

AWS Certified Solutions Architect Professional

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COURSE →



EXTRA PRACTICE EXAMS →

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- Best of luck for the exam and happy learning!

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AWS Certified Solutions Architect Professional Course

SAP-C02

Setting the right expectations for this course

- This course is all slides based
 - I'm assuming you have experience using AWS
 - No hands-on will come with the course. You should know the basics
 - It's fast paced. Your time is valuable. Feel free to slow me down to 0.75x
- If you just passed the AWS Certified Solutions Architect Associate cert
 - I recommend you go through AWS Certified Developer, SysOps & DevOps
 - I know you are eager to get the SAP certification, but take your time
- The AWS knowledge needed for the SA Pro exam
 - Is extremely similar to the knowledge for SAA
 - The questions are more complex, and knowing details is very important
 - It's possible that multiple answers are correct, but one is the most appropriate

The AWS Certified Solutions Architect Professional Exam

- Is HARD
- Tests real AWS experience
- Will test you on some very subtle service features
- I have included quizzes for every single section BUT...
 - The quizzes are not “scenario based” / “exam-like”
 - They only help you extract some important notions out of what you’re learning
 - This is my optimal way of teaching you about specific topics
 - Please trust my teaching process

Practice Exams

- This course does not come with practice exams
 - Practice Exams come separately
 - I really want to focus this course on the knowledge needed
- Warning:
 - This course is on the NEW CERTIFICATION (SAP-C02)
 - You may see outdated content in other practice exams, other courses, etc...
 - This course is not incomplete, it's more targeted towards the knowledge you actually need to know to pass the exam

Identity & Federation

IAM – What should you know by now

- Users: long term credentials
- Groups
- Roles: short-term credentials, uses STS
 - EC2 Instance Roles: uses the EC2 metadata service. One role at a time per instance
 - Service Roles: API Gateway, CodeDeploy, etc...
 - Cross Account roles
- Policies
 - AWS Managed
 - Customer Managed
 - Inline Policies
- Resource Based Policies (S3 bucket, SQS queue, etc...)

IAM Policies Deep Dive

- Anatomy of a policy: JSON doc with Effect, Action, Resource, Conditions, Policy Variables
- Explicit DENY has precedence over ALLOW
- Best practice: use least privilege for maximum security
 - Access Advisor: See permissions granted and when last accessed
 - Access Analyzer: Analyze resources that are shared with external entity
- Navigate Examples at:
https://docs.aws.amazon.com/IAM/latest/UserGuide/access_policies_examples.html

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": [  
                "ec2:AttachVolume",  
                "ec2:DetachVolume"  
            ],  
            "Resource": "arn:aws:ec2:*::instance/*",  
            "Condition": {  
                "StringEquals": {"ec2:ResourceTag/Department": "Development"}  
            }  
        },  
        {  
            "Effect": "Allow",  
            "Action": [  
                "ec2:AttachVolume",  
                "ec2:DetachVolume"  
            ],  
            "Resource": "arn:aws:ec2:*::volume/*",  
            "Condition": {  
                "StringEquals": {"ec2:ResourceTag/VolumeUser": "${aws:username}"}  
            }  
        }  
    ]  
}
```

IAM AWS Managed Policies

AdministratorAccess

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

IAM AWS Managed Policies

PowerUserAccess

```
{  
  "Version": "2012-10-17",  
  "Statement": [  
    {  
      "Effect": "Allow",  
      "NotAction": [  
        "iam:*",  
        "organizations:*",  
        "account:*"  
      ],  
      "Resource": "*"  
    },...  
    ...{  
      "Effect": "Allow",  
      "Action": [  
        "iam:CreateServiceLinkedRole",  
        "iam>DeleteServiceLinkedRole",  
        "iam>ListRoles",  
        "organizations:DescribeOrganization",  
        "account>ListRegions"  
      ],  
      "Resource": "*"  
    }  
  ]  
}
```

Note how "NotAction" is used instead of Deny

IAM Policies Conditions

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

Operators:

- String (StringEquals, StringNotEquals, StringLike...)
 - "Condition": {"StringEquals": {"aws:PrincipalTag/job-category": "iamuser-admin"}}
 - "Condition": {"StringLike": {"s3:prefix": ["", "home/", "home/\${aws:username}/"]}}
- Numeric (NumericEquals, NumericNotEquals, NumericLessThan...)
- Date (DateEquals, DateNotEquals, DateLessThan...)
- Boolean (Bool):
 - "Condition": {"Bool": {"aws:SecureTransport": "true"}}
 - "Condition": {"Bool": {"aws:MultiFactorAuthPresent": "true"}}
- (Not) IpAddress:
 - "Condition": {"IpAddress": {"aws:SourceIp": "203.0.113.0/24"}}
- ArnEquals, ArnLike
- Null: "Condition": {"Null": {"aws:TokenIssueTime": "true"}}

IAM Policies Variables and Tags

Example: \${aws:username}

- "Resource": ["arn:aws:s3:::mybucket/\${aws:username}/*"]

AWS Specific:

- aws:CurrentTime, aws:TokenIssueTime, aws:principalType, aws:SecureTransport, aws:SourceIp, aws:userId, ec2:SourceInstanceIdARN

Service Specific:

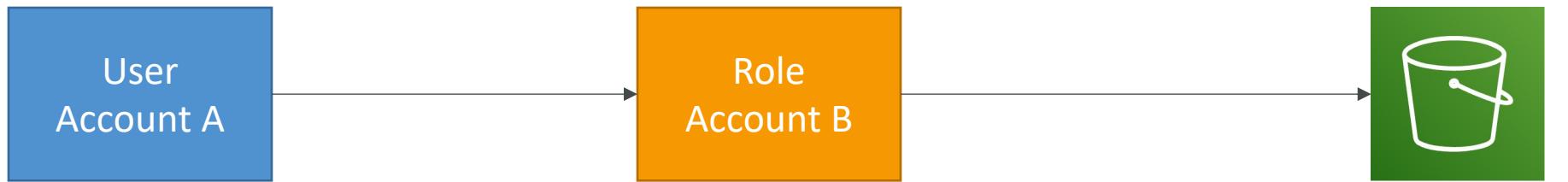
- s3:prefix, s3:max-keys, s3:x-amz-acl, sns:Endpoint, sns:Protocol...

Tag Based:

- iam:ResourceTag/key-name, aws:PrincipalTag/key-name...

IAM Roles vs Resource Based Policies

- Attach a policy to a resource (example: S3 bucket policy) versus attaching of a using a role as a proxy



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 any 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.
- Supported by: Amazon S3 buckets, SNS topics, SQS queues, Lambda functions, ECR, Backup, EFS, Glacier, Cloud9, AWS Artifact, Secrets Manager, ACM, KMS, CloudWatch Logs, API Gateway, EventBridge etc...

IAM Permission Boundaries

- IAM 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.

Example:

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": [  
                "s3:*",  
                "cloudwatch:*",  
                "ec2:*"  
            ],  
            "Resource": "*"  
        }  
    ]  
}
```



IAM Permission Boundary

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": "iam>CreateUser",  
            "Resource": "*"  
        }  
    ]  
}
```

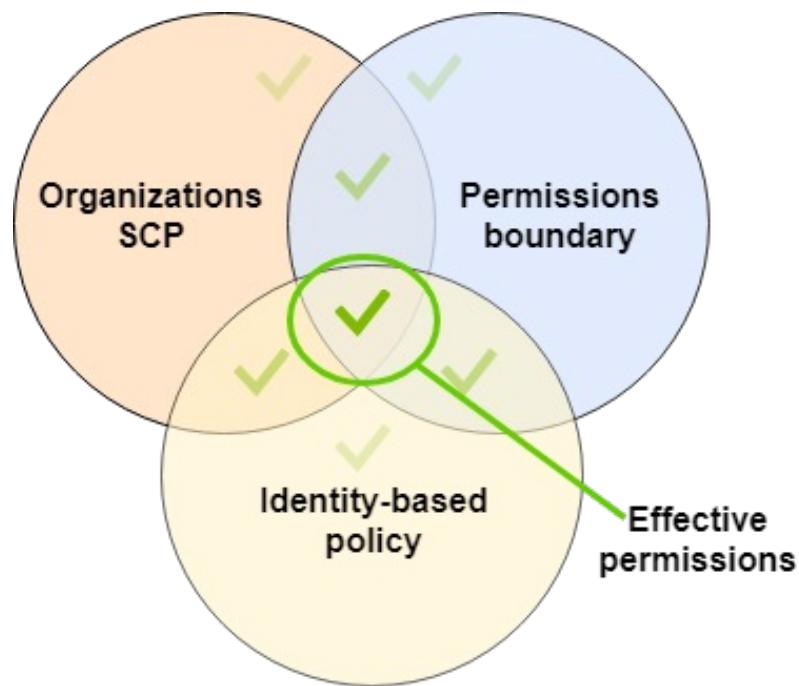
**IAM Permissions
Through IAM Policy**



No Permissions

IAM Permission Boundaries

- Can be used in combinations of AWS Organizations SCP



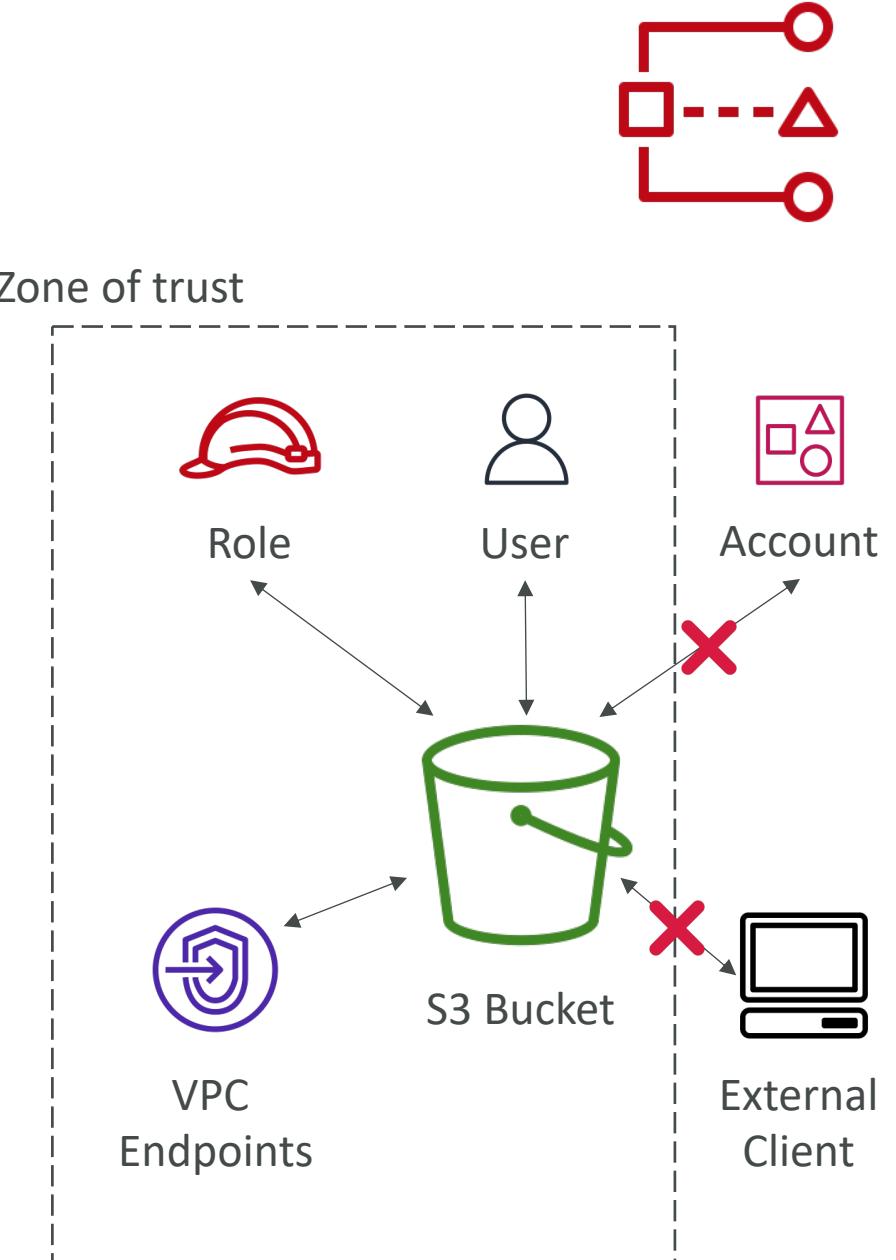
https://docs.aws.amazon.com/IAM/latest/UserGuide/access_policies_boundaries.html

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)

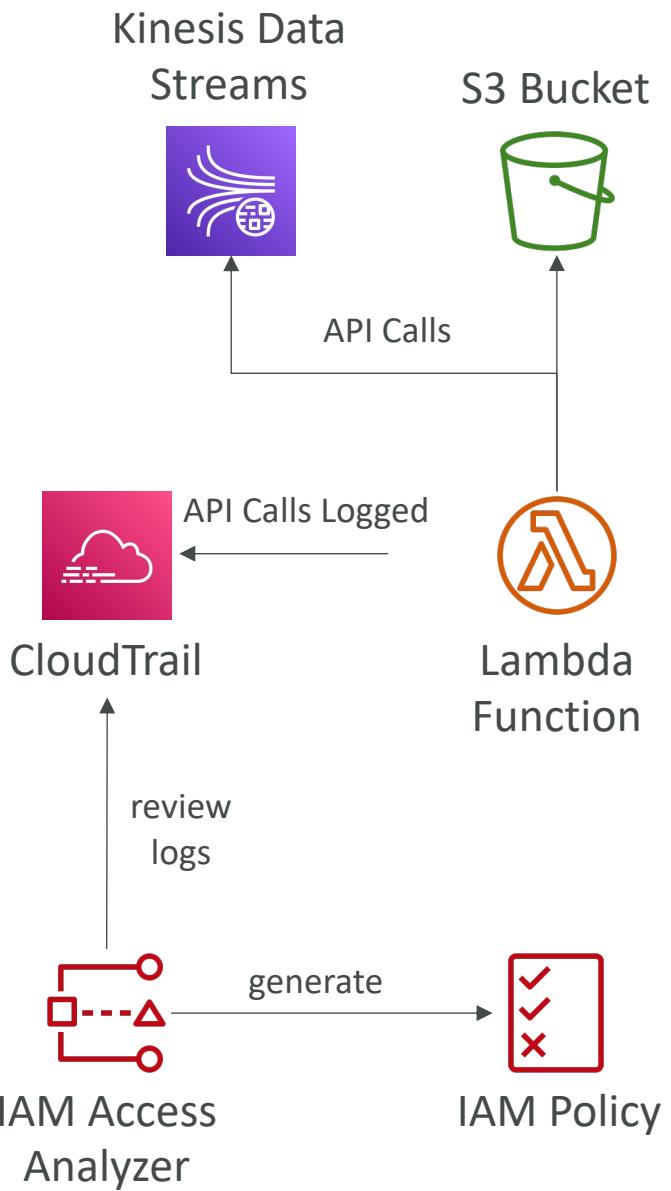
IAM Access Analyzer

- Find out which resources are shared externally
 - S3 Buckets
 - IAM Roles
 - KMS Keys
 - Lambda Functions and Layers
 - SQS queues
 - Secrets Manager Secrets
- Define **Zone of Trust** = AWS Account or AWS Organization
- Access outside zone of trusts => findings



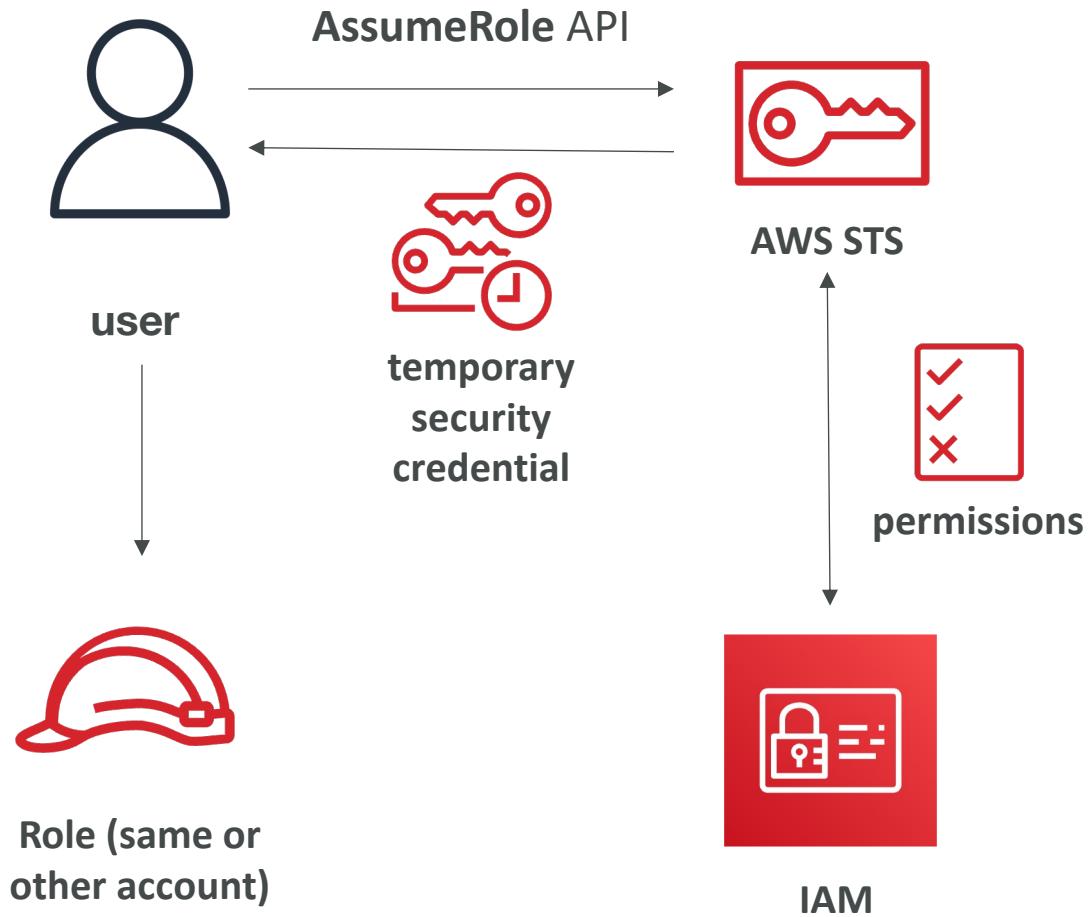
IAM Access Analyzer

- **IAM Access Analyzer Policy Validation**
 - Validates your policy against IAM policy grammar and best practices
 - General warnings, security warnings, errors, suggestions
 - Provides actionable recommendations
- **IAM Access Analyzer Policy Generation**
 - Generates IAM policy based on access activity
 - CloudTrail logs is reviewed to generate the policy with the **fine-grained permissions and the appropriate Actions and Services**
 - Reviews CloudTrail logs for up to 90 days



Using STS to Assume a Role

- Define an IAM Role within your account or cross-account
- Define which principals can access this IAM Role
- Use AWS STS (Security Token Service) to retrieve credentials and impersonate the IAM Role you have access to (`AssumeRole API`)
- Temporary credentials can be valid between 15 minutes to 12 hour



Assuming a Role with STS

- Provide access for an IAM user in one AWS account that you own to access resources in another account that you own
- Provide access to IAM users in AWS accounts owned by third parties
- Provide access for services offered by AWS to AWS resources
- Provide access for externally authenticated users (identity federation)
- Ability to revoke active sessions and credentials for a role
(by adding a policy using a time statement – AWSRevokeOlderSessions)

When you assume a role (user, application or service), you give up your original permissions and take the permissions assigned to the role

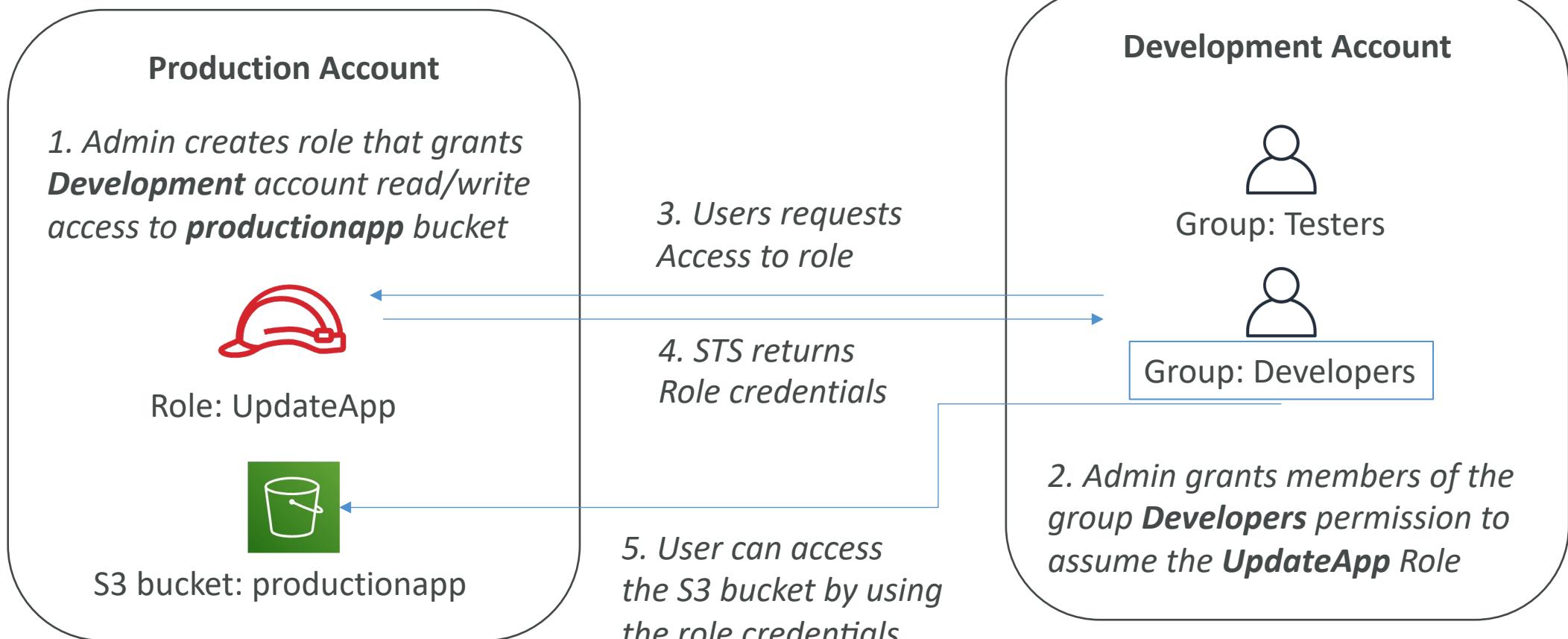
Providing Access to an IAM User in Your or Another AWS Account That You Own

- You can grant your IAM users permission to switch to roles within your AWS account or to roles defined in other AWS accounts **that you own**.



- Benefits:
 - You must explicitly grant your users permission to assume the role.
 - Your users must actively switch to the role using the AWS Management Console or assume the role using the AWS CLI or AWS API
 - **You can add multi-factor authentication (MFA) protection to the role** so that only users who sign in with an MFA device can assume the role
 - Least privilege + auditing using CloudTrail

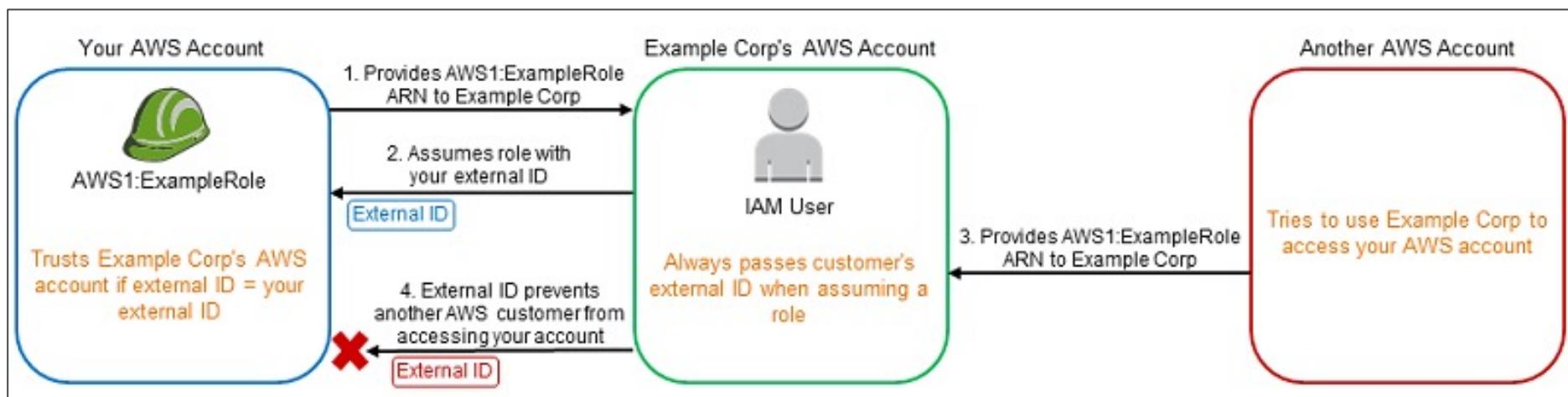
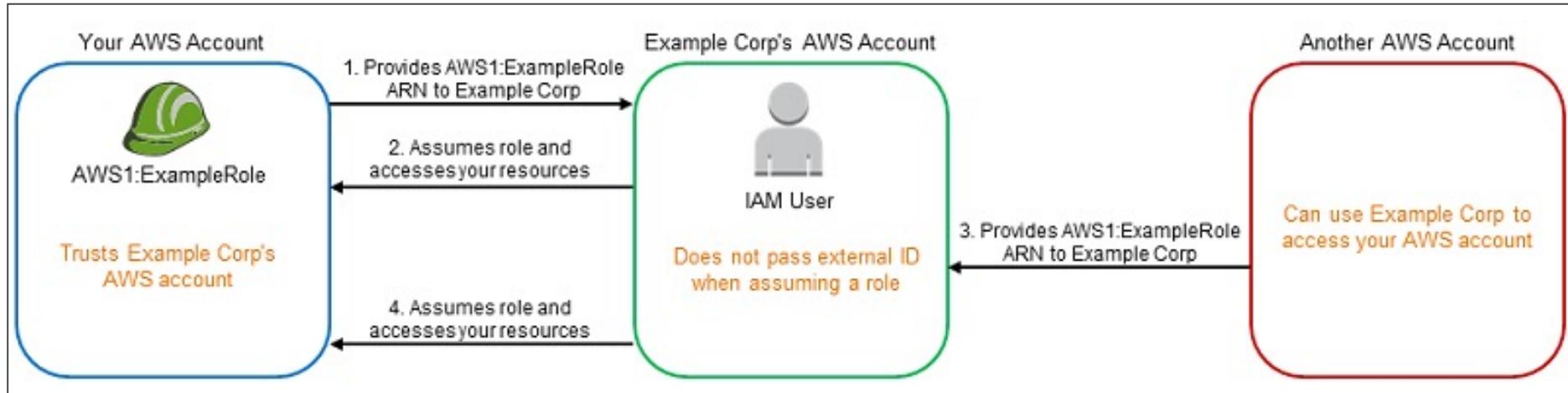
Cross account access with STS



Providing Access to AWS Accounts Owned by Third Parties

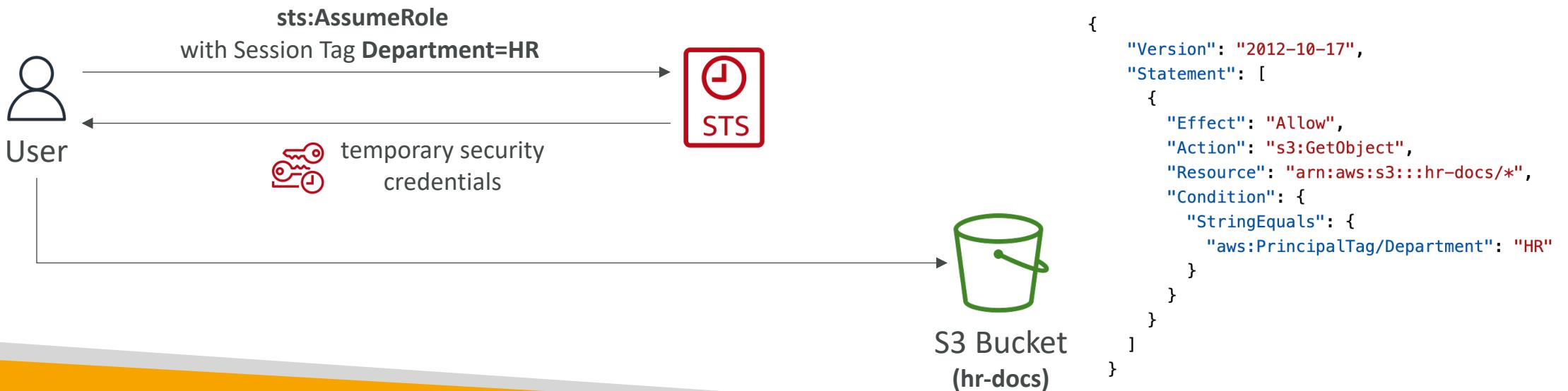
- Zone of trust = accounts, organizations that you own
- Outside Zone of Trust = 3rd parties
- Use IAM Access Analyzer to find out which resources are exposed
- For granting access to a 3rd party:
 - The 3rd party AWS account ID
 - An **External ID** (secret between you and the 3rd party)
 - To uniquely associate with the role between you and 3rd party
 - Must be provided when defining the trust and when assuming the role
 - Must be chosen by the 3rd party
 - Define permissions in the IAM policy

The confused deputy



Session Tags in STS

- Tags that you pass when you assume an IAM Role or federate user in STS
- aws:PrincipalTag Condition
 - Compares the tags attached to the principal making the request with the tag you specified in the policy
 - Example: allow a principal to pass session tags only if the principal making the request has the specified tags

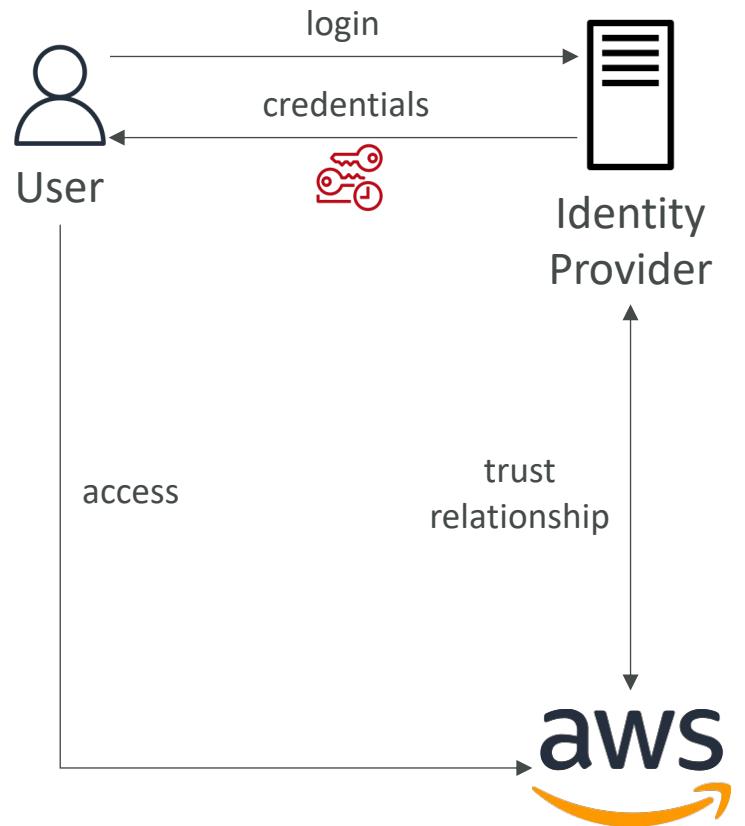


STS Important APIs

- **AssumeRole**: access a role within your account or cross-account
- **AssumeRoleWithSAML**: return credentials for users logged with SAML
- **AssumeRoleWithWebIdentity**: return creds for users logged with an IdP
 - Example providers include Amazon Cognito, Login with Amazon, Facebook, Google, or any OpenID Connect-compatible identity provider
 - AWS recommends using Cognito instead
- **GetSessionToken**: for MFA, from a user or AWS account root user
- **GetFederationToken**: obtain temporary creds for a federated user, usually a proxy app that will give the creds to a distributed app inside a corporate network

Identity Federation in AWS

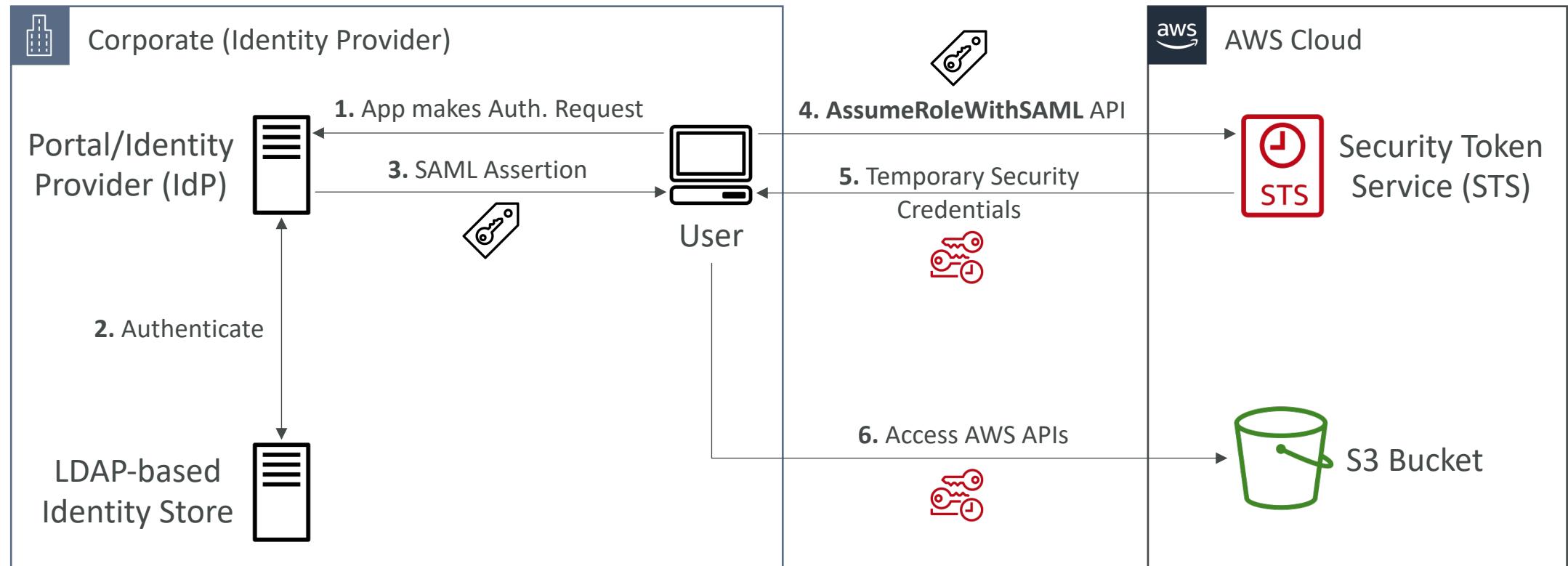
- Give users outside of AWS permissions to access AWS resources in your account
- You don't need to create IAM Users (user management is outside AWS)
- Use cases:
 - A corporate has its own identity system (e.g., Active Directory)
 - Web/Mobile application that needs access to AWS resources
- Identity Federation can have many flavors:
 - SAML 2.0
 - Custom Identity Broker
 - Web Identity Federation With(out) Amazon Cognito
 - Single Sign-On (SSO)



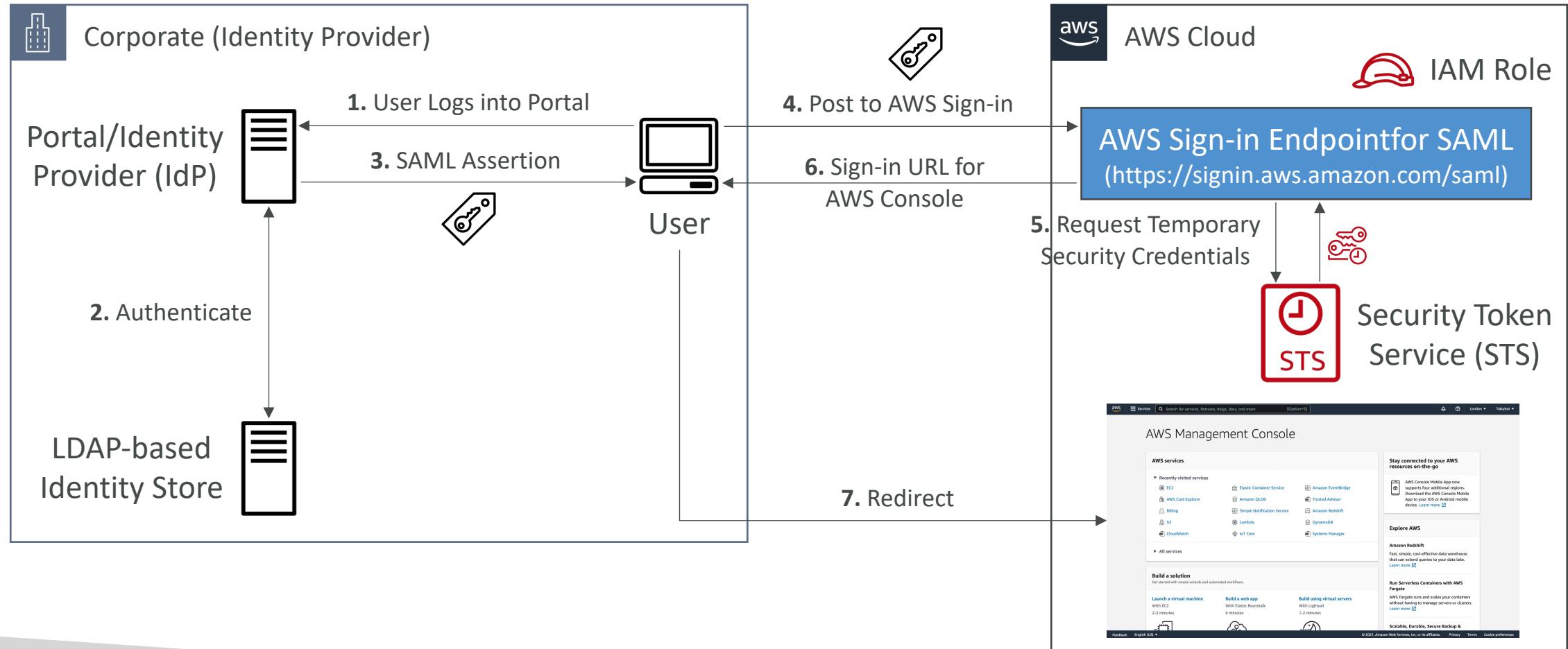
SAML 2.0 Federation

- Security Assertion Markup Language 2.0 (SAML 2.0)
- Open standard used by many identity providers (e.g., ADFS)
 - Supports integration with Microsoft Active Directory Federations Services (ADFS)
 - Or any SAML 2.0–compatible IdPs with AWS
- Access to AWS Console, AWS CLI, or AWS API using temporary credentials
 - No need to create IAM Users for each of your employees
 - Need to setup a trust between AWS IAM and SAML 2.0 Identity Provider (both ways)
- Under-the-hood: Uses the STS API `AssumeRoleWithSAML`
- SAML 2.0 Federation is the “old way”, Amazon Single Sign-On (AWS SSO) Federation is the new managed and simpler way
 - <https://aws.amazon.com/blogs/security/enabling-federation-to-aws-using-windows-active-directory-adfs-and-saml-2-0/>

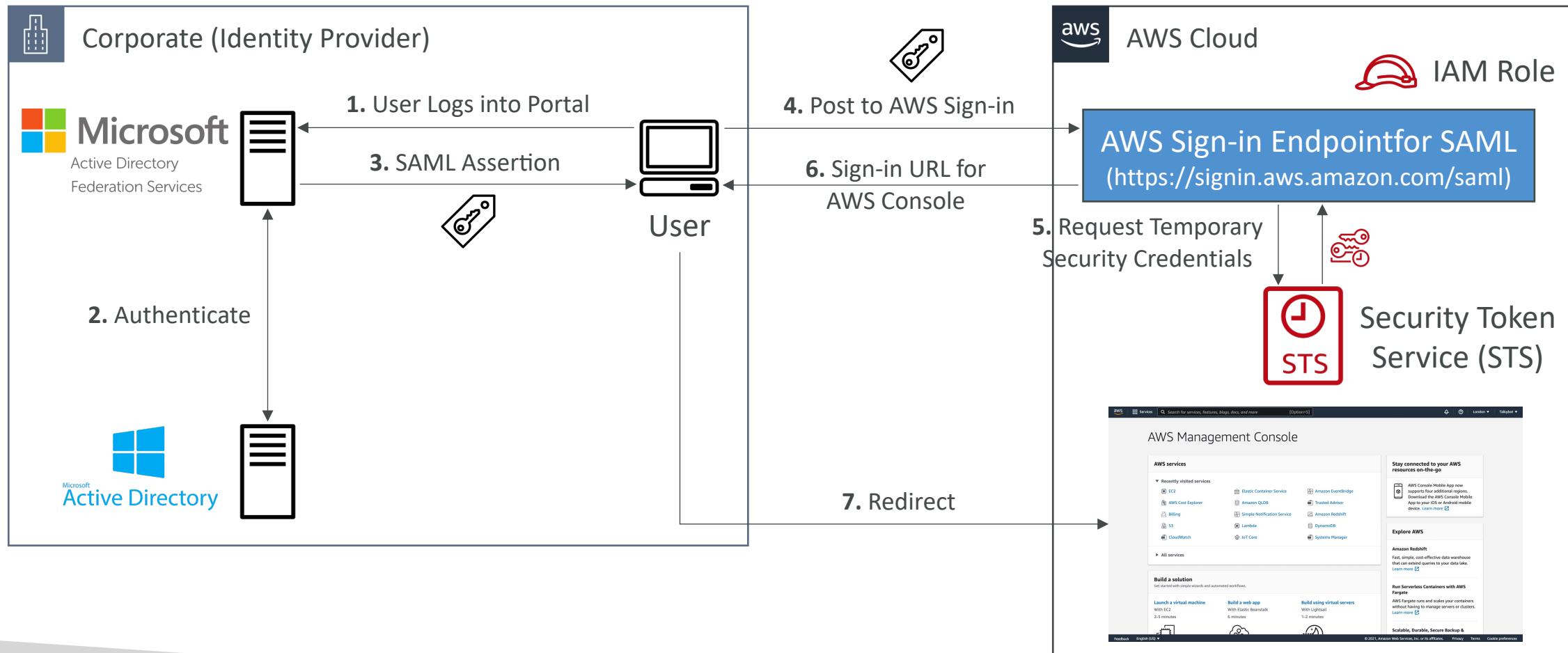
SAML 2.0 Federation – AWS API Access



SAML 2.0 Federation – AWS Console Access

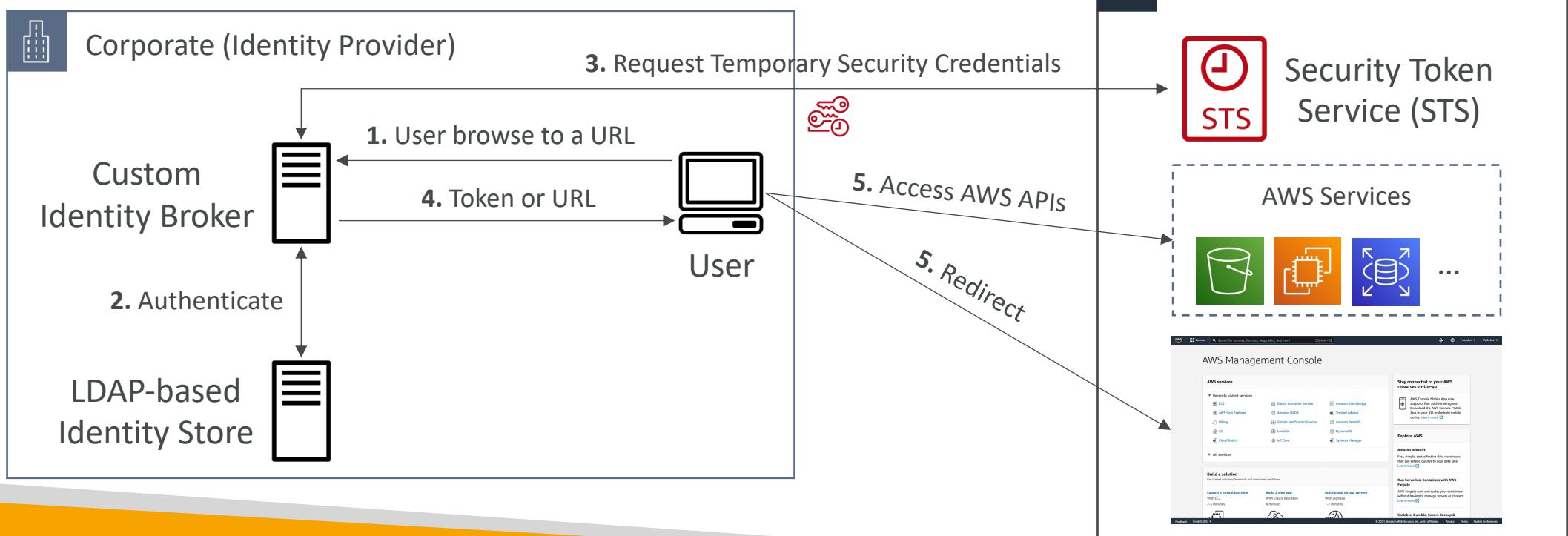


SAML 2.0 Federation – Active Directory FS (ADFS)



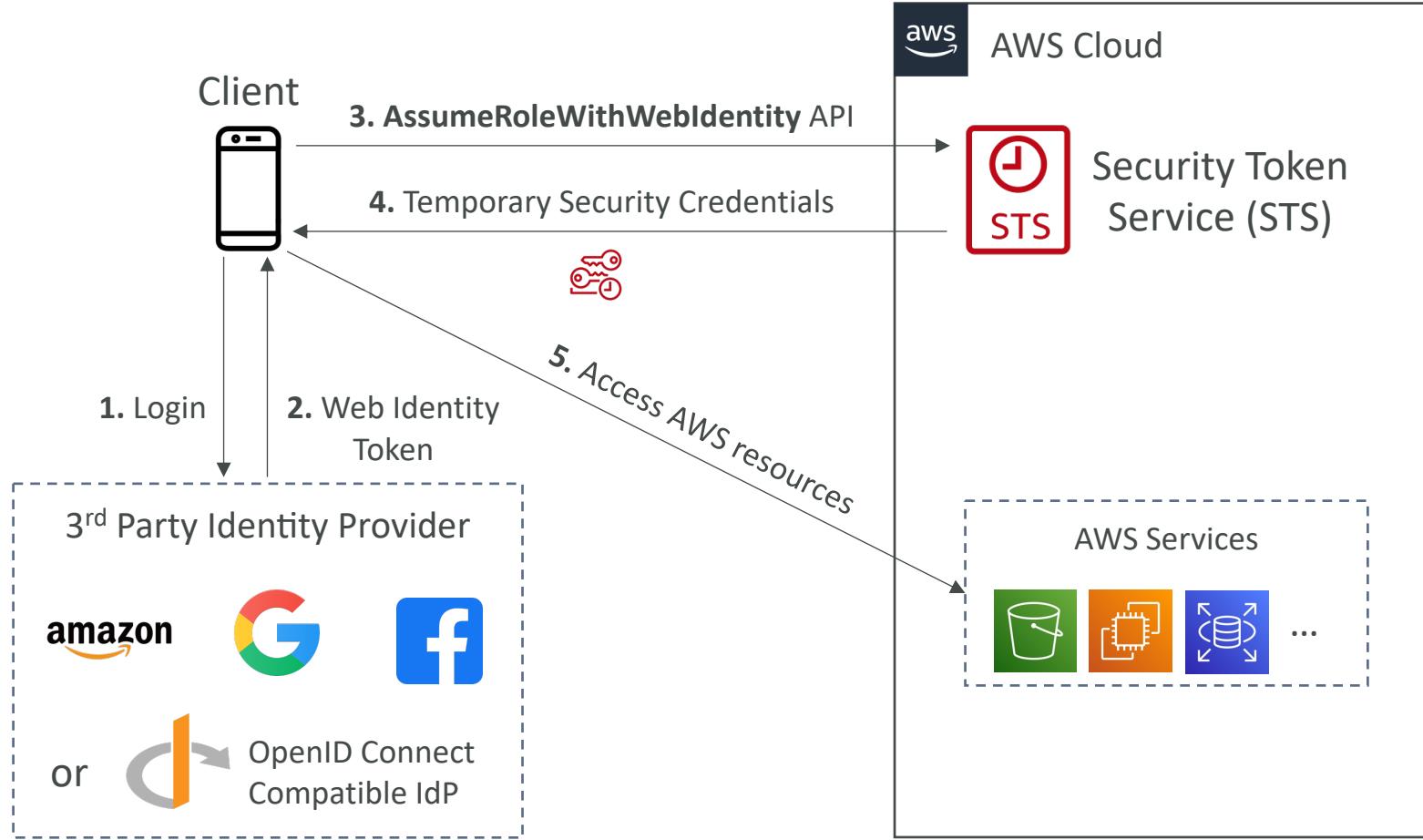
Custom Identity Broker Application

- Use only if Identity Provider is **NOT** compatible with SAML 2.0
- The Identity Broker Authenticates users & requests temporary credentials from AWS
- The Identity Broker must determine the appropriate IAM Role
- Uses the STS API AssumeRole or GetFederationToken



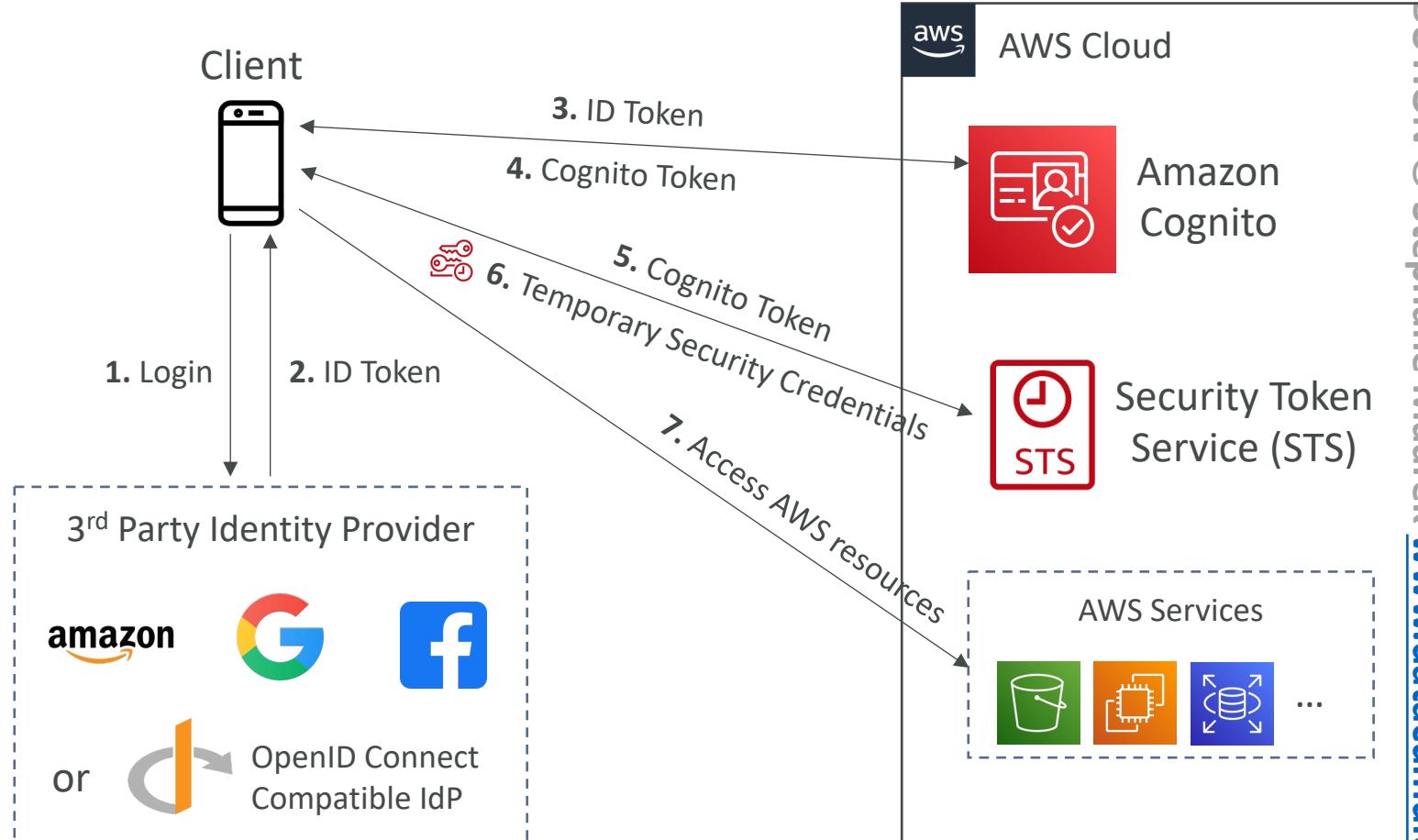
Web Identity Federation – Without Cognito

- Not recommended by AWS – use Cognito instead



Web Identity Federation – With Cognito

- Preferred over Web Identity Federation
 - Create IAM Roles using Cognito with the least privilege needed
 - Build trust between the OIDC IdP and AWS
- Cognito benefits:
 - Supports anonymous users
 - Supports MFA
 - Data Synchronization
- Cognito replaces a Token Vending Machine (TVM)



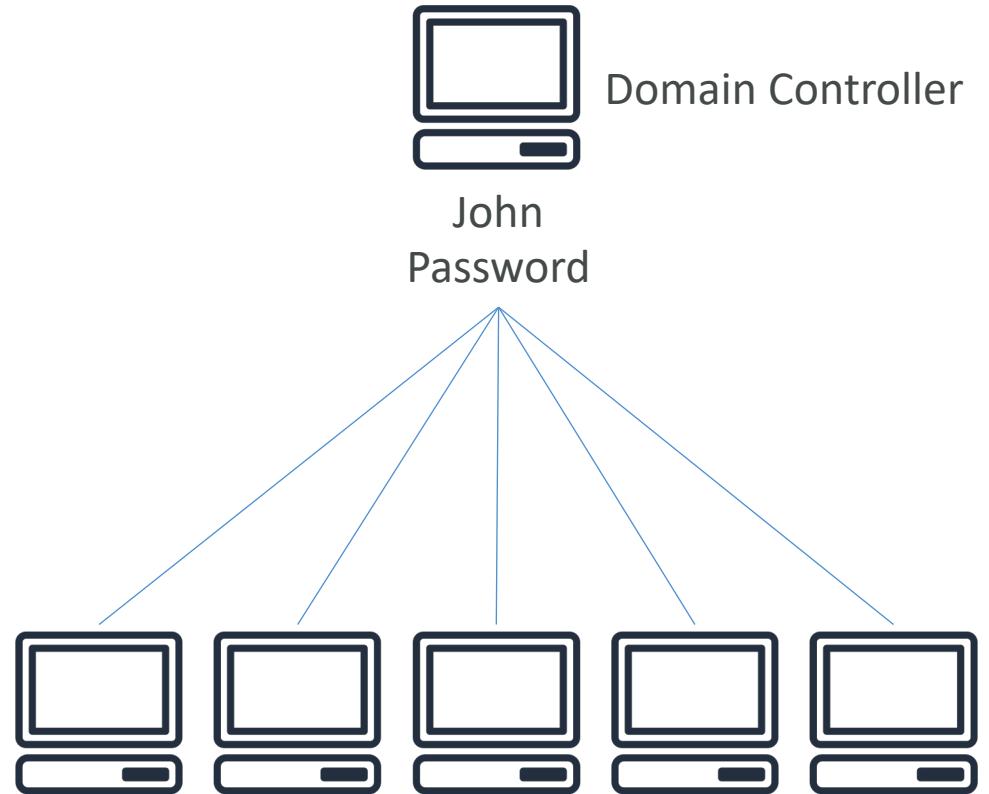
Web Identity Federation – IAM Policy

- After being authenticated with Web Identity Federation, you can identify the user with an IAM policy variable
- Examples:
 - cognito-identity.amazonaws.com:sub
 - www.amazon.com:user_id
 - graph.facebook.com:id
 - accounts.google.com:sub

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": "s3>ListBucket",  
            "Resource": "arn:aws:s3:::myBucket",  
            "Condition": {  
                "StringLike": {  
                    "s3:prefix": "Amazon/mynumbersgame/${www.amazon.com:user_id}/*"  
                }  
            }  
        }, {  
            "Effect": "Allow",  
            "Action": ["s3:GetObject", "s3:PutObject", "s3>DeleteObject"],  
            "Resource": [  
                "arn:aws:s3:::myBucket/Amazon/mynumbersgame/${www.amazon.com:user_id}",  
                "arn:aws:s3:::myBucket/Amazon/mynumbersgame/${www.amazon.com:user_id}/*"  
            ]  
        }  
    ]  
}
```

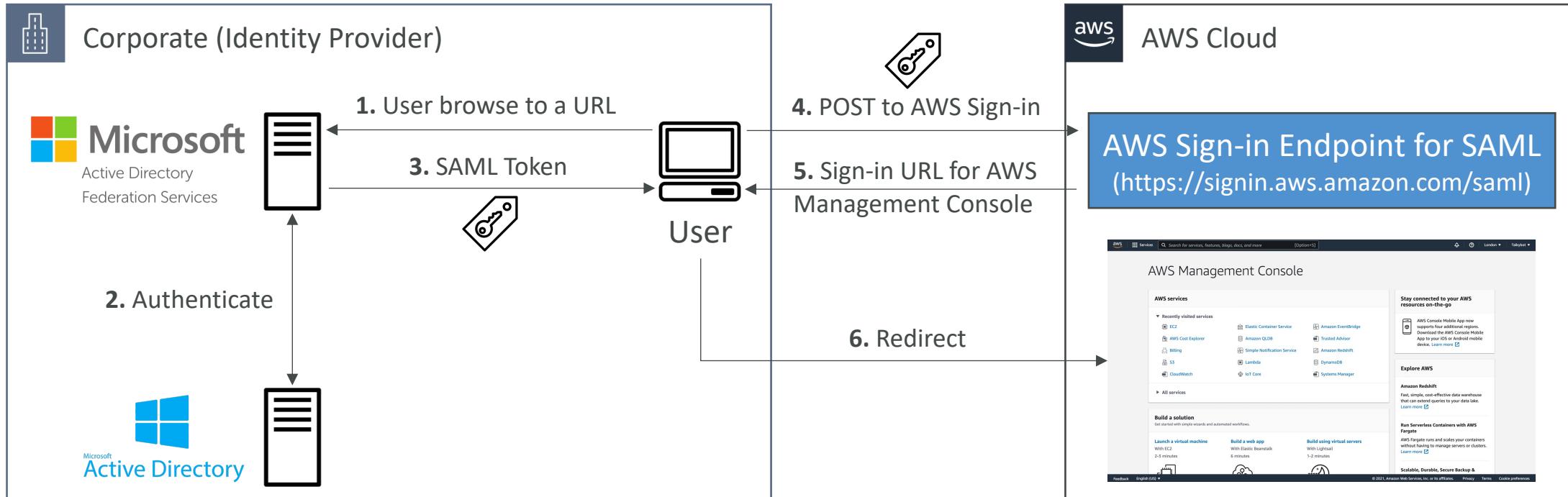
What is Microsoft Active Directory (AD)?

- Found on any Windows Server with AD Domain Services
- Database of **objects**: User Accounts, Computers, Printers, File Shares, Security Groups
- Centralized security management, create account, assign permissions
- Objects are organized in **trees**
- A group of trees is a **forest**



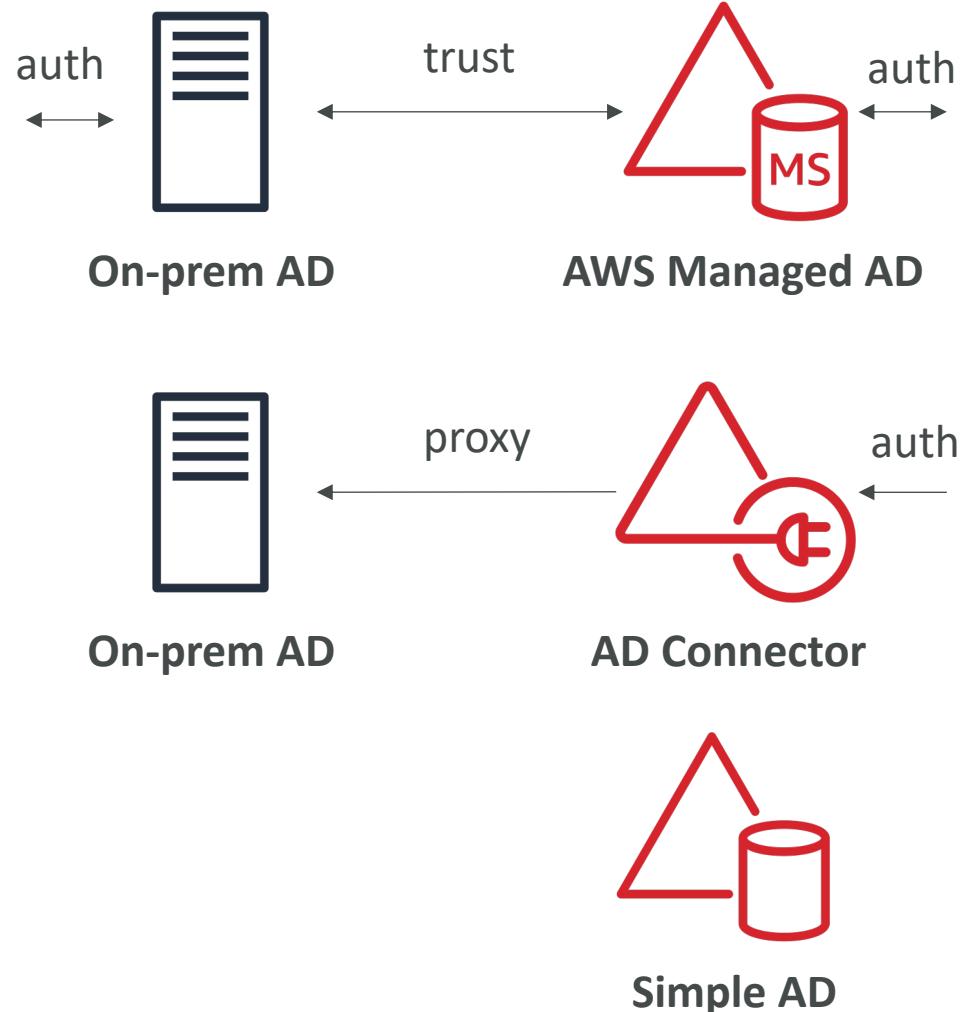
What is ADFS (AD Federation Services)?

- ADFS provides Single Sign-On across applications
- SAML across 3rd party: AWS Console, Dropbox, Office365, etc...



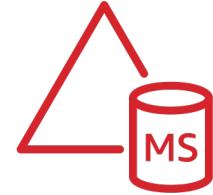
AWS Directory Services

- AWS Managed Microsoft AD
 - Create your own AD in AWS, manage users locally, supports MFA
 - Establish “trust” connections with your on-premises AD
- AD Connector
 - Directory Gateway (proxy) to redirect to on-premises AD, supports MFA
 - Users are managed on the on-premises AD
- Simple AD
 - AD-compatible managed directory on AWS
 - Cannot be joined with on-premises AD

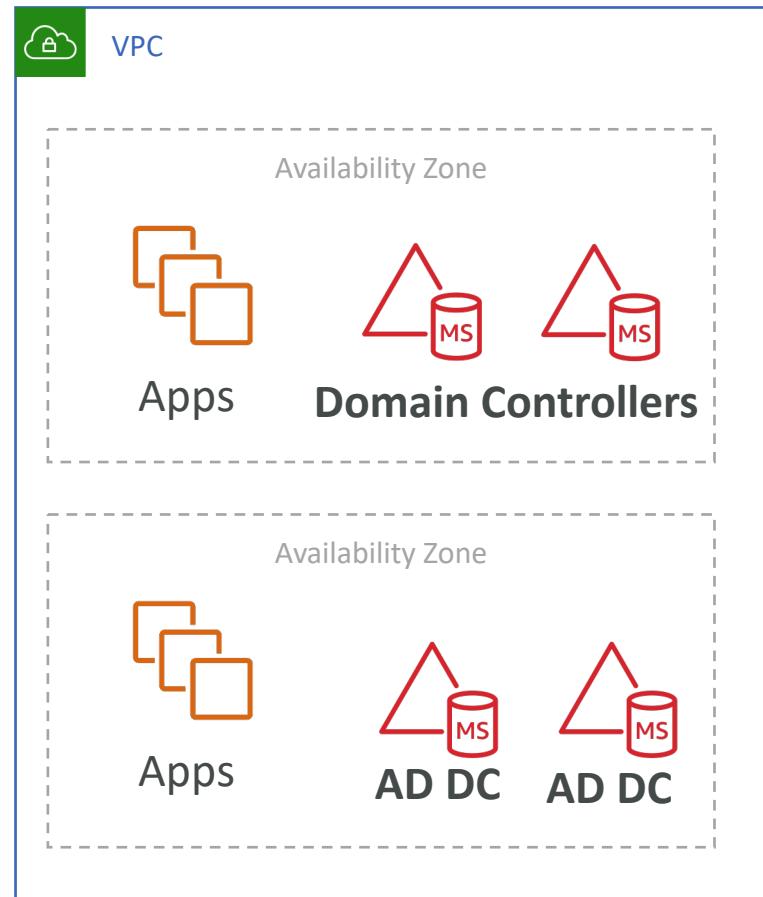


AWS Directory Services

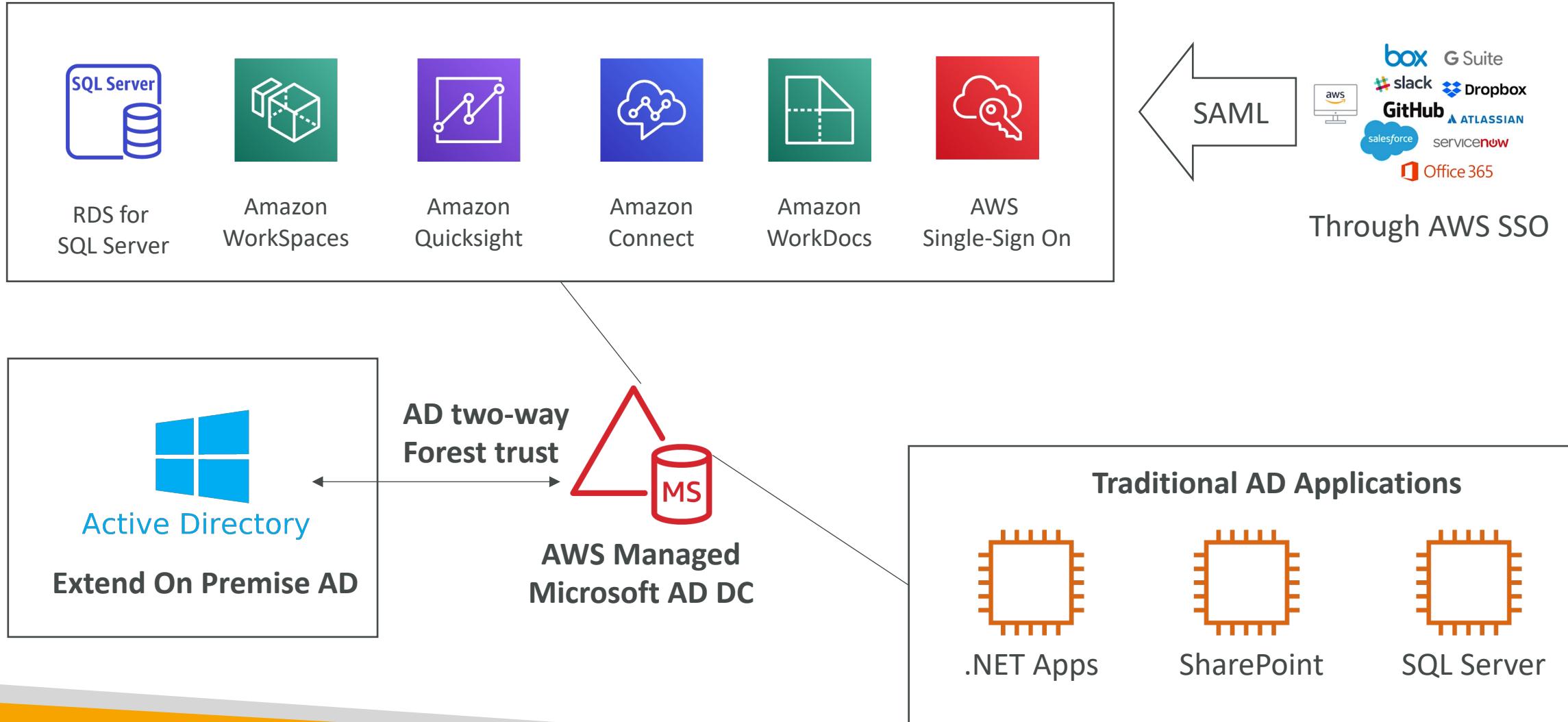
AWS Managed Microsoft AD



- Managed Service: Microsoft AD in your AWS VPC
- EC2 Windows Instances:
 - EC2 Windows instances can join the domain and run traditional AD applications (sharepoint, etc)
 - Seamlessly Domain Join Amazon EC2 Instances from Multiple Accounts & VPCs
- Integrations:
 - RDS for SQL Server, AWS Workspaces, Quicksight...
 - AWS SSO to provide access to 3rd party applications
- Standalone repository in AWS or joined to on-premises AD
- Multi AZ deployment of AD in 2 AZ, # of DC (Domain Controllers) can be increased for scaling
- Automated backups
- Automated Multi-Region replication of your directory

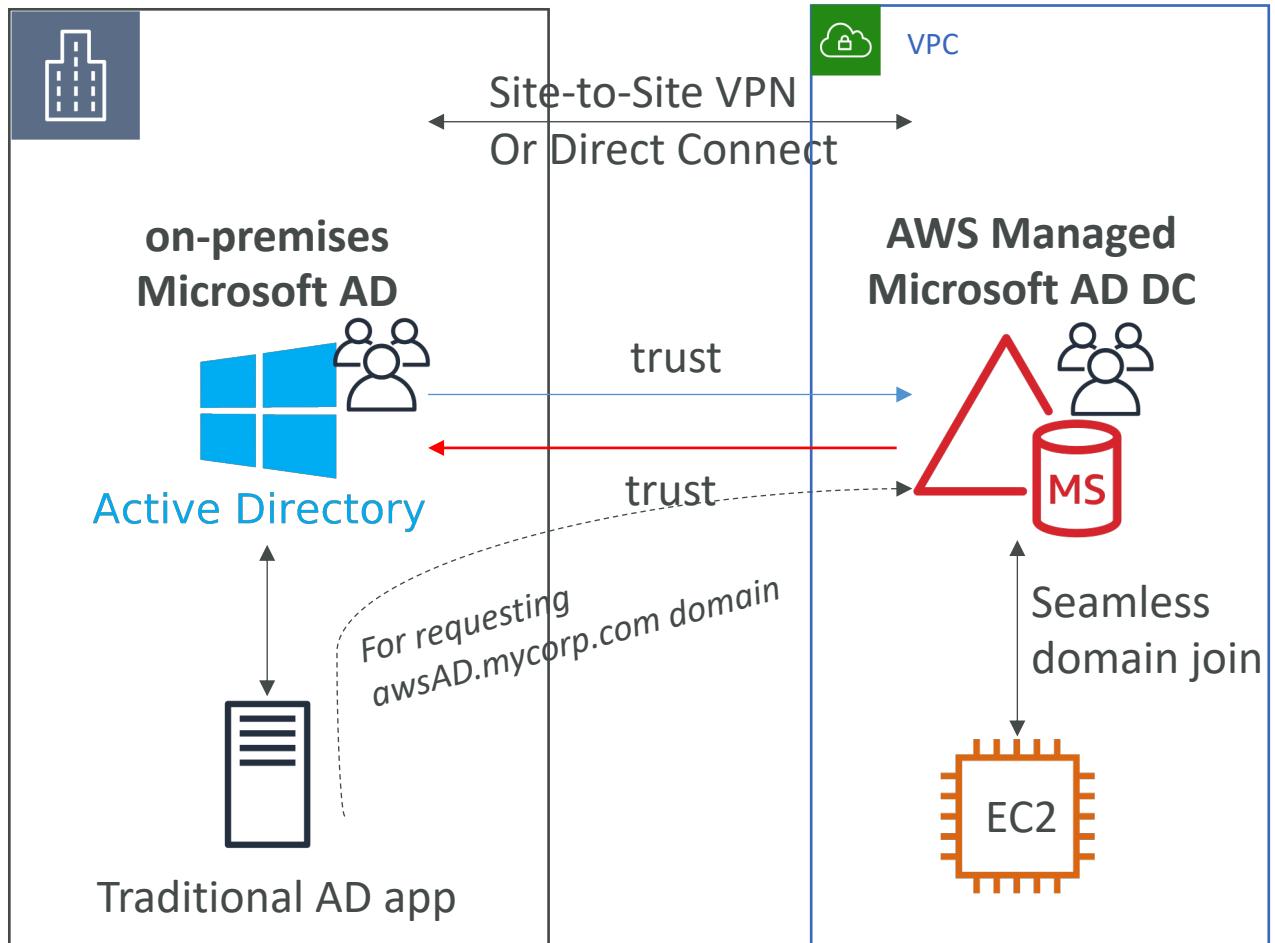


AWS Microsoft Managed AD - Integrations



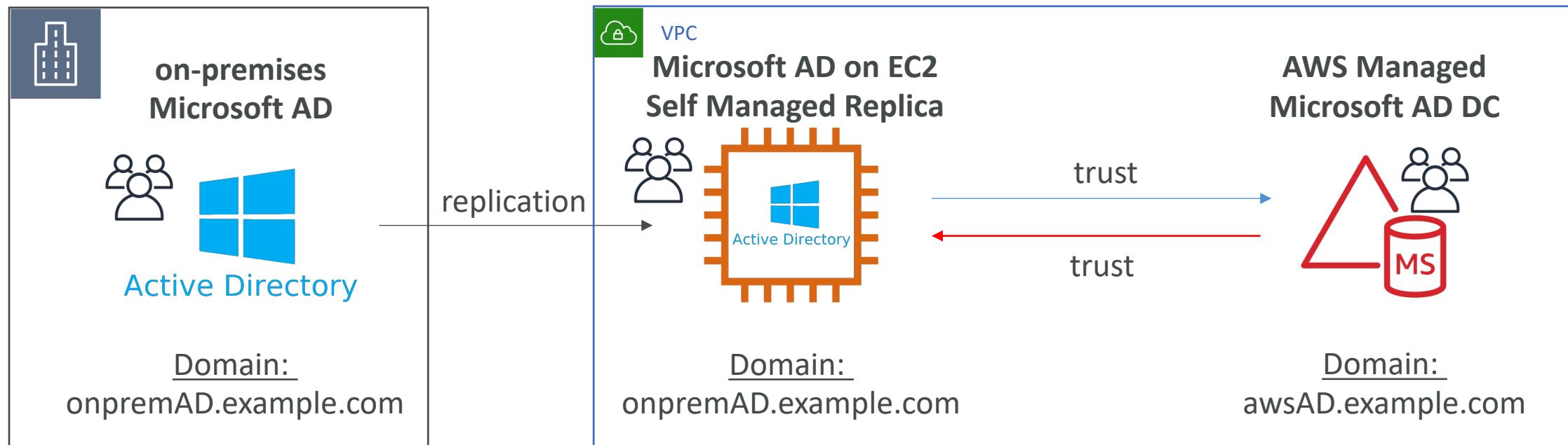
Connect to on-premises AD

- Ability to connect your on-premises Active Directory to AWS Managed Microsoft AD
- Must establish a Direct Connect (DX) or VPN connection
- Can setup three kinds of forest trust:
 - One-way trust: AWS => on-premises
 - One-way trust: on-premises => AWS
 - Two-way forest trust: AWS ⇄ on-premises
- Forest trust is different than synchronization



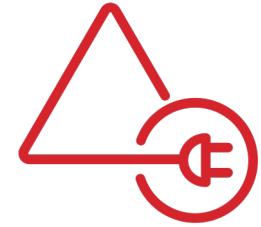
Solution Architecture: Active Directory Replication

- You may want to create a replica of your AD on EC2 in the cloud to minimize latency of in case DX or VPN goes down
- Establish trust between the AWS Managed Microsoft AD and EC2

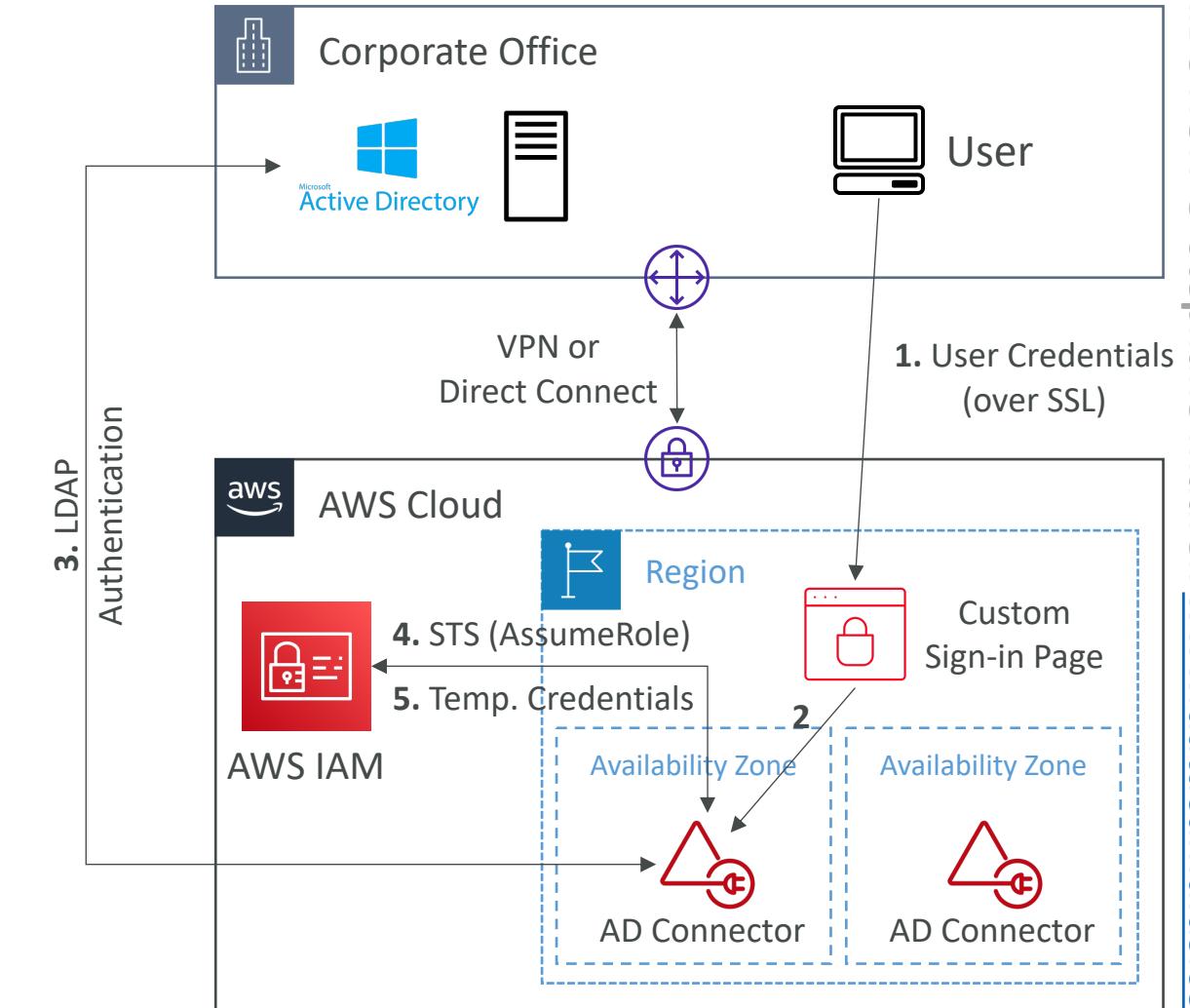


AWS Directory Services

AD Connector



- AD Connector is a directory gateway to redirect directory requests to your on-premises Microsoft Active Directory
- No caching capability
- Manage users solely on-premises, no possibility of setting up a trust
- VPN or Direct Connect
- Doesn't work with SQL Server, doesn't do seamless joining, can't share directory



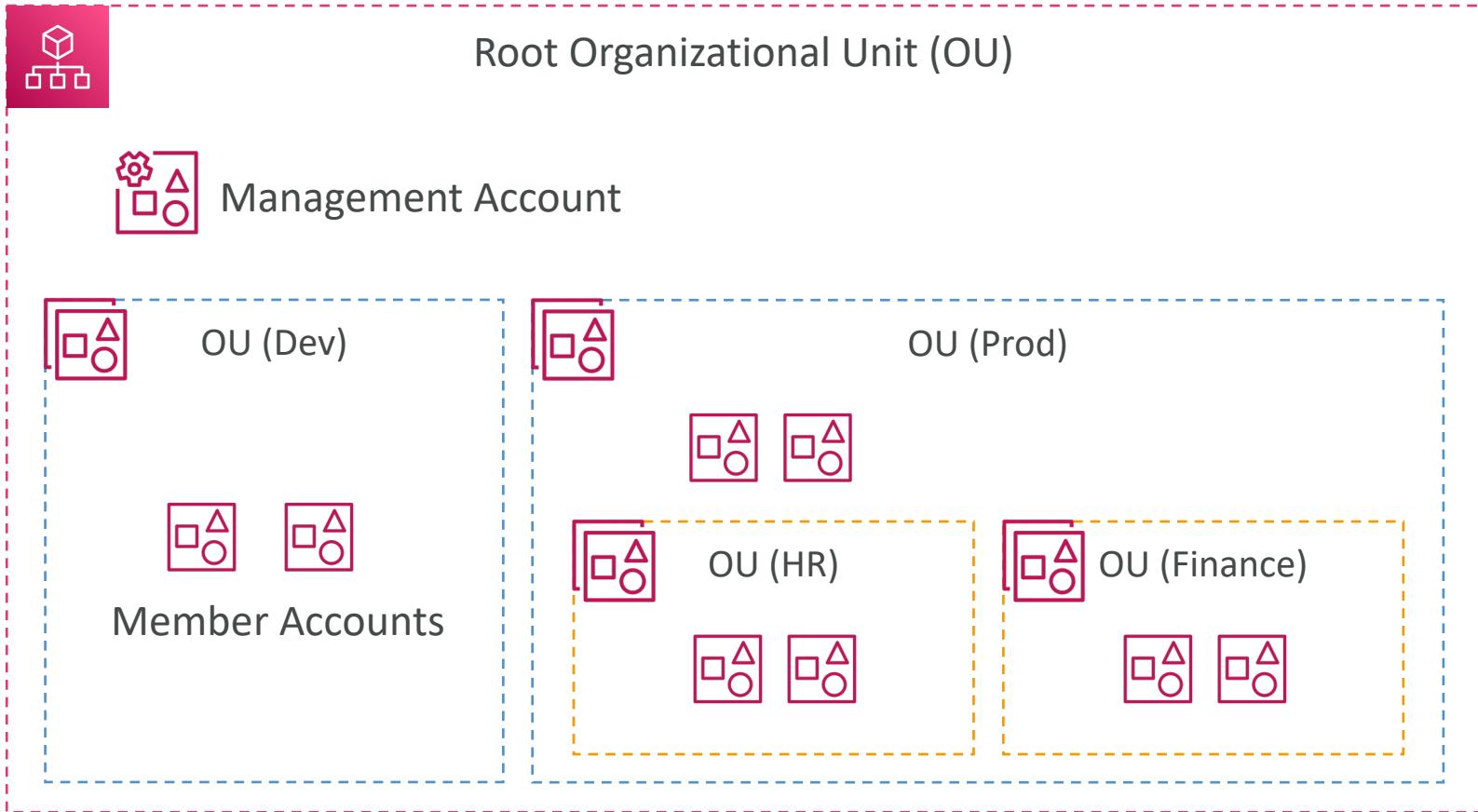
AWS Directory Services

Simple AD



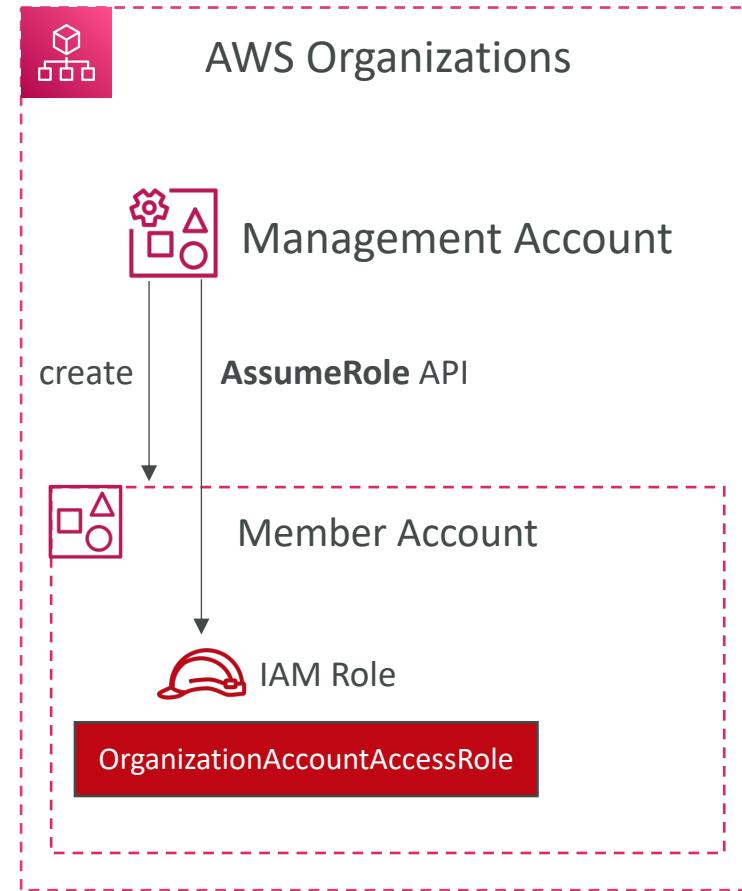
- Simple AD is an inexpensive Active Directory–compatible service with the common directory features.
- Supports joining EC2 instances, manage users and groups
- Does not support MFA, RDS SQL server, AWS SSO
- Small: 500 users, large: 5000 users
- Powered by Samba 4, compatible with Microsoft AD
- lower cost, low scale, basic AD compatible, or LDAP compatibility
- No trust relationship

AWS Organizations



AWS Organizations - OrganizationAccountAccessRole

- IAM role which grants full administrator permissions in the Member account to the Management account
- Used to perform admin tasks in the Member accounts (e.g., creating IAM users)
- Could be assumed by IAM users in the Management account
- Automatically added to all new Member accounts created with AWS Organizations
- Must be created manually if you invite an existing Member account

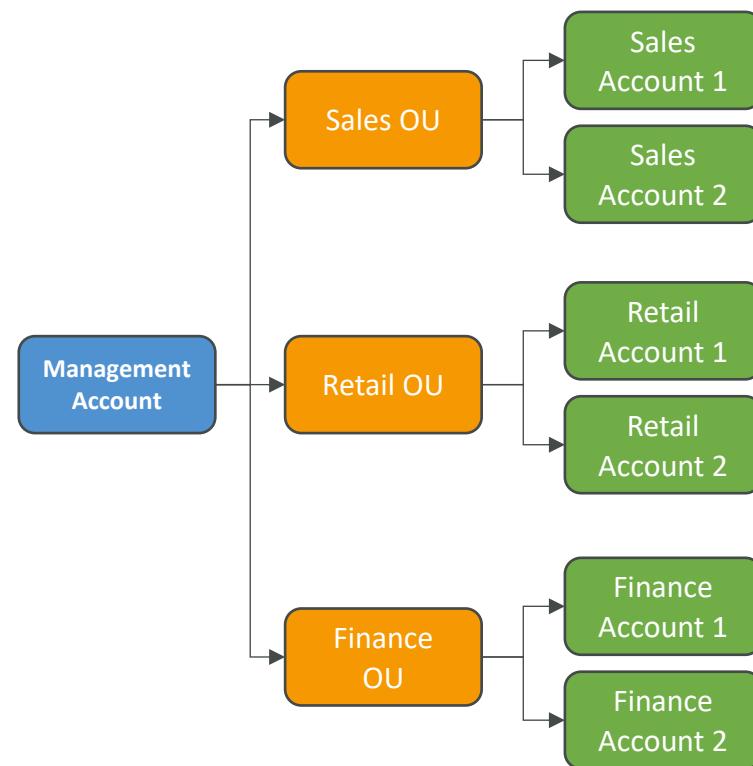


Multi Account Strategies

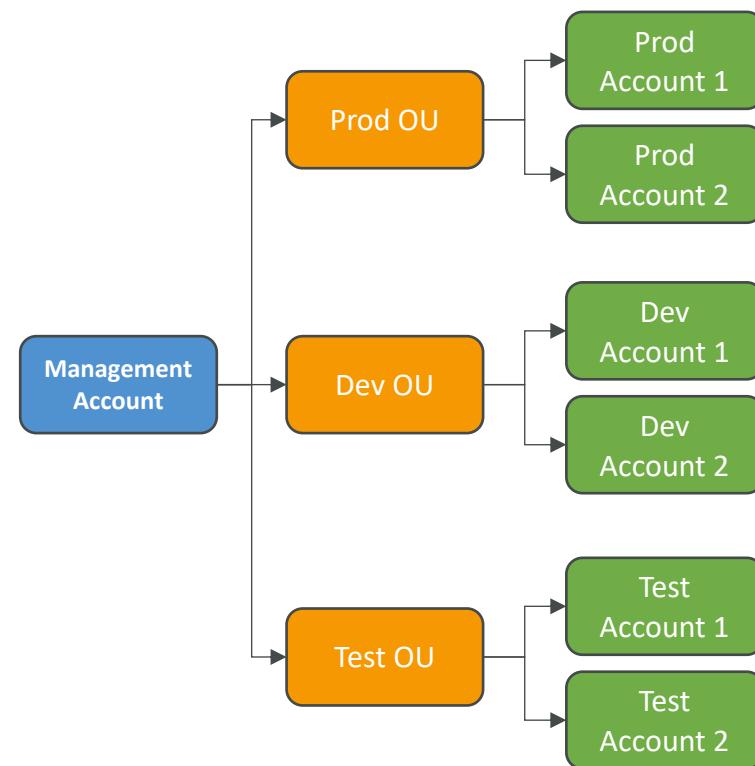
- Create accounts per **department**, per **cost center**, per **dev / test / prod**, based on **regulatory restrictions** (using SCP), for **better resource isolation** (ex:VPC), to have **separate per-account service limits**, isolated account for **logging**,
- Multi Account vs. One Account Multi VPC
- Use tagging standards for billing purposes
- Enable CloudTrail on all accounts, send logs to central S3 account
- Send CloudWatch Logs to central logging account
- Strategy to create an account for security

Organizational Units (OU) - Examples

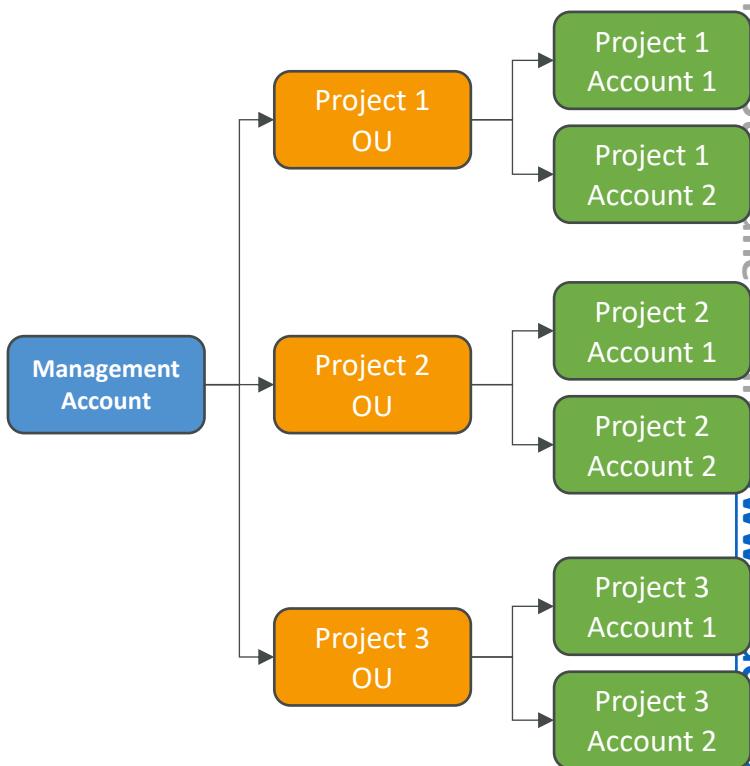
Business Unit



Environmental Lifecycle



Project-Based



AWS Organization - Feature Modes

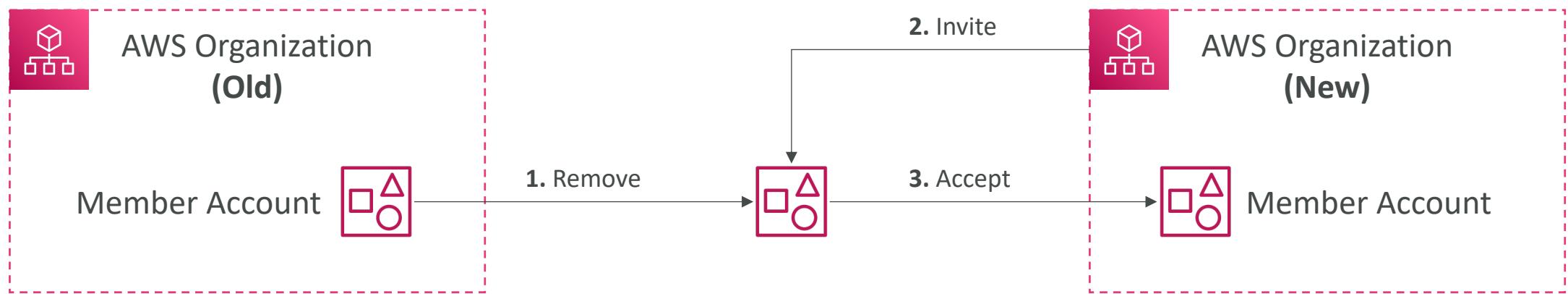
- Consolidated billing features:
 - Consolidated Billing across all accounts - single payment method
 - Pricing benefits from aggregated usage (volume discount for EC2, S3...)
- All Features (Default):
 - Includes consolidated billing features, SCP
 - Invited accounts must approve enabling all features
 - Ability to apply an SCP to prevent member accounts from leaving the org
 - Can't switch back to Consolidated Billing Features only

AWS Organizations – Reserved Instances

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

AWS Organizations – Moving Accounts

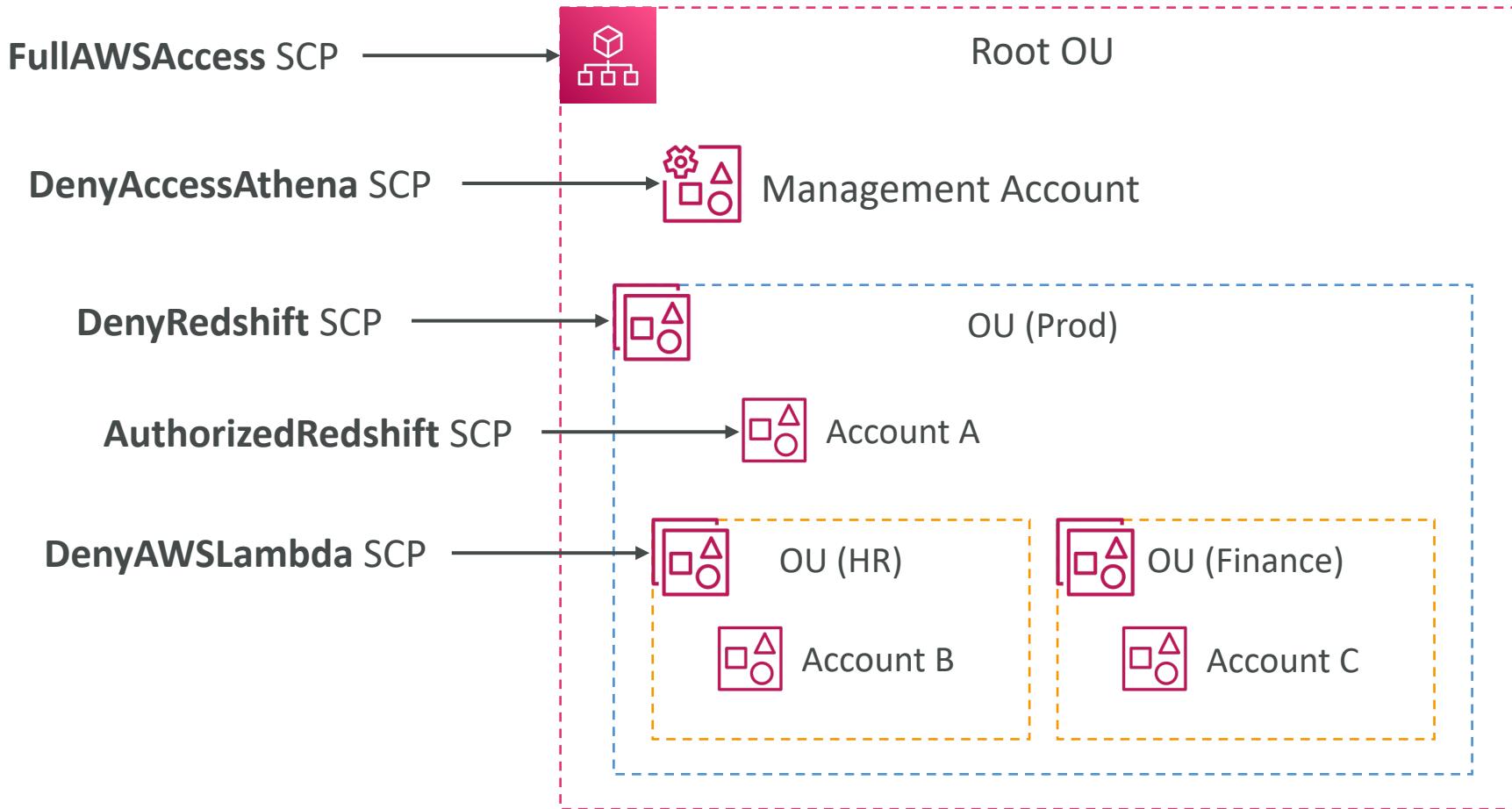
1. Remove the member account from the AWS Organization
2. Send an invite to the member account from the AWS Organization
3. Accept the invite to the new Organization from the member account



Service Control Policies (SCP)

- Define allowlist or blocklist IAM actions
- Applied at the **OU** or **Account** level
- Does not apply to the Management Account
- SCP is applied to all the **Users and Roles** in the account, including Root user
- 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

SCP Hierarchy



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

SCP Examples

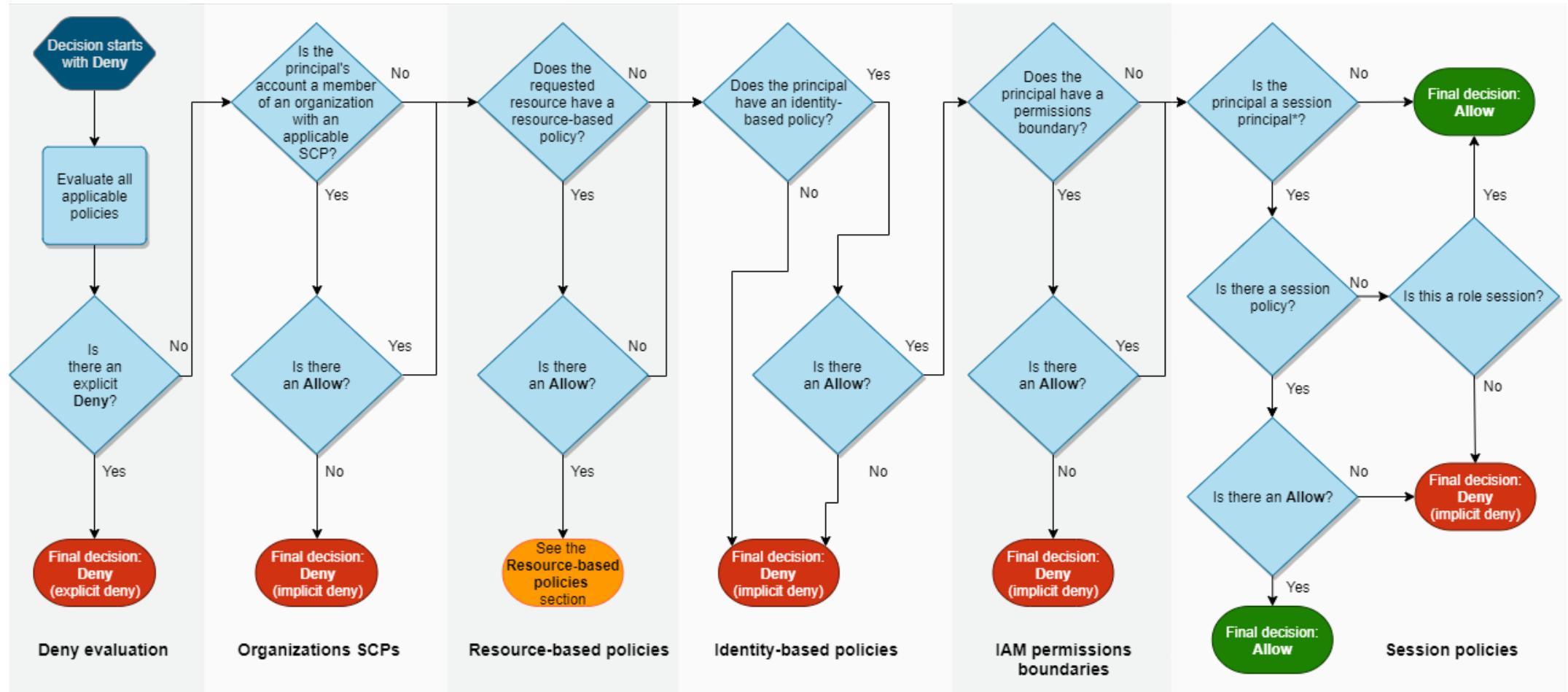
Blocklist and Allowlist strategies

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

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

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

IAM Policy Evaluation Logic



*A session principal is either a role session or an IAM federated user session.

https://docs.aws.amazon.com/IAM/latest/UserGuide/reference_policies_evaluation-logic.html

Restricting Tags with IAM Policies

- You can restrict specific Tags on AWS resources
- Using the `aws:TagKeys` Condition Key
 - Validate the Tag Keys attached to a resource against the Tag Keys in the IAM Policy
- Example: allow IAM users to create EBS Volumes only if it has the “Env” and “CostCenter” Tags
- Use either `ForAllValues` (must have all keys) or `ForAnyValue` (must have any of these keys at a minimum)

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": "ec2:CreateVolume",  
            "Resource": "arn:aws:ec2:*::volume/*",  
            "Condition": {  
                "ForAllValues:StringEquals": {  
                    "aws:TagKeys": ["Env", "CostCenter"]  
                }  
            }  
        }  
    ]  
}
```

Match All Keys

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": "ec2:CreateVolume",  
            "Resource": "arn:aws:ec2:*::volume/*",  
            "Condition": {  
                "ForAnyValue:StringEquals": {  
                    "aws:TagKeys": ["Env", "CostCenter"]  
                }  
            }  
        }  
    ]  
}
```

Match Any Keys

Using SCP to Deny a Region aws:RequestRegion

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Deny",  
            "Action": ["ec2:*", "rds:*", "dynamodb:*"],  
            "Resource": "*",  
            "Condition": {  
                "StringEquals": {  
                    "aws:RequestedRegion": ["eu-central-1", "eu-west-1"]  
                },  
                "ArnNotLike": {  
                    "aws:PrincipalARN": [  
                        "arn:aws:iam::*:role/Role1AllowedToBypassThisSCP",  
                        "arn:aws:iam::*:role/Role2AllowedToBypassThisSCP"  
                    ]  
                }  
            }  
        }  
    ]  
}
```

Using SCP to Restrict Creating Resources without appropriate Tags

- Prevent IAM Users/Roles in the affected Member accounts from creating resources if they don't have a specific Tags
- Example: restrict launching an EC2 instance if it doesn't have the “Project” and “CostCenter” Tags

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Sid": "DenyRunInstanceWithNoProjectTag",  
            "Effect": "Deny",  
            "Action": "ec2:RunInstances",  
            "Resource": ["arn:aws:ec2:***:instance/*", "arn:aws:ec2:***:volume/*"],  
            "Condition": {  
                "Null": {  
                    "aws:RequestTag/Project": "true"  
                }  
            }  
        },  
        {  
            "Sid": "DenyRunInstanceWithNoCostCenterTag",  
            "Effect": "Deny",  
            "Action": "ec2:RunInstances",  
            "Resource": ["arn:aws:ec2:***:instance/*", "arn:aws:ec2:***:volume/*"],  
            "Condition": {  
                "Null": {  
                    "aws:RequestTag/CostCenter": "true"  
                }  
            }  
        }  
    ]  
}
```

AWS Organizations – Tag Policies

- Helps you standardize tags across resources in an AWS Organization
- Ensure consistent tags, audit tagged resources, maintain proper resources categorization, ...
- You define Tag keys and their allowed values
- Helps with AWS Cost Allocation Tags and Attribute-based Access Control
- Prevent any non-compliant tagging operations on specified services and resources
- Generate a report that lists all tagged/non-compliant resources
- Use Amazon EventBridge to monitor non-compliant tags

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

AWS Organizations – AI Services Opt-out Policies

- Certain AWS AI services may use your content for continuous improvement of Amazon AI/ML services
- Example: Amazon Lex, Amazon Comprehend, Amazon Polly, ...
- You can opt-out of having your content stored or used by AWS AI services
- Create an Opt-out Policy that enforces this setting across all Member accounts and AWS Regions
- You can opt-out all AI services or selected services
- Can be attached to Organization Root, specific OU, or individual Member account

```
{  
  "services": {  
    "default": {  
      "opt_out_policy": {  
        "@@assign": "optOut"  
      }  
    }  
  }  
}  
  
All Services
```

```
{  
  "services": {  
    "rekognition": {  
      "opt_out_policy": {  
        "@@assign": "optOut"  
      }  
    },  
    "lex": {  
      "opt_out_policy": {  
        "@@assign": "optOut"  
      }  
    }  
  }  
}  
  
ONLY Rekognition & Lex
```

AWS Organizations – Backup Policies

- AWS Backup enables you to create Backup Plans that define how to backup your AWS resources
- JSON documents that define Backup Plans across an AWS Organization
- Gives you granular control over backing up your resources (e.g., backup frequency, time window, backup region, ...)
- Can be attached to Organization Root, specific OU, or individual Member account
- **Immutable** Backup Plans appear in Member accounts (view ONLY)

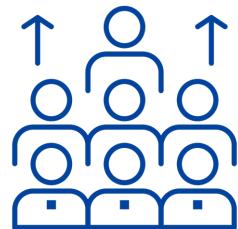
```
{  
  "plans": {  
    "PII_Backup_Plan": {  
      "regions": {  
        "@@assign": ["us-east-1"]  
      },  
      "rules": {  
        "My_Hourly_Rule": {  
          "schedule_expression": { "@@assign": "cron(0 5 * * *)" },  
          "start_backup_window_minutes": { "@@assign": "60" },  
          "complete_backup_window_minutes": { "@@assign": "604800" },  
          "enable_continuous_backup": { "@@assign": false },  
          "target_backup_vault_name": { "@@assign": "My_Backup_Vault" },  
          "lifecycle": {  
            "move_to_cold_storage_after_days": { "@@assign": "180" },  
            "delete_after_days": { "@@assign": "270" }  
          }  
        }  
      }  
    }  
  }  
}
```

AWS IAM Identity Center

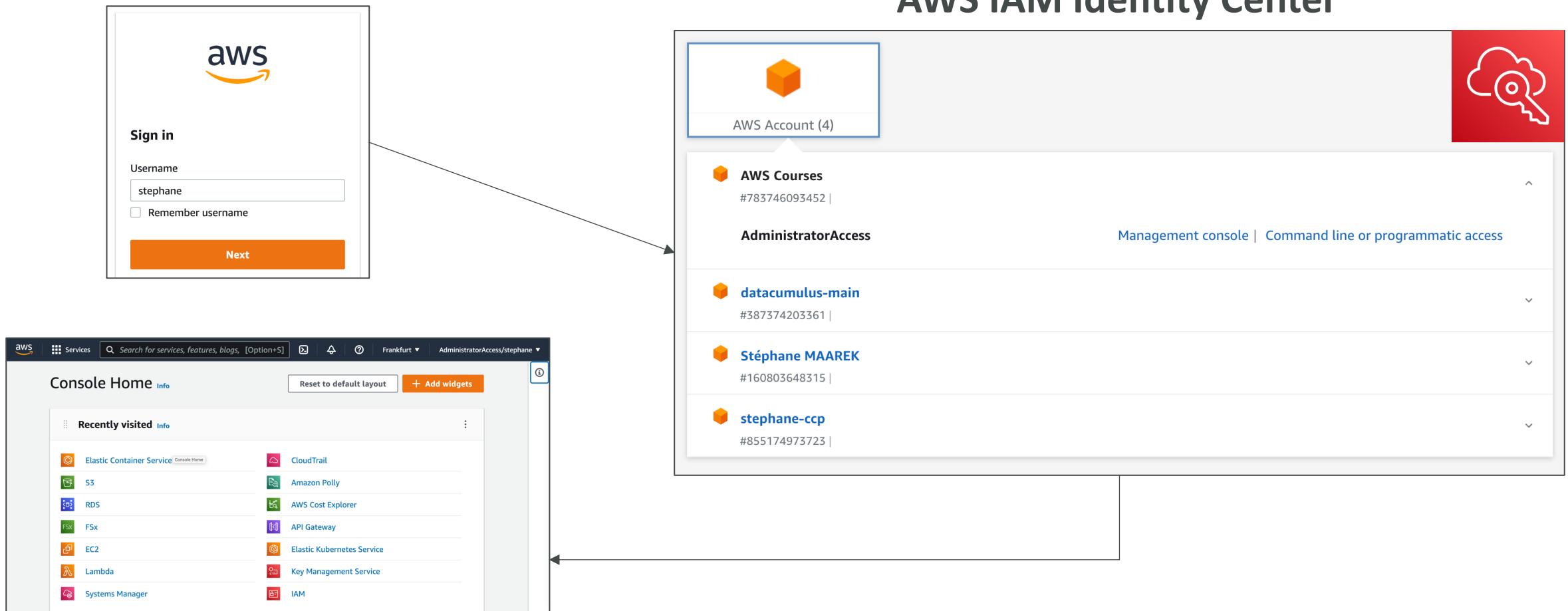
(successor to AWS Single Sign-On)



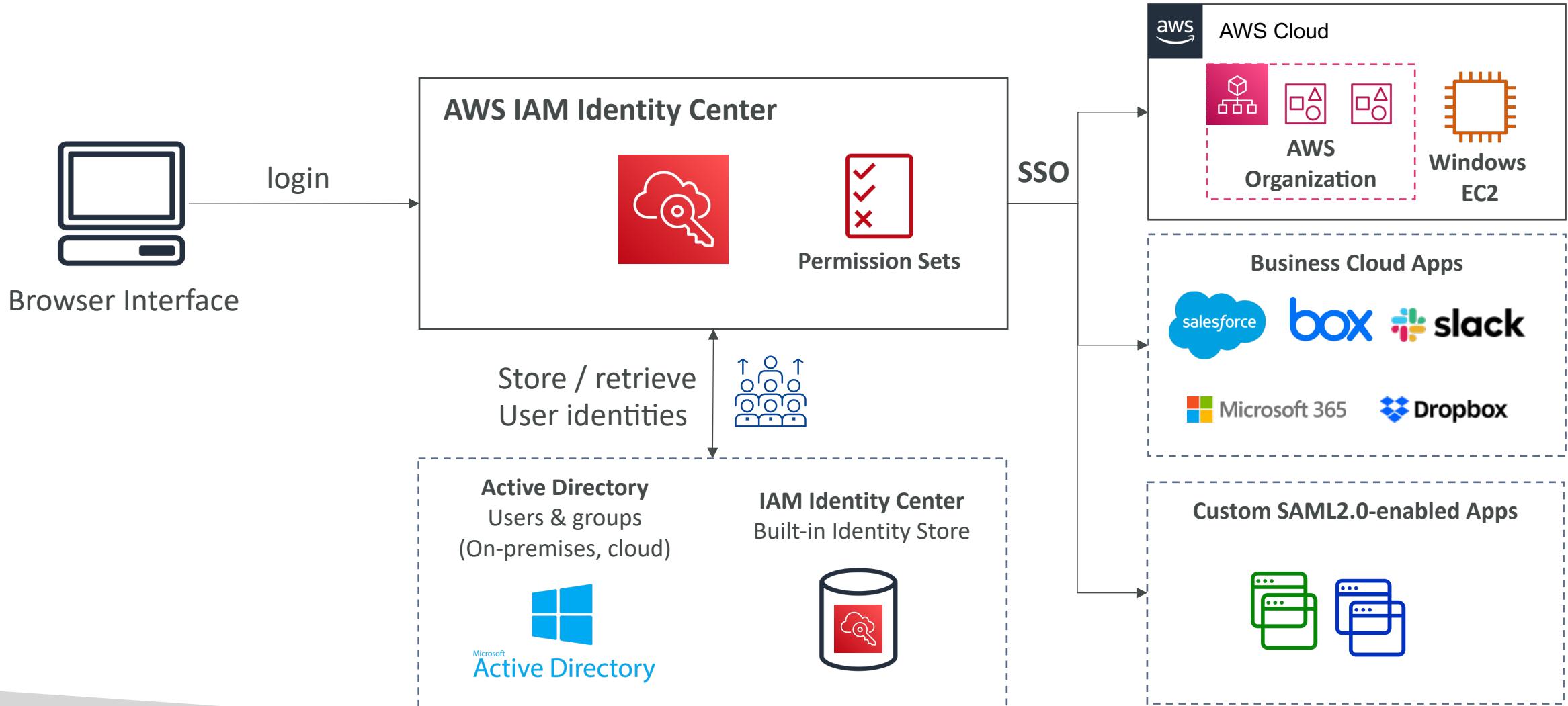
- One login (single sign-on) for all your
 - AWS accounts in AWS Organizations
 - Business cloud applications (e.g., Salesforce, Box, Microsoft 365, ...)
 - SAML2.0-enabled applications
 - EC2 Windows Instances
- Identity providers
 - Built-in identity store in IAM Identity Center
 - 3rd party: Active Directory (AD), OneLogin, Okta...



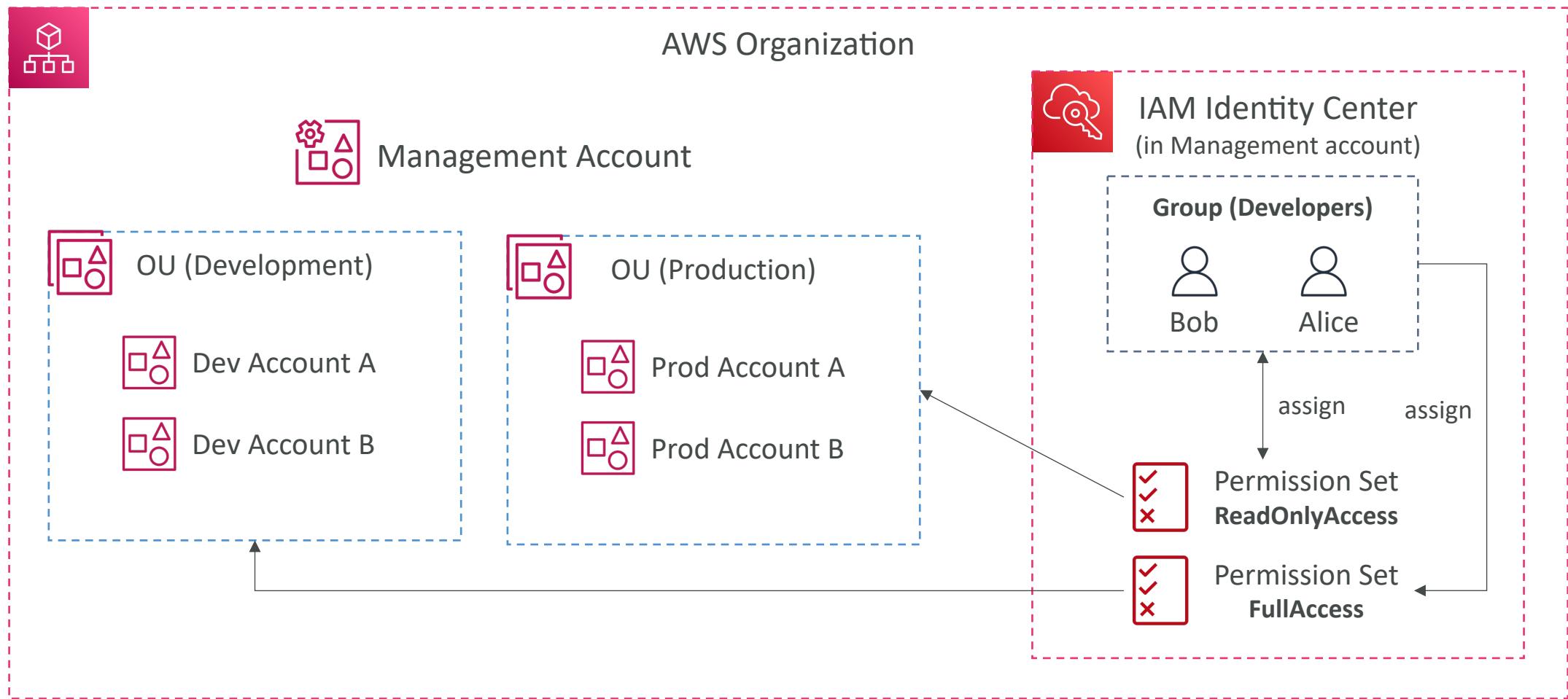
AWS IAM Identity Center – Login Flow



AWS IAM Identity Center



IAM Identity Center

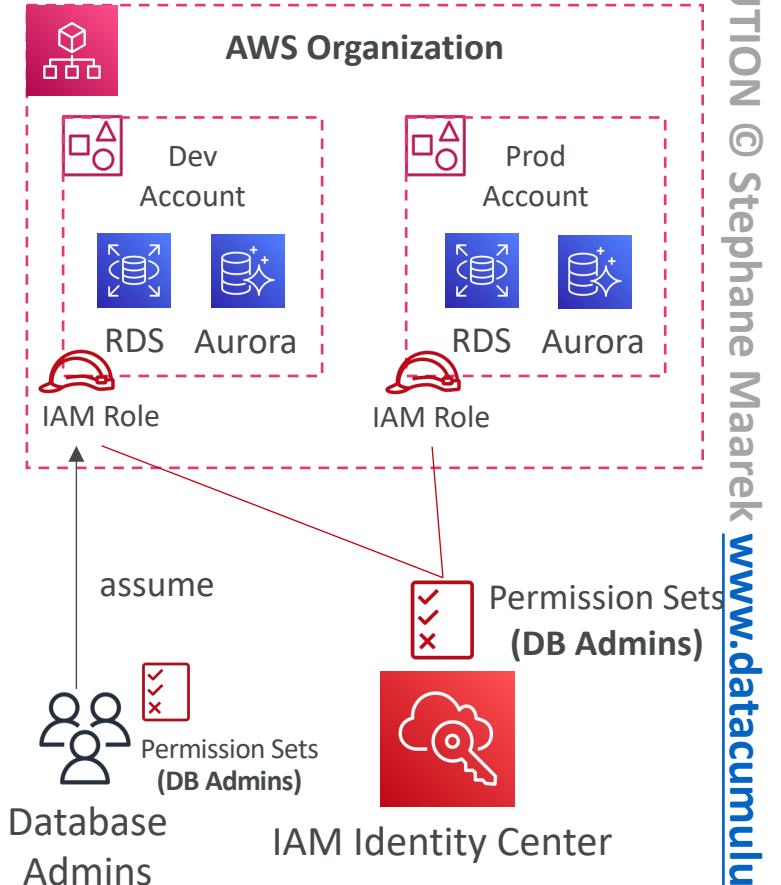


AWS IAM Identity Center

Fine-grained Permissions and Assignments



- Multi-Account Permissions
 - Manage access across AWS accounts in your AWS Organization
 - Permission Sets – a collection of one or more IAM Policies assigned to users and groups to define AWS access
- Application Assignments
 - SSO access to many SAML 2.0 business applications (Salesforce, Box, Microsoft 365, ...)
 - Provide required URLs, certificates, and metadata
- Attribute-Based Access Control (ABAC)
 - Fine-grained permissions based on users' attributes stored in IAM Identity Center Identity Store
 - Example: cost center, title, locale, ...
 - Use case: Define permissions once, then modify AWS access by changing the attributes



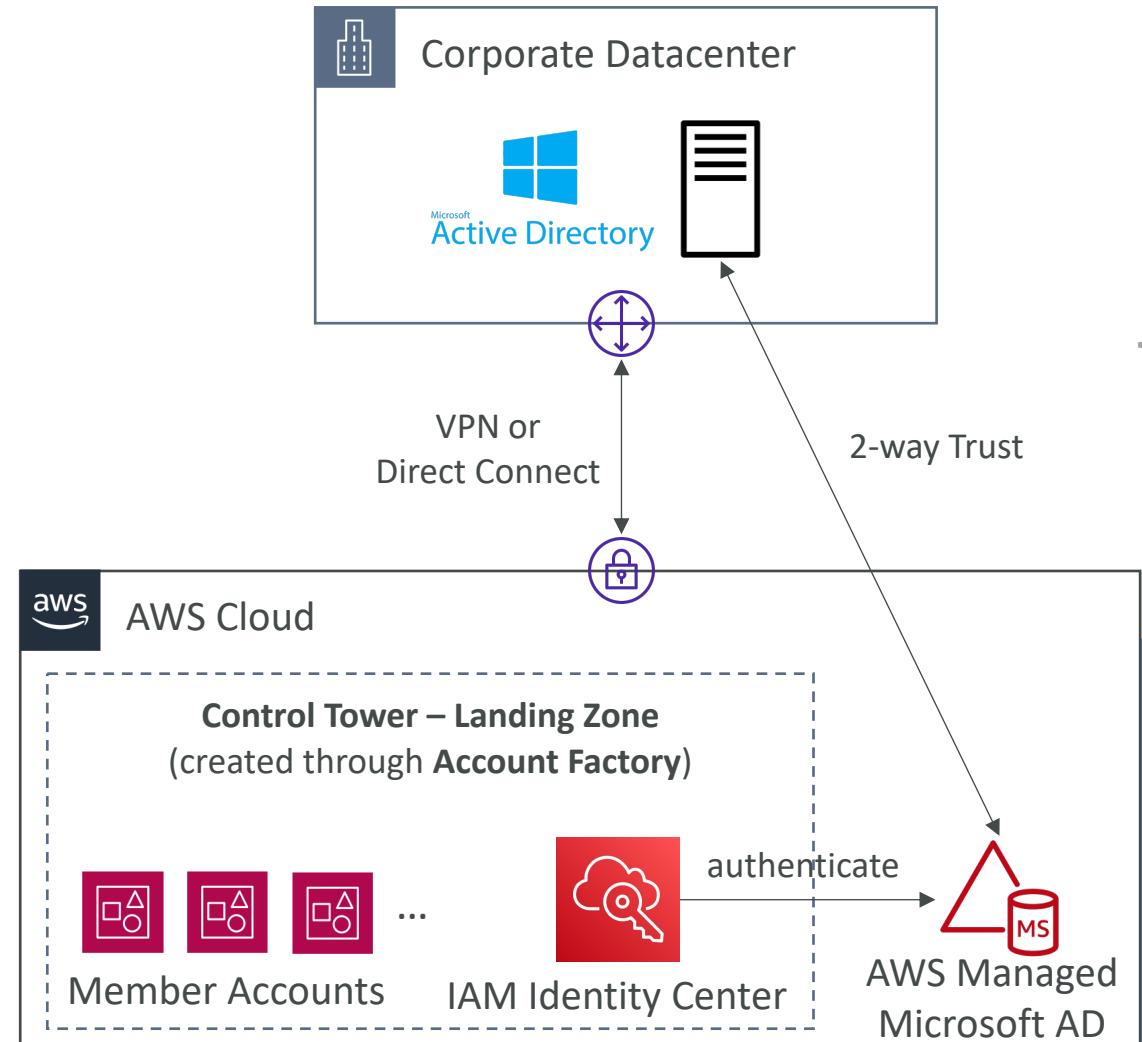
AWS Control Tower



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

AWS Control Tower – Account Factory

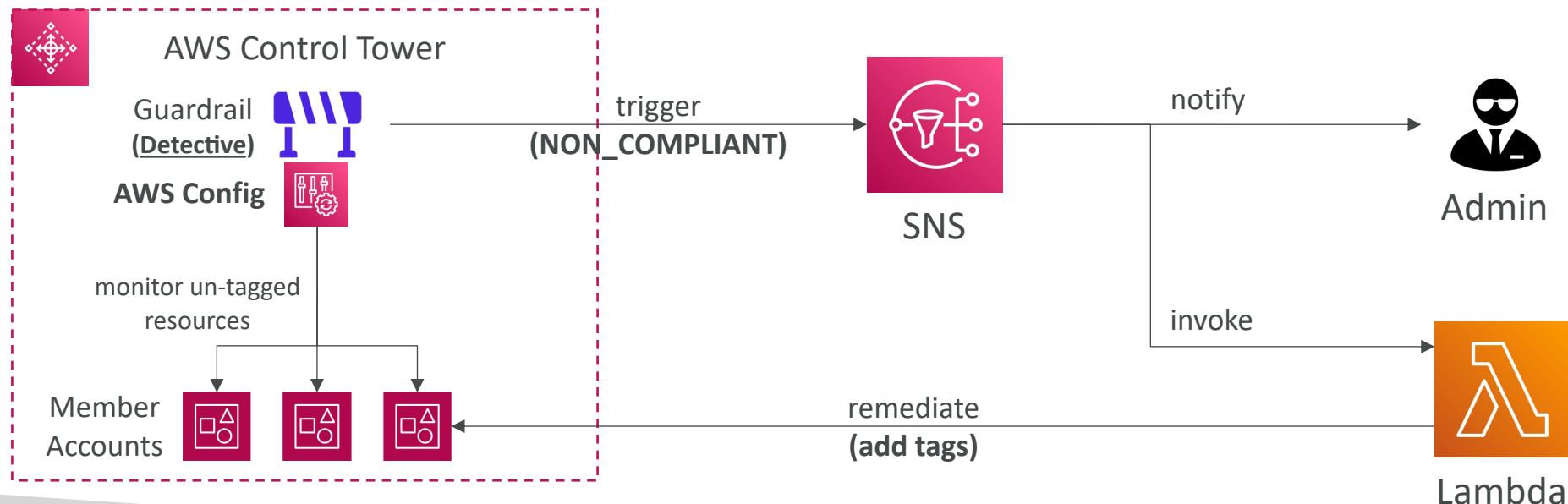
- Automates account provisioning and deployments
- Enables you to create pre-approved baselines and configuration options for AWS accounts in your organization (e.g., VPC default configuration, subnets, region, ...)
- Uses AWS Service Catalog to provision new AWS accounts



AWS Control Tower – Detect and Remediate Policy Violations

- Guardrail

- Provides ongoing governance for your Control Tower environment (AWS Accounts)
- Preventive – using SCPs (e.g., Disallow Creation of Access Keys for the Root User)
- Detective – using AWS Config (e.g., Detect Whether MFA for the Root User is Enabled)
- Example: identify non-compliant resources (e.g., untagged resources)



AWS Control Tower – Guardrails Levels

- **Mandatory**
 - Automatically enabled and enforced by AWS Control Tower
 - Example: Disallow public Read access to the Log Archive account
- **Strongly Recommended**
 - Based on AWS best practices (optional)
 - Example: Enable encryption for EBS volumes attached to EC2 instances
- **Elective**
 - Commonly used by enterprises (optional)
 - Example: Disallow delete actions without MFA in S3 buckets

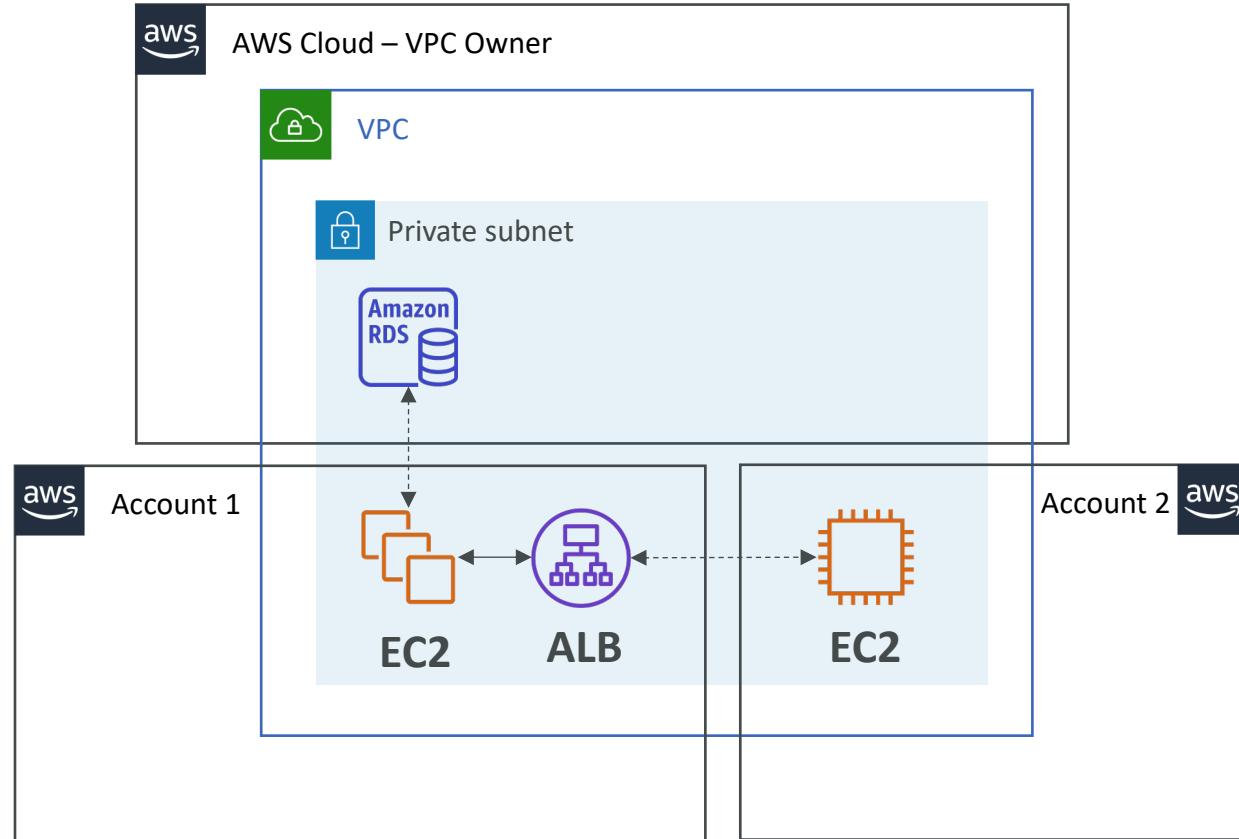
AWS Resource Access Manager (RAM)

- Share AWS resources that you own with other AWS accounts
- Share with any account or within your Organization
- Avoid resource duplication!
- **VPC Subnets**
 - Allow to have all the resources launched in the same subnets
 - Must be from the same AWS Organizations.
 - Cannot share security groups and default VPC
 - Participants can manage their own resources in there
 - Participants can't view, modify, delete resources that belong to other participants or the owner
- AWS Transit Gateway
- Route 53 (Resolver Rules, DNS Firewall Rule Groups)
- License Manager Configurations

AWS Resource Access Manager (RAM)

- Aurora DB Clusters
- ACM Private Certificate Authority
- CodeBuild Project
- EC2 (Dedicated Hosts, Capacity Reservation)
- AWS Glue (Catalog, Database, Table)
- AWS Network Firewall Policies
- AWS Resource Groups
- Systems Manager Incident Manager (Contacts, Response Plans)
- AWS Outposts (Outpost, Site)

Resource Access Manager – VPC example

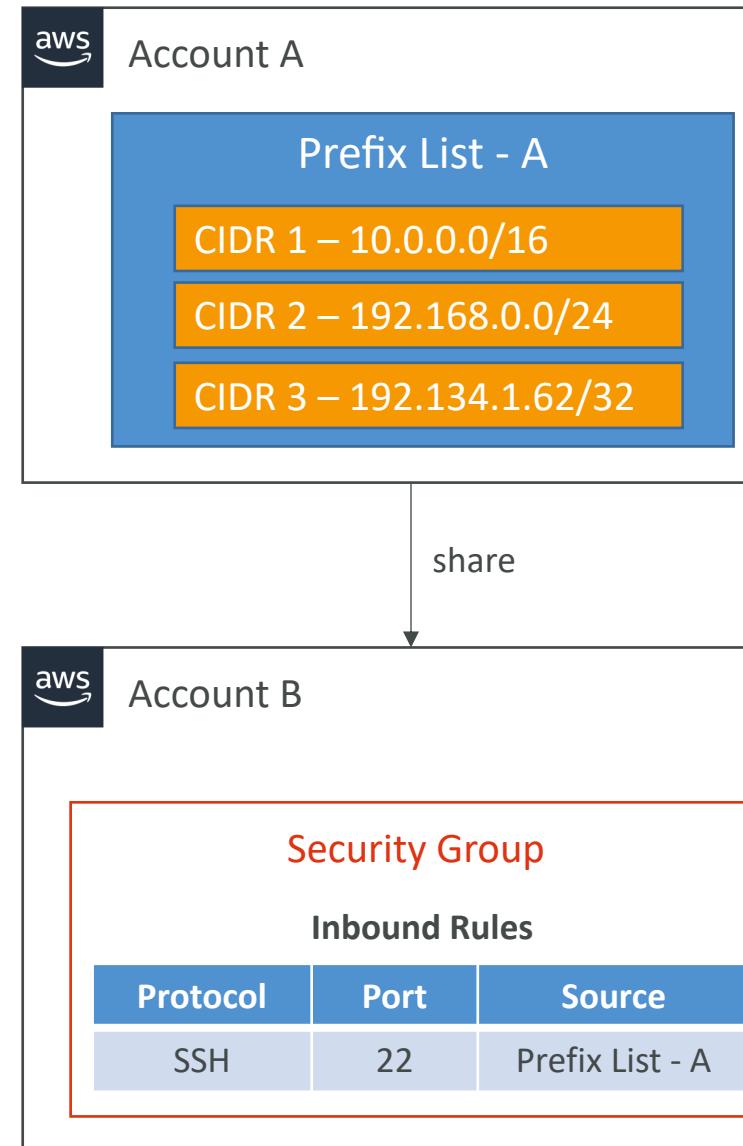


- Each account...
 - is responsible for its own resources
 - cannot view, modify or delete other resources in other accounts
- Network is shared so...
 - Anything deployed in the VPC can talk to other resources in the VPC
 - Applications are accessed easily across accounts, using private IP!
 - Security groups from other accounts can be referenced for maximum security
- Use cases
 - Applications within the same trust boundaries
 - Applications with a high degree of interconnectivity

Resource Access Manager

Managed Prefix List

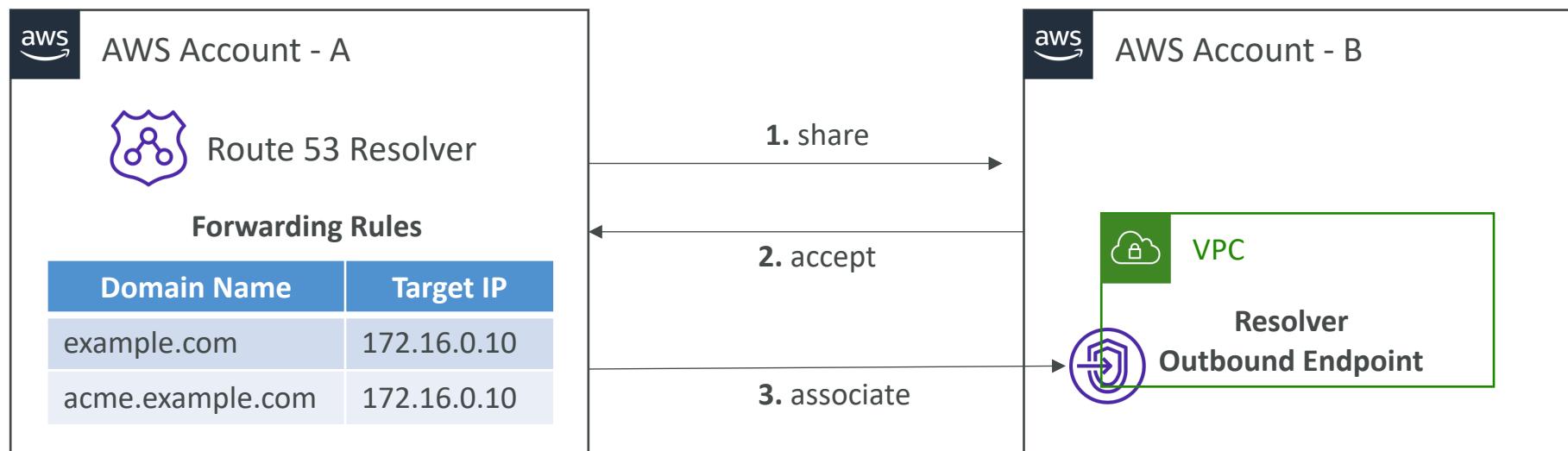
- A set of one or more CIDR blocks
- Makes it easier to configure and maintain Security Groups and Route Tables
- Customer-Managed Prefix List
 - Set of CIDRs that you define and manage by you
 - Can be shared with other AWS accounts or AWS Organization
 - Modify to update many security groups at once
- AWS-Managed Prefix List
 - Set of CIDRs for AWS services
 - You can't create, modify, share, or delete them



Resource Access Manager

Route 53 Outbound Resolver

- Helps you scale forwarding rules to your DNS in case you have multiple accounts and VPC



Summary of Identity & Federation

- Users and Accounts all in AWS
- AWS Organizations
- AWS Control Tower to setup secure & compliant multi-account AWS environment (best practices)
- Federation with SAML
- Federation without SAML with a custom IdP ([GetFederationToken](#))
- AWS Single Sign-On to connect to multiple AWS Accounts (Organization) and SAML apps
- Web Identity Federation (not recommended)
- Cognito for most web and mobile applications (has anonymous mode, MFA)
- AWS Directory Service:
 - **Managed Microsoft AD** – standalone or setup trust AD with on-premises, has MFA, seamless join, RDS integration
 - **AD Connector** – proxy requests to on-premises
 - **Simple AD** – standalone & cheap AD-compatible with no MFA, no advanced capabilities
- AWS RAM to share resources (example VPC subnets)

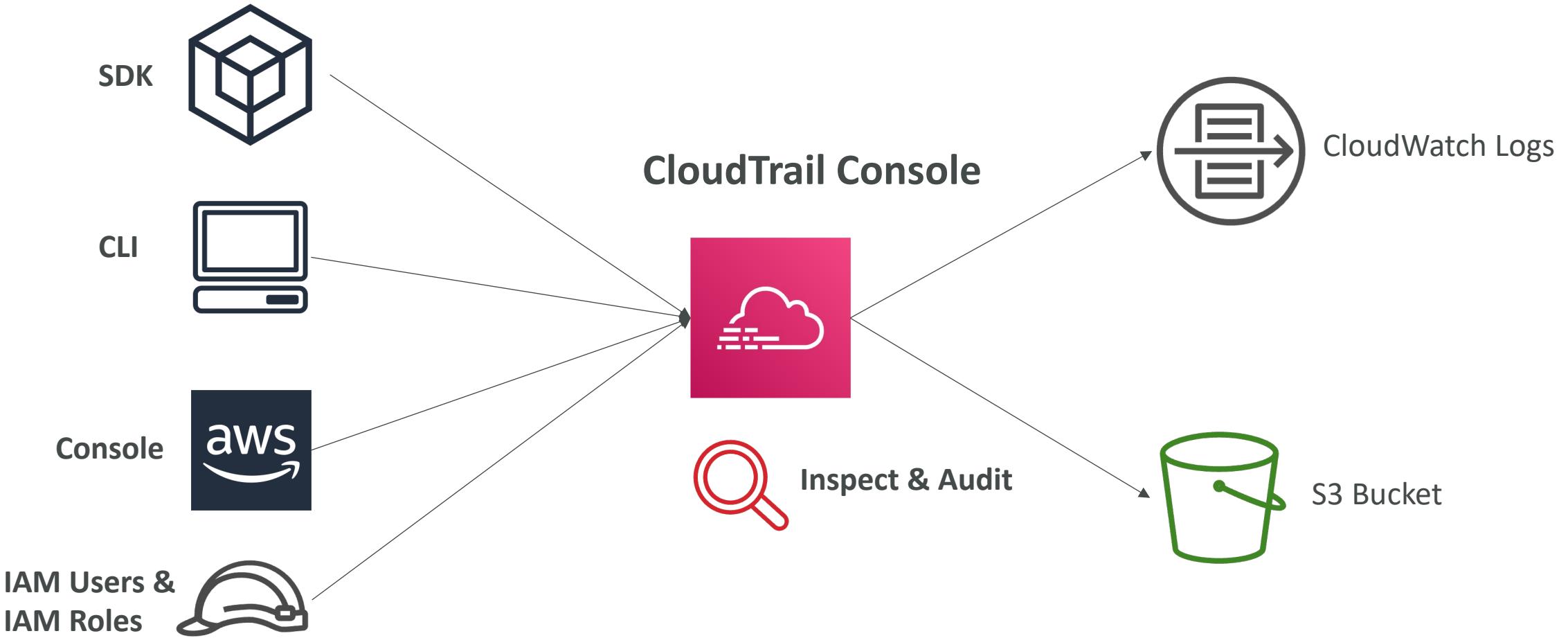
Security



AWS CloudTrail

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

CloudTrail Diagram





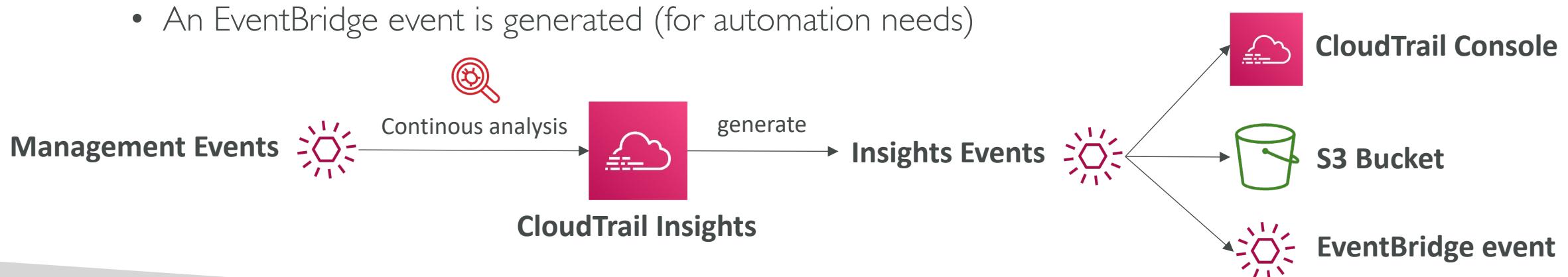
CloudTrail Events

- Management Events:
 - Operations that are performed on resources in your AWS account
 - Examples:
 - Configuring security (IAM `AttachRolePolicy`)
 - Configuring rules for routing data (Amazon EC2 `CreateSubnet`)
 - Setting up logging (AWS CloudTrail `CreateTrail`)
 - By default, trails are configured to log management events.
 - Can separate Read Events (that don't modify resources) from Write Events (that may modify resources)
- Data Events:
 - By default, data events are not logged (because high volume operations)
 - Amazon S3 object-level activity (ex: `GetObject`, `DeleteObject`, `PutObject`): can separate Read and Write Events
 - AWS Lambda function execution activity (the `Invoke` API)
- CloudTrail Insights Events:
 - See next slide ☺



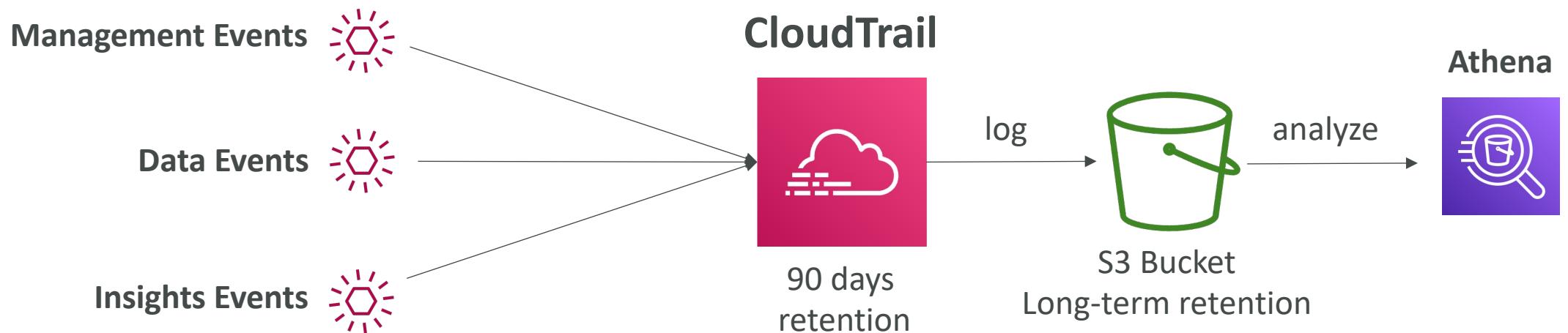
CloudTrail Insights

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

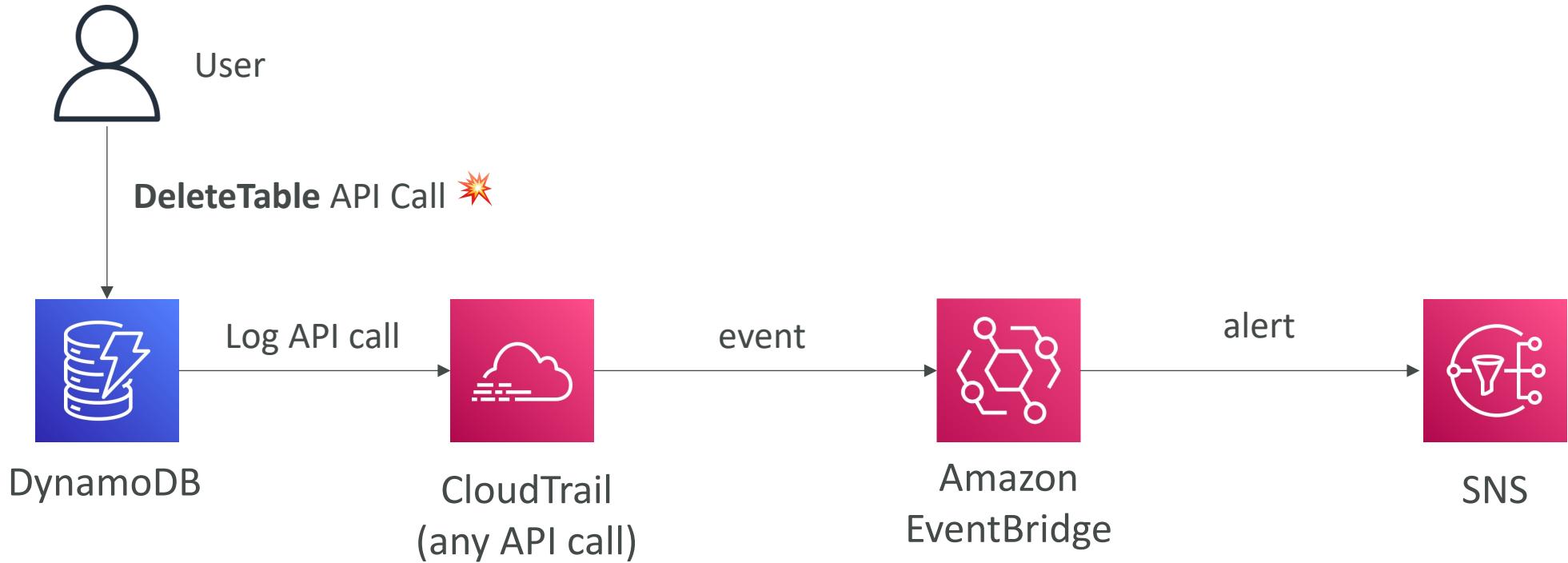


CloudTrail Events Retention

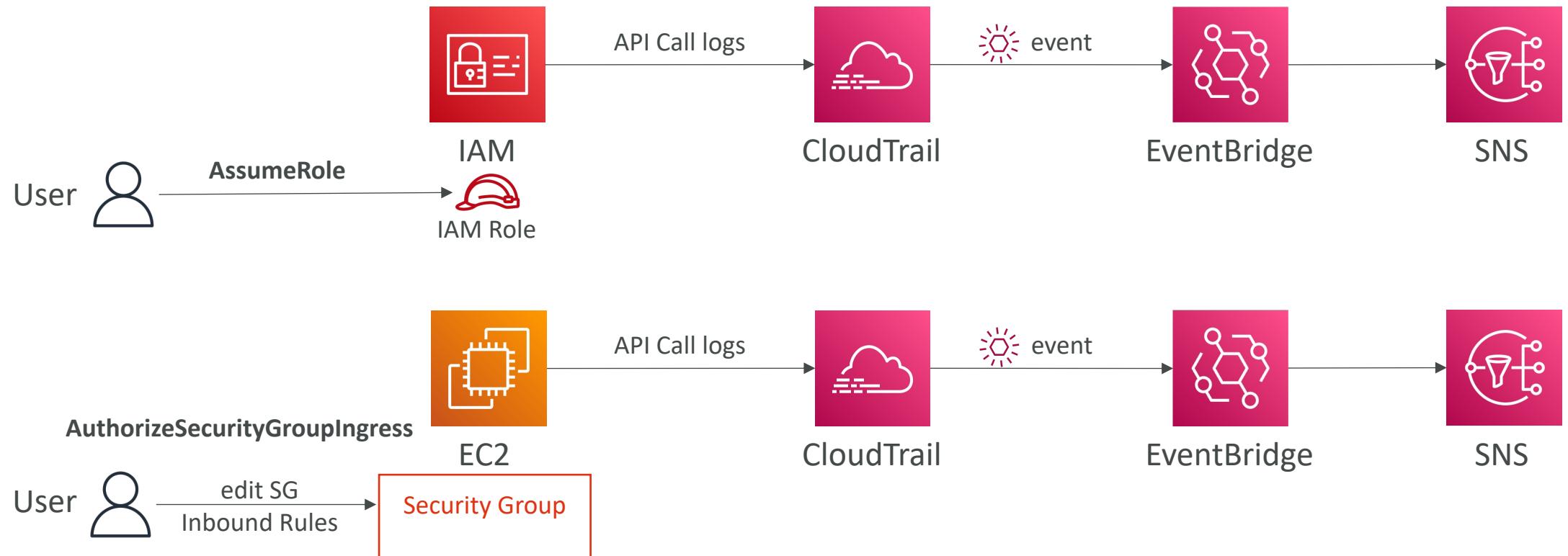
- Events are stored for 90 days in CloudTrail
- To keep events beyond this period, log them to S3 and use Athena



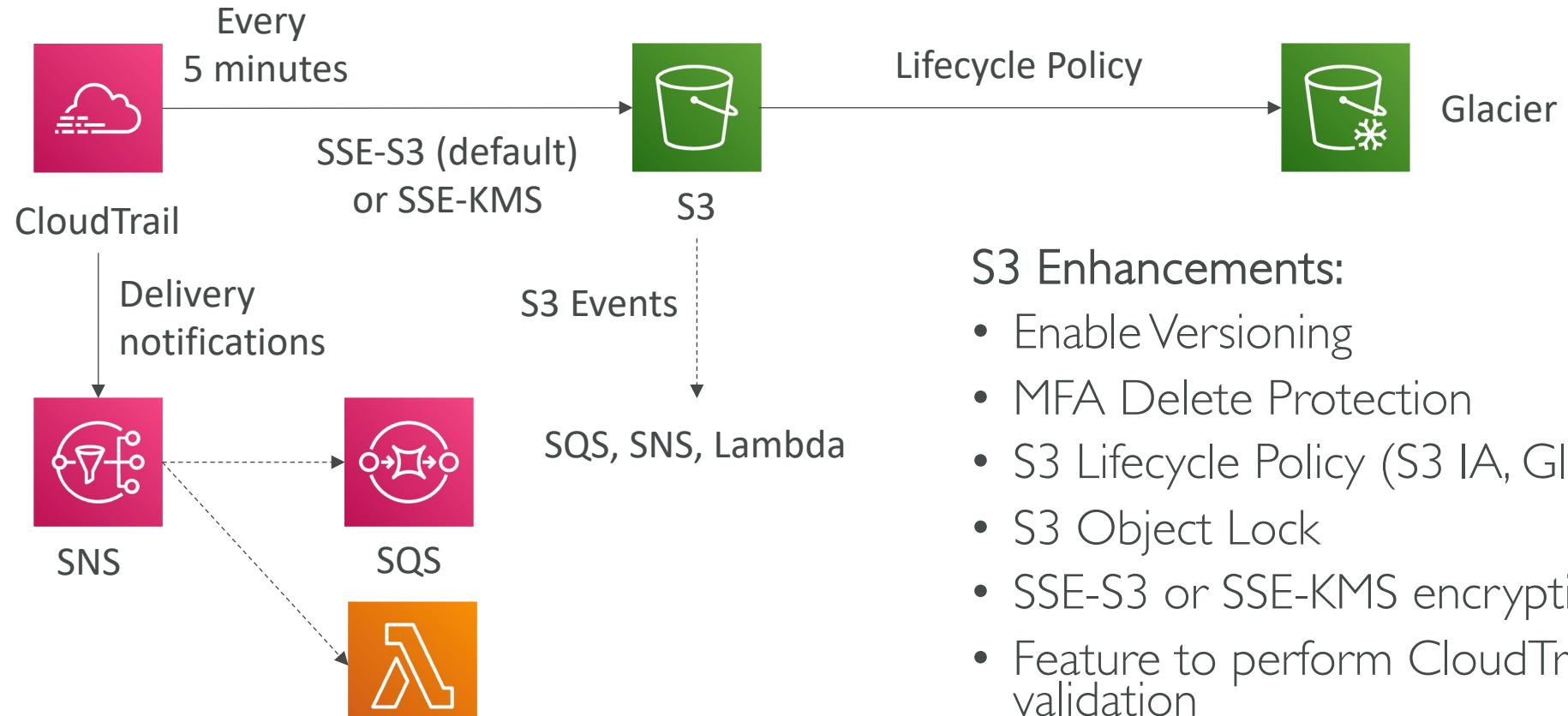
Amazon EventBridge – Intercept API Calls



Amazon EventBridge + CloudTrail



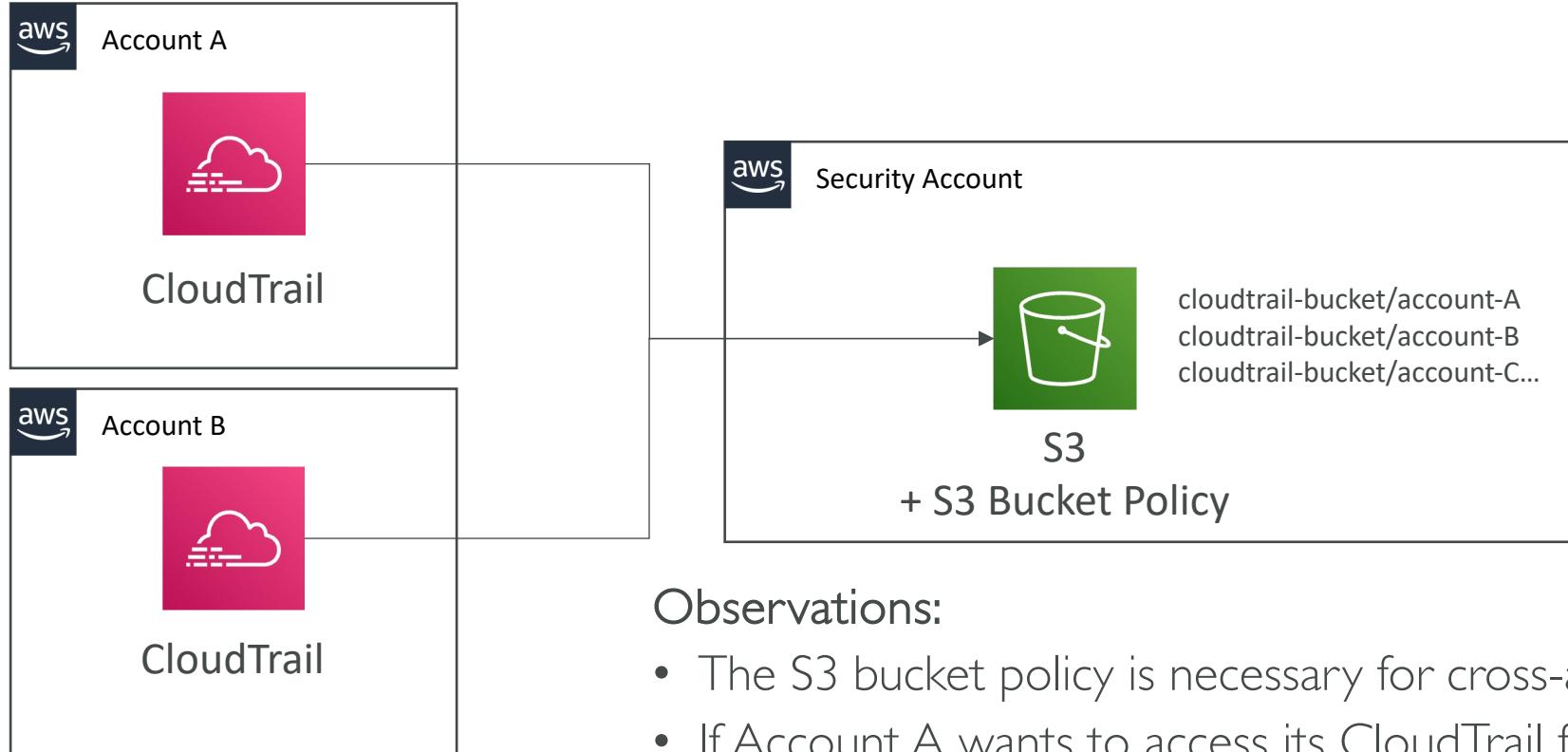
CloudTrail – Solution Architecture: Delivery to S3



S3 Enhancements:

- Enable Versioning
- MFA Delete Protection
- S3 Lifecycle Policy (S3 IA, Glacier...)
- S3 Object Lock
- SSE-S3 or SSE-KMS encryption
- Feature to perform CloudTrail Log File Integrity validation (SHA-256 for hashing and signing)

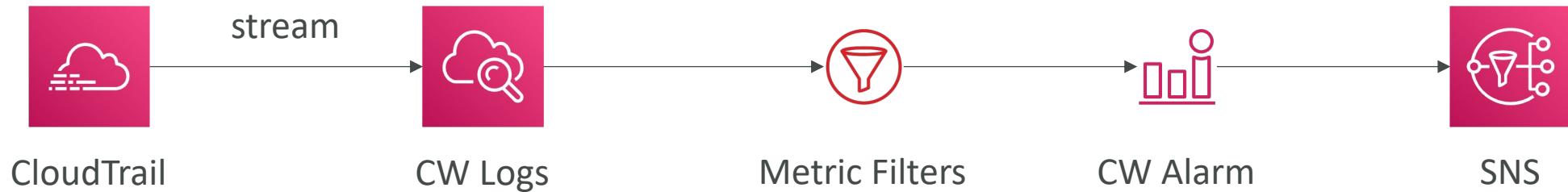
CloudTrail - Solution Architecture: Multi Account, Multi Region Logging



Observations:

- The S3 bucket policy is necessary for cross-account delivery
- If Account A wants to access its CloudTrail files:
 - Option 1: create a cross-account role and assume the role
 - Option 2: edit the bucket policy

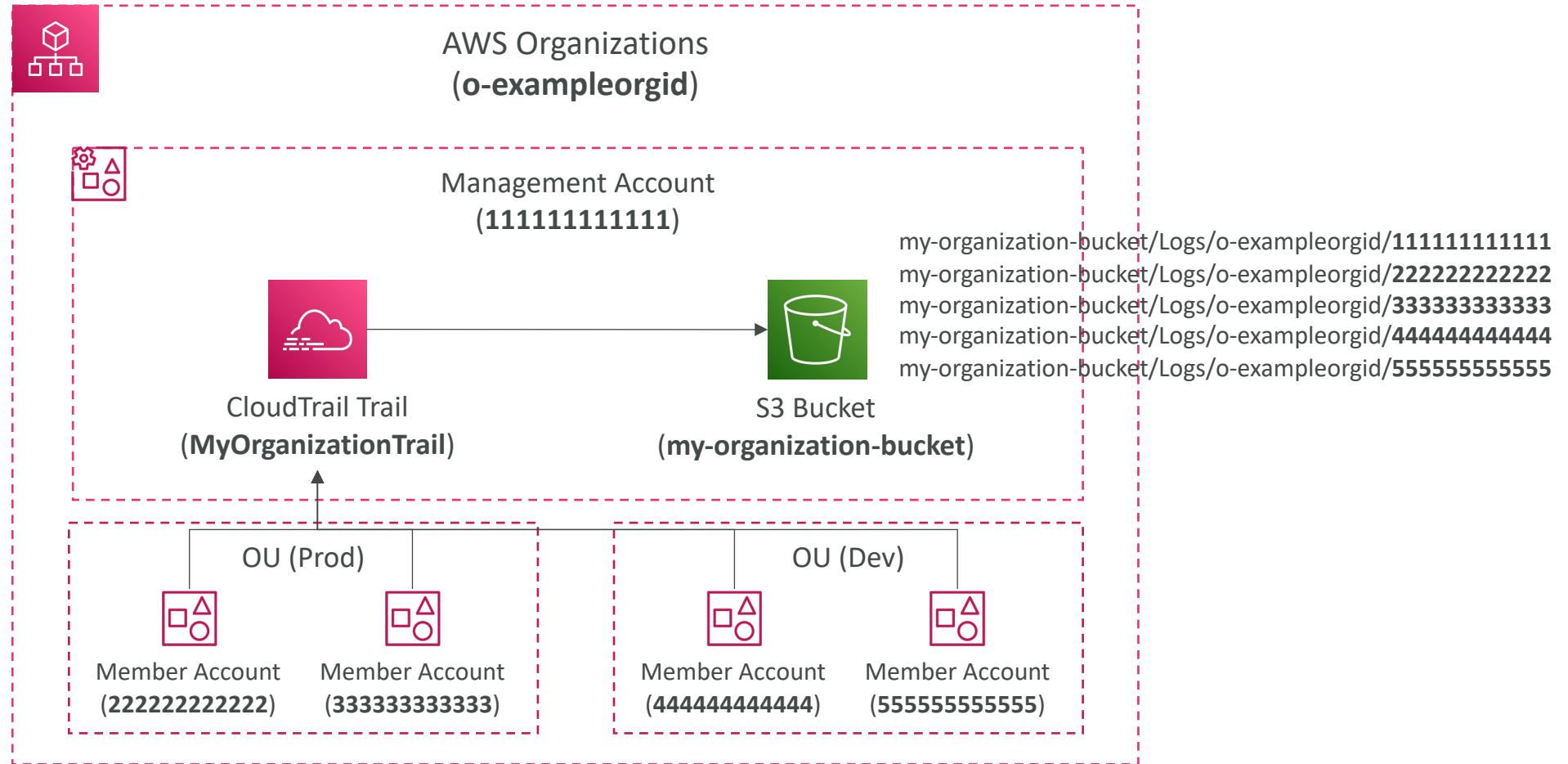
CloudTrail - Solution Architecture: Alert for API calls



- Log filter metrics can be used to detect a high level of API happening
- Ex: Count occurrences of EC2 `TerminateInstances` API
- Ex: Count of API calls per user
- Ex: Detect high level of Denied API calls

CloudTrail – Solution Architecture: Organizational Trail

The Organizational Trail is created in the management account.



CloudTrail: How to react to events the fastest?

Overall, CloudTrail may take up to 15 minutes to deliver events

- **EventBridge:**
 - Can be triggered for any API call in CloudTrail
 - The fastest, most reactive way
- **CloudTrail Delivery in CloudWatch Logs:**
 - Events are streamed
 - Can perform a metric filter to analyze occurrences and detect anomalies
- **CloudTrail Delivery in S3:**
 - Events are delivered every 5 minutes
 - Possibility of analyzing logs integrity, deliver cross account, long-term storage

AWS KMS (Key Management Service)



- Anytime you hear “encryption” for an AWS service, it’s most likely KMS
- Easy way to control access to your data, AWS manages keys for us
- Fully integrated with IAM for authorization
- Seamlessly integrated into:
 - 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
 - Etc...
- But you can also use the CLI / SDK

KMS – KMS Key Types

- **Symmetric (AES-256 keys)**
 - First offering of KMS, single encryption key that is used to Encrypt and Decrypt
 - AWS services that are integrated with KMS use Symmetric KMS keys
 - Necessary for envelope encryption
 - You never get access to the KMS key unencrypted (must call KMS API to use)
- **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
 - Use case: encryption outside of AWS by users who can't call the KMS API

Types of KMS Keys

- **Customer Managed Keys**
 - Create, manage and use, can enable or disable
 - Possibility of rotation policy (new key generated every year; old key preserved)
 - Can add a Key Policy (resource policy) & audit in CloudTrail
 - Leverage for envelope encryption
- **AWS Managed Keys**
 - Used by AWS service (aws/s3, aws/ebs, aws/redshift)
 - Managed by AWS (automatically rotated every 1 year)
 - View Key Policy & audit in CloudTrail
- **AWS Owned Keys**
 - Created and managed by AWS, use by some AWS services to protect your resources
 - Used in multiple AWS accounts, but they are not in your AWS account
 - You can't view, use, track, or audit

Types of KMS Keys

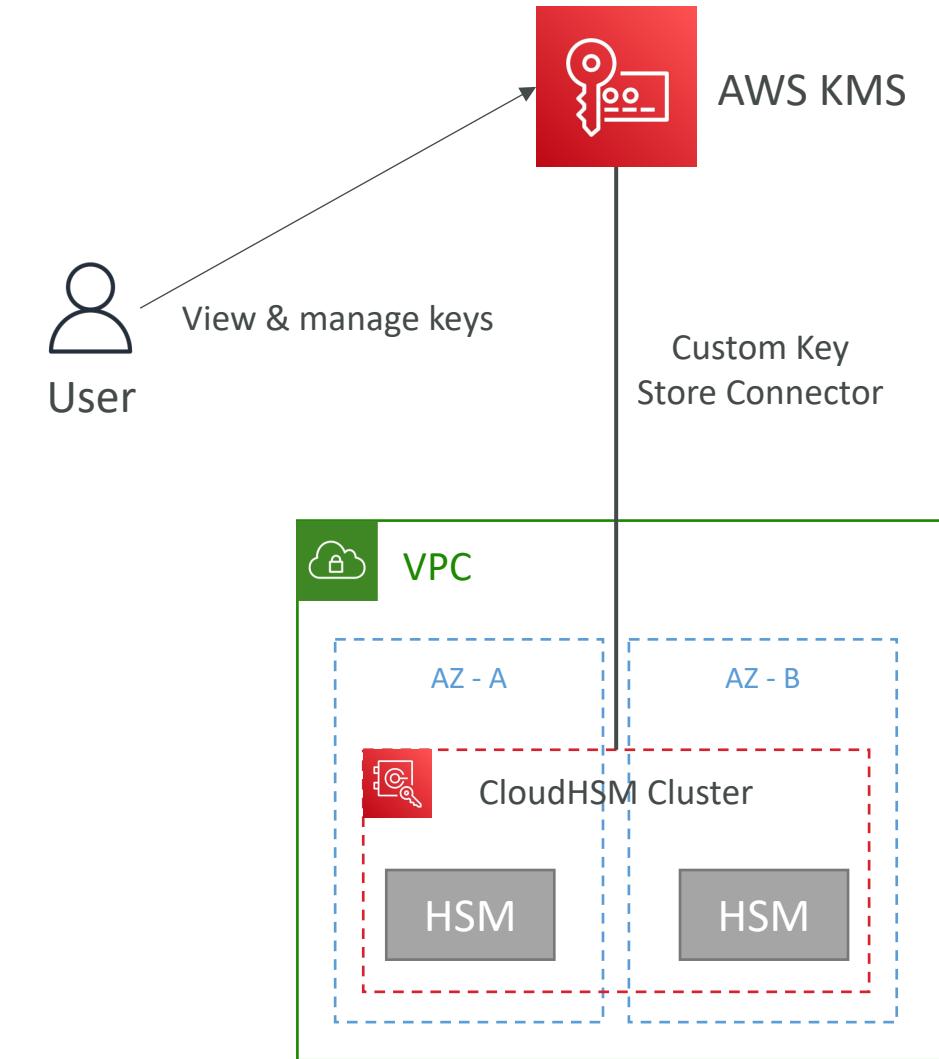
KMS Key	Customer Managed Key	AWS Managed Key	AWS Owned Key
Can view metadata?	✓	✓	✗
Can manage?	✓	✗	✗
Used only for my AWS account?	✓	✓	✗
Automatic Rotation	Optional (every 1 year)	Required (every 1 year)	Varies

KMS Key Material Origin

- Identifies the source of the key material in the KMS key
- Can't be changed after creation
- **KMS (AWS_KMS)** – default
 - AWS KMS creates and manages the key material in its own key store
- **External (EXTERNAL)**
 - You import the key material into the KMS key
 - You're responsible for securing and managing this key material outside of AWS
- **Custom Key Store (AWS_CLOUDHSM)**
 - AWS KMS creates the key material in a custom key store (CloudHSM Cluster)

KMS Key Source – Custom Key Store (CloudHSM)

- Integrate KMS with CloudHSM cluster as a Custom Key Store
- Key materials are stored in a CloudHSM cluster that you own and manage
- The cryptographic operations are performed in the HSMs
- Use cases:
 - You need direct control over the HSMs
 - KMS keys needs to be stored in a dedicated HSMs

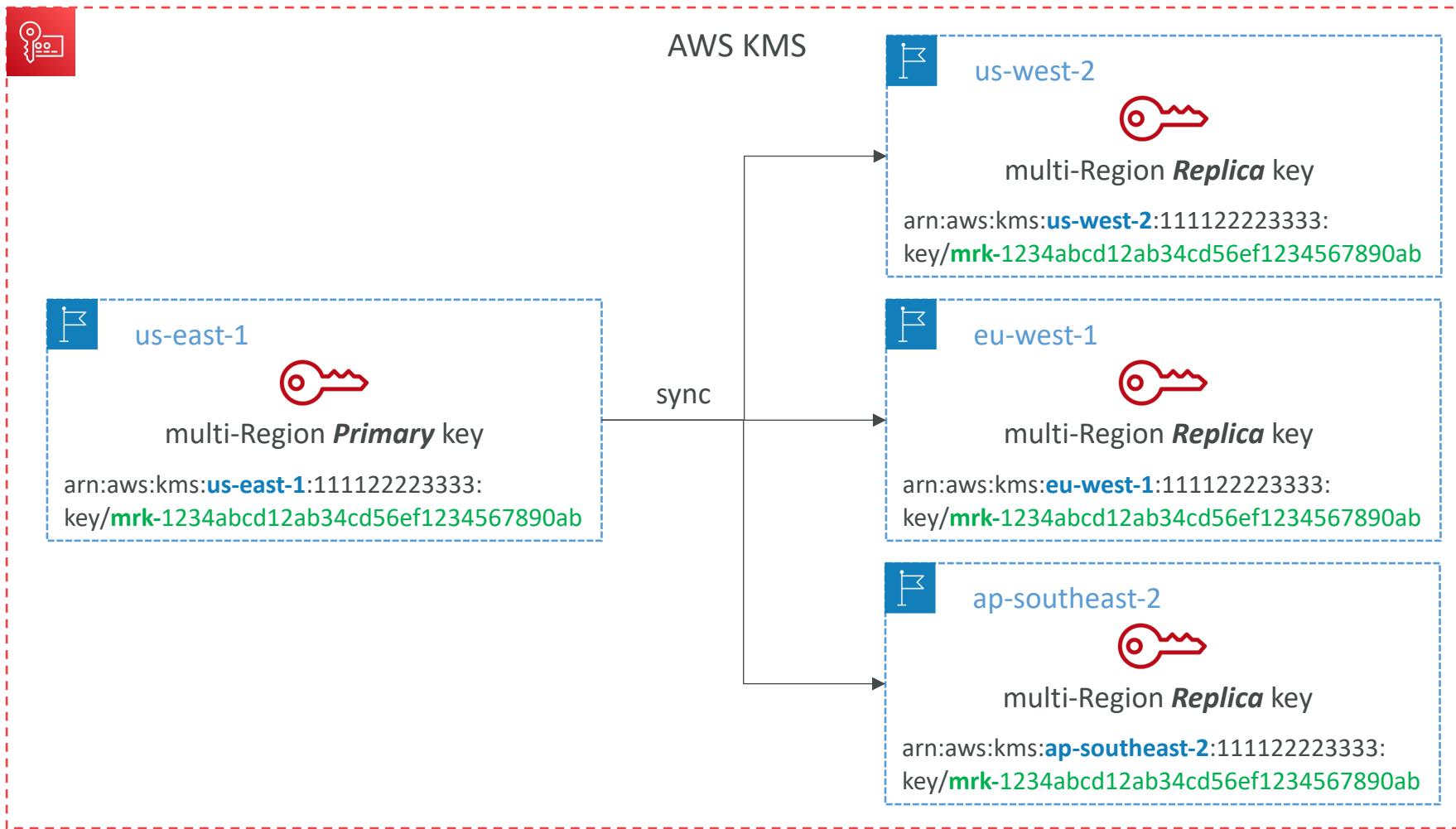


KMS Key Source - External

- Import your own key material into KMS key, Bring Your Own Key (BYOK)
- You're responsible for key material's security, availability, and durability outside of AWS
- Must be 256-bit **Symmetric** key (Asymmetric is NOT supported)
- Can't be used with Custom Key Store (CloudHSM)
- Manually rotate your KMS key (Automatic Key Rotation is NOT supported)



KMS Multi-Region Keys



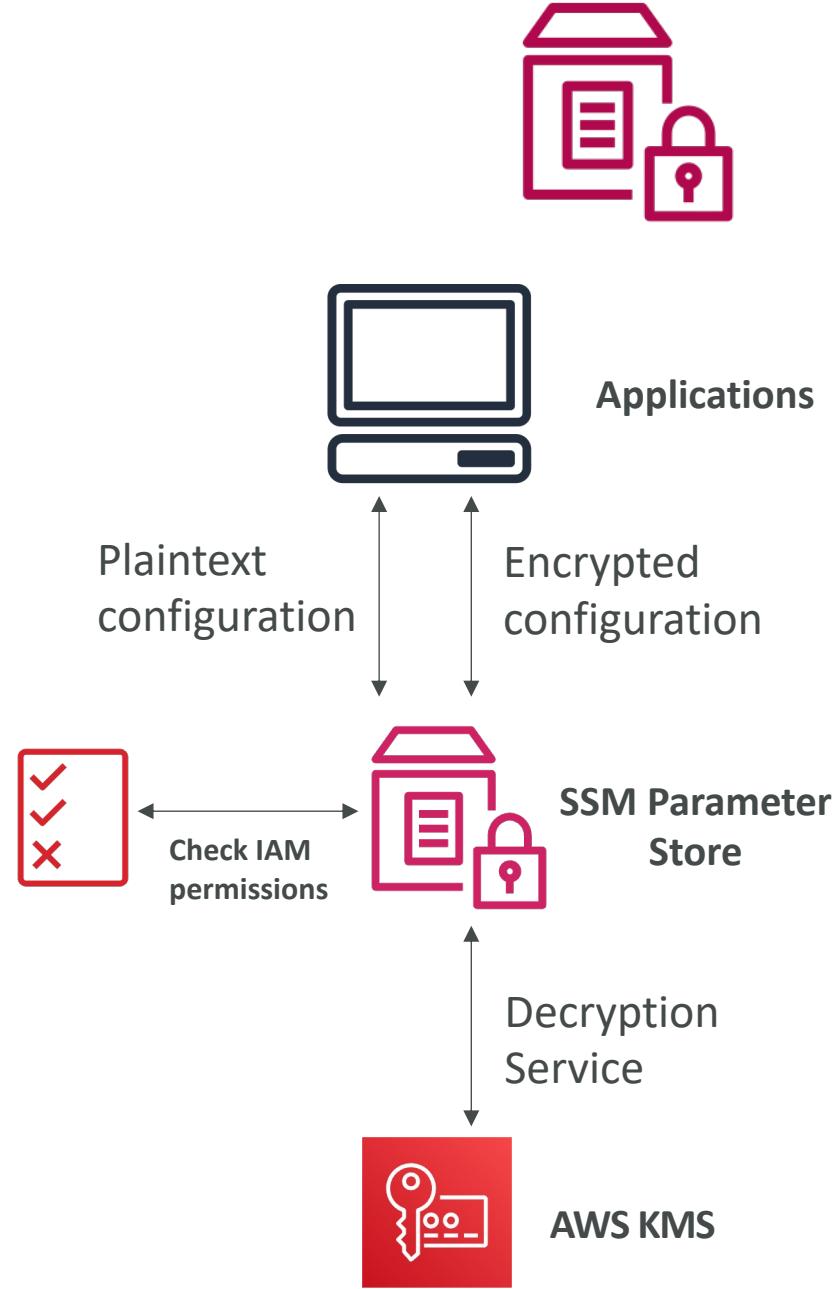
KMS Multi-Region Keys



- A set of identical KMS keys in different AWS Regions that can be used interchangeably (~ same KMS key in multiple Regions)
- Encrypt in one Region and decrypt in other Regions (No need to re-encrypt or making cross-Region API calls)
- Multi-Region keys have the same key ID, key material, automatic rotation, ...
- KMS Multi-Region are NOT global (Primary + Replicas)
- Each Multi-Region key is managed **independently**
- Only one primary key at a time, can promote replicas into their own primary
- Use cases: Disaster Recovery, Global Data Management (e.g., DynamoDB Global Tables), Active-Active Applications that span multiple Regions, Distributed Signing applications, ...

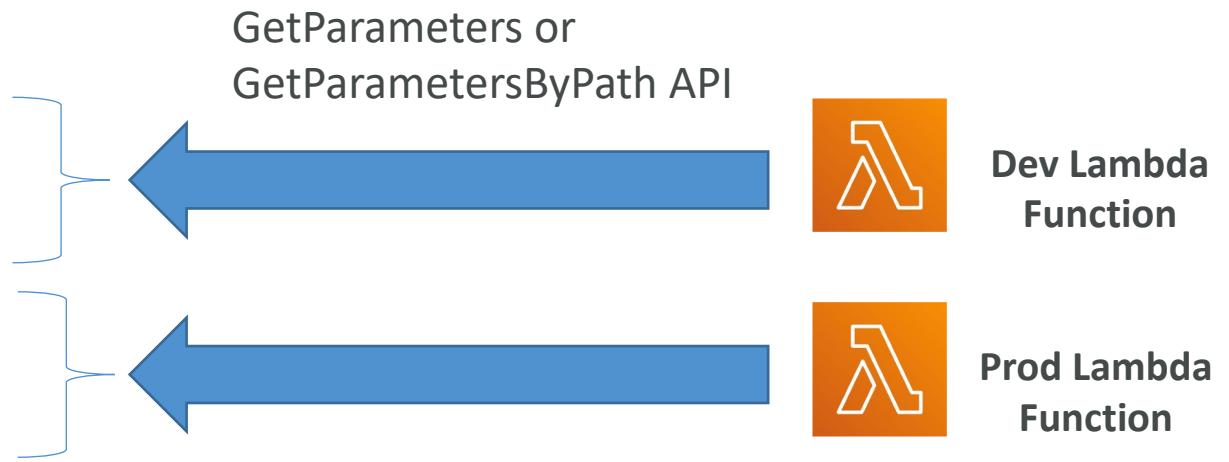
SSM Parameter Store

- Secure storage for configuration and secrets
- Optional Seamless Encryption using KMS
- Serverless, scalable, durable, easy SDK
- Version tracking of configurations / secrets
- Security through IAM
- Notifications with Amazon EventBridge
- Integration with CloudFormation



SSM Parameter Store Hierarchy

- /my-department/
 - my-app/
 - dev/
 - db-url
 - db-password
 - prod/
 - db-url
 - db-password
 - other-app/
 - /other-department/
 - /aws/reference/secretsmanager/secret_ID_in_Secrets_Manager
 - /aws/service/ami-amazon-linux-latest/amzn2-ami-hvm-x86_64-gp2 (public)



Standard and advanced parameter 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

Parameters Policies (for 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 (EventBridge)

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

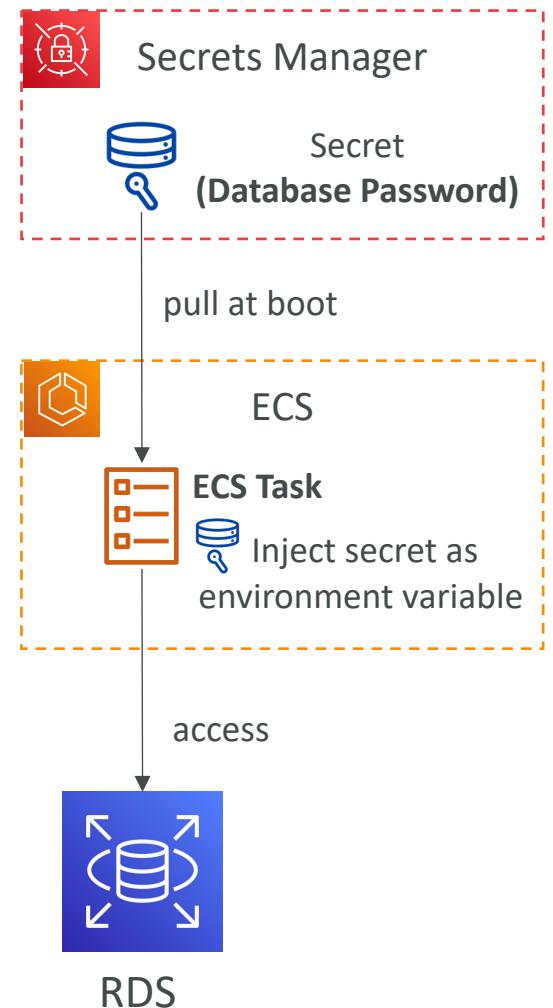
NoChangeNotification (EventBridge)

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

AWS Secrets Manager



- Meant for storing secrets (e.g., passwords, API keys, ...)
- Capability to force **rotation of secrets** every X days
 - Automate generation of secrets on rotation (uses Lambda)
 - Natively supports Amazon RDS (all supported DB engines), Redshift, DocumentDB
 - Support other databases and services (custom Lambda function)
- Control access to secrets using Resource-based Policy
- Integration with other AWS services to natively pull secrets from Secrets Manager: *CloudFormation, CodeBuild, ECS, EMR, Fargate, EKS, Parameter Store...*



Secrets Manager – with CloudFormation

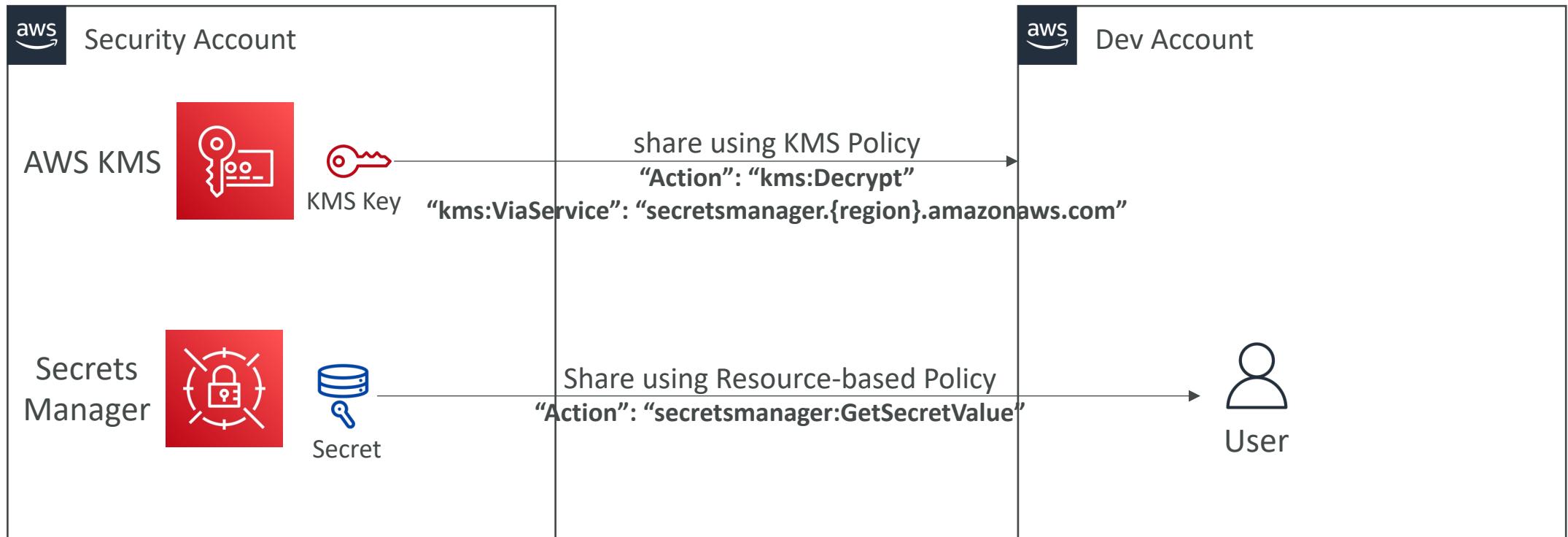
```
Resources:  
    # Secret resource with a randomly generated password in its SecureString JSON  
    MyRDSDBInstanceRotationSecret:  
        Type: AWS::SecretsManager::Secret  
        Properties:  
            GenerateSecretString:  
                SecretStringTemplate: '{"username": "admin"}'  
                GenerateStringKey: password  
                PasswordLength: 16  
                ExcludeCharacters: "\"@/\\\""  
  
    # RDS Instance resource. Its master username and password use dynamic references  
    # to resolve values from Secrets Manager  
    MyRDSDBInstance:  
        Type: AWS::RDS::DBInstance  
        Properties:  
            DBInstanceClass: db.t2.micro  
            Engine: mysql  
            MasterUsername: !Sub "{{resolve:secretsmanager:${MyRDSDBInstanceRotationSecret}:username}}"  
            MasterUserPassword: !Sub "{{resolve:secretsmanager:${MyRDSDBInstanceRotationSecret}:password}}"  
  
    # SecretTargetAttachment resource which updates the referenced Secret with properties  
    # about the referenced RDS instance  
    SecretRDSDBInstanceAttachment:  
        Type: AWS::SecretsManager::SecretTargetAttachment  
        Properties:  
            TargetType: AWS::RDS::DBInstance  
            SecretId: !Ref MyRDSDBInstanceRotationSecret  
            TargetId: !Ref MyRDSDBInstance
```

secret is generated

reference secret in
RDS DB instance

link the secret to
RDS DB instance

Secrets Manager – Sharing Across Accounts



SSM Parameter Store vs Secrets Manager

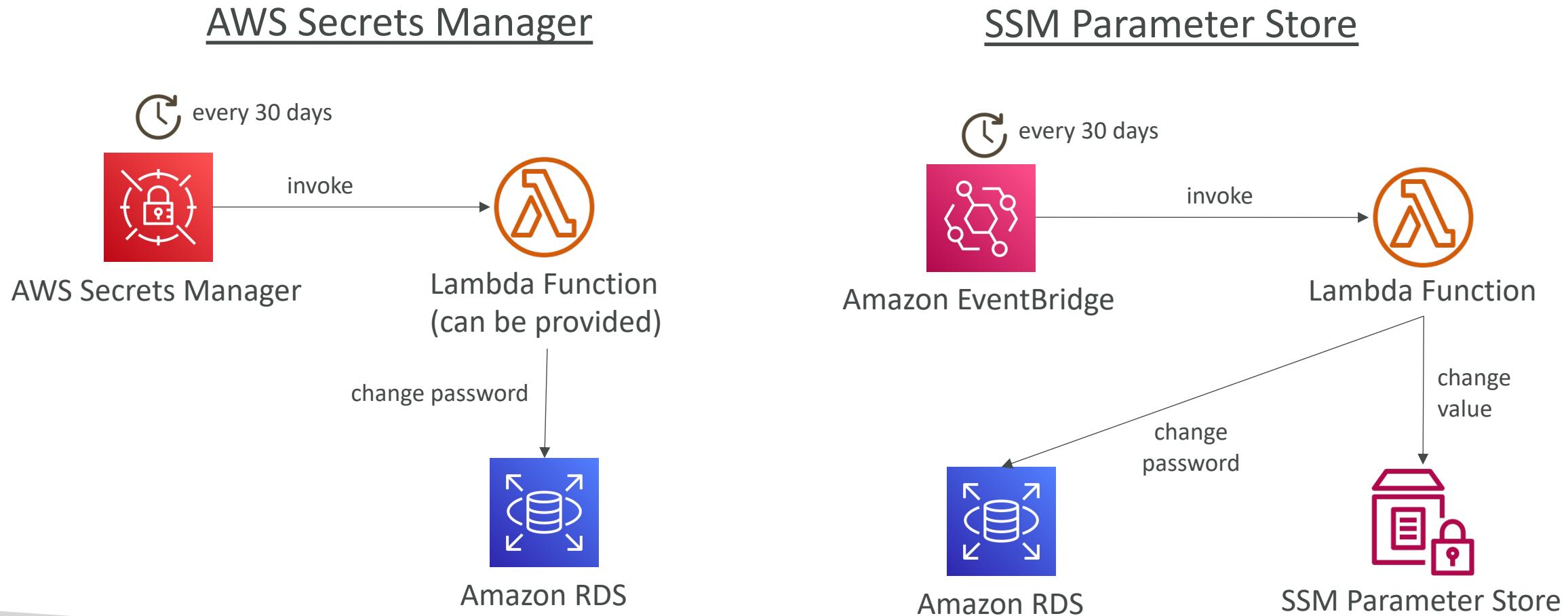
- **Secrets Manager (\$\$\$):**

- Automatic rotation of secrets with AWS Lambda
- Lambda function is provided for RDS, Redshift, DocumentDB
- KMS encryption is mandatory
- Can integration with CloudFormation

- **SSM Parameter Store (\$):**

- Simple API
- No secret rotation (can enable rotation using Lambda triggered by EventBridge)
- KMS encryption is optional
- Can integration with CloudFormation
- Can pull a Secrets Manager secret using the SSM Parameter Store API

SSM Parameter Store vs. Secrets Manager Rotation



RDS - Security

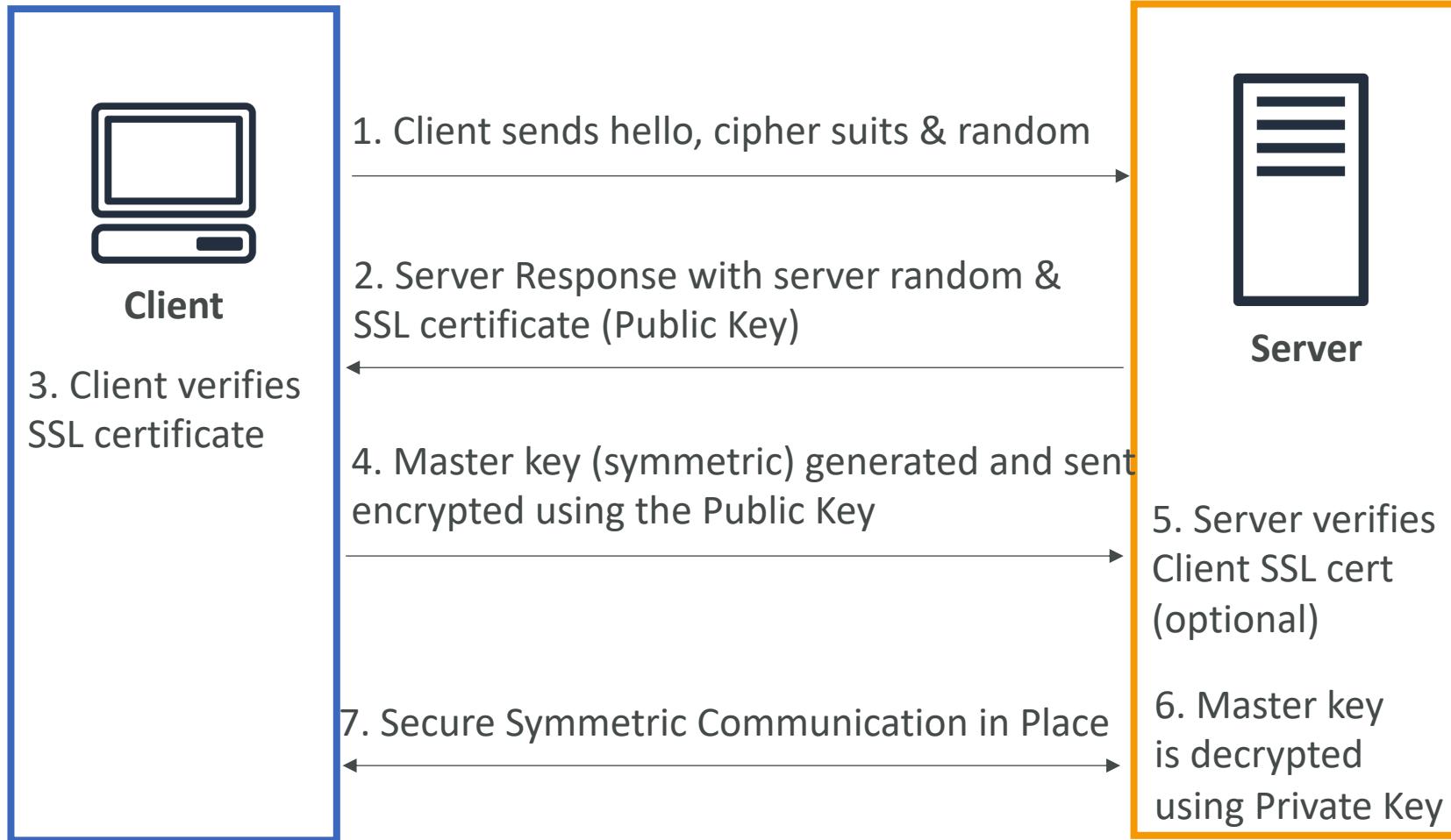


- KMS encryption at rest for underlying EBS volumes / snapshots
- Transparent Data Encryption (TDE) for Oracle and SQL Server
- SSL encryption to RDS is possible for all DB (in-flight)
- IAM authentication for MySQL, PostgreSQL and MariaDB
- Authorization still happens within RDS (not in IAM)
- Can copy an un-encrypted RDS snapshot into an encrypted one
- CloudTrail cannot be used to track queries made within RDS

SSL/TLS - Basics

- SSL refers to Secure Sockets Layer; used to encrypt connections
 - TLS refers to Transport Layer Security, which is a newer version
 - Nowadays, **TLS certificates are mainly used**, but people still refer as SSL
-
- Public SSL certificates are issued by Certificate Authorities (CA)
 - Comodo, Symantec, GoDaddy, GlobalSign, DigiCert, LetsEncrypt, etc...
-
- SSL certificates have an expiration date (you set) and must be renewed

SSL Encryption – How it works



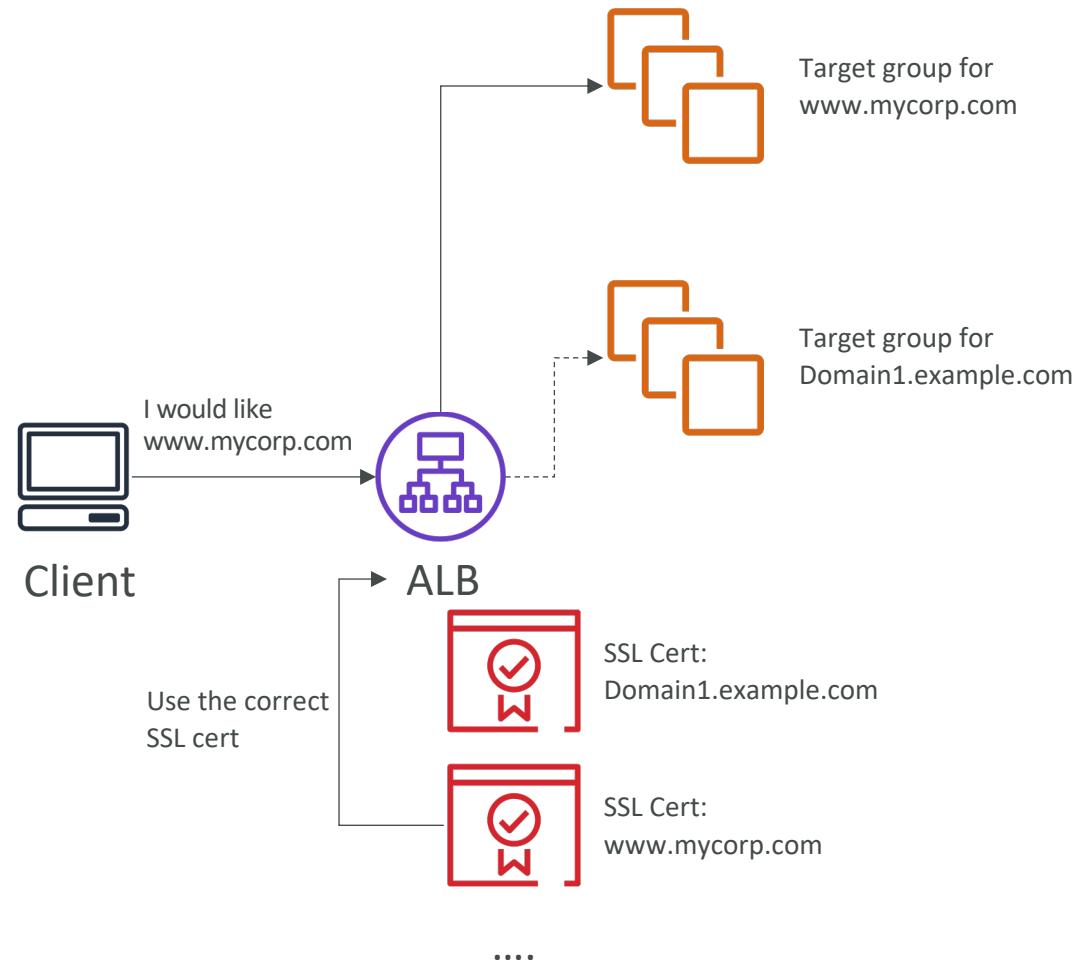
- Asymmetric Encryption is expensive (SSL)
- Symmetric encryption is cheaper
- Asymmetric handshake is used to exchange a per-client random symmetric key
- Possibility of client sending an SSL certificate as well (two-way certificate)

SSL – Server Name Indication (SNI)

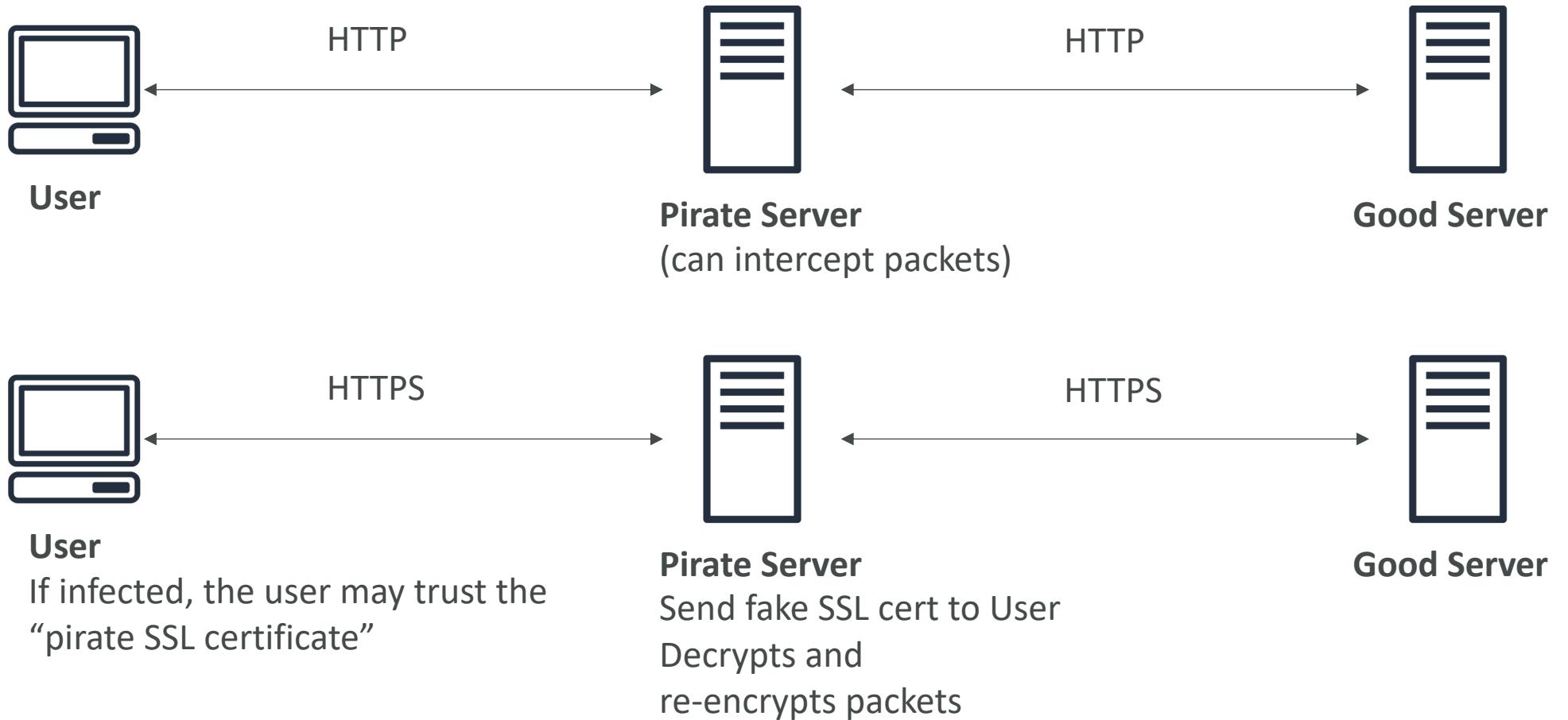
- SNI solves the problem of loading **multiple SSL certificates onto one web server** (to serve multiple websites)
- It's a “newer” protocol, and requires the client to **indicate** the hostname of the target server in the initial SSL handshake
- The server will then find the correct certificate, or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

Note:

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



SSL – Man in the Middle Attacks



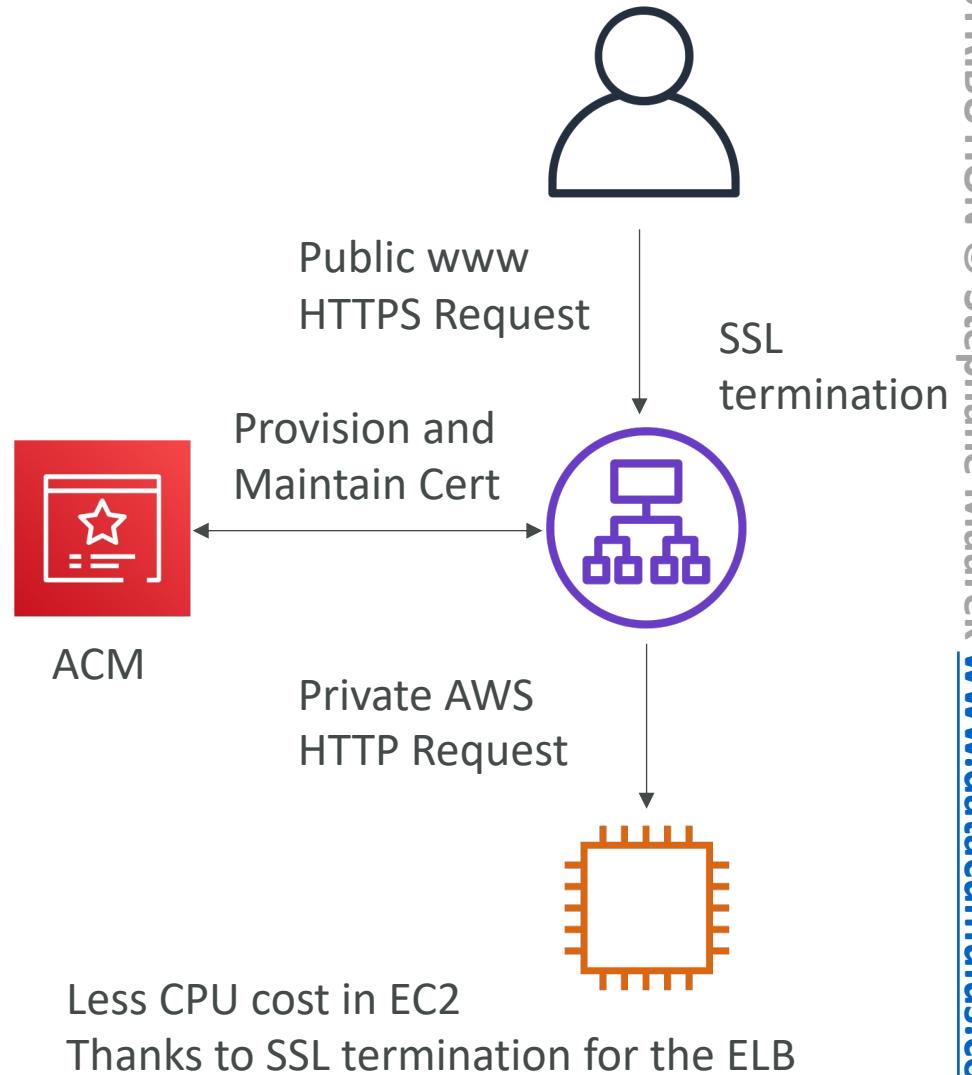
SSL – Man in the Middle Attack

How to prevent

1. Don't use public-facing HTTP, use HTTPS (meaning, use SSL/TLS certificates)
2. Use a DNS that has DNSSEC
 - To send a client to a pirate server, a DNS response needs to be “forged” by a server which intercepts them
 - It is possible to protect your domain name by configuring DNSSEC
 - Amazon Route 53 supports DNSSEC for domain registration.
 - Route 53 supports DNSSEC for DNS service as of December 2020 (using KMS)
 - You could also run a custom DNS server on Amazon EC2 for example (Bind is the most popular; dnsmasq, KnotDNS, PowerDNS).

