AWS

SOLUTIONS ARCHITECT

PREPARED BY

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A Sneak Peek into the Publication

Drop a message for complete publication.

AWS Solutions Architect: Arjunan K

▼ Section 1: Introduction - AWS Certified Solutions Architect Associate

▼ What is AWS

- AWS (Amazon Web Services) is a Cloud Provider
- They provide you with servers and services that you can use on demand and scale easily
- AWS has revolutionized IT over time
- AWS powers some of the biggest websites in the world
  - Amazon.com
  - Netflix

▼ What AWS services we will learn

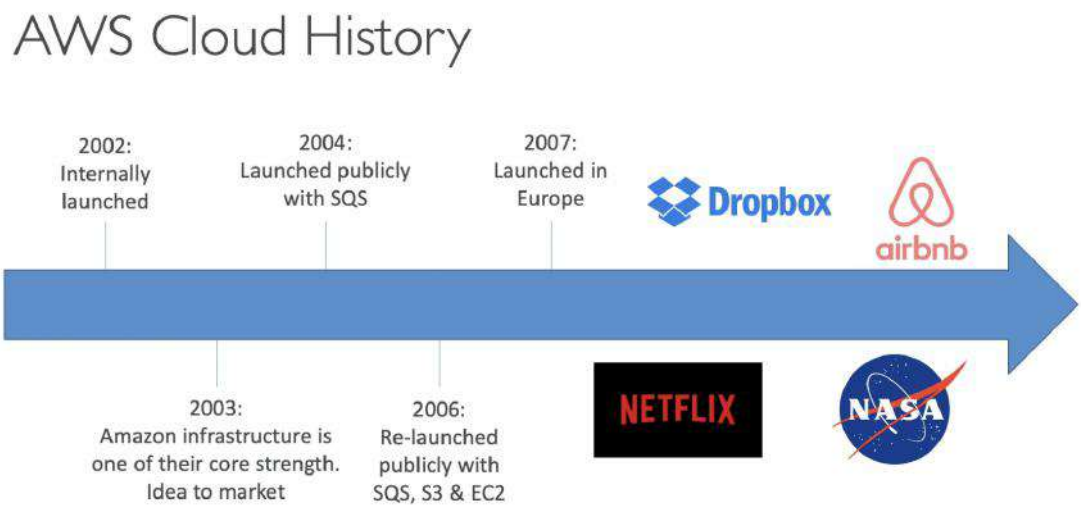
▼ Section 2: Code & Slides Download

AWS Certified Solutions Architect Associate Code & Slides

▼ Section 3: Getting started with AWS

▼ History of AWS Cloud

Several companies that use AWS services are shown below.

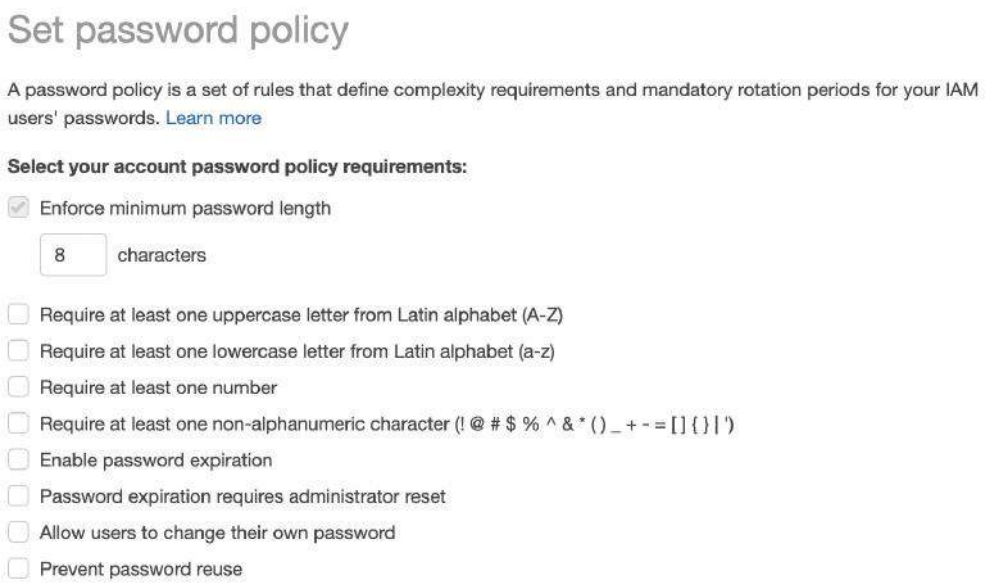


        - Allow all IAM users to change their own passwords
        - Require users to change their password after some time (password expiration)
        - Prevent password re-use

    ⛔ Prevents brute force attacks

- Edit password policy

  IAM → Account Settings → Change Password Policy



▼ IAM: Multi Factor Authentication

▼ Intro

- Both root and all of the IAM users should be secured using MFA.
- MFA = password you know + security device you own
- If the password is stolen or hacked, the account is not compromised
- MFA devices options:
    - Virtual MFA device (support for multiple tokens on a single device)
        - Google Authenticator (phone only)
        - Authy (multi-device)
    - Universal 2nd Factor (U2F) Security Key (support for multiple root and IAM users using a single security key)
        - YubiKey by Yubico (3rd party)
    - Hardware Key Fob MFA Device
        - Provided by Gemalto (3rd party)
    - Hardware Key Fob MFA Device for AWS GovCloud (US)
        - Provided by SurePassID (3rd party)

▼ Enable MFA

Account/User name (top right hand corner) → Security Credentials → MFA → Activate MFA → Virtual MFA device → Scan the QR code using Authy → Enter the current MFA token and the next token → Activate MFA

MFA will be required from the next login

▼ IAM: Roles

- Intro

▼ Sizing an Configuration

EC2 is highly customizable.

- Operating System (OS): Linux, Windows or Mac OS
- Compute power & cores (CPU)
- RAM
- Storage space:
  - Network-attached (EBS & EFS)
  - Hardware (EC2 Instance Store)
- Network card: speed of the card & Public IP address
- Firewall rules: security group
- Bootstrap script (configure at first launch): EC2 User Data

▼ User Data (bootstrap)

- It is possible to bootstrap our instances (launch some commands when a machine starts) using an EC2 User data script.
- User data script is only run once at the instance first start
- User data is used to automate boot tasks such as:
  - Installing updates
  - Installing software
  - Downloading common files from the internet
- The EC2 User Data Script runs with the root user privilege

▼ Create an instance

EC2 → Instances → Launch Instance → Select AMI → Choose instance type → Configure Instance Details → Add storage → Configure Security Groups → Review and Launch → Select an existing key pair or create a new one

▼ Adding User Data

User data (code that executes when the EC2 is booted for the first time) is setup during instance configuration. To setup a basic http server, use the shell script below

```
#!/bin/bash
# Use this for your user data (script from top to bottom)
# install httpd (Linux 2 version)
yum update -y
yum install -y httpd
systemctl start httpd
systemctl enable httpd
echo "<h1>Hello World from $(hostname -f)</h1>" > /var/www/html/index.html
```

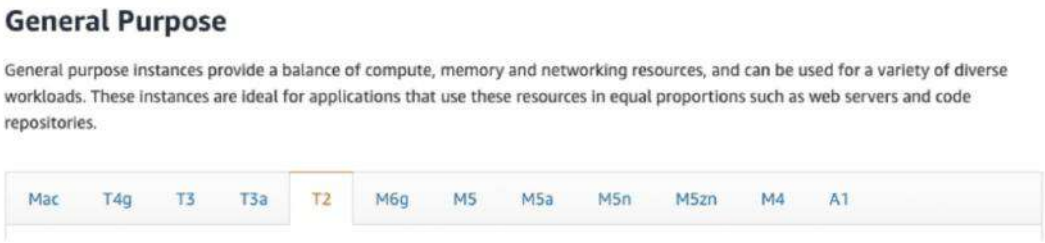
▼ Adding an HTTP rule

Add an HTTP rule to access the website from anywhere.

If we do this, we will be able to access the server using its public IP address.

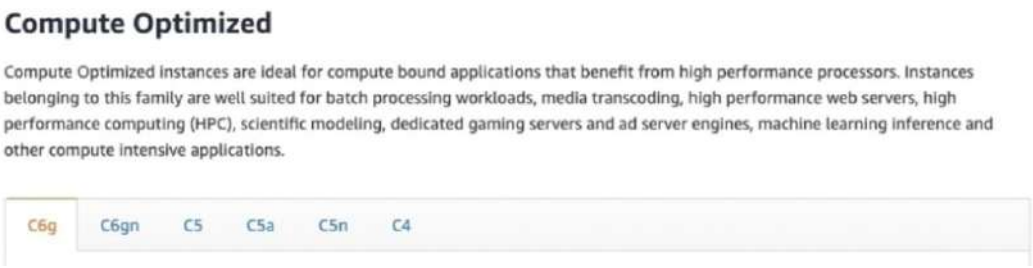
▼ Create a new key pair

Key pair will be used to SSH into our EC2 instance. Don't lose the downloaded key pair file.



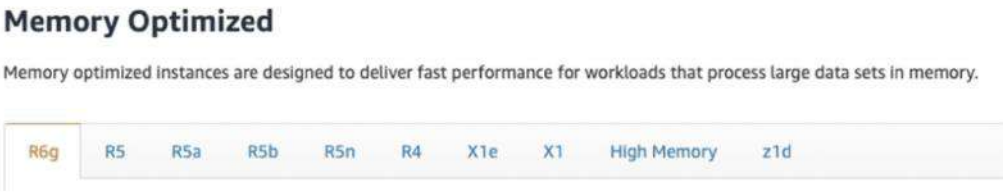
▼ Compute Optimized Instances

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



▼ Memory Optimized Instances

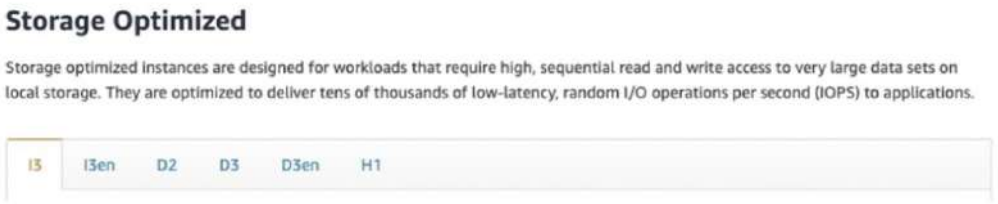
- Fast performance for workloads that process large data sets in memory
- Use cases:
  - High performance, relational / non-relational databases
  - Distributed web scale cache stores
  - In-memory databases optimized for Bl (business intelligence)
  - Applications performing real-time processing of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



▼ Storage Optimized Instances

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

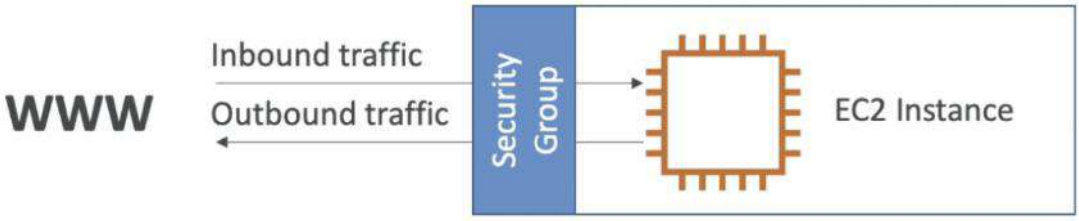
- Distributed file systems



▼ Security Groups

▼ Intro

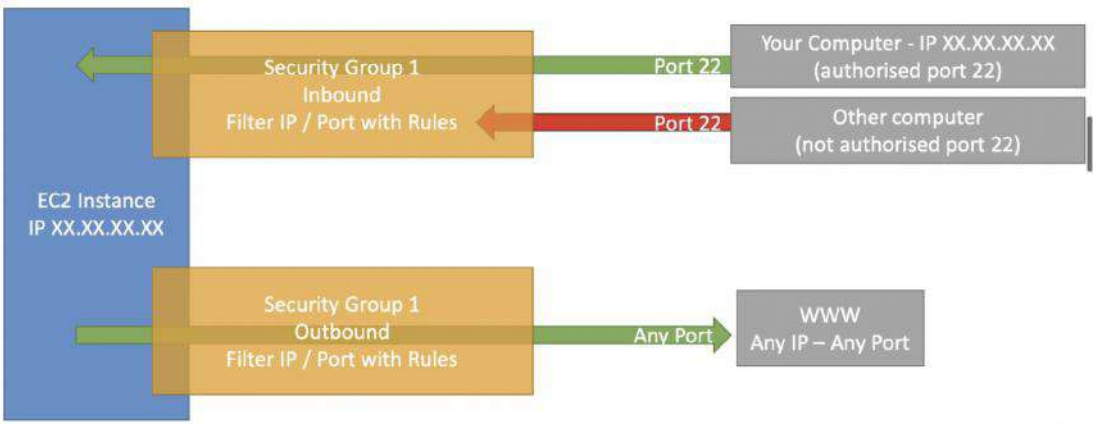
- They control how traffic is allowed into or out of our EC2 Instances.
- Security groups only contain allow rules
- Security groups rules can reference by IP or by security group
- Security groups act as a “firewall” on EC2 instances
- They regulate:
  - Access to Ports
  - Authorized IP ranges IPv4 and IPv6
  - Control of inbound & outbound network



▼ Firewall Diagram

In the diagram below, EC2 has only 1 security group which is shown separately for inbound and outbound traffic. Our computer comes under the authorized IP range, so it get access to the EC2 instance but any other computer whose IP doesn’t fall in the range will be denied access and the request will time out.

EC2 instances, by default, allow any traffic out of it. So, it can send a request to a web server.



▼ Important Points

- A security group can be attached to multiple instances
- An instance can have multiple security groups attached to it

- Attach IAM roles to EC2 instances

  EC2 → Instances → Select instance → Actions → Security → Modify IAM role → Select the IAM role → Attach

  To check this run `aws iam list-users` in ec2 instance connect and it shows all user details.

  This will allow the EC2 instance to perform allowed operations on the AWS resources.

▼ EC2 instances purchasing options

▼ Intro

If we need some instances for long term, choosing the right type of instance can save some us some cost.

- On-Demand Instances: short workload, predictable pricing
- Reserved: (1 & 3 years)
  - Reserved Instances: long workloads
  - Convertible Reserved Instances: long workloads with flexible instances
- Savings Plan (1 & 3 years) - commitment to 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 customer will share your hardware
- Capacity Reservation: Reserve Capacity in a specific AZ for a duration

▼ On Demand Instances

- 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 instances
- Reservation period: 1 year ⇒ +discount or 3 years ⇒ +++discount
- Purchasing options: no upfront | partial upfront ⇒ +discount | all upfront ⇒ ++discount
- Reserved Instance Scope - Regional or Zonal (reserve capacity in an AZ)
- Recommended for steady-state usage applications (like database)
- You can buy and sell in a Reserved Instance Marketplace
- **Convertible Reserved Instance**
  - can change the EC2 instance type, instance family, OS, scope and tenancy
  - Up to 66% discount

- In rare situations, the instance may be reclaimed

▼ Pricing

You can notice a significant price difference between the on demand instance and the spot instance.

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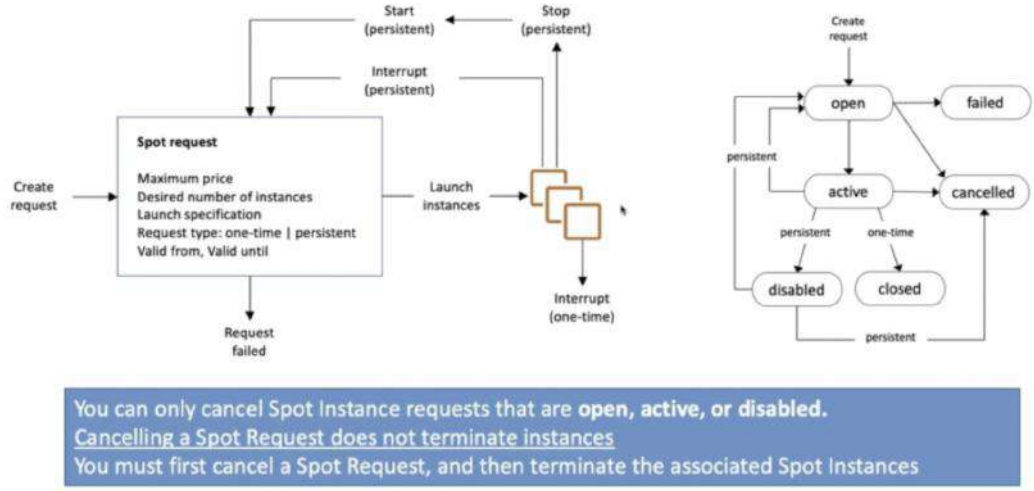
▼ Spot Request and Termination

Spot requests define request type as either one-time or persistent. One-time request, once opened, spins up the spot instances and the request closes. In case of persistent request, the request will stay disabled while the spot instances are up and running. Once these instances stop or terminate and need to be restarted, the request will become active again, ready to start the instances.

To terminate spot instances, we need to first terminated the spot request to prevent relaunching of these instances, and then terminate the spot instances.



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▼ Spot Fleets

▼ Intro

Spot fleets are basically a combination of spot instances and on-demand instances that tries to optimize for cost or capacity. It's like a smart way to let AWS choose the best set of spot instances for us to save cost.

- Spot Fleets = set of Spot Instances + On-Demand Instances (optional)

- The Spot Fleet will try to meet the target capacity with price constraints
  - Define possible launch pools: instance type (m5.large), OS, Availability Zone
  - Can have multiple launch pools, so that the fleet can choose
  - Spot Fleet stops launching instances when reaching capacity or max cost
- Strategies to allocate Spot Instances:
  - lowestPrice: from the pool with the lowest price (cost optimization, short workload)
  - diversified: distributed across all pools (great for availability, long workloads)
  - capacityOptimized: pool with the optimal capacity for the number of instances
- Spot Fleets allow us to automatically request Spot Instances with the lowest price

▼ Create a spot fleet request

EC2 → Spot Requests → Request Spot Instances

In this we can either configure the spot fleet manually or using a template. Templates allow us to have on-demand instances in the spot fleet.

▼ Create a single spot instance

When creating a normal EC2 instance, you have the option to make it a spot instance.

▼ Spot Instances: Hands on

- View Pricing History

  EC2 → Spot Requests → Pricing History

▼ Dedicated Hosts

- A physical server with EC2 instance capacity fully dedicated to your use.
- Allow you address compliance requirements and use your existing server bound software licenses (per-socket, per-scope, 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)
- More expensive
- Useful for software that have complicated licensing model (BYOL - Bring Your Own License) or for companies that have strong regulatory or compliance needs.

▼ Dedicated Instances

- Instances running 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)

- Can be geo located easily

▼ Private IP

- Private IP means the machine can only be identified on a private network only
- the IP must be unique across the private network
- But 2 different private network (2 companies) can have the same IPs
- machines connect to WWW using a NAT + internet gateway (a proxy)
- Specified range can be used as a private IP

▼ Elastic IPs

▼ Intro

- When you stop and then start an EC2 instance, it can change its public IP. If you need to have a fixed public IP for your instance, you need an Elastic IP.
- An Elastic IP is a public IPv4 IP you own as long as you don't delete it
- You can attach it to one instance at a time
- 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 (request AWS to increase that).
- Overall, try to avoid using Elastic IP. They often reflect poor architectural decisions. Instead, use a random public IP and register a DNS name to it or use a Load Balancer (Don't use Load Balancer).

▼ AWS EC2

- A public IP for WWW
- By default EC2 instance have a private IP for internal AWS Network

▼ SSH on EC2

- when doing SSH into our EC2 machines we can't use a private IP, because we are not in the same network
- We can only use the public IP.
- If EC2 instance is stopped and then started public IP can change

▼ Billing

Elastic IPs are billed as long as you own them and they are not attached to any instance.

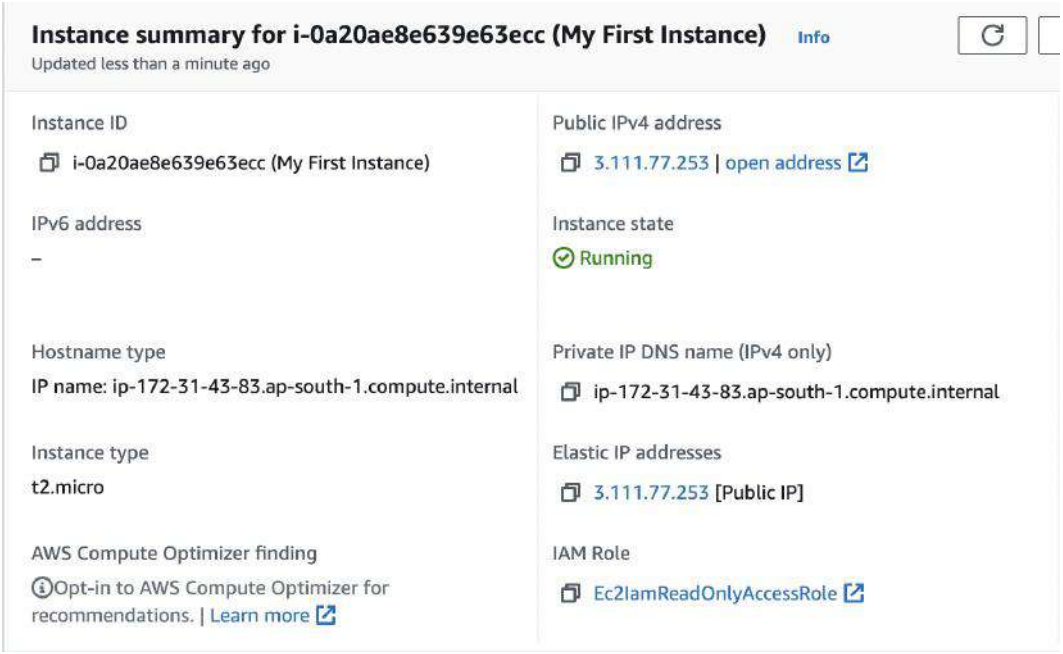
▼ Allocate Elastic IP & associate it to an EC2 instance

EC2 → Elastic IPs → Allocate Elastic IP address → Allocate

This will allocate for us an elastic IP from the pool of elastic IPs that AWS holds. Now, let's associate this IP to our EC2 instance.

Select the elastic IP → Actions → Associate elastic IP address → Choose the instance and private IP address of the instance → Associate

Now, in the instance summary we can see the elastic IP and public IP are identical and they will not change even if we restart the instance.



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▼ Disassociate & Release Elastic IP

EC2 → Elastic IPs → Select the IP → Actions → Disassociate elastic IP

This will detach the elastic IP from the instance. Next, release the elastic IP to prevent billing.

Select the IP → Actions → Release elastic IP

- IPs for EC2 instances

  If we have a VPN using which we can connect to our AWS VPC, we can use the private IP to SSH into our EC2 instance. Otherwise, we will have to use the public IP which might change when you stop and start your instance.

▼ Placement Groups

▼ Intro

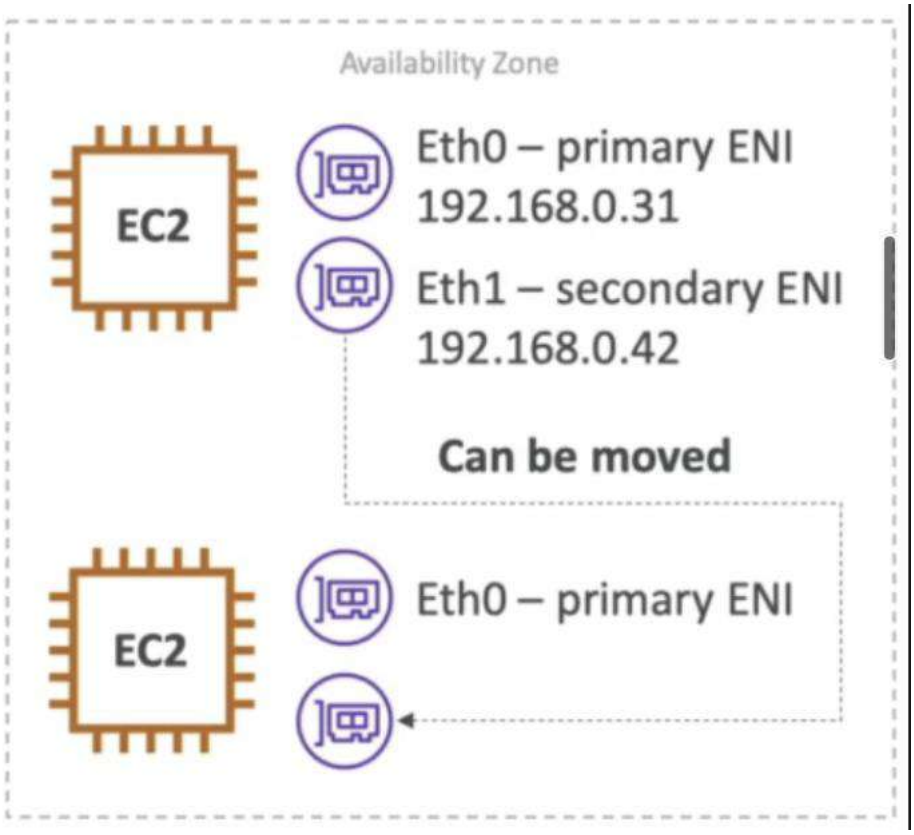
- Placement group lets us control the placement strategy of our instances within the AWS infrastructure.
- When you create a placement group, you specify one of the following strategies for the group:
  - Cluster - clusters instances into a low-latency group in a single Availability Zone
  - Spread - spreads instances across underlying hardware (max 7 instances per group per AZ) for 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)

▼ Cluster Placement Strategy (optimize for network)

All the instances are placed on the same hardware (same rack) which is obviously in the same availability zone.

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

- One or more security groups
- MAC address

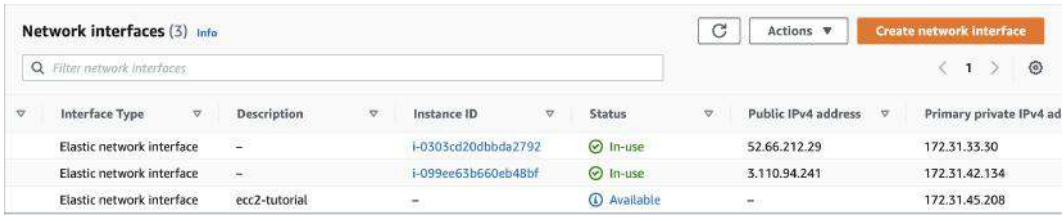


▼ Hands on

- Create an ENI

  EC2 → Network Interfaces → Create network interface → Give it a name and select the subnet (availability zone) for this ENI → Create

  Once created, the ENI will appear as available. The other two ENIs shown below are in use and they were created by default when two EC2 instances were started.



- Attach and Detach ENI to and from an EC2 instance

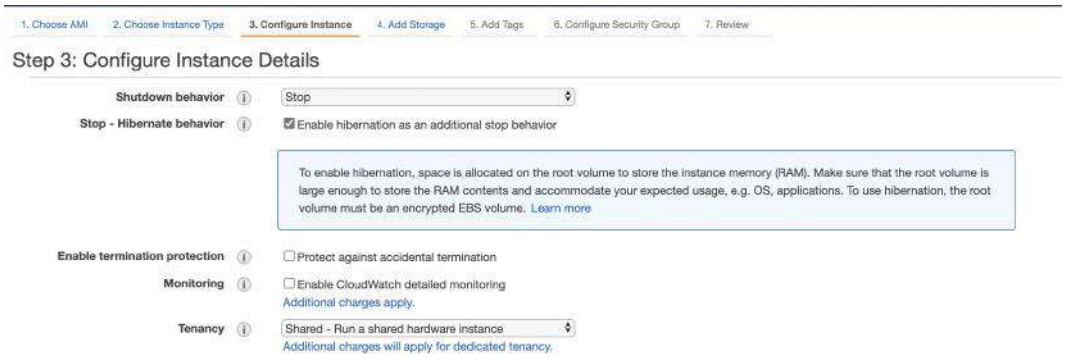
  To attach, EC2 → Network Interfaces → Select the ENI → Action → Attach → Select the instance → Attach

  - The attached ENIs can be viewed in the instance details

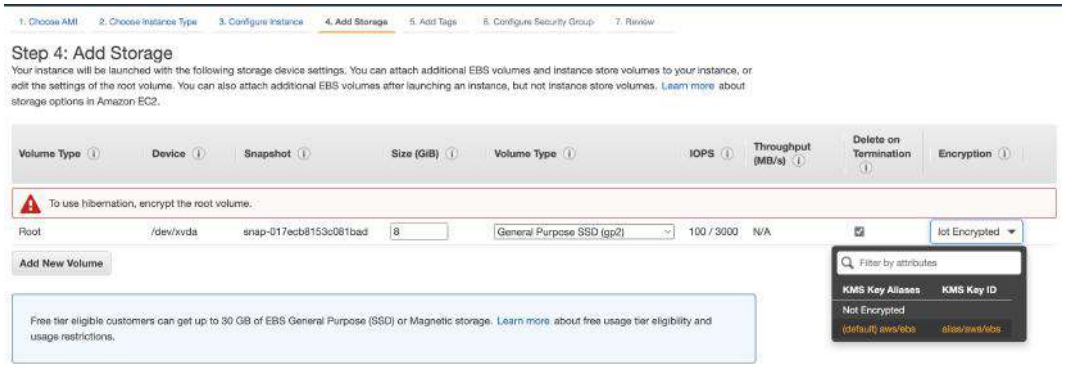
- Enable Hibernation for an EC2 instance

  When creating an EC2 instance:

  Enable hibernation as an additional stop behavior



  Encrypt the EBS storage



- Check if an instance was hibernating or stopped

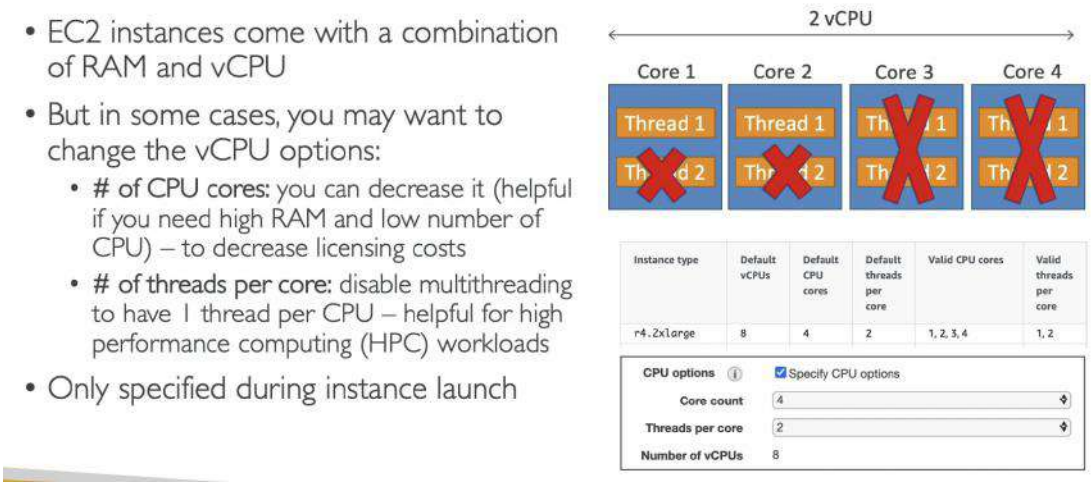
  SSH into the instance and run `uptime` which basically prints how long the instance has been on. In case of hibernation, the printed uptime will not be ~ 0

▼ EC2 Nitro

- New virtualization technology for next-gen EC2 instances
- Allows for better performance:
  - Better networking options (enhanced networking, HPC, IPv6)
  - Higher Speed EBS - Nitro is necessary for 64,000 EBS IOPS max 32,000 on non-Nitro
  - Better underlying security

▼ vCPU

- Intro
  - Multiple threads can run on one CPU (multi-threading)
  - vCPU is basically the total number of concurrent threads that can be run on an EC2 instance.
  - Usually 2 threads per CPU core (eg. 4 CPU ⇒ 8 vCPU)
- Optimizing vCPU options



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▼ Capacity Reservations

- Capacity Reservations ensure you have EC2 Capacity when needed
- Manual or planned end-date for the reservation
- No need for 1 or 3-year commitment
- Capacity access is immediate, you get billed as soon as it starts
- Specify:
  - The Availability Zone in which to reserve the capacity (only one)
  - The number of instances for which to reserve capacity
  - The instance attributes, including the instance type, tenancy, and platform/OS
- Combine with Reserved Instances and Savings Plans to do cost saving

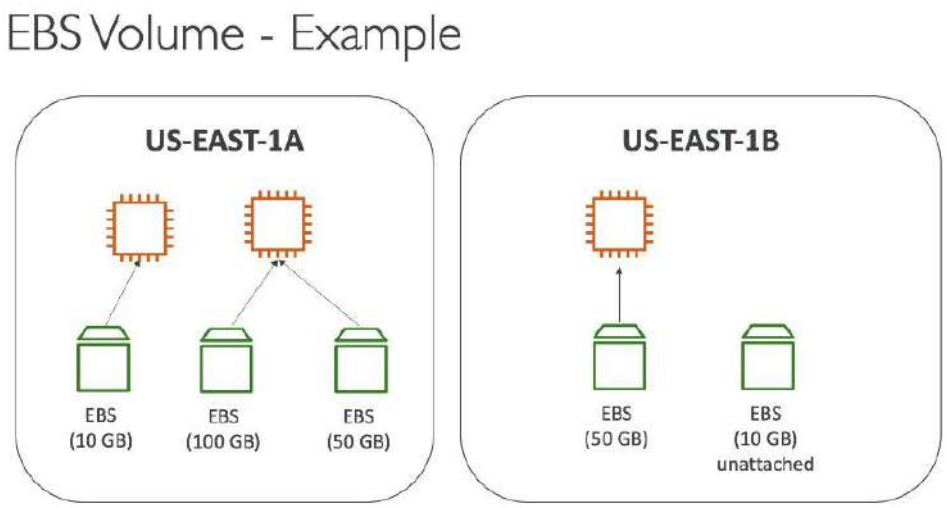
▼ Section 7: EC2 - Instance Storage

▼ Elastic Block Store (EBS)

▼ Theory

▼ Intro

- 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
- An instance can have multiple EBS volumes attached to it
- An EBS volume can be left unattached
- They are bound to a specific availability zone
  - An EBS volume on us-east- 1 a cannot be attached to another one quickly
  - to move a volume across first we need to snapshot it.
- It is a network drive, not a physical drive, it uses network to communicate with the instance so there will be bit of latency
- It can be detached from an EC2 instance and attached to another one quickly
- Capacity (size in GB & throughput in IOPS) must be provisioned
  - You get billed for the provisioned capacity
  - You can increase the provisioned capacity overtime



▼ Delete on termination

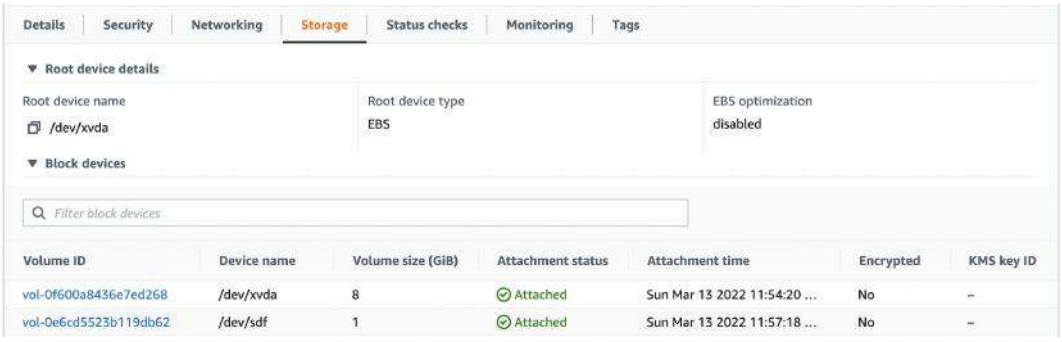
- By default, the root EBS volume is deleted upon instance termination (attribute enabled)
- By default, any other attached EBS volume is not deleted upon instance termination (attribute disabled)
- The default behavior can be overridden
- used to preserve root volume when instance is terminated

▼ Hands on

- Create a new EBS volume & attach it to an instance

  To create a new volume: EC2 → Volumes (under Elastic Block Store) → Create volume → Choose the storage size and availability zone → Create

  To attach an existing volume to an instance: Right click on the volume → Attach → Select the instance → Attach



- Create a snapshot of an EBS volume

  Select the volume → Right click → Create Snapshot

  To view the snapshots: EC2 → Snapshots (under Elastic Block Store)

- Create a volume from a snapshot (in different AZ)

  Select snapshot → Right click → Create volume from snapshot

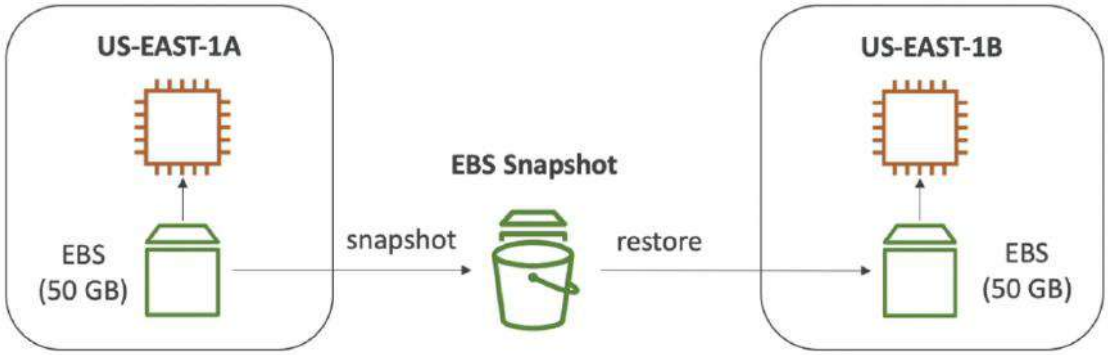
  During the above process, we can select a different availability zone from the one that contains the snapshot.

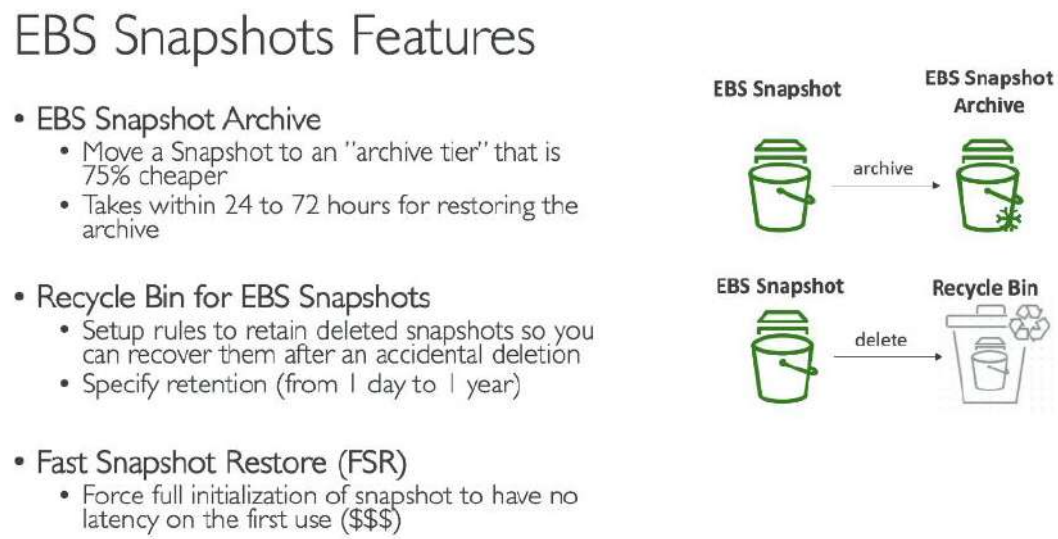
- Copy the snapshot (to a different region)

  Right click the snapshot → Copy snapshot → select the destination region → Copy snapshot

▼ EBS Snapshots

- Snapshots allow us to restore the contents of an EBS volume at a later point in time.
- Not necessary to detach volume to do snapshot, but recommended
- Can copy snapshots across AZ or Region (used to transfer data between availability zones or regions)





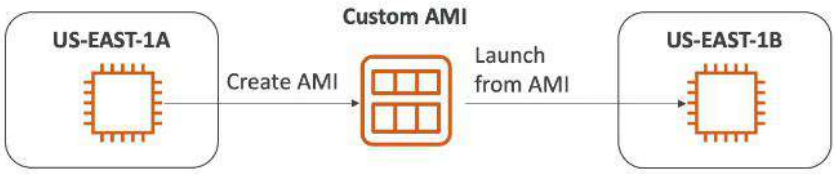
▼ Amazon Machine Image (AMI)

▼ Theory

- AMIs are the image of the instance after installing all the necessary OS, software and configuring everything. It boots much faster because the whole thing is pre-packaged and doesn't have to be installed separately for each instance.
- AMI are built for a specific region (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

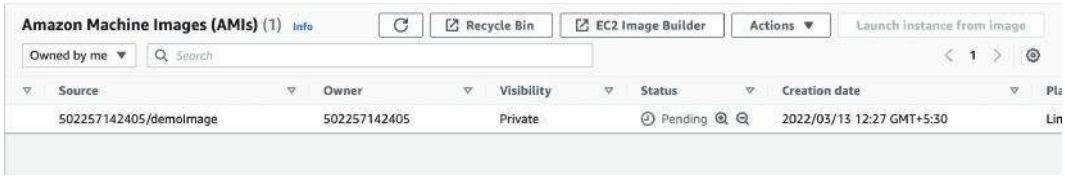


▼ Hands on

- Create an AMI from an existing EC2 instance

  EC2 → Instances → Right click on the instance → Image and Templates → Create image

  To view the created AMI: EC2 → AMIs (under Images)

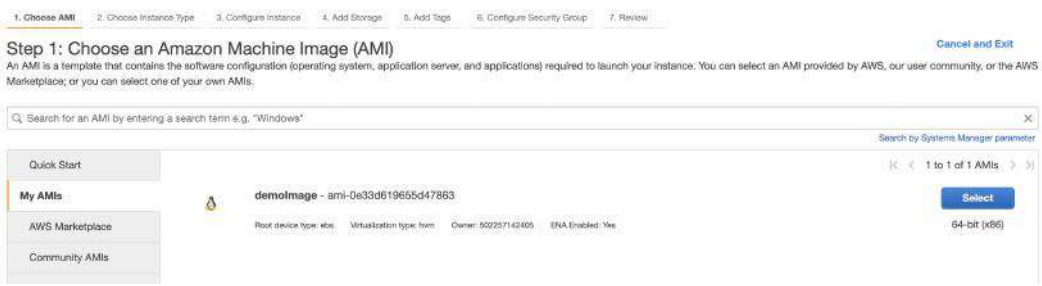


  Untitled

- Create an EC2 instance from an existing AMI

  ⛔ If you just created an AMI, it could take some time to become available to create instances from it.

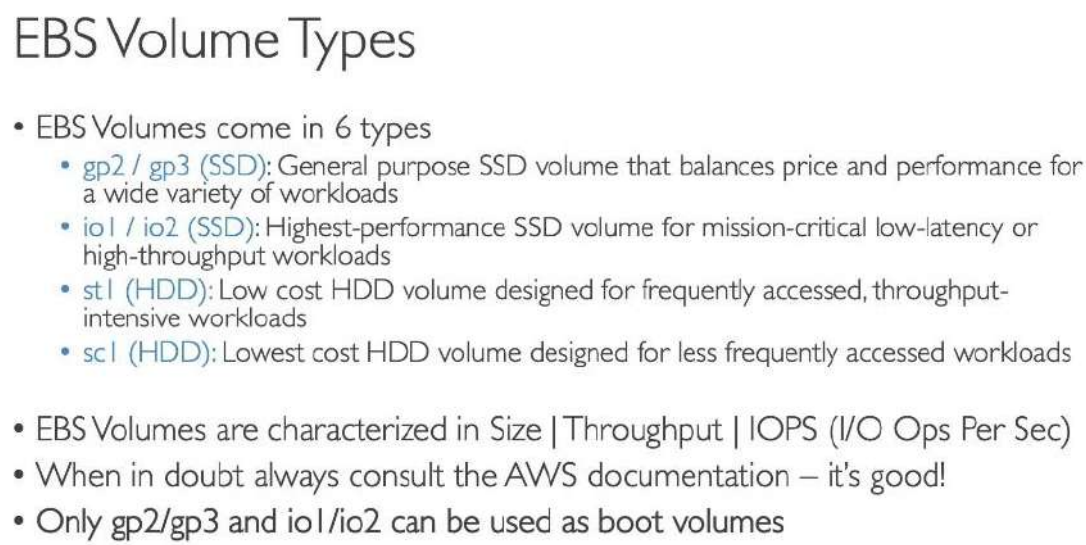
  When creating an EC2 instance, go to “My AMIs” to create an instance from your AMI.



▼ Instance Store

- Instance stores are hardware storages directly attached to EC2 instances (servers hosting the EC2 instances).
- Network isn’t involved, so the IO performance of instance store is very high, but unlike EBS, they lose data when the instance is stopped or terminated (ephemeral).
- Good for buffer / cache / scratch data / temporary content
- Risk of data loss if hardware fails

▼ EBS Volume Types



Only SSD based volumes (gp2/gp3 or io1/io2) can be used as root for EC2 instances.

▼ General Purpose SSD

- Cost effective storage, low-latency
- Good for system boot volumes, virtual desktops, development and test environments
- Storage: 1 GiB - 16 TiB
- gp3:
  - Baseline of 3,000 lOPS 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 (linked), means at 5,334 GB we are at the max lOPS

▼ Provisioned IOPS (PIOPS) SSD

- Good for critical business applications with sustained lOPS performance or applications that need more than 16,000 IOPS (max for gp3)
- Great for databases workloads (demanding storage performance and consistency)
- Supports EBS Multi-attach (attach volume to multiple instances)
- io1/io2:
  - Storage: 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:
  - Storage: 4 GiB - 64 TiB
  - Sub-millisecond latency
  - Max PIOPS: 256,000 with an lOPS: GiB ratio of 1,000: |

▼ Hard Disk Drives (HDD)

- Cannot be a boot volume

- Storage: 125 MiB 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

Amazon EBS volume types

▼ EBS Multi Attach

- Attach the same EBS volume to multiple EC2 instances in the same AZ
- Each instance has full read & write permissions to the volume
- Multi attach only works for Provisioned IOPS (io1 and io2 family)
- Use case:
  - Achieve higher application availability in clustered Linux applications (eg. Teradata)
  - Applications must manage concurrent write operations
  - Must use a file system that's cluster-aware (not XFS, EX4, etc…)
- **Up to 16 EC2 Instances at a time**

▼ EBS Encryption

▼ Intro

- When you create an encrypted EBS volume, you get the following:
  - Data at rest is encrypted inside the volume
  - All the data in-flight moving between the instance and the volume is encrypted
  - All snapshots are encrypted
  - All volumes created from the snapshot are encrypted
- Encryption and decryption are handled transparently (you have nothing to do)
- Encryption has a minimal impact on latency
- EBS Encryption leverages keys from KMS (AES-256)
- Copying an unencrypted snapshot allows encryption
- Snapshots of encrypted volumes are encrypted

▼ Encrypt EBS volumes upon creation

When creating EBS volumes, select the checkbox to encrypt the volume

▼ Encrypt an un-encrypted EBS volume

Follow the steps below in order.

- Create an EBS snapshot of the volume
- Copy the EBS snapshot and encrypt the new copy
- Create a new EBS volume from the encrypted snapshot (the volume will be automatically encrypted)

Shortcut way:

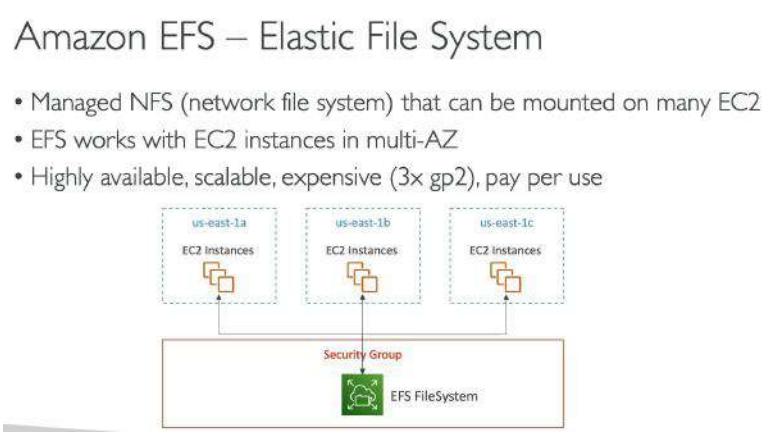
- Create an EBS snapshot of the volume
- Create a new EBS volume from the un-encrypted snapshot and select the checkbox to encrypt this volume.

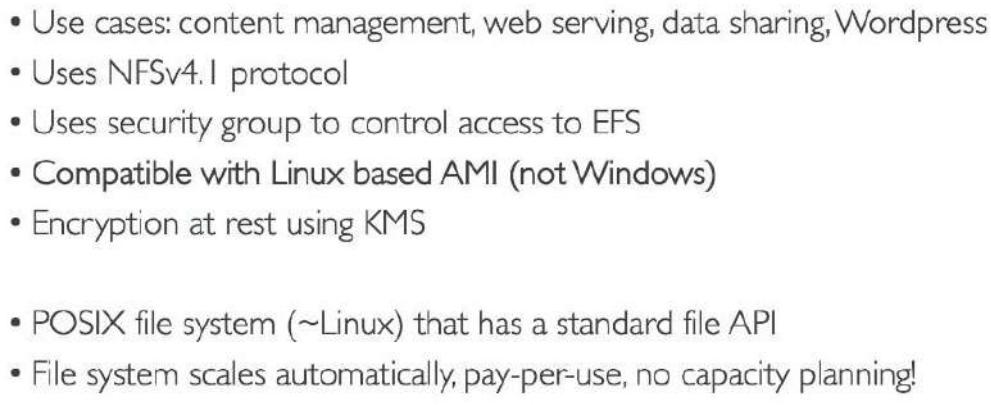
▼ **Elastic File System (EFS)**

▼ Theory

▼ Intro

Compatible with Linux based AMI (Not Windows)





▼ **Performance and Storage Class**

⛔ Really important for exam

- 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
  - By default, EFS is in bursting throughput mode (throughput scales with the file system size).

        - There's usually limit to how much you can vertically scale (hardware limit)
    - Horizontal Scalability (elasticity) (scaling out / in)
        - 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
        - Horizontal scaling is done through
            - Auto Scaling Group (ASG)
            - Load Balancer

▼ High Availability

- 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 is achieved though
    - Auto Scaling Group (multi AZ enabled)
    - Load Balancer (multi AZ enabled)

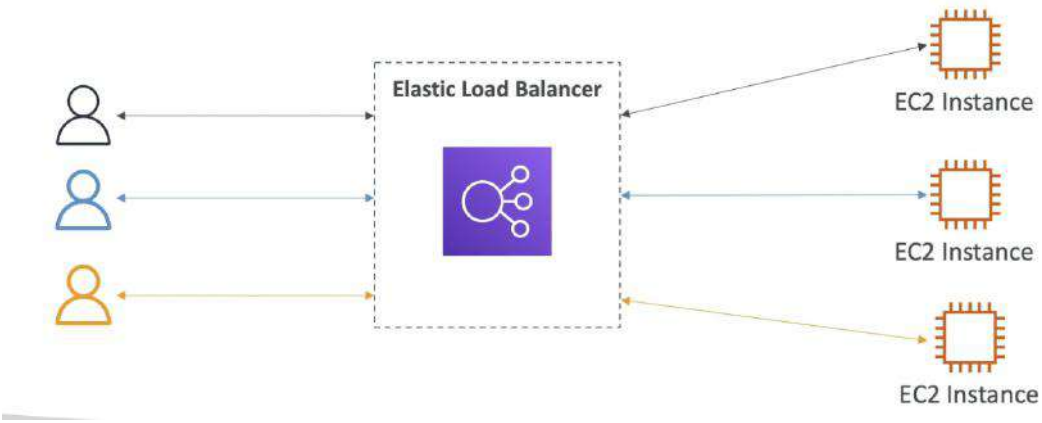
Example: having two call centers in different locations so that if one goes down, the other can keep running

- **Vertical Scaling: Increasing the instance size**
    - **from t2.nano - 0.5G of RAM, 1 vCPU**
    - **To: u-12tb 1.metal - 12.3 TB of RAM, 448 vCPUs**
- **Horizontal Scaling: Increasing number of instance**
    - **Auto Scaling Group**
    - **Load Balancer**
- **High Availability: Run instance for same application across multiple AZ**

▼ Elastic Load Balancer (ELB)

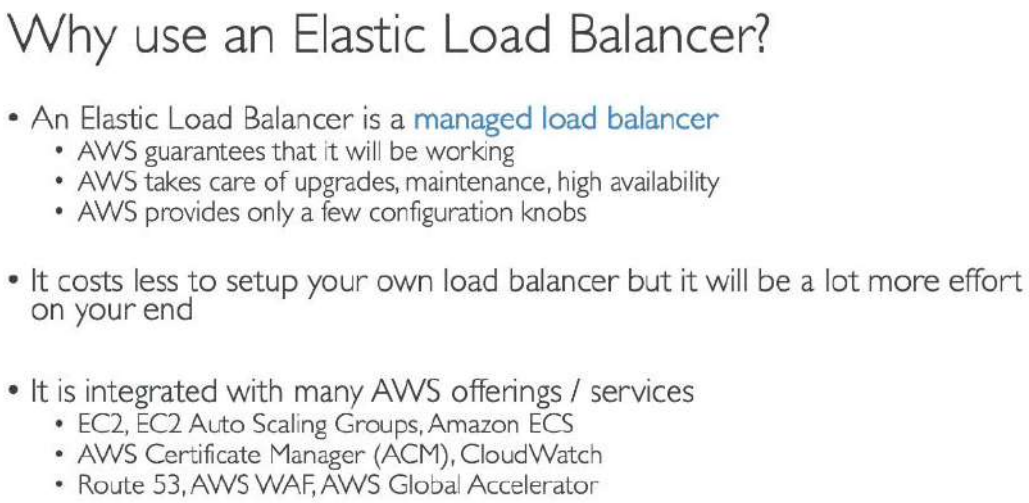
▼ Intro

- Load Balances are servers that forward traffic to multiple servers (e.g. EC2 instances) downstream.
- In the diagram below, none of these users know internally which EC2 instance they are connected to. ELB gives one endpoint of connectivity only.



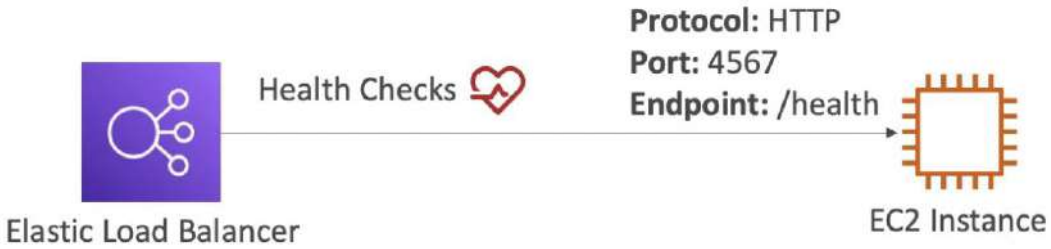
▼ Why use an ELB

- Spread load across multiple downstream instances
- Expose a single point of access (DNS) to your application
- Seamlessly handle failures of downstream instances (if an instance is down, ELB can route the traffic to another instance)
- 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
- It is integrated with many AWS offerings / services:
  - EC2, Auto Scaling Groups, Amazon ECS
  - AWS Certificate Manager (ACM), CloudWatch
  - Route 53, AWS WAF, AWS Global Accelerator



▼ Health Checks

- Health checks allow ELB to know which instances are working properly
- Health Checks are crucial for Load Balancers
- 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 and ELB will send the incoming traffic to another instance.

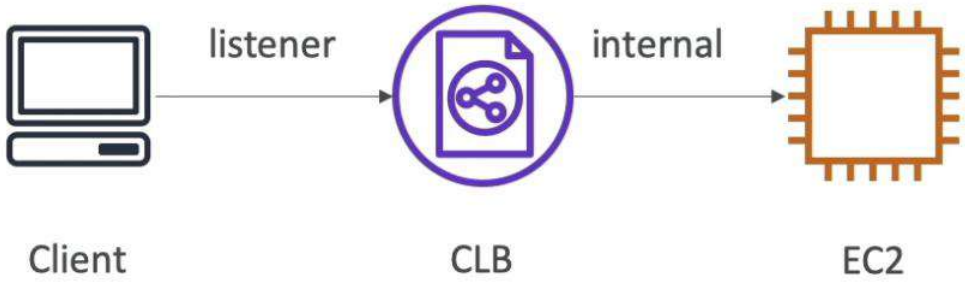


▼ Types of Load Balancers

▼ Classic Load Balancer (CLB) (deprecated)

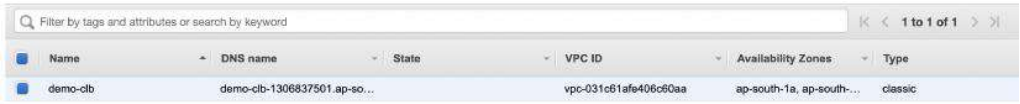
- Theory

- v1 - old generation (started in 2009)
- Provides load balancing to a single application
- Supports HTTP, HTTPS (layer 7) & TCP, SSL (secure TCP) (layer 3)
- Health checks are HTTP or TCP based
- Provides a fixed hostname (xxx.region.elb.amazonaws.com) where we can send traffic



Untitled

- Create a CLB and attach multiple EC2 instances to it
  - Create a CLB with a security group to allow HTTP traffic from anywhere: EC2 → Load Balancers → Create load balancer → CLB
  - Create a security group to only allow HTTP traffic from CLB's security group
  - Create multiple EC2 instances (with a server running on each of them)
  - Attach EC2 instances to CLB: Select CLB → Edit instances



Untitled

Wait for the instance status to become InService. After this, you can use the DNS (URL) provided by the CLB to access the webpage.

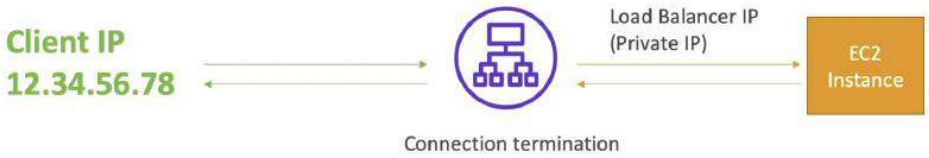
▼ Application Load Balancer (ALB)

▼ Theory

▼ Intro

- v2 - new generation (started in 2016)
- Supports only Layer 7 (HTTP, HTTPS and WebSocket)
- Supports load balancing to multiple HTTP applications across machines using target groups
- Supports load balancing to multiple applications on the same machine (eg. containers)
- ALB terminates the original connection and creates a new connection to the EC2 instance
- Support redirects (from HTTP to HTTPS for example)

- Supports both internal and external traffic
- ALBs are a great fit for micro services & container-based application (eg. Docker & Amazon ECS)
- Has a port mapping feature to redirect to a dynamic port in ECS
- In case of CLB, we'd need one CLB per application whereas one ALB can balance the load on multiple applications.
- ALB also provides a fixed hostname (XXX.region.elb.amazonaws.com)
- The application servers don't see the IP of the client (external user making the request) directly
  - The true IP of the client is inserted in the header X-Forwarded-For
  - We can also get Port (X-Forwarded-Port) and protocol (X-Forwarded-Proto)



▼ Target Groups

- Target groups could be:
  - 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)
- Traffic can be routed to different target groups based on:
  - Path in URL (example.com/users & example.com/posts)
  - Hostname In URL (one.example.com & other.example.com)
  - Query String (example.com/users?id=123&order=false)
  - Request Headers
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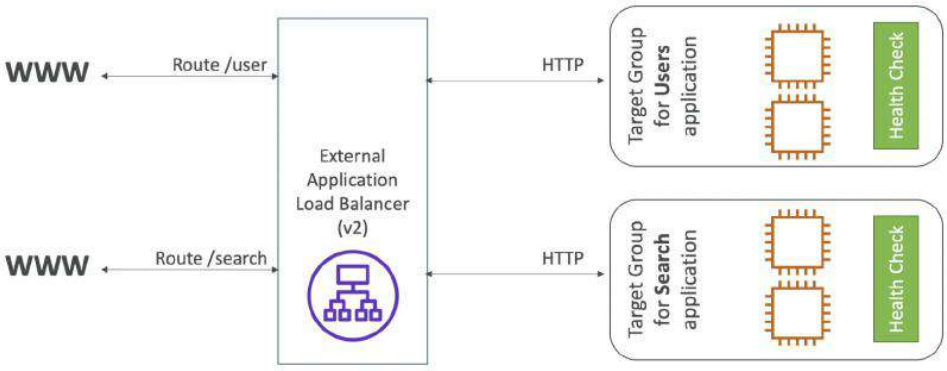
▼ ALB (path routing)

In the diagram below, we have two micro services: `/user` and `/search`. Both of these services are balanced by a single ALB. Both the services are kept under separate target groups. The ALB determines which target group to balance for using the URL path in the incoming request.



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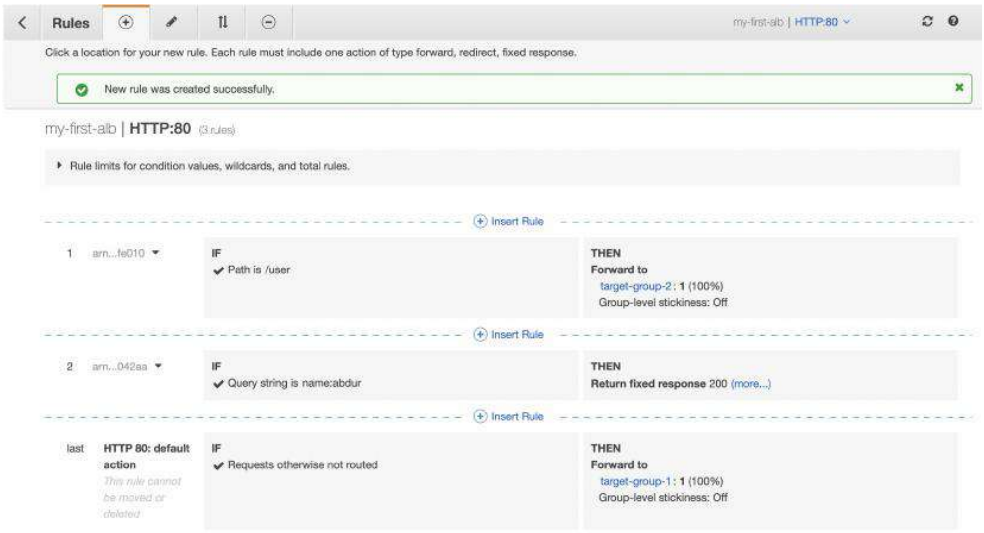

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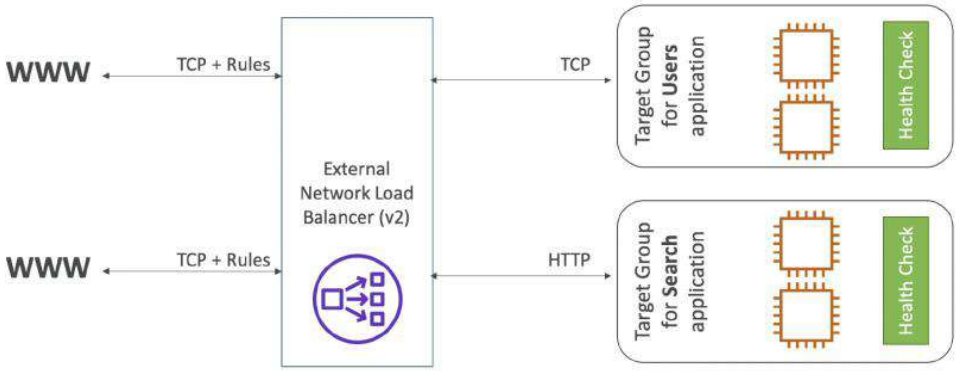
▼ Network Load Balancer (NLB)

▼ Theory

▼ Intro

- v2 - new generation (started in 2017)
- Supports Transport Layer (layer 4) traffic (TCP, TLS (secure TCP), UDP)
- Forward TCP & UDP traffic to your instances
- Can handle millions of request per seconds (extreme performance)
- Less latency ~ 100 ms (vs 400 ms for ALB)
- NLB has one static IP per AZ (vs a static hostname for CLB & ALB)
- Maintains the same connection from client all the way to the instance
- No security groups can be attached to NLBs. So, the attached instances must allow TCP traffic on port 80 (HTTP) from anywhere (as if no ELB is attached).
- Supports assigning Elastic IP (helpful for whitelisting specific IP)
- Not included in the AWS free tier
- We can configure rules to direct traffic to different target groups



▼ Target Groups

Within a target group, NLB can send traffic based on

- EC2 instances
- IP addresses

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), balancing load within the VPC, or external (public), balancing load coming from outside the VPC like website.

▼ Security groups for ELB

ELB will be publicly available on the internet, so it's security group should allow HTTP and HTTPS traffic from anywhere.

EC2 should only allow traffic from the ELB, so the it's security group should allow HTTP requests from ELB's security group.

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...

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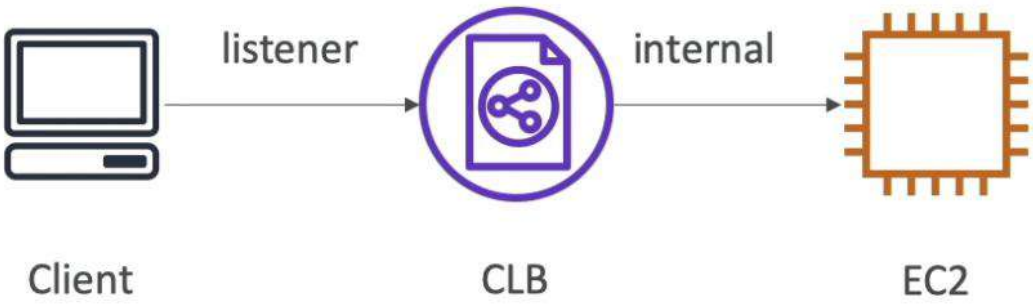

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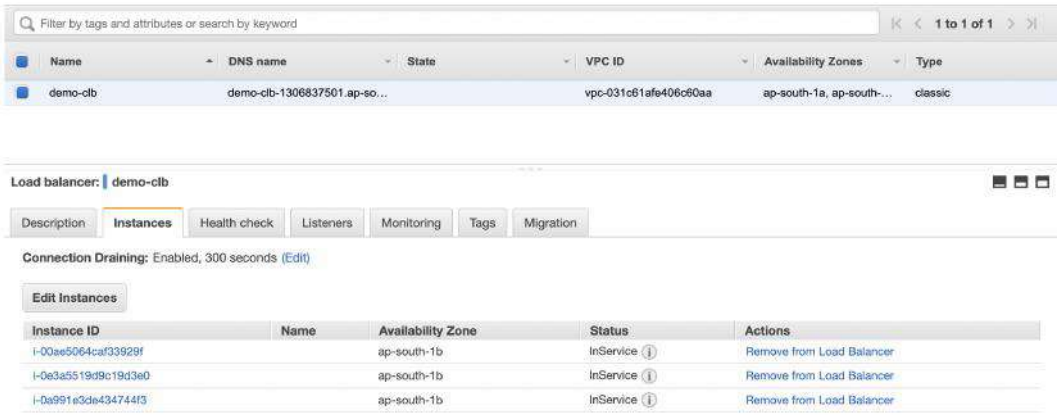

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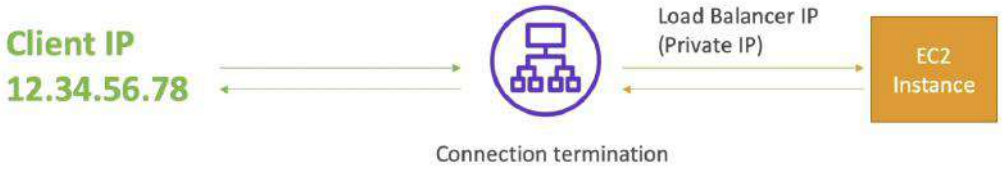

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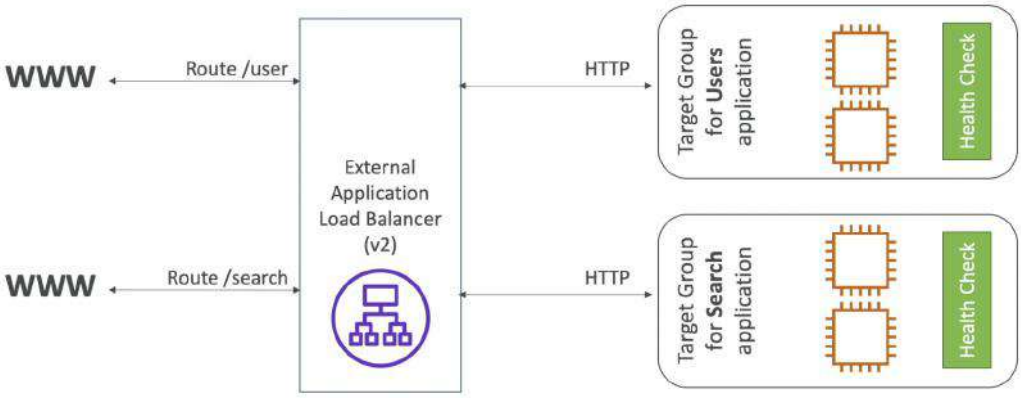
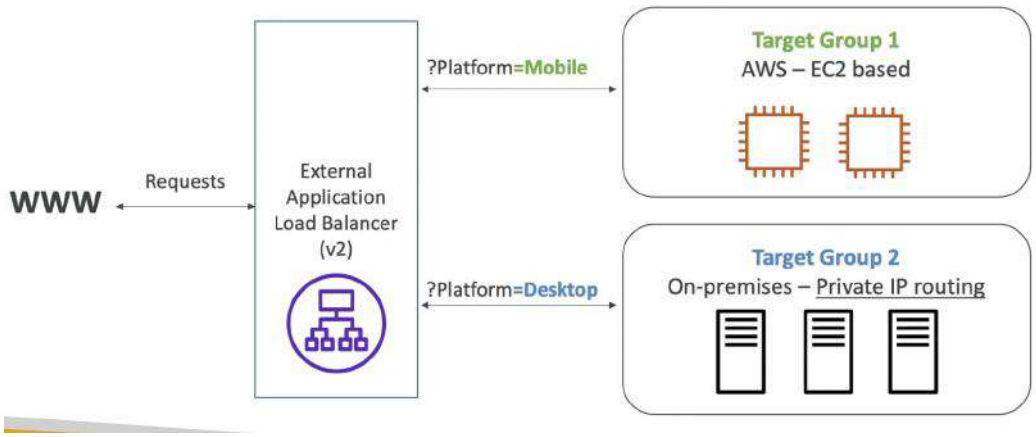


▼ ALB (query string parameter routing)

We can balance loads for two different target groups based on some query string parameters.



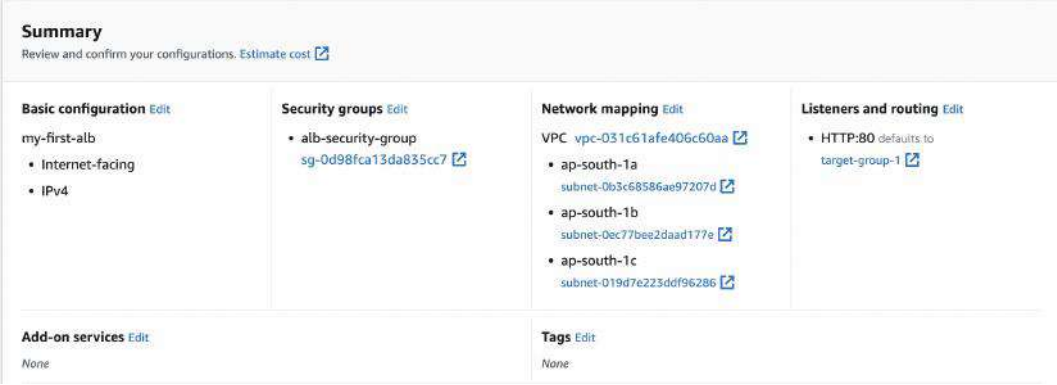
▼ Hands on

- Create an ALB and attach EC2 instances to it

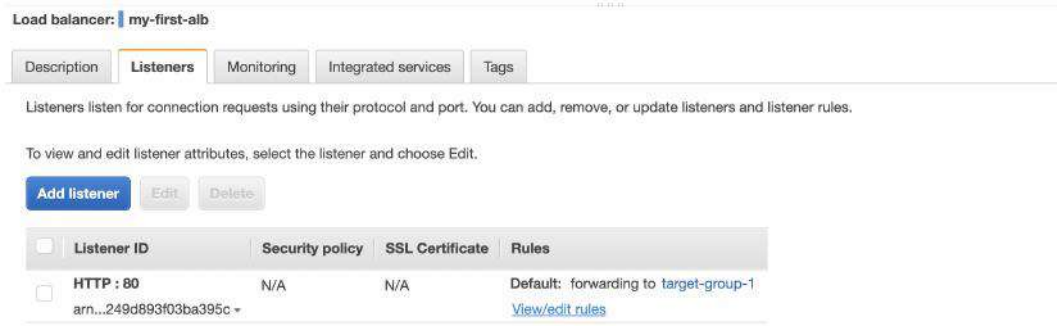
  EC2 → Load Balancers → Create → ALB

  EC2 instances will have to be added to target groups which can be created during the ALB creation.

  Sample summary for reference.

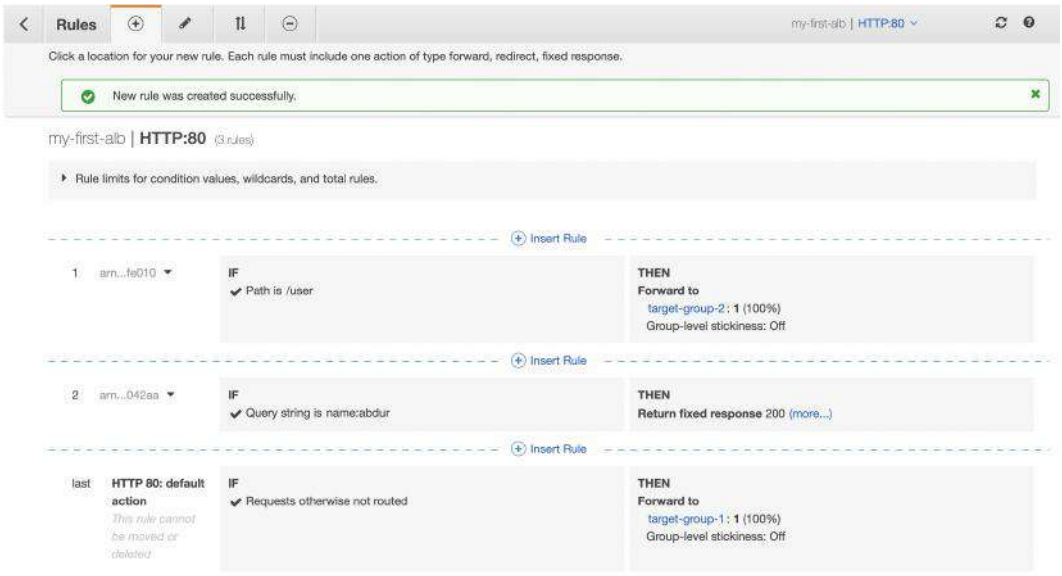


  We can also create additional target groups later and add them by editing the rules of the listener on the ALB.



- Edit listener rules

  We can add rules to direct traffic to different target groups based on the IP, path, hostname, query string parameter etc. We can also return fixed response if required.



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▼ Theory

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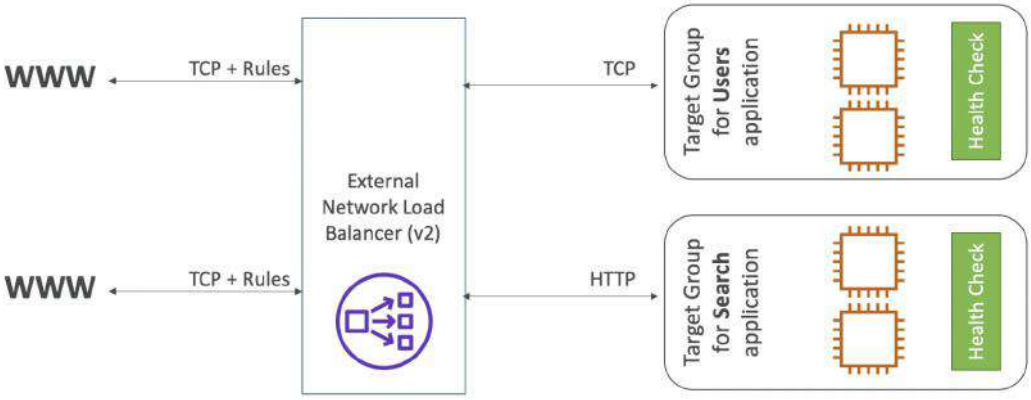
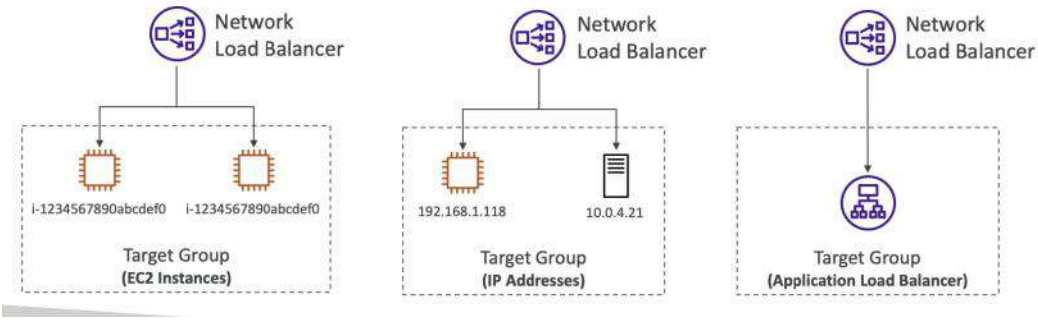


▼ Target Groups

Within a target group, NLB can send traffic based on

- EC2 instances

- IP addresses- must be private IPs
- Health Checks support the TCP, HTTP, HTTPS Protocols
- Used when you want to balance load for a physical server having a static IP.
- Application Load Balancer (ALB)
    - This setup is used when you want a static IP provided by a NLB but also want to use the features provided by ALB at the application layer.



▼ Create a NLB and attach EC2 instances to it

EC2 → Load Balancers → Create → NLB

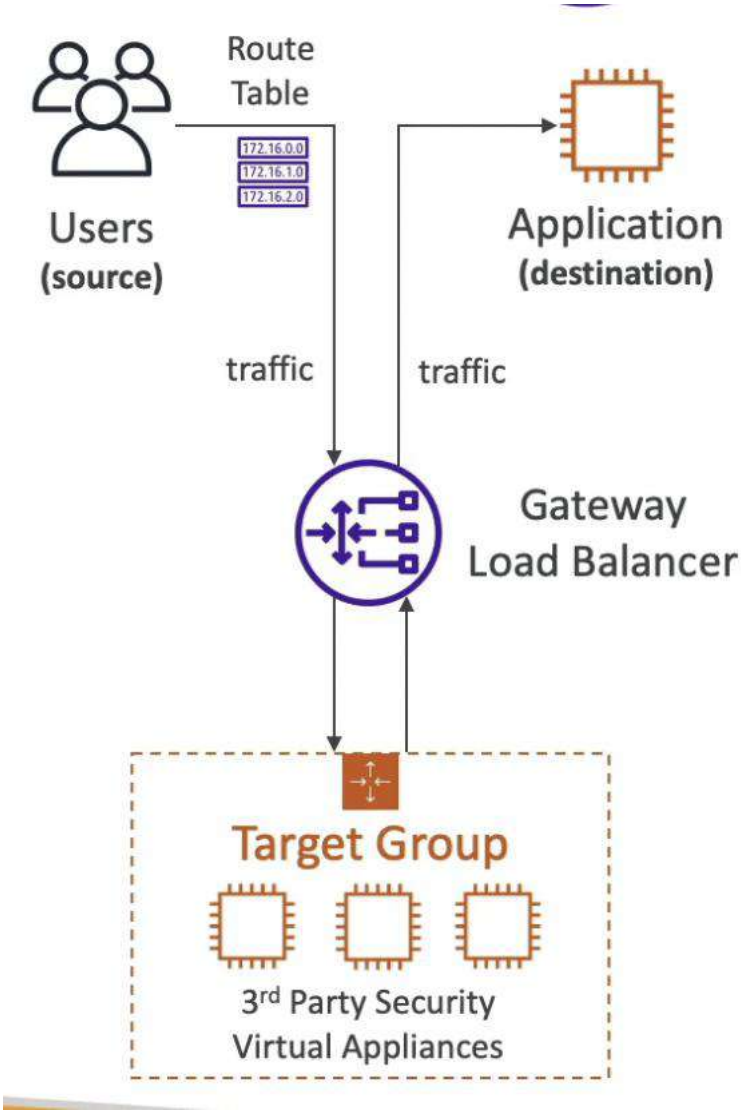
Separate target groups (that work on TCP) must be created for NLBs. Target groups created for ALB will not work with NLBs.

⛔ No security groups are attached to NLBs. They just forward the incoming traffic to the right target group as if those requests were directly coming from client. So, the attached instances must allow TCP traffic on port 80 from anywhere.

▼ Gateway Load Balancer (GWLB)

▼ Intro

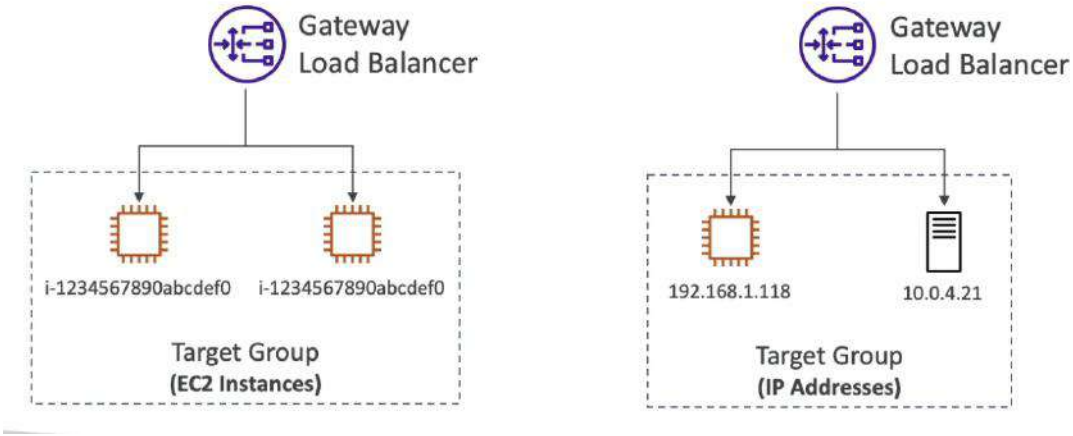
- Newest (started in 2020)
- Operates at layer 3 (Network layer) - IP Protocol
- Used to deploy, scale, and manage a fleet of 3rd party network virtual appliances in AWS. Example: Firewalls, Intrusion Detection and Prevention Systems (IDPS), Deep Packet Inspection Systems, payload manipulation, etc.
- Performs two 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**
- In the diagram below, all of the external traffic is first sent to a fleet of EC2 instances to perform security check on the traffic. If the request passes the security check, it is then routed to the application.



▼ Target Groups

Target groups for GWLB will be the external appliances. They could be:

- EC2 instances
- IP addresses - must be private IPs



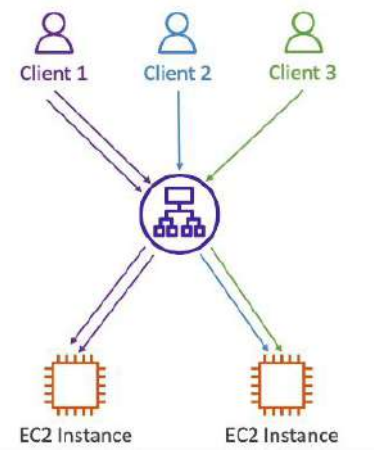
▼ Sticky Sessions (Session Affinity)

▼ Theory

▼ Intro

It is possible to implement stickiness so that the requests coming from a client is always redirected to the same instance behind the load balancer.

- It only works for CLB & ALB
- Cookie is used for stickiness. This cookie has an expiration date that you can control. After the cookie expires, the requests coming from the same user might be redirected to another instance.
- Use case: to make sure the user doesn't lose his session data (example login info). If sticky session is not enabled, it will result in the user being prompted to login again and again if they just navigate to a different webpage.
- Enabling stickiness may bring imbalance to the load over the backend EC2 instances



▼ Cookie types

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

▼ Hands on

- Enable stickiness

  EC2 → Target groups → Select target group → Actions → Edit attributes

  We have both Application based and Duration based cookie options. For Application based one, we need to specify the cookie name.

        - No charges for inter AZ data if enabled
    - 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

▼ Enable cross-zone load balancing

EC2 → Load Balancers (CLB/NLB) → Select load balancer → Activate cross-zone load balancing in the attributes

ALB is enable by default

▼ SSL / TLS Certificates

▼ Intro

- 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 and it is used to encrypt connections
- TLS refers to Transport Layer Security (newer version). Nowadays, TLS certificates are mainly used, but people still refer to them as SSL
- SSL certificates have an expiration date (you set) and must be renewed regularly to make sure they are authentic.
- Public SSL certificates are issued by Certificate Authorities (CA) like Comodo, Symantec, GoDaddy, GlobalSign, Digicert, Letsencrypt, etc.

▼ HTTPS encryption using SSL certificates

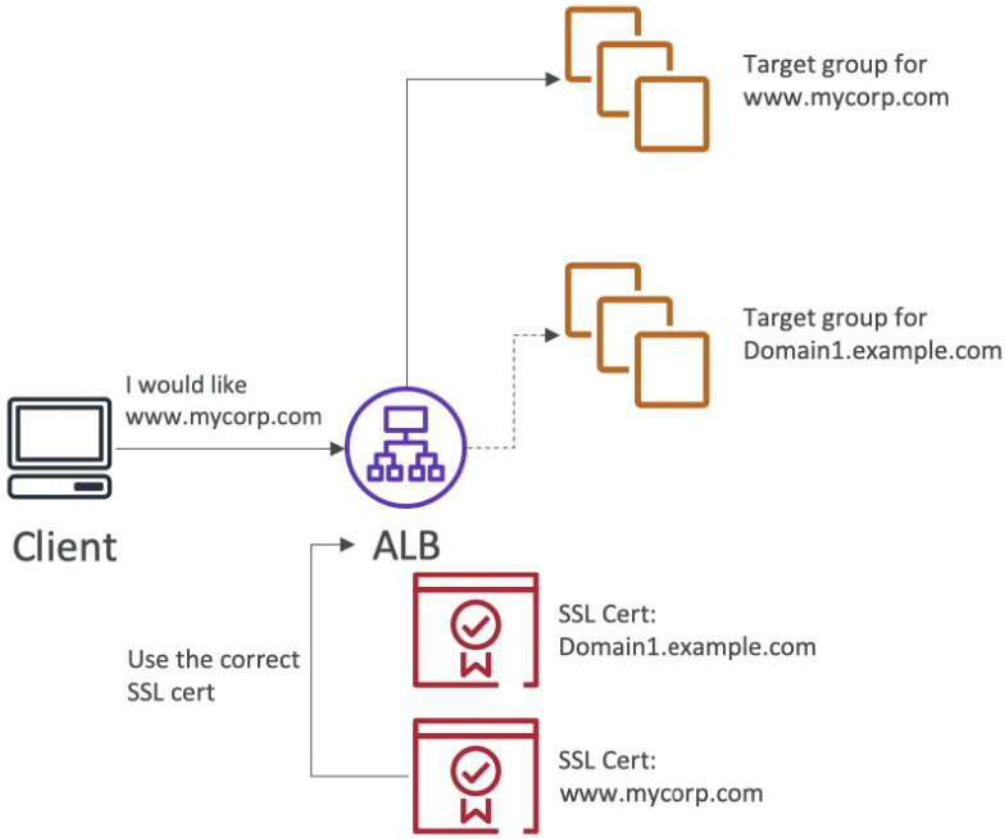
User to load balancer communication happens over HTTPS which is in-flight encrypted. Load balancer to EC2 instance communication happens over HTTP inside the VPC which is secure.

