AWS Certified Advanced Networking Specialty

By Stéphane Maarek & Chetan Agrawal

COURSE →

EXTRA PRACTICE EXAMS →

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- Best of luck for the exam and happy learning!

Table of Contents

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AWS Certified Networking Specialty Course

Welcome! We're starting in 5 minutes

- Let's prepare for the AWS Certified Advanced Networking exam
- Networking experience is preferred although we'll revisit the basics
- A previous associate-level certification is a must

Your instructors – Chetan & Stephane

- Chetan Agrawal:
  - AWS Networking expert
  - Over 15 years of experience
  - Covers most AWS services

- Stephane Maarek:
  - AWS expert
  - Over 8 years of experience
  - Teaches ELB, CloudFront, Route 53

Hello…I am Chetan !

- I have 20 years of IT industry experience
- I had been C/C++ developer in my early career followed by DevOps engineer
- Working as Cloud Solutions Architect from last 7 years

AWS with Chetan https://www.awswithchetan.com/

udemy https://www.udemy.com/user/chetan-agrawal-4/

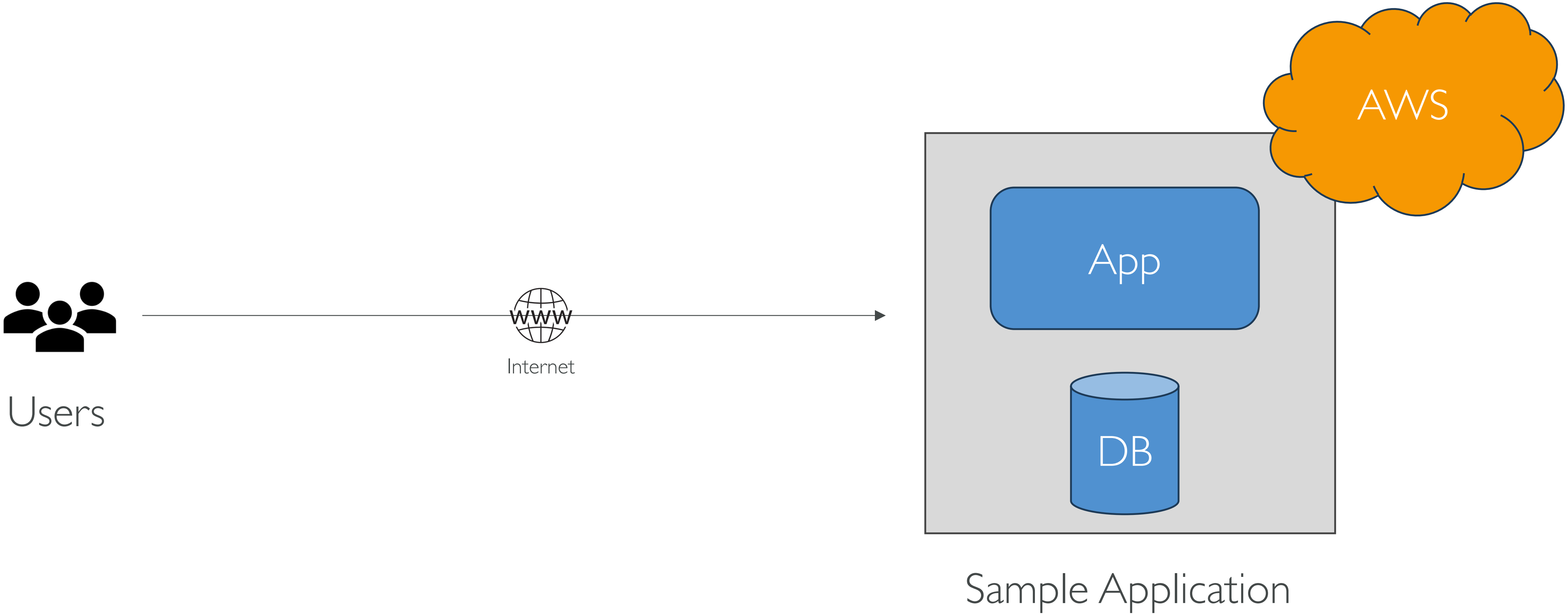
https://www.youtube.com/@AWSwithChetan

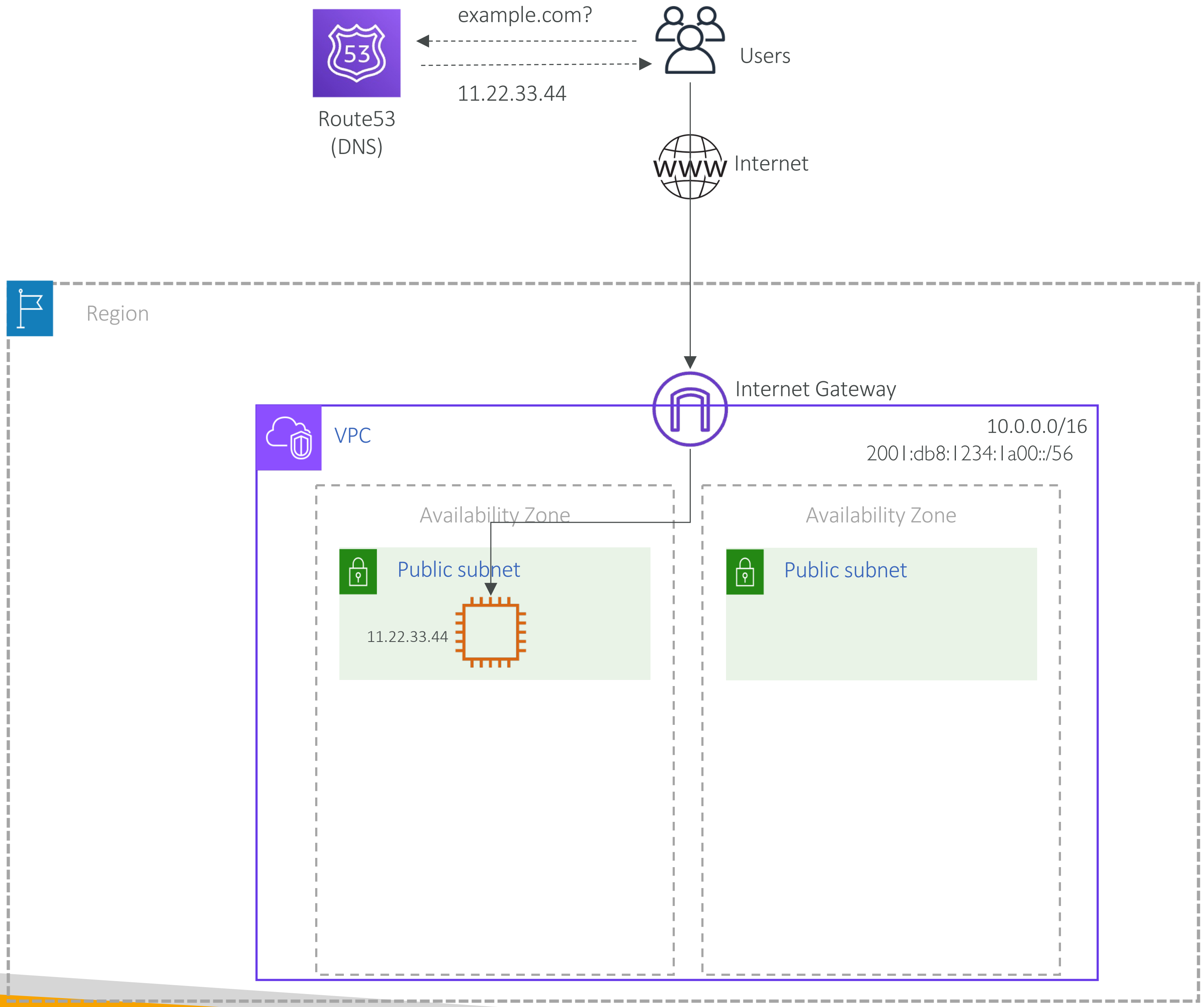
https://www.linkedin.com/in/chetan-agrawal-30107310/

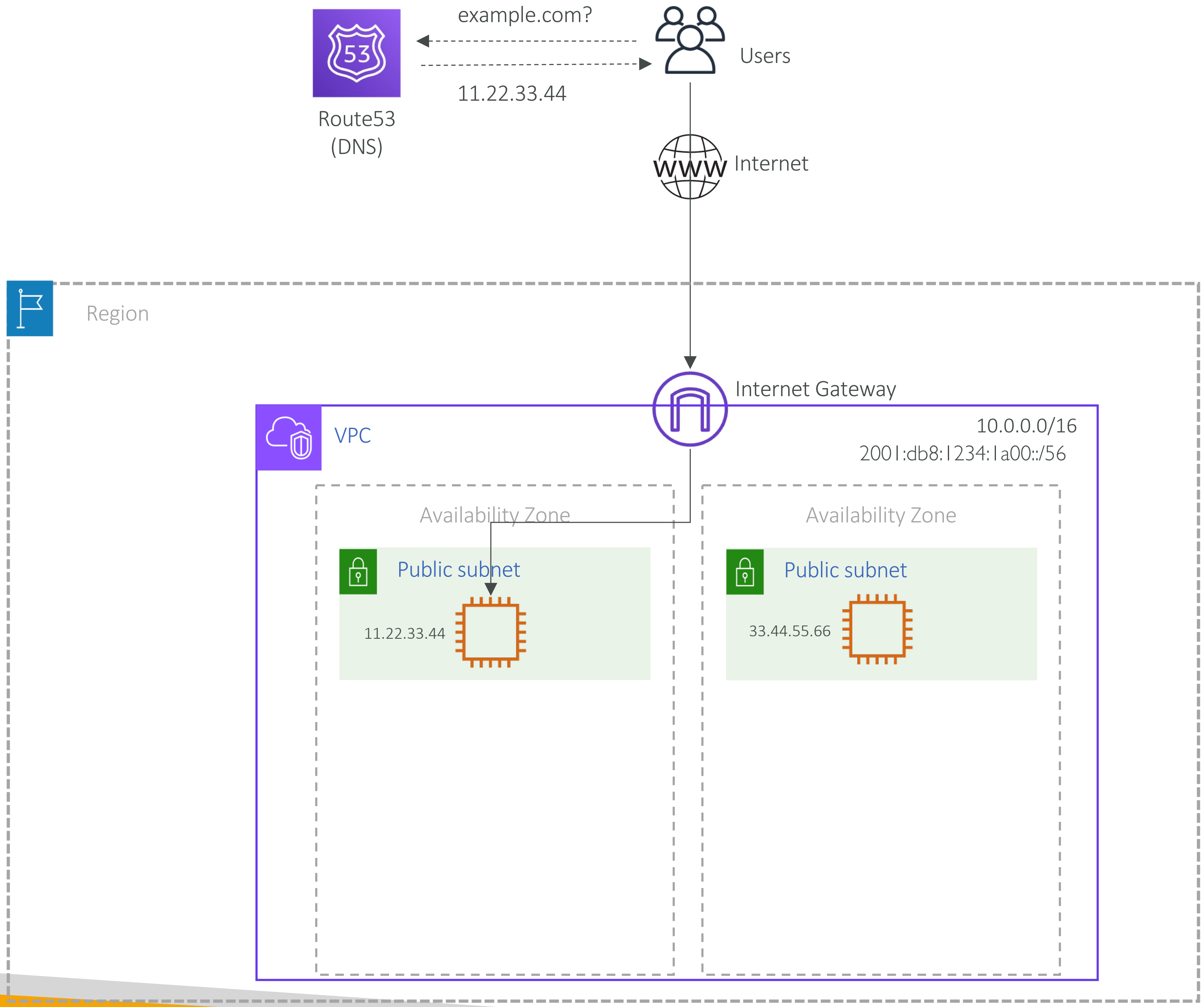
🙋 About my Indian English accent …

Overview of AWS Networking Services

We want to deploy this application in AWS




example.com?
Users
Route53
(DNS)
11.22.33.44
Internet
Region
Internet Gateway
VPC
10.0.0.0/16
2001:db8:1234:1a00::/56
Availability Zone
Availability Zone
Public subnet
Public subnet
11.22.33.44



example.com?
Users
11.22.33.44
Route53
(DNS)
Internet
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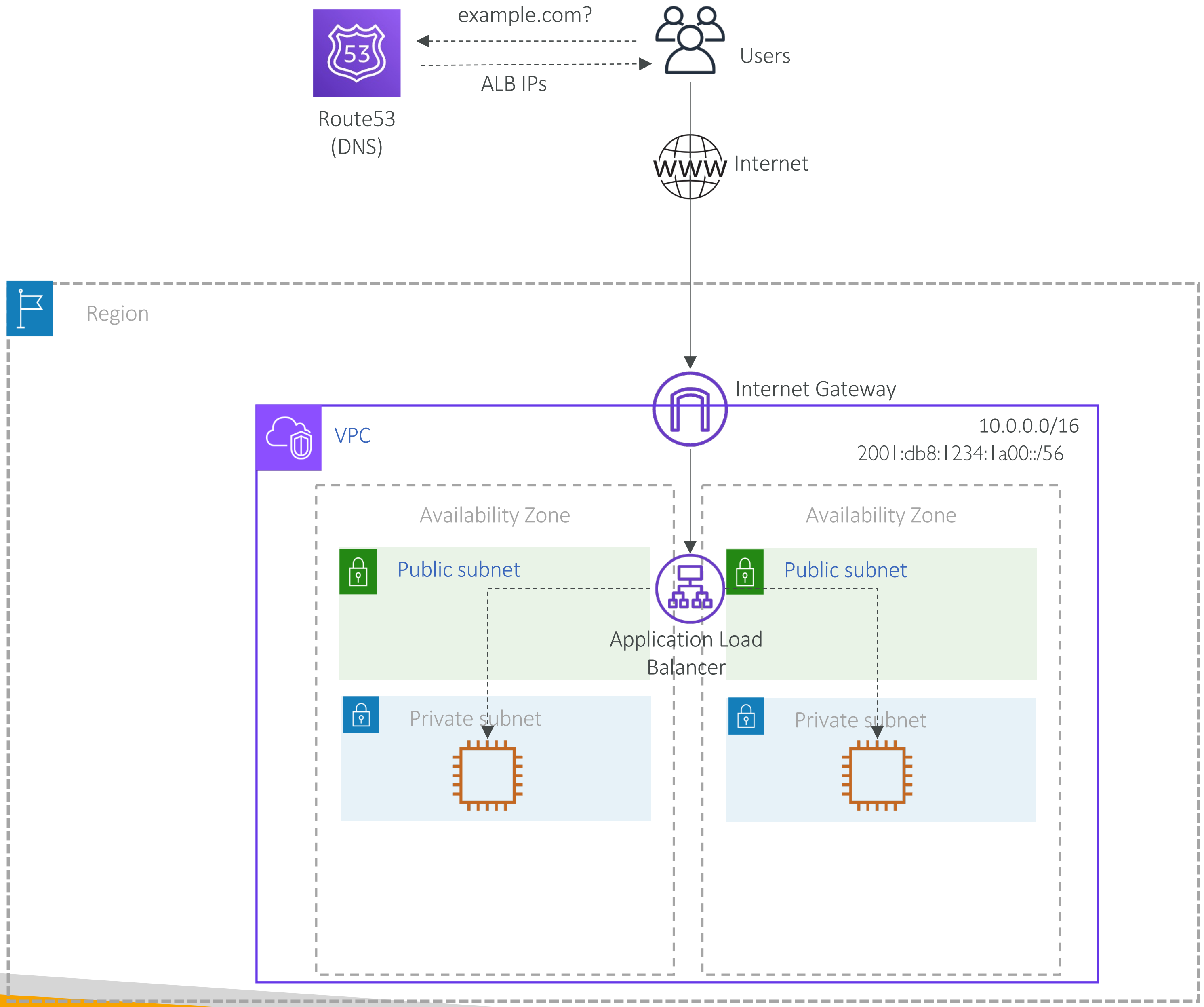
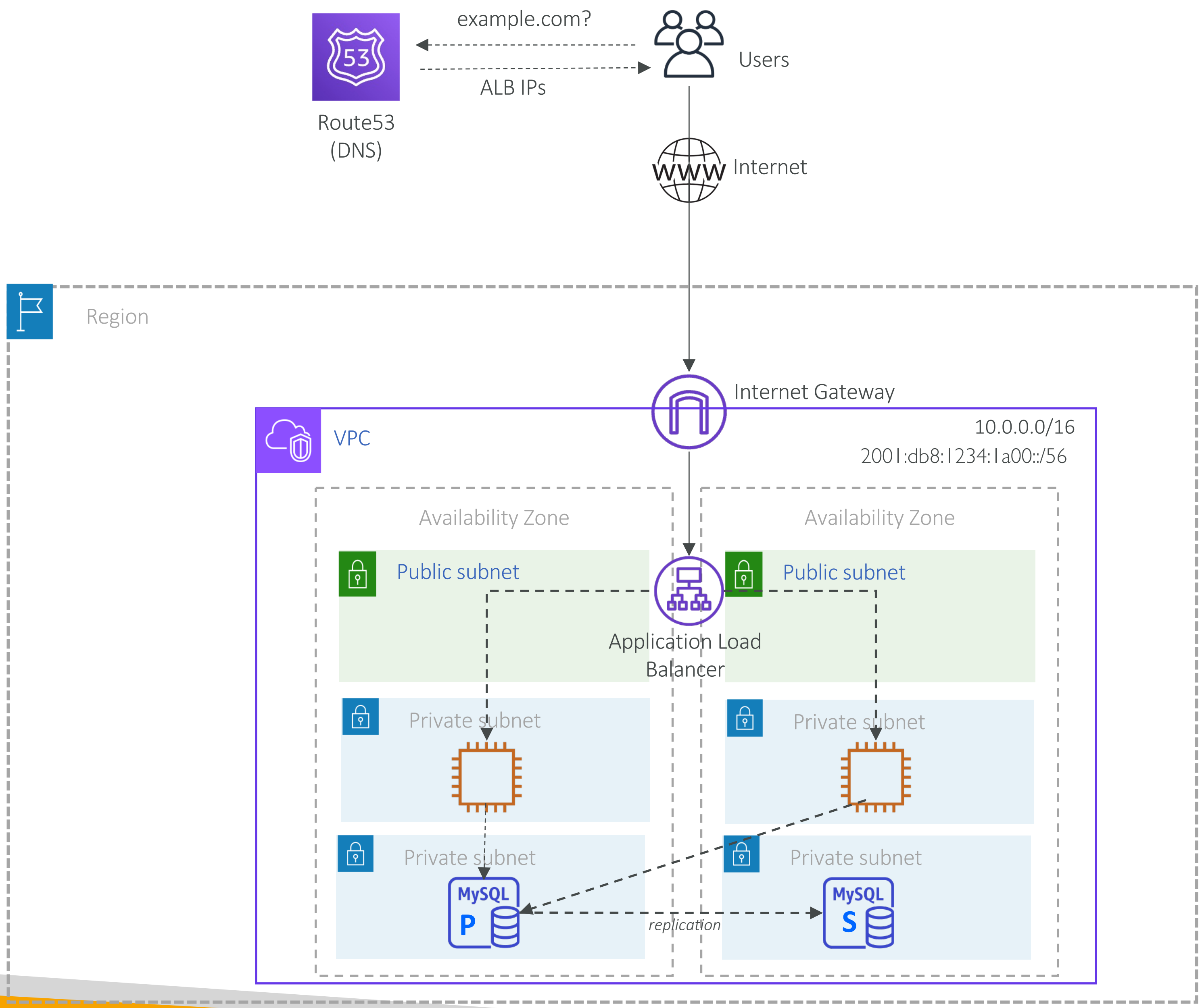
10.0.0.0/16
2001:db8:1234:1a00::/56
Availability Zone
Availability Zone
Public subnet
Public subnet
11.22.33.44
33.44.55.66


example.com?
ALB IPs
Users
Route53
(DNS)
Internet
Region
Internet Gateway
VPC
10.0.0.0/16
2001:db8:1234:1a00::/56
Availability Zone
Availability Zone
Public subnet
Public subnet
Application Load
Balancer
Private subnet
Private subnet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Region
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Availability Zone
Public subnet
Public subnet
Application Load
Balancer
Private subnet
Private subnet
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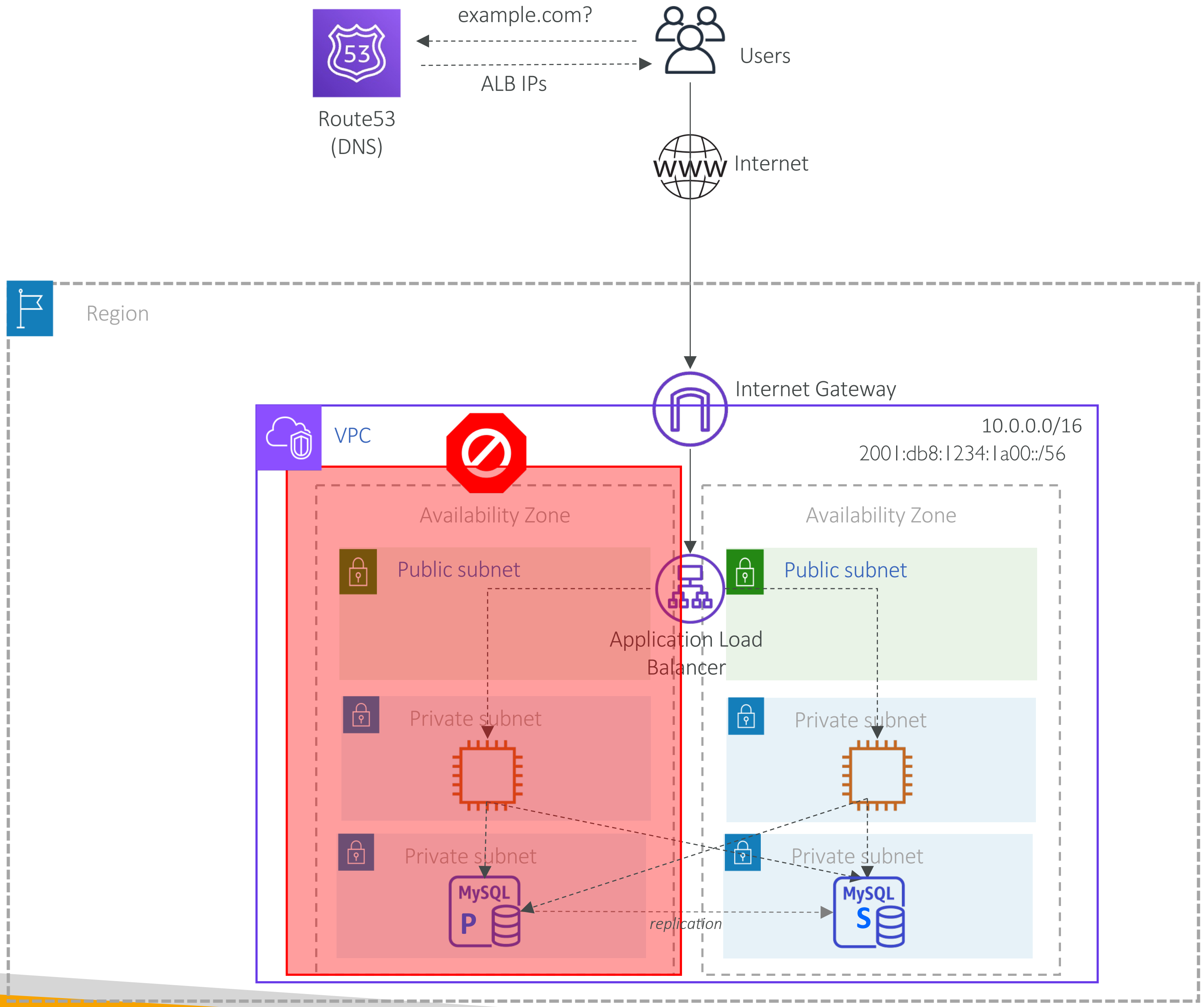
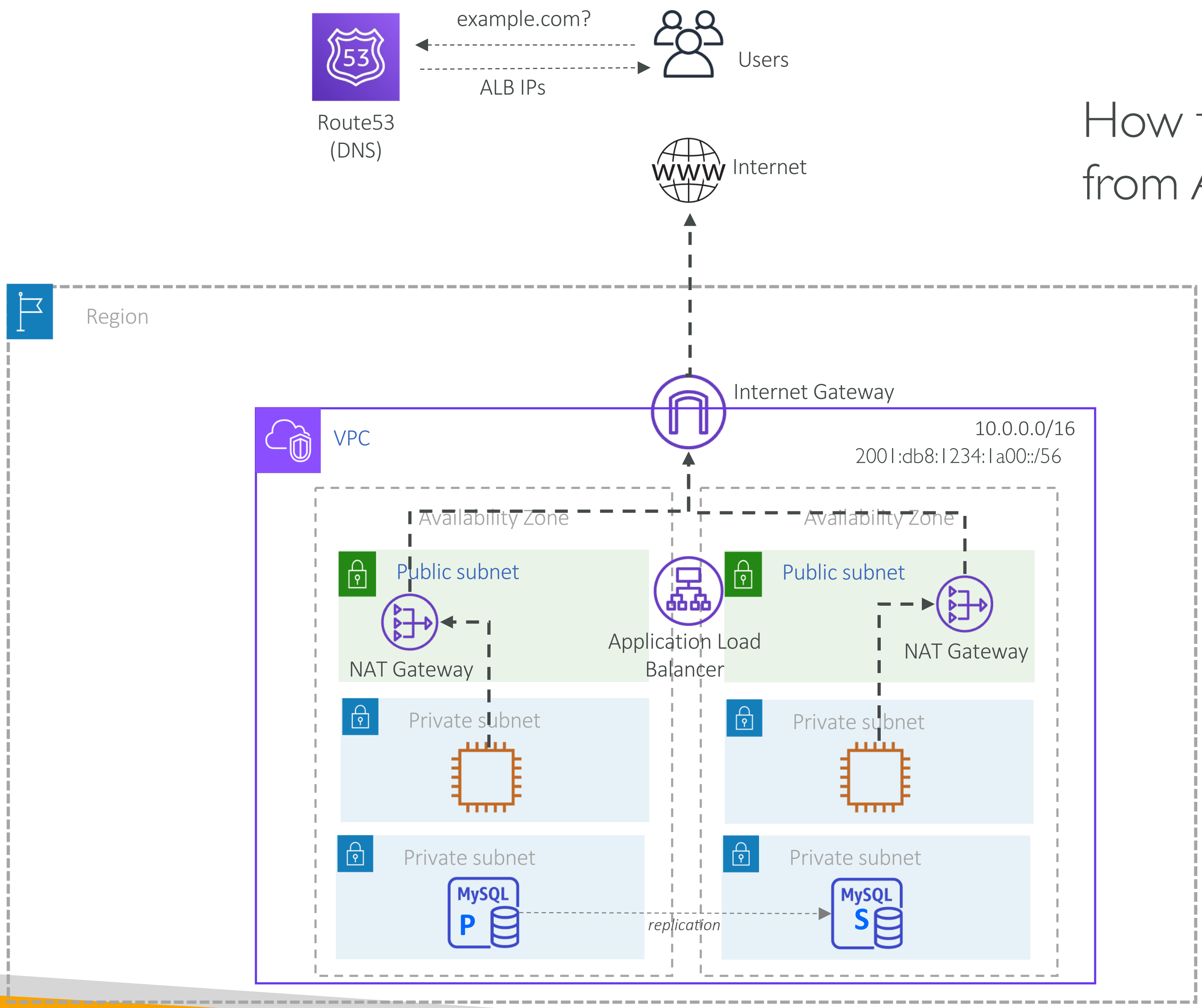
Private subnet
MySQL
P
MySQL
S
replication

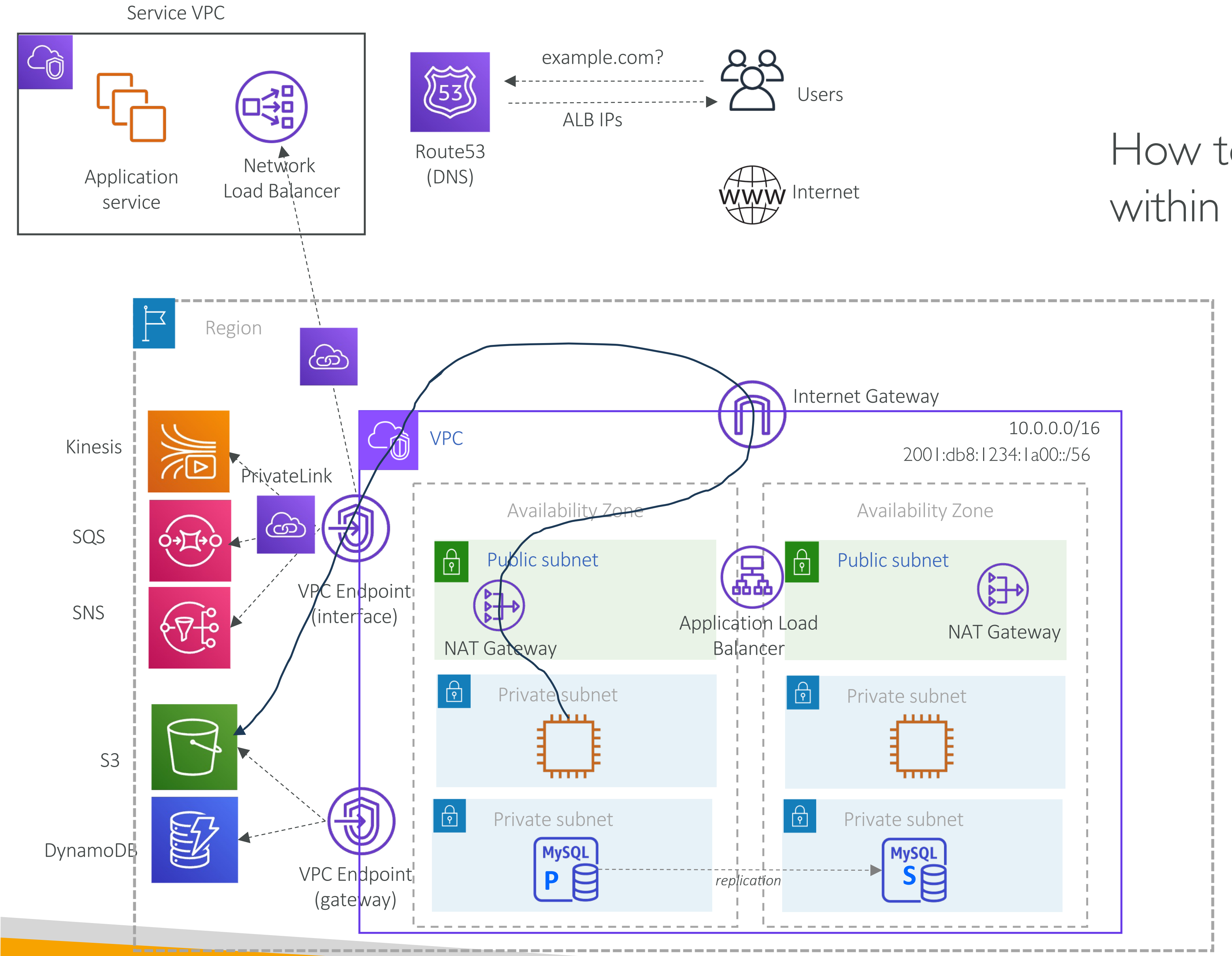


example.com?
Users
ALB IPs
Route53
(DNS)
Internet
Region
Internet Gateway
VPC
10.0.0.0/16
2001:db8:1234:1a00::/56
Availability Zone
Availability Zone
Public subnet
Public subnet
Application Load
Balancer
Private subnet
Private subnet
Private subnet
Private subnet
MySQL
P
MySQL
S
replication

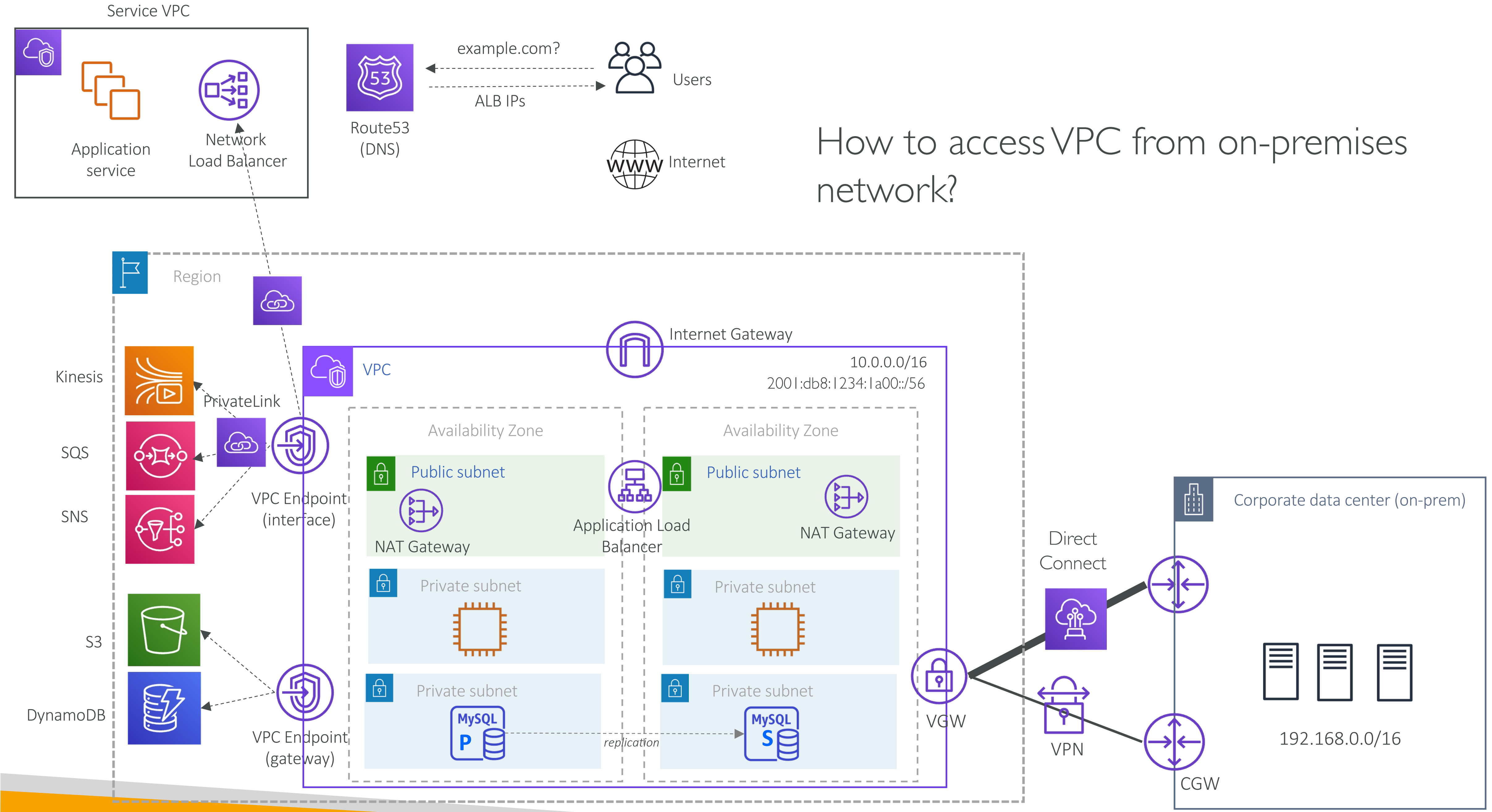
How to access outbound internet from Application servers?



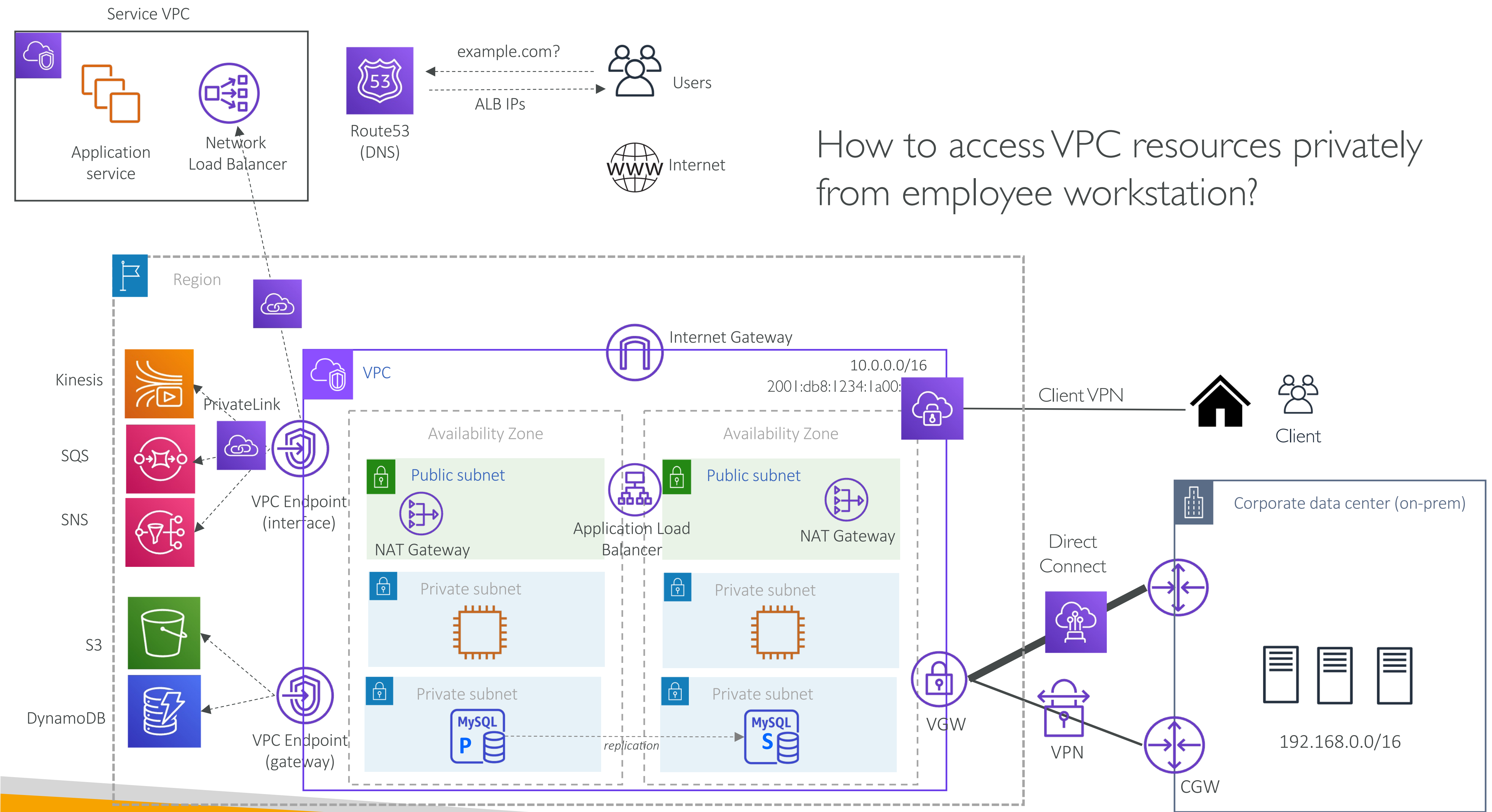
How to access AWS services from within the VPC?



How to access VPC from on-premises network?



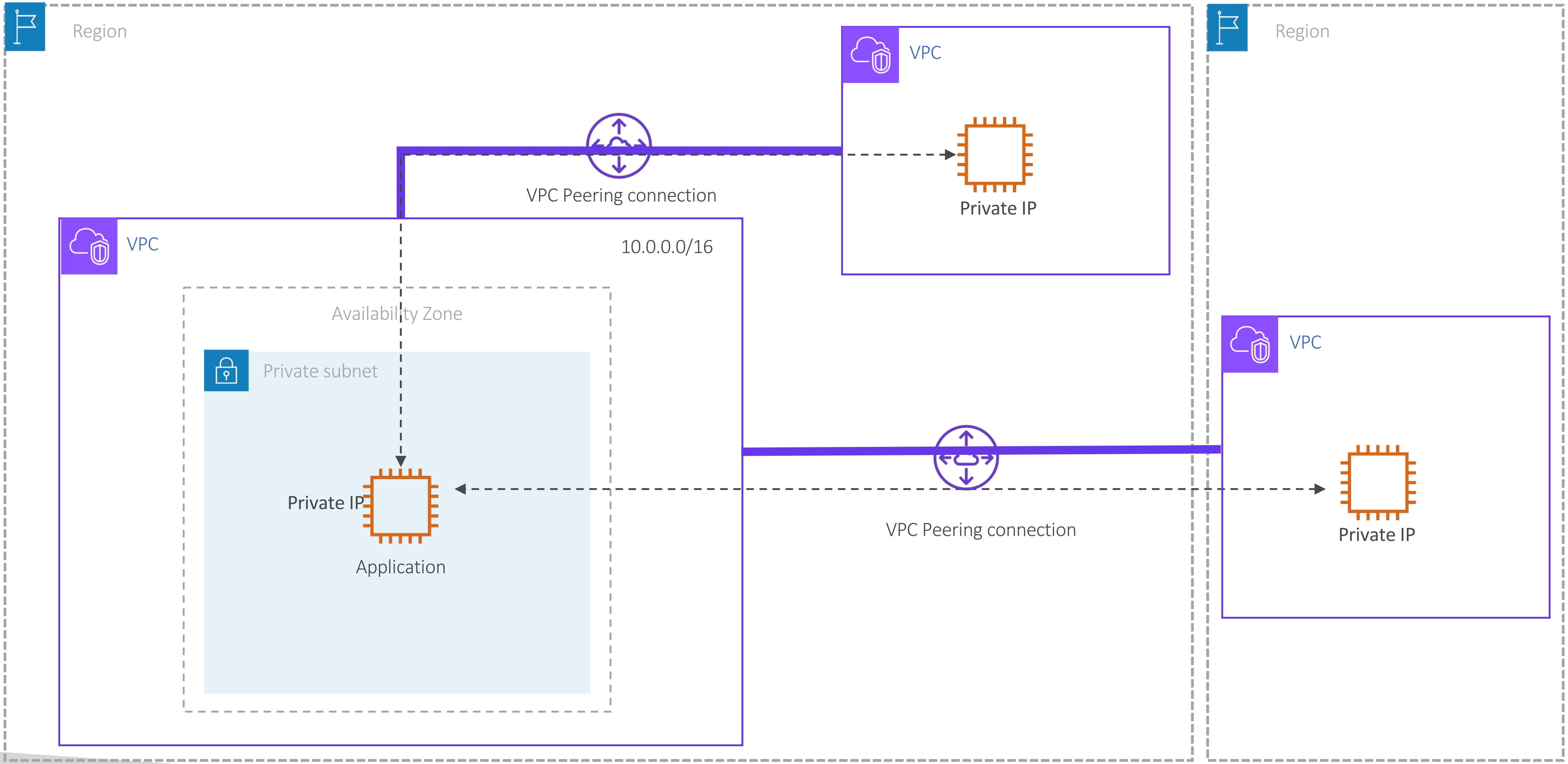
How to access VPC resources privately from employee workstation?



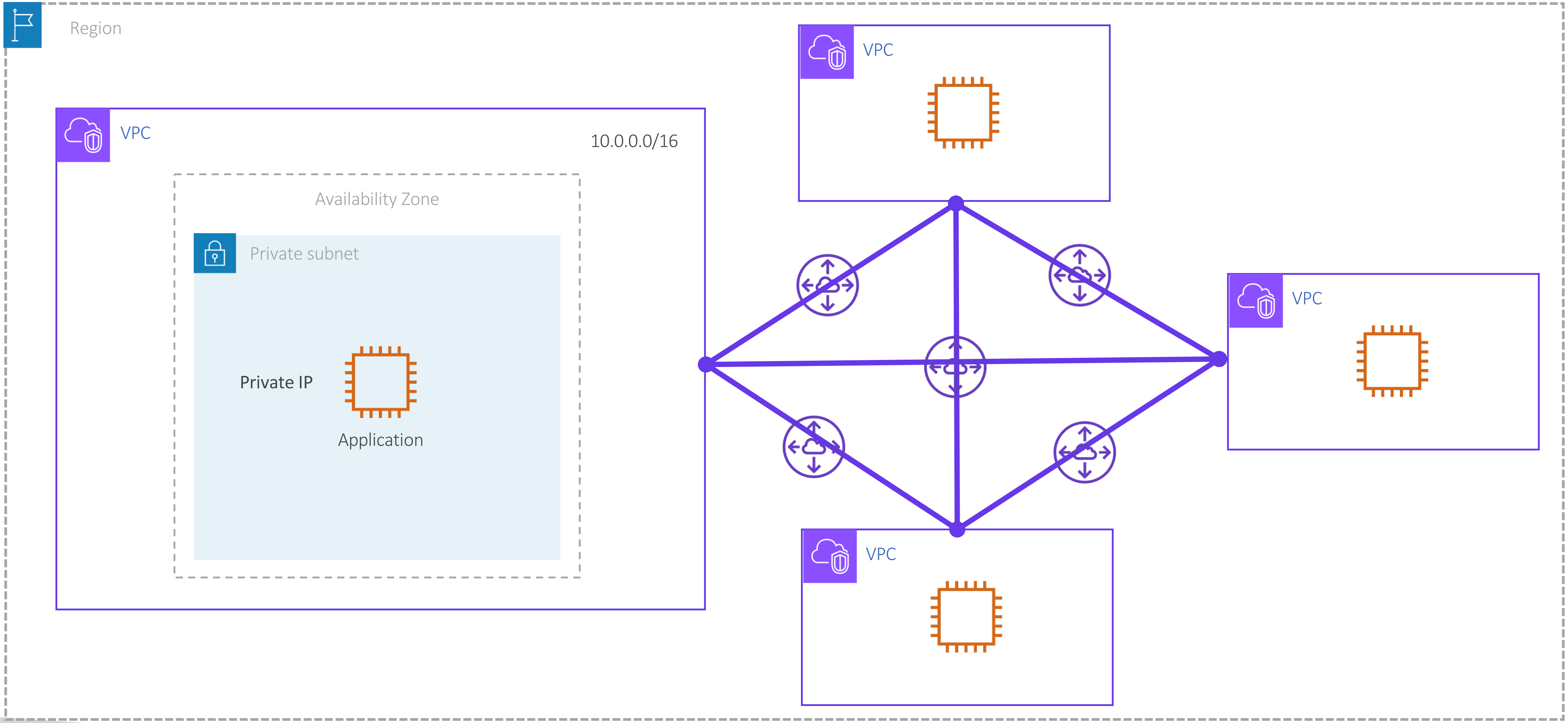
VPC Private connectivity options

- VPC Peering connection
- Transit Gateway
- Cloud WAN
- VPC Lattice

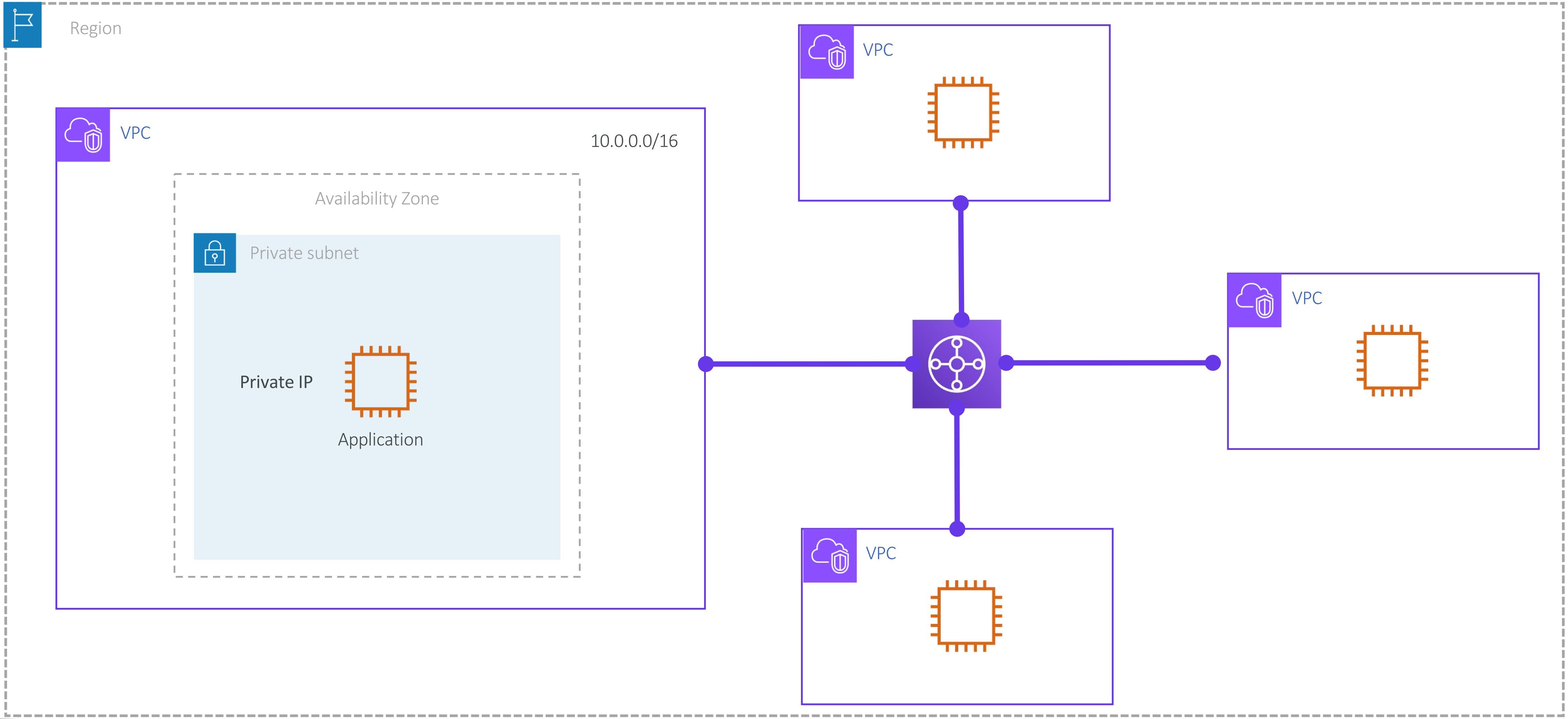
VPC Peering


Region
VPC
Private IP
VPC Peering connection
VPC
10.0.0.0/16
Availability Zone
Private subnet
Private IP
Application
Region
VPC
VPC Peering connection
Private IP

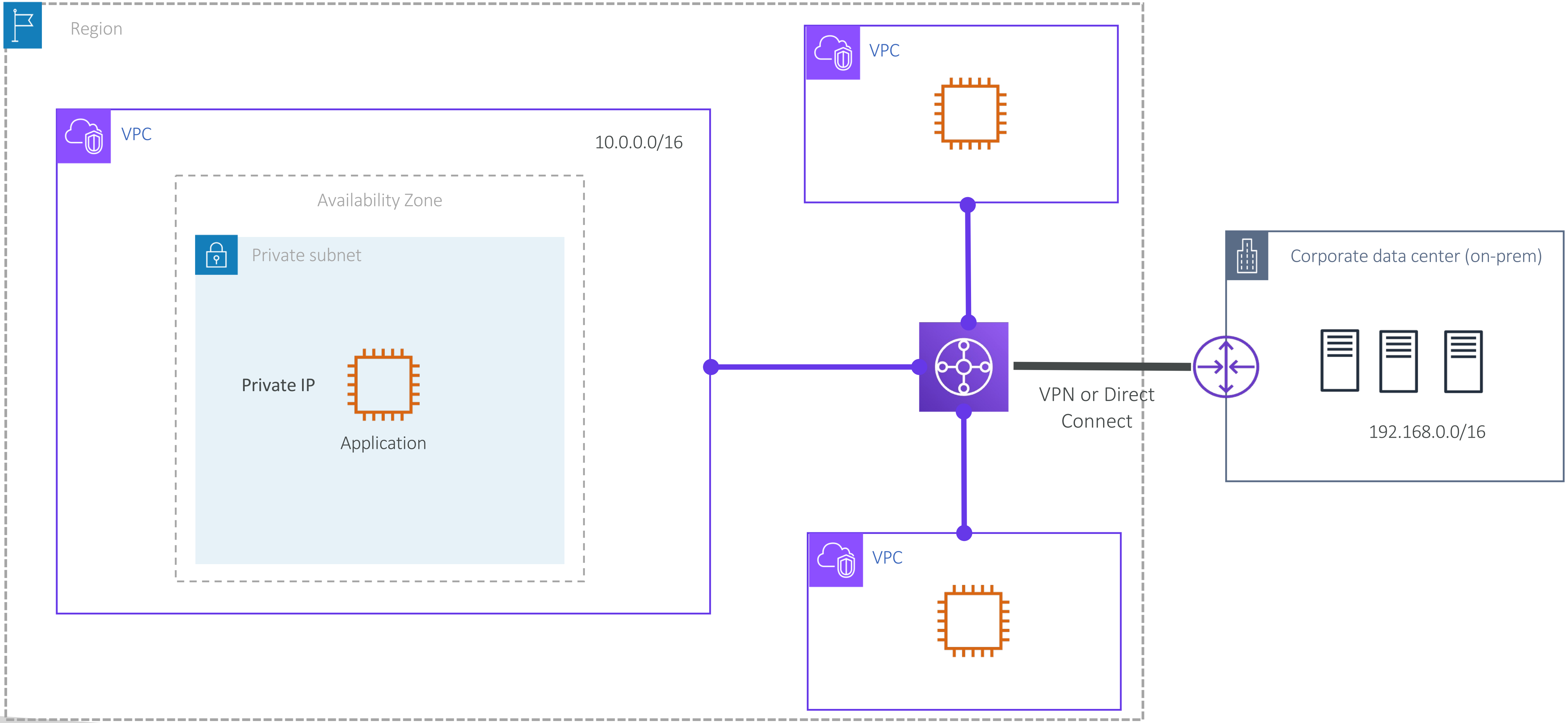
Transit Gateway



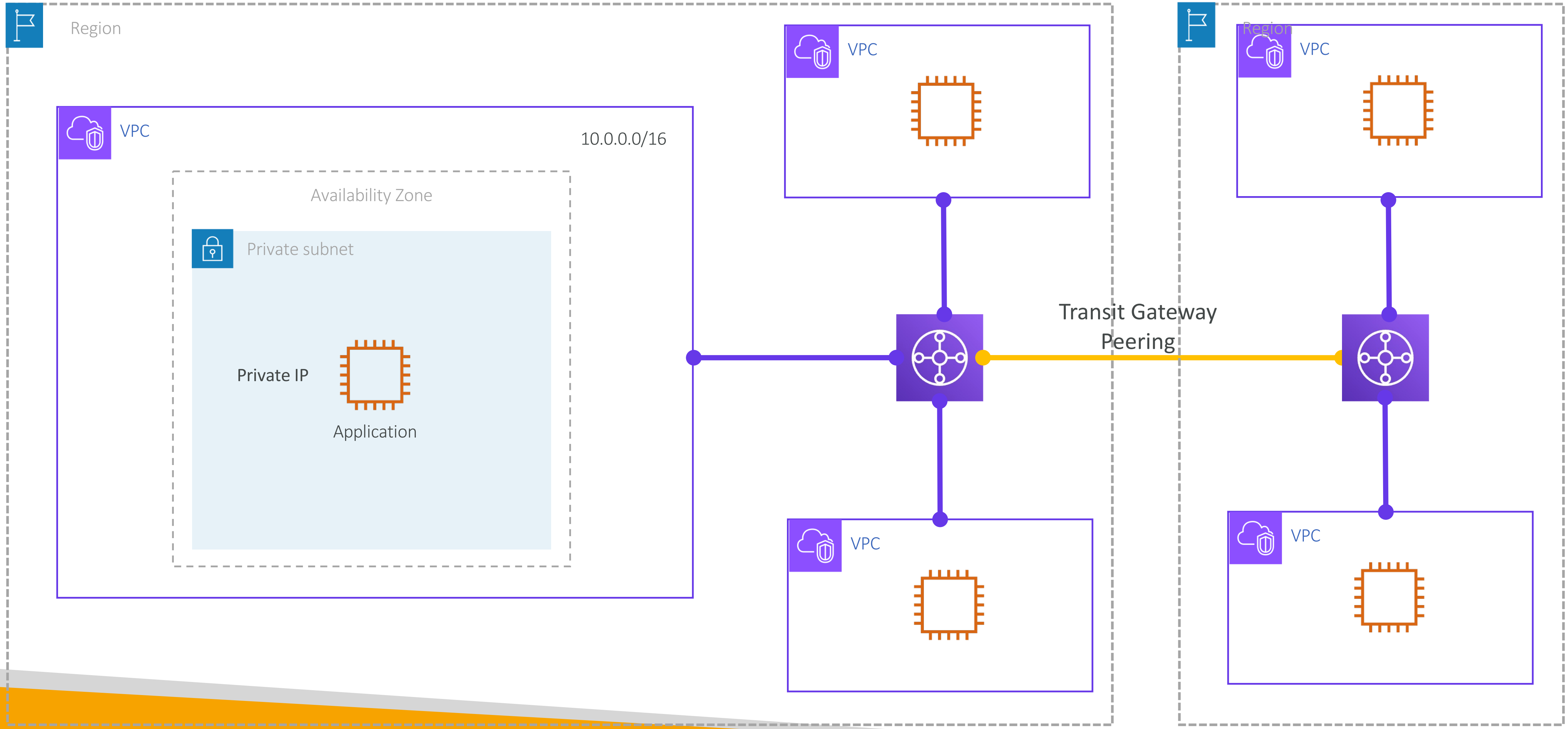
Transit Gateway

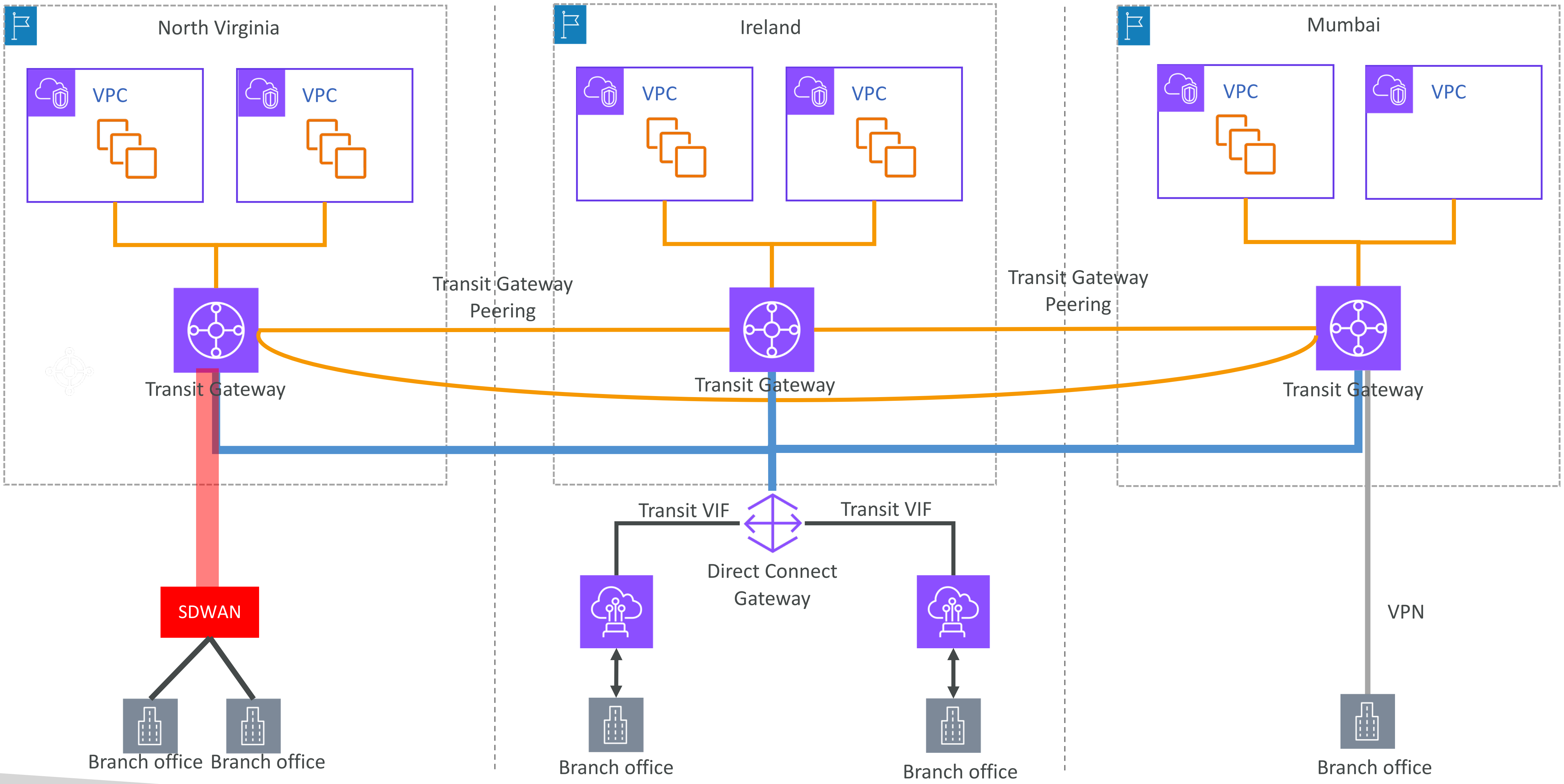


Transit Gateway

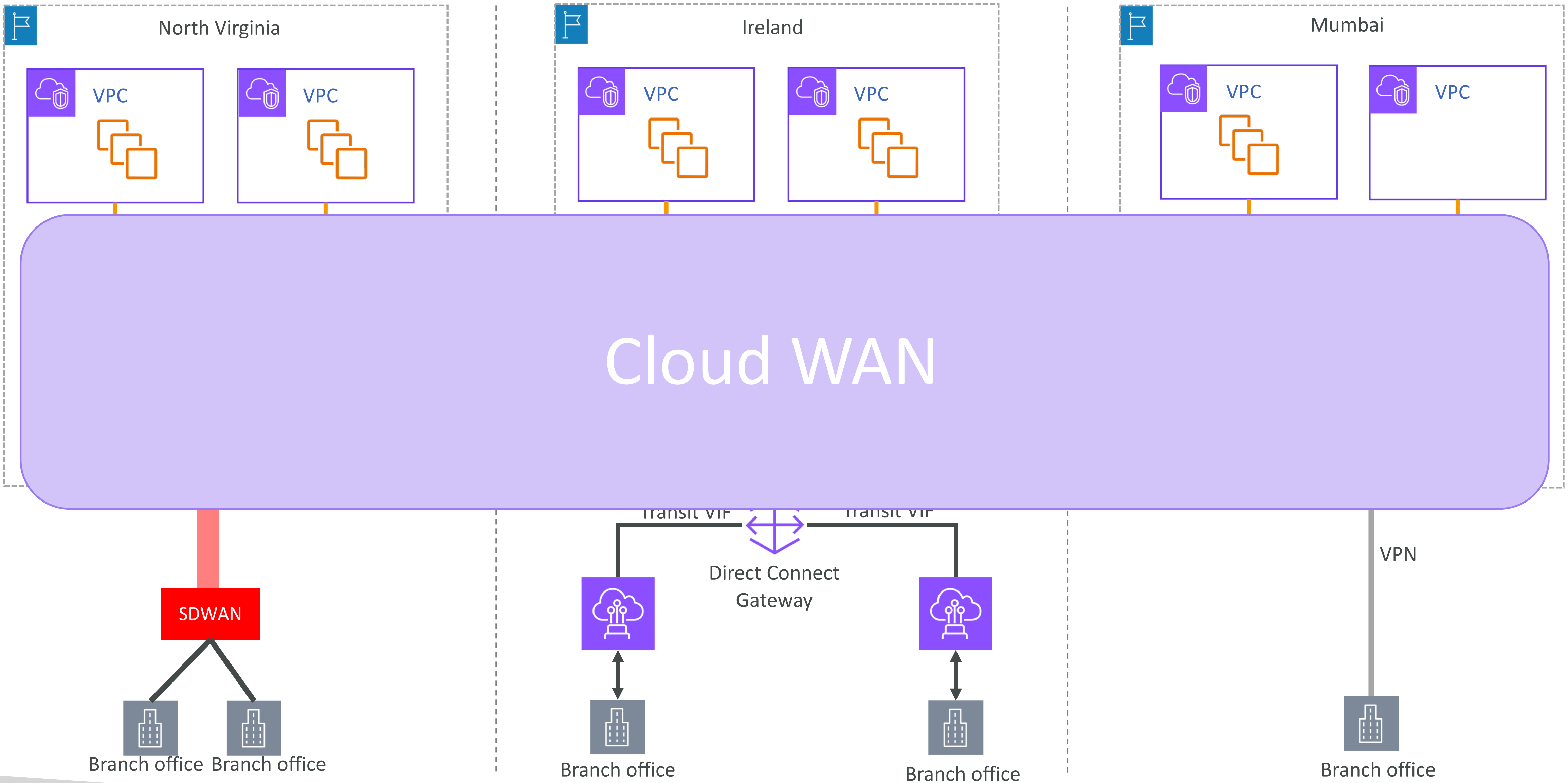


Transit Gateway

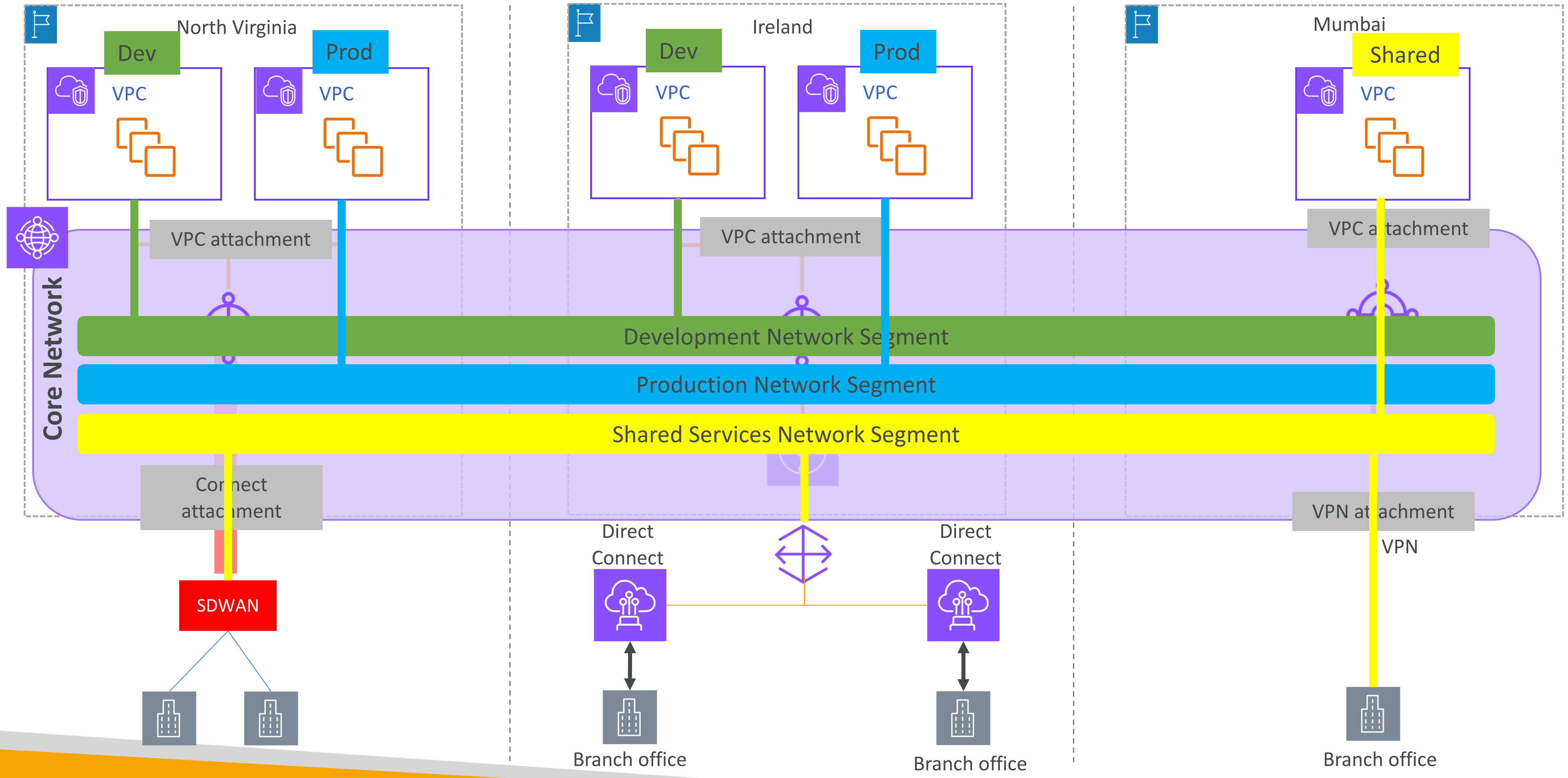




North Virginia
VPC
VPC
Ireland
VPC
VPC
Mumbai
VPC
VPC
Transit Gateway Peering
Transit Gateway Peering
Transit Gateway
Transit Gateway
Transit Gateway
Transit VIF
Transit VIF
Direct Connect Gateway
SDWAN
VPN
Branch office
Branch office
Branch office
Branch office
Branch office

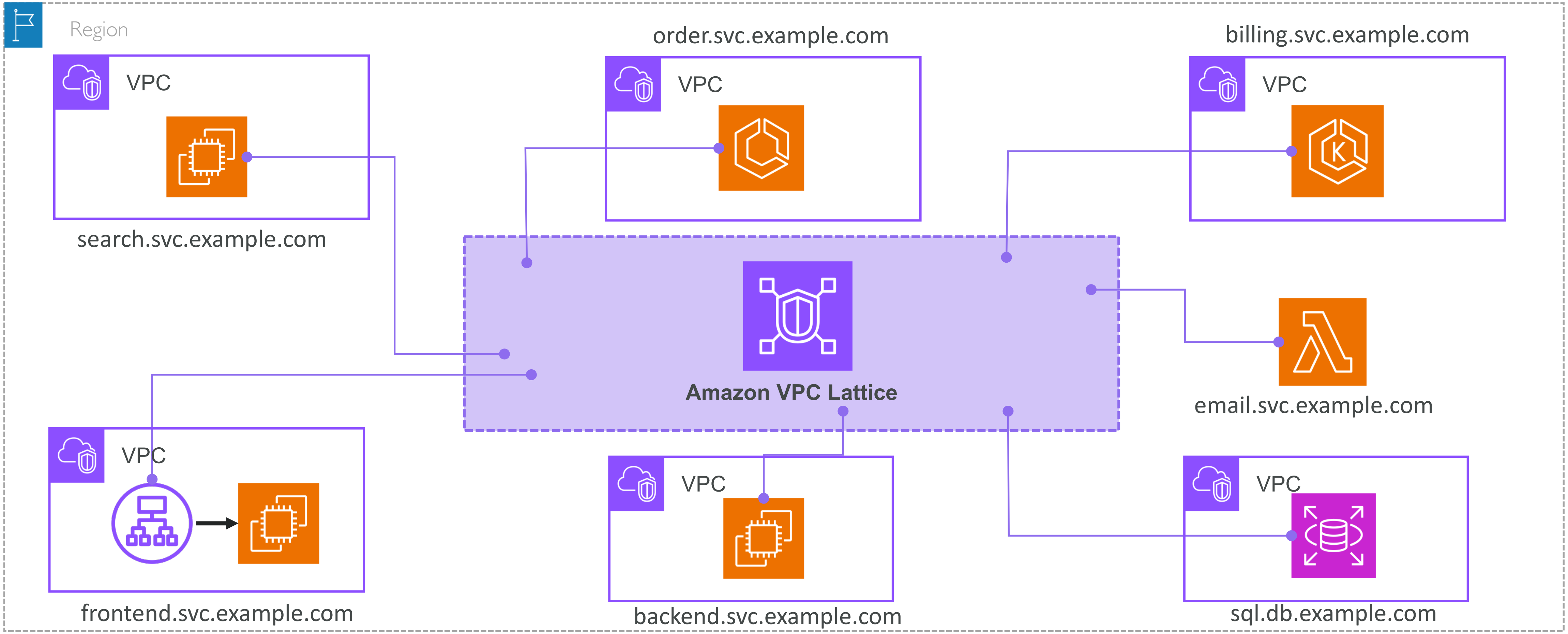

North Virginia
VPC
VPC
Ireland
VPC
VPC
Mumbai
VPC
VPC
Cloud WAN
Transit VIF
Transit VIF
Direct Connect
Gateway
SDWAN
VPN
Branch office
Branch office
Branch office
Branch office
Branch office

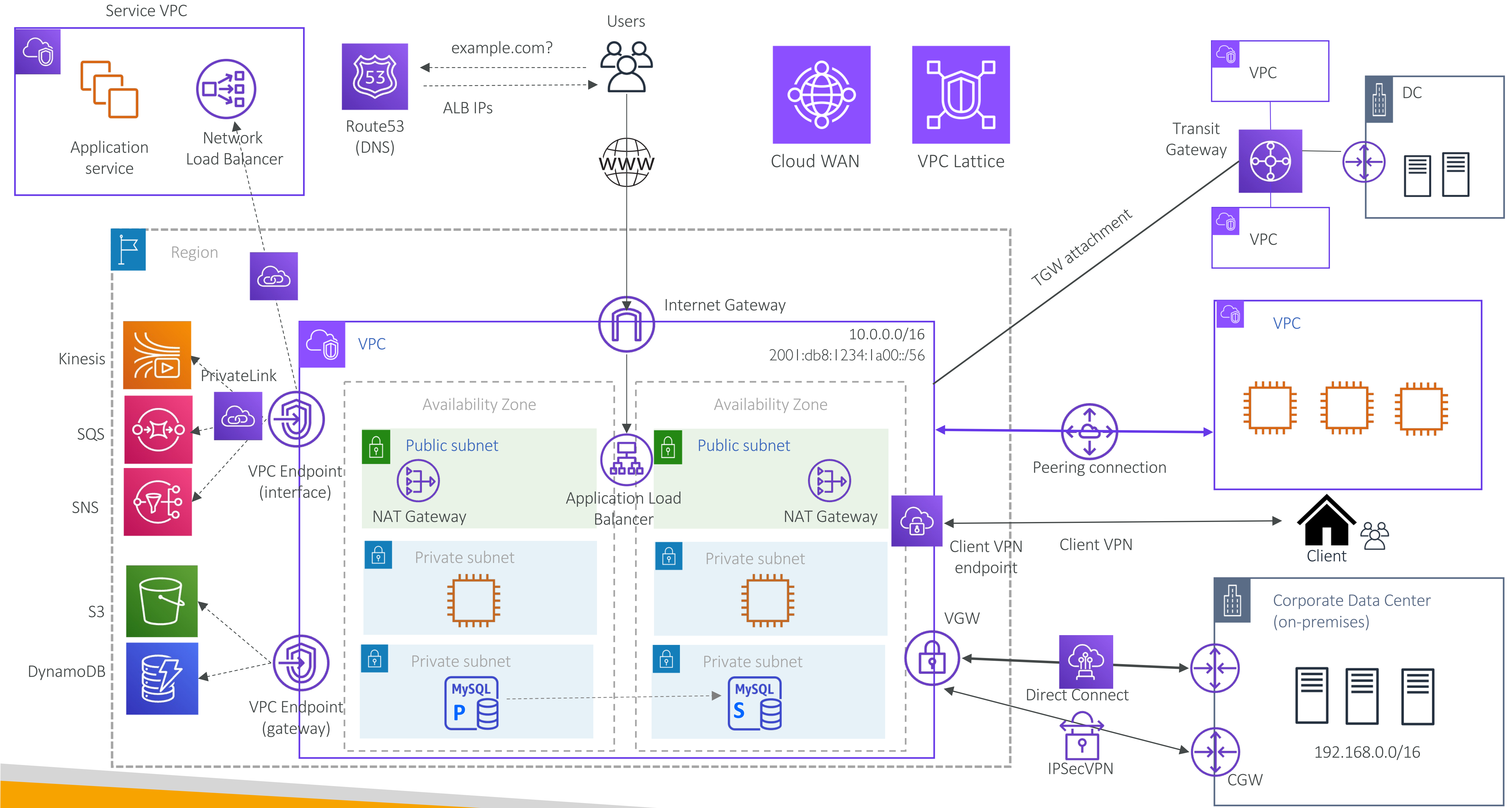
Cloud WAN



North Virginia
Dev
Prod
VPC
VPC
Ireland
Dev
Prod
VPC
VPC
Mumbai
Shared
VPC
Core Network
VPC attachment
VPC attachment
VPC attachment
Development Network Segment
Production Network Segment
Shared Services Network Segment
Connect attachment
VPN attachment
VPN
SDWAN
Direct Connect
Direct Connect
Branch office
Branch office
Branch office

VPC Lattice – Application networking




Service VPC
Application service
Network Load Balancer
Route53 (DNS)
example.com?
ALB IPs
Users
Cloud WAN
VPC Lattice
VPC
Transit Gateway
DC
VPC
TGW attachment
Region
Internet Gateway
VPC
10.0.0.0/16
2001:db8:1234:1a00::/56
Kinesis
PrivateLink
SQS
SNS
VPC Endpoint (interface)
Availability Zone
Availability Zone
Public subnet
Public subnet
NAT Gateway
NAT Gateway
Application Load Balancer
Private subnet
Private subnet
Private subnet
Private subnet
MySQL P
MySQL S
S3
DynamoDB
VPC Endpoint (gateway)
VPC
Peering connection
Client VPN endpoint
Client VPN
Client
VGW
Corporate Data Center (on-premises)
Direct Connect
IPSecVPN
CGW
192.168.0.0/16

Also..

- Network Architecture design patterns
- Network performance
- Network troubleshooting
- Network Security
- Network Management
- Networking in EKS (Kubernetes)
- Miscellaneous topics

Important to know before you start the course

- AWS service limits keep changing
- All the required topics are covered at required depth
- Newly launched AWS services/features
- AWS Console UI changes
- Your feedback is important

Important to know before you start the course

- **AWS service limits** (e.g., number of AWS regions, VPCs, NAT gateway bandwidth, VPN bandwidth, etc.) are constantly evolving. The certification exams do not focus on such limits, so don't worry if you spot the difference.
- In this course, not all topics will be covered at very deep level to ensure we stay focused on what matters most for your exam. This course is designed to be concise and efficient. Rest assured it offers what is required for the exam.
- Some of the newest features launched by AWS may not be immediately seen in the lectures. Generally, it takes up to 12 months for the new features to appear in the exam, so don't worry, we will add those when required.
- Finally, you might encounter errors or differences in behavior during hands-on exercises due to changes on the AWS side. If something doesn't work as expected, please let us know. We'll be happy to address and update the content accordingly.