AWS Certificate Manager (ACM)

- To host public SSL certificates in AWS, you can:
 - Buy your own and upload them using the CLI
 - Have ACM provision and renew public SSL certificates for you (free of cost)
- ACM loads SSL certificates on the following integrations:
 - Load Balancers (including the ones created by EB)
 - CloudFront distributions
 - APIs on API Gateways
- SSL certificates is overall a pain to manually manage, so ACM is great to leverage in your AWS infrastructure!



ACM – Good to know

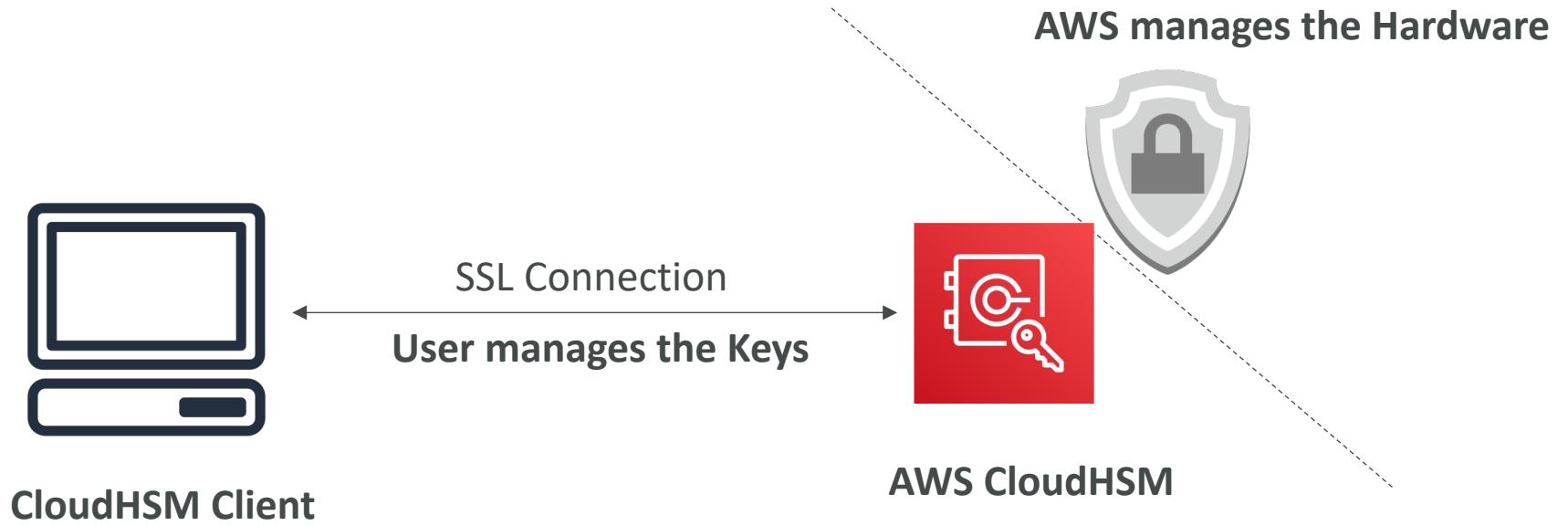
- Possibility of creating public certificates
 - Must verify public DNS
 - Must be issued by a trusted public certificate authority (CA)
- Possibility of creating private certificates
 - For your internal applications
 - You create your own private CA
 - Your applications must trust your private CA
- Certificate renewal:
 - Automatically done if generated provisioned by ACM
 - Any manually uploaded certificates must be renewed manually and re-uploaded
- ACM is a **regional** service
 - To use with a global application (multiple ALB for example), you need to issue an SSL certificate in each region where your application is deployed.
 - You cannot copy certs across regions

CloudHSM



- KMS => AWS manages the software for encryption
- CloudHSM => AWS provisions encryption **hardware**
- Dedicated Hardware (HSM = Hardware Security Module)
- You manage your own encryption keys entirely (not AWS)
- HSM device is tamper resistant, FIPS 140-2 Level 3 compliance
- Supports both symmetric and **asymmetric** encryption (SSL/TLS keys)
- No free tier available
- Must use the CloudHSM Client Software
- Redshift supports CloudHSM for database encryption and key management
- **Good option to use with SSE-C encryption**

CloudHSM Diagram



IAM permissions:

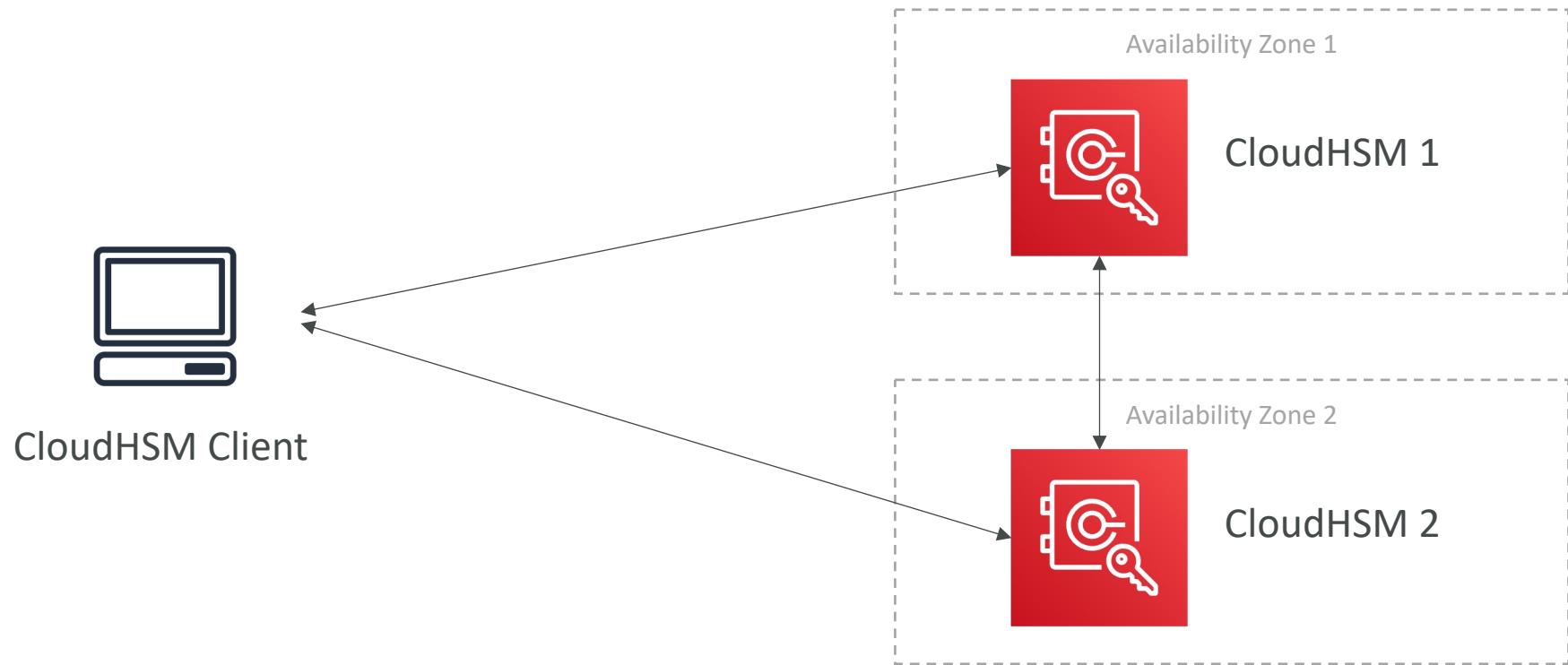
- CRUD an HSM Cluster

CloudHSM Software:

- Manage the Keys
- Manage the Users

CloudHSM – High Availability

- CloudHSM clusters are spread across Multi AZ (HA)
- Great for availability and durability



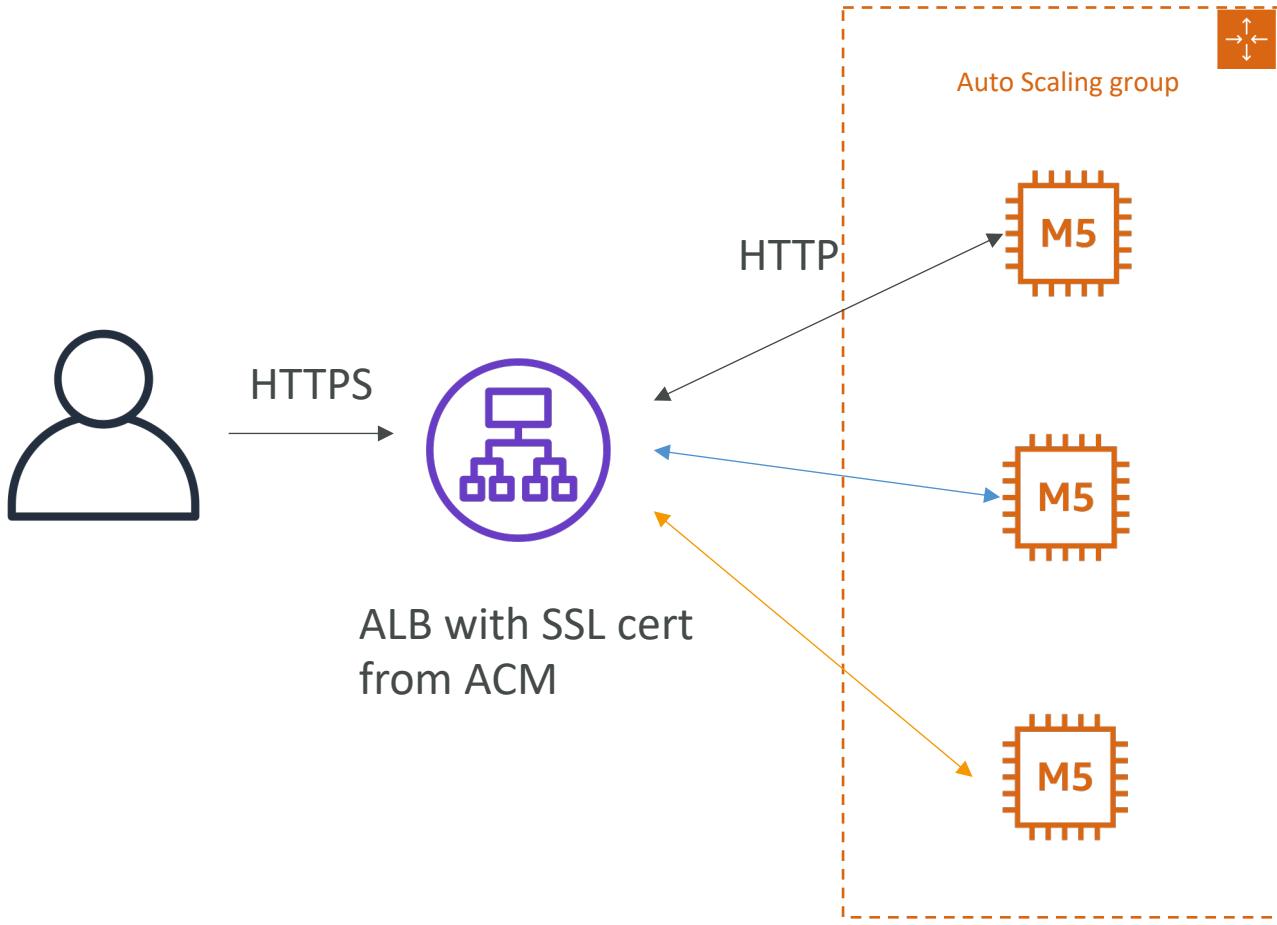
CloudHSM vs. KMS

Feature	AWS KMS	AWS CloudHSM
Tenancy	Multi-Tenant	Single-Tenant
Standard	FIPS 140-2 Level 3	FIPS 140-2 Level 3
Master Keys	<ul style="list-style-type: none">• AWS Owned Keys• AWS Managed Keys• Customer Managed KMS Keys	Customer Managed CMK
Key Types	<ul style="list-style-type: none">• Symmetric• Asymmetric• Digital Signing	<ul style="list-style-type: none">• Symmetric• Asymmetric• Digital Signing & Hashing
Key Accessibility	Accessible in multiple AWS regions KMS Key Replication	<ul style="list-style-type: none">• Deployed and managed in a VPC• Can be shared across VPCs (VPC Peering)
Cryptographic Acceleration	None	<ul style="list-style-type: none">• SSL/TLS Acceleration• Oracle TDE Acceleration
Access & Authentication	AWS IAM	You create users and manage their permissions

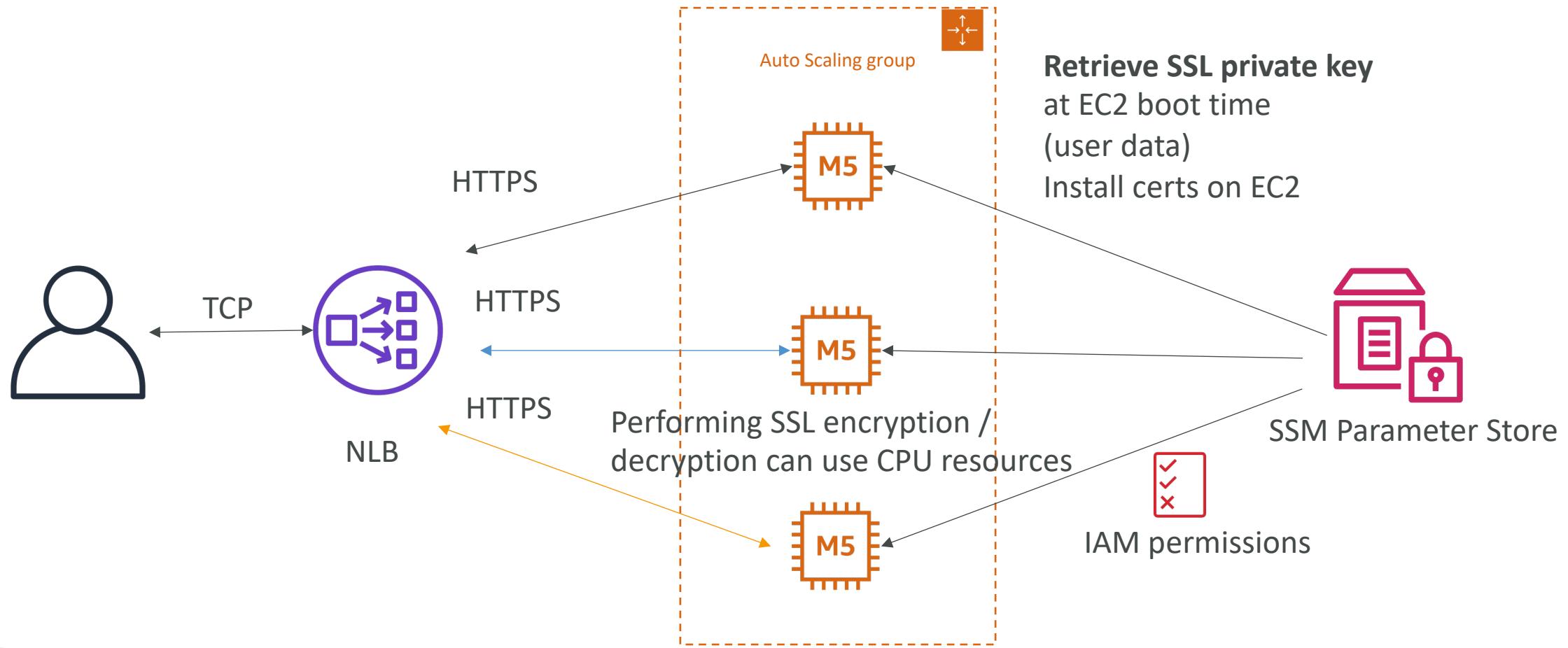
CloudHSM vs. KMS

Feature	AWS KMS	AWS CloudHSM
High Availability	AWS Managed Service	Add multiple HSMs over different AZs
Audit Capability	<ul style="list-style-type: none">• CloudTrail• CloudWatch	<ul style="list-style-type: none">• CloudTrail• CloudWatch• MFA support
Free Tier	Yes	No

Solution Architecture: SSL on ALB

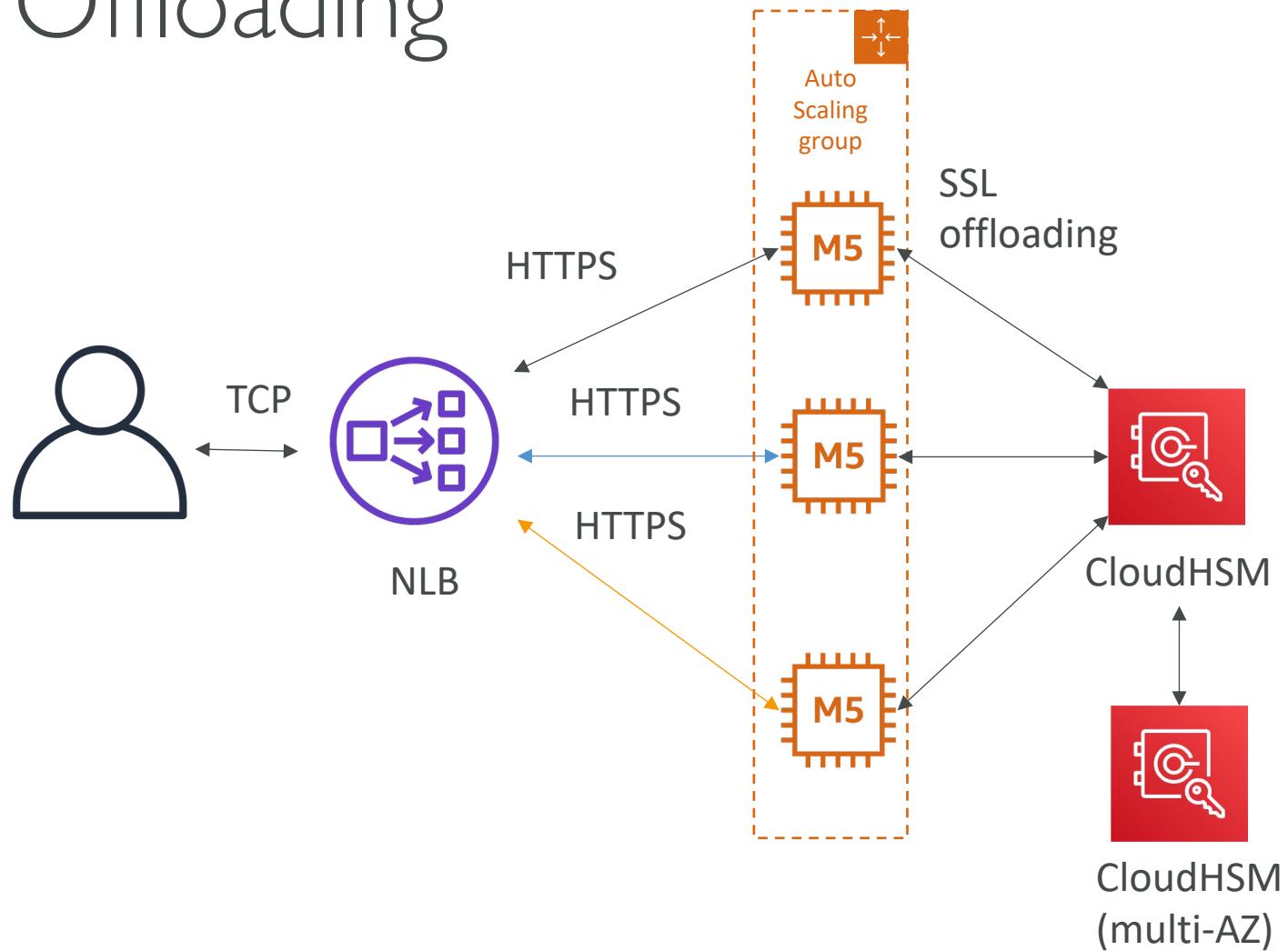


Solution Architecture: SSL on web server EC2 instances



Solution Architecture: CloudHSM – SSL Offloading

- You can offload SSL to CloudHSM (SSL Acceleration)
- Supported by NGINX, Apache Web servers and IIS for Windows Server
- Extra security: the SSL private key never leaves the HSM device
- Must setup a cryptographic user (CU) on the CloudHSM device



S3 Encryption for Objects

- **SSE-S3:** encrypts S3 objects using keys handled & managed by AWS
- **SSE-KMS:** leverage KMS to manage encryption keys
 - Key usage appears in CloudTrail
 - objects made public can never be read
 - On `s3:PutObject`, make the permission `kms:GenerateDataKey` is allowed
- **SSE-C:** when you want to manage your own encryption keys
- Client-Side Encryption
- **Glacier:** all data is AES-256 encrypted, key under AWS control

Encryption in transit (SSL / TLS)

- Amazon S3 exposes:
 - HTTP endpoint: non encrypted
 - HTTPS endpoint: encryption in flight
- You're free to use the endpoint you want, but HTTPS is recommended
- HTTPS is mandatory for SSE-C
- To enforce HTTPS, use a Bucket Policy with aws:SecureTransport

Events in S3 Buckets

- **S3 Access Logs:**
 - Detailed records for the requests that are made to a bucket
 - Might take hours to deliver
 - Might be incomplete (best effort)
- **S3 Events Notifications:**
 - Receive notifications when certain events happen in your bucket
 - E.g.: new objects created, object removal, restore objects, replication events
 - Destinations: SNS, SQS queue, Lambda
 - Typically delivered in seconds but can take minutes, notification for every object if versioning is enabled, else risk of one notification for two same object write done simultaneously
- **Trusted Advisor:**
 - Check the bucket permission (is the bucket public?)
- **Amazon EventBridge:**
 - Need to enable CloudTrail object level logging on S3 first
 - Target can be Lambda, SQS, SNS, etc...

S3 Security

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

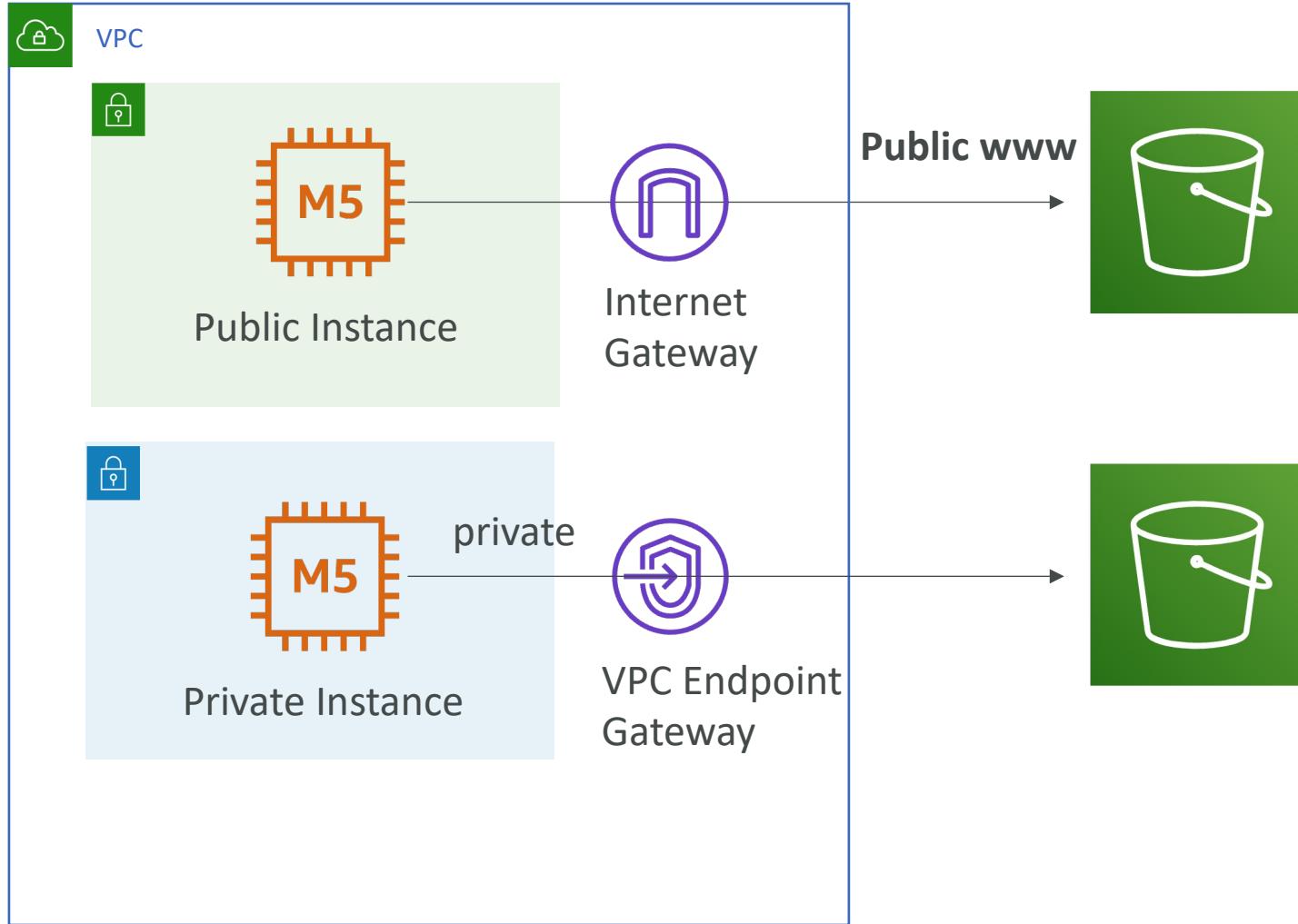
S3 Bucket Policies

- Use S3 bucket for policy to:
 - Grant public access to the bucket
 - Force objects to be encrypted at upload
 - Grant access to another account (Cross Account)
- Optional Conditions on:
 - `SourceIp`: Public IP or Elastic IP | `VpcSourceIp`: Private IP (through VPC Endpoint)
 - Source VPC or Source VPC Endpoint – only works with VPC Endpoints
 - CloudFront Origin Identity
 - MFA
- Examples here: <https://docs.aws.amazon.com/AmazonS3/latest/dev/example-bucket-policies.html>

S3 pre-signed URLs

- Can generate pre-signed URLs using SDK or CLI
 - For downloads (easy, can use the CLI)
 - For uploads (harder, must use the SDK)
- Valid for a default of 3600 seconds, 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
- Examples :
 - Allow only logged-in users to download a premium video on your S3 bucket
 - Allow an ever changing list of users to download files by generating URLs dynamically
 - Allow temporarily a user to upload a file to a precise location in our bucket

VPC Endpoint Gateway for S3



S3 Bucket
Bucket policy by **AWS:SourceIP** (public IP)

S3 Bucket
Bucket policy by
AWS:SourceVpc
(one or few endpoints)

OR

AWS:SourceVpc
(encompass all possible VPC endpoints)

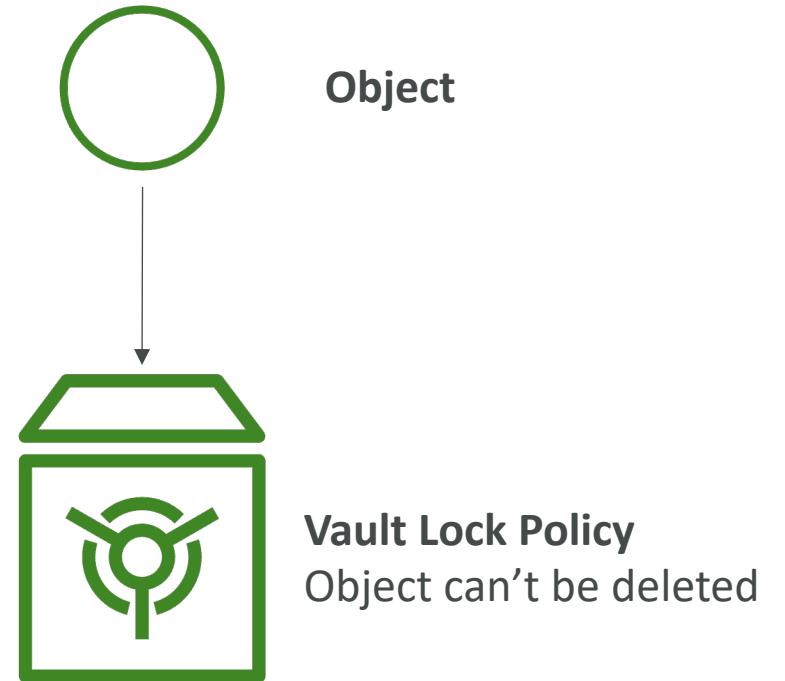
S3 Object Lock & Glacier Vault Lock

- **S3 Object Lock**

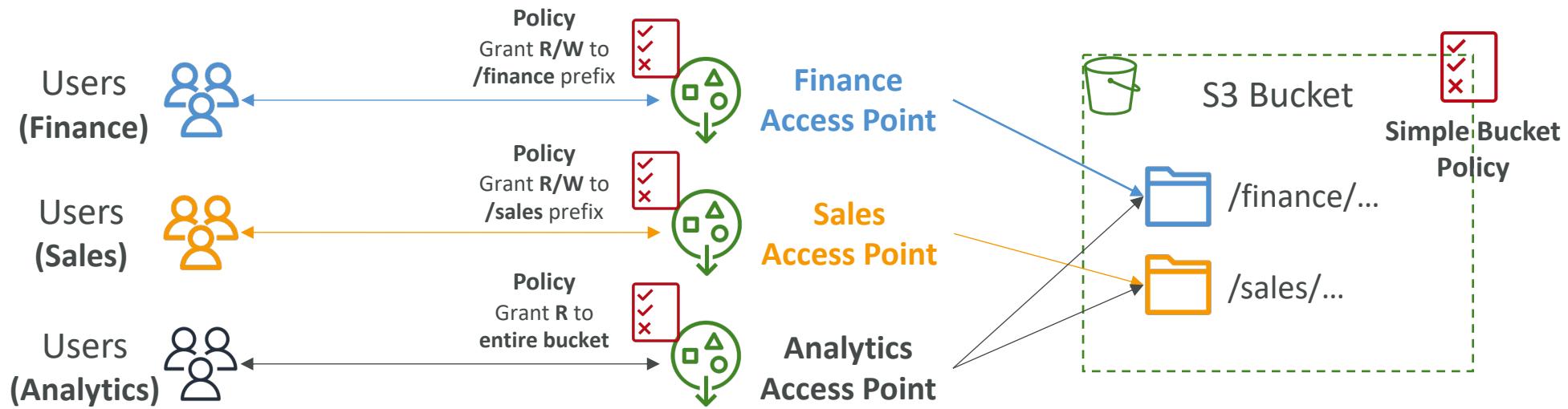
- Adopt a WORM (Write Once Read Many) model
- Block an object version deletion for a specified amount of time

- **Glacier Vault Lock**

- Adopt a WORM (Write Once Read Many) model
- Lock the policy for future edits (can no longer be changed)
- Helpful for compliance and data retention



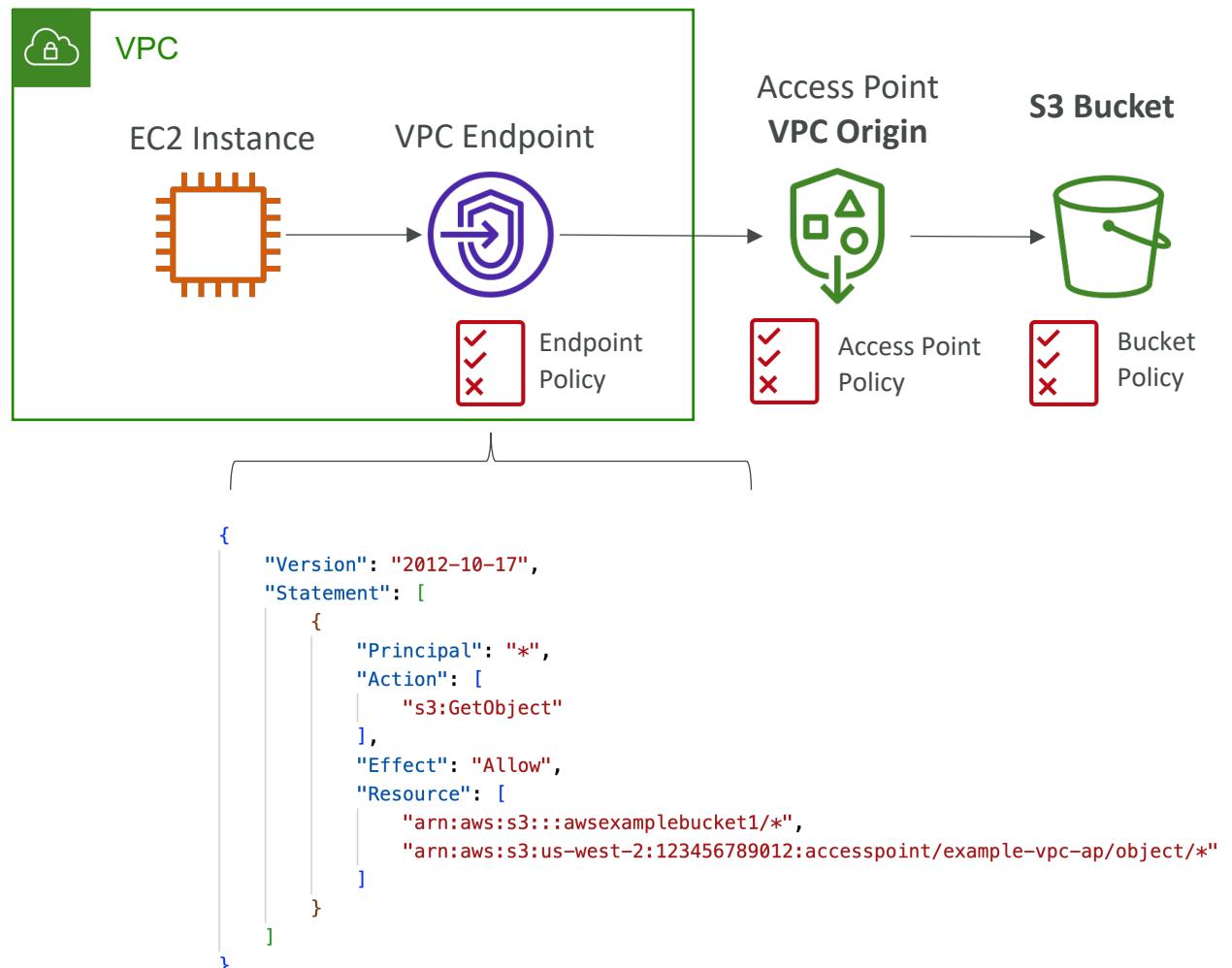
S3 – Access Points



- Access Points simplify security management for S3 Buckets
- Each Access Point has:
 - its own DNS name (Internet Origin or VPC Origin)
 - an access point policy (similar to bucket policy) – manage security at scale

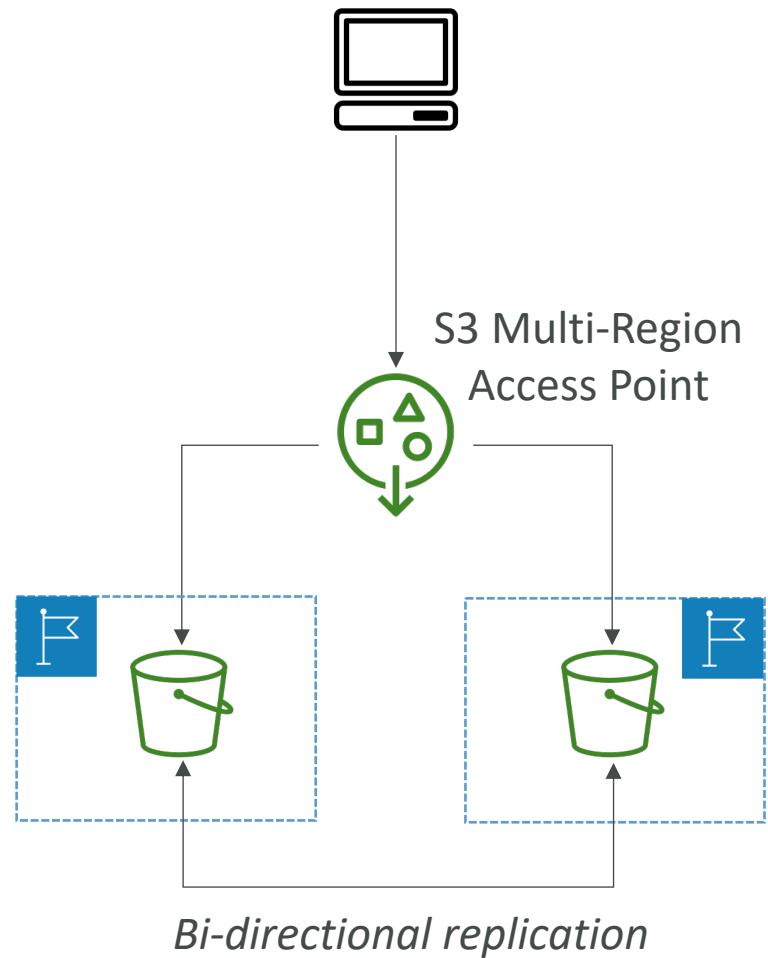
S3 – Access Points – VPC Origin

- We can define the access point to be accessible only from within the VPC
- You must create a VPC Endpoint to access the Access Point (Gateway or Interface Endpoint)
- The VPC Endpoint Policy must allow access to the target bucket and Access Point

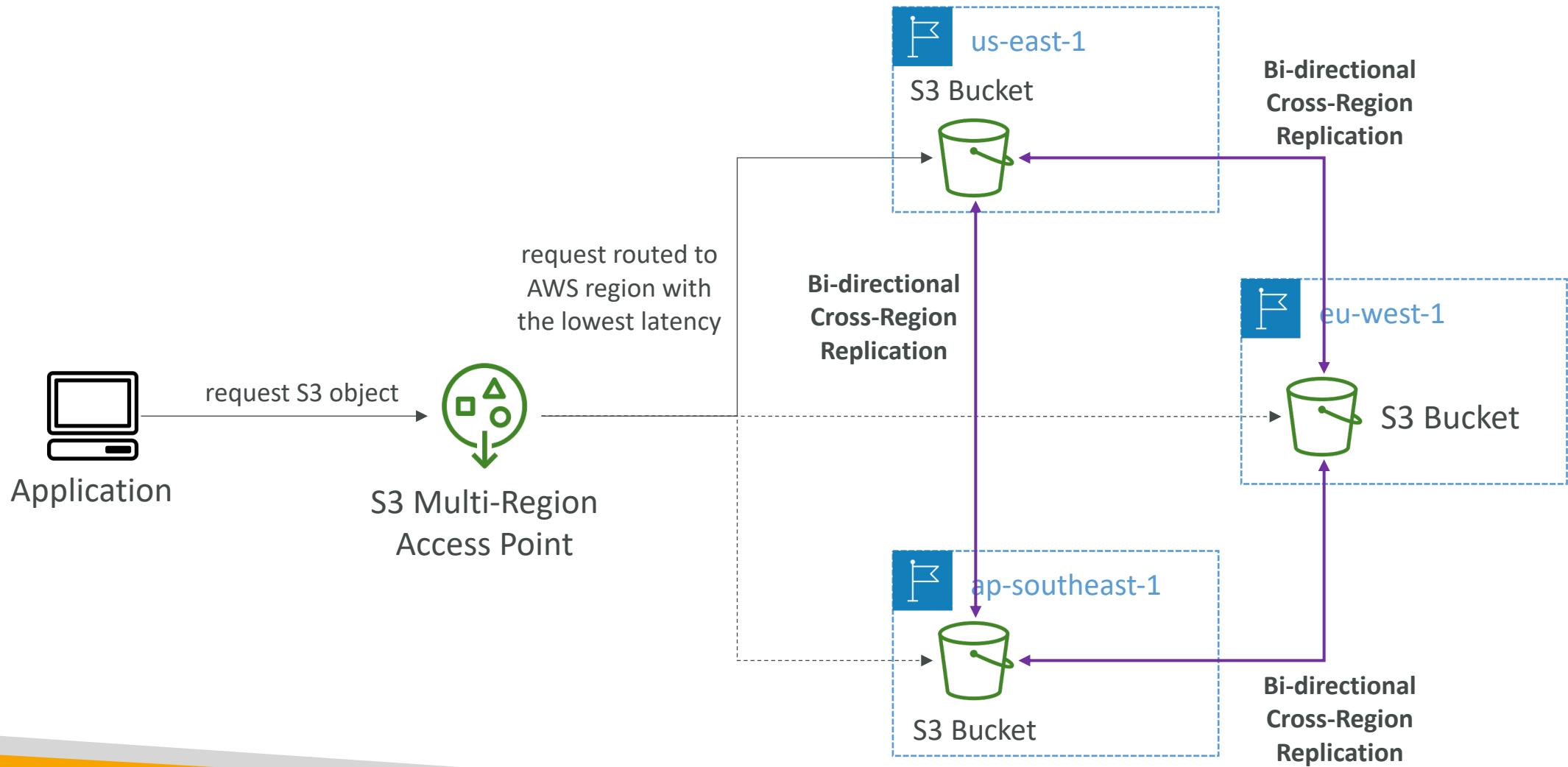


S3 – Multi-Region Access Points

- Provide a global endpoint that spans S3 buckets in multiple AWS regions
- Dynamically route requests to the nearest S3 bucket (lowest latency)
- Bi-directional S3 bucket replication rules are created to keep data in sync across regions
- **Failover Controls** – allows you to shift requests across S3 buckets in different AWS regions within minutes (Active-Active or Active-Passive)

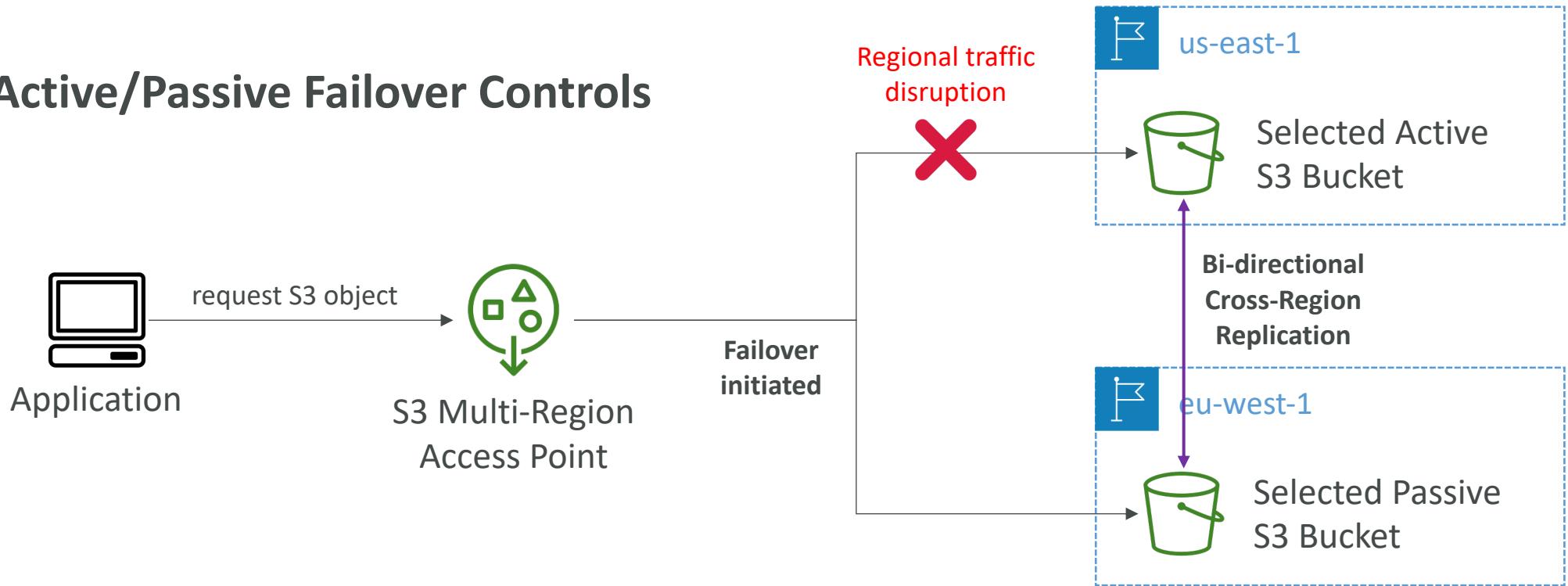


S3 – Multi-Region Access Points



Multi-Region Access Points – Failover Controls

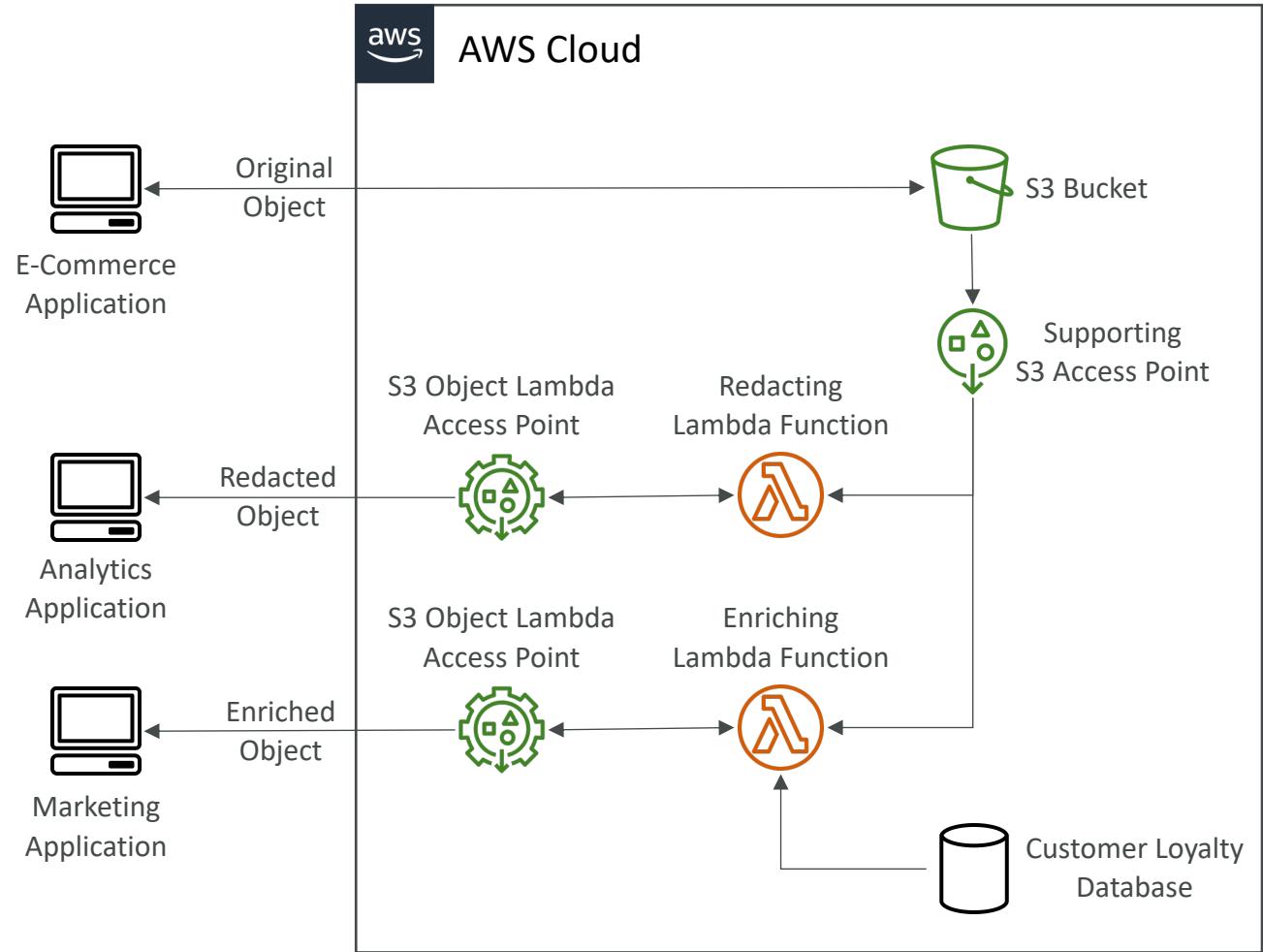
Active/Passive Failover Controls



Works with active/active or active/passive setups

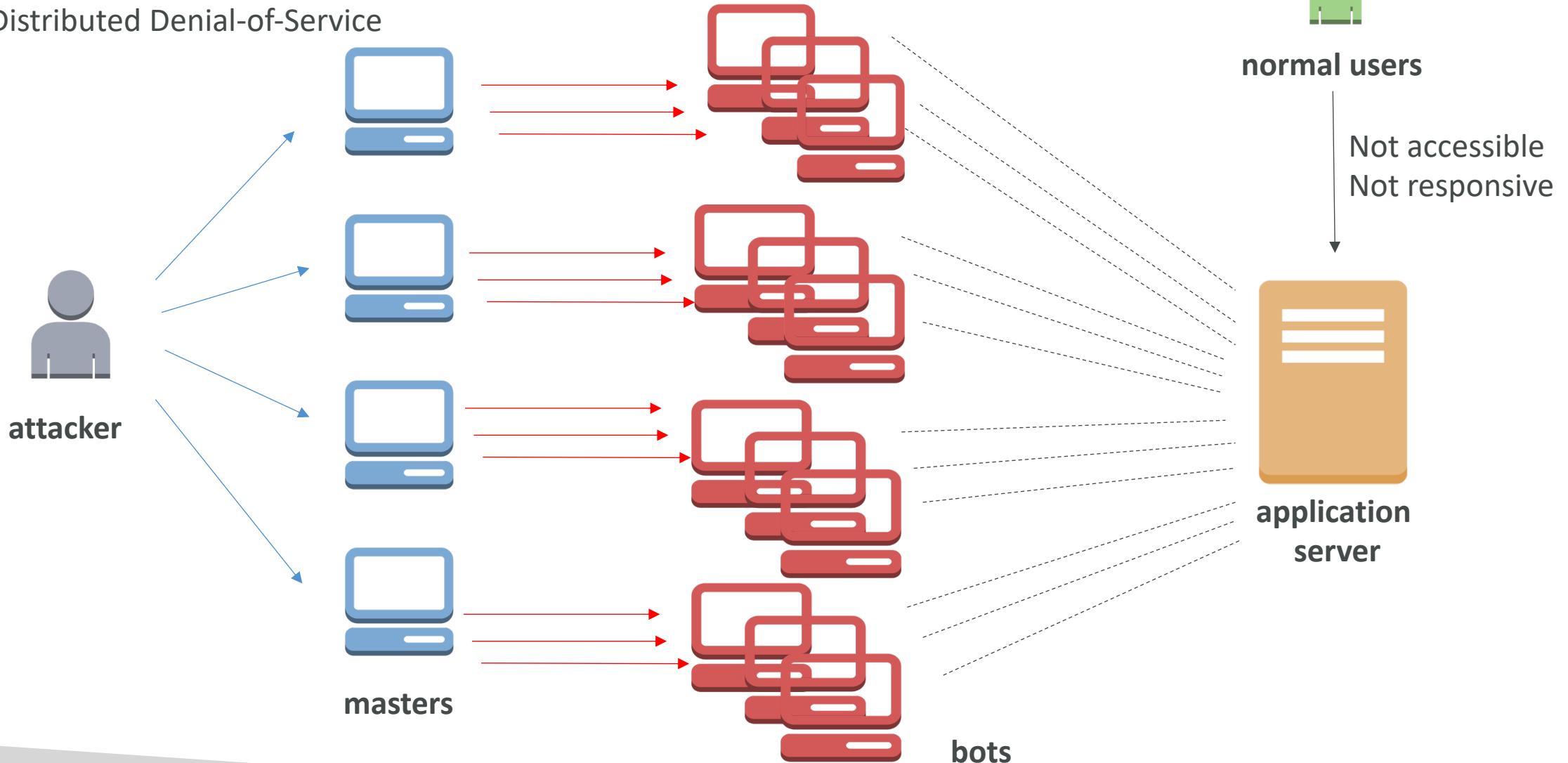
S3 Object Lambda

- Use AWS Lambda Functions to change the object before it is retrieved by the caller application
- Only one S3 bucket is needed, on top of which we create **S3 Access Point** and **S3 Object Lambda Access Points**.
- Use Cases:
 - Redacting personally identifiable information for analytics or non-production environments.
 - Converting across data formats, such as converting XML to JSON.
 - Resizing and watermarking images on the fly using caller-specific details, such as the user who requested the object.



What's a DDOS* Attack?

*Distributed Denial-of-Service



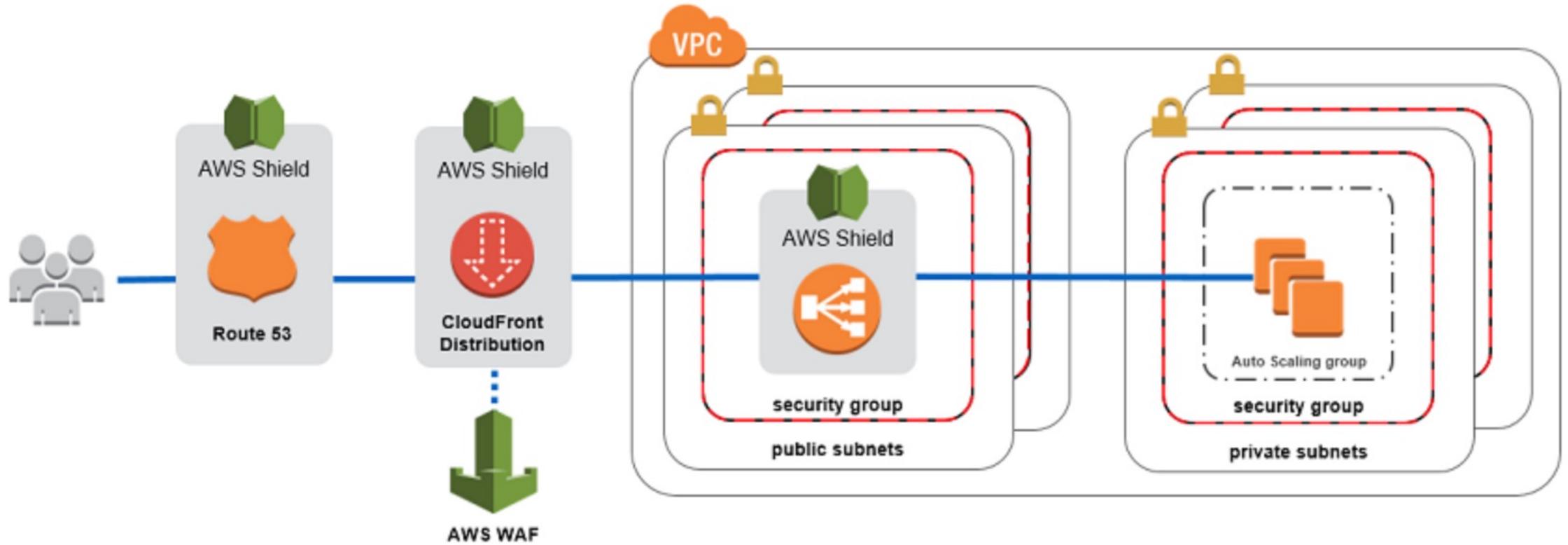
Type of Attacks on your infrastructure

- Distributed Denial of Service (DDoS):
 - When your service is unavailable because it's receiving too many requests
 - SYN Flood (Layer 4): send too many TCP connection requests
 - UDP Reflection (Layer 4): get other servers to send many big UDP requests
 - DNS flood attack: overwhelm the DNS so legitimate users can't find the site
 - Slow Loris attack: a lot of HTTP connections are opened and maintained
- Application level attacks:
 - more complex, more specific (HTTP level)
 - Cache bursting strategies: overload the backend database by invalidating cache

DDoS Protection on AWS

- **AWS Shield Standard:** protects against DDoS attack for your website and applications, for all customers at no additional costs
- **AWS Shield Advanced:** 24/7 premium DDoS protection
- **AWS WAF:** Filter specific requests based on rules
- **CloudFront and Route 53:**
 - Availability protection using global edge network
 - Combined with AWS Shield, provides DDoS attack mitigation at the edge
- Be ready to scale – leverage AWS Auto Scaling
- Separate static resources (S3 / CloudFront) from dynamic ones (EC2 / ALB)
- Read the whitepaper for details:
https://dl.awsstatic.com/whitepapers/Security/DDoS_White_Paper.pdf

Sample Reference Architecture



<https://aws.amazon.com/answers/networking/aws-ddos-attack-mitigation/>

AWS Shield



- AWS Shield Standard:
 - Free service that is activated for every AWS customer
 - Provides protection from attacks such as SYN/UDP Floods, Reflection attacks and other layer 3/layer 4 attacks
- AWS Shield Advanced:
 - Optional DDoS mitigation service (\$3,000 per month per organization)
 - Protect against more sophisticated attack on [Amazon EC2](#), [Elastic Load Balancing \(ELB\)](#), [Amazon CloudFront](#), [AWS Global Accelerator](#), [Route 53](#)
 - 24/7 access to AWS DDoS response team (DRP)
 - Protect against higher fees during usage spikes due to DDoS

AWS WAF – Web Application Firewall



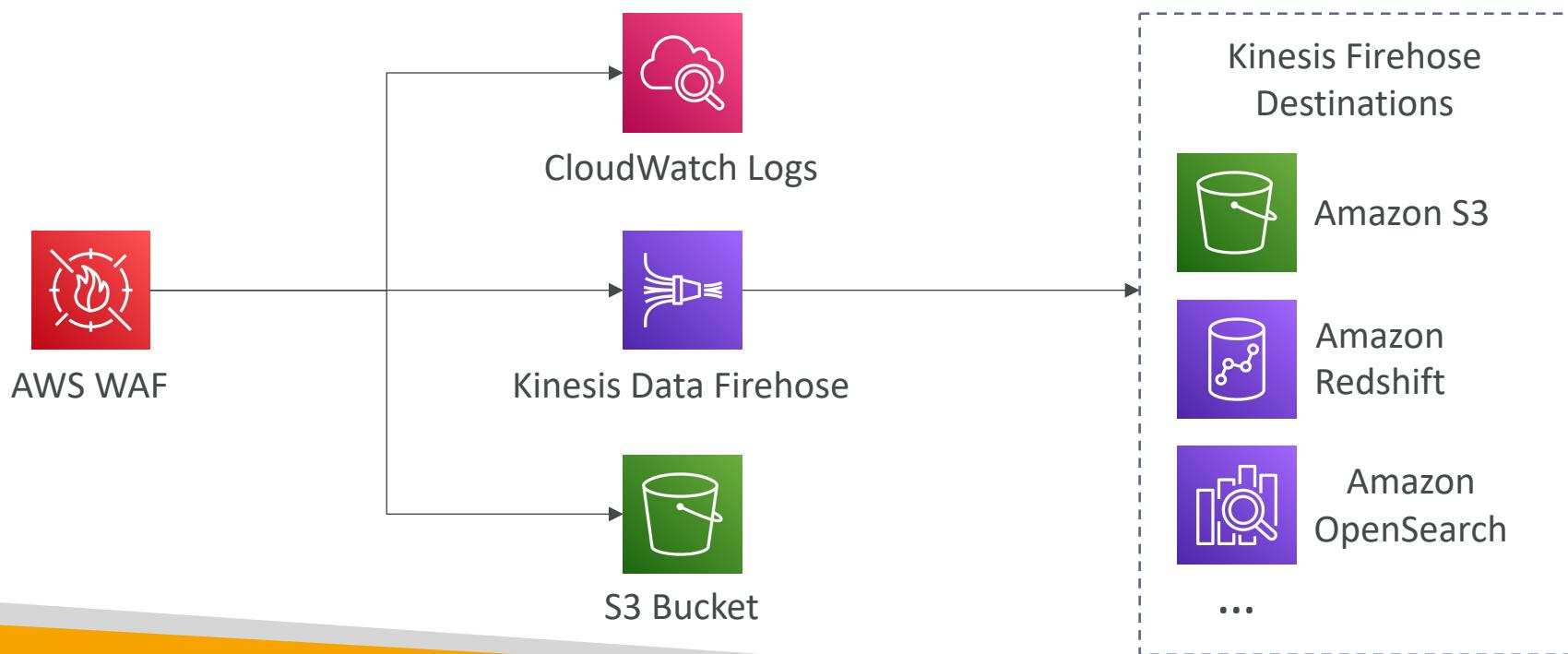
- Protects your web applications from common web exploits (Layer 7)
- Deploy on **Application Load Balancer** (localized rules)
- Deploy on **API Gateway** (rules running at the regional or edge level)
- Deploy on **CloudFront** (rules globally on edge locations)
 - Used to front other solutions: CLB, EC2 instances, custom origins, S3 websites
- Deploy on AppSync (protect your GraphQL APIs)
- WAF is not for DDoS protection
- Define Web ACL (Web Access Control List):
 - Rules can include **IP addresses**, HTTP headers, HTTP body, or URI strings
 - Protects from common attack - **SQL injection** and Cross-Site Scripting (**XSS**)
 - Size constraints, Geo match
 - Rate-based rules (to count occurrences of events)
- Rule Actions: Count | Allow | Block | CAPTCHA

AWS WAF – Managed Rules

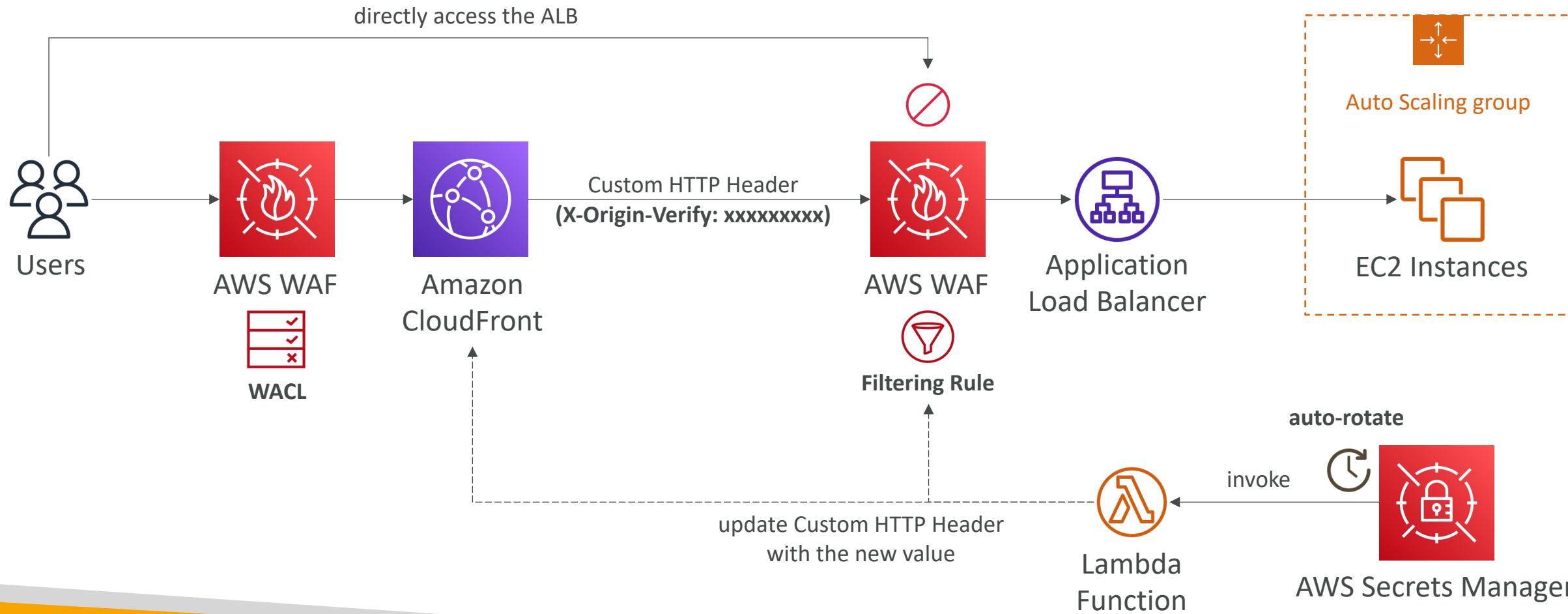
- Library of over 190 managed rules
- Ready-to-use rules that are managed by AWS and AWS Marketplace Sellers
- **Baseline Rule Groups** – general protection from common threats
 - AWSManagedRulesCommonRuleSet, AWSManagedRulesAdminProtectionRuleSet, ...
- **Use-case Specific Rule Groups** – protection for many AWS WAF use cases
 - AWSManagedRulesSQLiRuleSet, AWSManagedRulesWindowsRuleSet, AWSManagedRulesPHPRuleSet, AWSManagedRulesWordPressRuleSet, ...
- **IP Reputation Rule Groups** – block requests based on source (e.g., malicious IPs)
 - AWSManagedRulesAmazonIpReputationList, AWSManagedRulesAnonymousIpList
- **Bot Control Managed Rule Group** – block and manage requests from bots
 - AWSManagedRulesBotControlRuleSet

WAF - Web ACL – Logging

- You can send your logs to an:
 - Amazon CloudWatch Logs log group – 5 MB per second
 - Amazon Simple Storage Service (Amazon S3) bucket – 5 minutes interval
 - Amazon Kinesis Data Firehose – limited by Firehose quotas



Solution Architecture – Enhance CloudFront Origin Security with AWS WAF & AWS Secrets Manager



AWS Firewall Manager



- Manage rules in all accounts of an AWS Organization
- Security policy: common set of security rules
 - WAF rules (Application Load Balancer, API Gateways, CloudFront)
 - AWS Shield Advanced (ALB, CLB, NLB, Elastic IP, CloudFront)
 - Security Groups for EC2, Application Load Balancer and ENI resources in VPC
 - AWS Network Firewall (VPC Level)
 - Amazon Route 53 Resolver DNS Firewall
 - Policies are created at the region level
- Rules are applied to new resources as they are created (good for compliance) across all and future accounts in your Organization

WAF vs. Firewall Manager vs. Shield



AWS WAF



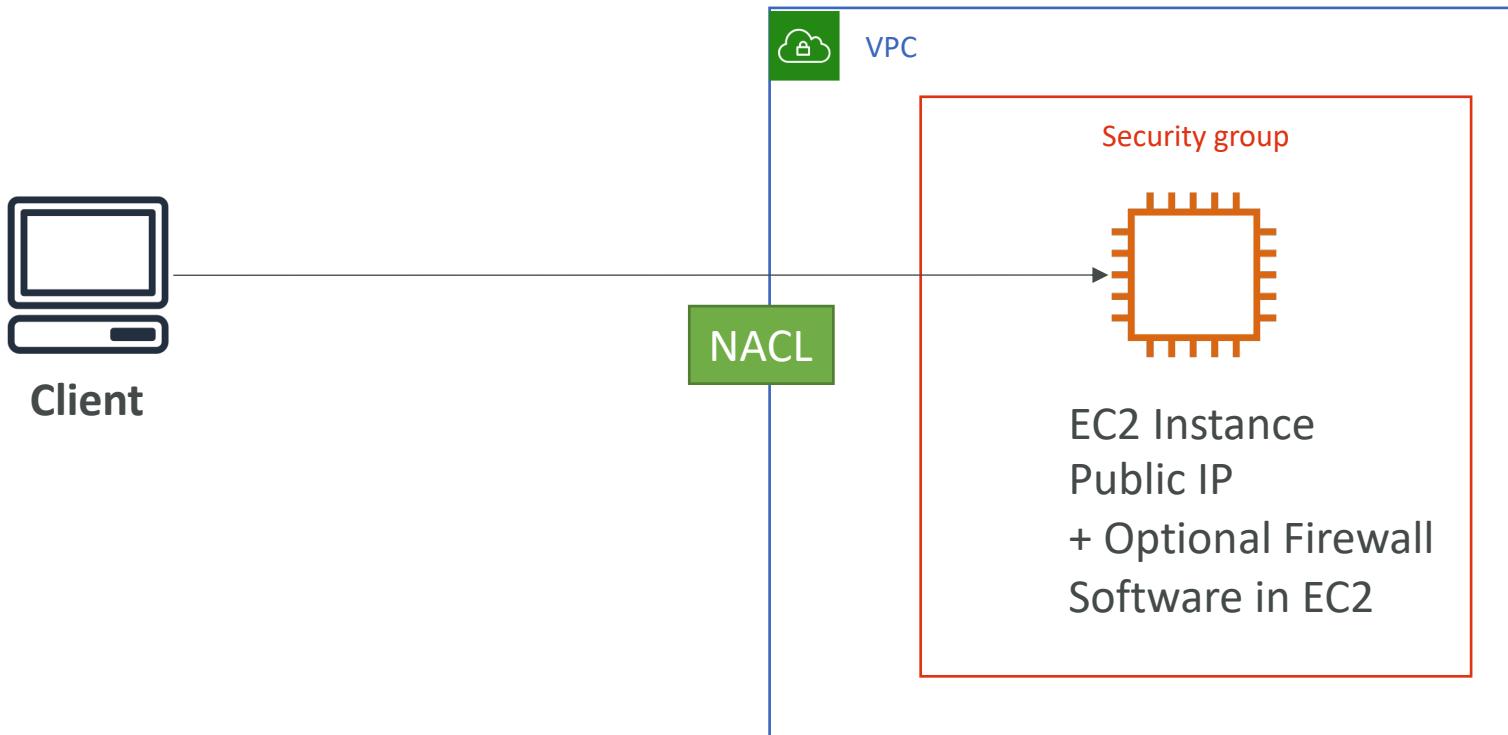
AWS Firewall Manager



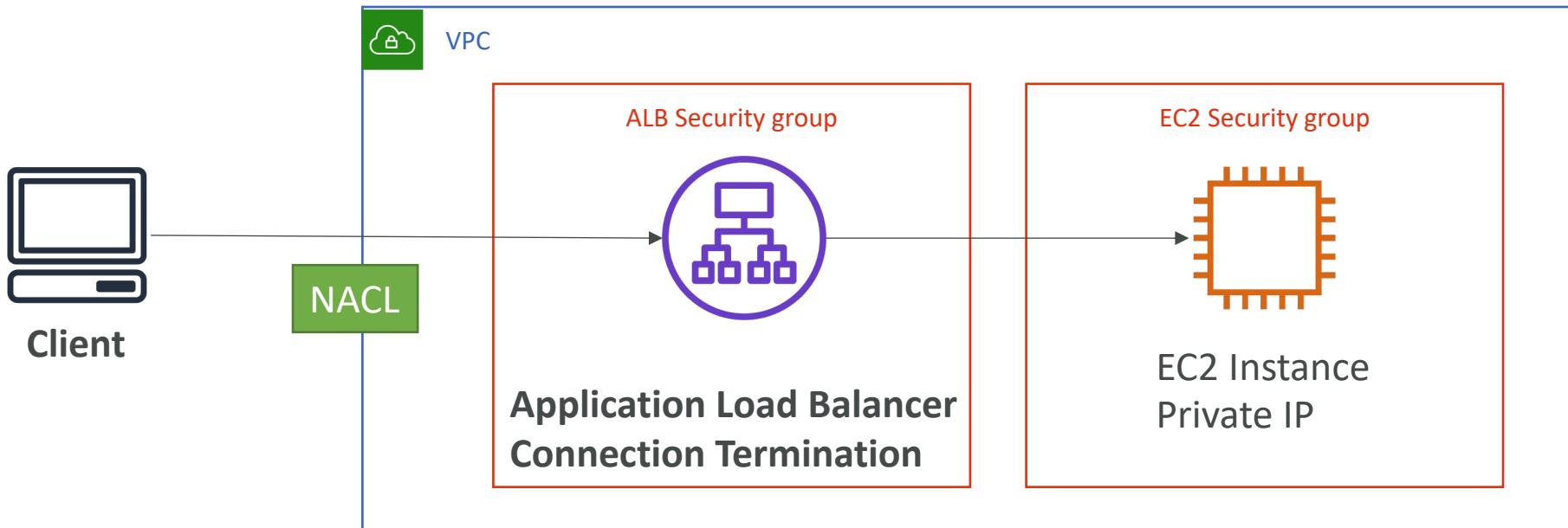
AWS Shield

- 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

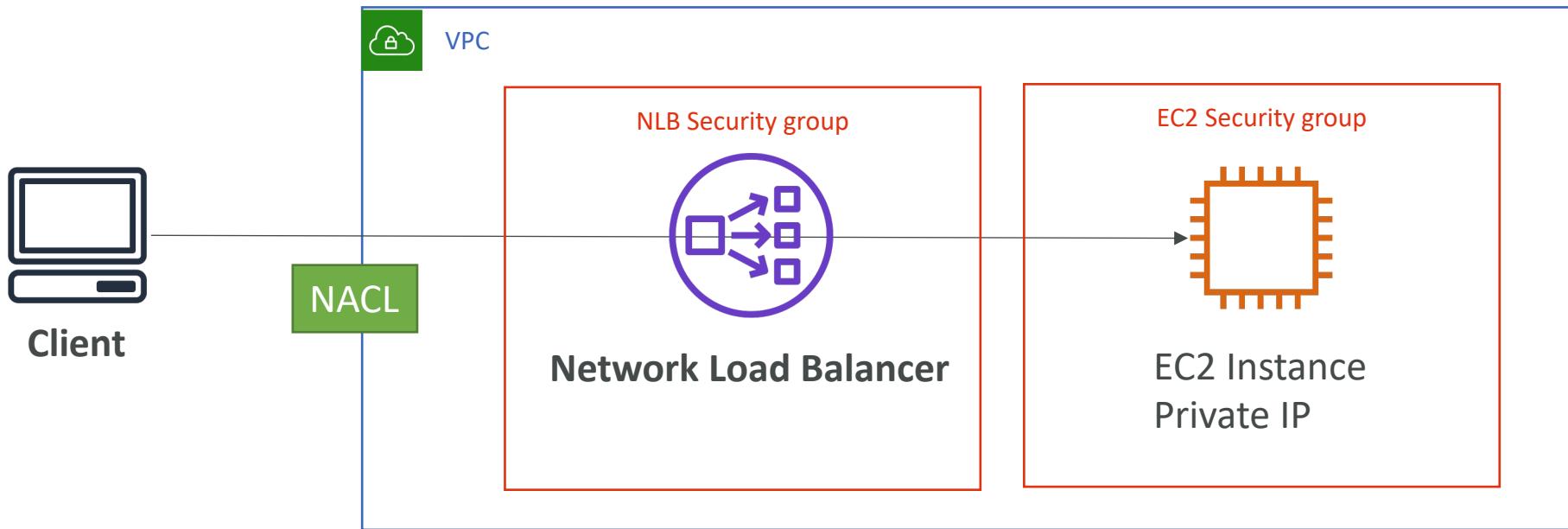
Blocking an IP address



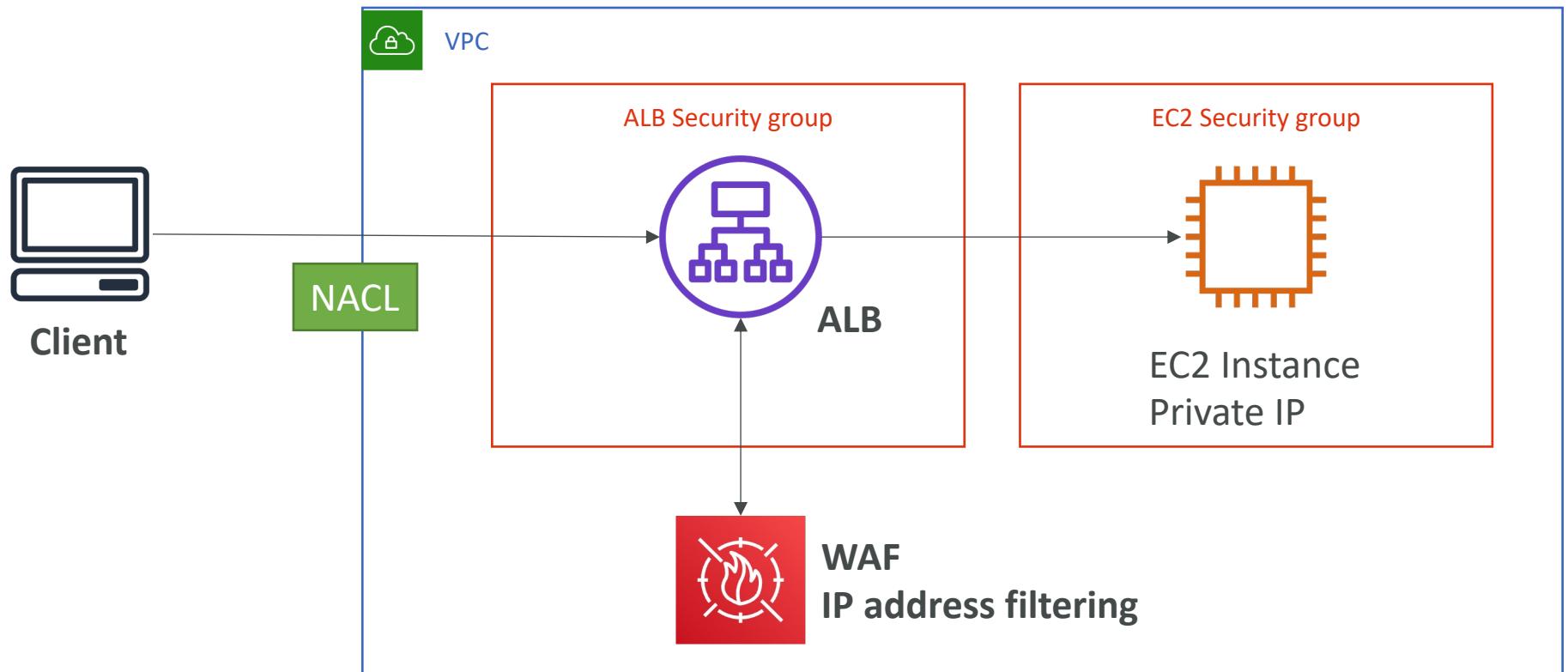
Blocking an IP address – with an ALB



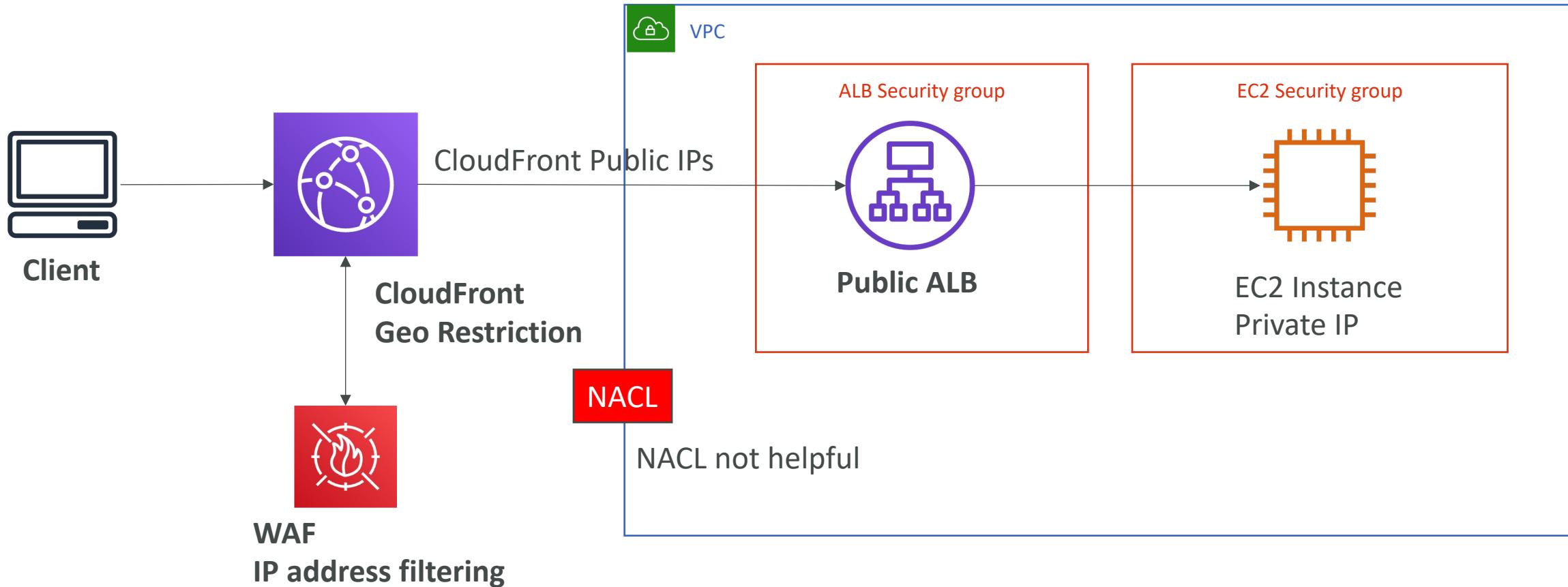
Blocking an IP address – with an NLB



Blocking an IP address – ALB + WAF

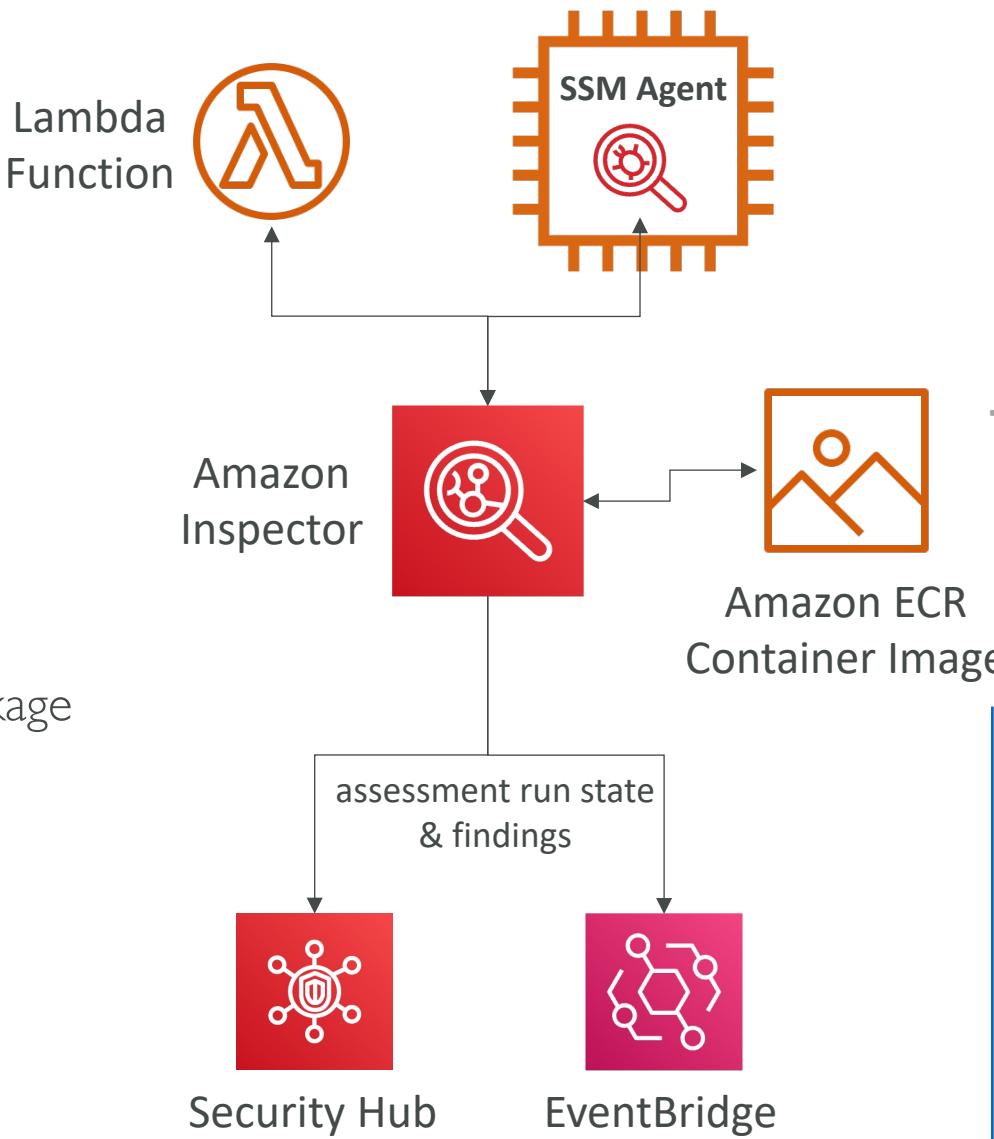


Blocking an IP address – ALB, CloudFront WAF



Amazon Inspector

- Automated Security Assessments
- For EC2 instances
 - Leveraging the AWS System Manager (SSM) agent
 - Analyze against unintended network accessibility
 - Analyze the running OS against known vulnerabilities
- For Container Images push to Amazon ECR
 - Assessment of Container Images as they are pushed
- For Lambda Functions
 - Identifies software vulnerabilities in function code and package dependencies
 - Assessment of functions as they are deployed
- Reporting & integration with AWS Security Hub
- Send findings to Amazon Event Bridge



What does Amazon Inspector evaluate?



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

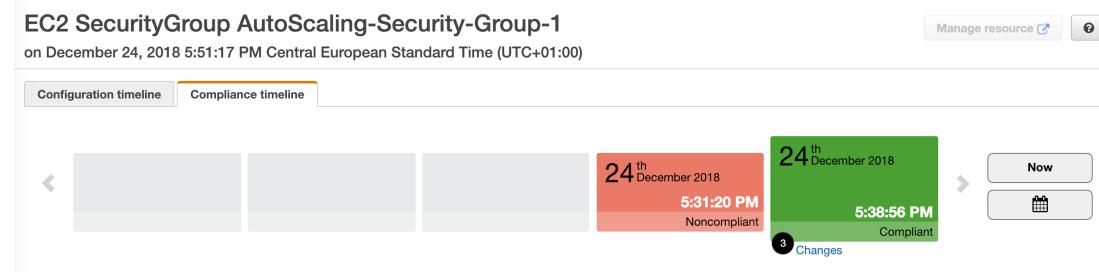


AWS Config

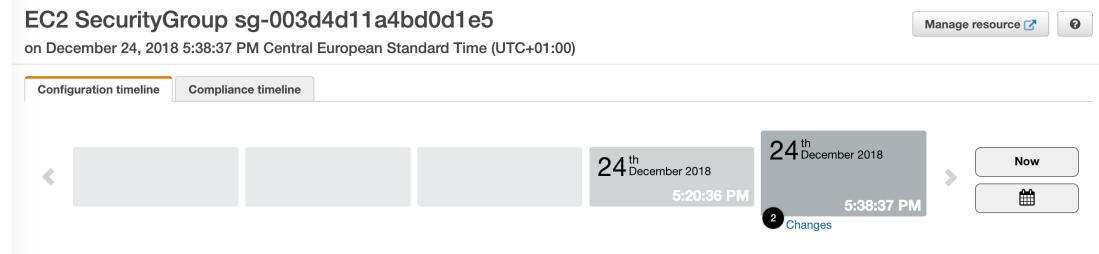
- Helps with auditing and recording **compliance** of your AWS resources
- Helps record configurations and changes over time
- **AWS Config Rules** does not prevent actions from happening (no deny)
- Questions that can be solved by AWS Config:
 - Is there unrestricted SSH access to my security groups?
 - 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

AWS Config Resource

- View compliance of a resource over time



- View configuration of a resource over time



- View CloudTrail API calls if enabled

AWS Config Rules

- Can use AWS managed config rules (over 75)
- Can make custom config rules (must be defined in AWS Lambda)
 - Evaluate if each EBS disk is of type gp2
 - Evaluate if each EC2 instance is t2.micro
- Rules can be evaluated / triggered:
 - For each config change
 - And / or: at regular time intervals
- Trigger Amazon EventBridge if the rule is non-compliant (chain with Lambda)
- Rules can have auto remediations through **SSM Automations**
 - If a resource is not compliant, you can trigger an auto remediation
 - Ex: remediate security group rules, stop instances with non-approved tags

AWS Managed Logs

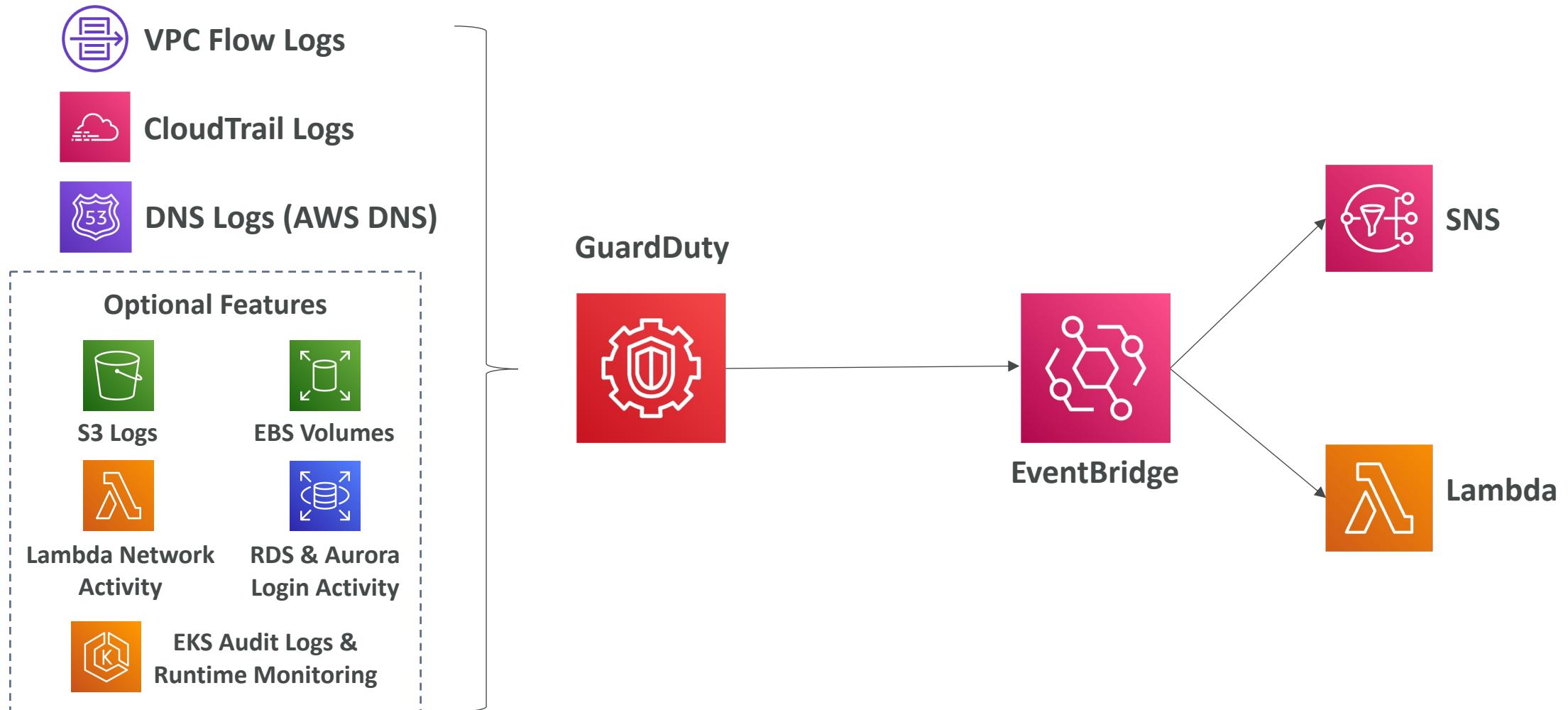
- **Load Balancer Access Logs (ALB, NLB, CLB)** => to S3
 - Access logs for your Load Balancers
- **CloudTrail Logs** => to S3 and CloudWatch Logs
 - Logs for API calls made within your account
- **VPC Flow Logs** => to S3, CloudWatch Logs, Kinesis Data Firehose
 - Information about IP traffic going to and from network interfaces in your VPC
- **Route 53 Access Logs** => to CloudWatch Logs
 - Log information about the queries that Route 53 receives
- **S3 Access Logs** => to S3
 - Server access logging provides detailed records for the requests that are made to a bucket
- **CloudFront Access Logs** => to S3
 - Detailed information about every user request that CloudFront receives
- **AWS Config** => to S3



Amazon GuardDuty

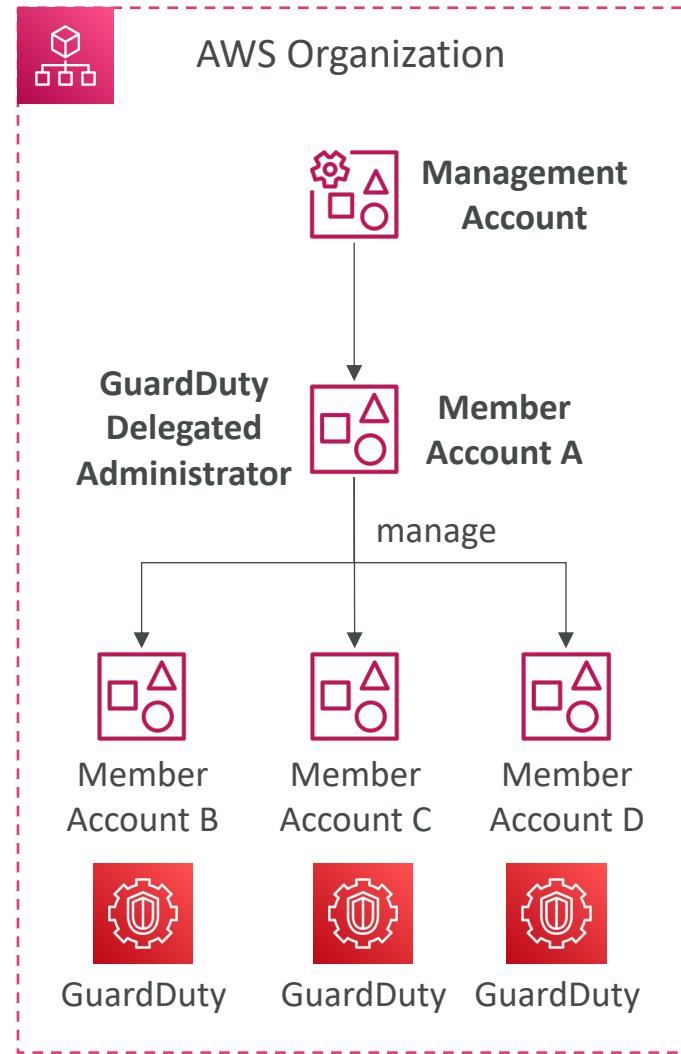
- Intelligent Threat discovery to protect your AWS Account
- Uses Machine Learning algorithms, anomaly detection, 3rd party data
- One click to enable (30 days trial), no need to install software
- Input data includes:
 - **CloudTrail Events Logs** – unusual API calls, unauthorized deployments
 - CloudTrail 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
 - **Optional Feature** – EKS Audit Logs, RDS & Aurora, EBS, Lambda, S3 Data Events...
- Can setup **EventBridge rules** to be notified in case of findings
- EventBridge rules can target AWS Lambda or SNS
- **Can protect against CryptoCurrency attacks** (has a dedicated “finding” for it)

Amazon GuardDuty



GuardDuty – Delegated Administrator

- AWS Organization member accounts can be designated to be a **GuardDuty Delegated Administrator**
- Have full permissions to enable and manage GuardDuty for all accounts in the Organization
- Can be done only using the Organization Management Account



IAM Conditions

aws:SourceIp

restrict the client IP from
which the API calls are being made

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

aws:RequestedRegion

restrict the region the
API calls are made to

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

IAM Conditions

ec2:ResourceTag

restrict based on **tags**

```
{  
  "Version": "2012-10-17",  
  "Statement": [  
    {  
      "Effect": "Allow",  
      "Action": ["ec2:startInstances", "ec2:StopInstances"],  
      "Resource": "arn:aws:ec2:us-east-1:123456789012:instance/*",  
      "Condition": {  
        "StringEquals": {  
          "ec2:ResourceTag/Project": "DataAnalytics",  
          "aws:PrincipalTag/Department": "Data"  
        }  
      }  
    }  
  ]  
}
```

aws:MultiFactorAuthPresent

to force MFA

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

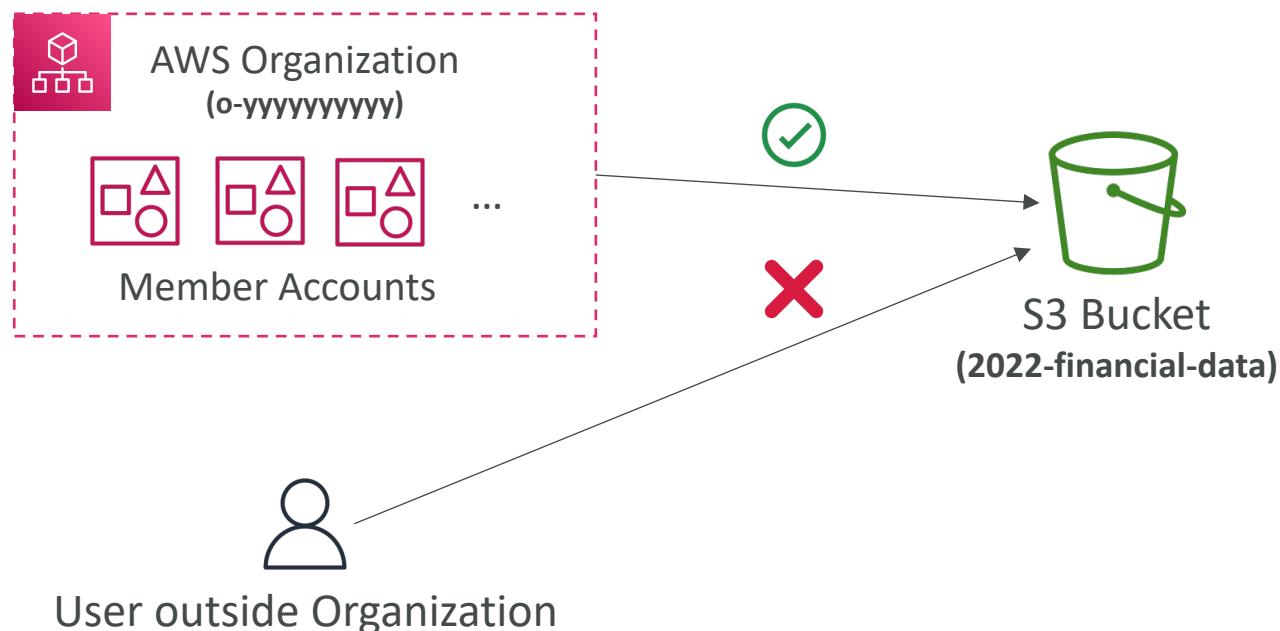
IAM for S3

- s3>ListBucket permission applies to
arn:aws:s3:::test
- => bucket level permission
- s3GetObject, s3PutObject,
s3DeleteObject 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/*"  
        }  
    ]  
}
```

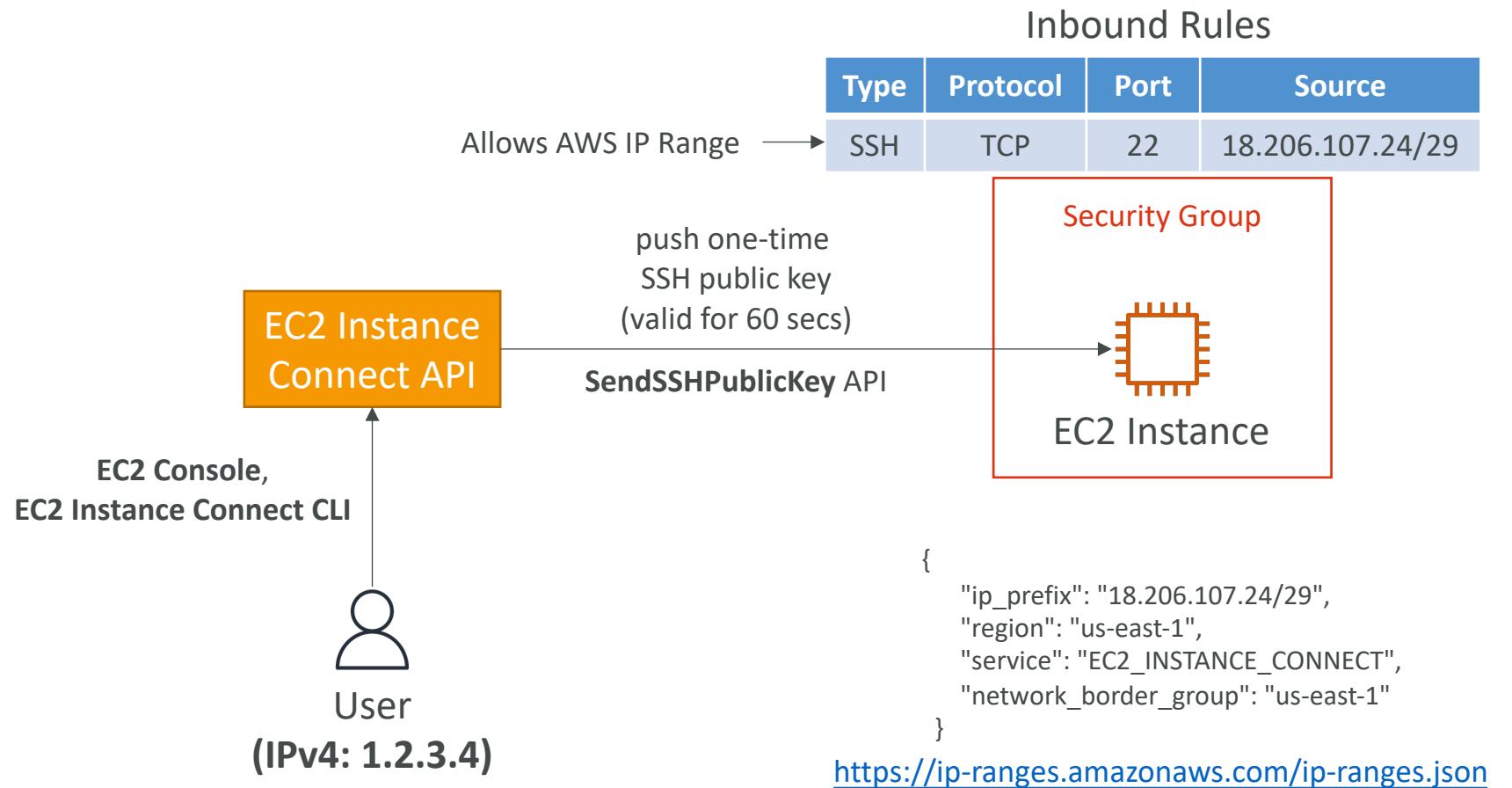
Resource Policies & aws:PrincipalOrgID

- aws:PrincipalOrgID can be used in any resource policies to restrict access to accounts that are member of an AWS Organization



```
{  
  "Version": "2012-10-17",  
  "Statement": [  
    {  
      "Effect": "Allow",  
      "Action": ["s3:PutObject", "s3:GetObject"],  
      "Resource": "arn:aws:s3:::2022-financial-data/*",  
      "Condition": {  
        "StringEquals": {  
          "aws:PrincipalOrgID": ["o-yyyyyyyyyy"]  
        }  
      }  
    }  
  ]  
}
```

EC2 Instance Connect (SendSSHPublicKey API)



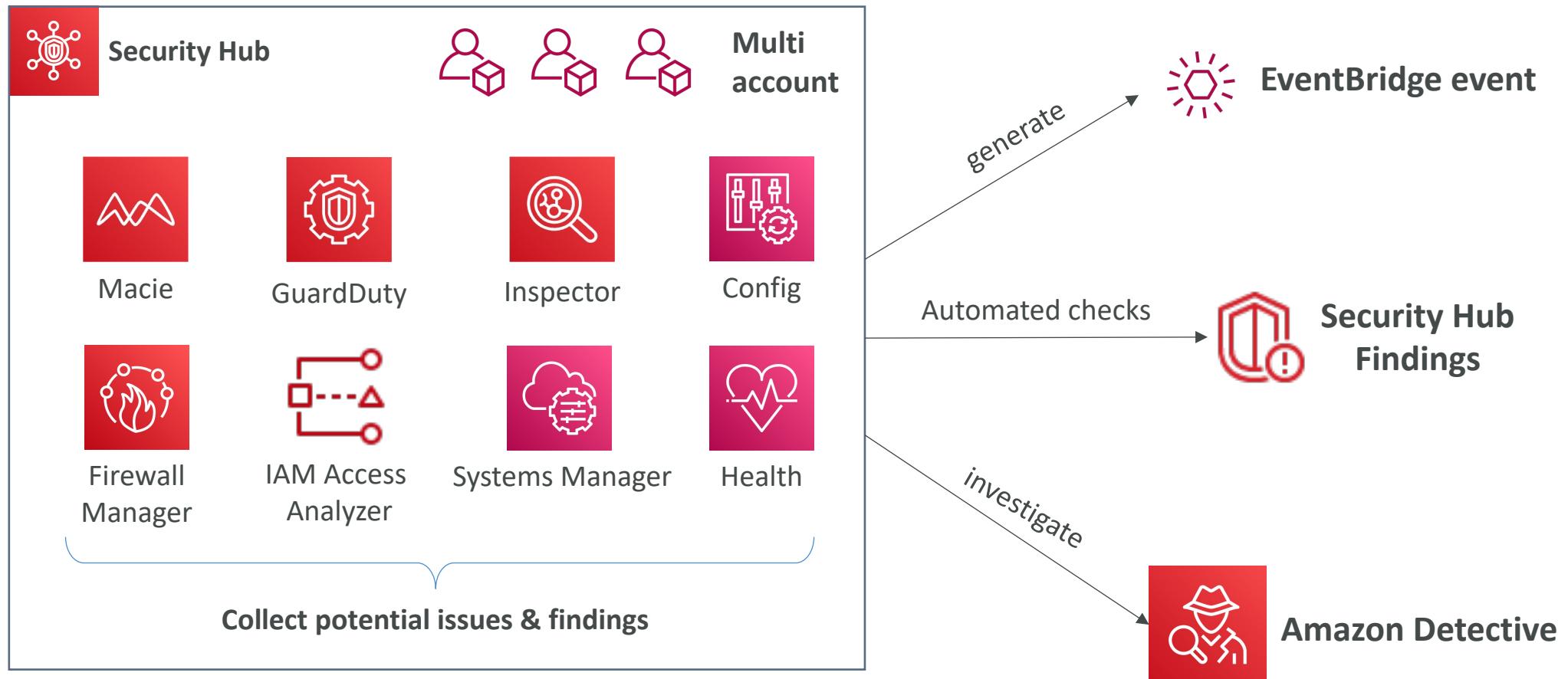
Note: All connections are logged in CloudTrail



AWS Security Hub

- Central security tool to manage security across several AWS accounts and automate security checks
- Integrated dashboards showing current security and compliance status to quickly take actions
- Automatically aggregates alerts in predefined or personal findings formats from various AWS services & AWS partner tools:
 - Config
 - GuardDuty
 - Inspector
 - Macie
 - IAM Access Analyzer
 - AWS Systems Manager
 - AWS Firewall Manager
 - AWS Health
 - AWS Partner Network Solutions
- Must first enable the AWS Config Service

AWS Security Hub



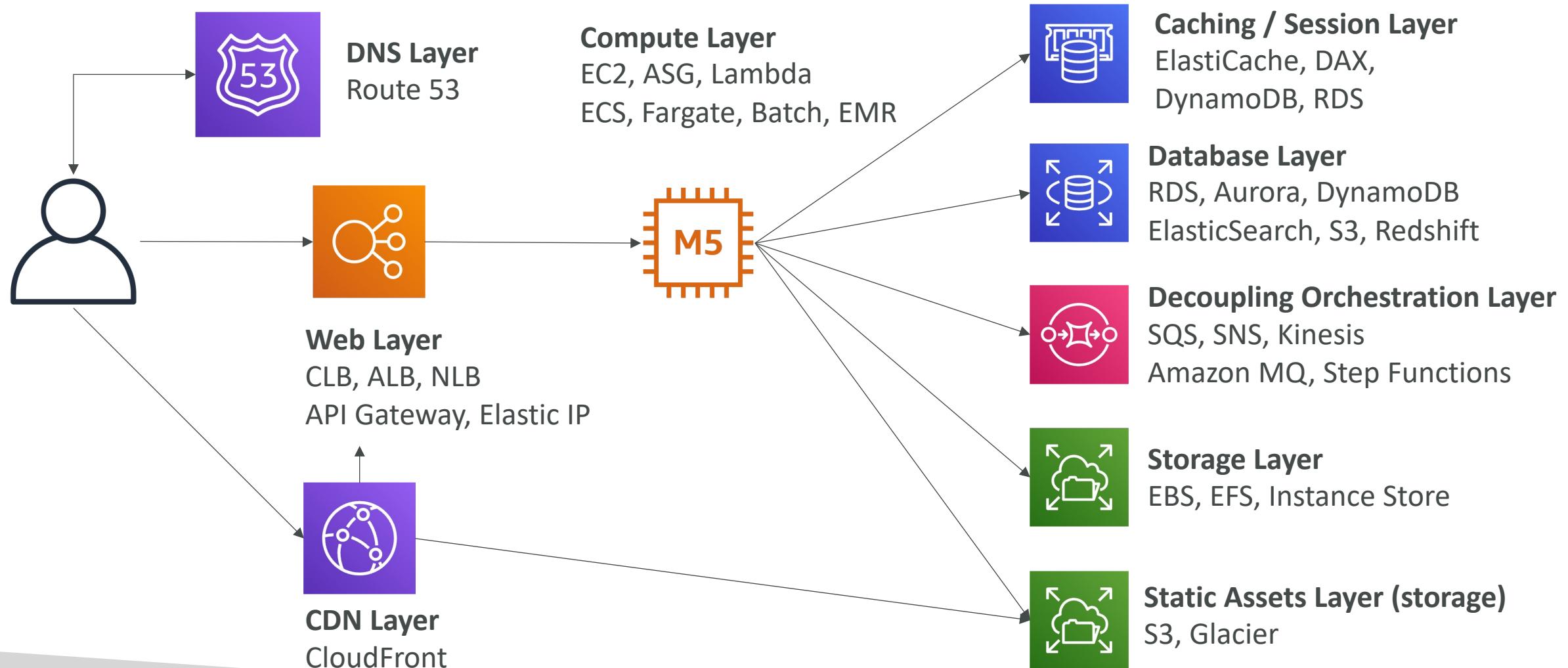
Amazon Detective



- GuardDuty, Macie, and Security Hub are used to identify potential security issues, or findings
- Sometimes security findings require deeper analysis to isolate the root cause and take action – it's a complex process
- Amazon Detective analyzes, investigates, and quickly identifies the root cause of security issues or suspicious activities (using ML and graphs)
- Automatically collects and processes events from VPC Flow Logs, CloudTrail, GuardDuty and create a unified view
- Produces visualizations with details and context to get to the root cause

Compute & Load Balancing

Solution Architecture on AWS



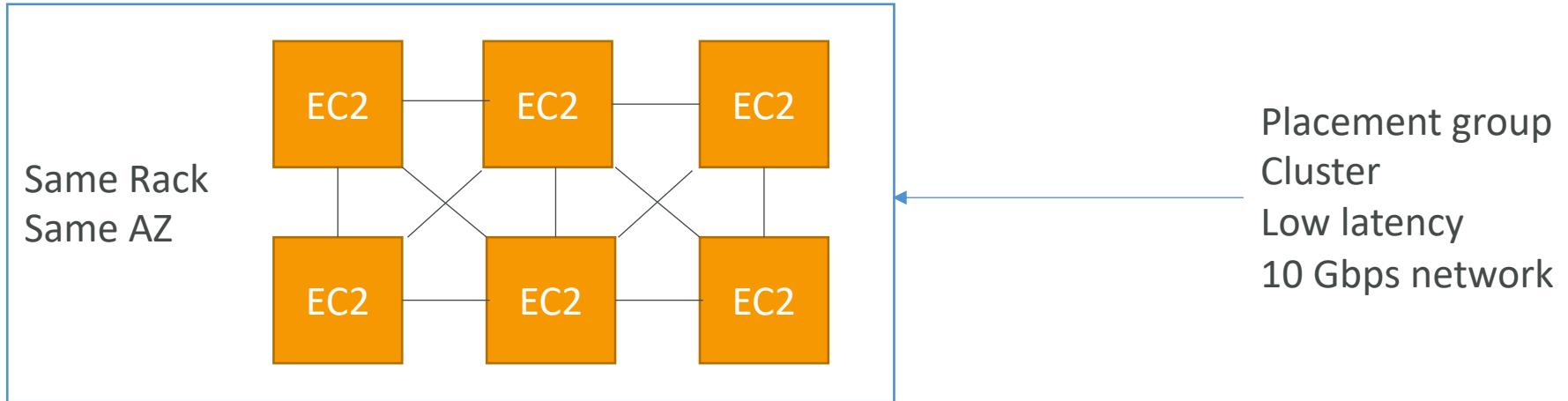
EC2 Instance Types – Main ones

- R: applications that needs a lot of RAM – in-memory caches
- C: applications that needs good CPU – compute / databases
- M: applications that are balanced (think “medium”) – general / web app
- I: applications that need good local I/O (instance storage) – databases
- G: applications that need a GPU – video rendering / machine learning
- T2 / T3: burstable instances (up to a capacity)
- T2 / T3 - unlimited: unlimited burst
- Real-world tip: use <https://www.ec2instances.info>

EC2 - Placement Groups

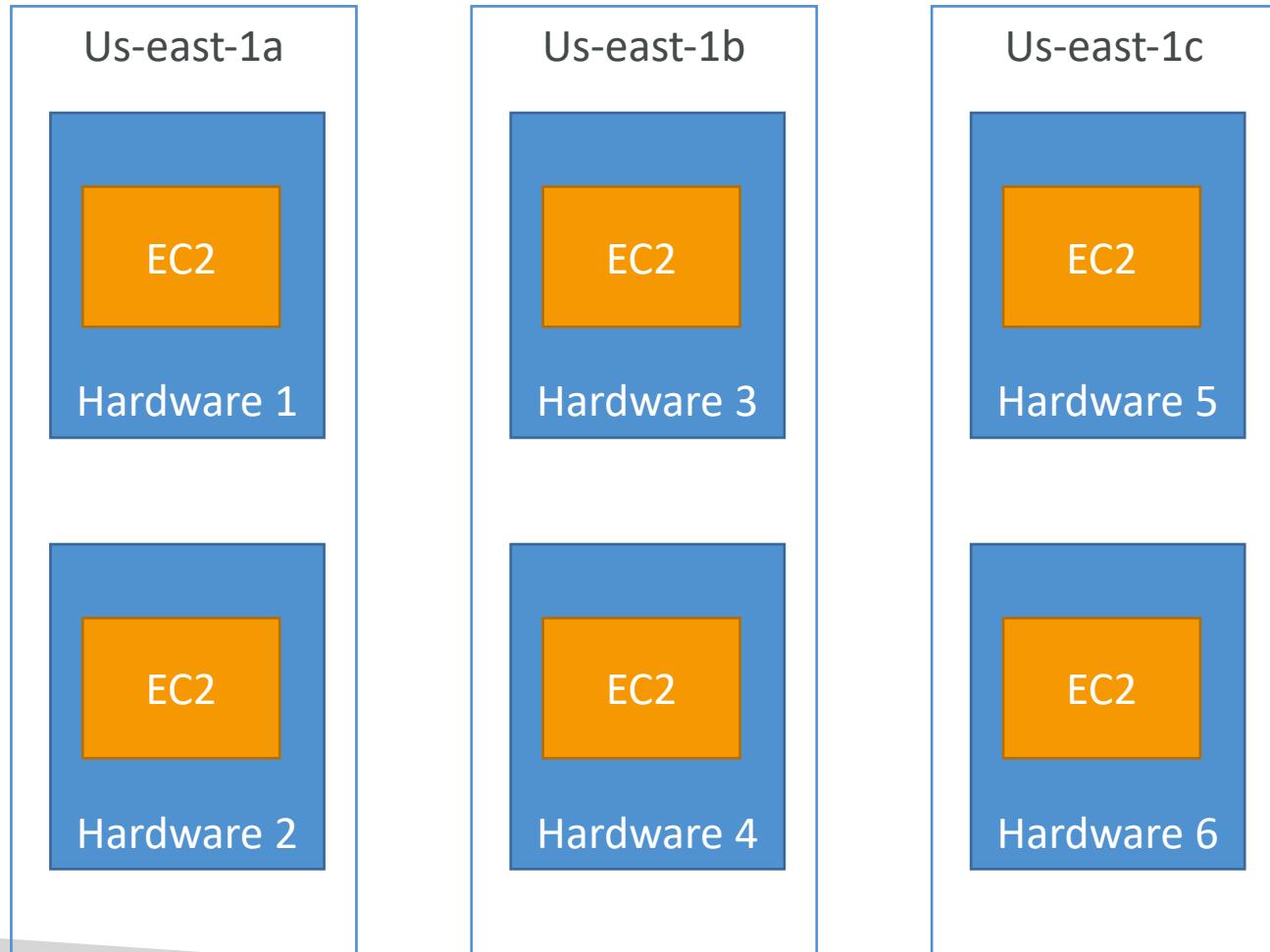
- Control the EC2 Instance placement strategy using placement groups
- Group Strategies:
 - *Cluster*—clusters instances into a low-latency group in a single Availability Zone
 - *Spread*—spreads instances across underlying hardware (max 7 instances per group per AZ) – critical applications
 - *Partition*—spreads instances across many different partitions (which rely on different sets of racks) within an AZ. Scales to 100s of EC2 instances per group (Hadoop, Cassandra, Kafka)
- **You can move** an instance into or out of a placement group
 - You first need to **stop** it
 - You then need to use the CLI (modify-instance-placement)
 - You can then **start** your instance

Placement Groups Cluster



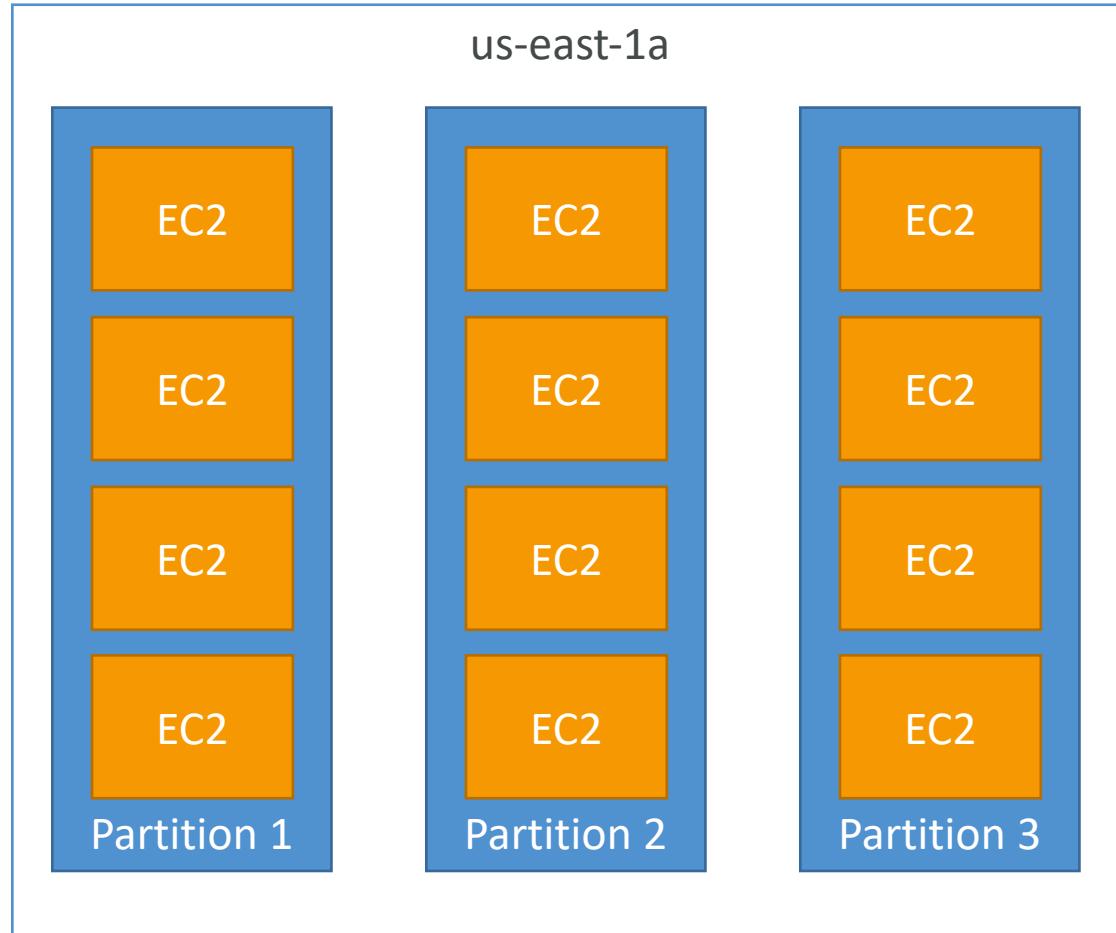
- Pros: Great network (10 Gbps bandwidth between instances with Enhanced Networking enabled - recommended)
- Cons: If the rack fails, all instances fail at the same time
- Use case:
 - Big Data job that needs to complete fast
 - Application that needs extremely low latency and high network throughput

Placement Groups Spread



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

Placements Groups Partition

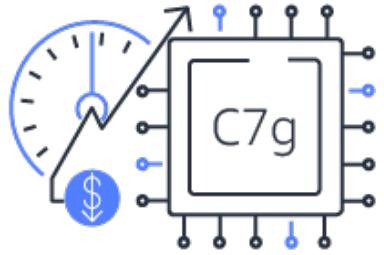


- Up to 7 partitions per AZ
- Up to 100s of EC2 instances
- The instances in a partition do not share racks with the instances in the other partitions
- A partition failure can affect many EC2 but won't affect other partitions
- EC2 instances get access to the partition information as metadata
- Use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

EC2 Instance Launch Types

- **On Demand Instances:** short workload, predictable pricing, reliable
- **Spot Instances:** short workloads, for cheap, can lose instances (not reliable)
- **Reserved:** (MINIMUM 1 year)
 - Reserved Instances: long workloads
 - Convertible Reserved Instances: long workloads with flexible instances
 - Highest to lowest discount: All Upfront payment, Partial Upfront payment, no Upfront
- **Dedicated Instances:** no other customers will share your hardware
- **Dedicated Hosts:** book an entire physical server; control instance placement
 - Great for software licenses that operate at the core, or CPU socket level
 - Can define **host affinity** so that instance reboots are kept on the same host

EC2 Graviton



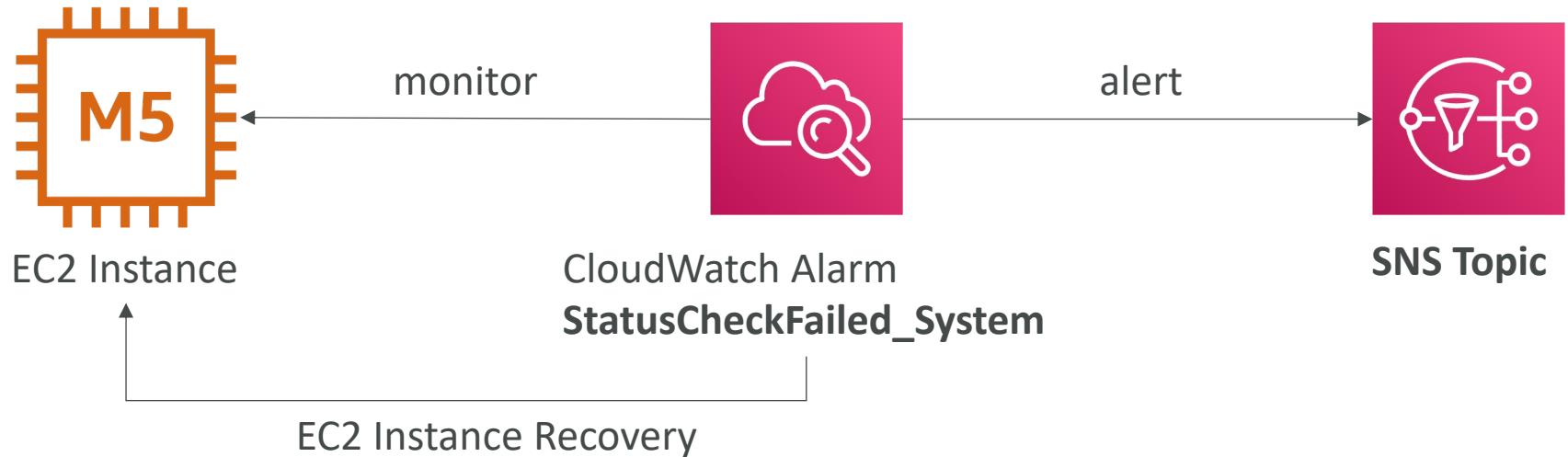
- AWS Graviton Processors deliver the best price performance
 - Supports many Linux OS, Amazon Linux 2, RedHat, SUSE, Ubuntu
 - Not available for Windows instances
-
- **Graviton2** – 40% better price performance over comparable 5th generation x86-based instances
 - **Graviton3** – Up to 3x better performance compared to Graviton2
 - Use cases: app servers, microservices, HPC, CPU-based ML, video encoding, gaming, in-memory caches, ...

EC2 included metrics

- CPU: CPU Utilization + Credit Usage / Balance
- Network: Network In / Out
- Status Check:
 - Instance status = check the EC2 VM
 - System status = check the underlying hardware
- Disk: Read / Write for Ops / Bytes (only for instance store)
- RAM is NOT included in the AWS EC2 metrics

EC2 Instance Recovery

- Status Check:
 - Instance status = check the EC2 VM
 - System status = check the underlying hardware



- **Recovery:** Same Private, Public, Elastic IP, metadata, placement group

High Performance Computing (HPC)

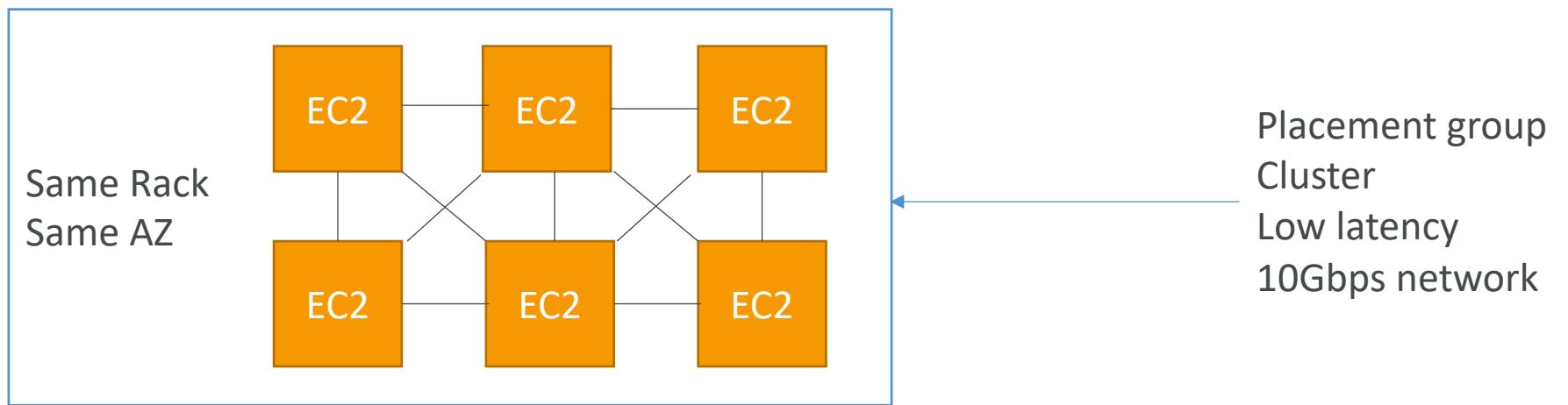
- The cloud is the perfect place to perform HPC
- You can create a very high number of resources in no time
- You can speed up time to results by adding more resources
- You can pay only for the systems you have used
- Perform genomics, computational chemistry, financial risk modeling, weather prediction,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

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 and Networking

- EC2 Instances:
 - CPU optimized, GPU optimized
 - Spot Instances / Spot Fleets for cost savings + Auto Scaling
- EC2 Placement Groups: Cluster for good network performance



Compute and Networking

- EC2 Enhanced Networking (SR-IOV)
 - Higher bandwidth, higher PPS (packet per second), lower latency
 - Option 1: Elastic Network Adapter (ENA) up to 100 Gbps
 - Option 2: Intel 82599 VF up to 10 Gbps – LEGACY
- Elastic Fabric Adapter (EFA)
 - Improved ENA for HPC, only works for Linux
 - Great for inter-node communications, **tightly coupled workloads**
 - Leverages Message Passing Interface (MPI) standard
 - Bypasses the underlying Linux OS to provide low-latency, reliable transport

Storage

- Instance-attached storage:
 - EBS: scale up to 256,000 IOPS 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
 - Amazon FSx for Lustre:
 - HPC optimized distributed file system, millions of IOPS
 - Backed by S3

Automation and Orchestration

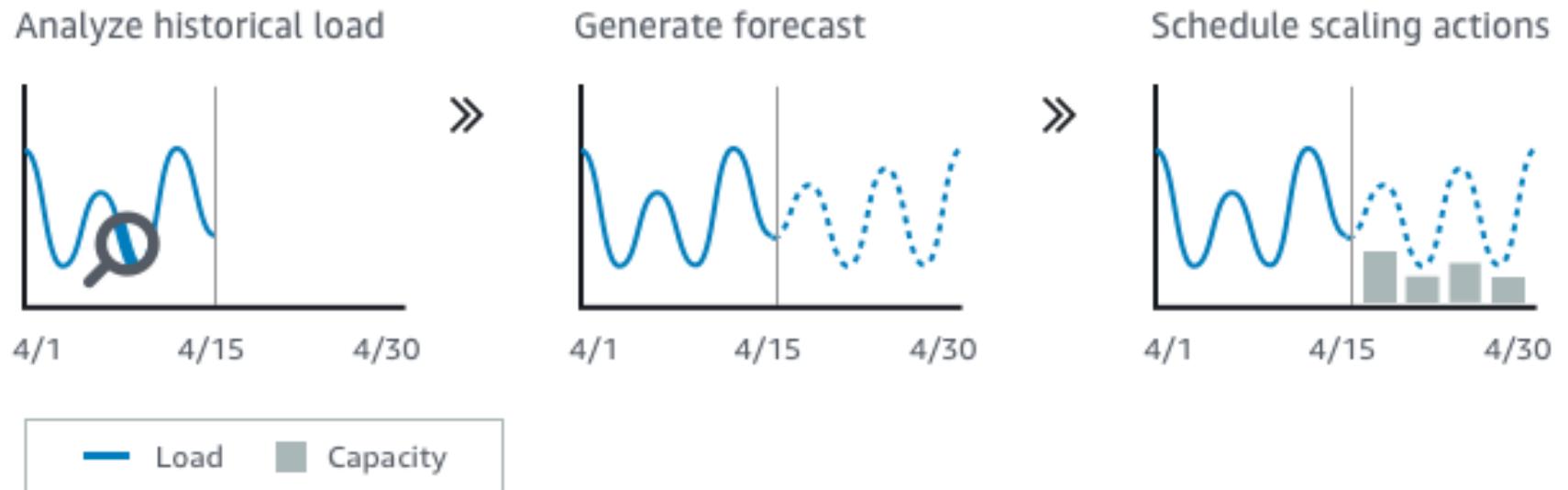
- AWS Batch
 - AWS Batch supports multi-node parallel jobs, which enables you to run single jobs that span multiple EC2 instances.
 - Easily schedule jobs and launch EC2 instances accordingly
- AWS ParallelCluster
 - Open source cluster management tool to deploy HPC on AWS
 - Configure with text files
 - Automate creation of VPC, Subnet, cluster type and instance types

Auto Scaling Groups – Dynamic Scaling Policies

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

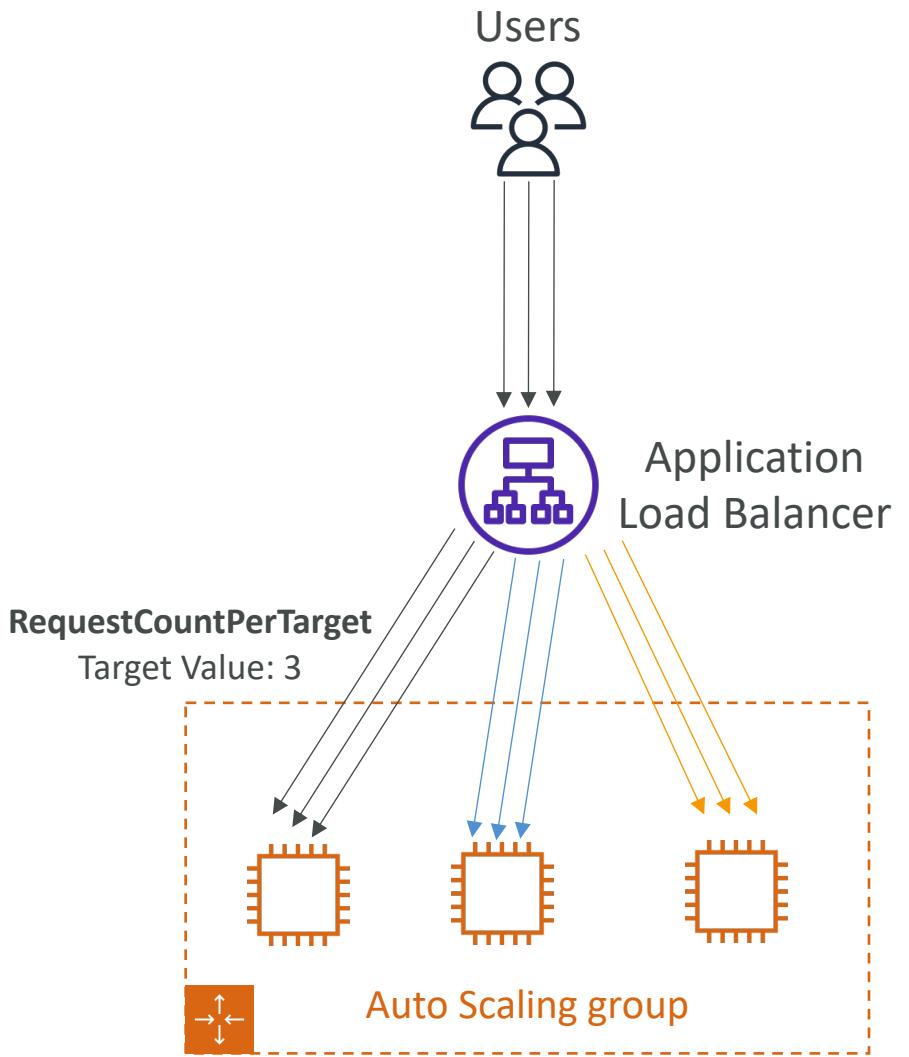
Auto Scaling Groups – Predictive Scaling

- Predictive scaling: continuously forecast load and schedule scaling ahead



Good metrics to scale on

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

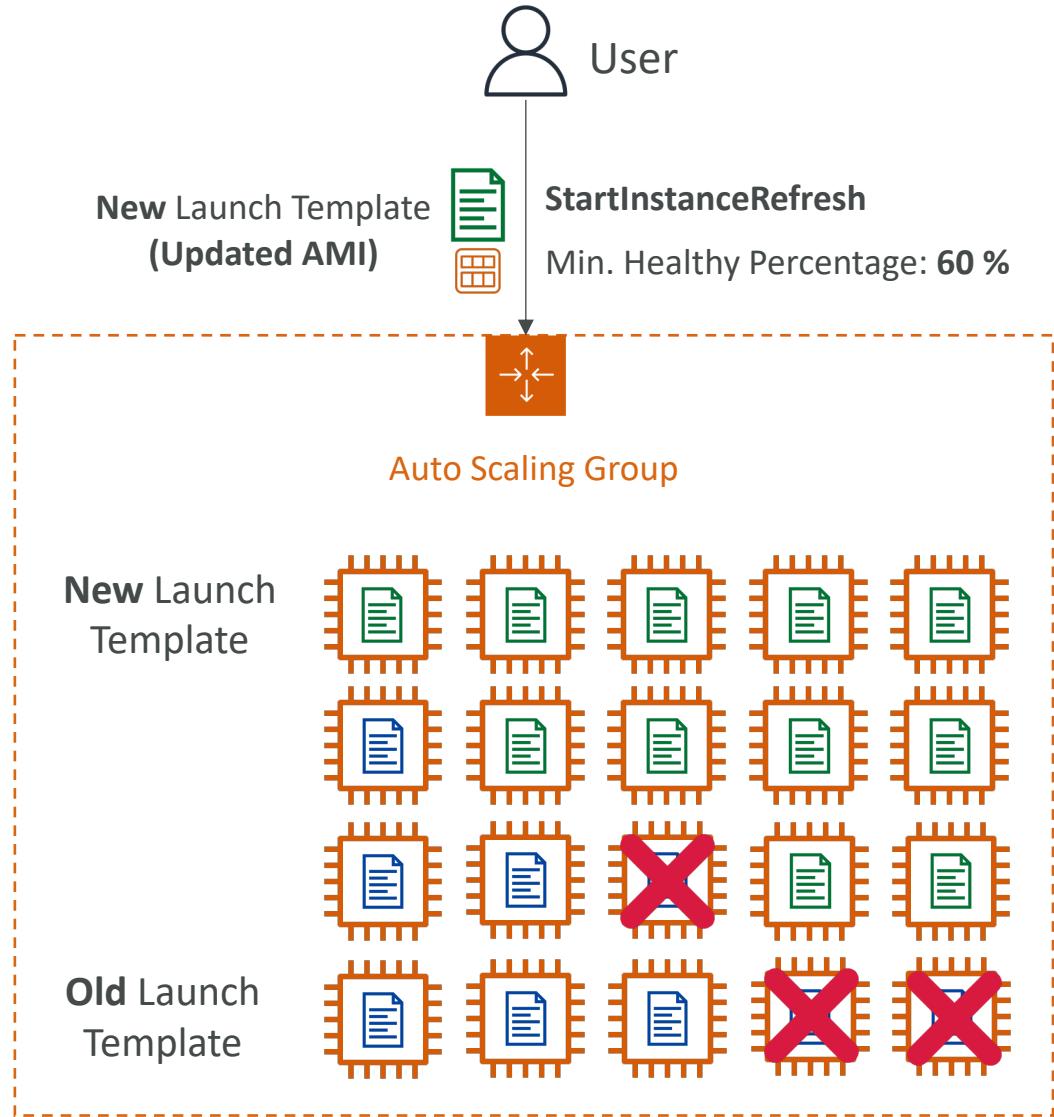


Auto Scaling – Good to know

- Spot Fleet support (mix on Spot and On-Demand instances)
- Lifecycle Hooks:
 - Perform actions before an instance is in service, or before it is terminated
 - Examples: cleanup, log extraction, special health checks
- To upgrade an AMI, must update the **launch configuration / template**
 - Then terminate instances manually (CloudFormation can help)
 - Or use EC2 Instance Refresh for Auto Scaling

Auto Scaling – Instance Refresh

- Goal: update launch template and then re-creating all EC2 instances
- For this we can use the native feature of Instance Refresh
- Setting of minimum healthy percentage
- Specify warm-up time (how long until the instance is ready to use)



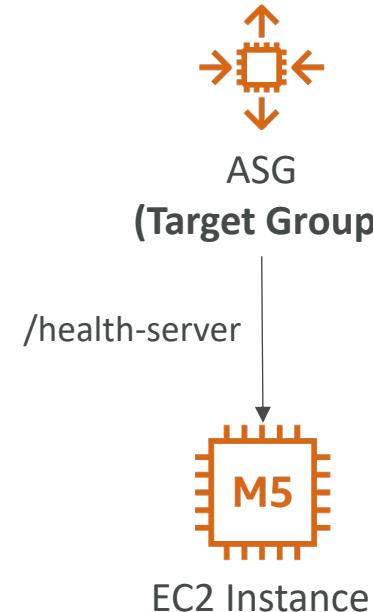
Auto Scaling – Scaling Processes

- **Launch:** Add a new EC2 to the group, increasing the capacity
- **Terminate:** Removes an EC2 instance from the group, decreasing its capacity.
- **HealthCheck:** Checks the health of the instances
- **ReplaceUnhealthy:** Terminate unhealthy instances and re-create them
- **AZRebalance:** Balancer the number of EC2 instances across AZ
- **AlarmNotification:** Accept notification from CloudWatch
- **ScheduledActions:** Performs scheduled actions that you create.
- **AddToLoadBalancer:** Adds instances to the load balancer or target group
- **InstanceRefresh:** Perform an instance refresh
- We can suspend these processes!

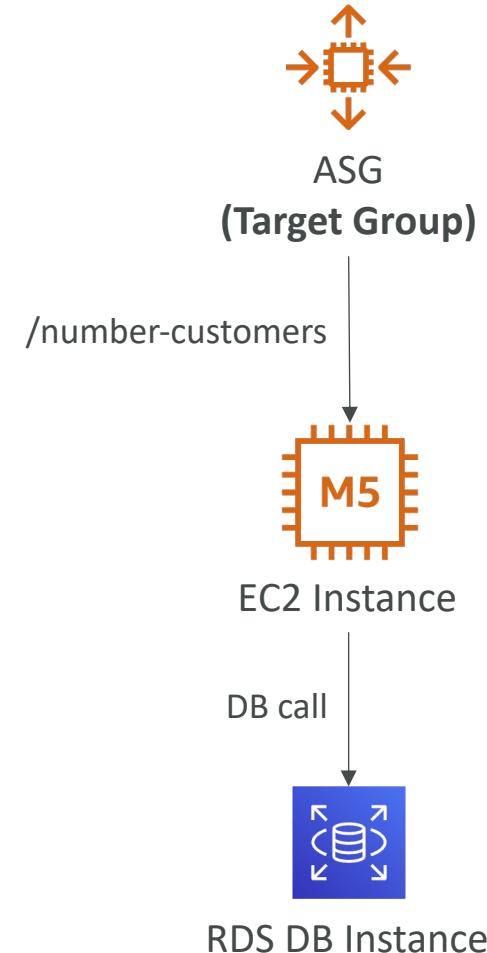
Auto Scaling – Health Checks

- Health checks available:
 - EC2 Status Checks
 - ELB Health Checks (HTTP)
 - Custom Health Checks – send instance's health to an ASG using AWS CLI or AWS SDK (**set-instance-health**)
- ASG will launch a new instance after terminating an unhealthy one
- Make sure the health check is simple and checks the correct thing

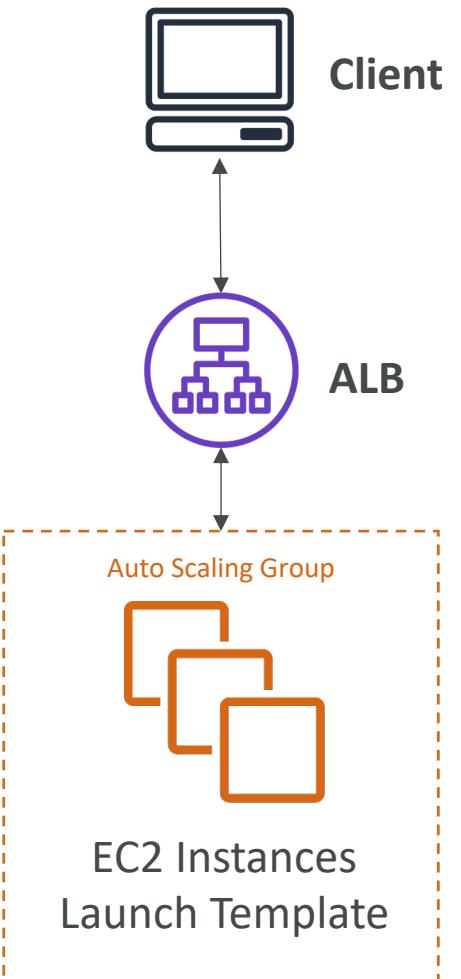
GOOD HEALTH CHECK



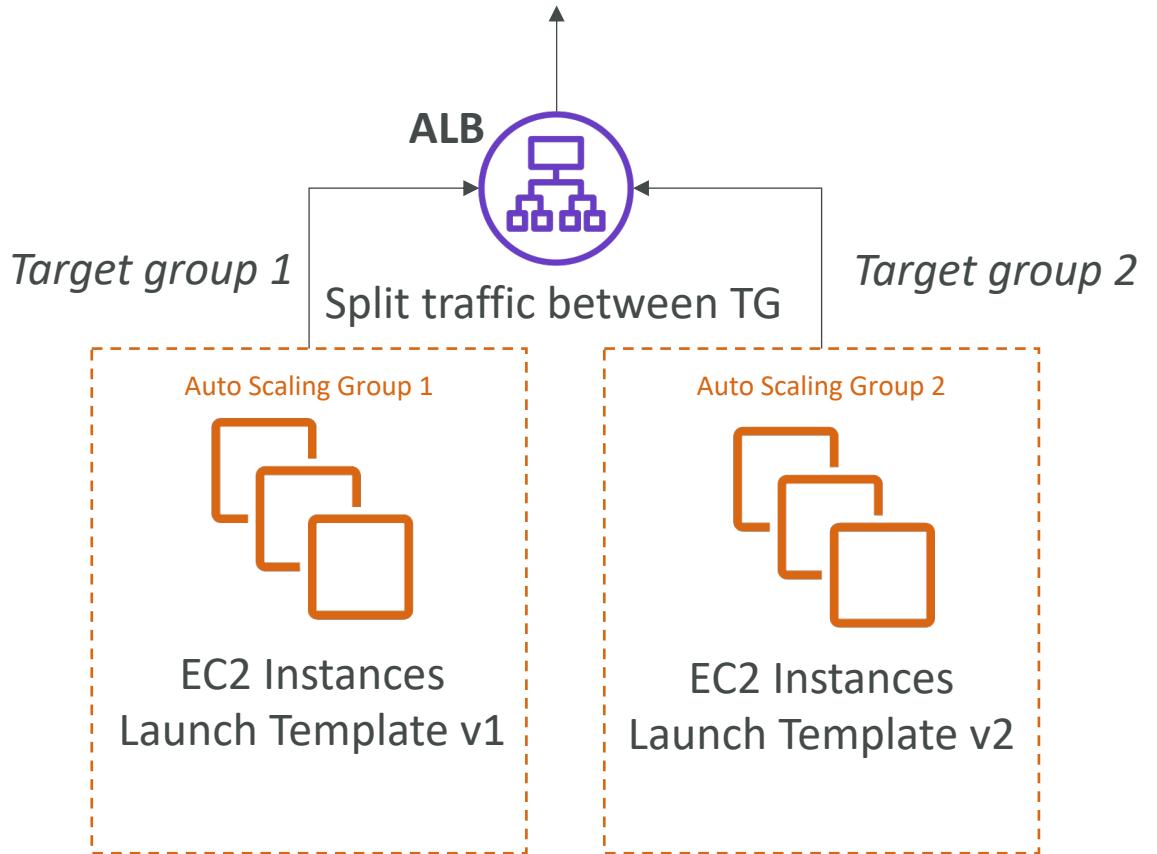
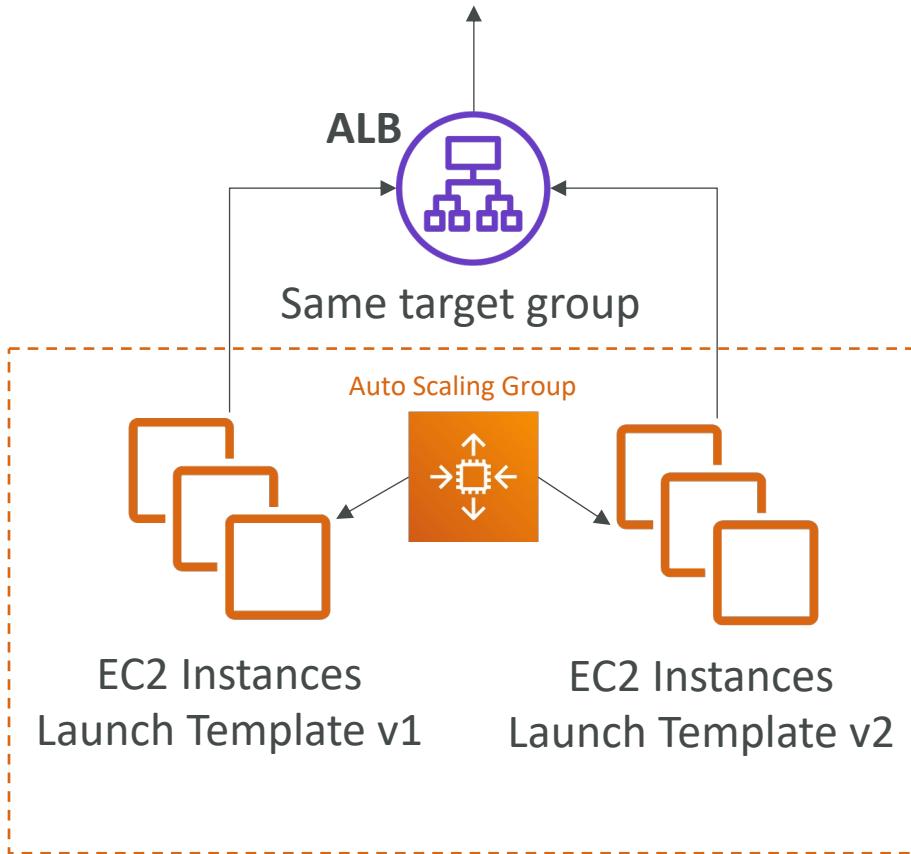
BAD HEALTH CHECK



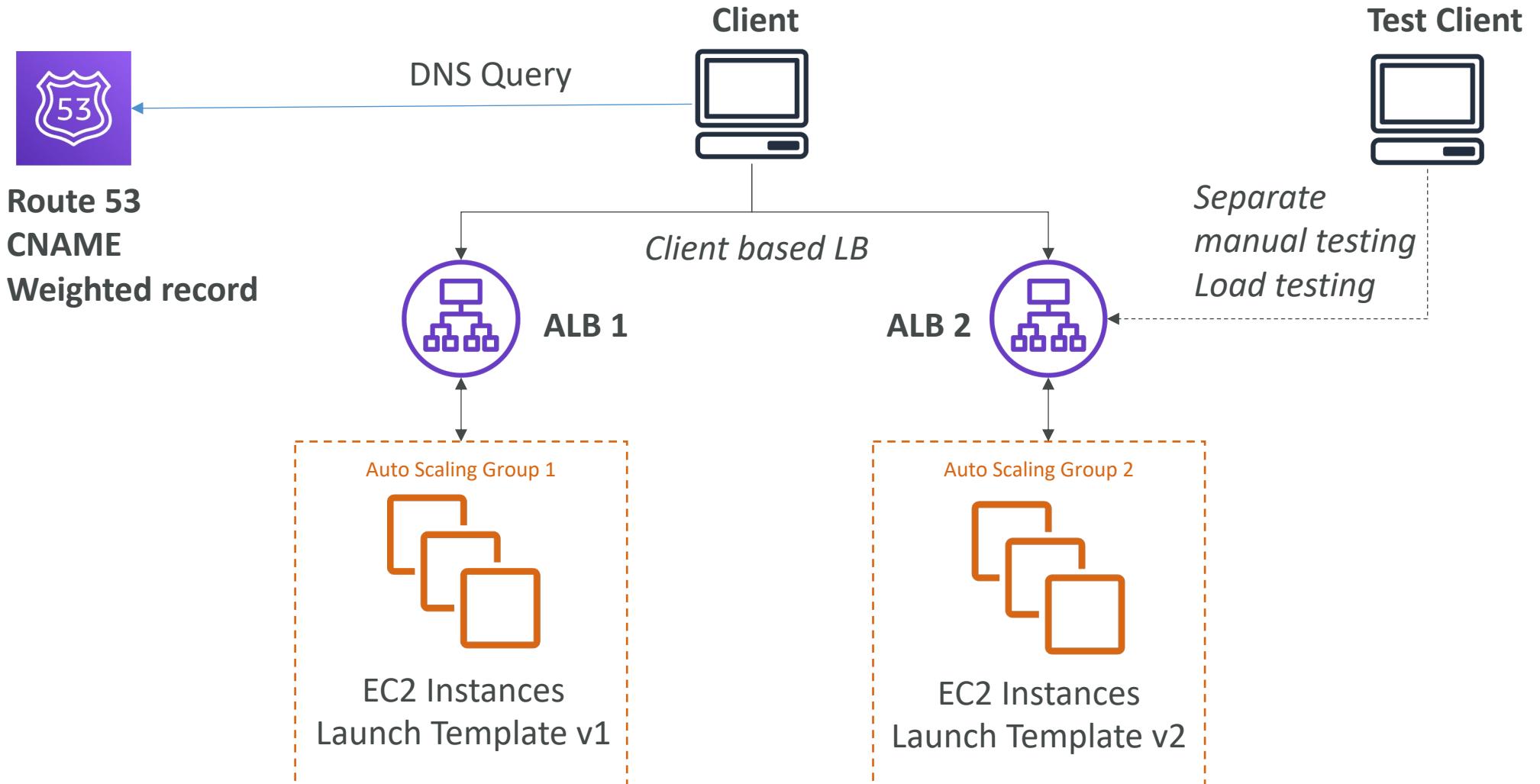
Auto Scaling – Updating an application



Auto Scaling – Solution Architecture



Auto Scaling – Solution Architecture

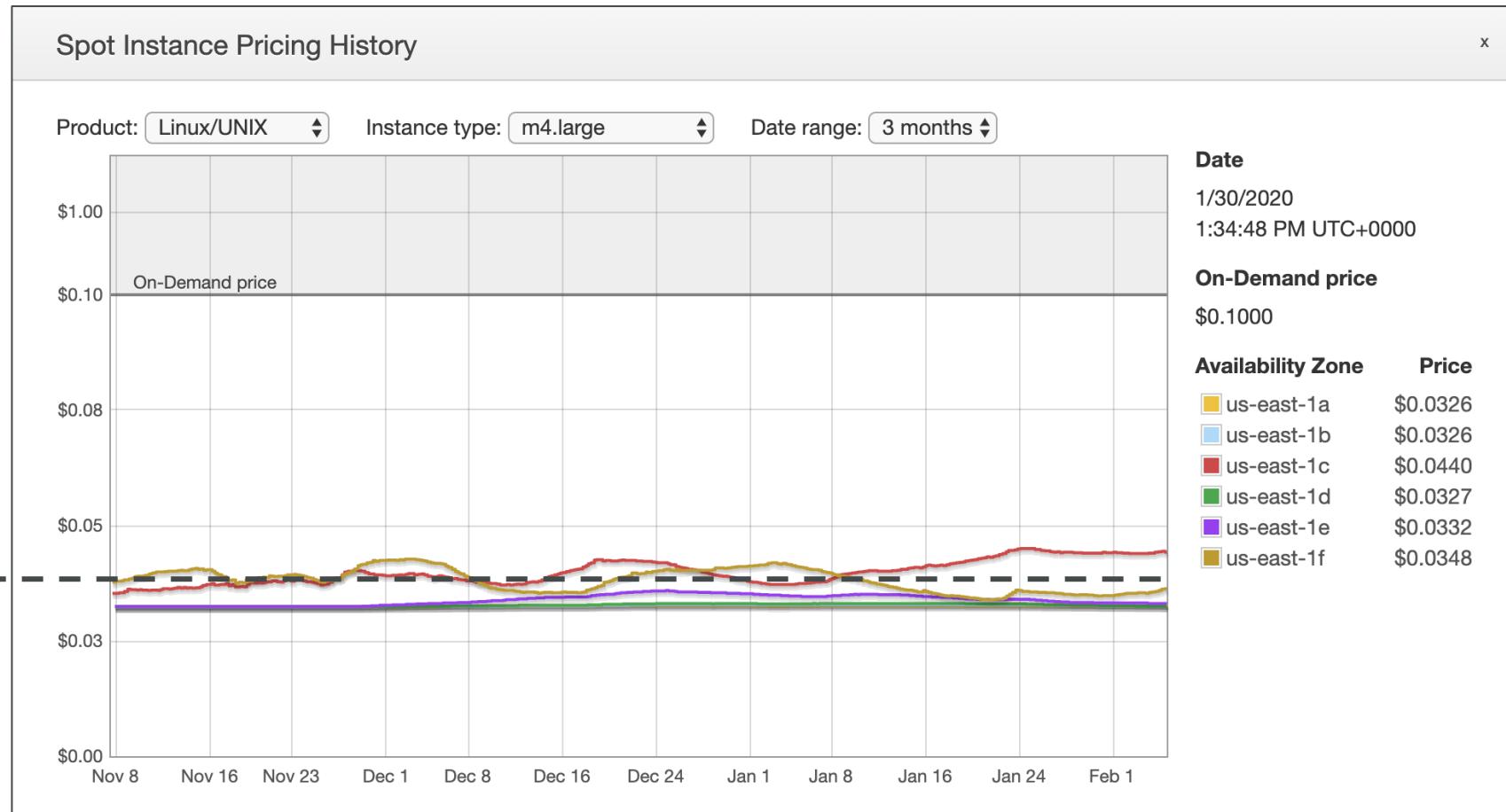




EC2 Spot Instances

- Can get a discount of up to 90% compared to On-Demand
- Define **max spot price** and get the instance while **current spot price < max**
 - The hourly spot price varies based on offer and capacity
 - If the current spot price > your max price you can choose to **stop** or **terminate** your instance with a 2 minutes grace period.
- Used for batch jobs, data analysis, or workloads that are resilient to failures.
- Not great for critical jobs or databases

EC2 Spot Instances



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

Spot Fleets

- Spot Fleets = set of Spot Instances + (optional) On-Demand Instances
- 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
 - **priceCapacityOptimized (recommended)**: pools with highest capacity available, then select the pool with the lowest price (best choice for most workloads)
- Spot Fleets allow us to automatically request Spot Instances with the lowest price



What is Docker?

- 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
- Control how much memory / CPU is allocated to your container
- Scale containers up and down very quickly (seconds)
- More efficient than Virtual machines

Docker Containers Management on AWS

- To manage containers, we need a container management platform
- Amazon Elastic Container Service (Amazon ECS)
 - Amazon's own container platform
- Amazon Elastic Kubernetes Service (Amazon EKS)
 - Amazon's managed Kubernetes (open source)
- AWS Fargate
 - Amazon's own Serverless container platform
 - Works with ECS and with EKS



Amazon ECS



Amazon EKS



AWS Fargate

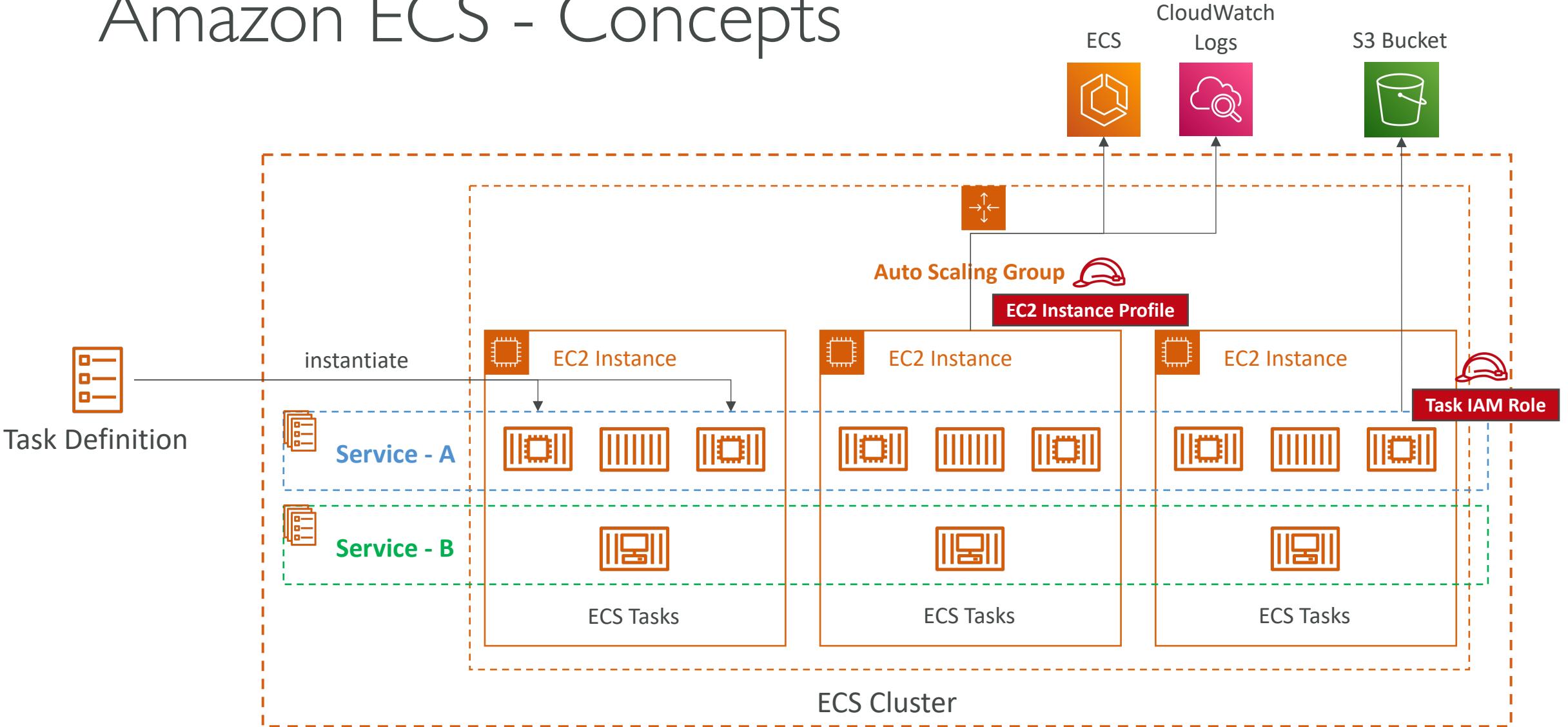
Amazon ECS – Use cases

- Run Microservices
 - Run multiple Docker containers on the same machine
 - Easy Service Discovery features to enhance communication
 - Direct integration with Application Load Balancer and Network Load Balancer
 - Auto Scaling capability
- Run Batch Processing / Scheduled Tasks
 - Schedule ECS tasks to run on On-demand / Reserved / Spot instances
- Migrate Applications to the Cloud
 - Dockerize legacy applications running on-premises
 - Move Docker containers to run on Amazon ECS

Amazon ECS – Concepts

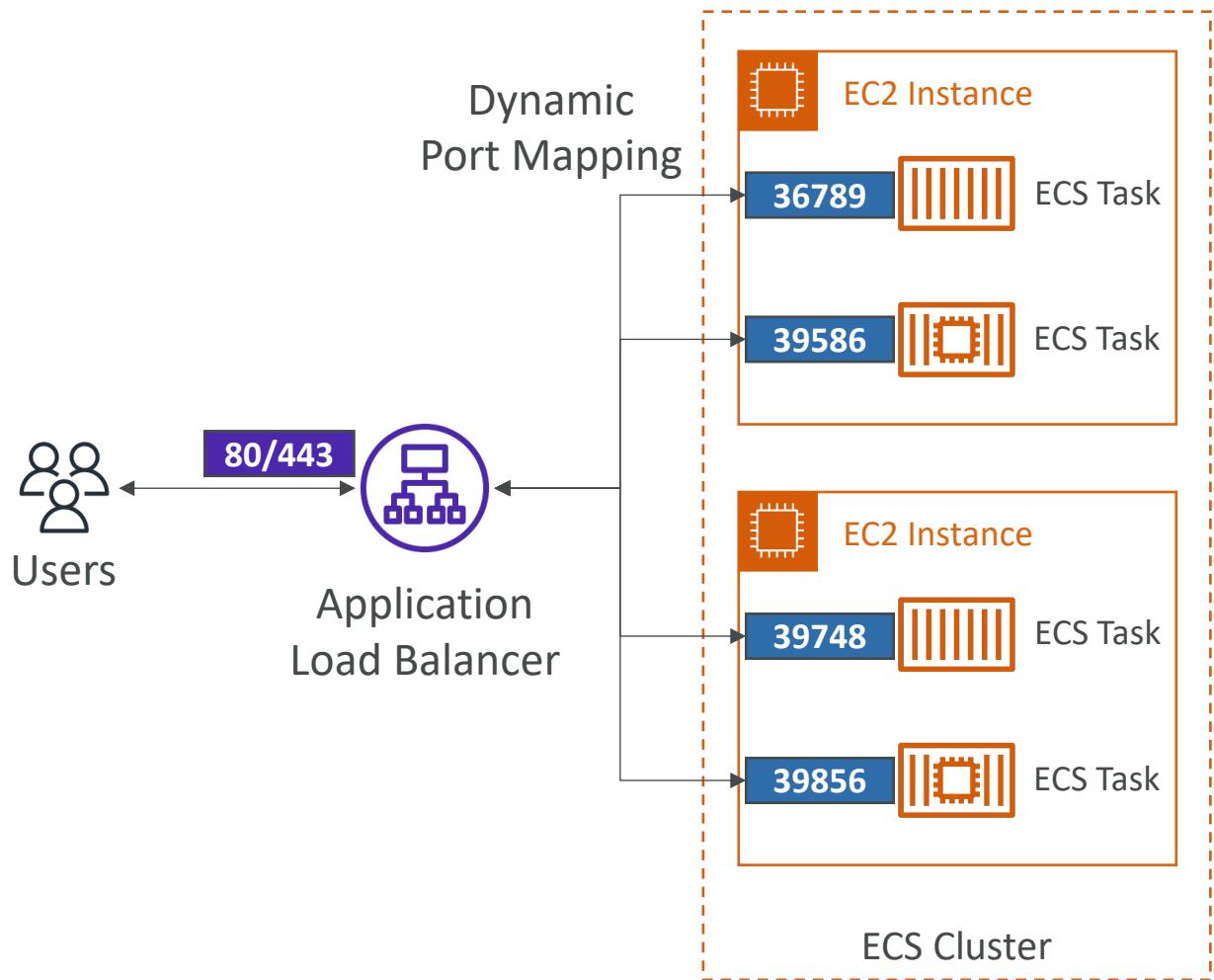
- **ECS Cluster** – logical grouping of EC2 instances
- **ECS Service** – defines how many tasks should run and how they should be run
- **Task Definitions** – metadata in **JSON form** to tell ECS how to run a Docker container (image name, CPU, RAM, ...)
- **ECS Task** – an instance of a Task Definition, a running Docker container(s)
- **ECS IAM Roles**
 - **EC2 Instance Profile** – used by the EC2 instance (e.g., make API calls to ECS, send logs, ...)
 - **ECS Task IAM Role** – allow each task to have a specific role (e.g., make API calls to S3, DynamoDB, ...)

Amazon ECS - Concepts



Amazon ECS – ALB Integration

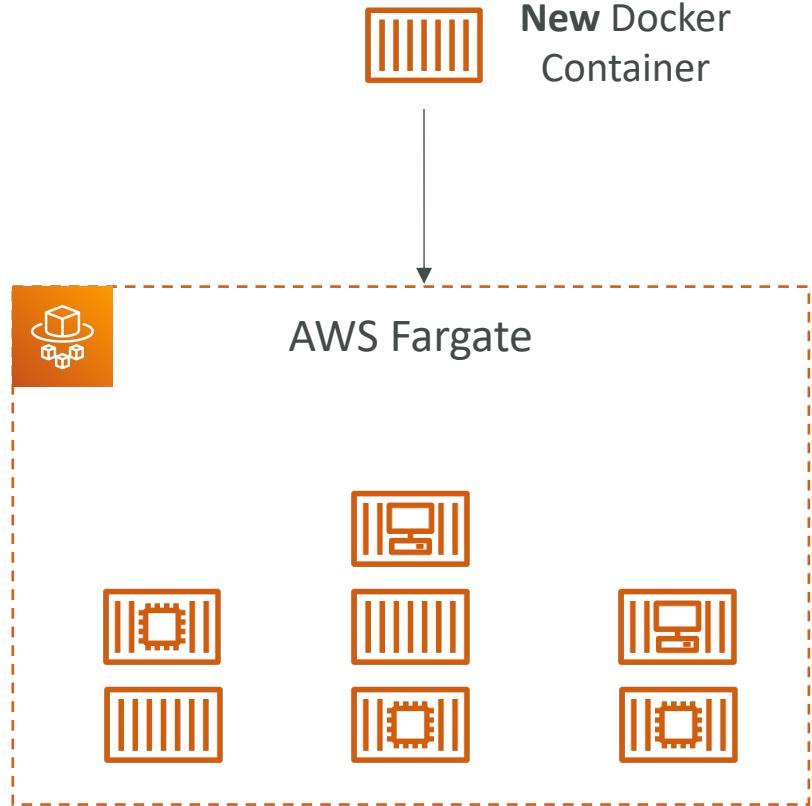
- We get Dynamic Port Mapping
- Allows you to run multiple instances of the same application on the same EC2 instance
- The ALB finds the right port on your EC2 Instances
- Use cases:
 - Increased resiliency even if running on one EC2 instance
 - Maximize utilization of CPU / cores
 - Ability to perform rolling upgrades without impacting app uptime



AWS Fargate

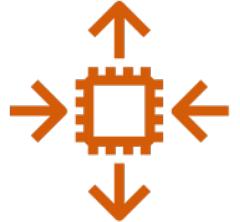


- Launch Docker containers on AWS
- You do not provision the infrastructure
(no EC2 instances to manage)
- It's all serverless!
- You create task definitions
- AWS runs containers for you based on
the CPU / RAM you need
- To scale, just increase the number of
tasks. Simple! No more EC2 instances ☺



Amazon ECS – Security & Networking

- You can inject secrets and configurations as Environment Variables into running Docker containers
 - Integration with SSM Parameter Store and Secrets Manager
- **ECS Tasks Networking**
 - **none** – no network connectivity, no port mappings
 - **bridge** – uses Docker's virtual container-based network
 - **host** – bypass Docker's network, uses the underlying host network interface
 - **awsvpc**
 - Every tasks launched on the instance gets its own ENI and a private IP address
 - Simplified networking, enhanced security, Security Groups, monitoring, VPC Flow Logs
 - Default mode for Fargate tasks



Amazon ECS – Service Auto Scaling

- Automatically increase/decrease the desired number of tasks
- Amazon ECS leverages **AWS Application Auto Scaling**
- CPU and RAM is tracked in CloudWatch at the ECS Service level
- 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**)



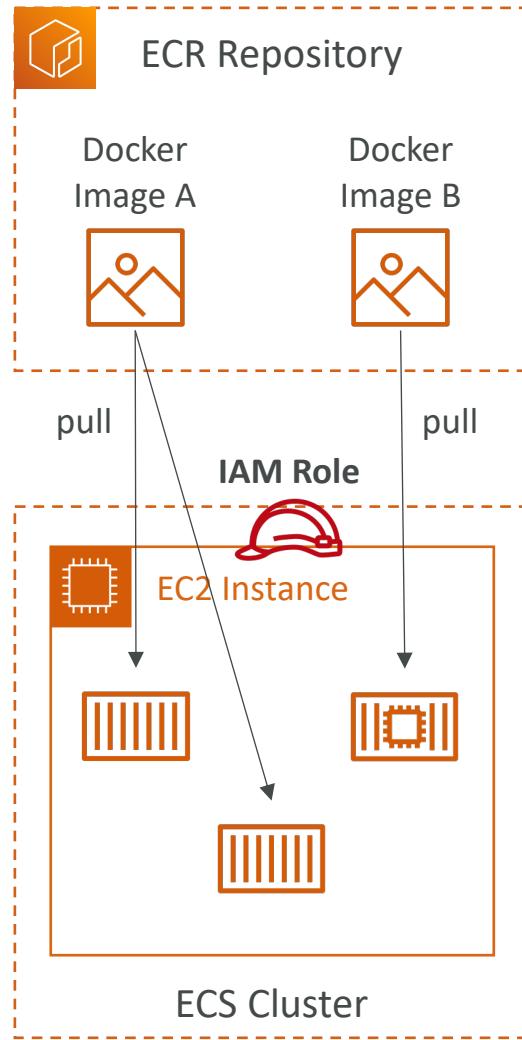
Amazon ECS – Spot Instances

- **ECS Classic (EC2 Launch Type)**
 - Can have the underlying EC2 instances as Spot Instances (managed by an ASG)
 - Instances may go into draining mode to remove running tasks
 - Good for cost savings, but will impact reliability
- **AWS Fargate**
 - Specify minimum of tasks for on-demand baseline workload
 - Add tasks running on FARGATE_SPOT for cost-savings (can be reclaimed by AWS)
 - Regardless of On-demand or Spot, Fargate scales well based on load

Amazon ECR - Elastic Container Registry

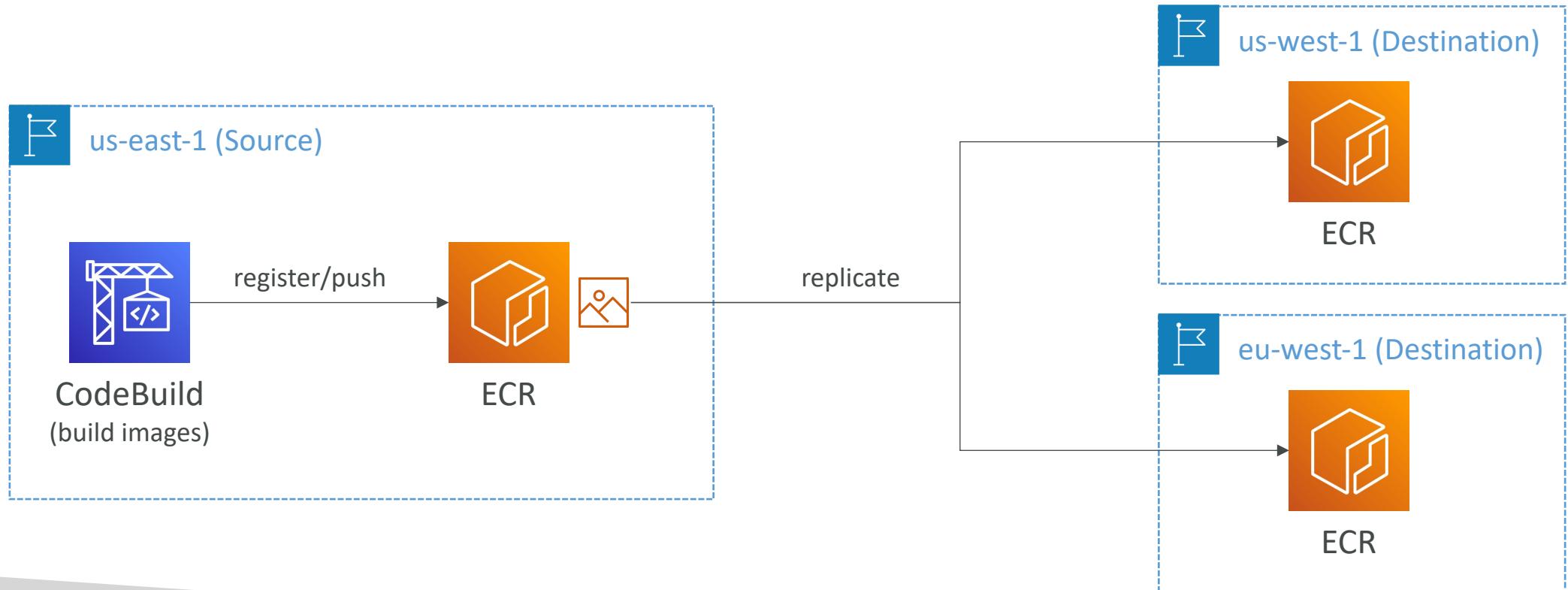


- Store and manage Docker images on AWS
- Private and Public repository (Amazon ECR Public Gallery <https://gallery.ecr.aws>)
- Fully integrated with ECS
- Access is controlled through IAM (permission errors => check policy)
- Supports image vulnerability scanning, versioning, image tags, image lifecycle, ...



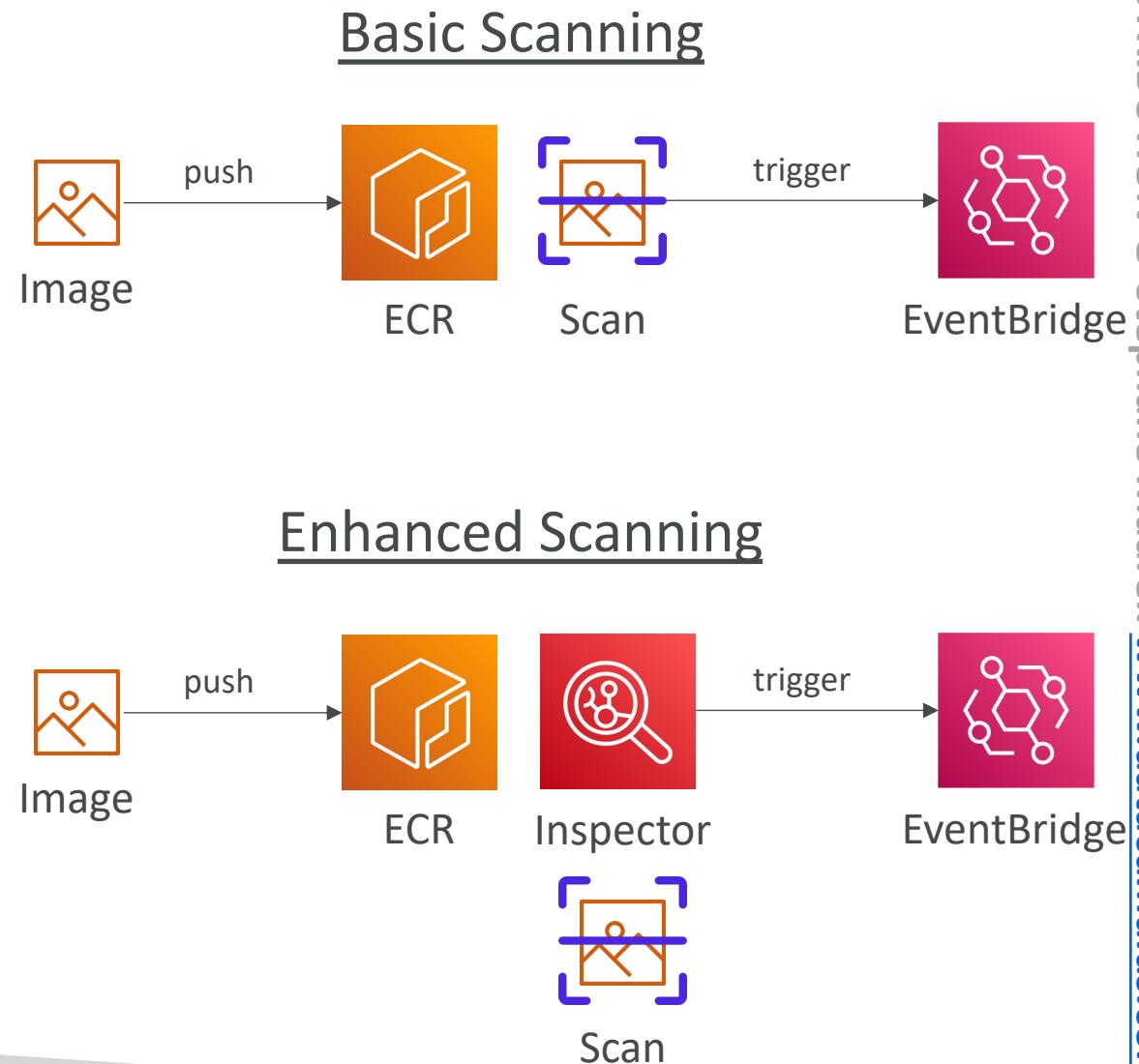
Amazon ECR – Cross Region Replication

- ECR private registry supports both cross-Region and cross-account replication



Amazon ECR – Image Scanning

- Manual Scan or Scan on Push
- Basic Scanning – Common CVE
- Enhanced Scanning – Leverages Amazon Inspector (OS & Programming Language vulnerabilities)
- Scan results can be retrieved from within the AWS console

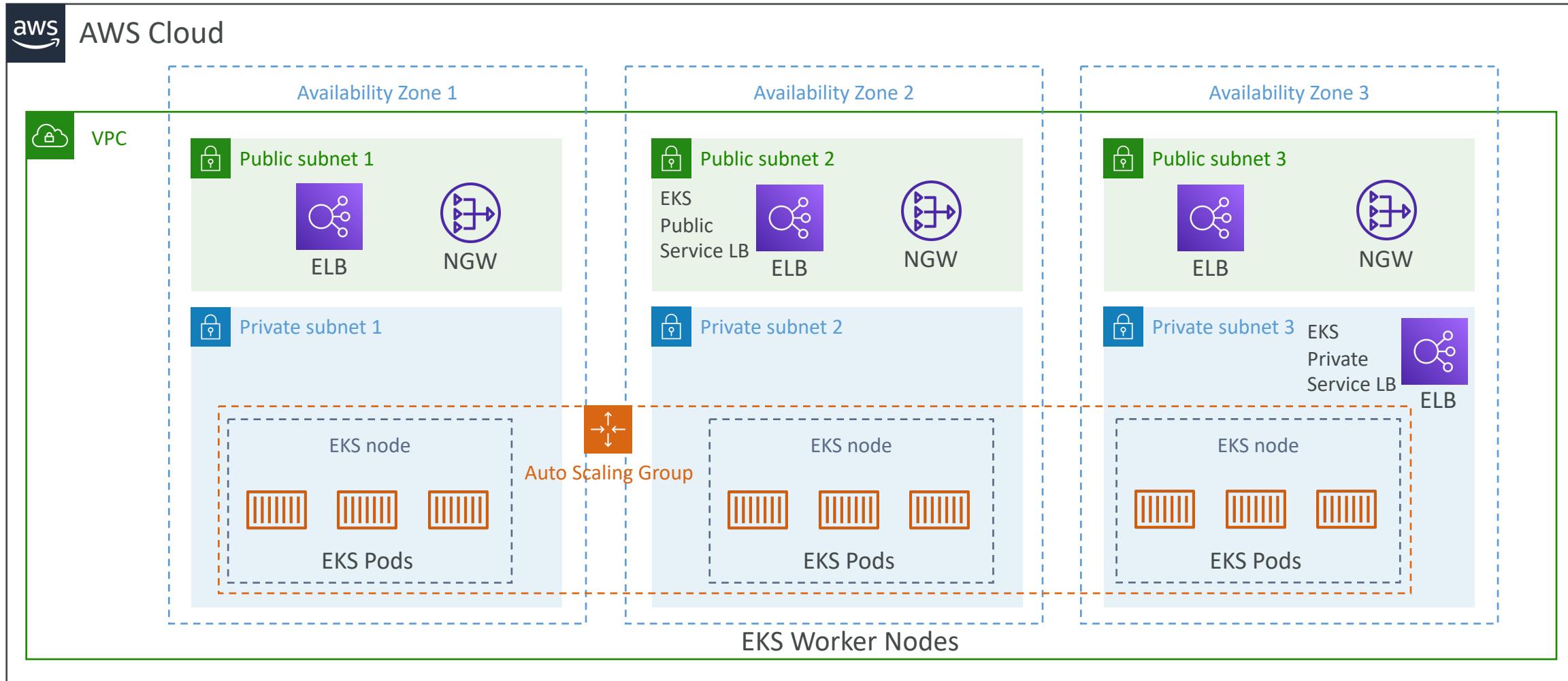


Amazon EKS Overview



- Amazon EKS = Amazon Elastic **Kubernetes** Service
- It is a way to launch **managed Kubernetes clusters** on AWS
- Kubernetes is an **open-source system** for automatic deployment, scaling and management of containerized (usually Docker) application
- It's an alternative to ECS, similar goal but different API
- EKS supports **EC2** if you want to deploy worker nodes or **Fargate** to deploy serverless containers
- **Use case:** if your company is already using Kubernetes on-premises or in another cloud, and wants to migrate to AWS using Kubernetes
- **Kubernetes is cloud-agnostic** (can be used in any cloud – Azure, GCP...)
- For multiple regions, deploy one EKS cluster per region
- Collect logs and metrics using **CloudWatch Container Insights**

Amazon EKS - Diagram

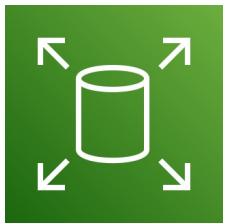


Amazon EKS – Node Types

- **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

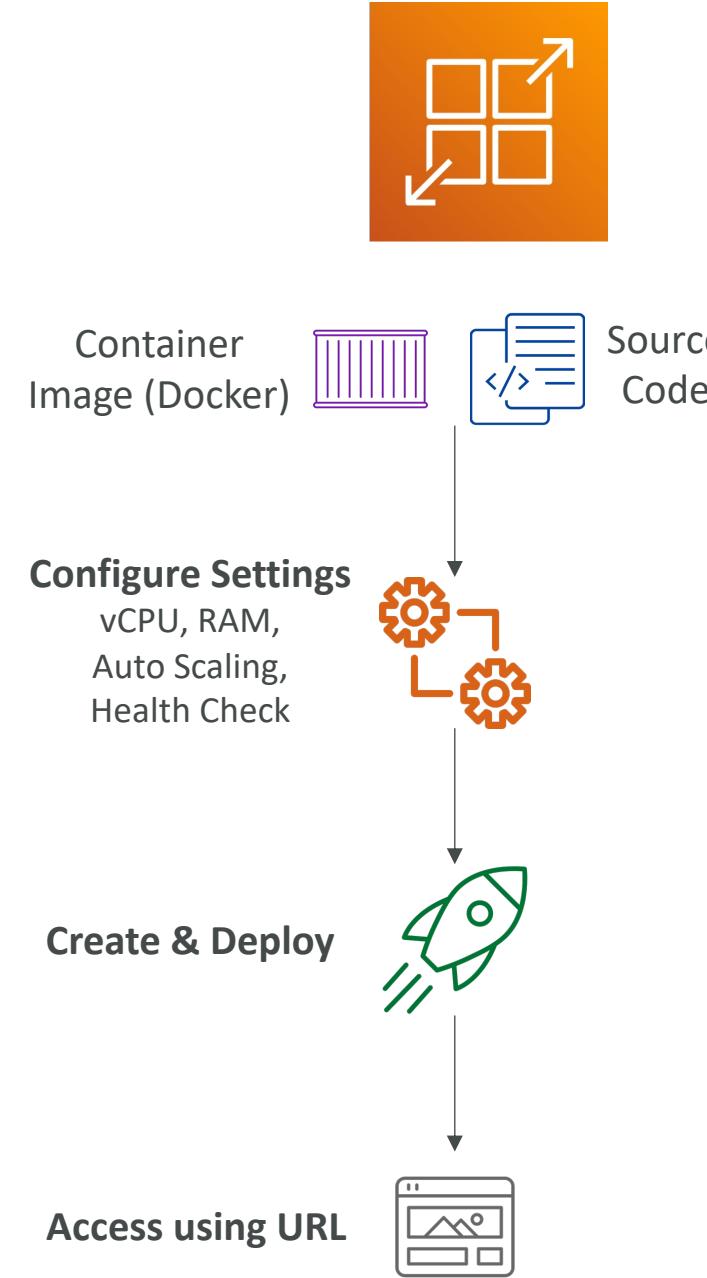
Amazon EKS – Data Volumes

- 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

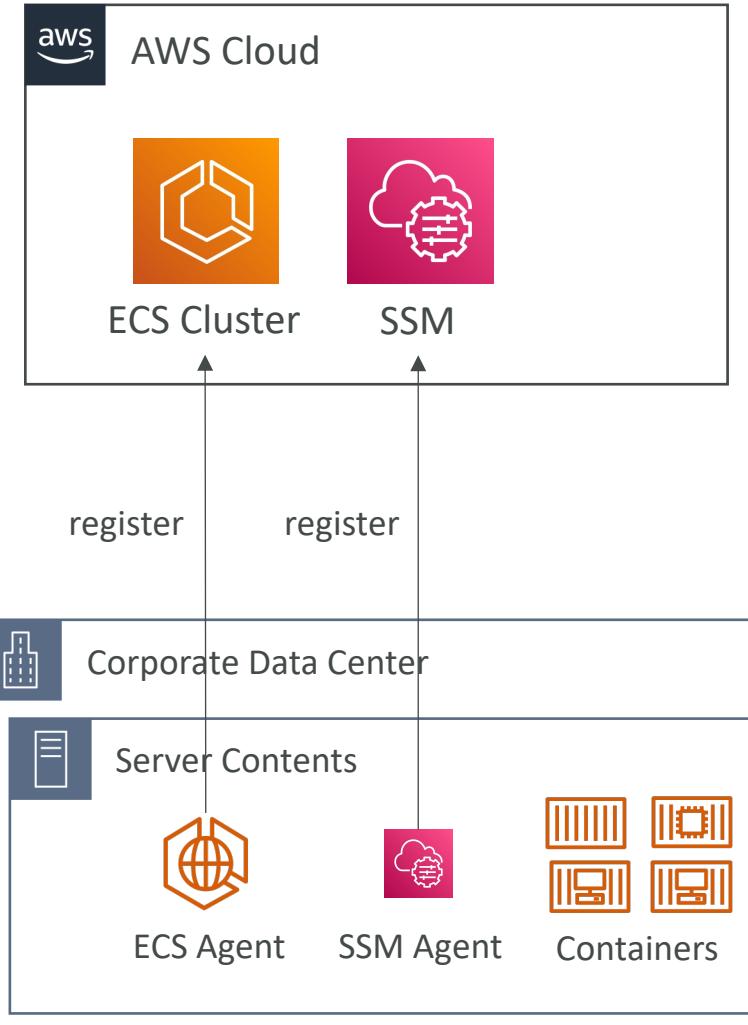
- Fully managed service that makes it easy to deploy web applications and APIs at scale
- No infrastructure experience required
- Start with your source code or container image
- Automatically builds and deploy the web app
- Automatic scaling, highly available, load balancer, encryption
- VPC access support
- Connect to database, cache, and message queue services
- Build from source code (Python, Node.JS, Java)
- Use cases: web apps, APIs, microservices, rapid production deployments



Amazon ECS Anywhere

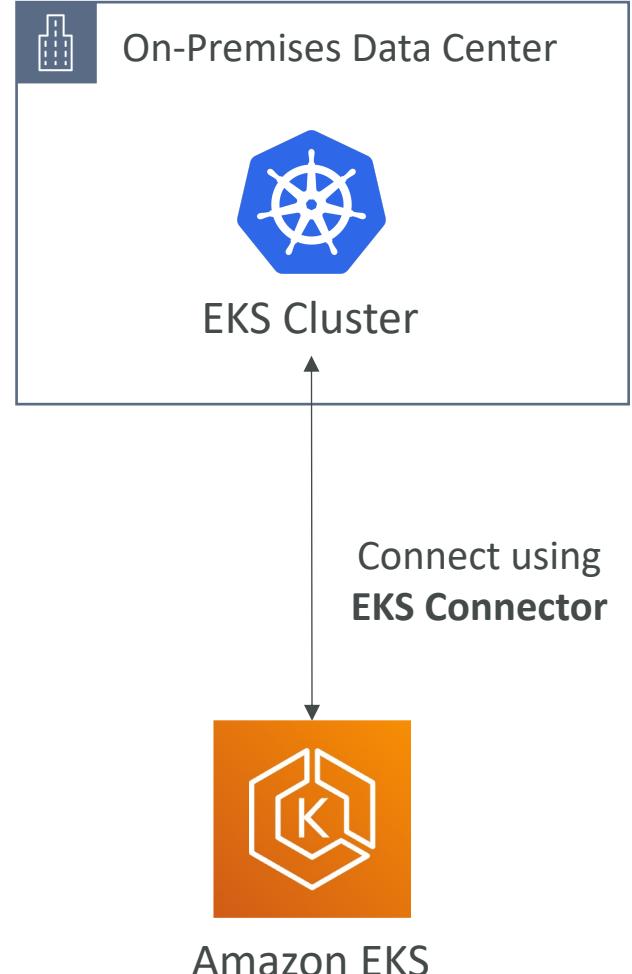


- Easily run containers on Customer-managed infrastructure (on-premises, VMs, ...)
- Allows customers to deploy native Amazon ECS tasks in any environment
- Fully-managed Amazon ECS Control Plane
- **ECS Container Agent** and **SSM Agent** needs to be installed
- “**EXTERNAL**” Launch Type
- Must have a stable connection to the AWS Region
- Use cases:
 - Meet compliance, regulatory, and latency requirements
 - Run apps outside AWS Regions and closer to their other services
 - On-premises ML, video processing, data processing, ...



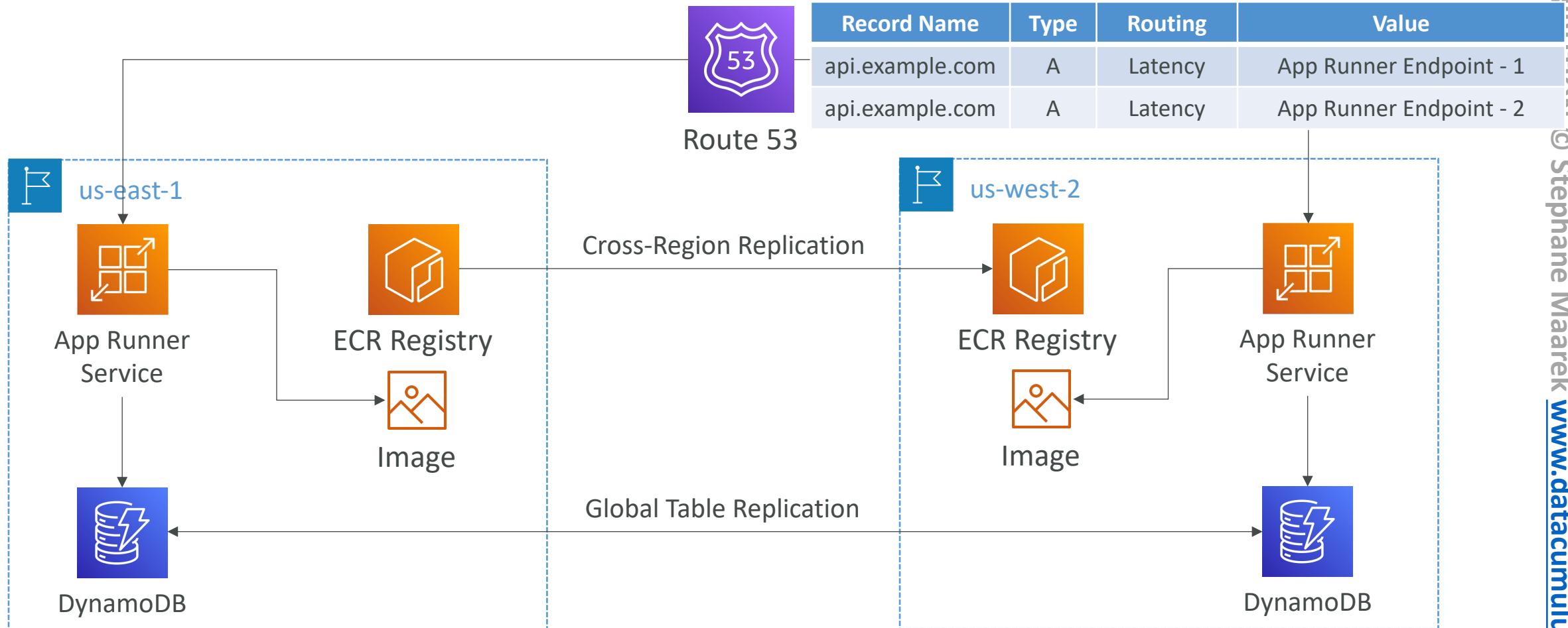
Amazon EKS Anywhere

- Create and operate Kubernetes clusters created outside AWS
- Leverage the **Amazon EKS Distro** (AWS' bundled release of Kubernetes)
- Reduce support costs and avoid maintaining redundant 3rd party tools
- Install using the **EKS Anywhere Installer**
- Optionally use the **EKS Connector** to connect the EKS Anywhere clusters to AWS
 - **Fully Connected & Partially Disconnected**: you can connect to Amazon EKS Anywhere clusters to AWS, and leverage the EKS console
 - **Fully Disconnected**: must install the EKS Distro and leverage open-source tools to manage your clusters



Solution Architecture

App Runner Multi-Region Architecture



AWS Lambda Integrations

Main ones



API Gateway



Kinesis



DynamoDB



AWS S3 –
Simple Storage Service



AWS IoT
Internet of Things



Amazon EventBridge



CloudWatch Logs



AWS SNS

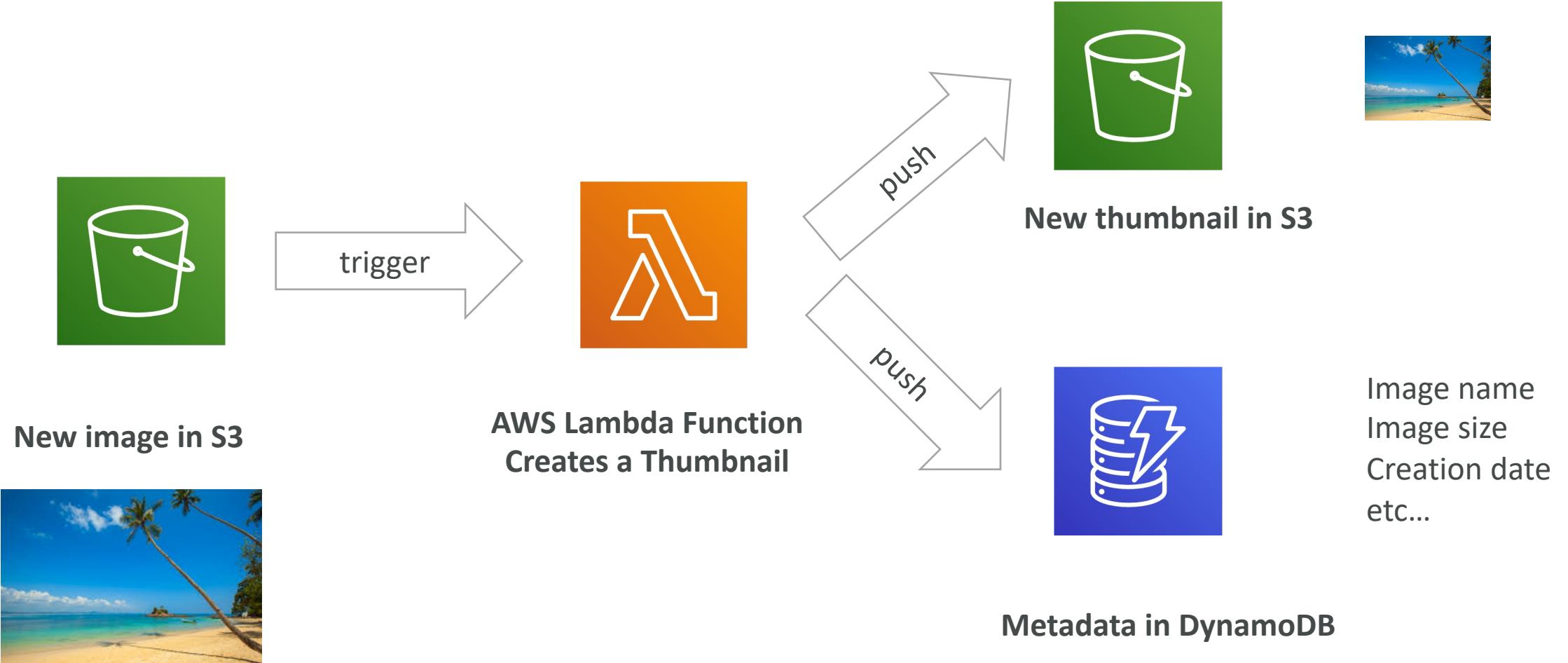


AWS Cognito



Amazon
SQS

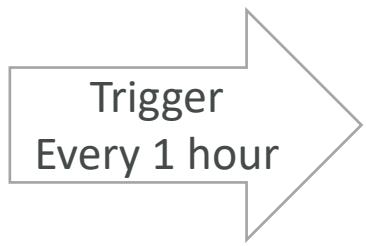
Example: Serverless Thumbnail creation



Example: Serverless CRON Job



Amazon EventBridge



AWS Lambda Function
Perform a task

AWS Lambda Language Support (runtimes)

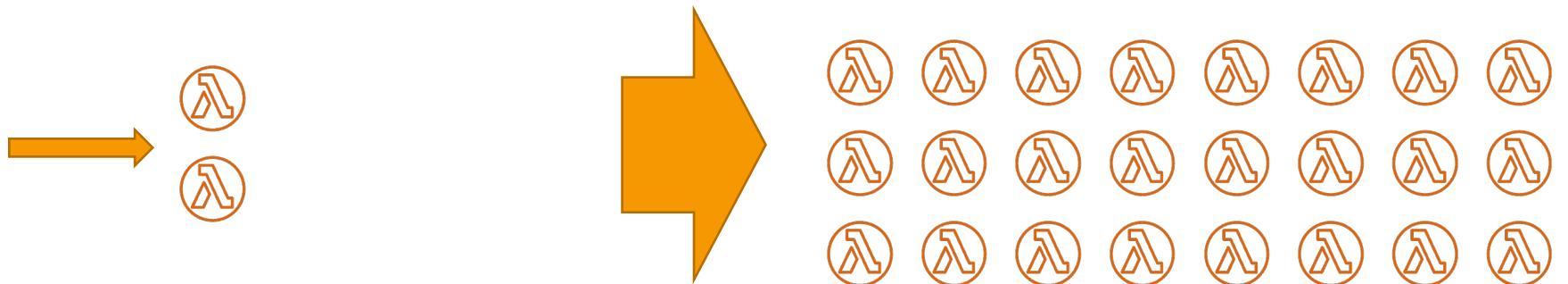
- Node.js (JavaScript)
- Python
- Java
- C# (.NET Core)
- Golang
- C# / Powershell
- Ruby
- Custom Runtime API (community supported, example Rust)
- Lambda Container Image
 - The container image must implement the Lambda Runtime API
 - ECS / Fargate is preferred for running arbitrary Docker images

Lambda – Limits to know

- RAM – 128 MB to 10,240 MB (10 GB)
- CPU – is linked to RAM (cannot be set manually)
 - 2 vCPUs are allocated at 1,769 MB of RAM
 - 6 vCPUs are allocated at 10,240 MB of RAM
- Timeout – up to 15 minutes
- /tmp Storage – 10,240 MB
- Deployment Package – 50 MB (zipped) , 250 MB (unzipped) including layers
- Concurrent Executions – 1000 (soft limit that can be increased)
- Container Image Size – 10 GB
- Invocation Payload (request/response) – 6 MB (sync), 256 KB (async)

Lambda Concurrency and Throttling

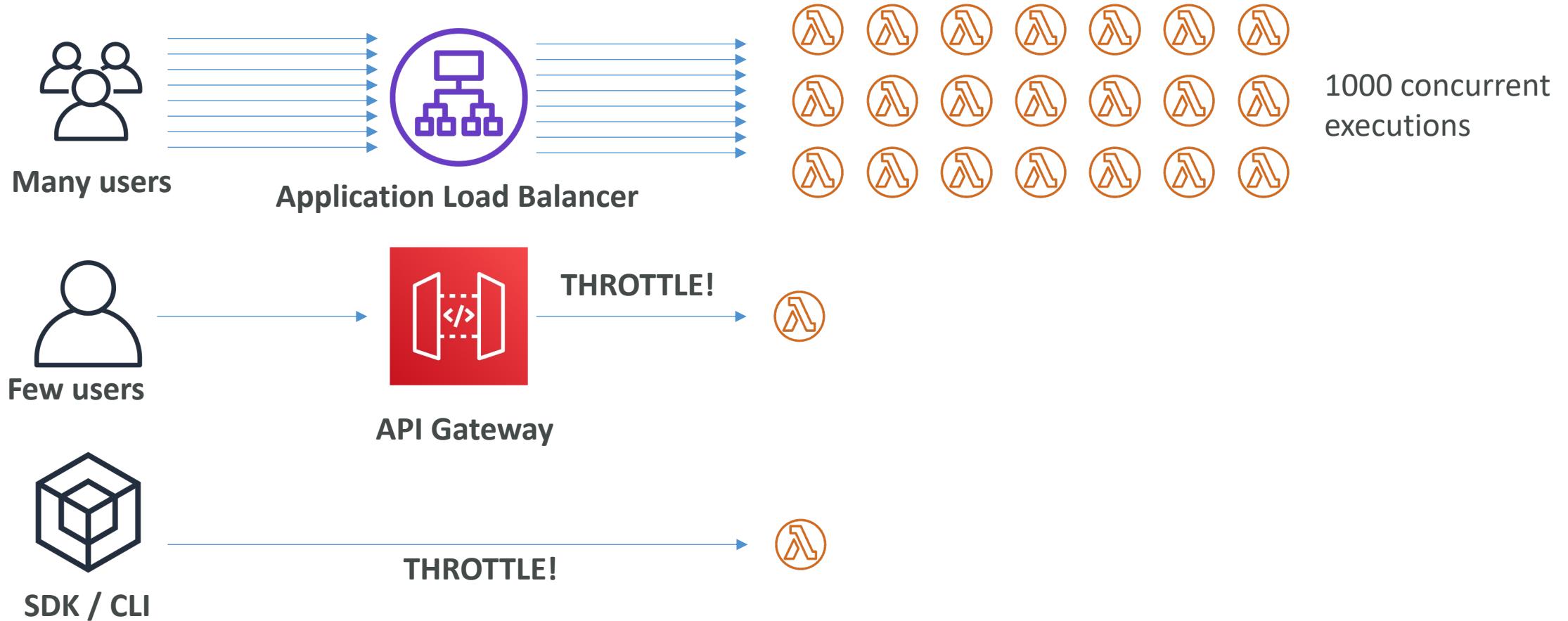
- Concurrency limit: up to 1000 concurrent executions



- Can set a “reserved concurrency” at the function level (=limit)
- Each invocation over the concurrency limit will trigger a “Throttle”
- Can request a quota increase in AWS Service Quotas

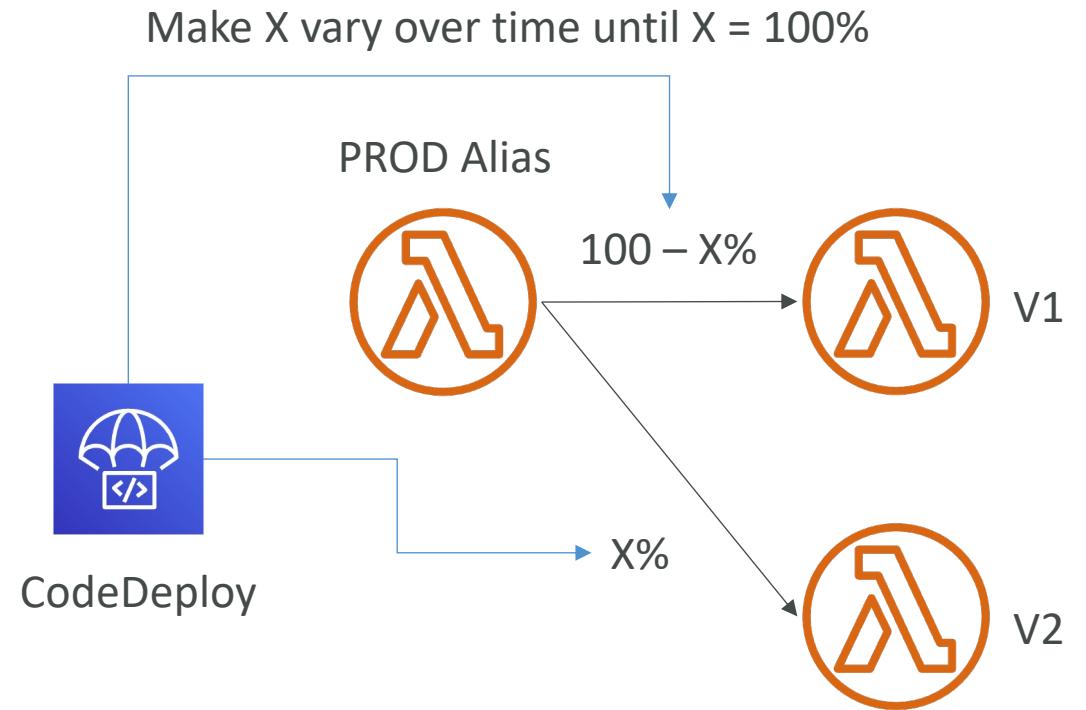
Lambda Concurrency Issue

- If you don't reserve (=limit) concurrency, the following can happen:



Lambda & CodeDeploy

- CodeDeploy can help you automate traffic shift for Lambda aliases
- Feature is integrated within the SAM framework
- **Linear:** grow traffic every N minutes until 100%
 - Linear10PercentEvery3Minutes
 - Linear10PercentEvery10Minutes
- **Canary:** try X percent then 100%
 - Canary10Percent5Minutes
 - Canary10Percent30Minutes
- **AllAtOnce:** immediate
- Can create Pre & Post Traffic hooks to check the health of the Lambda function

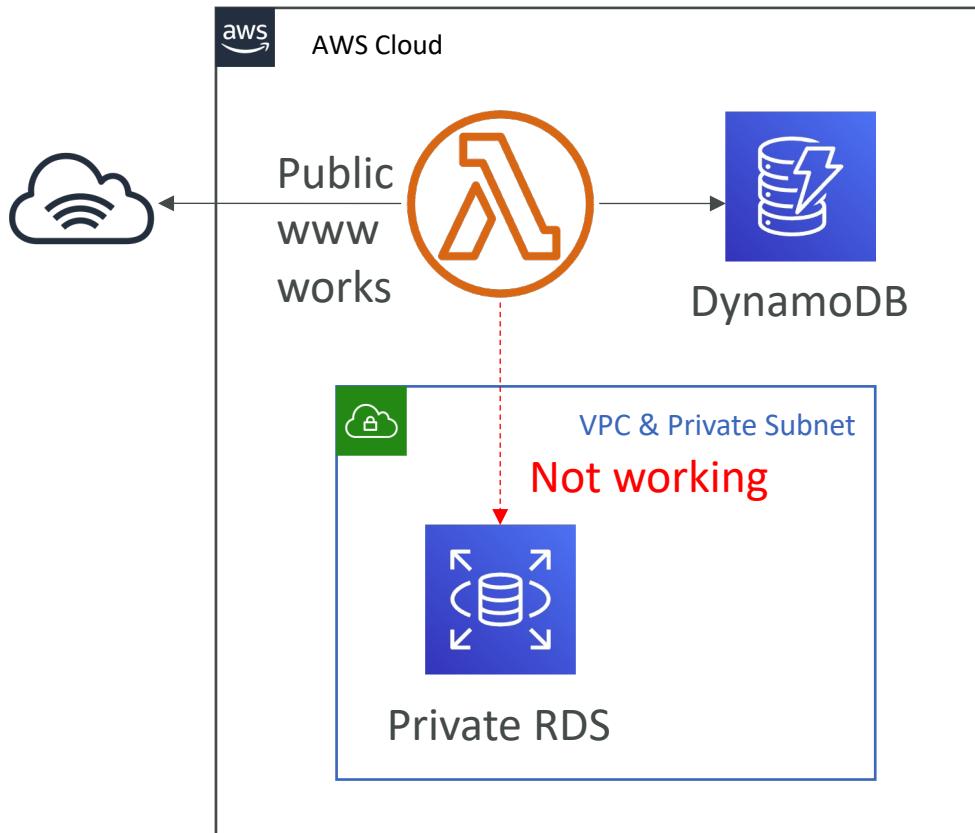


AWS Lambda Logging, Monitoring and Tracing

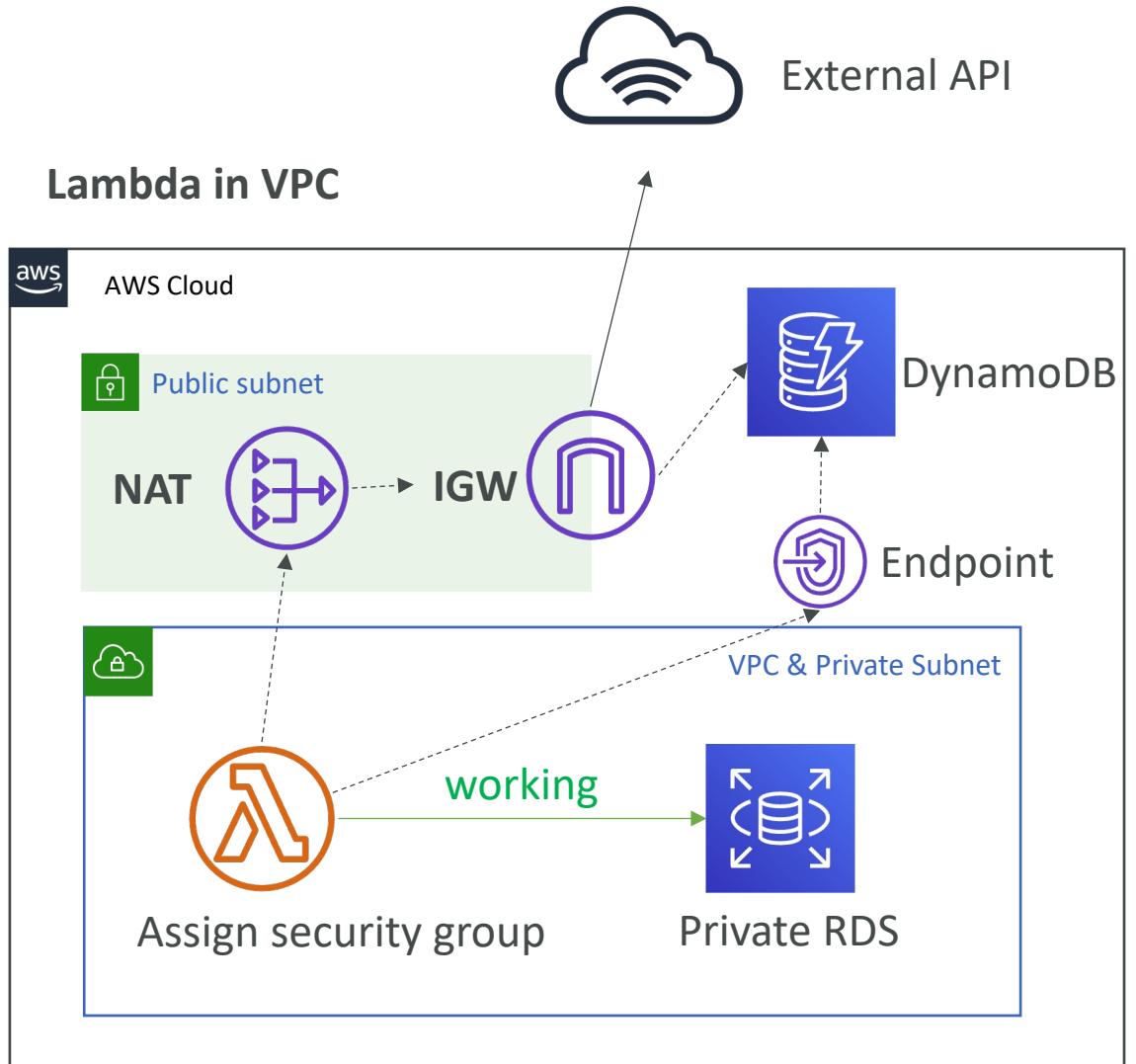
- CloudWatch:
 - AWS Lambda execution logs are stored in AWS CloudWatch Logs
 - AWS Lambda metrics are displayed in AWS CloudWatch Metrics (successful invocations, error rates, latency, timeouts, etc...)
 - **Make sure your AWS Lambda function has an execution role with an IAM policy that authorizes writes to CloudWatch Logs**
- X-Ray:
 - It's possible to trace Lambda with X-Ray
 - Enable in Lambda configuration (runs the X-Ray daemon for you)
 - Use AWS SDK in Code
 - **Ensure Lambda Function has correct IAM Execution Role**

Lambda in a VPC

Default Lambda Deployment

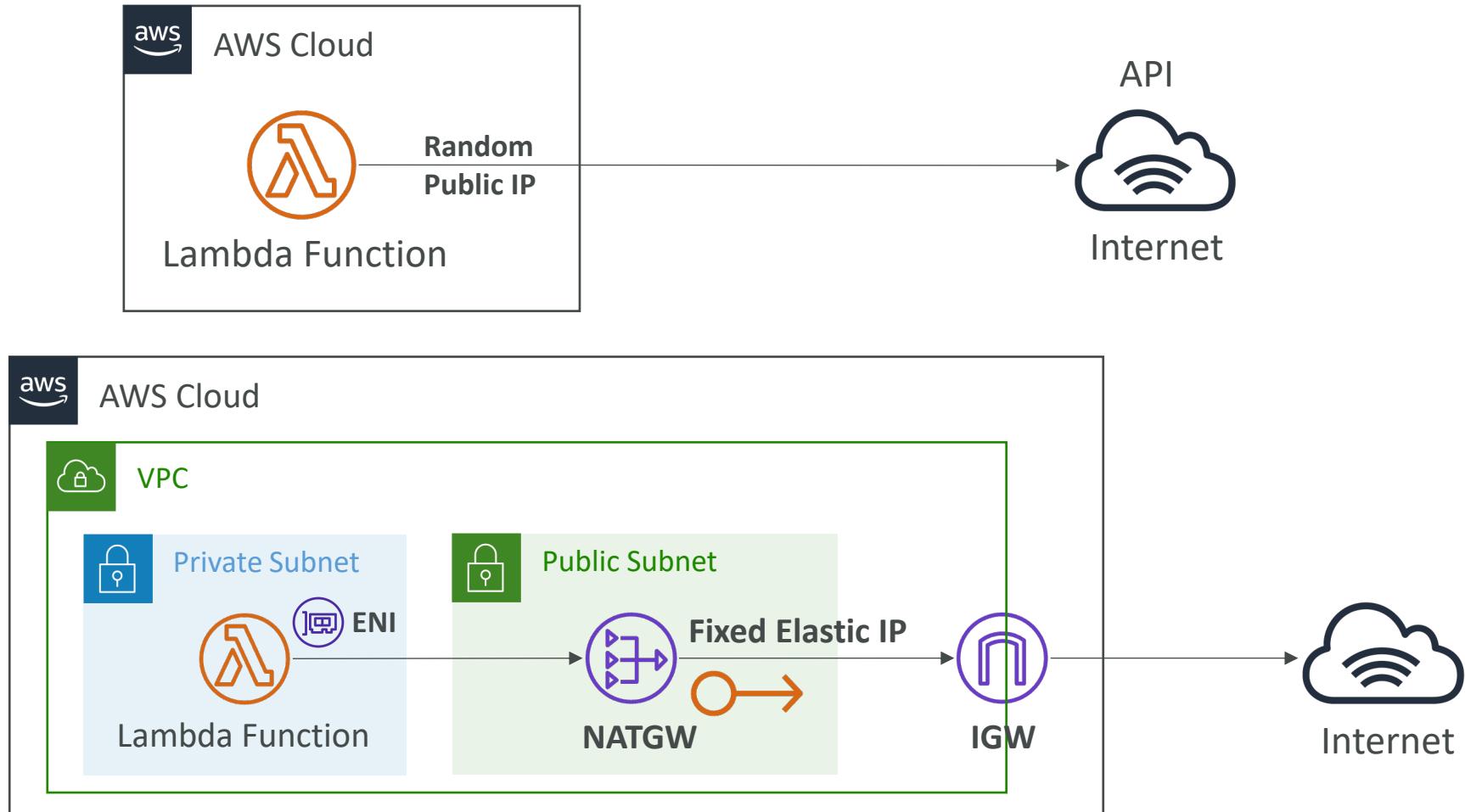


Lambda in VPC



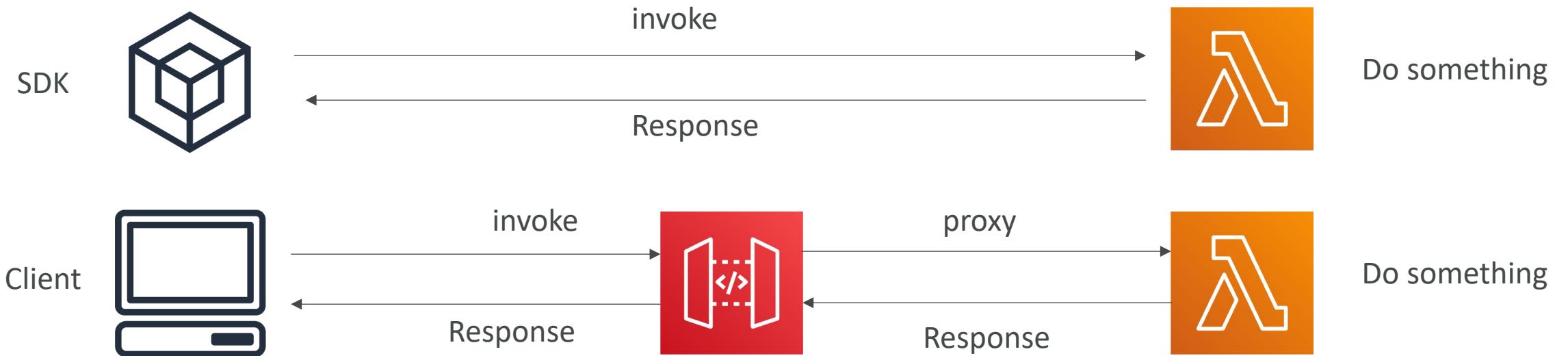
Note: Lambda - CloudWatch Logs works even without endpoint or NAT Gateway

Lambda – Fixed Public IP for external comms



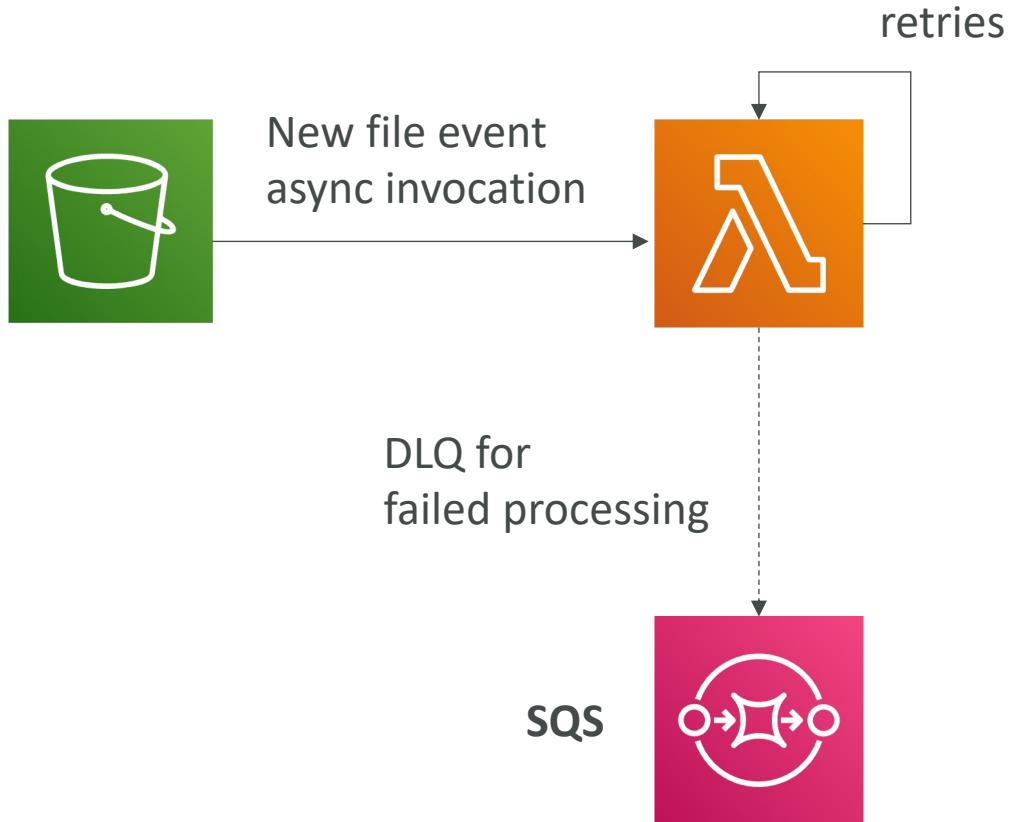
Lambda – Synchronous Invocations

- Synchronous: CLI, SDK, API Gateway
 - Results is returned right away
 - Error handling must happen client side (retries, exponential backoff, etc...)



Lambda – Asynchronous Invocation

- S3, SNS, Amazon EventBridge...
- Lambda attempts to retry on errors (3 tries total)
- Make sure the processing is **idempotent** (in case of retries)
- Can define a DLQ (dead-letter queue) – SNS or SQS – for failed processing

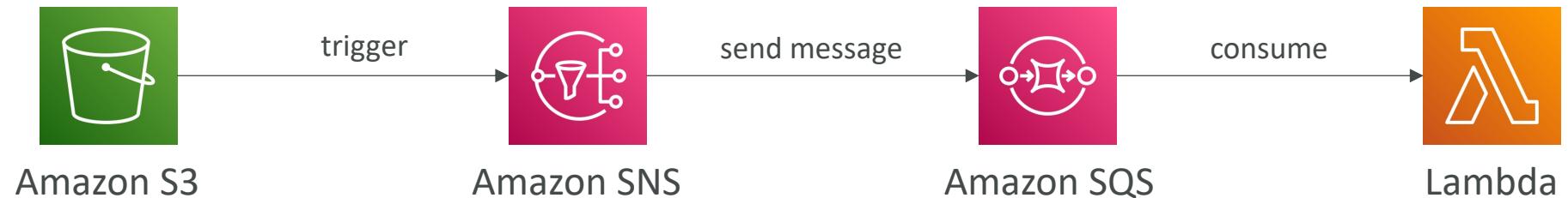


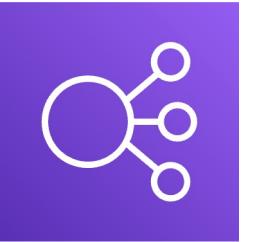
Lambda – Architecture Discussion

Starts immediately
Parallel executions



Batched execution
Delay



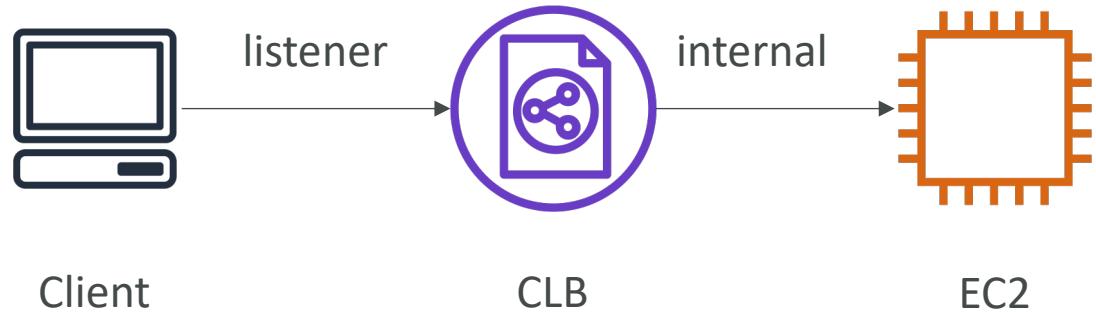


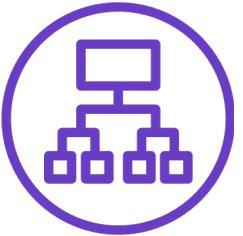
Types of load balancer on AWS

- AWS has **4 kinds of managed Load Balancers**
- **Classic Load Balancer** (v1 - old generation) – 2009 – CLB
 - HTTP, HTTPS, TCP, SSL (secure TCP)
- **Application Load Balancer** (v2 - new generation) – 2016 – ALB
 - HTTP, HTTPS, WebSocket
- **Network Load Balancer** (v2 - new generation) – 2017 – NLB
 - TCP, TLS (secure TCP), UDP
- **Gateway Load Balancer** – 2020 – GWLB
 - Operates at layer 3 (Network layer) – IP Protocol
- Overall, it is recommended to use the newer generation load balancers as they provide more features
- Some load balancers can be setup as **internal** (private) or **external** (public) ELBs

Classic Load Balancers (v1)

- Health Checks can be HTTP (L7) or TCP (L4) based including with SSL
- Supports only one SSL certificate
 - The SSL certificate can have many SAN (Subject Alternate Name), but the SSL certificate must be changed anytime a SAN is added / edited / removed
 - Better to use ALB with SNI (Server Name Indication) if possible
 - Can use multiple CLB if you want distinct SSL certificates
- TCP => TCP passes all the traffic to the EC2 instance
 - Only way to use 2-way SSL authentication



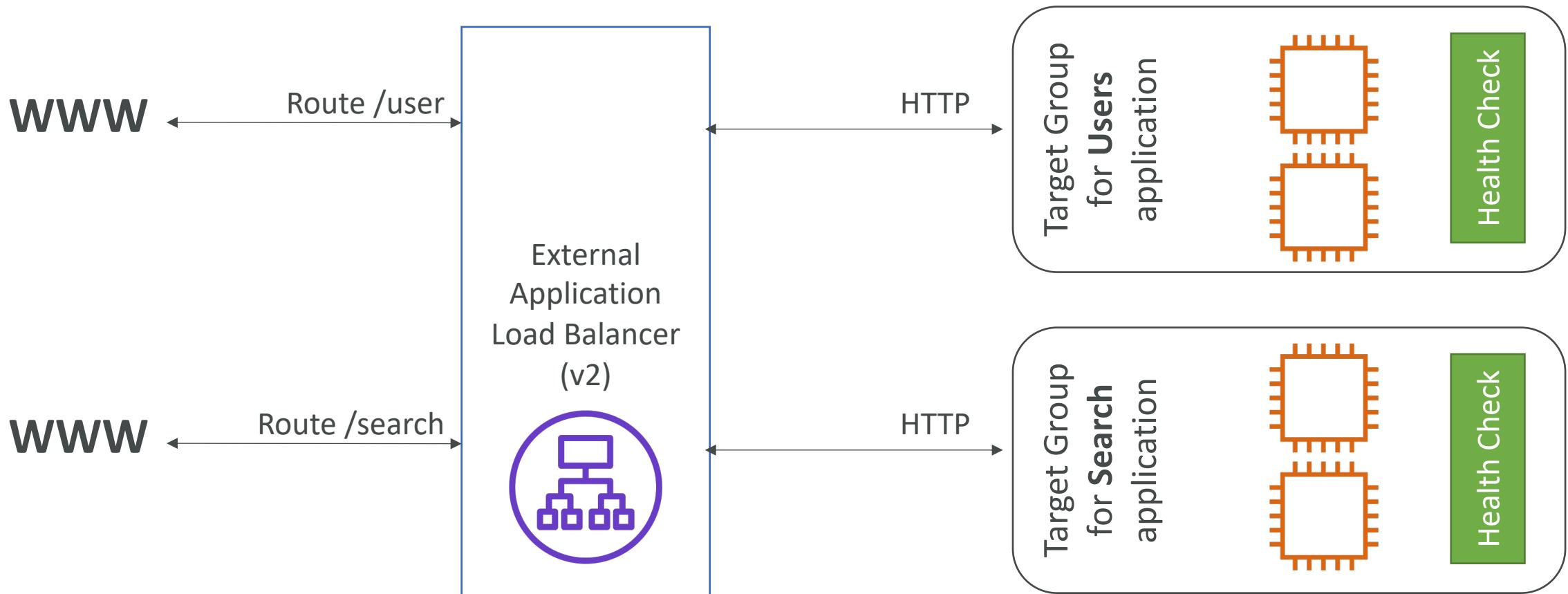


Application Load Balancer (v2)

- Application load balancers is Layer 7 (HTTP)
- Load balancing to multiple HTTP applications across machines (target groups)
- Load balancing to multiple applications on the same machine (ex: containers) – great fit with ECS, has dynamic port mapping
- Support for HTTP/2 and WebSocket
- Support redirects (from HTTP to HTTPS for example)
- Routing Rules for path, headers, query string

Application Load Balancer (v2)

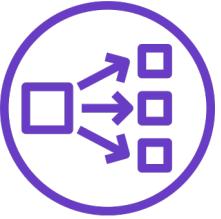
HTTP Based Traffic



Application Load Balancer (v2)

Target Groups

- EC2 instances (can be managed by an Auto Scaling Group) – HTTP
 - ECS tasks (managed by ECS itself) – HTTP
 - Lambda functions – HTTP request is translated into a JSON event
 - IP Addresses – must be private IPs
-
- ALB can route to multiple target groups
 - Health checks are at the target group level

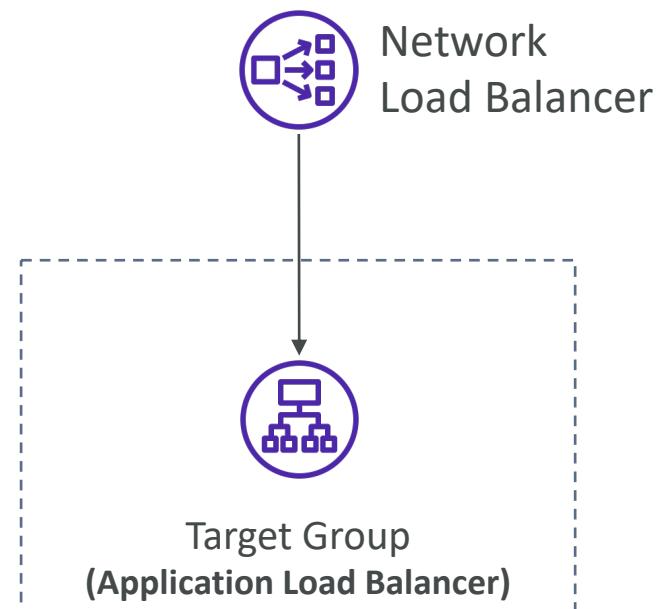
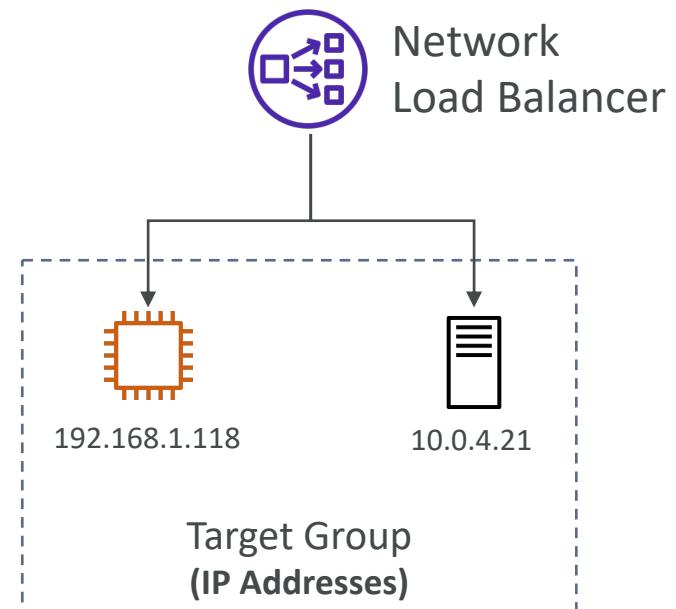
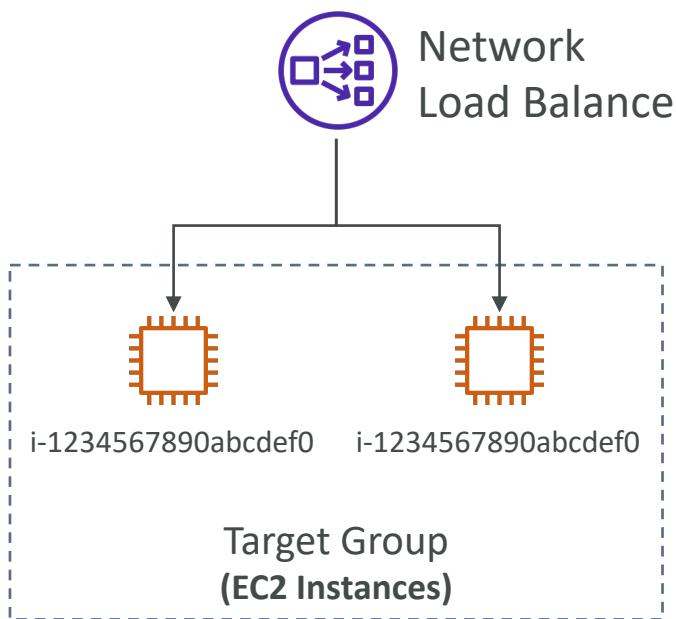


Network Load Balancer (v2)

- Network load balancers (Layer 4) allow to:
 - Forward TCP & UDP traffic to your instances
 - Handle millions of requests per second
 - Less latency ~100 ms (vs 400 ms for ALB)
- NLB has one static IP per AZ, and supports assigning Elastic IP (helpful for whitelisting specific IP)
- NLB are used for extreme performance, TCP or UDP traffic
- Not included in the AWS free tier

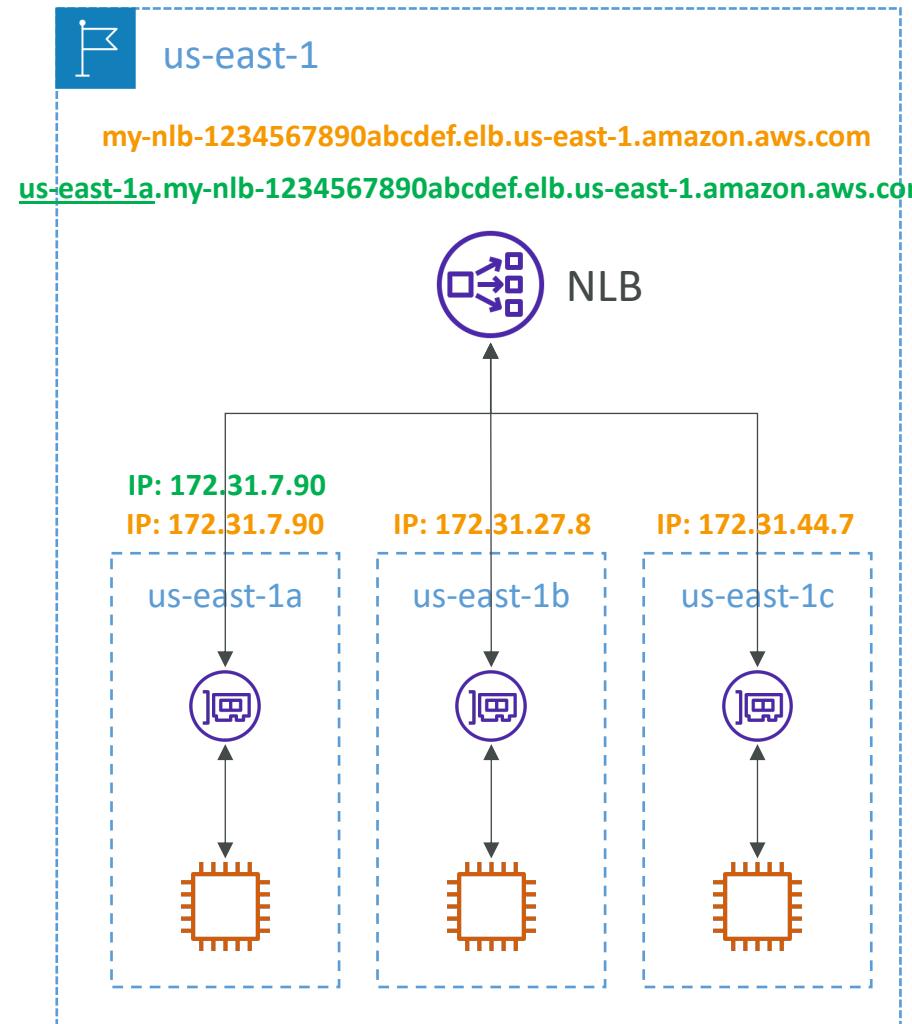
Network Load Balancer – Target Groups

- EC2 instances
- IP Addresses – must be private IPs
- Application Load Balancer



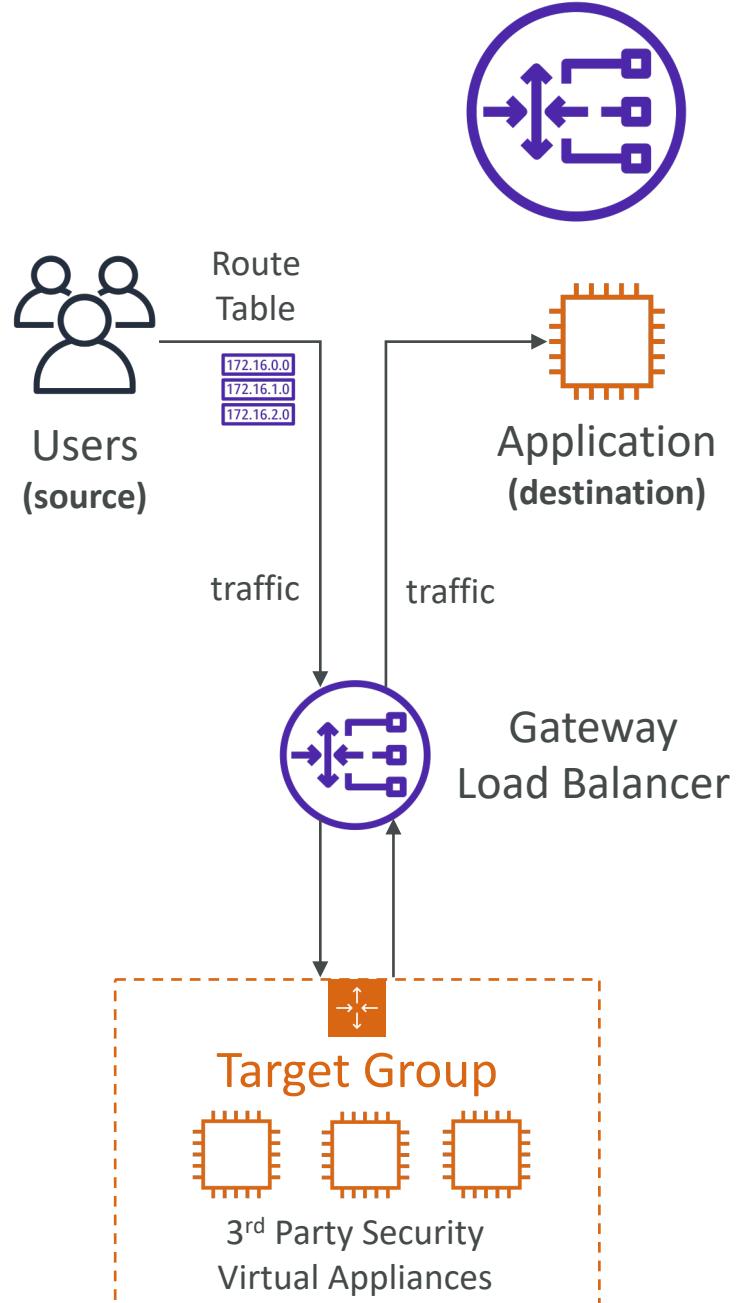
Network Load Balancer – Zonal DNS Name

- Resolving **Regional NLB DNS name** returns the IP addresses for all NLB nodes in all enabled AZs
 - my-nlb-1234567890abcdef.elb.us-east-1.amazonaws.com
- **Zonal DNS Name**
 - NLB has DNS names for each of its nodes
 - Use to determine the IP address of each node
 - **us-east-1a.my-nlb-1234567890abcdef.elb.us-east-1.amazonaws.com**
 - Used to minimize latency and data transfer costs
 - You need to implement app specific logic



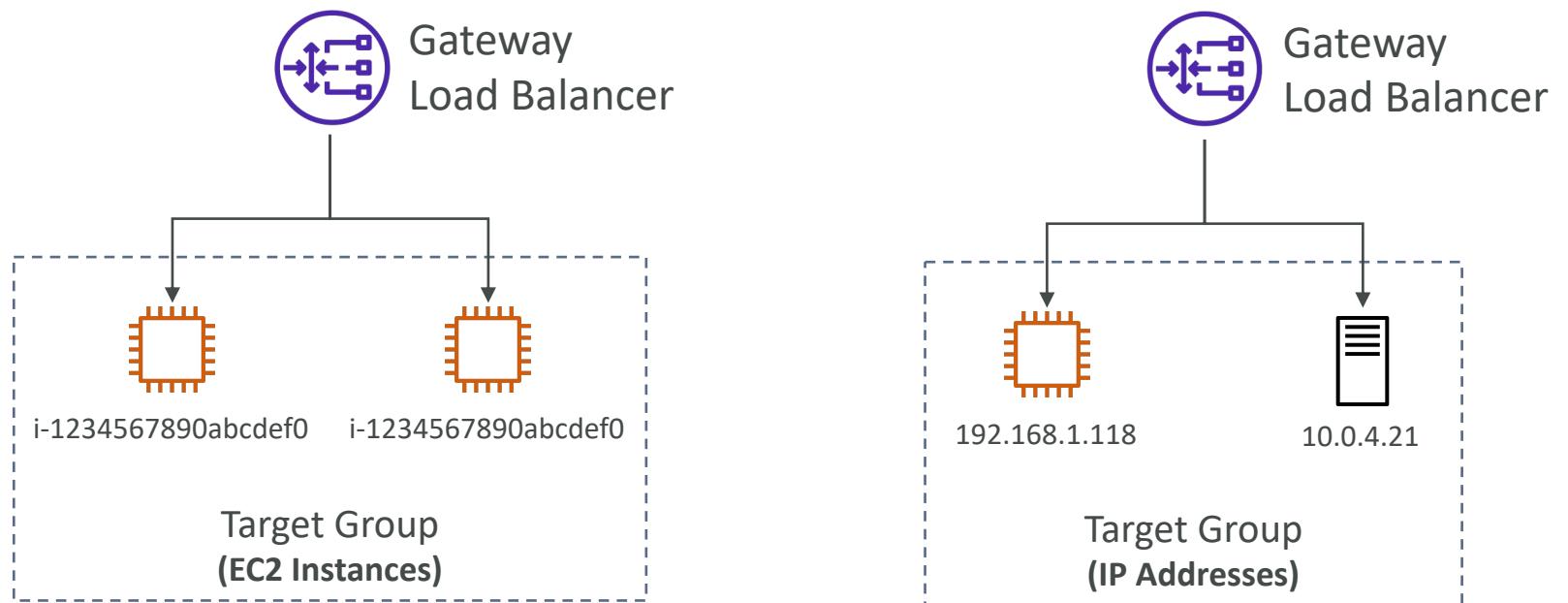
Gateway Load Balancer

- Deploy, scale, and manage a fleet of 3rd party network virtual appliances in AWS
- Example: Firewalls, Intrusion Detection and Prevention Systems, Deep Packet Inspection Systems, payload manipulation, ...
- Operates at Layer 3 (Network Layer) – IP Packets
- Combines the following functions:
 - **Transparent Network Gateway** – single entry/exit for all traffic
 - **Load Balancer** – distributes traffic to your virtual appliances
- Uses the **GENEVE** protocol on port 6081



Gateway Load Balancer – Target Groups

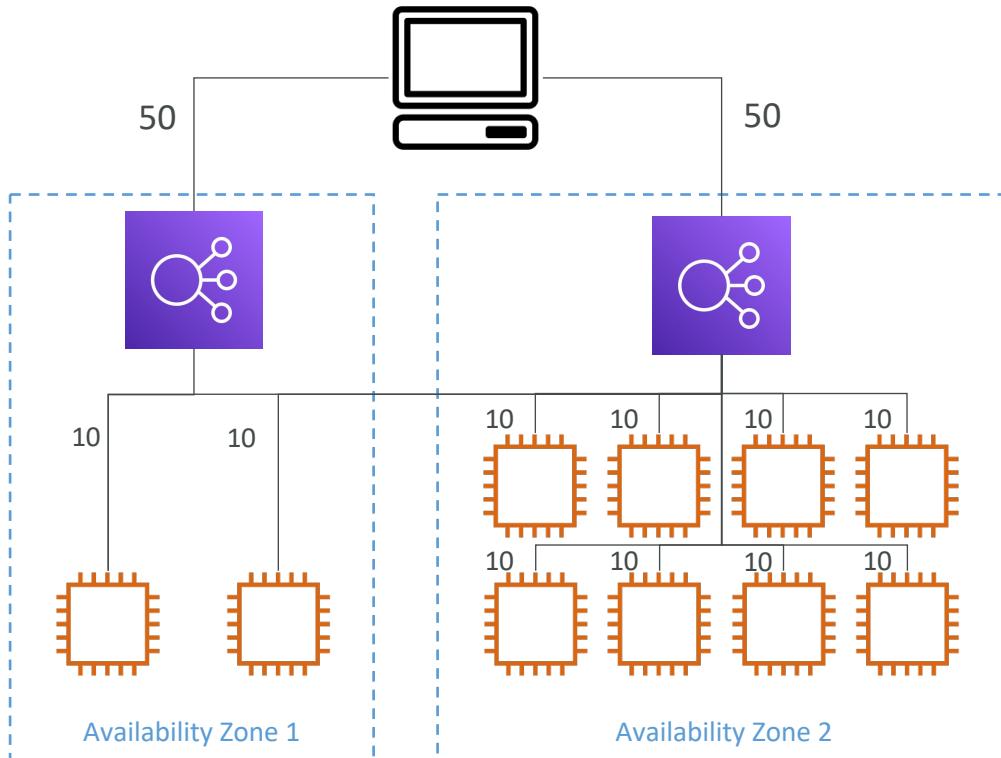
- EC2 instances
- IP Addresses – must be private IPs



Cross-Zone Load Balancing

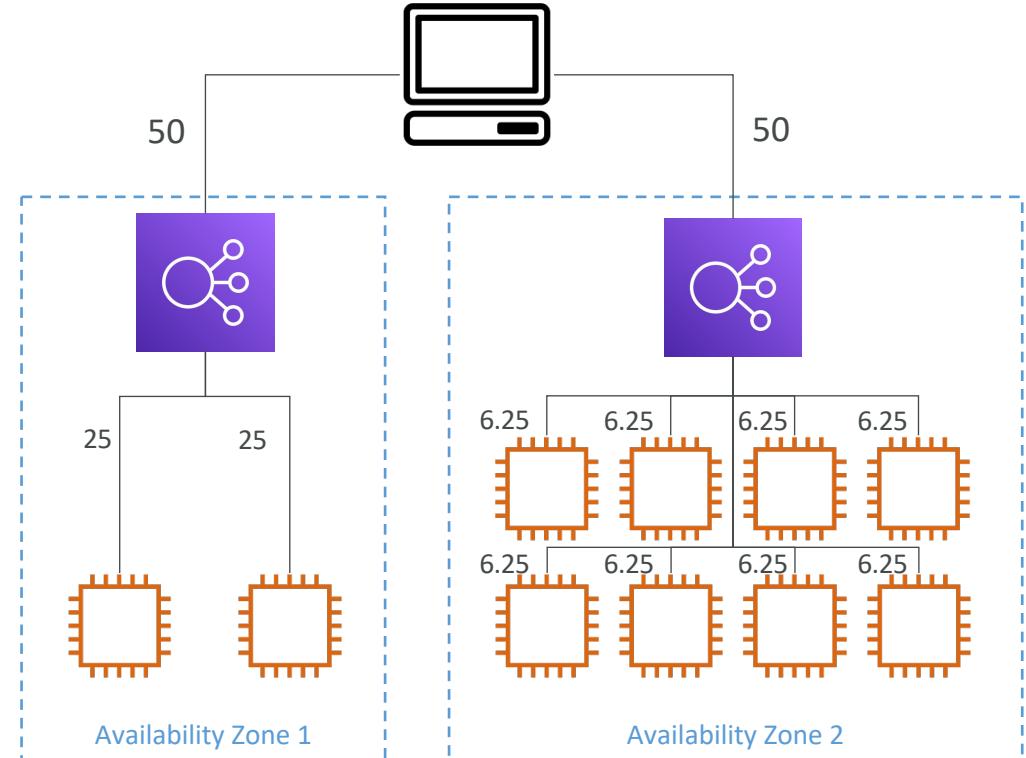
With Cross Zone Load Balancing:

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



Without Cross Zone Load Balancing:

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

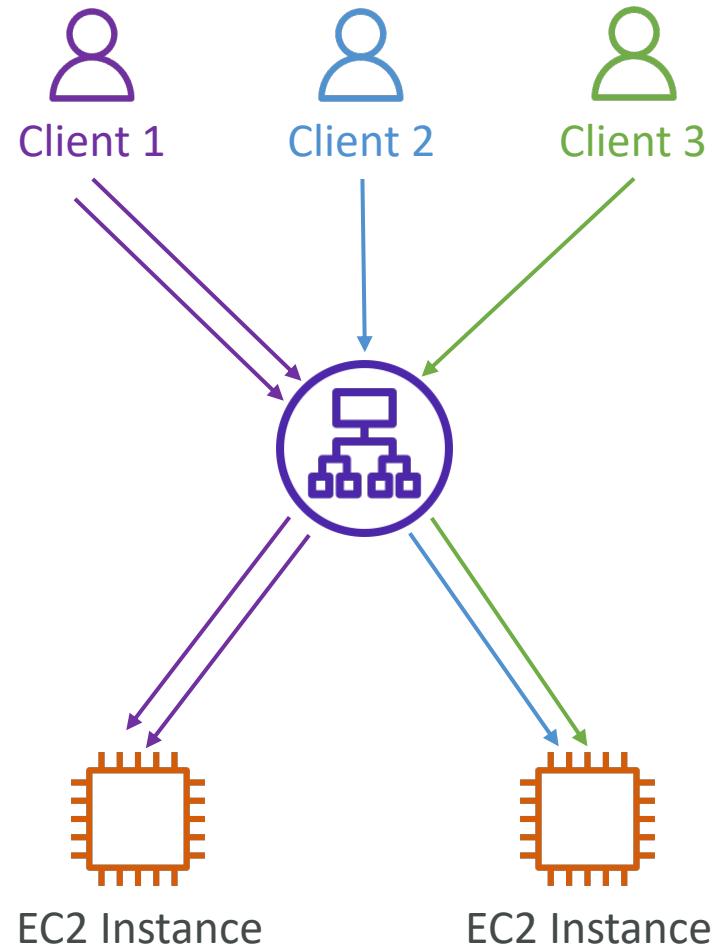


Cross-Zone Load Balancing

- **Classic Load Balancer**
 - Disabled by default
 - 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
- **Gateway Load Balancer**
 - Disabled by default
 - You pay charges (\$) for inter AZ data if enabled

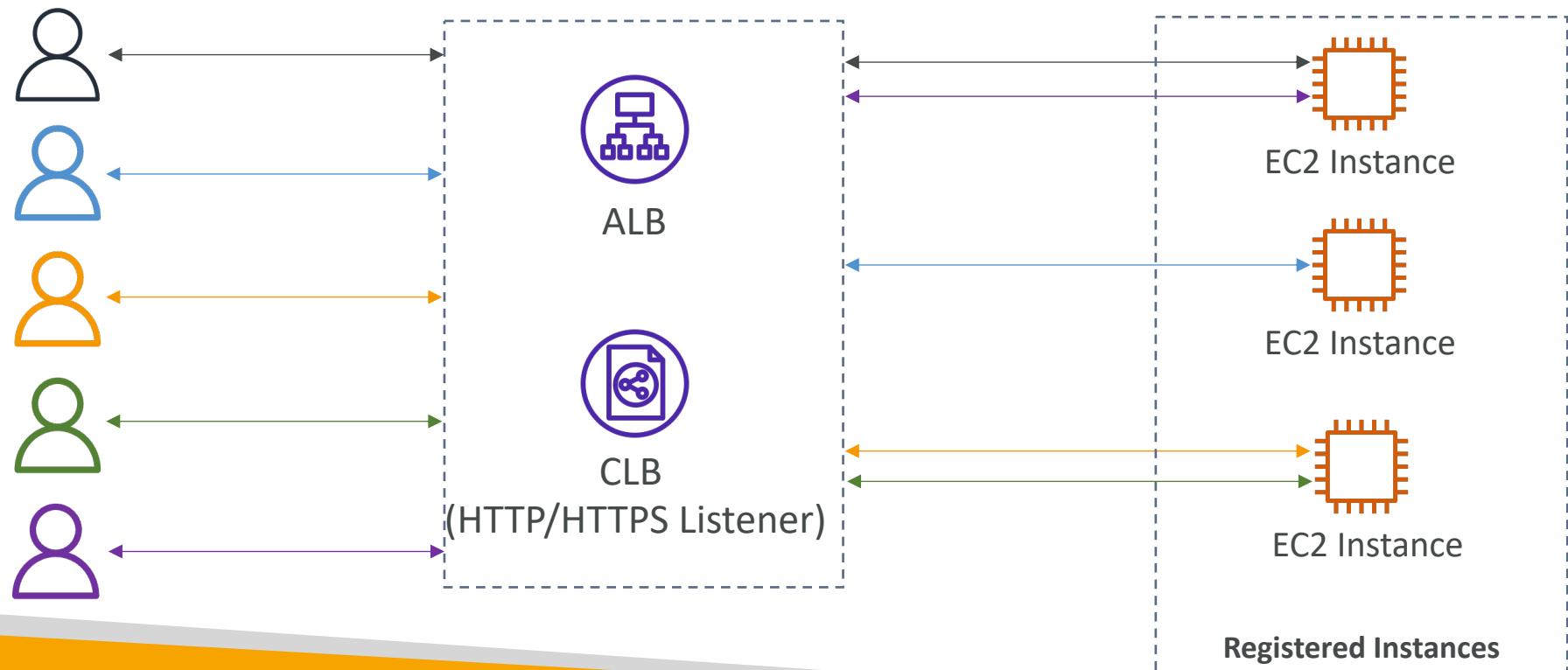
Sticky Sessions (Session Affinity)

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



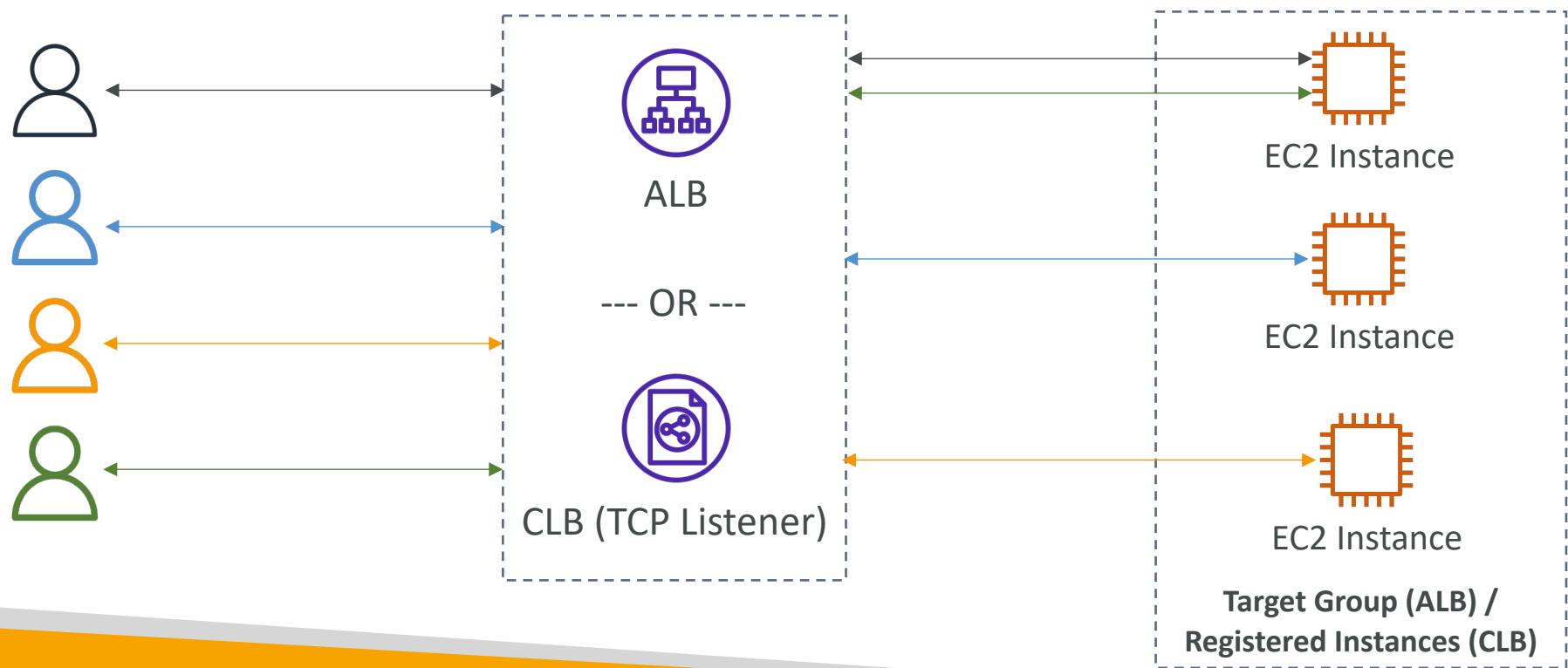
Request Routing Algorithms – Least Outstanding Requests

- The next instance to receive the request is the instance that has the lowest number of pending/unfinished requests
- Works with Application Load Balancer and Classic Load Balancer (HTTP/HTTPS)



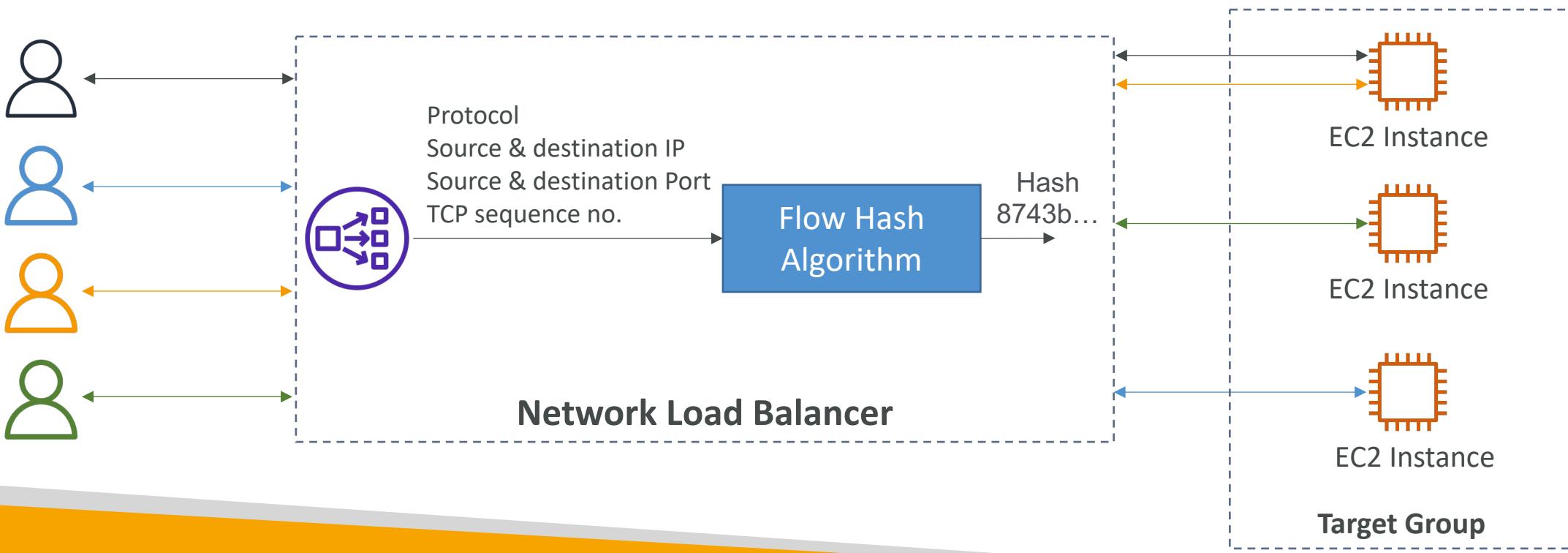
Request Routing Algorithms – Round Robin

- Equally choose the targets from the target group
- Works with Application Load Balancer and Classic Load Balancer (TCP)

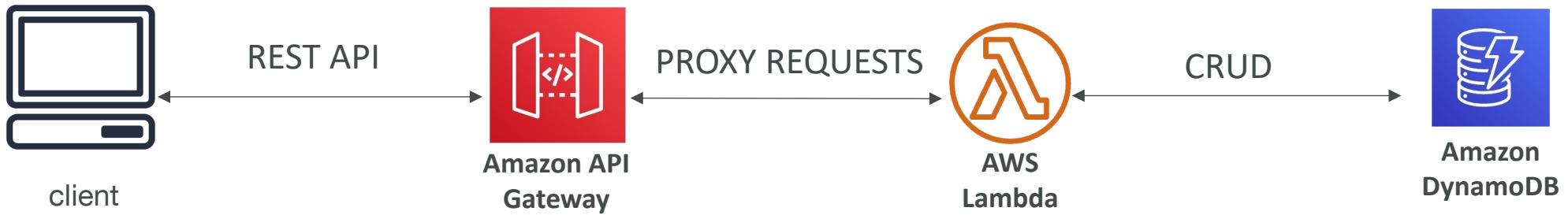


Request Routing Algorithms – Flow Hash

- Selects a target based on the protocol, source/destination IP address, source/destination port, and TCP sequence number
- Each TCP/UDP connection is routed to a single target for the life of the connection
- Works with Network Load Balancer



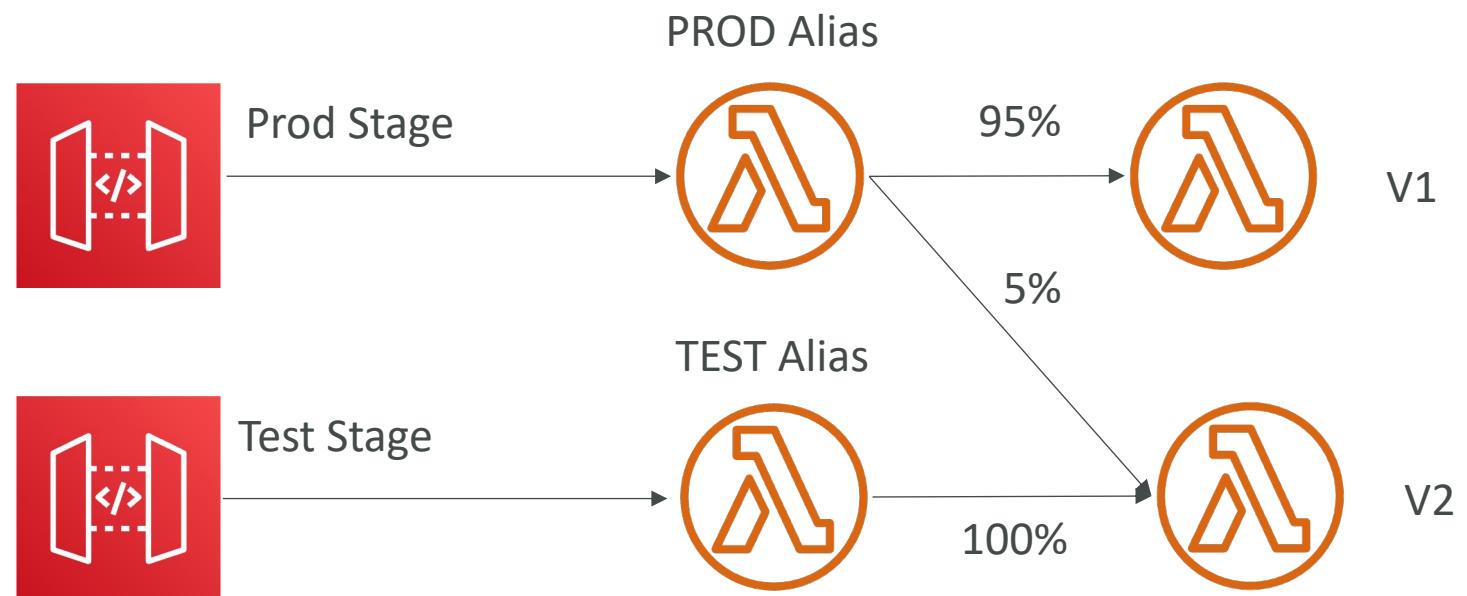
API Gateway – Overview



- Helps expose Lambda, HTTP & AWS Services as an API
- API versioning, authorization, traffic management (API keys, throttles), huge scale, serverless, req/resp transformations, OpenAPI spec, CORS
- **Limits to know:**
 - 29 seconds timeout
 - 10 MB max payload size

API Gateway – Deployment Stages

- API changes are deployed to “Stages” (as many as you want)
- Use the naming you like for stages (dev, test, prod)
- Stages can be rolled back as a history of deployments is kept

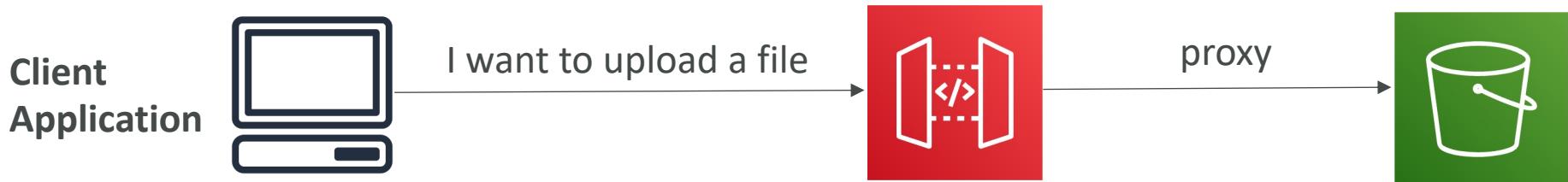


API Gateway – Integrations

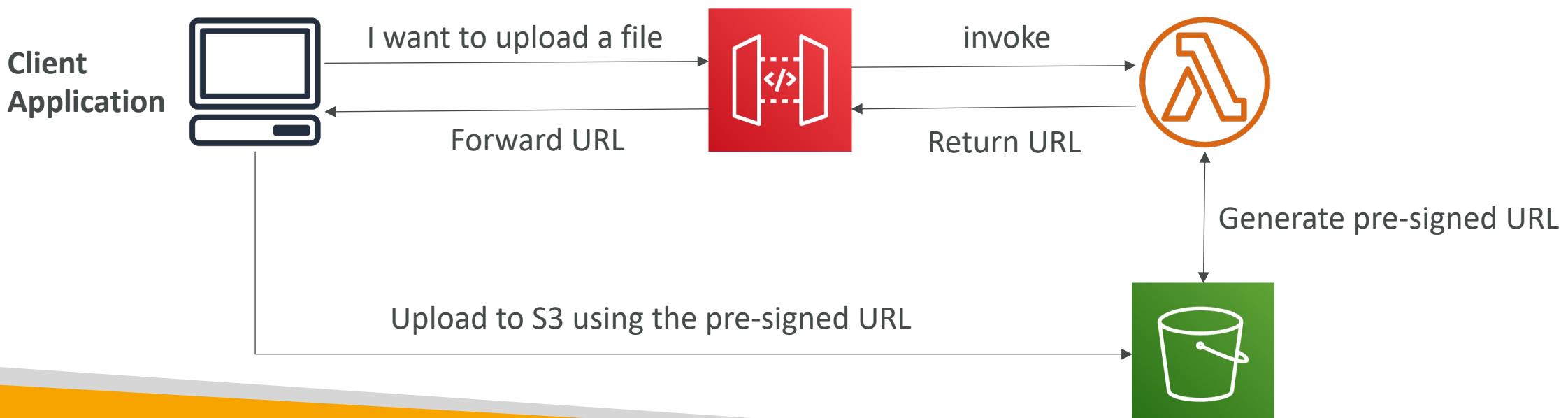
- **HTTP**
 - Expose HTTP endpoints in the backend
 - Example: internal HTTP API on premise, Application Load Balancer...
 - Why? Add rate limiting, caching, user authentications, API keys, etc...
- **Lambda Function**
 - Invoke Lambda function
 - Easy way to expose REST API backed by AWS Lambda
- **AWS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

Solution Architecture Discussion: API Gateway in front of S3

- You will be impacted by the 10 MB payload size limit



- Better architecture:

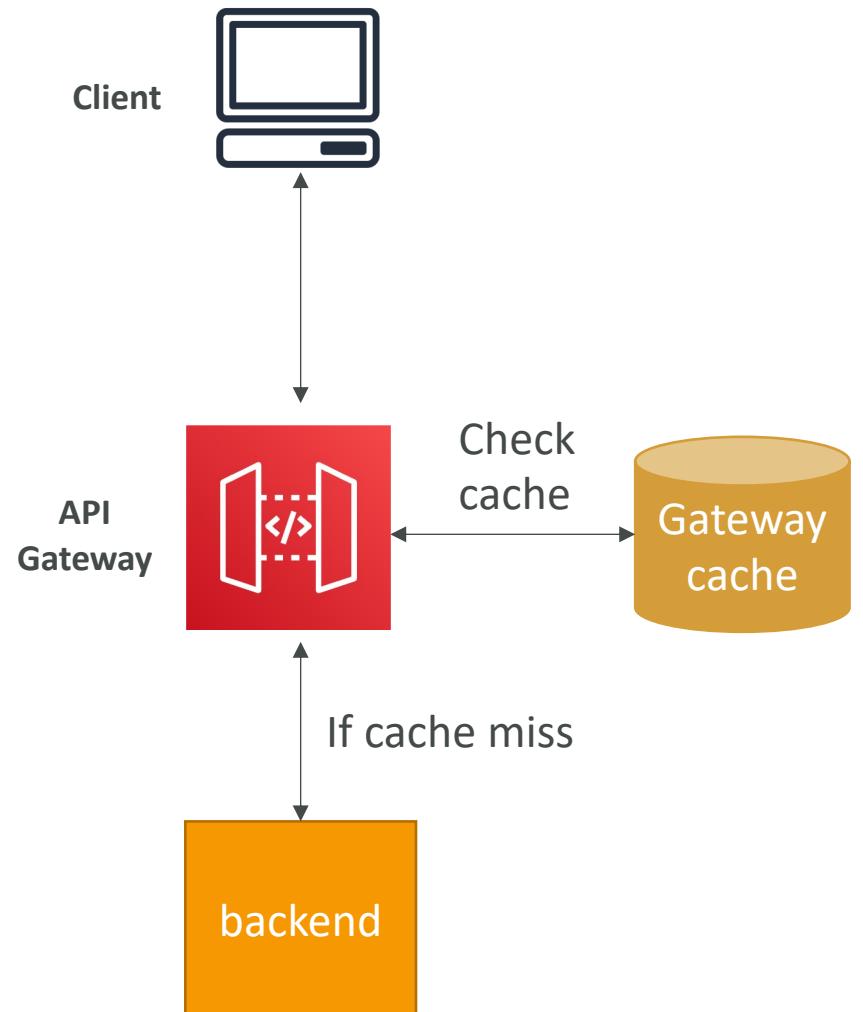


API Gateway - Endpoint Types

- **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
- **Regional:**
 - For clients within the same region
 - Could manually combine with CloudFront (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

Caching API responses

- Caching reduces the number of calls made to the backend
- Default TTL (time to live) is 300 seconds (min: 0s, max: 3600s)
- Caches are defined **per stage**
- Possible to override cache settings **per method**
- Clients can invalidate the cache with header: **Cache-Control: max-age=0** (with proper IAM authorization)
- Able to flush the entire cache (invalidate it) immediately
- Cache encryption option
- Cache capacity between 0.5GB to 237GB



API Gateway - Errors

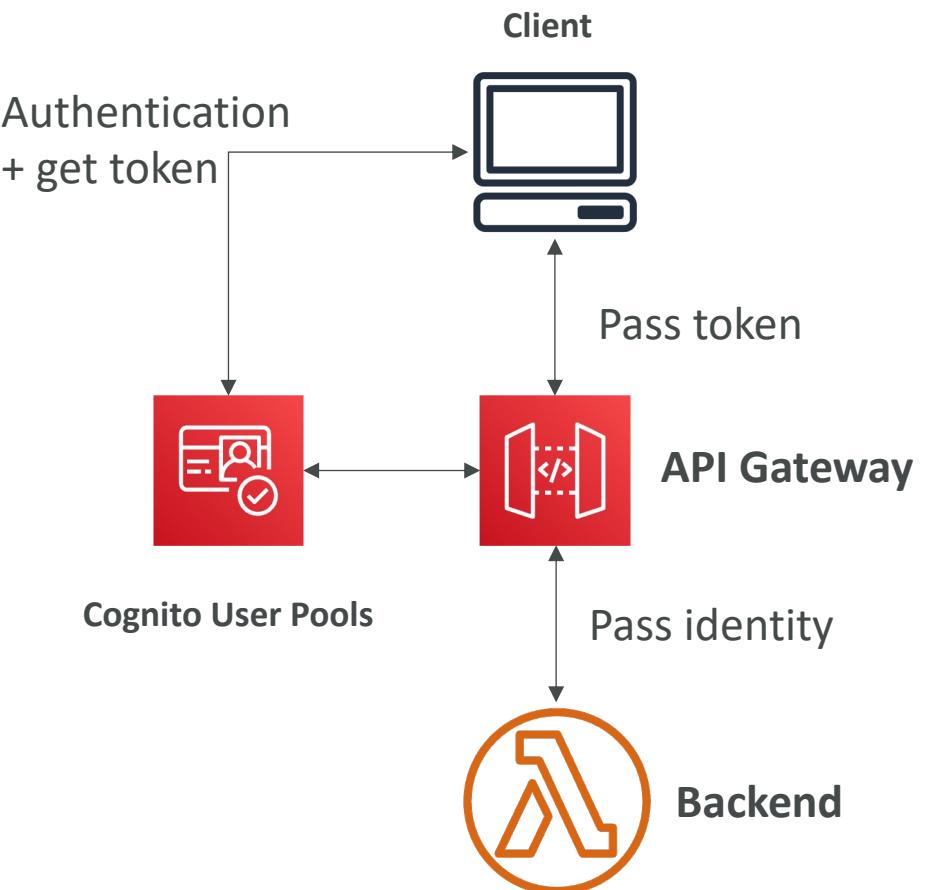
- 4xx means Client errors
 - 400: Bad Request
 - 403: Access Denied, WAF filtered
 - 429: Quota exceeded, Throttle
- 5xx means Server errors
 - 502: Bad Gateway Exception, usually for an incompatible output returned from a Lambda proxy integration backend and occasionally for out-of-order invocations due to heavy loads.
 - 503: Service Unavailable Exception
 - 504: Integration Failure – ex Endpoint Request Timed-out Exception
API Gateway requests time out after 29 second maximum

API Gateway – Security

- Load SSL certificates and use Route53 to define a CNAME
- Resource Policy (~S3 Bucket Policy):
 - control who can access the API
 - Users from AWS accounts, IP or CIDR blocks, VPC or VPC Endpoints
- IAM Execution Roles for API Gateway at the API level
 - To invoke a Lambda Function, an AWS service...
- CORS (Cross-origin resource sharing):
 - Browser based security
 - Control which domains can call your API

API Gateway – Authentication

- IAM based access (`AWS_IAM`)
 - Good for providing access within your infrastructure
 - Pass IAM credentials in headers through SigV4
- Lambda Authorizer (formerly Custom Authorizer)
 - Use Lambda to verify a custom OAuth / SAML / 3rd party authentication
- Cognito User Pools
 - Client authenticates with Cognito
 - Client passes the token to API Gateway
 - API Gateway knows out-of-the-box how to verify to token



API Gateway – Logging, Monitoring, Tracing

- **CloudWatch Logs:**

- Enable CloudWatch logging at the Stage level (with Log Level – ERROR, INFO)
- Can log full requests / responses data
- Can send API Gateway Access Logs (customizable)
- Can send logs directly into Kinesis Data Firehose (as an alternative to CW logs)

- **CloudWatch Metrics:**

- Metrics are by stage, possibility to enable detailed metrics
- *IntegrationLatency, Latency, CacheHitCount, CacheMissCount*

- **X-Ray:**

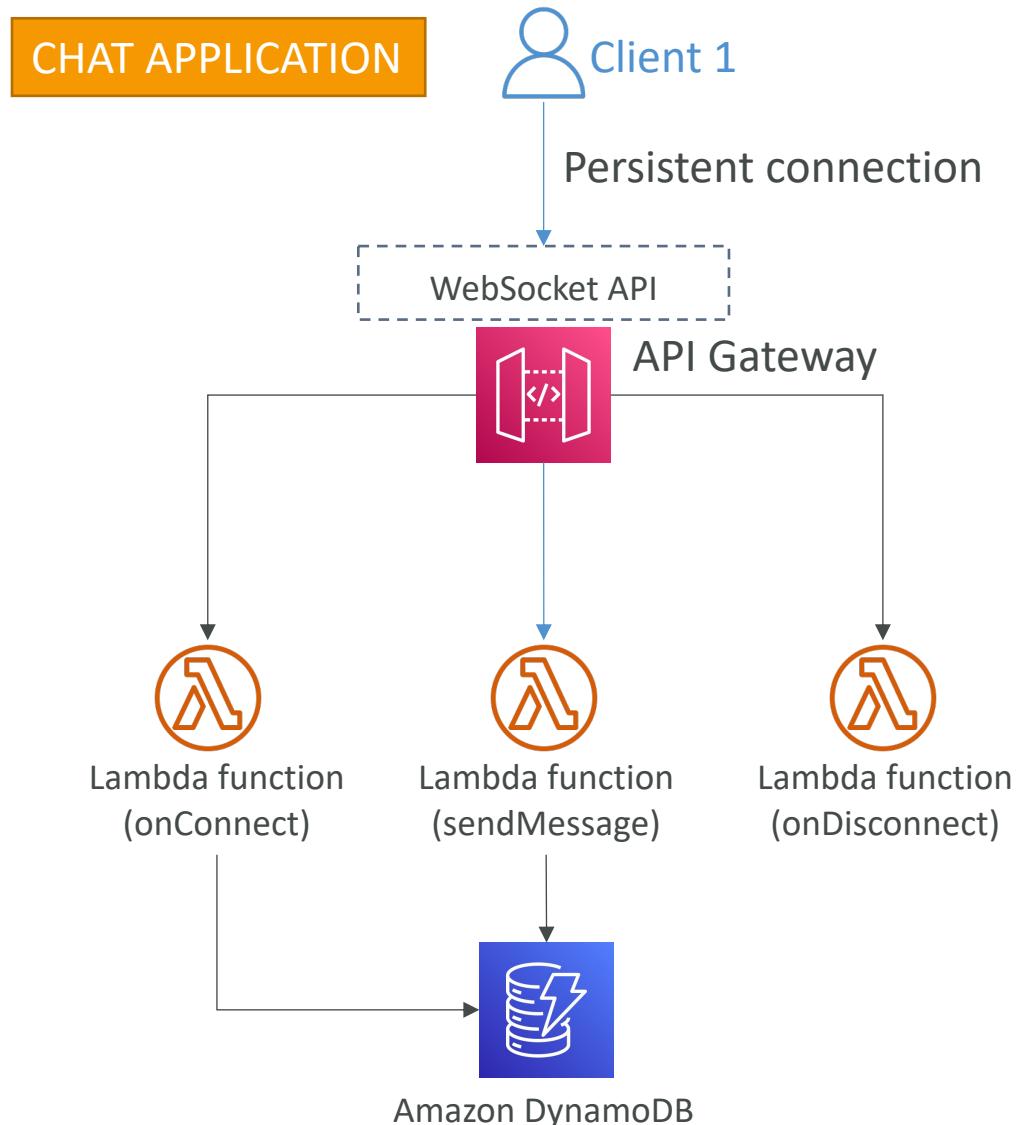
- Enable tracing to get extra information about requests in API Gateway
- X-Ray API Gateway + AWS Lambda gives you the full picture

API Gateway – Usage Plans & API Keys

- If you want to make an API available as an offering (\$) to your customers
- **Usage Plan:**
 - who can access one or more deployed API stages and methods
 - how much and how fast they can access them
 - uses API keys to identify API clients and meter access
 - configure throttling limits and quota limits that are enforced on individual client
- **API Keys:**
 - alphanumeric string values to distribute to your customers
 - Ex: WBjHxNtoAb4WPKBC7cGm64CBiblb24b4jt8jjHo9
 - Can use with usage plans to control access
 - Throttling limits are applied to the API keys
 - Quotas limits is the overall number of maximum requests
- **429 Too Many Requests:**
 - Account level throttling across all APIs in a region
 - Clients must implement retry mechanisms

API Gateway – WebSocket API – Overview

- What's WebSocket?
 - Two-way interactive communication between a user's browser and a server
 - Server can push information to the client
 - This enables **stateful** application use cases
- WebSocket APIs are often used in **real-time applications** such as chat applications, collaboration platforms, multiplayer games, and financial trading platforms.
- Works with AWS Services (Lambda, DynamoDB) or HTTP endpoints

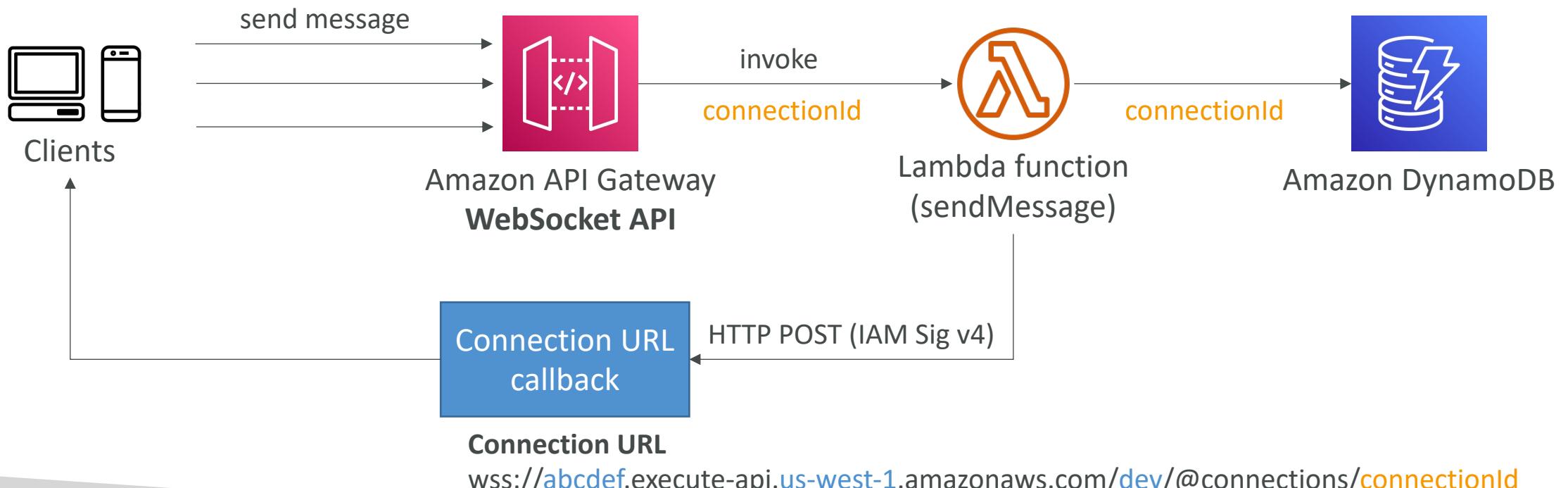


Server to Client Messaging

@connections used for replies to clients

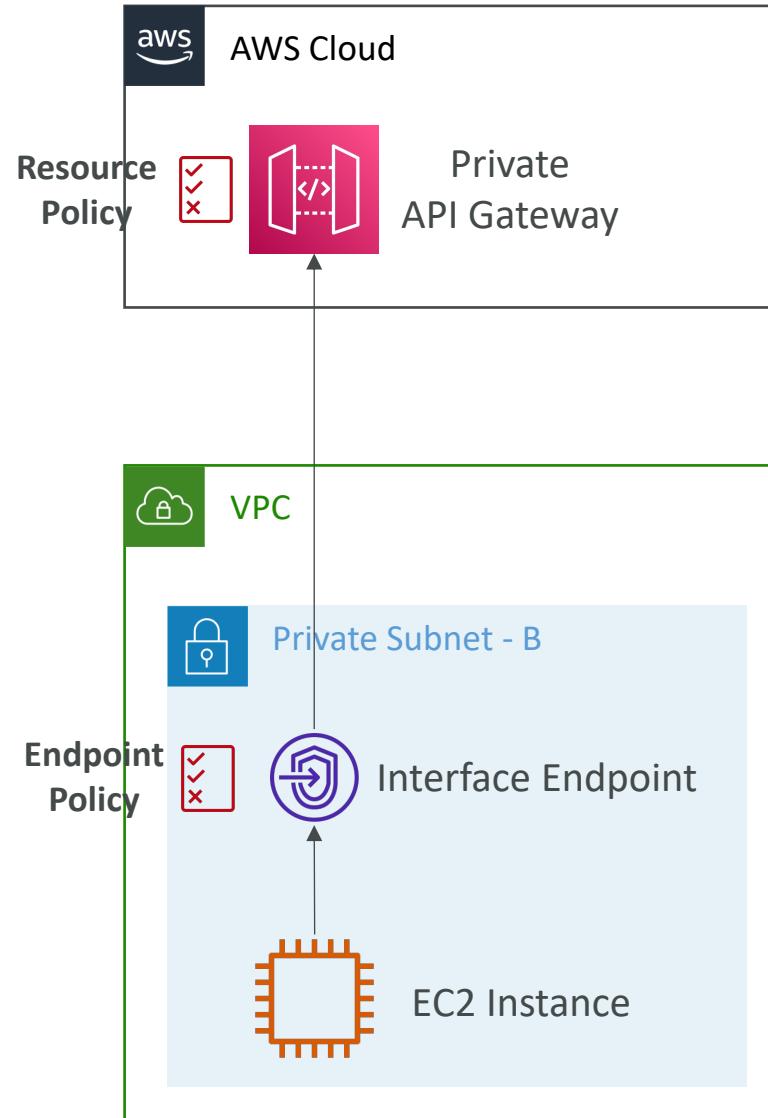
WebSocket URL

wss://abcdef.execute-api.us-west-1.amazonaws.com/dev



API Gateway – Private APIs

- Can only be accessed from your VPC by using an VPC Interface Endpoint
- Each VPC Interface Endpoint can be used to access multiple Private APIs
- **API Gateway Resource Policy**
 - Allow or deny access to API from selected VPCs and VPC Endpoints, including across AWS accounts
 - `aws:SourceVpc` and `aws:SourceVpce`

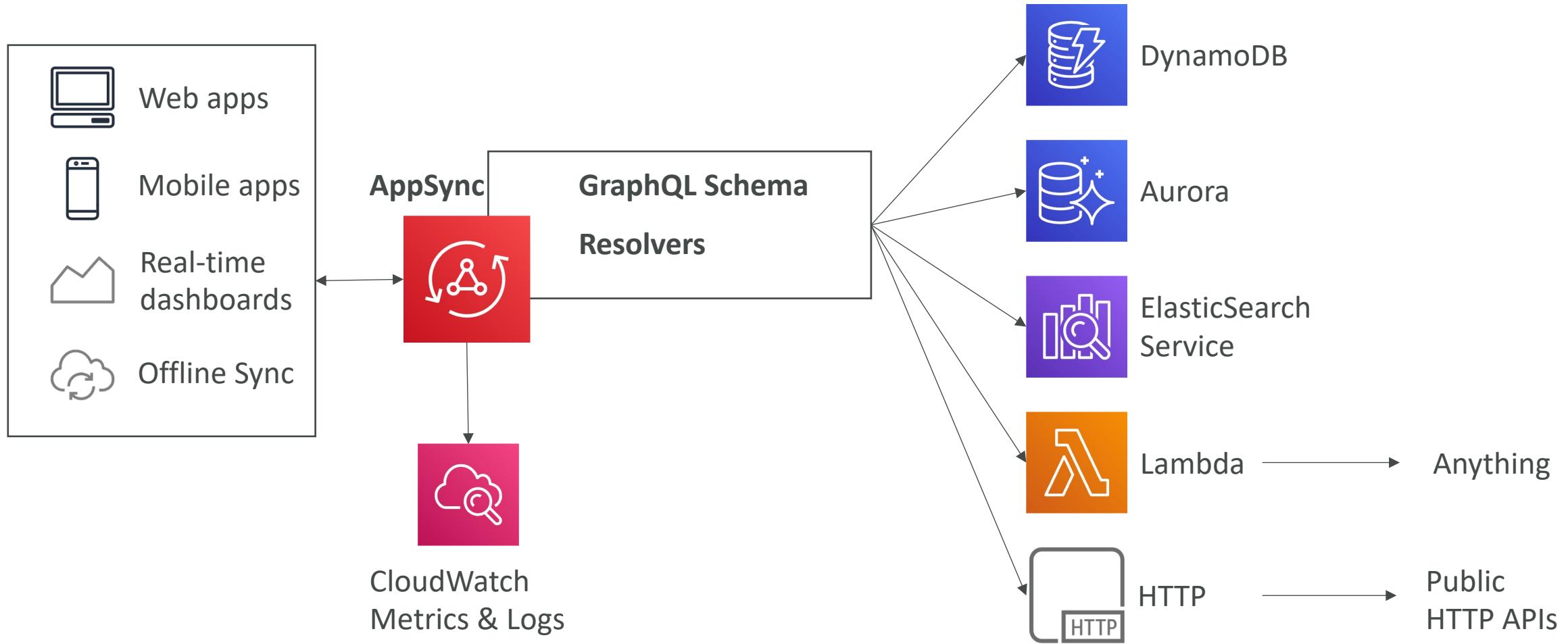


AWS AppSync - Overview



- AppSync is a managed service that uses **GraphQL**
- **GraphQL** makes it easy for applications to get exactly the data they need.
- This includes combining data from **one or more sources**
 - NoSQL data stores, Relational databases, HTTP APIs...
 - Integrates with DynamoDB, Aurora, Elasticsearch & others
 - Custom sources with AWS Lambda
- Retrieve data in **real-time** with WebSocket or MQTT on WebSocket
- For mobile apps: local data access & data synchronization
- It all starts with uploading one **GraphQL schema**

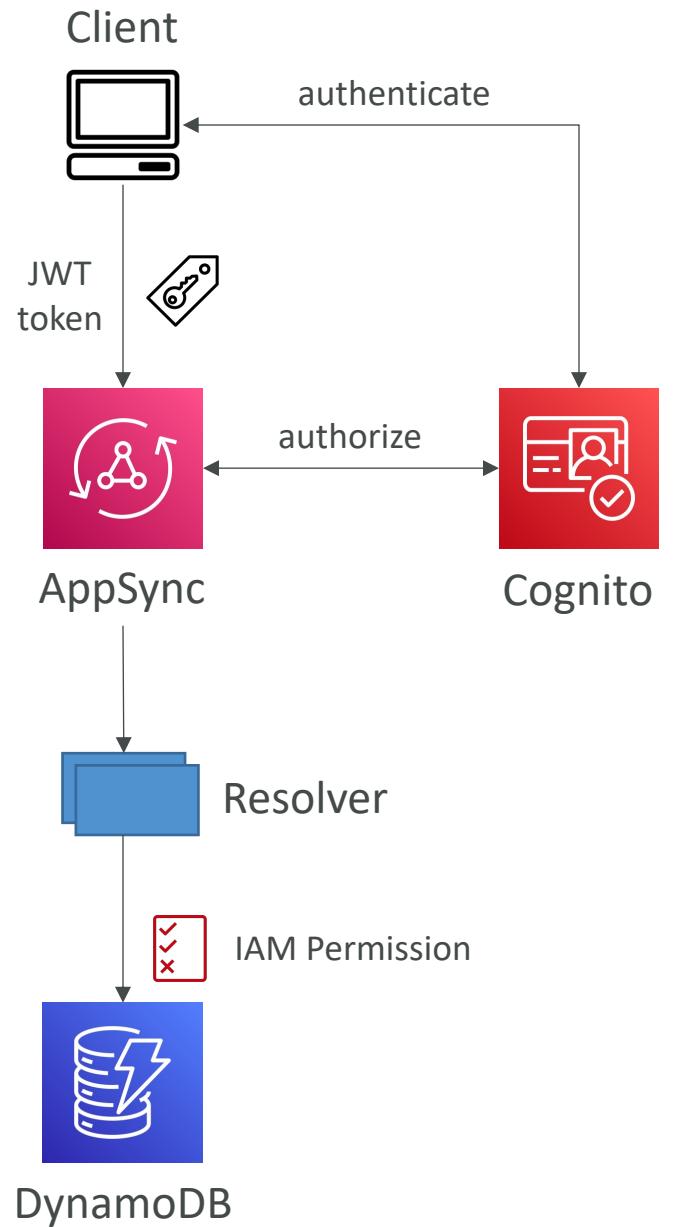
AppSync Diagram



AppSync – Cognito Integration

- Perform authorization on Cognito users based on the groups they belong to
- In the GraphQL schema, you can specify the security for Cognito groups

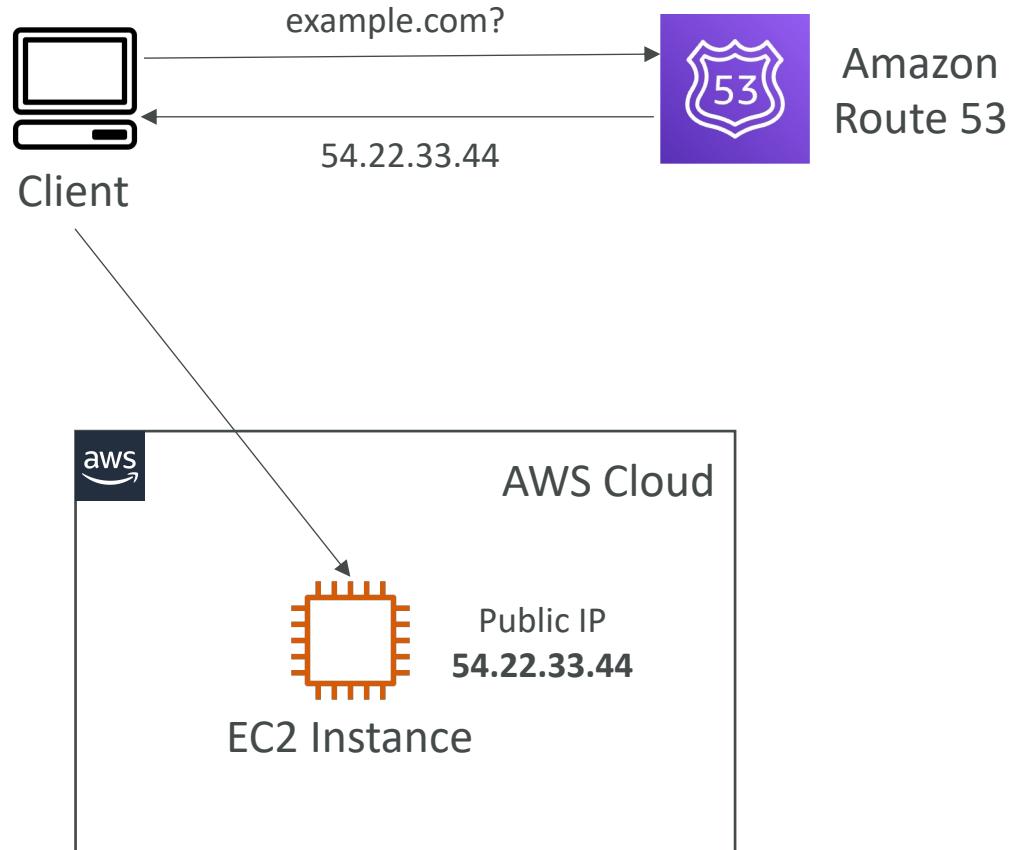
```
type Query {  
    posts: [Post!]!  
    @aws_auth(cognito_groups: ["Bloggers", "Readers"])  
}  
  