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

▼ Server Name Indication (SNI)

- SNI allows us to load multiple SSL certificates onto one web server (to serve multiple websites securely)
- It's a "newer" protocol, and requires the client to indicate the hostname of the target server in the initial SSL handshake. The server will then find the correct certificate to encrypt the traffic, or return the default one.
- Since it is a newer protocol, not every client supports it yet.
- Only works for ALB & NLB. They can load multiple certificates on each listener using SNI. Each certificate will be used for a separate target group.

- SNI is not supported in CLB. CLBs only support one SSL certificate. Need to use multiple CLBs for multiple hostnames in order to use multiple SSL certificates.
- SNI is supported in CloudFront
- In the diagram below, the ALB is routing HTTPS traffic to two target groups, each with a different hostname. So, the ALB needs to have two SSL certificates (one for each target group). SNI allows the ALB to have multiple SSL certificates on one listener and use the right one.



Elastic Load Balancers – SSL Certificates

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

▼ Steps

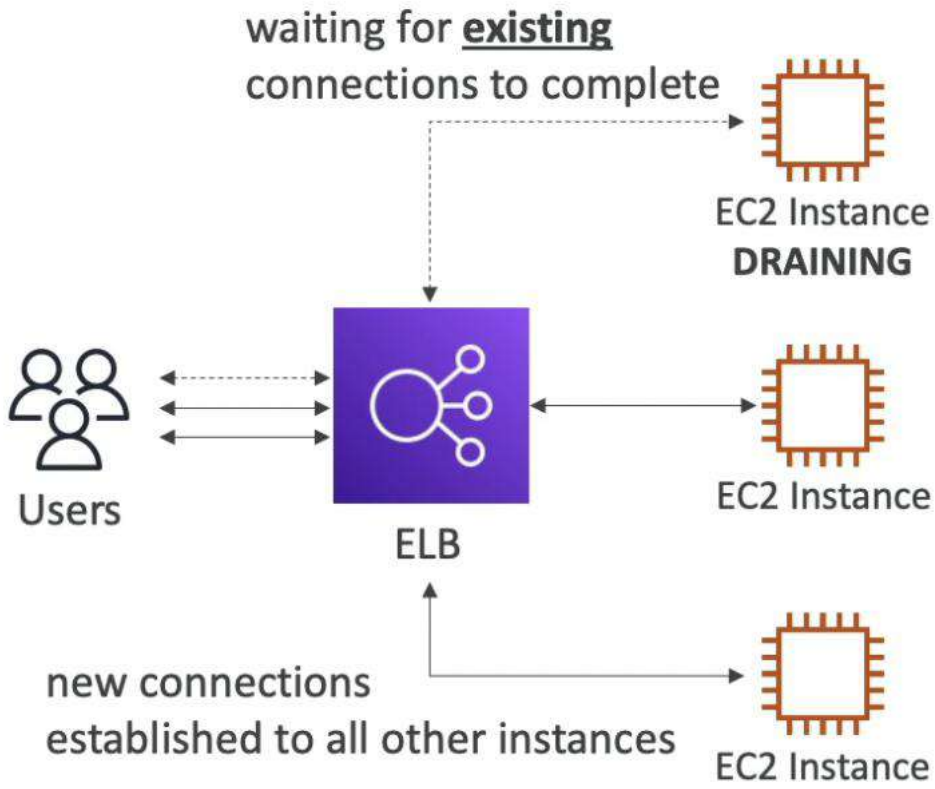
Load Balancer → CLB → Listeners → edit → add → HTTPS → Cipher → SSL Certificate from ACM/Upload → Save

Load Balancer → ALB → Add listener → HTTPS → Default Action → Forward to → target ALB grp → Security Policy → Default SSL certificate → ACM/IAM/import → Add

Load Balancer → NLB → Add listener → TLS → Default Action → Forward to → target ALB grp → Security Policy → Default SSL certificate → ACM/IAM/import → Add

▼ Connection Draining / De-registration Delay

- While the instance is de-registering or unhealthy (going offline), the “in-flight requests” being served by that instance are given time to complete before shutting down the instance. The ELB stops sending new requests to the EC2 instance which is de-registering.
- **Called as Connection Draining for CLB and De-registration Delay for ALB & NLB**
- The de-registration delay can be set manually (between 1 to 3600 seconds) (default: 300 seconds)
- Set to a low value if your requests are short and vice versa
- Can be disabled (set value to 0)



▼ Auto Scaling Groups (ASG)

▼ Theory

▼ Purpose of ASG

In real life load on a website can change. ASG helps us to deal this issue.

- 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 machines running
- Automatically Register new instances to a load balancer
- Re-Create EC2 instance incase a previous one was terminated (eg: If Unhealthy)

Untitled

▼ Good metrics to scale on

- CPU Utilization: average CPU utilization across your instances
- RequestCountPerTarget: to make sure the number of requests per EC2 instances is stable
- Average Network In / Out: if you're application is network bound, meaning it involves a lot of download or upload and the network could become a bottleneck
- Any custom metric (that you push using CloudWatch)

  We can auto scale based on a custom metric (ex: number of connected users). To set this up:

  1. Send custom metric from application on EC2 to CloudWatch using the PutMetric API
  2. Create CloudWatch alarm to react to low / high values
  3. Use the CloudWatch alarm as the scaling policy for ASG

new →

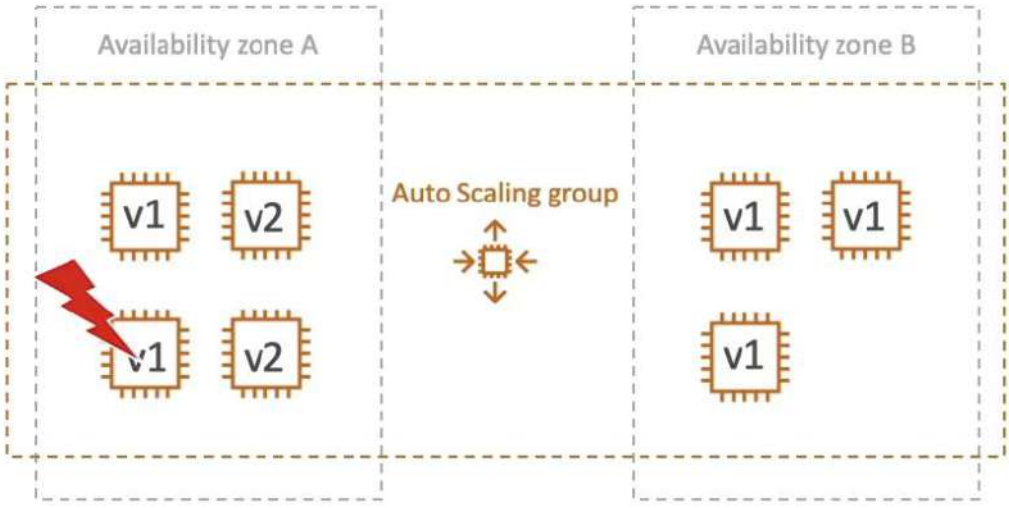
▼ Important

- ASGs use Launch configurations or Launch Templates which are a newer version of launch configuration.
- To update an ASG, you must provide a new launch configuration / launch template
- IAM roles attached to an ASG will get assigned to EC2 instances
- ASGs are free. You pay for the underlying resources being launched
- Having instances under an ASG means that if they get terminated for whatever reason, the ASG will automatically create new ones as a replacement.
- ASG can terminate instances marked as unhealthy by an ELB (and hence replace them)

▼ Default Termination Policy (simplified)

Select the AZ with the most number of instances. If there are multiple instances in this AZ, delete the one with the **oldest** launch configuration. By default, ASG prioritizes to balance the number of instances across AZ.

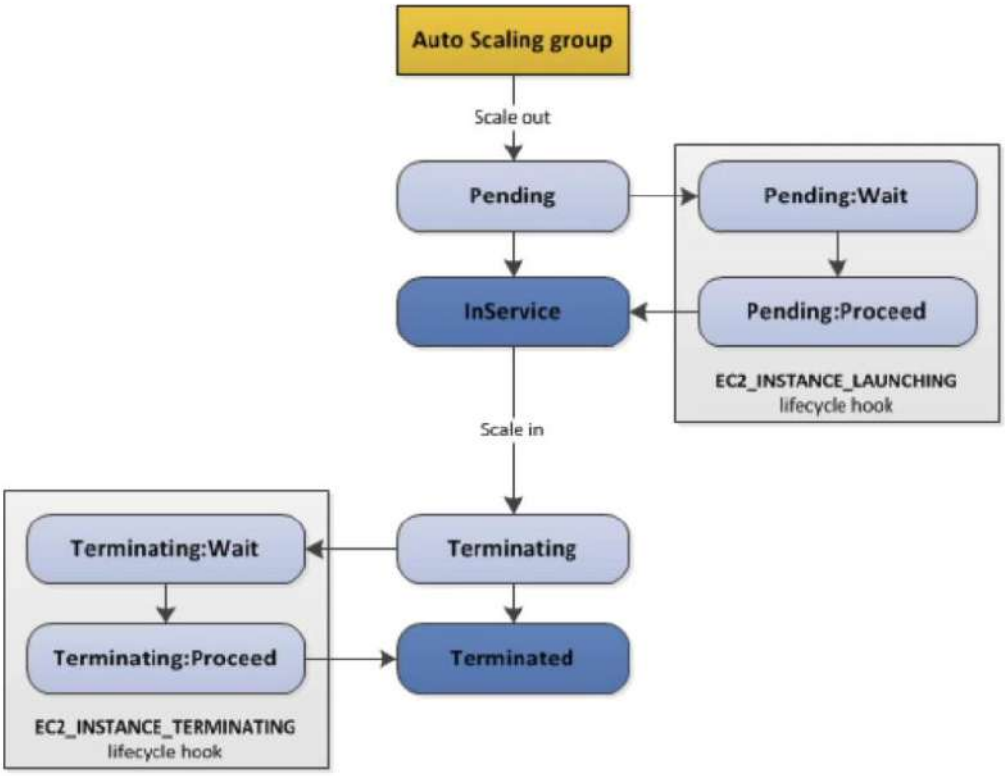
In the diagram below, if an instance has to be dropped, it will be a v1 instance in A.



▼ Lifecycle Hooks

It is a feature of ASG which allows us to perform extra steps before creating or terminating an instance. Example: install some extra software or do some checks (during pending state) before declaring the instance as "in service". Similarly, before the instance is terminated (terminating state), extract the log files.

Without lifecycle hooks, pending and terminating states are avoided.



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▼ Launch Template vs Launch Configuration

- Both allow us to configure the ID of the AMI, the instance type, a key pair, security groups, and the other parameters that you use to launch EC2 instances (tags, EC2 user-data, etc.)
- Launch Configuration (legacy):
  - Must be re-created every time you want to make some changes to the configuration
- Launch Template (newer):
  - Can have multiple versions
  - Create parameters subsets (partial configuration for re-use and inheritance)
  - Provision using both On-Demand and Spot instances (or a mix)
  - Can use T2 unlimited burst feature
  - Recommended by AWS going forward

▼ Hands on

▼ Create an ASG

EC2 → Auto Scaling Groups → Create ASG

Create a launch template to configure the EC2 instances that ASG will be creating

Choose multiple AZs as ASG can balance the instance creation across all the zones.

Attach a load balancer to the ASG

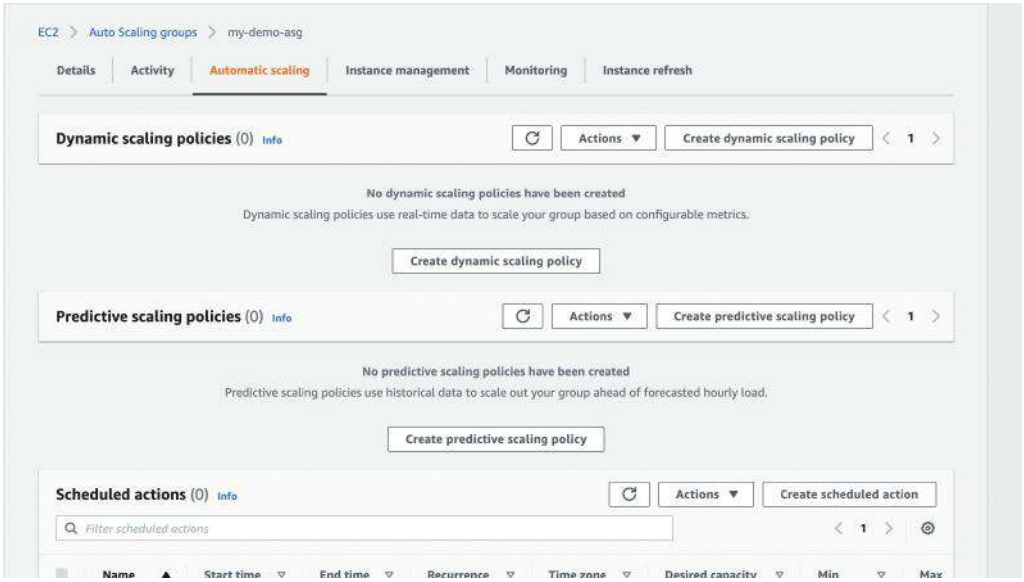
Enable health checks on both EC2 and ELB level

⛔ Right after creation, the ASG will automatically create EC2 instances based on the scaling policy or desired instances count.

▼ Setup Scaling Policies for ASG

- Navigate to Scaling Policies

  Select the ASG → Automatic Scaling (tab)



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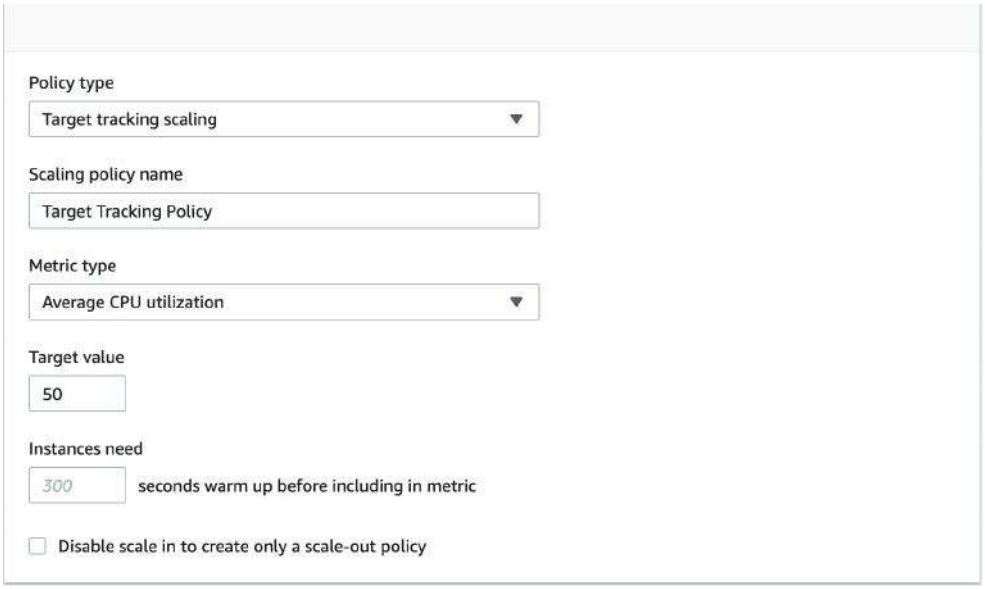
- Dynamic Scaling
  - Target Scaling

    Just specify the metric and target value to maintain. The ASG will scale accordingly by automatically setting up cloudwatch alarms that trigger the scaling action.



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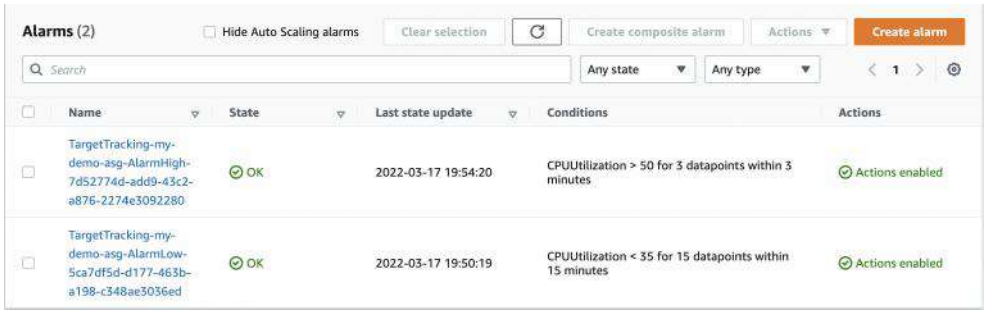

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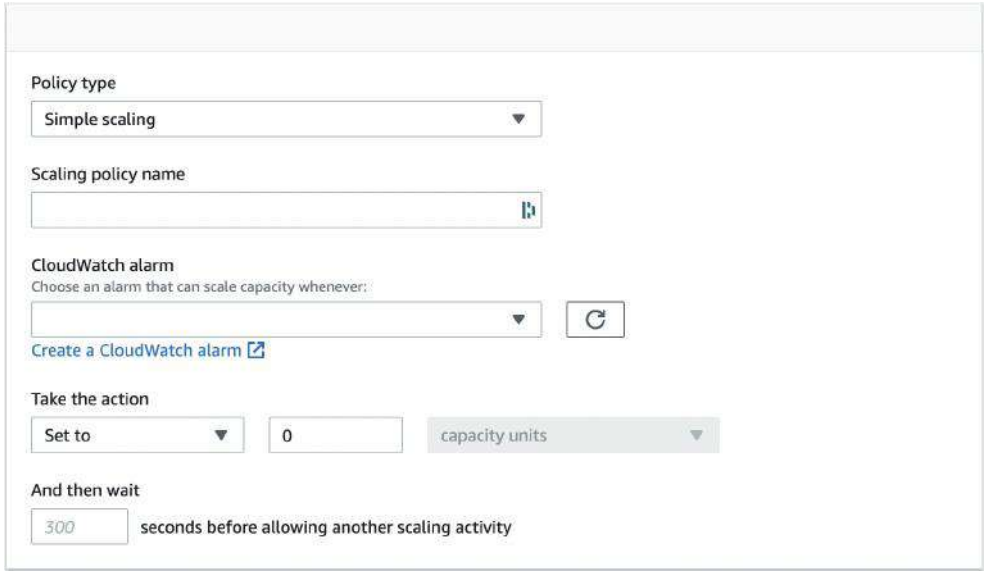
- Simple Scaling

  Here, we need to specify a CloudWatch alarm and the action.



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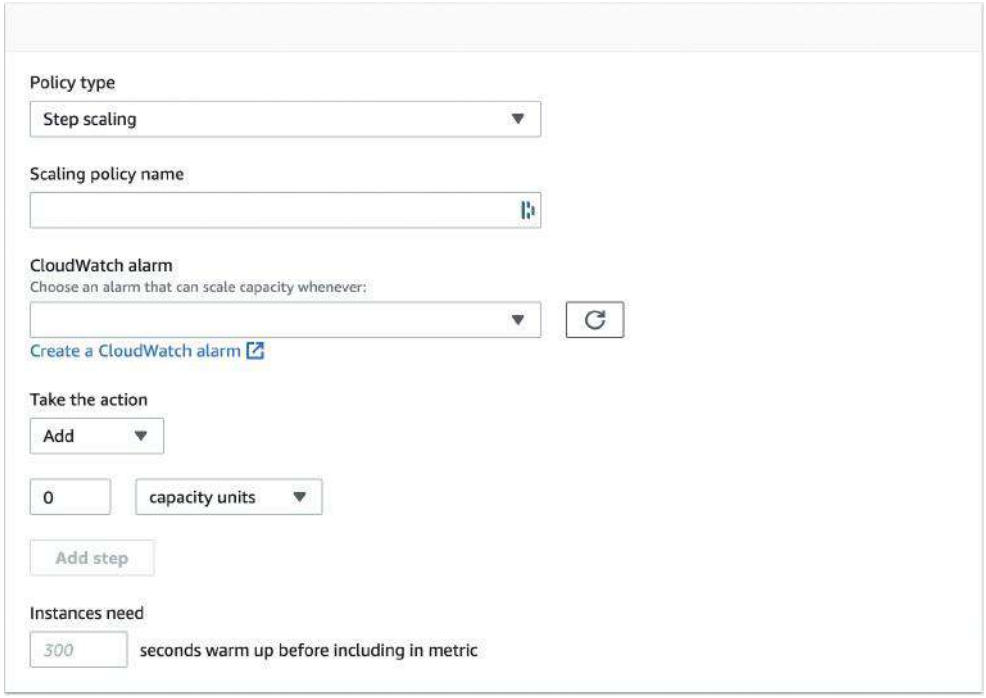
- Step Scaling

  Like simple scaling, but we can specify steps to scale gradually.



Untitled

- Test scaling by stressing the EC2 instance

  Connect to an EC2 instance and install stress by running these two linux commands:

  ```
  sudo amazon-linux-extras install epel -y
  sudo yum install stress -y
  ```

  After installing:

  Stress 4 vCPUs: `stress -c 4`

  This will make the CPU utilization go up and should trigger scaling if your metric was set to CPU utilization.

  To stop the stressing, reboot all the active instances.

▼ Scaling Policies

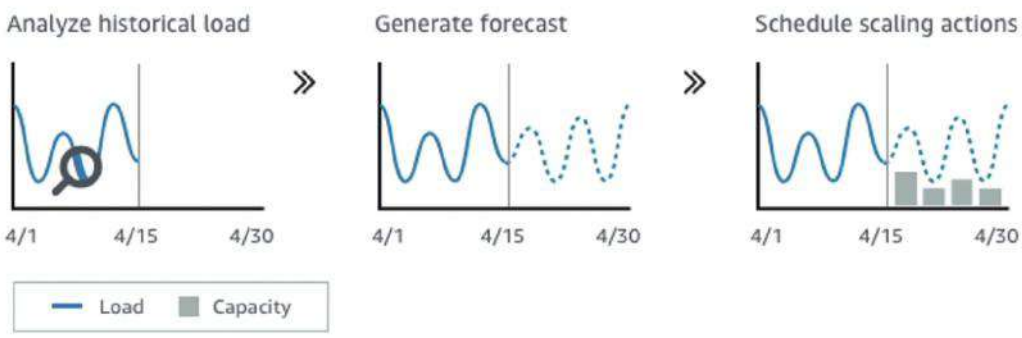
Two types of scaling Policies

▼ Dynamic Scaling Policies

- Scheduled Actions
  - Anticipate a scaling based on known usage patterns
  - Example: increase the min capacity to 10 at 5 pm on Fridays
- Target Tracking Scaling
  - Most simple and easy to set-up. Just ask the ASG to maintain a metric and scale accordingly. The ASG automatically creates cloudwatch alarms for this to work.
  - Example: I want the average ASG CPU to stay at around 40% and let ASG scale accordingly
- Simple / Step Scaling
  - Need to setup CloudWatch alarms and specify the actions.
  - Example: When CPU > 70%, then add 2 units and when CPU < 30%, then remove 1 unit. CloudWatch alarms will be the trigger points in this case.

▼ Predictive Scaling Policies

This is a new kind of scaling where the historical data is used to predict the load patterns using ML forecast load and schedule scaling ahead. We need to specify the metric based on which we want to scale our ASG and it will automatically create a forecast for that metric and scale accordingly.



▼ Good metrics to scale on

- CPU Utilization: average CPU utilization across your instances
- RequestCountPerTarget: to make sure the number of requests per EC2 instances is stable
- Average Network In / Out: if you're application is network bound, meaning it involves a lot of download or upload and the network could become a bottleneck
- Any custom metric (that you push using CloudWatch)

  We can auto scale based on a custom metric (ex: number of connected users). To set this up:

  1. Send custom metric from application on EC2 to CloudWatch using the PutMetric API
  2. Create CloudWatch alarm to react to low / high values
  3. Use the CloudWatch alarm as the scaling policy for ASG

▼ Scaling Cooldown

After a scaling activity happens, the ASG is in a cooldown period (default 300 seconds) during which it will not launch or terminate additional instances (it will ignore scaling requests) to allow the metrics to stabilize.

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

▼ Section 9: AWS Fundamentals: RDS + Aurora + ElastiCache

▼ Relational Database Service (RDS)

▼ Theory

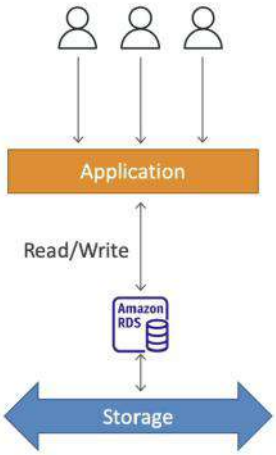
▼ Intro

- It's a managed DB service where SQL is used as the query language.
- Supported database engines:
  - Postgres
  - MySQL
  - MariaDB
  - Oracle
  - Microsoft SQL Server
  - Aurora (AWS Proprietary database)
- 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)
- You can't SSH into your RDS instances. Since RDS is managed by AWS, we don't have access to the underlying EC2 instances.

▼ Storage Auto Scaling

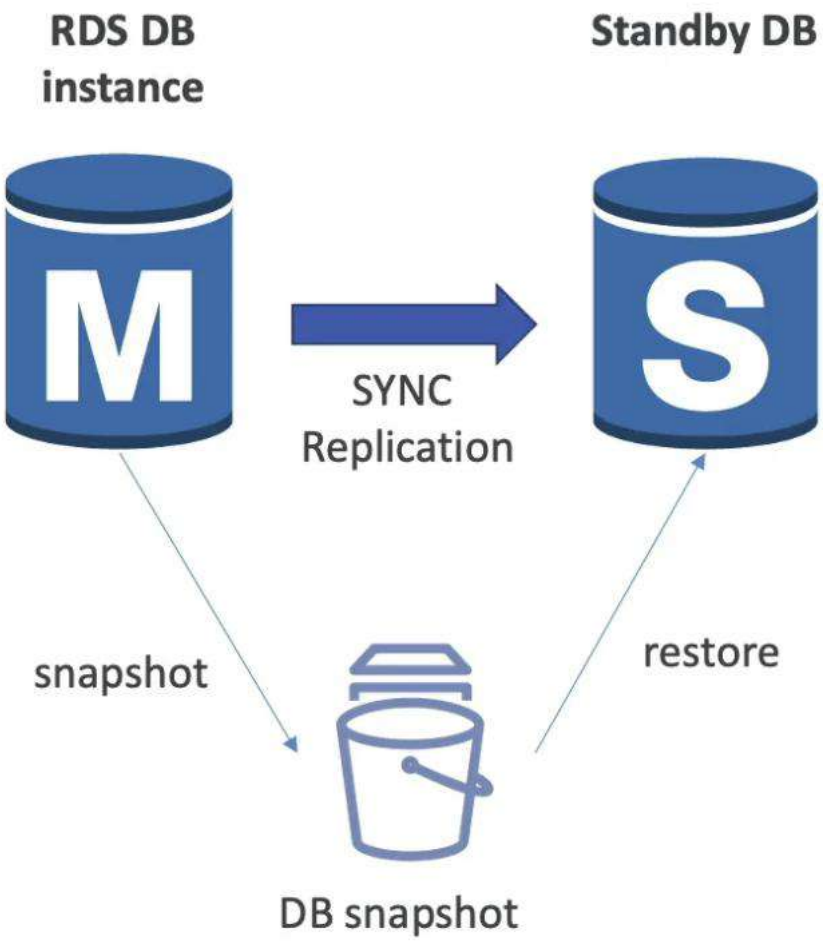
- Helps you increase storage on your RDS DB instance dynamically. When RDS detects that your DB is running out of free space, it scales automatically within a maximum storage threshold (set by you).
- Condition for automatic storage scaling:
  - Free storage is less than 10% of allocated storage
  - Low-storage lasts at least 5 minutes
  - 6 hours have passed since last modification
- Avoids manually scaling your database storage
- Useful for applications with unpredictable workloads
- Supports all RDS database engines (MariaDB, MySQL, PostgreSQL, SQL Server, Oracle.



▼ **RDS Read Replicas**

▼ Intro

- Read Replicas allow us to scale the read operation on RDS. This is done by creating up to 5 replicas of the original DB within AZ, cross AZ or cross region.
- Replication is asynchronous, so reads are eventually consistent. This means if the application reads some data from any of the replicas before the new data is replicated, the application might receive the old data. Example: You have set up read replicas on your RDS database, but users are complaining that upon updating their social media posts, they do not see their updated posts right away.
- Replicas can be promoted to their own DB
- Applications must update the connection string to leverage read replicas
- Read replicas are used for SELECT (read only kind of statements not INSERT, UPDATE, DELETE)



▼ RDS Custom

new →

▼ Backups

- Automated Backups (automatically enabled in RDS)
  - Daily full backup of the database (during the maintenance window that you define)

        - Transaction logs are backed-up by RDS every 5 minutes which gives us the ability to restore to any point in time (from oldest backup to 5 minutes ago)
        - 7 days retention (can be increased to 35 days)
    - DB Snapshots:
        - Manually triggered by the user
        - Retention of backup for as long as you want

▼ Encryption

▼ Intro

▼ At rest encryption

- Possibility to encrypt the master & read replicas with AWS KMS AES-256 encryption
- Encryption has to be defined while creating the database
- If the master is not encrypted, the read replicas cannot be encrypted
- Transparent Data Encryption (TE) available for Oracle and SQL Server (alternative way of encrypting)
- Snapshots of un-encrypted RDS databases are un-encrypted
- Snapshots of encrypted RDS databases are encrypted

▼ In-flight encryption

- SSL certificates are required to encrypt data to RDS in flight
- Need to provide SSL options with trust certificate when connecting to database
- To enforce SSL:
    - PostgreSQL: rds.force_ssl=1 in the AWS RDS Console (Parameter Group)
    - MySQL: Within the DB: GRANT USAGE ON ** TO ‘mysqluser’@‘%’ REQUIRE SSL; (SQL command)

▼ Encryption Operations

- Encrypting RDS snapshots
    - Take a snapshot of the RDS (unencrypted)
    - Copy the snapshot and enable encryption for it
- To encrypt an un-encrypted RDS database:
    - Create a snapshot of the un-encrypted database
    - Copy the snapshot and enable encryption for the snapshot
    - Restore the database from the encrypted snapshot
    - Migrate applications to the new database, and delete the old database

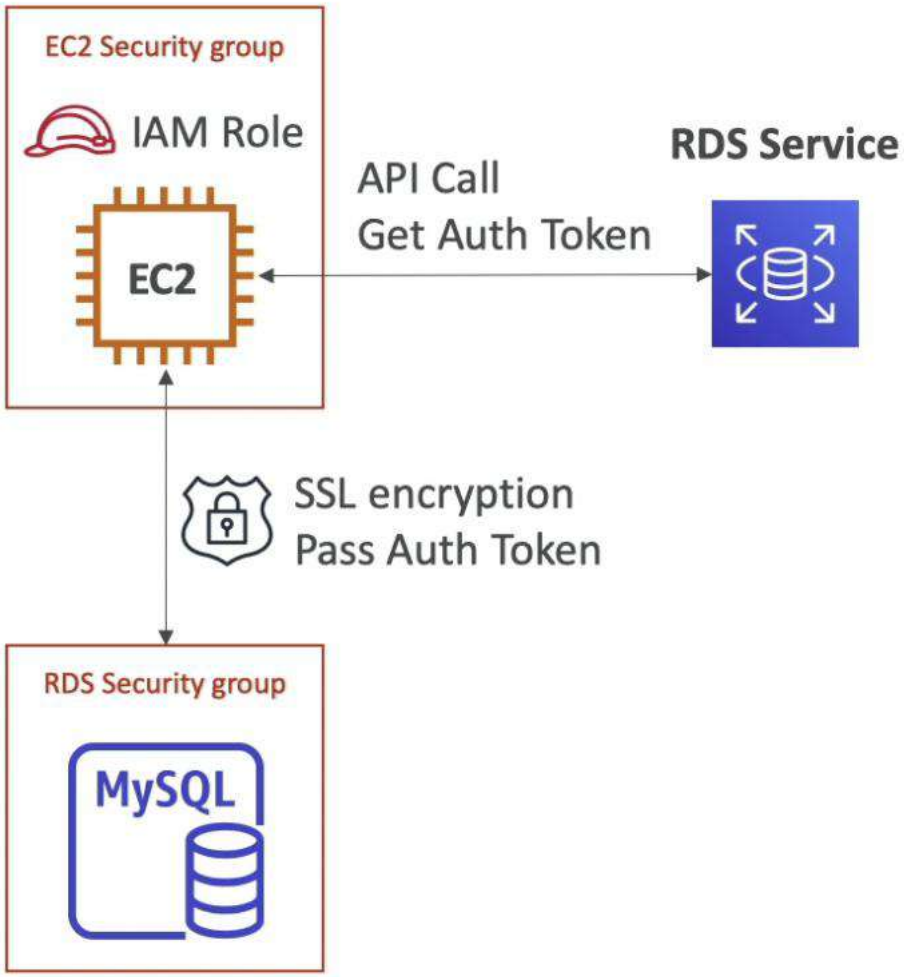
▼ Network Security

- RDS databases are usually deployed within a private subnet, not in a public one
- RDS security works by leveraging security groups (the same concept as for EC2 instances) it controls which IP / security group can communicate with RDS

▼ IAM

- IAM policies help control who can **manage** (create or modify) AWS RDS (through the RDS API)
- Traditional Username and Password can be used to login into the database
- IAM-based authentication can be used to login into RDS MySQL & PostgreSQL

  In the diagram below, the EC2 instance has an IAM role which allows is to make an API call to the RDS service to get the Auth token which it uses to access the MySQL database.



- To access the database, you don’t need a password, just an authentication token obtained through IAM & RDS API calls
- IAM database authentication works with MySQL and PostgreSQL
- Auth token has a lifetime of 15 minutes
- Benefits:
  - Network in/out is encrypted using SSL
  - Users are centrally managed by IAM instead of RDS
  - Can leverage IAM Roles and EC2 Instance profiles for easy integration

▼ Responsibilities

Your responsibility:

- Check the ports / IP / security group inbound rules in DB’s SG
- In-database user creation and permissions or manage through IAM
- Creating a database with or without public access
- Ensure parameter groups or DB is configured to only allow SSL connections

AWS responsibility:

- No SSH access
- No manual DB patching
- No manual OS patching

- No way to audit the underlying instance

▼ Hands On

- Create an RDS database

  RDS → Databases → Create database

  Engine type: MySQL

  Template: production

  Credentials: arkalim : guitar123

  DB instance class: burstable (for free tier)

  Instance type: t2micro

  Storage type: gp2

  Public Access: enabled (for accessing via the internet)

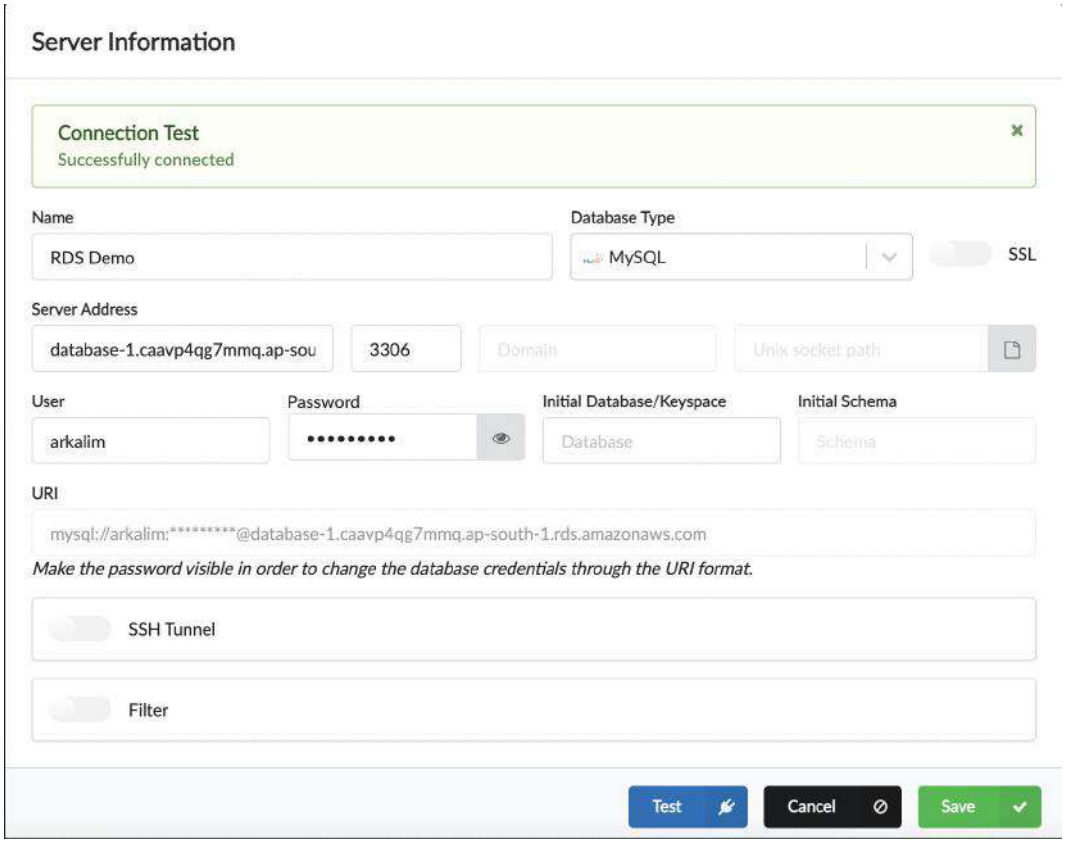
  ⛔ The security group that you create during the RDS database creation will only allow incoming TCP traffic on port 3306 (DB port) from your public IP at the time of creating the database. So, if you don't have a static IP, you need to modify the security group to allow incoming traffic from anywhere.

- Connect to RDS database

  Download SQL electron GUI (DB client)

  Sqlectron - One single DB client for any relational DB

  Open SQL Electron and create a new connection using the RDS endpoint as the server address.



  Once connected, we can run SQL queries.

- Delete an RDS database

  Select the DB → Modify → Disable deletion protection → Select the DB → Action → Delete

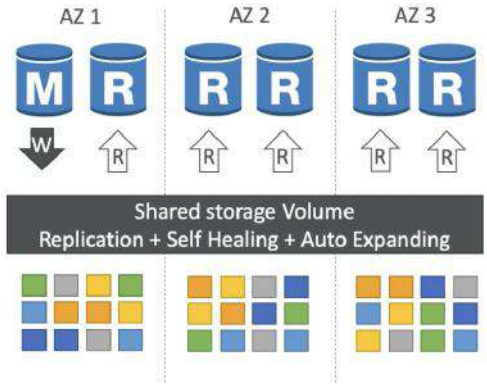
▼ Amazon Aurora (part of RDS)

▼ Intro

- 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 (best feature)
- 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
- Natively supports High Availability
- Aurora costs more than RDS (20% more) but is more efficient

▼ High Availability and Read Scaling

In the diagram below, each color square represents a unit of data. So, in total 6 copies of a data is maintained across 3 AZ. Also, one master and 5 read replicas are present.

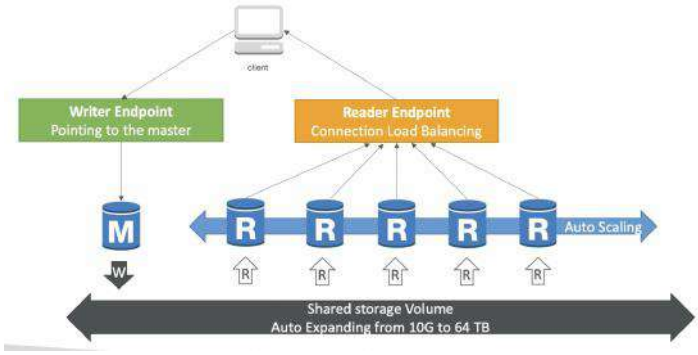


- Aurora maintains 6 copies of your data across 3 AZ:
  - 4 copies out of 6 needed for writes (can still write if 1 AZ completely fails)
  - 3 copies out of 6 need for reads
- Self healing with peer-to-peer replication (if some data is corrupted, it will be automatically healed)
- Storage is striped across 100s of volumes (more resilient)
- Only one Aurora instance (master) takes writes. But master + up to 15 Aurora Read Replicas can serve reads
- Automated failover for master in less than 30 seconds. So, if the master is down, one of the read replicas will replace it as the new master within 30 seconds.
- Support for Cross Region Replication

▼ Aurora DB Cluster

The Aurora DB cluster consists of a master DB and some read replicas. Only the master is allowed to perform write operations. So, there is a writer endpoint (always pointing to the master) which is used by the client to write data into the DB. The read replicas have auto scaling which can dynamically change the number of read replicas at a given point in time. So, there is load balancing implemented at the connection level (not at the statement level). So, all the read replicas are connected to the reader endpoint which is used by the client to read data from DB.

⛔ Aurora also features multi-master which allows multiple write instances to be connected to the same storage



▼ 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 (amazing feature)

▼ Hands on

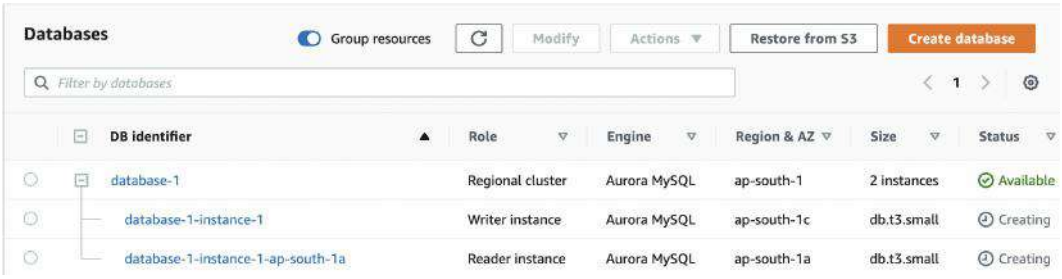
▼ Create an Aurora DB

RDS → Create database

Engine type: Aurora

DB type: t3.small

Once created, the Aurora cluster will contain 2 instances (reader and writer). Both of these instances will have separate endpoints (reader and writer endpoints) which can be used by the application to read / write data into the DB. Since, I enabled multi AZ instance creation, the reader and writer instances are in different AZs.



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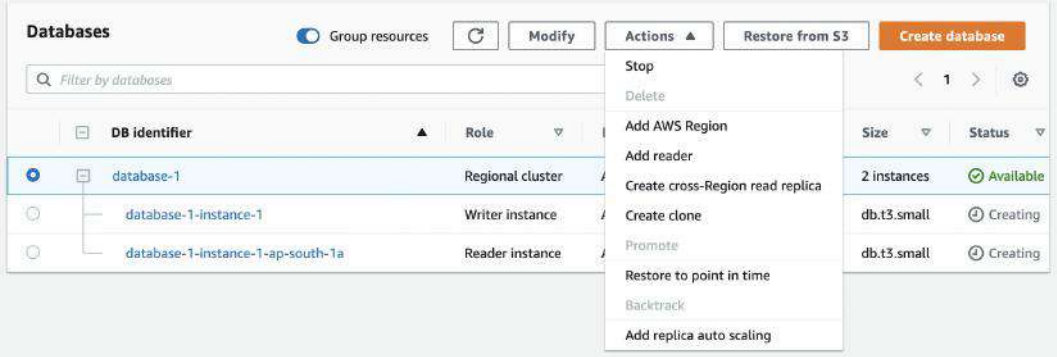
We can also add a reader to the cluster or create a cross-region read replica.



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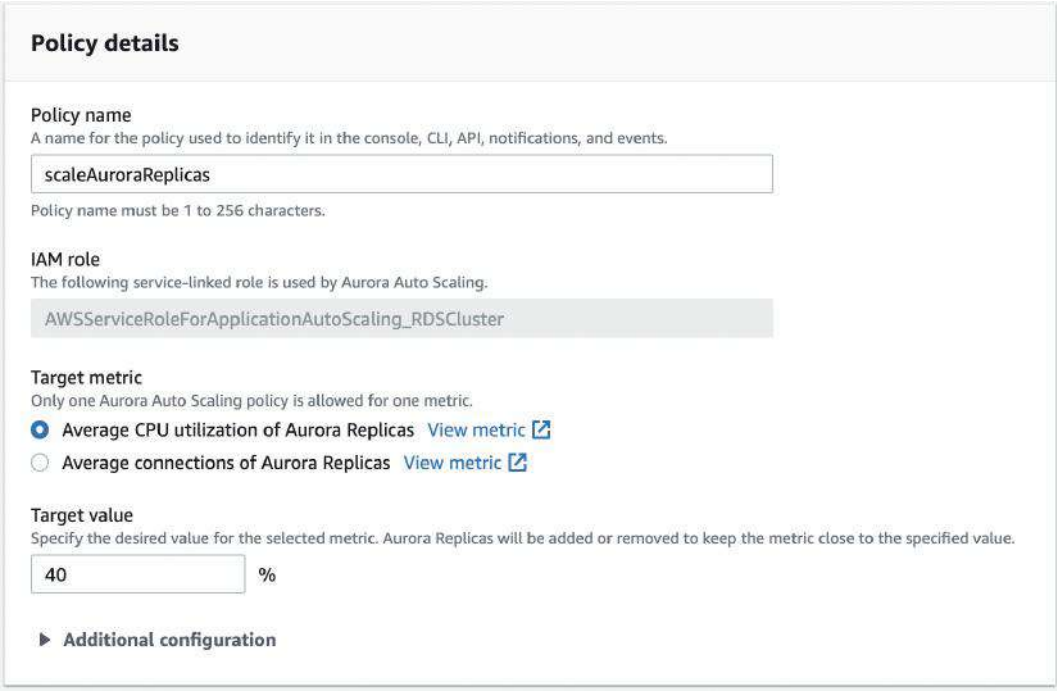
▼ Add replica auto scaling

This allows the read replicas to auto scale horizontally based on the target metric.

RDS → Databases → Select database → Actions → Add replica auto scaling



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▼ Delete Aurora DB Cluster

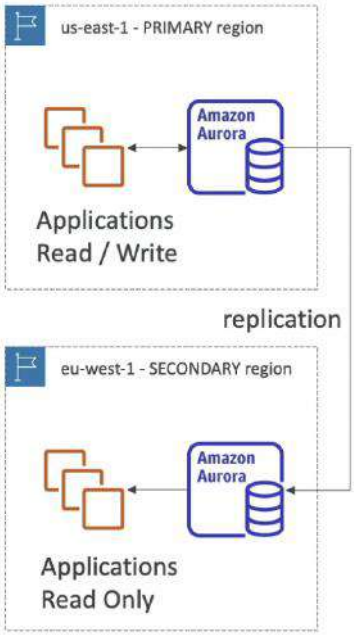
▼ Global Aurora

Aurora Cross Region Read Replicas:

- Read replicas are created in other regions
- Useful for disaster recovery
- Simple to put in place

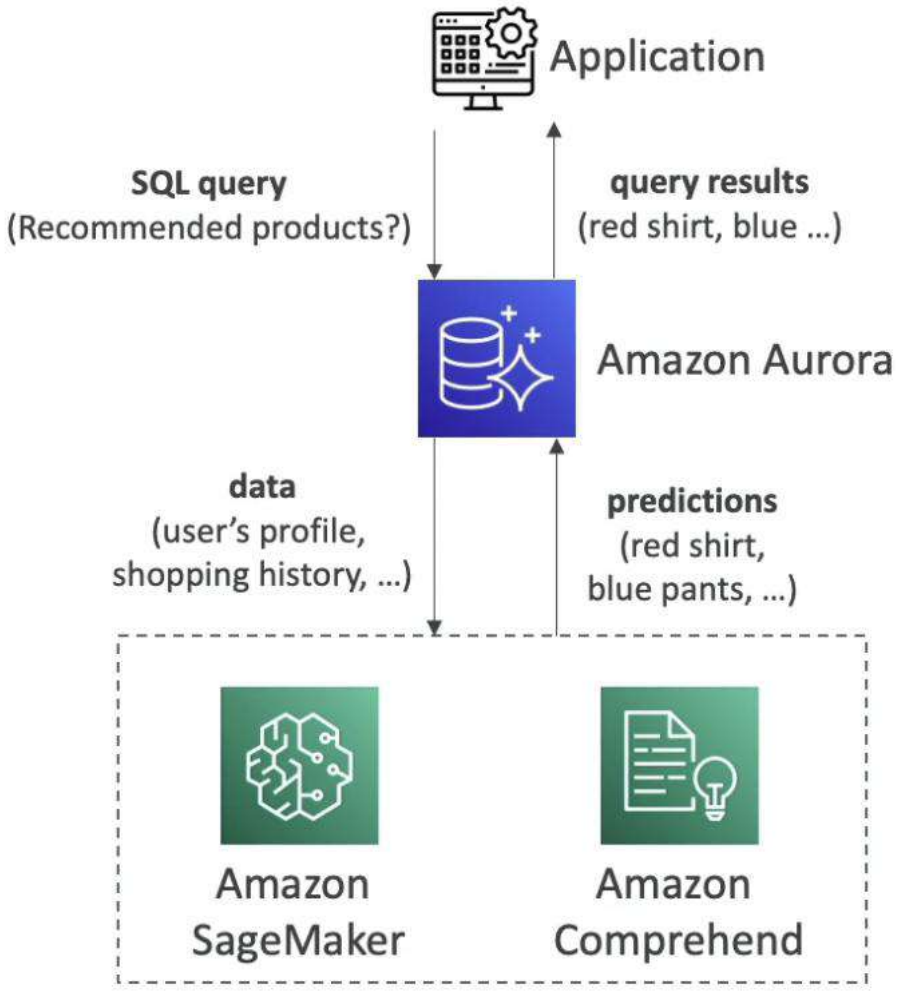
Aurora Global Database (recommended):

- Entire database is replicated across regions
- 1 Primary Region (read / write)
- Up to 5 secondary (read-only) regions (replication lag < 1 second)
- Up to 16 Read Replicas per secondary region
- Helps for decreasing latency (for clients in other geographical regions)
- **In case there is a database outage in one region, promoting another region (for disaster recovery) has an RTO (recovery time objective) of less than 1 minute.**



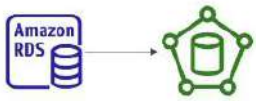
▼ Machine Learning (ML)

- Enables you to add ML-based predictions to your applications via SQL
- Simple, optimized, and secure integration between Aurora and AWS ML services
- Supported services
  - Amazon Sage Maker (create any ML model in the backend)
  - Amazon Comprehend (for sentiment analysis)
- You don’t need to have ML experience
- Use cases: fraud detection, ads targeting, sentiment analysis, product recommendations



▼ RDS and Aurora - Backup and Monitoring

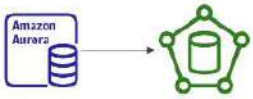
RDS Backups



- Automated backups:
  - Daily full backup of the database (during the maintenance window)
  - Transaction logs are backed-up by RDS every 5 minutes
  - => ability to restore to any point in time (from oldest backup to 5 minutes ago)
  - 1 to 35 days of retention, set 0 to disable automated backups
- Manual DB Snapshots
  - Manually triggered by the user
  - Retention of backup for as long as you want

- Trick: in a stopped RDS database, you will still pay for storage. If you plan on stopping it for a long time, you should snapshot & restore instead

Aurora Backups



- Automated backups
  - 1 to 35 days (cannot be disabled)
  - point-in-time recovery in that timeframe
- Manual DB Snapshots
  - Manually triggered by the user
  - Retention of backup for as long as you want

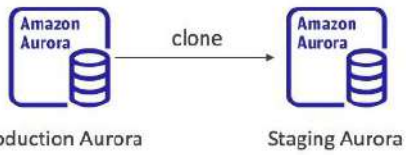
RDS & Aurora Restore options

- Restoring a RDS / Aurora backup or a snapshot creates a new database
- Restoring MySQL RDS database from S3
  - Create a backup of your on-premises database
  - Store it on Amazon S3 (object storage)
  - Restore the backup file onto a new RDS instance running MySQL

- Restoring MySQL Aurora cluster from S3
  - Create a backup of your on-premises database using Percona XtraBackup
  - Store the backup file on Amazon S3
  - Restore the backup file onto a new Aurora cluster running MySQL

Aurora Database Cloning

- Create a new Aurora DB Cluster from an existing one
- Faster than snapshot & restore
- The new DB cluster uses the same cluster volume and data as the original but will change when data updates are made
- Very fast & cost-effective
- Useful to create a "staging" database from a "production" database without impacting the production database

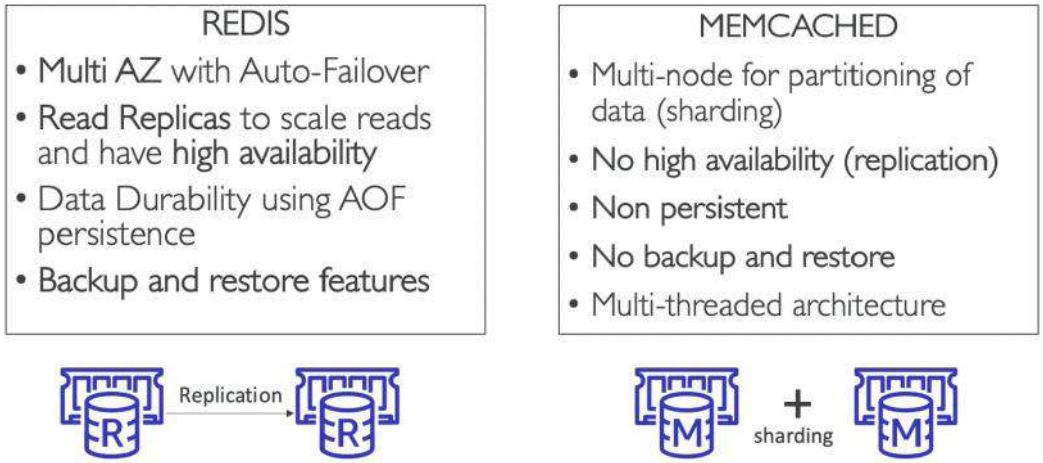


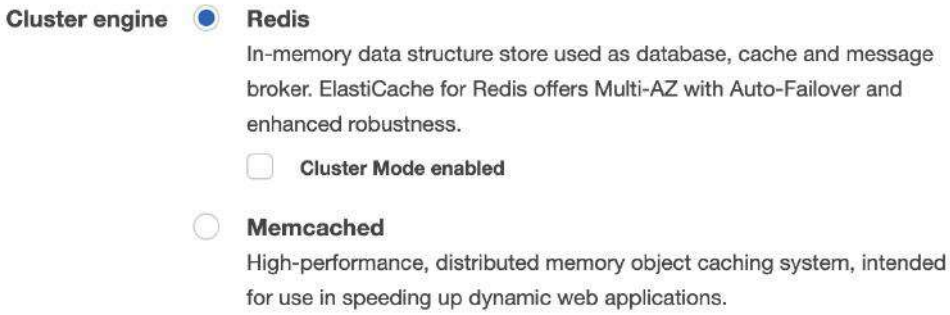
▼ Security

▼ **Redis vs Memcached**

Amazon ElastiCache for Redis is a blazing fast in-memory data store that provides sub-millisecond latency to power internet-scale real-time applications. Amazon ElastiCache for Redis is a great choice for real-time transactional and analytical processing use cases such as caching, chat/messaging, gaming leaderboards, geospatial, machine learning, media streaming, queues, real-time analytics, and session store. ElastiCache for Redis supports replication, high availability, and cluster sharding right out of the box. Amazon ElastiCache for Redis is also HIPAA Eligible Service.

Amazon ElastiCache for Memcached is a Memcached-compatible in-memory key-value store service that can be used as a cache or a data store. Amazon ElastiCache for Memcached is a great choice for implementing an in-memory cache to decrease access latency, increase throughput, and ease the load off your relational or NoSQL database. Session stores are easy to create with Amazon ElastiCache for Memcached. Elasticache for Memcached is not HIPAA eligible.





▼ Create an ElastiCache

ElastiCache → Redis → Create

Encryption at rest: Uses KMS

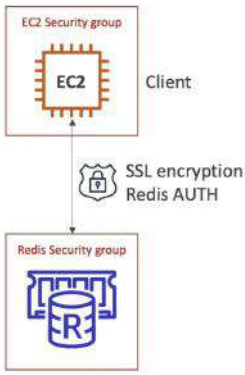
Encryption in transit:

We can enable Redis Auth: In this case, we need to create a Redis Auth Token which will be required by our applications to connect to Redis.

▼ Cache Security

- All caches in ElastiCache do not support IAM authentication. IAM policies on ElastiCache are only used for AWS API-level security such as creating / deleting caches.
- To authenticate to Redis, we can use Redis Auth. This requires us to set a “password/token” when we create a Redis cluster. This is an extra level of security for your cache (on top of security groups). It also supports SSL in flight encryption.
- Memcached supports SASL-based authentication (advanced)

Redis’ security group should only allow EC2 security group for incoming requests. Additionally, Redis Auth can be used for authentication if we are using Redis as the caching engine. SSL encryption is used for in-flight encryption.



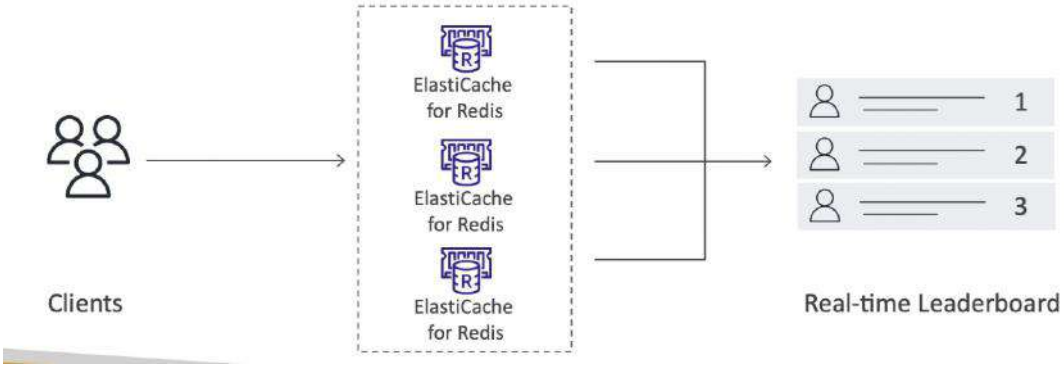
▼ Write patterns for ElastiCache

- Lazy Loading: all the read data is cached, data can become stale in cache
- Write Through: Add or update data in the cache when written to a DB (no stale data)
- Session Store: store temporary session data in a cache and remove the data based on TTL (time to live) for the session data

▼ Gaming Leaderboard using Redis - Use Case

- Gaming Leaderboards are computationally complex
- **Redis Sorted Sets** guarantee both uniqueness and element ordering
- Each time a new element added, it’s ranked in real time, then added in correct order

Using the Sorted Sets in a Redis cluster, we can build a real-time leaderboard where every instance of ElastiCache has the same up to date leaderboard.



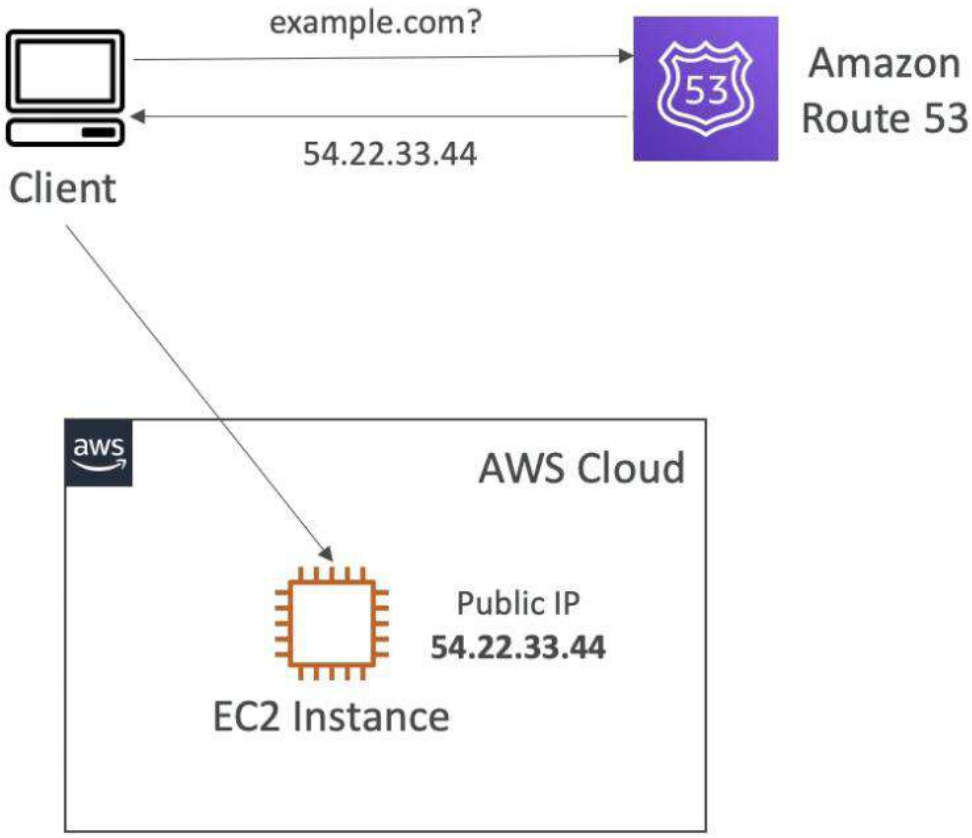
▼ List of Ports to be familiar with

Important ports:

- FTP: 21
- SSH: 22
- SFTP: 22 (same as SSH)
- HTTP: 80
- HTTPS: 443

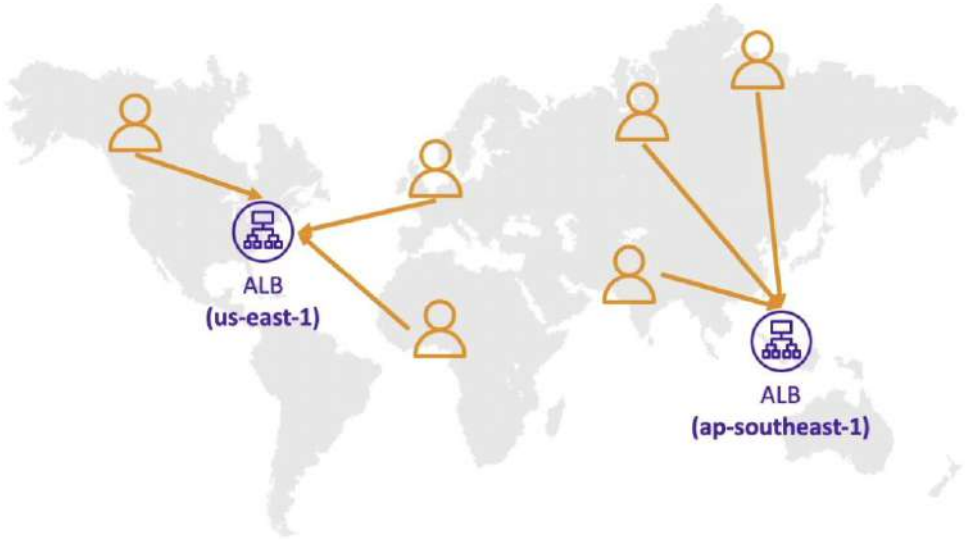
vs RDS Databases ports:

- PostgreSQL: 5432
- MySQL: 3306
- Oracle RDS: 1521
- MSSQL Server: 1433
- MariaDB: 3306 (same as MySQL)



▼ Records

- In Route 53, we are going to define a bunch of records which define how we want to route traffic for a domain. Each record contains:
  - Domain / Subdomain Name: e.g. example.com
  - Record Type: e.g. A, AAAA, CNAME etc.
  - Value: e.g. 12.34.56.78
  - Routing Policy: how Route 53 responds to queries
  - ▼ TTL: amount of time the records are cached at DNS Resolvers
    - High TTL (e.g. 24 hr)
      - Less traffic on Route 53
      - Possibly outdated records
    - Low TTL e.g., 60 sec.
      - More traffic on Route 53 (more cost)
      - Records are outdated for less time
      - Easy to change records as the change will be updated quickly in the client's cache.
    - Except for Alias records, TTL is mandatory for each DNS record



Create a record → same except Routing policy as Latency → When we put a IP we need to specify the region

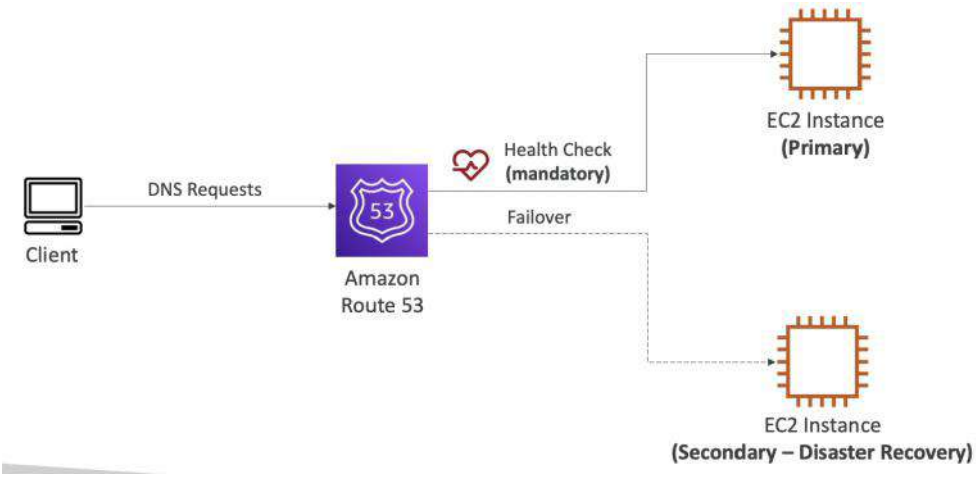
when we add a record again for a IP we need to specify the region

We can use VPN to check this by using different places near to set Regions

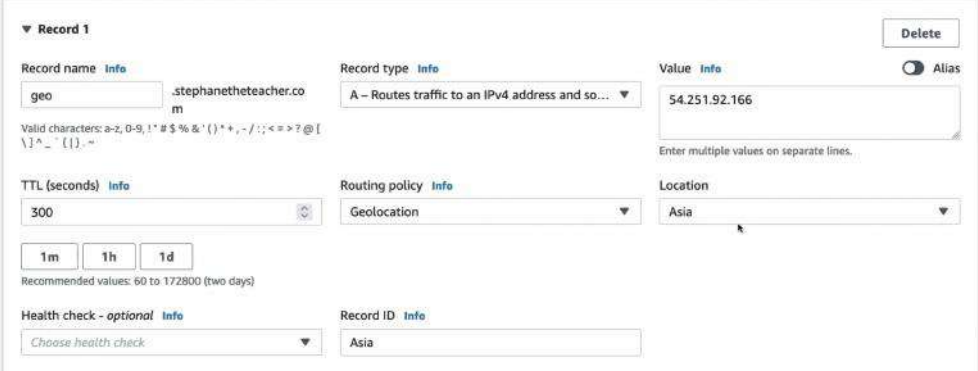
☐	latency.arkalim.org	A	Latency	Asia Paci...	35.154.11.198
☐	latency.arkalim.org	A	Latency	Europe (...	18.184.10.179
☐	latency.arkalim.org	A	Latency	US East ...	52.87.202.214

▼ Failover

Here, we can setup a primary EC2 instance with a mandatory health check. If the health check fails, the Route 53 will route the traffic to the secondary instance.

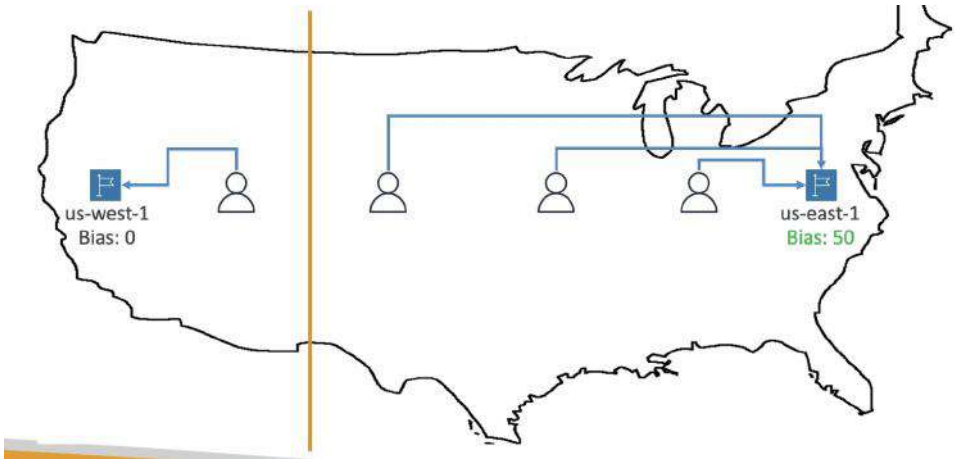


To achieve this we need to create two records of type failover in the hosted zone, one will be labelled as primary and the other will be secondary. A health check must be attached to the primary record.



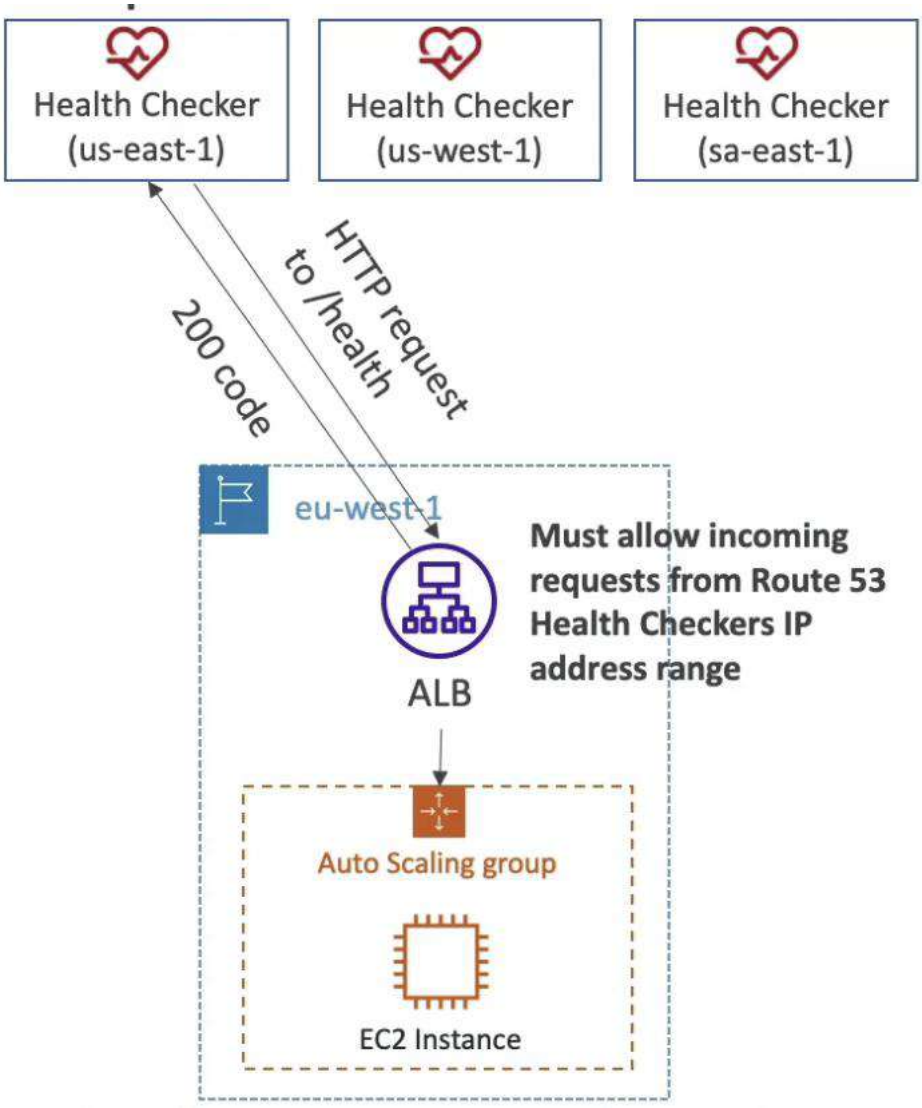
▼ Geo Proximity (using Route 53 Traffic Flow feature)

- Route traffic to your resources based on the geographic location of users and resources
- It provides the ability to shift more traffic to resources based on the defined bias. To change the size of the geographic region, specify bias values:
  - To expand (1 to 99) → more traffic to the resource
  - To shrink (-1 to-99) → less traffic to the resource
- Resources can be:
  - AWS resources (specify AWS region)
  - Non-AWS resources (specify Latitude and Longitude)
- You must use Route 53 Traffic Flow (advanced) to use this feature
- No bias means going to the close Region
- The higher the bias, the farther the decision boundary will be from that resource.
- **High Bias take more users to that Resource therefore increase the traffic**
- **Low Bias try to remove more users from that Resource, therefore decrease the traffic**



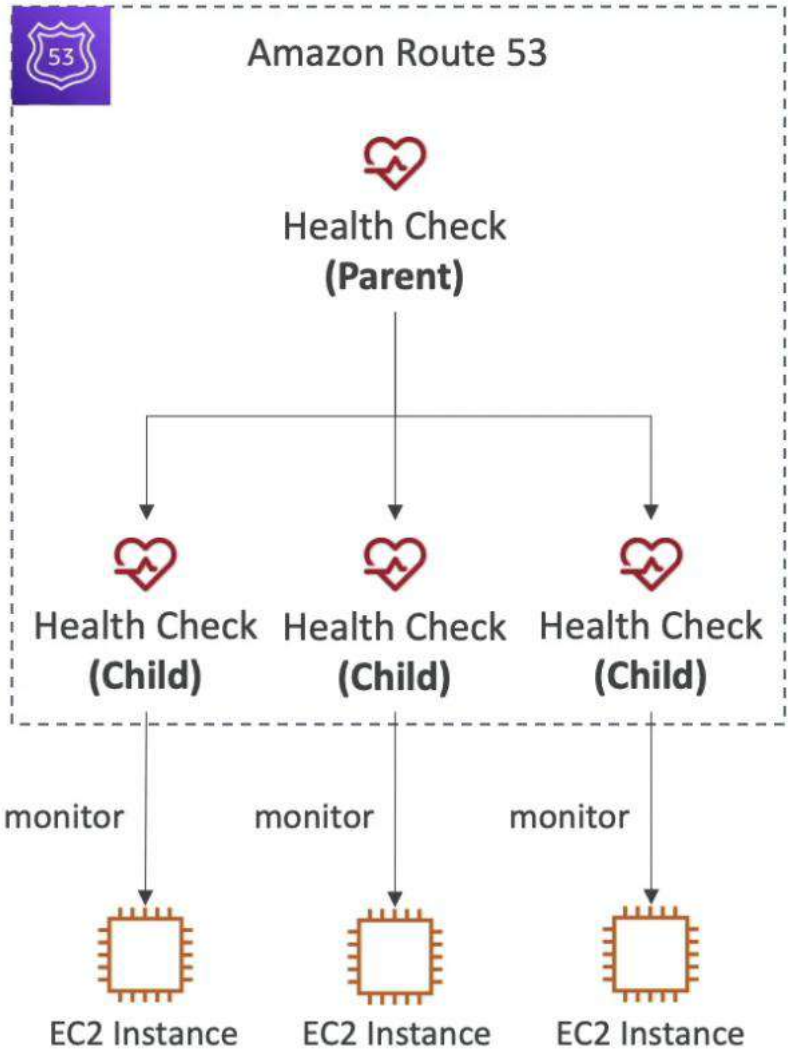
▼ Multi-Value

- Use when routing traffic to multiple resources
- Route 53 return multiple (max 8) values / resources
- Can be associated with Health Checks (only healthy resources will be returned). It is not possible in case you return multiple values from a simple routing policy since they don't support health checks. So, some of the returned values in that case may be unhealthy.
- Multi-Value (client-side load balancing) is not a substitute for having an ELB (server-side load balancing)



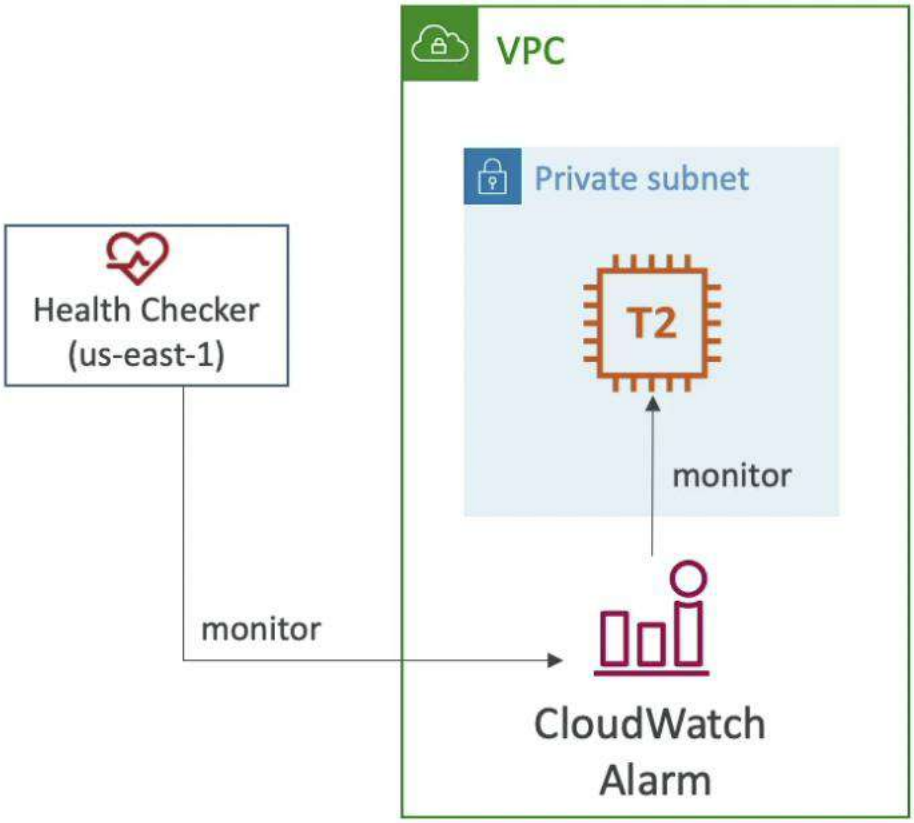
▼ Calculated Health Checks

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



▼ Health checks for private hosted zones

Route 53 health checkers are outside the VPC. They are not designed to perform health checks on private resources. They can’t access private endpoints (private VPC or on-premises resource). Instead, you can create a CloudWatch Metric and associate a CloudWatch Alarm to it, then create a Health Check that checks the CW alarm.



▼ Hands on

▼ Create health checks to monitor EC2 instances

Route 53 → Health Checks → Create health check

IP address should be of the EC2 instance

Untitled

▼ Create a calculated health check

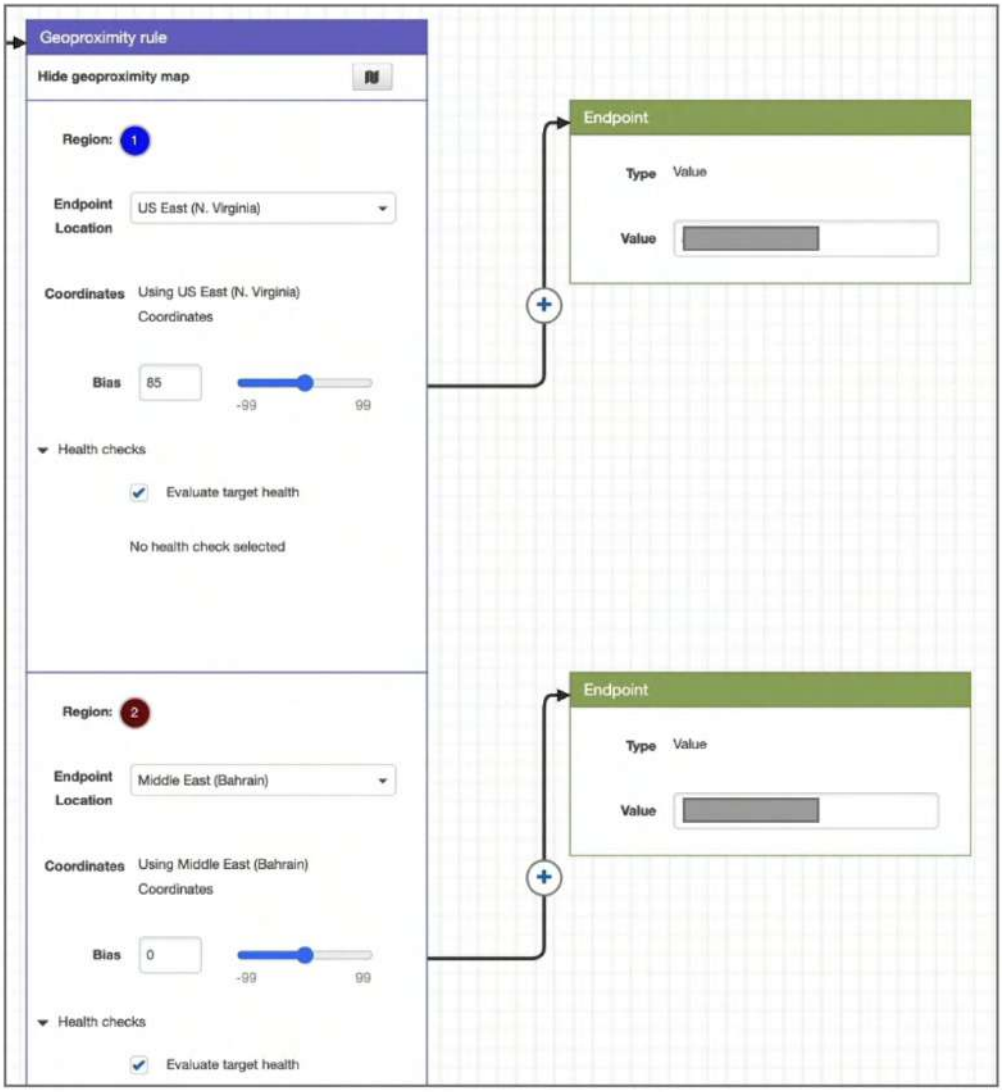
Since one of the instances is unhealthy, the calculated health check is also unhealthy.

Untitled

new →

▼ Traffic Policies

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



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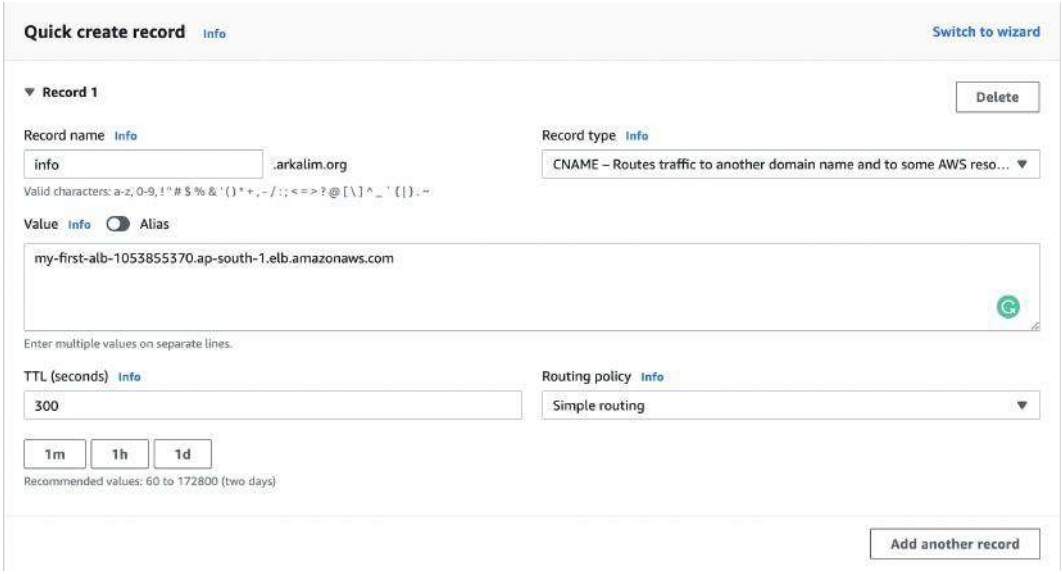
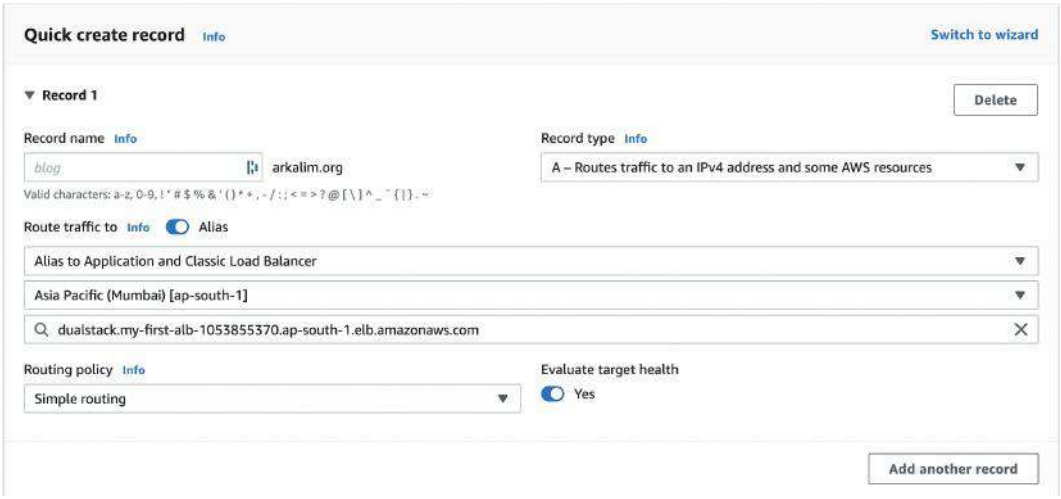


- Create an Alias record mapping the Zone Apex to an ALB

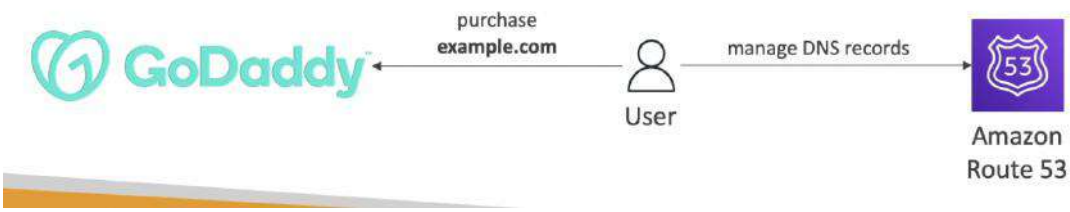
  Only Alias records can be used for this. CNAME records cannot map to root level hostnames.



