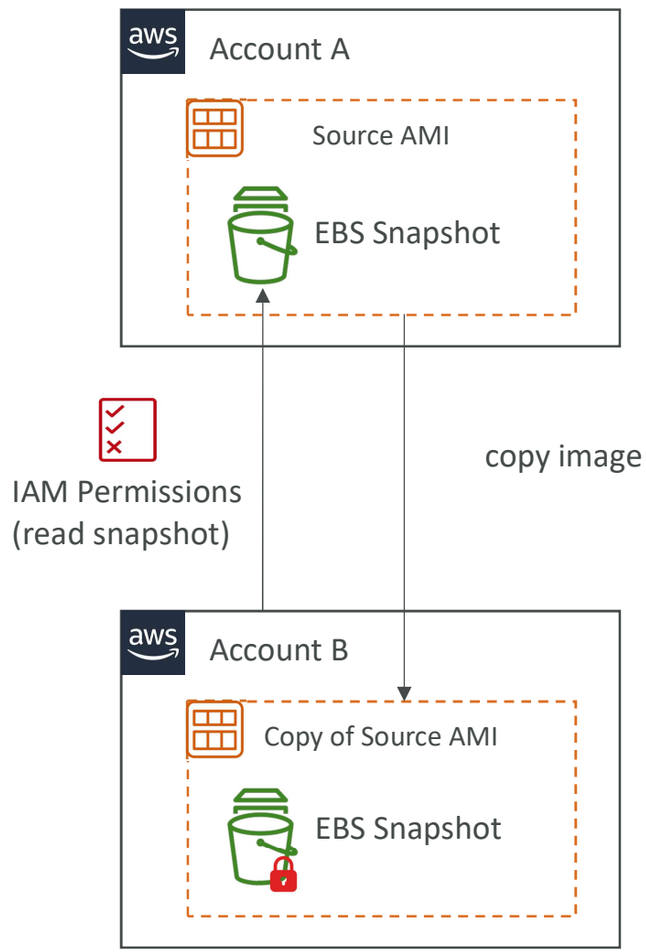


EC2 Instance Migration between AZ



Cross-Account AMI Copy

- If you copy an AMI that has been shared with your account, you are the owner of the target AMI in your account
- The owner of the source AMI must grant you read permissions for the storage that backs the AMI (EBS Snapshot)
- If the shared AMI has encrypted snapshots, the owner must share the key or keys with you as well
- Can encrypt the AMI with your own CMK while copying



Management of EC2 at scale

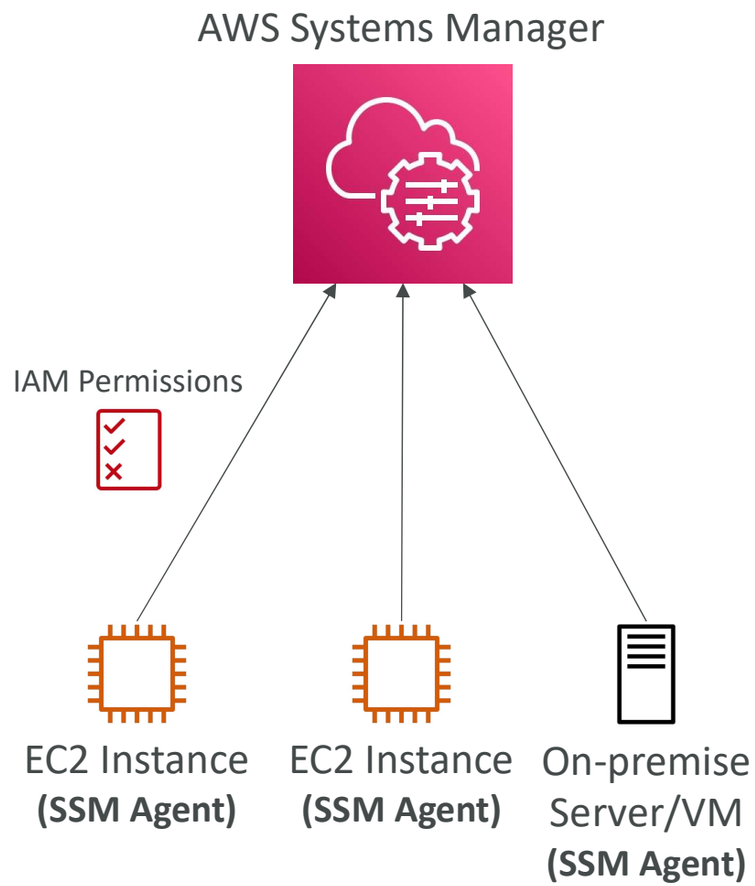
Systems Manager & OpsWorks

AWS Systems Manager Overview

- Helps you manage your **EC2 and On-Premises** systems at scale
- Get operational insights about the state of your infrastructure
- Easily detect problems
- **Patching automation for enhanced compliance**
- Works for both Windows and Linux OS
- Integrated with CloudWatch metrics / dashboards
- Integrated with AWS Config
- Free service

How Systems Manager works

- We need to install the SSM agent onto the systems we control
- Installed by default on Amazon Linux 2 AMI & some Ubuntu AMI
- If an instance can't be controlled with SSM, it's probably an issue with the SSM agent!
- Make sure the EC2 instances have a proper IAM role to allow SSM actions

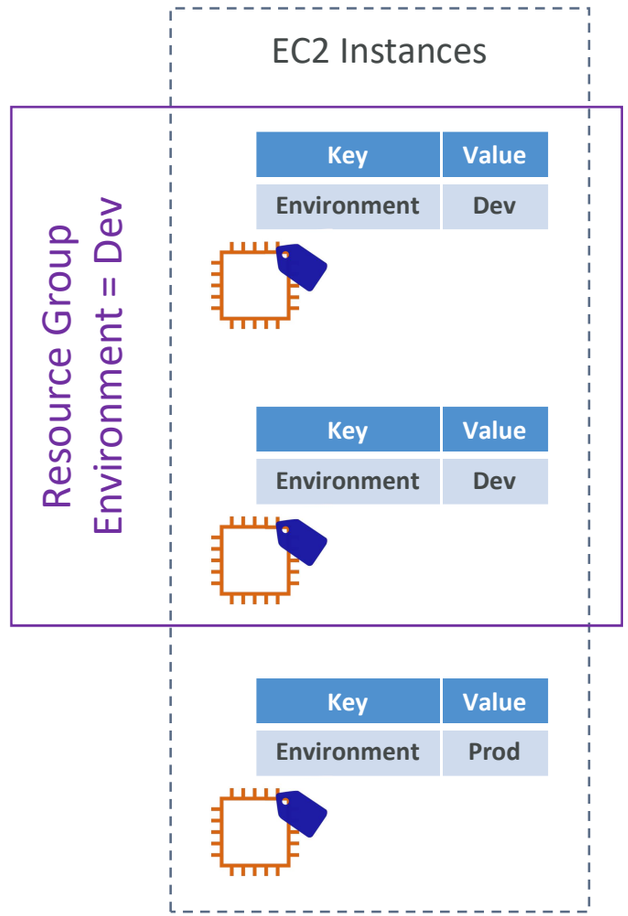


AWS Tags

- You can add text key-value pairs called Tags to many AWS resources
- Commonly used in EC2
- Free naming, common tags are Name, Environment, Team …
- They're used for
  - Resource grouping
  - Automation
  - Cost allocation
- Better to have too many tags than too few!

Resource Groups

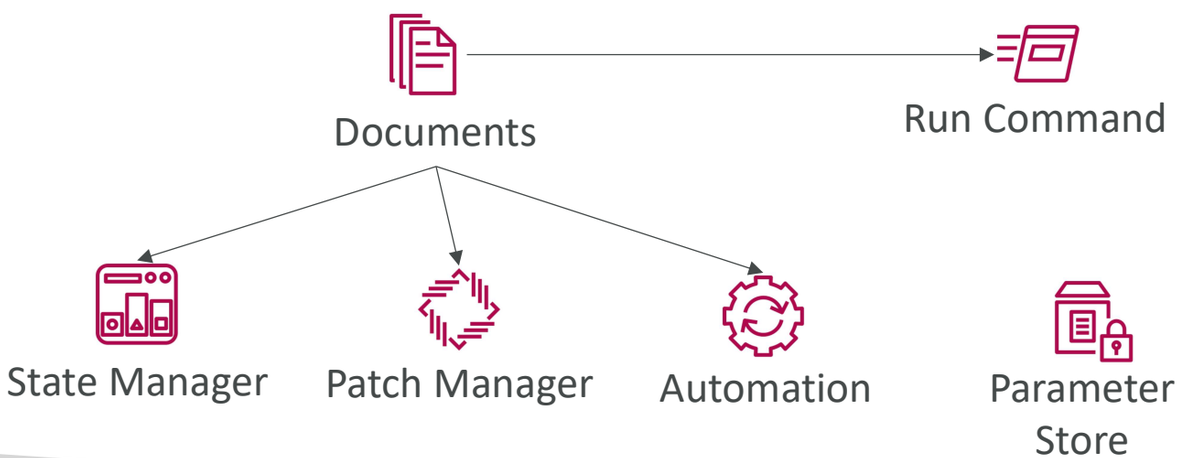
- Create, view or manage logical group of resources thanks to **tags**
- Allows creation of logical groups of resources such as
  - Applications
  - Different layers of an application stack
  - Production versus development environments
- Regional service
- Works with EC2, S3, DynamoDB, Lambda, etc…



SSM – Documents

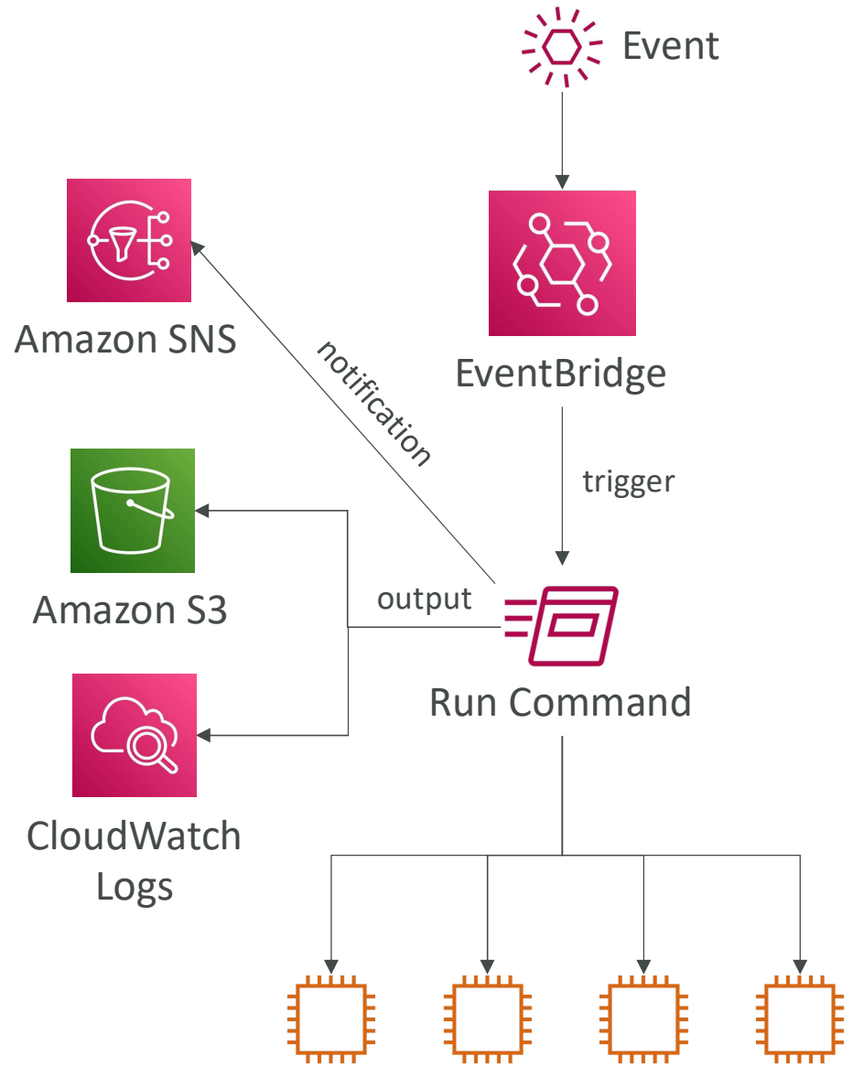
- Documents can be in JSON or YAML
- You define parameters
- You define actions
- Many documents already exist in AWS

```yaml
---
schemaVersion: '2.2'
description: State Manager Bootstrap Example
parameters: {}
mainSteps:
  - action: aws:runShellScript
    name: configureServer
    inputs:
      runCommand:
        - sudo yum install -y httpd
        - sudo yum --enablerepo=epel install -y clamav
```



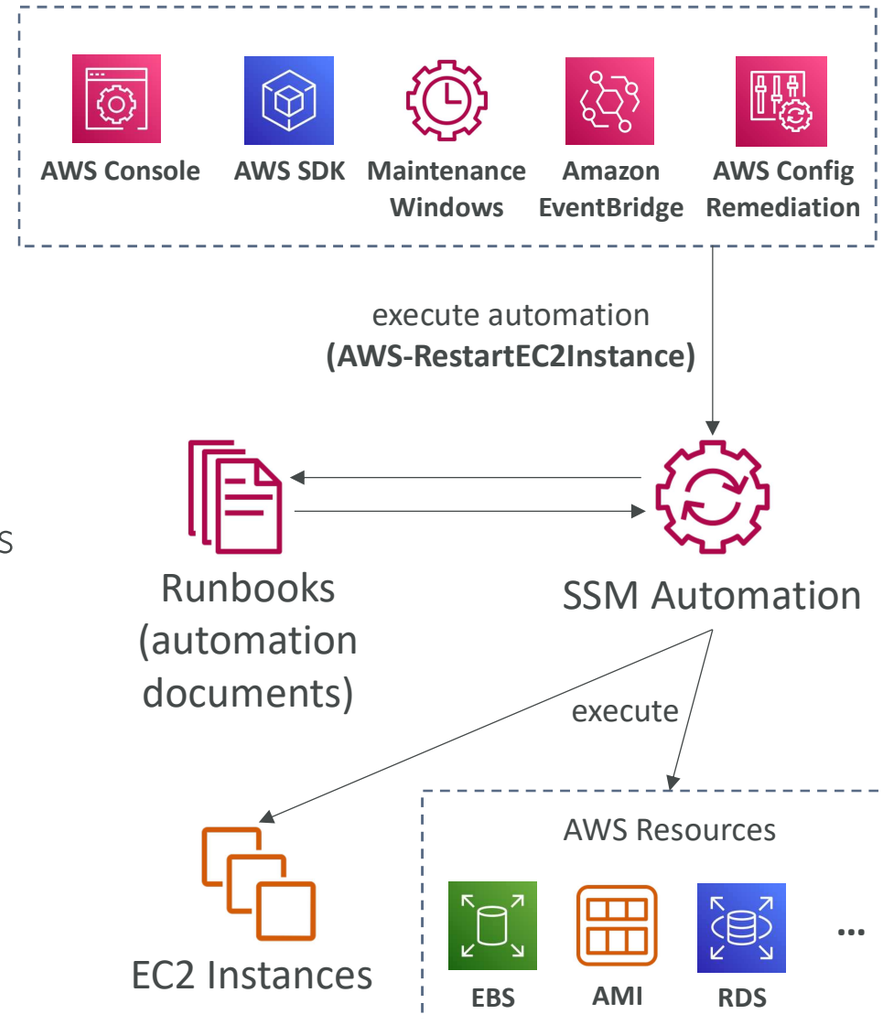
SSM – Run Command

- Execute a document (= script) or just run a command
- Run command across multiple instances (using resource groups)
- Rate Control / Error Control
- Integrated with IAM & CloudTrail
- No need for SSH
- Command Output can be shown in the Console, sent to S3 bucket or CloudWatch Logs
- Send notifications to SNS about command statues (In progress, Success, Failed, …)
- Can be invoked using EventBridge



SSM - Automation

- Simplifies common maintenance and deployment tasks of EC2 instances and other AWS resources
- Example: restart instances, create an AMI, EBS snapshot
- Automation Runbook
  - SSM Documents of type Automation
  - Defines actions preformed on your EC2 instances or AWS resources
  - Pre-defined runbooks (AWS) or create custom runbooks
- Can be triggered
  - Manually using AWS Console, AWS CLI or SDK
  - By Amazon EventBridge
  - On a schedule using Maintenance Windows
  - By AWS Config for rules remediations



EC2 High Availability and Scalability

Load Balancer and Auto Scaling Groups

Scalability and High Availability

- Load Balancers:
  - Troubleshooting
  - Advanced options and logging
  - CloudWatch integrations

- Auto Scaling
  - Troubleshooting
  - Advanced options and logging
  - CloudWatch integrations

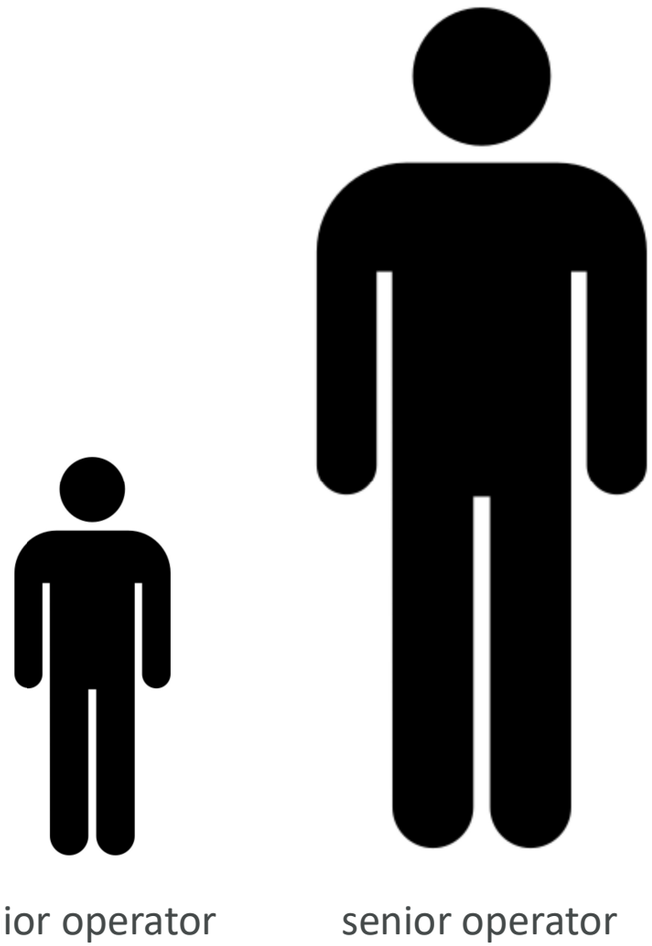
Scalability & High Availability

- 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)

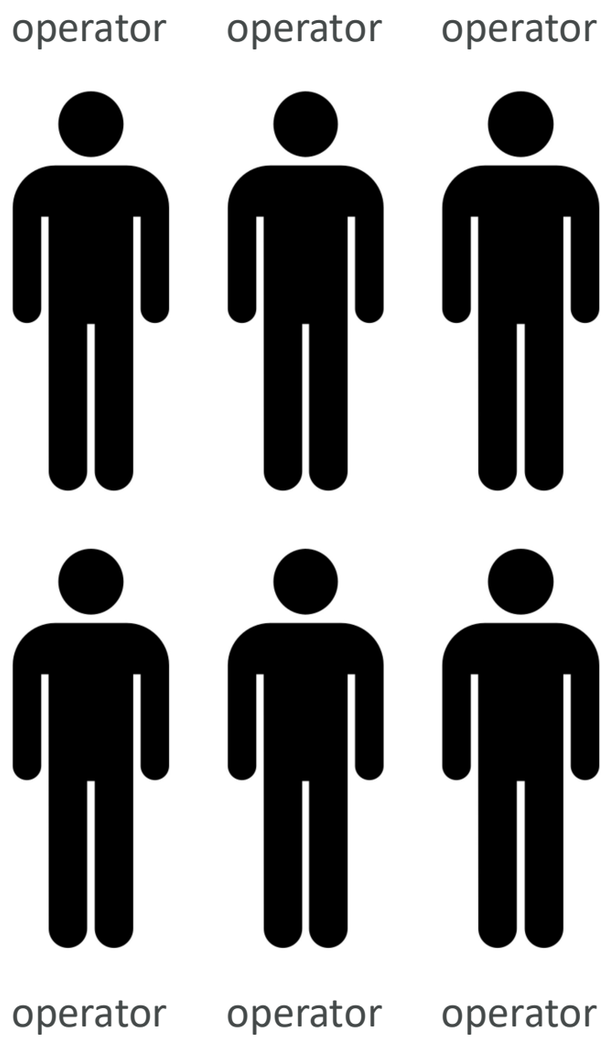


Horizontal Scalability

- 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

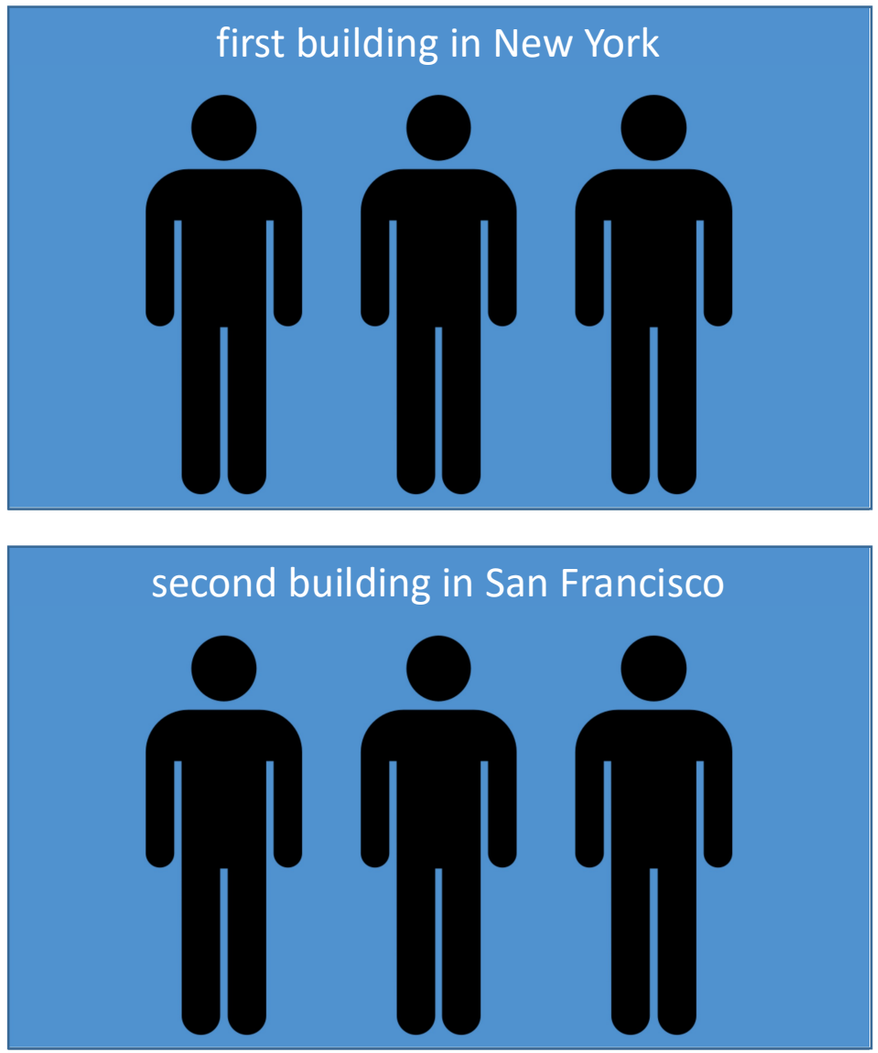
- It's easy to horizontally scale thanks the cloud offerings such as Amazon EC2



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)

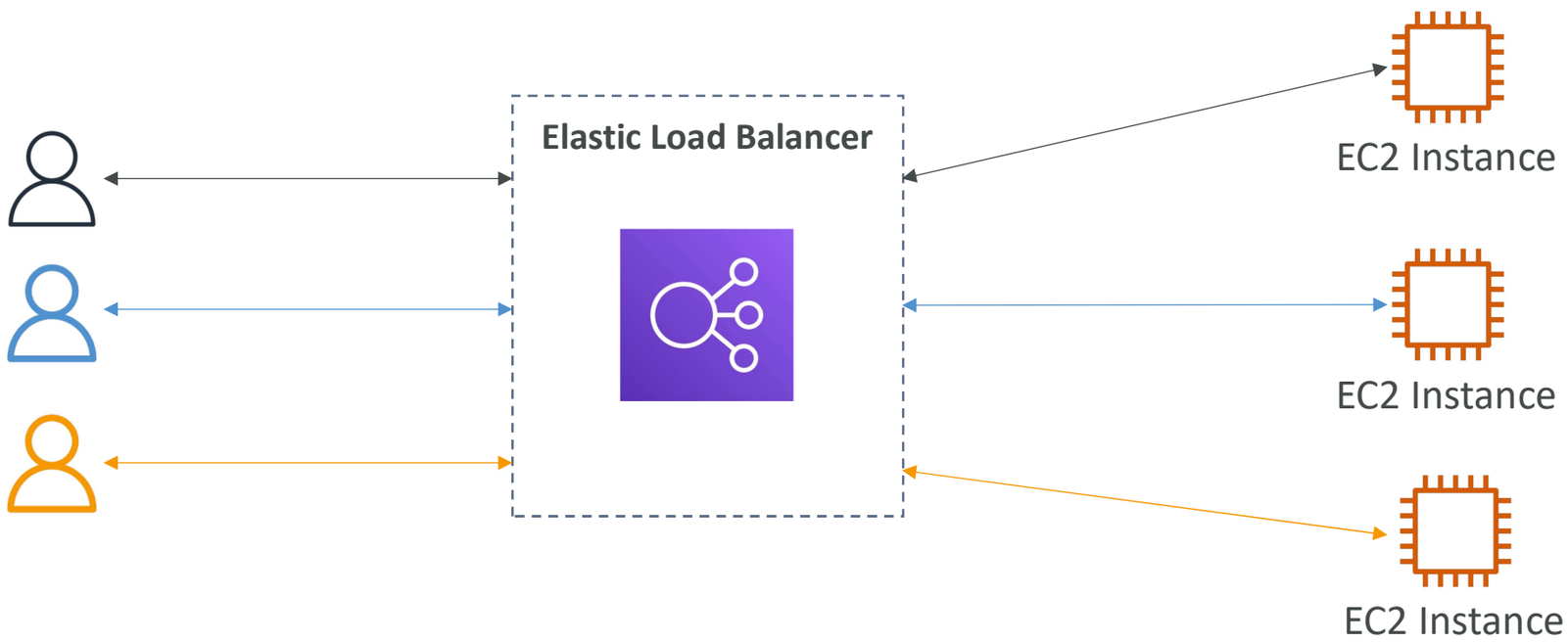


High Availability & Scalability For EC2

- 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

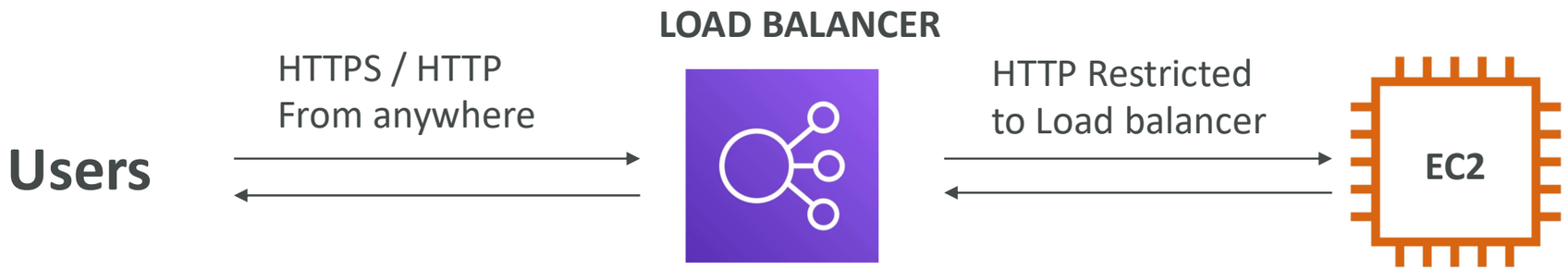
- Health Checks are crucial for Load Balancers
- They enable the load balancer to know if instances it forwards traffic to are available to reply to requests
- The health check is done on a port and a route (/health is common)
- If the response is not 200 (OK), then the instance is unhealthy

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:

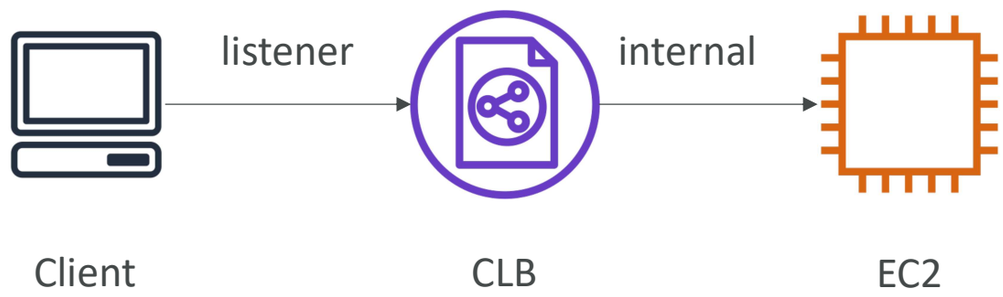
Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	0.0.0.0/0	Allow HTTP from an...
HTTPS	TCP	443	0.0.0.0/0	Allow HTTPS from a...

Application Security Group: Allow traffic only from Load Balancer

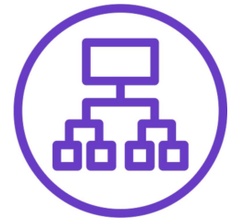
Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	sg-054b5ff5ea02f2b6e (load-b	Allow Traffic only...

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



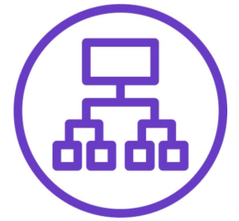
Application Load Balancer (v2)



- 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)

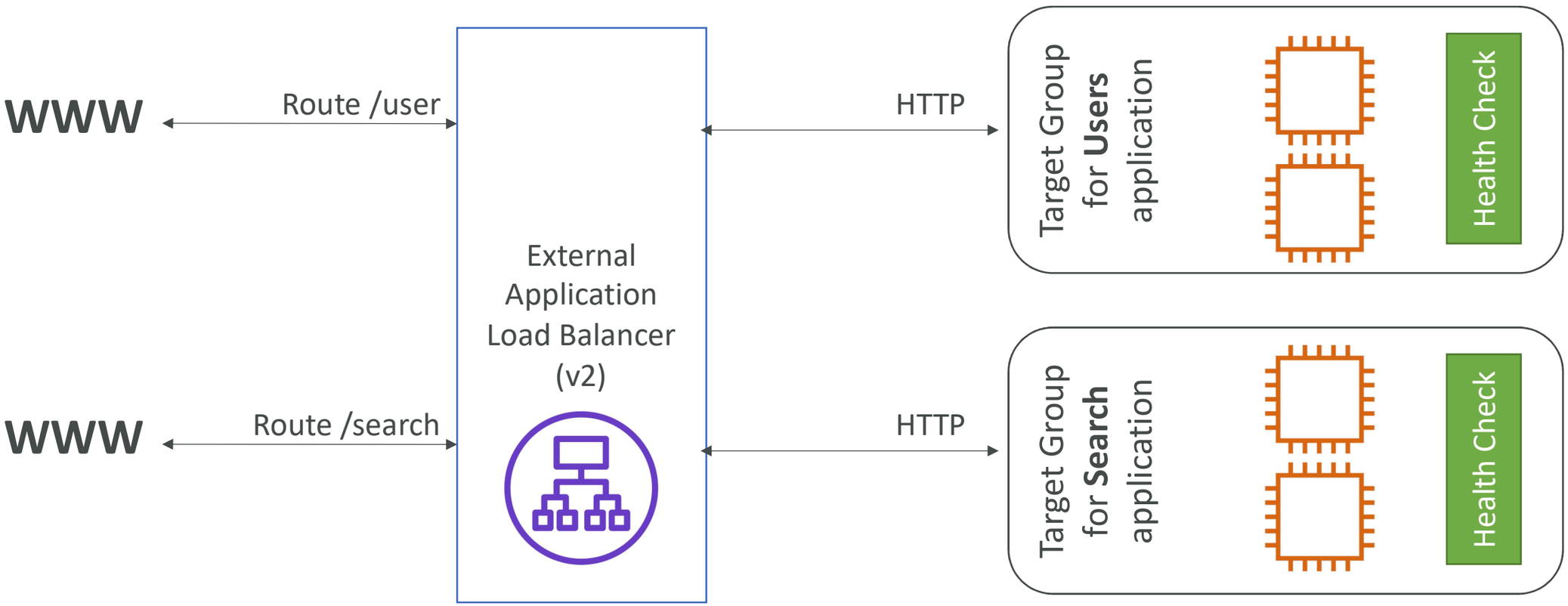
Application Load Balancer (v2)



- 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

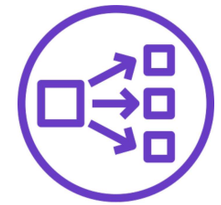


Application Load Balancer (v2)
Target Groups

- 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

Network Load Balancer (v2)

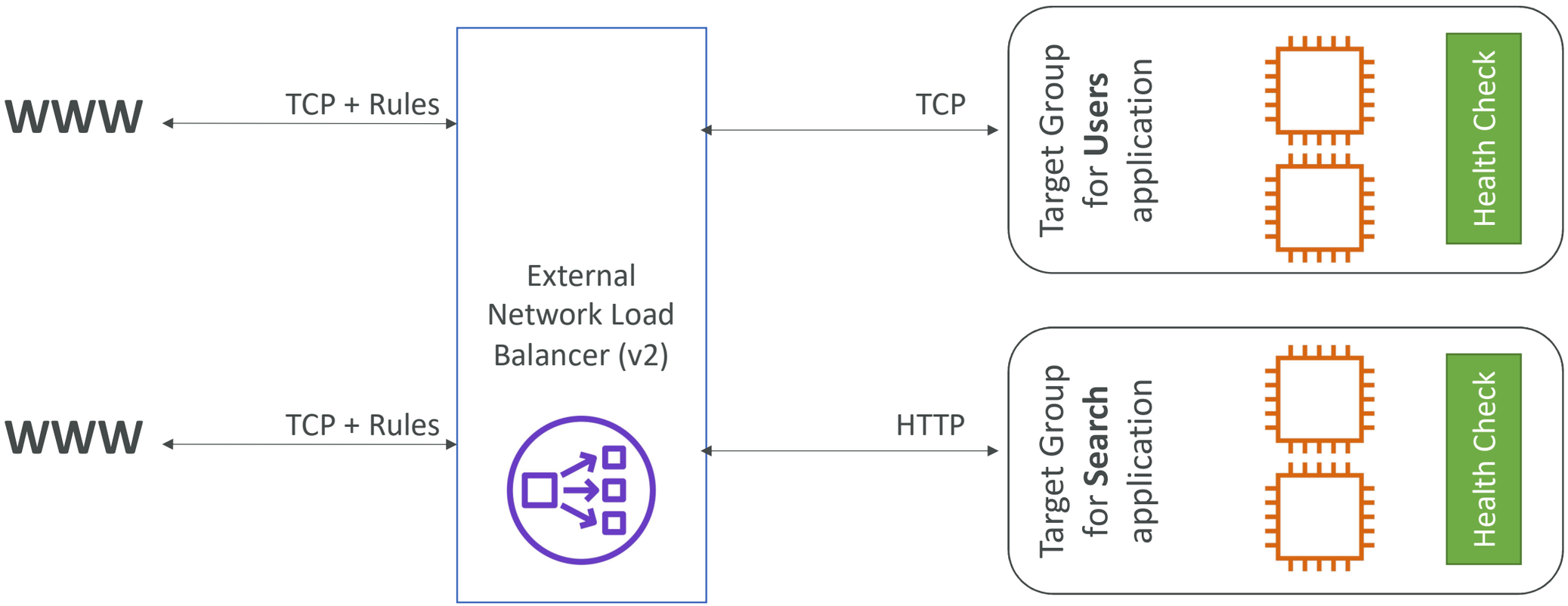


- Network load balancers (Layer 4) allow to:
  - **Forward TCP & UDP traffic to your instances**
  - Handle millions of request per seconds
  - Less latency ~100 ms (vs 400 ms for ALB)