Type Mutation {  
    addPost(id: ID!, title: String!): Post!  
    @aws_auth(cognito_groups: ["Bloggers"])  
}
```



Route 53 – Record Types

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

Route 53 – Diagram for A record



Route 53 – CNAME vs. Alias

- AWS Resources (Load Balancer, CloudFront...) expose an AWS hostname:
 - lb-1234.us-east-2.elb.amazonaws.com and you want myapp.mydomain.com
- CNAME:
 - Points a hostname to any other hostname. (app.mydomain.com => blabla.anything.com)
 - ONLY FOR NON ROOT DOMAIN (aka. something.mydomain.com)
- Alias:
 - Points a hostname to an AWS Resource (app.mydomain.com => blabla.amazonaws.com)
 - Works for ROOT DOMAIN and NON ROOT DOMAIN (aka mydomain.com)
 - Free of charge
 - Native health check

Route 53 – Alias Records Targets

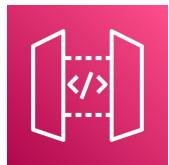
- Elastic Load Balancers
- CloudFront Distributions
- API Gateway
- Elastic Beanstalk environments
- S3 Websites
- VPC Interface Endpoints
- Global Accelerator accelerator
- Route 53 record in the same hosted zone
- You cannot set an ALIAS record for an EC2 DNS name



Elastic
Load Balancer



Amazon
CloudFront



Amazon
API Gateway



Elastic Beanstalk



S3 Websites



VPC Interface
Endpoints



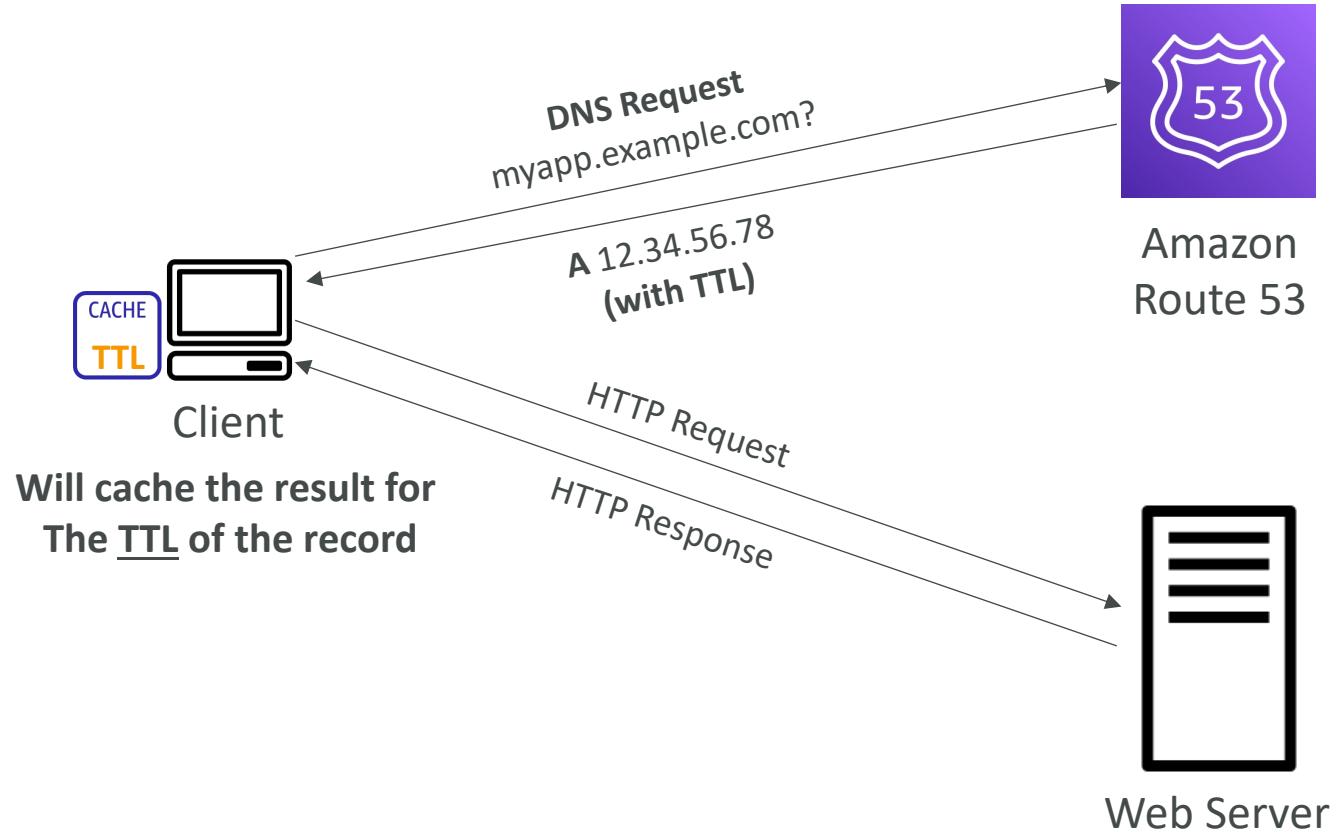
Global Accelerator



Route 53 Record
(same Hosted Zone)

Route 53 – Records TTL (Time To Live)

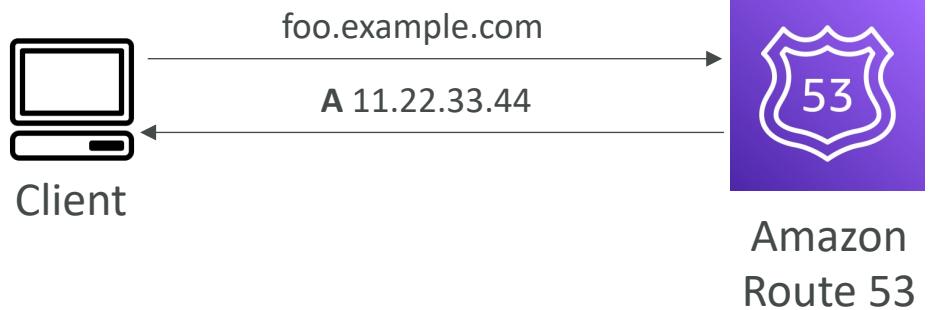
- High TTL – e.g., 24 hr
 - Less traffic on Route 53
 - Possibly outdated records
- Low TTL – e.g., 60 sec.
 - More traffic on Route 53 (\$\$)
 - Records are outdated for less time
 - Easy to change records
- Except for Alias records, TTL is mandatory for each DNS record



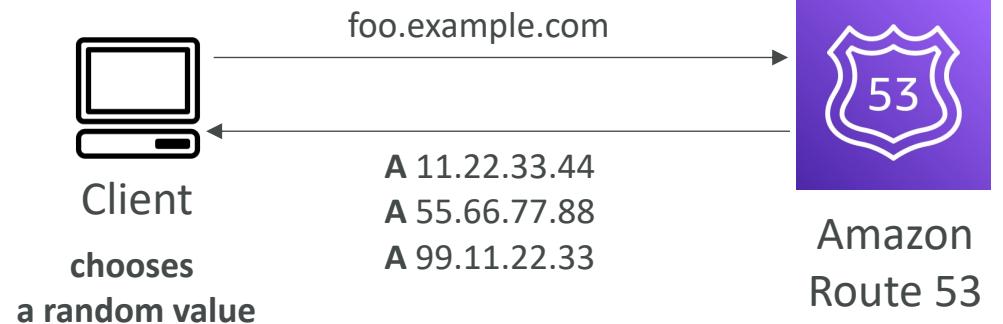
Routing Policies – Simple

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

Single Value

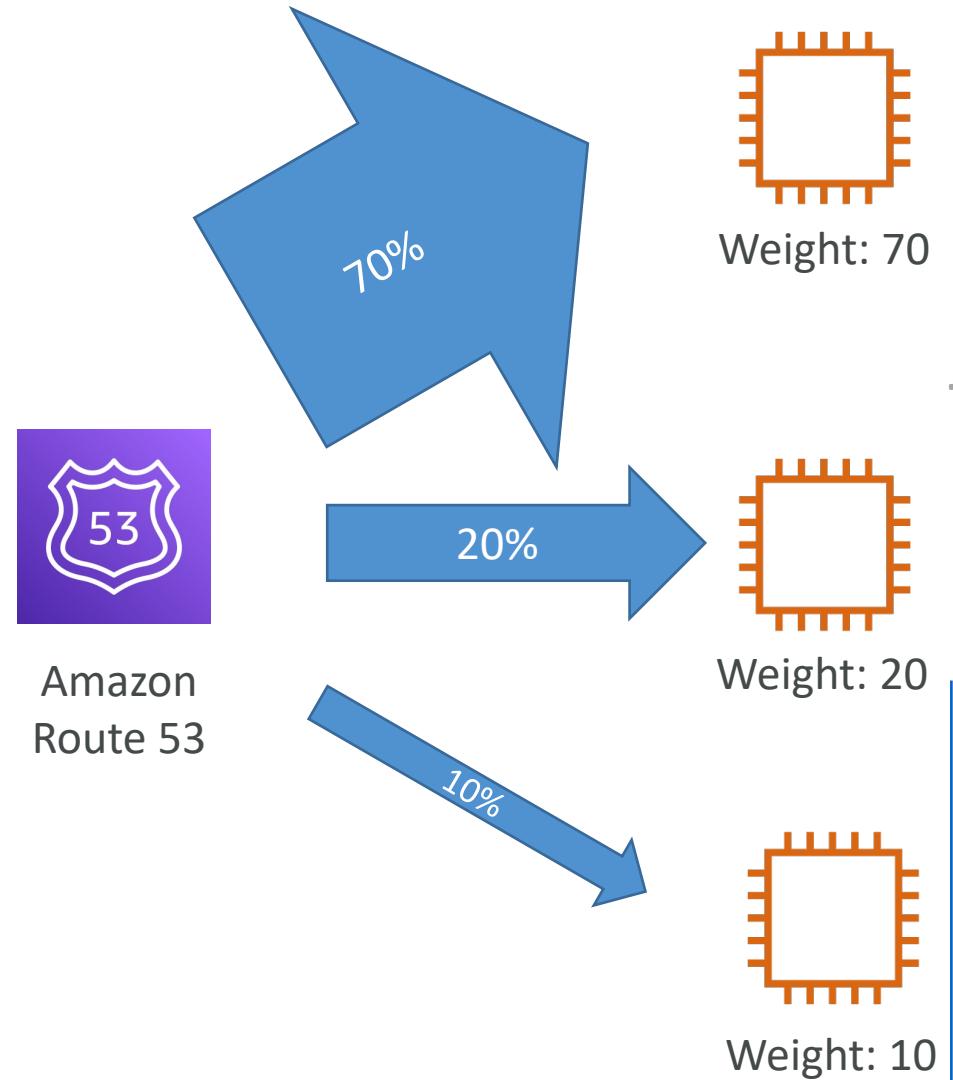


Multiple Value



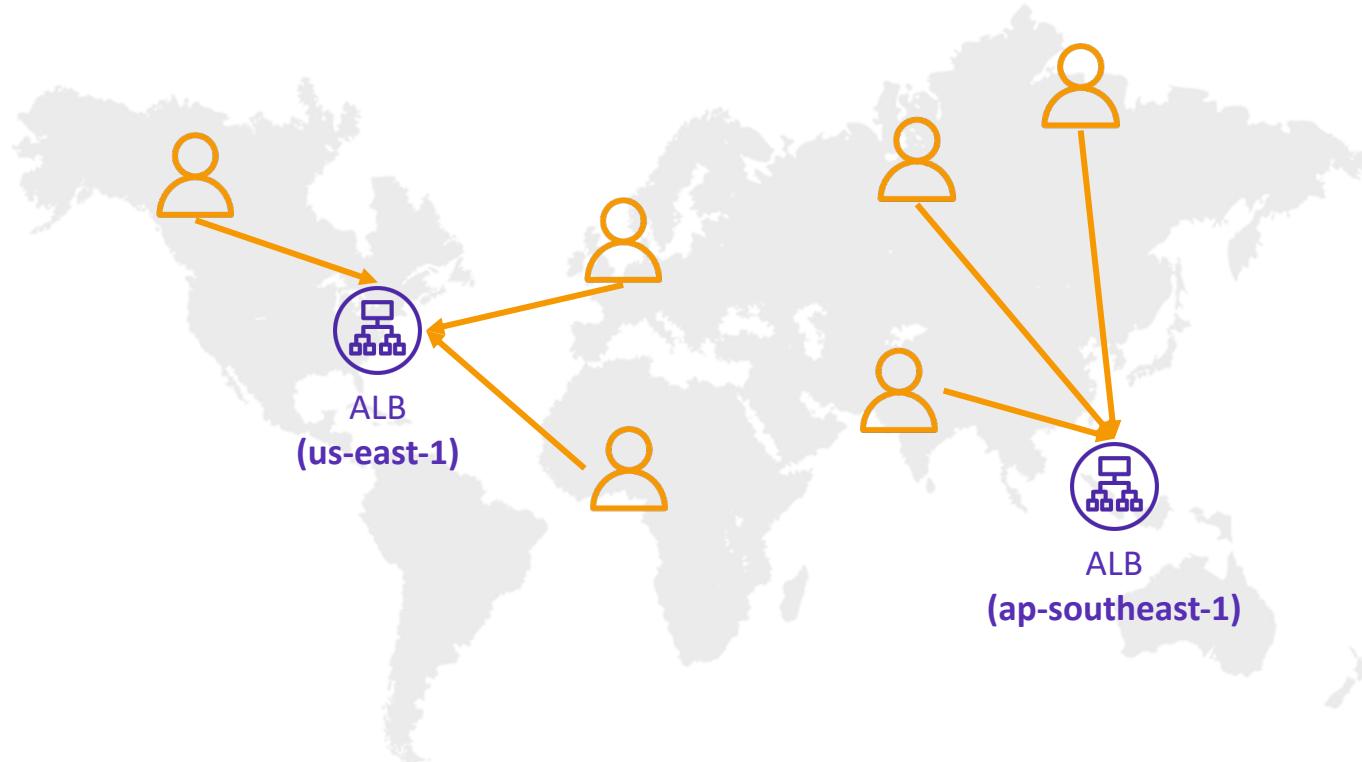
Routing Policies – Weighted

- Control the % of the requests that go to each specific resource
- Can be associated with Health Checks
- Use cases: load balancing between regions, testing new application versions...

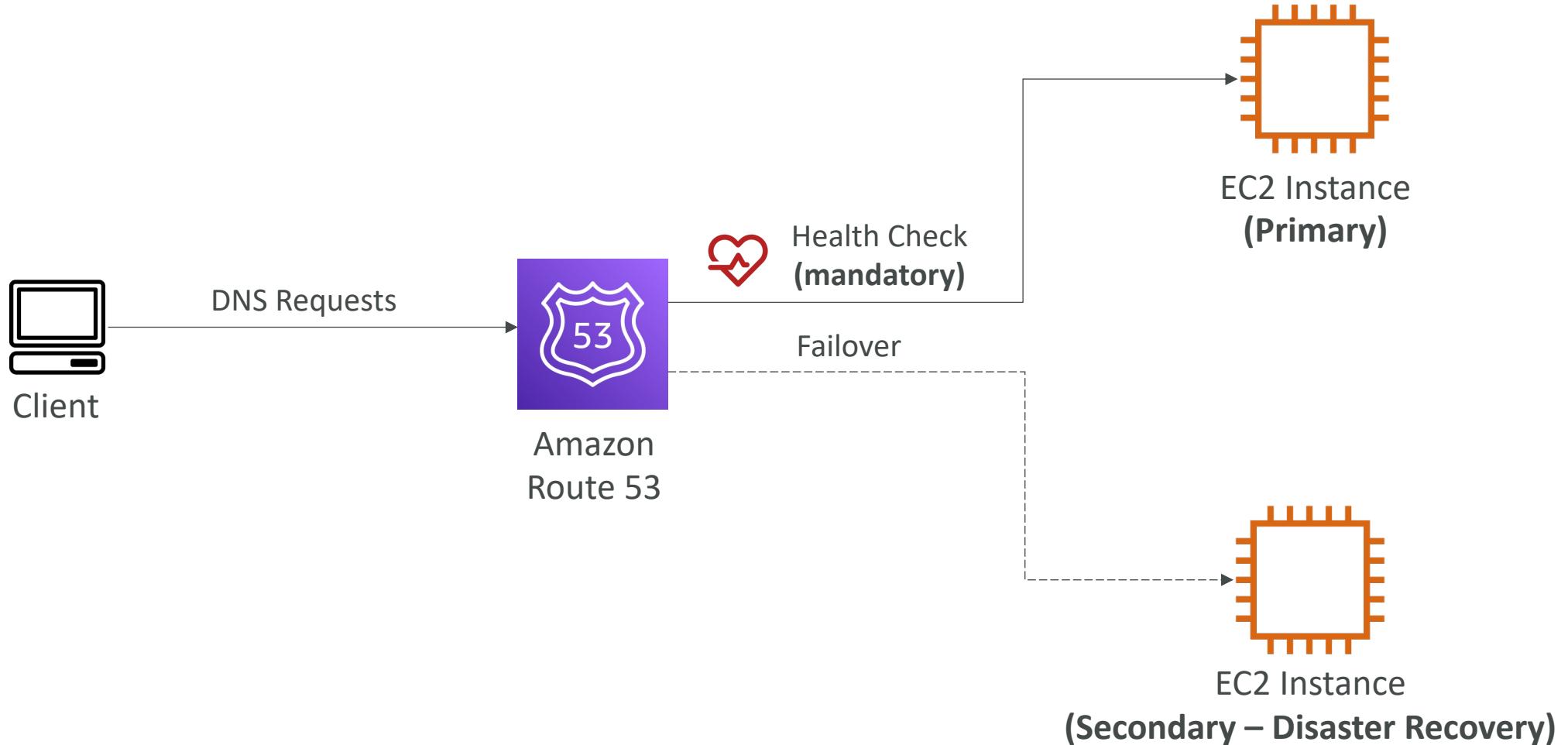


Routing Policies – Latency-based

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

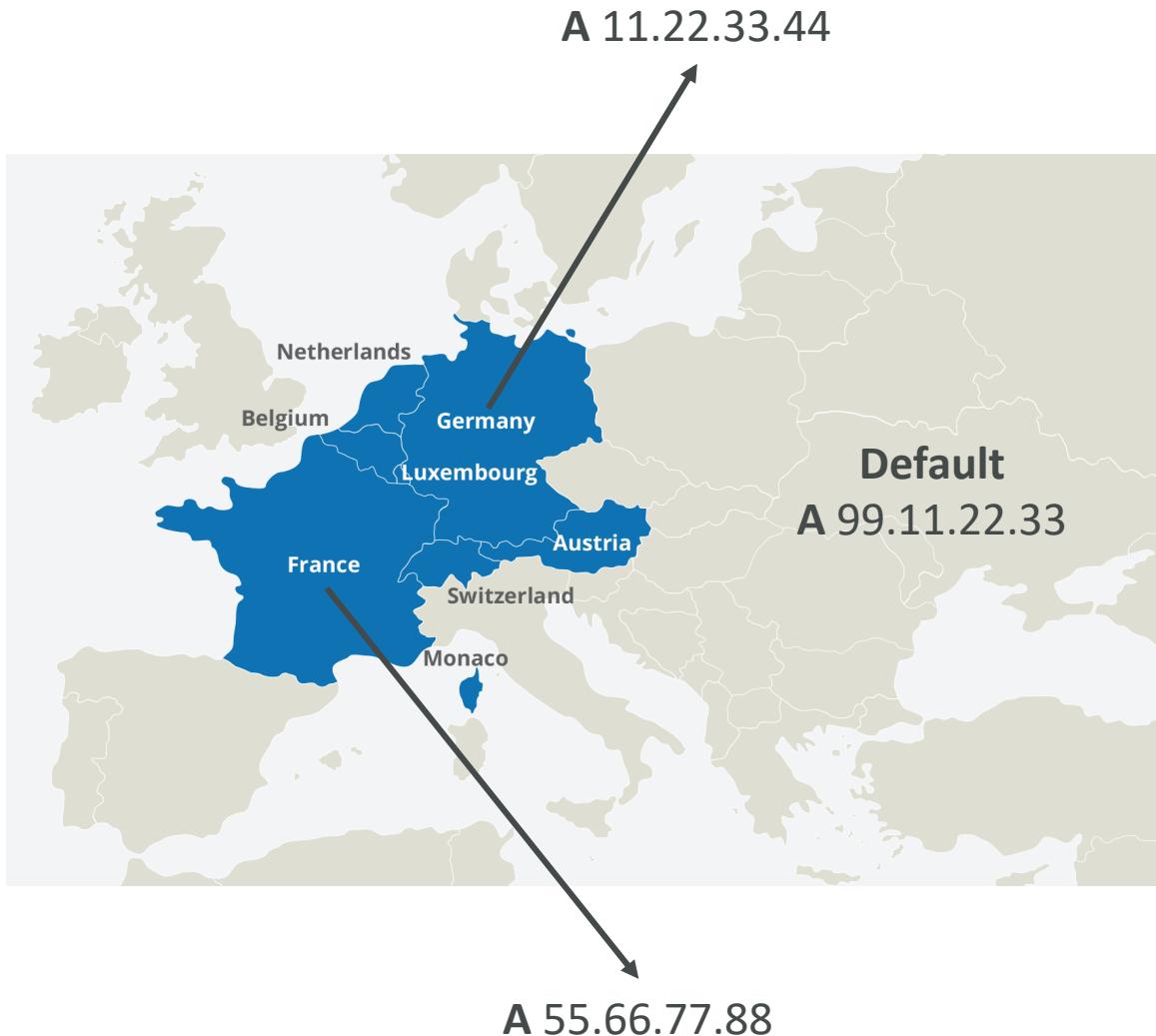


Routing Policies – Failover (Active-Passive)



Routing Policies – Geolocation

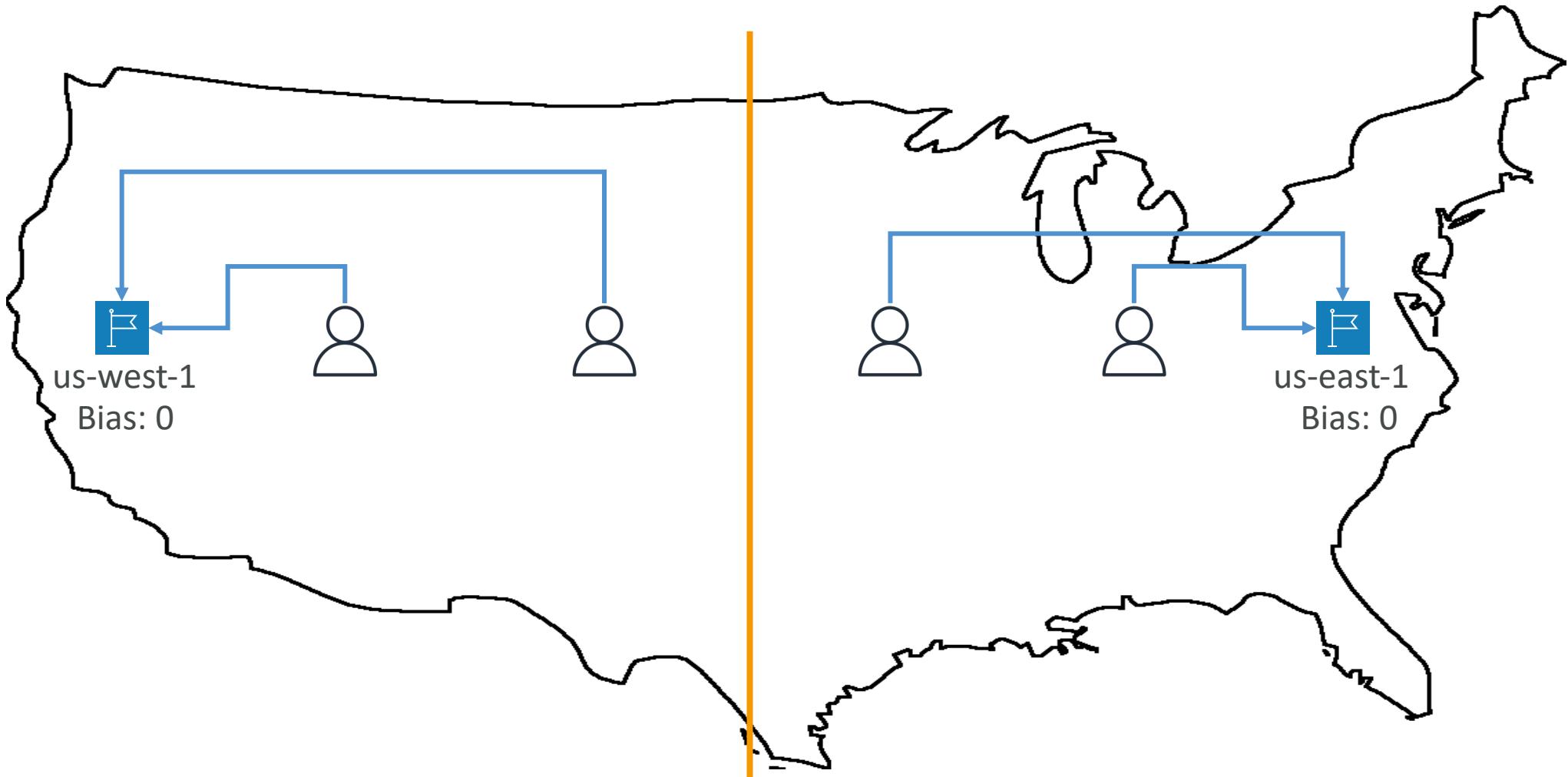
- Different from Latency-based!
- This routing is based on user location
- Specify location by Continent, Country or by US State (if there's overlapping, most precise location selected)
- Should create a “Default” record (in case there's no match on location)
- Use cases: website localization, restrict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



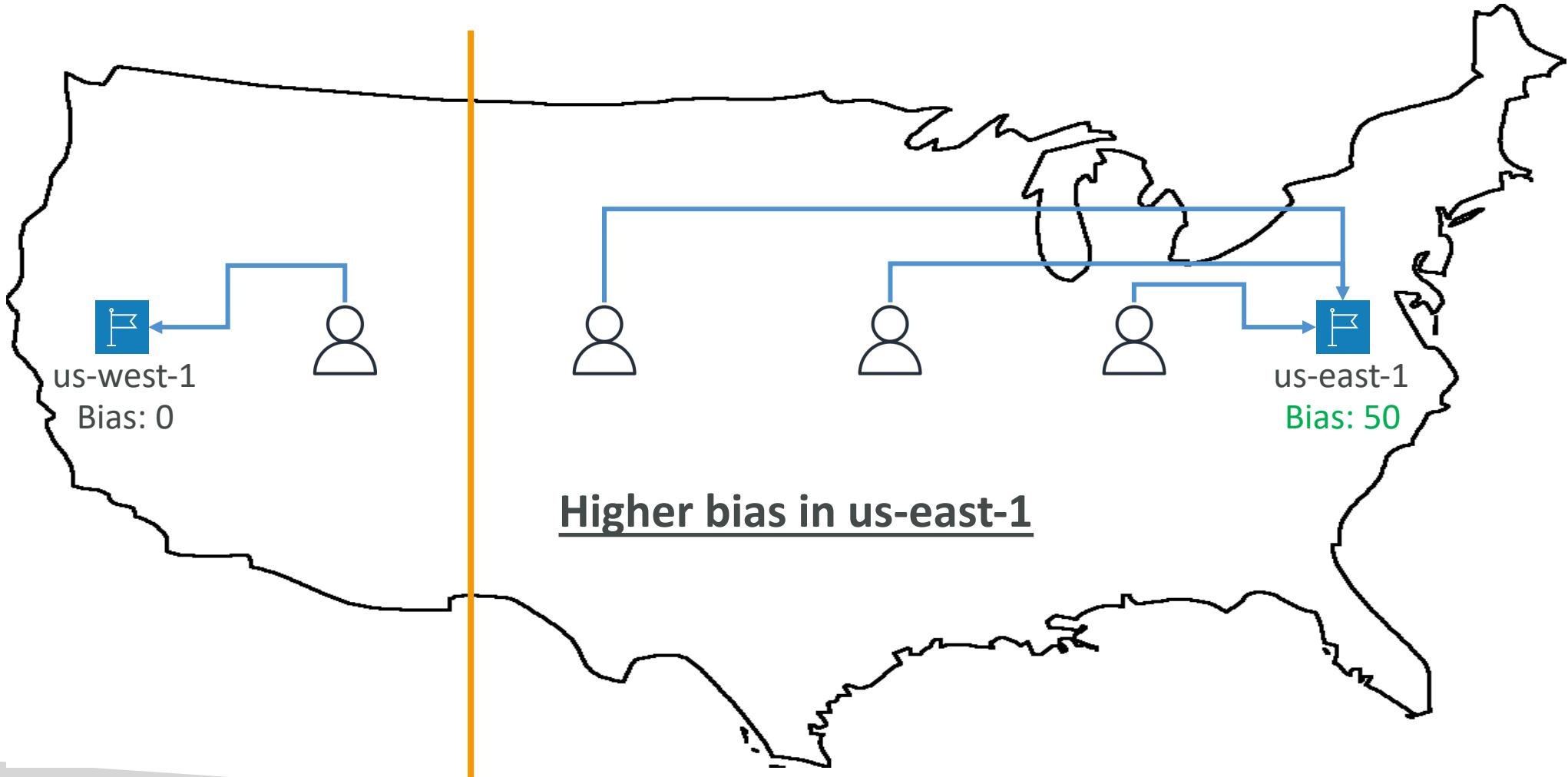
Routing Policies – Geoproximity

- Route traffic to your resources based on the geographic location of users and resources
- Ability **to shift more traffic to resources based on the defined bias**
- To change the size of the geographic region, specify **bias** values:
 - To expand (1 to 99) – more traffic to the resource
 - To shrink (-1 to -99) – less traffic to the resource
- Resources can be:
 - AWS resources (specify AWS region)
 - Non-AWS resources (specify Latitude and Longitude)
- You must use Route 53 Traffic Flow to use this feature

Routing Policies – Geoproximity

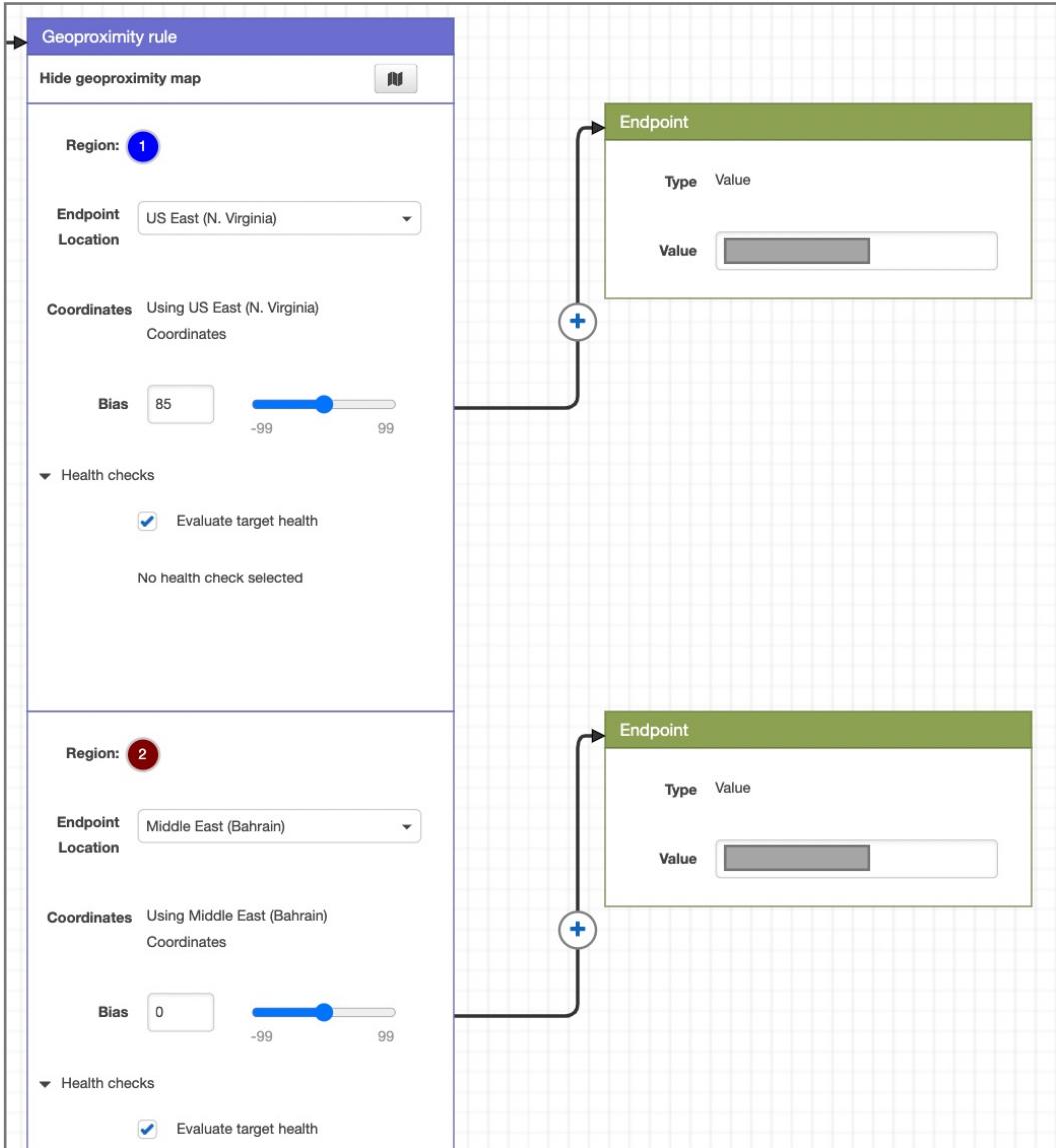


Routing Policies – Geoproximity



Route 53 – Traffic flow

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



Routing Policies – Multi-Value

- Use when routing traffic to multiple resources
- Route 53 return multiple values/resources
- Can be associated with Health Checks (return only values for healthy resources)
- Up to 8 healthy records are returned for each Multi-Value query
- Multi-Value is not a substitute for having an ELB

Name	Type	Value	TTL	Set ID	Health Check
www.example.com	A Record	192.0.2.2	60	Web1	A
www.example.com	A Record	198.51.100.2	60	Web2	B
www.example.com	A Record	203.0.113.2	60	Web3	C

Routing Policies – IP-based Routing

- Routing is based on clients' IP addresses
- You provide a list of CIDRs for your clients and the corresponding endpoints/locations (user-IP-to-endpoint mappings)
- Use cases: Optimize performance, reduce network costs...
- Example: route end users from a particular ISP to a specific endpoint



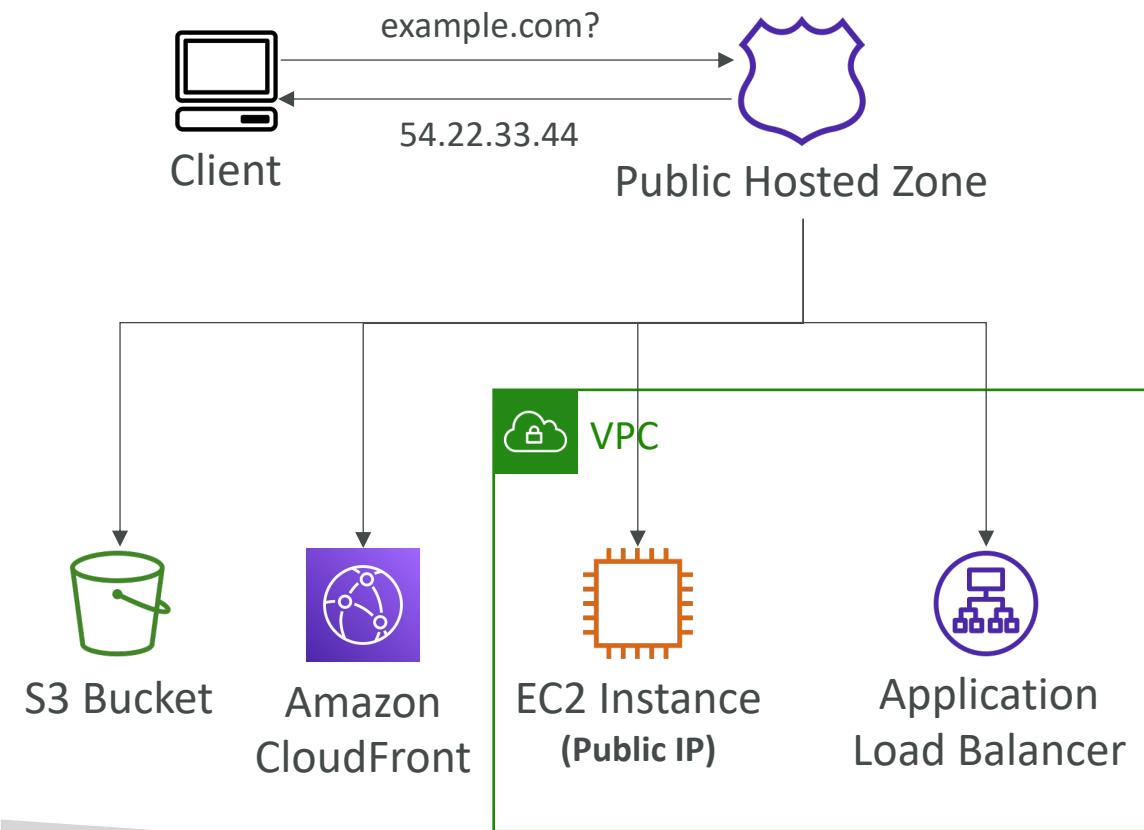


Route 53 – Hosted Zones

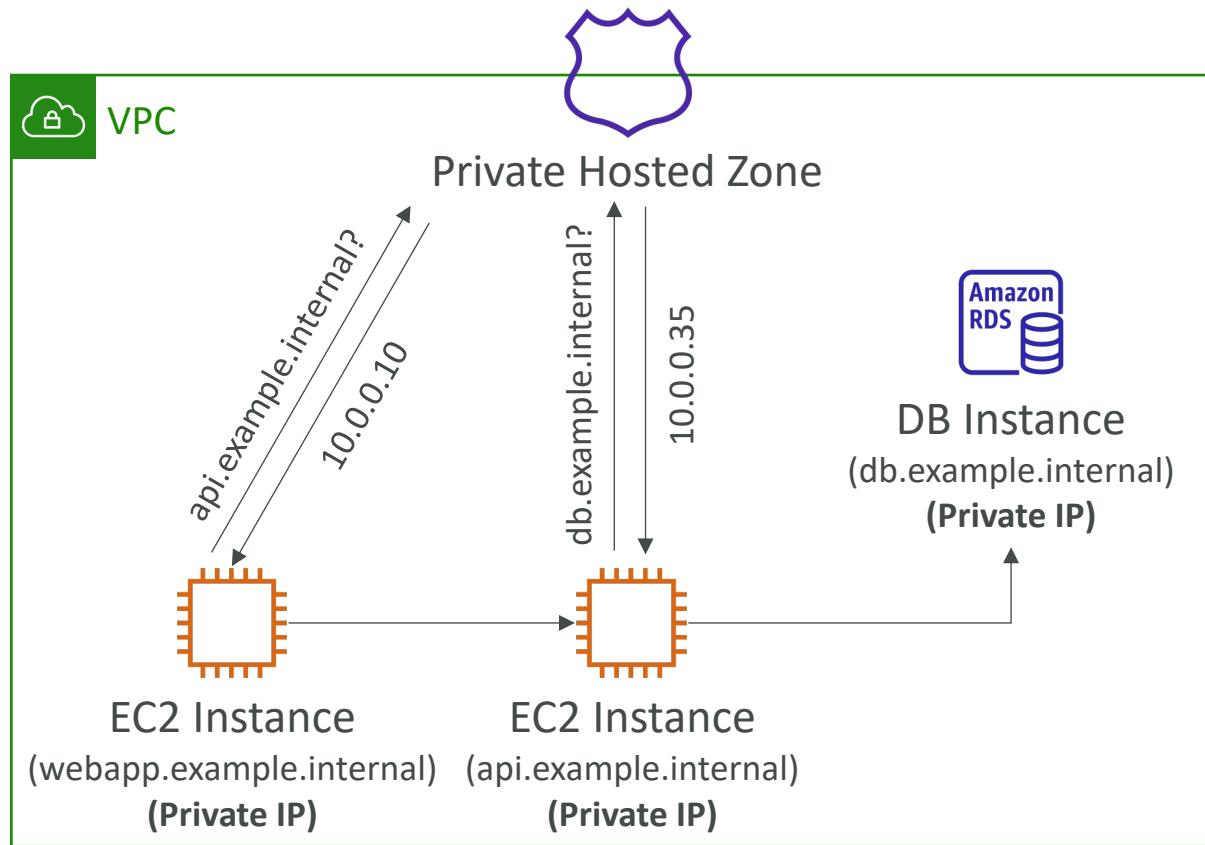
- A container for records that define how to route traffic to a domain and its subdomains
- **Public Hosted Zones** – contains records that specify how to route traffic on the Internet (public domain names)
application1.mypublicdomain.com
- **Private Hosted Zones** – contain records that specify how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

Route 53 – Public vs. Private Hosted Zones

Public Hosted Zone



Private Hosted Zone

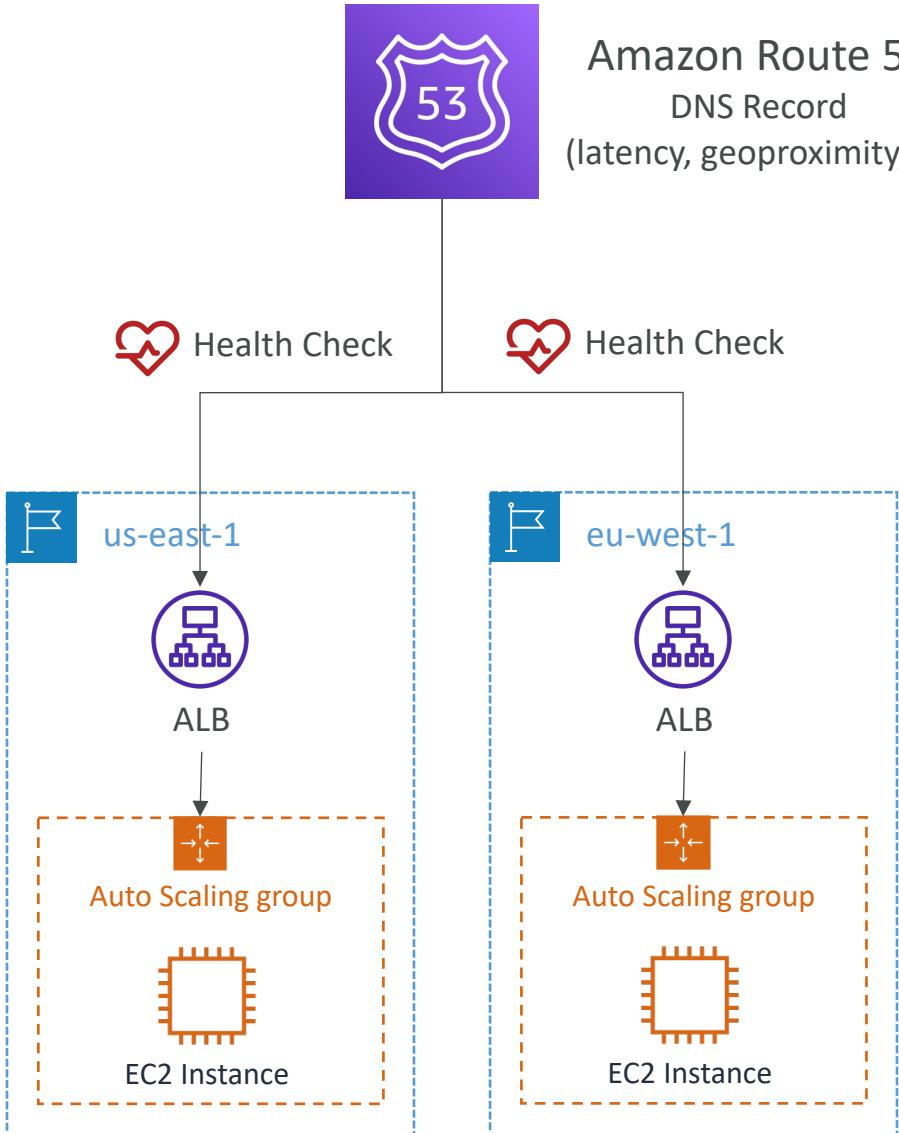


Route 53 – Good to Know

- For internal private DNS (Private Hosted Zone), you must enable the VPC settings `enableDnsHostnames` and `enableDnsSupport`
- **DNS Security Extensions (DNSSEC)**
 - A protocol for securing DNS traffic, verifies DNS data integrity and origin
 - Protects against Man in the Middle (MITM) attacks
 - Route 53 supports both DNSSEC for Domain Registration and DNSSEC Signing
 - Works only with **Public Hosted Zones**
- **Route 53 with 3rd Registrar**
 - You can buy the domain out of AWS and use Route 53 as the DNS provider
 - Update the NS records on the 3rd party Registrar

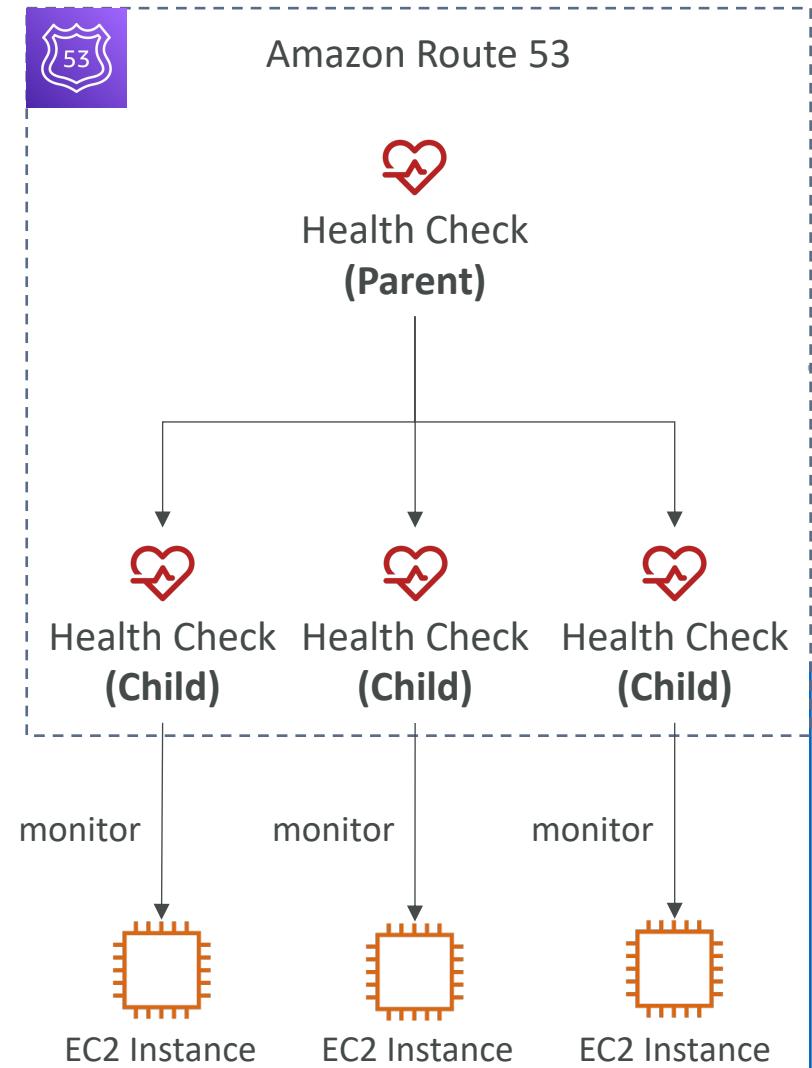
Route 53 – Health Checks

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



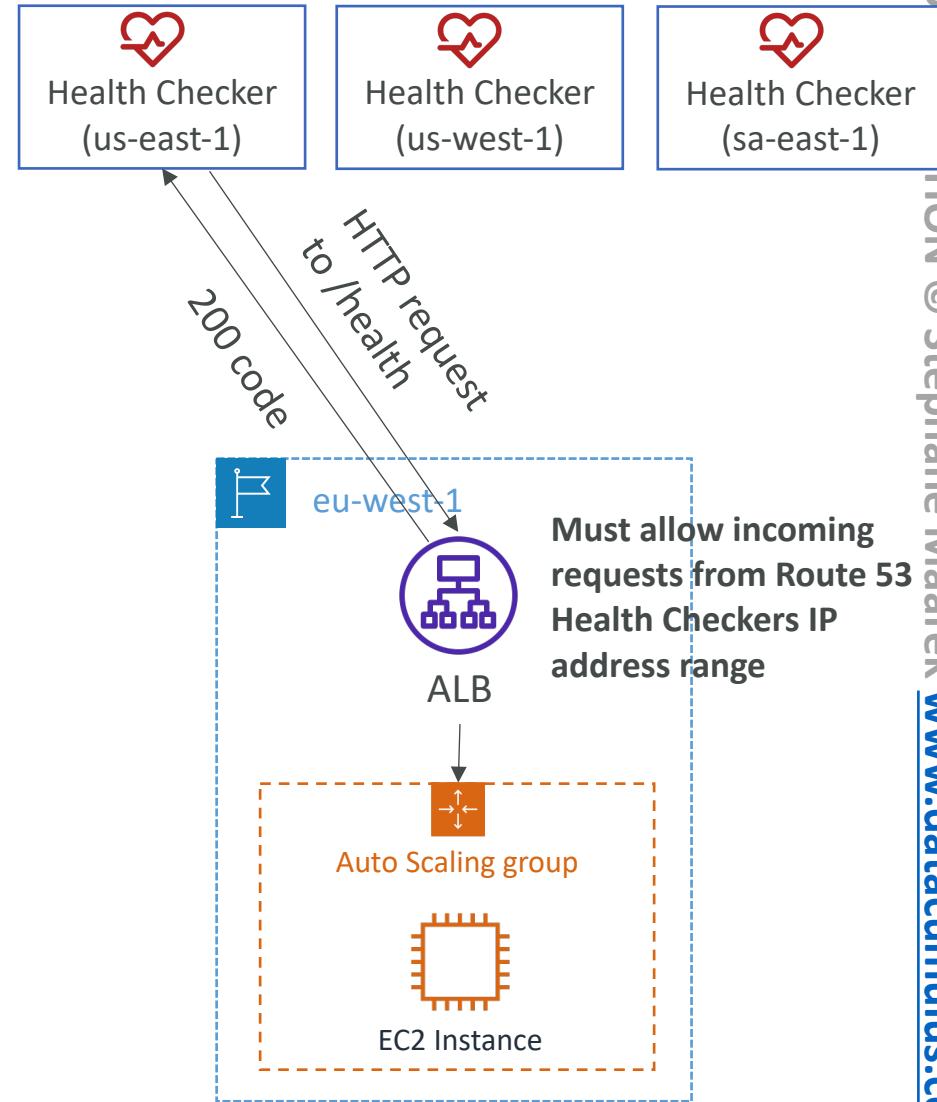
Route 53 – Calculated Health Checks

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



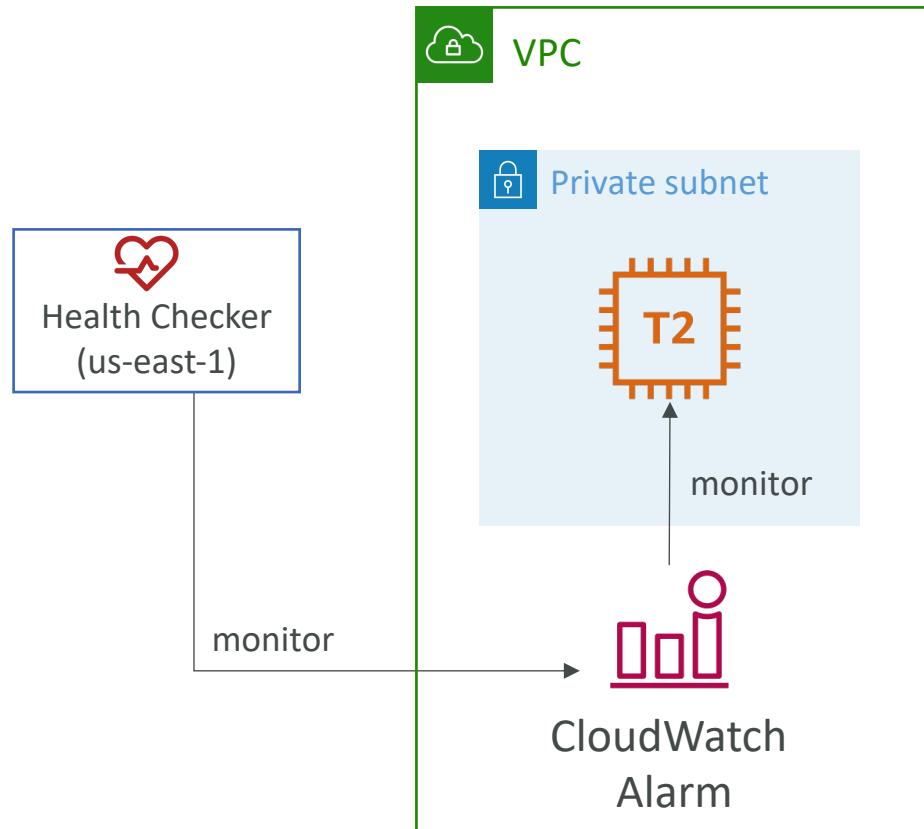
Health Checks – Monitor an Endpoint

- About 15 global health checkers will check the endpoint health
- Health Checks pass only when the endpoint responds with the 2xx and 3xx status codes
- Health Checks can be setup to pass / fail based on the text in the first 5120 bytes of the response



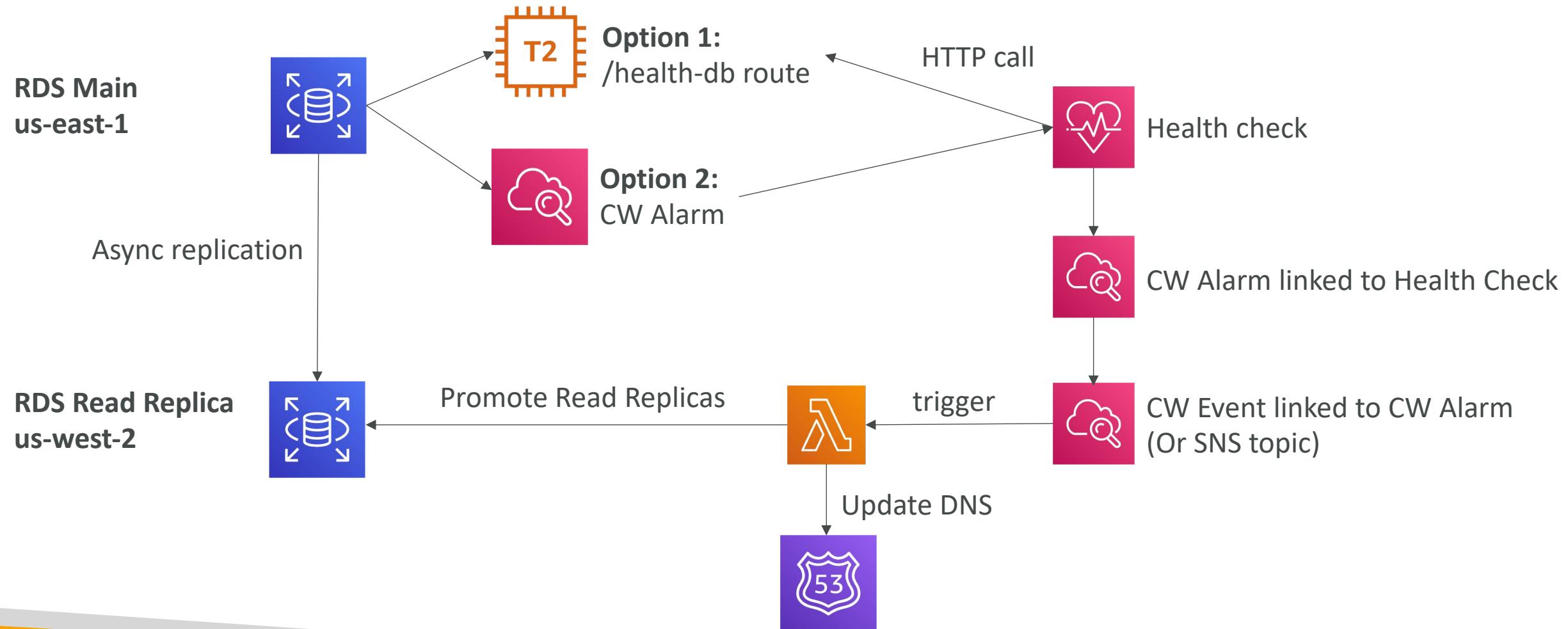
Health Checks – Private Hosted Zones

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



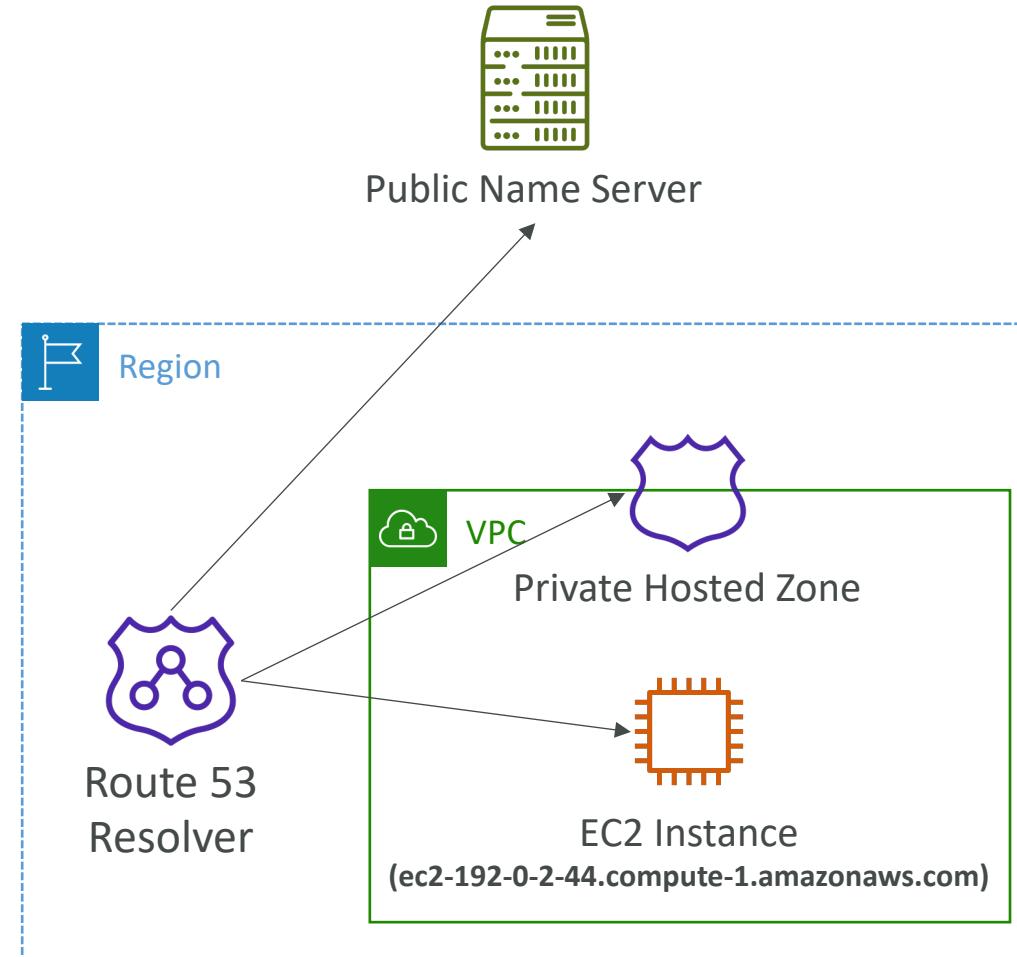
Health Checks Solution Architecture

RDS multi-region failover



Route 53 – Hybrid DNS

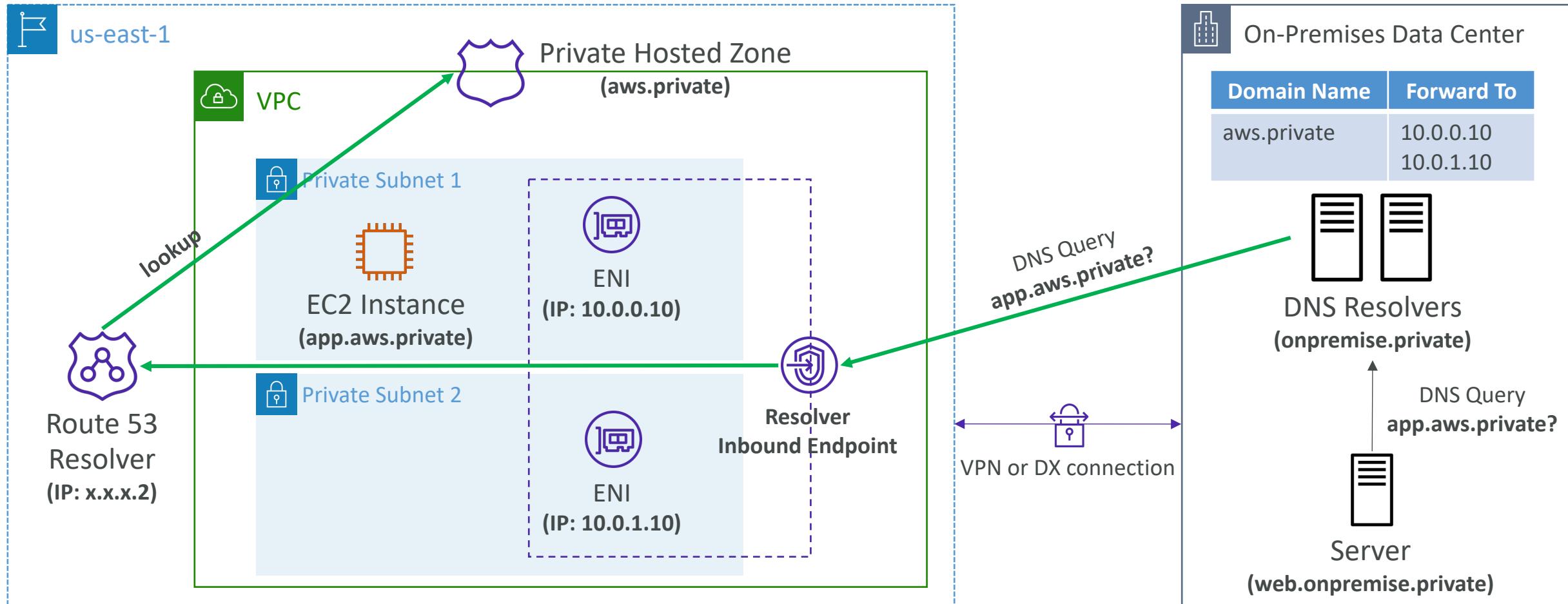
- By default, Route 53 Resolver automatically answers DNS queries for:
 - Local domain names for EC2 instances
 - Records in Private Hosted Zones
 - Records in public Name Servers
- **Hybrid DNS** – resolving DNS queries between VPC (Route 53 Resolver) and your networks (other DNS Resolvers)
- Networks can be:
 - VPC itself / Peered VPC
 - On-premises Network (connected through Direct Connect or AWS VPN)



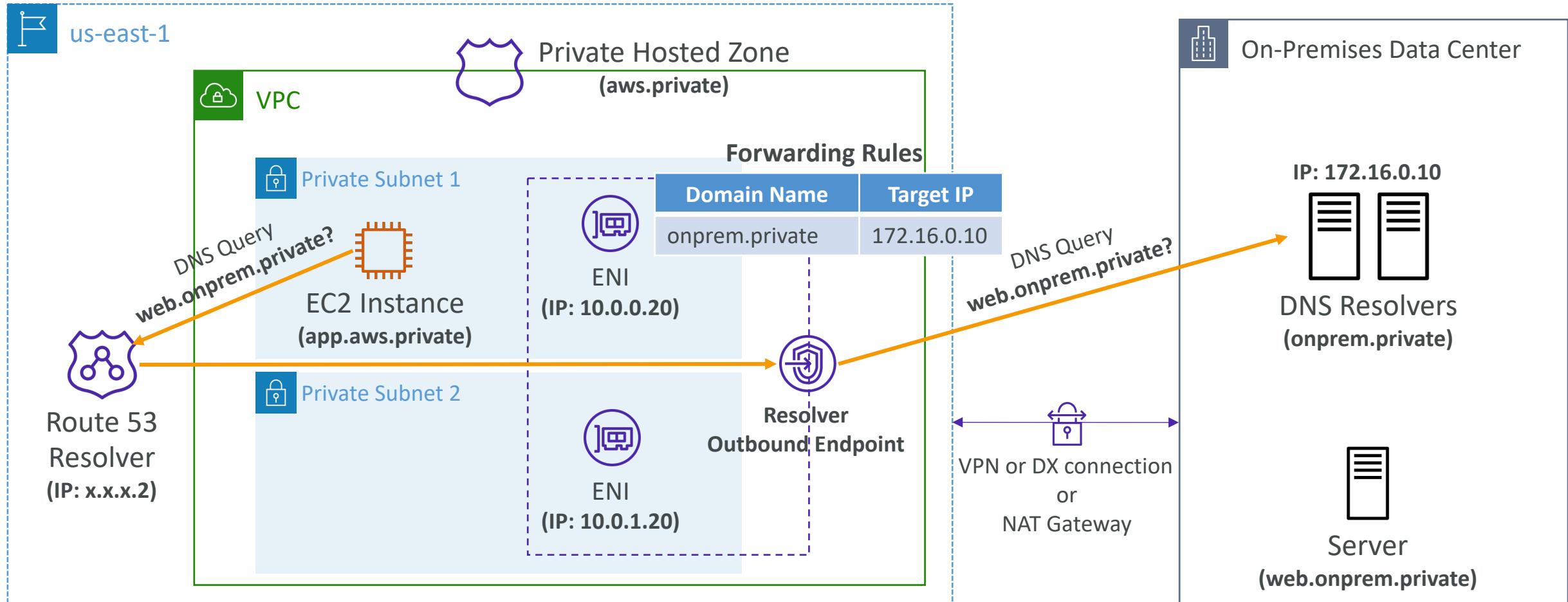
Route 53 – Resolver Endpoints

- **Inbound Endpoint**
 - DNS Resolvers on your network can forward DNS queries to Route 53 Resolver
 - Allows your DNS Resolvers to resolve domain names for AWS resources (e.g., EC2 instances) and records in Route 53 Private Hosted Zones
- **Outbound Endpoint**
 - Route 53 Resolver conditionally forwards DNS queries to your DNS Resolvers
 - Use **Resolver Rules** to forward DNS queries to your DNS Resolvers
- Associated with one or more VPCs in the same AWS Region
- Create in two AZs for high availability
- Each Endpoint supports 10,000 queries per second per IP address

Route 53 – Resolver Inbound Endpoints

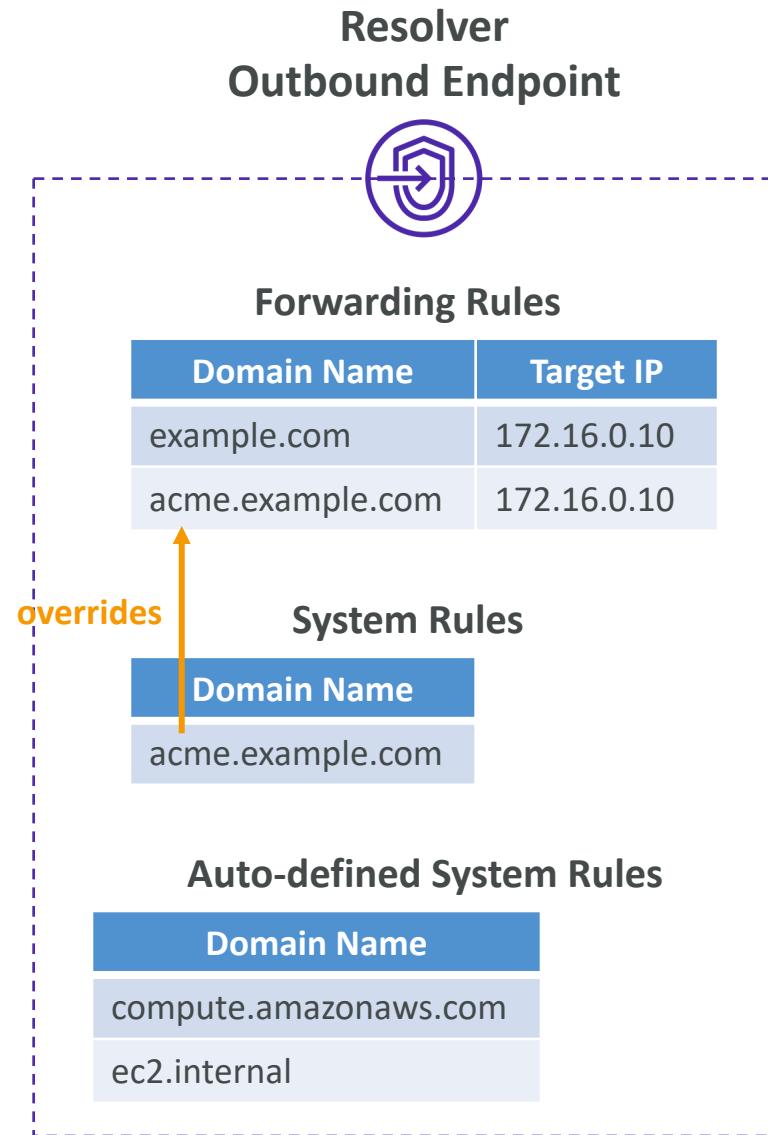


Route 53 – Resolver Outbound Endpoints



Route 53 – Resolver Rules

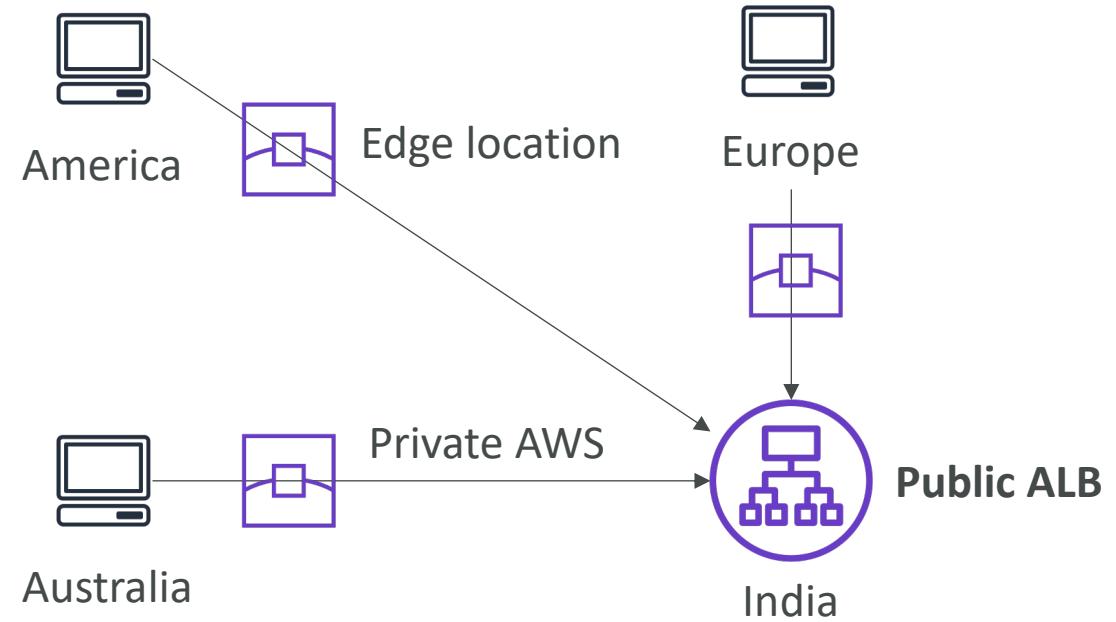
- Control which DNS queries are forwarded to DNS Resolvers on your network
- **Conditional Forwarding Rules (Forwarding Rules)**
 - Forward DNS queries for a specified domain and all its subdomains **to target IP addresses**
- **System Rules**
 - Selectively overriding the behavior defined in Forwarding Rules (e.g., don't forward DNS queries for a subdomain acme.example.com)
- **Auto-defined System Rules**
 - Defines how DNS queries for selected domains are resolved (e.g., AWS internal domain names, Private Hosted Zones)
- If multiple rules matched, Route 53 Resolver chooses the most specific match
- **Resolver Rules can be shared across accounts using AWS RAM**
 - Manage them centrally in one account
 - Send DNS queries from multiple VPC to the target IP defined in the rule



AWS Global Accelerator



- Leverage the AWS internal network to route to your application
- 2 Anycast IP are created for your application
- The Anycast IP send traffic directly to Edge Locations
- The Edge locations send the traffic to your application



AWS Global Accelerator

- Works with Elastic IP, EC2 instances, ALB, NLB, public or private
- Supports Client IP Address Preservation **except for NLBs and EIPs endpoints**
- Consistent Performance
 - Intelligent routing to lowest latency and fast regional failover
 - No issue with client cache (because the IP doesn't change)
 - 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)
 - Great for disaster recovery (thanks to the health checks)
- Security
 - only 2 external IP need to be whitelisted
 - DDoS protection thanks to AWS Shield

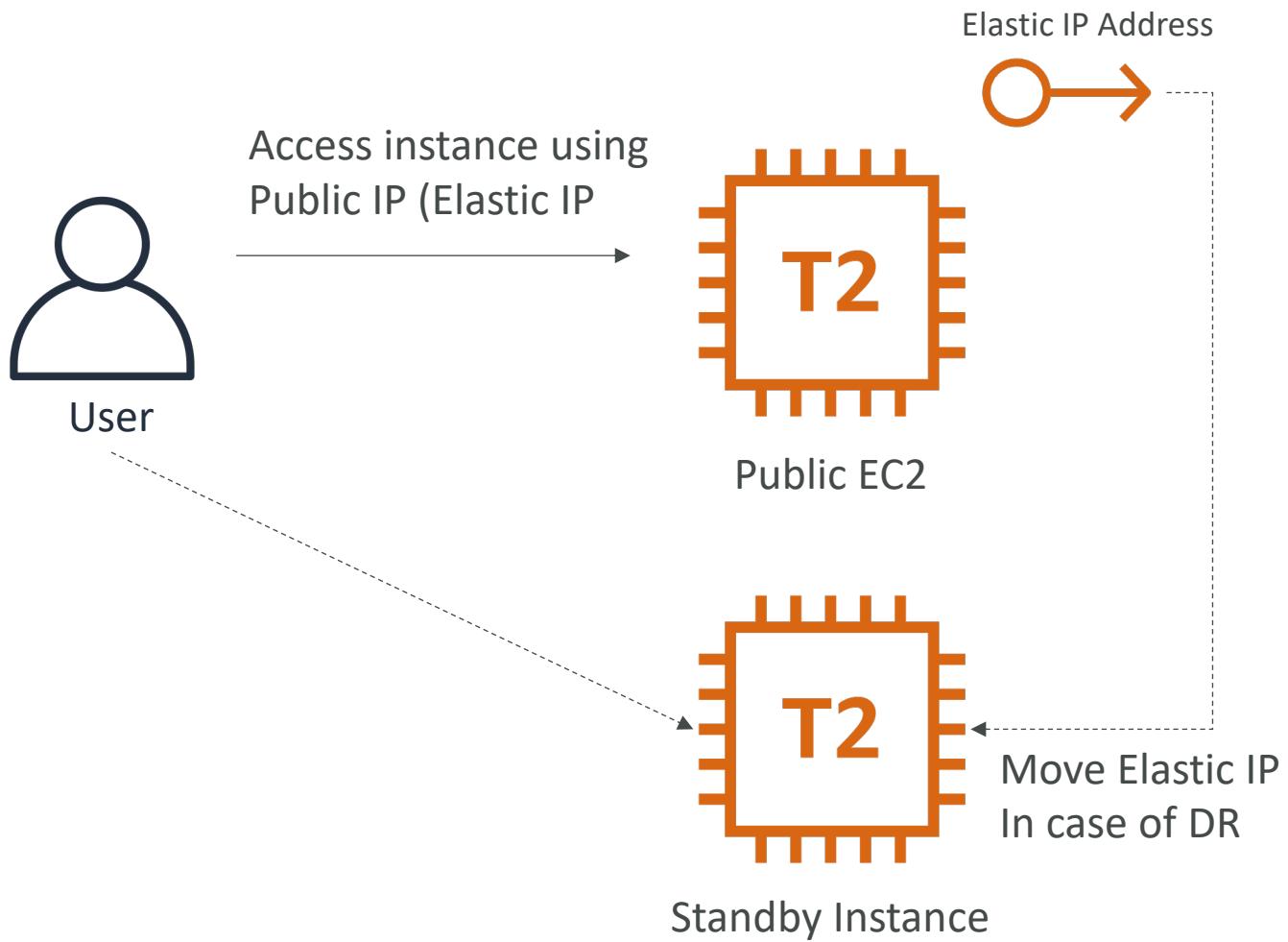
AWS Global Accelerator vs CloudFront

- They both use the AWS global network and its edge locations around the world
- Both services integrate with AWS Shield for DDoS protection.
- **CloudFront**
 - Improves performance for both cacheable content (such as images and videos)
 - Dynamic content (such as API acceleration and dynamic site delivery)
 - Content is served at the edge
- **Global Accelerator**
 - Improves performance for a wide range of applications over TCP or UDP
 - Proxying packets at the edge to applications running in one or more AWS Regions.
 - Good fit for non-HTTP use cases, such as gaming (UDP), IoT (MQTT), or Voice over IP
 - Good for HTTP use cases that require static IP addresses
 - Good for HTTP use cases that required deterministic, fast regional failover

Solution Architecture Comparisons

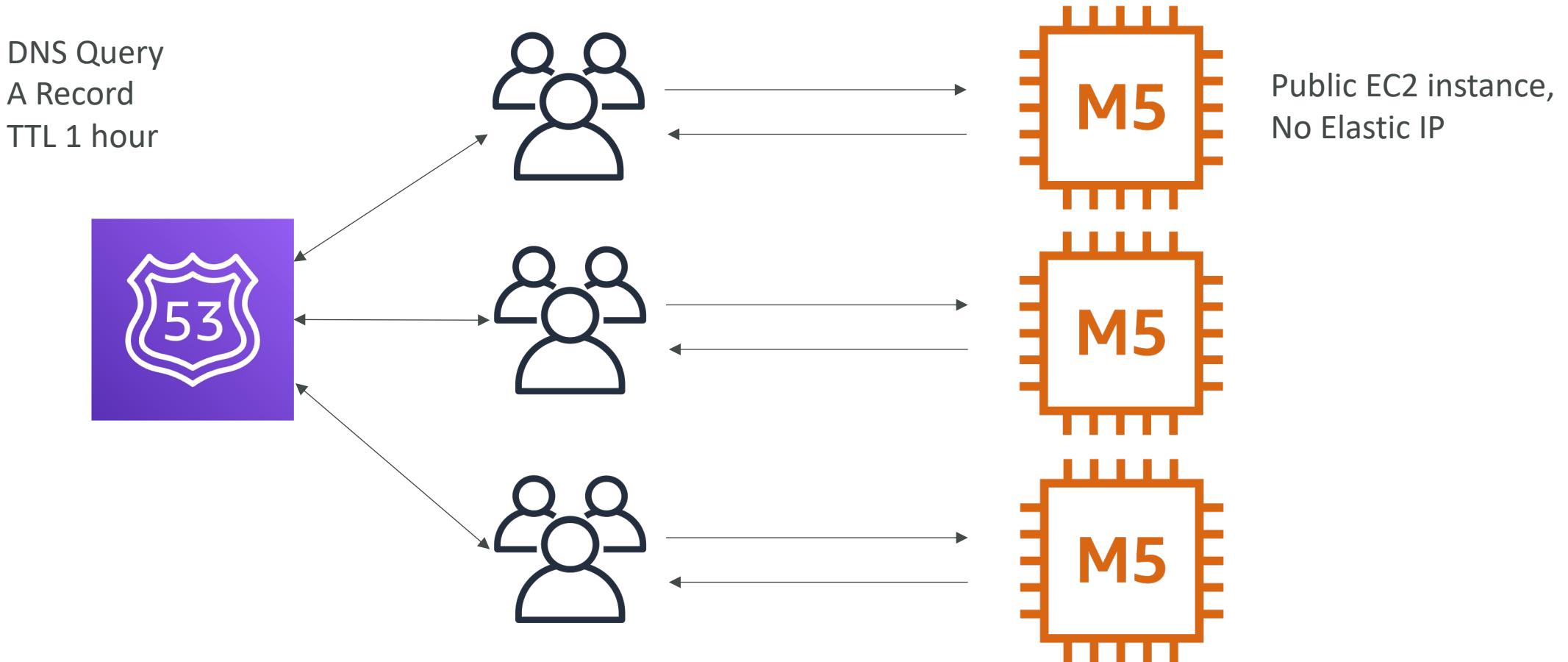
- EC2 on its own with Elastic IP
- EC2 with Route53
- ALB + ASG
- ALB + ECS on EC2
- ALB + ECS on Fargate
- ALB + Lambda
- API Gateway + Lambda
- API Gateway + AWS Service
- API Gateway + HTTP backend (ex: ALB)

EC2 with Elastic IP

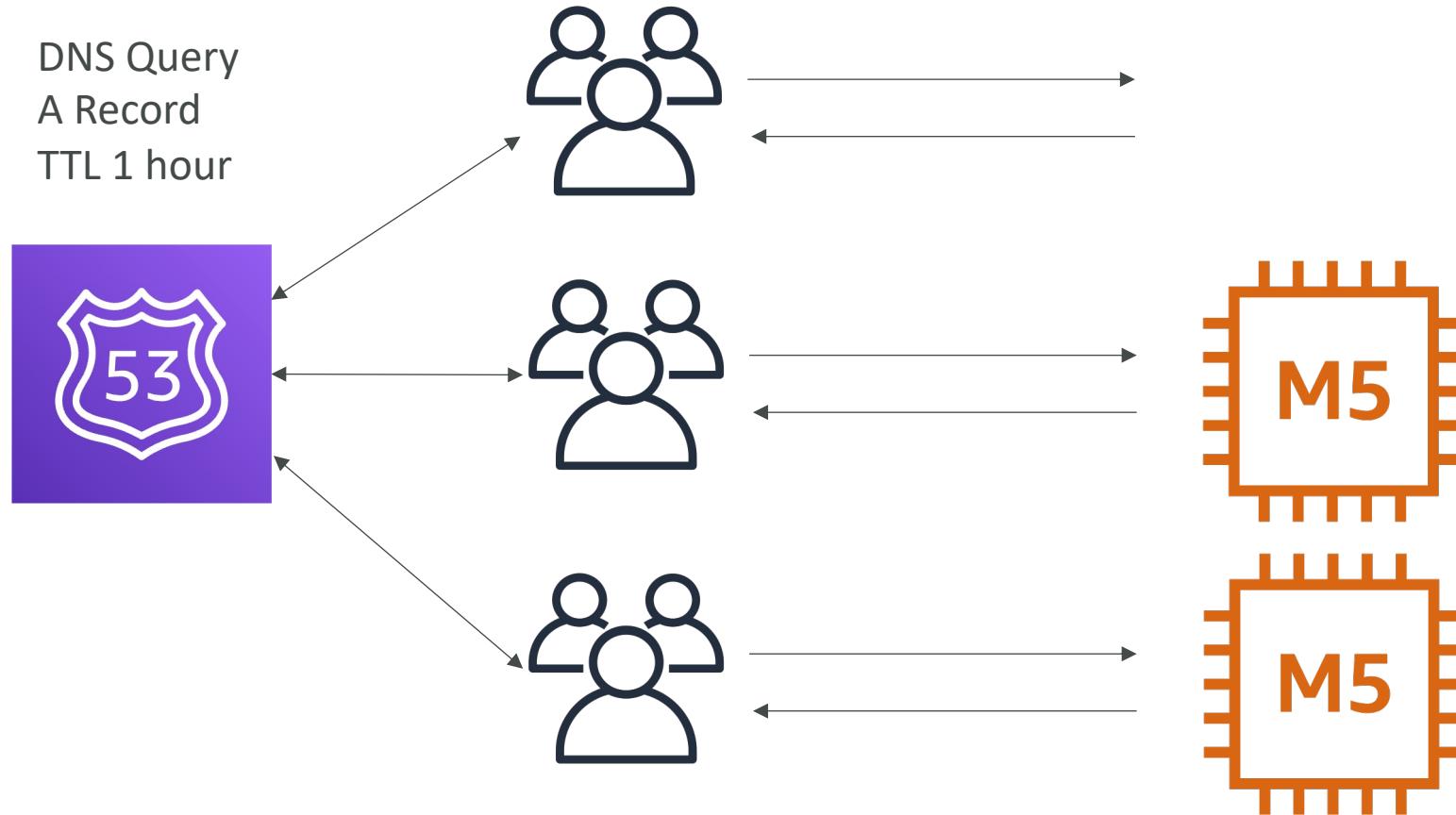


- Quick failover
- The client should not see the change happen
- Helpful if the client needs to resolve by static Public IP address
- Does not scale
- Cheap

Stateless web app - scaling horizontally

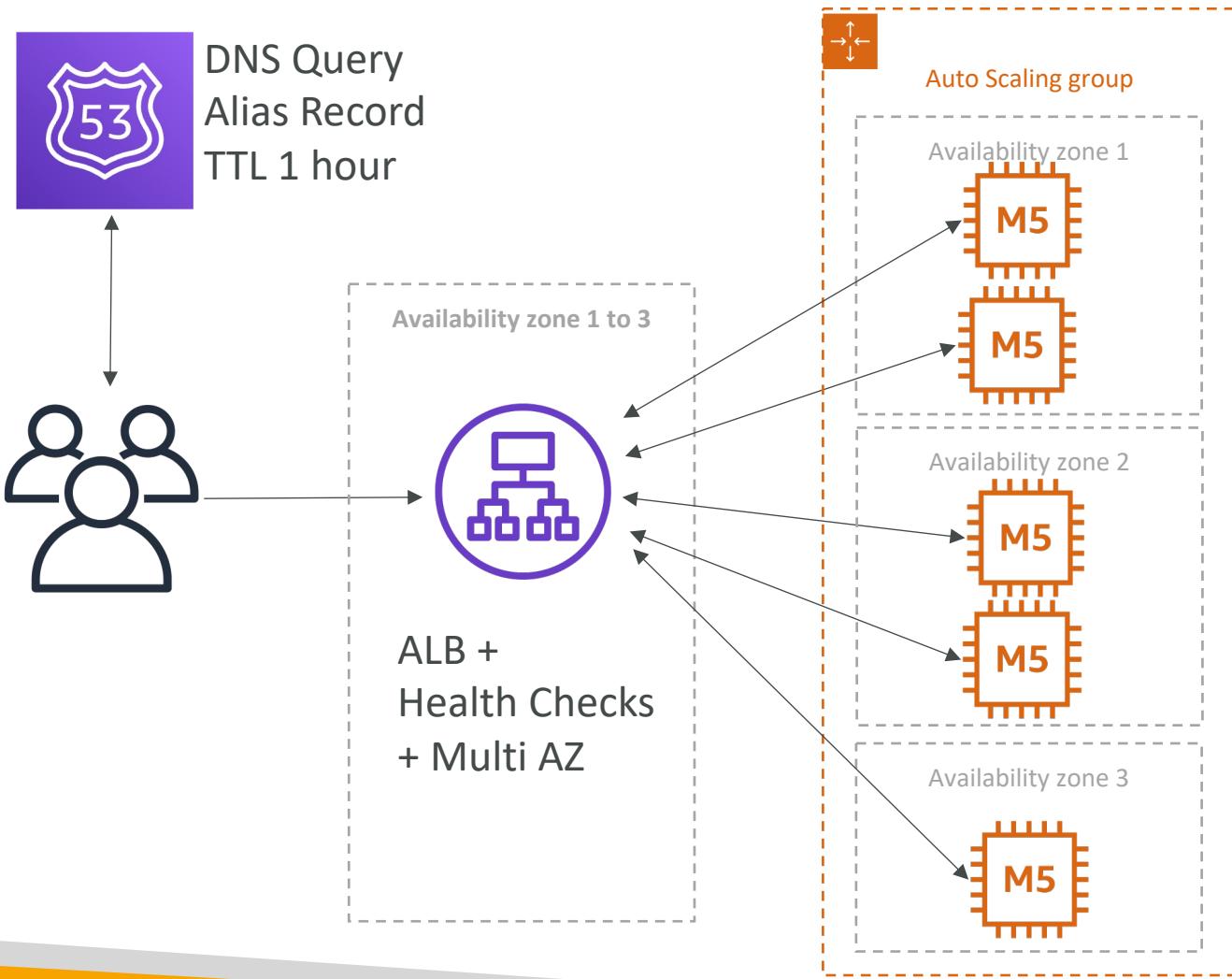


Stateless web app - scaling horizontally



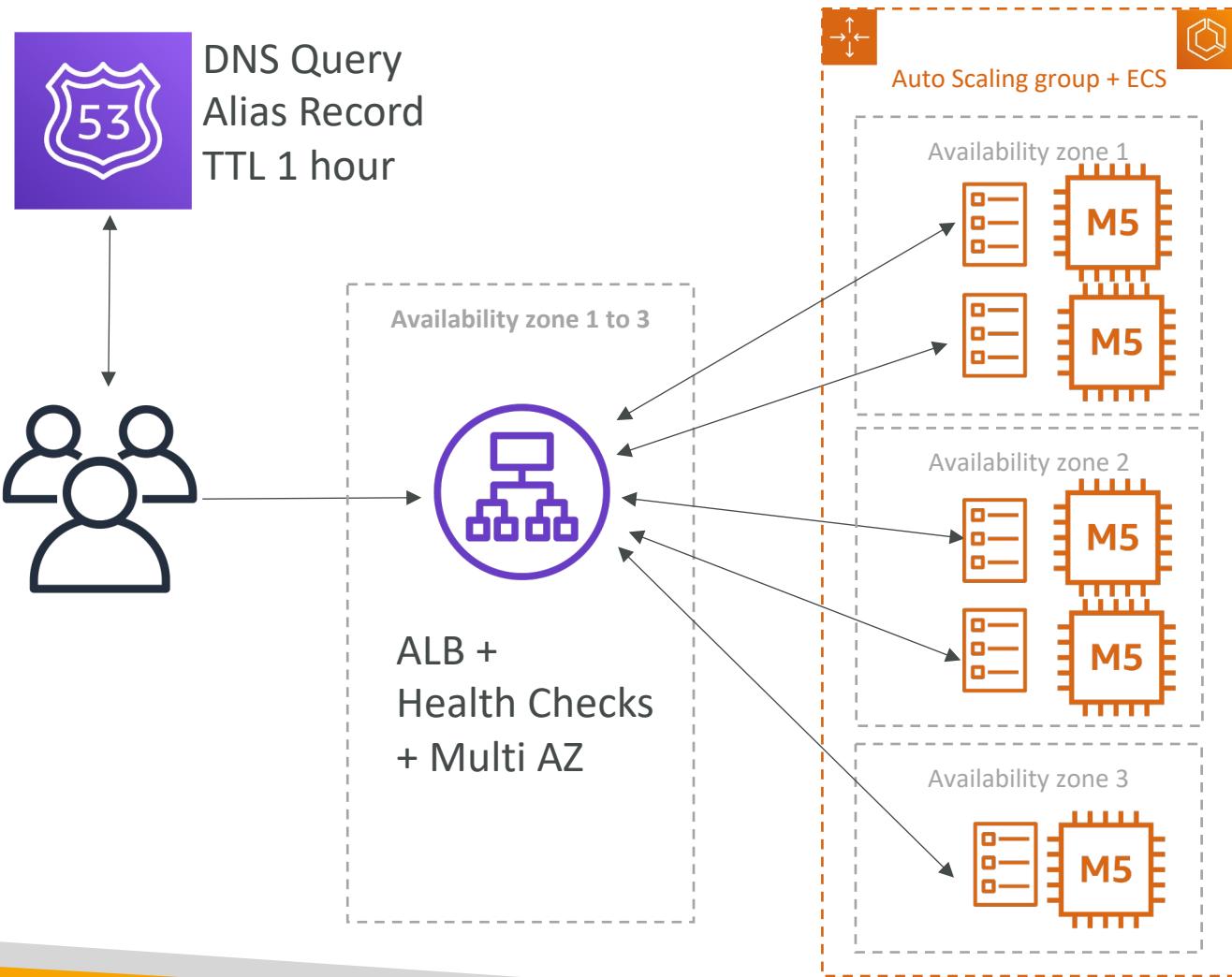
- “DNS-based load balancing”
- Ability to use multiple instances
- Route53 TTL implies client may get outdated information
- Clients must have logic to deal with hostname resolution failures
- Adding an instance may not receive full traffic right away due to DNS TTL

ALB + ASG



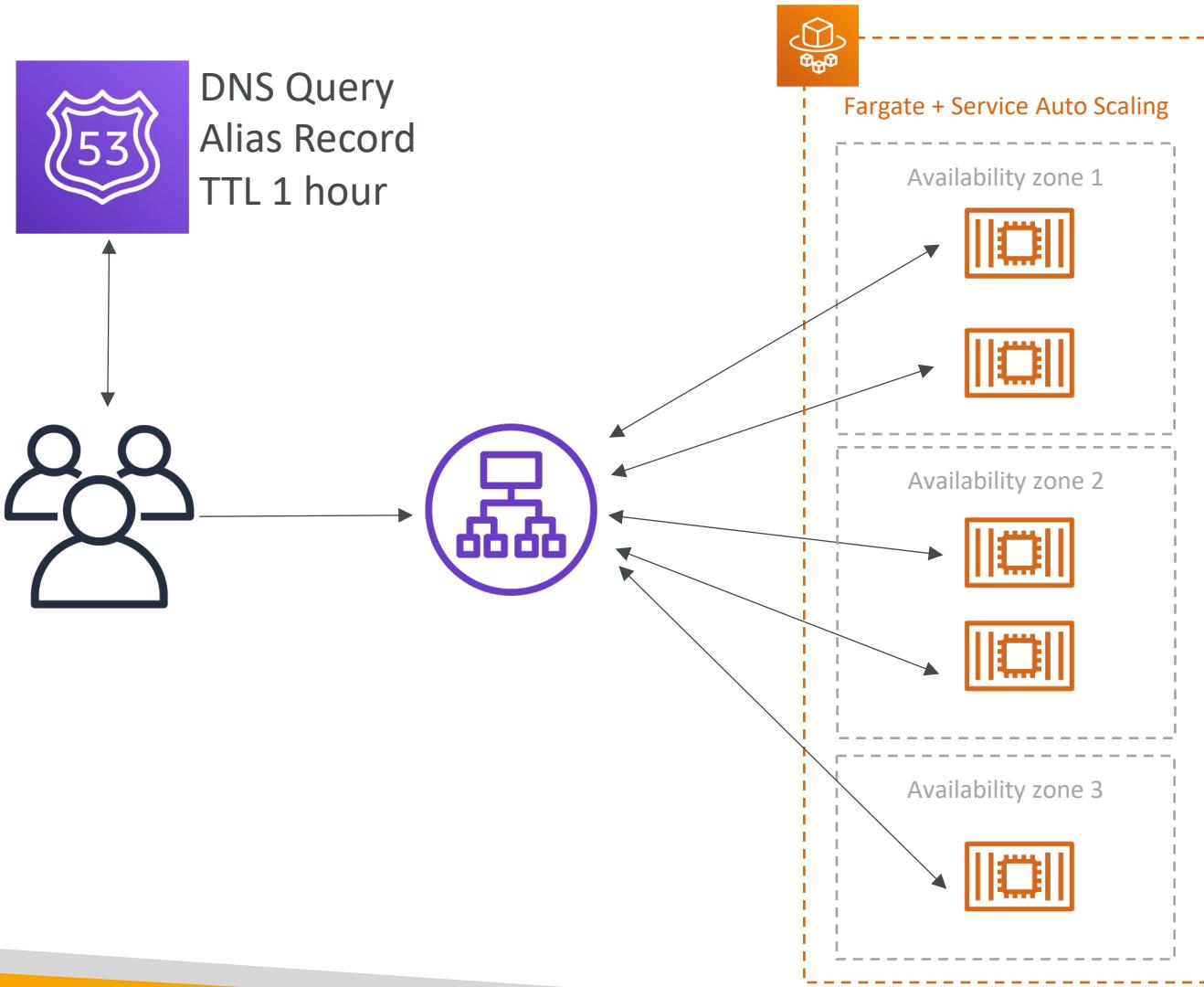
- Scales well, classic architecture
 - New instances are in service right away.
 - Users are not sent to instances that are out-of-service
 - Time to scale is slow (EC2 instance startup + bootstrap) – AMI can help
 - ALB is elastic but can't handle sudden, huge peak of demand (pre-warm)
 - Could lose a few requests if instances are overloaded
 - CloudWatch used for scaling
 - Cross-Zone balancing for even traffic distribution
-
- Target utilization should be between 40% and 70%

ALB + ECS on EC2 (backed by ASG)



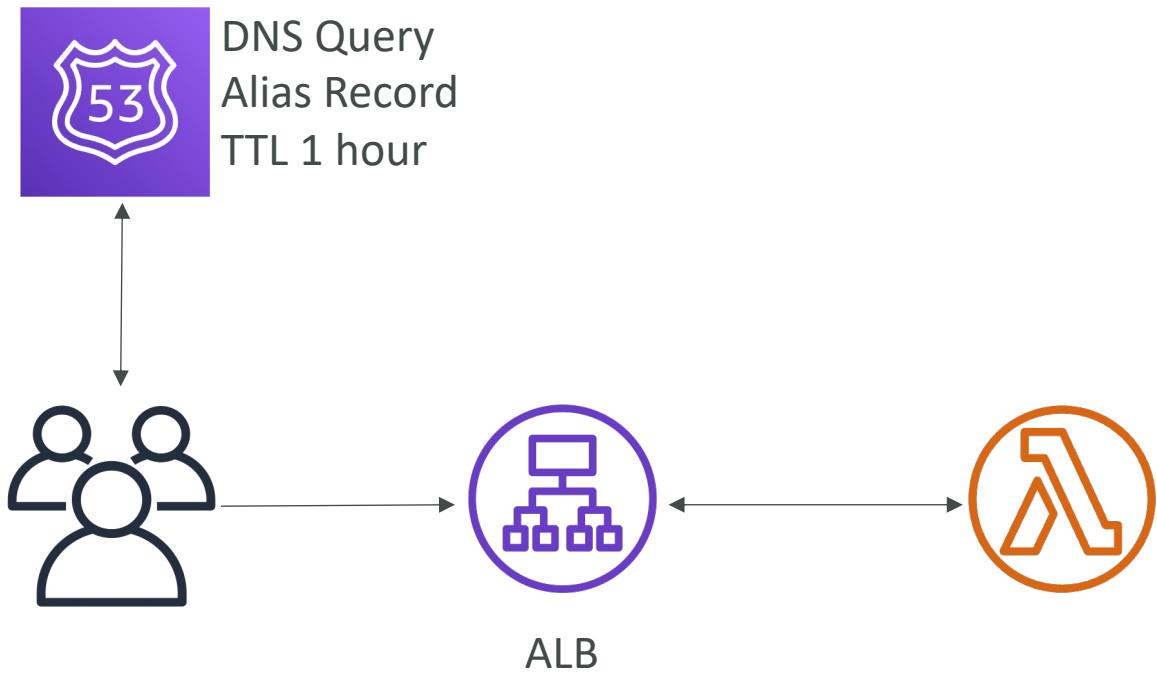
- Same properties as ALB + ASG
- Application is run on Docker
- ASG + ECS allows to have dynamic port mappings
- Tough to orchestrate ECS service auto-scaling + ASG auto-scaling

ALB + ECS on Fargate



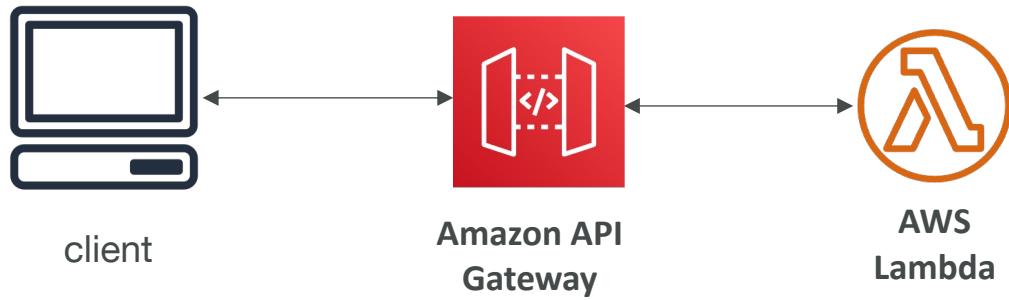
- Application is run on Docker
- Service Auto Scaling is easy
- Time to be in-service is quick (no need to launch an EC2 instance in advance)
- Still limited by the ALB in case of sudden peaks
- “serverless” application tier
- “managed” load balancer

ALB + Lambda



- Limited to Lambda's runtimes
- Seamless scaling thanks to Lambda
- Simple way to expose Lambda functions as HTTP/S without all the features from API Gateway
- Can combine with WAF (Web Application Firewall)
- Good for hybrid microservices
- Example: use ECS for some requests, use Lambda for others

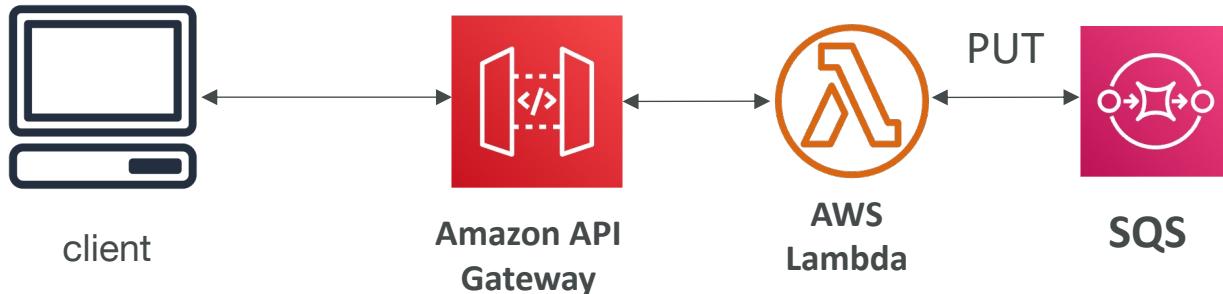
API Gateway + Lambda



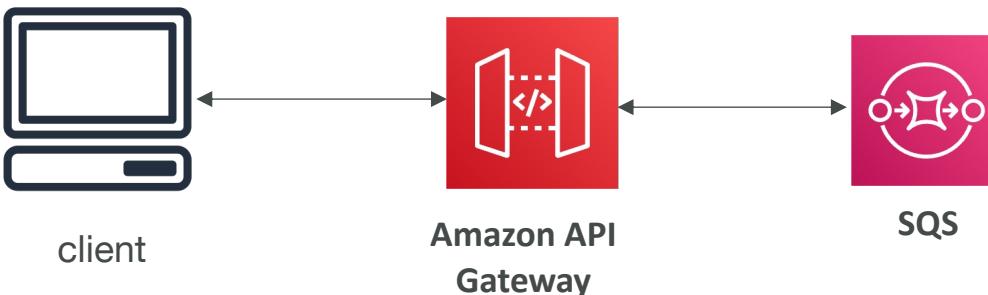
- Pay per request, seamless scaling, fully serverless
- Soft limits: 10000/s API Gateway, 1000 concurrent Lambda
- API Gateway features: authentication, rate limiting, caching, etc...
- Lambda Cold Start time may increase latency for some requests
- Fully integrated with X-Ray

API Gateway + AWS Service (as a proxy)

OK

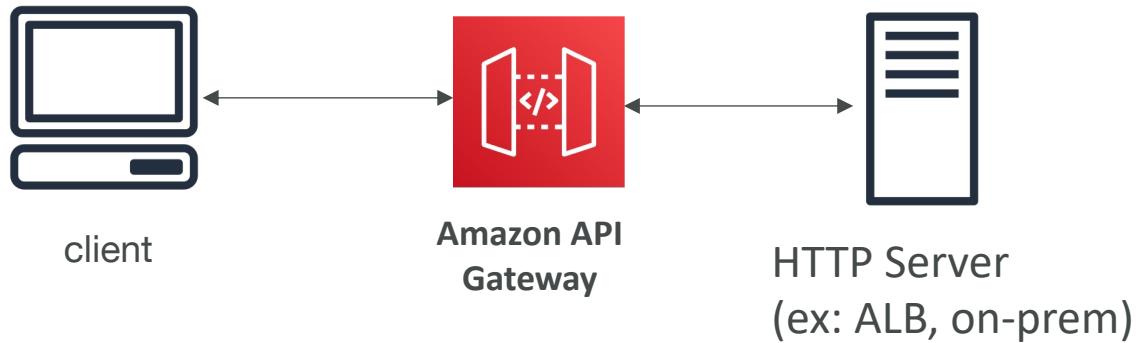


BETTER



- Lower latency, cheaper
- Not using Lambda concurrent capacity, no custom code
- Expose AWS APIs securely through API Gateway
- SQS, SNS, Step Functions...
- Remember API Gateway has a payload limit of 10 MB (can be a problem for S3 proxy)

API Gateway + HTTP backend (ex: ALB)

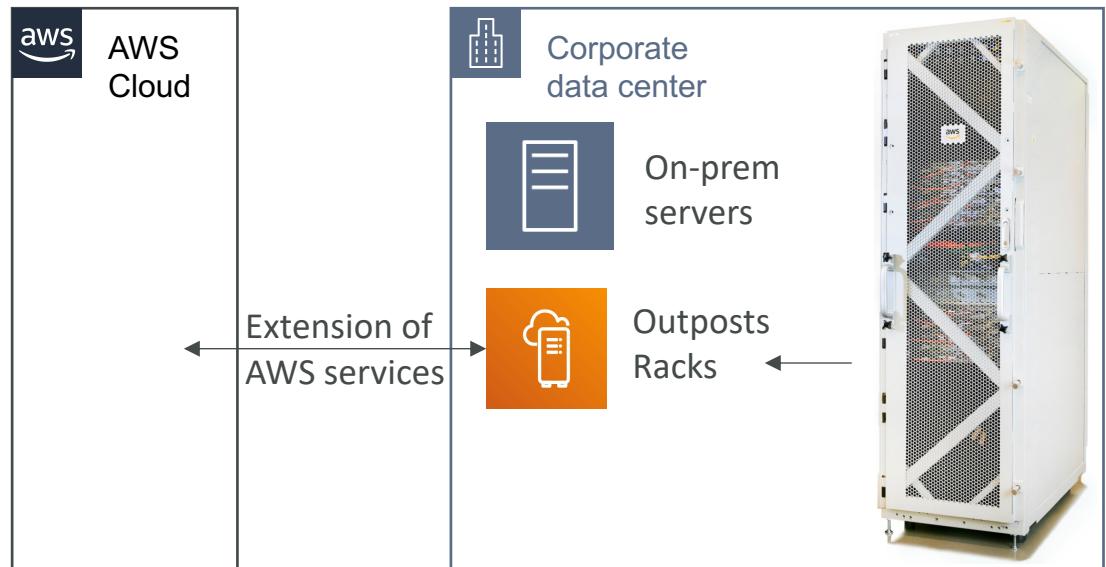


- Use API Gateway features on top of custom HTTP backend (authentication, rate control, API keys, caching...)
- Can connect to...
 - on-premises service
 - Application Load Balancer
 - 3rd party HTTP service

AWS Outposts



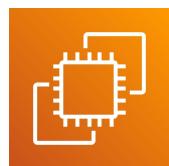
- **Hybrid Cloud:** businesses that keep an on-premises infrastructure alongside a cloud infrastructure
- Therefore, two ways of dealing with IT systems:
 - One for the AWS cloud (using the AWS console, CLI, and AWS APIs)
 - One for their on-premises infrastructure
- **AWS Outposts** are “server racks” that offers the same AWS infrastructure, services, APIs & tools to build your own applications on-premises just as in the cloud
- **AWS will setup and manage “Outposts Racks”** within your on-premises infrastructure and you can start leveraging AWS services on-premises
- You are responsible for the Outposts Rack physical security



AWS Outposts



- Benefits:
 - Low-latency access to on-premises systems
 - Local data processing
 - Data residency
 - Easier migration from on-premises to the cloud
 - Fully managed service
- Some services that work on Outposts:



Amazon EC2



Amazon EBS



Amazon S3



Amazon EKS



Amazon ECS



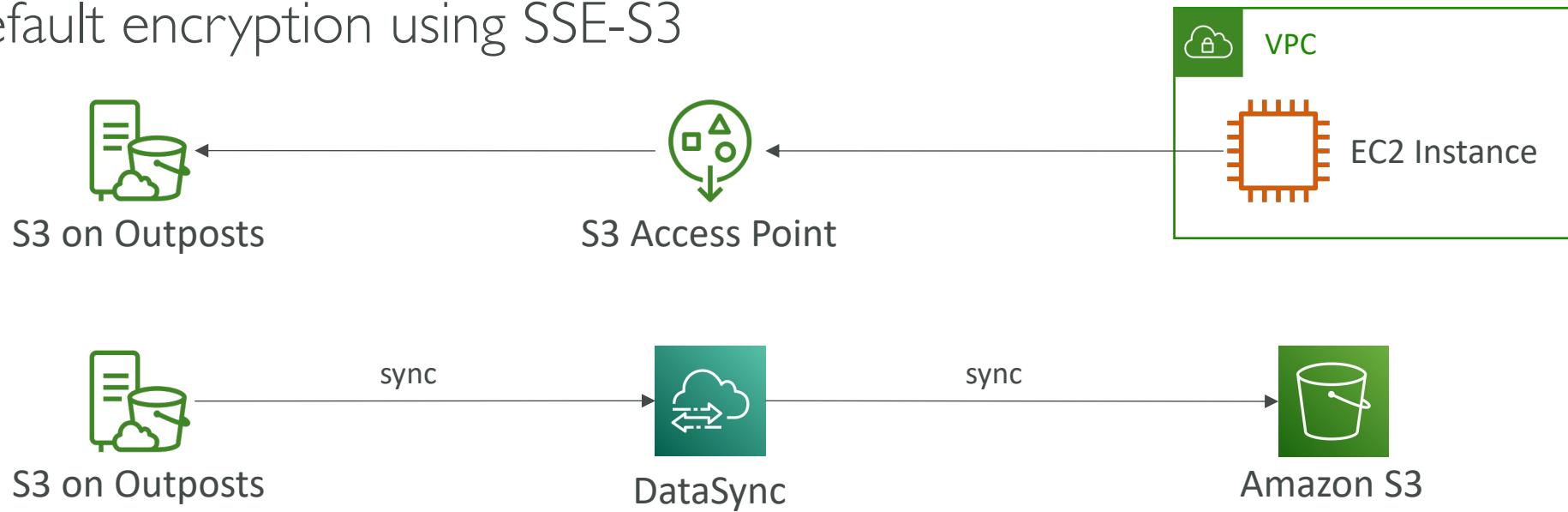
Amazon RDS



Amazon EMR

S3 on AWS Outposts

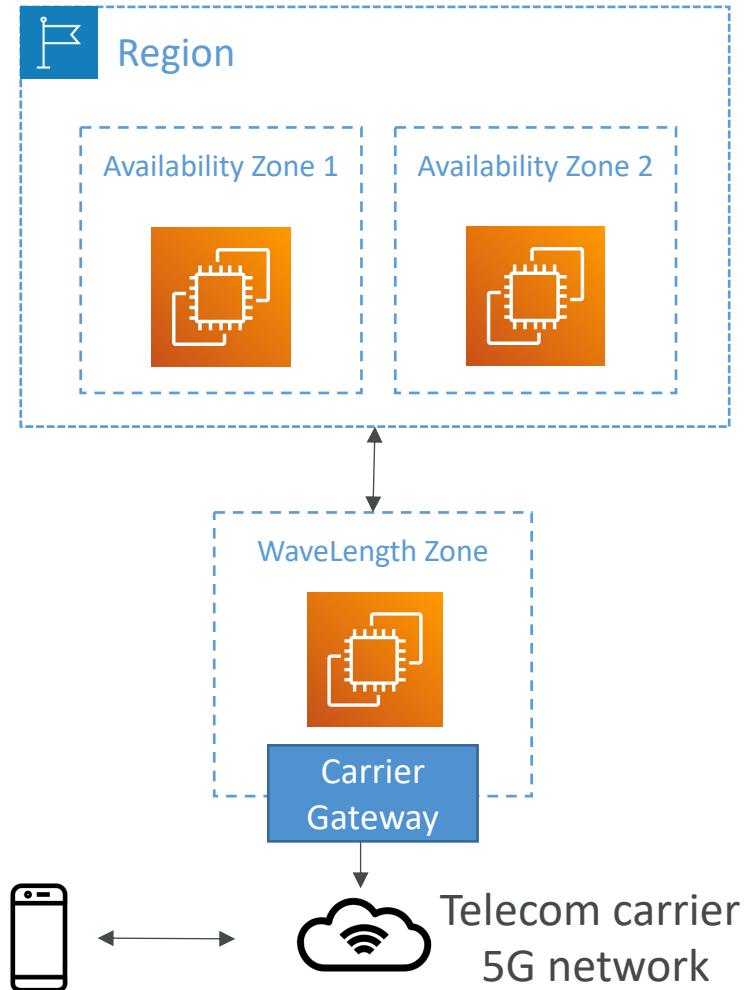
- Use S3 APIs to store and retrieve data *locally* on AWS Outposts
- Keeping data close to on-premises applications
- Reduce data transfers to AWS Regions
- S3 Storage Class named **S3 Outposts**
- Default encryption using SSE-S3



AWS WaveLength



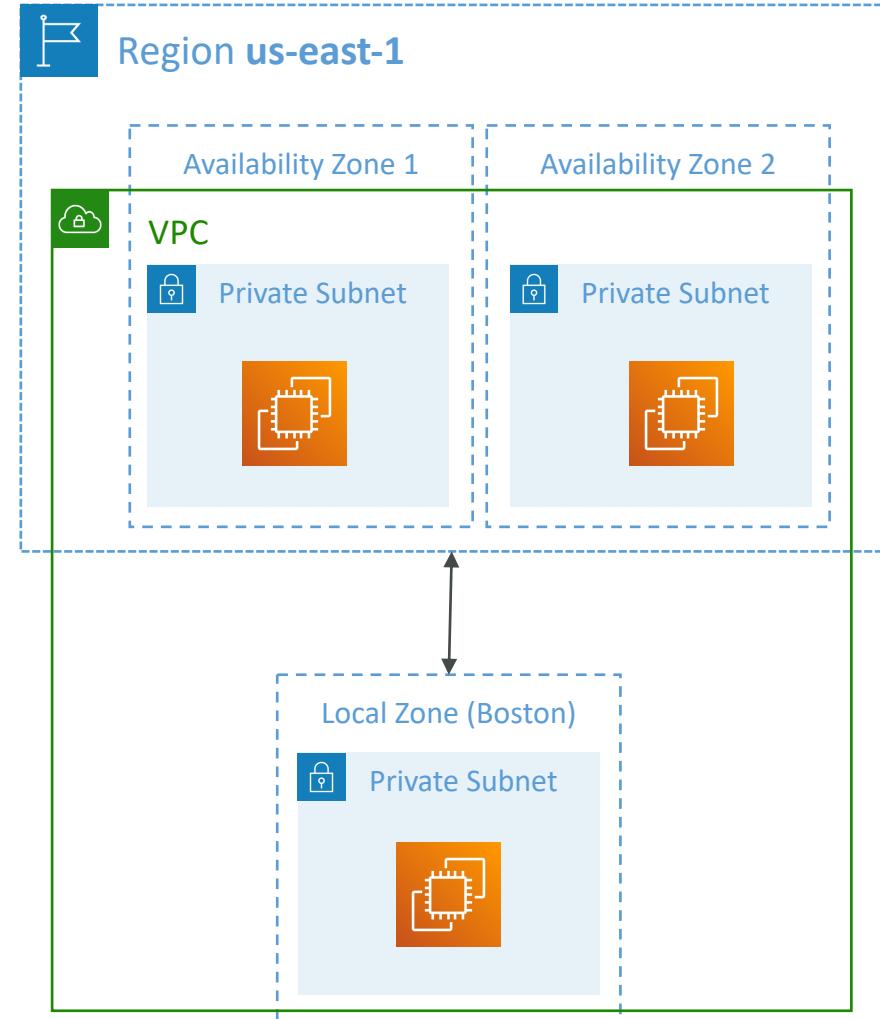
- **WaveLength Zones** are infrastructure deployments embedded within the telecommunications providers' datacenters at the edge of the 5G networks
- Brings AWS services to the edge of the 5G networks
- Example: EC2, EBS, VPC...
- Ultra-low latency applications through 5G networks
- Traffic doesn't leave the Communication Service Provider's (CSP) network
- High-bandwidth and secure connection to the parent AWS Region
- No additional charges or service agreements
- Use cases: Smart Cities, ML-assisted diagnostics, Connected Vehicles, Interactive Live Video Streams, AR/VR, Real-time Gaming, ...



AWS Local Zones



- Places AWS compute, storage, database, and other selected AWS services closer to end users to run latency-sensitive applications
- Extend your VPC to more locations – “Extension of an AWS Region”
- Compatible with EC2, RDS, ECS, EBS, ElastiCache, Direct Connect ...
- Example:
 - AWS Region: N.Virginia (us-east-1)
 - AWS Local Zones: Boston, Chicago, Dallas, Houston, Miami, ...

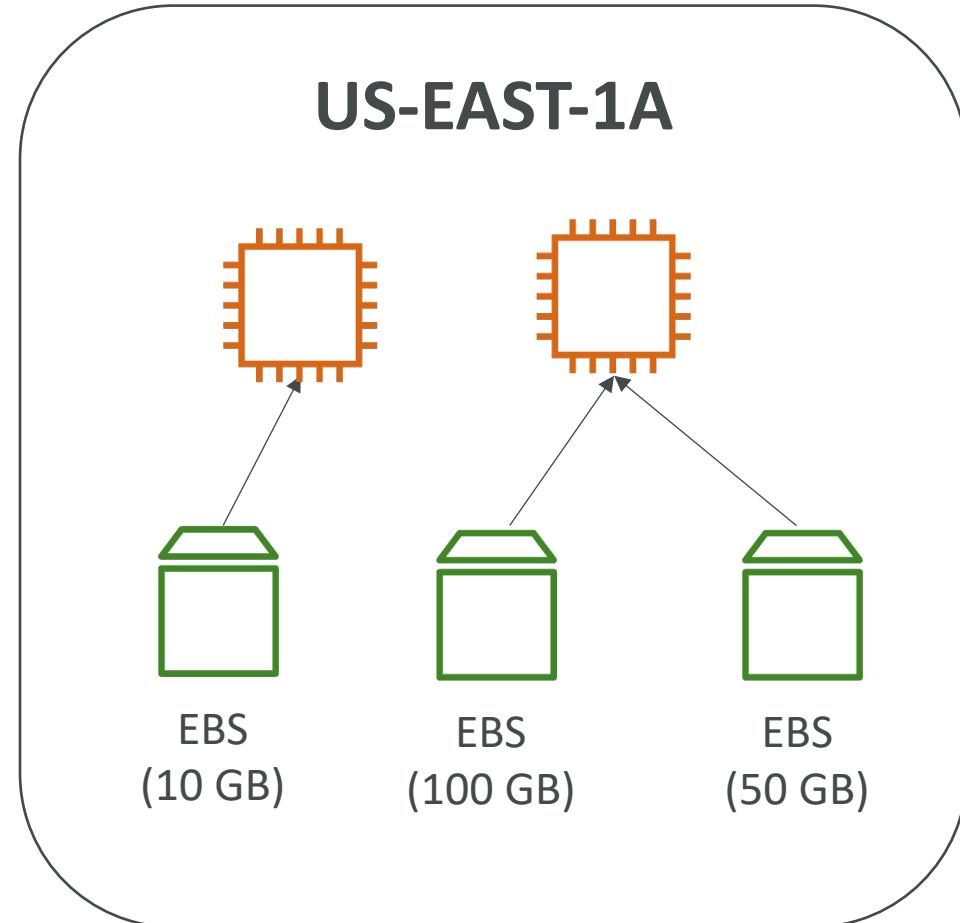


Storage

EBS



- Network drive you attach to ONE instance only
- Linked to a specific availability zone (transfer: snapshot => restore)
- Volumes can be resized
- Make sure you choose an instance type that is EBS optimized to enjoy maximum throughput



EBS Volume Types

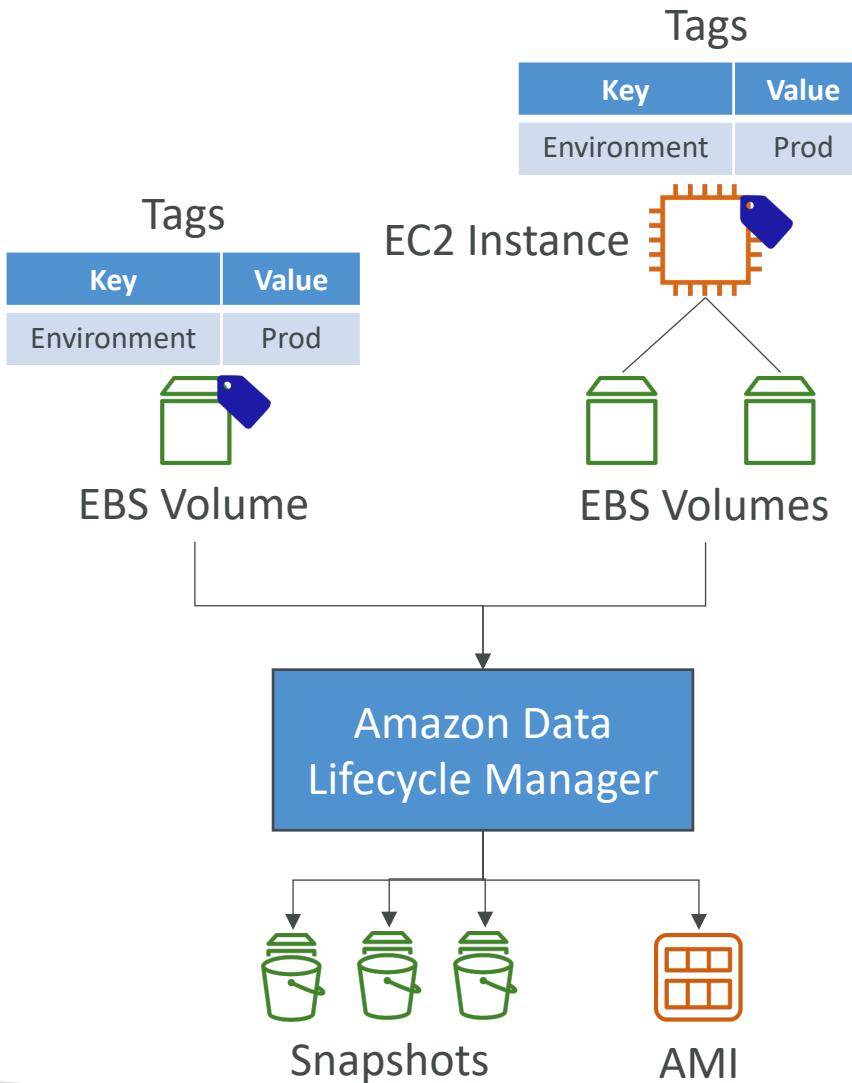
- EBS Volumes come in 6 types
 - [gp2 / gp3 \(SSD\)](#): General purpose SSD volume that balances price and performance for a wide variety of workloads
 - [io1 / io2 \(SSD\) / io2 Block Express](#): Highest-performance SSD volume for mission-critical low-latency or high-throughput workloads
 - [st1 \(HDD\)](#): Low cost HDD volume designed for frequently accessed, throughput-intensive workloads
 - [sc1 \(HDD\)](#): Lowest cost HDD volume designed for less frequently accessed workloads
- EBS Volumes are characterized in Size | Throughput | IOPS (I/O Ops Per Sec)
- When in doubt always consult the AWS documentation – it's good!
- Only gp2/gp3 and io1/io2 can be used as boot volumes

EBS Snapshots

- Incremental – only backup changed blocks
- EBS backups use IO, and you shouldn't run them while your application is handling a lot of traffic
- Snapshots will be stored in S3 (but you won't directly see them)
- Not necessary to detach volume to do snapshot, but recommended
- Can copy snapshots across region (for DR)
- Can make Image (AMI) from Snapshot
- EBS volumes restored by snapshots need to be pre-warmed (use the Fast Snapshot Restore FSR feature or fio/dd command to read the entire volume)

Amazon Data Lifecycle Manager

- Automate the creation, retention, and deletion of EBS snapshots and EBS-backed AMIs
- Schedule backups, cross-account snapshot copies, delete outdated backups, ...
- Uses resource tags to identify the resources (EC2 instances, EBS volumes)
- Can't be used to manage snapshots/AMIs created outside DLM
- Can't be used to manage instance-store backed AMIs



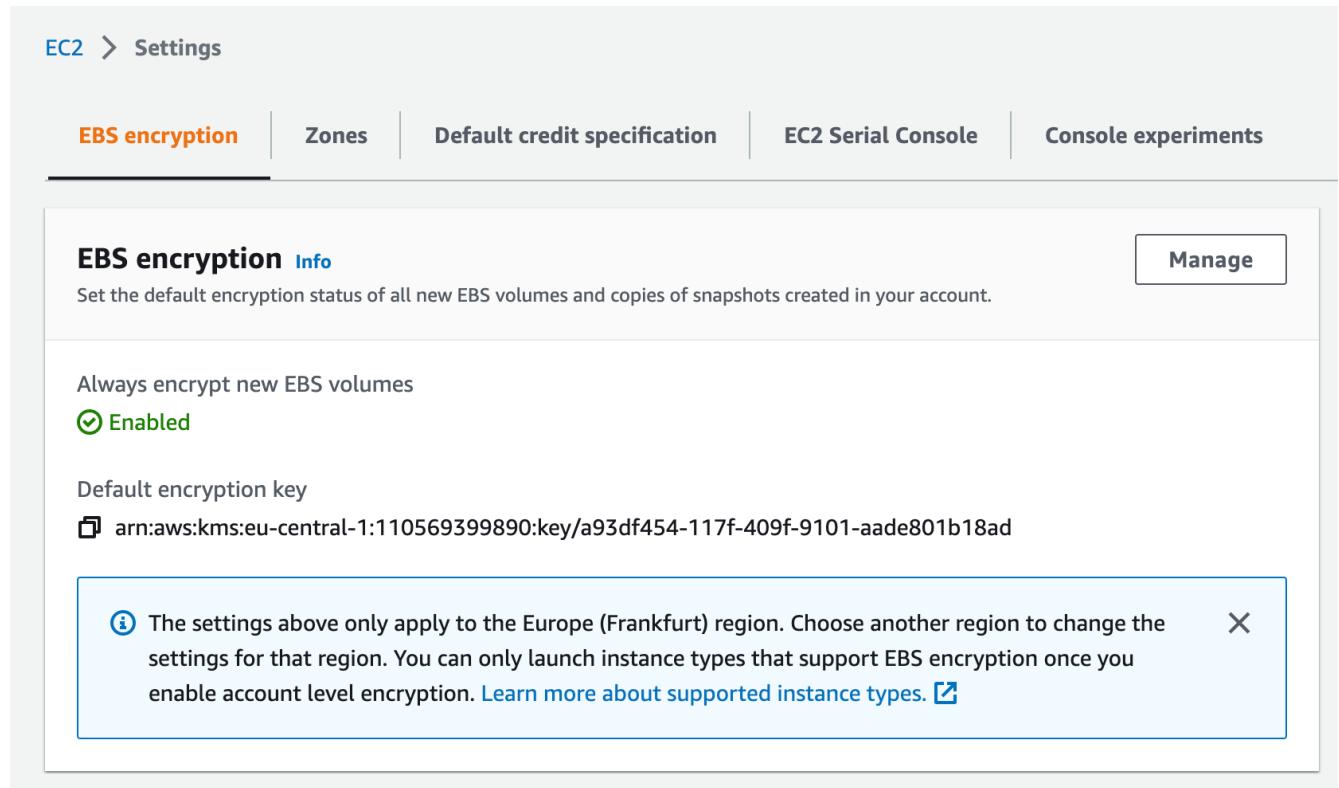
Amazon Data Lifecycle Manager vs. AWS Backup

- Use Data Lifecycle Manager
 - when you want to automate the creation, retention, and deletion of EBS Snapshots
- Use AWS Backup
 - to manage and monitor backups across the AWS services you use, including EBS volumes, from a single place



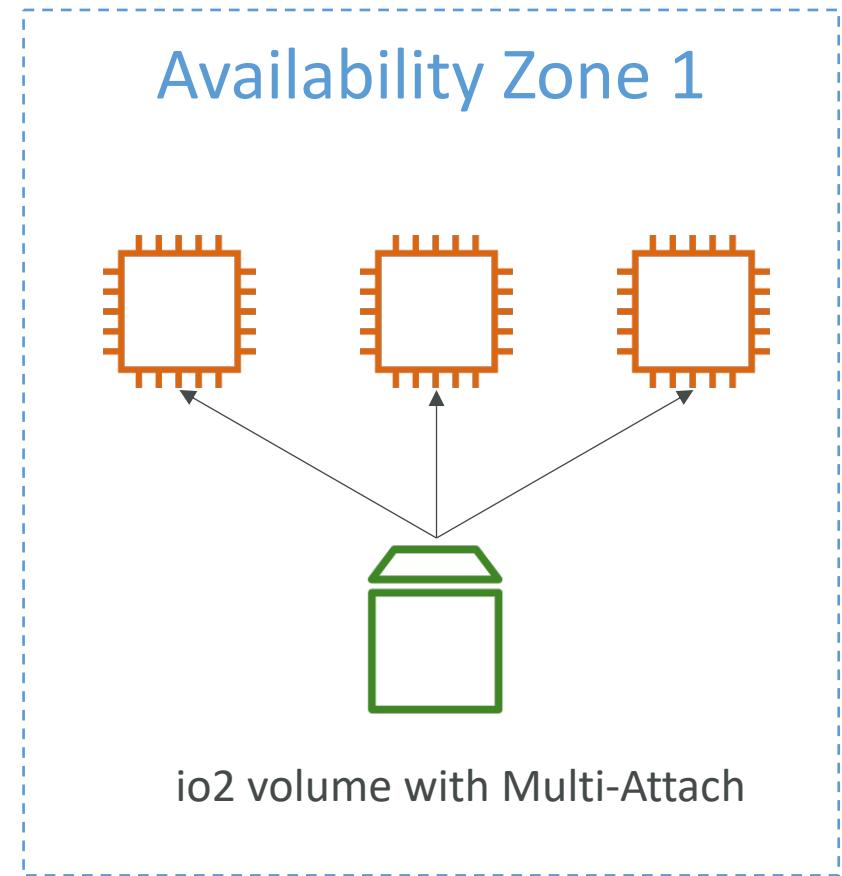
EBS Encryption – Account level setting

- New Amazon EBS volumes aren't encrypted by default
- There's an account-level setting to encrypt automatically new EBS volumes and Snapshots
- This setting needs to be enabled on a per-region basis



EBS Multi-Attach – io1/io2 family

- Attach the same EBS volume to multiple EC2 instances in the same AZ
- Each instance has full read & write permissions to the volume
- Use case:
 - Achieve higher application availability in clustered Linux applications (ex:Teradata)
 - Applications must manage concurrent write operations
- Must use a file system that's cluster-aware (not XFS, EXT4, etc...)



Local EC2 Instance Store

Very high IOPS

- Physical disk attached to the physical server where your EC2 is
- Very High IOPS (because physical)
- Disks up to 7.5 TiB (can change over time), striped to reach 60 TiB (can change over time...)
- Block Storage (just like EBS)
- Cannot be increased in size
- Risk of data loss if hardware fails

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

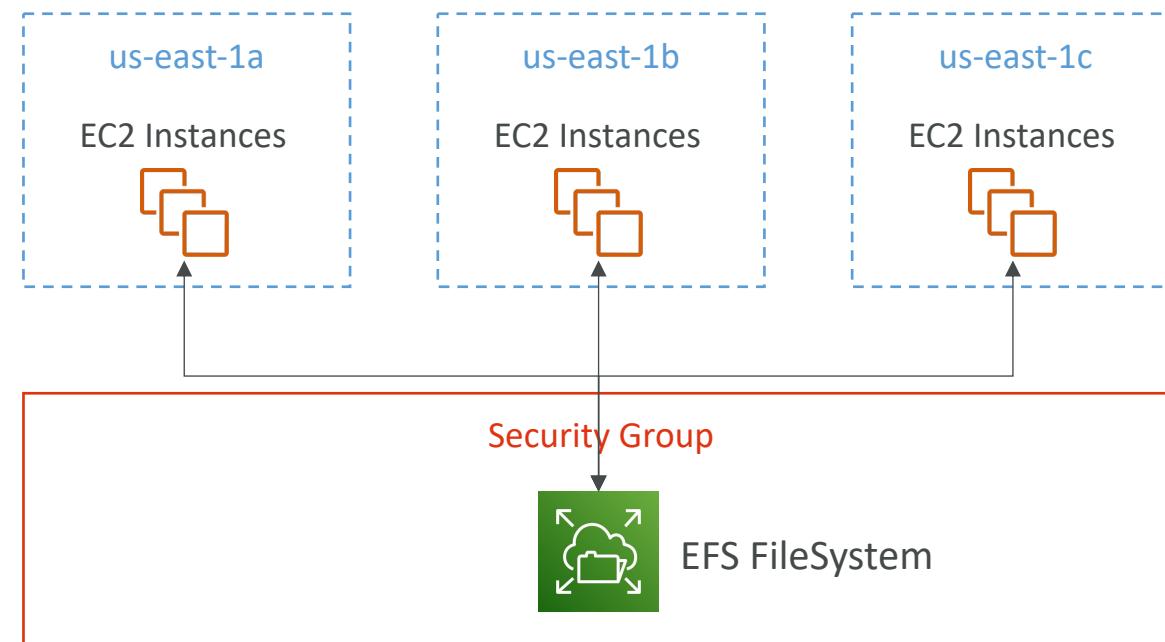
Instance Store vs EBS

- Instance store is physically attached to the machine (ephemeral storage)
- EBS is a network drive (persistent)
- Pros:
 - Better I/O performance (EBS gp2 has a max IOPS of 16000, io1 of 64000, io2 Block Express of 256000)
 - Good for buffer / cache / scratch data / temporary content
 - Data survives reboots
- Cons:
 - On stop or termination, the instance store is lost
 - You can't resize the instance store
 - Backups must be operated by the user

EFS – Elastic File System



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



EFS – Elastic File System

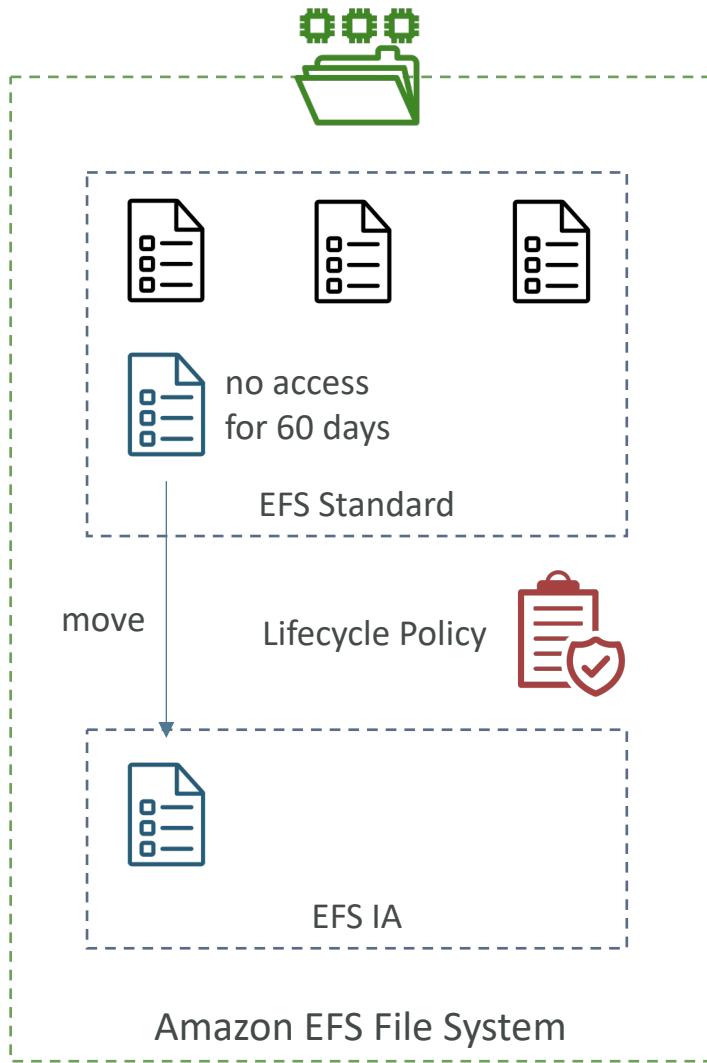
- Use cases: content management, web serving, data sharing, WordPress
- Compatible with Linux based AMI (not Windows), **POSIX**-compliant
- Uses NFSv4.1 protocol
- Uses security group to control access to EFS
- Encryption at rest using KMS
- Can only attach to one VPC, create one ENI (mount target) per AZ
- POSIX file system (~Linux) that has a standard file API
- File system scales automatically, pay-per-use, no capacity planning!

EFS – Performance & Storage Classes

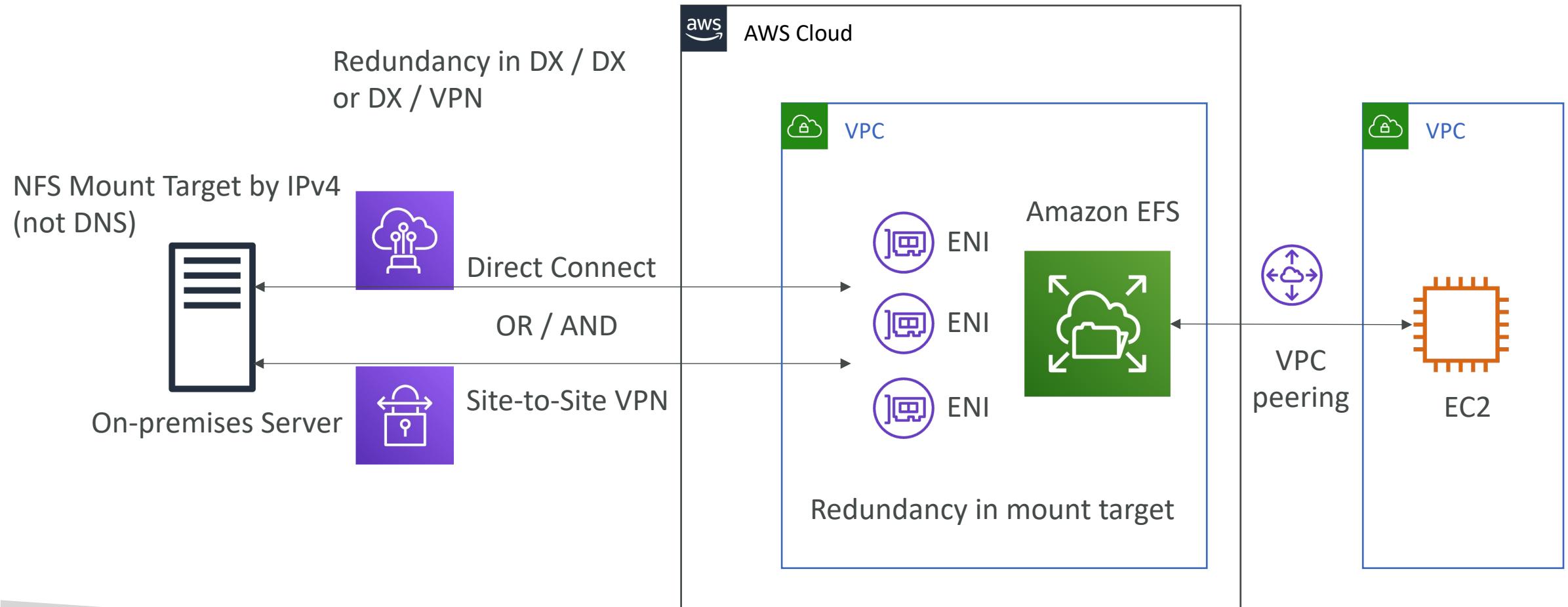
- EFS Scale
 - 1000s of concurrent NFS clients, 10 GB+ /s throughput
 - Grow to Petabyte-scale network file system, automatically
- Performance Mode (set at EFS creation time)
 - General Purpose (default) – latency-sensitive use cases (web server, CMS, etc...)
 - Max I/O – higher latency, throughput, highly parallel (big data, media processing)
- Throughput Mode
 - Bursting – 1 TB = 50MiB/s + burst of up to 100MiB/s
 - Provisioned – set your throughput regardless of storage size, ex: 1 GiB/s for 1 TB storage
 - Elastic – automatically scales throughput up or down based on your workloads
 - Up to 3GiB/s for reads and 1GiB/s for writes
 - Used for unpredictable workloads

EFS – Storage Classes

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

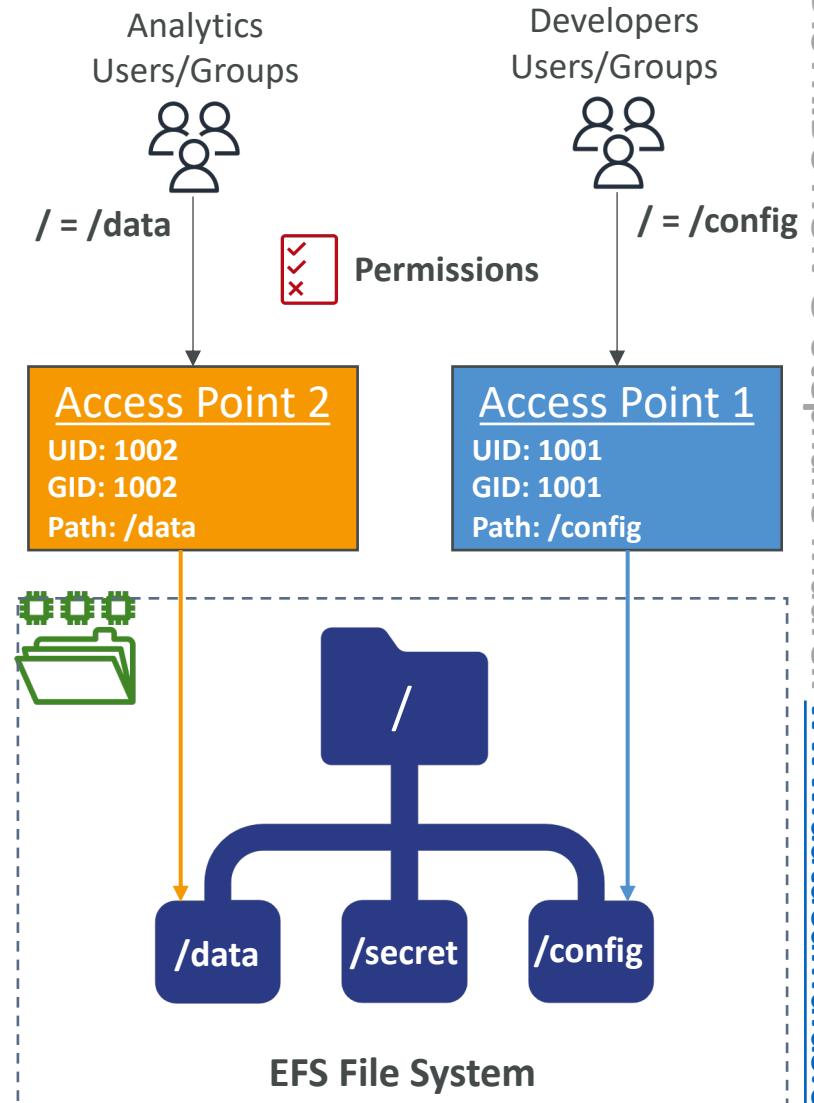


EFS - On-premises & VPC Peering



EFS – Access Points

- Easily manage applications access to NFS environments
- Enforce a POSIX user and group to use when accessing the file system
- Restrict access to a directory within the file system and optionally specify a different root directory
- Can restrict access from NFS clients using IAM policies



EFS – File System Policies

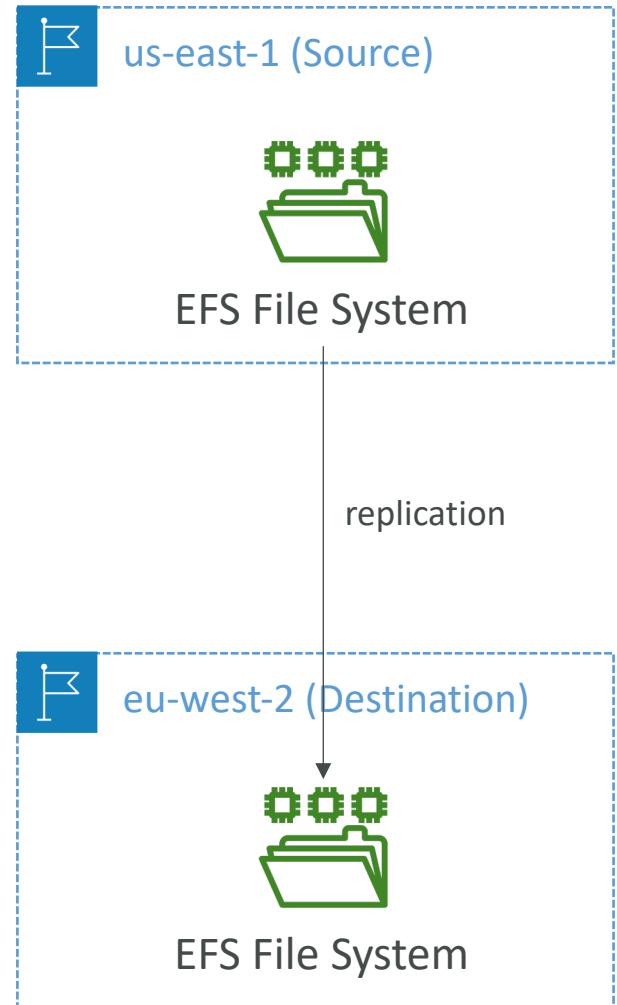
- Resource-based policy to control access to EFS File Systems (same as S3 bucket policy)
- By default, it grants full access to all clients