- Delete a hosted zone
  - First delete all the records except the NS and SOA

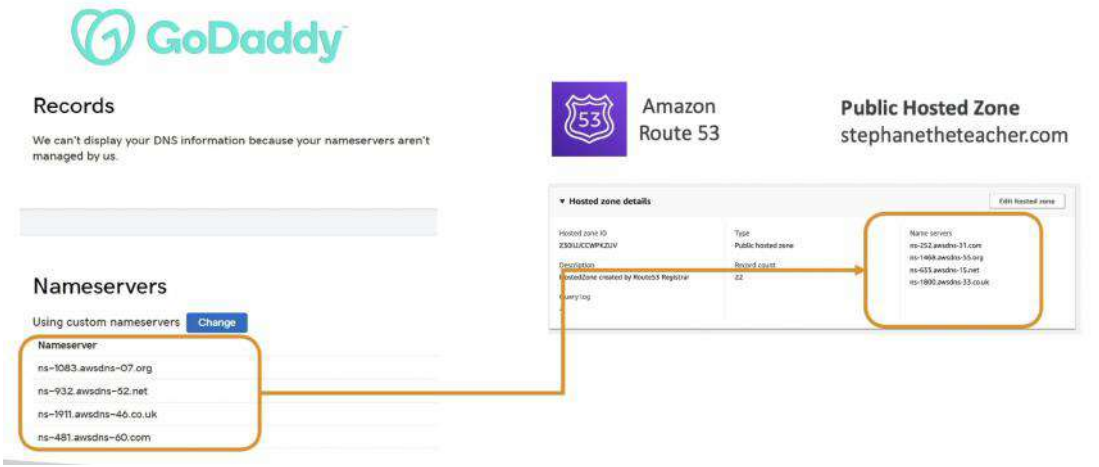
▼ 3rd party Domains and Route 53

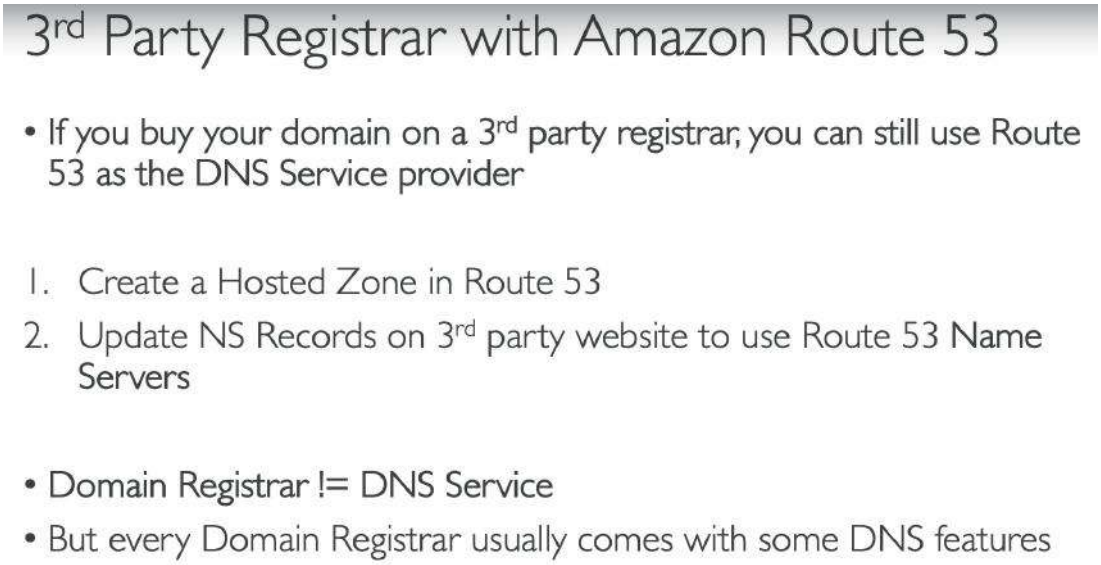
- Theory
  - You buy or register your domain name with a Domain Registrar typically by paying annual charges (e.g. GoDaddy, Amazon Registrar, etc.). The Domain Registrar usually provides you with a DNS service to manage your DNS records.
  - You can use another DNS service to manage your DNS records. Example: purchase the domain from GoDaddy and use Route 53 to manage your DNS records



- Use GoDaddy as registrar and Route 53 as DNS

  Once we register a hostname at GoDaddy, we need to update the name servers (NS) of GoDaddy to match the name servers of a public hosted zone created in Route 53. This way, GoDaddy will use Route 53's DNS.





▼ Section 11: Classic Solutions Architecture Discussions

▼ Solutions

In this section, we will see how all the technologies we have learned so far connects together to provide a solution. We will look at some case studies:

▼ WhatIsTheTime.com

Allows people to know the current time.

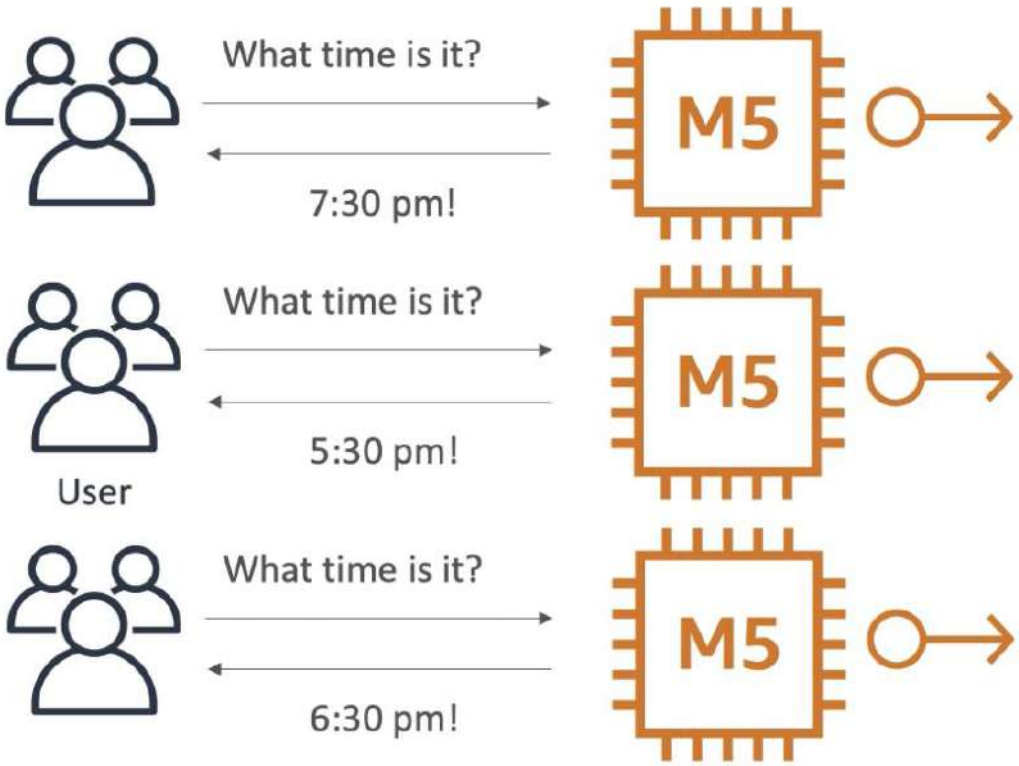
Stateless Web App: Database not needed

▼ Version 1

Single public EC2 instance with an elastic IP to keep it static.

Problem: if load increases, need to scale vertically.

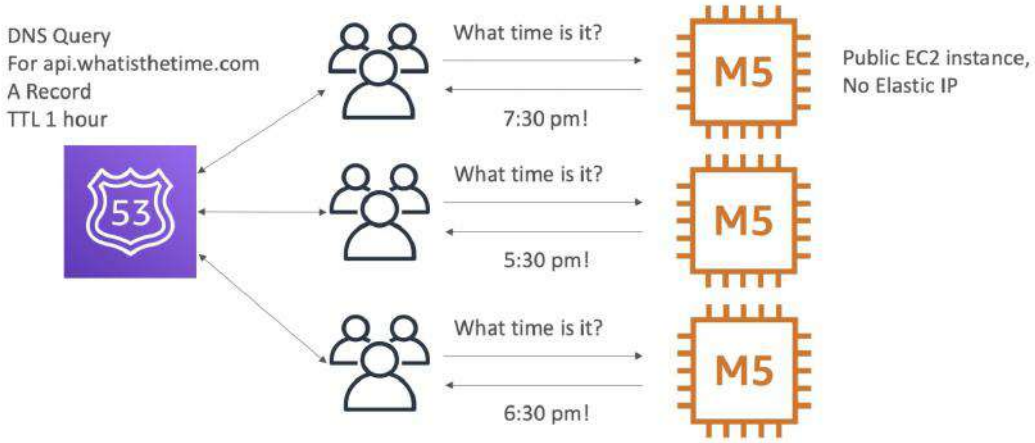
Problem: Users need to be aware of all the IPs and we can only have 5 elastic IPs max



▼ Version 4

Instead of using elastic IPs, use Route 53 to return the list of IPs of all the EC2 instances.

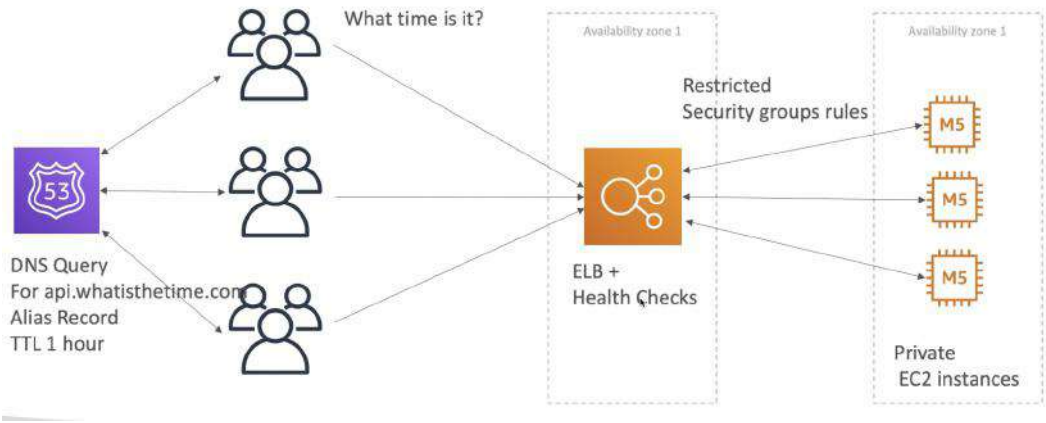
Problem: if an instance goes down, DNS will take some time to update based on health check (1h), so some users will experience down time. Also, not easy to add or remove instances as DNS takes some time to update.



▼ Version 5

Instead of letting the client select a public EC2 instance, we can do the load balancing on the server side using a load balancer. This will allow the EC2 instances to be private and restricted to be accessed only by the ELB (using security groups). Route 53 will have an alias record pointing to the ELB which using health checks will direct the traffic only to live instances.

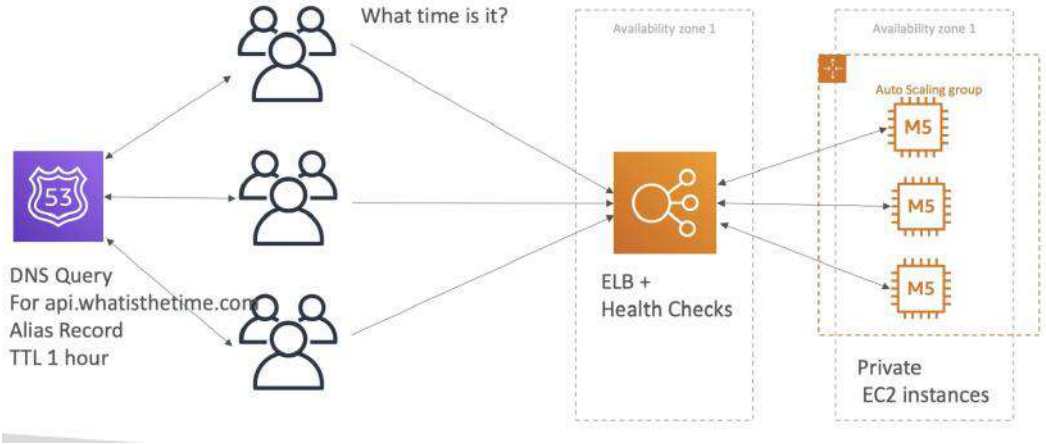
Problem: Horizontal Scaling is still manual



▼ Version 6

Auto scaling group is used to dynamically add or remove instances (horizontal scaling) and attach them to ELB.

Problem: Since all the instances and ELB are hosted in the same AZ, they might go down in case of a disaster.



▼ Version 7

Let’s make our app multi-AZ by setting up ELB in all the AZs and making the ASG span all the AZs. This will make our app highly available and resilient to failure.

Problem: Expensive as all the EC2 instances are on-demand even though we know that the minimum number of instances required to be highly available is 2.

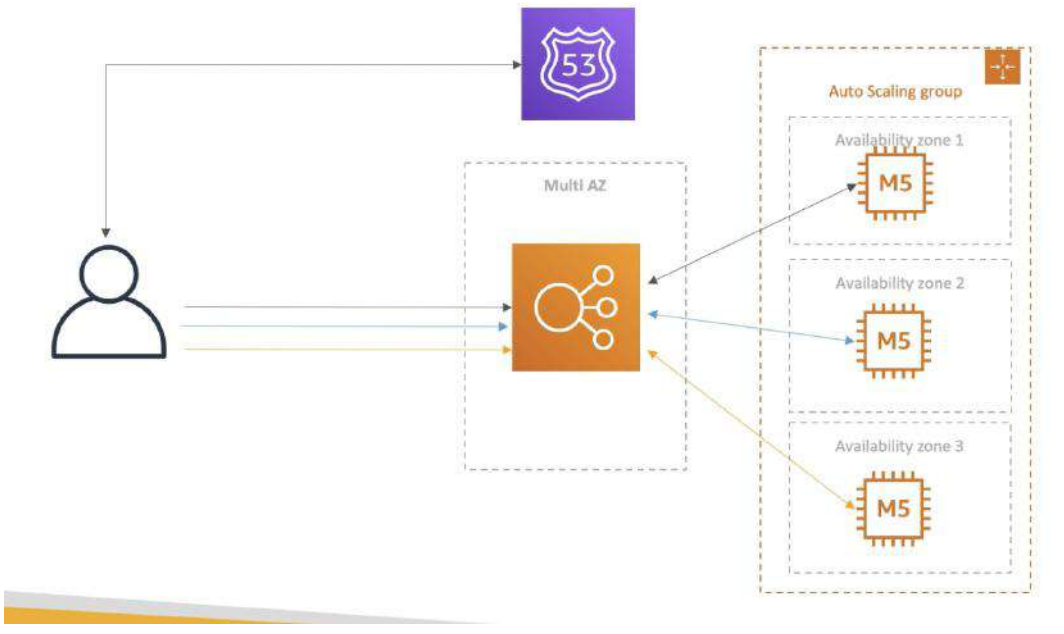
▼ MyClothes.com

Allows people to buy clothes online (100s of users at the same time). We need horizontal scalability and keep our web application as stateless as possible. Users should have their address stored in a database (stateful web app).

▼ Version 1

Multi AZ ASG with ELB (horizontally scalable solution)

Problem: User loses the cart info while navigating the website because ELB routes every request to a different instance.



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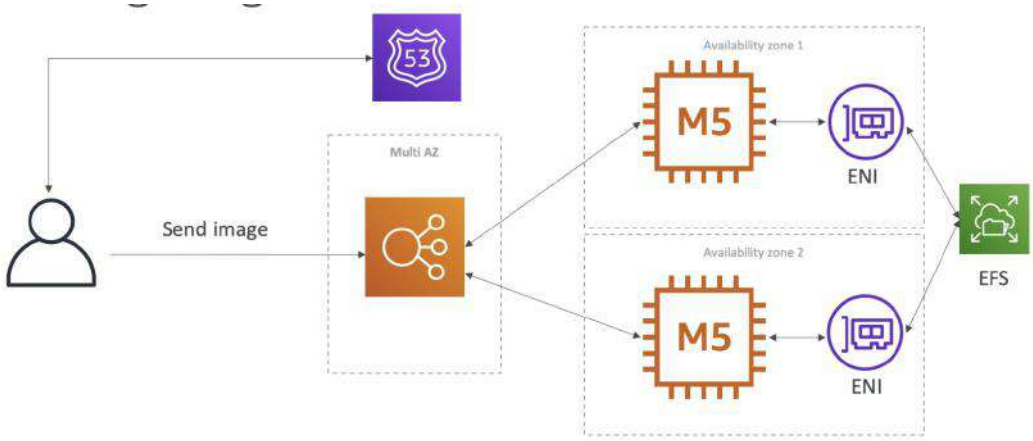
▼ Version 2

Implement session affinity (stickiness) at ELB. This will route all of the requests coming from a user to the same EC2 instance. Will solve the lost cart info issue.

Problem: if the instance serving user goes down, the state info will be lost.



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▼ Outro

- Aurora Database to have easy Multi-AZ and Read-Replicas
- Storing data in EBS (single instance application)
- Vs Storing data in EFS (distributed application)

▼ Instantiating Applications Quickly

EC2 Instances:

- Use a Golden AMI: Install your applications, OS dependencies etc.. beforehand and launch your EC2 instance from the Golden AMI. This is good for static configurations that will remain the same for every EC2 instances that we want to launch.
- Bootstrap using User Data: This is good for dynamic configurations that need to be fetched specifically for each EC2 instance. Example private IP, region etc.
- Hybrid: mix of Golden AMI and User Data (Elastic Beanstalk)

RDS Databases:

- Restore from a snapshot: the database will have schemas and data ready!

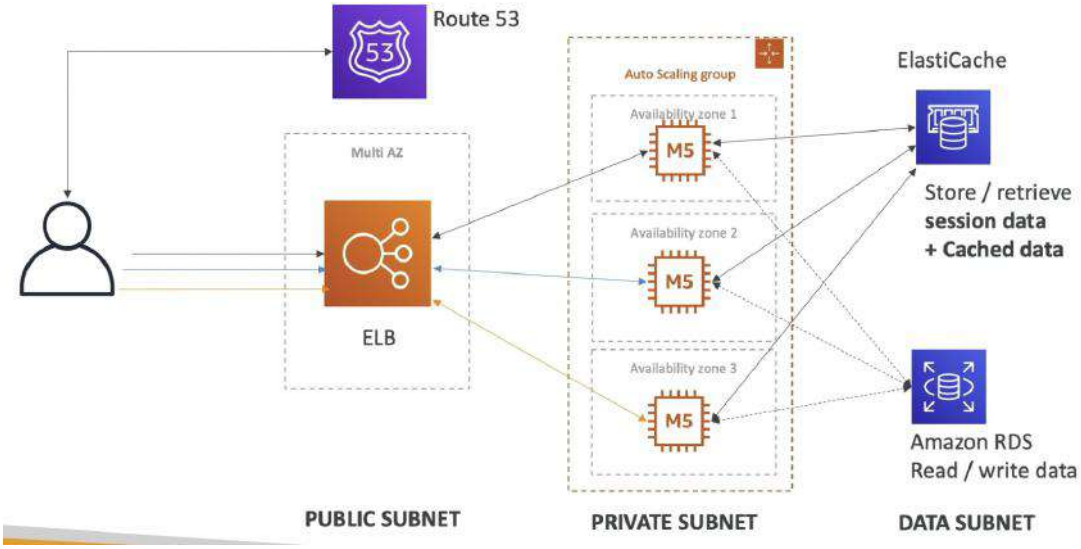
EBS Volumes:

- Restore from a snapshot: the disk will already be formatted and have data!

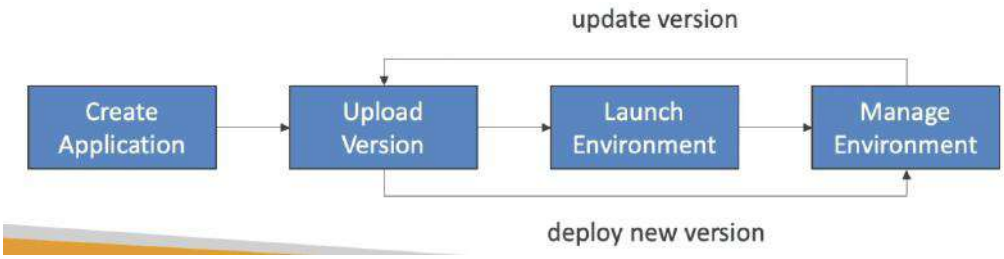
▼ Beanstalk

▼ Typical 3-tier Web App Architecture

This architecture (consisting of a public subnet, private subnet along with some database and cache) will be followed in pretty much every application that we build.



- Elastic Beanstalk
  - Theory
    - Intro
      - Elastic Beanstalk is a developer centric view of deploying an application on AWS. It re-uses all the components required to setup the web app architecture.
      - Managed by AWS
      - Automatically handles capacity provisioning, load balancing, scaling, application health monitoring, instance configuration, etc. but we still have full control over the configuration but it will be bundled in a single interface under Beanstalk.
      - Just the application code is the responsibility of the developer
      - Beanstalk is free but you pay for the underlying instances
    - Components
      - Application: collection of Elastic Beanstalk components (environments, versions, configurations, etc.)
      - Application Version: an iteration of your application code
      - Environment: Collection of AWS resources running an application version (can only have one application version at a time inside an environment). You can create multiple environments (dev, test, prod, etc.)
        - Tiers: Web Server Environment Tier & Worker Environment Tier
    - Process



    - Supported Platforms
      - Go
      - Ruby
      - Java SE
      - Packer Builder

▼ Section 12: Amazon S3 Introduction

▼ Intro

- S3 is a global AWS service
- Amazon S3 allows us 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
- Objects (files) have a key (the full path to the object):
  - s3://my-bucket/my_file.txt
  - s3://my-bucket/my_folderl/another_folder/my_file.txt
- The key is composed of prefix + object name
  - s3://my-bucket/my_folderl/another_folder/my_file.txt
- There’s no concept of “directories” within buckets (just keys with very long names that contain slashes). However, the UI will trick you to think otherwise by displaying S3 buckets as containing folders.
- Object values are the content of the body:
  - Max Object Size is 5TB, but if uploading an object of more than 5GB, must upload it in parts (multi-part upload).
  - Objects can have Metadata (list of text key / value pairs - system or user metadata)
  - Objects can have Tags (Unicode key / value pair up to 10) - useful for security / lifecycle
  - Objects will have a Version ID (if versioning is enabled)

▼ Buckets & Objects - Hands on

- Create an S3 bucket

  S3 → Create bucket

- Upload files

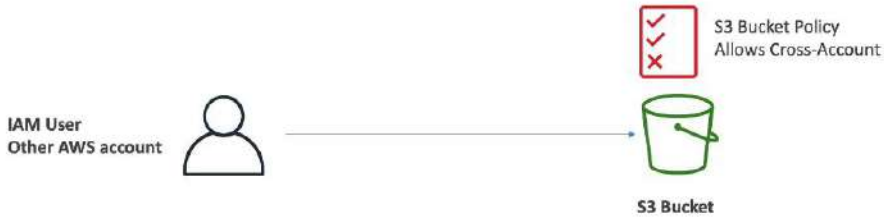
  Select the bucket → Upload

- View uploaded file

  Select the object → Open

  This will use a pre-signed URL (containing temporary access credentials to allow us to view the file in browser). If we click on the Object URL (unsigned), we will get access denied as the S3 bucket is not public.

- Grant bucket access to another account (Cross Account)



- Bucket setting: Block public access

- Force objects to be encrypted at upload

new →

⛔ An IAM principal can access an S3 object if the user lAM permissions allow it OR the resource policy ALLOWS it AND there's no explicit DENY. Example if the User policy allows the resource to be accessed but if the resource policy explicitly denies it, then access is restricted.

- Object Access Control List (ACL) - finer grain
- Bucket Access Control List (ACL) - less common

new →

- Public access can be applied at the bucket level or the object level when uploading objects into the bucket

Networking:

- Supports VPC Endpoints (to allow resources inside the VPC connect to S3 without public internet)

Logging and Audit:

- S3 Access Logs can be stored in other S3 bucket
- API calls can be logged in AWS CloudTrail (service to log API calls)

User Security:

- MFA Delete: MFA 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)

▼ Bucket settings to 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. These settings can be set at the account level

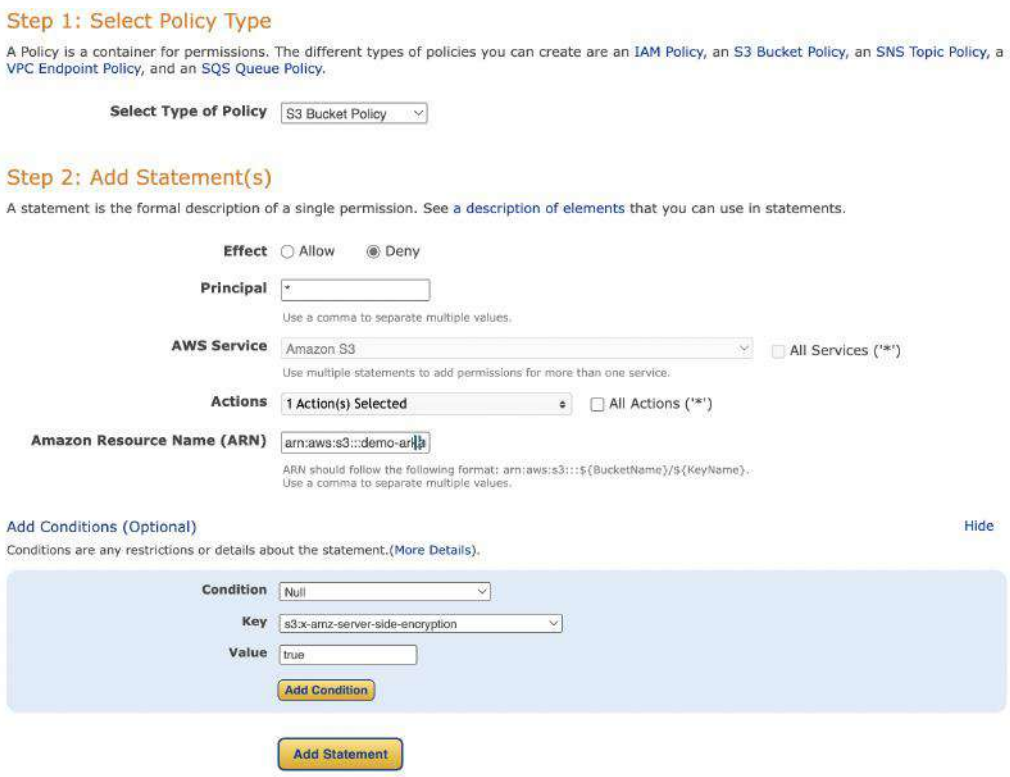
▼ Hands on

▼ Create bucket policy

Select S3 bucket → Permissions → Bucket Policy → Edit → Policy Generator

Type of policy: S3 bucket policy

- Statement to deny upload if SSE is disabled during uploading



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- Statement to deny upload if SSE-S3 is not used for SSE during uploading

• *	Deny	• s3:PutObject	arn:aws:s3:::demo-arkalim/*	• StringNotEquals ◦ s3:x-amz-server-side-encryption: "AES256"

Untitled

Copy generated policy and paste it as JSON.

If we now try to upload without SSE-S3 encryption, we get access denied error.

▼ Block public access of all S3 buckets in the account

S3 → **Block Public Access settings for this account → Edit**

▼ S3 Static Websites

▼ Theory

- S3 can host static websites and have them accessible on the public internet
- The website URL will be `<bucket-name>.s3-website-<AWS-region>.amazonaws.com`
- If you get a 403 (Forbidden) error, make sure the bucket policy allows public reads

▼ Hands on

- Disable Server side encryption
- In the S3 bucket upload:
  - index.html

```
<html>
    <head>
        <title>My First Webpage</title>
    </head>
    <body>
        <h1>I love coffee</h1>
        <p>Hello world!</p>
    </body>

    <img src="coffee.jpg" width=500/>

    <!-- CORS demo -->
    <div id="tofetch"/>
    <script>
        var tofetch = document.getElementById("tofetch");

        fetch('http://demo-other-origin-stephane.s3-website.ca-central-1.amazonaws.com/extra-page.html')
        .then((response) => {
            return response.text();
        })
        .then((html) => {
            tofetch.innerHTML = html
        });
    </script>
</html>
```

  - error.html

```
<h1>Uh oh, there was an error</h1>
```

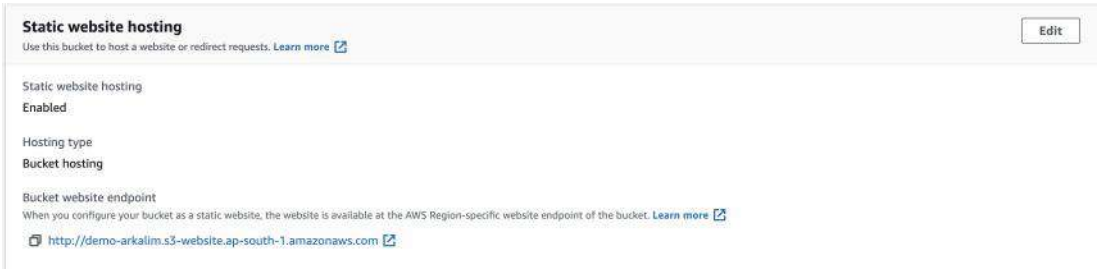
  - coffee.jpg

    coffee.jpg
- Properties → Static website hosting → Edit → Enable
- Permissions → Enable public access (otherwise 403 error)
- Permissions → Add policy to allow any principal to read objects from S3

Principal(s)	Effect	Action	Resource	Conditions
• *	Allow	• s3:GetObject	arn:aws:s3:::demo-arkalim/*	*None*

Untitled

The website link will be available under the Properties tab



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▼ Versioning

▼ Theory

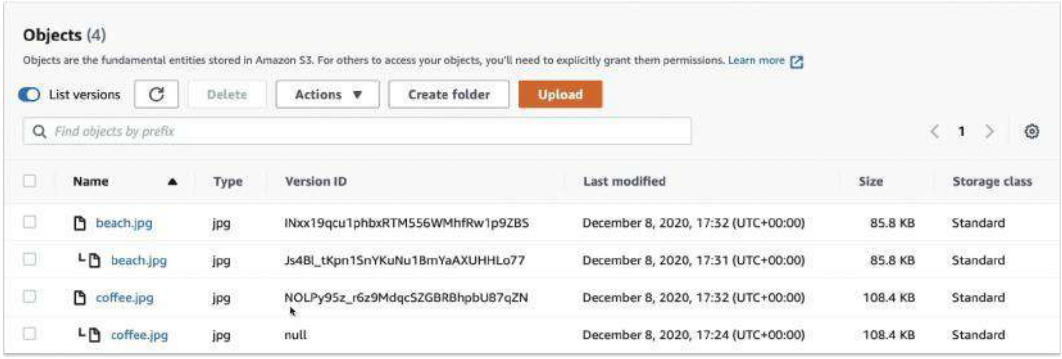
- You can version your files in Amazon S3. It is enabled at the bucket level.
- When versioning is enabled, if you upload a file with a key that is already existing in the bucket, S3 will increment the version of that file.
- It is best practice to version your buckets to protect against unintended deletes.
- It also provides the ability to restore to a previous version.
- Any file that is not versioned prior to enabling versioning will have version “null”
- Suspending versioning does not delete the previous versions, it just disables it for the future.

▼ Hands on

- Enable versioning for a bucket

  Select the bucket → Properties → Edit bucket versioning

  We can toggle “List Versions” to view all the versions for the files. Here, coffee.jpg was first uploaded before the versioning was enabled, that’s why the old version has id = null.



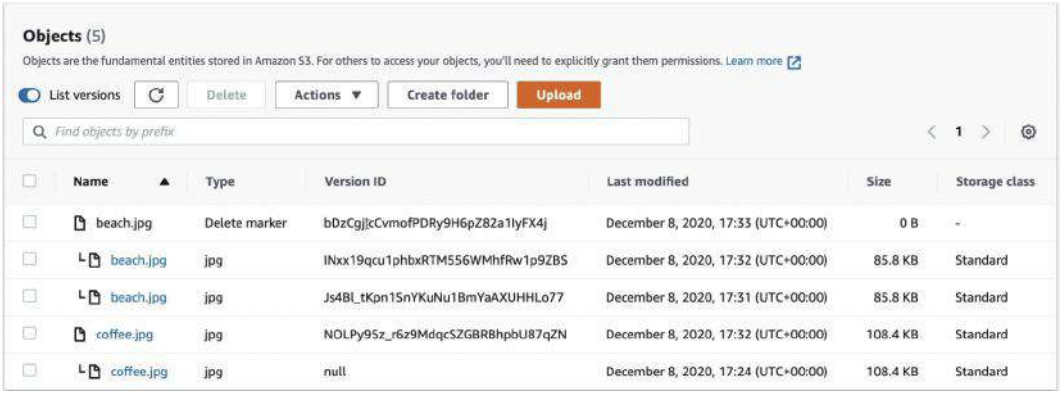
  Untitled

- Deleting a versioned file

  Without the versions of the file listed, delete the file.

  If a versioned file is deleted, it’s not actually removed from S3, instead it is marked as “Deleted”. To restore the file, view the versions and delete the “Delete marker”.

  To permanently delete a versioned file, select the current version from the list and delete it.



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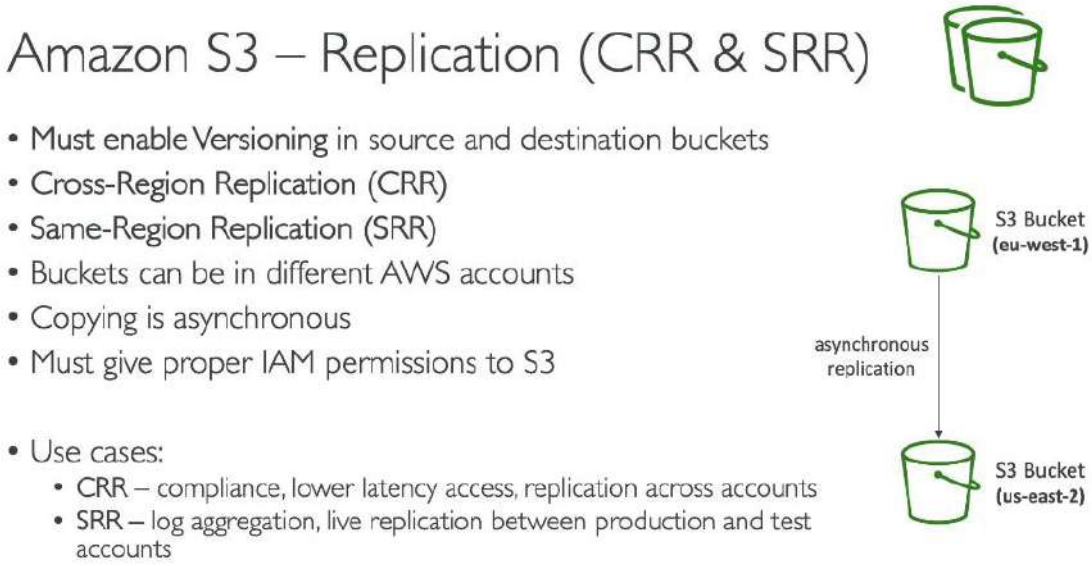
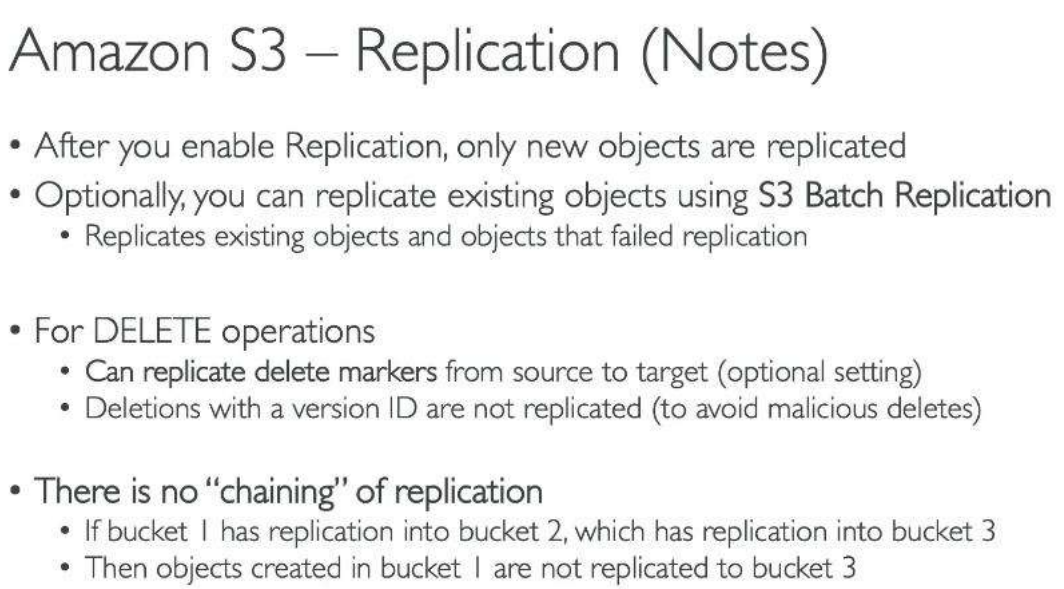
▼ S3 Replication





▼ S3 Storage Classes

▼ Durability and Availability

S3 Durability and Availability

- Durability:
  - High durability (99.999999999%, 11 9's) of objects across multiple AZ
  - If you store 10,000,000 objects with Amazon S3, you can on average expect to incur a loss of a single object once every 10,000 years
  - Same for all storage classes

- Availability:
  - Measures how readily available a service is
  - Varies depending on storage class
  - Example: S3 standard has 99.99% availability = not available 53 minutes a year

We can move between classes manually or using S3 lifecycle configurations.

Types of S3 storage classes,

▼ Amazon S3 Standard - General Purpose

S3 Standard – General Purpose

- 99.99% Availability
- Used for frequently accessed data
- Low latency and high throughput
- Sustain 2 concurrent facility failures

- Use Cases: Big Data analytics, mobile & gaming applications, content distribution…

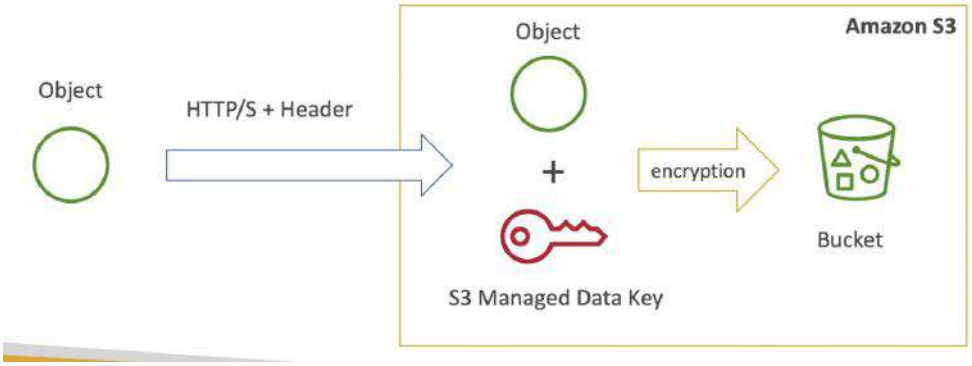
▼ Amazon S3 Standard - Infrequent Access (IA) & One Zone-Infrequent Access

S3 Storage Classes – Infrequent Access

- For data that is less frequently accessed, but requires rapid access when needed
- Lower cost than S3 Standard

- Amazon S3 Standard-Infrequent Access (S3 Standard-IA)
  - 99.9% Availability
  - Use cases: Disaster Recovery, backups

- Amazon S3 One Zone-Infrequent Access (S3 One Zone-IA)
  - High durability (99.999999999%) in a single AZ; data lost when AZ is destroyed
  - 99.5% Availability
  - Use Cases: Storing secondary backup copies of on-premise data, or data you can recreate



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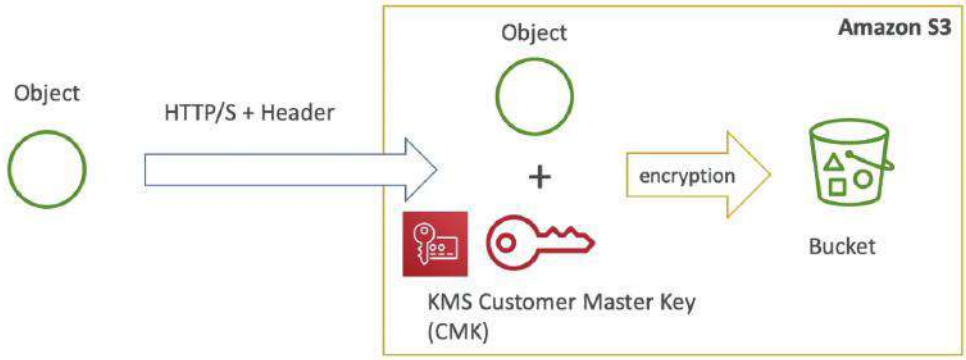
▼ SSE-KMS

- Encryption using keys handled & managed by KMS (Key Management Service)
- HTTP or HTTPS can be used
- KMS provides control over who has access to what keys as well as audit trails
- Must set header: `"x-amz-server-side-encryption": "aws:kms"`



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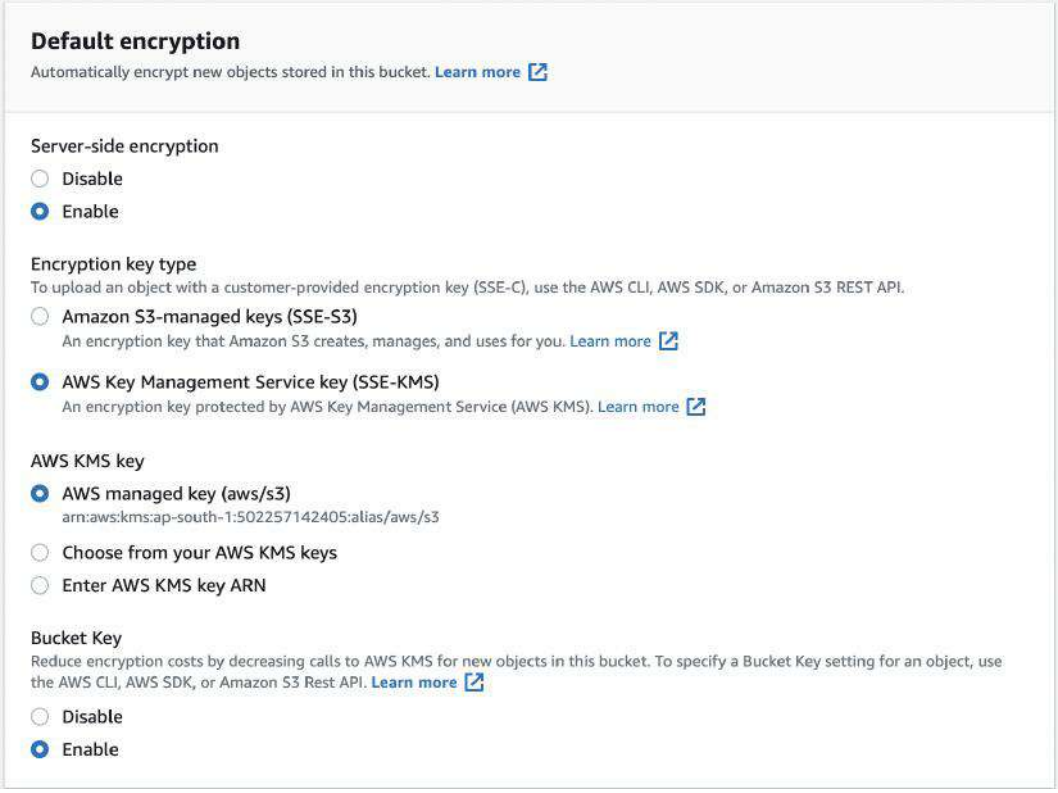
▼ SSE-C

- Data keys fully managed by the customer outside of AWS. More work for us.
- Amazon S3 does not store the encryption key you provide for encryption or decryption of the object. After the operation, S3 discards the key.
- HTTPS must be used when sending the request as key (secret) is being transferred.
- Encryption key must provided in HTTPS headers, for every HTTPS request made as S3 doesn't store the key for future requests.

▼ Client Side Encryption (CSE)

- Client encrypts the object before sending it to S3 and decrypts it after retrieving it from S3.
- Client library such as the Amazon S3 Encryption Client is used to encrypt / decrypt the data on the client's end.
- Customer fully manages the keys and encryption cycle.



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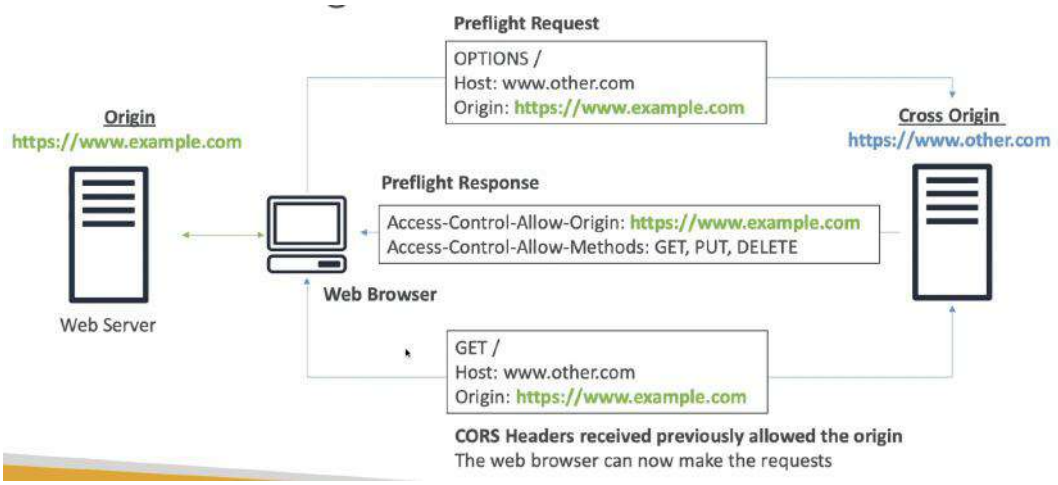
▼ Cross Origin Resource Sharing (CORS)

▼ Theory

- An origin is a combination of scheme (protocol), host (domain) and port. Eg: https://www.example.com (implied port is 443 for HTTPS, 80 for HTTP)
- Same origin: http://example.com/app1 & http://example.com/app2 Different origins: http://www.example.com & http://other.example.com
- CORS is a web browser based security to allow requests to other origins while visiting the main origin only if the other origin allows for the requests from the main origin, using CORS Headers (`Access-Control-Allow-Origin` & `Access-Control-Allow-Methods`)
- In the diagram below, web browser is on www.example.com and the server wants to redirect it to www.other.com In this case, the web browser will first send a preflight request to www.other.com via OPTIONS method, which requests permitted communication options for a given URL or server (www.example.com). The cross origin server responds with the methods that www.example.com is allowed to perform.



- Remember the difference:
  - Metadata = Info about the EC2 instance
  - Userdata = launch script of the EC2 instance

▼ Hands on

- **curl http://169.254.169.254/latest/meta-data/**
- **curl http://169.254.169.254/latest/meta-data/iam/security-credentials/DemoRoleForEC2**
- curl http://169.254.169.254/latest/meta-data/identity-credentials/ec2/security-credentials/ec2-instance
- SSH into your EC2 instance

  `ssh -i EC2Tutorial.pem ec2-user@13.234.78.195`
- Hit the metadata URL

```
[ec2-user@ip-172-31-44-172 ~]$ curl http://169.254.169.254/latest/meta-dataami-idami-launch-indexami-manifest-pathb
lock-device-mapping/events/hibernation/hostnameidentity-credentials/instance-actioninstance-idinstance-life-cyclein
stance-typelocal-hostnamelocal-ipv4macmetrics/network/placement/profilepublic-hostnamepublic-ipv4public-keys/reserv
ation-idsecurity-groups
```

- We can modify the curl request to get specific Metadata

```
[ec2-user@ip-172-31-44-172 ~]$ curl http://169.254.169.254/latest/meta-data/security-groupslaunch-wizard-1
```

▼ AWS SDK

- Used to perform actions on AWS directly from the code without using CLI
- AWS CLI uses Python SDK (boto3)
- We have to use SDK when coding against AWS services such as DynamoDB
- Supported languages
  - Java
  - .NET
  - Node.js
  - PHP
  - Python (named boto3 / botocore)
  - Go
  - Ruby
  - C++

💡 If you don’t specify or configure a default region, then us-east-1 - N. Virginia will be chosen by default by the SDK

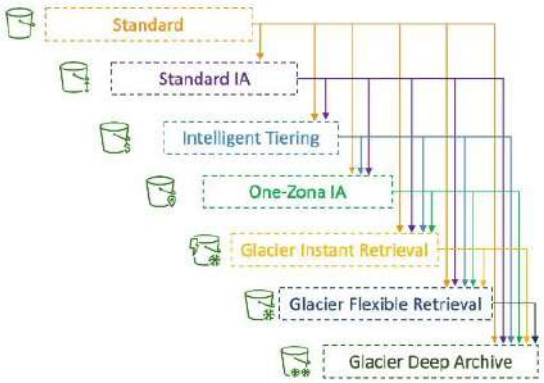
▼ Section 14: Advanced Amazon S3

▼ S3 Lifecycle Rules (With S3 Analytics)

▼ Intro

Amazon S3 – Moving between Storage Classes

- You can transition objects between storage classes
- For infrequently accessed object, move them to **Standard IA**
- For archive objects that you don't need fast access to, move them to **Glacier or Glacier Deep Archive**
- Moving objects can be automated using a **Lifecycle Rules**



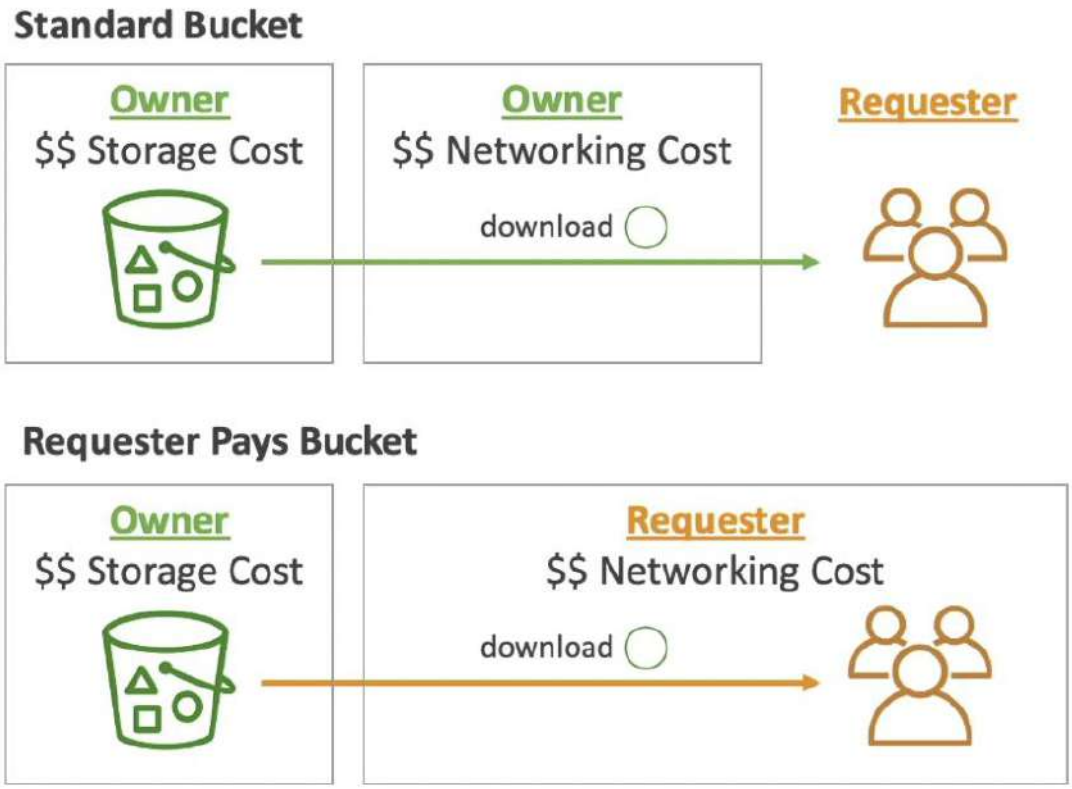
Amazon S3 – Lifecycle Rules

- **Transition Actions** – configure objects to transition to another storage class
  - Move objects to Standard IA class 60 days after creation
  - Move to Glacier for archiving after 6 months
- **Expiration actions** – configure objects to expire (delete) after some time
  - Access log files can be set to delete after a 365 days
  - Can be used to delete old versions of files (if versioning is enabled)
  - Can be used to delete incomplete Multi-Part uploads
- Rules can be created for a certain prefix (example: *s3://mybucket/mp3/**)
- Rules can be created for certain objects Tags (example: *Department: Finance*)

▼ Scenario 1

Amazon S3 – Lifecycle Rules (Scenario 1)

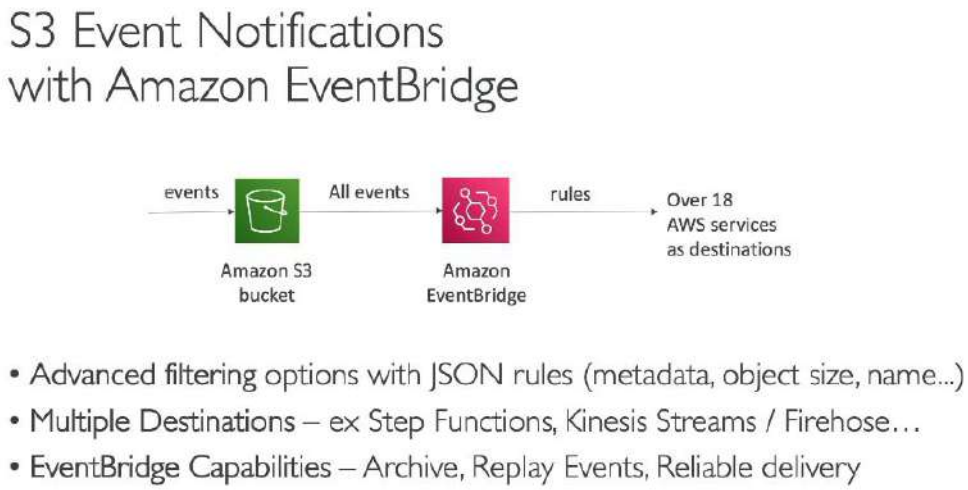
- Your application on EC2 creates images thumbnails after profile photos are uploaded to Amazon S3. These thumbnails can be easily recreated, and only need to be kept for 60 days. The source images should be able to be immediately retrieved for these 60 days, and afterwards, the user can wait up to 6 hours. How would you design this?
- S3 source images can be on **Standard**, with a lifecycle configuration to transition them to **Glacier** after 60 days
- S3 thumbnails can be on **One-Zone IA**, with a lifecycle configuration to expire them (delete them) after 60 days



▼ S3 Event Notification

▼ Theory

- We can configure S3 to generate events for operations performed on the bucket (ex: S3:ObjectCreated, S3:ObjectRemoved, S3:ObjectRestore, S3: Replication)
- Object name filtering is possible using prefix and suffix matching
- Use case: generate thumbnails of images uploaded to S3
- Can create as many “S3 events” as desired
- S3 event notifications typically deliver events in seconds but can sometimes take a minute or longer
- If two writes are made to a single non-versioned object at the same time, it is possible that only a single event notification will be sent. So, if you want to ensure that an event notification is sent for every successful write, you should enable versioning on your bucket.
- Possible targets for S3 event notifications:
  - SNS
  - SQS
  - Lambda Functions
  - Amazon EventBridge



▼ Hands on

- Create an SQS queue to receive the S3 notifications.
- Edit the access policy of the queue to allow S3 bucket to send messages to the queue.

```
{  "Id": "Policy1648391999215",  "Version": "2012-10-17",  "Statement": [    {      "Sid": "Stmt1648391992940",
"Action": [        "sqs:SendMessage"      ],      "Effect": "Allow",      "Resource": "arn:aws:sqs:ap-south-1:50225
7142405:s3-notification-queue",      "Principal": "*"    }  ]}
```

- Select bucket → Properties → Event Notifications → Create

  Specify prefix and suffix to trigger this event based on the object name

  Destination: SQS queue

- Now, uploading an object to the S3 bucket will send a notification to the queue

```
{  "Records": [    {      "eventVersion": "2.1",      "eventSource": "aws:s3",      "awsRegion": "ap-south-1",
"eventTime": "2022-03-27T14:41:35.322Z",      "eventName": "ObjectCreated:Put",      "userIdentity": {        "prin
cipalId": "AWS:AIDAXJ4G3ZKC2IKTBJ3ZT"      },      "requestParameters": {        "sourceIPAddress": "49.37.79.214"
},      "responseElements": {        "x-amz-request-id": "WT356ZHV6M3C72CF",        "x-amz-id-2": "wMTXMM/phl+rNx0E
GoWuYCvmAr0Fx4msr70T6kU1guTdI1ZriH0zD+f8Nt9FkysnjJqUiQ3+ycp3pdJWEhU2RFKaqtJp0vlF"      },      "s3": {        "s3Sc
hemaVersion": "1.0",        "configurationId": "object-created-event",        "bucket": {          "name": "demo-ar
kalim",          "ownerIdentity": {            "principalId": "AK8ZF569RJE3E"          },          "arn": "arn:aws:
s3:::demo-arkalim"        },        "object": {          "key": "wallpapersden.com_small-memory_3840x2160.jpg",
"size": 4424844,          "eTag": "097840a2a79d31dfb78e13b2352ca7de",          "versionId": "xXYgQ9xaLoQ5Exq8MQPrr9
qfQIvEo.x2",          "sequencer": "006240779F29A73D7D"        }      }    }  ]}
```

▼ S3 Performance

▼ Baseline performance

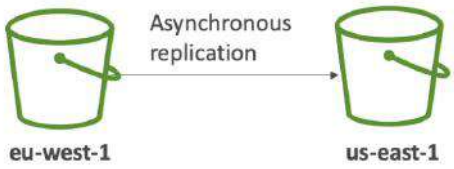
- Amazon S3 automatically scales to high request rates and it has very low latency 100-200 ms for the first byte read
- Your application can achieve at least 3,500 PUT/COPY/POST/DELETE and 5,500 GET/HEAD requests per second per prefix in a bucket.
- There are no limits to the number of prefixes in a bucket.
- Object path ⇒ Prefix (path between the bucket and the file):
  - bucket/folder1/sub1/file ⇒ /folder1/sub1/
  - bucket/folder1/sub2/file ⇒ /folder1/sub2/
  - bucket/1/file ⇒ /1/
  - bucket/2/file ⇒ /2/
- If you spread reads across four prefixes evenly, you can achieve 22,000 requests per second for GET and HEAD

▼ Performance optimization

▼ S3 Replication

▼ Theory

- Replicate the contents of an S3 bucket to another bucket possibly in another region and account.
- Must enable versioning in source and destination buckets
- Cross Region Replication (CRR)
- Same Region Replication (SRR)
- Buckets can be in different accounts
- Replication is asynchronous but happens very quickly
- Must give proper lAM permissions to S3 buckets
- Use cases:
  - CRR: compliance, lower latency access, replication across accounts
  - SRR: log aggregation, live replication between production and test accounts
- After activating replication, only new objects are replicated (not retroactive)
- For DELETE operations:
  - Can replicate delete markers from source to target (optional setting)
  - Deletions with a version ID are not replicated (to avoid malicious deletes)
- There is no “chaining” of replication. So, if bucket 1 has replication into bucket 2, which has replication into bucket 3. Then objects created in bucket 1 are not replicated to bucket 3.



Untitled

▼ Hands on

- Create a replica bucket in another region than the origin bucket and enable versioning for both buckets
- Add a replication rule to the origin bucket

  Select the origin bucket → Management → Replication rules → Create

  Rule scope: apply to all objects in this bucket

  Destination: replica bucket

  IAM Role: Create new

  Delete marker replication: checked

        - Data lost when AZ is destroyed
        - 99.5% Availability
        - Use Cases: Storing secondary backup copies of on-premise data, or data you can recreate

▼ S3 Glacier

- Low-cost object storage meant for archiving / backup
- Pricing: price for storage + object retrieval cost
    - S3 Glacier Instant Retrieval
        - Millisecond retrieval
        - Minimum storage duration of 90 days
        - Great for data accessed once a quarter
        - When you want to archive some data but need it instantly
    - S3 Glacier Flexible Retrieval
        - Formerly known as Amazon S3 Glacier
        - 3 retrieval flexibility (decreasing order of cost):
            - Expedited (1 to 5 minutes)
            - Standard (3 to 5 hours)
            - Bulk (5 to 12 hours) - free
        - Minimum storage duration of 90 days
    - S3 Glacier Deep Archive
        - 2 flexible retrieval:
            - Standard (12 hours)
            - Bulk (48 hours)
        - Minimum storage duration of 180 days
        - Lowest cost
- Object cannot be directly accessed, it first needs to be restored which could take some time (depending on the tier) to fetch the object.

▼ S3 Intelligent Tiering

- Moves objects automatically between Access Tiers based on usage
- Small monthly monitoring and auto-tiering fee
- No retrieval charges in S3 Intelligent-Tiering
- Access Tiers:
    - Frequent Access (automatic): default tier
    - Infrequent Access (automatic): objects not accessed for 30 days
    - Archive Instant Access (automatic): objects not accessed for 90 days
    - Archive Access (optional): configurable from 90 days to 700+ days
    - Deep Archive Access (optional): configurable from 180 days to 700+ days

Can move between classes manually or using S3 Lifecycle configurations.

▼ Comparison

▼ S3 Analytics

- You can setup S3 Analytics to help determine when to transition objects from Standard to Standard_IA
- Does not work for ONEZONE_IA or GLACIER
- Report is updated daily
- Takes about 24h to 48h hours to first start
- Setting up S3 analytics is a good first step to determine the optimal Lifecycle Rules

▼ Amazon Athena

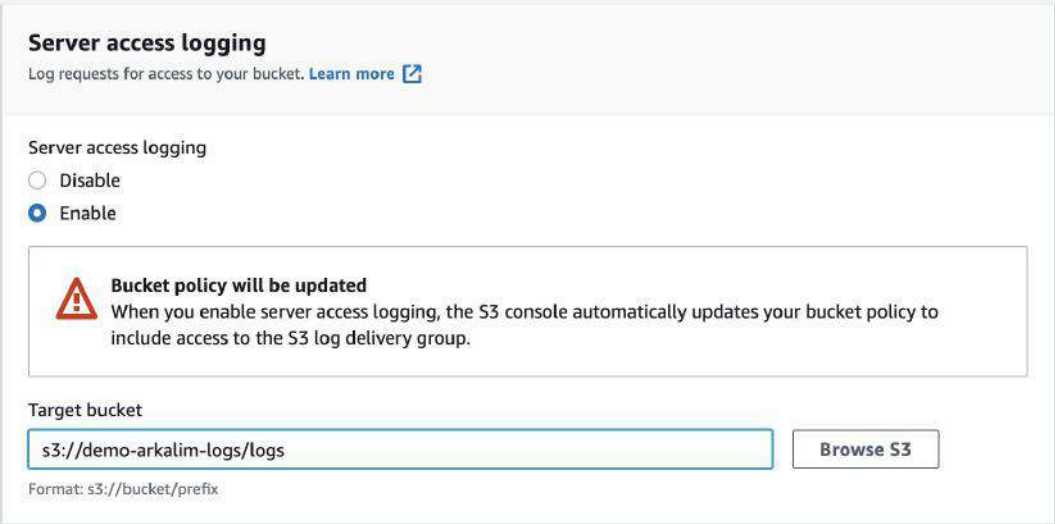
- Theory
  - Athena is a serverless query service to perform analytics on S3 objects
  - Uses standard SQL language to query the files.
  - S3 objects don't need to be loaded in Athena, it runs directly on S3.
  - Supports CSV, JSON, ORC, AvI and Parquet file formats (built on Presto engine)
  - Pricing: $5.00 per TB of data scanned
  - Use compressed or columnar data for cost-savings (due to less scan)
  - 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 ⇒ Athena

▼ Section 15: Amazon S3 Security

▼ S3 Encryption

Select bucket → Properties → Server access logging → Edit → Choose the logging bucket → Specify a path to group all the logs for the main bucket under that folder (ex: `/logs`)

The above step will automatically modify the ACL (access control list) of the logs bucket to allow the main bucket to write log info.



▼ S3 Pre-signed URL

▼ Theory

- Pre-signed URLs for S3 have temporary access token as query string parameters which allow anyone with the URL to temporarily access the resource.
- Can generate pre-signed URLs using SDK or CLI
  - Pre-signed URL for Downloads (easy, can use the CLI)
  - Pre-signed URL for Uploads (harder, must use the SDK)
- Valid for a default of 3600 seconds (1h), can change timeout with `-expires-in [TIME_BY_SECONDS]` argument
- Users given a pre-signed URL inherit the permissions of the person who generated the URL for GET / PUT request
- Use cases
  - Allow only logged-in users to download a premium video on your S3 bucket
  - Allow an ever changing list of users (difficult to manage permissions) to download files by generating URLs dynamically
  - Allow temporarily a user to upload a file to a precise location in our bucket (ex: uploading their profile picture)

▼ Hands on

- click on file you want to share → object action → share with pre signed URL → set minutes/hours → create pre signed URL and share it.

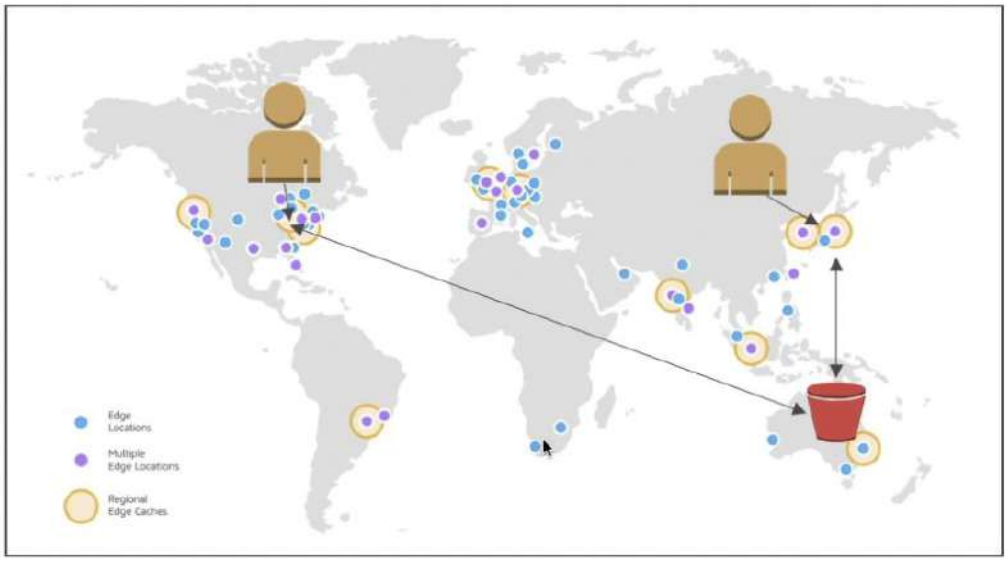
▼ Glacier Vault Lock

- It allows us to lock the data after writing it once (WORM - Write Once Read Many model)
- Lock the policy from future edits (no one can change the data or policy)
- Helpful for compliance and data retention

▼ S3 Object Lock

- Adopt a WORM (Write Once Read Many) model
- Block an object version deletion for a specified amount of time
- Object retention can be based on:
  - Retention Period: specifies a fixed period to secure the S3

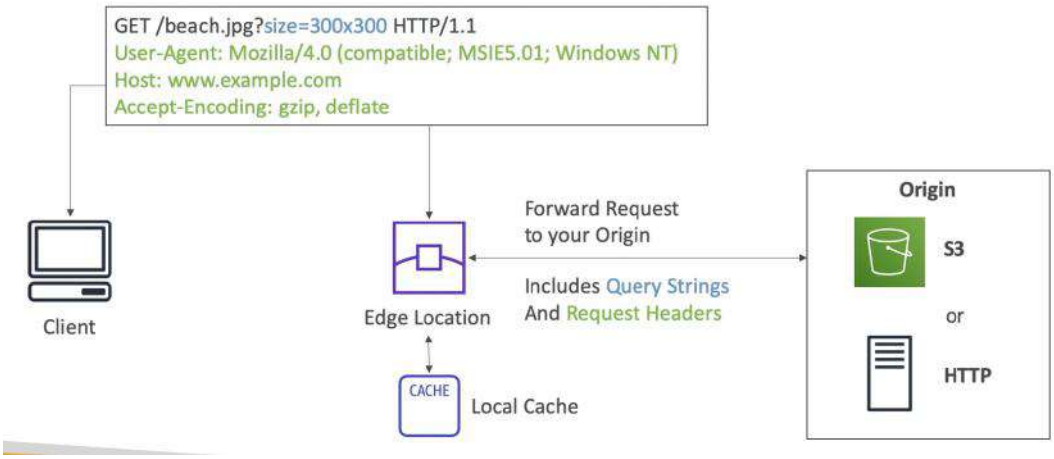
- 216 Point of Presence globally (edge locations)
- DDoS (distributed DoS) protection, integration with Shield & AWS Web Application Firewall
- Can expose external HTTPS and can talk to internal HTTPS backends
- Supports HTTP/RTMP protocol (does not support UDP protocol)
- With CloudFront, if a user in NA accesses some file in an S3 bucket in AU, the content will be fetched to an edge location in NA (over the private AWS network) and cached there. This allows the reads to be distributed and therefore reduces load on the main S3 bucket.



▼ Origins for CloudFront

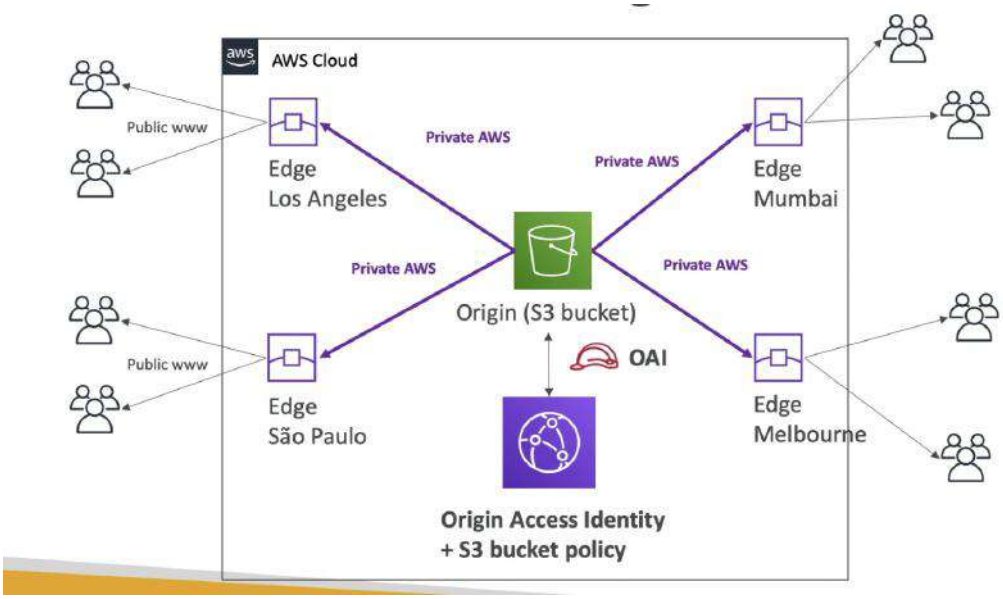
▼ CloudFront working

The client sends the request to CloudFront at an edge location which will forward it to the origin (along with the query string and request headers). The fetched file will be cached at the edge location. So, if another user requests the same file, it will be available at the edge location.



▼ S3 bucket

- For distributing files and caching them at edge locations
- Enhanced security with CloudFront Origin Access Identity (OAl) which allows the S3 bucket to only be accessed by CloudFront.
- CloudFront can be used as an ingress (to upload files to S3)



▼ Custom Origin (must use HTTP) ALB or EC2

▼ EC2 instance

In this case, EC2 instance will fetch the content and deliver it to the edge location.

- EC2 instances need to be publicly accessible on HTTP by public IPs of edge locations (range provided by AWS). This is because edge locations are present outside the VPC.

Untitled

▼ Application Load Balancer

Since ALB only needs to be publicly accessible by the public IPs of edge locations, EC2 instances can be private

- S3 website (must first enable the bucket as a static S3 website)
- HTTP backend (on premises)

▼ CloudFront vs S3 Cross Region Replication

CloudFront:

- Global Edge network
- Files are cached for a TTL
- Great for static content that must be available everywhere

S3 Cross Region Replication:

- Must be setup for each region you want replication to happen
- Files are updated in near real-time
- Read only
- Great for dynamic content that needs to be available at low-latency in few regions

▼ Hands on

- Create an S3 bucket

  Upload:

  - index.html

    ```
    <html>    <head>        <title>My First Webpage</title>    </head>    <body>        <h1>I love coffee</h1>
    <p>Hello world!</p>    </body>    <img src="coffee.jpg" width=500/></html>
    ```

  - error.html

    ```
    <h1>Uh oh, there was an error</h1>
    ```

  - coffee.jpg

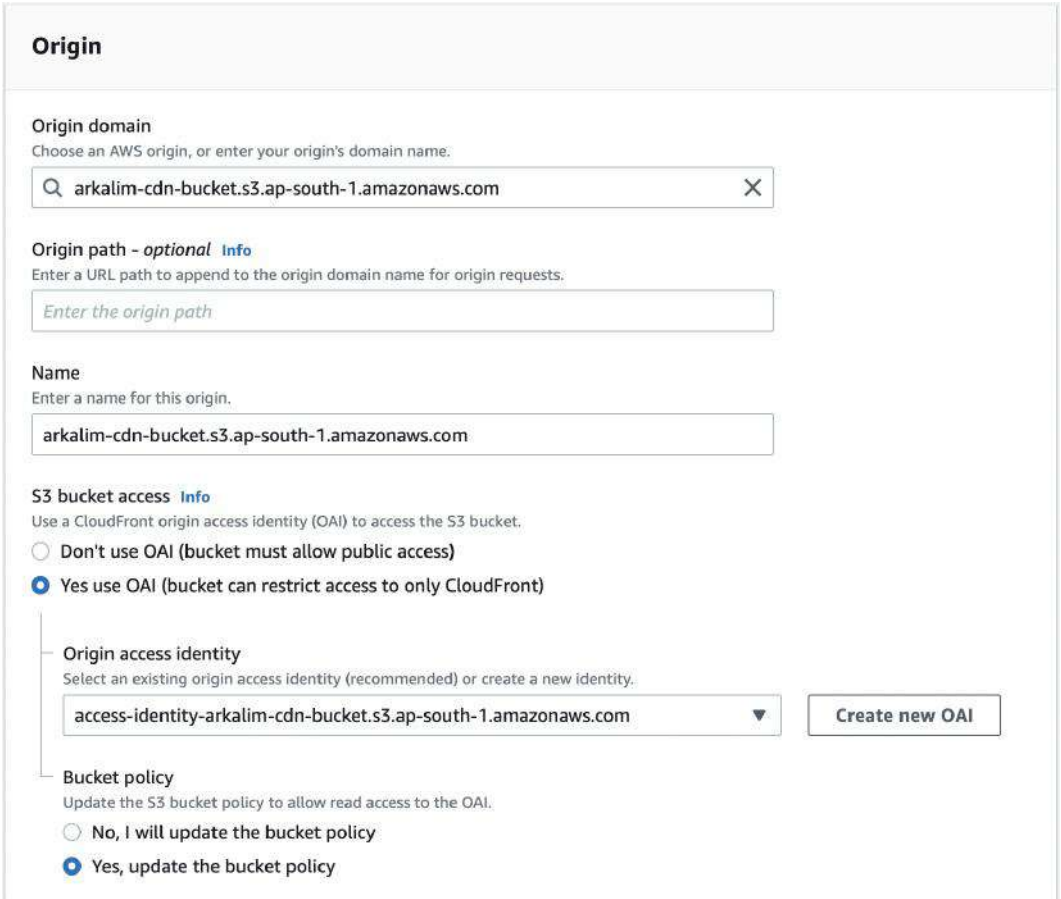
    coffee.jpg

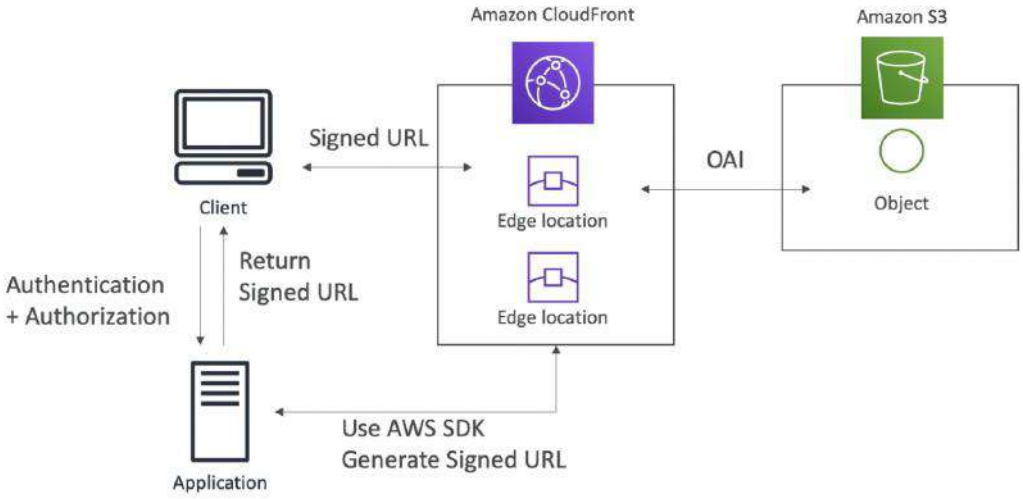
  💡 Don't turn on S3 website

- Create a CloudFront distribution

  Select the bucket as the origin, create a new OAI and update the bucket policy to allow CF to get objects from it.

  Default root object: `index.html`





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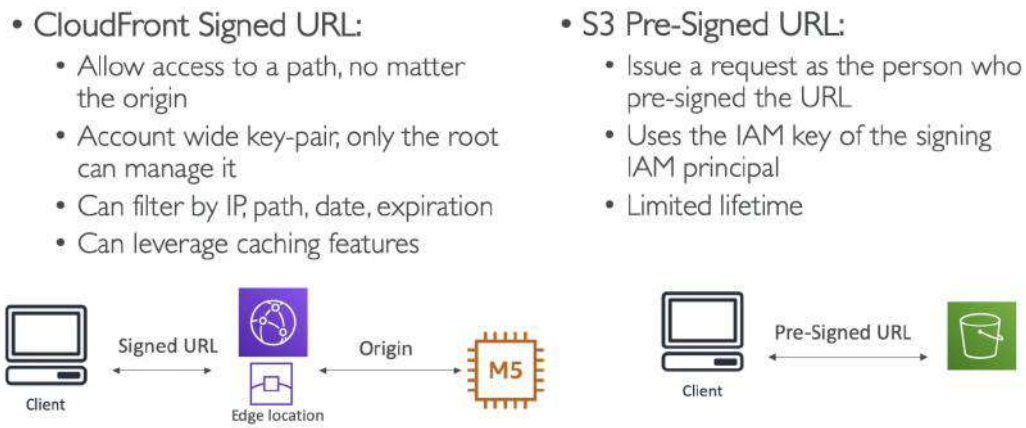
▼ CloudFront Signed URL vs S3 Pre-Signed URL



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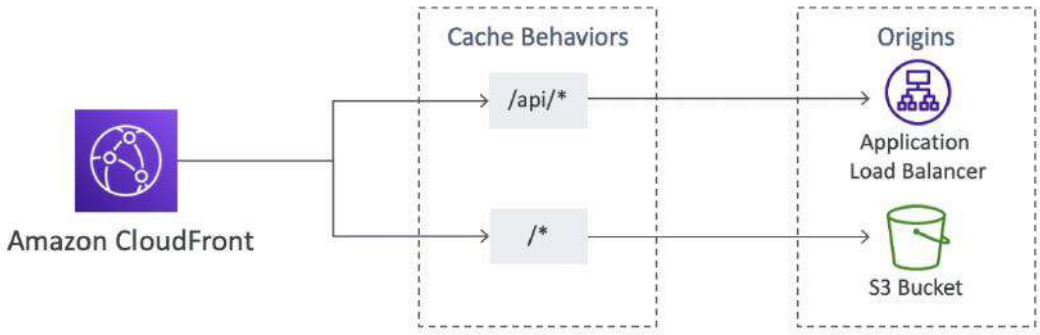
▼ Multiple Origin

To route to different kind of origins based on the content type (based on path pattern). We can configure cache behaviors to route to different origins accordingly.



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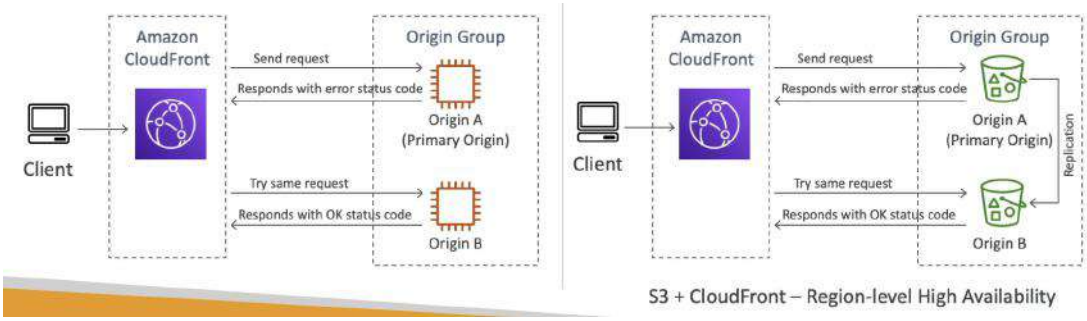
▼ Origin Groups (for HA)

- To achieve high-availability and do failover

- Origin Group consists of one primary and one secondary origin. If the primary origin fails, the second one is used.



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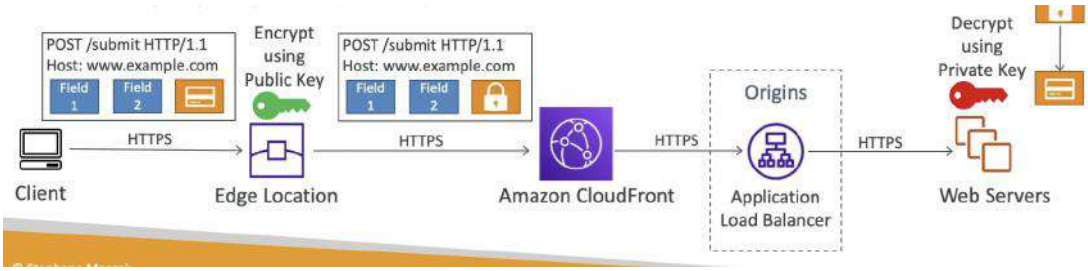
▼ Field Level Encryption

- Used to protect user sensitive information through application stack
- Adds an additional layer of security along with HTTPS
- Sensitive information sent by the user is encrypted at the edge close to user. This encrypted information can only be decrypted by the web server. None of the intermediate services will be able to see the encrypted info.
- Uses asymmetric encryption (public & private key)
- Usage:
  - Specify set of fields in POST requests that you want to be encrypted (up to 10 fields)
  - Specify the public key to encrypt them
- In the diagram below, the client is sending their credit card info as a sensitive field which is being encrypted at the edge location.



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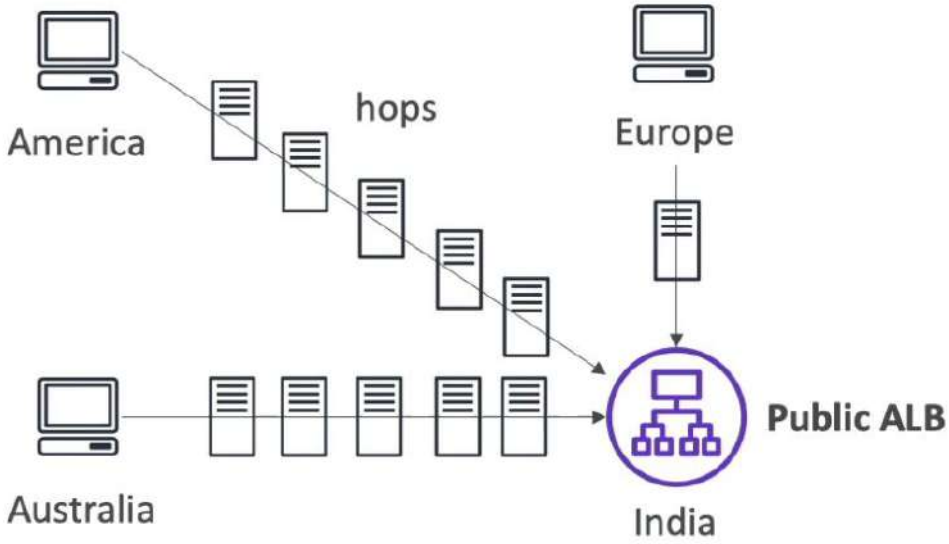
▼ AWS Global Accelerator

▼ Theory

▼ AWS Problem to solve

You have deployed an application in a region but have global users who want to access it directly. They will have to use the public internet for this, which can add a lot of latency due to many hops and also increases the chance of lost packets. We wish to go as fast as possible through the private AWS network to minimize latency.

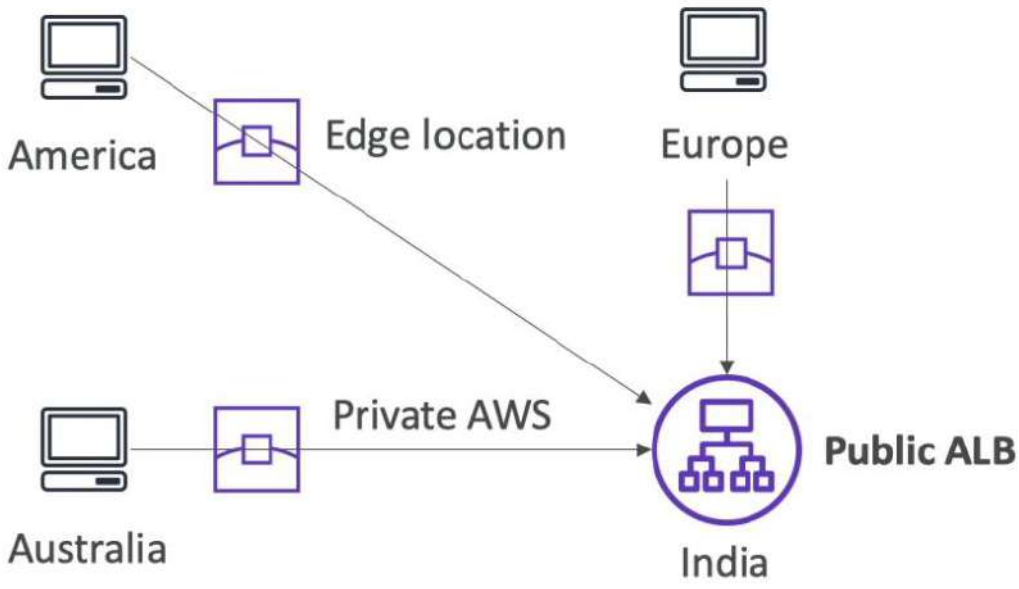


▼ Unicast vs Anycast IP

Unicast IP: one server holds one IP address

Anycast IP: all servers hold the same IP address and the client is routed to the nearest one

▼ AWS Global Accelerator



AWS Global Accelerator is a service that improves the availability and performance of your applications with local or global users. It provides static IP addresses that act as a fixed entry point to your application endpoints in a single or multiple AWS Regions, such as your Application Load Balancers, Network Load Balancers or Amazon EC2 instances. Global Accelerator is a good fit for non-HTTP use cases, such as gaming (UDP), IoT (MQTT), or Voice over IP, as well as for HTTP use cases that specifically require static IP addresses or deterministic, fast regional failover.

- Used to leverage the AWS internal network to route to your application
- 2 anycast public IPs (static) are created for your application globally. Requests from clients hitting these IPs will automatically be routed to the nearest edge location. The Edge locations send the traffic to your application through

the private AWS network. The application could be distributed in multiple regions (global).

- No caching is done by Global Accelerator, it only makes our application globally available.
- Works with Elastic IP, EC2 instances, ALB, NLB and can be public or private
- Consistent Performance
  - Intelligent routing to lowest latency edge location and fast regional failover
  - Client doesn't cache anything because the 2 anycast IPs are static
  - Internal AWS network
- Health Checks
  - Global Accelerator performs a health check of your applications
  - Helps make your application global (failover less than 1 minute for unhealthy endpoints)
  - Great for disaster recovery (thanks to the health checks)
- Security
  - only 2 external IP need to be whitelisted
  - DDoS protection is built into the Global Accelerator using AWS Shield

▼ Hands on

▼ Create two EC2 instance in different regions

User data:

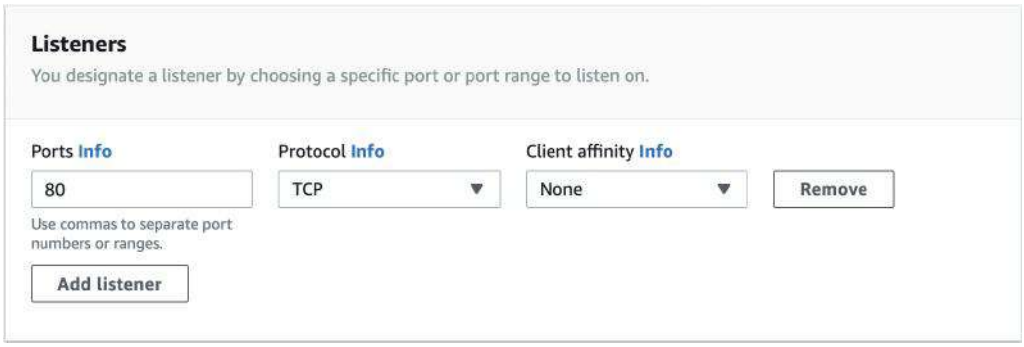
```
#!/bin/bashyum update -yyum install -y httpdsystemctl start httpdsystemctl enable httpdEC2_AVAIL_ZONE=$(curl -s htt
p://169.254.169.254/latest/meta-data/placement/availability-zone)echo "<h1>Hello World from $(hostname -f) in AZ $E
C2_AVAIL_ZONE </h1>" > /var/www/html/index.html
```

▼ Create an accelerator

- Listeners

  Choose port 80 on TCP for HTTP

  Client affinity is the stickiness



  Untitled

- Endpoint groups

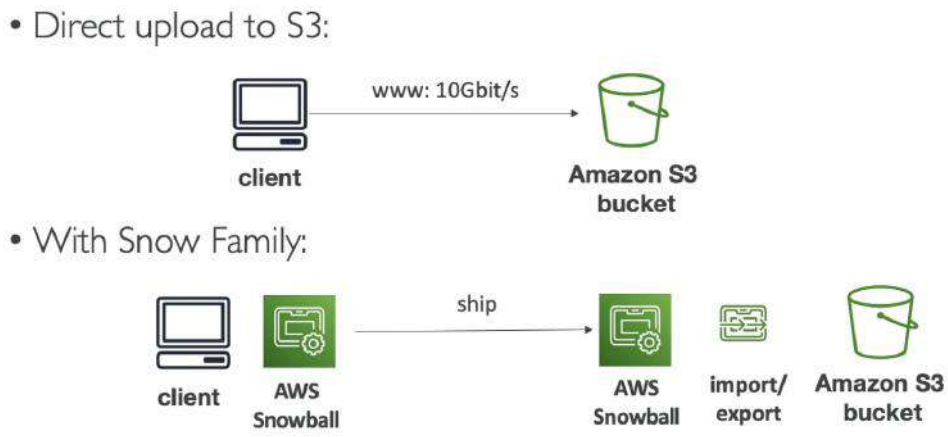
  Endpoints are grouped into regions

  Traffic dial is the percentage of traffic to be sent to that endpoint group.