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

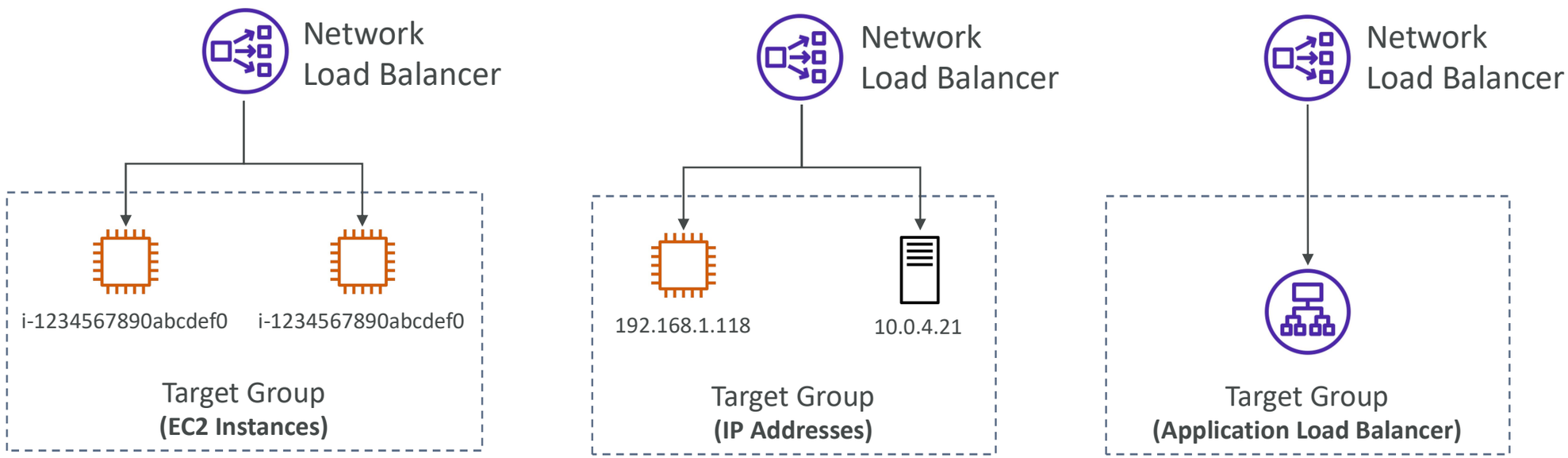
- NLB are used for extreme performance, TCP or UDP traffic
- Not included in the AWS free tier

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



Network Load Balancer – Target Groups

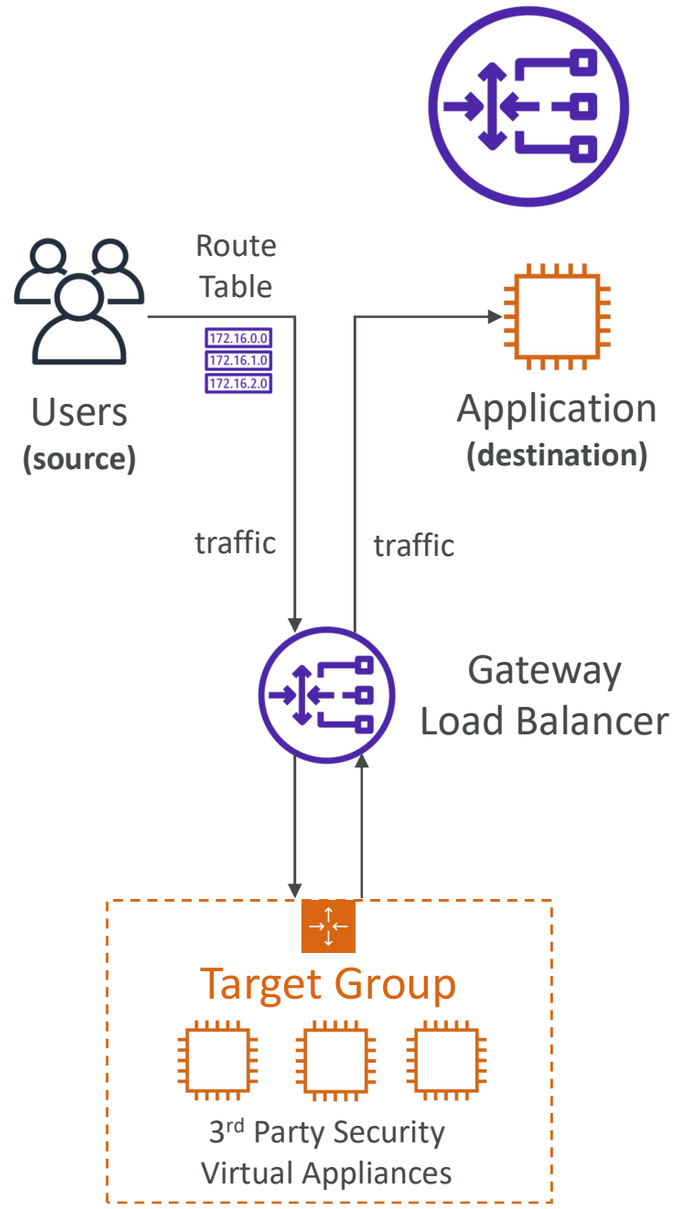
- EC2 instances
- IP Addresses – must be private IPs
- Application Load Balancer
- Health Checks support the TCP, HTTP and HTTPS Protocols



Gateway Load Balancer

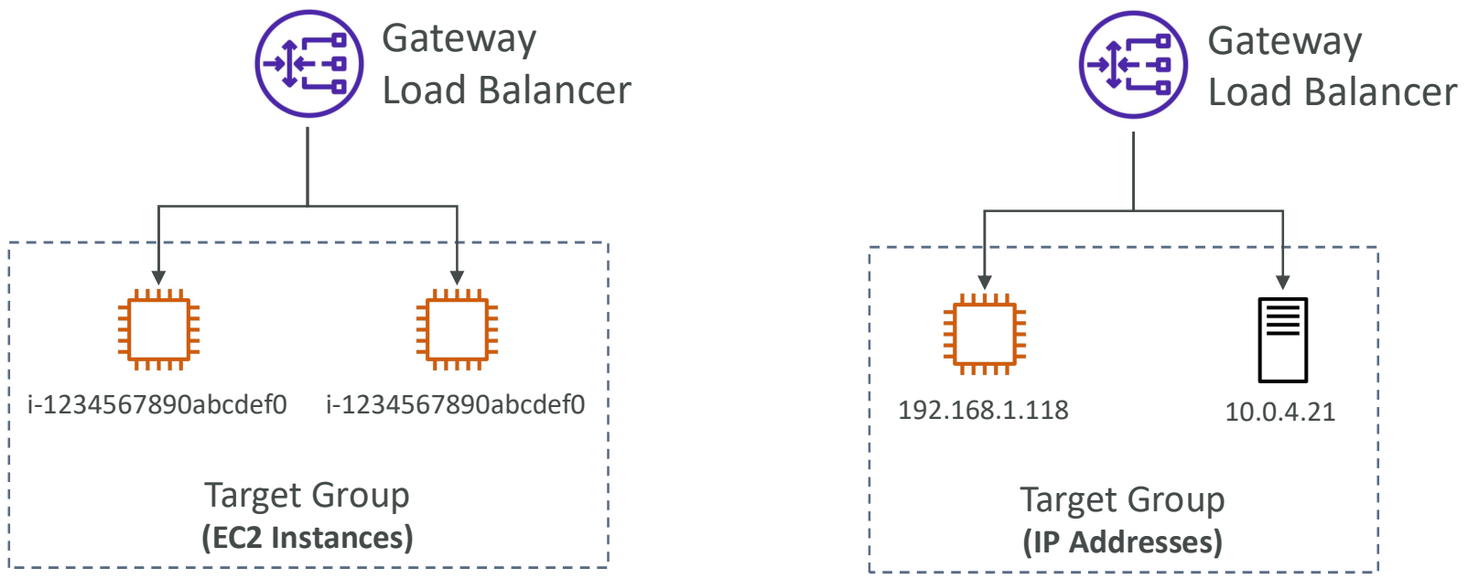
- Deploy, scale, and manage a fleet of 3rd party network virtual appliances in AWS
- Example: Firewalls, Intrusion Detection and Prevention Systems, Deep Packet Inspection Systems, payload manipulation, …

- 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**



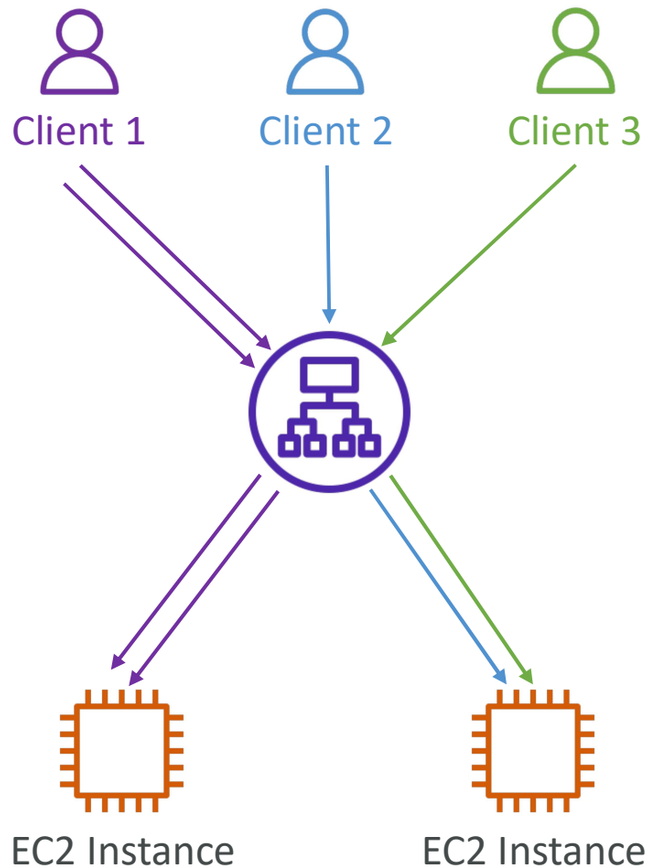
Gateway Load Balancer – Target Groups

- EC2 instances
- IP Addresses – must be private IPs



Sticky Sessions (Session Affinity)

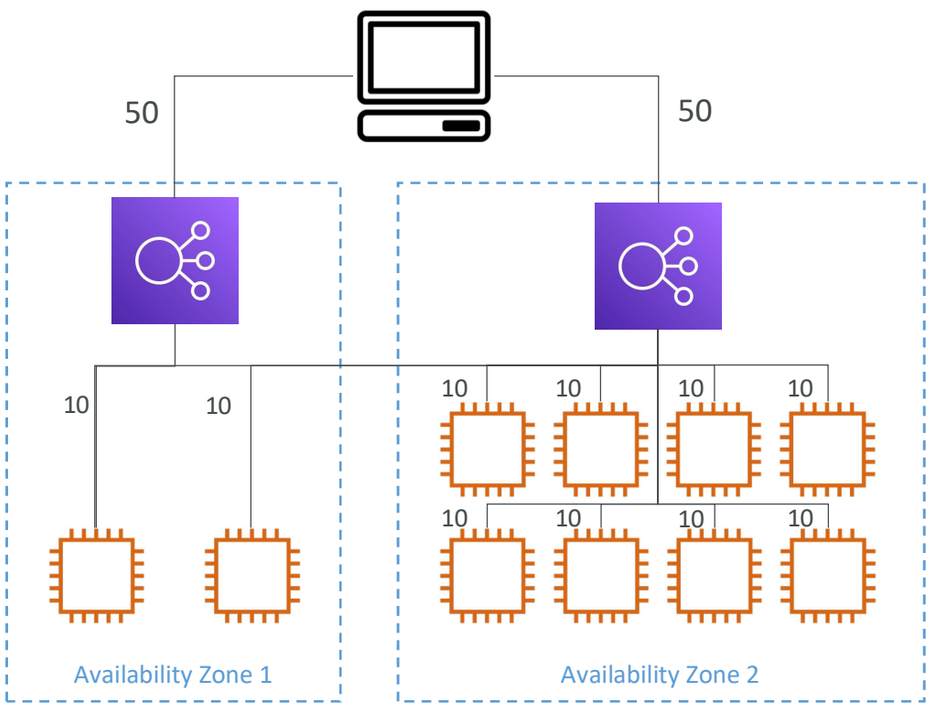
- It is possible to implement stickiness so that the same client is always redirected to the same instance behind a load balancer
- This works for Classic Load Balancers & Application Load Balancers
- The "cookie" used for stickiness has an expiration date you control
- Use case: make sure the user doesn't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



Cross-Zone Load Balancing

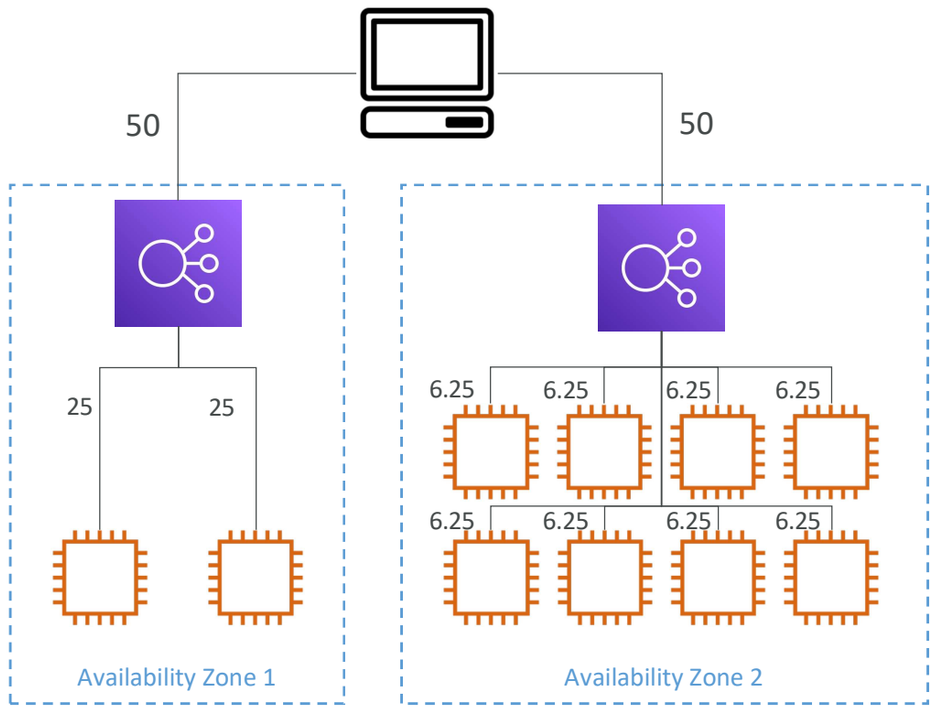
With Cross Zone Load Balancing:

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
  - Always on (can't be disabled)
  - No charges for inter AZ data
- Network 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

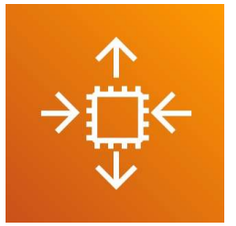
- An SSL Certificate allows traffic between your clients and your load balancer to be encrypted in transit (in-flight encryption)

- **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

What's an Auto Scaling Group?

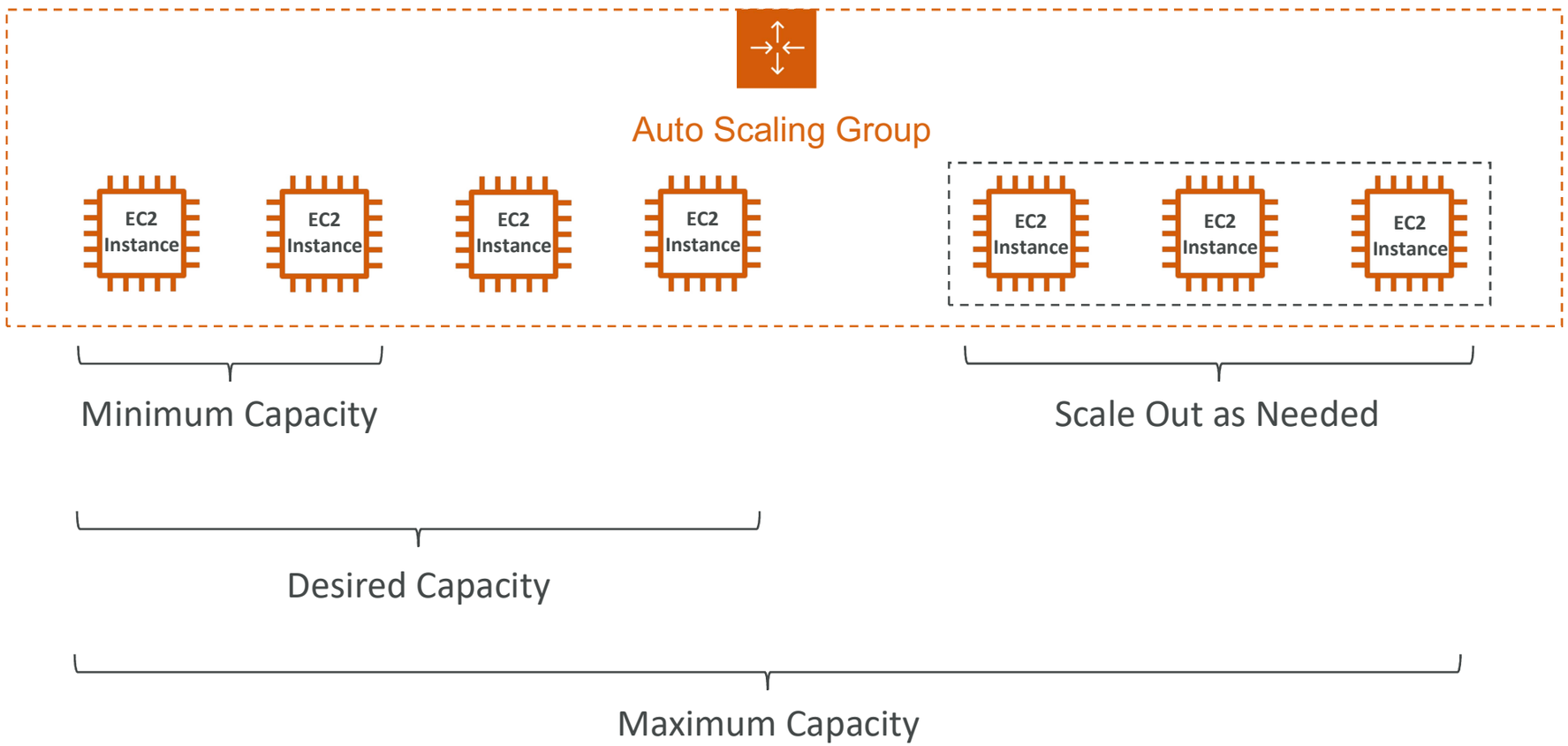


- In real-life, the load on your websites and application can change
- In the cloud, you can create and get rid of servers very quickly

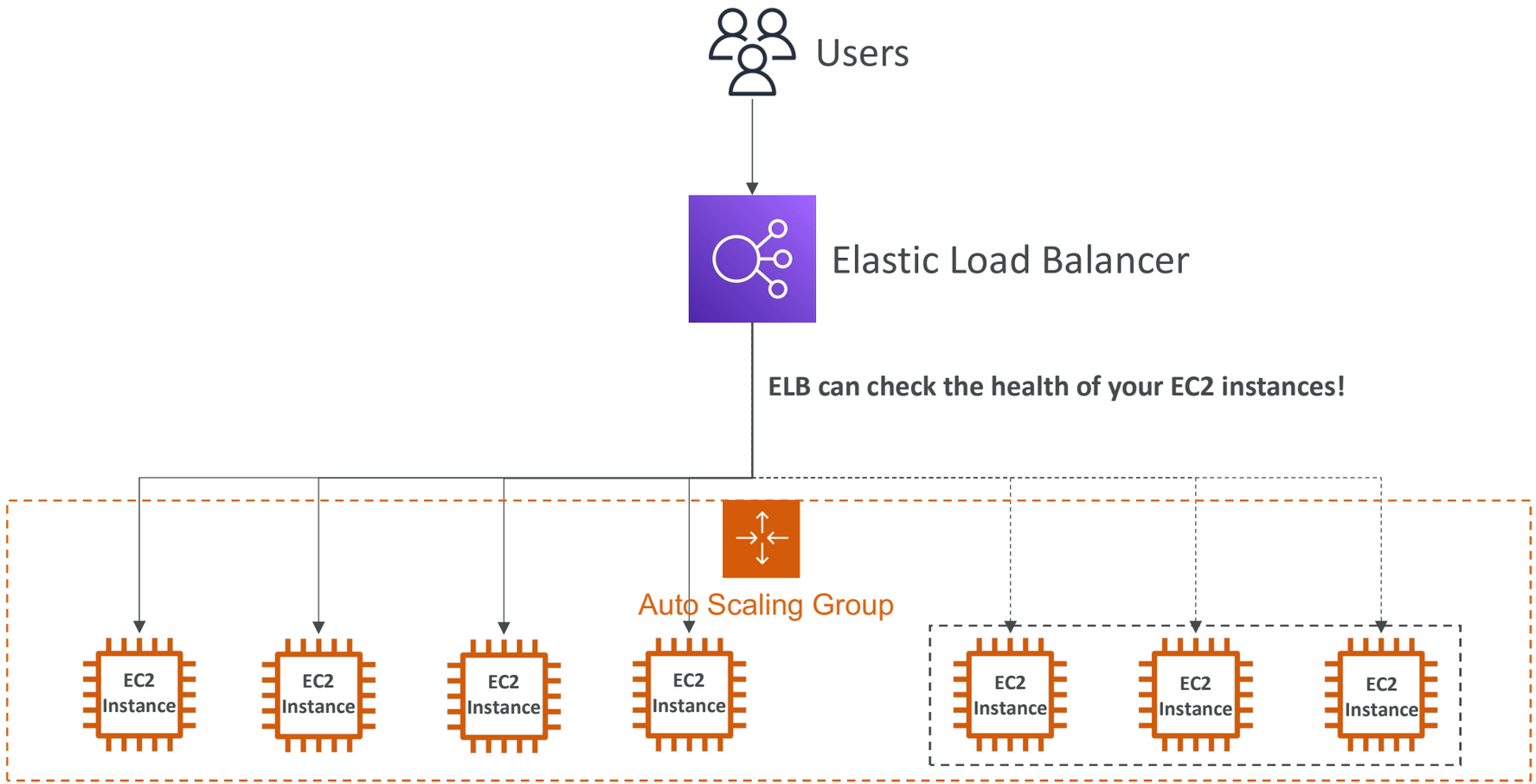
- The goal of an Auto Scaling Group (ASG) is to:
  - Scale out (add EC2 instances) to match an increased load
  - Scale in (remove EC2 instances) to match a decreased load
  - Ensure we have a minimum and a maximum number of EC2 instances running
  - Automatically register new instances to a load balancer
  - 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

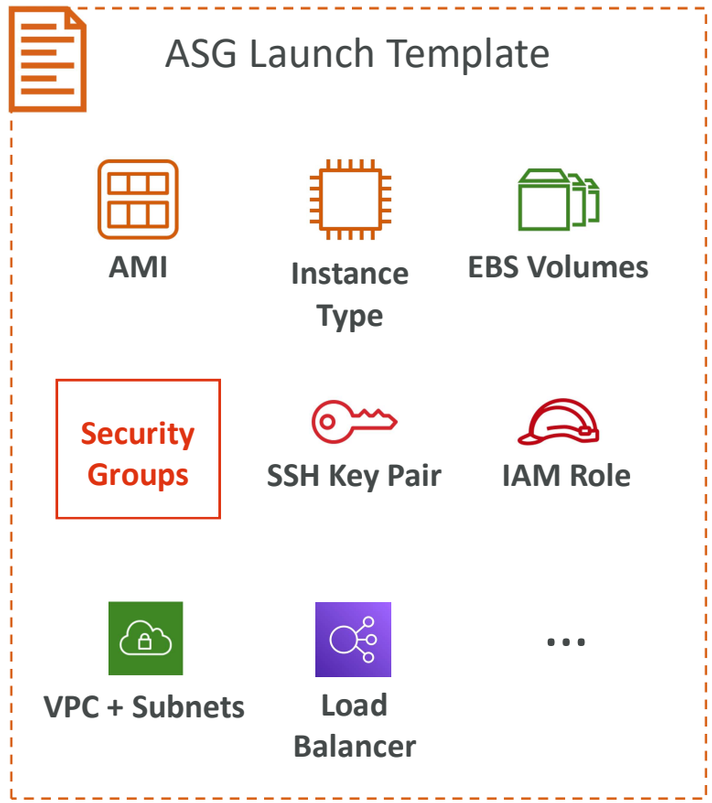


Auto Scaling Group in AWS With Load Balancer



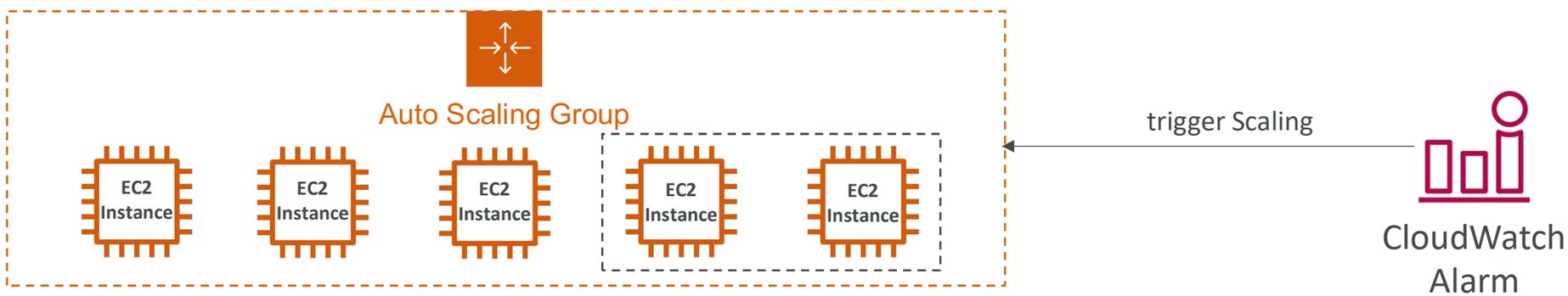
Auto Scaling Group Attributes

- 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



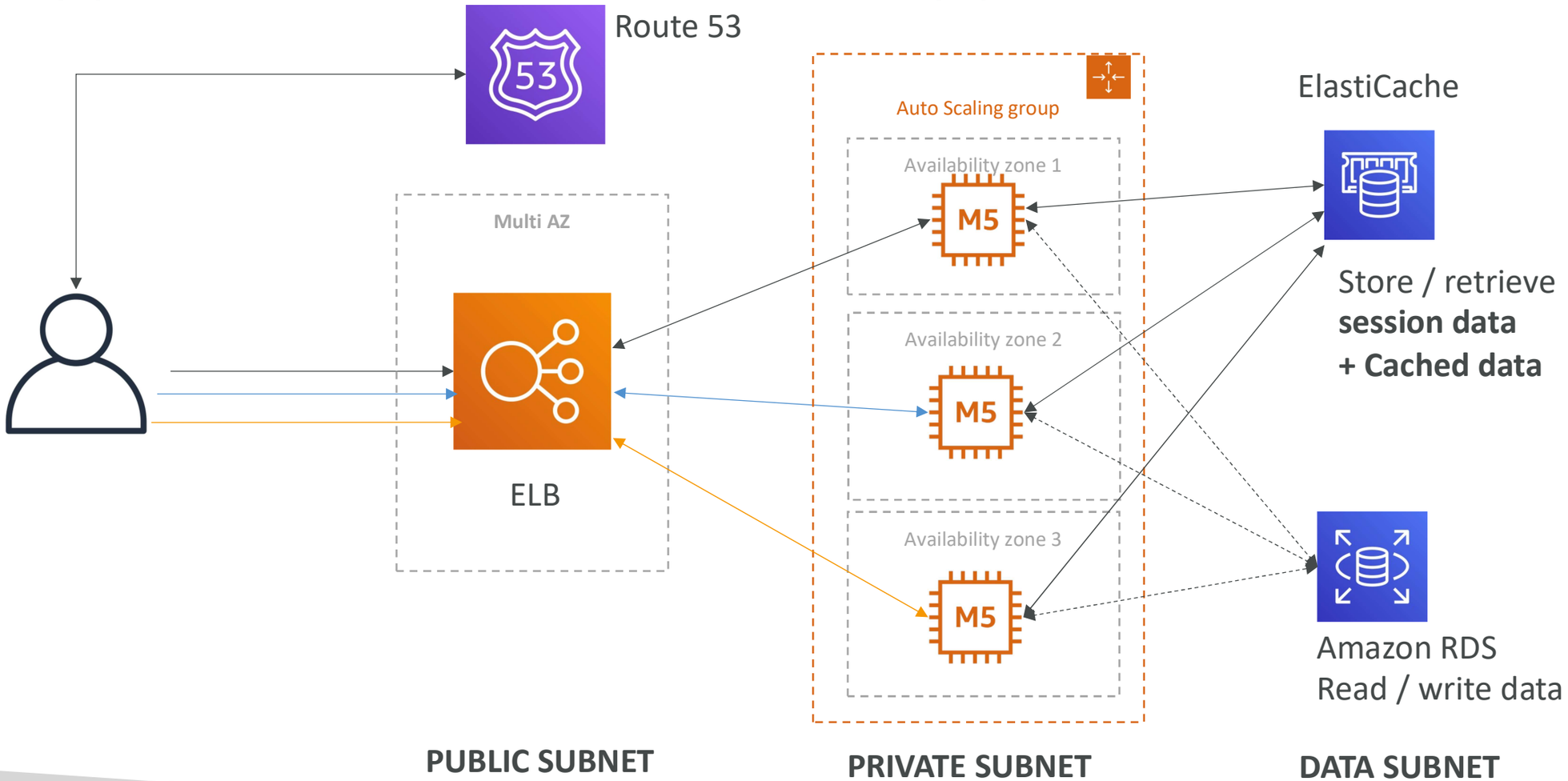
Auto Scaling - CloudWatch Alarms & Scaling

- 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)



Elastic Beanstalk

Typical architecture: Web App 3-tier



Developer problems on AWS

- Managing infrastructure
- Deploying Code
- Configuring all the databases, load balancers, etc
- Scaling concerns

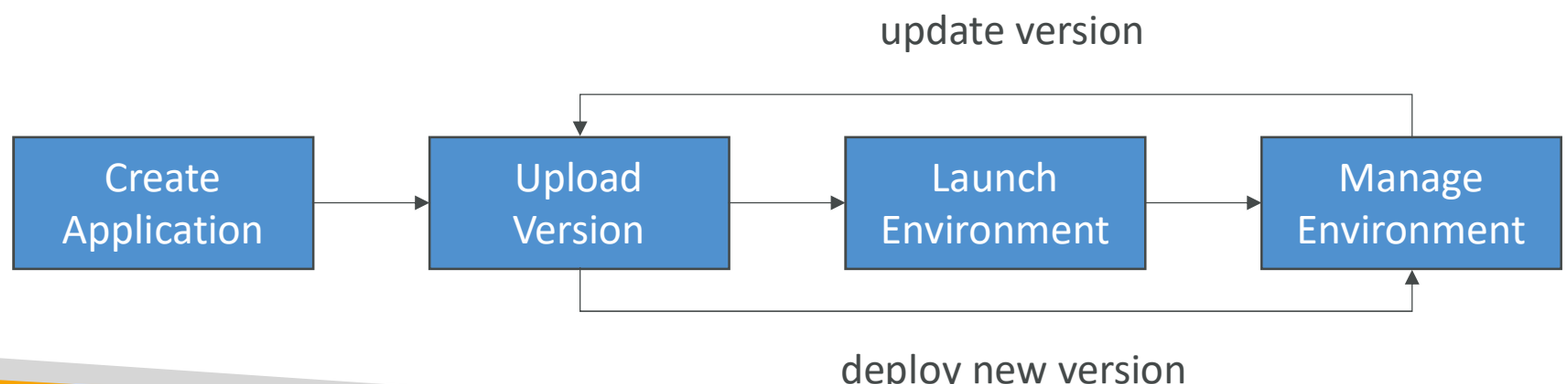
- Most web apps have the same architecture (ALB + ASG)
- All the developers want is for their code to run!
- Possibly, consistently across different applications and environments

Elastic Beanstalk – Overview

- Elastic Beanstalk is a developer centric view of deploying an application on AWS
- It uses all the component's we've seen before: EC2, ASG, ELB, RDS, …
- Managed service
  - Automatically handles capacity provisioning, load balancing, scaling, application health monitoring, instance configuration, …
  - Just the application code is the responsibility of the developer
- We still have full control over the configuration
- Beanstalk is free but you pay for the underlying instances

Elastic Beanstalk – Components

- **Application:** collection of Elastic Beanstalk components (environments, versions, configurations, …)
- **Application Version:** an iteration of your application code
- **Environment**
  - Collection of AWS resources running an application version (only one application version at a time)
  - **Tiers:** Web Server Environment Tier & Worker Environment Tier
  - You can create multiple environments (dev, test, prod, …)

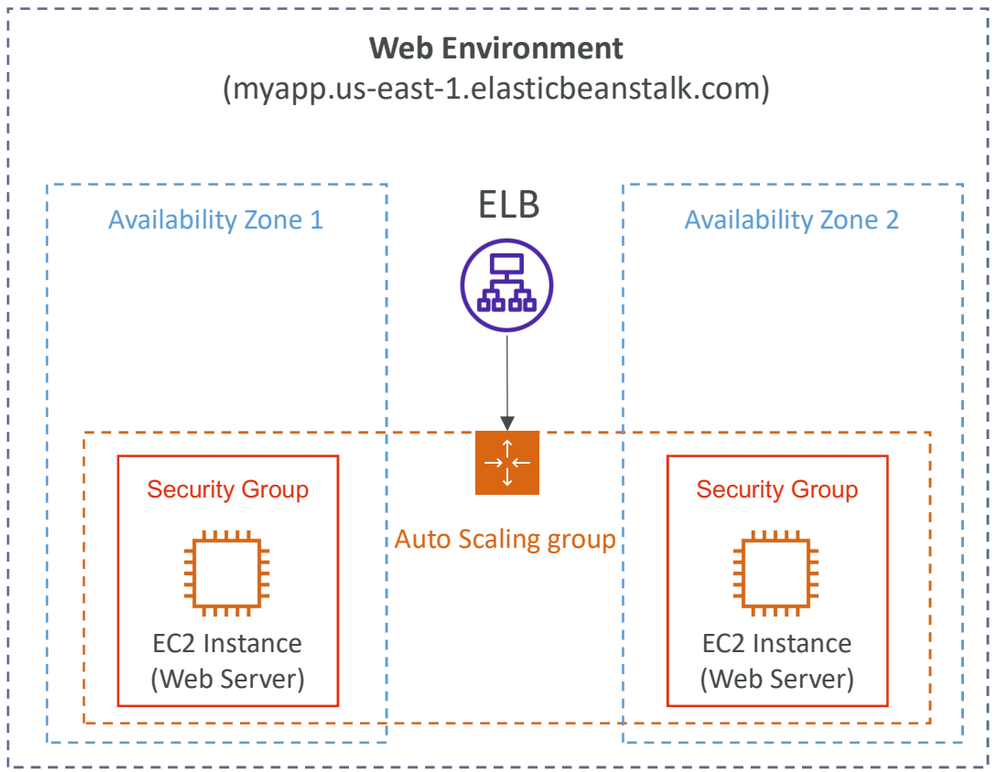


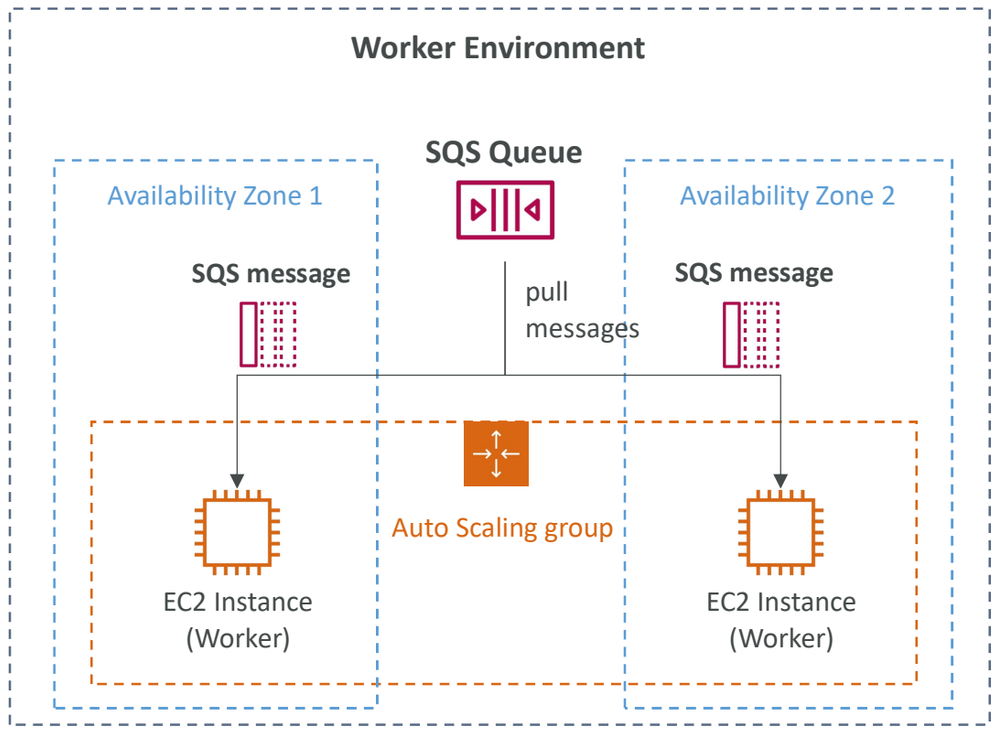
Elastic Beanstalk – Supported Platforms

- Go
- Java SE
- Java with Tomcat
- .NET Core on Linux
- .NET on Windows Server
- Node.js
- PHP
- Python
- Ruby
- Packer Builder
- Single Container Docker
- Multi-container Docker
- Preconfigured Docker

- If not supported, you can write your custom platform (advanced)

Web Server Tier vs. Worker Tier





- Scale based on the number of SQS messages
- Can push messages to SQS queue from another Web Server Tier

AWS CloudFormation

Managing your infrastructure as code

Infrastructure as Code

- Currently, we have been doing a lot of manual work
- All this manual work will be very tough to reproduce:
  - In another region
  - in another AWS account
  - Within the same region if everything was deleted

- Wouldn't it be great, if all our infrastructure was… code?
- That code would be deployed and create / update / delete our infrastructure

What is CloudFormation

- CloudFormation is a declarative way of outlining your AWS Infrastructure, for any resources (most of them are supported).
- For example, within a CloudFormation template, you say:
  - I want a security group
  - I want two EC2 machines using this security group
  - I want two Elastic IPs for these EC2 machines
  - I want an S3 bucket
  - I want a load balancer (ELB) in front of these machines
- Then CloudFormation creates those for you, in the **right order**, with the **exact configuration** that you specify

Benefits of AWS CloudFormation (1/2)

- Infrastructure as code
  - No resources are manually created, which is excellent for control
  - The code can be version controlled for example using git
  - Changes to the infrastructure are reviewed through code

- Cost
  - Each resources within the stack is stagged with an identifier so you can easily see how much a stack costs you
  - You can estimate the costs of your resources using the CloudFormation template
  - Savings strategy: In Dev, you could automation deletion of templates at 5 PM and recreated at 8 AM, safely

Benefits of AWS CloudFormation (2/2)

- Productivity
  - Ability to destroy and re-create an infrastructure on the cloud on the fly
  - Automated generation of Diagram for your templates!
  - Declarative programming (no need to figure out ordering and orchestration)

- Separation of concern: create many stacks for many apps, and many layers. Ex:
  - VPC stacks
  - Network stacks
  - App stacks

- Don't re-invent the wheel
  - Leverage existing templates on the web!
  - Leverage the documentation

How CloudFormation Works

- Templates have to be uploaded in S3 and then referenced in CloudFormation
- To update a template, we can't edit previous ones. We have to re-upload a new version of the template to AWS
- Stacks are identified by a name
- Deleting a stack deletes every single artifact that was created by CloudFormation.