```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Principal": { "AWS": "arn:aws:iam::123456789012:user/Stephane" },  
            "Action": [  
                "elasticfilesystem:ClientMount",  
                "elasticfilesystem:ClientWrite"  
            ],  
            "Condition": {  
                "Bool": { "aws:SecureTransport": "true" }  
            }  
        }  
    ]  
}
```

Grant Read & Write Access to A specific IAM User

EFS – Cross-Region Replication

- Replicate objects in an EFS file system to another AWS Region
- Setup for new or existing EFS file systems
- Provides RPO and RTO of minutes
- Doesn't affect the provisioned throughput of the EFS file system
- Use cases: meet your compliance and business continuity goals



S3 – Overview

- Object storage, serverless, unlimited storage, pay-as-you-go
- Good to store static content (image, video files)
- Access objects by key, no indexing facility
- Not a filesystem, cannot be mounted natively on EC2
- Anti patterns:
 - Lots of small files
 - POSIX file system (use EFS instead), file locks
 - Search features, queries, rapidly changing data
 - Website with dynamic content

S3 Storage Classes Comparison

	Standard	Intelligent-Tiering	Standard-IA	One Zone-IA	Glacier Instant Retrieval	Glacier Flexible Retrieval	Glacier Deep Archive
Durability	99.999999999% == (11 9's)						
Availability	99.99%	99.9%	99.9%	99.5%	99.9%	99.99%	99.99%
Availability Zones	>= 3	>= 3	>= 3	1	>= 3	>= 3	>= 3
Min. Storage Duration Charge	None	None	30 Days	30 Days	90 Days	90 Days	180 Days
Min. Billable Object Size	None	None	128 KB	128 KB	128 KB	40 KB	40 KB
Retrieval Fee	None	None	Per GB retrieved	Per GB retrieved	Per GB retrieved	Per GB retrieved	Per GB retrieved

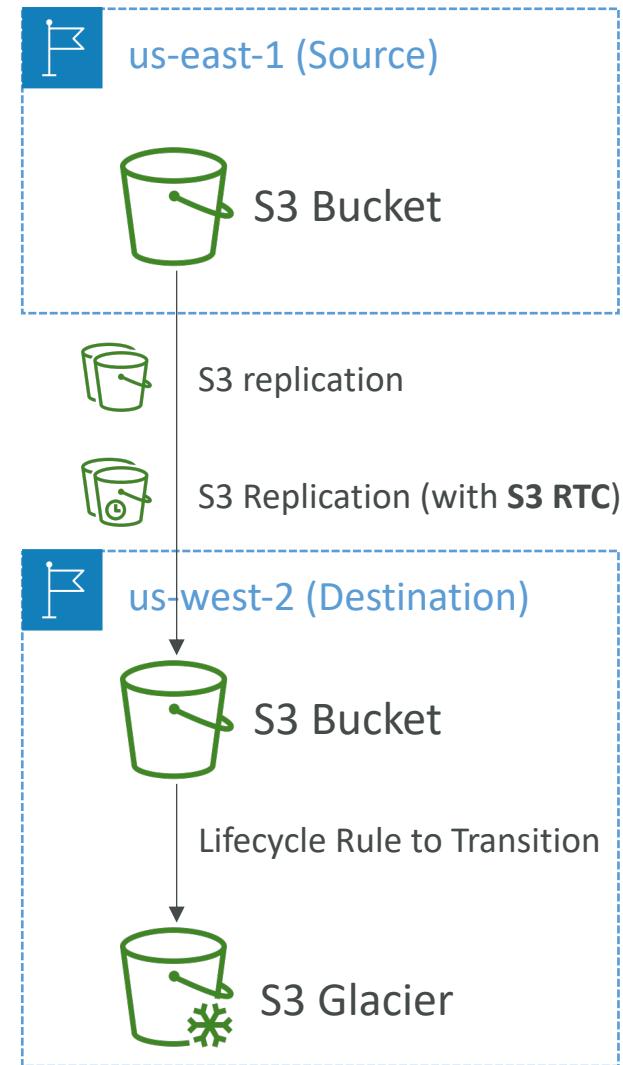
- You can transition objects between tiers (or delete) using S3 Lifecycle Policies

<https://aws.amazon.com/s3/storage-classes/>

S3 – Replication (Versioning enabled)

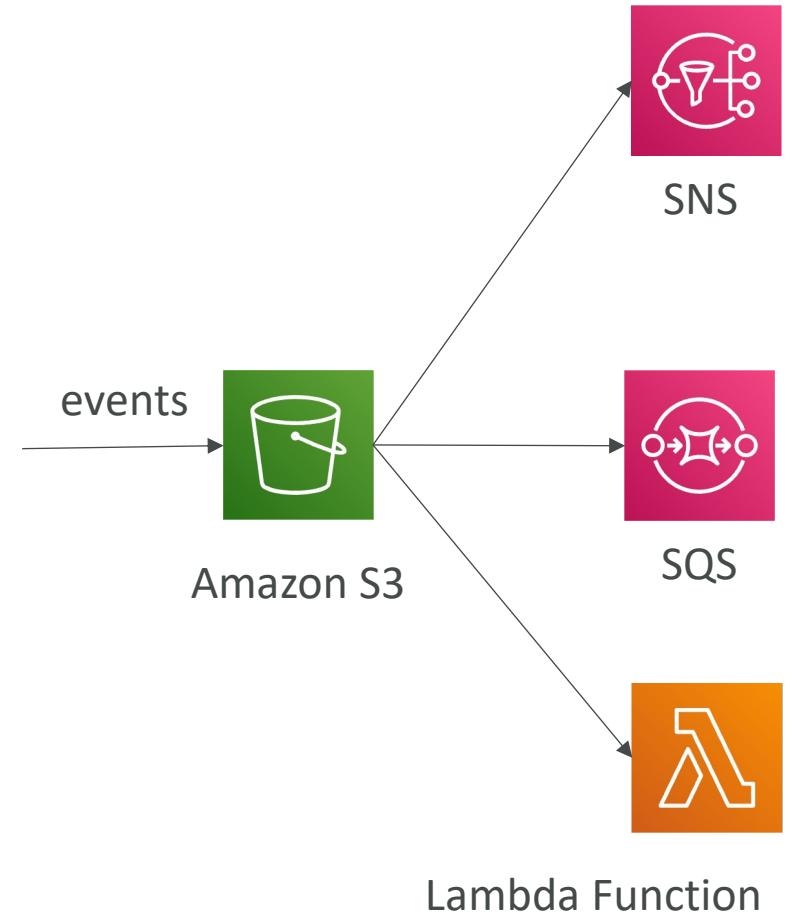


- Cross Region Replication (CRR)
- Same Region Replication (SRR)
- Combine with Lifecycle Rules
- Helpful to reduce latency, disaster recovery, security
- **S3 Replication Time Control (S3 RTC)**
 - Replicates most objects that you upload to Amazon S3 in seconds, and 99.99% of those objects within 15 minutes
 - Helpful for compliance, DR, etc..

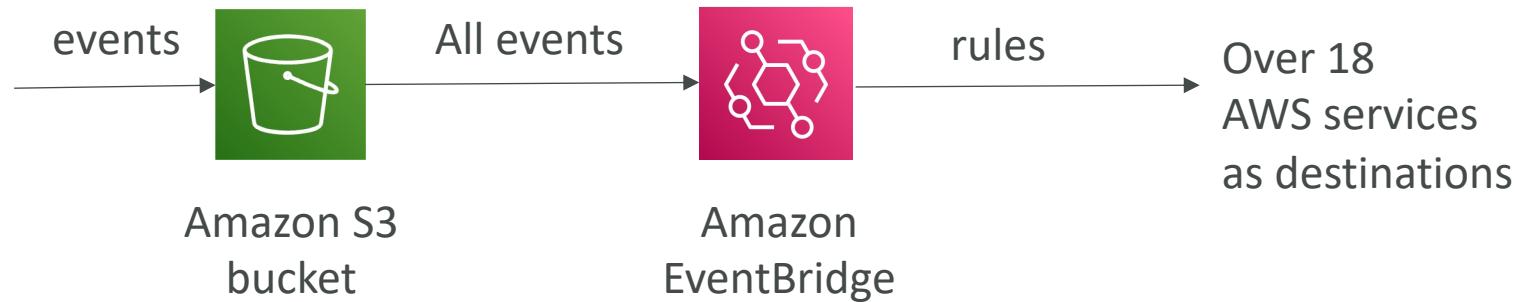


S3 Event Notifications

- 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



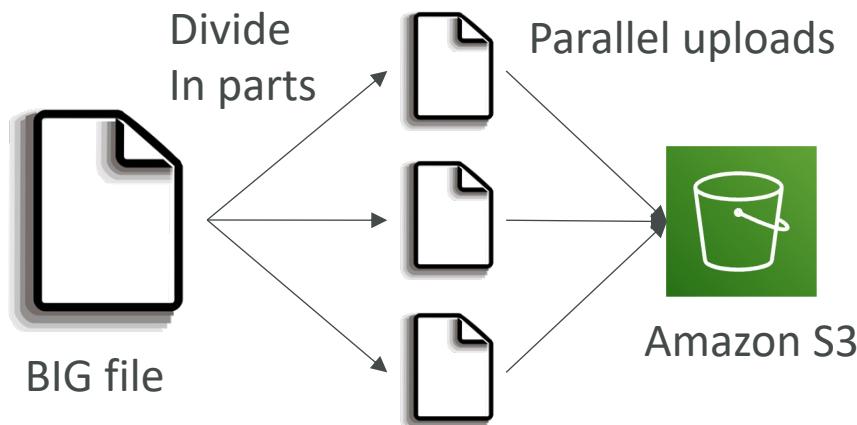
- Advanced filtering options with JSON rules (metadata, object size, name...)
- Multiple Destinations – ex Step Functions, Kinesis Streams / Firehose...
- EventBridge Capabilities – Archive, Replay Events, Reliable delivery

S3 – Baseline Performance

- Amazon S3 automatically scales to high request rates, latency 100-200 ms
- Your application can achieve at least 3,500 PUT/COPY/POST/DELETE or 5,500 GET/HEAD requests per second per prefix in a bucket.
- There are no limits to the number of prefixes in a bucket.
- Example (object path => prefix):
 - 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 all four prefixes evenly, you can achieve 22,000 requests per second for GET and HEAD

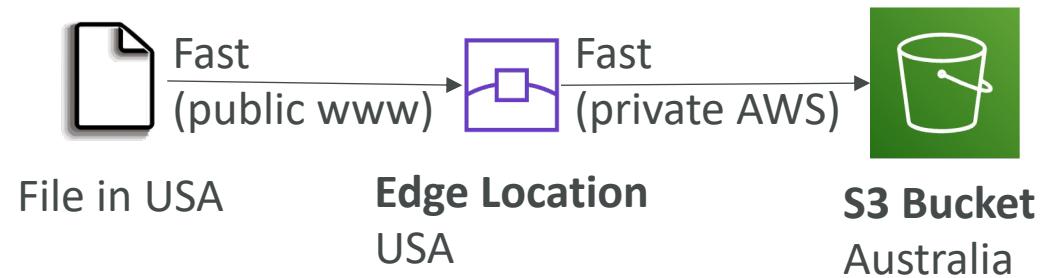
S3 Performance

- Multi-Part upload:
 - recommended for files > 100MB, must use for files > 5GB
 - Can help parallelize uploads (speed up transfers)



- S3 Transfer Acceleration

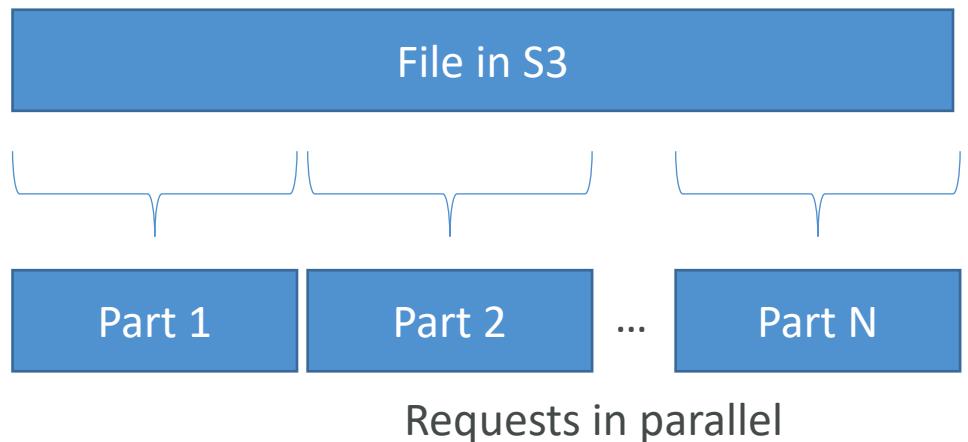
- Increase transfer speed by transferring file to an AWS edge location which will forward the data to the S3 bucket in the target region
- Compatible with multi-part upload



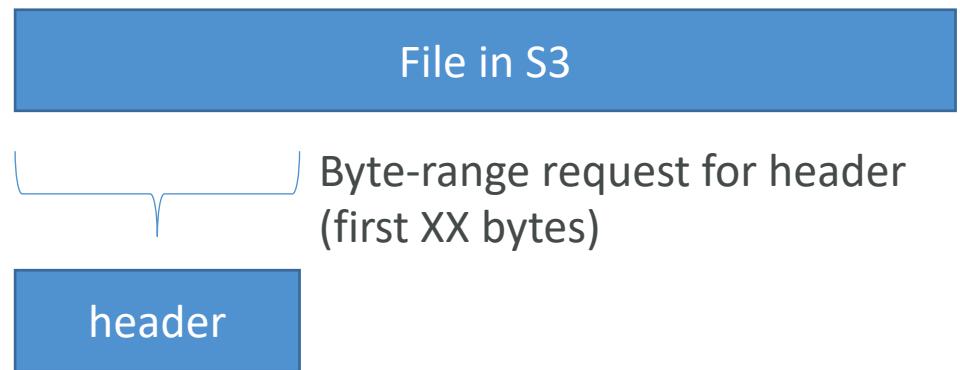
S3 Performance – S3 Byte-Range Fetches

- Parallelize GETs by requesting specific byte ranges
- Better resilience in case of failures

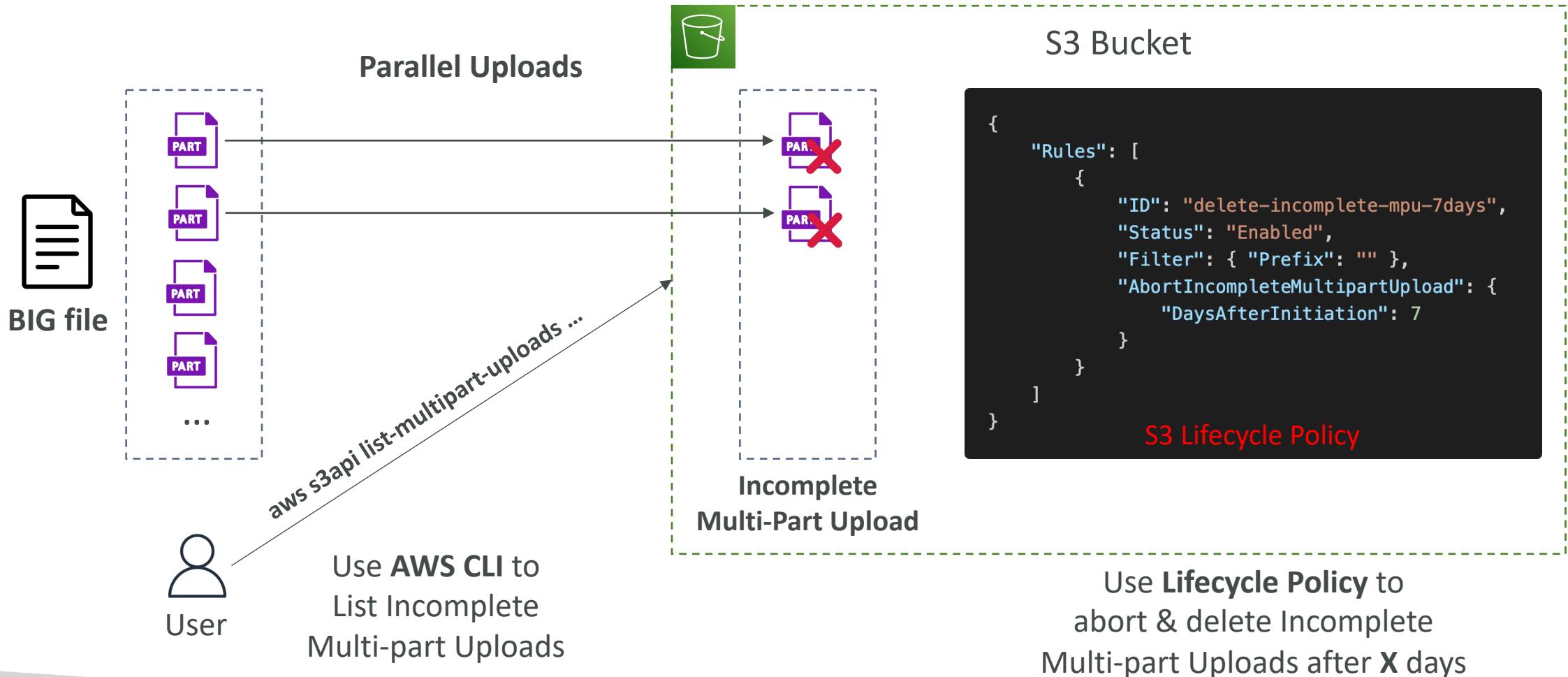
Can be used to speed up downloads



Can be used to retrieve only partial data (for example the head of a file)

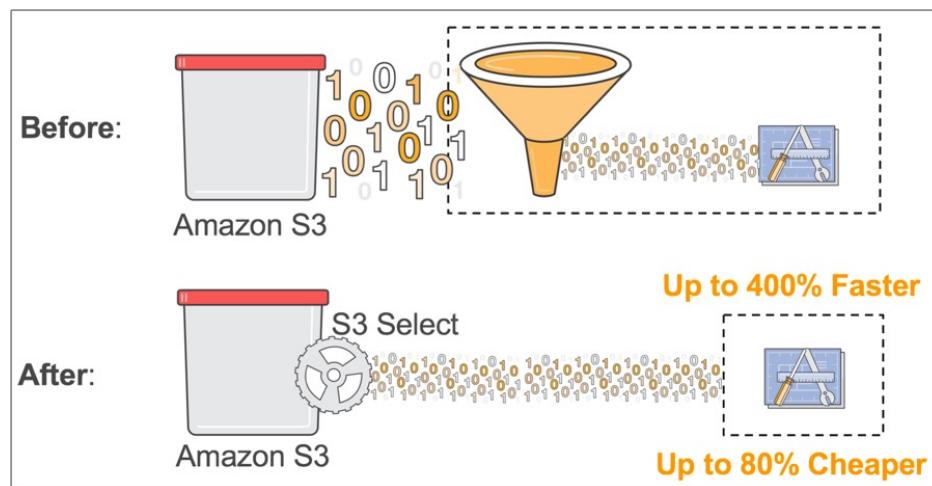


S3 Multi-Part Upload – Remove Incomplete Parts



S3 Select & Glacier Select

- Retrieve less data using SQL by performing **server side filtering**
- Can filter by rows & columns (simple SQL statements)
- Less network transfer, less CPU cost client-side

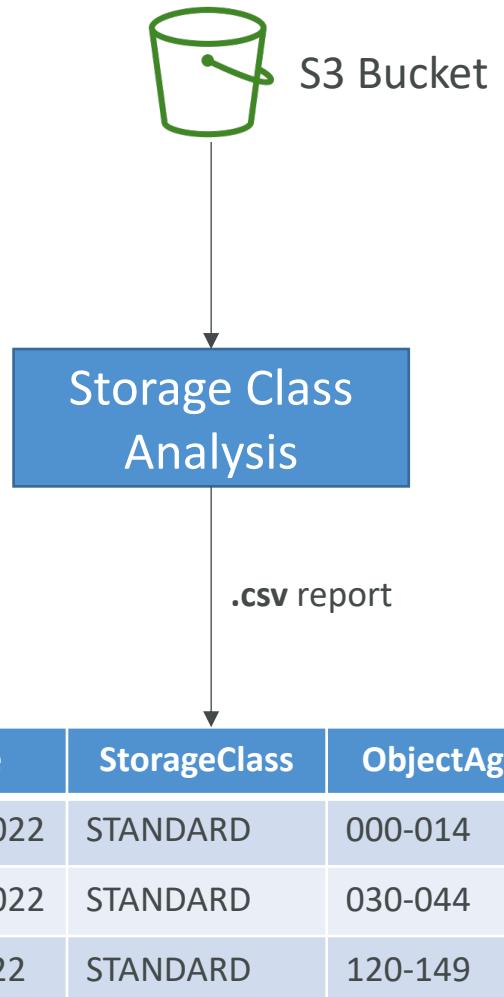


<https://aws.amazon.com/blogs/aws/s3-glacier-select/>



S3 Analytics – Storage Class Analysis

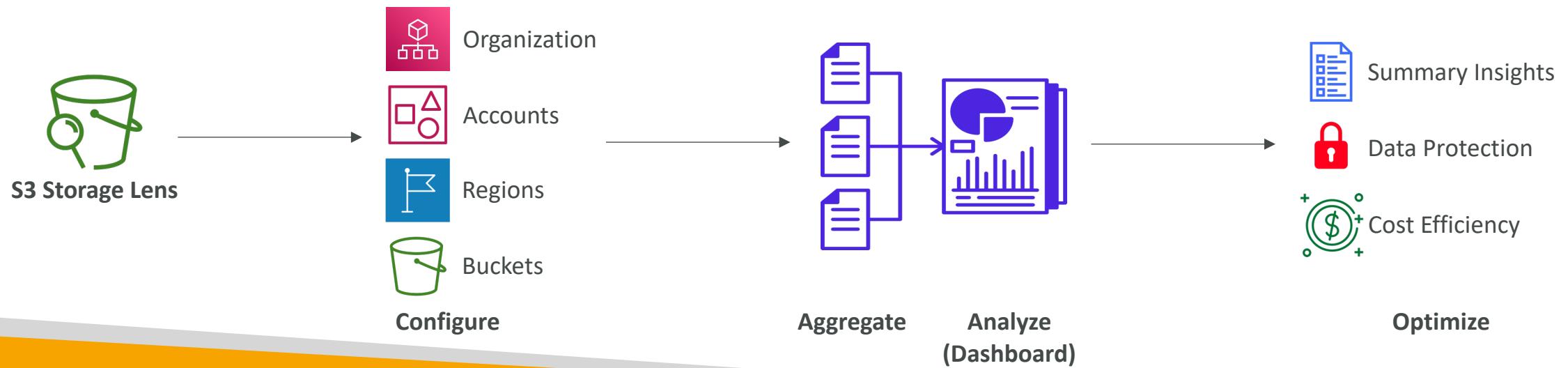
- May be seen as “Storage Class Analysis” at the exam
- Help you decide when to transition objects to the right storage class
- Recommendations for **Standard** and **Standard IA**
 - Does NOT work for One-Zone IA or Glacier
- Report is updated daily
- 24 to 48 hours to start seeing data analysis
- Visualize data in Amazon QuickSight
- Good first step to put together Lifecycle Rules (or improve them)!



S3 – Storage Lens



- Understand, analyze, and optimize storage across entire AWS Organization
- Discover anomalies, identify cost efficiencies, and apply data protection best practices across entire AWS Organization (30 days usage & activity metrics)
- Aggregate data for Organization, specific accounts, regions, buckets, or prefixes
- Default dashboard or create your own dashboards
- Can be configured to export metrics daily to an S3 bucket (CSV, Parquet)



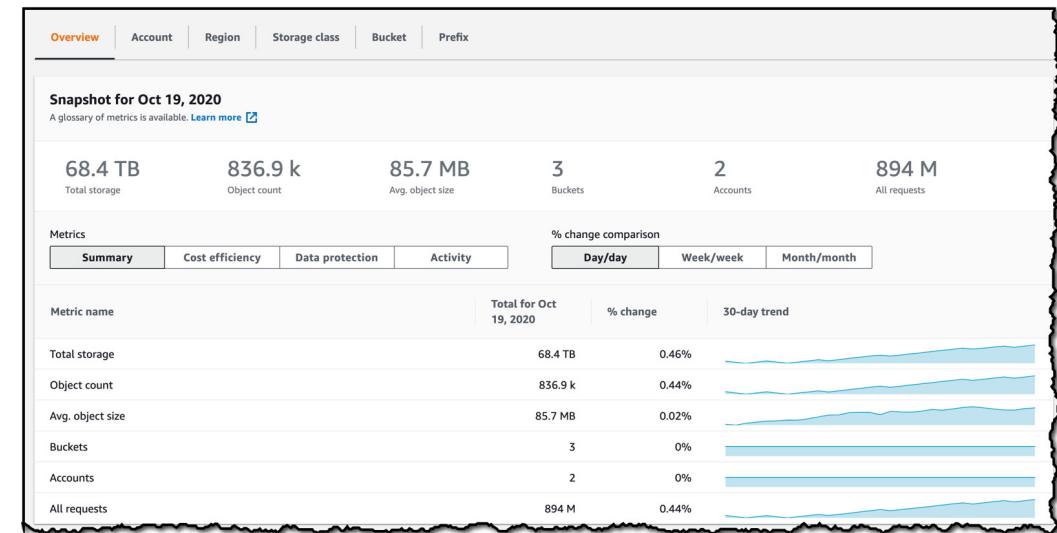


Storage Lens – Default Dashboard

- Visualize summarized insights and trends for both free and advanced metrics
- Default dashboard shows Multi-Region and Multi-Account data
- Preconfigured by Amazon S3
- Can't be deleted, but can be disabled

The screenshot shows the 's3-lens-demo' configuration page. It includes sections for 'Accounts' (2/2 selected), 'Regions' (3/3 selected), 'Storage classes' (2/2 selected), 'Buckets' (3/3 selected), and 'Prefixes' (3/3 selected). Each section has checkboxes for 'Select all [category]' and dropdown menus for 'Choose [category]'. Buttons for 'View dashboard configuration', 'Delete', 'Disable', and a date selector ('2020/10/19') are at the top right.

<https://aws.amazon.com/blogs/aws/s3-storage-lens/>



<https://aws.amazon.com/blogs/aws/s3-storage-lens/>



Storage Lens – Free vs. Paid

- **Free Metrics**

- Automatically available for all customers
- Contains around 28 usage metrics
- Data is available for queries for 14 days

- **Advanced Metrics and Recommendations**

- Additional paid metrics and features
- **Advanced Metrics** – Activity, Advanced Cost Optimization, Advanced Data Protection, Status Code
- **CloudWatch Publishing** – Access metrics in CloudWatch without additional charges
- **Prefix Aggregation** – Collect metrics at the prefix level
- Data is available for queries for 15 months

Metrics selection
Choose additional metrics and functionality.

Metrics selection

Free metrics
Includes usage metrics aggregated at the bucket level. Data is available for queries for 14 days. [Learn more](#)

Advanced metrics and recommendations
Includes options for additional metrics and aggregations and other advanced capabilities. Data is available for queries for 15 months. See [Storage Lens metrics pricing](#) on the Management & analytics tab.

Advanced metrics and recommendations features [Info](#)

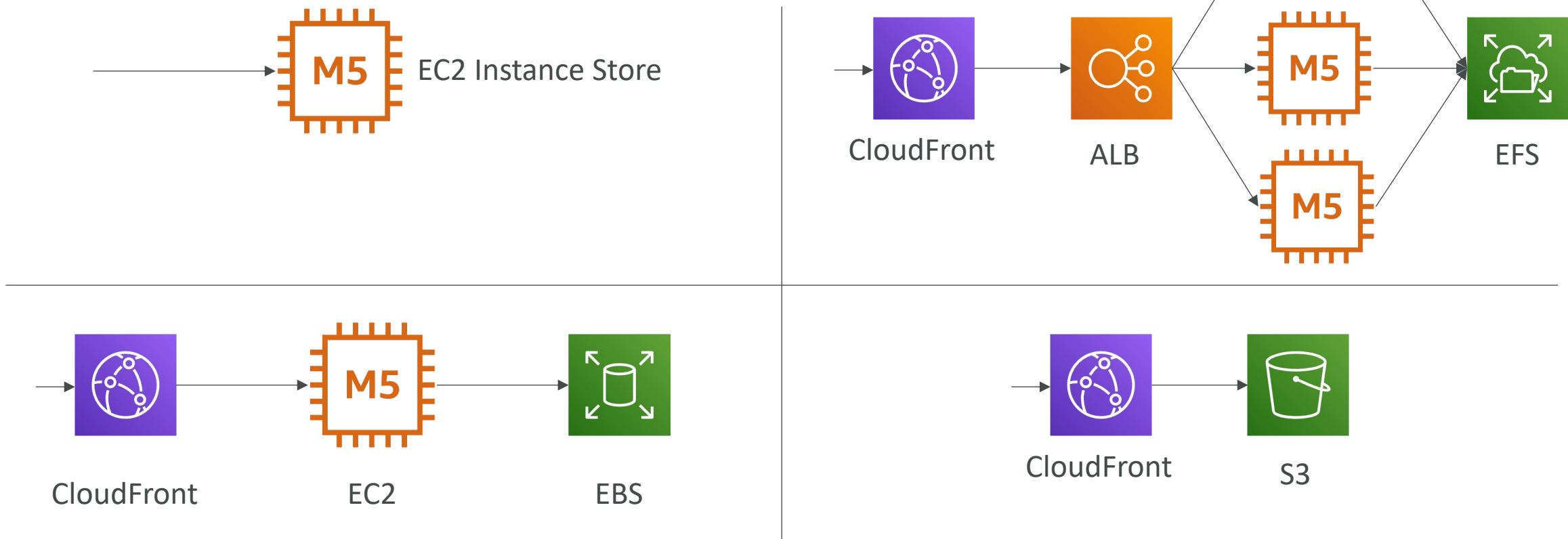
Advanced metrics <input checked="" type="checkbox"/> Choose advanced metrics categories to display in the dashboard. Advanced metrics are not available at the prefix level.	CloudWatch publishing <input type="checkbox"/> Access metrics in CloudWatch without incurring separate CloudWatch metrics publishing charges. See CloudWatch Pricing Prefix-level metrics are not available in CloudWatch.	Prefix aggregation <input type="checkbox"/> Generate insights for usage metrics aggregated by top prefixes.
---	---	---

Advanced metrics categories
Specify which advanced metrics categories to display in the dashboard. [Learn more](#)

Activity metrics
Generate metrics that show details about how your storage is requested, such as requests, bytes uploaded/downloaded, and errors aggregated by bucket.

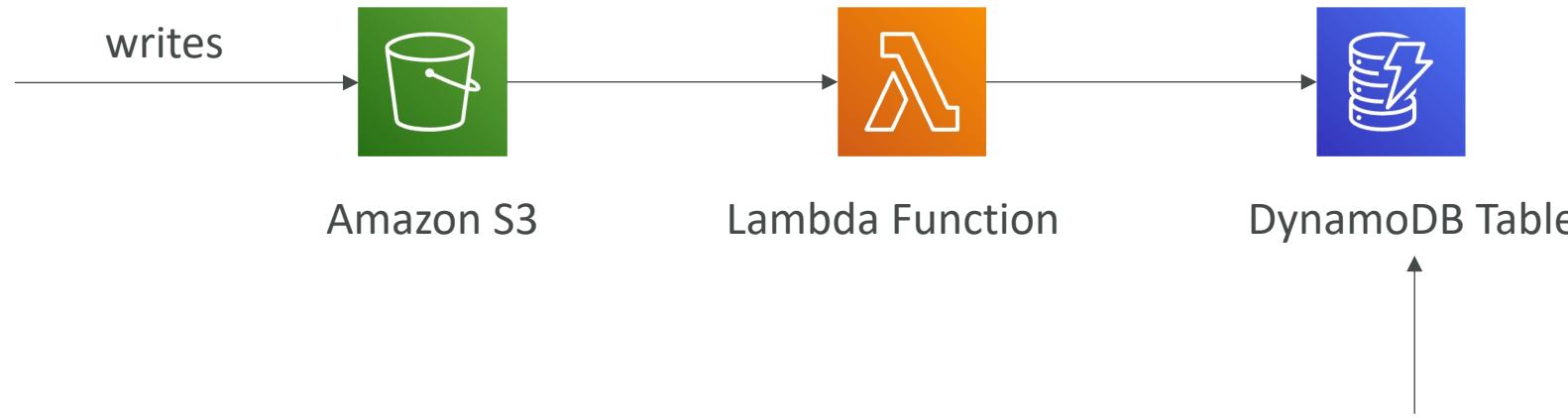
Detailed status code metrics - new

S3 Solution Architecture Exposing Static Objects



S3 Solution Architecture

Indexing objects in DynamoDB

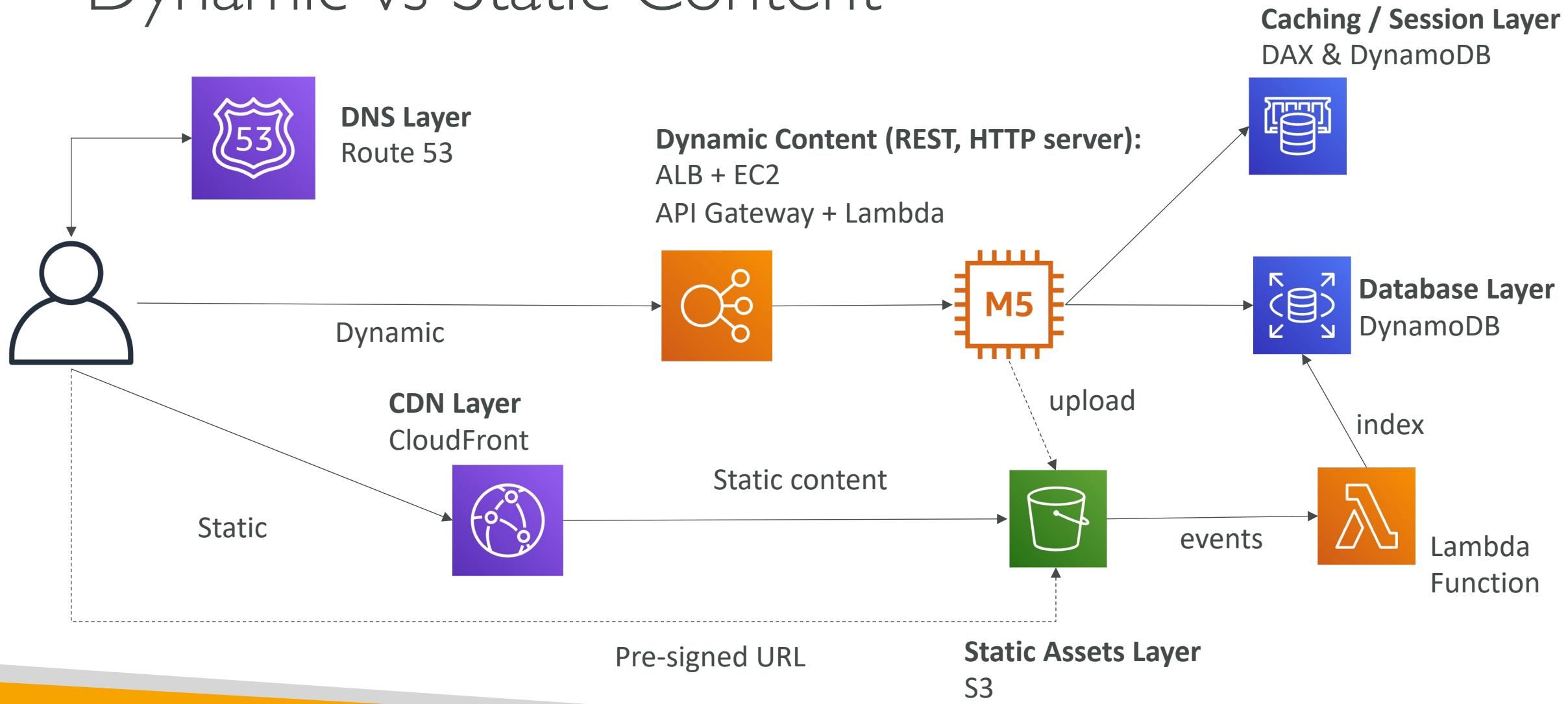


API for object metadata

- Search by date
- Total storage used by a customer
- List of all objects with certain attributes
- Find all objects uploaded within a date range

Solution Architecture on AWS

Dynamic vs Static Content



Amazon FSx – Overview



- Launch 3rd party high-performance file systems on AWS
- Fully managed service



FSx for Lustre



FSx for
Windows
File Server



FSx for
NetApp ONTAP



FSx for
OpenZFS

Amazon FSx for Windows (File Server)



- 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
- Supports Microsoft's Distributed File System (DFS) Namespaces (group files across multiple FS)
- Scale up to 10s of GB/s, millions of IOPS, 100s PB of data
- Storage Options:
 - SSD – latency sensitive workloads (databases, media processing, data analytics, ...)
 - HDD – broad spectrum of workloads (home directory, CMS, ...)
- Can be accessed from your on-premises infrastructure (VPN or Direct Connect)
- Can be configured to be Multi-AZ (high availability)
- Data is backed-up daily to S3

Amazon FSx for Lustre



- Lustre is a type of parallel distributed file system, for large-scale computing
- The name Lustre is derived from “Linux” and “cluster”
- Machine Learning, **High Performance Computing (HPC)**
- Video Processing, Financial Modeling, Electronic Design Automation
- Scales up to 100s GB/s, millions of IOPS, sub-ms latencies
- Storage Options:
 - SSD – low-latency, IOPS intensive workloads, small & random file operations
 - HDD – throughput-intensive workloads, large & sequential file operations
- **Seamless integration with S3**
 - Can “read S3” as a file system (through FSx)
 - Can write the output of the computations back to S3 (through FSx)
- **Can be used from on-premises servers (VPN or Direct Connect)**

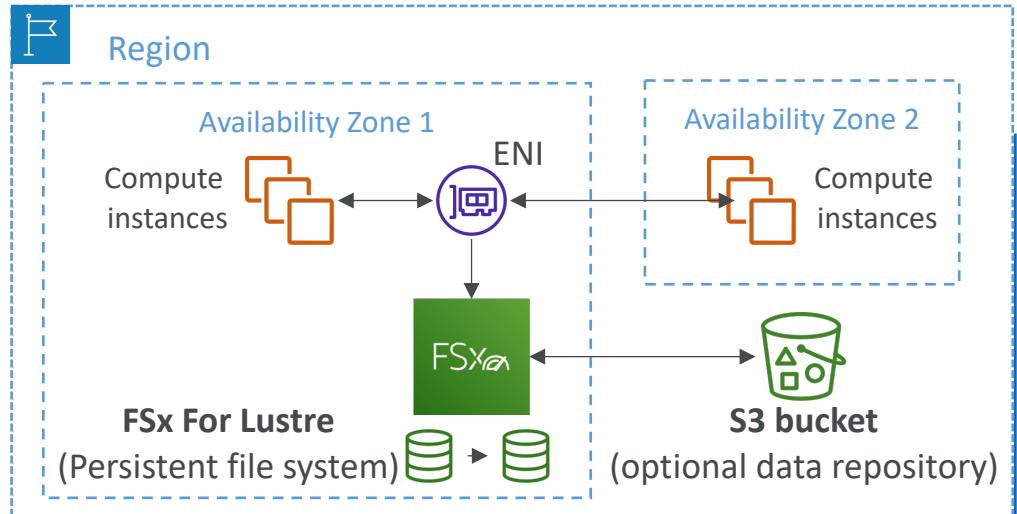
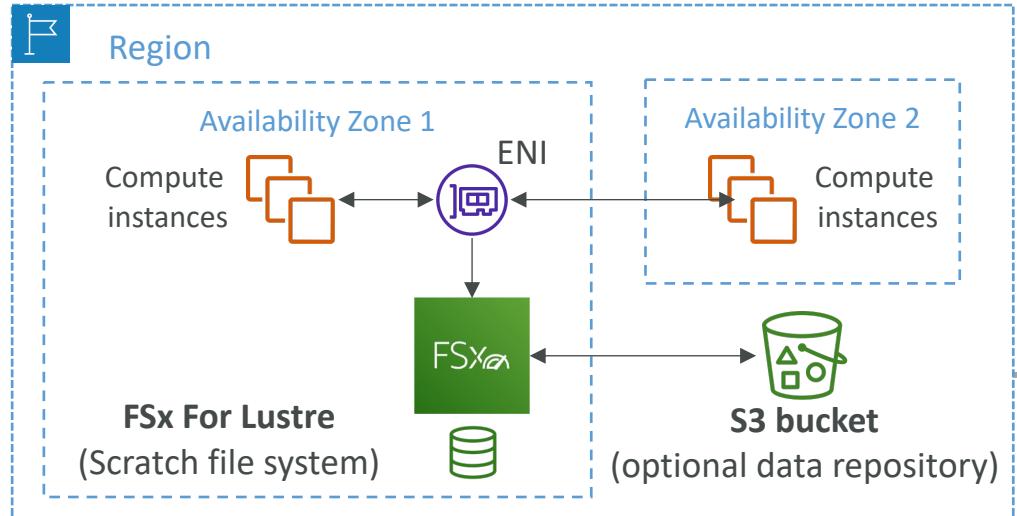
FSx Lustre - File System Deployment Options

• Scratch File System

- Temporary storage
- Data is not replicated (doesn't persist if file server fails)
- High burst (6x faster, 200MBps per TiB)
- Usage: short-term processing, optimize costs

• Persistent File System

- Long-term storage
- Data is replicated within same AZ
- Replace failed files within minutes
- Usage: long-term processing, sensitive data



Amazon FSx for NetApp ONTAP



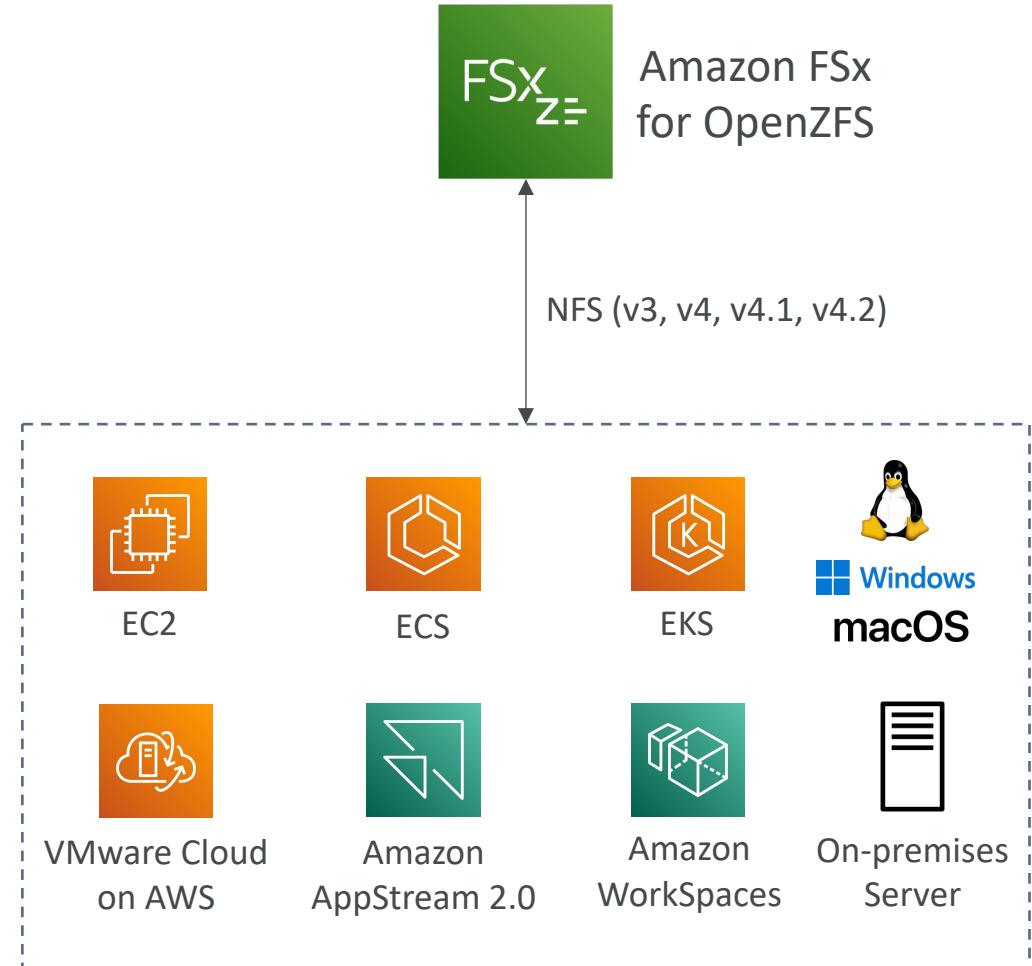
- Managed NetApp ONTAP on AWS
- File System compatible with NFS, SMB, iSCSI protocol
- Move workloads running on ONTAP or NAS to AWS
- Works with:
 - Linux
 - Windows
 - MacOS
 - VMware Cloud on AWS
 - Amazon Workspaces & AppStream 2.0
 - Amazon EC2, ECS and EKS
- Storage shrinks or grows automatically
- Snapshots, replication, low-cost, compression and data de-duplication
- Point-in-time instantaneous cloning (helpful for testing new workloads)



Amazon FSx for OpenZFS

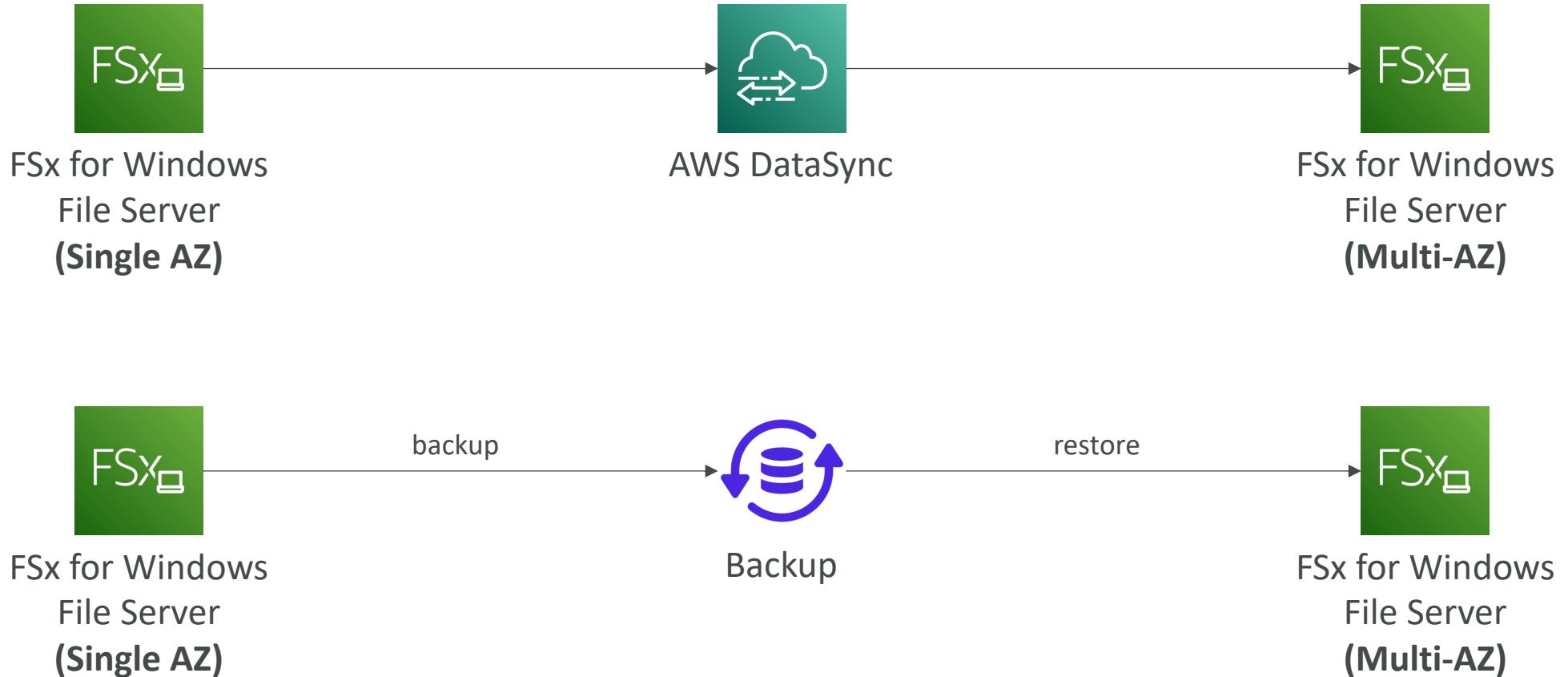


- Managed OpenZFS file system on AWS
- File System compatible with NFS (v3, v4, v4.1, v4.2)
- Move workloads running on ZFS to AWS
- Works with:
 - Linux
 - Windows
 - MacOS
 - VMware Cloud on AWS
 - Amazon Workspaces & AppStream 2.0
 - Amazon EC2, ECS and EKS
- Up to 1,000,000 IOPS with < 0.5ms latency
- Snapshots, compression and low-cost
- **Point-in-time instantaneous cloning (helpful for testing new workloads)**



FSx – Solution Architecture

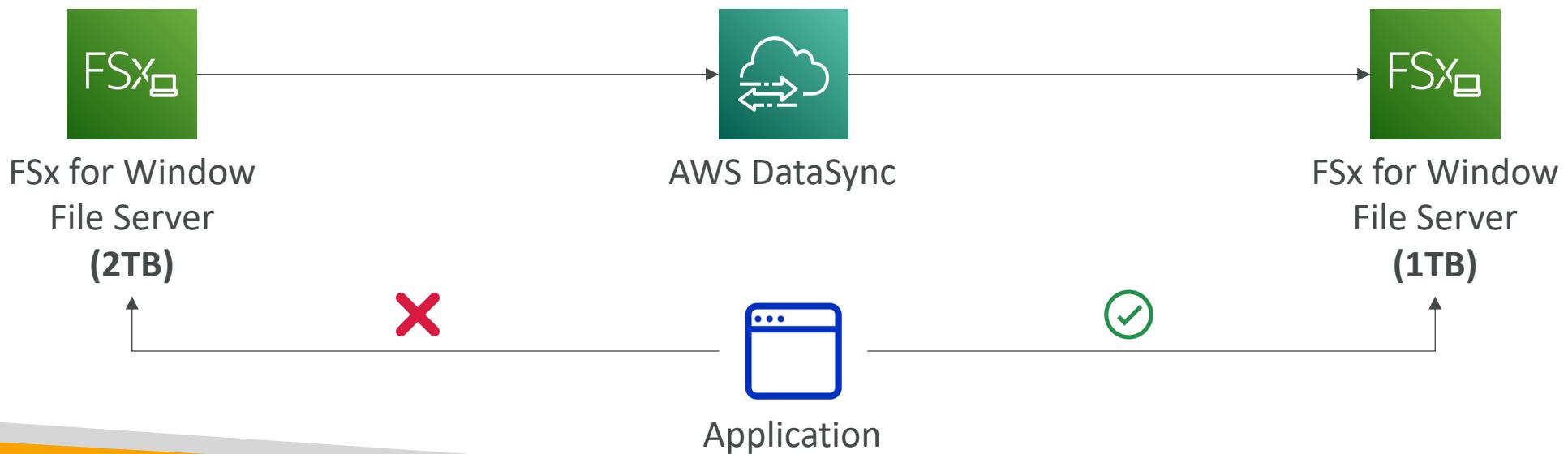
Migration from Single AZ to Multi AZ



FSx – Solution Architecture

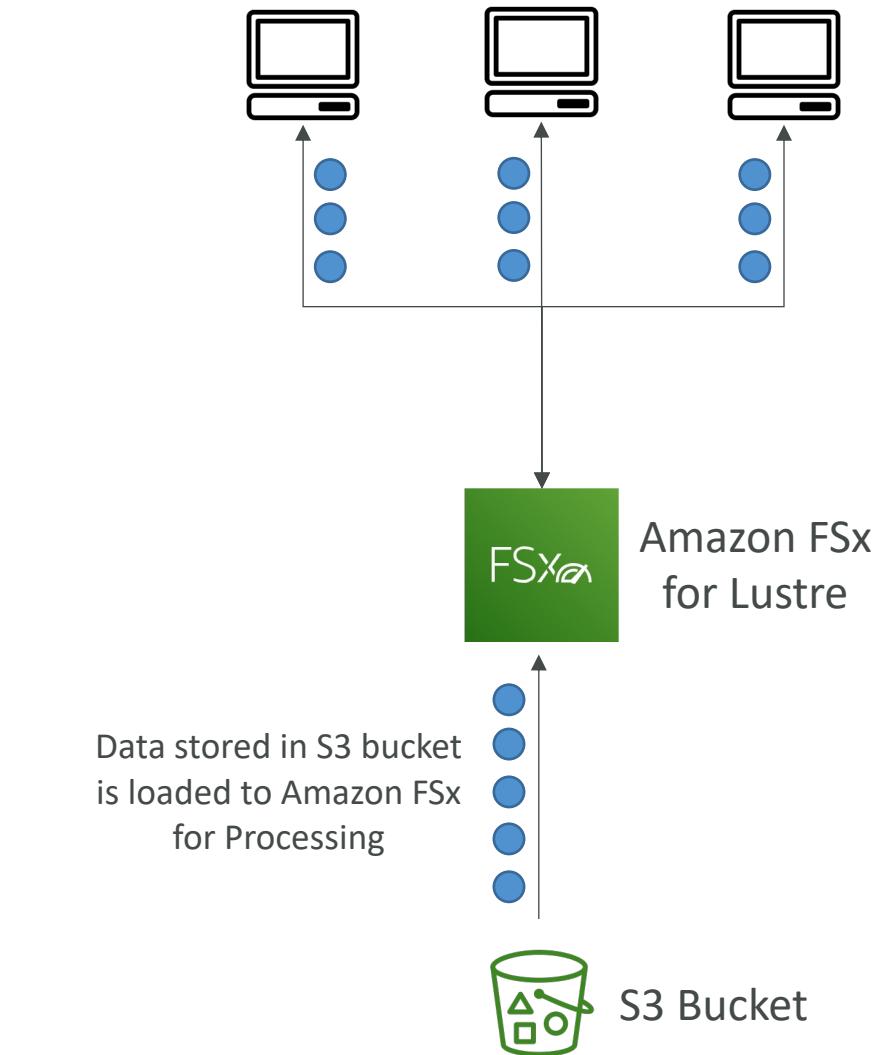
Decrease FSx Volume Size

- If you take a backup, you can only restore to a same size
- You can only *increase* the amount of storage capacity for a file system; you cannot decrease storage capacity.
- Instead, create a new FSx (smaller), use DataSync to sync data and then migrate your app over



FSx for Lustre – Data Lazy Loading

- Any data processing job on Lustre with S3 as an input data source can be started without Lustre doing a full download of the dataset first
- Data is lazy loaded: only the data that is actually processed is loaded, meaning you can decrease your costs and latency
- Data is also loaded only once, therefore you reduce your requests on Amazon S3



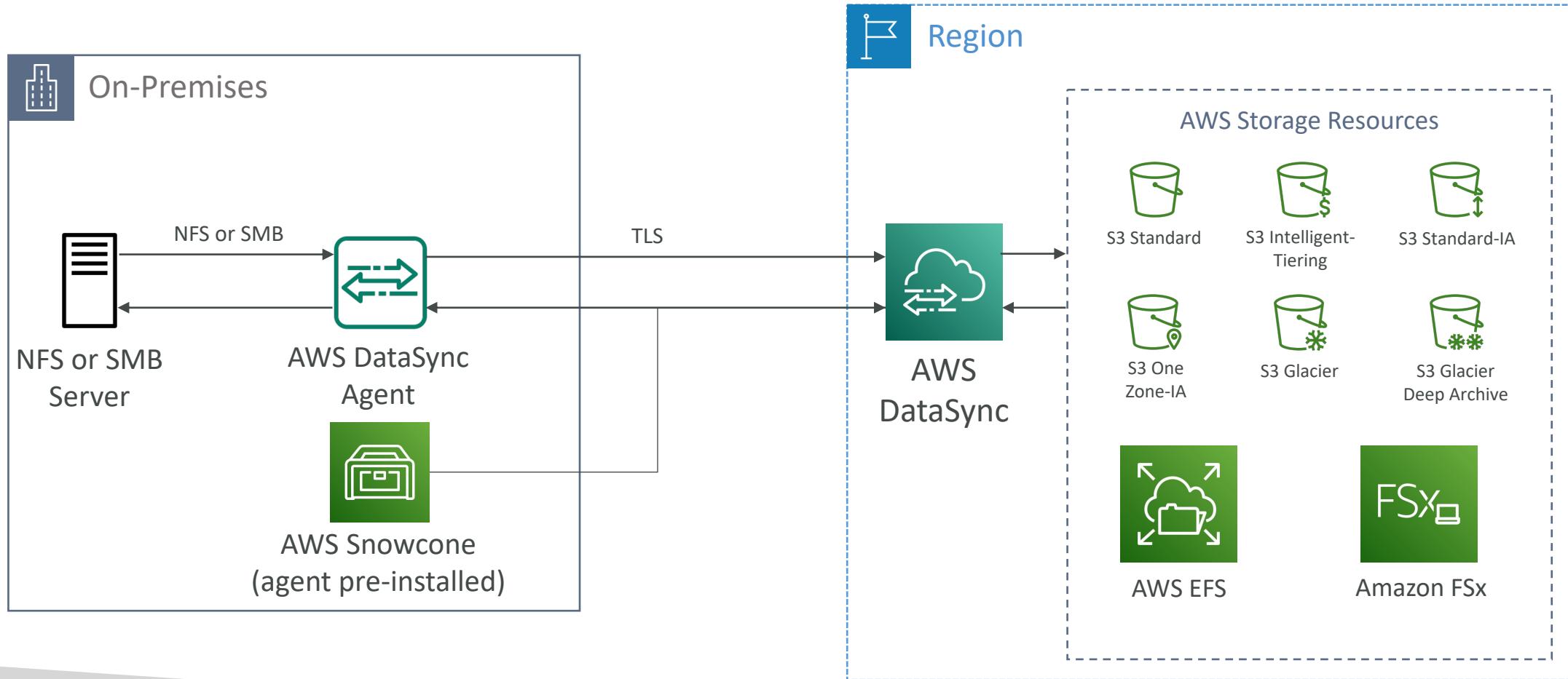


AWS DataSync

- Move large amount of data to and from
 - On-premises / other cloud to AWS (NFS, SMB, HDFS, S3 API...) – needs agent
 - AWS to AWS (different storage services) – no agent needed
- Can synchronize to:
 - Amazon S3 (any storage classes – including Glacier)
 - Amazon EFS
 - Amazon FSx (Windows, Lustre, NetApp, OpenZFS...)
- Replication tasks can be scheduled hourly, daily, weekly
- **File permissions and metadata are preserved (NFS POSIX, SMB...)**
- One agent task can use 10 Gbps, can setup a bandwidth limit

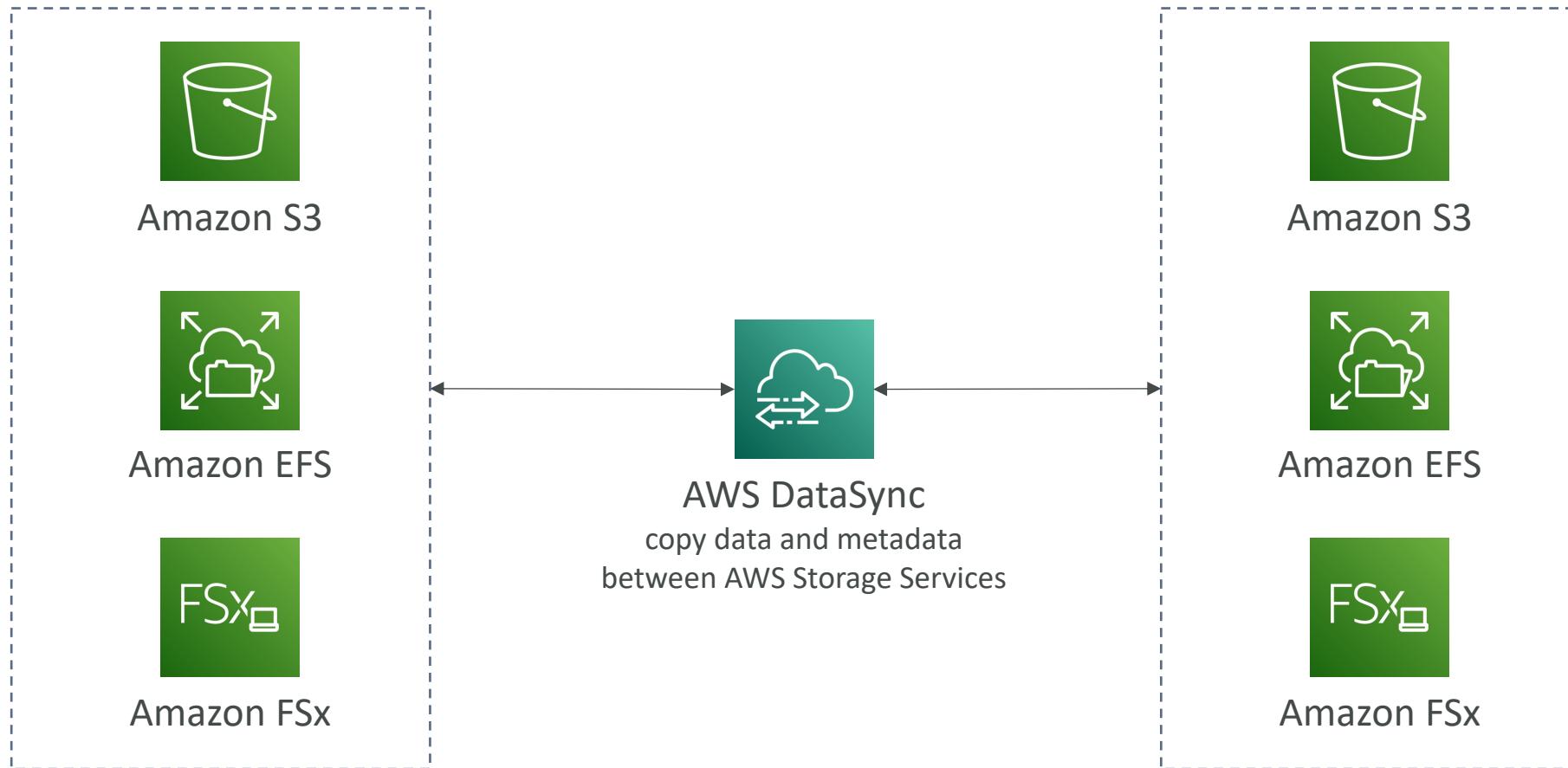
AWS DataSync

NFS / SMB to AWS (S3, EFS, FSx...)



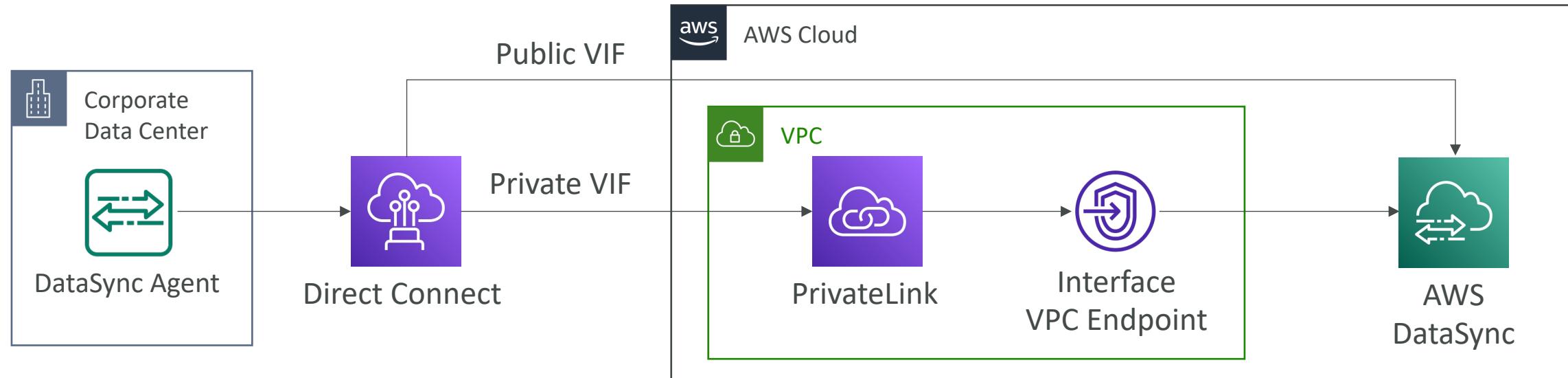
AWS DataSync

Transfer between AWS storage services

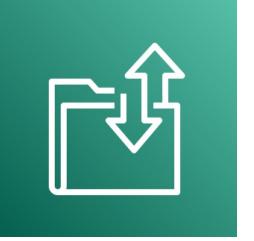


AWS DataSync

Private VIF through Direct Connect

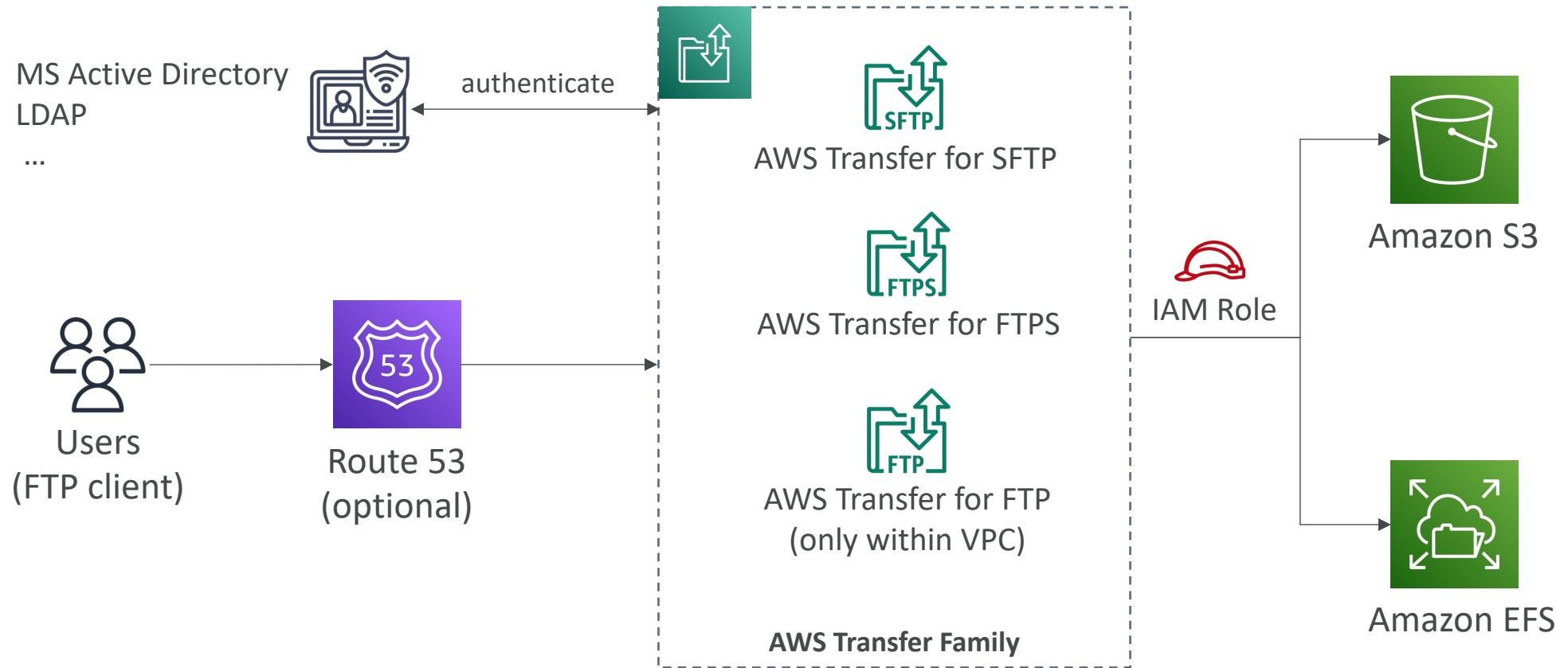


AWS Transfer Family



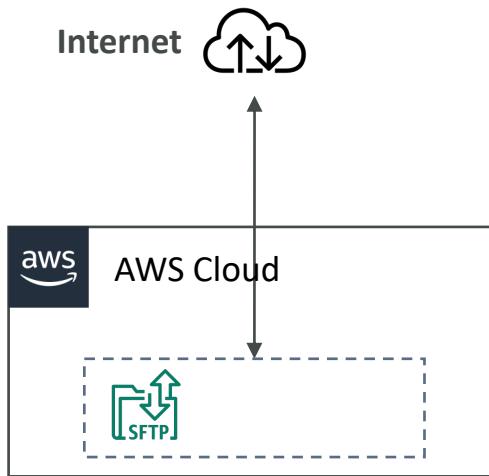
- A fully-managed service for file transfers into and out of Amazon S3 or Amazon EFS using the FTP protocol
- Supported Protocols
 - AWS Transfer for FTP (File Transfer Protocol (FTP))
 - AWS Transfer for FTPS (File Transfer Protocol over SSL (FTPS))
 - AWS Transfer for SFTP (Secure File Transfer Protocol (SFTP))
- Managed infrastructure, Scalable, Reliable, Highly Available (multi-AZ)
- Pay per provisioned endpoint per hour + data transfers in GB
- Store and manage users' credentials within the service
- Integrate with existing authentication systems (Microsoft Active Directory, LDAP, Okta, Amazon Cognito, custom)
- Usage: sharing files, public datasets, CRM, ERP, ...

AWS Transfer Family



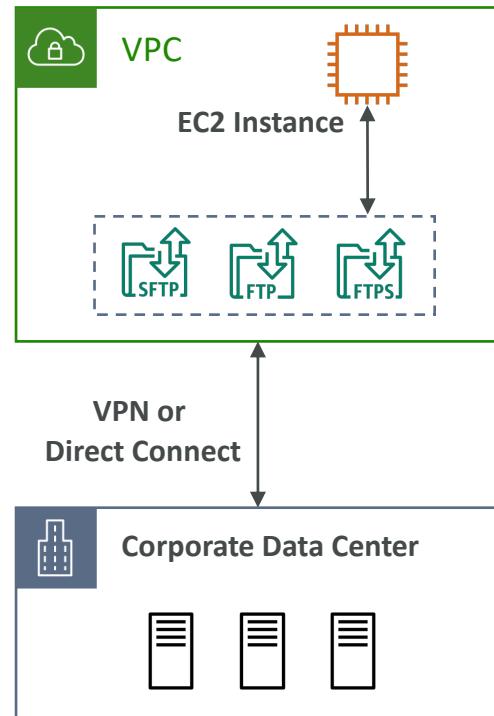
AWS Transfer Family – Endpoint Types

Public Endpoint



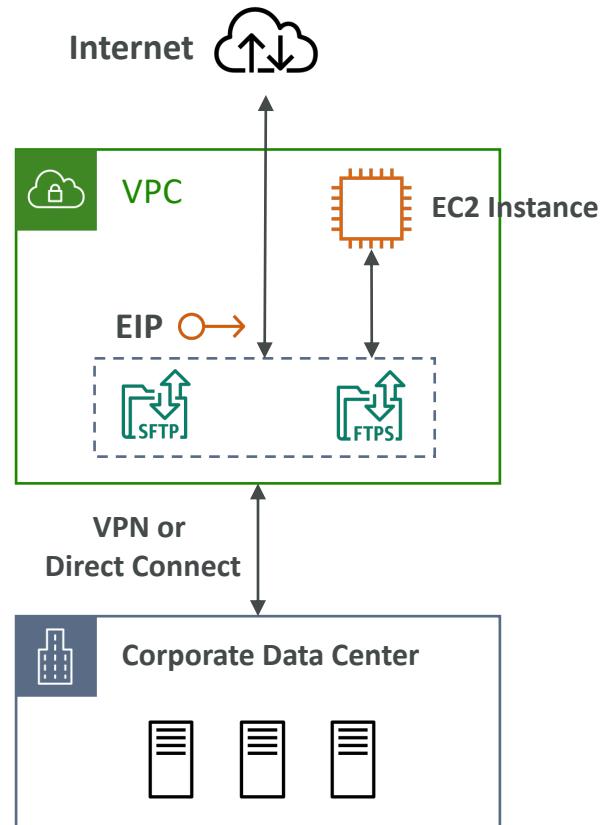
- IPs managed by AWS (subject to change, use DNS names)
- Can't setup allow lists by source IP addresses

VPC Endpoint with Internal Access



- Static private IPs
- Setup allow lists (SGs & NACLs)

VPC Endpoint with Internet-facing Access



- Static private IPs
- Static public IPs (EIPs)
- Setup Security Groups

Price of Storage (GB Month)

S3 (GB/Month)

Class	Price
Standard	\$0.023
Standard IA	\$0.0125
One-Zone IA	\$0.01
Intelligent Tiering	\$0.023
Glacier Instant Retrieval	\$0.004
Glacier Flexible Retrieval	\$0.0036
Glacier Deep Arcvhive	\$0.00099

EBS (GB/Month)

Class	Price
io1	\$0.125 + \$0.065/iops
io2	\$0.125 + \$0.065/iops
gp2	\$0.10
gp3	\$0.08
st1	\$0.045
sc1	\$0.015

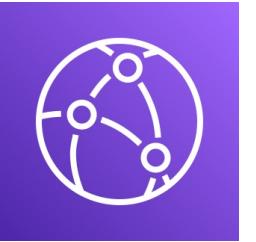
EFS (GB/Month)

Class	Price
Standard	\$0.30
One-Zone	\$0.16
Standard IA	\$0.025
One-Zone IA	\$0.0133

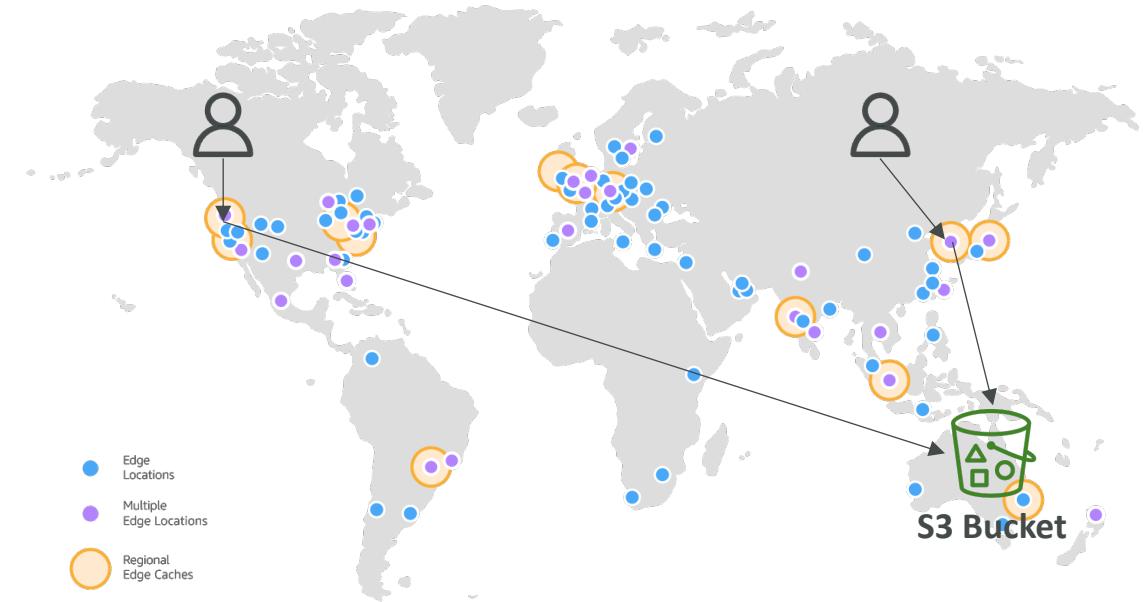


Caching

Amazon CloudFront



- Content Delivery Network (CDN)
- Improves read performance, content is cached at the edge
- 225+ Point of Presence globally (215+ Edge Locations & 13 Regional Edge Caches)
- Protect against Network and Application layer attacks (e.g., DDoS attacks)
- Integration with AWS Shield, AWS WAF, and Route 53
- Can expose external HTTPS and can talk to internal HTTPS backends
- Supports WebSocket protocol

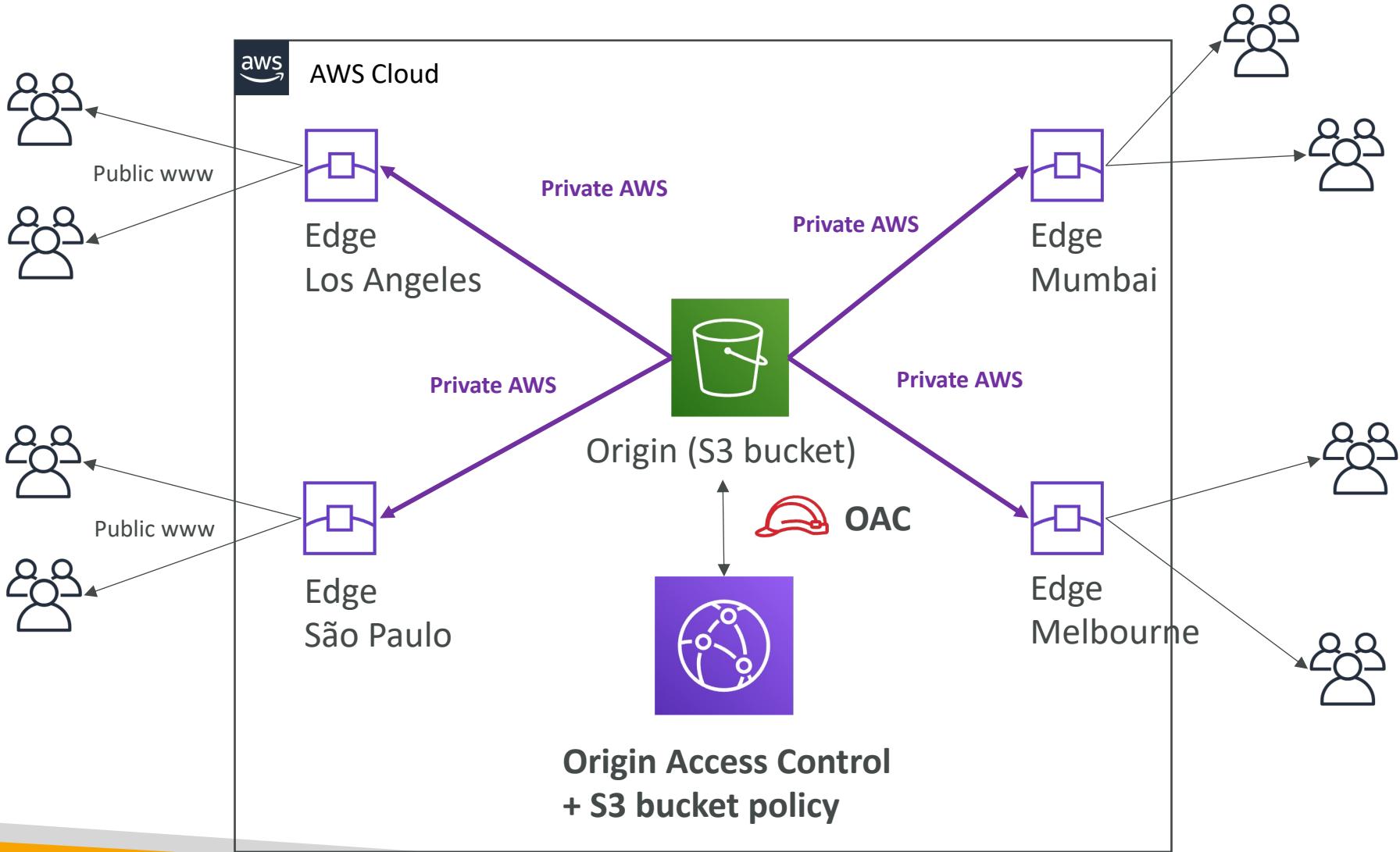


Source: <https://aws.amazon.com/cloudfront/features/>

CloudFront – Origins

- S3 Bucket
 - For distributing files
 - Enhanced security with CloudFront Origin Access Control (OAC)
 - OAC is replacing Origin Access Identity (OAI)
 - CloudFront can be used as an ingress (to upload files to S3)
- S3 Bucket configured as a website
 - First, enable Static Website hosting on the bucket
- MediaStore Container & MediaPackage Endpoint
 - To deliver Video On Demand (VOD) or live streaming video using AWS Media Services
- Custom Origin (HTTP)
 - EC2 instance
 - Elastic Load Balancer (CLB or ALB)
 - API Gateway (for more control... otherwise use API Gateway Edge)
 - Any HTTP backend you want

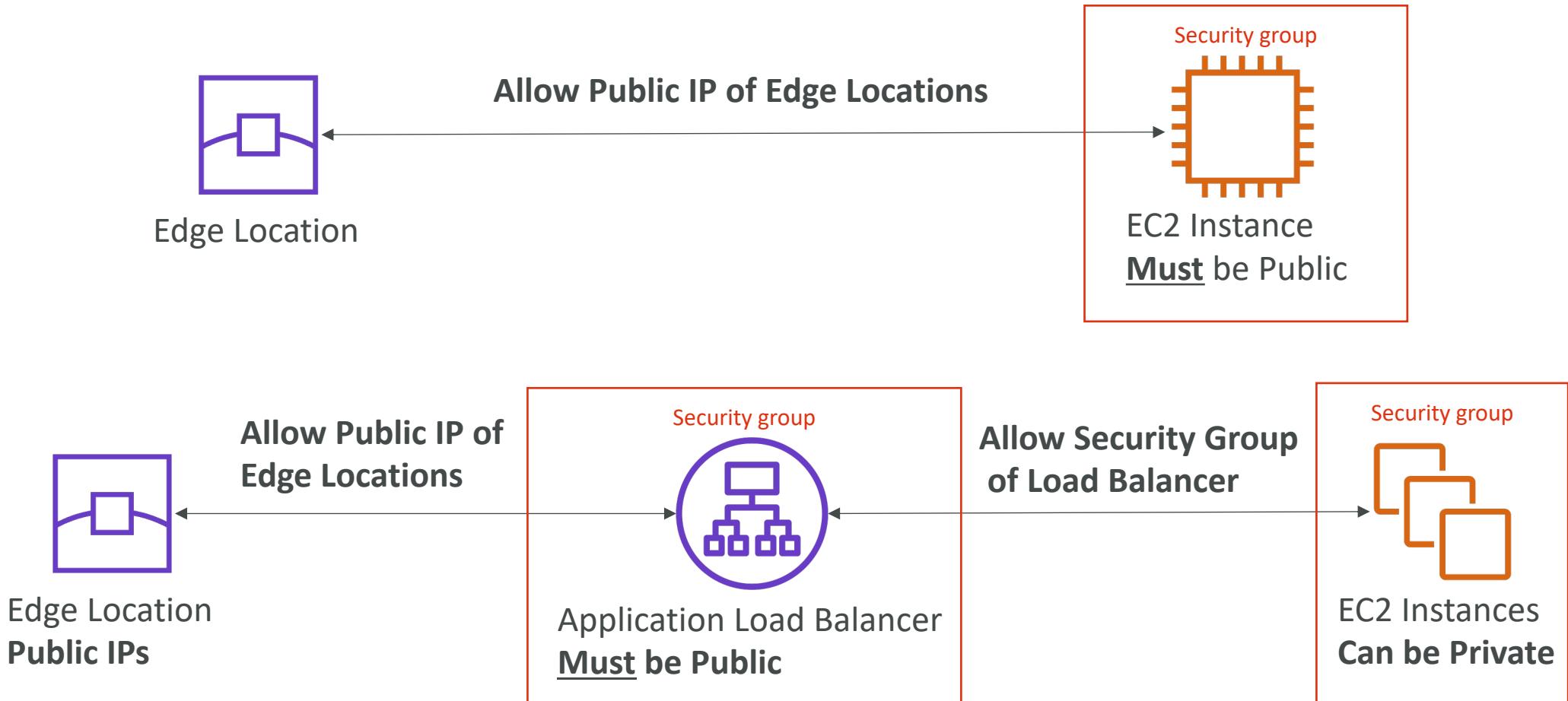
CloudFront – S3 as an Origin



CloudFront vs S3 Cross Region Replication

- CloudFront:
 - Global Edge network
 - Files are cached for a TTL (maybe a day)
 - 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

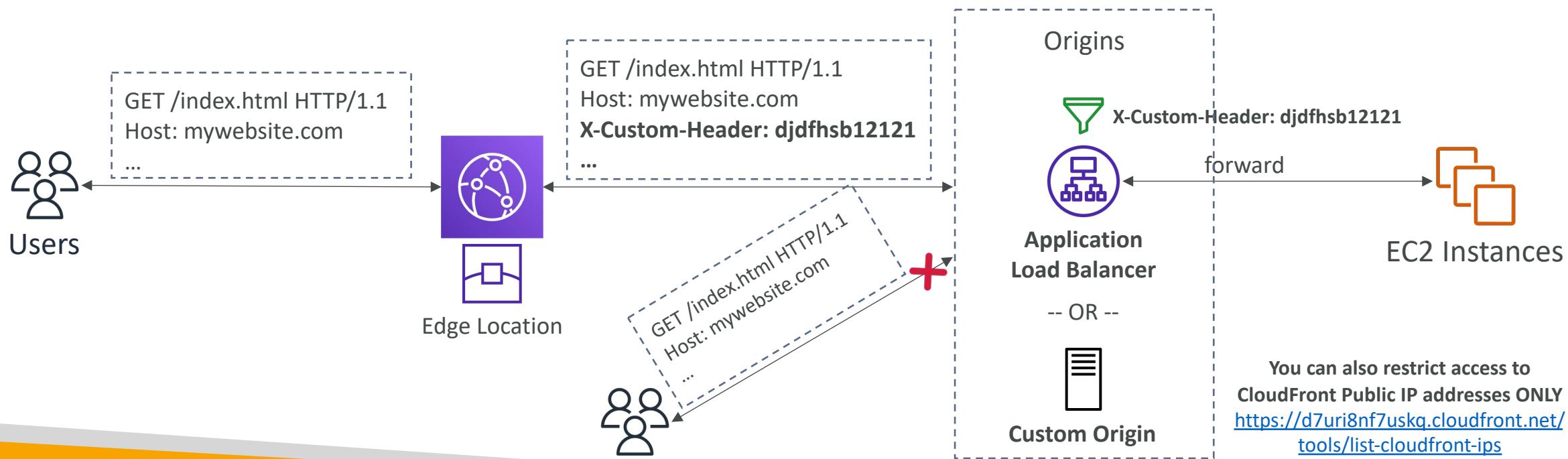
CloudFront – EC2 or ALB as an origin



<http://d7uri8nf7uskq.cloudfront.net/tools/list-cloudfront-ips>

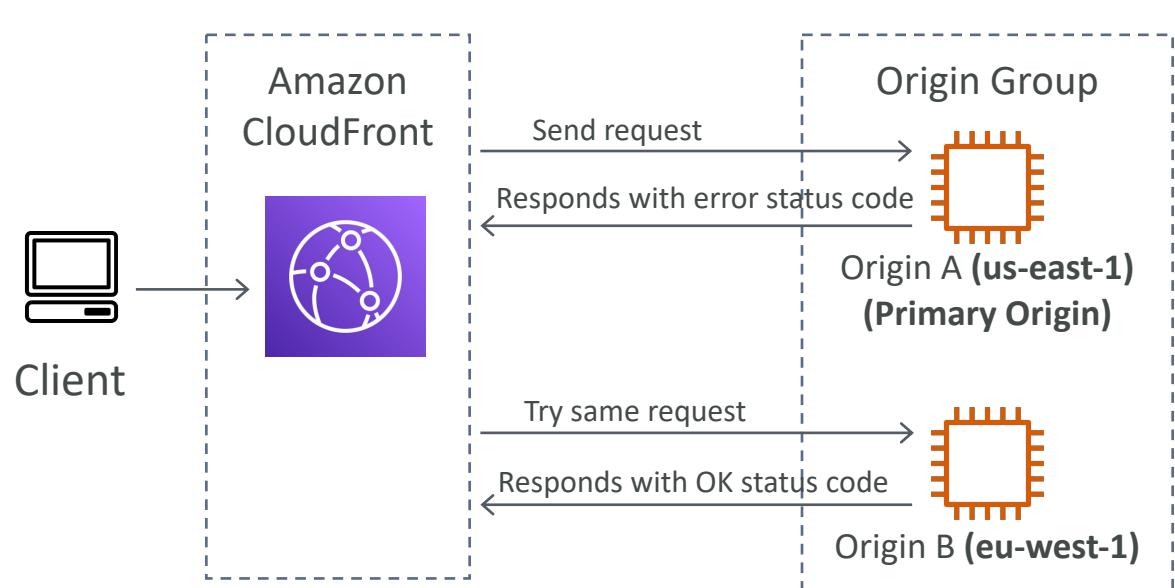
CloudFront – Restrict Access to Application Load Balancers and Custom Origins

- Prevent direct access to your ALB or Custom Origins (only access through CloudFront)
- First, configure CloudFront to add a **Custom HTTP Header** to requests it sends to the ALB
- Second, configure the ALB to only forward requests that contain that Custom HTTP Header
- Keep the custom header name and value secret!

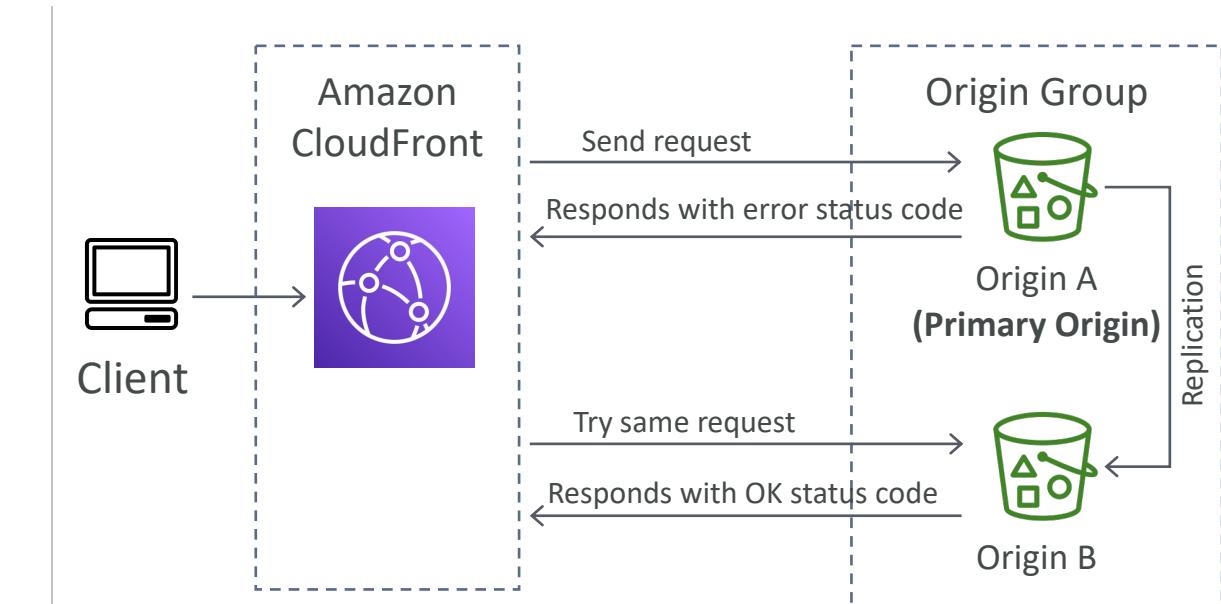


CloudFront – Origin Groups

- To increase high-availability and do failover
- Origin Group: one primary and one secondary origin
- If the primary origin fails, the second one is used
- Origins can be cross AWS Regions



Cross-Region High Availability



S3 + CloudFront – Region-level High Availability

CloudFront Geo Restriction

- You can restrict who can access your distribution
 - **Allow list:** Allow your users to access your content only if they're in one of the countries on a list of approved countries.
 - **Block list:** Prevent your users from accessing your content if they're in one of the countries on a blacklist of banned countries.
- The “country” is determined using a 3rd party Geo-IP database
- Use case: Copyright Laws to control access to content
- Note: the geo header *CloudFront-Viewer-Country* is in Lambda@Edge

CloudFront – Pricing

- CloudFront Edge locations are all around the world
- The cost of data out per edge location varies

Per Month	United States, Mexico, & Canada	Europe & Israel	South Africa, Kenya, & Middle East	South America	Japan	Australia & New Zealand	Hong Kong, Philippines, Singapore, South Korea, Taiwan, & Thailand	India
First 10TB	\$0.085	\$0.085	\$0.110	\$0.110	\$0.114	\$0.114	\$0.140	\$0.170
Next 40TB	\$0.080	\$0.080	\$0.105	\$0.105	\$0.089	\$0.098	\$0.135	\$0.130
Next 100TB	\$0.060	\$0.060	\$0.090	\$0.090	\$0.086	\$0.094	\$0.120	\$0.110
Next 350TB	\$0.040	\$0.040	\$0.080	\$0.080	\$0.084	\$0.092	\$0.100	\$0.100
Next 524TB	\$0.030	\$0.030	\$0.060	\$0.060	\$0.080	\$0.090	\$0.080	\$0.100
Next 4PB	\$0.025	\$0.025	\$0.050	\$0.050	\$0.070	\$0.085	\$0.070	\$0.100
Over 5PB	\$0.020	\$0.020	\$0.040	\$0.040	\$0.060	\$0.080	\$0.060	\$0.100

lower higher

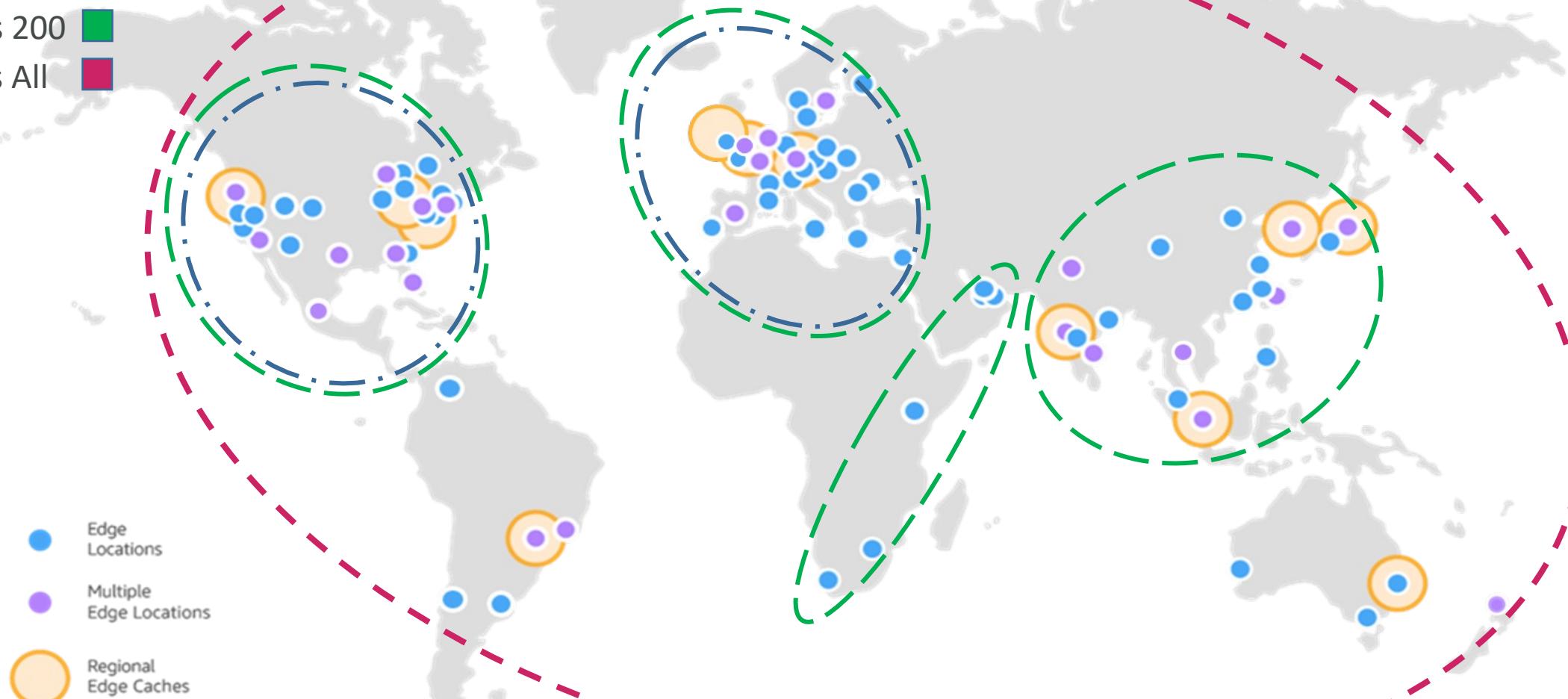

CloudFront – Price Classes

- You can reduce the number of edge locations for cost reduction
- Three price classes:
 - I. Price Class All: all regions – best performance
 2. Price Class 200: most regions, but excludes the most expensive regions
 3. Price Class 100: only the least expensive regions

Edge Locations Included Within	United States, Mexico, & Canada	Europe & Israel	South Africa, Kenya, & Middle East	South America	Japan	Australia & New Zealand	Hong Kong, Philippines, Singapore, South Korea, Taiwan, & Thailand	India
Price Class All	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Price Class 200	Yes	Yes	Yes	x	Yes	x	Yes	Yes
Price Class 100	Yes	Yes	x	x	x	x	x	x

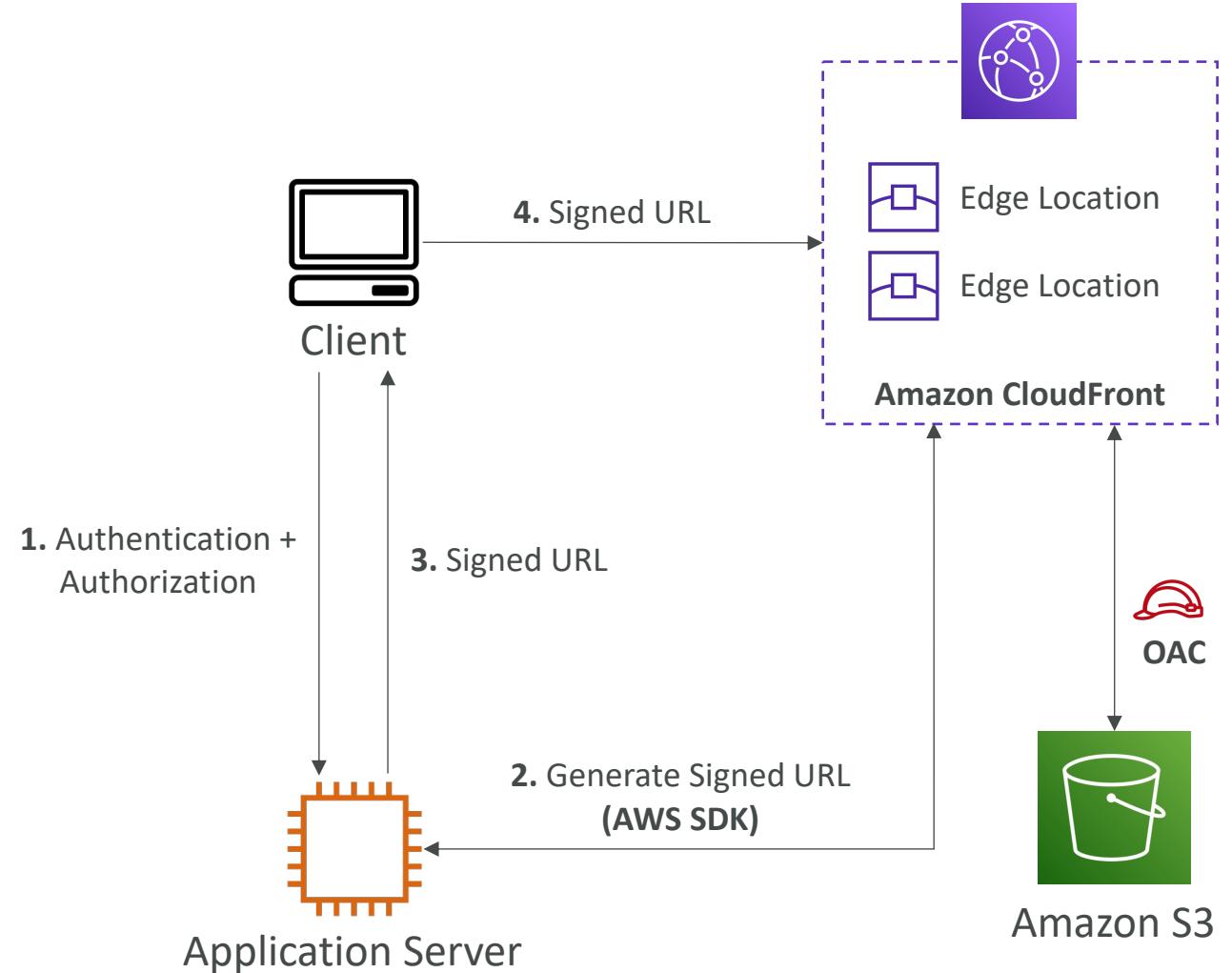
CloudFront - Price Class

Prices Class 100 ■
Prices Class 200 ■
Prices Class All ■



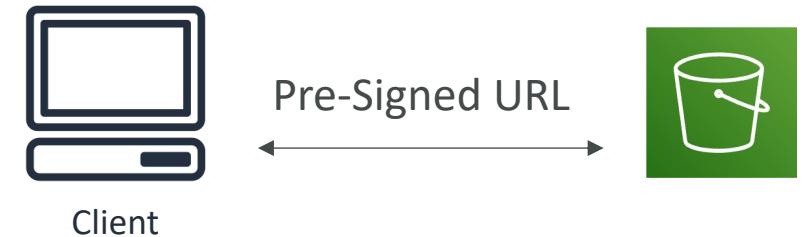
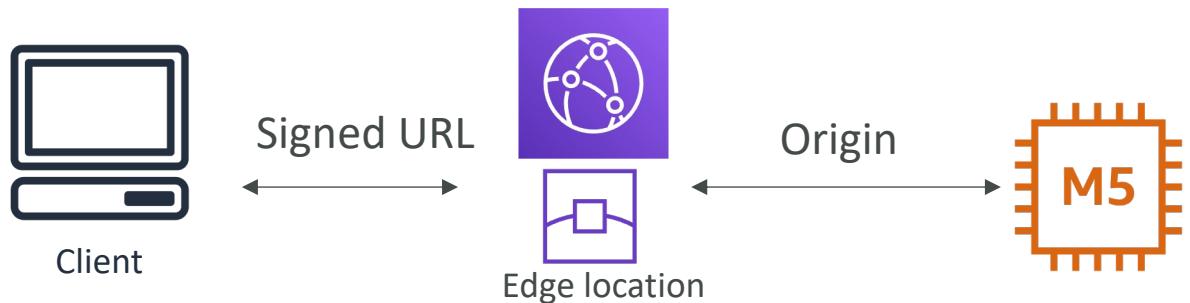
CloudFront Signed URL Diagram

- Signed URL with expiration to control access to content in CloudFront
- The Signed URLs are generated by an API call into CloudFront as a trusted signer



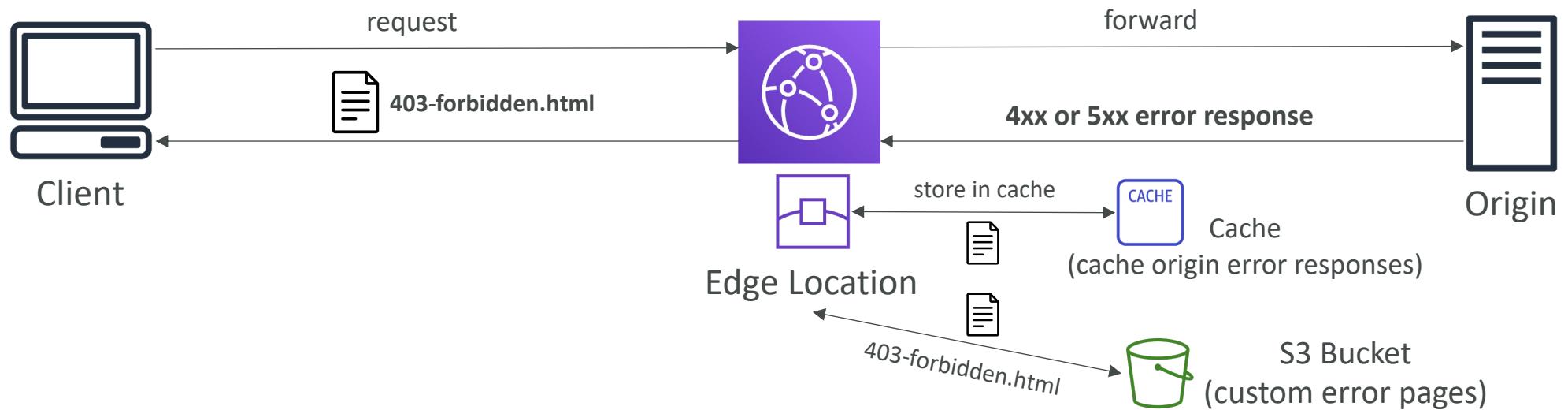
CloudFront Signed URL vs S3 Pre-Signed URL

- CloudFront Signed URL:
 - Allow access to a path, no matter the origin
 - Account wide key-pair, only the root can manage it
 - Can filter by IP, path, date, expiration
 - Can leverage caching features
- S3 Pre-Signed URL:
 - Issue a request as the person who pre-signed the URL
 - Uses the IAM key of the signing IAM principal
 - Limited lifetime



CloudFront – Custom Error Pages

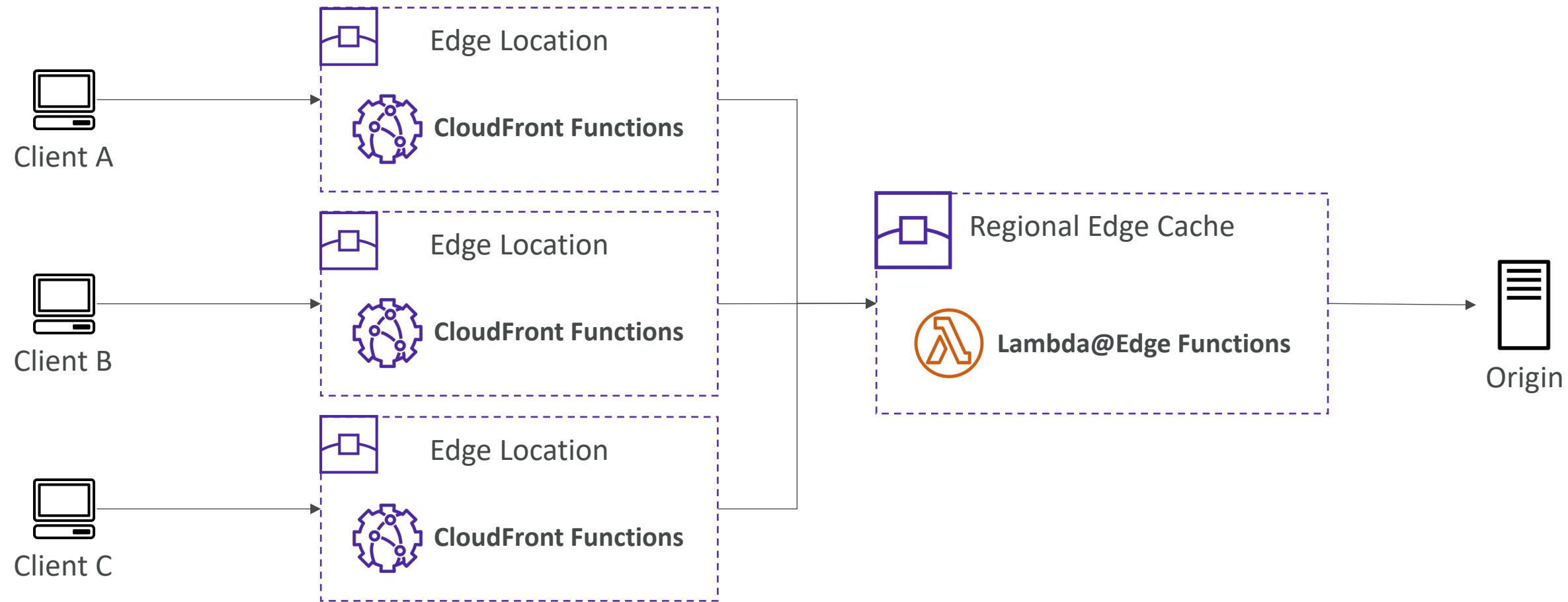
- Return an object to the viewer (e.g., .html) when your origin returns an HTTP 4xx or 5xx status code to CloudFront
- Use **Error Caching Minimum TTL** to specify how long CloudFront caches the custom error pages



CloudFront – Customization At The Edge

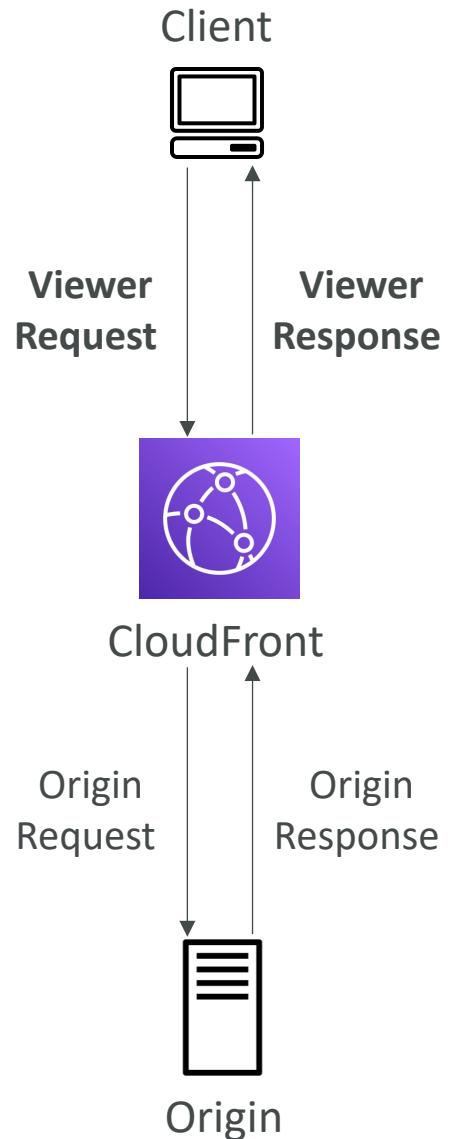
- Many modern applications execute some form of the logic at the edge
- **Edge Function:**
 - A code that you write and attach to CloudFront distributions
 - Runs close to your users to minimize latency
 - Doesn't have any cache, only to change requests/responses
 - CloudFront provides two types: **CloudFront Functions & Lambda@Edge**
- Use cases:
 - Manipulate HTTP requests and responses
 - Implement request filtering before reaching your application
 - User authentication and authorization
 - Generate HTTP responses at the edge
 - A/B Testing
 - Bot mitigation at the edge
- You don't have to manage any servers, deployed globally

CloudFront Functions & Lambda@Edge



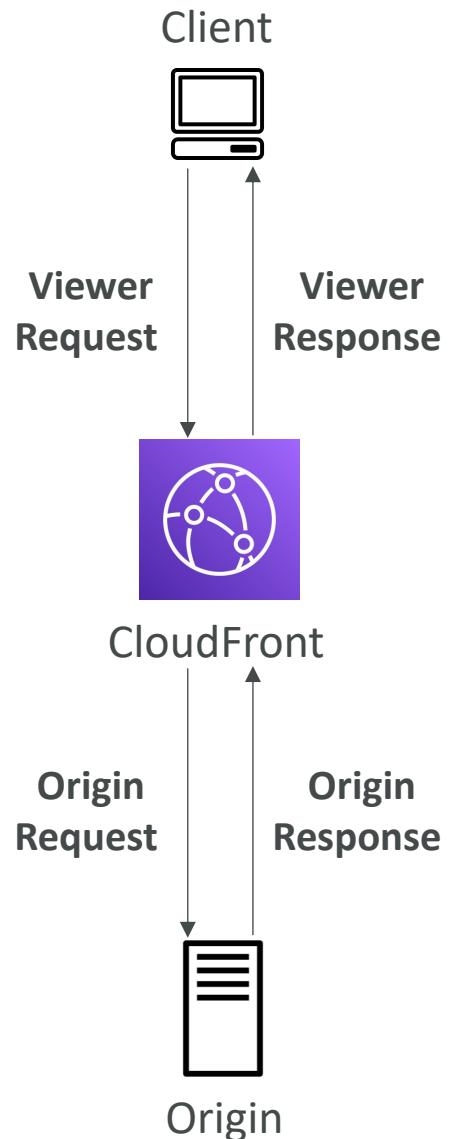
CloudFront – CloudFront Functions

- Lightweight functions written in JavaScript
- For high-scale, latency-sensitive CDN customizations
- Sub-ms startup times, millions of requests/second
- Run at Edge Locations
- Process-based isolation
- Used to change Viewer requests and responses:
 - **Viewer Request:** after CloudFront receives a request from a viewer
 - **Viewer Response:** before CloudFront forwards the response to the viewer
- Native feature of CloudFront (manage code entirely within CloudFront)



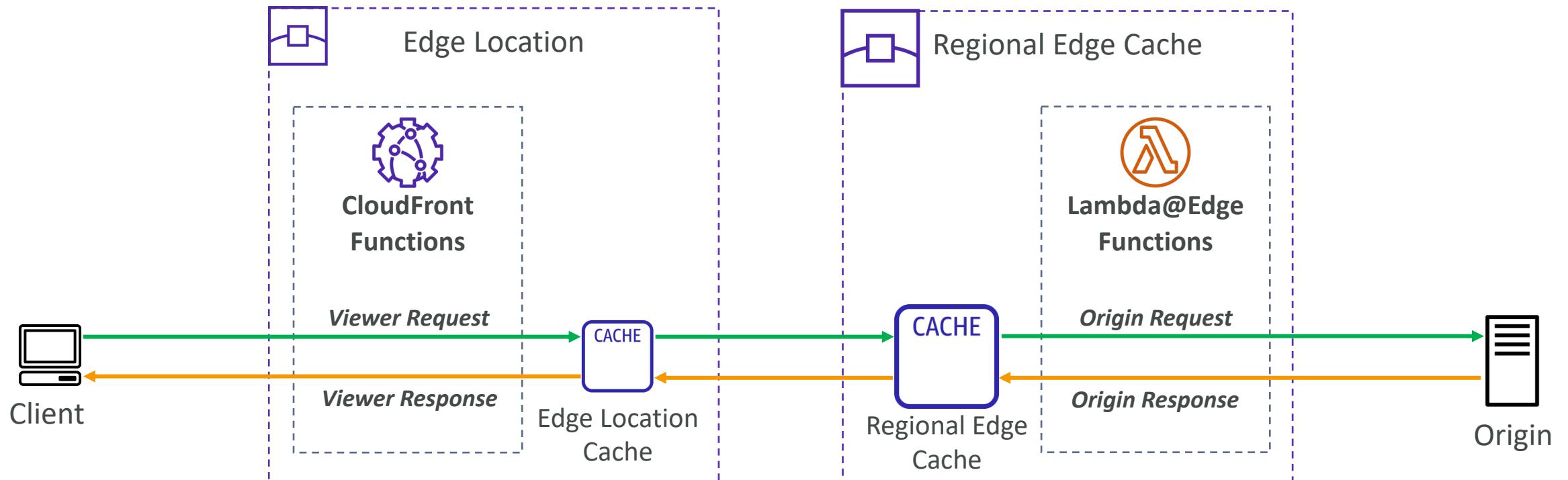
CloudFront – Lambda@Edge

- Lambda functions written in NodeJS or Python
- Scales to 1000s of requests/second
- Runs at the nearest Regional Edge Cache
- VM-based isolation
- Used to change CloudFront requests and responses:
 - **Viewer Request** – after CloudFront receives a request from a viewer
 - **Origin Request** – before CloudFront forwards the request to the origin
 - **Origin Response** – after CloudFront receives the response from the origin
 - **Viewer Response** – before CloudFront forwards the response to the viewer
- Author your functions in one AWS Region (us-east-1), then CloudFront replicates to its locations



CloudFront Functions with Lambda@Edge

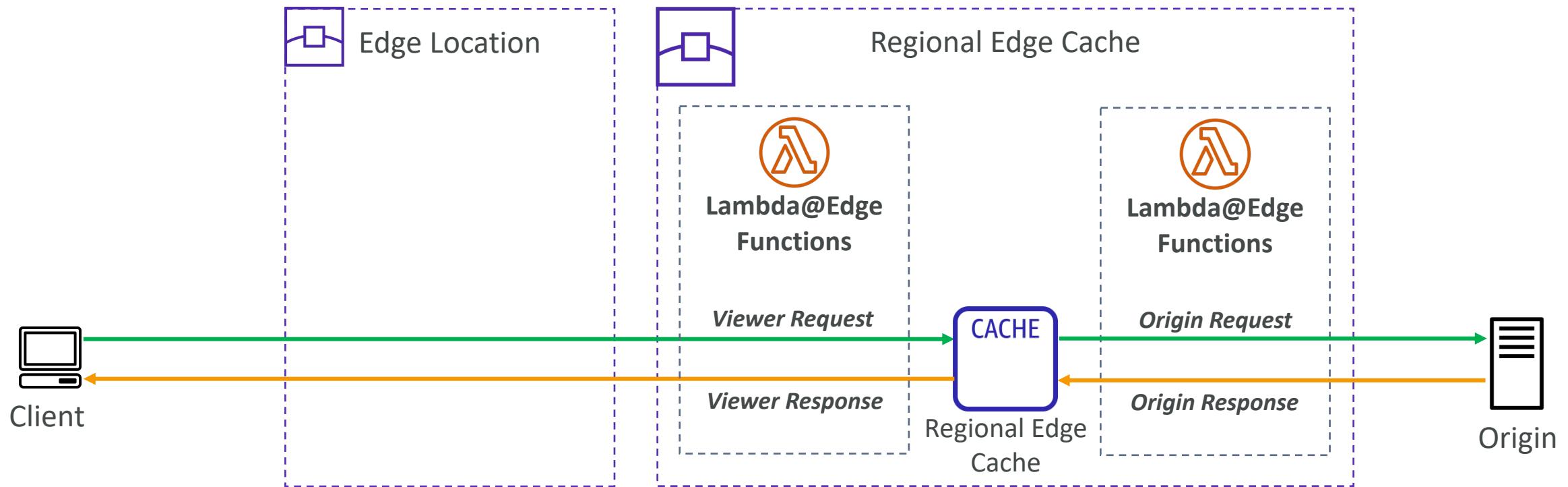
CloudFront Functions and Lambda@Edge can be used together



NOTE: You can't combine CloudFront Functions and Lambda@Edge in viewer events (viewer request & viewer response)

Using Lambda@Edge Only

Use when you need some of the capabilities of Lambda@Edge that aren't available with CloudFront Functions (e.g., longer execution time, network access, ...)



CloudFront Functions vs. Lambda@Edge

	CloudFront Functions	Lambda@Edge
Runtime Support	JavaScript	Node.js, Python
Execution Location	Edge Locations	Regional Edge Caches
CloudFront Triggers	- Viewer Request/Response	- Viewer Request/Response - Origin Request/Response
Isolation	Process-based	VM-based
Max. Execution Time	< 1 ms	- 5 seconds (viewers triggers) - 30 seconds (origin triggers)
Max. Memory	2 MB	- 128 MB (viewer triggers) - 10 GB (origin triggers)
Total Package Size	10 KB	- 1 MB (viewer triggers) - 50 MB (origin t
Network Access, File System Access	No	Yes
Access to the Request Body	No	Yes
Pricing	Free tier available, 1/6 th price of @Edge	No free tier, charged per request & duration

CloudFront Functions vs. Lambda@Edge – Use Cases

CloudFront Functions

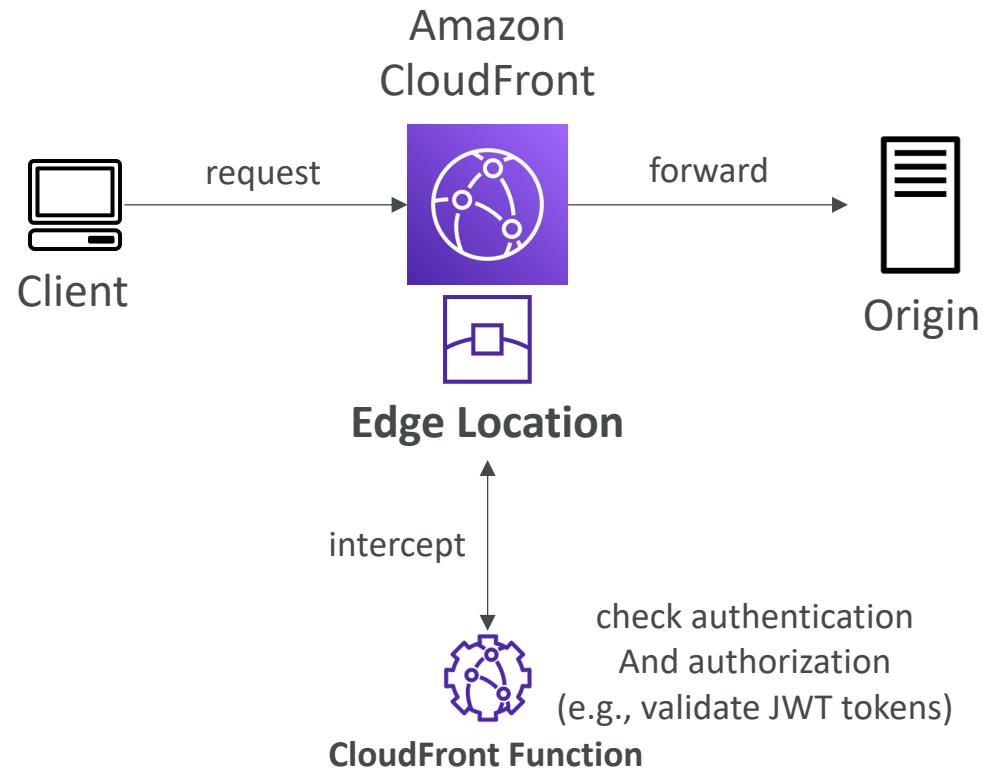
- Cache key normalization
 - Transform request attributes (headers, cookies, query strings, URL) to create an optimal Cache Key
- Header manipulation
 - Insert/modify/delete HTTP headers in the request or response
- URL rewrites or redirects
- Request authentication & authorization
 - Create and validate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

Lambda@Edge

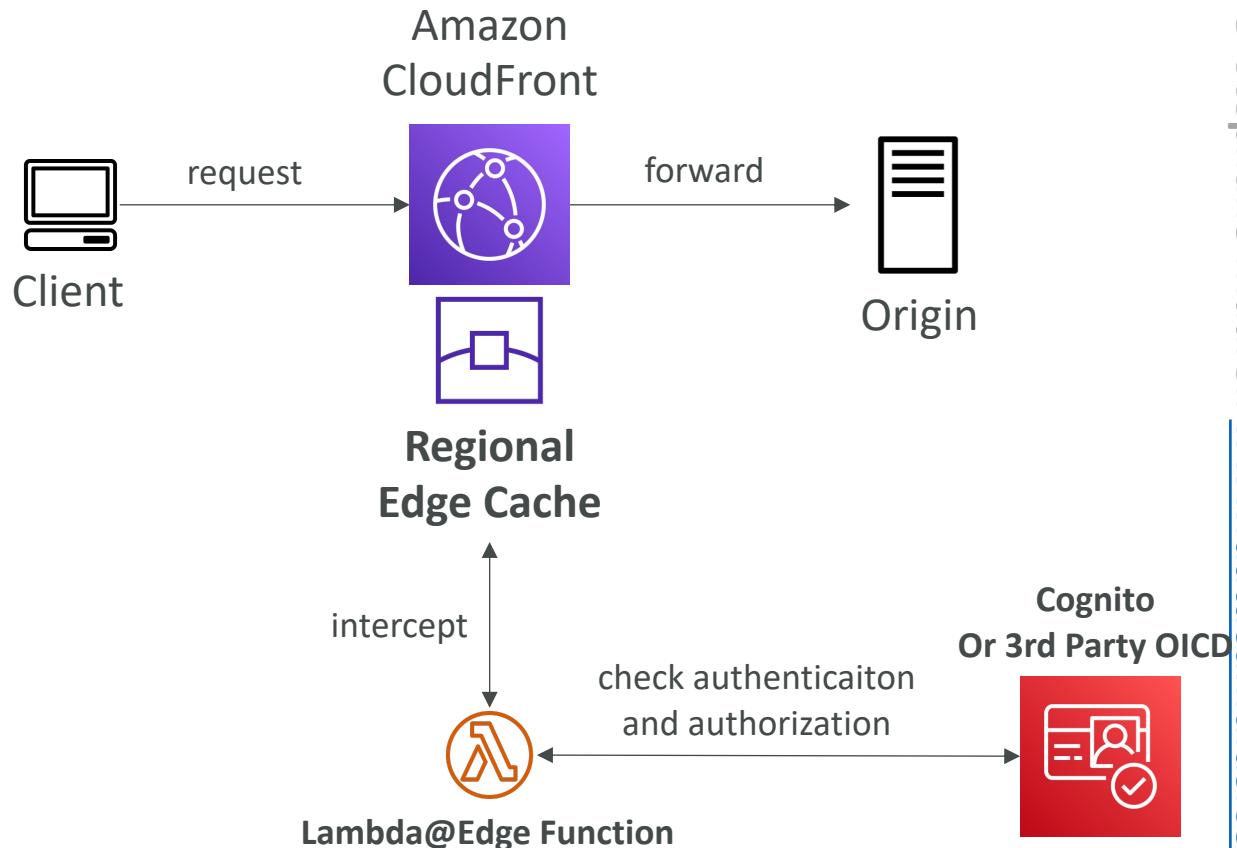
- Longer execution time (several ms)
- Adjustable CPU or memory
- Your code depends on a 3rd libraries (e.g., AWS SDK to access other AWS services)
- Network access to use external services for processing
- File system access or access to the body of HTTP requests

CloudFront Functions vs. Lambda@Edge – Authentication and Authorization

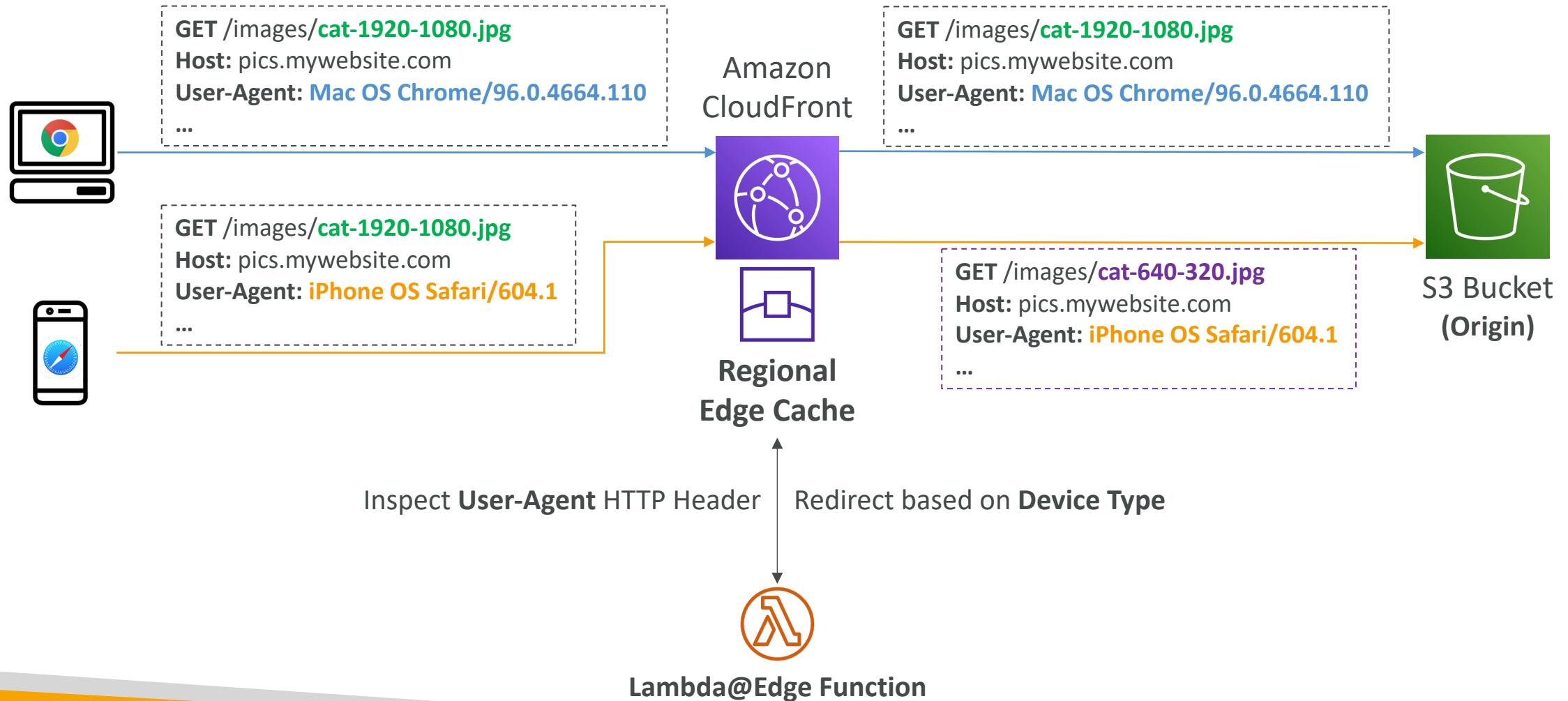
CloudFront Functions



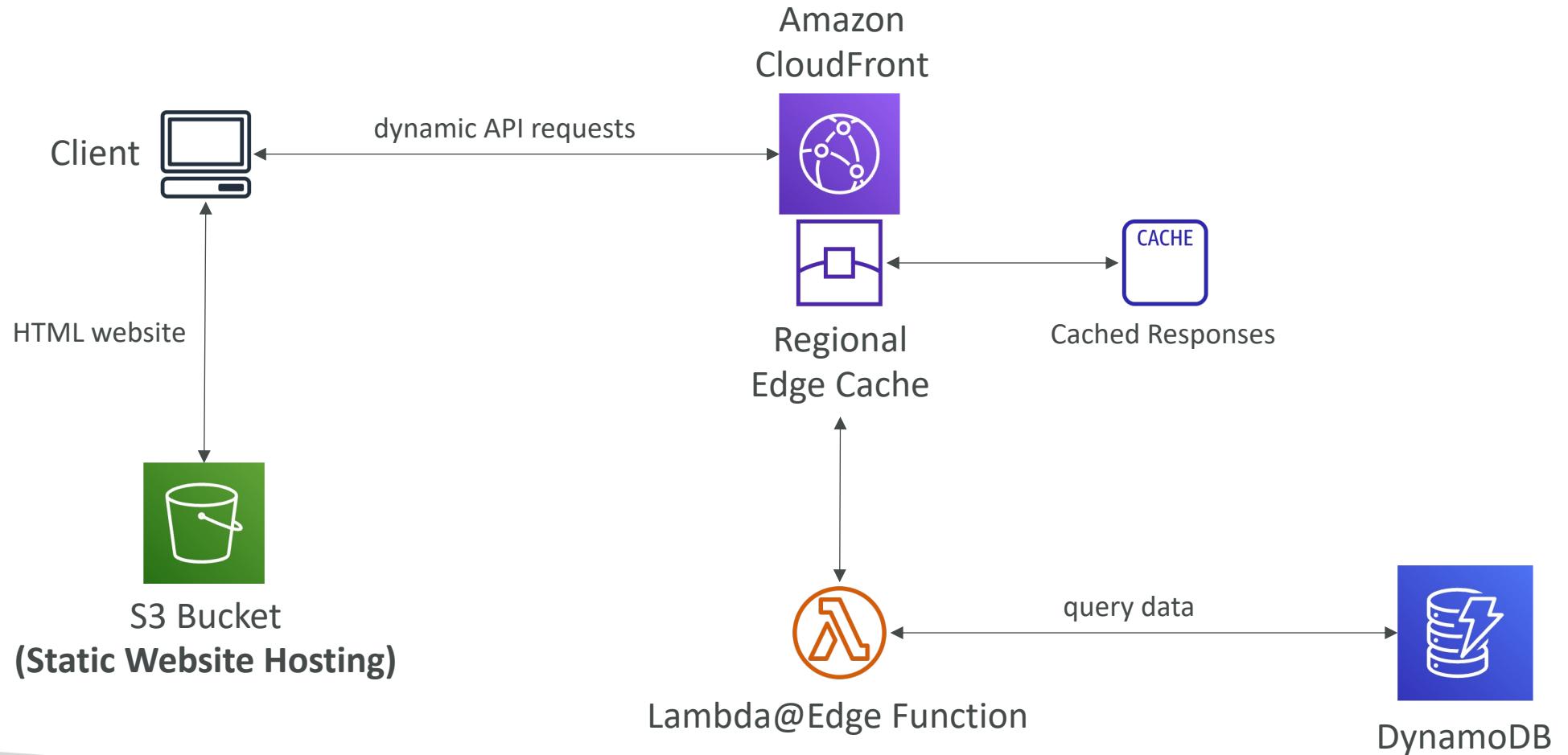
Lambda@Edge



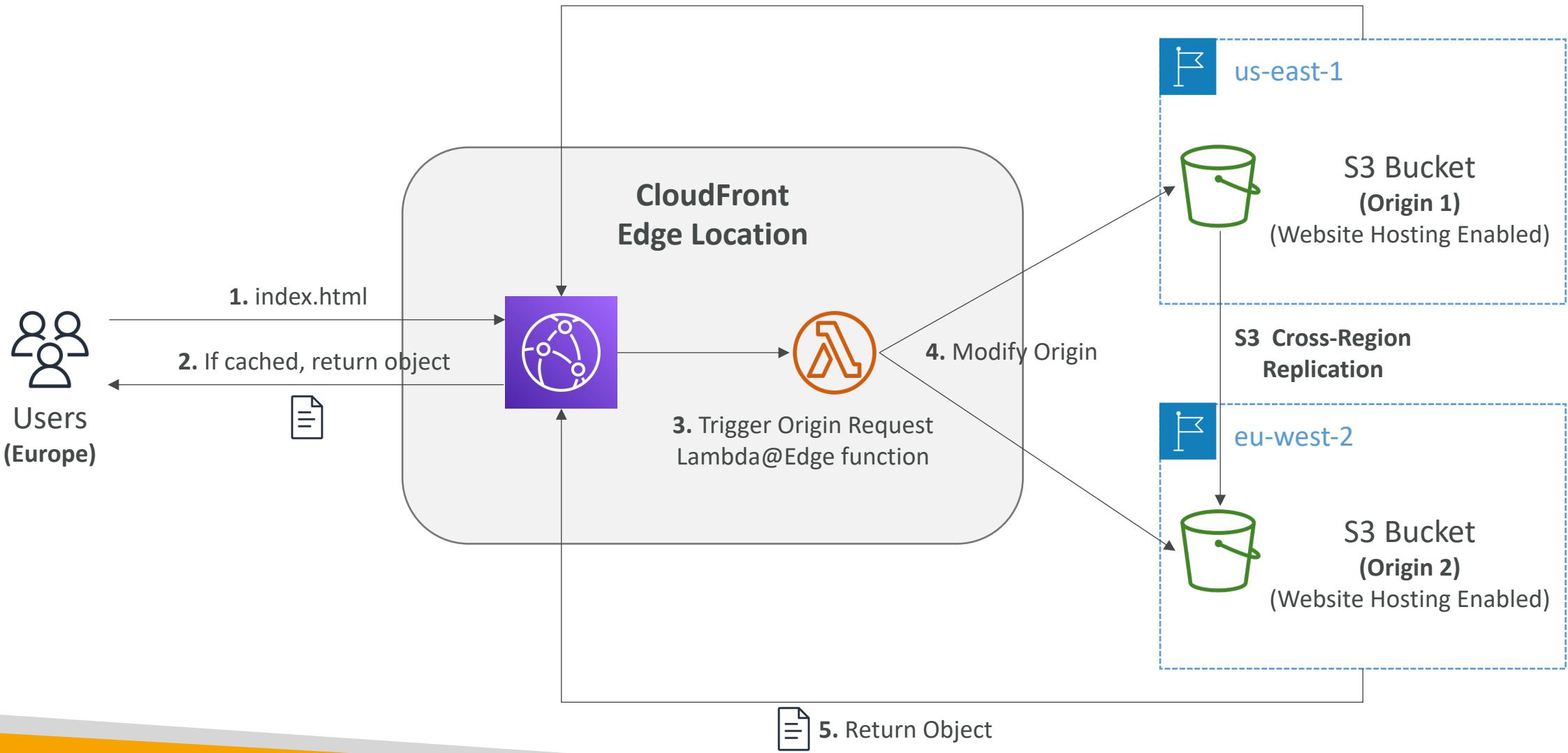
Lambda@Edge: Loading content based on User-Agent



Lambda@Edge – Global Application



Lambda@Edge – Route to Different Origin





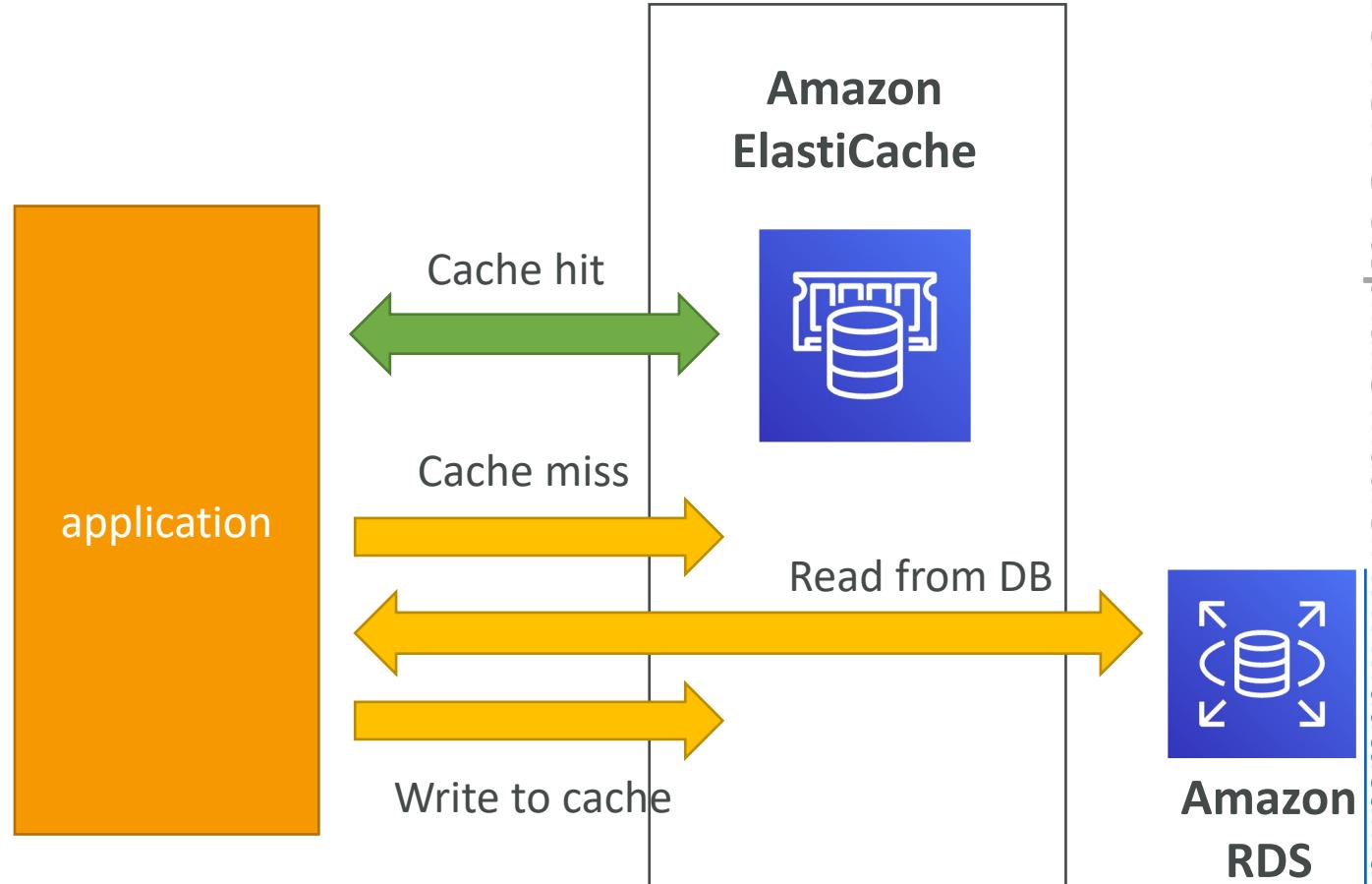
Amazon ElastiCache Overview

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

ElastiCache

Solution Architecture - DB Cache

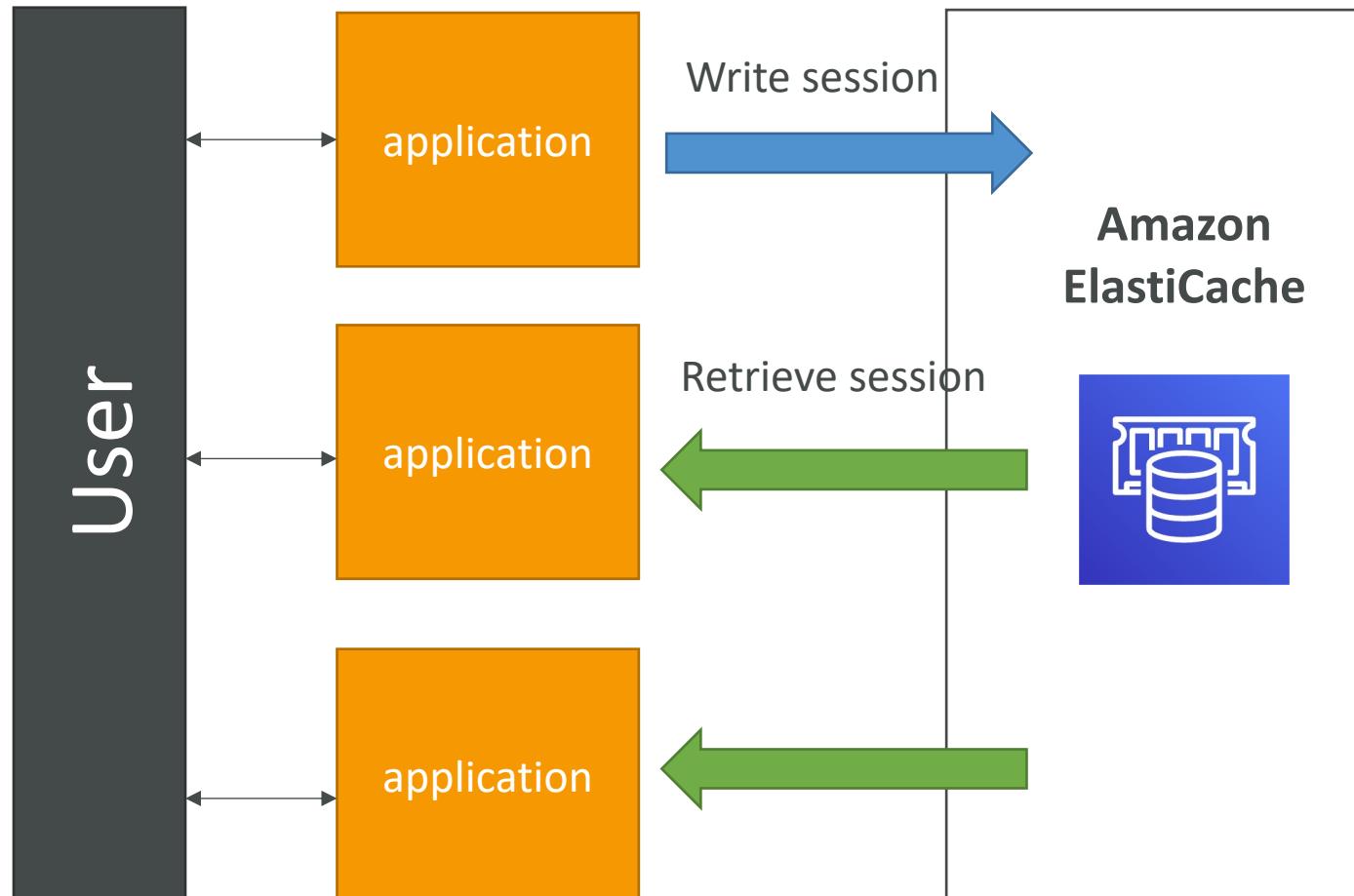
- Applications queries ElastiCache, if not available, get from RDS and store in ElastiCache.
- Helps relieve load in RDS
- Cache must have an invalidation strategy to make sure only the most current data is used in there.



ElastiCache

Solution Architecture – User Session Store

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



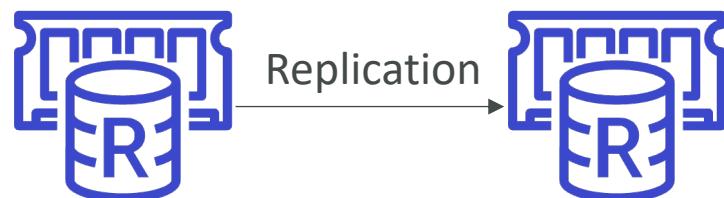
ElastiCache – Redis vs Memcached

REDIS

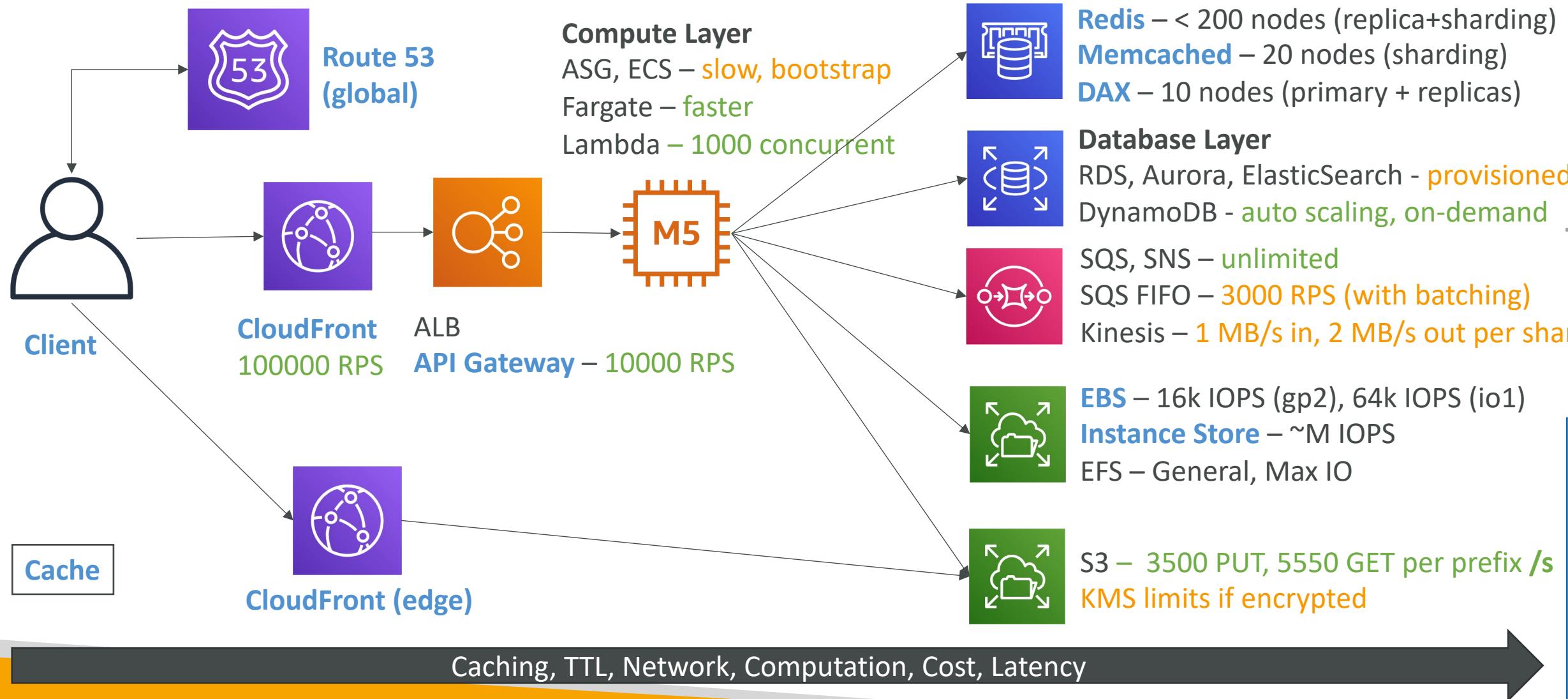
- Multi AZ with Auto-Failover
- Read Replicas to scale reads and have high availability
- Persistent, Data Durability: Append Only File (AOF), backup and restore features

MEMCACHED

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



Handling Extreme Rates



Databases

DynamoDB – in short



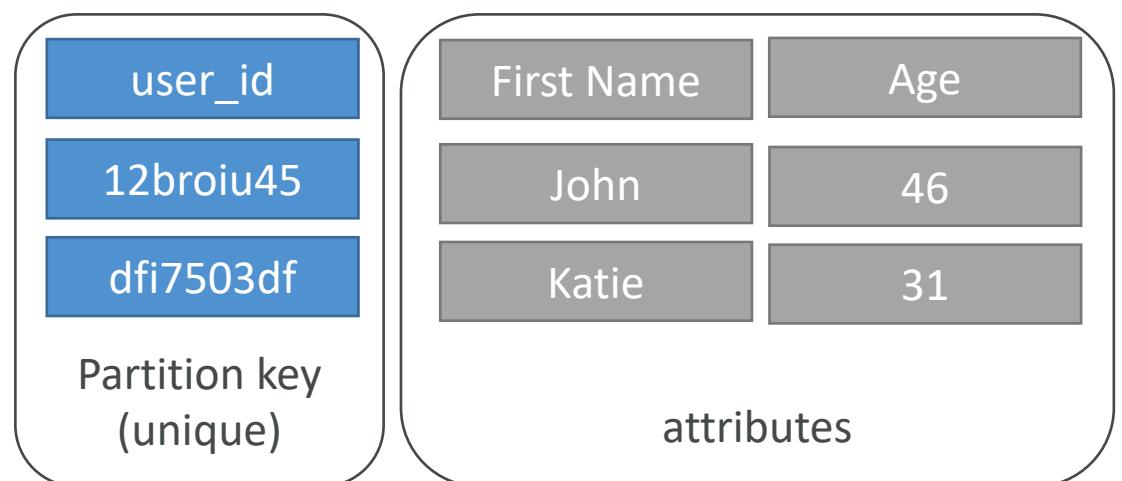
- NoSQL database, fully managed, massive scale (1,000,000 rps)
- Similar to Apache Cassandra (can migrate to DynamoDB)
- No disk space to provision, max object size is 400 KB
- Capacity: provisioned (WCU, RCU, & Auto Scaling) or on-demand
- Supports CRUD (Create Read Update Delete)
- Read: eventually or strong consistency
- Supports transactions across multiple tables (ACID support)
- Backups available, point in time recovery
- Table classes: Standard and Infrequent Access (IA)

DynamoDB - Basics

- DynamoDB is made of **tables**
- Each table has a **Primary Key** (must be decided at creation time)
- Each table can have an infinite number of items (= rows)
- Each item has **attributes** (can be added over time – can be null)
- Maximum size of a item is 400KB
- Data types supported are:
 - Scalar Types: String, Number, Binary, Boolean, Null
 - Document Types: List, Map
 - Set Types: String Set, Number Set, Binary Set

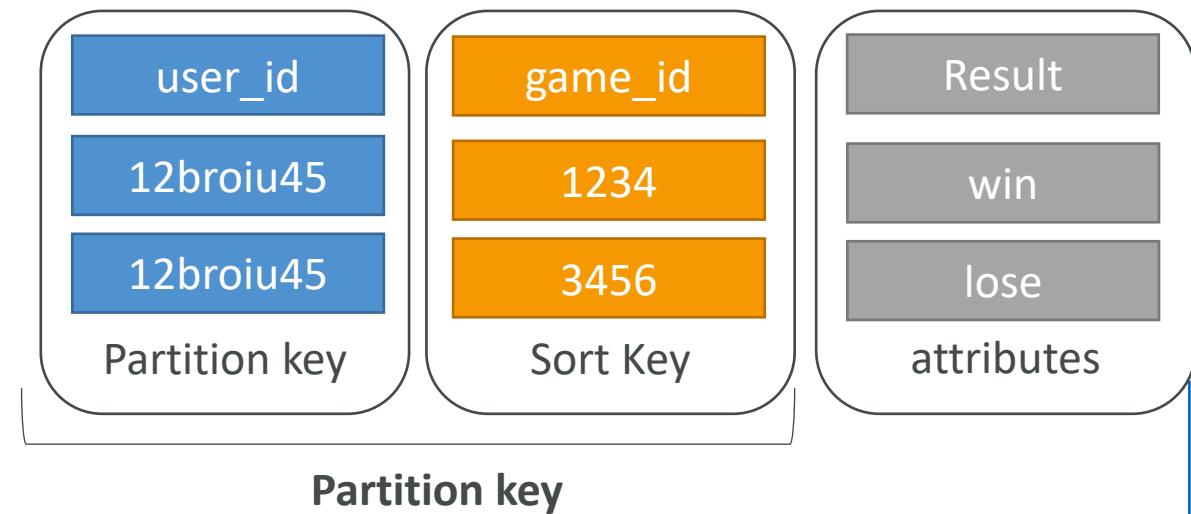
DynamoDB – Primary Keys

- Option 1: Partition Key only (HASH)
- Partition key must be unique for each item
- Partition key must be “diverse” so that the data is distributed
- Example: user_id for a users table



DynamoDB – Primary Keys

- Option 2: Partition Key + Sort Key
- The combination must be unique
- Data is grouped by partition key
- Sort key == range key
- Example: users-games table
 - user_id for the partition key
 - game_id for the sort key
- Example good sort key: timestamp

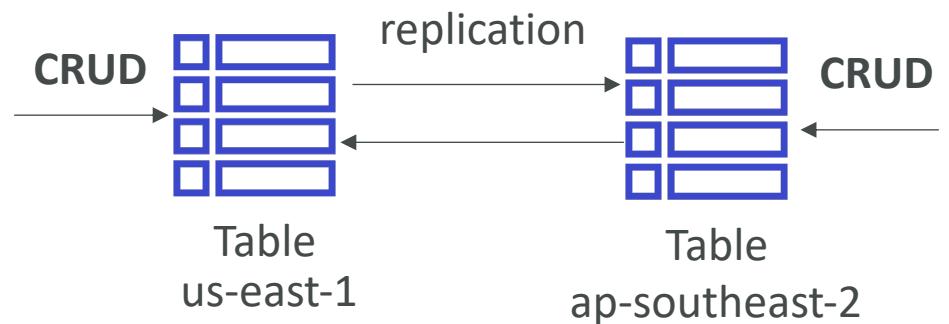
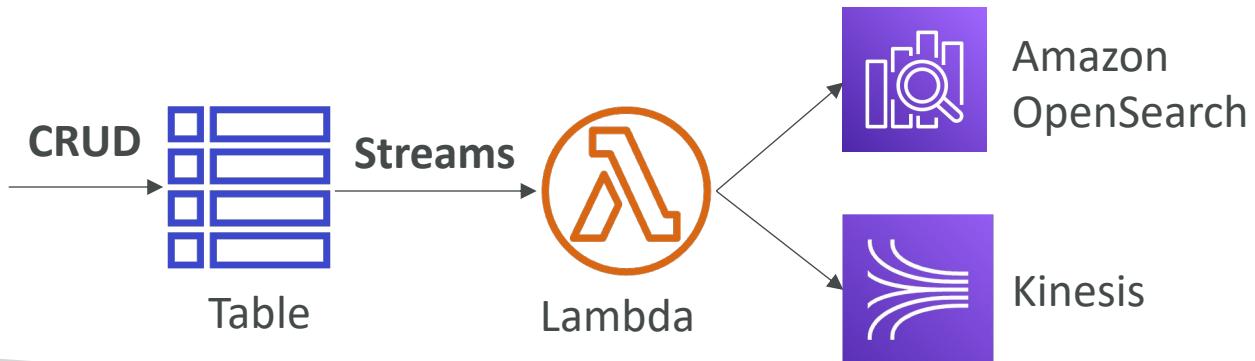


DynamoDB – Indexes

- Object = partition key + optional sort key + attributes
- LSI – Local Secondary Index
 - Keep the same primary key
 - Select an alternative sort key
 - Must be defined at table creation time
- GSI – Global Secondary Index
 - Change the partition key and optional sort sort
 - Can be defined after the table is created
- You can only query by PK + sort key on the main table & indexes (**≠ RDS**)

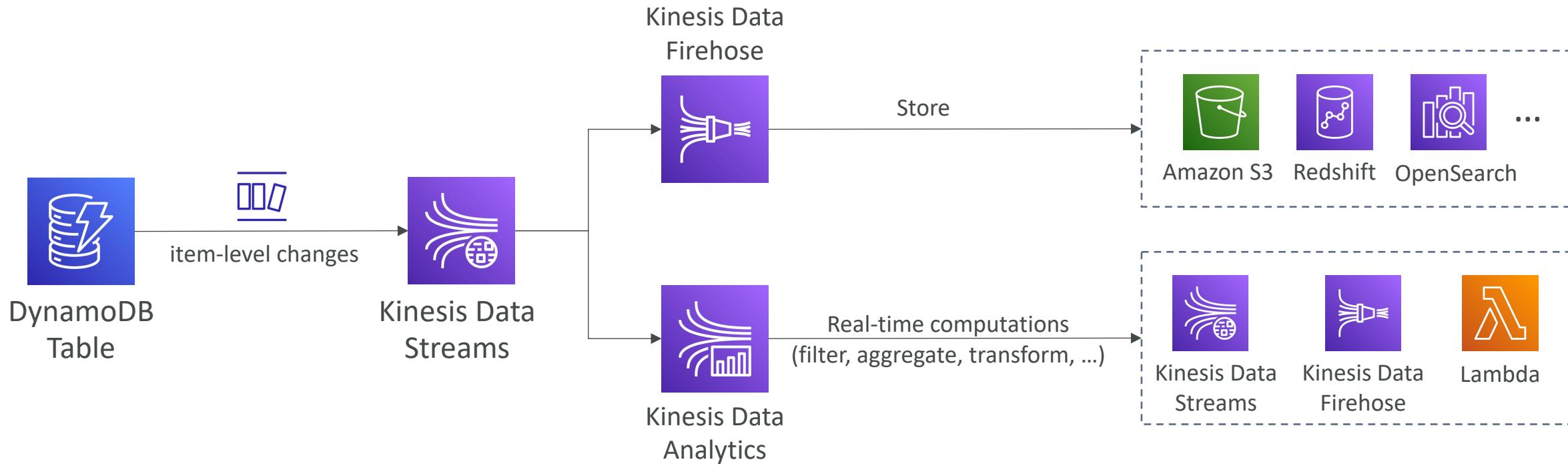
DynamoDB – Important Features

- TTL: automatically expire row after a specified epoch date
- **DynamoDB Streams:**
 - react to changes to DynamoDB tables in real time
 - Can be read by AWS Lambda, EC2...
 - 24 hours retention of data
- **Global Tables:** (cross region replication)
 - Active Active replication, many regions
 - Must enable DynamoDB Streams
 - Useful for low latency, DR purposes



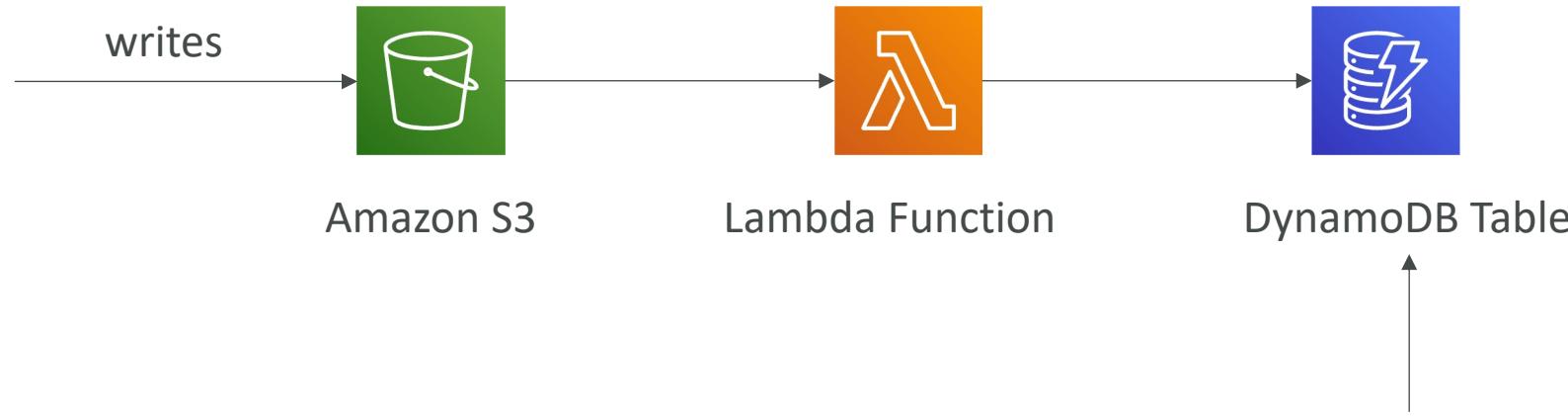
Amazon Kinesis Data Streams for DynamoDB

- You can use Kinesis Data Streams to capture item-level changes in DynamoDB
- Custom and longer data retention period (> 24 hours in DynamoDB Streams)



DynamoDB Solution Architecture

Indexing objects in DynamoDB

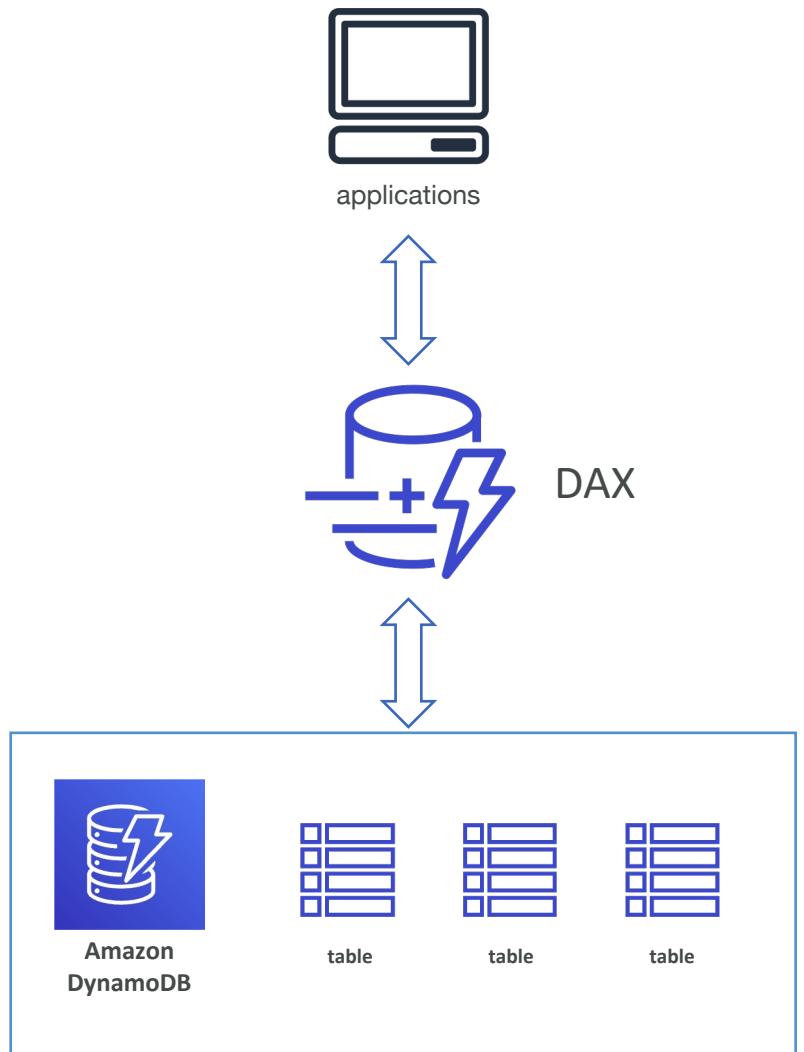


API for object metadata

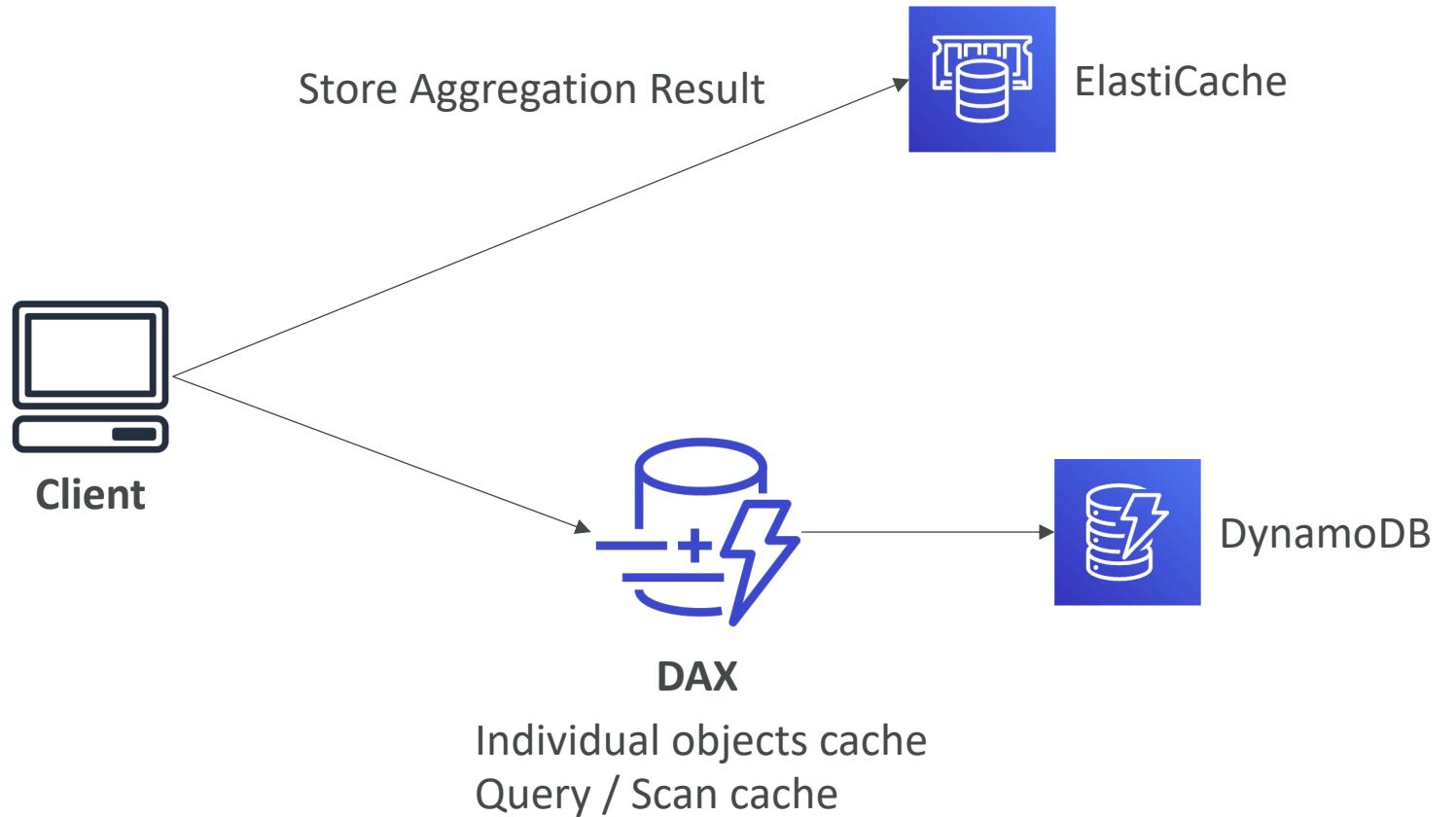
- Search by date
- Total storage used by a customer
- List of all objects with certain attributes
- Find all objects uploaded within a date range

DynamoDB - DAX

- DAX = DynamoDB Accelerator
- Seamless cache for DynamoDB, no application re-write
- Writes go through DAX to DynamoDB
- Micro second latency for cached reads & queries
- Solves the Hot Key problem (too many reads)
- 5 minutes TTL for cache by default
- Up to 10 nodes in the cluster
- Multi AZ (3 nodes minimum recommended for production)
- Secure (Encryption at rest with KMS,VPC, IAM, CloudTrail...)



DynamoDB – DAX vs ElastiCache





Amazon OpenSearch (ex ElasticSearch)

- New name is Amazon OpenSearch
- ElasticSearch => OpenSearch
- Kibana => OpenSearch Dashboards

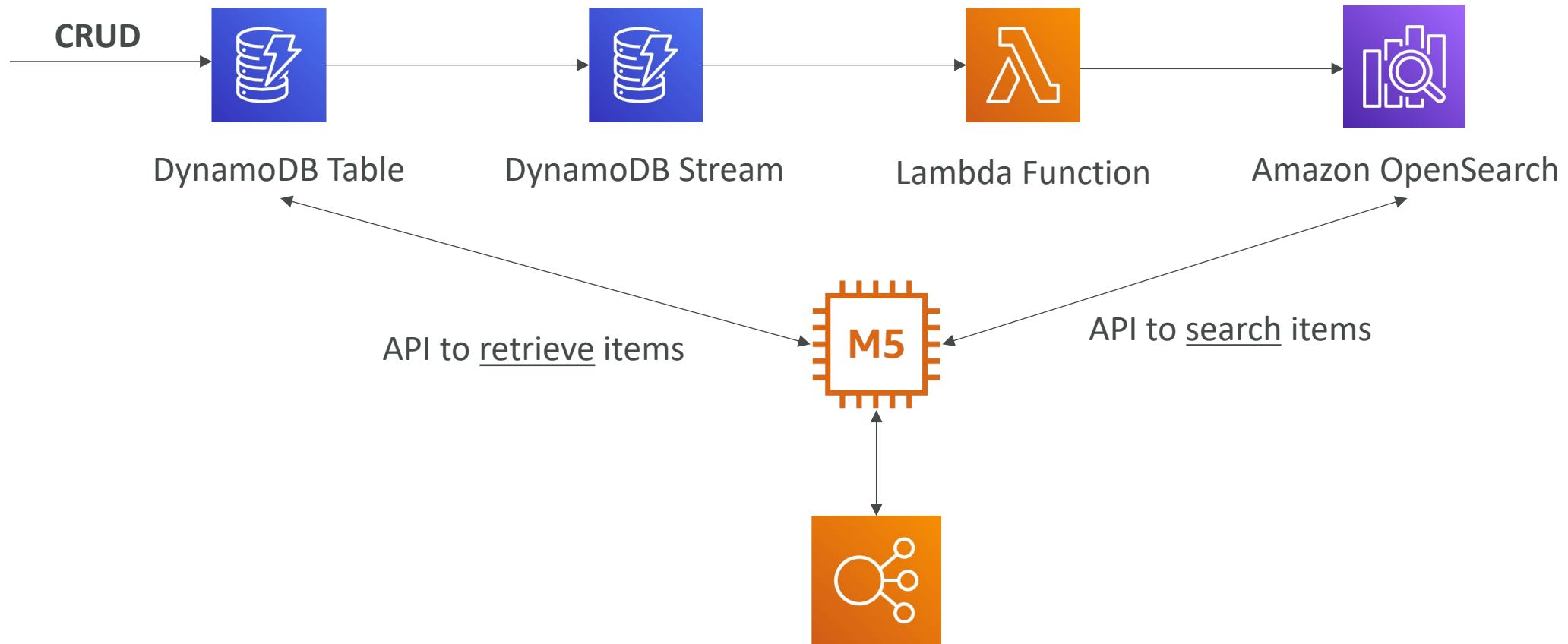
- Managed version of OpenSearch (open-source project, fork of ElasticSearch)
- Needs to run on servers (not a serverless offering)
- Use cases:
 - Log Analytics
 - Real Time application monitoring
 - Security Analytics
 - Full Text Search
 - Clickstream Analytics
 - Indexing

OpenSearch + OS Dashboards + Logstash

- OpenSearch (ex ElasticSearch): provide search and indexing capability
 - You must specify instance types, multi-AZ, etc
- OpenSearch Dashboards (ex Kibana):
 - Provide real-time dashboards on top of the data that sits in OpenSearch
 - Alternative to CloudWatch dashboards (more advanced capabilities)
- Logstash:
 - Log ingestion mechanism, use the “Logstash Agent”
 - Alternative to CloudWatch Logs (you decide on retention and granularity)

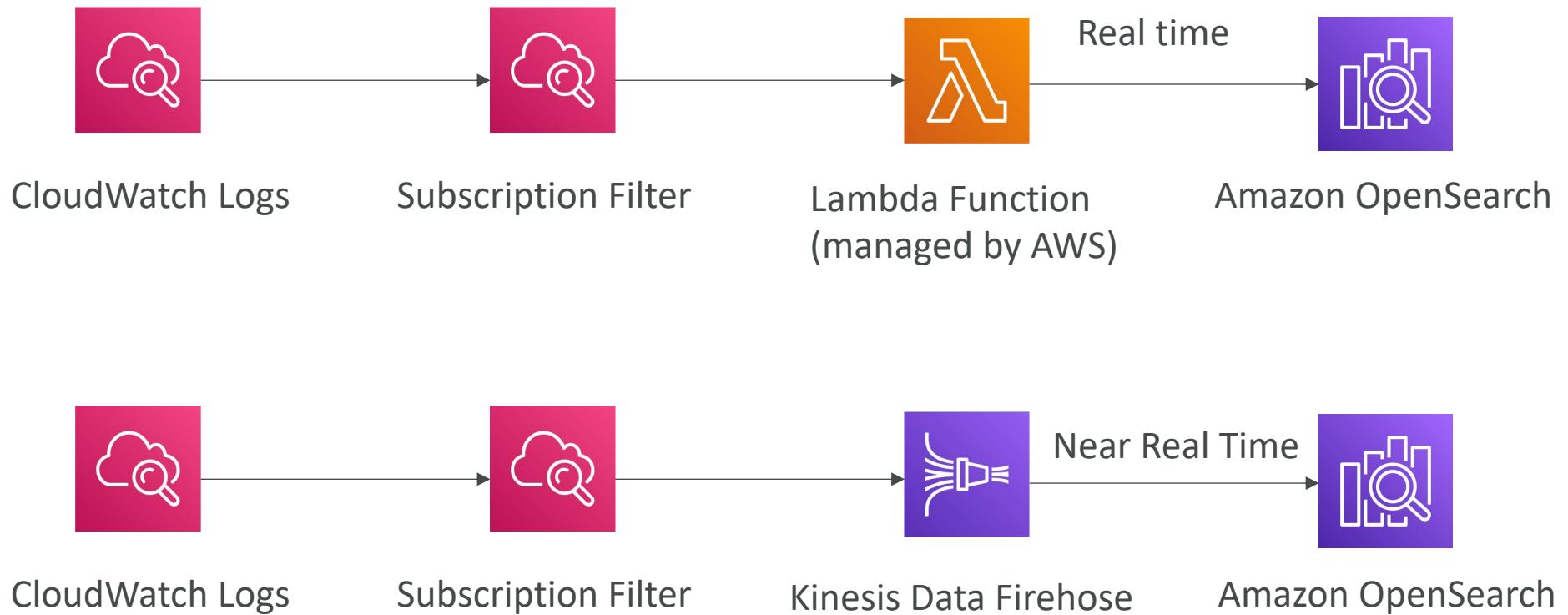
OpenSearch patterns

DynamoDB



OpenSearch patterns

CloudWatch Logs



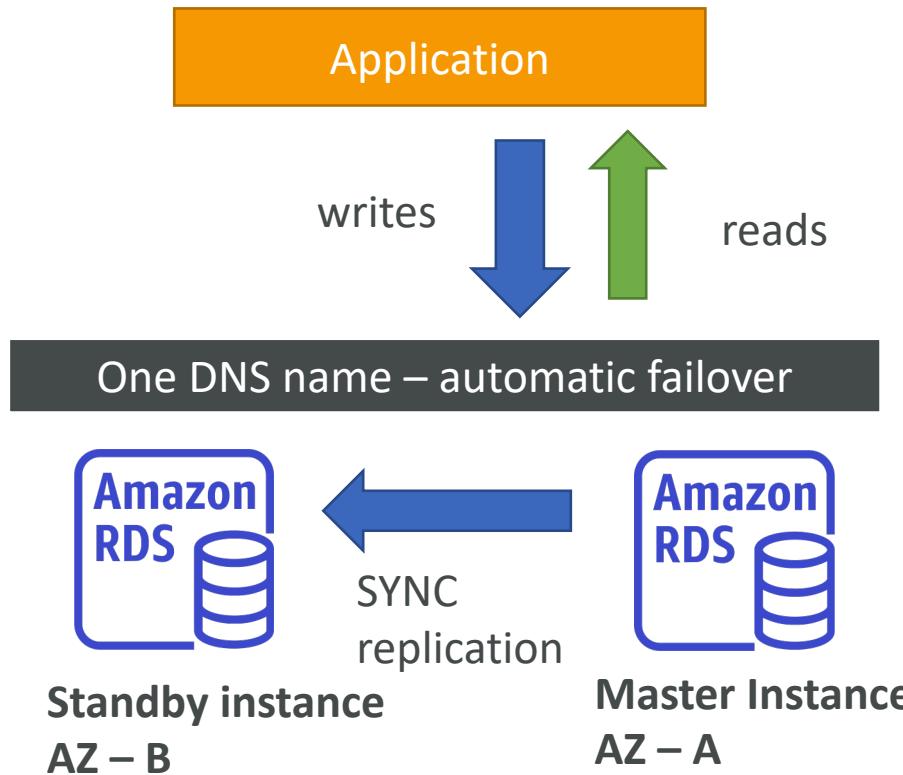
RDS



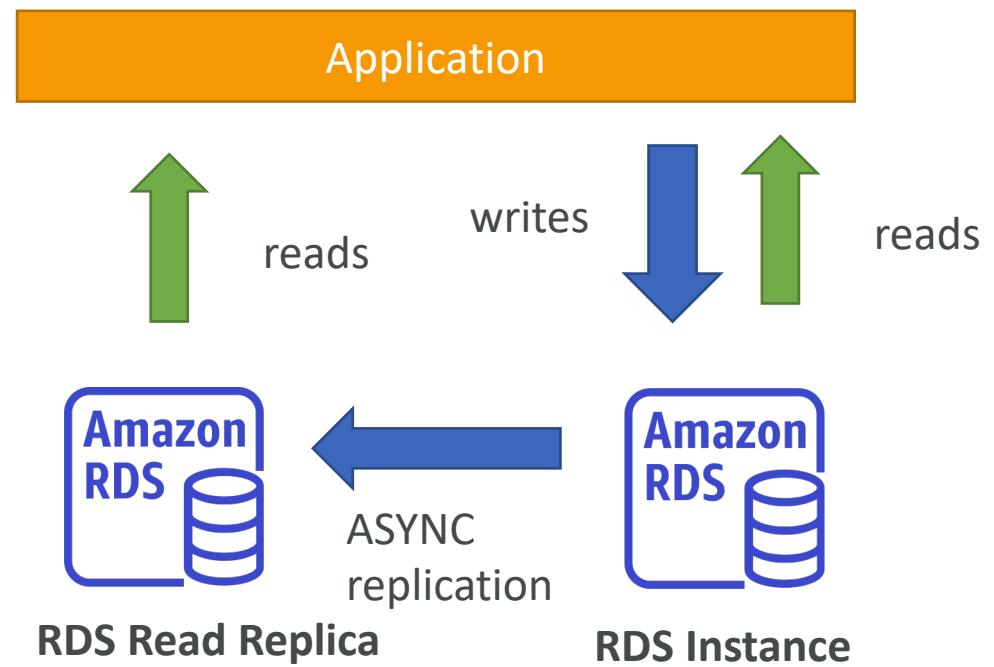
- **Engines:** PostgreSQL, MySQL, MariaDB, Oracle, Microsoft SQL Server
- **Managed DB:** provisioning, backups, patching, monitoring
- **Launched within a VPC,** usually in private subnet, control network access using security groups (important when using Lambda)
- **Storage by EBS** (gp2 or io1), can increase volume size with auto-scaling
- **Backups:** automated with point-in-time recovery. Backups expire
- **Snapshots:** manual, can make copies of snapshots cross region
- **RDS Events:** get notified via SNS for events (operations, outages...)

RDS – Multi AZ & Read Replicas

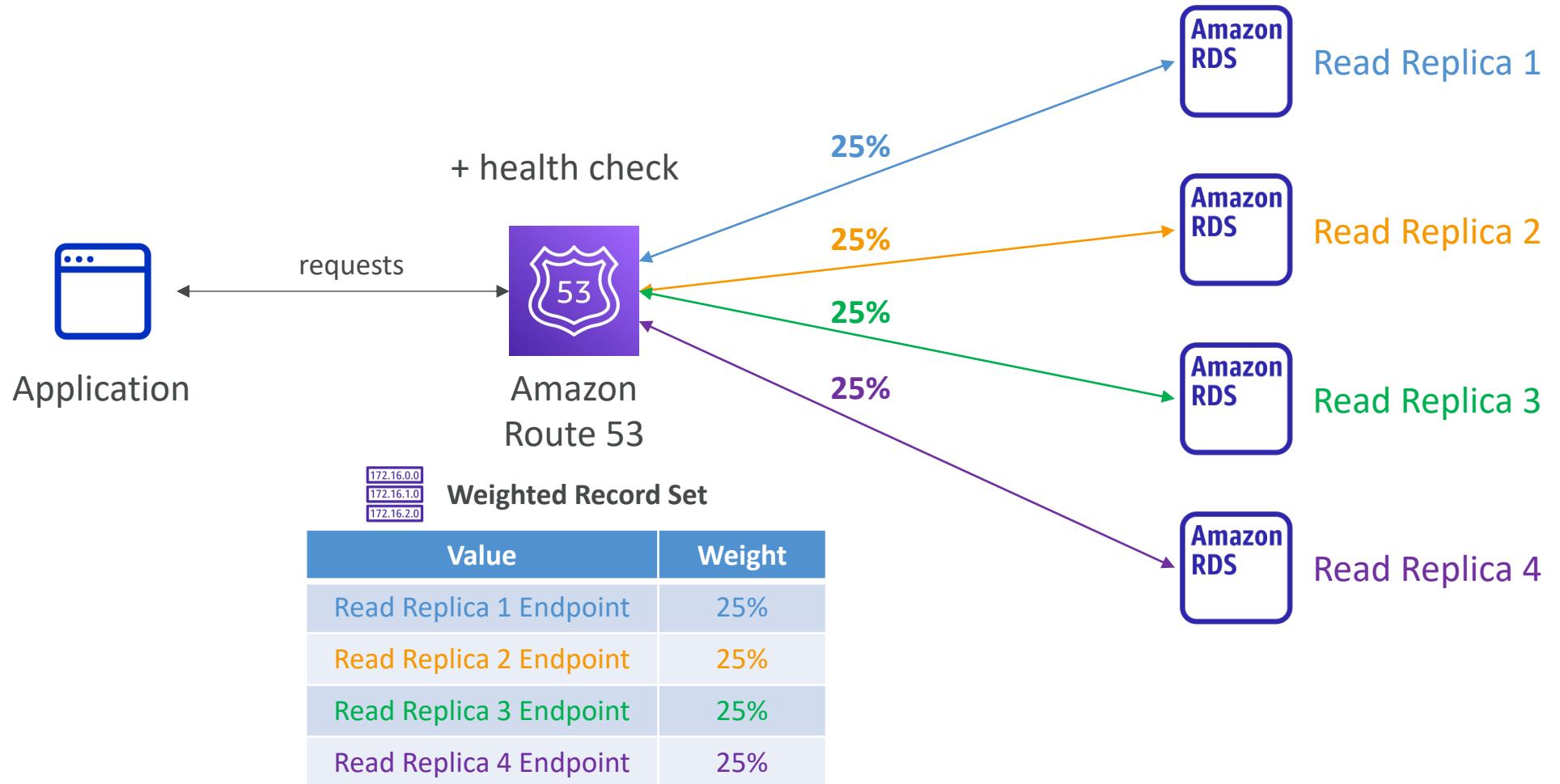
- Multi-AZ: Standby instance for failover in case of outage



- Read Replicas: Increase read throughput. Eventual consistency. Can be cross-region



RDS – Distributing Reads across Replicas



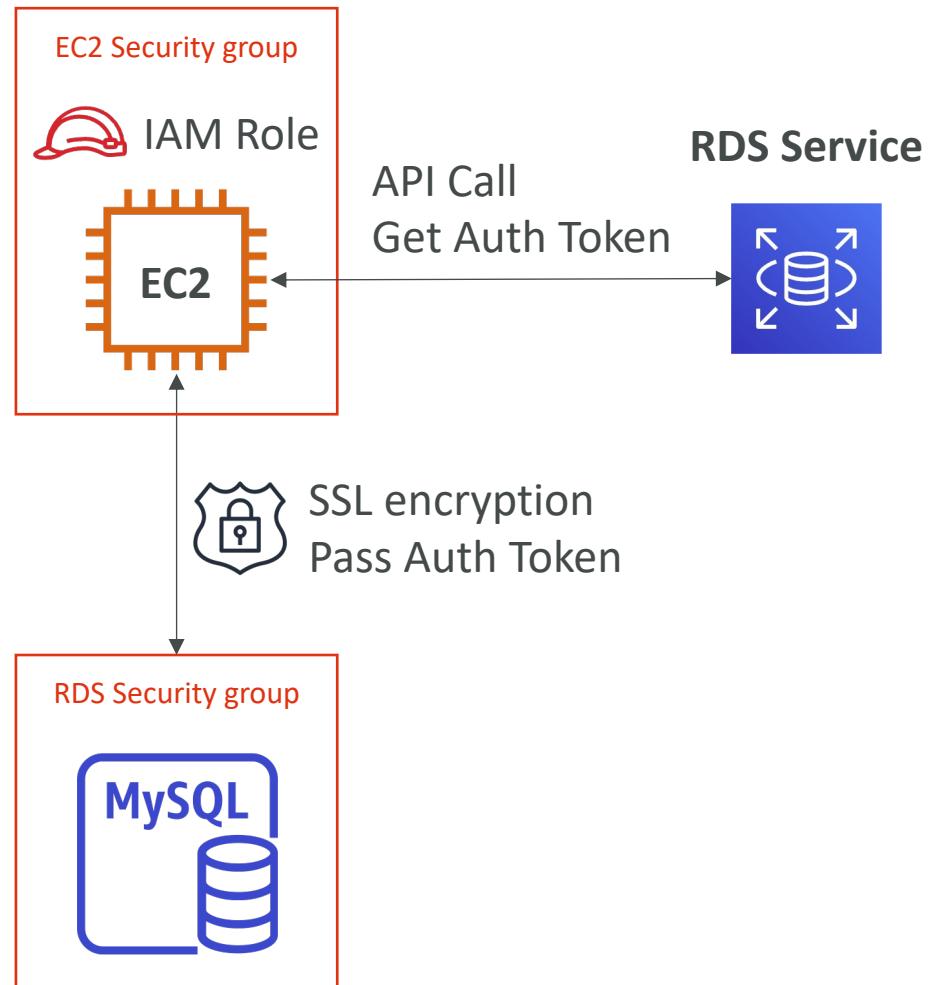
RDS – Security (reminder)



- KMS encryption at rest for underlying EBS volumes / snapshots
- Transparent Data Encryption (TDE) for Oracle and SQL Server
- SSL encryption to RDS is possible for all DB (in-flight)
- IAM authentication for MySQL, PostgreSQL and MariaDB
- Authorization still happens within RDS (not in IAM)
- Can copy an un-encrypted RDS snapshot into an encrypted one
- CloudTrail cannot be used to track queries made within RDS

RDS - IAM Authentication

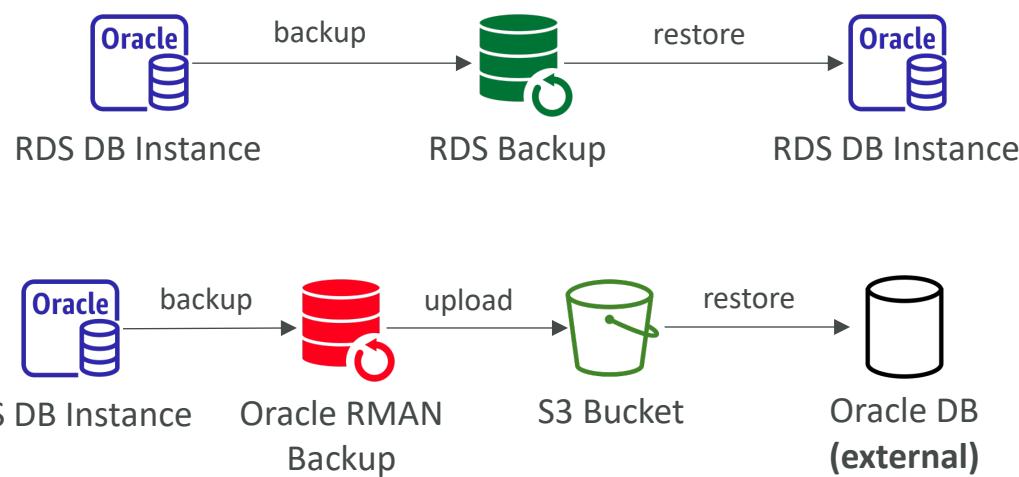
- IAM database authentication works with MariaDB, MySQL and PostgreSQL
- You don't need a password, just an authentication token obtained through IAM & RDS API calls
- Auth token has a lifetime of 15 minutes
- Benefits:
 - Network in/out must be encrypted using SSL
 - IAM to centrally manage users instead of DB
 - Can leverage IAM Roles and EC2 Instance profiles for easy integration



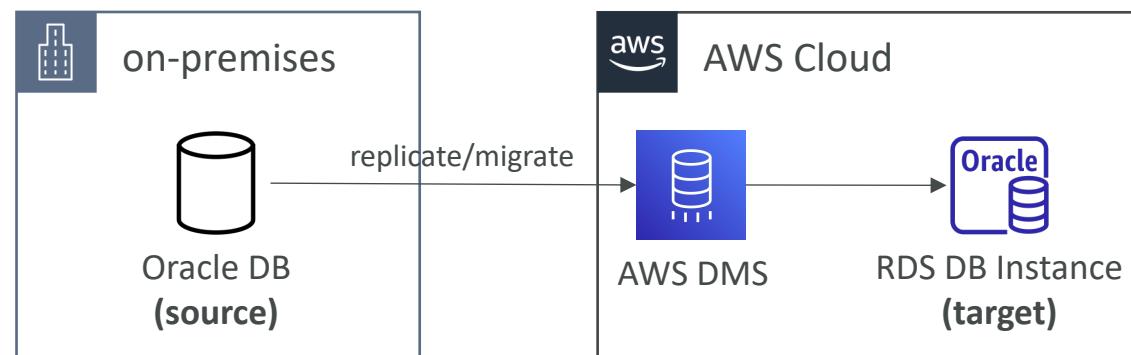
About RDS for Oracle – Exam Tips

Backups

- Use RDS Backups for backups & restore to Amazon RDS for Oracle
- Use Oracle RMAN (Recovery Manager) for backups & restore to non-RDS (RDS not supported)

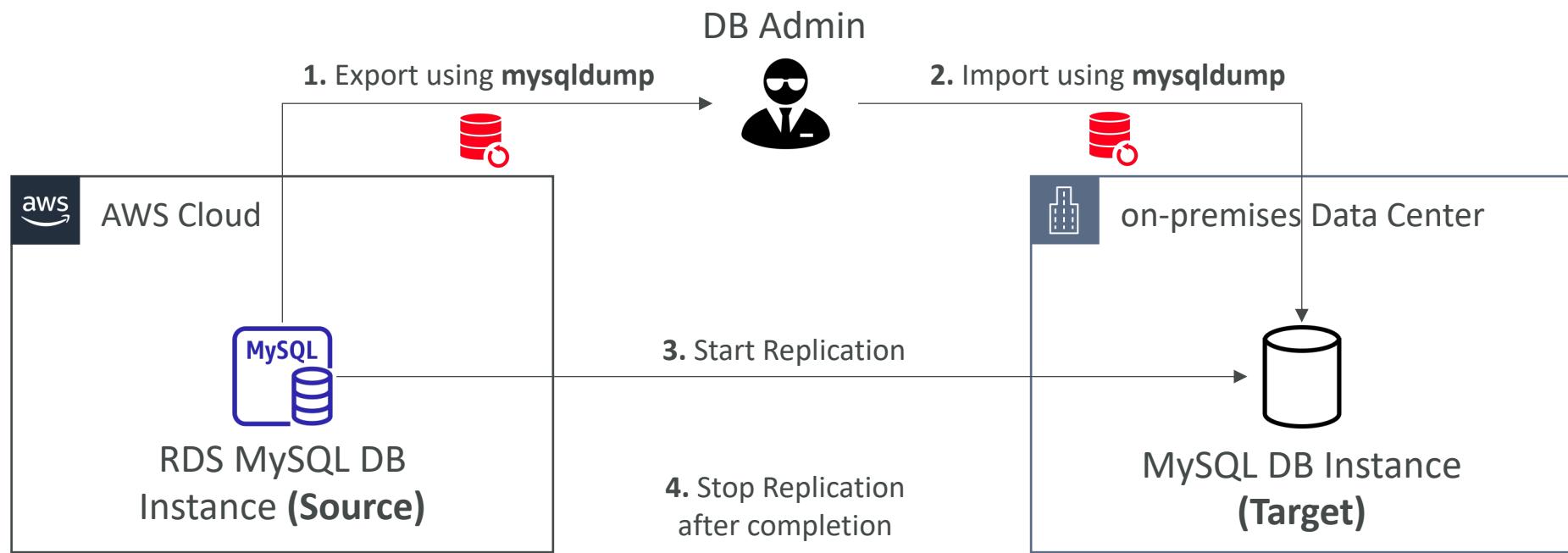


- Real Application Clusters (RAC)
 - RDS for Oracle does NOT support RAC
 - RAC is working on Oracle on EC2 Instances because you have full control
- RDS for Oracle supports Transparent Data Encryption (TDE) to encrypt data before it's written to storage
- DMS works on Oracle RDS



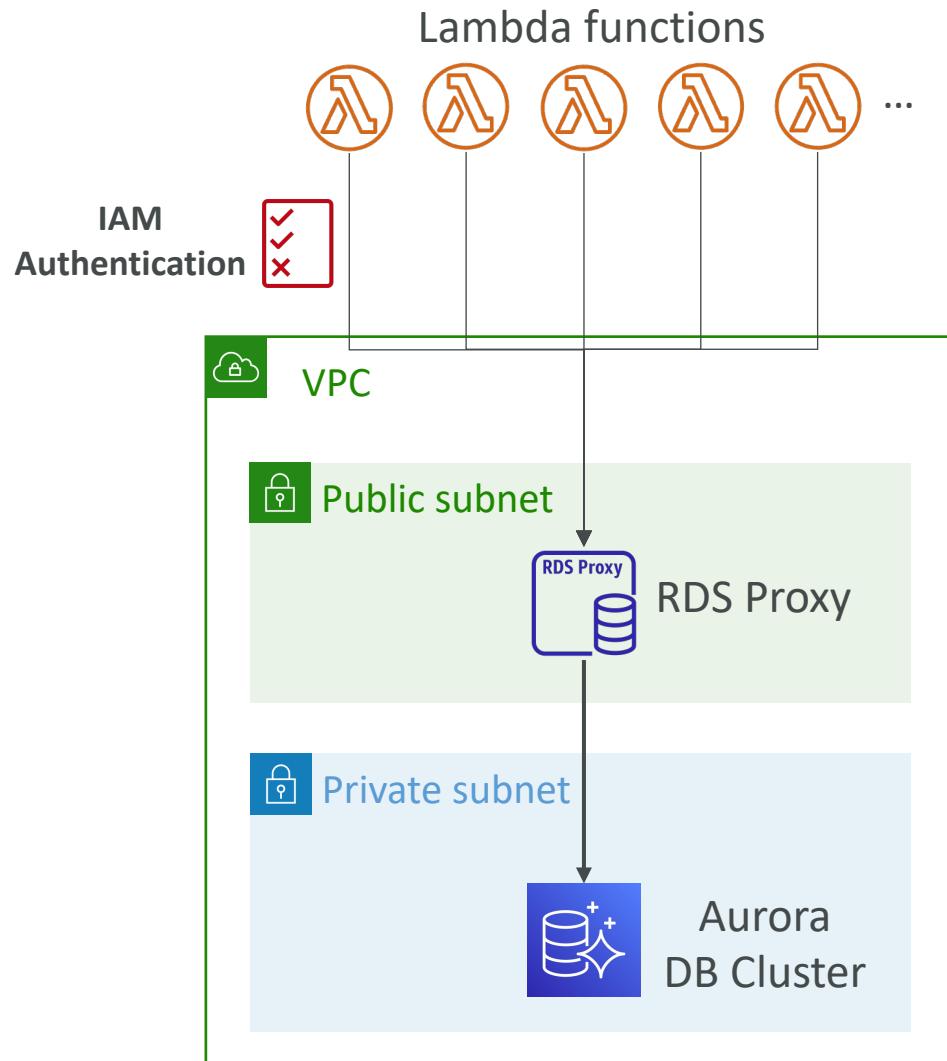
About RDS for MySQL

- You can use the native `mysqldump` to migrate a MySQL RDS DB to non-RDS
- The external MySQL database can run either on-premises in your data center, or on an Amazon EC2 instance



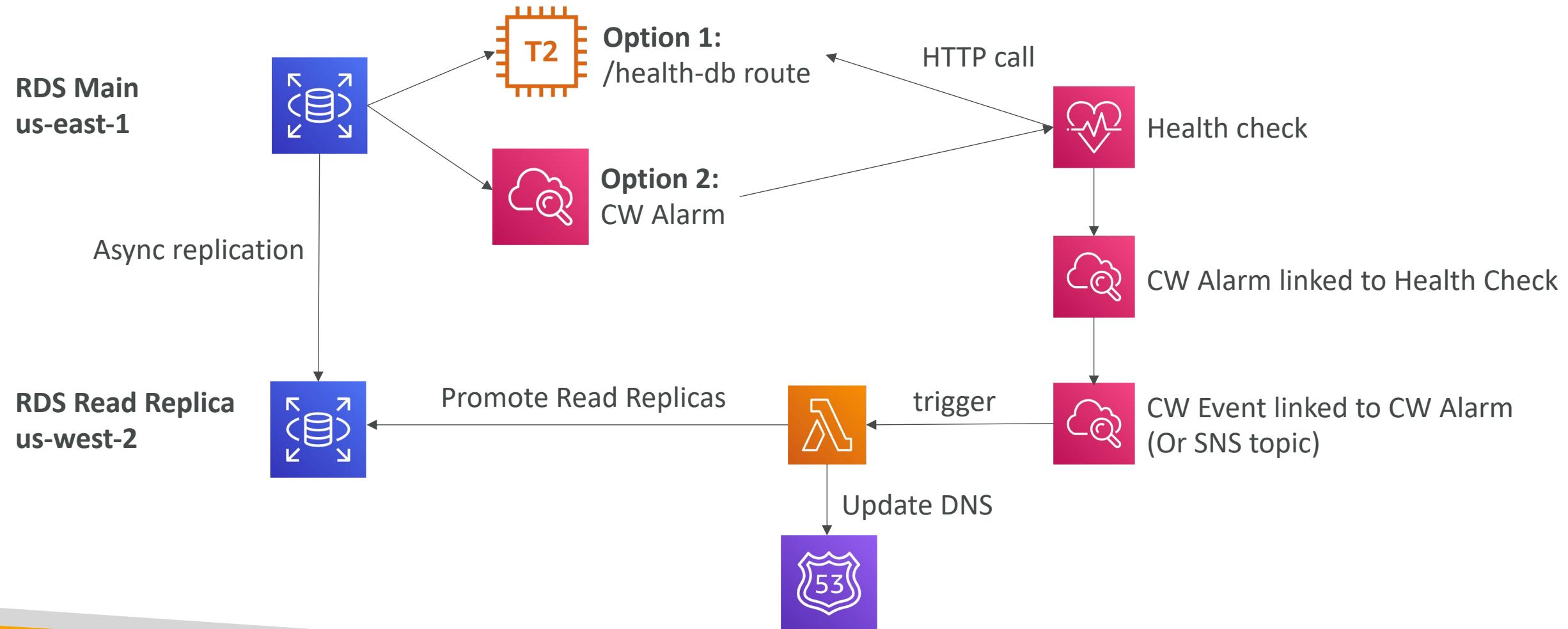
RDS Proxy for AWS Lambda

- When using Lambda functions with RDS, it opens and maintains a database connection
- This can result in a “TooManyConnections” exception
- With **RDS Proxy**, you no longer need code that handles cleaning up idle connections and managing connection pools
- Supports IAM authentication or DB authentication, auto-scaling
- The Lambda function must have connectivity to the Proxy (public proxy => public Lambda, private proxy => Lambda in VPC)



RDS Solution Architecture

Cross Region Failover



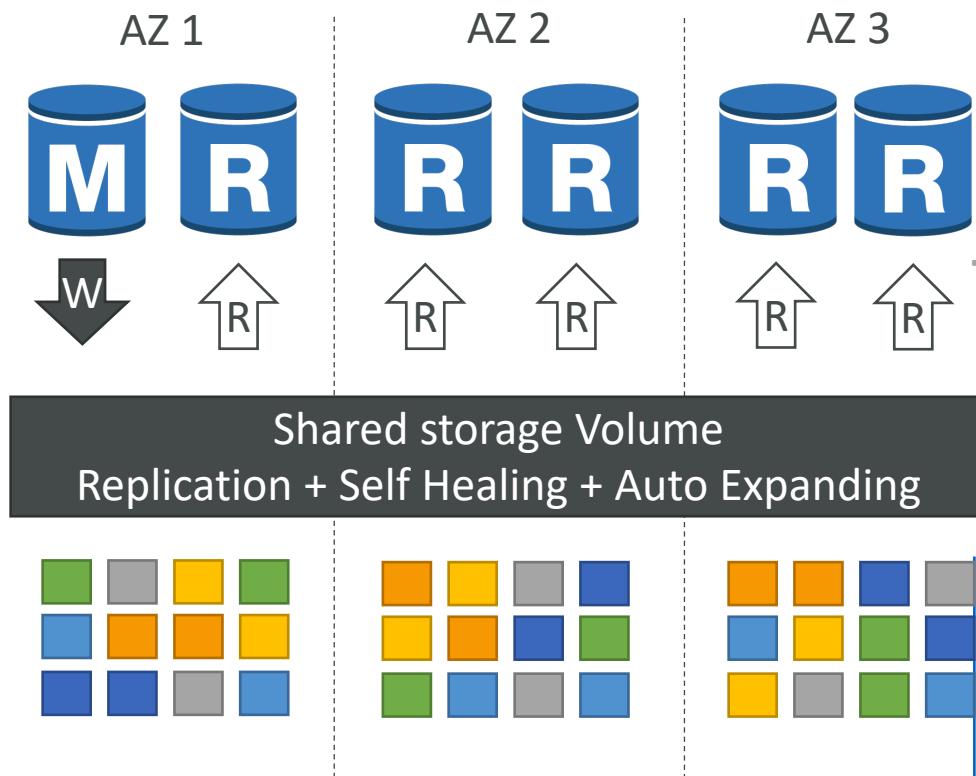
Aurora



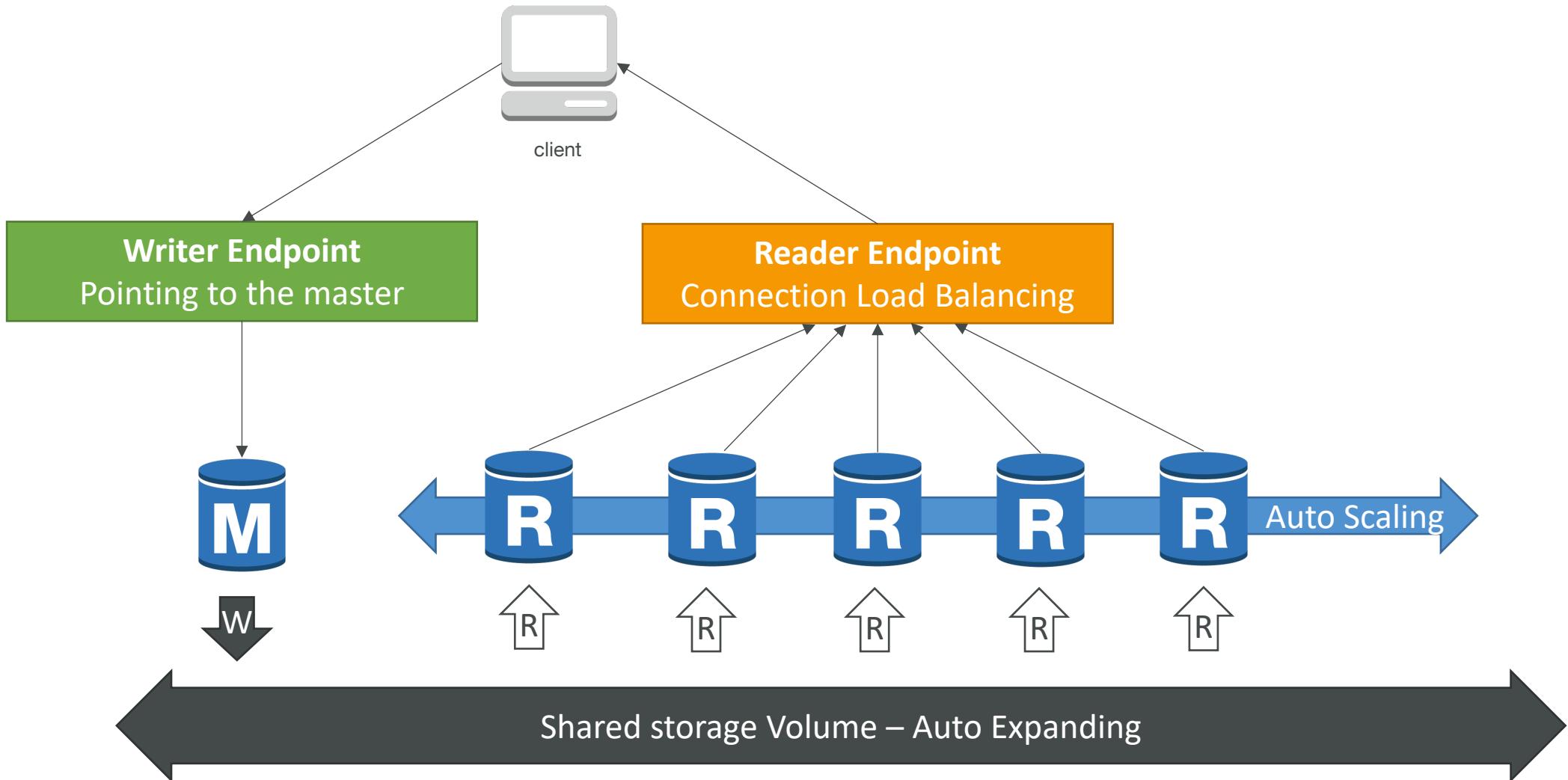
- **DB Engines:** PostgreSQL-compatible & MySQL-compatible
- **Storage:** automatically grows up to 128 TB, 6 copies of data, multi-AZ
- **Read Replicas:** up to 15 RR, reader endpoint to access them all
- **Cross Region RR:** entire database is copied (not select tables)
- **Load / Offload data directly from / to S3:** efficient use of resources
- **Backup, Snapshots & Restore:** same as RDS

Aurora High Availability and Read Scaling

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



Aurora DB Cluster

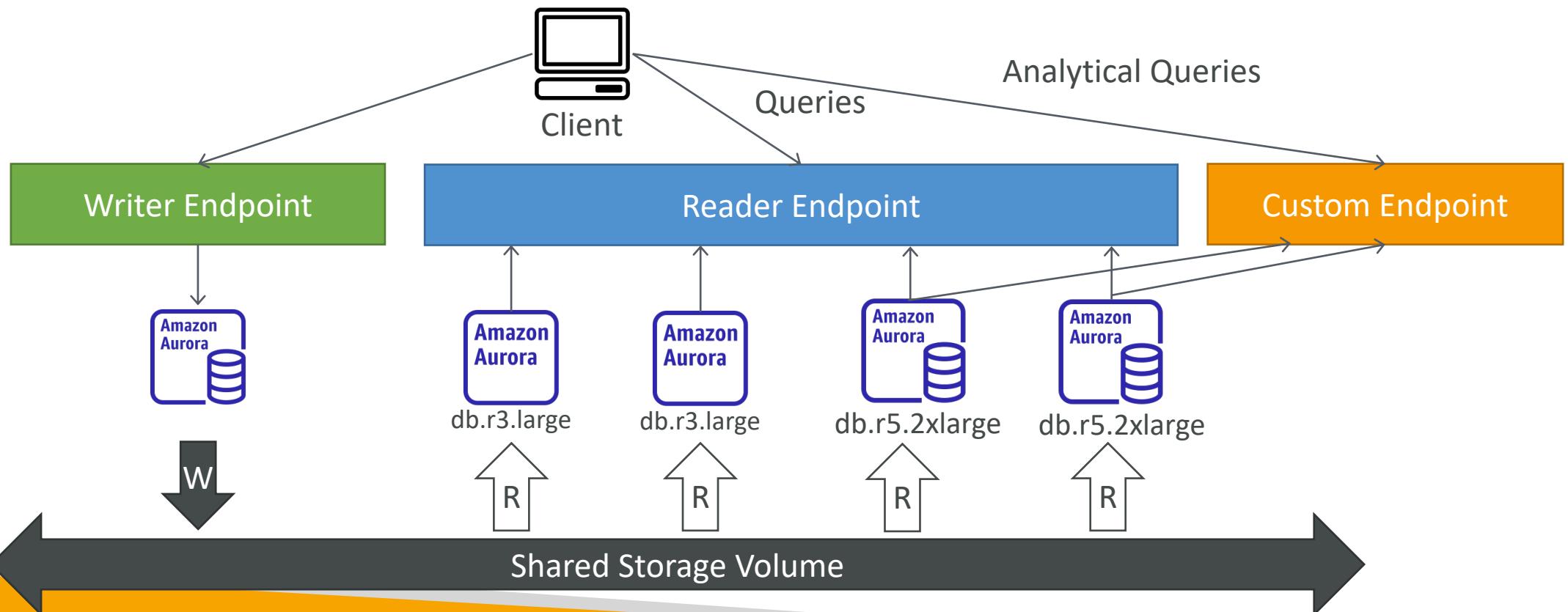


Aurora Endpoints

- Endpoint = Host Address + Port
- Cluster Endpoint (Writer Endpoint)
 - Connects to the current primary DB instance in the Aurora cluster
 - Used for all write operations in the DB cluster (inserts, updates, deletes, and queries)
- Reader Endpoint
 - Provides load-balancing for read only connections to all Aurora Replicas in the Aurora cluster
 - Used only for read operations (queries)
- Custom Endpoint
 - Represents a set on DB instances that you choose in the Aurora cluster
 - Used when you want to connect to different subsets of DB instances with different capacities and configurations (e.g., different DB parameter group)
- Instance Endpoint
 - Connects to a specific DB instance in the Aurora cluster
 - Used when you want to diagnosis and fine tune a specific DB instance

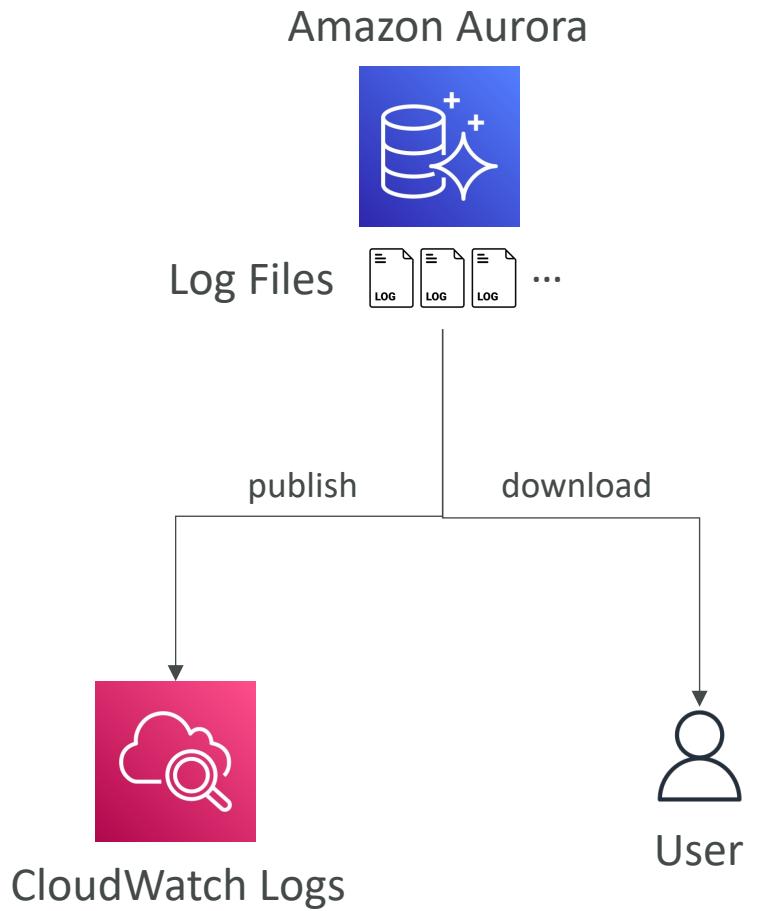
Aurora – Custom Endpoints

- Define a subset of Aurora Instances as a Custom Endpoint
- Example: Run analytical queries on specific replicas
- The Reader Endpoint is generally not used after defining Custom Endpoints



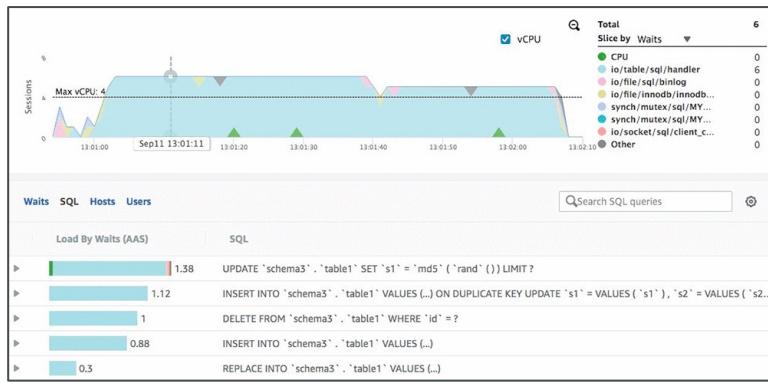
Aurora Logs

- You can monitor the following types of Aurora MySQL log files:
 - Error log
 - Slow query log
 - General log
 - The audit log
- These log files are either downloaded or published to CloudWatch Logs

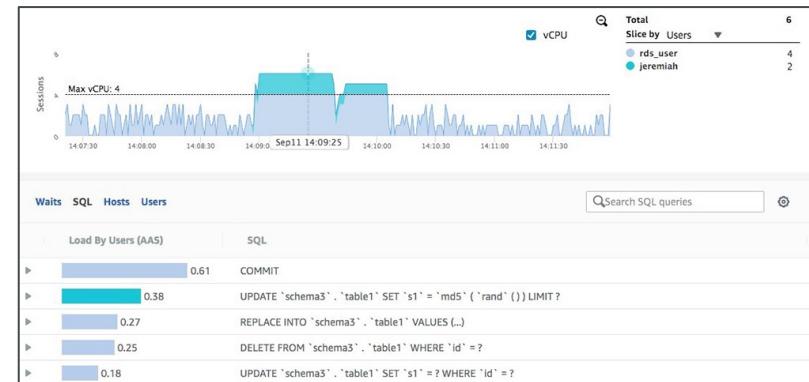


Troubleshooting RDS & Aurora Performance

- Performance Insights: find issues by waits, SQL statements, hosts and users



SQL Statements

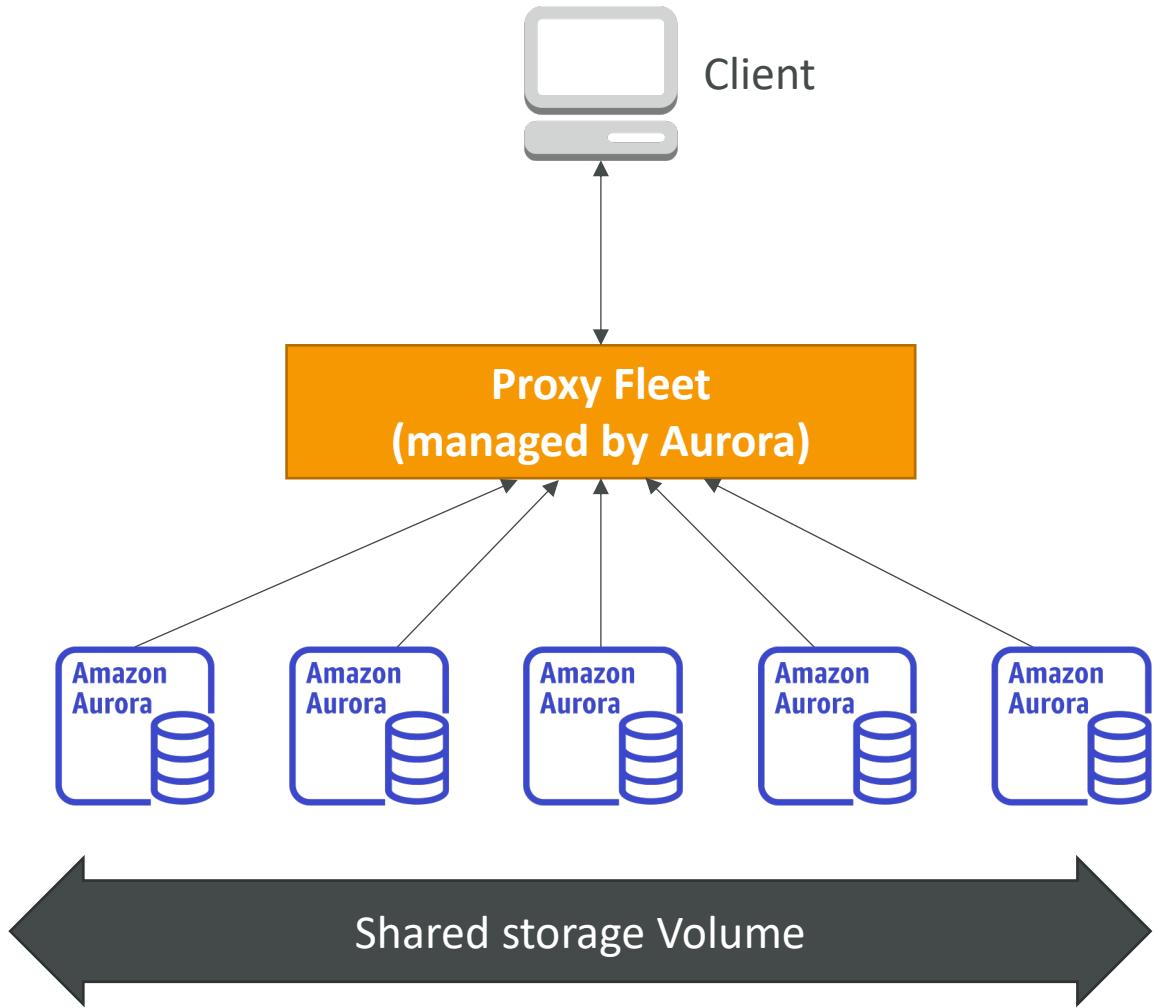


Users

- CloudWatch Metrics: CPU, Memory, Swap Usage
- Enhanced Monitoring Metrics: at host level, process view, per-second metric
- Slow Query logs

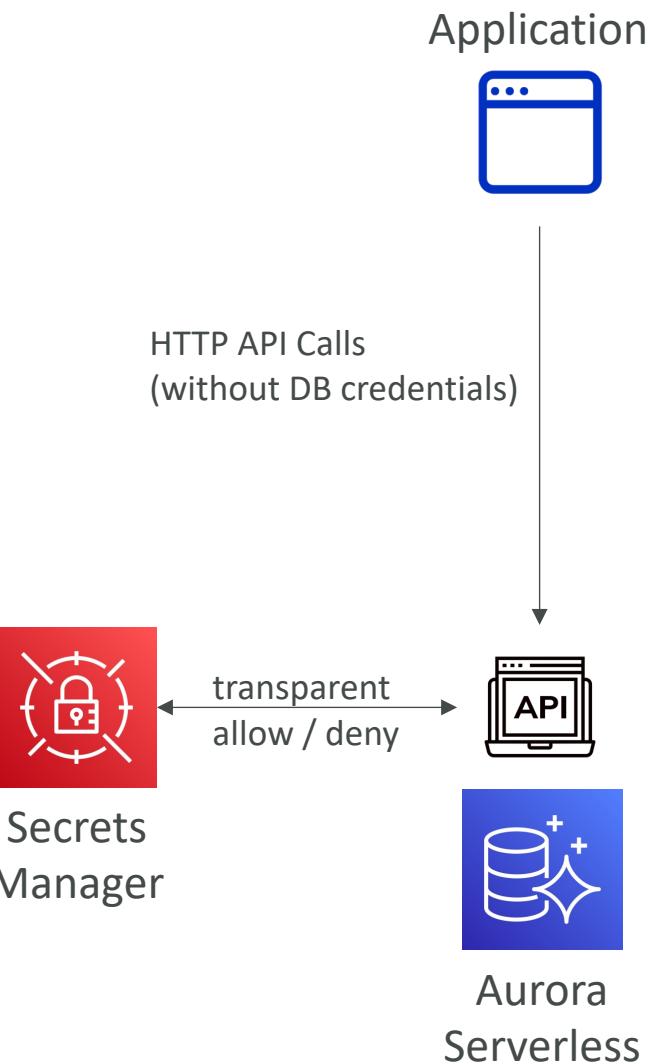
Aurora Serverless

- Automated database instantiation and auto-scaling based on actual usage
- Good for infrequent, intermittent or unpredictable workloads
- No capacity planning needed
- Pay per second, can be more cost-effective

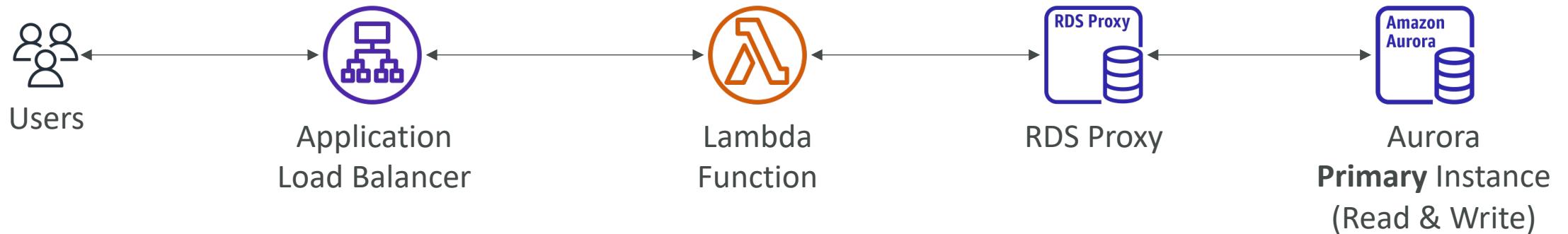


Aurora Serverless – Data API

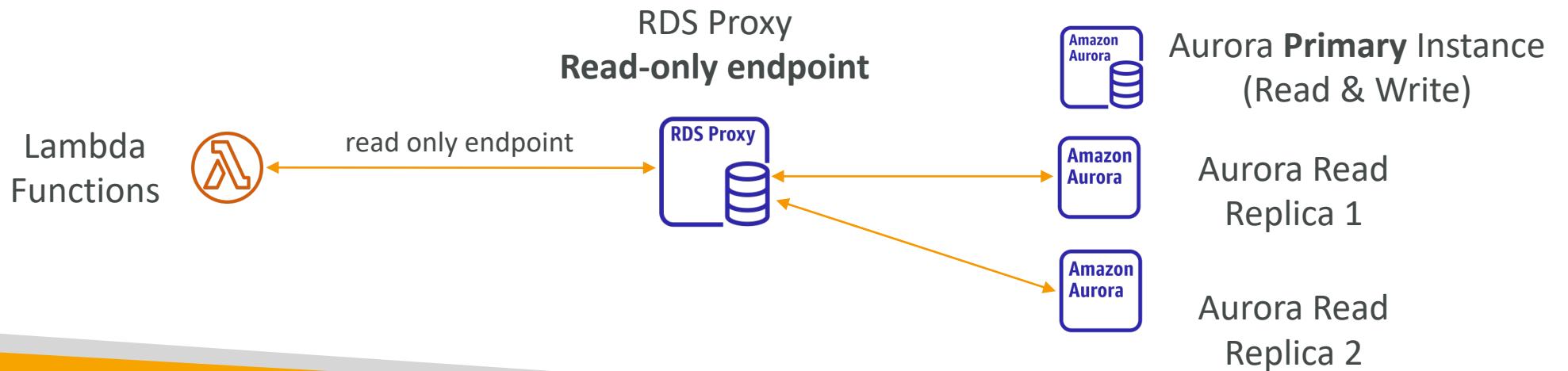
- Access Aurora Serverless DB with a simple API endpoint (no JDBC connection needed)
- Secure HTTPS endpoint to run SQL statements
- No persistent DB connections management
- Users must be granted permissions to Data API and Secrets Manager (where credentials are checked)



RDS Proxy for Aurora

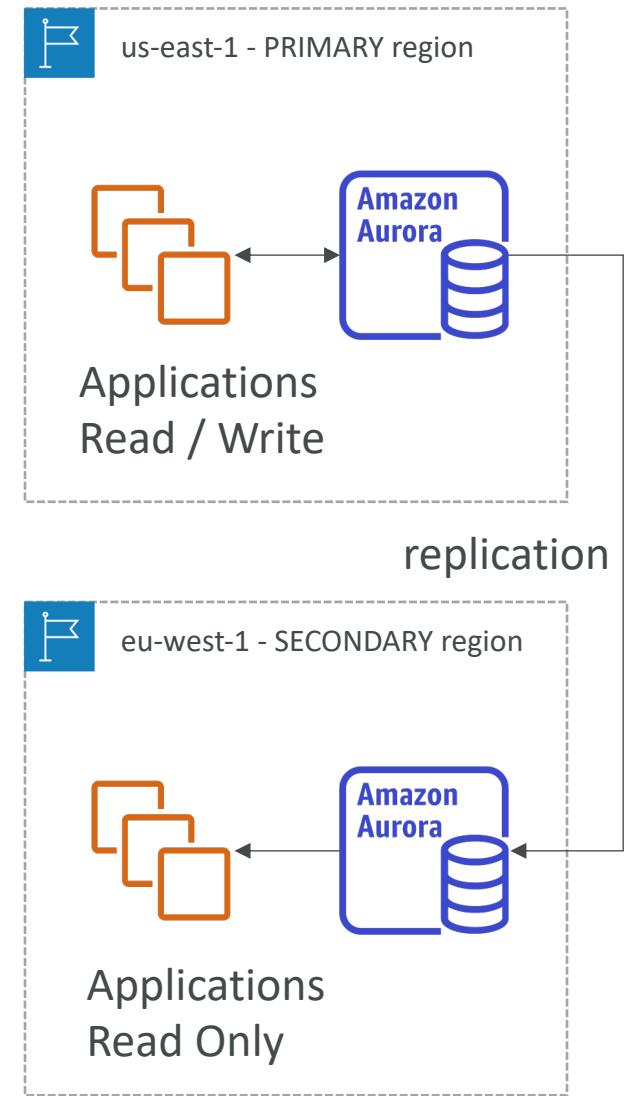


- Ability to create an additional read-only endpoint that connects to Aurora Read Replicas only



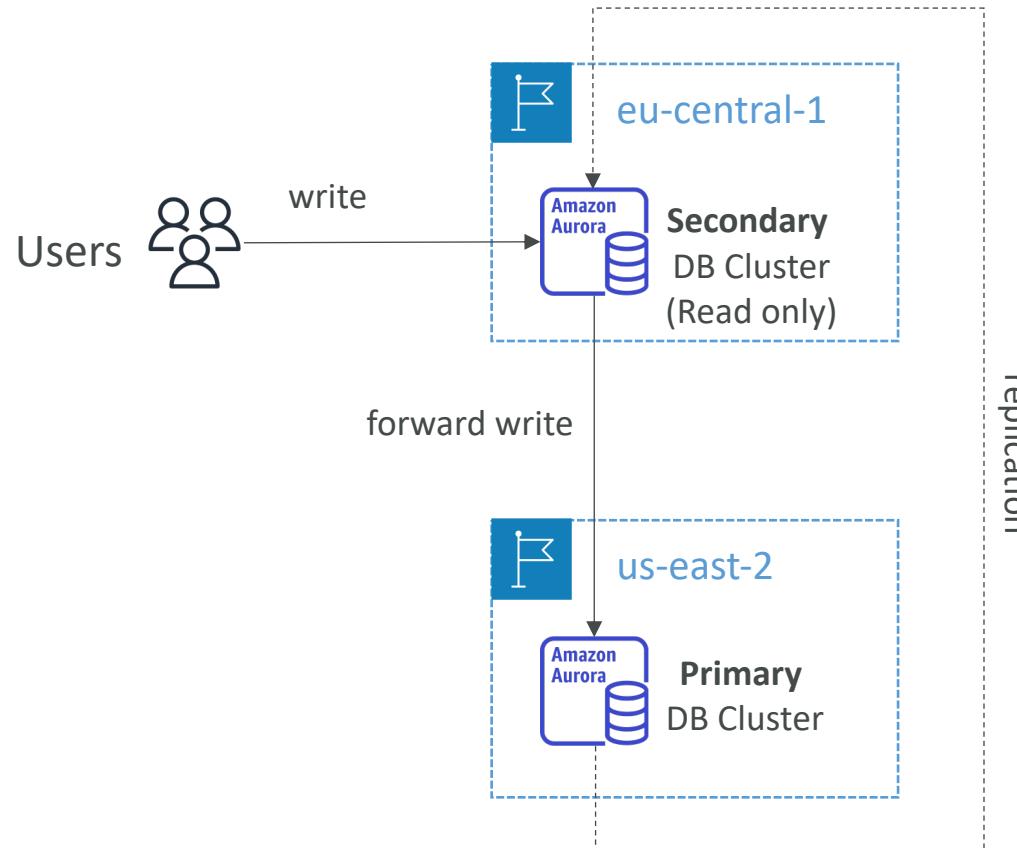
Global Aurora

- Aurora Cross Region Read Replicas
 - Useful for disaster recovery
 - Simple to put in place
- Aurora Global Database (recommended)
 - 1 Primary Region (read / write)
 - Up to 5 secondary (read-only) regions, replication lag is less than 1 second
 - Up to 16 Read Replicas per secondary region
 - Helps for decreasing latency
 - Promoting another region (for disaster recovery) has an RTO of < 1 minute
 - Ability to manage the RPO in Aurora for PostgreSQL

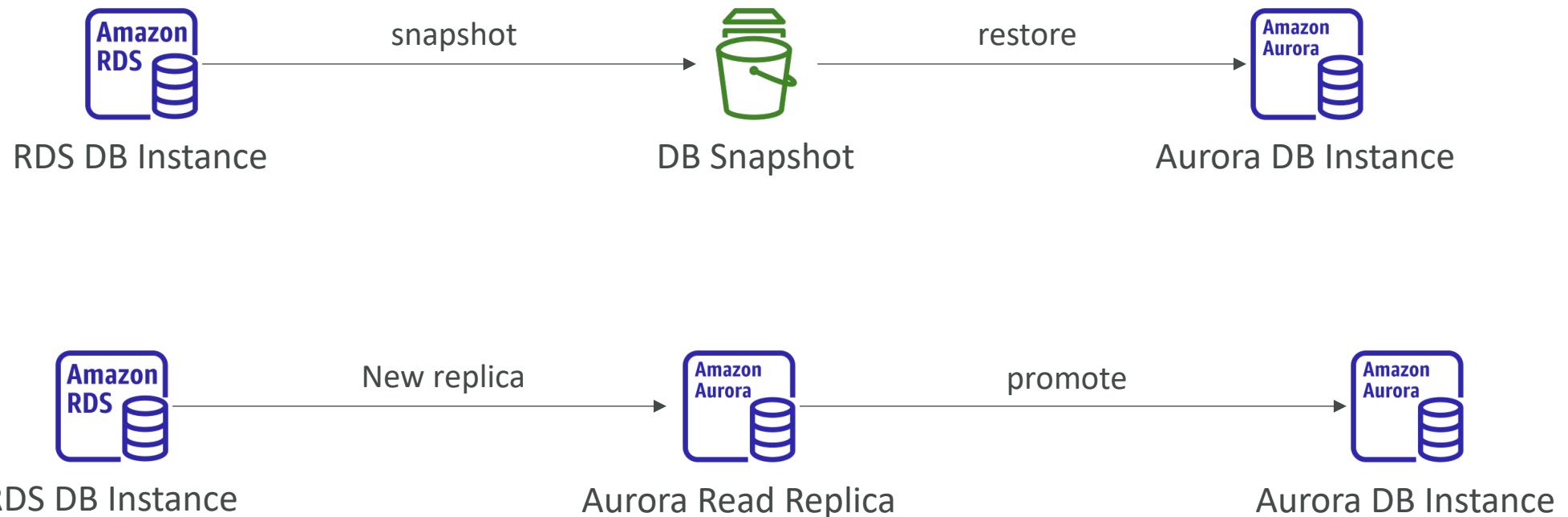


Aurora Global – Write Forwarding

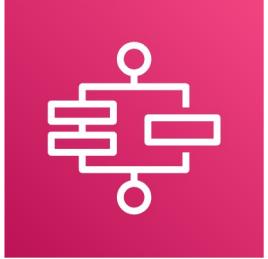
- Enables Secondary DB Clusters to forward SQL statements that perform write operations to the Primary DB Cluster
- Data is always changed first on the Primary DB Cluster, then replicated to the Secondary DB Clusters
- Primary DB Cluster always has an up-to-date copy of all data
- Reduces the number of endpoints to manage



Convert RDS to Aurora



Service Communication

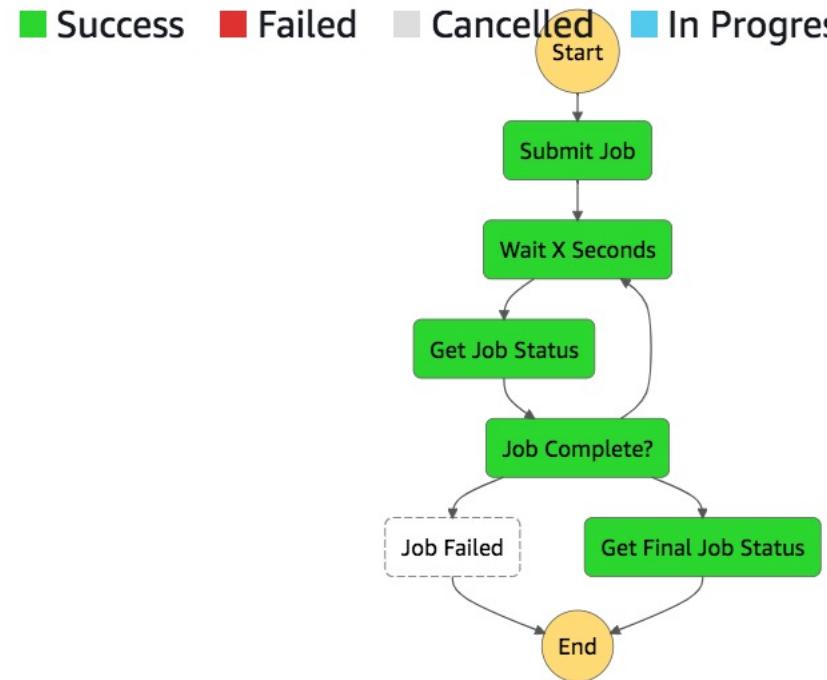
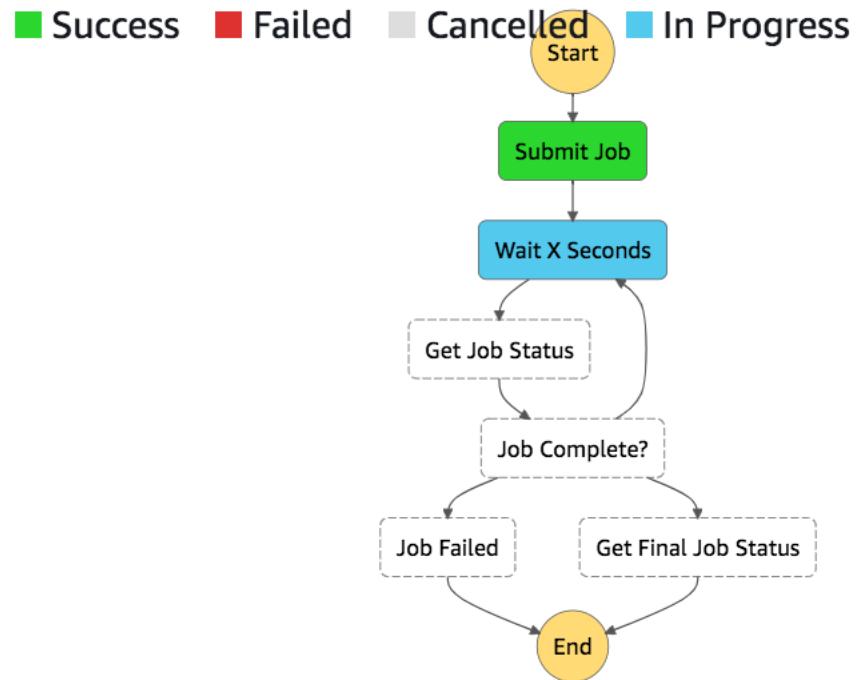
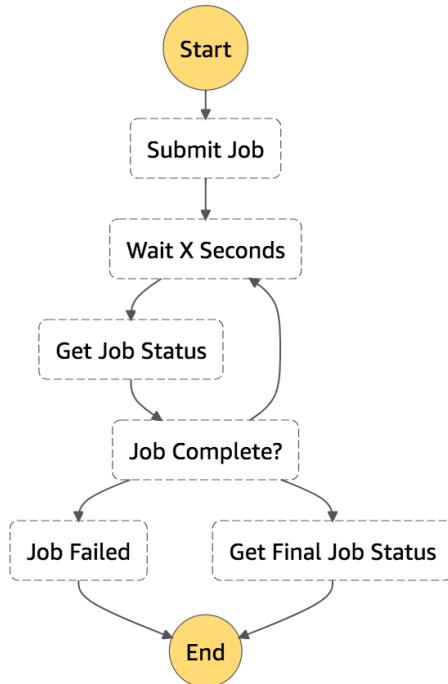


AWS Step Functions

- Build serverless visual workflow to orchestrate your Lambda functions
- Represent flow as a **JSON state machine**
- Features: sequence, parallel, conditions, timeouts, error handling...
- Maximum execution time of 1 year
- Possibility to implement human approval feature

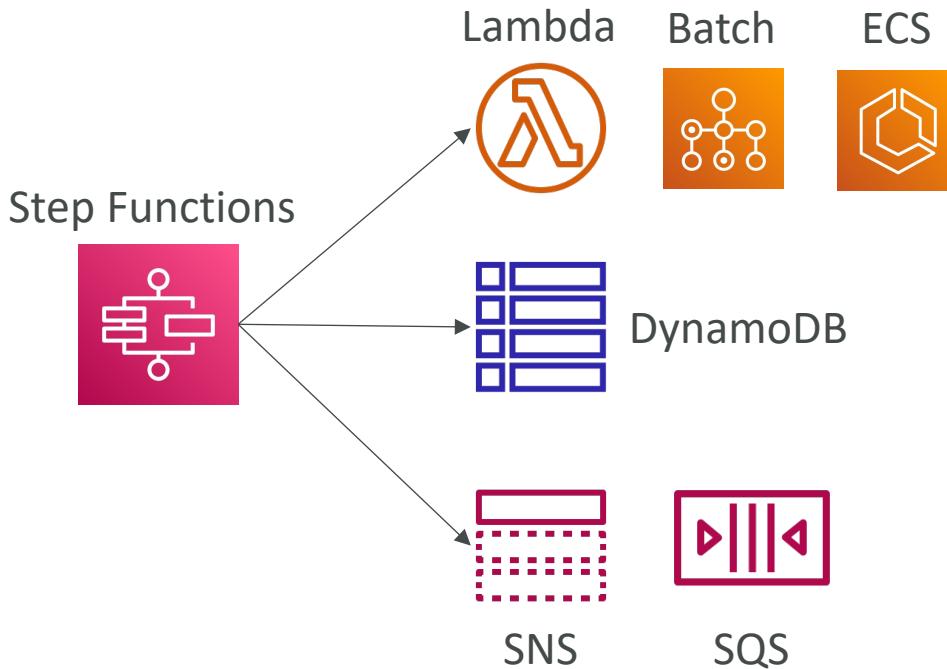
- If you chain Lambda functions using Step Functions, be mindful of the added latency to pass the calls.

Visual workflow in Step Functions



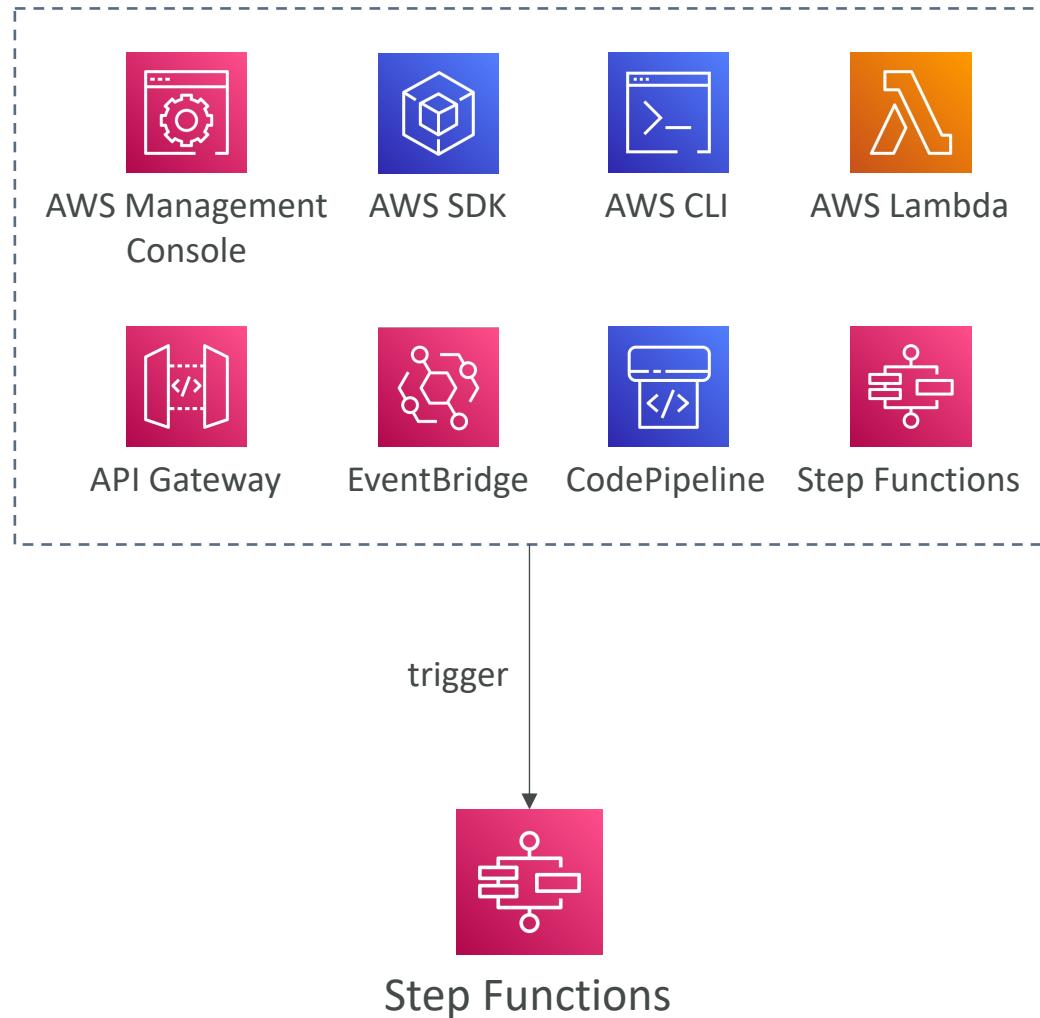
Step Function Integrations

- Optimized Integrations
 - Can invoke a Lambda function
 - Run an AWS Batch job
 - Run an ECS task and wait for it to complete
 - Insert an item from DynamoDB
 - Publish message to SNS, SQS
 - Launch an EMR, Glue, or SageMaker jobs
 - Launch another Step Function workflow...
- AWS SDK Integrations
 - Access 200+ AWS services from your State Machine
 - Works like standard AWS SDK API call



Step Functions Workflow Triggers

- You can invoke a Step Function Workflow (State Machine) using:
 - AWS Management Console
 - AWS SDK (`StartExecution` API call)
 - AWS CLI (`start-execution`)
 - AWS Lambda (`StartExecution` API call)
 - API Gateway
 - EventBridge
 - CodePipeline
 - Step Functions



Step Functions – Sample Projects

- <https://console.aws.amazon.com/states/home?region=us-east-1#/sampleProjects>

The grid contains 11 sample projects:

- Process high-volume messages from SQS** (New)
Use an Express state machine to process SQS messages at a very high rate. (Amazon SQS, AWS Lambda)
- Selective checkpointing example** (New)
Combine Standard and Express state machines to run an e-commerce workflow that does selective checkpointing. (Amazon SQS, AWS Lambda)
- Job Poller**
Manage an asynchronous job using a serverless polling loop (AWS Lambda, AWS Batch)
- Start a workflow within a workflow**
Combine different workflows together by triggering the execution of one state machine from within another.
- Dynamically process data with a Map state**
Dynamically iterate a series of steps by passing an array to a Map state (AWS Lambda, Amazon SQS, Amazon SNS, Amazon DynamoDB).
- Train a machine learning model**
Train a machine learning model and batch transform a test dataset (Amazon SageMaker, AWS Lambda, Amazon S3)
- Tune a machine learning model**
Tune hyperparameters of a machine learning model and batch transform a test dataset (Amazon SageMaker, AWS Lambda, Amazon S3)
- Callback pattern example**
Send a message to SQS, pausing the workflow until it receives a callback from an external service (in this case Lambda) with success or failure (Amazon SQS, Amazon SNS, AWS Lambda)
- Manage a batch job**
Trigger a notification on success or failure of a batch job (AWS Batch, Amazon SNS)
- Manage a container task**
Trigger a notification on success or failure of a container task (AWS Fargate, Amazon SNS)
- Transfer data records**
Iteratively read items from a database table and send each item as messages to a queue (Amazon DynamoDB, Amazon SQS)
- Task Timer**
Trigger a notification after a certain period of time (Amazon SNS)
- Manage an EMR job**
Create an EMR cluster, add multiple steps and run them, then terminate the cluster (Amazon EMR)

Step Functions – Tasks

- Lambda Tasks:
 - Invoke a Lambda function
- Activity Tasks:
 - Activity worker (HTTP), EC2 Instances, mobile device, on premise DC
 - They poll the Step functions service
- Service Tasks:
 - Connect to a supported AWS service
 - Lambda function, ECS Task, Fargate, DynamoDB, Batch job, SNS topic, SQS queue
- Wait Task:
 - To wait for a duration or until a timestamp
- Note: Step Functions does not integrate natively with AWS Mechanical Turk

Step Functions – Standard vs. Express

	Standard Workflows	Express Workflows
Maximum duration	1 year.	5 minutes.
Supported execution start rate	Over 2,000 per second	Over 100,000 per second
Supported state transition rate	Over 4,000 per second per account	Nearly unlimited
Pricing	Priced per state transition. A state transition is counted each time a step in your execution is completed (more expensive)	Priced by the number of executions you run, their duration, and memory consumption (cheaper)
Execution history	Executions can be listed and described with Step Functions APIs, and visually debugged through the console. They can also be inspected in CloudWatch Logs by enabling logging on your state machine.	Executions can be inspected in CloudWatch Logs by enabling logging on your state machine.
Execution semantics	Exactly-once workflow execution.	At-least-once workflow execution.

Step Functions – Express Workflow – Synchronous vs. Asynchronous

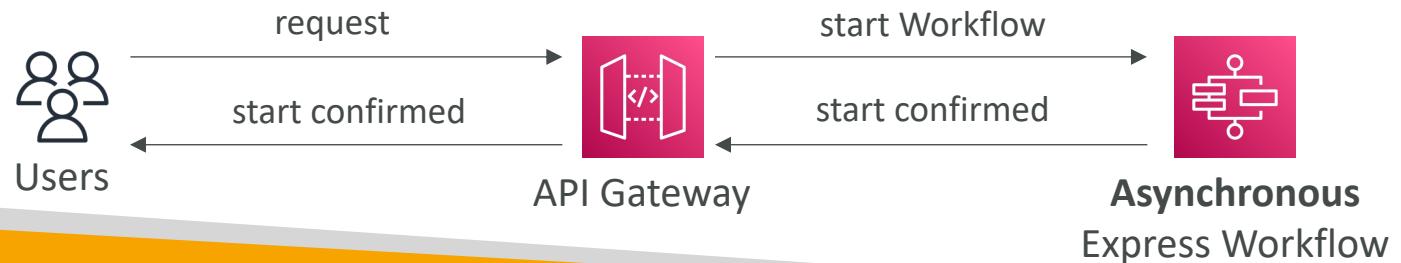
- **Synchronous Express Workflows**

- Wait until the Workflow completes, then return the result
- Examples: orchestrate microservices, handle errors, retries, parallel tasks, ...



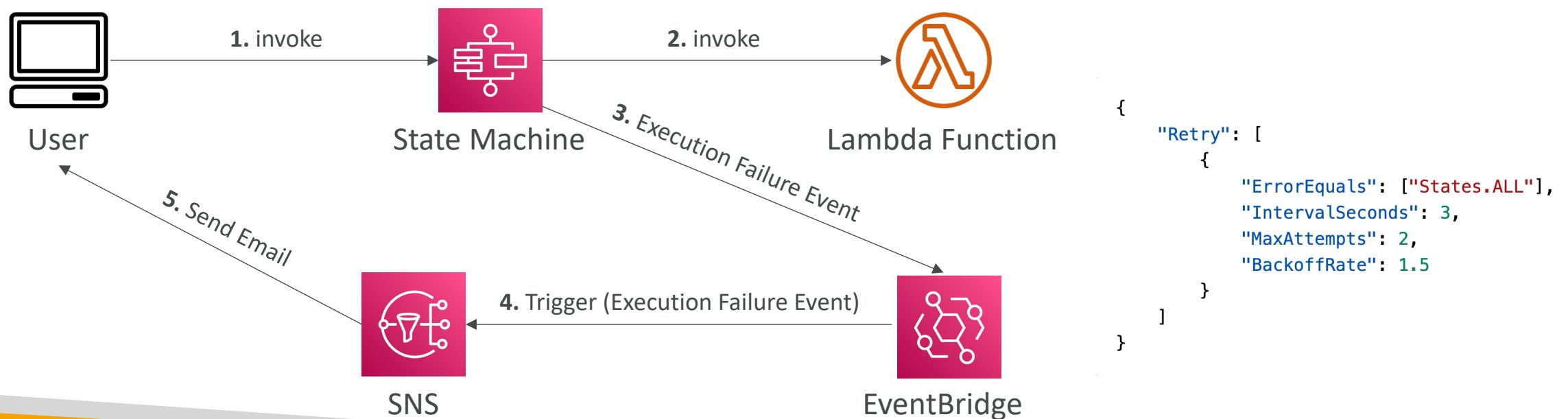
- **Asynchronous Express Workflows**

- Doesn't wait for the Workflow to complete
- Examples: Workflows that don't require immediate response, messaging, ...

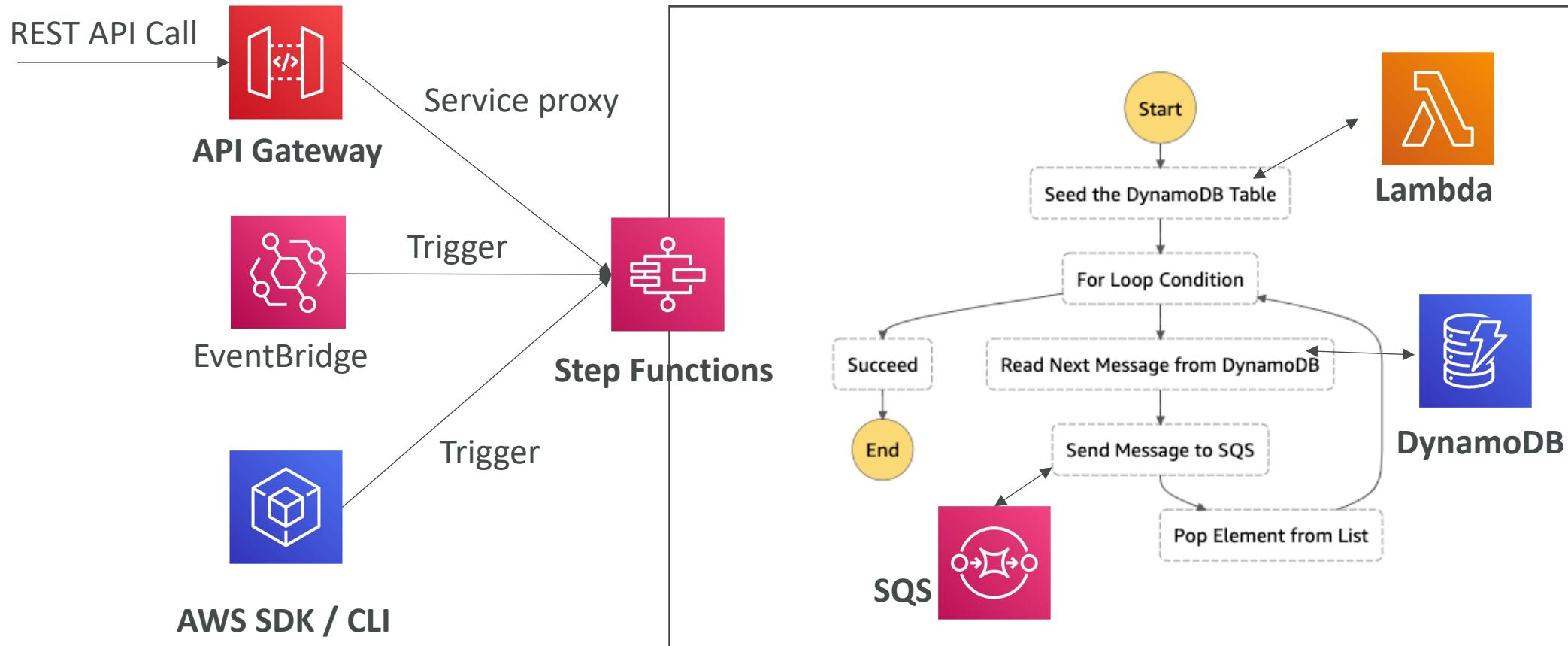


Step Functions – Error Handling

- You can enable error handling, retries, and add alerting to Step Function State Machine
- Example: set up EventBridge to alert via email if a State Machine execution fails



Step Functions – Solution Architecture



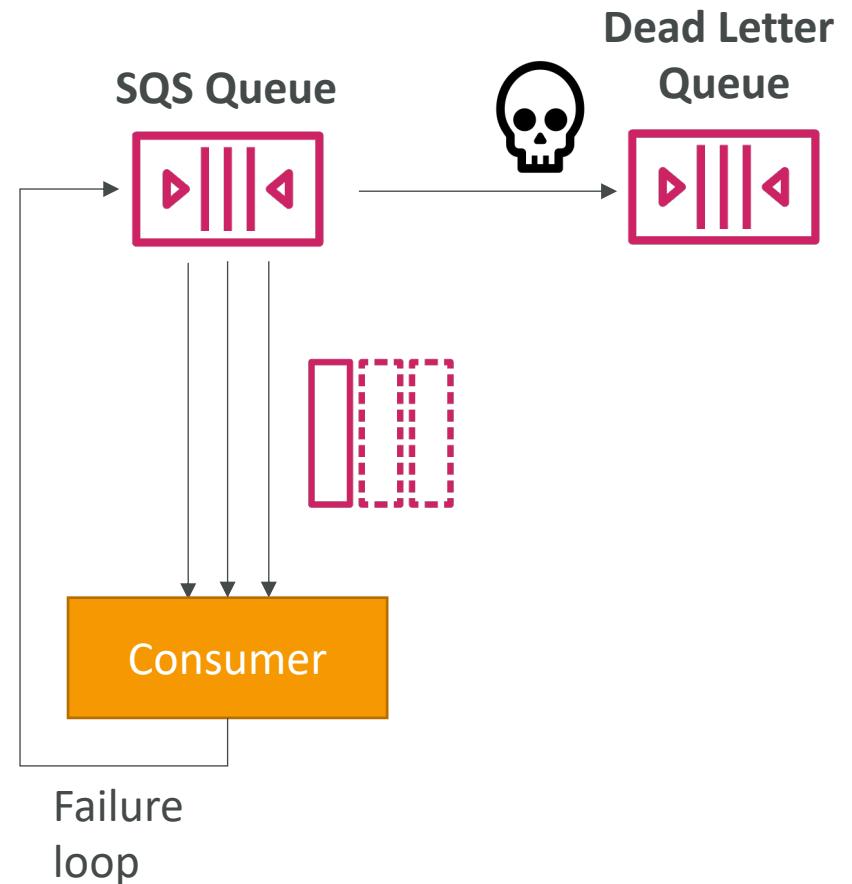
Amazon SQS



- Serverless, managed queue, integrated with IAM
- Can handle extreme scale, no provisioning required
- Used to **decouple** services
- Message size of max 256 KB (use a pointer to S3 for large messages)
- Can be read from EC2 (optional ASG), Lambda
- SQS could be used as a write buffer for DynamoDB
- **SQS FIFO:**
 - receive messages in order they were sent
 - 300 messages/s without batching, 3000 /s with batching

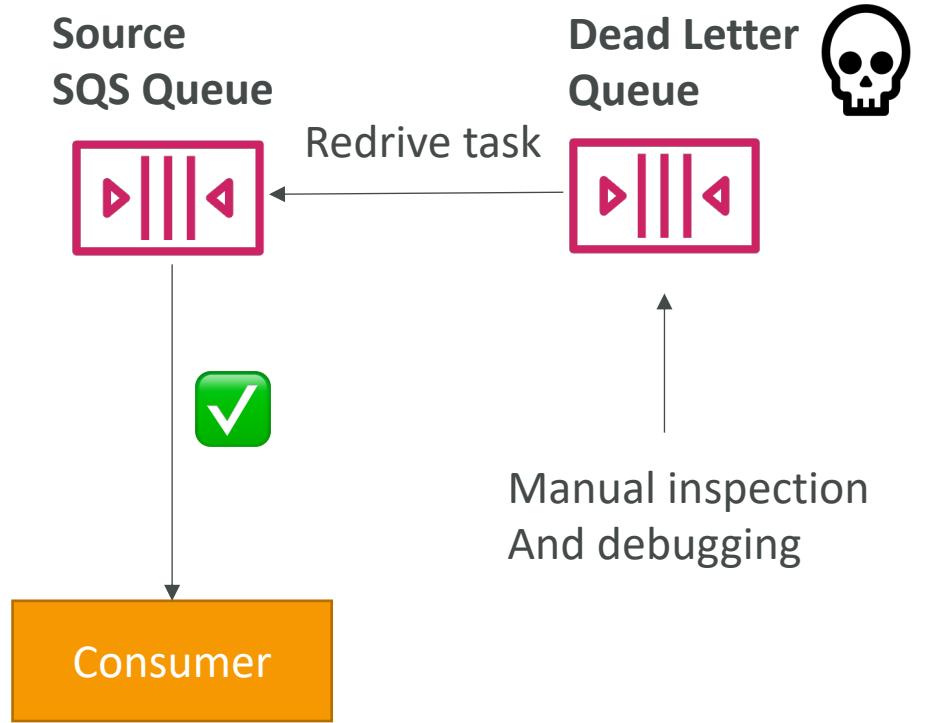
Amazon SQS – Dead Letter Queue (DLQ)

- 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 message goes into a Dead Letter Queue (DLQ)
- Useful for debugging!
- DLQ of a FIFO queue must also be a FIFO queue
- DLQ of a Standard queue must also be a Standard queue
- Make sure to process the messages in the DLQ before they expire:
 - Good to set a retention of 14 days in the DLQ



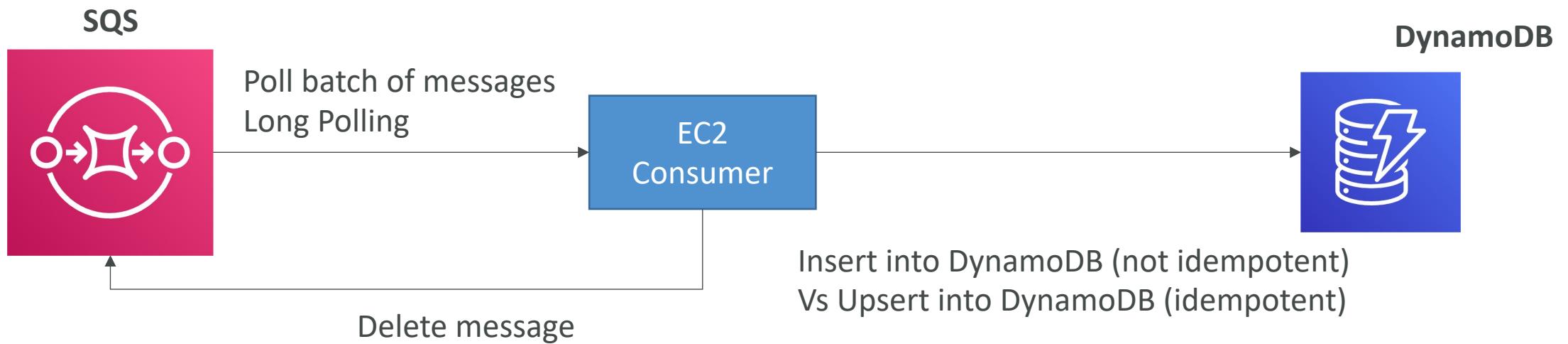
SQS DLQ – Redrive to Source

- Feature to help consume messages in the DLQ to understand what is wrong with them
- When our code is fixed, we can redrive the messages from the DLQ back into the source queue (or any other queue) in batches without writing custom code



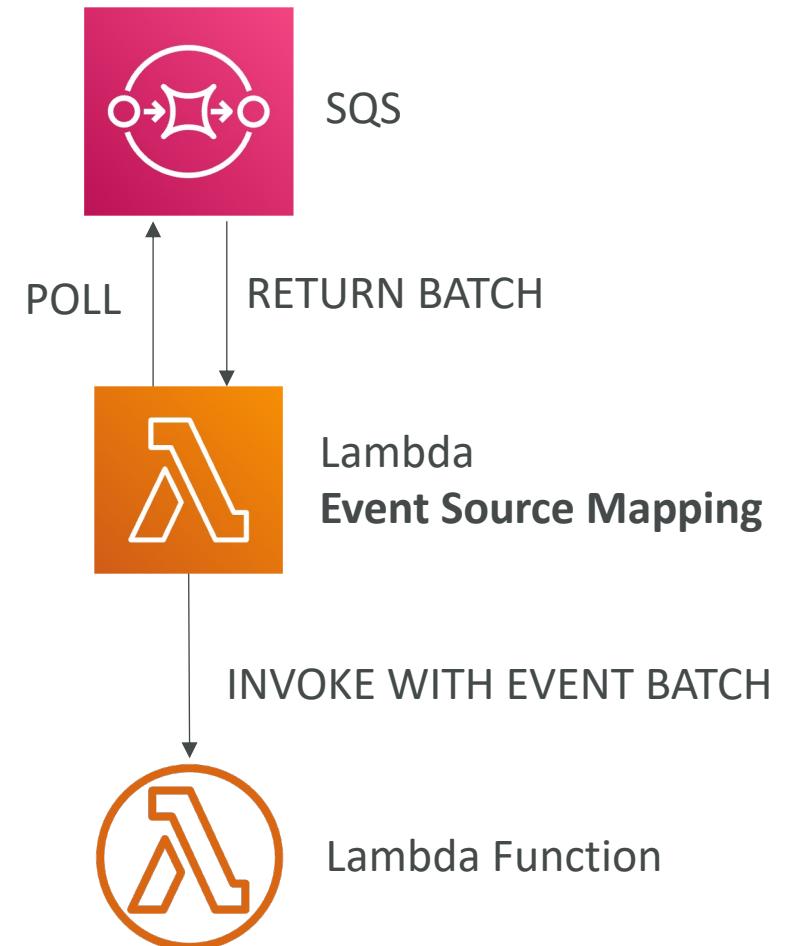
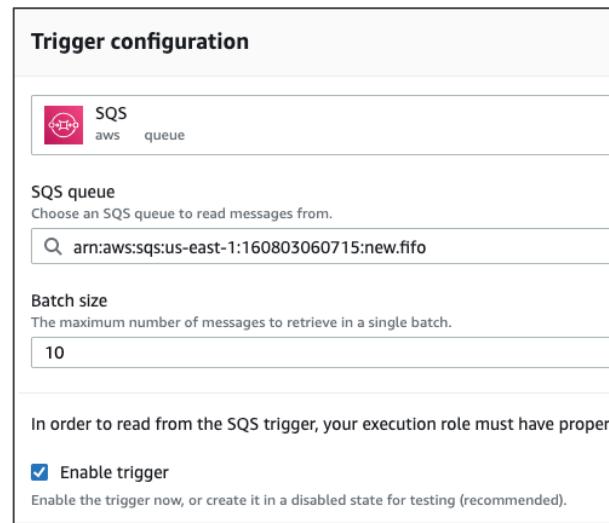
SQS – Solution Architecture Idempotency

- Messages can be processed twice by consumer (in case of failures, timeouts, etc)
- To hedge against that problem, implement **idempotency** at the consumer level
- Means the same action done twice by the consumer won't duplicate the effect



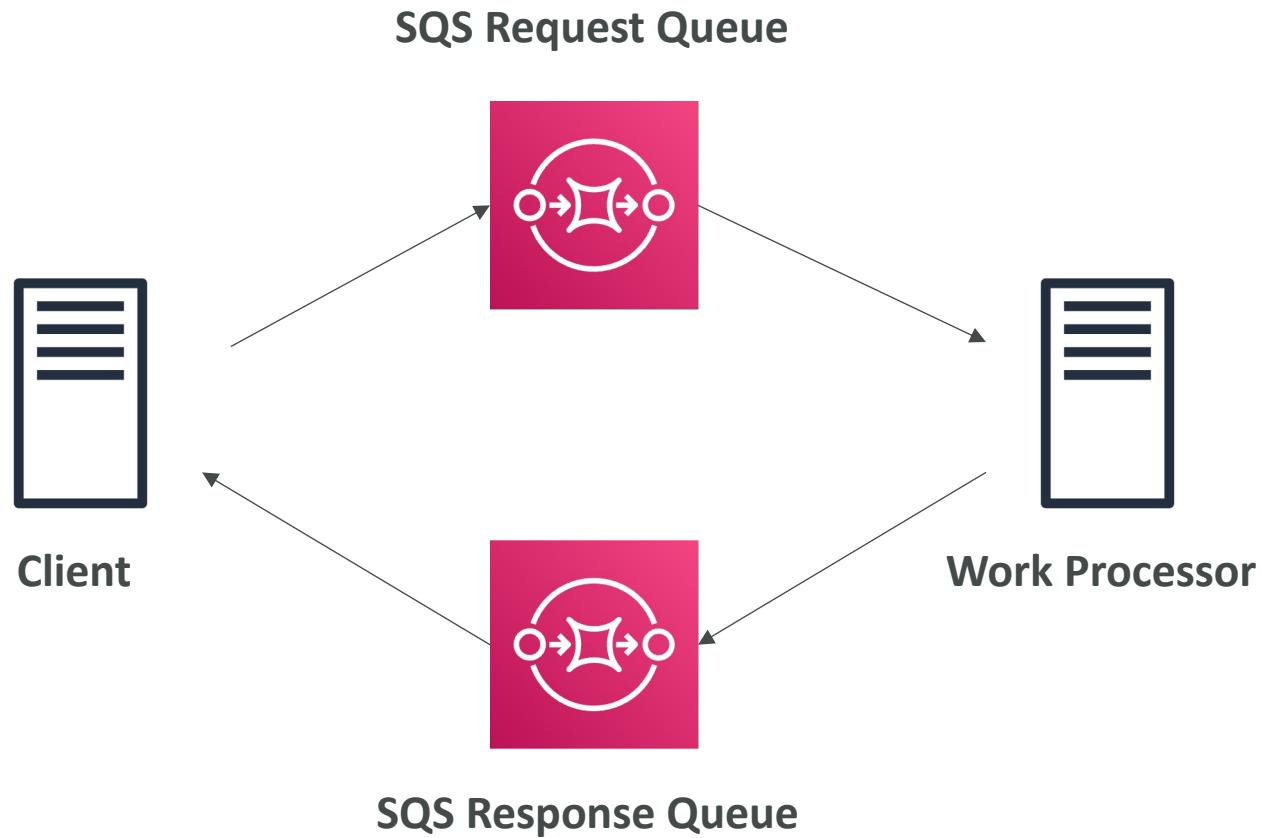
Lambda – Event Source Mapping SQS & SQS FIFO

- Event Source Mapping will poll SQS (Long Polling)
- Specify batch size (1-10 messages)
- Recommended: Set the queue visibility timeout to 6x the timeout of your Lambda function
- To use a DLQ
 - set-up on the SQS queue, not Lambda (DLQ for Lambda is only for async invocations)
 - Or use a Lambda destination for failures



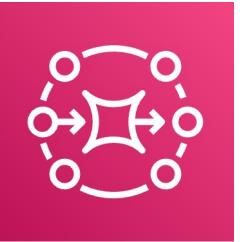
SQS - Solution Architecture

Request / Response queue (async)



- Decoupling
- Fault-Tolerance
- Load Balancing

Amazon MQ



- SQS, SNS are “cloud-native” services: proprietary protocols from AWS
- Traditional applications running from on-premises may use open protocols such as: MQTT, AMQP, STOMP, Openwire, WSS
- When migrating to the cloud, instead of re-engineering the application to use SQS and SNS, we can use Amazon MQ
- Amazon MQ is a managed message broker service for

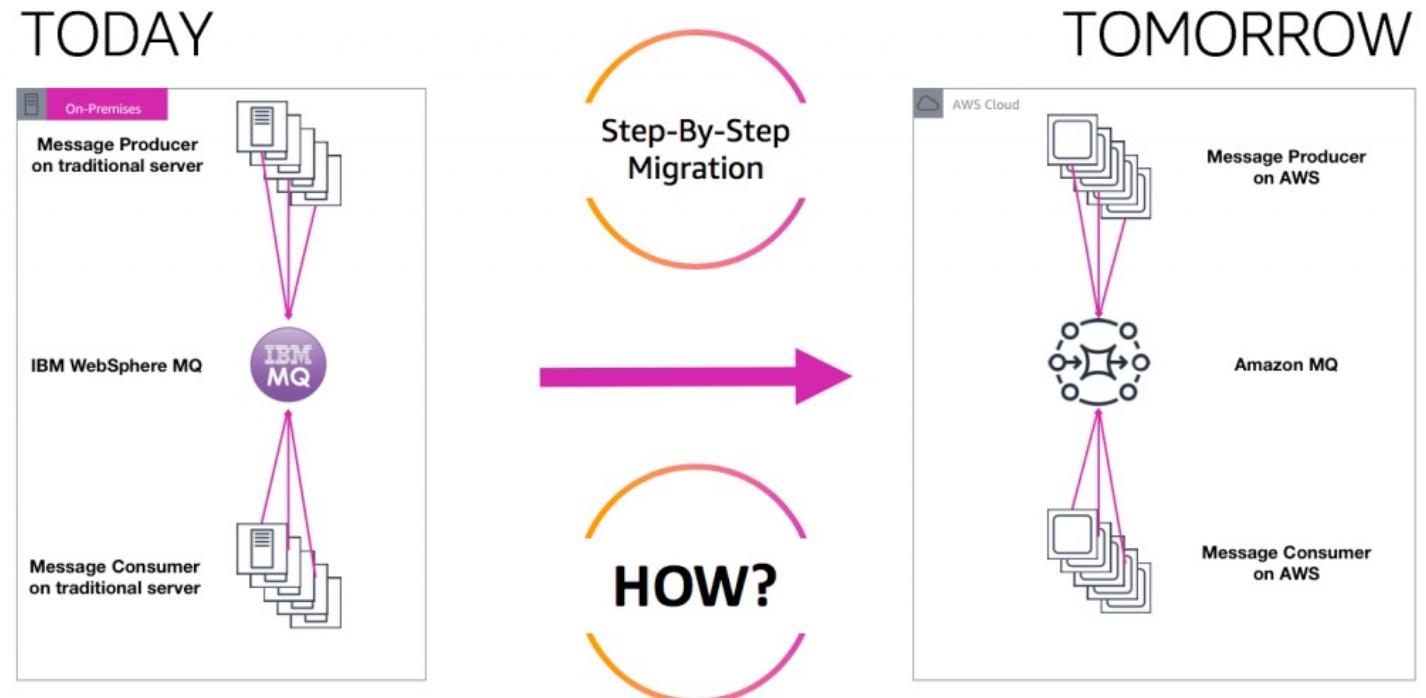
 RabbitMQ™



- Amazon MQ doesn’t “scale” as much as SQS / SNS
- Amazon MQ runs on servers, can run in Multi-AZ with failover
- Amazon MQ has both queue feature (~SQS) and topic features (~SNS)

Amazon MQ – Re-platform

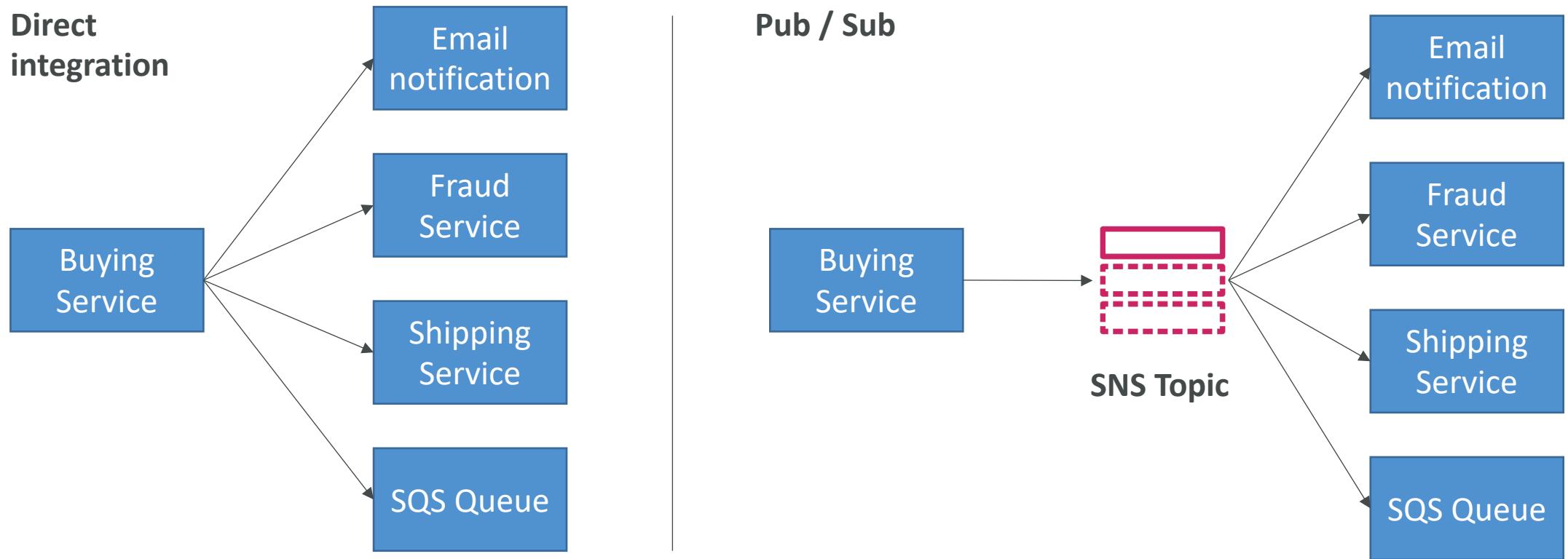
- IBM MQ, TIBCO EMS, Rabbit MQ, and Apache ActiveMQ can be migrated to Amazon MQ



<https://aws.amazon.com/blogs/compute/migrating-from-ibm-mq-to-amazon-mq-using-a-phased-approach/>

Amazon SNS

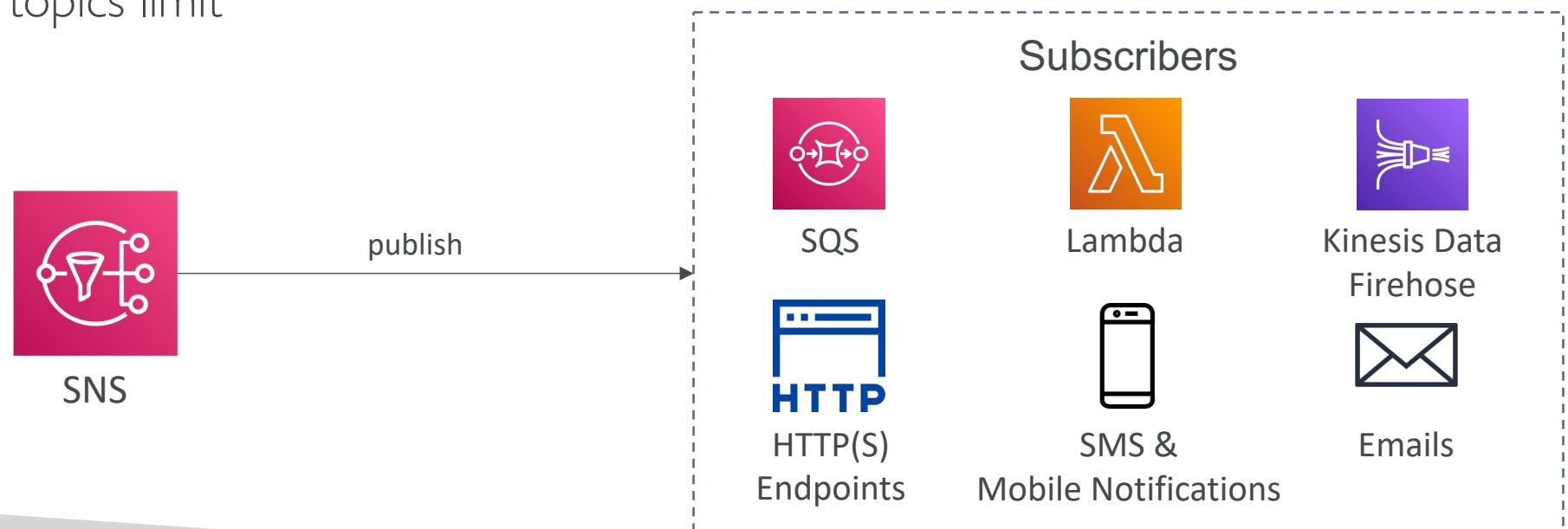
- What if you want to send one message to many receivers?



Amazon SNS

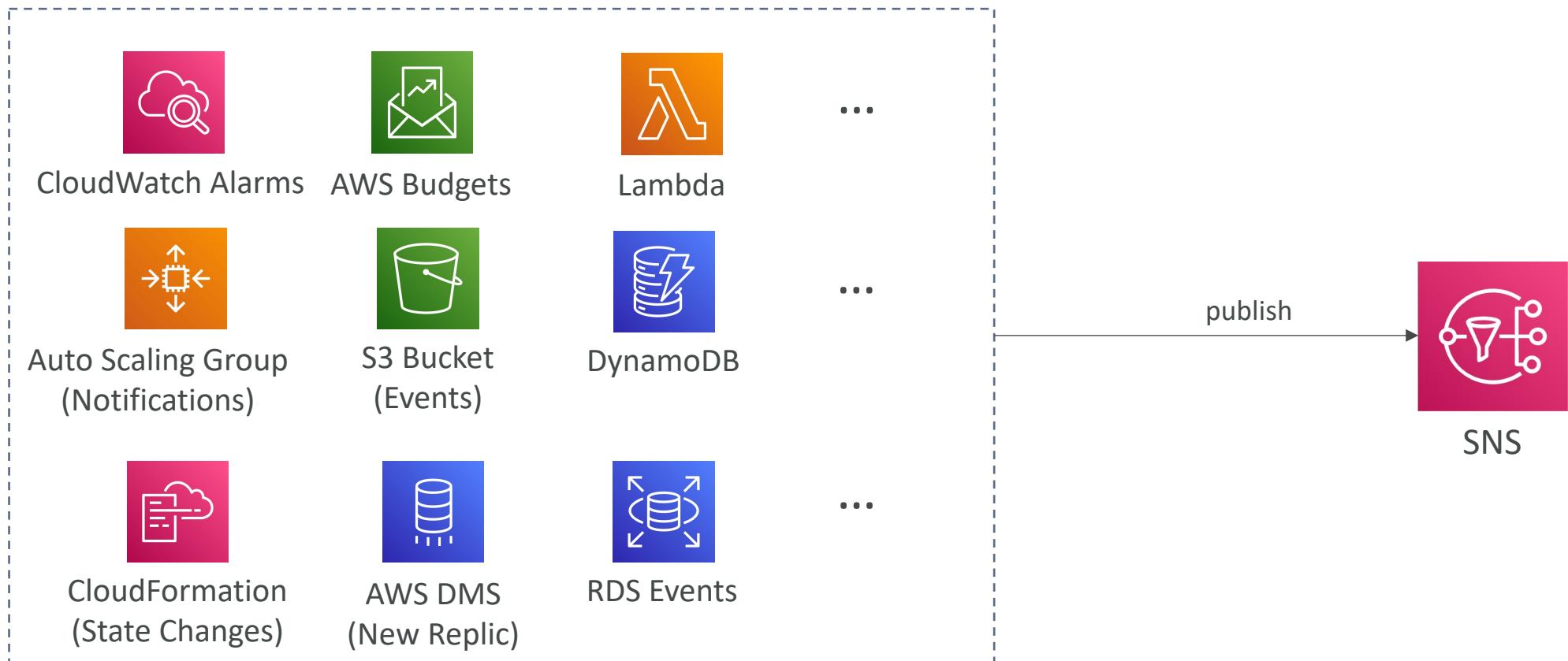


- The “event producer” only sends message to one SNS topic
- As many “event receivers” (subscriptions) as we want to listen to the SNS topic notifications
- Each subscriber to the topic will get all the messages (note: new feature to filter messages)
- Up to 12,500,000 subscriptions per topic
- 100,000 topics limit



SNS integrates with a lot of AWS services

- Many AWS services can send data directly to SNS for notifications



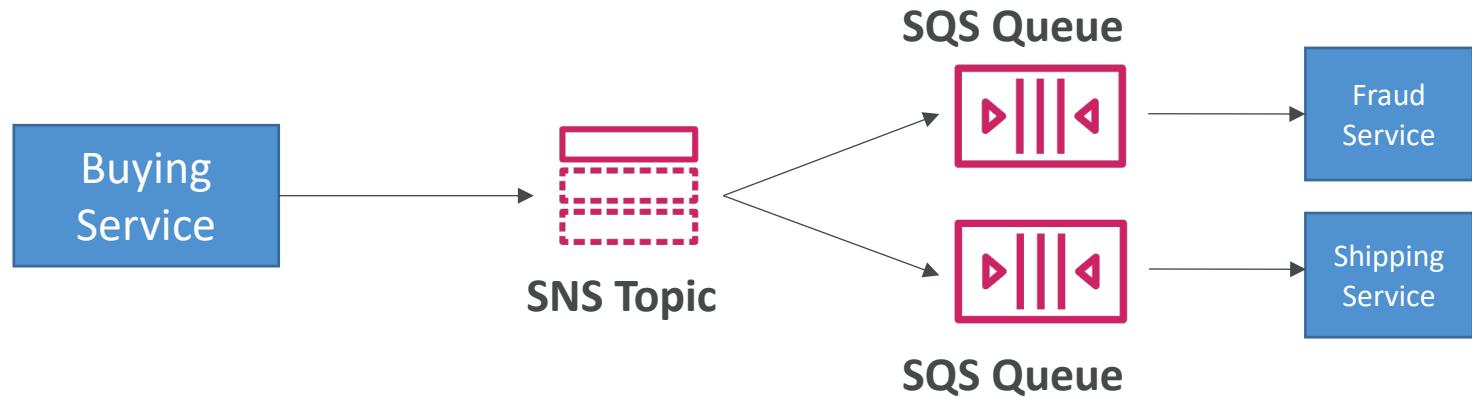
Amazon SNS – How to publish

- Topic Publish (using the SDK)
 - Create a topic
 - Create a subscription (or many)
 - Publish to the topic
- Direct Publish (for mobile apps SDK)
 - Create a platform application
 - Create a platform endpoint
 - Publish to the platform endpoint
 - Works with Google GCM, Apple APNS, Amazon ADM...

Amazon SNS – 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 itself
- **Access Controls:** IAM policies to regulate access to the SNS API
- **SNS Access Policies** (similar to S3 bucket policies)
 - Useful for cross-account access to SNS topics
 - Useful for allowing other services (S3...) to write to an SNS topic

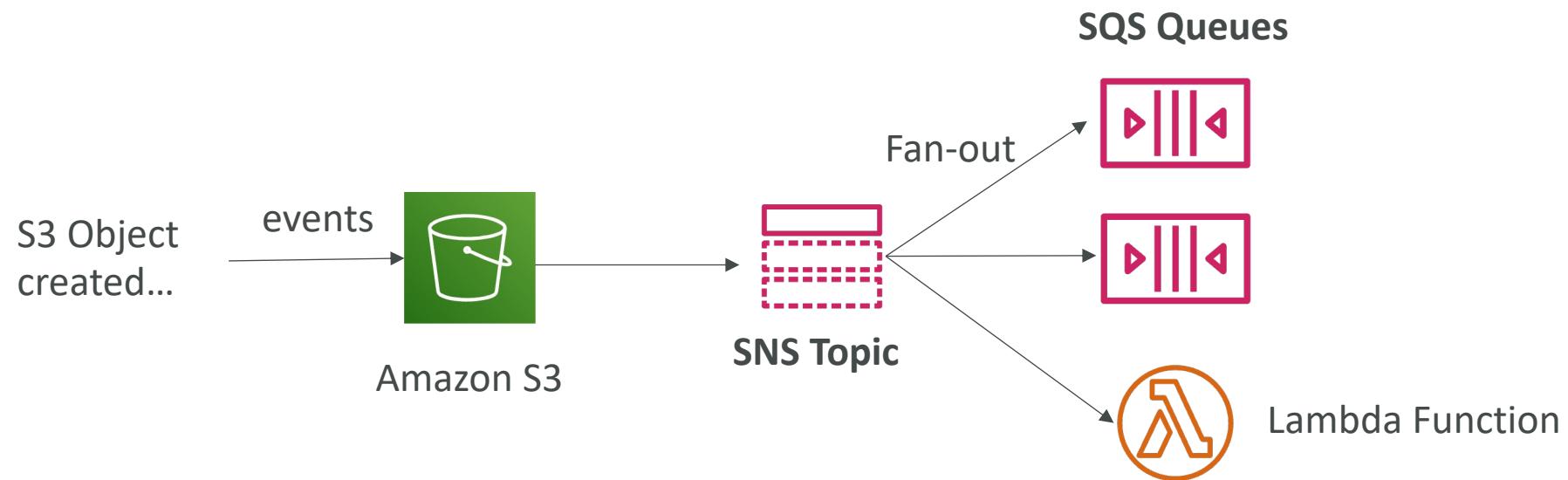
SNS + SQS: Fan Out



- Push once in SNS, receive in all SQS queues that are subscribers
- 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
- Cross-Region Delivery: works with SQS Queues in other regions

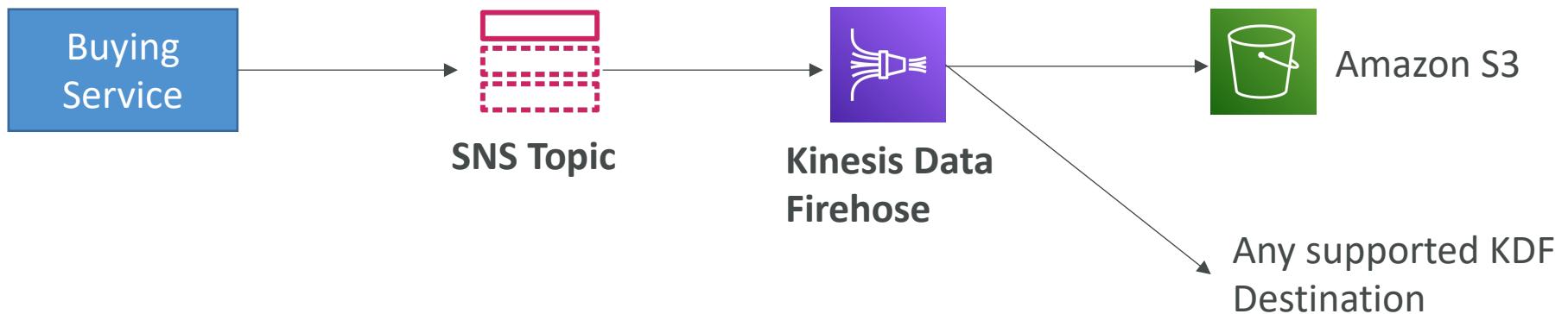
Application: S3 Events to multiple queues

- For the same combination of: **event type** (e.g. object create) and **prefix** (e.g. images/) you can only have one S3 Event rule
- If you want to send the same S3 event to many SQS queues, use fan-out



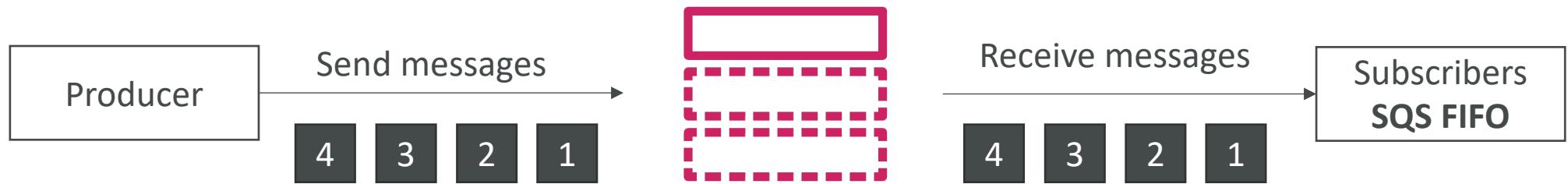
Application: SNS to Amazon S3 through Kinesis Data Firehose

- SNS can send to Kinesis and therefore we can have the following solutions architecture:



Amazon SNS – FIFO Topic

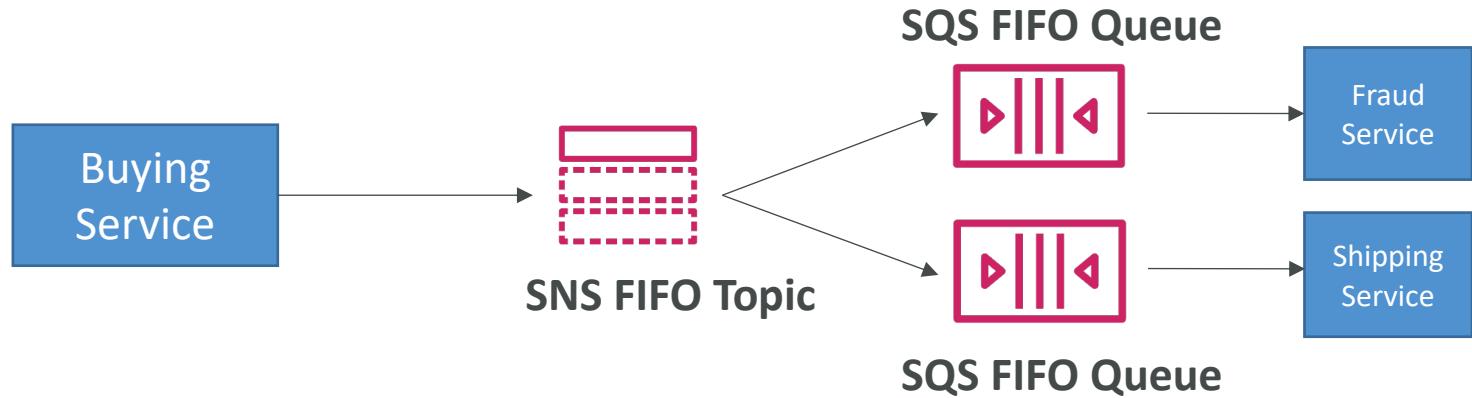
- FIFO = First In First Out (ordering of messages in the topic)



- 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 have SQS Standard and FIFO queues as subscribers
- Limited throughput (same throughput as SQS FIFO)

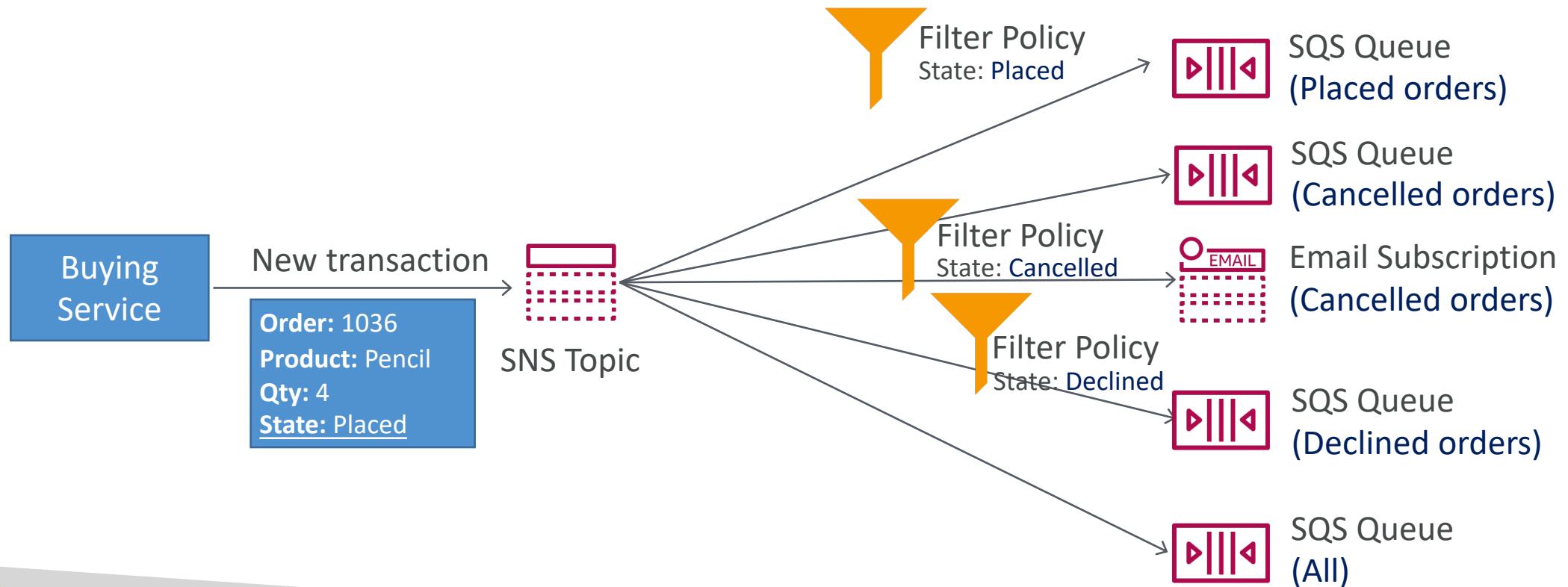
SNS FIFO + SQS FIFO: Fan Out

- In case you need fan out + ordering + deduplication



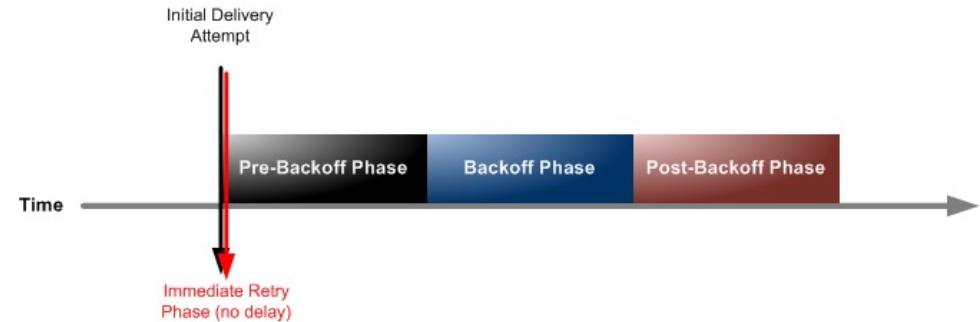
SNS – Message Filtering

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



SNS – Message Delivery Retries

- When a message is delivered to an SNS subscriber, in case of server-side errors, a delivery policy is applied



Endpoint type	Delivery protocols	Immediate retry (no delay) phase	Pre-backoff phase	Backoff phase	Post-backoff phase	Total attempts
AWS managed endpoints	Amazon Kinesis Data Firehose	3 times, without delay	2 times, 1 second apart	10 times, with exponential backoff, from 1 second to 20 seconds	100,000 times, 20 seconds apart	100,015 times, over 23 days
	AWS Lambda					
	Amazon SQS					
Customer managed endpoints	SMTP	0 times, without delay	2 times, 10 seconds apart	10 times, with exponential backoff, from 10 seconds to 600 seconds (10 minutes)	38 times, 600 seconds (10 minutes) apart	50 attempts, over 6 hours

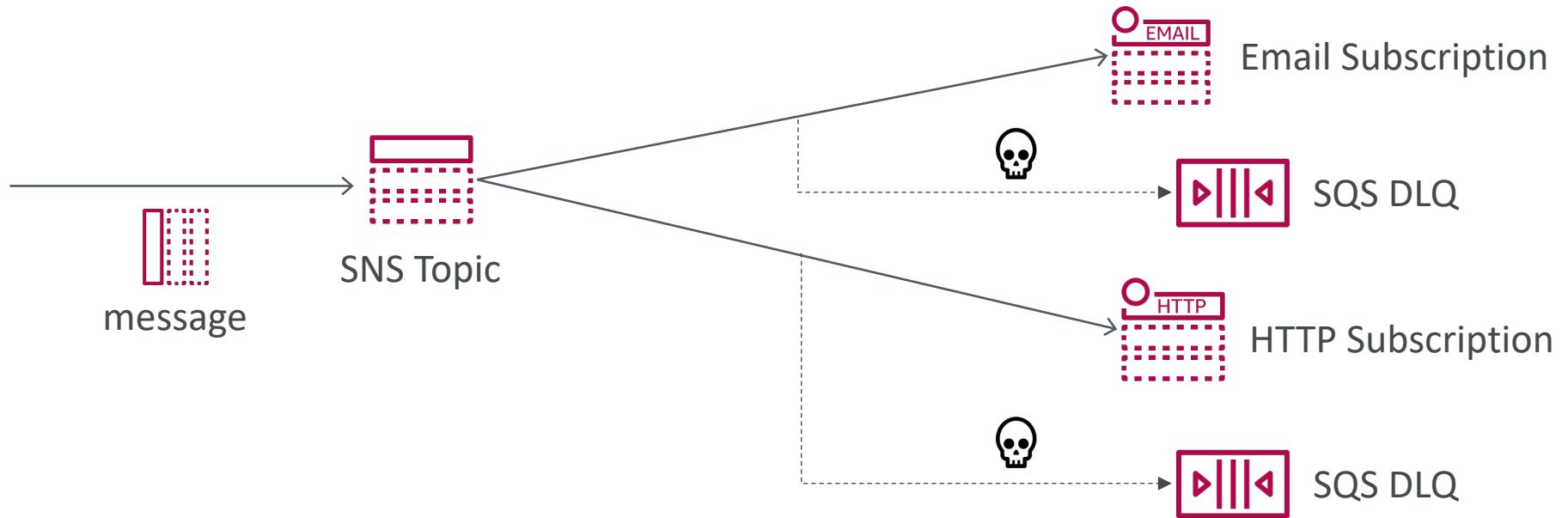
SNS – Custom Delivery Policies

- Only HTTP/S supports custom policies