	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

▼ Snow family vs Direct migration to S3

AWS Snow Family contains offline devices to perform data migrations. AWS sends an actual physical device through post on which we upload the data locally. We then have to ship the device back to AWS. They will plug the device in their infrastructure and upload the data to the cloud at a much faster rate.



▼ Snow family devices for Data Migration

	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	

▼ Usage process

1. Request Snowball devices from the AWS console for delivery
2. Install the snowball client / AWS OpsHub on your servers
3. Connect the snowball to your servers and copy files using the client
4. Ship back the device when you're done (goes to the right AWS facility)
5. Data will be loaded into an S3 bucket

6. Snowball is completely wiped

💡 Rule of thumb: If it takes more than a week to transfer over the network, use Snowball devices

▼ Edge Computing (collect and process data at the edge) - Snowcone, Snowmobile

▼ What is edge computing

- Process data while it's being created on an edge location. Edge location could be anything that doesn't have internet or access to cloud (ex: a truck on the road, a ship on the sea, a mining station underground).
- These locations may have
  - Limited / no internet access
  - Limited / no easy access to computing power
- We setup a Snowball Edge / Snowcone device to do edge computing
- Use cases of Edge Computing:
  - Preprocess data
  - Machine learning at the edge
  - Transcoding media streams
- Eventually (if need be) we can ship back the device to AWS (for transferring processed data to the cloud)

▼ Snow family devices for Edge Computing

- Snowcone (smaller)
  - 2 CPUs, 4 GB of memory, wired or wireless access
  - USB-C power using a cord or the optional battery
- Snowball Edge - Compute Optimized
  - 52 vCPUs, 208 GiB of RAM
  - Optional GPU (useful for video processing or machine learning)
  - 42 TB usable storage
- Snowball Edge - Storage Optimized
  - Up to 40 CPUs, 80 GiB of RAM
  - Object storage clustering available

💡 All the above can run EC2 Instances & AWS Lambda functions locally (using AWS loT Greengrass) Long-term deployment options for reduced cost: 1 and 3 years discounted pricing

- Snow family contains 3 devices:

▼ Snowball Edge

- 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
- Provides block storage and Amazon S3-compatible object storage
- Two flavors of Snowball Edge
  - 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:
  - Data cloud migrations
  - Data center decommissioning

- Disaster recovery by backing up the data

▼ Snowcone

- Small, portable, rugged & secure device used for edge computing, storage, and data transfer
- Light (4.5 pounds, 2.1 kg)
- 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

▼ Snowmobile

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

▼ Snowball into Galcier

- Snowball cannot import to Glacier directly
- You must use Amazon S3 first, in combination with an S3 lifecycle policy to transitions the data into Glacier

Untitled

▼ Amazon FSx

▼ Intro

- It’s a fully-managed AWS service that allows us to launch 3rd party high-performance file systems on AWS.
- Useful when we don’t want to use an AWS managed file system like S3.

▼ FSx for Windows (shared file system for windows)

- EFS is a shared POSIX system for Linux systems which allows us to create shared file systems on linux. But, we can’t use it for creating shared file system in windows.
- FSx for Windows is a fully managed Windows file system share drive
- Supports SMB protocol, Windows NTFS, Microsoft Active Directory integration, ACLs, user quotas
- can be mounted on Linux EC2 instances
- Support Microsoft Distributed File System (DFS) Namespaces (group files across multiple FS)
- Built on SSD & HDD, scale up to 10s of GB/s, millions of IOPS, 100s PB of data
- SSD - Latency sensitive workloads (database, media processing, data analytics, …..)
- HDD - Broad spectrum of workloads (home directory, CMS,…..)
- Can be accessed from your on-premise infrastructure
- Can be configured to be Multi-AZ (high availability)
- Data is backed-up daily to S3

▼ FSx for Lustre (shared file system for linux distributed computing and HPC)

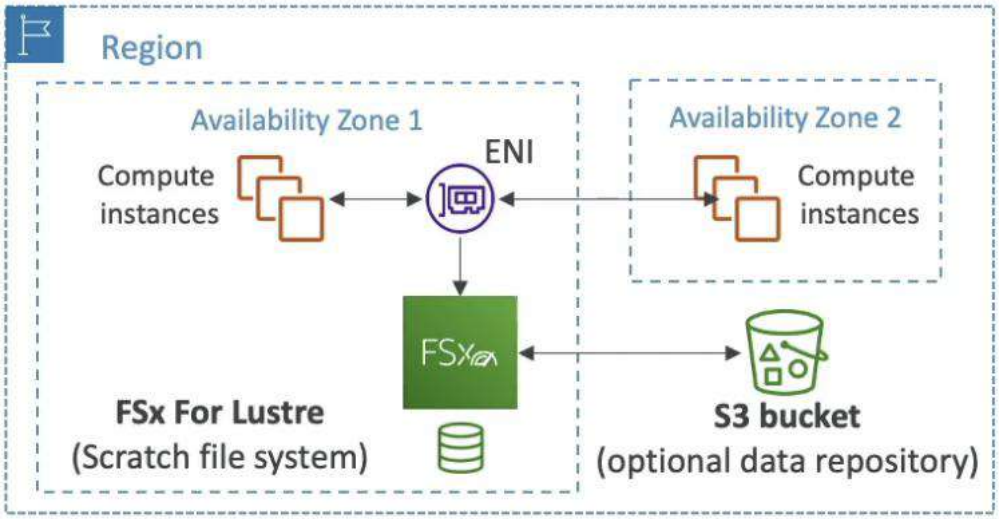
- Lustre is a type of parallel distributed file system, for large-scale computing. The name Lustre is derived from “Linux” and “cluster”.
- **Used for Machine Learning, High Performance Computing (HPC) tasks like Video Processing, Financial Modeling, Electronic Design Automation**
- Scales up to 100s GB/s, millions of IOPS, sub-ms latencies

- SSD - low latency, IOPS, intensive workloads, small and random file operations
- HDD - throughput-intensive workloads, large & sequential file operations
- Seamless integration with S3
  - Can read S3 buckets as a file system (through FSx)
  - **Can write the output of the computations back to S3 (through FSx)**
- Can be used from on-premise servers

▼ FSx Deployment Options

▼ Scratch File System

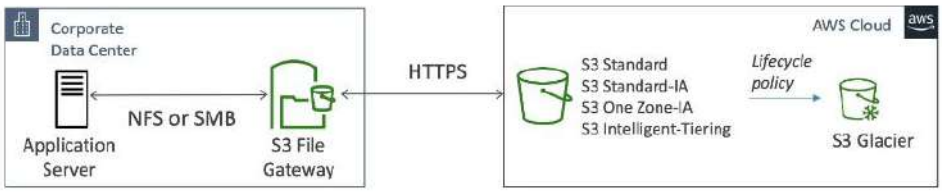
- Temporary storage
- Data is not replicated (data is lost if the file server fails)
- High burst (6x faster than persistent file system, 200MBps per TiB throughput)
- Usage: short-term processing, optimize costs



▼ Persistent File System

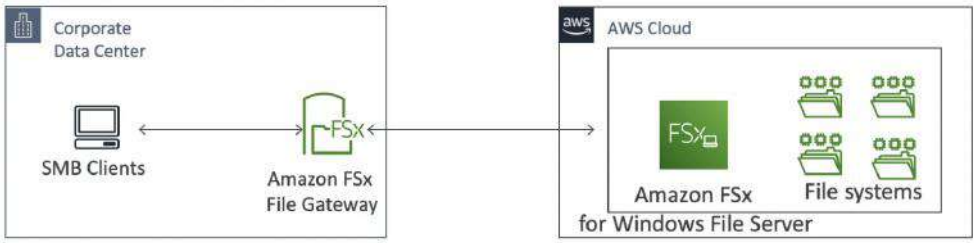
- Long-term storage
- Data is replicated within same AZ (multiple copies)
- Failed files are replaced within minutes
- Usage: long-term processing, sensitive data

latency access.



▼ FSx File Gateway

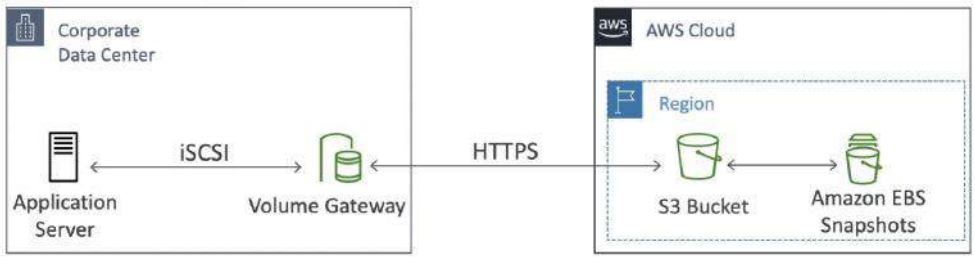
- Equivalent to S3 File Gateway but for Windows FSx
- Native access to Amazon FSx for Windows File Server
- Local cache for frequently accessed data
- Windows native compatibility (SMB, NTFS, Active Directory, etc.)
- Useful for group file shares and home directories



▼ Volume Gateway

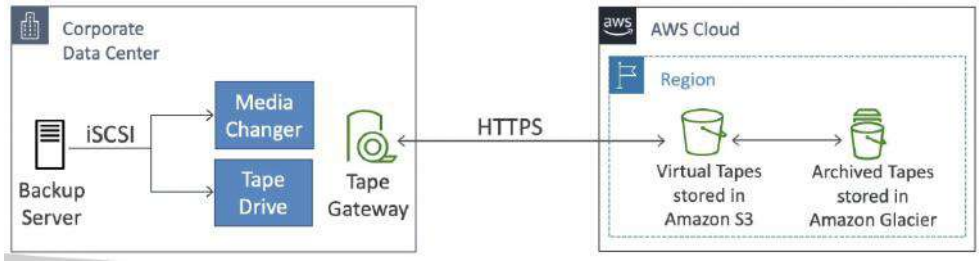
- Block storage using iSCSI protocol backed by S3
- On-premises storage volumes are backed by EBS snapshots which can help restore these volumes later
- Two kinds of volumes:
  - Cached volumes: low latency access to most recent data
  - Stored volumes: entire dataset is on premise, scheduled backups to S3

Here, the primary purpose of cloud storage is to backup on-premises storage volumes



▼ Tape Gateway

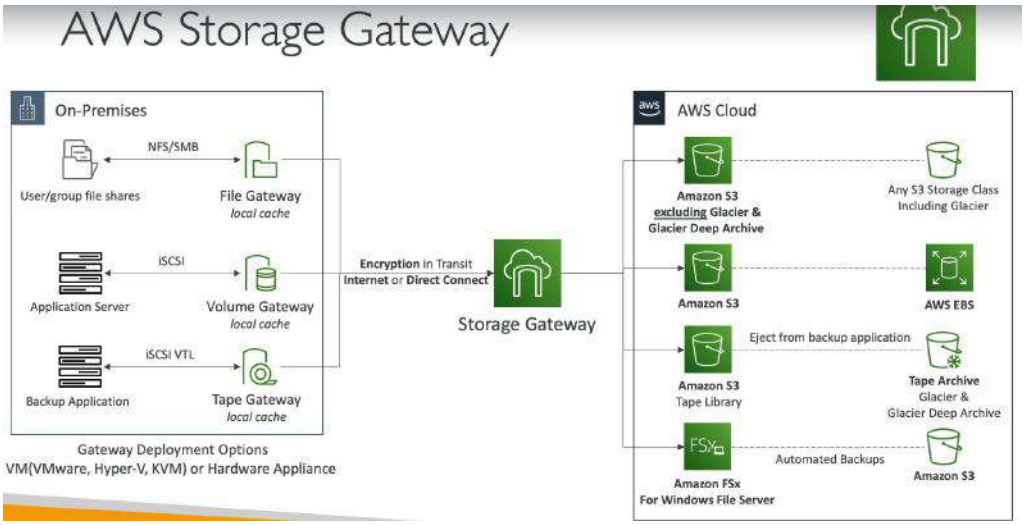
- Some companies have backup processes using physical tapes
- With Tape Gateway, companies use the same processes but, in the cloud Virtual Tape Library (VTL) is backed by Amazon S3 and Glacier
- Back up data using existing tape-based processes (and iSCSI interface)
- Works with leading backup software vendors



▼ Storage Gateway - Hardware appliance

- Using Storage Gateway means you need on-premises virtualization. If you don't have virtualization available, you can use a Storage Gateway - Hardware Appliance. It is a mini server that you need to install on-premises.
- You can buy it on amazon.com
- Works with File Gateway, Volume Gateway, Tape Gateway (not FSx)
- Has the required CPU, memory, network, SSD cache resources
- Helpful for daily NFS backups in small data centers

▼ Outro



▼ AWS Transfer Family

- A fully-managed service for file transfers in and out of S3 or EFS using the FTP protocol (instead of using proprietary methods)
- Supported Protocols
  - FTP (File Transfer Protocol) - unencrypted in flight

    - Physically attached storage to the EC2 instance
    - Extremely high IOPS
    - If the instance goes down, data is lost
- EFS
    - Network file system for linux
    - POSIX file system
    - Shared across AZ
- FSx for Windows
    - Just like EFS but for windows
- FSx for Lustre
    - High performance computing (HPC)
    - Supports Linux
    - High IOPS
    - Integrated with S3 in backend
- FSx for NetApp ONTAP
    - High OS compatibility for any Network file system
- FSx for OpenZFS
    - Managed ZFS file system
- Storage Gateway
    - bridge between on-premises storage and AWS
- Transfer Family
    - FTP, FTPS, SFTP interface on top of the amazon S3 or Amazon EFS
- DataSync
    - Schedule data sync from on-premises to AWS or AWS to AWS
- Snow Family
    - Move large amounts of data physically to the AWS cloud into S3
- Database
    - For specific workloads, usually with indexing and querying

▼ Section 18: Decoupling applications: SQS, SNS, Kinesis, ActiveMQ

▼ Application Communication

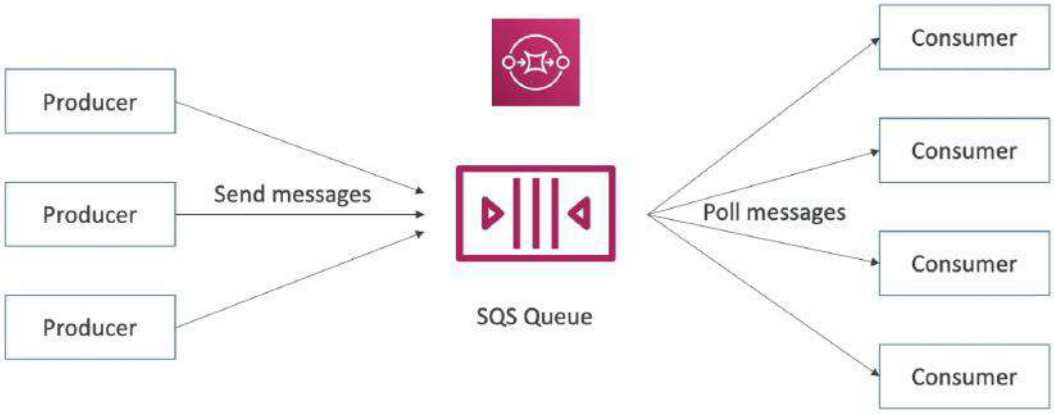
- Deployed services need to communicate with one another to do useful stuff.
- There are two patterns of application communication
    - Synchronous (application → application)
    - Asynchronous / Event-based (application → queue → application)

- Synchronous between applications can be problematic if there are sudden spikes of traffic and one of the services gets overwhelmed. In that case, it's better to asynchronously decouple your applications. We can use 3 services for this:
  - SQS: queue model
  - SNS: pub/sub model
  - Kinesis: real-time streaming model for large amount of data
- These services can scale independently from our application

▼ SQS - Simple Queue Service

▼ Decoupling

- SQS acts a buffer that stores message temporarily allowing us to decouple applications
- Multiple producers can send messages into a queue and multiple consumers can poll the queue for any message
- Once a consumer reads a message from the queue, the consumer deletes that message from the queue.



▼ Intro

- Fully managed service, used to decouple applications
- Oldest offering (over 10 years old)
- Two types:

▼ Standard Queue

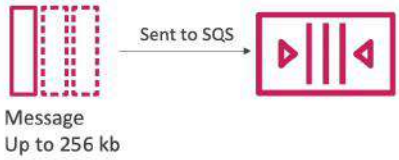
- Unlimited throughput (can publish any number of message per second into the queue)
- Unlimited number of messages in queue
- Default retention of messages: 4 days (max: 14 days)
- Low latency (<10 ms on publish and receive)
- Max message size: 256KB
- Can have duplicate messages (at least once delivery)
- Can have out of order messages (best effort ordering)
- Messages are put into the SQS queue using the SendMessage API using the SDK
- Consumers could be EC2 instances or Lambda functions
- Consumers could receive a maximum of 10 messages at a time
- Only when the consumer has completed processing a message, it is removed from the queue.

SQS – Producing Messages

- Produced to SQS using the SDK (SendMessage API)
- The message is **persisted** in SQS until a consumer deletes it
- Message retention: default 4 days, up to 14 days

- Example: send an order to be processed
  - Order id
  - Customer id
  - Any attributes you want

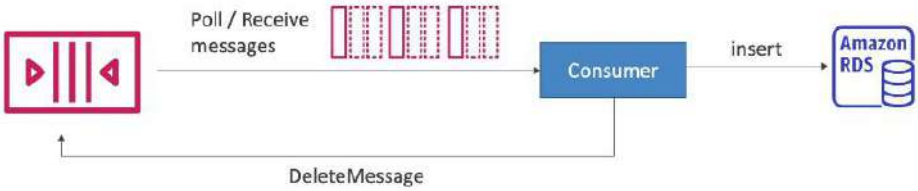
- SQS standard: unlimited throughput



▼ Consuming Messages

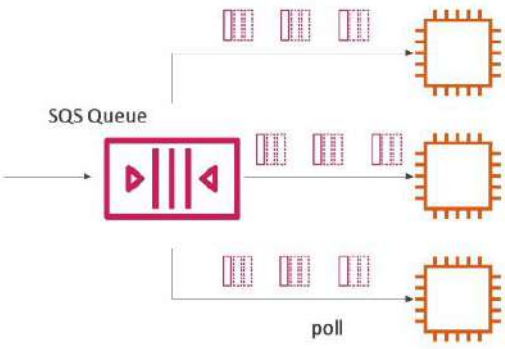
SQS – Consuming Messages

- Consumers (running on EC2 instances, servers, or AWS Lambda)…
- Poll SQS for messages (receive up to 10 messages at a time)
- Process the messages (example: insert the message into an RDS database)
- Delete the messages using the DeleteMessage API



▼ Outro

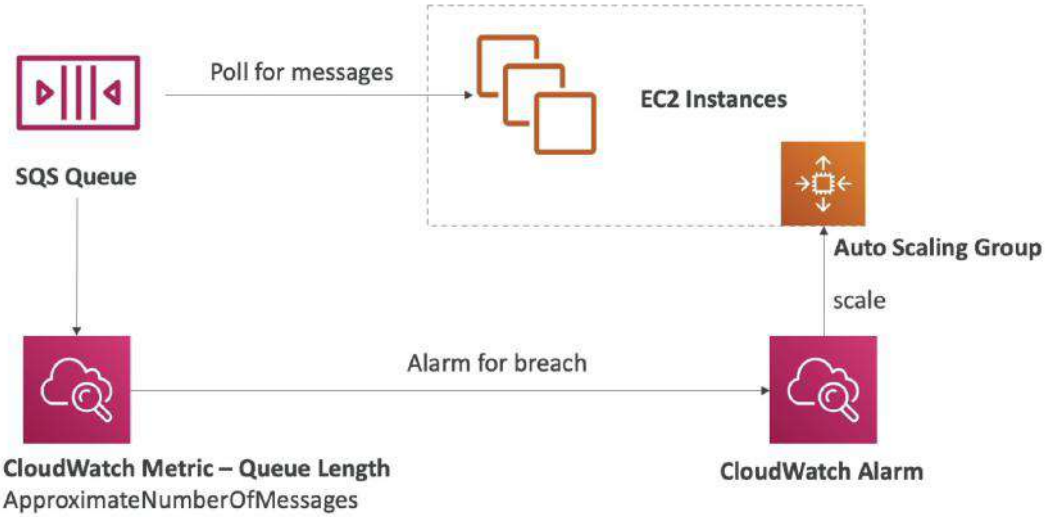
SQS – Multiple EC2 Instances Consumers



- Consumers receive and process messages in parallel
- At least once delivery
- Best-effort message ordering
- Consumers delete messages after processing them
- We can scale consumers horizontally to improve throughput of processing

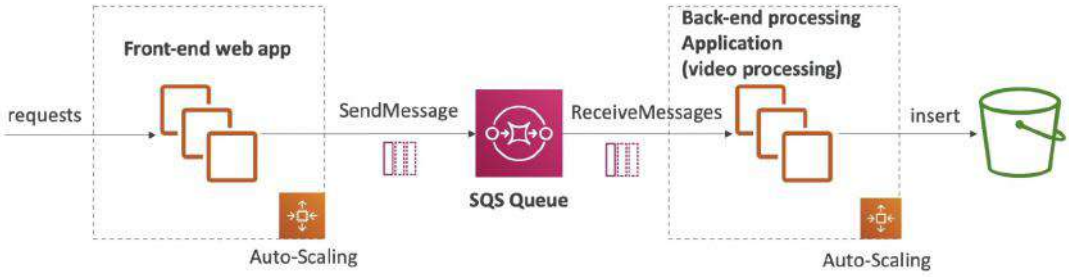
▼ SQS with ASG

We can attach an ASG to the consumer instances which will scale based on the Queue Length (approximate number of messages in the queue) CW metric. If the queue length goes above a certain threshold, a CW alarm will be triggered which will trigger the ASG to scale.



▼ Decoupling Application Tiers

For a video processing website, we can decouple the front-end and back-end using an SQS queue. This way both front-end and back-end can scale independently of each other within their own ASG. The front-end is only responsible for sending the requests (messages) into the queue. The back-end is only responsible for polling the messages and processing the video. Since, SQS has unlimited capacity and throughput. This system is reliable.



▼ Security

▼ Encryption:

- In-flight encryption using HTTPS API
- At-rest encryption using KMS keys
- Client-side encryption if the client wants to perform encryption / decryption themselves

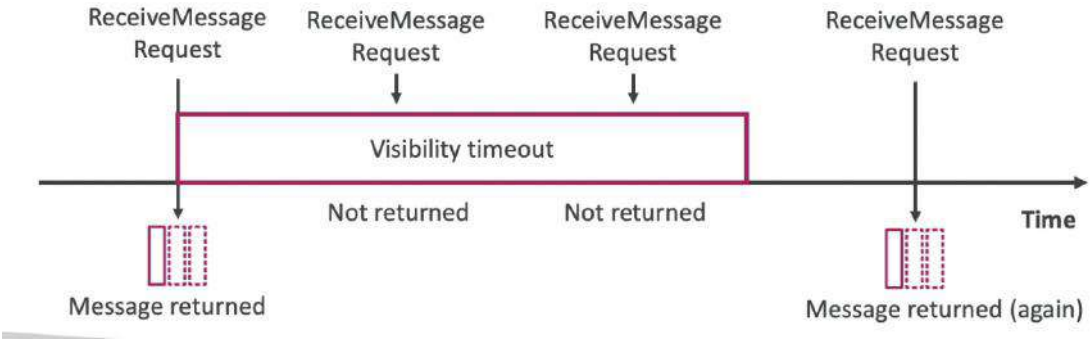
▼ Access Controls:

- IAM policies to regulate access to the SQS API
- SQS Access Policies (similar to S3 bucket policies)
  - Useful for cross-account access to SQS queues
  - Useful for allowing other services (SNS, S3, etc.) to write to an SQS queue

▼ Message Visibility Timeout

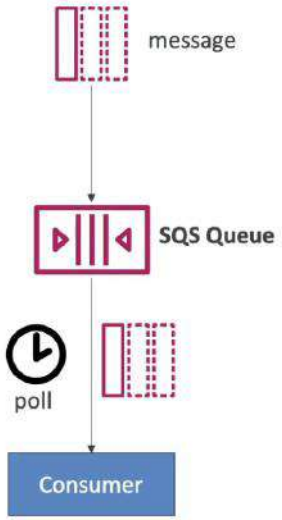
- After a message is polled by a consumer, it becomes invisible to other consumers
- By default, the “message visibility timeout” is 30 seconds which means the message has 30 seconds to be processed by a consumer otherwise it will be visible in the queue and may get picked by another consumer.

- After the message visibility timeout is over, the message is visible in the SQS queue
- If a message is not processed within the visibility timeout, it will be processed twice. However, a consumer could call the **Change MessageVisibility API** to change the visibility timeout for that specific message. This will get the consumer more time to process the message.
- Visibility timeout can be configured for the entire queue also:
    - If visibility timeout is high (hours), and the consumer crashes, re-processing of the pending message will take a lot of time
    - If visibility timeout is too low (seconds), we may get duplicate processing of messages

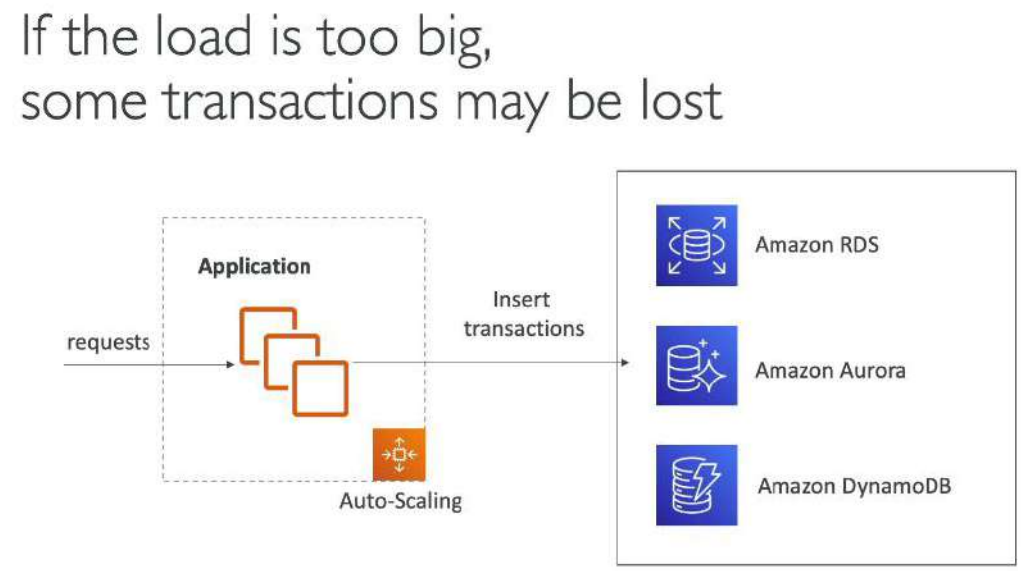


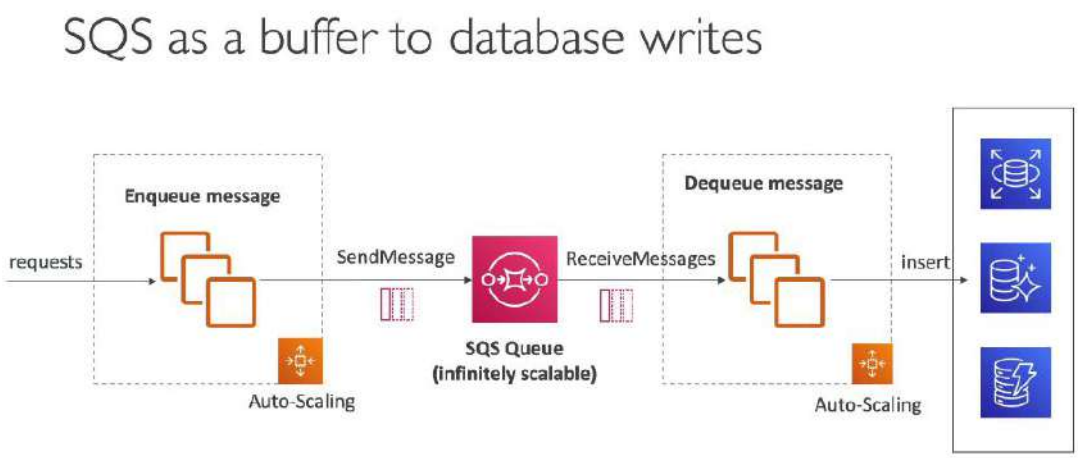
▼ Long Polling

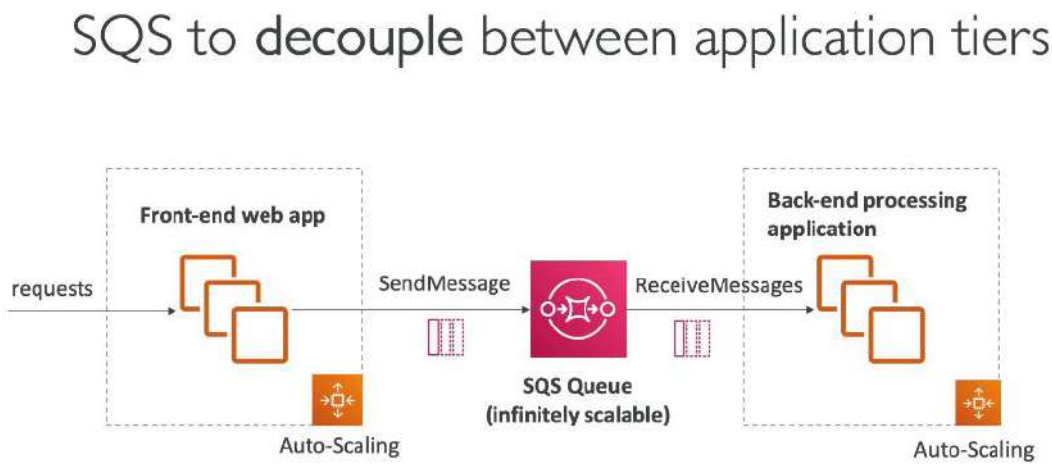
- When a consumer requests messages from the queue, it can optionally “wait” for messages to arrive if there are none in the queue. This is called Long Polling.
- LongPolling decreases the number of API calls made to SQS
- It also reduces the latency of your application as any incoming message during the polling will be read instantaneously.
- The wait time can be between 1 sec to 20 sec (20 sec preferable)
- Long Polling is preferable to Short Polling
- Long polling can be enabled at the queue level or at the API level by the consumer using **WaitTimeSeconds**



▼ SQS + ASG







▼ Hands on

- Create Queue

  SQS → Create Queue

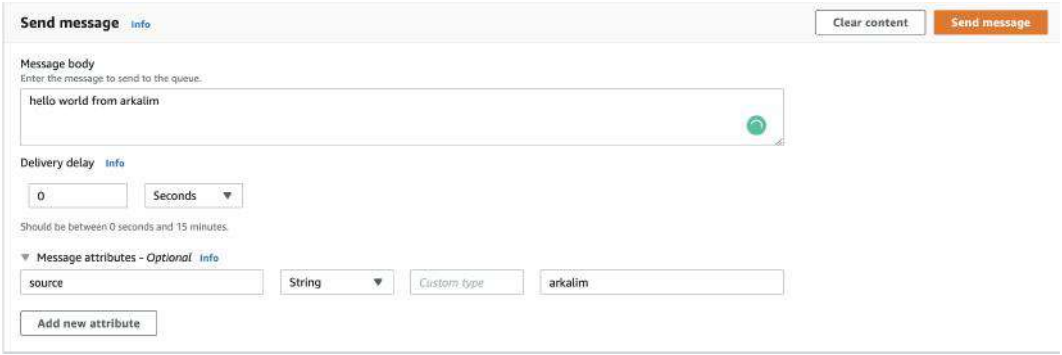
  In-transit encryption is enabled by default, we can configure at-rest encryption as well.

Untitled

- Send messages

  Select queue → Send and receive messages

  Attributes allow us to send key-value pairs of data along with the stringified message.

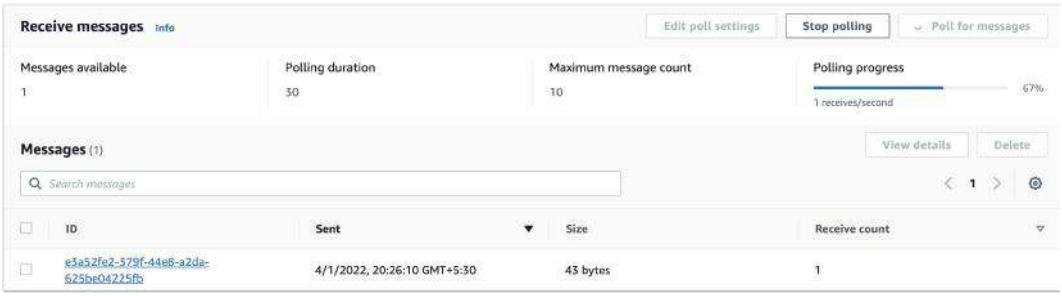


Untitled

- Receive messages

  To receive messages present in the queue, click on “poll for message”

  If we don’t delete the messages, they will remain in the queue and will be received every time we poll.



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- Purge queue

  Empties the queue of all the messages.

- Publish S3 events into SQS
  - Create S3 bucket
  - Modify SQS access policy to allow the S3 bucket to send messages to it

    To modify:
    - Resource: queue ARN
    - `aws:SourceArn` : change the bucket name

- `aws:SourceAccount` : account ID (top right hand corner)

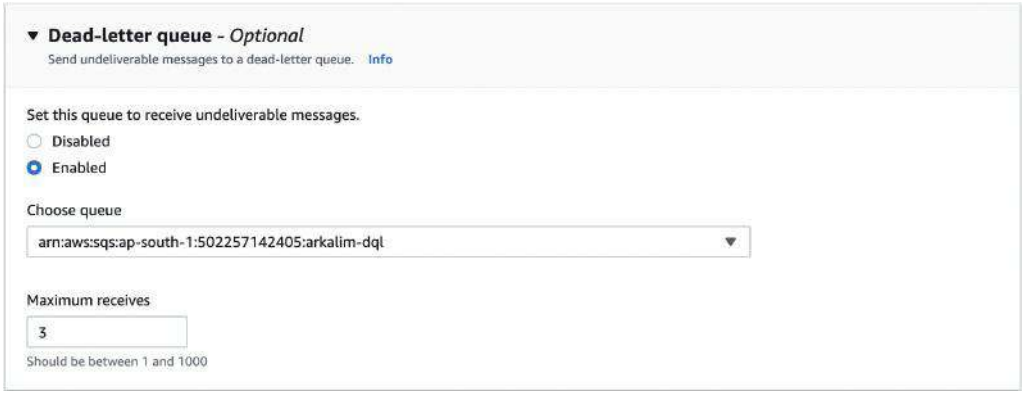
```
{    "Version": "2012-10-17",    "Id": "example-ID",    "Statement": [        {            "Sid": "example-sta
tement-ID",            "Effect": "Allow",            "Principal": {                "Service": "s3.amazonaws.co
m"            },            "Action": [                "SQS:SendMessage"            ],            "Resource":
 "arn:aws:sqs:us-east-1:502257142405:arkalim-queue",            "Condition": {                "ArnLike": {
"aws:SourceArn": "arn:aws:s3:*:*:arkalim-demo-bucket"                },                "StringEquals": {
"aws:SourceAccount": "502257142405"                }            }        }    ]}
```

The sample policy JSON can be found by googling

Granting permissions to publish event notification messages to a destination

- Enable S3 notifications with the SQS queue as destination (will not work if the previous step is missed)
- Upload anything in the bucket and poll the queue for messages

- Dead Letter Queues
  - Create another SQS queue with a high message retention period
  - Edit the original queue to configure the DQL



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Now, if a message doesn't get processed even after appearing 3 times in polling, it will be removed from the original queue and put into DLQ.

- Delay Queues

  Set the Delivery Delay parameter to a non-zero value for any SQS queue.

▼ Delay Queue

- Delay a message (consumers don't see it immediately) (max delay: 15 minutes)
- Default is 0 seconds (message is available right away)
- Delivery delay parameter can be set at the queue level
- Can override the default queue delay for a specific message using the **DelaySeconds** parameter in the message.

▼ Dead Letter Queue

- It is just a normal SQS queue which is used to store failing to be processed messages in another queue.
- If a consumer fails to process a message within the Visibility Timeout, the message goes back to the queue. We can set a threshold of how many times a message can go back to the queue. After the MaximumReceives threshold is exceeded, the

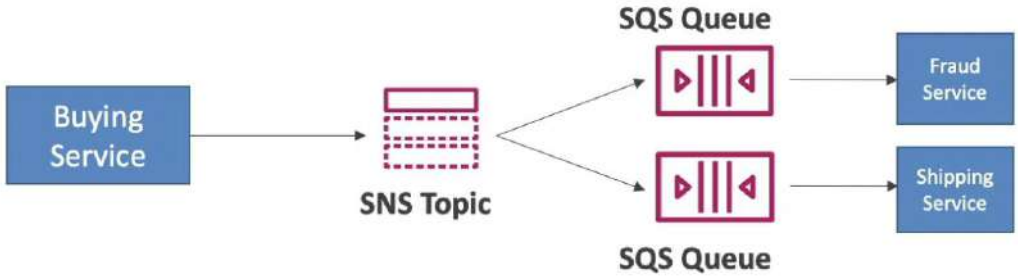
    - Create a topic
    - Create subscriptions
    - Publish to the topic
- Direct Publish (for mobile apps SDK)
  Works with Google GCM, Apple APNS, Amazon ADM, etc. to publish mobile notifications
    - Create a platform application
    - Create a platform endpoint
    - Publish to the platform endpoint

▼ Security

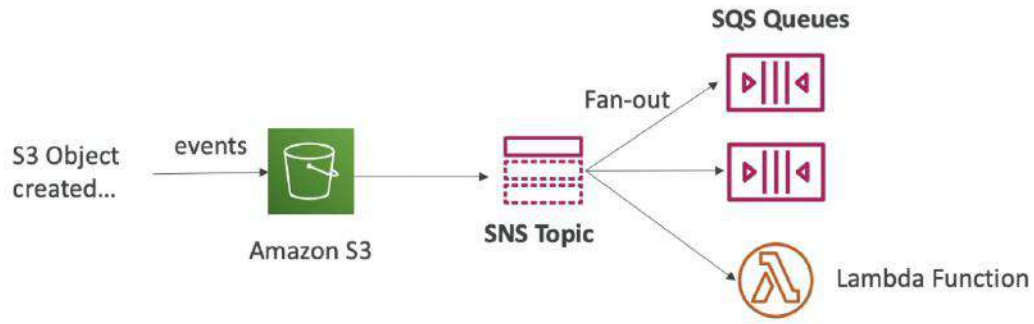
- Encryption:
    - In-flight encryption by default using HTTPS API
    - At-rest encryption using KMS keys (optional)
    - Client-side encryption if the client wants to perform encryption/decryption themselves
- Access Controls:
    - lAM policies to regulate access to the SNS API
    - SNS Access Policies (similar to SQS access policies)
        - Useful for cross-account access to SNS topics
        - Useful for allowing other AWS services (like S3) to write to an SNS topic

▼ SNS + SQS Fanout Pattern

- Intro

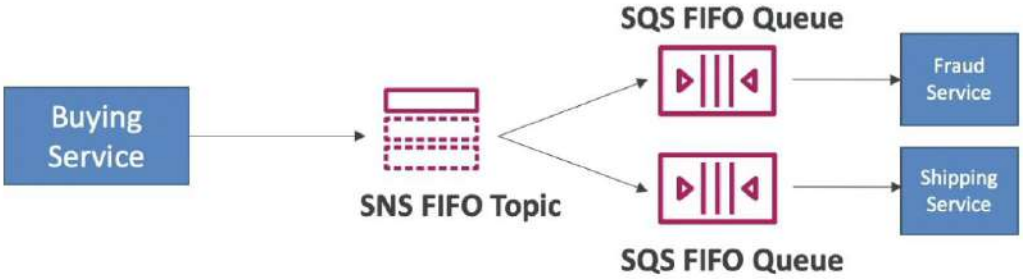


    - If the publisher sends message individually to each SQS queue without the use of SNS, there might be failure in between when the publisher application crashes after sending the message to just 1 or 2 queues.
    - Fully decoupled, no data loss
    - SQS allows for: data persistence, delayed processing and retries of work
    - Ability to add more SQS subscribers over time
    - Make sure your SQS queue access policy allows for SNS to write
- S3 events to multiple queues
    - For the same combination of: event type (e.g. object create) and prefix (e.g. images/) you can only have one S3 Event rule. In simple terms, S3 events cannot be fanned out directly.
    - If you want to send the same S3 event to multiple SQS queues and other AWS services, use SNS.



- SNS FIFO + SQS FIFO fan out

  Fan out with ordering or messages and deduplication.



▼ FIFO Topic

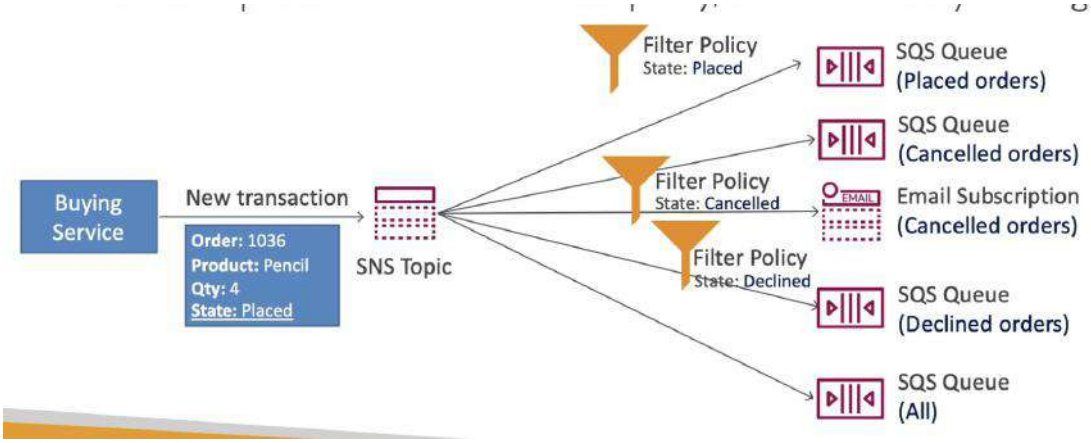
- FIFO topic guarantees ordering of messages in the topic.
- Similar features as SQS FIFO:
  - Ordering by Message Group ID (all messages in the same group are ordered)
  - Deduplication using a Deduplication ID or Content Based Deduplication
- Can only have SQS FIFO queues as subscribers
- Limited throughput (same throughput as SQS FIFO) because only SQS FIFO queues can read from FIFO topics.
- The topic name must end with `.fifo`

SNS FIFO + SQS FIFO: Fan Out

- In case you need fan out + ordering + deduplication

▼ Message Filtering

- JSON policy used to filter messages sent to SNS topic's subscriptions.
- Each subscriber will have its own filter policy.
- If a subscription doesn't have a filter policy, it receives every message



▼ Hands on

- Create an SNS Topic

  SNS → Create Topic

- Create Subscription

  Select the topic → Create subscription

  Protocol: email

  Subscription filter policy: configure if you want to filter messages received by this subscriber

▼ Kinesis

▼ Intro

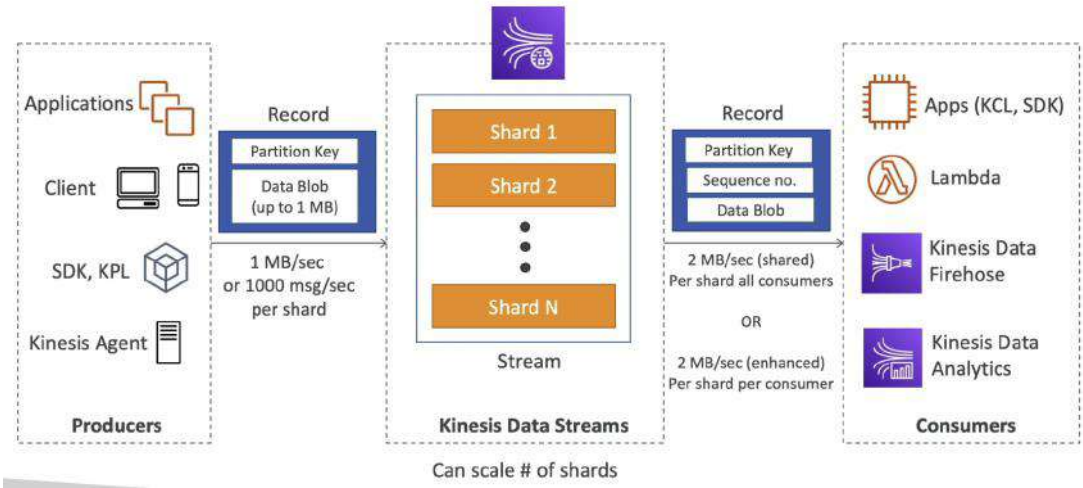
Amazon Kinesis Data Streams (KDS) is a massively scalable and durable real-time data streaming service. It can continuously capture gigabytes of data per second from hundreds of sources such as website clickstreams, database event streams, financial transactions, social media feeds, IT logs, and location-tracking events.

- Makes it easy to collect, process, and analyze streaming data in real-time
- Ingest real-time data such as: Application logs, Metrics, Website clickstreams, loT telemetry data, etc.
- Four services:

- Kinesis Data Streams: capture, process, and store data streams
- Kinesis Data Firehose: load data streams into AWS data stores
- Kinesis Data Analytics: analyze data streams with SQL or Apache Flink
- Kinesis Video Streams: capture, process, and store video streams

▼ Kinesis Data Streams

- Kinesis streams scale their throughput using shards. The more the number of shards, higher the throughput (manual scaling).
- Mostly used to ingest data in real time
- Producers could be applications, or client. They use the SDK, Kinesis Producer Library (KPL) or Kinesis Agent to publish a record on the stream. A record consists of a partition key (used to partition data coming from multiple publishers) and data blob (max 1MB).
- Throughput of publishing on a stream will be 1MB/sec per shard or 1000 msg/sec per shard.
- Consumers use the SDK or Kinesis Client Library (KCL) to consume the records. Consumption throughput could be of two types as mentioned below (second one has higher throughput but more expensive).
- Billing is per shard provisioned, can have as many shards as you want
- Retention between 1 day (default) to 365 days
- Ability to reprocess (replay) data
- Once data is inserted in Kinesis, it can’t be deleted (immutability)
- Data that shares the same partition goes to the same shard (ordering)

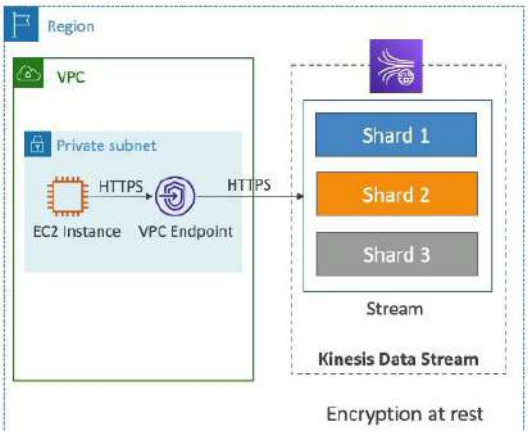


Kinesis Data Streams – Capacity Modes

- Provisioned mode:
  - You choose the number of shards provisioned, scale manually or using API
  - Each shard gets 1MB/s in (or 1000 records per second)
  - Each shard gets 2MB/s out (classic or enhanced fan-out consumer)
  - You pay per shard provisioned per hour
- On-demand mode:
  - No need to provision or manage the capacity
  - Default capacity provisioned (4 MB/s in or 4000 records per second)
  - Scales automatically based on observed throughput peak during the last 30 days
  - Pay per stream per hour & data in/out per GB

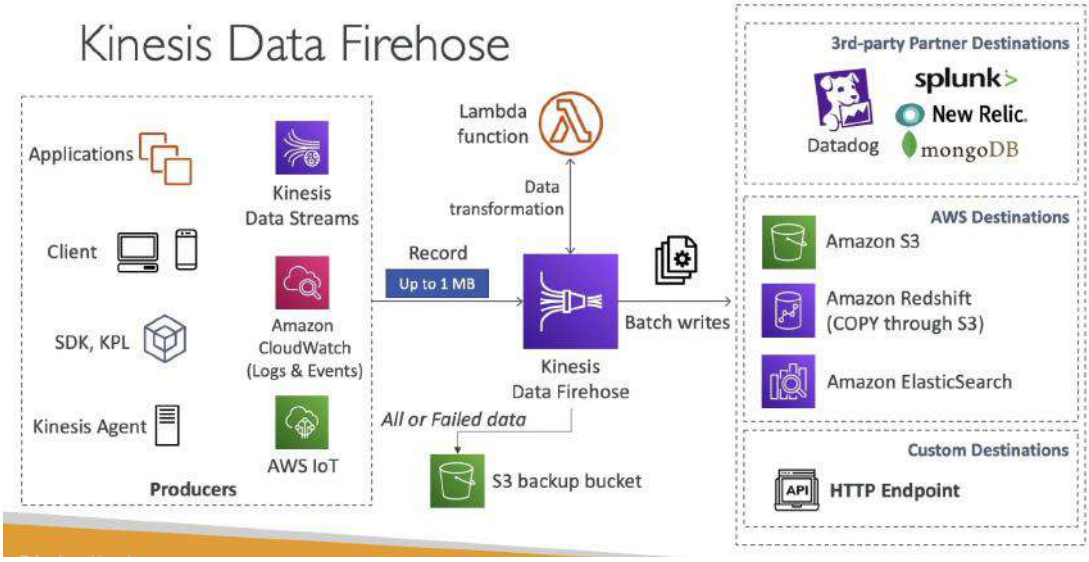
Kinesis Data Streams Security

- Control access / authorization using IAM policies
- Encryption in flight using HTTPS endpoints
- Encryption at rest using KMS
- You can implement encryption/decryption of data on client side (harder)
- VPC Endpoints available for Kinesis to access within VPC
- Monitor API calls using CloudTrail

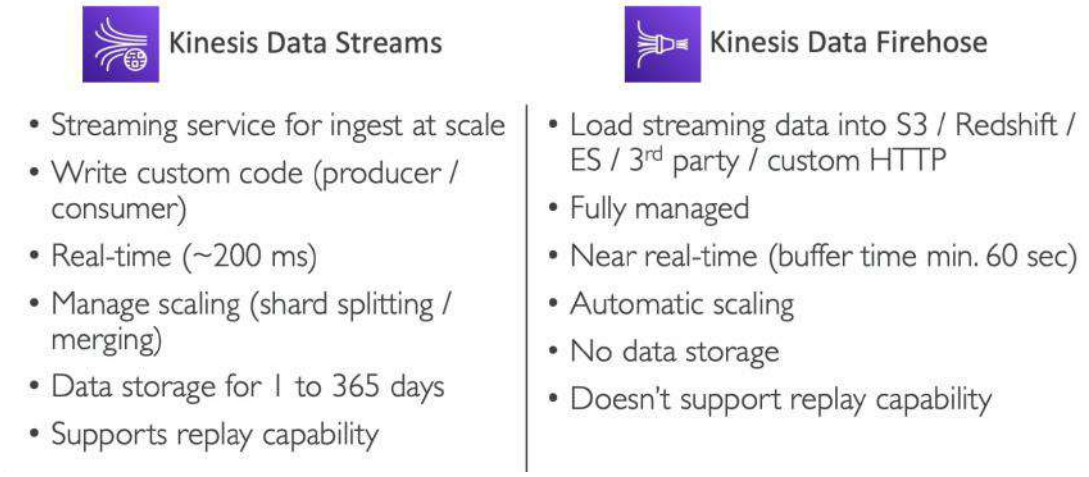


▼ Kinesis Data Firehose

- Firehose is used to store data into a target location.
- Firehose writes data in batches efficiently (not real time).
- Fully Managed Service, no administration required, automatic scaling, serverless
- Destinations:
  - AWS: Redshift, Amazon S3, ElasticSearch
  - 3rd party partner: Splunk, MongoDB, DataDog, NewRelic, etc.
  - Custom: send to any HTTP endpoint
- Pay for data going through Firehose, provisioning not required
- Near Real Time (60 seconds latency minimum) for non full batches (limited throughput) or if the data is < 1 MB. These number can be configured, but these are the minimum values. Higher the buffer size (batch size), higher the write efficiency.
- Supports many data formats, conversions, transformations, compression
- Supports custom data transformations using AWS Lambda
- Can send failed or all data to a backup S3 bucket



▼ Data Stream vs Firehose

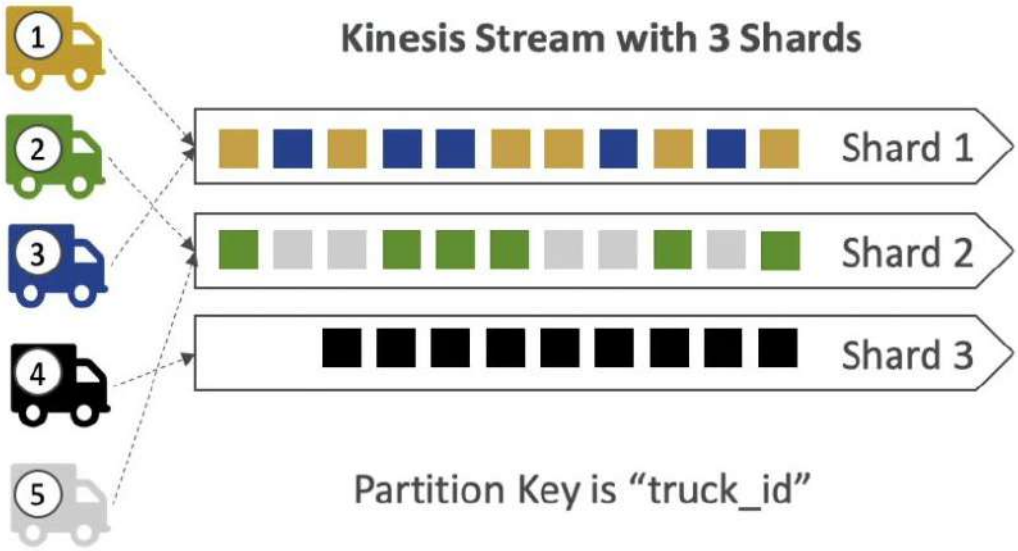


▼ Ordering data into Kinesis

Imagine you have 100 trucks each having unique ID (truck_1 truck_2, truck_100) on the road sending their GPS positions regularly into AWS. You want to consume the data in order for each truck, so that you can track their movement accurately. How should you send that data into Kinesis?

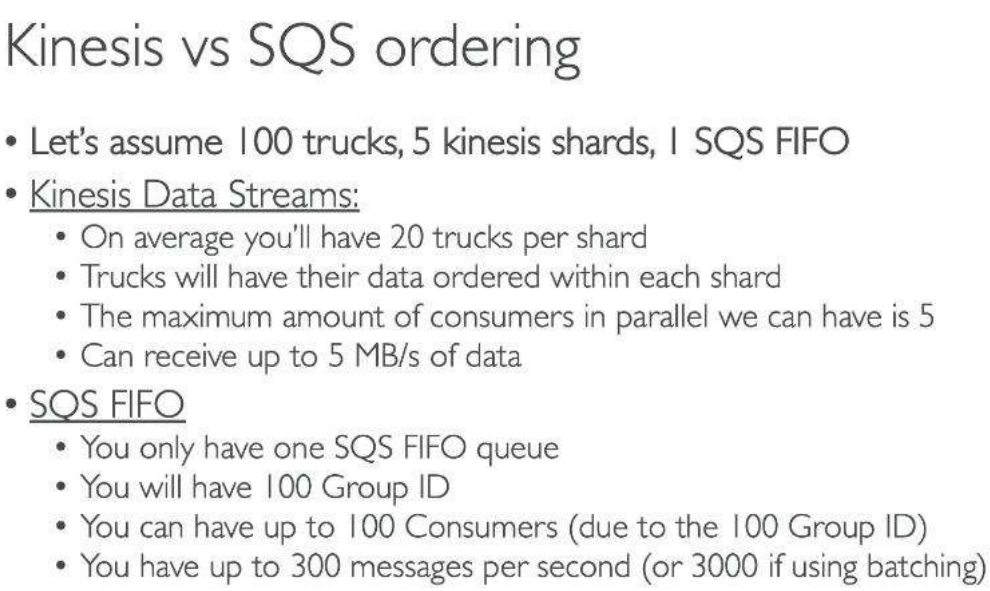
Answer: send using a “Partition Key” = value of the “truck id”. The same key will always go to the same shard. Which key should go to which shard is determined by Kinesis using a hash function. Data will be ordered in each shard.

💡 Number of consumers = number of shards (one consumer per shard)



It’s better to solve the above problem using a SQS FIFO queue.

- You only have one SQS FIFO queue
  - You will have 100 Group ID
  - You can have up to 100 Consumers (due to the 100 Group ID)
  - You have up to 300 messages per second (or 3000 if using batching) - throughput limitation



▼ Hands on

- Create a Kinesis Data Stream
- Create a Kinesis Firehose and configure it to read data from the data stream and write into an S3 bucket.

▼ SQS vs SNS vs Kinesis

SQS:

- Consumer "pull data"
- Data is deleted after being consumed
- Can have as many workers (consumers) as we want
- No need to provision throughput
- Ordering guarantees only on FIFO queues
- Individual message delay capability

SNS:

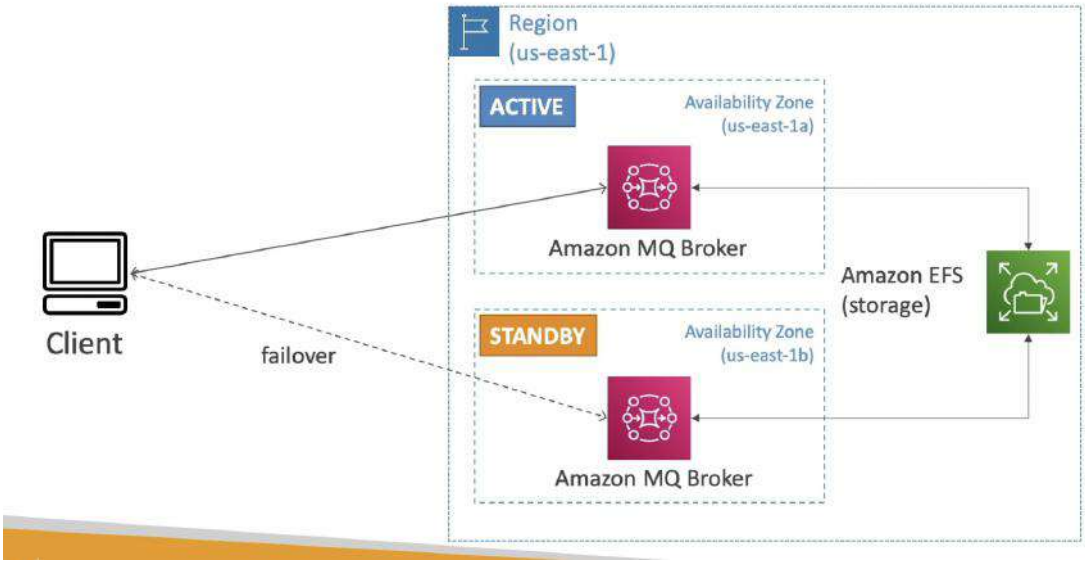
- Push data to many subscribers
- Up to 12,500,000 subscribers
- Data is not persisted (lost if not delivered)
- Pub/Sub
- Up to 100,000 topics
- No need to provision throughput
- Integrates with SQS for fan-out architecture pattern
- FIFO capability for SQS FIFO

Kinesis:

- Standard: pull data
  - 2 MB per shard
- Enhanced-fan out: push data
  - 2 MB per shard per consumer
- Possibility to replay data
- Meant for real-time big data, analytics and ETL
- Ordering at the shard level
- Data expires after X days
- Must provision throughput

▼ Amazon MQ

- SQS & SNS are "cloud-native" services, and they're using proprietary protocols from AWS that are not standards in the market.
- If you have some traditional applications running from on-premise, they may use open protocols such as: MQTT, AMQP, STOMP, Openwire, WSS, etc.
- When migrating to the cloud, instead of re-engineering the application to use SQS and SNS, we can use Amazon MQ (managed Apache ActiveMQ)
- Amazon MQ is a managed message broker service for RabbitMQ, Active MQ
- Amazon MQ doesn't "scale" as much as SQS / SNS because it is provisioned
- Amazon MQ runs on a dedicated machine, can run in HA (high availability) with failover
- Amazon MQ has both queue feature (SQS) and topic features (SNS)
- High availability in Amazon MQ works by leveraging MQ broker in multi AZ (active and standby). EFS (NFS that can be mounted to multi AZ) is used to keep the files safe in case the main AZ is down. If the main AZ is down, failover happens.



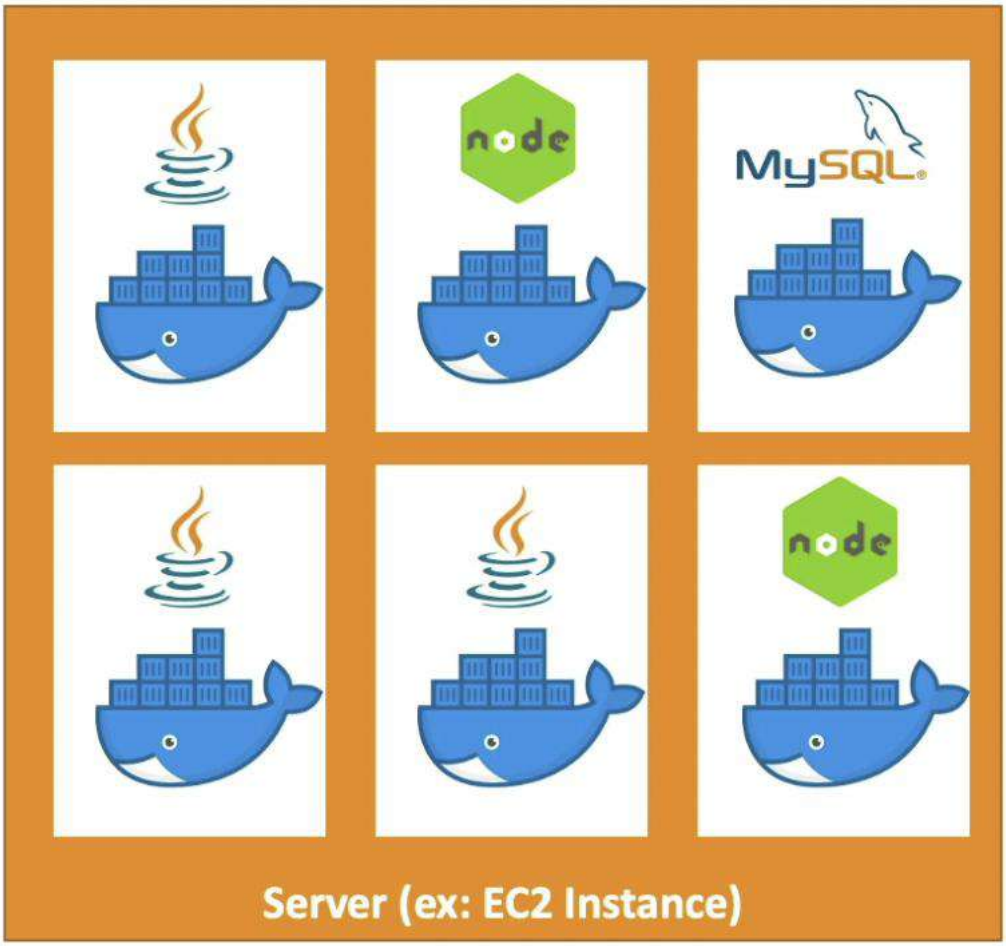
▼ Section 19: Containers on AWS: ECS, Fargate, ECR & EKS

▼ Docker

▼ Intro

- Docker is a software development platform to deploy apps

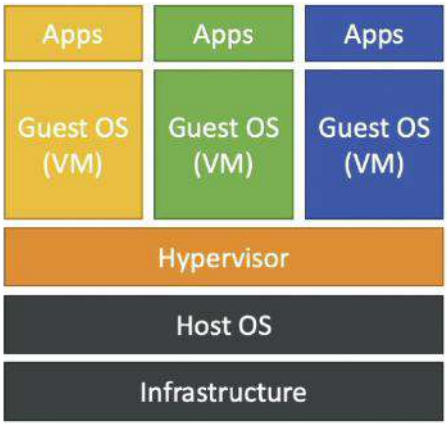
- Apps are packaged in containers that can be run on any OS
- Apps run the same, regardless of where they’re run
  - Any machine
  - No compatibility issues
  - Predictable behavior
  - Less work
  - Easier to maintain and deploy
  - Works with any language, any OS, any technology
- We can run a bunch of Docker containers on an EC2 instance. These docker containers could internally be running anything. But from the EC2 instance’s perspective, it only sees docker containers.

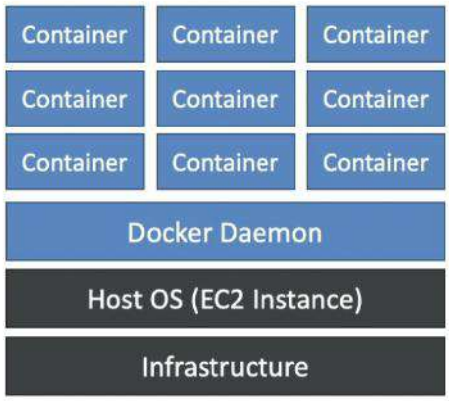


- Docker containers are created from Docker images which are stored in Docker Repositories.
- Docker Repositories:
  - Public:
    - Docker Hub https://hub.docker.com/ where we can find base images for many technologies or OS like Ubuntu, Java, MySQL, NodeJS, etc.
    - Public: Amazon ECR Public
  - Private:
    - Amazon ECR (Elastic Container Registry)

▼ Docker vs VM

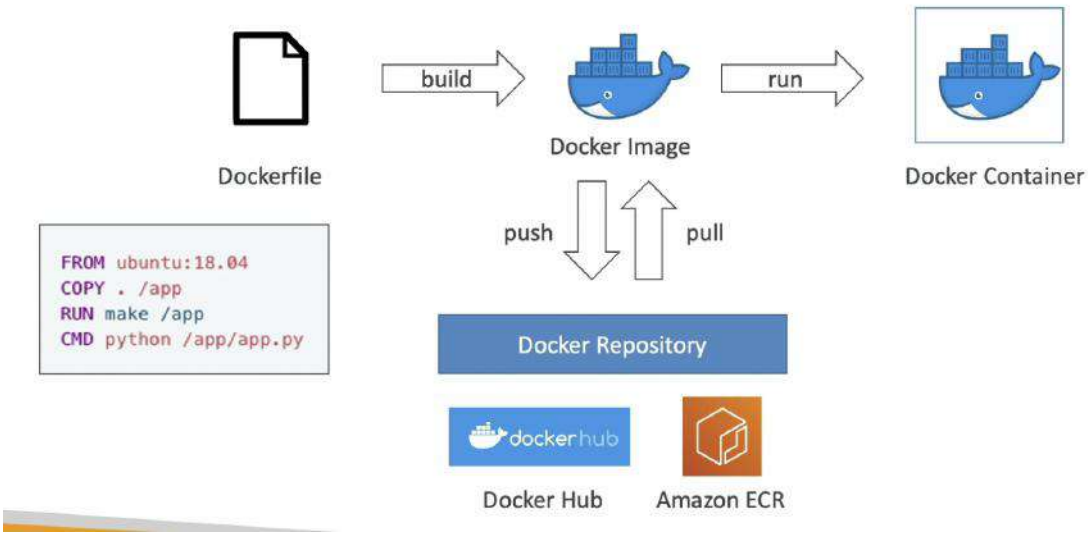
- Docker is “sort of” a virtualization technology, but not exactly
- In case of VMs, every virtual OS is isolated from each other. They don’t share resources.
- In case of Docker, many lightweight containers share the same resource. So, we can run many containers on the same hardware.





▼ Docker lifecycle

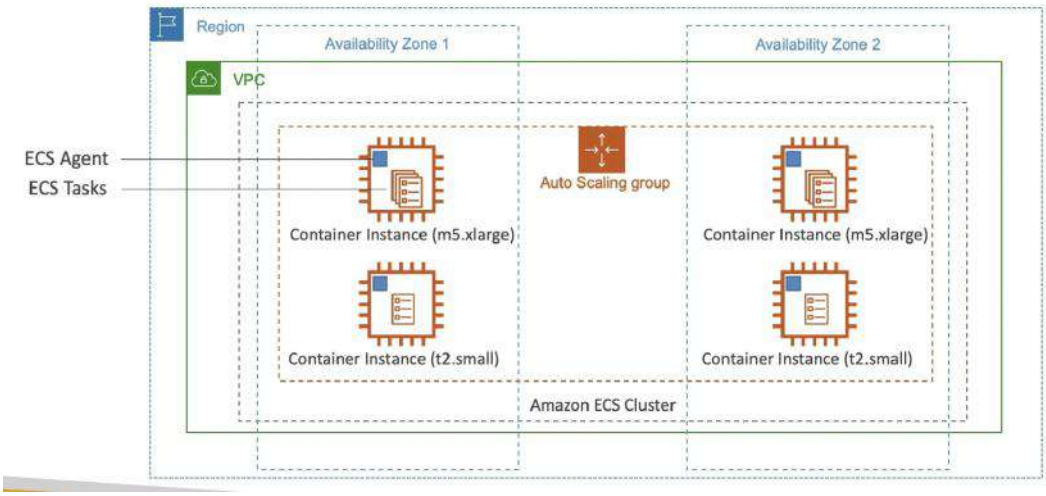
- First create a docker file
- Building the docker file will give docker image
- Running the docker image will give docker container
- Optionally, you can push the docker image to a repository and pull from there and run.



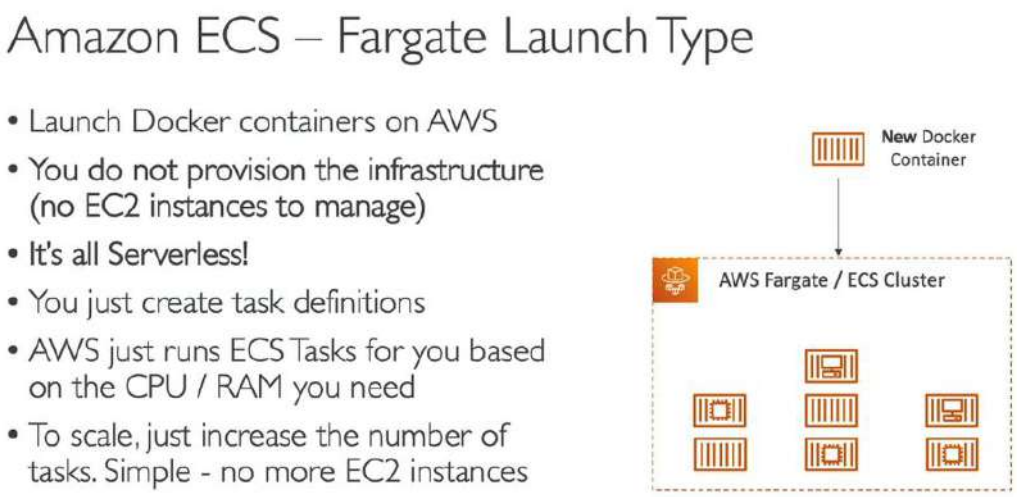
▼ ECS - Elastic Container Service

▼ Intro

- Allows us to launch Docker containers on AWS
- You must provision & maintain the infrastructure (EC2 instances)
- AWS takes care of starting / stopping containers
- ECS has integrations with ALB
- The EC2 instances will be the underlying hardware for containers to run. When a new container is to be launched, ECS will check all the available EC2 instances to check for available resources to determine where to launch the container.



▼ Fargate launch type for ECS



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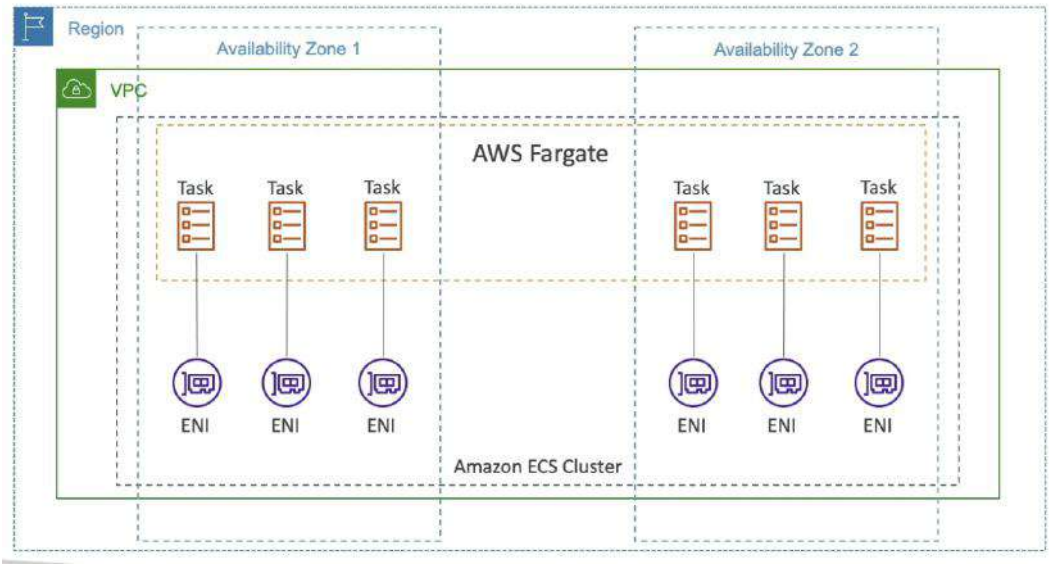
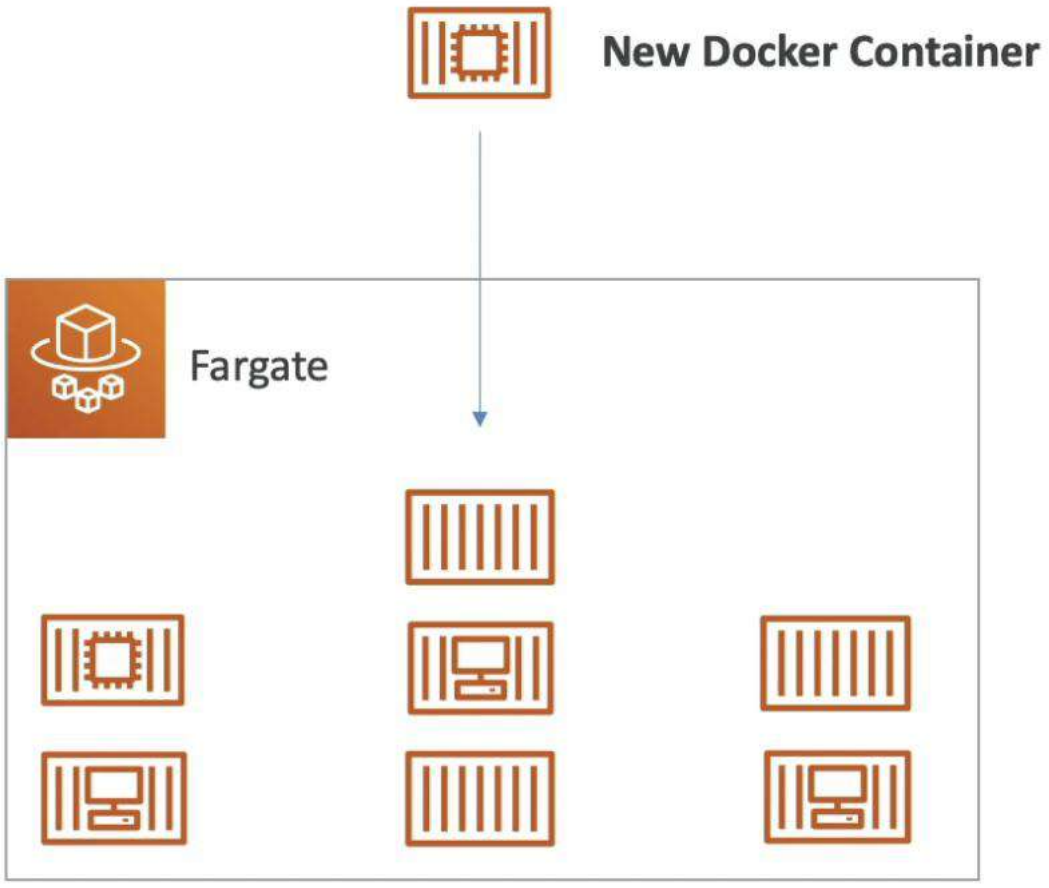
VPC and ECS cluster are setup the same way as in EC2 launch type, but instead of using ASG with EC2 instances, we have a Fargate cluster spanning multiple AZ. The fargate cluster will run ECS tasks anywhere within the cluster and attach an ENI (with a unique private IP) to each task. So, if we have a lot of ECS tasks, we need sufficient free private IPs.



▼ Fargate

- Launch Docker containers on AWS without worrying about infrastructure management
- You do not provision the infrastructure (no EC2 instances to manage) - simpler
- Serverless
- AWS just runs containers for you based on the CPU / RAM you need. You won't know where these containers are running.



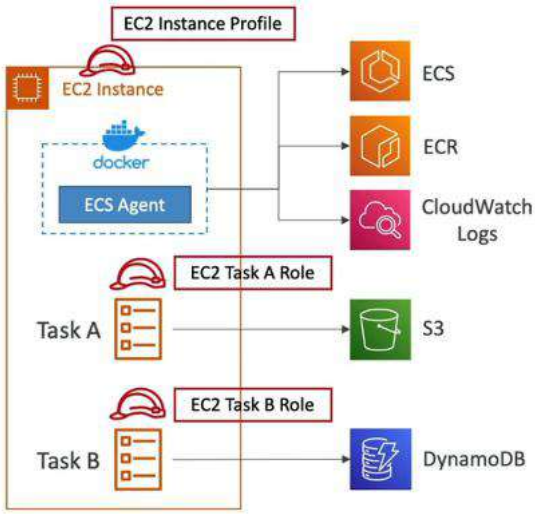
▼ IAM Roles for ECS tasks

▼ EC2 Instance Profile (IAM role for the EC2 instance):

- Used by the ECS agent to:
  - Make API calls to ECS service
  - Send container logs to Cloud Watch Logs
  - Pull Docker image from ECR
  - Reference sensitive data in Secrets Manager or SSM Parameter Store

▼ ECS Task Role:

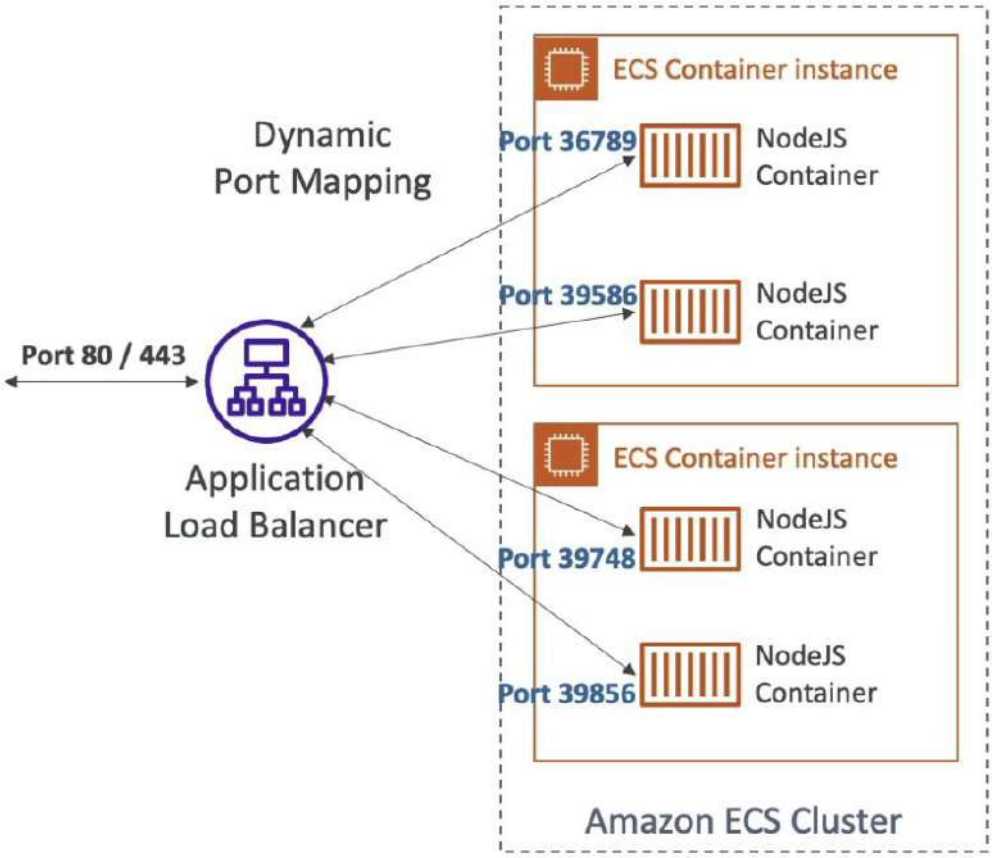
- ECS Task Role allows the ECS tasks to access resources within AWS.
- Allow each task to have a specific role
- Use different roles for the different ECS Services you run
- Task Role is defined in the task definition



▼ Load Balancing

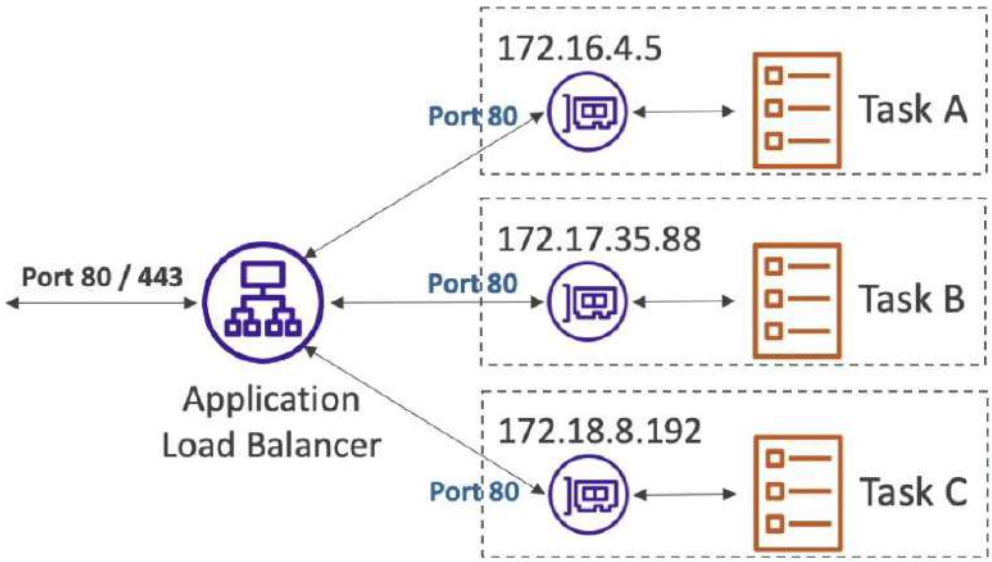
▼ Load Balancing for EC2 launch type

- Dynamic port is assigned to randomly ECS tasks
- Once the ALB is registered to a service in the ECS cluster, it will find the right port on your EC2 Instances
- You must allow on the EC2 instance's security group any port from the ALB security group because it may attach on any port.



▼ Load Balancing for Fargate launch type

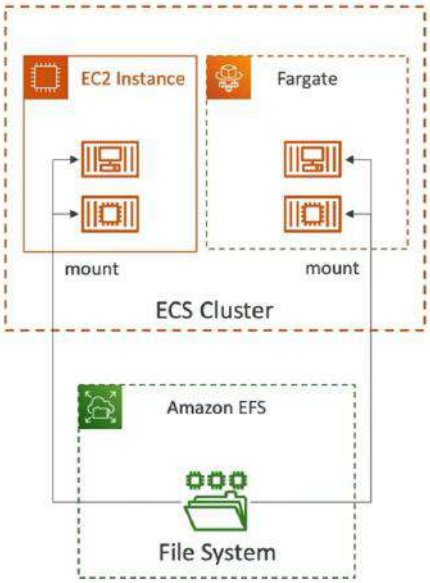
- Each task has a unique IP but same port (80)
- You must allow on the ENI's security group the task port (80) from the ALB security group



▼ ECS + EFS

- EFS volumes are used as storage for ECS tasks
- Works for both EC2 Tasks and Fargate tasks

- Ability to mount EFS volumes onto tasks
- Tasks launched in any AZ will be able to share the same data in the EFS volume since EFS spans multi AZ.
- Fargate + EFS ⇒ serverless + data storage without managing servers
- Use case: persistent multi-AZ shared storage for your containers
- AWS S3 cannot be mounted as a file system.

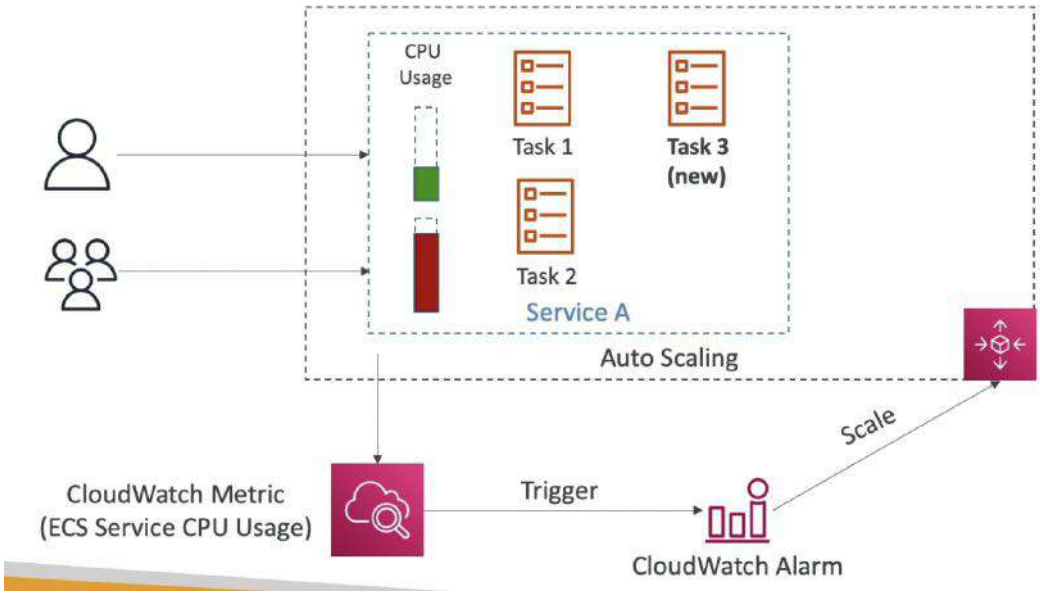


▼ Scaling

▼ ECS Service Auto Scaling

ECS Service Auto Scaling

- Automatically increase/decrease the desired number of ECS tasks
- Amazon ECS Auto Scaling uses **AWS Application Auto Scaling**
  - ECS Service Average CPU Utilization
  - ECS Service Average Memory Utilization - Scale on RAM
  - ALB Request Count Per Target – metric coming from the ALB
- **Target Tracking** – scale based on target value for a specific CloudWatch metric
- **Step Scaling** – scale based on a specified CloudWatch Alarm
- **Scheduled Scaling** – scale based on a specified date/time (predictable changes)
- ECS Service Auto Scaling (task level) ≠ EC2 Auto Scaling (EC2 instance level)
- Fargate Auto Scaling is much easier to setup (because **Serverless**)



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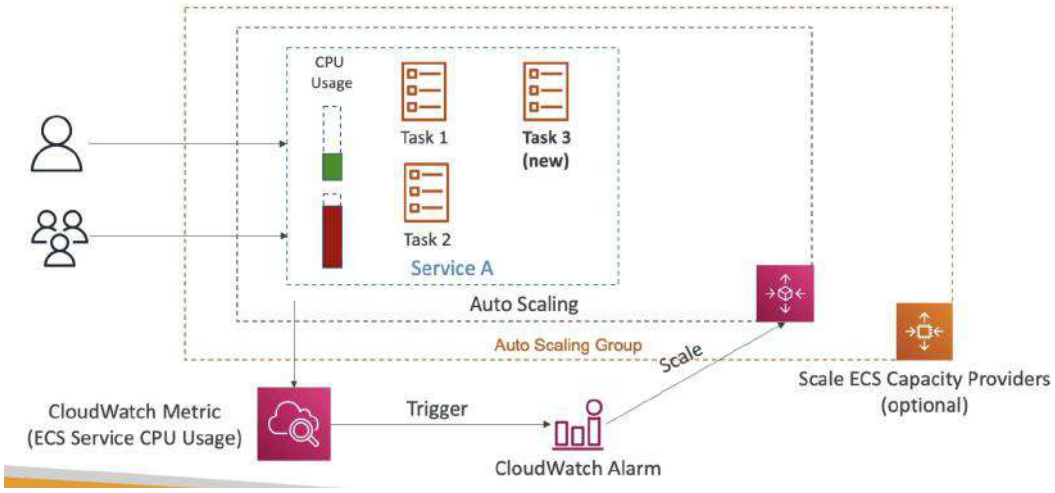
▼ EC2 - on Service CPU usage

Along with the service, we also need to scale the ECS cluster by adding more EC2 instances otherwise we will run out of resources to run new tasks.