Deploying CloudFormation templates

- Manual way:
  - Editing templates in the CloudFormation Designer
  - Using the console to input parameters, etc

- Automated way:
  - Editing templates in a YAML file
  - Using the AWS CLI (Command Line Interface) to deploy the templates
  - Recommended way when you fully want to automate your flow

CloudFormation Building Blocks

Templates components (one course for each):

1. **Resources: your AWS resources declared in the template (MANDATORY)**
2. Parameters: the dynamic inputs for your template
3. Mappings: the static variables for your template
4. Outputs: References to what has been created
5. Conditionals: List of conditions to perform resource creation
6. Metadata

Templates helpers:

1. References
2. Functions

Note:
This is an Introduction to CloudFormation

- It can take over 3 hours to properly learn and master CloudFormation
- This is meant so you get a good idea of how it works
- We'll be slightly less hands-on than in other sections

- We'll learn everything we need to answer questions for the exam
- The exam does not require you to actually write CloudFormation
- The exam expects you to understand how to read CloudFormation

Introductory Example

- We're going to create a simple EC2 instance.
- Then we're going to create to add an Elastic IP to it
- And we're going to add two security groups to it
- For now, forget about the code syntax.
- We'll look at the structure of the files later on

- We'll see how in no-time, we are able to get started with CloudFormation!

YAML Crash Course

```yaml
invoice:        34843
date   :        2001-01-23
bill-to:
    given  :    Chris
    family :    Dumars
    address:
        lines: |
            458 Walkman Dr.
            Suite #292
        city     : Royal Oak
        state    : MI
        postal   : 48046
product:
    - sku         : BL394D
      quantity    : 4
      description : Basketball
      price       : 450.00
    - sku         : BL4438H
      quantity    : 1
      description : Super Hoop
      price       : 2392.00
```

- YAML and JSON are the languages you can use for CloudFormation.
- JSON is horrible for CF
- YAML is great in so many ways
- Let's learn a bit about it!

- Key value Pairs
- Nested objects
- Support Arrays
- Multi line strings
- Can include comments!

What are resources?

- Resources are the core of your CloudFormation template (MANDATORY)
- They represent the different AWS Components that will be created and configured
- Resources are declared and can reference each other

- AWS figures out creation, updates and deletes of resources for us
- There are over 224 types of resources (!)
- Resource types identifiers are of the form:

```
AWS::aws-product-name::data-type-name
```

How do I find resources documentation?

- I can't teach you all of the 224 resources, but I can teach you how to learn how to use them.
- All the resources can be found here: http://docs.aws.amazon.com/AWSCloudFormation/latest/UserGuide/aws-template-resource-type-ref.html
- Then, we just read the docs ☺
- Example here (for an EC2 instance): http://docs.aws.amazon.com/AWSCloudFormation/latest/UserGuide/aws-properties-ec2-instance.html

Analysis of CloudFormation Template

- Going back to the example of the introductory , let's learn why itwas written this way.
- Relevant documentation can be found here:
  - http://docs.aws.amazon.com/AWSCloudFormation/latest/UserGuide/aws-properties-ec2-instance.html
  - http://docs.aws.amazon.com/AWSCloudFormation/latest/UserGuide/aws-properties-ec2-security-group.html
  - http://docs.aws.amazon.com/AWSCloudFormation/latest/UserGuide/aws-properties-ec2-eip.html

What are parameters?

- Parameters are a way to provide inputs to your AWS CloudFormation template
- They're important to know about if:
  - You want to reuse your templates across the company
  - Some inputs can not be determined ahead of time
- Parameters are extremely powerful, controlled, and can prevent errors from happening in your templates thanks to types.

When should you use a parameter?

- Ask yourself this:
  - Is this CloudFormation resource configuration likely to change in the future?
  - If so, make it a parameter.

- You won't have to re-upload a template to change its content ☺

```
Parameters:
  SecurityGroupDescription:
    Description: Security Group Description
    (Simple parameter)
    Type: String
```

Parameters Settings

Parameters can be controlled by all these settings:

- Type:
  - String
  - Number
  - CommaDelimitedList
  - List<Type>
  - AWS Parameter (to help catch invalid values – match against existing values in the AWS Account)
- Description
- Constraints
- ConstraintDescription (String)
- Min/MaxLength
- Min/MaxValue
- Defaults
- AllowedValues (array)
- AllowedPattern (regexp)
- NoEcho (Boolean)

How to Reference a Parameter

- The Fn::Ref function can be leveraged to reference parameters
- Parameters can be used anywhere in a template.
- The shorthand for this in YAML is !Ref
- The function can also reference other elements within the template

```
DbSubnet1:
  Type: AWS::EC2::Subnet
  Properties:
    VpcId: !Ref MyVPC
```

EC2 Storage and Data Management

EBS, Instance Store & EFS

What's an EBS Volume?

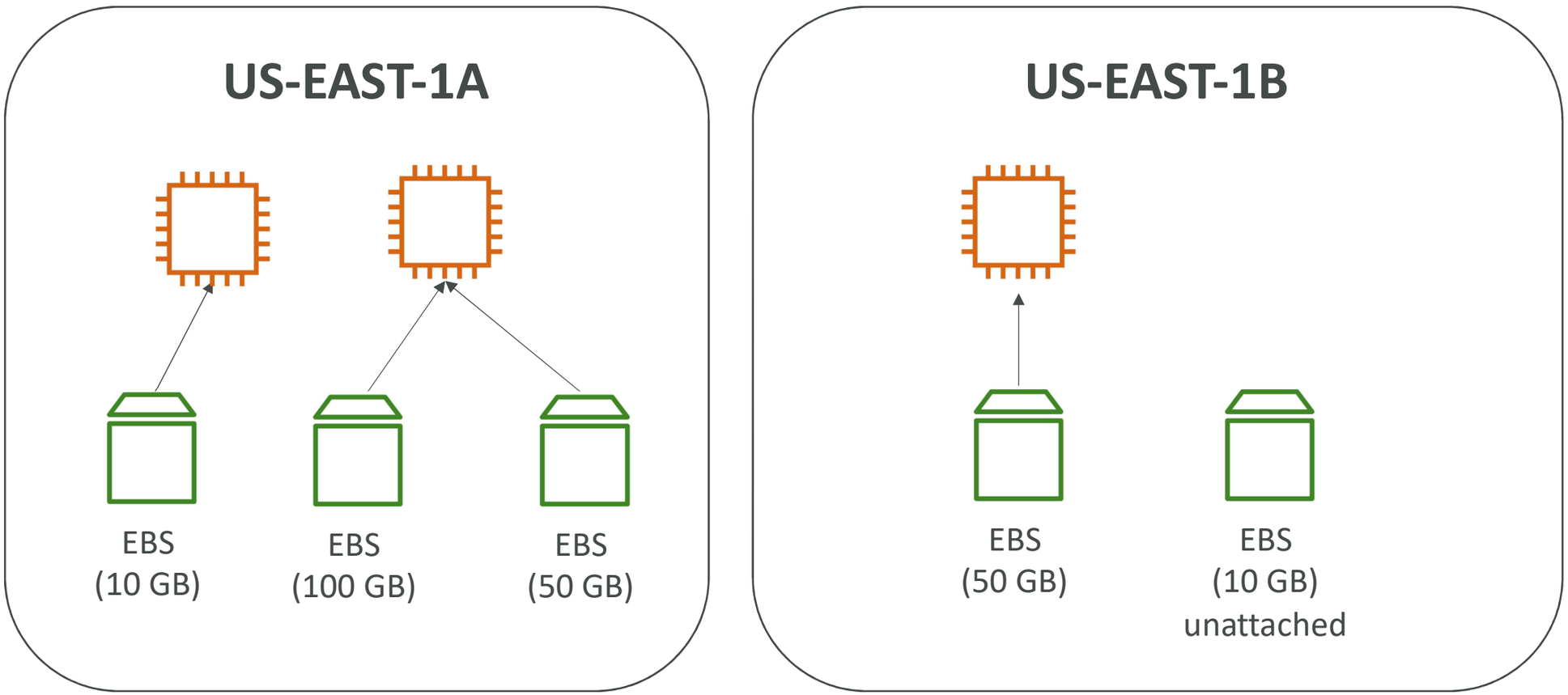
- An EBS (Elastic Block Store) Volume is a network drive you can attach to your instances while they run
- It allows your instances to persist data, even after their termination
- **They can only be mounted to one instance at a time** (at the CCP level)
- They are bound to **a specific availability zone**

- 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

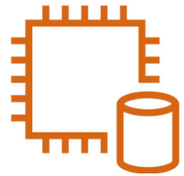
EBS Volume

- 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



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

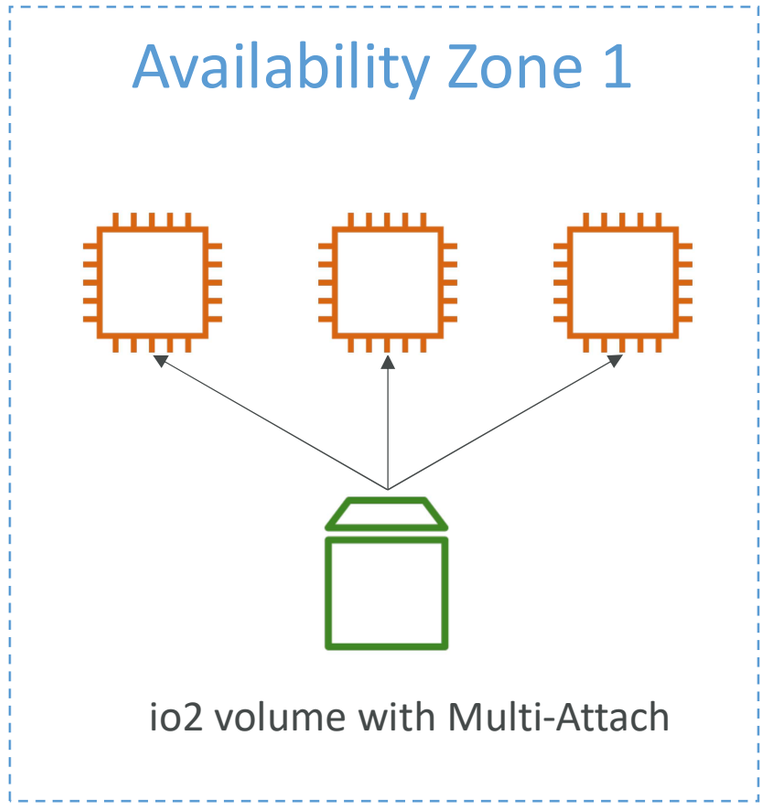
	General Purpose SSD		Provisioned IOPS SSD		
Volume type	gp3	gp2	io2 Block Express ‡	io2	io1
Durability	99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)	99.8% - 99.9% durability (0.1% - 0.2% annual failure rate)	99.999% durability (0.001% annual failure rate)		99.8% - 99.9% durability (0.1% - 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

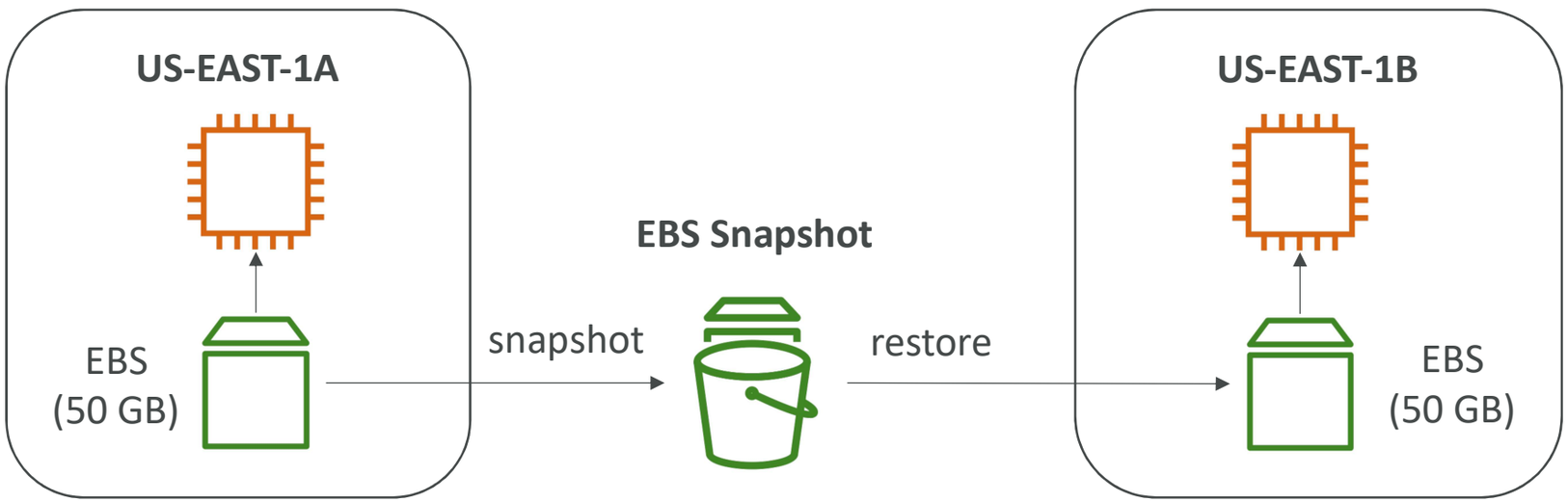
EBS Multi-Attach – io1/io2 family

- 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…)



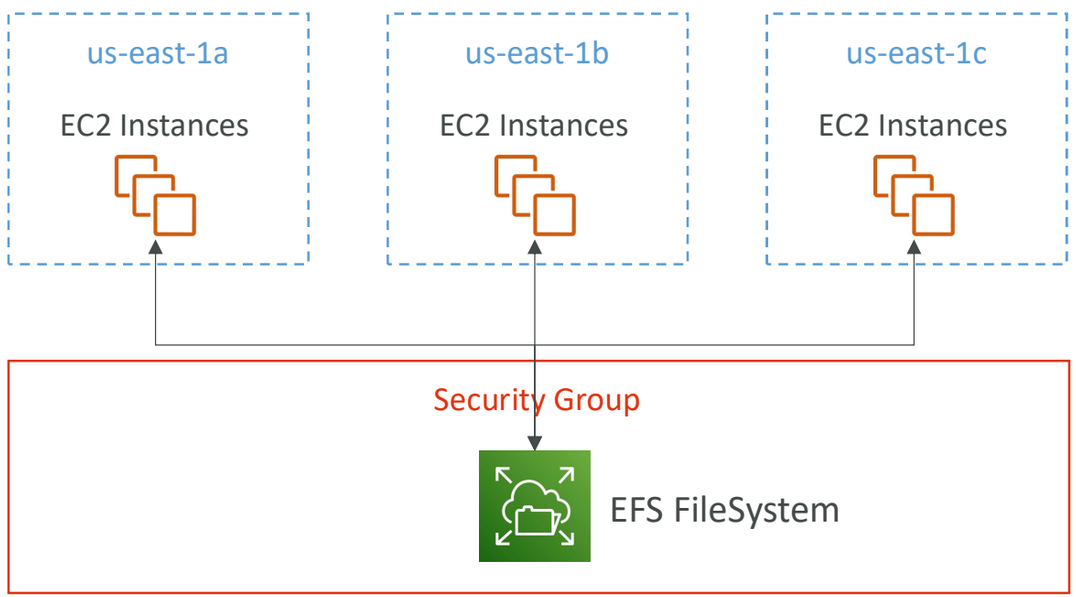
EBS Snapshots

- 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



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

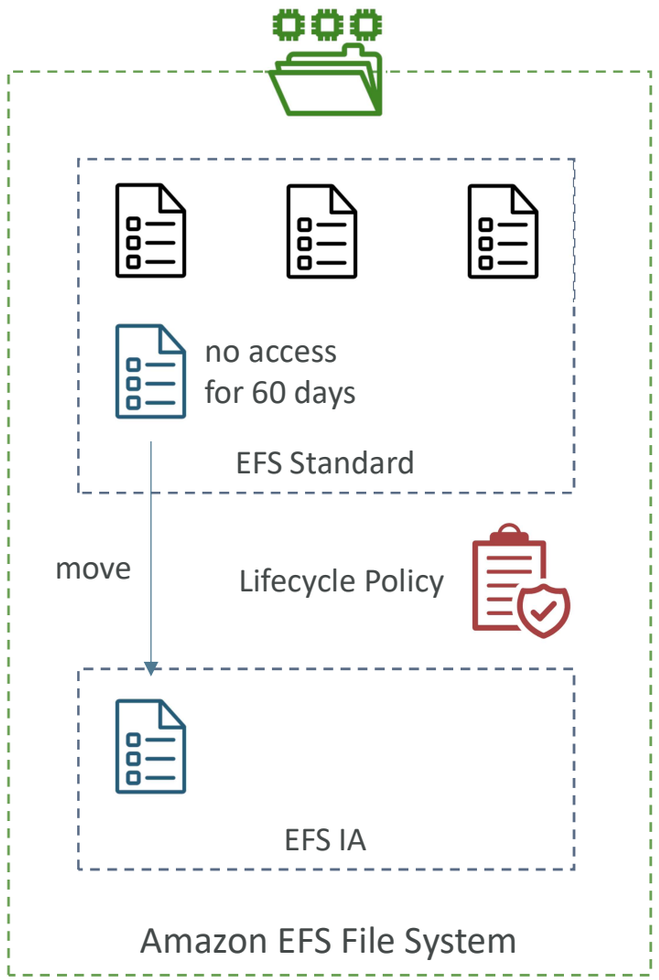
- EFS Scale
  - 1000s of concurrent NFS clients, 10 GB+ /s throughput
  - Grow to Petabyte-scale network file system, automatically

- 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

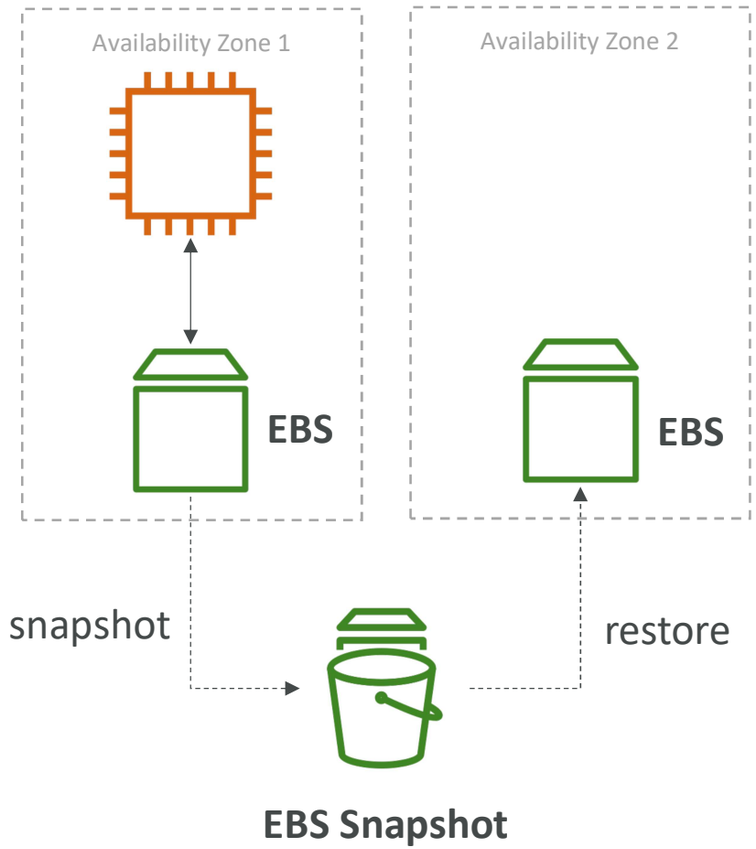
EFS – Storage Classes

- 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…
  - can be attached to only one instance at a time
  - 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)

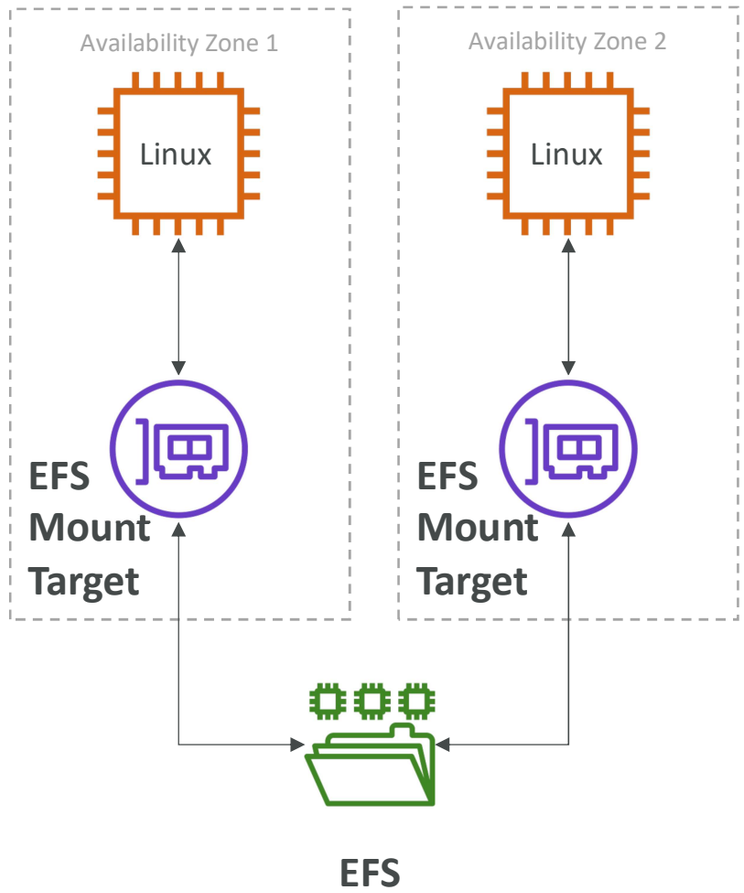


EBS vs EFS – Elastic File System

- 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



S3 Storage and Data Management

S3, Glacier, Athena

Introduction

- Amazon S3 is one of the main building blocks of AWS
- It's advertised as "infinitely scaling" storage
- It's widely popular and deserves its own section

- Many websites use Amazon S3 as a backbone
- Many AWS services uses Amazon S3 as an integration as well

- We'll have a step-by-step approach to S3

Amazon S3 Overview - Buckets

- Amazon S3 allows people to store objects (files) in "buckets" (directories)
- Buckets must have a **globally unique name**
- Buckets are defined at the region level
- Naming convention
  - No uppercase
  - No underscore
  - 3-63 characters long
  - Not an IP
  - Must start with lowercase letter or number

Amazon S3 Overview - Objects

- Objects (files) have a Key
- The key is the **FULL** path:
  - s3://my-bucket/my_file.txt
  - s3://my-bucket/my_folder1/another_folder/my_file.txt
- The key is composed of prefix + object name
  - s3://my-bucket/my_folder1/another_folder/my_file.txt
- There's no concept of "directories" within buckets (although the UI will trick you to think otherwise)
- Just keys with very long names that contain slashes ("/")

Amazon S3 Overview – Objects (continued)

- Object values are the content of the body:
  - Max Object Size is 5TB (5000GB)
  - If uploading more than 5GB, must use "multi-part upload"

- Metadata (list of text key / value pairs – system or user metadata)
- Tags (Unicode key / value pair – up to 10) – useful for security / lifecycle
- Version ID (if versioning is enabled)

Amazon S3 - Versioning

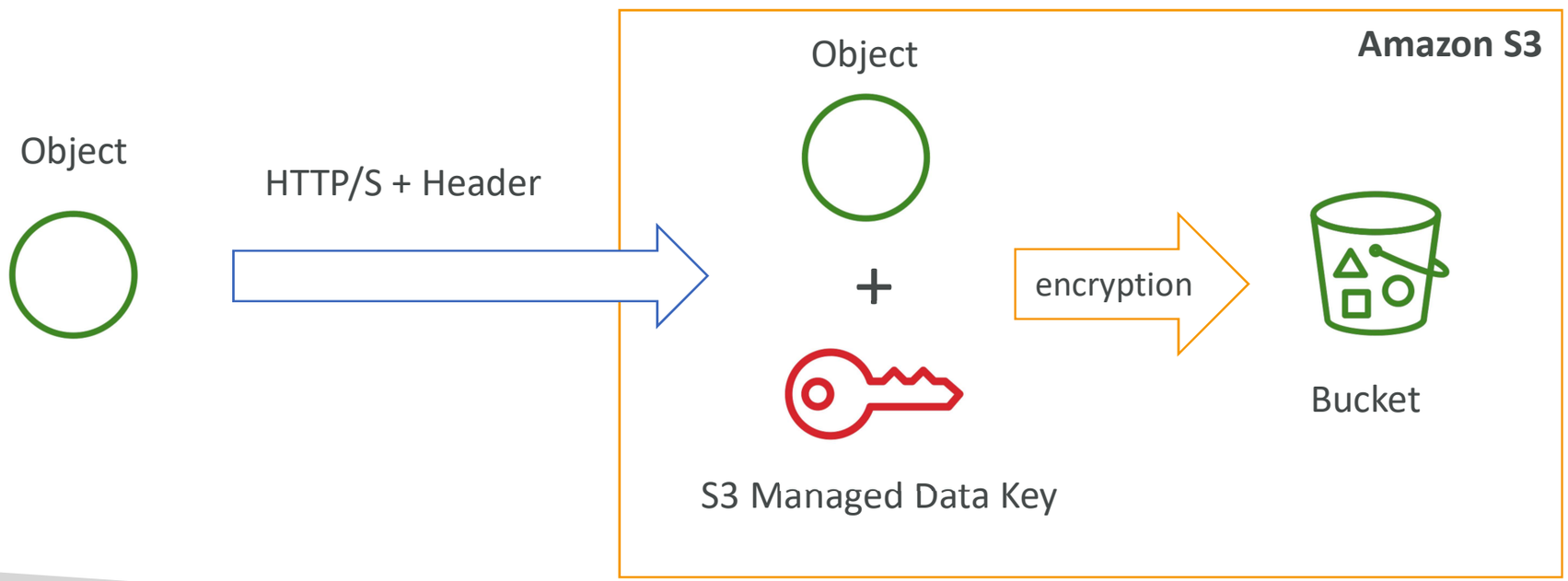
- You can version your files in Amazon S3
- It is enabled at the **bucket level**
- Same key overwrite will increment the "version": 1, 2, 3….
- It is best practice to version your buckets
  - Protect against unintended deletes (ability to restore a version)
  - Easy roll back to previous version
- Notes:
  - Any file that is not versioned prior to enabling versioning will have version "null"
  - Suspending versioning does not delete the previous versions

S3 Encryption for Objects

- There are 4 methods of encrypting objects in S3
  - SSE-S3: encrypts S3 objects using keys handled & managed by AWS
  - SSE-KMS: leverage AWS Key Management Service to manage encryption keys
  - SSE-C: when you want to manage your own encryption keys
  - Client Side Encryption
- It's important to understand which ones are adapted to which situation for the exam

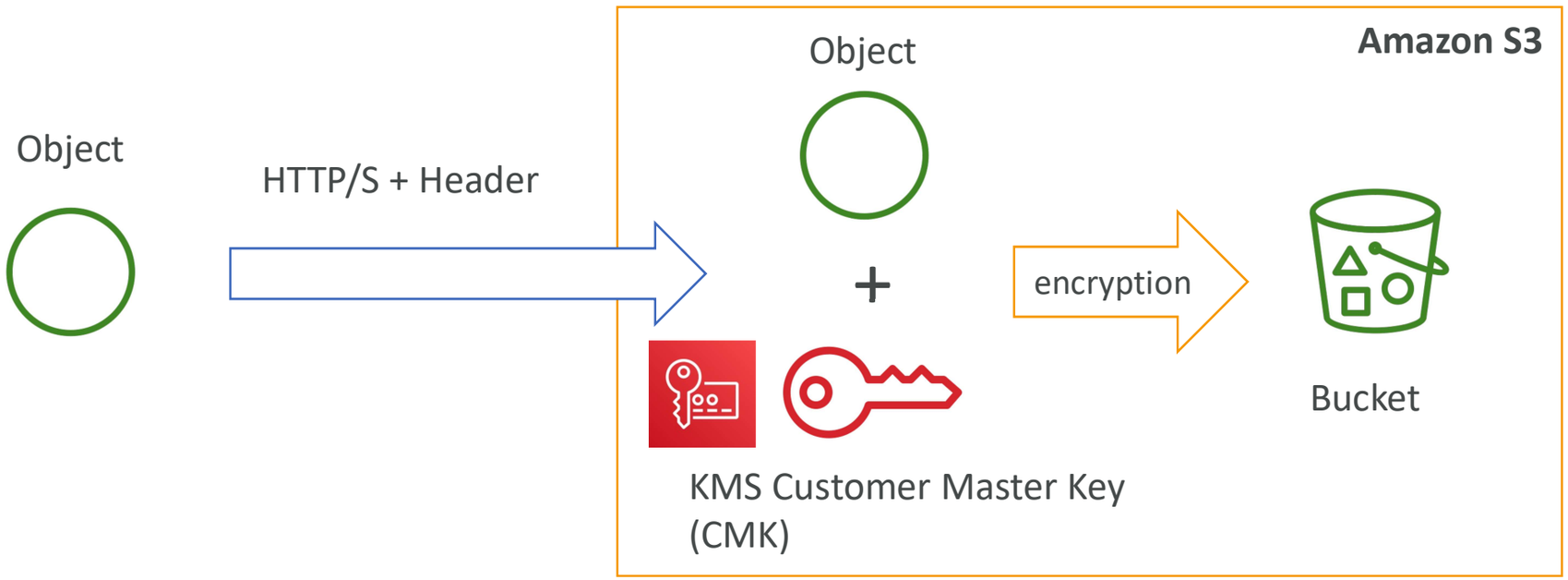
SSE-S3

- SSE-S3: encryption using keys handled & managed by Amazon S3
- Object is encrypted server side
- AES-256 encryption type
- Must set header: “x-amz-server-side-encryption": "AES256"



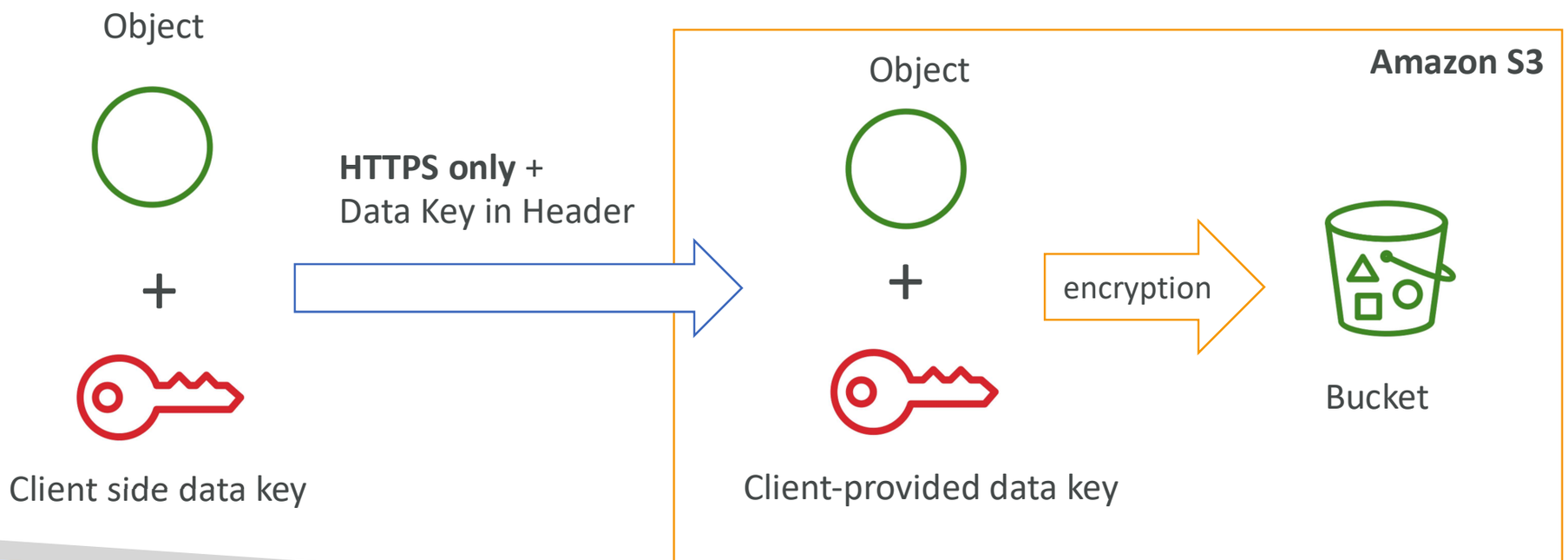
SSE-KMS

- SSE-KMS: encryption using keys handled & managed by KMS
- KMS Advantages: user control + audit trail
- Object is encrypted server side
- Must set header: “x-amz-server-side-encryption": ”aws:kms"