```
{  
  "healthyRetryPolicy": {  
    "minDelayTarget": 1,  
    "maxDelayTarget": 60,  
    "numRetries": 50,  
    "numNoDelayRetries": 3,  
    "numMinDelayRetries": 2,  
    "numMaxDelayRetries": 35,  
    "backoffFunction": "exponential"  
  },  
  "sicklyRetryPolicy": null,  
  "throttlePolicy": {  
    "maxReceivesPerSecond": 10  
  }  
}
```

SNS – Dead Letter Queues

- After exhausting the delivery policy, messages that haven't been delivered are discarded unless you set a DLQ (Dead Letter Queue)
- DLQ are Amazon SQS queues or Amazon SQS FIFO queues (for SNS FIFO)
- Dead Letter Queues are attached to a subscription (rather than a topic)



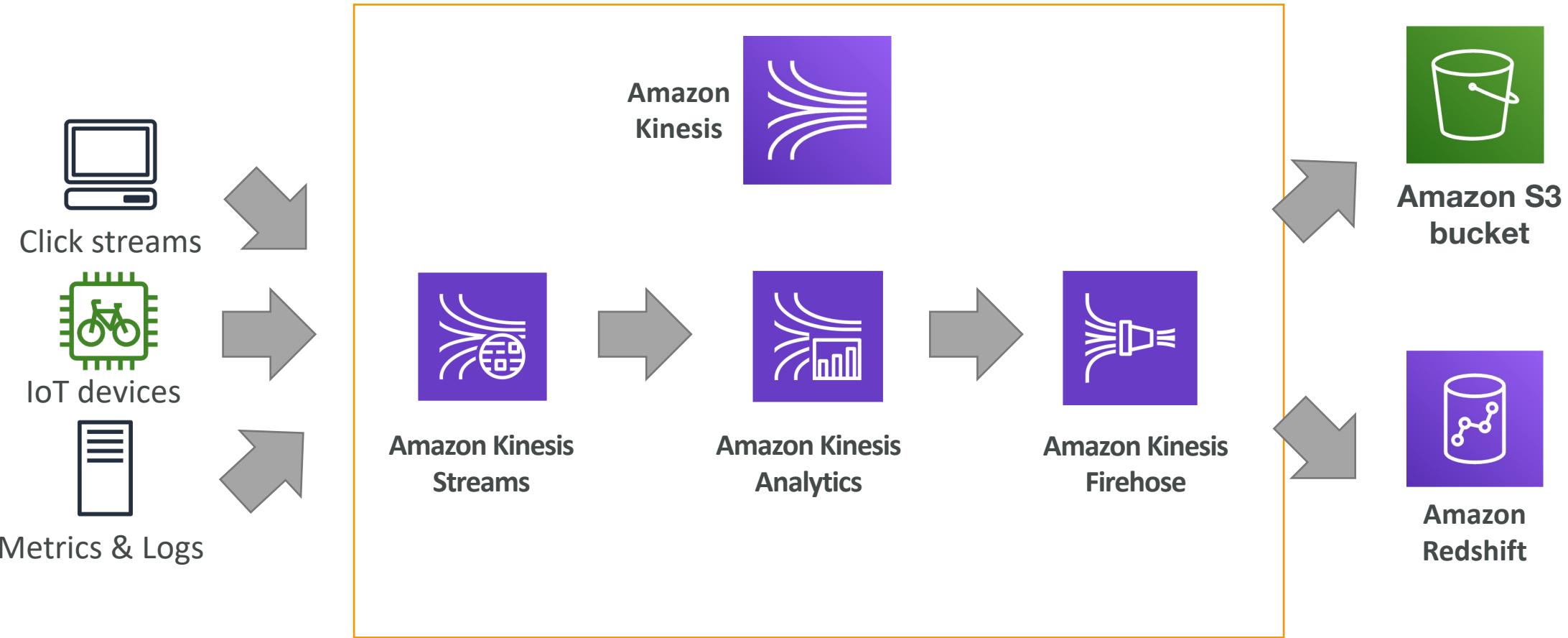
Data Engineering

AWS Kinesis Overview



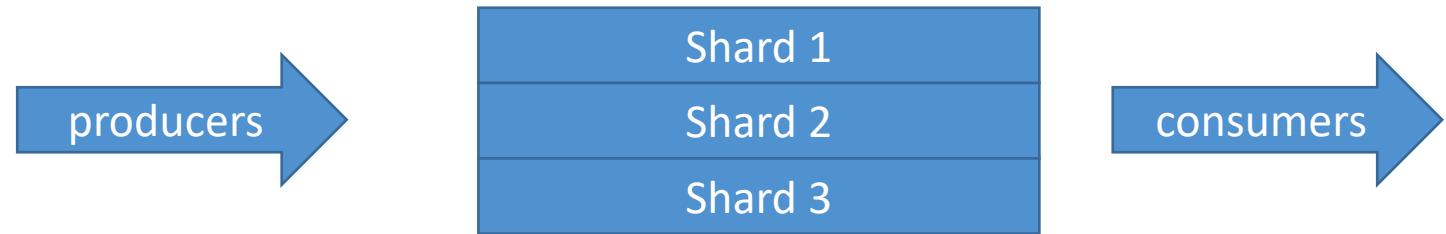
- Kinesis is a managed “data streaming” service
 - Great for application logs, metrics, IoT, clickstreams
 - Great for “real-time” big data
 - Great for streaming processing frameworks (Spark, NiFi, etc...)
 - Data is automatically replicated synchronously to 3 AZ
-
- Kinesis Streams: low latency streaming ingest at scale
 - Kinesis Analytics: perform real-time analytics on streams using SQL
 - Kinesis Firehose: load streams into S3, Redshift, ElasticSearch & Splunk

Kinesis



Kinesis Streams Overview

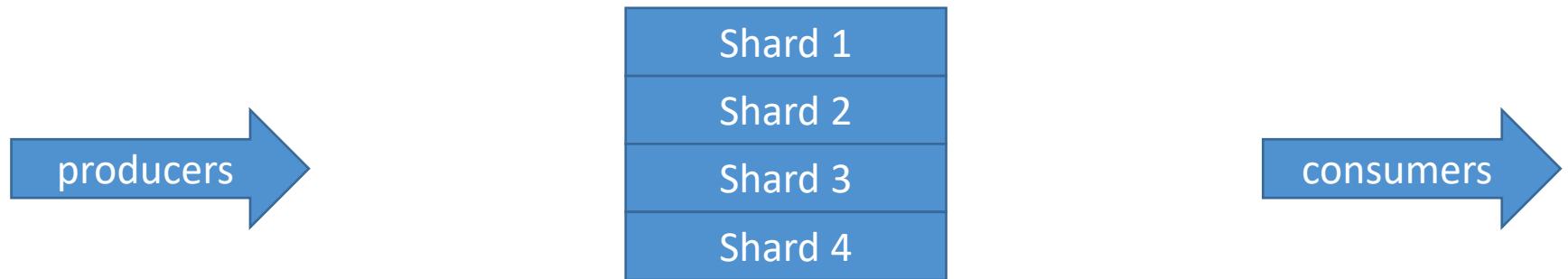
- Streams are divided in ordered Shards / Partitions



- Data retention is 24 hours by default, can go up to 365 days
- Ability to reprocess / replay data
- Multiple applications can consume the same stream
- Real-time processing with scale of throughput
- Once data is inserted in Kinesis, it can't be deleted (immutability)

Kinesis Streams Shards

- Two modes for capacity:
 - On-demand: no capacity planning, Kinesis scales shards automatically
 - Provisioned: you manage the shards over time
- Batching available or per message calls.
- The number of shards can evolve over time (reshard / merge)
- Records are ordered per shard



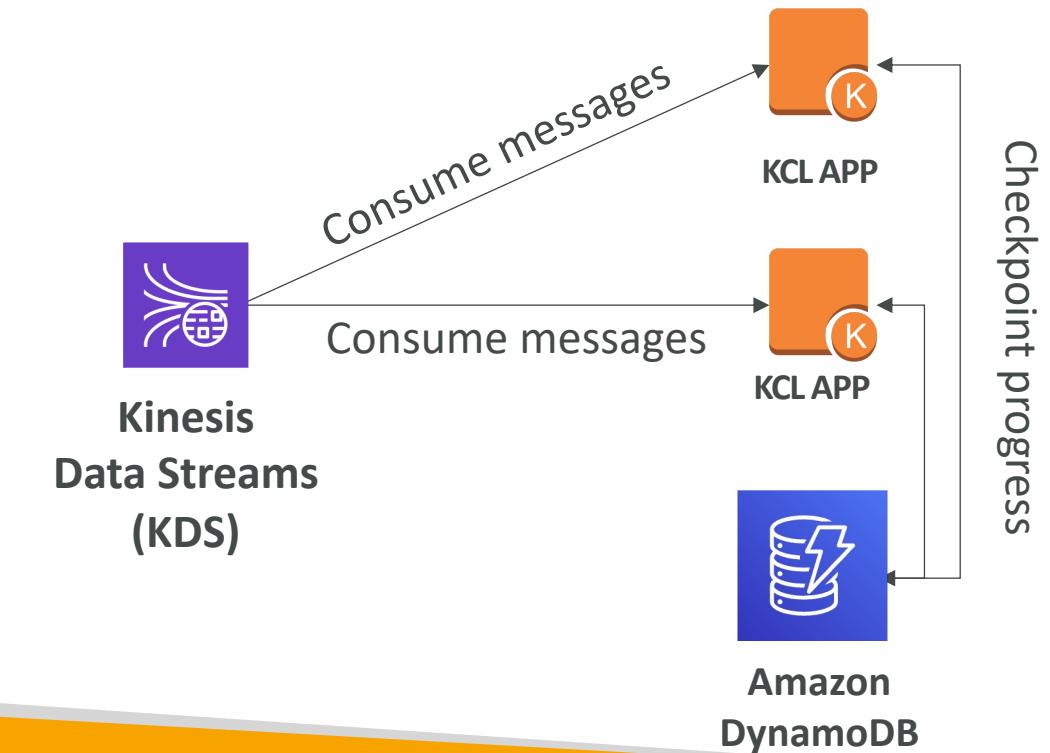
Kinesis Producers & Consumers

KINESIS PRODUCERS

- AWS SDK: simple producer
- Kinesis Producer Library (KPL): batch, compression, retries, C++, Java
- Kinesis Agent:
 - Monitor log files and sends them to Kinesis directly
 - can write to Kinesis Data Streams AND Kinesis Data Firehose

KINESIS CONSUMERS

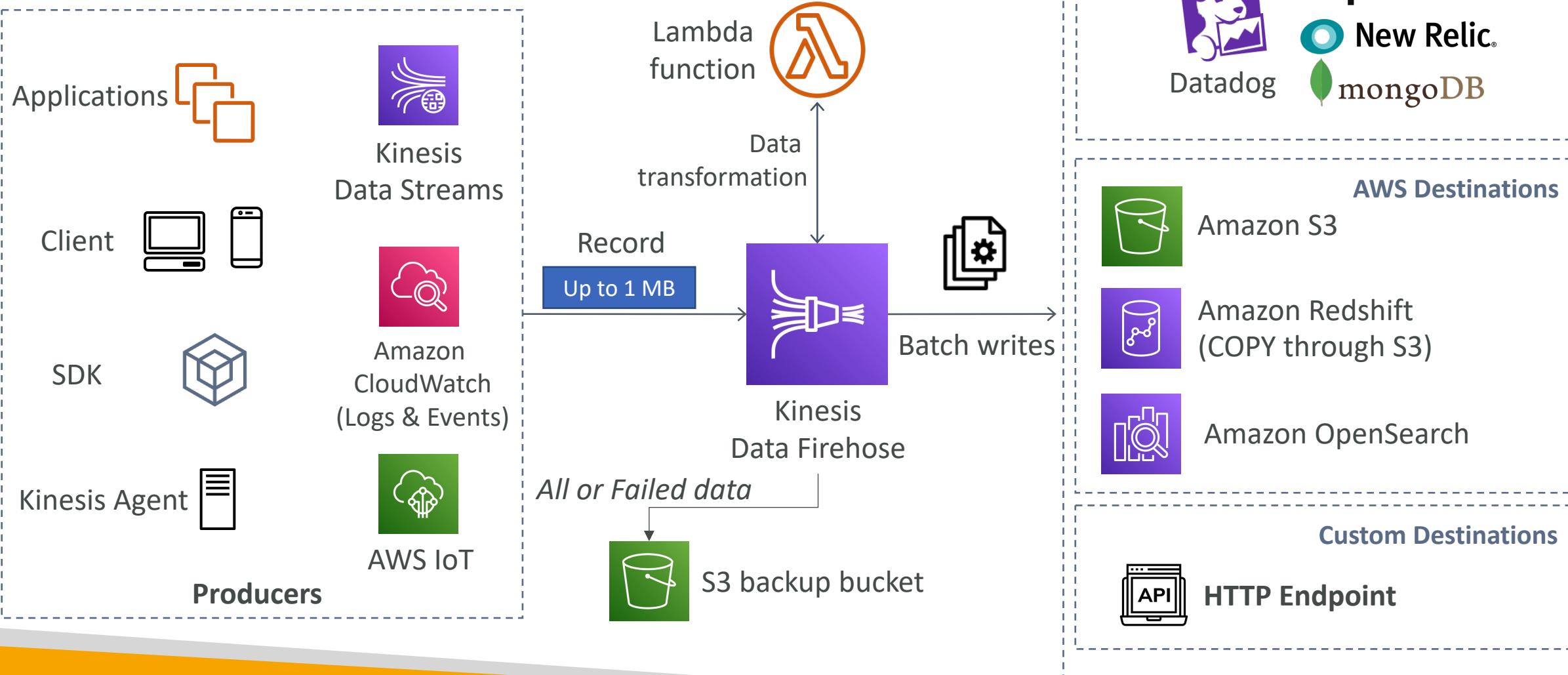
- AWS SDK: simple consumer
- Lambda: (through Event source mapping)
- KCL: checkpointing, coordinated reads



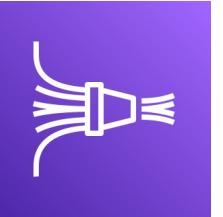
Kinesis Data Streams Limits to know

- Producer:
 - 1MB/s or 1000 messages/s at write PER SHARD
 - “ProvisionedThroughputException” otherwise
- Consumer Classic:
 - 2MB/s at read PER SHARD across all consumers
 - 5 API calls per second PER SHARD across all consumers
- Consumer Enhanced Fan-Out:
 - 2MB/s at read PER SHARD, PER ENHANCED CONSUMER
 - No API calls needed (push model)
- Data Retention:
 - 24 hours data retention by default
 - Can be extended to 365 days

Kinesis Data Firehose

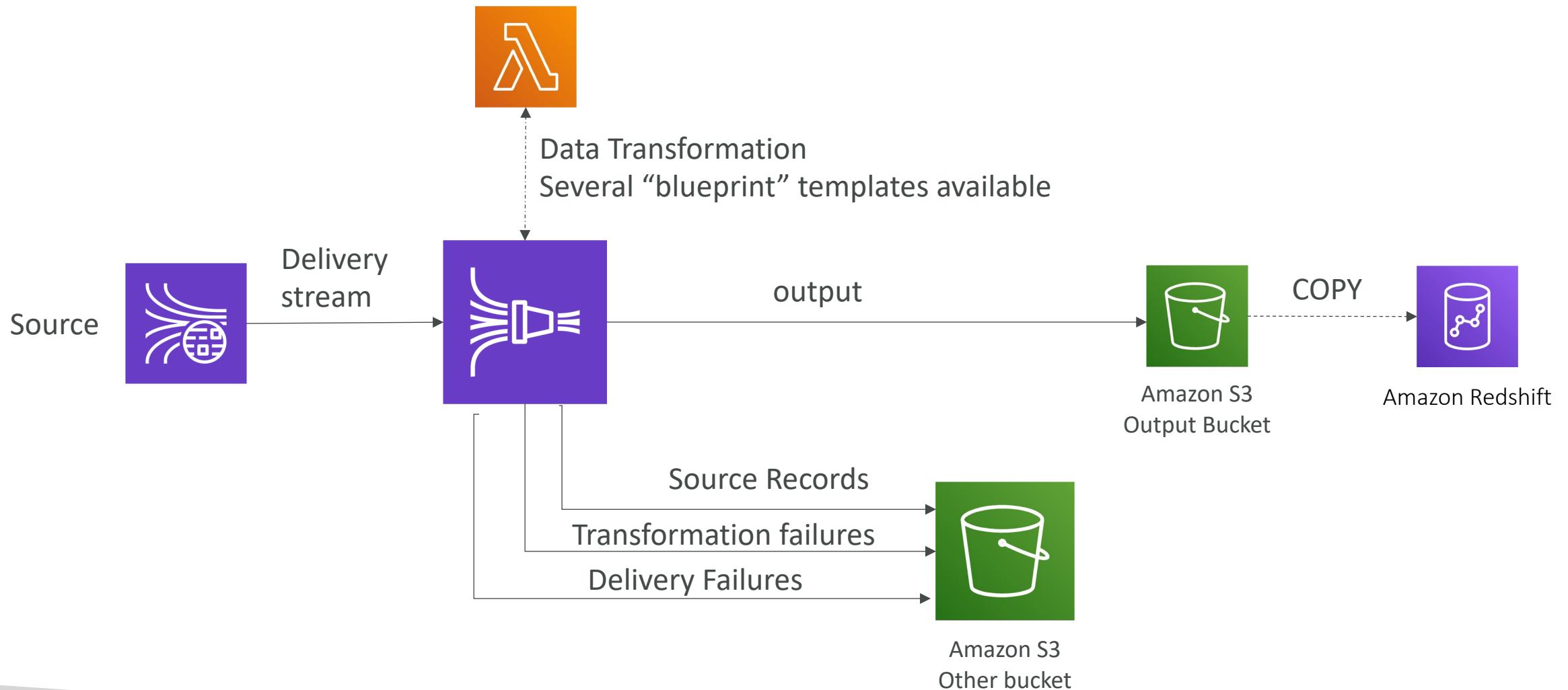


Kinesis Data Firehose



- Fully Managed Service, no administration, automatic scaling, serverless
 - AWS: Redshift / Amazon S3 / OpenSearch
 - 3rd party partner: Splunk / MongoDB / DataDog / NewRelic / ...
 - Custom: send to any HTTP endpoint
- Pay for data going through Firehose
- **Near Real Time**
 - 60 seconds latency minimum for non full batches
 - Or minimum 1 MB of data at a time
- 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

Kinesis Data Firehose Delivery Diagram



Firehose Buffer Sizing

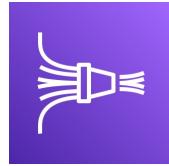
- Firehose accumulates records in a buffer
- The buffer is flushed based on time and size rules
- **Buffer Size (ex: 32MB)**: if that buffer size is reached, it's flushed
- **Buffer Time (ex: 1 minute)**: if that time is reached, it's flushed
- Firehose can automatically increase the buffer size to increase throughput
- High throughput => Buffer Size will be hit
- Low throughput => Buffer Time will be hit
- If real-time flush from Kinesis Data Streams to S3 is needed, use Lambda

Kinesis Data Streams vs Firehose



Kinesis Data Streams

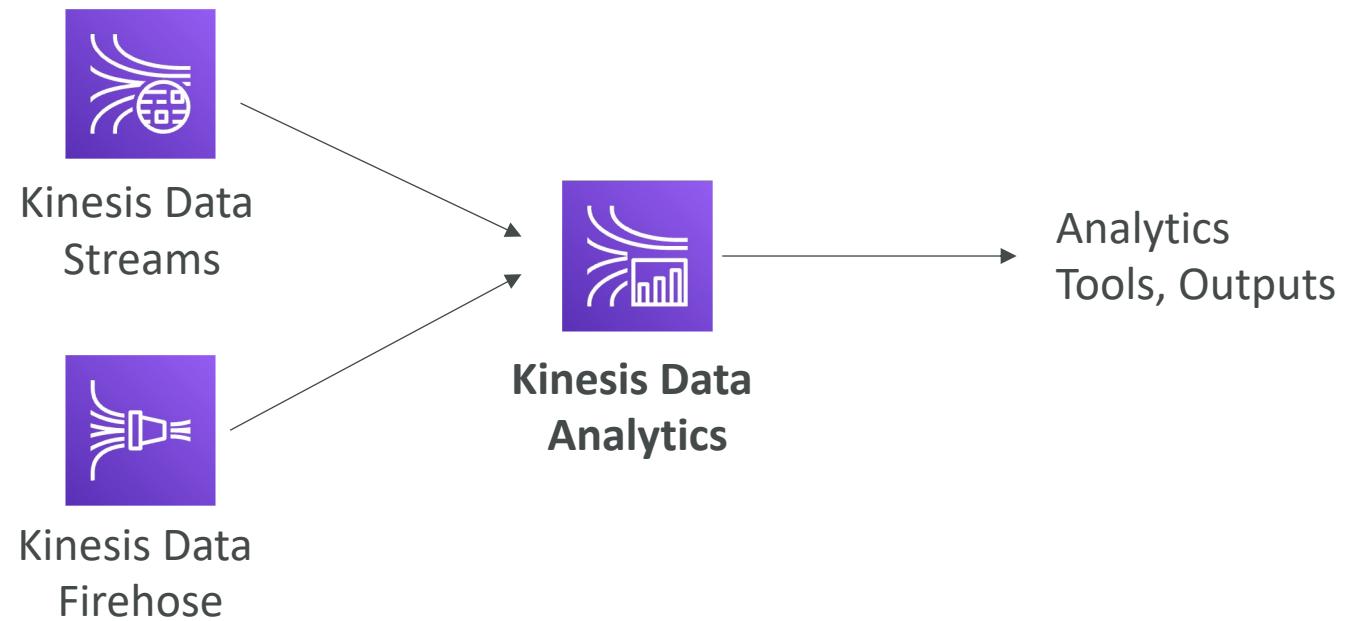
- Streaming service for ingest at scale
- Write custom code (producer / consumer)
- Real-time (~200 ms)
- Manage scaling (shard splitting / merging)
- Data storage for 1 to 365 days
- Supports replay capability



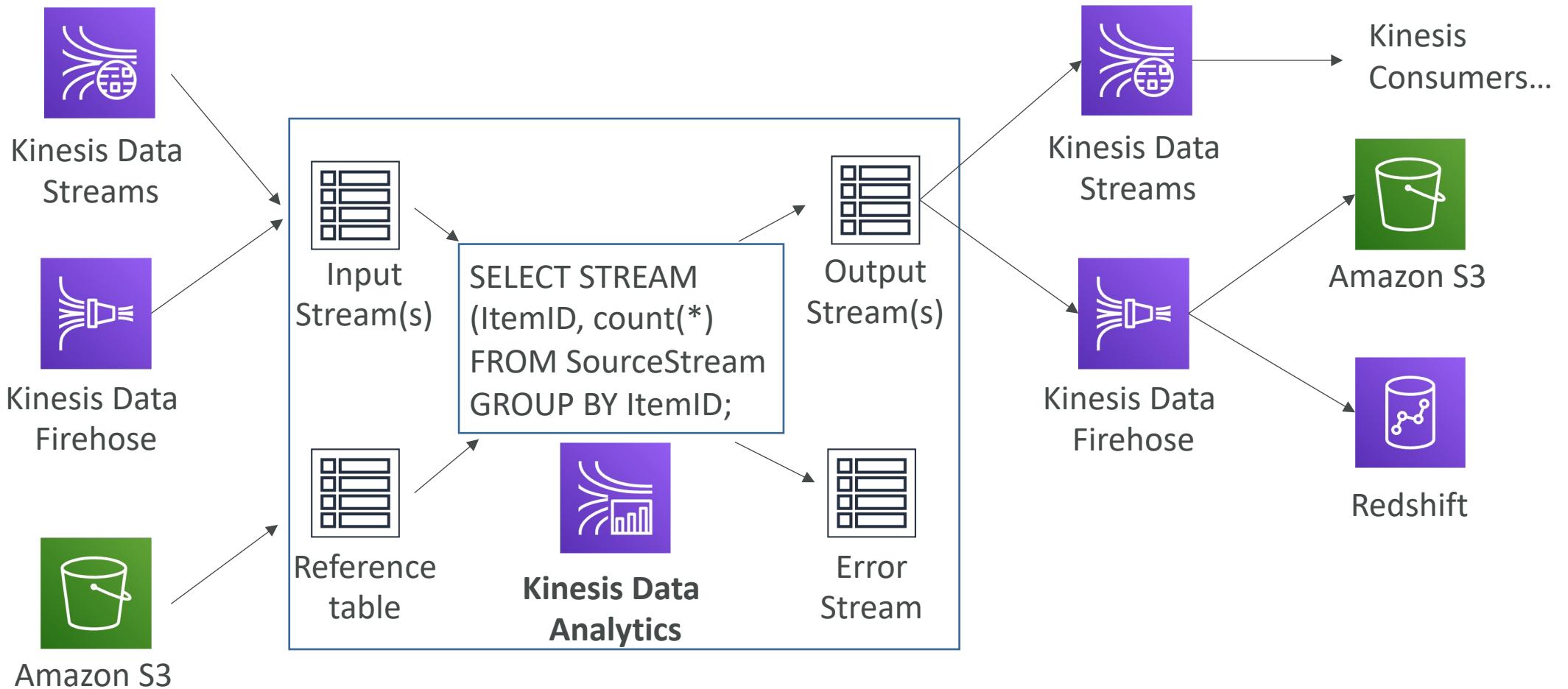
Kinesis Data Firehose

- Load streaming data into S3 / Redshift / ES / 3rd party / custom HTTP
- Fully managed
- Near real-time (buffer time min. 60 sec)
- Automatic scaling
- No data storage
- Doesn't support replay capability

Kinesis Analytics, Conceptually...



Kinesis Analytics, In more depth...





Kinesis Data Analytics

- Use cases
 - Streaming ETL: select columns, make simple transformations, on streaming data
 - Continuous metric generation: live leaderboard for a mobile game
 - Responsive analytics: look for certain criteria and build alerting (filtering)
- Features
 - Pay only for resources consumed (but it's not cheap)
 - Serverless; scales automatically
 - Use IAM permissions to access streaming source and destination(s)
 - SQL or Flink to write the computation
 - Schema discovery
 - Lambda can be used for pre-processing

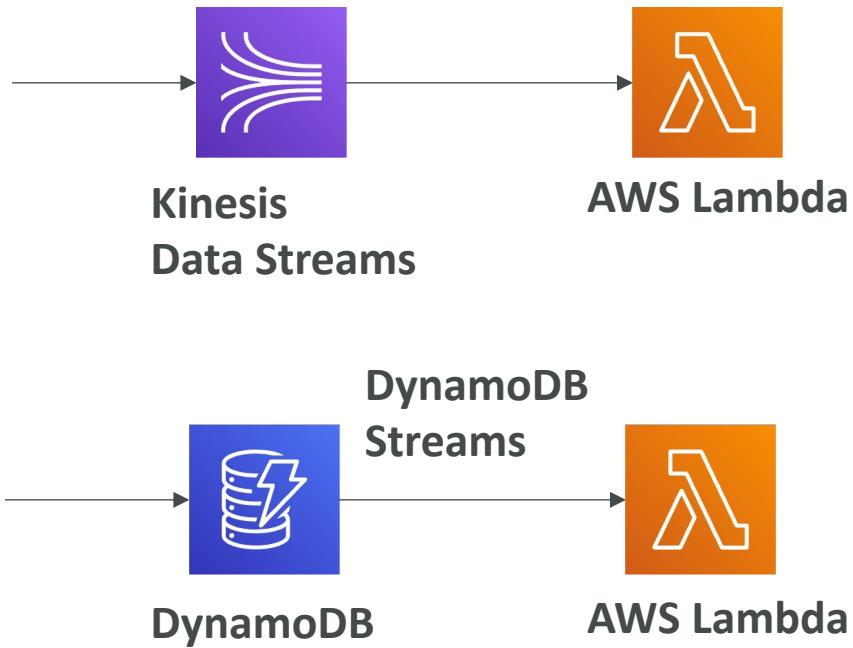
Full Data Engineering Pipeline

Real-Time Layer



Streaming Architectures

3000 messages of 1 KB per second



Kinesis

- 3 shards: 3MB/s in
- $3 * \$0.015/\text{hr} = \$32.4/\text{mth}$
- Must use KDF for output to S3

DynamoDB + Streams

- $3000 \text{ WCU} = 3 \text{ MB/s}$
- $= \$1,450.90 / \text{month}$
- Storage in DynamoDB

Comparison Charts

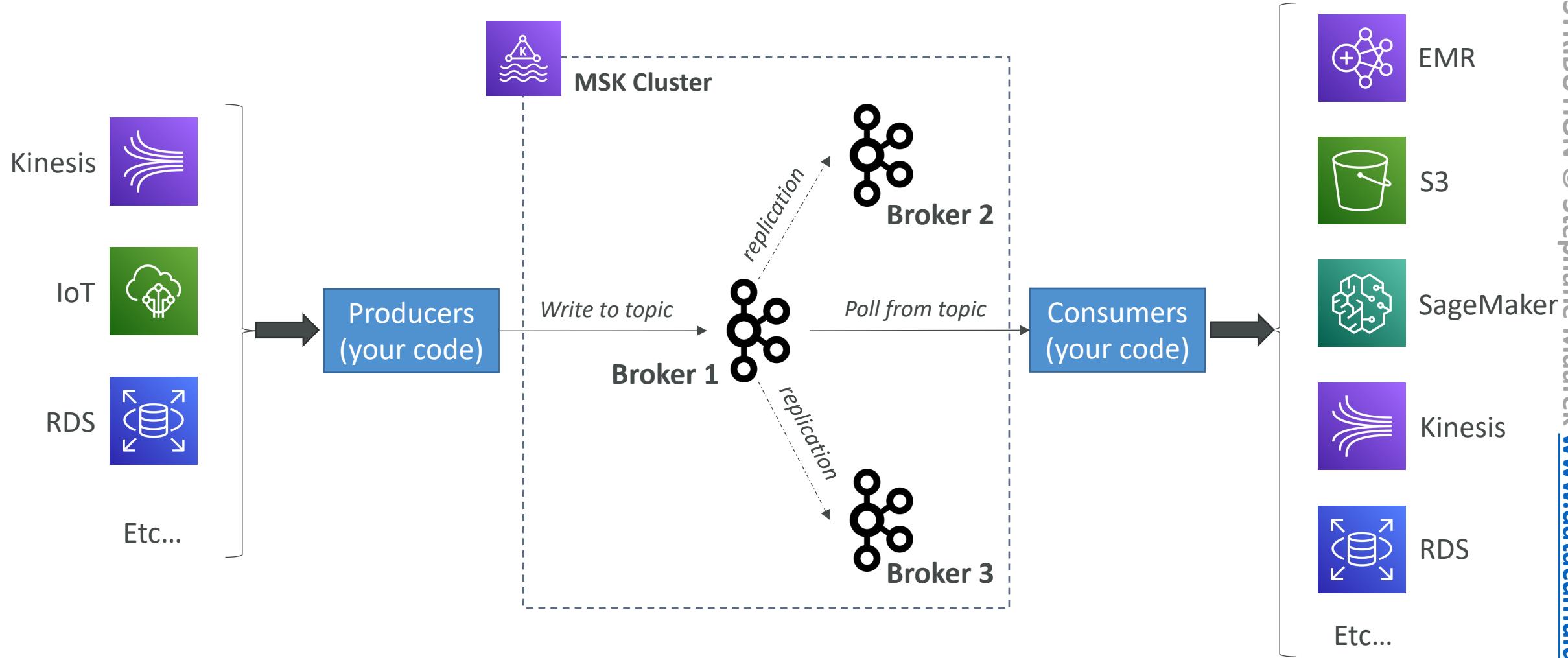
	Kinesis Data Streams	SQS	SQS FIFO	SNS	DynamoDB	S3
Data	Immutable	Immutable	Immutable	Immutable	Mutable	Mutable
Retention	1-365 days, export to S3 using KDF	1-14 days	1-14 days	No retention	Infinite or can implement TTL	Infinite, can setup lifecycle policies
Ordering	Per shard	No ordering	Per group-id	No ordering	No ordering	No ordering
Scalability	Provision shards	Soft limit	300 msg/s Or 3000 if batch	Soft limit	WCU & RCU On-demand	Infinite 3500 PUT 5500 GET / prefix
Readers	EC2, Lambda, KDF, KDA, KCL (checkpoint)	EC2, Lambda	EC2, Lambda	HTTP, Lambda, Email, SQS...	DynamoDB Streams	SDK, S3 Events
Latency	KDS (200 ms) KDF (1 min)	Low (10-100ms)	Low (10-100ms)	Low (10-100ms)	Low (10-100ms)	Low (10-100ms)

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

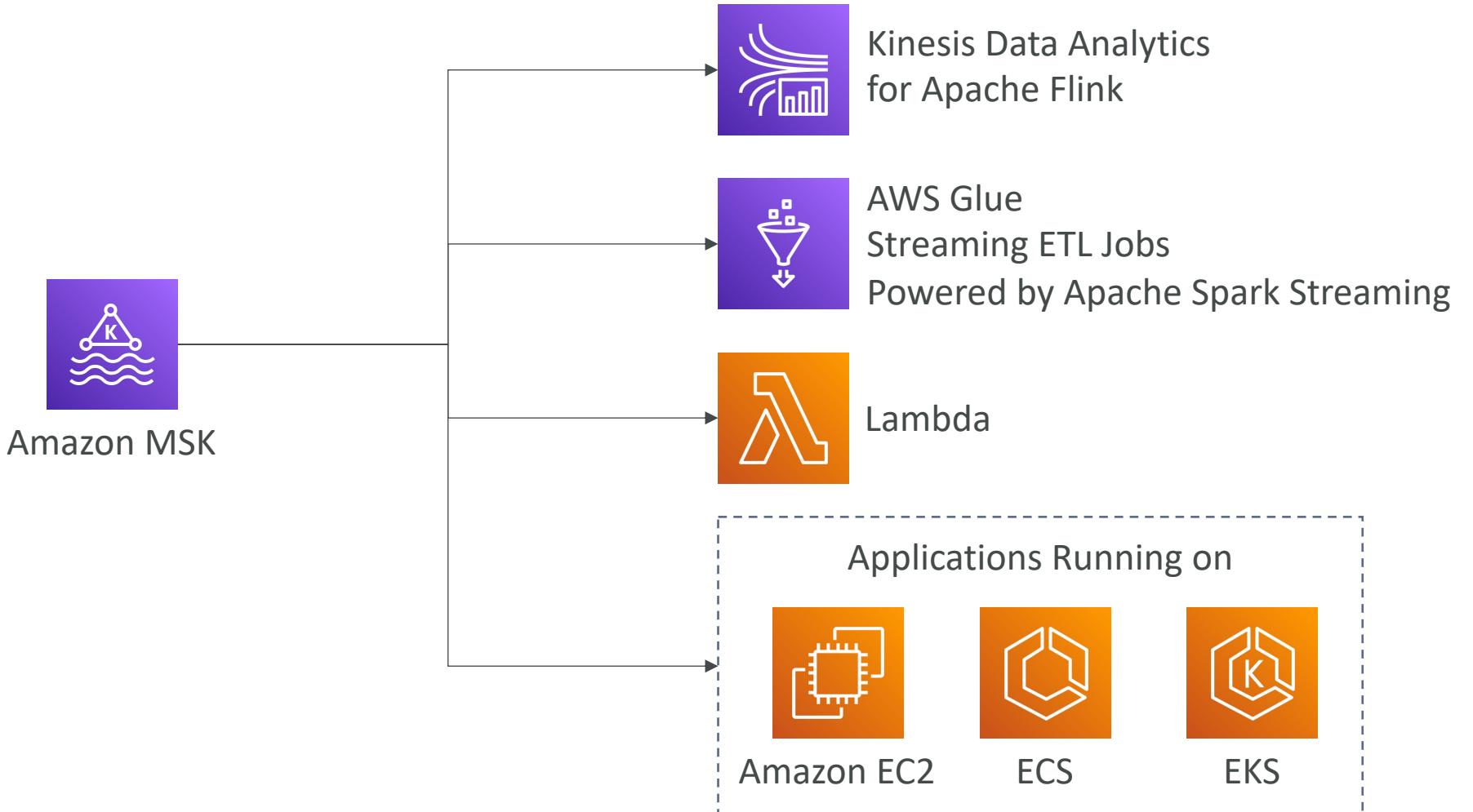
- 1 MB message size limit
- Data Streams with Shards
- Shard Splitting & Merging
- TLS In-flight encryption
- KMS at-rest encryption



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 MSK Consumers

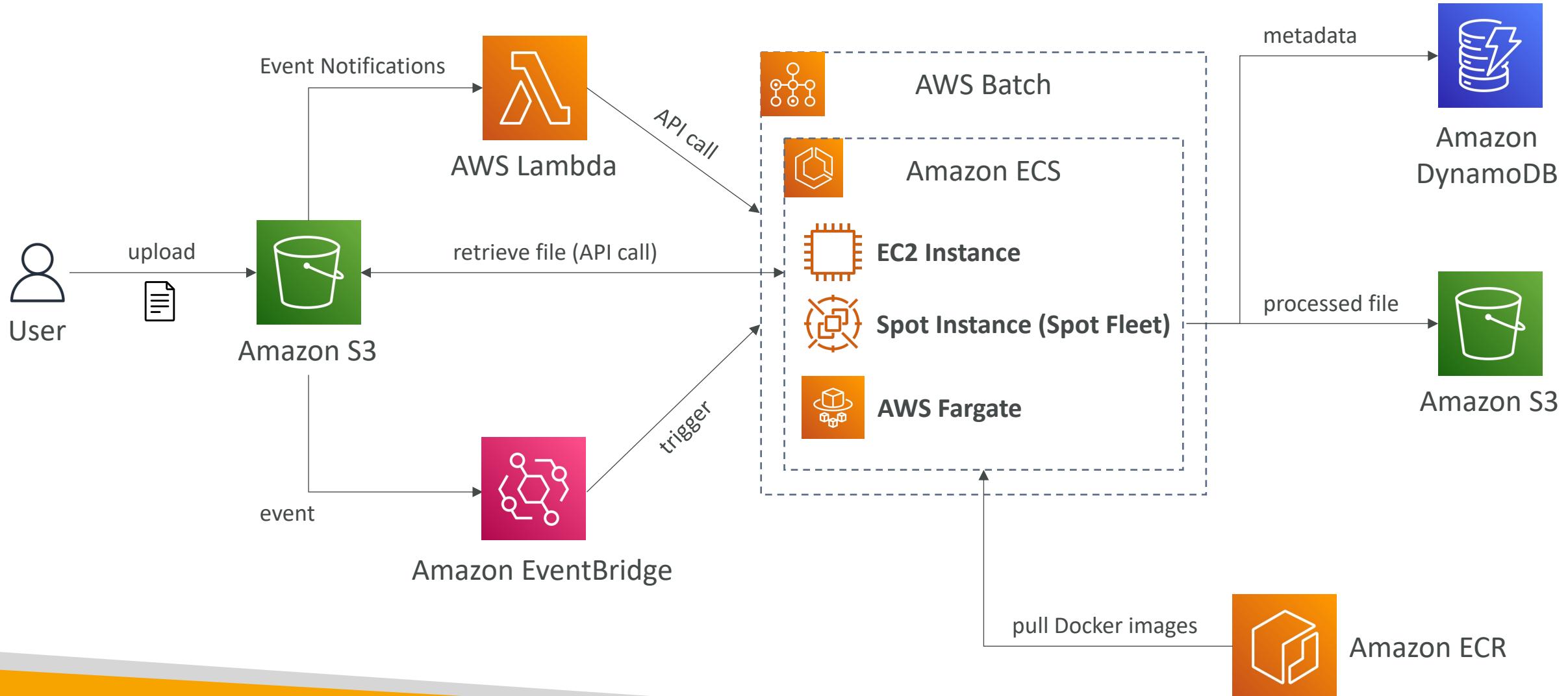


AWS Batch



- Run batch jobs as Docker images
- Two options:
 1. Run on AWS Fargate (fully serverless offering)
 2. Dynamic provisioning of the instances (EC2 & Spot Instances) – in VPC
- Optimal quantity and type based on volume and requirements
- No need to manage clusters, fully **serverless**
- You just pay for the underlying resources used
- Example: batch process of images, running thousands of concurrent jobs
- Schedule Batch Jobs using Amazon EventBridge
- Orchestrate Batch Jobs using AWS Step Functions

AWS Batch – Solution Architecture



Batch vs. Lambda

- Lambda:
 - Time limit
 - Limited runtimes (built in runtimes, or Docker images built for Lambda)
 - 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) or AWS Fargate

AWS Batch – Compute Environments

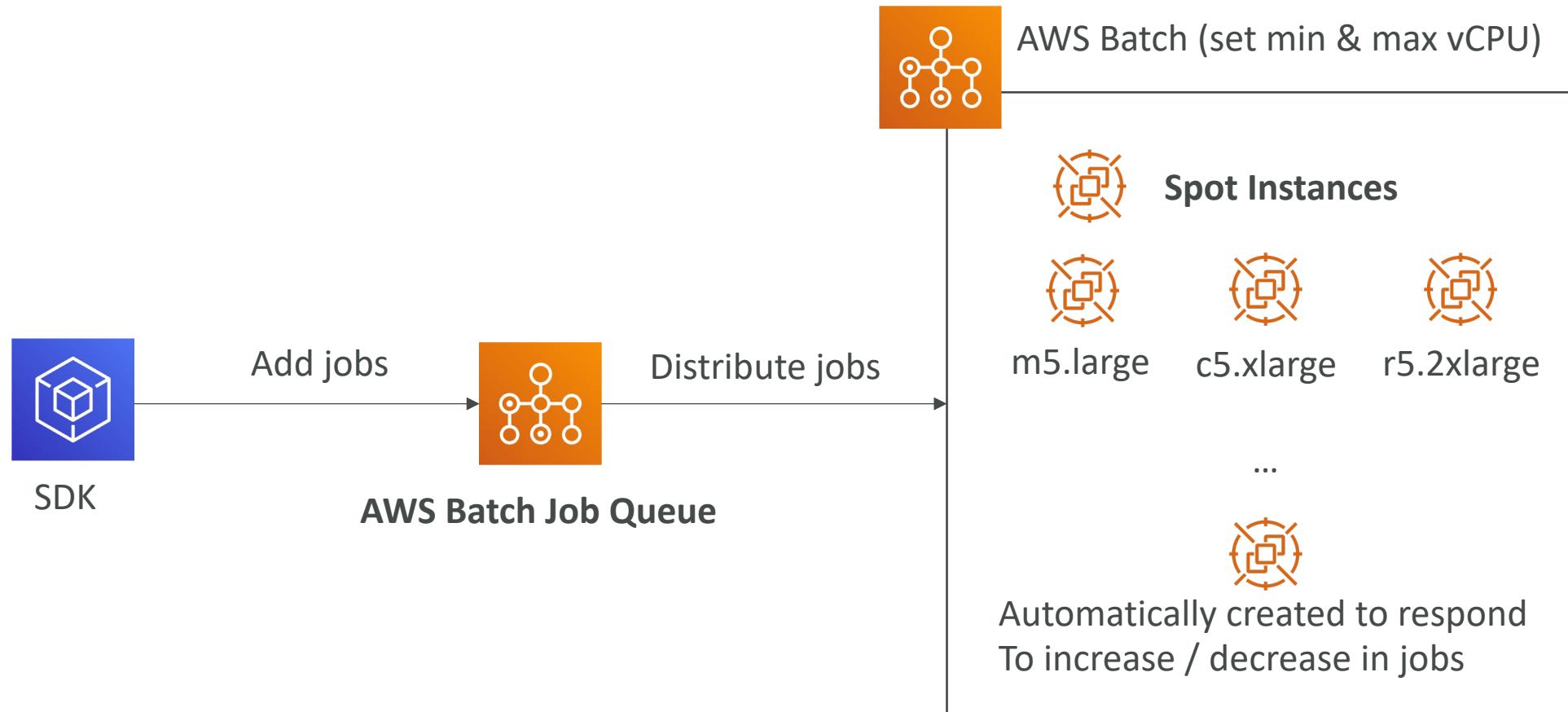
- Managed Compute Environment:

- AWS Batch managed the capacity and instance types within the environment
- You can choose EC2 On-Demand or Spot Instances
- You can choose Fargate On-Demand or Fargate Spot Instances
- You can set a maximum price for Spot Instances
- Launched within your own VPC
 - If you launch within your own private subnet, make sure it has access to the ECS service
 - Either using a NAT gateway / instance or using VPC Endpoints for ECS

- Unmanaged Compute Environment

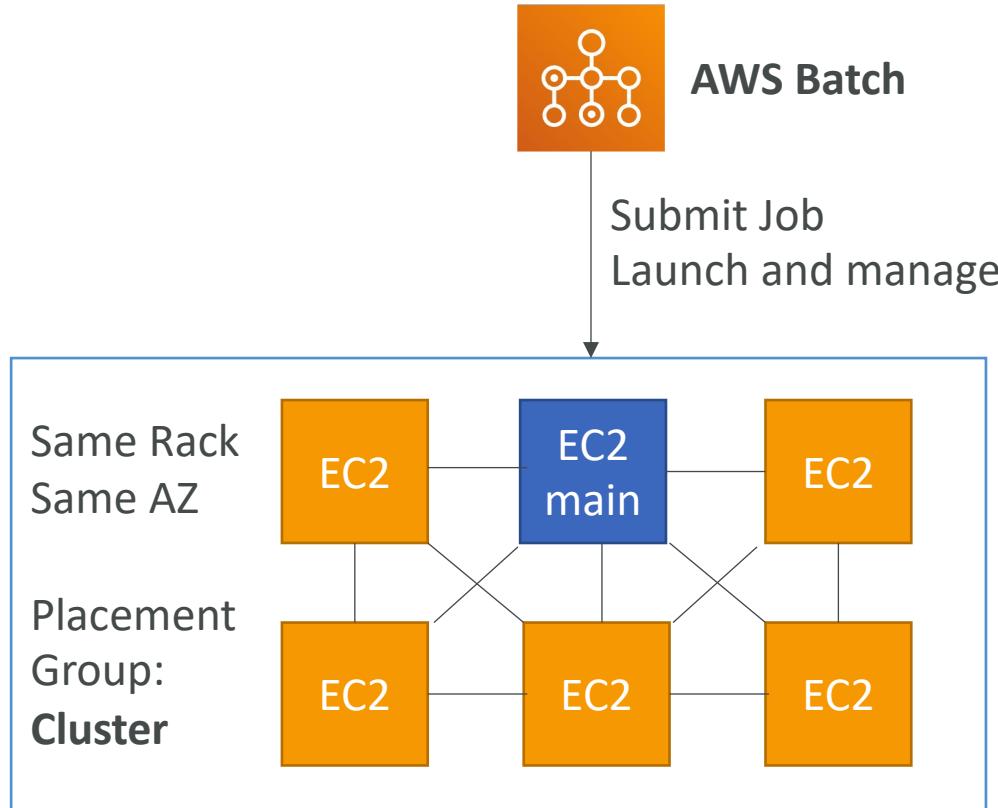
- You control and manage EC2 instance configuration, provisioning and scaling

AWS Batch – Managed Compute Environment

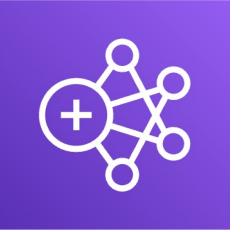


AWS Batch – Multi Node Mode

- **Multi Node:** large scale, good for HPC (high performance computing)
 - Leverages multiple EC2 / ECS instances at the same time
 - Good for tightly coupled workloads
 - Represents a single job, and specified how many nodes to create for the job
 - 1 main node, and many child node.
 - **Does not work with Spot Instances**
 - Works better if your EC2 launch mode is a placement group "cluster"

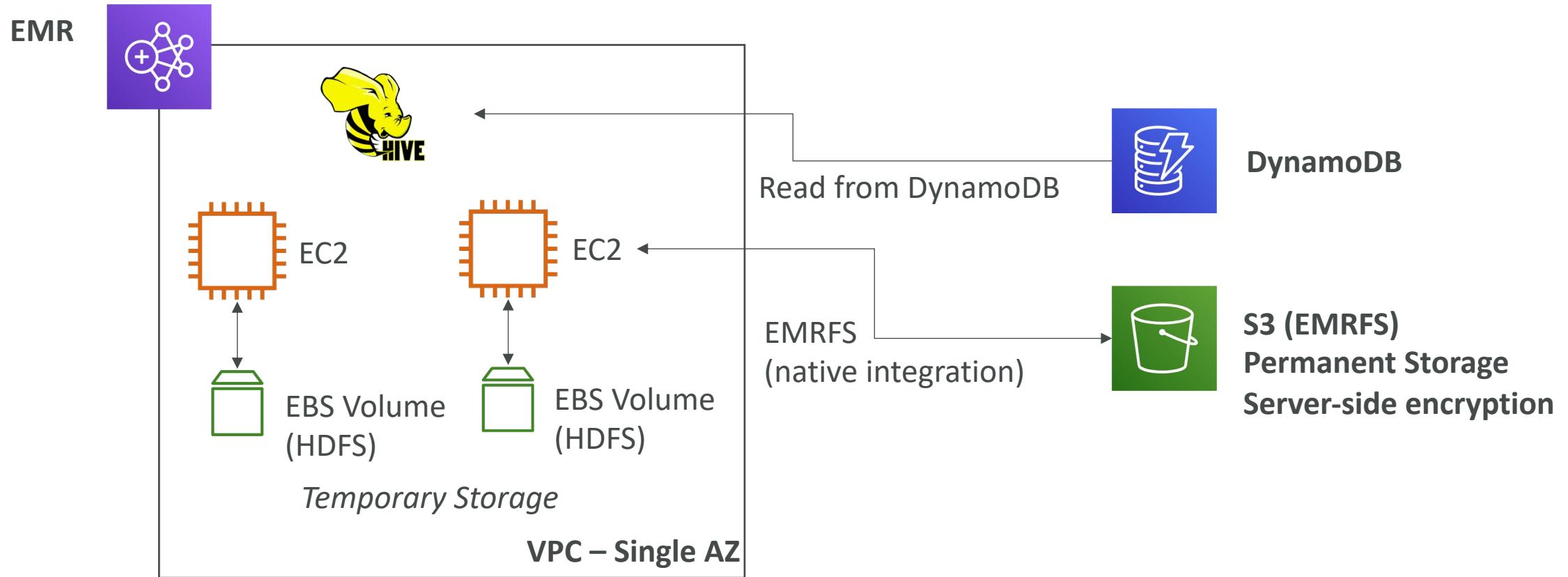


Amazon EMR



- EMR stands for “Elastic MapReduce”
- 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 of EC2
- Auto-scaling with CloudWatch
- Use cases: data processing, machine learning, web indexing, big data...

EMR – Integrations



Amazon EMR – Node types & purchasing

- **Master Node:** Manage the cluster, coordinate, manage health – long running
- **Core Node:** Run tasks and store data – long running
- **Task Node (optional):** Just to run tasks – usually Spot
- **Purchasing options:**
 - On-demand: reliable, predictable, won't be terminated
 - Reserved (min 1 year): cost savings (EMR will automatically use if available)
 - Spot Instances: cheaper, can be terminated, less reliable
- Can have long-running cluster, or transient (temporary) cluster

Amazon EMR – Instance Configuration

- Uniform instance groups: select a single instance type and purchasing option for each node (has auto scaling)

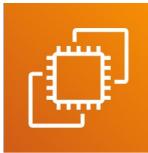
Node type	Instance type	Instance count	Purchasing option
Master Master - 1	m5.xlarge 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB	1 Instances	<input checked="" type="radio"/> On-demand <small>i</small> <input type="radio"/> Spot <small>i</small> Use on-demand as max price <small>i</small>
Core Core - 2	m5.xlarge 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB	2 Instances	<input checked="" type="radio"/> On-demand <small>i</small> <input type="radio"/> Spot <small>i</small> Use on-demand as max price <small>i</small>
Task X Task - 3	c4.xlarge 4 vCore, 7.5 GiB memory, EBS only storage EBS Storage: 64 GiB	4 Instances	<input checked="" type="radio"/> On-demand <small>i</small> <input type="radio"/> Spot <small>i</small> Use on-demand as max price <small>i</small>
Task X Task - 4	d2.xlarge 8 vCore, 30.5 GiB memory, 6144 SSD GB storage EBS Storage: none	3 Instances	<input type="radio"/> On-demand <small>i</small> <input checked="" type="radio"/> Spot <small>i</small> Use on-demand as max price <small>i</small>

- Instance fleet: select target capacity, mix instance types and purchasing options (no Auto Scaling)

Node type	Fleet instance types	Target capacity
Master Master - 1	m5.xlarge 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB Maximum Spot price: <input style="width: 100px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 10px;" type="button" value="On-Demand"/> 100 Add / remove instance types to fleet	<input checked="" type="radio"/> On-demand <input type="radio"/> Spot The master fleet consists of one EC2 instance
Core Core - 2	c5d.xlarge 4 vCore, 8 GiB memory, 100 SSD GB storage EBS Storage: none Maximum Spot price: <input style="width: 100px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 10px;" type="button" value="On-Demand"/> 100 Each instance counts as 4 units <small>i</small>	6 On-demand units 10 Spot units 16 Total units
Task X Task - 3	m5.xlarge 4 vCore, 16 GiB memory, EBS only storage EBS Storage: 64 GiB Maximum Spot price: <input style="width: 100px; height: 20px; border: 1px solid #ccc; border-radius: 5px; padding: 2px 10px;" type="button" value="On-Demand"/> 100 Each instance counts as 4 units <small>i</small> Add / remove instance types to fleet	2 On-demand units 20 Spot units 22 Total units

Running Jobs on AWS

**Strategy 1: Provision EC2 instance
(long running - CRON jobs)**



EC2

Strategy 3: Reactive Workflow

EventBridge

S3 Events

API Gateway

SQS, SNS

Etc...



**Strategy 2: Amazon EventBridge + Lambda
(cron)**



cron schedule

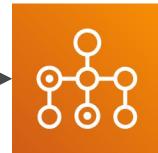


EventBridge

Strategy 4: use AWS Batch



EventBridge



Batch

Strategy 5: use Fargate



EventBridge

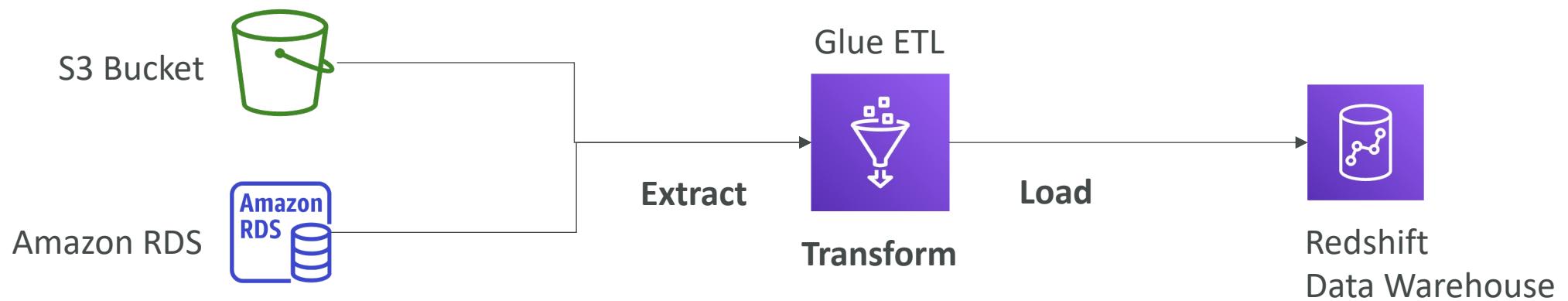


Fargate

AWS Glue



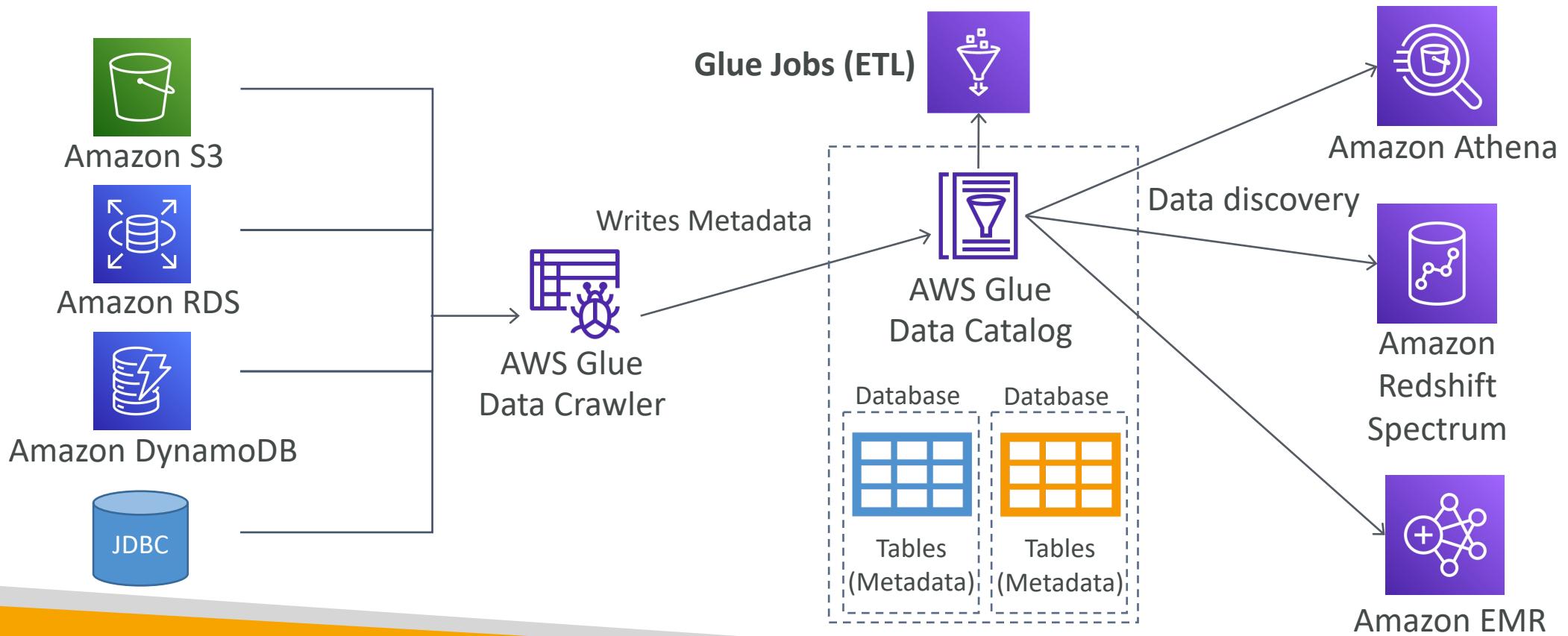
- Managed **extract, transform, and load (ETL)** service
- Useful to prepare and transform data for analytics
- Fully **serverless** service



Glue Data Catalog



- Glue Data Catalog: catalog of datasets



Redshift Overview



- Redshift is based on PostgreSQL, but it's not used for OLTP
- It's OLAP – online analytical processing (analytics and data warehousing)
- 10x better performance than other data warehouses, scale to PBs of data
- Columnar storage of data (instead of row based)
- Massively Parallel Query Execution (MPP)
- Pay as you go based on the instances provisioned
- Has a SQL interface for performing the queries
- BI tools such as AWS Quicksight or Tableau integrate with it

Redshift Continued...



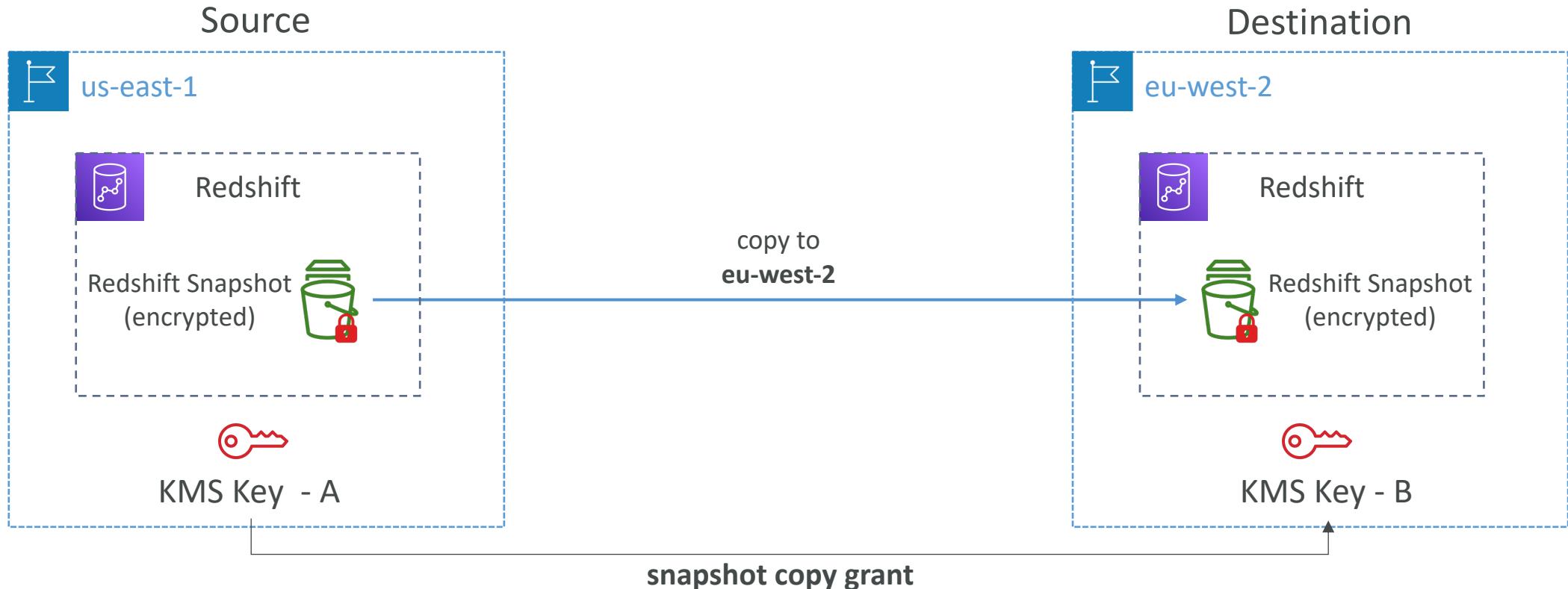
- Data is loaded from S3, Kinesis Firehose, DynamoDB, DMS...
- Based on node type: up to 100+ nodes, up to 16 TB of space per node
- Can provision multiple nodes, with **Multi-AZ** only for some clusters
- Leader node: for query planning, results aggregation
- Compute node: for performing the queries, send results to leader
- Backup & Restore, Security VPC / IAM / KMS, Monitoring
- Redshift Enhanced VPC Routing: COPY / UNLOAD goes through VPC
- Redshift is provisioned, so it's worth it when you have a sustained usage
(use Athena if the queries are sporadic instead)

Redshift – Snapshots & DR

- Snapshots are point-in-time backups of a cluster, stored internally in S3
- Snapshots are incremental (only what has changed is saved)
- You can restore a snapshot into a **new cluster**
- Automated: every 8 hours, every 5 GB, or on a schedule. Set retention
- Manual: snapshot is retained until you delete it

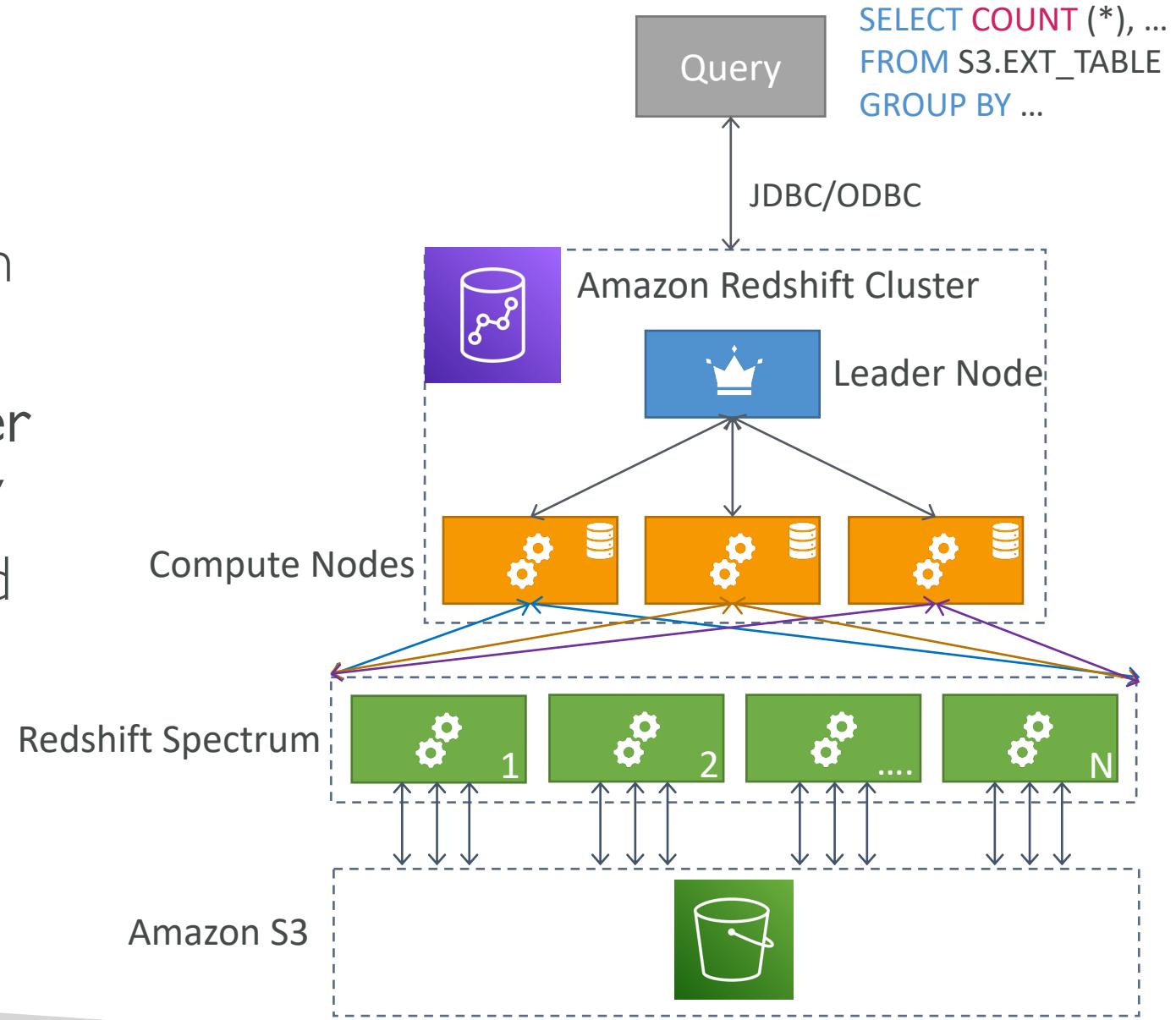
- You can configure Amazon Redshift to automatically copy snapshots (automated or manual) of a cluster to another AWS Region

Cross-Region Snapshot Copy for an KMS-Encrypted Redshift



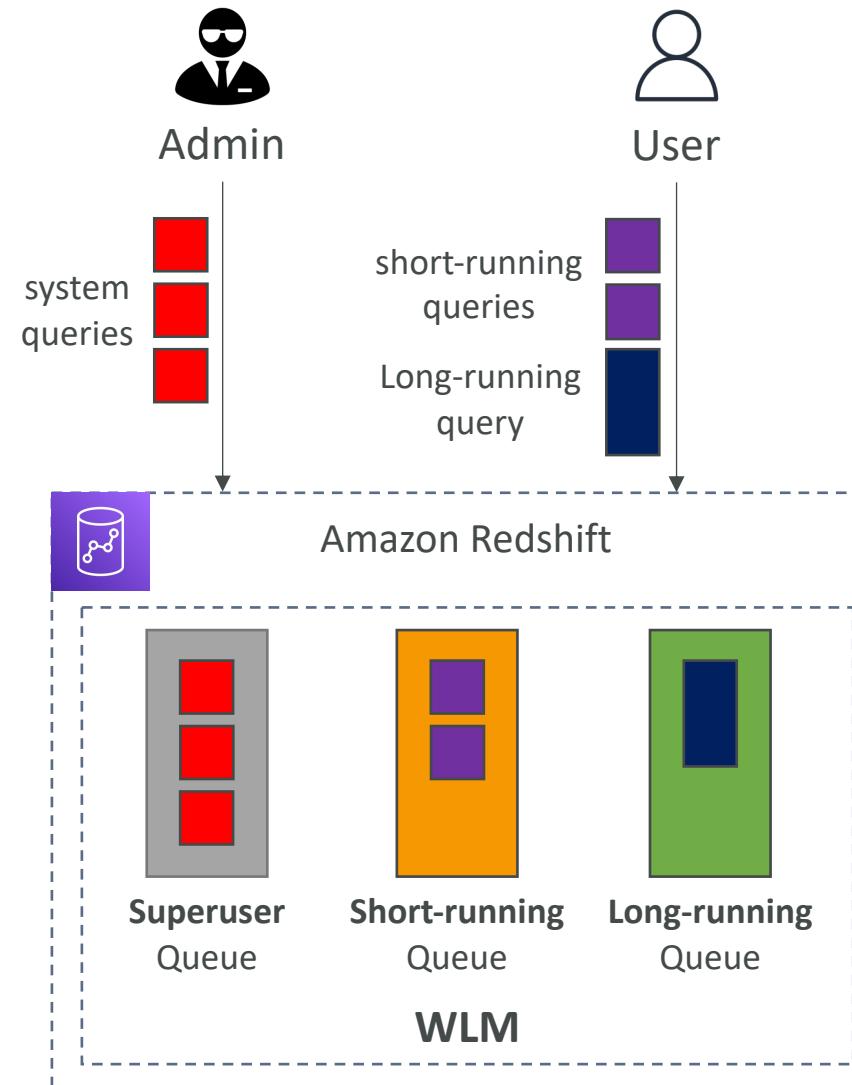
Redshift Spectrum

- Query data that is already in S3 without loading it
- Must have a Redshift cluster available to start the query
- The query is then submitted to thousands of Redshift Spectrum nodes



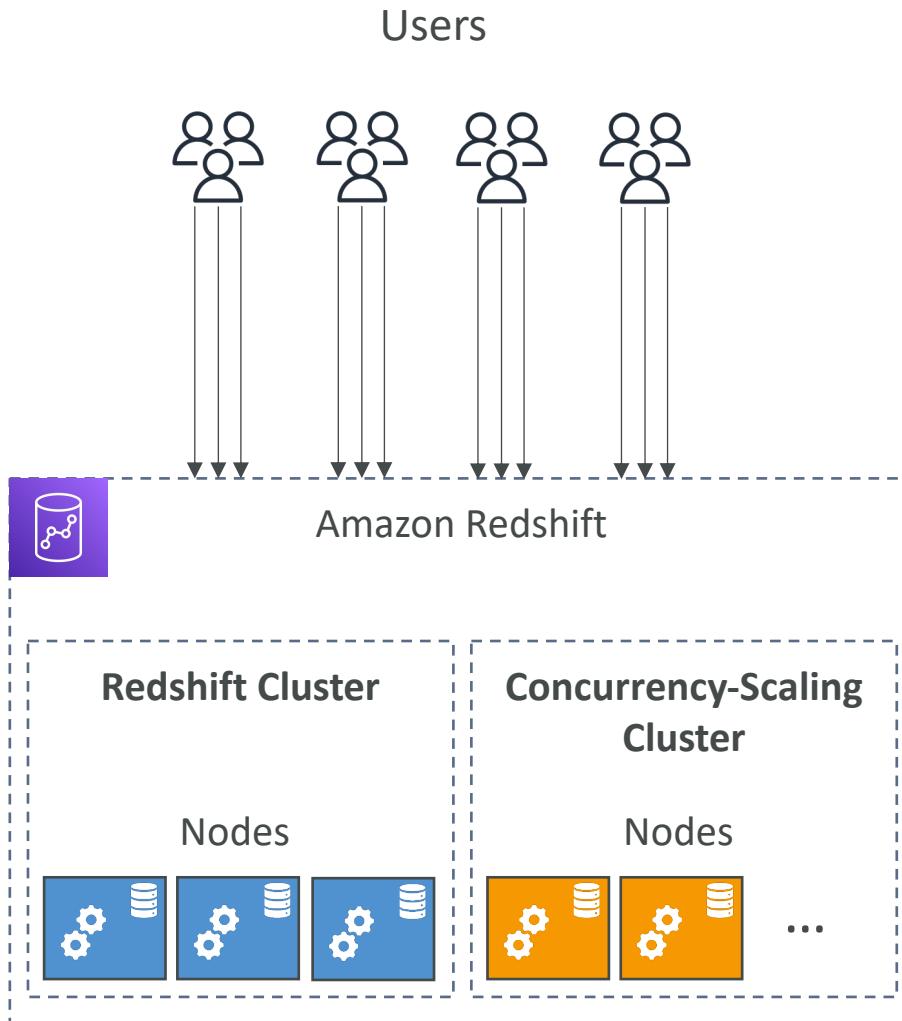
Redshift Workload Management (WLM)

- Enables you to flexibly manage queries' priorities within workloads
- Example: prevent short, fast-running queries from getting stuck behind long-running queries
- Define multiple query queues (Superuser queue, User-defined queues)
- Route queries to the appropriate queues at runtime
- **Automatic WLM** – queues and resources managed by Redshift
- **Manual WLM** – queues and resources managed by you



Redshift Concurrency Scaling

- Enables you to provide consistently fast performance with virtually unlimited concurrent users and queries
- Redshift automatically adds additional cluster capacity (**Concurrency-Scaling Cluster**) to process an increase in requests
- Ability to decide which queries sent to the concurrency-Scaling Cluster using WLM
- Charged per second



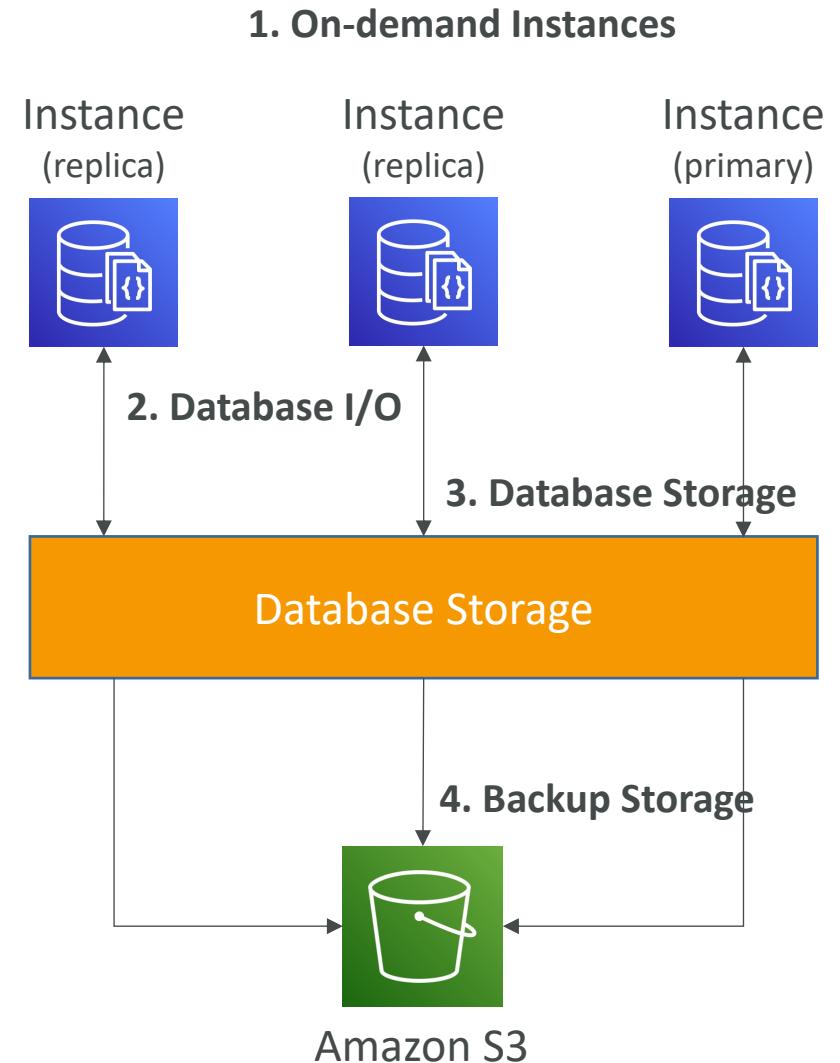
DocumentDB



- 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
-
- Automatically scales to workloads with millions of requests per seconds

DocumentDB – Pricing

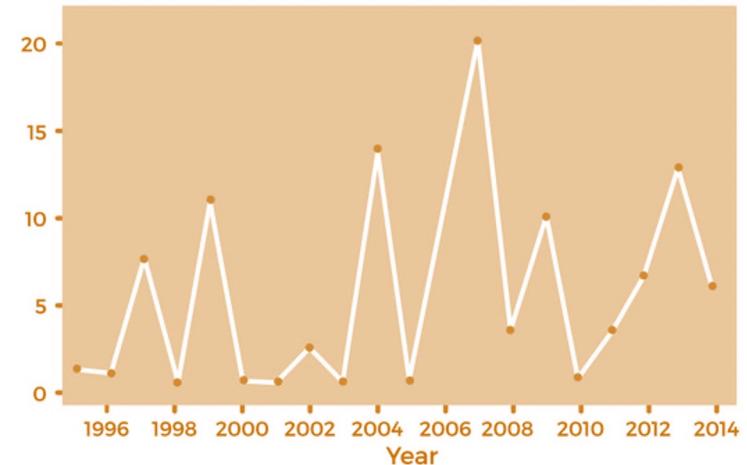
- Pay for what you use, no upfront costs
- **On-demand Instances** (per second with minimum of 10 minutes)
- **Database I/O** – amount of I/O used when read and write (per million I/Os)
- **Database Storage** (per GB/month)
- **Backup Storage** (per GB/month)



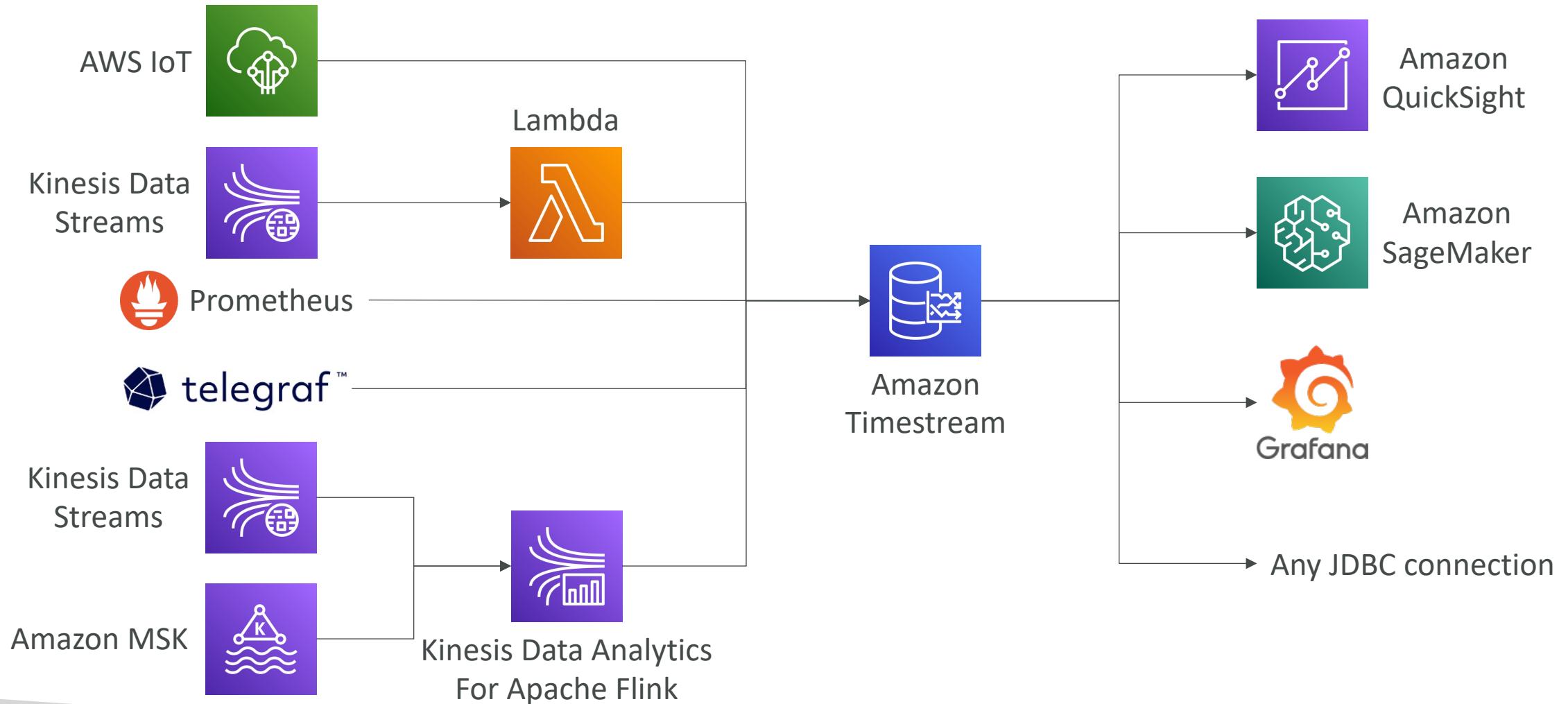
Amazon Timestream



- 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



Amazon Athena



- Serverless query service to analyze data stored in Amazon S3
- Uses standard SQL language to query the files (built on Presto)
- Supports CSV, JSON, ORC, Avro, and Parquet
- Pricing: \$5.00 per TB of data scanned
- Commonly used with Amazon Quicksight for reporting/dashboards
- **Use cases:** Business intelligence / analytics / reporting, analyze & query VPC Flow Logs, ELB Logs, CloudTrail trails, etc...
- **Exam Tip:** analyze data in S3 using serverless SQL, use Athena

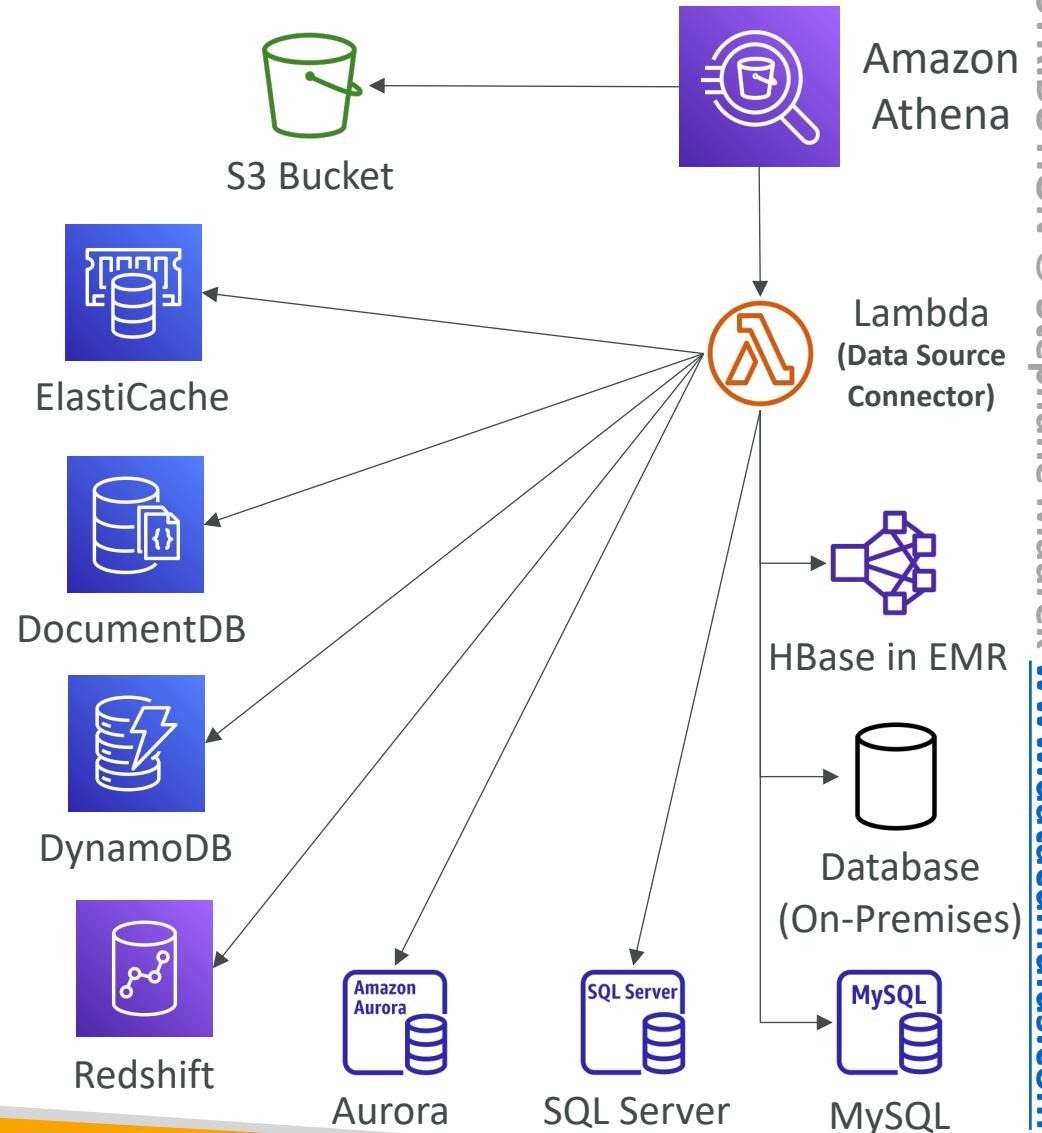


Amazon Athena – Performance Improvement

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

Amazon Athena – Federated Query

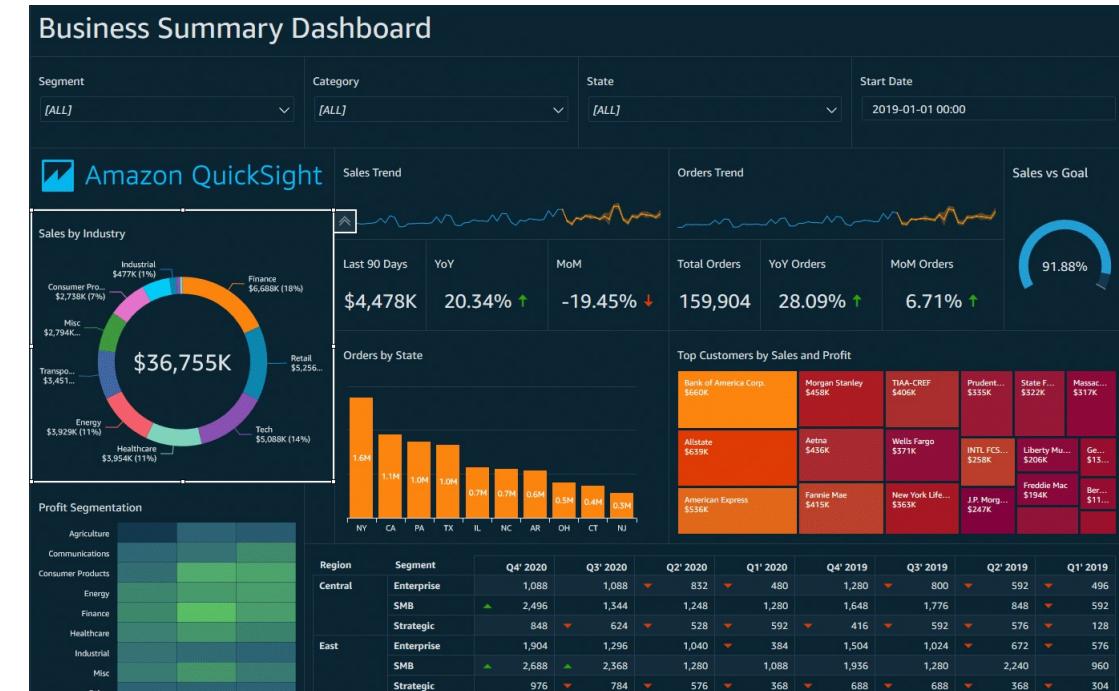
- Allows you to run SQL queries across data stored in relational, non-relational, object, and custom data sources (AWS or on-premises)
- Uses Data Source Connectors that run on AWS Lambda to run Federated Queries (e.g., CloudWatch Logs, DynamoDB, RDS, ...)
- Store the results back in Amazon S3



Amazon QuickSight

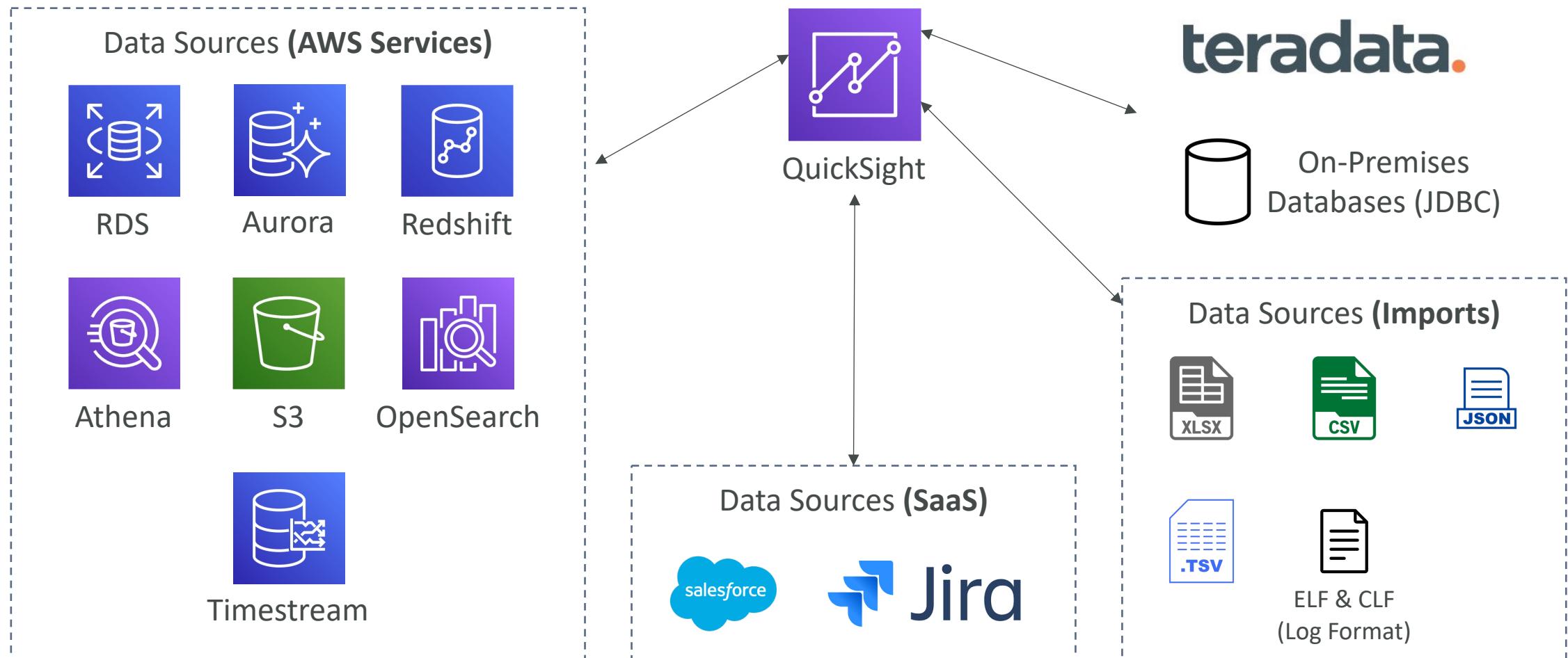


- Serverless machine learning-powered business intelligence service to create interactive dashboards
- Fast, automatically scalable, embeddable, with per-session pricing
- Use cases:
 - Business analytics
 - Building visualizations
 - Perform ad-hoc analysis
 - Get business insights using data
- Integrated with RDS, Aurora, Athena, Redshift, S3...
- In-memory computation using SPICE engine if data is imported into QuickSight
- Enterprise edition: Possibility to setup Column-Level security (CLS)



<https://aws.amazon.com/quicksight/>

QuickSight Integrations

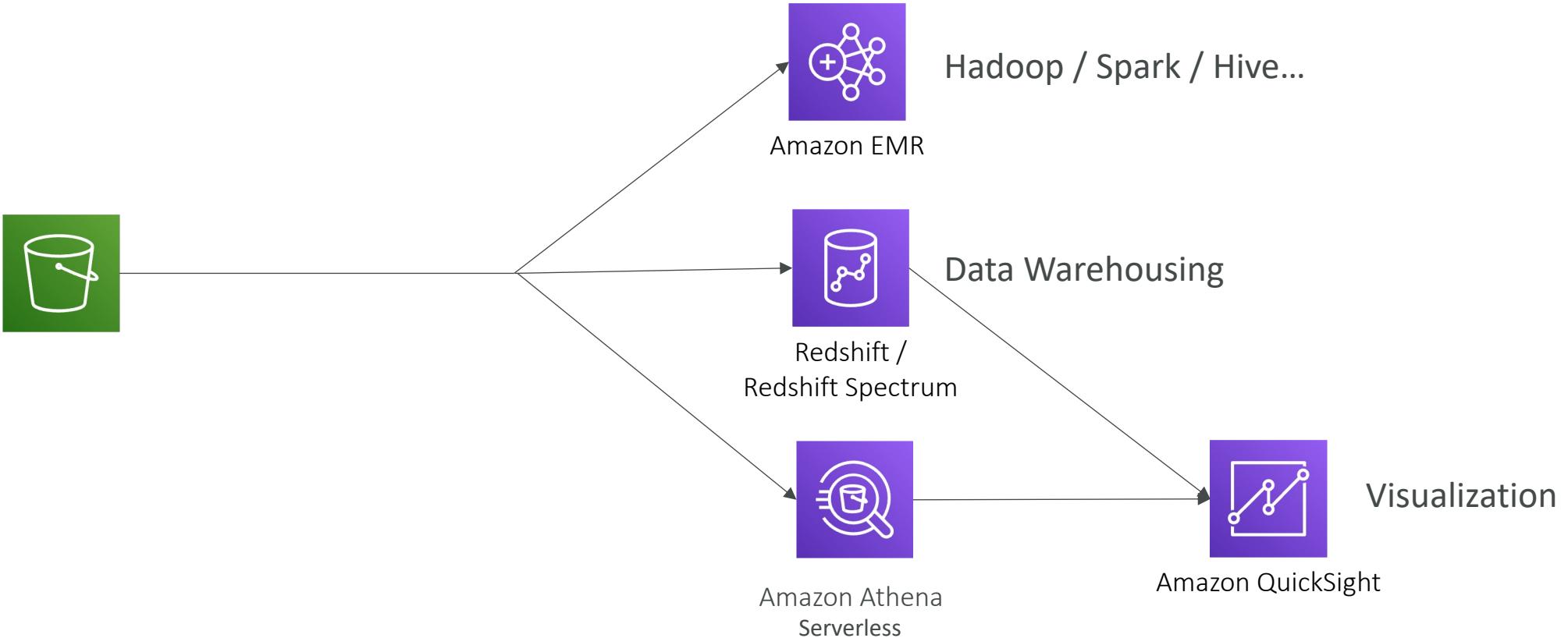


QuickSight – Dashboard & Analysis

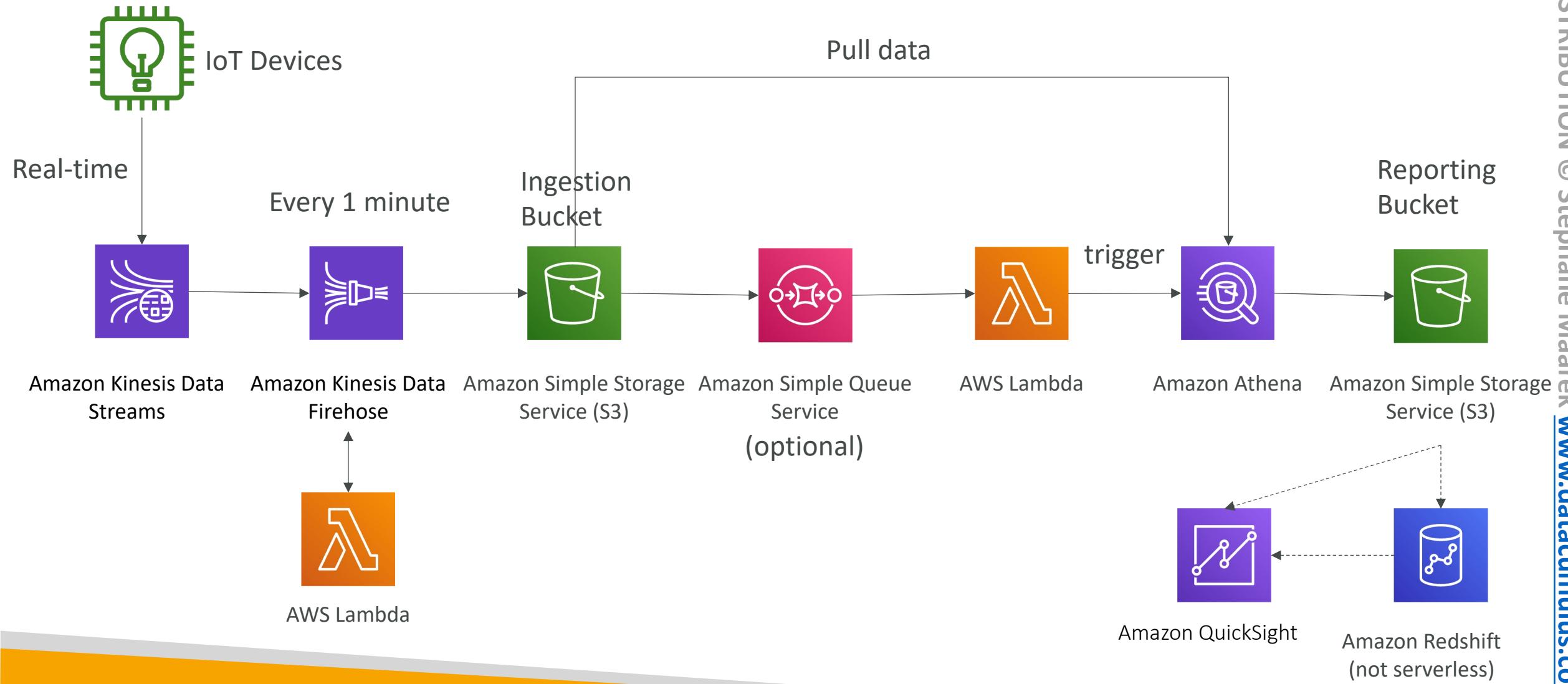
- Define Users (standard versions) and Groups (enterprise version)
 - These users & groups only exist within QuickSight, not IAM !!
- A *dashboard*...
 - is a read-only snapshot of an analysis that you can share
 - preserves the configuration of the analysis (filtering, parameters, controls, sort)
-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

Full Data Engineering Pipeline

Analytics layer



Big Data Ingestion Pipeline



Comparison of warehousing technologies

- **EMR**

- Need to use Big Data tools such as Apache Hive, Spark
- One long-running cluster, many jobs, with auto-scaling, or one cluster per job?
- Purchasing options – Spot, On Demand, Reserved Instances
- Can access data in DynamoDB and / or S3
- Scratch data on EBS disks (HDFS) and long term storage in S3 (EMRFS)

- **Athena**

- Simple queries and aggregations, data must live in S3
- Serverless, simple SQL queries, out-of-the-box queries for many services (cost & billing..)
- Audit queries through CloudTrail

- **Redshift**

- Advanced SQL queries, must provision servers
- Can leverage Redshift Spectrum for serverless queries on S3

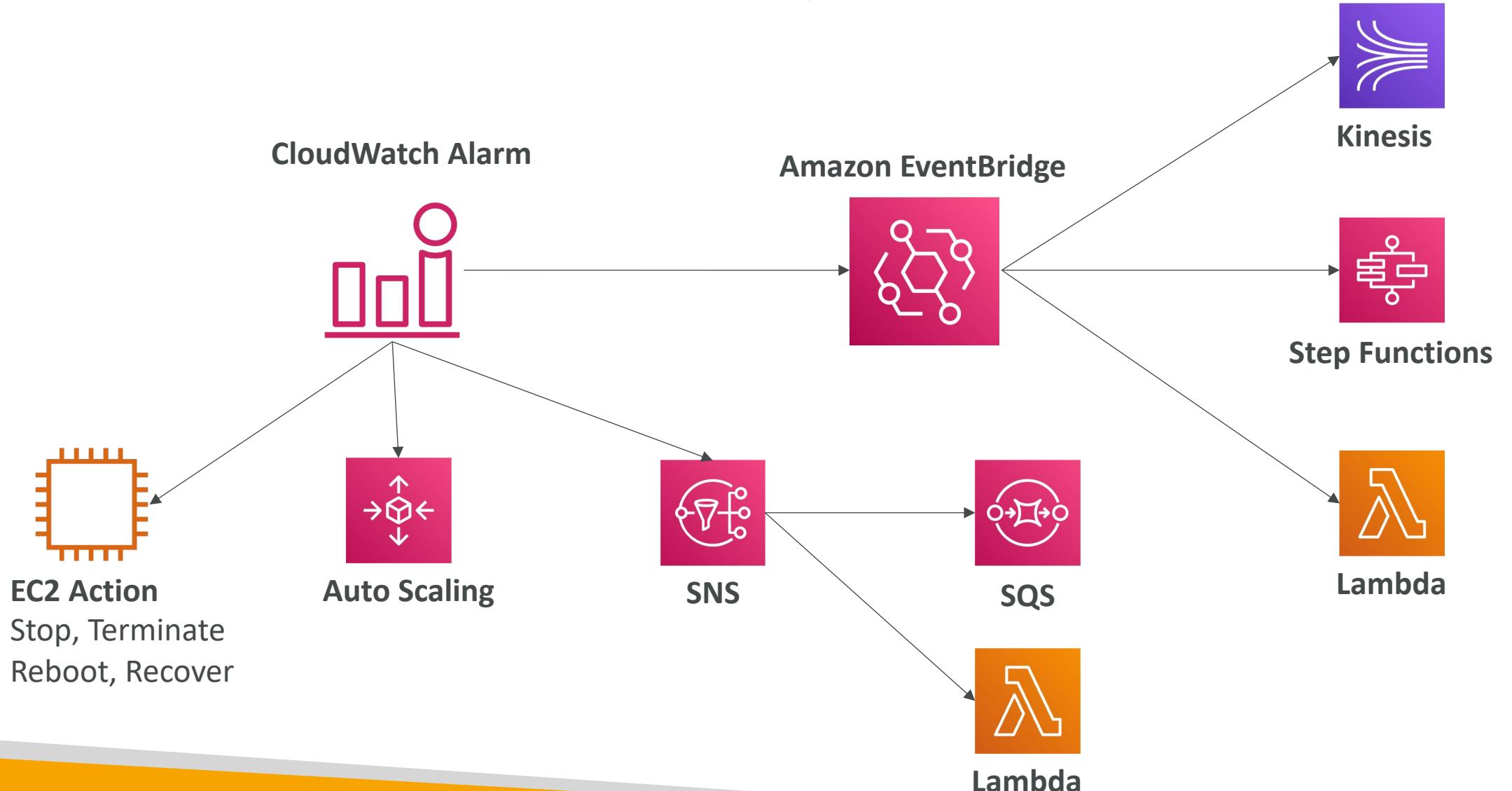
Monitoring



CloudWatch

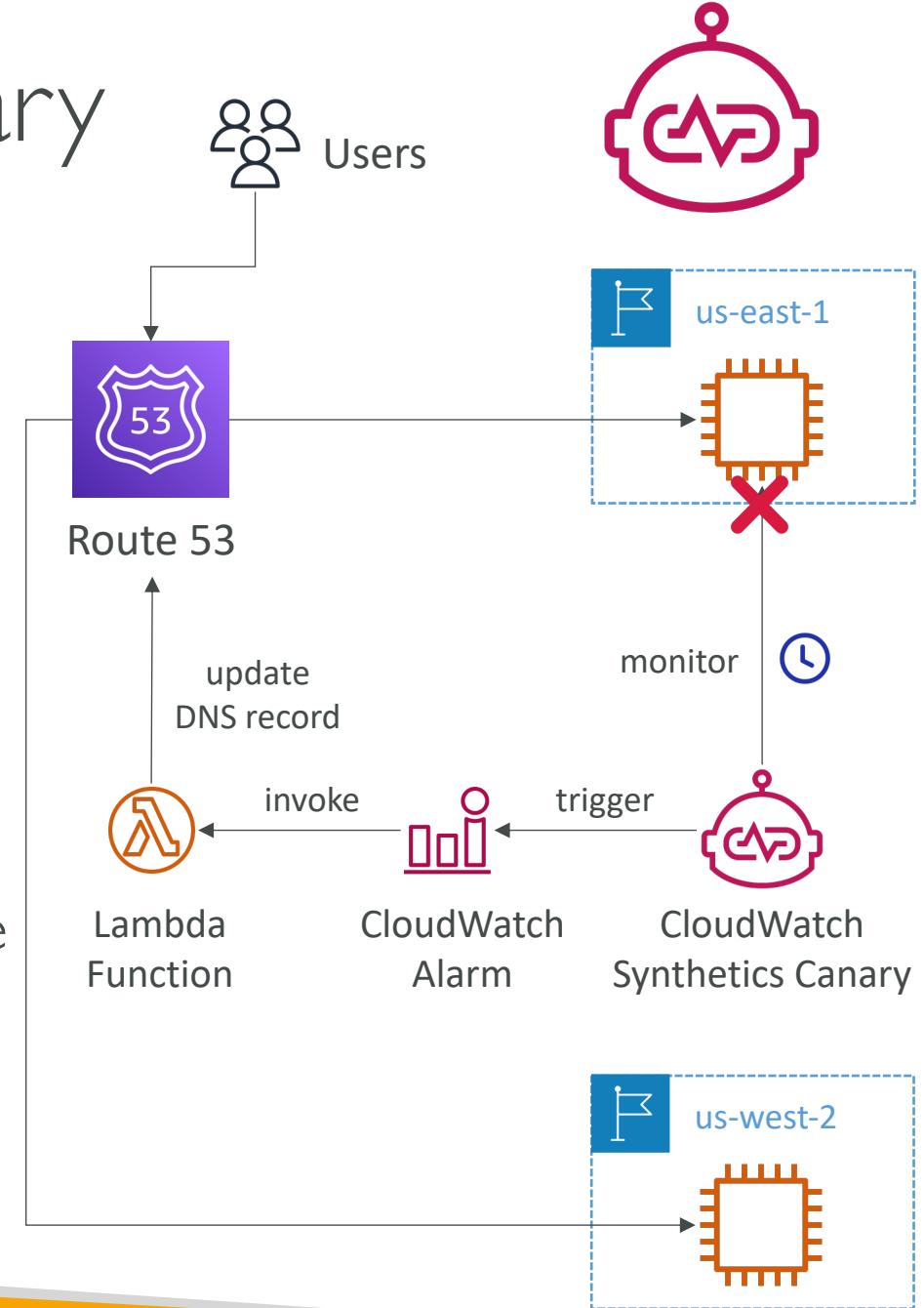
- CloudWatch Metrics
 - Provided by many AWS services
 - EC2 standard: 5 minutes, detailed monitoring: 1 minute
 - EC2 RAM is not a built-in metric
 - Can create custom metrics: standard resolution 1 minute, high resolution 1 sec
- CloudWatch Alarms
 - Can trigger actions: EC2 action (reboot, stop, terminate, recover), Auto Scaling, SNS
 - Alarm events can be intercepted by Amazon EventBridge
- CloudWatch Dashboards
 - Display metrics and alarms
 - Can show metrics of multiple regions

CloudWatch Alarms integrations



CloudWatch Synthetics Canary

- Configurable script that monitor your APIs, URLs, Websites, ...
- Reproduce what your customers do programmatically to find issues before customers are impacted
- Checks the availability and latency of your endpoints and can store load time data and screenshots of the UI
- Integration with CloudWatch Alarms
- Scripts written in Node.js or Python
- Programmatic access to a headless Google Chrome browser
- Can run once or on a regular schedule



CloudWatch Synthetics Canary Blueprints

- **Heartbeat Monitor** – load URL, store screenshot and an HTTP archive file
- **API Canary** – test basic read and write functions of REST APIs
- **Broken Link Checker** – check all links inside the URL that you are testing
- **Visual Monitoring** – compare a screenshot taken during a canary run with a baseline screenshot
- **Canary Recorder** – used with CloudWatch Synthetics Recorder (record your actions on a website and automatically generates a script for that)
- **GUI Workflow Builder** – verifies that actions can be taken on your webpage (e.g., test a webpage with a login form)

AWS CloudWatch Logs - Sources

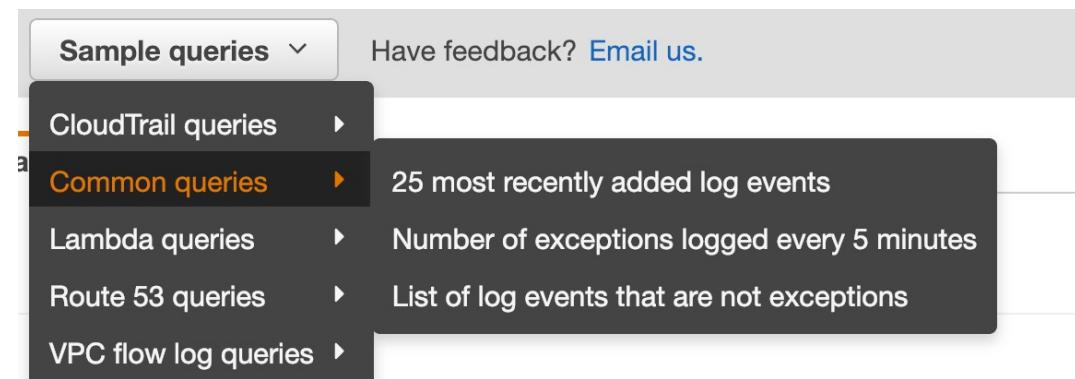
- SDK, CloudWatch Logs Agent, CloudWatch Unified Agent
- Elastic Beanstalk: collection of logs from application
- ECS: collection from containers
- AWS Lambda: collection from function logs
- VPC Flow Logs: VPC specific logs
- API Gateway
- CloudTrail based on filter
- CloudWatch log agents: for example on EC2 machines
- Route53: Log DNS queries

CloudWatch Logs

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

CloudWatch Logs Metric Filter & Insights

- CloudWatch Logs can use filter expressions
 - For example, find a specific IP inside of a log
 - Or count occurrences of “ERROR” in your logs
 - Metric filters can be used to trigger alarms
- CloudWatch Logs Insights can be used to query logs and add queries to CloudWatch Dashboards



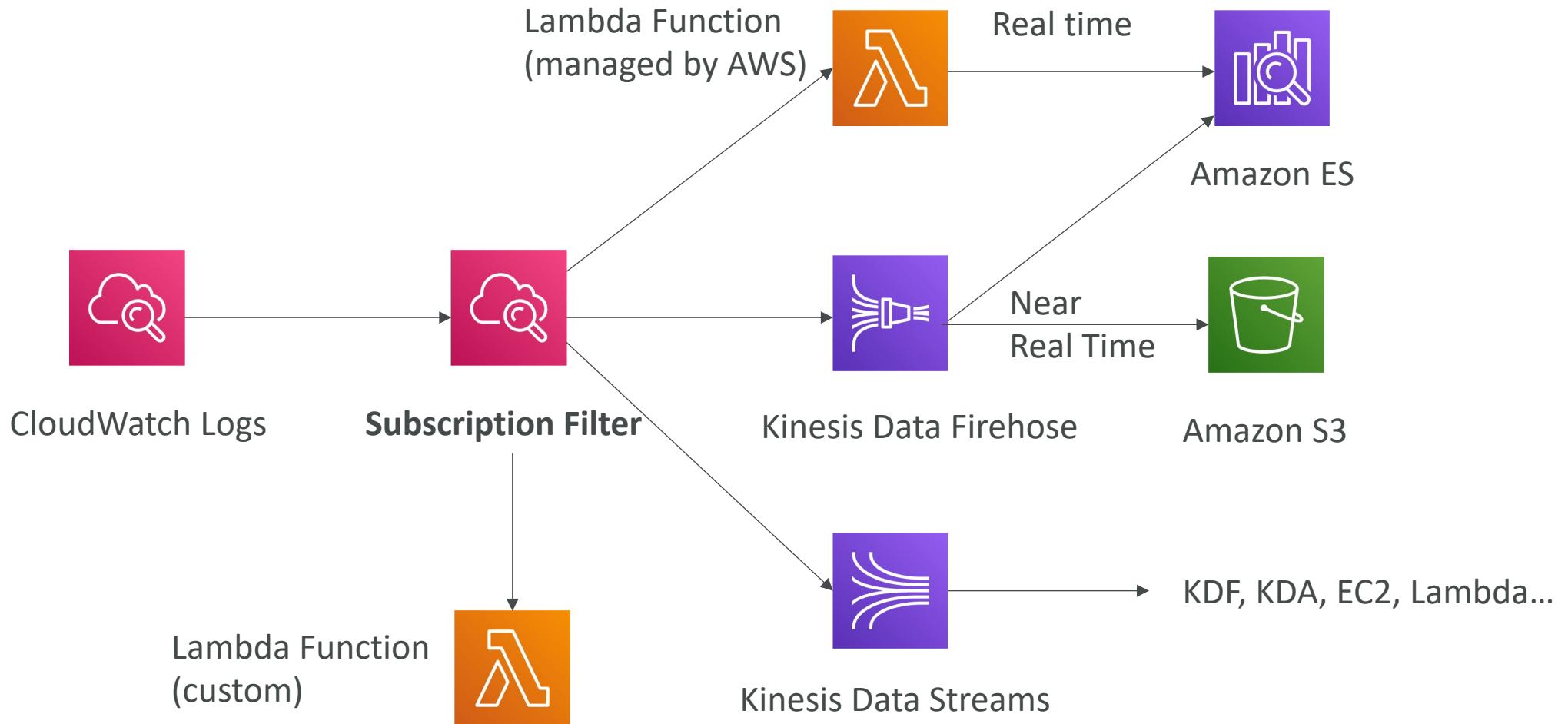
CloudWatch Logs – S3 Export



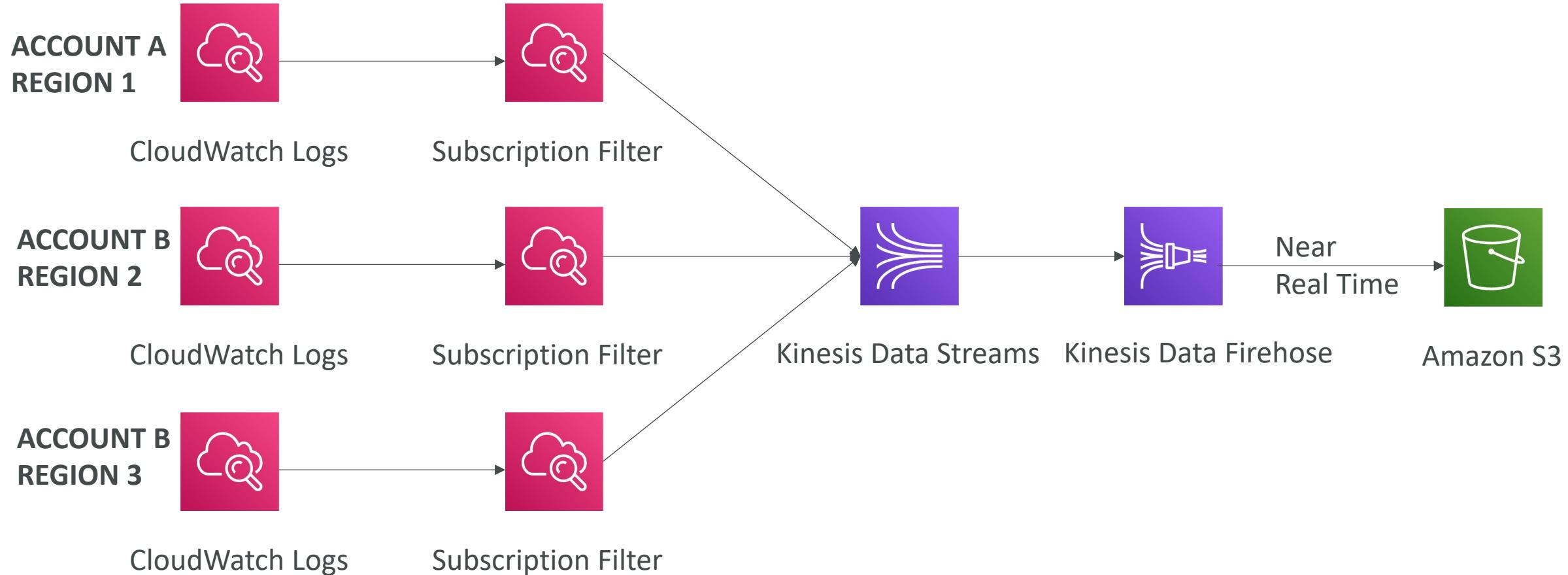
- S3 buckets must be encrypted with AES-256 (SSE-S3) or SSE-KMS
- Log data can take up to 12 hours to become available for export
- The API call is `CreateExportTask`

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

CloudWatch Logs Subscriptions

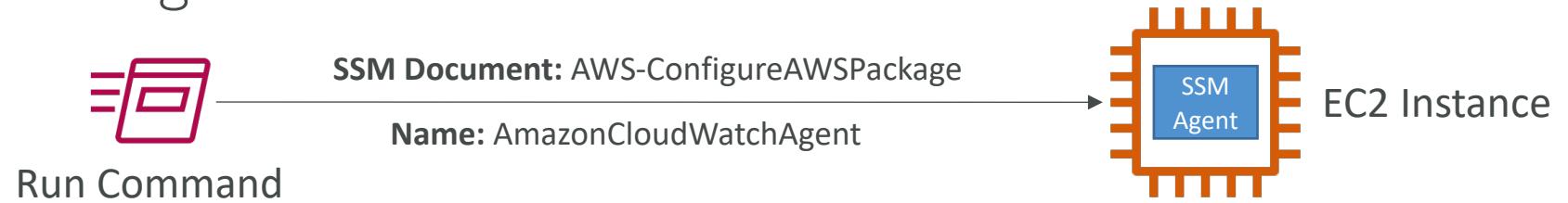


CloudWatch Logs Aggregation Multi-Account & Multi Region

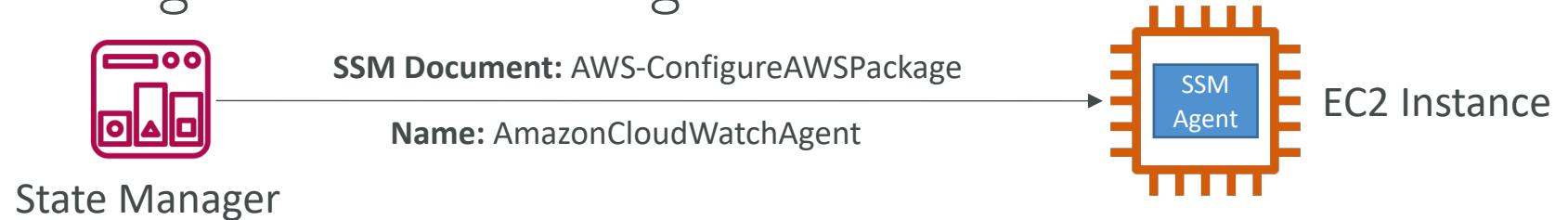


CloudWatch Agent – Integration with SSM

- Install CW Agent using SSM Run Command



- Install CW Agent using SSM State Manager



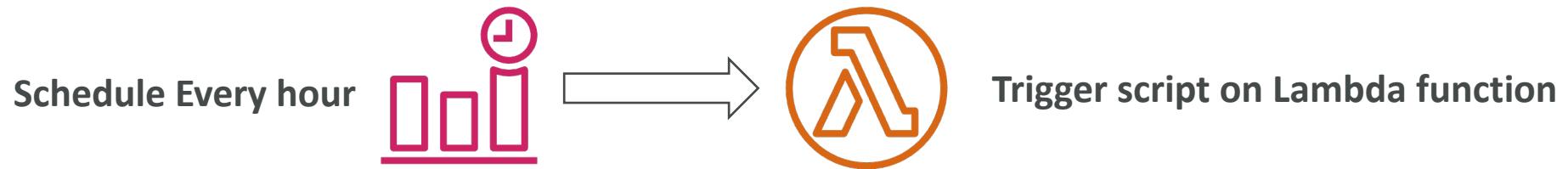
- Configure CW Agent by storing config. in SSM Parameter Store



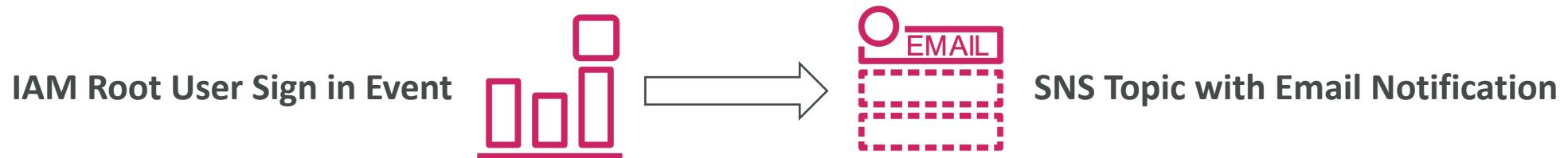
Amazon EventBridge (formerly CloudWatch Events)



- Schedule: Cron jobs (scheduled scripts)

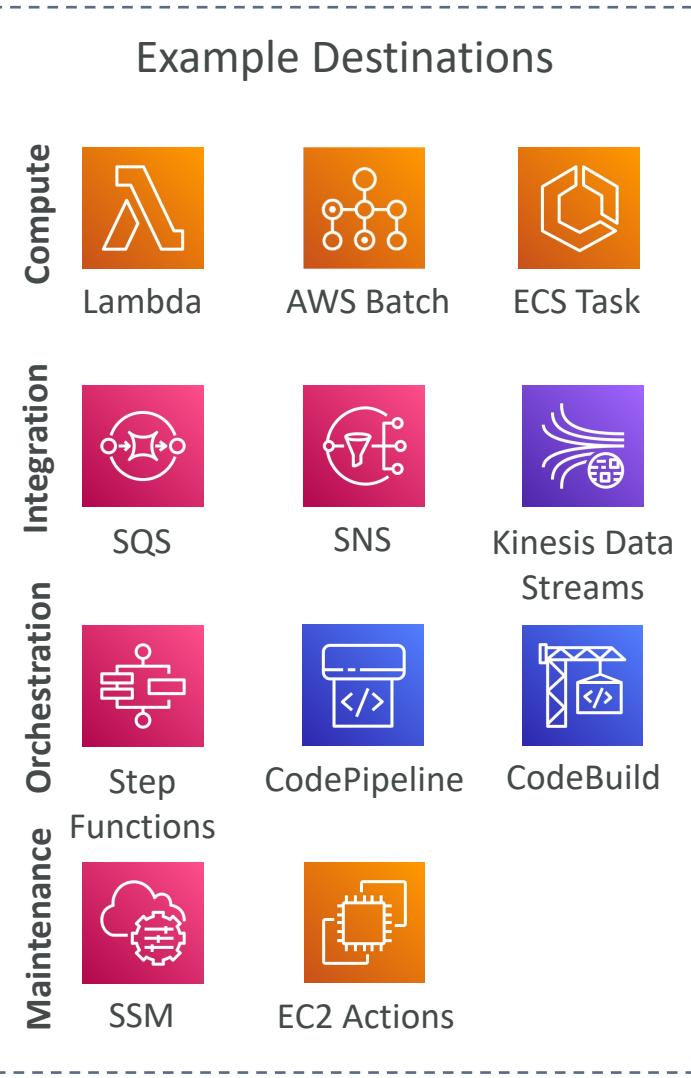
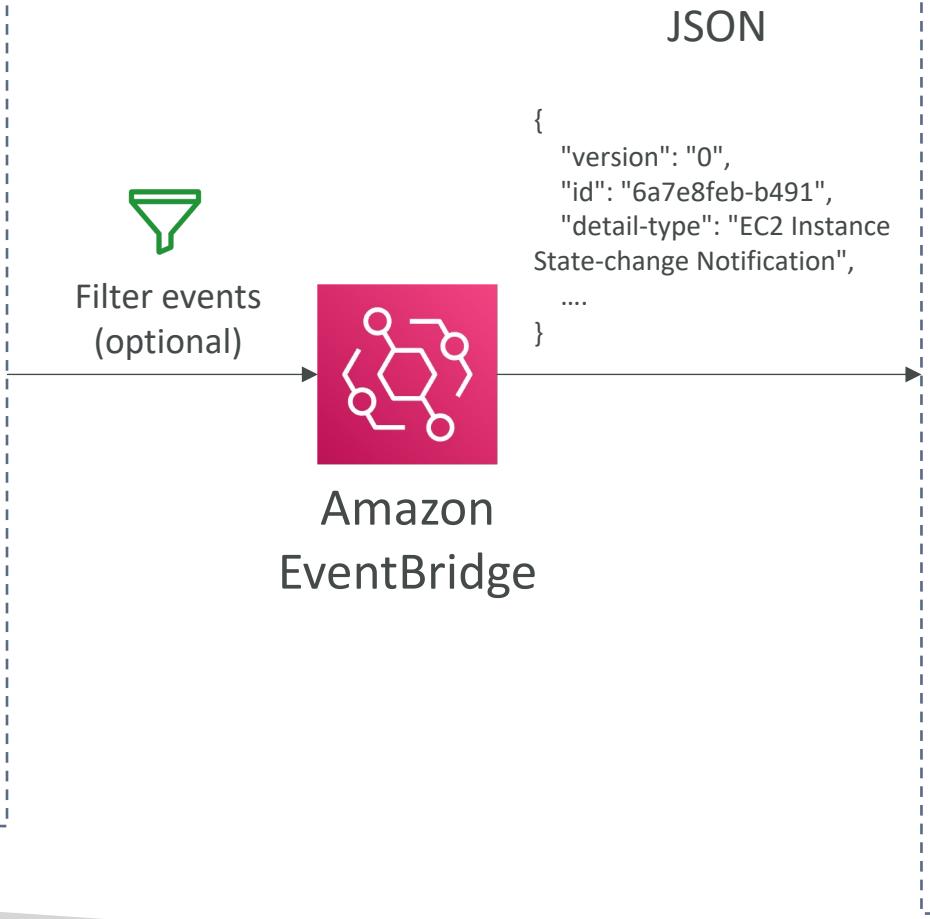
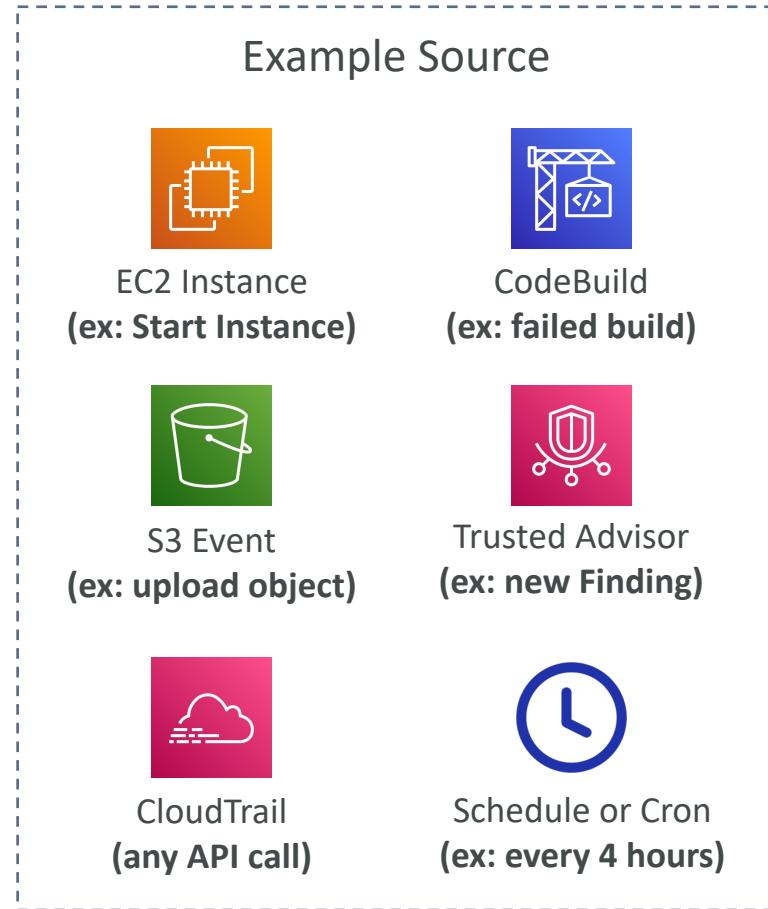


- Event Pattern: Event rules to react to a service doing something

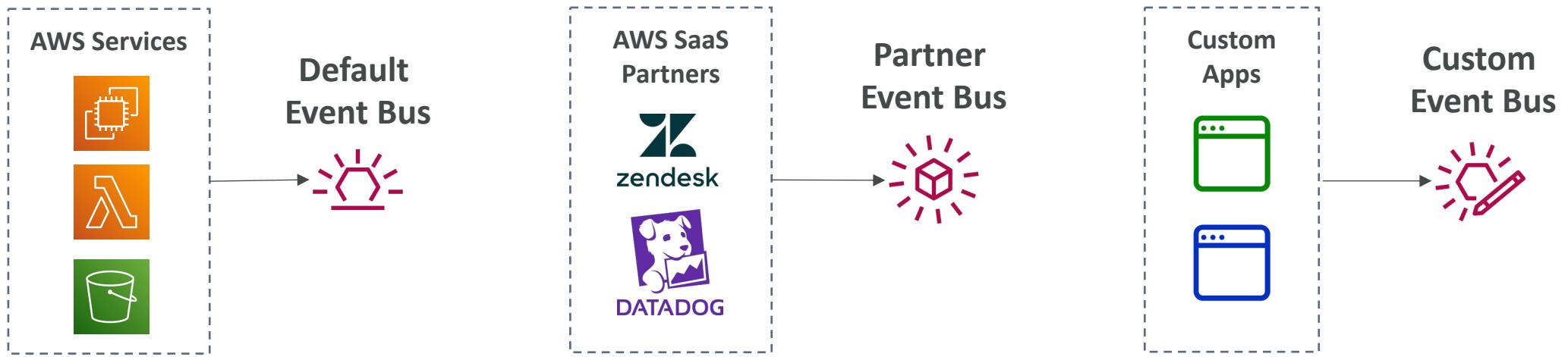


- Trigger Lambda functions, send SQS/SNS messages...

Amazon EventBridge Rules



Amazon EventBridge



- Event buses can be accessed by other AWS accounts using Resource-based Policies
- You can **archive events** (all/filter) sent to an event bus (indefinitely or set period)
- Ability to **replay** archived events

Amazon EventBridge – Schema Registry

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

The screenshot shows the AWS Schema Registry interface. At the top, there's a header with the URL "aws.codepipeline@CodePipelineActionExecutionStateChange". Below it, a section titled "Schema details" provides the following information:

Schema name	Last modified	Schema ARN
aws.codepipeline@CodePipelineActionExecutionStateChange	Dec 1, 2019, 12:11 AM GMT	-
Description	Schema for event type CodePipelineActionExecutionStateChange, published by AWS service aws.codepipeline	Schema registry aws.events Number of versions 1 Schema type OpenAPI 3.0

Below this, a section titled "Version 1" shows the schema definition:

Version 1 Created on Dec 1, 2019, 12:11 AM GMT

Action ▾ Download code bindings

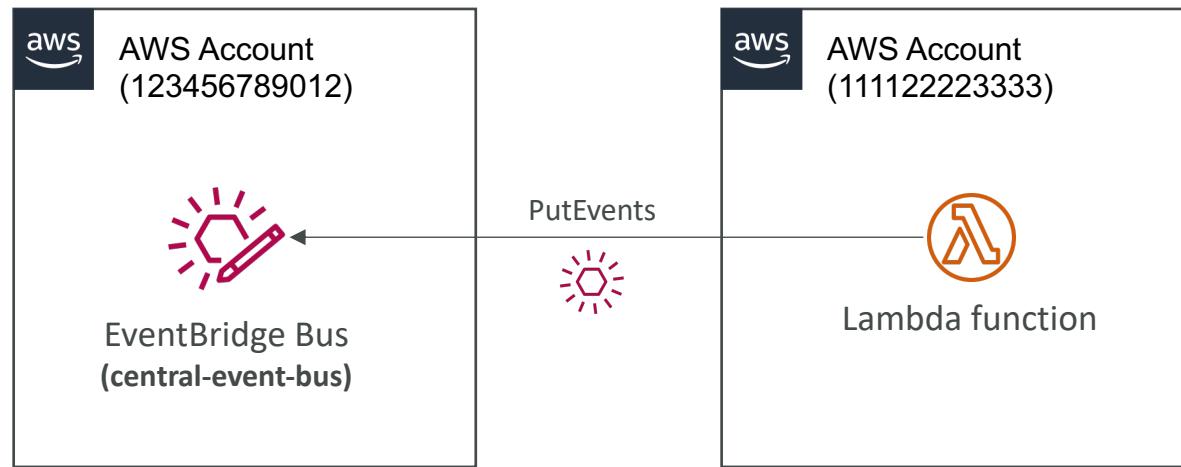
```
1 {
2   "openapi": "3.0.0",
3   "info": {
4     "version": "1.0.0",
5     "title": "CodePipelineActionExecutionStateChange"
6   },
7   "paths": {},
8   "components": {
9     "schemas": {
10       "AWSEvent": {
```

Amazon EventBridge – Resource-based Policy

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

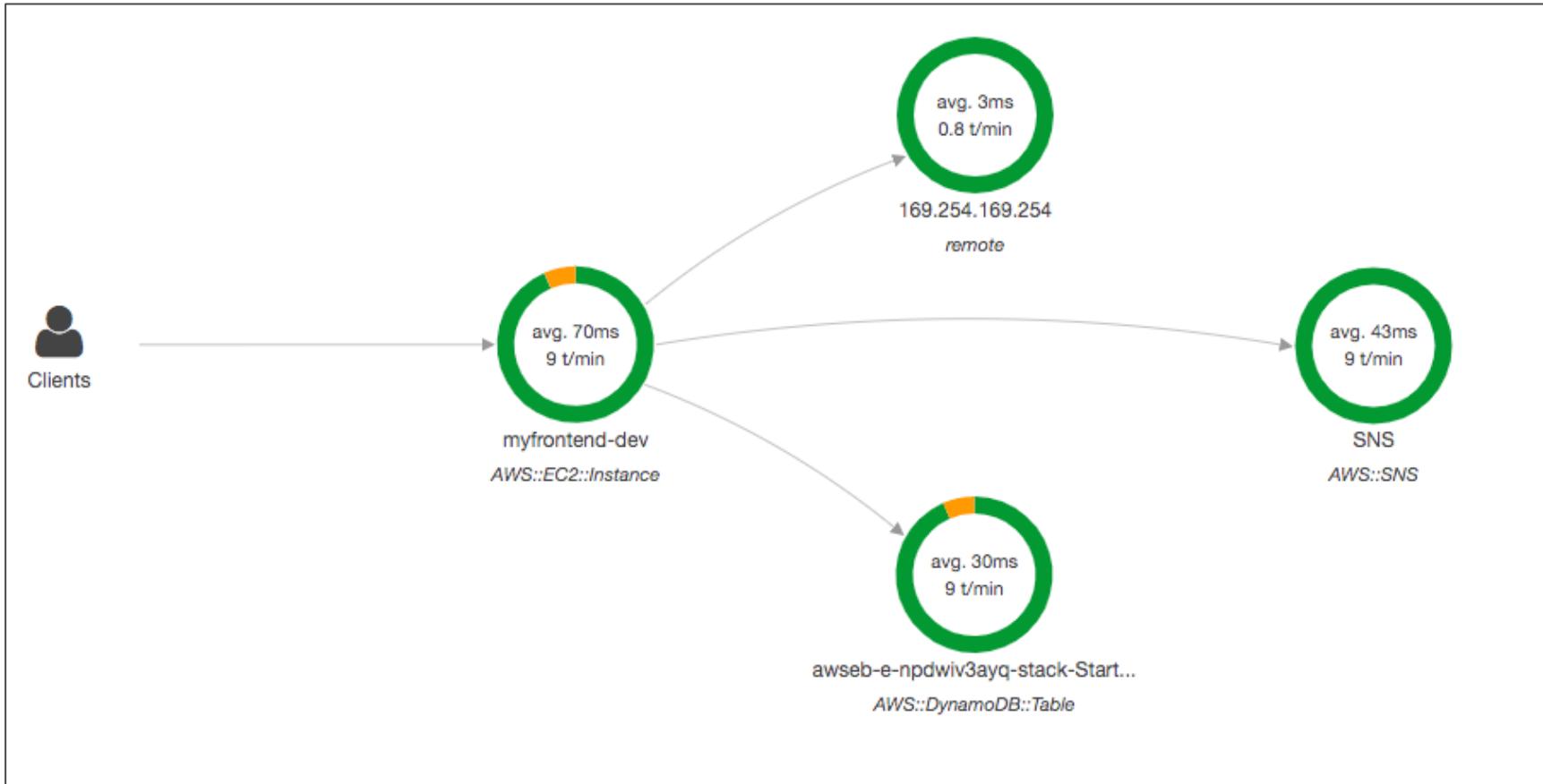
```
{  
    "Version": "2012-10-17",  
    "Statement": [  
        {  
            "Effect": "Allow",  
            "Action": "events:PutEvents",  
            "Principal": { "AWS": "111122223333" },  
            "Resource": "arn:aws:events:us-east-1:123456789012:  
event-bus/central-event-bus"  
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