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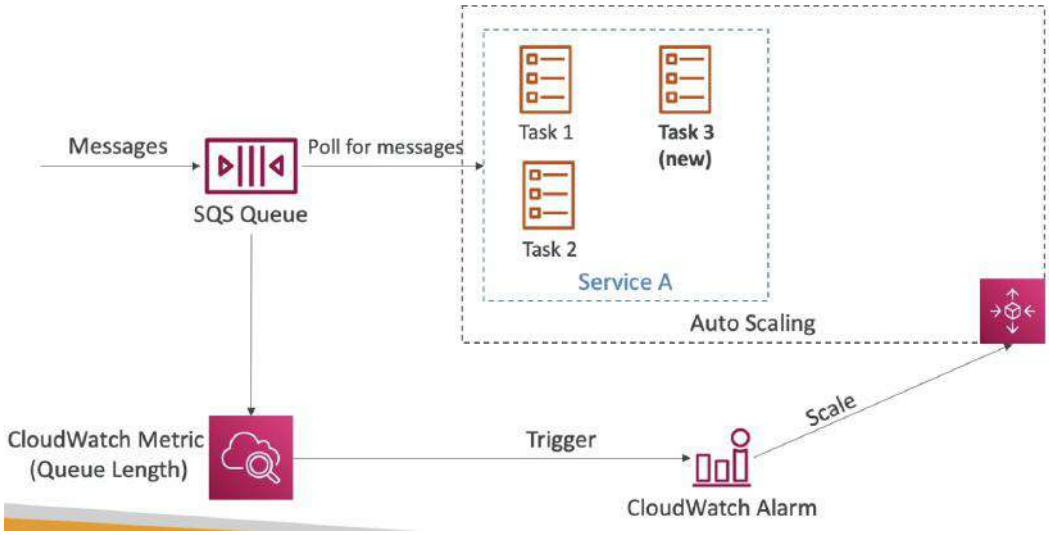
▼ Fargate - on SQS queue length



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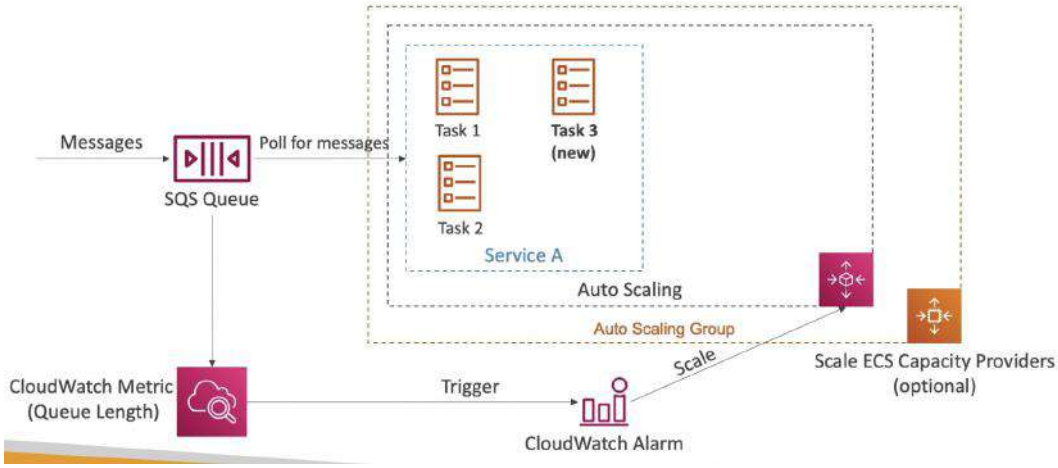
▼ EC2 - on SQS queue length



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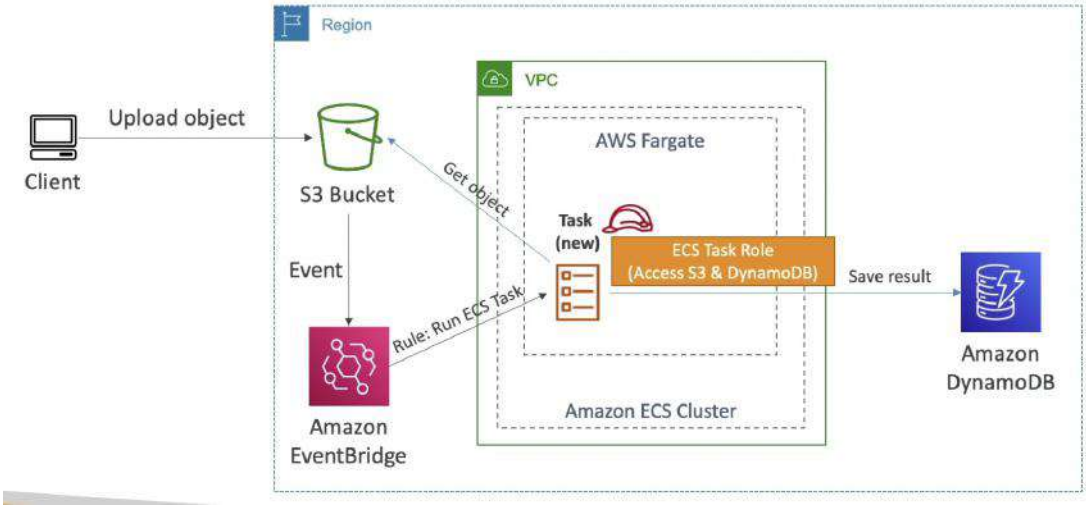
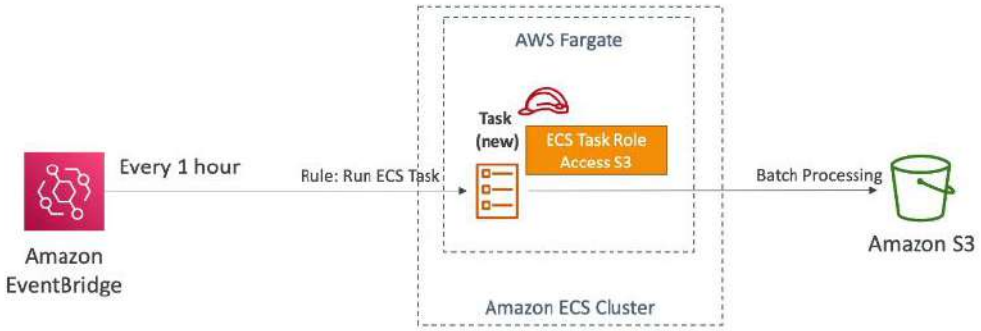
▼ ECS Tasks invoked by EventBridge

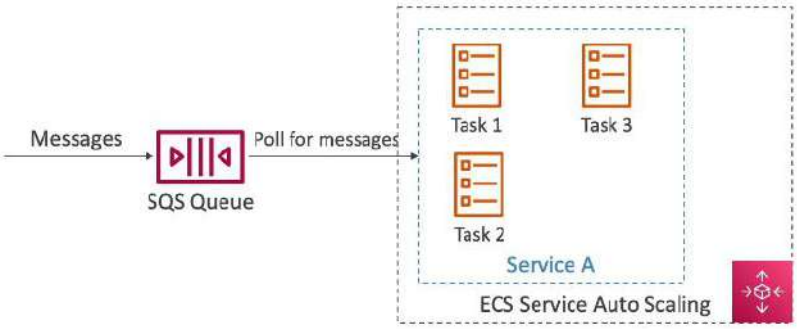
Example: When the user uploads an object to S3, create an ECS task to process the object and store the result in DynamoDB.



ECS tasks invoked by Event Bridge Schedule



ECS – SQS Queue Example



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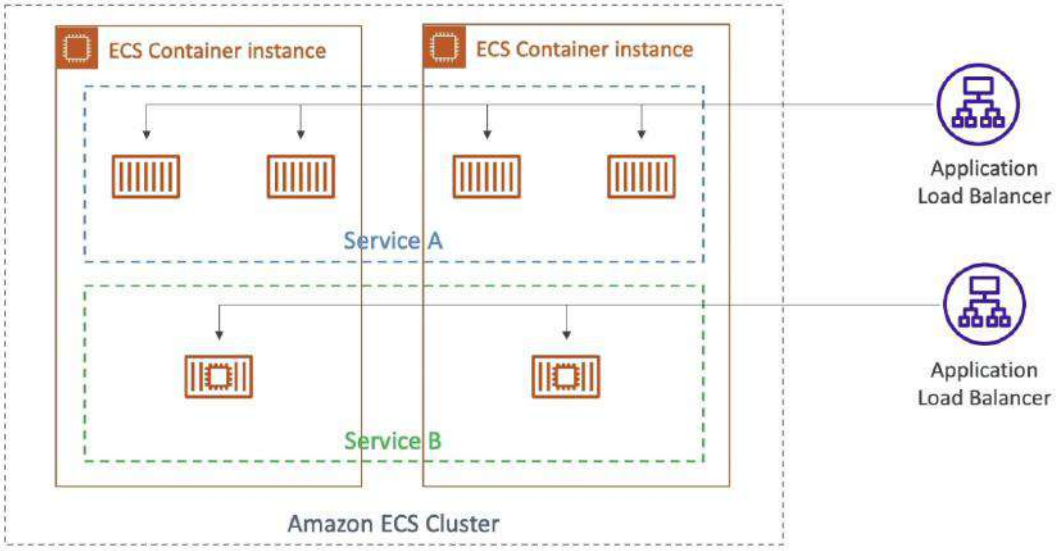
▼ ECS Services & Tasks

Inside the ECS cluster, we can have multiple services running which span multiple instances each running some tasks. We can use ALBs to send requests to each of these tasks.

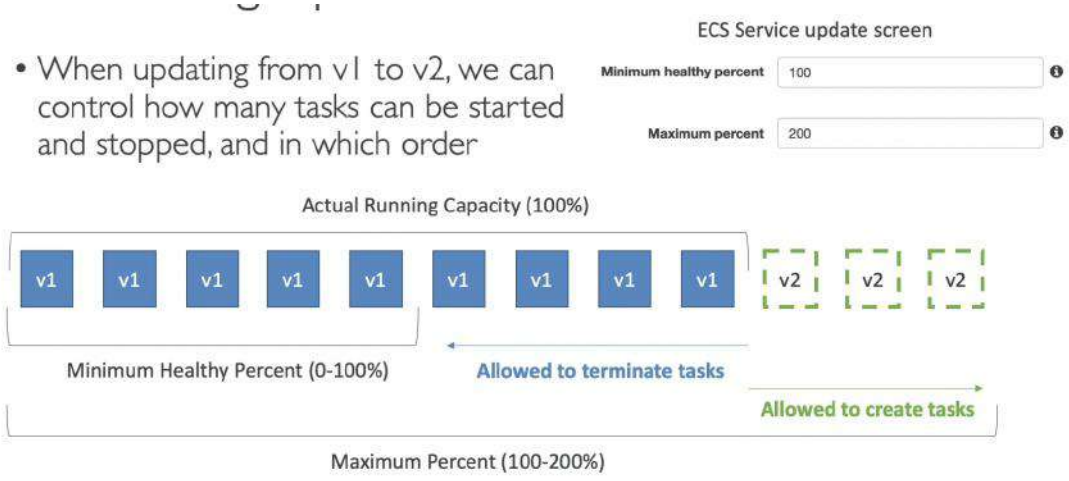


▼ Rolling Updates

When we need to update an ECS service, we need to do it gradually to avoid system downtime.

In the ECS service update screen, we have two settings:

- Minimum healthy percentage - determines how many tasks, running the current version, we can terminate while staying above the threshold.
- Maximum percentage - determines how many new tasks, running the new version, we can launch while staying below the threshold.



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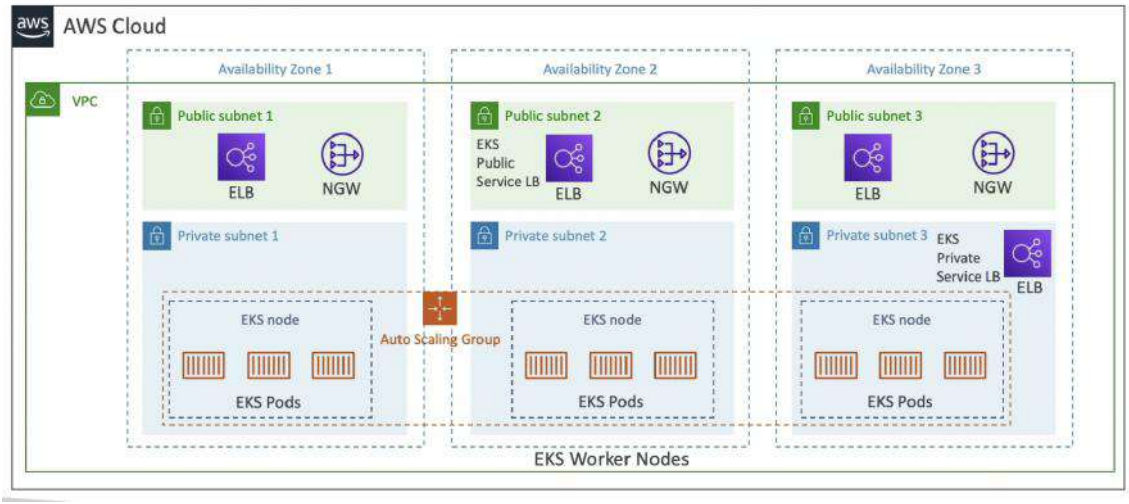
Example: Min: 50% and Max: 100% and starting number of tasks 4



Amazon EKS – Node Types

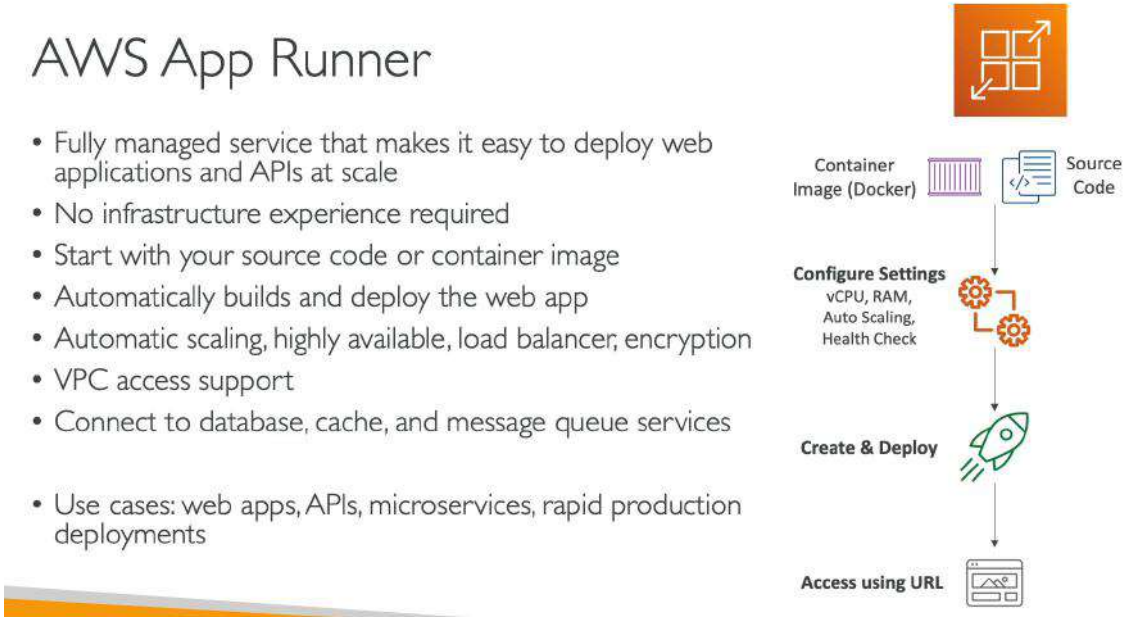
- Managed Node Groups
  - Creates and manages Nodes (EC2 instances) for you
  - Nodes are part of an ASG managed by EKS
  - Supports On-Demand or Spot Instances
- Self-Managed Nodes
  - Nodes created by you and registered to the EKS cluster and managed by an ASG
  - You can use prebuilt AMI - Amazon EKS Optimized AMI
  - Supports On-Demand or Spot Instances
- AWS Fargate
  - No maintenance required; no nodes managed

Amazon EKS – Data Volumes

- Need to specify **StorageClass** manifest on your EKS cluster
- Leverages a **Container Storage Interface (CSI)** compliant driver

- Support for…
- Amazon EBS
- Amazon EFS (works with Fargate)
- Amazon FSx for Lustre
- Amazon FSx for NetApp ONTAP

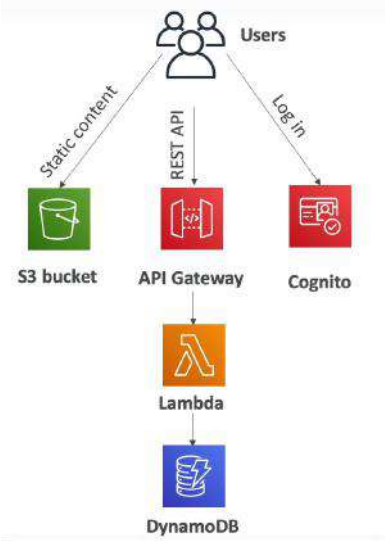
▼ AWS App Runner



▼ Section 20: Serverless Overview from a Solution Architect Perspective

▼ Serverless

- Serverless is a new paradigm in which the developers don't have to manage servers. They just deploy code.
- Serverless does not mean there are no servers, it means you just don't manage / provision / see them.
- Initially, serverless was just about deploying function as a service (FaaS).
- Serverless was pioneered by AWS Lambda but now also includes anything that's not required to be managed by the developers such as:
  - AWS Lambda
  - DynamoDB
  - AWS Cognito
  - AWS API Gateway
  - Amazon S3
  - AWS SNS & SQS
  - AWS Kinesis Data Firehose
  - Aurora Serverless
  - Step Functions
  - Fargate



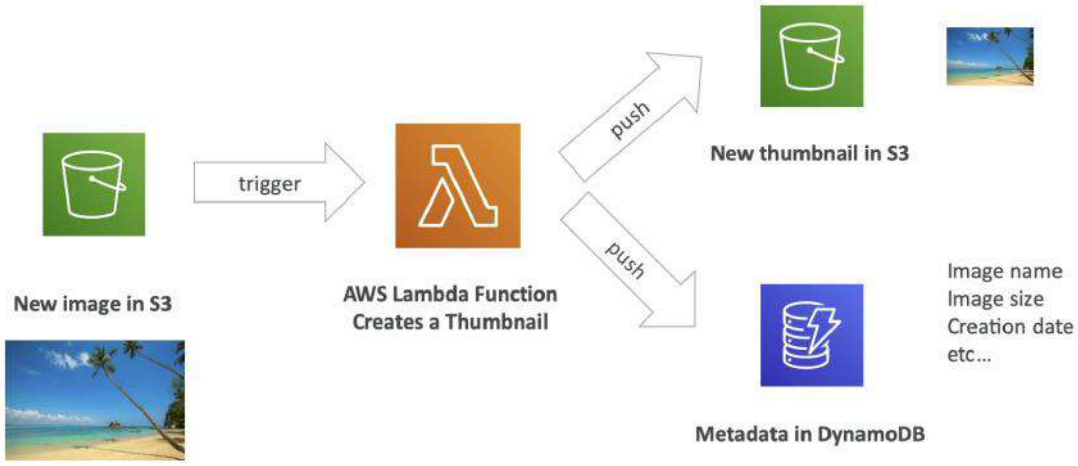
▼ Lambda

▼ Intro

- Virtual functions - no servers to manage
- Limited by time - short executions (max 15 mins)
- Run on-demand
- Scaling is automated, AWS automatically adds more functions to scale horizontally.
- Inexpensive Pricing
  - Pay per request (number of invocations) and compute time
  - Free tier of 1,000,000 AWS Lambda requests and 400,000 GBs of compute time
  - Pay per lambda invocation:
    - First 1,000,000 requests are free
    - $0.20 per million requests thereafter ($0.0000002 per request)
  - Pay per duration: (in increment of ms)
    - 400,000 GBs (400,000 seconds of execution at 1 GB RAM consumption) of compute time per month for free
    - After that $1.00 for 600,000 GBs
  - It is usually very cheap to run AWS Lambda, so it’s very popular
- Integrated with the whole AWS suite of services
  - API Gateway - to build REST APIs to invoke lambda functions
  - Kinesis - to perform transformations on Kinesis streams
  - DynamoDB - to take some action based on a DynamoDB event
  - S3 - to take some action based on an S3 notification
  - EventBridge - to take some action based on an EB event
  - CloudWatch - to get logs for Lambda functions
  - SNS - to react to a notification
  - SQS - to poll for messages in the queue and process them
  - Cognito - to take some action if a user logs in
- Supports many programming languages
  - Node.js (JavaScript)

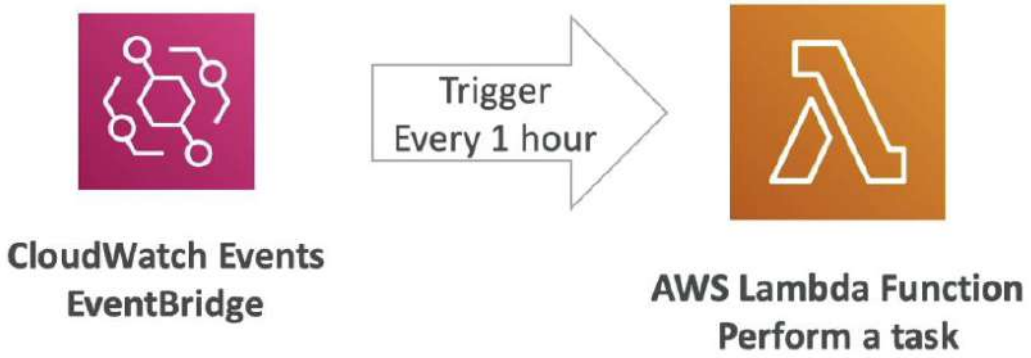
    - Python
    - Java (Java 8 compatible)
    - C# (.NET Core)
    - Golang
    - C# / Powershell
    - Ruby
    - any other language using Custom Runtime API (community supported, example Rust)
- Easy monitoring through AWS CloudWatch
- Easy to get more resources per functions (up to 10GB of RAM)
- Increasing RAM will also improve CPU and network
- In order to use containers on lambda, the container image must implement the Lambda Runtime API, otherwise it is preferred to be run on ECS / Fargate. Docker is not designed for Lambda, but for Fargate and ECS.

▼ Serverless thumbnail creation



▼ Serverless CRON Job

Instead of running the CRON on an EC2 instance which runs full time. We can setup an EventBridge rule to trigger an event every 1 hour. This event will trigger a lambda function.



▼ Limits

- Execution:
    - Memory allocation: 128 MB - 10GB (1 MB increments)
    - Maximum execution time: 900 seconds (15 minutes)

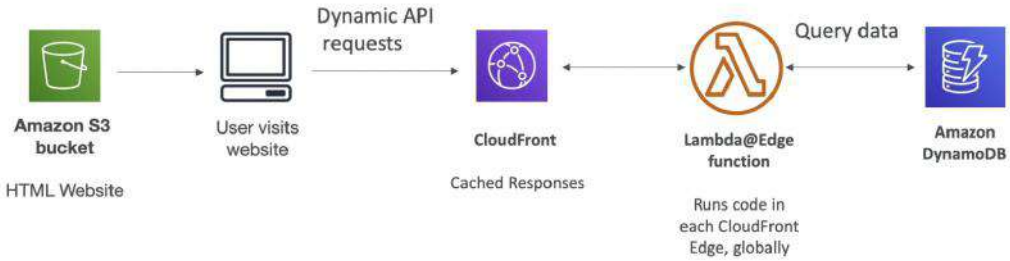
- Environment variables: 4 KB
- Disk capacity in the “function container” (in /tmp): 512 MB to 10 GB
- Concurrent executions: 1000 (can be increased by requesting AWS)

- Deployment:
  - Lambda function deployment size (compressed .zip): 50 MB
  - Size of uncompressed deployment (code + dependencies): 250 MB
  - If more space is needed, can use the `/tmp` directory to load other files at startup
  - Size of environment variables: 4 KB

▼ Lambda@Edge

- You have deployed a CDN using CloudFront. What if you wanted to run a global AWS Lambda alongside each edge location to filter requests before reaching your application?
- For this, you can use Lambda@Edge:
  - Deploy Lambda functions alongside your CloudFront CDN
  - Customize the CDN content using Lambda
  - Build more responsive applications
  - You don’t manage servers, Lambda is deployed globally
  - Pay for what you use, no provisioning needed
- You can use Lambda to modify CloudFront requests and responses (4 types). You can also generate responses to viewers without ever sending the request to the origin.

- We can create a global application using Lambda@Edge where S3 hosts a static website which uses client side JS to send requests to CF which will process the request in a lambda function in that edge location to perform some operation like fetching data from DynamoDB.



- Use cases
  - Website Security and Privacy
  - Dynamic Web Application at the Edge
  - Search Engine Optimization (SEO)
  - Intelligently Route Across Origins and Data Centers
  - Bot Mitigation at the Edge

- Real-time Image Transformation
- A/B Testing
- User Authentication and Authorization
- User Prioritization
- User Tracking and Analytics

CloudFront Functions vs. Lambda@Edge

	CloudFront Functions	Lambda@Edge
Runtime Support	JavaScript	Node.js, Python
# of Requests	**Millions** of requests per second	**Thousands** of requests per second
CloudFront Triggers	- Viewer Request/Response	- Viewer Request/Response - Origin Request/Response
Max. Execution Time	< 1 ms	5 – 10 seconds
Max. Memory	2 MB	128 MB up to 10 GB
Total Package Size	10 KB	1 MB – 50 MB
Network Access, File System Access	No	Yes
Access to the Request Body	No	Yes
Pricing	Free tier available, 1/6th price of @Edge	No free tier, charged per request & duration

CloudFront Functions vs. Lambda@Edge - Use Cases

CloudFront Functions

- Cache key normalization
  - Transform request attributes (headers, cookies, query strings, URL) to create an optimal Cache Key
- Header manipulation
  - Insert/modify/delete HTTP headers in the request or response
- URL rewrites or redirects
- Request authentication & authorization
  - Create and validate user-generated tokens (e.g., JWT) to allow/deny requests

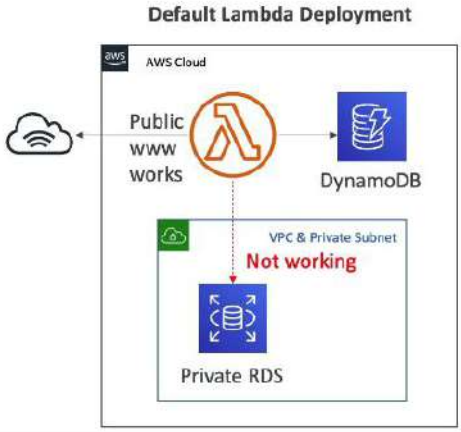
Lambda@Edge

- Longer execution time (several ms)
- Adjustable CPU or memory
- Your code depends on a 3rd libraries (e.g., AWS SDK to access other AWS services)
- Network access to use external services for processing
- File system access or access to the body of HTTP requests

▼ Lambda in VPC

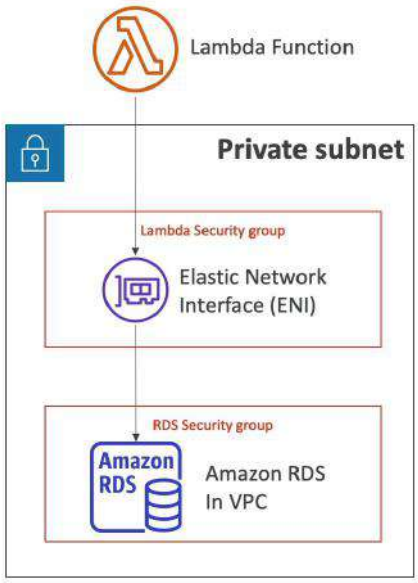
Lambda by default

- 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…)



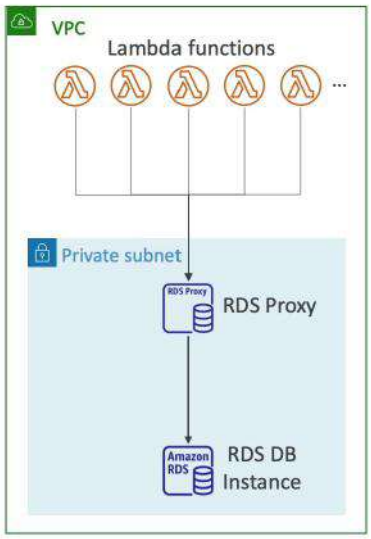
Lambda in VPC

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



Lambda with RDS Proxy

- If Lambda functions directly access your database, they may open too many connections under high load
- RDS Proxy
  - Improve scalability by pooling and sharing DB connections
  - Improve availability by reducing by 66% the failover time and preserving connections
  - Improve security by enforcing IAM authentication and storing credentials in Secrets Manager
- The Lambda function must be deployed in your VPC, because RDS Proxy is never publicly accessible



- Possibility to add auto-scaling mode for RCU & WCU (eg. set RCU and WCU to 80% and the capacities will be scaled automatically based on the workload to match the set values)

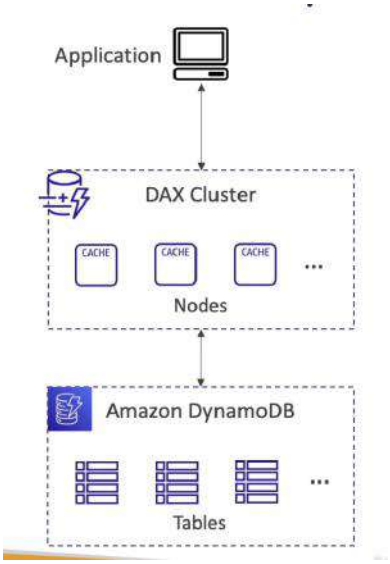
- On-Demand Mode
  - Read/writes automatically scale up/down with your workloads
  - No capacity planning needed
  - Pay for what you use, more expensive
  - Great for unpredictable workloads, steep sudd

▼ DynamoDB Accelerator (DAX)

▼ Intro

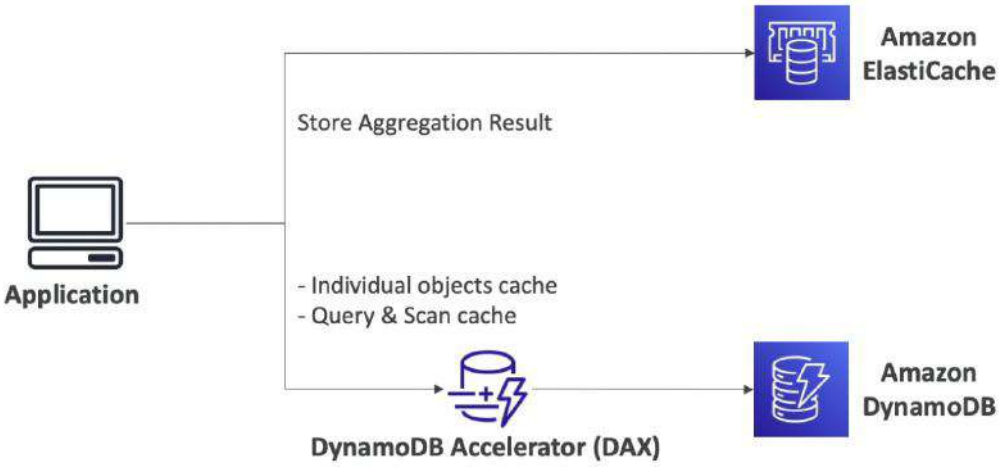
DynamoDB Accelerator (DAX) is a fully managed, highly available, in-memory cache for DynamoDB that delivers up to 10x performance improvement. It caches the most frequently used data, thus offloading the heavy reads on hot keys off your DynamoDB table, hence preventing the “ProvisionedThroughputExceededException” exception.

- Fully-managed, highly available, seamless in-memory cache for DynamoDB
- Help solve read congestion by caching
- Microseconds latency for cached data
- Doesn’t require application logic modification (compatible with existing DynamoDB APIs)
- 5 minutes TTL for cache (default)



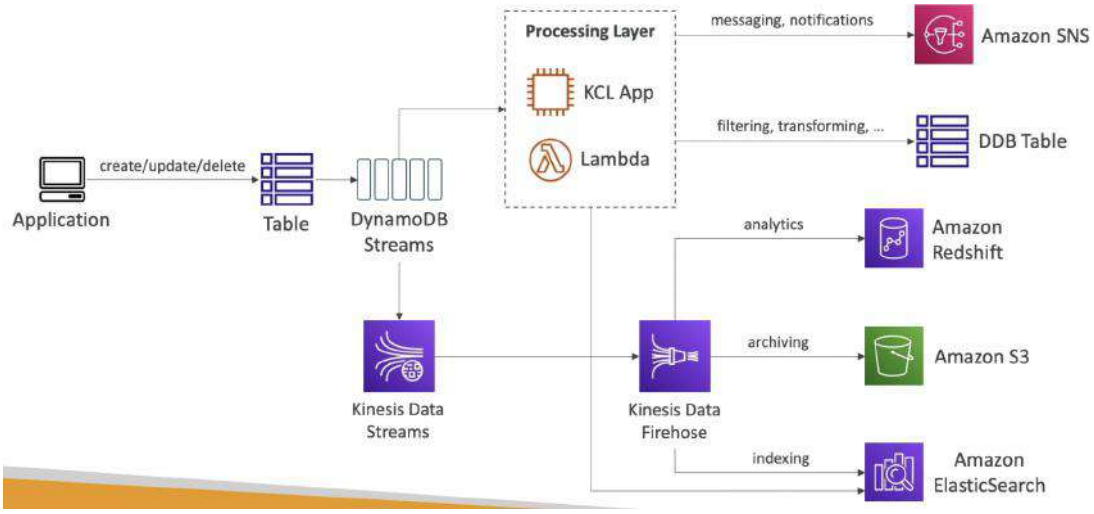
▼ DAX vs ElastiCache

- DAX is designed to cache the query and scan of DynamoDB items (objects) to make reads faster.
- ElastiCache is good for caching computation results (eg. result of computation of dynamodb item after fetching)



▼ DynamoDB Streams

- Ordered stream of notifications of item-level modifications (create/update/delete) in a table
- Stream records can be
  - Sent to Kinesis Data Streams
  - Read by AWS Lambda
  - Read by Kinesis Client Library applications
- Data Retention for up to 24 hours
- Use cases:
  - React to changes in real-time (eg. welcome email to users once they are added into the table)
  - Analytics
  - Insert into derivative tables
  - Insert into ElasticSearch
  - Implement cross-region replication



▼ DynamoDB Global Table

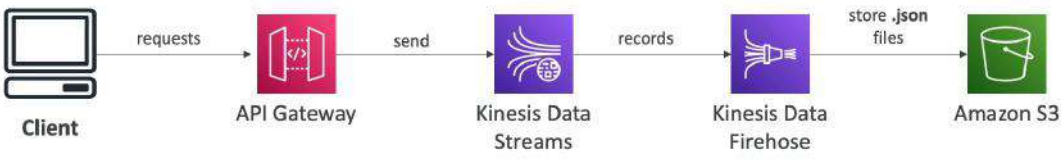
- Make a DynamoDB table accessible with low latency in multiple-regions
- Active-Active replication

▼ Intro

- Serverless offering from AWS to build REST APIs
- Using this, we can reach our lambda functions through REST APIs and API gateway will proxy the request to lambda.
- Support for the WebSocket Protocol
- Handle API versioning (v1, v2…)
- Handle different environments (dev, test, prod)
- Handle security (Authentication and Authorization)
- Create API keys
- Rate limiting (throttle requests if too many clients are connecting at once)
- Support to import/export to common API standards like Swagger / Open API
- Transform and validate requests and responses
- Cache API responses
- Generate SDK and API specifications
- Using API Gateway, Lambda and DynamoDB, we can build a serverless CRUD application.

▼ Integration

- Lambda Function
  - Invoke Lambda function
  - Easy way to expose REST API backed by AWS Lambda
- HTTP
  - Expose HTTP endpoints in the backend to leverage features like rate limiting, caching, user authentications, API keys, etc.
  - Example: internal HTTP API on premise, Application Load Balancer, etc.
- AWS Service
  - Expose any AWS API through the API Gateway to add authentication, deploy publicly, rate control, etc.
  - Example: start an AWS Step Function workflow, post a message to SQS, etc.



▼ Endpoint types

API Gateway can be deployed in three ways:

- Edge-Optimized (default)
  - For global clients
  - Requests are routed through the CloudFront Edge locations (improves latency)

    - The API Gateway still lives in only one region but it is accessible efficiently through edge locations.
  - Regional
    - For clients within the same region
    - Could manually combine with your own CloudFront distribution for global deployment but this way you will have more control over the caching strategies and the distribution.
  - Private
    - Can only be accessed from your VPC using an interface VPC endpoint (ENI)
    - Use a resource policy to define access

▼ Hands on

API Gateway → Create REST API → New API

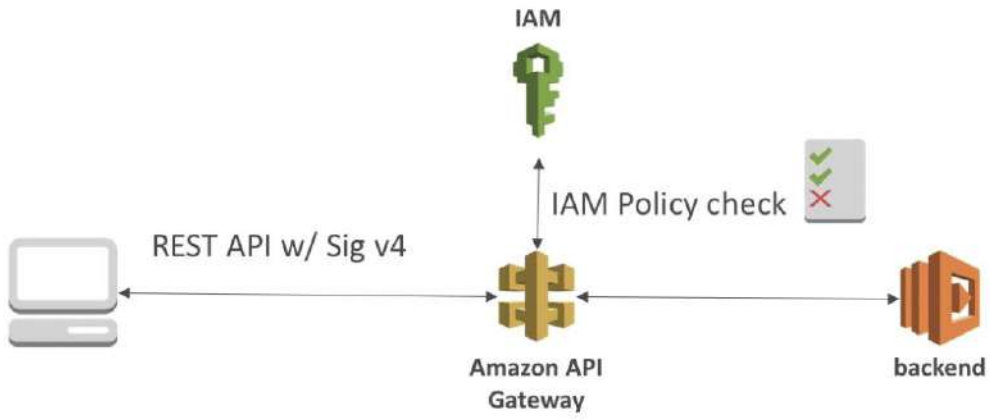
Actions:

- Add method: add a method at the current route
- Add resource: create a new sub route
- Deploy API: deploy the API for use. Once deployed, invoke URL can be used as the base route.

▼ Security

▼ IAM Permissions

- Create an IAM policy authorization and attach to User / Role to allow it to call an API
- API Gateway verifies IAM permissions passed by the calling application
- Good to provide access within your own infrastructure (users or roles within your account)
- Leverages “Sig v4” capability where lAM credential are in headers. If the IAM policy check passes, the API gateway will call the backend.



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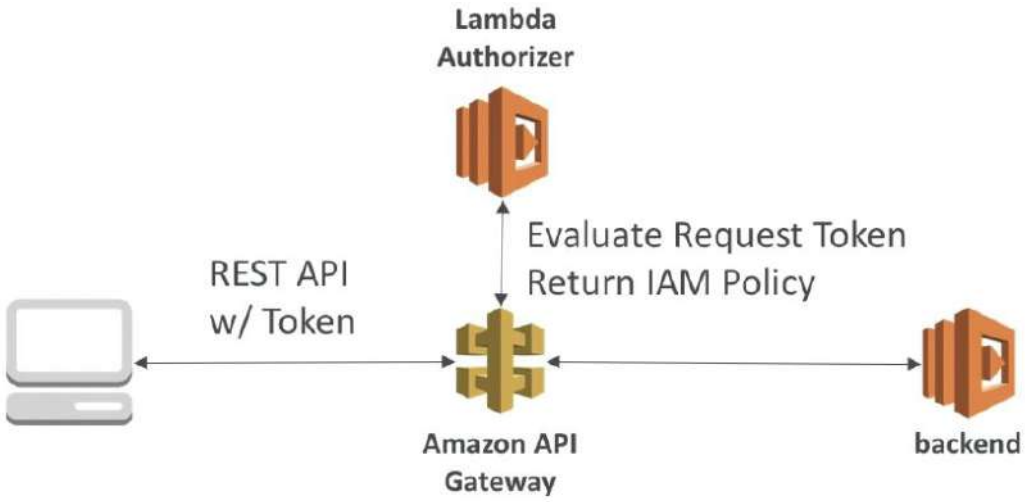
▼ Lambda Authorizer (formerly Custom Authorizer)

- Uses AWS Lambda to validate the token being passed in the header and return an lAM policy to determine if the user should be allowed to access the resource.
- Option to cache result of authentication, so the authorizer lambda will not be called repeatedly for the same client.
- Helps to use OAuth / SAML / 3rd party type of authentication



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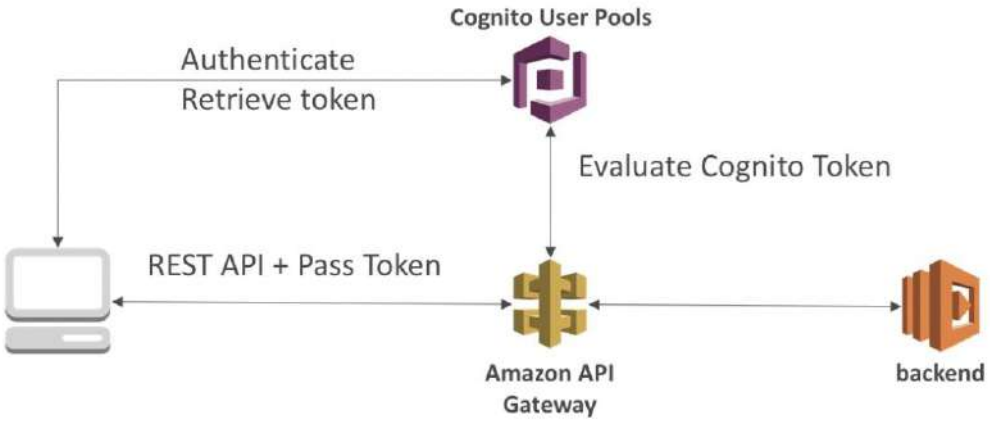
▼ Cognito User Pools

- Cognito fully manages user lifecycle
- You manage your own user pool (can be backed by FB, Google, etc.)
- API gateway verifies identity automatically from AWS Cognito
- No custom implementation (eg. authorization lambda) is required
- Cognito only helps with authentication, not authorization
- Authorization pattern must be implemented in the backend.
- The client (user) first authenticates with Congnito and gets the access token which it passes in the header to API gateway. API gateway validates the token using Cognito and then hits the backend if the token is valid.



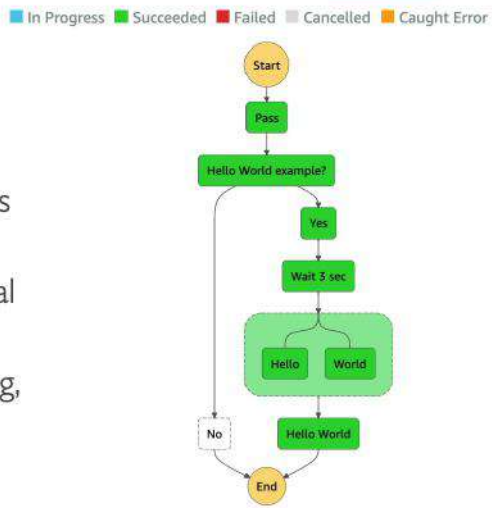
API Gateway – Security

- User Authentication through
  - IAM Roles (useful for internal applications)
  - Cognito (identity for external users – example mobile users)
  - Custom Authorizer (your own logic)
- Custom Domain Name HTTPS security through integration with AWS Certificate Manager (ACM)
  - If using Edge-Optimized endpoint, then the certificate must be in us-east-1
  - If using Regional endpoint, the certificate must be in the API Gateway region
  - Must setup CNAME or A-alias record in Route 53

▼ Step Function

AWS Step Functions

- Build serverless visual workflow to orchestrate your Lambda functions
- **Features:** sequence, parallel, conditions, timeouts, error handling, …
- Can integrate with EC2, ECS, On-premises servers, API Gateway, SQS queues, etc…
- Possibility of implementing human approval feature
- **Use cases:** order fulfillment, data processing, web applications, any workflow



▼ Cognito

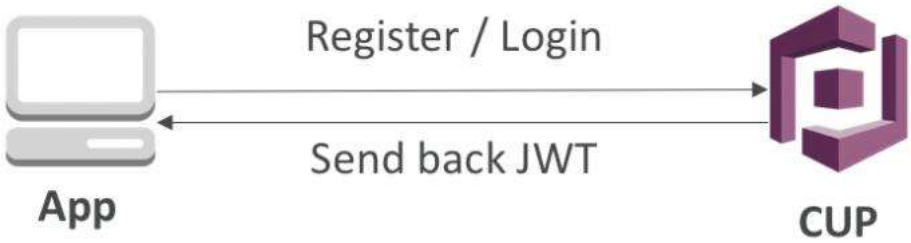
Amazon Cognito lets you add user sign-up, sign-in, and access control to your web and mobile apps quickly and easily. Amazon Cognito scales to millions of users and supports sign-in with social identity providers, such as Apple, Facebook, Google, and Amazon, and enterprise identity providers via SAML 2.0 and OpenID Connect.

It is used when we want to give our users an identity so that they can interact with our application.

▼ Cognito User Pools (CUP):

- It is an identity provider (provides sign in functionality for app users)
- Serverless database of user for your mobile apps
- Simple login: Username (or email) / password combination
- Possibility to verify emails / phone numbers and add MFA
- Can enable Federated Identities allowing users to authenticate via third party identity provider like Facebook, Google, SAML, etc.
- Sends back a JSON Web Tokens (JWT) which is used to verify the identity of the user.

- Can be integrated with API Gateway for authentication



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▼ Cognito Identity Pools (Federated Identity):

- Provide AWS credentials to users (clients) so they can access AWS resources directly
- Integrate with Cognito User Pools as an identity provider
- Process
  - Log in to federated identity provider or remain anonymous. The identity provider will return a token.
  - Use this token to authenticate to FIP. The FIP will verify the token.
  - Once verified, FIP will get the temporary credentials from STS service and send it to user.
  - These credentials come with a pre-defined IAM policy stating their permissions
- Example: provide temporary access to write to an S3 bucket after authenticating the user via FaceBook.

▼ Cognito Sync (deprecated):

- Deprecated (use AWS AppSync now)
- Store user preferences, configuration, state of app
- Cross device synchronization (any platform iOS, Android, etc.)
- Offline capability (synchronization when back online)
- Requires Federated Identity Pool in Cognito (not User Pool)
- Store data in datasets (up to 1MB)
- Upto 20 datasets to synchronize

▼ Serverless Application Model (SAM)

- Framework for developing and deploying serverless applications
- All the configuration is YAML code
  - Lambda Functions
  - DynamoDB tables
  - API Gateway
  - Cognito User Pools
- SAM can help you to run Lambda, API Gateway, DynamoDB locally for development and debugging
- SAM can use CodeDeploy to deploy Lambda functions

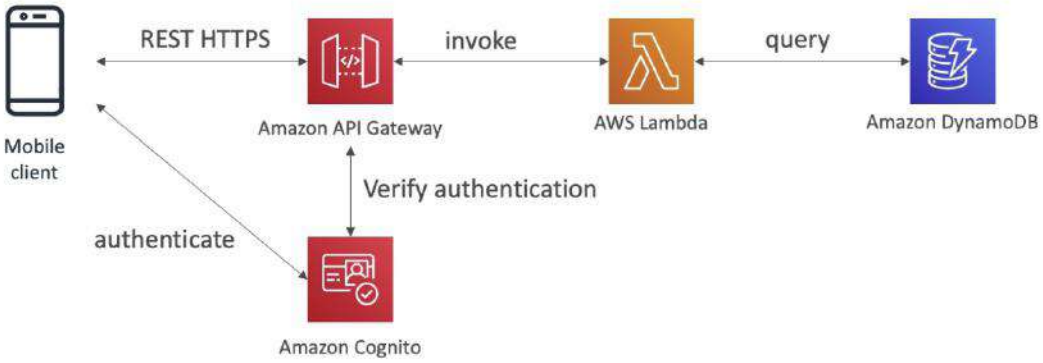
▼ Section 21: Serverless Solution Architecture Discussions

▼ ToDo List App

- Requirements
  - Expose as REST API with HTTPS
  - Serverless architecture

- Users should be able to directly interact with their own folder in S3
- Users should authenticate through a managed serverless service
- Users can write and read to-dos, but they mostly read them
- The database should scale, and have some high read throughput

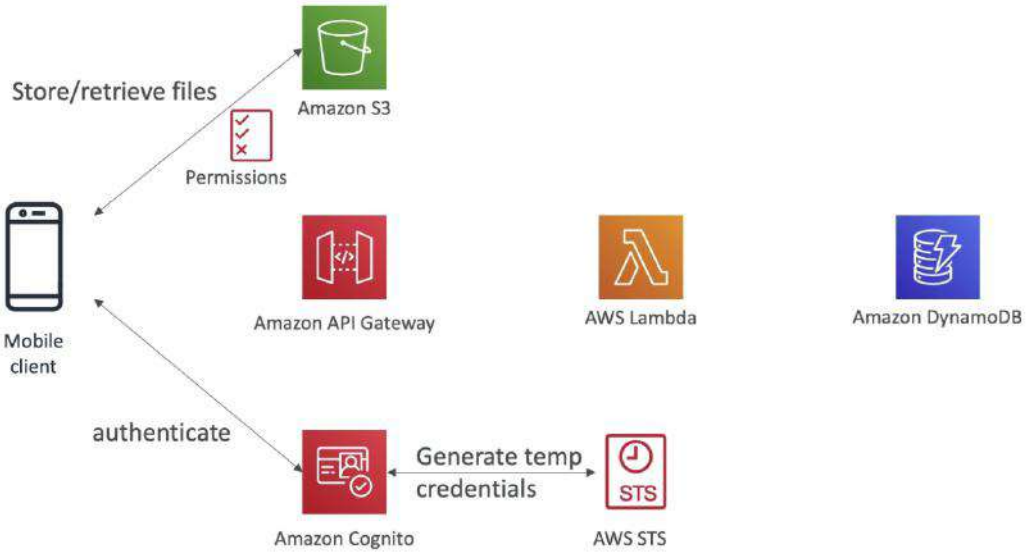
- REST API Layer



- Giving users access to a folder in S3

  Cognito Identity Pool can be used to get temporary credentials after authenticating using CUP.

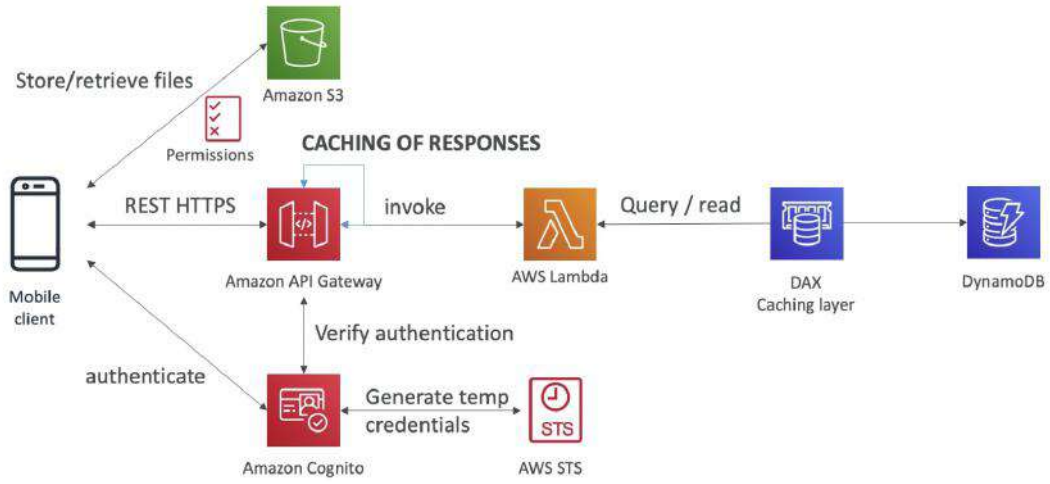
  Pre-signed URL isn't used since we need to provide access to the bucket and not an object.



- Improving read throughputs

  We can implement a DAX layer to cache DynamoDB queries.

  Caching can also be implemented as the API gateway level if the read responses don't change much.

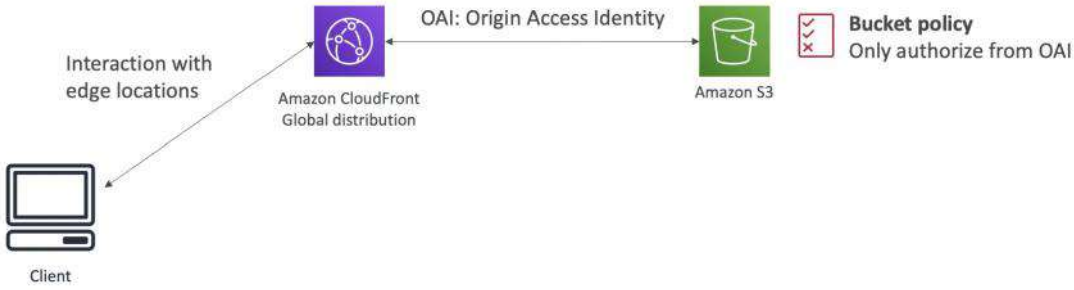


▼ Blogging Website

- Requirements
  - This website should scale globally
  - Blogs are rarely written, but often read
  - Some of the website is purely static files, the rest is a dynamic REST API (public)
  - Caching must be implement where possible
  - Any new users that subscribes should receive a welcome email
  - Any photo uploaded to the blog should have a thumbnail generated
- Serve content globally

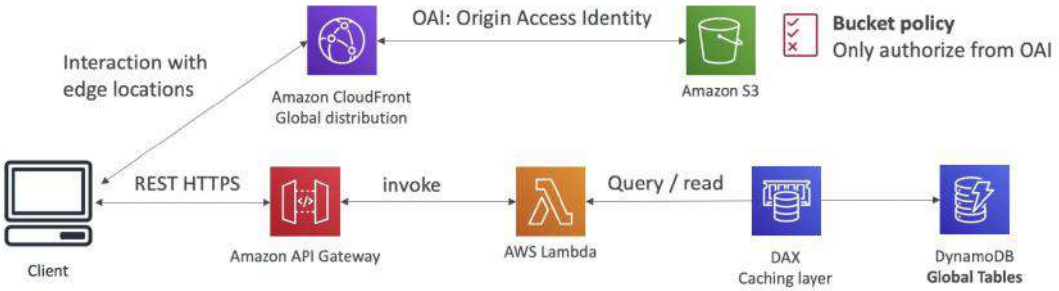
  CF will distribute the content globally.

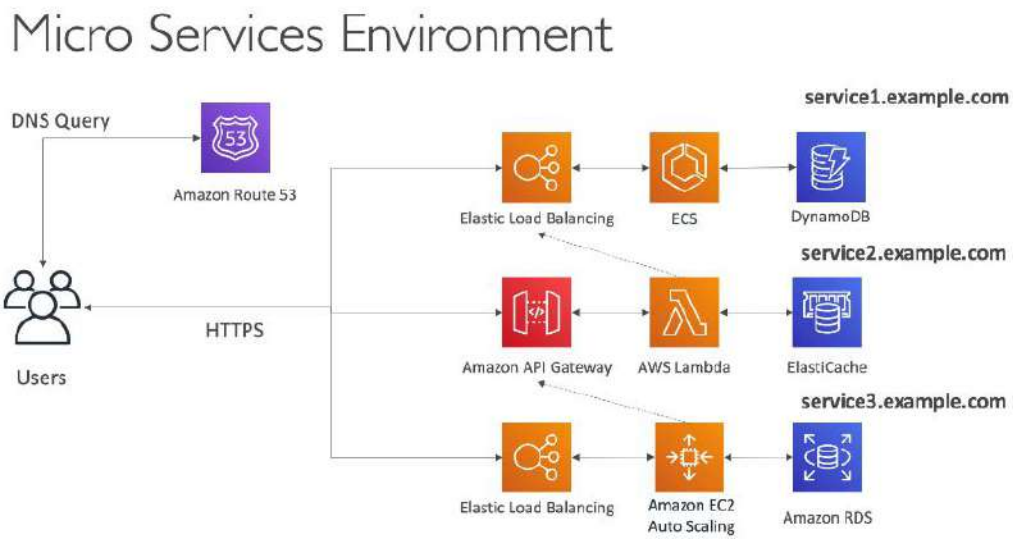
  Using OAI, S3 bucket policy will only allow CF to access the data in S3. Client's cannot connect to S3 directly.



- REST APIs

  Since the website will be accessed globally, use DynamoDB global tables.





- Each service can scale independently of each other
- Each service has a separate code repository
- Communication between services:
  - Synchronous patterns: API Gateway, Load Balancers
  - Asynchronous patterns: SQS, Kinesis, SNS
- Challenges with micro-services:
  - Repeated overhead for creating each new microservice
  - Issues with optimizing server density/utilization
  - Complexity of running multiple versions of multiple microservices simultaneously
  - Proliferation of client-side code requirements to integrate with many separate services.
- Some of the challenges are solved by Serverless patterns:
  - API Gateway, Lambda scale automatically and you pay per usage
  - You can easily clone API, reproduce environments
  - Generated client SDK through Swagger integration for the API Gateway

▼ Software updates distribution

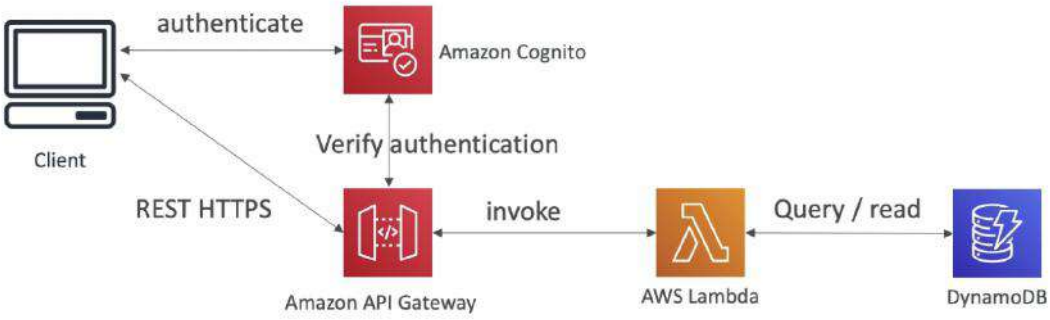
- Requirements
  - We have an application running on EC2, that distributes software updates once in a while
  - When a new software update is out, we get a lot of request and the content is distributed in mass over the network. It’s very costly
  - We don’t want to change our application, but want to optimize our cost and CPU
- Current state of application

  ALB along with EC2 instances in multi AZ with ASG attached for scaling. EFS volume is mounted to each instance as a network storage.

- We want to be fully serverless

- Premium Service

  Since the user must login to view premium videos, we can use Cognito for authentication. If the user is authenticated, API gateway will send the login info to Lambda which can query the DynamoDB to check whether the authenticated user is premium or not.

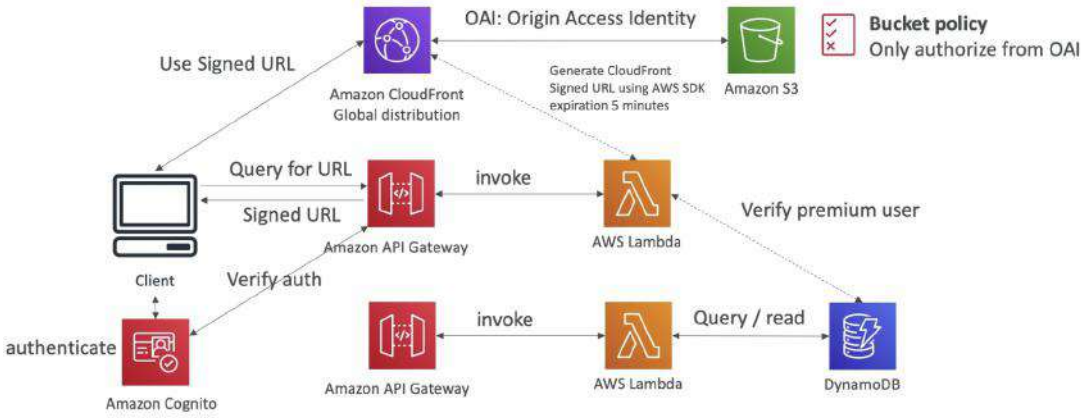


- Distribute paid content to premium users

  We need to use another API endpoint to get signed URL from CloudFront. The API gateway after verifying the authentication of the client using Cognito, will invoke a lambda function that will query the DB to check if the user is premium. If so, it will use SDK to generate CF pre-signed URL and return it to client. The client will use the signed URL to access paid content via CF.

  We are not using S3 signed URL as they are not optimized for global access.

  💡 CloudFront signed URLs also have IP restriction security.



▼ Data ingestion pipeline

- Requirements
  - We want the ingestion pipeline to be fully serverless
  - We want to collect data in real time
  - We want to transform the data
  - We want to query the transformed data using SQL
  - The reports created using the queries should be in S3
  - We want to load that data into a warehouse and create dashboards
- Solution

  In the example below, data is published by IoT devices. The data go to KDS and then into KDF with a lambda for transformation. KDF writes data into S3 in batches. S3 notifications invoke a lambda that triggers Athena to query the transformed data and store the query results in another S3 bucket for further analysis.

▼ RDS

Amazon RDS – Summary

- Managed PostgreSQL / MySQL / Oracle / SQL Server / MariaDB / Custom
- Provisioned RDS Instance Size and EBS Volume Type & Size
- Auto-scaling capability for Storage
- Support for Read Replicas and Multi AZ
- Security through IAM, Security Groups, KMS , SSL in transit
- Automated Backup with Point in time restore feature (up to 35 days)
- Manual DB Snapshot for longer-term recovery
- Managed and Scheduled maintenance (with downtime)
- Support for IAM Authentication, integration with Secrets Manager
- RDS Custom for access to and customize the underlying instance (Oracle & SQL Server)

- **Use case:** Store relational datasets (RDBMS / OLTP), perform SQL queries, transactions

▼ Aurora

Amazon Aurora – Summary

- Compatible API for PostgreSQL / MySQL, separation of storage and compute
- Storage: data is stored in 6 replicas, across 3 AZ – highly available, self-healing, auto-scaling
- Compute: Cluster of DB Instance across multiple AZ, auto-scaling of Read Replicas
- Cluster: Custom endpoints for writer and reader DB instances
- Same security / monitoring / maintenance features as RDS
- Know the backup & restore options for Aurora
- **Aurora Serverless** – for unpredictable / intermittent workloads, no capacity planning
- **Aurora Multi-Master** – for continuous writes failover (high write availability)
- **Aurora Global**: up to 16 DB Read Instances in each region, < 1 second storage replication
- **Aurora Machine Learning**: perform ML using SageMaker & Comprehend on Aurora
- **Aurora Database Cloning**: new cluster from existing one, faster than restoring a snapshot
- **Use case:** same as RDS, but with less maintenance / more flexibility / more performance / more features

▼ ElastiCache

Amazon ElastiCache – Summary

- Managed Redis / Memcached (similar offering as RDS, but for caches)
- In-memory data store, sub-millisecond latency
- Must provision an EC2 instance type
- Support for Clustering (Redis) and Multi AZ, Read Replicas (sharding)
- Security through IAM, Security Groups, KMS, Redis Auth
- Backup / Snapshot / Point in time restore feature
- Managed and Scheduled maintenance
- Requires some application code changes to be leveraged

- Use Case: Key/Value store, Frequent reads, less writes, cache results for DB queries, store session data for websites, cannot use SQL.

▼ DynamoDB

Amazon DynamoDB – Summary

- AWS proprietary technology, managed serverless NoSQL database, millisecond latency
- Capacity modes: provisioned capacity with optional auto-scaling or on-demand capacity
- Can replace ElastiCache as a key/value store (storing session data for example, using TTL feature)
- Highly Available, Multi AZ by default, Read and Writes are decoupled, transaction capability
- DAX cluster for read cache, microsecond read latency
- Security, authentication and authorization is done through IAM
- Event Processing: DynamoDB Streams to integrate with AWS Lambda, or Kinesis Data Streams
- Global Table feature: active-active setup
- Automated backups up to 35 days with PITR (restore to new table), or on-demand backups
- Export to S3 without using RCU within the PITR window, import from S3 without using WCU
- Great to rapidly evolve schemas

- Use Case: Serverless applications development (small documents 100s KB), distributed serverless cache, doesn't have SQL query language available

▼ S3

Amazon S3 – Summary

- S3 is a… key / value store for objects
- Great for bigger objects, not so great for many small objects
- Serverless, scales infinitely, max object size is 5 TB, versioning capability
- **Tiers:** S3 Standard, S3 Infrequent Access, S3 Intelligent, S3 Glacier + lifecycle policy
- **Features:** Versioning, Encryption, Replication, MFA-Delete, Access Logs…
- **Security:** IAM, Bucket Policies, ACL, Access Points, Object Lambda, CORS, Object/Vault Lock
- **Encryption:** SSE-S3, SSE-KMS, SSE-C, client-side, TLS in transit, default encryption
- **Batch operations** on objects using S3 Batch, listing files using S3 Inventory
- **Performance:** Multi-part upload, S3 Transfer Acceleration, S3 Select
- **Automation:** S3 Event Notifications (SNS, SQS, Lambda, EventBridge)
- **Use Cases:** static files, key value store for big files, website hosting

▼ DocumentDB

DocumentDB

- Aurora is an "AWS-implementation" of PostgreSQL / MySQL …
- DocumentDB is the same for MongoDB (which is a NoSQL database)

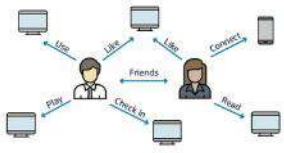
- MongoDB is used to store, query, and index JSON data
- Similar "deployment concepts" as Aurora
- Fully Managed, highly available with replication across 3 AZ
- DocumentDB storage automatically grows in increments of 10GB, up to 64 TB.

- Automatically scales to workloads with millions of requests per seconds

▼ Neptune

Amazon Neptune

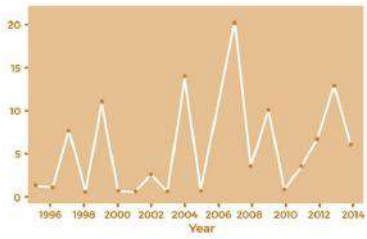
- Fully managed **graph** database
- A popular **graph dataset** would be a **social network**
  - Users have friends
  - Posts have comments
  - Comments have likes from users
  - Users share and like posts…
- Highly available across 3 AZ, with up to 15 read replicas
- Build and run applications working with highly connected datasets – optimized for these complex and hard queries
- Can store up to billions of relations and query the graph with milliseconds latency
- Highly available with replications across multiple AZs
- Great for knowledge graphs (Wikipedia), fraud detection, recommendation engines, social networking



▼ Keyspaces for Apache Cassandra

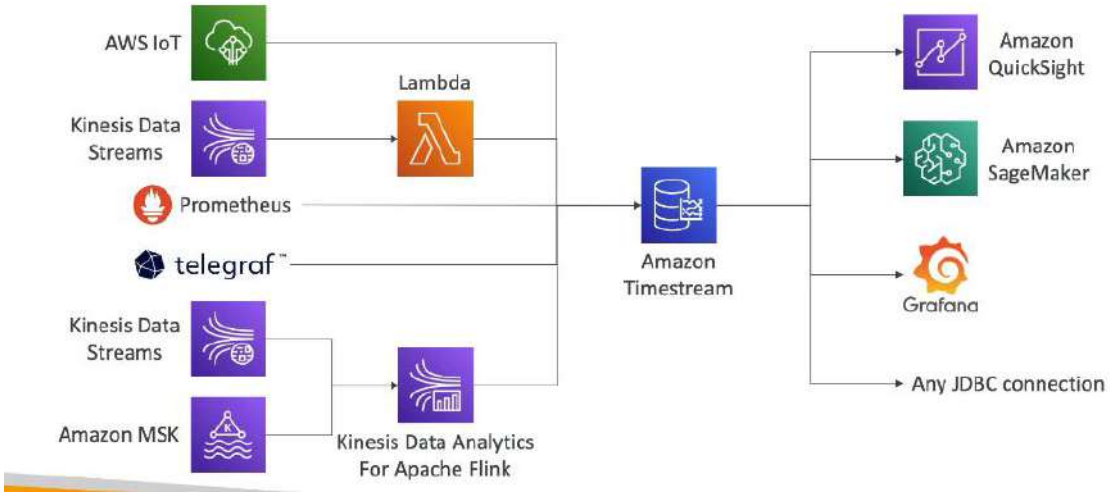
Amazon Timestream

- Fully managed, fast, scalable, serverless **time series database**
- Automatically scales up/down to adjust capacity
- Store and analyze trillions of events per day
- 1000s times faster & 1/10th the cost of relational databases
- Scheduled queries, multi-measure records, SQL compatibility
- Data storage tiering: recent data kept in memory and historical data kept in a cost-optimized storage
- Built-in time series analytics functions (helps you identify patterns in your data in near real-time)
- Encryption in transit and at rest



- Use cases: IoT apps, operational applications, real-time analytics, …

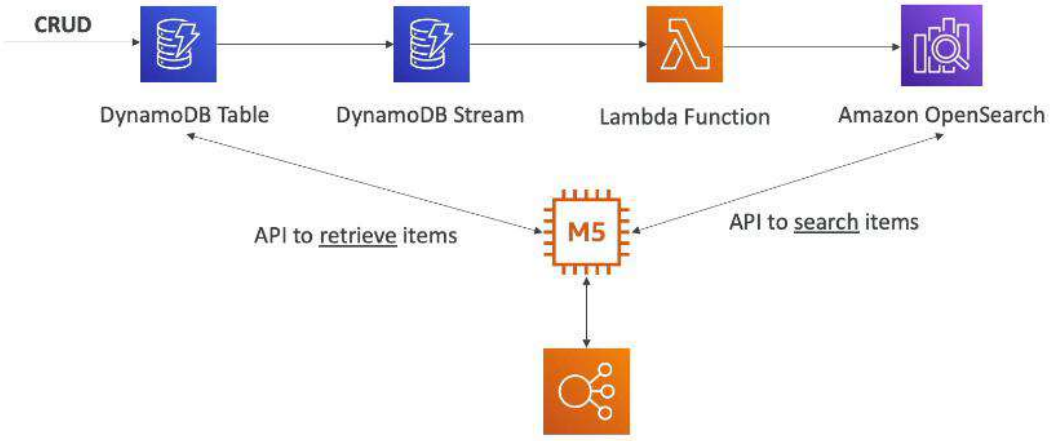
Amazon Timestream – Architecture



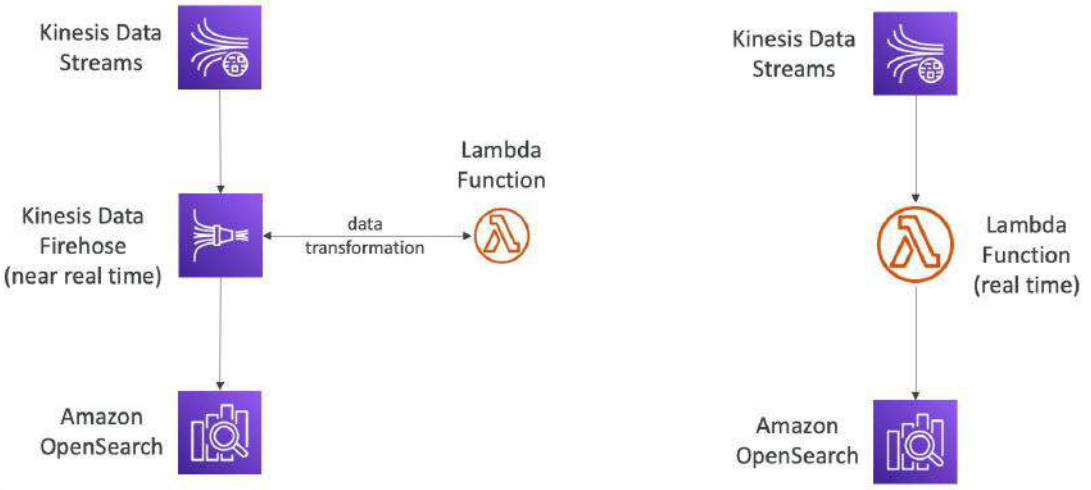
▼ **Section 23: Data & Analytics**

▼ Athena

OpenSearch patterns
DynamoDB

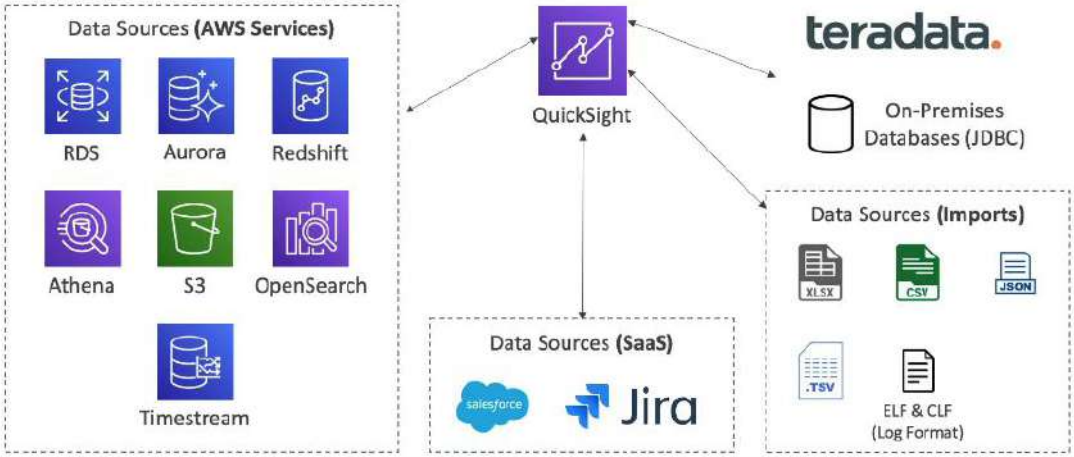


OpenSearch patterns
Kinesis Data Streams & Kinesis Data Firehose



▼ EMR

QuickSight Integrations



QuickSight – Dashboard & Analysis

- Define Users (standard versions) and Groups (enterprise version)
  - These users & groups only exist within QuickSight, not IAM !!
- A *dashboard*…
  - is a read-only snapshot of an analysis that you can share
  - preserves the configuration of the analysis (filtering, parameters, controls, sort)

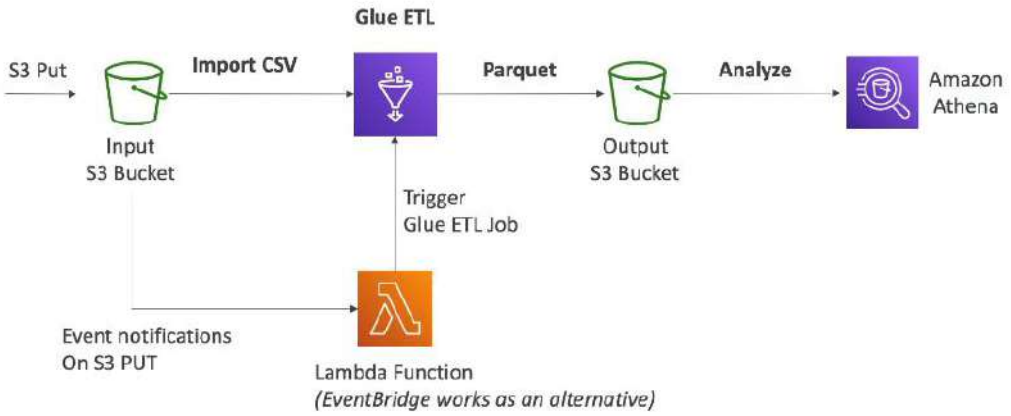
- You can share the analysis or the dashboard with Users or Groups
- To share a dashboard, you must first publish it
- Users who see the dashboard can also see the underlying data

▼ AWS Glue

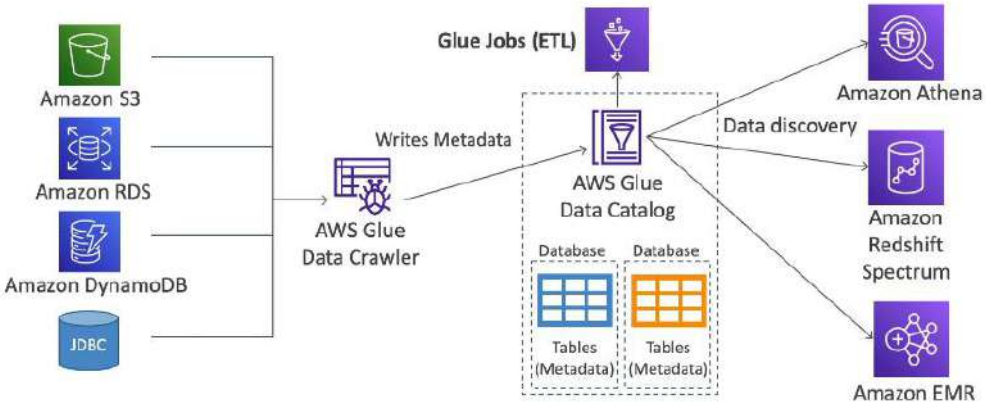
AWS Glue

- Managed **extract, transform, and load (ETL)** service
- Useful to prepare and transform data for analytics
- Fully **serverless** service

AWS Glue – Convert data into Parquet format



Glue Data Catalog: catalog of datasets



Glue – things to know at a high-level

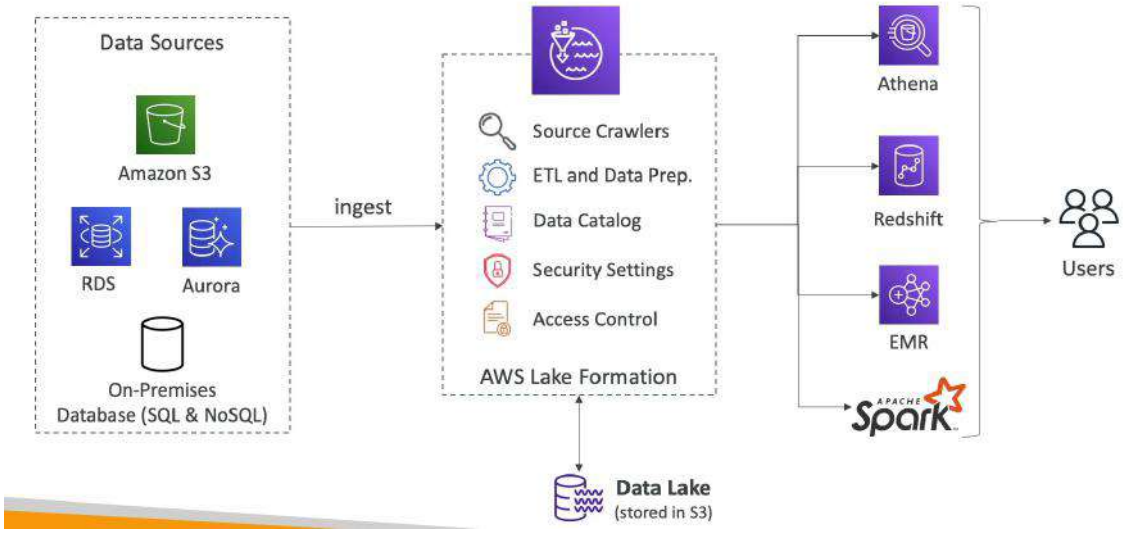
- **Glue Job Bookmarks:** prevent re-processing old data
- **Glue Elastic Views:**
  - Combine and replicate data across multiple data stores using SQL
  - No custom code, Glue monitors for changes in the source data, serverless
  - Leverages a "virtual table" (materialized view)
- **Glue DataBrew:** clean and normalize data using pre-built transformation
- **Glue Studio:** new GUI to create, run and monitor ETL jobs in Glue
- **Glue Streaming ETL** (built on Apache Spark Structured Streaming): compatible with Kinesis Data Streaming, Kafka, MSK (managed Kafka)

▼ Lake Formation

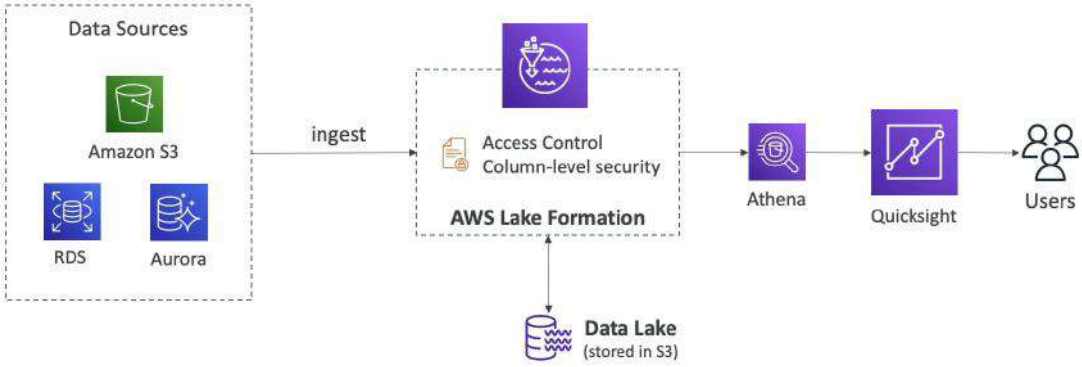
AWS Lake Formation

- Data lake = central place to have all your data for analytics purposes
- Fully managed service that makes it easy to setup a **data lake** in days
- Discover, cleanse, transform, and ingest data into your Data Lake
- It automates many complex manual steps (collecting, cleansing, moving, cataloging data, …) and de-duplicate (using ML Transforms)
- Combine structured and unstructured data in the data lake
- **Out-of-the-box source blueprints:** S3, RDS, Relational & NoSQL DB…
- **Fing-grained Access Control for your applications (row and column-level)**
- Built on top of AWS Glue

AWS Lake Formation



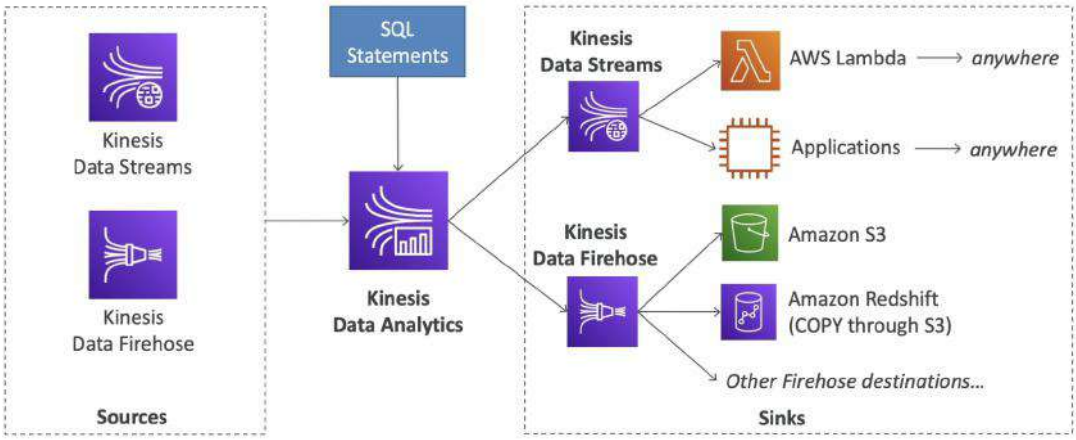
AWS Lake Formation
Centralized Permissions Example



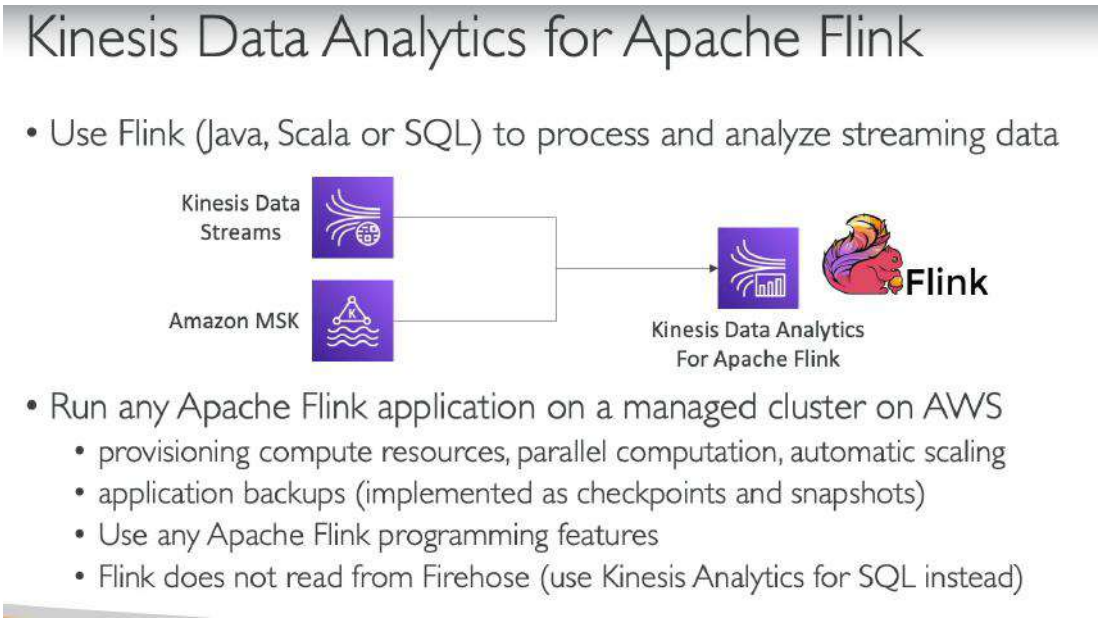
▼ KDA

▼ Kinesis Data Analytics for SQL

- Perform real-time analytics on Kinesis Streams using SQL
- Fully managed, no servers to provision
- Automatic scaling
- Real-time analytics
- Pay for actual consumption rate (data processed)
- Output:
  - Kinesis Data Stream
  - Kinesis Data Firehose
- Can create streams out of the real-time queries
- Use cases:
  - Time-series analytics
  - Real-time dashboards
  - Real-time metrics



▼ Kinesis Data Analytics for Apache Flink

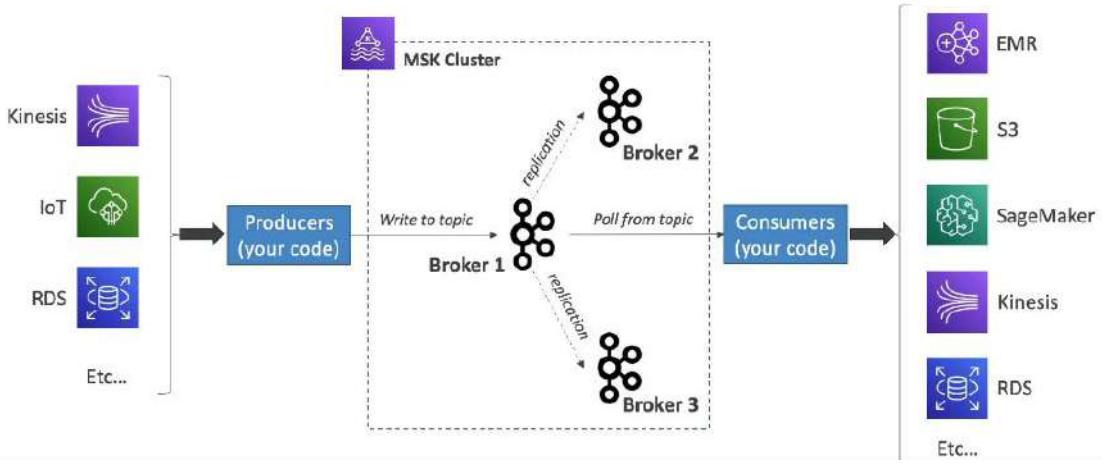


▼ MSK

Amazon Managed Streaming for Apache Kafka (Amazon MSK)

- Alternative to Amazon Kinesis
- Fully managed Apache Kafka on AWS
  - Allow you to create, update, delete clusters
  - MSK creates & manages Kafka brokers nodes & Zookeeper nodes for you
  - Deploy the MSK cluster in your VPC, multi-AZ (up to 3 for HA)
  - Automatic recovery from common Apache Kafka failures
  - Data is stored on EBS volumes for as long as you want
- MSK Serverless
  - Run Apache Kafka on MSK without managing the capacity
  - MSK automatically provisions resources and scales compute & storage

Apache Kafka at a high level



Kinesis Data Streams vs. Amazon MSK

Kinesis Data Streams

- 1 MB message size limit
- Data Streams with Shards
- Shard Splitting & Merging
- TLS In-flight encryption
- KMS at-rest encryption

Amazon MSK

- 1MB default, configure for higher (ex: 10MB)
- Kafka Topics with Partitions
- Can only add partitions to a topic
- PLAINTEXT or TLS In-flight Encryption
- KMS at-rest encryption

Amazon Transcribe

- Automatically convert speech to text
- Uses a deep learning process called automatic speech recognition (ASR) to convert speech to text quickly and accurately
- Automatically remove Personally Identifiable Information (PII) using Redaction
- Supports Automatic Language Identification for multi-lingual audio
- Use cases:
  - transcribe customer service calls
  - automate closed captioning and subtitling
  - generate metadata for media assets to create a fully searchable archive

"Hello my name is Stéphane.
I hope you're enjoying the course!