Amazon VPC Fundamentals

Topics

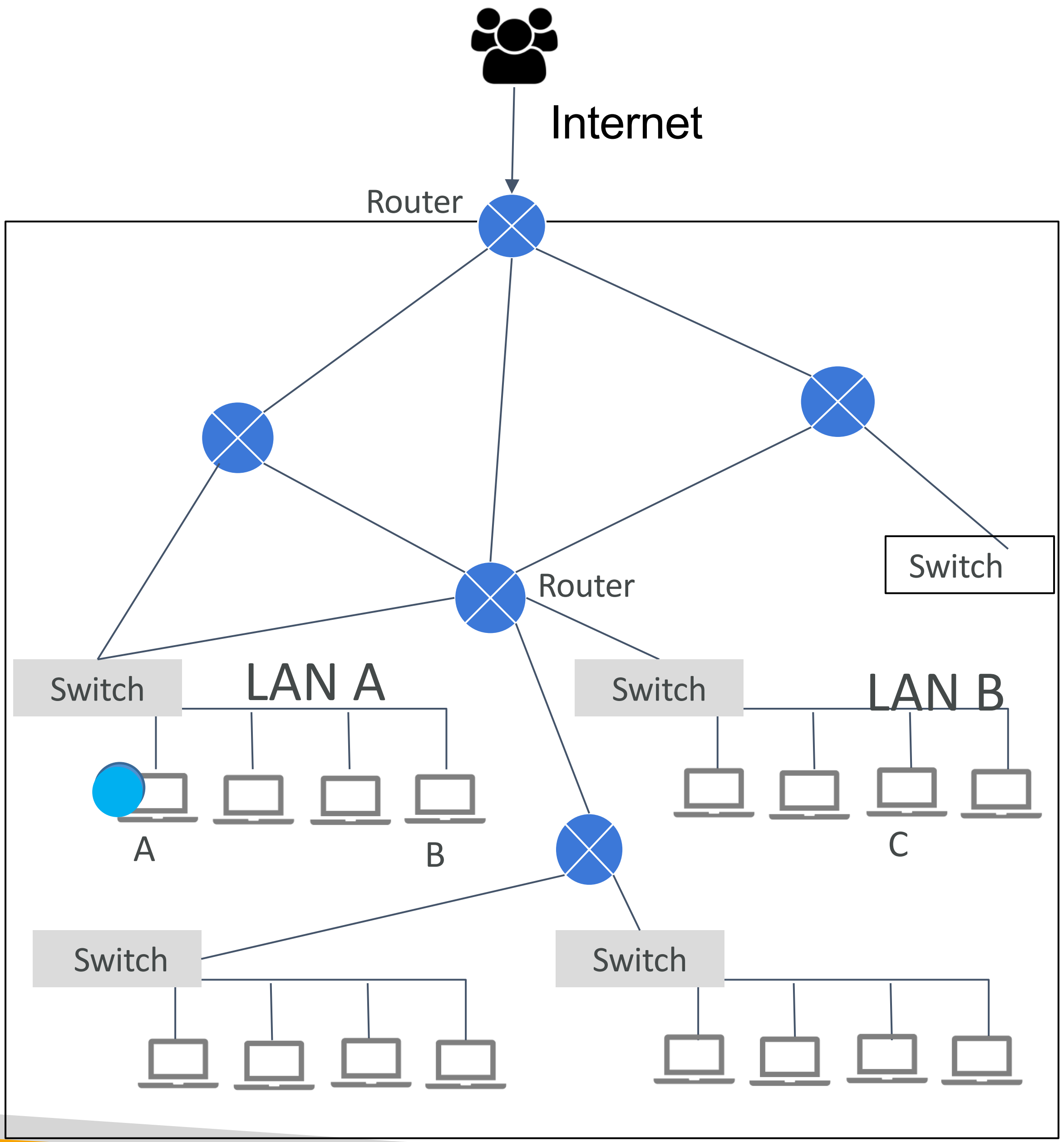
- What is VPC?
- AWS Services scope with respect to Region, AZ and VPC
- AWS Services inside and outside of VPC
- VPC Addressing (CIDR)
- VPC Subnets and Route Tables (Public/Private)
- IP Addresses (IPv4, IPv6, Private/Public/Elastic)
- Security Groups and Network ACL
- NAT gateway and NAT instance

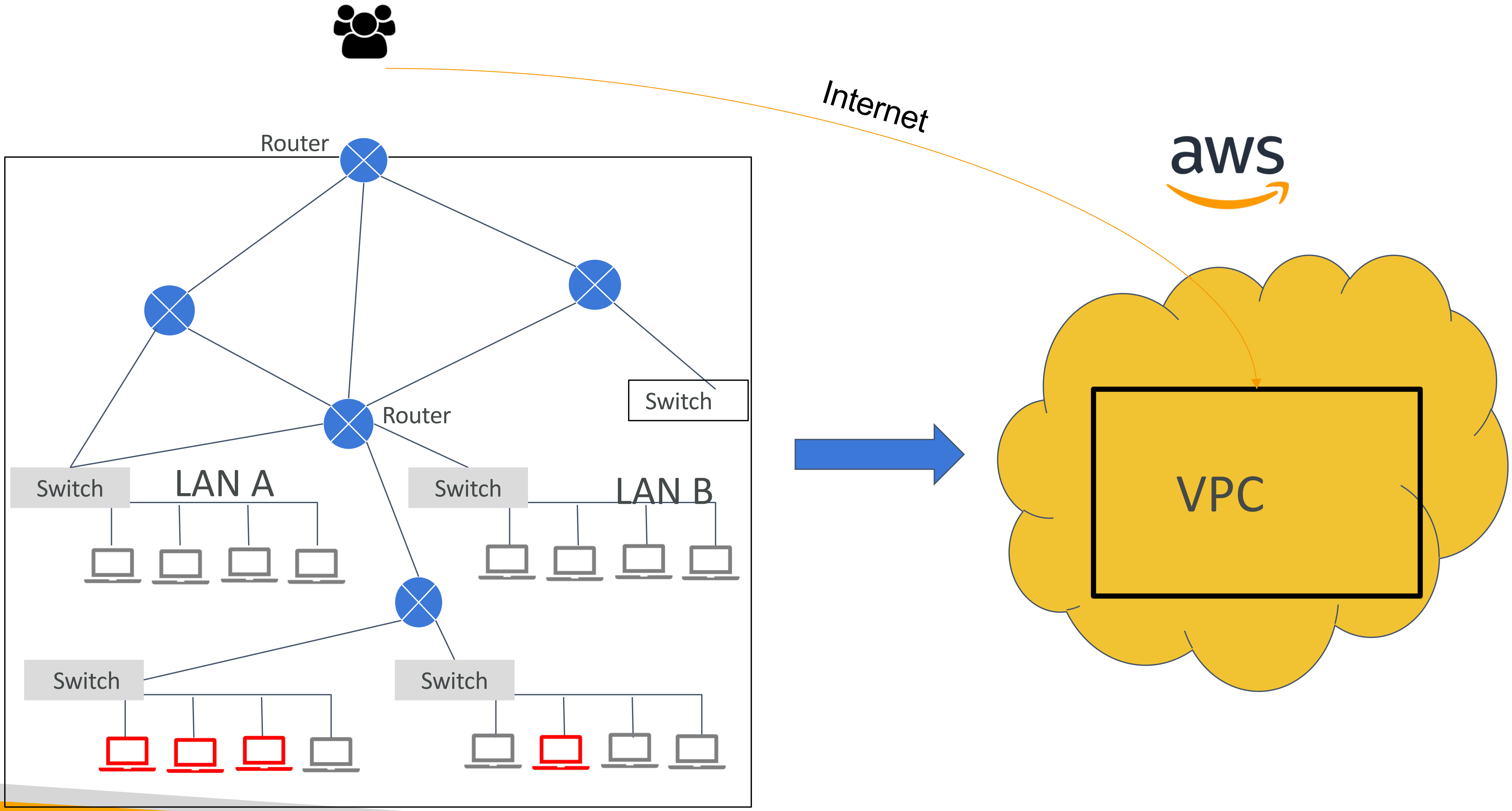
Amazon VPC

Virtual Private Cloud (VPC)

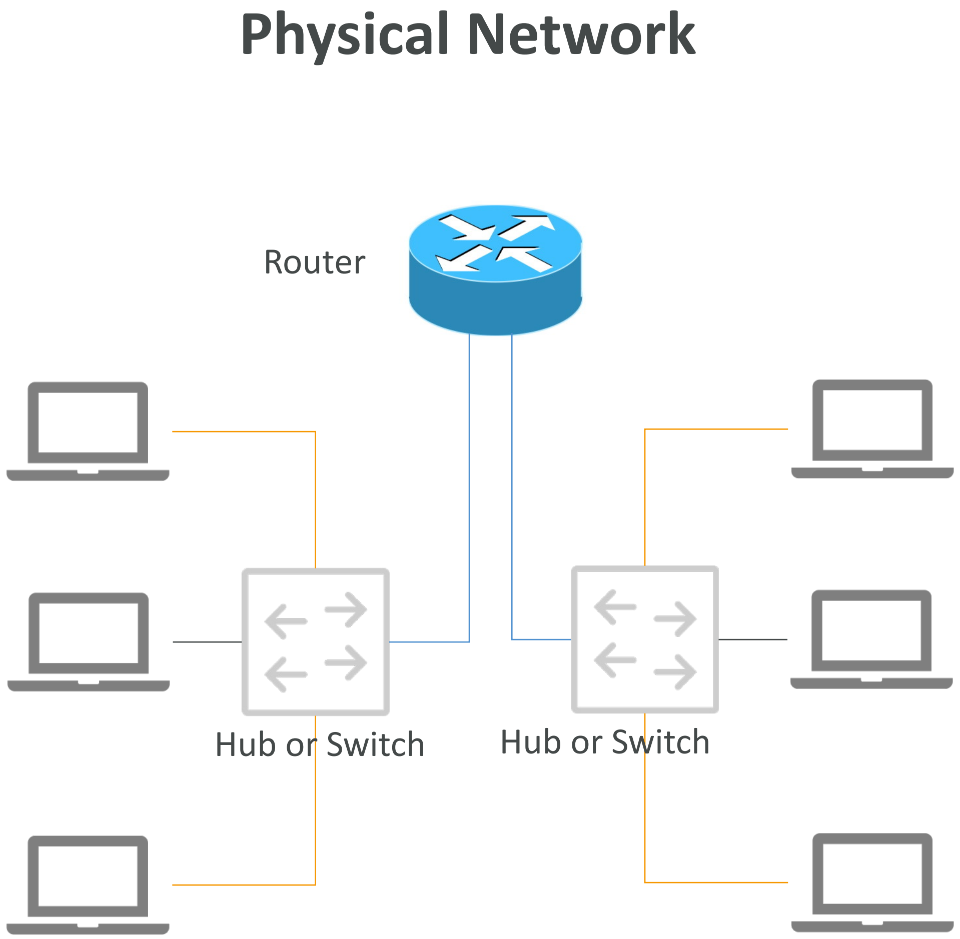
- Amazon VPC = Amazon Virtual Private Cloud
- Launch AWS resources into a virtual network that you've defined.
- VPC closely resembles a traditional on-premises network
- VPC benefits of using the scalable infrastructure of AWS

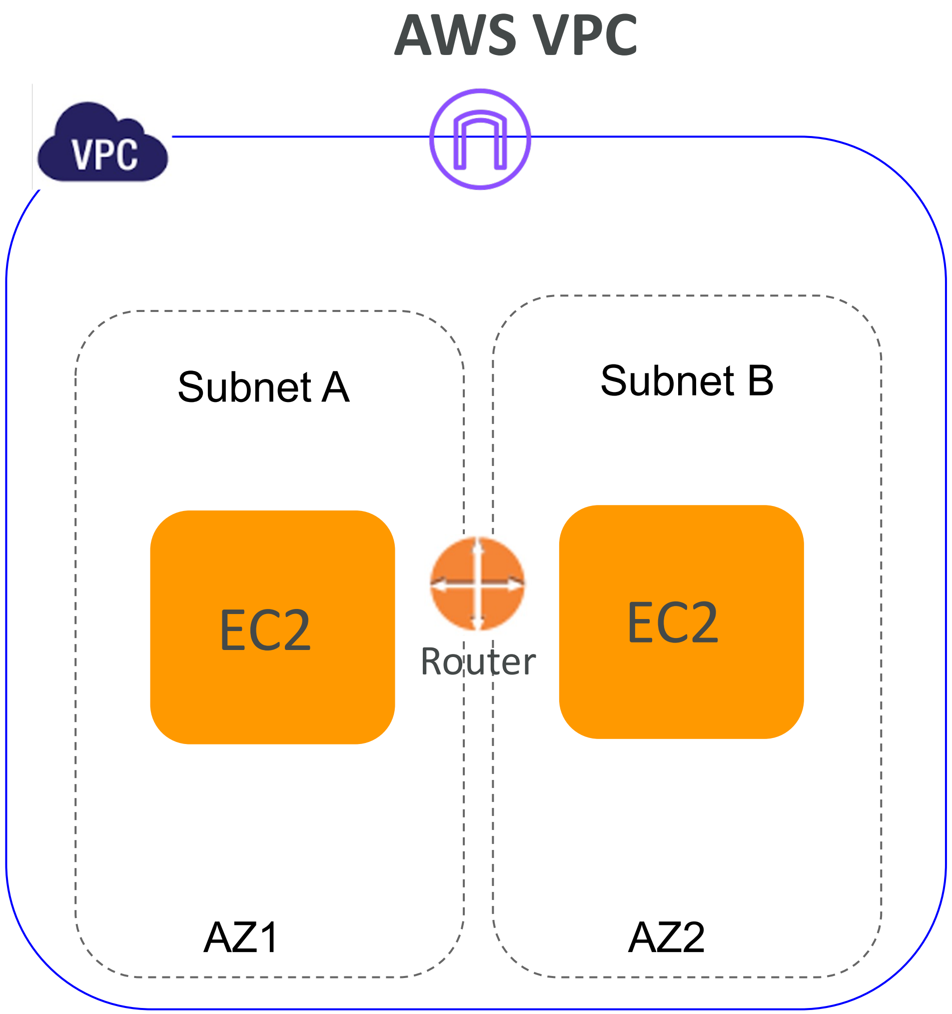
Moving from traditional on-premises network to virtual network in the Cloud


Internet
Router
Router
Switch
Switch
LAN A
Switch
LAN B
A
B
C
Switch
Switch


Internet
Router
Router
Switch
Switch
LAN A
Switch
LAN B
Switch
Switch
aws
VPC

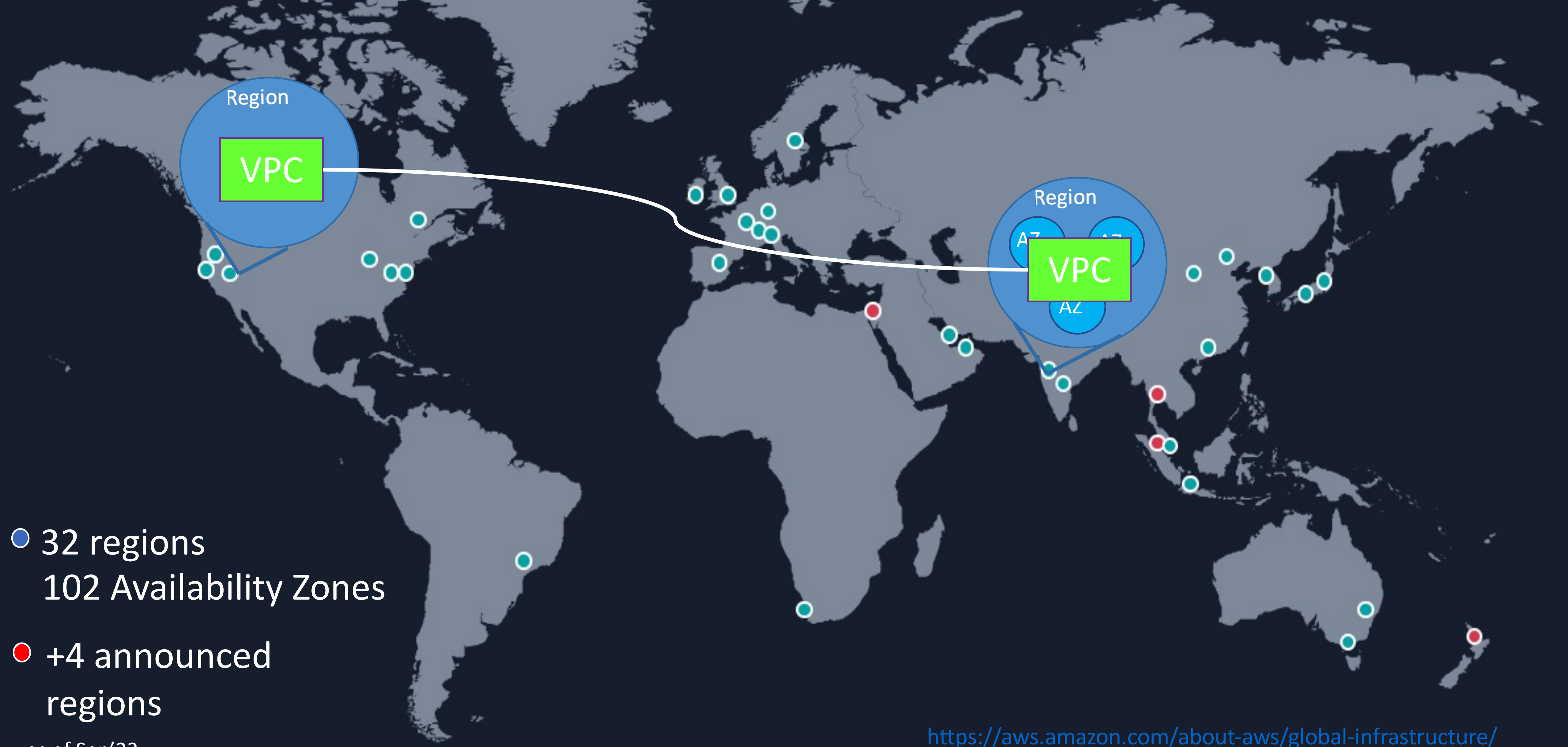
Traditional IT network vs VPC





AWS Account -> Region & AZ -> VPC

1 Region = Multiple Availability Zones

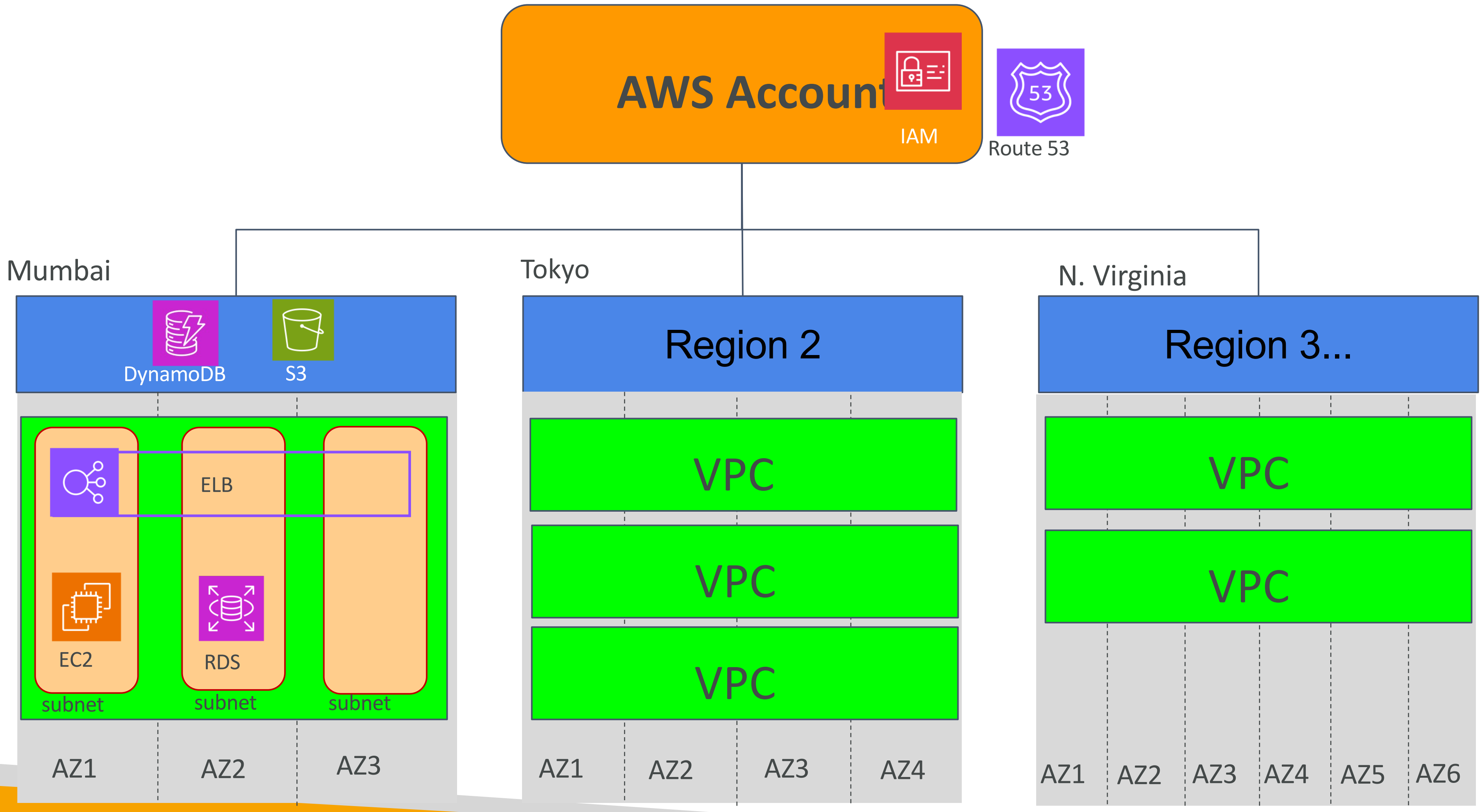


- 32 regions
  102 Availability Zones
- +4 announced regions

..as of Sep'23

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

AWS services scope with respect to VPC



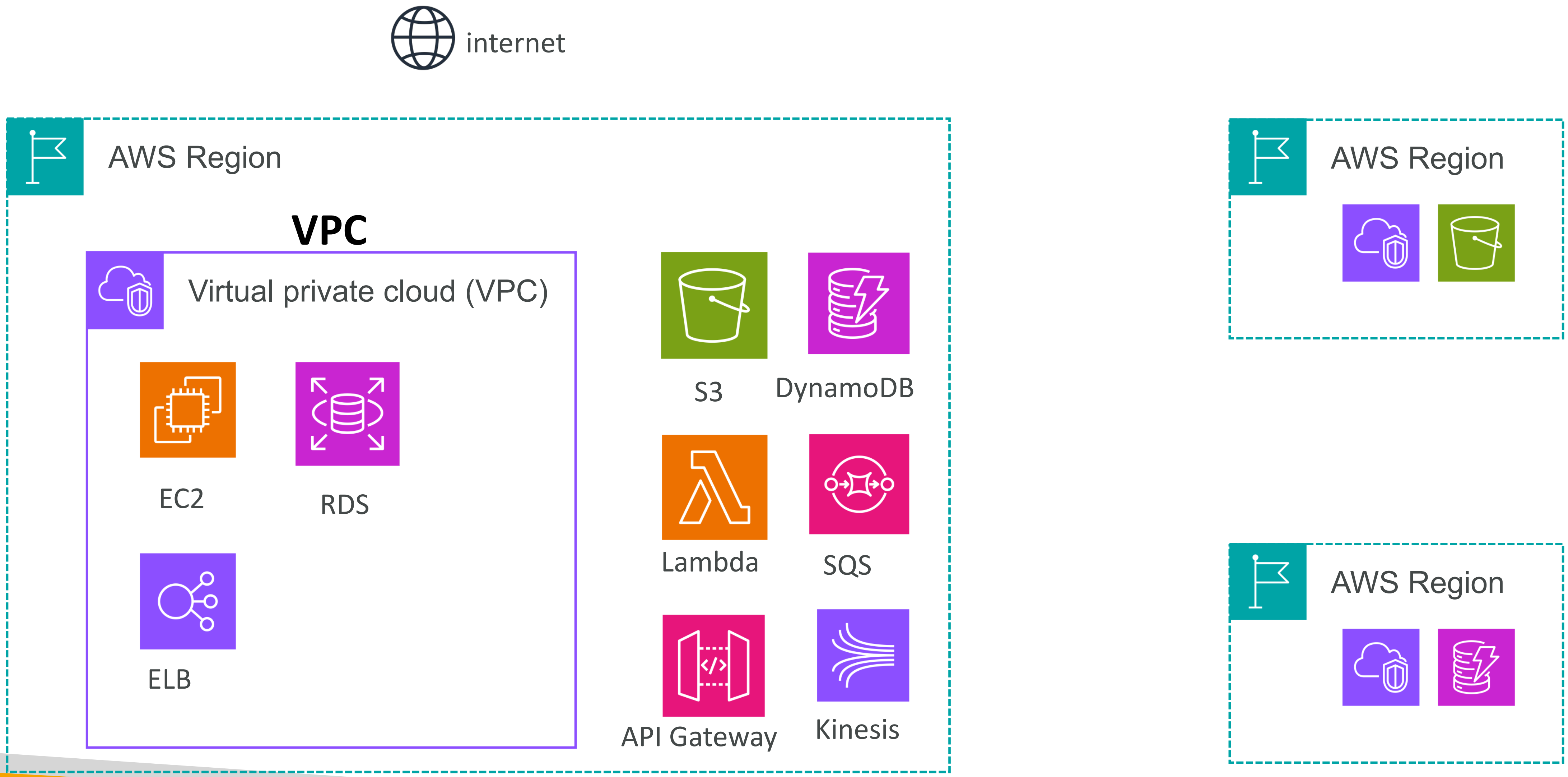
Route53, Billing, IAM

S3, DynamoDB

VPC, ELB

EC2, RDS

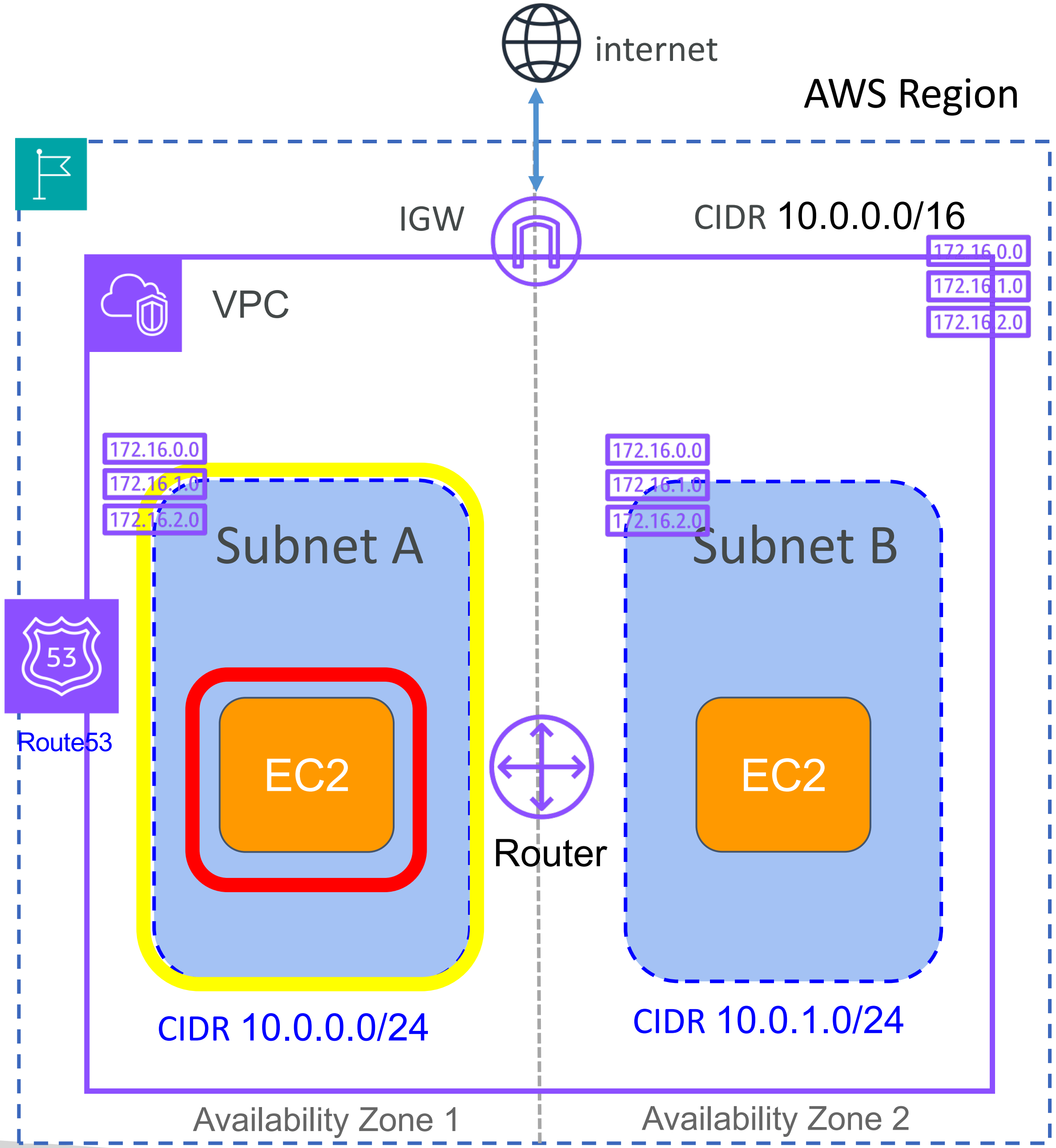
AWS services inside VPC and outside VPC



VPC Building blocks

VPC Building blocks

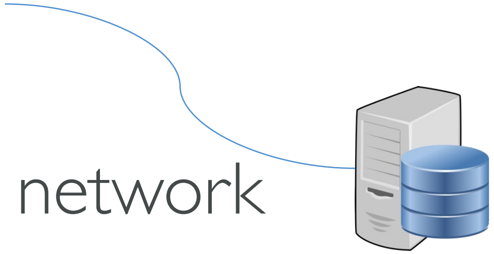
- CIDR
- Subnets
- Route Tables
- Internet Gateway
- Security Groups
- Network ACL
- Domain Name Server (DNS)
  - AWS DNS Server (Route53 Resolver) *



VPC CIDR

IPv4 and IPv6 addresses

- IP address is the identity of the each host in the network
- There are 2 types of IP addresses
  - IPv4 (32 bit)
  - IPv6 (128 bit)
- IPv4 address
  - Represented as four octets (4 x 8 bits)
  - Each octet represented in decimal value 0-255. Example: 192.168.56.212



12.34.56.67

fe80:cd00:0000:0cde:1257:0000:211e:729c

192.168.56.212

192 = 128 + 64 = 2^7 + 2^6

Bits	7	6	5	4	3	2	1	0

1 1 0 0 0 0 0 .10101000.00111000.110101
0 00

CIDR – Classless Inter Domain Routing

- IP addressing scheme that replaces old address style of Class A, B, C
- Represented as a IP address and prefix

  Example: IPv4 CIDR 192.168.0.0/16

192 .168 .0 .0 /16

1 1 0 0 0 0 0 0 . 1 0 1 0 1 0 0 0. 0 0 0 0 0 0 0 0 .0 0 0 0 0 0/16
0 0 0

16 bits

16 bits

Network Address
192.168
Fixed

Host Addresses
0-255.0-255
0 to 255 in each available octate

CIDR – Classless Inter Domain Routing

Example: IPv4 CIDR 192.168.22.0/24

192 .168 .22 .0 /24

1 1 0 0 0 0 0 0 . 1 0 1 0 1 0 0 0. 0 0 0 1 0 1 1 0 .0 0 0 0 0 0/24
0 0 0

24 bits

8 bits

Network Address

192.168.2
2

Host Addresses

0-255

Understanding CIDRs - Little exercise

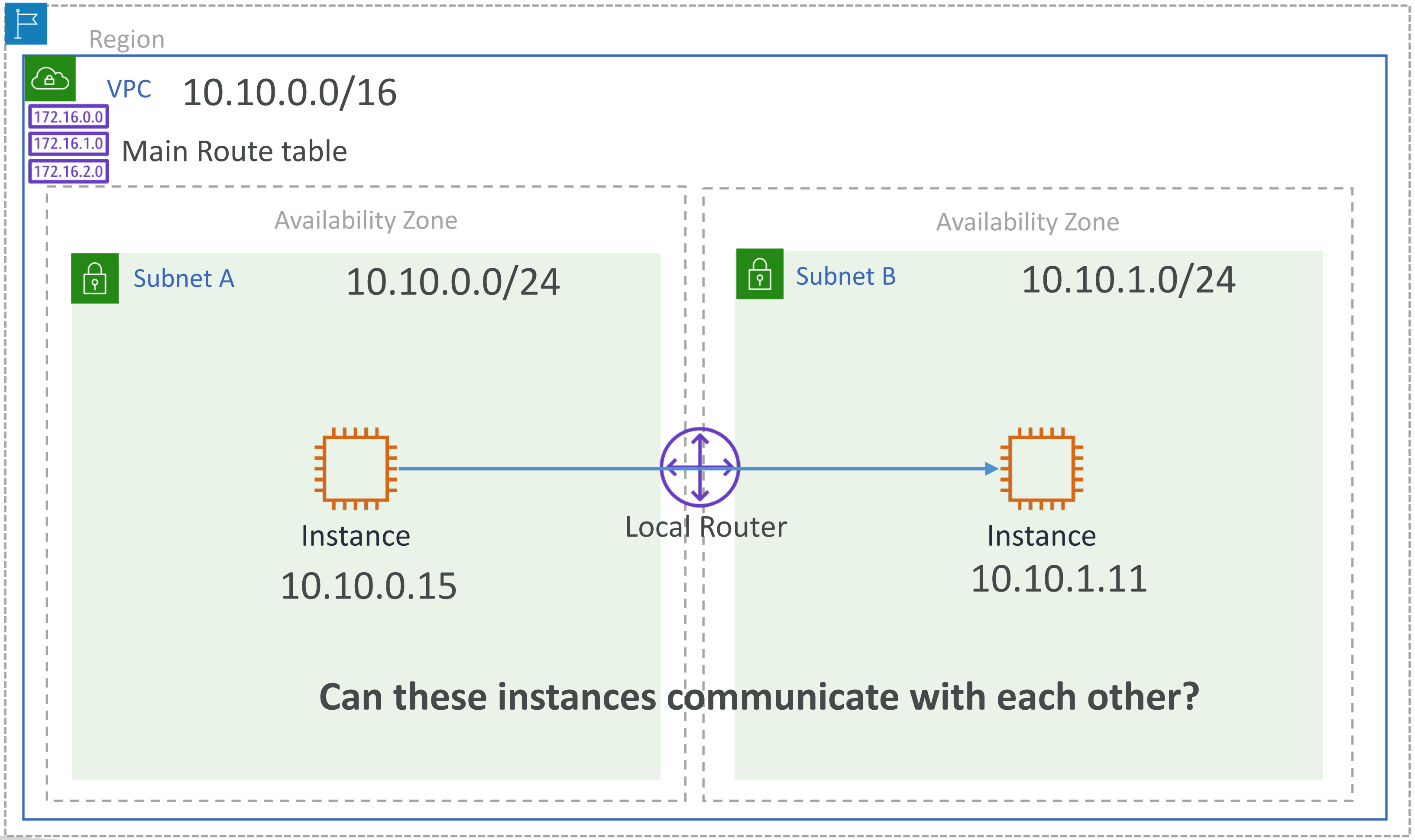
- 192.168.0.0/24 = … ?
  - 192.168.0.0 – 192.168.0.255 (256 IP)
- 192.168.0.0/16 = … ?
  - 192.168.0.0 – 192.168.255.255 (65,536 IP)
- 134.56.78.123/32 = … ?
  - Just 134.56.78.123
- 0.0.0.0/0
  - All IP!
- When in doubt, use this website: https://www.ipaddressguide.com/cidr

VPC Addressing

- **AWS VPC CIDR (IPv4)**
  - VPC prefix between /16 (65536 IPs) and /28 (16 IPs)
  - RFC 1918 IP ranges for Private network and corresponding AWS recommended ranges
    - 10.0.0.0/8 => 10.0.0.0 – 10.255.255.255 **=> AWS CIDR 10.X.0.0/16**
    - 172.16.0.0/12 => 172.16.0.0 - 172.31.255.255 **=> AWS CIDR 172.16.0.0/16 to 172.31.0.0/16**
    - 192.168.0.0/16 => 192.168.0.0 - 192.168.255.255 **=> AWS CIDR 192.168.0.0/16**
  - Subnet CIDR prefix between /16 to /28 (same as VPC CIDR)
- **AWS VPC CIDR (IPv6)**
  - VPC CIDR with prefix /56 (2^72 IPs)
  - IPv6 CIDR is allocated by AWS
  - Subnet CIDR prefix /64
  - IPv6 IP addresses are globally unique and publicly routable

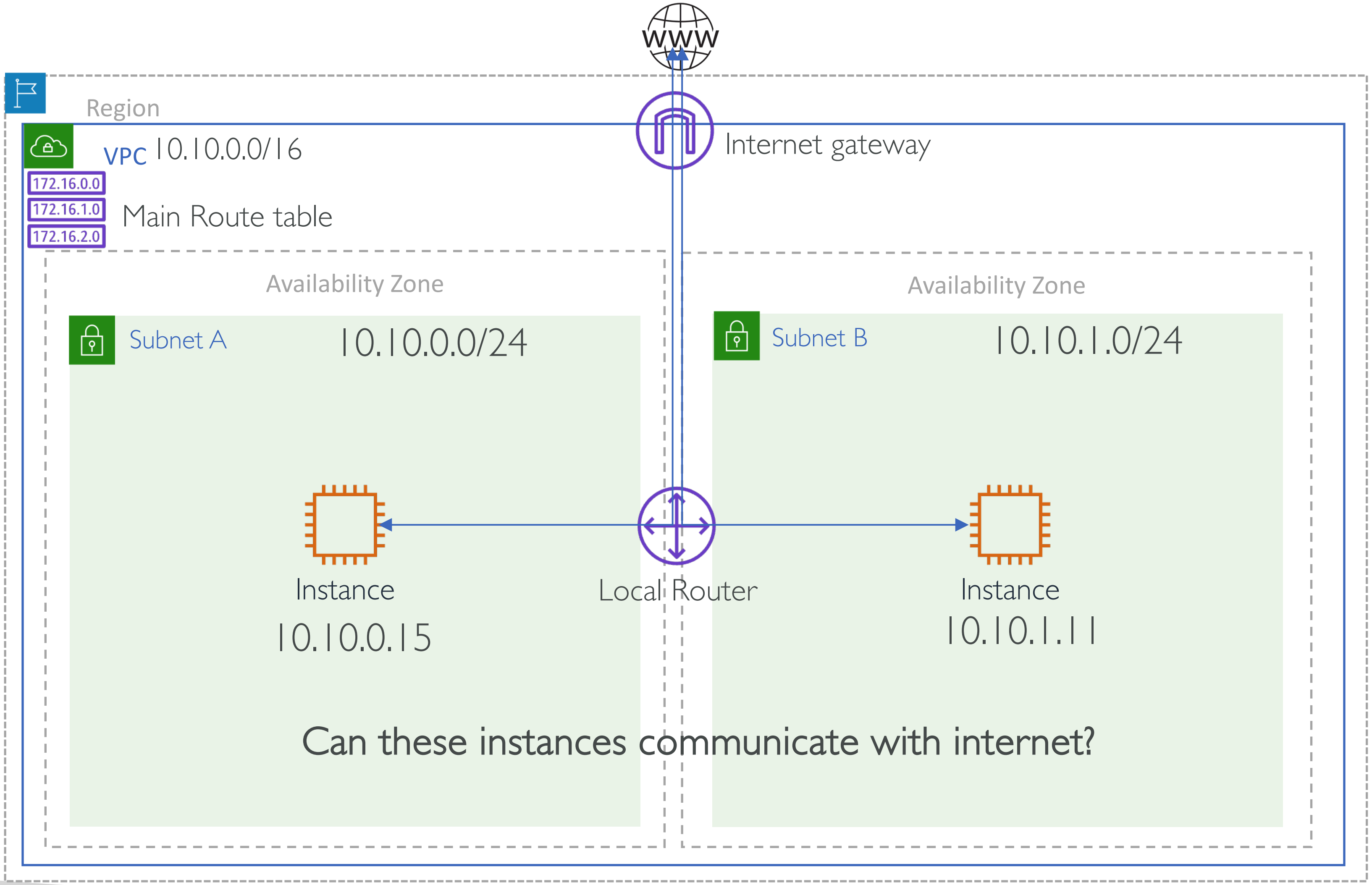
Subnets, Route Tables and Internet Gateway

Subnets, Route Tables and Internet Gateway



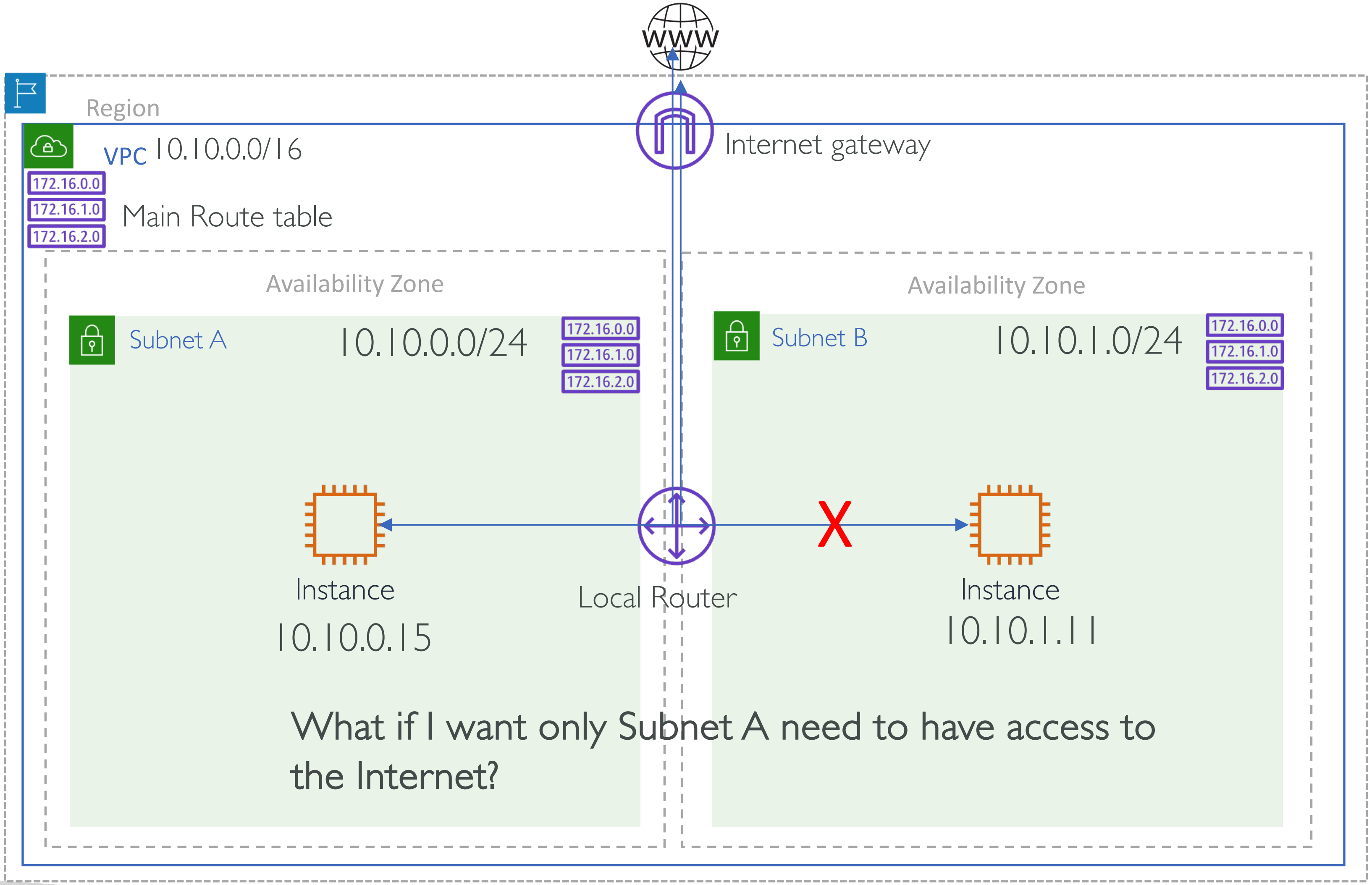
Destination	Target
10.10.0.0/16	Local

Subnets, Route Tables and Internet Gateway



Destination	Target
10.10.0.0/16	Local
0.0.0.0/0	Internet Gateway

Subnets, Route Tables and Internet Gateway



Subnet A Route Table

Destination	Target
10.10.0.0/16	Local
0.0.0.0/0	**Internet Gateway**

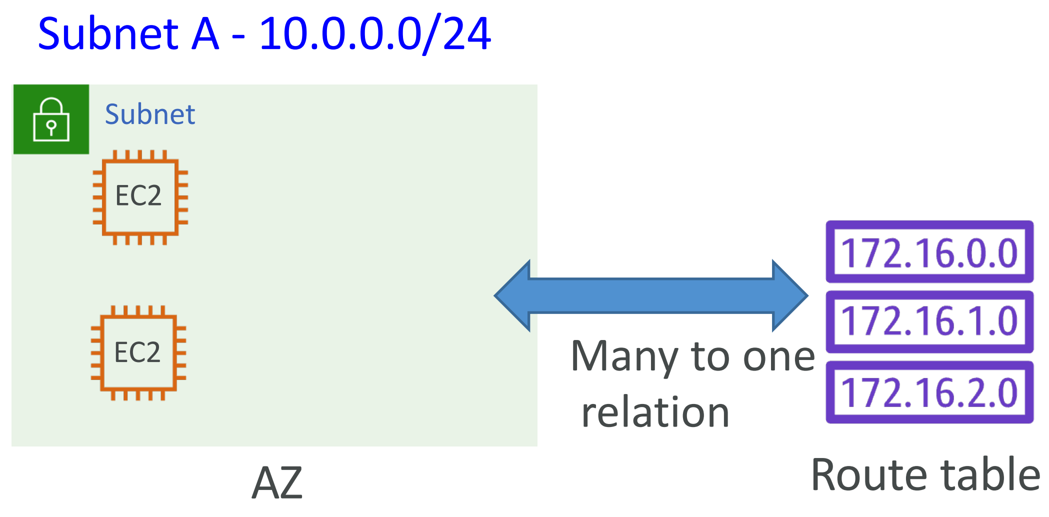
Subnet B Route Table

Destination	Target
10.10.0.0/16	Local

Now subnets are not following Main Route Table

Route Table

- Contains rules to route the traffic in/out of Subnets/VPC
- Main route table at VPC level
- Custom route table at Subnet level
- Each route table contains default immutable local route for VPC
- If no custom route table is defined, then new subnets are associated with Main route table
- We can modify main route table



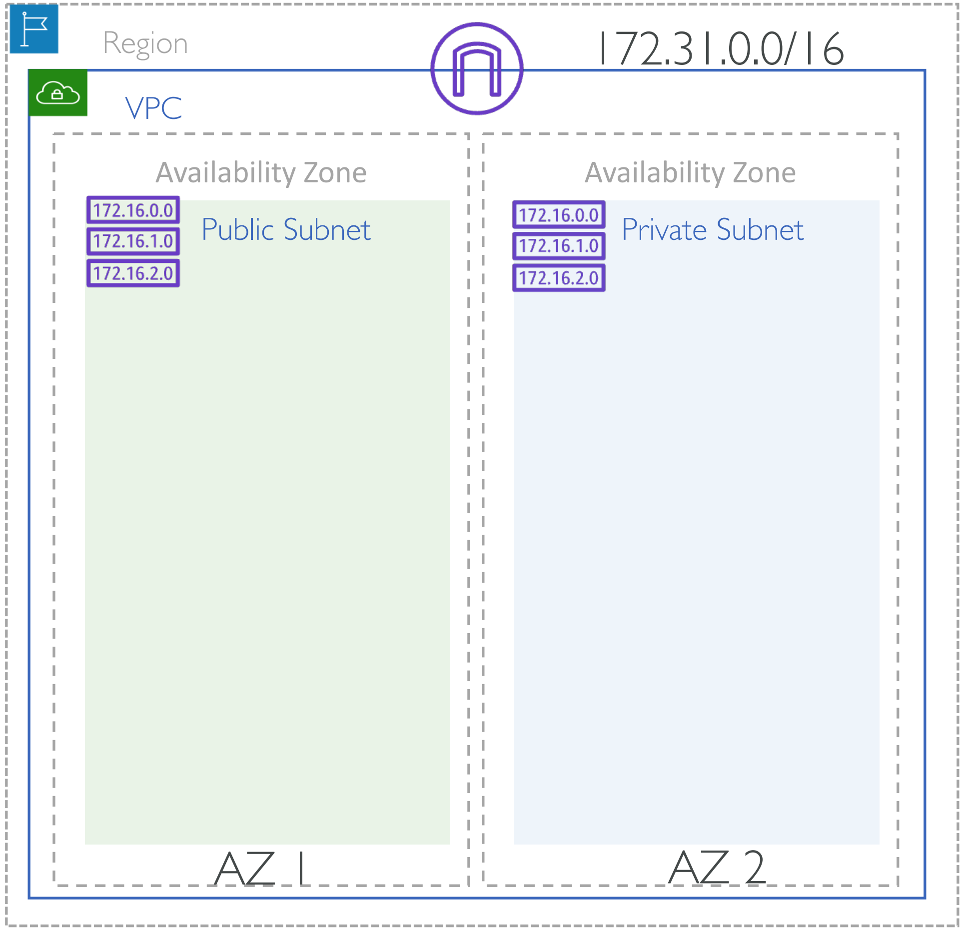
Destination	Target
10.0.0.0/16	local
0.0.0.0/0	igw-id

Subnets

- Public Subnet
  - Has route for Internet
  - Instances with Public IP can communicate to internet
  - Ex: NAT, Web servers, Load balancer

Destination	Target
172.31.0.0/16	local
0.0.0.0/0	igw-xxx

1 Subnet => 1 AZ

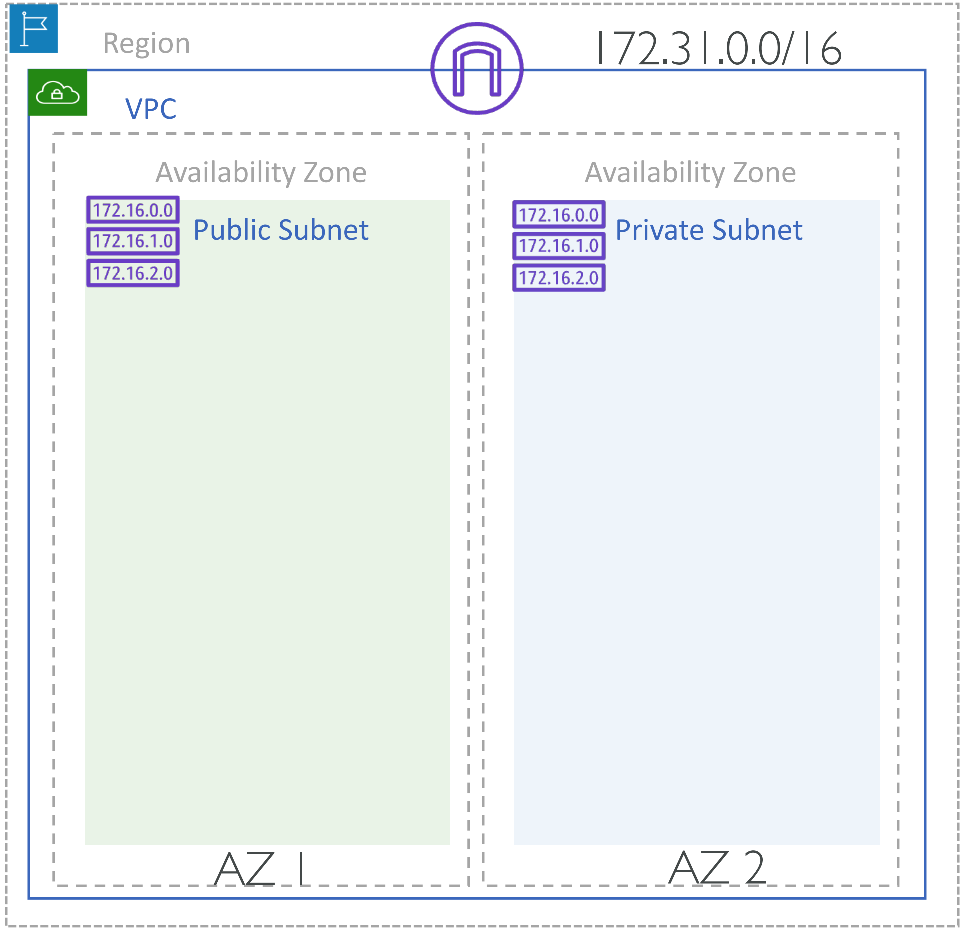


Subnets

- Private Subnet
  - No route to Internet
  - Instances receive private IPs
  - Typically uses NAT for instances to have internet access
  - Ex: Database, App server

Destination	Target
172.31.0.0/16	local

1 Subnet => 1 AZ



Subnets - IPv4

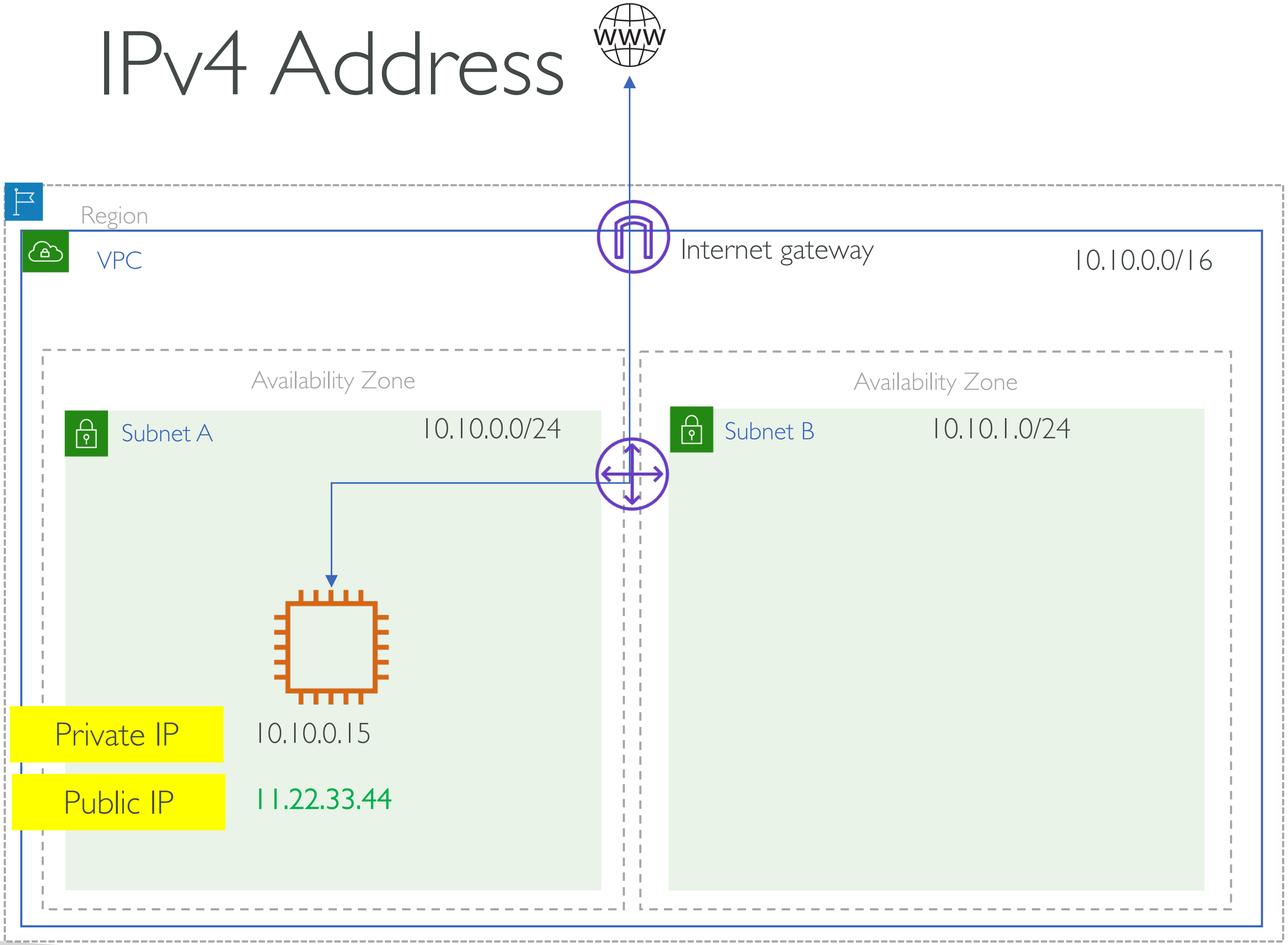
- AWS reserves 5 IPs address (first 4 and last 1 IP address) in each Subnet
- These 5 IPs are not available for use and cannot be assigned to an instance
- Ex, if CIDR block 10.0.0.0/24, reserved IP are:
  - 10.0.0.0: Network address
  - 10.0.0.1: Reserved by AWS for the VPC router
  - 10.0.0.2: Reserved by AWS for mapping to Amazon-provided DNS
  - 10.0.0.3: Reserved by AWS for future use
  - 10.0.0.255: Network broadcast address. AWS does not support broadcast in a VPC, therefore the address is reserved
- Exam Tip:
  - If you need 29 IP addresses for EC2 instances, you can't choose a Subnet of size /27 (32 IP)
  - You need at least 64 IP, Subnet size /26 (64-5 = 59 > 29, but 32-5 = 27 < 29)

IP Addresses in VPC

IPv4 and IPv6 addresses

- IPv4 and IPv6 are two versions of the Internet Protocol (IP) addressing system
- IPv4 uses a 32-bit address format and can address 2^32 devices => 4,294,967,296 => ~4 billion addressees.
- IPv4 is proving to be insufficient in its addressing range. In 2011 we exhausted all public IPv4 addresses.
- IPv6 uses 128-bit address format and can address 2^128 devices = 340,282,366,920,938,000,000,000,000,000,000,000,000 which is more than sufficient for the forceable future
- IPv4 address: 172.31.22.5
- IPv6 address: 2001:0db8:85a3:0000:0000:8a2e:0370:7334

IPv4 Address



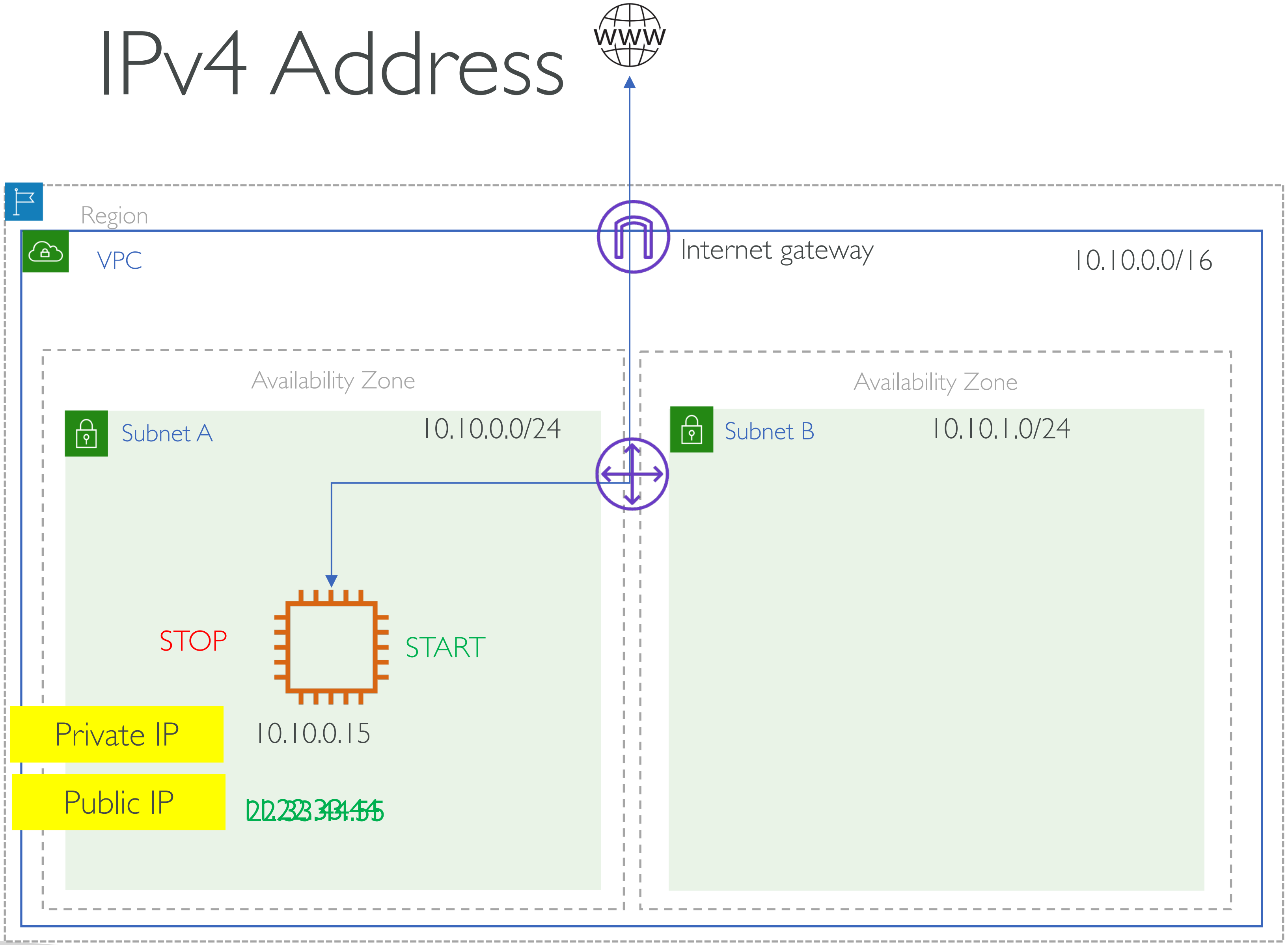
Private IP

- Private IP is assigned from the subnet range

Public IP

- Public IP is assigned from the Amazon's pool of Public IPs

IPv4 Address



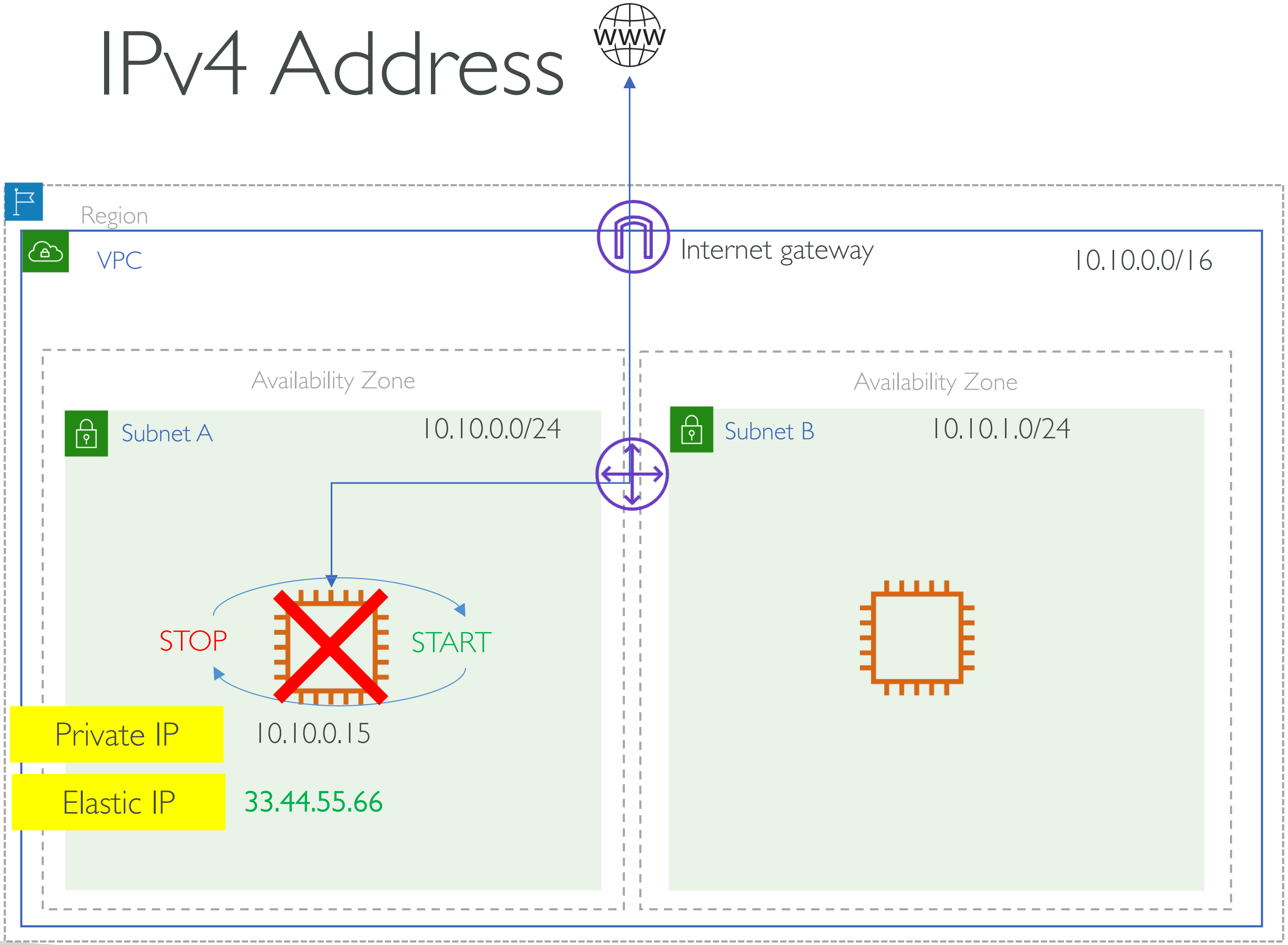
Private IP

- Private IP is assigned from the subnet range

Public IP

- Public IP is assigned from the Amazon's pool of Public IPs
- Public IP will change when you stop and start the instance

IPv4 Address



Elastic IP

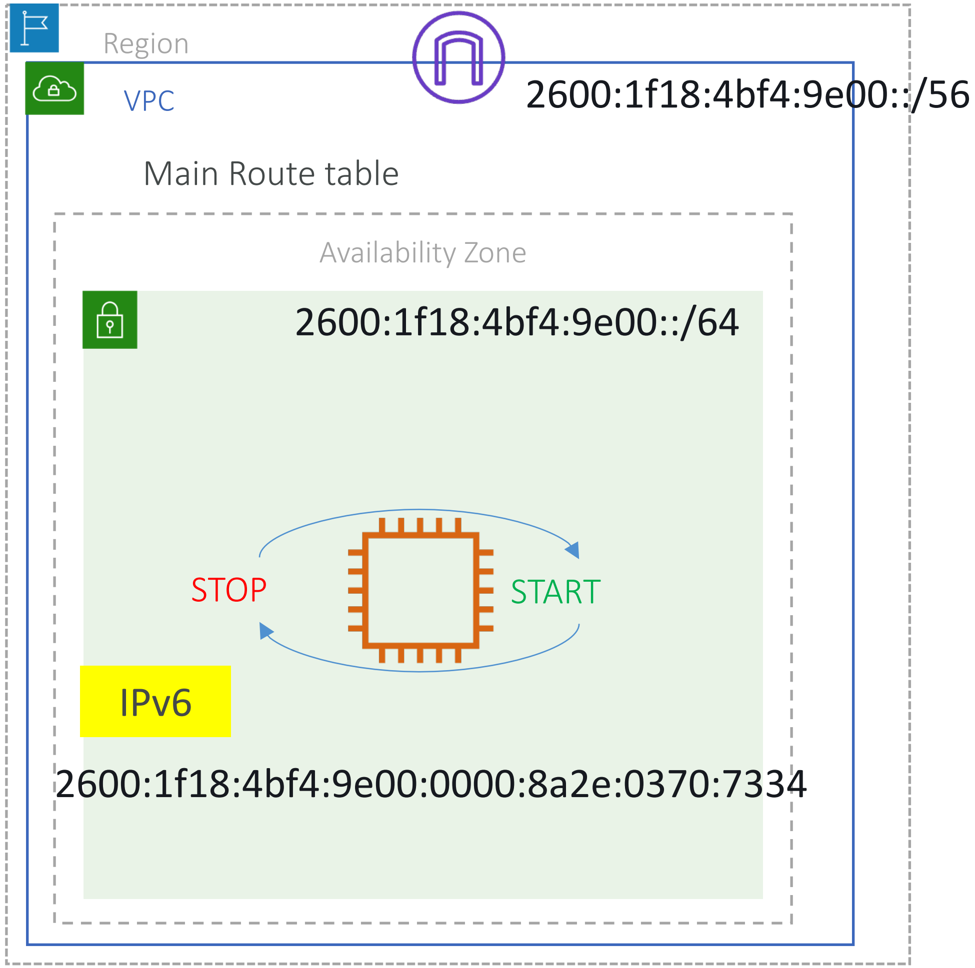
- Elastic IP is allocated to your AWS account
- Remains allocated until released
- Does not change on instance stop/start
- Can be remapped to another instance

IPv4 address - Private, Public and Elastic IP

Feature	Private IP	Public IP	Elastic IP
Communication	Communication within VPC	Can communicate over internet	Can communicate over internet
Address range	Gets IP address from subnet range. Ex: 10.200.0.1	Gets IP address from Amazon Pool within region	Gets IP address from Amazon Pool within region
Instance restart behavior	Once assigned cannot be changed	Changes over instance restart	Do not change over instance restart.
Releasing IP	Released when instance is terminated	Released to Amazon Pool when instance is stopped or terminated	Not released. Remains in your account.
Automatic Assignment	Receives private IP on launch on EC2 instance	Receives public IP on launch on EC2 instance if "Public IP addressing attribute" is set to true for subnet	Must explicitly allocate and attach EIP to EC2 instance. Can be reattached to other EC2,
Examples	Application servers, databases	Web servers, Load Balancers, Websites	Web servers, Load Balancers, Websites

IPv6 Addresses

- AWS VPC also supports IPv6 addresses
- IPv6 address is 128 bits in size with 8 blocks of 16 bits each
  - Example: 2001:0db8:85a3:0000:0000:8a2e:0370:7334
- VPC CIDR with prefix /56 (2^72 IPs) and Subnet CIDR prefix /64
- IPv6 addresses are public and globally unique, and allows resources to communicate with the internet
- VPC can operate in dual-stack mode where VPC resources can communicate over IPv4, or IPv6, or both
- IPv6 address persists when you stop and start your instance, and is released when you terminate your instance



VPC having both IPv4 and IPv6 subnets

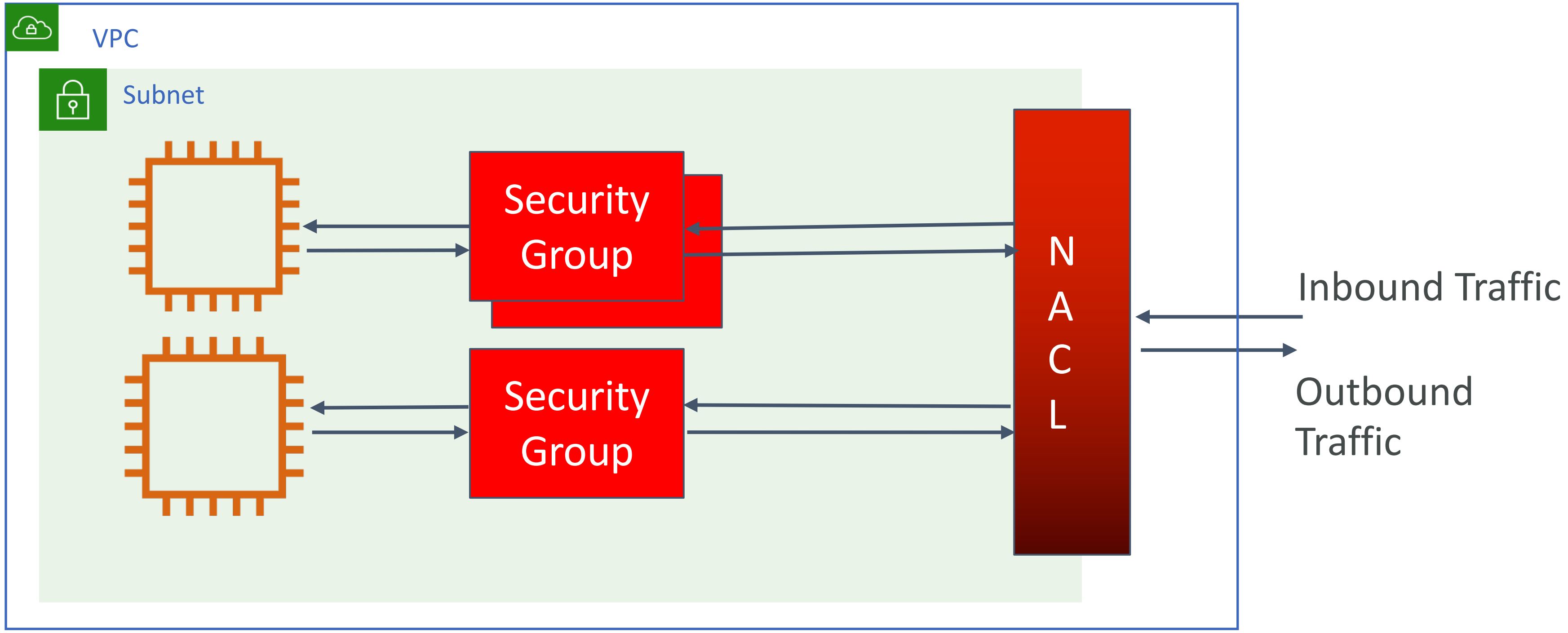
- VPC supports dual-stack mode
- Resources inside VPC can communicate over IPv4 or IPv6 or both
- IPv4 support can not be disabled for the VPC
- VPC supports IPv6-only subnets

IPv4 vs IPv6 Addresses

IPv4	IPv6
Default and required for all VPCs; cannot be removed.	Opt-in only
The VPC/Subnet CIDR block size can be from /16 to /28.	The VPC CIDR block size is fixed at /56. Subnet block is fixed at /64
You can choose the private IPv4 CIDR block for your VPC	IPv6 CIDR block is allocated to VPC from Amazon's pool of IPv6 addresses. We cannot select the range.
Supports both Private and Public IPs	No distinction between public and private IP addresses. IPv6 addresses are public.
An instance receives an Amazon-provided private DNS hostname that corresponds to its private/Public IPv4 address	Amazon-provided DNS hostnames are not supported.

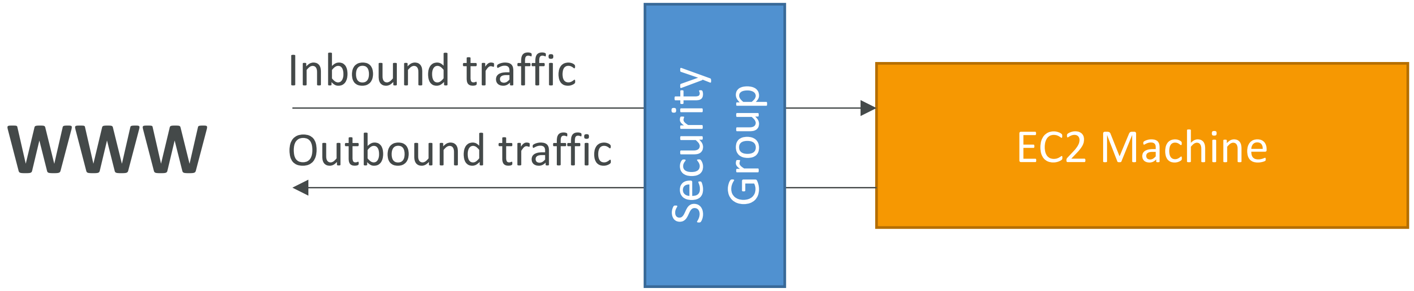
Firewalls inside VPC

- Security Groups
- Network Access Control List (NACL)



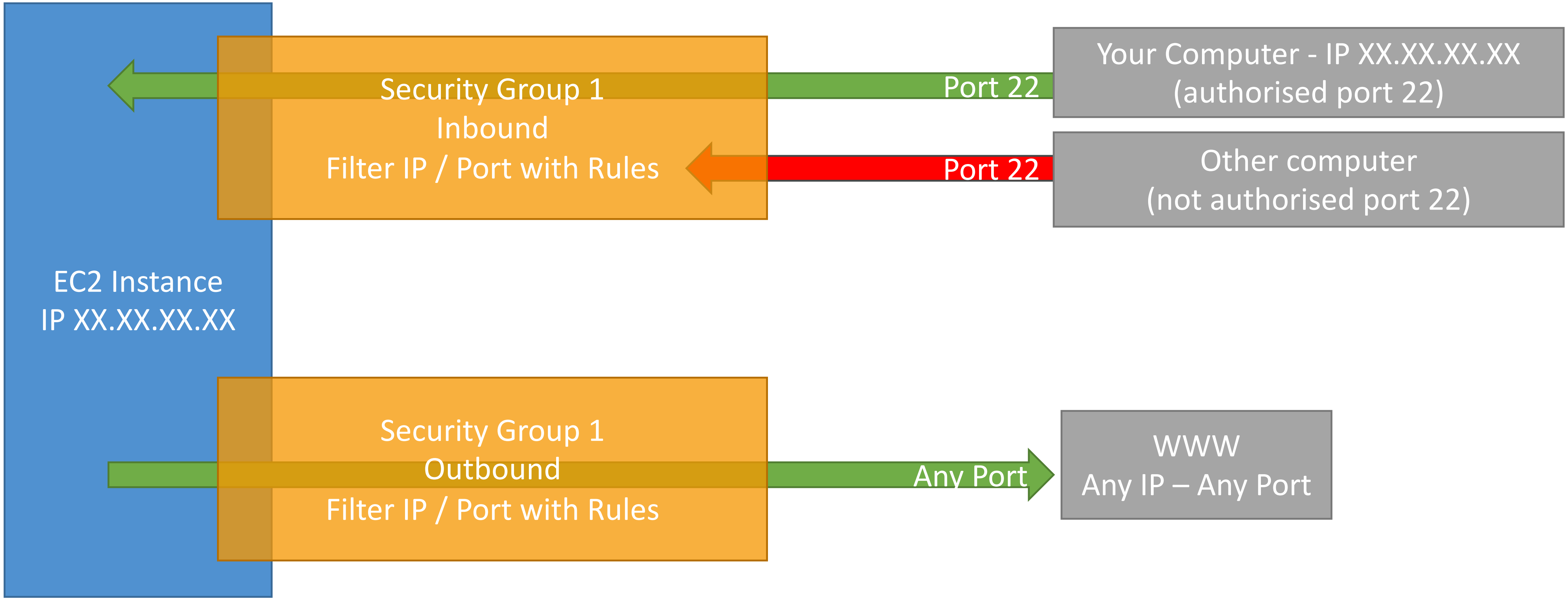
Security Groups

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



- It is the most fundamental skill to learn to troubleshoot networking issues
- In this lecture, we'll learn how to use them to allow, inbound and outbound ports

Security Groups - Diagram



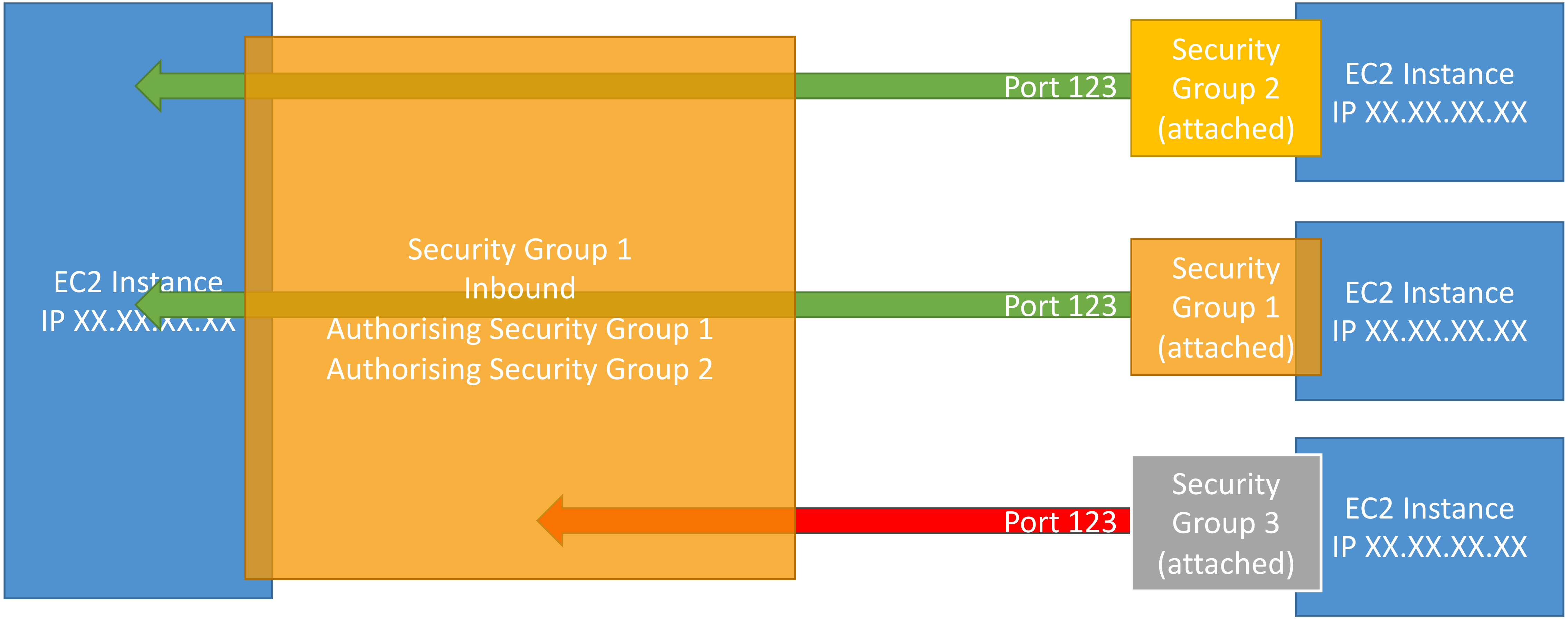
Security Groups - Deeper Dive

- They regulate:
  - Access to Ports
  - Authorised IP ranges – IPv4 and IPv6
  - Control of inbound network (from other to the instance)
  - Control of outbound network (from the instance to other)
- Security groups are stateful
- You can reference another Security group as source

Inbound Rules - example

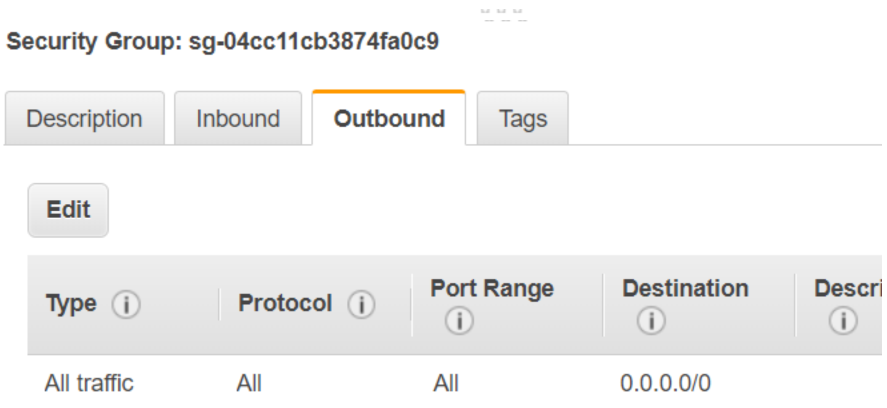
Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	0.0.0.0/0	test http page
SSH	TCP	22	122.149.196.85/32	
Custom TCP Rule	TCP	4567	0.0.0.0/0	java app

Referencing other security groups - Diagram



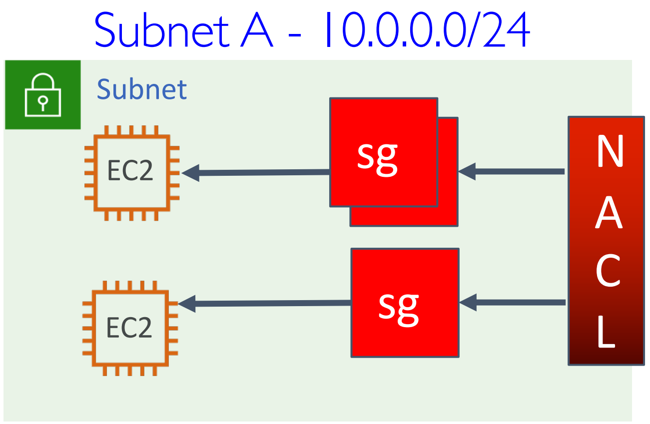
Security Groups - Good to know

- Can be attached to multiple instances
- Locked down to a Region / VPC combination
- Does live "outside" the EC2 – if traffic is blocked the EC2 instance won't see it
- If your application is not accessible (time out), then it's a security group issue
- If your application gives a "connection refused" error, then it's an application error or it's not yet in running state
- All inbound traffic is blocked by default
- All outbound traffic is authorised by default



Network Access Control List (NACL)

- Works at Subnet level – Hence automatically applied to all instances
- Stateless – We need to explicitly open outbound traffic
- Contains both Allow and Deny rules
- Rules are evaluated in the order of rule number
- Default NACL allows all inbound and outbound traffic
- NACL are a great way of blocking a specific IP at the subnet level



#Rule	Type	Protocol	Port	Source	Allow/Deny
100	ALL Traffic	ALL	ALL	180.151.138.43/32	DENY
101	HTTPS	TCP	443	0.0.0.0/0	ALLOW
*	ALL Traffic	ALL	ALL	0.0.0.0/0	DENY

Network ACL inbound rules

Network ACLs vs Security Groups

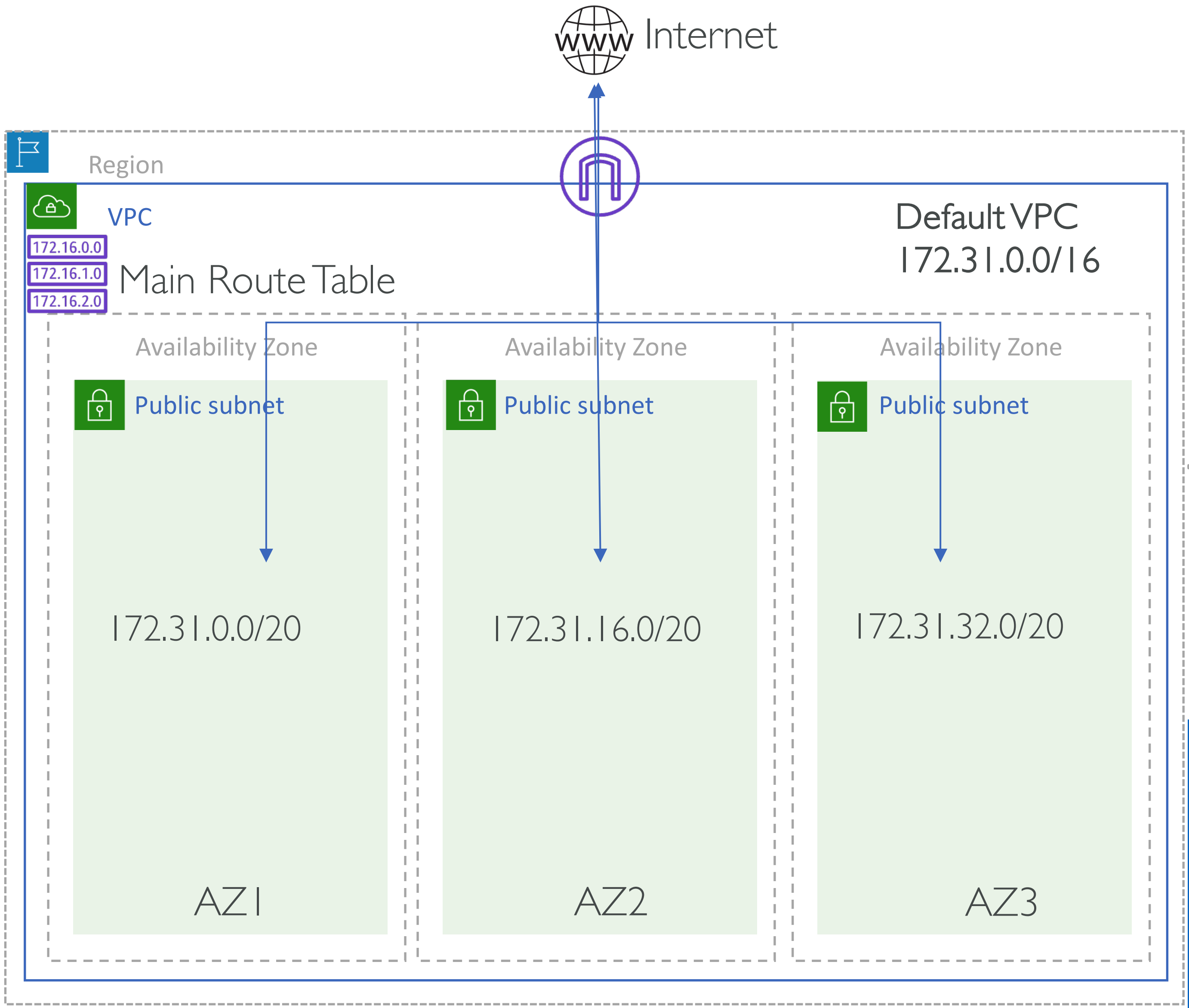
Security Group	Network ACL
Operates at the instance level	Operates at the subnet level
Supports allow rules only	Supports allow rules and deny rules
Is stateful: Return traffic is automatically allowed, regardless of any rules	Is stateless: Return traffic must be explicitly allowed by rules
We evaluate all rules before deciding whether to allow traffic	We process rules in number order when deciding whether to allow traffic
Applies to an instance only if someone specifies the security group when launching the instance, or associates the security group with the instance later on	Automatically applies to all instances in the subnets it's associated with (therefore, you don't have to rely on users to specify the security group)

https://docs.aws.amazon.com/vpc/latest/userguide/VPC_Security.html#VPC_Security_Comparison

Default VPC

- AWS Creates Default VPC in each AWS region
- Creates VPC with CIDR - 172.31.0.0/16
- Creates Subnets in every AZ with CIDR /20
- Creates Internet Gateway
- Main route table with route to Internet which make all subnets public

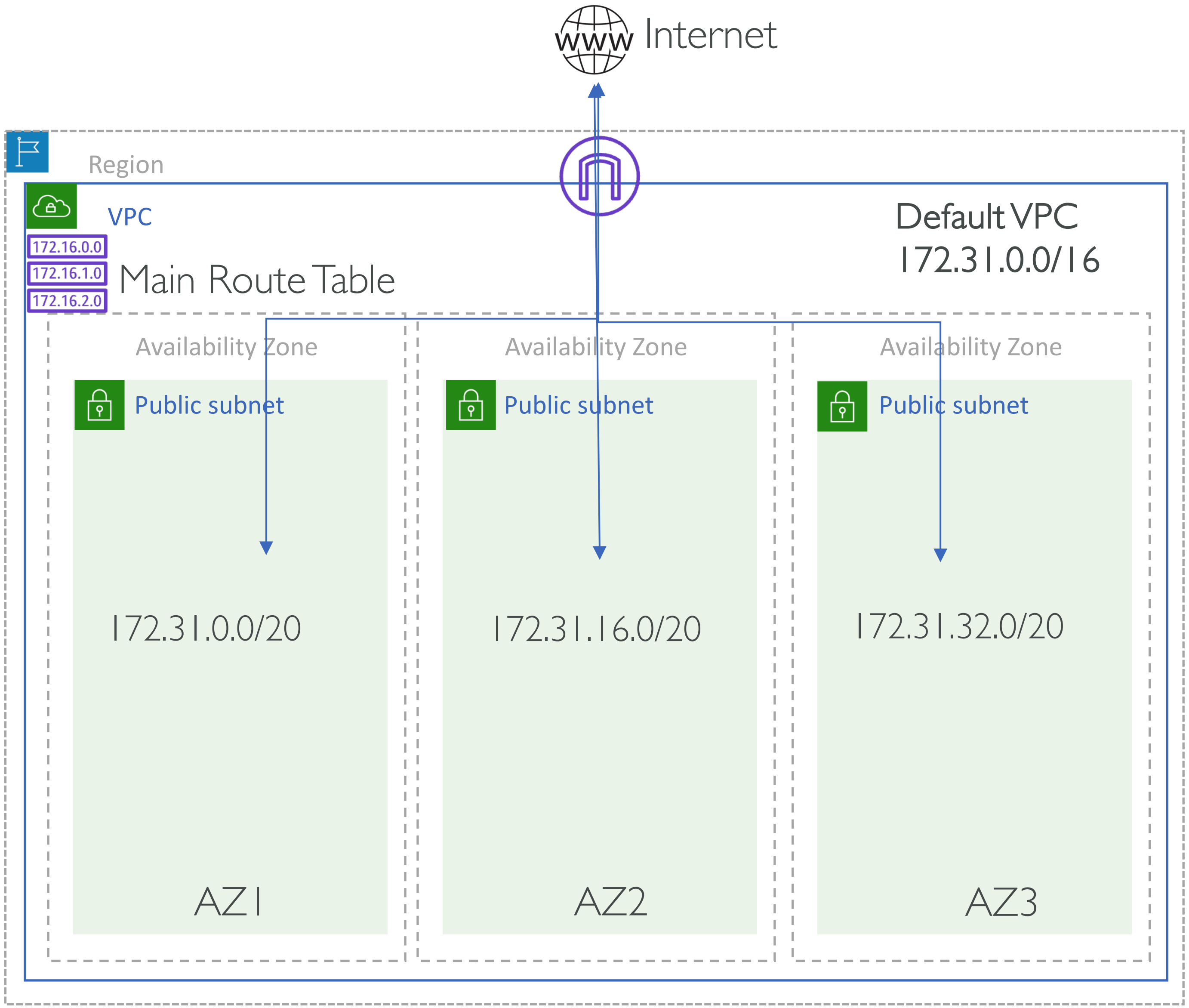
Destination	Target
172.31.0.0/16	local
0.0.0.0/0	igw-xxxxxx



Mumbai Region default VPC

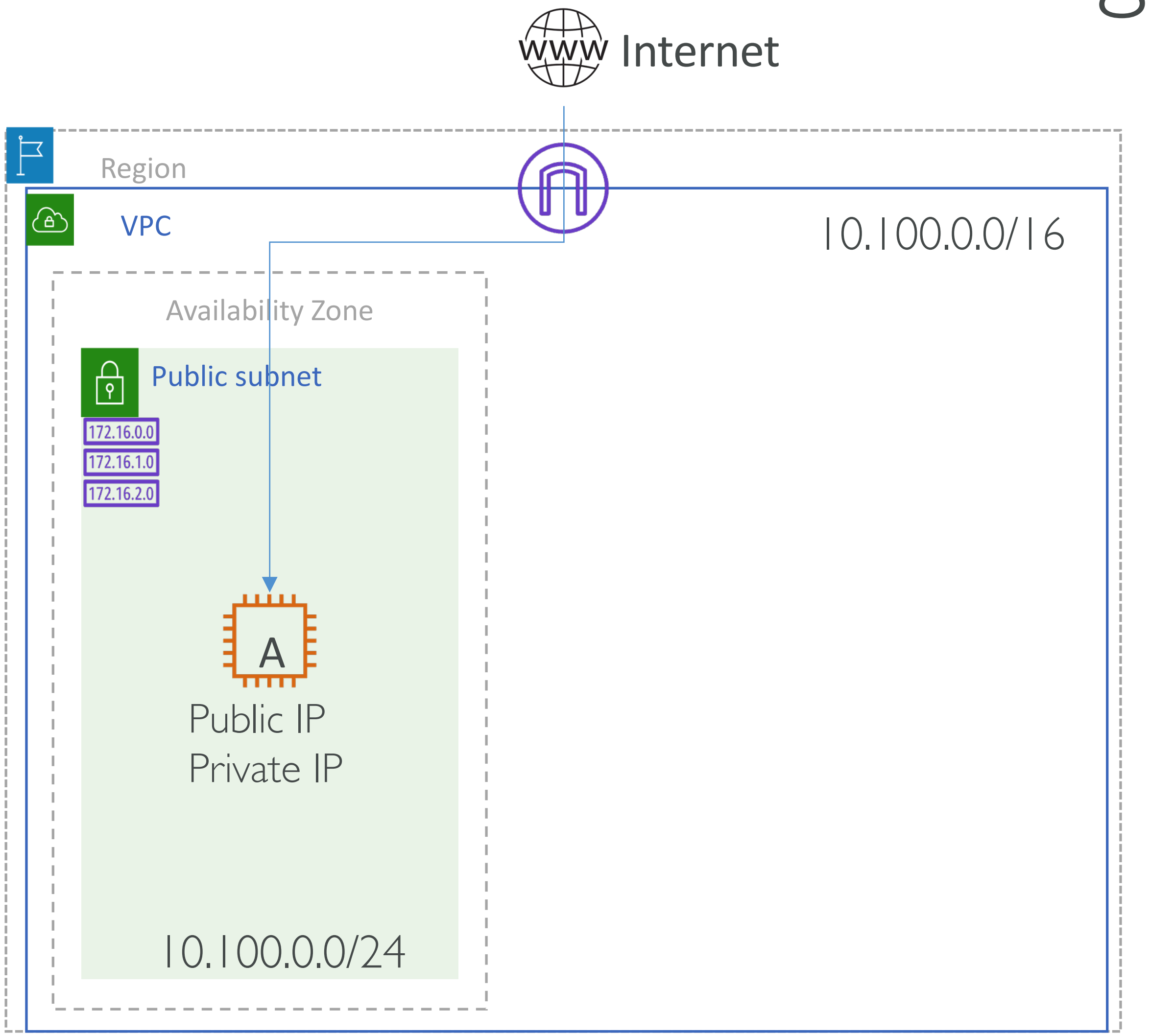
Default VPC

- If deleted, you can recreate default VPC
- Console
  - -> VPC Service
  - -> Your VPCs
  - -> Action
  - ->Create Default VPC



Mumbai Region default VPC

Demo - VPC with Single Public Subnet



Public Subnet Route Table

Destination	Target
10.100.0.0/16	local
0.0.0.0/0	igw-xxx

Note: For EC2 instance to be reachable from internet, it must be in Public Subnet and must have Public/Elastic IP

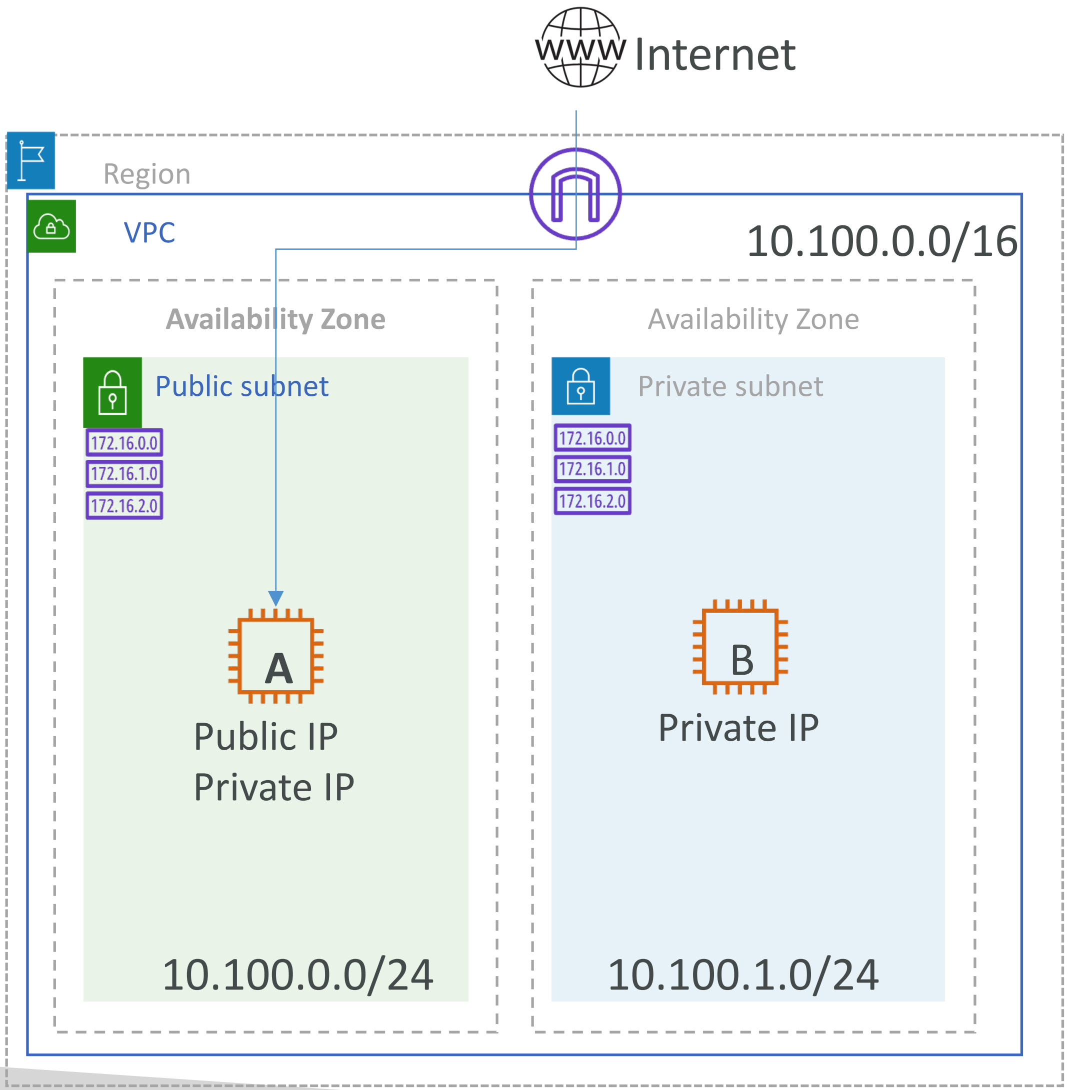
Exercise 1

1. Delete default VPC (We will create our own VPC)
2. Create VPC
   a. Go to VPC service => Your VPCs => Create VPC (Name: MyVPC, CIDR: 10.100.0.0/16) => Create
3. Create Internet Gateway
   a. Internet Gateways => Create internet gateway
4. Attach Internet Gateway to VPC
   a. Select Internet gateway => Actions => Attach to VPC => Select your VPC
5. Create Subnet
   a. Subnets => Create subnet (Name: MyVPC-Public, VPC: MyVPC, AZ: Select first AZ - ap-south-1a, CIDR: 10.100.0.0/24)
   b. Select Subnet => Action => Modify Auto Assign Public IP => Enable => Save
6. Create Route table
   a. Route Tables => Create Route Table (Name: MyVPC-Public, VPC: MyVPC)
   b. Select Route table => Routes => Edit => Add another route (Destination: 0.0.0.0/0, Target: Internet gateway => igw-xxx) => Save