Allow **events** from another AWS account



AWS X-Ray

Visual analysis of our applications





X-Ray

- Tracing requests across your microservices (distributed systems)
- Integrations with:
 - EC2 – install the X-Ray agent
 - ECS – install the X-Ray agent or Docker container
 - Lambda
 - Beanstalk - agent is automatically installed
 - API Gateway – helpful to debug errors (such as 504)
- The X-Ray agent or services need IAM permissions to X-Ray



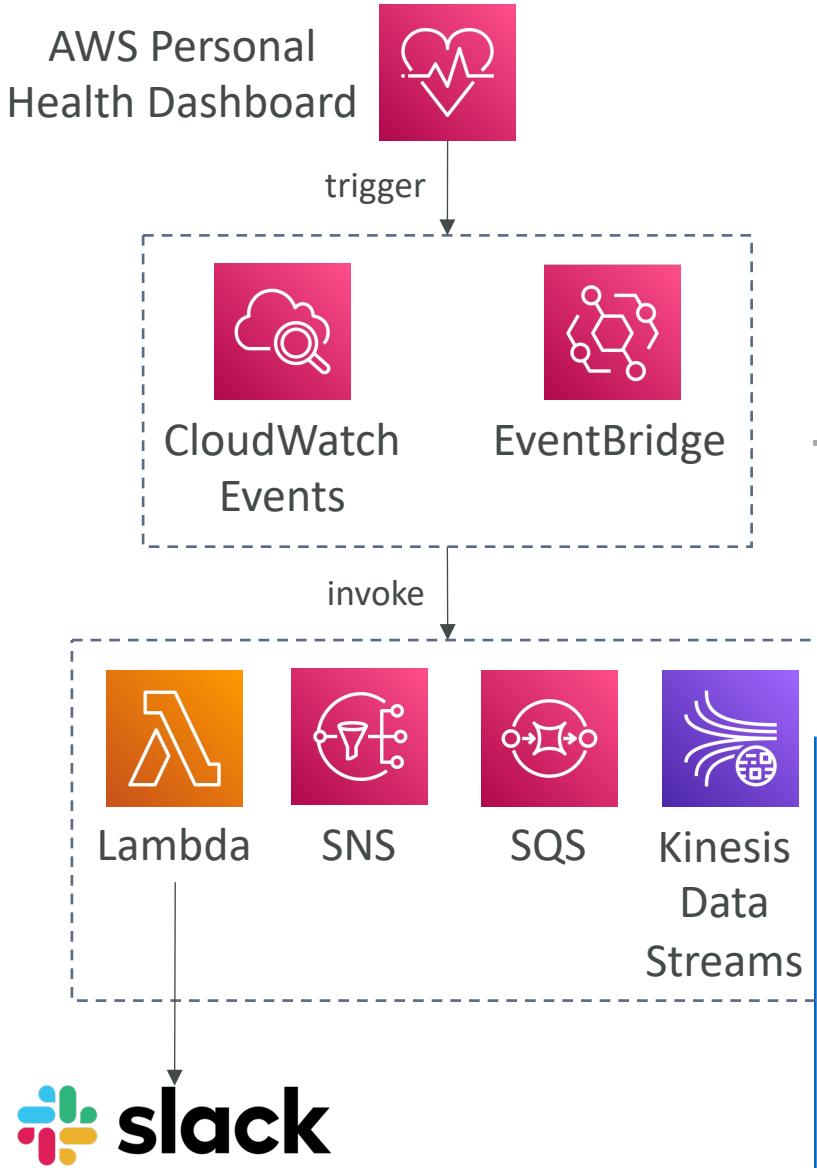
AWS Personal Health Dashboard

AWS Management Console

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

Health Event Notifications

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



Deployment & Instance Management

AWS Elastic Beanstalk Overview



- Elastic Beanstalk is a developer centric view of deploying an application on AWS
- It uses all the component's we've seen before: EC2, Auto Scaling Group, Elastic Load Balancers, RDS, etc...
- But it's all in one view that's easy to make sense of!
- **We still have full control over the configuration of each component**
- Beanstalk is free but you pay for the underlying instances

Elastic Beanstalk

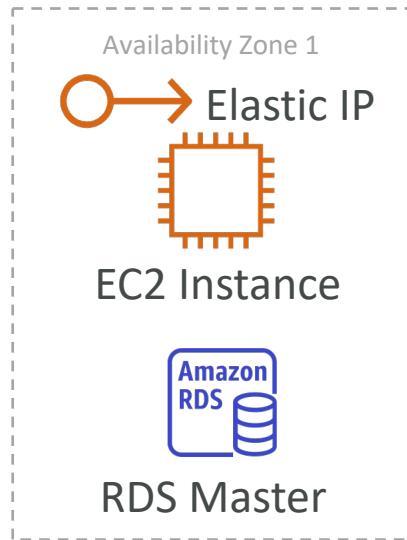
- Support for many platforms:
 - Go
 - Java SE
 - Java with Tomcat
 - .NET on Windows Server with IIS
 - Node.js
 - PHP
 - Python
 - Ruby
 - Packer Builder
 - Single Container Docker
- Multicontainer Docker
- Preconfigured Docker
- If not supported, you can write your custom platform (advanced)
- Beanstalk is great to “Replatform” your application from on-premises to the cloud

Elastic Beanstalk

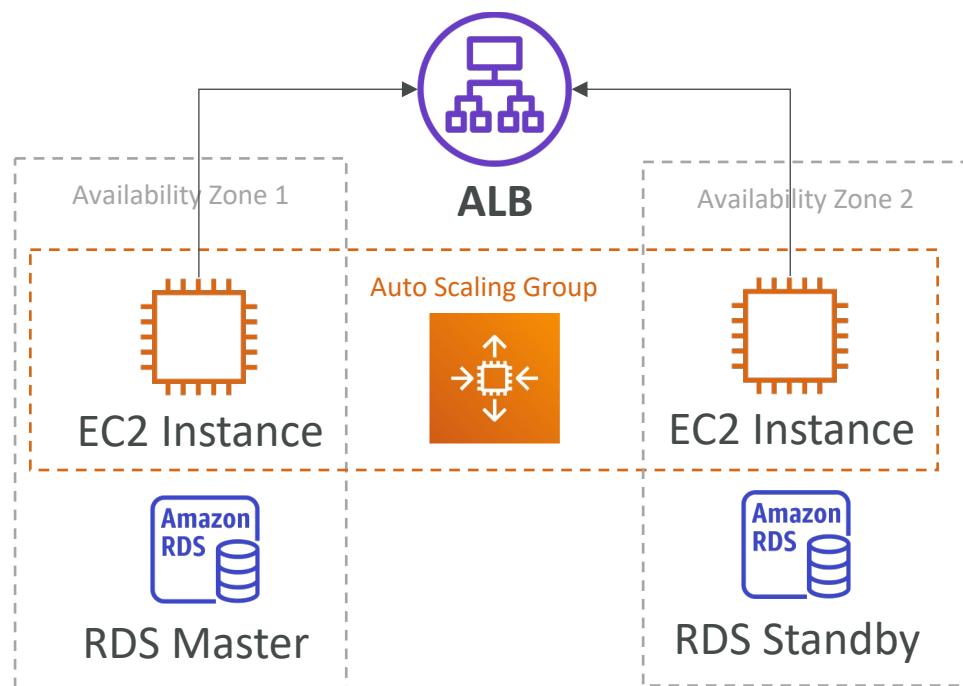
- Managed service
 - Instance configuration / OS is handled by Beanstalk
 - Deployment strategy is configurable but performed by Elastic Beanstalk
- Just the application code is the responsibility of the developer
- Three architecture models:
 - Single Instance deployment: good for dev
 - LB + ASG: great for production or pre-production web applications
 - ASG only: great for non-web apps in production (workers, etc..)

Beanstalk Environments

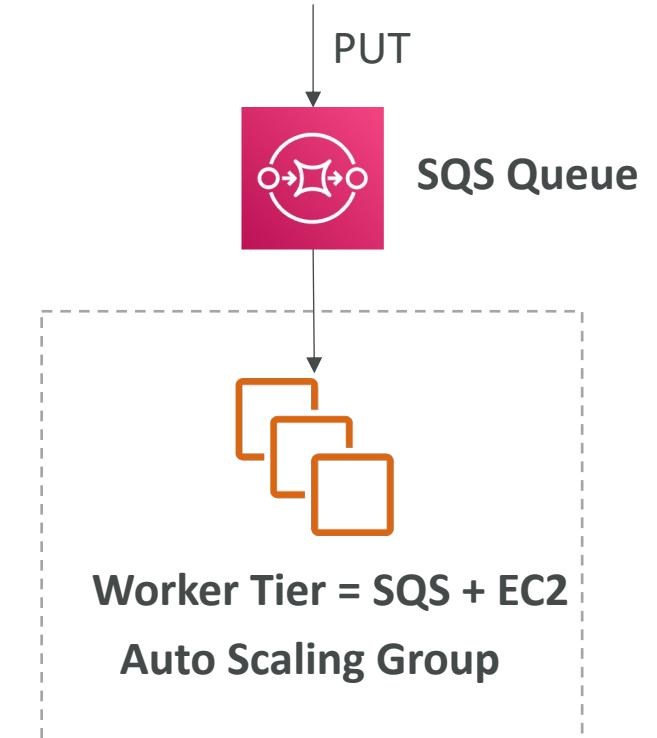
Single Instance
Great for dev



High Availability with Load Balancer
Great for prod

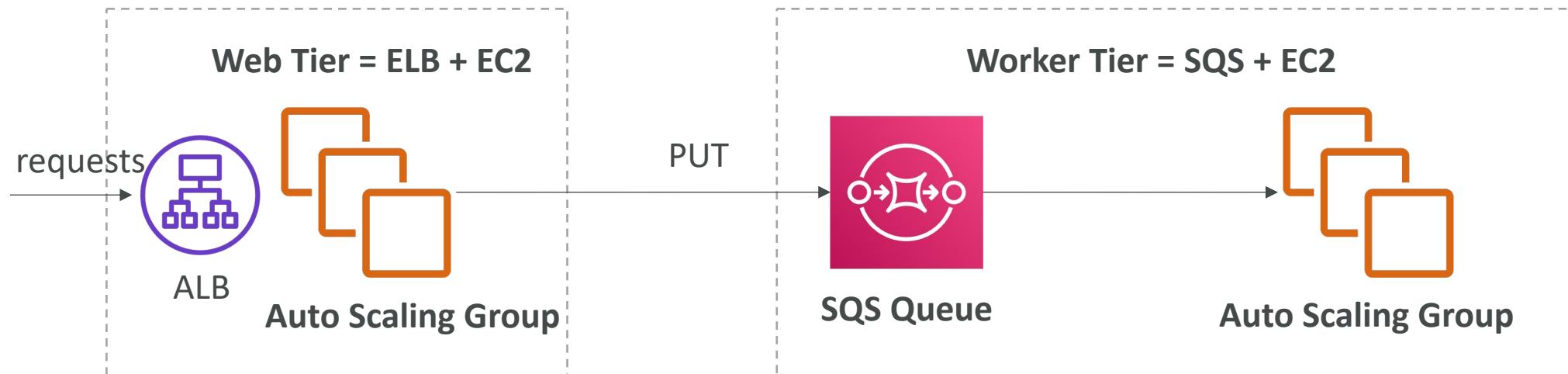


Worker Tier



Web Server vs Worker Environment

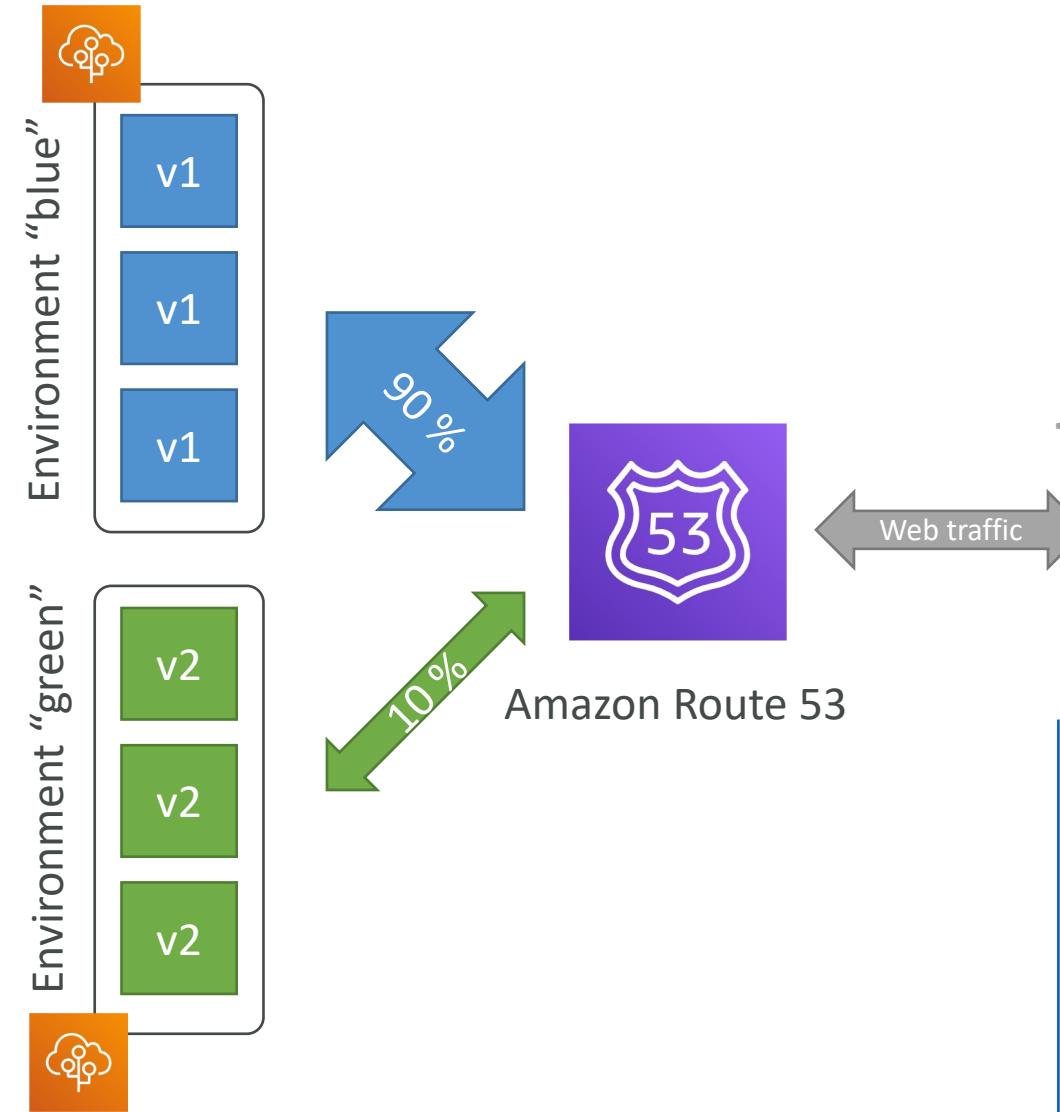
- If your application performs tasks that are long to complete, offload these tasks to a dedicated **worker environment**
- Decoupling your application into two tiers is common
- Example: processing a video, generating a zip file, etc
- You can define periodic tasks in a file `cron.yaml`



Elastic Beanstalk Deployment

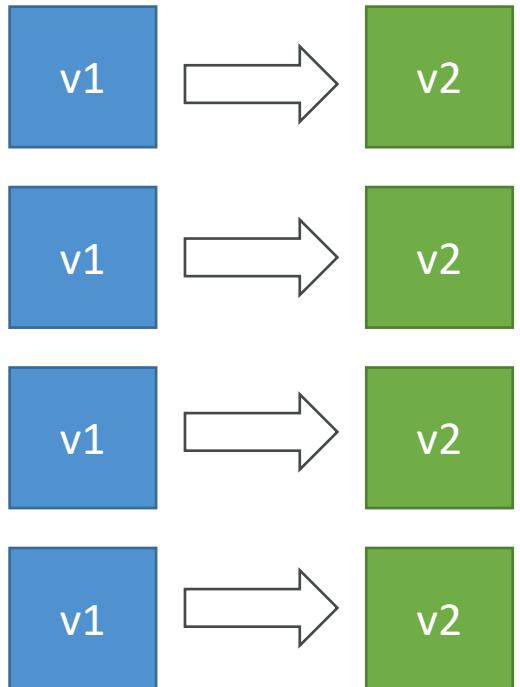
Blue / Green

- Not a “direct feature” of Elastic Beanstalk
- Zero downtime and release facility
- Create a new “stage” environment and deploy v2 there
- The new environment (green) can be validated independently and roll back if issues
- Route 53 can be setup using weighted policies to redirect a little bit of traffic to the stage environment
- Using Beanstalk, “swap URLs” (DNS swap) when done with the environment test



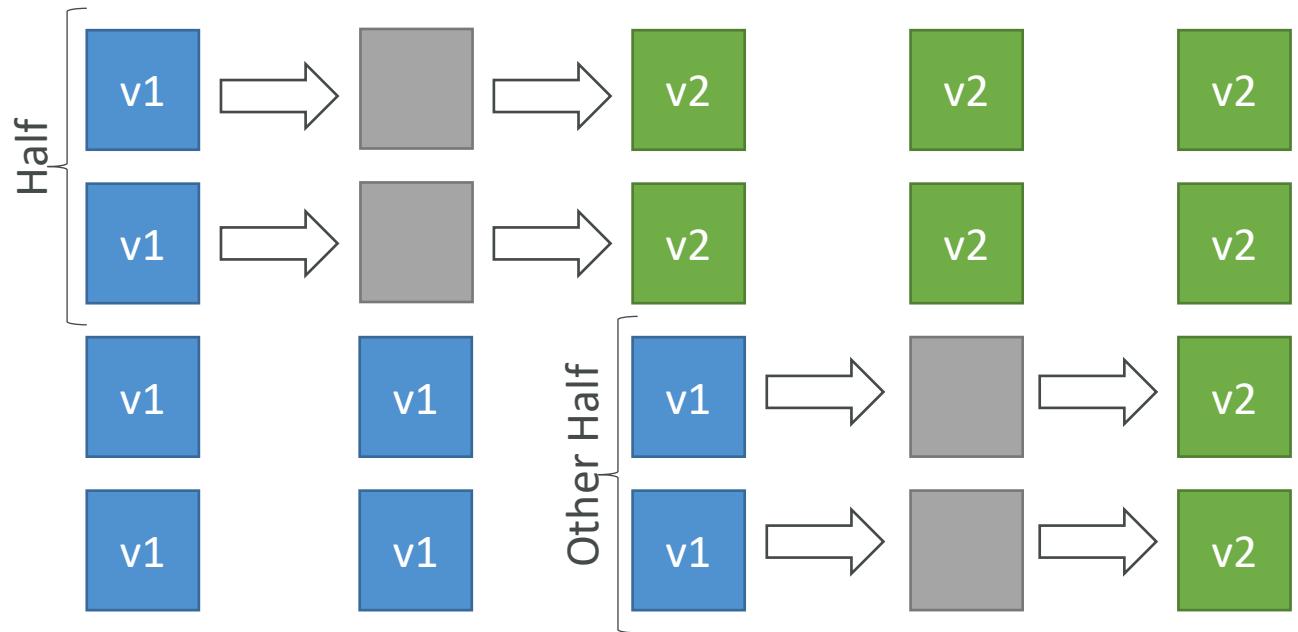
AWS CodeDeploy

- We want to deploy our application automatically to many EC2 instances
- These instances are not managed by Elastic Beanstalk
- There are several ways to handle deployments using open source tools (Ansible, Terraform, Chef, Puppet, etc...)
- We can use the managed Service AWS CodeDeploy
- CodeDeploy can deploy to: **EC2, ASG, ECS & Lambda**



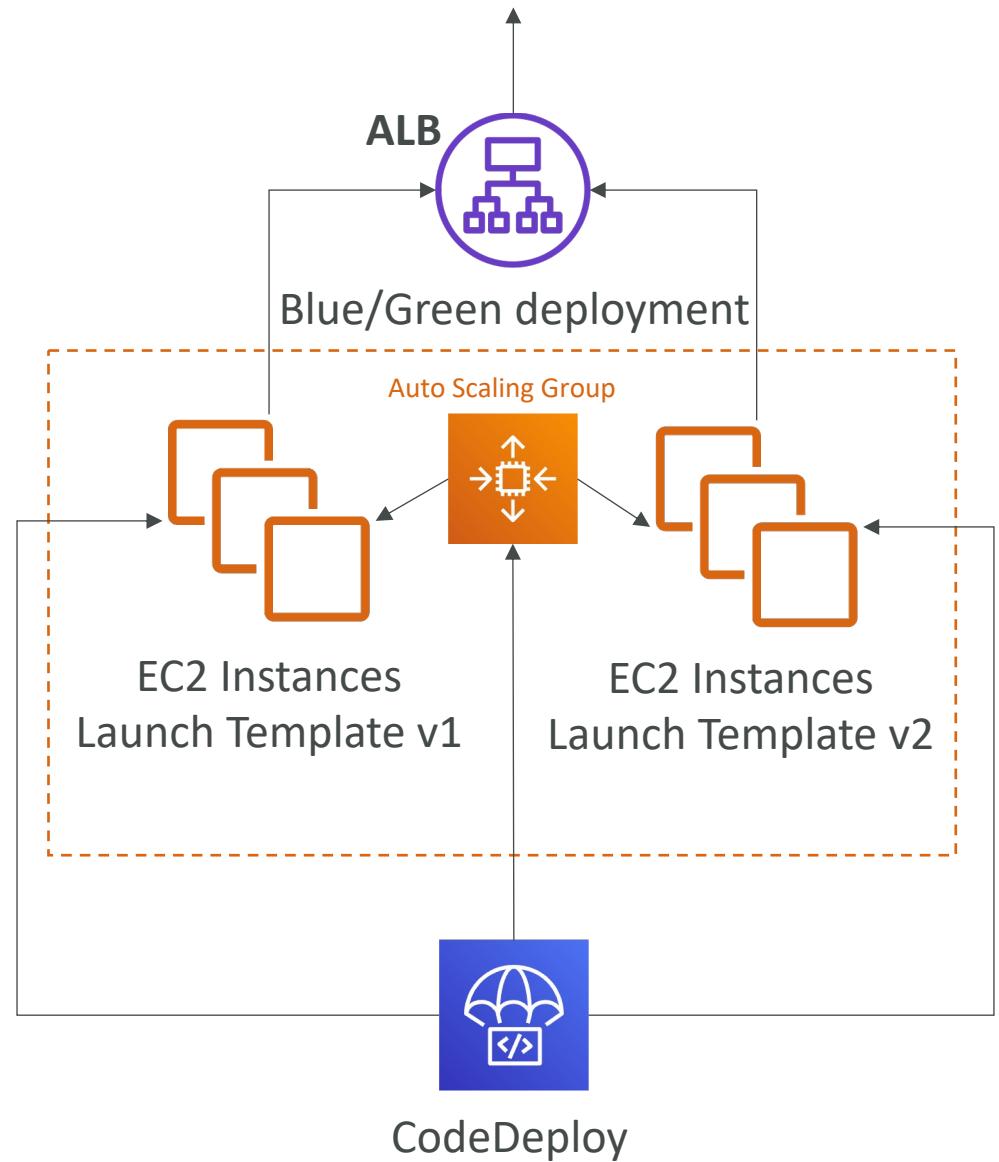
CodeDeploy to EC2

- Define how to deploy the application using appspec.yml + deployment strategy
- Will do in-place update to your fleet of EC2 instances
- Can use hooks to verify the deployment after each deployment phase



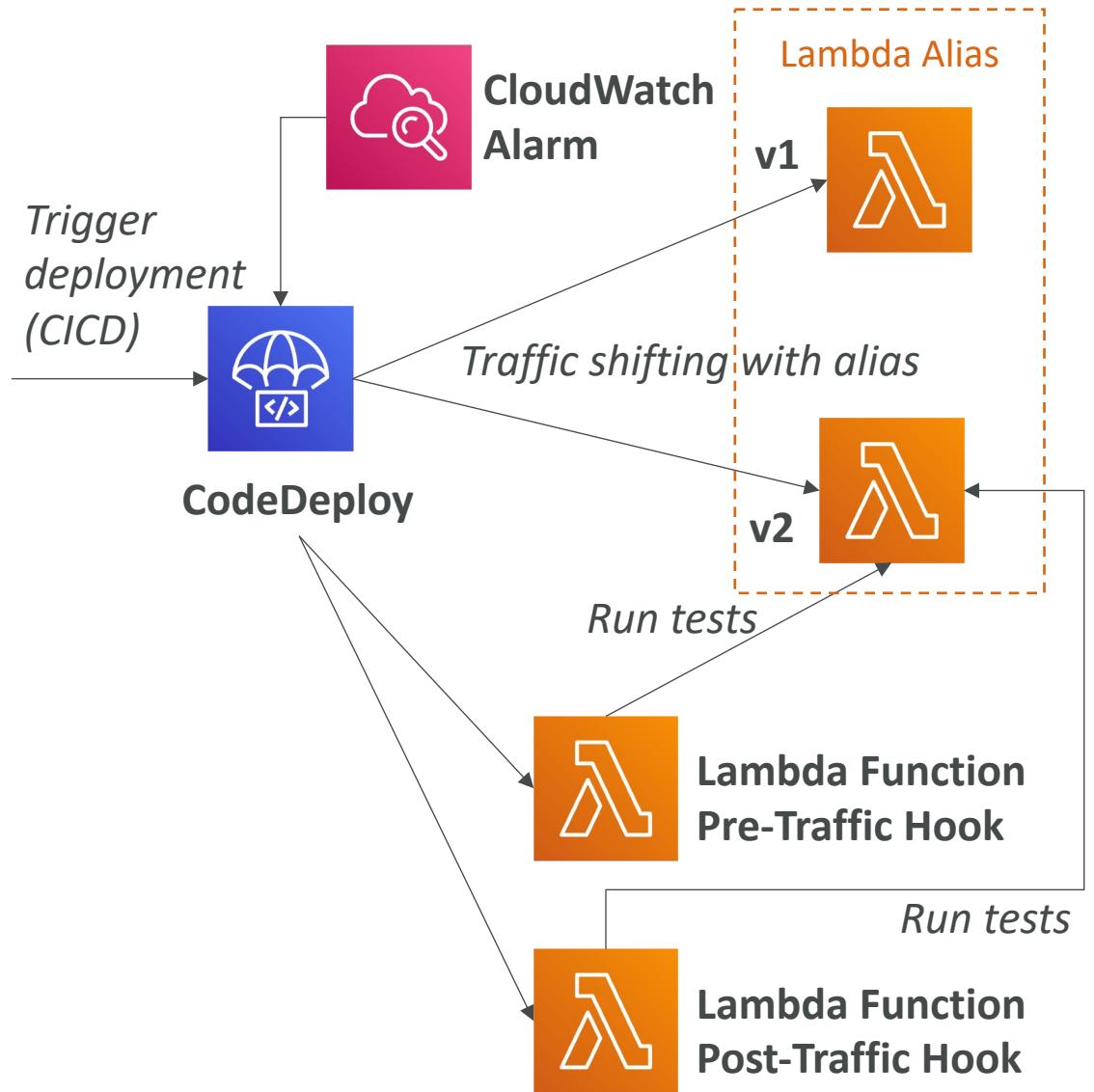
CodeDeploy to ASG

- In place updates:
 - Updates current existing EC2 instances
 - Instances newly created by an ASG will also get automated deployments
- Blue / green deployment:
 - A new auto-scaling group is created (settings are copied)
 - Choose how long to keep the old instances
 - Must be using an ELB



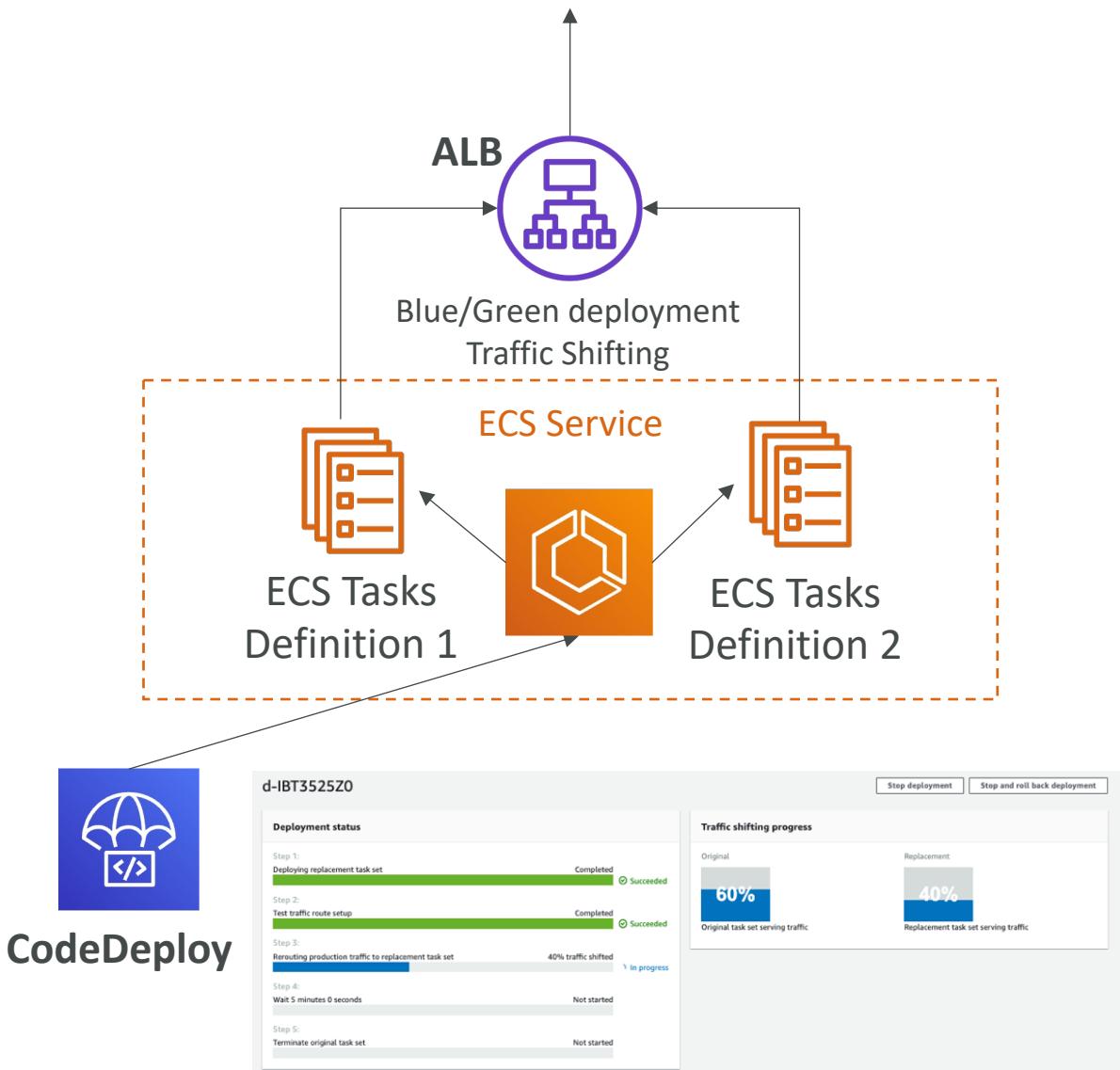
CodeDeploy to AWS Lambda

- Traffic Shifting feature
- Pre and Post traffic hooks features to validate deployment (before the traffic shift starts and after it ends)
- Easy & automated rollback using CloudWatch Alarms
- SAM framework natively uses CodeDeploy



CodeDeploy to ECS

- Support for Blue/Green deployments for Amazon ECS and AWS Fargate
- Setup is done within the ECS service definition
- A new task set is created, and traffic is re-routed to the new task test.
- Then if everything is stable for X minutes, the old task set is terminated (so you have time to notice issues)
- Supports Canary deployments (Canary|0Percent5Minutes)



AWS CloudFormation



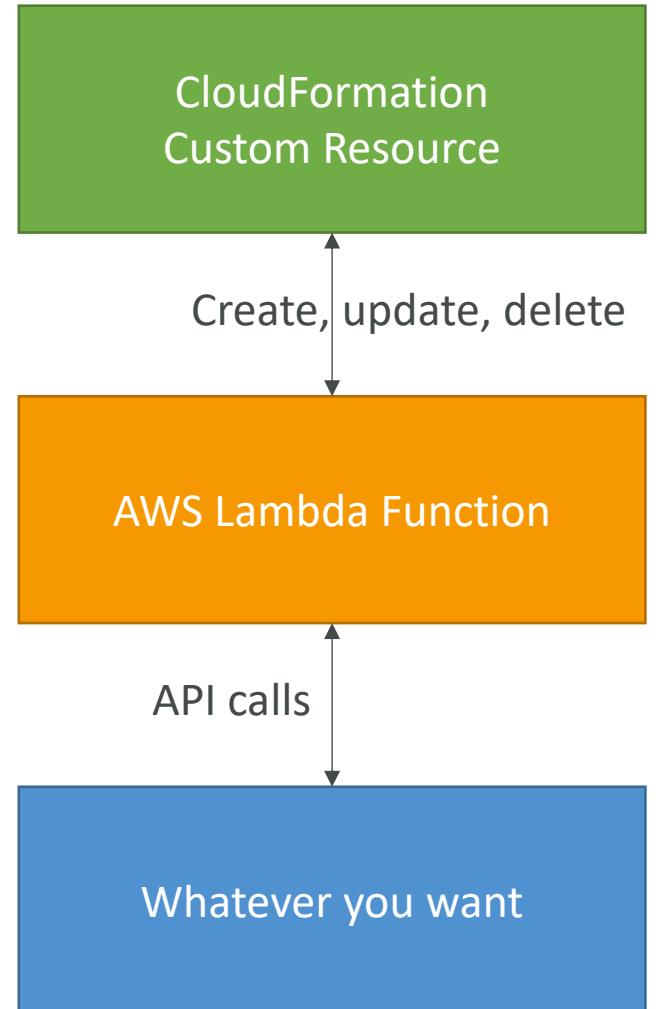
- Infrastructure as code (IaC) in AWS
- Portability of stacks across multiple accounts and regions
- Backbone of the Elastic Beanstalk service
- Backbone of the Service Catalog service
- Backbone of the SAM (Serverless Application Model) framework
- Must-know service as a developer / sysops / devops

Retaining Data on Deletes

- You can put a `DeletionPolicy` on any resource to control what happens when the CloudFormation template is deleted
- `DeletionPolicy=Retain`:
 - Specify on resources to preserve / backup in case of CloudFormation deletes
 - To keep a resource, specify `Retain` (works for any resource / nested stack)
- `DeletionPolicy=Snapshot`:
 - EBS Volume, ElastiCache Cluster, ElastiCache ReplicationGroup
 - RDS DBInstance, RDS DBCluster, Redshift Cluster
- `DeletePolicy=Delete` (default behavior):
 - Note: for `AWS::RDS::DBCluster` resources, the default policy is Snapshot
 - Note: to delete an S3 bucket, you need to first empty the bucket of its content

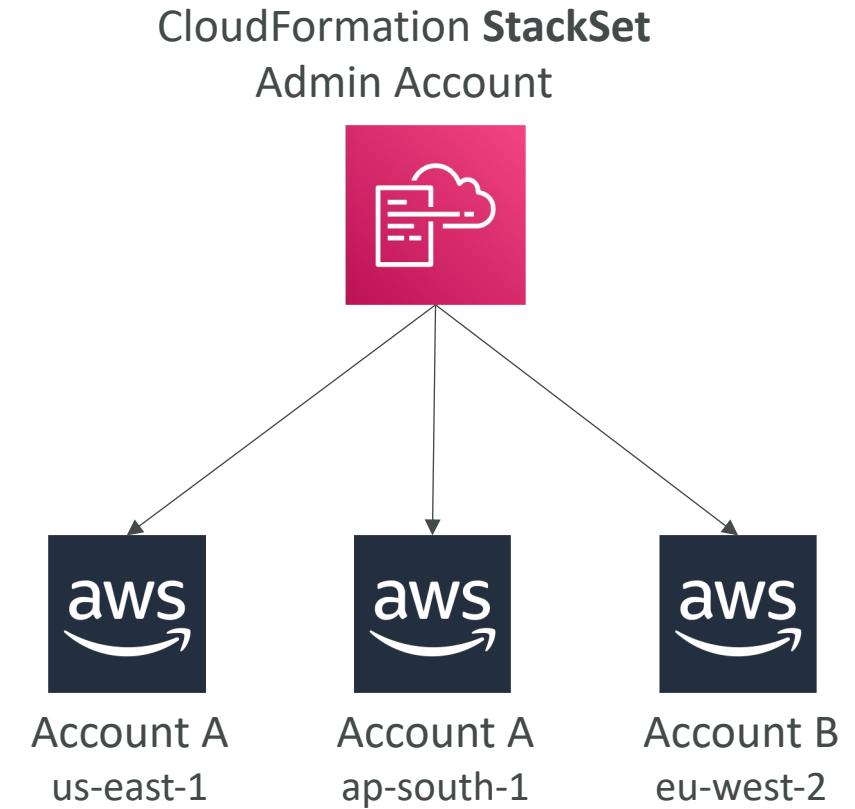
CloudFormation Custom Resources (Lambda)

- You can define a Custom Resource in CloudFormation to address any of these use cases:
- An AWS resource is **not yet supported** (new service for example)
- An **on-premises** resource
- Emptying an S3 bucket before being deleted
- Fetch an AMI id
- Anything you want...!



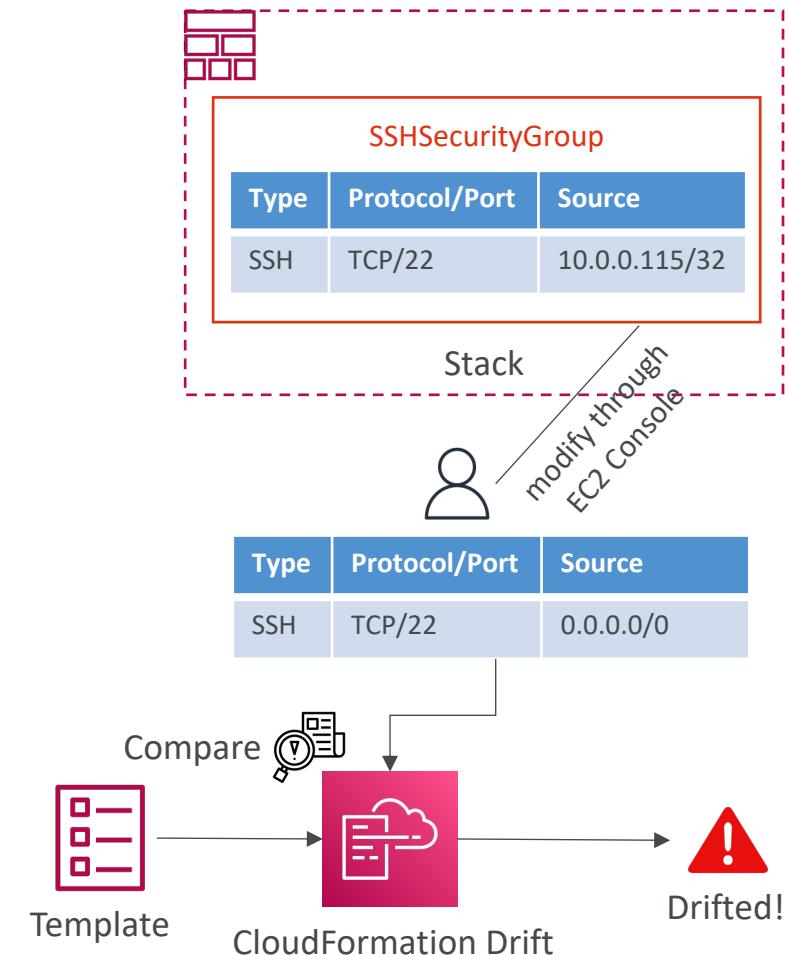
CloudFormation – StackSets

- Create, update, or delete stacks across **multiple accounts and regions** with a single operation
- Administrator account to create StackSets
- Trusted accounts to create, update, delete stack instances from StackSets
- When you update a stack set, *all* associated stack instances are updated throughout all accounts and regions
- Enable **Automatic Deployment** feature to automatically deploy to accounts in AWS Organization or OUs



CloudFormation Drift Overview

- CloudFormation allows you to create infrastructure
 - But it doesn't protect you against manual configuration changes
 - How do we know if our resources have drifted?
-
- We can use CloudFormation Drift!
 - Detect drift on an entire stack or on individual resources within a stack



CloudFormation – Integration with Secrets Manager

```
Resources:  
  # Secret resource with a randomly generated password in its SecureString JSON  
  MyRDSDBInstanceRotationSecret:  
    Type: AWS::SecretsManager::Secret  
    Properties:  
      GenerateSecretString:  
        SecretStringTemplate: '{"username": "admin"}'  
        GenerateStringKey: password  
        PasswordLength: 16  
        ExcludeCharacters: "\"@/\\\""  
  
  # RDS Instance resource. Its master username and password use dynamic references  
  # to resolve values from Secrets Manager  
  MyRDSDBInstance:  
    Type: AWS::RDS::DBInstance  
    Properties:  
      DBInstanceClass: db.t2.micro  
      Engine: mysql  
      MasterUsername: !Sub "{{resolve:secretsmanager:${MyRDSDBInstanceRotationSecret}:username}}"  
      MasterUserPassword: !Sub "{{resolve:secretsmanager:${MyRDSDBInstanceRotationSecret}:password}}"  
  
  # SecretTargetAttachment resource which updates the referenced Secret with properties  
  # about the referenced RDS instance  
  SecretRDSDBInstanceAttachment:  
    Type: AWS::SecretsManager::SecretTargetAttachment  
    Properties:  
      TargetType: AWS::RDS::DBInstance  
      SecretId: !Ref MyRDSDBInstanceRotationSecret  
      TargetId: !Ref MyRDSDBInstance
```

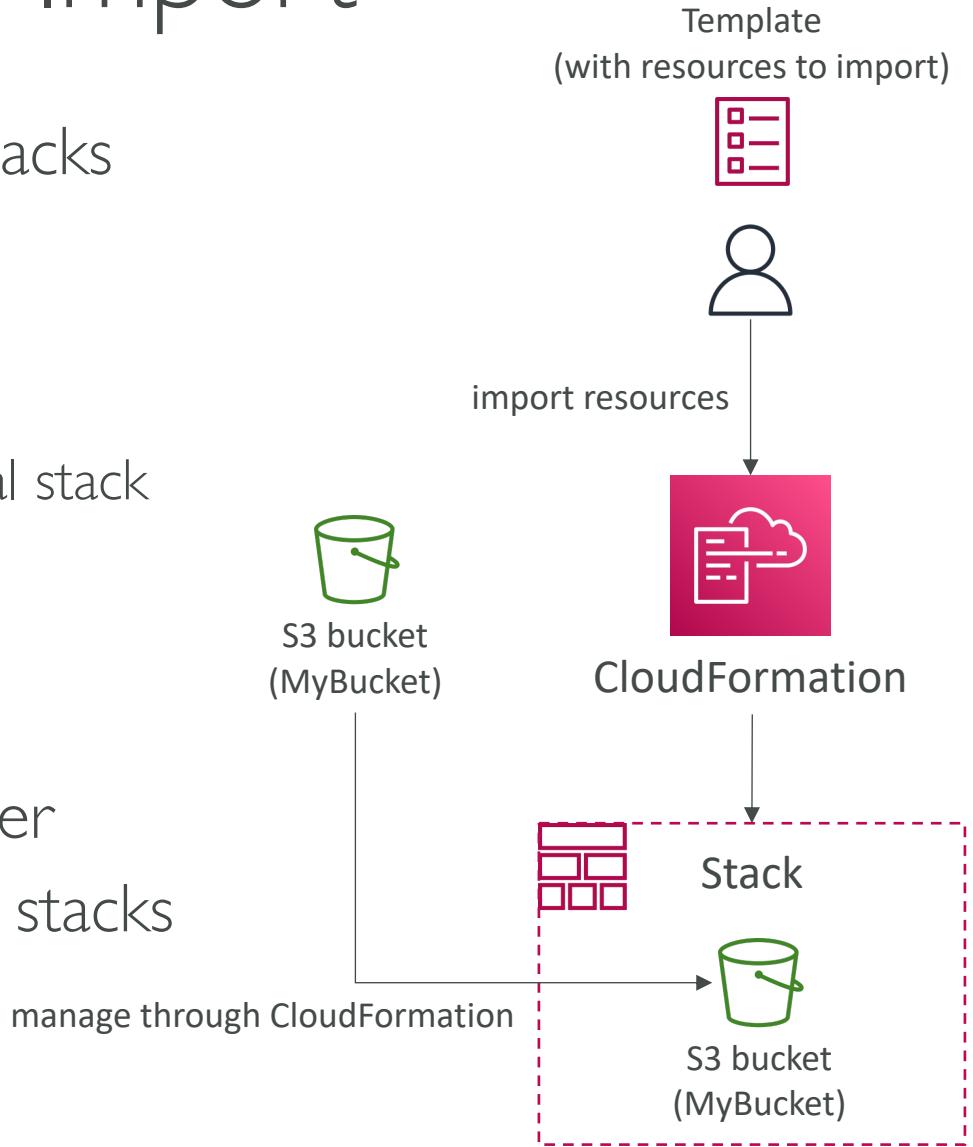
secret is generated

reference secret in RDS DB instance

link the secret to RDS DB instance

CloudFormation - Resource Import

- Import existing resources into existing/new stacks
- You don't need to delete and re-create the resources as part of a CloudFormation stack
- During import operation, you'll need
 - A template that describes the entire stack (original stack resources & target resources to import)
 - A Unique identifier for each target resource (ex. BucketName for S3 buckets)
- Each resource to import must have a **DeletionPolicy** attribute (any value) & Identifier
- Can't import the same resource into multiple stacks



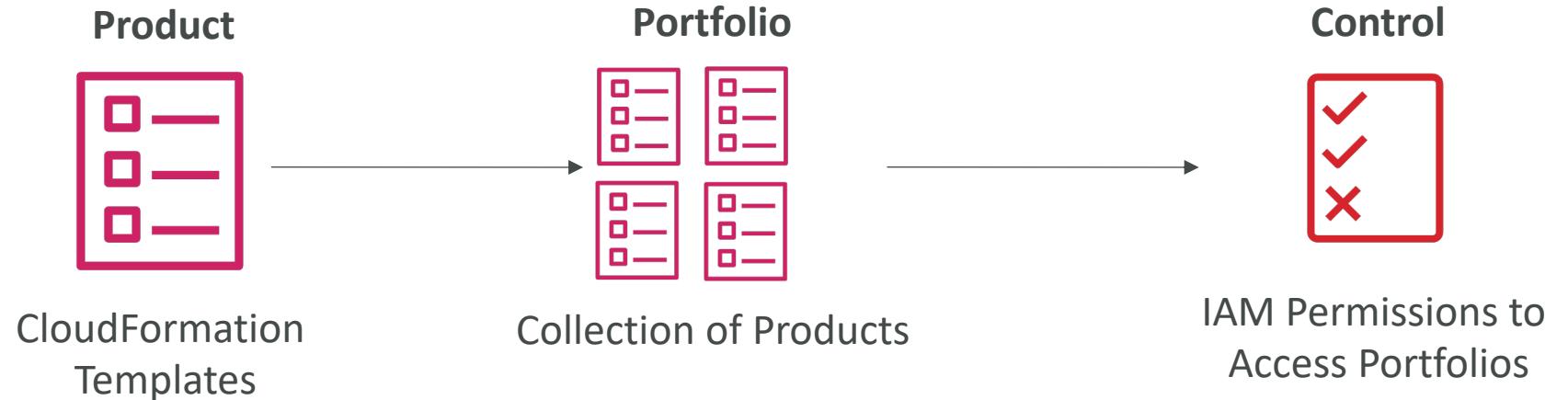
AWS Service Catalog



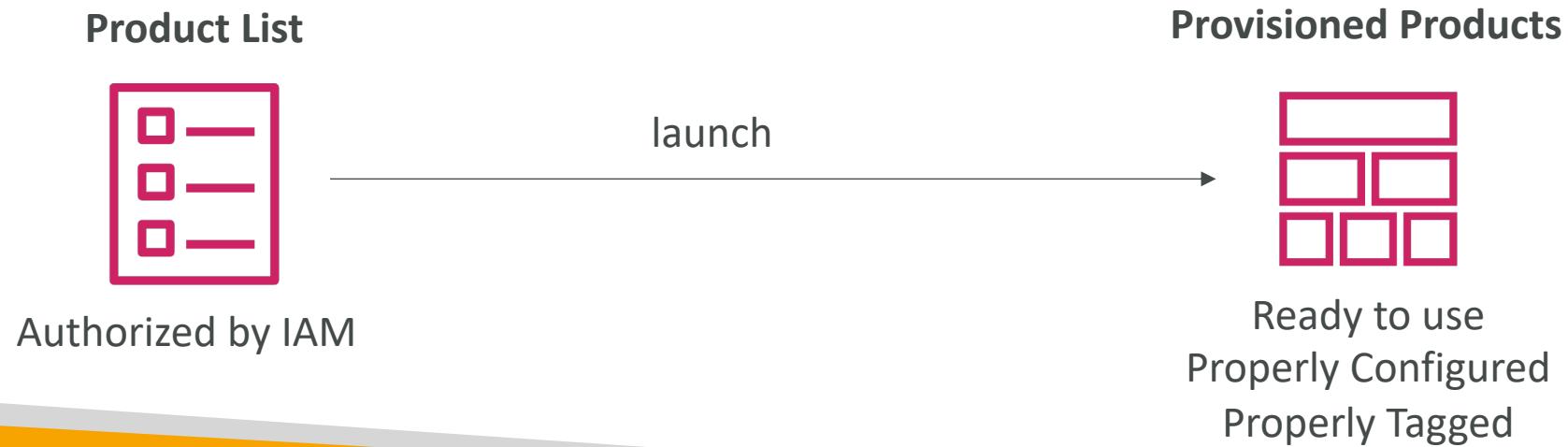
- Users that are new to AWS have too many options, and may create stacks that are not compliant / in line with the rest of the organization
- Some users just want a quick **self-service portal** to launch a set of authorized products pre-defined by admins
- Includes: virtual machines, databases, storage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

Service Catalog diagram

ADMIN TASKS



USER TASKS



AWS Service Catalog



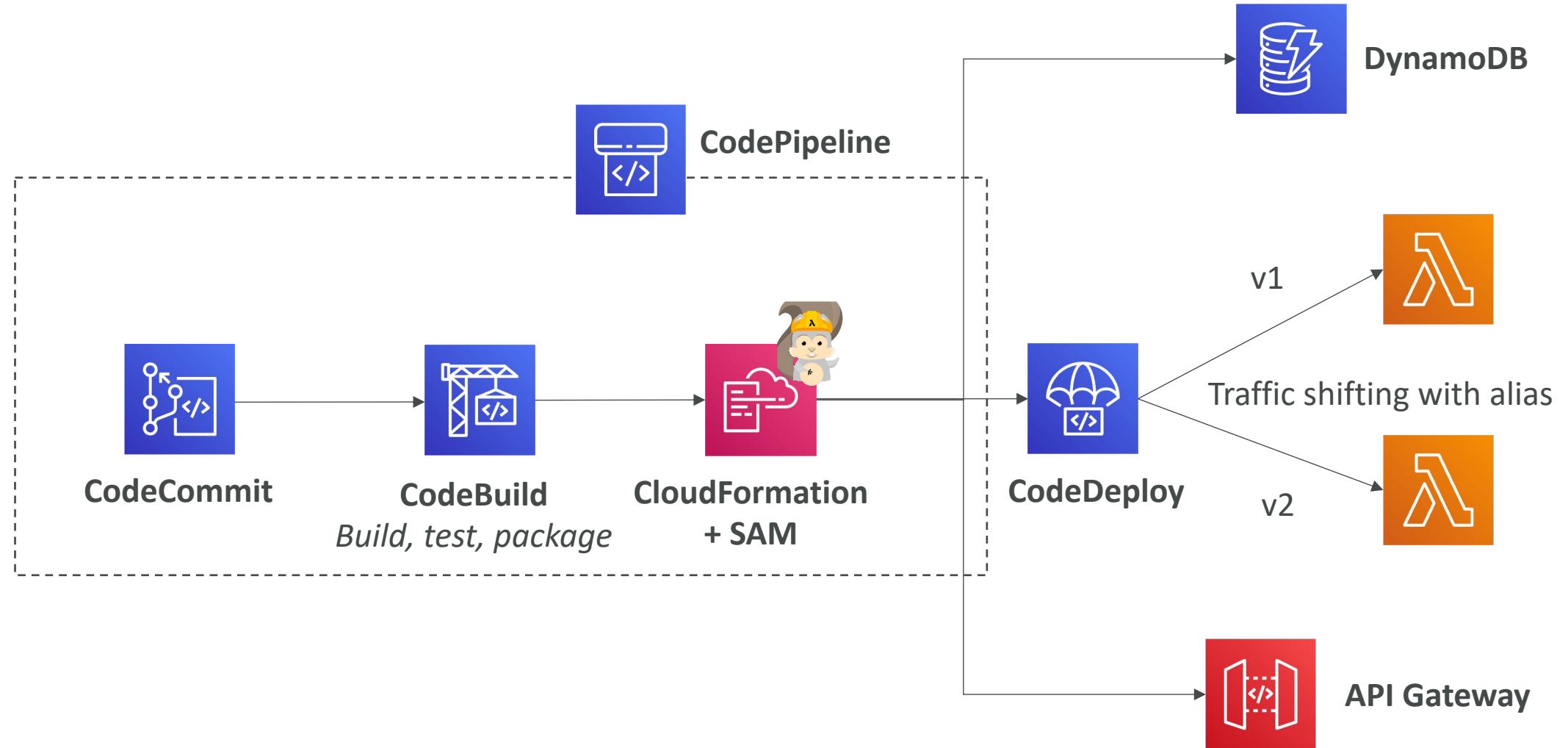
- Create and manage catalogs of IT services that are approved on AWS
- The “products” are CloudFormation templates
- Ex: Virtual machine images, Servers, Software, Databases, Regions, IP address ranges
- **CloudFormation helps ensure consistency, and standardization by Admins**
- They are assigned to Portfolios (teams)
- Teams are presented a self-service portal where they can launch the products
- All the deployed products are centrally managed deployed services
- **Helps with governance, compliance, and consistency**
- Can give user access to launching products without requiring deep AWS knowledge
- Integrations with “self-service portals” such as ServiceNow

AWS SAM - Serverless Application Model



- SAM = Serverless Application Model
- Framework for developing and deploying serverless applications
- All the configuration is YAML code. Examples:
 - Lambda Functions (AWS::Serverless::Function)
 - DynamoDB tables (AWS::Serverless::SimpleTable)
 - API Gateway (AWS::Serverless::API)
 - StepFunction - State Machine (AWS::Serverless::StateMachine)
- SAM can help you to run Lambda, API Gateway, DynamoDB locally
- SAM can use CodeDeploy to deploy Lambda functions (traffic shifting)
- Leverages CloudFormation in the backend

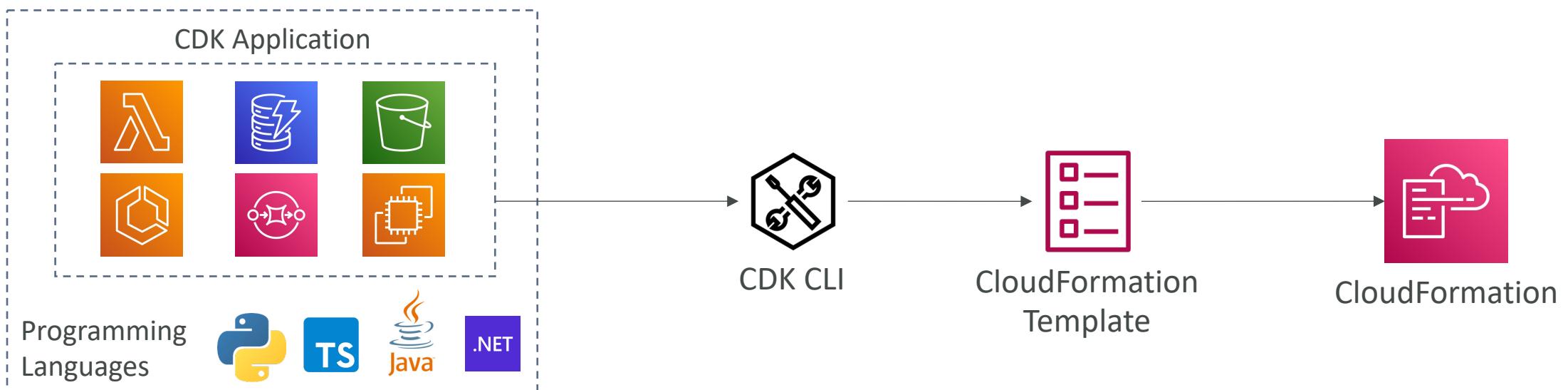
CICD Architecture for SAM





AWS Cloud Development Kit (CDK)

- Define your cloud infrastructure using a familiar language:
 - JavaScript/TypeScript, Python, Java, and .NET
- The code is “compiled” into a CloudFormation template (JSON/YAML)
- You can therefore deploy infrastructure and application runtime code together
 - Great for Lambda functions
 - Great for Docker containers in ECS / EKS



CDK Example

```
export class MyEcsConstructStack extends core.Stack {
  constructor(scope: core.App, id: string, props?: core.StackProps) {
    super(scope, id, props);

    const vpc = new ec2.Vpc(this, "MyVpc", {
      maxAzs: 1 // Default is all AZs in region
    });

    const cluster = new ecs.Cluster(this, "MyCluster", {
      vpc
    });

    // Create a load-balanced Fargate service and make it public
    new ecs_patterns.ApplicationLoadBalancedFargateService(this, "My
      cluster: cluster, // Required
      cpu: 512, // Default is 256
      desiredCount: 6, // Default is 1
      taskImageOptions: { image: ecs.ContainerImage.fromRegistry("an
      memoryLimitMiB: 2048, // Default is 512
      publicLoadBalancer: true // Default is false
    });
  }
}
```

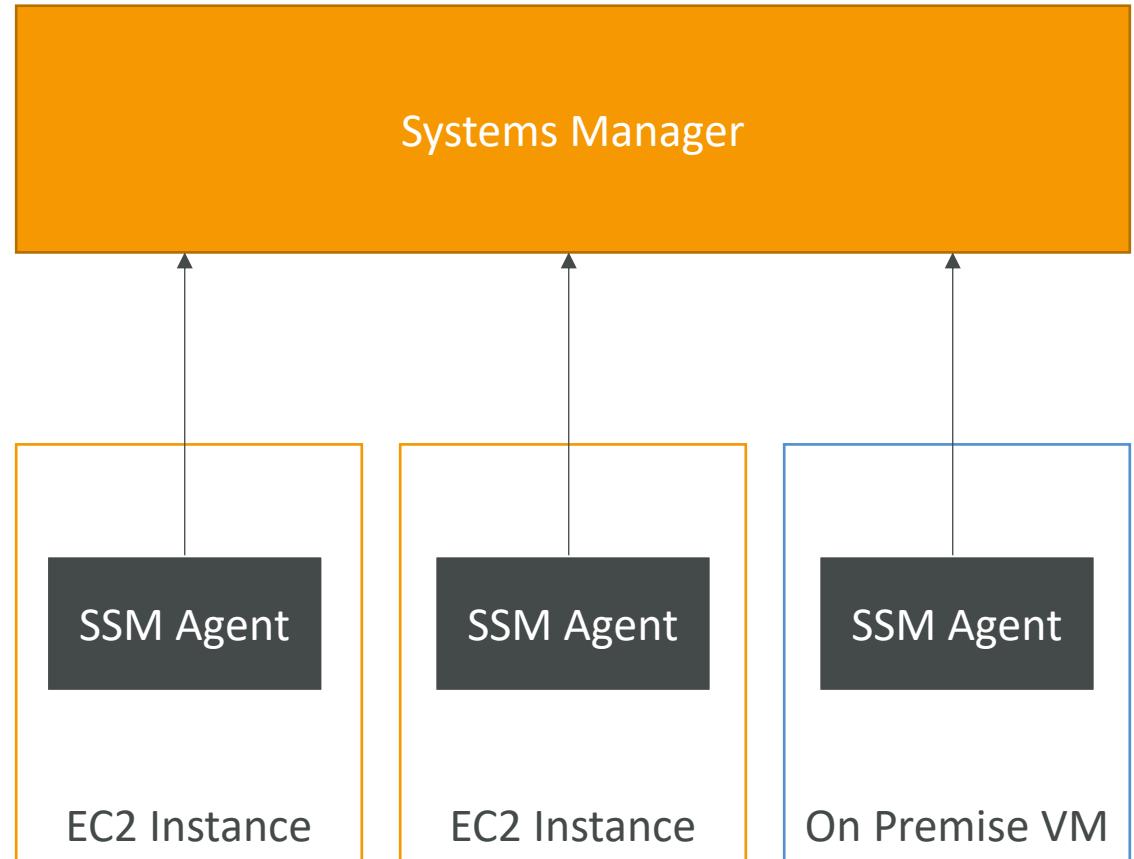
AWS Systems Manager Overview



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

How Systems Manager works

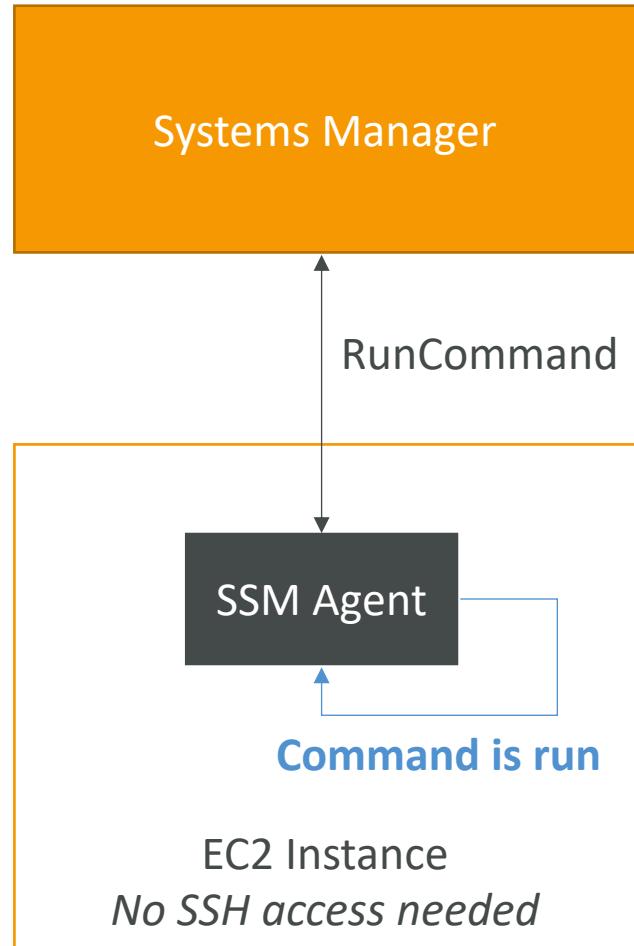
- We need to install the SSM agent onto the systems we control
- Installed by default on Amazon Linux AMI & some Ubuntu AMI
- If an instance can't be controlled with Systems Manager, it's probably an issue with the SSM agent!
- Make sure the EC2 instances have a proper IAM role to allow Systems Manager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



AWS Systems Manager

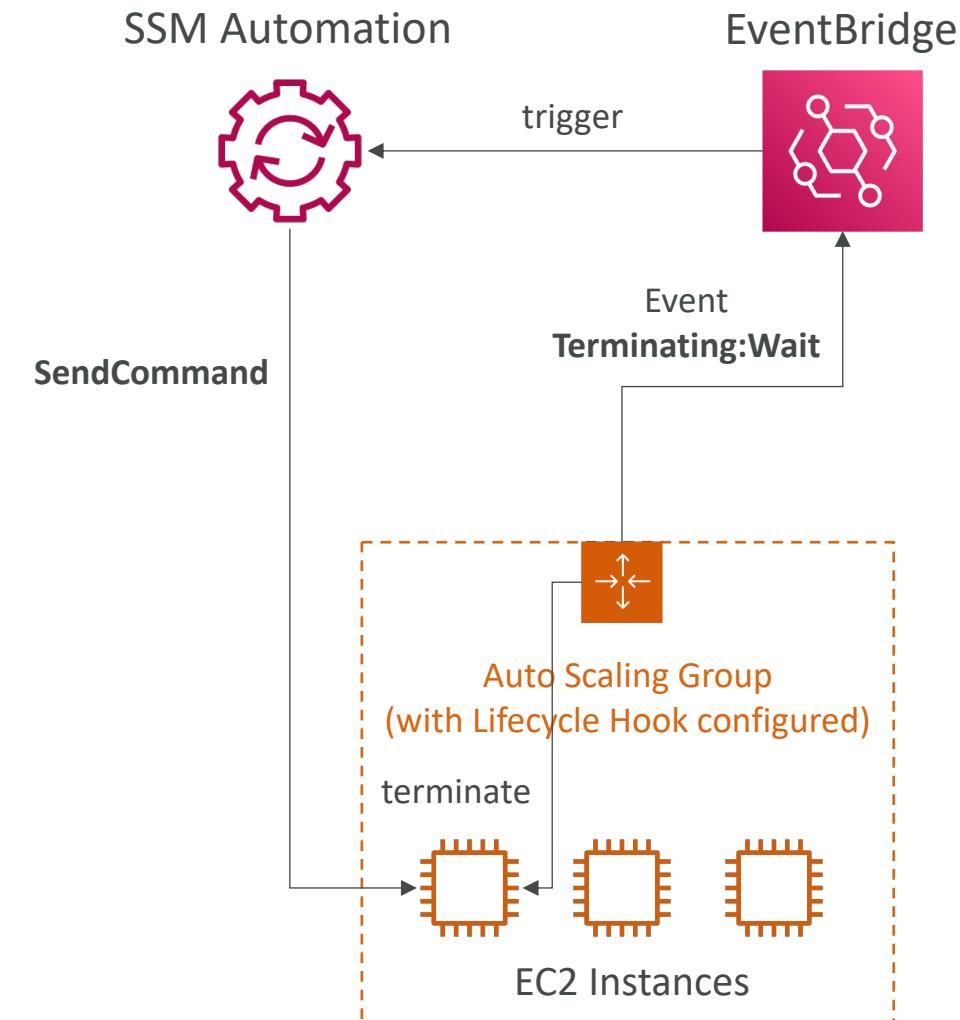
Run Command

- Execute a document (= script) or just run a command
- Run command across multiple instances (using resource groups)
- Rate Control / Error Control
- Integrated with IAM & CloudTrail
- No need for SSH
- Results in the console



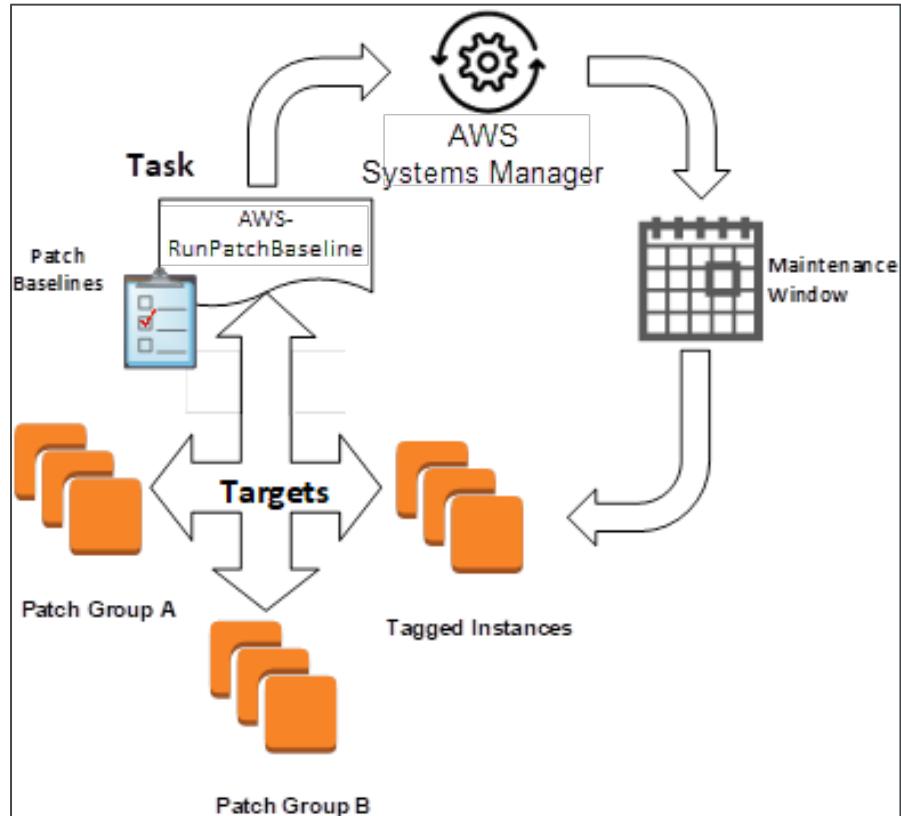
AWS Systems Manager – Send Command before an ASG Instance is Terminated

- Perform any action before the ASG terminates an EC2 instance
- Create a ASG Lifecycle Hook that puts the instance in **Terminating:Wait** state
- Monitor the **Terminating:Wait** state using EventBridge
- Trigger a SSM Automation Document to perform the actions on the instance before termination



Systems Manager Patch Managers – Steps

1. Define a **patch baseline** to use (or multiple if you have multiple environments)
2. Define patch groups: define based on tags, example different environments (dev, test, prod) – use tag **Patch Group**
3. Define **Maintenance Windows** (schedule, duration, registered targets/patch groups and registered tasks)
4. Add the **AWS-RunPatchBaseline Run Command** as part of the registered tasks of the Maintenance Window (works cross platform Linux & Windows)
5. Define **Rate Control** (concurrency & error threshold) for the task
6. Monitor Patch Compliance using SSM Inventory

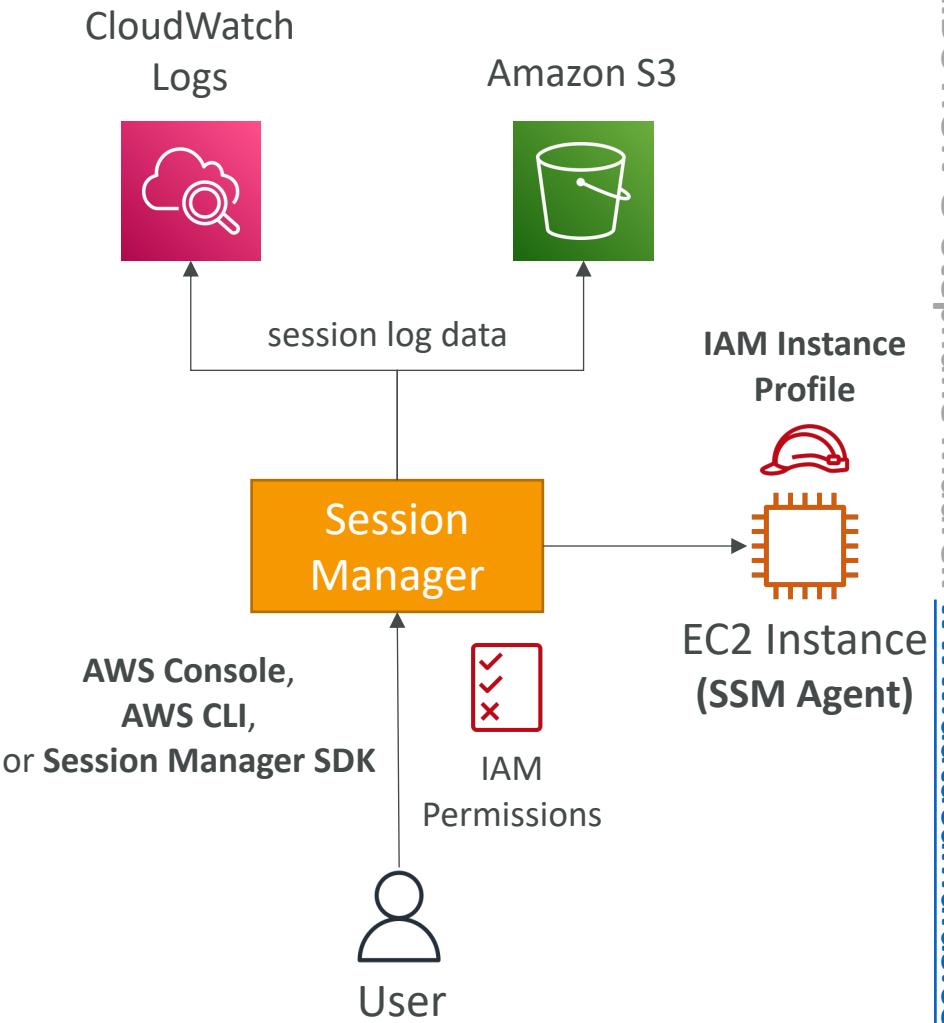


<https://aws.amazon.com/blogs/mt/patching-your-windows-ec2-instances-using-aws-systems-manager-patch-manager/>

Systems Manager Session Manager



- Allows you to start a secure shell on your EC2 and on-premises servers
- Access through AWS Console, AWS CLI, or Session Manager SDK
- Does not need SSH access, bastion hosts, or SSH keys
- Supports Linux, macOS, and Windows
- Log connections to your instances and executed commands
- Session log data can be sent to S3 or CloudWatch Logs
- CloudTrail can intercept **StartSession** events





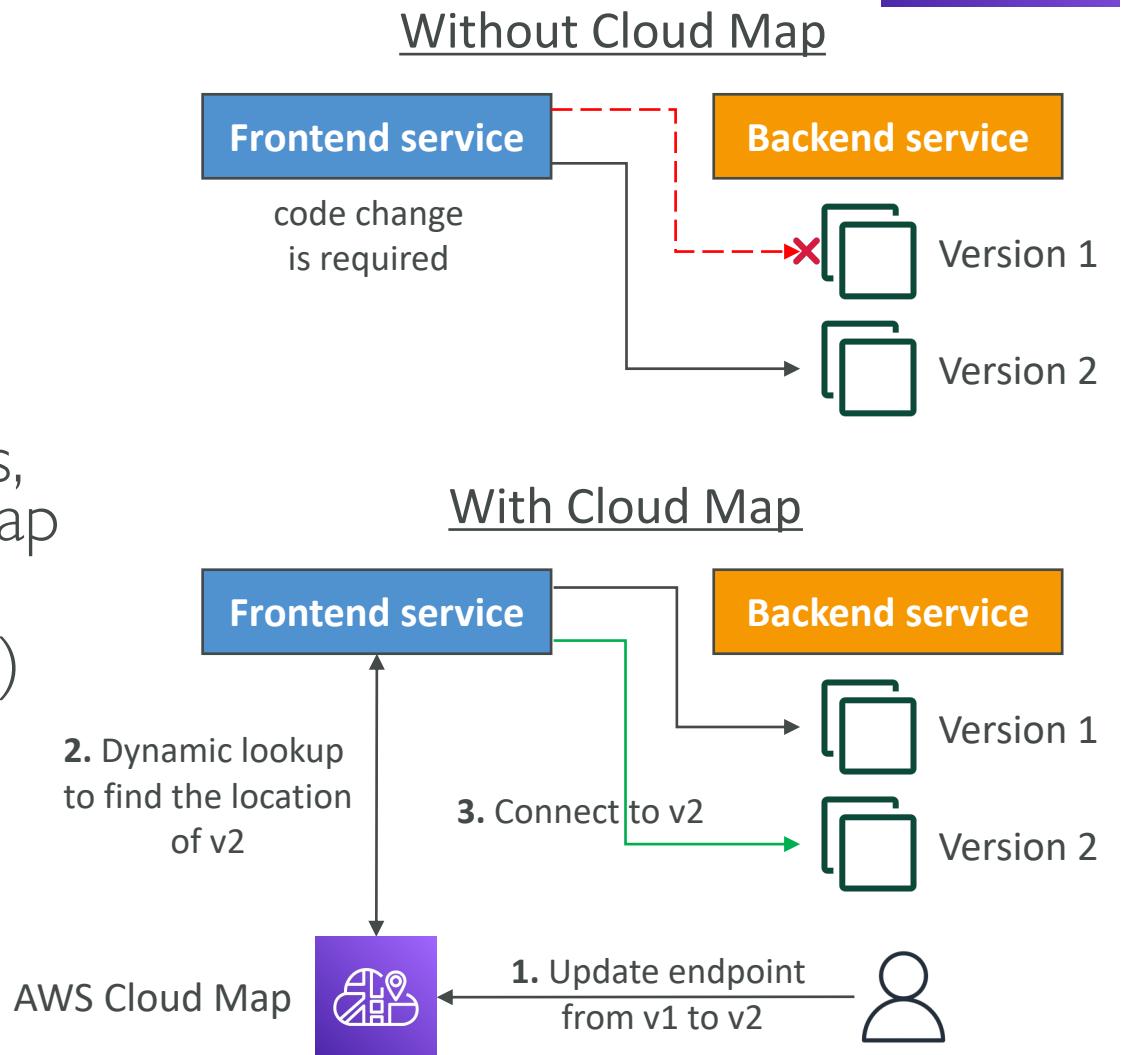
Systems Manager OpsCenter

- Resolve Operational Issues (OpsItems) related to AWS resources
- **OpsItems** – issues, events and alerts
- Aggregates information to resolve issues on each OpsItems such as:
 - AWS Config changes and relationships
 - CloudTrail Logs
 - CloudWatch Alarms
 - CloudFormation Stack information
- Provides Automation Runbooks that you can use to resolve issues
- EventBridge or CloudWatch Alarms can create OpsItems

AWS Cloud Map



- A fully managed resource discovery service
- Creates a map of the backend services/resources that your applications depend on
- You register your application components, their locations, attributes, and health status with AWS Cloud Map
- Integrated health checking (stop sending traffic to unhealthy endpoints)
- Your applications can query AWS Cloud Map using AWS SDK, API, or DNS



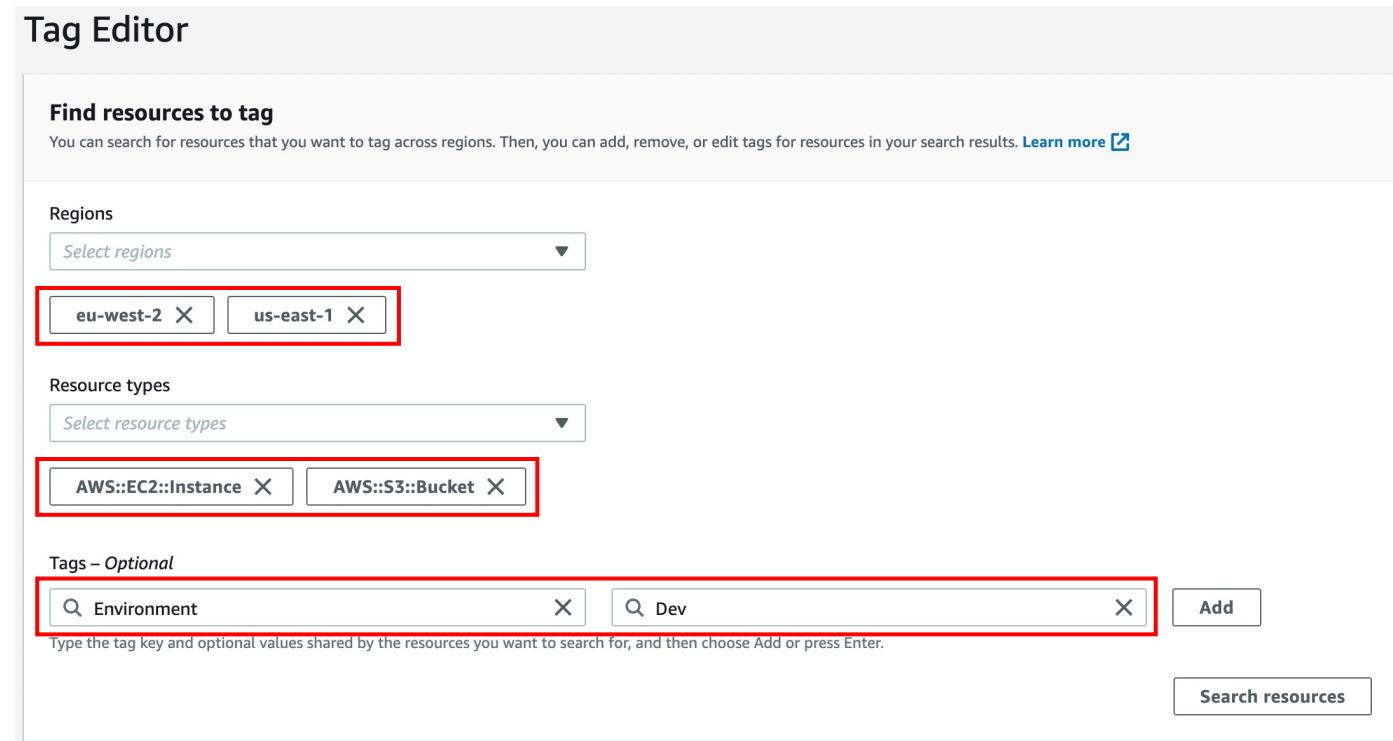
Cost Control

AWS Cost Allocation Tags

- With Tags we can track resources that relate to each other
- With Cost Allocation Tags we can enable detailed costing reports
- Just like Tags, but they show up as columns in Reports
- AWS Generated Cost Allocation Tags
 - Automatically applied to the resource you create
 - Starts with Prefix **aws:** (e.g. `aws: createdBy`)
 - They're not applied to resources created before the activation
- User tags
 - Defined by the user
 - Starts with Prefix **user:**
- Cost Allocation Tags just appear in the Billing Console
- Takes up to 24 hours for the tags to show up in the report

AWS Tag Editor

- Allows you to manage tags of multiple resources at once
- You can add/update/delete tags
- Search tagged/untagged resources in all AWS Regions





Trusted Advisor

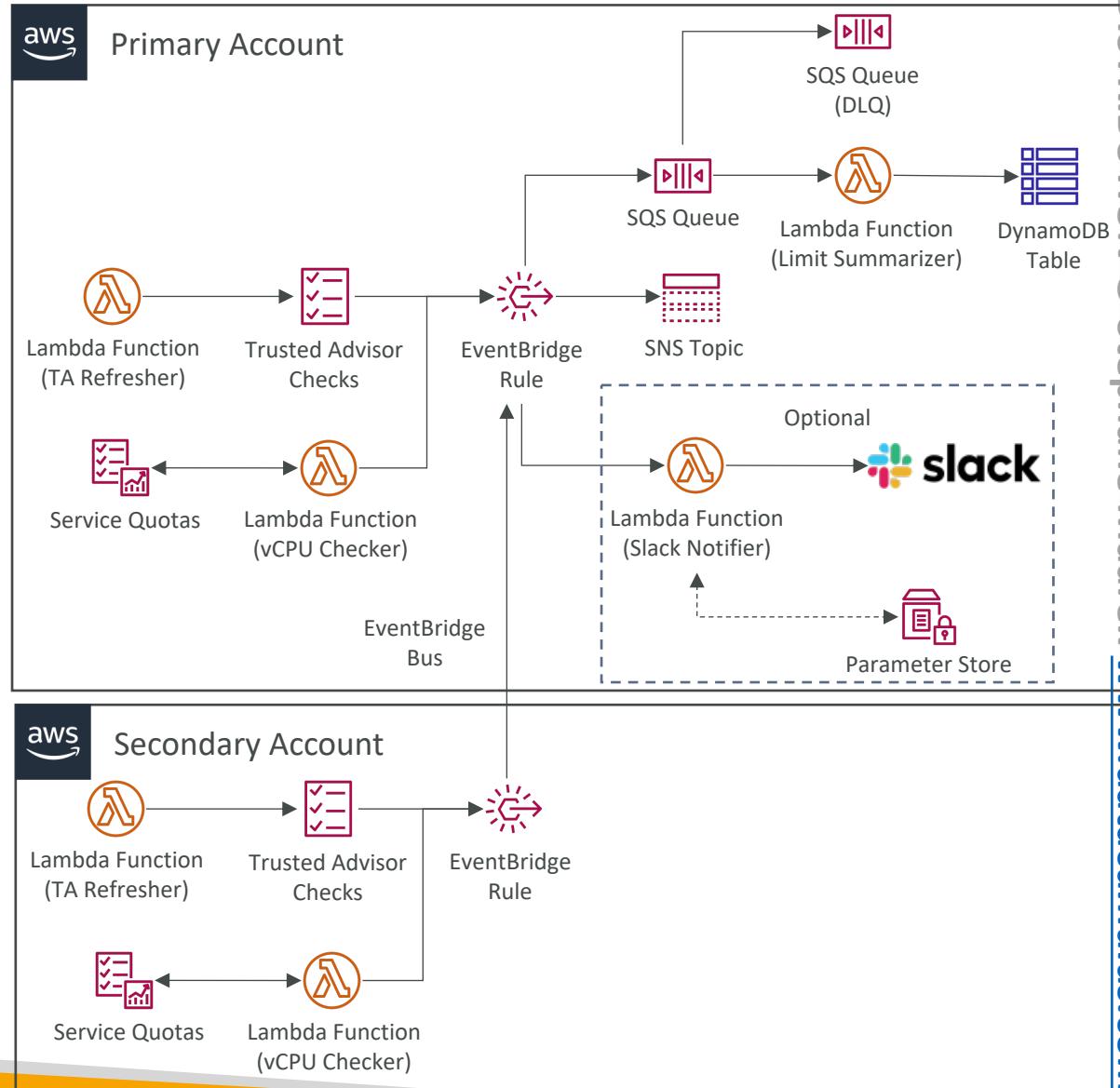
- No need to install anything – high level AWS account assessment
- Analyze your AWS accounts and provides recommendation:
 - Cost Optimization & Recommendations
 - Performance
 - Security
 - Fault Tolerance
 - Service Limits
- Core Checks and recommendations – all customers
- **Can enable weekly email notification from the console**
- Full Trusted Advisor – Available for Business & Enterprise support plans
 - Ability to set CloudWatch alarms when reaching limits
 - Programmatic Access using AWS Support API

AWS Support Plans

	<u>Basic Support</u>	<u>Developer</u>	<u>Business</u>	<u>Enterprise</u>
	<i>included for all AWS customers and free</i>	<i>Recommended if you are experimenting or testing in AWS.</i>	<i>Recommended if you have production workloads in AWS.</i>	<i>Recommended if you have business and/or mission critical workloads in AWS.</i>
AWS Trusted Advisor Best Practice Checks	7 Core checks	7 Core checks	Full set of checks + Programmatic Access using AWS Support API	Full set of checks + Programmatic Access using AWS Support API
Enhanced Technical Support	24x7 access to customer service, documentation, whitepapers, and support forums.	Business hours email access to Cloud Support Associates Unlimited cases / 1 primary contact	24x7 phone, email, and chat access to Cloud Support Engineers Unlimited cases / unlimited contacts (IAM supported)	24x7 phone, email, and chat access to Cloud Support Engineers Unlimited cases / unlimited contacts (IAM supported)
Case Severity / Response Times		General guidance: < 24 business hours** System impaired: < 12 business hours**	General guidance: < 24 hours System impaired: < 12 hours Production system impaired: < 4 hours Production system down: < 1 hour	General guidance: < 24 hours System impaired: < 12 hours Production system impaired: < 4 hours Production system down: < 1 hour Business-critical system down: < 15 minutes

Trusted Advisor – Good to know

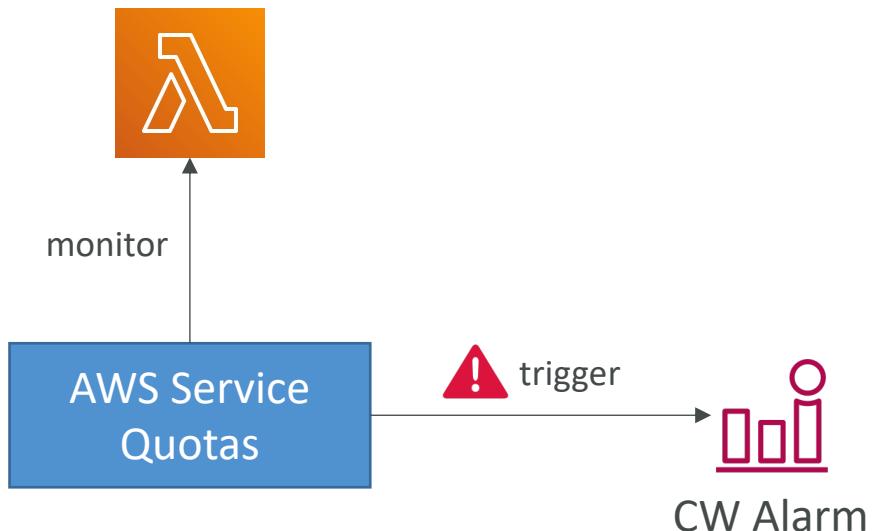
- Can check if an S3 bucket is made public
 - But cannot check for S3 objects that are public inside of your bucket!
 - Use Amazon EventBridge / S3 Events instead / AWS Config Rules
- Service Limits
 - **Limits can only be monitored in Trusted Advisor (cannot be changed)**
 - Cases must be created manually in **AWS Support Centre** to increase limits
 - OR use the **AWS Service Quotas** service



AWS Service Quotas

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

AWS Lambda Quota



Create a CloudWatch alarm: Concurrent executions

Description
The maximum number of events that functions can process simultaneously in the current Region.

Alarm threshold
This alarm will notify you based on the threshold you choose.

Alarm name

Required. Alarm names must be unique within an AWS account.

Region
US East (N. Virginia) us-east-1

Pricing
Using CloudWatch can incur costs. [CloudWatch pricing](#)

[Cancel](#) [Create](#)

EC2 Instance Launch Types

- **On Demand Instances:** short workload, predictable pricing, reliable
- **Spot Instances:** short workloads, for cheap, can lose instances (not reliable)
- **Reserved:** (MINIMUM 1 year)
 - Reserved Instances: long workloads
 - Convertible Reserved Instances: long workloads with flexible instances
- **Dedicated Instances:** no other customers will share your hardware
- **Dedicated Hosts:** book an entire physical server; control instance placement
 - Great for software licenses that operate at the core, or socket level
 - Can define **host affinity** so that instance reboots are kept on the same host

AWS Savings Plan



- New pricing model to get a discount based on long-term usage
- Commit to a certain type of usage: ex \$10 per hour for 1 to 3 years
- Any usage beyond the savings plan is billed at the on-demand price
- **EC2 Instance Savings plan** (up to 72% - same discount as Standard RIs)
 - Select instance family (e.g. M5, C5...), and locked to a specific region
 - Flexible across size (m5.large to m5.4xlarge), OS (Windows to Linux), tenancy (dedicated or default)
- **Compute Savings plan** (up to 66% - same discount as Convertible RIs)
 - Ability to move between instance family (move from C5 to M5), region (Ireland to US), compute type (EC2, Fargate, Lambda), OS & tenancy
- **SageMaker Savings plan** (up to 64% off)

S3 Storage Classes

- Amazon S3 Standard - General Purpose
- Amazon S3 Standard-Infrequent Access (IA)
- Amazon S3 One Zone-Infrequent Access
- Amazon S3 Glacier Instant Retrieval
- Amazon S3 Glacier Flexible Retrieval
- Amazon S3 Glacier Deep Archive
- Amazon S3 Intelligent Tiering
- Can move between classes manually or using S3 Lifecycle configurations

S3 – Other Cost Savings

- S3 Select & Glacier Select: save in network and CPU cost
- S3 Lifecycle Rules: transition objects between tiers
- Compress objects to save space
- S3 Requester Pays:
 - In general, bucket owners pay for all Amazon S3 storage and data transfer costs associated with their bucket
 - With Requester Pays buckets, the requester instead of the bucket owner pays the cost of the request and the data download from the bucket
 - The bucket owner always pays the cost of storing data
 - Helpful when you want to share large datasets with other accounts
 - If an IAM role is assumed, the owner account of that role pays for the request

S3 Storage Classes

- Amazon S3 Standard - General Purpose
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- Amazon S3 Glacier Instant Retrieval
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- Amazon S3 Glacier Deep Archive
- Amazon S3 Intelligent Tiering
- Can move between classes manually or using S3 Lifecycle configurations

S3 Durability and Availability

- Durability:
 - High durability (99.99999999%, 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



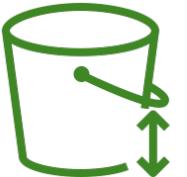
S3 Standard – General Purpose

- 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...

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 (99.99999999%) 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



Amazon S3 Glacier Storage Classes

- Low-cost object storage meant for archiving / backup
- Pricing: price for storage + object retrieval cost
- **Amazon S3 Glacier Instant Retrieval**
 - Millisecond retrieval, great for data accessed once a quarter
 - Minimum storage duration of 90 days
- **Amazon S3 Glacier Flexible Retrieval** (formerly Amazon S3 Glacier):
 - Expedited (1 to 5 minutes), Standard (3 to 5 hours), Bulk (5 to 12 hours) – free
 - Minimum storage duration of 90 days
- **Amazon S3 Glacier Deep Archive** – for long term storage:
 - Standard (12 hours), Bulk (48 hours)
 - Minimum storage duration of 180 days





S3 Intelligent-Tiering

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

S3 Storage Classes Comparison

	Standard	Intelligent-Tiering	Standard-IA	One Zone-IA	Glacier Instant Retrieval	Glacier Flexible Retrieval	Glacier Deep Archive
Durability	99.999999999% == (11 9's)						
Availability	99.99%	99.9%	99.9%	99.5%	99.9%	99.99%	99.99%
Availability SLA	99.9%	99%	99%	99%	99%	99.9%	99.9%
Availability Zones	>= 3	>= 3	>= 3	1	>= 3	>= 3	>= 3
Min. Storage Duration Charge	None	None	30 Days	30 Days	90 Days	90 Days	180 Days
Min. Billable Object Size	None	None	128 KB	128 KB	128 KB	40 KB	40 KB
Retrieval Fee	None	None	Per GB retrieved	Per GB retrieved	Per GB retrieved	Per GB retrieved	Per GB retrieved

<https://aws.amazon.com/s3/storage-classes/>

S3 Storage Classes – Price Comparison

Example: us-east-1

	Standard	Intelligent-Tiering	Standard-IA	One Zone-IA	Glacier Instant Retrieval	Glacier Flexible Retrieval	Glacier Deep Archive
Storage Cost (per GB per month)	\$0.023	\$0.0025 - \$0.023	\$0.0125	\$0.01	\$0.004	\$0.0036	\$0.00099
Retrieval Cost (per 1000 request)	GET: \$0.0004 POST: \$0.005	GET: \$0.0004 POST: \$0.005	GET: \$0.001 POST: \$0.01	GET: \$0.001 POST: \$0.01	GET: \$0.01 POST: \$0.02	GET: \$0.0004 POST: \$0.03 Expedited: \$10 Standard: \$0.05 Bulk: free	GET: \$0.0004 POST: \$0.05 Standard: \$0.10 Bulk: \$0.025
Retrieval Time	Instantaneous						Expedited (1 – 5 mins) Standard (3 – 5 hours) Bulk (5 – 12 hours)
Monitoring Cost (pet 1000 objects)		\$0.0025					

<https://aws.amazon.com/s3/pricing/>

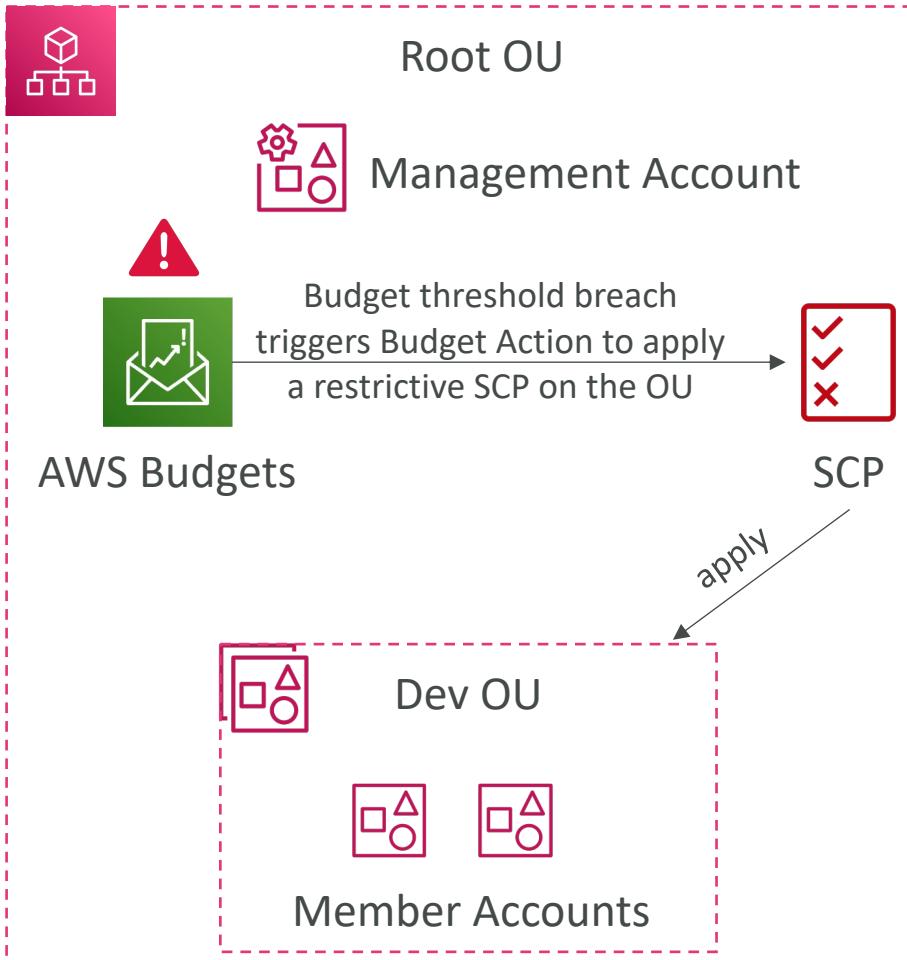
AWS Budgets



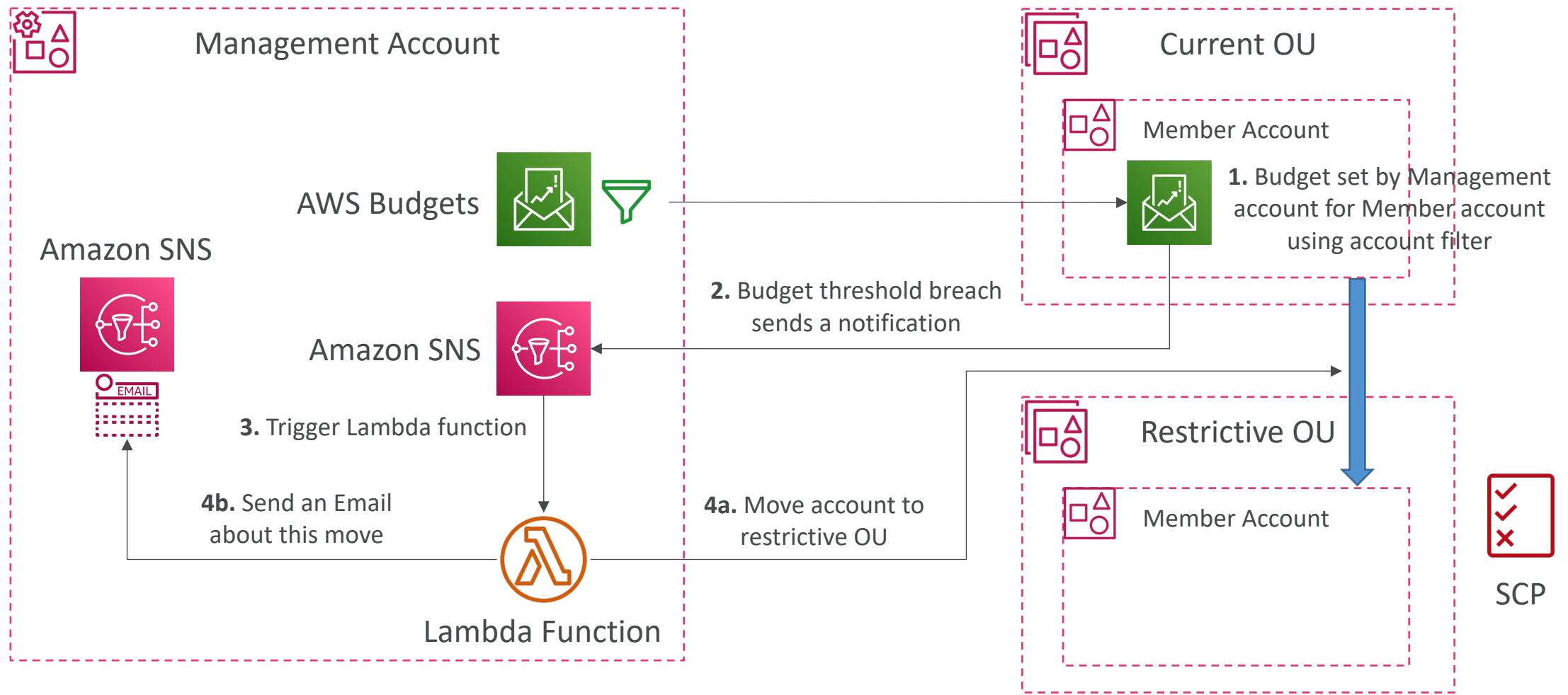
- Create budget and send alarms when costs exceeds the budget
- 4 types of budgets: Usage, Cost, Reservation, Savings Plans
- For Reserved Instances (RI)
 - Track utilization
 - Supports EC2, ElastiCache, RDS, Redshift
- Up to 5 SNS notifications per budget
- Can filter by: Service, Linked Account, Tag,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

Budget Actions

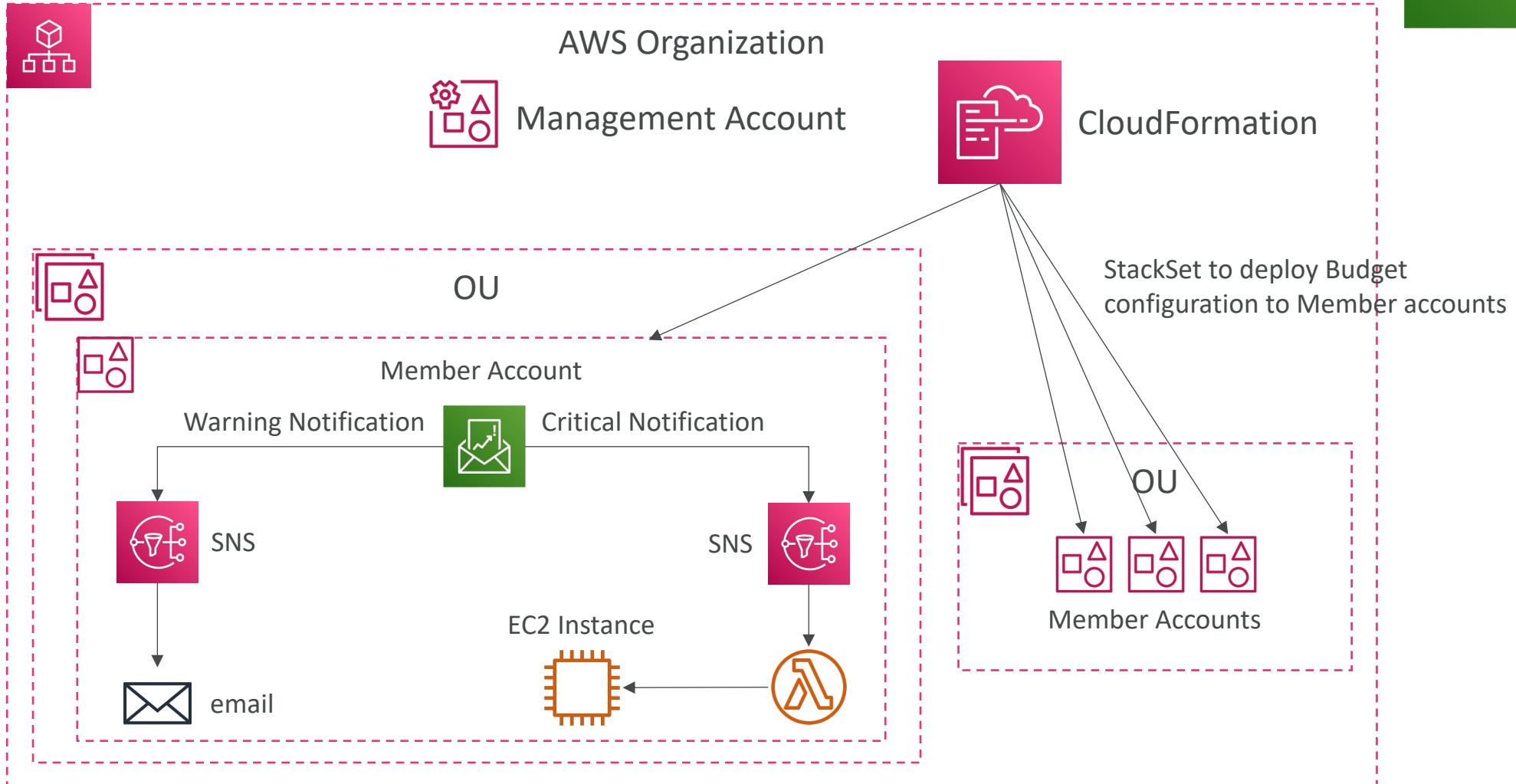
- Run actions on your behalf when a budget exceeds a certain cost or usage threshold
- Supports 3 action types:
 - Applying an IAM Policy to a user, group, or IAM role
 - Applying Service Control Policy (SCP) to an OU
 - Stop EC2 or RDS Instances
- Actions can be executed automatically or require a workflow approval process
- Reduces unintentional overspending in your account



Centralized Budget Management



Decentralized Budget Management

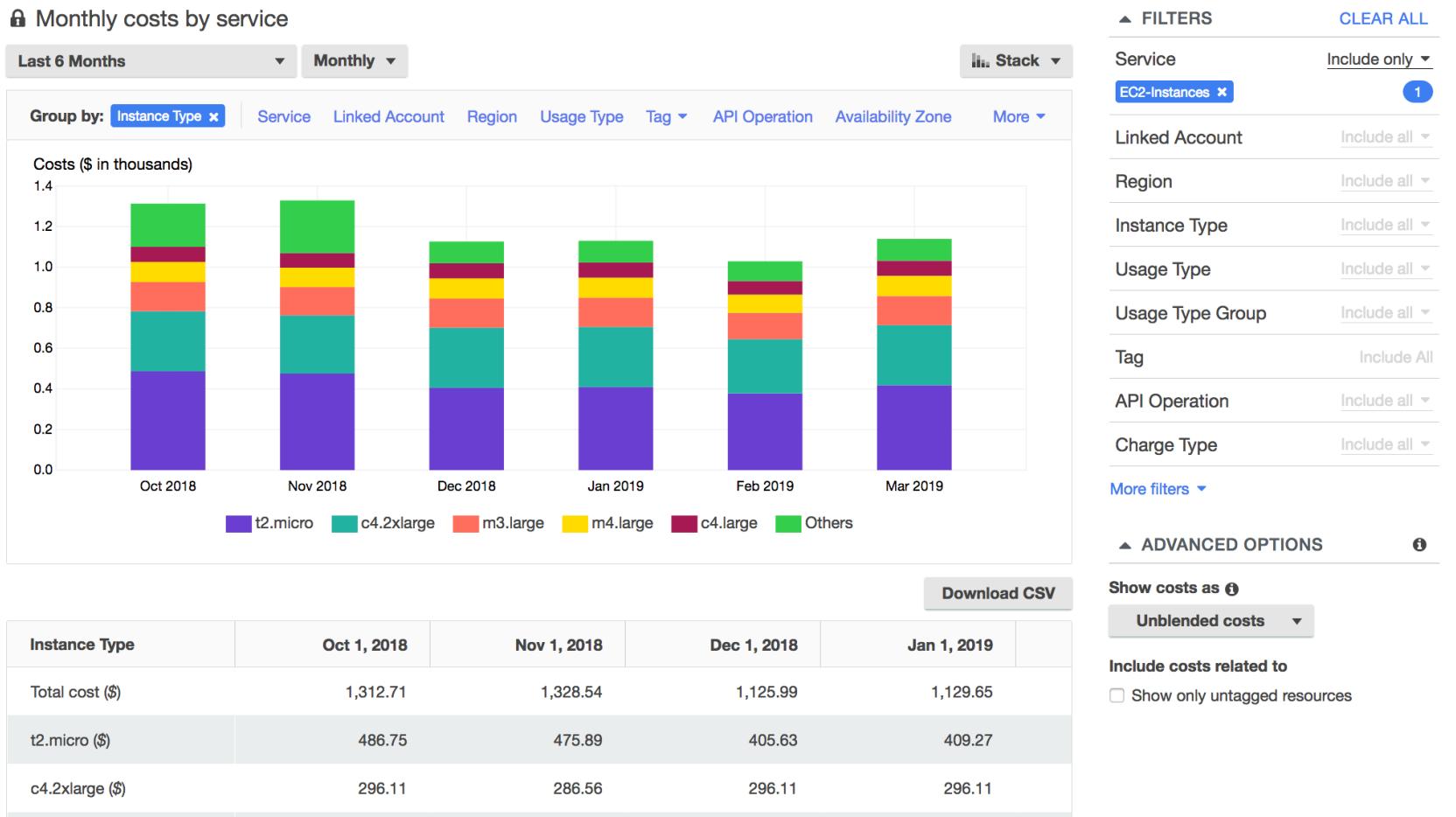


Cost Explorer



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

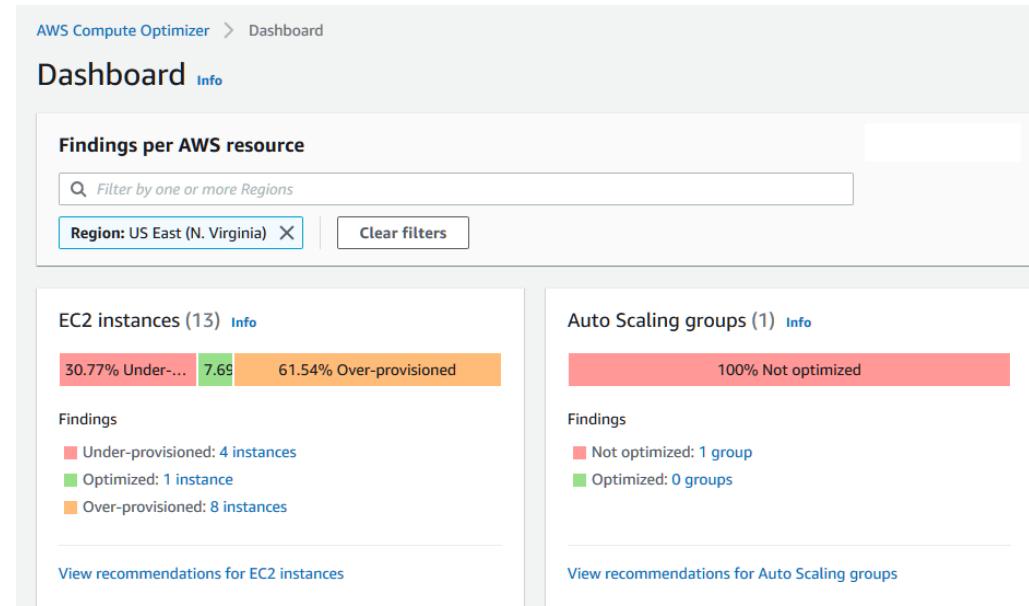
Cost Explorer – Example



AWS Compute Optimizer

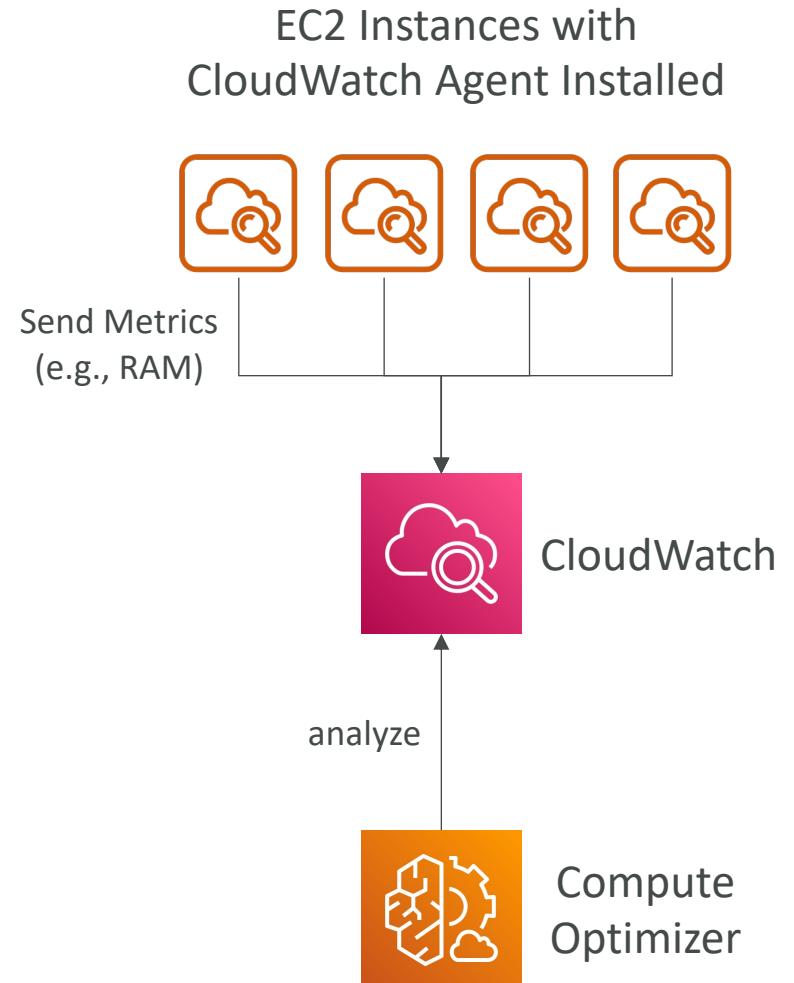


- Reduce costs and improve performance by recommending optimal AWS resources for your workloads
- Helps you choose optimal configurations and right-size your workloads (over/under provisioned)
- Uses Machine Learning to analyze your resources' configurations and their utilization CloudWatch metrics
-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



Compute Optimizer – CloudWatch Agent

- Needed to analyze Memory Utilization
- Not needed for CPU, NetworkIn/Out, DiskReadOps, DiskWriteOps, ...



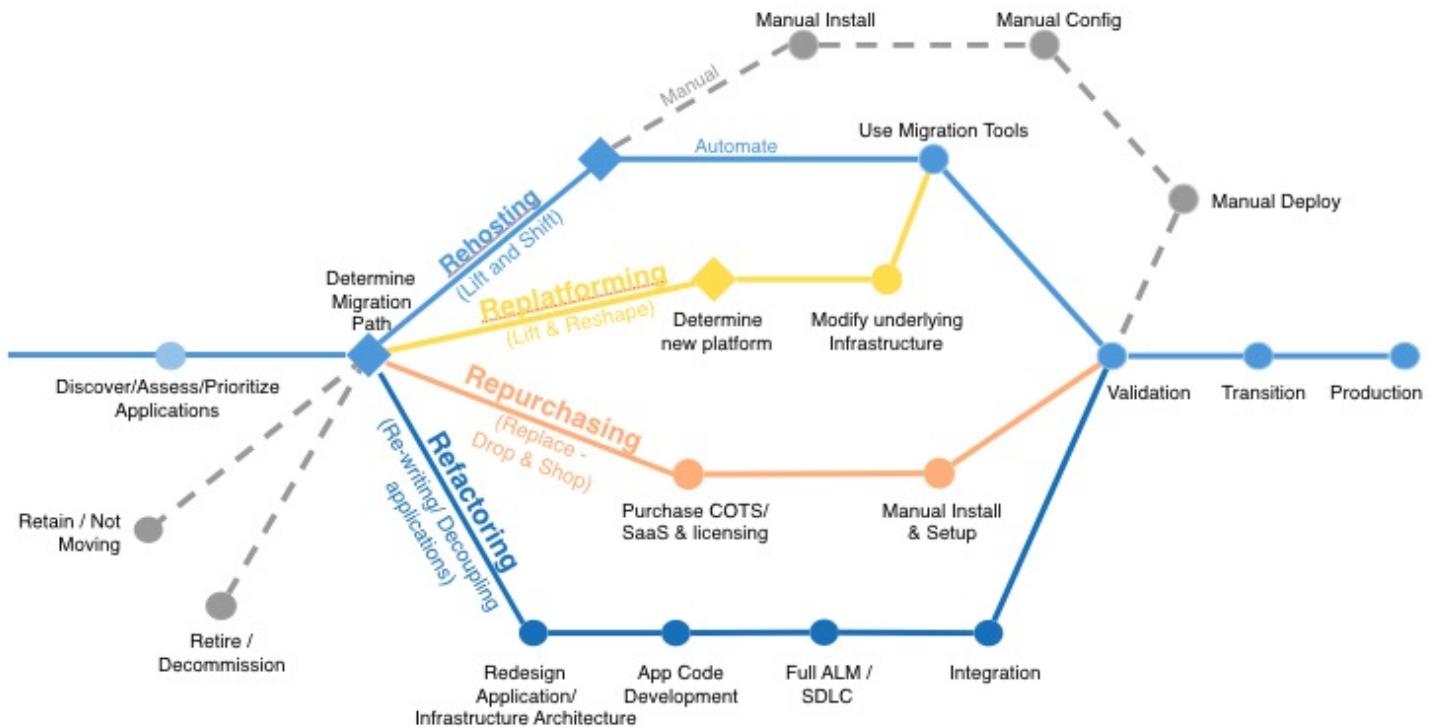
Reserved Instances

- Reserved Instances in an AWS Organization
 - all accounts share the Reserved Instances and Savings Plan
 - The payer account (Management account) of an organization can turn off Reserved Instance (RI) discount and Savings Plans discount sharing for any accounts in that organization, including the payer account
- Renewal of Reserved Instances
 - You can queue (schedule and reserve ahead of time) your reserved instances
 - To renew a RI, just queue an RI purchase whenever the previous one expires

Migrations

Cloud Migration: The 6R

- From: <https://aws.amazon.com/blogs/enterprise-strategy/6-strategies-for-migrating-applications-to-the-cloud/>



Cloud Migration: The 6R

- **Rehosting:** “lift and shift”
 - Simple migrations by re-hosting on AWS (applications, databases, data...)
 - No cloud optimizations being done, application is migrated as is
 - Could save as much as 30% on cost
 - Example: Migrate using AWS VM Import/Export, AWS Server Migration Service
- **Replatforming:**
 - Example: migrate your database to RDS
 - Example: migrate your application to Elastic Beanstalk (Java with Tomcat)
 - Not changing the core architecture, but leverage some cloud optimizations

Cloud Migration: The 6R

- **Repurchase:** “drop and shop”
 - Moving to a different product while moving to the cloud
 - Often you move to a SaaS platform
 - Expensive in the short term, but quick to deploy
 - Example: CRM to Salesforce.com, HR to Workday, CMS to Drupal
- **Refactoring / Re-architecting:**
 - Reimagining how the application is architected using Cloud Native features
 - Driven by the need of the business to add features, scale, performance
 - Example: move an application to Serverless architectures, use AWS S3

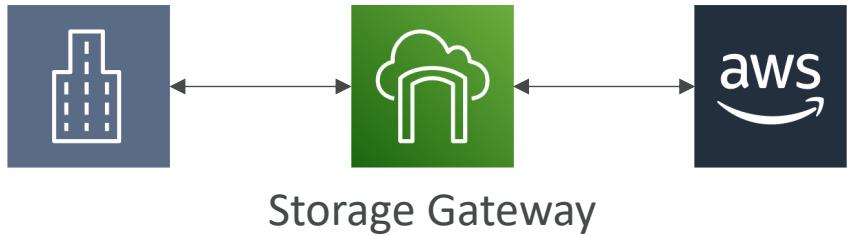
Cloud Migration: The 6R

- Retire
 - Turn off things you don't need (maybe as a result of Re-architecting)
 - Helps with reducing the surface areas for attacks (more security)
 - Save cost, maybe up to 10% to 20%
 - Focus your attention on resources that must be maintained
- Retain
 - Do nothing for now (for simplicity, cost reason, importance...)
 - It's still a decision to make in a Cloud Migration

AWS Storage Gateway

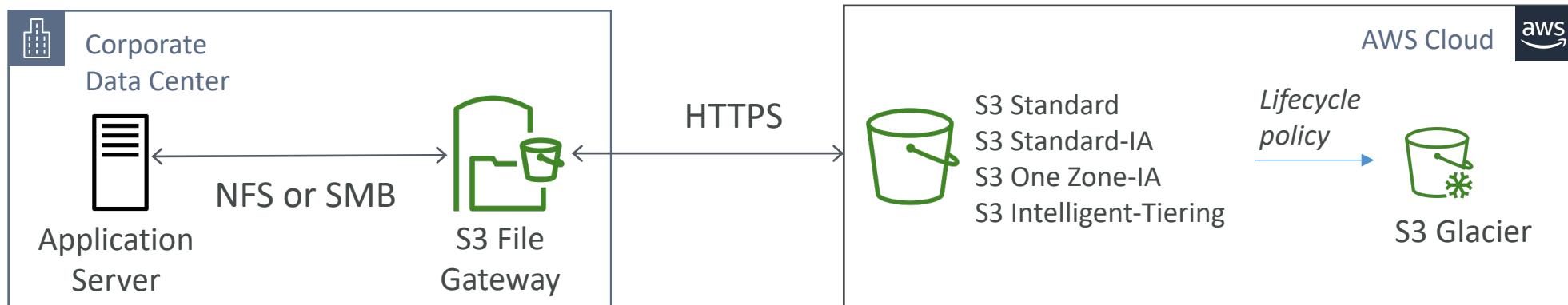


- Bridge between on-premises data and cloud data
- Use cases:
 - disaster recovery
 - backup & restore
 - tiered storage
 - on-premises cache & low-latency files access
- Types of Storage Gateway:
 - S3 File Gateway
 - FSx File Gateway
 - Volume Gateway
 - Tape Gateway



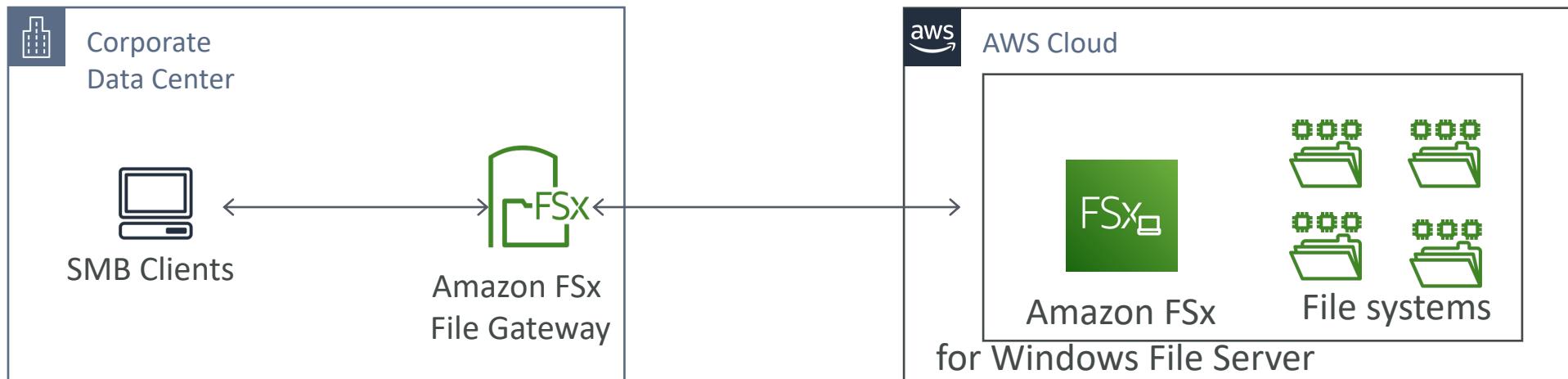
Amazon S3 File Gateway

- Configured S3 buckets are accessible using the NFS and SMB protocol
- Most recently used data is cached in the file gateway
- Supports S3 Standard, S3 Standard IA, S3 One Zone A, S3 Intelligent Tiering
- Transition to S3 Glacier using a Lifecycle Policy
- Bucket access using IAM roles for each File Gateway
- SMB Protocol has integration with Active Directory (AD) for user authentication



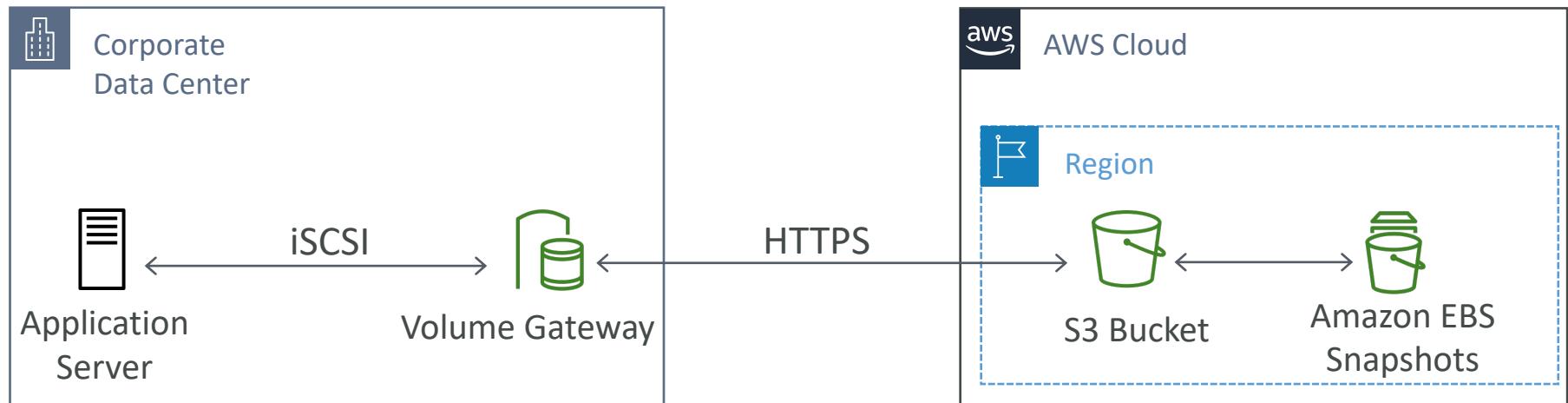
Amazon FSx File Gateway

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



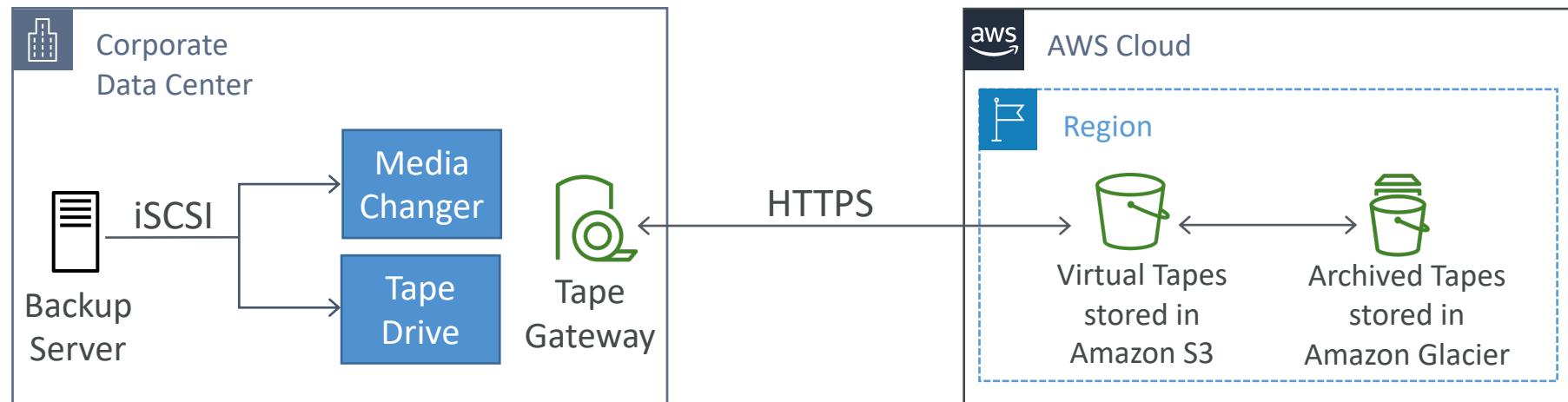
Volume Gateway

- Block storage using iSCSI protocol backed by S3
- Backed by EBS snapshots which can help restore on-premises volumes!
- **Cached volumes:** low latency access to most recent data
- **Stored volumes:** entire dataset is on premise, scheduled backups to S3



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) 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
- Otherwise, you can use a **Storage Gateway Hardware Appliance**
- You can buy it on amazon.com

- Works with File Gateway, Volume Gateway, Tape Gateway
- Has the required CPU, memory, network, SSD cache resources
- Helpful for daily NFS backups in small data centers

Select host platform

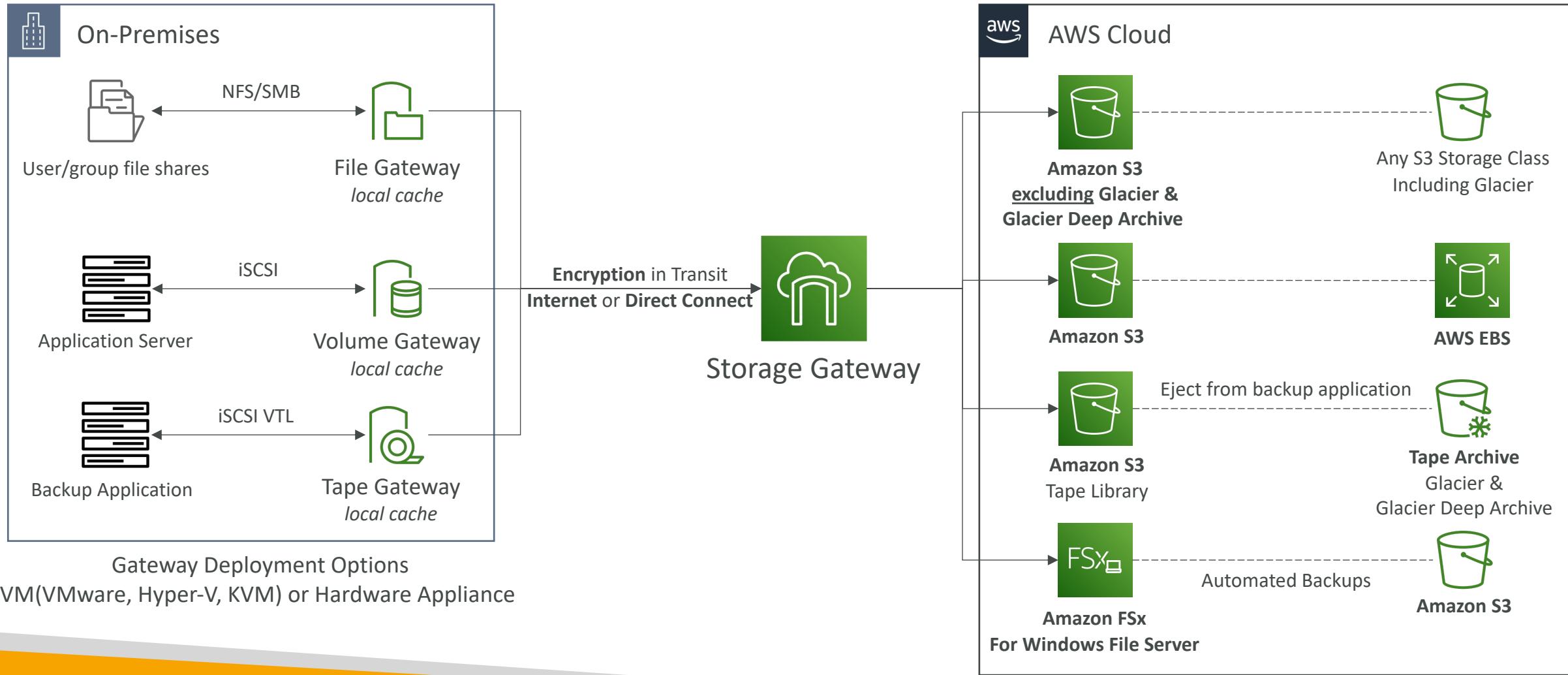
- VMware ESXi
- Microsoft Hyper-V 2012R2/2016
- Linux KVM
- Amazon EC2
- Hardware Appliance

[Buy on Amazon](#)

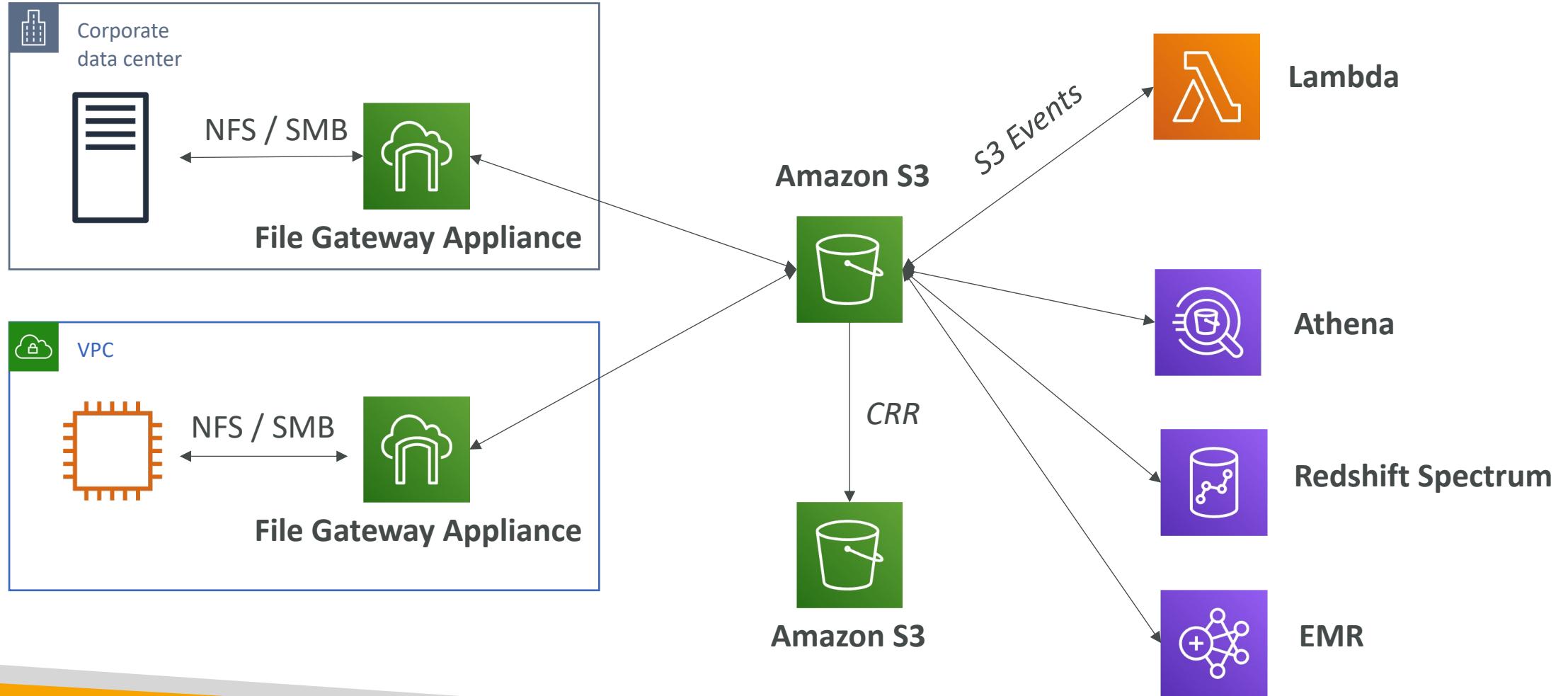
[Activate Appliance](#)



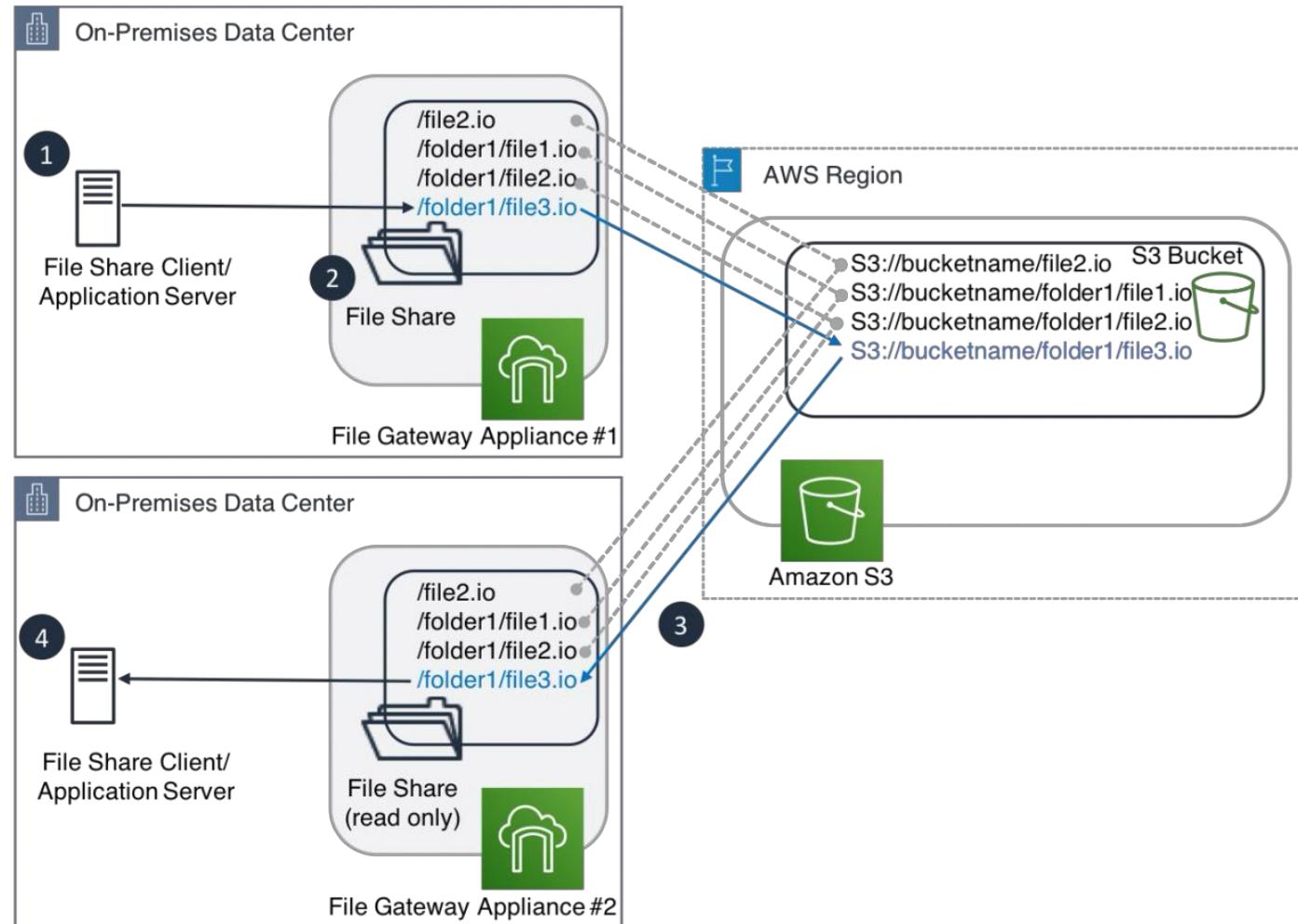
AWS Storage Gateway



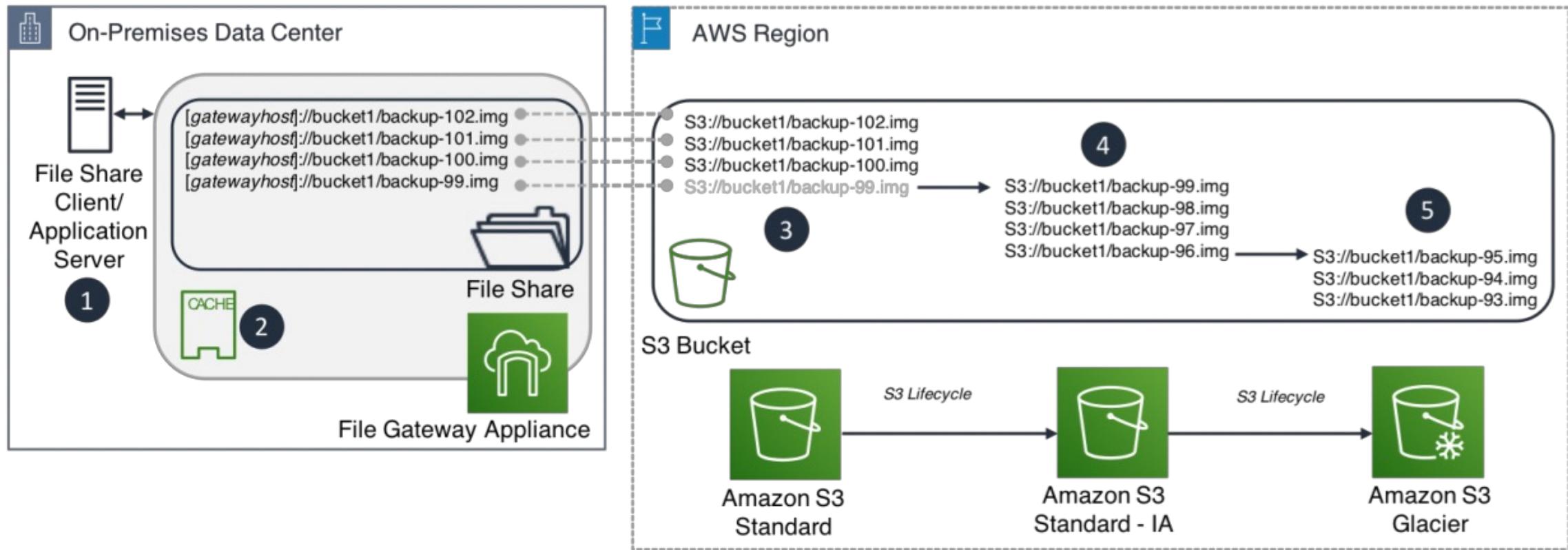
File Gateway: Extensions



File Gateway: Read Only Replicas



File Gateway: Backup and Lifecycle Policies



File Architectures: Other possibilities

- **Amazon S3 Object Versioning**

- Ability to store multiple object versions as they are modified
- Helpful to restore a file to a previous version
- Could restore an entire file system to a previous version
- Must use the “RefreshCache” API on the Gateway to be notified of restore

- **Amazon S3 Object Lock**

- Enables to have the File Gateway for Write Once Read Many (WORM) data
- If there are file modifications or renames in the file share clients, the file gateway creates a new version of the object without affecting priori versions, and the original locked version will remain unchanged

AWS Snow Family

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

- Data migration:



Snowcone



Snowball Edge



Snowmobile

- Edge computing:



Snowcone



Snowball Edge

Data Migrations with AWS Snow Family

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

Challenges:

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

AWS Snow Family: offline devices to perform data migrations

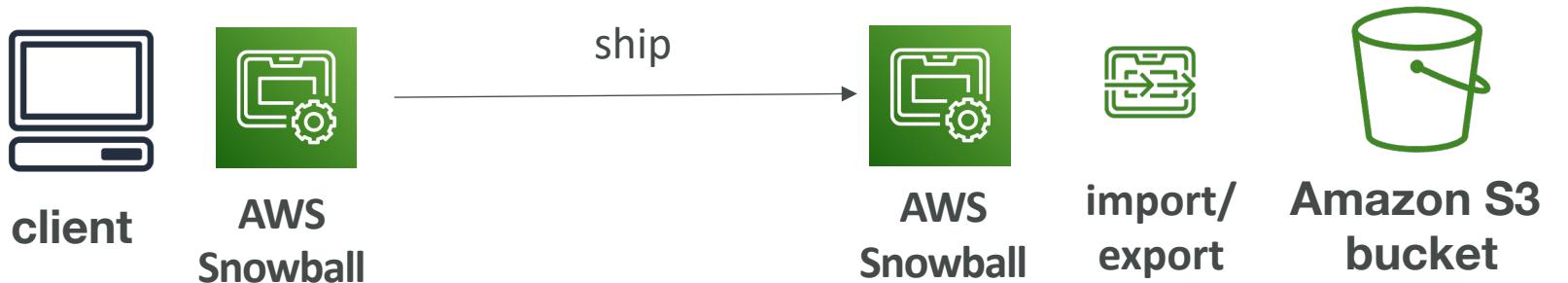
If it takes more than a week to transfer over the network, use Snowball devices!