▼ Polly

Amazon Polly

- Turn text into lifelike speech using deep learning
- Allowing you to create applications that talk

Hi! My name is Stéphane
and this is a demo of Amazon Polly

Amazon Polly – Lexicon & SSML

- Customize the pronunciation of words with Pronunciation lexicons
  - Stylized words: St3ph4ne => "Stephane"
  - Acronyms: AWS => "Amazon Web Services"
- Upload the lexicons and use them in the SynthesizeSpeech operation

- Generate speech from plain text or from documents marked up with Speech Synthesis Markup Language (SSML) – enables more customization
  - emphasizing specific words or phrases
  - using phonetic pronunciation
  - including breathing sounds, whispering
  - using the Newscaster speaking style

Amazon Comprehend

- For **Natural Language Processing – NLP**
- Fully managed and serverless service
- Uses machine learning to find insights and relationships in text
  - Language of the text
  - Extracts key phrases, places, people, brands, or events
  - Understands how positive or negative the text is
  - Analyzes text using tokenization and parts of speech
  - Automatically organizes a collection of text files by topic
- Sample use cases:
  - analyze customer interactions (emails) to find what leads to a positive or negative experience
  - Create and groups articles by topics that Comprehend will uncover

▼ Comprehend Medical

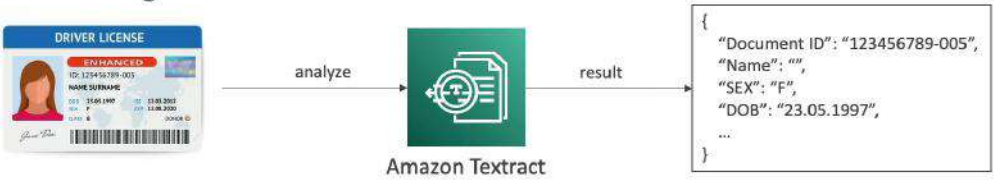
Amazon Comprehend Medical

- Amazon Comprehend Medical detects and returns useful information in unstructured clinical text:
  - Physician's notes
  - Discharge summaries
  - Test results
  - Case notes
- **Uses NLP to detect Protected Health Information (PHI) – *DetectPHI* API**
- Store your documents in Amazon S3, analyze real-time data with Kinesis Data Firehose, or use Amazon Transcribe to transcribe patient narratives into text that can be analyzed by Amazon Comprehend Medical.

▼ SageMaker

Amazon Textract

- Automatically extracts text, handwriting, and data from any scanned documents using AI and ML



- Extract data from forms and tables
- Read and process any type of document (PDFs, images, …)
- Use cases:
  - Financial Services (e.g., invoices, financial reports)
  - Healthcare (e.g., medical records, insurance claims)
  - Public Sector (e.g., tax forms, ID documents, passports)

▼ ML Summary

AWS Machine Learning - Summary

- **Rekognition:** face detection, labeling, celebrity recognition
- **Transcribe:** audio to text (ex: subtitles)
- **Polly:** text to audio
- **Translate:** translations
- **Lex:** build conversational bots – chatbots
- **Connect:** cloud contact center
- **Comprehend:** natural language processing
- **SageMaker:** machine learning for every developer and data scientist
- **Forecast:** build highly accurate forecasts
- **Kendra:** ML-powered search engine
- **Personalize:** real-time personalized recommendations

/ima

▼ Section 25: AWS Monitoring & Audit: CloudWatch, CloudTrail & Config

▼ CloudWatch

▼ Metrics

▼ Intro

- CloudWatch provides metrics for every service in AWS
- Metric is a variable to monitor (CPUUtilization, etc.)
- Metrics are segregated by namespaces (which AWS service they monitor)

- Dimension is an attribute of a metric (instance id, environment, etc.)
- Up to 10 dimensions per metric
- Metrics have timestamps
- We can create CloudWatch dashboards of metrics

▼ EC2 Monitoring

- EC2 instance metrics have metrics “every 5 minutes”
- With detailed monitoring (for a cost), you get a data “every 1 minute”
- Use detailed monitoring if you want to react faster to changes (eg. 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)

▼ Custom Metrics

- Possibility to define and send your own custom metrics to CloudWatch
- We can create a custom namespace with custom dimensions (attributes) to segment metrics (eg. instanceId, environmentName, etc.)
- Example: memory (RAM) usage, disk space, number of logged in users
- Use API call PutMetricData to send metrics data to CloudWatch
- Metric resolution (StorageResolution API parameter) - frequency of sending metric data:
  - Standard: 1 minute (60 seconds)
  - High Resolution: 1/5/10/30 second(s) - higher cost
- Accepts metric data points two weeks in the past and two hours in the future (make sure to configure your EC2 instance time correctly)

▼ Logs

▼ Intro

- Used to store generated logs in our application
- Regional service
- 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
- Logs can be written using SDK, CloudWatch Logs Agent, CloudWatch Unified Agent (deprecated)
- These services automatically log data in CloudWatch logs:
  - 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

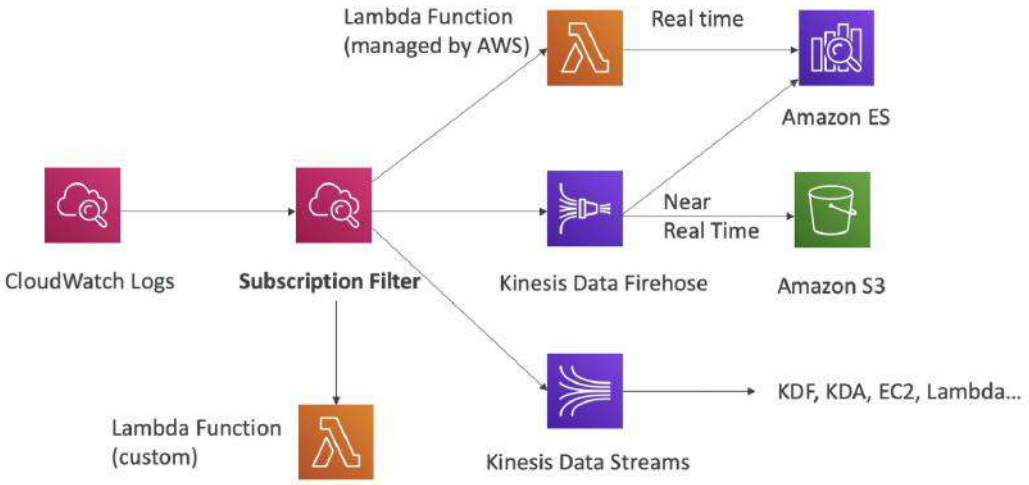
    - Route53: Log DNS queries
  - CloudWatch Logs have metric filters which can be used to filter expressions and use the count to trigger CloudWatch alarms. Example filters:
    - find a specific IP inside of a log
    - count occurrences of “ERROR” in your logs
  - Cloud Watch Logs Insights can be used to query logs and add queries to CloudWatch Dashboards

▼ S3 Export

- Log data can take up to 12 hours to become available for export (not near-real time or real-time)
- The API call is CreateExportTask
- If you want to stream logs from CloudWatch, use Logs Subscriptions instead

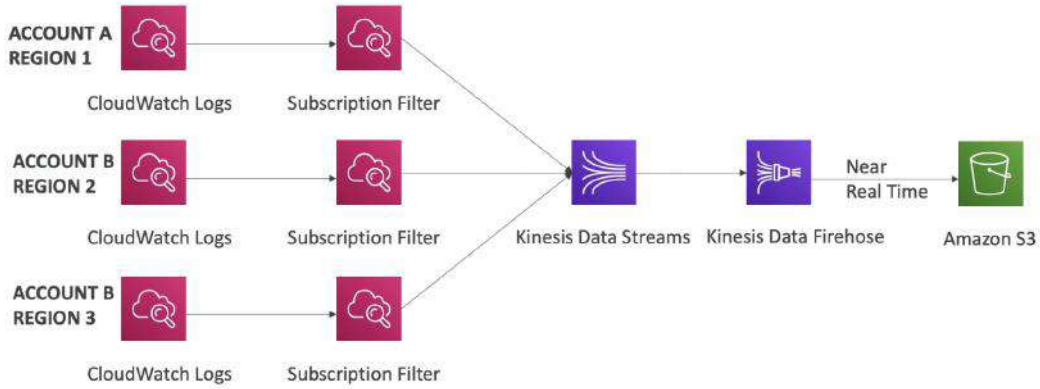
▼ Logs Subscriptions

- S3 export is non real-time
- To stream logs, we can apply a subscription filter on logs and then send them to various services in real time.



▼ Logs Aggregation (multi-account & multi-region)

Logs from multiple accounts and regions can be aggregated using logs subscription.



▼ CloudWatch Unified Agent & CloudWatch Logs Agent

- By default, no logs from your EC2 machine will go to CloudWatch
- You need to run a CloudWatch agent on EC2 to push the log files
- Make sure lAM permissions allow the instance to push logs to CloudWatch

- The Cloud Watch logs agent can be setup on-premises too
- Both are used to send logs for virtual servers (EC2 instances, on-premise servers, etc.)
- CloudWatch Logs Agent
  - Old version
  - Can only send logs to CloudWatch
- Cloud Watch Unified Agent
  - Can send logs & additional system-level metrics such as:
    - CPU (active, guest, idle, system, user, steal)
    - Disk metrics (free, used, total), Disk IO (writes, reads, bytes, iops)
    - RAM (free, inactive, used, total, cached)
    - Netstat (number of TCP and UDP connections, net packets, bytes)
    - Processes (total, dead, bloqued, idle, running, sleep)
    - Swap Space (free, used, used %)
  - Centralized configuration using SSM Parameter Store

▼ Alarms

▼ Intro

- Alarms are used to trigger notifications for any metric
- Various options to trigger alarm (sampling, %, max, min, etc.)
- Alarm States:
  - OK
  - INSUFFICIENT_DATA
  - ALARM
- Period:
  - Length of time in seconds to evaluate the metric before triggering the alarm
  - High resolution custom metrics: 10 sec, 30 sec or multiples of 60 sec
- Targets:
  - Stop, Terminate, Reboot, or Recover an EC2 Instance
  - Trigger Auto Scaling Action (ASG)
  - Send notification to SNS (from which you can do pretty much anything)
- Alarms can be created based on Cloud Watch Logs Metrics Filters

- To test alarms and notifications, set the alarm state to Alarm using CLI

```
aws cloudwatch set-alarm-state --alarm-name "myalarm" --state-value ALARM --state-reason "testing purposes"
```

▼ EC2 Instance Recovery using CloudWatch Alarms

EC2 Status Checks:

- Instance status - check the EC2 VM
- System status - check the underlying hardware

If either of the two status checks fail, the EC2 instance is down. At this time, CW alarm will be triggered which will perform instance recovery.

During recovery, the private IP, public IP, elastic IP, metadata and placement group of the instance is preserved.

The alarm can also write to an SNS topic, signifying that the EC2 instance is being recovered.

▼ Hands on

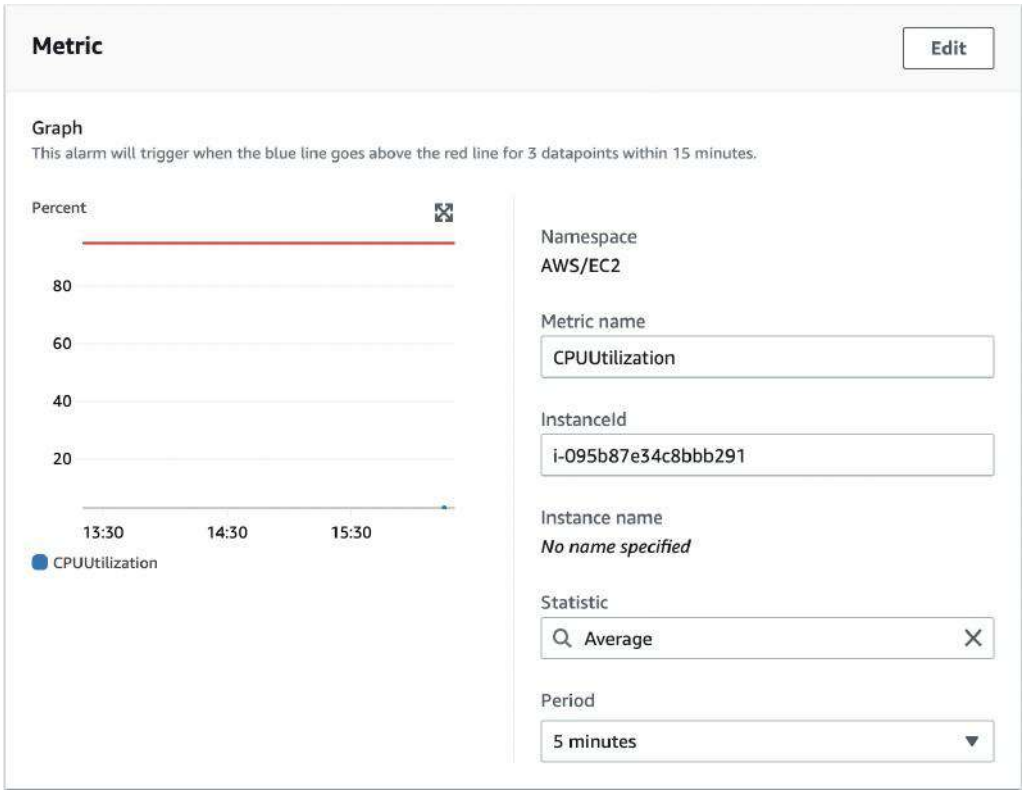
- Launch an EC2 instance
- Create a CloudWatch alarm for max CPU utilization

  CloudWatch → Alarms → Create alarm

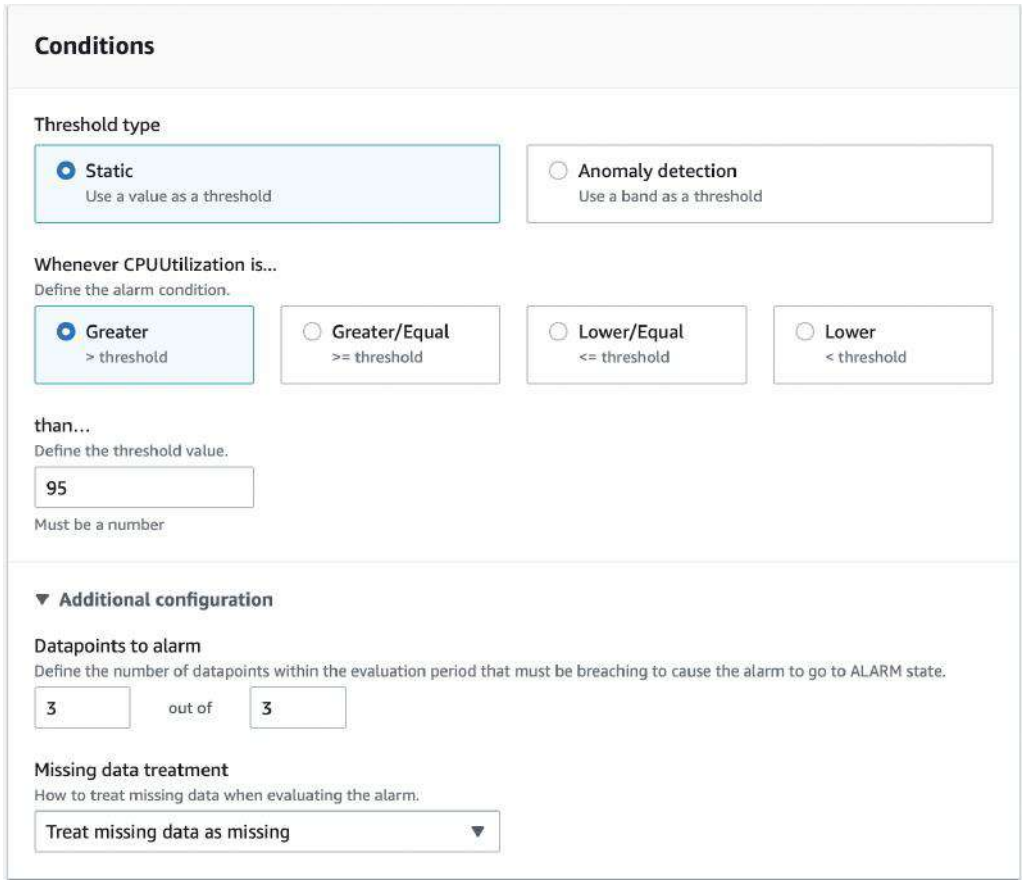
  Namespace: EC2

  Metrics: paste the EC2 instance ID → If the metric CPU Utilization doesn't appear, wait for some time → Once appeared, select the metric

  Configure the metric

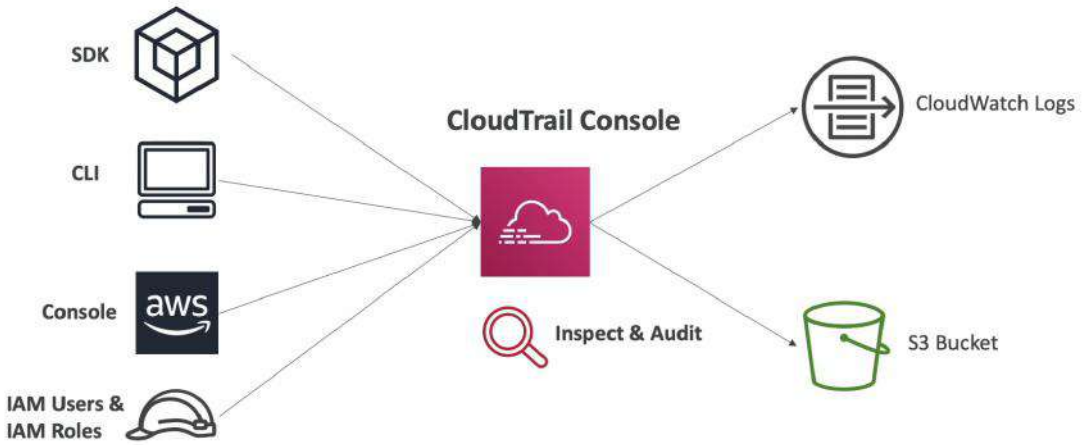


If the CPU Utilization is greater than 95% for 3 data points (separated by 5 mins), trigger the alarm.



Action will be to stop the EC2 instance.

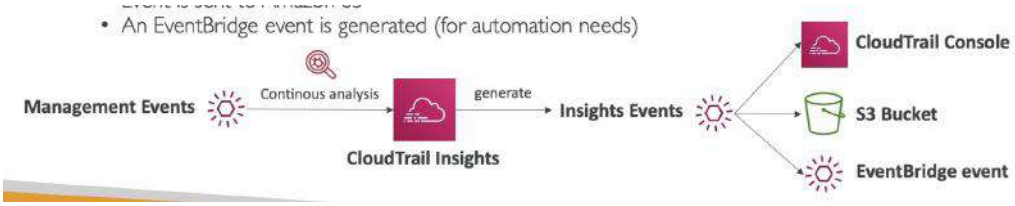
- CloudTrail
  - Intro
    - Provides governance, compliance and audit for your AWS Account
    - CloudTrail is enabled by default
    - Get a history of events / API calls made within your AWS account by:
      - Console
      - SDK
      - CLI
      - all AWS Services
    - Can put logs from CloudTrail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



  - Event types
    - 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 into CloudTrail (because high volume operations)
      - Amazon S3 object-level activity (ex: Get0bject, Delete0bject, Put0bject): can separate Read and Write Events
      - AWS Lambda function execution activity (the Invoke API)
    - Insight Events (for CloudTrail Insights)
      - Enable CloudTrail Insights to detect unusual activity in your account
        - inaccurate resource provisioning
        - hitting service limits
        - bursts of AWS IAM actions

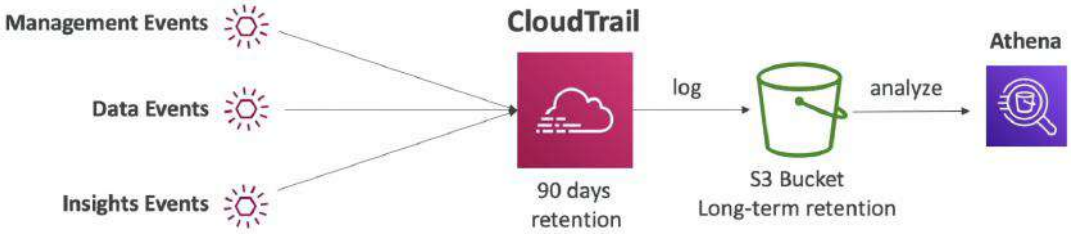
- gaps in periodic maintenance activity

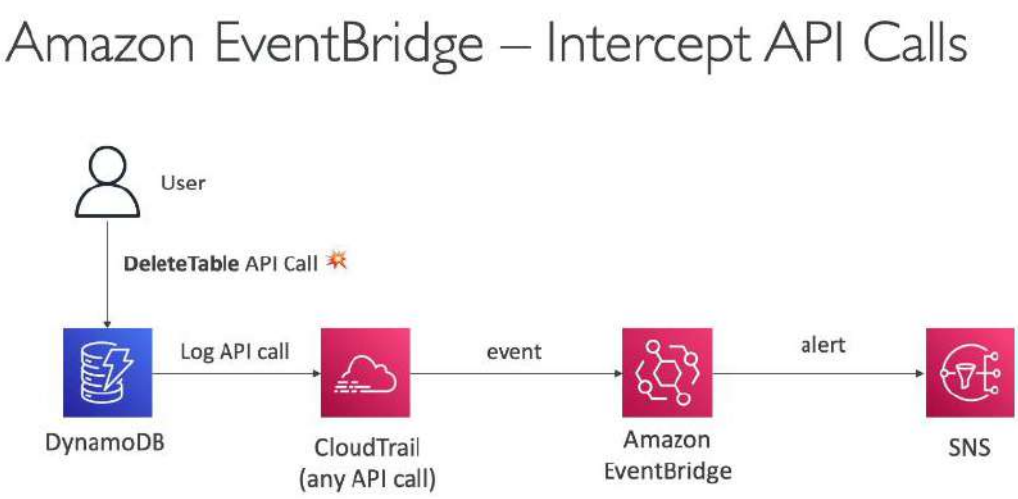
- CloudTrail Insights analyzes normal management events to create a baseline and then continuously analyzes write events to detect unusual patterns. If that happens, CloudTrail generates insight events that
  - show anomalies in the Cloud Trail console
  - can can be logged to S3
  - can trigger an EventBridge event for automation



▼ Event Retention

- Events are stored for 90 days in Cloud Trail, after that they are deleted automatically
- To keep events beyond this period, log them to S3 and use Athena to analyze them when needed





▼ Hands on

- View Events History

  Cloudtrail → Dashboard → Event History

- Create a trail to send events to an S3 bucket and CloudWatch logs

  CloudTrail → Trails → Create trail

  After some time, the events will appear in the S3 bucket and CloudWatch

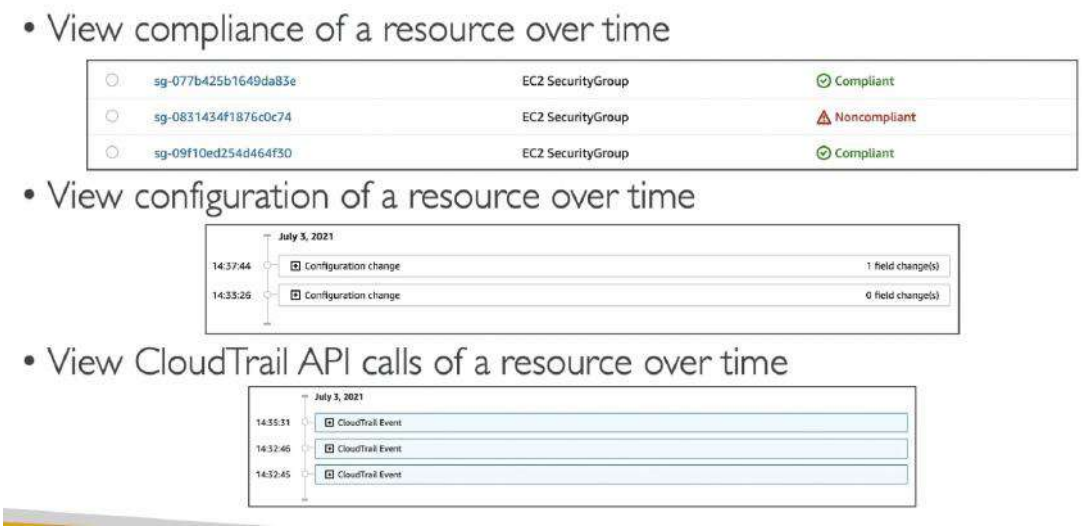
▼ AWS Config

▼ Intro

- Helps record configurations and changes over time to rollback the infrastructure if required.
- 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)
- Can use AWS managed config rules (over 75)
- Can make custom config rules (must be defined in AWS Lambda) such as:
  - Check if each EBS disk is of type gp2
  - Check if each EC2 instance is t2.micro
- Rules can be evaluated / triggered:
  - For each config change (ex. configuration of EBS volume is changed, evaluate the rule)
  - And / or: at regular time intervals (ex. every 2 hours, evaluate the rule)
- AWS Config Rules are used only to evaluate the compliance of resources over time, 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

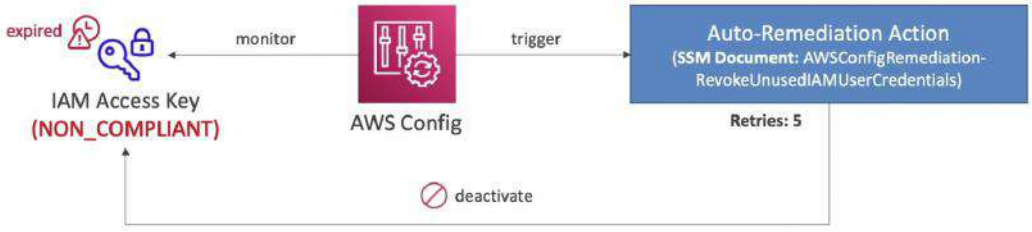
▼ Applications

Link AWS Config with CloudTrail to get a full picture of the change in configuration and compliance overtime.



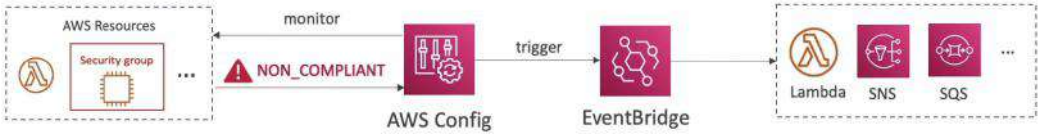
▼ Remediations

- 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 to automate something
- You can set Remediation Retries if the resource is still non-compliant after auto remediation
- Ex. if IAM access key expires (non-compliant), trigger an auto-remediation action to revoke unused IAM user credentials.

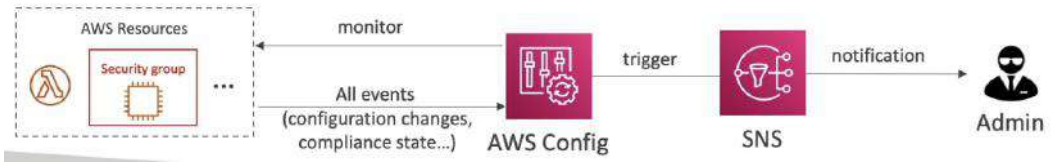


▼ Notifications

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



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



▼ Hands on

Config → Create rules

- We can specify rules that evaluate on resource configuration change to check for things like
  - whether or not all the EC2 instances were booted from a specific AMI. If they are not, we can set a remediation policy to terminate those instance.
  - whether or not all the security groups restrict HTTP access from the public internet. Those security groups that do are displayed as non-compliant.

▼ CloudWatch vs CloudTrail vs Config

▼ Theory

- 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

▼ ELB example

- CloudWatch:

        - Monitoring Incoming connections metric
        - Visualize error codes as % over time
        - Make a dashboard to get an idea of your load balancer performance
    - CloudTrail:
        - Track who made any changes to the Load Balancer with API calls
    - 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)

▼ Section 26: Identity and Access Management (IAM) - Advanced

▼ AWS Organizations

▼ Intro

- Global service
- Allows to manage multiple AWS accounts
- The main account is the master account, you can’t change it
- 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, etc.)
- API is available to automate AWS account creation (on demand account creation)

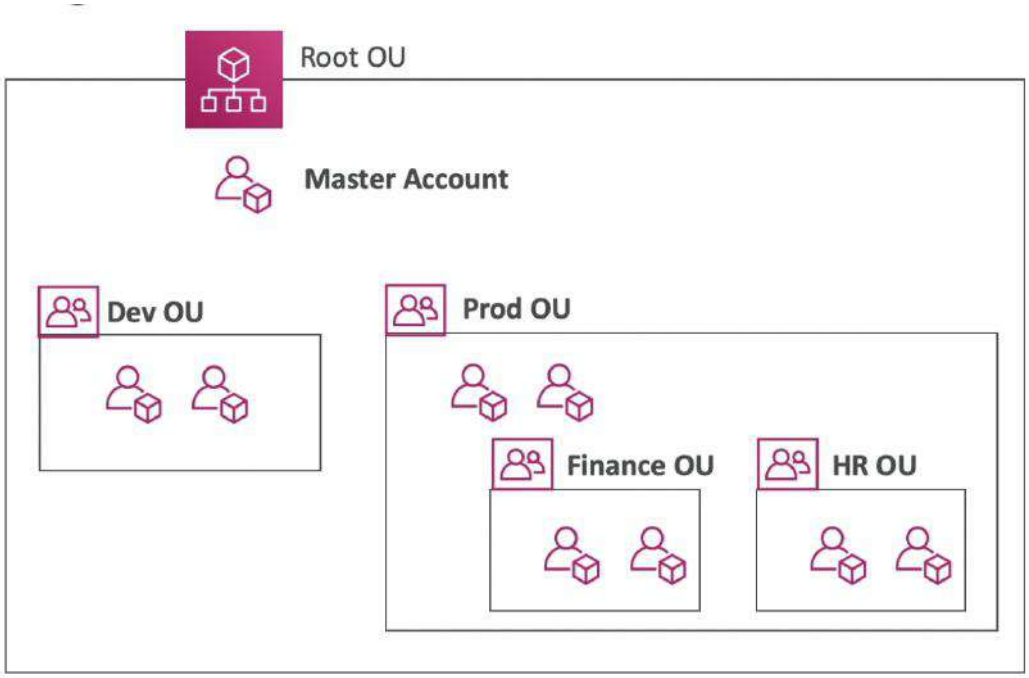
▼ Multi-account strategies

- Create accounts:
    - per department
    - per cost center
    - per env (dev / test / prod)
    - based on regulatory restrictions (using SCP)
    - for better resource isolation (ex: VPC so that resources in different accounts can’t talk to one another)
    - to have separate per-account service limits
    - for isolated account for logging
- 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 where the master account can assume an admin role in any of the children accounts

▼ Organizational Units (OU)

- We organize all the accounts using OUs.

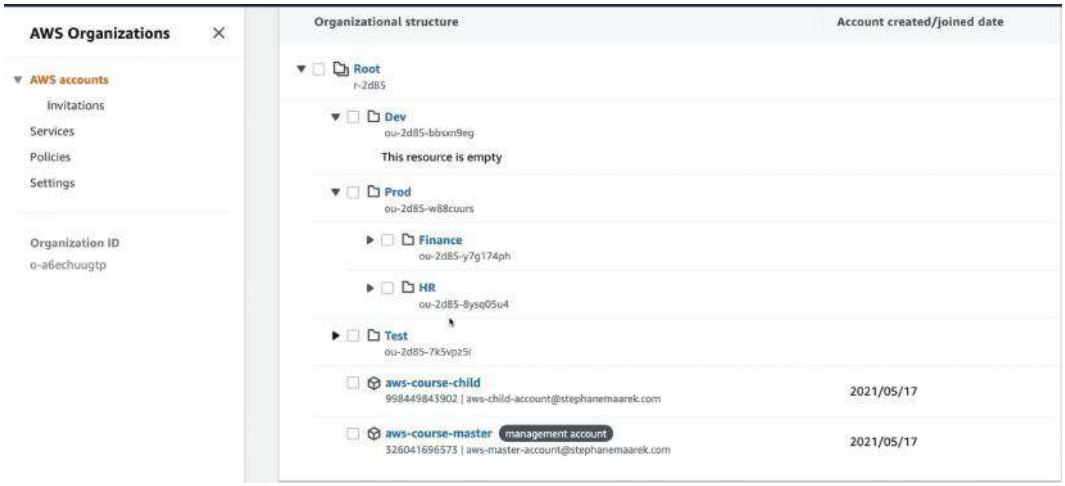
- Can nest OUs inside other OUs.



▼ Service Control Policies (SCP)

▼ Intro

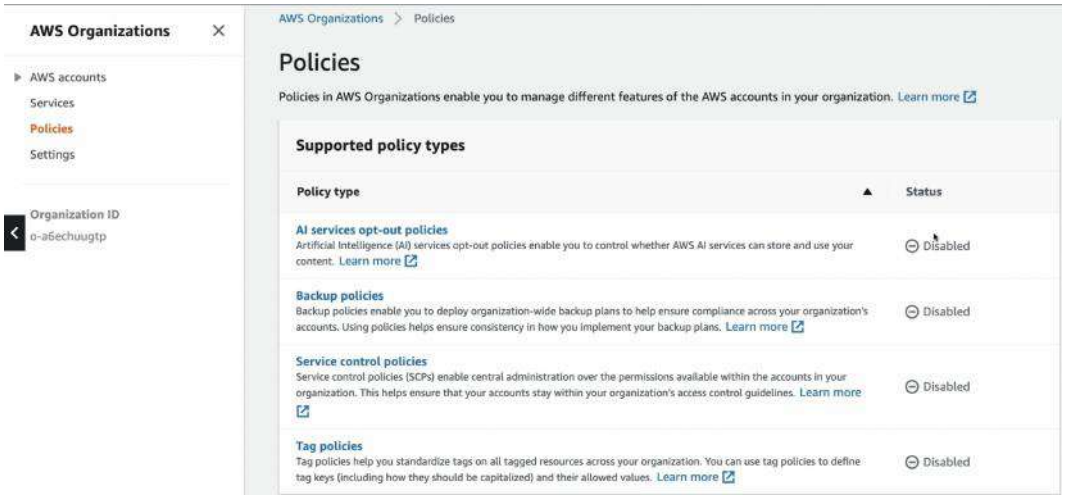
- Whitelist or blacklist IAM actions applied at the OU or Account level
- Does not apply to the Master Account
- SCP is applied to all the Users and Roles of the Account, including root user. So, if something is restricted for that account, even the root user of that account won't be able to do it.
- The SCP does not affect service-linked roles (service-linked roles enable other AWS services to integrate with AWS Organizations and can't be restricted by SCPs)
- SCP must have an explicit Allow (does not allow anything by default)
- Use cases:
  - Restrict access to certain services (for example: can't use EMR)
  - Enforce PCI compliance by explicitly disabling services



Untitled

- Policies

  We can create Service Control Policies and attach them to OUs or Accounts to allow or deny access to AWS resources within our organization.



Untitled

▼ IAM Advanced

▼ IAM Conditions

Ways to make your IAM policies bit more restrictive using conditions

```
{
    "Version": "2012-10-17",
    "Statement": {
        "Effect": "Deny",
        "Action": "*",
        "Resource": "*",
        "Condition": {
            "NotIpAddress": {
                "aws:SourceIp": [
                    "192.0.2.0/24",
                    "203.0.113.0/24"
                ]
            },
```

aws:SourceIP: restrict the client IP **from** which the API calls are being made

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "AllowOnlyInsideEU",
            "Effect": "Allow",
            "Action": [
                "ec2:*",
                "rds:*",
                "dynamodb:*"
            ],
            "Resource": "*",
            "Condition": {
                "StringEquals": {
                    "aws:RequestedRegion": [
                        "eu-central-1",
                        "eu-west-1"
                    ]
                }
            }
        }
    ]
}
```

Aws:RequestedRegion: restrict the region The API calls are made **to**

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "StartStopIfTags",
            "Effect": "Allow",
            "Action": [
                "ec2:StartInstances",
                "ec2:StopInstances",
                "ec2:DescribeTags"
            ],
            "Resource": "arn:aws:ec2:region:account-id:instance/*",
            "Condition": {
                "StringEquals": {
                    "ec2:ResourceTag/Project": "DataAnalytics",
                    "aws:PrincipalTag/Department": "Data"
                }
            }
        }
    ]
}
```

Restrict based on tags

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Sid": "AllowAllActionsForEC2",
            "Effect": "Allow",
            "Action": "ec2:*",
            "Resource": "*"
        },
        {
            "Sid": "DenyStopAndTerminateWhenMFAIsNotPresent",
            "Effect": "Deny",
            "Action": [
                "ec2:StopInstances",
                "ec2:TerminateInstances"
            ],
            "Resource": "*",
            "Condition": {
                "BoolIfExists": {"aws:MultiFactorAuthPresent": false}
            }
        }
    ]
}
```

Force MFA

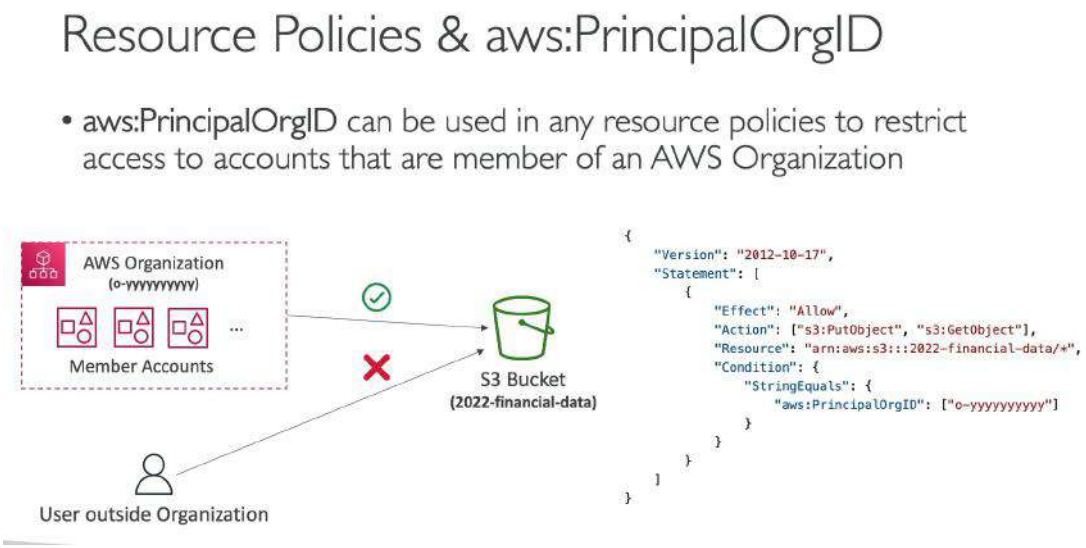
▼ S3 bucket policies & object policies

- ListBucket permission applies to arn:aws:s3:::test
- => bucket level permission

- GetObject, PutObject, DeleteObject applies to arn:awn:s3:::test/*
- => object level permission

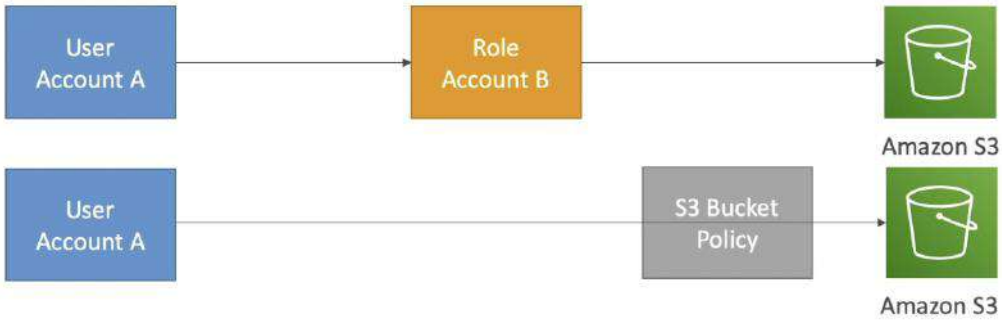
```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Effect": "Allow",
      "Action": ["s3:ListBucket"],
      "Resource": ["arn:aws:s3:::test"]
    },
    {
      "Effect": "Allow",
      "Action": [
        "s3:PutObject",
        "s3:GetObject",
        "s3:DeleteObject"
      ],
      "Resource": ["arn:aws:s3:::test/*"]
    }
  ]
}
```

▼ Resource based policies

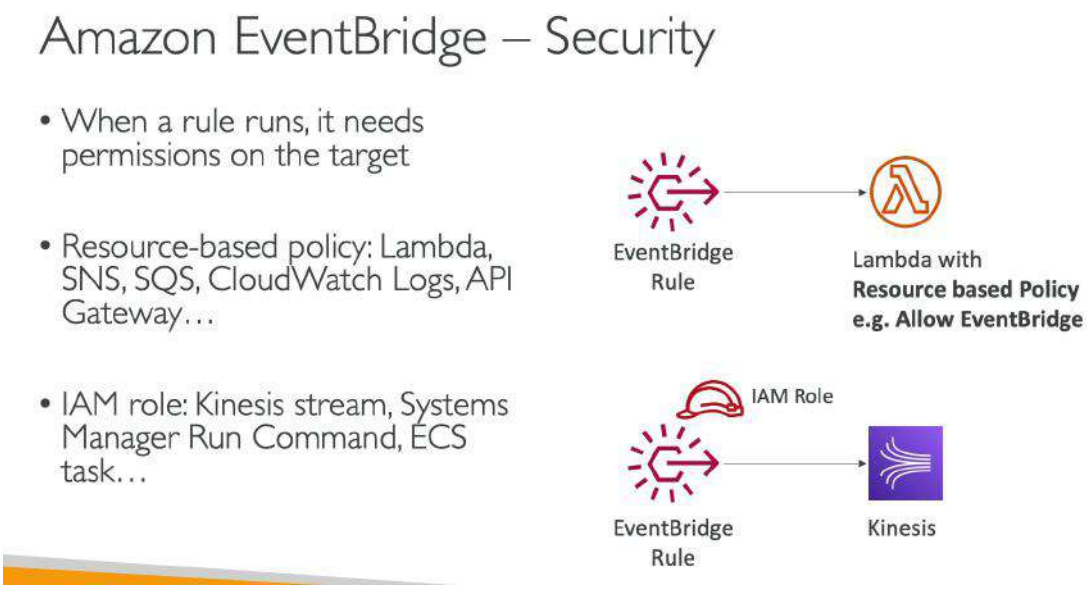


▼ IAM Roles vs Resource based policies

- When you assume a role (user, application or service), you give up your original permissions and take the permissions assigned to the role
- When using a resource based policy, the principal doesn't have to give up his permissions
- Example: User in account A needs to scan a DynamoDB table in Account A and dump it in an S3 bucket in Account B.
    - Need to use S3 bucket policy in account B. Cannot use IAM role because first scan the table in account A using the original role then assume another role in account B to write it in S3 bucket, but now you can't read the scanned data from account A.



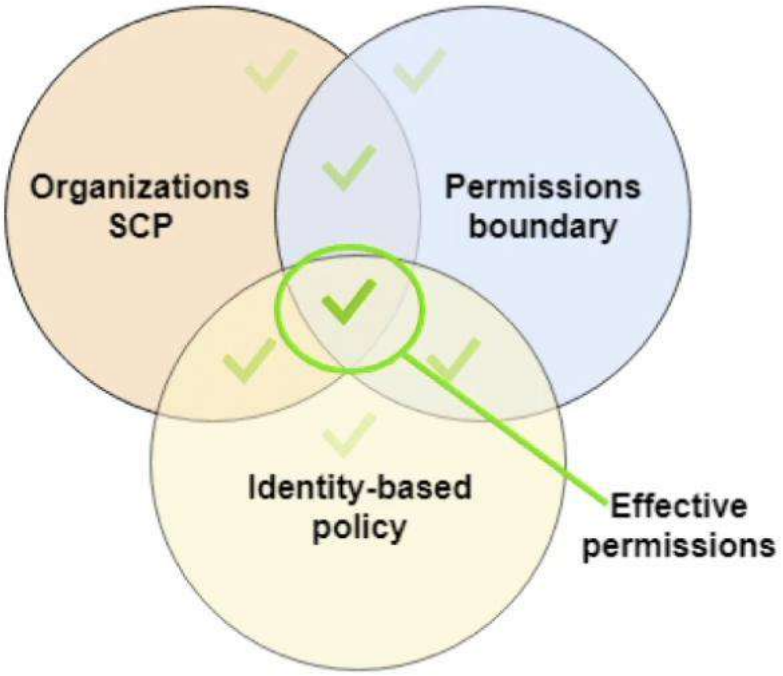
- Resource based policies are supported by Amazon S3 buckets, SNS topics, SQS queues



▼ IAM Permission Boundaries

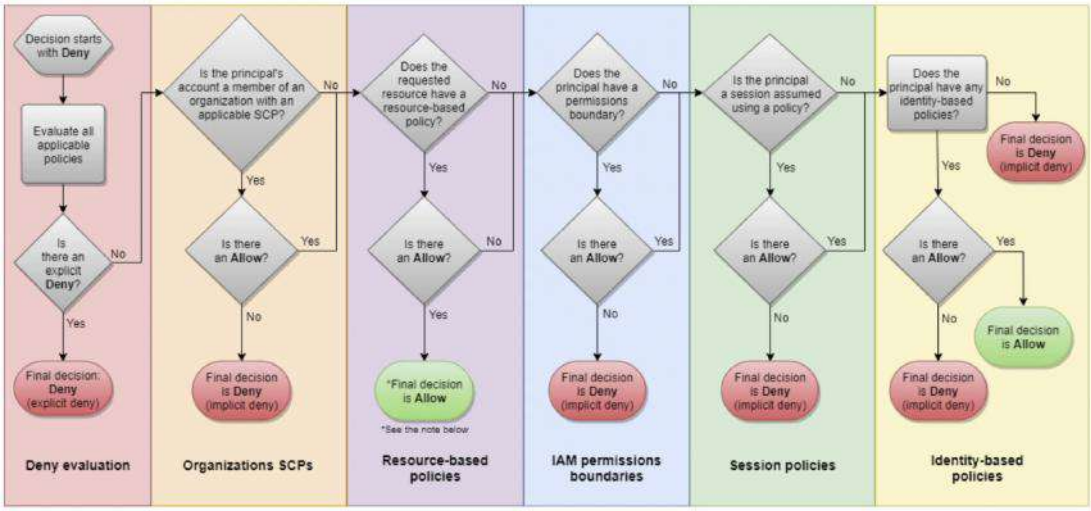
▼ Intro

- lAM Permission Boundaries are supported for users and roles (not groups)
- Advanced feature to use a managed policy to set the maximum permissions an IAM entity can get
- Even if the user has admin access, the maximum permission is still based on the permission boundary.
- To set permission boundary for a user: IAM → Users → Select user → Permission boundary
- Use cases:
  - Delegate responsibilities to non-administrators within their permission boundaries, for example create new IAM users
  - Allow developers to self-assign policies and manage their own permissions, while making sure they can’t escalate their privileges (make themselves admin)
  - Useful to restrict one specific user (instead of a whole account using organizations & SCP)
- Can be used in combination of SCP and identity-based policy



▼ Example

▼ Policy Evaluation Logic



Cognito User Pools (CUP) - Integrations

- CUP integrates with API Gateway and Application Load Balancer

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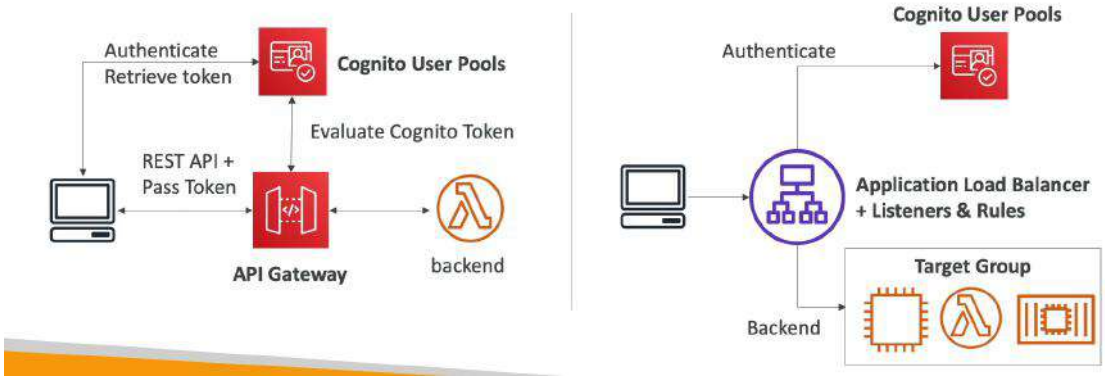
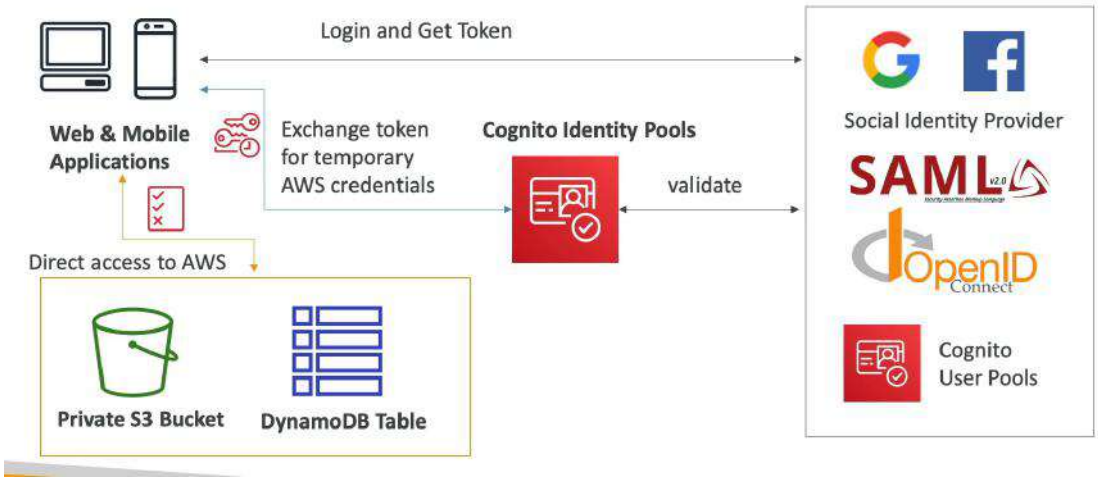


Cognito Identity Pools (Federated Identities)

- Get identities for "users" so they obtain temporary AWS credentials
- Users source can be Cognito User Pools, 3rd party logins, etc…

- Users can then access AWS services directly or through API Gateway
- The IAM policies applied to the credentials are defined in Cognito
- They can be customized based on the user_id for fine grained control
- Default IAM roles for authenticated and guest users

Cognito Identity Pools – Diagram



Cognito Identity Pools
Row Level Security in DynamoDB

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Action": [
                "dynamodb:GetItem", "dynamodb:BatchGetItem", "dynamodb:Query",
                "dynamodb:PutItem", "dynamodb:UpdateItem", "dynamodb:DeleteItem",
                "dynamodb:BatchWriteItem"
            ],
            "Resource": [
                "arn:aws:dynamodb:us-west-2:123456789012:table/MyTable"
            ],
            "Condition": {
                "ForAllValues:StringEquals": {
                    "dynamodb:LeadingKeys": [
                        "${cognito-identity.amazonaws.com:sub}"
                    ]
                }
            }
        }
    ]
}
```

▼ AWS IAM Identity Center - Single Sign-On (SSO)

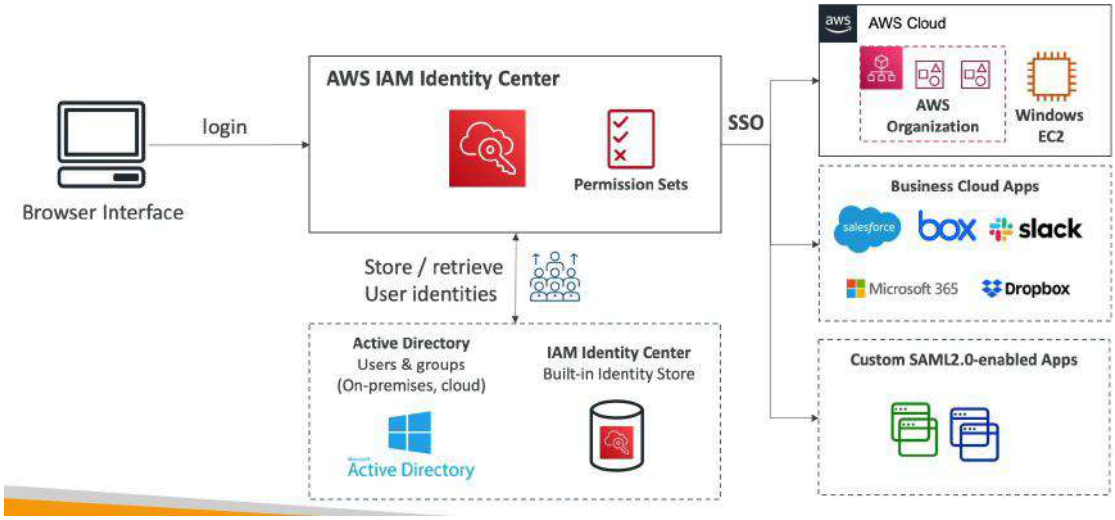
AWS IAM Identity Center (successor to AWS Single Sign-On)

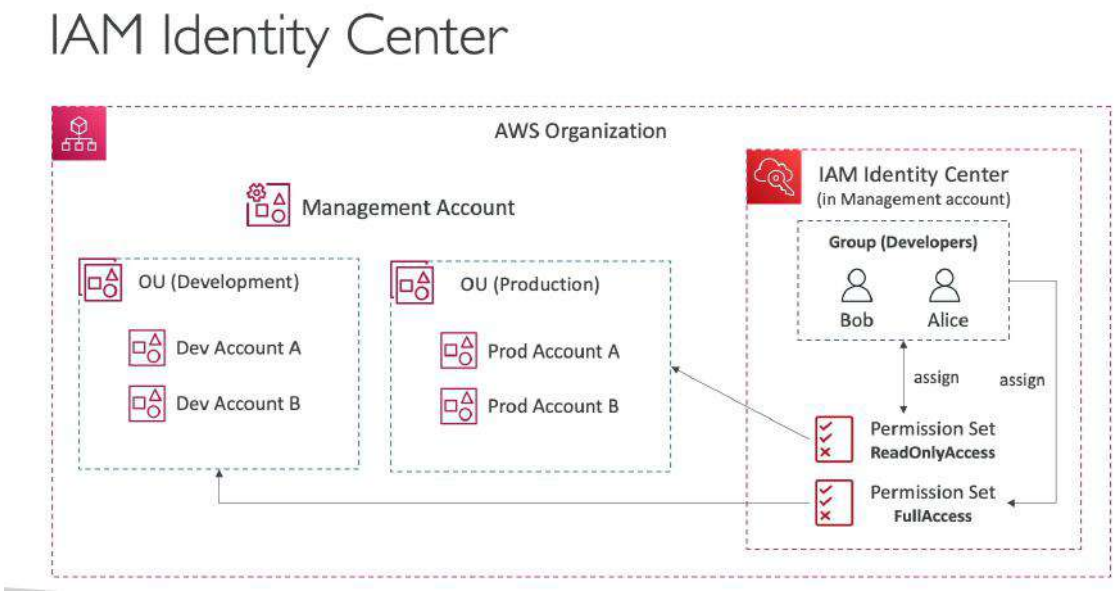
- One login (single sign-on) for all your
  - AWS accounts in AWS Organizations
  - Business cloud applications (e.g., Salesforce, Box, Microsoft 365, …)
  - SAML2.0-enabled applications
  - EC2 Windows Instances

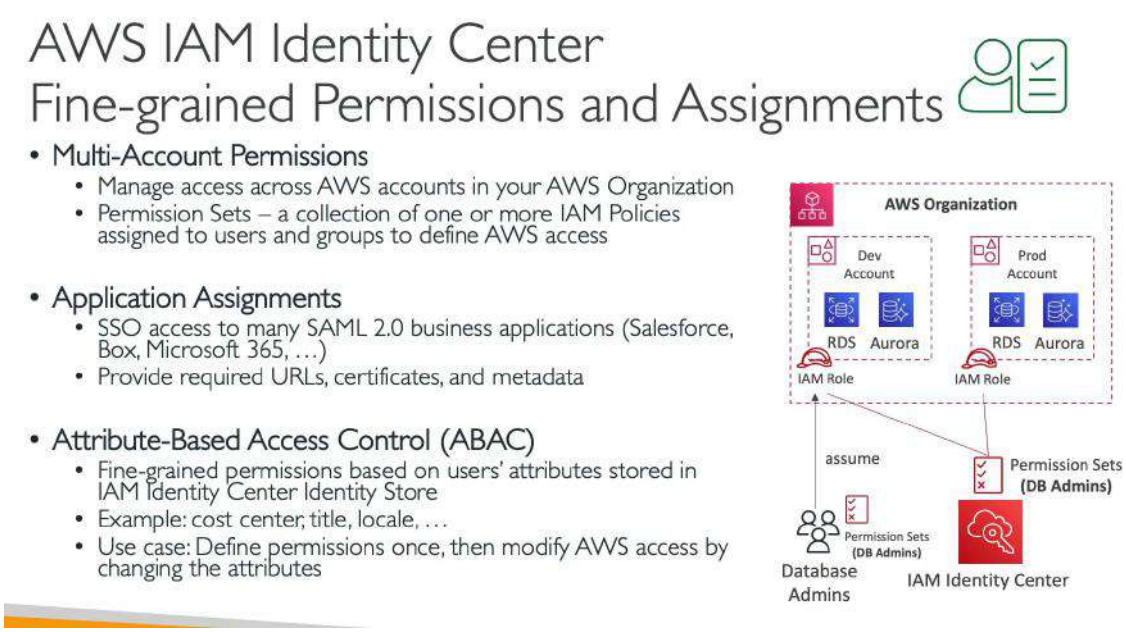
- Identity providers
  - Built-in identity store in IAM Identity Center
  - 3rd party: Active Directory (AD), OneLogin, Okta…

AWS IAM Identity Center – Login Flow

AWS IAM Identity Center

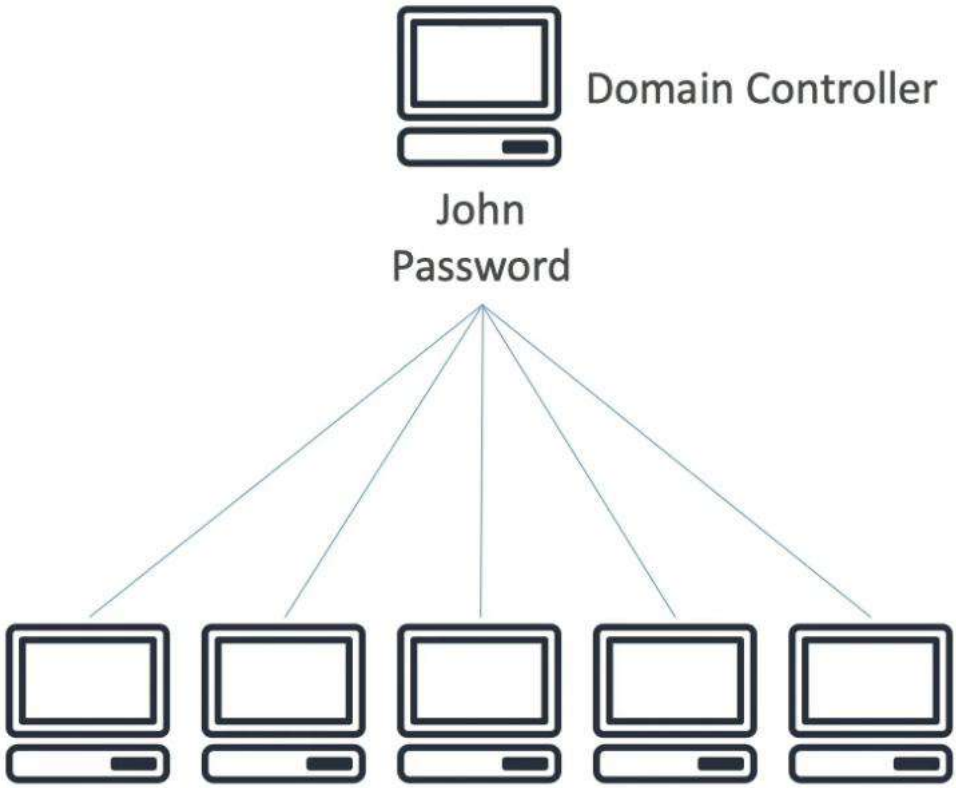






▼ Microsoft Active Directory (AD)

- It is a way to share login credentials of the users with all the machines within the network.
- Found on any Windows Server with AD Domain Services
- Database of objects: User Accounts, Computers, Printers, File Shares, Security Groups, etc.
- Centralized security management. You can create account, assign permissions, etc.
- Objects are organized in trees. A group of trees is a forest
- There is a domain controller. We will create an account there. Since each windows machine on the network is connected to the domain controller, this user can be logged in from any machine on the network.



▼ AWS Directory Services

Used to extend the network by involving services like EC2 to be a part of the AD to share login credentials.

▼ AWS Managed Microsoft AD

- Create your own AD in AWS to share login credentials between on-premise and AWS AD
- Manage users on-premise and on AWS Managed AD
- Supports MFA
- Establish “trust” connections with your on premise AD

▼ AD Connector

- AD connector will proxy all the requests to the on-premise AD.
- Supports MFA
- Users are managed on the on-premise AD only

▼ Simple AD

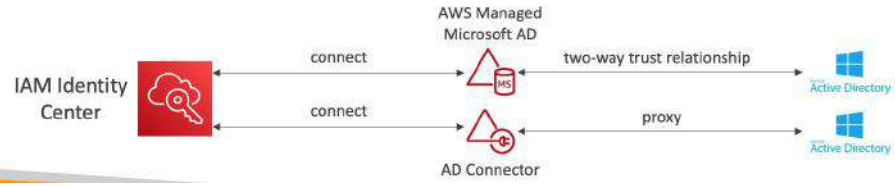
- AD-compatible managed directory on AWS
- Users are managed on the AWS AD only
- Cannot be joined with on-premise AD
- Use when you don’t have an on-premise AD

▼ Setup

IAM Identity Center – Active Directory Setup

- Connect to an AWS Managed Microsoft AD (Directory Service)
  - Integration is out of the box

- Connect to a Self-Managed Directory
  - Create Two-way Trust Relationship using AWS Managed Microsoft AD
  - Create an AD Connector



▼ Control Tower

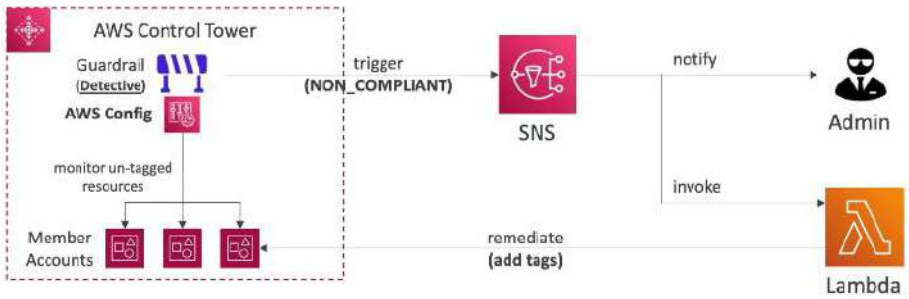
AWS Control Tower

- Easy way to set up and govern a secure and compliant multi-account AWS environment based on best practices
- AWS Control Tower uses AWS Organizations to create accounts

- 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 – Guardrails

- Provides ongoing governance for your Control Tower environment (AWS Accounts)
- **Preventive Guardrail – using SCPs** (e.g., Restrict Regions across all your accounts)
- **Detective Guardrail – using AWS Config** (e.g., identify untagged resources)

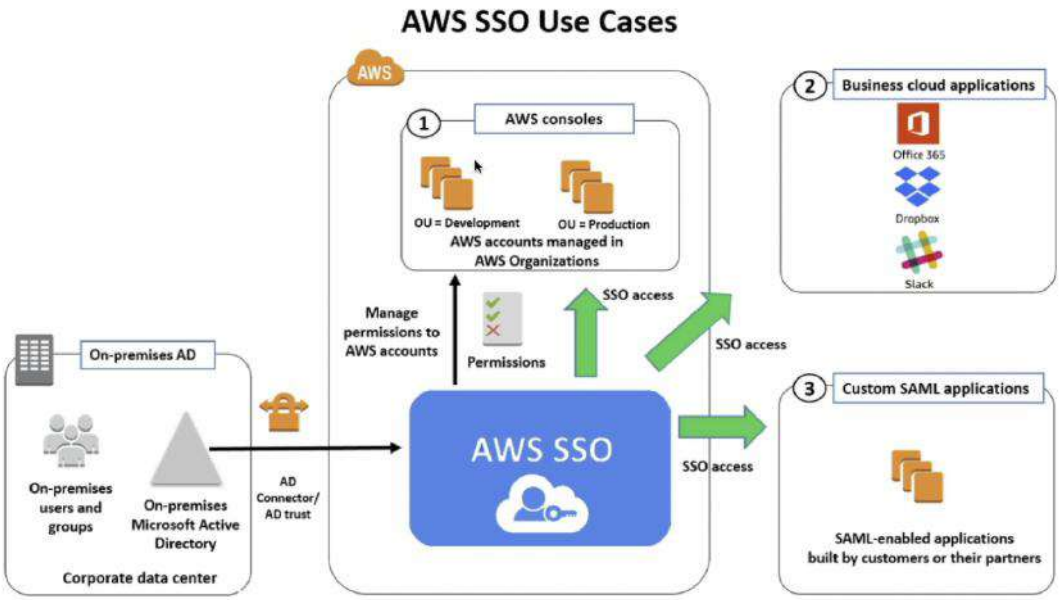


▼ AWS IAM Identity Center - Single Sign-On (SSO)

▼ Intro

- Centrally manage Single Sign-On to access multiple accounts and 3rd-party business applications.
- Free service (no pricing)
- Integrated with AWS Organizations (login once for your organization and you can access all the accounts within that org)
- Supports SAML 2.0 markup
- Integration with on-premise Active Directory
- Centralized permission management
- Centralized auditing with CloudTrail

▼ SSO with Microsoft AD

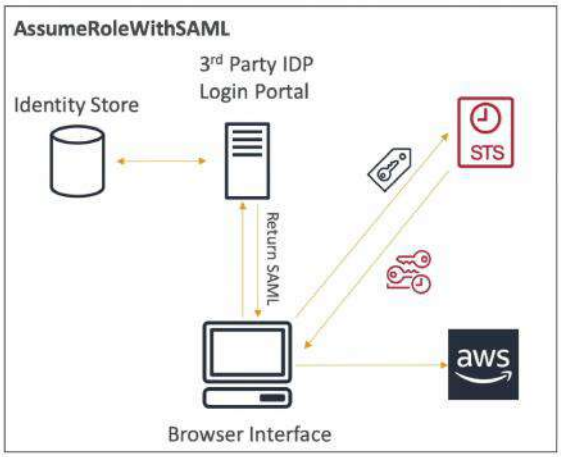


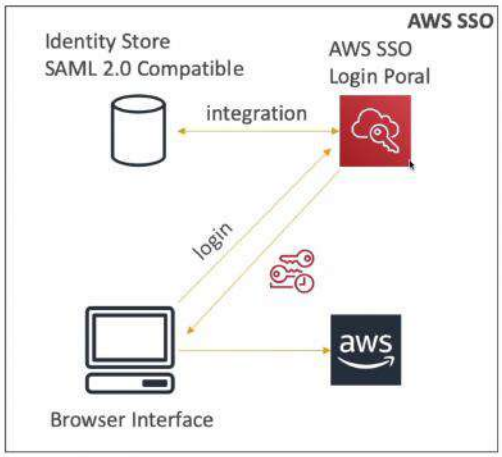
Once users are logged in from AD, they can access AWS consoles, business cloud applications and any custom SAML applications.

▼ AssumeRoleWthSAML vs SSO

With AssumeRoleWithSAML, we need to maintain a 3rd party identity provider login portal. This portal checks in the identity store and returns a SAML assertion that we send to STS for access keys.

With AWS SSO, we don’t need to manage the login portal, it is done through the AWS SSO service. SSO service automatically scales with the number of accounts.





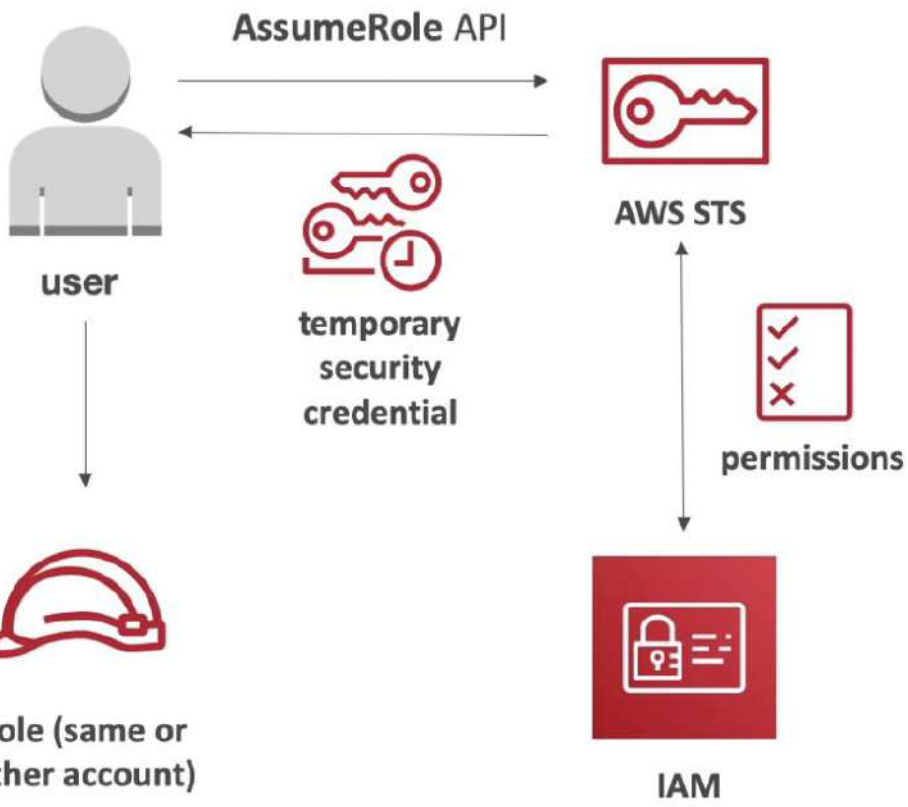
▼ Hands on

AWS SSO → Enable SSO

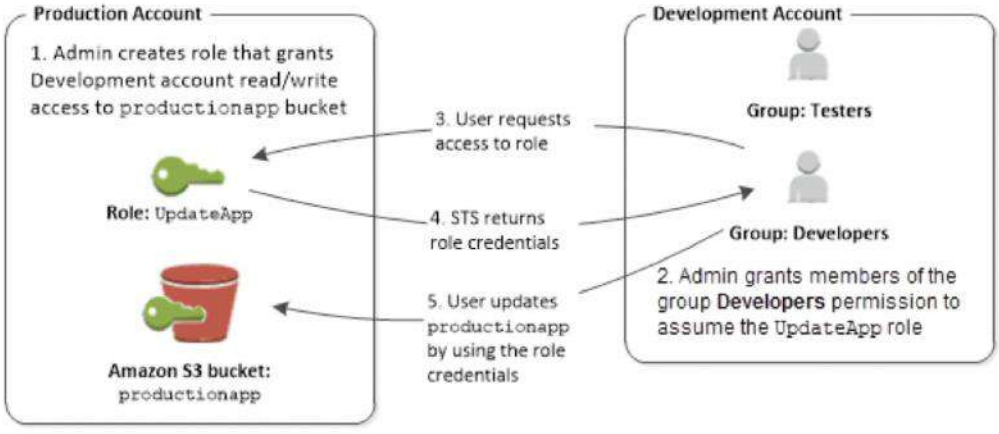
Once enabled, do the following.

▼ Security Token Service (STS)

- Allows to grant limited and temporary access to AWS resources
- Token is valid for up to one hour (must be refreshed)
- Use cases
  - ▼ AssumeRole
    - Within your own account: for additional security (ex. terminating an EC2 instance first requires users to temporarily assume a role)
    - Cross Account Access: assume role in target account to perform actions there
    - To assign a temporary role to an IAM user
    - Steps
      - Define an lAM Role within your account or cross-account
      - Define which principals can access this lAM Role (who should be allowed to assume this role)
      - Use AWS STS (Security Token Service) to retrieve credentials and impersonate the lAM Role you have access to (AssumeRole API). STS will check whether or not the user is allowed to assume that role.
      - Temporary credentials can be valid between 15 minutes to I hour



- Cross-account access with STS



▼ AssumeRoleWithSAML

- return credentials for users logged with SAML (non IAM users)

▼ AssumeRoleWithWebIdentity

- return creds for users logged with an identity provider (Facebook Login, Google Login, OIDC compatible…)
- AWS recommends against using this (recommended to use Cognito instead)

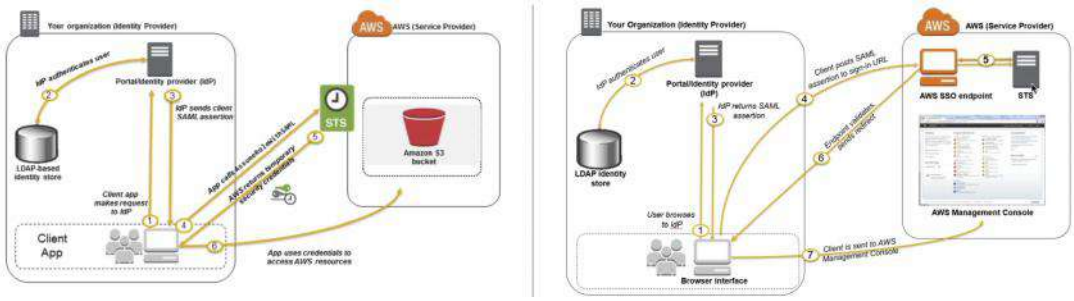
▼ GetSessionToken

- for MFA, from a user or AWS account root user

▼ Identity Federation in AWS

▼ Intro

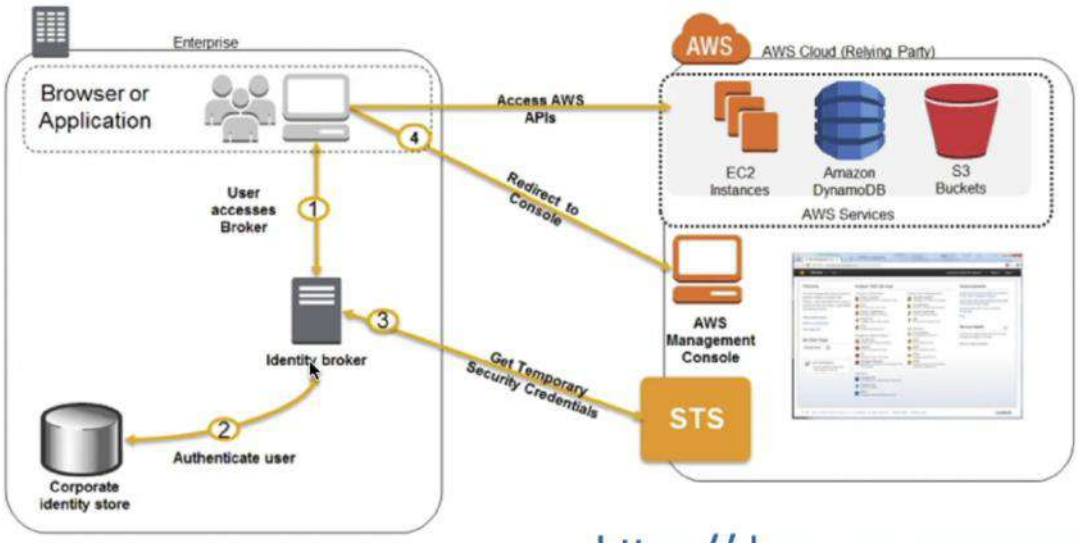
- SAML assertion is exchanged for security credentials from STS.



- Needs to setup a trust between AWS IAM and SAML (both ways)
- SAML 2.0 enables web-based, cross domain SSO
- Uses the STS API: AssumeRoleWithSAML
- Note: federation through SAML is the old way, Amazon Single Sign On (SSO) Federation is the new managed and simpler way.

▼ Custom Identity Broker Application

- Use only if identity provider is not compatible with SAML 2.0
- The identity broker must determine the appropriate lAM policy
- Uses the STS API: AssumeRole or GetFederationToken
- In this case instead of client asking STS for temporary security credentials, identity broker does this task.

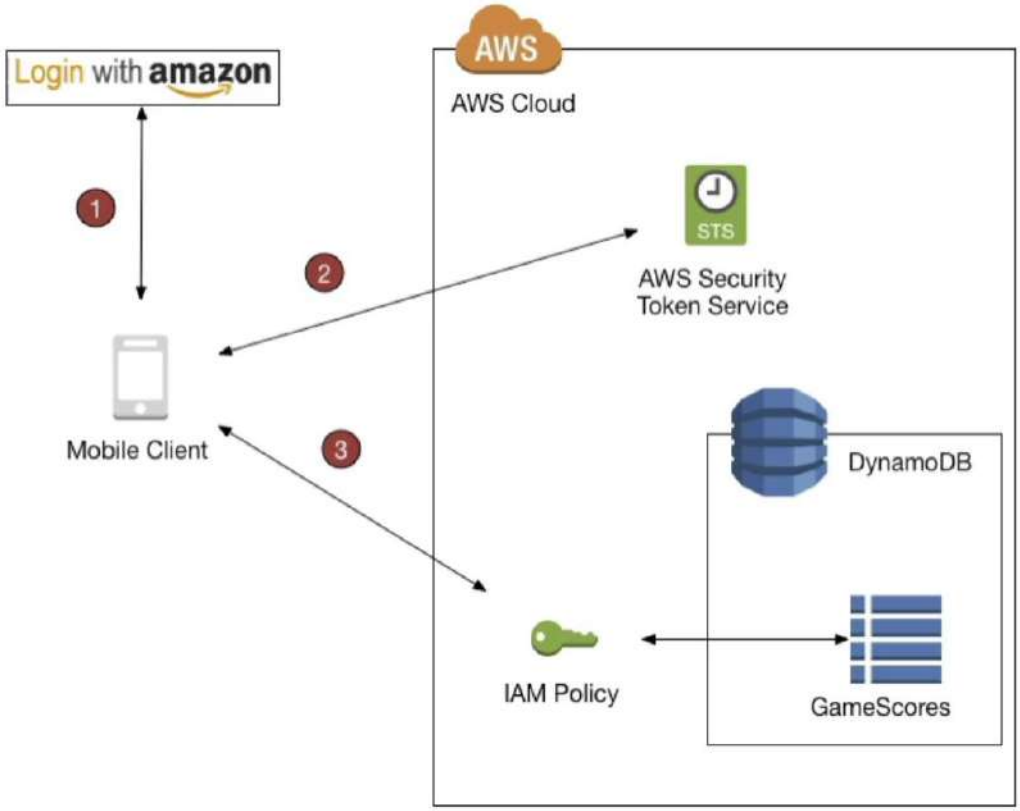


▼ Web Identity Federation

- Used to provide the users (non AWS) of our application, access to AWS resources.

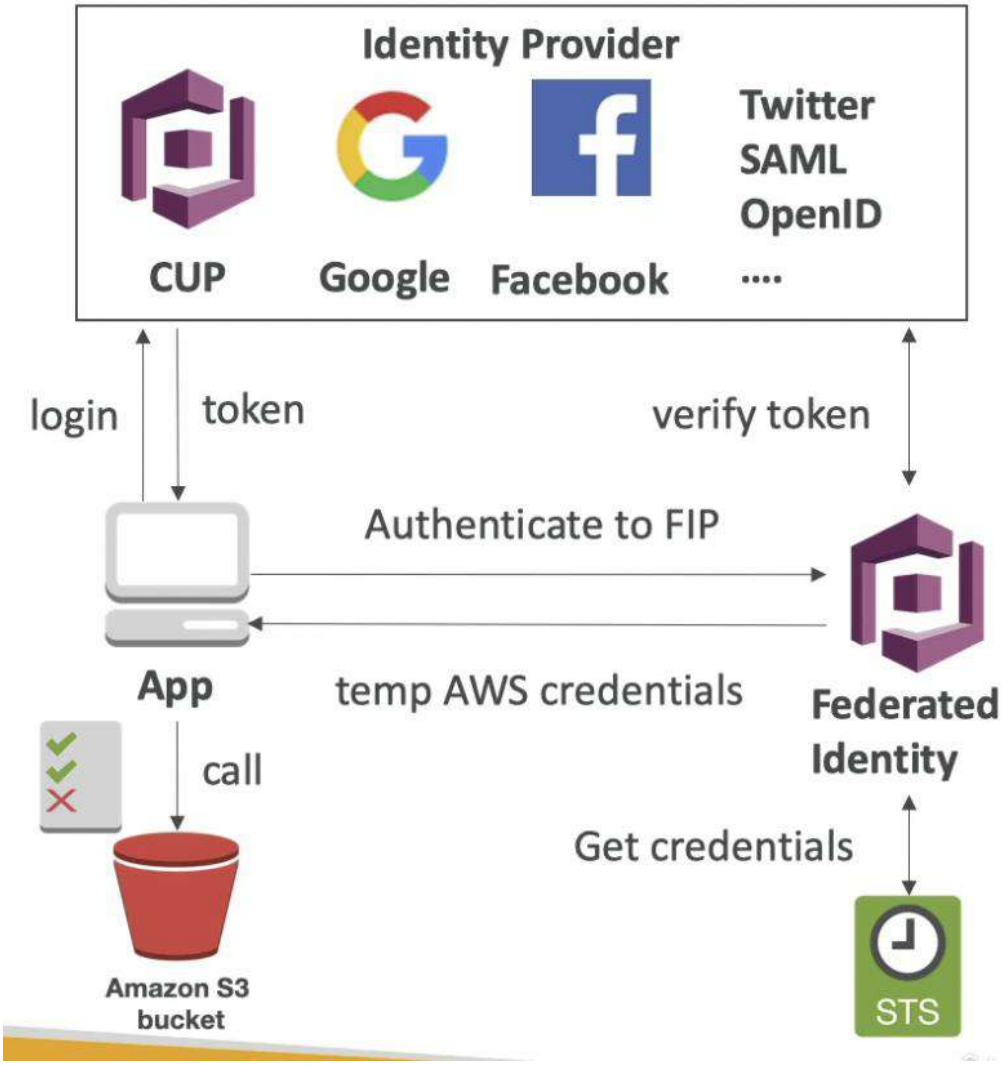
▼ Without Cognito

- Not recommended by AWS, use Cognito instead (allows for anonymous users, data synchronization, MFA)
- In the diagram below, Amazon is acting as the identity provider. It can also be FB or Google.