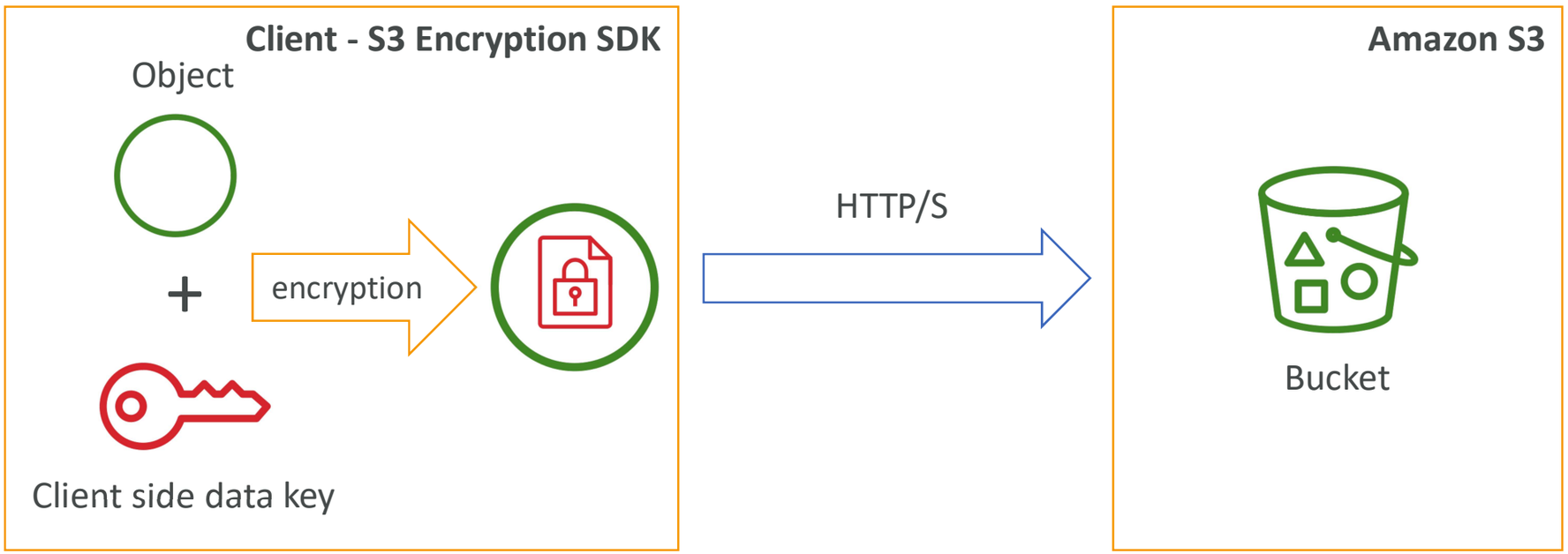
SSE-C

- SSE-C: server-side encryption using data keys fully managed by the customer outside of AWS
- Amazon S3 does not store the encryption key you provide
- HTTPS must be used
- Encryption key must provided in HTTP headers, for every HTTP request made



Client Side Encryption

- Client library such as the Amazon S3 Encryption Client
- Clients must encrypt data themselves before sending to S3
- Clients must decrypt data themselves when retrieving from S3
- Customer fully manages the keys and encryption cycle



Encryption in transit (SSL/TLS)

- Amazon S3 exposes:
  - HTTP endpoint: non encrypted
  - HTTPS endpoint: encryption in flight

- You're free to use the endpoint you want, but HTTPS is recommended
- Most clients would use the HTTPS endpoint by default

- HTTPS is mandatory for SSE-C
- Encryption in flight is also called SSL / TLS

S3 Security

- **User based**
  - IAM policies - which API calls should be allowed for a specific user from IAM console
- **Resource Based**
  - Bucket Policies - bucket wide rules from the S3 console - allows cross account
  - Object Access Control List (ACL) – finer grain
  - Bucket Access Control List (ACL) – less common

- **Note:** an IAM principal can access an S3 object if
  - the user IAM permissions allow it OR the resource policy ALLOWS it
  - AND there's no explicit DENY

S3 Bucket Policies

- JSON based policies
  - Resources: buckets and objects
  - Actions: Set of API to Allow or Deny
  - Effect: Allow / Deny
  - Principal: The account or user to apply the policy to

- Use S3 bucket for policy to:
  - Grant public access to the bucket
  - Force objects to be encrypted at upload
  - Grant access to another account (Cross Account)

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "PublicRead",
            "Effect": "Allow",
            "Principal": "*",
            "Action": [
                "s3:GetObject"
            ],
            "Resource": [
                "arn:aws:s3:::examplebucket/*"
            ]
        }
    ]
}
```

Bucket settings for Block Public Access

- Block public access to buckets and objects granted through
  - *new* access control lists (ACLs)
  - *any* access control lists (ACLs)
  - *new* public bucket or access point policies
- Block public and cross-account access to buckets and objects through *any* public bucket or access point policies

- **These settings were created to prevent company data leaks**
- If you know your bucket should never be public, leave these on
- Can be set at the account level

S3 Security - Other

- Networking:
  - Supports VPC Endpoints (for instances in VPC without www internet)
- Logging and Audit:
  - S3 Access Logs can be stored in other S3 bucket
  - API calls can be logged in AWS CloudTrail
- User Security:
  - MFA Delete: MFA (multi factor authentication) can be required in versioned buckets to delete objects
  - Pre-Signed URLs: URLs that are valid only for a limited time (ex: premium video service for logged in users)

S3 Websites

- S3 can host static websites and have them accessible on the www
- The website URL will be:
  - <bucket-name>.s3-website-<AWS-region>.amazonaws.com

  OR
  - <bucket-name>.s3-website.<AWS-region>.amazonaws.com

- If you get a 403 (Forbidden) error, make sure the bucket policy allows public reads!

Amazon S3 Glacier

- Low-cost object storage meant for archiving / backup
- Data is retained for the longer term (10s of years)
- Alternative to on-premises magnetic tape storage
- Average annual durability is 99.999999999%
- Cost per storage per month ($0.004 / GB – Standard | $0.00099 / GB Deep Archive)

- Each item in Glacier is called "**Archive**" (up to 40TB)
- Archives are stored in "**Vaults**"
- By default, data encrypted at rest using AES-256 – keys managed by AWS

- Exam tip: archival from S3 after XXX days => use Glacier

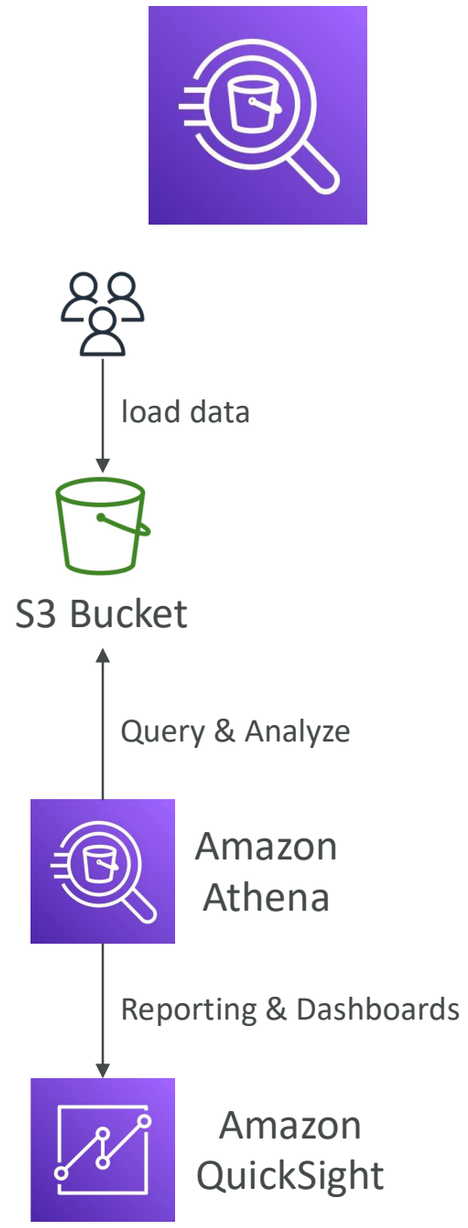
Amazon S3 Glacier Operations

- Vault Operations:
  - Create & Delete – delete only when there's no archives in it
  - Retrieving Metadata – creation date, number of archives, total size of all archives, …
  - Download Inventory – list of archives in the vault (archive ID, creation date, size, …)
- Glacier Operations:
  - Upload - single operation or by parts (MultiPart upload) for larger archives
  - Download - first initiate a retrieval job for the archive, Glacier then prepares it for download. User then has a limited time to download the data from staging server. (optionally, specify a range or portion of bytes to retrieve)
  - Delete - use Glacier Rest API or AWS SDKs by specifying archive ID
- Restore links have an expiry date
- Retrieval Options:
  - Expedited (1 to 5 minutes retrieval) – $0.03 per GB and $10 per 1000 requests
  - Standard (3 to 5 hours) - $0.01 per GB and 0.03 per 1000 requests
  - Bulk (5 to 12 hours) - $0.0025 per GB and $0.025 per 1000 requests

Amazon Athena

- **Serverless** query service to analyze data stored in Amazon S3
- Uses standard SQL language to query the files (built on Presto)
- Supports CSV, JSON, ORC, Avro, and Parquet
- Pricing: $5.00 per TB of data scanned
- Commonly used with Amazon Quicksight for reporting/dashboards

- **Use cases:** Business intelligence / analytics / reporting, analyze & query VPC Flow Logs, ELB Logs, **CloudTrail trails**, etc...
- **Exam Tip:** analyze data in S3 using serverless SQL, use Athena



Amazon Athena – Performance Improvement

- Use **columnar data** for cost-savings (less scan)
  - Apache Parquet or ORC is recommended
  - Huge performance improvement
  - Use Glue to convert your data your Parquet or ORC
- **Compress data** for smaller retrievals (bzip2, gzip, lz4, snappy, zlip, zstd…)
- **Partition** datasets in S3 for easy querying on virtual columns
  - s3://yourBucket/pathToTable
    /<PARTITION_COLUMN_NAME>=<VALUE>
    /<PARTITION_COLUMN_NAME>=<VALUE>
    /<PARTITION_COLUMN_NAME>=<VALUE>
    /etc…
  - Example: s3://athena-examples/flight/parquet/year=1991/month=1/day=1/
- **Use larger files** (> 128 MB) to minimize overhead

Amazon S3 Security

Amazon S3 – Object Encryption

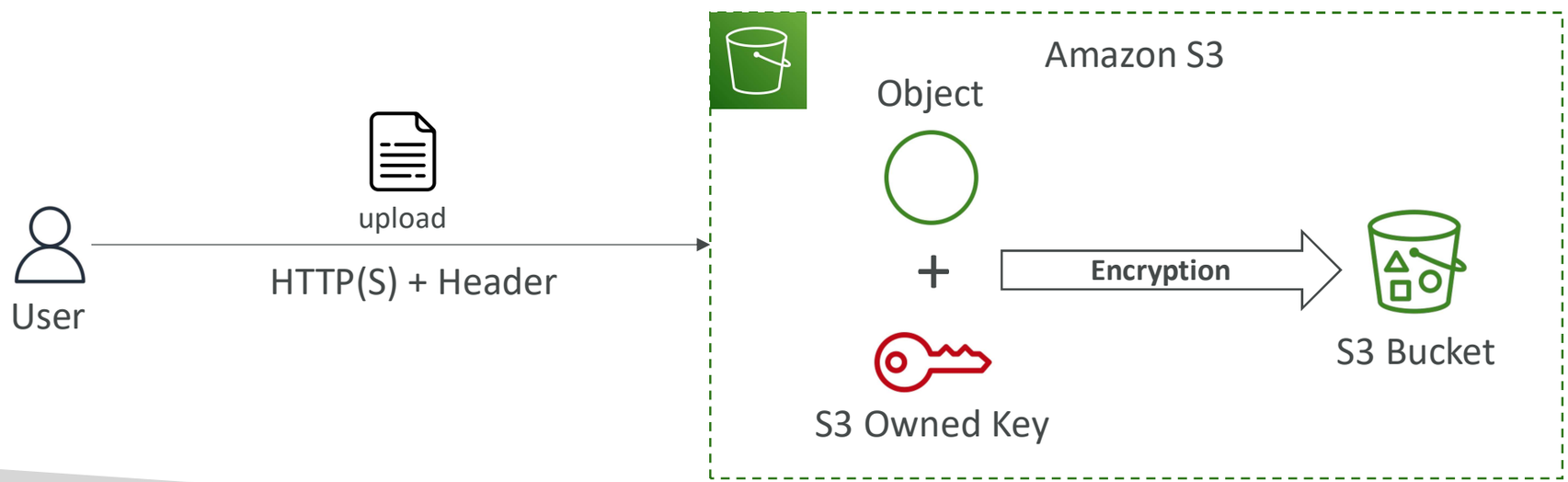
- You can encrypt objects in S3 buckets using one of 4 methods

- Server-Side Encryption (SSE)
  - Server-Side Encryption with Amazon S3-Managed Keys (SSE-S3)
    - Encrypts S3 objects using keys handled, managed, and owned by AWS
  - Server-Side Encryption with KMS Keys stored in AWS KMS (SSE-KMS)
    - Leverage AWS Key Management Service (AWS KMS) to manage encryption keys
  - Server-Side Encryption with Customer-Provided Keys (SSE-C)
    - When you want to manage your own encryption keys
- Client-Side Encryption

- It's important to understand which ones are for which situation for the exam

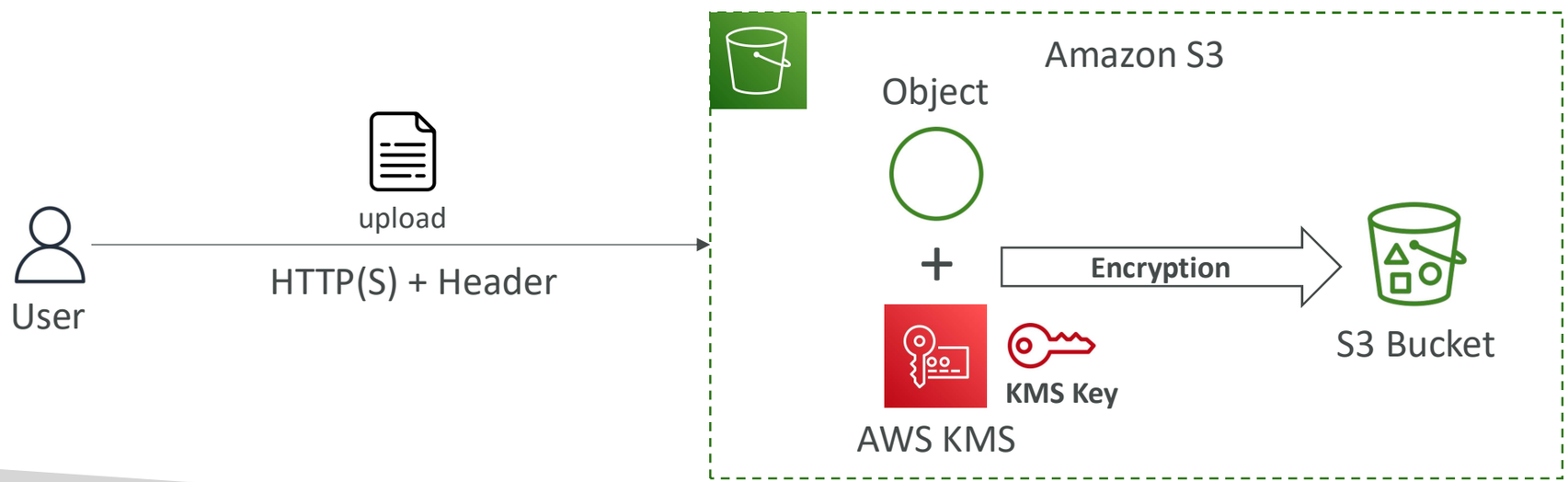
Amazon S3 Encryption – SSE-S3

- Encryption using keys handled, managed, and owned by AWS
- Object is encrypted server-side
- Encryption type is AES-256
- Must set header "x-amz-server-side-encryption": "AES256"



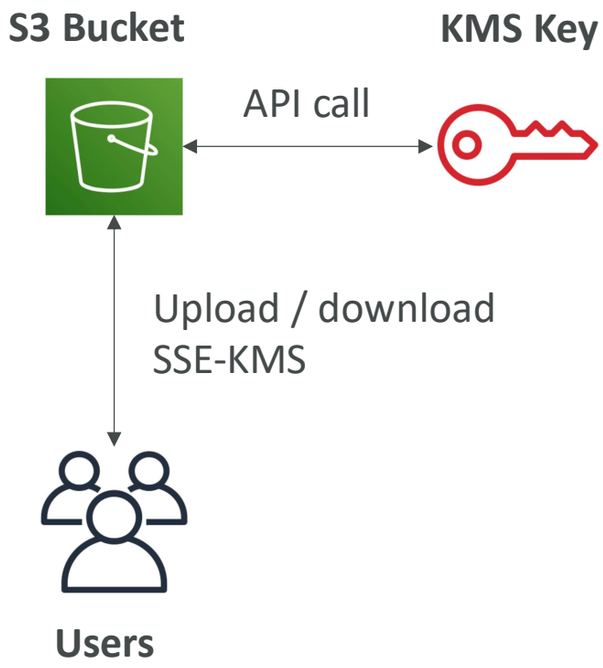
Amazon S3 Encryption – SSE-KMS

- Encryption using keys handled and managed by AWS KMS (Key Management Service)
- KMS advantages: user control + audit key usage using CloudTrail
- Object is encrypted server side
- Must set header **"x-amz-server-side-encryption": "aws:kms"**



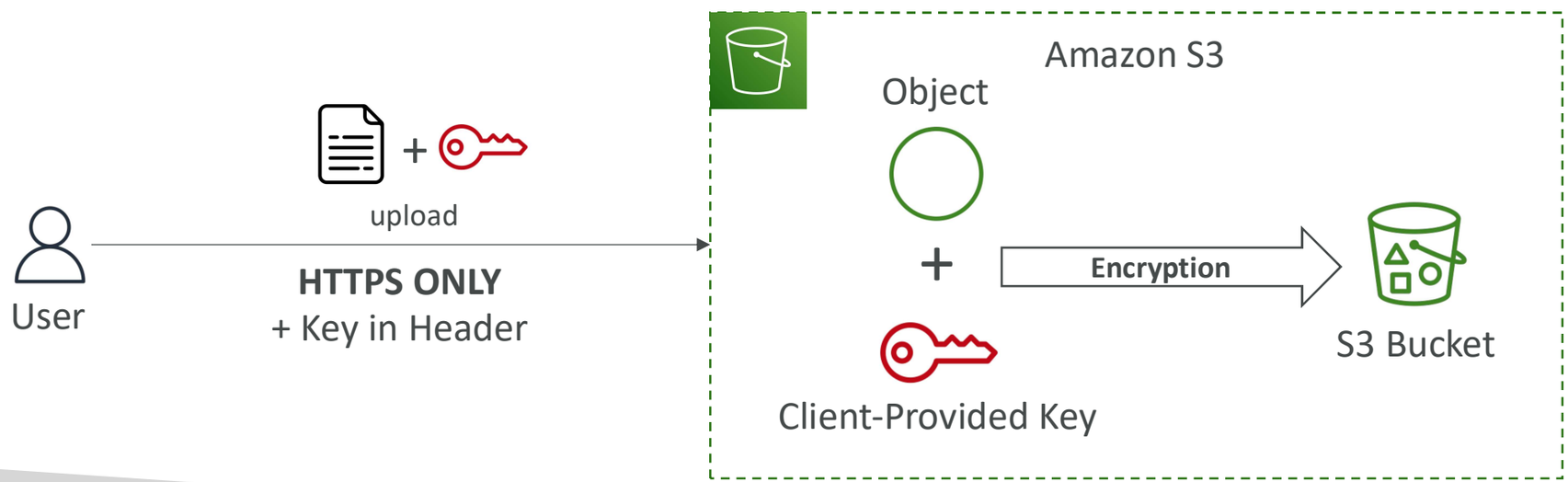
SSE-KMS Limitation

- If you use SSE-KMS, you may be impacted by the KMS limits
- When you upload, it calls the **GenerateDataKey** KMS API
- When you download, it calls the **Decrypt** KMS API
- Count towards the KMS quota per second (5500, 10000, 30000 req/s based on region)
- You can request a quota increase using the Service Quotas Console



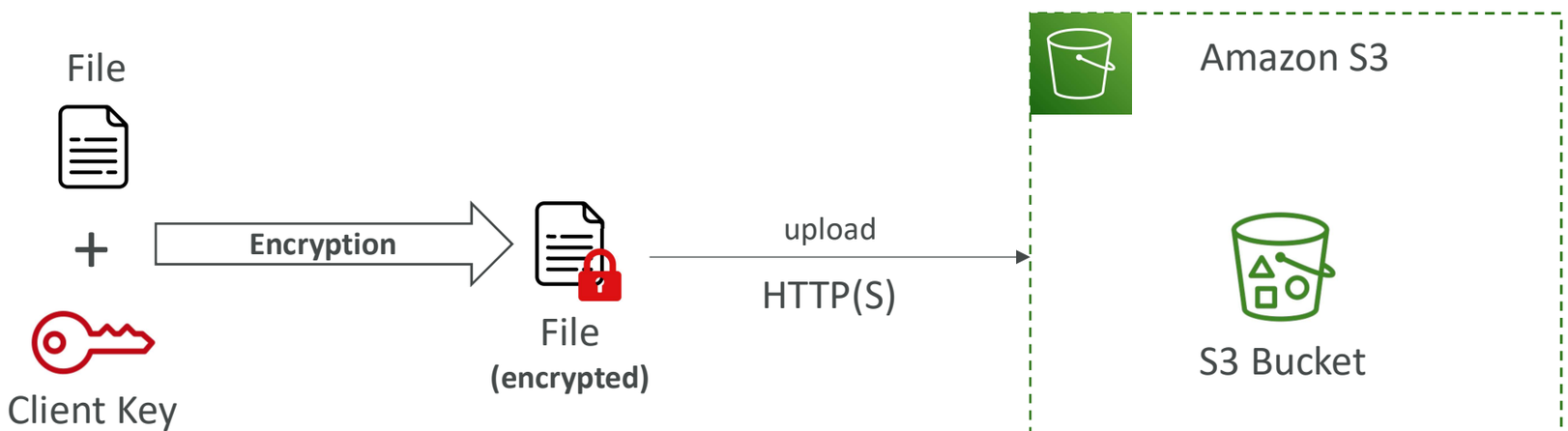
Amazon S3 Encryption – SSE-C

- Server-Side Encryption using keys fully managed by the customer outside of AWS
- Amazon S3 does **NOT** store the encryption key you provide
- **HTTPS must be used**
- Encryption key must provided in HTTP headers, for every HTTP request made



Amazon S3 Encryption – Client-Side Encryption

- Use client libraries such as **Amazon S3 Client-Side Encryption Library**
- Clients must encrypt data themselves before sending to Amazon S3
- Clients must decrypt data themselves when retrieving from Amazon S3
- Customer fully manages the keys and encryption cycle



Amazon S3 – Encryption in transit (SSL/TLS)

- Encryption in flight is also called SSL/TLS

- Amazon S3 exposes two endpoints:
  - **HTTP Endpoint** – non encrypted
  - **HTTPS Endpoint** – encryption in flight

- **HTTPS is recommended**
- **HTTPS is mandatory for SSE-C**
- Most clients would use the HTTPS endpoint by default

Amazon S3 – Default Encryption vs. Bucket Policies

One way to "force encryption" is to use a bucket policy and refuse any API call to PUT an S3 object without encryption headers

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "DenyIncorrectDecryptionHeader",
            "Effect": "Deny",
            "Principal": "*",
            "Action": [ "s3:PutObject" ],
            "Resource": [ "arn:aws:s3:::examplebucket/*" ],
            "Condition": {
                "StringNotEquals": {
                    "s3:x-amz-server-side-encryption": "AES256"
                }
            }
        }
    ]
}
```

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "DenyUnencryptedObjectUploads",
            "Effect": "Deny",
            "Principal": "*",
            "Action": [ "s3:PutObject" ],
            "Resource": [ "arn:aws:s3:::examplebucket/*" ],
            "Condition": {
                "Null": {
                    "s3:x-amz-server-side-encryption": true
                }
            }
        }
    ]
}
```

Another way is to use the "default encryption" option in S3

Note: Bucket Policies are evaluated before "default encryption"

Amazon S3 – MFA Delete

- **MFA (Multi-Factor Authentication)** – force users to generate a code on a device (usually a mobile phone or hardware) before doing important operations on S3
- MFA will be required to:
  - Permanently delete an object version
  - Suspend Versioning on the bucket
- MFA won't be required to:
  - Enable Versioning
  - List deleted versions
- To use MFA Delete, **Versioning must be enabled** on the bucket
- **Only the bucket owner (root account) can enable/disable MFA Delete**

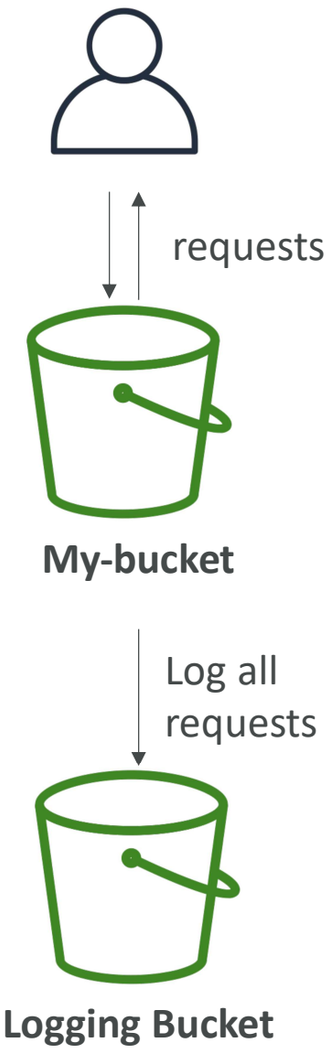
Google Authenticator

MFA Hardware Device

S3 Access Logs

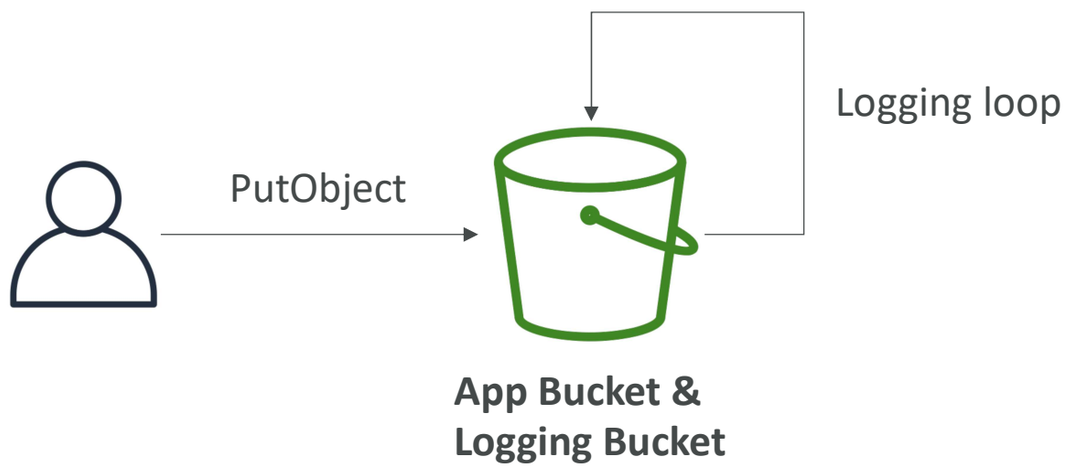
- For audit purpose, you may want to log all access to S3 buckets
- Any request made to S3, from any account, authorized or denied, will be logged into another S3 bucket
- That data can be analyzed using data analysis tools…
- The target logging bucket must be in the same AWS region

- The log format is at: https://docs.aws.amazon.com/AmazonS3/latest/dev/LogFormat.html



S3 Access Logs: Warning

- Do not set your logging bucket to be the monitored bucket
- It will create a logging loop, and **your bucket will grow exponentially**

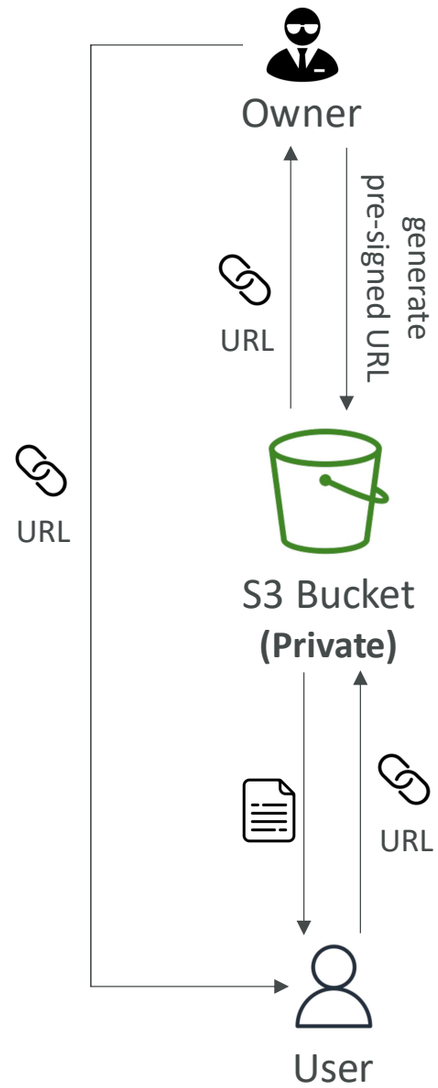


Do not try this at home ☺

Amazon S3 – Pre-Signed URLs

- Generate pre-signed URLs using the **S3 Console, AWS CLI or SDK**
- **URL Expiration**
  - **S3 Console** – 1 min up to 720 mins (12 hours)
  - **AWS CLI** – configure expiration with *--expires-in* parameter in seconds (default 3600 secs, max. 604800 secs ~ 168 hours)
- Users given a pre-signed URL inherit the permissions of the user that generated the URL for GET / PUT

- Examples:
  - Allow only logged-in users to download a premium video from your S3 bucket
  - Allow an ever-changing list of users to download files by generating URLs dynamically
  - Allow temporarily a user to upload a file to a precise location in your S3 bucket



S3 Bucket Policies

- Use S3 bucket for policy to:
  - Grant public access to the bucket
  - Force objects to be encrypted at upload
  - **Grant access to another account (Cross Account)**
- Optional Conditions on:
  - Public IP or Elastic IP (not on Private IP)
  - Source VPC or Source VPC Endpoint – only works with VPC Endpoints
  - CloudFront Origin Identity
  - MFA
- Examples here: https://docs.aws.amazon.com/AmazonS3/latest/dev/example-bucket-policies.html

Bucket Policies – Advanced Examples

- Restrict access to only principals from AWS accounts inside an AWS Organization using **aws:PrincipalOrgID** condition key

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Principal": "*",
            "Action": "s3:GetObject",
            "Resource": "arn:aws:s3:::mybucket/*",
            "Condition": {
                "StringEquals": {
                    "aws:PrincipalOrgID": ["o-exampleorgid"]
                }
            }
        }
    ]
}
```

- Prevent uploads of unencrypted objects to an S3 bucket using **s3:x-amz-server-side-encryption** condition key