Exercise 1

6. Associate Route table with Subnet to make it Public subnet
   a. Select Route table => Subnet Associations => Edit => Check the MyVPC-Public subnet => Save
7. Launch EC2 instance in newly created Public Subnet
   a. Go to EC2 Service => Instances
   b. Launch EC2 Instance => Select Amazon Linux 2 => Select t2.micro
   c. Configure Instance Details:
      i. Network: MyVPC
      ii. Subnet: MyVPC-Public (rest all defaults)
   d. Add storage (all defaults)
   e. Add Tags
      i. Key=Name, Value=EC2-A
   f. Configure Security Group
      i. Add rule for SSH port 22 for source as MyIP
   g. Review and Launch
8. Connect to EC2 instance (Public IP) from your desktop/laptop using Putty or terminal (ec2-user)

Demo - VPC with Public and Private Subnet



Private Subnet Route Table

Destination	Target
10.100.0.0/16	local

Exercise 2 (Continuing with previous setup)

1. Create a Private subnet
   a. Create subnet (Name: MyVPC-Private, VPC: MyVPC, AZ: Select different AZ (ap-south-1b), CIDR: 10.100.1.0/24)
2. Create Private route table
   a. Route Tables => Create Route Table (Name: MyVPC-Private, VPC: MyVPC)
3. Associate Route table with Subnet to make it Private subnet
   a. Select Route table => Subnet Associations => Edit => Check the MyVPC-Private subnet => Save
4. Launch another EC2 instance in same VPC but in newly created **Private subnet.**
   a. Tag this instance with Name=EC2-B
   b. New security group
      - Add rule SSH for CIDR of Public Subnet source CIDR
      - Add rule All-ICMP IPv4 for Public Subnet source CIDR
5. Note down EC2-B private IP address

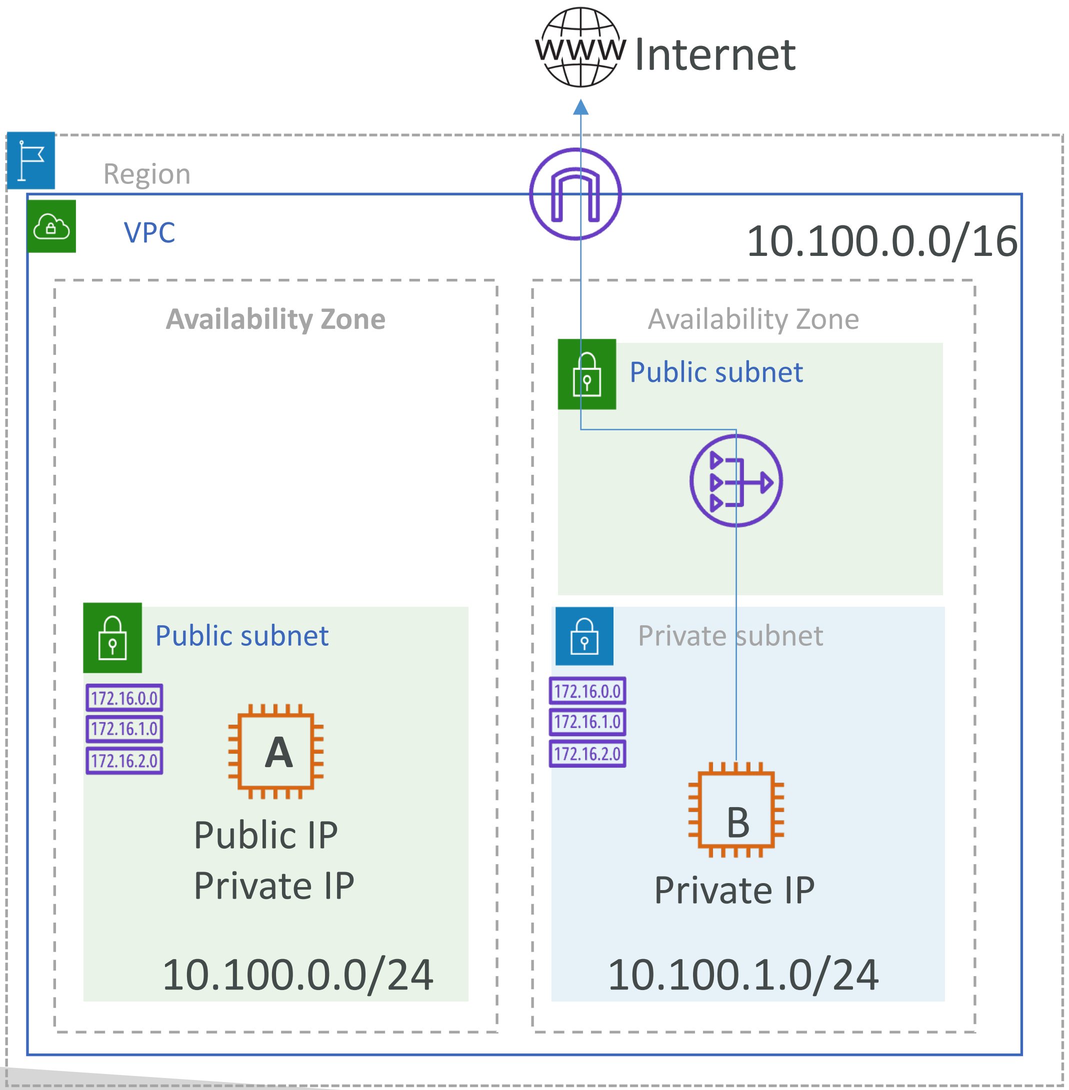
Exercise 2 (Continuing with previous setup)

6. Try to ping EC2-B Private IP from EC2-A instance => Should work
7. Try to connect to EC2-B instance from EC2-A (Permissions denied..Why?)
   a. $ssh ec2-user@10.100.1.x   (Replace this ip with your EC2-B IP address)

6. Get your ssh .pem file on EC2-A instance
   a. Open local .pem file with nodepad and copy the content (CTRLA => CTRL+C)
   b. On EC2 A terminal => vi key.pem => enter => press i => paste using right click => esc => :wq => enter
   c. chmod 600 key.pem
   d. ssh -i key.pem ec2-user@10.100.1.x => should be able to connect

6. Try to ping google.com from EC2-B instance
   a. ping google.com (You should not be able to ping. Why?)

VPC with Public and Private Subnet



Private Subnet Route Table

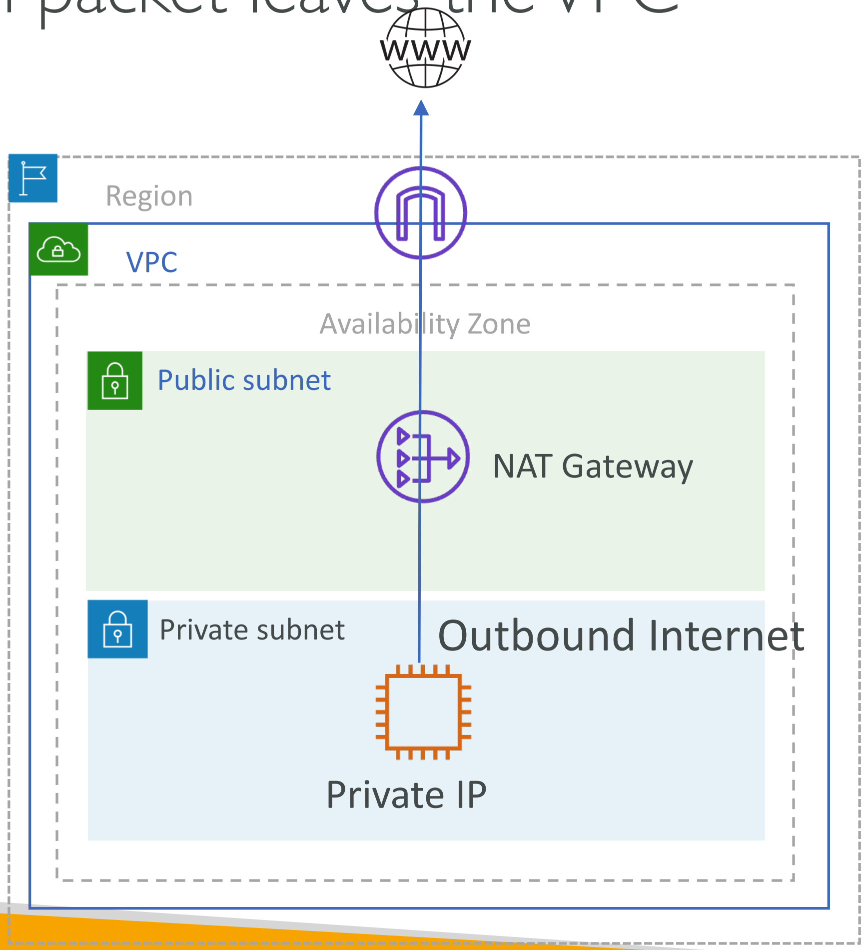
Destination	Target
10.100.0.0/16	local

NAT Gateway and NAT Instance

- To provide Internet Access to instances in private subnet without IGW
- Performs Network Address translation when packet leaves the VPC

- Nat Gateway:
  - Managed by AWS
  - Highly available within AZ

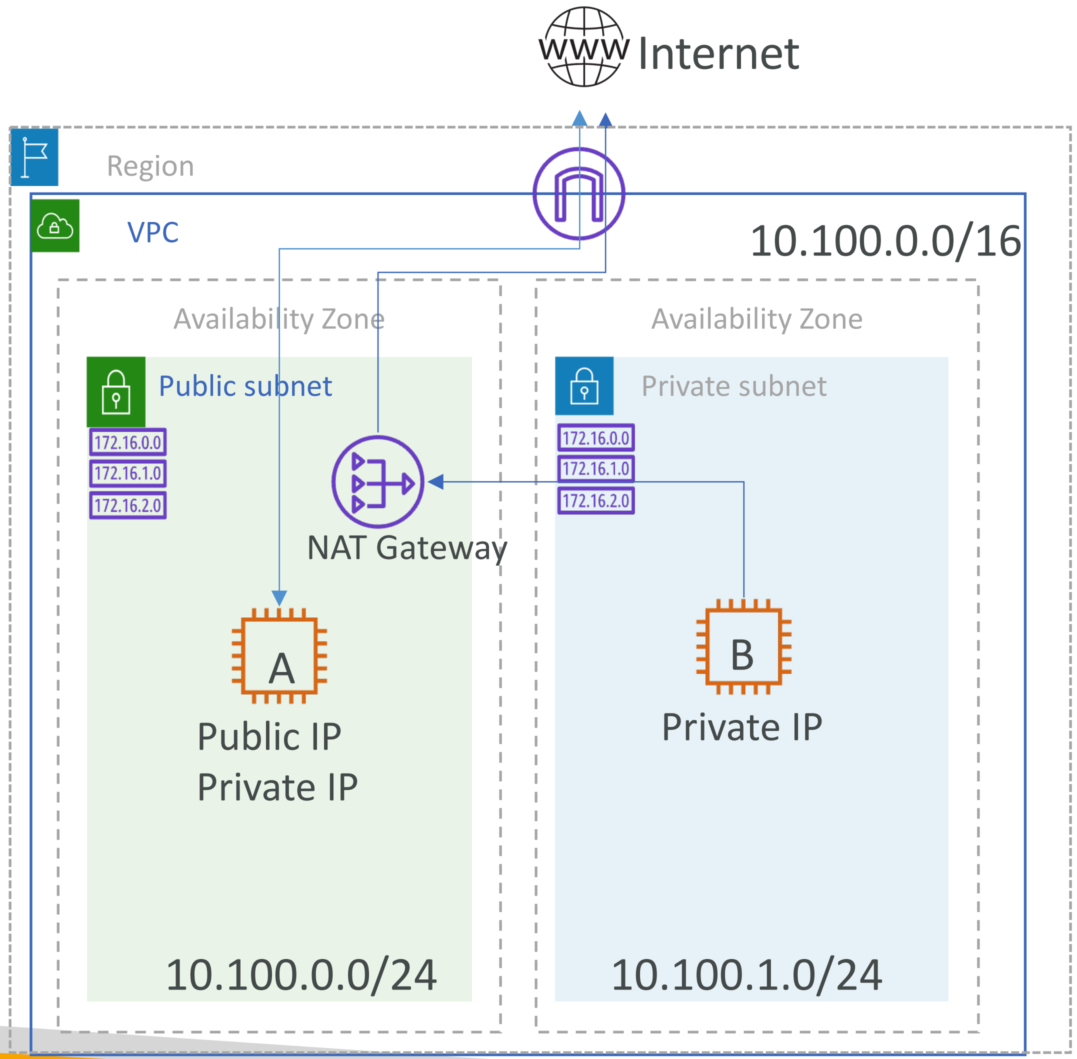
- NAT Instance
  - NAT EC2 can be launched using Amazon Linux Nat AMI
  - Disable Source/Destination check on instance
  - Allocate EIP



NAT Gateway

- AWS managed NAT, higher bandwidth, better availability, no admin
- Pay by the hour for usage and bandwidth
- NAT is created in a specific AZ, uses an EIP
- 5 Gbps of bandwidth with automatic scaling up to 100 Gbps
- No security group to manage / required. NACL at subnet level applies to NAT Gateway.
- Supported protocols: TCP, UDP, and ICMP
- Uses ports 1024–65535 for outbound connection

Demo – NAT Gateway



- NAT Gateway must be created in Public Subnet so that it can communicate with the Internet
- NAT Gateway should be allocated Elastic IP

Private Subnet Route Table

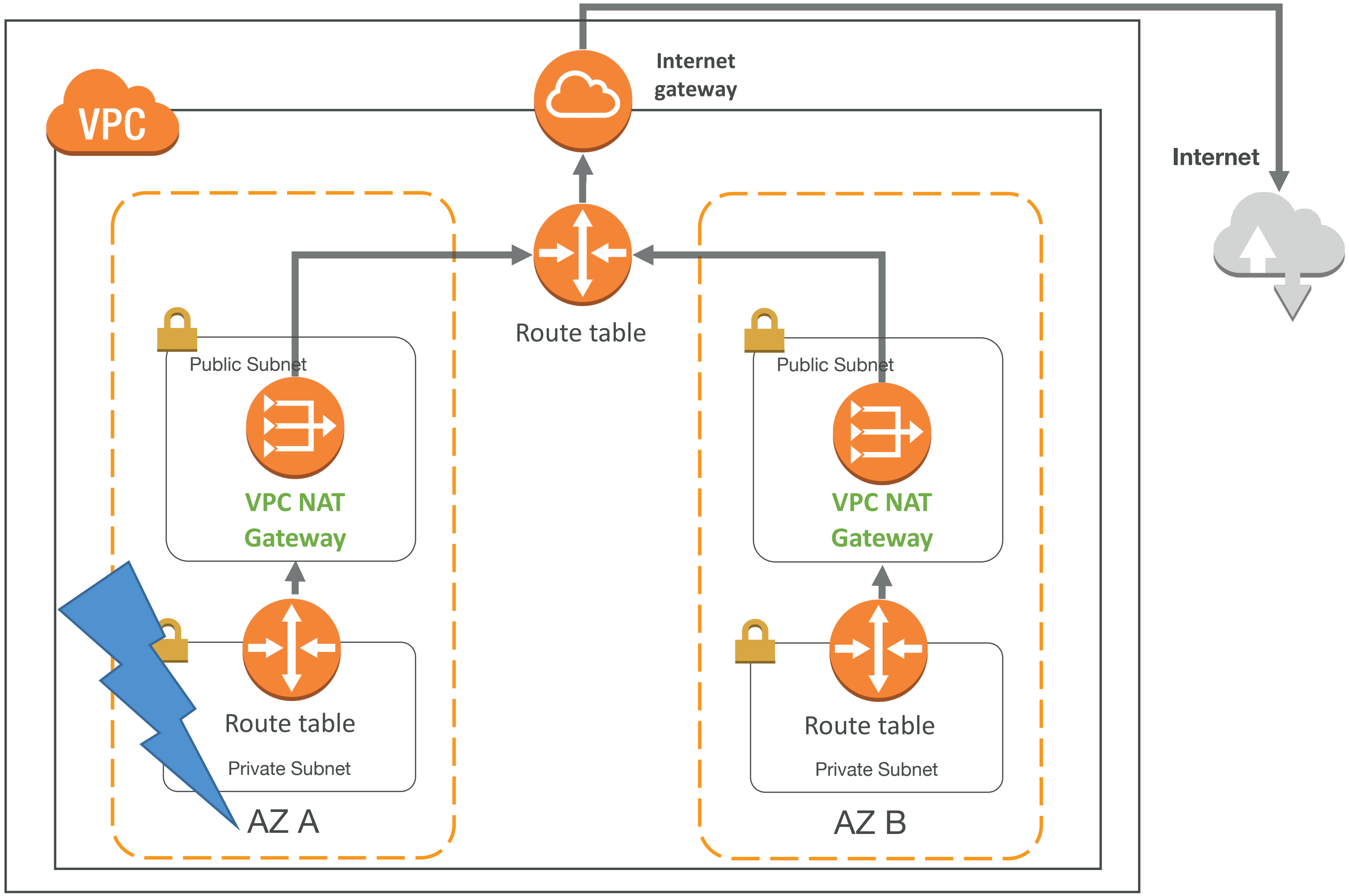
Destination	Target
10.100.0.0/16	local
0.0.0.0/0	nat-xxxxxxx

Exercise 3 (Continuing with previous setup)

- Create a NAT Gateway in your VPC
  - VPC => NAT Gateways => Create NAT Gateway
    - Subnet: MyVPC-Public (Must select Public Subnet)
    - EIP: Create New EIP
    - Create NAT Gateway
    - It takes 5-10 minutes for NAT Gateway to be Active
- Add a route in Private subnet for internet traffic and route through NAT Gateway
  - Route Tables => Select MyVPC-Private route table
  - Routes => Edit => Add another route
    - Destination: 0.0.0.0/0
    - Target: nat-gateway
    - Save
- Now again try to ping google.com from EC2-B
  - ping google.com

NAT Gateway with High Availability

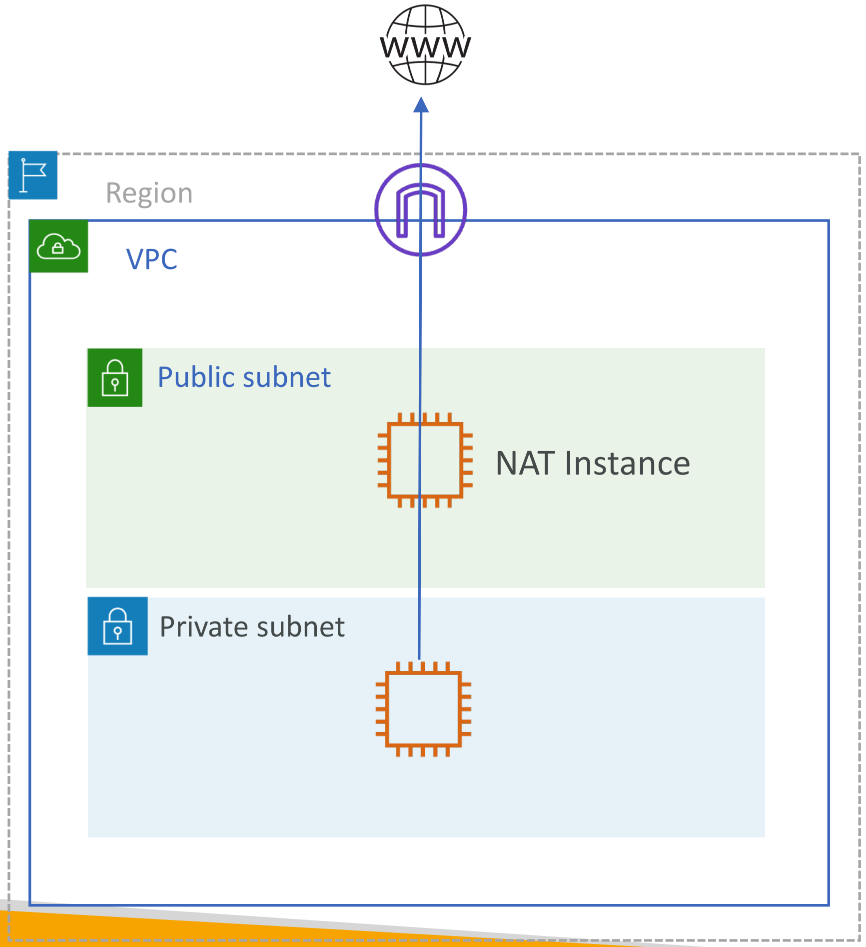
- NAT Gateway is resilient within a single-AZ
- Must create **multiple NAT Gateway** in **multiple AZ** for fault-tolerance
- There is no cross AZ failover needed because if an AZ goes down it doesn't need NAT



Setup your own NAT on EC2 (NAT Instance)

- Must be in Public Subnet
- Must have Public or Elastic IP
- Should be launched using AWS provided NAT AMIs
- Disable Source/Destination Check
- Update Private subnet route tables.
- For internet traffic set target as NAT Instance ID

Reference: [Setting up NAT Instance]()



Nat Gateway vs NAT Instance

Attribute	NAT Gateway	NAT Instance
Availability	Highly available within AZ. Create a NAT Gateway in each Availability Zone to ensure zone-independent architecture.	Use a script to manage failover between instances.
Bandwidth	Can scale up to 45 Gbps.	Depends on the bandwidth of the instance type.
Maintenance	Managed by AWS. You do not need to perform any maintenance.	Managed by you, for example, by installing software updates or operating system patches on the instance.
Performance	Software is optimized for handling NAT traffic.	A generic Amazon Linux AMI that's configured to perform NAT.
Cost	Charged depending on the number of NAT Gateways you use, duration of usage, and amount of data that you send through the NAT Gateways.	Charged depending on the number of NAT Instances that you use, duration of usage, and instance type and size.
Type and size	Uniform offering; you don't need to decide on the type or size.	Choose a suitable instance type and size, according to your predicted workload.
Public IP addresses	Choose the Elastic IP address to associate with a NAT Gateway at creation.	Use an Elastic IP address or a public IP address with a NAT Instance.
Security groups	Cannot be associated with a NAT Gateway. You can associate security groups with your resources behind the NAT Gateway to control inbound and outbound traffic.	Associate with your NAT Instance and the resources behind your NAT Instance to control inbound and outbound traffic.
Port forwarding	Not supported.	Manually customize the configuration to support port forwarding.
Bastion servers	Not supported.	Use as a bastion server.

NAT Gateway Troubleshooting / Rules / Limitations

- https://docs.aws.amazon.com/vpc/latest/userguide/nat-gateway-troubleshooting.html
- https://docs.aws.amazon.com/vpc/latest/userguide/vpc-nat-gateway.html#nat-gateway-limits
- https://aws.amazon.com/premiumsupport/knowledge-center/vpc-resolve-port-allocation-errors/
- https://docs.aws.amazon.com/vpc/latest/userguide/nat-gateway-troubleshooting.html#nat-gateway-troubleshooting-tcp-issues

Recap / Important Concepts Covered

- We saw how Physical network transformed into virtual network in Cloud
- AWS Region, Availability zone and VPC relation
- VPC Addressing – CIDR
- VPC Components – Subnets, Route Tables, Internet Gateway
- IP Addresses – Private vs Public vs Elastic
- Elastic Network Interfaces
- Firewalls – Security groups and Network ACLs
- NAT – Nat Gateways and NAT Instance

Exam Essentials

- Maximum size of VPC/Subnet is /16 which contains 65536 IP addresses
- Minimum size of VPC/Subnet is /28 which contains 16 IP addresses
- In every subnet 5 IPs are un-usable – first 4 and last IP in the subnet
- Subnet is associated with AZ. One subnet can not span across AZs. However one AZ may contain any number of subnets.
- All subnets by default follow VPC main route table unless explicitly attached to custom route table
- All route tables have a default local route which you can't remove. This route enables inter VPC communication between all subnets.

Exam Essentials

- You can't block any IP with Security group. Use Network ACL.
- Security groups is stateful - No need to explicitly add outbound rule for incoming return traffic or inbound rules for outbound return traffic
- Network ACL is stateless – Rules must be created for both side of the traffic
- NAT Gateway must be created in each AZ for High Availability.
- NAT Gateways must be created in Public Subnet
- NAT Gateway does not have security group hence traffic should be controlled by using Network ACL
- You don't get access to NAT Gateway machine. It's managed by AWS.
- NAT Instance may be cost effective but may not be as performant and resilient as NAT Gateway.
- For NAT Instance, Source/Destination check must be disabled

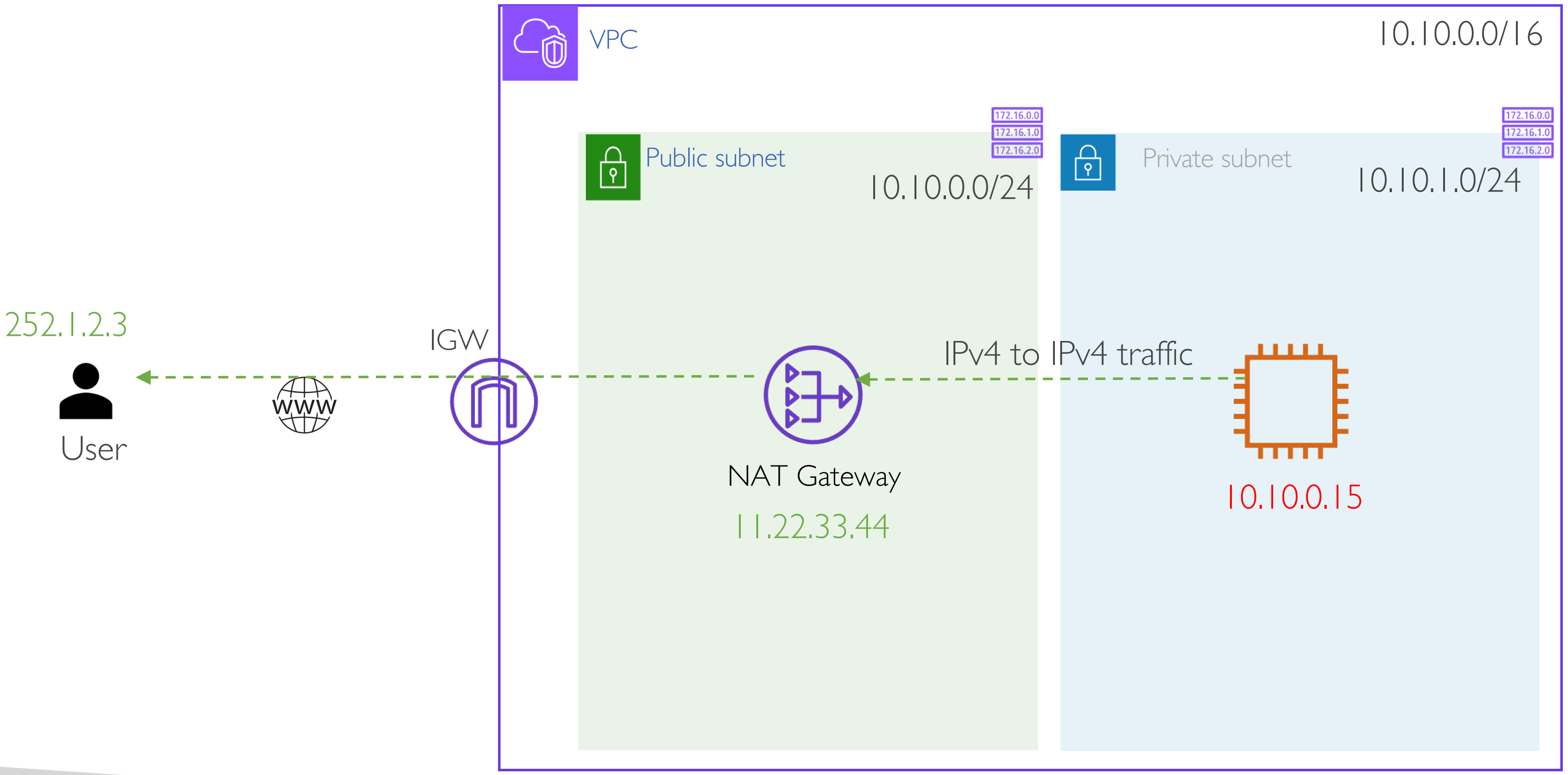
Additional VPC features

In this section..

1. Egress-only Internet Gateway
2. Extending VPC address space by adding secondary VPC CIDRs
3. Elastic Network Interface (ENI) and ENI use cases
4. Bring your own IP (BYOIP) – IPv4 and IPv6

Egress-only internet gateway

Internet access for instance in a Private subnet (IPv4)



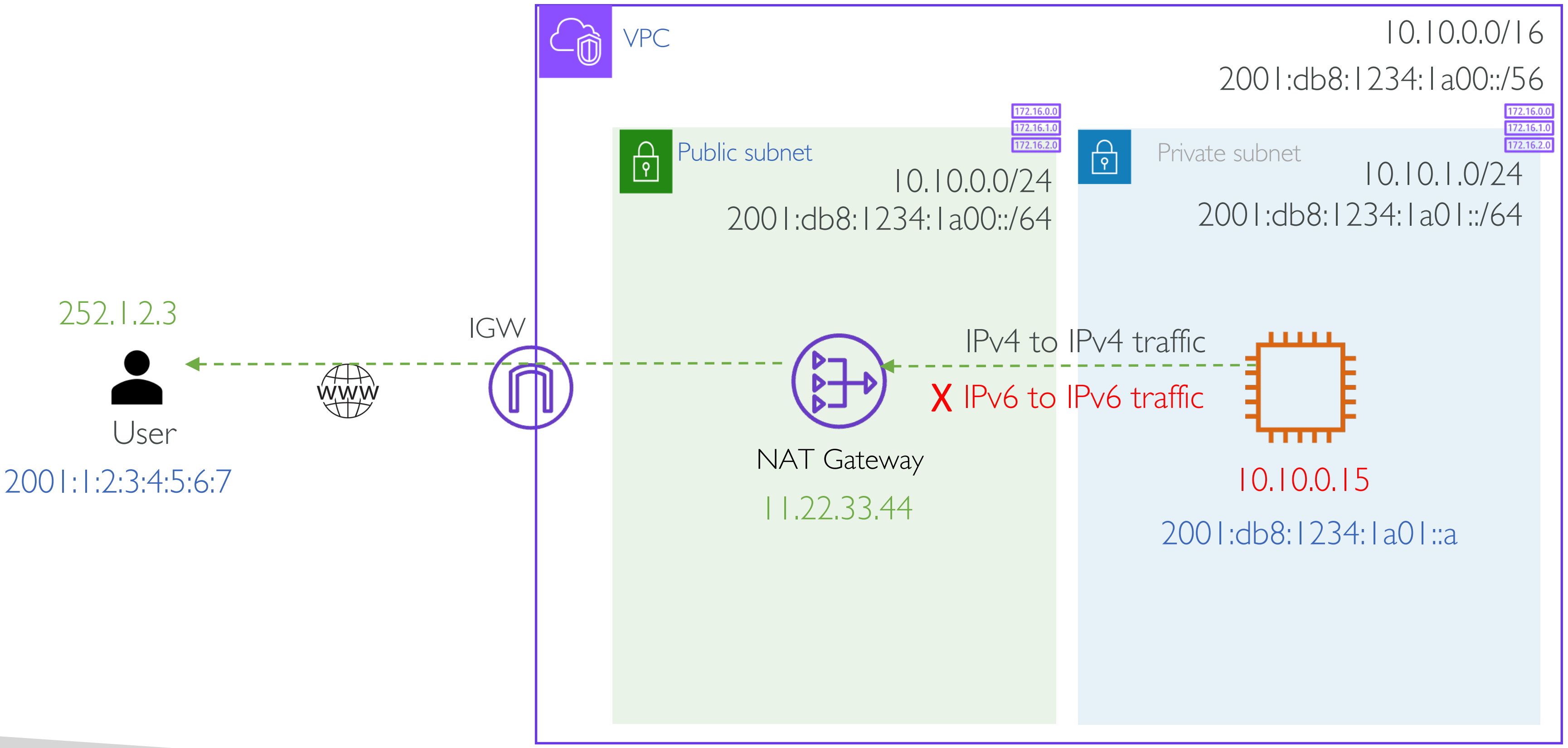
Destination	Target
10.0.0.0/16	Local
0.0.0.0/0	IGW

Destination	Target
10.0.0.0/16	Local
0.0.0.0/0	NAT-GW

IPv6 in VPC

- VPC supports dual-stack mode
- Resources inside VPC can communicate over IPv4 or IPv6 or both
- IPv4 support can not be disabled for the VPC
- VPC supports IPv6-only subnets
- IPv6 addresses are Public by default

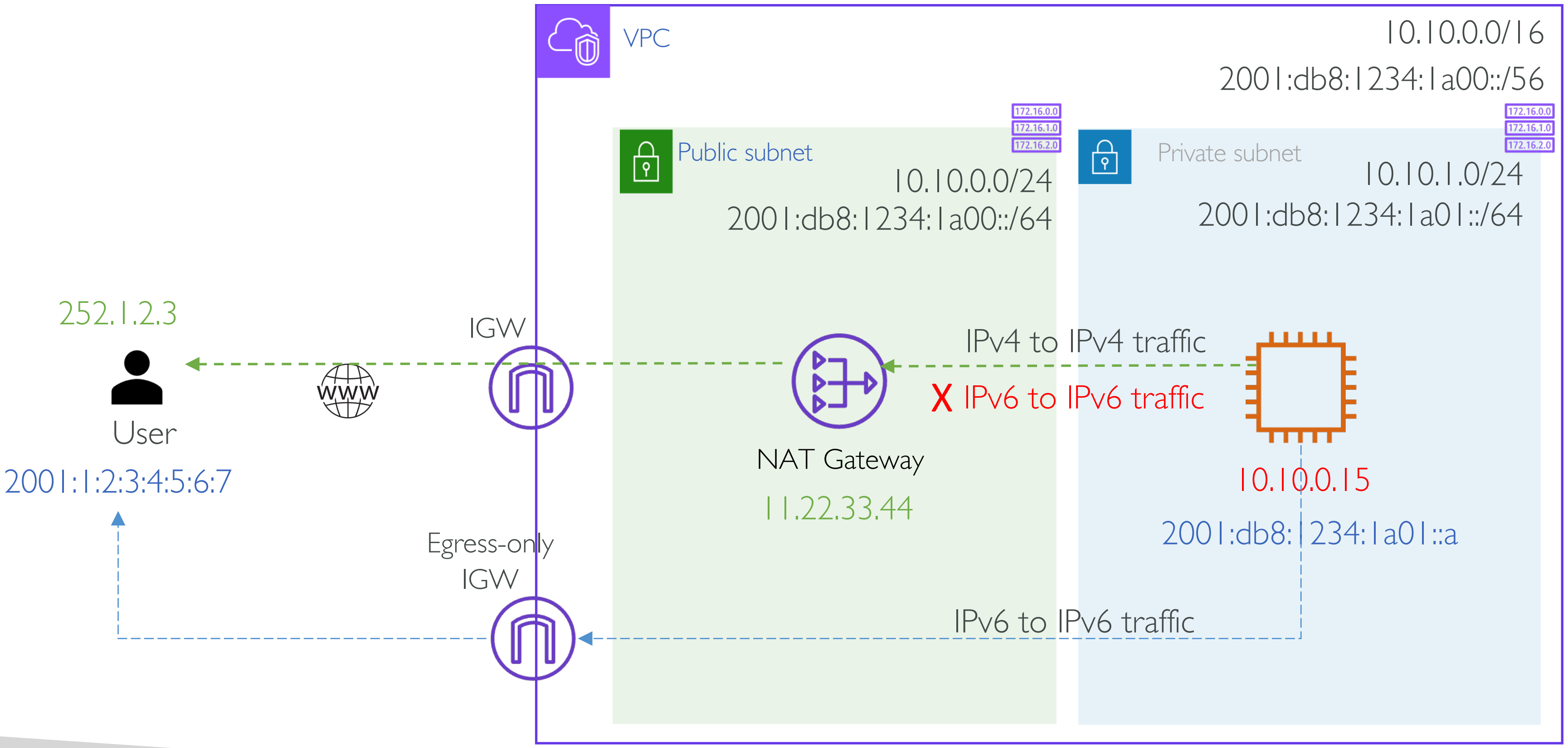
Internet access for instance in a Private subnet (IPv6)



Destination	Target
10.0.0.0/16	Local
2001:db8:1234:1a00::/56	Local
0.0.0.0/0	IGW

Destination	Target
10.0.0.0/16	Local
2001:db8:1234:1a00::/56	Local
0.0.0.0/0	NAT-GW

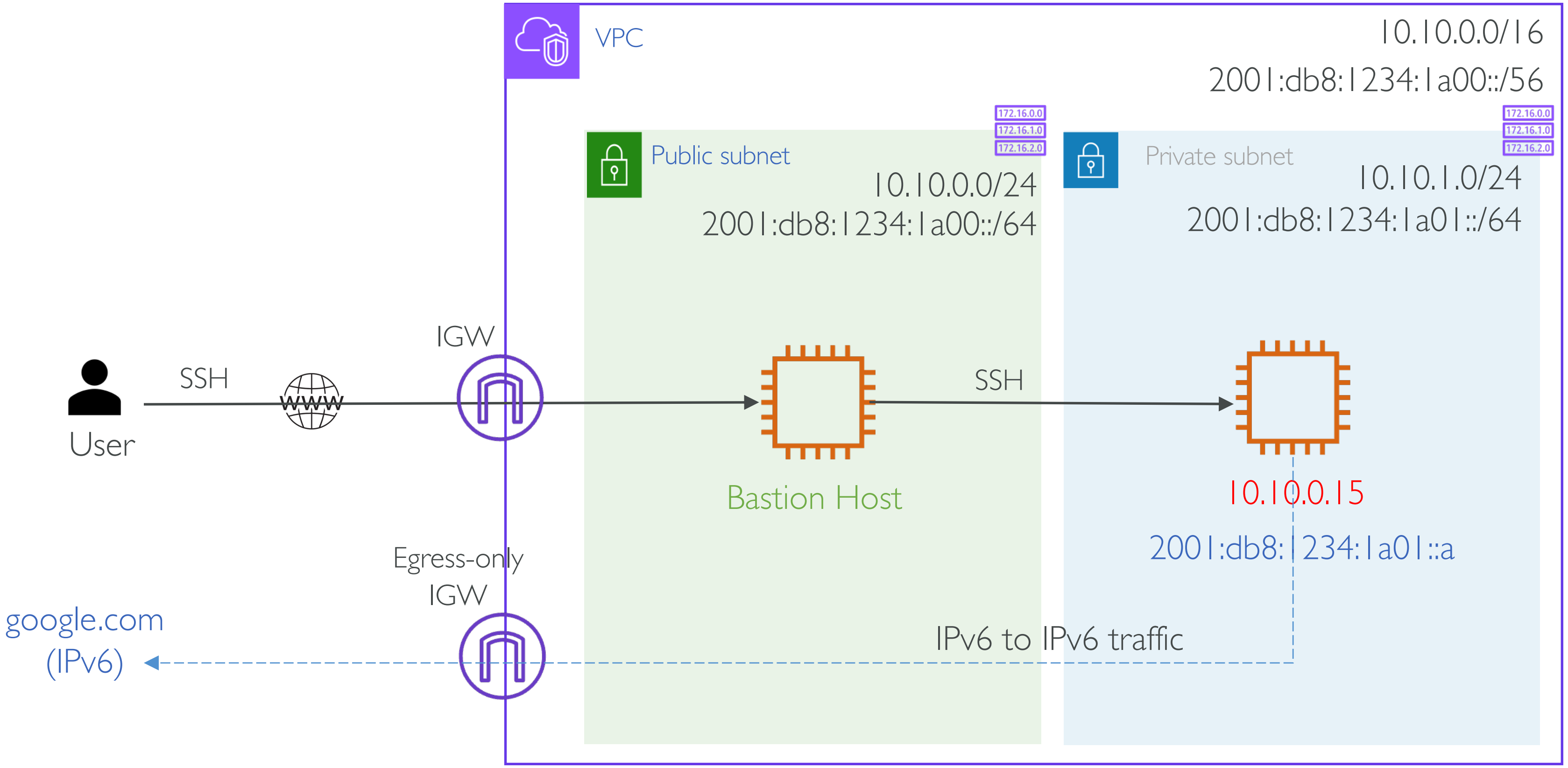
Egress-only internet gateway



Destination	Target
10.0.0.0/16	Local
2001:db8:1234:1a00::/56	Local
0.0.0.0/0	IGW

Destination	Target
10.0.0.0/16	Local
2001:db8:1234:1a00::/56	Local
0.0.0.0/0	NAT-GW
::/0	Egress-IGW

Exercise – IPv6 traffic with egress-only internet gateway



Destination	Target
10.0.0.0/16	Local
2001:db8:1234:1a00::/56	Local
0.0.0.0/0	IGW

Destination	Target
10.0.0.0/16	Local
2001:db8:1234:1a00::/56	Local

Steps

1. Create VPC and add both IPv4 (10.0.0.0/16) and Amazon provided IPv6 CIDR
2. Create an Internet Gateway and associate with the VPC
3. Create a Public subnet with both IPv4 (10.0.0.0/24) and IPv6 CIDR (/64). Create a Route table and add route for 0.0.0.0/0 with target as Internet gateway. Associate route table with the Public subnet.
4. Create a Private subnet with both IPv4 (10.0.1.0/24) and IPv6 CIDR (/64). Create a Route table & associate.
5. Launch a bastion host EC2 instance in a Public subnet. Should have Public IPv4 IP.
6. Launch a Private EC2 instance in a Private subnet. It should have both Private IPv4 and IPv6 address.
7. SSH into bastion host and from there SSH into Private EC2 instance using EC2 private IPv4.
8. From Private EC2 instance, try to ping to google.com with IPv4 address: ping -4 google.com
9. From Private EC2 instance, try to ping to google.com with IPv6 address: ping6 google.com
10. Create an Egress-only internet gateway and associate with the VPC.
11. Update the Private subnet route table and route for ::/0 destination to target as Egress-only IGW
12. From Private EC2 instance now try again to ping to google.com for both IPv4 and IPv6. IPv6 should be successful.

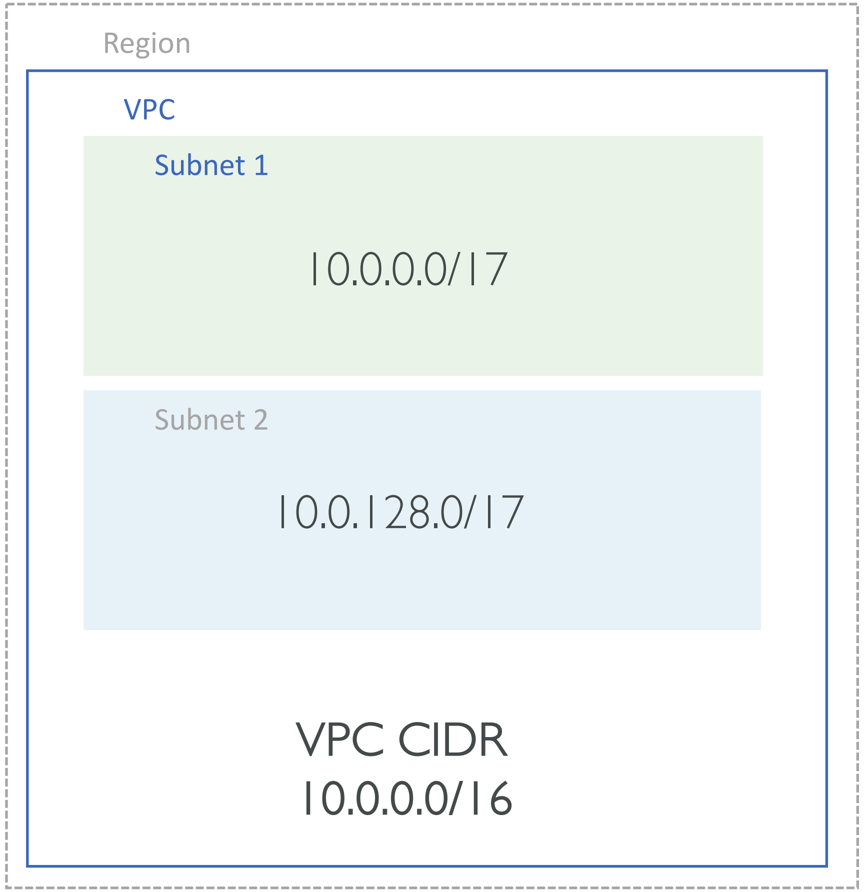
Extending VPC address space

VPC secondary CIDR blocks

1. You can add secondary VPC CIDRs to existing VPC
2. CIDR block must not overlap with existing CIDR or peered VPC CIDR
3. If Primary CIDR is from RFC1918 then you can not add secondary CIDR from other RFC1918 IP ranges (10.0.0.0/8, 172.16.0.0/12, 192.168.0.0/16)
4. CIDR block must not be same or larger than the CIDR range of routes in any of the VPC Route tables

   For example, if VPC primary CIDR block is 10.0.0.0/16 and you want to associate a secondary CIDR block in the 10.2.0.0/16 range. You already have a route with a destination of 10.2.0.0/24 to a virtual private gateway, therefore you cannot associate a CIDR block of the same range or larger. However, you can associate a CIDR block of 10.2.0.0/25 or smaller.
5. You can have total 5 IPv4 and 1 IPv6 CIDR block for VPC

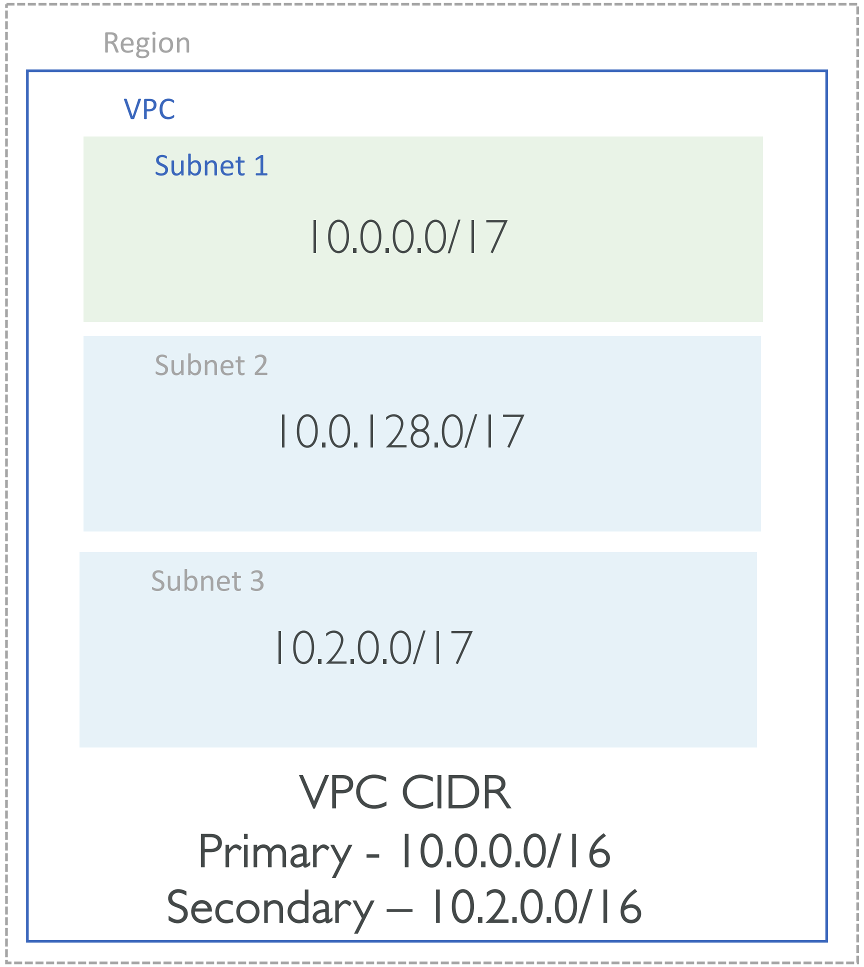
VPC with Primary CIDR Block



Main Route Table

Destination	Target
10.0.0.0/16	local

VPC with Primary and Secondary CIDR Block



Main Route Table

Destination	Target
10.0.0.0/16	local
10.2.0.0/16	local

Example 1

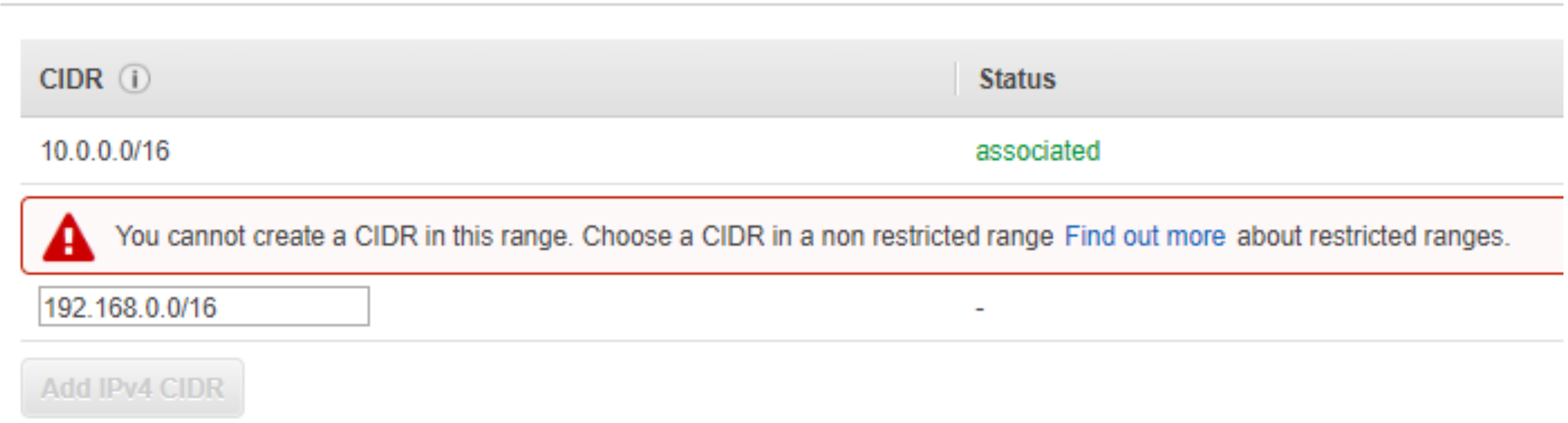
- Create a VPC with CIDR 10.0.0.0/16
- Select VPC => Actions => Edit CIDR => Add new IPv4 CIDR from 10.1.0.0/16, 10.2.0.0/16 etc

CIDR	Status	Status reason	
10.0.0.0/16	associated	-	
10.1.0.0/16	associated	-	
10.2.0.0/16	associated	-	
10.3.0.0/16	associated	-	
10.4.0.0/16	associated	-	

Add IPv4 CIDR

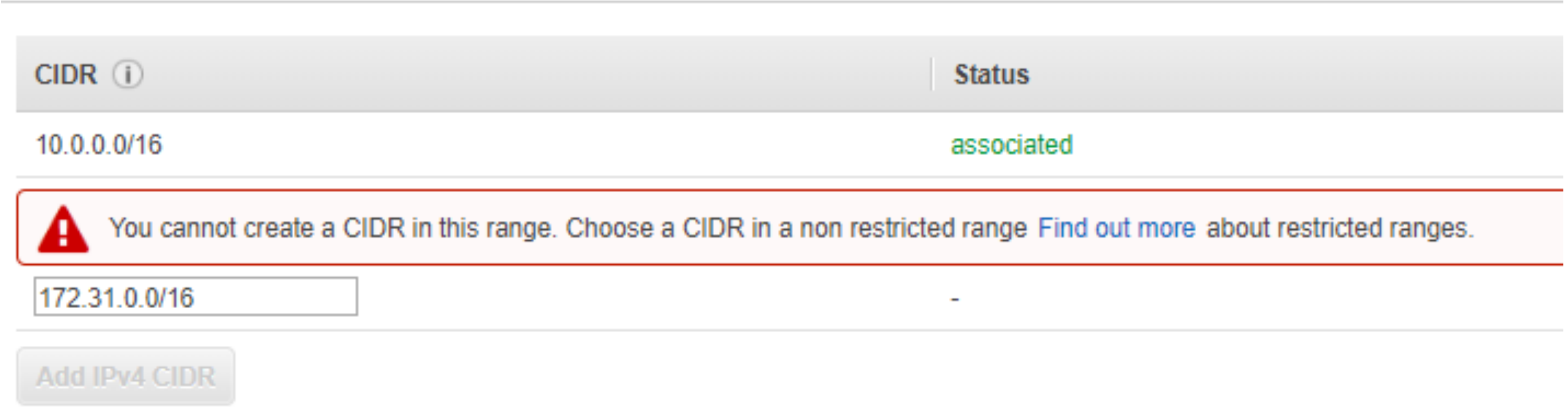
Example 2

- Create a VPC with CIDR 10.0.0.0/16
- Select VPC => Actions => Edit CIDR => Add other IPv4 CIDR from RFC1918 range 192.168.0.0/16 or 172.16.0.0/16



Example 2

- Create a VPC with CIDR 10.0.0.0/16
- Select VPC => Actions => Edit CIDR => Add new IPv4 CIDR 192.168.0.0/16 or 172.16.0.0/16



Example 3

- Create a VPC with CIDR 10.0.0.0/16
- Select VPC => Actions => Edit CIDR => Add new IPv4 CIDR 100.64.0.0/16 (Non RFC1918 range)

CIDR	Status	Status reason	
10.0.0.0/16	associated	-	
100.64.0.0/16	associated	-	

Add IPv4 CIDR

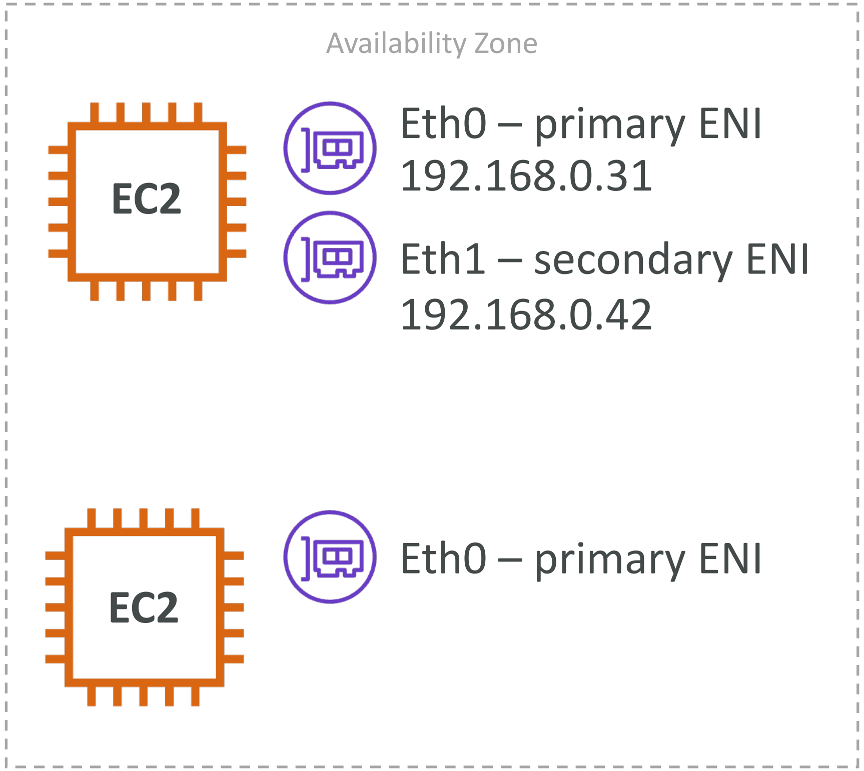
Examples:

Primary CIDR	Allowed Secondary CIDR	Not allowed Secondary CIDRs
10.0.0.0/16	• 10.1.0.0/16 etc. in the range of 10.0.0.0/8 • 100.64.0.0/16 etc. in the range of 100.64.0.0/10 • Public IPv4 Ranges	192.168.0.0/16, 172.16.0.0/12, Any overlapping CIDR
172.16.0.0/16	• 172.17.0.0/16 etc. (except 172.31.0.0/16) in the range of 172.16.0.0/12 • 100.64.0.0/16 etc. in the range of 100.64.0.0/10 • Public IPv4 Ranges	172.31.0.0/16 192.168.0.0/16, 10.0.0.0/8, Any overlapping CIDR
100.64.0.0/16	• 100.65.0.0/16 etc. in the range of 100.64.0.0/10 • Public IPv4 Ranges	192.168.0.0/16, 10.0.0.0/8, 172.16.0.0/12, Any overlapping CIDR

Elastic Network Interface (ENI)

Elastic Network Interfaces (ENI)

- Logical component in a VPC that represents a **virtual network card**
- ENIs are bound to a specific availability zone (AZ)
- The ENI can have the following attributes:
  - A primary private IPv4 address from the IPv4 address range of the VPC
  - A primary IPv6 address from the IPv6 address range of your VPC
  - One or more secondary private IPv4 addresses from the IPv4 address range of your VPC
  - One Elastic IP address (IPv4) per private IPv4 address
  - One public IPv4 address
  - One or more IPv6 addresses
  - **One or more security groups**
  - **A MAC address**
  - A source/destination check flag



IP Addresses per instance

Instance type	Maximum network interfaces	Private IPv4 addresses per interface	IPv6 addresses per interface
a1.medium	2	4	4
a1.large	3	10	10
a1.xlarge	4	15	15
a1.2xlarge	4	15	15
a1.4xlarge	8	30	30
a1.metal	8	30	30
c1.medium	2	6	IPv6 not supported
c1.xlarge	4	15	IPv6 not supported
c3.large	3	10	10

https://docs.aws.amazon.com/AWSEC2/latest/UserGuide/using-eni.html#AvailableIpPerENI

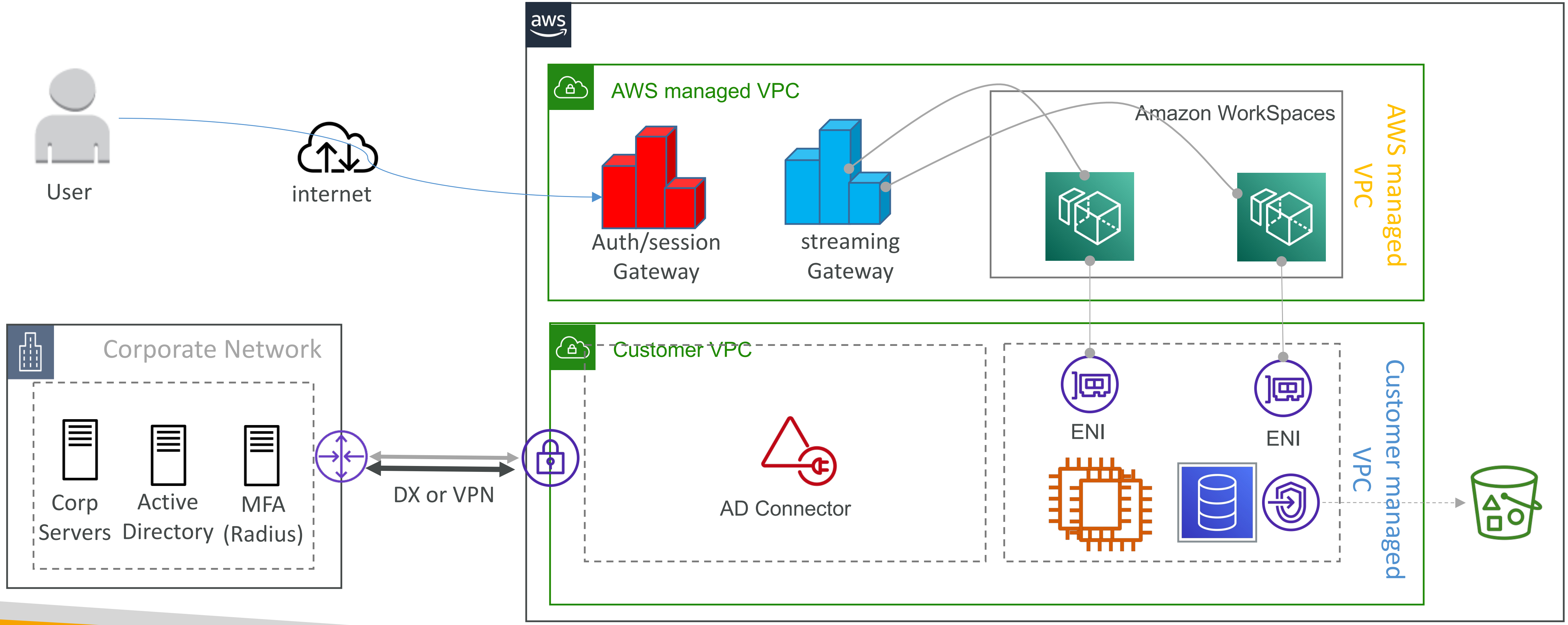
ENI Use cases

- Requester managed ENIs that AWS creates in your VPC
- Creating Management Network / Dual home instances
- Preserving EC2 IP address in case of instance failure
- Using ENI secondary IPs for EKS Pods

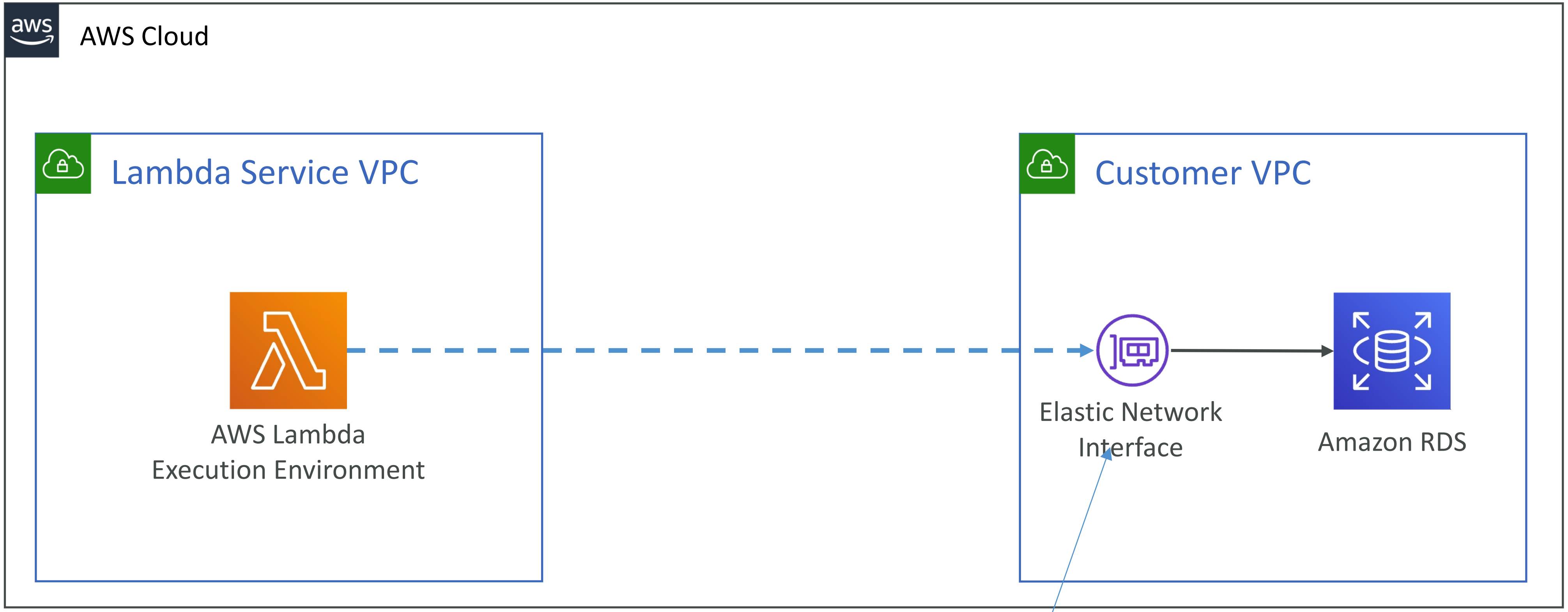
Requester managed ENIs

- RDS DB instance is fully managed by AWS but allows customer to control the traffic using security groups. For this, AWS creates a requester managed ENI into customer VPC.
- EKS (Control Plane) master nodes are launched in AWS managed VPC and it creates ENIs into your VPC so that it can communicate with EKS worker nodes
- For AWS Workspaces or Appstream2.0, the underlying EC2 instances are launched inside AWS managed VPC and ENIs are created into your VPC so that those instances can communicate with applications inside your VPC

Example: Amazon Workspaces/Appstream 2.0

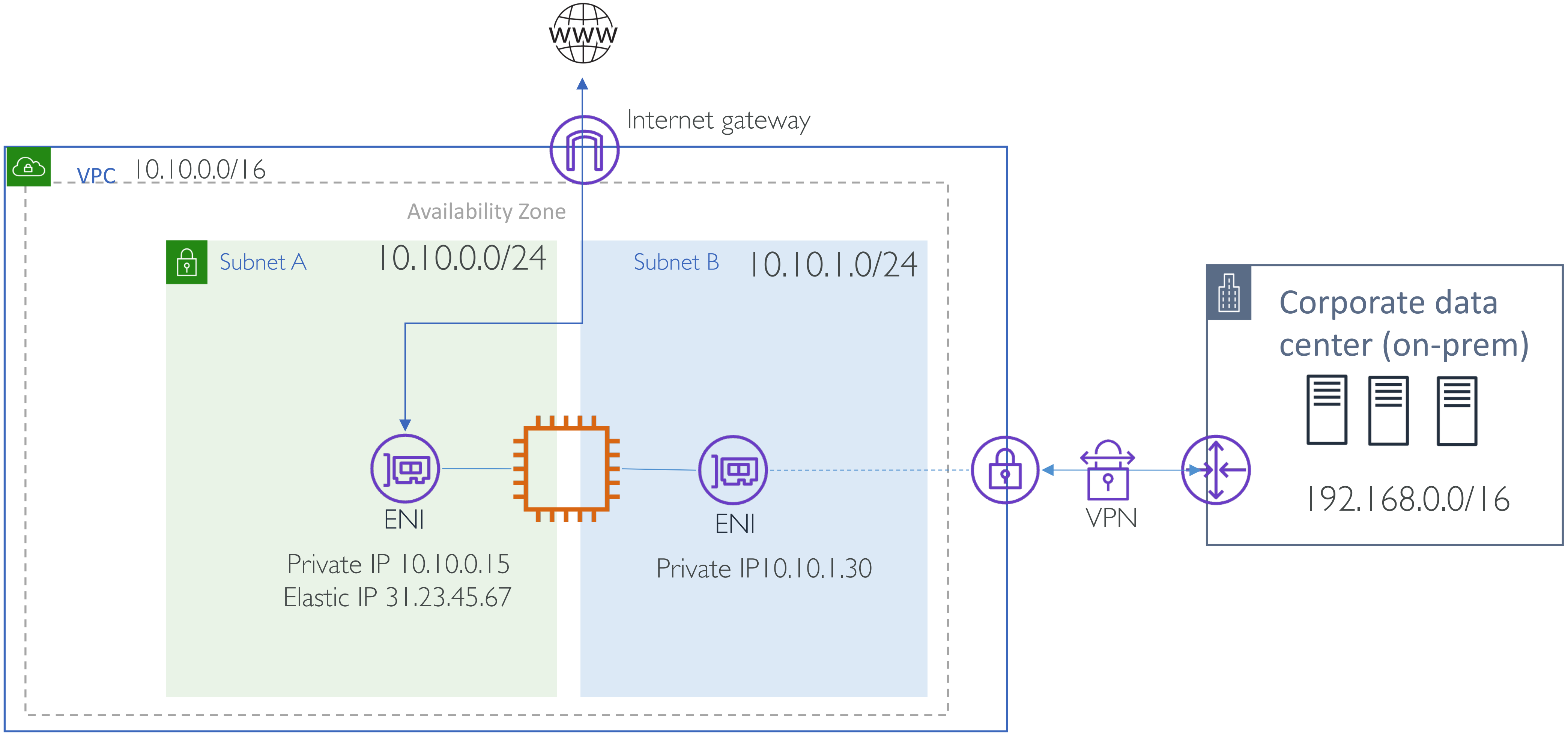


Example: AWS Lambda to access VPC resources

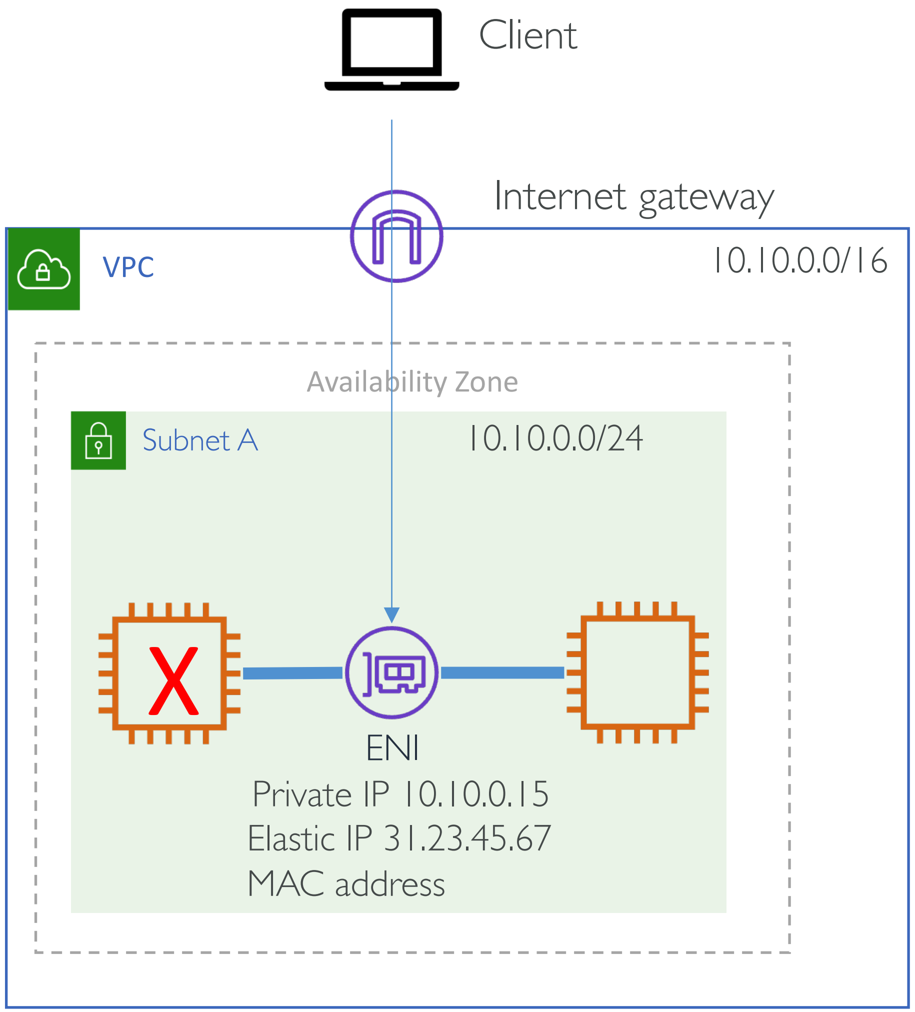


AWS creates ENI in your VPC

Creating Management Network / Dual home instances

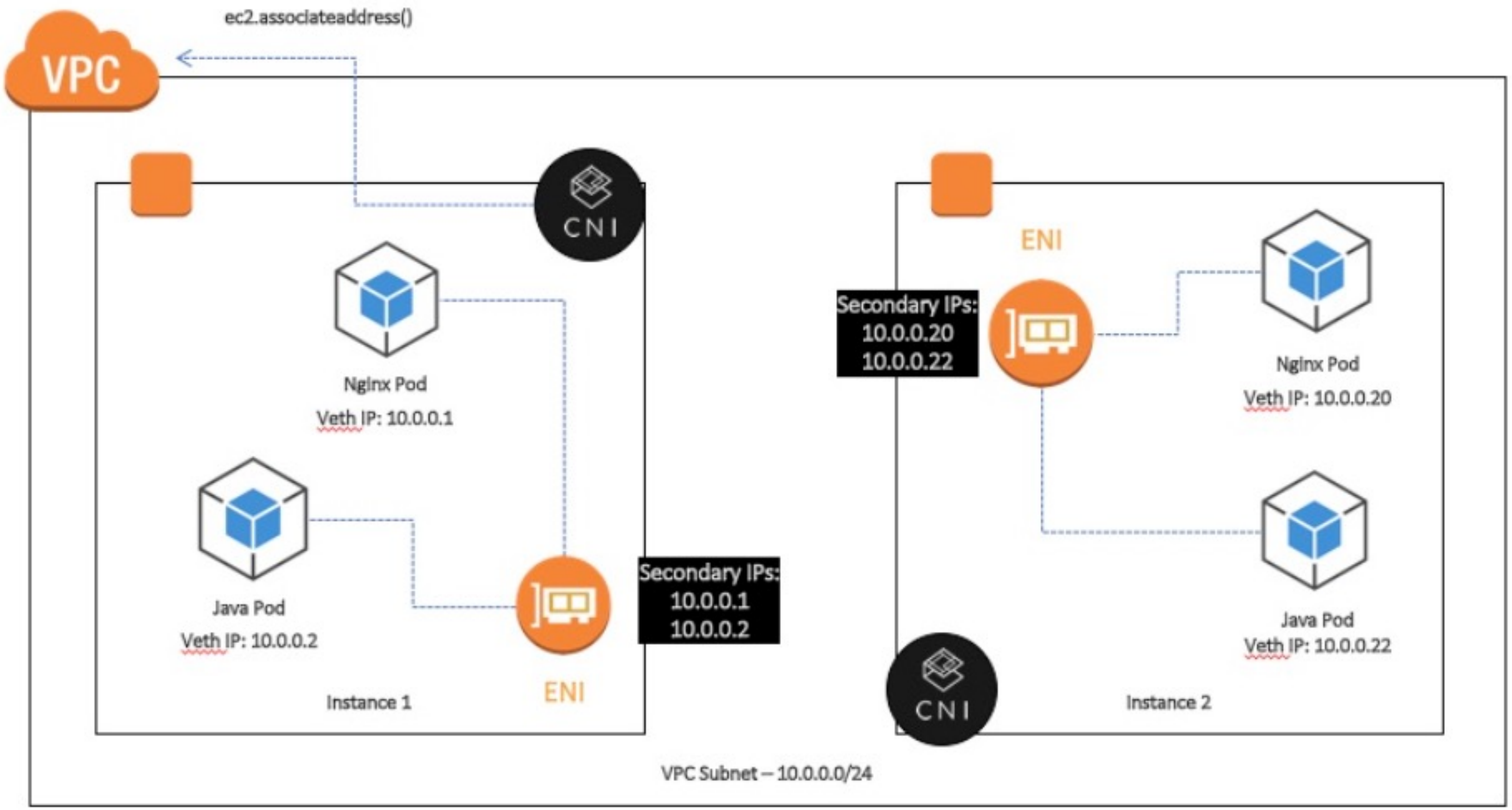


High availability solution



- Attach the ENI to hot-standby instance in case primary instance fails
- No changes in routing or DNS configuration
- Brief loss of connectivity may be experienced

Secondary IPs for PODs in EKS

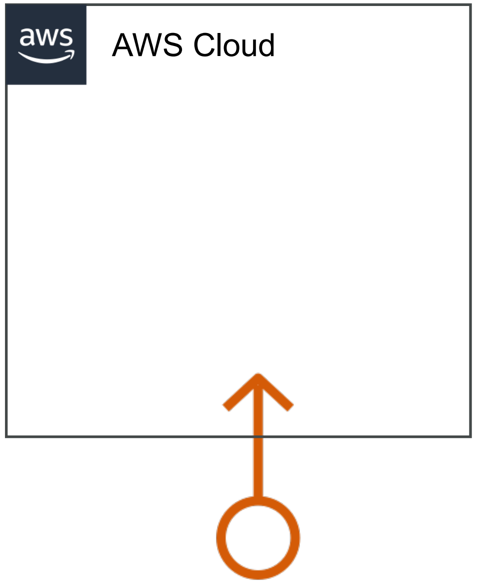


Exam essentials

1. The number of ENIs that you can attach to instance and number of secondary IP addresses per ENI depends on EC2 instance type
2. You can not detach primary network interface from an instance. Secondary ENI can be detached and attached to another instance in the same AZ.
3. You associate security groups with network interfaces and not with individual IP addresses.
4. For applications licenses which are bound to MAC addresses, you can preserve the MAC address by using the same ENI
5. Second ENI allows instance to be multi-homed (subnets) **in same AZ, it can be created across AWS account** (e.g. requester managed ENI)
6. ENIs can not be used for **NIC teaming** which means they can not be used together to increase instance network bandwidth
7. If you attach two or more network interfaces from the same subnet to an instance, you might encounter networking issues such as asymmetric routing. If possible, use a secondary private IPv4 address on the primary network interface instead.

Bring Your Own IP

- You can migrate your publicly routable IPv4 and IPv6 IP addresses to AWS
- But Why?
  - Keep your IP address reputation
  - Avoid changes to IP Address whitelisting
  - Move applications without change in the IP addresses
  - AWS as a hot standby



Pre-requisites to BYOIP

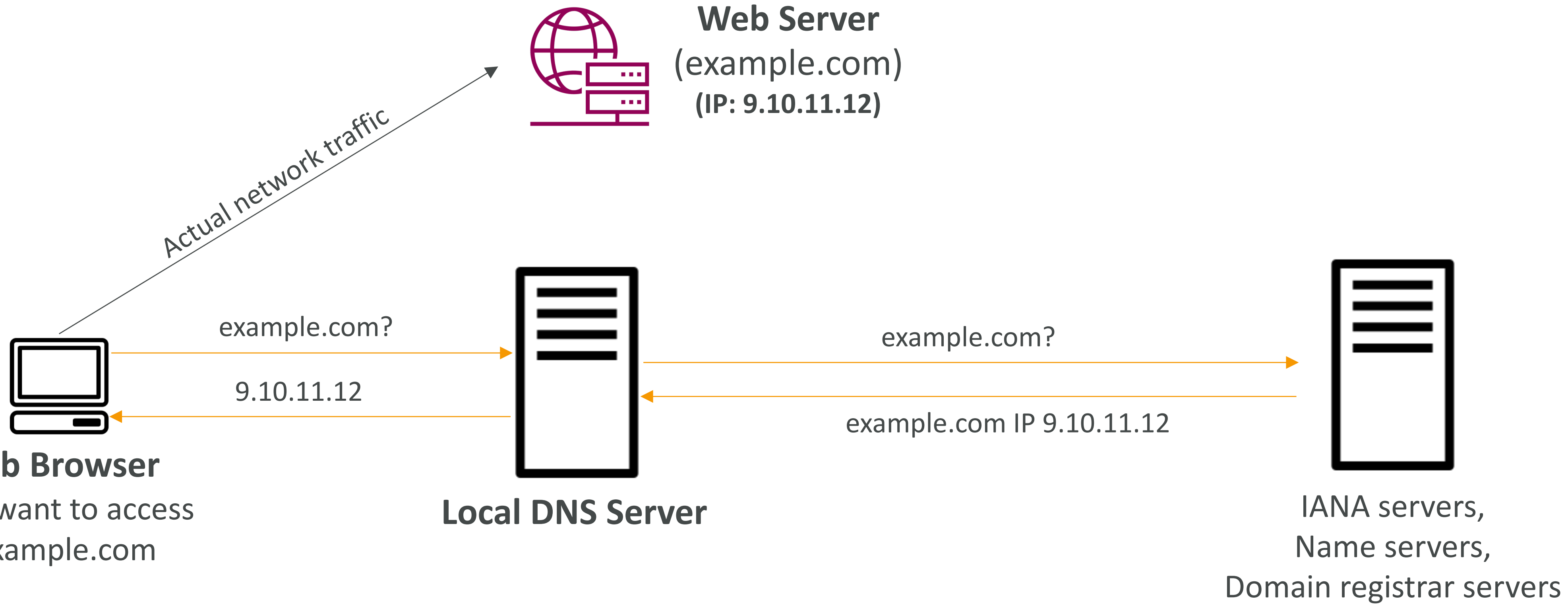
- The address range must be registered with regional internet registry (RIR) – ARIN or RIPE or APNIC
- The addresses in the IP address range must have a clean history. AWS reserve the right to reject poor reputation IP address ranges.
- The most specific IPv4 address range that you can bring is /24
- The most specific IPv6 address range that you can bring is /48 for CIDRs that are publicly advertised
- The most specific IPv6 address range that you can bring is /56 for CIDRs that are not publicly advertised (can be advertised over Direct Connect if required)
- Create a Route Origin Authorization (ROA) to authorize Amazon ASNs 16509 and 14618 to advertise your address range

Good to know about BYOIP

- You continue to own the address range, but AWS advertises it on the internet by default
- After you bring the address range to AWS, it appears in your AWS account as an address pool.
- You can associate these IP addresses to Amazon EC2 instances, Network Load Balancers, and NAT gateways
- You can bring a total of five IPv4 and IPv6 address ranges per Region to your AWS account.

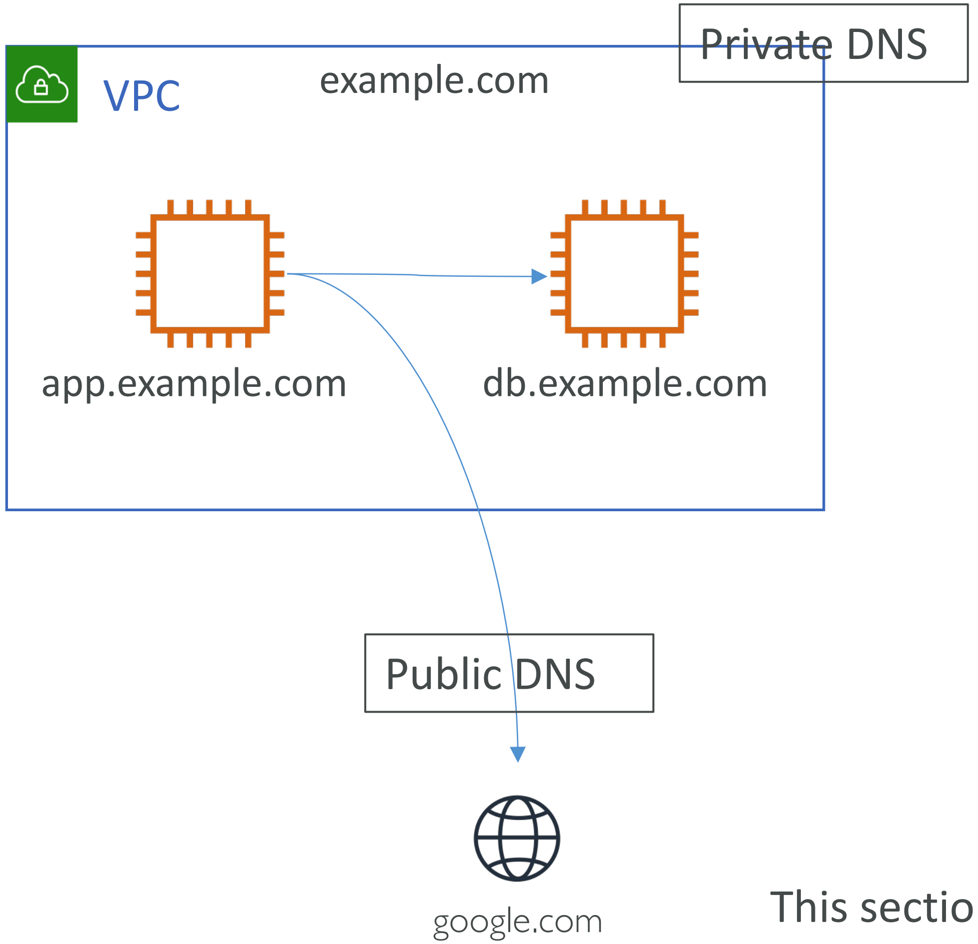
VPC DNS & DHCP

What is DNS and how it works?