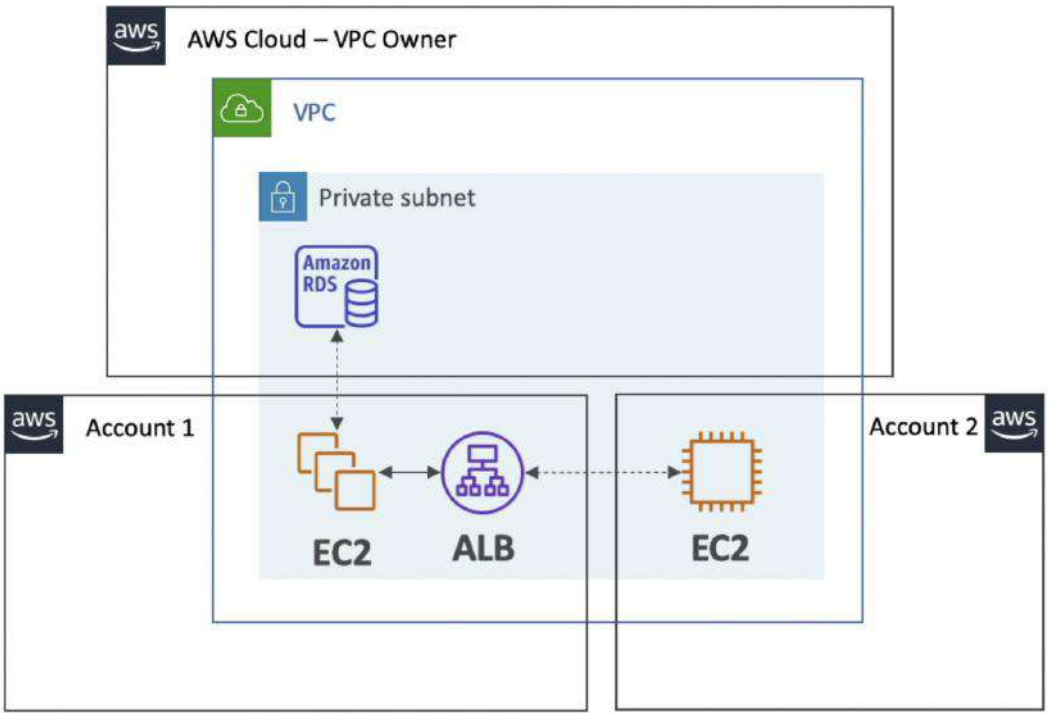
▼ With Cognito

- Provide direct access to AWS Resources from the Client Side (mobile, web app)
- Example: provide (temporary) access to write to S3 bucket using Facebook Login
- We don’t want to create lAM users for our app users as there could be millions of them.
- Steps
  - Log in to federated identity provider or remain anonymous
  - Use the token to authenticate to Federated Identity Pool
  - Get temporary AWS credentials back from the Federated Identity Pool
  - These credentials come with a pre-defined IAM policy stating their permissions



▼ AWS Resource Access Manager (RAM)

- Share AWS resources with other AWS accounts to avoid resource duplication
- Share with any account or within your Organization
- Example:
  - ▼ VPC Subnets:
    - allow to have all the resources launched in the same subnets
    - must be from the same AWS Organization
    - cannot share security groups and default VPC
    - each participating account manage their own resources
    - participating accounts can’t view, modify, delete resources that belong to other participants or the owner
    - Network is shared
      - anything deployed in the VPC can talk to other resources in the VPC
      - applications are accessed easily across accounts, using private IP
      - security groups from other accounts can be referenced



- AWS Transit Gateway
- Route53 Resolver Rules
- License Manager Configurations

▼ Section 27: AWS Security & Encryption: KMS, SSM Parameter Store, CloudHSM, Shield, WAF

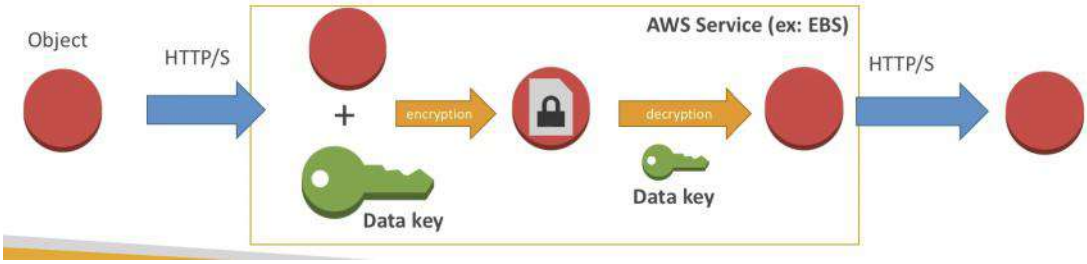
▼ Encryption

▼ Encryption in flight (SSL - Secure Sockets Layer)

- Data is encrypted before sending and decrypted after receiving
- SSL certificates help with encryption (HTTPS)
- Encryption in flight ensures no MITM (man in the middle) attack
- Ex: sending credit card info for online payments

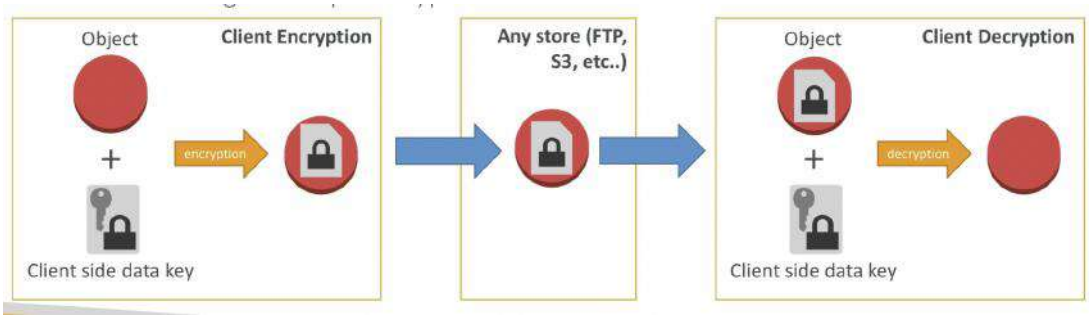
▼ Server side encryption at rest

- Data is encrypted after being received by the server
- Data is decrypted before being sent from the server
- It is stored in an encrypted form thanks to a key (usually a data key)
- The encryption / decryption keys must be managed somewhere and the server must have access to it (KMS)



▼ Client side encryption at rest

- Data is encrypted by the client and never decrypted by the server
- Data will be decrypted by a receiving client
- The server should not be able to decrypt the data
- Could leverage Envelope Encryption



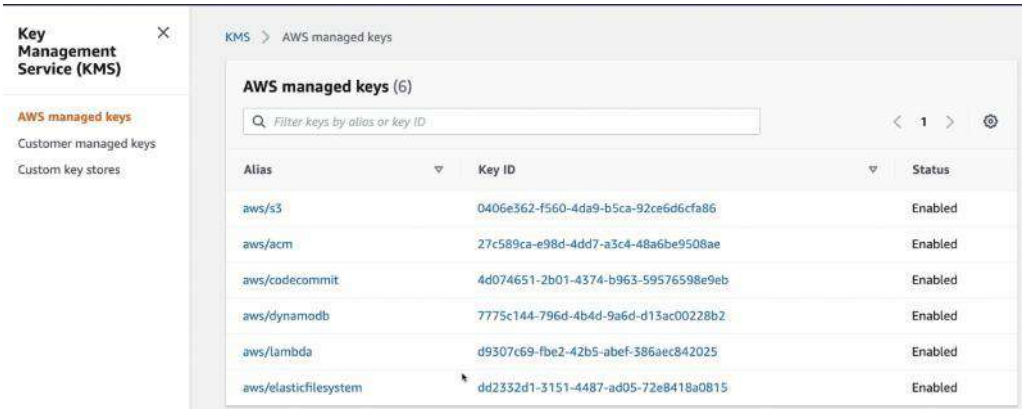
▼ Key Management Service (KMS)

▼ Intro

- Fully integrated with lAM for authorization
- KMS keys are bound to a specific region
- Seamlessly integrated into multiple AWS services such as:
  - Amazon EBS: encrypt volumes
  - Amazon S3: Server side encryption of objects
  - Amazon Redshift: encryption of data
  - Amazon RDS: encryption of data
  - Amazon SSM: Parameter store
- Can not only use with AWS services but also with the CLI & SDK
- Anytime you need to share sensitive information, use KMS
  - Database passwords
  - Credentials to external service
  - Private Key of SSL certificates
- CMK used to encrypt data can never be retrieved by the user, and the CMK can be rotated for extra security
- Encrypted secrets can be stored in the code or environment variables
- KMS can only help in encrypting up to 4KB of data per call. If data > 4 KB, use envelope encryption
- To give access to KMS to someone:
  - Make sure the Key Policy allows the user
  - Make sure the lAM Policy allows the API calls

▼ Customer Master Key (CMK)

- Able to fully manage the keys & policies:
  - Create
  - Rotation policies
  - Disable
  - Enable
- Able to audit key usage (using CloudTrail)
- Three types of Customer Master Keys
  - ▼ AWS Managed Service Default CMK (free)
    - Separate default KMS key for each supported service
    - Used to encrypt/decrypt anything in a specific AWS service
    - They are fully managed by AWS, we can’t view, rotate or delete them



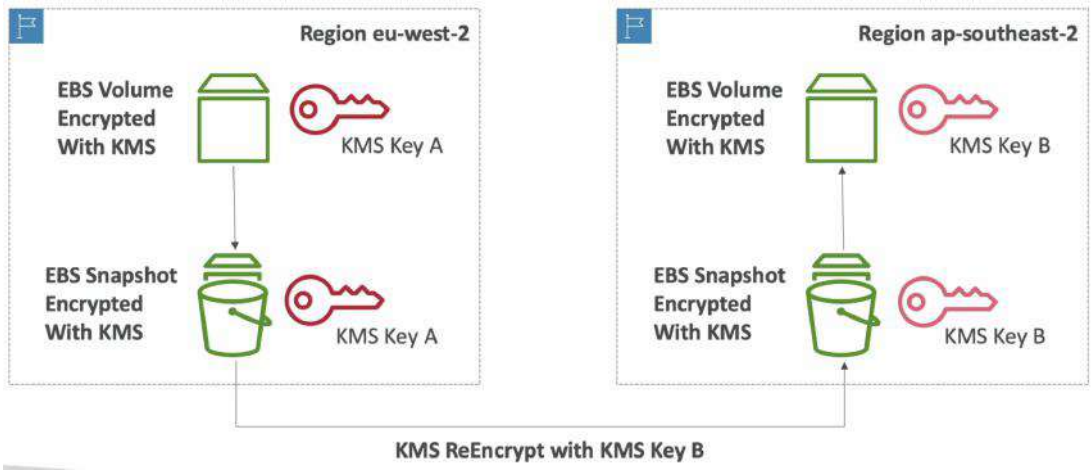
  - ▼ User Keys created in KMS ($1 / month)
    - Option to enable rotation every year for additional security
  - ▼ User Keys generated and imported from outside AWS ($1 / month)
    - Not recommended
    - Must be 256-bit symmetric key
- pay for API call to KMS ($0.03 / 10000 calls)

▼ Symmetric & Asymmetric Keys

- ▼ Symmetric (AES-256 keys)
  - First offering of KMS, single encryption key that is used to Encrypt and Decrypt data
  - AWS services that are integrated with KMS use Symmetric CMKs
  - Must call KMS API to encrypt data
  - Necessary for envelope encryption
- ▼ Asymmetric (RSA & ECC key pairs)
  - Public (Encrypt) and Private Key (Decrypt) pair
  - Used for Encrypt/Decrypt, or Sign/Verify operations
  - The public key is downloadable, but you can’t access the Private Key unencrypted
  - No need to call the KMS API to encrypt data (data can be encrypted by the client)
  - Not eligible for automatic rotation
  - Use case: encryption outside of AWS by users who can’t call the KMS API

▼ Encrypted Snapshot migration across regions

- Create a snapshot (encrypted) of the encrypted volume
- Copy the snapshot to another region along with re-encryption using a new key in the new region (keys are bound to a region)
- Make a volume using the snapshot in the new region

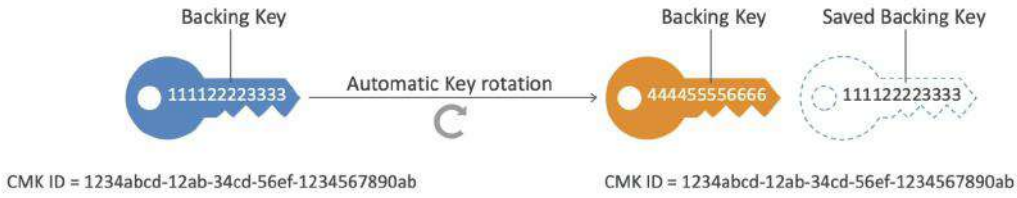


▼ KMS key policies

- Control access to KMS keys, “similar” to S3 bucket policies, you cannot access KMS keys without them
- Default KMS Key Policy:
  - Created if you don’t provide a specific KMS Key Policy
  - Complete access to the key for the root user ⇒ any user or role can access the key (most permissible)
  - Gives access to the IAM policies to the KMS key
- Custom KMS Key Policy:
  - Define users, roles that can access the KMS key
  - Define who can administer the key
  - Useful for cross-account access of your KMS key

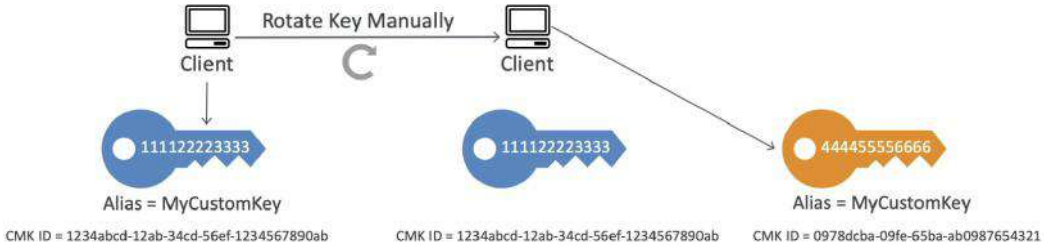
▼ Encrypted Snapshot migration across accounts

- Create a Snapshot, encrypted with your own CMK
- Attach a KMS Key Policy to authorize cross-account access
- Share the encrypted snapshot
- In the target account, create a copy of the snapshot (decryption will require the main CMS key),
- Encrypt it with a new KMS Key in your account
- Create a volume from the snapshot

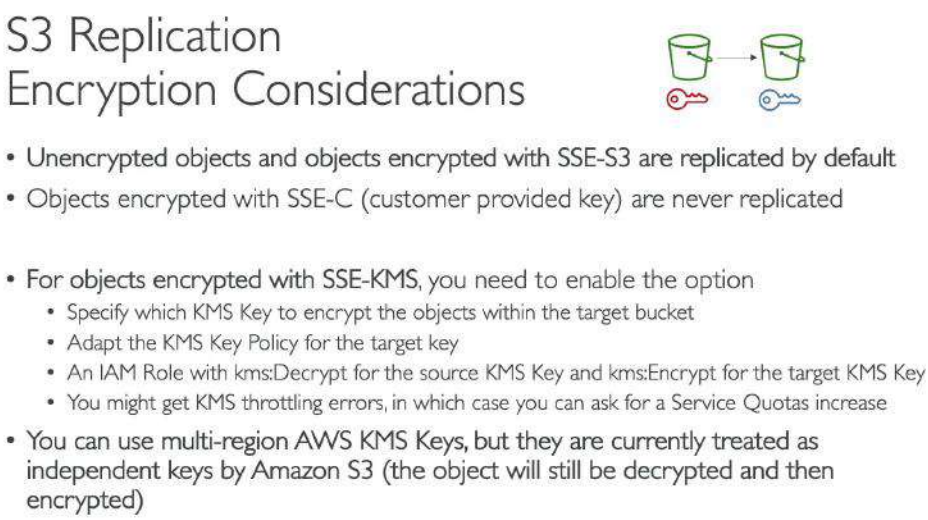


▼ Manual

- When you want to rotate key every 90 days or 180 days
- New Key has a different CMK ID
- Keep the previous key active so that you can decrypt old data
- Better to use aliases in this case as CMK id changes after rotation (to hide the change of key for the application). After rotation, use UpdateAlias API to point the alias to the new key.
- Good solution to rotate CMK that are not eligible for automatic rotation (asymmetric CMK)



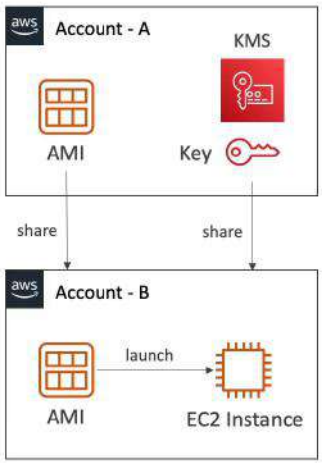
▼ S3 Replication & Encryption



▼ AMI Sharing Process Encrypted via KMS

AMI Sharing Process Encrypted via KMS

1. AMI in Source Account is encrypted with KMS Key from Source Account
2. Must modify the image attribute to add a **Launch Permission** which corresponds to the specified target AWS account
3. Must share the KMS Keys used to encrypted the snapshot the AMI references with the target account / IAM Role
4. The IAM Role/User in the target account must have the permissions to DescribeKey, ReEncrypted, CreateGrant, Decrypt
5. When launching an EC2 instance from the AMI, optionally the target account can specify a new KMS key in its own account to re-encrypt the volumes

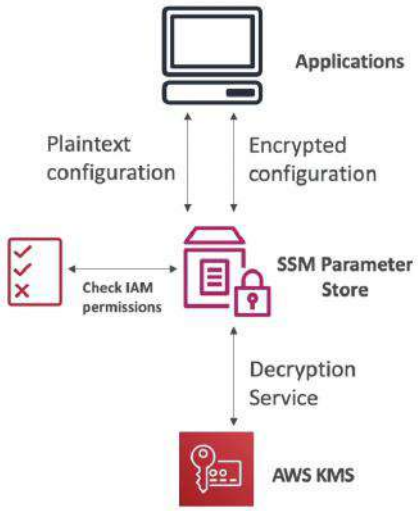


▼ SSM Parameter Store

▼ Intro

SSM Parameters Store can be used to store parameters and has built-in version tracking capability. Each time you edit the value of a parameter, SSM Parameter Store creates a new version of the parameter and retains the previous versions. You can view the details, including the values, of all versions in a parameter's history.

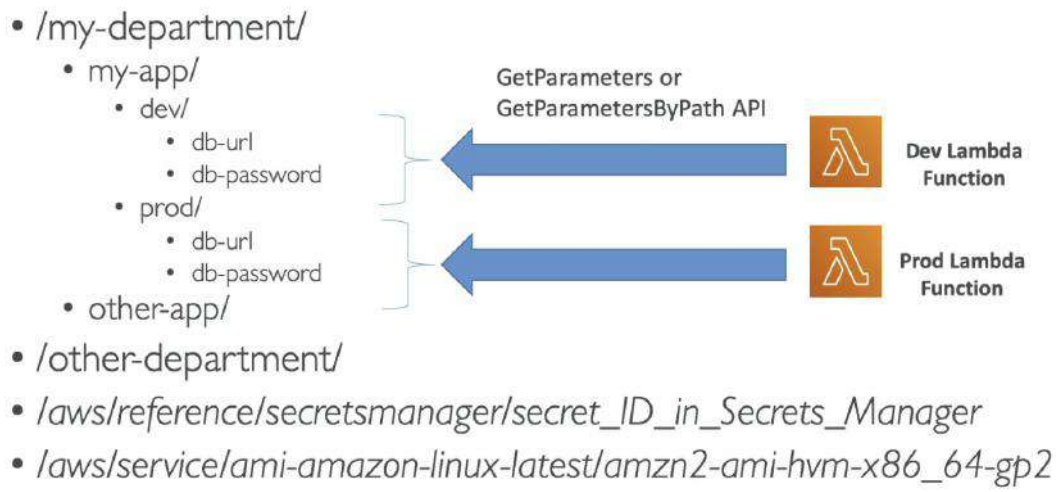
- Secure storage for configuration and secrets for our application
- Optional Seamless Encryption using KMS for encryption and decryption of stored secrets
- Serverless, scalable, durable, easy SDK
- Version tracking of configurations / secrets
- Configuration management using path & IAM
- Notifications with CloudWatch Events
- Integration with CloudFormation



▼ Hierarchy

- Parameters are stored in hierarchical fashion.
- Can be used to reference secrets from secrets manager

- Can directly access parameters from AWS (ex. to get AMI ID for the latest Amazon Linux 2 AMI)



▼ Standard & Advanced tiers

	Standard	Advanced
Total number of parameters allowed (per AWS account and Region)	10,000	100,000
Maximum size of a parameter value	4 KB	8 KB
Parameter policies available	No	Yes
Cost	No additional charge	Charges apply
Storage Pricing	Free	$0.05 per advanced parameter per month
API Interaction Pricing (higher throughput = up to 1000 Transactions per second)	Standard Throughput: free Higher Throughput: $0.05 per 10,000 API interactions	Standard Throughput: $0.05 per 10,000 API interactions Higher Throughput: $0.05 per 10,000 API interactions

▼ Parameter Policies (advanced parameters)

- Allow to assign a TTL to a parameter (expiration date) to force updating or deleting sensitive data such as passwords
- Can assign multiple policies at a time

Expiration (to delete a parameter)

```
{
    "Type":"Expiration",
    "Version":"1.0",
    "Attributes":{
        "Timestamp":"2020-12-02T21:34:33.000Z"
    }
}
```

ExpirationNotification (CW Events)

```
{
    "Type":"ExpirationNotification",
    "Version":"1.0",
    "Attributes":{
        "Before":"15",
        "Unit":"Days"
    }
}
```

NoChangeNotification (CW Events)

```
{
    "Type":"NoChangeNotification",
    "Version":"1.0",
    "Attributes":{
        "After":"20",
        "Unit":"Days"
    }
}
```

▼ Hands on

- Get Parameters (CLI)

```
aws ssm get-parameters --names /my-app/dev/db-url /my-app/dev/db-password --with-decryption
aws ssm get-parameters-by-path --path /my-app/ --recursive --with-decryption
```

▼ Secrets Manager

▼ Web Application Firewall (WAF)

▼ Intro

- Protects your web applications from common web exploits (Layer 7 - HTTP)
- Layer 7 has more data about the structure of the incoming request than layer 4 - TCP, UDP
- Can only be deployed on
  - Application Load Balancer
  - API Gateway
  - CloudFront
- Define Web ACL (Web Access Control List)
  - Rules can include:
    - IP addresses
    - HTTP headers
    - HTTP body
    - URI strings
    - Size constraints (ex. max 5kb)
    - Geo-match (block countries)
    - Rate-based rules (to count occurrences of events per IP) for DDoS protection
  - Protects from common attack SQL injection and Cross-Site Scripting (XSS)

WAF vs. Firewall Manager vs. Shield


AWS WAF


AWS Firewall Manager

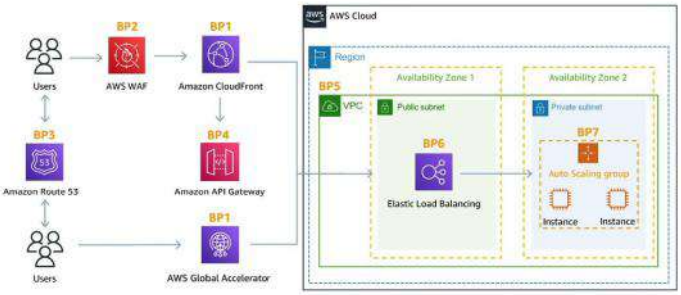

AWS Shield

- WAF, Shield and Firewall Manager are used together for comprehensive protection
- Define your Web ACL rules in WAF
- For granular protection of your resources, WAF alone is the correct choice
- If you want to use AWS WAF across accounts, accelerate WAF configuration, automate the protection of new resources, use Firewall Manager with AWS WAF
- Shield Advanced adds additional features on top of AWS WAF, such as dedicated support from the Shield Response Team (SRT) and advanced reporting.
- If you're prone to frequent DDoS attacks, consider purchasing Shield Advanced

▼ DDoS Protection Best Practices

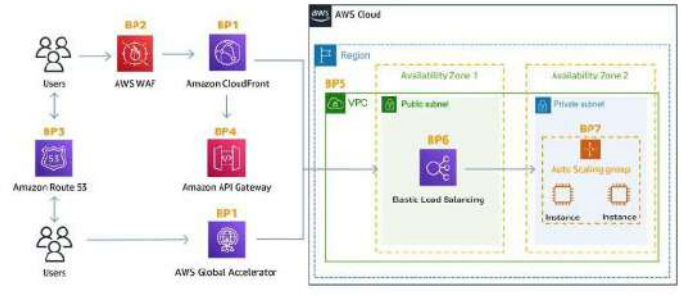
AWS Best Practices for DDoS Resiliency Edge Location Mitigation (BP1, BP3)

- BP1 – CloudFront
  - Web Application delivery at the edge
  - Protect from DDoS Common Attacks (SYN floods, UDP reflection…)
- BP1 – Global Accelerator
  - Access your application from the edge
  - Integration with Shield for DDoS protection
  - Helpful if your backend is not compatible with CloudFront
- BP3 – Route 53
  - Domain Name Resolution at the edge
  - DDoS Protection mechanism



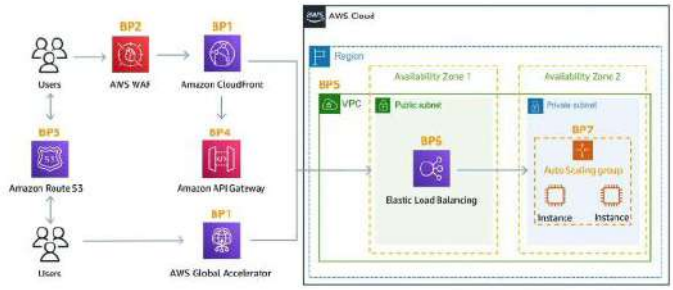
AWS Best Practices for DDoS Resiliency Best pratices for DDoS mitigation

- Infrastructure layer defense (BP1, BP3, BP6)
  - Protect Amazon EC2 against high traffic
  - That includes using Global Accelerator, Route 53, CloudFront, Elastic Load Balancing
- Amazon EC2 with Auto Scaling (BP7)
  - Helps scale in case of sudden traffic surges including a flash crowd or a DDoS attack
- Elastic Load Balancing (BP6)
  - Elastic Load Balancing scales with the traffic increases and will distribute the traffic to many EC2 instances



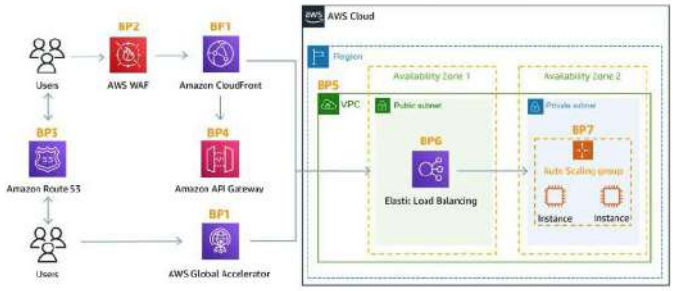
AWS Best Practices for DDoS Resiliency
Application Layer Defense

- Detect and filter malicious web requests (BP1, BP2)
  - CloudFront cache static content and serve it from edge locations, protecting your backend
  - AWS WAF is used on top of CloudFront and Application Load Balancer to filter and block requests based on request signatures
  - WAF rate-based rules can automatically block the IPs of bad actors
  - Use managed rules on WAF to block attacks based on IP reputation, or block anonymous Ips
  - CloudFront can block specific geographies
- Shield Advanced (BP1, BP2, BP6)
  - Shield Advanced automatic application layer DDoS mitigation automatically creates, evaluates and deploys AWS WAF rules to mitigate layer 7 attacks



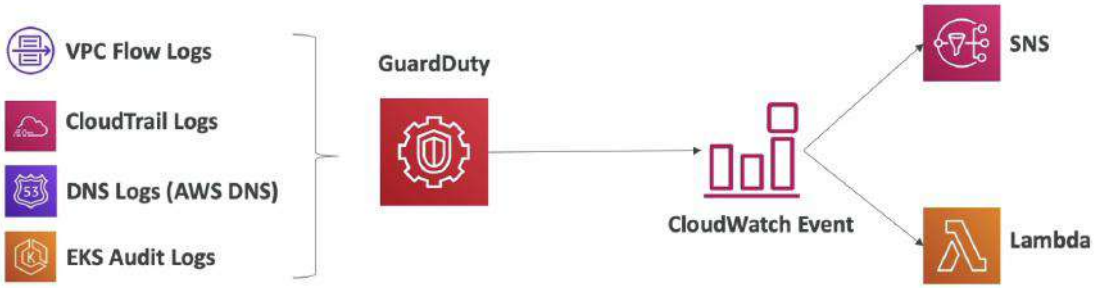
AWS Best Practices for DDoS Resiliency
Attack surface reduction

- Obfuscating AWS resources (BP1, BP4, BP6)
  - Using CloudFront, API Gateway, Elastic Load Balancing to hide your backend resources (Lambda functions, EC2 instances)
- Security groups and Network ACLs (BP5)
  - Use security groups and NACLs to filter traffic based on specific IP at the subnet or ENI-level
  - Elastic IP are protected by AWS Shield Advanced
- Protecting API endpoints (BP4)
  - Hide EC2, Lambda, elsewhere
  - Edge-optimized mode, or CloudFront + regional mode (more control for DDoS)
  - WAF + API Gateway: burst limits, headers filtering, use API keys



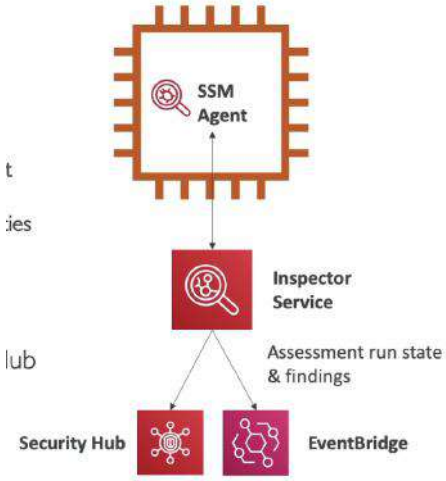
▼ Amazon GuardDuty

- Intelligent threat discovery to protect AWS account
- Uses Machine Learning algorithms, anomaly detection, 3rd party data
- One click to enable (30 days trial), no need to install software
- Automatically monitors:
  - Cloud Trail Events Logs unusual API calls, unauthorized deployments
    - CloudTrail Management Events - create VPC subnet, create trail,
    - CloudTrail S3 Data Events - get object, list objects, delete object, …
  - VPC Flow Logs - unusual internal traffic, unusual IP address
  - DNS Logs - compromised EC2 instances sending encoded data within DNS queries
  - Kubernetes Audit Logs - suspicious activities and potential EKS cluster compromises
- Can setup CloudWatch Event rules to be notified in case of findings
- CloudWatch Events rules can target AWS Lambda or SNS for automation
- Can protect against CryptoCurrency attacks (has a dedicated “finding” for it)



▼ Amazon Inspector

- Automated Security Assessments for
  - EC2 instances
    - Leveraging the AWS System Manager (SSM) agent running on EC2 instances for continuous assessment of EC2 instances
    - Analyze against unintended network accessibility
    - Analyze the running OS against known vulnerabilities
  - Containers push to Amazon ECR - Elastic Container Registry
    - Assessment of containers as they are pushed
- Reporting & integration with AWS Security Hub
- Send findings to Amazon Event Bridge
- It will give a risk score associated with all vulnerabilities for prioritization



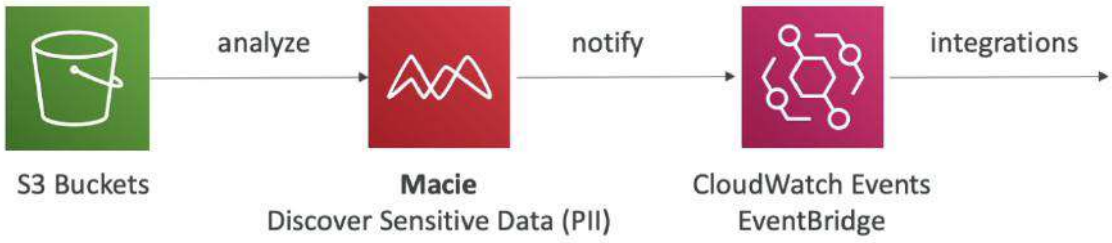
What does AWS Inspector evaluate?

- Remember: only for EC2 instances and container infrastructure
- Continuous scanning of the infrastructure, only when needed
- Package vulnerabilities (EC2 & ECR) – database of CVE
- Network reachability (EC2)
- A risk score is associated with all vulnerabilities for prioritization

▼ Amazon Macie

Amazon Macie is a fully managed data security service that uses Machine Learning to discover and protect your sensitive data stored in S3 buckets. It automatically provides an inventory of S3 buckets including a list of unencrypted buckets, publicly accessible buckets, and buckets shared with other AWS accounts. It allows you to identify and alert you to sensitive data, such as Personally Identifiable Information (PII).

- Amazon Macie is a fully managed data security and data privacy service that uses machine learning and pattern matching to discover and protect your sensitive data in AWS.
- Macie helps identify and alert you to sensitive data, such as personally identifiable information (PII) in an S3 bucket.
- One click to enable
- Notifies through an EB event



▼ CloudHSM

▼ Intro

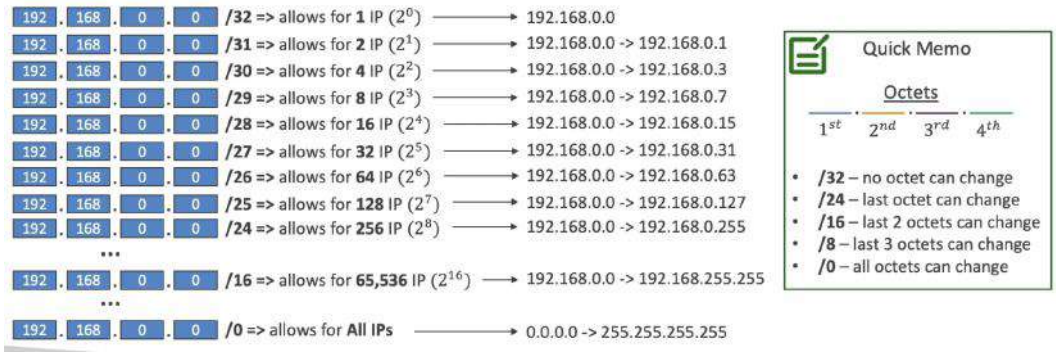
- AWS provisions encryption hardware (Hardware Security Module)
- You manage your own encryption keys entirely (not AWS)
- HSM device is stored in AWS (tamper resistant, FIPS 140-2 Level 3 compliance)
- Supports both symmetric and asymmetric encryption (SSL/TLS keys)
- No free tier available
- CloudHSM clusters are spread across Multi AZ (HA)
- Redshift supports CloudHSM for database encryption and key manasgement
- Good option to use with SSE-C encryption
- IAM permissions are required to perform CRUD operations on HSM cluster

        - Audit the underlying instance and disks & guarantee it functions
    - Your responsibility:
        - Check the ports / IP / security group inbound rules in DB's SG
        - In-database user creation and permissions
        - Creating a database with or without public access
        - Ensure parameter groups or DB is configured to only allow SSL connections
        - Database encryption setting
- S3 - example
    - AWS responsibility:
        - Guarantee you get unlimited storage
        - Guarantee you get encryption if you enable it
        - Ensure separation of the data between different customers
        - Ensure AWS employees can't access your data
    - Your responsibility:
        - Bucket configuration
        - Bucket policy / public setting
        - IAM user and roles
        - Enabling encryption

▼ Section 28: Networking - VPC

▼ Classless Inter-Domain Routing (CIDR)

- It is a method for allocating IP addresses
- CIDR consists of 2 components
    - Base IP
    - Subnet Mask
        - Defines how many bits are frozen from the left side
        - Can be represented in two ways
            - /8 = 255.0.0.0
            - /16 = 255.255.0.0
            - /24 = 255.255.255.0
            - /32 = 255.255.255.255



- 0.0.0.0/0 ⇒ all IP space

- The Internet Assigned Numbers Authority (IANA) established certain blocks of IPv4 addresses for the use of private (LAN) and public (Internet) addresses
- Private IP can only allow certain values:
  - 10.0.0.0 - 10.255.255.255 (10.0.0.0/8) ⇒ used in big networks (24 bits can change)
  - 172.16.0.0 - 172.31.255.255 (172.16.0.0/12) ⇒ AWS default VPC
  - 192.168.0.0 - 192.168.255.255 (192.168.0.0/16) ⇒ home networks
- All the rest of the IP addresses on the Internet are Public
- https://www.ipaddressguide.com/

▼ VPC (Virtual Private Cloud)

▼ Theory

- You can have multiple VPCs in an AWS region (max. 5 per region - soft limit, can be increased)
- Max. CIDR per VPC is 5
- For each CIDR:
  - Min. size is /28 (16 IP addresses)
  - Max. size is /16 (65536 IP addresses)
- Because VPC is private, only the Private IPv4 ranges are allowed
- When we create a VPC, we need to specify an IPv4 CIDR. Once created, a default route table and network ACL will be attached to the subnets of this VPC.
- A VPC consists of subnets (sub-range of IP addresses) where each subnet is bound to a specific AZ
- All new AWS accounts have a default VPC
- New EC2 instances are launched into the default VPC if no subnet is specified
- Default VPC has Internet connectivity and all EC2 instances inside it have public IPv4 addresses and public and a private IPv4 DNS names

▼ Hands on

- Create a VPC

  VPC → Create

  CIDR: 10.0.0.0/16 (max size)

  We can edit the CIDR and add up to 5 CIDRs in the VPC.

▼ Subnets

▼ Theory

- A sub range of IPv4 addresses within your VPC
- Each subnet is bound to a specific AZ
- Subnets in a VPC cannot have overlapping CIDRs
- AWS reserves 5 IP addresses (first 4 & last 1) in each subnet. These 5 IP addresses are not available for use. Example: if CIDR block 10.0.0.0/24, then reserved IP addresses are:
  - 10.0.0.0 ⇒ Network Address

- 10.0.0.1 ⇒ Reserved by AWS for the VPC router
- 10.0.0.2 ⇒ Reserved by AWS for mapping to Amazon-provided DNS
- 10.0.0.3 ⇒ Reserved by AWS for future use
- 10.0.0.255 ⇒ Network Broadcast Address. AWS does not support broadcast in a VPC, therefore the address is reserved

- Exam Tip: If you need 29 IP addresses for EC2 instances: You can't choose a subnet of size /27 (32 IP addresses, 32 - 5 = 27 < 29) You need to choose a subnet of size /26 (64 IP addresses, 64 - 5 = 59 > 29)

▼ Hands on

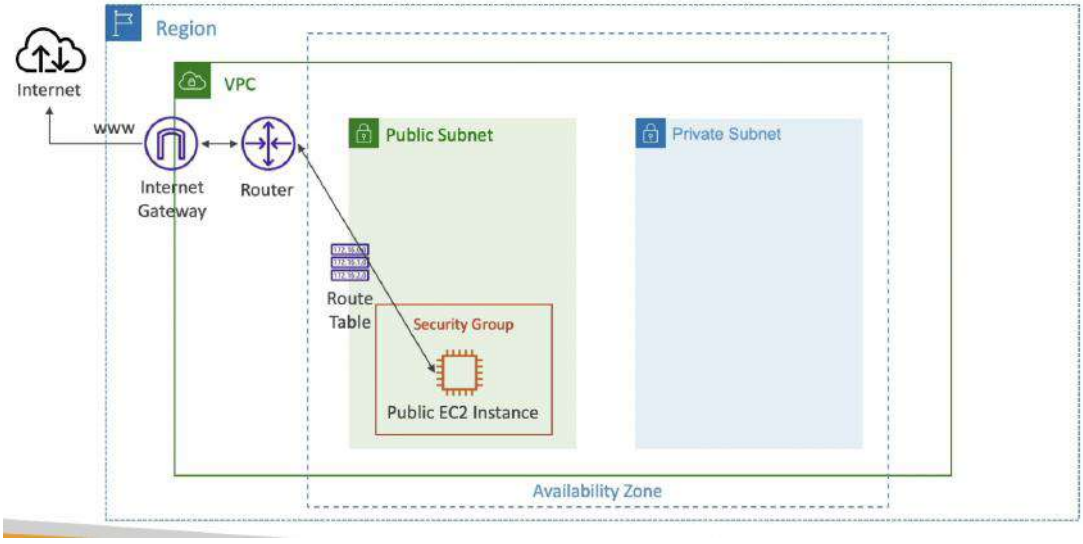
Inside the custom VPC, create 4 subnets

Name	Subnet ID	State	VPC	IPv4 CIDR
PrivateSubnetA	subnet-0311bc3bf6e2a09b0	Available	vpc-02952b588e6c3092a | ark...	10.0.16.0/20
PublicSubnetB	subnet-04ac2867bf8f2a8db	Available	vpc-02952b588e6c3092a | ark...	10.0.1.0/24
PrivateSubnetB	subnet-0b7235a34770aecd3	Available	vpc-02952b588e6c3092a | ark...	10.0.32.0/20
PublicSubnetA	subnet-085c70d12a0042d46	Available	vpc-02952b588e6c3092a | ark...	10.0.0.0/24

▼ Internet Gateway (IGW)

▼ Theory

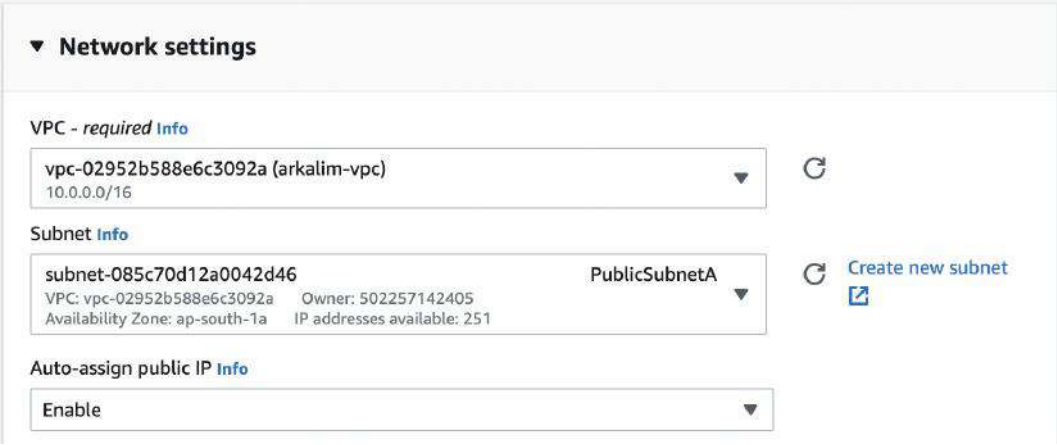
- Allows resources in a VPC connect to the Internet
- Should be used to connect public resources to the internet (use NAT gateway for private resources)
- It scales horizontally and is highly available and redundant
- Must be created separately from a VPC
- One VPC can only be attached to one IGW and vice versa
- Internet Gateways on their own do not allow Internet access, route table of the public subnets must also be edited to allow requests destined outside the VPC to be routed to the IGW.



▼ Hands on

- Create an EC2 instance in a public subnet

  Now, if we try to connect to this instance, it will not work as the internet gateway is not configured.



Untitled

- Create Internet Gateway & attach it to VPC

  VPC → Internet Gateways → Create

- Create Public and Private route tables and assign them to respective subnets

  Create PublicRouteTable and associate it to PublicSubnetA & PublicSubnetB. Do the same with PrivateRouteTable.

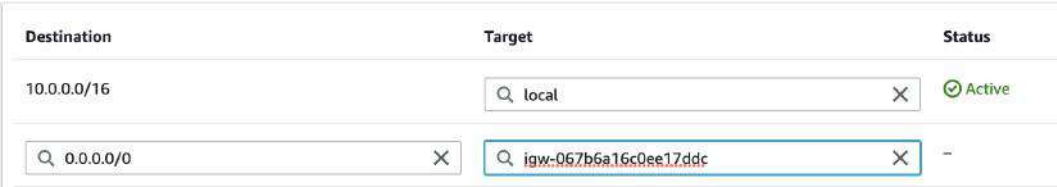
Name	Route table ID	Explicit subnet associat...	Edge associations	Main	VPC
–	rtb-05fa61f520066ab4f	–	–	Yes	vpc-02952b588e6c3092a | ark...
PrivateRouteTable	rtb-093b43cd2641e6e95	–	–	No	vpc-02952b588e6c3092a | ark...
PublicRouteTable	rtb-07494864bf598820d	–	–	No	vpc-02952b588e6c3092a | ark...

Untitled

- Add route to Public Route Table to send traffic to IGW

  The below routes say:

  - If the traffic is destined to VPC, route it locally (to VPC)
  - If the destination IP doesn't match the above criteria, send it to the internet gateway



Untitled

Now, we can connect to our EC2 instance in the public subnets from the public internet

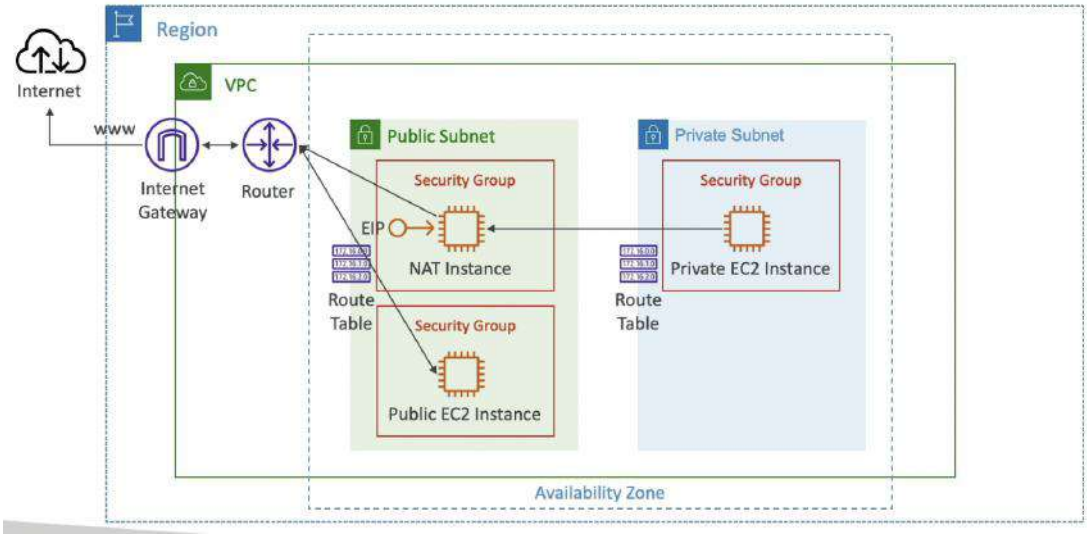
▼ Bastion Hosts

▼ Theory

- It is an EC2 instance running in the public subnet of our VPC to allow users to SSH into the instances in the private subnet.
- Users from the internet SSH into the Bastion Host which will then SSH into the EC2 instance of the private subnet.
- Security groups of the private instances should only allow traffic from the bastion host.
- Exam Tip: Make sure the bastion host only has port 22 traffic from the IP address you need (tightened security).

- Not highly available or resilient out of the box. You need to create an ASG in multi-AZ + resilient user-data script
- Internet traffic bandwidth depends on EC2 instance type
- You must manage Security Groups & rules:
  - Inbound:
    - Allow HTTP / HTTPS traffic coming from Private Subnets
    - Allow SSH from your home network (access is provided through Internet Gateway)
  - Outbound:
    - Allow HTTP / HTTPS traffic to the Internet

▼ Architecture



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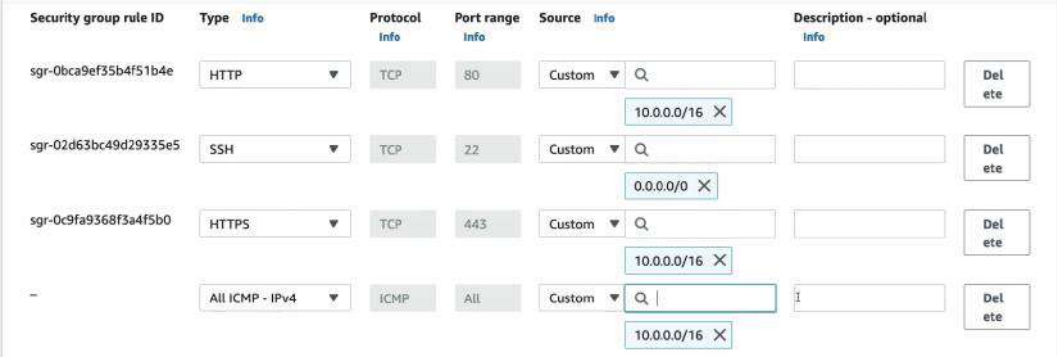
▼ Hands on

- Create a NAT instance using a pre-configured AMI

  Security group rules for NAT instance: allow incoming HTTP, HTTPS and ICMP-IPv4 traffic from our VPC



- Disable source/destination check on the NAT instance
- Edit PrivateRouteTable to send all requests destined to public internet to the NAT instance

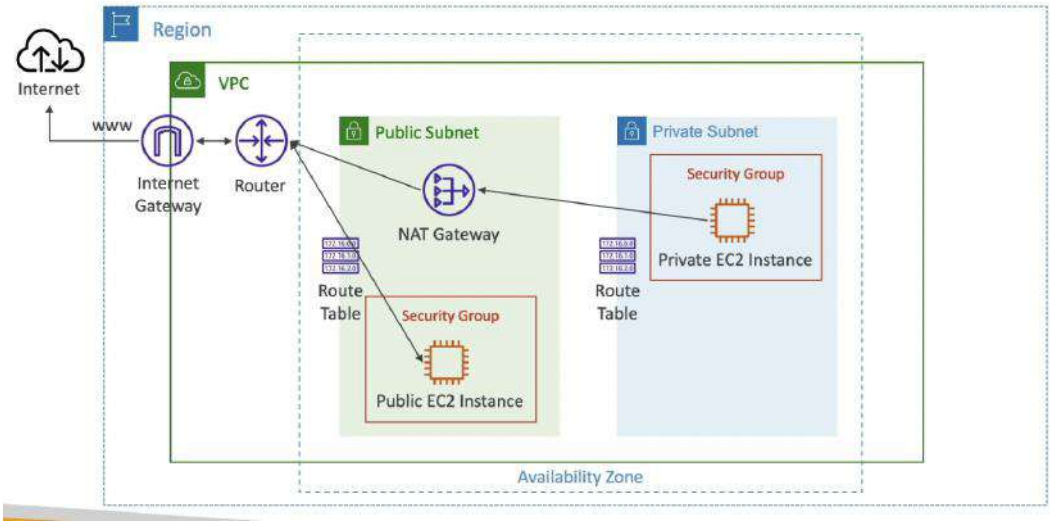
Untitled

Now if we `ping google.com` from the private instance, we will get the result back.

▼ NAT Gateway

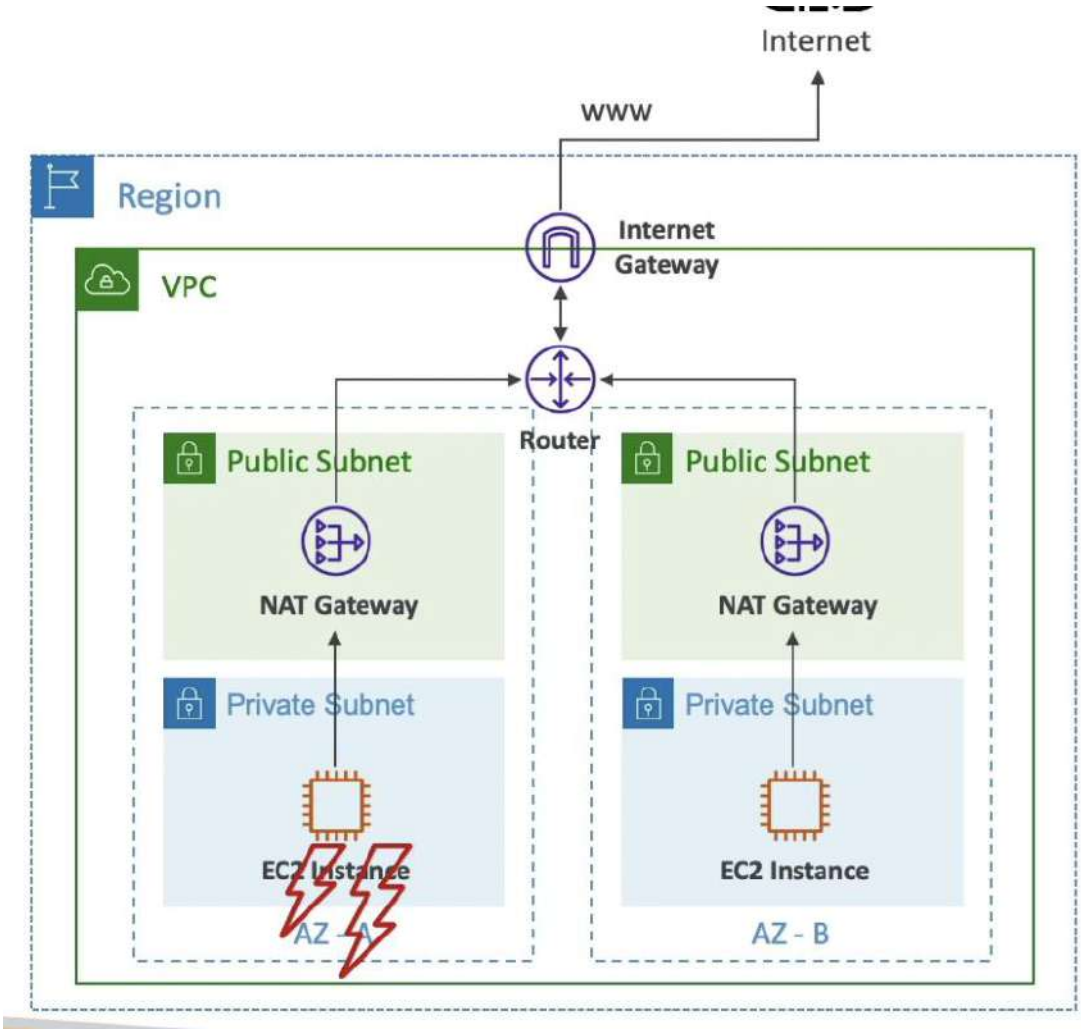
▼ Intro

- Used to allow instances in private subnet to connect to internet but not be accessed over the internet.
- AWS-managed NAT, higher bandwidth, high availability, no administration
- Pay per hour for usage and bandwidth
- NATGW is created in a specific Availability Zone
- Just like NAT instances, NAT gateway uses an Elastic IP
- Can’t be used by EC2 instances in the same subnet (only from other subnets)
- Routing of requests: Private Subnet ⇒ NATGW ⇒ IGW
- 5 Gbps of bandwidth with automatic scaling up to 45 Gbps
- No Security Groups required
- Route table of the private subnets need to be updated to route public requests to NAT gateway



▼ High availability

- NAT Gateway is resilient within a single Availability Zone
- Must create multiple NAT Gateways in multiple AZs for fault-tolerance
- There is no cross-AZ failover needed because if an AZ goes down, all of the instances in that AZ are also down. So, they don’t need NAT.



▼ NAT Gateway vs NAT Instance

	NAT Gateway	NAT Instance
Availability	Highly available within AZ (create in another AZ)	Use a script to manage failover between instances
Bandwidth	Up to 45 Gbps	Depends on EC2 instance type
Maintenance	Managed by AWS	Managed by you (e.g., software, OS patches, ...)
Cost	Per hour & amount of data transferred	Per hour, EC2 instance type and size, + network $
Public IPv4	✓	✓
Private IPv4	✓	✓
Security Groups	✗	✓
Use as Bastion Host?	✗	✓

▼ Hands on

- Create a NAT Gateway

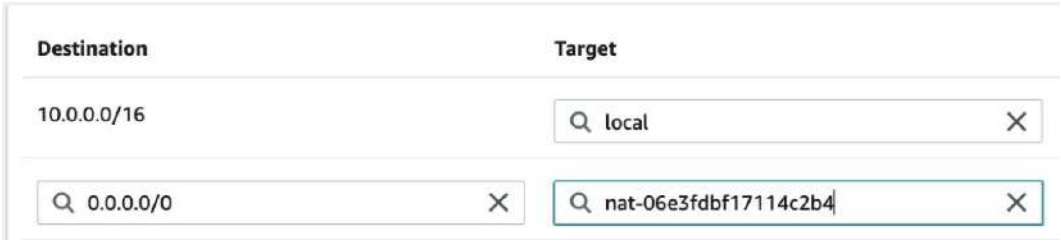
  VPC → NAT Gateways → Create

  Subnet: any public subnet

  Connectivity type: Public

  Need to allocate an elastic IP

- Edit PrivateRouteTable to send public requests to NAT Gateway



Untitled

Now, we can hit public endpoints from the instances in our private subnets.

▼ Network Access Control List (NACL)

▼ Intro

- NACL are like a firewall which control traffic from and to subnets
- One NACL per subnet but a single NACL can be attached to multiple subnets
- New subnets are assigned the Default NACL
- You define NACL Rules:
  - Rules have a number (1-32766), lower number has higher precedence
  - First rule match will drive the decision
  - Example: if you define #100 ALLOW 10.0.0.10/32 and #200 DENY 10.0.0.10/32, the IP address will be allowed because 100 has a higher precedence over 200
  - The last rule is an asterisk (*) and denies a request in case of no rule match
  - AWS recommends adding rules by increment of 100 so that you can add rules in between if needed
- Newly created NACLs will deny everything
- NACL are a great way of blocking a specific IP address at the subnet level

▼ Default NACL

- Allows everything inbound/outbound
- Do NOT modify the Default NACL, instead create custom NACLs
- If this NACL is associated with any subnet, it will allow all traffic in and out of the subnet

Default NACL for a VPC that supports IPv4

Inbound Rules

Rule #	Type	Protocol	Port Range	Source	Allow/Deny
100	All IPv4 Traffic	All	All	0.0.0.0/0	ALLOW
*	All IPv4 Traffic	All	All	0.0.0.0/0	DENY

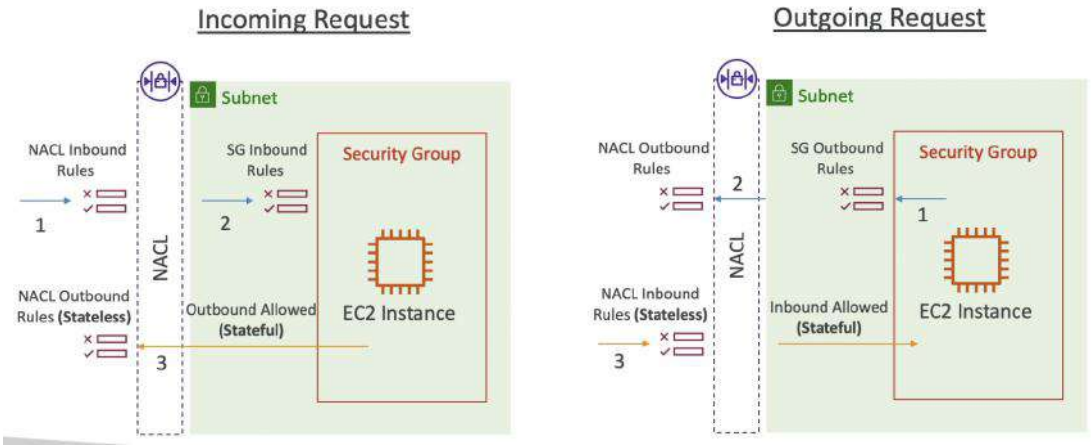
Outbound Rules

Rule #	Type	Protocol	Port Range	Destination	Allow/Deny
100	All IPv4 Traffic	All	All	0.0.0.0/0	ALLOW
*	All IPv4 Traffic	All	All	0.0.0.0/0	DENY

▼ NACL & Security Groups

- NACL evaluates the incoming and outgoing requests at the subnet level.
- NACL is stateless whereas Security Groups are stateful

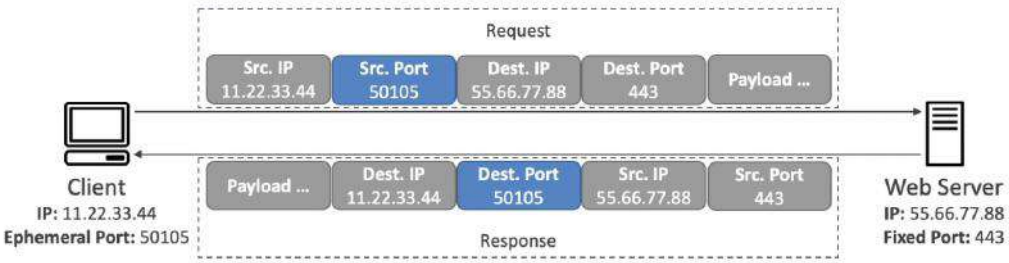
- Incoming requests: Evaluated by NACL before entering the subnet → Evaluated by SG → Response passes through the SG without check (stateful) → Response evaluated at NACL (stateless)
- The above point can be verified by running a HTTP server on a public instance in the VPC and blocking outbound traffic on the security group. The response will still travel out from the security group (stateful). On the other hand, adding a higher precedence rule in the NACL to block the outbound traffic will not allow the response from the server to reach back to client.



▼ NACL with Ephemeral Ports

▼ Ephemeral Ports

When a client sends an HTTP request to a server, it does so on a fixed IP and port of the server. In the request, the client also sends a temporary port for the server to respond back. The server when sending the response uses this port which is only lived for the duration of this HTTP connection.

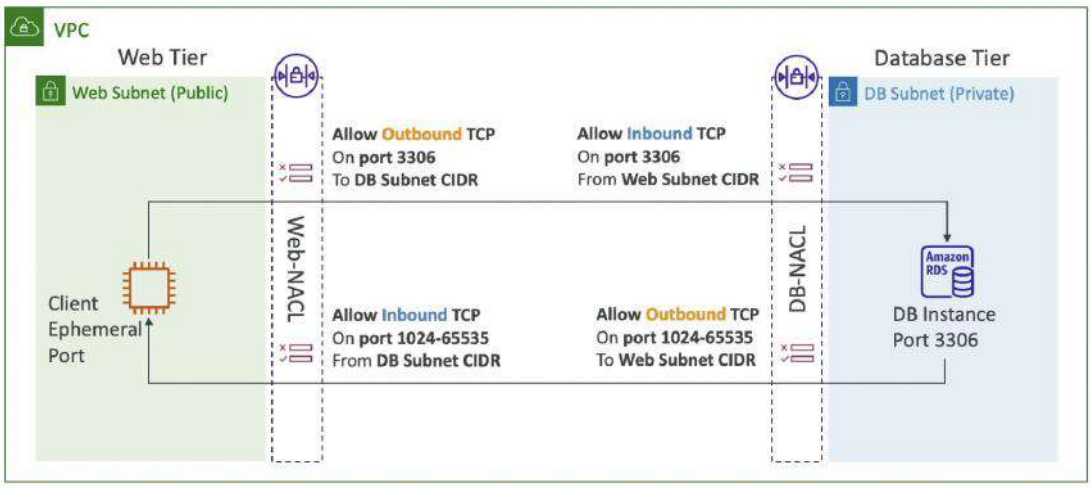


Ephemeral Ports

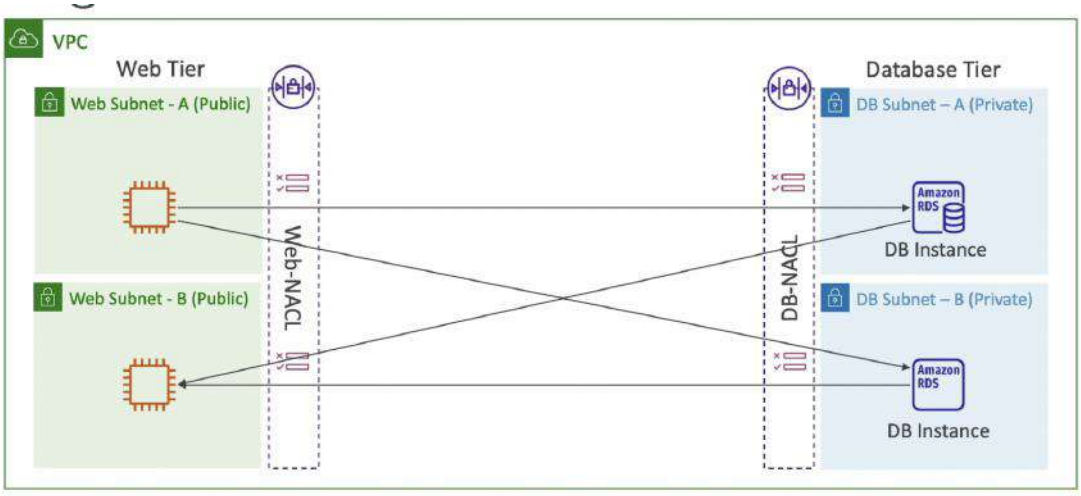
- For any two endpoints to establish a connection, they must use ports
- Clients connect to a **defined port**, and expect a response on an **ephemeral port**
- Different Operating Systems use different port ranges, examples:
  - IANA & MS Windows 10 ➔ 49152 – 65535
  - Many Linux Kernels ➔ 32768 – 60999

In the example below, the client EC2 instance needs to connect to DB instance.

Since the ephemeral port can be randomly assigned from a range of ports, the Web Subnets's NACL must allow inbound traffic from that range of ports and similarly DB Subnet's NACL must allow outbound traffic on the same range of ports.



Multiple subnets ⇒ configure NACL for cross subnet connections too.



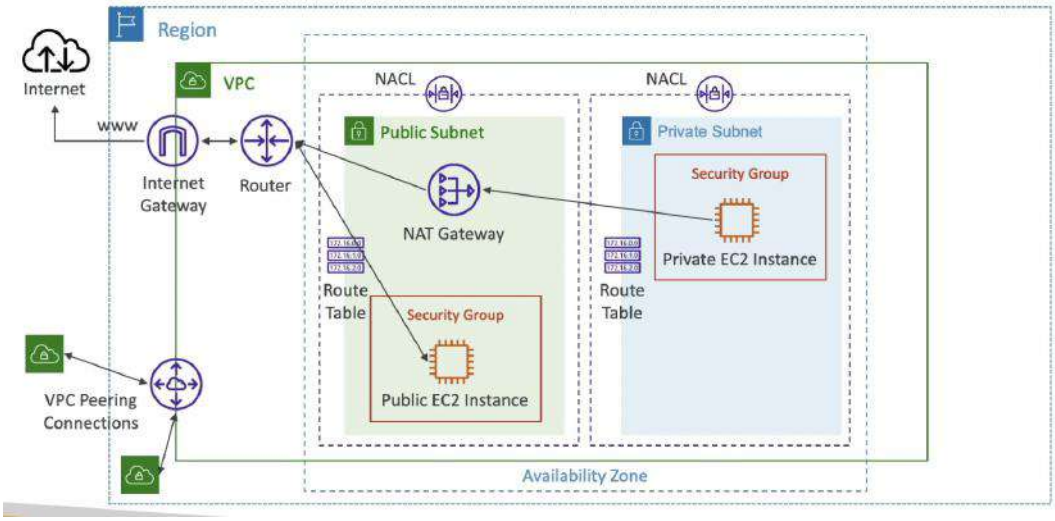
▼ NACL vs Security Groups

Security Group	NACL
Operates at the instance level	Operates at the subnet level
Supports allow rules only	Supports allow rules and deny rules
Stateful: return traffic is automatically allowed, regardless of any rules	**Stateless:** return traffic must be explicitly allowed by rules (think of ephemeral ports)
All rules are evaluated before deciding whether to allow traffic	Rules are evaluated in order (lowest to highest) when deciding whether to allow traffic, first match wins
Applies to an EC2 instance when specified by someone	Automatically applies to all EC2 instances in the subnet that it's associated with

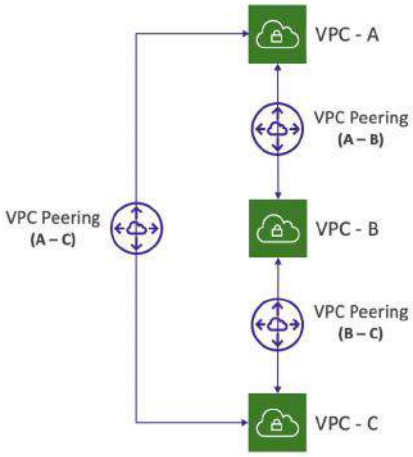
▼ VPC Peering

▼ Theory

- Privately connect two VPCs (could be in different region or account) using AWS' network to make them behave as if they were in the same network



- Participating VPCs must not have overlapping CIDRs
- VPC Peering connection is NOT transitive (A - B, B - C ≠> A - C)



- You must update route tables in each VPC's subnets to ensure EC2 instances across VPCs can communicate with each other
- You can reference a security group in a peered VPC across account or region. This allows us to use SGs instead of CIDRs when configuring rules.

Type	Protocol	Port range	Source
HTTP	TCP	80	sg-04991f9af3473b939 / default
HTTP	TCP	80	[redacted] / sg-027ad1f7865d4be76

Account ID

▼ Hands on

- Launch an EC2 instance in the Default VPC

- Launch an EC2 instance in the public subnet of custom VPC with a simple HTTP server
- Create a peering connection between the default VPC and custom VPC

  VPC → Peering Connection → Create

  Accept the peering request
- Configure the PublicRouteTable for custom VPC

  Route the traffic destined to Default VPC through the peering connection.

Destination	Target	Status
172.31.0.0/16	pcx-05678f8a1b857f1a0	Active
10.0.0.0/16	local	Active
0.0.0.0/0	igw-067b6a16c0ee17ddc	Active

  Untitled
- Configure the DefaultRouteTable for default VPC

  Route the traffic destined to Custom VPC through the peering connection.

Destination	Target	Status
172.31.0.0/16	local	Active
10.0.0.0/16	pcx-05678f8a1b857f1a0	Active
0.0.0.0/0	igw-0415625903e109727	Active

  Untitled

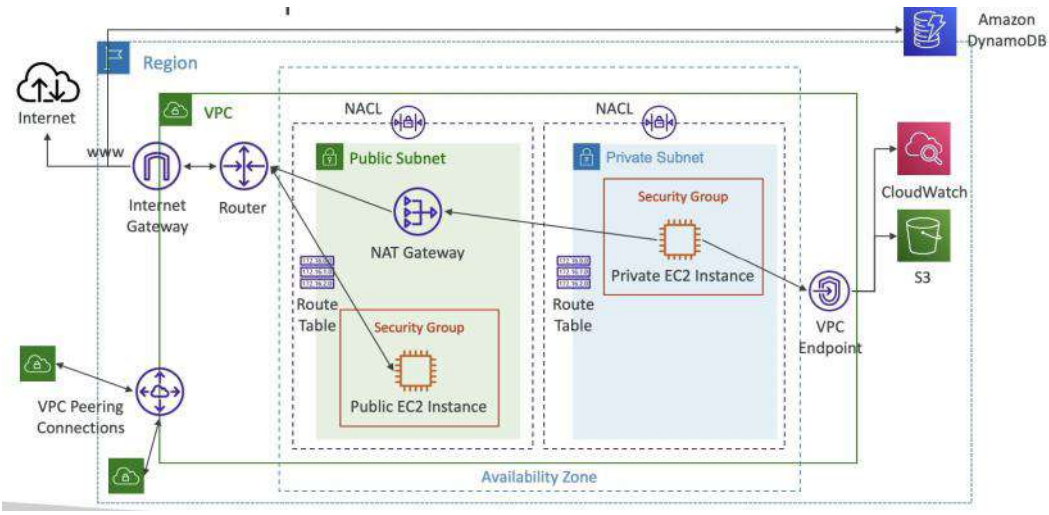
Now the two VPCs will behave as one but with different CIDRs.

To test, run `curl private_ip_of_the_instance_in_custom_vpc`

▼ VPC Endpoints (AWS PrivateLink)

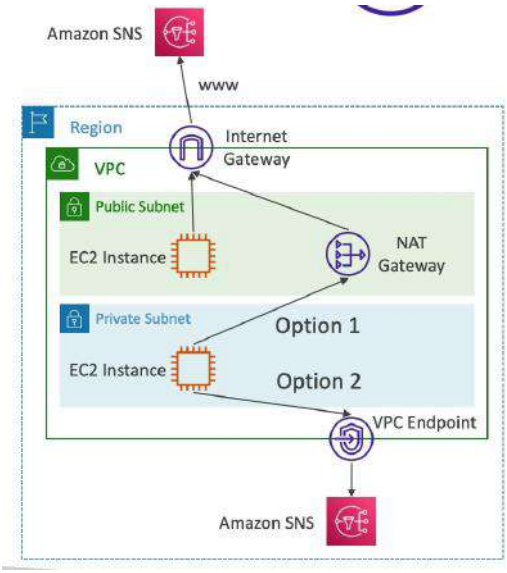
▼ Intro

- These are private endpoints within your VPC that allow AWS services to privately connect to resources within the VPC without traversing the public internet.
- In the diagram below, DynamoDB is connected through the public internet (more cost due to the request being routed through NATGW & IGW) but CloudWatch and S3 are connected within the AWS network.



- They’re redundant and scale horizontally

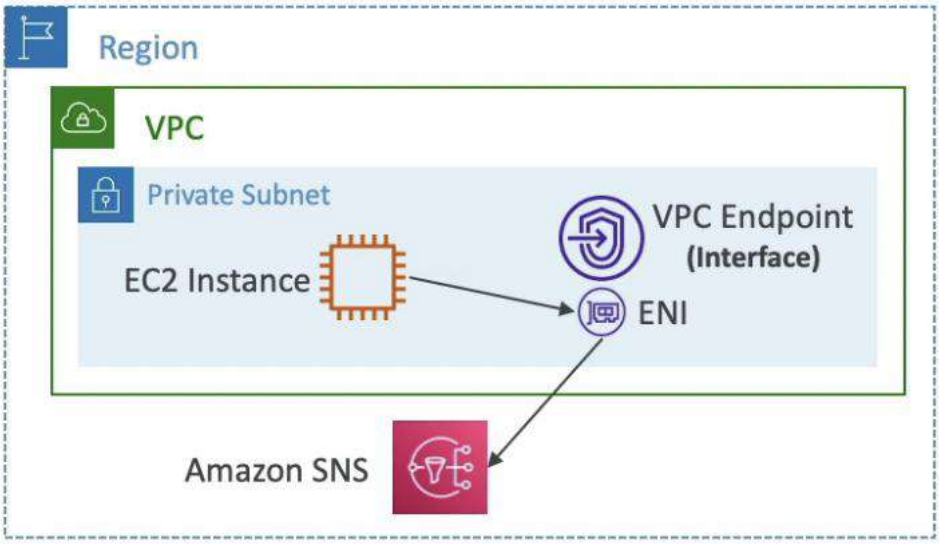
- They remove the need of IGW, NATGW, etc. to access AWS Services
- In case of issues:
  - Check DNS Setting Resolution in your VPC
  - Check Route Tables



▼ Types of VPC Endpoints

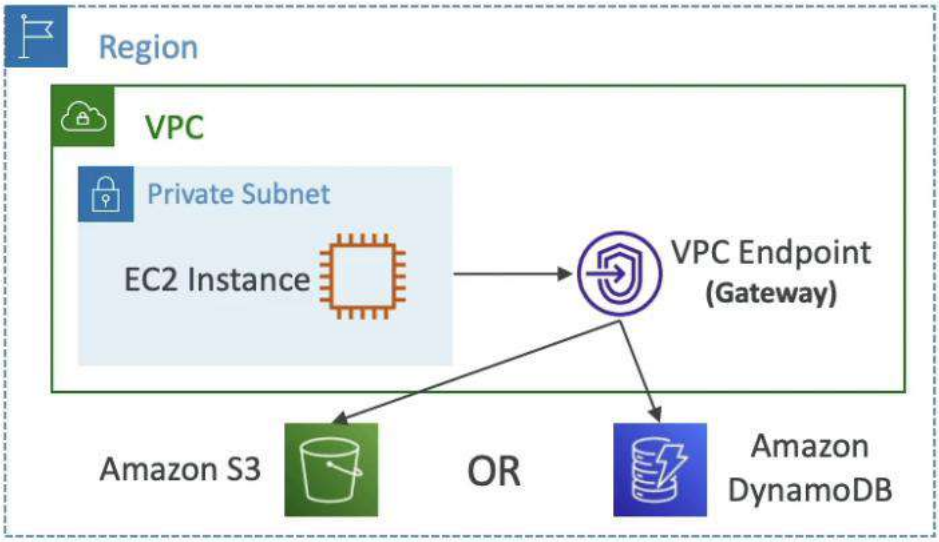
▼ Interface Endpoints

- Provisions an ENI (private IP address) as an entry point per subnet
- Need to attach a security group to the VPC endpoint to control access to the VPC endpoint
- Supports most AWS services
- $ per hour + $ per GB of data processed



▼ Gateway Endpoints

- Provisions a gateway and must be used as a target in a route table
- Supports only S3 and DynamoDB
- free



▼ Hands on

- Access S3 bucket through the public internet
  - Attach an IAM role policy to allow the private instance to access S3 buckets within the account
    - Select instance → Actions → Instance settings → Modify IAM Role
  - SSH into Bastion Host → SSH into private instance → `aws s3 ls` this command will work
- Remove internet access to Private Subnet

  Edit the route table of private subnet → Remove the route which redirects public destined packets to NAT gateway for internet access

  Now, `aws s3 ls` command will not work as it routes through the public internet
- Create a VPC endpoint to allow access to S3

  VPC → Endpoints → Create

  VPC: Custom VPC

  Route Table: PrivateRouteTable

  Now, a new managed route will be added to the private route table to route S3 requests internally through the private network.

Destination	Target	Status
10.0.0.0/16	local	Active
pl-78a54011	vpce-08083ca1d7c701efa	Active

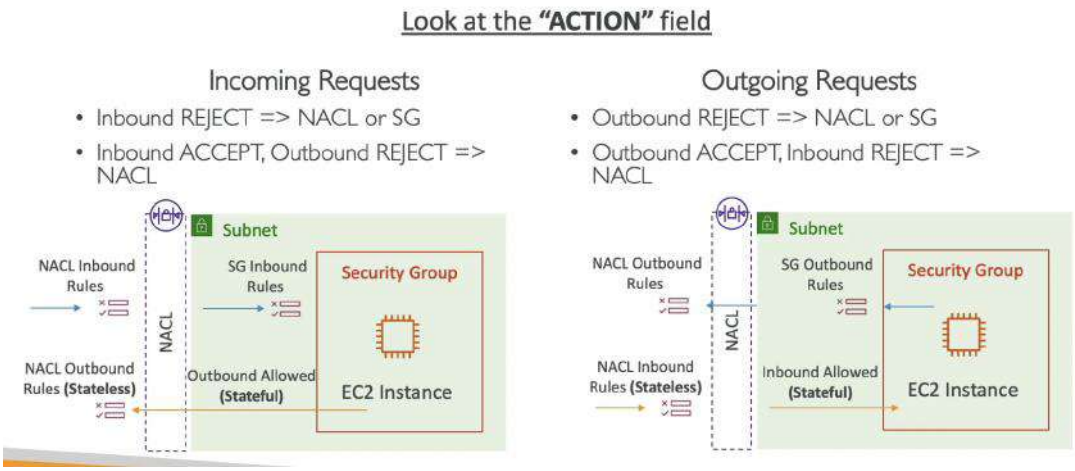
  Untitled

  Now, we can run `aws s3 ls --region ap-south-1` with the region as in AWS CLI, the default region is us-east-1

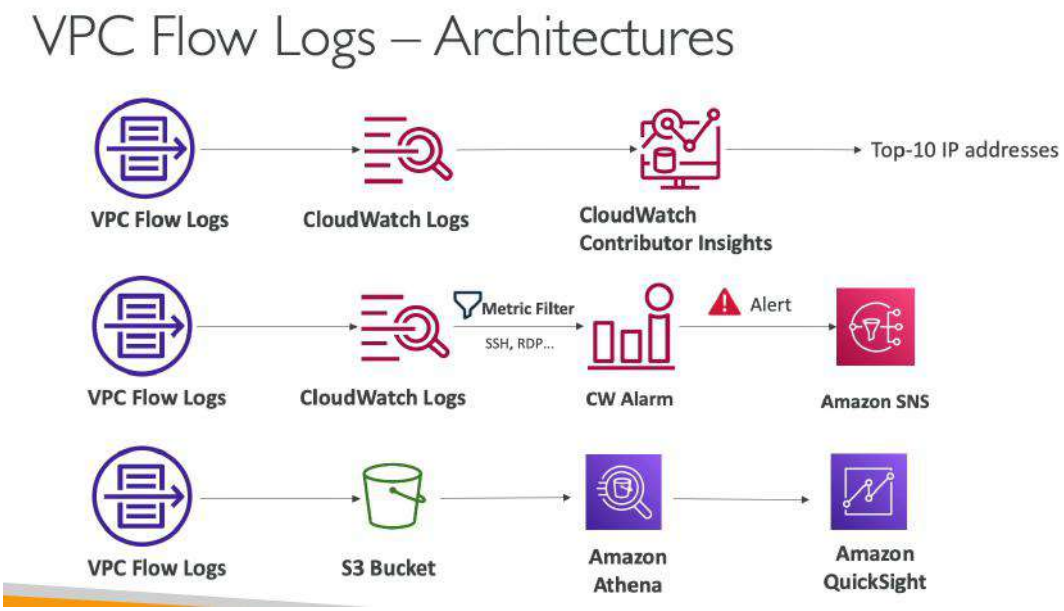
▼ VPC Flow Logs

▼ Theory

- Capture information about IP traffic going into your interfaces
- Flow Logs can be at three levels:
  - VPC Flow Logs
  - Subnet Flow Logs
  - Elastic Network Interface (ENI) Flow Logs



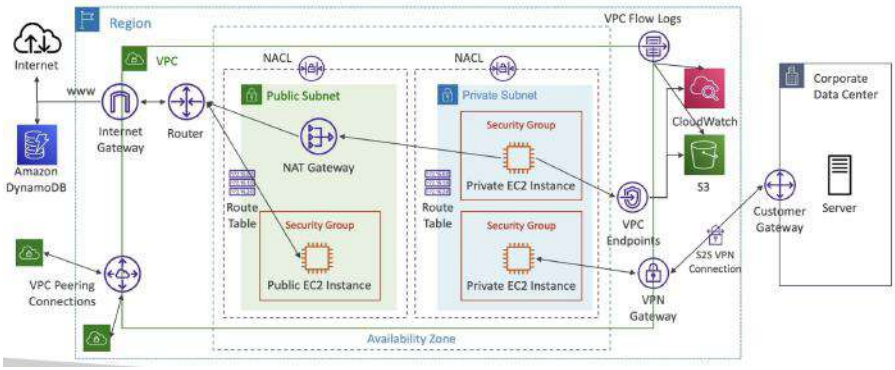
▼ VPC Flow Logs - Architectures



▼ Site-to-Site VPN

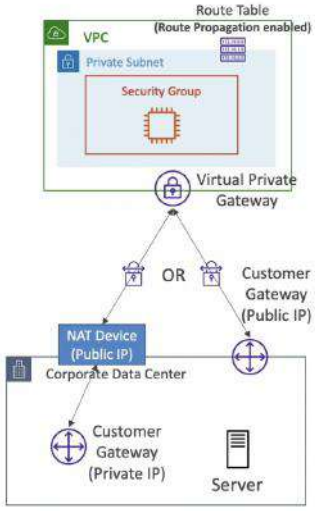
▼ Intro

- Used to connect our VPC to the network of a corporate data center.
- Customer gateway on the corporate data center and VPN gateway on the VPC are connected via a VPN connection (encrypted) that goes through the public internet.
- Virtual Private Gateway (VGW)
  - VPN concentrator on the AWS side of the VPN connection
  - VGW is created and attached to the VPC from which you want to create the Site-to-Site VPN connection
  - Possibility to customize the ASN (Autonomous System Number)
- Customer Gateway (CGW)
  - Software application or physical device on customer side of the VPN connection



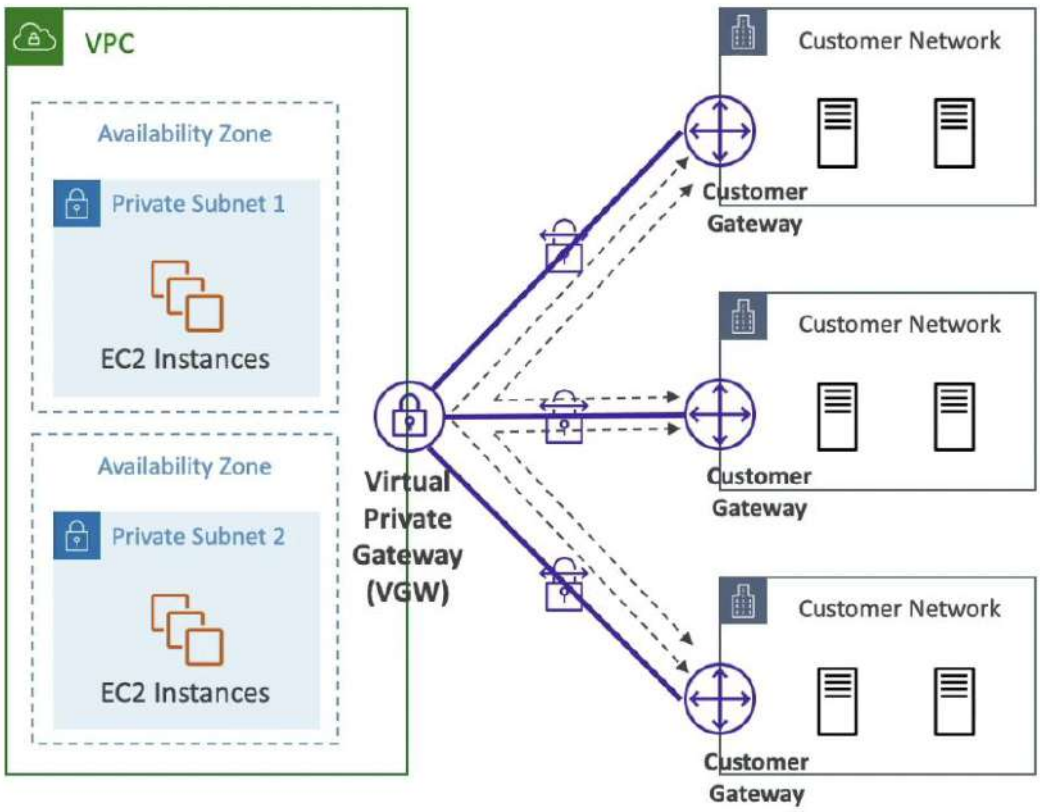
▼ Connection

- If the customer gateway device has a public internet-routable IP address, VPN will connect to it.
- If the customer gateway device is behind a NAT device that's enabled for NAT traversal (NAT-T), use the public IP address of the NAT device to connect with VPN.
- **Important step: enable Route Propagation for the Virtual Private Gateway in the route table that is associated with your subnets**
- If you need to ping your EC2 instances from on-premises, make sure you add the ICMP protocol on the inbound rules of your security groups



▼ VPN CloudHub

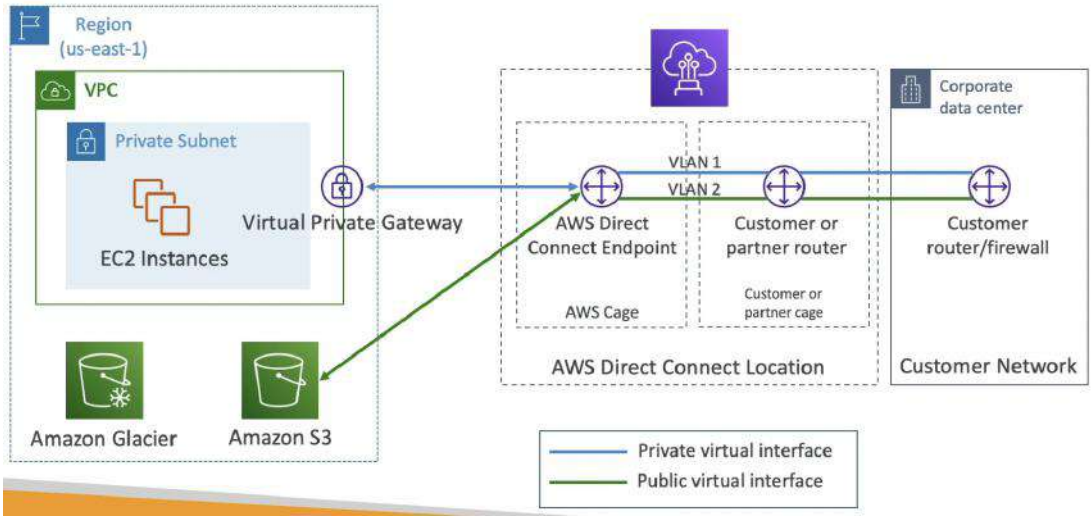
- Provide secure communication between multiple sites, if you have multiple VPN connections
- Low-cost hub-and-spoke model for primary or secondary network connectivity between different locations (VPN only)
- It's a VPN connection so it goes over the public Internet but the connection is encrypted in flight
- Every participating network can communicate with one another through the VPN connection
- To set it up, connect multiple VPN connections on the same VGW, setup dynamic routing and configure route tables



▼ Direct Connect (DX)

▼ Intro

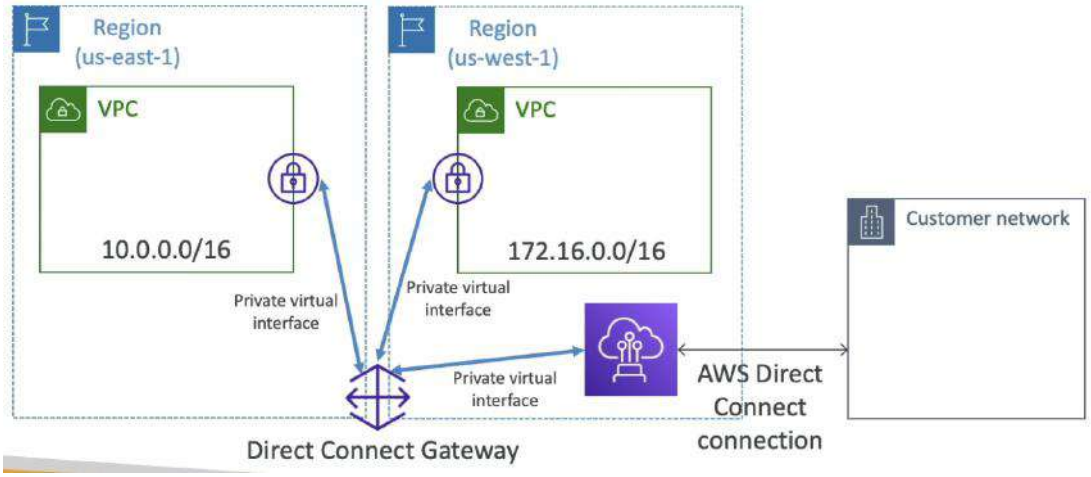
- Provides a dedicated private connection from a remote network to your VPC, more stable and secure than Site-to-Site VPN
- AWS Direct Connect Location is a physical location that needs to be commissioned
- Dedicated connection must be setup between your DC and AWS Direct Connect locations
- You need to setup a Virtual Private Gateway on your VPC
- Access public resources (S3) and private (EC2) on same connection
- Supports both IPv4 and IPv6
- Use Cases:
  - Increase bandwidth throughput - working with large data sets - lower cost
  - More consistent network experience - applications using real-time data feeds
  - Supports Hybrid Environments (on premises + cloud)
- Lead times are often longer than 1 month to establish a new connection
- Private Virtual Interface (VIF) is used to connect to private instances and similarly for public instances.