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Deny",
            "Principal": "*",
            "Action": "s3:PutObject",
            "Resource": "arn:aws:s3:::mybucket/*",
            "Condition": {
                "Null": {
                    "s3:x-amz-server-side-encryption": true
                }
            }
        }
    ]
}
```

Advanced Storage Solutions

AWS Snow Family

- Highly-secure, portable devices to **collect and process data at the edge**, and **migrate data into and out of AWS**

- Data migration:


Snowcone


Snowball Edge


Snowmobile

- Edge computing:


Snowcone


Snowball Edge

Data Migrations with AWS Snow Family

	Time to Transfer		
	100 Mbps	**1Gbps**	**10Gbps**
10 TB	12 days	30 hours	3 hours
100 TB	124 days	12 days	30 hours
1 PB	3 years	124 days	12 days

Challenges:

- Limited connectivity
- Limited bandwidth
- High network cost
- Shared bandwidth (can't maximize the line)
- Connection stability

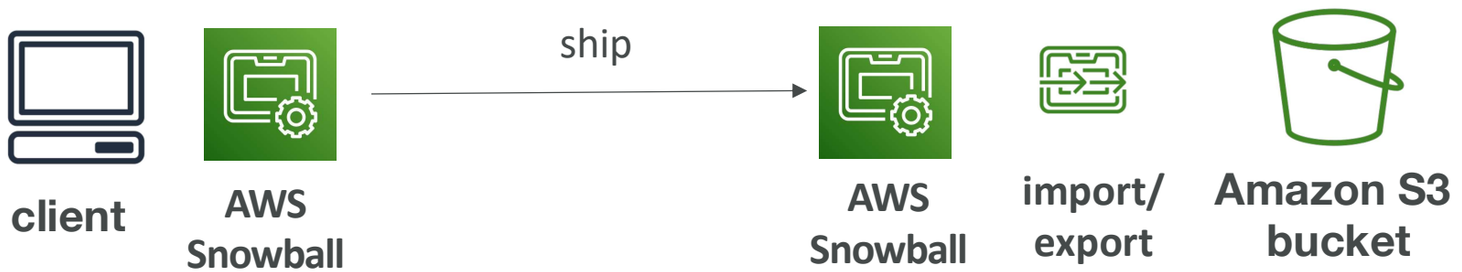
AWS Snow Family: offline devices to perform data migrations

If it takes more than a week to transfer over the network, use Snowball devices!

Diagrams

- Direct upload to S3:

- With Snow Family:



Snowball Edge (for data transfers)

- Physical data transport solution: move TBs or PBs of data in or out of AWS
- Alternative to moving data over the network (and paying network fees)
- Pay per data transfer job
- Provide block storage and Amazon S3-compatible object storage
- Snowball Edge Storage Optimized
  - 80 TB of HDD capacity for block volume and S3 compatible object storage
- Snowball Edge Compute Optimized
  - 42 TB of HDD capacity for block volume and S3 compatible object storage
- Use cases: large data cloud migrations, DC decommission, disaster recovery

AWS Snowcone

- **Small, portable computing, anywhere, rugged & secure, withstands harsh environments**
- Light (4.5 pounds, 2.1 kg)
- Device used for edge computing, storage, and data transfer
- **8 TBs of usable storage**
- Use Snowcone where Snowball does not fit (space-constrained environment)
- Must provide your own battery / cables

- Can be sent back to AWS offline, or connect it to internet and use **AWS DataSync** to send data

AWS Snowmobile

- Transfer exabytes of data (1 EB = 1,000 PB = 1,000,000 TBs)
- Each Snowmobile has 100 PB of capacity (use multiple in parallel)
- High security: temperature controlled, GPS, 24/7 video surveillance
- **Better than Snowball if you transfer more than 10 PB**

AWS Snow Family for Data Migrations

Snowcone

Snowball Edge

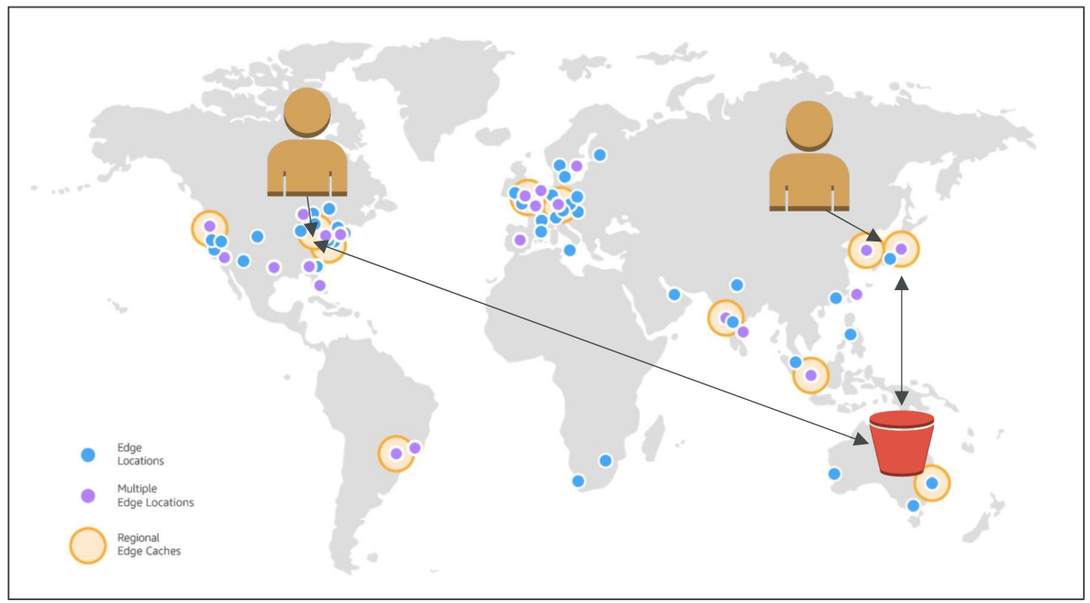
Snowmobile

	Snowcone	Snowball Edge Storage Optimized	Snowmobile
Storage Capacity	8 TB usable	80 TB usable	< 100 PB
Migration Size	Up to 24 TB, online and offline	Up to petabytes, offline	Up to exabytes, offline
DataSync agent	Pre-installed		
Storage Clustering		Up to 15 nodes	

CloudFront

Amazon CloudFront

- Content Delivery Network (CDN)
- Improves read performance, content is cached at the edge
- 216 Point of Presence globally (edge locations)
- DDoS protection, integration with Shield, AWS Web Application Firewall
- Can expose external HTTPS and can talk to internal HTTPS backends

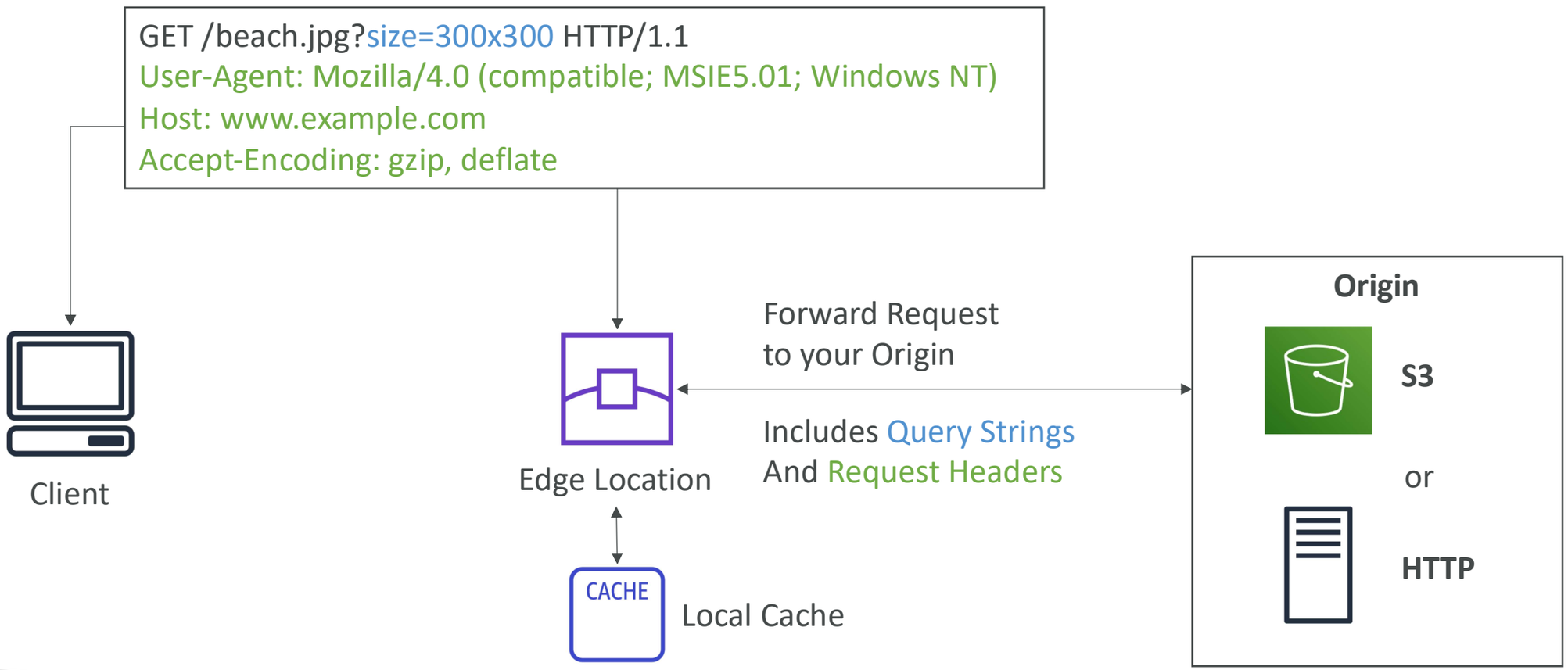


Source: https://aws.amazon.com/cloudfront/features/?nc=sn&loc=2

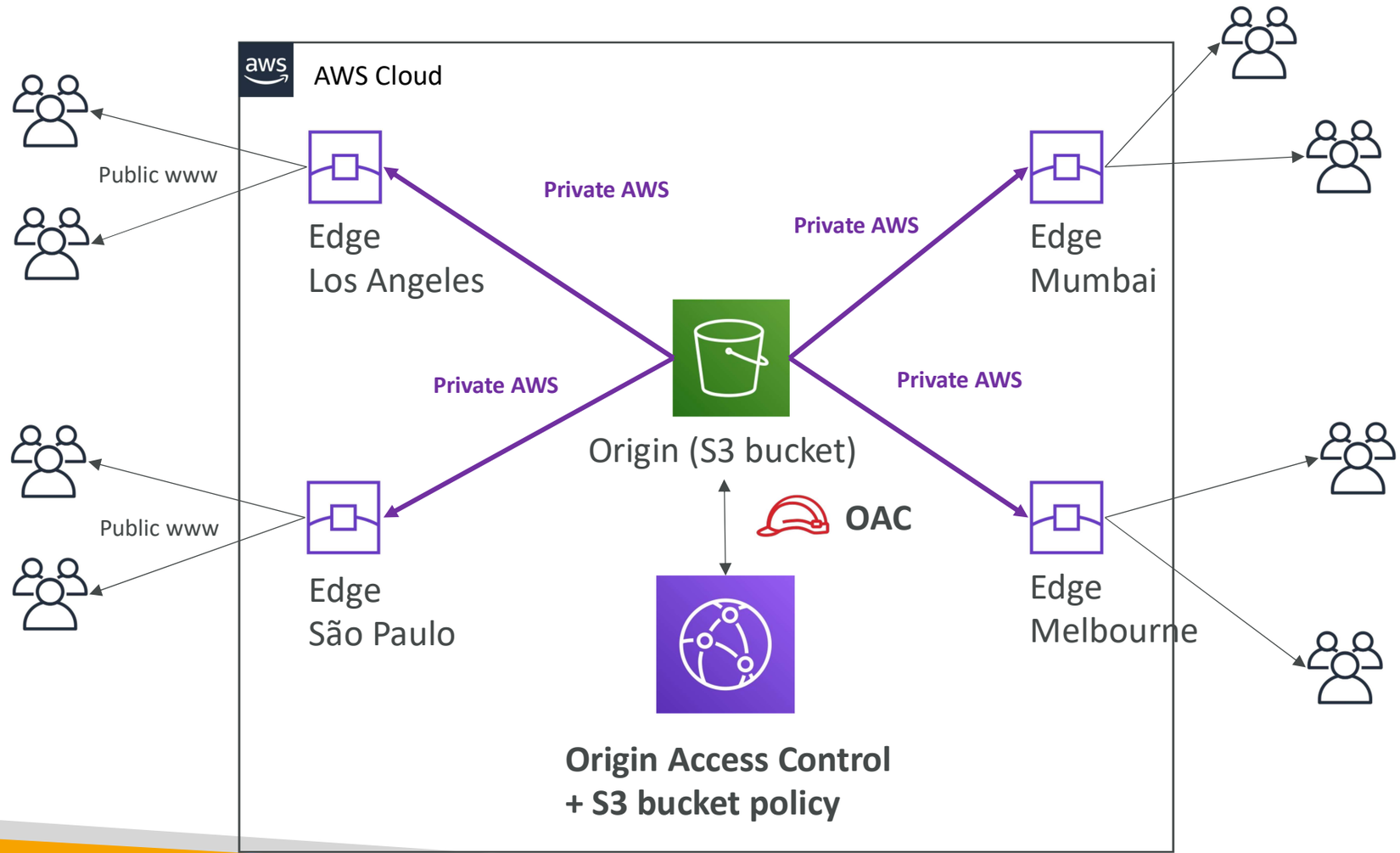
CloudFront – Origins

- S3 bucket
  - For distributing files and caching them at the edge
  - Enhanced security with CloudFront **Origin Access Control (OAC)**
  - OAC is replacing Origin Access Identity (OAI)
  - CloudFront can be used as an ingress (to upload files to S3)
- Custom Origin (HTTP)
  - Application Load Balancer
  - EC2 instance
  - S3 website (must first enable the bucket as a static S3 website)
  - Any HTTP backend you want

CloudFront at a high level

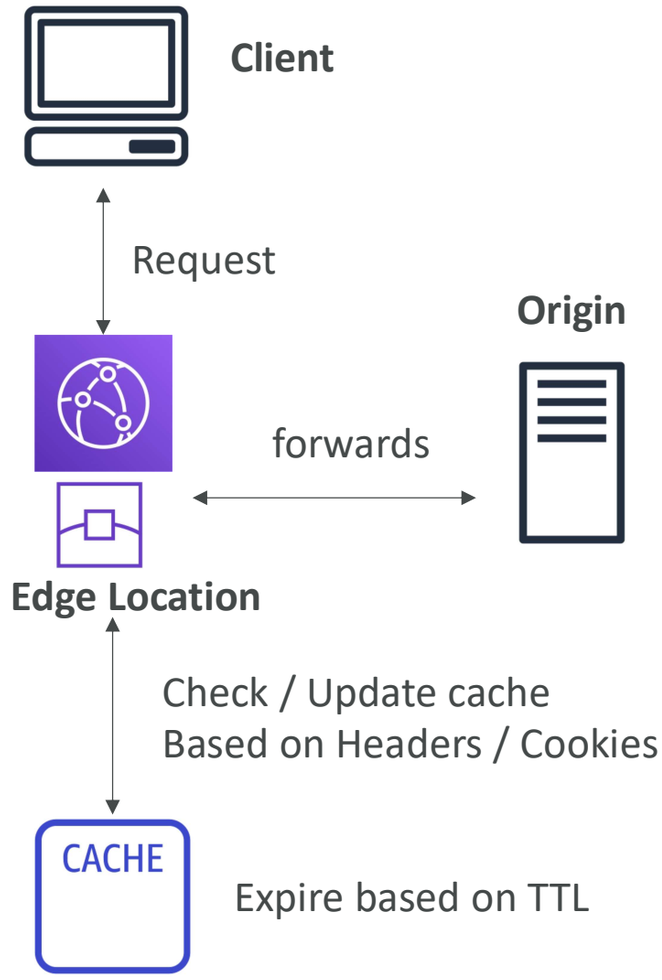


CloudFront – S3 as an Origin



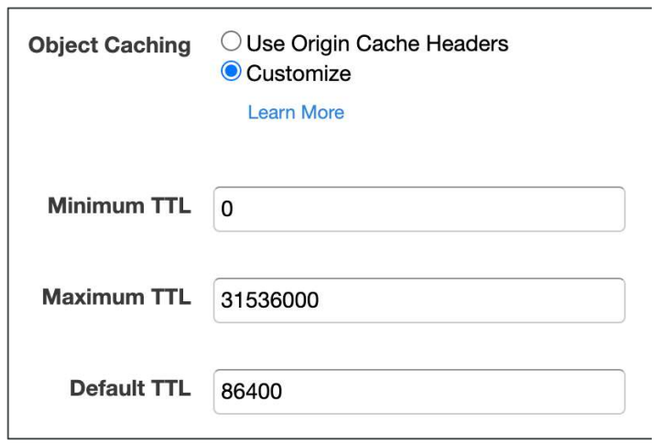
CloudFront Caching

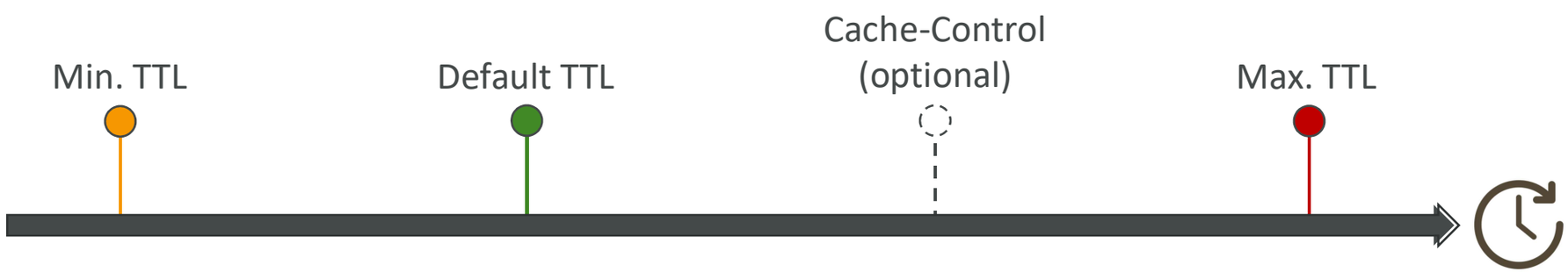
- Cache based on
  - Headers
  - Session Cookies
  - Query String Parameters
- The cache lives at each CloudFront **Edge Location**
- You want to maximize the cache hit rate to minimize requests on the origin
- Control the TTL (0 seconds to 1 year), can be set by the origin using the Cache-Control header, Expires header…
- You can invalidate part of the cache using the **CreateInvalidation** API



CloudFront Caching TTL

- "Cache-Control: max-age" is preferred to "Expires" header
- If the origin always sends back the header Cache-Control , then you can set the TTL to be controlled only by that header
- In case you want to set min/max boundaries, you choose "customize" for the Object Caching setting
- In case the Cache-Control header is missing, it will default to "default value"





Databases

Amazon RDS Overview

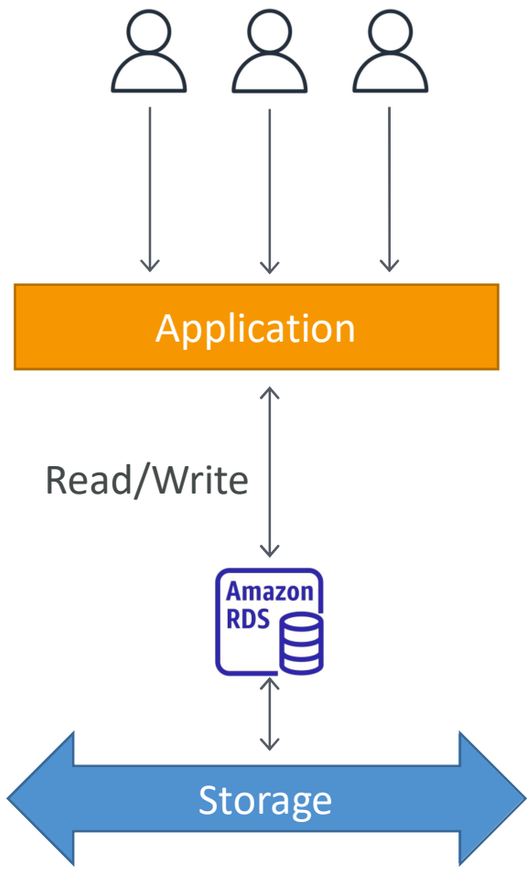
- RDS stands for Relational Database Service
- It's a managed DB service for DB use SQL as a query language.
- It allows you to create databases in the cloud that are managed by AWS
  - Postgres
  - MySQL
  - MariaDB
  - Oracle
  - Microsoft SQL Server
  - Aurora (AWS Proprietary database)

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

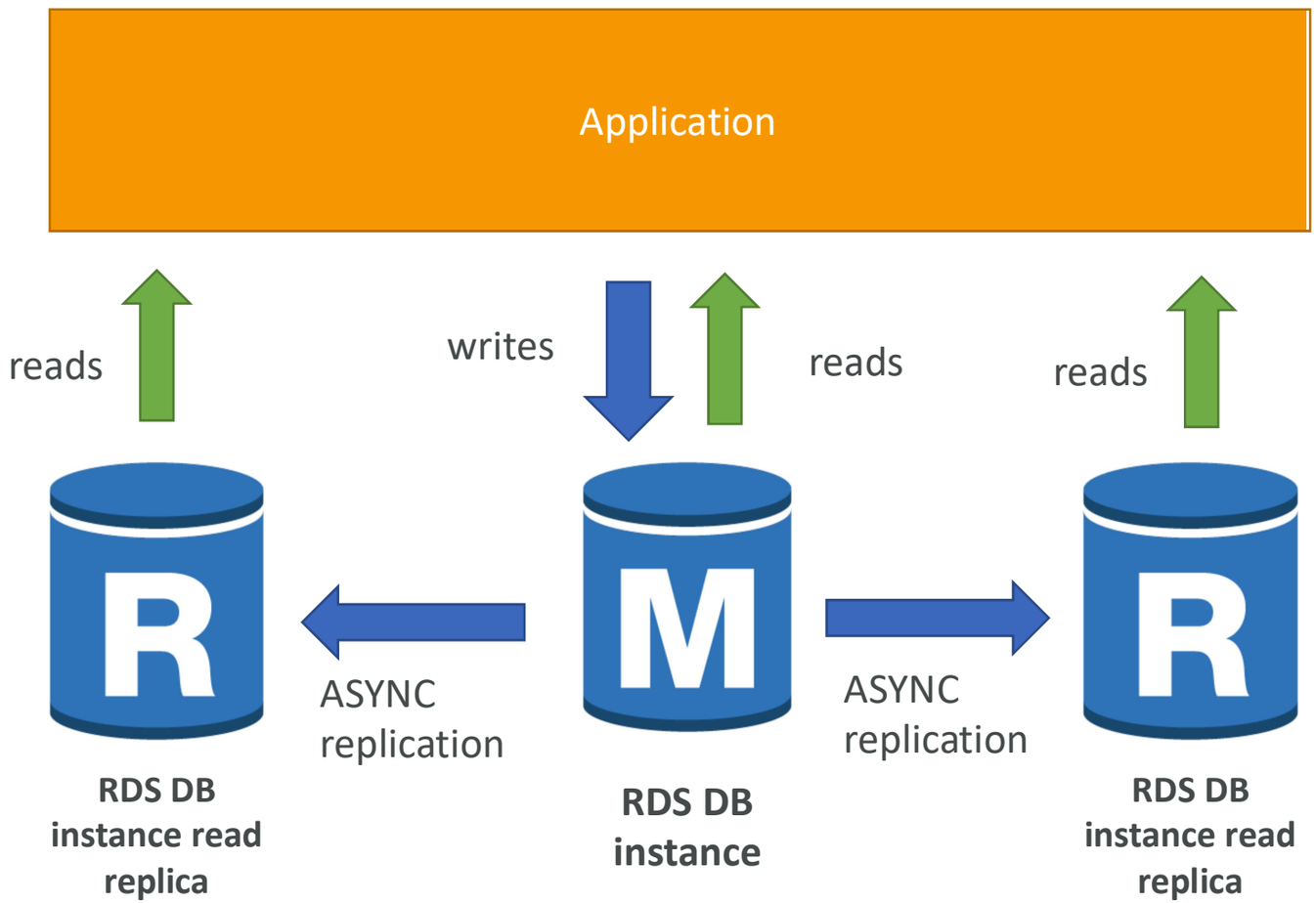
RDS – Storage Auto Scaling

- 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)



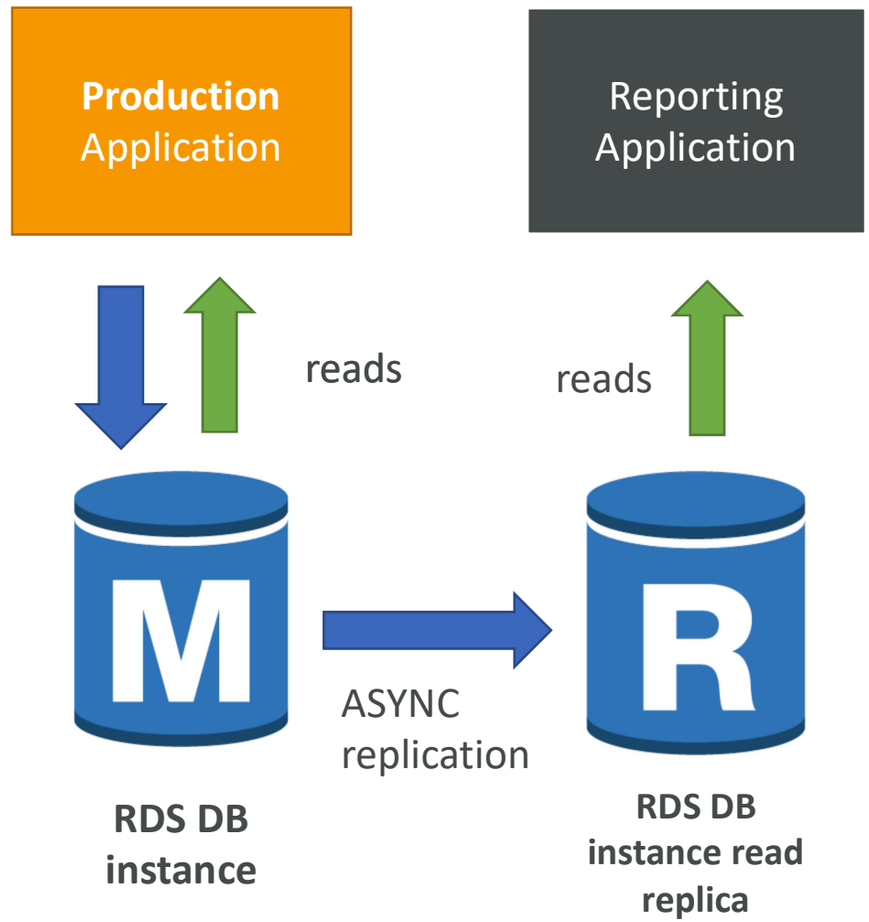
RDS Read Replicas for read scalability

- 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



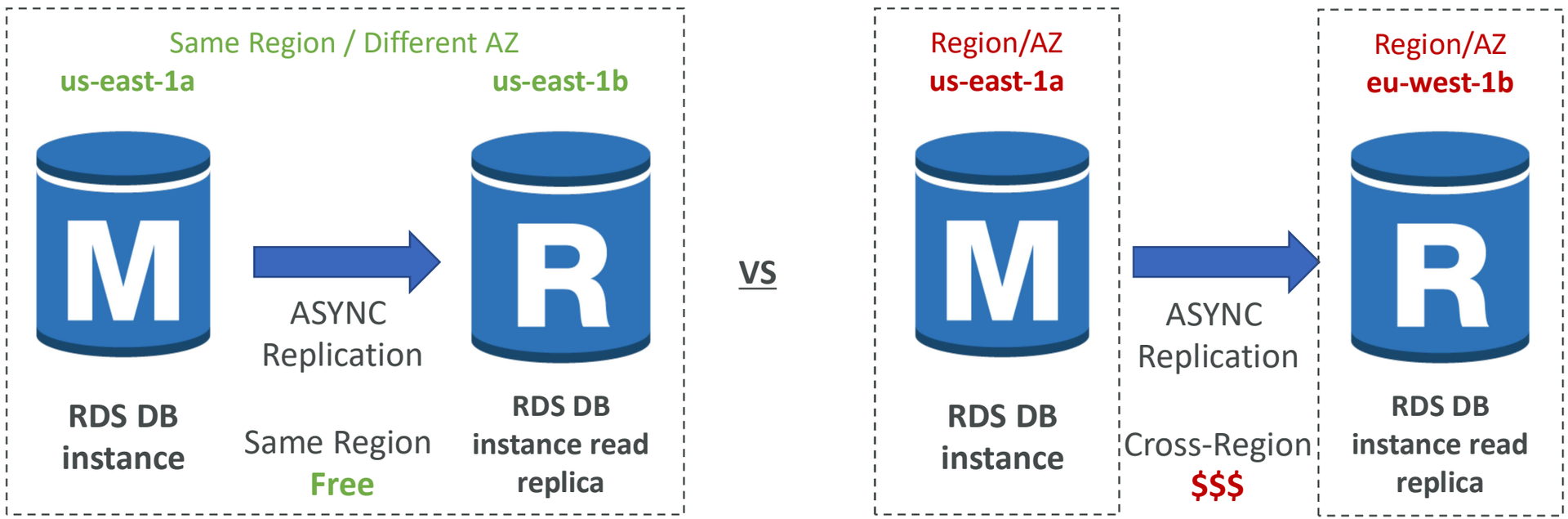
RDS Read Replicas – Use Cases

- 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)



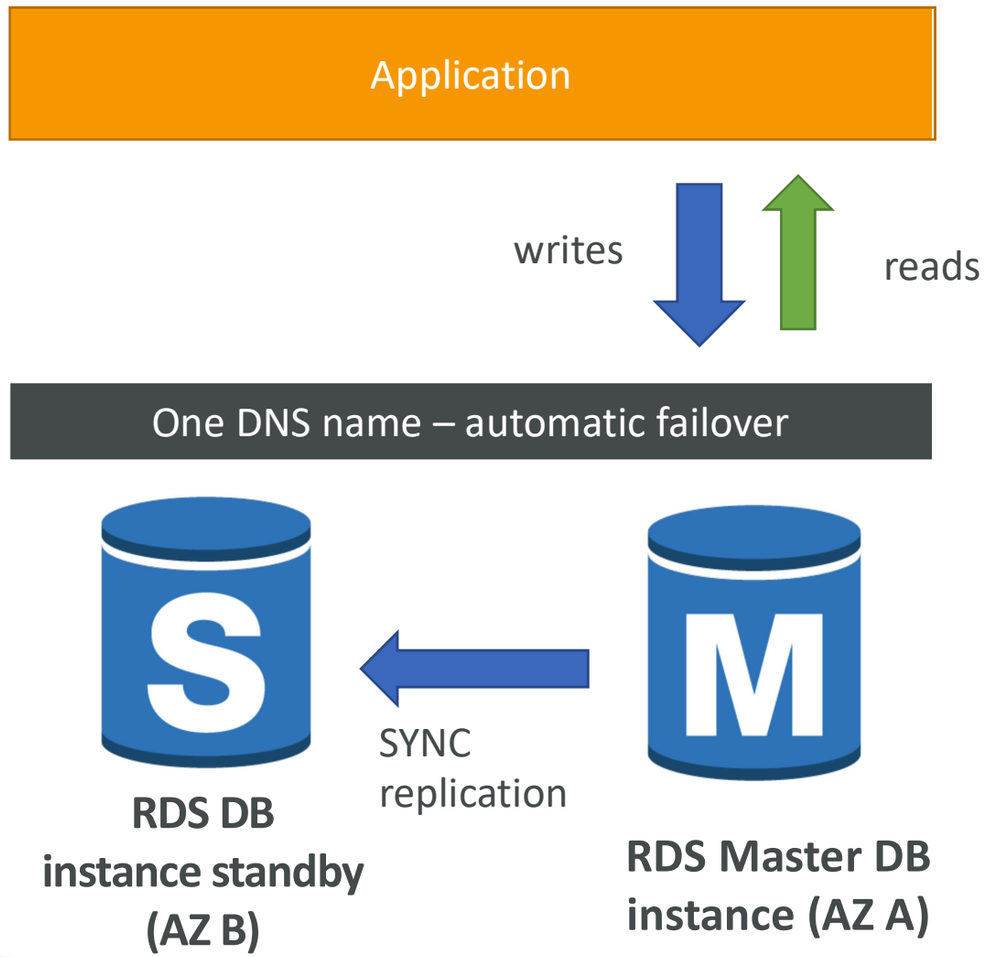
RDS Read Replicas – Network Cost

- 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)



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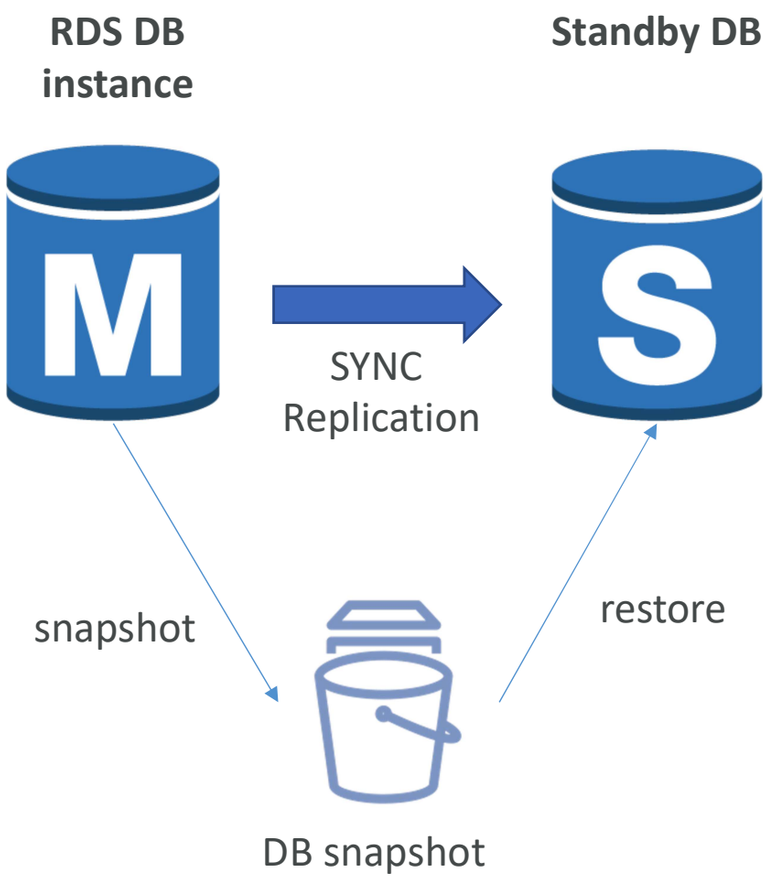
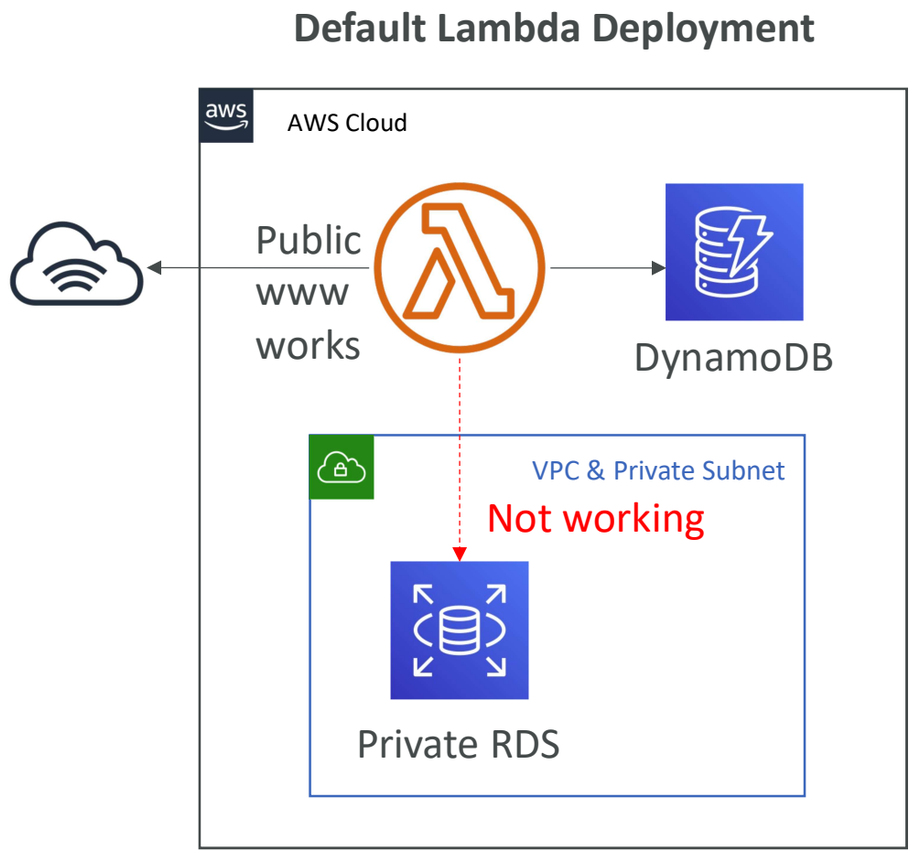
RDS – From Single-AZ to Multi-AZ

- 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



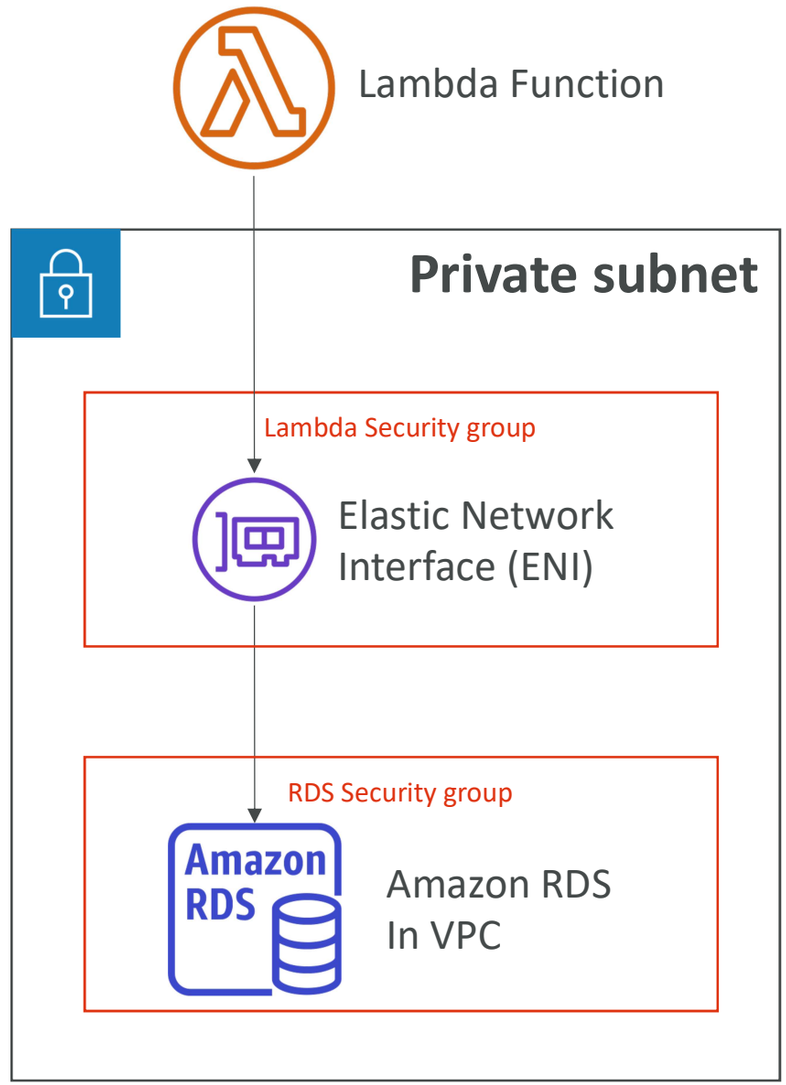
Lambda by default

- By default, your Lambda function is launched outside your own VPC (in an AWS-owned VPC)
- Therefore, it cannot access resources in your VPC (RDS, ElastiCache, internal ELB…)



Lambda in VPC

- You must define the VPC ID, the Subnets and the Security Groups
- Lambda will create an ENI (Elastic Network Interface) in your subnets
- AWSLambdaVPCAccessExecutionRole



DB Parameter Groups

- You can configure the DB engine using Parameter Groups
- Dynamic parameters are applied immediately
- Static parameters are applied after instance reboot
- You can modify parameter group associated with a DB (must reboot)
- See documentation for list of parameters for a DB technology

- Must-know parameter:
  - PostgreSQL / SQL Server: **rds.force_ssl=1** => force SSL connections
  - Reminder: for SSL on MySQL / MariaDB, you must run:
    GRANT SELECT ON mydatabase.* TO 'myuser'@'%' IDENTIFIED BY '....' REQUIRE SSL;

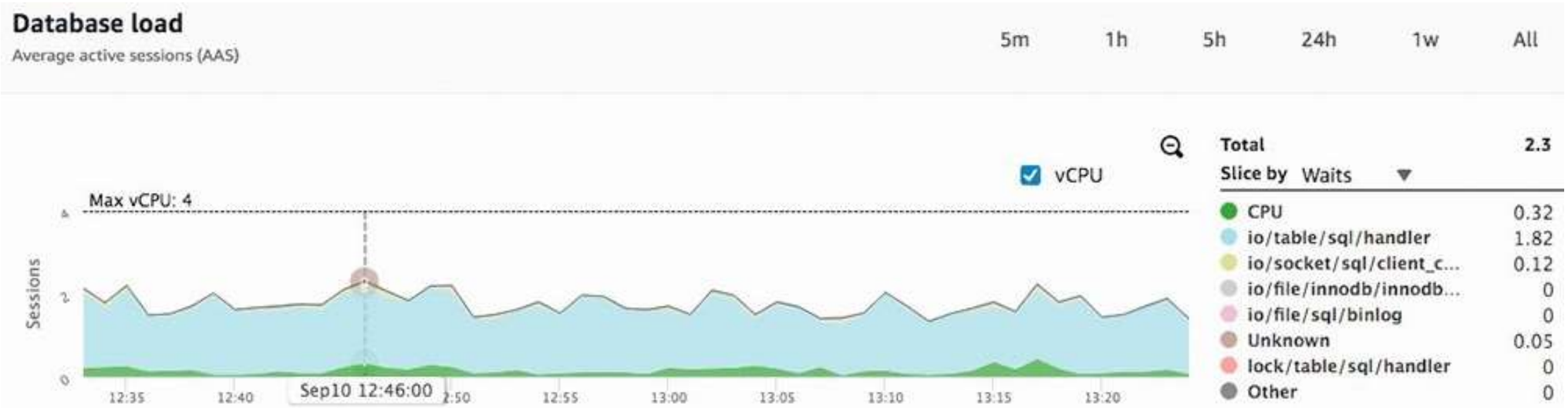
RDS with CloudWatch

- CloudWatch metrics associated with RDS (gathered from the hypervisor):
  - DatabaseConnections
  - SwapUsage
  - ReadIOPS / WriteIOPS
  - ReadLatency / WriteLatency
  - ReadThroughPut / WriteThroughPut
  - DiskQueueDepth
  - FreeStorageSpace
- Enhanced Monitoring (gathered from an agent on the DB instance)
  - Useful when you need to see how different processes or threads use the CPU
  - Access to over 50 new CPU, memory, file system, and disk I/O metrics

RDS Performance Insights

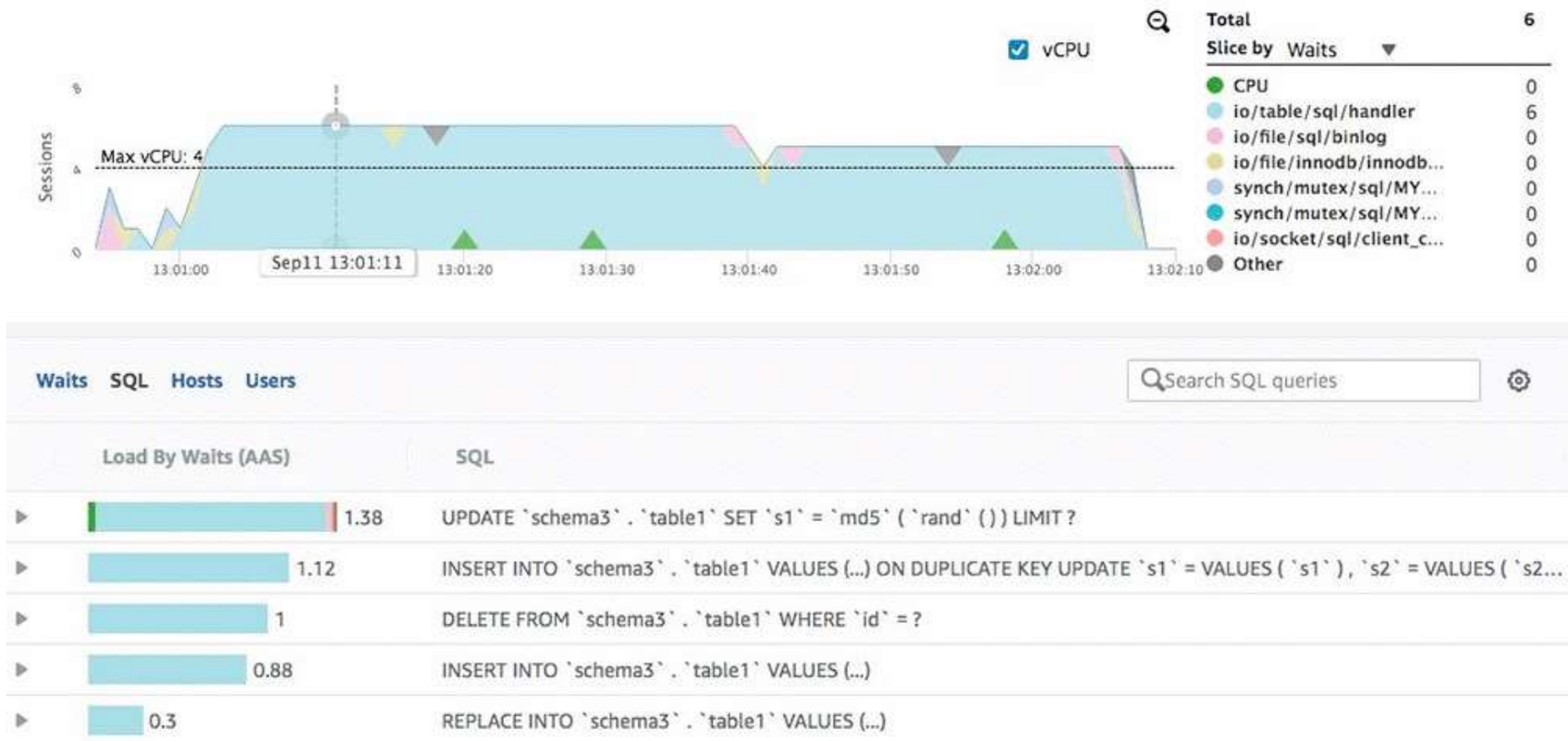
- Visualize your database performance and analyze any issues that affect it
- With the Performance Insights dashboard, you can visualize the database load and filter the load:
  - By Waits => find the resource that is the bottleneck (CPU, IO, lock, etc…)
  - By SQL statements => find the SQL statement that is the problem
  - By Hosts => find the server that is using the most our DB
  - By Users => find the user that is using the most our DB
- DBLoad = the number of active sessions for the DB engine
- You can view the SQL queries that are putting load on your database

Performance Insights Screenshots
DB Waits



From: https://aws.amazon.com/blogs/database/tuning-amazon-rds-for-mysql-with-performance-insight

Performance Insights Screenshots
SQL



From: https://aws.amazon.com/blogs/database/tuning-amazon-rds-for-mysql-with-performance-insight

Performance Insights Screenshots
Users

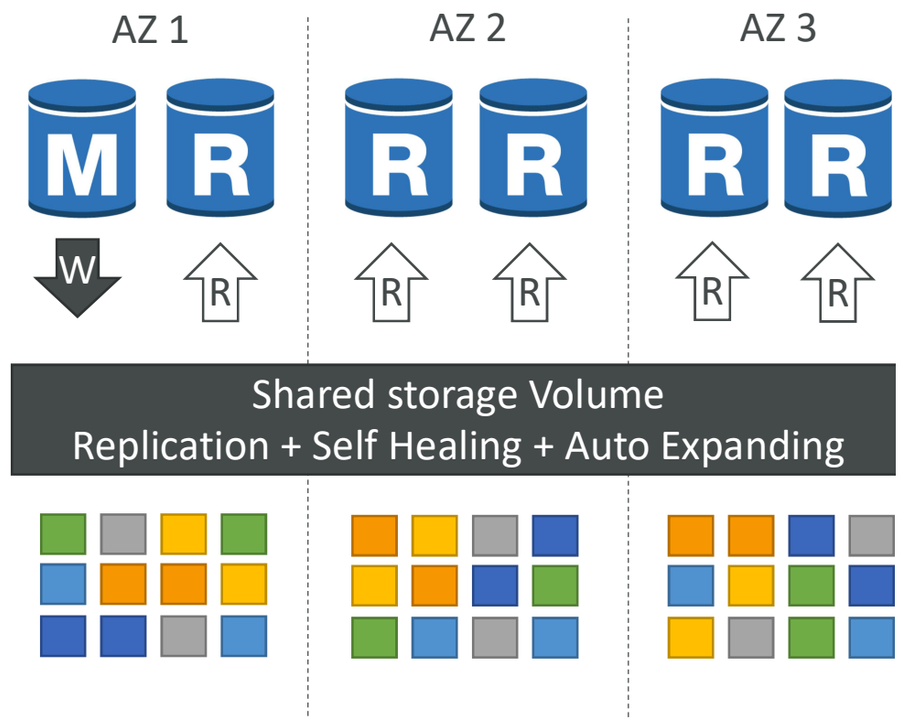
From: https://aws.amazon.com/blogs/database/tuning-amazon-rds-for-mysql-with-performance-insight

Amazon Aurora

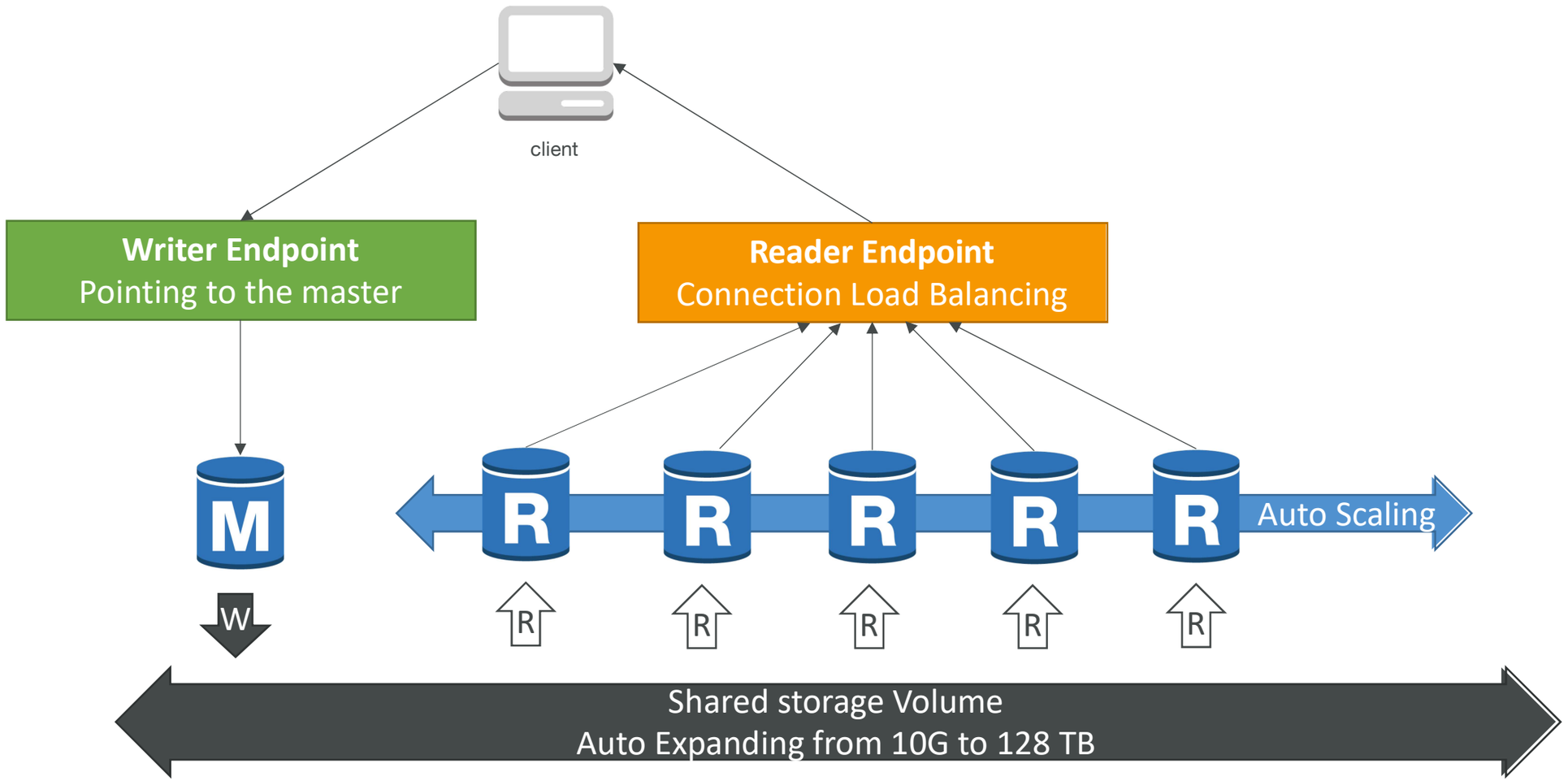
- Aurora is a proprietary technology from AWS (not open sourced)
- Postgres and MySQL are both supported as Aurora DB (that means your drivers will work as if Aurora was a Postgres or MySQL database)
- Aurora is "AWS cloud optimized" and claims 5x performance improvement over MySQL on RDS, over 3x the 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

Backups, Backtracking & Restores in Aurora

- Automatic Backups
  - Retention period 1-35 days (can't be disabled)
  - PITR, restore your DB cluster within 5 minutes of the current time
  - Restore to a new DB cluster
- Aurora Backtracking
  - Rewind the DB cluster back and forth in time (up to 72 hours)
  - Doesn't create a new DB cluster (in-place restore)
  - Supports Aurora MySQL only
- Aurora Database Cloning
  - Creates a new DB cluster that uses the same DB cluster volume as the original cluster
  - Uses *copy-on-write* protocol (use the original/single copy of the data and allocate storage only when changes made to the data)
  - Example: create a test environment using your production data

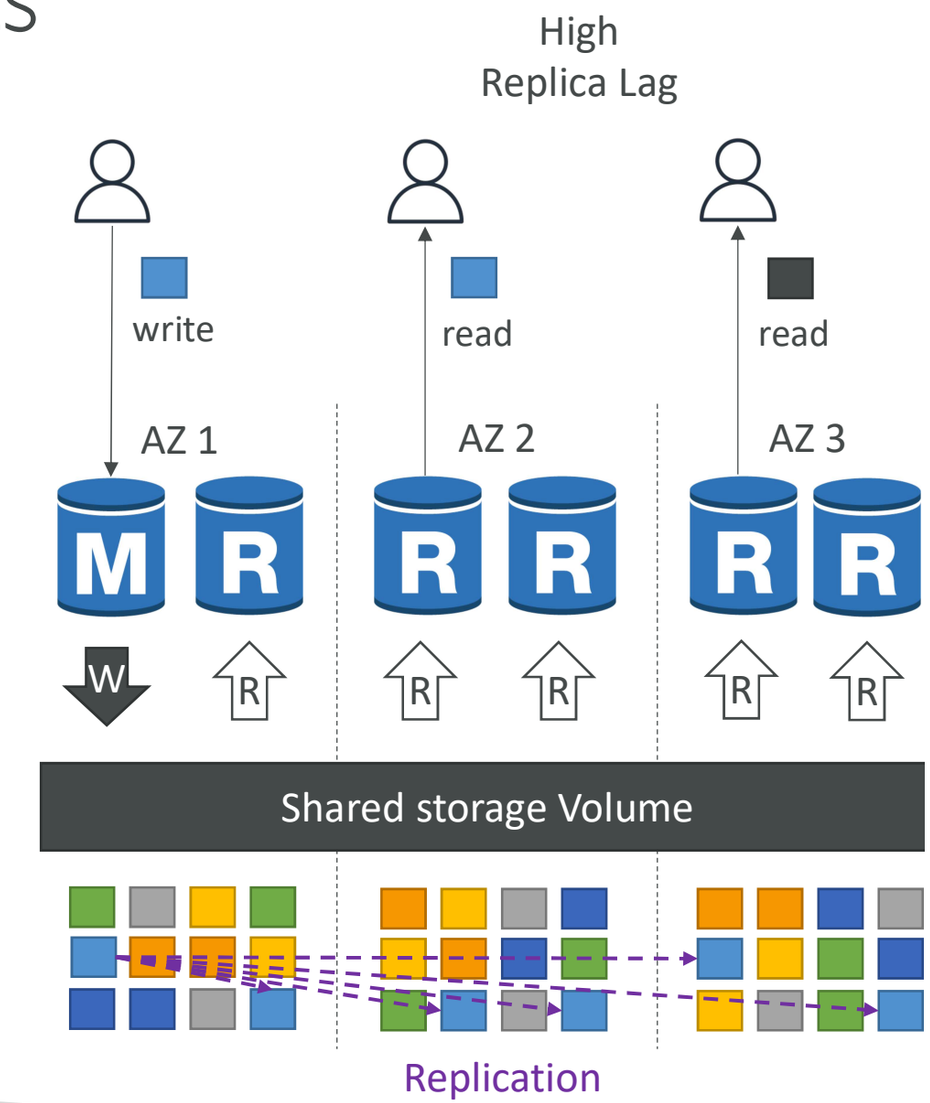
Aurora for SysOps

- You can associate a priority tier (0-15) on each Read Replica
  - Controls the failover priority
  - RDS will promote the Read Replica with the highest priority (lowest tier)
  - If replicas have the same priority, RDS promotes the largest in size
  - If replicas have the same priority and size, RDS promotes arbitrary replica

- You can migrate an RDS MySQL snapshot to Aurora MySQL Cluster

Aurora: CloudWatch metrics

- **AuroraReplicaLag:** amount of lag when replicating updates from the primary instance
- **AuroraReplicaLagMaximum:** max. amount of lag across all DB instances in the cluster
- **AuroraReplicaLagMinimum:** min. amount of lag across all DB instances in the cluster
- If replica lag is high, that means the users will have a different experience based on which replica they get the data from (eventual consistency)
- **DatabaseConnections:** current number of connections to a DB instance
- **InsertLatency:** average duration of insert operations

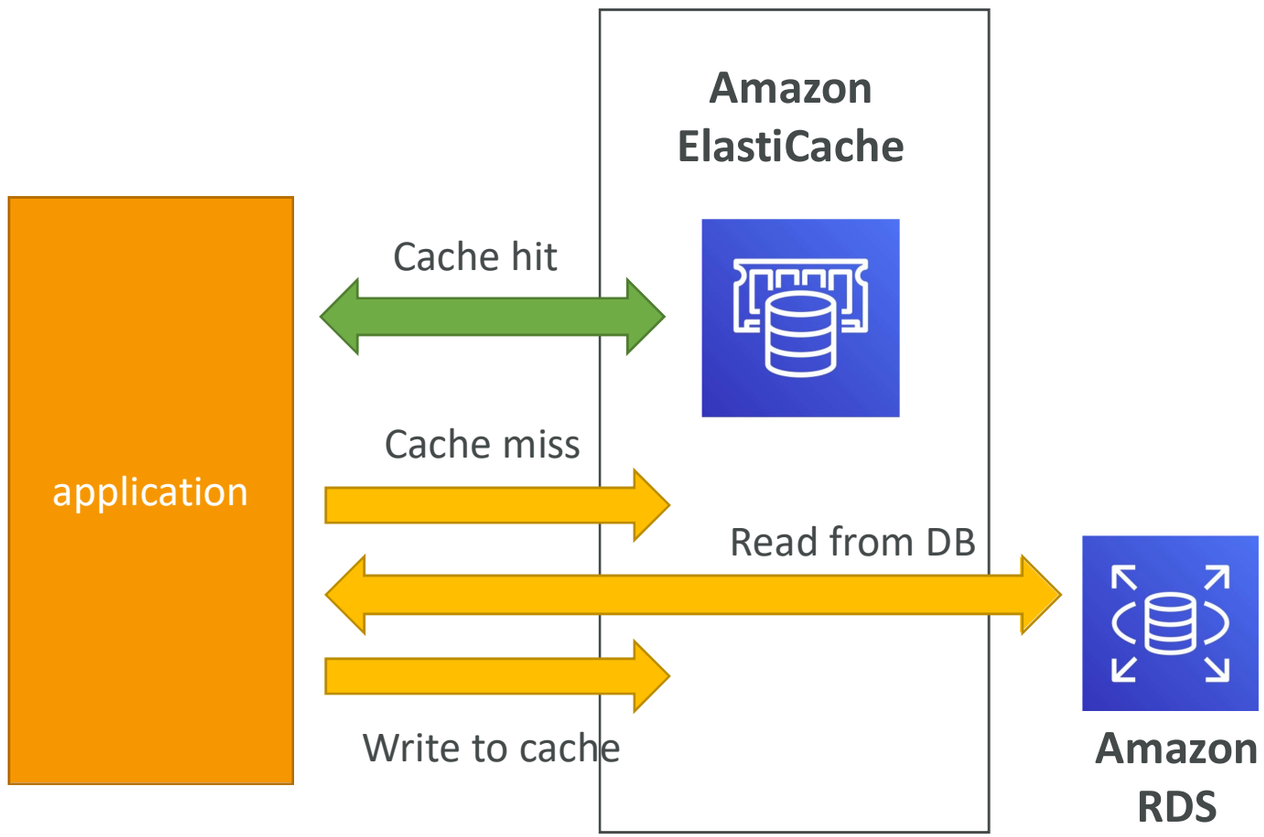


Amazon ElastiCache Overview

- 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

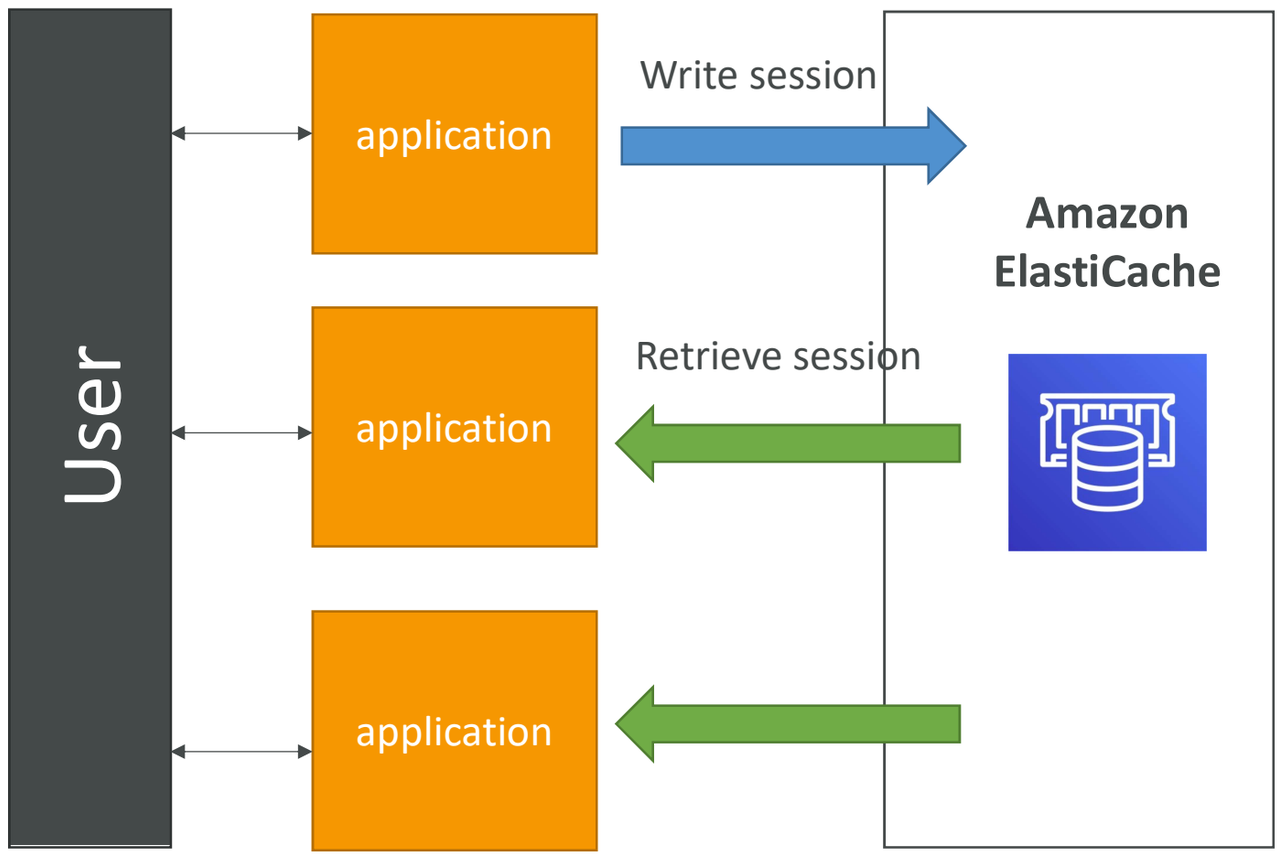
ElastiCache
Solution Architecture - DB Cache

- 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



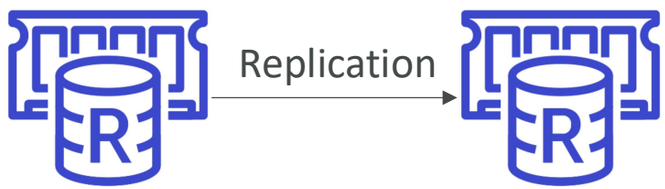
ElastiCache – Redis vs Memcached

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



AWS Monitoring, Audit and Performance

CloudWatch, CloudTrail & AWS Config

AWS CloudWatch Metrics

- CloudWatch provides metrics for *every* services in AWS
- **Metric** is a variable to monitor (CPUUtilization, NetworkIn…)
- Metrics belong to **namespaces**
- **Dimension** is an attribute of a metric (instance id, environment, etc…).
- Up to 10 dimensions per metric
- Metrics have **timestamps**
- Can create CloudWatch dashboards of metrics

EC2 Detailed monitoring

- EC2 instance metrics have metrics "every 5 minutes"
- With detailed monitoring (for a cost), you get data "every 1 minute"
- Use detailed monitoring if you want to scale faster for your ASG!

- The AWS Free Tier allows us to have 10 detailed monitoring metrics

- Note: EC2 Memory usage is by default not pushed (must be pushed from inside the instance as a custom metric)

CloudWatch Custom Metrics

- Possibility to define and send your own custom metrics to CloudWatch
- Example: memory (RAM) usage, disk space, number of logged in users …
- Use API call **PutMetricData**
- Ability to use dimensions (attributes) to segment metrics
  - Instance.id
  - Environment.name
- Metric resolution (**StorageResolution** API parameter – two possible value):
  - Standard: 1 minute (60 seconds)
  - High Resolution: 1/5/10/30 second(s) – Higher cost
- **Important:** Accepts metric data points two weeks in the past and two hours in the future (make sure to configure your EC2 instance time correctly)

CloudWatch Dashboards

- Great way to setup custom dashboards for quick access to key metrics and alarms
- **Dashboards are global**
- **Dashboards can include graphs from different AWS accounts and regions**
- You can change the time zone & time range of the dashboards
- You can setup automatic refresh (10s, 1m, 2m, 5m, 15m)
- Dashboards can be shared with people who don't have an AWS account (public, email address, 3rd party SSO provider through Amazon Cognito)

- Pricing:
  - 3 dashboards (up to 50 metrics) for free
  - $3/dashboard/month afterwards

CloudWatch Logs

- **Log groups:** arbitrary name, usually representing an application
- **Log stream:** instances within application / log files / containers
- Can define log expiration policies (never expire, 30 days, etc..)
- **CloudWatch Logs can send logs to:**
  - Amazon S3 (exports)
  - Kinesis Data Streams
  - Kinesis Data Firehose
  - AWS Lambda
  - ElasticSearch

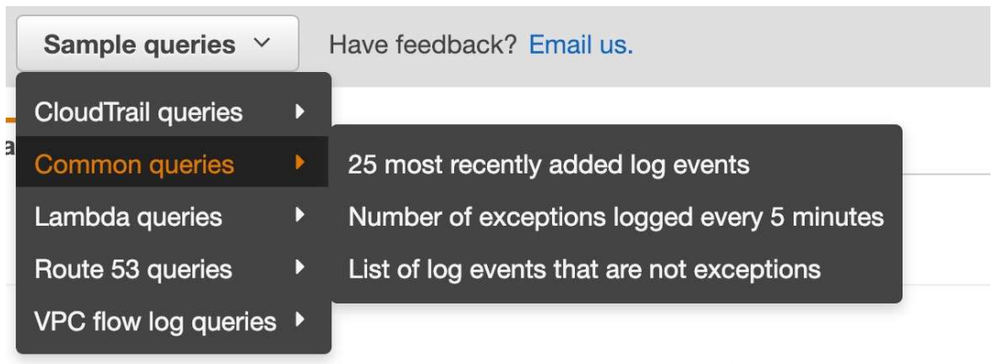
CloudWatch Logs - Sources

- SDK, CloudWatch Logs Agent, CloudWatch Unified Agent
- Elastic Beanstalk: collection of logs from application
- ECS: collection from containers
- AWS Lambda: collection from function logs
- VPC Flow Logs: VPC specific logs
- API Gateway
- CloudTrail based on filter
- Route53: Log DNS queries

CloudWatch Logs Metric Filter & Insights

- CloudWatch Logs can use filter expressions
  - For example, find a specific IP inside of a log
  - Or count occurrences of "ERROR" in your logs
- Metric filters can be used to trigger CloudWatch alarms

- CloudWatch Logs Insights can be used to query logs and add queries to CloudWatch Dashboards

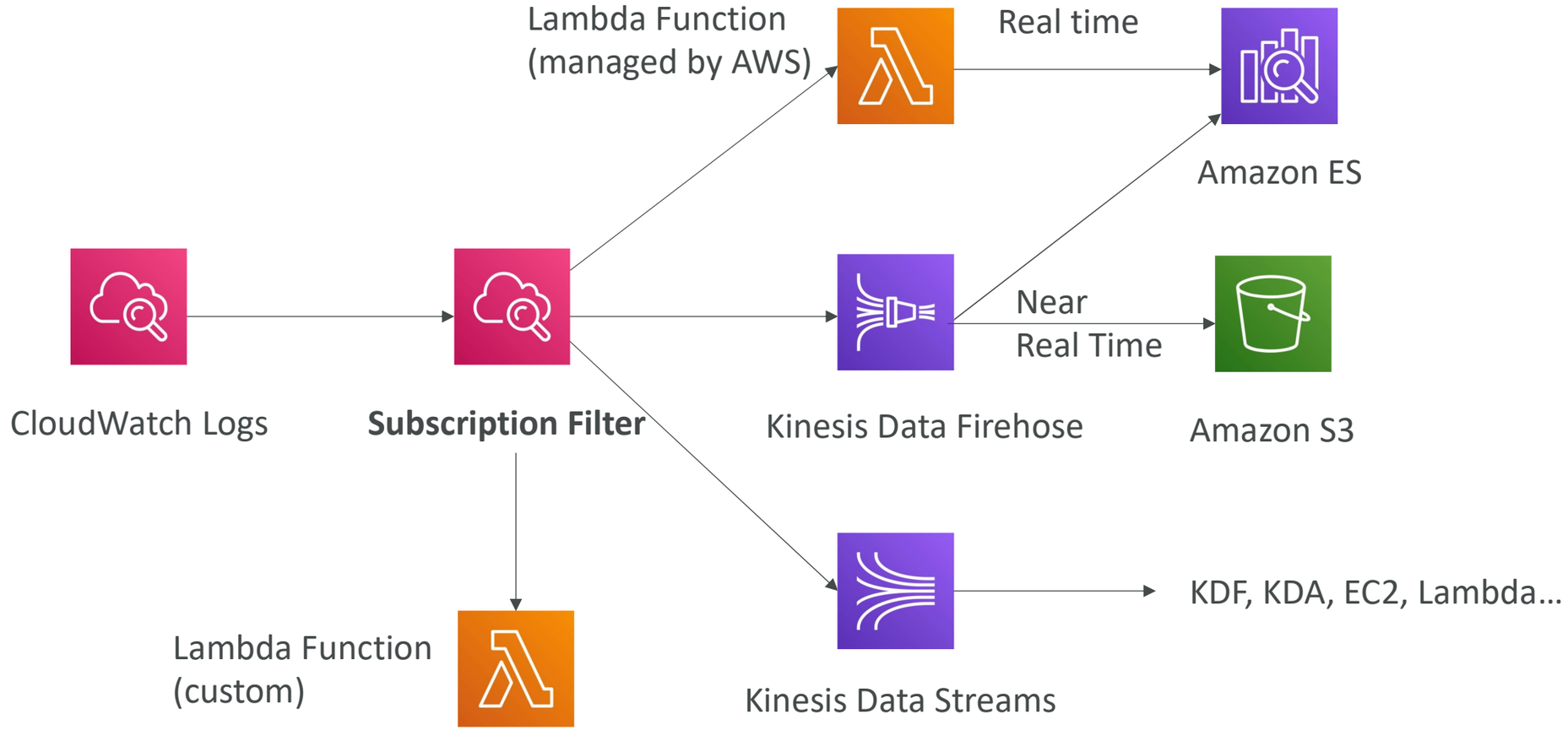


CloudWatch Logs – S3 Export

- Log data can take **up to 12 hours** to become available for export
- The API call is **CreateExportTask**

- Not near-real time or real-time… use Logs Subscriptions instead

CloudWatch Logs Subscriptions

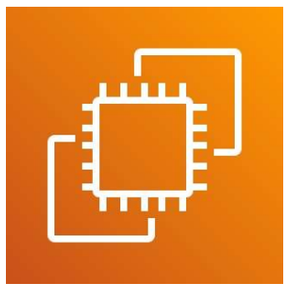


CloudWatch Alarms

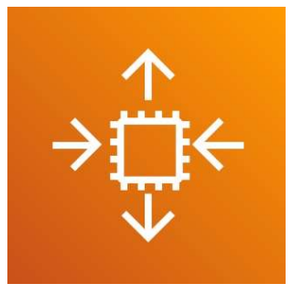
- Alarms are used to trigger notifications for any metric
- Various options (sampling, %, max, min, etc…)
- Alarm States:
  - OK
  - INSUFFICIENT_DATA
  - ALARM
- Period:
  - Length of time in seconds to evaluate the metric
  - High resolution custom metrics: 10 sec, 30 sec or multiples of 60 sec

CloudWatch Alarm Targets

- Stop, Terminate, Reboot, or Recover an EC2 Instance
- Trigger Auto Scaling Action
- Send notification to SNS (from which you can do pretty much anything)



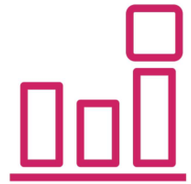
Amazon EC2



EC2 Auto Scaling

Amazon SNS

CloudWatch Events



- Event Pattern: Intercept events from AWS services (Sources)
  - Example sources: EC2 Instance Start, CodeBuild Failure, S3, Trusted Advisor
  - Can intercept any API call with CloudTrail integration
- Schedule or Cron (example: create an event every 4 hours)

- A JSON payload is created from the event and passed to a target…
  - **Compute:** Lambda, Batch, ECS task
  - **Integration:** SQS, SNS, Kinesis Data Streams, Kinesis Data Firehose
  - **Orchestration:** Step Functions, CodePipeline, CodeBuild
  - **Maintenance:** SSM, EC2 Actions

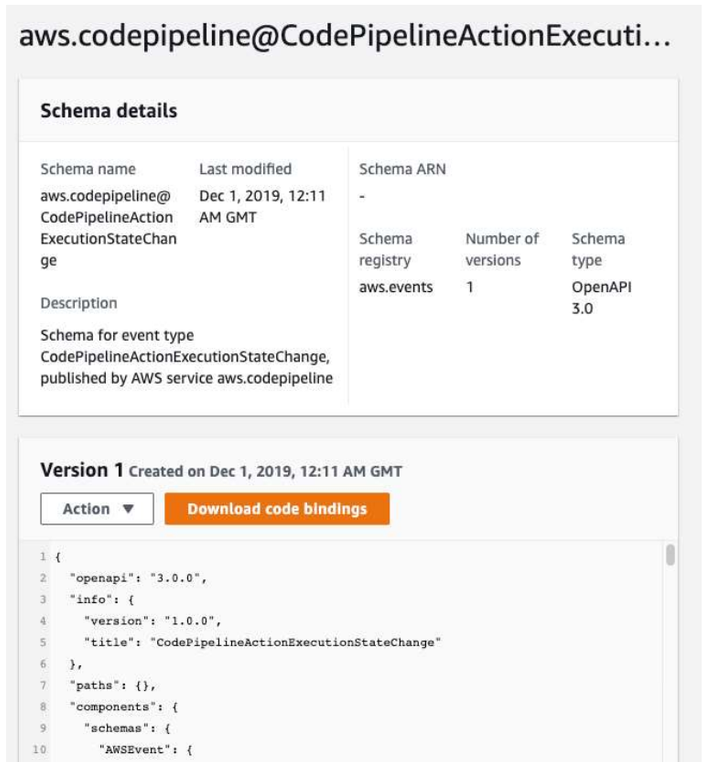
Amazon EventBridge

- EventBridge is the next evolution of CloudWatch Events
- **Default Event Bus** – generated by AWS services (CloudWatch Events)
- **Partner Event Bus** – receive events from SaaS service or applications (Zendesk, DataDog, Segment, Auth0…)
- **Custom Event Buses** – for your own applications
- Event buses can be accessed by other AWS accounts
- You can **archive events** (all/filter) sent to an event bus (indefinitely or set period)
- Ability to **replay archived events**

- **Rules:** how to process the events (like CloudWatch Events)

Amazon EventBridge – Schema Registry

- EventBridge can analyze the events in your bus and infer the **schema**
- The **Schema Registry** allows you to generate code for your application, that will know in advance how data is structured in the event bus
- Schema can be versioned

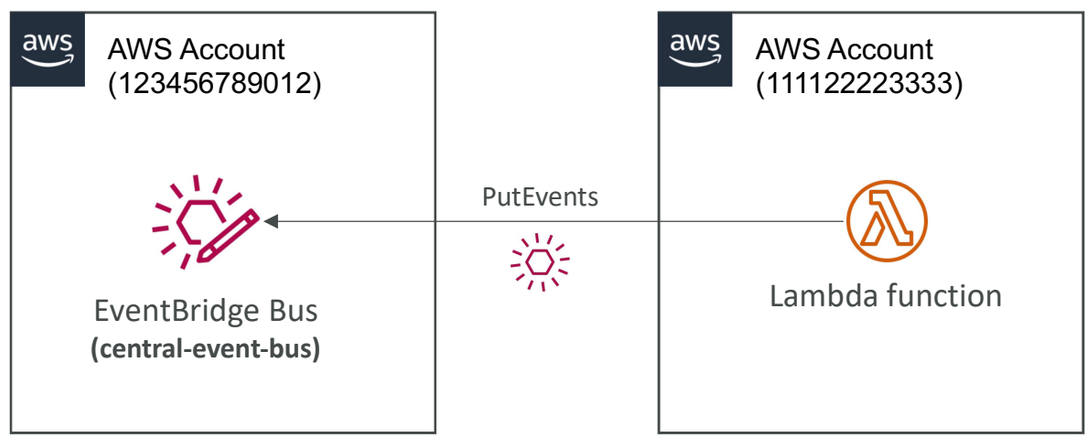


Amazon EventBridge – Resource-based Policy

- Manage permissions for a specific Event Bus
- Example: allow/deny events from another AWS account or AWS region
- Use case: aggregate all events from your AWS Organization in a single AWS account or AWS region

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": "events:PutEvents",
            "Principal": { "AWS": "111122223333" },
            "Resource": "arn:aws:events:us-east-1:123456789012:
event-bus/central-event-bus"
        }
    ]
}
```