DNS is the backbone of the Internet

DNS resolution for Amazon VPC



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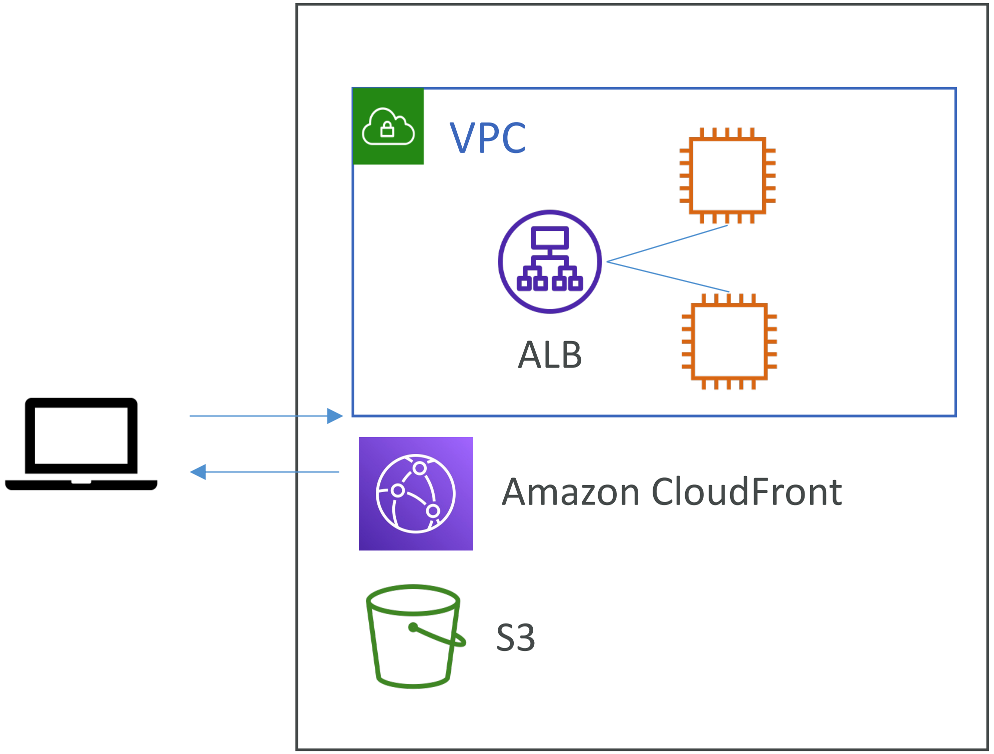


Amazon Route 53
Section

VPC DNS and DHCP

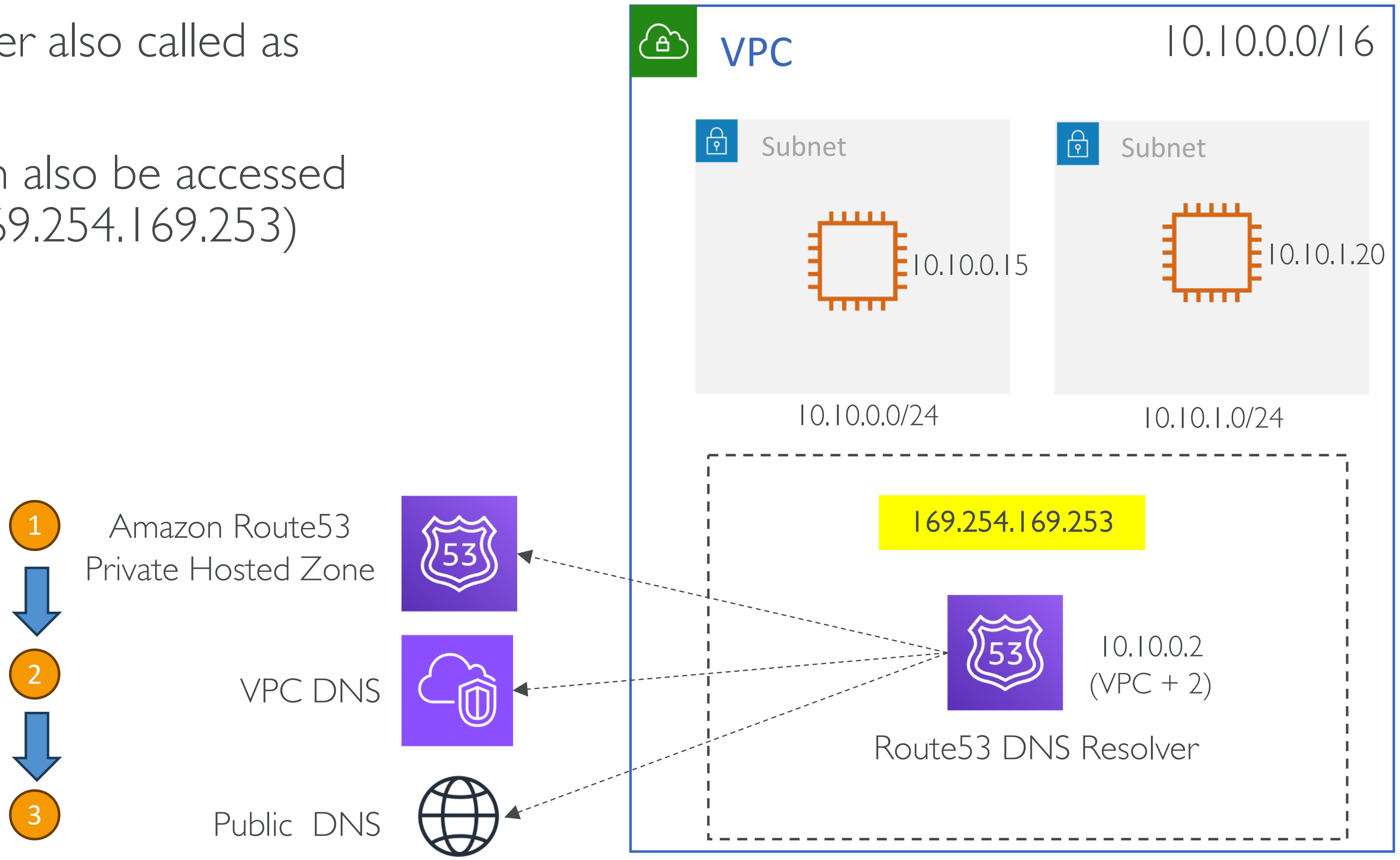
- Amazon VPC DNS server (Route53 DNS Resolver)
- DHCP Option sets
- EC2 DNS names – internal and external
- VPC DNS Attributes - enableDnsSupport and enableDnsHostname
- Hands-on:
  - VPC DNS with Route53 Hosted Zones
  - VPC DNS with custom DNS server
- Introduction to Route 53 resolver endpoints

Amazon VPC DNS server

Route53 DNS Resolver

Amazon DNS Server - Amazon Route 53 Resolver

- VPC comes with default DNS server also called as Route53 DNS Resolver
- Runs at VPC Base + 2 Address (can also be accessed from within the VPC at virtual IP 169.254.169.253)
- Resolves DNS requests from:
  - Route 53 Private Hosted Zone
  - VPC internal DNS
  - Forwards other requests to Public DNS (including Route 53 Public Hosted Zones)
- Accessible from within the VPC



Amazon DNS Server - Amazon Route 53 Resolver

Amazon Route 53 Private Hosted Zone

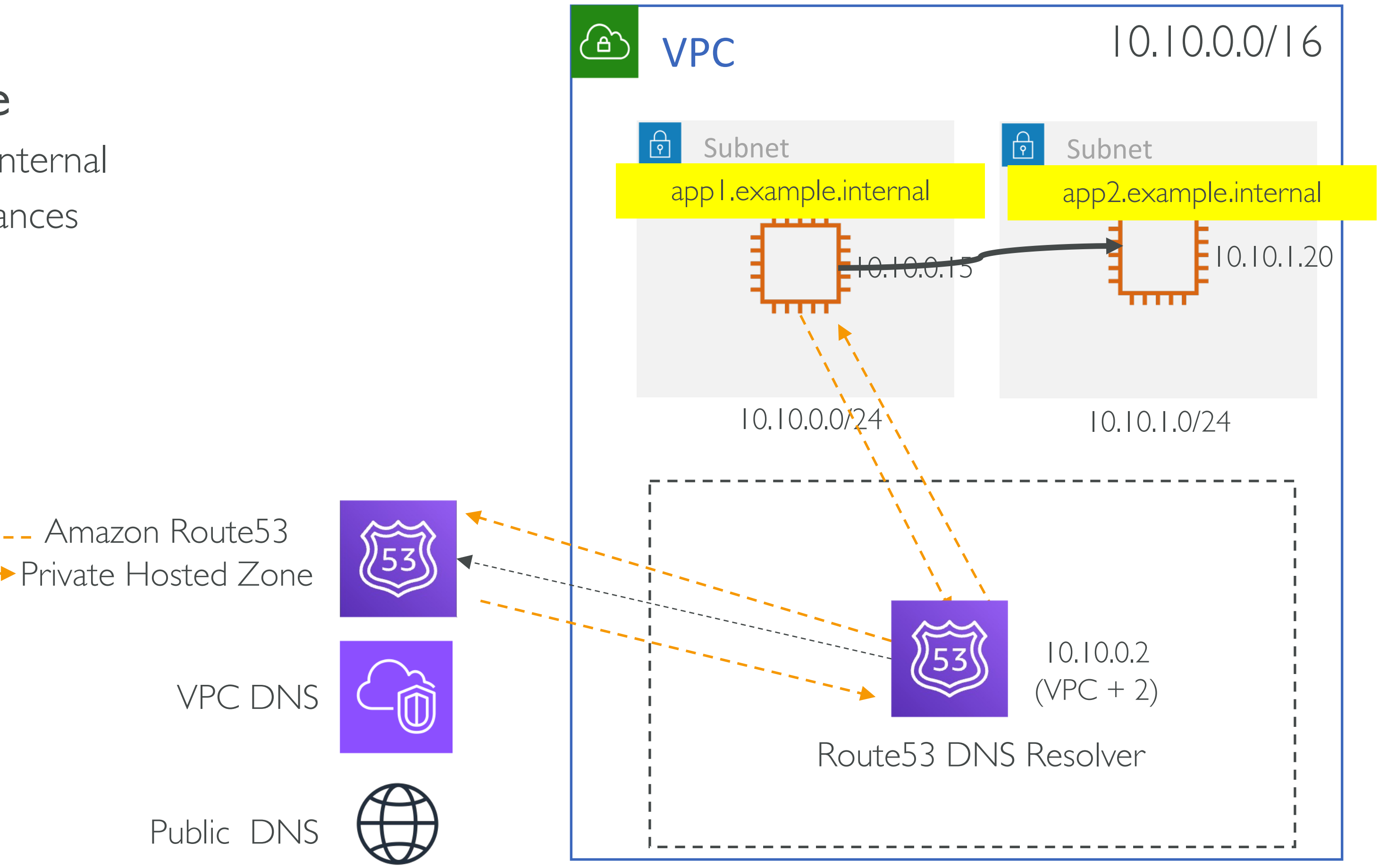
1. Create a private hosted zone: example.internal
2. Create record sets pointing to EC2 instances private Ips
3. DNS queries from within the VPC

Records (4) Info

Automatic mode is the current search behavior optimized for best filter results. To change modes go to se

Filter records by property or value

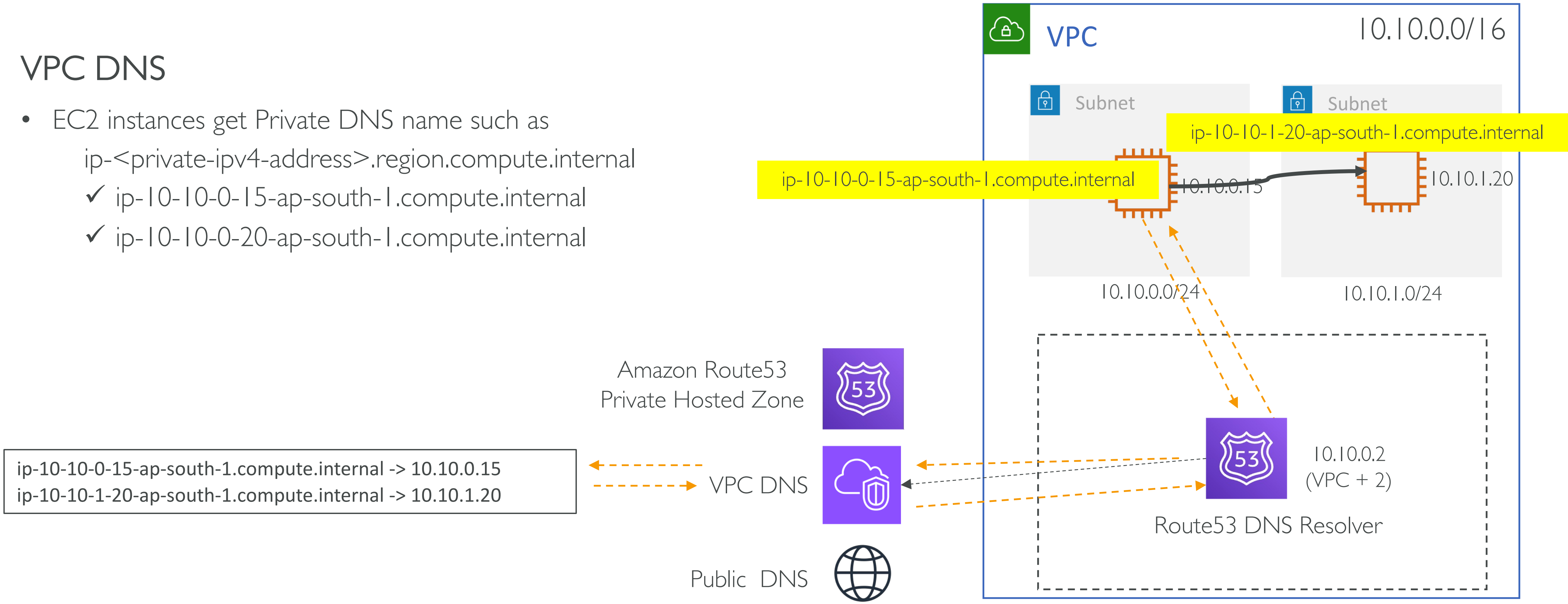
	Record name	Type	Value/Route traffic to
☐	example.internal	NS	ns-1536.awsdns-00.co.uk. ns-0.awsdns-00.com. ns-1024.awsdns-00.org. ns-512.awsdns-00.net.
☐	example.internal	SOA	ns-1536.awsdns-00.co.uk. a...
☐	app1.example.internal	A	10.10.0.15
☐	app2.example.internal	A	10.10.1.20



Amazon DNS Server - Amazon Route 53 Resolver

VPC DNS

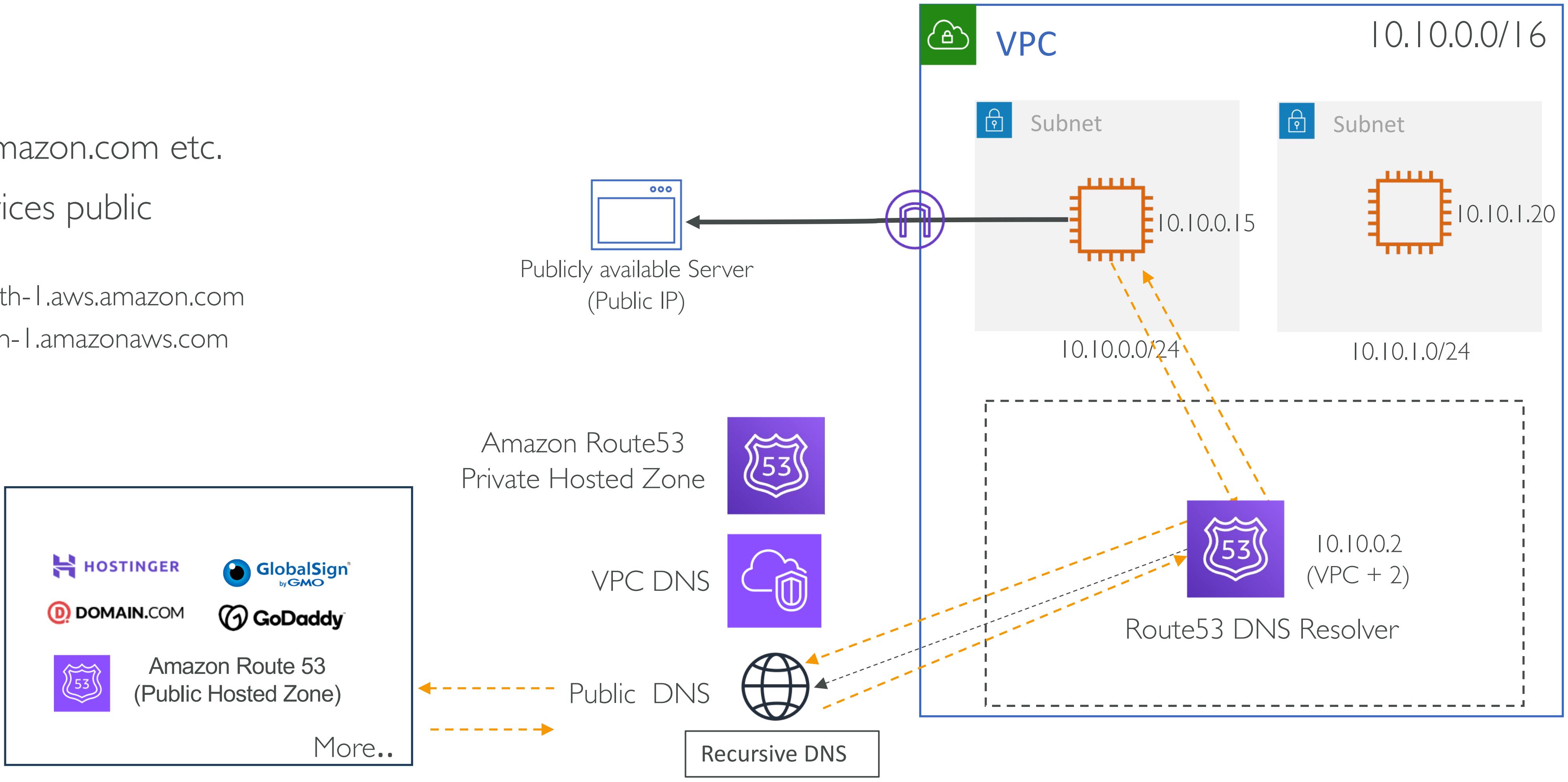
- EC2 instances get Private DNS name such as
  ip-<private-ipv4-address>.region.compute.internal
  - ✓ ip-10-10-0-15-ap-south-1.compute.internal
  - ✓ ip-10-10-0-20-ap-south-1.compute.internal



Amazon DNS Server - Amazon Route 53 Resolver

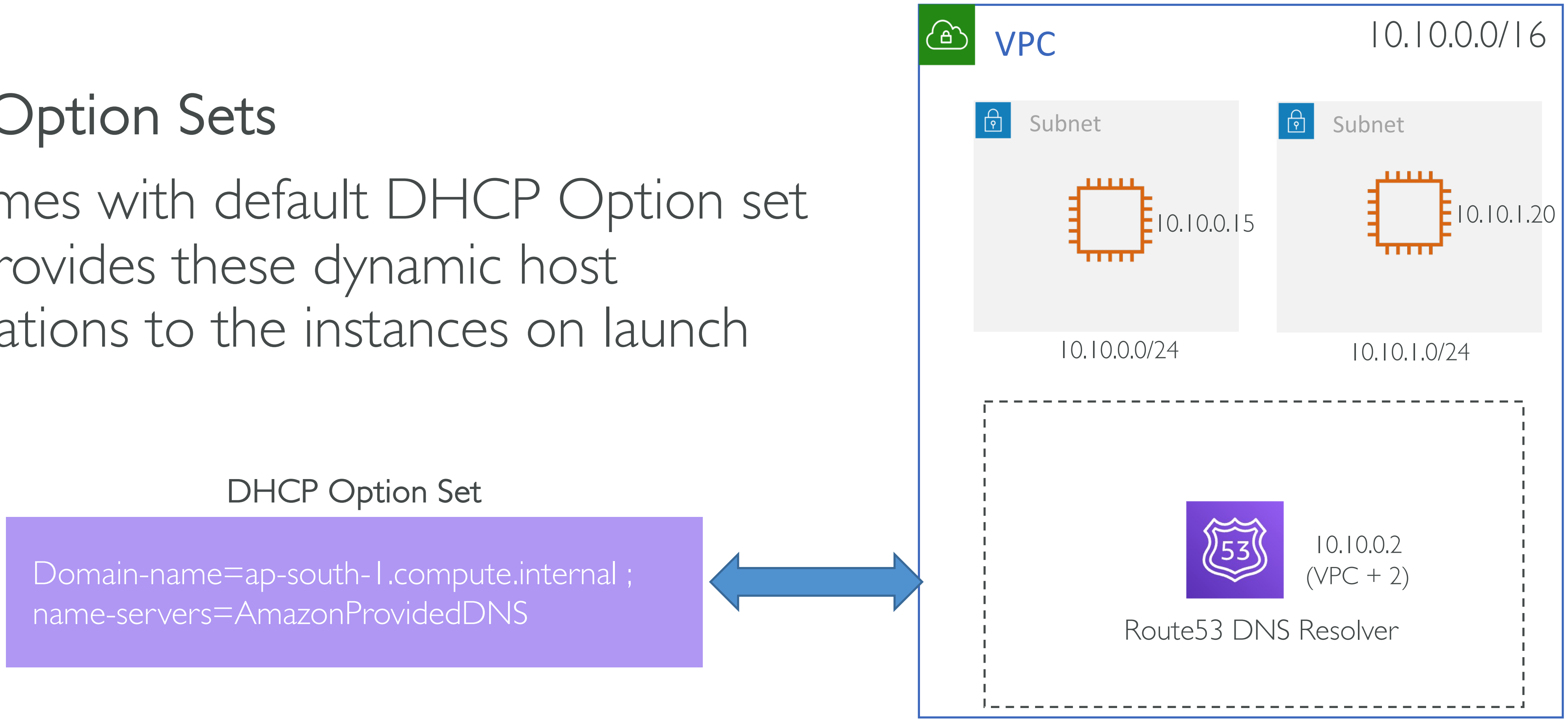
Public DNS

- goole.com, amazon.com etc.
- Amazon services public endpoints
  - sqs.ap-south-1.aws.amazon.com
  - s3.ap-south-1.amazonaws.com



How VPC knows about this Amazon DNS Server?

- DHCP Option Sets
- VPC comes with default DHCP Option set which provides these dynamic host configurations to the instances on launch



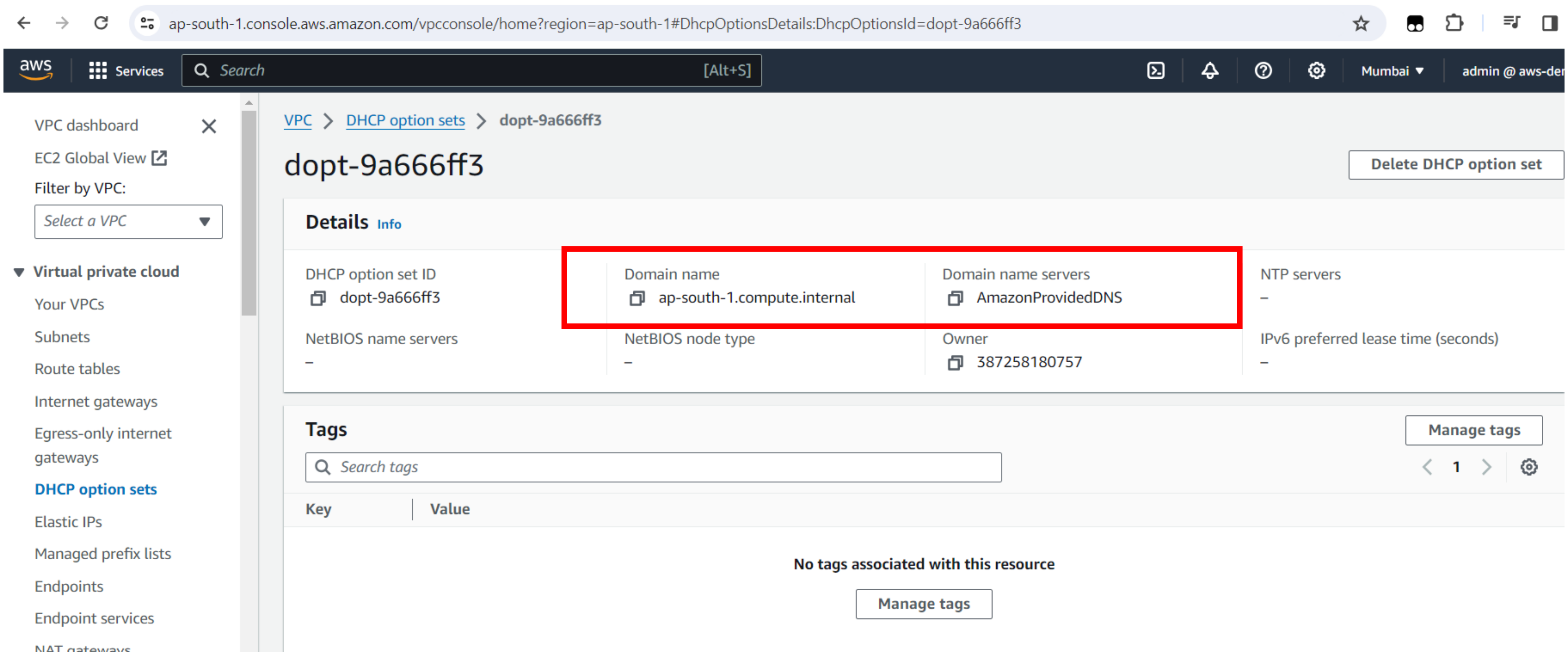
VPC DHCP Option sets

EC2 DNS names, DNS attributes

DHCP Option Sets

- The options field of a Dynamic Host Configuration Protocol message contains the configuration parameters like domain name, **domain name server**, NTP server and the NetBIOS node type
- AWS automatically creates and associates a DHCP option set for your VPC upon creation and sets following parameters:
  - **domain-name-servers:** This defaults to **AmazonProvidedDNS**
  - **domain-name:** This defaults to the internal Amazon domain name for your region (e.g <ip>.ap-south-1.compute.internal)

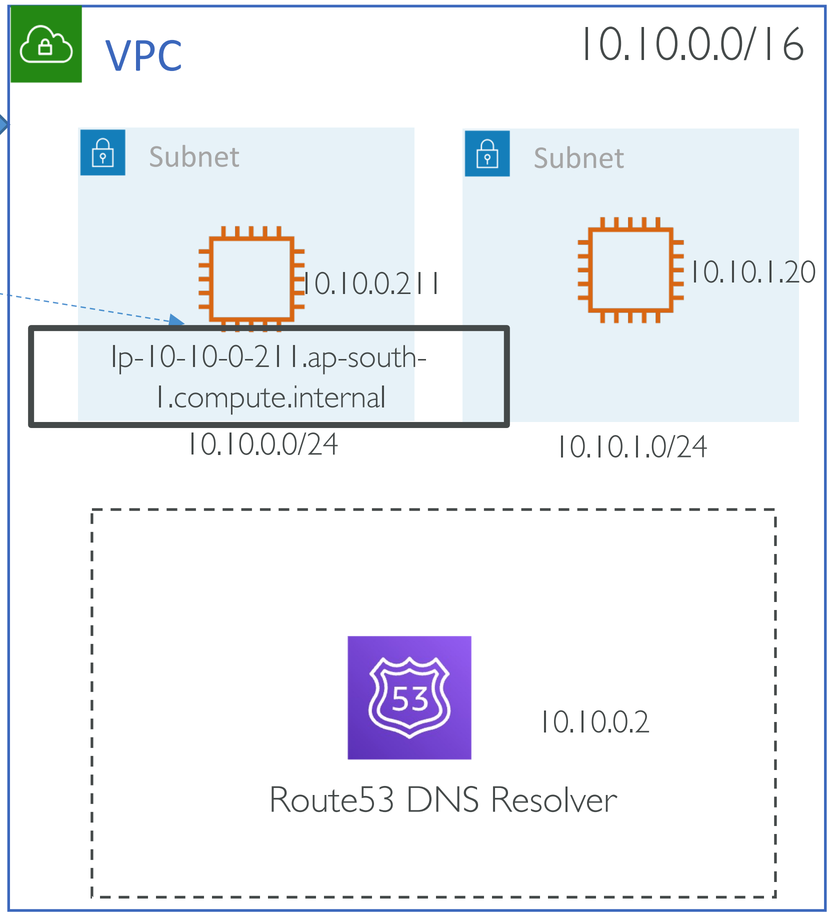
DHCP Options Sets



DHCP Option sets – How it works

Domain-name=ap-south-1.compute.internal;
name-servers=AmazonProvidedDNS

DHCP Options Set (default)



1. Sets the hostname

ec2-user@ip-10-10-0-211:~

```
       __|  __|_  )
       _|  (     /   Amazon Linux 2 AMI
      ___|\___|___|

https://aws.amazon.com/amazon-linux-2/
13 package(s) needed for security, out of 32 available
Run "sudo yum update" to apply all updates.
[ec2-user@ip-10-10-0-211 ~]$ hostname
ip-10-10-0-211.ap-south-1.compute.internal
```

2. Sets the resolv.conf

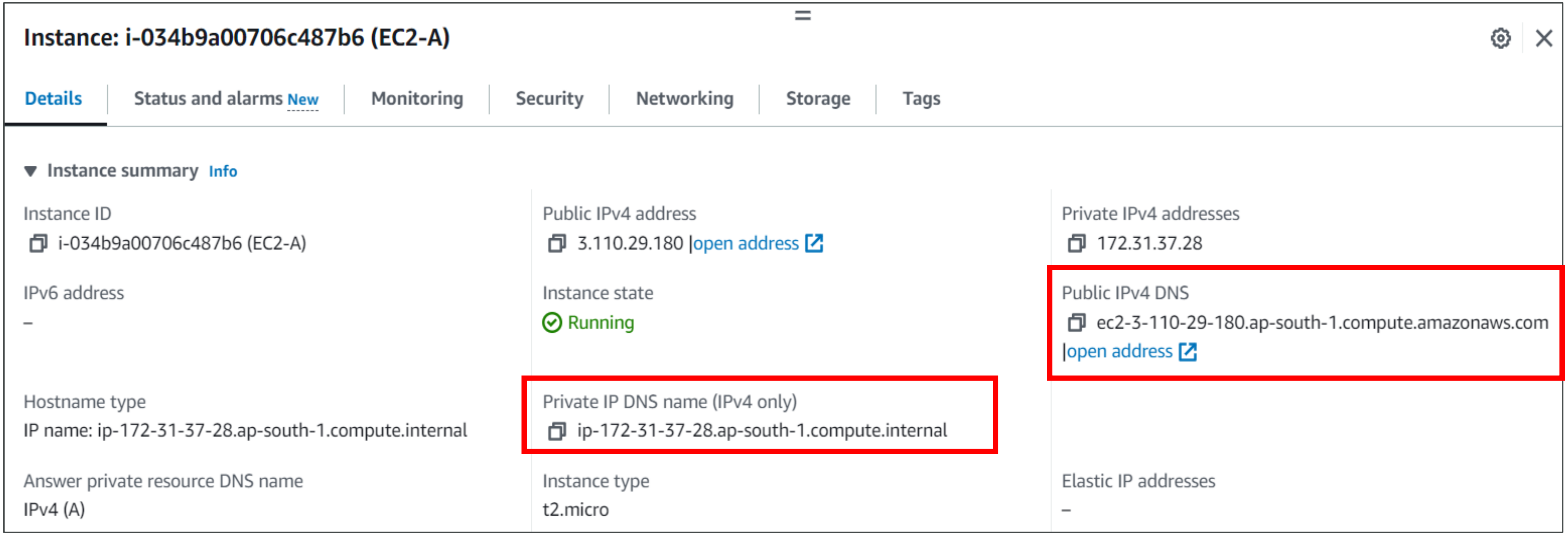
```
[ec2-user@ip-10-10-0-211 ~]$ cat /etc/resolv.conf
; generated by /usr/sbin/dhclient-script
search ap-south-1.compute.internal
options timeout:2 attempts:5
nameserver 10.10.0.2
```

AWS assigned domain names for EC2

- Internal DNS
  - ip-<private-ipv4-address>.ec2.internal (for the US-East-1 region)
  - ip-<private-ipv4-address>.region.compute.internal (for all other regions)

- External DNS (If instance has Public IP)
  - ec2-<public-ipv4-address>.compute-1.amazonaws.com (for the US-East-1 region)
  - ec2-<public-ipv4-address>.region.amazonaws.com (for other regions)

AWS assigned domain names for EC2



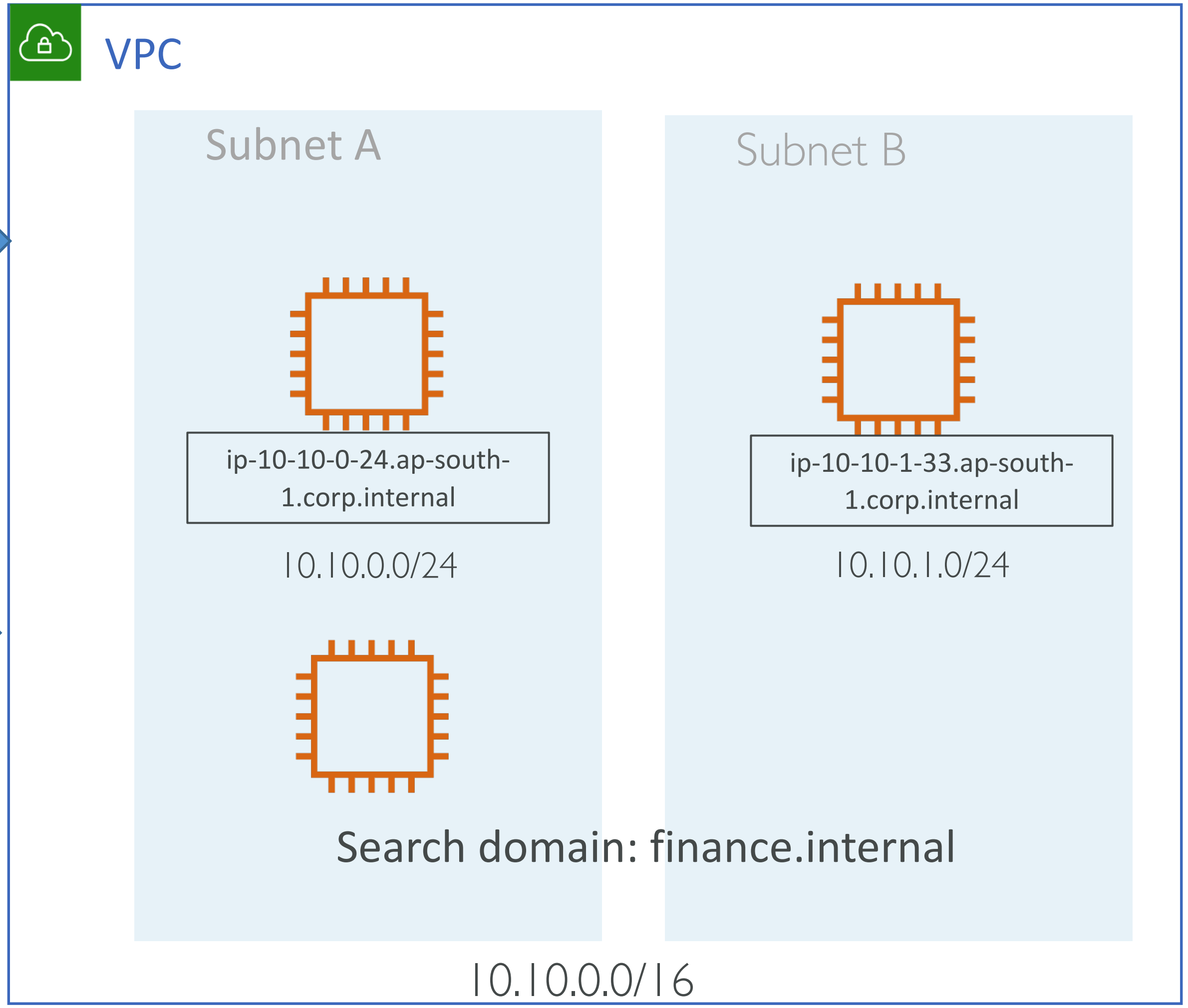
Attaching VPC a new DHCP Options set

DHCP Options Set (old)

Domain-name=ap-south-1.corp.internal;
name-servers=AmazonProvidedDNS

DHCP Options Set (new)

Domain-name=finance.internal;
name-servers=AmazonProvidedDNS



VPC DNS Attributes

- enableDnsSupport: (= DNS Resolution setting)
  - Default True
  - Helps decide if DNS resolution is supported for the VPC
  - If True, queries the AWS DNS server at 169.254.169.253 (=> VPC+2)
- enableDnsHostname: (= DNS Hostname setting)
  - False by default for newly created VPC, True by default for Default VPC
  - Won't do anything unless enableDnsSupport=true
  - If True, assigns public hostname to EC2 instance if it has a public IP
- If you use custom DNS domain names in a Route 53 Private hosted zone, you must set both these attributes to true

Try it out

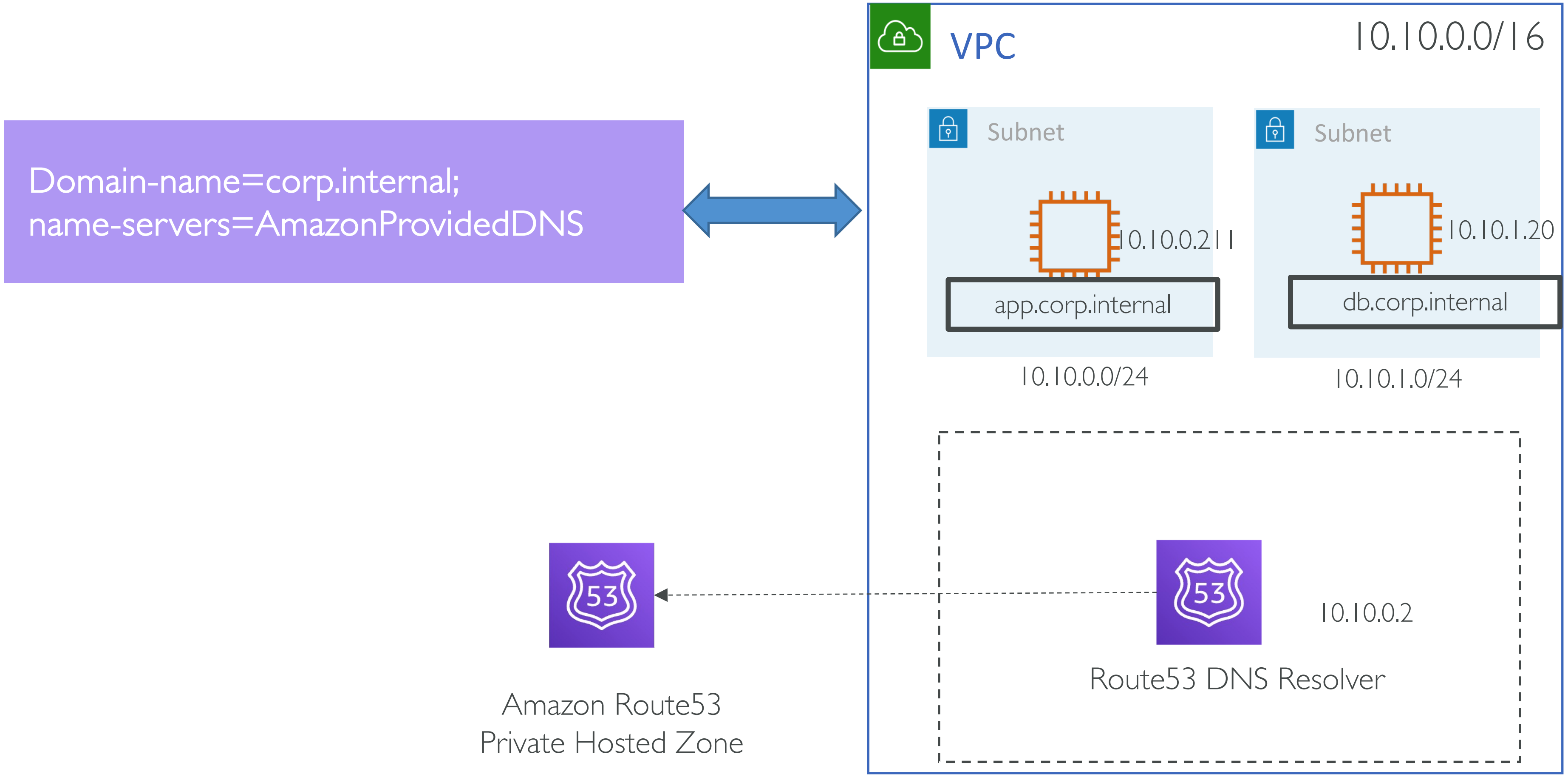
- When enableDnsHostname is not set
- When enableDnsHostname is set

DHCP Options Sets – good to know

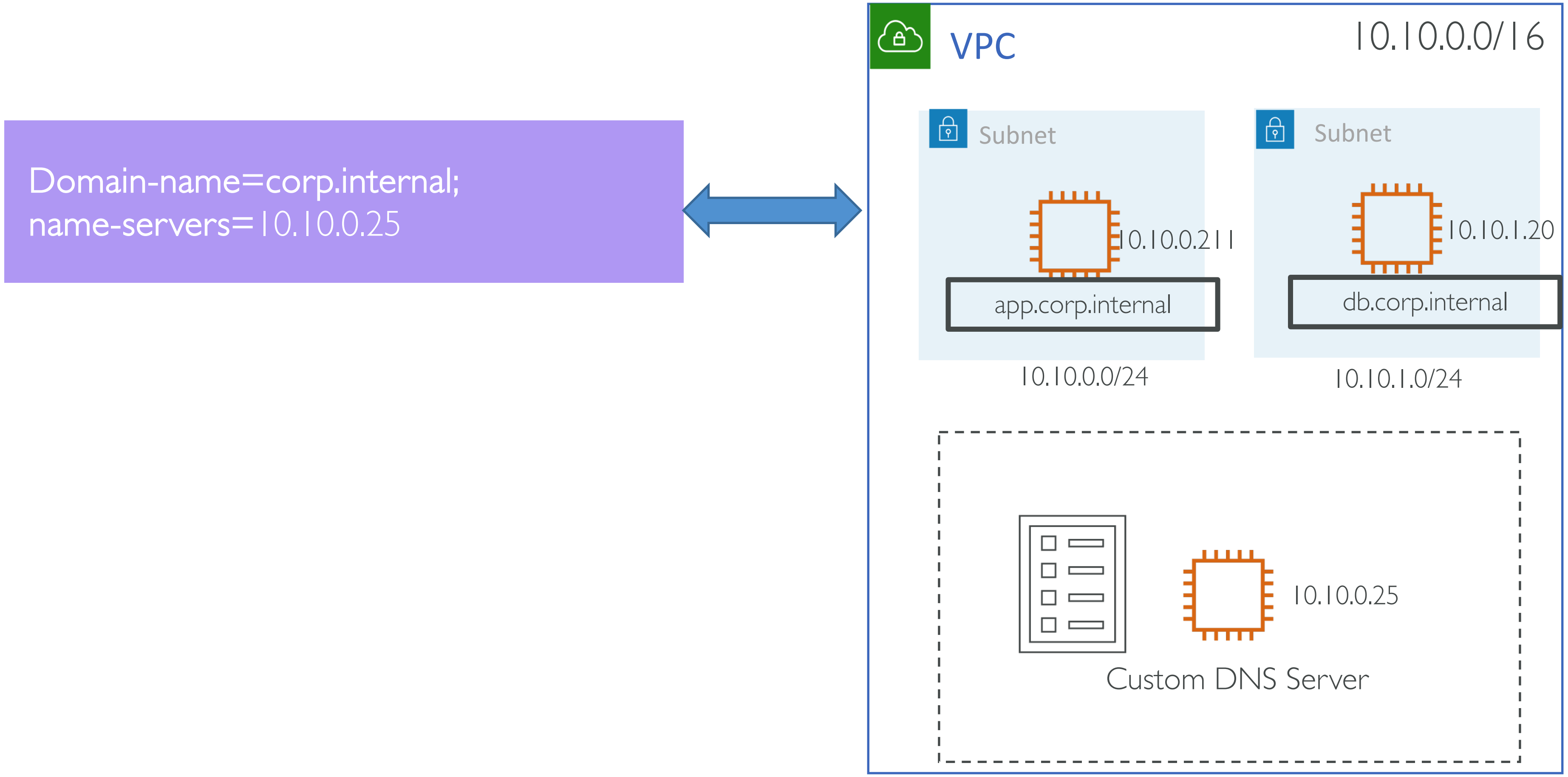
- Once created, you **can not** modify DHCP Options set however you can create new DHCP Options set and associate it with VPC
- You can only associate a single DHCP Options set with a VPC
- VPC can also be setup without DHCP Options set. In that case the instances in the VPC can't access the internet as there is no access to a DNS server.
- After DHCP Option set is associated with VPC, the instances automatically use new option set, but this may take a few hours
- You can also refresh the DHCP option parameters using an operating system command:
  - Example Linux command: *$sudo dhclient -r eth0*

Hands-on: VPC DNS

Scenario 1: Using Amazon Route53 DNS resolver and Amazon Route53 Private hosted zone

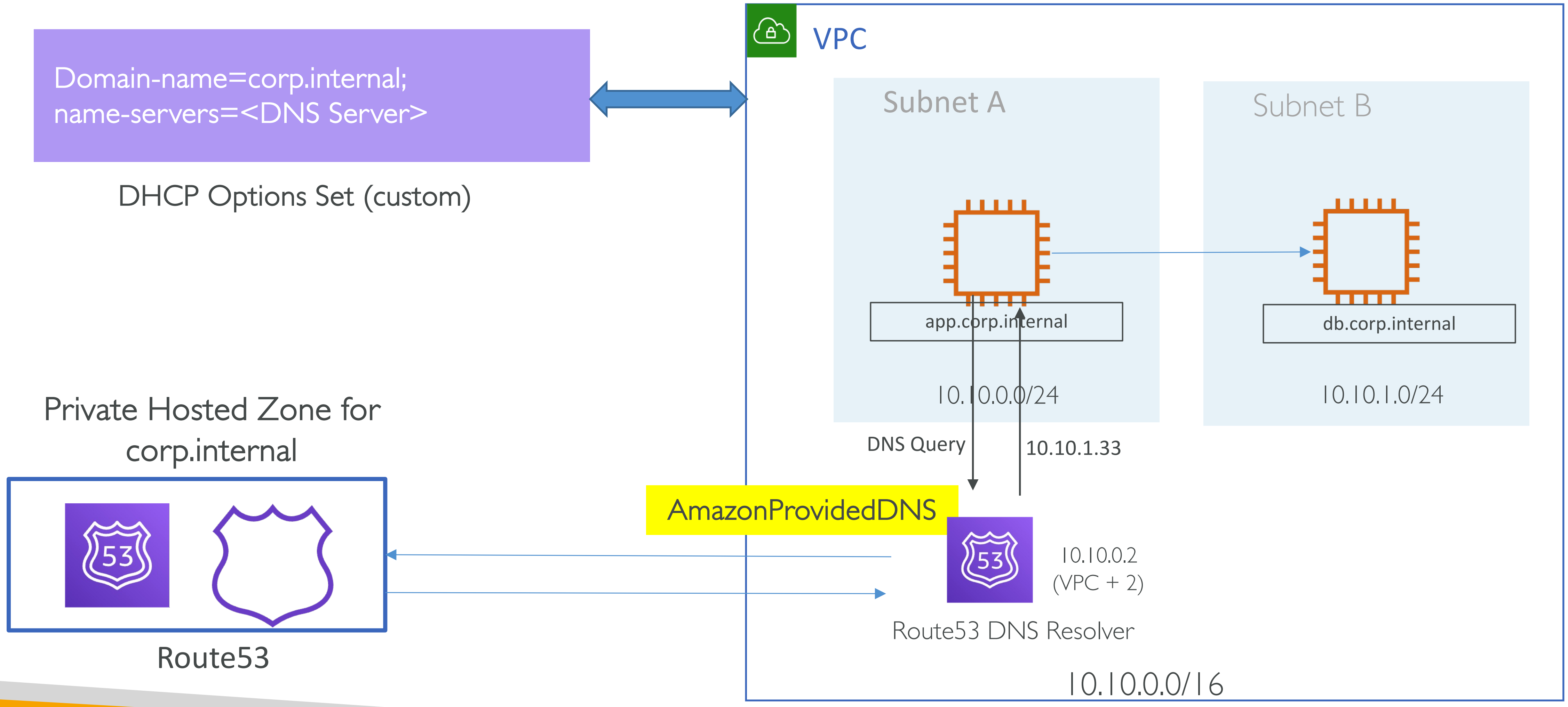


Scenario 2: Using custom DNS server



Hands-on: VPC DNS with Route 53 Private hosted zone

VPC custom domain name with Route53 Private hosted zone

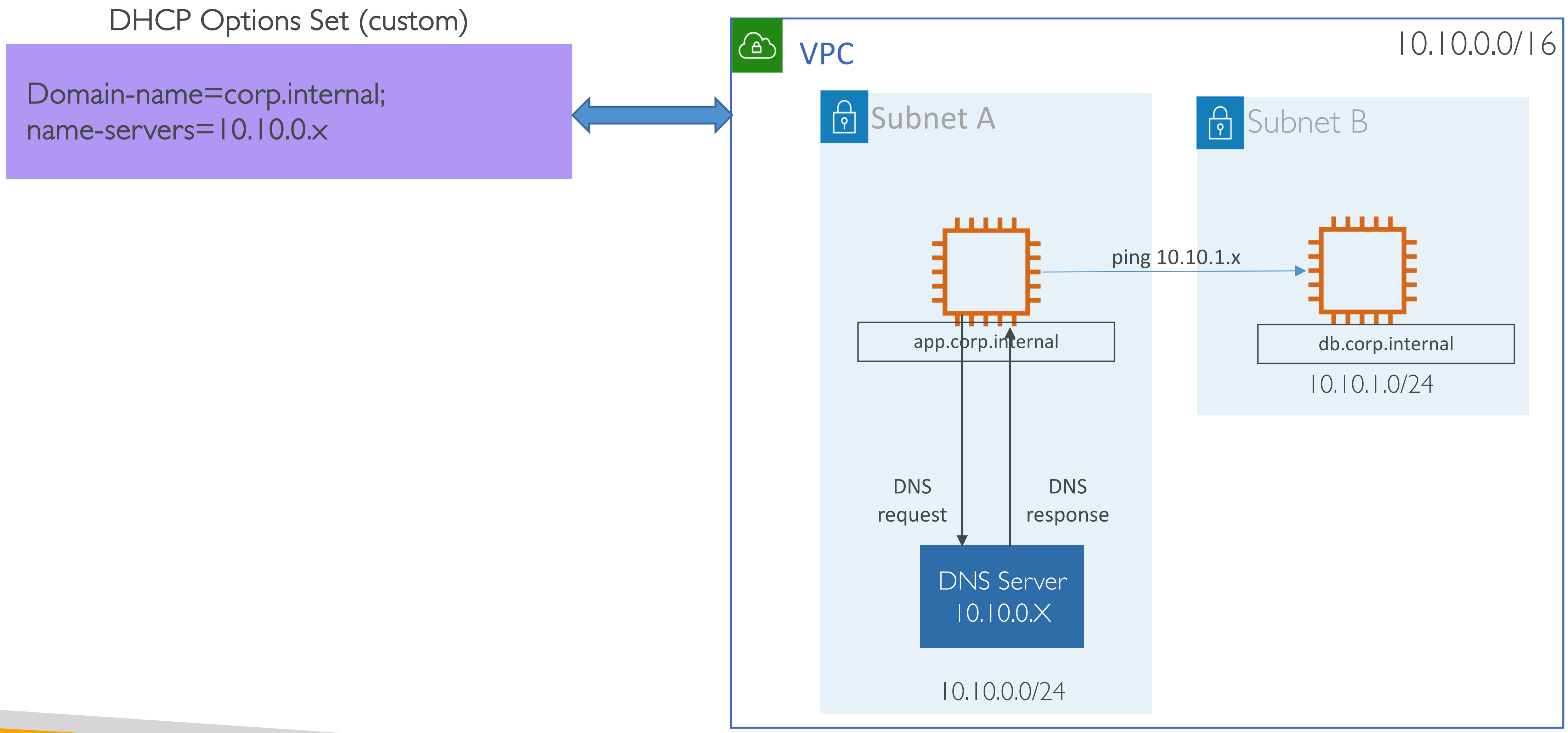


Steps

- Create a VPC with Public & Private subnet
- (Optional) Create DHCP Option set with domain as corp.internal and associate with your VPC
- Launch one EC2 instance in Public subnet (say app) and one instance in Private subnet (say db).
  - Allow SSH and ICMP IPv4 in the security group
- Create Route 53 Private hosted zone and associate with the VPC
- Create A records for ec2 instances pointing to their Private IPs
- SSH into Public EC2 instance and ping to other instance using it's DNS name

Hands-on: VPC DNS with custom DNS server

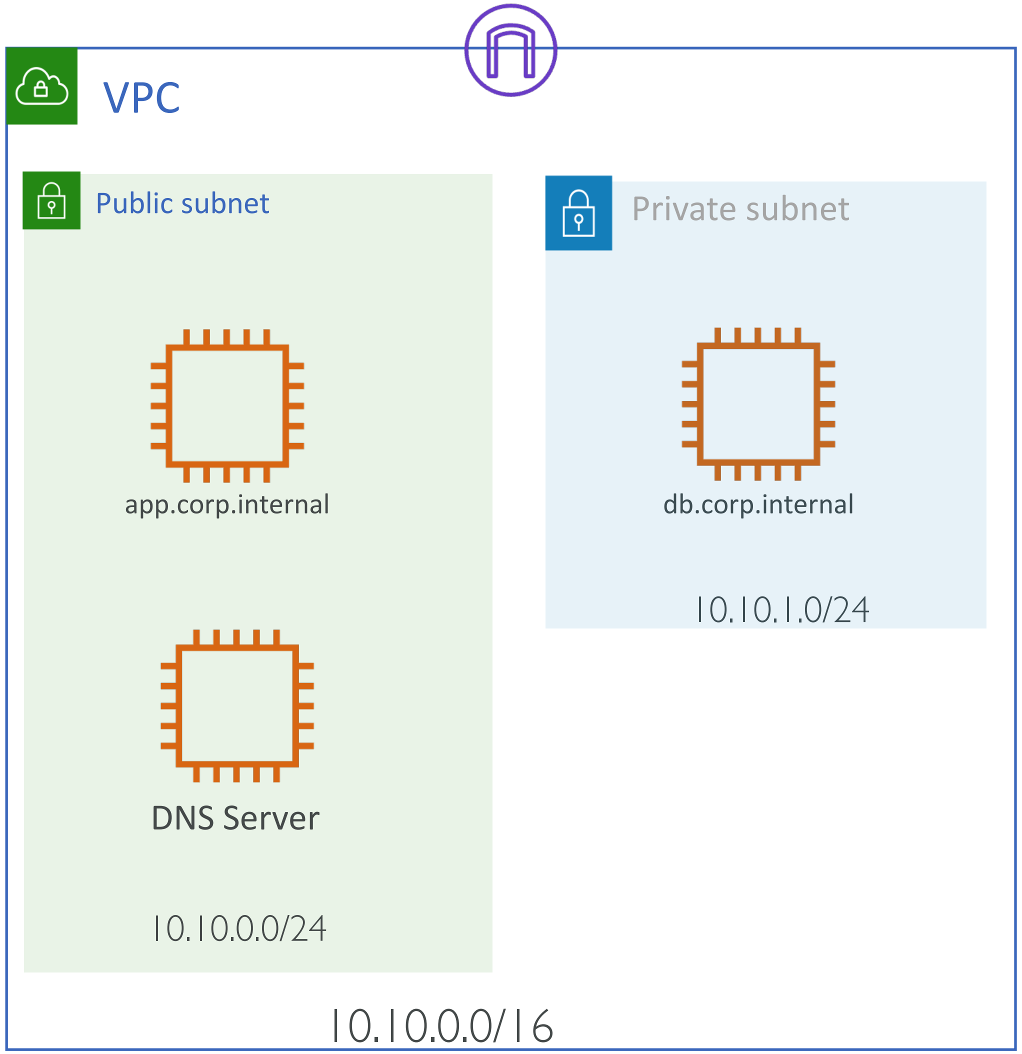
VPC DNS with custom DNS server



Step 1 – Setup a VPC and launch instances

- Create a VPC with public and private subnets
- Launch DNS server ec2 instance:
  - Security group to allow UDP 53 from VPC CIDR, SSH (22)
- Launch an app server & db server ec2 instances:
  - Security group to allow SSH (22), ICMP IPv4 All (ping)

Already created to save time



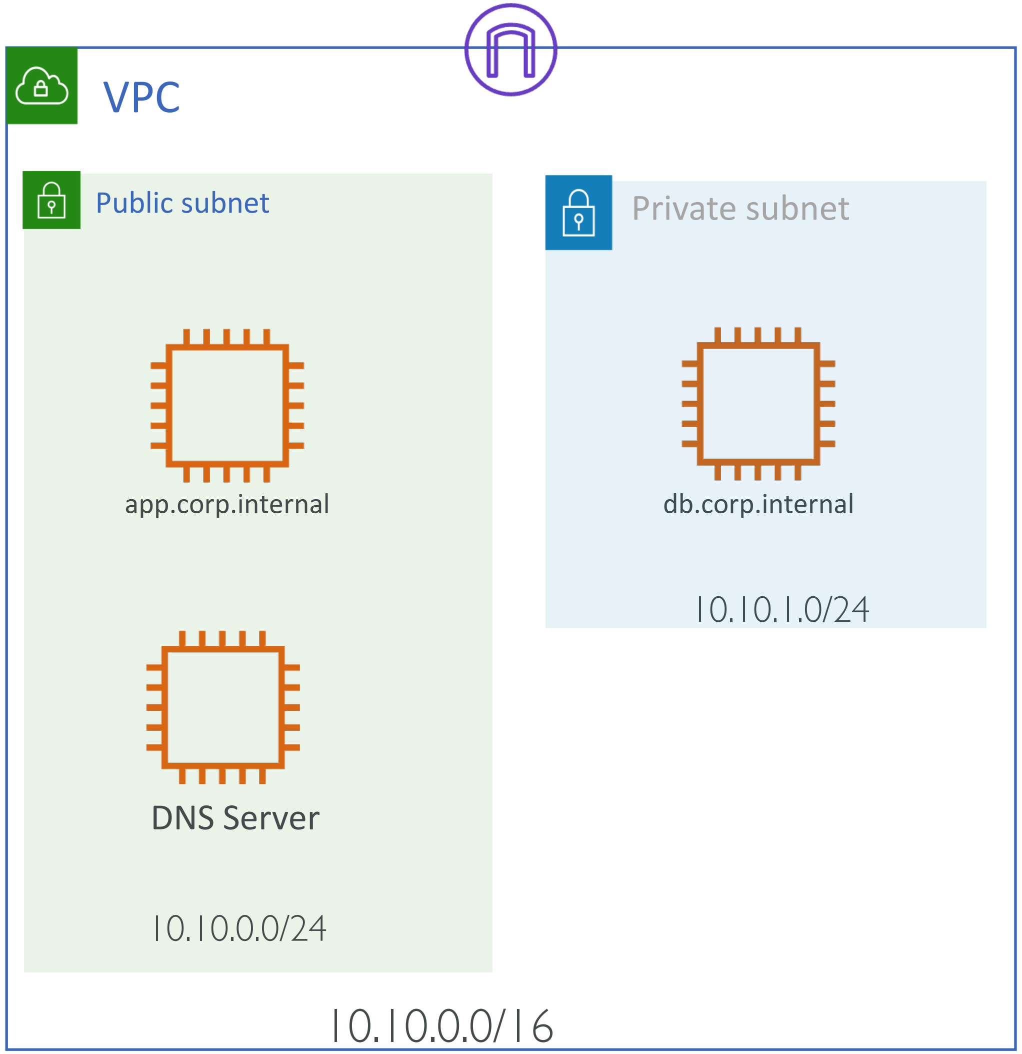
Step 2a – Setup DNS server

1. Login to DNS server
2. Install DNS server packages

    $sudo su

    $yum update –y

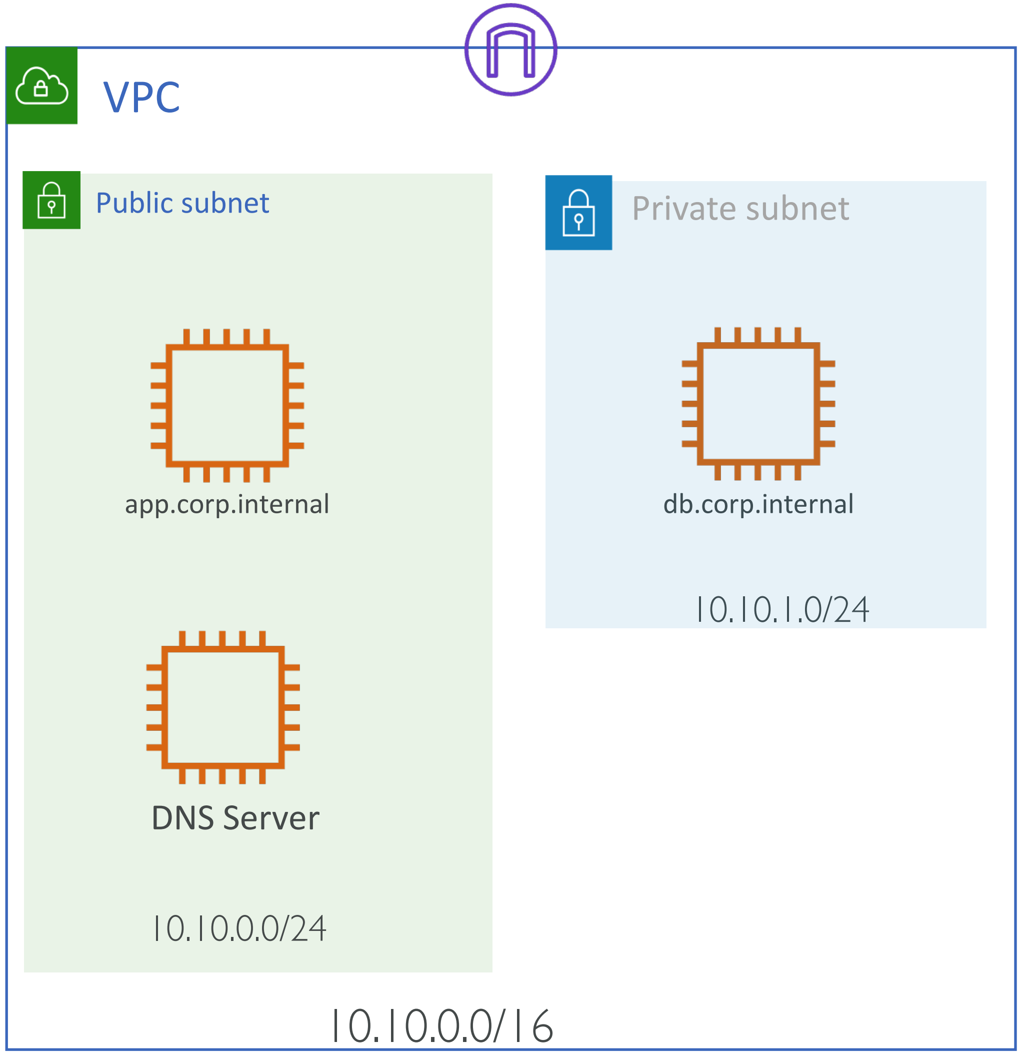
    $yum install bind bind-utils –y



Step 2b – Configure DNS server

3. Create file /var/named/corp.internal.zone *[Replace X]*

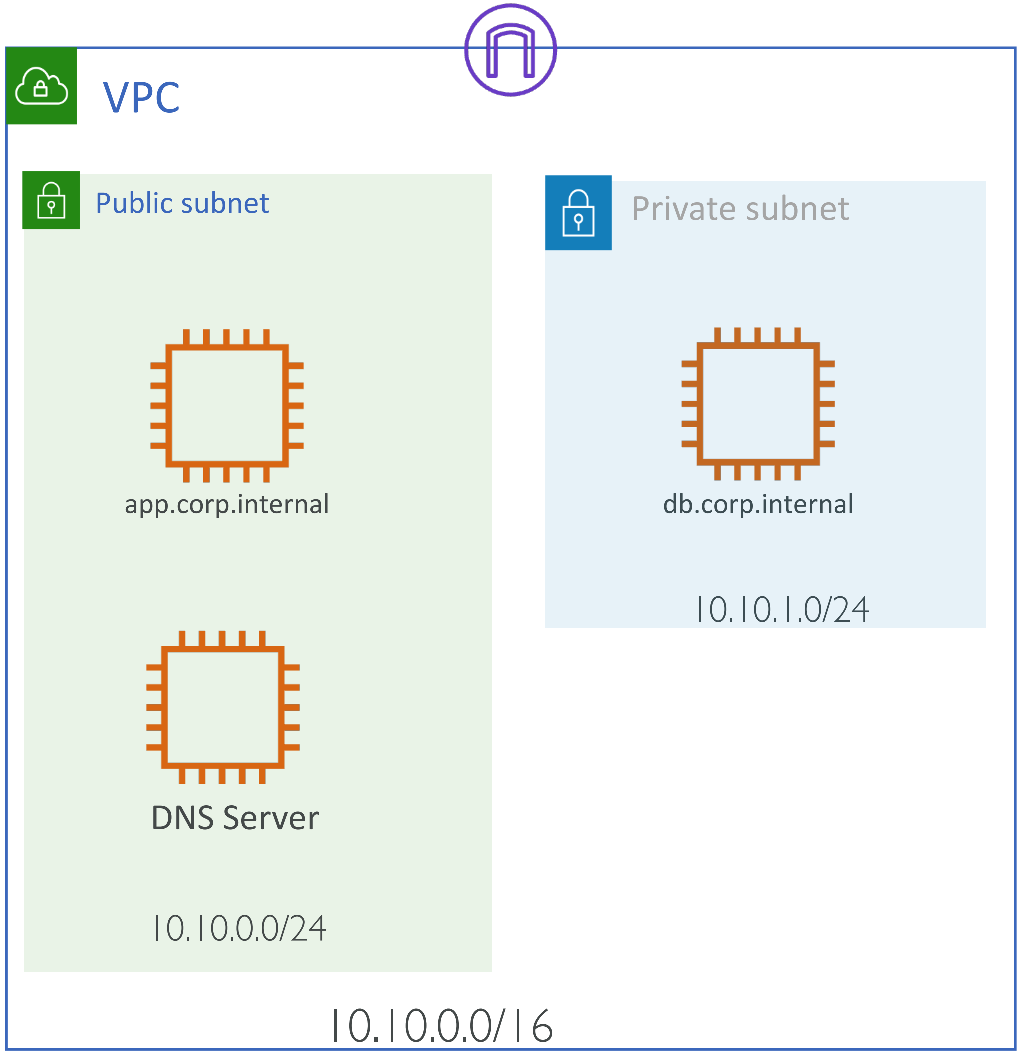
```
$TTL 86400
@   IN  SOA     ns1.corp.internal. root.corp.internal. (
        2013042201  ;Serial
        3600        ;Refresh
        1800        ;Retry
        604800      ;Expire
        86400       ;Minimum TTL
)
; Specify our two nameservers
    IN  NS    dnsA. corp.internal.
    IN  NS    dnsB. corp.internal.
; Resolve nameserver hostnames to IP, replace with your two droplet IP addresses.
dnsA    IN  A   1.1.1.1
dnsB    IN  A   8.8.8.8

; Define hostname -> IP pairs which you wish to resolve
@     IN  A   10.10.0.x
app   IN  A   10.10.0.x
db   IN  A   10.10.1.x
```



Step 2c – Configure DNS server

4. Create file /etc/named.conf [Replace X with your DNS server IP]

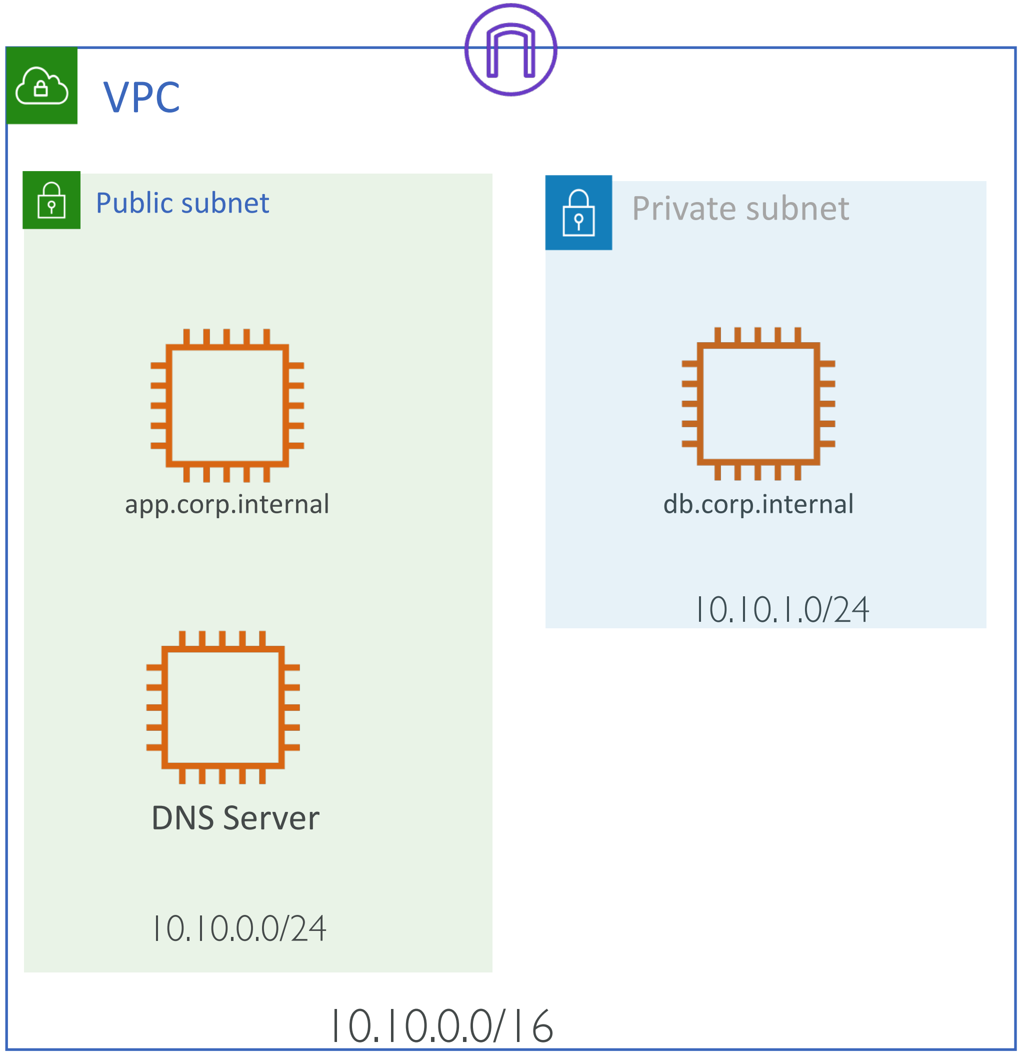
```
options {
  directory "/var/named";
  dump-file "/var/named/data/cache_dump.db";
  statistics-file "/var/named/data/named_stats.txt";
  memstatistics-file "/var/named/data/named_mem_stats.txt";
  allow-query { any; };
  allow-transfer     { localhost; 10.10.0.X; };
  recursion yes;
  forward first;
  forwarders {
    10.10.0.2;
  };
  dnssec-enable yes;
  dnssec-validation yes;
  dnssec-lookaside auto;
  /* Path to ISC DLV key */
  bindkeys-file "/etc/named.iscdlv.key";
  managed-keys-directory "/var/named/dynamic";
};
zone "corp.internal" IN {
    type master;
    file "corp.internal.zone";
    allow-update { none; };
};
```



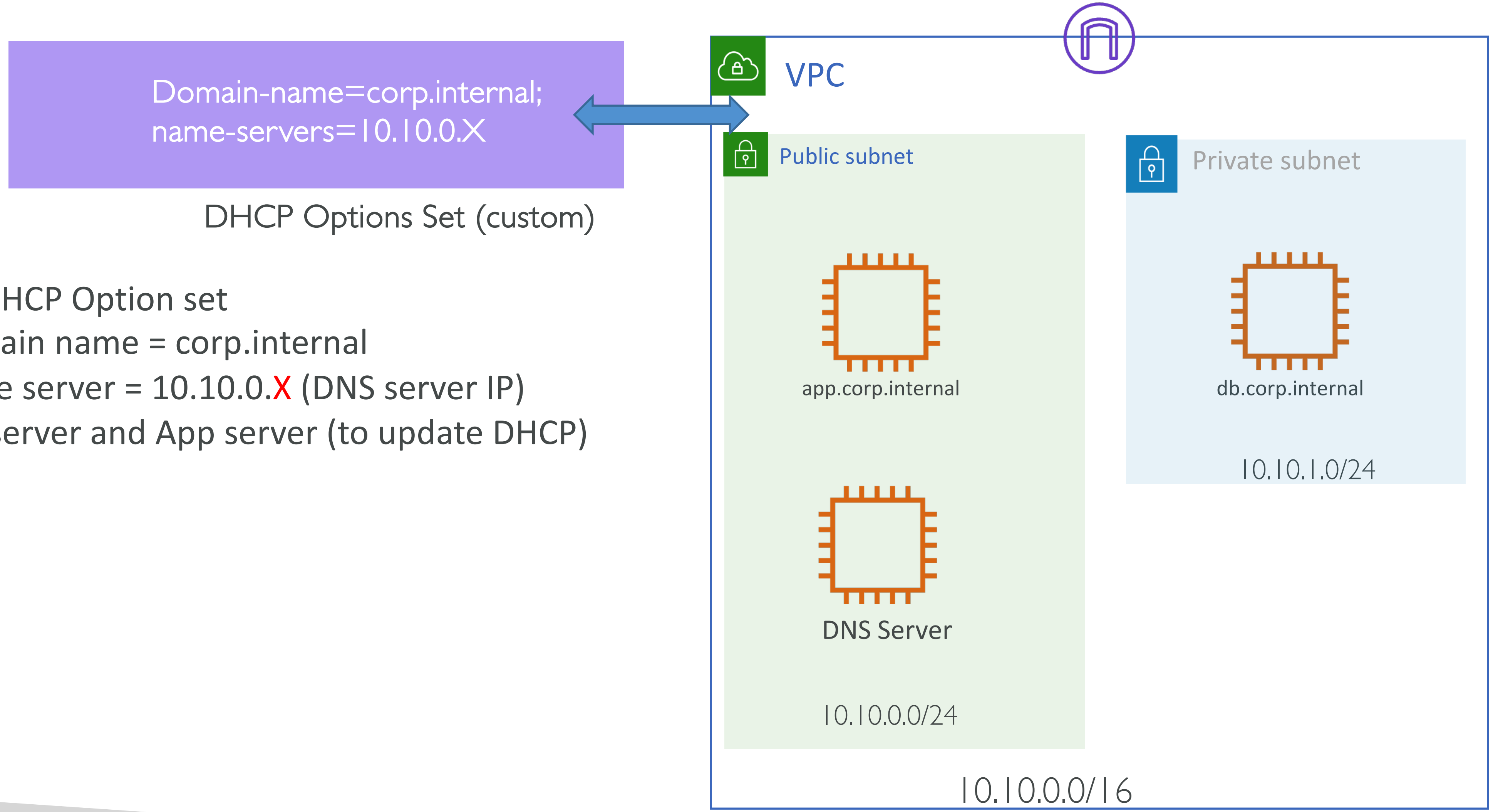
Step 2d – Configure DNS server

5. Restart **named** service

$service named restart
$chkconfig named on

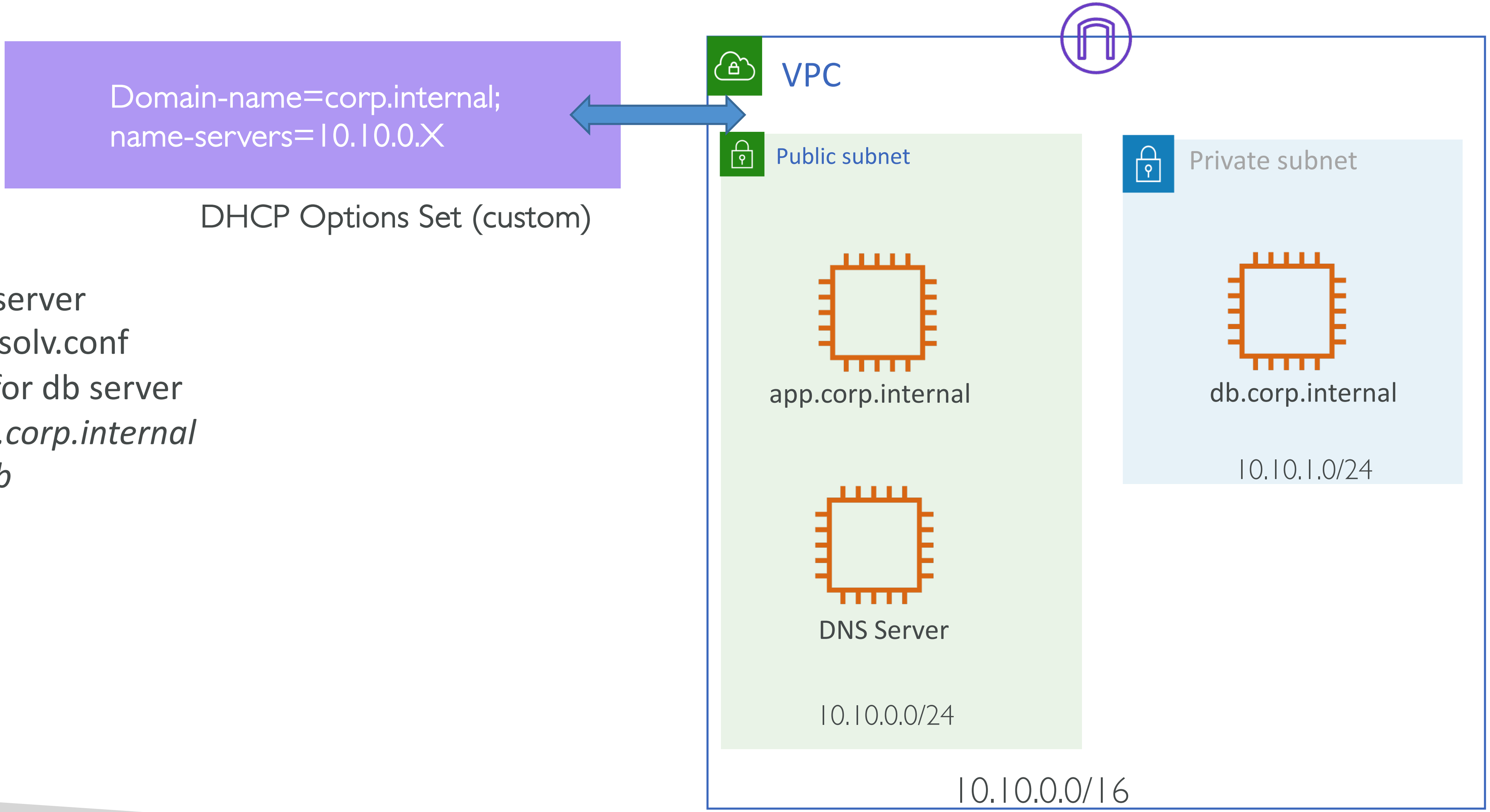


Step 3 – Create DHCP Option set



1. Create new DHCP Option set
    1. Set Domain name = corp.internal
    2. Set name server = 10.10.0.X (DNS server IP)
2. Reboot DNS server and App server (to update DHCP)

Step 4 – Verify custom domain names



1. Login to App server
2. Check /etc/resolv.conf
3. Resolve DNS for db server

   $nslooup db.corp.internal

   $nslookup db

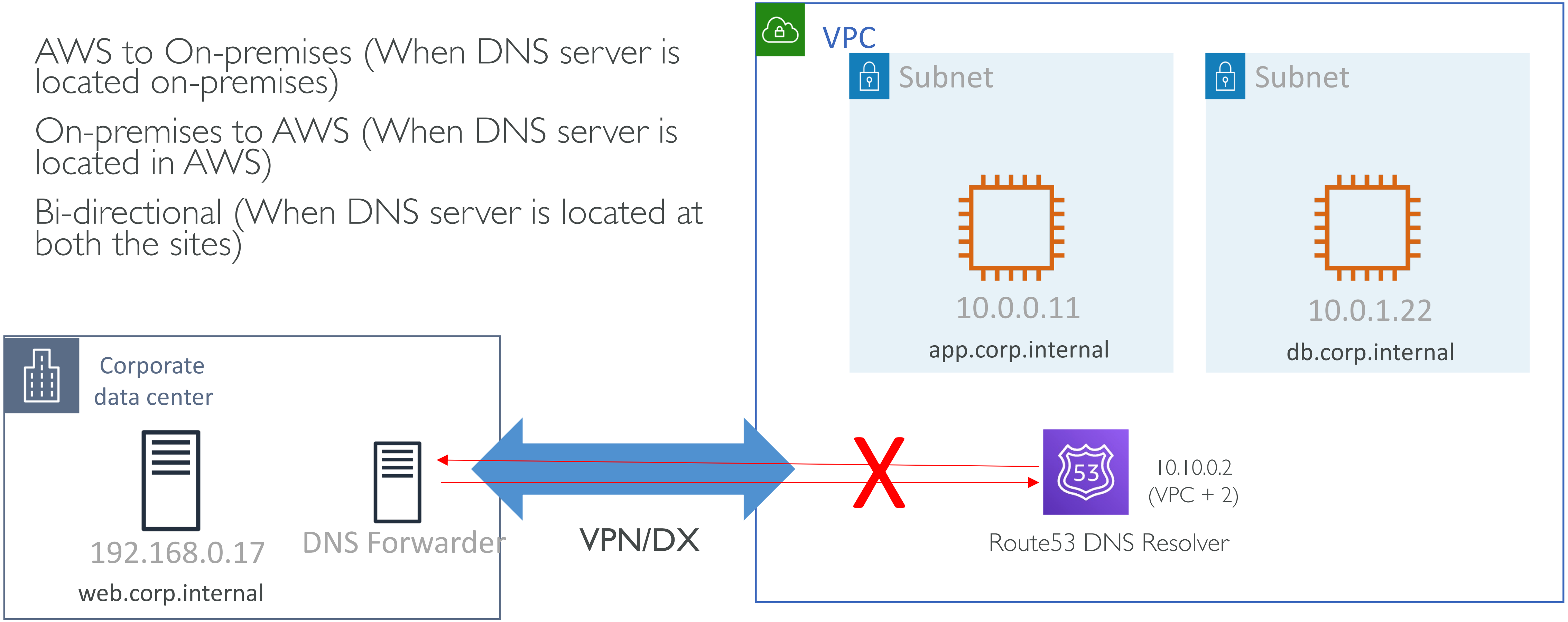
   $ping db

Introduction

Route 53 Resolver Endpoints

What about DNS resolution from outside VPC?

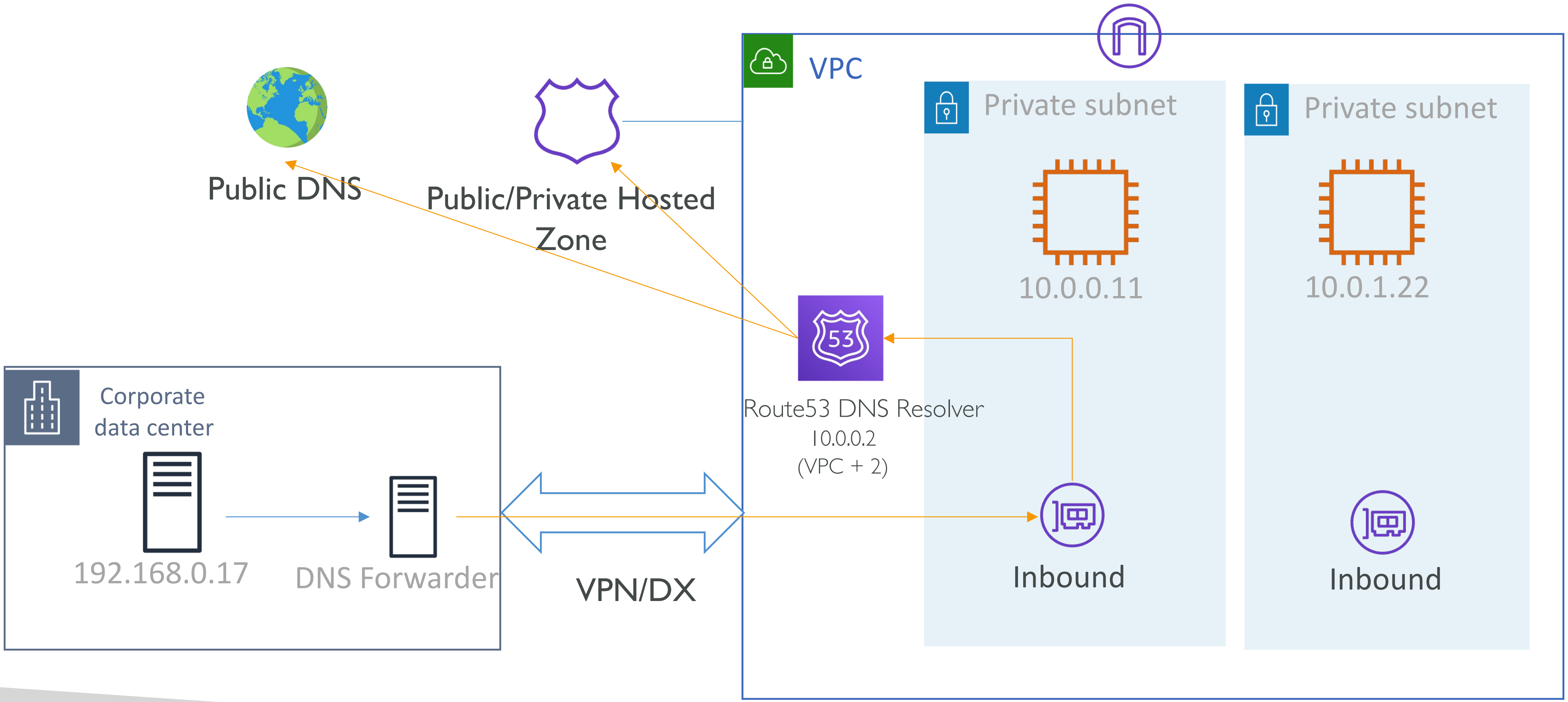
1. AWS to On-premises (When DNS server is located on-premises)
2. On-premises to AWS (When DNS server is located in AWS)
3. Bi-directional (When DNS server is located at both the sites)



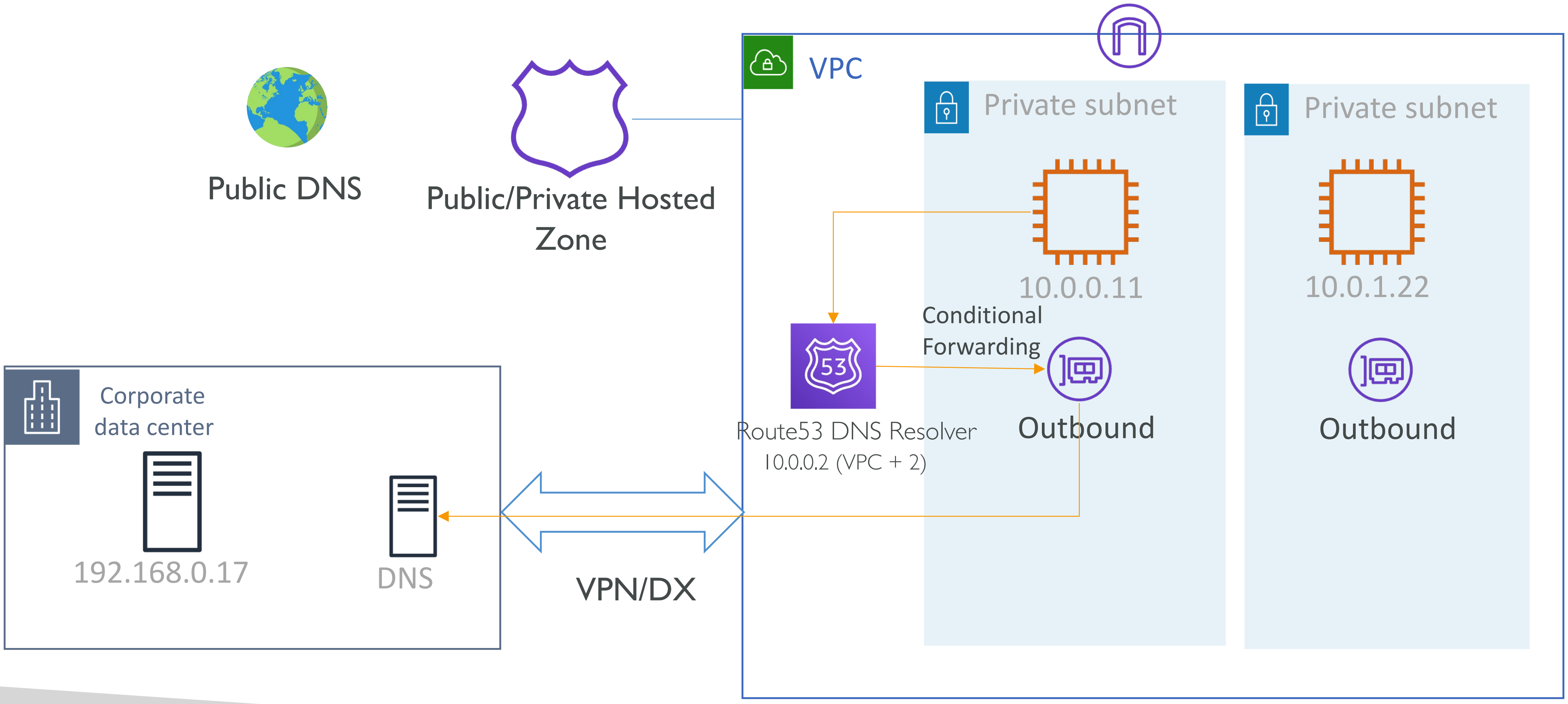
Route53 Resolver Endpoint

- Officially named the .2 DNS resolver to **Route 53 Resolver**
- Provides Inbound & Outbound Route53 resolver endpoints
- Provisions ENI in the VPC which are accessible over VPN or DX
- Inbound -> On-premise forwards DNS request to R53 Resolver
- Outbound -> Conditional forwarders for AWS to On-premise

Route53 Resolver Endpoint - Inbound



Route53 Resolver Endpoint - Outbound



VPC DNS & DHCP exam essentials

- VPC has a default DNS server **AmazonProvidedDNS**
- AWS Provided DNS server runs at VPC base + 2 IP address. You can also query DNS server at this IP or 169.254.169.253 virtual IP from within the VPC
- AmazonProvidedDNS resolves DNS from AWS Route53 Private Hosted Zone, VPC internal DNS and Public DNS
- VPC DNS settings can be changed using DHCP Option sets
- DHCP Option set can not be edited. Create new one and associate it with VPC.
- You can have only one DHCP option set associated with a VPC at a time.
- For hostname resolution, we should enable both **enableDnsSupport** and **enableDnsHostname**
- For hybrid DNS resolution between VPC and on-premises network, use Route53 Resolver endpoints.

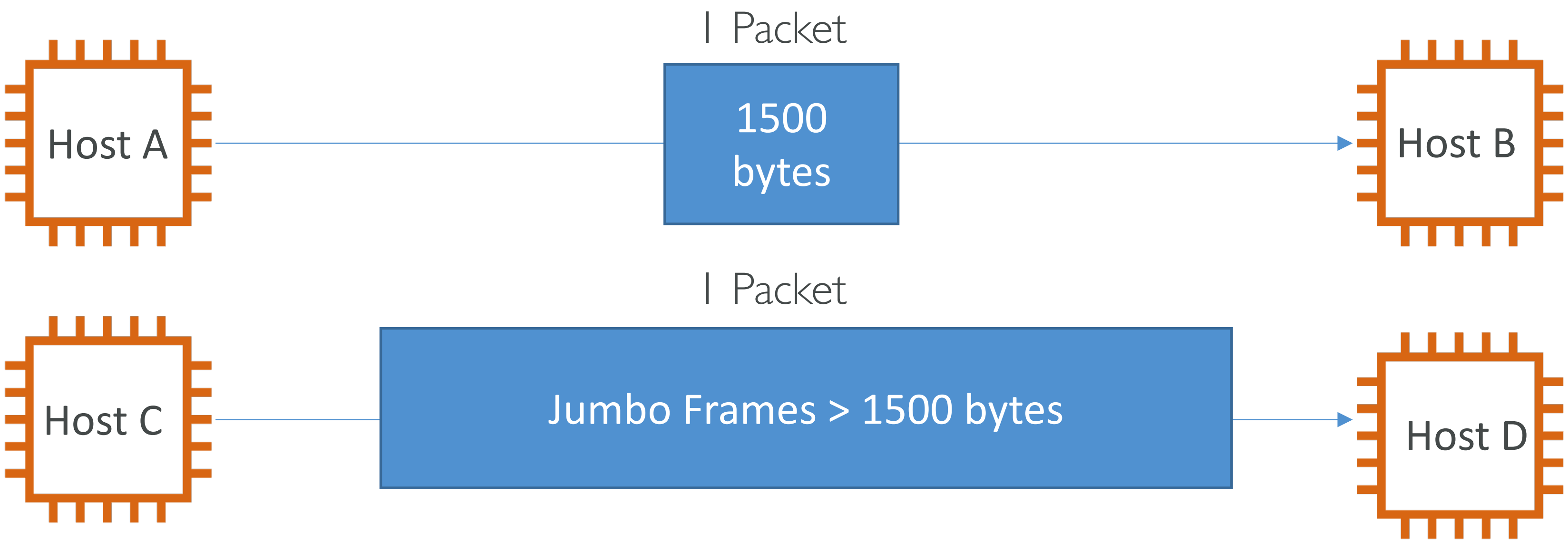
VPC Network Performance & Optimization

VPC Network Performance and Optimization

Network Performance - Basics

- Bandwidth – Maximum rate of transfer over the network
- Latency – Delay between two points in a network
  - Delays include propagation delays for signals to travel across medium
  - Also includes the processing delays by network devices
- Jitter – Variation in inter-packet delays.
- Throughput – Rate of successful data transfer (measured in bits per sec)
  - Bandwidth, Latency and Packet loss directly affects the throughput
- Packet Per Second (PPS) – How many packets processed per seconds
- Maximum Transmission Unit (MTU) – Largest packet that can be sent over the network

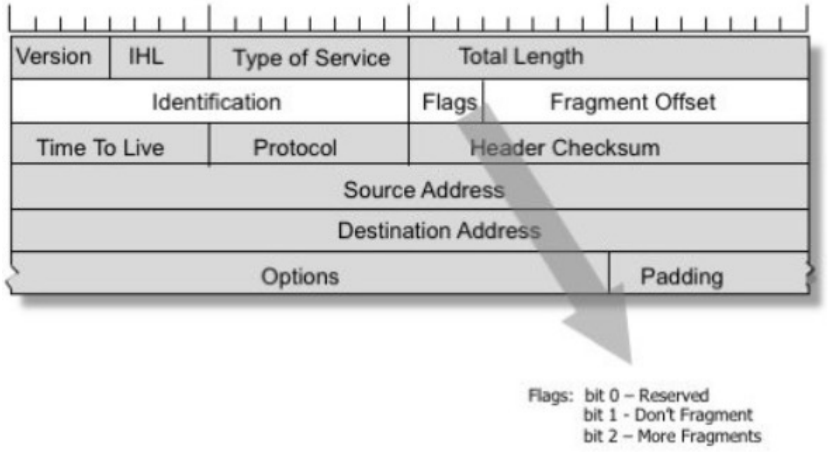
MTU



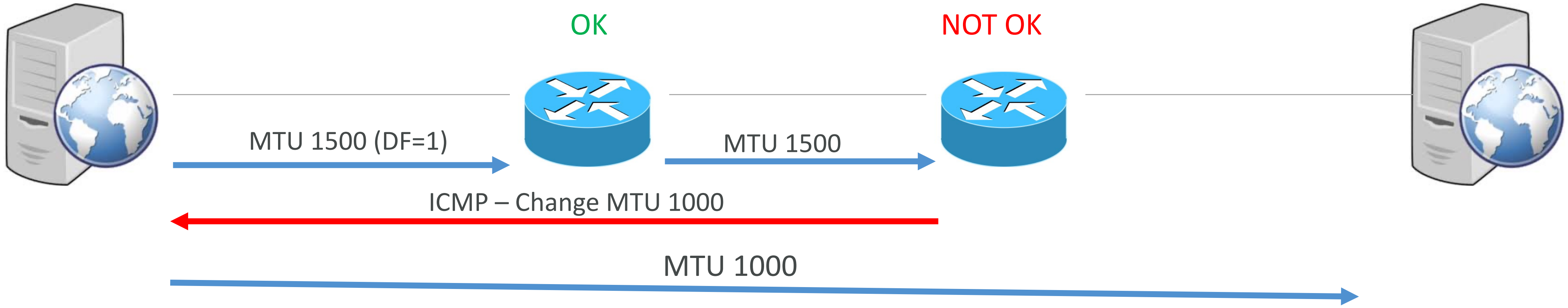
- Most of the networks support MTU of 1500 bytes
- Jumbo Frames packets are larger than 1500 bytes up to 9001 bytes
- Benfits of using Jumbo frames
  - Less packets
  - More throughput
  - Increasing the MTU increases the throughput when you can't increase the Packet Per Second (PPS)

-

Path MTU Discovery example



For MTU Path Discovery
ICMP must be allowed

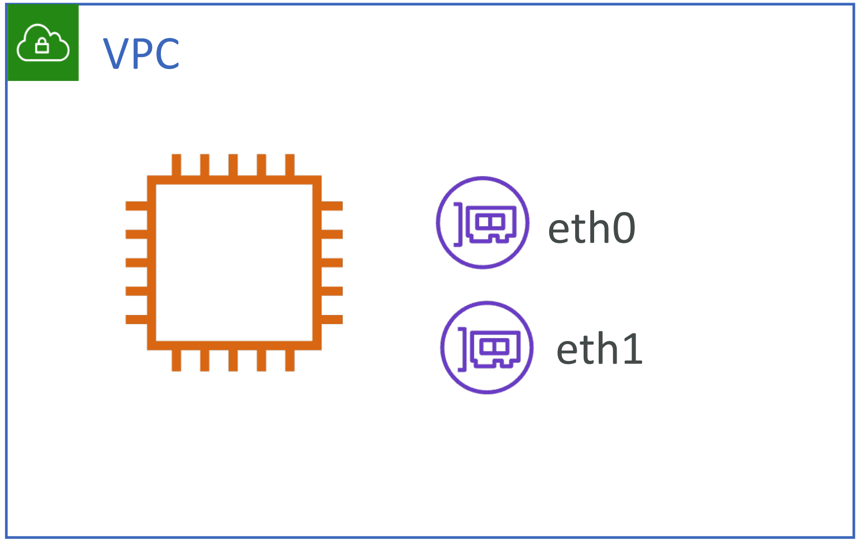


Jumbo Frames

- 9001 MTU
- Jumbo frames are enabled in a VPC by default
- AWS supports Jumbo frame within VPC however traffic leaving VPC over IGW or inter region VPC peering does not support Jumbo frames (Limited to 1500 byte)
- Jumbo frames are also supported between VPC and on-premises network using AWS Direct Connect.
- Using Jumbo frames inside EC2 cluster placement groups provides maximum network throughput
- Jumbo frames should be used with caution for traffic leaving the VPC. If packets are over 1500 bytes, they are fragmented, or they are dropped if the Don't Fragment flag is set in the IP header.