Diagrams

- Direct upload to S3:



- With Snow Family:



Snowball Edge (for data transfers)



- Physical data transport solution: move TBs or PBs of data in or out of AWS
- Alternative to moving data over the network (and paying network fees)
- Pay per data transfer job
- Provide block storage and Amazon S3-compatible object storage
- **Snowball Edge Storage Optimized**
 - 80 TB of HDD capacity for block volume and S3 compatible object storage
- **Snowball Edge Compute Optimized**
 - 42 TB of HDD or 28TB NVMe capacity for block volume and S3 compatible object storage
- Use cases: large data cloud migrations, DC decommission, disaster recovery



AWS Snowcone & Snowcone SSD



- Small, portable computing, anywhere, rugged & secure, withstands harsh environments
- Light (4.5 pounds, 2.1 kg)
- Device used for edge computing, storage, and data transfer
- Snowcone – 8 TB of HDD Storage
- Snowcone SSD – 14 TB of SSD Storage
- Use Snowcone where Snowball does not fit (space-constrained environment)
- Must provide your own battery / cables
- Can be sent back to AWS offline, or connect it to internet and use **AWS DataSync** to send data



AWS Snowmobile



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

AWS Snow Family for Data Migrations



Snowcone



Snowball Edge



Snowmobile

	Snowcone & Snowcone SSD	Snowball Edge Storage Optimized	Snowmobile
Storage Capacity	8 TB HDD 14 TB SSD	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		

Snow Family – 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

What is Edge Computing?

- Process data while it's being created on **an edge location**
 - 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 data for example)

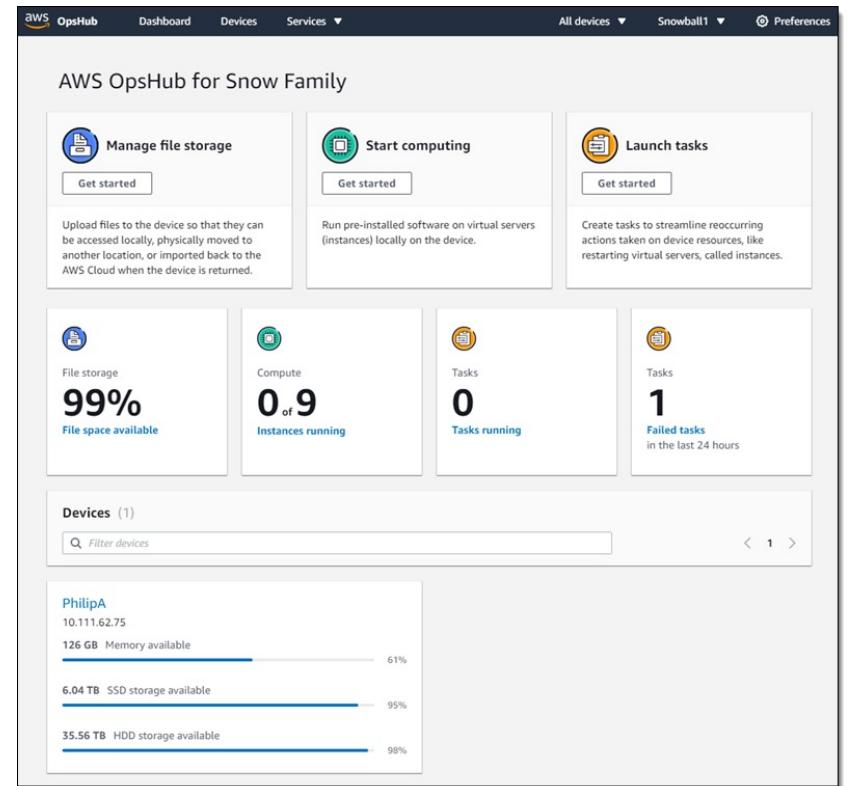
Snow Family – Edge Computing

- Snowcone & Snowcone SSD (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
 - 104 vCPUs, 416 GiB of RAM
 - Optional GPU (useful for video processing or machine learning)
 - 28 TB NVMe or 42TB HDD usable storage
 - Storage Clustering available (up to 16 nodes)
- Snowball Edge – Storage Optimized
 - Up to 40 vCPUs, 80 GiB of RAM, 80 TB storage
- All: Can run EC2 Instances & AWS Lambda functions (using AWS IoT Greengrass)
- Long-term deployment options: 1 and 3 years discounted pricing



AWS OpsHub

- Historically, to use Snow Family devices, you needed a CLI (Command Line Interface tool)
- Today, you can use **AWS OpsHub** (a software you install on your computer / laptop) to manage your Snow Family Device
 - Unlocking and configuring single or clustered devices
 - Transferring files
 - Launching and managing instances running on Snow Family Devices
 - Monitor device metrics (storage capacity, active instances on your device)
 - Launch compatible AWS services on your devices (ex: Amazon EC2 instances, AWS DataSync, Network File System (NFS))



<https://aws.amazon.com/blogs/aws/aws-snowball-edge-update/>

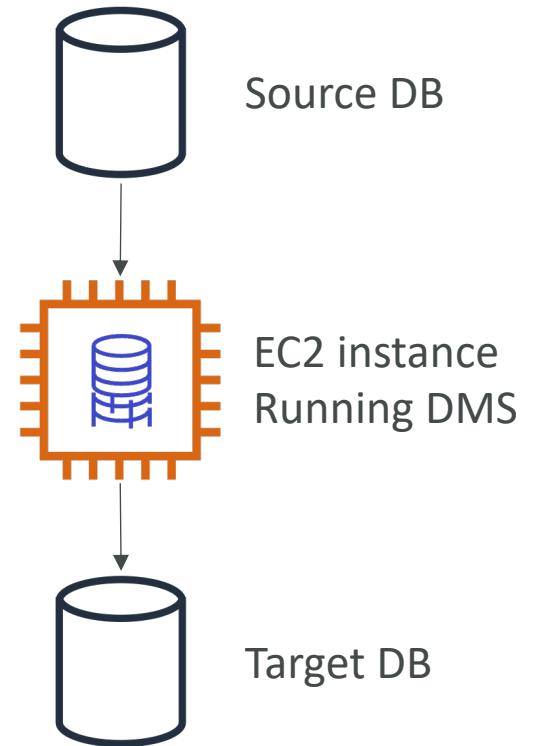
Snow Family – Improving Transfer Performance

- Most impactful to least:
 - Perform multiple write operations at one time - from multiple terminals
 - Transfer small files in batches – zip up small files until at least 1MB
 - Don't perform other operations on files during transfer
 - Reduce local network use
 - Eliminate unnecessary hops – directly connect to the computer
- The data transfer rate using the file interface is typically between 25 MB/s and 40 MB/s. If you need to transfer data faster than this, use the **Amazon S3 Adapter for Snowball**, which has a data transfer rate typically between 250 MB/s and 400 MB/s



DMS – Database Migration Service

- Quickly and securely migrate databases to AWS, resilient, self healing
- The source database remains available during the migration
- Supports:
 - Homogeneous migrations: ex Oracle to Oracle
 - Heterogeneous migrations: ex Microsoft SQL Server to Aurora
- Continuous Data Replication using CDC
- You must create an EC2 instance to perform the replication tasks



DMS Sources and Targets

SOURCES:

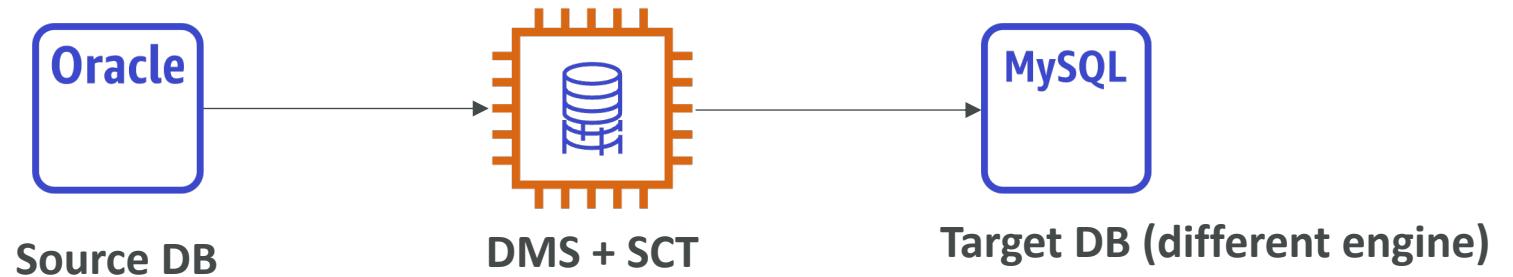
- On-premises and EC2 instances databases: Oracle, MS SQL Server, MySQL, MariaDB, PostgreSQL, MongoDB, SAP, DB2
- Azure: *Azure SQL Database*
- Amazon RDS: all including Aurora
- Amazon S3
- DocumentDB

TARGETS:

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

AWS Schema Conversion Tool (SCT)

- Convert your Database's Schema from one engine to another
- Example OLTP: (SQL Server or Oracle) to MySQL, PostgreSQL, Aurora
- Example OLAP: (Teradata or Oracle) to Amazon Redshift



- You do not need to use SCT if you are migrating the same DB engine
 - Ex: on-premises PostgreSQL => RDS PostgreSQL
 - The DB engine is still PostgreSQL (RDS is the platform)

DMS – Good things to know

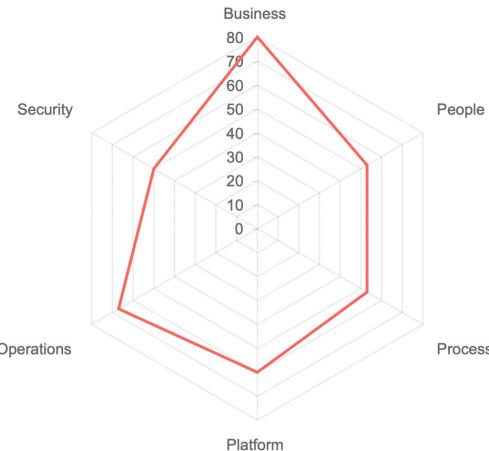
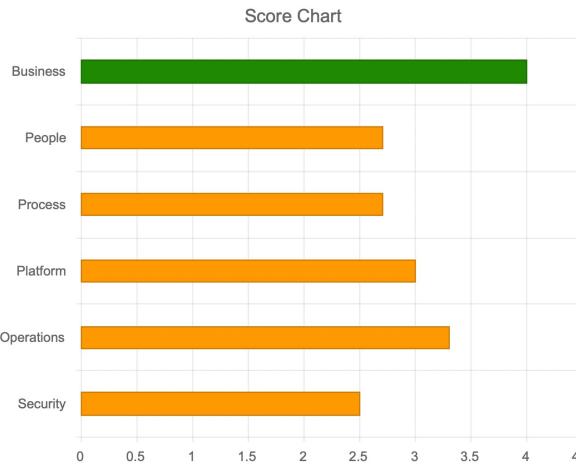
- Works over VPC Peering, VPN (site to site, software), Direct Connect
- Supports Full Load, Full Load + CDC, or CDC only
- **Oracle:**
 - Source: Supports TDE for the source using “BinaryReader”
 - Target: Supports BLOBs in tables that have a primary key, and TDE
- **OpenSearch:**
 - Source: does not exist
 - Target: possible to migrate from a relational database using DMS
 - Therefore, DMS cannot be used to replicate OpenSearch data

Snowball + Database Migration Service (DMS)

- Larger data migrations can include many terabytes of information.
- Can be limited due to network bandwidth or size of data
- AWS DMS can use Snowball Edge & Amazon S3 to speed up migration
- **Following stages:**
 1. You use the AWS Schema Conversion Tool (AWS SCT) to extract the data locally and move it to an Edge device.
 2. You ship the Edge device or devices back to AWS.
 3. After AWS receives your shipment, the Edge device automatically loads its data into an Amazon S3 bucket.
 4. AWS DMS takes the files and migrates the data to the target data store. If you are using change data capture (CDC), those updates are written to the Amazon S3 bucket and then applied to the target data store.

AWS Cloud Adoption Readiness Tool (CART)

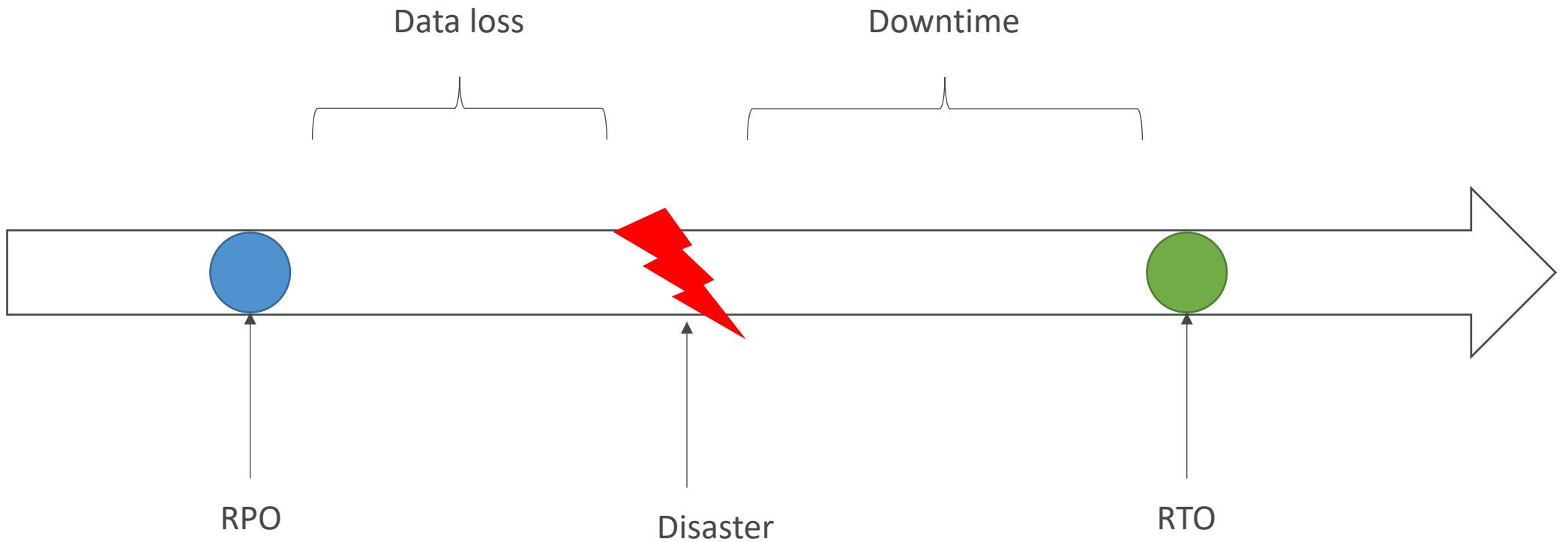
- Helps organizations develop efficient and effective plans for cloud adoption and migrations
- Transforms your idea of moving to the cloud into a detailed plan that follows AWS best practices
- Answer a set of questions across six perspectives (business, people, process, platform, operations, security)
- Generates a custom report on your level of migration readiness



Disaster Recovery Overview

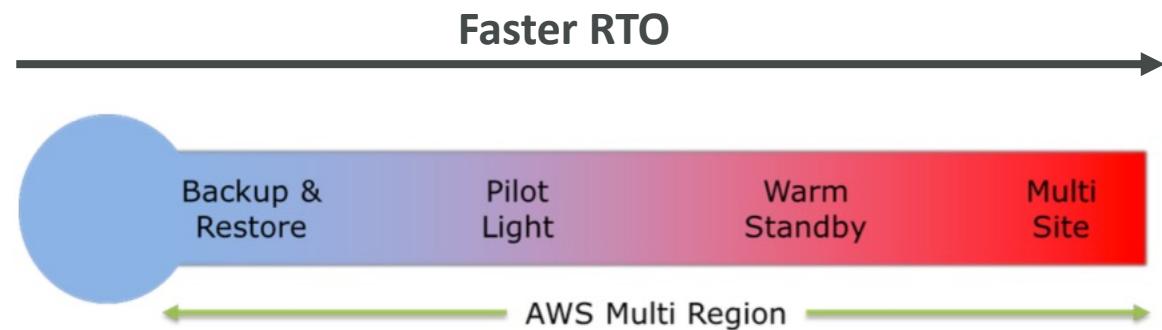
- Any event that has a negative impact on a company's business continuity or finances is a disaster
- Disaster recovery (DR) is about preparing for and recovering from a disaster
- What kind of disaster recovery?
 - on-premises => on-premises: traditional DR, and very expensive
 - on-premises => AWS Cloud: hybrid recovery
 - AWS Cloud Region A => AWS Cloud Region B
- Need to define two terms:
 - RPO: Recovery Point Objective
 - RTO: Recovery Time Objective

RPO and RTO

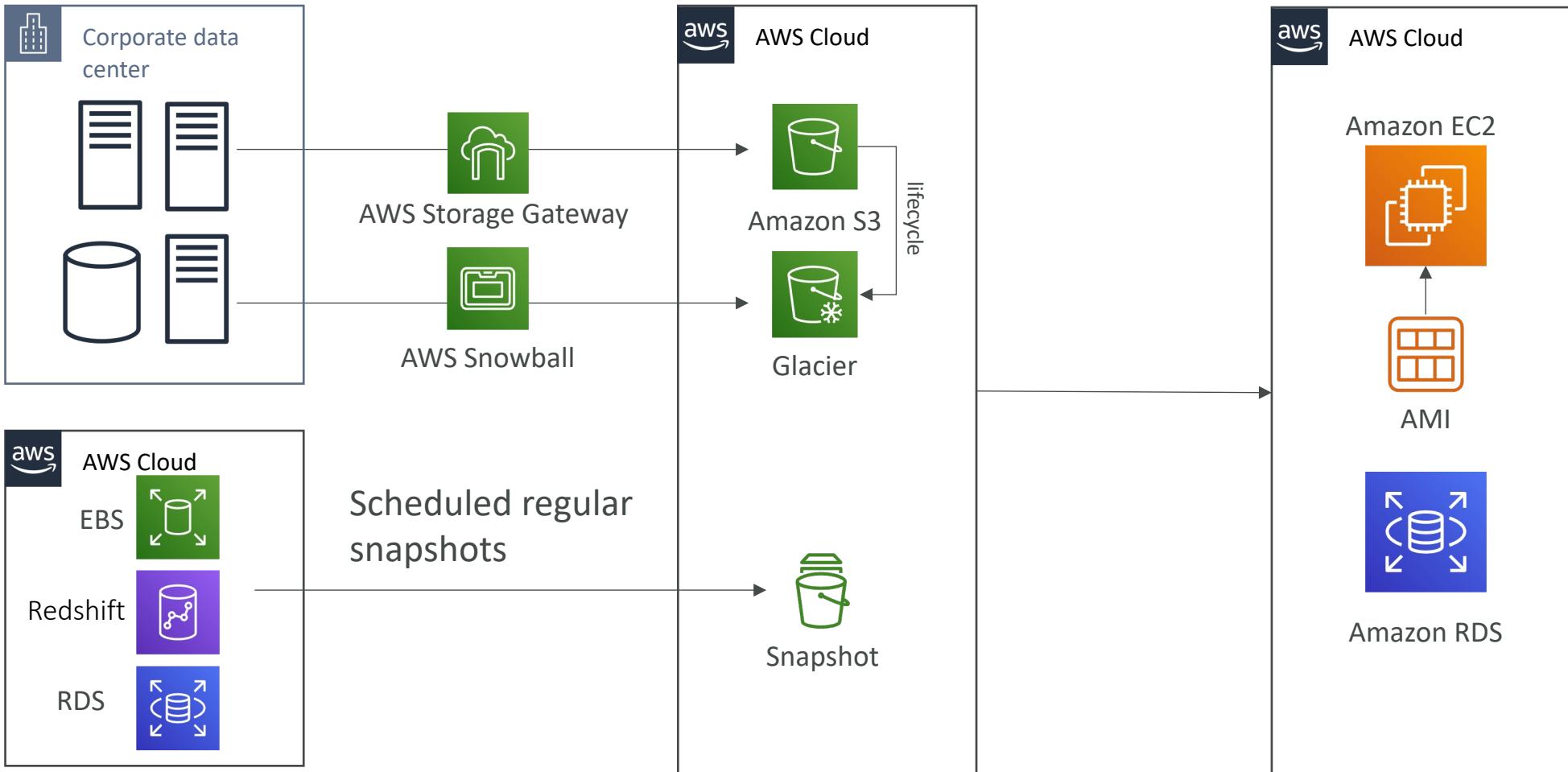


Disaster Recovery Strategies

- Backup and Restore
- Pilot Light
- Warm Standby
- Hot Site / Multi Site Approach

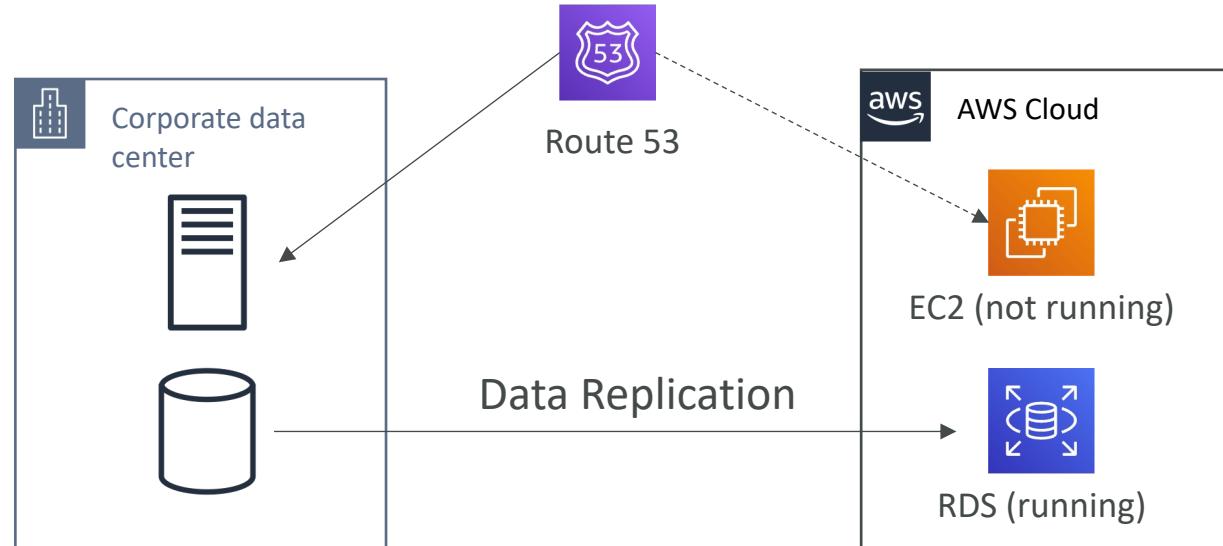


Backup and Restore (High RPO)



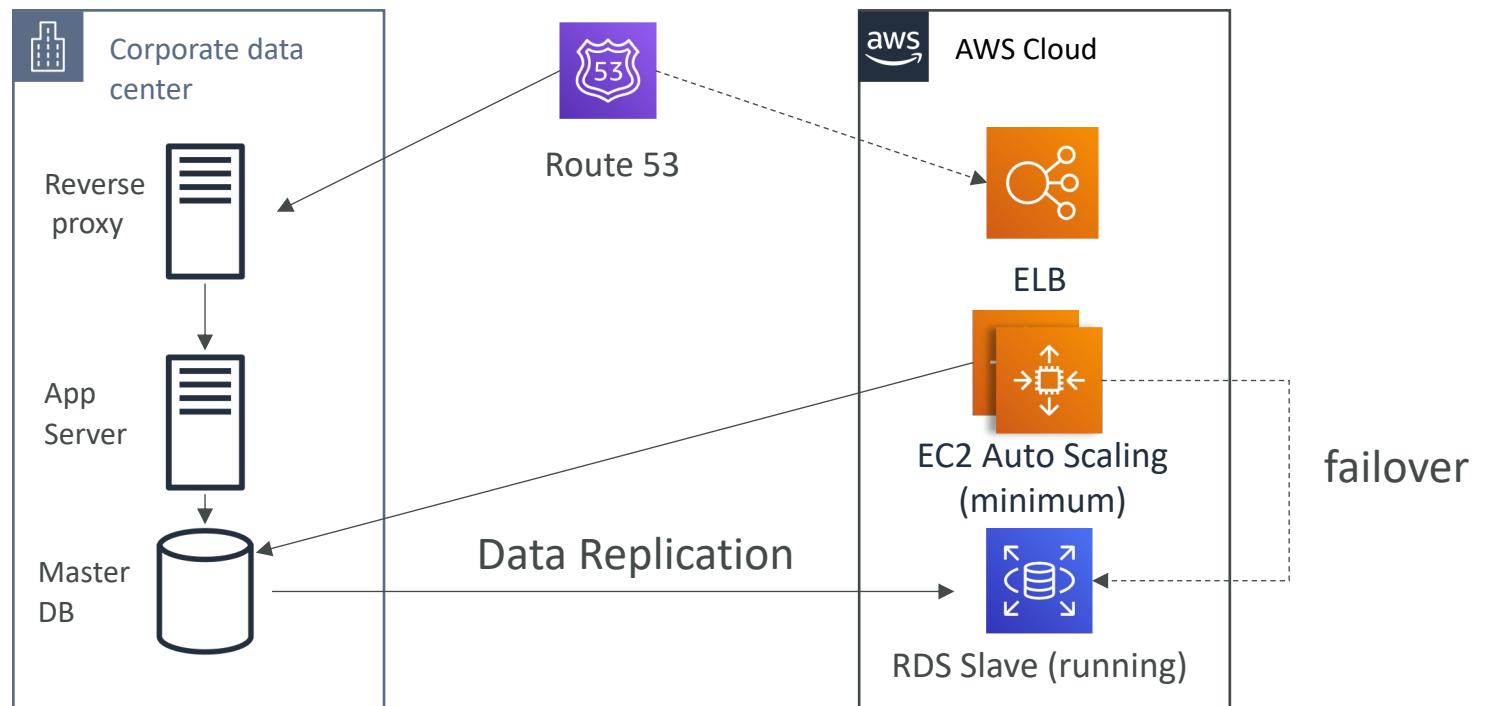
Disaster Recovery – Pilot Light

- A small version of the app is always running in the cloud
- Useful for the critical core (pilot light)
- Very similar to Backup and Restore
- Faster than Backup and Restore as critical systems are already up



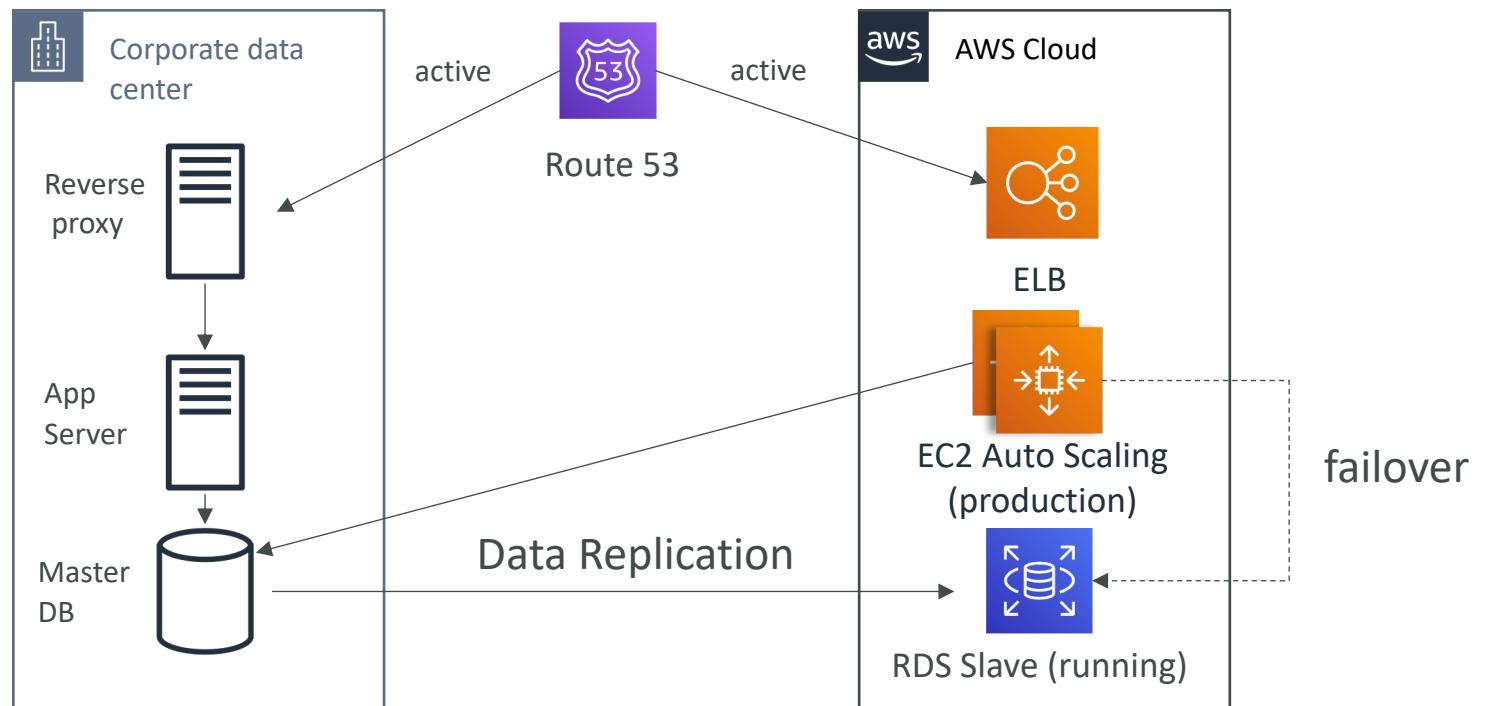
Warm Standby

- Full system is up and running, but at minimum size
- Upon disaster, we can scale to production load

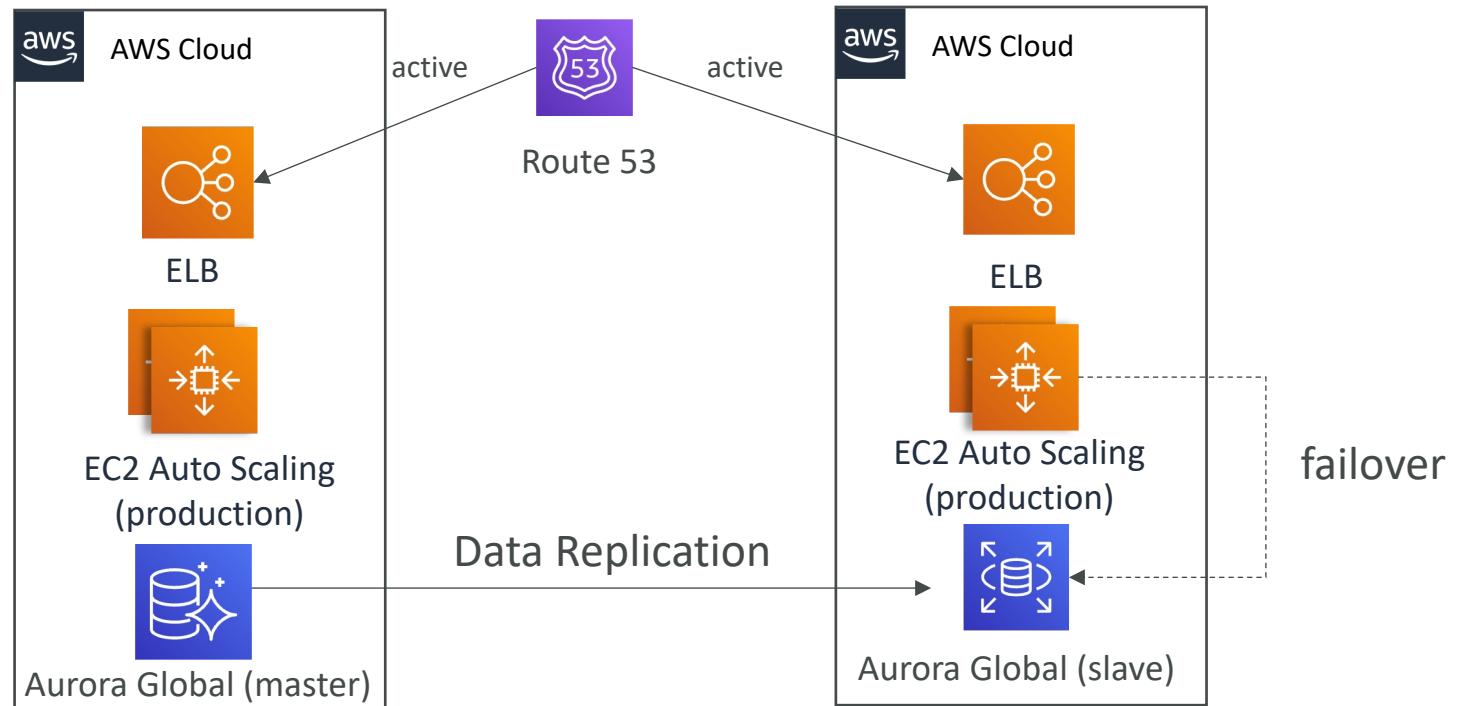


Multi Site / Hot Site Approach

- Very low RTO (minutes or seconds) – very expensive
- Full Production Scale is running AWS and On Premise



All AWS Multi Region



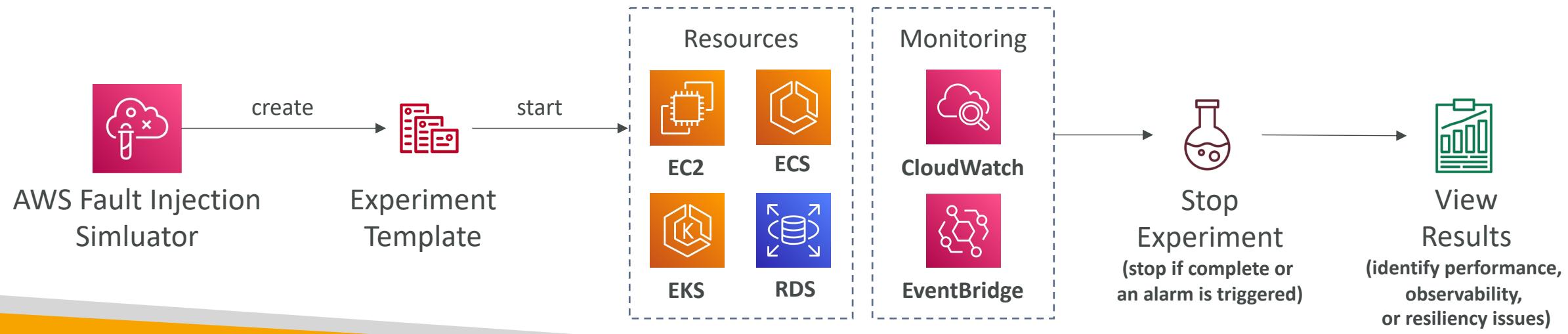
Disaster Recovery Tips

- Backup
 - EBS Snapshots, RDS automated backups / Snapshots, etc...
 - Regular pushes to S3 / S3 IA / Glacier, Lifecycle Policy, Cross Region Replication
 - From on-premises: 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 Database
 - Database replication from on-premises 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

AWS Fault Injection Simulator (FIS)



- A fully managed service for running fault injection experiments on AWS workloads
- Based on **Chaos Engineering** – stressing an application by creating disruptive events (e.g., sudden increase in CPU or memory), observing how the system responds, and implementing improvements
- Helps you uncover hidden bugs and performance bottlenecks
- Supports the following AWS services: EC2, ECS, EKS, RDS...
- Use pre-built templates that generate the desired disruptions



AWS Application Discovery Service

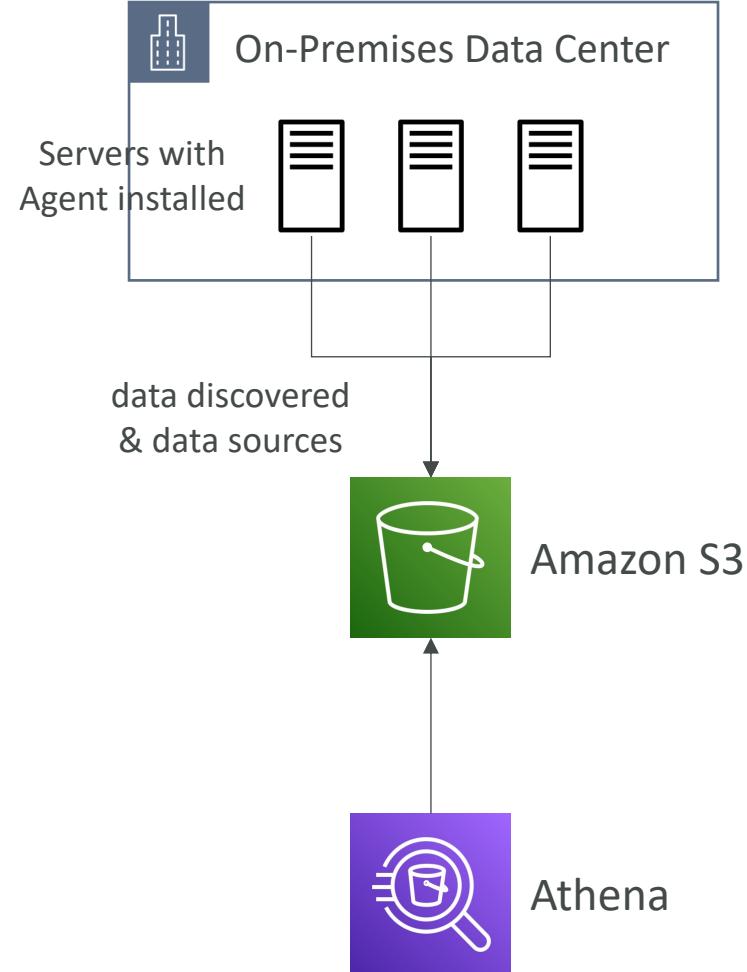


- Plan migration projects by gathering information about on-premises data centers
- Server utilization data and dependency mapping are important for migrations
- **Agentless Discovery (AWS Agentless Discovery Connector)**
 - Open Virtual Appliance (OVA) package that can be deployed to a VMware host
 - VM inventory, configuration, and performance history such as CPU, memory, and disk usage
 - OS agnostic
- **Agent-based Discovery (AWS Application Discovery Agent)**
 - System configuration, system performance, running processes, and details of the network connections between systems
 - Supports Microsoft Server, Amazon Linux, Ubuntu, RedHat, CentOS, SUSE...
- Resulting data can be exported as CSV or viewed within AWS Migration Hub
- Data can be explored using pre-defined queries in Amazon Athena

AWS Application Discovery Service – Migration Hub Data Exploration



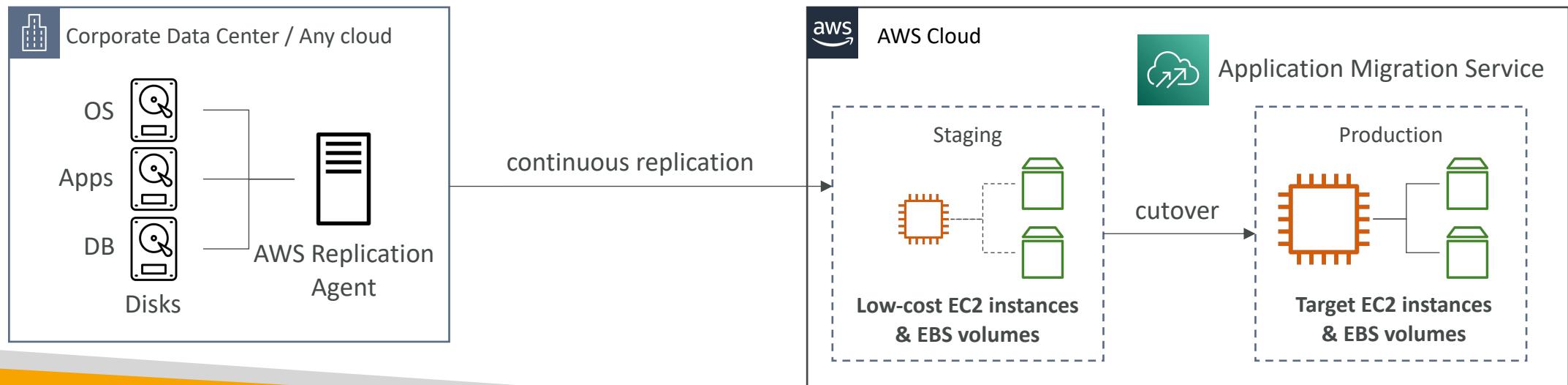
- Allows you to use Amazon Athena to analyze data collected from on-premises servers during discovery
- Data is automatically stored in S3 bucket at regular intervals
- Use Pre-defined or custom queries in Amazon Athena to analyze data
- Example: type of processes running on each server
- Ability to upload additional data sources such as Configuration Management Database (CMDB) exports
- Integrate Athena with QuickSight to visualize data



AWS Application Migration Service (MGN)



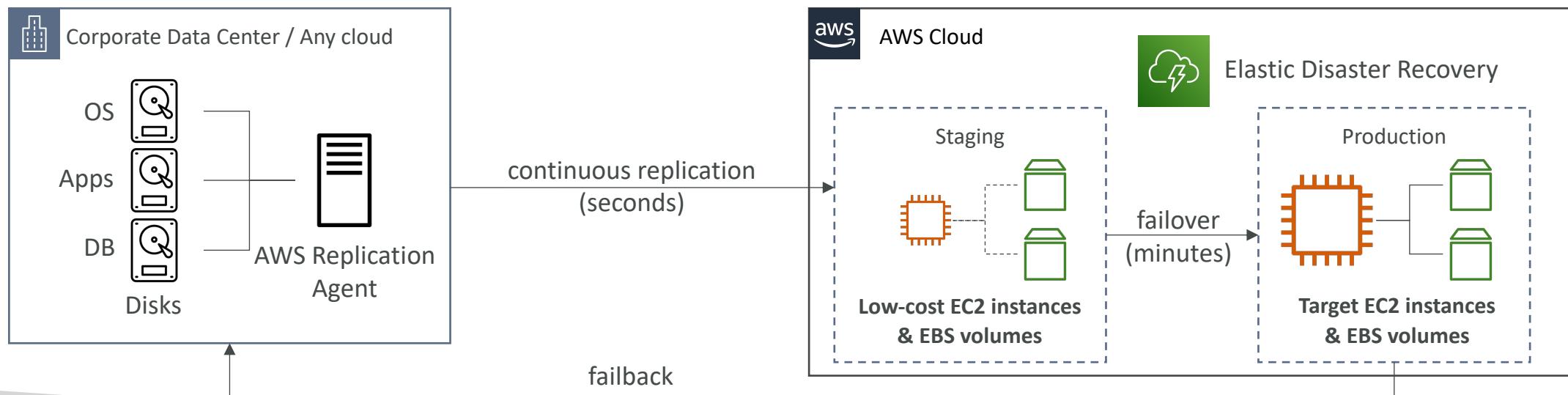
- The “AWS evolution” of CloudEndure Migration, replacing AWS Server Migration Service (SMS)
- Lift-and-shift (rehost) solution which simplify **migrating** applications to AWS
- Converts your physical, virtual, and cloud-based servers to run natively on AWS
- Supports wide range of platforms, Operating Systems, and databases
- Minimal downtime, reduced costs



AWS Elastic Disaster Recovery (DRS)



- Used to be named “CloudEndure Disaster Recovery”
- Quickly and easily **recover** your physical, virtual, and cloud-based servers into AWS
- Example: protect your most critical databases (including Oracle, MySQL, and SQL Server), enterprise apps (SAP), protect your data from ransomware attacks, ...
- Continuous block-level replication for your servers



On-premises strategy with AWS

- Ability to download Amazon Linux 2 AMI as a VM (.iso format)
 - VMWare, KVM, VirtualBox (Oracle VM), Microsoft Hyper-V
- AWS Application Discovery Service
 - Gather information about your on-premises servers to plan a migration
 - Server utilization and dependency mappings
 - Track with AWS Migration Hub
- AWS Application Migration Service (MGN)
 - Replacing AWS Server Migration Services & CloudEndure Migration
 - Incremental replication of on-premises live servers to AWS
 - Migrates the entire VM into AWS
- AWS Elastic Disaster Recovery (DRS)
 - Replacing CloudEndure Disaster Recovery
 - Recover on-premises workloads onto AWS
- AWS Database Migration Service (DMS)
 - replicate on-premises => AWS , AWS => AWS, AWS => on-premises
 - Works with various database technologies (Oracle, MySQL, DynamoDB, etc..)



AWS Application
Discovery Service



AWS Application
Migration Service

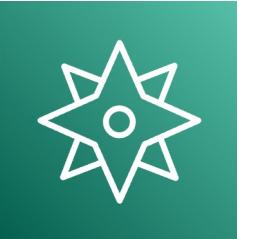


AWS Elastic
Disaster Recovery

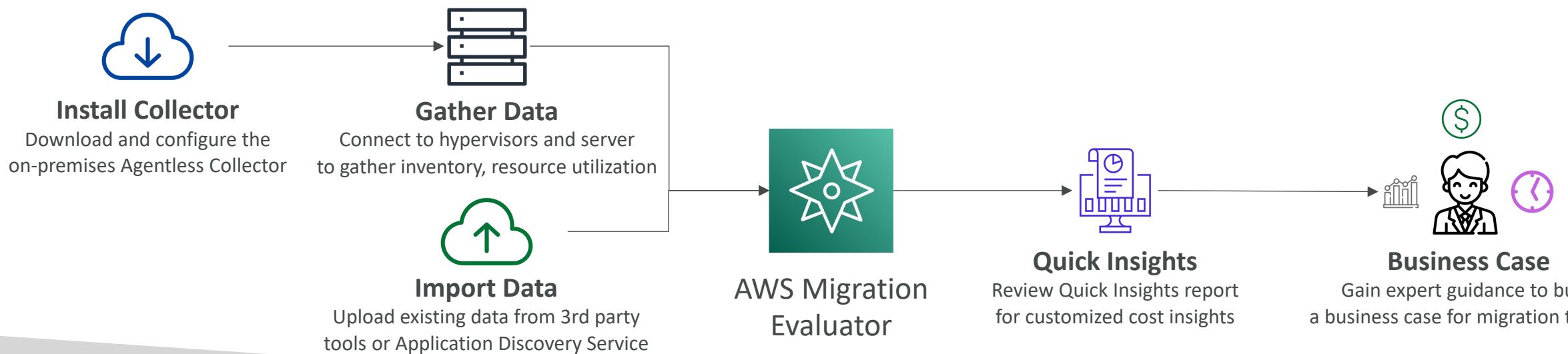


AWS Database
Migration Service

AWS Migration Evaluator



- Helps you build a data-driven business case for migration to AWS
- Provides a clear baseline of what your organization is running today
- Install Agentless Collector to conduct broad-based discovery
- Take a snapshot of on-premises foot-print, server dependencies, ...
- Analyze current state, define target state, then develop migration plan





AWS Backup

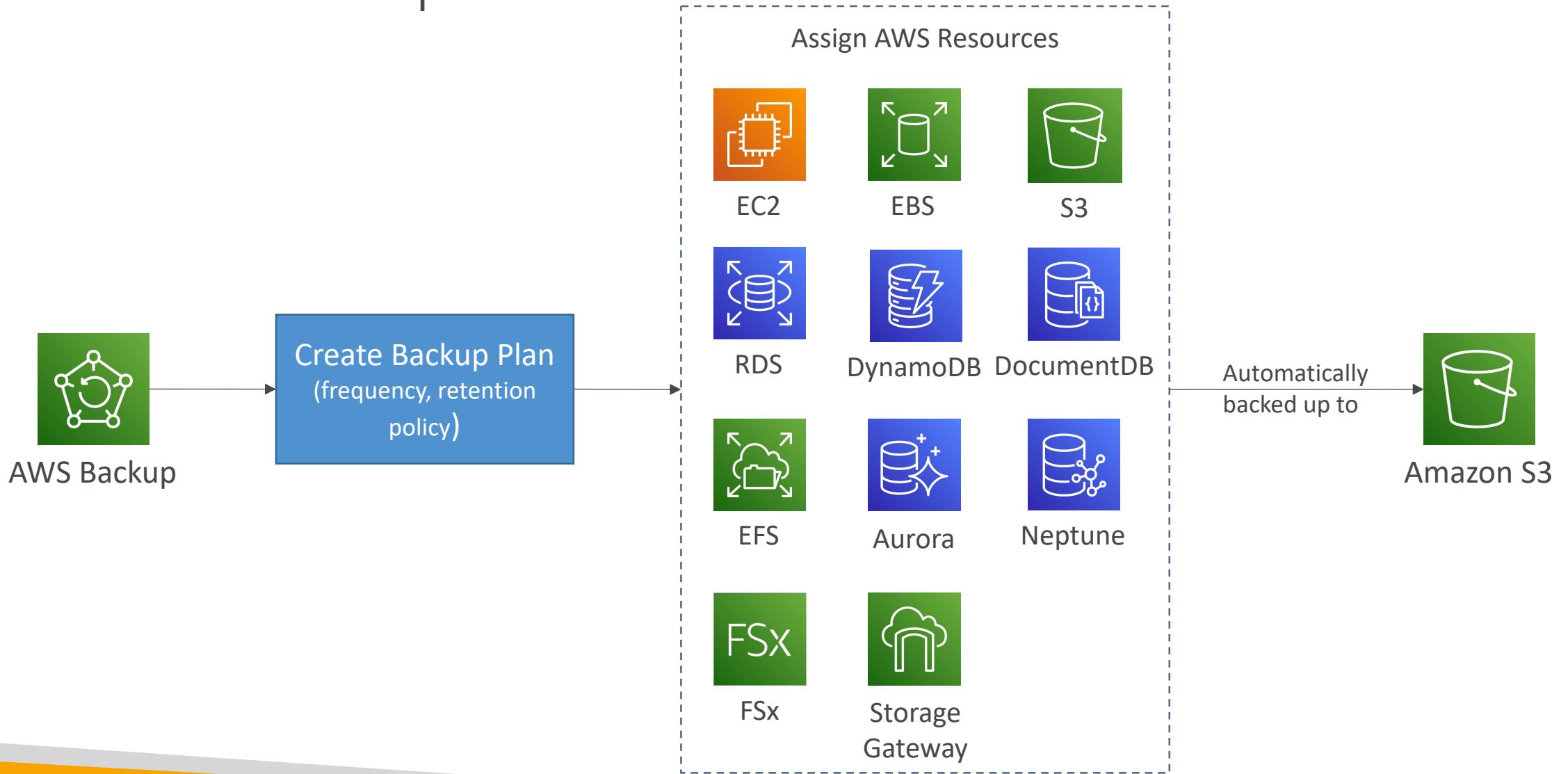
- Fully managed service
- Centrally manage and automate backups across AWS services
- No need to create custom scripts and manual processes
- Supported services:
 - Amazon EC2 / Amazon EBS
 - Amazon S3
 - Amazon RDS (all DBs engines) / Amazon Aurora / Amazon DynamoDB
 - Amazon DocumentDB / Amazon Neptune
 - Amazon EFS / Amazon FSx (Lustre & Windows File Server)
 - AWS Storage Gateway (Volume Gateway)
- Supports cross-region backups
- Supports cross-account backups

AWS Backup



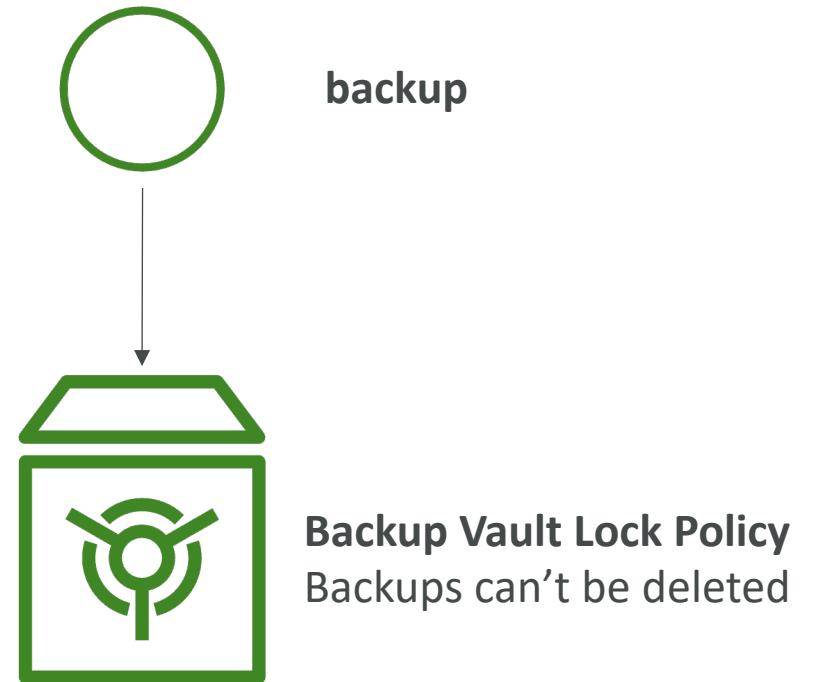
- Supports PITR for supported services
- On-Demand and Scheduled backups
- Tag-based backup policies
- You create backup policies known as **Backup Plans**
 - Backup frequency (every 12 hours, daily, weekly, monthly, cron expression)
 - Backup window
 - Transition to Cold Storage (Never, Days, Weeks, Months, Years)
 - Retention Period (Always, Days, Weeks, Months, Years)

AWS Backup



AWS Backup 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



Amazon VPC

VPC Basics

- **CIDR:** Block of IP address
 - Example: $192.168.0.0/26$: 192.168.0.0 – 192.168.0.63 (64 IP)
 - Used for security groups, route tables, VPC, subnets, etc...
- **Private IP**
 - 10.0.0.0 – 10.255.255.255 (10.0.0.0/8) <= in big networks
 - 172.16.0.0 – 172.31.255.255 (172.31.0.0/12)
 - 192.168.0.0 – 192.168.255.255 (192.168.0.0/16) <= example: home networks
- **Public IP**
 - All the rest

VPC Basics

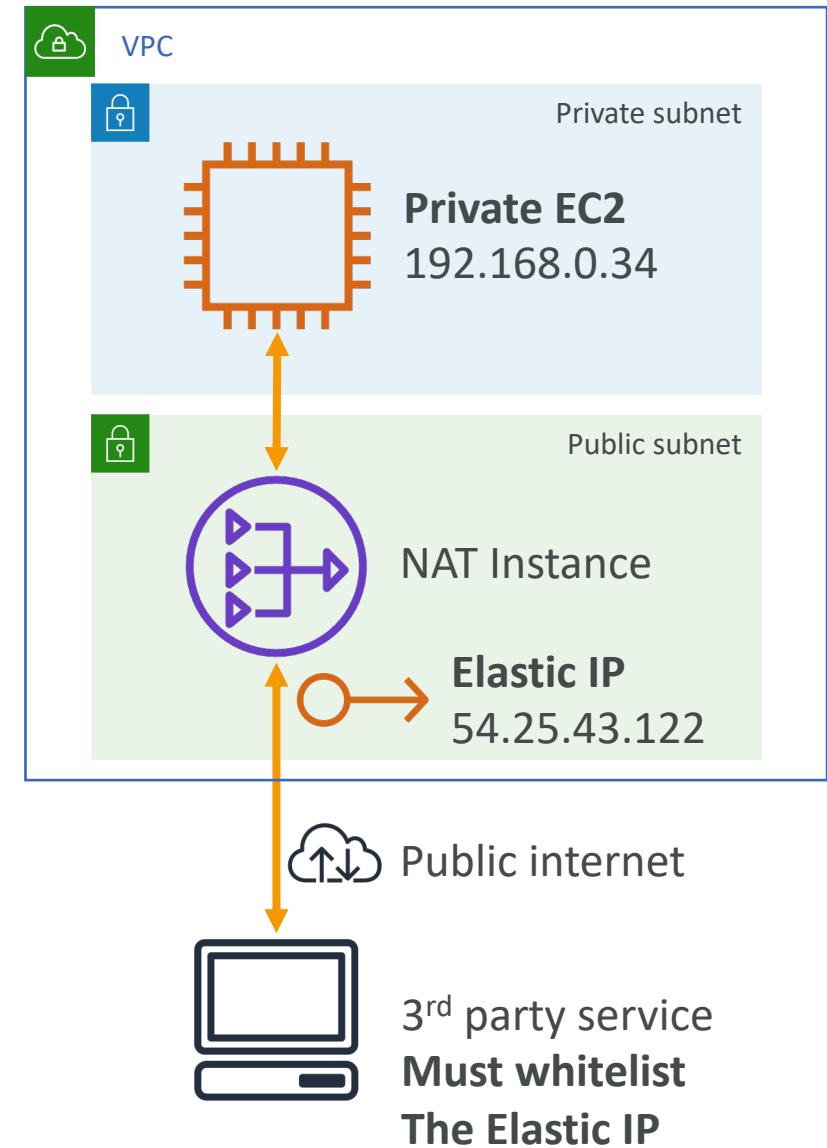
- **VPC**
 - A VPC must have a defined list of CIDR blocks, that cannot be changed
 - Each CIDR within VPC: min size is /28, max size is /16 (65536 IP addresses)
 - VPC is private, so only Private IP CIDR ranges are allowed
- **Subnets**
 - Within a VPC, defined as a CIDR that is a subset of the VPC CIDR
 - All instances within subnets get a private IP
 - First 4 IP and last one in every subnet is reserved by AWS
- **Route Tables**
 - Used to control where the network traffic is directed to
 - Can be associated with specific subnets
 - The “most specific” routing rule is always followed (192.168.0.1/24 beats 0.0.0.0/0)

VPC Basics

- **Internet Gateway (IGW)**
 - Helps our VPC connect to the internet, HA, scales horizontally
 - Acts as a NAT for instances that have a public IPv4 or public IPv6
- **Public Subnets**
 - Has a route table that sends 0.0.0.0/0 to an IGW
 - Instances must have a public IPv4 to talk to the internet
- **Private Subnets**
 - Access internet with a NAT Instance or NAT Gateway setup in a public subnet
 - Must edit routes so that 0.0.0.0/0 routes traffic to the NAT

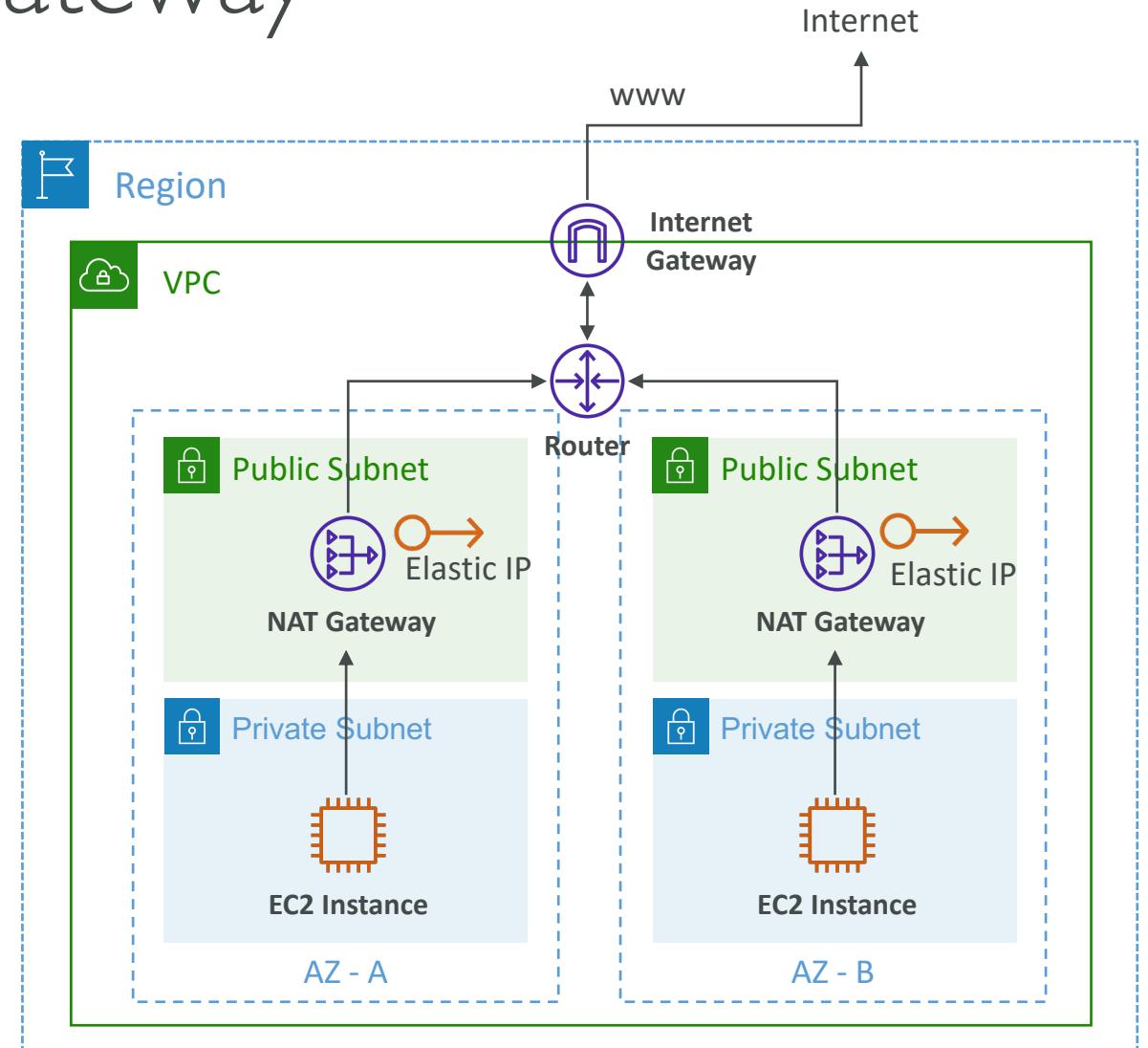
VPC Basics - NAT Instance

- EC2 instance you deploy in a public subnet
- Edit the route in your private subnet to route 0.0.0.0/0 to your NAT instance
- Not resilient to failure, limited bandwidth based on instance type, cheap
- Must manage failover yourself
- Must disable Source/Destination Check (EC2 setting)



VPC Basics – NAT Gateway

- Managed NAT solution, bandwidth scales automatically
- Resilient to failure within a single AZ
- Must deploy multiple NAT Gateways in multiple AZ for HA
- Has an Elastic IP, external services see the IP of the NAT Gateway as the source



VPC Basics

- Network ACL (NACL)
 - Stateless firewall defined at the subnet level, applies to all instances within
 - Support for allow and deny rules
 - Stateless = return traffic must be explicitly allowed by rules
 - Helpful to quickly and cheaply block specific IP addresses
- Security Groups
 - Applied at the instance level, only support for allow rules, no deny rules
 - Stateful = return traffic is automatically allowed, regardless of rules
 - Can reference other security groups in the same region (peered VPC, cross-account)

VPC Basics

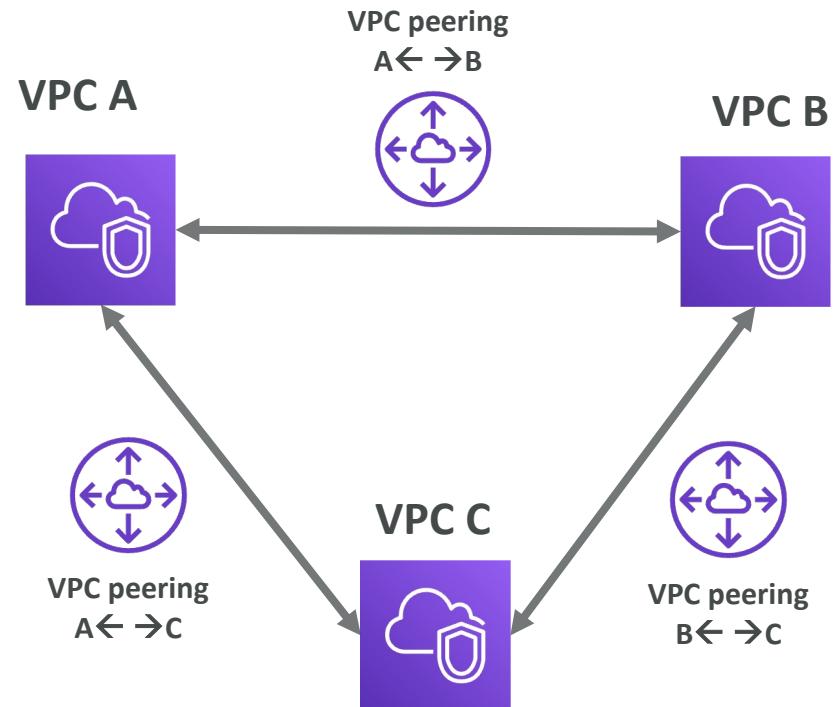
- **VPC Flows Logs**
 - Log internet traffic going through your VPC
 - Can be defined at the VPC level, Subnet level, or ENI-level
 - Helpful to capture “denied internet traffic”
 - Can be sent to CloudWatch Logs and Amazon S3
- **Bastion Hosts**
 - SSH into private EC2 instances through a public EC2 instance (bastion host)
 - You must manage these instances yourself (failover, recovery)
 - SSM Session Manager is a more secure way to remote control without SSH

VPC Basics

- IPv6 in short
 - All IPv6 addresses are public, total 3.4×10^{38} addresses (vs 4.3 billion IPv4)
 - Example CIDR: 2600:1f18:80c:a900::/56
 - Addresses are “random” and can’t be scanned online (because too many)
- VPC support for IPv6
 - Create an IPv6 CIDR for VPC & use an IGW (supports IPv6)
 - Public subnet:
 - Create an instance with IPv6 support
 - Create a route table entry to ::/0 (IPv6 “all”) to the IGW
 - Private subnet (instances cannot be reached by IPv6 but can reach IPv6):
 - Create an **Egress-Only Internet Gateway** in the VPC
 - Add a route table entry for the private subnet from ::/0 to the Egress-Only IGW

VPC Peering

- Connect two VPC, privately using AWS' network
- Make them behave as if they were in the same network
- Must not have overlapping CIDR
- VPC Peering connection is **not transitive** (must be established for each VPC that need to communicate with one another)
- You can do VPC peering with another AWS account
- You must update route tables in each VPC's subnets to ensure instances can communicate



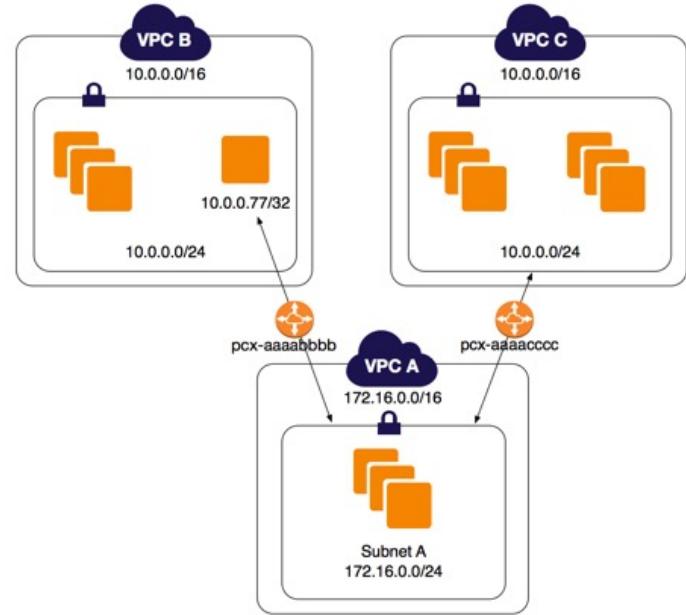
VPC Peering – Good to know

- VPC peering can work inter-region, cross-account
- You can reference a security group of a peered VPC (works cross account)

Type	Protocol	Port Range	Source
HTTP	TCP	80	sg-00d2b0f5fd6de757e
HTTP	TCP	80	sg-013347765f7a63aae/12356788

VPC Peering – Longest Prefix Match

- VPC uses the longest prefix match to select the most specific route



Route Table	Destination	Target
VPC A	172.16.0.0/16	Local
	10.0.0.77/32	pcx-aaaabbbb
	10.0.0.0/16	pcx-aaacccccc
VPC B	10.0.0.0/16	Local
	172.16.0.0/16	pcx-aaaabbbb
VPC C	10.0.0.0/16	Local
	172.16.0.0/16	pcx-aaacccccc

- Here the longest prefix for 10.0.0.77 is 10.0.0.77/32 (route table VPC A)
- (other way of saying it is “most specific route”)

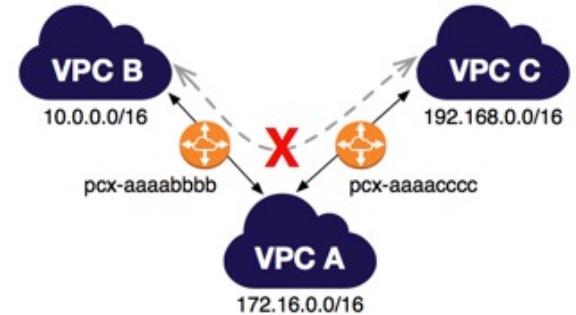
<https://docs.aws.amazon.com/vpc/latest/peering/peering-configurations-partial-access.html#one-to-two-vpcs-lpm>

VPC Peering – Invalid Configurations

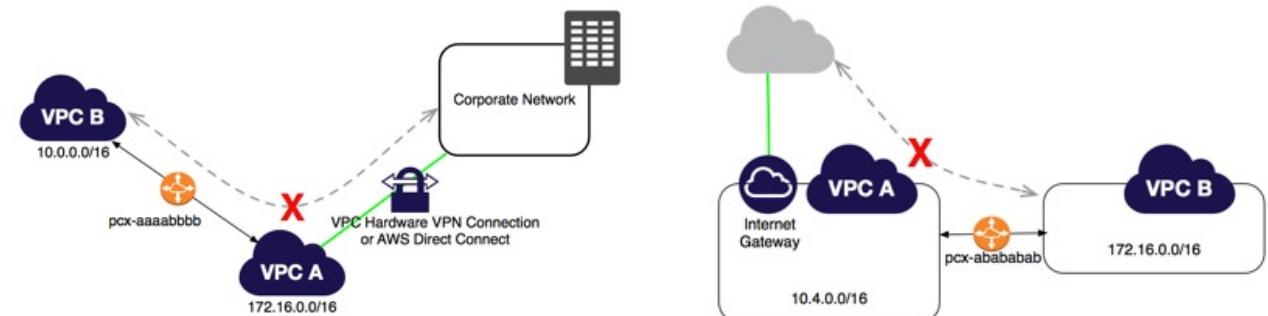
Overlapping CIDR for IPv4



No Transitive VPC Peering



No Edge to Edge Routing



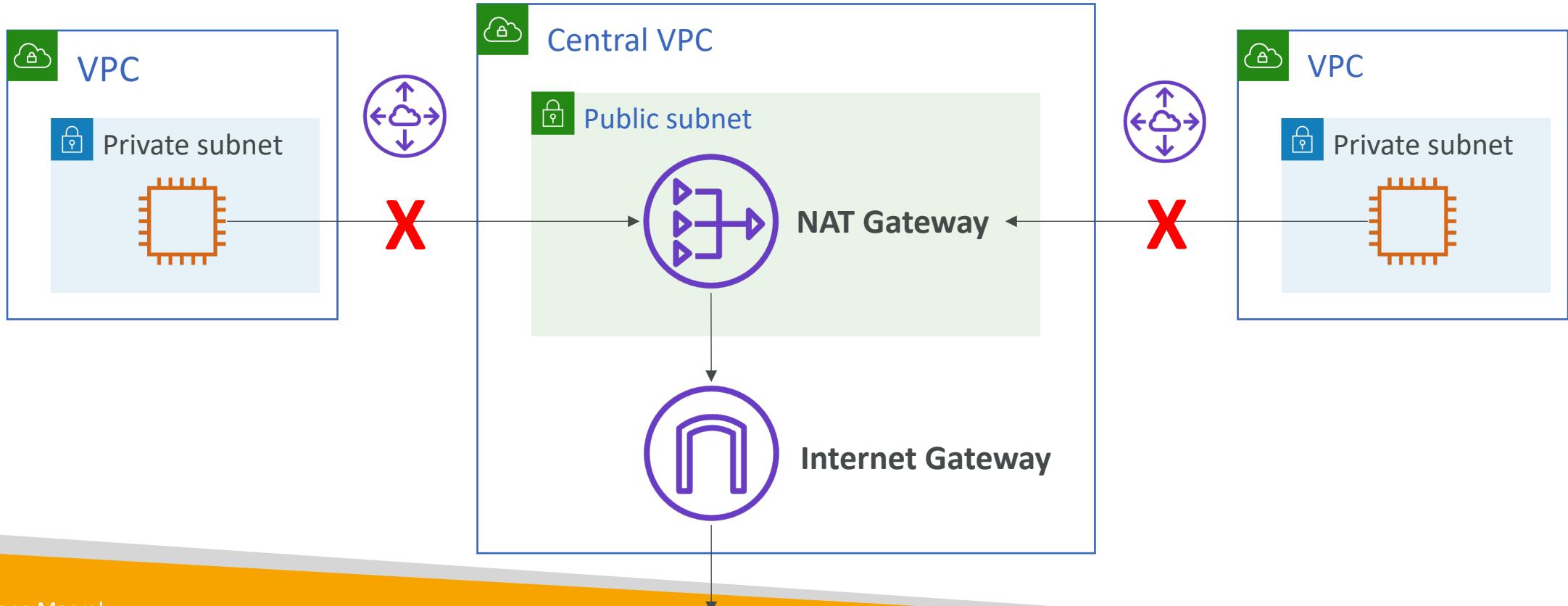
VPN, Direct Connect, IGW, NAT, Gateway VPC Endpoint (S3 & DynamoDB)

<https://docs.aws.amazon.com/vpc/latest/peering/invalid-peering-configurations.html>

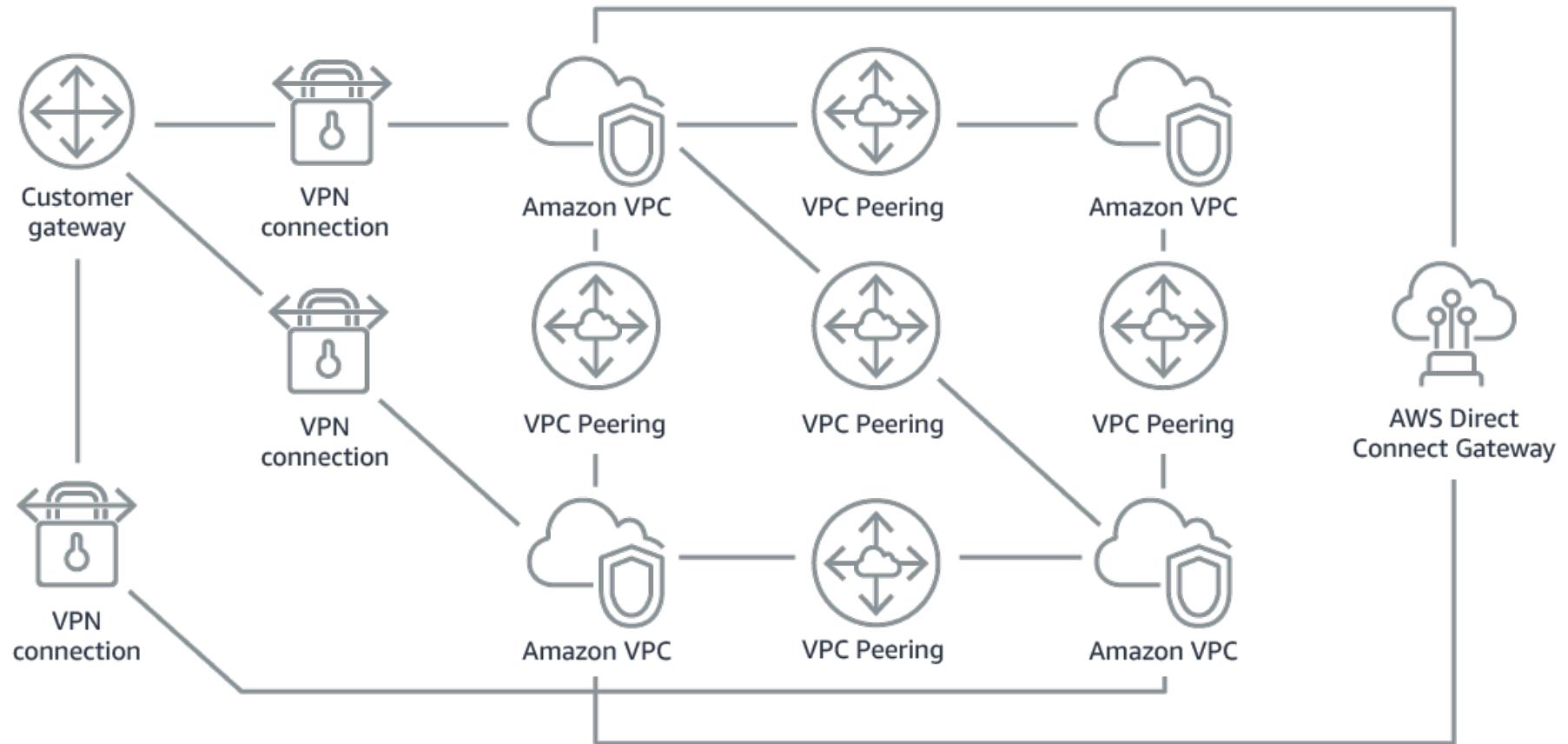
VPC Peering – Invalid Configuration

No edge to edge routing

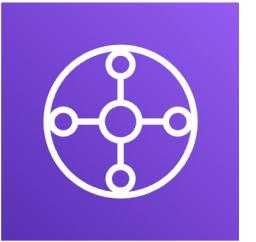
- This is an invalid configuration
- VPC Peering does not support edge to edge routing for NAT devices



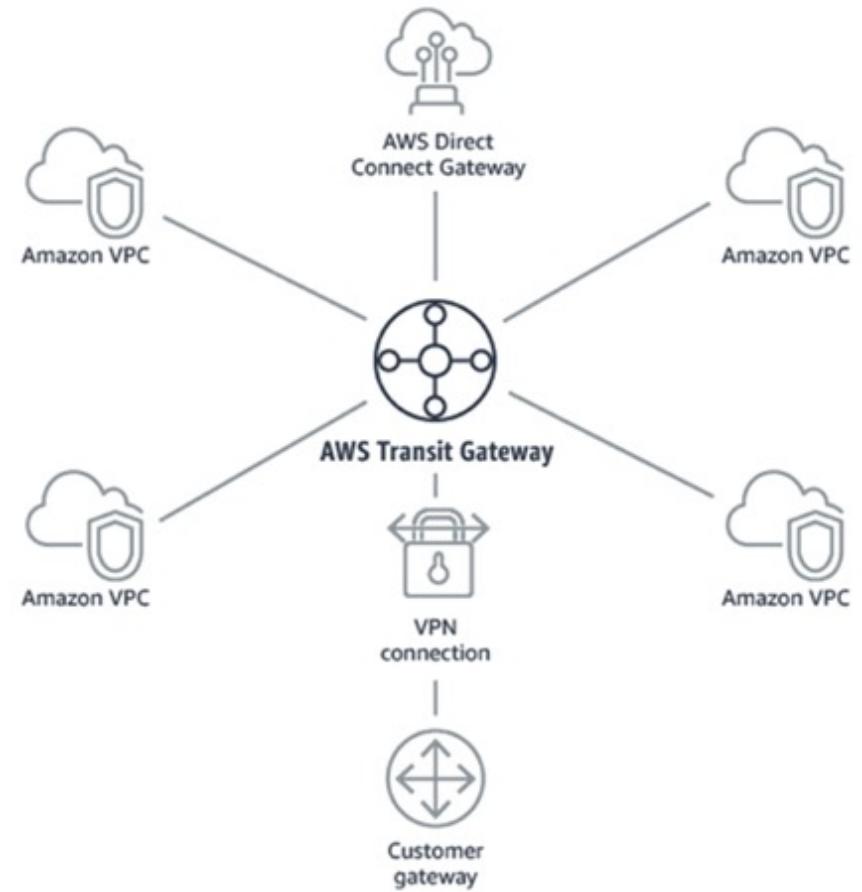
Network topologies can become complicated



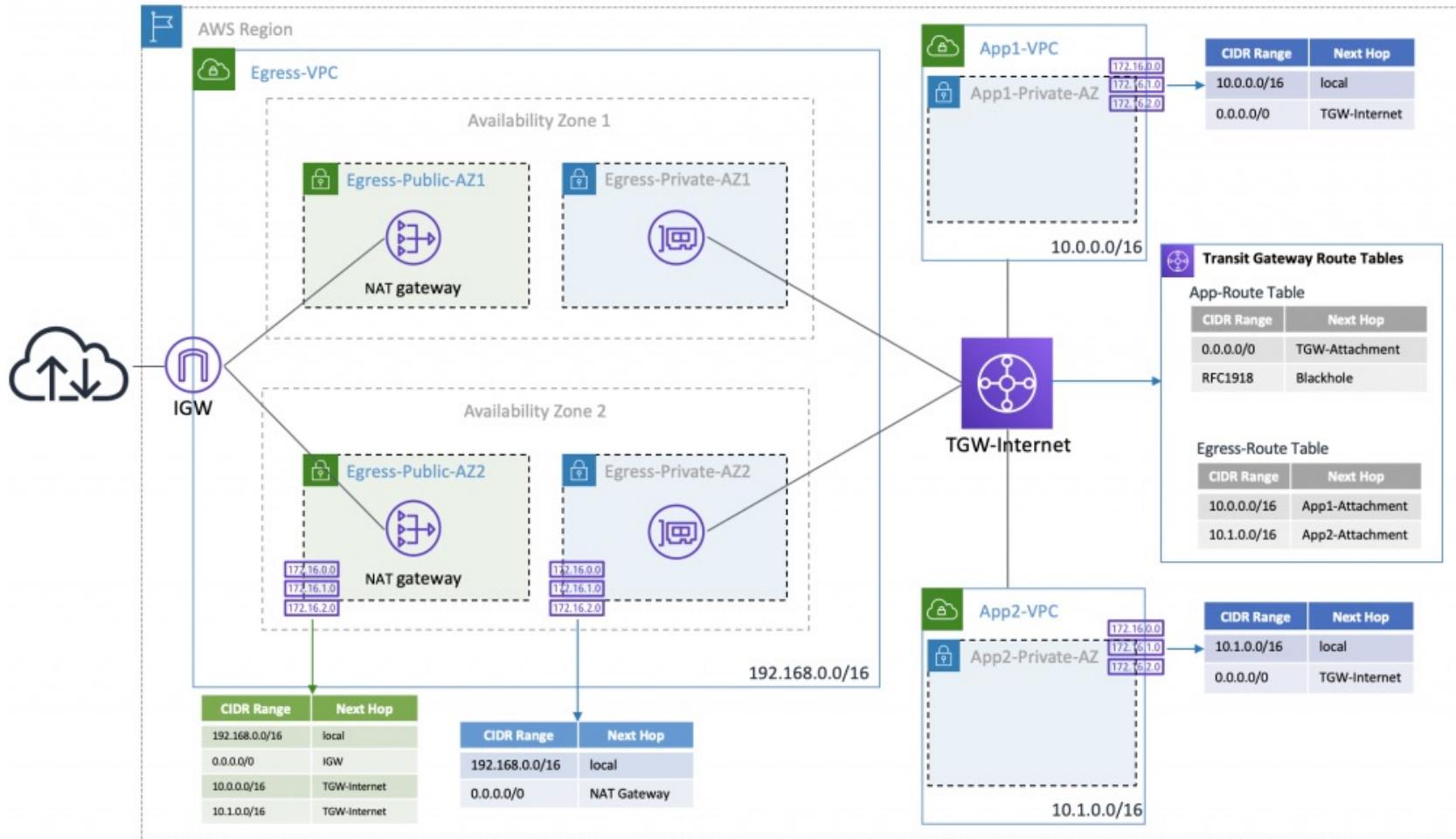
Transit Gateway



- For having transitive peering between thousands of VPC and on-premises, hub-and-spoke (star) connection
- Regional resource, can work cross-region
- Share cross-account using Resource Access Manager (RAM)
- You can peer Transit Gateways across regions
- Route Tables: limit which VPC can talk with other VPC
- Works with Direct Connect Gateway, VPN connections
- Supports IP Multicast (not supported by any other AWS service)
- Instances in a VPC can access a NAT Gateway, NLB, PrivateLink, and EFS in other VPCs attached to the AWS Transit Gateway.



Transit Gateway – Central NAT Gateway

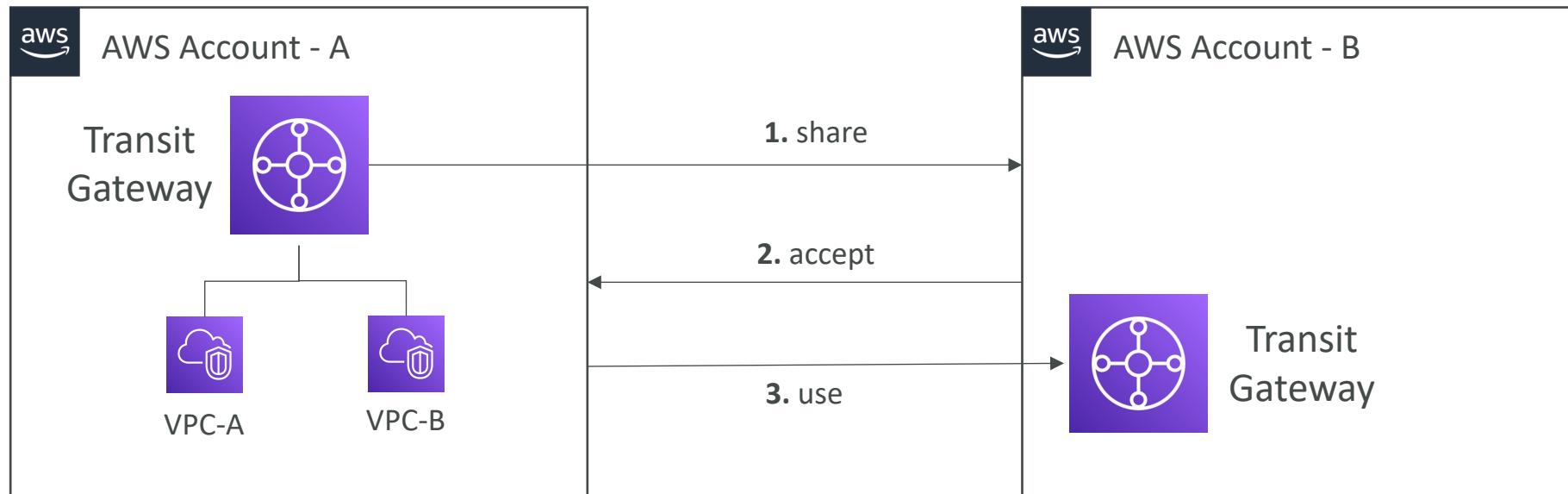


- The NAT Gateway is shared in the Egress-VPC
- The private App VPC can access internet through the TGW
- In this example: the App VPCs cannot communicate with each other based on the TGW route table

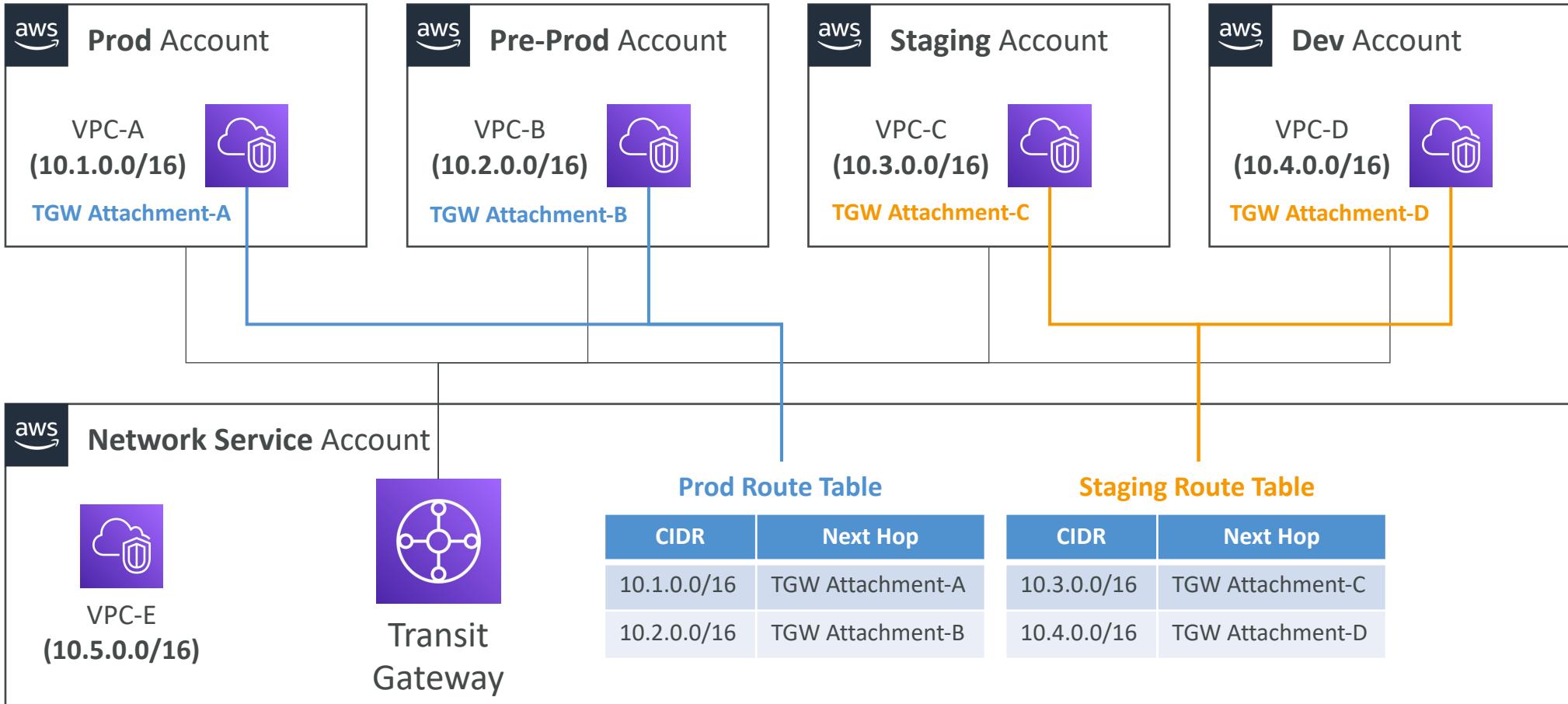
<https://aws.amazon.com/blogs/networking-and-content-delivery/creating-a-single-internet-exit-point-from-multiple-vpcs-using-aws-transit-gateway/>

Transit Gateway – Sharing through RAM

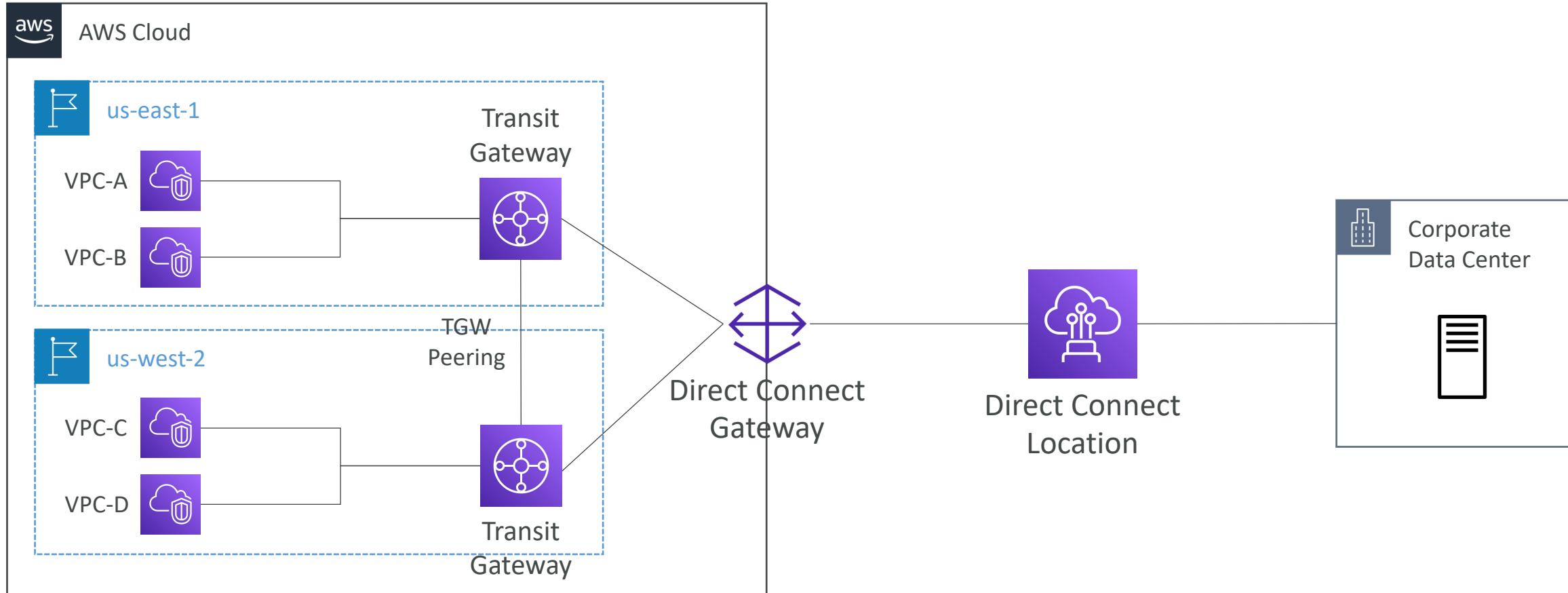
- You can use AWS RAM to share a Transit Gateway for VPC attachments across accounts or across AWS Organization



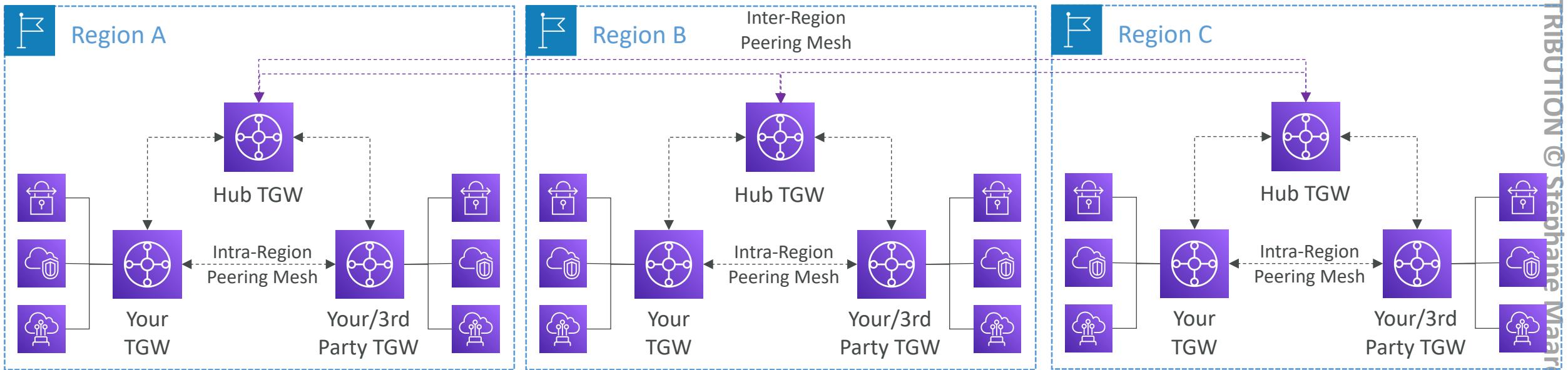
Transit Gateway – Use Different Route Tables to Prevent VPC from Communicating



Transit Gateway to Direct Connect Gateway



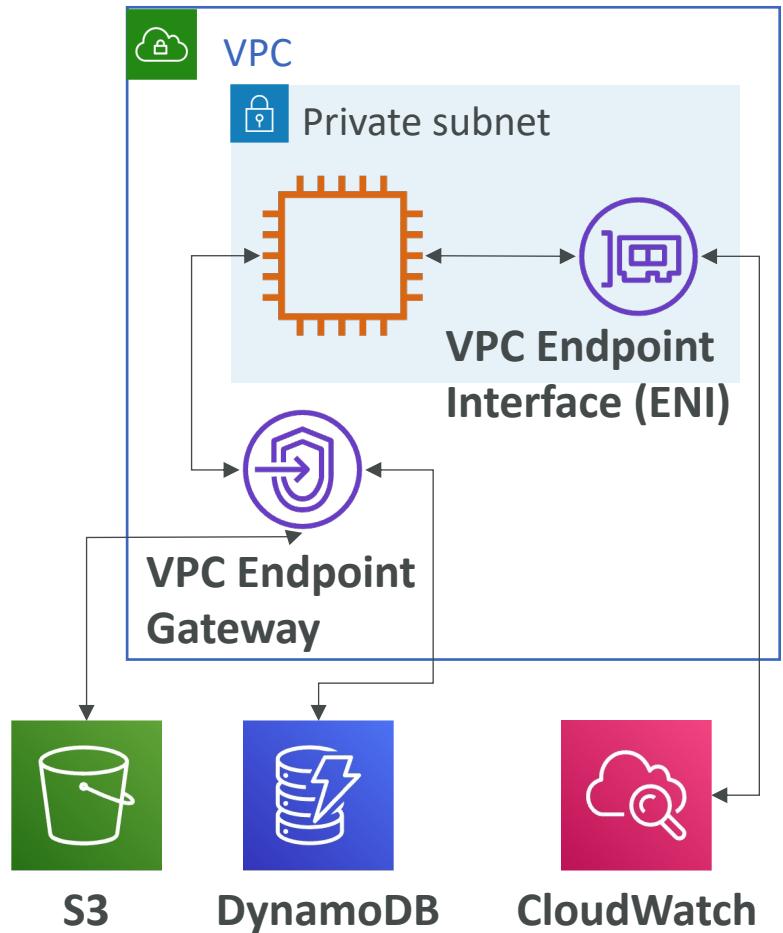
Transit Gateway – Inter & Intra Region Peering



- Billed hourly for each peering attachment, no data processing charges
- If data goes cross-region through the attachment, standard charges
- Specify the Transit Gateway ID

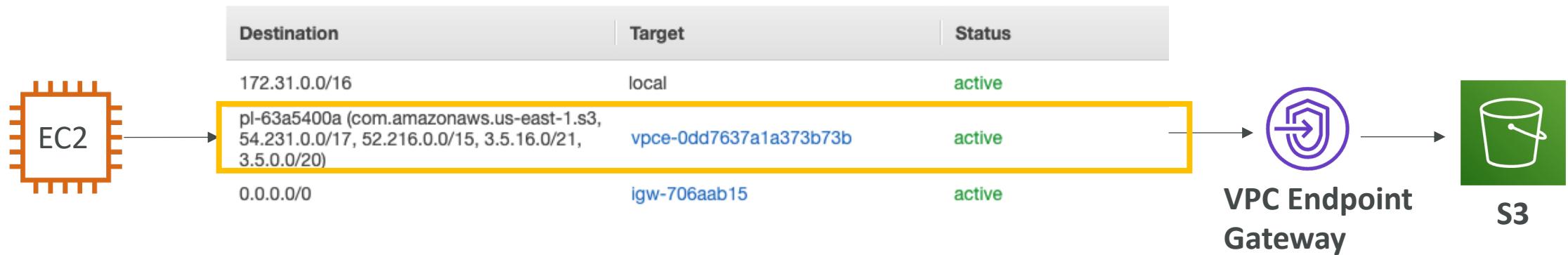
VPC Endpoints

- Endpoints allow you to connect to AWS Services using a private network instead of the public www network
- They scale horizontally and are redundant
- No more IGW, NAT, etc... to access AWS Services
- VPC Endpoint Gateway (S3 & DynamoDB)
- VPC Endpoint Interface (all except DynamoDB)
- In case of issues:
 - Check DNS Setting Resolution in your VPC
 - Check Route Tables



VPC Endpoint Gateway

- Only works for S3 and DynamoDB, must create one gateway per VPC
- Must update route tables entries
- Gateway is defined at the VPC level



- DNS resolution must be enabled in the VPC
- The same public hostname for S3 can be used
- Gateway endpoint cannot be extended out of a VPC (VPN, DX, TGW, peering)

VPC Endpoints Interface

- Provision an ENI that will have a private endpoint interface hostname
- Leverage Security Groups for security
- Private DNS (setting when you create the endpoint)
 - The public hostname of a service will resolve to the private Endpoint Interface hostname
 - VPC Setting: “Enable DNS hostnames” and “Enable DNS Support” must be ‘true’
 - Example for Athena:
 - vpce-0b7d2995e9dfe5418-mwrths3x.athena.us-east-1.vpce.amazonaws.com
 - vpce-0b7d2995e9dfe5418-mwrths3x-us-east-1a.athena.us-east-1.vpce.amazonaws.com
 - vpce-0b7d2995e9dfe5418-mwrths3x-us-east-1b.athena.us-east-1.vpce.amazonaws.com
 - athena.us-east-1.amazonaws.com (private DNS name)
- Interface can be accessed from Direct Connect and Site-to-Site VPN

VPC Endpoint Policies

- Endpoint Policies are JSON documents to control access to services
- Does not override or replace IAM user policies or service-specific policies (such as S3 bucket policies)

```
{  
  "Statement": [  
    {"Action": ["sns:Publish"],  
     "Effect": "Allow",  
     "Resource": "arn:aws:sns:us-east-2:123456789012:MyTopic",  
     "Principal": "  
       "AWS": "arn:aws:iam:123456789012:user/MyUser"  
     }  
   ]  
}
```

- **Note:** the IAM user can still use other SQS API from outside the VPC Endpoint
- You could add an SQS queue policy to deny any action not done through the VPC endpoint

VPC Endpoint Policy & S3 bucket policy

- VPC Endpoint Policy to restrict access to bucket “my_secure_bucket”

```
{  
  "Statement": [  
    {  
      "Sid": "Access-to-specific-bucket-only",  
      "Principal": "*",  
      "Action": [  
        "s3:GetObject",  
        "s3:PutObject"  
      ],  
      "Effect": "Allow",  
      "Resource": ["arn:aws:s3:::my_secure_bucket",  
                  "arn:aws:s3:::my_secure_bucket/*"]  
    }  
  ]  
}
```

VPC Endpoint Policy & S3 bucket policy

- VPC Endpoint Policy to allow access to Amazon Linux 2 repositories

```
{  
  "Statement": [  
    {  
      "Sid": "AmazonLinux2AMIRRepositoryAccess",  
      "Principal": "*",  
      "Action": [  
        "s3:GetObject"  
      ],  
      "Effect": "Allow",  
      "Resource": [  
        "arn:aws:s3:::amazonlinux.*.amazonaws.com/*"  
      ]  
    }  
  ]  
}
```

VPC Endpoint Policy & S3 bucket policy

- S3 bucket policy may have
 - Condition: "aws:sourceVpce": "vpce-1a2b3c4d" to Deny any traffic that doesn't come from a specific VPC endpoint (more secure)
 - Condition: "aws:sourceVpc": "vpc-111bbb22" for a specific VPC
- The **aws:sourceVpc** condition only works for VPC Endpoints, in case you have multiple endpoints and want to manage access to your S3 buckets for all your endpoints
- The S3 bucket policies can restrict access only from a specific **public** IP address or an elastic IP address. You can't restrict based on private IP
- Therefore aws:SourceIp condition doesn't apply for VPC endpoints

Example S3 bucket policies

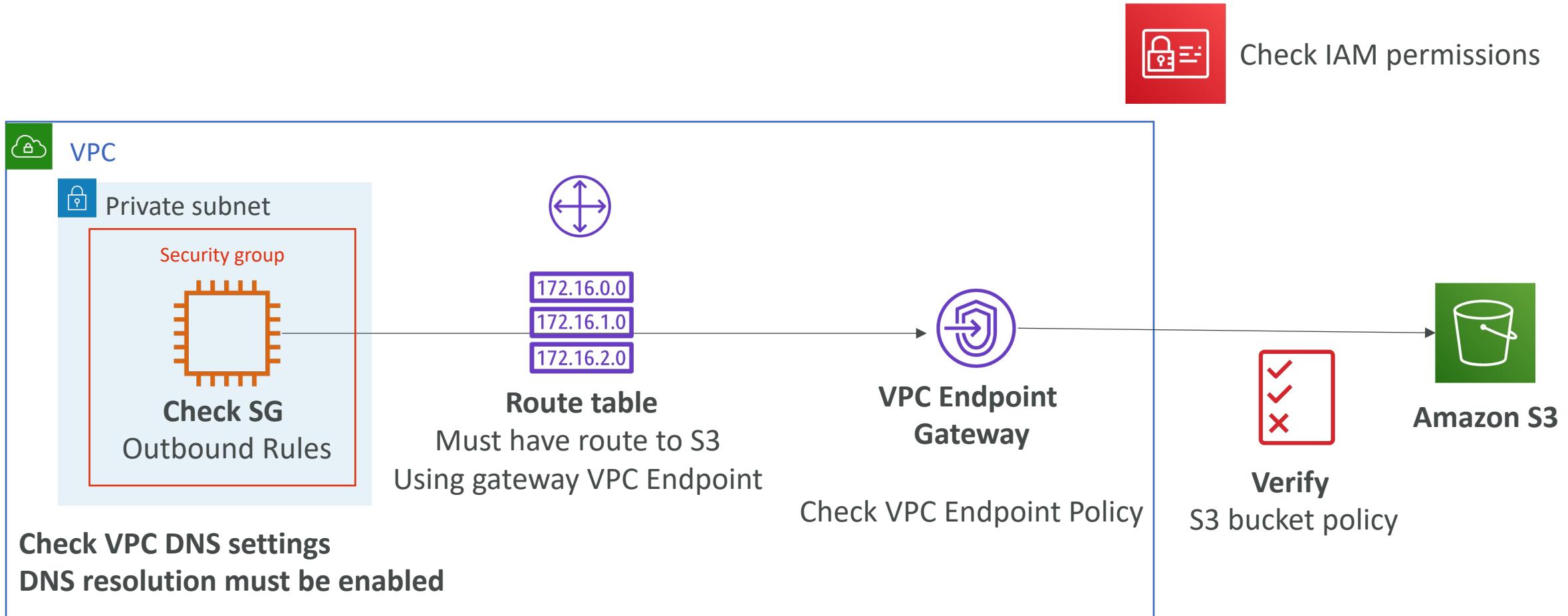
- S3 bucket policy to restrict to one specific VPC Endpoint

```
{  
  "Version": "2012-10-17",  
  "Id": "Policy1415115909152",  
  "Statement": [  
    {  
      "Sid": "Access-to-specific-VPCE-only",  
      "Principal": "*",  
      "Action": "s3:*",  
      "Effect": "Deny",  
      "Resource": ["arn:aws:s3:::my_secure_bucket",  
                  "arn:aws:s3:::my_secure_bucket/*"],  
      "Condition": {  
        "StringNotEquals": {  
          "aws:sourceVpce": "vpce-1a2b3c4d"  
        }  
      }  
    }  
  ]  
}
```

- S3 bucket policy to restrict to an entire VPC (multiple VPC Endpoints)

```
{  
  "Version": "2012-10-17",  
  "Id": "Policy1415115909152",  
  "Statement": [  
    {  
      "Sid": "Access-to-specific-VPCE-only",  
      "Principal": "*",  
      "Action": "s3:*",  
      "Effect": "Deny",  
      "Resource": ["arn:aws:s3:::my_secure_bucket",  
                  "arn:aws:s3:::my_secure_bucket/*"],  
      "Condition": {  
        "StringNotEquals": {  
          "aws:sourceVpc": "vpc-111bbb22"  
        }  
      }  
    }  
  ]  
}
```

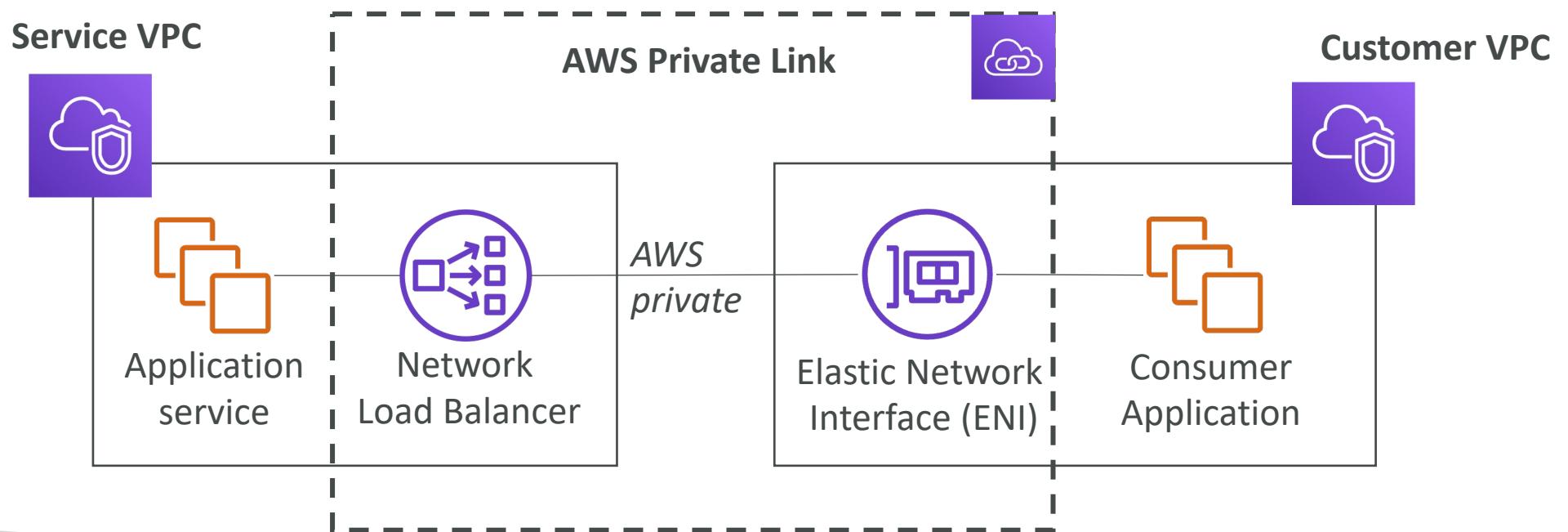
VPC Endpoint Policies for S3 Troubleshooting



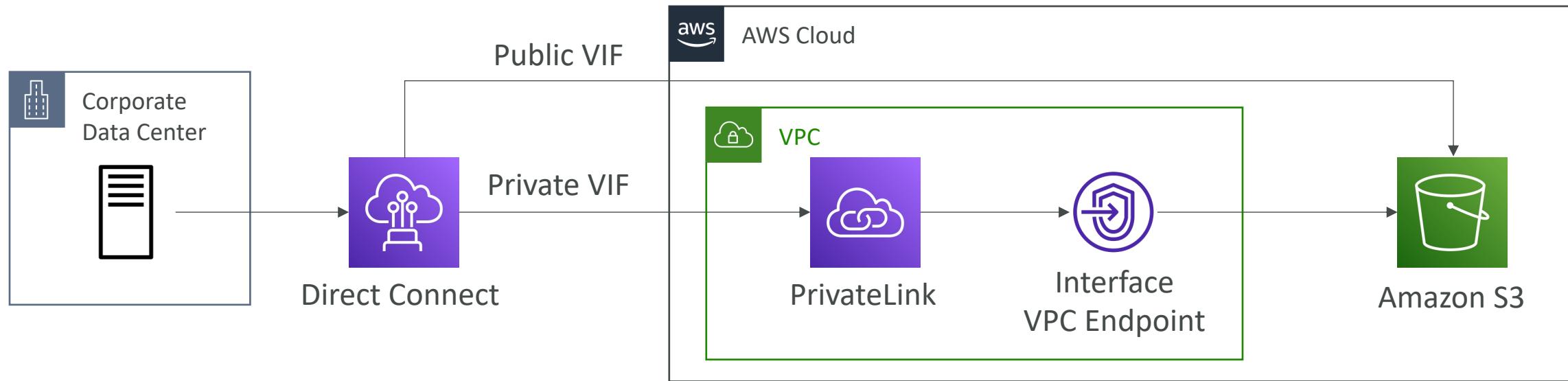
AWS PrivateLink (VPC Endpoint Services)



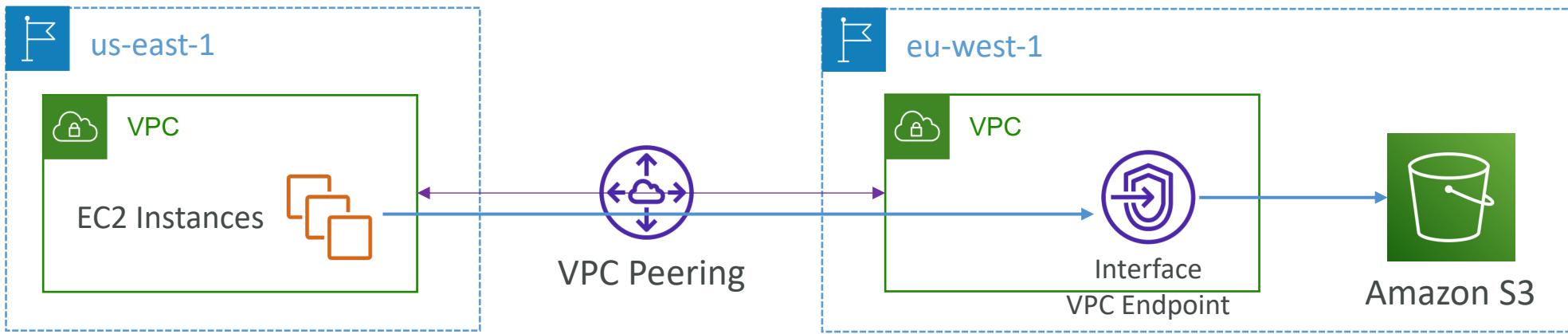
- Most secure & scalable way to expose a service to 1000s of VPC (own or other accounts)
- Does not require VPC peering, internet gateway, NAT, route tables...
- Requires a network load balancer (Service VPC) and ENI (Customer VPC)
- If the NLB is in multiple AZ, and the ENI in multiple AZ, the solution is fault tolerant!



PrivateLink for Amazon S3 with Direct Connect



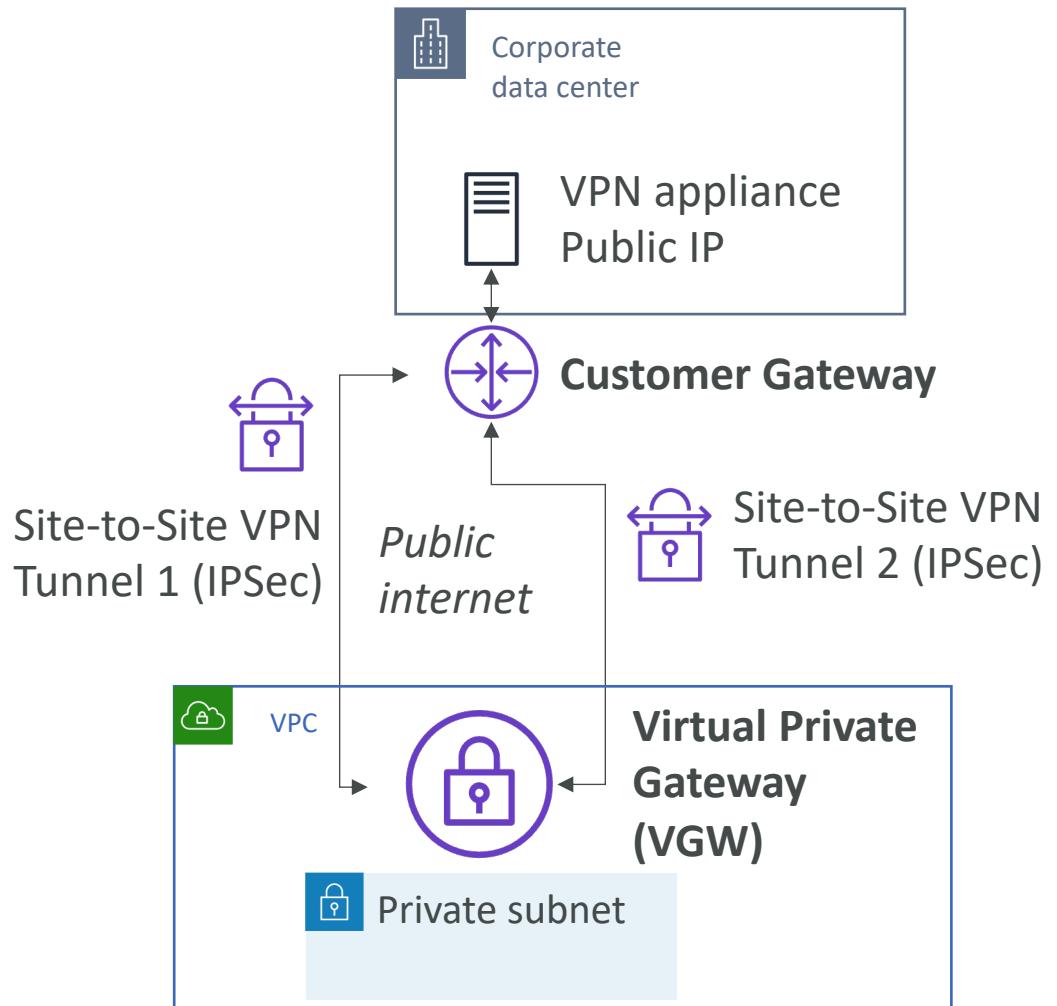
VPC Endpoints / PrivateLink and VPC Peering



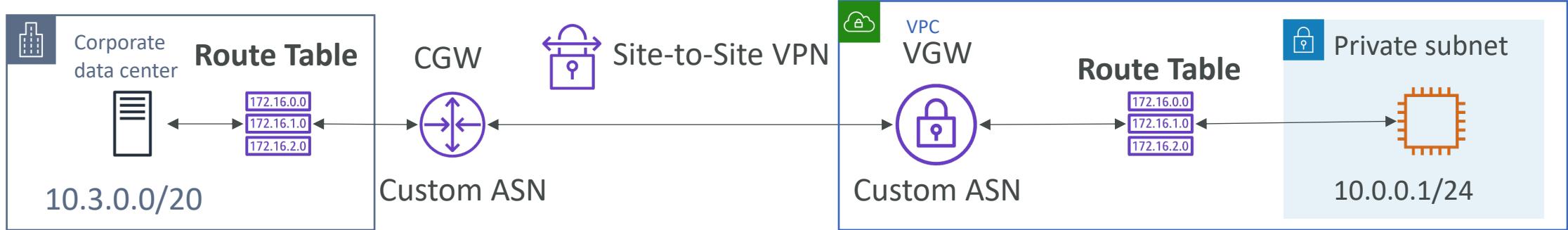
Site to Site VPN (AWS Managed VPN)



- **on-premises:**
 - Setup a software or hardware VPN appliance to your on-premises network.
 - The on-premises VPN should be accessible using a public IP
- **AWS-side:**
 - Setup a Virtual Private Gateway (VGW) and attach to your VPC
 - Setup a Customer Gateway to point the on-premises VPN appliance
- Two VPN connections (tunnels) are created for redundancy, encrypted using IPSec
- Can optionally accelerate it using Global Accelerator (for worldwide networks)



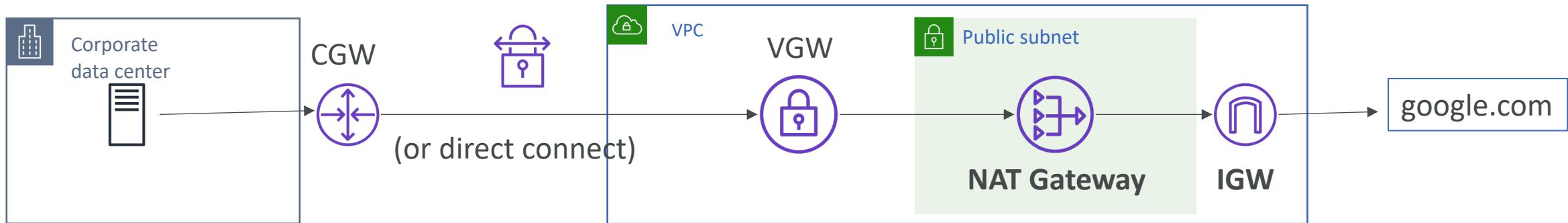
Route Propagation in Site-to-Site VPN



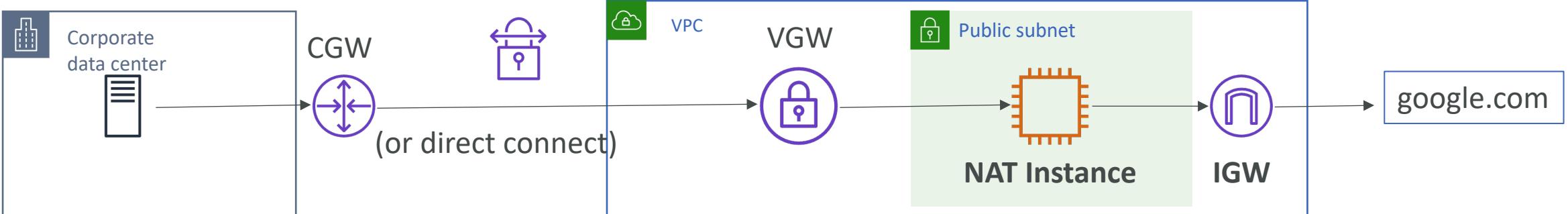
- **Static Routing:**
 - Create static route in corporate data center for 10.0.0.1/24 through the CGW
 - Create static route in AWS for 10.3.0.0/20 through the VGW
- **Dynamic Routing (BGP):**
 - Uses BGP (Border Gateway Protocol) to share routes automatically (eBGP for internet)
 - We don't need to update the routing tables, it will be done for us dynamically
 - Just need to specify the ASN (Autonomous System Number) of the CGW and VGW

Site to Site VPN and Internet Access

- NOT OKAY (blocked by NAT Gateway restrictions)

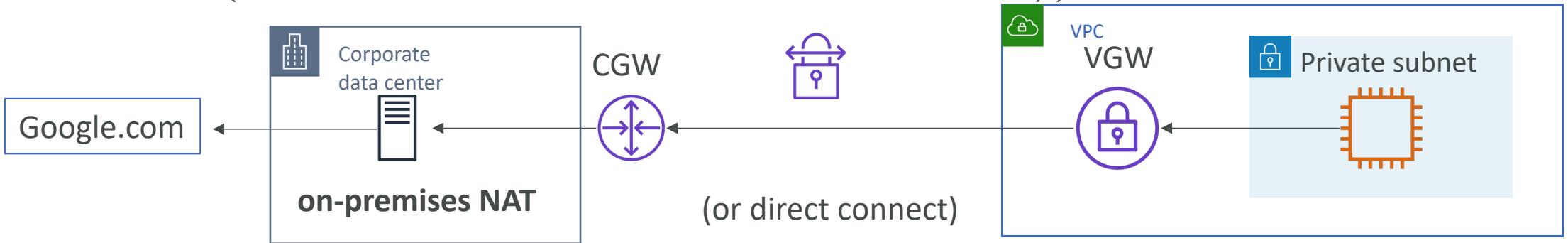


- OKAY (self managed NAT Instance – more control)



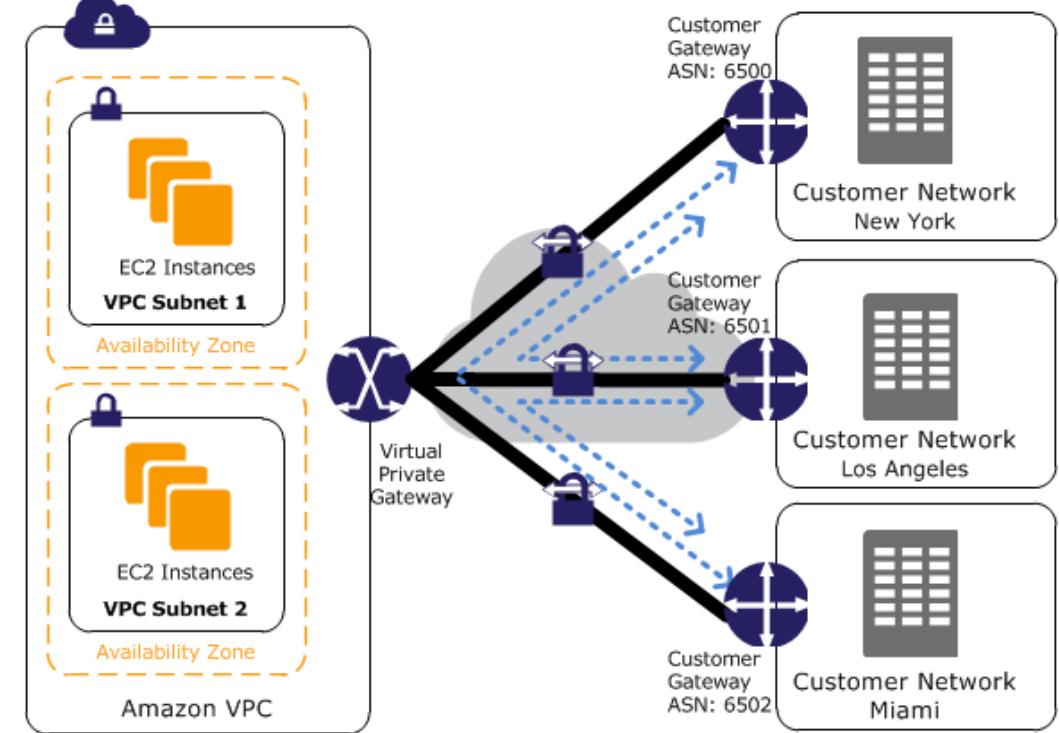
Site to Site VPN and Internet Access

- **OKAY** (alternative to NAT Instances / Gateway)



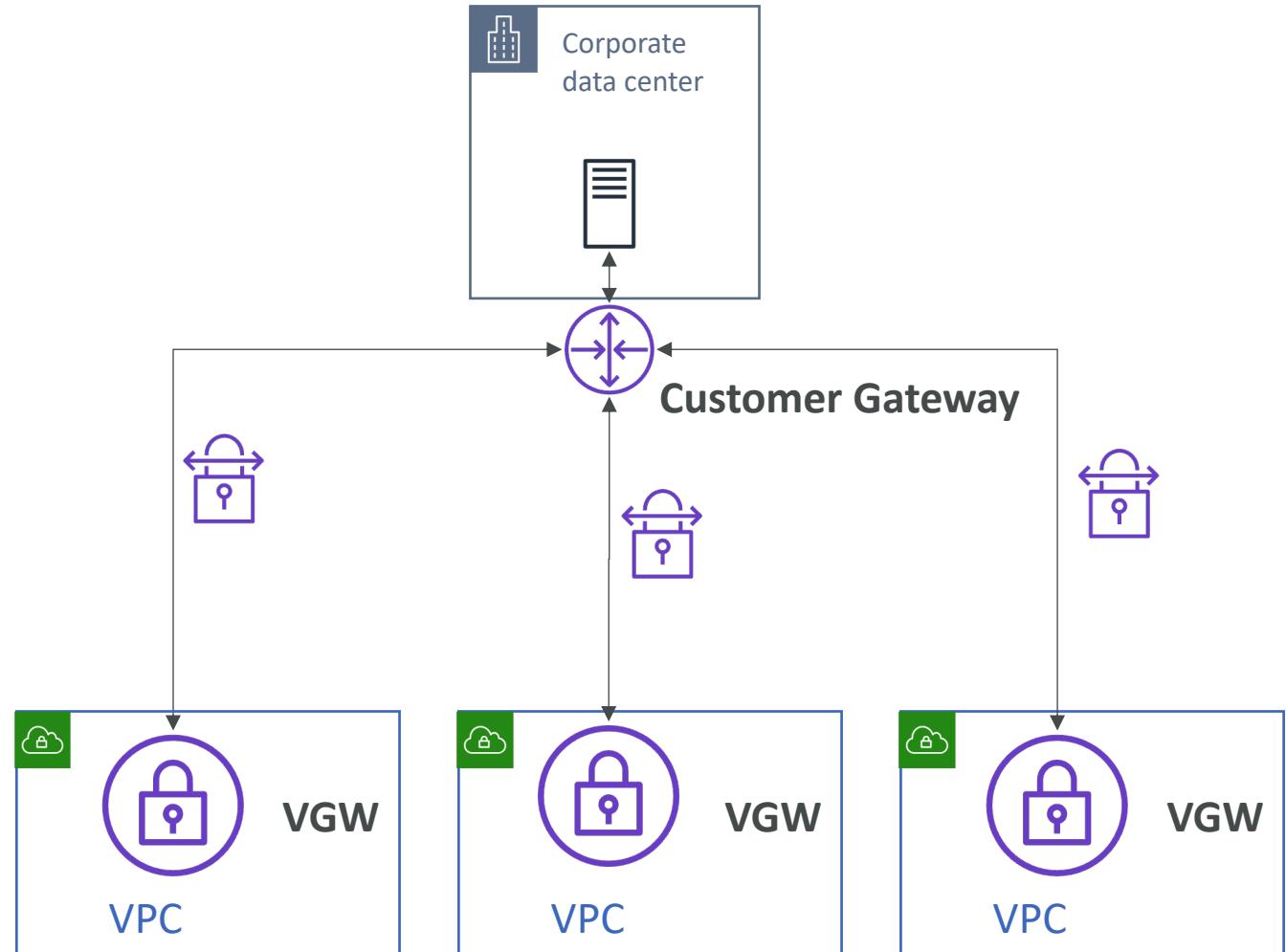
AWS VPN CloudHub

- Can connect up to 10 Customer Gateway for each Virtual Private Gateway (VGW)
- Low cost hub-and-spoke model for primary or secondary network connectivity between locations
- Provide secure communication between sites, if you have multiple VPN connections
- It's a VPN connection so it goes over the public internet
- Can be a **failover connection** between your on-premises locations



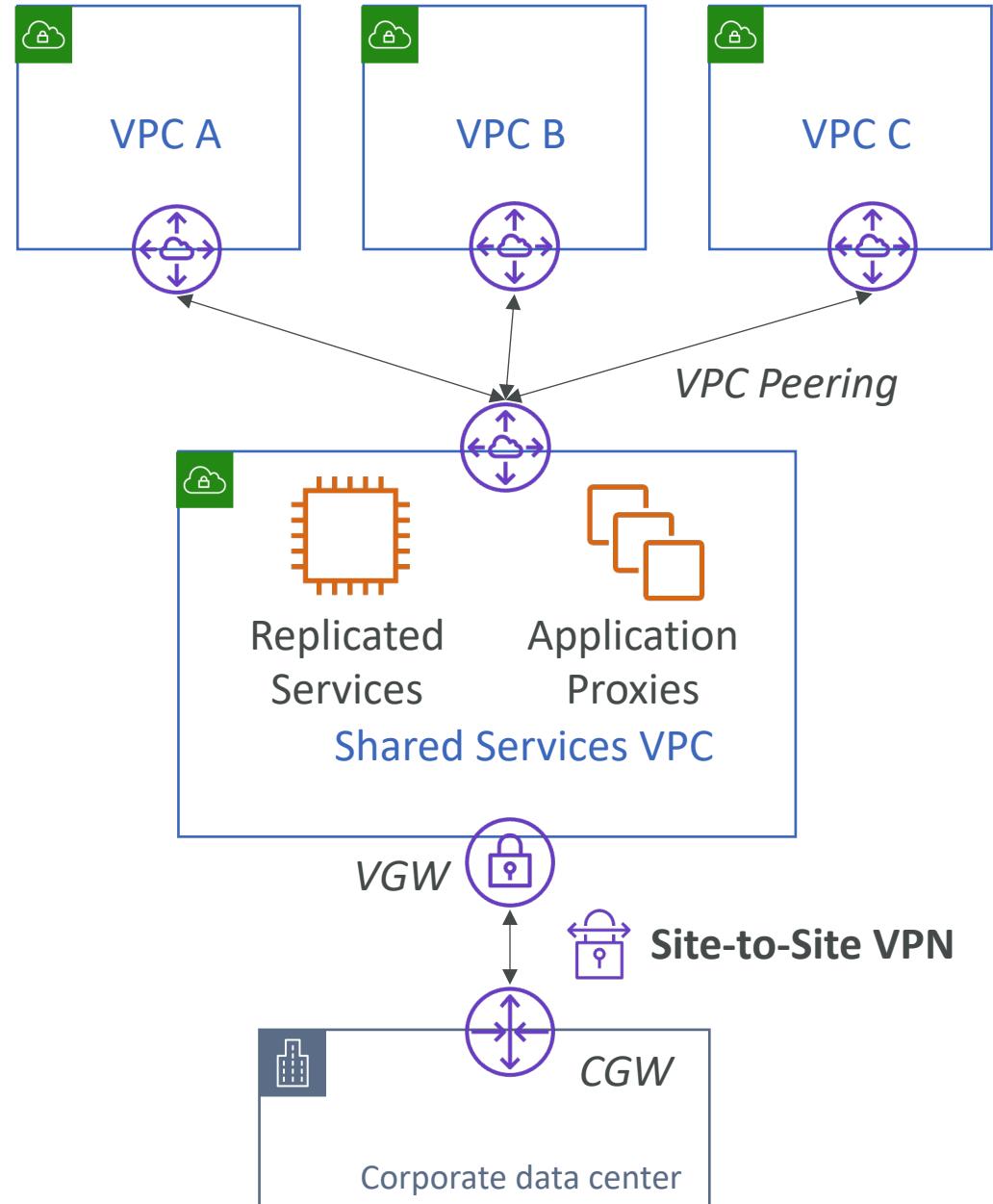
VPN to multiple VPC

- For VPN-based customers, AWS recommends creating a separate VPN connection for each customer VPC.
- Direct Connect is recommended because it has a Direct Connect Gateway



Shared Services VPC

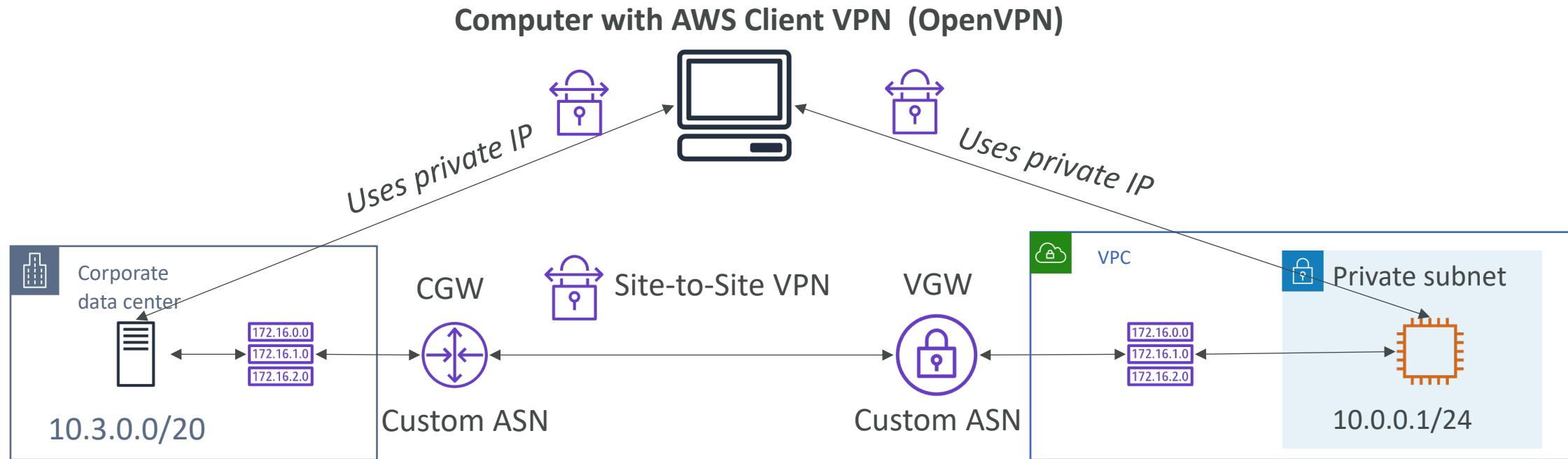
- Create a VPN connection between on-premises and shared service VPC
- Replicate services, applications, databases between on-premises and the Shared Services VPC or deploy proxies in the shared service VPC
- Do VPC peering between the VPC and the shared service VPC
- VPCs can directly access the Shared Service VPC services and do not need VPN connections to on-premises



AWS Client VPN

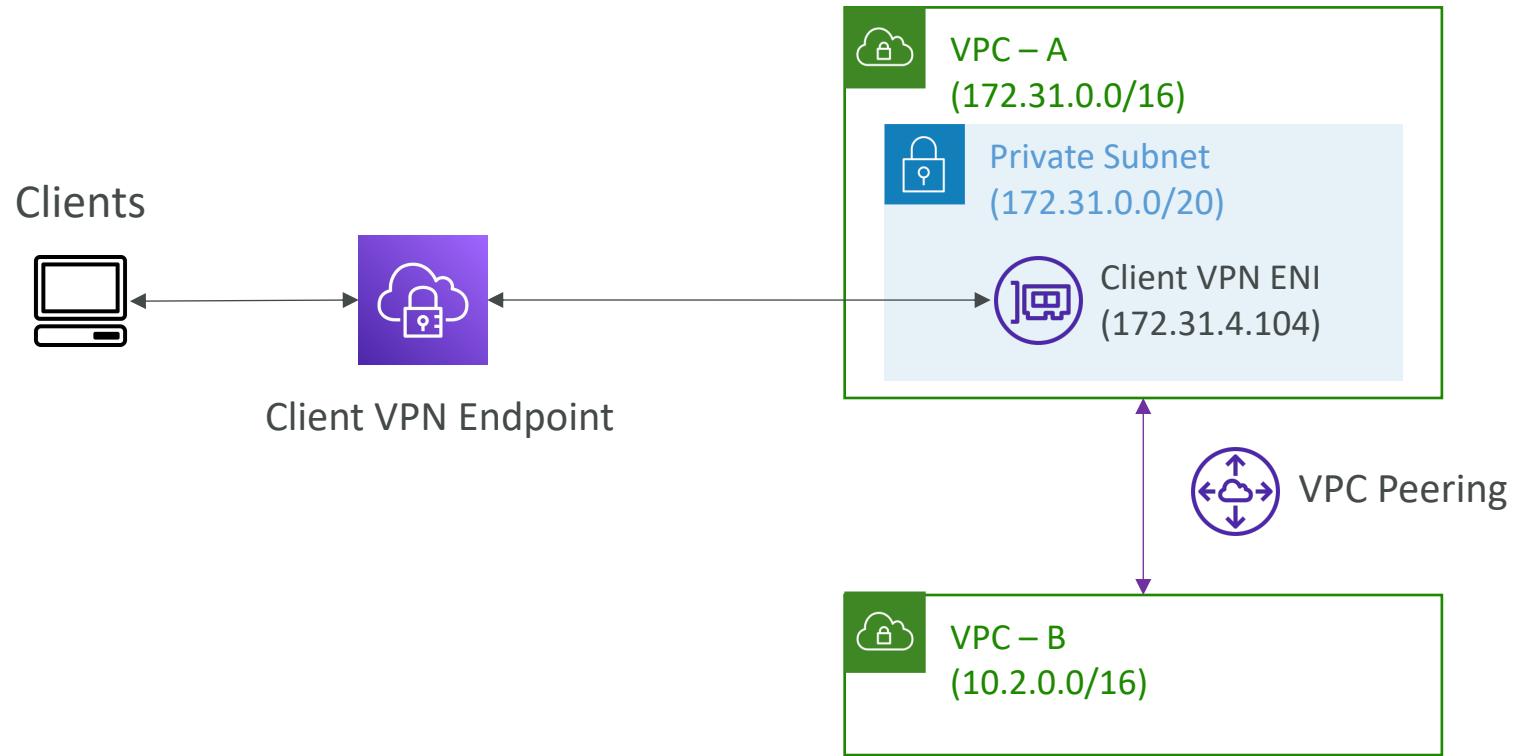


- Connect from your computer using OpenVPN to your private network in AWS and on-premises



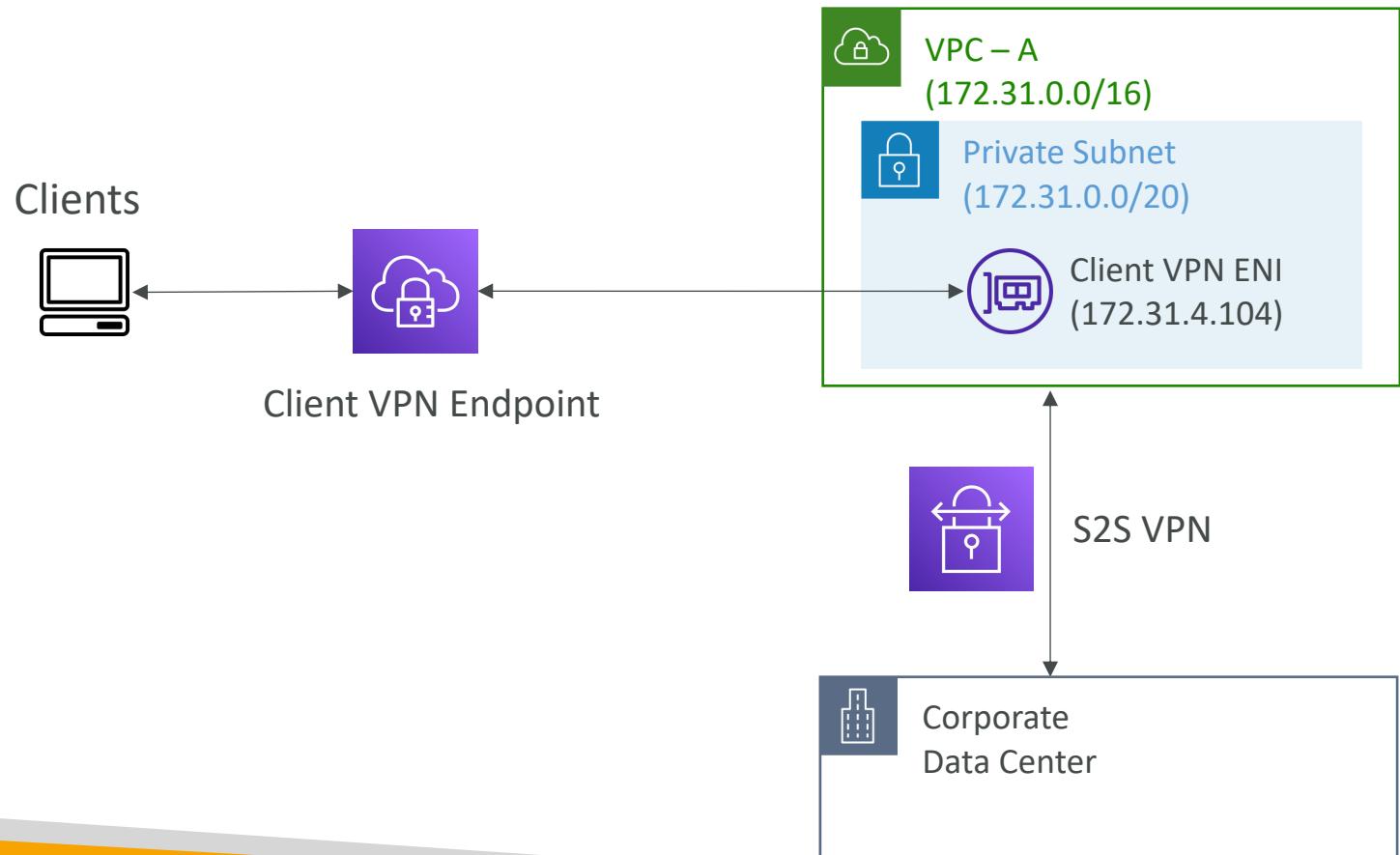
Client VPN – Peered VPC

- Client VPN is compatible with VPC peering

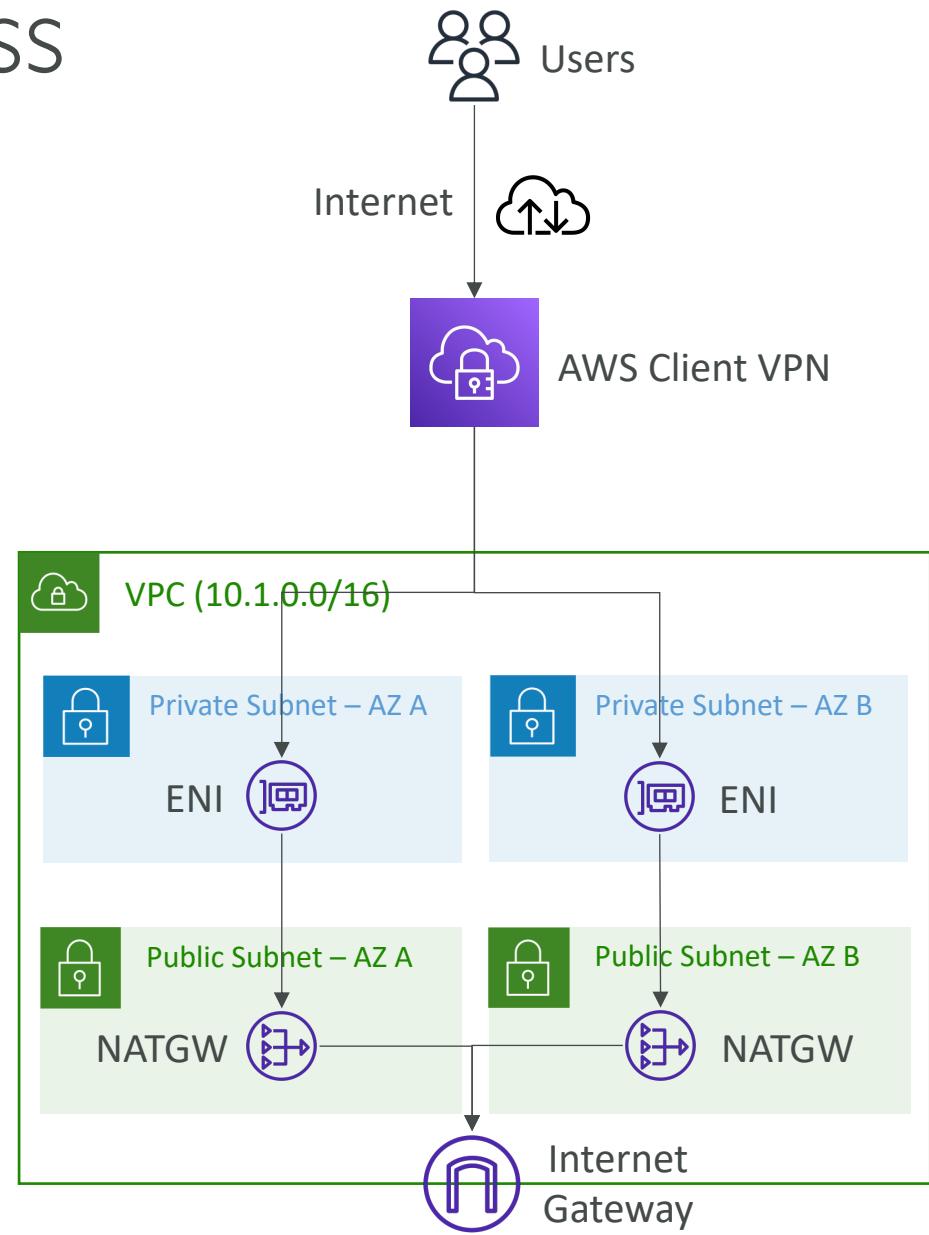
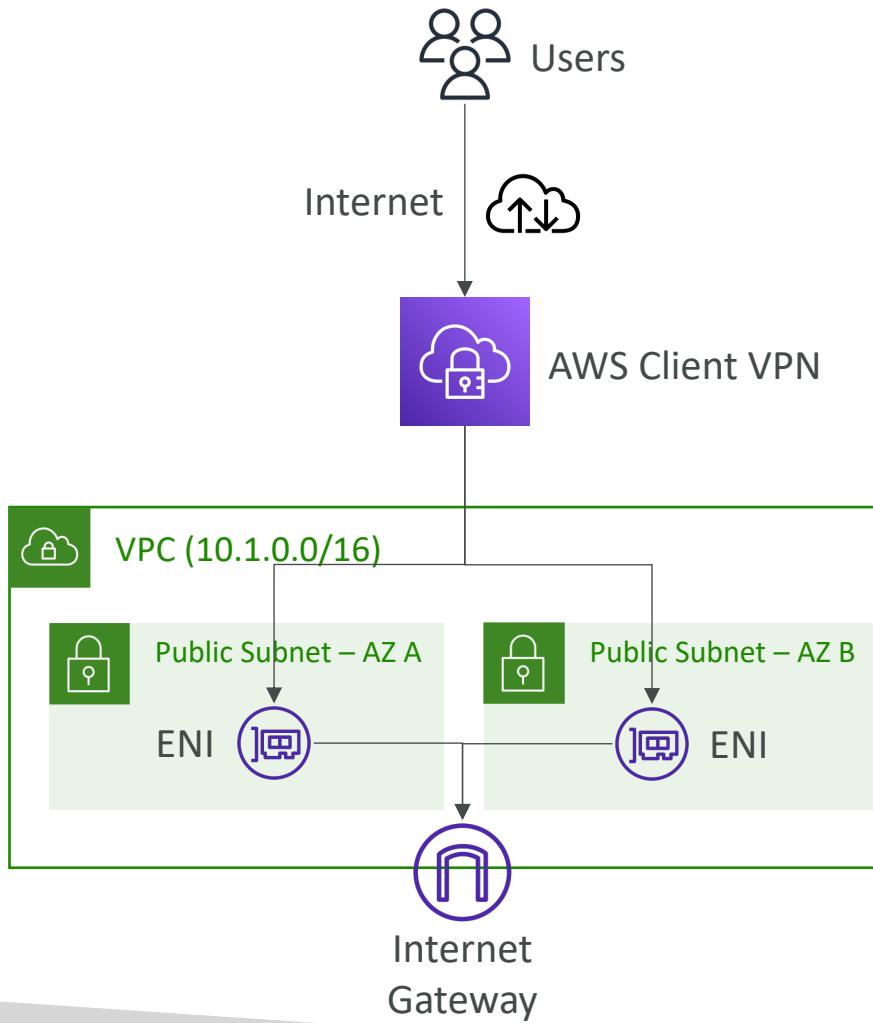


Client VPN – Access to On-Premises

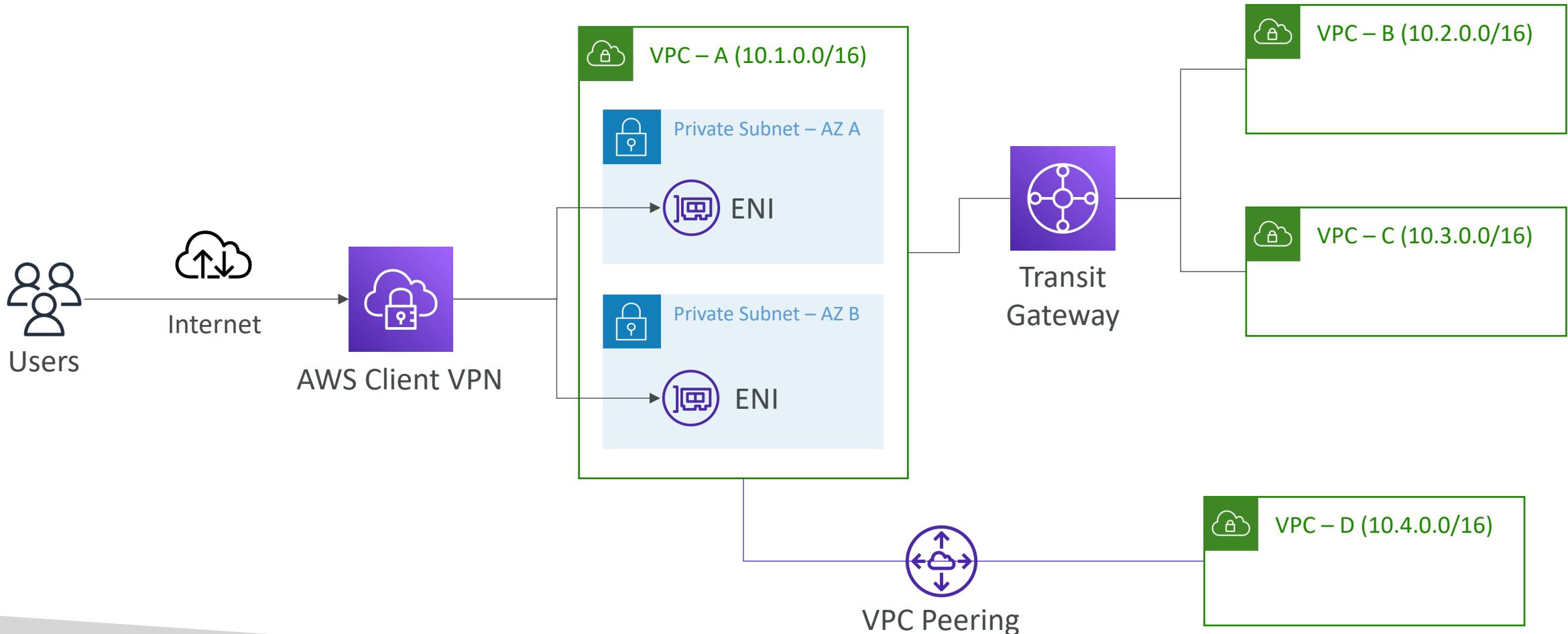
- Access On-Premises resources through AWS with Client VPN



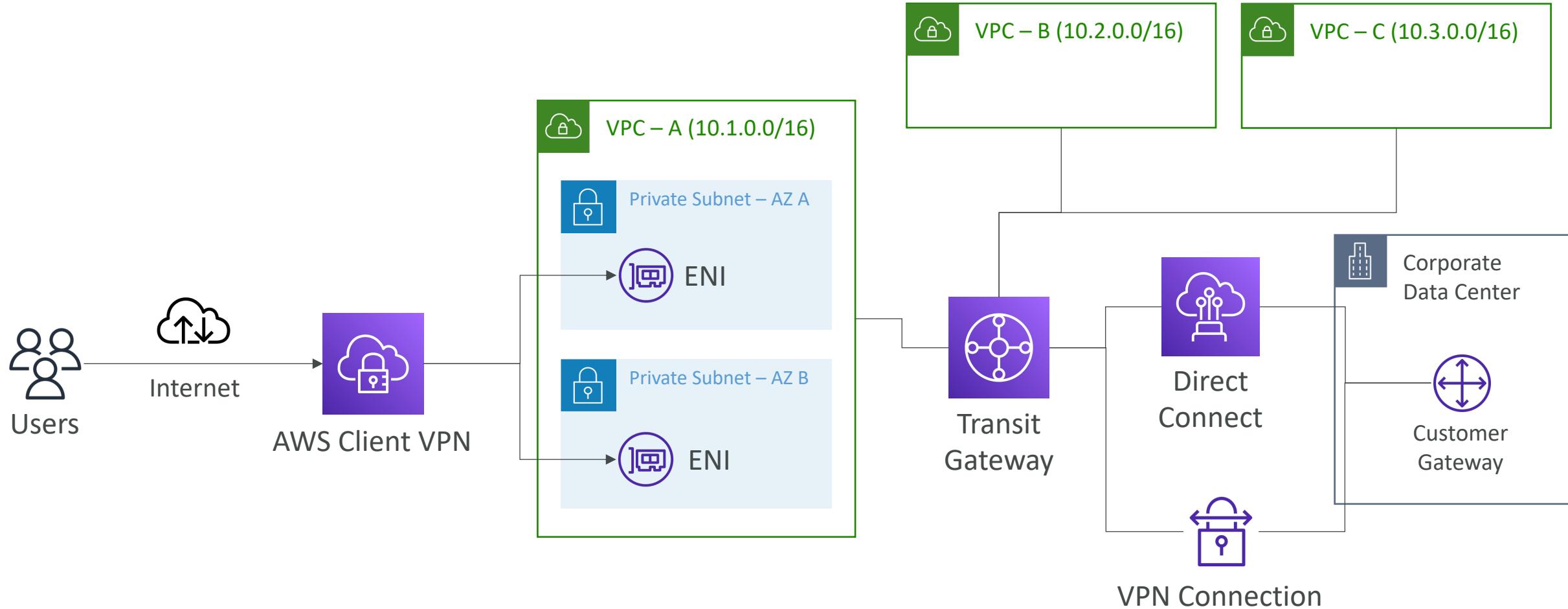
Client VPN – Internet Access



Client VPN – Transit Gateway



Client VPN – Transit Gateway



Direct Connect

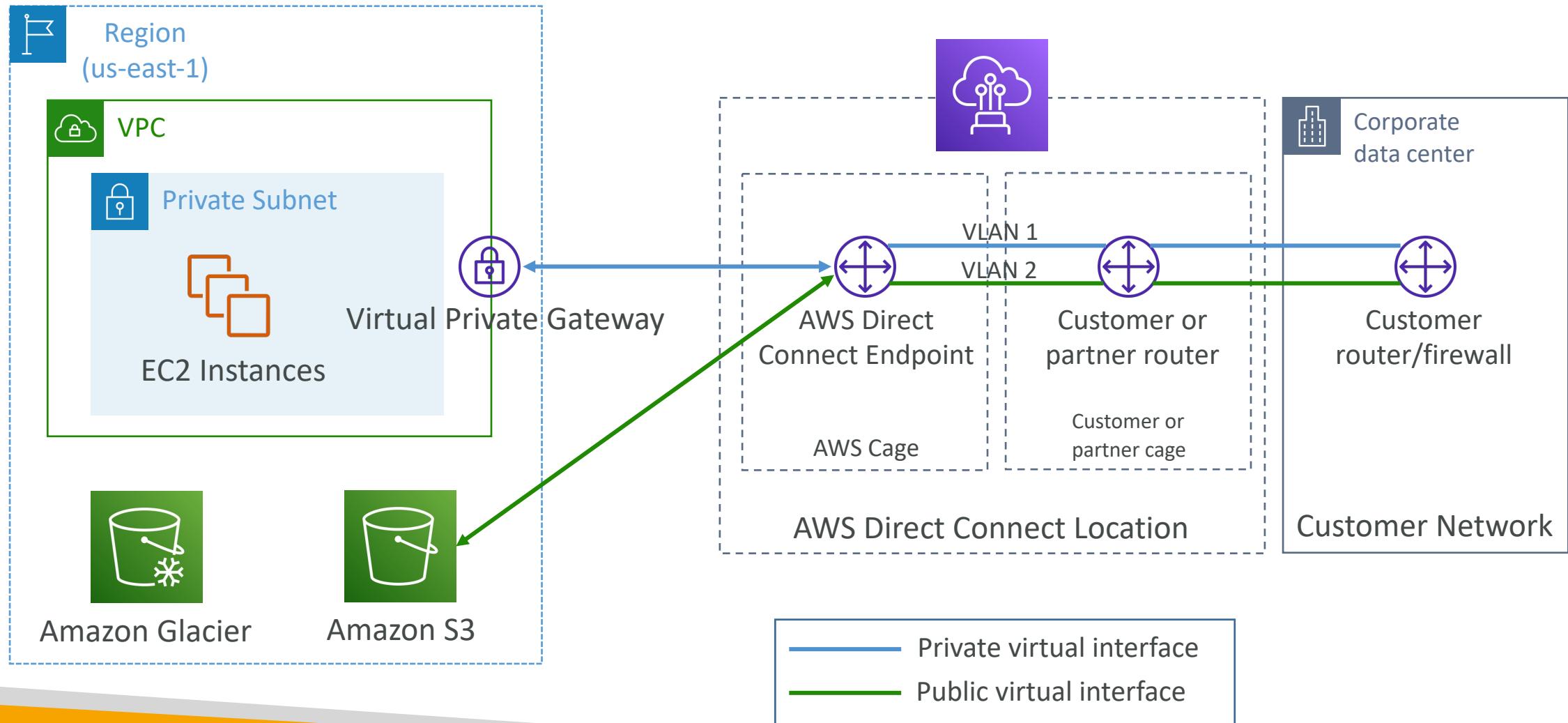


- Provides a dedicated private connection from a remote network to your VPC
- Dedicated connection must be setup between your DC and AWS Direct Connect locations
- More expensive than running a VPN solution
- Private access to AWS services through VIF
- Bypass ISP, reduce network cost, increase bandwidth and stability
- Not redundant by default (must setup a failover DX or VPN)

Direct Connect – Virtual Interfaces (VIF)

- Public VIF – connect to Public AWS Endpoints (S3 buckets, EC2 service, anything AWS ...)
- Private VIF – connect to resources in your VPC (EC2 instances, ALB, ...)
- Transit Virtual Interface – connect to resources in a VPC using a Transit Gateway
- VPC Interface Endpoints can be accessed through Private VIF

Direct Connect Diagram

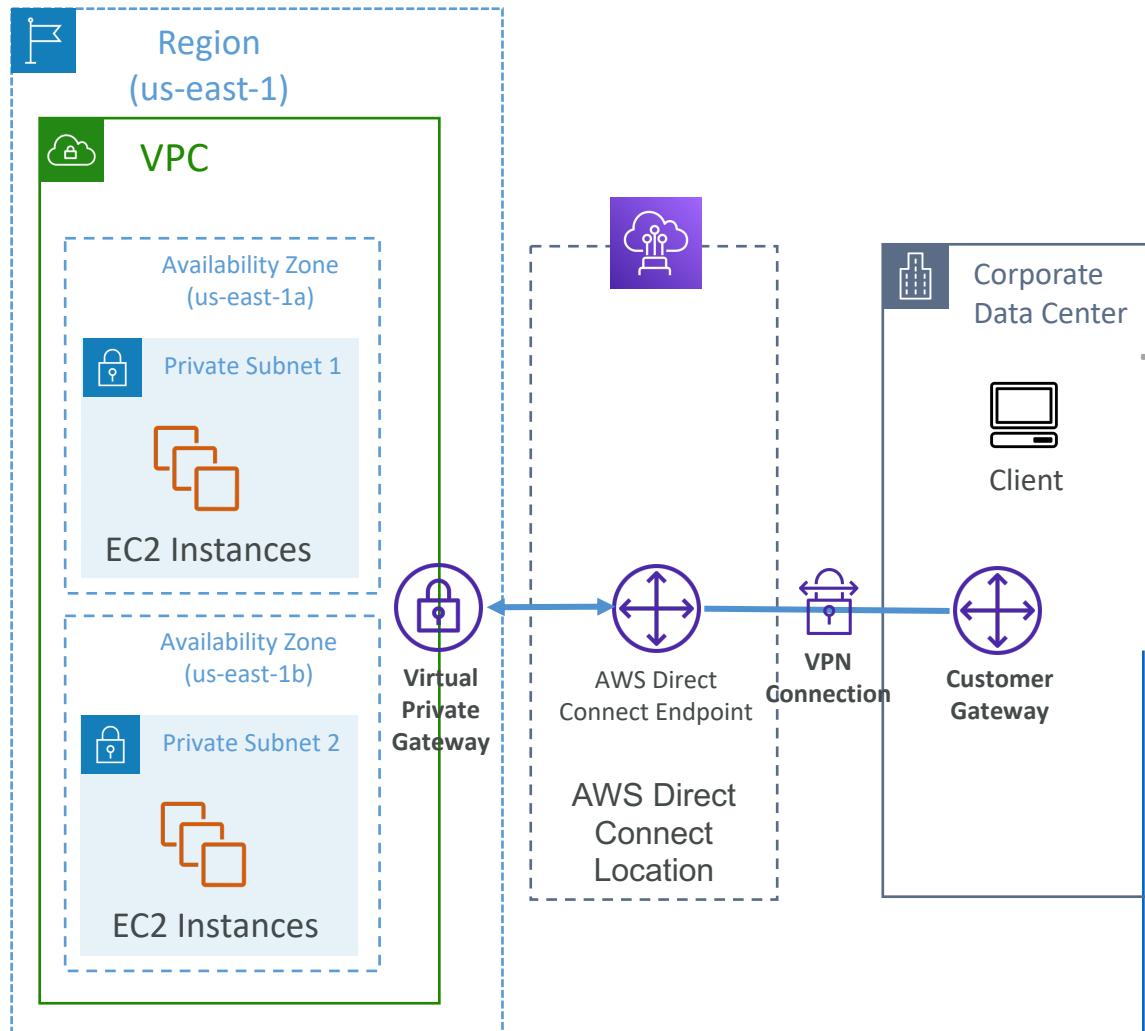


Direct Connect – Connection Types

- **Dedicated Connections:** 1 Gbps, 10 Gbps, 100 Gbps capacity
 - Physical ethernet port dedicated to a customer
 - Request made to AWS first, then completed by AWS Direct Connect Partners
- **Hosted Connections:** 50Mbps, 500 Mbps, to 10 Gbps
 - Connection requests are made via AWS Direct Connect Partners
 - Capacity can be **added or removed on demand**
 - 1, 2, 5, 10 Gbps available at select AWS Direct Connect Partners
- Lead times are often longer than 1 month to establish a new connection

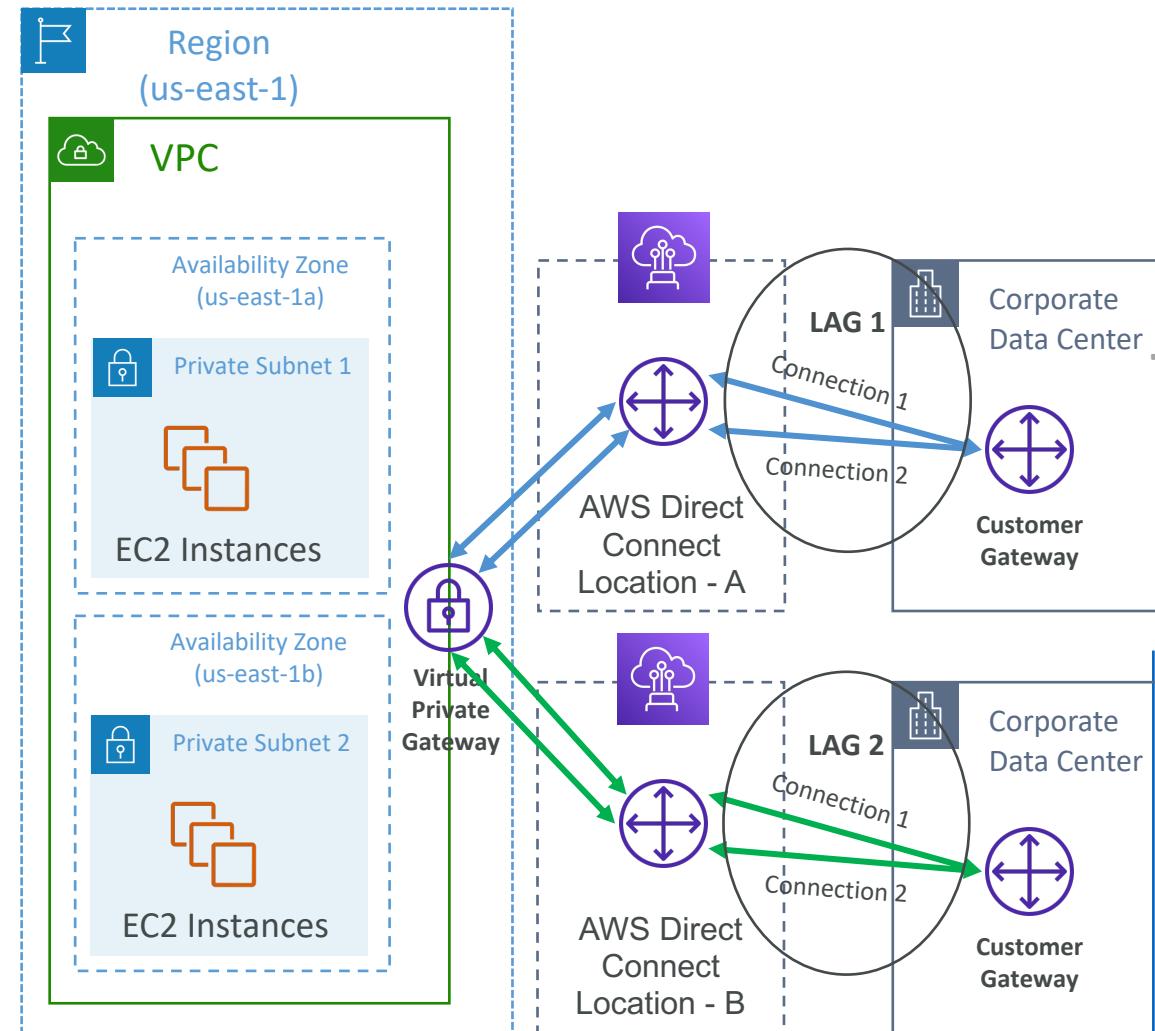
Direct Connect – Encryption

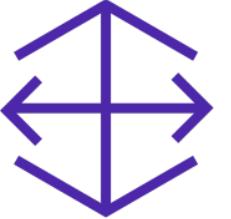
- Data in transit is not encrypted but is private
- AWS Direct Connect + VPN provides an IPsec-encrypted private connection
- VPN over Direct Connect connection Uses Public VIF
- Good for an extra level of security, but slightly more complex to put in place



Direct Connect – Link Aggregation Groups (LAG)

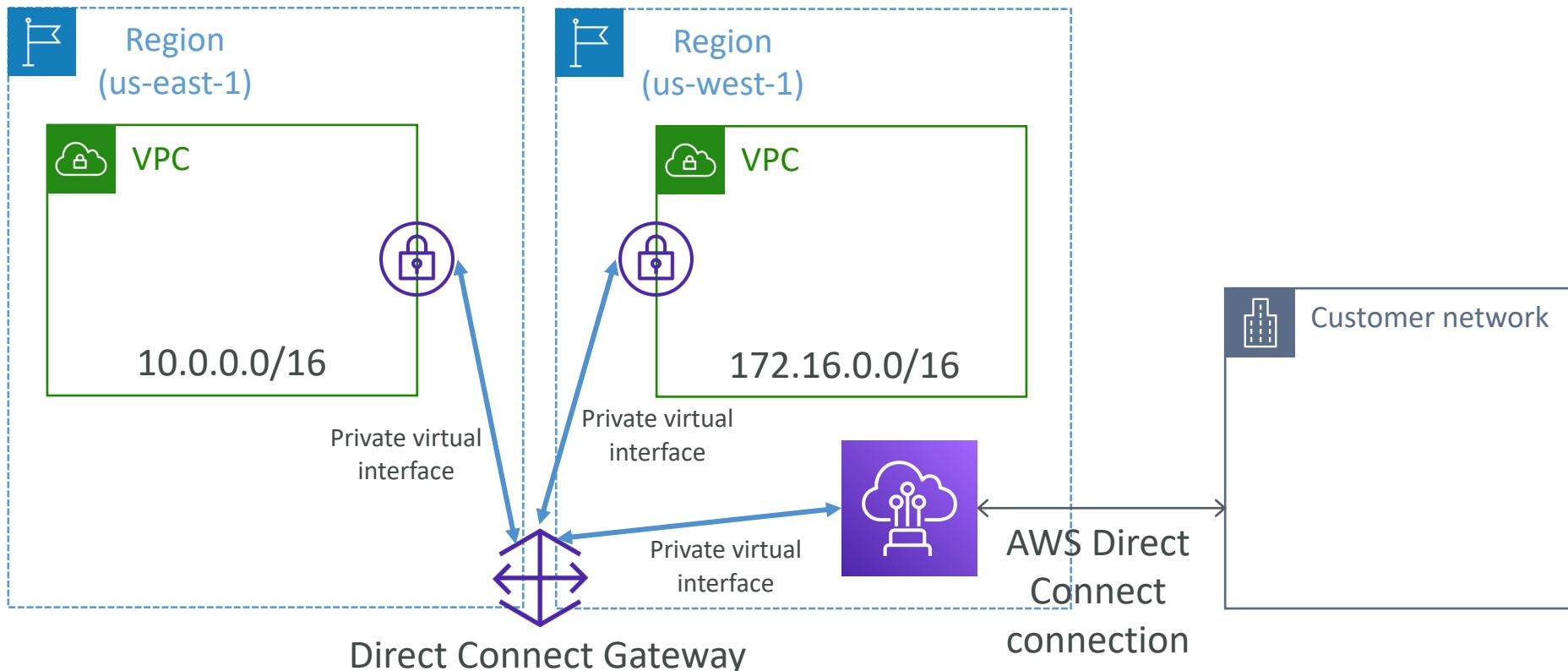
- Get **increased speed** and **failover** by summing up existing DX connections into a **logical one**
- Can aggregate up to 4 connections (active-active mode)
- Can add connections over time to the LAG
- All connections in the LAG:
 - Must be dedicated connections
 - Must have the same bandwidth
 - Must terminate at the same AWS Direct Connect Endpoint
- Can set a minimum number of connections for the LAG to function



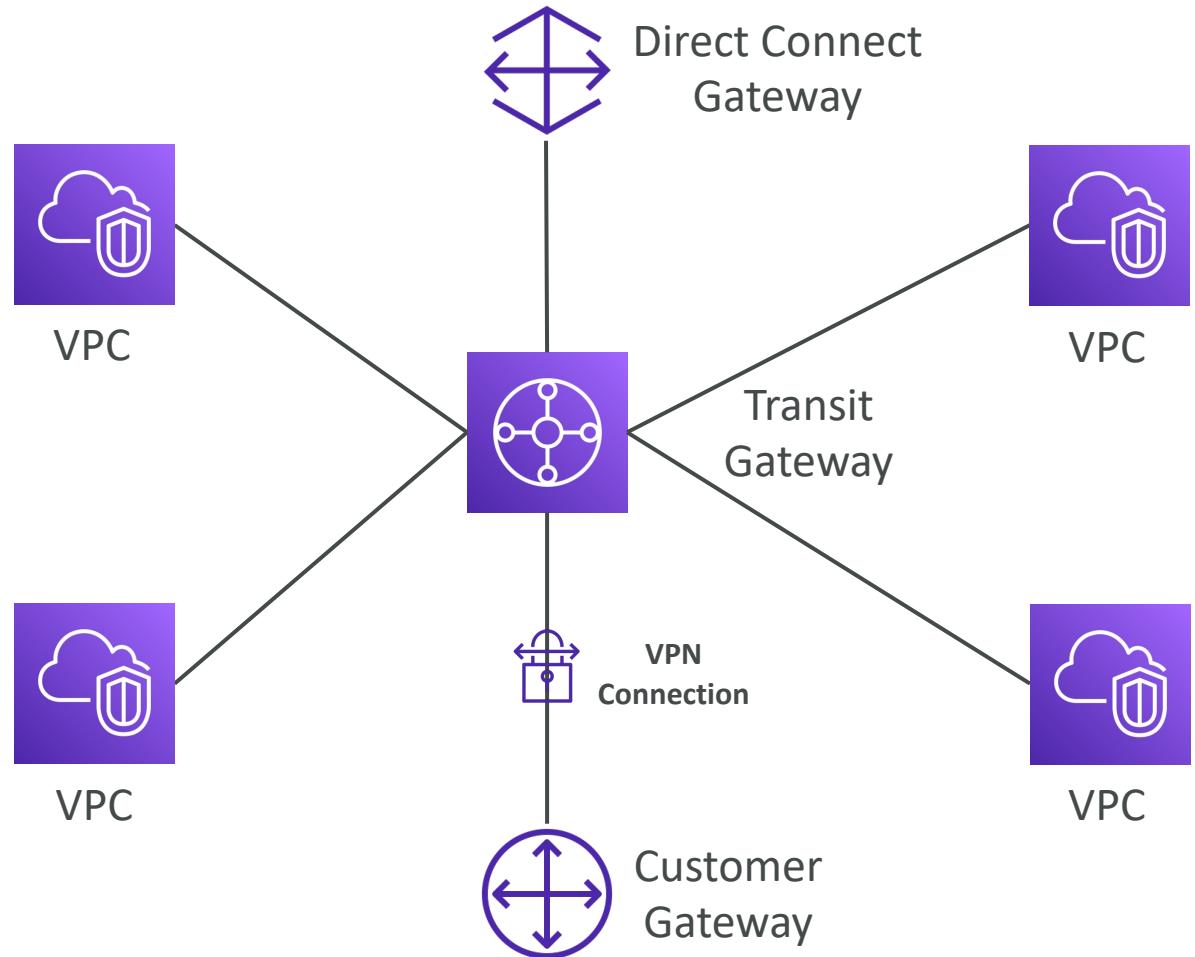


Direct Connect Gateway

- If you want to setup a Direct Connect to one or more VPC in many different regions (same/cross account), you must use a Direct Connect Gateway

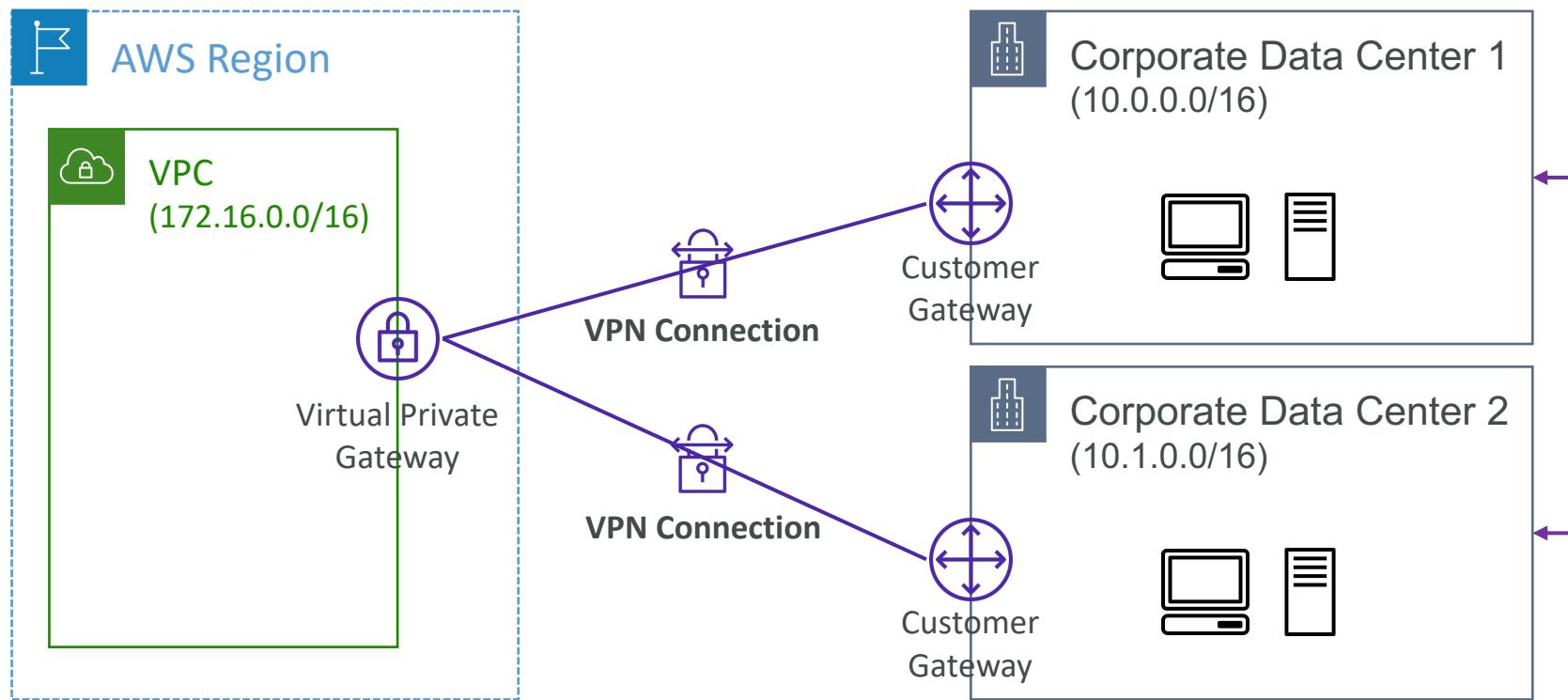


Direct Connect Gateway + Transit Gateway



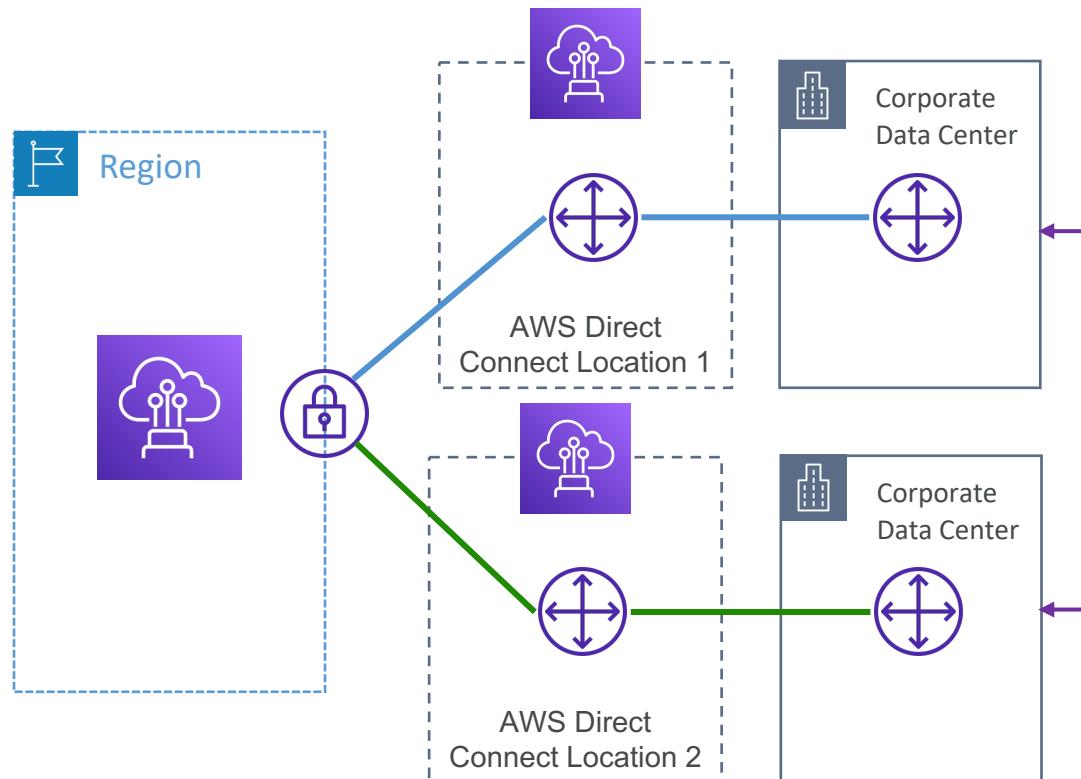
Site-to-Site Active-Active Connection

Active-Active VPN Connection



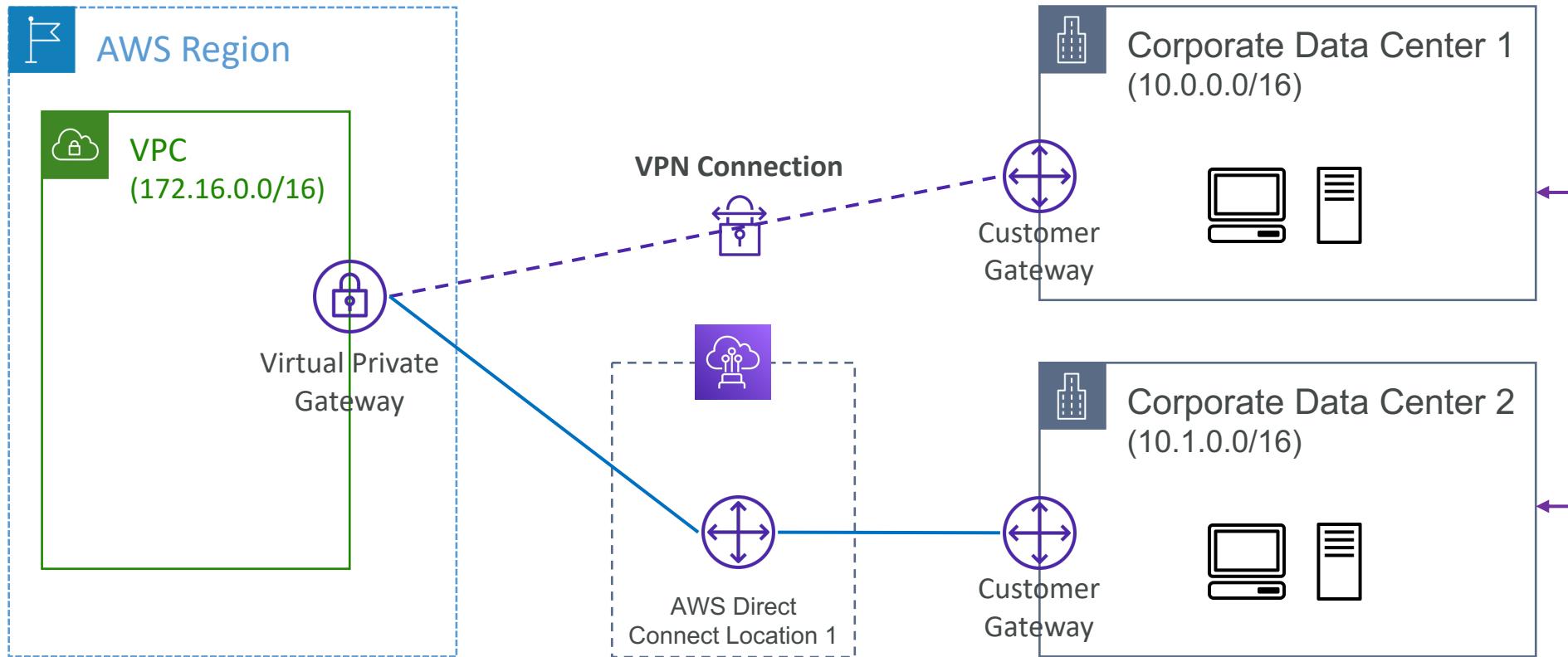
Direct Connect – High Availability

Multiple connections at multiple AWS Direct Connect locations



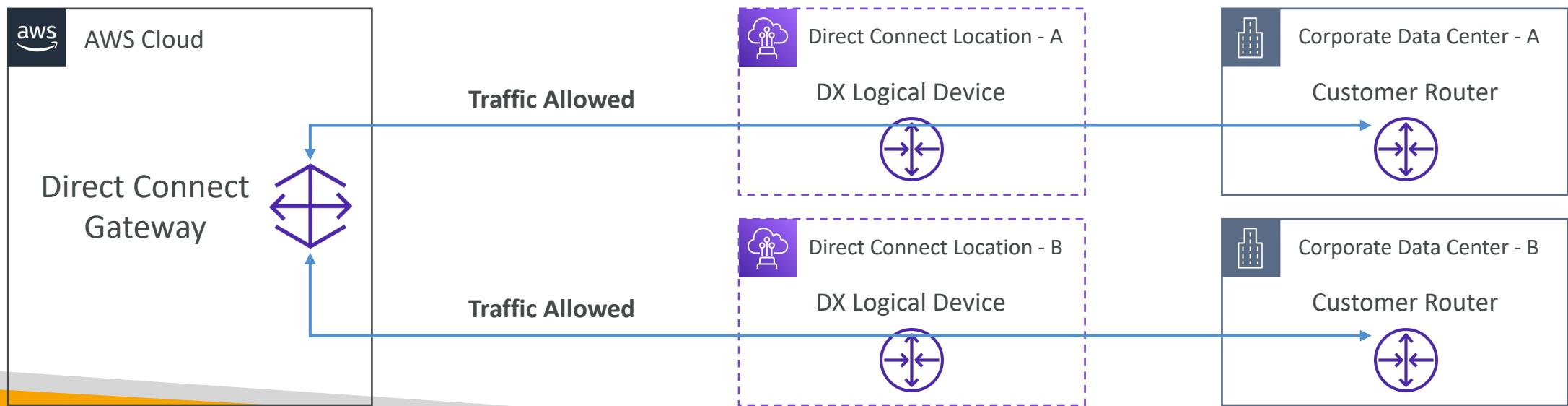
Direct Connect – High Availability

Backup VPN Connection



Direct Connect Gateway – SiteLink

- Allows you to send data from one Direct Connect location to another
- Bypassing AWS Regions
- Use cases: create private network connections between on-premises data centers by connecting them to Direct Connect locations
- Data is sent over the fastest path between Direct Connect locations





VPC Flow Logs

- Capture information about IP traffic going into your interfaces:
 - VPC Flow Logs
 - Subnet Flow Logs
 - Elastic Network Interface (ENI) Flow Logs
- Helps to monitor & troubleshoot connectivity issues
- Flow logs data can go to S3, CloudWatch Logs, and Kinesis Data Firehose
- Captures network information from AWS managed interfaces too: ELB, RDS, ElastiCache, Redshift, WorkSpaces, NATGW, Transit Gateway...