Allow **events** from another AWS account



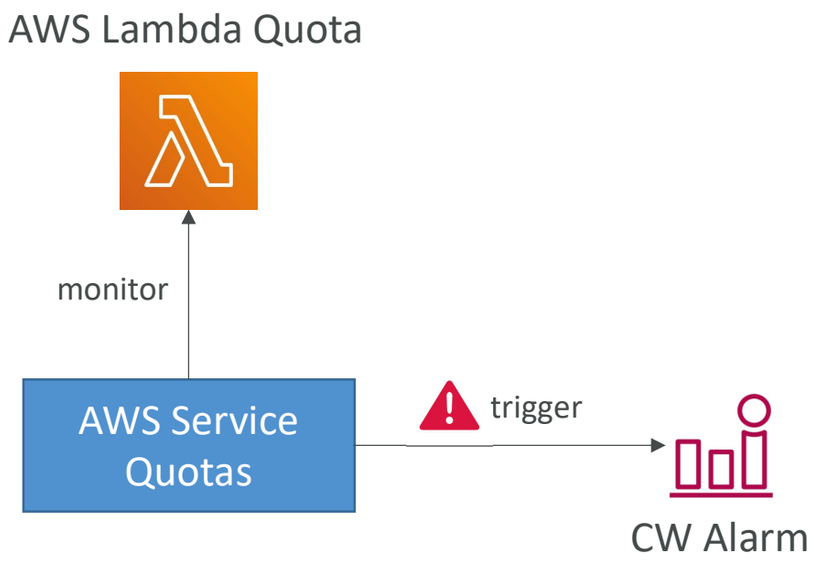
Amazon EventBridge vs CloudWatch Events

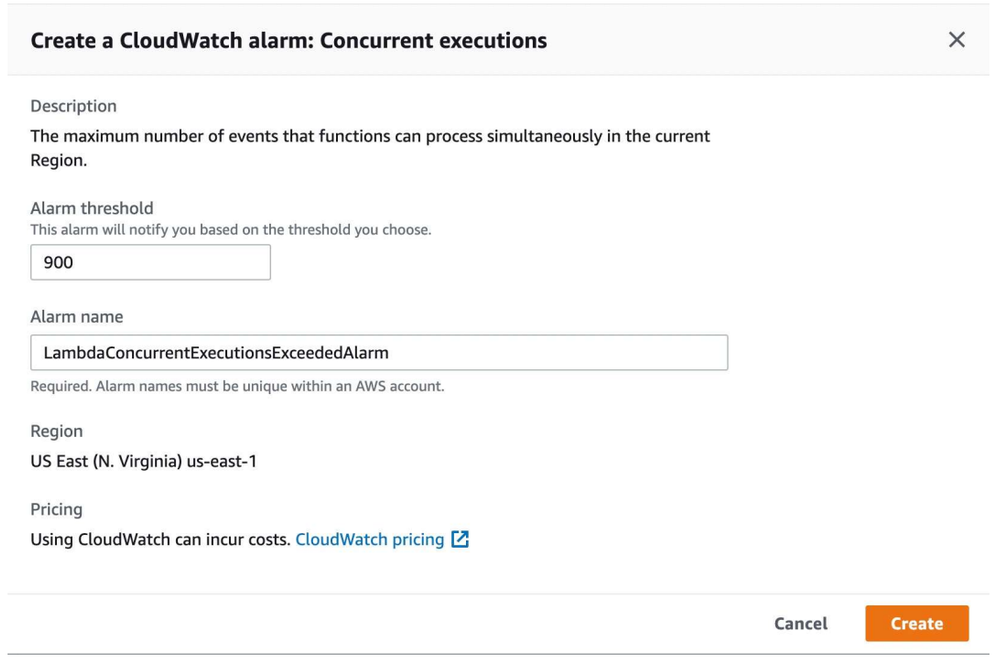
- Amazon EventBridge builds upon and extends CloudWatch Events.
- It uses the same service API and endpoint, and the same underlying service infrastructure.
- EventBridge allows extension to add event buses for your custom applications and your third-party SaaS apps.
- Event Bridge has the Schema Registry capability

- EventBridge has a different name to mark the new capabilities
- Over time, the CloudWatch Events name will be replaced with EventBridge.