Defining MTU on EC2 instances

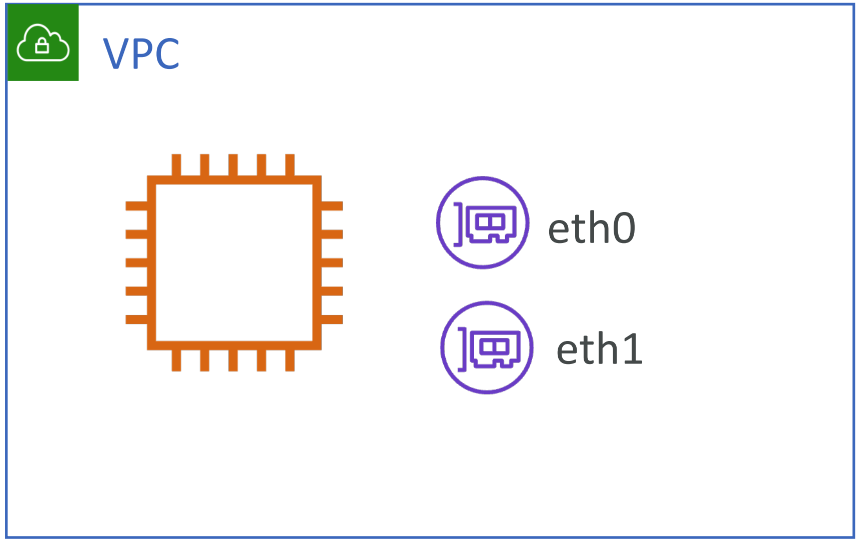
- MTU also depends on Instance Type
- Defined at the ENI level
- You can check the path MTU between your device and target endpoint using tracepath command
  - *tracepath amazon.com*
- To check the MTU on your interface
  - *ip link show eth0*
- To set MTU value on Linux
  - *sudo ip link set dev eth0 mtu 9001*



Demo – MTU for EC2

1. Launch 2 EC2 instances in Public Subnet and connect to any one
2. Check MTU using EC2 Public IP: $tracepath <Public IP>
3. Check MTU using EC2 Private IP: $tracepath <Private IP>
4. Check MTU on EC2 interface

   $ip link show eth0



MTU

- Within AWS:
  - Within VPC : Supports Jumbo frames (9001 bytes)
  - Over the VPC Endpoint : MTU 8500 bytes
  - Over the Internet Gateway : MTU 1500 bytes
  - Intra region VPC Peering: MTU 9001 bytes
  - Inter region VPC Peering : MTU 1500 bytes
- On-premise network:
  - Over the VPN using VGW : MTU 1500 bytes
  - Over the VPN via Transit Gateway : MTU 1500 for traffic for Site to Site VPN
  - Over the DirectConnect (DX) : Supports Jumbo frames (9001 bytes)
  - Over the DX via Transit Gateway : MTU 8500 for VPC attachments connected over the Direct Connect

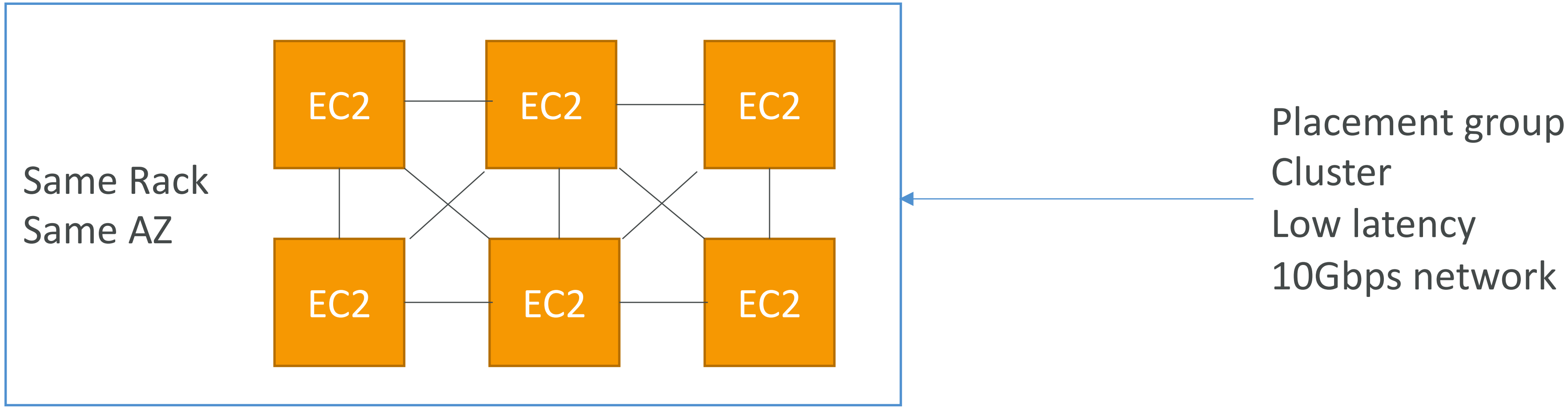
Optimizing Network Performance

EC2 Network optimization

- Cluster Placement Groups
- EBS Optimized Instances
- Enhanced Networking

Placement Groups – Cluster

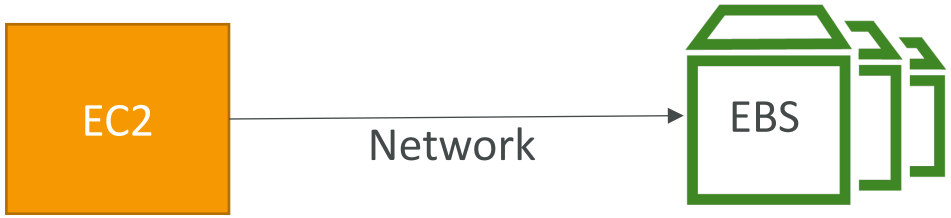
- A logical grouping of instances within single Availability zone
- Ideal for distributed applications that require low latency like HPC



EBS Optimized Instances

- EBS is a network drive (i.e. not a physical drive)
  - It uses the network to communicate the instance, which means there might be a bit of latency
- Hence, EBS input and output affect network performance
- **Amazon EBS-optimized instances** deliver dedicated throughput between Amazon EC2 and Amazon EBS
- This minimizes contention between Amazon EBS Input/Output (I/O) and other traffic from Amazon EC2 instance

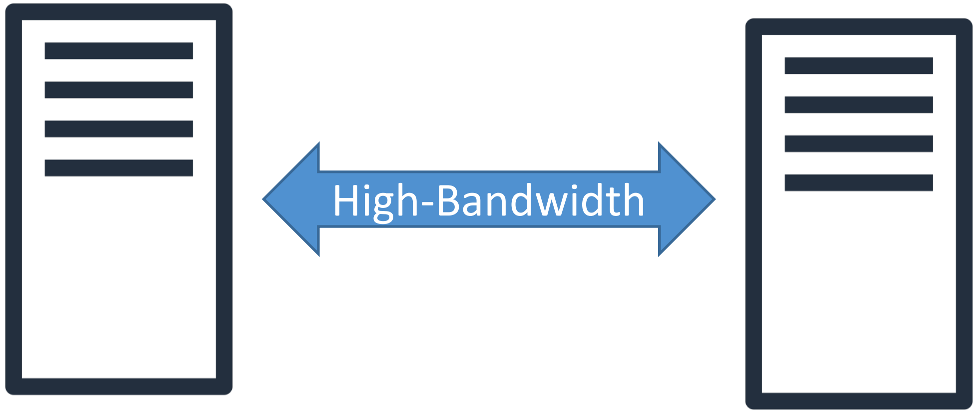
M6g, M5, M4, C6g, C5, C4, R6g, P3, P2, G3, and D2 and more



Enhanced Networking

Enhanced Networking – What is it?

- Over 1M PPS performance
- Reduces instance-to-instance latencies
- SR-IOV with PCI passthrough, to get the hypervisor out of the way and for consistent performance
- Enabled using intel ixgbevf driver or Elastic Network Adapter (ENA)



SR-IOV and PCI for Enhanced Networking

- SR-IOV and PCI passthrough are methods of device virtualization that provide higher I/O performance and lower CPU utilization
- SR-IOV allows a single physical NIC to present itself as multiple vNICs
- PCI passthrough enables PCI devices such as ENI to appear as if they are physically attached to the guest operating system bypassing hypervisor
- Ultimately in combination this allows low latency, high rate data transfer (>1 M PPS)

Enhanced Networking pre-requisites

- Depending on Instance Type, Enhanced Networking can be enabled using one of the following Network drivers
  - Option 1: Intel 82599 VF up to 10 Gbps (VF uses ixgbevf driver)
  - Option 2: Elastic Network Adapter (ENA) up to 100 Gbps
- The eligible EC2 instance families support **either of** the above two drivers

Remember:

For Enhanced Networking, it requires support from both EC2 operating system (AMI) and Instance Type that is flagged for Enhanced Networking

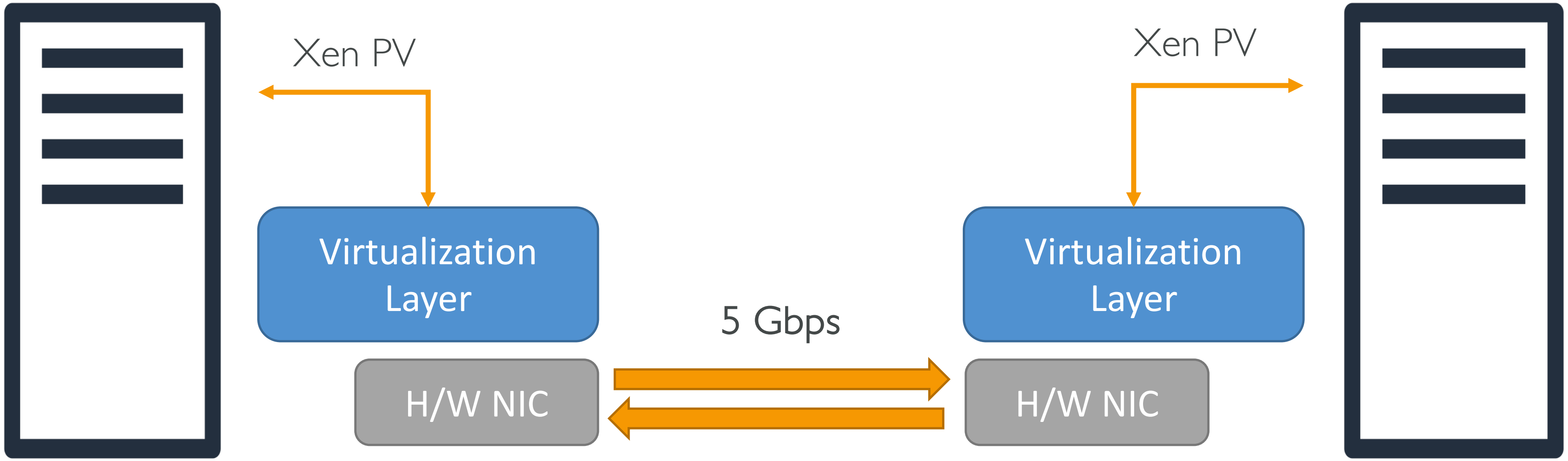
Supported Instance types

- Instances supporting **Elastic Network Adapter (ENA) for speed upto 100 Gbps**
  - A1, C5, C5a, C5d, C5n, C6g, F1, G3, G4, H1, I3, I3en etc
- Instances supporting **Intel 82599 Virtual Function (VF) interface for speed upto 10 Gbps**
  - C3, C4, D2, I2, M4 (excluding m4.16xlarge), and R3 etc

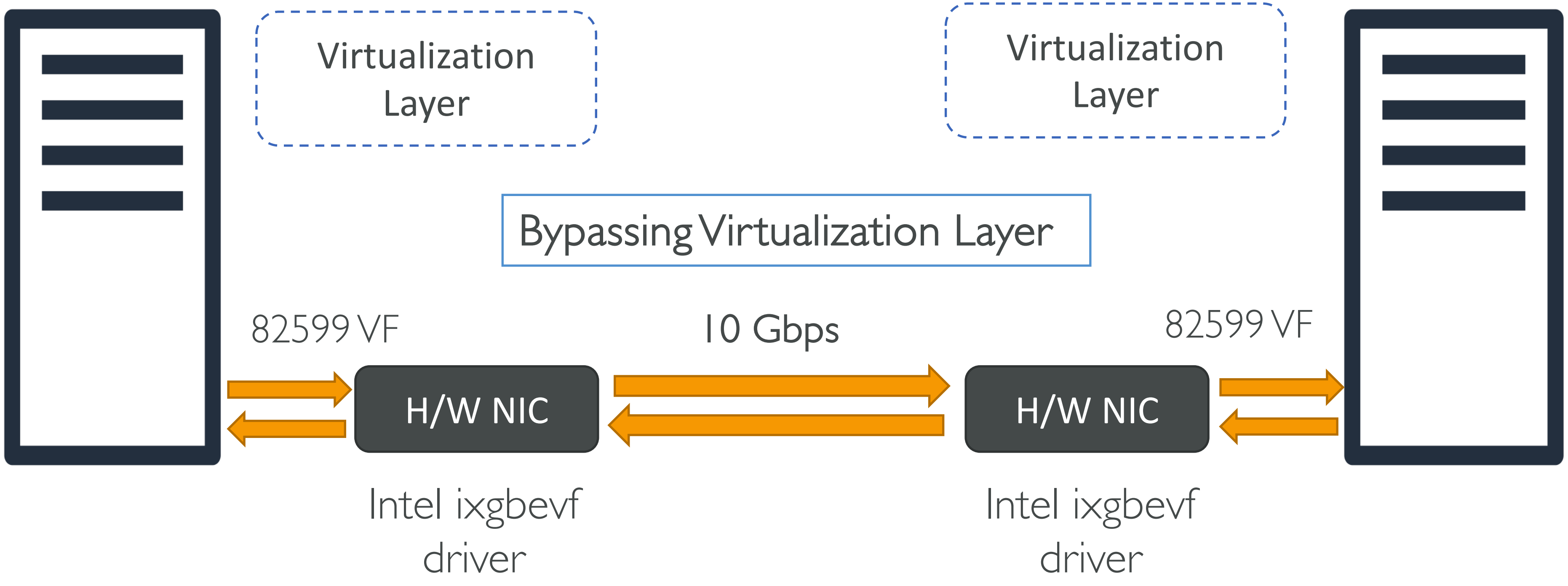
Verifying enhanced networking

Intel VF ixgbevf	ENA
$ ethtool -i eth0	*$ ethtool -i eth0*
driver: ixgbevf	*driver: ena*
C3, C4, D2, I2, R3, M4 (not m4.16xlarge)	C5, F1, G3, P2, P3, R4, I3, X1, X1e, m4.16xlarge

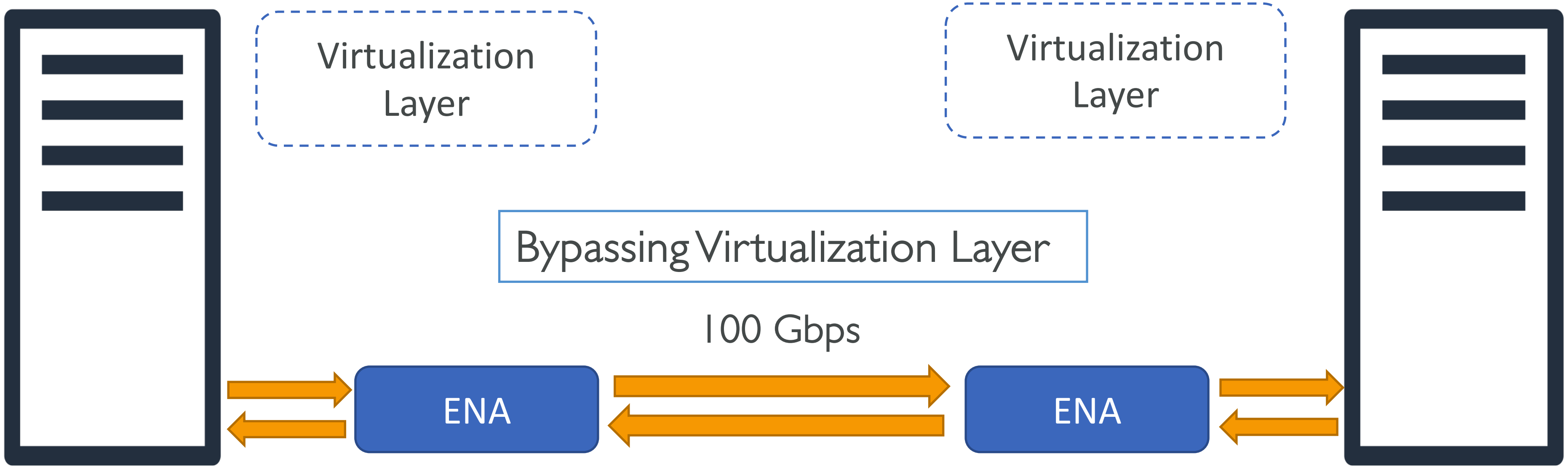
EC2 Networking - default



EC2 Enhanced Networking – with Intel VF



EC2 Enhanced Networking – with ENA



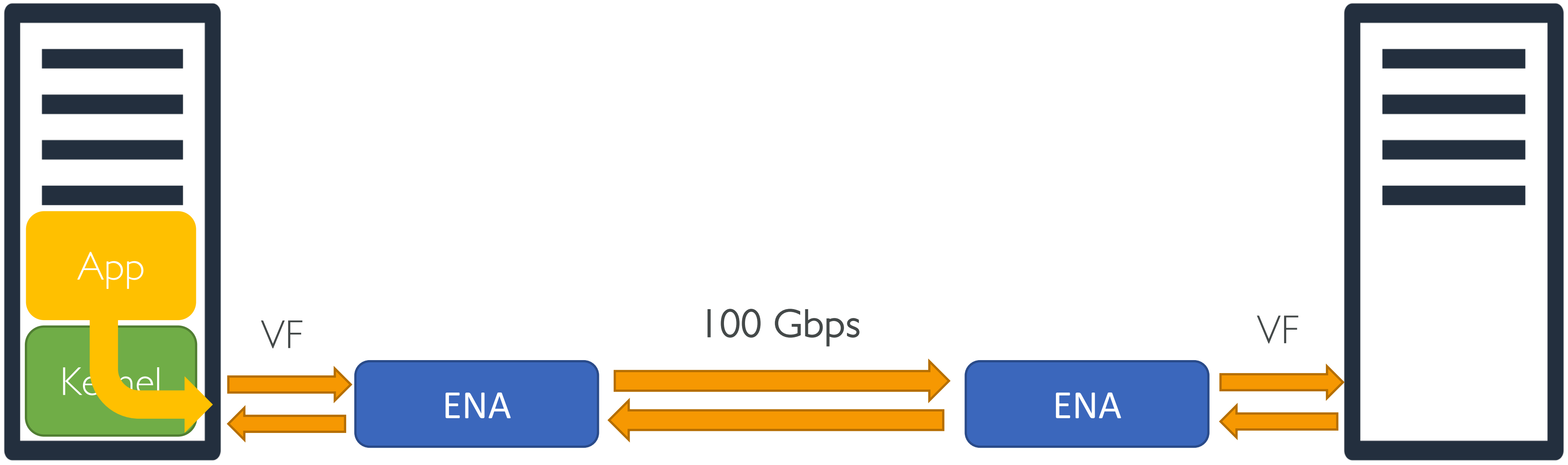
End

Additional Network optimization techniques - DPDK & EFA

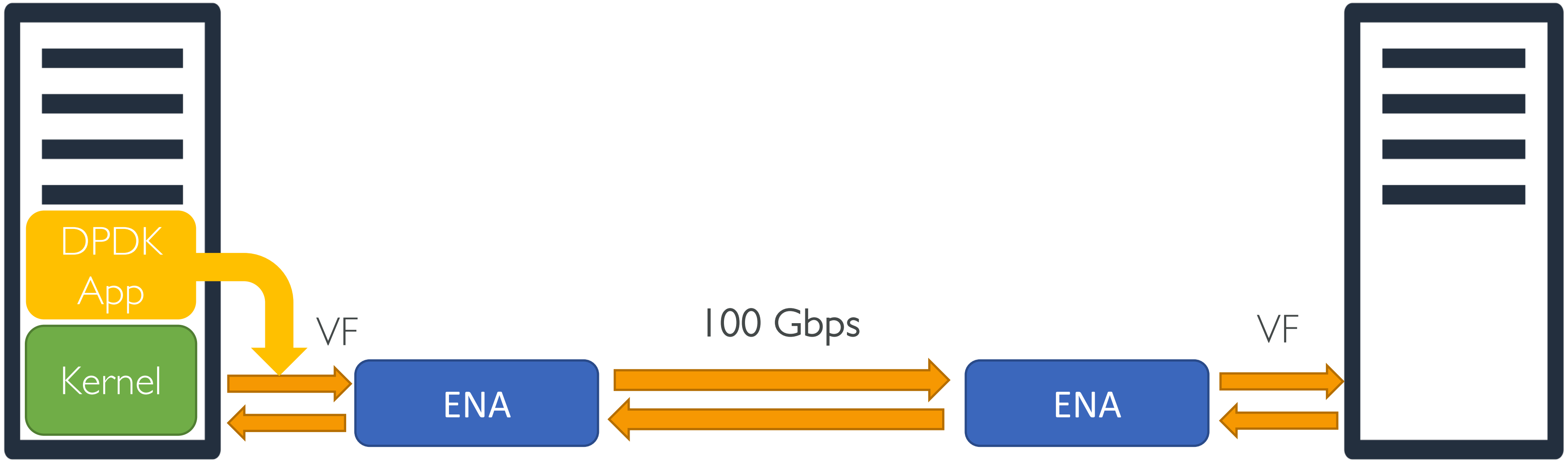
Additional Tuning & Optimization - DPDK

- Intel Data Plane Development Kit (**DPDK**) is a set of libraries and drivers for fast packet processing.
- While Enhanced Networking and SR-IOV reduce overhead of packet processing between Instance and Hypervisor, **DPDK** reduces overhead of packet processing inside the **Operating System**
- DPDK provides
  - Lower latency due to Kernel bypass
  - More control of packer processing
  - Lower CPU overhead

Packet processing without DPDK



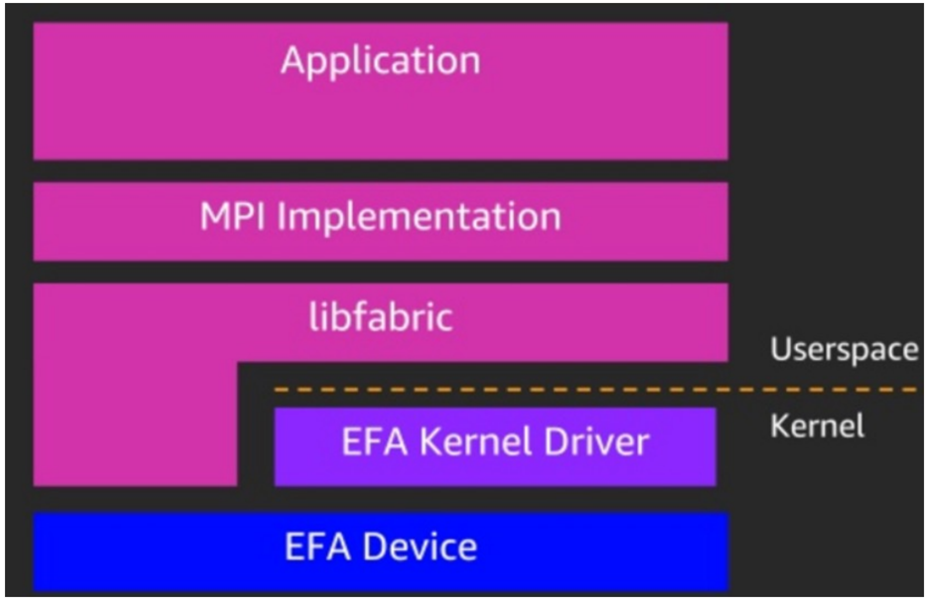
Packet processing with DPDK



Application is developed to use DPDK libraries

EFA – Elastic Fabric Adapter

- EFA is an ENA with added capabilities
- Provides lower latency and higher throughput
- Provides OS bypass functionality (Linux)
- For windows instance, it acts just as ENA
- With an EFA, HPC applications use MPI to interface with the Libfabric API which bypasses OS kernel and communicates directly with the EFA device to put packets on the network



c5n.18xlarge, p3dn.24xlarge

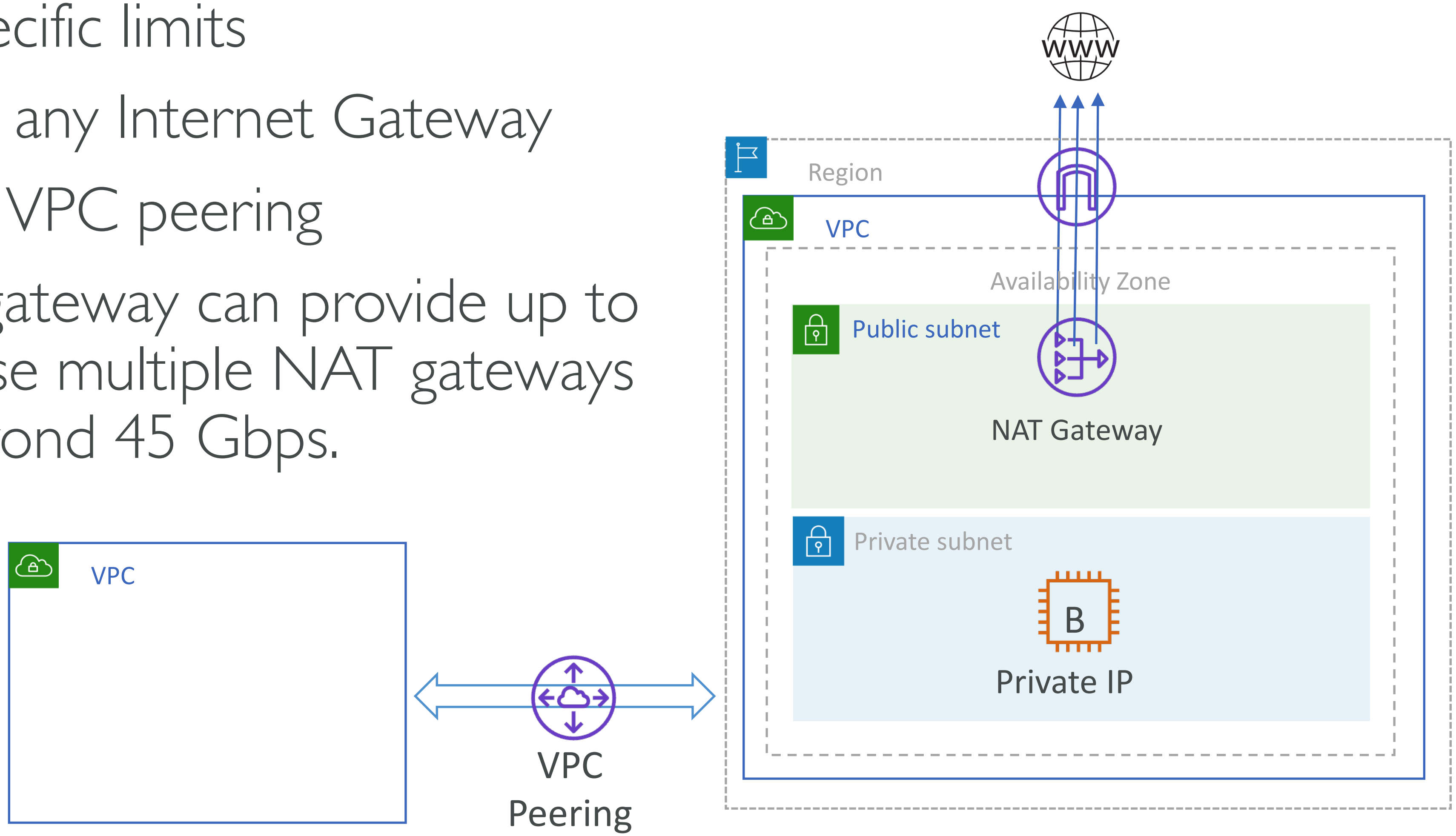
Network Bandwidth Limits

Let's discuss..

- VPC Bandwidth Limits – Internet Gateway, NAT Gateway, VPC Peering
- EC2 Bandwidth Limits
- Bandwidth over a VPN Connection & AWS Direct Connect & Transit Gateway
- Network Flow
  - Network flow is a 5 tuple point to point connection (Protocol Src IP, Src Port, Dest IP, Dest Port)
  - Multiple flows allow to scale the network performance

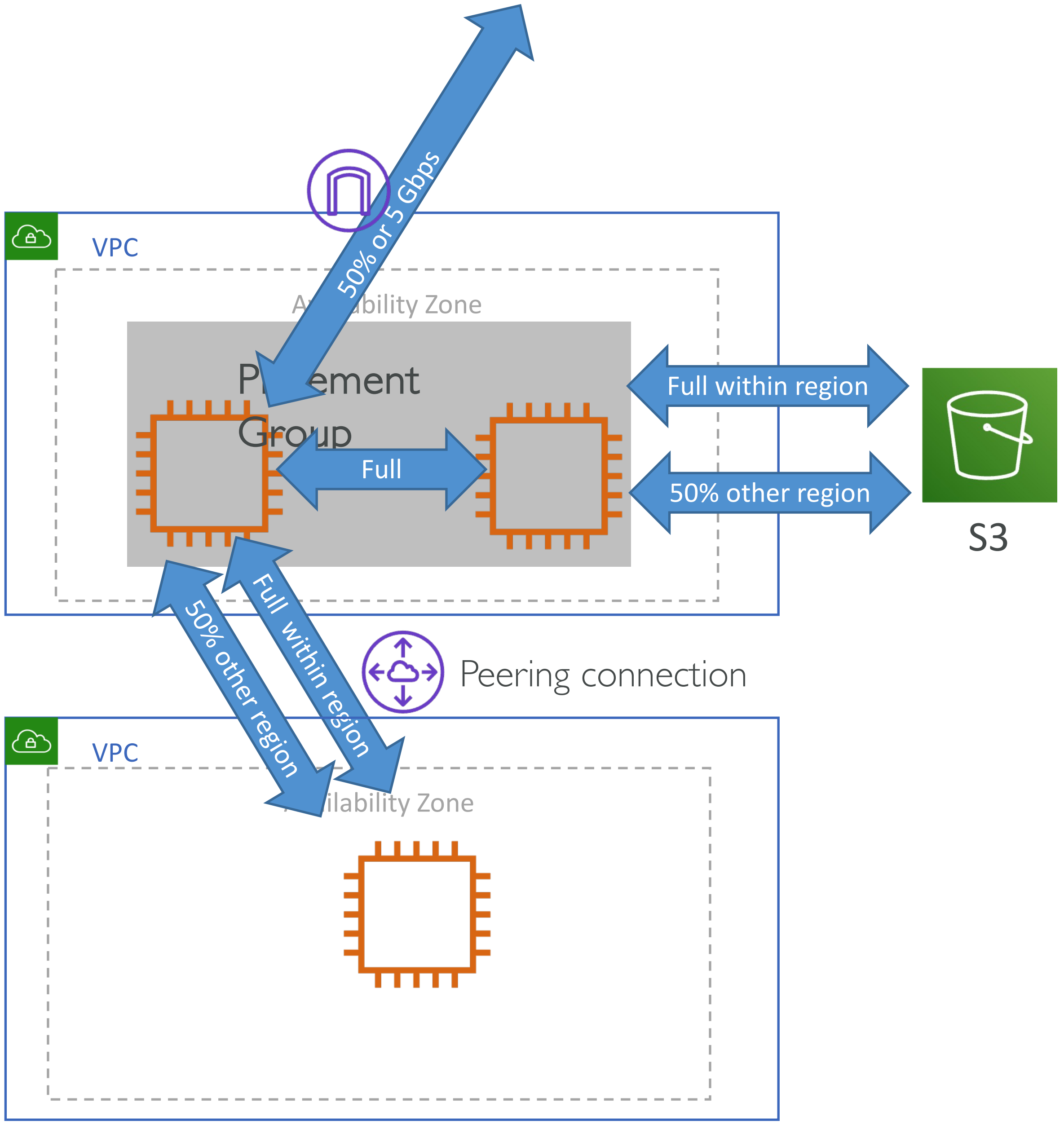
VPC Bandwidth limits

- No VPC specific limits
- No limit for any Internet Gateway
- No limit for VPC peering
- Each NAT gateway can provide up to 45 Gbps. Use multiple NAT gateways to scale beyond 45 Gbps.



EC2 Bandwidth limits

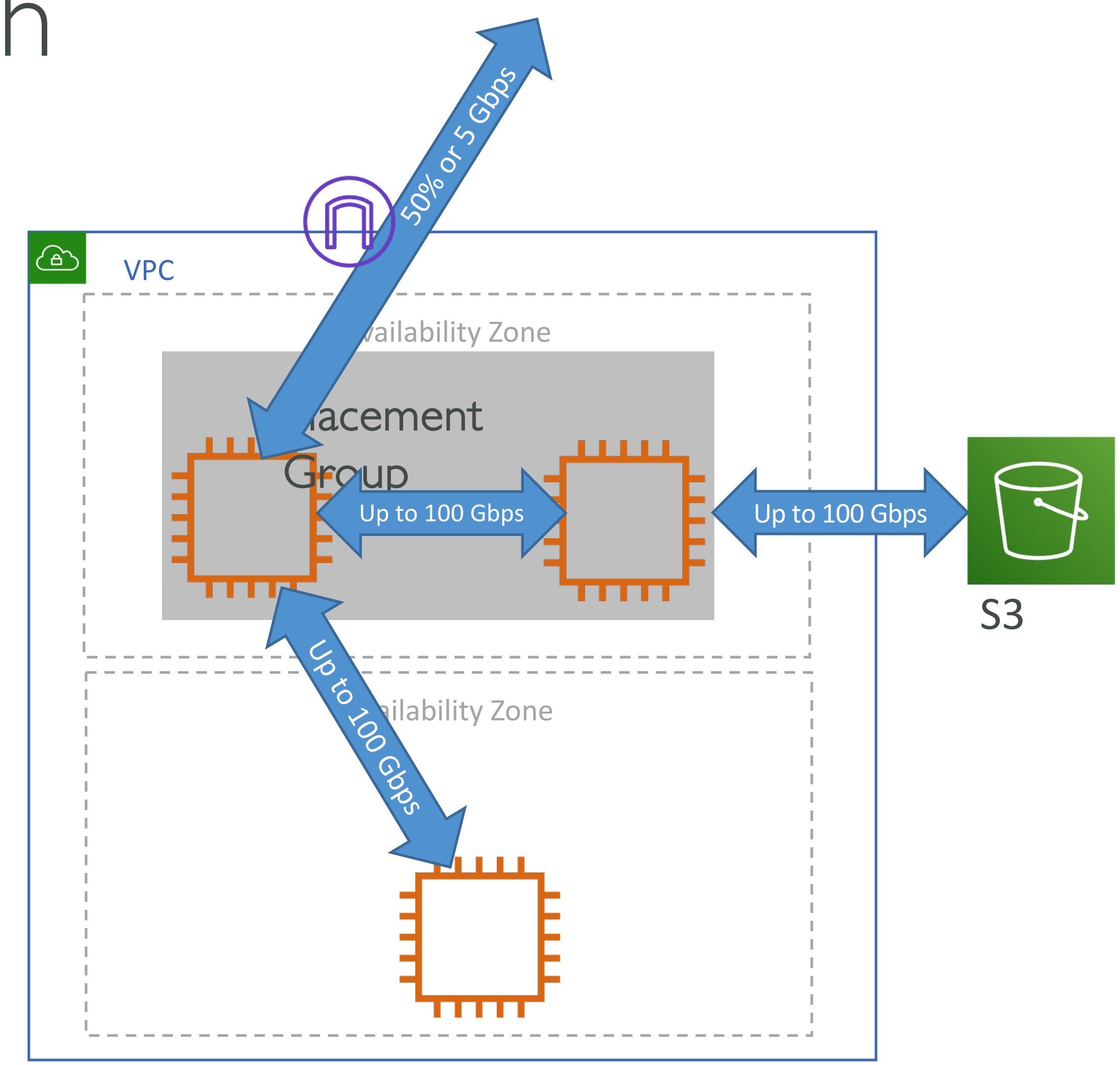
- Depends on factors like Instance family, vCPU, traffic destination etc.
- Within the Region
  - Can utilize the full network bandwidth available to the instance.
- To other Regions, an internet gateway, or Direct Connect
  - Can utilize up to 50% of the network bandwidth (current generation instance with a minimum of 32 vCPUs)
  - Otherwise limited to 5 Gbps.



EC2 maximum bandwidth

- With Intel 82599 VF interface
  - 10 Gbps aggregate and 5 Gbps flow-based bandwidth limit
- With AWS ENA driver
  - 10 Gbps flow limit inside a placement group
  - 5 Gbps flow limit outside of a placement group
  - Aggregate bandwidth of 100 Gbps with multiple flows within a VPC or a peered VPC or to S3 (using VPC endpoint) in the same region

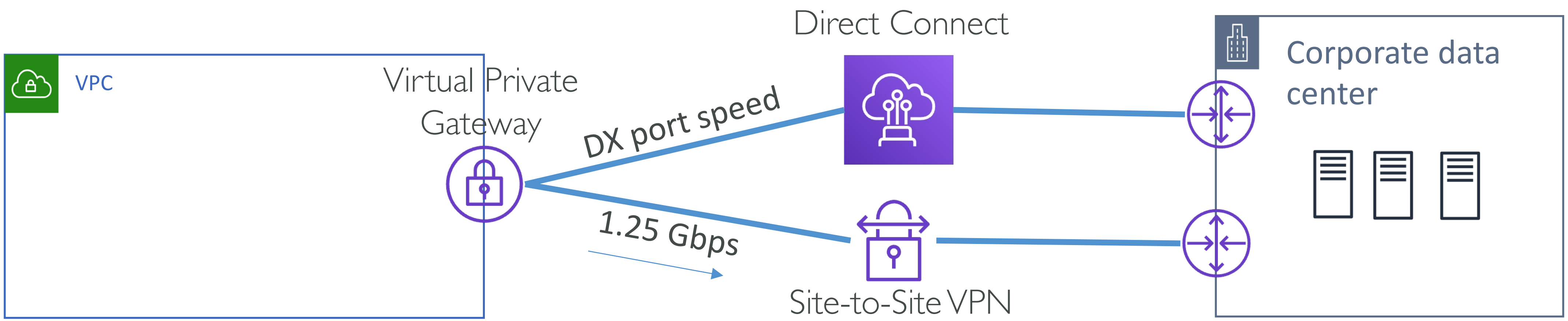
AWS P4d instances deployed in UltraClusters supercomputer provides 400 Gbps networking



EC2 max bandwidth with ENA

VPN and DX Bandwidth

- 1.25 Gbps aggregate bandwidth per Virtual Private Gateway for traffic from AWS to on-premises
- Multiple VPN connections to the same Virtual Private Gateway are bound by an aggregate throughput limit
- AWS Direct connect bandwidth is defined by Port Speed opted
- For AWS Direct Connect connection on a Virtual Private Gateway, the throughput is bound by the Direct Connect physical port itself.
- Transit Gateway supports 1.25Gbps per VPN tunnel and 50 Gbps total VPN bandwidth



Network I/O Credits

Network Credits

- Instance families such as R4 and C5 use a network I/O credit mechanism
- Most application do not consistently need a high network performance
- These instances perform well above baseline n/w performance during peak requirement
- Make sure that you consider the accumulated n/w credits before doing performance benchmark for instances supporting network I/O credits mechanism

Use cases for high performance networks

- High Performance Computing (HPC) workloads
  - Using cluster placement groups with HPC enables access to a low-latency, high-bandwidth network for tightly coupled, IO-intensive, and storage-intensive workloads.
  - For faster Amazon EBS IO, it is recommend using Amazon EBS-optimized instances and Provisioned IOPS volumes for high performance.
- Real Time Media
  - For applications like VoIP, Media streaming using RTP and RTMP
  - Enhanced networking provides smoother packet delivery with less packet loss and jitter
- More use cases: Data Processing, Backup, On-prem Data Transfer, etc.

Summary

Summary

- For high network bandwidth and throughput, consider using Jumbo Frames, EC2 Enhanced Networking, Placement groups, EBS optimized instances, DPDK
- Instance level network optimization with
  - Enhanced Networking (SR-IOV, ENA, Intel VF 82599)
  - Placement Groups
  - EBS-Optimized Instances
- Operating system level network optimization with DPDK
- EFA is ENA with additional OS-bypass capability which provides further improved network performance for HPC workloads

Exam Essentials

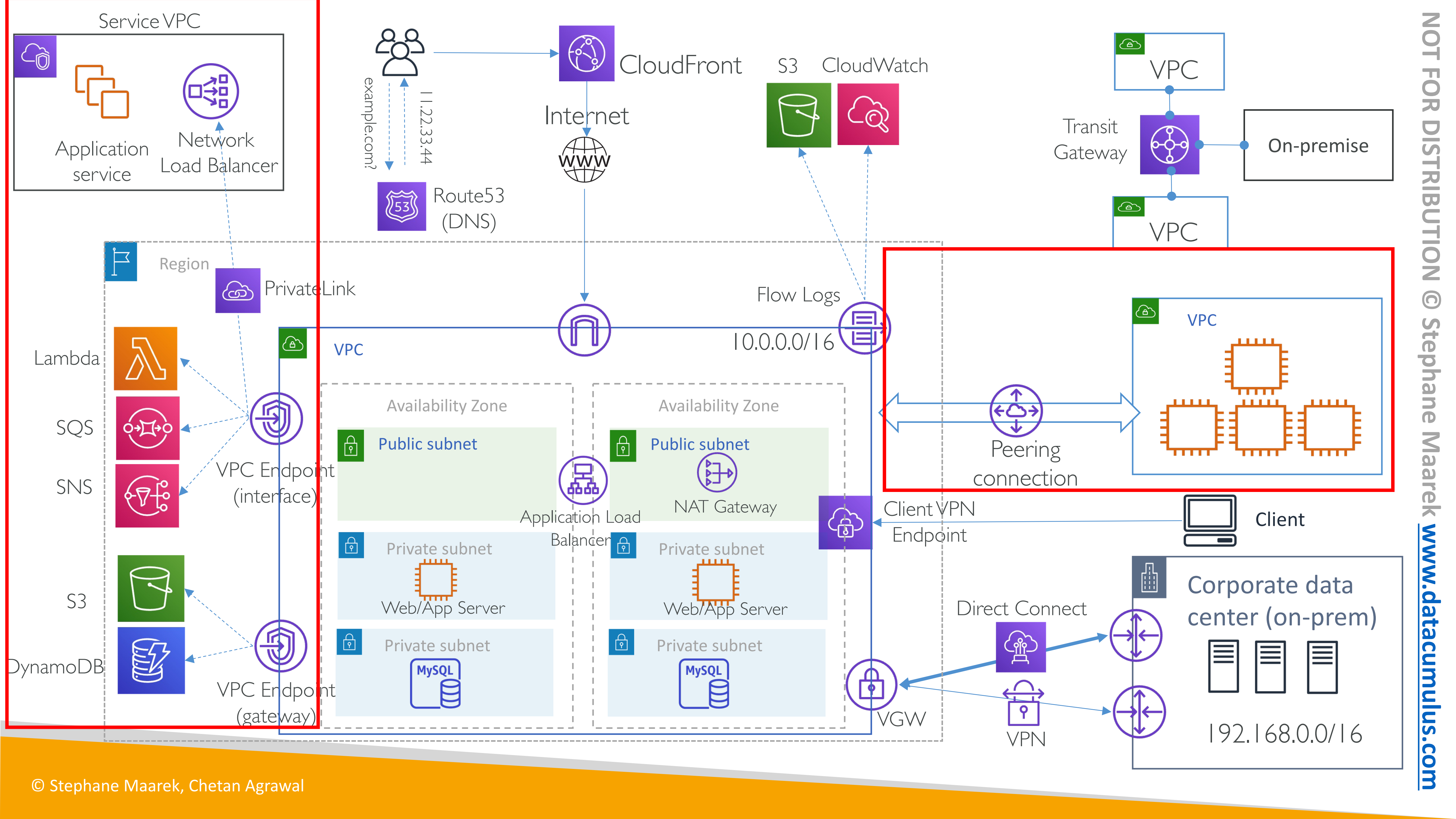
Exam Essentials

- Within VPC the MTU size can be 9001 bytes with Jumbo Frames
- For the following cases the maximum MTU is 1500 bytes:
  - Traffic over an internet gateway
  - Traffic over an inter-region VPC peering connection
  - Traffic over VPN connections
- **When PPS is bottleneck, increased MTU provides more throughput**
- While Enhanced Networking and placement groups lowers the latency between EC2 and hypervisor, DPDK improves the packet processing at OS level

Exam Essentials

- EC2 network bandwidth depends on many factors including Instance family, size, enhance networking support etc.
- Bandwidth for aggregate multi-flow traffic available to an instance depends on the destination of the traffic
  - Within the Region
    - Full bandwidth of the [EC2 instance]
    - Within the AWS region you can get up to 100 Gbps bandwidth between EC2 instances or between EC2 and S3 by using multiple-flows
  - Outside of the Region, Internet or Direct Connect
    - 50% of the available network bandwidth for current generation instances with minimum 32vcpu
    - 5 Gbps for the instances with less than 32 vcpu
- Bandwidth for single-flow (5-tuple) traffic is limited to 5 Gbps and can get up to 10 Gbps if the instances are within the Cluster placement group

Amazon VPC – DNS & DHCP



Service VPC
Application service
Network Load Balancer
example.com?
11.22.33.44
Route53 (DNS)
CloudFront
Internet
S3
CloudWatch
VPC
Transit Gateway
On-premise
VPC
Region
PrivateLink
Flow Logs
10.0.0.0/16
VPC
Lambda
SQS
SNS
VPC Endpoint (interface)
Availability Zone
Availability Zone
Public subnet
Public subnet
NAT Gateway
Application Load Balancer
Private subnet
Private subnet
Web/App Server
Web/App Server
Private subnet
Private subnet
MySQL
MySQL
S3
DynamoDB
VPC Endpoint (gateway)
VPC
Peering connection
Client VPN Endpoint
Client
Direct Connect
Corporate data center (on-prem)
192.168.0.0/16
VGW
VPN
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VPC traffic Monitoring, Troubleshooting and Analysis

In this section

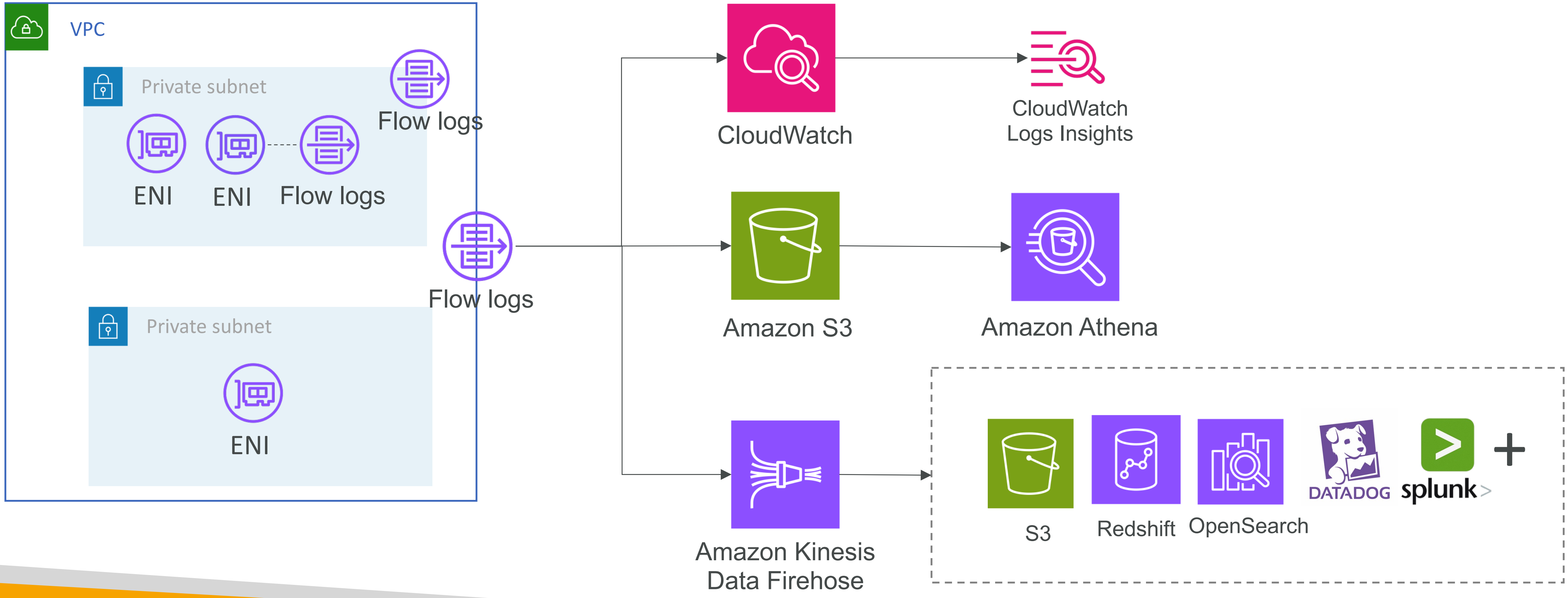
- VPC Traffic monitoring (VPC flow logs and other tools)
- VPC Traffic mirroring
- VPC Traffic Analysis using
  - VPC Reachability Analyzer
  - Network Access Analyzer

VPC Traffic Monitoring

VPC Flow Logs

- Capture information about IP traffic going in/out of your interfaces:
  - VPC Flow Logs
  - Subnet Flow Logs
  - Elastic Network Interface Flow Logs
- Helps to monitor & troubleshoot connectivity issues
- Flow logs data can go to S3 / CloudWatch Logs / Kinesis Data Firehose
- Captures network information from AWS managed interfaces too: ELB, RDS, ElastiCache, Redshift, Amazon WorkSpaces
- There is no impact to network performance for enabling VPC flow logs.

Publishing VPC flow logs



VPC Flow Logs default format

- *<version> <account-id> <interface-id> <srcaddr> <dstaddr> <srcport> <dstport> <protocol> <packets> <bytes> <start> <end> <action> <log-status>*
- Supported flow logs versions 2,3,4,5. Default version is 2.
- Srcaddr, dstaddr help identify problematic IP
- Srcport, dstport help identity 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

Example:

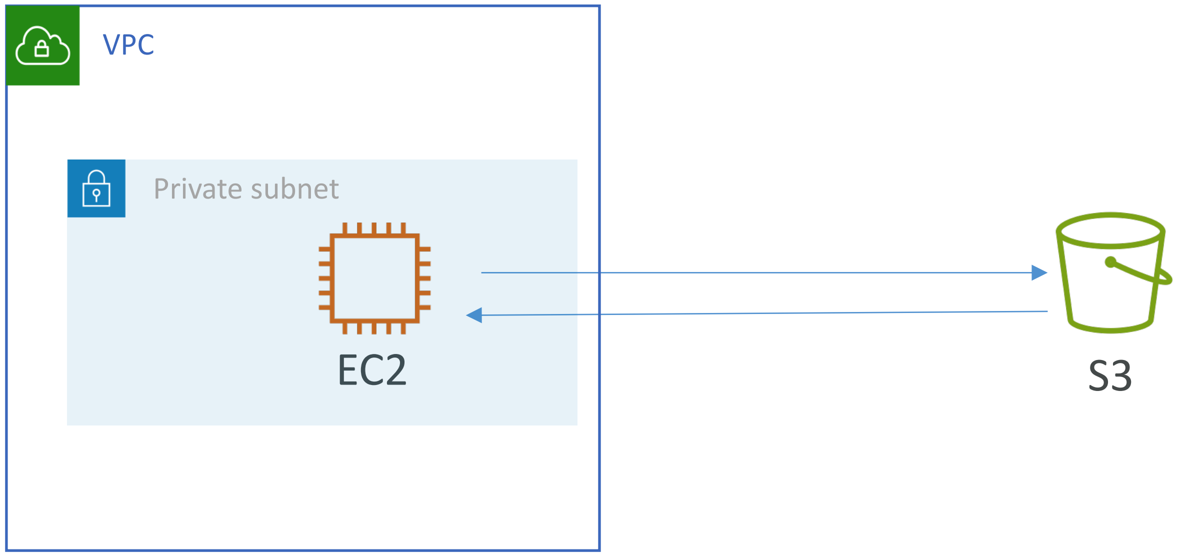
version account-id interface-id srcaddr dstaddr srcport dstport protocol packets bytes start end action log-status

```
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28472 80 6 2 92 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 10.100.0.224 27.57.246.36 80 28472 6 1 52 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28595 80 6 4 173 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 10.100.0.224 27.57.246.36 80 28595 6 3 144 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 45.129.33.8 10.100.0.224 58523 30018 6 1 40 1608988983 1608989040 REJECT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28478 443 6 1 52 1608988983 1608989040 REJECT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28090 443 6 2 104 1608988983 1608989040 REJECT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28103 443 6 1 52 1608988983 1608989040 REJECT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28472 443 6 1 52 1608988983 1608989040 REJECT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28605 22 6 6 528 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 10.100.0.224 27.57.246.36 22 28605 6 6 240 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 27.57.246.36 10.100.0.224 28108 443 6 2 104 1608988983 1608989040 REJECT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 46.227.200.78 10.100.0.224 123 58455 17 1 76 1608988983 1608989040 ACCEPT OK
2020-12-26T18:53:0…    2 523265502623 eni-0e6a89b99a1bac86d 10.100.0.224 46.227.200.78 58455 123 17 1 76 1608988983 1608989040 ACCEPT OK
```

VPC Flow Logs custom format

- vpc-id
- subnet-id
- instance-id
- type: IPv4, IPv6
- pkt-srcaddr
- pkt-dstaddr
- pkt-src-aws-service
- pkt-dst-aws-service
- region
- az-id
- flow-direction

+more



Custom flow logs example

version srcaddr dstaddr srcport protocol dstport start-time end-time type packets bytes account-id vpc-id subnet-id

```
5 52.95.128.179 10.0.0.71 80 34210 6 1616729292 1616729349 IPv4 14 15044 123456789012
vpc-abcdefab012345678 subnet-aaaaaaaa012345678 i-0c50d5961bcb2d47b eni-1235b8ca123456789
ap-southeast-2 apse2-az3 - - ACCEPT 19 52.95.128.179 10.0.0.71 S3 - - ingress OK
```

pkt-dstaddr log-status instance-id interface-id region az-id action pkt-srcaddr

traffic-flow-direction sublocation-type tcp-flags

sublocation-id

pkt-src-aws-service traffic-path

pkt-dst-aws-service

Lab - Analyze VPC Flows logs with CloudWatch Insights

1. Find out rejects on particular ENI

```
stats sum(packets) as packetsTransferred by srcAddr, dstAddr
    | sort packetsTransferred  desc
    | limit 15
```

2. Find out rejects on particular ENI

```
fields @timestamp, interfaceId, srcAddr, dstAddr, action
| filter (interfaceId = 'eni-xxxxxxxxxx' and action = 'REJECT')
| sort @timestamp desc
| limit 5
```

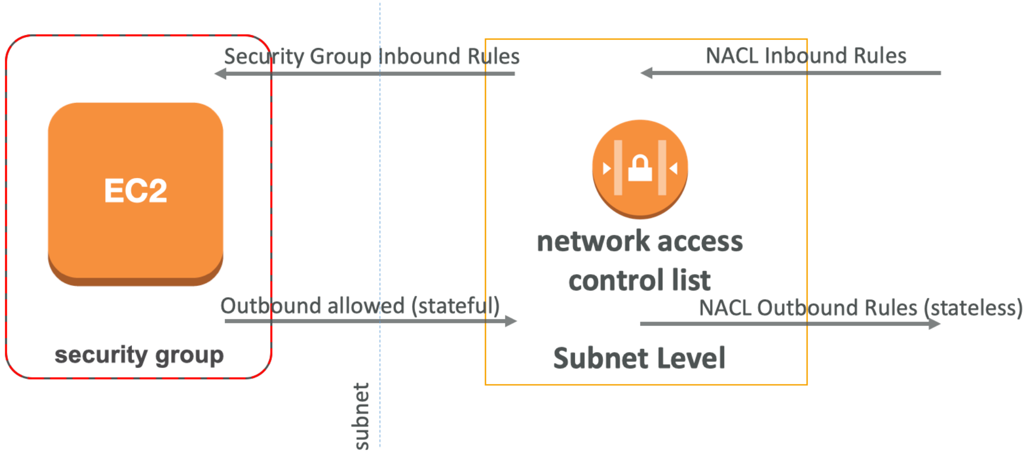
3. List IP addresses trying to connect to specific IP or CIDR

```
fields @timestamp, srcAddr, dstAddr
 | sort @timestamp desc
 | limit 5
 | filter srcAddr like “xxx.xxx.xxx.xxx"
```

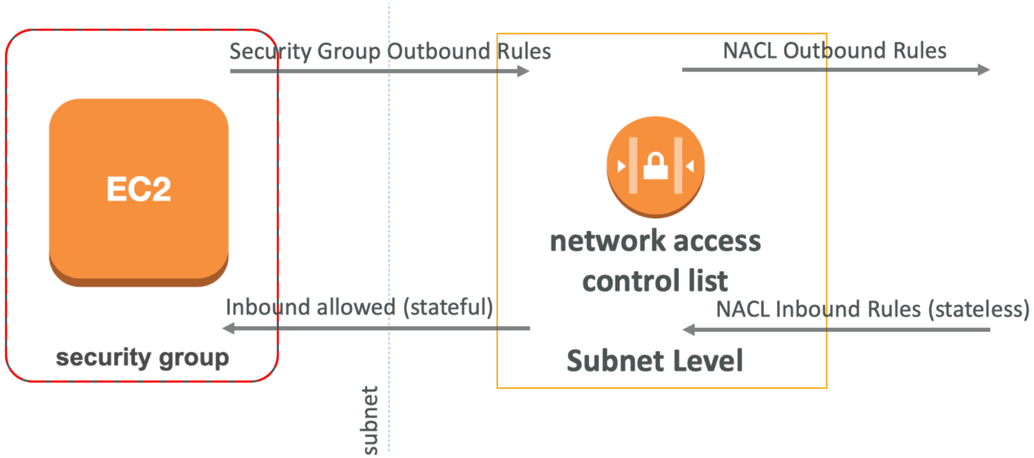
How to troubleshoot SG vs NACL issue?

"ACTION" Field

For incoming requests
Inbound REJECT: NACL or SG
Inbound ACCEPT, outbound REJECT: NACL



For outgoing requests
Outbound REJECT: NACL or SG
Outbound ACCEPT, inbound REJECT: NACL



Lab – Custom flow logs

- Custom flow logs with access to EC2 instance over internet
  - Remove the NACL outbound rule
  - Remove the Security group inbound rule

Flow Logs limitation

Amazon VPC Flow Logs do not record traffic

- To and from VPC-native DNS services
- Amazon EC2 metadata service
- Dynamic Host Configuration Protocol (DHCP) services
- Windows license activation server

Other Traditional Tools for Network Monitoring

- Packet Capture (for deep packet inspection)
  - **Wireshark** (Windows/Linux) and **tcpdump** (Linux) which can be run on EC2 instance
- traceroute
- telnet
- nslookup - Used to resolve the hostnames into IP addresses
- ping
  - Ping records network round trips using Internet Control Message Protocol
  - ICMP traffic should be allowed through Security Groups, NACL

Security Group: sg-0dbfbf97c45a30961

Description | **Inbound** | Outbound | Tags

Edit

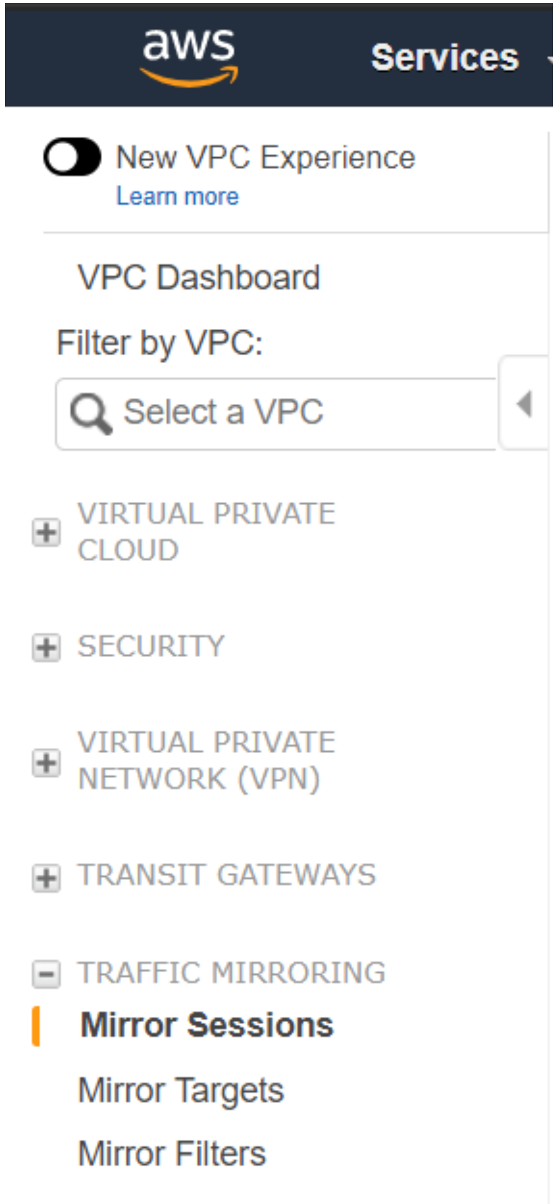
Type	Protocol	Port Range	Source	Description
SSH	TCP	22	182.70.87.195/32	SSH Traffic
All ICMP - IPv4	All	N/A	0.0.0.0/0	PING - ICMP Traffi...

End

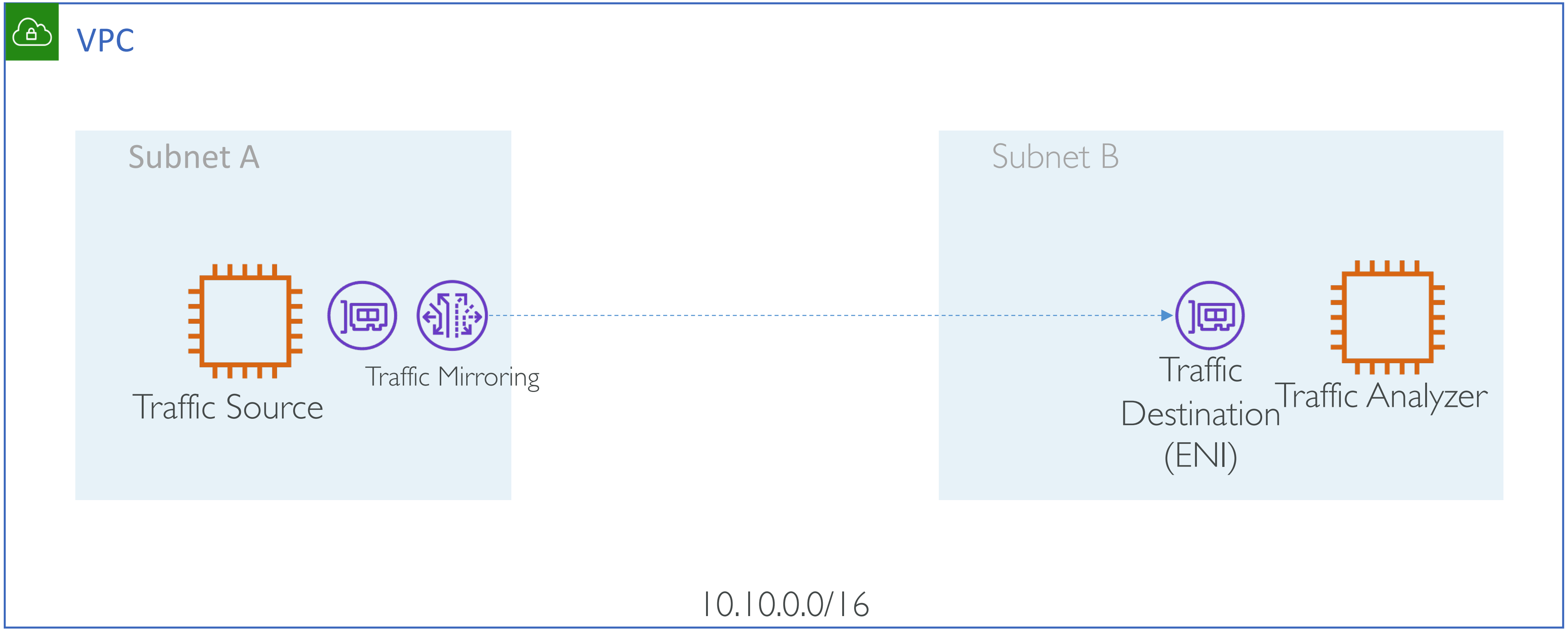
VPC Traffic Mirroring

VPC Traffic Mirroring

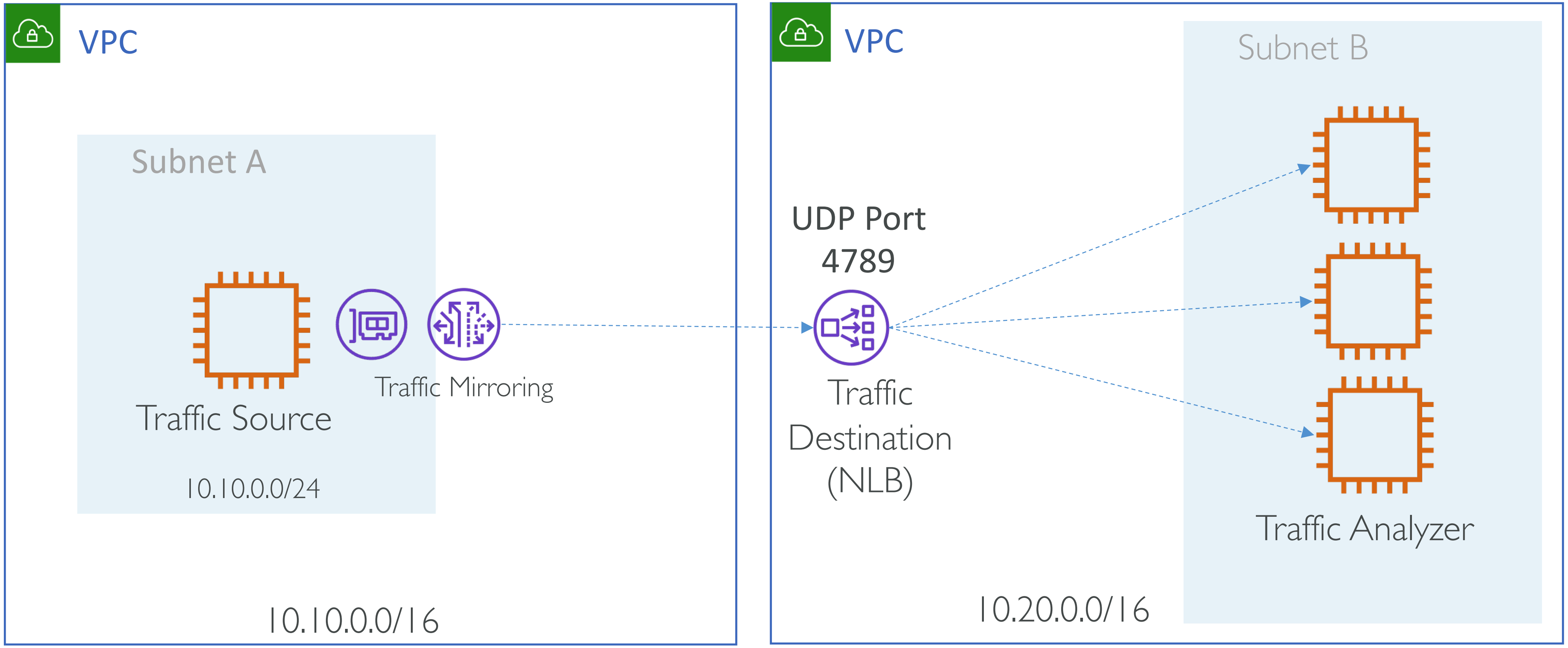
- Copy network traffic from an elastic network interface of Amazon EC2 instances
- Send the traffic to out-of-band security and monitoring appliances for Content inspection or threat monitoring or for troubleshooting
- How to set up Traffic Mirroring (via AWS VPC console)
  - Create the Mirror Target
  - Define the Traffic Filter
  - Create Mirror Session



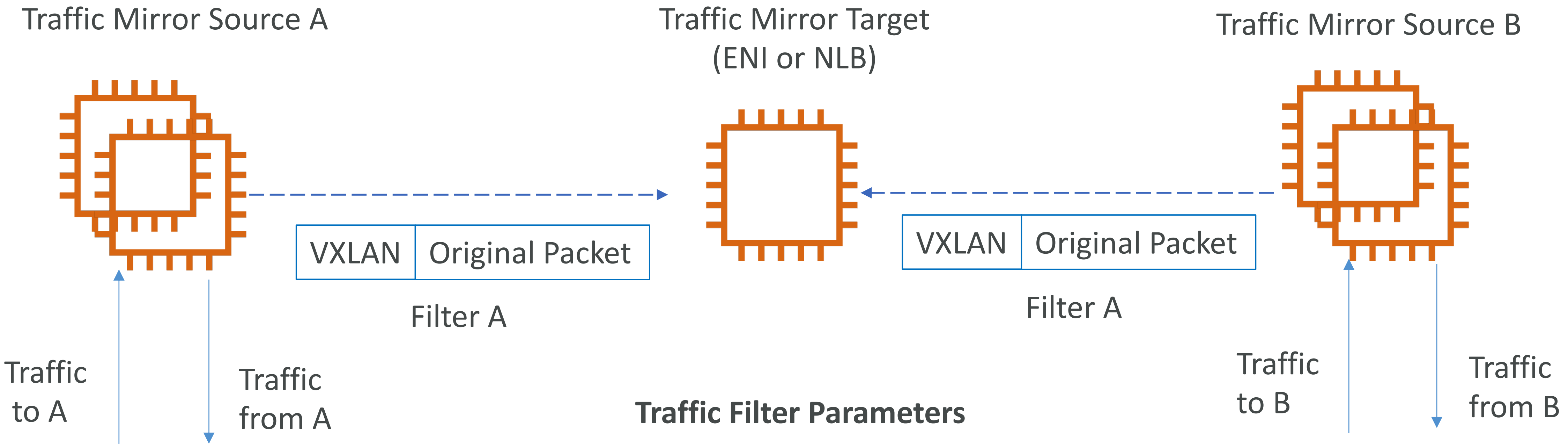
VPC Traffic Mirroring – ENI as Target



VPC Traffic Mirroring – NLB as Target



VPC Traffic Mirroring Filters



Traffic Filter Parameters

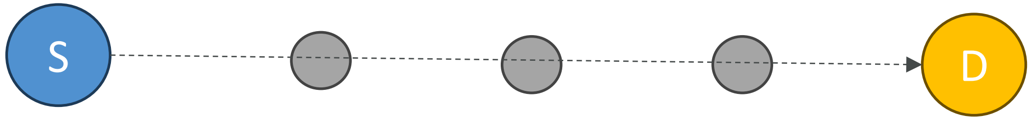
- Traffic Direction: Inbound or Outbound
- Action: Accept or Reject
- Protocol: L4
- Source Port Range/ Destination Port range
- Source CIDR block/ Destination CIDR block

VPC Traffic Mirroring – Good to know

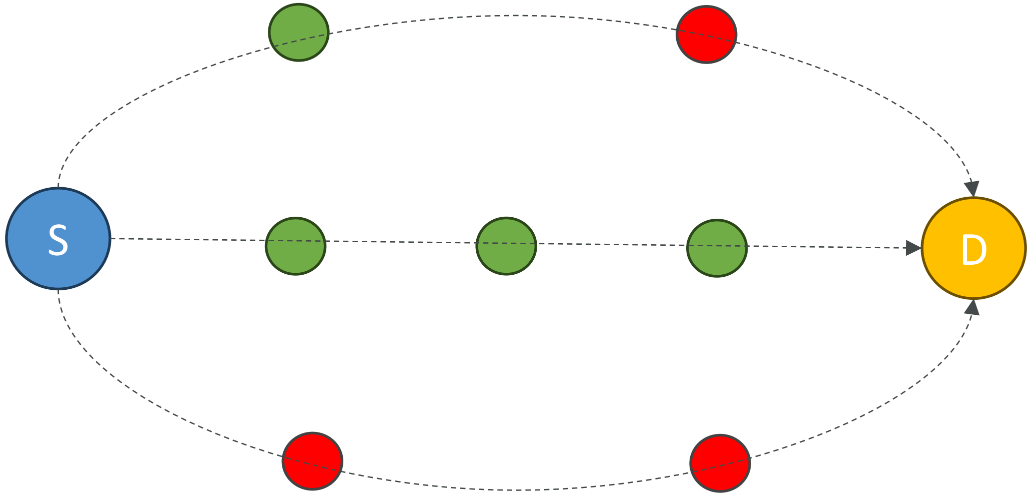
- Mirrors the traffic flowing in/out of VPC and routes it to network analysis tools to detect the potential network & security anomalies
- Mirror source is ENI
- Mirror target could be another ENI or Network Load Balancer (UDP - 4789)
- Mirror Filter – To capture only the traffic you are interesting in
  - Filter the traffic by specifying Protocols, Source/Destination port ranges, and CIDR Blocks
  - Define rules (numbered) to send the traffic to respective destination
- The traffic mirror source and the traffic mirror target (monitoring appliance) can be in the same VPC or they can be in a different VPC connected via intra-Region VPC peering or a transit gateway
- Source and Destination can be in different AWS accounts

VPC Network Analysis

Reachability Analyzer

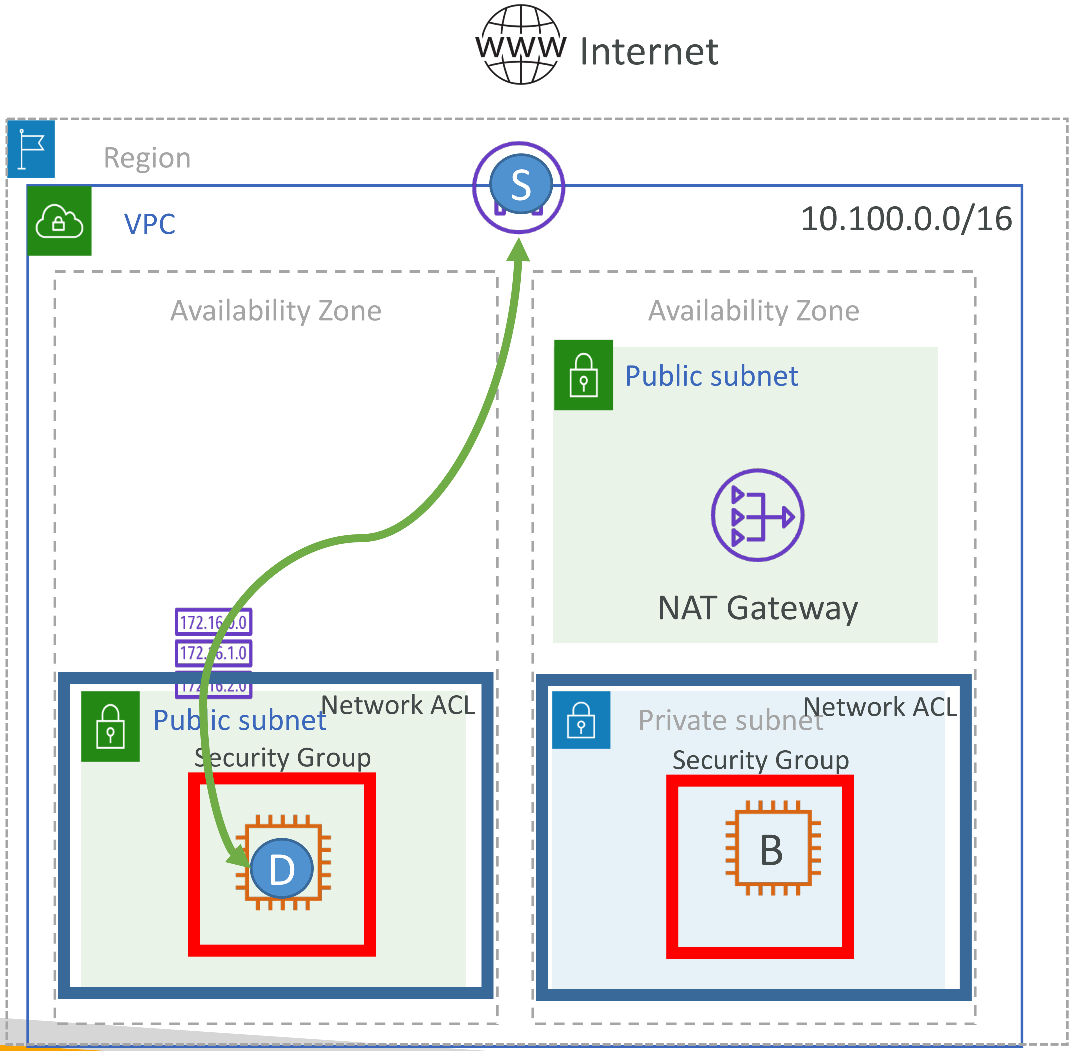


Network Access Analyzer



VPC Reachability Analyzer

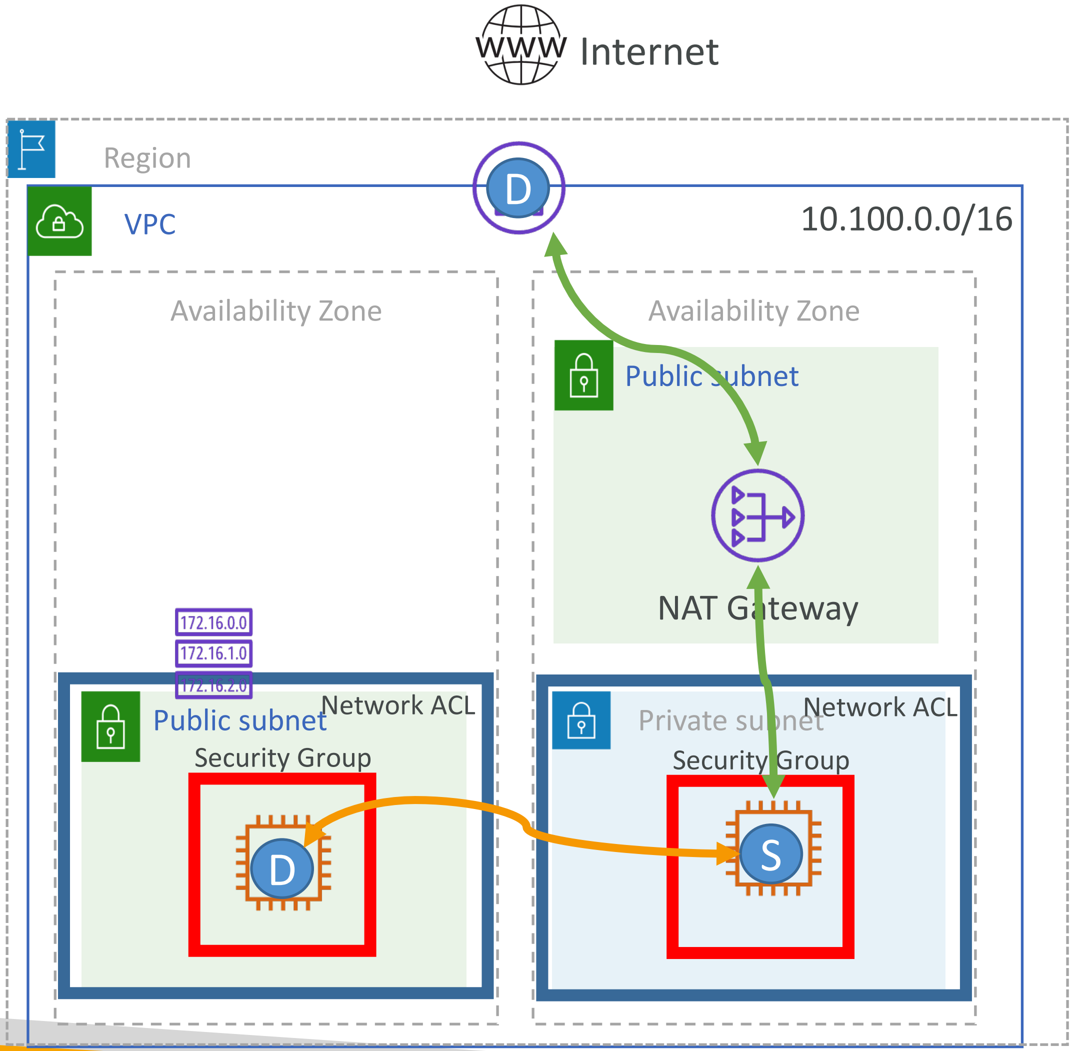
VPC Reachability Analyzer



- Connectivity testing between the source resource and a destination resource

VPC Reachability Analyzer

Reachability Analyzer



- Connectivity testing between the source resource and a destination resource
- Produces hop-by-hop details of the virtual network path
- Points out the blocking components when traffic is not reachable
- Does not send real packets. It uses network configurations to find out if network is reachable

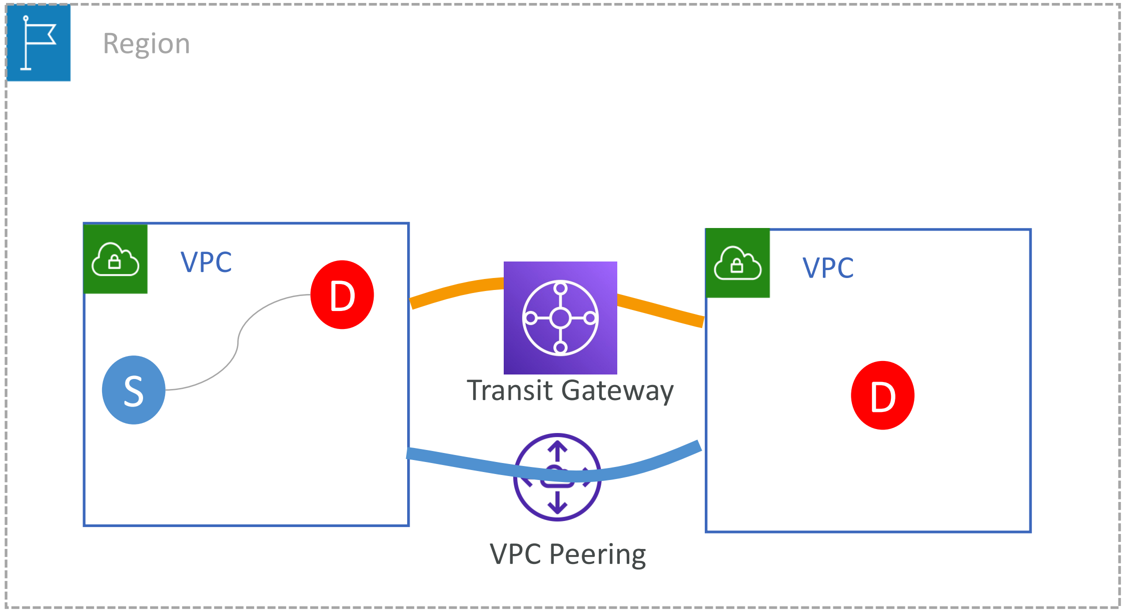
Use cases:

- Troubleshoot connectivity issues caused by network misconfiguration.
- Automate the verification of connectivity after network configuration changes

VPC Reachability Analyzer

Reachability Analyzer

- Supported Source & Destination:
  - Instance
  - Internet Gateway
  - Network Interfaces
  - Transit Gateway
  - Transit Gateway Attachments
  - VPC endpoints
  - VPC peering connections
  - VPN gateways
- Intermediate components:
  - ALB and NLB
  - NAT gateways
  - TGW, TGW attachment, VPC peering



The source and destination resources:

- Must be in the same Region
- Must be in the same VPC or VPCs connected through a VPC peering or Transit Gateway

VPC Reachability Analyzer

- Supported Source & Destination:
  - Instance
  - Internet Gateway
  - Network Interfaces
  - Transit Gateway
  - Transit Gateway Attachments
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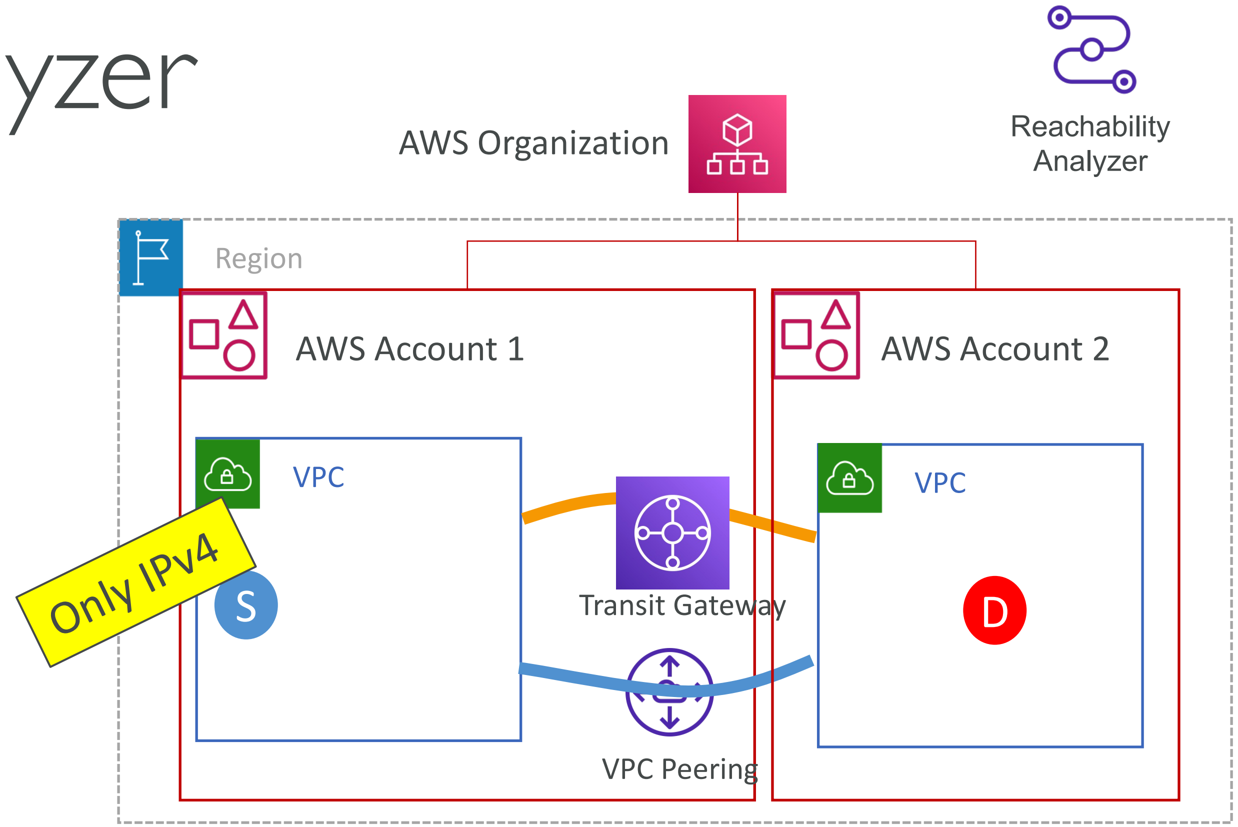
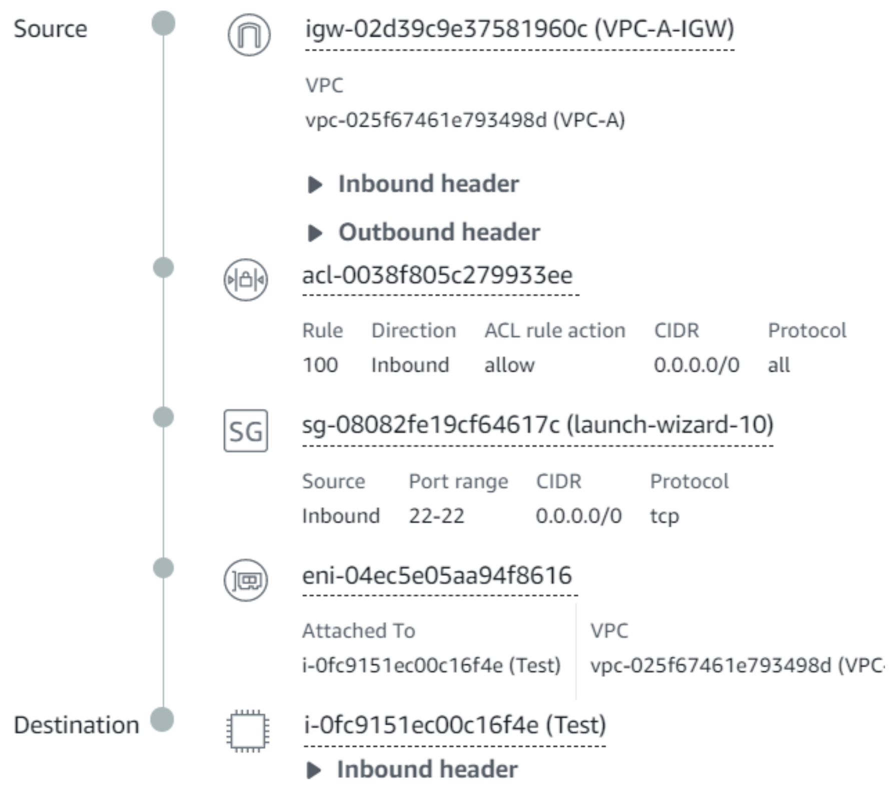