▼ Direct Connect Gateway

Used when you want to setup a Direct Connect to multiple VPCs in many different regions (same account)

Using DX, we will create a VIF to the Direct Connect Gateway which will extend the VIF to Virtual Private Gateway (VGW) in the two regions.



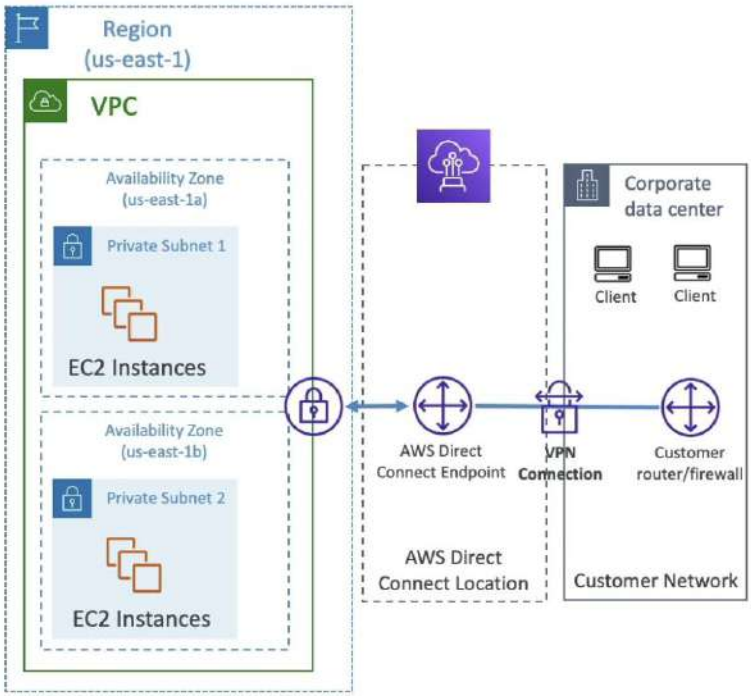
▼ Connection types

- Dedicated Connection
  - 1 Gbps and 10 Gbps capacity
  - Physical ethernet port dedicated to a customer
  - Request made to AWS first, then completed by AWS Direct Connect Partners
- Hosted Connection
  - 50Mbps, 500 Mbps, to 10 Gbps
  - Connection requests are made via AWS Direct Connect Partners
  - Capacity can be added or removed on demand (more flexible than dedicated connection)
  - 1, 2, 5, 10 Gbps available at select AWS Direct Connect Partners

▼ Encryption

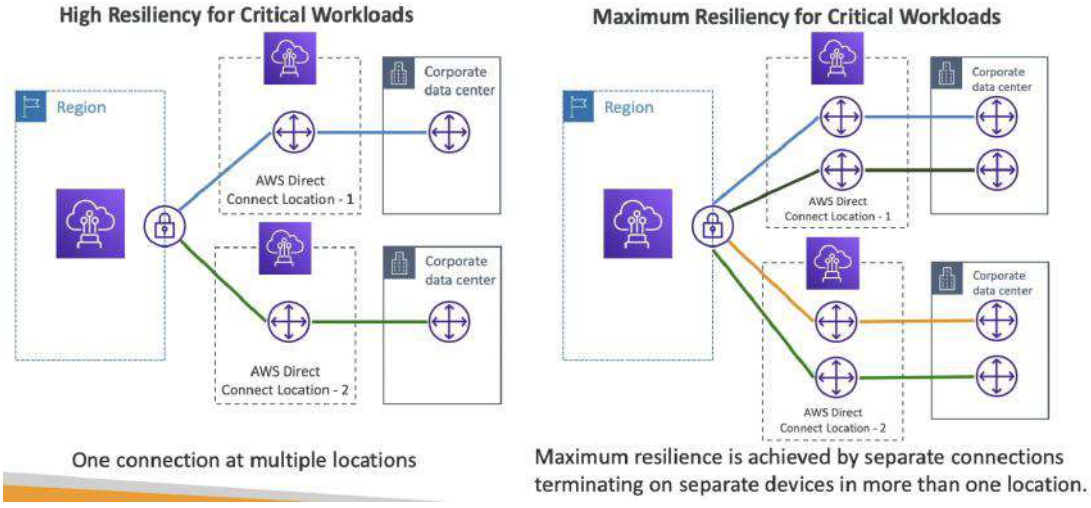
- Data in transit is not encrypted but is private as the connection is private
- To have encryption in flight, use AWS Direct Connect + VPN which provides an IPsec-encrypted private connection. Good for an extra level of security, but slightly more complex to put in place.

- Data is shared through a VPN between the customer router and AWS Direct Connection Endpoint. So, all the traffic will be encrypted.

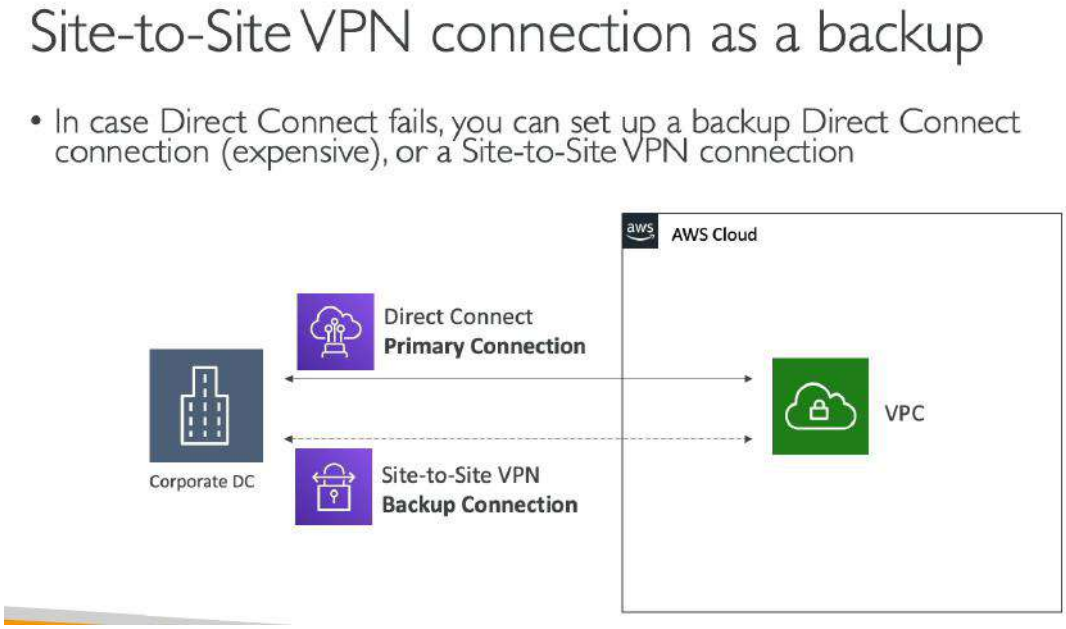


▼ Resiliency

In the diagram below, each VIF is private.



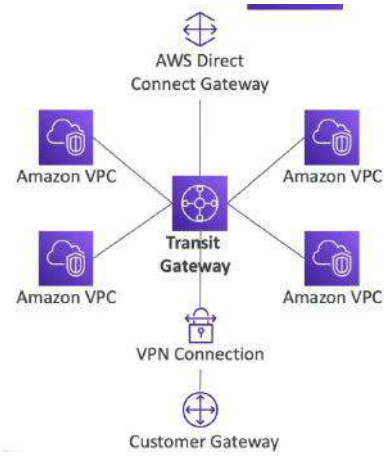
▼ Direct Connect + Site to Site VPN



▼ Transit Gateway

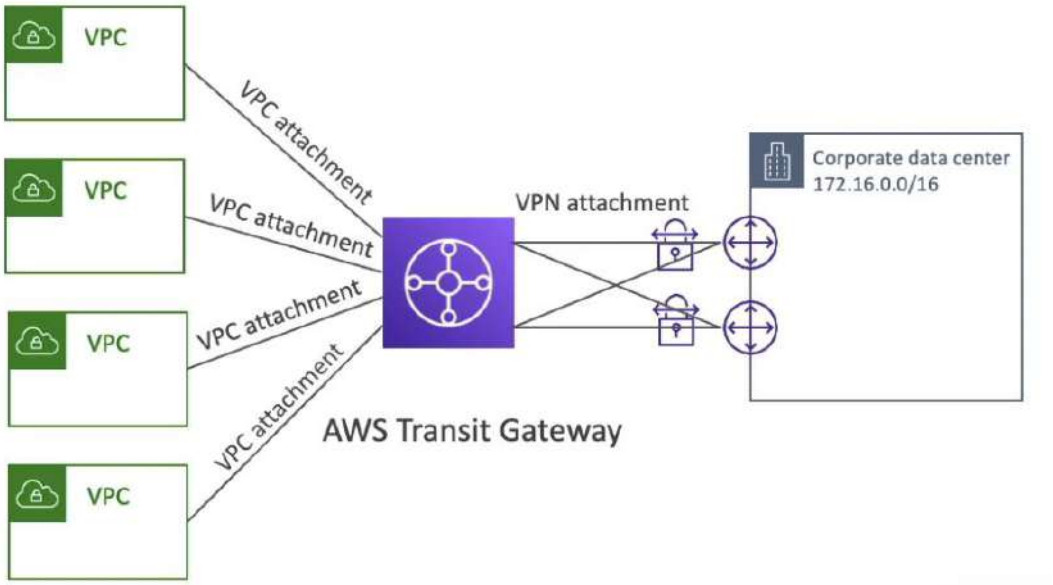
▼ Intro

- Transit Gateway solves the problem of common network topologies getting complicated
- Transitive peering between thousands of VPCs and on-premise data centers, hub-and-spoke (star) connection
- Transit Gateway is a regional resource, can work cross-region too
- Can peer Transit Gateways across regions
- Can share Transit Gateway across accounts using Resource Access Manager (used to connect Direct Connect Gateway to VPCs in multiple accounts)
- Route Tables: limit which VPC can talk with other VPC
- Works with Direct Connect Gateway, VPN connections and VPCs
- **Supports IP Multicast (not supported by any other AWS service)**



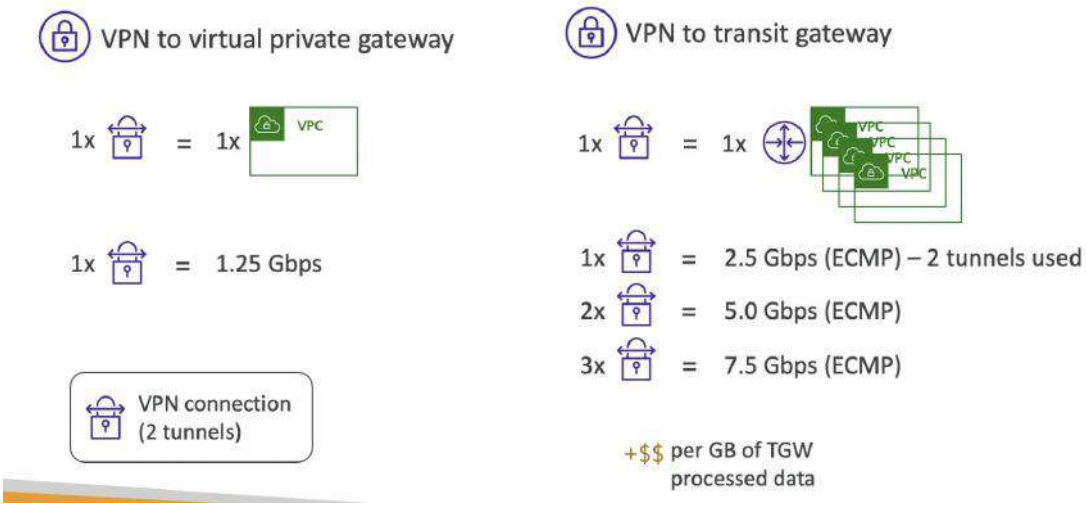
▼ Increasing BW of Side-to-Side VPN connection using ECMP

- ECMP (Equal-cost multi-path routing) is a routing strategy to allow to forward a packet over multiple best path
- To increase the bandwidth of the connection between Transit Gateway and corporate data center, multiple site-to-site VPN connections can be created each with 2 tunnels for increased bandwidth.



▼ Transit Gateway throughput with ECMP

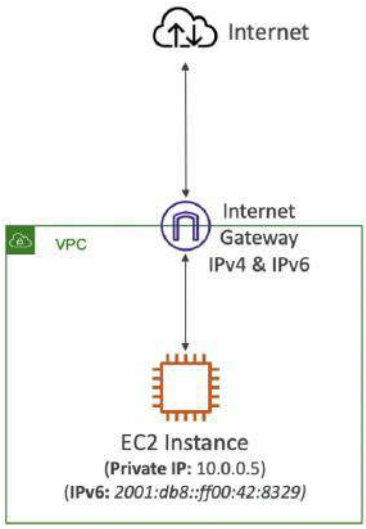
- If we connect a VPN to a Virtual Private Gateway (VGW), we only get one connection into a single VPC. The connection has 2 tunnels, out of which only 1 is used ~ 1.25 Gbps.
- If we connect a VPN to a transit gateway, we get one side-to-side VPN into many VPC. Each connection has 2 tunnels, both of which are used ~ 2.5 Gbps. To increase the throughput, increase the number of side-to-side VPN connections through ECMP.
- Pay per GB of data going through the transit gateway (added cost for multiple connections)



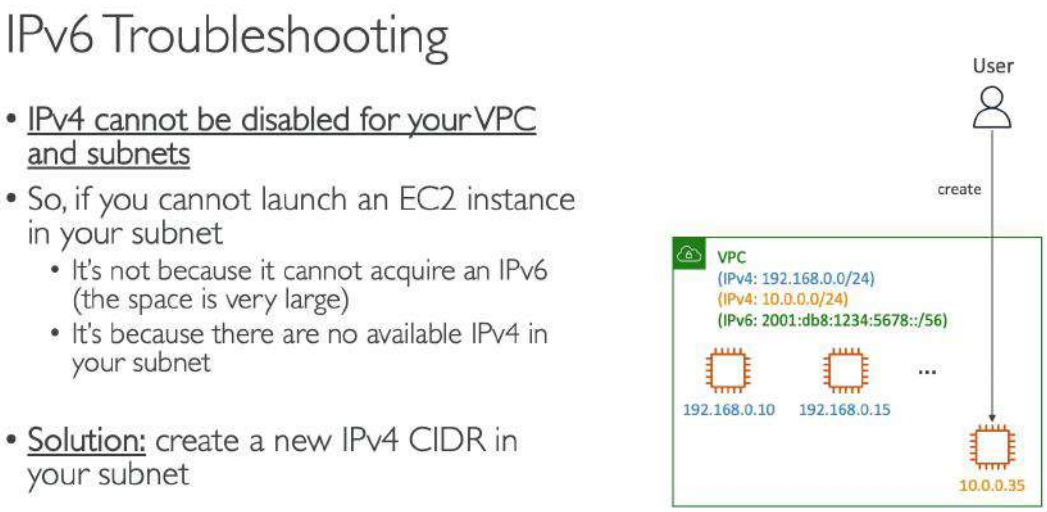
▼ Share Direct Connect between multiple AWS accounts

Using Transit Gateway, we can share a direct connect connection between multiple accounts and VPCs.

- Every IPv6 address is public and Internet-routable (no private range)
- Format x.x.x.x.x.x.x.x (x is hexadecimal, range can be from 0000 to ffff)
- Examples:
  - 2001:db8:3333:4444:5555:6666:7777:8888
  - 2001:db8:3333:4444:cccc:dddd:eeee:ffff
  - :: ⇒ all 8 segments are zero
  - 2001:db8:: ⇒ the last 6 segments are zero
  - ::1234:5678 ⇒ the first 6 segments are zero
  - 2001:db8::1234:5678 ⇒ the middle 4 segments are zero
- **IPv4 cannot be disabled for your VPC and subnets**
- You can enable IPv6 to operate in dual-stack mode in which your EC2 instances will get at least a private IPv4 and a public IPv6. They can communicate using either IPv4 or IPv6 to the internet through an Internet Gateway.



- If you cannot launch an EC2 instance in your subnet, It's not because it cannot acquire an IPv6 (the space is very large). It's because there are no available IPv4 in your subnet. Solution: create a new IPv4 CIDR in your subnet.



▼ Egress-only Internet Gateway

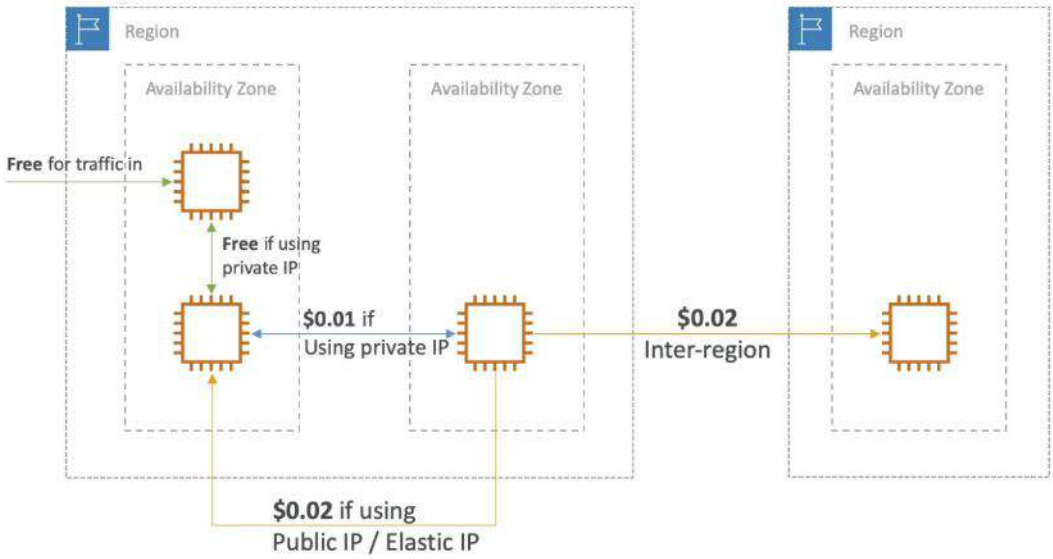
▼ Intro

- CIDR ⇒ IP Range
- VPC - Virtual Private Cloud, we define a list of IPv4 & IPv6 CIDR
- Subnets tied to an AZ, we define a CIDR for each subnet
- Internet Gateway at the VPC level, provide IPv4 & IPv6 Internet Access
- Route Tables must be edited to add routes from subnets to the IGW, VPC Peering Connections, VPC Endpoints, etc. to ensure that the traffic flows properly.
- Bastion Host public EC2 instance to SSH into, that has SSH connectivity to EC2 instances in private subnets
- NAT Instances gives Internet access to EC2 instances in private subnets. Old, must be setup in a public subnet, disable Source / Destination check flag
- NAT Gateway managed by AWS, provides scalable Internet access to private EC2 instances, IPv4 only
- Private DNS + Route 53 ⇒ enable DNS Resolution + DNS Hostnames (VPC)
- NACL ⇒ stateless, subnet rules for inbound and outbound, ephemeral ports
- Security Groups ⇒ stateful, operate at the EC2 instance level
- Reachability Analyzer ⇒ perform network connectivity testing between AWS resources
- VPC Peering ⇒ connect two VPCs with non overlapping CIDR, non-transitive
- VPC Endpoints ⇒ provide private access to AWS Services (S3, DynamoDB, CloudFormation, SSM) within a VPC
- VPC Flow Logs can be setup at the VPC / Subnet / ENI Level, for ACCEPT and REJECT traffic, helps identifying attacks, analyze using Athena or Cloud Watch Logs Insights
- Site-to-Site VPN ⇒ setup a Customer Gateway on DC, a Virtual Private Gateway on VPC, and site-to-site VPN over public Internet
- AWS VPN CloudHub ⇒ hub-and-spoke VPN model to connect your sites
- Direct Connect ⇒ setup a Virtual Private Gateway on VPC, and establish a direct private connection to an AWS Direct Connect Location. More secure and stable connection but takes longer to setup.
- Direct Connect Gateway ⇒ setup Direct Connect to many VPCs in different AWS regions
- AWS PrivateLink / VPC Endpoint Services:
  - Connect services privately from your service VPC to customers VPC
  - Doesn’t need VPC Peering, public Internet, NAT Gateway, Route Tables
  - Must be used with Network Load Balancer & ENI
  - Can connect AWS services to 1000s of VPCs
- ClassicLink ⇒ connect EC2-Classic EC2 instances privately to your VPC (deprecated)
- Transit Gateway ⇒ transitive peering connections for VPC, VPN & DX Gateway
- Traffic Mirroring ⇒ copy network traffic from ENIs for further analysis
- Egress-only Internet Gateway ⇒ like a NAT Gateway, but for IPv6

▼ Networking Costs in AWS

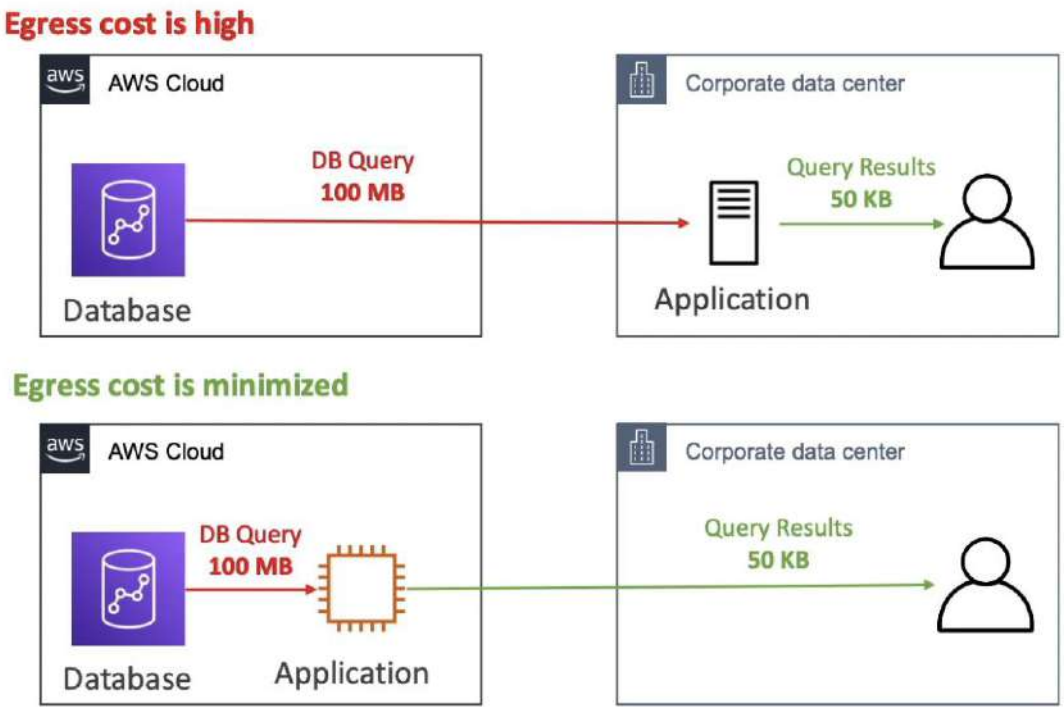
▼ Inter-AZ & Inter-Region Networking

- Use Private IP instead of Public IP for good savings and better network performance
- Use same AZ for maximum savings (at the cost of high availability)



▼ Egress Traffic Network Cost

- Egress traffic: outbound traffic - from AWS to outside (paid)
- Ingress traffic: inbound traffic - from outside to AWS (typically free)
- Try to keep as much internet traffic within AWS to minimize costs
- Direct Connect location that are co-located in the same AWS Region result in lower cost for egress network

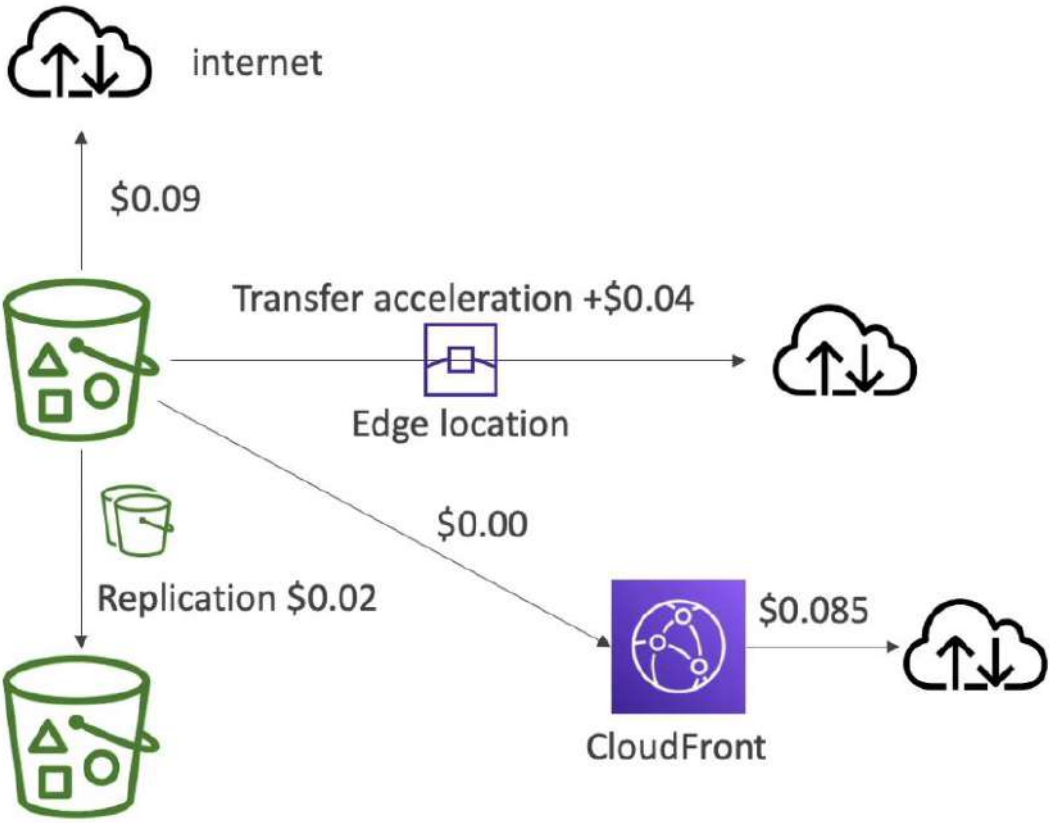


▼ S3 Data Transfer Pricing

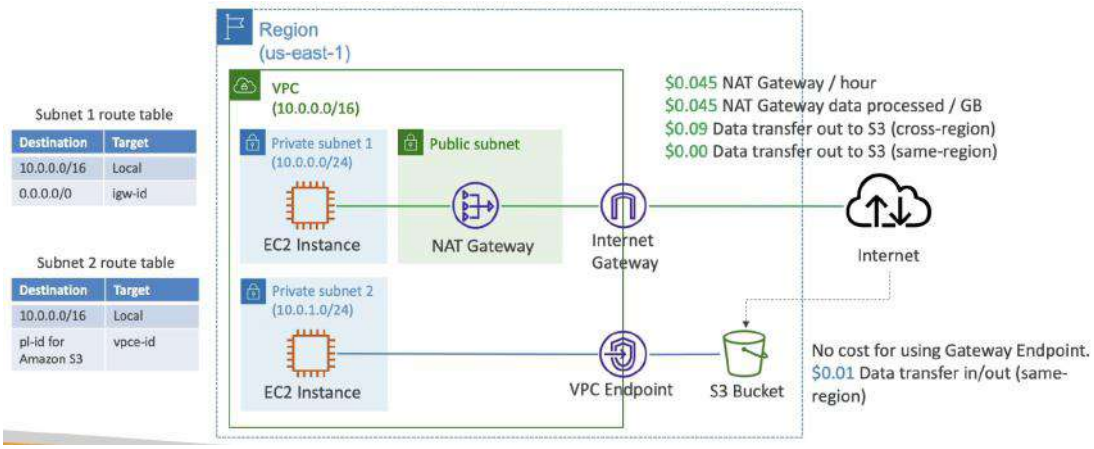
- S3 ingress (uploading to S3): free
- S3 to Internet: $0.09 per GB
- S3 Transfer Acceleration:
  - Faster transfer times (50 to 500% better)

- Additional cost on top of Data Transfer (+$0.04 to $0.08 per GB)

- S3 to CloudFront: free (internal network)
- CloudFront to Internet: $0.085 per GB (slightly cheaper than S3)
  - Caching capability (lower latency)
  - Reduce costs associated with S3 Requests (7x cheaper with CloudFront)
- S3 Cross Region Replication: $0.02 per GB



▼ NAT Gateway vs VPC Endpoint



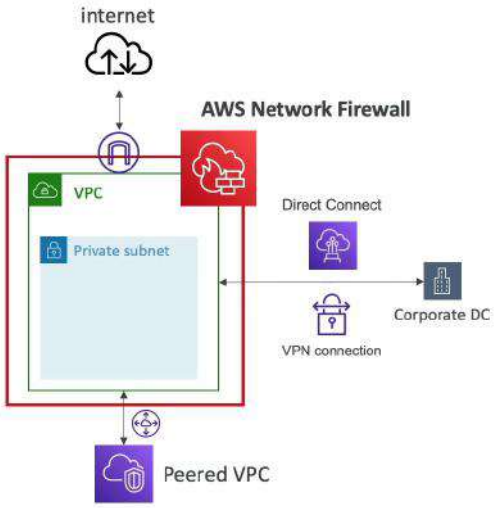
▼ Network Protection on AWS

Network Protection on AWS

- To protect network on AWS, we've seen
  - Network Access Control Lists (NACLs)
  - Amazon VPC security groups
  - AWS WAF (protect against malicious requests)
  - AWS Shield & AWS Shield Advanced
  - AWS Firewall Manager (to manage them across accounts)
- But what if we want to protect in a sophisticated way our entire VPC?

AWS Network Firewall

- Protect your entire Amazon VPC
- From Layer 3 to Layer 7 protection
- Any direction, you can inspect
  - VPC to VPC traffic
  - Outbound to internet
  - Inbound from internet
  - To / from Direct Connect & Site-to-Site VPN
- Internally, the AWS Network Firewall uses the AWS Gateway Load Balancer
- Rules can be centrally managed cross-account by AWS Firewall Manager to apply to many VPCs



Network Firewall – Fine Grained Controls

- Supports 1000s of rules
  - IP & port - example: 10,000s of IPs filtering
  - Protocol – example: block the SMB protocol for outbound communications
  - Stateful domain list rule groups: only allow outbound traffic to *.mycorp.com or third-party software repo
  - General pattern matching using regex
- **Traffic filtering: Allow, drop, or alert for the traffic that matches the rules**
- **Active flow inspection** to protect against network threats with intrusion-prevention capabilities (like Gateway Load Balancer, but all managed by AWS)
- Send logs of rule matches to Amazon S3, CloudWatch Logs, Kinesis Data Firehose

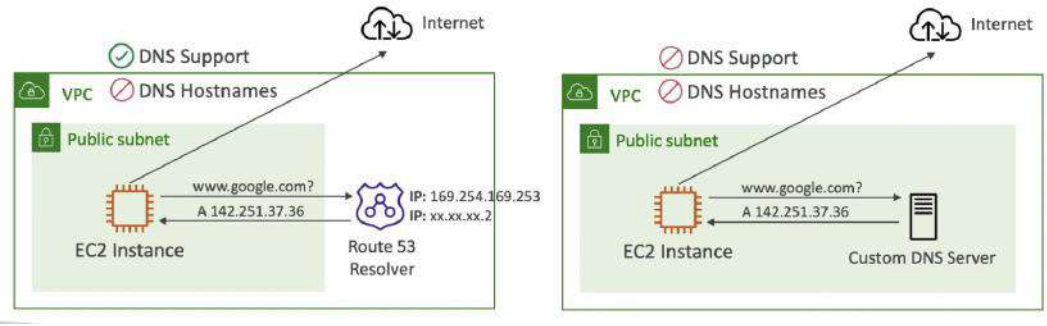
▼ DNS Resolution in VPC

▼ Theory

Two settings need to be enabled to allow DNS resolution within a VPC:

▼ DNS Support (enableDnsSupport)

- Enabled by default, allows the resources within the VPC to query the DNS provided by Route 53 Resolver at 169.254.169.253 or the reserved IP address at the base of the VPC IPv4 network range plus two (.2)
- If disabled, we need to provide a custom DNS server otherwise we won't be able to hit hostnames



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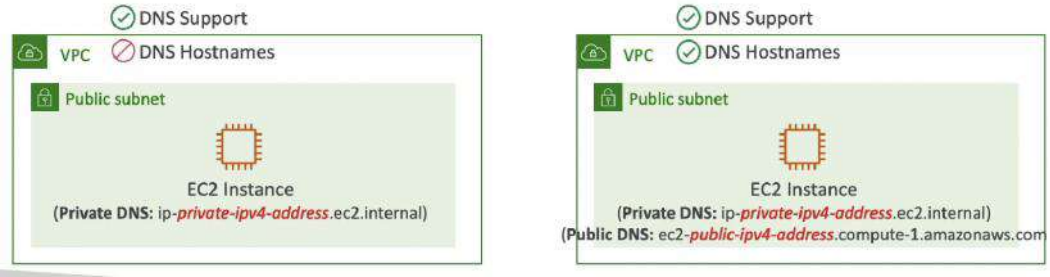
▼ DNS Hostnames (enableDnsHostnames)

- If enabled, assigns public hostname to EC2 instance in our VPC if it has a public IPv4
- Won't do anything unless enableDnsSupport=true
- By default
  - Default VPC - Enabled
  - Custom VPC - Disabled
- When DNS Hostnames is enabled, the instances have both public and private hostnames.
- When disabled, instances in the VPC will have a public IP but no public DNS.



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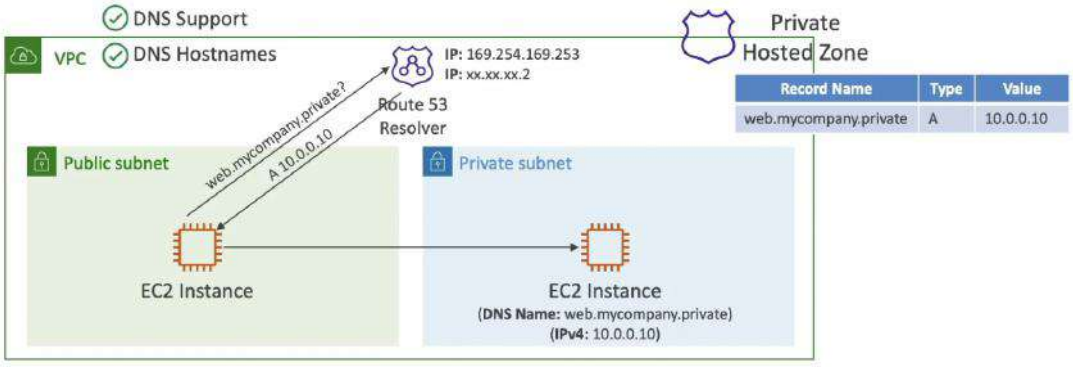
If you use custom DNS domain names in a Private Hosted Zone in Route 53, you must set both these attributes (enableDnsSupport & enableDnsHostname) to true.



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▼ EC2 Classic & AWS ClassicLink

- EC2-Classic: instances run in single network shared with other customers (this is how AWS started)
- Amazon VPC: your instances run logically isolated to your AWS account (this is what AWS has become)
- ClassicLink allows you to link EC2-Classic instances to a VPC in your account
  - Must associate a security group
  - Enables communication using private IPv4 addresses
  - Removes the need to make use of public IPv4 addresses or Elastic IP addresses

💡 Likely to be distractors at the exam

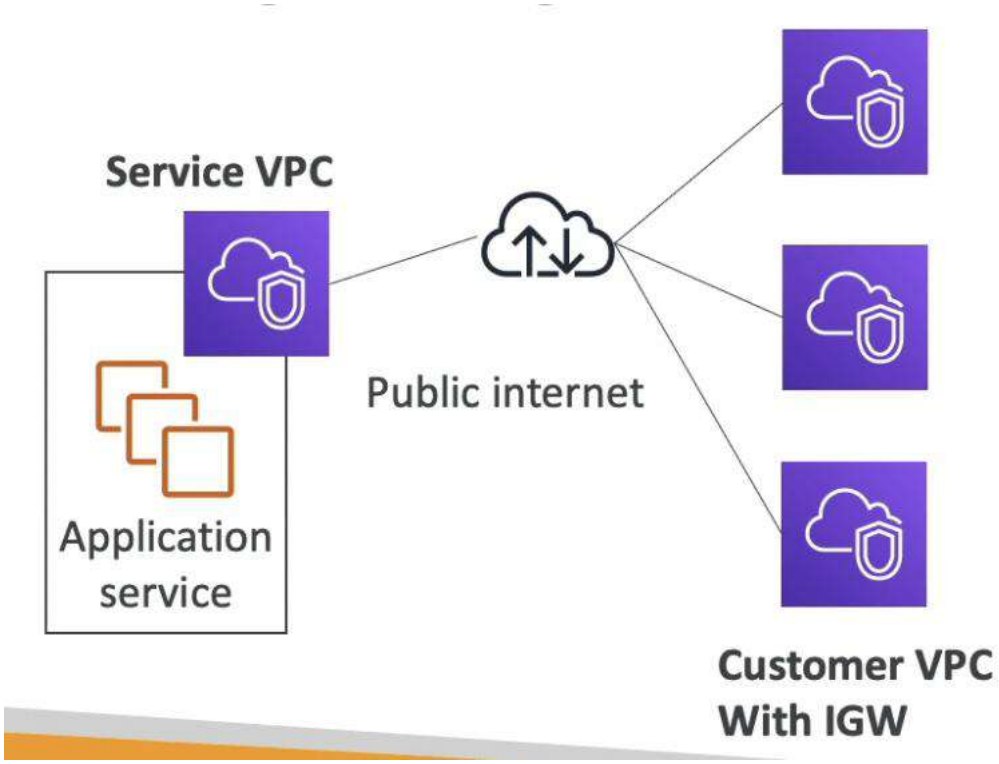
▼ AWS PrivateLink

▼ Exposing services in your VPC to other VPCs

▼ Option 1: Make it public

- Traffic goes through the public internet

- Tough to manage access



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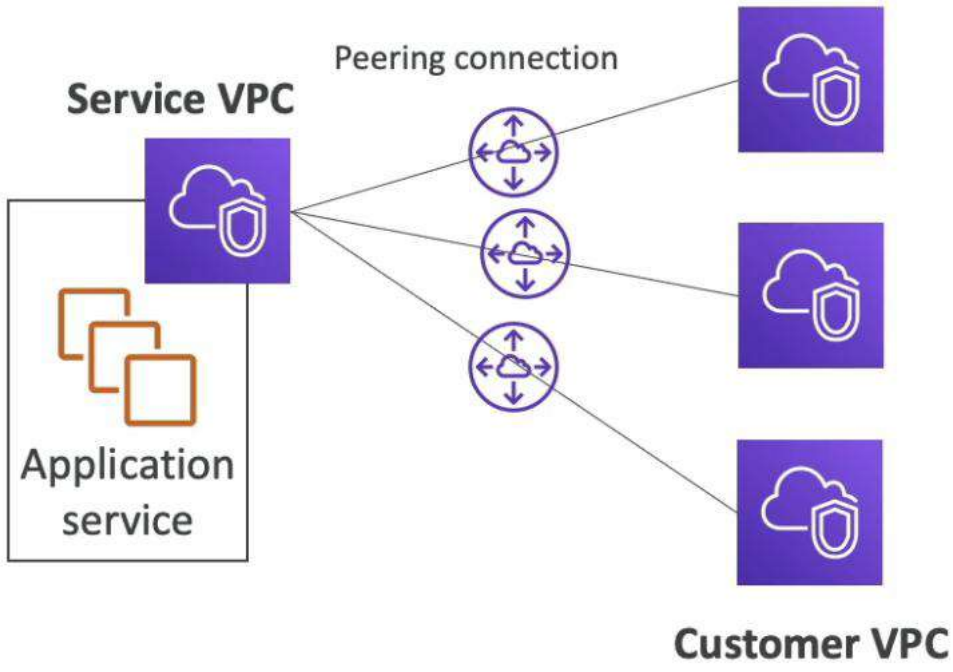
▼ Option 2: VPC Peering

- Each peer connection exposes the whole network even though we want to externalize just a few services



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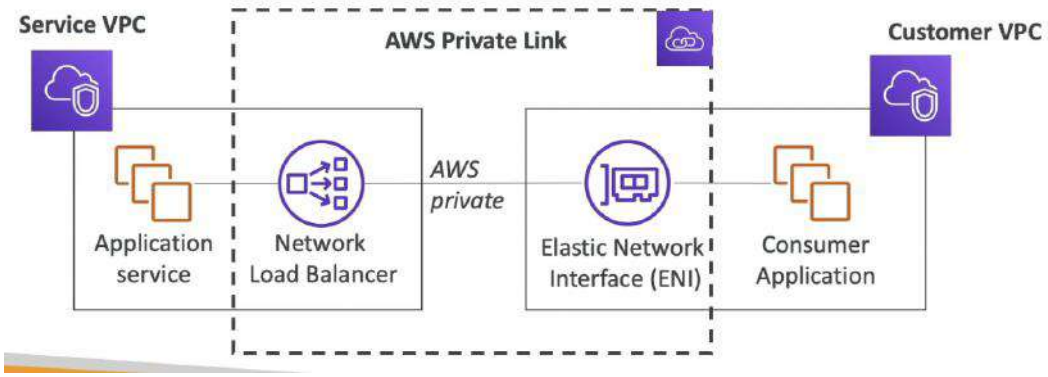
▼ Option 3: AWS PrivateLink

- Most secure & scalable way to expose service to 1000s of VPCs in the same or other accounts
- Does not require VPC peering, internet gateway, NAT, route tables, etc.
- Requires a Network Load Balancer (most common) or GWLB (Service VPC) and ENI (Customer VPC)
- If the NLB is in multiple AZ, then you need ENIs in multiple AZ and the solution is fault tolerant
- The NLB in the Service VPC and ENI in the Customer VPC talk directly through the AWS PrivateLink



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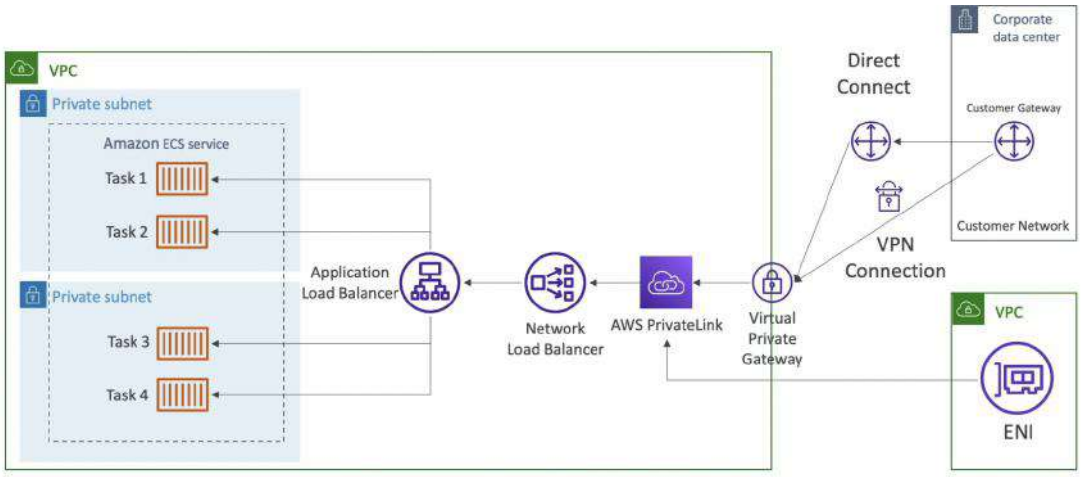
▼ PrivateLink with ECS

- ECS tasks require an ALB. So, we can connect the ALB to the NLB for PrivateLink.
- Corporate Data Centers will still connect through the VPN or Direct Connect.

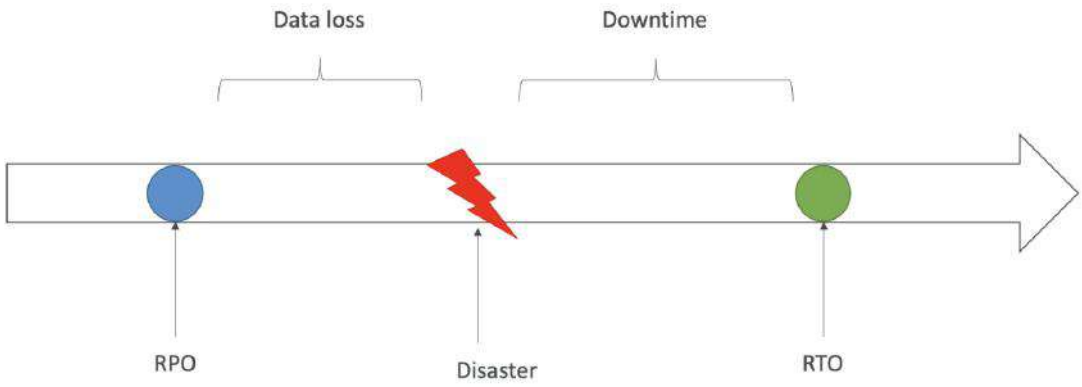


▼ Section 29: Disaster Recovery & Migrations

▼ Disaster Recovery

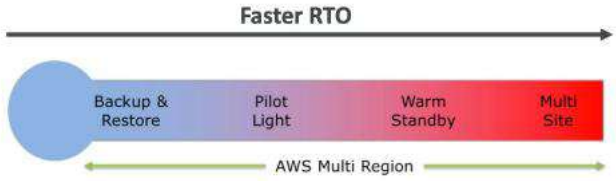
▼ Intro

- Any event that has a negative impact on a company's business continuity or finances is a disaster
- Disaster recovery (DR) is about preparing for and recovering from a disaster
- Recovery Point Objective: how often you backup your data or how much data are you willing to lose in case of a disaster
- Recovery Time Objective: how long it takes to recover from the disaster (down time)



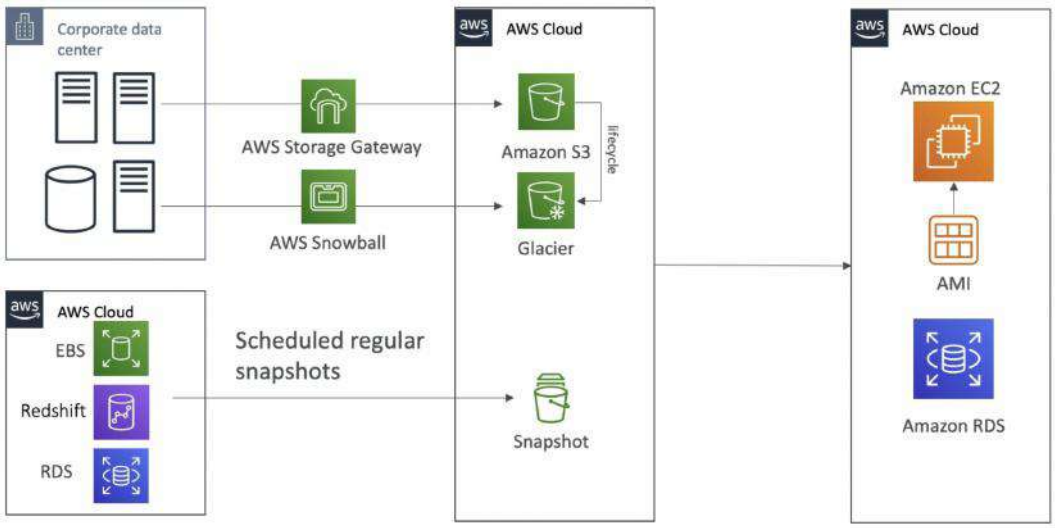
▼ Strategies

▼ Intro



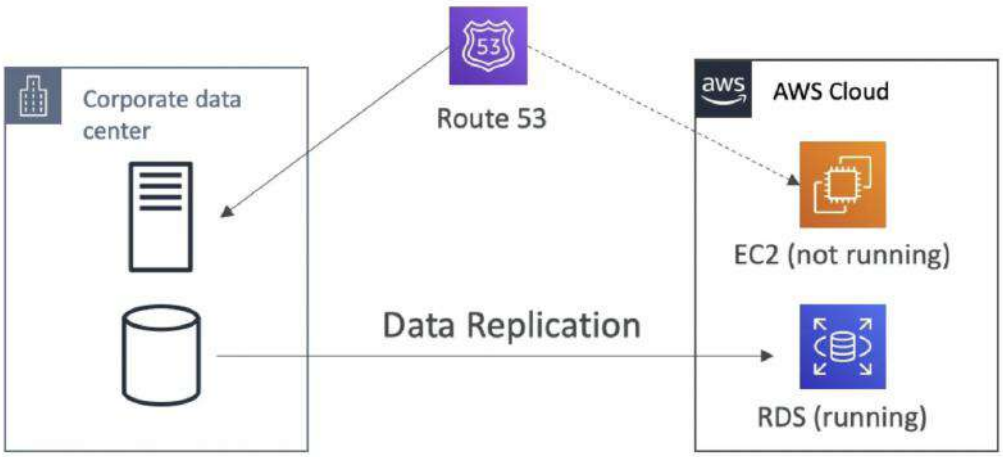
▼ Backup & Restore

- High RPO (backup every day or week)
- High RTO (in case of a disaster, need to spin up instances and restore volumes from snapshots, takes time)
- Less management
- Low cost



▼ Pilot Light

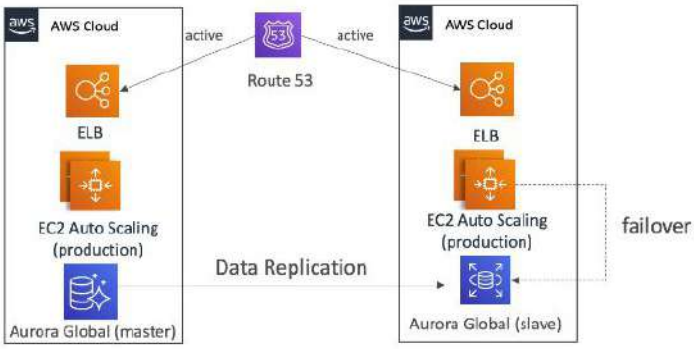
- Critical parts of the app are always running in the cloud (eg. continuous replication of data to another region, if one region fails, quickly failover to the other region)
- Faster than Backup and Restore as critical systems are already up
- Low RPO and RTO
- In the diagram below, DB is critical so it is replicated continuously in RDS but EC2 instance is spin up only when a disaster strikes.



▼ Warm Standby

- A complete backup system is up and running but at the minimum capacity. This system is quickly scaled to production capacity in case of a disaster.
- Very low RPO & RTO
- Expensive

All AWS Multi Region



▼ Outro

Disaster Recovery Tips

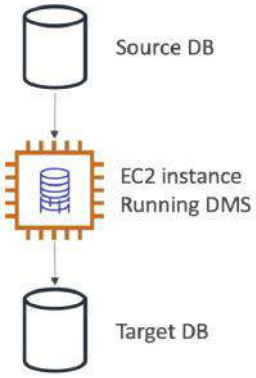
- Backup
  - EBS Snapshots, RDS automated backups / Snapshots, etc…
  - Regular pushes to S3 / S3 IA / Glacier, Lifecycle Policy, Cross Region Replication
  - From On-Premise: Snowball or Storage Gateway
- High Availability
  - Use Route53 to migrate DNS over from Region to Region
  - RDS Multi-AZ, ElastiCache Multi-AZ, EFS, S3
  - Site to Site VPN as a recovery from Direct Connect
- Replication
  - RDS Replication (Cross Region), AWS Aurora + Global Databases
  - Database replication from on-premise to RDS
  - Storage Gateway
- Automation
  - CloudFormation / Elastic Beanstalk to re-create a whole new environment
  - Recover / Reboot EC2 instances with CloudWatch if alarms fail
  - AWS Lambda functions for customized automations
- Chaos
  - Netflix has a "simian-army" randomly terminating EC2

▼ Database Migration Service (DMS)

▼ Intro

- Quickly and securely migrate databases from on-premises to AWS cloud
- The source database remains available during the migration
- Supports:
  - Homogeneous migrations (eg. Oracle to Oracle)
  - Heterogeneous migrations (eg. Microsoft SQL Server to Aurora)
- Continuous Data Replication using CDC (change data capture)

- You must create an EC2 instance running the DMS software to perform the replication tasks. If the amount of data is large, use a large instance. If multi-AZ is enabled, multiple instances will be created in different AZs.



DMS Sources and Targets

SOURCES:

- On-Premise and EC2 instances databases: *Oracle, MS SQL Server, MySQL, MariaDB, PostgreSQL, MongoDB, SAP, DB2*
- Azure: *Azure SQL Database*
- Amazon RDS: all including Aurora
- Amazon S3

TARGETS:

- On-Premise and EC2 instances databases: Oracle, MS SQL Server, MySQL, MariaDB, PostgreSQL, SAP
- Amazon RDS
- Amazon Redshift
- Amazon DynamoDB
- Amazon S3
- ElasticSearch Service
- Kinesis Data Streams
- DocumentDB

- **If the source and target DBs aren't running the same engine, we need to use Schema Conversion Tool (SCT) to convert the DB's schema from one engine to another.**

▼ DMS Continuous Migration

In the example below, source and target engines are different. SCT is installed on premises and the schema conversion is written to RDS (target). DMS instance with CDC is used for continuous data migration.

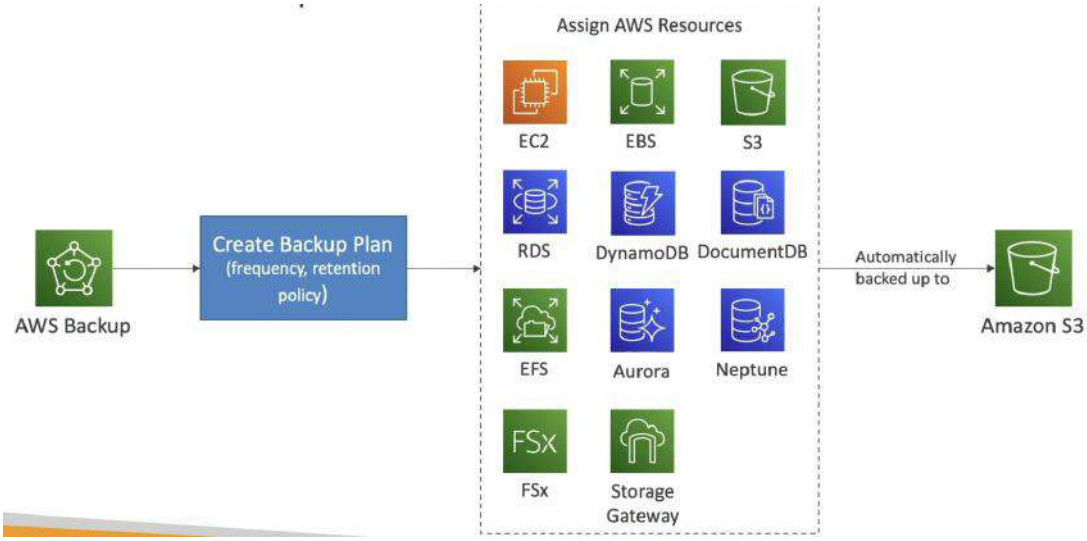
▼ AWS On-premises strategies

- Ability to download Amazon Linux 2 AMI as a VM (.iso format) and run on virtualization softwares like VMWare, KVM, Virtual Box (Oracle VM), Microsoft Hyper-V
- VM Import / Export
  - Migrate existing applications as VMs into EC2
  - Create a DR repository strategy for your on-premise VMs
  - Can export back the VMs from EC2 to on-premise
- AWS Application Discovery Service
  - Gather information about your on-premise servers to plan a migration
  - Server utilization and dependency mappings
  - Track with AWS Migration Hub
- AWS Database Migration Service (DMS)
  - replicate On-premise ⇒ AWS , AWS ⇒ AWS, AWS ⇒ On-premise
  - Works with various database technologies (Oracle, MySQL, DynamoDB, etc..)
- AWS Server Migration Service (SMS)
  - Incremental replication of on-premise live servers to AWS

▼ AWS Backup

▼ Intro

- Fully managed service
- Centrally manage and automate backups across AWS services
- No need to create custom scripts and manual processes
- Supported services:
  - Amazon EC2 / Amazon EBS
  - Amazon S3
  - Amazon RDS (all DBs engines) / Amazon Aurora / Amazon DynamoDB
  - Amazon DocumentDB / Amazon Neptune
  - Amazon EFS / Amazon FSx (Lustre & Windows File Server)
  - AWS Storage Gateway (Volume Gateway)
- Supports cross-region backups
- Supports cross-account backups
- Supports point in time recovery (PITR) for supported services
- On-Demand and Scheduled backups
- Tag-based backup policies
- You create backup policies known as Backup Plans
  - Backup frequency (every 12 hours, daily, weekly, monthly, cron expression)
  - Backup window
  - Transition to Cold Storage (Never, Days, Weeks, Months, Years)
  - Retention Period (Always, Days, Weeks, Months, Years)



▼ Vault Lock

- Enforce a WORM (Write Once Read Many) state for all the backups that you store in your AWS Backup Vault
- Additional layer of defense to protect your backups against:
  - Inadvertent or malicious delete operations
  - Updates that shorten or alter retention periods
- Even the root user cannot delete backups when enabled

▼ Application Migration Service - MGN

AWS Application Discovery Service

- Plan migration projects by gathering information about on-premises data centers
- Server utilization data and dependency mapping are important for migrations

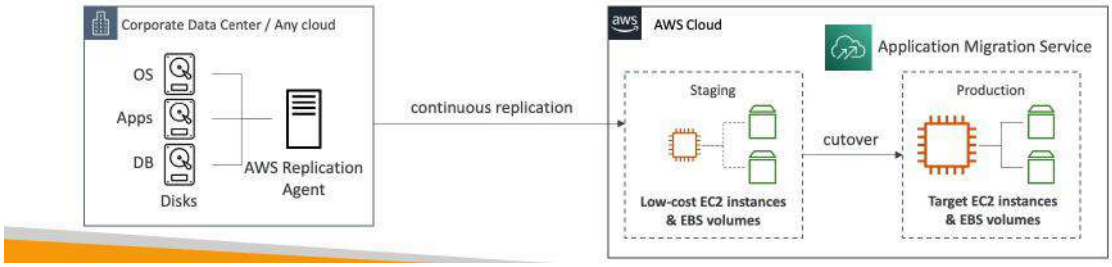
- Agentless Discovery (AWS Agentless Discovery Connector)
  - VM inventory, configuration, and performance history such as CPU, memory, and disk usage
- Agent-based Discovery (AWS Application Discovery Agent)
  - System configuration, system performance, running processes, and details of the network connections between systems

- Resulting data can be viewed within AWS Migration Hub

AWS Application Migration Service (MGN)

- *The "AWS evolution" of CloudEndure Migration, replacing AWS Server Migration Service (SMS)*

- Lift-and-shift (rehost) solution which simplify migrating applications to AWS
- Converts your physical, virtual, and cloud-based servers to run natively on AWS
- Supports wide range of platforms, Operating Systems, and databases
- Minimal downtime, reduced costs



▼ Transferring large amount of data into AWS

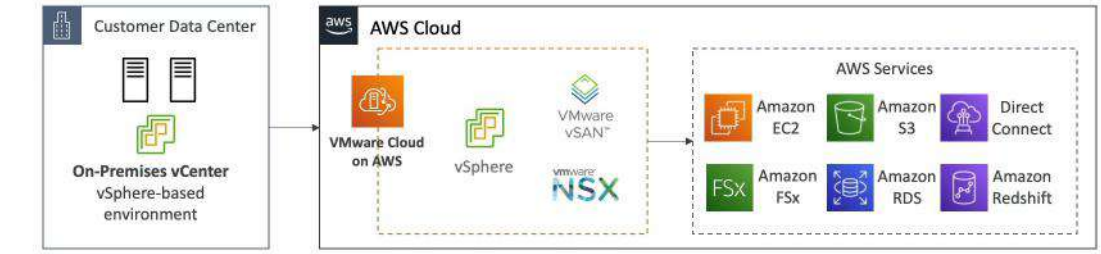
Example: transfer 200 TB of data to the cloud. We have a 100 Mbps internet connection.

- Over the internet / Site-to-Site VPN:
  - Immediate to setup
  - Will take 200(TB)* 1000(GB)* 1000(MB)*8(Mb)/100 Mbps = 16,000,000s = 185d
- Over direct connect - 1Gbps:
  - Long for the one-time setup (over a month)
  - Will take 200(TB)*1000(GB)*8(Gb)/| Gbps = 1,600,000 = 18.5d
- Over Snowball:
  - Will take 2 to 3 snowballs in parallel
  - Takes about 1 week for the end-to-end transfer
  - Can be combined with DMS
- For on-going replication transfers: Site-to-Site VPN or DX with DMS or DataSync

▼ VMware cloud on AWS

VMware Cloud on AWS

- Some customers use VMware Cloud to manage their on-premises Data Center
- They want to extend the Data Center capacity to AWS, but keep using the VMware Cloud software
- …Enter VMware Cloud on AWS
- Use cases
  - Migrate your VMware vSphere-based workloads to AWS
  - Run your production workloads across VMware vSphere-based private, public, and hybrid cloud environments
  - Have a disaster recover strategy

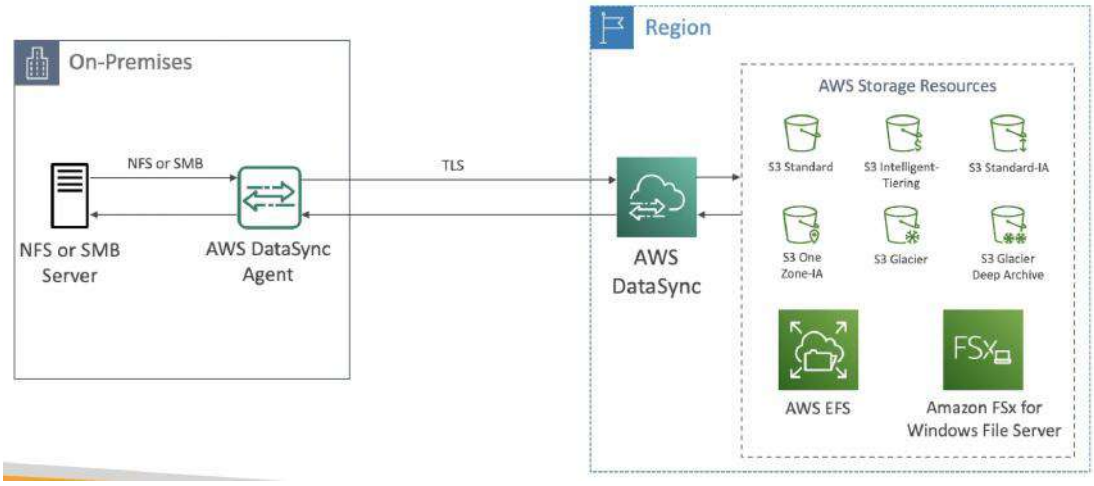


▼ AWS DataSync

▼ Intro

- Move large amount of data from on-premise to AWS over the public internet using TLS
- Can synchronize to: Amazon S3 (any storage classes including Glacier), Amazon EFS, Amazon FSx for Windows
- Move data from your NAS or file system via NFS or SMB
- Replication tasks can be scheduled hourly, daily, weekly (not continuous replication)
- Need to install AWS DataSync Agent on premises
- Can setup a bandwidth limit

▼ NFS / SMB to AWS



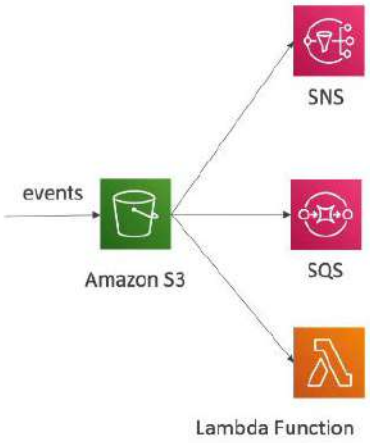
▼ EFS to EFS

▼ S3 Event Notifications

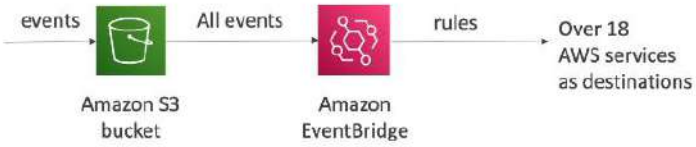
S3 Event Notifications

- S3:ObjectCreated, S3:ObjectRemoved, S3:ObjectRestore, S3:Replication…
- Object name filtering possible (*.jpg)
- Use case: generate thumbnails of images uploaded to S3
- Can create as many "S3 events" as desired

- S3 event notifications typically deliver events in seconds but can sometimes take a minute or longer



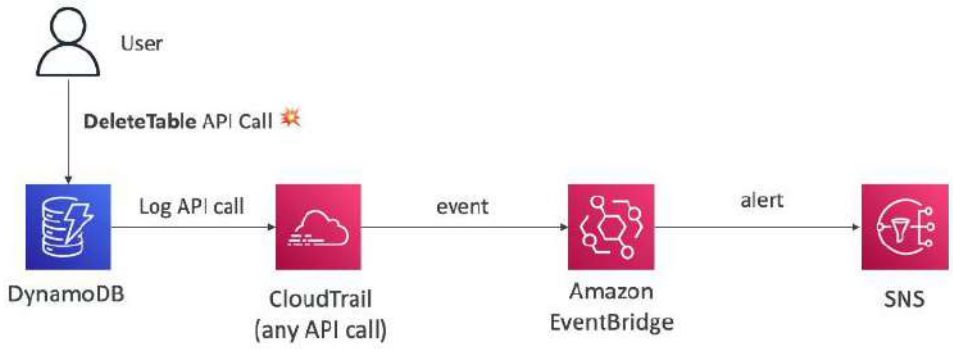
S3 Event Notifications with Amazon EventBridge

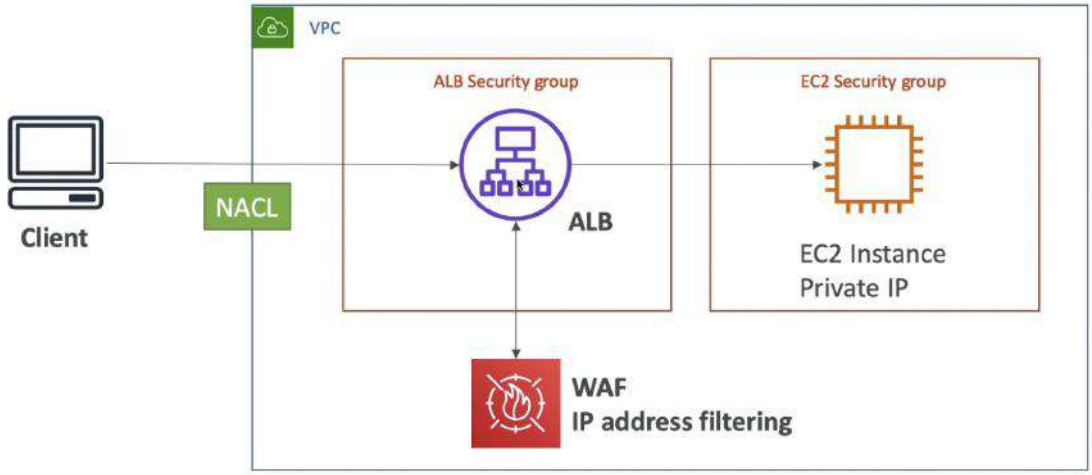


- **Advanced filtering** options with JSON rules (metadata, object size, name...)
- **Multiple Destinations** – ex Step Functions, Kinesis Streams / Firehose…
- **EventBridge Capabilities** – Archive, Replay Events, Reliable delivery

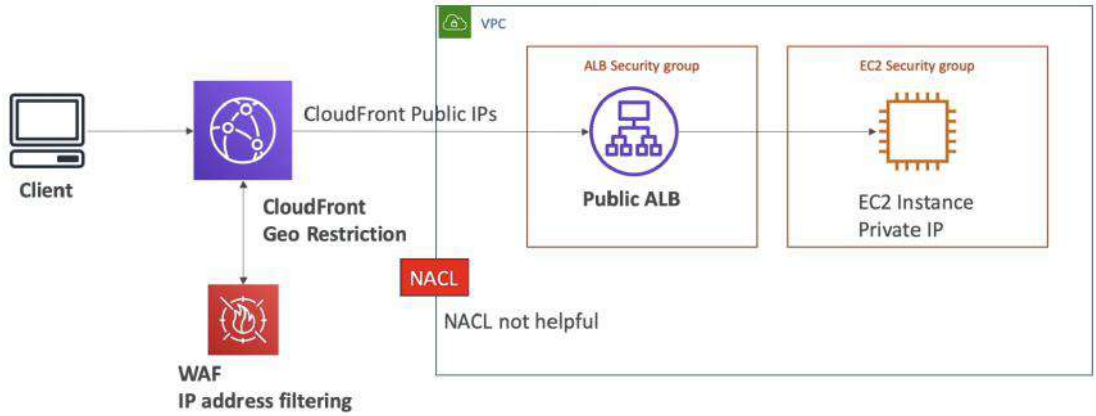
▼ EventBridge - Intercept API Calls

Amazon EventBridge – Intercept API Calls





- CloudFront distribution sits outside the VPC. The ALB gets to see the CF's public IPs only (not the client IP). So, NACL isn't helpful in this case. To block a specific IP, use WAF at the CF level.



▼ High Performance Computing (HPC)

▼ Intro

- The cloud is the perfect place to perform HPC
- You can create a very high number of resources in no time
- You can speed up time to results by adding more resources
- You can pay only for the systems you have used
- Perform genomics, computational chemistry, financial risk modeling, weather prediction, machine learning, deep learning, autonomous driving

▼ Data Management & Transfer

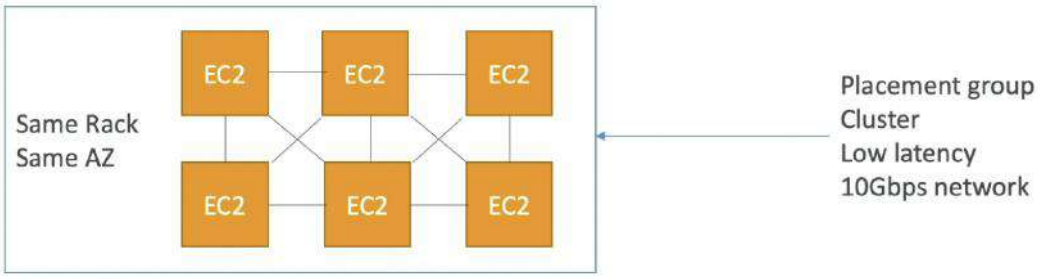
- AWS Direct Connect:
  - Move GB/s of data to the cloud, over a private secure network
- Snowball & Snowmobile
  - Move PB of data to the cloud
- AWS DataSync
  - Move large amount of data between on-premise and S3, EFS, FSx for Windows

▼ Compute & Networking

- EC2 Instances:
  - CPU optimized, GPU optimized

- Spot Instances / Spot Fleets for cost savings + Auto Scaling

- EC2 Placement Groups: Cluster for good network performance



- EC2 Enhanced Networking (SR-IOV)
  - Higher bandwidth
  - Higher PPS (packet per second)
  - Lower latency
  - Can be achieved in two ways:
    - **Option I: Elastic Network Adapter (ENA) - up to 100 Gbps**
    - **Option 2: Intel 82599 VF up to 10 Gbps - legacy (old standard)**
- Elastic Fabric Adapter (EFA)
  - Improved ENA for HPC, only works for Linux
  - Great for inter-node communications, tightly coupled workloads
  - Leverages Message Passing Interface (MP) standard
  - Bypasses the underlying Linux OS to provide low-latency, reliable transport

▼ Storage

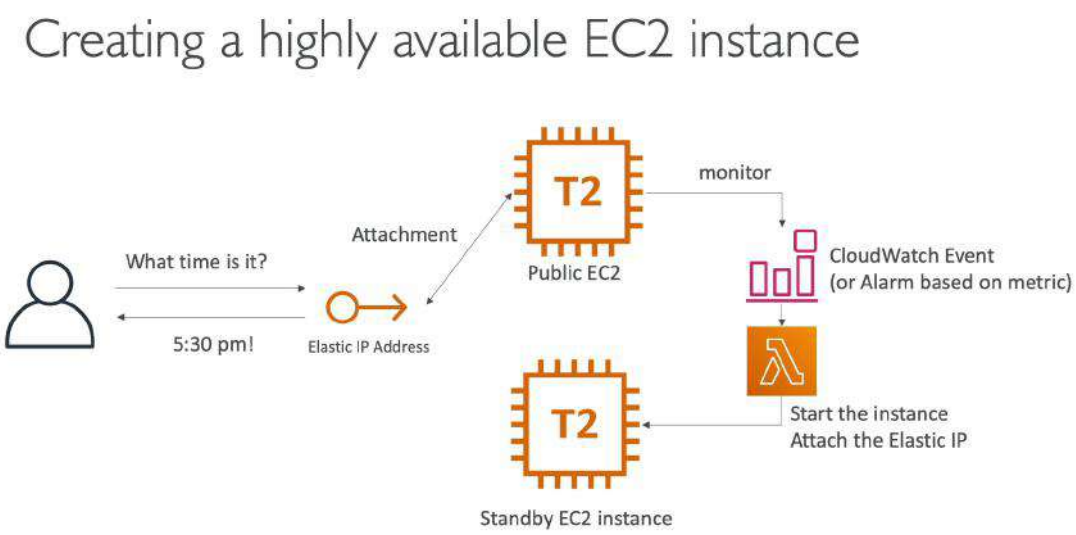
- Instance-attached storage:
  - EBS: scale up to 256,000 lOPS with io2 Block Express
  - Instance Store: scale to millions of IOPS, linked to EC2 instance, low latency
- Network storage:
  - Amazon S3: large blob, not a file system
  - Amazon EFS: scale IOPS based on total size, or use provisioned IOPS mode
  - Amazon FSx for Lustre:
    - HPC optimized distributed file system, millions of IOPS
    - Backed by S3

▼ Automation & Orchestration

- AWS Batch
  - AWS Batch supports multi-node parallel jobs, which enables you to run single jobs that span multiple EC2 instances.
  - Easily schedule jobs and launch EC2 instances accordingly
- AWS Parallel Cluster
  - Open-source cluster management tool to deploy HPC on AWS
  - Configure with text files
  - Automate creation of VPC, Subnet, cluster type and instance types
  - Ability to enable EFA on the cluster (improves network performance)

▼ EC2 High Availability

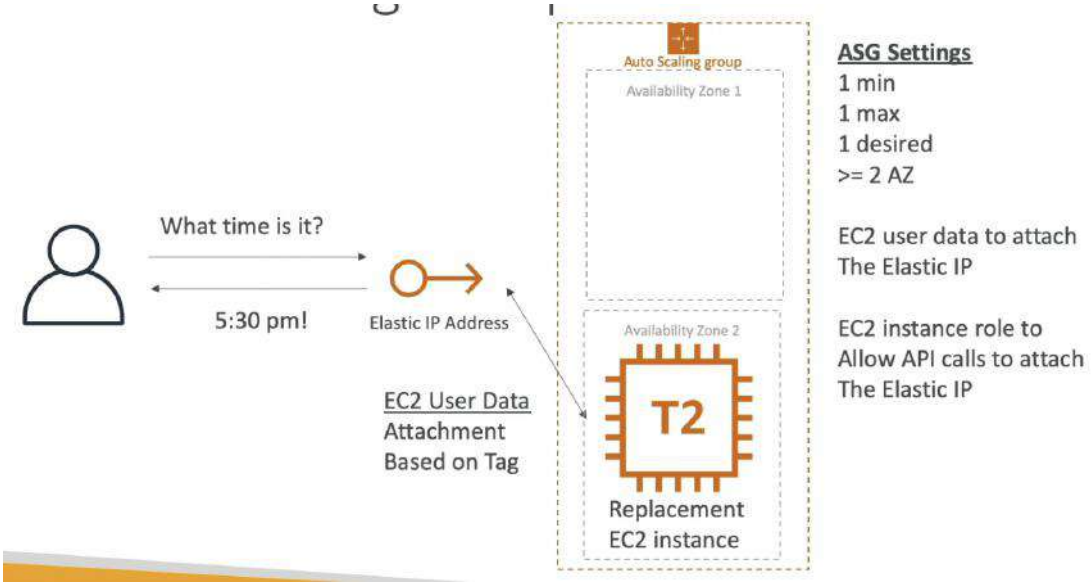
▼ Method 1



▼ Method 2 - Stateless

Create a system where only 1 EC2 instance stays active at a time. If the instance goes down, ASG will start a new one. Also, the

EC2 instance will issue an API call to attach the Elastic IP based on tag.



▼ Method 3 - Stateful

The EC2 instance maintains state in an EBS volume (attached to an AZ). If the instance goes down, create a snapshot of the EBS volume which will be triggered on ASG Terminate lifecycle hook. Similarly, when a new instance is spun up, create a new EBS volume in the appropriate instance using the ASG Launch lifecycle hook.

▼ Section 31: Other Services

▼ CloudFormation

▼ 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
- IaC allows us to write our infrastructure as a config file which can be easily replicated

▼ CloudFormation Intro

- CloudFormation is a declarative way of outlining your AWS Infrastructure, for any resources (most of them are supported).
- CloudFormation creates the resources for you, in the right order, with the exact configuration that you specify
- 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 tagged 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
- Productivity
  - Ability to destroy and re-create an infrastructure on the cloud on the fly
  - Automated generation of Diagram for your templates for PPT slides
  - Declarative programming (no need to figure out ordering and orchestration)
- Separation of concern: create many stacks for many apps and many layers (eg. VPC stacks, Network stacks, App stacks, etc.)
- Don’t re-invent the wheel
  - Leverage existing templates on the web!
  - Leverage the documentation

▼ How it 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 (very clean way of deleting resources)

▼ 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

▼ Building Blocks

Amazon Elastic Transcoder

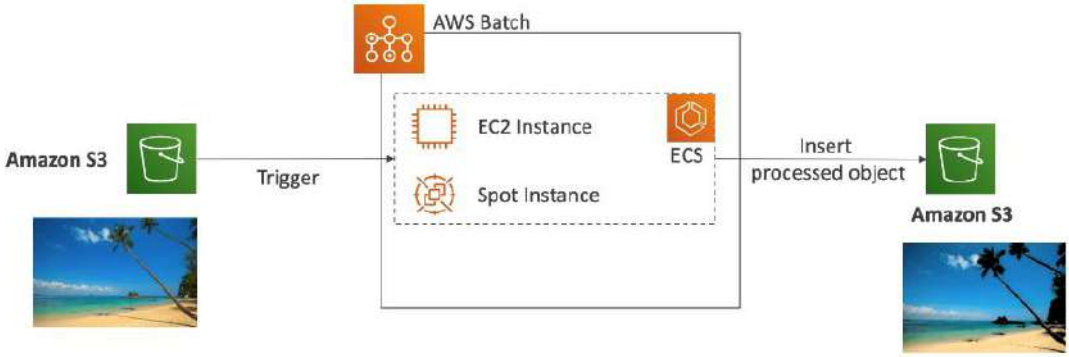
- Elastic Transcoder is used to **convert media files stored in S3 into media files in the formats required by consumer playback devices (phones etc..)**
- Benefits:
  - Easy to use
  - Highly scalable – can handle large volumes of media files and large file sizes
  - Cost effective – duration-based pricing model
  - Fully managed & secure, pay for what you use

▼ AWS Batch

AWS Batch

- **Fully managed** batch processing at **any scale**
- Efficiently run 100,000s of computing batch jobs on AWS
- A "batch" job is a job with a start and an end (opposed to continuous)
- Batch will dynamically launch **EC2 instances** or **Spot Instances**
- AWS Batch provisions the right amount of compute / memory
- You submit or schedule batch jobs and AWS Batch does the rest!
- Batch jobs are defined as **Docker images** and **run on ECS**
- Helpful for cost optimizations and focusing less on the infrastructure

AWS Batch – Simplified Example



Batch vs Lambda

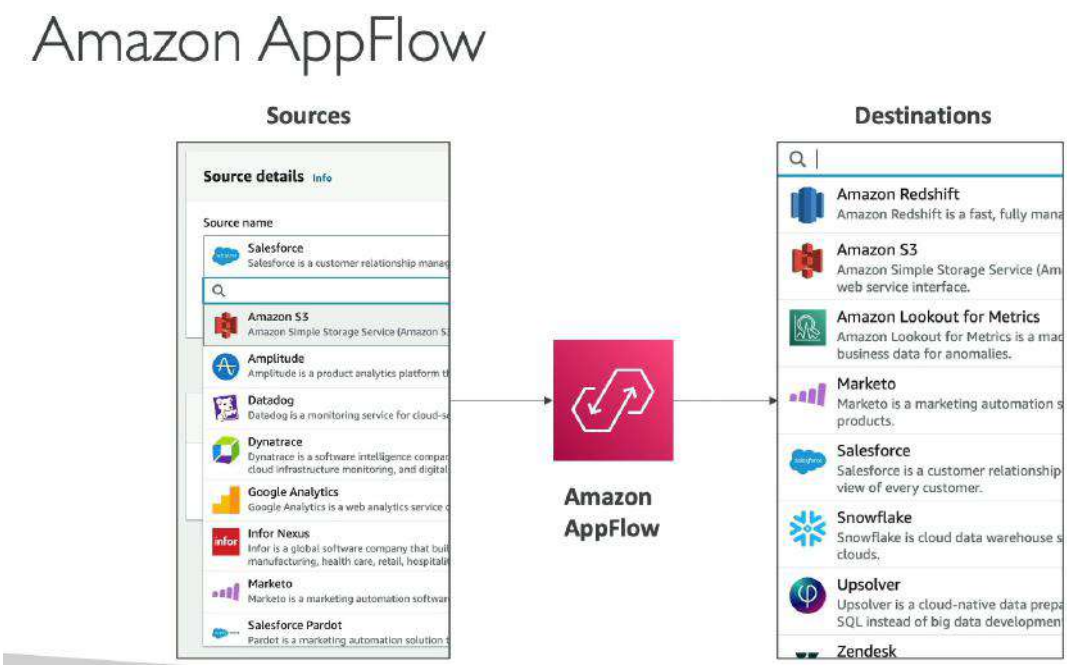
- Lambda:
  - Time limit
  - Limited runtimes
  - Limited temporary disk space
  - Serverless

- Batch:
  - No time limit
  - Any runtime as long as it's packaged as a Docker image
  - Rely on EBS / instance store for disk space
  - Relies on EC2 (can be managed by AWS)

▼ AppFlow

Amazon AppFlow

- Fully managed integration service that enables you to securely transfer data between **Software-as-a-Service (SaaS) applications and AWS**
- Sources: **Salesforce**, SAP, Zendesk, Slack, and ServiceNow
- Destinations: AWS services like **Amazon S3, Amazon Redshift** or non-AWS such as SnowFlake and Salesforce
- Frequency: on a schedule, in response to events, or on demand
- Data transformation capabilities like filtering and validation
- Encrypted over the public internet or privately over AWS PrivateLink
- Don't spend time writing the integrations and leverage APIs immediately



▼ CICD (Continuous Integration - Continuous Delivery)

▼ Continuous Integration

- Developers push the code to a code repository often (GitHub / CodeCommit / Bitbucket / etc…)
- A testing / build server checks the code as soon as it’s pushed (CodeBuild / Jenkins CI etc…)
- The developer gets feedback about the tests and checks that have passed / failed
- Find bugs early, fix bugs
- Deliver faster as the code is tested
- Deploy often
- Happier developers, as they’re unblocked

- Built-in “human intervention” step
- Example: order fulfilment from web to warehouse to delivery
- Step Functions are recommended to be used for new applications, except:
  - If you need external signals to intervene in the processes
  - If you need child processes that return values to parent processes

▼ Elastic Map Reduce (EMR)

- EMR helps creating Hadoop clusters (Big Data) to analyze and process vast amount of data
- The clusters can be made of hundreds of EC2 instances
- Also supports Apache Spark, HBase, Presto, Flink…..
- EMR takes care of all the provisioning and configuration
- Auto-scaling and integrated with Spot instances
- Use cases: data processing, machine learning, web indexing, big data…

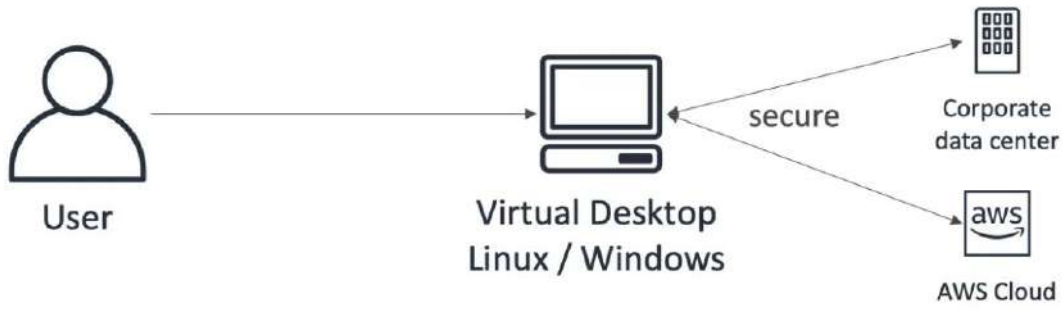
▼ OpsWorks

- Chef & Puppet are two open-source softwares that help you perform server configuration automatically, or repetitive actions
- They work great with EC2 & On Premise VM
- AWS OpsWorks is nothing but AWS Managed Chef & Puppet
- It’s an alternative to AWS SSM
- Exam tip: Chef & Puppet ⇒ AWS OpsWorks

▼ Amazon WorkSpaces

Amazon WorkSpaces is a fully managed, persistent desktop virtualization service that enables your users to access data, applications, and resources they need, anywhere, anytime, from any supported device. It can be used to provision either Windows or Linux desktops.

- Managed & Secure Cloud Desktop
- Great to eliminate management of on-premise VDI (Virtual Desktop Infrastructure)
- On Demand, pay per by usage
- Secure, Encrypted, Network Isolation
- Integrated with Microsoft Active Directory



▼ AppSync

- Store and sync data across mobile and web apps in real-time
- Makes use of GraphQL (mobile technology from Facebook)
- Client Code can be generated automatically
- Integrations with DynamoDB/ Lambda
- Real-time subscriptions

- Offline data synchronization (replaces Cognito Sync)
- Fine Grained Security

▼ Section 32: WhitePapers & Architectures

▼ AWS Well Architected Framework Guidelines

- Stop guessing your capacity needs
- Test systems at production scale
- Automate to make architectural experimentation easier
- Allow for evolutionary architectures
- Design based on changing requirements
- Drive architectures using data
- Improve through game days
  - Simulate applications for flash sale days (load testing)

▼ AWS Well Architected Framework Pillars

1. Cost Optimization
2. Performance Efficiency
3. Reliability
4. Security
5. Sustainability
6. Operational Excellence

▼ AWS Well Architected Tool

- Free tool to review your architectures against the 6 pillars Well-Architected
- Framework and adopt architectural best practices
- How does it work?
  - Select your workload and answer questions
  - Review your answers against the 6 pillars
  - Obtain advice: get videos and documentations, generate a report, see the results in a dashboard

Let's have a look: https://console.aws.amazon.com/wellarchitected

▼ AWS Trusted Advisor

- Service that analyzes your AWS accounts and provides recommendations on:
  - Cost Optimization:
    - low utilization EC2 instances, idle load balancers, under-utilized EBS volumes…
    - Reserved instances & savings plans optimizations
  - Performance:
    - High utilization EC2 instances, CloudFront CDN optimizations
    - EC2 to EBS throughput optimizations, Alias records recommendations
  - Security:
    - MFA enabled on Root Account, IAM key rotation, exposed Access Keys
    - S3 Bucket Permissions for public access, security groups with unrestricted ports
  - Fault Tolerance:
    - EBS snapshots age, Availability Zone Balance
    - ASG Multi-AZ, RDS Multi-AZ, ELB configuration, etc.

Thank You

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