Service Quotas CloudWatch Alarms

- Notify you when you're close to a service quota value threshold
- Create CloudWatch Alarms on the Service Quotas console
- Example: Lambda concurrent executions
- Helps you know if you need to request a quota increase or shutdown resources before limit is reached

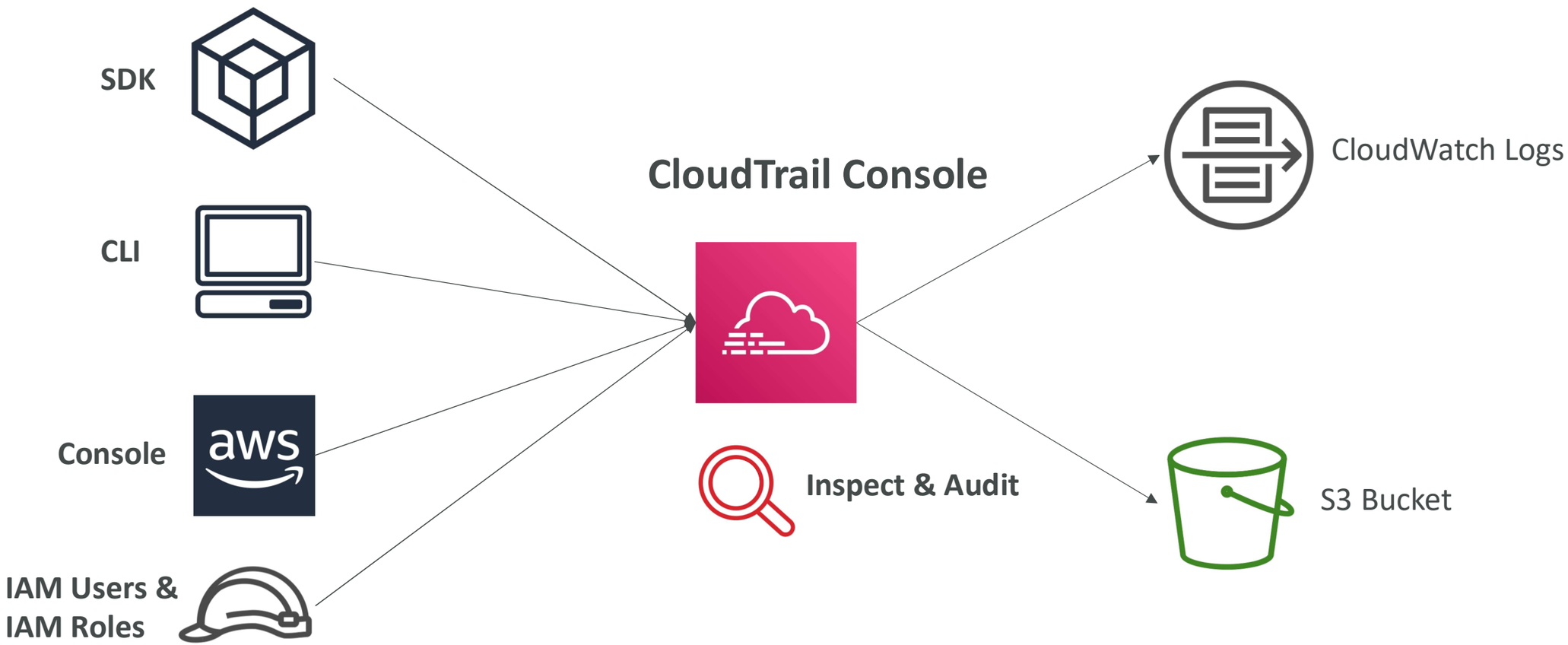




AWS CloudTrail

- Provides governance, compliance and audit for your AWS Account
- CloudTrail is enabled by default!
- Get an history of events / API calls made within your AWS Account by:
  - Console
  - SDK
  - CLI
  - AWS Services
- Can put logs from CloudTrail into CloudWatch Logs or S3
- A trail can be applied to All Regions (default) or a single Region.
- If a resource is deleted in AWS, investigate CloudTrail first!

CloudTrail Diagram



CloudTrail Events

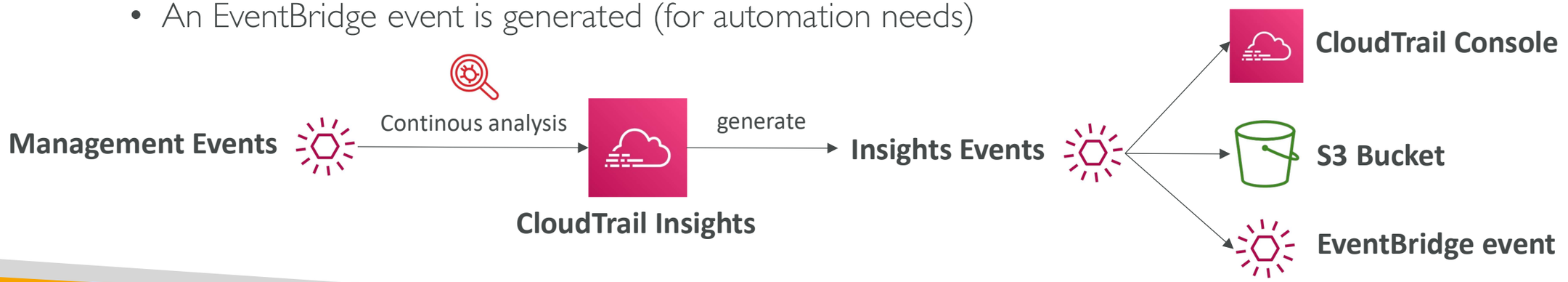
- Management Events:
  - Operations that are performed on resources in your AWS account
  - Examples:
    - Configuring security (IAM `AttachRolePolicy`)
    - Configuring rules for routing data (Amazon EC2 `CreateSubnet`)
    - Setting up logging (AWS CloudTrail `CreateTrail`)
  - **By default, trails are configured to log management events.**
  - Can separate **Read Events** (that don't modify resources) from **Write Events** (that may modify resources)

- Data Events:
  - **By default, data events are not logged (because high volume operations)**
  - Amazon S3 object-level activity (ex: `GetObject`, `DeleteObject`, `PutObject`): can separate Read and Write Events
  - AWS Lambda function execution activity (the `Invoke` API)

- CloudTrail Insights Events:
  - See next slide ☺

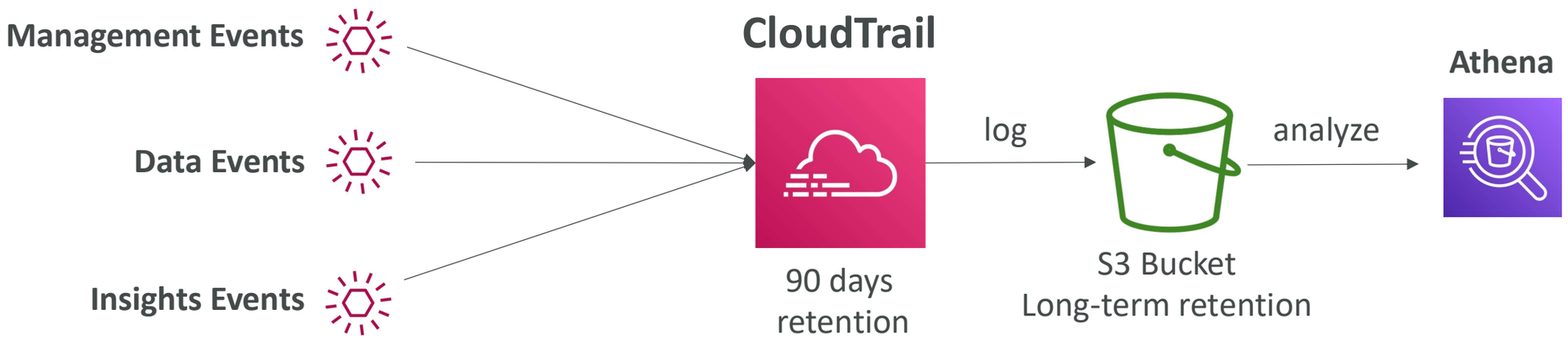
CloudTrail Insights

- Enable **CloudTrail Insights to detect unusual activity** in your account:
  - inaccurate resource provisioning
  - hitting service limits
  - Bursts of AWS IAM actions
  - Gaps in periodic maintenance activity
- CloudTrail Insights analyzes normal management events to create a baseline
- And then **continuously analyzes write events to detect unusual patterns**
  - Anomalies appear in the CloudTrail console
  - Event is sent to Amazon S3
  - An EventBridge event is generated (for automation needs)

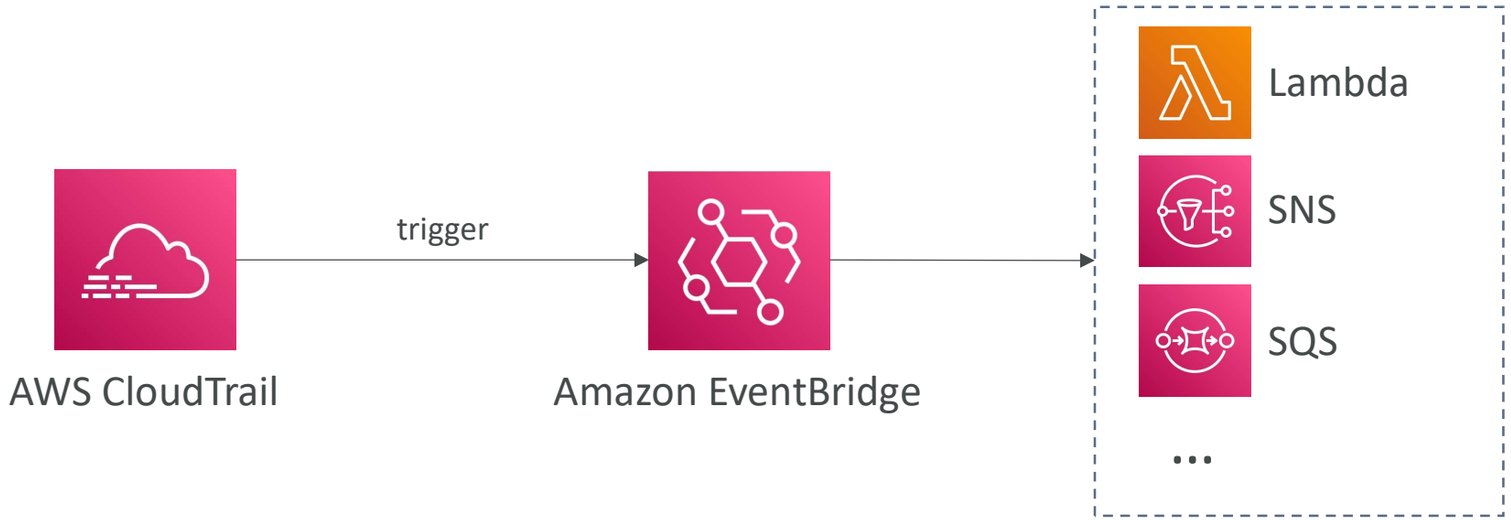


CloudTrail Events Retention

- Events are stored for 90 days in CloudTrail
- To keep events beyond this period, log them to S3 and use Athena

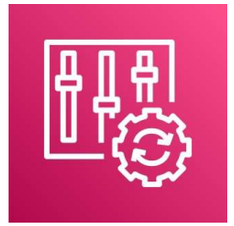


CloudTrail – Integration with EventBridge



- Used to react to any API call being made in your account
- CloudTrail is not "real-time":
  - Delivers an event within 15 minutes of an API call
  - Delivers log files to an S3 bucket every 5 minutes

AWS Config



- Helps with auditing and recording **compliance** of your AWS resources
- Helps record configurations and changes over time
- Questions that can be solved by AWS Config:
  - Is there unrestricted SSH access to my security groups?
  - Do my buckets have any public access?
  - How has my ALB configuration changed over time?
- You can receive alerts (SNS notifications) for any changes
- AWS Config is a per-region service
- Can be aggregated across regions and accounts
- Possibility of storing the configuration data into S3 (analyzed by Athena)

Config Rules

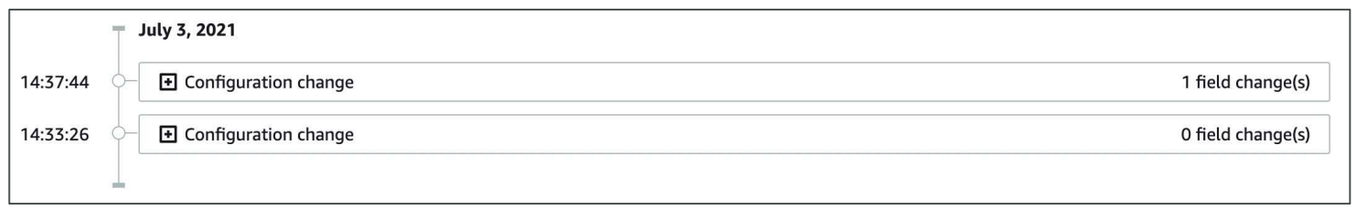
- Can use AWS managed config rules (over 75)
- Can make custom config rules (must be defined in AWS Lambda)
  - Ex: evaluate if each EBS disk is of type gp2
  - Ex: evaluate if each EC2 instance is t2.micro
- Rules can be evaluated / triggered:
  - For each config change
  - And / or: at regular time intervals
- AWS Config Rules does not prevent actions from happening (no deny)

- Pricing: no free tier, $0.003 per configuration item recorded per region, $0.001 per config rule evaluation per region

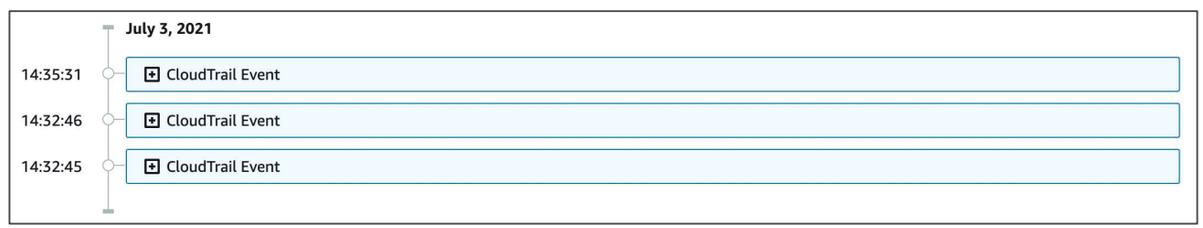
AWS Config Resource

- View compliance of a resource over time

- View configuration of a resource over time

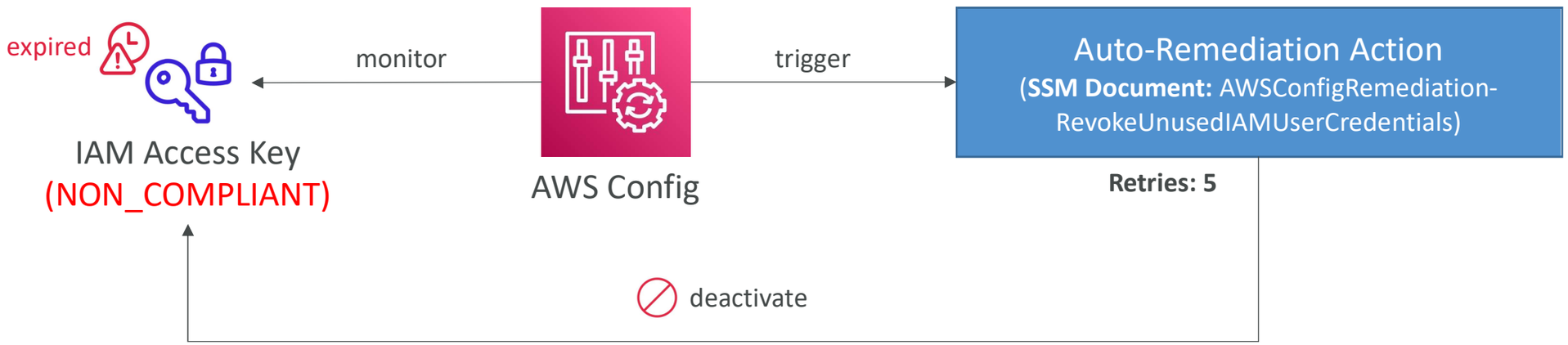


- View CloudTrail API calls of a resource over time



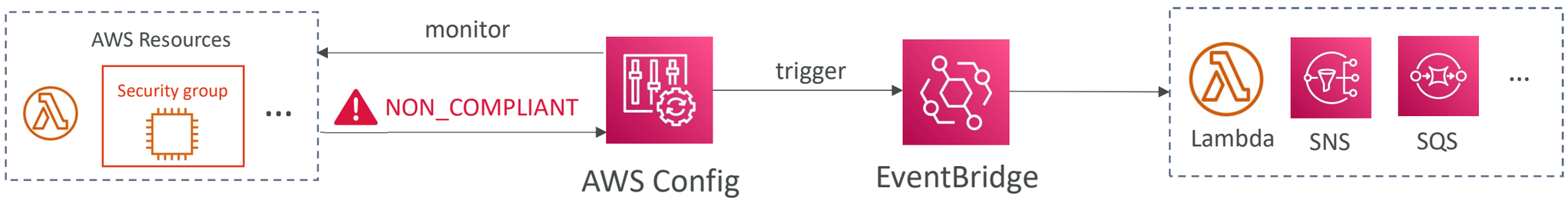
Config Rules – Remediations

- Automate remediation of non-compliant resources using SSM Automation Documents
- Use AWS-Managed Automation Documents or create custom Automation Documents
  - Tip: you can create custom Automation Documents that invokes Lambda function
- You can set **Remediation Retries** if the resource is still non-compliant after auto-remediation

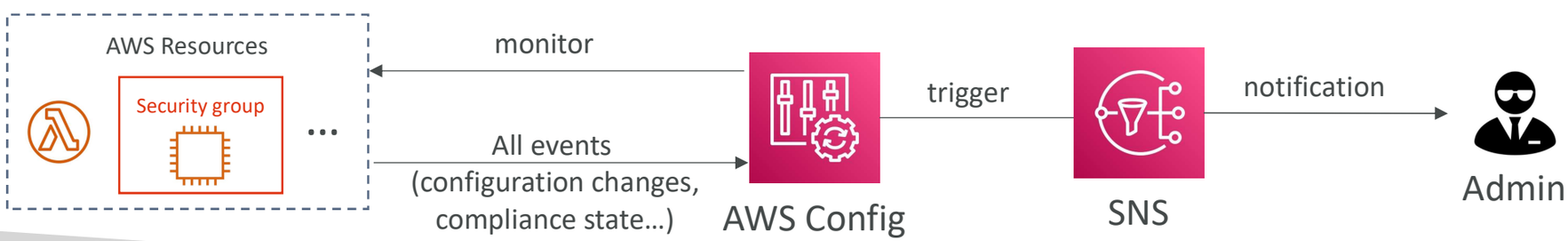


Config Rules – Notifications

- Use EventBridge to trigger notifications when AWS resources are non-compliant



- Ability to send configuration changes and compliance state notifications to SNS (all events – use SNS Filtering or filter at client-side)



CloudWatch vs CloudTrail vs Config

- CloudWatch
  - Performance monitoring (metrics, CPU, network, etc…) & dashboards
  - Events & Alerting
  - Log Aggregation & Analysis
- CloudTrail
  - Record API calls made within your Account by everyone
  - Can define trails for specific resources
  - Global Service
- Config
  - Record configuration changes
  - Evaluate resources against compliance rules
  - Get timeline of changes and compliance

For an Elastic Load Balancer

- CloudWatch:
  - Monitoring Incoming connections metric
  - Visualize error codes as a % over time
  - Make a dashboard to get an idea of your load balancer performance
- Config:
  - Track security group rules for the Load Balancer
  - Track configuration changes for the Load Balancer
  - Ensure an SSL certificate is always assigned to the Load Balancer (compliance)
- CloudTrail:
  - Track who made any changes to the Load Balancer with API calls

AWS Account Management

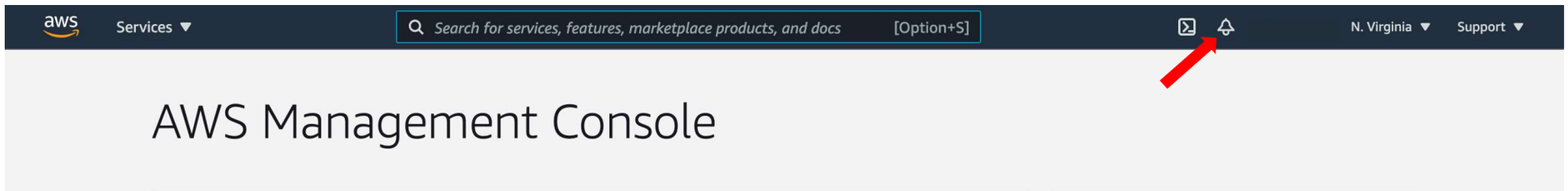
Health Dashboards, AWS Organizations and Billing Console

AWS Status - Service Health Dashboard

- Shows all regions, all services health
- Shows historical information for each day
- Has an RSS feed you can subscribe to

- https://status.aws.amazon.com/

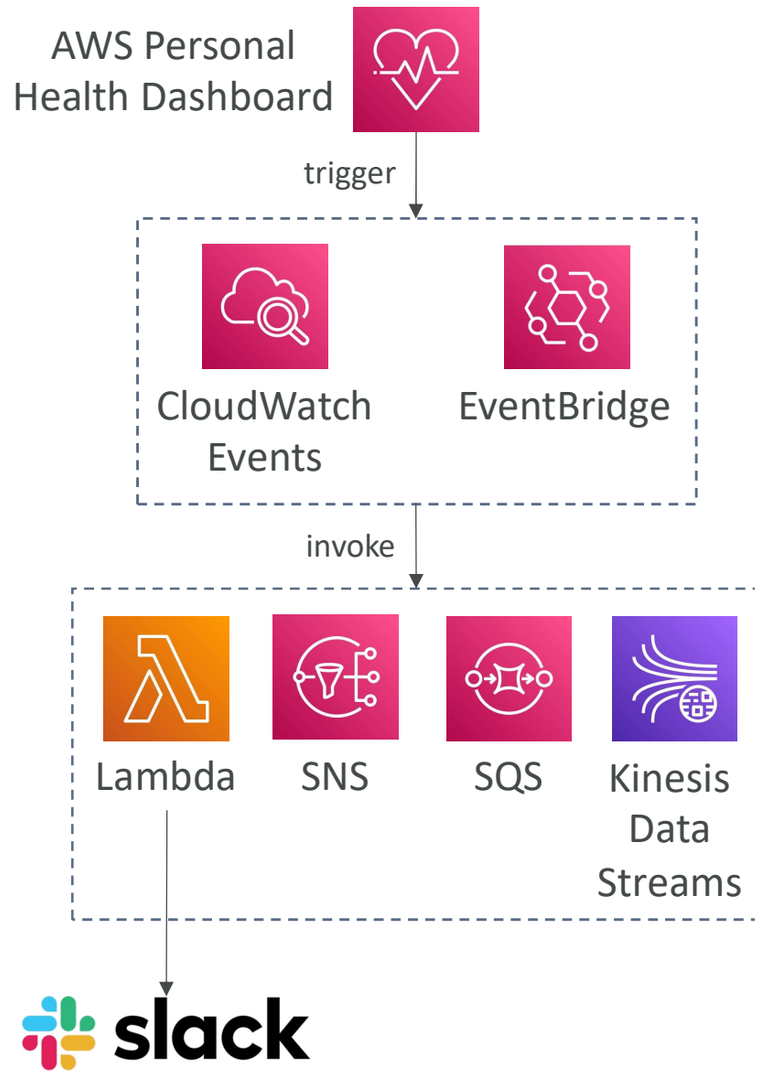
AWS Personal Health Dashboard



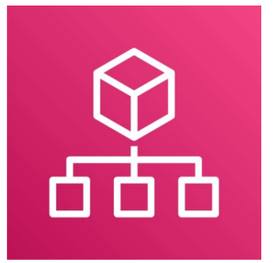
- Global service
- Show how AWS outages directly impact you
- Show the impact on your resources
- List issues and actions you can do to remediate them
- Will show **maintenance** events from AWS
- Programmatically accessible through the **AWS Health API**
- Aggregations across multiple accounts of an **AWS Organization**
- https://phd.aws.amazon.com/

Health Event Notifications

- Use EventBridge (CloudWatch Events) to react to changes for AWS Health events in your AWS account
- Example: receive email notifications when EC2 instances in your AWS account are scheduled for updates
- Can't be used to return public events from the Service Health Dashboard
- Use cases: send notifications, capture event information, take corrective action, …

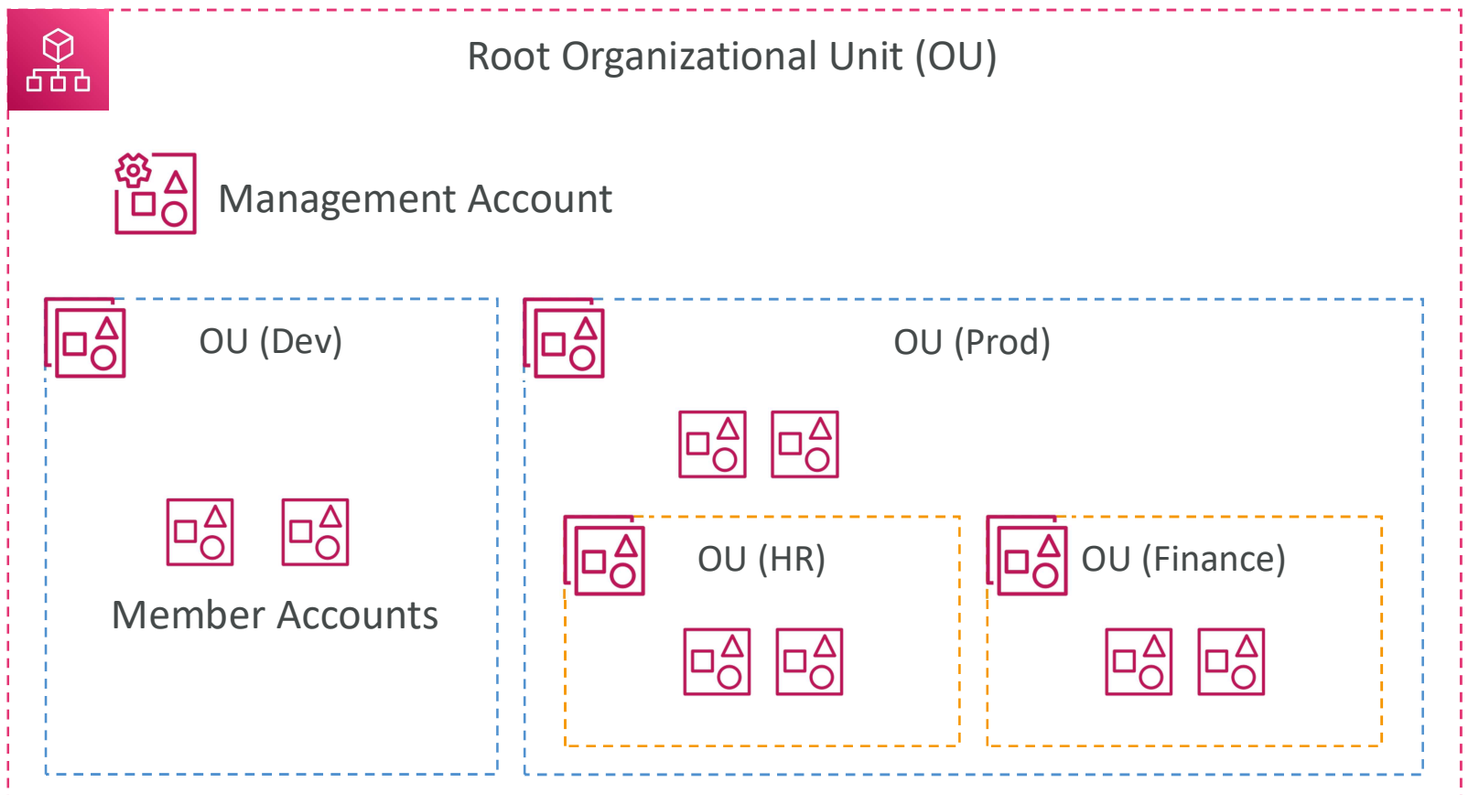


AWS Organizations



- Global service
- Allows to manage multiple AWS accounts
- The main account is the management account
- Other accounts are member accounts
- Member accounts can only be part of one organization
- Consolidated Billing across all accounts - single payment method
- Pricing benefits from aggregated usage (volume discount for EC2, S3…)
- **Shared reserved instances and Savings Plans discounts across accounts**
- API is available to automate AWS account creation

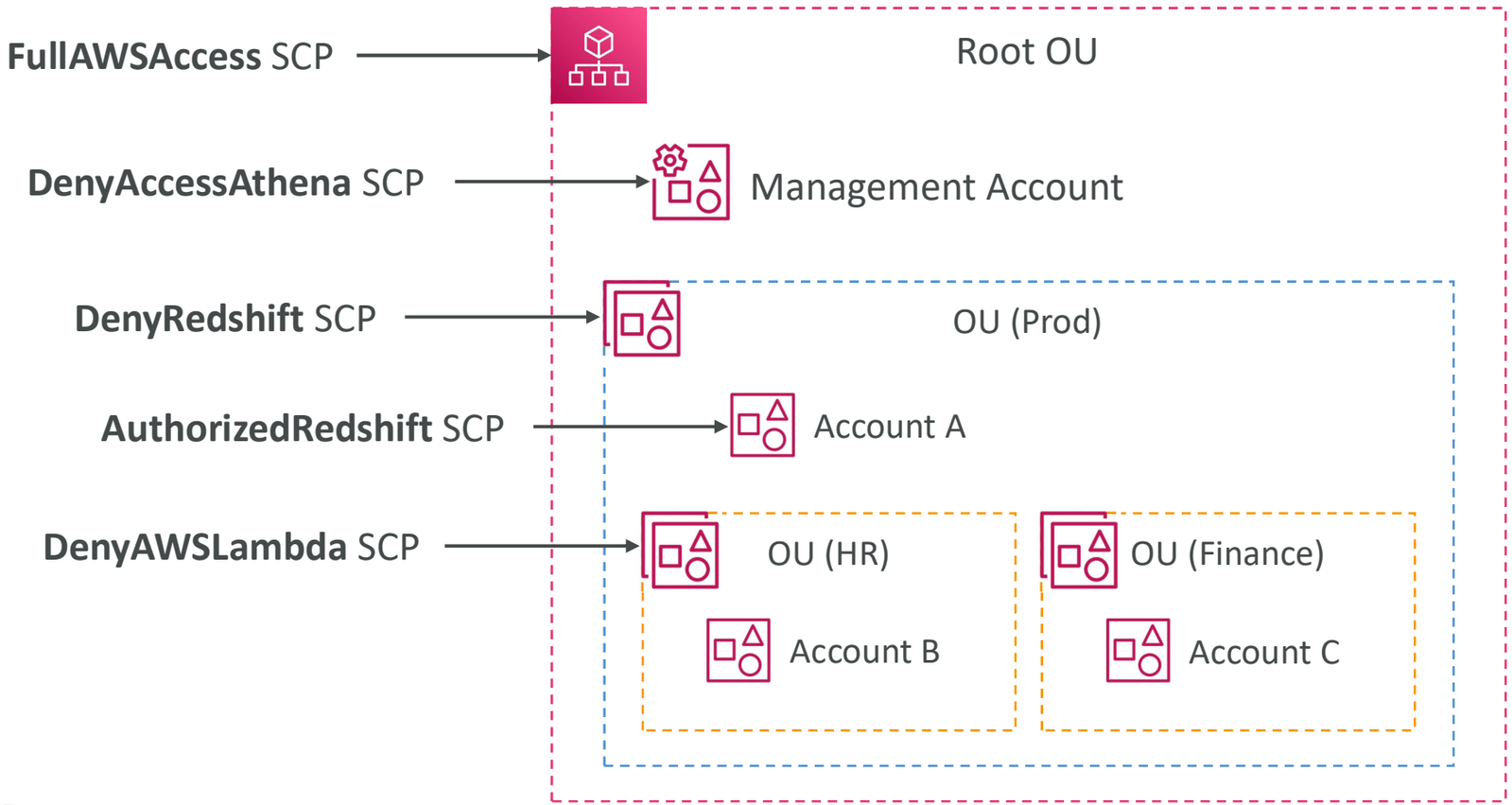
AWS Organizations



AWS Organizations

- Advantages
  - Multi Account vs One Account Multi VPC
  - Use tagging standards for billing purposes
  - Enable CloudTrail on all accounts, send logs to central S3 account
  - Send CloudWatch Logs to central logging account
  - Establish Cross Account Roles for Admin purposes
- Security: Service Control Policies (SCP)
  - IAM policies applied to OU or Accounts to restrict Users and Roles
  - They do not apply to the management account (full admin power)
  - Must have an explicit allow (does not allow anything by default – like IAM)