The source and destination resources:

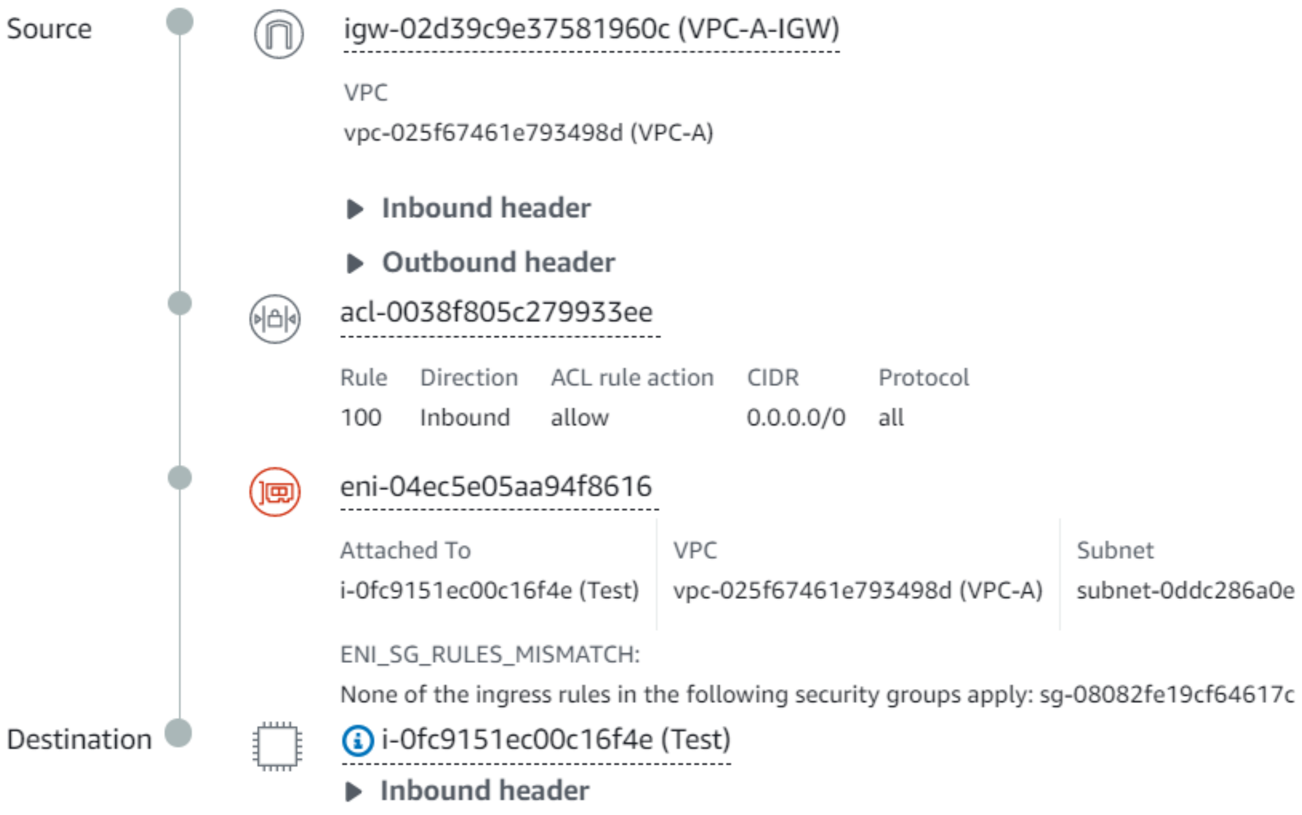
- Must be in the same Region
- Must be in the same VPC or VPCs connected through a VPC peering or Transit Gateway
- Can be across AWS accounts in the same AWS organization

VPC Reachability Analyzer output

- Destination reachable



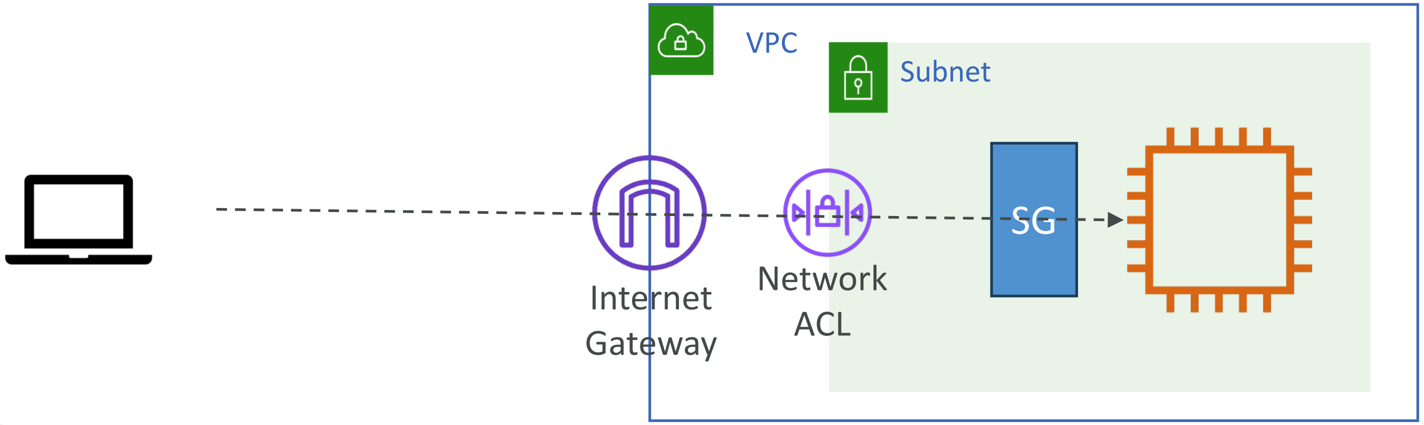
- Destination unreachable



Exercise

Pricing: $0.10 per analysis

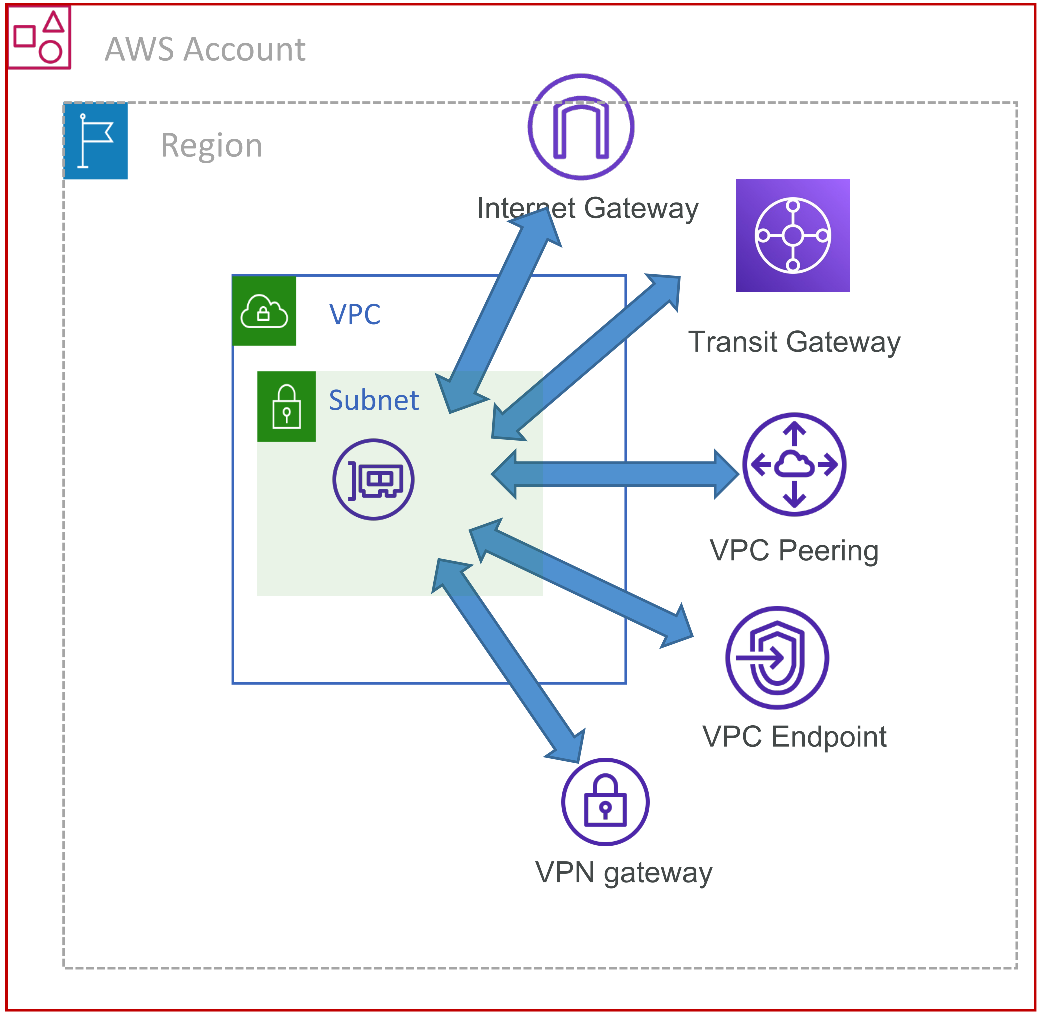
1. Launch an EC2 instance in a Private subnet and access over SSH (22)
2. Modify the subnet route to make the subnet Public
3. Remove NACL inbound rule for inbound traffic
4. Add NACL inbound rule and remove Security group inbound rule to allow SSH (22) access



Network Access Analyzer

VPC Network Access Analyzer

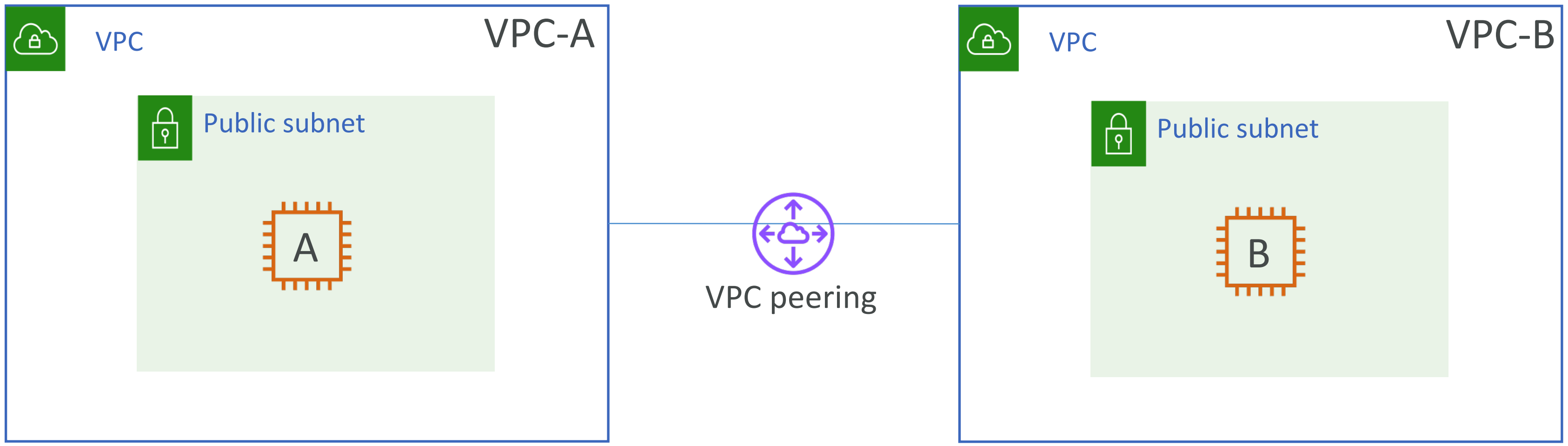
- Identify un-intended network access to the AWS resources
  - Isolated network segments
    - No communication between production and development VPCs
  - Internet accessibility
    - Only required resources can be reached over the internet
  - Trusted network paths
    - NAT gateway or firewalls in the path
  - Trusted network access
    - Accessible only from specific resource, IP range, port, protocol etc.
- Specify network access scope and analyze if it meets your compliance

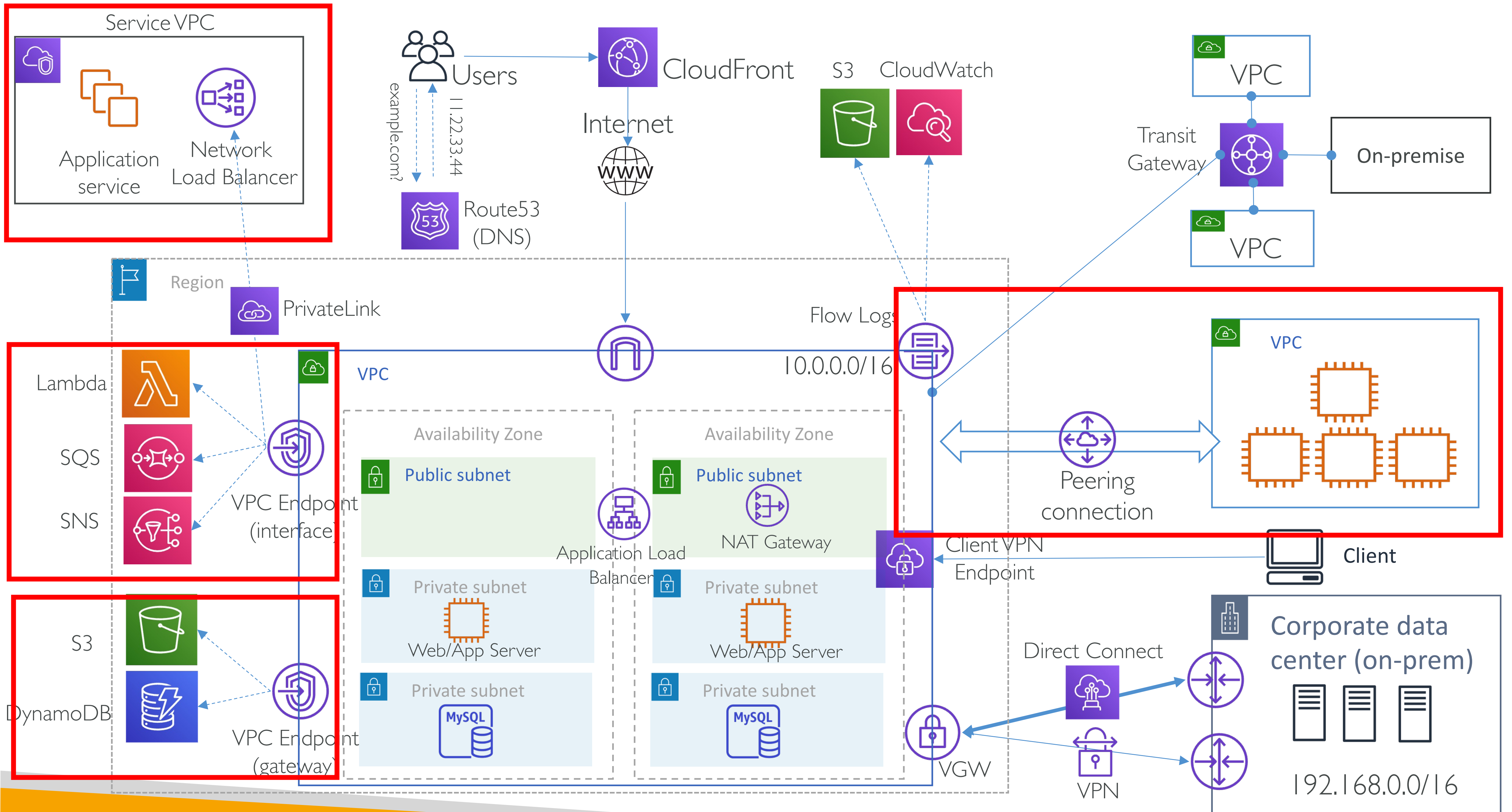


Walkthrough

Pricing: $0.002 per ENI analysed for network assessment

- Verify that 2 VPCs are isolated
- Setup VPC peering and check again





Service VPC
Application service
Network Load Balancer
Users
example.com?
11.22.33.44
Route53 (DNS)
CloudFront
Internet
www
S3
CloudWatch
Transit Gateway
VPC
On-premise
VPC
Region
PrivateLink
Flow Logs
10.0.0.0/16
VPC
Lambda
SQS
SNS
VPC Endpoint (interface)
Availability Zone
Public subnet
Application Load Balancer
Availability Zone
Public subnet
NAT Gateway
Private subnet
Web/App Server
Private subnet
Web/App Server
Private subnet
MySQL
Private subnet
MySQL
Peering connection
VPC
Client VPN Endpoint
Client
S3
DynamoDB
VPC Endpoint (gateway)
Direct Connect
Corporate data center (on-prem)
VGW
VPN
192.168.0.0/16

Why do we need Private Connectivity?

Disadvantages of having Internet based traffic

- Traffic flows over the internet (can be considered less secured)
- Internet connectivity may not provide consistent bandwidth and latency
- NAT devices comes with considerable per hour running cost and data processing charges
- You might have to un-necessarily expose your servers publicly even if they don't need to be public (e.g. Databases, Application servers, Intranet application servers)

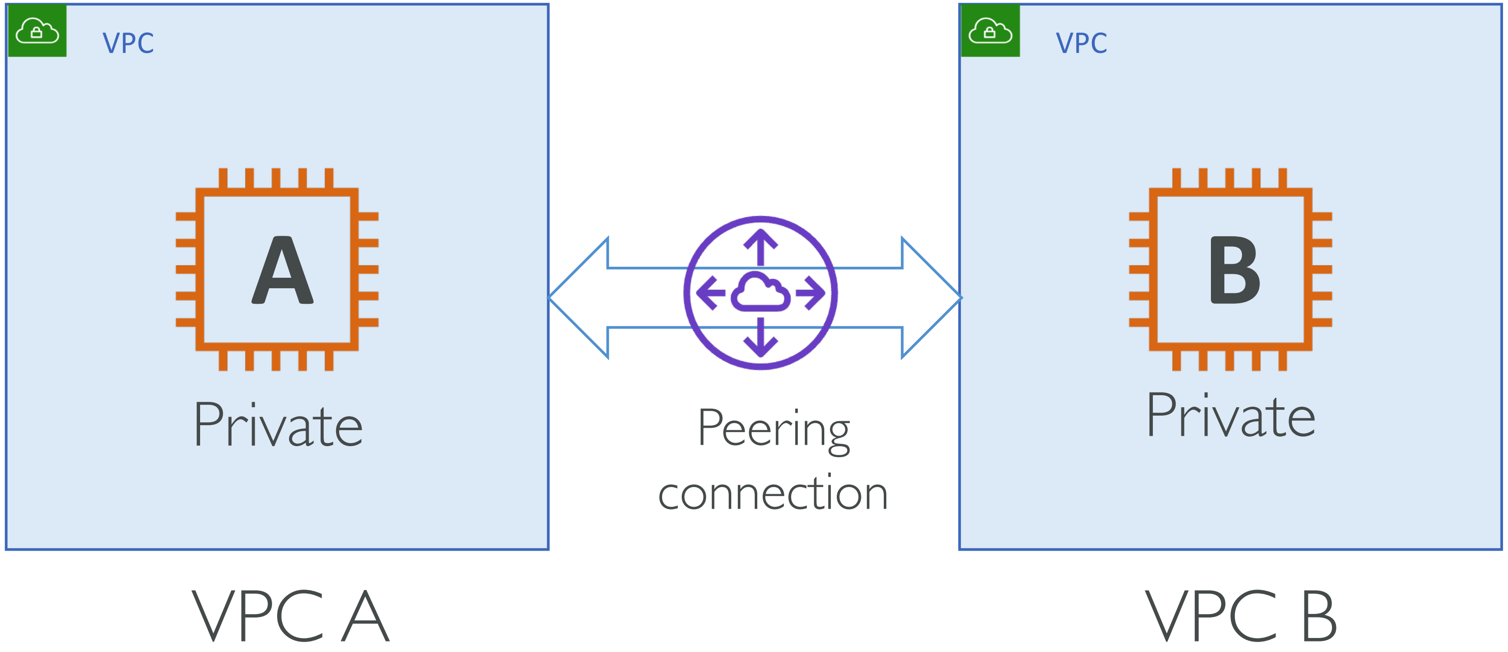
Lets look at how VPC Peering, VPC endpoints and VPC PrivateLink help solve these problems !

Topics

- VPC Peering
- VPC Endpoints – Gateway and Interface
- VPC Private Link

VPC Peering

VPC Peering



VPC Peering

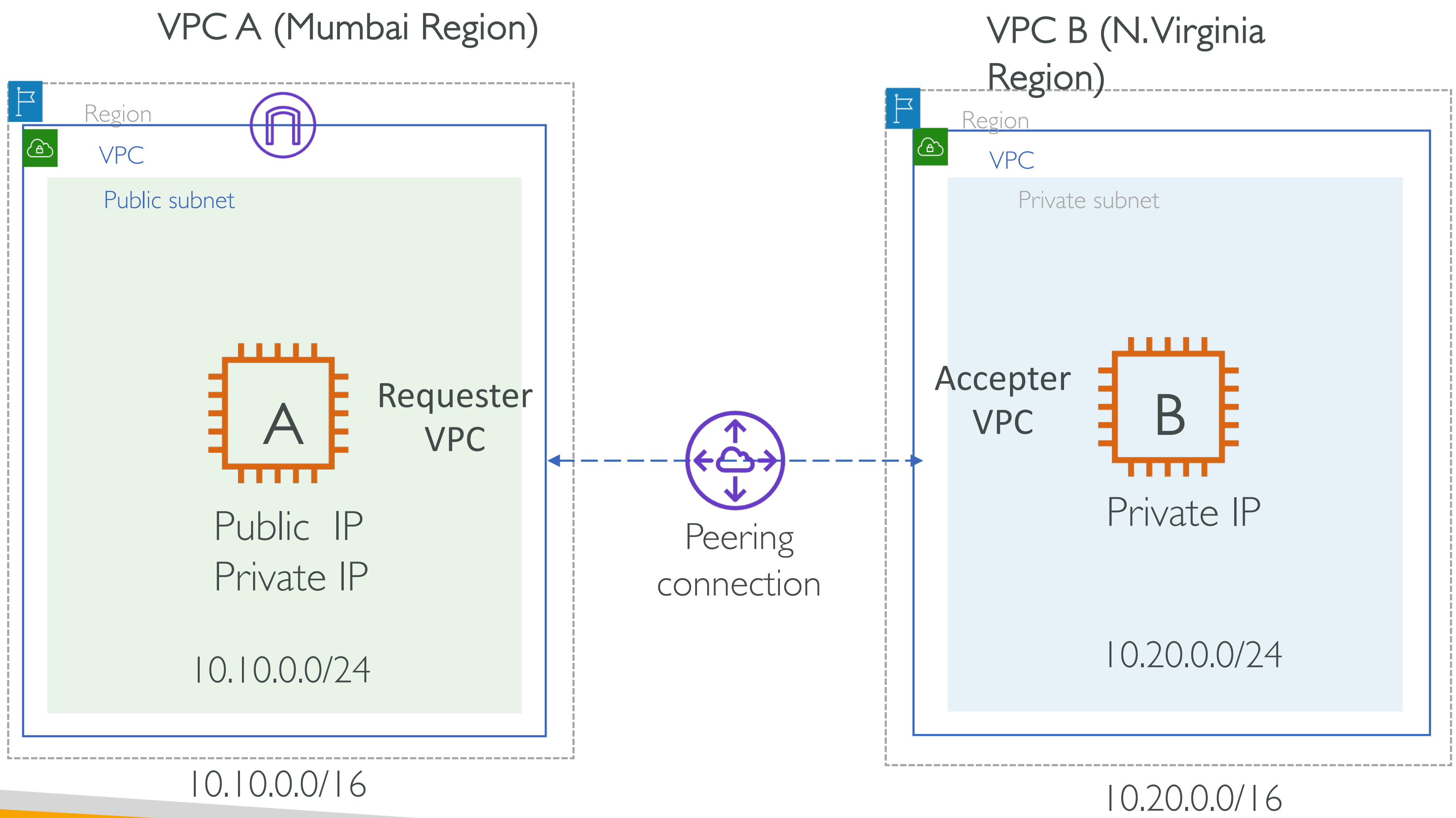
- Connect two VPC, privately using **AWS' network**
- Make them behave as if they were in the same network
- Peered VPCs can be in same AWS region or across AWS regions
- You can do VPC peering with another AWS account

Caveats:

- VPC CIDRs should be non-overlapping
- You must update route tables in each VPC's subnets to ensure instances can communicate across VPC

VPC Peering Demo

VPC Peering - Demo



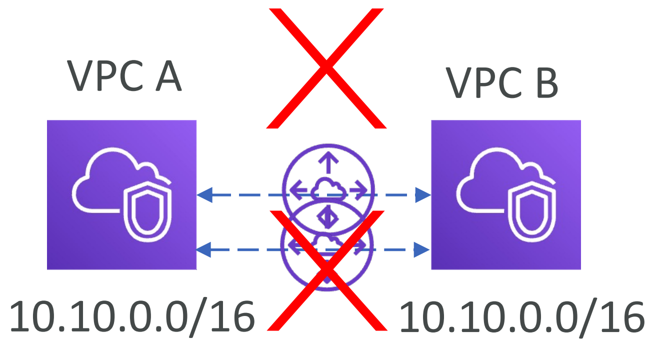
Steps

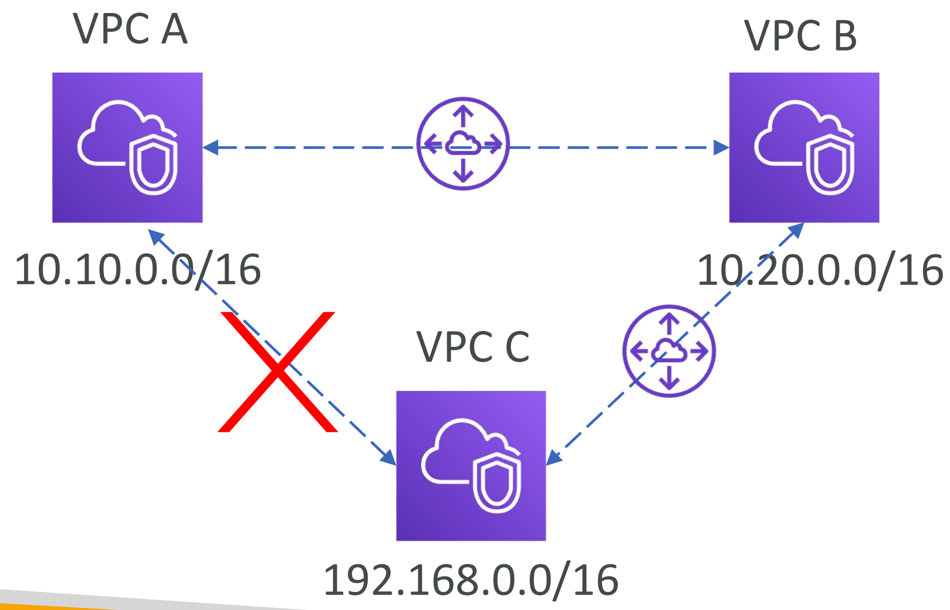
- Create VPC-A in Mumbai (ap-south-1) region (CIDR: 10.10.0.0/16)
- Create Internet Gateway and Attach to VPC-A
- Create Public Subnet in VPC-A (10.10.0.0/24)
- Launch EC2 instance and assign Public IP. Open inbound port 22 for your IP.
- Create VPC-B in North Virginia (us-east-1) region (CIDR: 10.20.0.0/16)
- Create Private Subnet in VPC-B (10.20.0.0/24)
- Launch EC2 instance in private subnet. Open inbound port 22 and ICMP for VPC-A CIDR range
- Create VPC peering connection request from VPC-A to VPC-B
- Accept the connection request in VPC-B
- Modify route tables on both sides for traffic on other VPC
- Login To EC2-A instance and try to connect to EC2-B (ping or SSH)

VPC Peering Limitations

VPC Peering Limitations

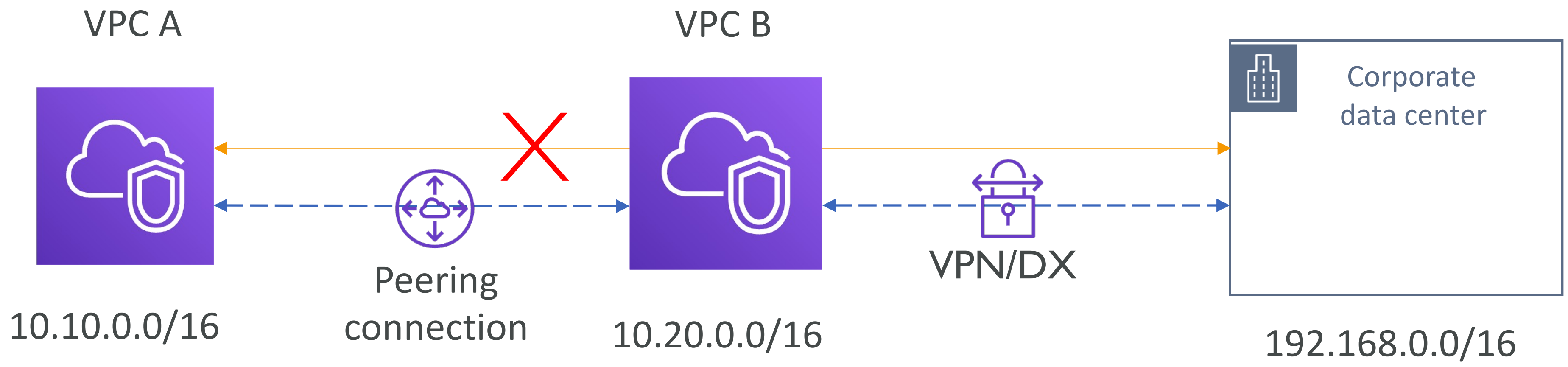
- Must not have overlapping CIDR
- VPC Peering connection is **not transitive** (must be established for each VPC that need to communicate with one another)
- You can setup only 1 VPC peering connection between 2 VPCs
- Maximum 125 VPC peering connections per VPC





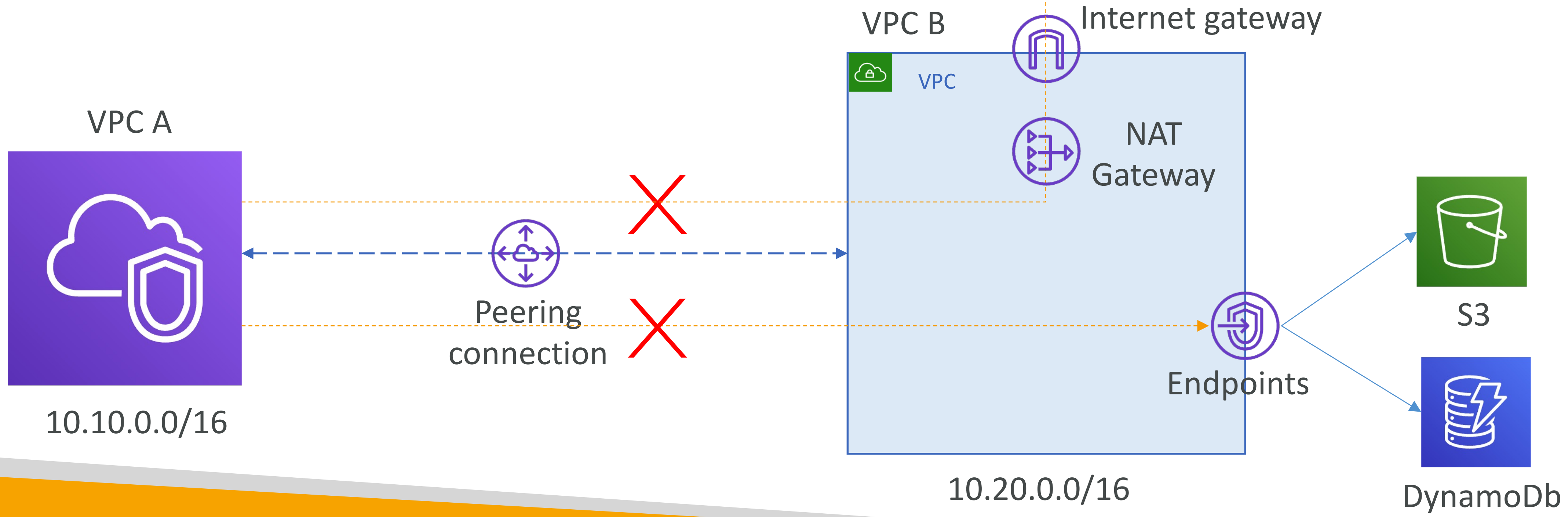
VPC Peering invalid scenarios – VPN or DX

- VPN or Direct Connect connection to on-premises network



VPC Peering invalid scenarios – IGW

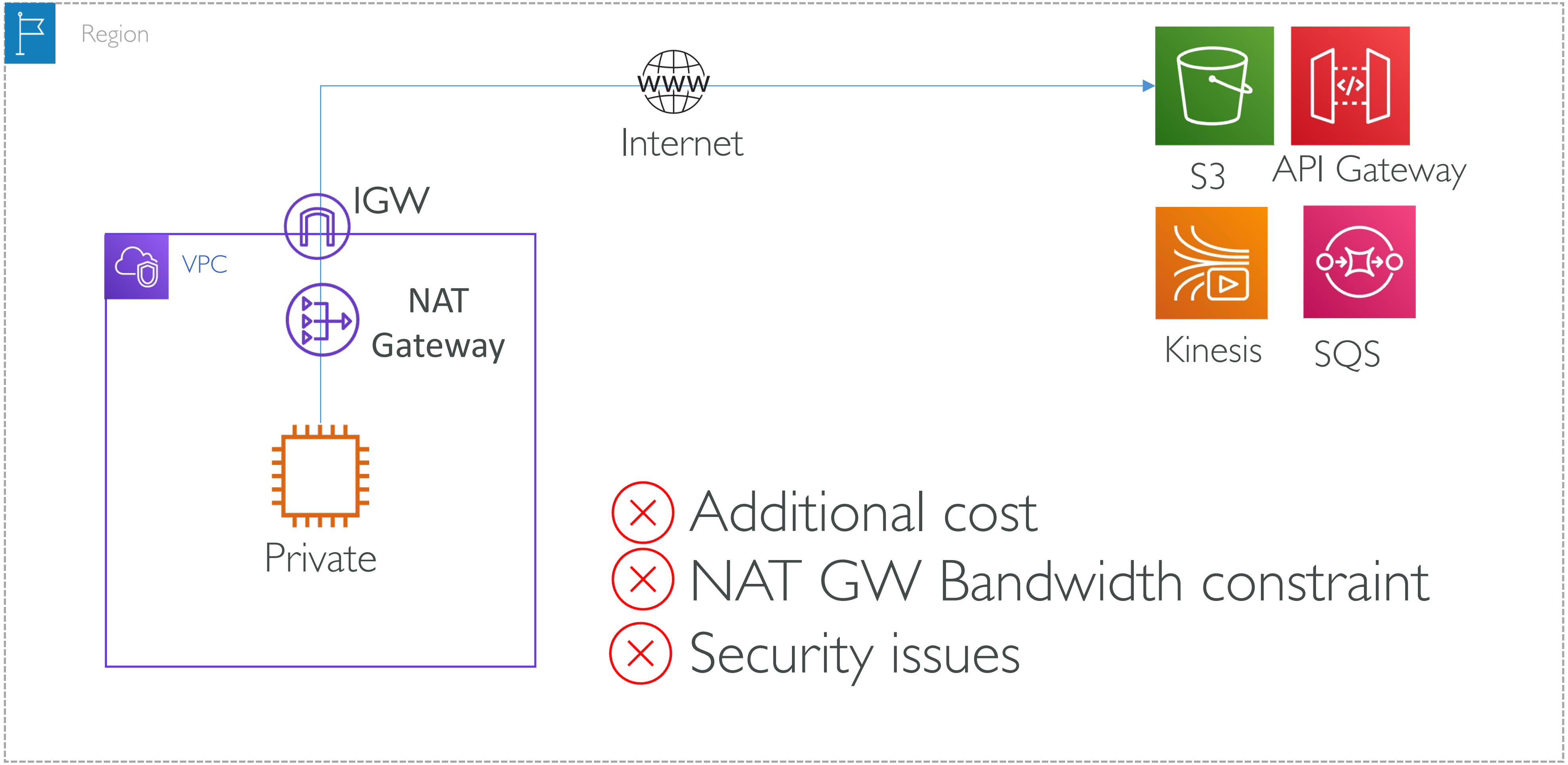
- Internet access through peered VPC internet gateway
- Internet access through peered VPC NAT Gateway
- Access to S3/DynamoDB through VPC endpoint



End

VPC Endpoint and PrivateLink

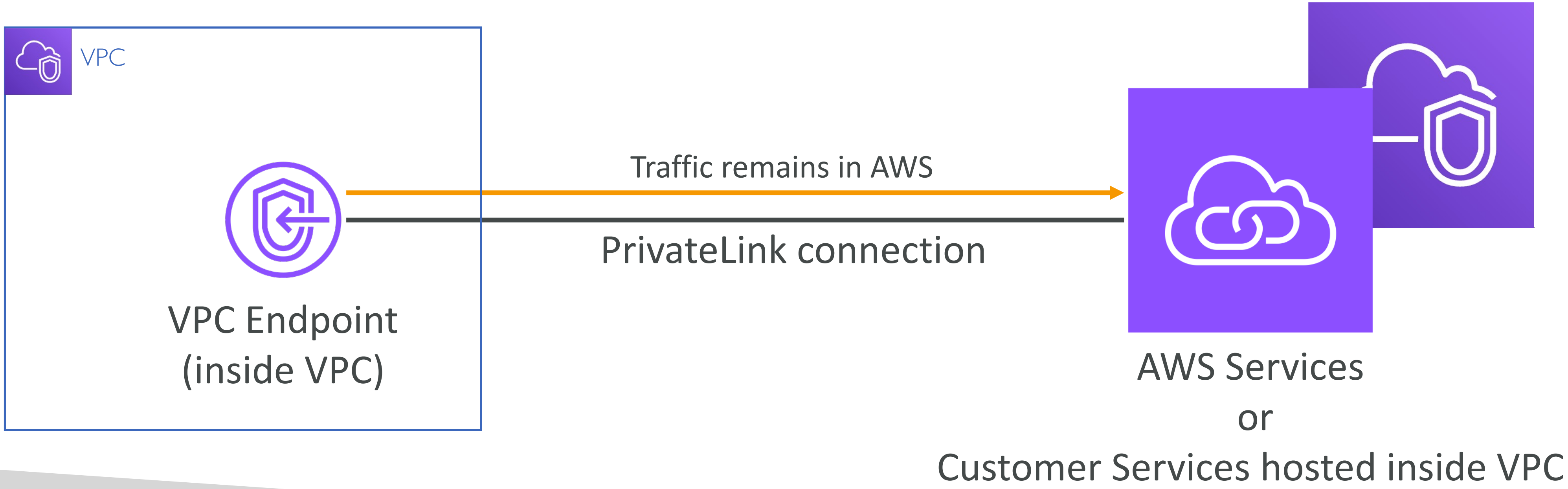
Accessing AWS services from VPC



- Additional cost
- NAT GW Bandwidth constraint
- Security issues

VPC endpoint and PrivateLink

- VPC endpoints and AWS PrivateLink work together to establish secure & private connections between your VPC and supported AWS services, including those hosted by other AWS customers or partners.



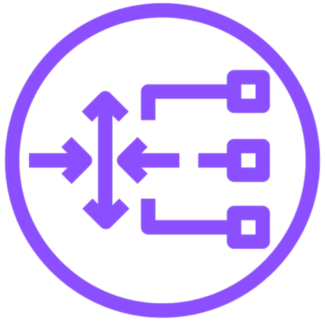
Why VPC endpoint?

- Enables private connections - It facilitates secure, private communication between your VPC and services, without exposing traffic to the public internet.
- Reduces security risks - It eliminates the need for internet gateways, NAT devices, or VPN connections, minimizing the risk of exposure to the internet.
- Supports various services - It works with a wide range of AWS services, including those hosted by AWS, other AWS customers, and AWS Marketplace partners.

Types of endpoints

VPC Gateway Endpoint

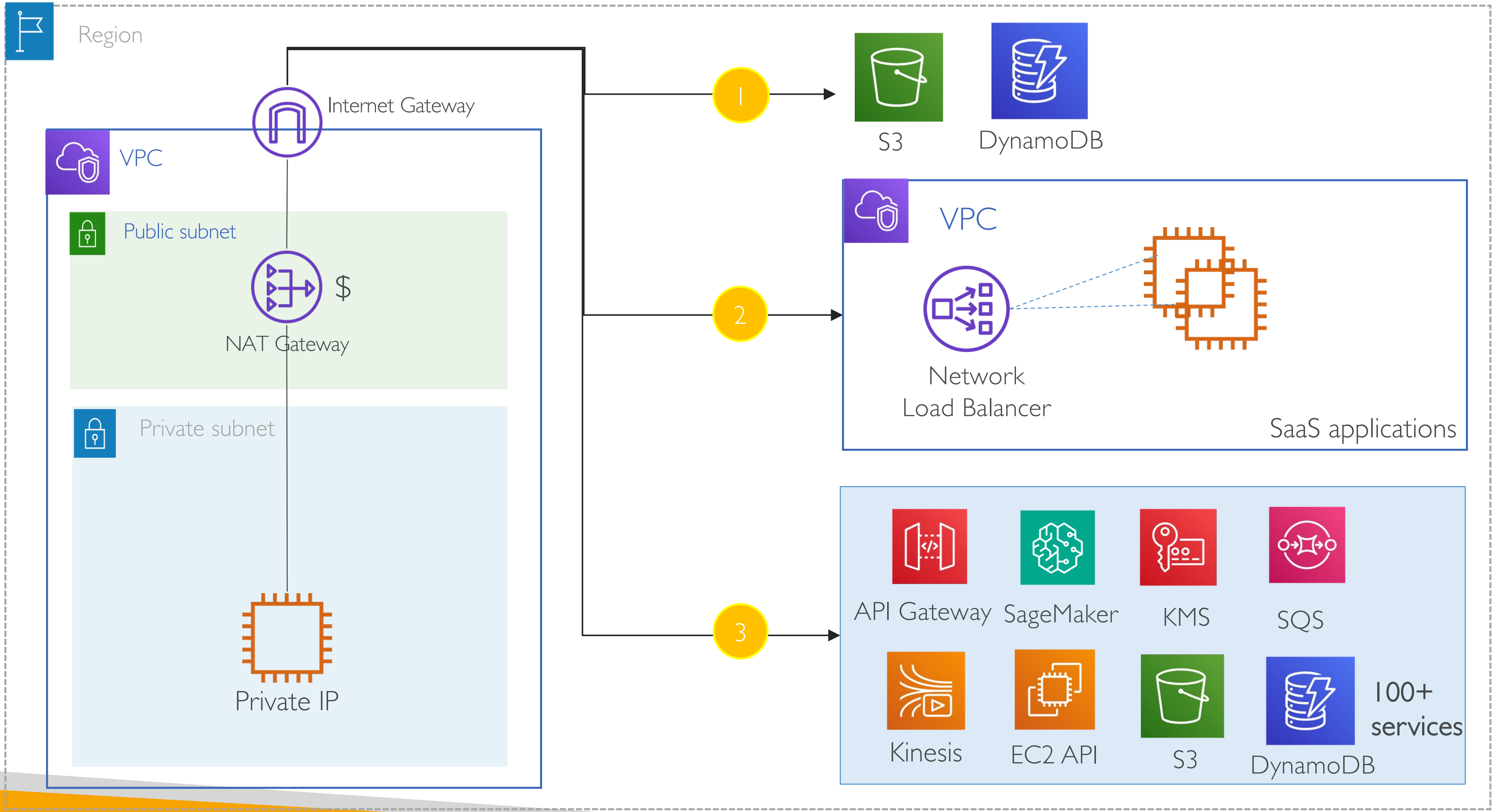
- **VPC Interface Endpoint**
- VPC Resource Endpoint
- VPC Service-Network Endpoint



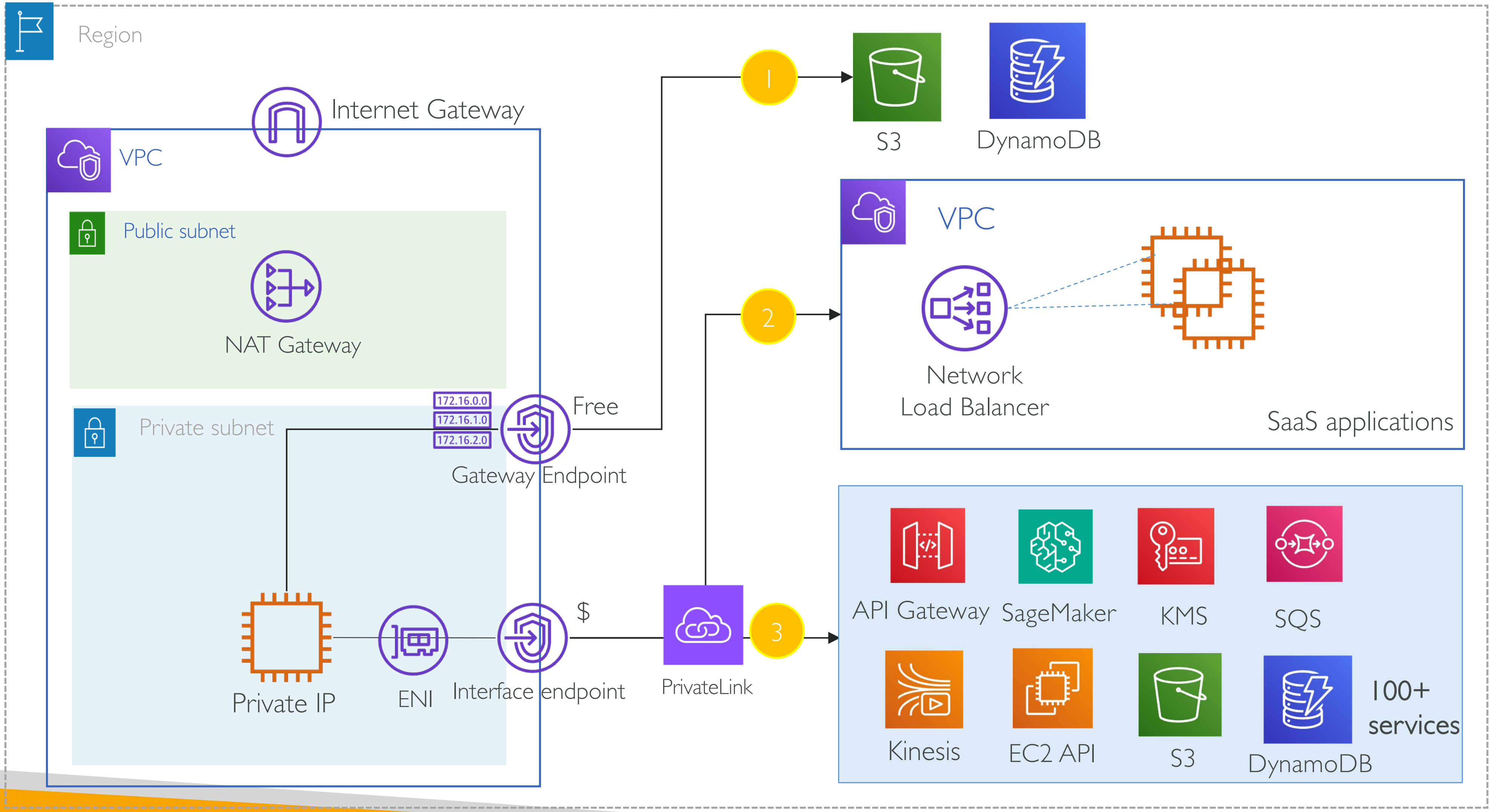
Gateway Load Balancer Endpoint

Powered by VPC Private Link

Without VPC endpoints and PrivateLink



With VPC endpoints and PrivateLink



VPC Endpoints and PrivateLink

- VPC Endpoints allow you to connect to resources in another VPCs and AWS Services using a private network instead of the public network
- They remove the need of IGW, NAT GW to access AWS Services
- Endpoint devices are horizontally scaled, redundant and highly available without any bandwidth constraint on your network traffic
- Gateway Endpoint: To access Amazon S3 and DynamoDB only
- Interface Endpoint: To access your services deployed in other VPCs and AWS accounts as well as broad set of other AWS services
- Other types of Endpoints: Gateway Load Balancer, Resource, Service-network

VPC Gateway Endpoint

Types of endpoints

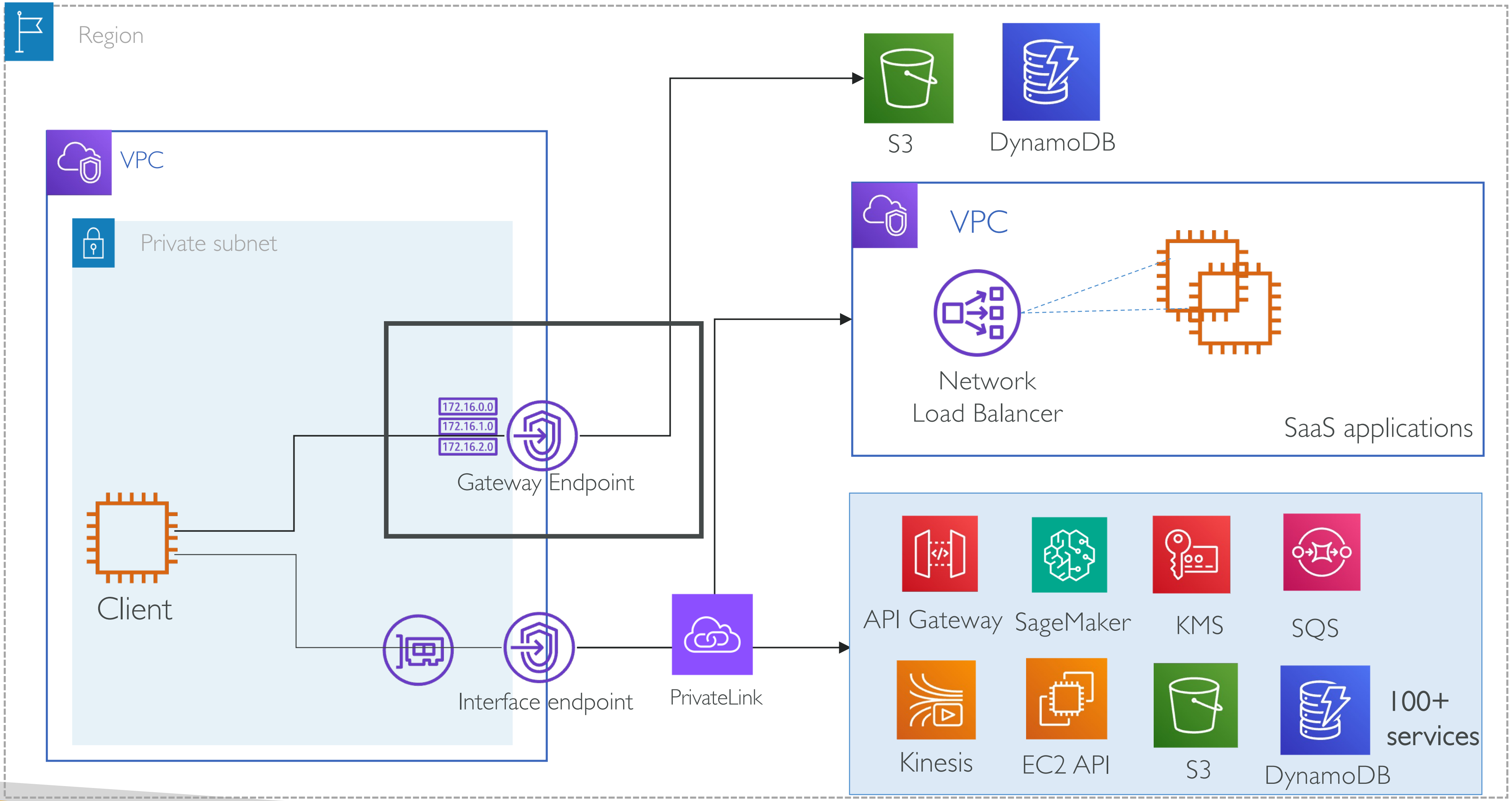
VPC Gateway Endpoint

- **VPC Interface Endpoint**
- VPC Resource Endpoint
- VPC Service-Network Endpoint

Gateway Load Balancer Endpoint

Powered by VPC Private Link

VPC Gateway Endpoint



VPC Gateway Endpoint

- Enables private connection between VPC and S3/DynamoDB
- Need to modify the route tables and add an entry to route the traffic to S3 or DynamoDB through the gateway VPC endpoint
- When we create Gateway endpoint, a *prefix list is* created in VPC
- The prefix list is the collection of IP addresses for AWS services such as Amazon S3 or DynamoDB.
- The Prefix list is formatted as pl-xxxxxxxx and becomes an available option in both subnet routing tables and security groups

Destination	Target	Status
10.0.0.0/16	local	active
pl-78a54011 (com.amazonaws.ap-south-1.s3, 52.219.62.0/23, 3.5.212.0/23, 3.5.208.0/22, 52.219.64.0/22)	vpce-0e89398e630ab0bcf	active
0.0.0.0/0	nat-085190f27ccf2ca3e	active

VPC Gateway Endpoint

- Prefix list should be added in Security group Outbound rule (if Security group outbound rules do not have default "Allow All" rule)

Security Group: sg-17f47973

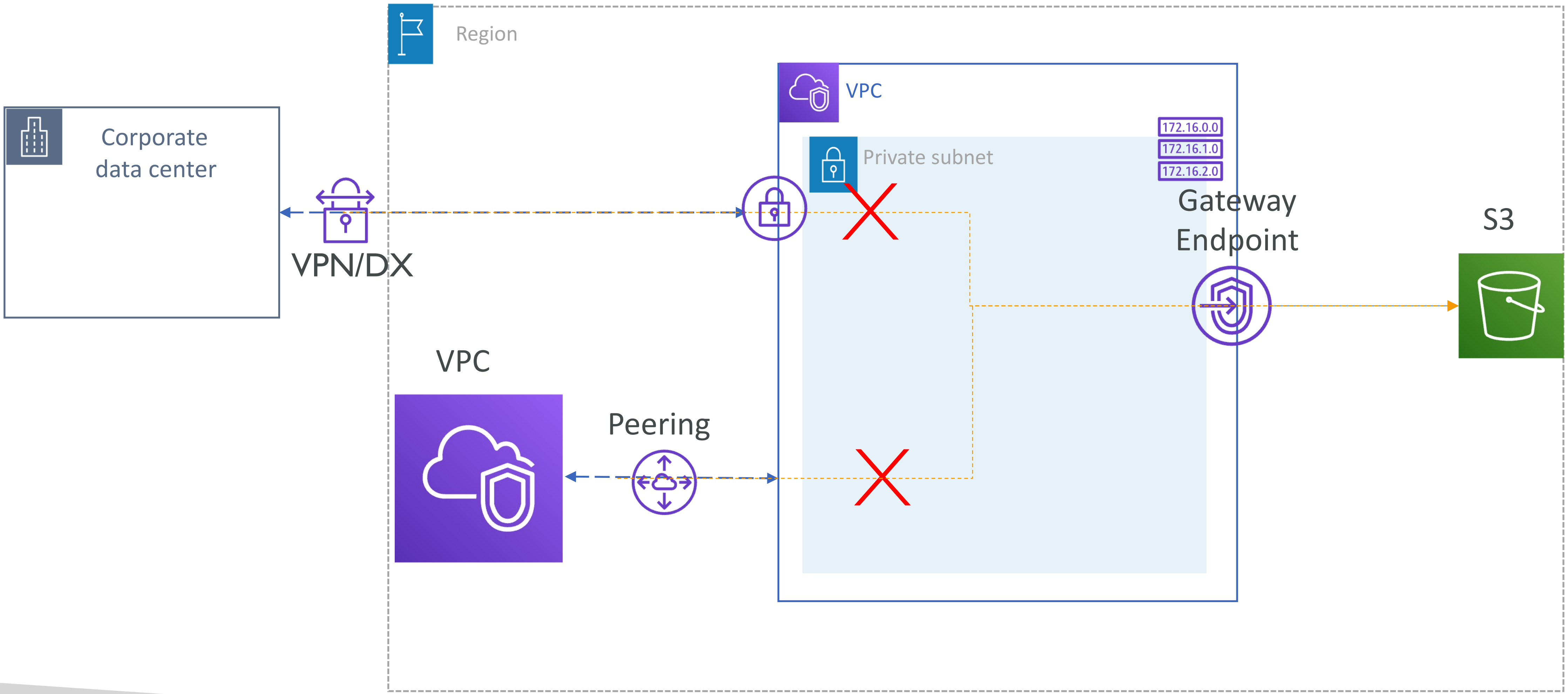
Description | Inbound | **Outbound** | Tags

Edit

Type	Protocol	Port Range	Destination
HTTPS	TCP	443	pl-68a54001
HTTP	TCP	80	pl-68a54001

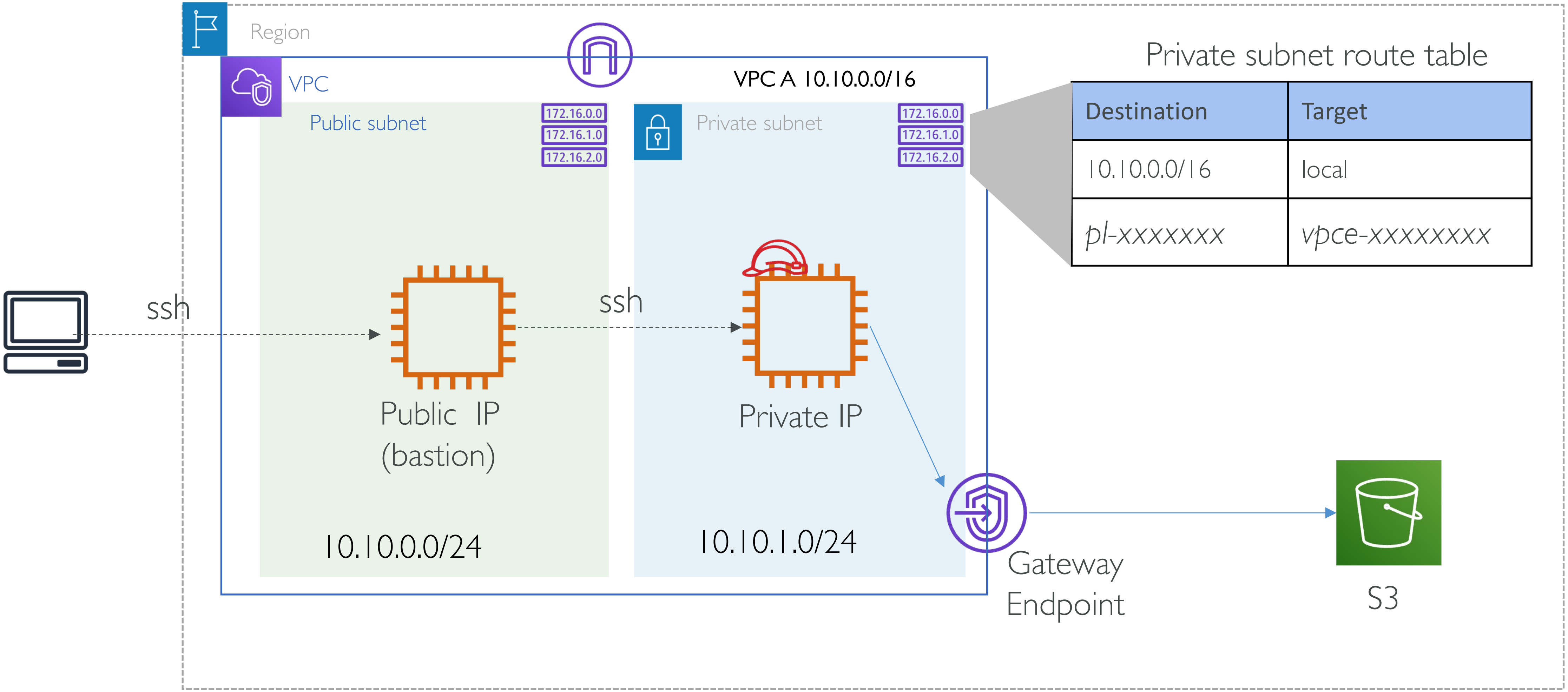
- VPC Gateway endpoint can only be accessed from within the VPC in which it's created in the same AWS region
- It's free to use and hence always recommended to use VPC Gateway endpoint when you want to access Amazon S3 or DynamoDB from applications deployed in the VPC

Gateway endpoint access from Remote Networks



VPC Gateway Endpoint - Demo

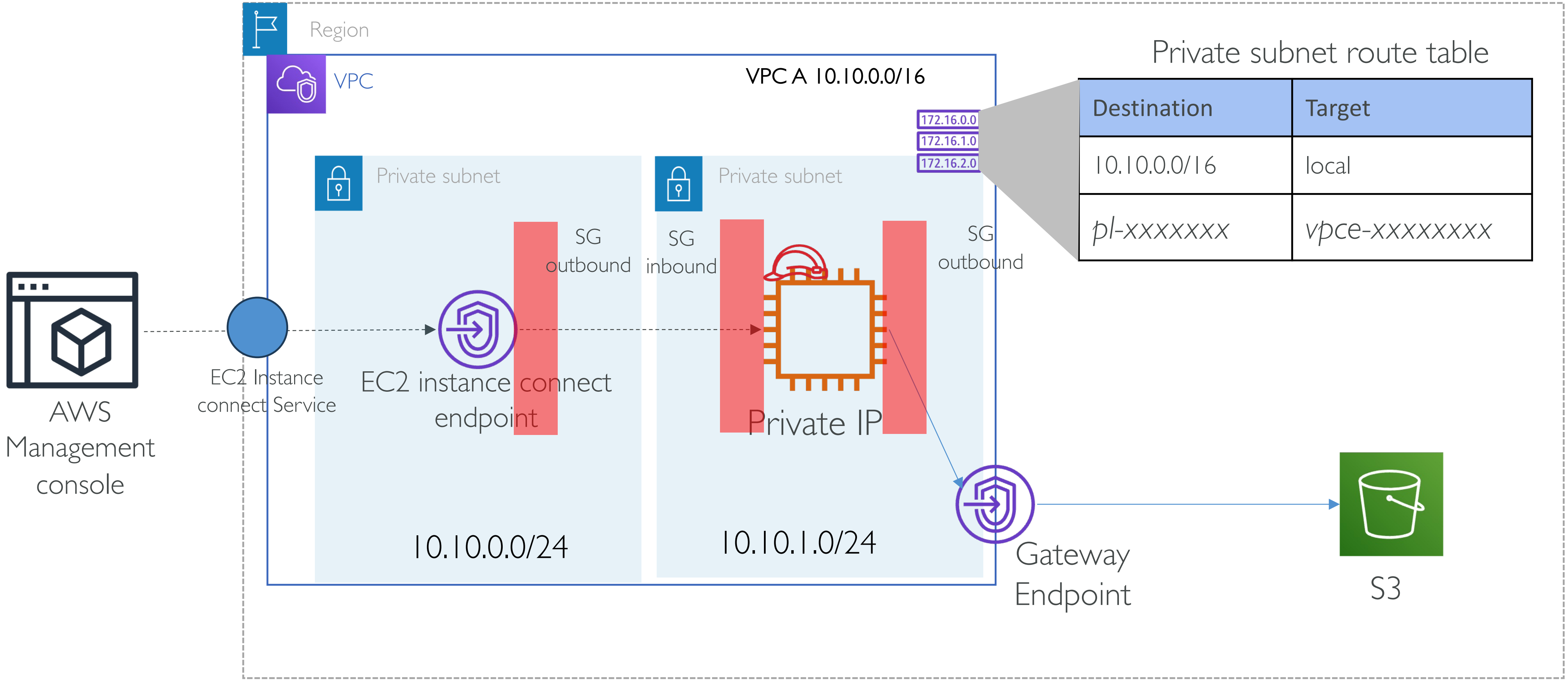
VPC Endpoint for S3 - Demo



Private subnet route table

Destination	Target
10.10.0.0/16	local
pl-xxxxxxx	*vpce-xxxxxxxx*

VPC Endpoint for S3 - Demo



Private subnet route table

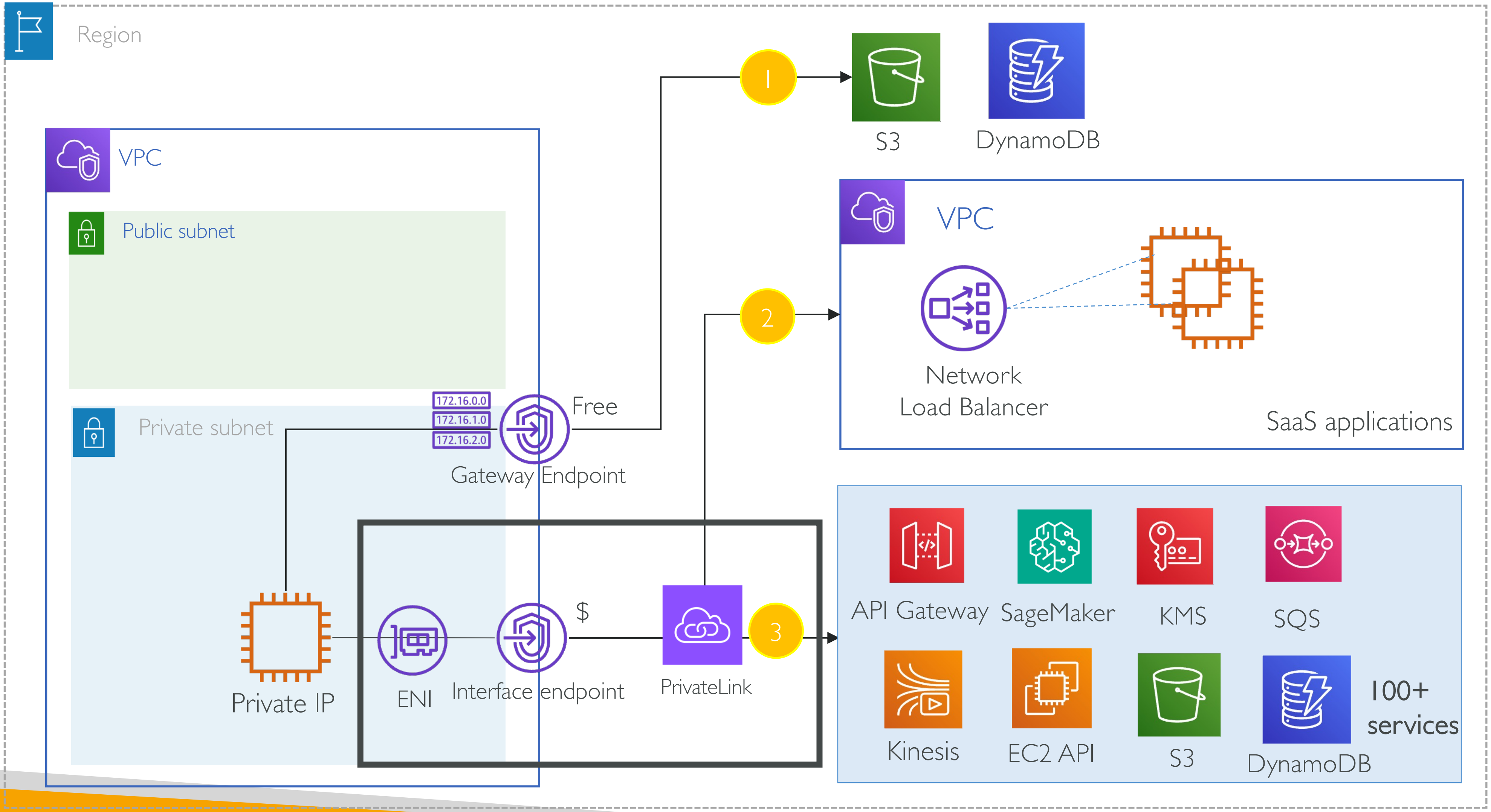
Destination	Target
10.10.0.0/16	local
pl-xxxxxxx	*vpce-xxxxxxxx*

Steps

1. Create VPC with two private subnets - Subnet1 for EC2Instance endpoint and Subnet2 for EC2 instance
2. Create Security group for EC2 instance - Inbound to allow SSH (22) and Outbound to allow HTTPS (443)
3. Create Security group for EC2 instance connect endpoint – Outbound to allow SSH (22) to EC2 instance
4. Create IAM role for EC2 instance to allow S3Full permissions
5. Launch EC2 instance in subnet2 – Associate SG and IAM role
6. Create EC2 instance connect endpoint in subnet1 – Associate SG
7. Create VPC Gateway endpoint for S3 - Select Subnet1
8. Modify Subnet2 route table to route traffic to S3 via VPC gateway endpoint
9. Login to EC2 instance using EC2 instance connect option from AWS console
10. Test the connectivity to S3 by uploading/downloading some files

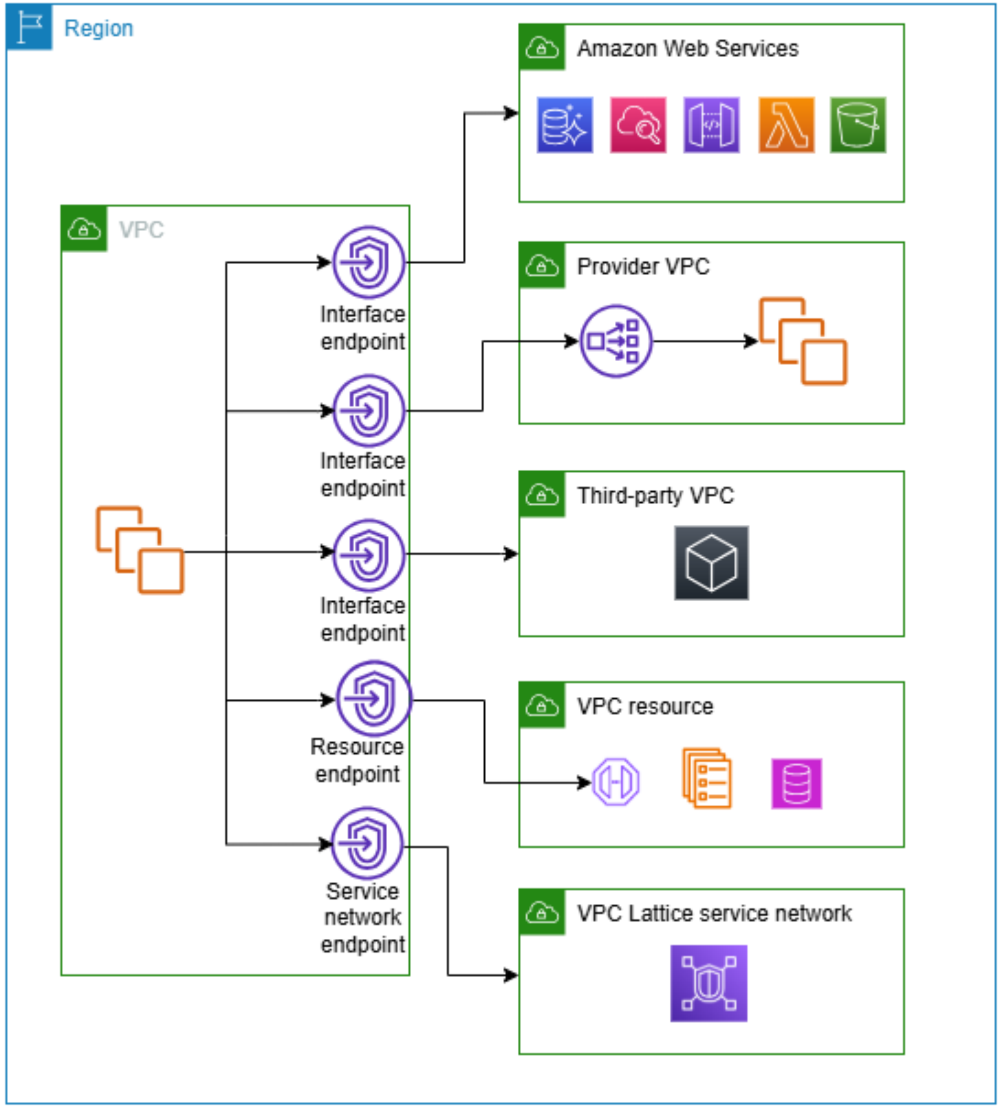
VPC endpoint and PrivateLink

With VPC endpoints & PrivateLink

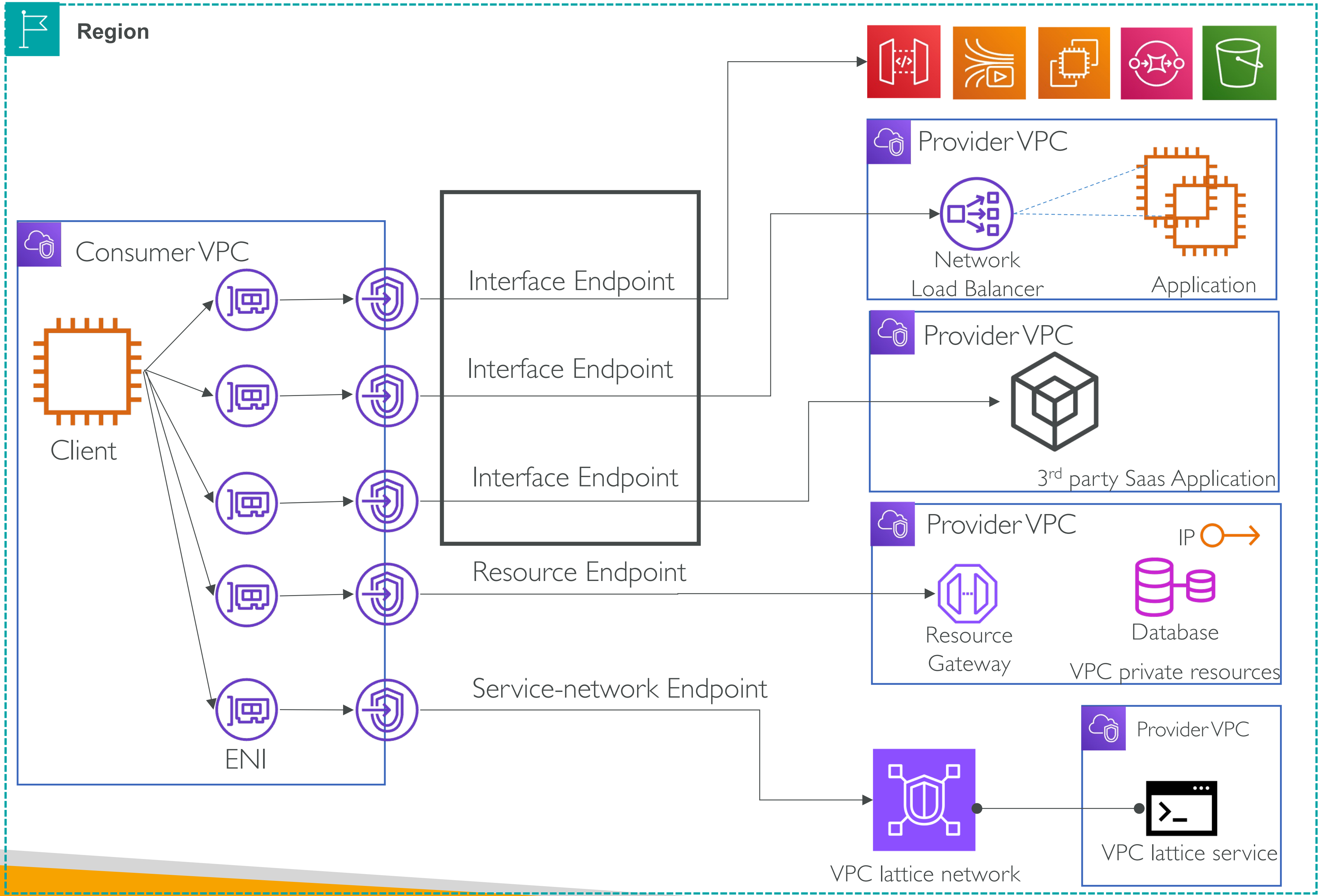


What's new?

- Types of endpoints
  - Interface endpoint
  - Resource endpoint NEW
  - Service-network endpoint NEW
- Support for IPv4 and IPv6 NAT
- Cross-region VPC endpoints NEW
- UDP traffic support over IPv4 and IPv6 NEW



VPC PrivateLink

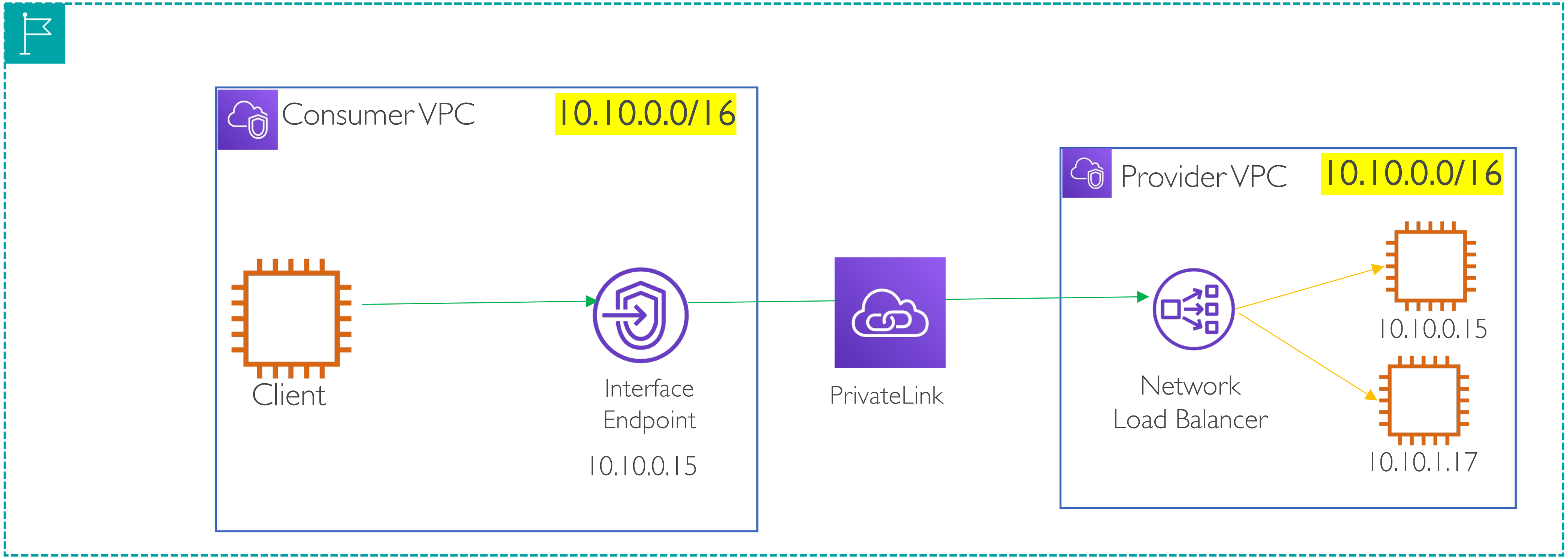


VPC PrivateLink – Important to know

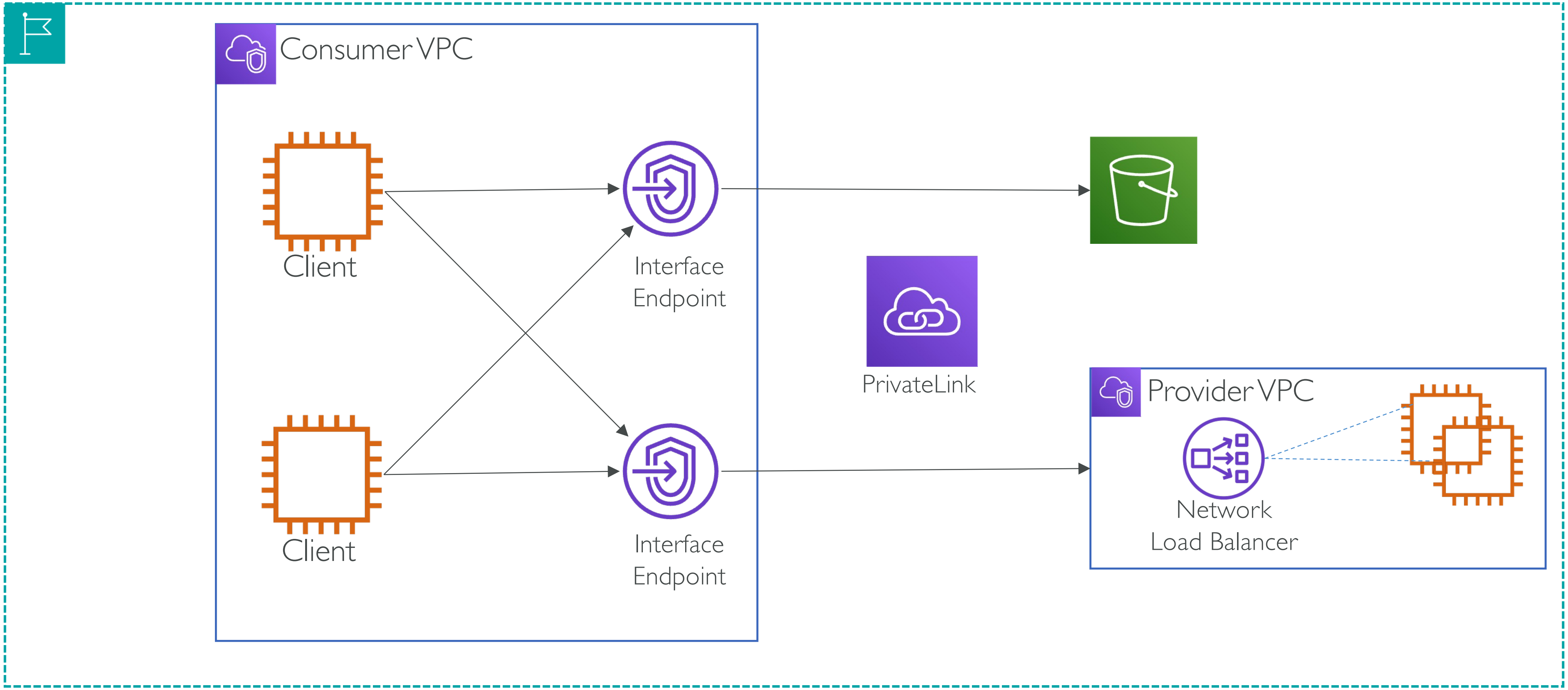
VPC PrivateLink – important to know

- VPC endpoints create local IP addresses (using ENI) in your VPC.
- VPC endpoint can be used to connect services inside VPCs with overlapping CIDR blocks
- For High Availability create VPC endpoints across multiple Availability zones
- Uses Security Groups – inbound rules
- VPC endpoint supports IPv4 and IPv6 traffic.
- VPC endpoint supports traffic over TCP and UDP
- VPC endpoint can be accessed from other networks e.g. Peered VPCs, Transit gateway, VPN or Direct Connect