VPC Flow Logs Syntax

version	interface-id	dstaddr	dstport	packets	start	action
2	123456789010	eni-1235b8ca123456789	172.31.16.139	172.31.16.21	20641	ACCEPT OK
2	123456789010	eni-1235b8ca123456789	172.31.9.69	172.31.9.12	49761	REJECT OK
account-id	srcaddr	srcport	protocol	bytes	end	log-status

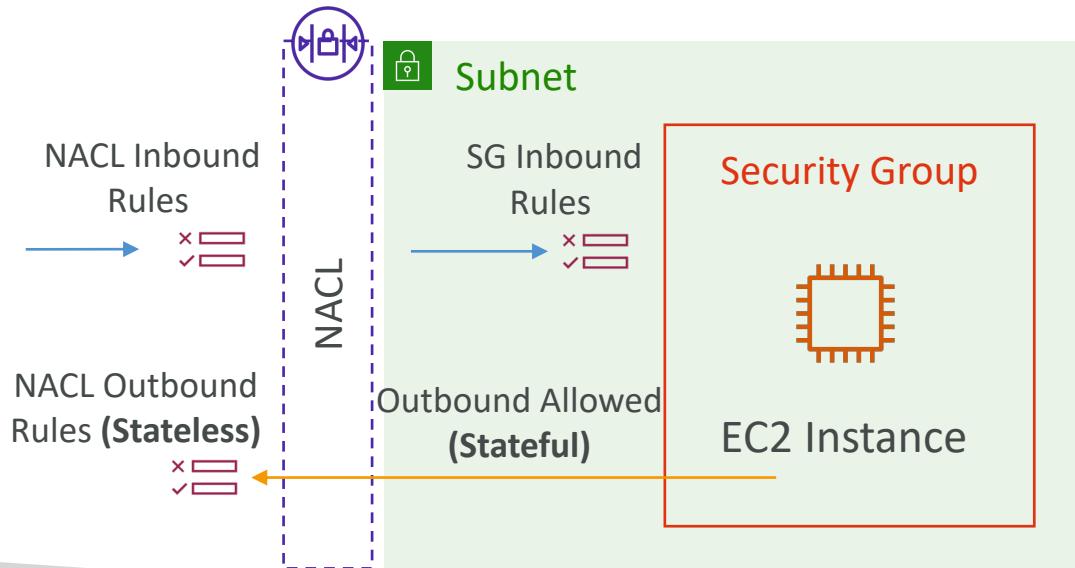
- srcaddr & dstaddr – help identify problematic IP
- srcport & dstport – help identify problematic ports
- Action – success or failure of the request due to Security Group / NACL
- Can be used for analytics on usage patterns, or malicious behavior
- Query VPC flow logs using Athena on S3 or CloudWatch Logs Insights
- Flow Logs examples: <https://docs.aws.amazon.com/vpc/latest/userguide/flow-logs-records-examples.html>

VPC Flow Logs – Troubleshoot SG & NACL issues

Look at the “ACTION” field

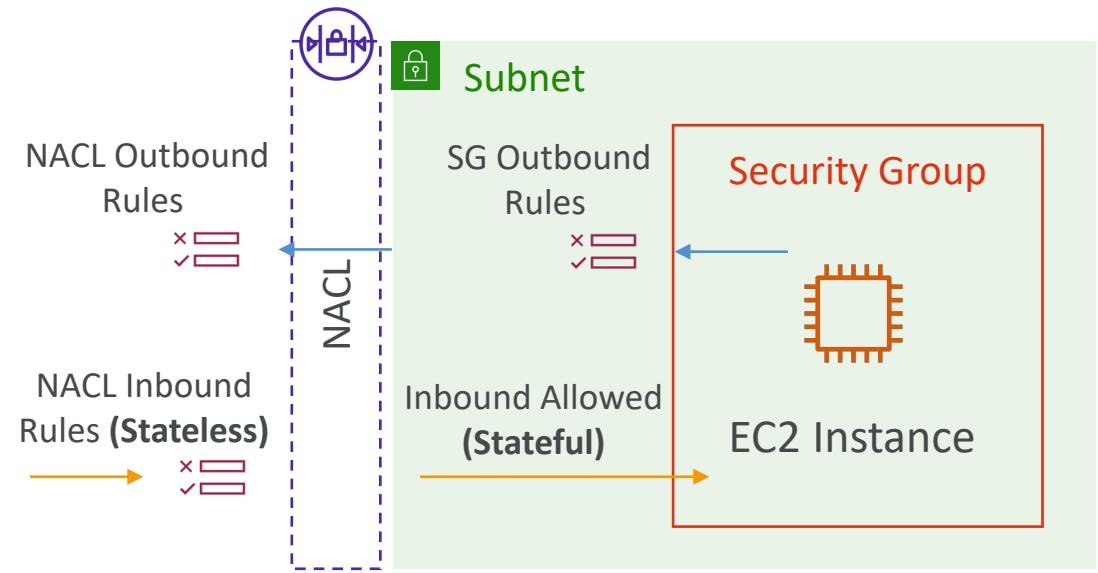
Incoming Requests

- Inbound REJECT => NACL or SG
- Inbound ACCEPT, Outbound REJECT => NACL



Outgoing Requests

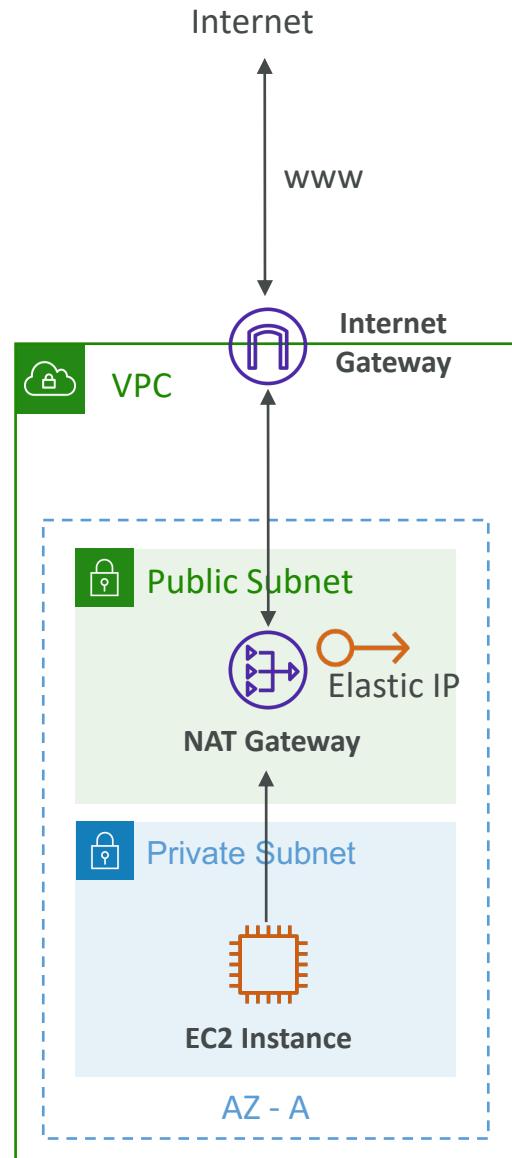
- Outbound REJECT => NACL or SG
- Outbound ACCEPT, Inbound REJECT => NACL



VPC Flow Logs – with NAT Gateway

- My Virtual Private Cloud (VPC) flow logs show Action = ACCEPT for inbound traffic coming from public IP addresses. However, my understanding of network address translation (NAT) gateways was that they don't accept traffic from the internet. Is my NAT gateway accepting inbound traffic from the internet?
- **Inbound traffic is permitted by Security Group or NACLs**
 - Traffic isn't permitted by the NAT Gateway, it's dropped
 - To confirm run the following query in CloudWatch Log Group


```
filter (dstAddr like 'xxx.xxx' and srcAddr like 'public IP')
| stats sum(bytes) as bytesTransferred by srcAddr, dstAddr
| limit 10
```
- Make 'xxx.xxx' the first two octets of your VPC CIDR
- Replace Public IP with the IP you see in logs
- You will see traffic on the Private IP of the NAT Gateway but nowhere else: traffic was unsolicited and then dropped

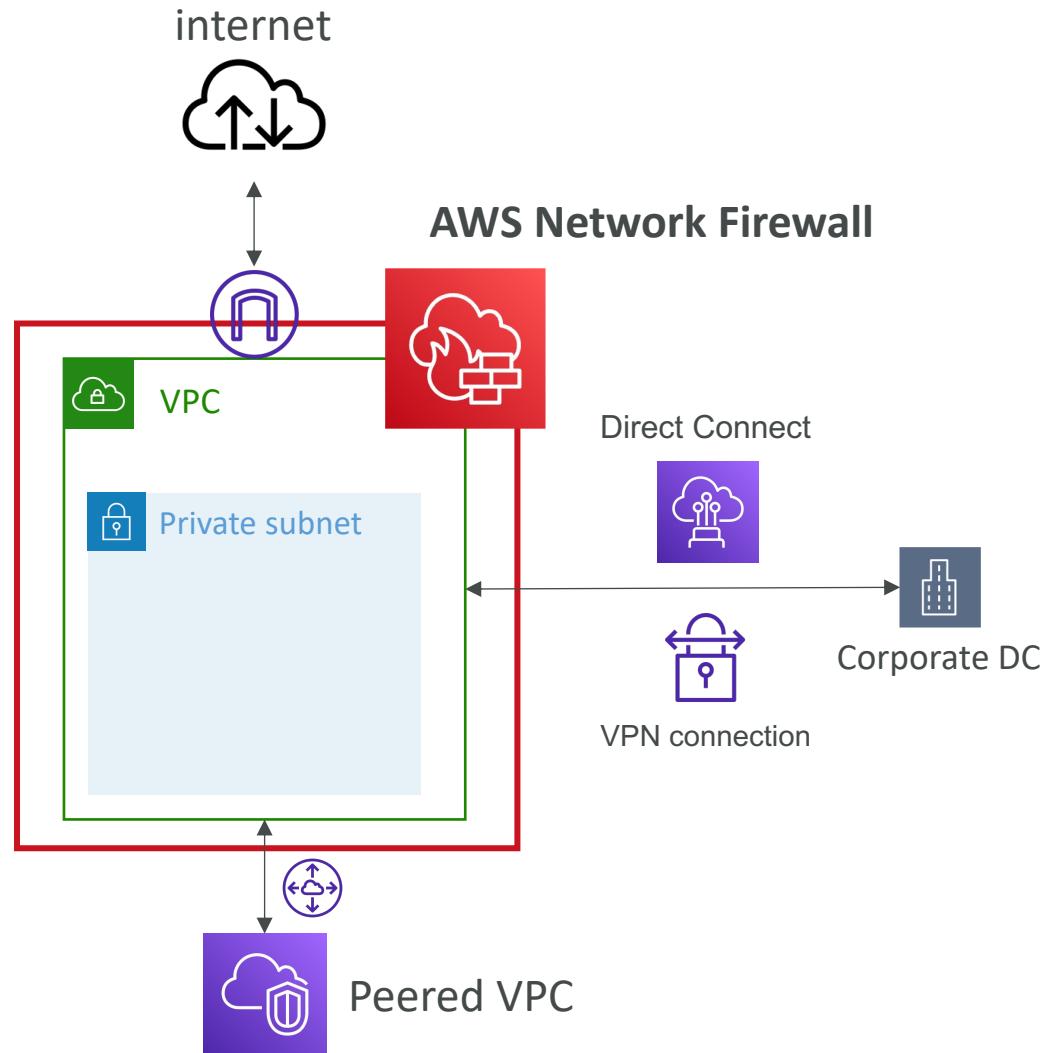


Network Protection on AWS

- 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



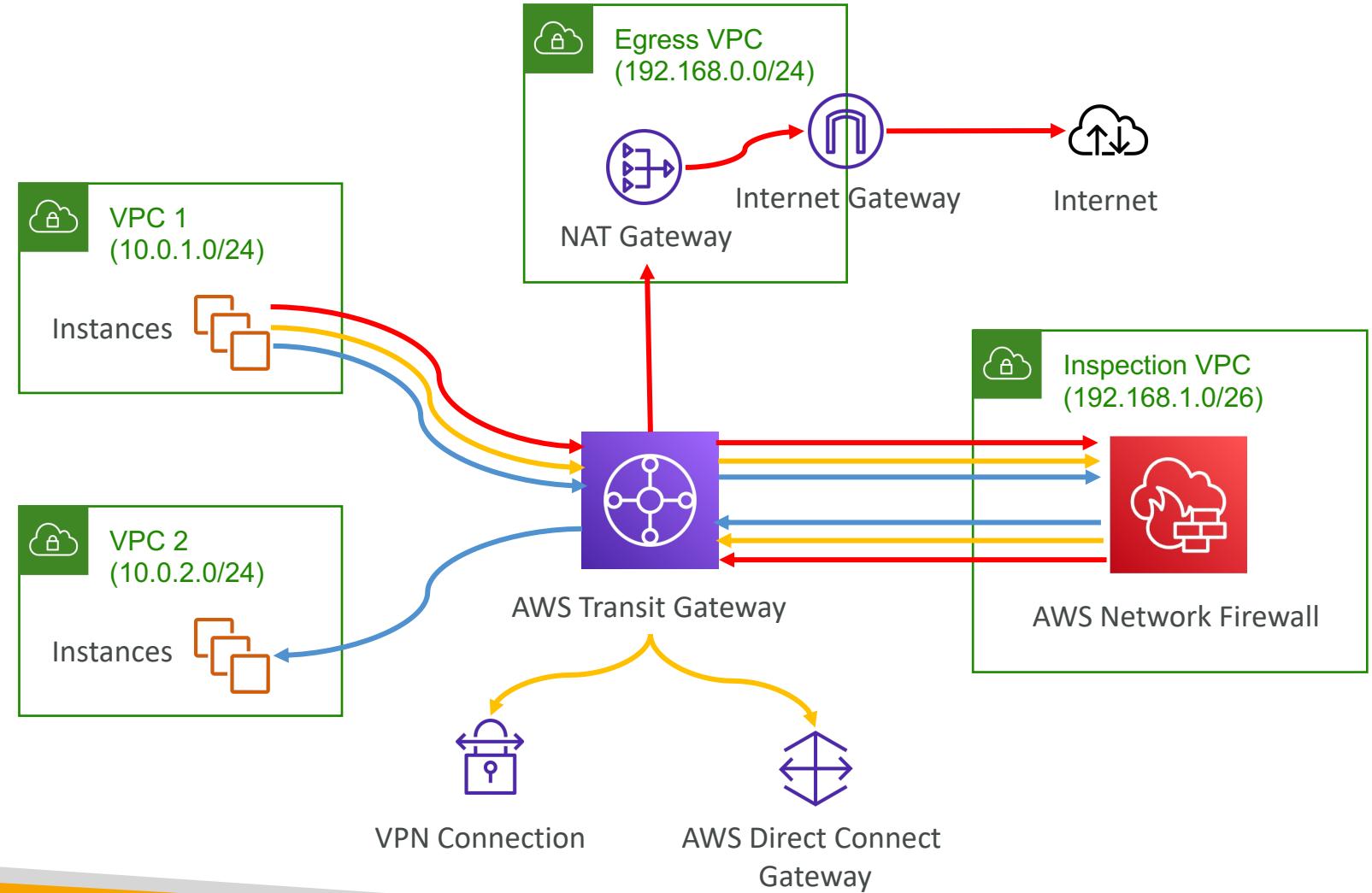


Network Firewall – Fine Grained Controls

- 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

AWS Network Firewall - Architecture

- North-South VPC egress to Internet
- North-South VPC to VPN or Direct Connect
- East-West VPC to VPC



Machine Learning

Amazon Rekognition



- Find objects, people, text, scenes in images and videos using ML
- Facial analysis and facial search to do user verification, people counting
- Create a database of “familiar faces” or compare against celebrities
- Use cases:
 - Labeling
 - Content Moderation
 - Text Detection
 - Face Detection and Analysis (gender, age range, emotions...)
 - Face Search and Verification
 - Celebrity Recognition
 - Pathing (ex: for sports game analysis)

Amazon Rekognition – Content Moderation

- Detect content that is inappropriate, unwanted, or offensive (image and videos)
- Used in social media, broadcast media, advertising, and e-commerce situations to create a safer user experience
- Set a **Minimum Confidence Threshold** for items that will be flagged
- Flag sensitive content for manual review in Amazon Augmented AI (A2I)
- Help comply with regulations



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



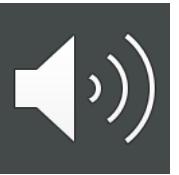
*"Hello my name is Stéphane.
I hope you're enjoying the course!"*

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 Translate



- Natural and accurate language translation
- Amazon Translate allows you to **localize content** - such as websites and applications - for **international users**, and to easily translate large volumes of text efficiently.

Source language

Auto (auto)

Target language

French (fr)

Hi my name is Stéphane

Bonjour, je m'appelle Stéphane.

Portuguese (pt)

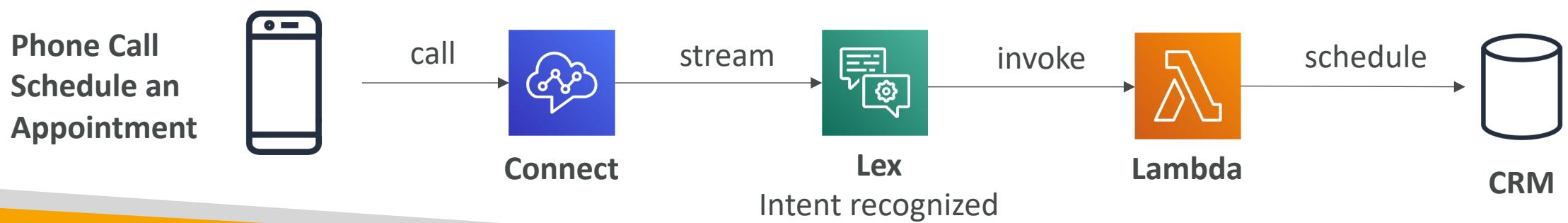
Oi, meu nome é Stéphane.

Hindi (hi)

हाय मेरा नाम स्टीफन है

Amazon Lex & Connect

- **Amazon Lex:** (same technology that powers Alexa)
 - Automatic Speech Recognition (ASR) to convert speech to text
 - Natural Language Understanding to recognize the intent of text, callers
 - Helps build chatbots, call center bots
- **Amazon Connect:**
 - Receive calls, create contact flows, cloud-based virtual contact center
 - Can integrate with other CRM systems or AWS
 - No upfront payments, 80% cheaper than traditional contact center solutions





Amazon Comprehend

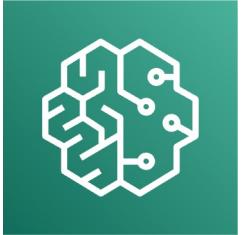
- For Natural Language Processing – NLP
- Fully managed and serverless service
- Uses machine learning to find insights and relationships in text
 - Language of the text
 - Extracts key phrases, places, people, brands, or events
 - Understands how positive or negative the text is
 - Analyzes text using 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



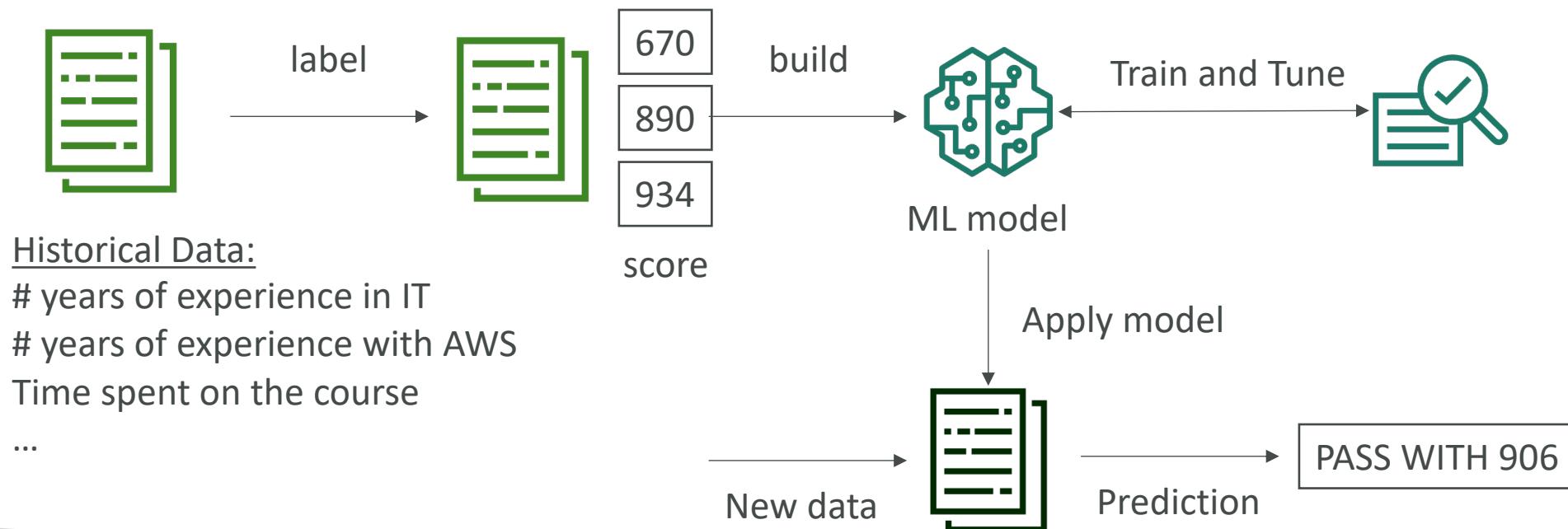
Amazon Comprehend Medical

- 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.

Amazon SageMaker



- Fully managed service for developers / data scientists to build ML models
- Typically, difficult to do all the processes in one place + provision servers
- Machine learning process (simplified): predicting your exam score



Amazon Forecast



- Fully managed service that uses ML to deliver highly accurate forecasts
- Example: predict the future sales of a raincoat
- 50% more accurate than looking at the data itself
- Reduce forecasting time from months to hours
- Use cases: Product Demand Planning, Financial Planning, Resource Planning, ...

Historical Time-series Data:

Product features

Prices

Discounts

Website traffic

Store locations

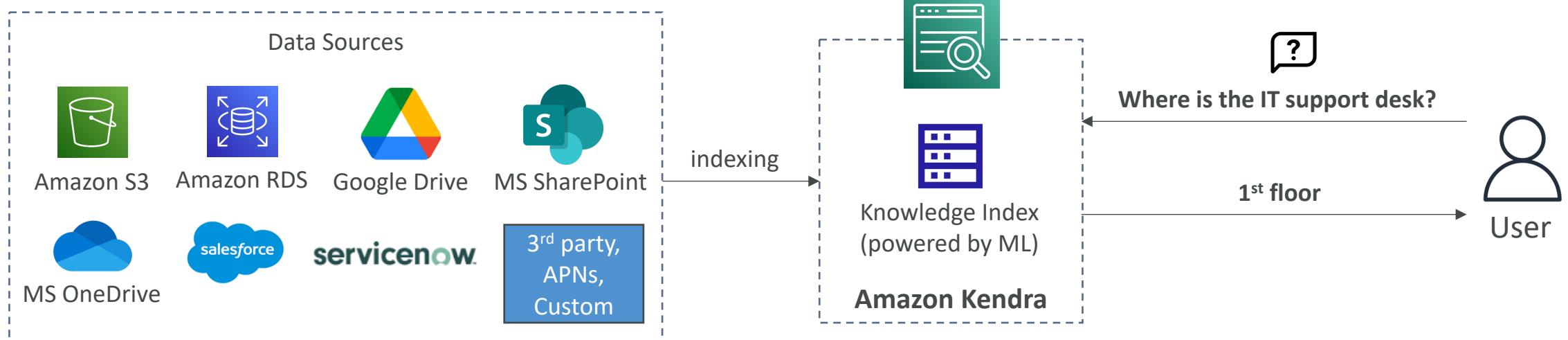
...



Amazon Kendra



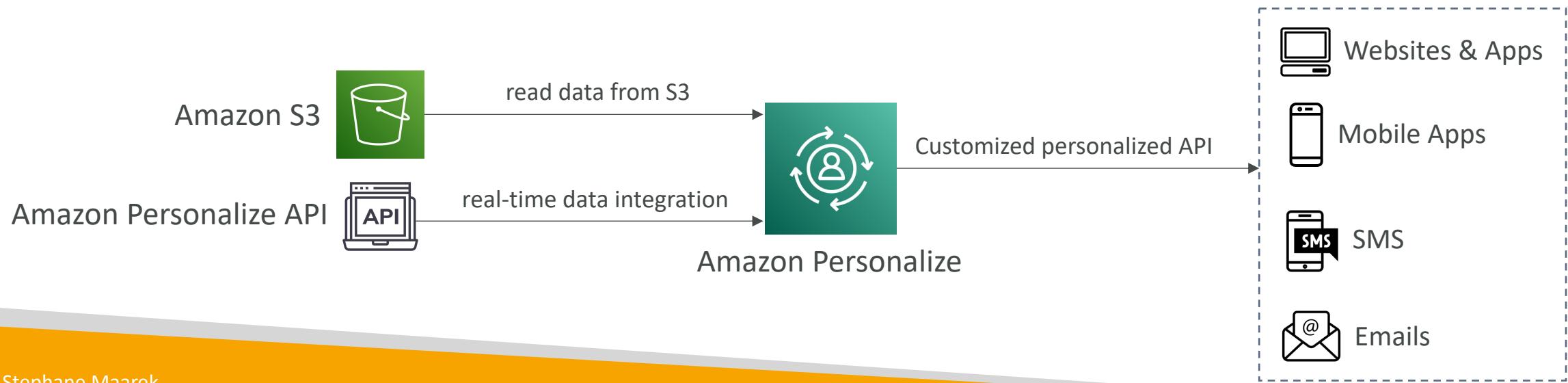
- Fully managed **document search service** powered by Machine Learning
- Extract answers from within a document (text, pdf, HTML, PowerPoint, MS Word, FAQs...)
- Natural language search capabilities
- Learn from user interactions/feedback to promote preferred results (**Incremental Learning**)
- Ability to manually fine-tune search results (importance of data, freshness, custom, ...)



Amazon Personalize



- Fully managed ML-service to build apps with real-time personalized recommendations
- Example: personalized product recommendations/re-ranking, customized direct marketing
 - Example: User bought gardening tools, provide recommendations on the next one to buy
- Same technology used by Amazon.com
- Integrates into existing websites, applications, SMS, email marketing systems, ...
- Implement in days, not months (you don't need to build, train, and deploy ML solutions)
- Use cases: retail stores, media and entertainment...



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)

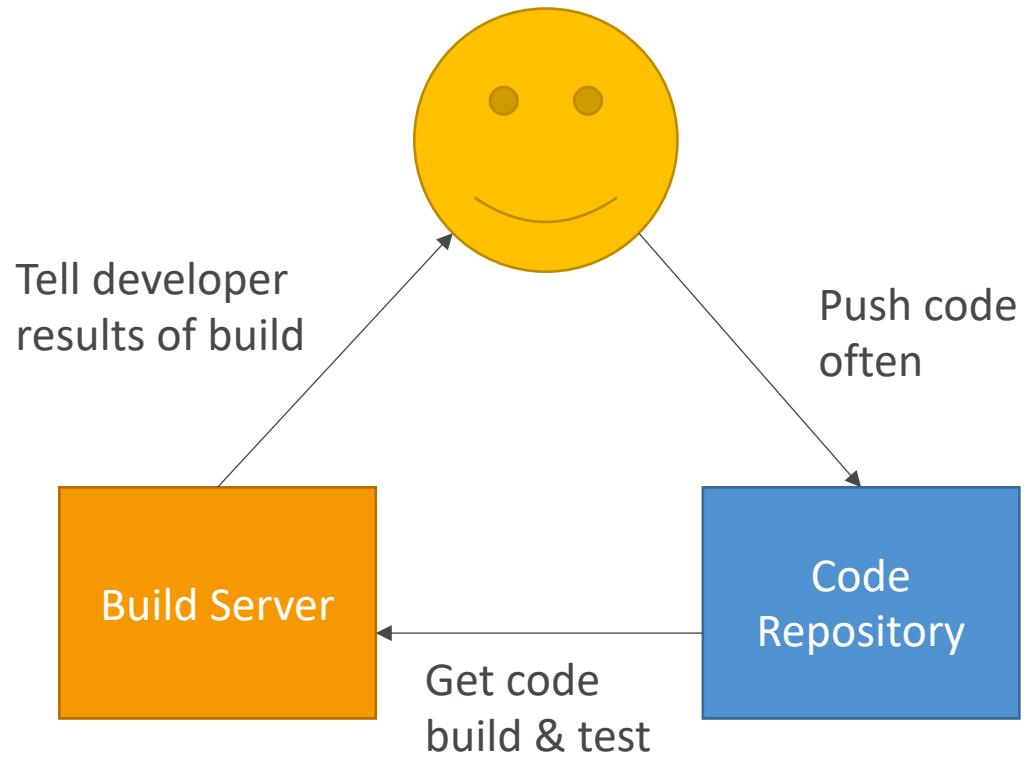
AWS Machine Learning - Summary

- **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
- **Textract:** detect text and data in documents

Other Services

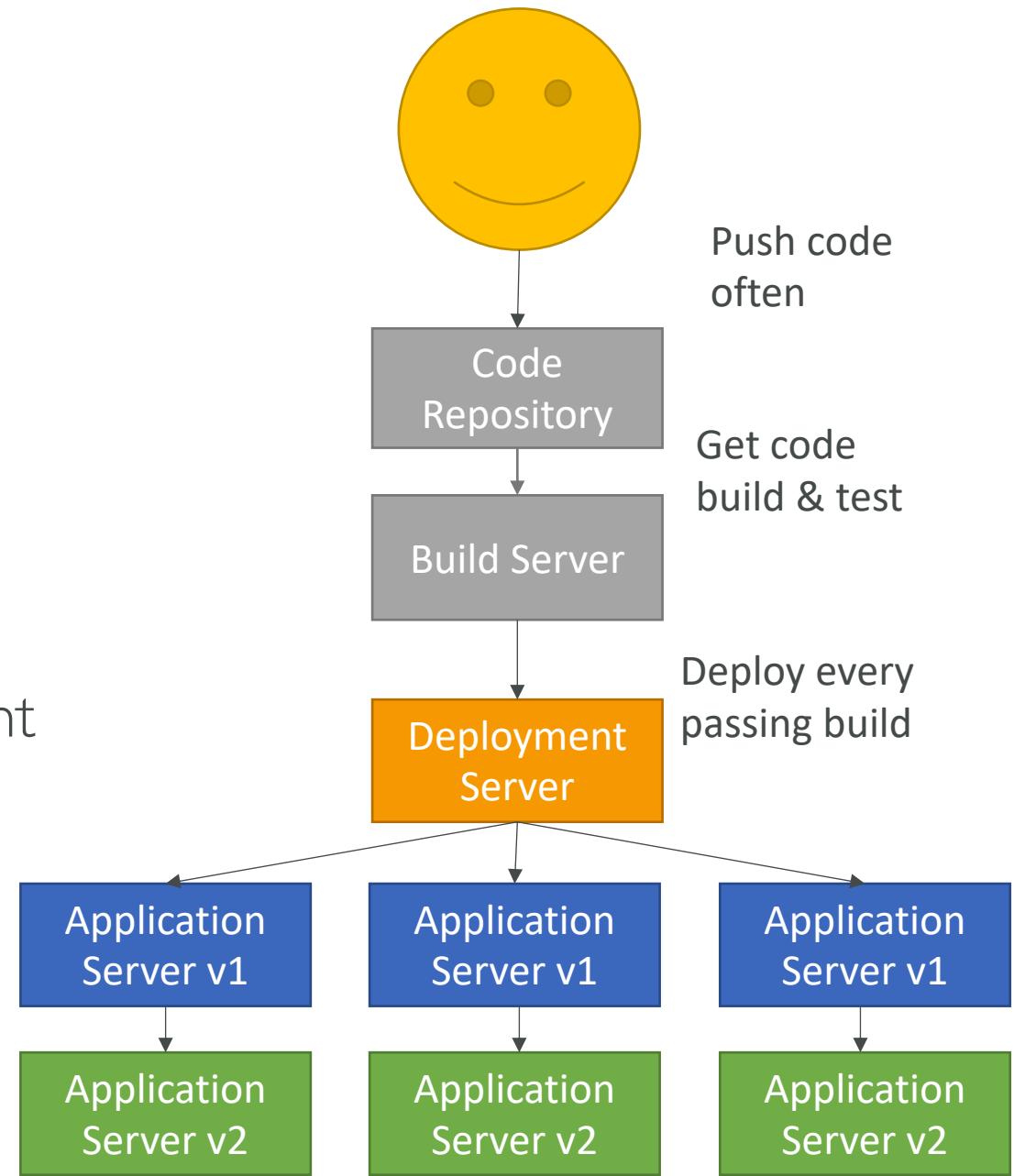
Continuous Integration

- 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

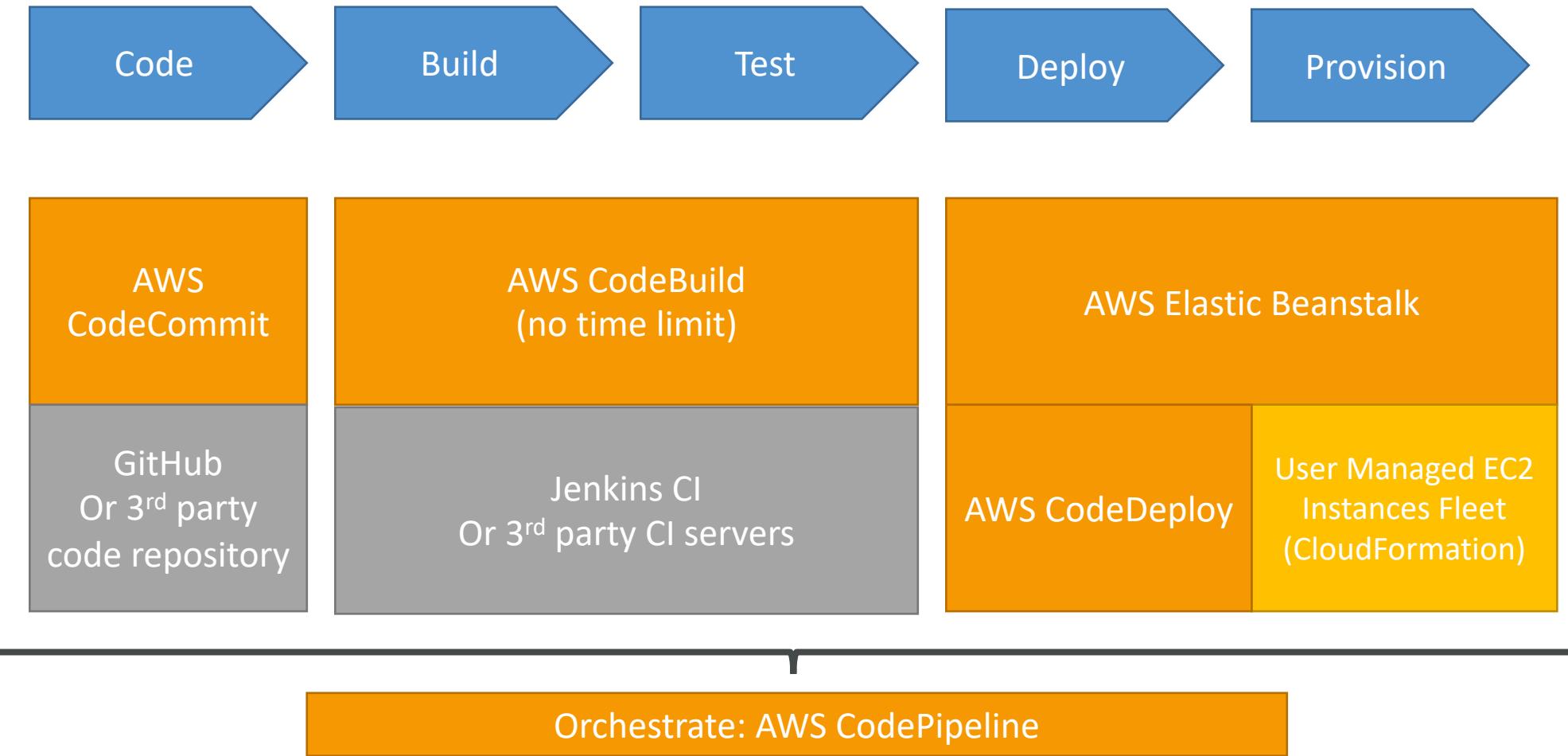


Continuous Delivery

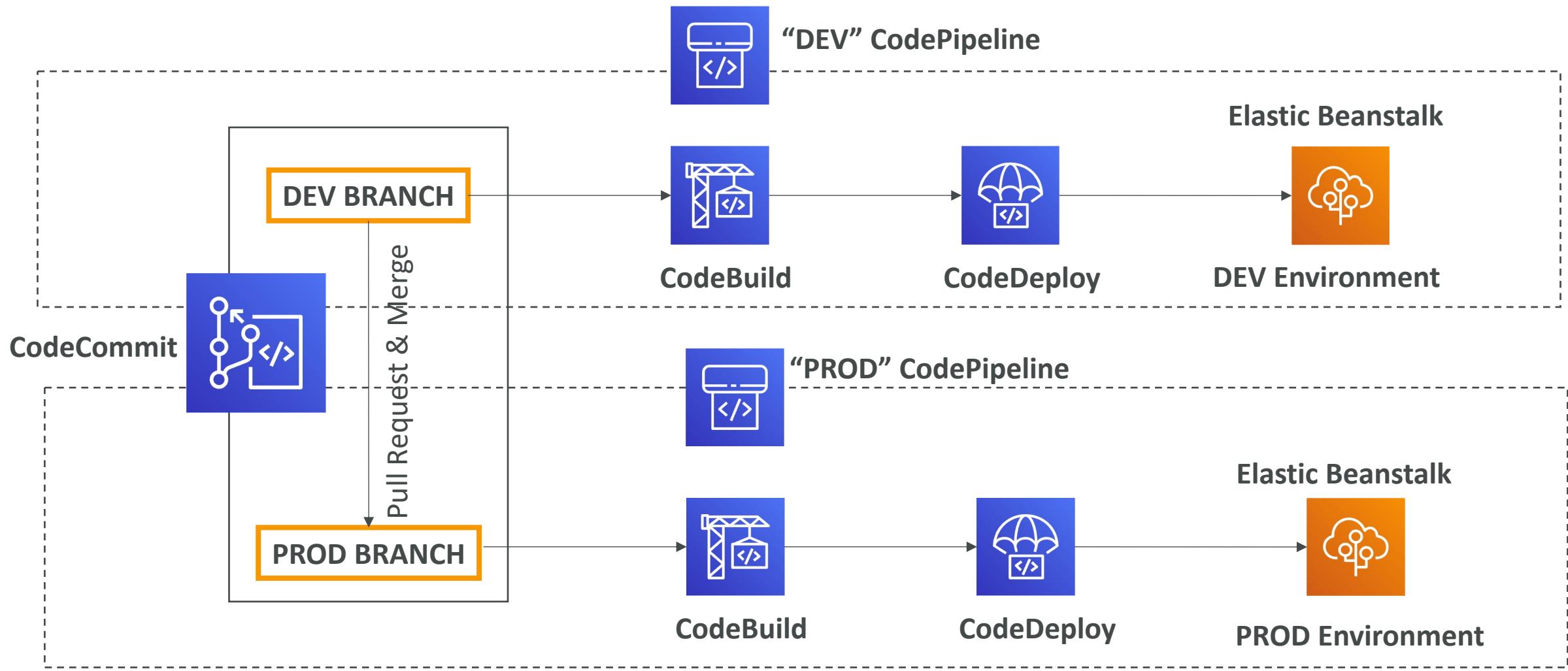
- Ensure that the software can be released reliably whenever needed.
- Ensures deployments happen often and are quick
- Shift away from “one release every 3 months” to “5 releases a day”
- That usually means automated deployment
 - CodeDeploy
 - Jenkins CD
 - Spinnaker
 - Etc...



Technology Stack for CICD

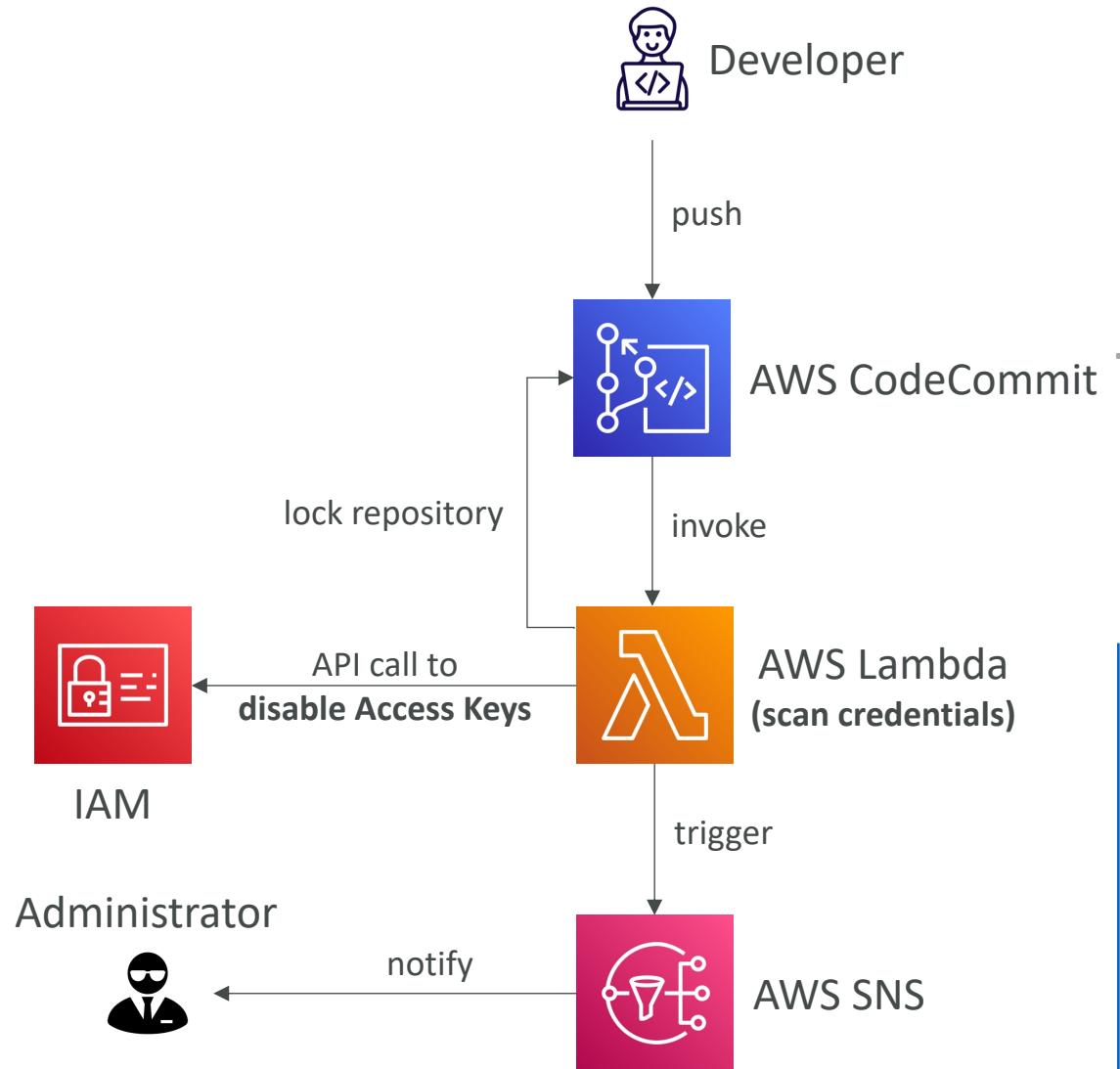


CICD Architecture



CodeCommit Trigger for AWS Lambda

- Every push to CodeCommit can trigger a Lambda function
- The Lambda function can scan for leaked AWS credentials on every code push, and disable them automatically to remedy the issue



Good to know – CICD

- You can use a manual approval stage in CodePipeline
- Running unit tests CodeCommit + CodeBuild + Code Pipeline

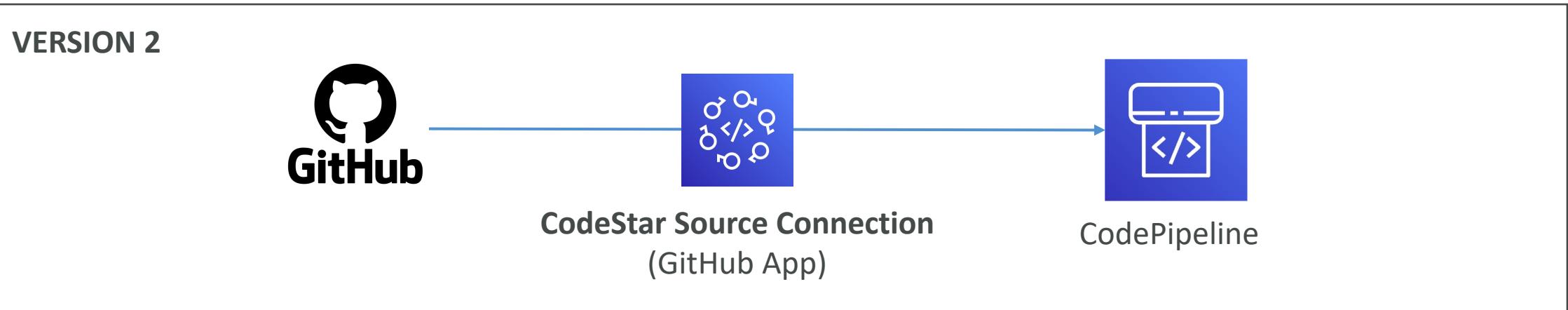


- Build and Store Docker Images: CodeBuild + ECR



- Automated CloudFormation deployment: CodePipeline

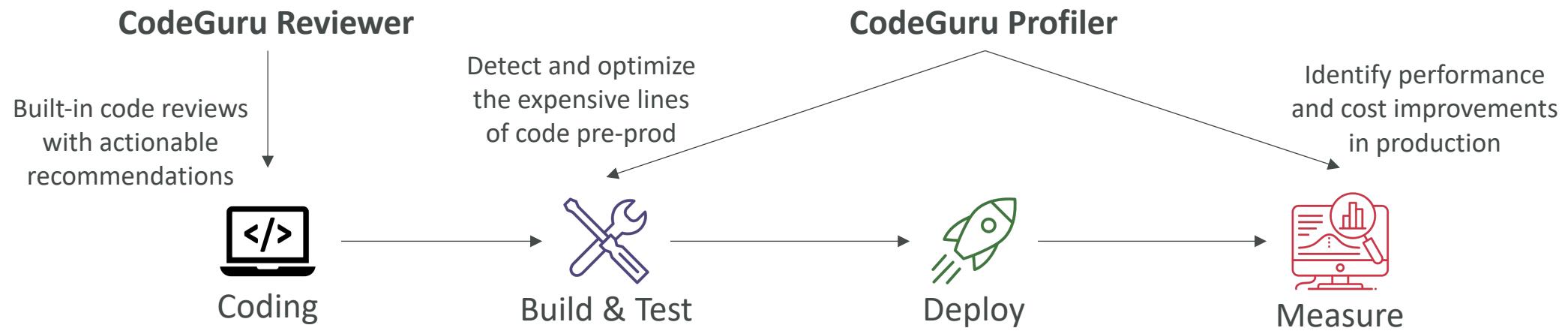
CodePipeline – GitHub integration



Amazon CodeGuru



- An ML-powered service for automated code reviews and application performance recommendations
- Provides two functionalities
 - **CodeGuru Reviewer:** automated code reviews for static code analysis (development)
 - **CodeGuru Profiler:** visibility/recommendations about application performance during runtime (production)



Amazon CodeGuru Reviewer

- Identify critical issues, security vulnerabilities, and hard-to-find bugs
- Example: common coding best practices, resource leaks, security detection, input validation
- Uses Machine Learning and automated reasoning
- Hard-learned lessons across millions of code reviews on 1000s of open-source and Amazon repositories
- Supports Java and Python
- Integrates with GitHub, Bitbucket, and AWS CodeCommit

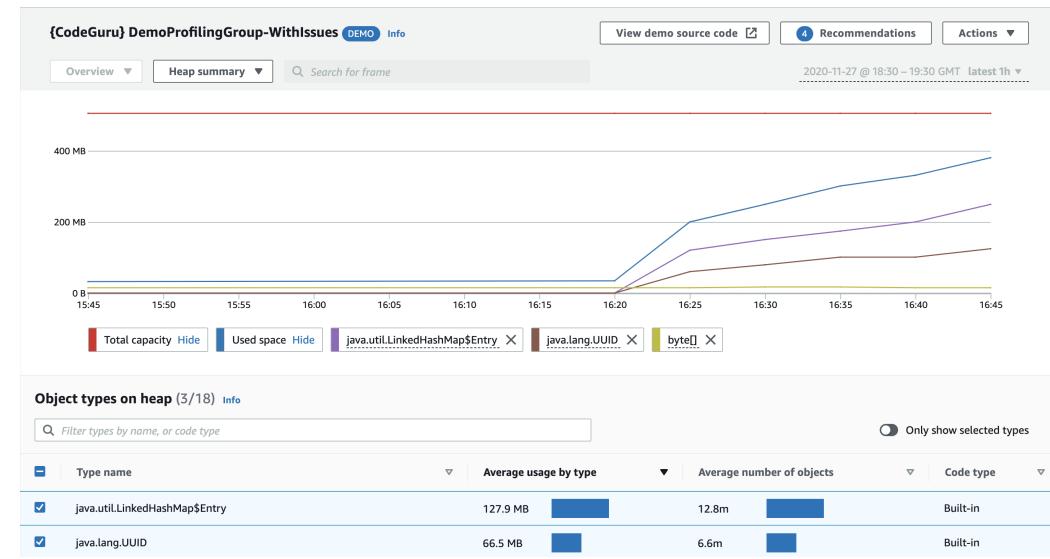
The screenshot shows the Amazon CodeGuru Reviewer interface. At the top, there's a navigation bar with 'CodeGuru' > 'Code reviews' > 'mw2tsa56o0000000'. Below it is a card for 'RepositoryAnalysis-amazon-codeguru-reviewer-sample-app-master-mw2tsa56o0000000'. The card displays details like Status (Completed), Recommendations (4), Metered lines of code (80), Time created (10 Nov 2020 08:08:47 AM GMT-0800), and Last updated (10 Nov 2020 08:11:44 AM GMT-0800). To the right, there's a sidebar with repository metadata: Type (RepositoryAnalysis), Provider (GitHub), Repository (amazon-codeguru-reviewer-sample-app), and Branch name (master). Below the main card, there's a section for 'Recommendations (4)' with a search bar. Three specific recommendations are listed:

- EventHandler.java Line: 79**
This code appears to be waiting for a resource before it runs. You could use the waiters feature to help improve efficiency. Consider using ObjectExists or ObjectNotExists. For more information, see <https://aws.amazon.com/blogs/developer/waiters-in-the-aws-sdk-for-java/>
Was this helpful?
- EventHandler.java Line: 100**
This code might not produce accurate results if the operation returns paginated results instead of all results. Consider adding another call to check for additional results.
Was this helpful?
- EventHandler.java Line: 100**
This code uses an outdated API. [ListObjectsV2](#) is the revised List Objects API, and we recommend you use this revised API for new application developments.
Was this helpful?

<https://aws.amazon.com/codeguru/features/>

Amazon CodeGuru Profiler

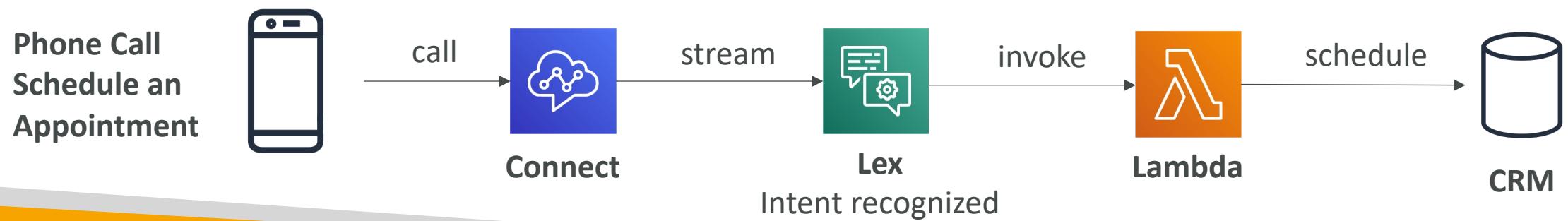
- Helps understand the runtime behavior of your application
- Example: identify if your application is consuming excessive CPU capacity on a logging routine
- Features:
 - Identify and remove code inefficiencies
 - Improve application performance (e.g., reduce CPU utilization)
 - Decrease compute costs
 - Provides heap summary (identify which objects using up memory)
 - Anomaly Detection
- Support applications running on AWS or on-premise
- Minimal overhead on application



<https://aws.amazon.com/codeguru/features/>

Alexa for Business, Lex & Connect

- Alexa for Business:
 - Use Alexa to help employees be more productive in meeting rooms and their desk
 - Measure and increase the utilization of meeting rooms in their workplace
- Amazon Lex: (same technology that powers Alexa)
 - Automatic Speech Recognition (ASR) to convert speech to text
 - Natural Language Understanding to recognize the intent of text, callers
 - Helps build chatbots, call center bots
- Amazon Connect:
 - Receive calls, create contact flows, cloud-based virtual contact center
 - Can integrate with other CRM systems or AWS

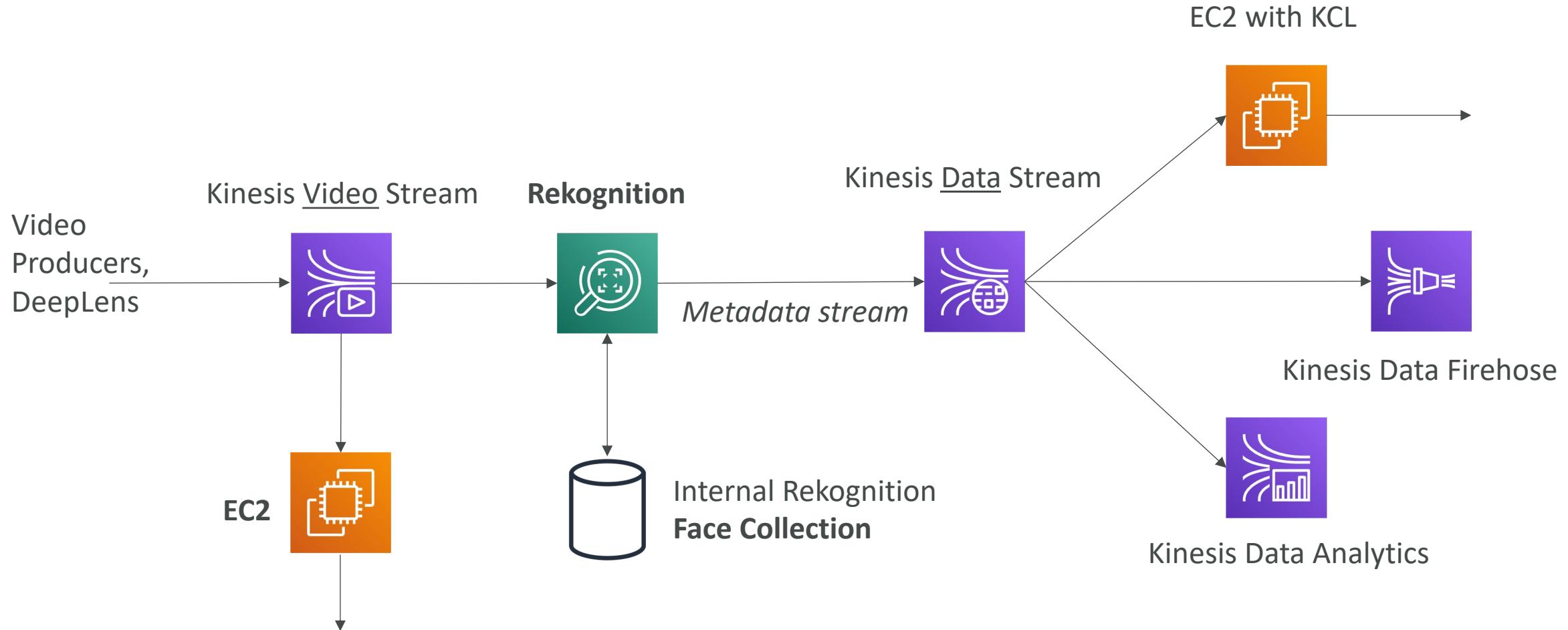




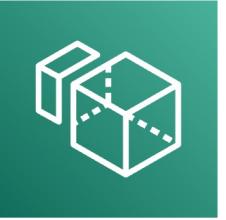
Kinesis Video Streams

- One video stream per streaming device (producers)
 - Security cameras, body worn camera, smartphone
 - Can use a Kinesis Video Streams Producer library
- Underlying data is stored in S3 (but we don't have access to it)
- Cannot output the stream data to S3 (must build custom solution)
- Consumers:
 - Consumed by EC2 instances for real time analysis, or in batch
 - Can leverage the Kinesis Video Stream Parser Library
 - Integration with AWS Rekognition for facial detection

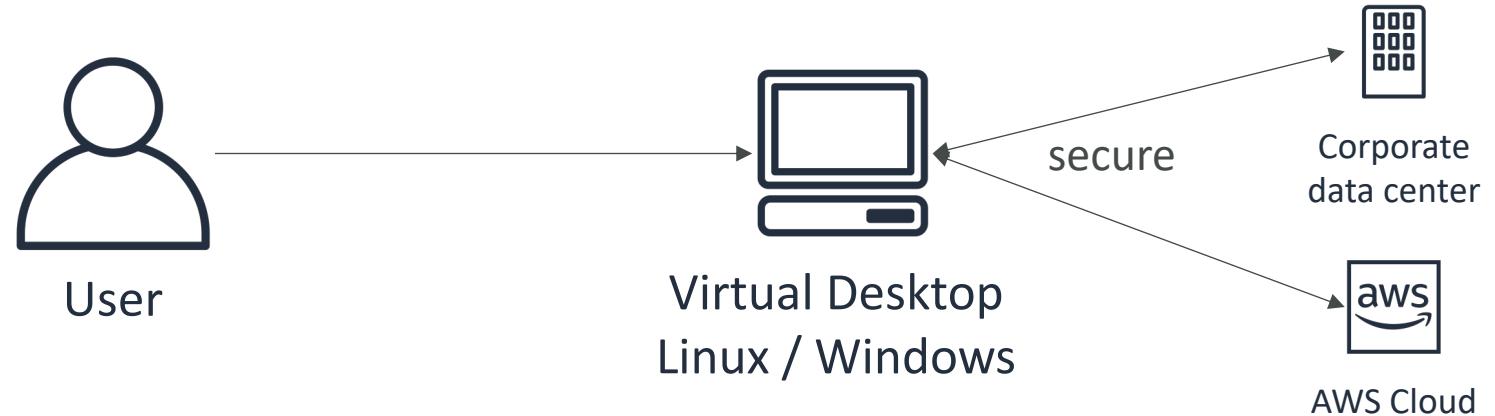
Video Streaming & Rekognition



Amazon WorkSpaces



- Managed, Secure Cloud Desktop
- Great to eliminate management of on-premises VDI (Virtual Desktop Infrastructure)
- Pricing is either on-demand (pay per hour) or monthly subscription
- Secure, Encrypted, Network Isolation
- Integrated with Microsoft Active Directory



Amazon WorkSpaces

- **WorkSpaces Application Manager (WAM)**
 - Deploy and Manage applications as virtualized application containers
 - Provision at scale, and keep the applications updated using WAM
- **Windows Updates**
 - By default, Amazon Workspaces are configured to install software updates
 - Amazon WorkSpaces with Windows will have Windows Update turned on
 - You have full control over the Windows Update frequency
- **Maintenance Windows**
 - Updates are installed during maintenance windows (you define them)
 - Always On WorkSpaces: default is from 00h00 to 04h00 on Sunday morning
 - AutoStop WorkSpaces: automatically starts once a month to install updates
 - Manual maintenance: you define your windows and perform maintenance

Amazon WorkSpaces - Cross Region Redirection

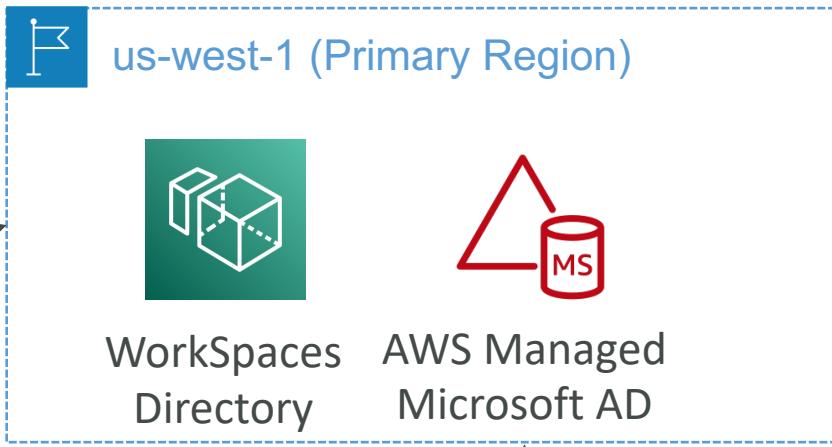
Route 53 desktop.example.com
TXT Record
Failover type



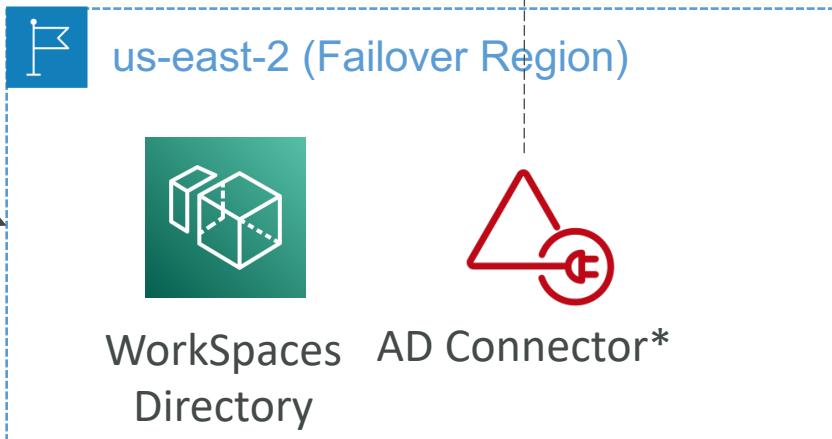
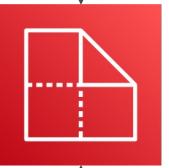
Connection alias
Connection alias



Alarm



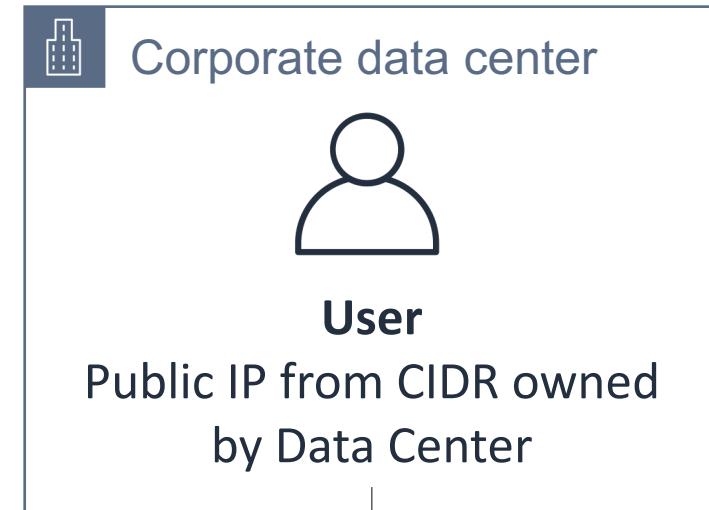
Amazon WorkDocs
(persistence for user data)



*must use AD Connector, can't use multi-region AWS Managed Microsoft AD

Amazon WorkSpaces IP Access Control Groups

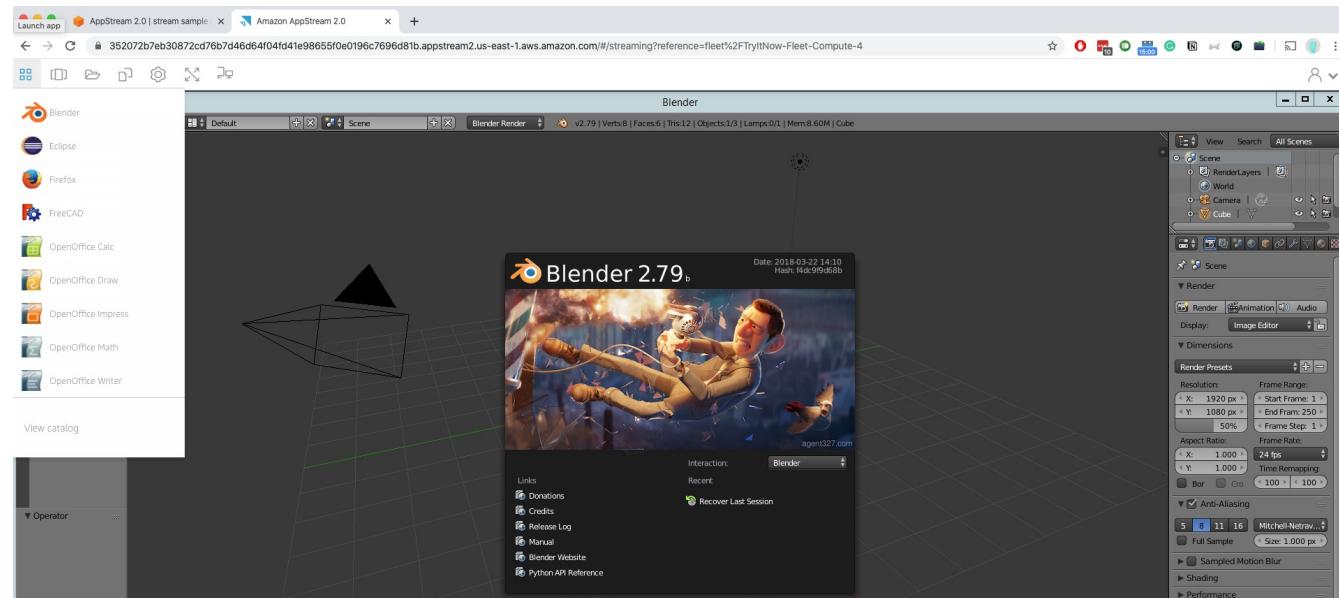
- Similar to security groups for Amazon WorkSpaces
- List of IP addresses / CIDR address ranges that users are authorized to connect from
- If users access WorkSpaces through VPN or NAT, the IP Access Control Group must authorize the public IP of these





Amazon AppStream 2.0

- Desktop Application Streaming Service
- Deliver to any computer; without acquiring, provisioning infrastructure
- The application is delivered from within a web browser



Amazon AppStream 2.0 vs WorkSpaces

- **Workspaces**

- Fully managed VDI and desktop available
- The users connect to the VDI and open native or WAM applications
- Workspaces are on-demand or always on

- **AppStream 2.0**

- Stream a desktop application to web browsers (no need to connect to a VDI)
- Works with any device (that has a web browser)
- Allow to configure an instance type per application type (CPU, RAM, GPU)

AWS Device Farm



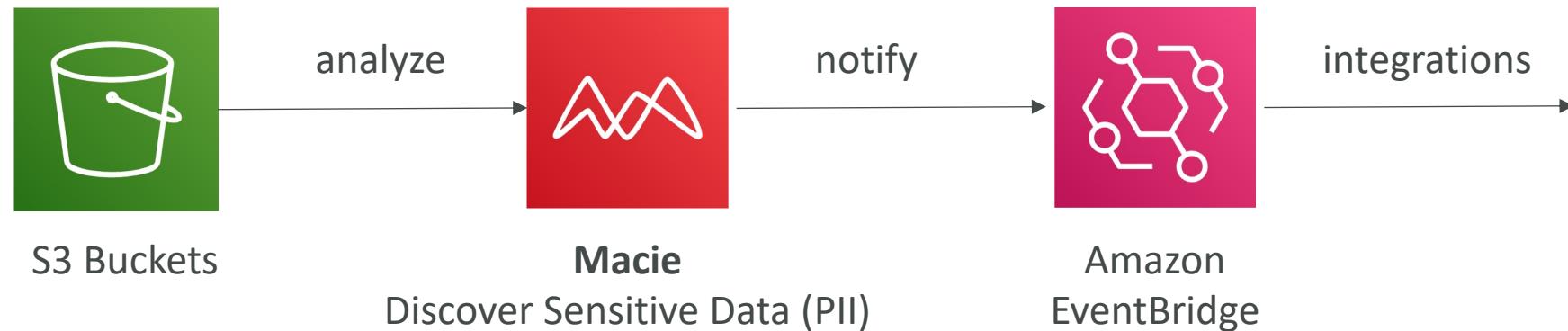
- Application testing service for your mobile and web applications
- Test across **real browsers** and **real mobiles devices**
- Fully automated using framework
- Improve the quality of web and mobile apps
- Generates videos and logs to document the issues encountered
- Can **remotely log-in** to devices for debugging

Device	Test Results	Created
HTC One M7 (AT&T)	4.4.2 (Green, Yellow, Red)	2015-07-07T15:06-0700
HTC One M8 (Sprint)	4.4.4 (Green, Yellow, Red)	2015-07-07T15:06-0700
LG G Flex2 (Sprint)	5.0.1 (Green, Yellow, Red)	2015-07-07T15:06-0700

AWS Macie



- 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)



Amazon Simple Email Service (Amazon SES)

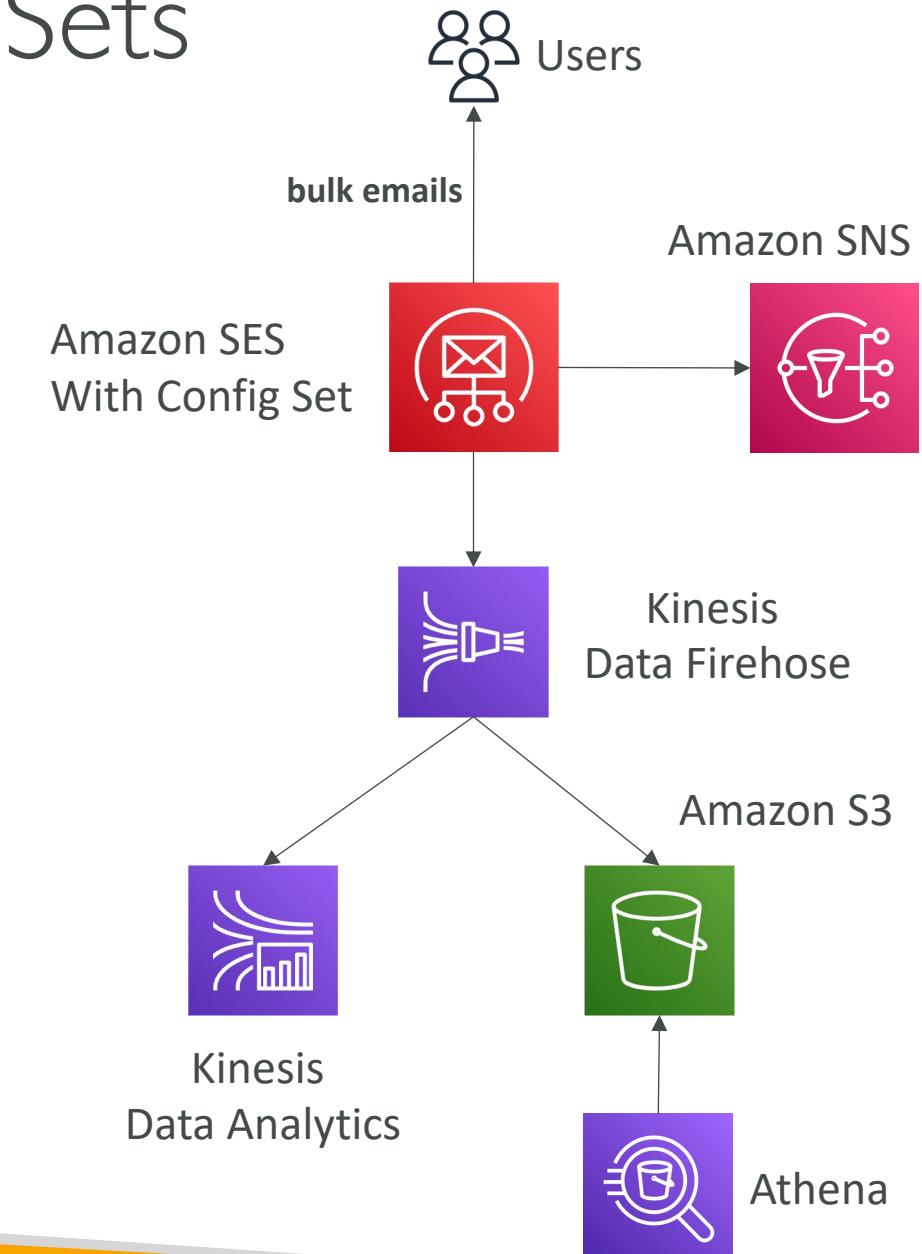


- Fully managed service to send emails securely, globally and at scale
- Allows inbound/outbound emails
- Reputation dashboard, performance insights, anti-spam feedback
- Provides statistics such as email deliveries, bounces, feedback loop results, email open
- Supports DomainKeys Identified Mail (DKIM) and Sender Policy Framework (SPF)
- Flexible IP deployment: shared, dedicated, and customer-owned IPs
- Send emails using your application using AWS Console, APIs, or SMTP
- Use cases: transactional, marketing and bulk email communications



Amazon SES – Configuration Sets

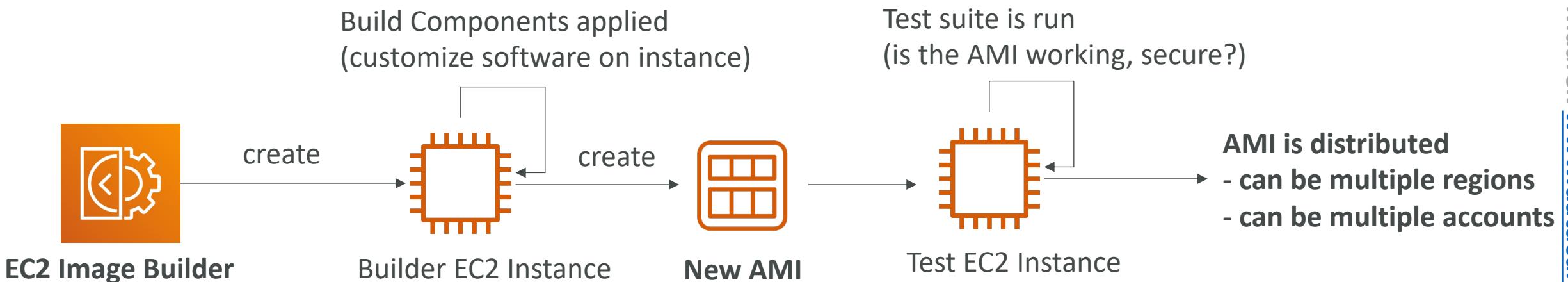
- Configuration sets help you customize and analyze your email send events
- **Event destinations:**
 - Kinesis Data Firehose: receives metrics (numbers of sends, deliveries, opens, clicks, bounces, and complaints) for each email
 - SNS: for immediate feedback on bounce and complaint information
- **IP pool management:** use IP pools to send particular types of emails



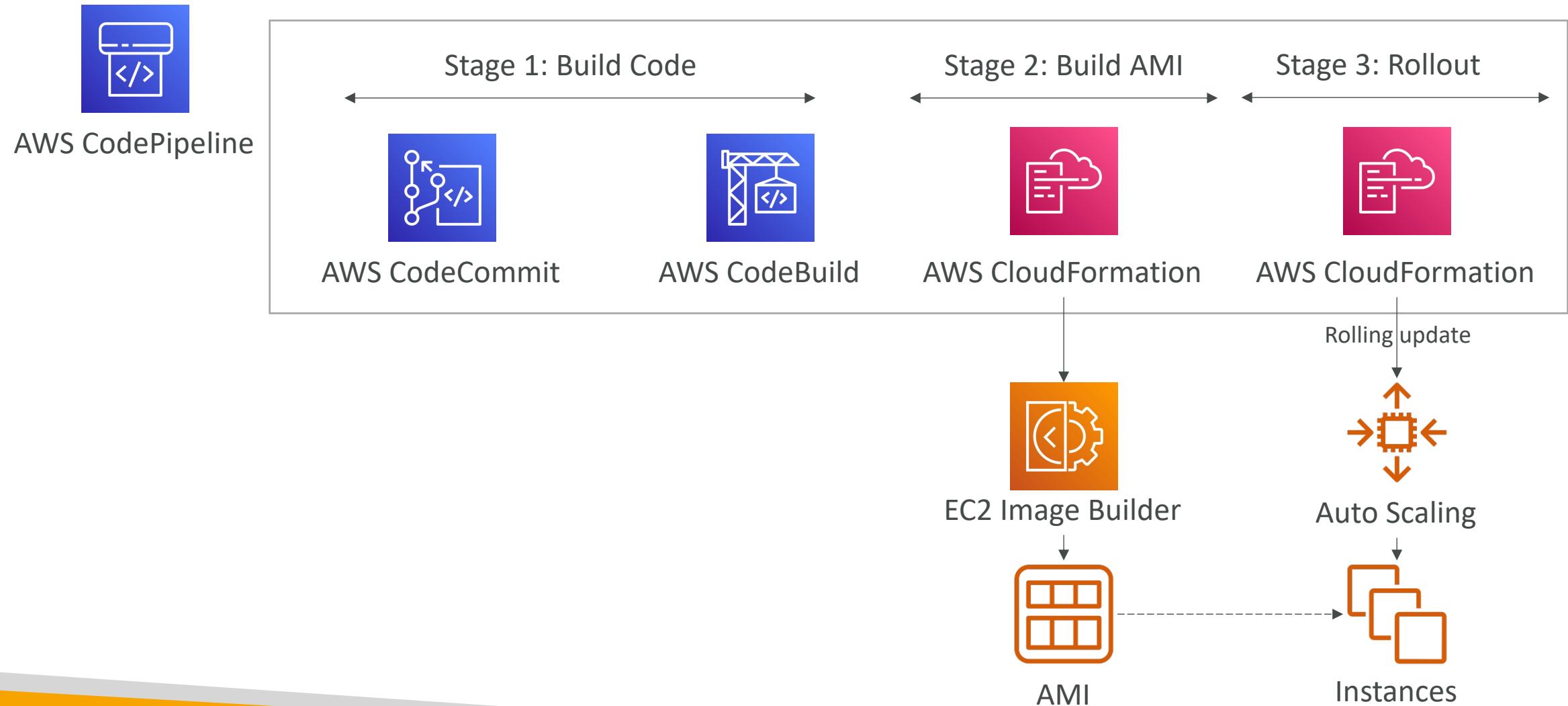
EC2 Image Builder



- Used to automate the creation of Virtual Machines or container images
- => Automate the creation, maintain, validate and test EC2 AMIs
- Can be run on a schedule (weekly, whenever packages are updated, etc...)
- Free service (only pay for the underlying resources)
- Can publish AMI to multiple regions and multiple accounts



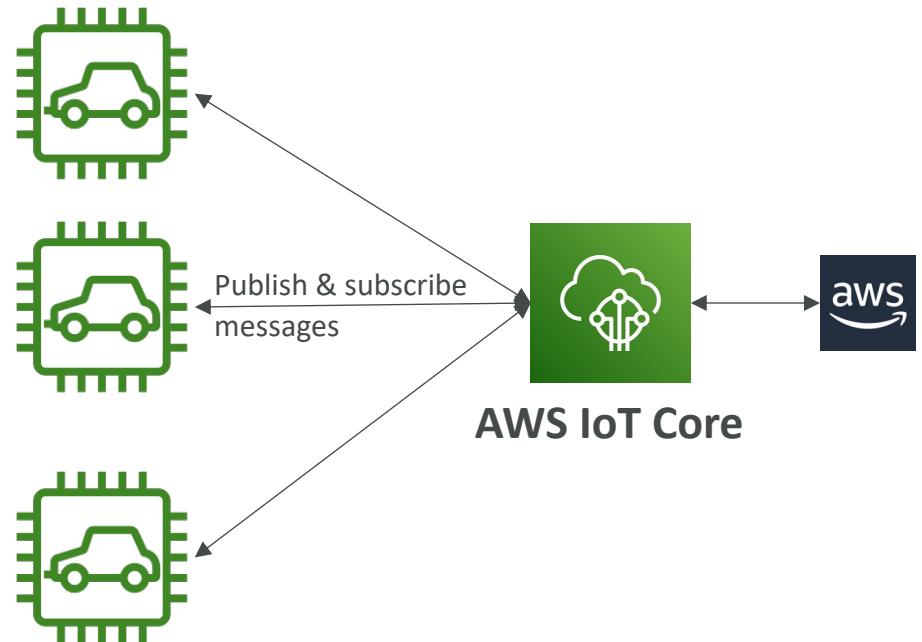
EC2 Image Builder – CICD Architecture



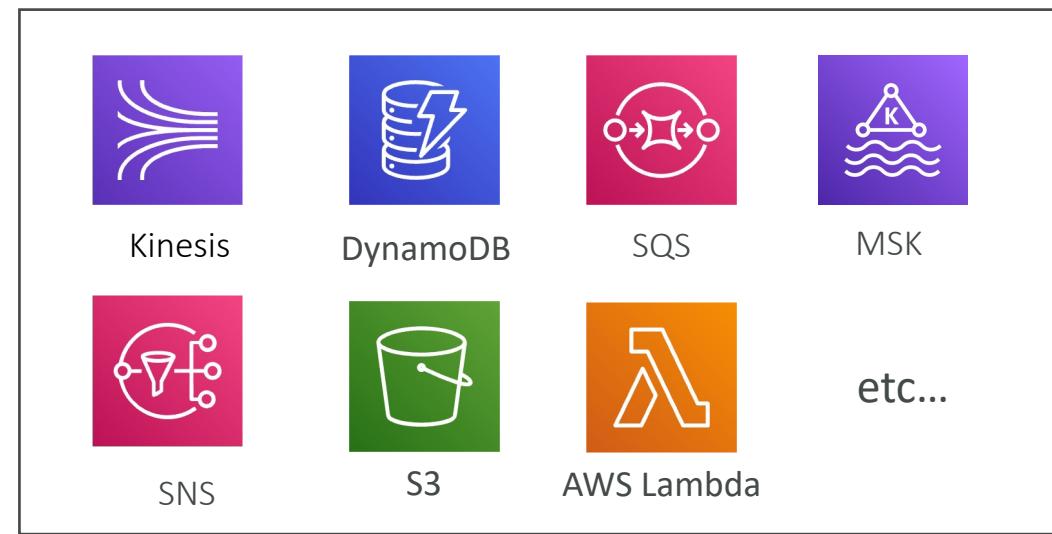
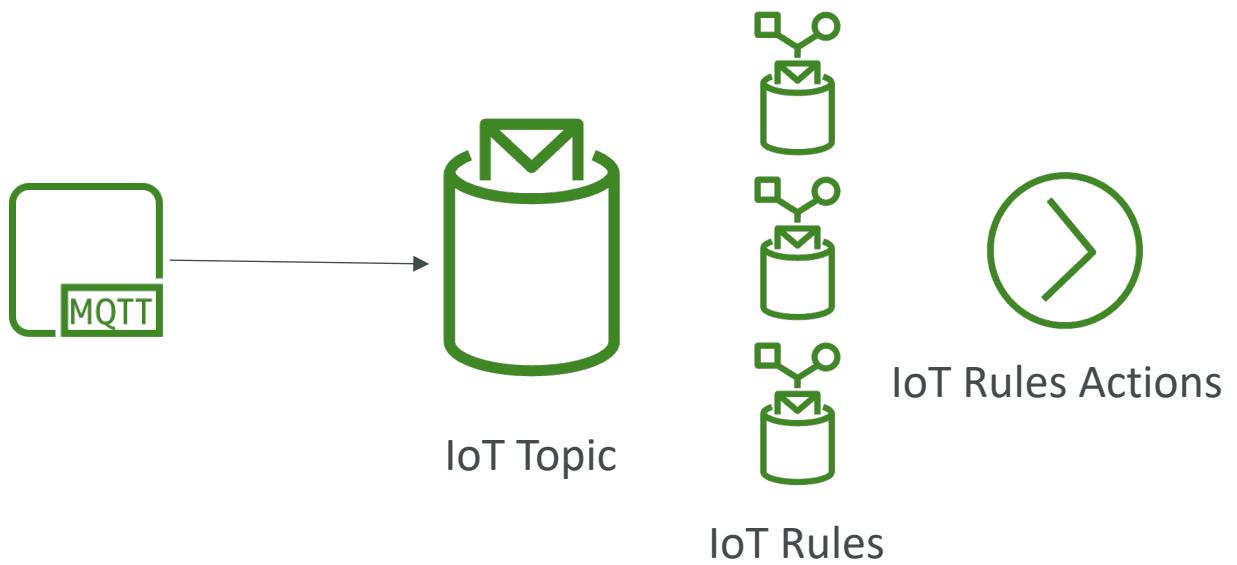
AWS IoT Core



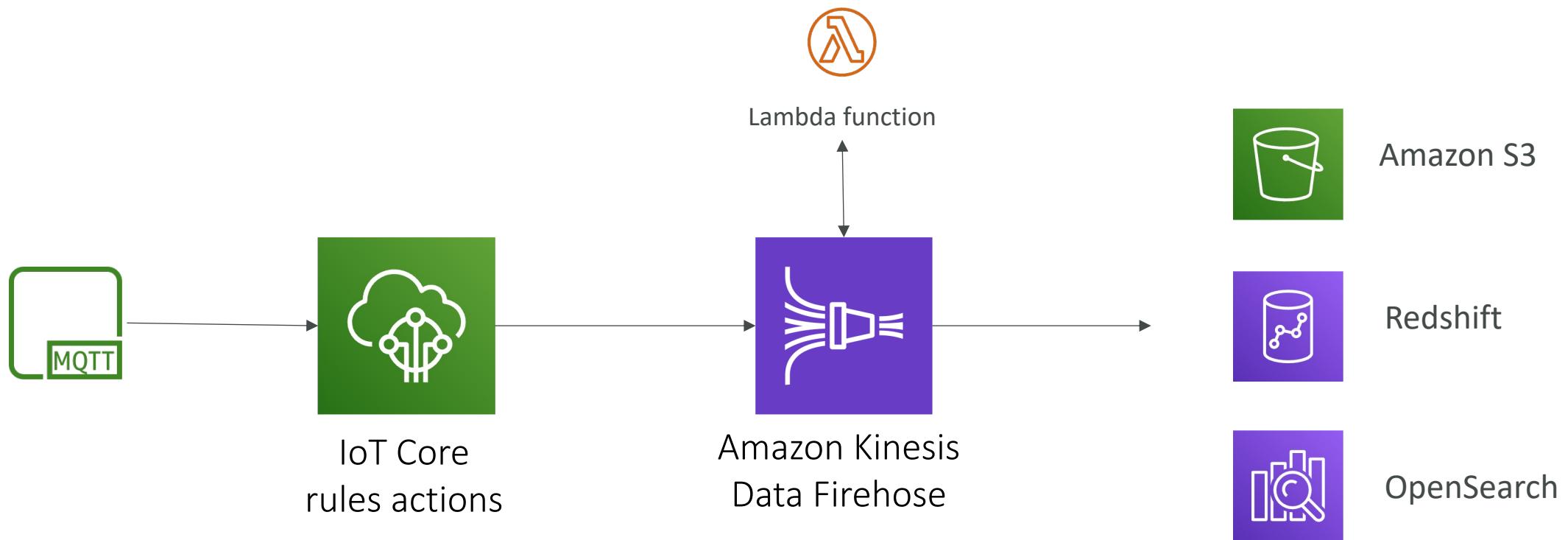
- IoT stands for “Internet of Things” – the network of internet-connected devices that are able to collect and transfer data
- AWS IoT Core allows you to **easily connect IoT devices to the AWS Cloud**
- **Serverless, secure & scalable** to billions of devices and trillions of messages
- Integrates with a lot of AWS services (Lambda, S3, SageMaker, etc.)
- Build IoT applications that gather, process, analyze, and act on data



IoT Core - Integrations



IoT Core – Kinesis Data Firehose



Exam Preparation

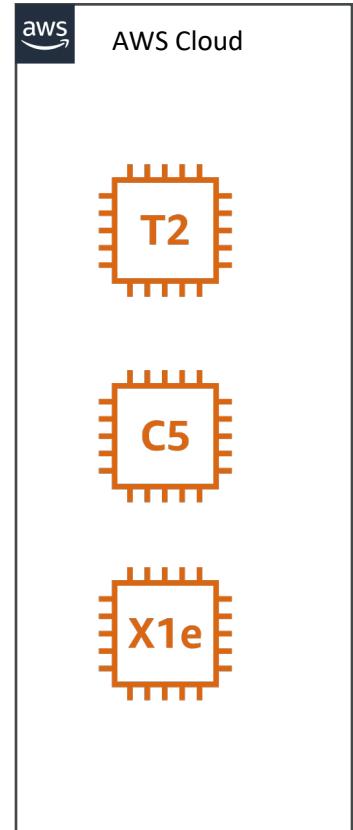
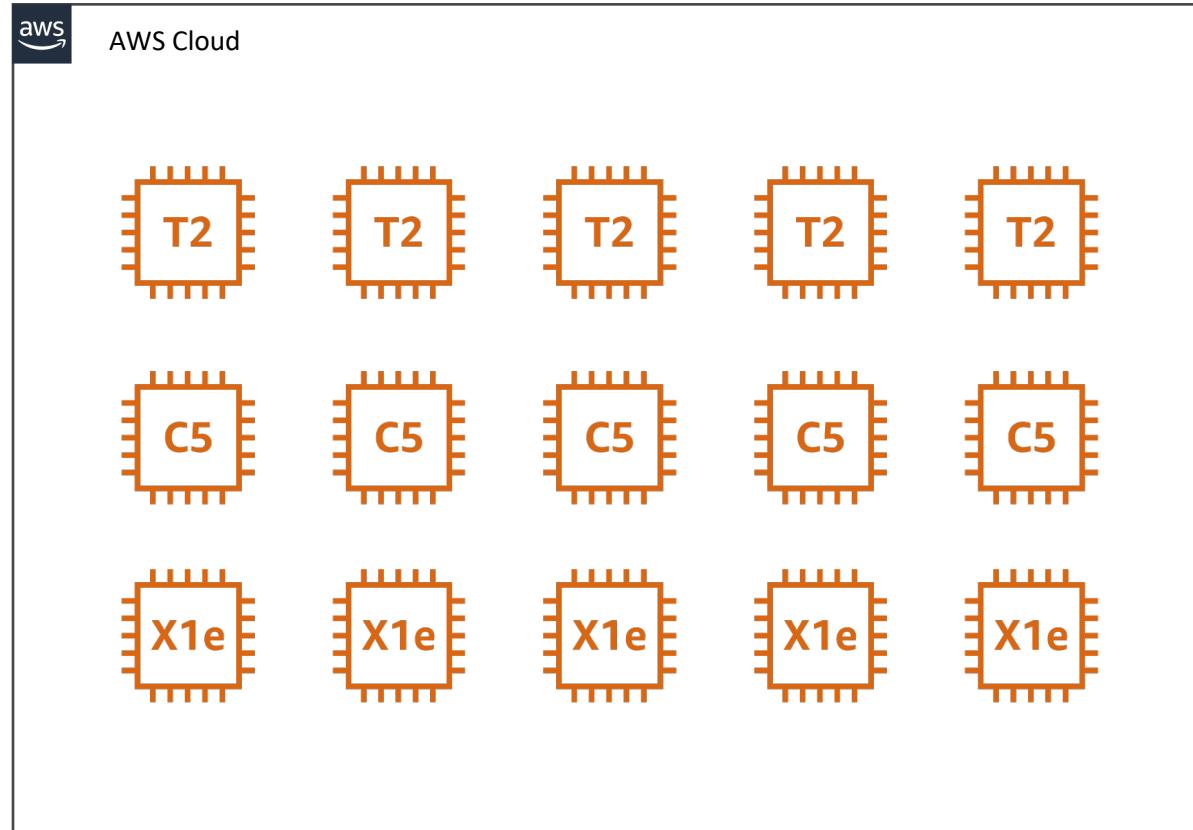
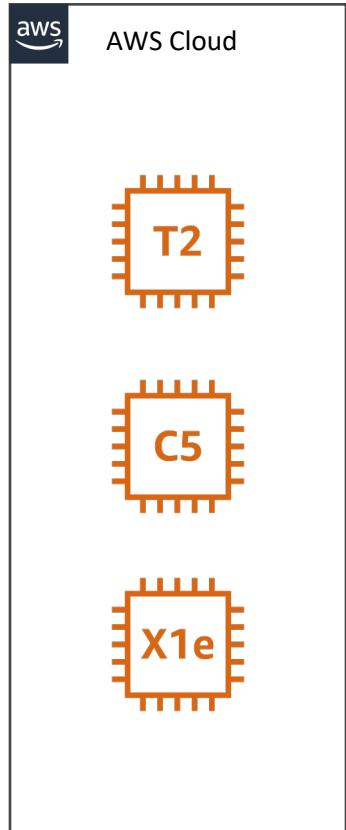
Analysis from the Practice Sample questions

- Exam Page: <https://aws.amazon.com/certification/certified-solutions-architect-professional/>

Question 1

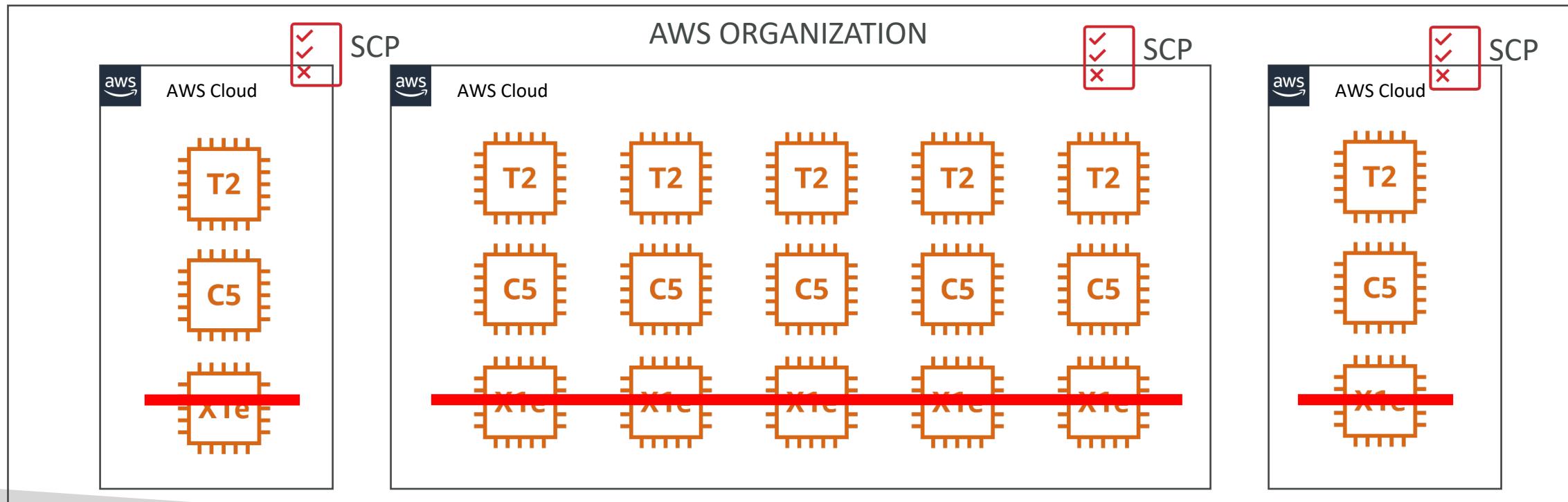
- An enterprise has a large number of AWS accounts owned by separate business groups. One of the accounts was recently compromised. The attacker launched a large number of instances, resulting in a high bill for that account.
- The security breach was addressed, but management has asked a solutions architect to develop a solution to **prevent excessive spending** in all accounts. **Each business group wants to retain full control over its AWS account.**
- Which solution should the solutions architect recommend to meet these requirements?

Question I – Architecture Diagram



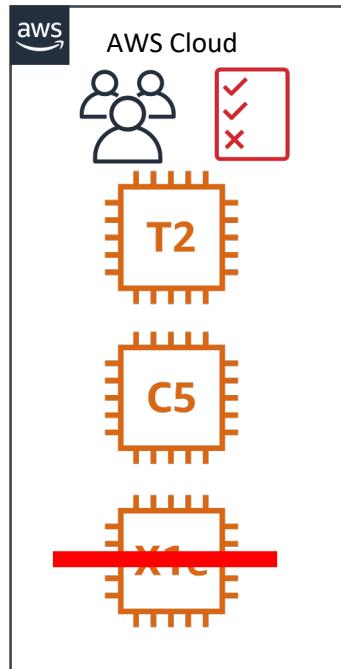
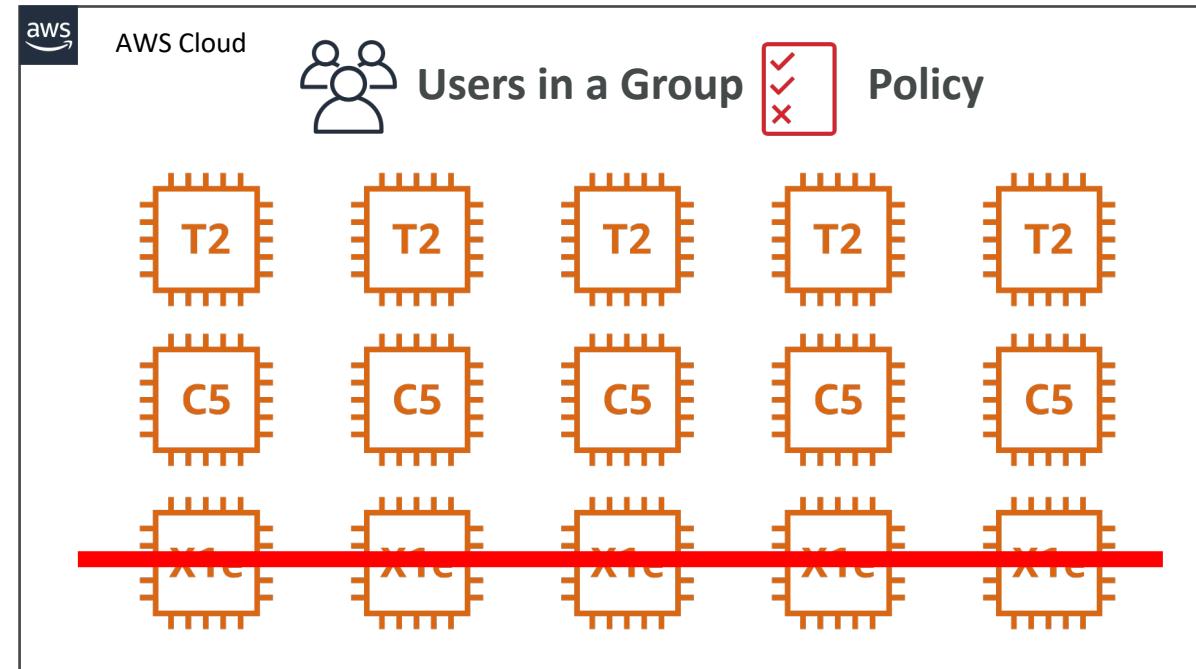
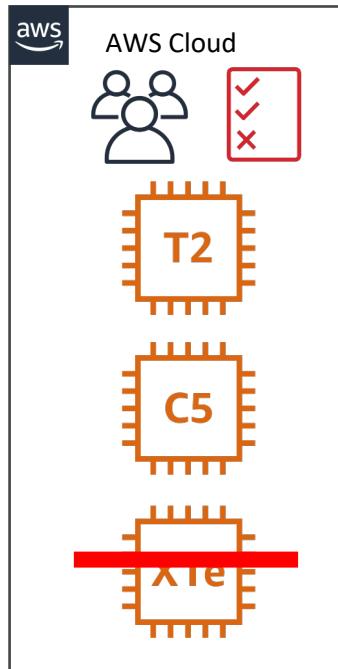
Option A

- Use AWS Organizations to add each AWS account to the master account. Create a service control policy (SCP) that uses the `ec2:instanceType` condition key to prevent the launch of high-cost instance types in each account.



Option B

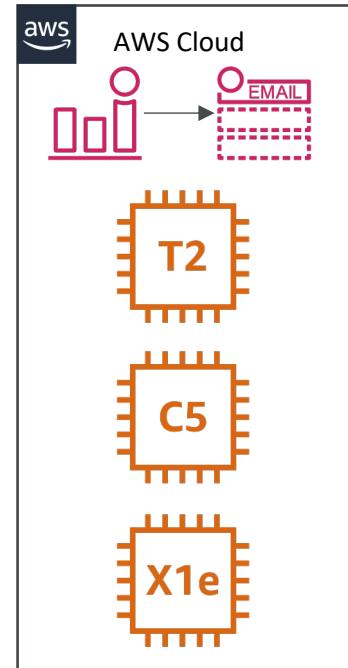
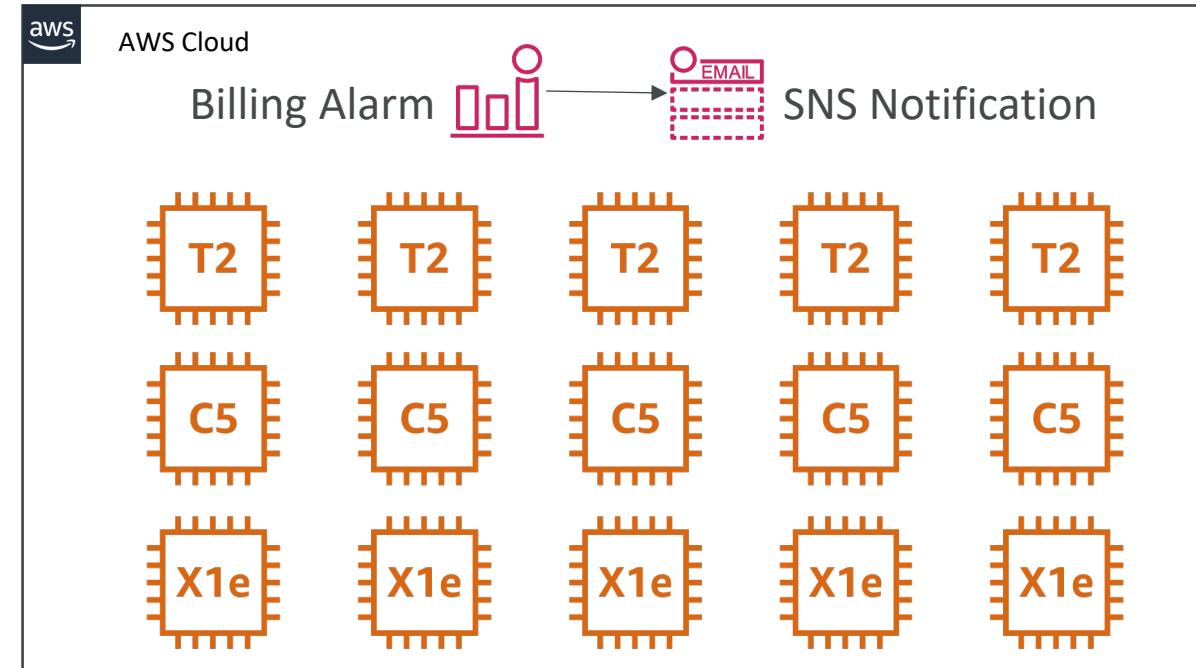
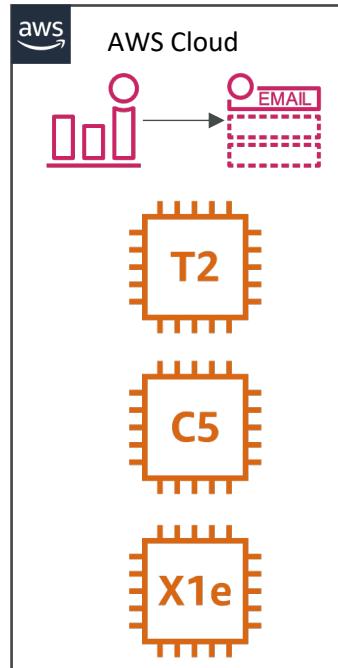
- Attach a new customer-managed IAM policy to an IAM group in each account that uses the `ec2:instanceType` condition key to prevent the launch of high-cost instance types. Place all of the existing IAM users in each group.



CORRECT ANSWER

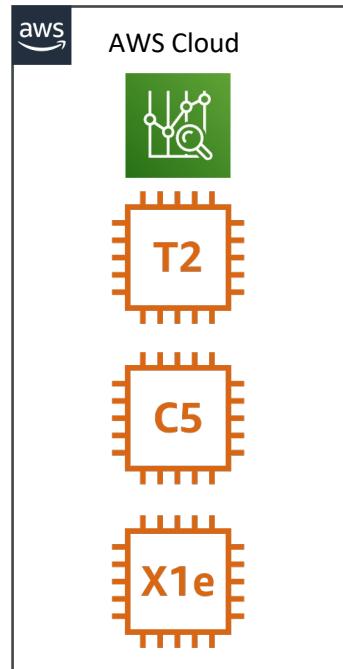
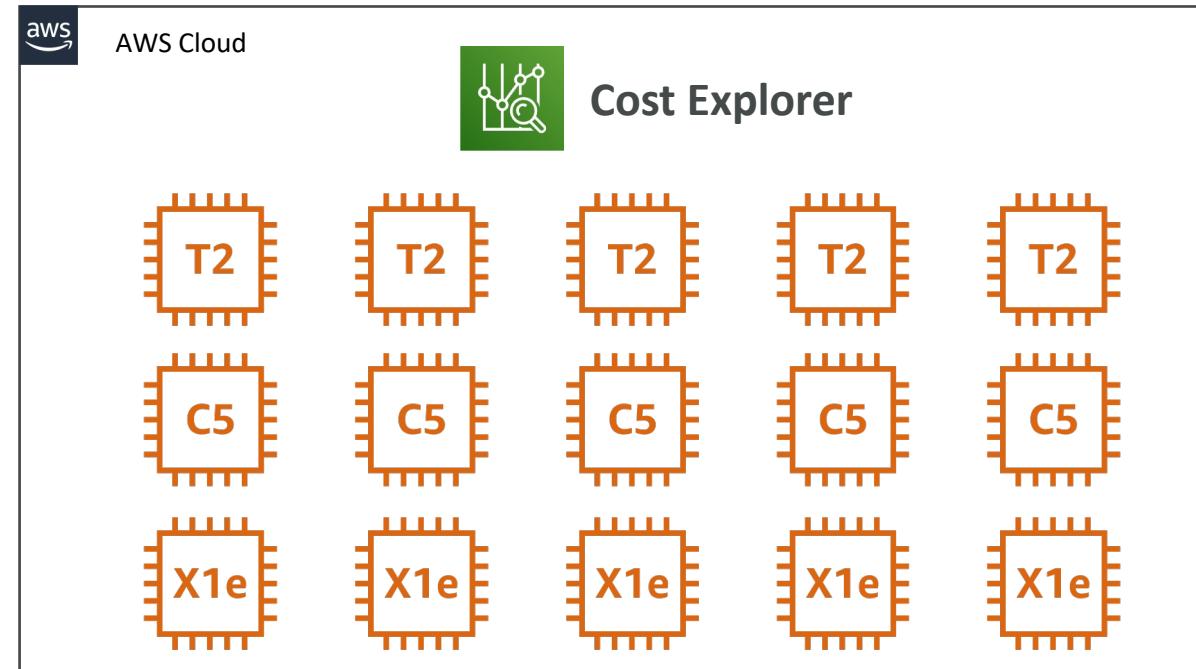
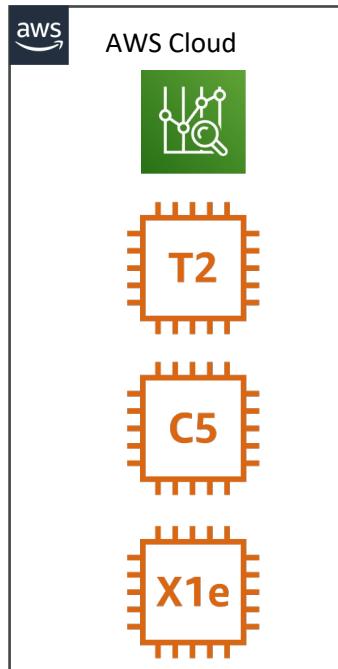
Option C

- Enable billing alerts on each AWS account. Create Amazon CloudWatch alarms that send an Amazon SNS notification to the account administrator whenever their account exceeds the spending budget.



Option D

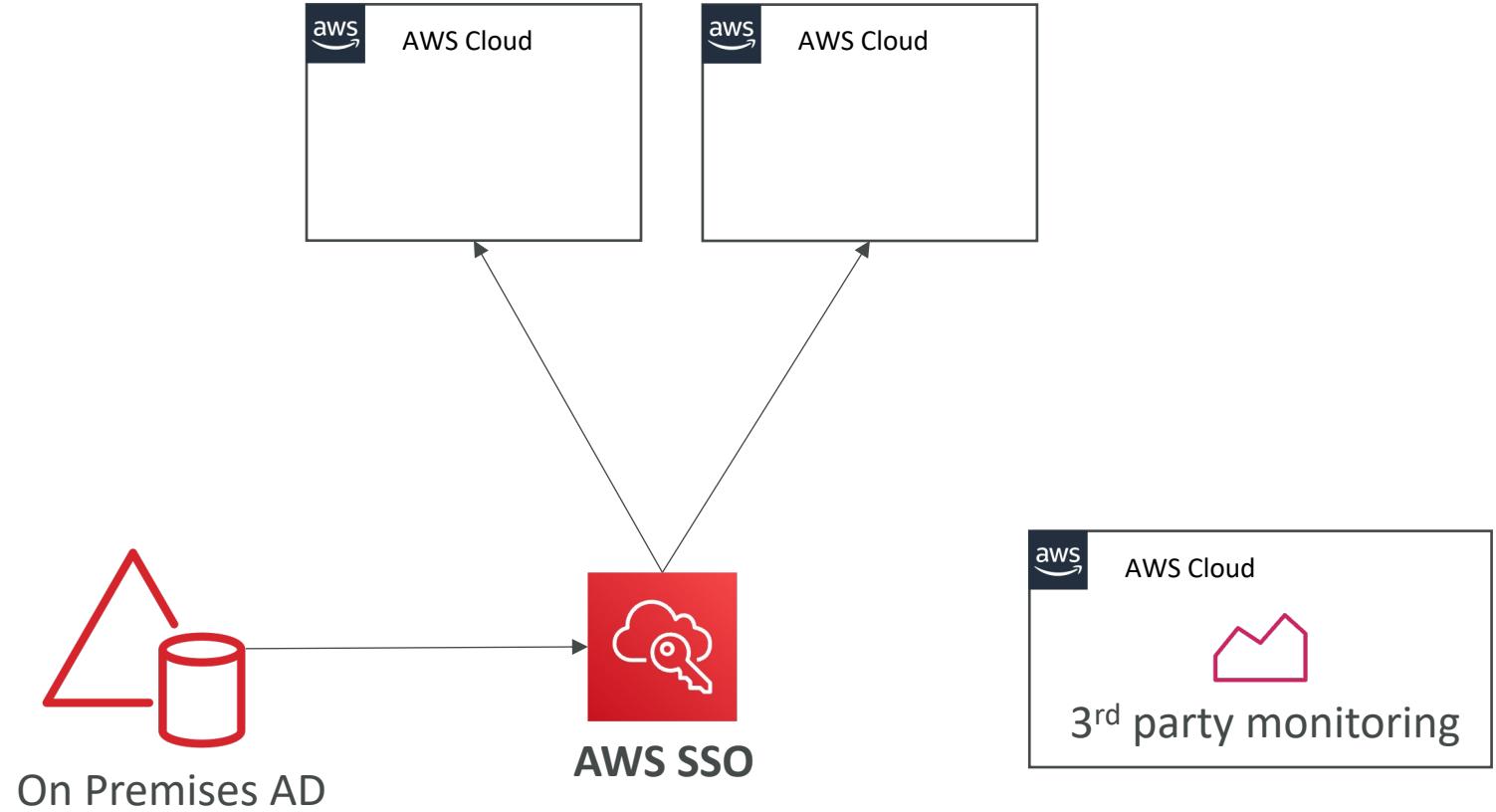
- Enable AWS Cost Explorer in each account. Regularly review the Cost Explorer reports for each account to ensure spending does not exceed the planned budget



Question 2

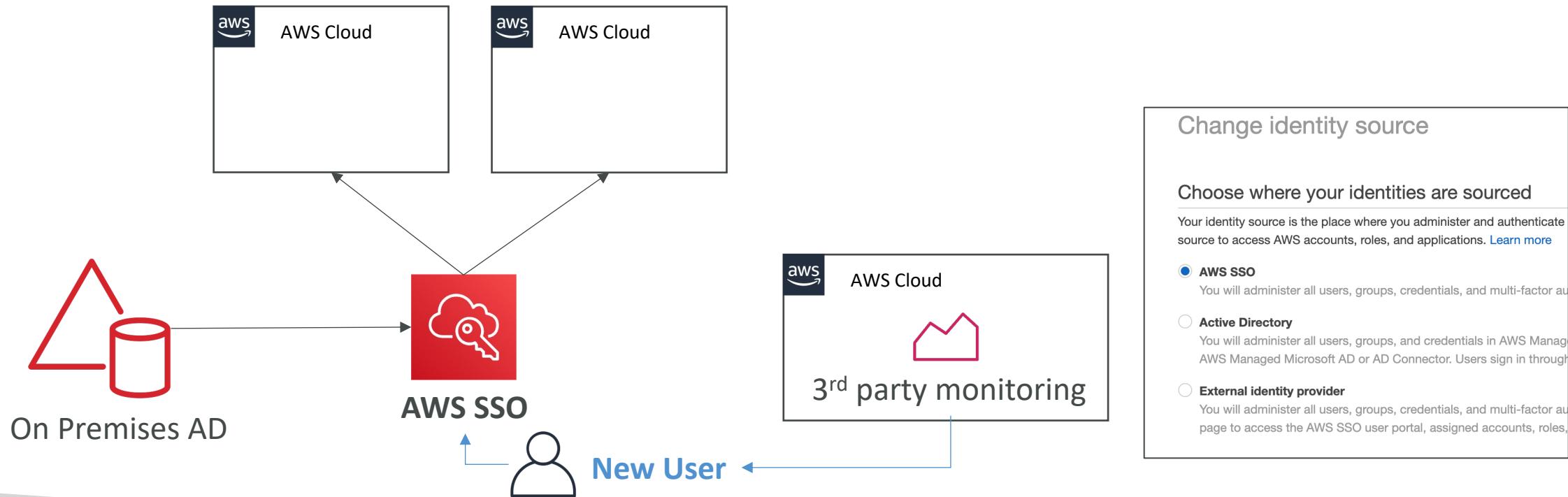
- A company has multiple AWS accounts. The company has integrated its on-premises Active Directory (AD) with AWS SSO to grant AD users least privilege abilities to manage infrastructure across all the accounts.
- A solutions architect must integrate a third-party monitoring solution that requires **read-only** access across all AWS accounts. The monitoring solutions will run **in its own AWS account**.
- How can the monitoring solution be given the required permissions?

Question 2 - Architecture



Option A

- Create a user in an AWS SSO directory and assign a read-only permissions set. Assign all AWS accounts to be monitored to the new user. Provide the third-party monitoring solution with the user name and password.

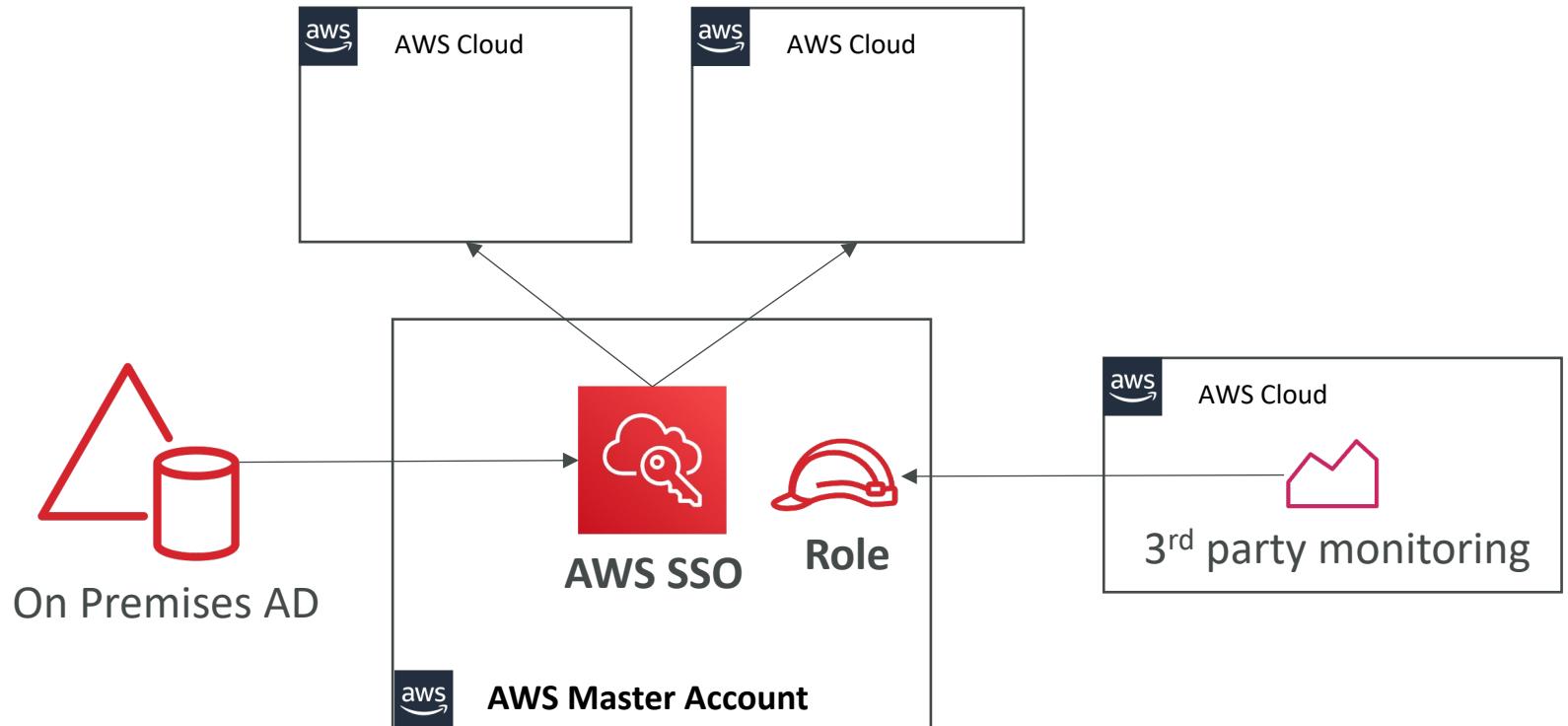


Note on option A

- Currently, the sample question PDF says:
- “A is incorrect because credentials supplied by AWS SSO are temporary, so the application would lose permissions and have to re-login”
- That is wrong.
- Users created in AWS SSO have a password that doesn't change and must respect the password policy defined.
- Here Option A is wrong because you can't have both users defined in AWS SSO and in Active Directory. SSO only allows for one Identity source (SSO, AD or IdP).

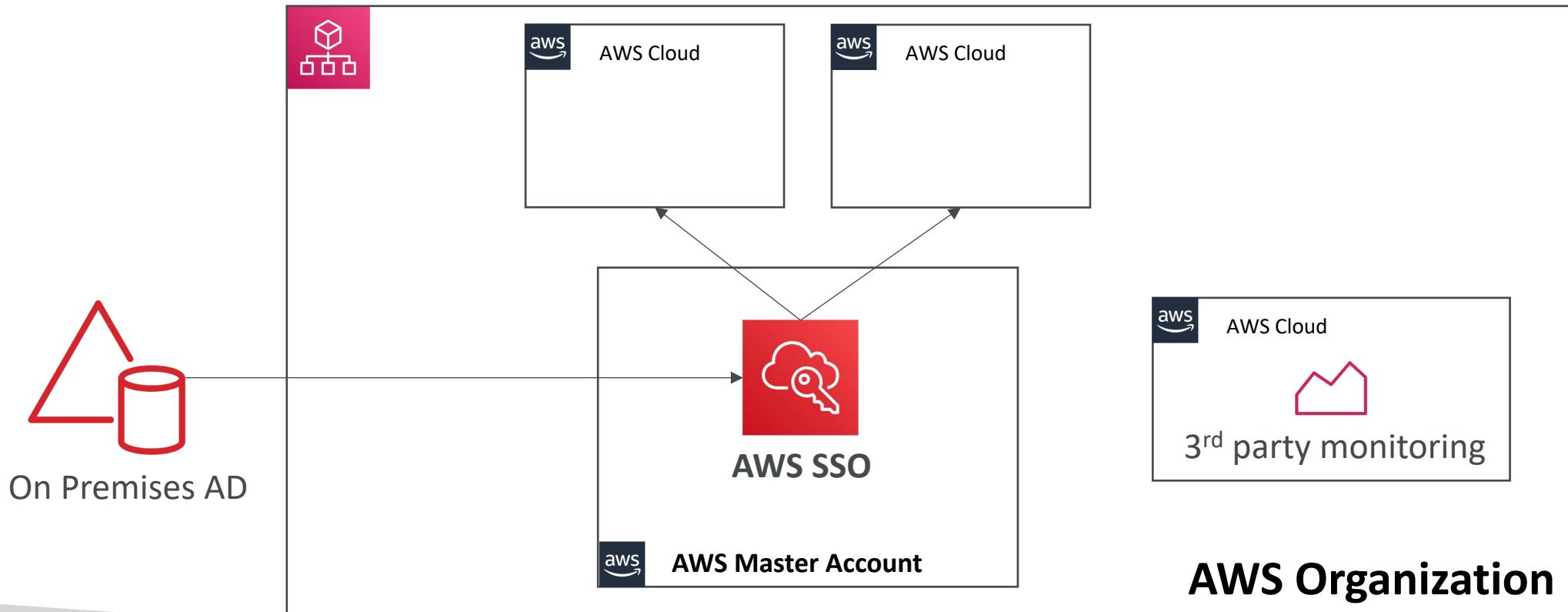
Option B

- Create an AWS IAM role in the organization's master account. Allow the AWS account of the third-party monitoring solution to assume the role.



Option C

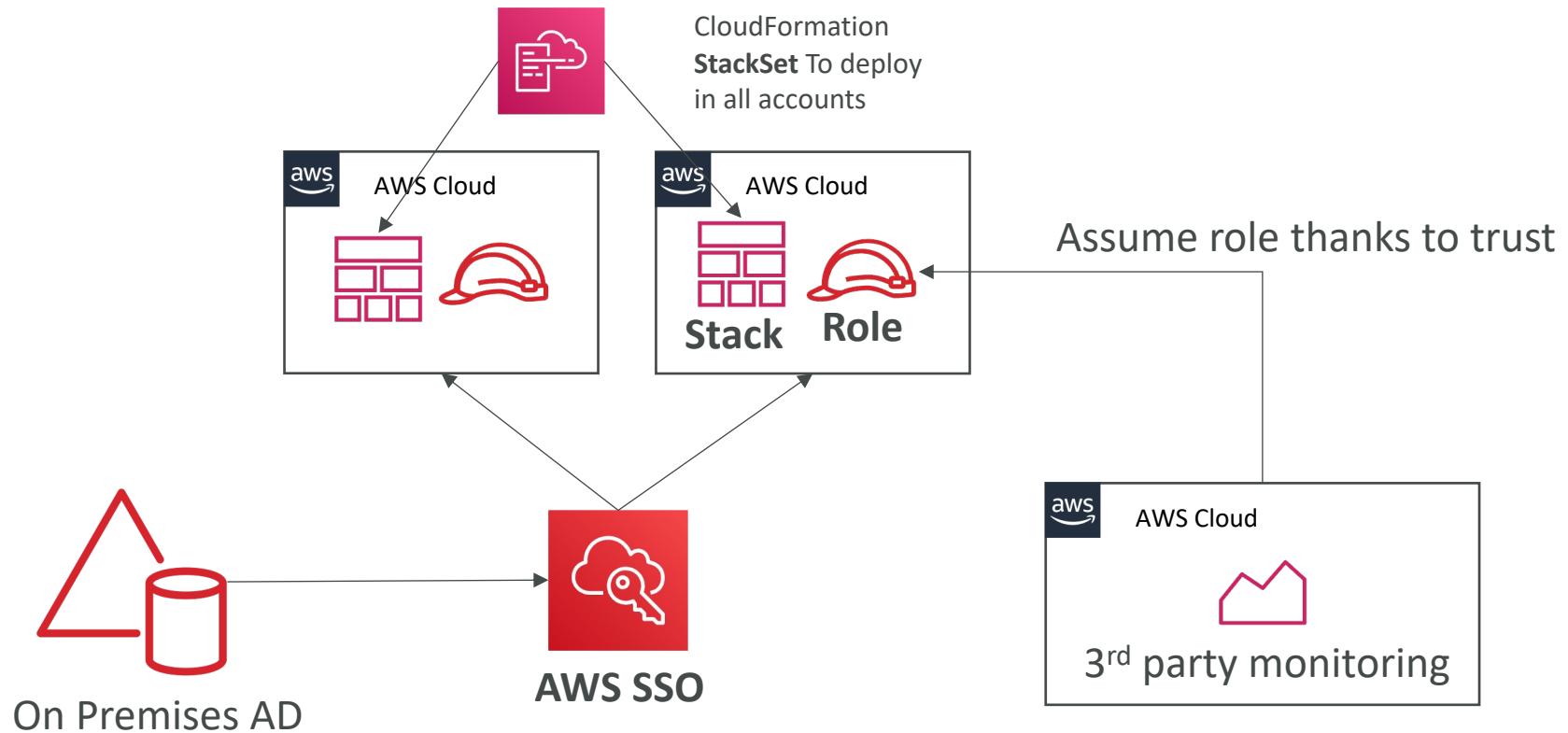
- Invite the AWS account of the third-party monitoring solution to join the organization. Enable all features



CORRECT ANSWER

Option D

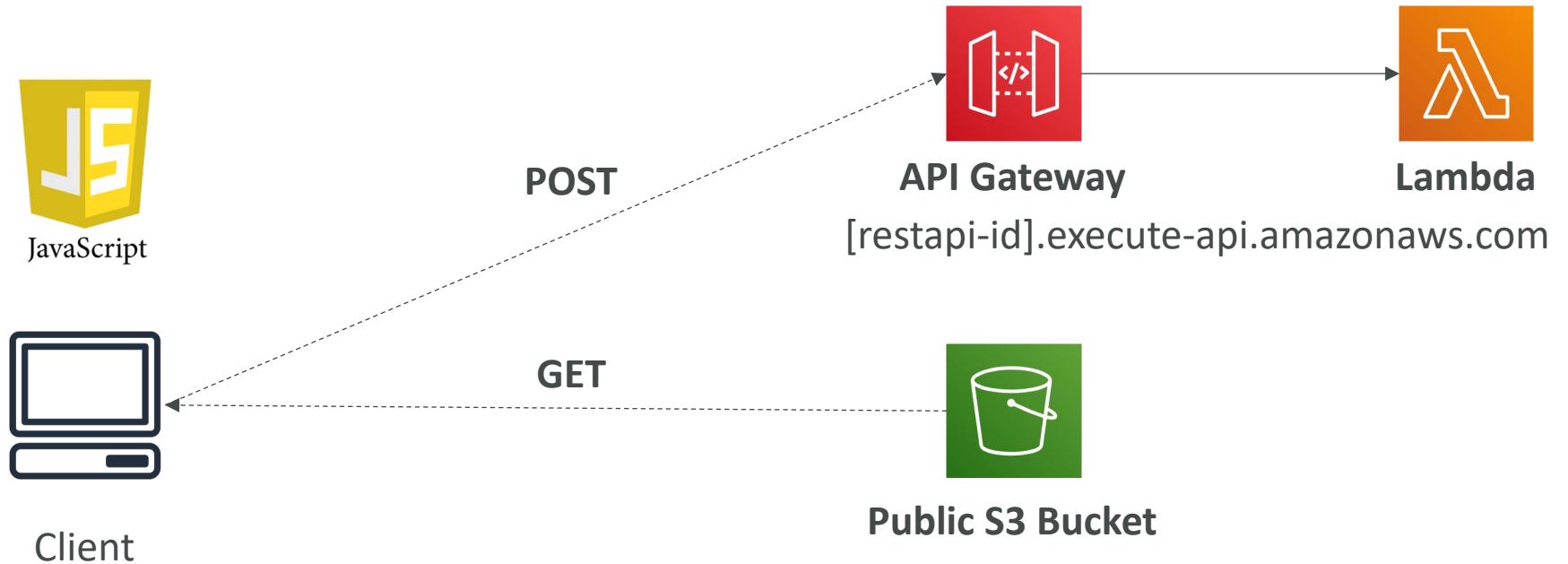
- Create an AWS CloudFormation template that defines a new AWS IAM role for the third-party monitoring solution with the account of the third party listed in the trust policy. Create the IAM role across all linked AWS accounts by using a stack set.



Question 3

- A team is building an **HTML form hosted in a public Amazon S3 bucket**. The form uses **JavaScript to post data to an Amazon API Gateway endpoint**. The endpoint is integrated with AWS Lambda functions. The team has tested each method in the API Gateway console and received valid responses.
- Which combination of steps must be completed for the form **to successfully post to the API Gateway** and receive a valid response? (Select **TWO**.)

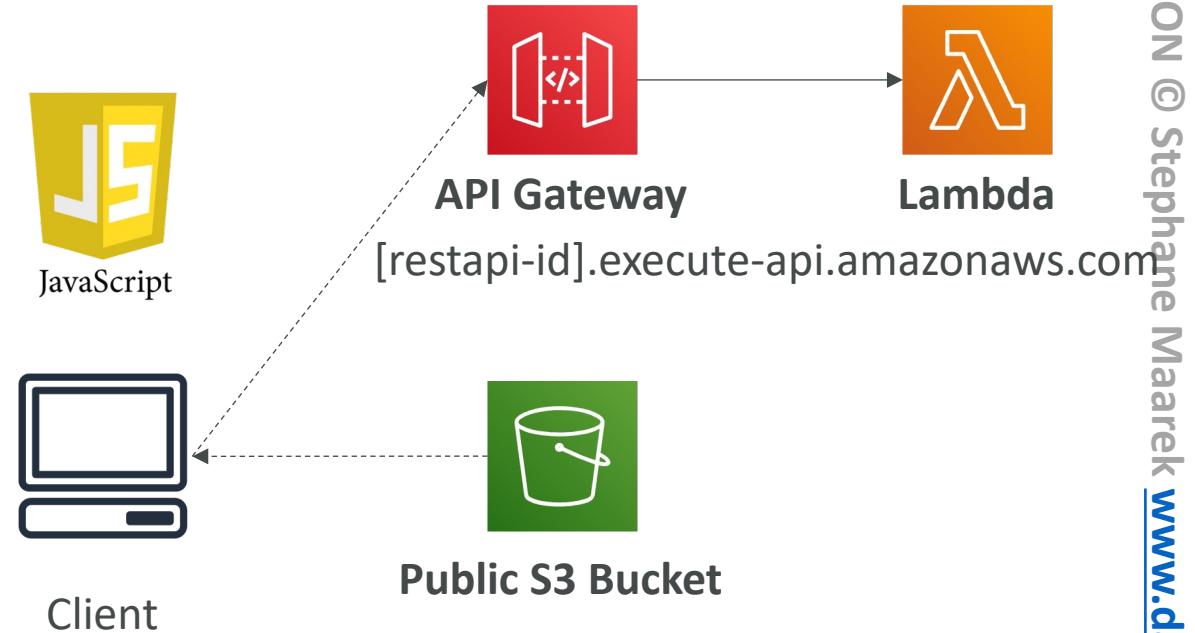
Question 3 – Architecture



CORRECT ANSWERS D,E

Options

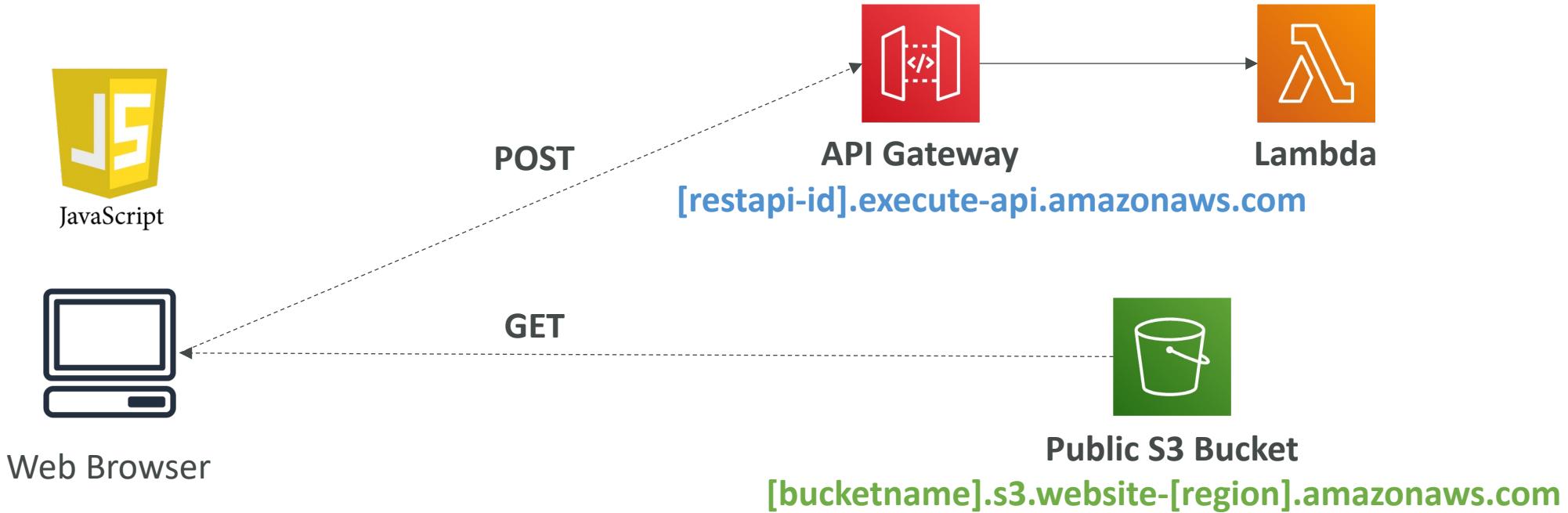
- A) Configure the S3 bucket to allow cross-origin resource sharing (CORS).
- B) Host the form on Amazon EC2 rather than Amazon S3.
- C) Request a limit increase for API Gateway.
- D) Enable cross-origin resource sharing (CORS) in API Gateway.
- E) Configure the S3 bucket for web hosting.



Question 3 – Final Architecture

CORS is a Browser based security

CORS to allow calls with Origin **[bucketname].s3.website-[region].amazonaws.com**
Using the header **Access-Control-Allow-Origin**

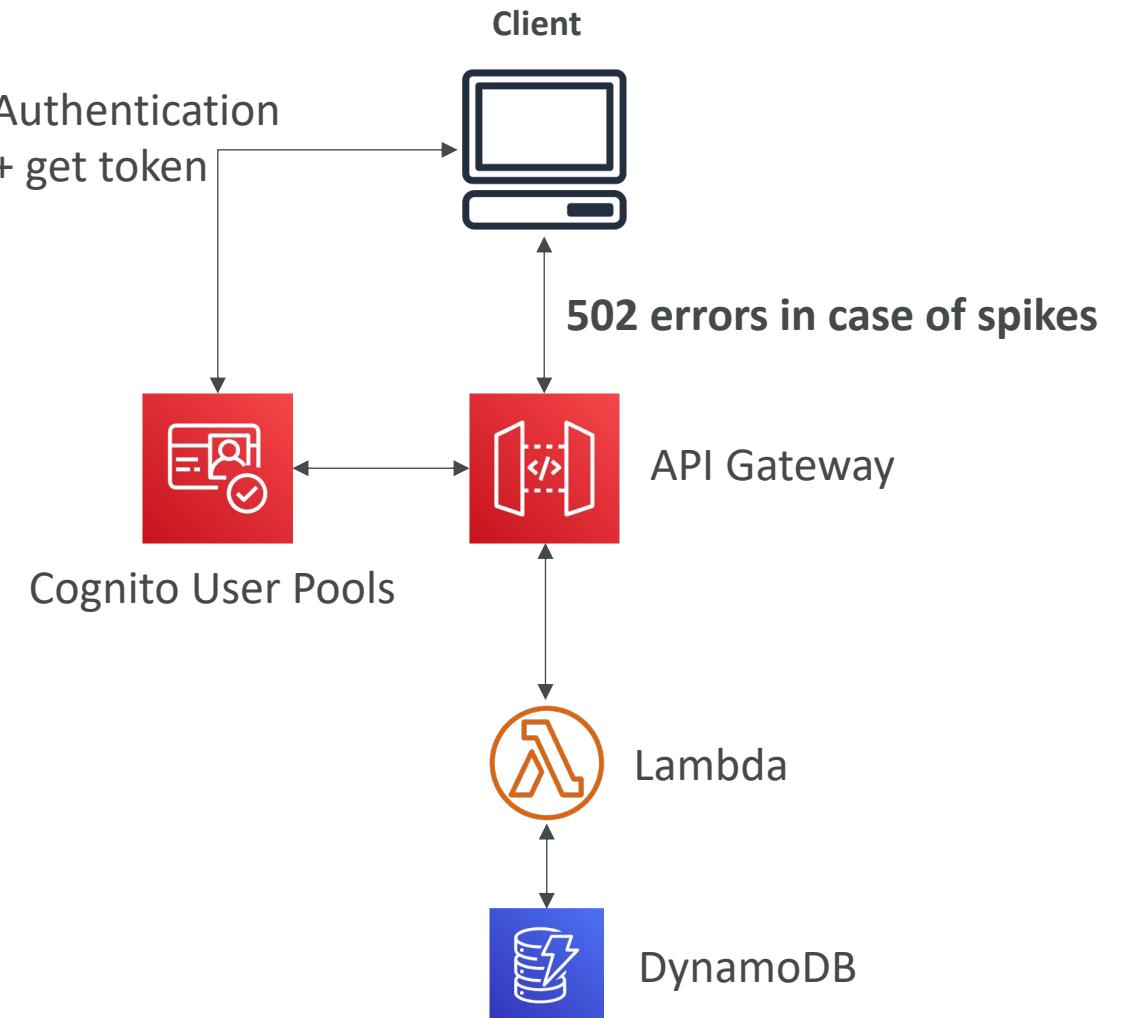


Visits **[bucketname].s3.website-[region].amazonaws.com**
Makes API calls to **[restapi-id].execute-api.amazonaws.com**
With **Origin: [bucketname].s3.website-[region].amazonaws.com**

Question 4

- A retail company runs a serverless mobile app built on Amazon API Gateway, AWS Lambda, Amazon Cognito, and Amazon DynamoDB. During **heavy holiday traffic spikes**, the company receives complaints of **intermittent system failures**. Developers find that the API Gateway endpoint is returning **502 Bad Gateway errors** to seemingly valid requests.
- Which method should address this issue?

Question 4 – Architecture



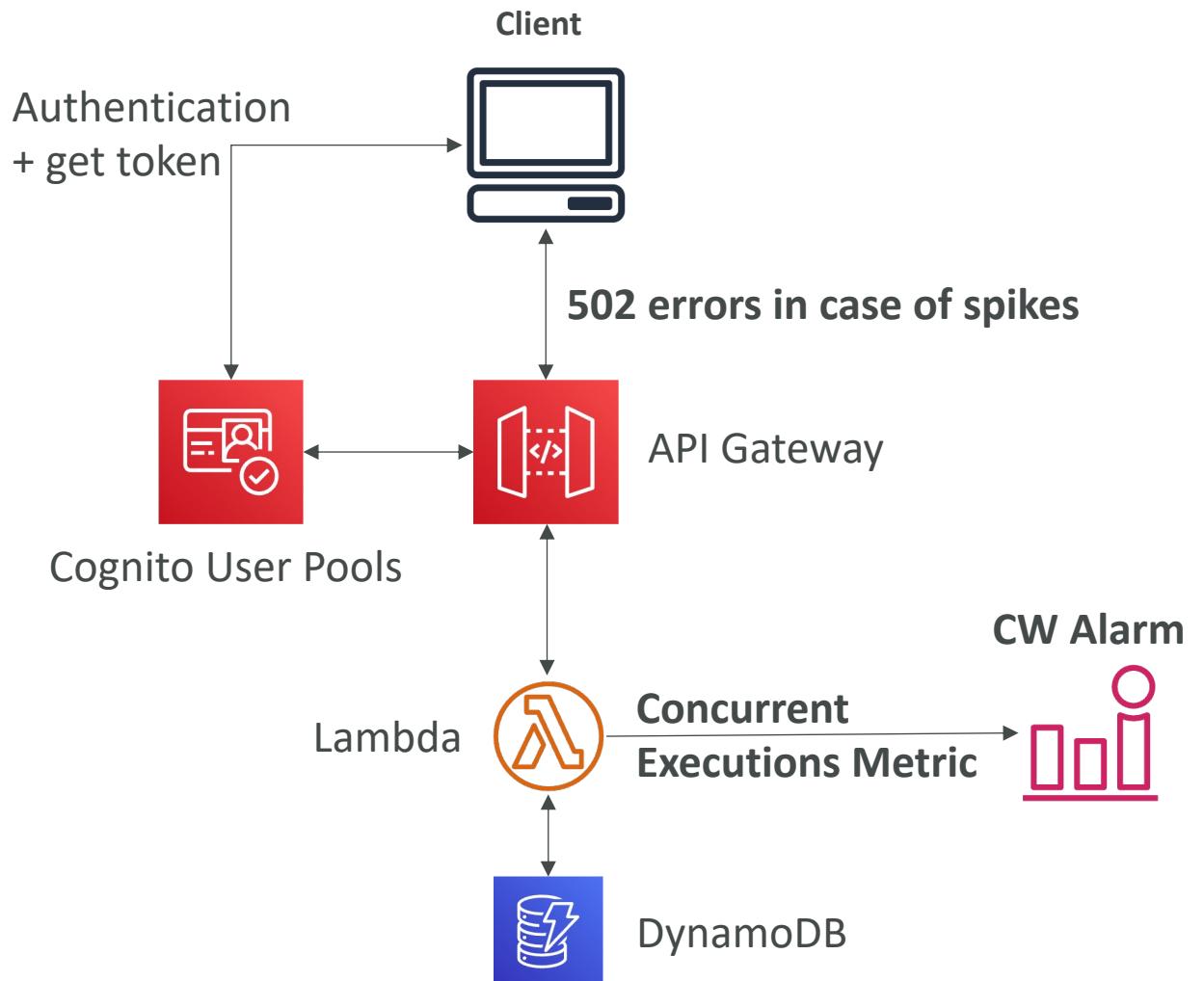
API Gateway - Errors

- 4xx means Client errors
 - 400: Bad Request
 - 403: Access Denied, WAF filtered
 - 429: Quota exceeded, Throttle
- 5xx means Server errors
 - 502: Bad Gateway Exception, usually for an incompatible output returned from a Lambda proxy integration backend and occasionally for out-of-order invocations due to heavy loads.
 - 503: Service Unavailable Exception
 - 504: Integration Failure – ex Endpoint Request Timed-out Exception
API Gateway requests time out after 29 second maximum

CORRECT ANSWER

Option A

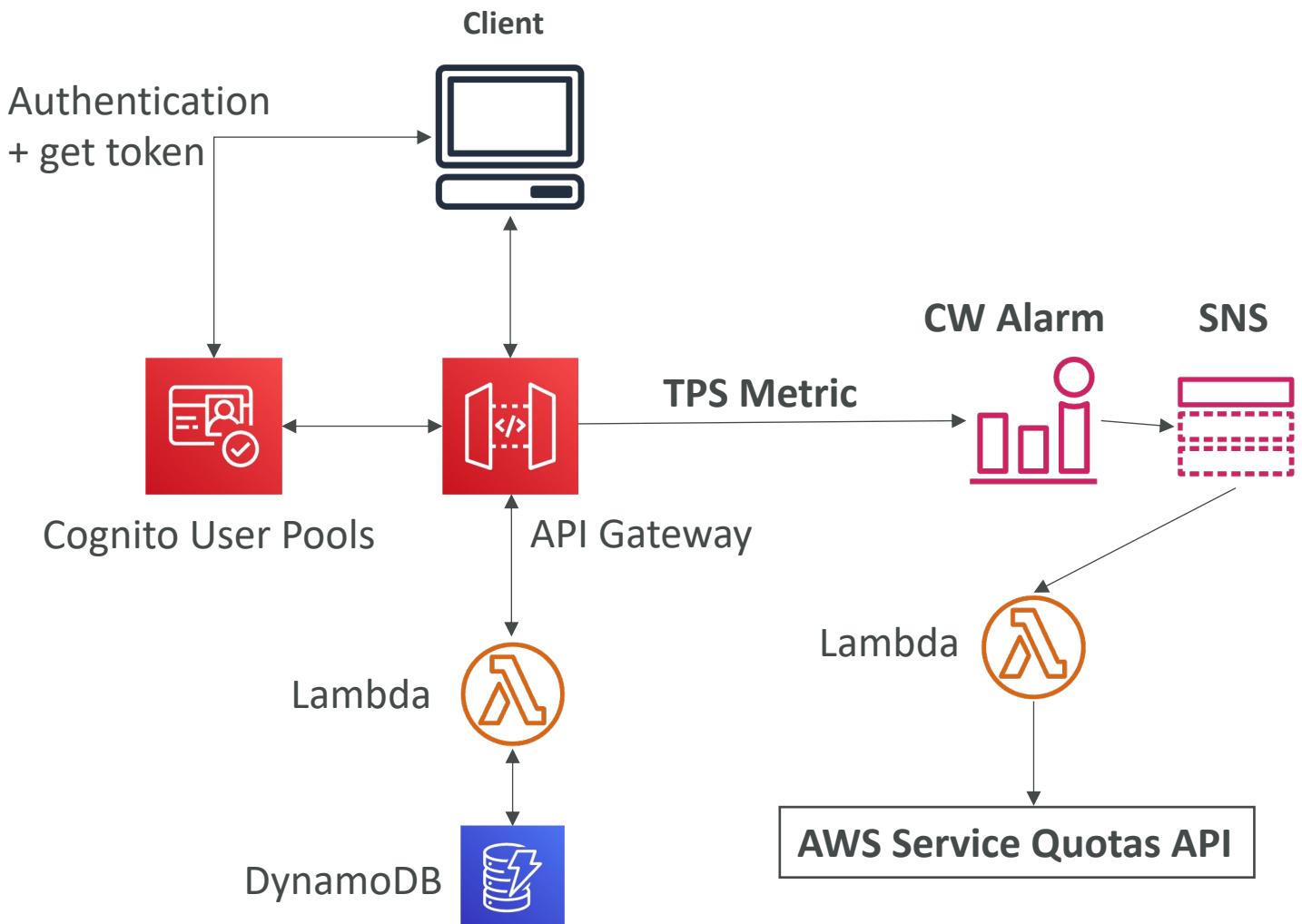
- Increase the concurrency limit for Lambda functions and configure notification alerts to be sent by Amazon CloudWatch when the `ConcurrentExecutions` metric approaches the limit.



Option B

- Configure notification alerts for the limit of transactions per second on the API Gateway endpoint and create a Lambda function that will increase this limit, as needed.

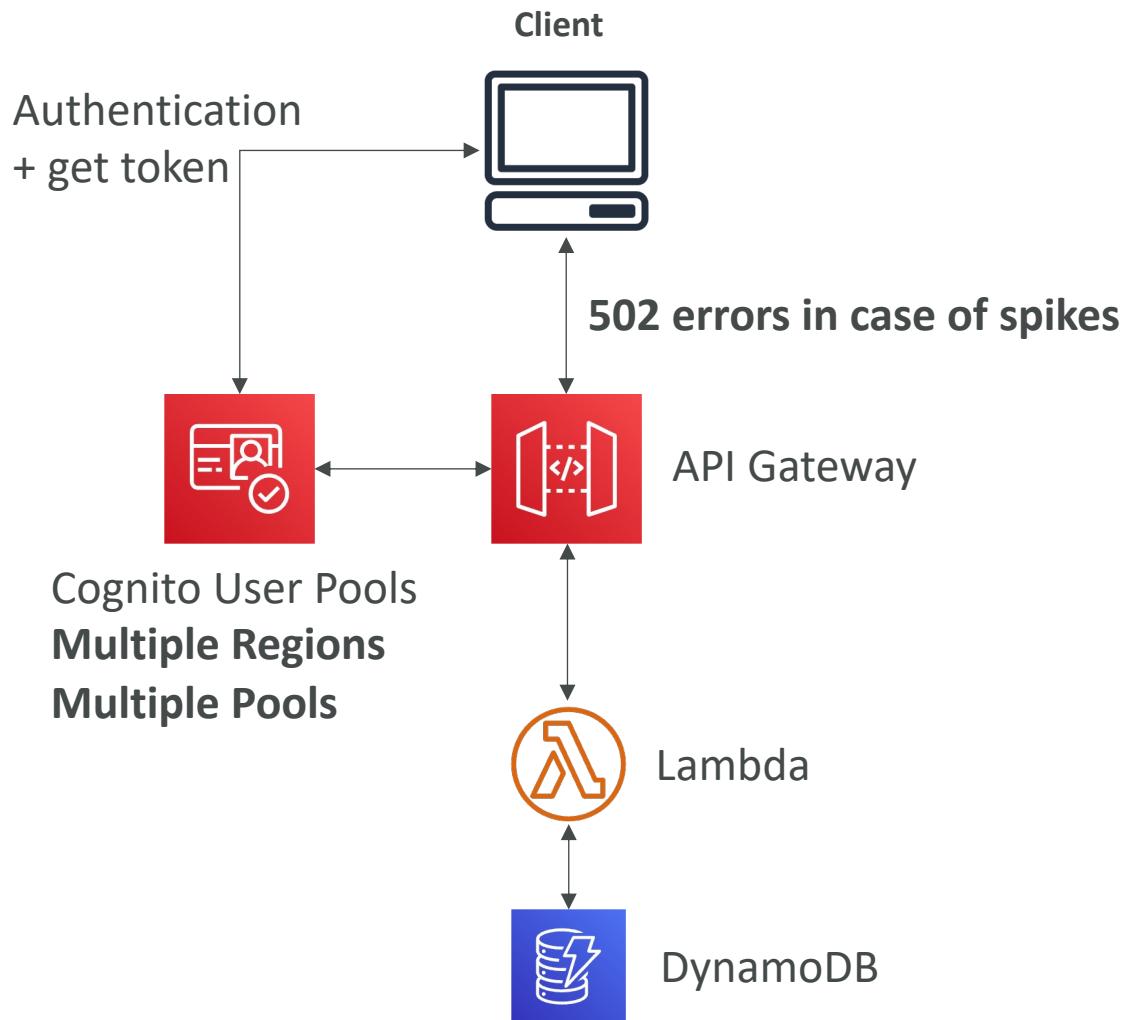
Option B would work if we were receiving 429 errors
429: Quota exceeded, Throttle



Option C

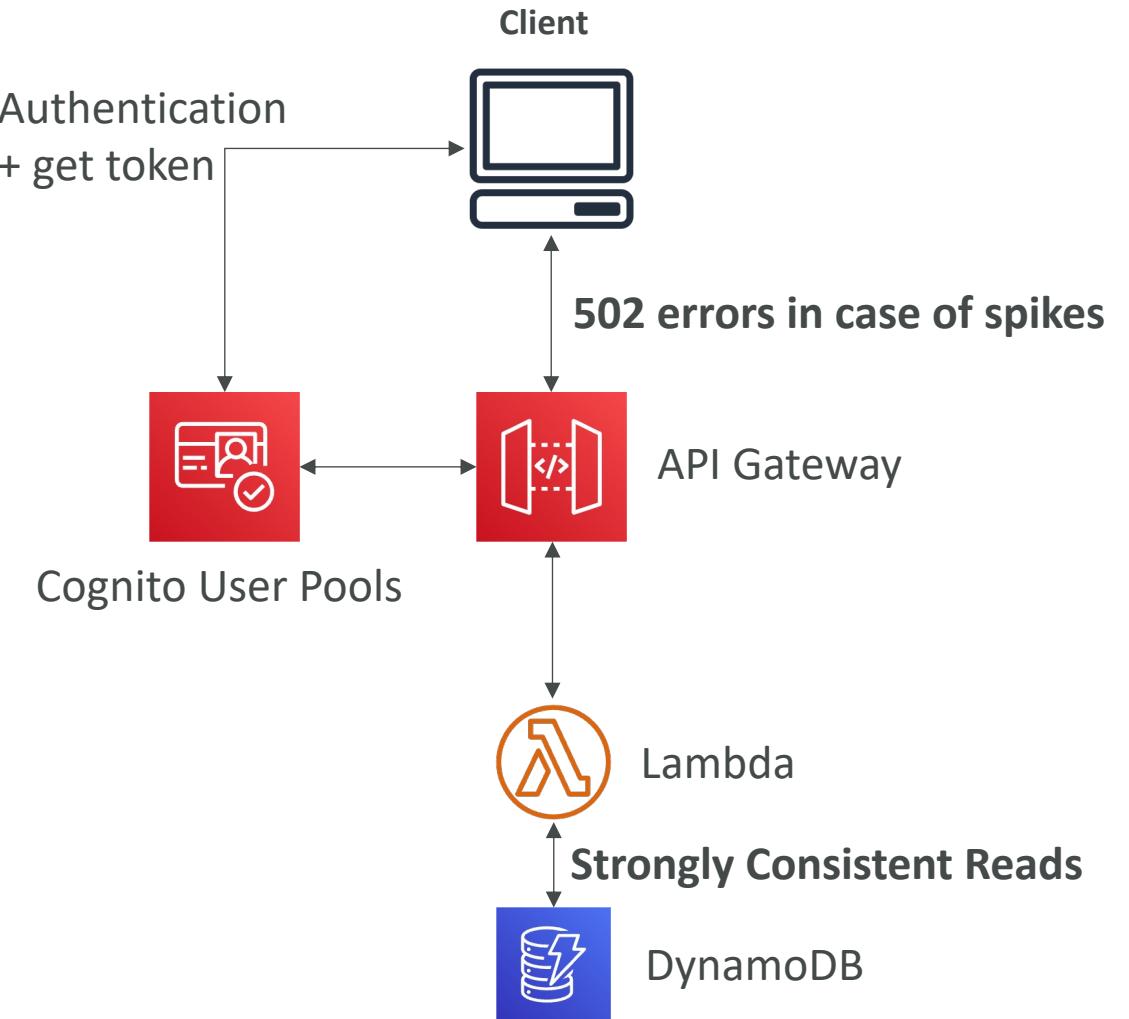
- Shard users to Amazon Cognito user pools in multiple regions to reduce user authentication latency.

Option C would be valid if we had performance issues At Cognito User Pools, but that's not the question



Option D

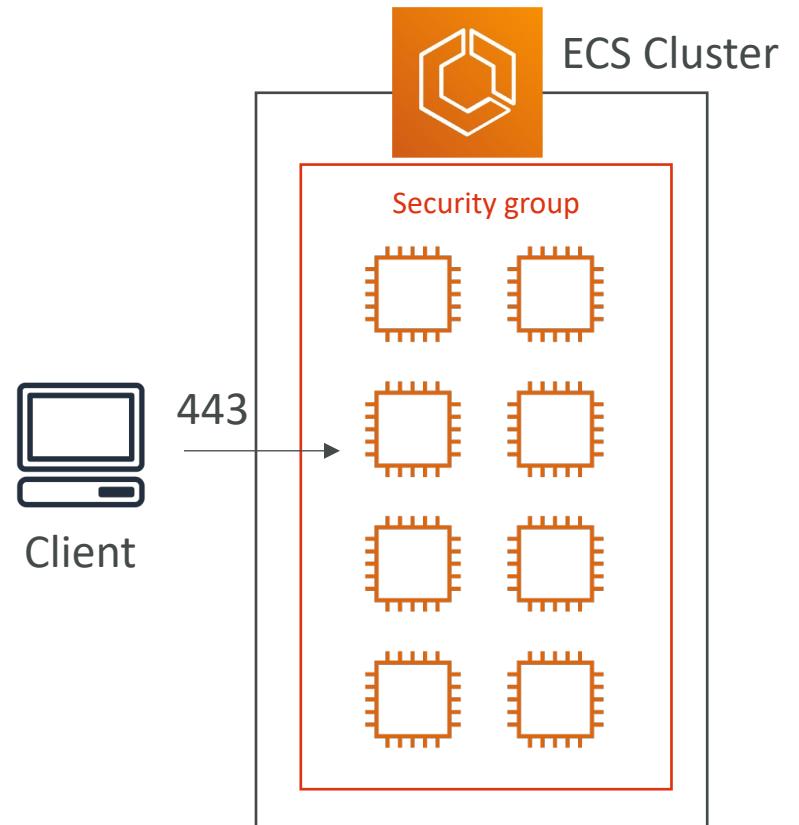
- Use DynamoDB strongly consistent reads to ensure the latest data is always returned to the client application.



Question 5

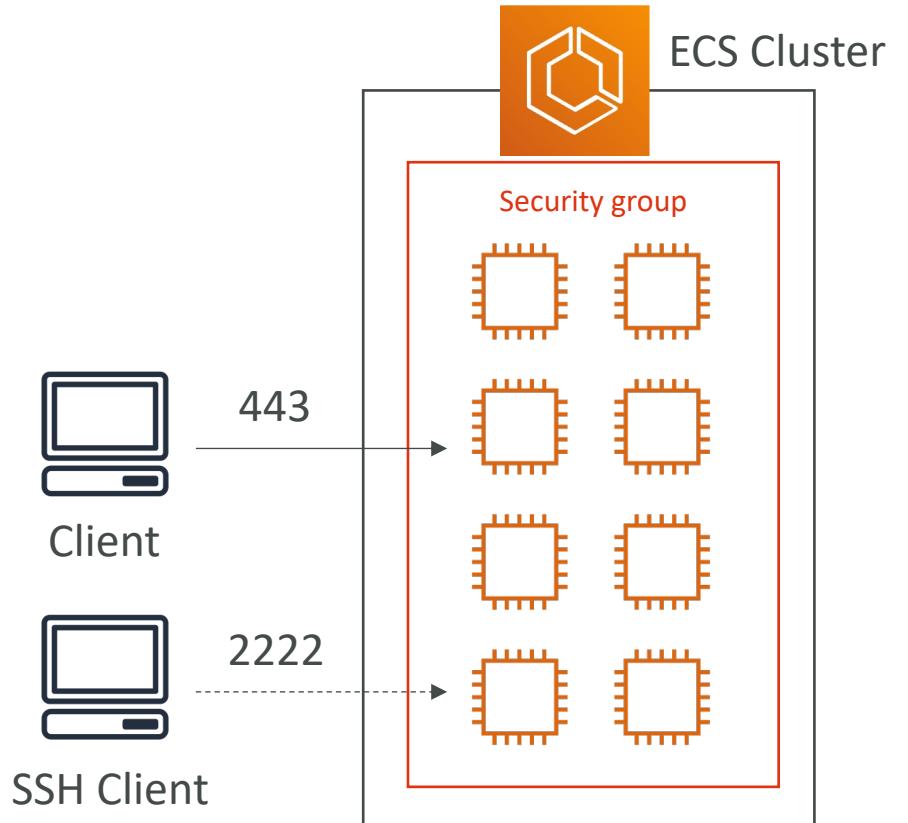
- A company is launching a new web service on an Amazon ECS cluster. Company policy requires that the security group on the cluster instances block all inbound traffic but HTTPS (port 443). The cluster consists of Amazon 100 EC2 instances. Security engineers are responsible for managing and updating the cluster instances. The security engineering team is small, so any management efforts must be minimized.
- How can the service be designed to meet these operational requirements?

Question 5 – Architecture



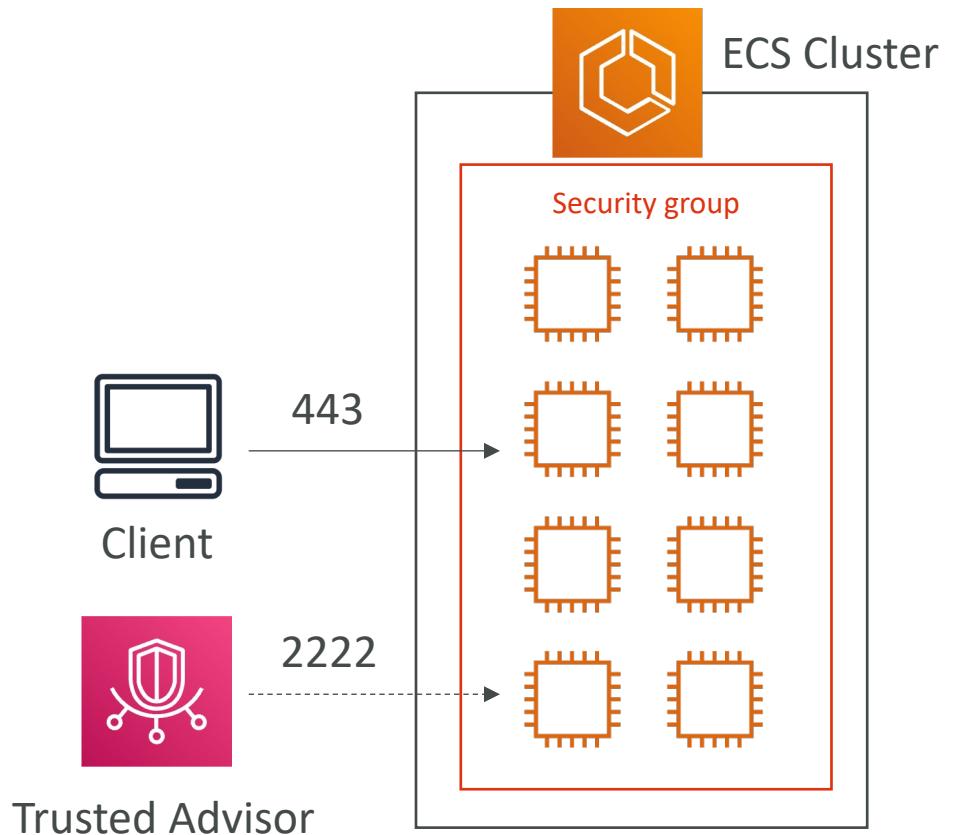
Option A

- Change the SSH port to 2222 on the cluster instances with a user data script. Log in to each instance using SSH over port 2222



Option B

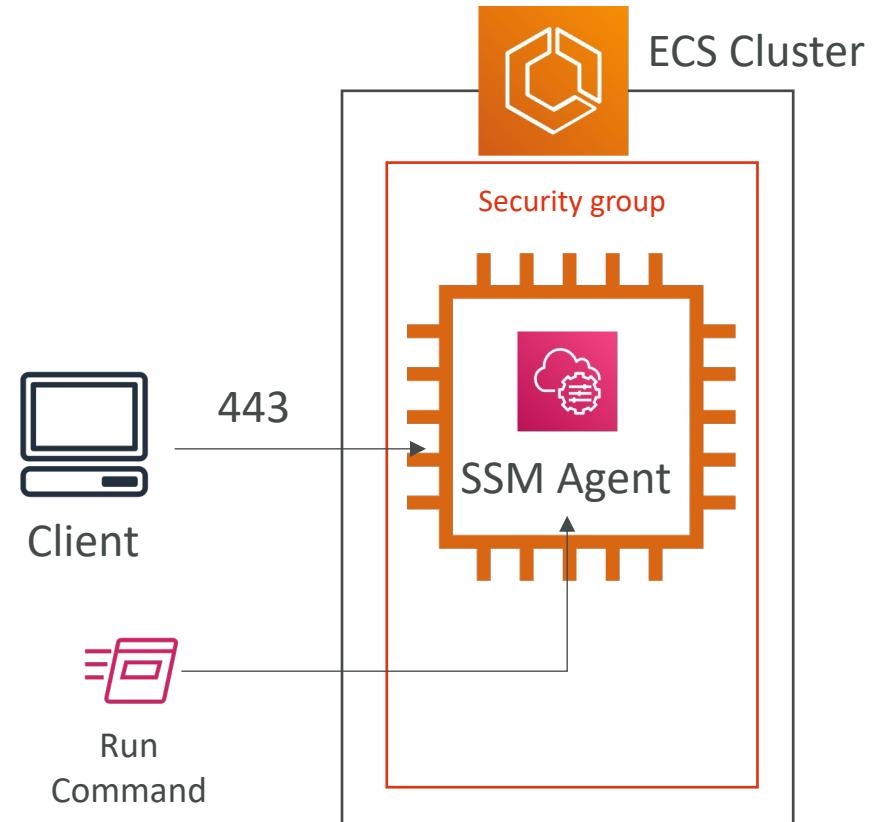
- Change the SSH port to 2222 on the cluster instances with a user data script. Use AWS Trusted Advisor to remotely manage the cluster instances over port 2222



CORRECT ANSWER

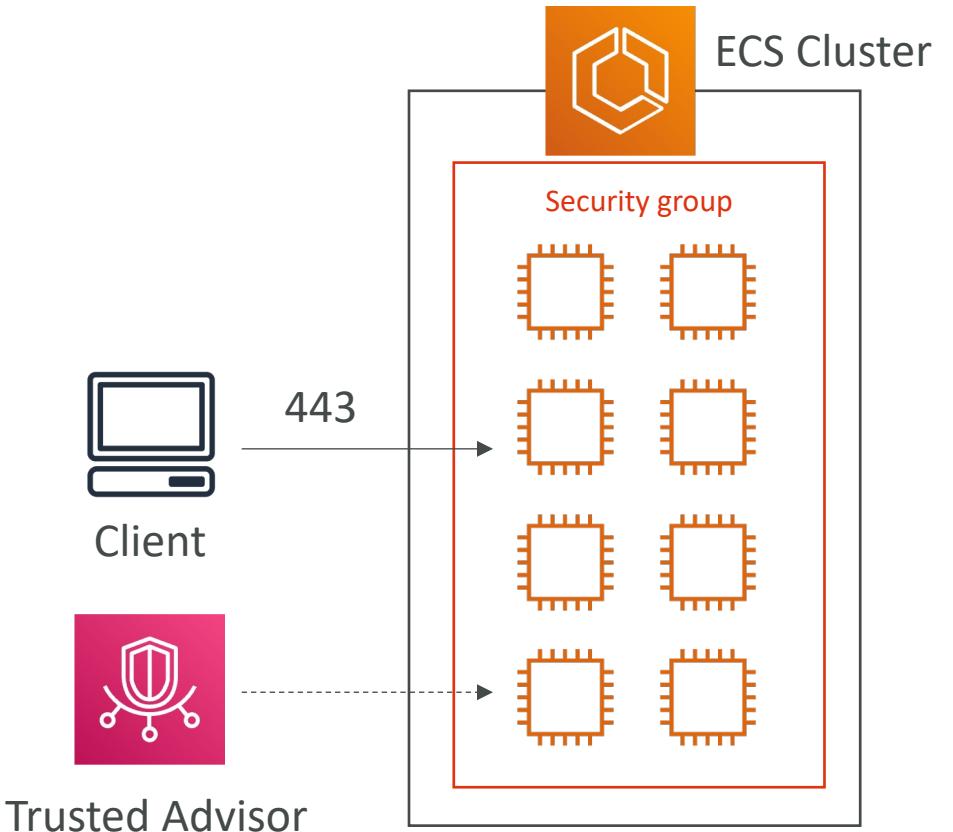
Option C

- Launch the cluster instances with no SSH key pairs. Use the Amazon EC2 Systems Manager Run Command to remotely manage the cluster instances



Option D

- Launch the cluster instances with no SSH key pairs. Use AWS Trusted Advisor to remotely manage the cluster instances.



Question 6

- A company has two AWS accounts: one for production workloads and one for development workloads. Creating and managing these workloads are a development team and an operations team. The company needs a security strategy that meets the following requirements:
 - Developers need to create and delete development application infrastructure.
 - Operators need to create and delete both development and production application infrastructure.
 - Developers should have no access to production infrastructure.
 - All users should have a single set of AWS credentials.
- What strategy meets these requirements?

Option A

- In the development account:
 - Create a development IAM group with the ability to create and delete application infrastructure.
 - Create an IAM user for each operator and developer and assign them to the development group.
- In the production account:
 - Create an operations IAM group with the ability to create and delete application infrastructure.
 - Create an IAM user for each operator and assign them to the operations group.

Option B

- In the development account:
 - Create a development IAM group with the ability to create and delete application infrastructure.
 - Create an IAM user for each developer and assign them to the development group.
 - Create an IAM user for each operator and assign them to the development group and the operations group in the production account.
- In the production account:
 - Create an operations IAM group with the ability to create and delete application infrastructure.

Option C

- In the development account:
 - Create a shared IAM role with the ability to create and delete application infrastructure in the production account.
 - Create a development IAM group with the ability to create and delete application infrastructure.
 - Create an operations IAM group with the ability to assume the shared role.
 - Create an IAM user for each developer and assign them to the development group.
 - Create an IAM user for each operator and assign them to the development group and the operations group.

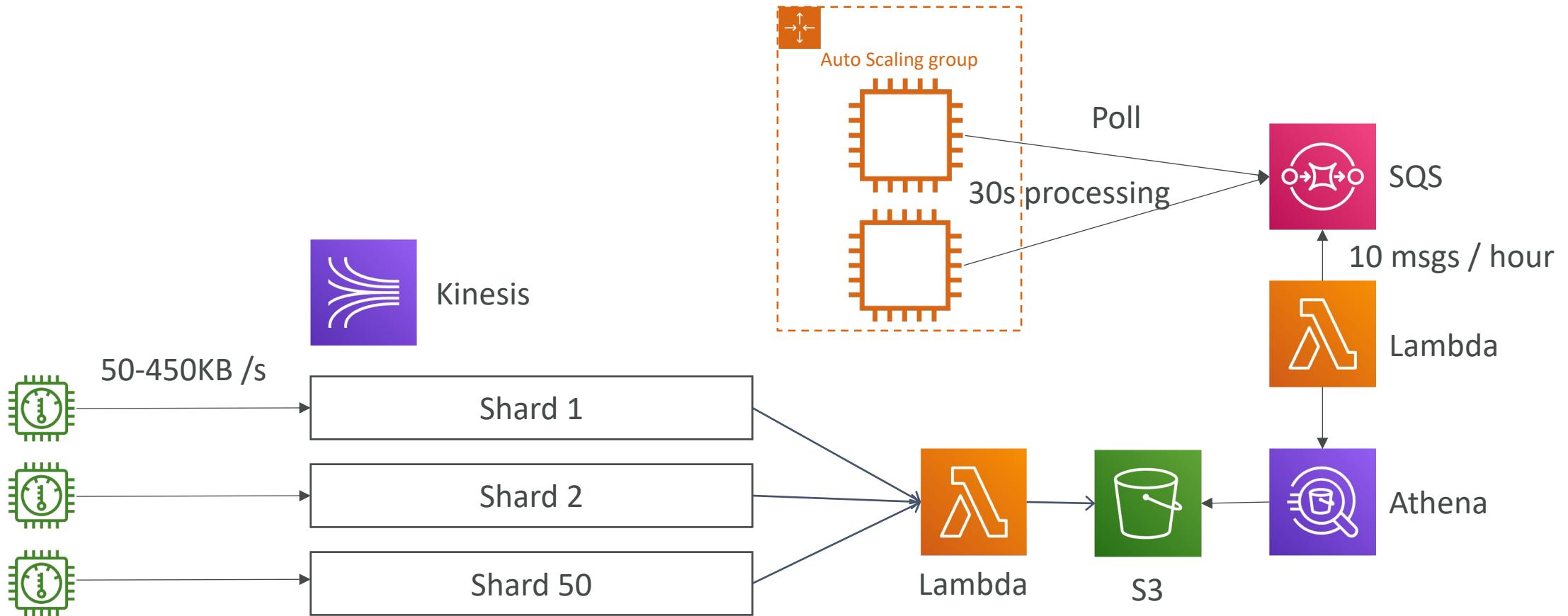
Option D

- In the development account:
 - Create a development IAM group with the ability to create and delete application infrastructure.
 - Create an operations IAM group with the ability to assume the shared role in the production account.
 - Create an IAM user for each developer and assign them to the development group.
 - Create an IAM user for each operator and assign them to the development group and the operations group.
- In the production account:
 - Create a shared IAM role with the ability to create and delete application infrastructure.
 - Add the development account to the trust policy for the shared role.

Question 7

- A solutions architect needs to reduce costs for a big data application. The application environment consists of hundreds of devices that send events to Amazon Kinesis Data Streams. The device ID is used as the partition key, so each device gets a separate shard. Each device sends between 50 KB and 450 KB of data per second. The shards are polled by an AWS Lambda function that processes the data and stores the result on Amazon S3.
- Every hour, an AWS Lambda function runs an Amazon Athena query against the result data that identifies any outliers and places them in an Amazon SQS queue. An Amazon EC2 Auto Scaling group of two EC2 instances monitors the queue and runs a short (approximately 30-second) process to address the outliers. The devices submit an average of 10 outlying values every hour.
- Which combination of changes to the application would MOST reduce costs? (Select TWO.)

Question 7 – Architecture



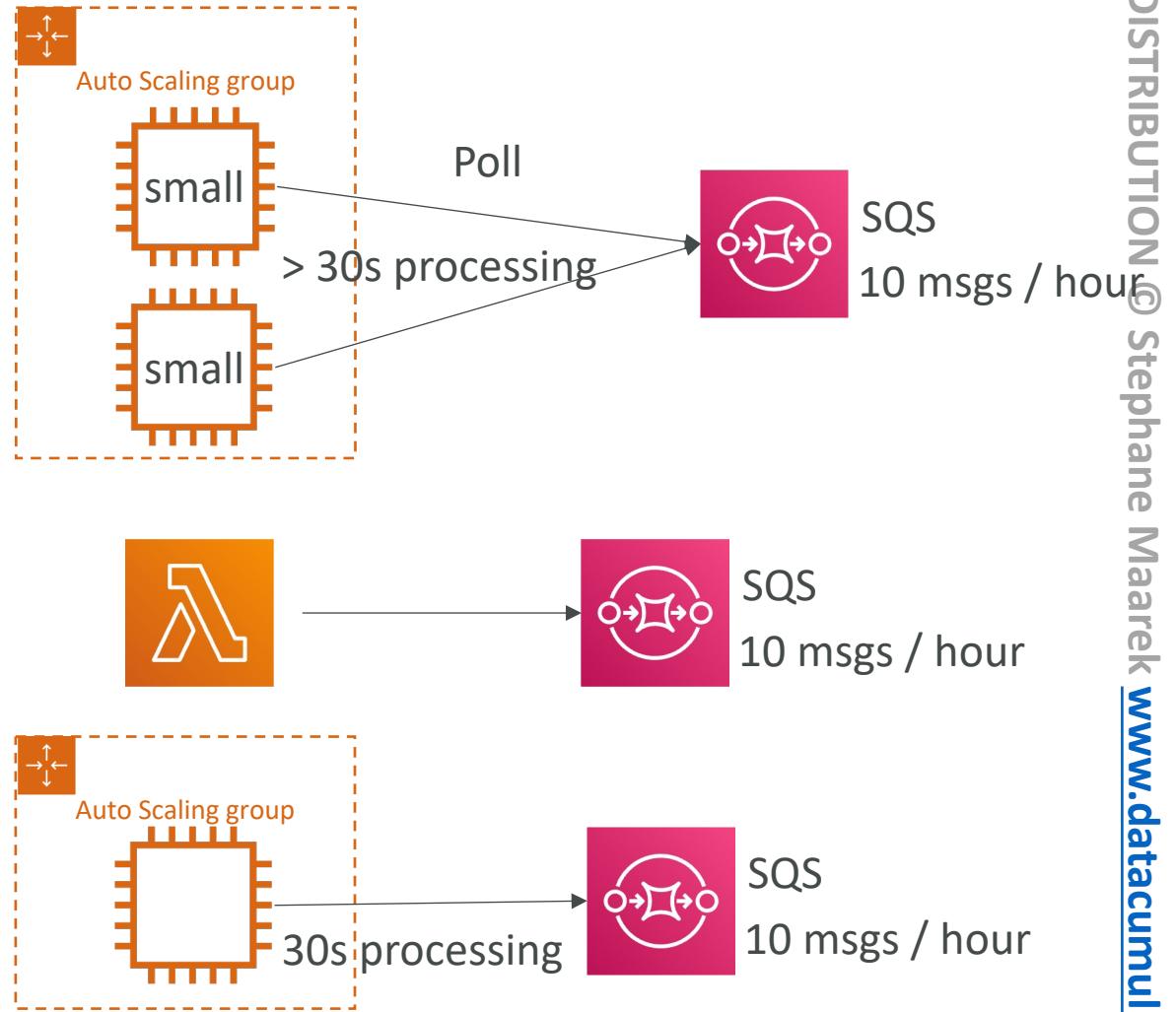
Options (choose 2)

- A) Change the Auto Scaling group launch configuration to use smaller instance types in the same instance family.
- B) Replace the Auto Scaling group with an AWS Lambda function triggered by messages arriving in the Amazon SQS queue.
- C) Reconfigure the devices and data stream to set a ratio of 10 devices to 1 data stream shard.
- D) Reconfigure the devices and data stream to set a ratio of 2 devices to 1 data stream shard.
- E) Change the desired capacity of the Auto Scaling group to a single EC2 instance.

CORRECT ANSWER B

Option Group I

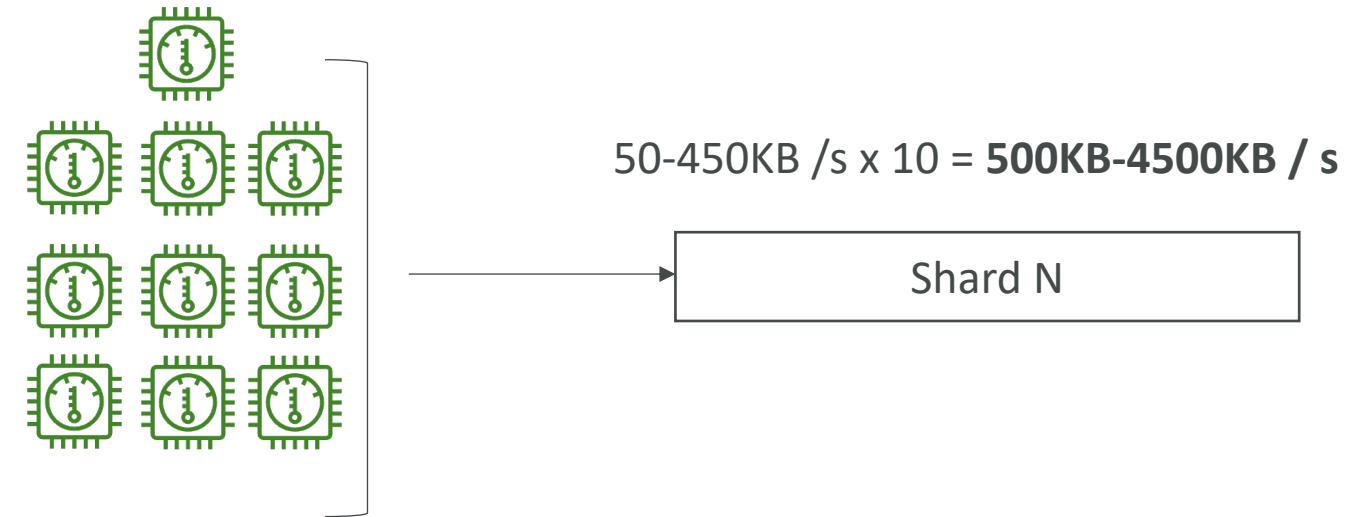
- A) Change the Auto Scaling group launch configuration to use smaller instance types in the same instance family.
- B) Replace the Auto Scaling group with an AWS Lambda function triggered by messages arriving in the Amazon SQS queue.
- E) Change the desired capacity of the Auto Scaling group to a single EC2 instance.



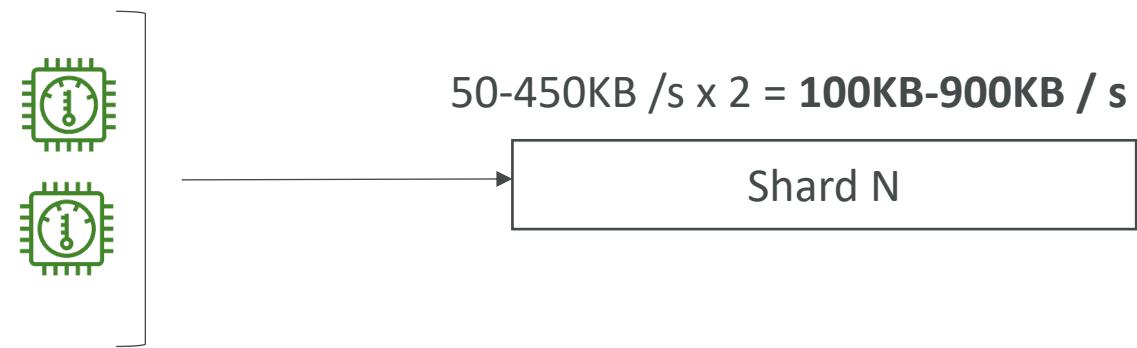
CORRECT ANSWER D

Option Group 2

C) Reconfigure the devices and data stream to set a ratio of 10 devices to 1 data stream shard.



D) Reconfigure the devices and data stream to set a ratio of 2 devices to 1 data stream shard.

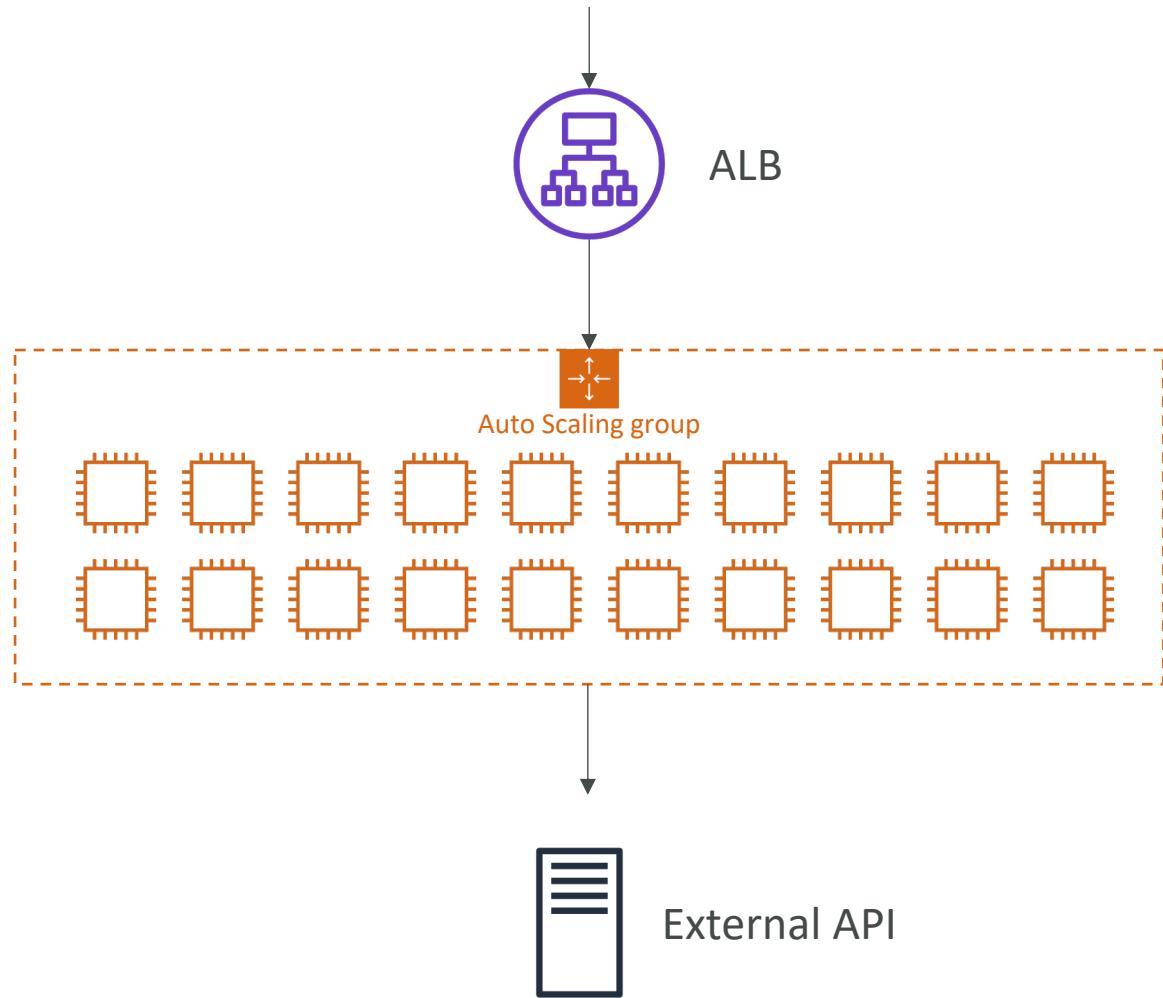


Each shard has a limit of 1MB/s = 1000KB/s

Question 8

- A company operates an ecommerce application on Amazon EC2 instances behind an ELB Application Load Balancer. The instances run in an Amazon EC2 Auto Scaling group across multiple Availability Zones. After an order is successfully processed, the application immediately posts order data to an external third-party affiliate tracking system that pays sales commissions for order referrals. During a highly successful marketing promotion, the number of EC2 instances increased from 2 to 20. The application continued to work correctly, but the increased request rate overwhelmed the third-party affiliate and resulted in failed requests.
- Which combination of architectural changes could ensure that the entire process functions correctly under load? (Select TWO.)

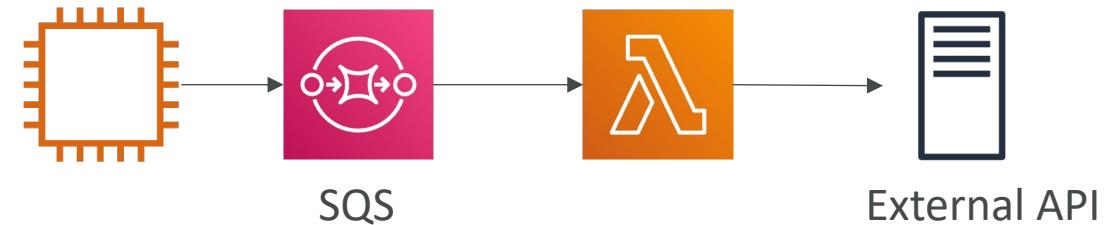
Question 8 – Architecture



CORRECT ANSWER B

Option Group I

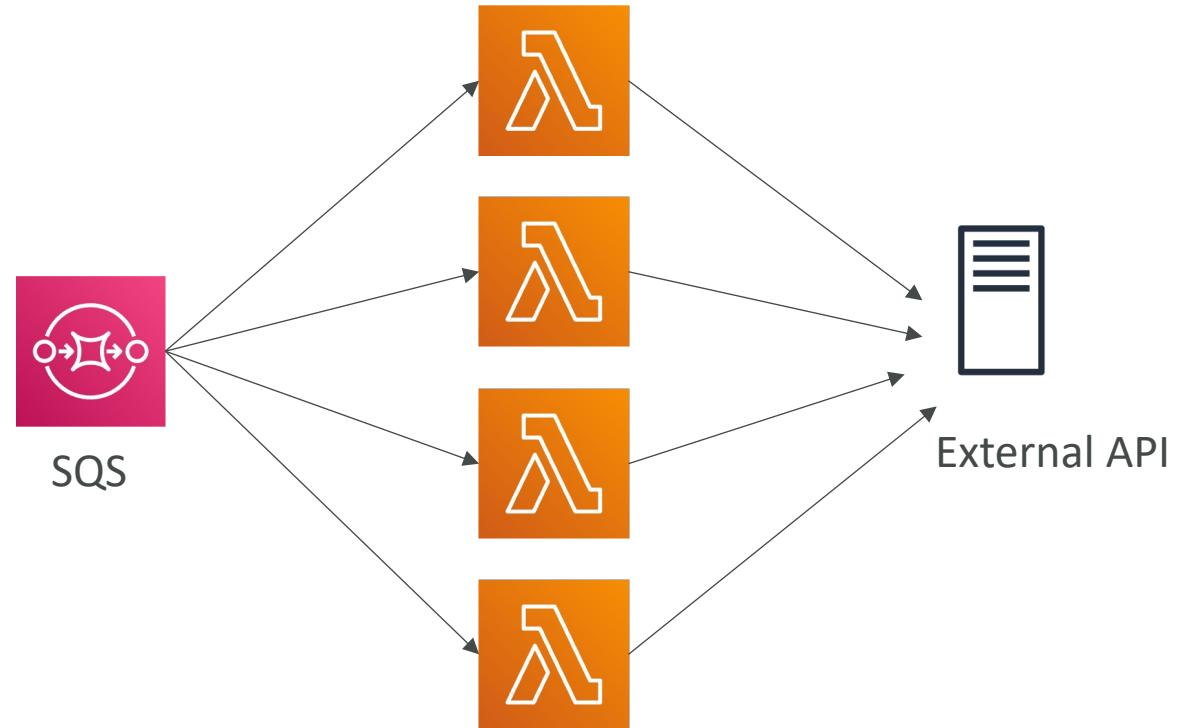
- A) Move the code that calls the affiliate to a new AWS Lambda function. Modify the application to invoke the Lambda function asynchronously.
- B) Move the code that calls the affiliate to a new AWS Lambda function. Modify the application to place the order data in an Amazon SQS queue. Trigger the Lambda function from the queue.



CORRECT ANSWER D

Option Group 2

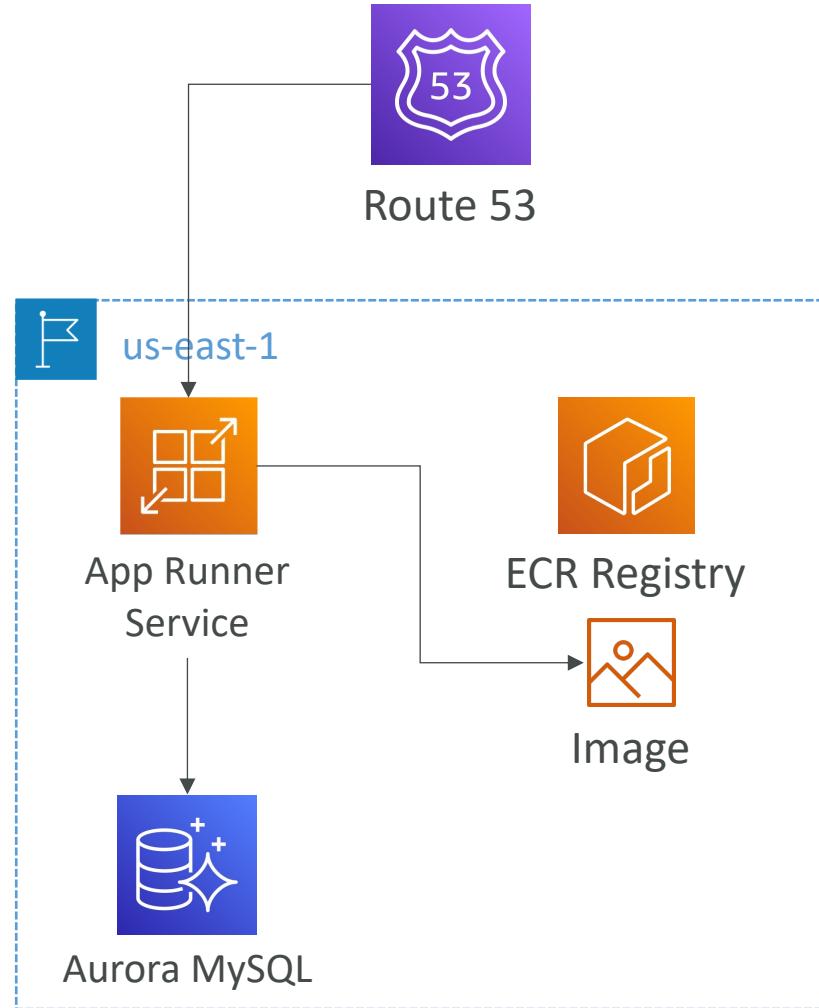
- C) Increase the timeout of the new AWS Lambda function.
- D) Adjust the concurrency limit of the new AWS Lambda function.
- E) Increase the memory of the new AWS Lambda function.



Question 9

- A company has built an online ticketing web application on AWS. The application is hosted on AWS App Runner and uses images that are stored in an Amazon Elastic Container Registry (Amazon ECR) repository. The application stores data in an Amazon Aurora MySQL DB cluster. The company has set up a domain name in Amazon Route 53.
- The company needs to deploy the application across two AWS Regions in an active-active configuration.
- Which combination of steps will meet these requirements with the LEAST change to the architecture? (Select THREE.)

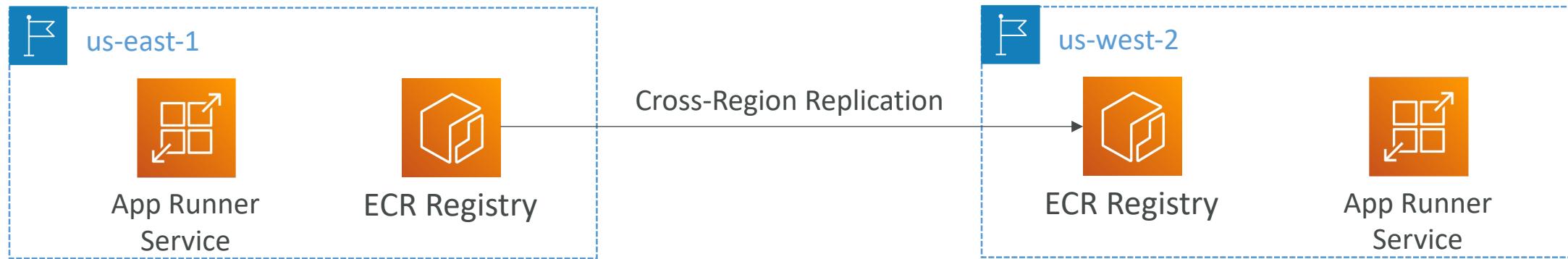
Question 9 - Architecture



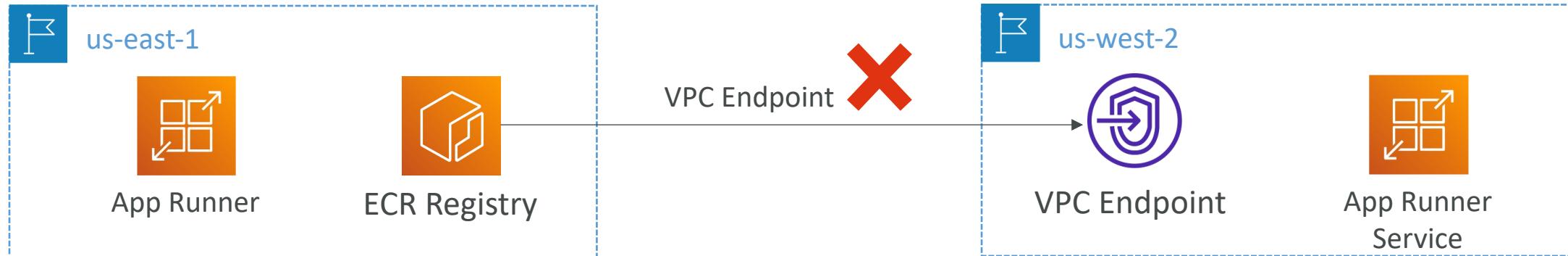
CORRECT ANSWER A

Option Group I

- A) Set up Cross-Region Replication to the second Region for the ECR images



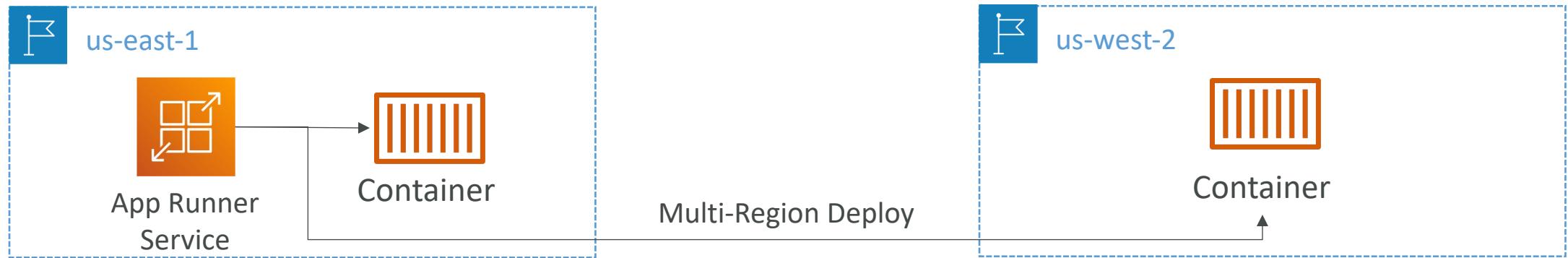
- B) Create a VPC endpoint from the ECR repository in the second Region



CORRECT ANSWER D

Option Group 2

- C) Edit the App Runner configuration by adding a second deployment target to the second Region.



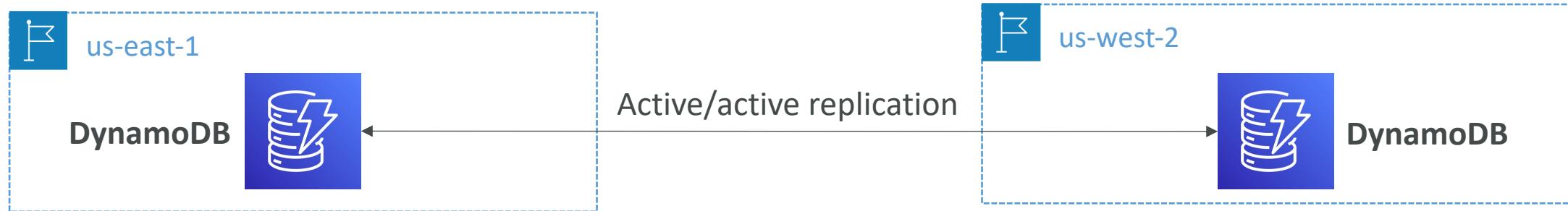
- D) Deploy App Runner to the second Region. Set up Route 53 latency-based routing.



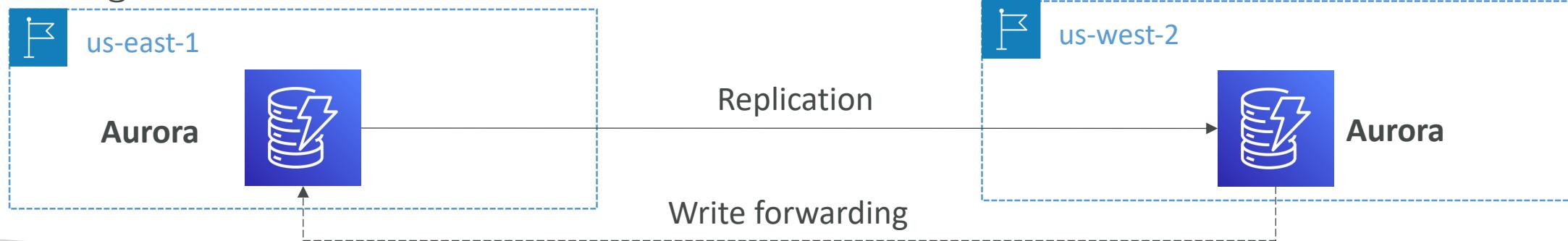
CORRECT ANSWER F

Option Group 3

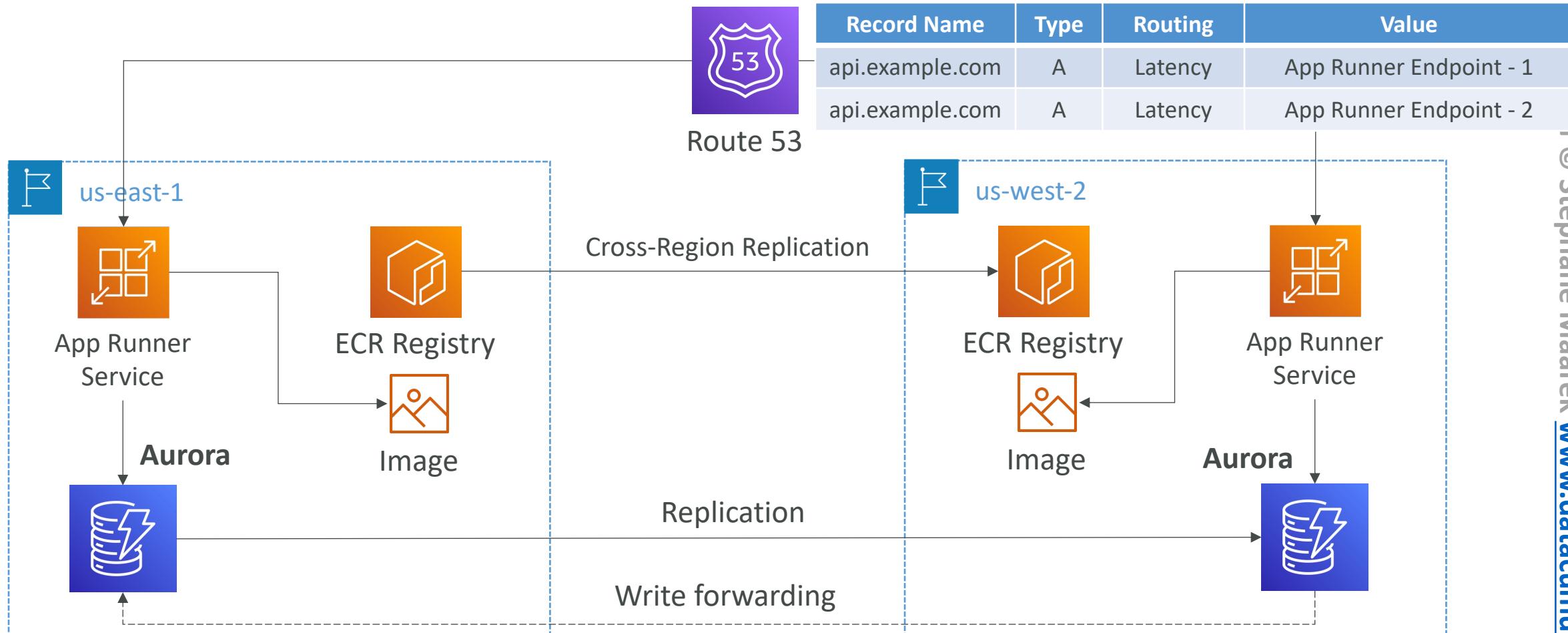
- E) Change the database by using Amazon DynamoDB global tables in the two desired Regions.



- F) Use an Aurora global database with write forwarding enabled in the second Region.



Final Architecture

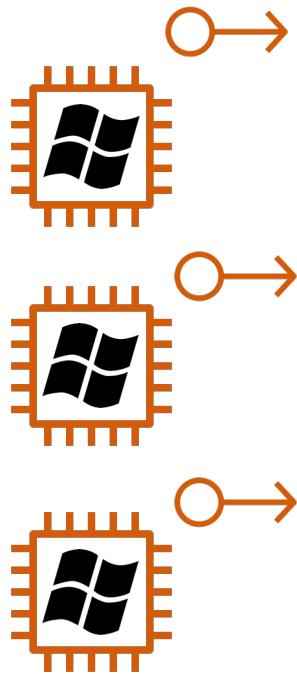


Question 10

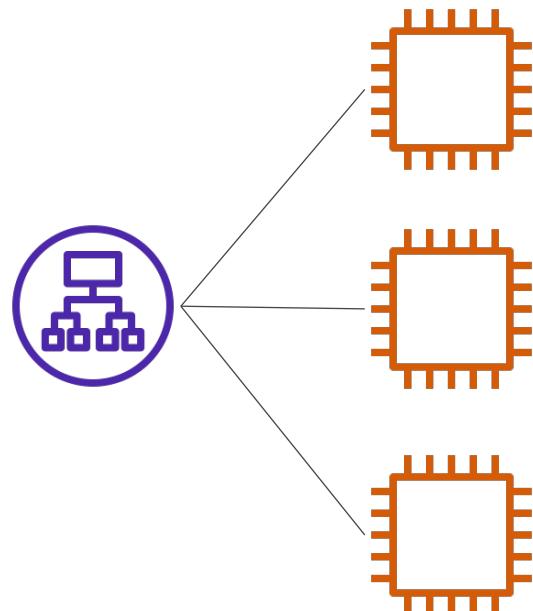
- A company has deployed a multi-tier web application in the AWS Cloud. The application consists of the following tiers:
 - A Windows-based web tier that is hosted on Amazon EC2 instances with Elastic IP addresses
 - A Linux-based application tier that is hosted on EC2 instances that run behind an Application Load Balancer (ALB) that uses path-based routing
 - A MySQL database that runs on a Linux EC2 instance
- All the EC2 instances are using Intel-based x86 CPUs. A solutions architect needs to modernize the infrastructure to achieve better performance. The solution must minimize the operational overhead of the application.
- Which combination of actions should the solutions architect take to meet these requirements? (Select TWO.)

Question 10 - Architecture

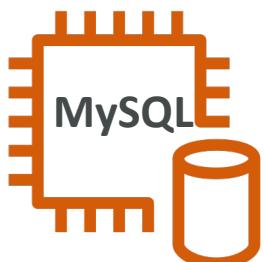
Web Tier



Application Tier



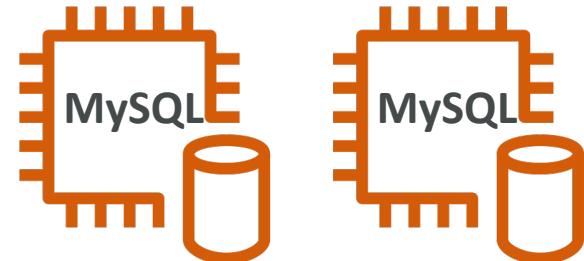
Database Tier



CORRECT ANSWER C

Option Group I

- A) Run the MySQL database on multiple EC2 instances.



- C) Migrate the MySQL database to Amazon Aurora Serverless.



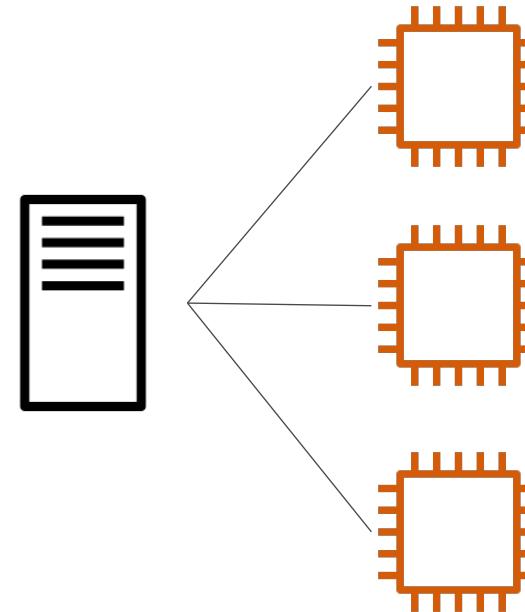
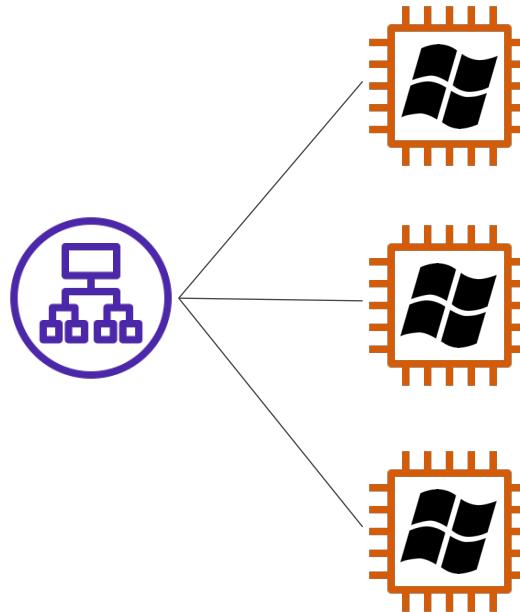
- D) Migrate all EC2 instance types to Graviton2.
 - Not available for Windows Instances



CORRECT ANSWER B

Option Group 2

- B) Place the web tier instances behind an ALB.
- E) Replace the ALB for the application tier instances with a company-managed load balancer.



AWS Certification Paths – Architecture

Architecture

Solutions Architect

Design, develop, and manage cloud infrastructure and assets, work with DevOps to migrate applications to the cloud



Architecture

Application Architect

Design significant aspects of application architecture including user interface, middleware, and infrastructure, and ensure enterprise-wide scalable, reliable, and manageable systems



https://d1.awsstatic.com/training-and-certification/docs/AWS_certification_paths.pdf

AWS Certification Paths – Operations

Operations

Systems Administrator

Install, upgrade, and maintain computer components and software, and integrate automation processes



Operations

Cloud Engineer

Implement and operate an organization's networked computing infrastructure and Implement security systems to maintain data safety



AWS Certification Paths – DevOps

DevOps

Test Engineer

Embed testing and quality best practices for software development from design to release, throughout the product life cycle



DevOps

Cloud DevOps Engineer

Design, deployment, and operations of large-scale global hybrid cloud computing environment, advocating for end-to-end automated CI/CD DevOps pipelines



DevOps

DevSecOps Engineer

Accelerate enterprise cloud adoption while enabling rapid and stable delivery of capabilities using CI/CD principles, methodologies, and technologies



AWS Certification Paths – Security

Security

Cloud Security Engineer

Design computer security architecture and develop detailed cyber security designs.
Develop, execute, and track performance of security measures to protect information



Security

Cloud Security Architect

Design and implement enterprise cloud solutions applying governance to identify, communicate, and minimize business and technical risks



AWS Certification Paths – Data Analytics & Development

Data Analytics

Cloud Data Engineer

Automate collection and processing of structured/semi-structured data and monitor data pipeline performance



Dive Deep

Development

Software Development Engineer

Develop, construct, and maintain software across platforms and devices

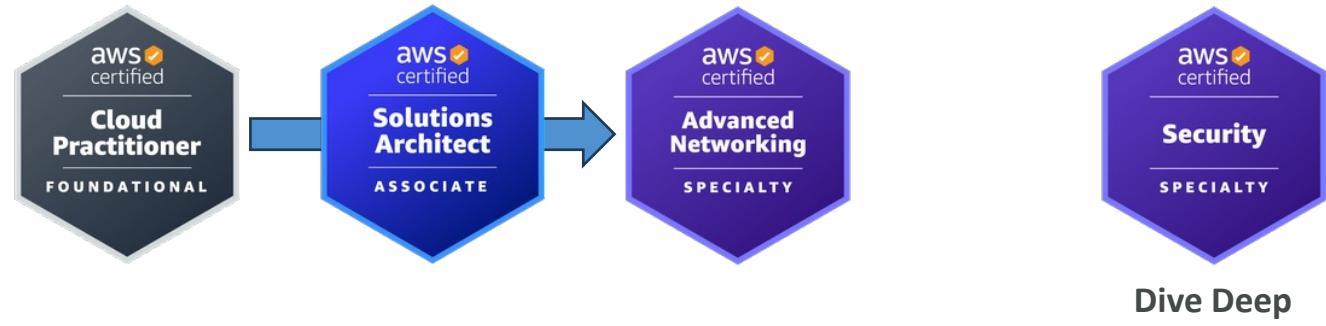


AWS Certification Paths – Networking & AI/ML

Networking

Network Engineer

Design and implement computer and information networks, such as local area networks (LAN), wide area networks (WAN), intranets, extranets, etc.



AI/ML

Machine Learning Engineer

Research, build, and design artificial intelligence (AI) systems to automate predictive models, and design machine learning systems, models, and schemes



Congratulations

Next steps

- Congratulations, you have covered all the domains!
- Make sure you revisit the lectures as much as possible
- The AWS Certified SA Pro exam is hard, and tests experience...
- Make sure you master every single concept outlined in this course
- For Hands On experience, have a look at the AWS Solutions Architect Associate, Developer Associate, SysOps Administrator Associate, DevOps Professional courses