SCP Hierarchy



- Management Account
  - Can do anything
  - (no SCP apply)
- Account A
  - Can do anything
  - EXCEPT access Redshift (explicit Deny from OU)
- Account B
  - Can do anything
  - EXCEPT access Redshift (explicit Deny from Prod OU)
  - EXCEPT access Lambda (explicit Deny from HR OU)
- Account C
  - Can do anything
  - EXCEPT access Redshift (explicit Deny from Prod OU)

SCP Examples
Blocklist and Allowlist strategies

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "AllowsAllActions",
            "Effect": "Allow",
            "Action": "*",
            "Resource": "*"
        },
        {
            "Sid": "DenyDynamoDB",
            "Effect": "Deny",
            "Action": "dynamodb:*",
            "Resource": "*"
        }
    ]
}
```

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

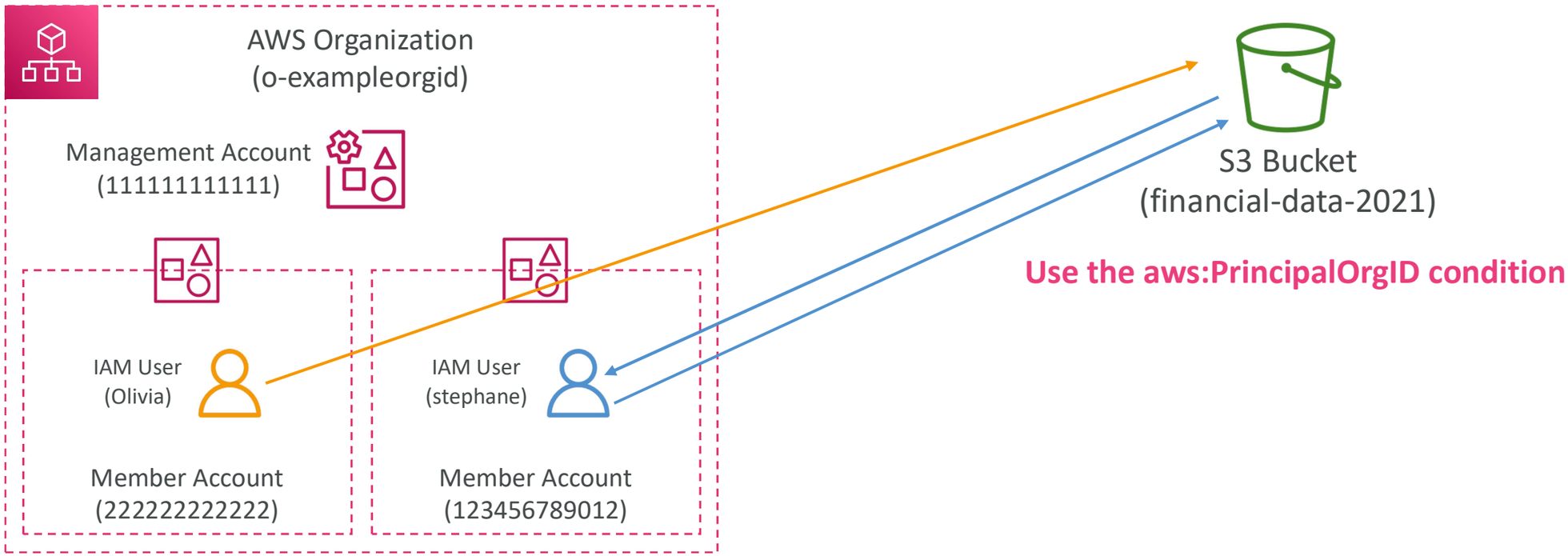
More examples: https://docs.aws.amazon.com/organizations/latest/userguide/orgs_manage_policies_example-scps.html

AWS Organizations – Reserved Instances

- For billing purposes, the consolidated billing feature of AWS Organizations treats all the accounts in the organization as one account.
- This means that **all accounts** in the organization can receive the hourly cost benefit of Reserved Instances that are purchased **by any other account.**
- **The payer account (master account) of an organization** can turn off Reserved Instance (RI) discount and Savings Plans discount sharing for any accounts in that organization, including the payer account
- This means that RIs and Savings Plans discounts aren't shared between any accounts that have sharing turned off.
- To share an RI or Savings Plans discount with an account, both accounts must have sharing turned on.

AWS Organizations – IAM Policies

- Use **aws:PrincipalOrgID** condition key in your resource-based policies to restrict access to IAM principals from accounts in an AWS Organization



AWS Organizations – Tag Policies

- Helps you standardize tags across resources in an AWS Organization
- Ensure consistent tags, audit tagged resources, maintain proper resources categorization, …
- You define tag keys and their allowed values
- Helps with AWS Cost Allocation Tags and Attribute-based Access Control
- Prevent any non-compliant tagging operations on specified services and resources (has no effect on resources without tags)
- Generate a report that lists all tagged/non-compliant resources
- Use CloudWatch Events to monitor non-compliant tags

```
{
    "tags": {
        "costcenter": {
            "tag_key": {
                "@@assign": "CostCenter"
            },
            "tag_value": {
                "@@assign": ["100", "200"]
            },
            "enforced_for": {
                "@@assign": ["secretsmanager:*"]
            }
        }
    }
}
```

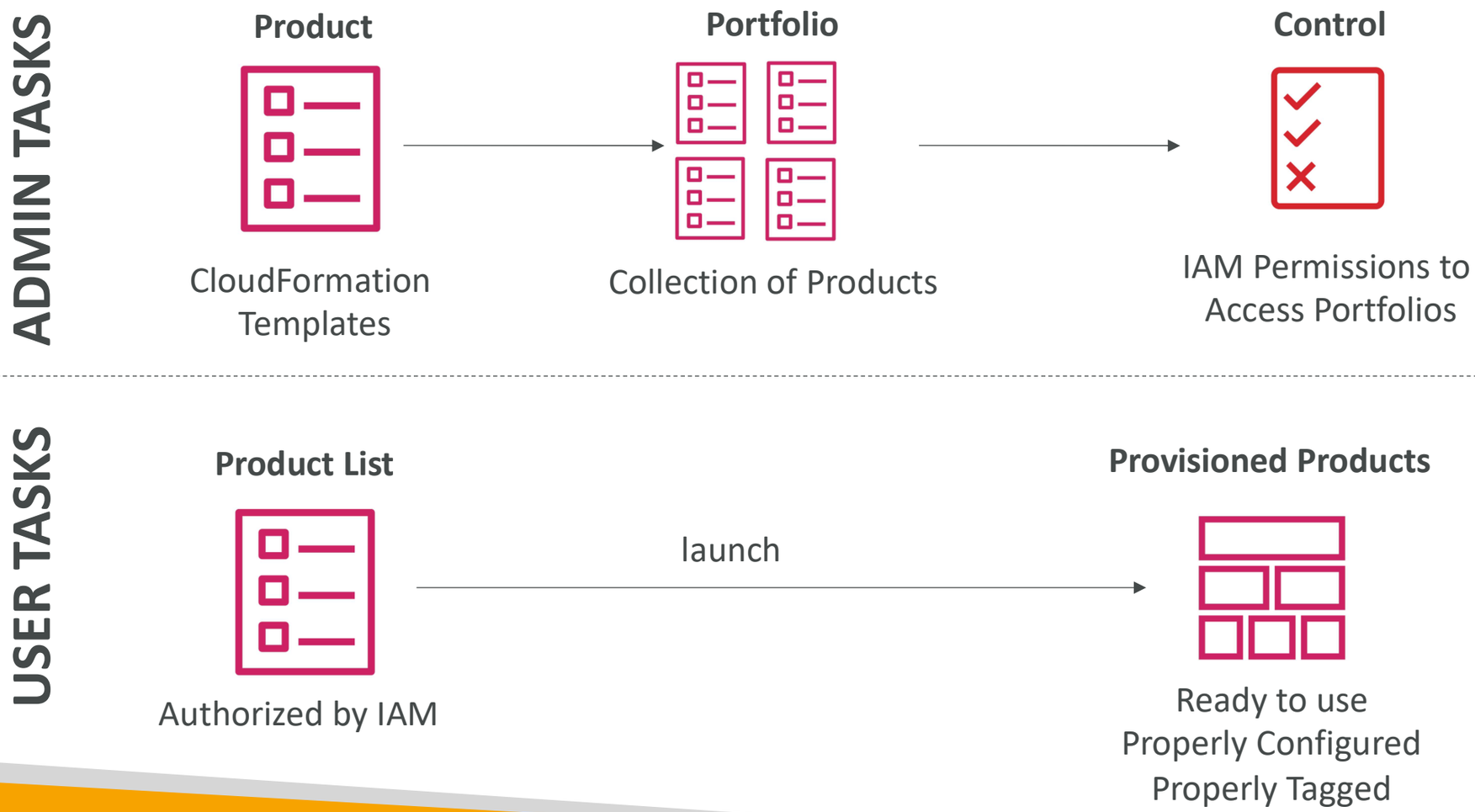
AWS Control Tower

- Easy way to **set up and govern a secure and compliant multi-account AWS environment** based on best practices
- Benefits:
  - Automate the set up of your environment in a few clicks
  - Automate ongoing policy management using guardrails
  - Detect policy violations and remediate them
  - Monitor compliance through an interactive dashboard
- AWS Control Tower runs on top of AWS Organizations:
  - It automatically sets up AWS Organizations to organize accounts and implement SCPs (Service Control Policies)

AWS Service Catalog

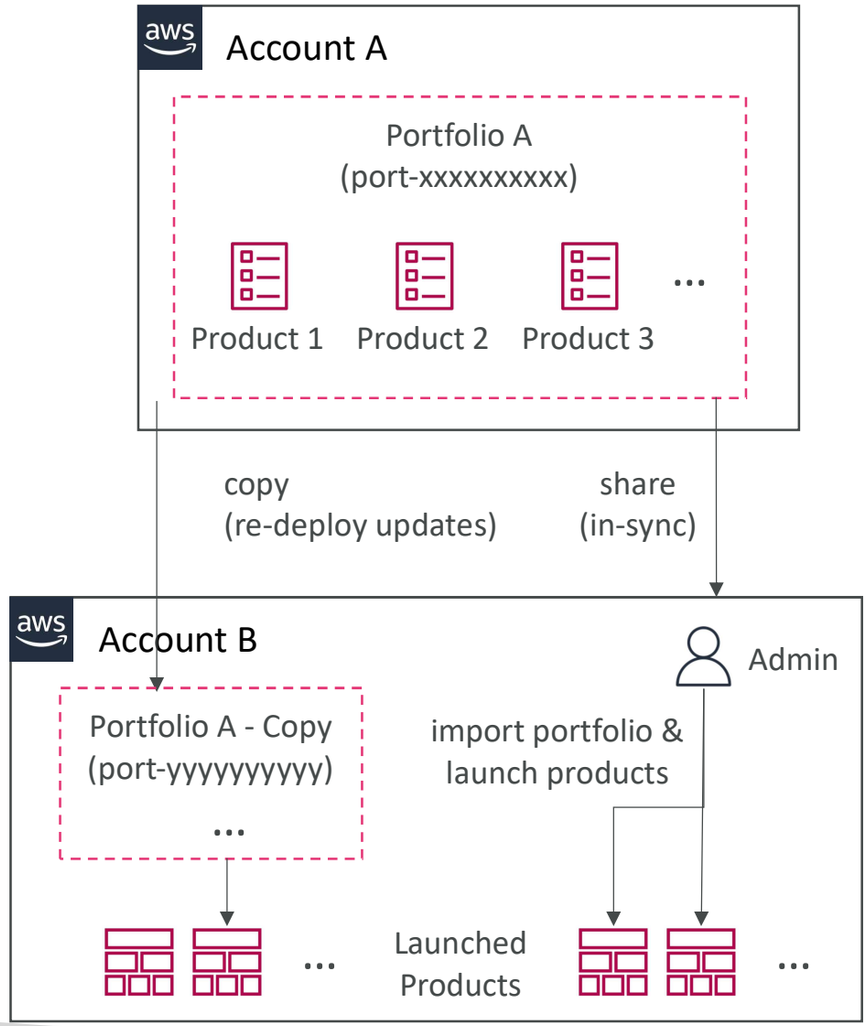
- Users that are new to AWS have too many options, and may create stacks that are not compliant / in line with the rest of the organization
- Some users just want a quick **self-service portal** to launch a set of **authorized products** pre-defined **by admins**
- Includes: virtual machines, databases, storage options, etc…
- Enter AWS Service Catalog!

Service Catalog diagram



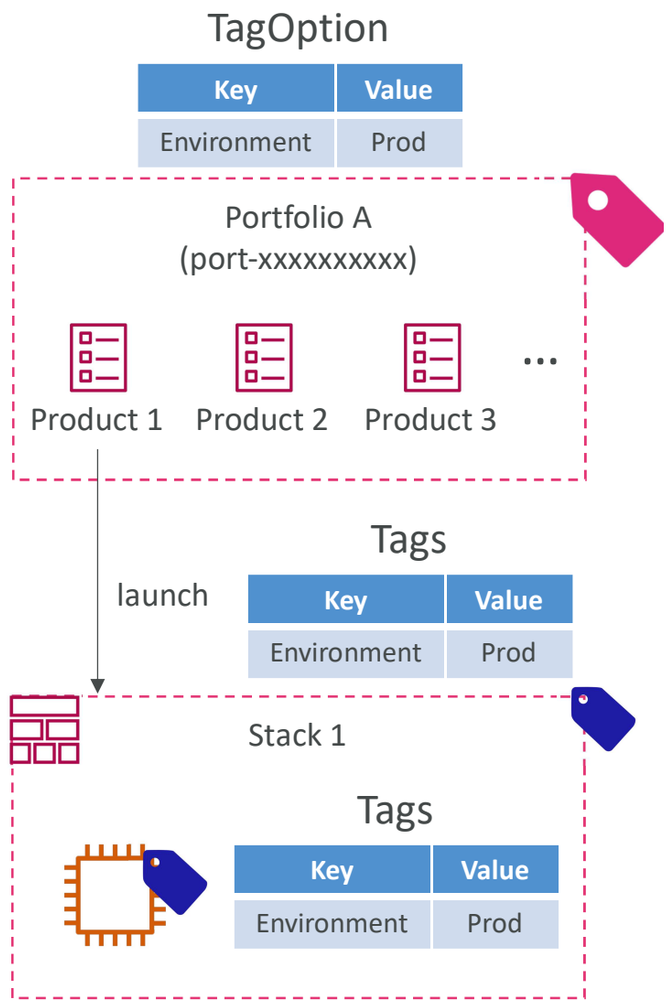
AWS Service Catalog – Sharing Catalogs

- Share portfolios with individual AWS accounts or AWS Organizations
- Sharing options:
  - Share a reference of the portfolio, then import the shared portfolio in the recipient account (stays in-sync with the original portfolio)
  - Deploy a copy of the portfolio into the recipient account (must re-deploy any updates)
- Ability to add products from the imported portfolio to the local portfolio



AWS Service Catalog – TagOptions Library

- Easily manage tags on provisioned products
- TagOption:
  - Key-value pair managed in AWS Service Catalog
  - Used to create an AWS Tag
- Can be associated with Portfolios and Products
- Use cases: proper resources tagging, defined allowed tags, …
- Can be shared with other AWS accounts and AWS Organizations



AWS Billing Alarms

- **Billing data metric is stored in CloudWatch us-east-1**
- Billing data are for overall **worldwide** AWS costs
- It's for actual cost, not for project costs

- Let's create a billing alarm together!

Cost Explorer

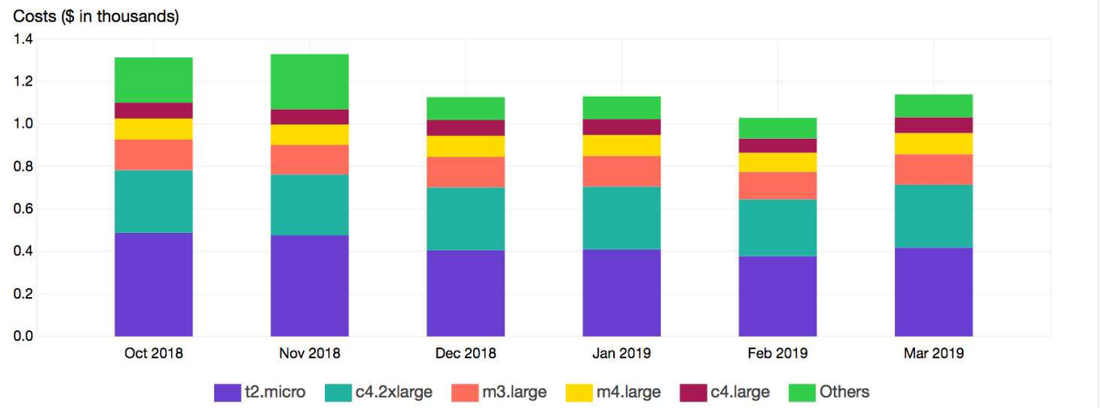
- Visualize, understand, and manage your AWS costs and usage over time
- Create custom reports that analyze cost and usage data.
- Analyze your data at a high level: total costs and usage across all accounts
- Or Monthly, hourly, resource level granularity
- Choose an optimal **Savings Plan** (to lower prices on your bill)
- **Forecast usage up to 12 months based on previous usage**

Cost Explorer – Monthly Cost by AWS Service

Monthly costs by service

Last 6 Months | Monthly | Stack

Group by: Instance Type | Service | Linked Account | Region | Usage Type | Tag | API Operation | Availability Zone | More



Download CSV

Instance Type	Oct 1, 2018	Nov 1, 2018	Dec 1, 2018	Jan 1, 2019
Total cost ($)	1,312.71	1,328.54	1,125.99	1,129.65
t2.micro ($)	486.75	475.89	405.63	409.27
c4.2xlarge ($)	296.11	286.56	296.11	296.11

FILTERS CLEAR ALL

Service: Include only — EC2-Instances (1)

Linked Account: Include all

Region: Include all

Instance Type: Include all

Usage Type: Include all

Usage Type Group: Include all

Tag: Include All

API Operation: Include all

Charge Type: Include all

More filters

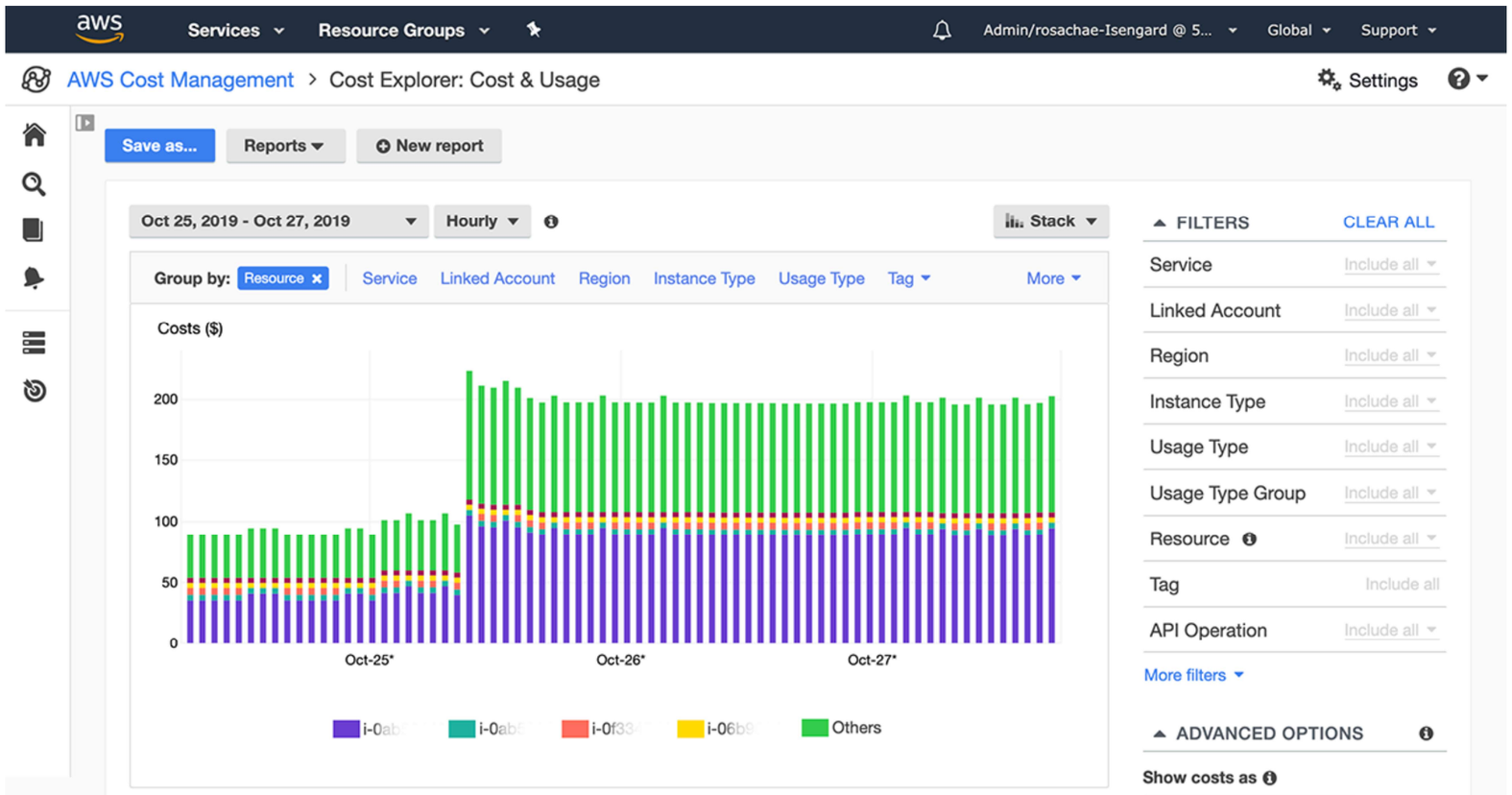
ADVANCED OPTIONS

Show costs as: Unblended costs

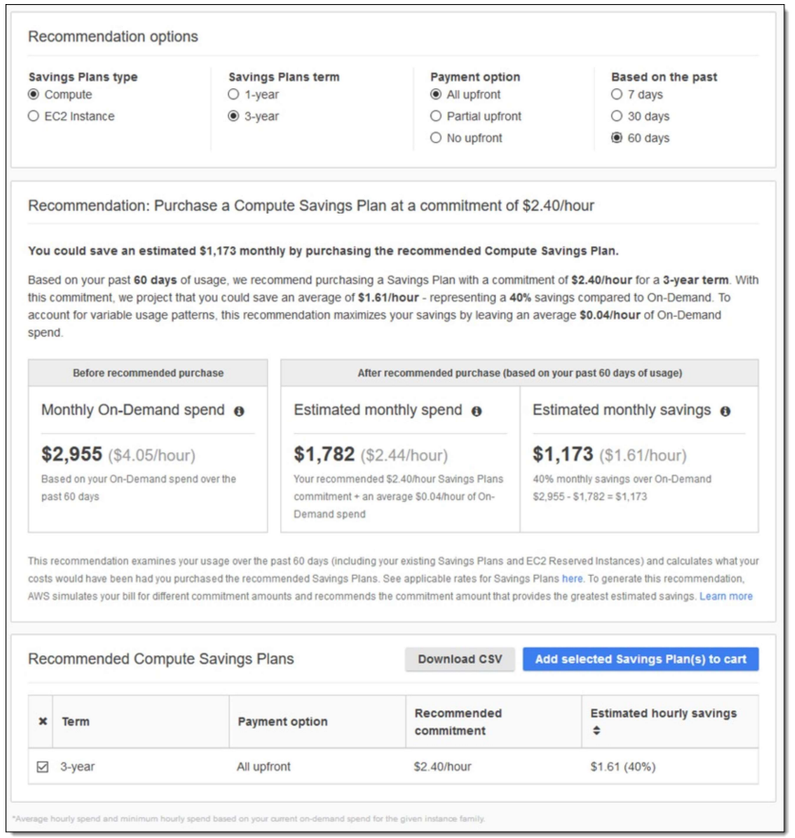
Include costs related to

Show only untagged resources

Cost Explorer– Hourly & Resource Level



Cost Explorer – Savings Plan Alternative to Reserved Instances



Recommendation options

Savings Plans type
- (•) Compute
- ( ) EC2 Instance

Savings Plans term
- ( ) 1-year
- (•) 3-year

Payment option
- (•) All upfront
- ( ) Partial upfront
- ( ) No upfront

Based on the past
- ( ) 7 days
- ( ) 30 days
- (•) 60 days

Recommendation: Purchase a Compute Savings Plan at a commitment of $2.40/hour

You could save an estimated $1,173 monthly by purchasing the recommended Compute Savings Plan.

Based on your past **60 days** of usage, we recommend purchasing a Savings Plan with a commitment of **$2.40/hour** for a **3-year term**. With this commitment, we project that you could save an average of **$1.61/hour** - representing a **40%** savings compared to On-Demand. To account for variable usage patterns, this recommendation maximizes your savings by leaving an average **$0.04/hour** of On-Demand spend.

Before recommended purchase	After recommended purchase (based on your past 60 days of usage)	
Monthly On-Demand spend	Estimated monthly spend	Estimated monthly savings
$2,955 ($4.05/hour)	**$1,782** ($2.44/hour)	**$1,173** ($1.61/hour)
Based on your On-Demand spend over the past 60 days	Your recommended $2.40/hour Savings Plans commitment + an average $0.04/hour of On-Demand spend	40% monthly savings over On-Demand $2,955 - $1,782 = $1,173

This recommendation examines your usage over the past 60 days (including your existing Savings Plans and EC2 Reserved Instances) and calculates what your costs would have been had you purchased the recommended Savings Plans. See applicable rates for Savings Plans here. To generate this recommendation, AWS simulates your bill for different commitment amounts and recommends the commitment amount that provides the greatest estimated savings. Learn more

Recommended Compute Savings Plans — Download CSV — Add selected Savings Plan(s) to cart

✖	Term	Payment option	Recommended commitment	Estimated hourly savings
☑	3-year	All upfront	$2.40/hour	$1.61 (40%)

*Average hourly spend and minimum hourly spend based on your current on-demand spend for the given instance family.

Cost Explorer – Forecast Usage

AWS Budgets

- Create budget and **send alarms when costs exceeds the budget**
- 4 types of budgets: Usage, Cost, Reservation, Savings Plans
- For Reserved Instances (RI)
  - Track utilization
  - Supports EC2, ElastiCache, RDS, Redshift
- Up to 5 SNS notifications per budget
- Can filter by: Service, Linked Account, Tag, Purchase Option, Instance Type, Region, Availability Zone, API Operation, etc…
- Same options as AWS Cost Explorer!
- 2 budgets are free, then $0.02/day/budget

Cost Allocation Tags

- Use **cost allocation tags** to track your AWS costs on a detailed level
- **AWS generated tags**
  - Automatically applied to the resource you create
  - Starts with Prefix **aws:** **(e.g. aws: createdBy)**
- **User-defined tags**
  - Defined by the user
  - Starts with Prefix **user:**

Total Cost	user:Owner	user:Stack	user:Cost Center	user:Application
0.95	DbAdmin	Test	80432	Widget2
0.01	DbAdmin	Test	80432	Widget2
3.84	DbAdmin	Prod	80432	Widget2
6.00	DbAdmin	Test	78925	Widget1
234.63	SysEng	Prod	78925	Widget1
0.73	DbAdmin	Test	78925	Widget1
0.00	DbAdmin	Prod	80432	Portal
2.47	DbAdmin	Prod	78925	Portal

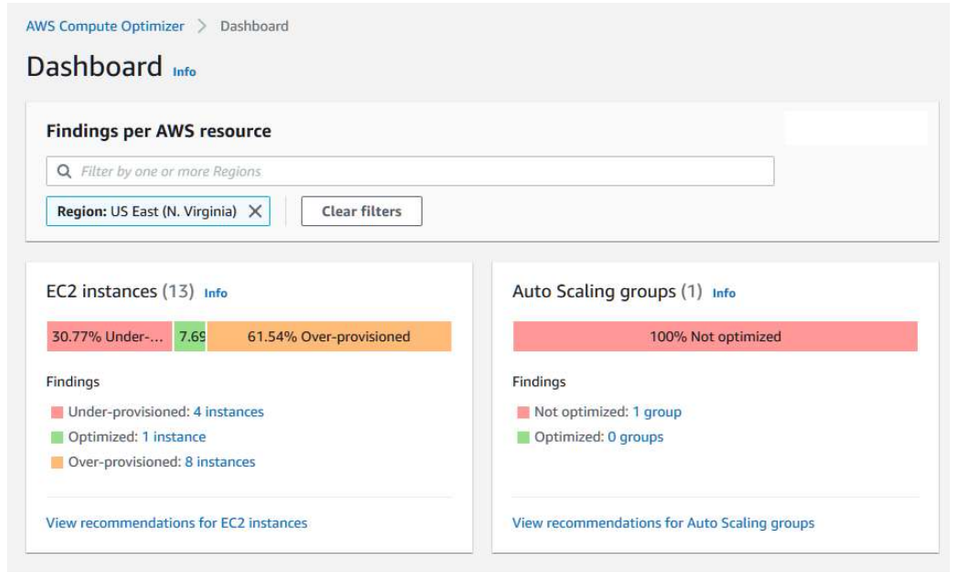
Cost and Usage Reports

- Dive deeper into your AWS costs and usage
- The AWS Cost & Usage Report contains **the most comprehensive set of AWS cost and usage data available**
- Includes additional metadata about AWS services, pricing, and reservations **(e.g., Amazon EC2 Reserved Instances (RIs))**

- The AWS Cost & Usage Report lists AWS usage for each:
  - service category used by an account
  - in hourly or daily line items
  - any tags that you have activated for cost allocation purposes
- Can be configured for daily exports to S3
- Can be integrated with Athena, Redshift or QuickSight

AWS Compute Optimizer

- **Reduce costs** and **improve performance by** recommending optimal AWS resources for your workloads
- Helps you choose optimal configurations and right-size your workloads (over/under provisioned)
- Uses Machine Learning to analyze your **resources' configurations** and their **utilization CloudWatch metrics**
- Supported resources
  - EC2 instances
  - EC2 Auto Scaling Groups
  - EBS volumes
  - Lambda functions
- Lower your costs by up to 25%
- Recommendations can be exported to S3



Cost and Usage Reports

	M	N	O	P	R	S	T
1	lineItem/ProductCode	lineItem/UsageType	lineItem/Operation	lineItem/AvailabilityZone	lineItem/UsageAmount	lineItem/CurrencyCode	lineItem/LineItemDescription
2	AmazonEC2	CW:AlarmMonitorUsage	Unknown		0.00134409	USD	$0.00 per alarm-month - first 10 alarms
3	AmazonS3	Requests-Tier1	ListAllMyBuckets		2	USD	$0.00 per request - PUT, COPY, POST, or LIST requests under the monthly global free tier
4	AmazonEC2	CW:AlarmMonitorUsage	Unknown		0.00134409	USD	$0.00 per alarm-month - first 10 alarms
5	AmazonEC2	APS2-EBS:VolumeUsage.gp2	CreateVolume-Gp2		0.01344086	USD	$0.00 per GB-month of General Purpose (SSD) provisioned storage under monthly free tier
6	AmazonEC2	APS2-EBS:VolumeUsage.gp2	CreateVolume-Gp2		0.01344086	USD	$0.00 per GB-month of General Purpose (SSD) provisioned storage under monthly free tier
7	AmazonEC2	USW2-BoxUsage:t2.micro	RunInstances:0002	us-west-2a	1	USD	$0.00 per Windows t2.micro instance-hour (or partial hour) under monthly free tier
8	AmazonEC2	USW2-USE1-AWS-Out-Bytes	PublicIP-Out		0.00000174	USD	$0.000 per GB - data transfer out under the monthly global free tier
9	AmazonEC2	USW2-USE1-AWS-In-Bytes	PublicIP-In		0.00000138	USD	$0.00 per GB - US West (Oregon) data transfer from US East (Northern Virginia)
10	AmazonEC2	USW2-USW1-AWS-In-Bytes	PublicIP-In		0.00000149	USD	$0.00 per GB - US West (Oregon) data transfer from US West (Northern California)
11	AmazonS3	Requests-Tier1	ListAllMyBuckets		2	USD	$0.00 per request - PUT, COPY, POST, or LIST requests under the monthly global free tier
12	AmazonEC2	USW2-DataTransfer-Out-Bytes	RunInstances		0.00038144	USD	$0.000 per GB - data transfer out under the monthly global free tier
13	AmazonEC2	USW2-USW1-AWS-Out-Bytes	PublicIP-Out		0.00000174	USD	$0.000 per GB - data transfer out under the monthly global free tier
14	AmazonEC2	USW2-DataTransfer-In-Bytes	RunInstances		0.00030951	USD	$0.000 per GB - data transfer in per month
15	AmazonEC2	USW2-BoxUsage:t2.micro	RunInstances:0002	us-west-2a	1	USD	$0.00 per Windows t2.micro instance-hour (or partial hour) under monthly free tier
16	AmazonEC2	USW2-USW1-AWS-Out-Bytes	PublicIP-Out		0.00000349	USD	$0.000 per GB - data transfer out under the monthly global free tier
17	AmazonEC2	USW2-USW1-AWS-In-Bytes	PublicIP-In		0.00000276	USD	$0.00 per GB - US West (Oregon) data transfer from US West (Northern California)
18	AmazonEC2	APS2-EBS:VolumeUsage.gp2	CreateVolume-Gp2		0.01344086	USD	$0.00 per GB-month of General Purpose (SSD) provisioned storage under monthly free tier
19	AmazonEC2	CW:AlarmMonitorUsage	Unknown		0.00134409	USD	$0.00 per alarm-month - first 10 alarms
20	AmazonEC2	USW2-BoxUsage:t2.micro	RunInstances:0002	us-west-2a	1	USD	$0.00 per Windows t2.micro instance-hour (or partial hour) under monthly free tier
21	AmazonEC2	USW2-DataTransfer-Regional-Bytes	PublicIP-Out		0.00000349	USD	$0.000 per GB - regional data transfer under the monthly global free tier
22	AmazonEC2	USW2-DataTransfer-In-Bytes	RunInstances		0.00032071	USD	$0.000 per GB - data transfer in per month
23	AmazonEC2	USW2-DataTransfer-Regional-Bytes	PublicIP-In		0.00000302	USD	$0.000 per GB - regional data transfer under the monthly global free tier
24	AmazonEC2	USW2-USE1-AWS-Out-Bytes	PublicIP-Out		0.00000174	USD	$0.000 per GB - data transfer out under the monthly global free tier
25	AmazonEC2	USW2-DataTransfer-Out-Bytes	RunInstances		0.00045736	USD	$0.000 per GB - data transfer out under the monthly global free tier
26	AmazonEC2	USW2-DataTransfer-In-Bytes	RunInstances		0.00036737	USD	$0.000 per GB - data transfer in per month
27	AmazonEC2	USW2-APN2-AWS-In-Bytes	PublicIP-In		0.00000005	USD	$0.00 per GB - US West (Oregon) data transfer from Asia Pacific (Seoul)
28	AmazonEC2	USW2-APN2-AWS-Out-Bytes	PublicIP-Out		0.00000018	USD	$0.000 per GB - data transfer out under the monthly global free tier
29	AmazonEC2	USW2-USE1-AWS-In-Bytes	PublicIP-In		0.00000153	USD	$0.00 per GB - US West (Oregon) data transfer from US East (Northern Virginia)
30	AmazonEC2	USW2-DataTransfer-Out-Bytes	RunInstances		0.00039945	USD	$0.000 per GB - data transfer out under the monthly global free tier
31	AmazonEC2	CW:AlarmMonitorUsage	Unknown		0.00134409	USD	$0.00 per alarm-month - first 10 alarms