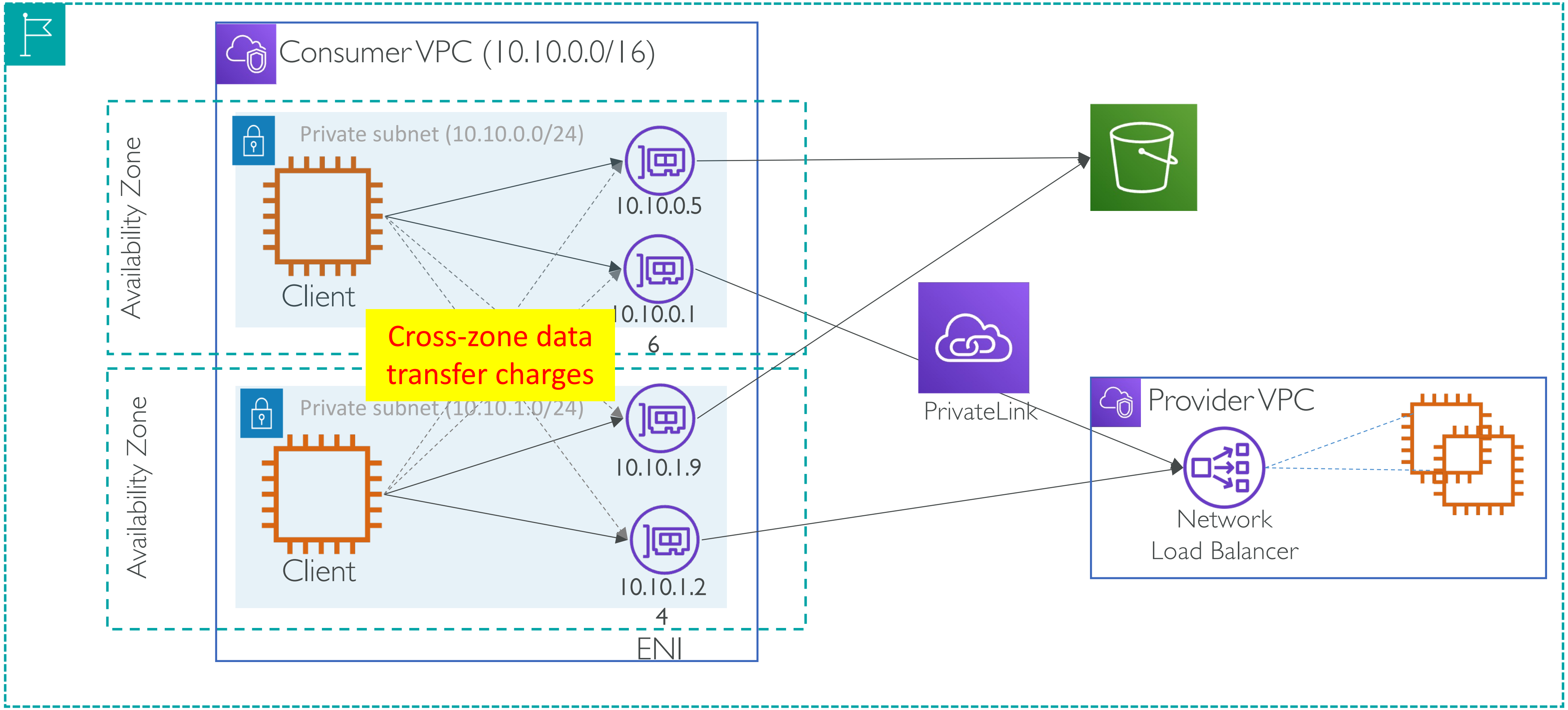
VPCs with overlapping CIDRs



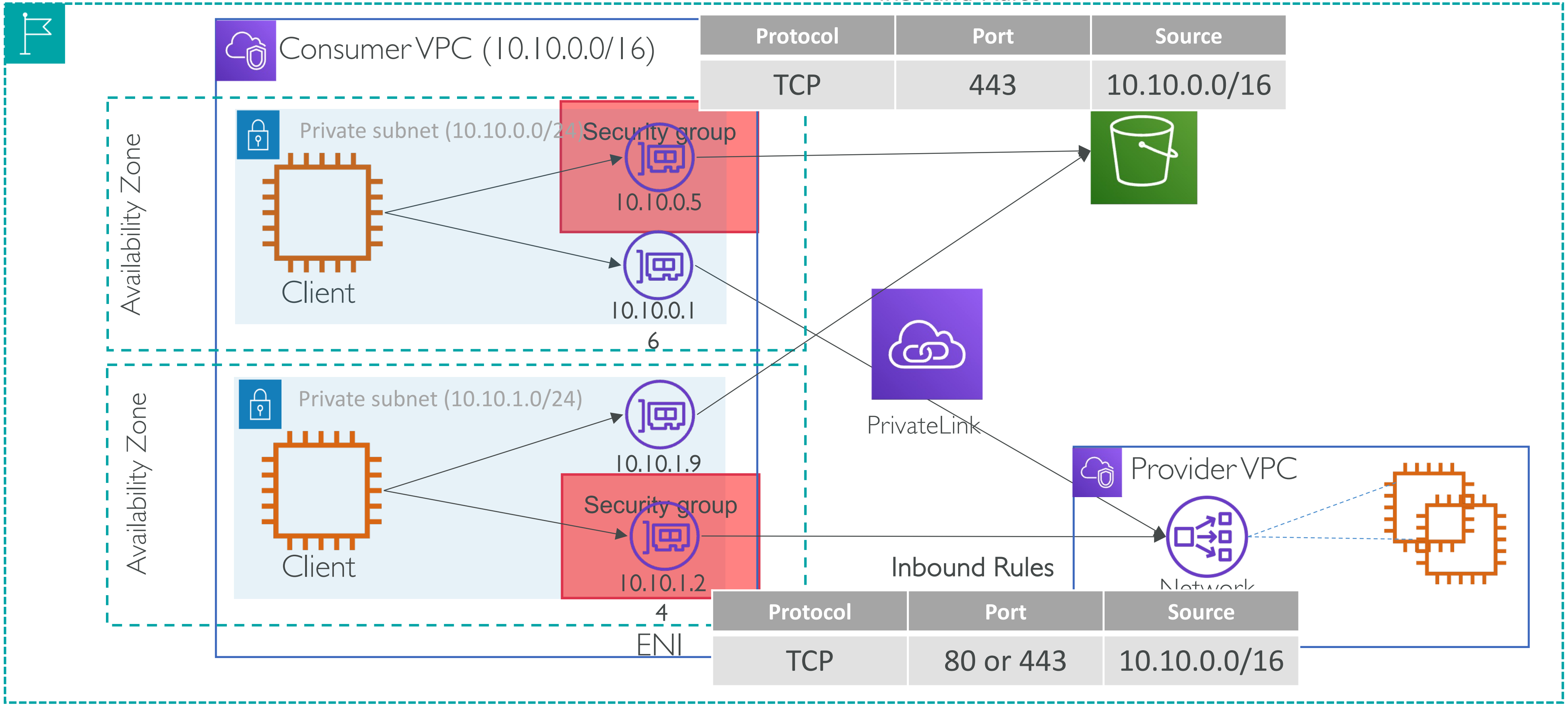
VPC endpoint - Availability zones



VPC endpoint - Availability zones



VPC endpoint - Security group



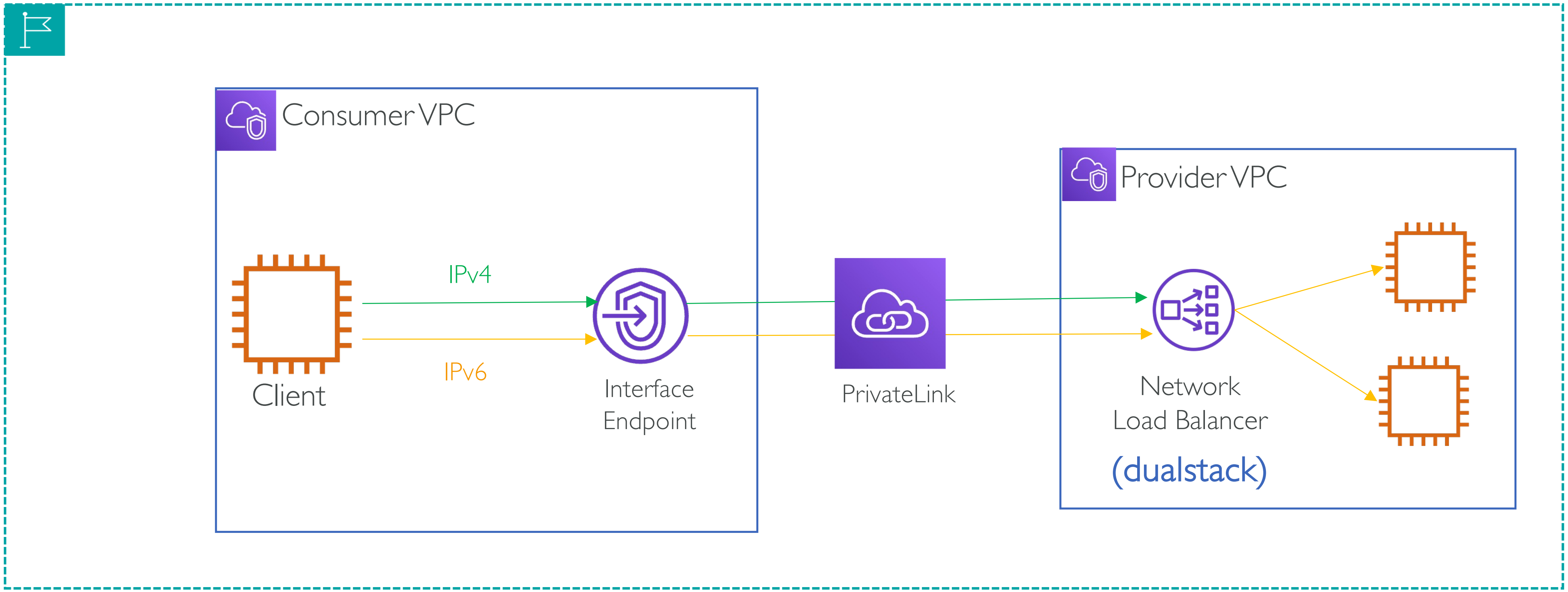
Inbound Rules

Protocol	Port	Source
TCP	443	10.10.0.0/16

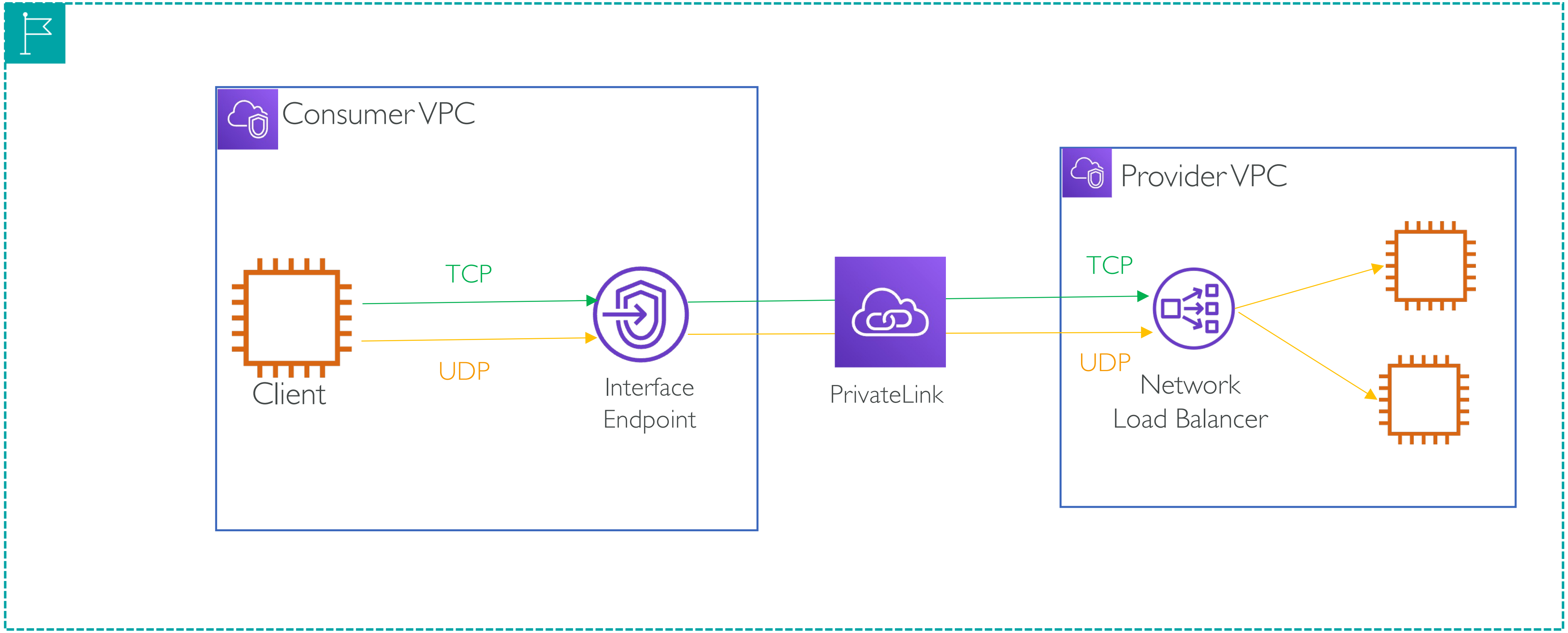
Inbound Rules

Protocol	Port	Source
TCP	80 or 443	10.10.0.0/16

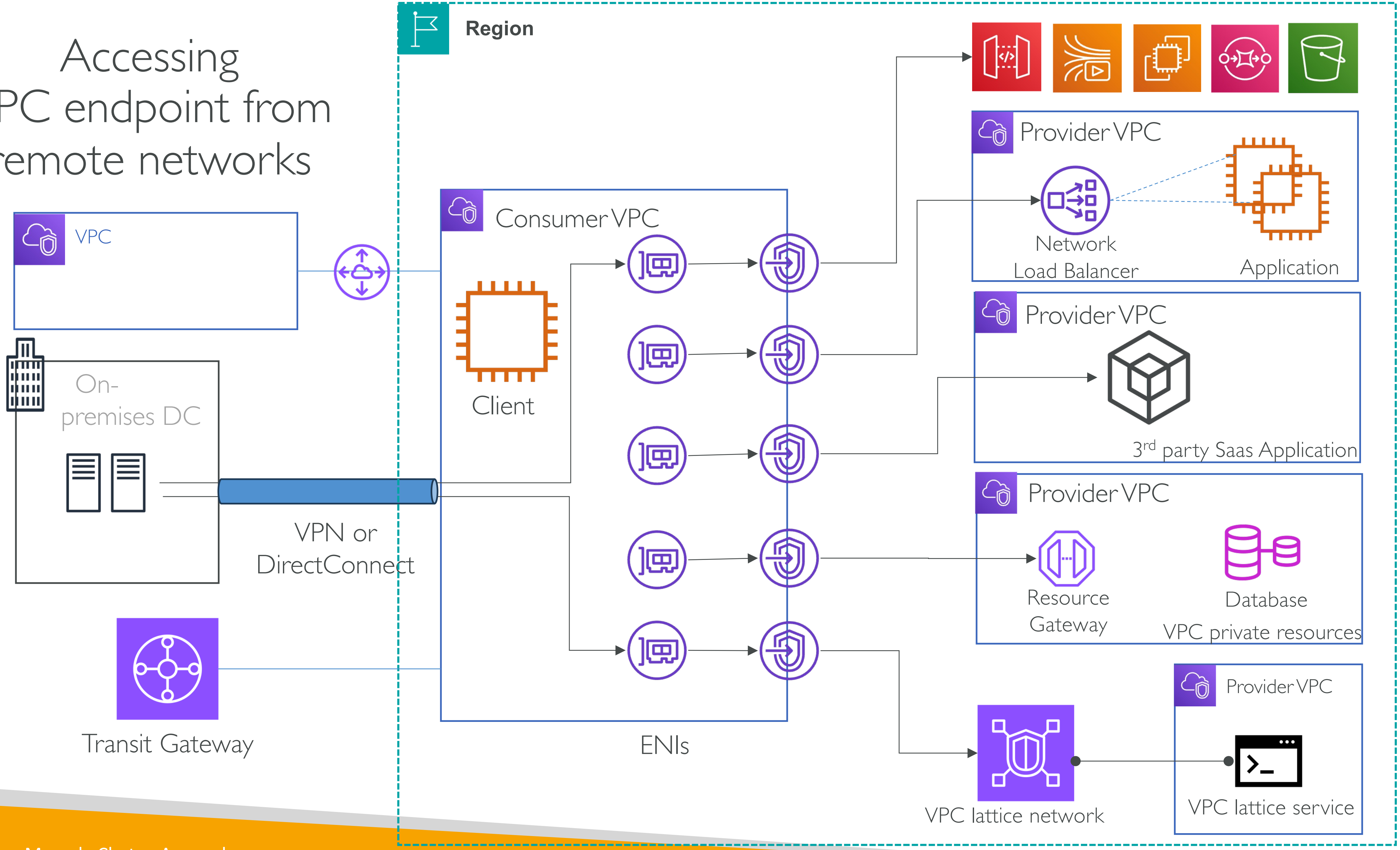
VPC endpoint – IP protocol support



VPC endpoint – Network protocol



Accessing VPC endpoint from remote networks



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- VPC endpoint can be accessed from other networks e.g. Peered VPCs, Transit gateway, VPN or Direct Connect

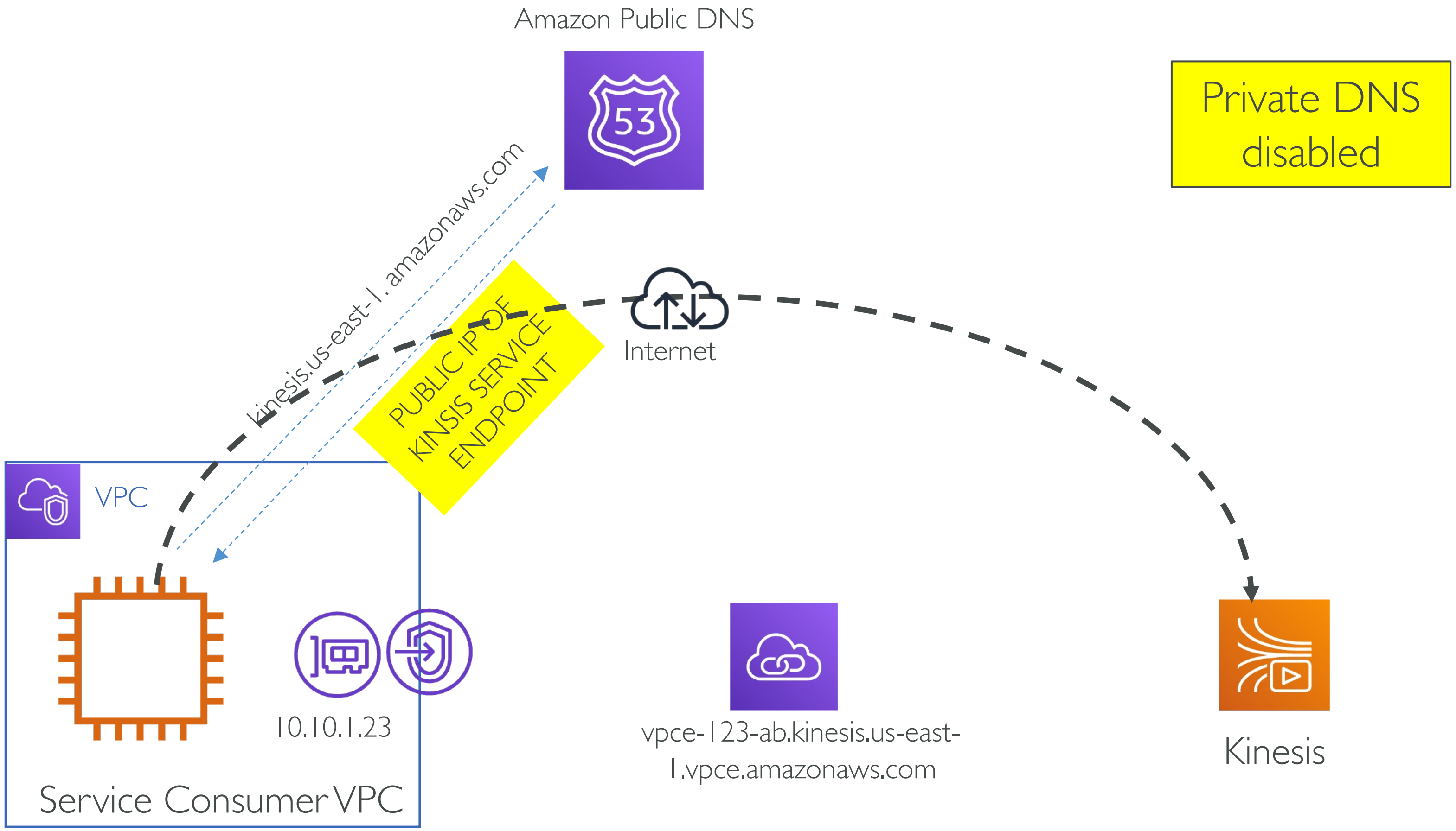
VPC Endpoint DNS

VPC Endpoint DNS

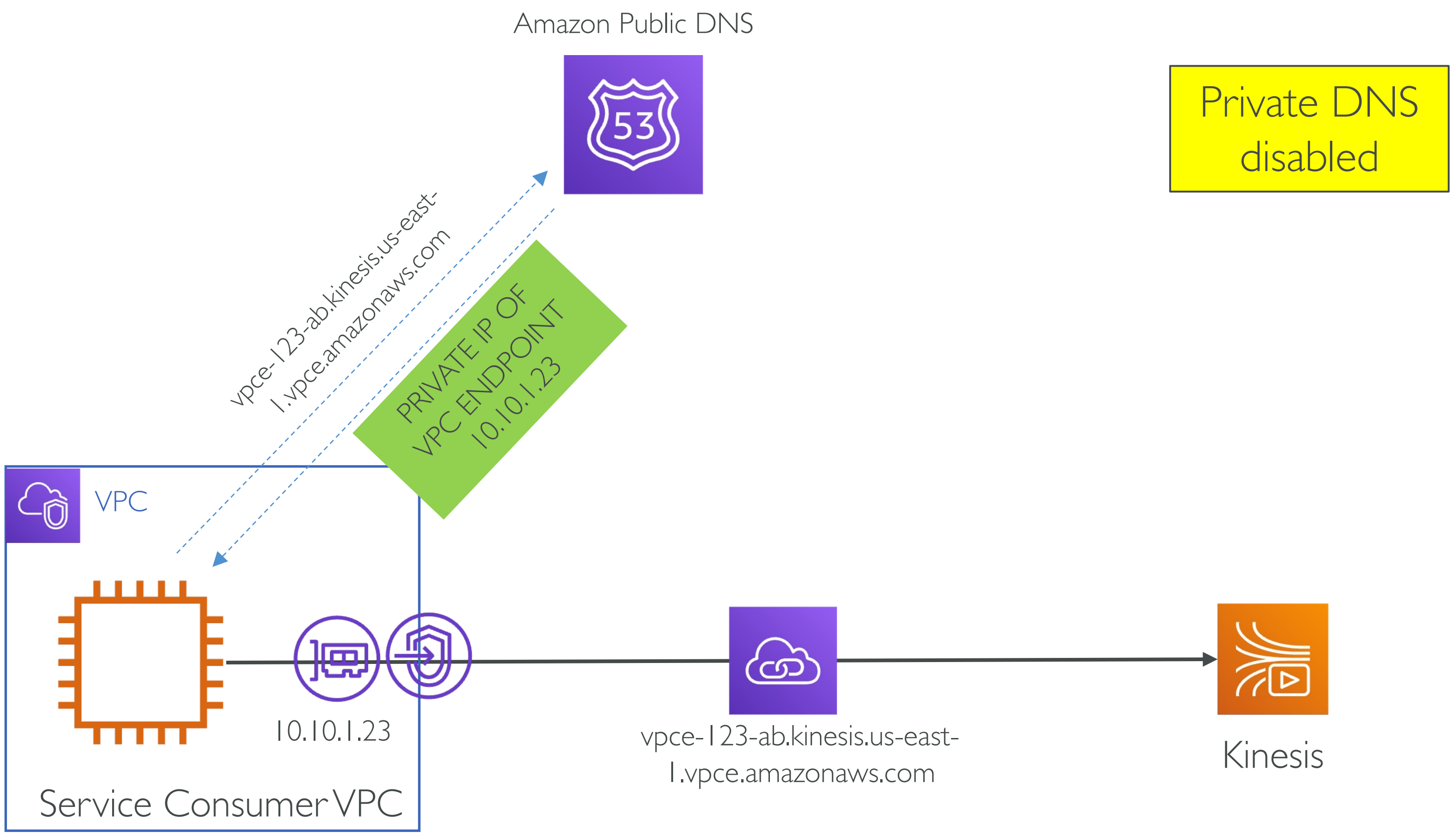
- AWS assigns DNS names to the VPC endpoint. It creates availability zone specific DNS and a regional DNS which resolves to Private IP address of the endpoint ENIs
  - **Regional:** vpce-0b7d2995e9dfe5418-mwrths3x.athena.us-east-1.vpce.amazonaws.com
  - **Zonal:** vpce-0b7d2995e9dfe5418-mwrths3x-us-east-1a.athena.us-east-1.vpce.amazonaws.com
  - **Zonal:** vpce-0b7d2995e9dfe5418-mwrths3x-us-east-1b.athena.us-east-1.vpce.amazonaws.com
- Optionally, we can enable Private DNS for the endpoint
  - With Private DNS enabled, the consumer VPC can access the endpoint services using Service's default DNS e.g kinesis.ap-south-1.amazonaws.com instead of using endpoint specific DNS e.g vpce-12345-ab.kinesis.ap-south-1.vpce.amazonaws.com
  - VPC Setting "Enable DNS hostnames" and "Enable DNS Support" must be 'true'

VPC Endpoint DNS

- With Private DNS disabled the API/CLI calls to the AWS service endpoint resolves to Public IP

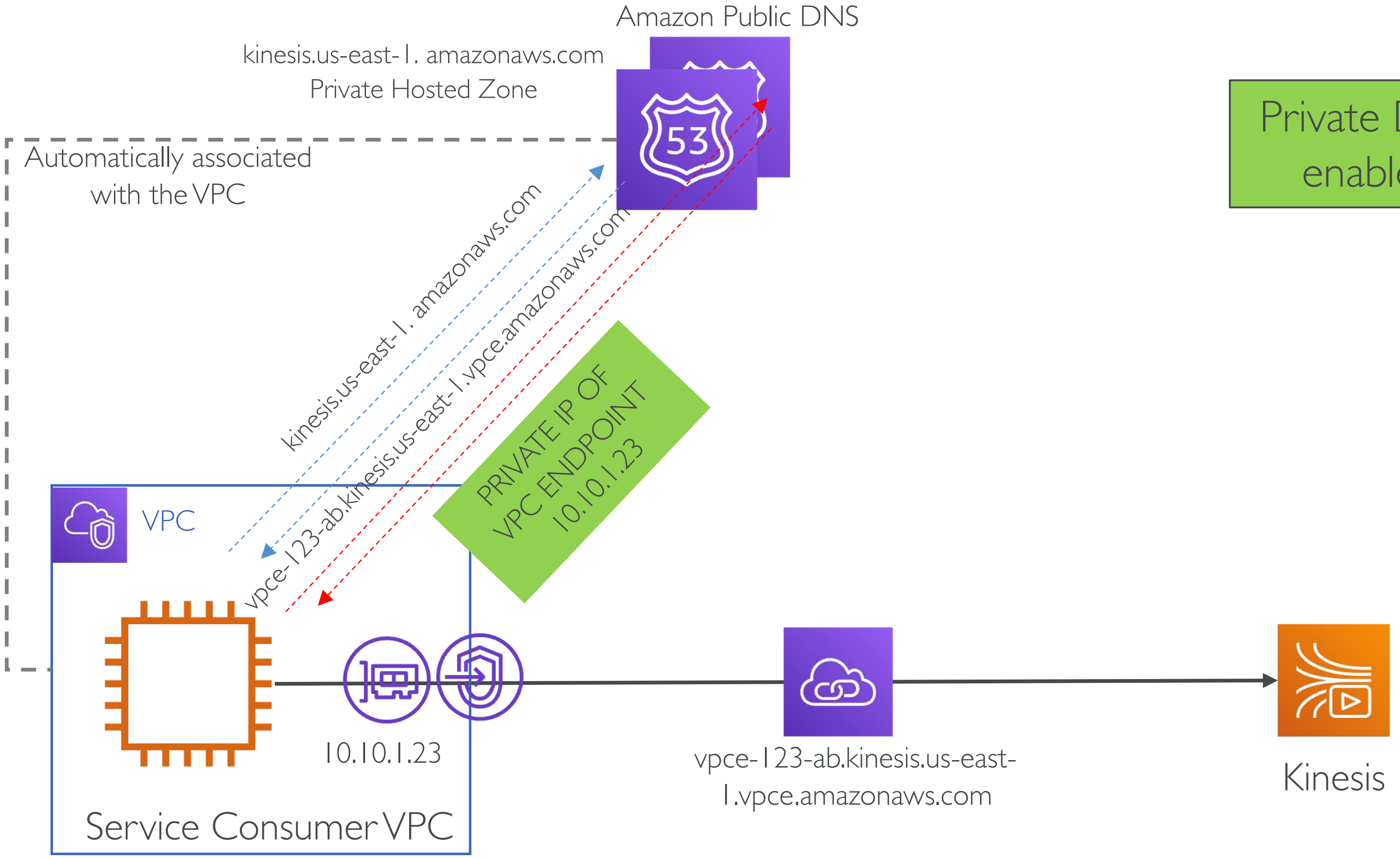


VPC Endpoint DNS



- Using endpoint specific DNS name
- This resolves to Private IP of the endpoint and connects to AWS service endpoint privately
- Using endpoint DNS in API/CLI is not desirable

VPC Endpoint DNS



Private DNS enabled

- With Private DNS enabled, Application inside VPC using API/CLI/SDK do not need any change for accessing AWS service

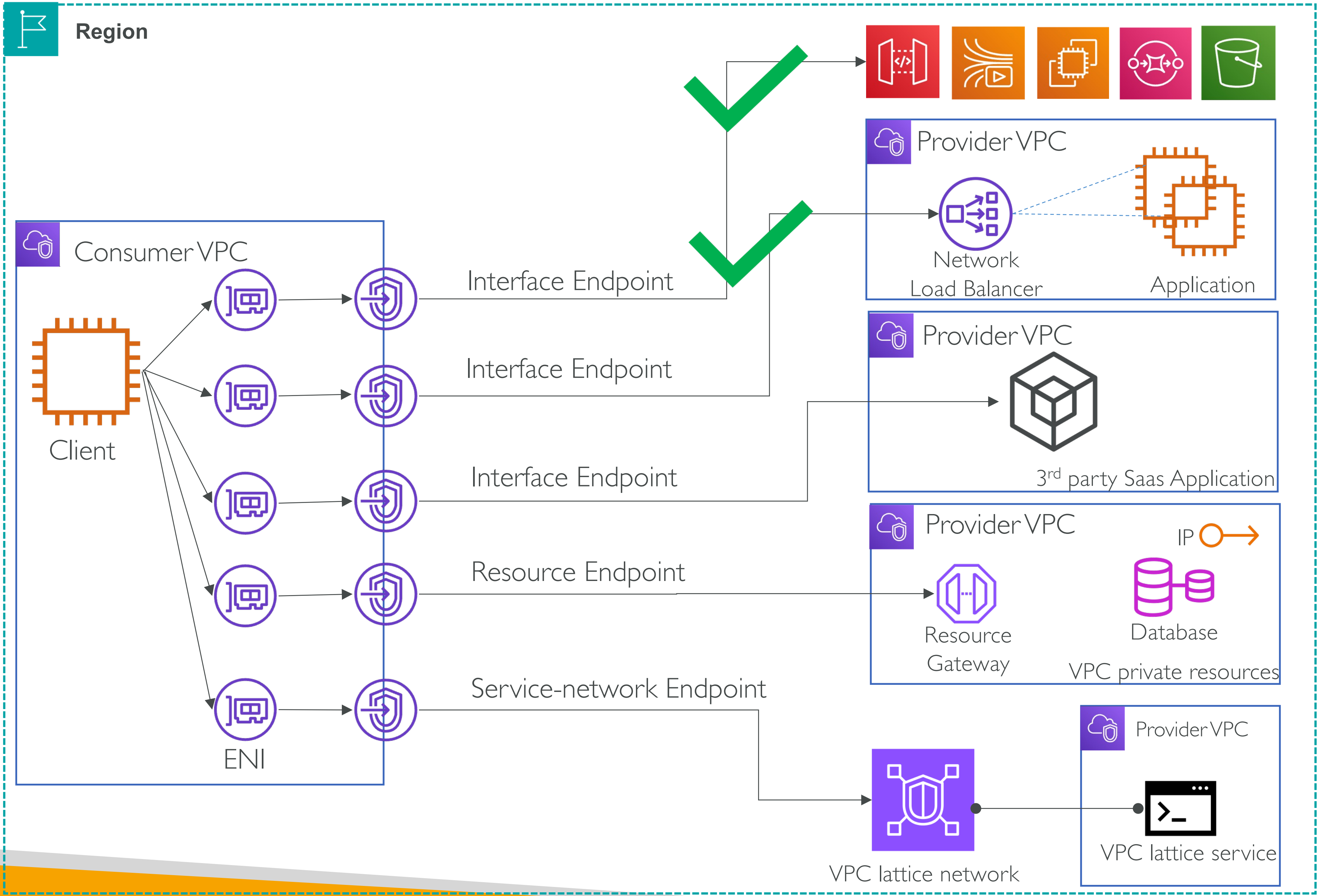
VPC endpoints DNS Summary

- With Private DNS enabled
  - The public hostname of a service will resolve to the private Endpoint Interface hostname
  - For AWS services (e.g SQS, Kinesis etc) AWS creates Private Hosted Zone and associate it with your VPC
  - Example: With Private DNS enabled, the consumer VPC can access the endpoint services using Service's default DNS e.g **ec2.us-east-1.amazonaws.com** instead of using endpoint specific DNS e.g vpce-12345-ab.ec2.us-east-1.vpce.amazonaws.com

- VPC Setting: "Enable DNS hostnames" and "Enable DNS Support" must be 'true'

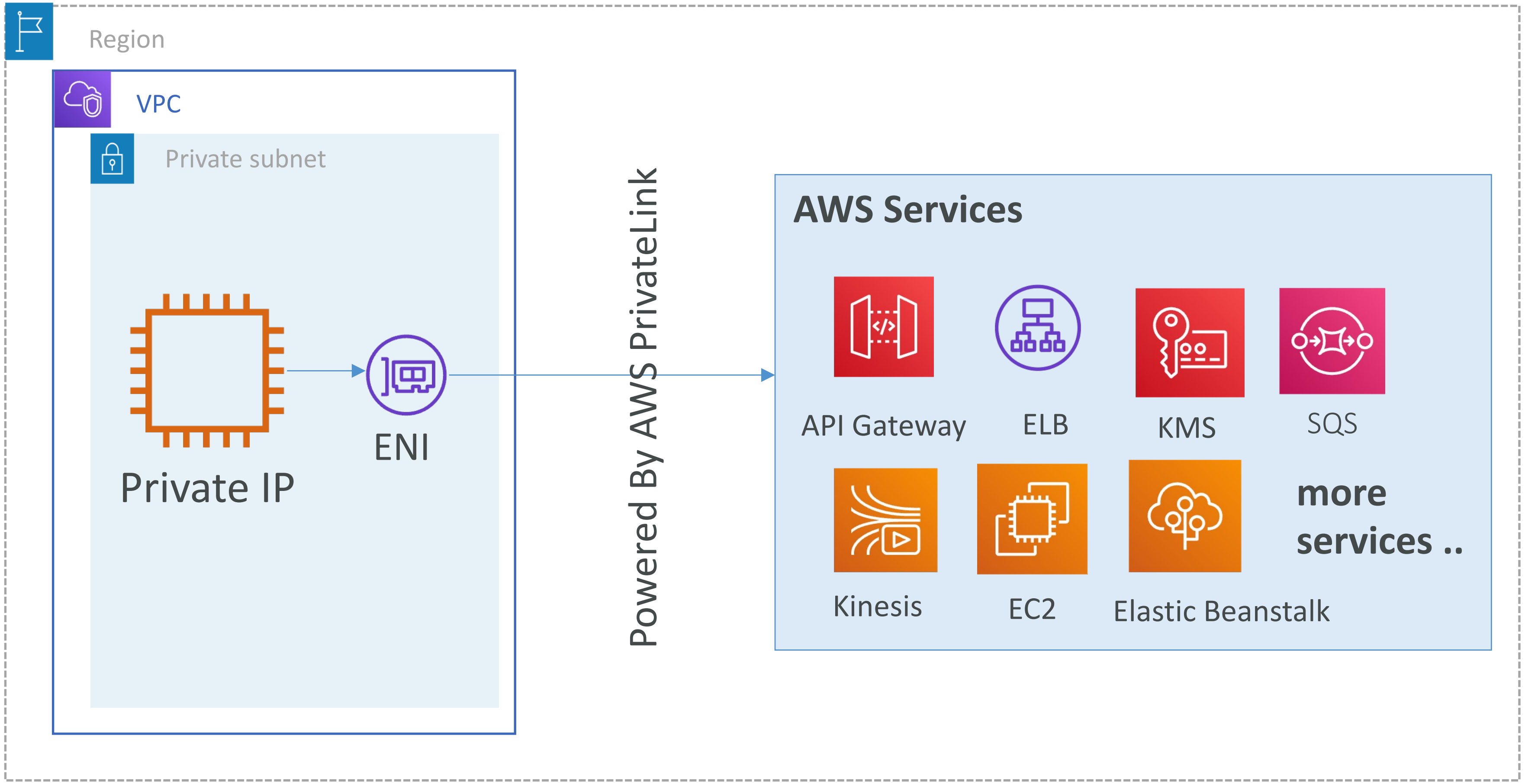
Accessing services using VPC endpoint & PrivateLink

VPC endpoints



Accessing AWS Services

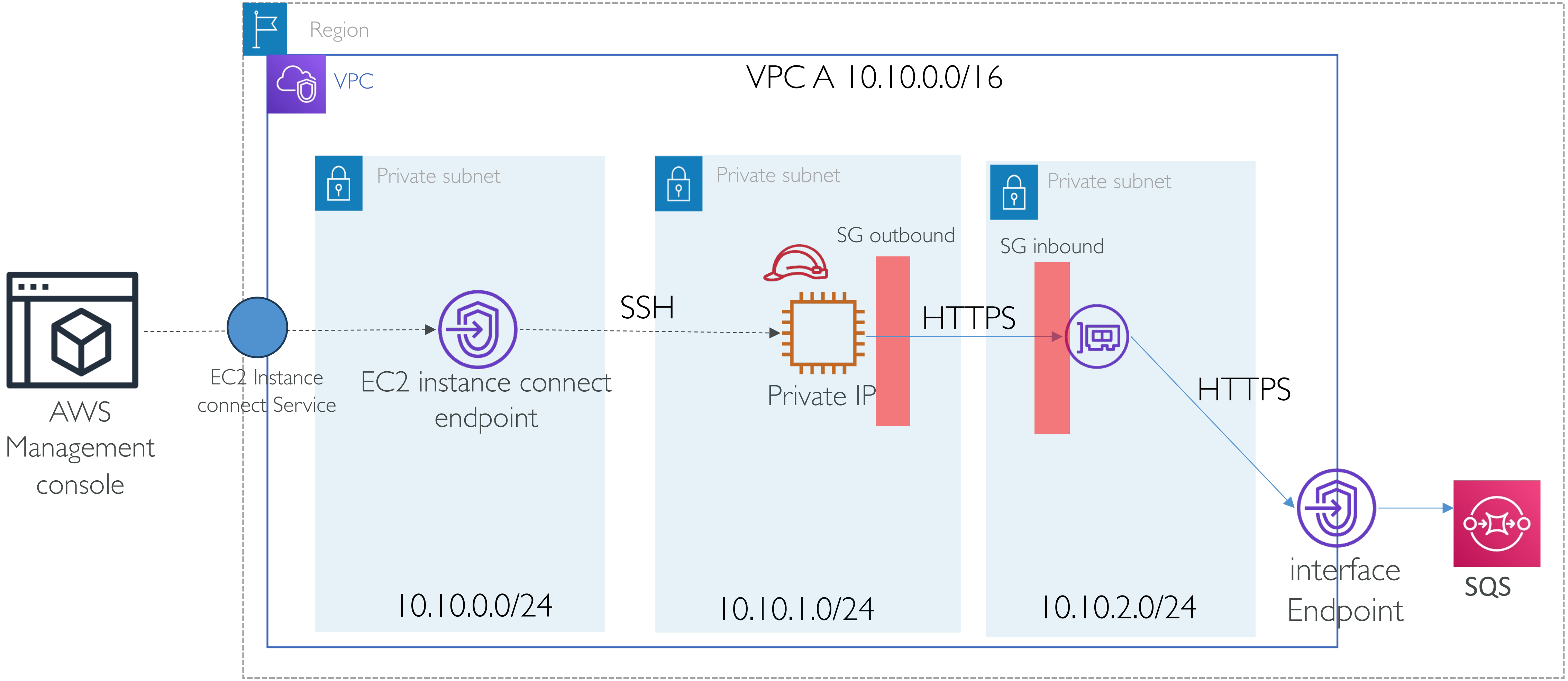
VPC Endpoint – Accessing AWS Services



VPC Endpoint for AWS Service

- AWS Services have their own Public DNS e.g. sqs.ap-south-1.amazonaws.com
- This DNS name will by default resolve to SQS service Public IP
- Private DNS settings for VPC 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:
    - **Regional:** vpce-0b7d2995e9dfe5418-mwrths3x.sqs.us-east-1.vpce.amazonaws.com
    - **Zonal:** vpce-0b7d2995e9dfe5418-mwrths3x-us-east-1a.sqs.us-east-1.vpce.amazonaws.com
    - **Zonal:** vpce-0b7d2995e9dfe5418-mwrths3x-us-east-1b.sqs.us-east-1.vpce.amazonaws.com
    - **Service DNS:** sqs.us-east-1.amazonaws.com (private DNS name)
- With Private DNS enabled, the consumer VPC can access the endpoint services using Service's default DNS e.g **ec2.us-east-1.amazonaws.com** instead of using endpoint specific DNS e.g vpce-12345-ab.ec2.us-east-1.vpce.amazonaws.com

Accessing AWS service - Demo



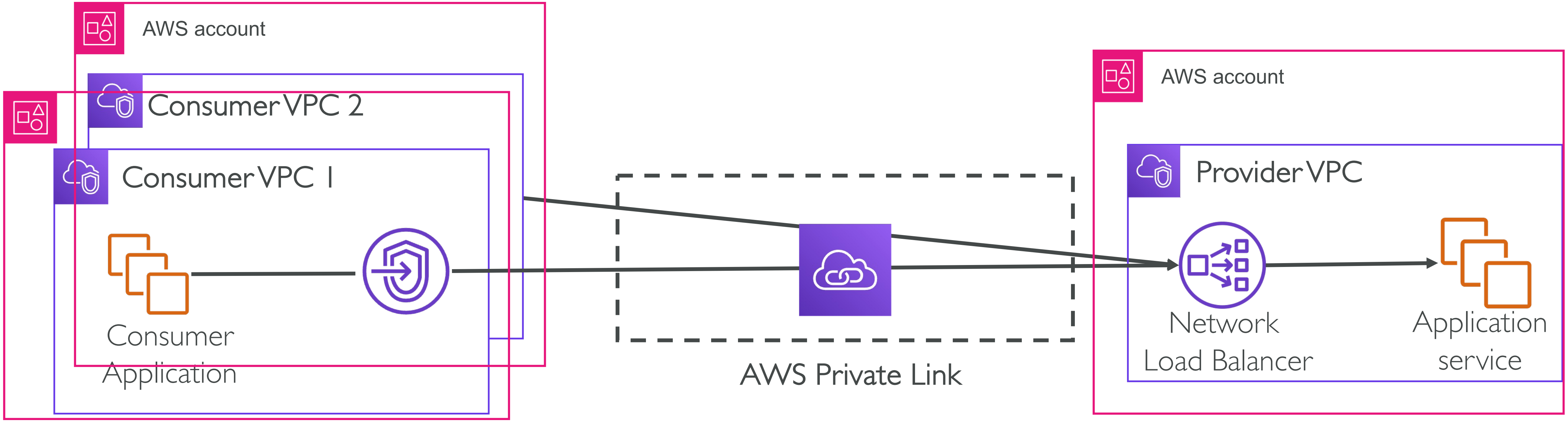
Steps

1. Create VPC with three private subnets - Subnet1 for EC2Instance endpoint, Subnet2 for EC2 instance and Subnet 3 for VPC endpoint
2. Enable Enable DNS hostnames" and "Enable DNS Support for the VPC
3. Create Security group for EC2 instance - Inbound to allow SSH (22) and Outbound to allow HTTPS (443)
4. Create Security group for EC2 instance connect endpoint – Outbound to allow SSH (22) to EC2 instance
5. Create Security group for VPC endpoint ENI – Inbound HTTPS (443) from EC2 instance
6. Create IAM role for EC2 instance to allow Amazon SQS permissions
7. Create EC2 instance connect endpoint in subnet1 – Associate SG
8. Launch EC2 instance in subnet2 – Associate SG and IAM role
9. Create VPC interface endpoint for SQS - Select Subnet3, Enable Private DNS
10. Login to EC2 instance using EC2 instance connect option from AWS console
11. Test the connectivity to SQS by sending some messages

Accessing VPC endpoint service

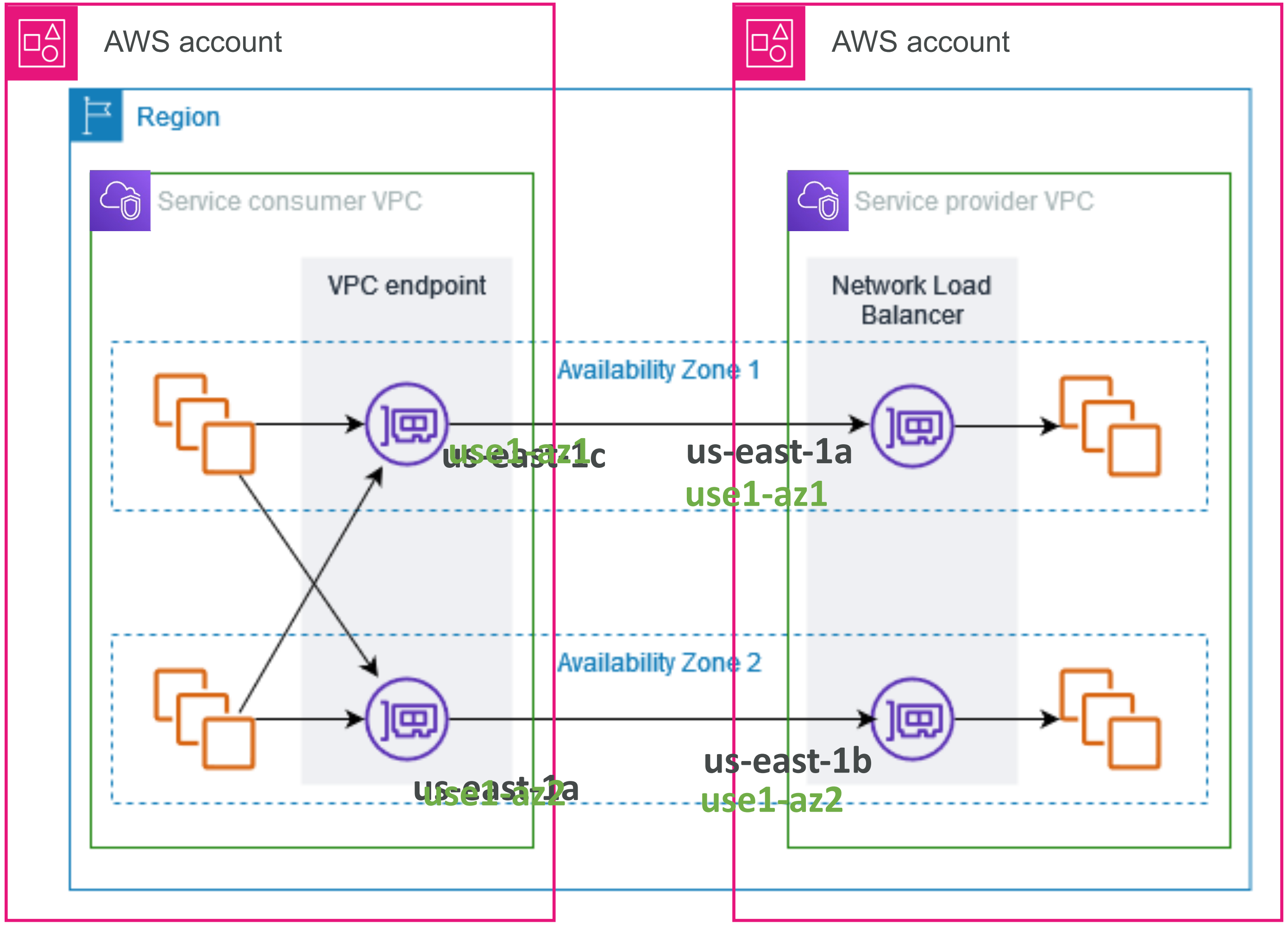
VPC Endpoint Services

- Most secure & scalable way to expose a service to 1000s of VPC (across AWS accounts)
- Does not require VPC peering, internet gateway, NAT, route tables…
- Requires a network load balancer in Provider VPC and VPC endpoint in customer VPC



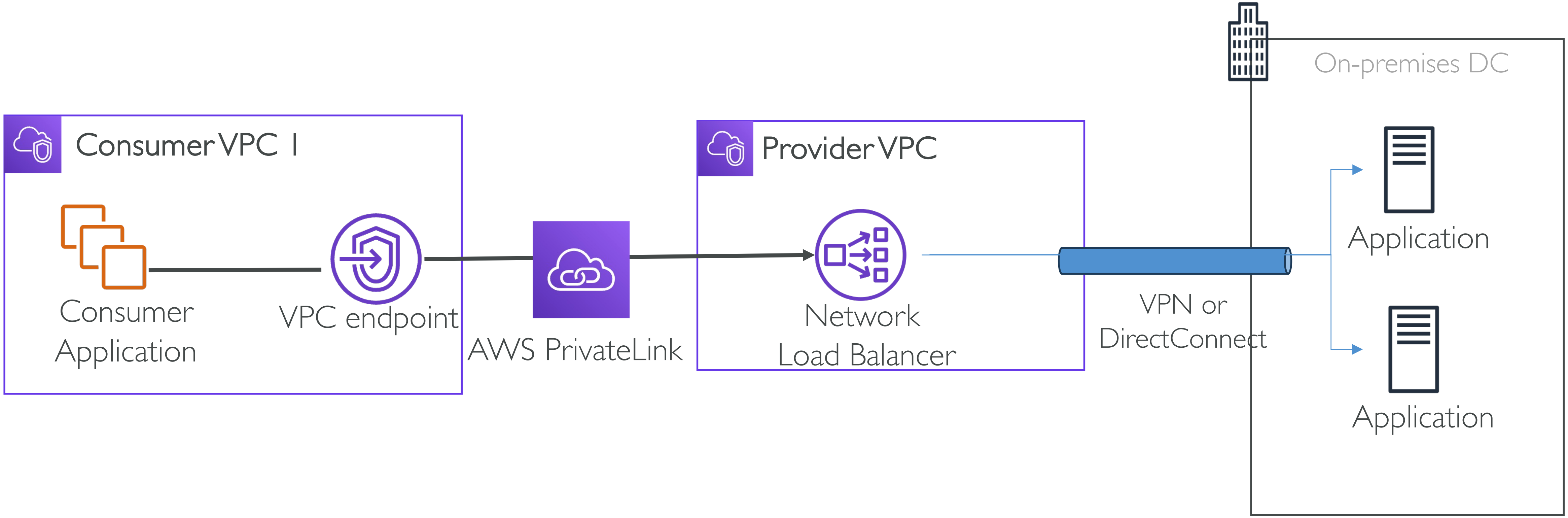
VPC Endpoint Service AZ considerations

- Service provider VPC should have targets across multiple AZs
- VPC Endpoint in Service Consumer VPC should also be created in corresponding AZs
- In Consumer VPC, application to use zone specific DNS for keeping the traffic in the same AZ
- If using regional endpoint, then DNS will resolve the ENI IPs in round robin fashion
- Optionally enable cross-zone load balancing for NLB so that it can sent traffic to backend instances in another AZ (*inter-AZ data transfer charges apply)



VPC Endpoint service with on-premises targets

- Network Load Balancer can have target IPs from your on-premises network if VPC is connected to the on-premises network over the VPN or Direct Connect

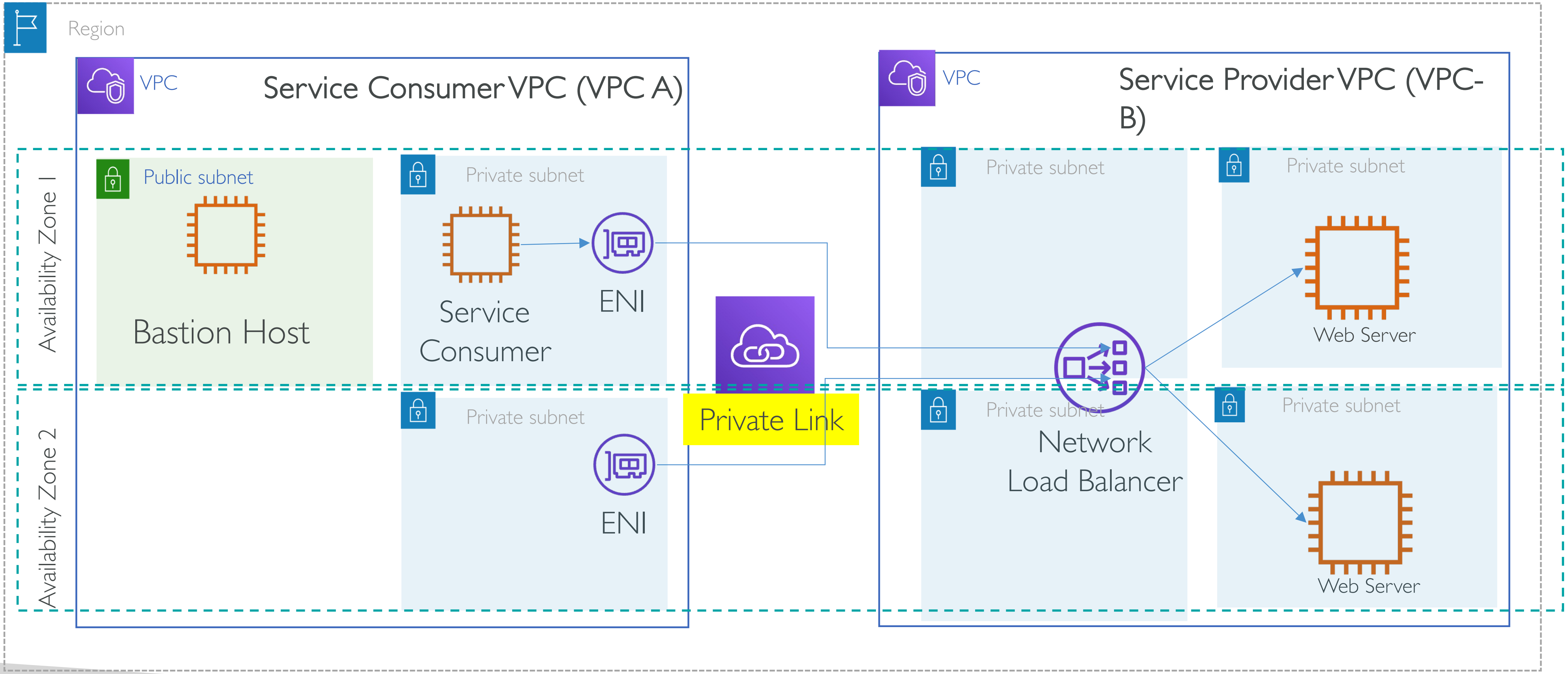


Exercise – VPC endpoint service

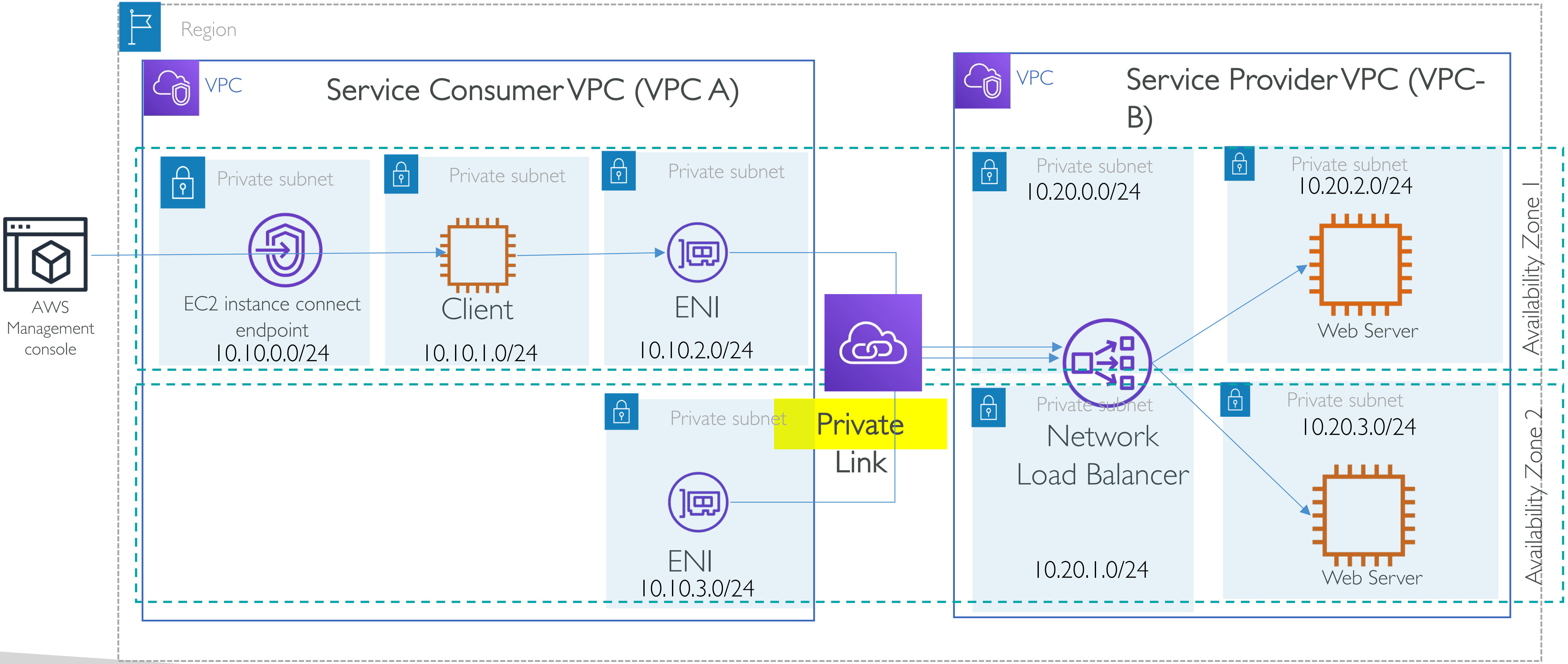
To create VPC endpoint service in Service Provider VPC

- Choose the Network Load Balancer (+availability zones) and register the targets in the Target group
- Create a VPC endpoint Service
  - Choose AWS regions for **Cross-region access** to the service
  - Configure "Require Acceptance" flag
  - Optionally configure "Enable Private DNS" – The DNS must be owned by you
  - Configure supported IP type – IPv4 or IPv4 or both
  - Allow other AWS accounts to access your endpoint service by adding AWS account or Role or User ARN in the "Allow Principals" setting

Exercise – VPC endpoint service



Exercise – VPC endpoint service



Exercise steps

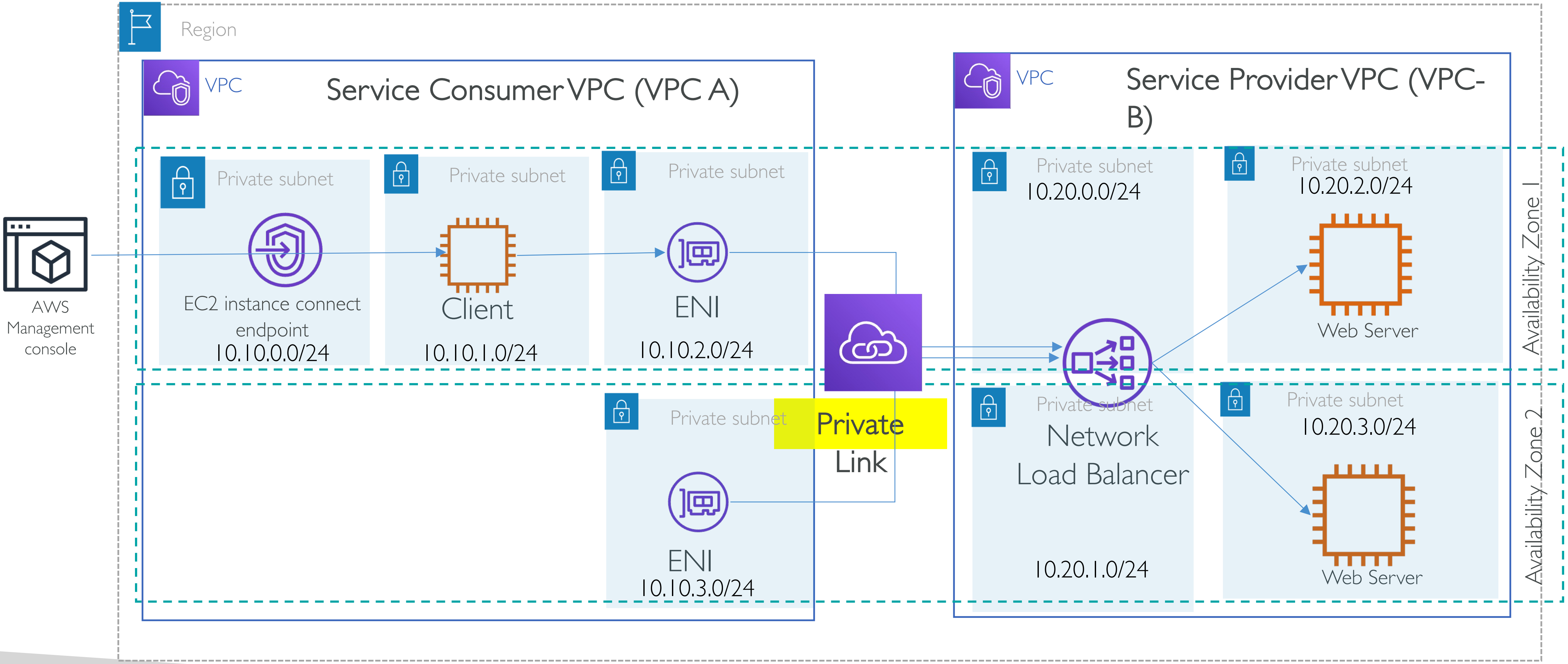
- **Pre-requisites:** Create EC2 AMI having httpd webserver. We need this to launch Private EC2 instances in VPC-B to host the dummy service.
- Create VPC-B with 4 Private Subnets – 2 for NLB and 2 for Webservers
- Launch 2 EC2 instances in a Private Subnets using AMI created earlier
- Create NLB in 2 Private Subnets and register EC2 instances in Target group
- Create VPC Endpoint Service in VPC-B using NLB
- Allow the VPC-A AWS account (if both VPCs are in different AWS accounts)
- Create Service Consumer VPC (VPC-A) with 4 private subnets as shown.
- Create EC2 instance connect endpoint in the VPC-A in the first private subnet
- Launch a consumer EC2 instance in one of the private subnet
- Login to Private EC2 instance (via EC2 instance connect endpoint) in VPC-A
- Create VPC endpoint in VPC-A and search for endpoint service created above
- Verify the connectivity to VPC endpoint service (webserver) using zonal and regional endpoints
- Optionally enable the Private DNS for the VPC endpoint service and verify the connectivity using private DNS (you must own the domain name and should be able to verify the ownership)

How to create AMI for the webserver?

- Use below userdata to launch an EC2 instance in a default VPC
- Once launched, verify that you can access web page using Public IP
- Create AMI from this instance

```
#!/bin/bash
yum install -y httpd
systemctl start httpd.service
systemctl enable httpd.service
echo THIS SERVICE IS FOR VPC ENDPOINT DEMO > /var/www/html/index.html
```

Exercise – VPC endpoint service with Private Domain name



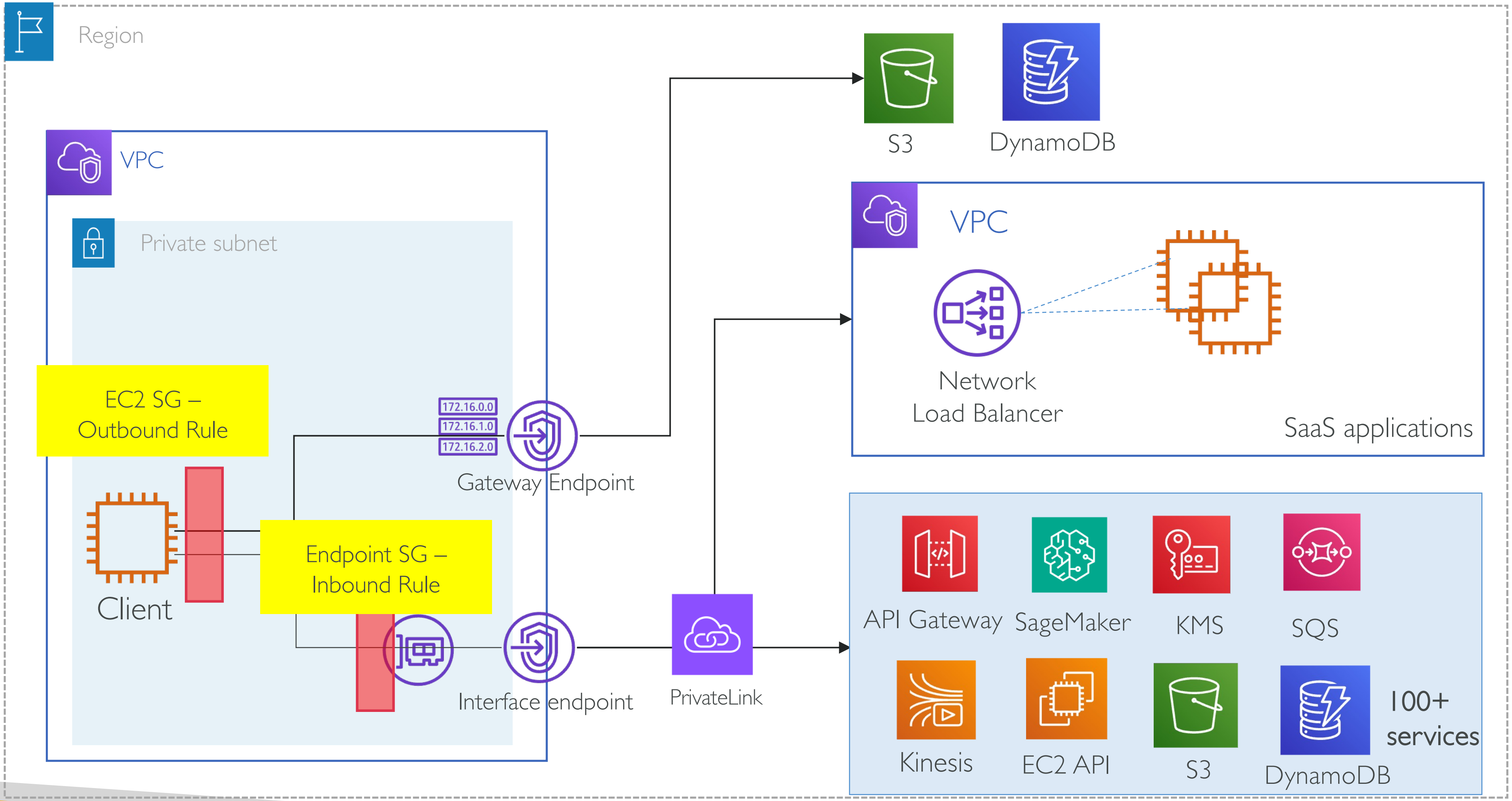
How to use Private domain name?

- Enable Private DNS for the VPC endpoint service (in Service provider VPC)
- Enable Private DNS for the VPC endpoint (in Service consumer VPC)
- VPC Setting: "Enable DNS hostnames" and "Enable DNS Support" must be 'true'

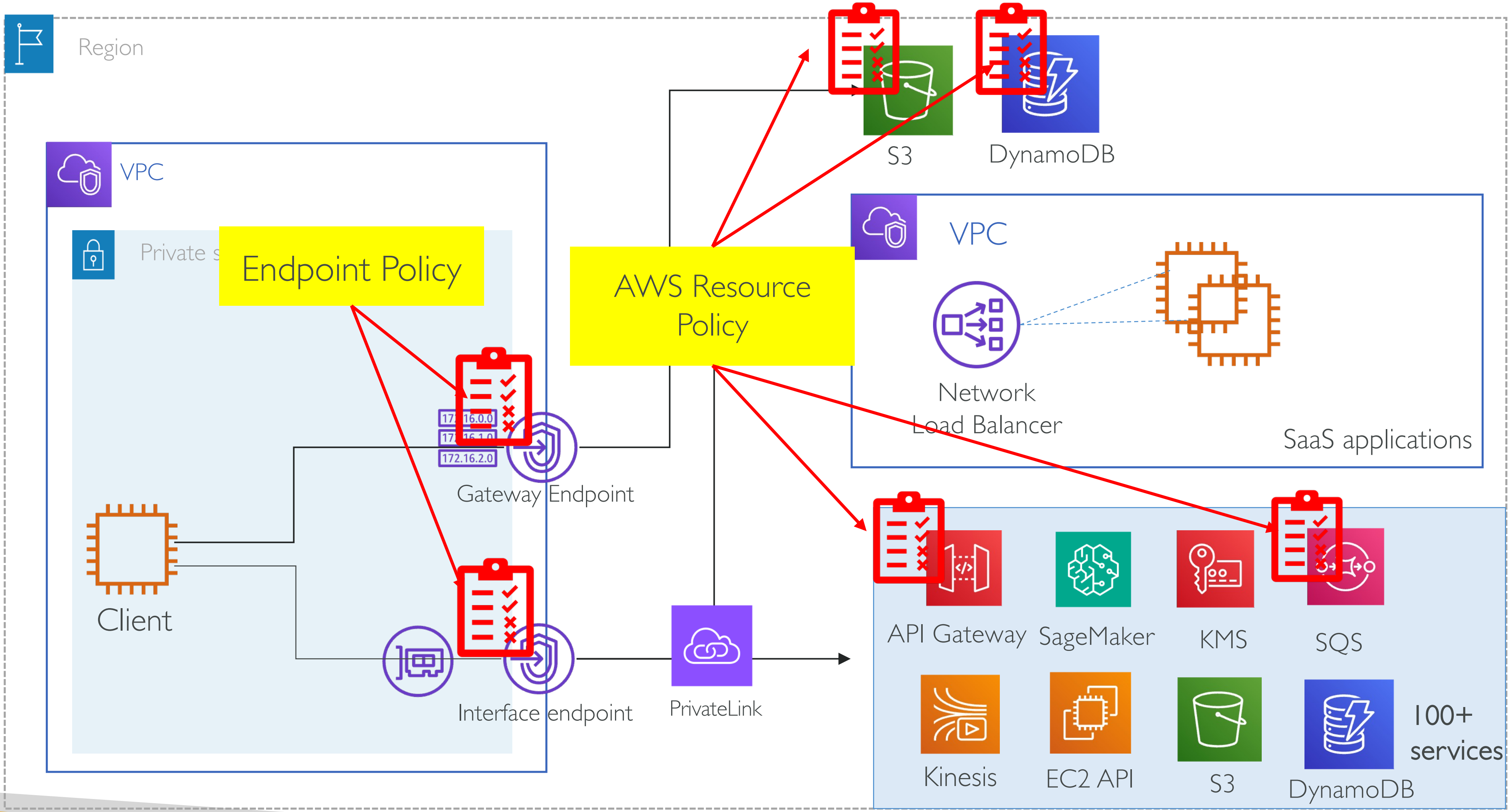
Note: Domain name must be owned by you and you should be able to verify the domain ownership.

VPC endpoint security

VPC endpoint security – Network layer



VPC endpoint security – IAM policies



VPC endpoint default policy

- If no policy is explicitly assigned the default policy is applied
- Custom VPC endpoint Policy can be applied for the supported AWS services
- You can check whether endpoint policy is supported for a given AWS service
- For VPC endpoint service, the default policy is applied

```
{
    "Statement": [
        {
            "Effect": "Allow",
            "Principal": "*",
            "Action": "*",
            "Resource": "*"
        }
    ]
}
```

```
aws ec2 describe-vpc-endpoint-services \
  --service-name "com.amazonaws.us-east-1.s3" \
  --region us-east-1 \
  --query ServiceDetails[*].VpcEndpointPolicySupported \
  --output text
```

VPC Endpoint Policy

- VPC Endpoint Policy to restrict access to a specific AWS service resource

Restrict access to S3 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/*"]
    }
  ]
}
```

Restrict access to DynamoDB table

```
{
  "Statement": [
    {
      "Sid": "AccessToSpecificTable",
      "Principal": "*",
      "Action": [
        "dynamodb:Batch*",
        "dynamodb:Delete*",
        "dynamodb:DescribeTable",
        "dynamodb:GetItem",
        "dynamodb:PutItem",
        "dynamodb:Update*"
      ],
      "Effect": "Allow",
      "Resource": "arn:aws:dynamodb:us-east-1:123456789012:table/StockTable"
    }
  ]
}
```

VPC Endpoint Policy

- VPC Endpoint Policy to restrict access for a specific IAM account/user/role

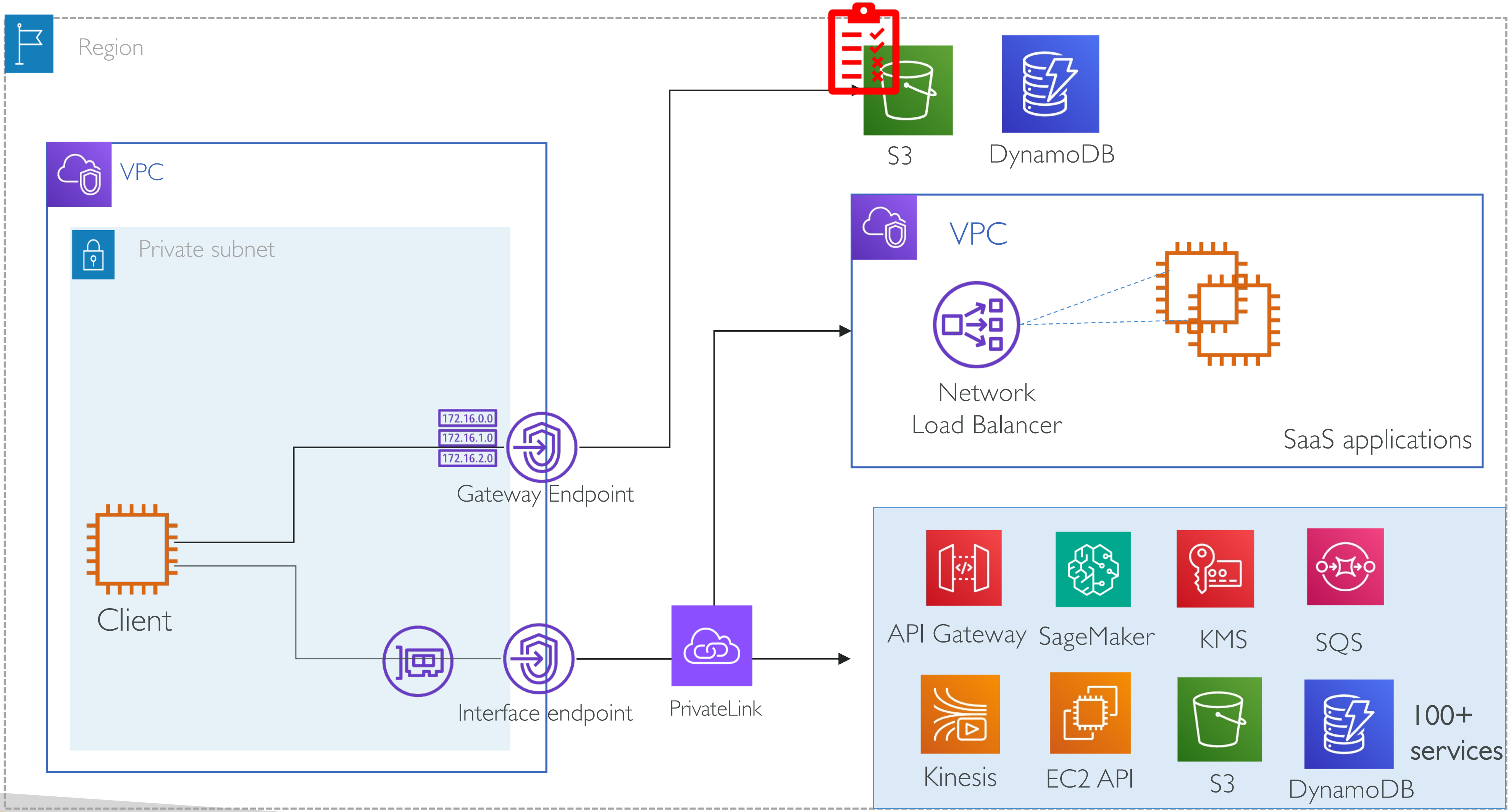
Restrict access for specific AWS account

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Sid": "Allow-callers-from-specific-account",
      "Effect": "Allow",
      "Principal": "*",
      "Action": "*",
      "Resource": "*",
      "Condition": {
        "StringEquals": {
          "aws:PrincipalAccount": "111122223333"
        }
      }
    }
  ]
}
```

Restrict access for specific IAM Role

```
{
  "Version": "2012-10-17",
  "Statement": [
    {
      "Sid": "Allow-access-to-specific-IAM-role",
      "Effect": "Allow",
      "Principal": "*",
      "Action": "*",
      "Resource": "*",
      "Condition": {
        "ArnEquals": {
          "aws:PrincipalArn": "arn:aws:iam::111122223333:role/role_name"
        }
      }
    }
  ]
}
```

VPC endpoint security – IAM policies



AWS Resource based 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. It's useful if there are multiple VPC endpoints in case you have multiple endpoints and want to manage access to your S3 buckets for all your endpoints
- The **aws:SourceIp** condition allows to specify the source Private IP/Range in the context of VPC endpoint only.

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-VPC-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"
        }
```

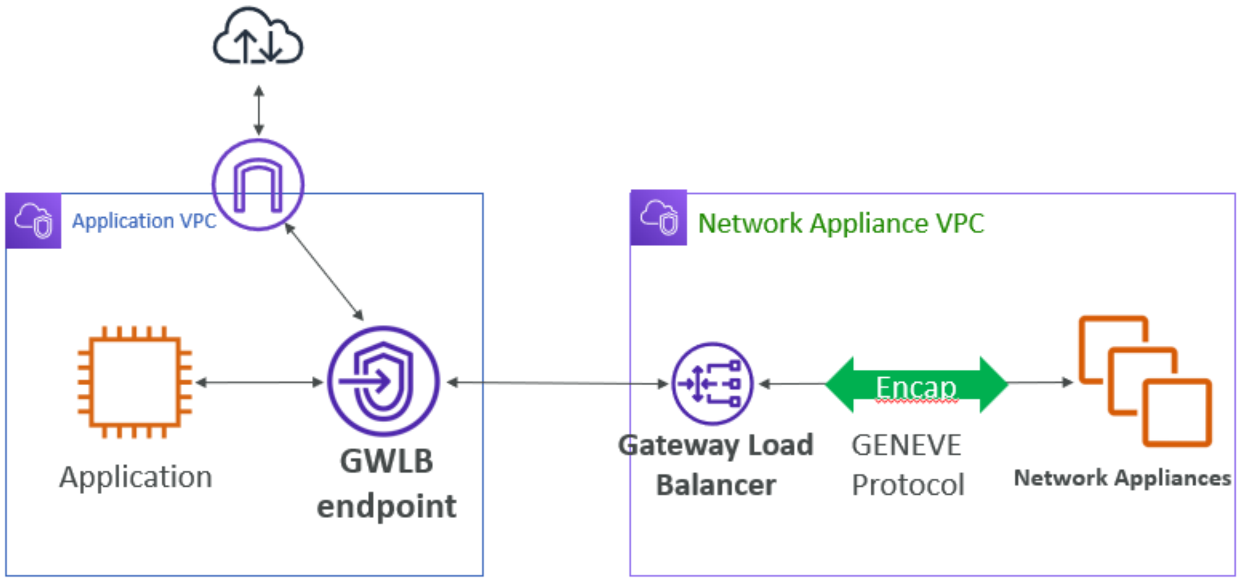
Important: Be careful while adding S3 bucket policies. If you Deny access to S3 bucket (except from VPCE) then no other users from the internet or other VPCs will be able to access S3 bucket.

Other VPC endpoint types

Gateway Load Balancer endpoint

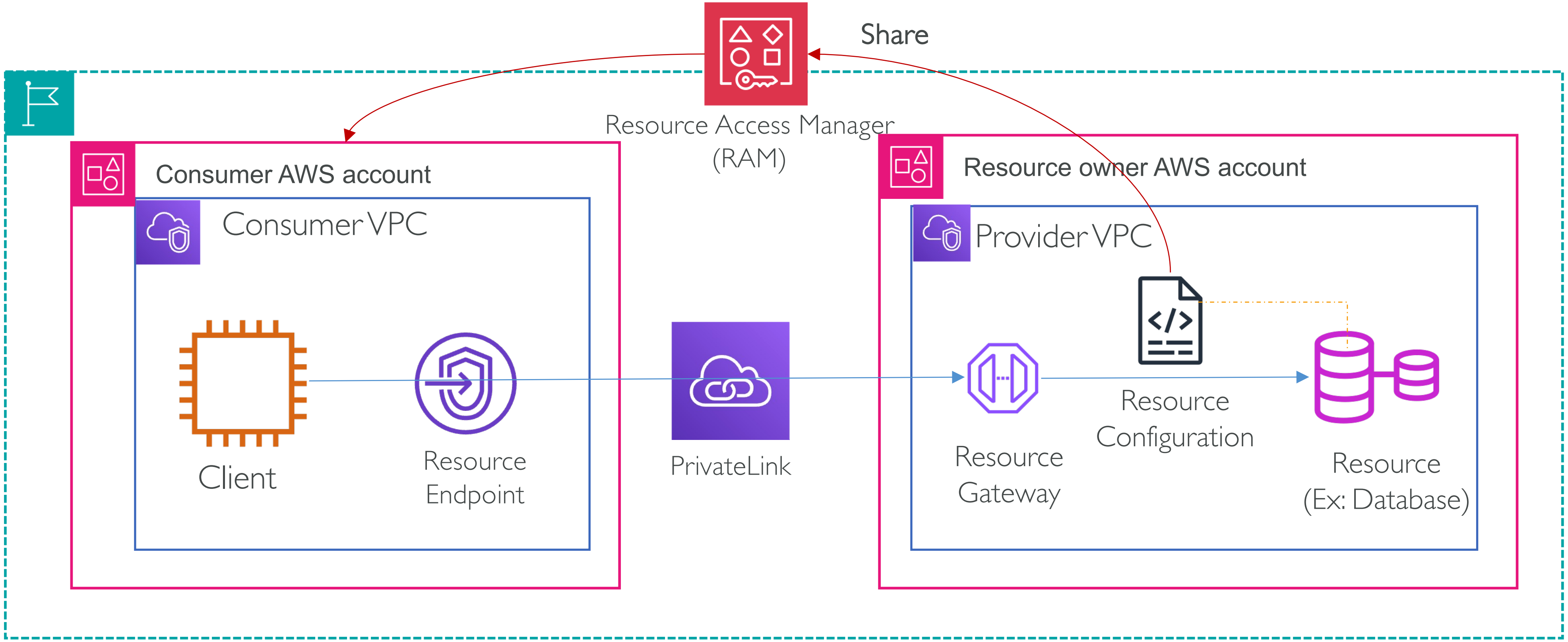
Gateway load balancer endpoint

- An endpoint to direct traffic from VPC to GWLB
- Primarily used to insert third-party virtual appliances (e.g., firewalls, IDS/IPS) transparently into traffic flows.



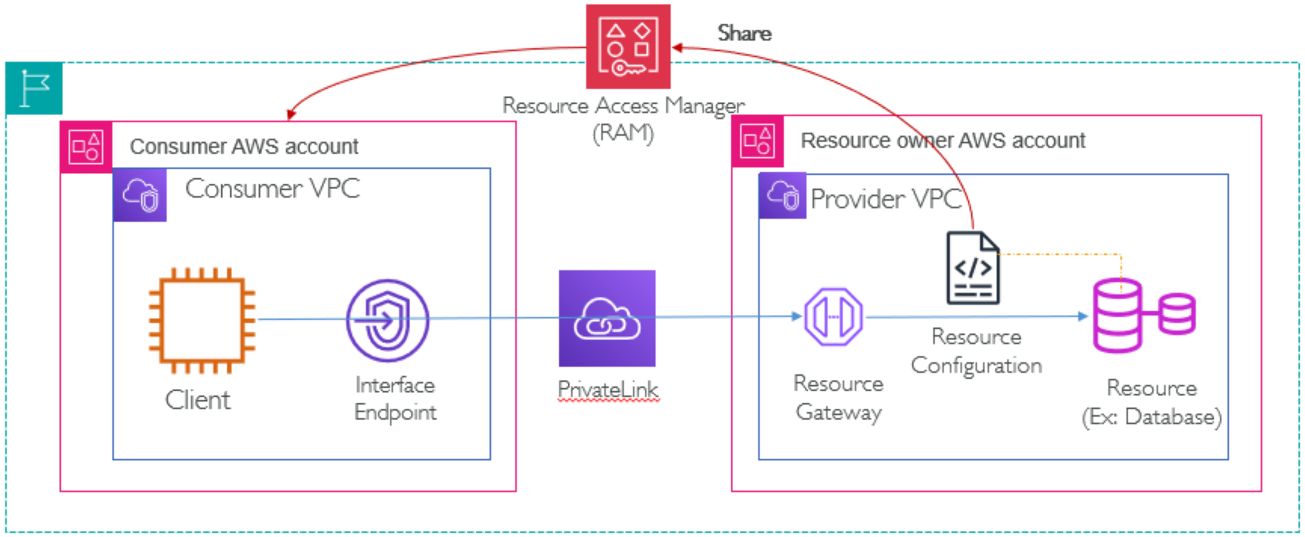
Resource endpoint

Resource endpoint



Resource endpoint

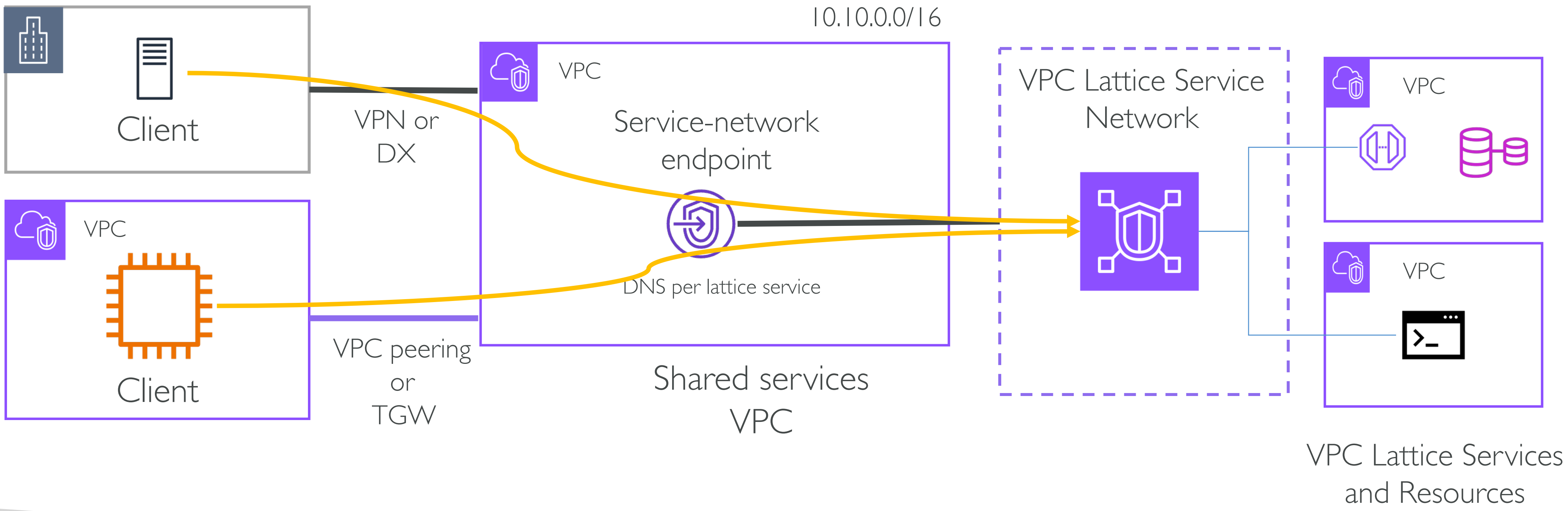
- Access VPC resources privately using Privatelink
- For cross-account access the resource need to be shared using RAM
- Resource can be identified using ARN (for RDS) or publicly resolvable domain-name or private IPv4 address range 10.0.0.0/8, 100.64.0.0/10, 172.16.0.0/12, 192.168.0.0/16 or IPv6 address
- No need to have NLB



Service-network endpoint

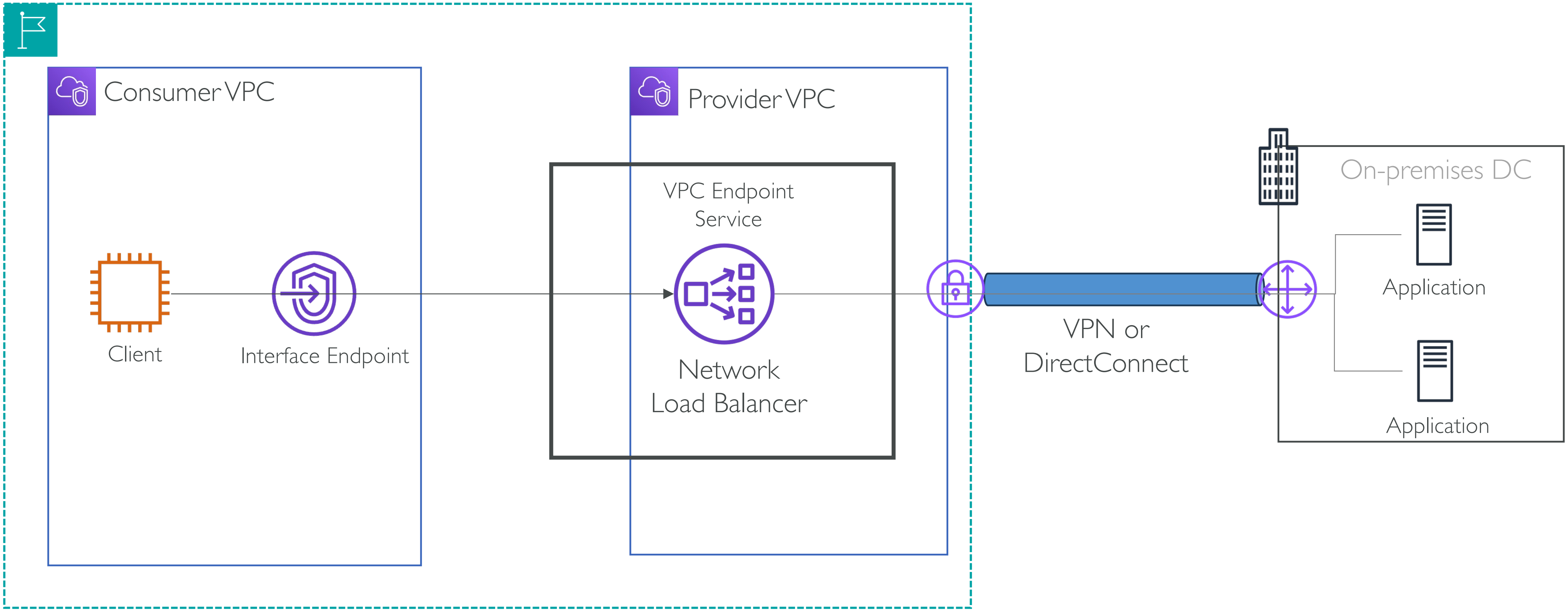
VPC endpoint for lattice network

- A VPC endpoint of type **service network** connects a VPC to a service network.
- Client traffic that comes from outside the VPC over a VPC peering connection, Transit Gateway, Direct Connect, or VPN can use the VPC endpoint to reach lattice services.



VPC endpoint & PrivateLink Architectures

Accessing on-premise hosted services using VPC endpoint service



Accessing VPC endpoint service from other networks

VPC Interface endpoint can be accessed from over the

- VPC peering connection
- AWS Transit Gateway

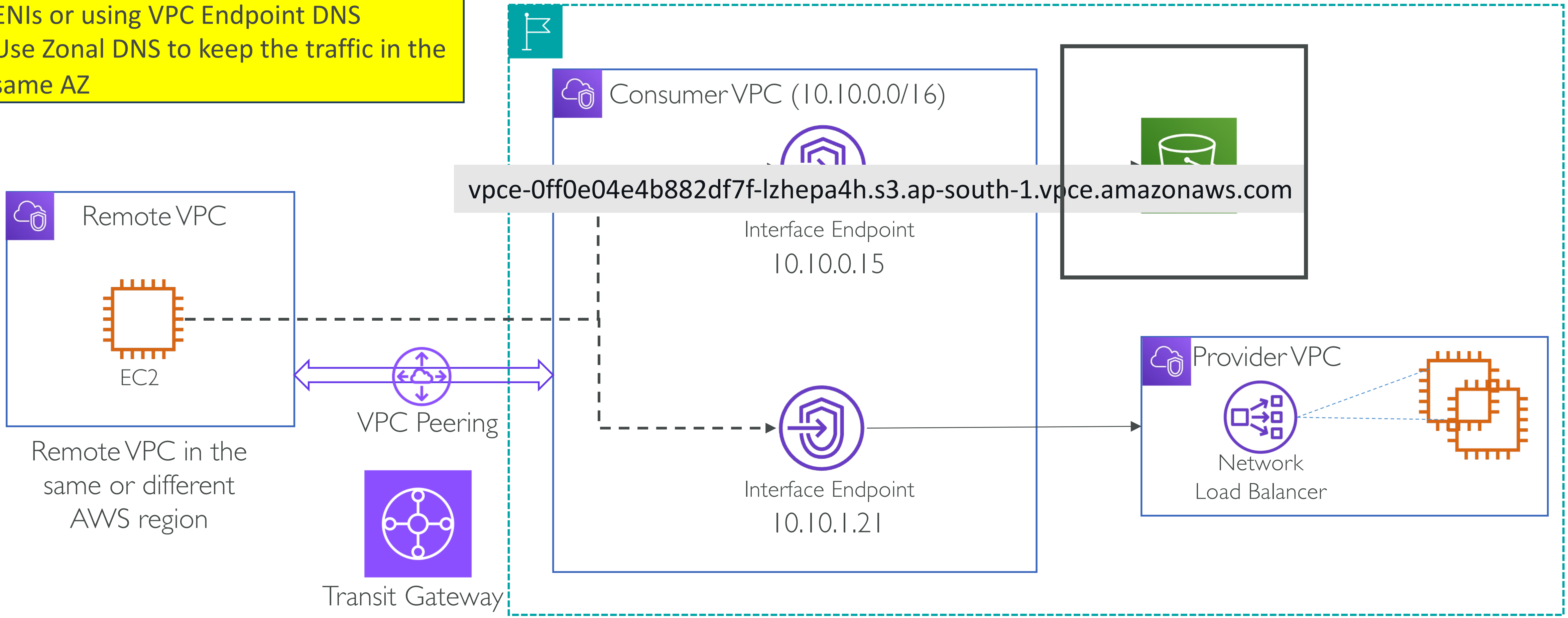
From inside AWS

- AWS Direct Connect
- AWS Site-to-Site VPN

From outside AWS

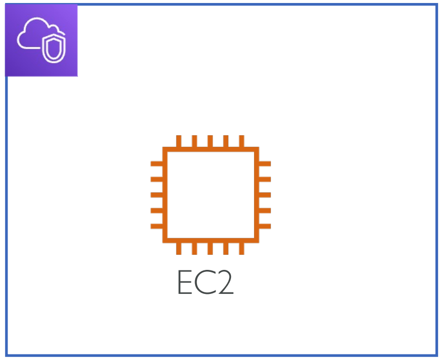
Accessing VPC endpoint from other VPCs

- Using Private IPs of the VPC endpoint ENIs or using VPC Endpoint DNS
- Use Zonal DNS to keep the traffic in the same AZ



*Use TGW peering when VPCs are in different regions

Accessing VPC endpoint from other VPCs



> aws s3 cp somefile.log s3://my-s3-bucket/logs/

- Resolves s3.ap-south-1.amazonaws.com to S3 Public IPs
- Traffic is routed over the internet to S3

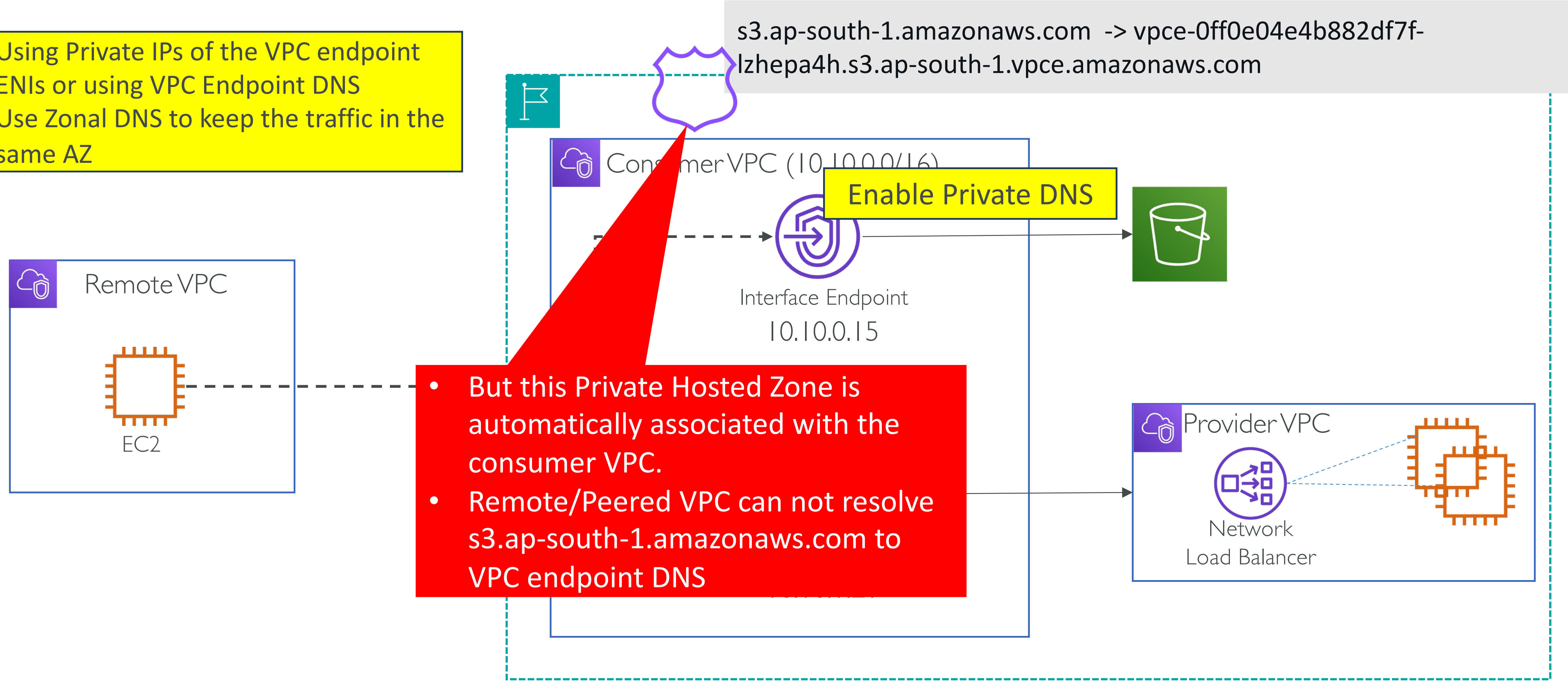
> aws s3 cp somefile.log s3://my-s3-bucket/logs/ --endpoint-url vpce-0ff0e04e4b882df7f-lzhepa4h.s3.ap-south-1.vpce.amazonaws.com

- Resolves to VPC endpoint Private IPs
- Traffic is routed over the VPN or DirectConnect to VPC

But it's not feasible to add --endpoint-url to every command. It should resolve the S3 public endpoint to the VPC endpoint Private IPs. But how?

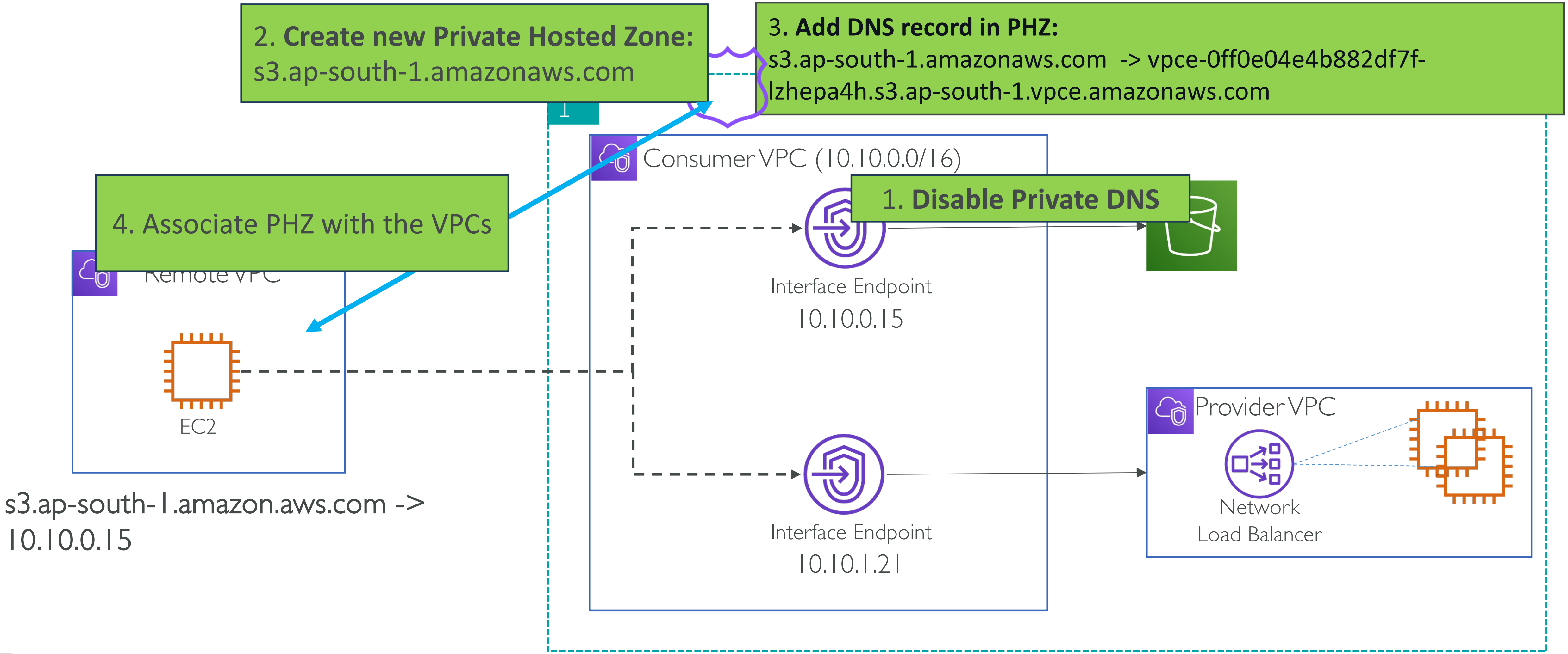
Accessing VPC endpoint from other VPCs

- Using Private IPs of the VPC endpoint ENIs or using VPC Endpoint DNS
- Use Zonal DNS to keep the traffic in the same AZ

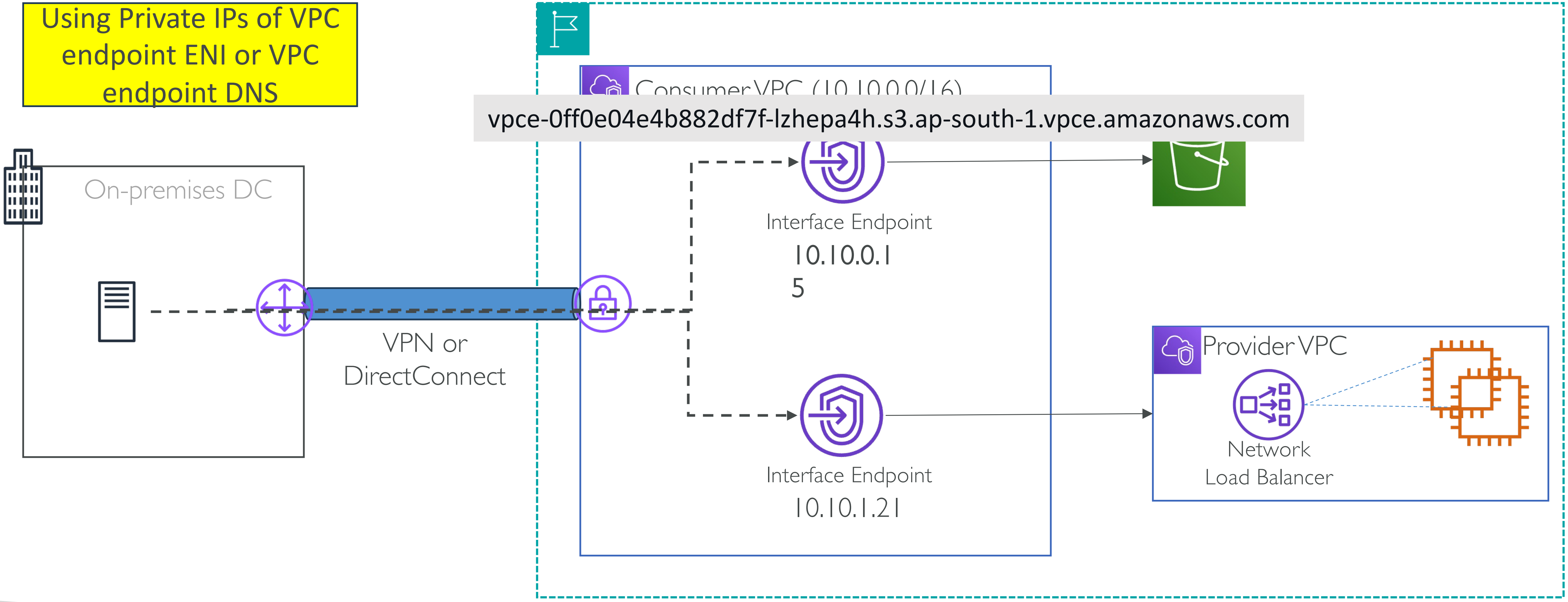


- But this Private Hosted Zone is automatically associated with the consumer VPC.
- Remote/Peered VPC can not resolve s3.ap-south-1.amazonaws.com to VPC endpoint DNS

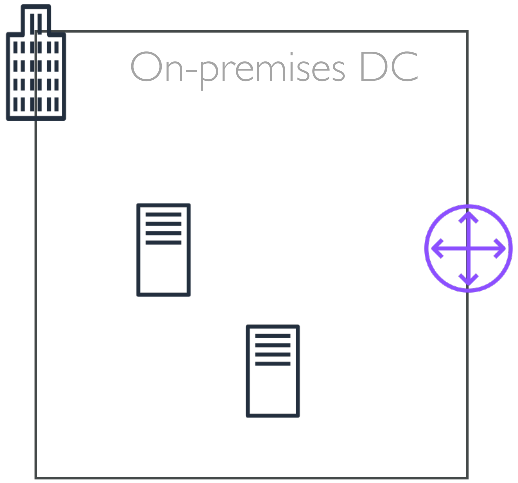
Accessing VPC endpoint from other VPCs



Accessing VPC endpoint from on-premises n/w



Accessing VPC endpoint from on-premises n/w




```
> aws s3 cp somefile.log s3://my-s3-bucket/logs/
```

- Resolves s3.ap-south-1.amazonaws.com to S3 Public IPs
- Traffic is routed over the internet to S3

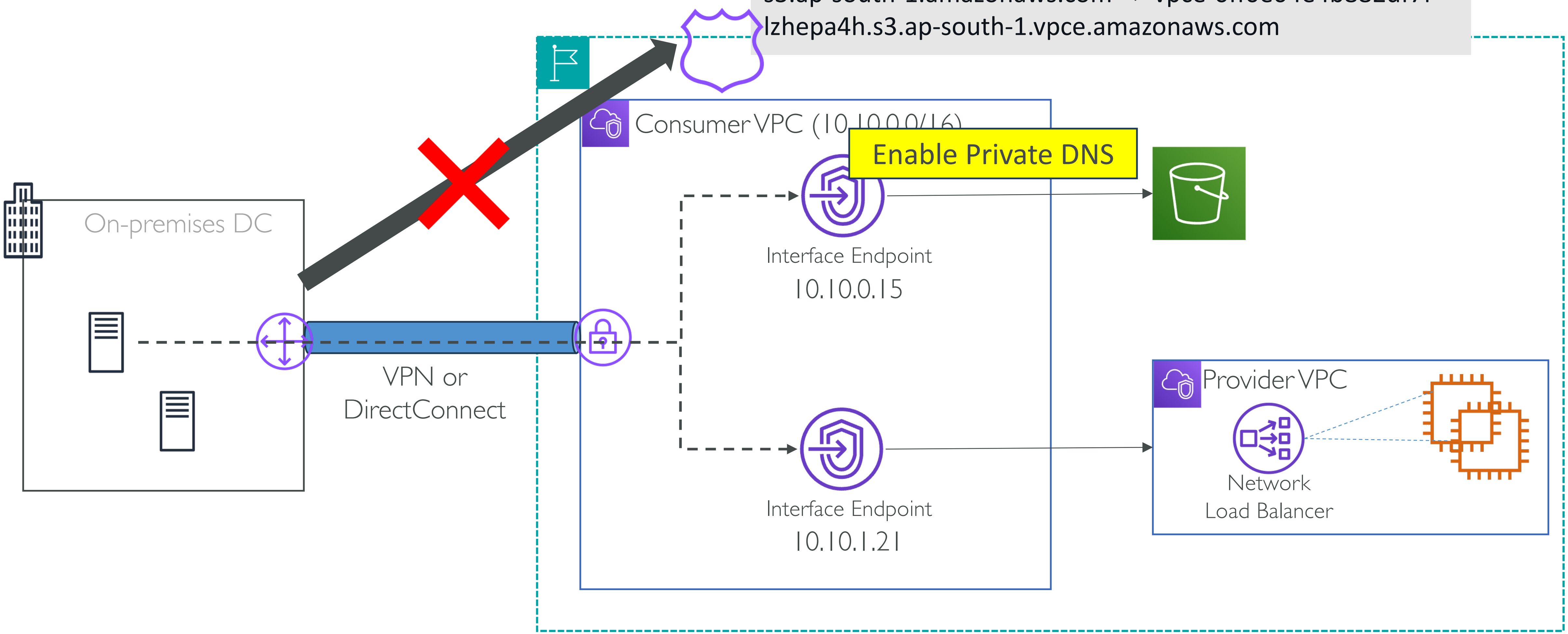
```
> aws s3 cp somefile.log s3://my-s3-bucket/logs/ --endpoint-url vpce-0ff0e04e4b882df7f-lzhepa4h.s3.ap-south-1.vpce.amazonaws.com
```

- Resolves to VPC endpoint Private IPs
- Traffic is routed over the VPN or DirectConnect to VPC

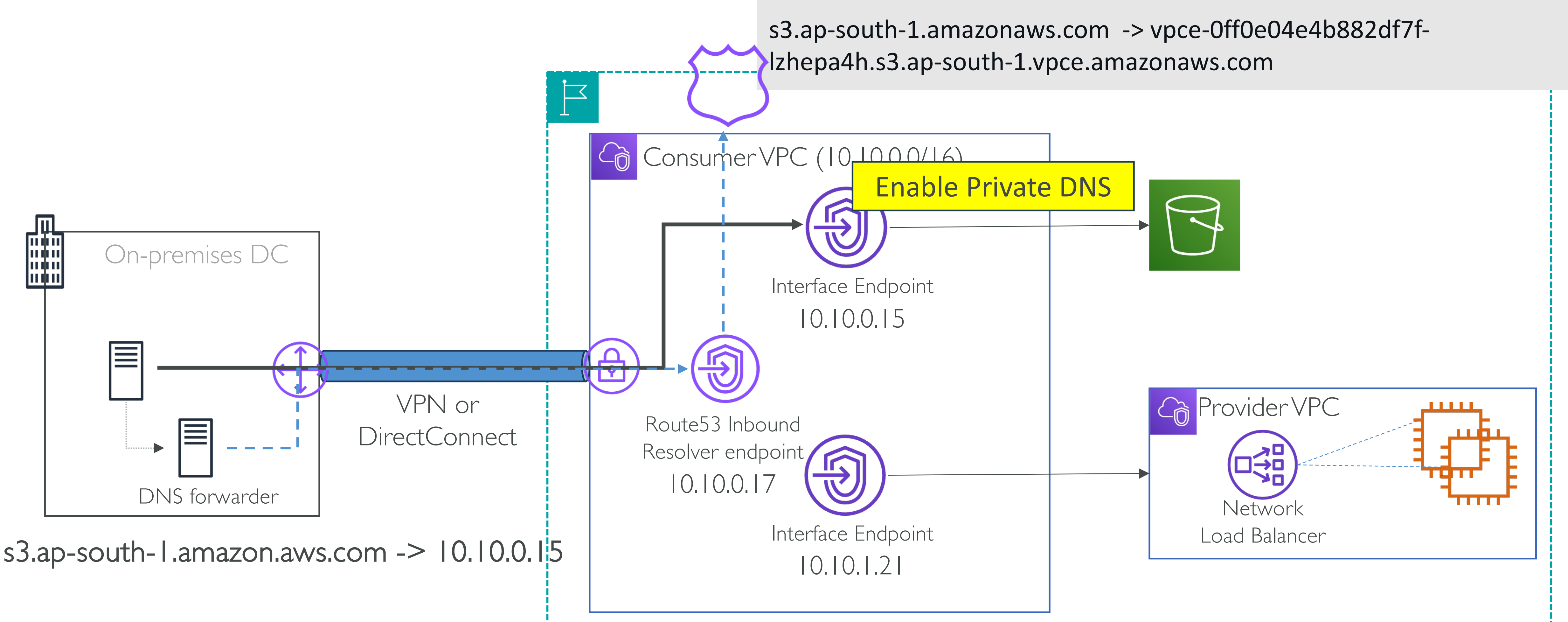
But it's not feasible to add --endpoint-url to every command. It should resolve the S3 public endpoint to the VPC endpoint Private IPs. How?

Accessing VPC endpoint from on-premises n/w

s3.ap-south-1.amazonaws.com -> vpce-0ff0e04e4b882df7f-lzhepa4h.s3.ap-south-1.vpce.amazonaws.com

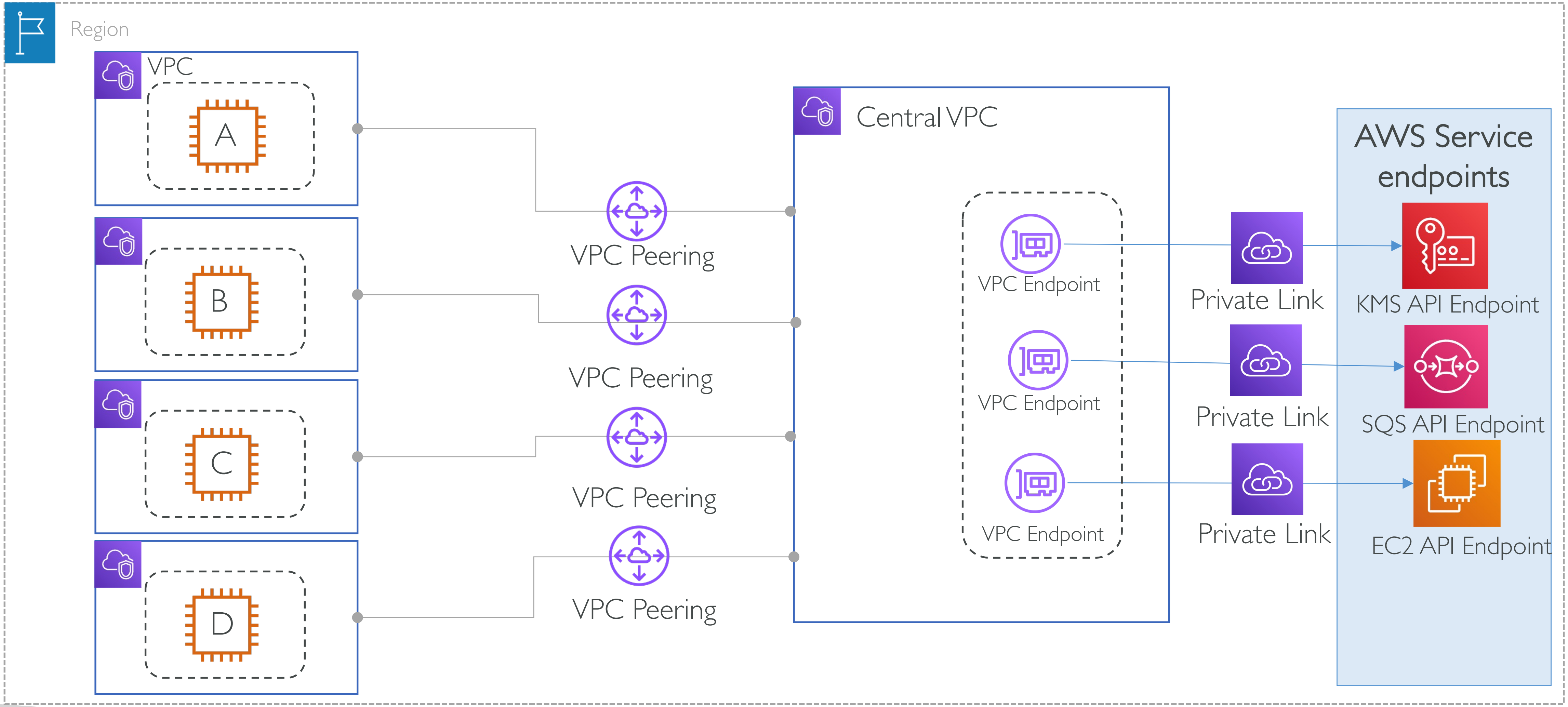


Accessing VPC endpoint from on-premises n/w

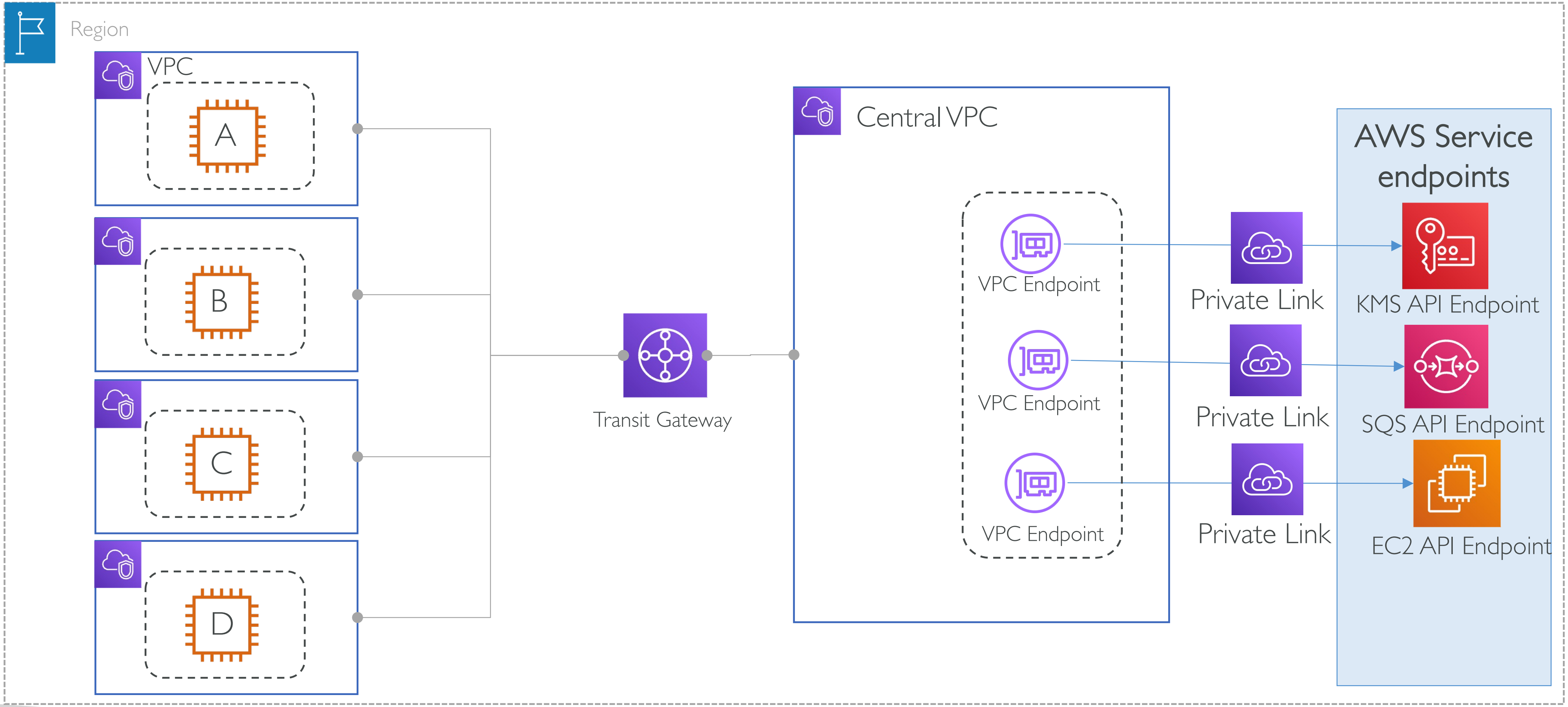


Centralized VPC endpoints

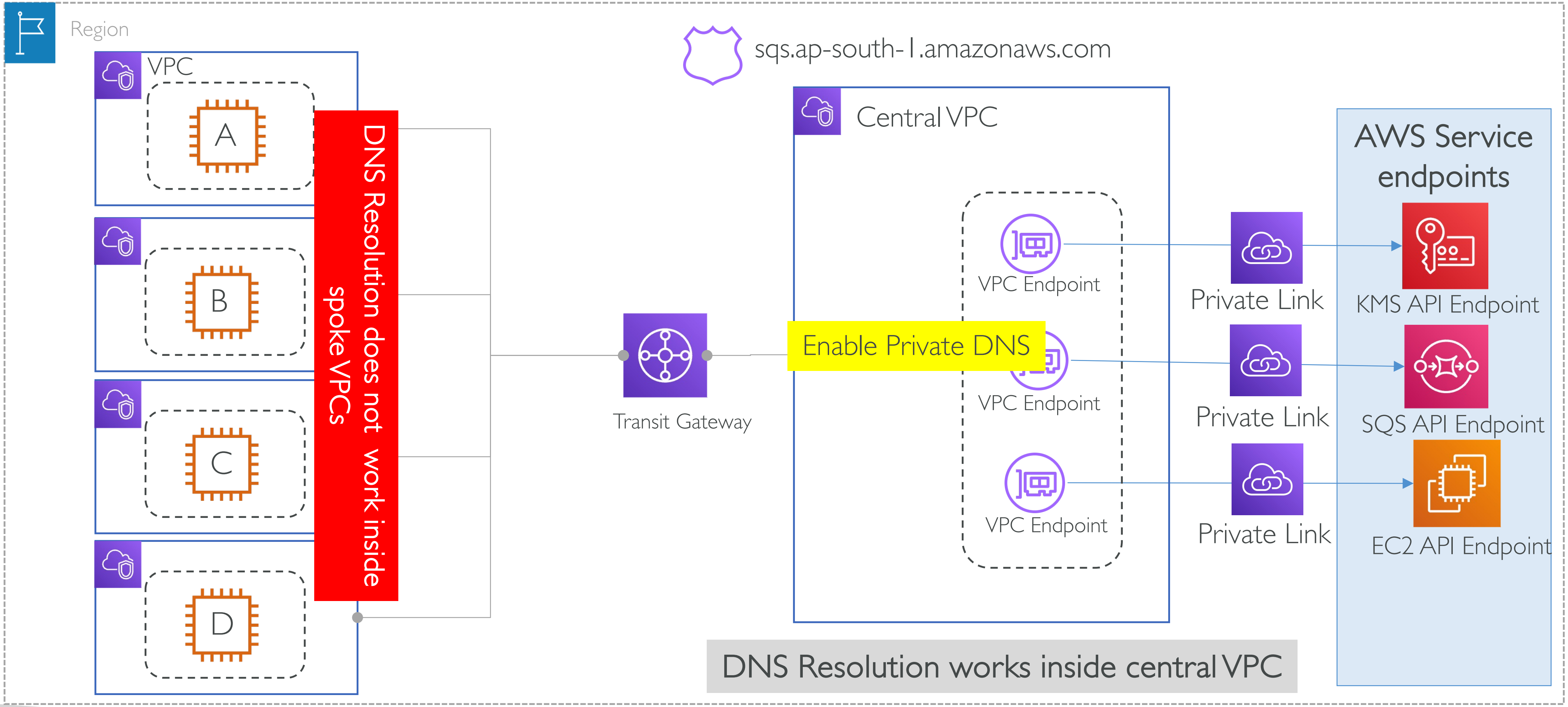
Centralized VPC interface endpoints



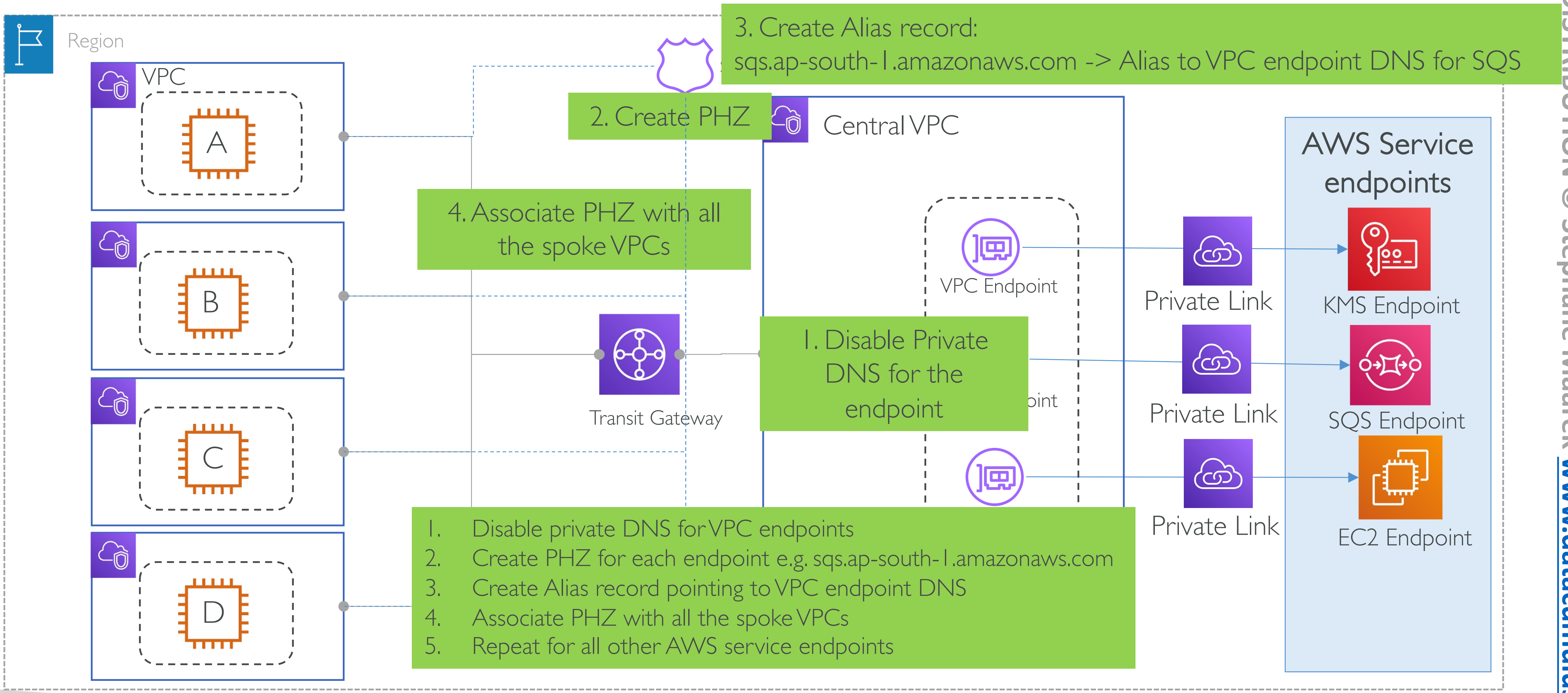
Centralized VPC interface endpoints



Centralized VPC interface endpoints

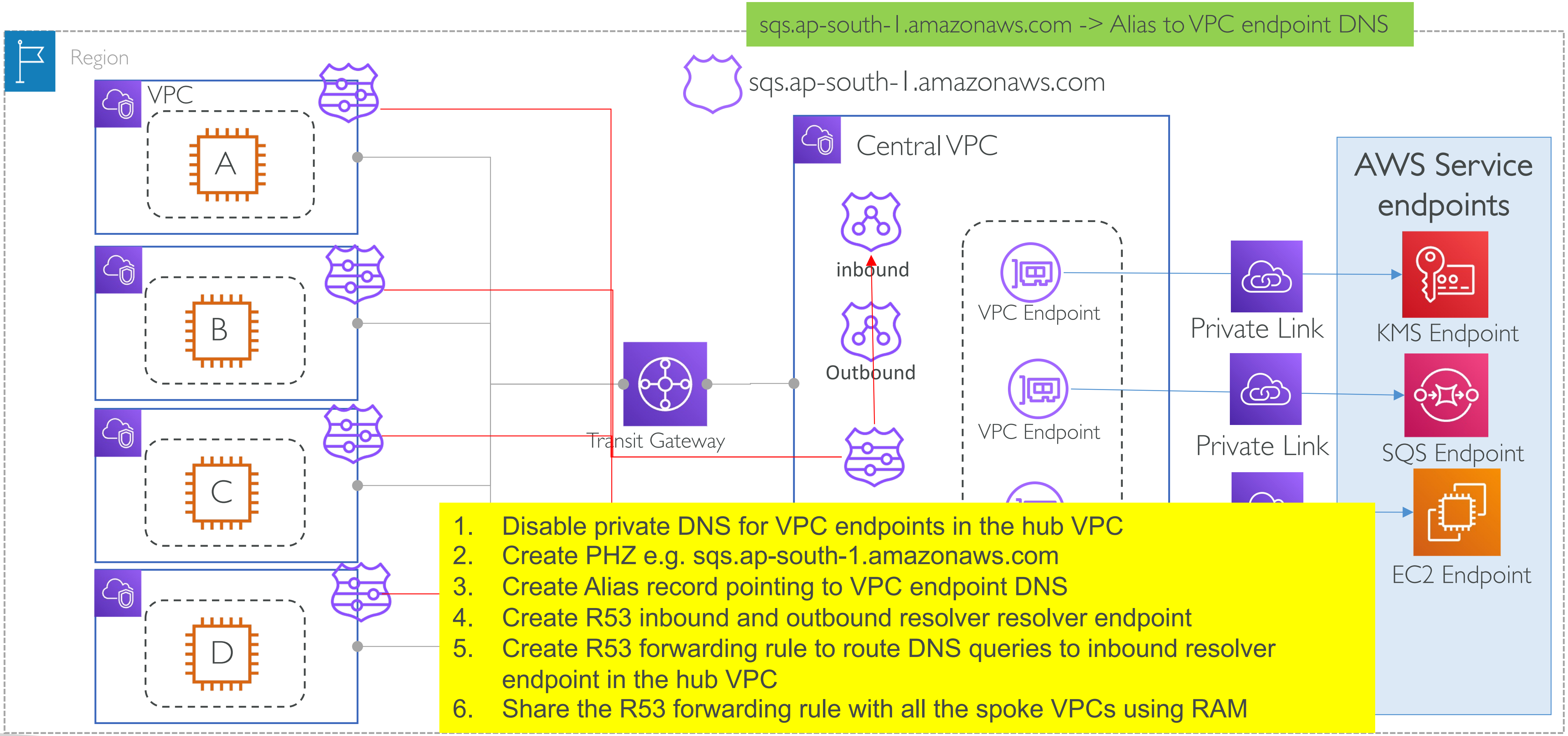


DNS resolution option 1 – Create PHZ and associate with spoke VPCs



1. Disable private DNS for VPC endpoints
2. Create PHZ for each endpoint e.g. sqs.ap-south-1.amazonaws.com
3. Create Alias record pointing to VPC endpoint DNS
4. Associate PHZ with all the spoke VPCs
5. Repeat for all other AWS service endpoints

DNS resolution option 2 – Use R53 resolver endpoints



1. Disable private DNS for VPC endpoints in the hub VPC
2. Create PHZ e.g. sqs.ap-south-1.amazonaws.com
3. Create Alias record pointing to VPC endpoint DNS
4. Create R53 inbound and outbound resolver resolver endpoint
5. Create R53 forwarding rule to route DNS queries to inbound resolver endpoint in the hub VPC
6. Share the R53 forwarding rule with all the spoke VPCs using RAM

VPC PrivateLink vs VPC Peering

AWS PrivateLink vs VPC Peering

- VPC peering is useful when there are many resources that should communicate between peered VPCs
- PrivateLink should be used when you want to allow access to only single application hosted in your VPC to other VPCs without peering the VPCs
- When there is overlapping CIDRs, VPC peering connection can not be created. However private link does support overlapping CIDR
- We can create a maximum of 125 peering connections. There is no limit on private link connections.
- VPC peering enables bidirectional traffic origin. PrivateLink allows only consumer to originate the traffic.

Exam Essentials

Exam essentials

- VPC endpoints enables the private connectivity between VPC and AWS services or customer services hosted inside the VPC
- We don't need to have IGW or NAT gateway thereby the communication is secure, scalable and cost efficient
- VPC gateway endpoint:
  - Enables private connectivity to S3 or DynamoDB in same AWS region
  - To route traffic through VPC gateway endpoint, you should modify the route table of the required subnet
  - Gateway endpoint is not accessible over Direct Connect/VPN or VPC Peering

Exam essentials

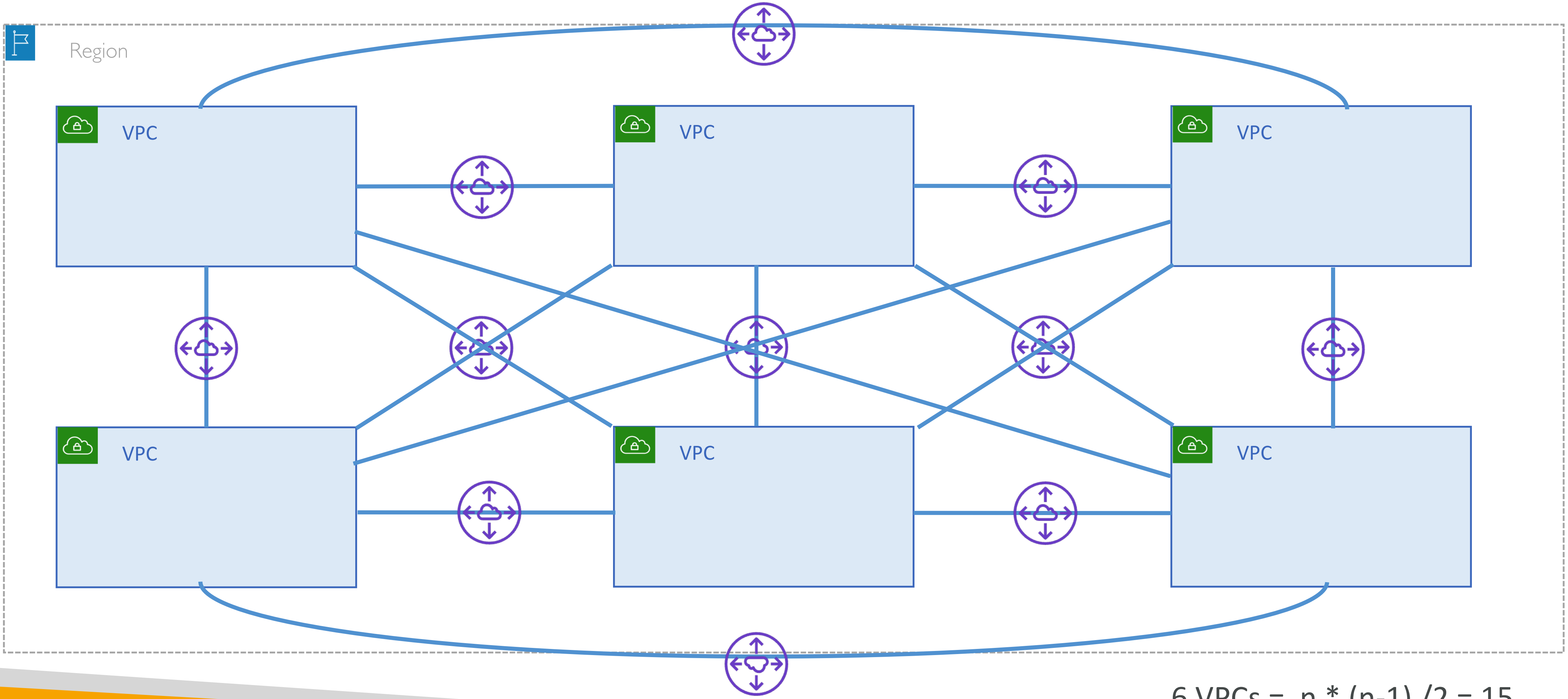
- There are different types of the VPC endpoints (PrivateLink):
  - Interface endpoint
  - Gateway Load Balancer endpoint
  - Resource endpoint
  - Service-network endpoint (VPC lattice)
- Interface endpoint creates ENI into the consumer VPC subnets (AZs) and receives Private IP address from the subnet CIDR range.
- Uses Security Groups – inbound rules
- VPC endpoint supports IPv4 and IPv6 traffic.
- VPC endpoint supports traffic over TCP and UDP

Exam essentials

- VPC endpoint can be used to connect VPCs with overlapping CIDR blocks
- VPC endpoint can be accessed from other networks e.g. Peered VPCs, Transit gateway, VPN or Direct Connect
- VPC interface endpoint supports cross-region access
- Traffic originates from the resources in the consumer VPC, and endpoint service can only respond to the request.
- VPC Interface endpoint receives the Regional and zonal DNS name.
- Use AZ specific DNS to save cross-AZ data transfer cost
- VPC endpoint policy to restrict access to specific AWS resources and principals

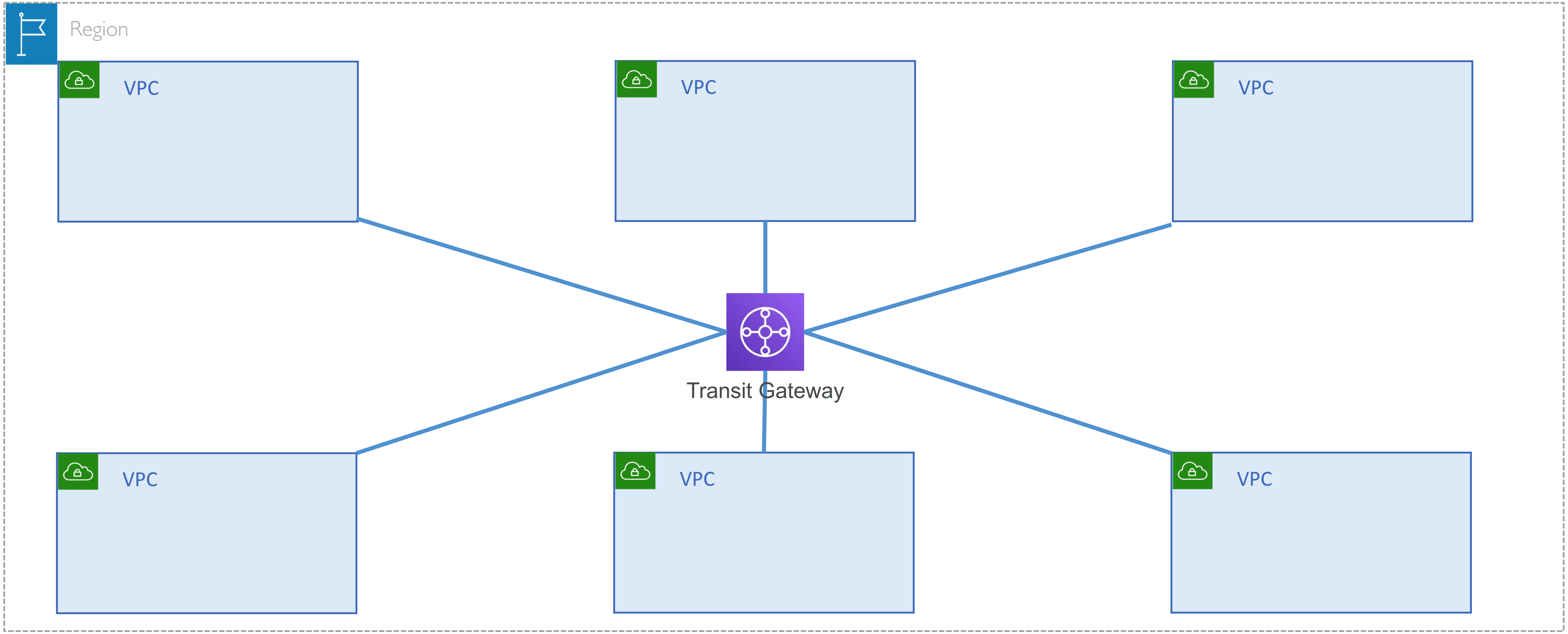
Transit Gateway (TGW)

Why Transit Gateway?



6 VPCs = n * (n-1) /2 = 15

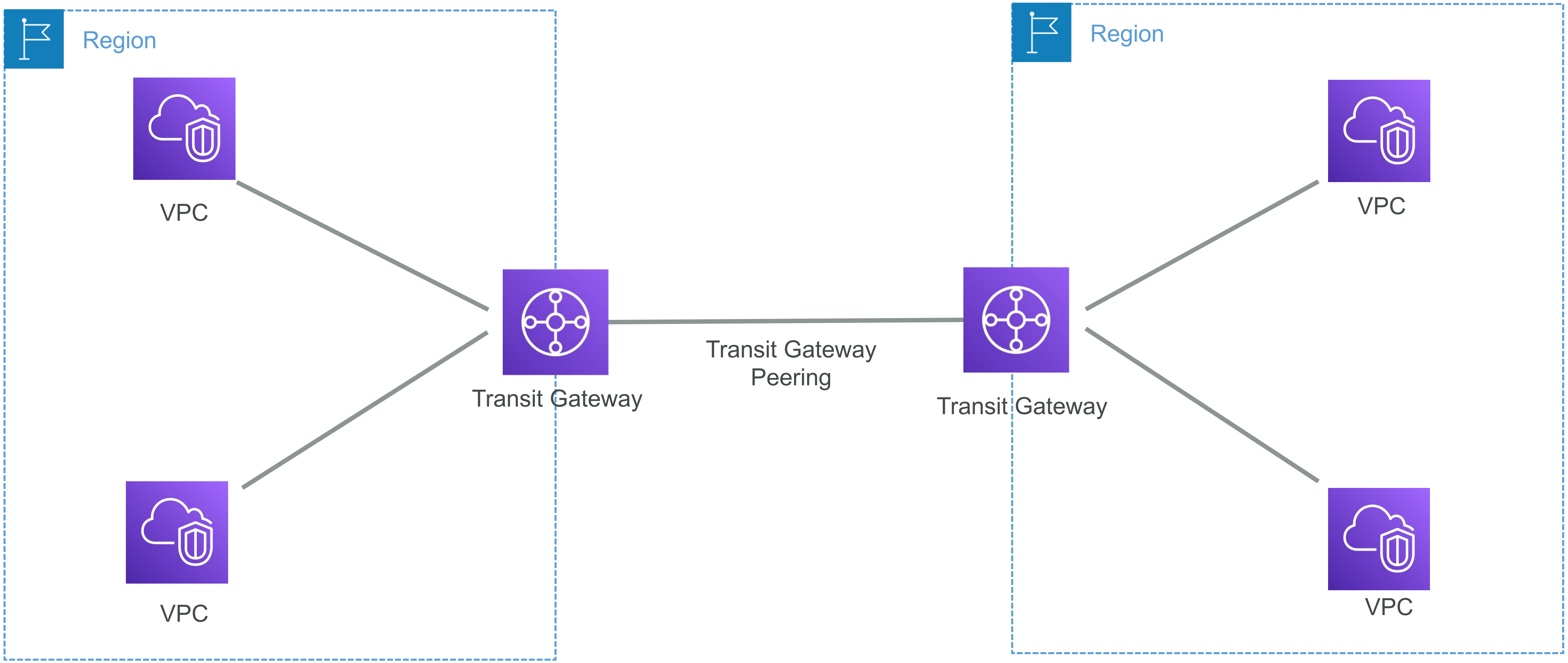
Transit Gateway with multiple VPCs



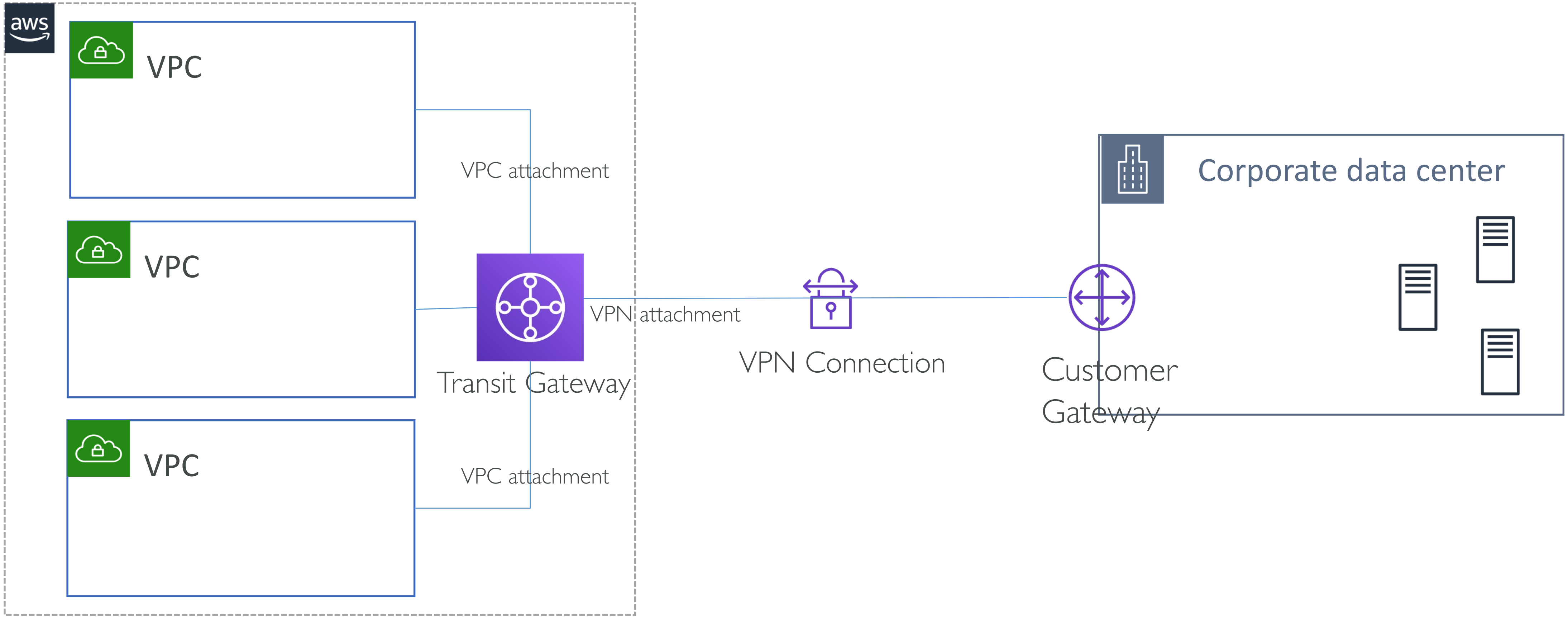
AWS Transit Gateway

- Allows customers to interconnect thousands of Virtual Private Clouds (VPCs) and on-premises networks.
- **Transit Gateway attachments:**
  - One or more VPCs
  - Peering connection with another Transit Gateway
  - A Connect SD-WAN/third-party network appliance
  - VPN
  - Direct Connect Gateway
- Transit Gateway features – Multicast support, MTU, Appliance mode, AZ consideration, TGW Sharing
- Transit Gateway architectures – Centralized traffic inspection, egress, interface endpoints etc.

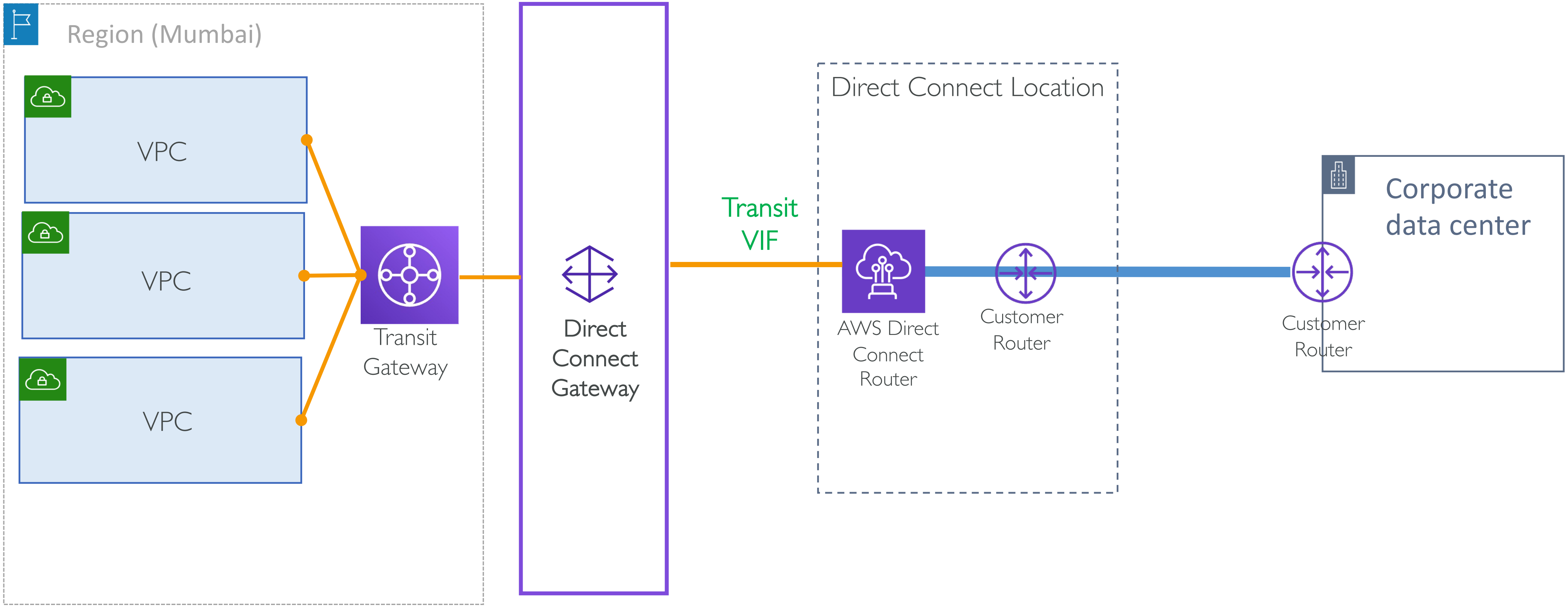
Transit Gateway Peering across AWS regions



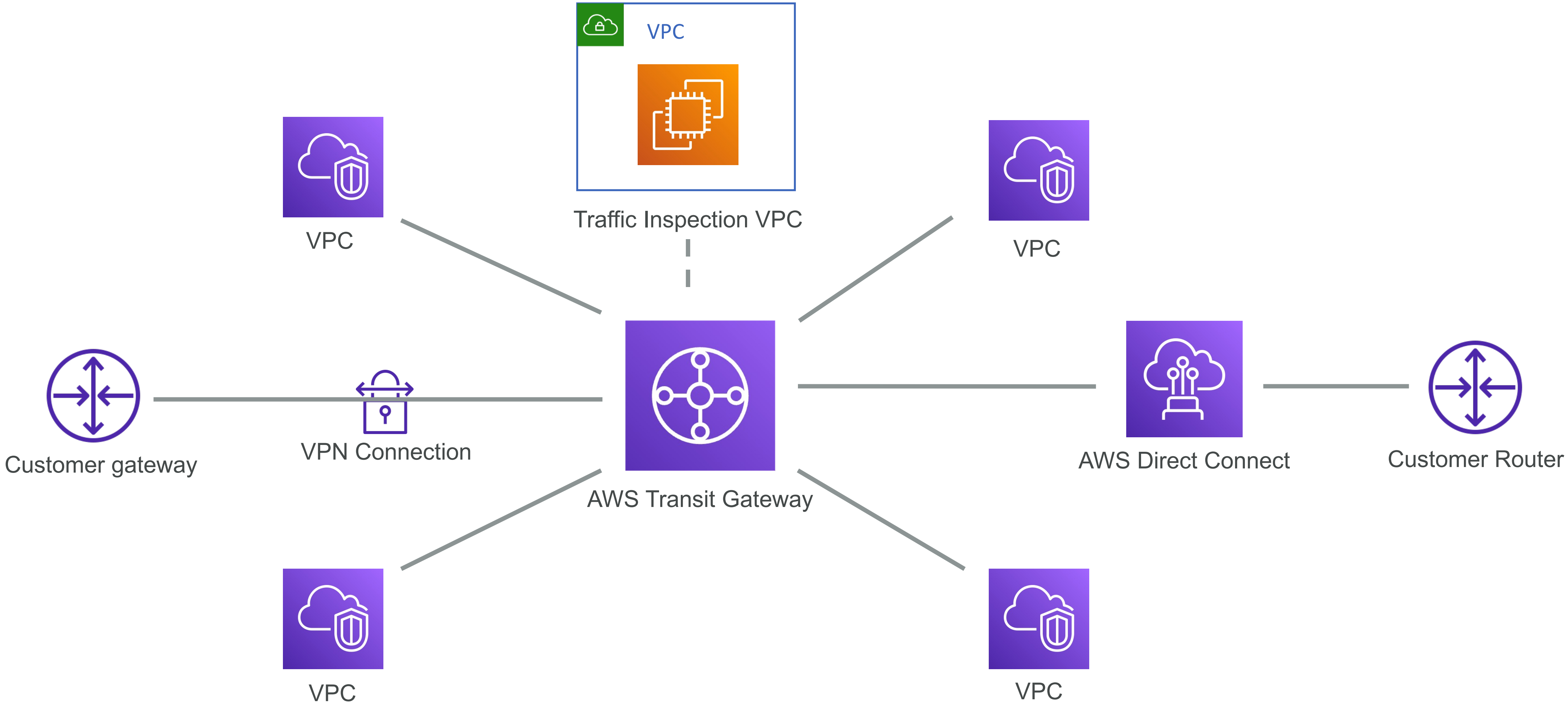
Transit Gateway with AWS site-to-site VPN



Transit gateway with Direct Connect

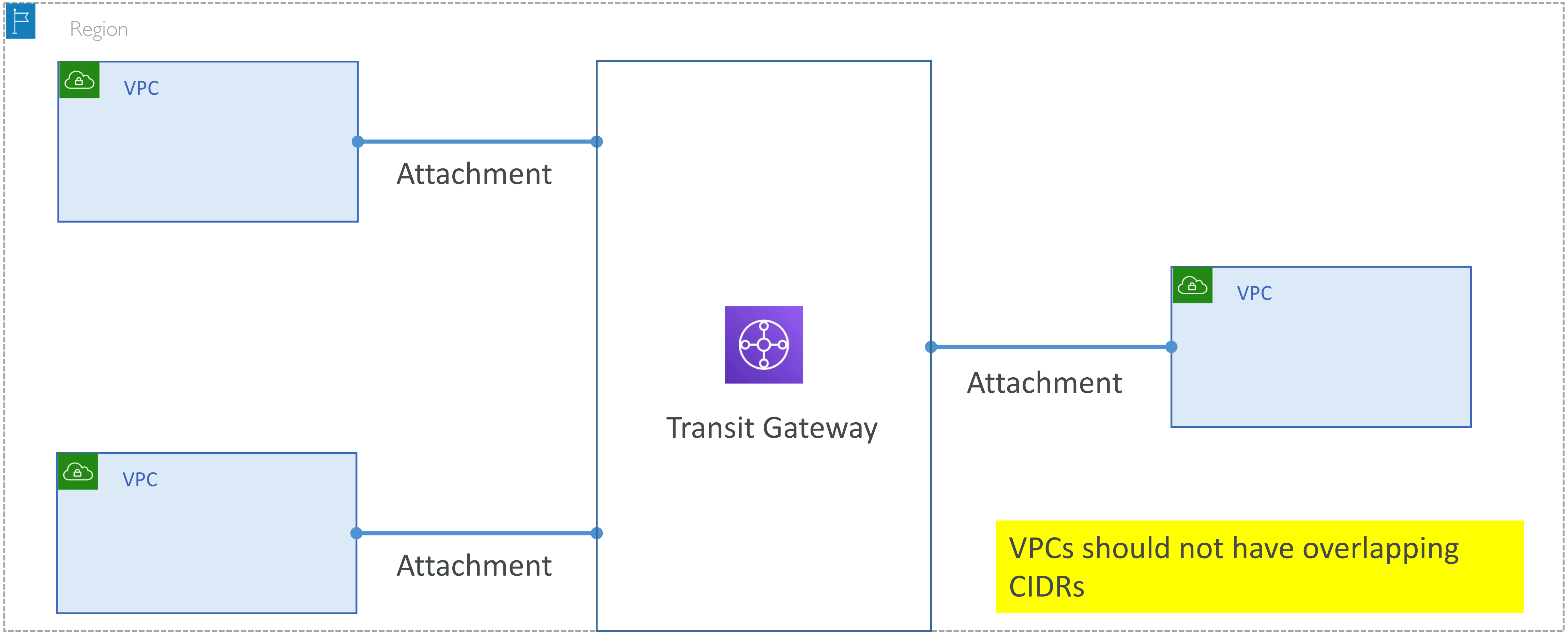


Transit Gateway with 3rd party appliances for traffic inspection

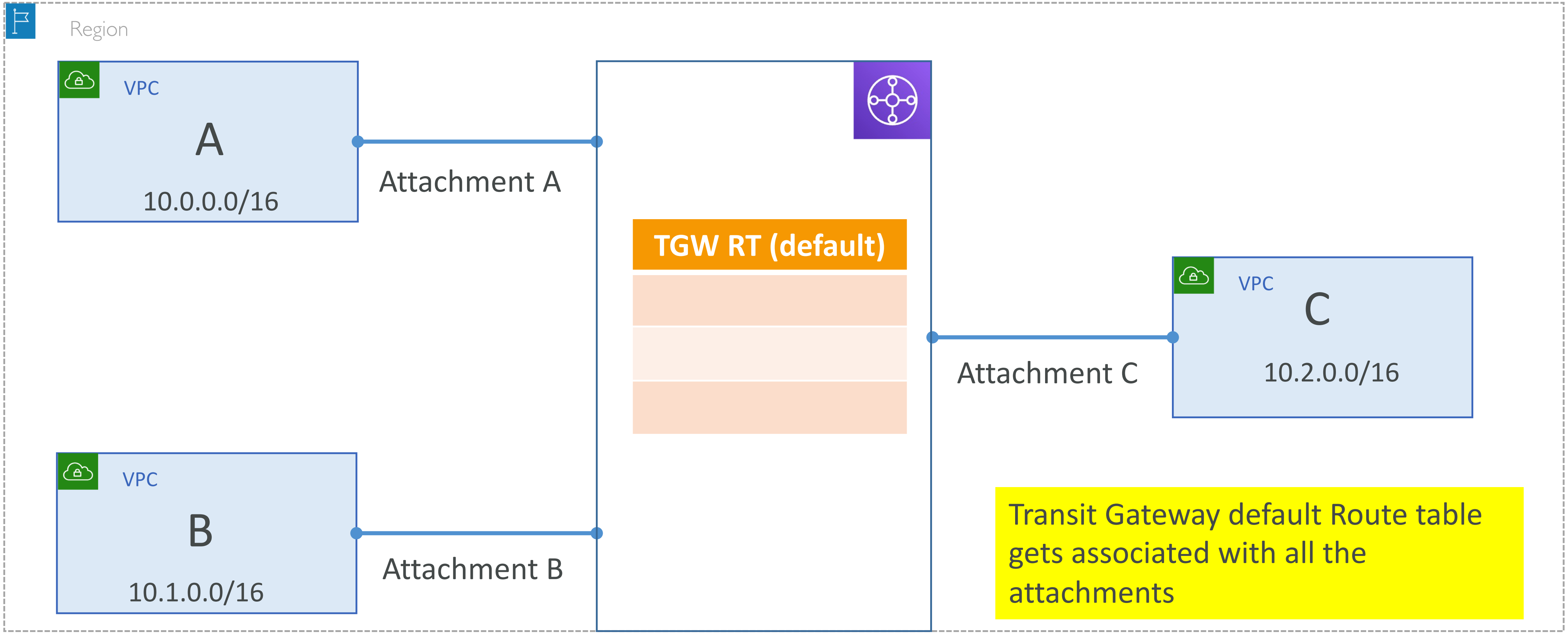


Transit Gateway VPC attachments

Transit Gateway attachments

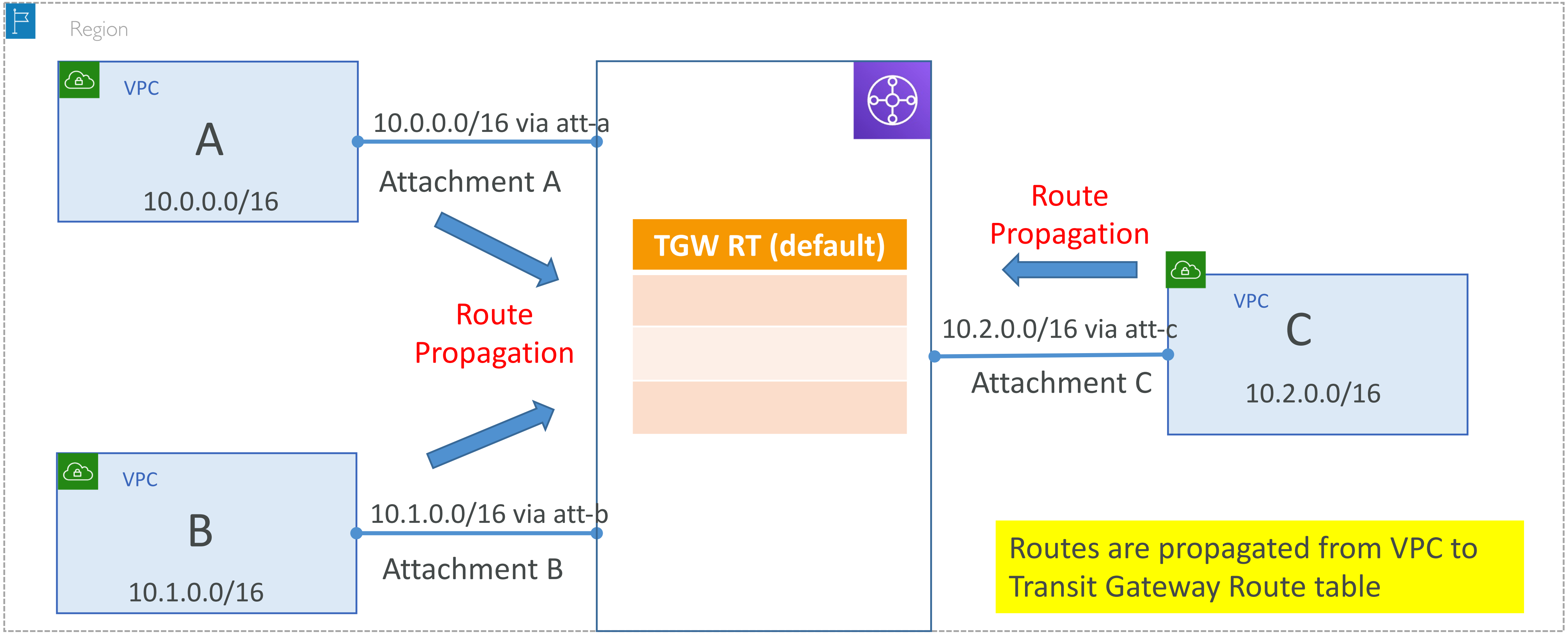


Transit Gateway Route tables



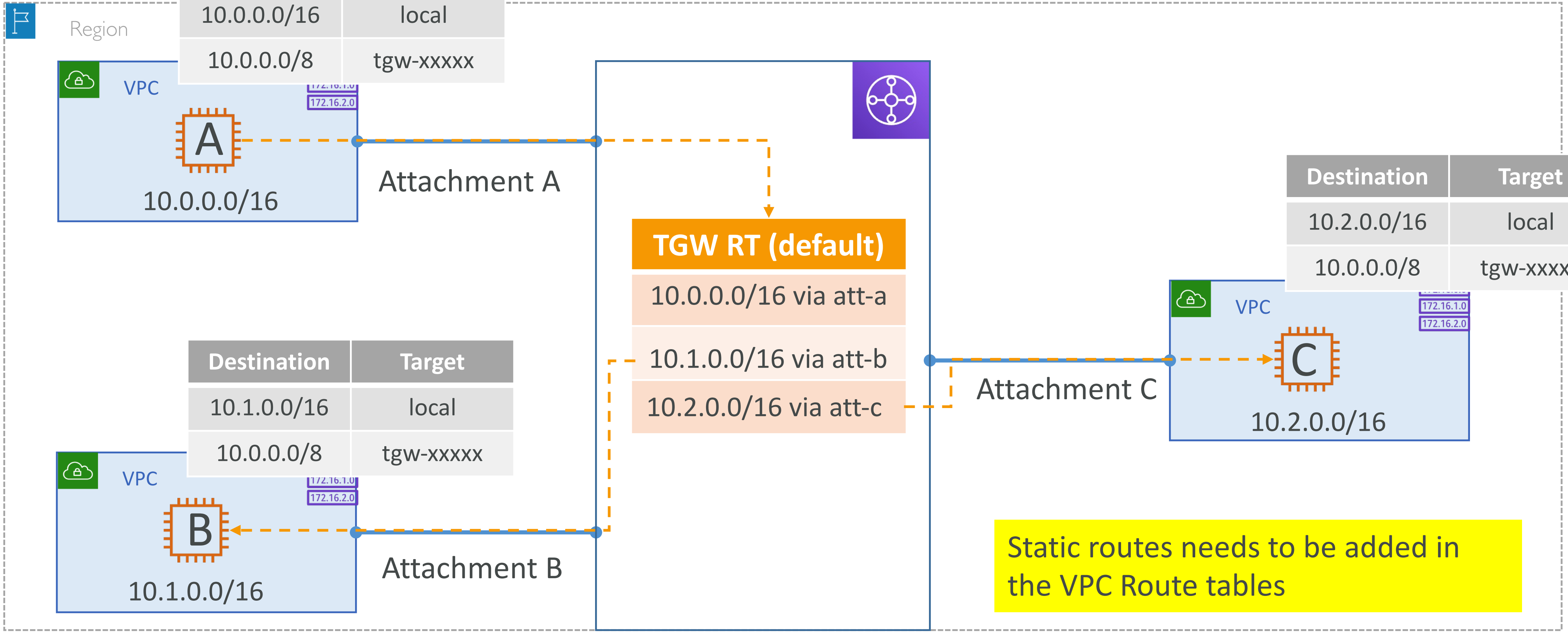
Transit Gateway default Route table gets associated with all the attachments

Transit Gateway Route tables



Routes are propagated from VPC to Transit Gateway Route table

VPC Route tables



Destination	Target
10.0.0.0/16	local
10.0.0.0/8	tgw-xxxxx

Destination	Target
10.1.0.0/16	local
10.0.0.0/8	tgw-xxxxx

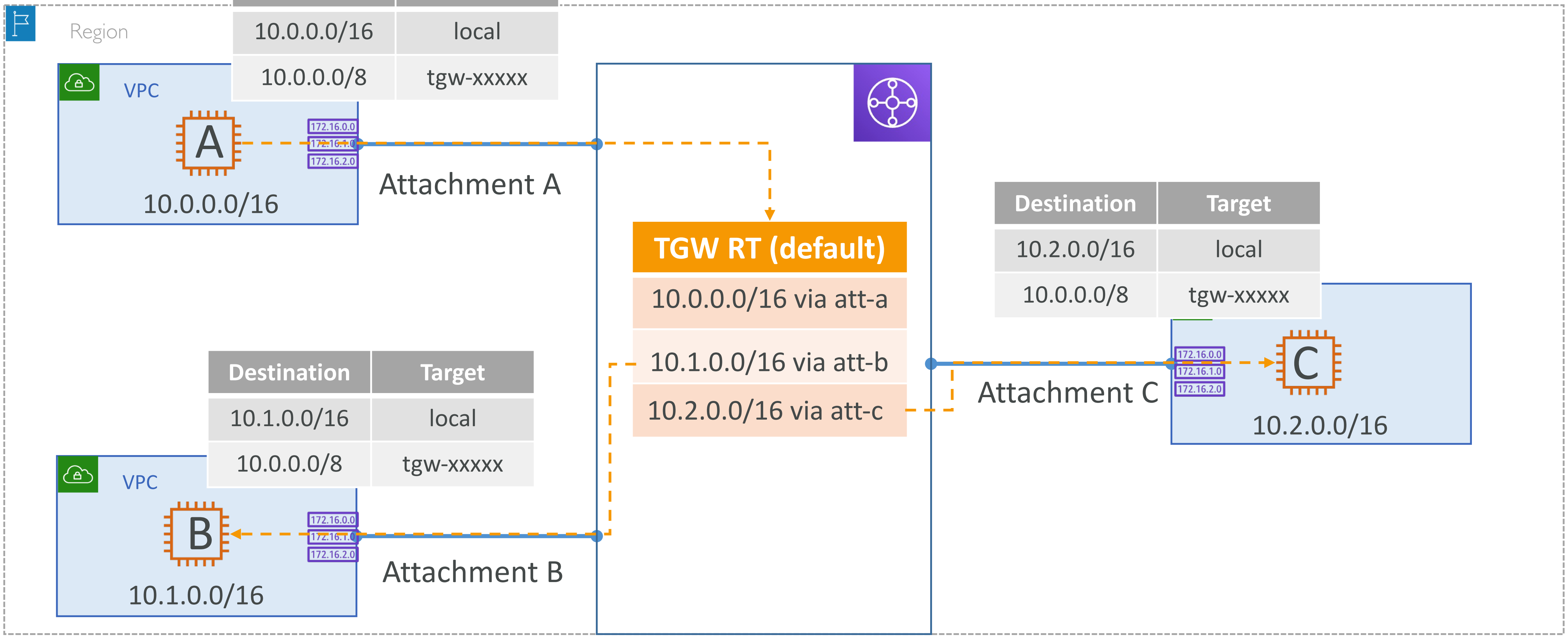
TGW RT (default)
10.0.0.0/16 via att-a
10.1.0.0/16 via att-b
10.2.0.0/16 via att-c

Destination	Target
10.2.0.0/16	local
10.0.0.0/8	tgw-xxxxx

Static routes needs to be added in the VPC Route tables

Transit Gateway Lab – Three VPCs with full connectivity

Lab – Let's set this up and test connectivity

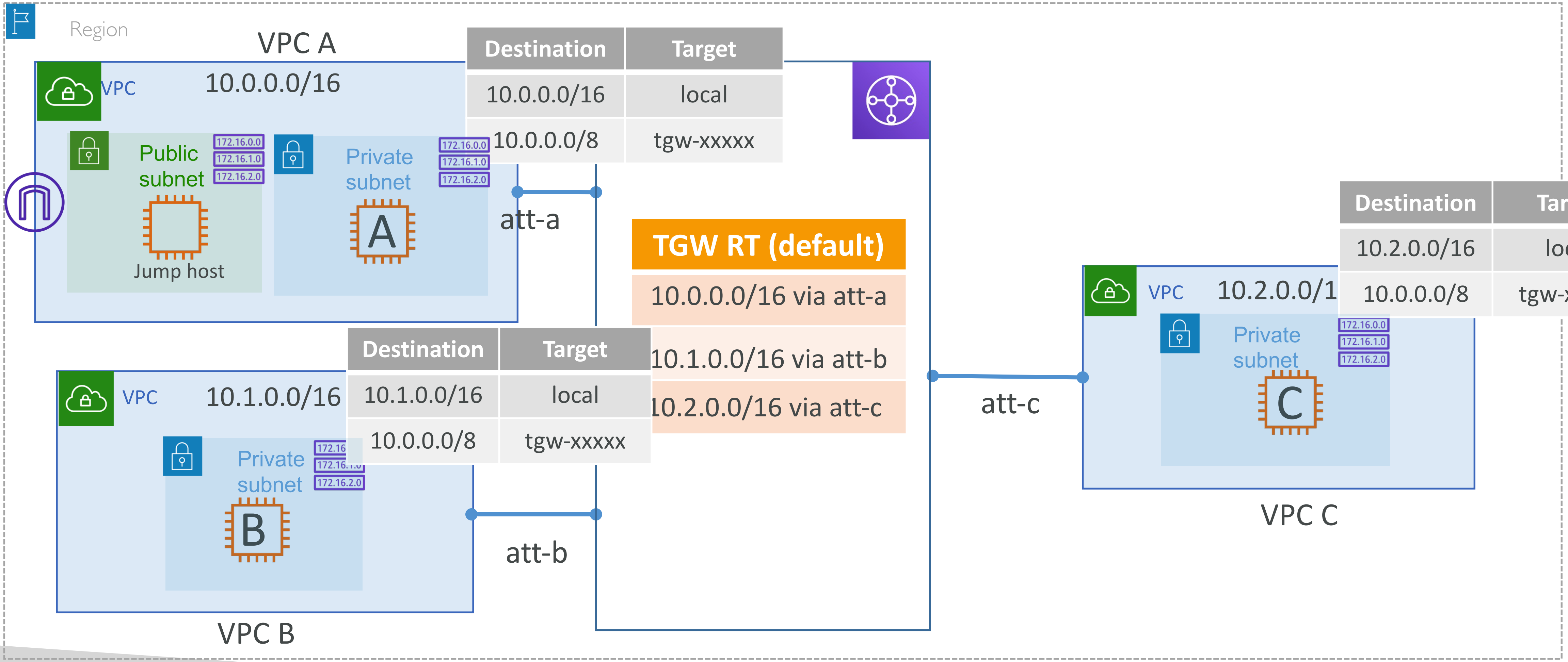


Destination	Target
10.0.0.0/16	local
10.0.0.0/8	tgw-xxxxx

Destination	Target
10.1.0.0/16	local
10.0.0.0/8	tgw-xxxxx

Destination	Target
10.2.0.0/16	local
10.0.0.0/8	tgw-xxxxx

Lab setup



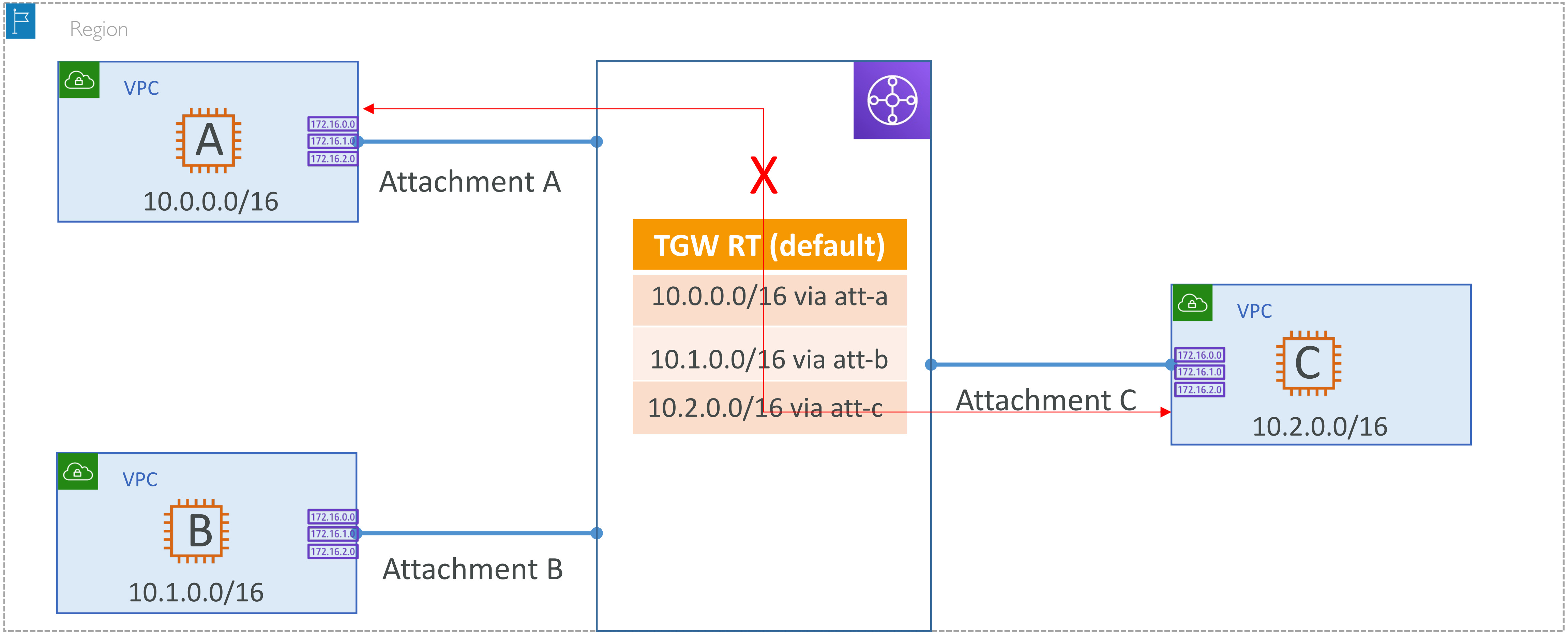
Region
VPC A
VPC
10.0.0.0/16
Public subnet
172.16.0.0
172.16.1.0
172.16.2.0
Jump host
Private subnet
172.16.0.0
172.16.1.0
172.16.2.0
A
Destination | Target
10.0.0.0/16 | local
10.0.0.0/8 | tgw-xxxxx
att-a
TGW RT (default)
10.0.0.0/16 via att-a
10.1.0.0/16 via att-b
10.2.0.0/16 via att-c
VPC
10.1.0.0/16
Private subnet
172.16.2.0
B
Destination | Target
10.1.0.0/16 | local
10.0.0.0/8 | tgw-xxxxx
att-b
VPC B
att-c
Destination | Target
10.2.0.0/16 | local
10.0.0.0/8 | tgw-xxxxx
VPC
10.2.0.0/1
Private subnet
172.16.0.0
172.16.1.0
172.16.2.0
C
VPC C

Lab Steps

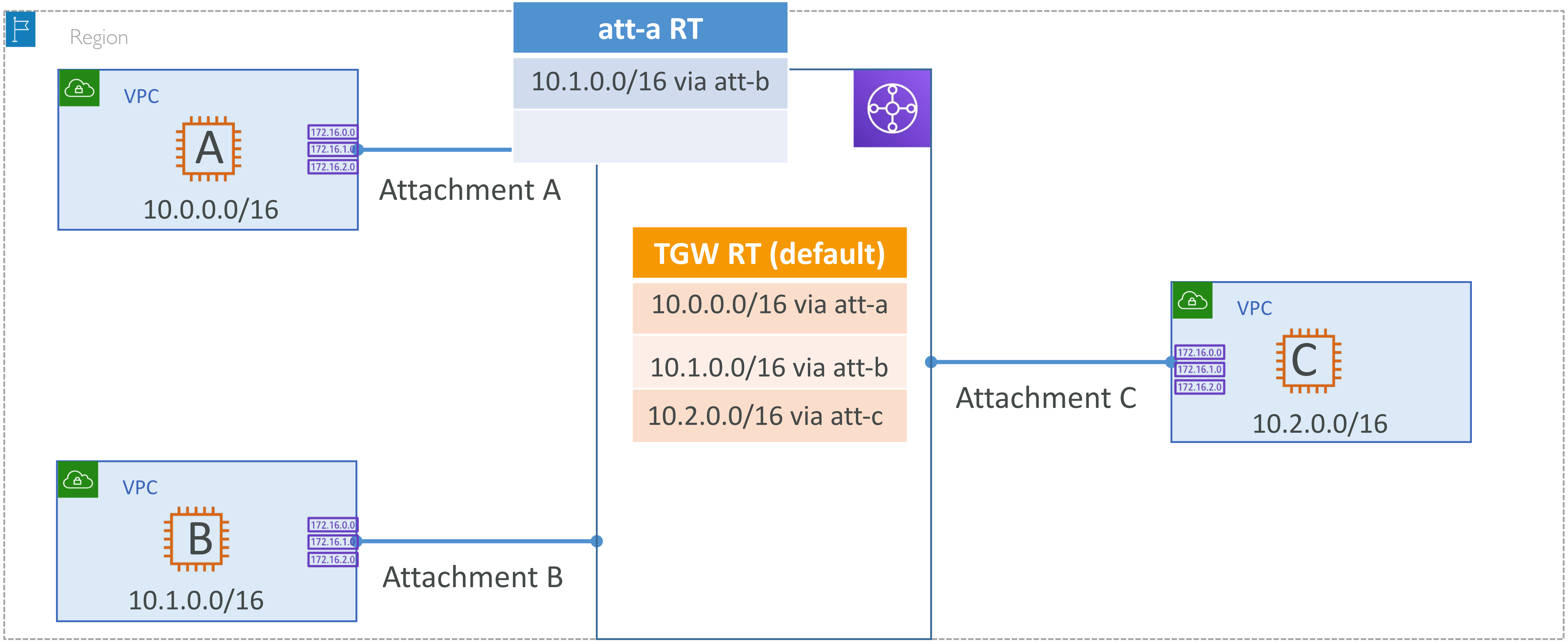
1. Create 3 VPCs and corresponding private subnets. For VPC A – additionally create a Public Subnet (we need that for jump host)
2. Create Transit Gateway
3. Create 3 VPC attachments for the Transit Gateway
4. Modify all Private subnet route table and add route for 10.0.0.0/8 via the Transit gateway attachment
5. SSH to VPC A Jump host -> SSH to EC2-A -> Ping to EC2-B or EC2-C using a Private IP

Transit Gateway Attachment specific routing

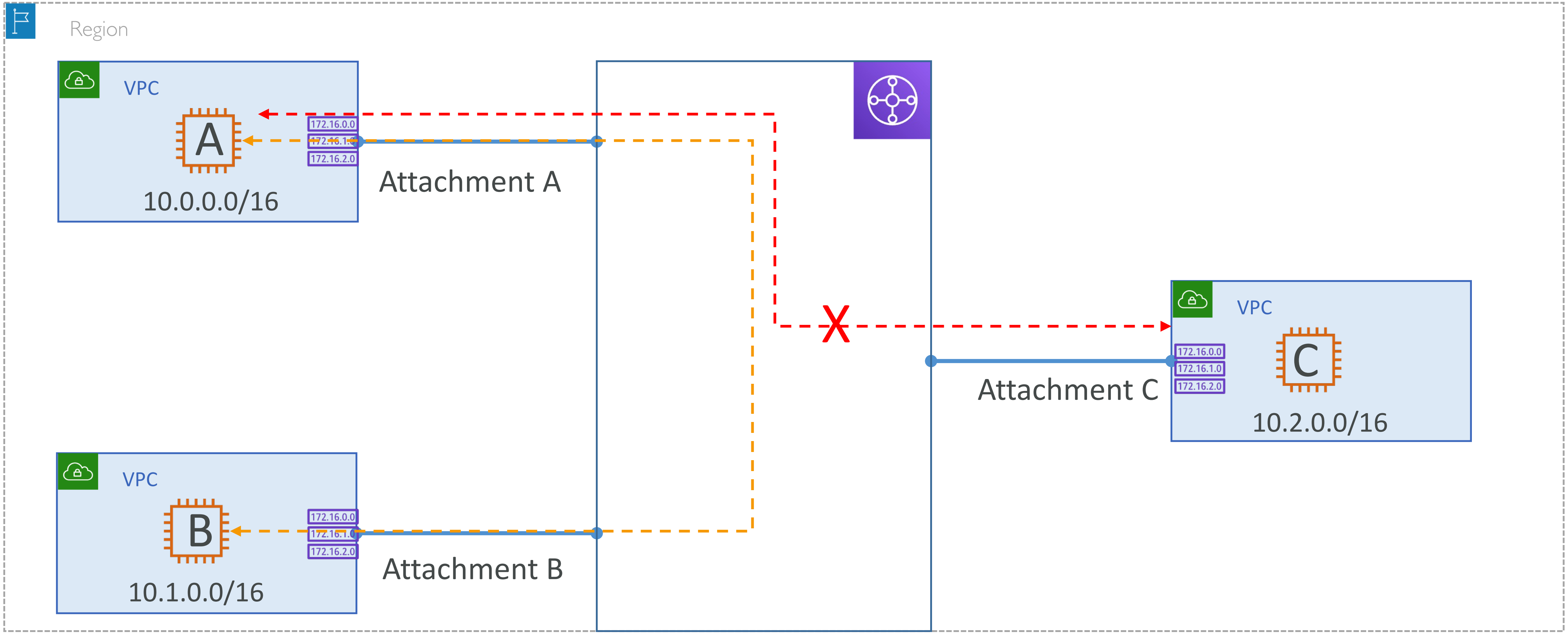
Routing control with attachment Route Tables



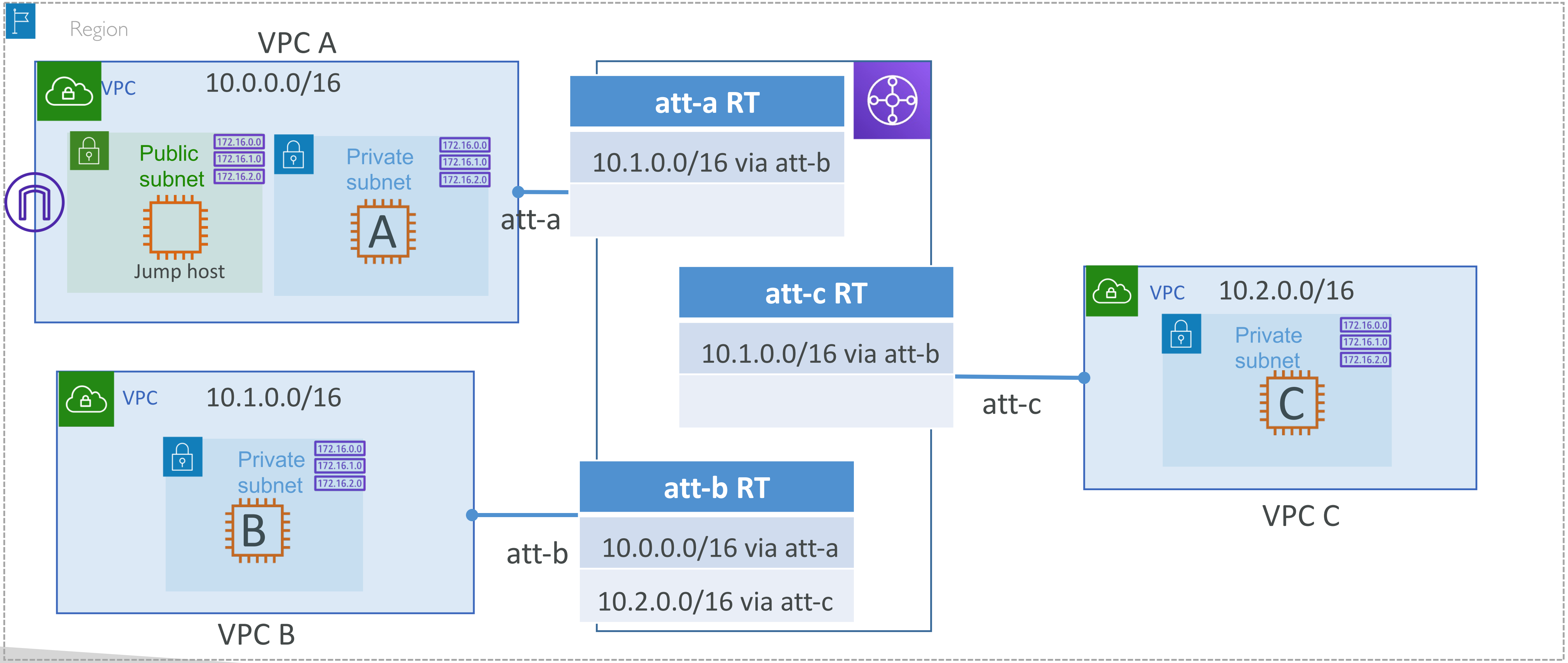
Create attachment specific route table



Lab – Let's set this up and test connectivity



Lab setup



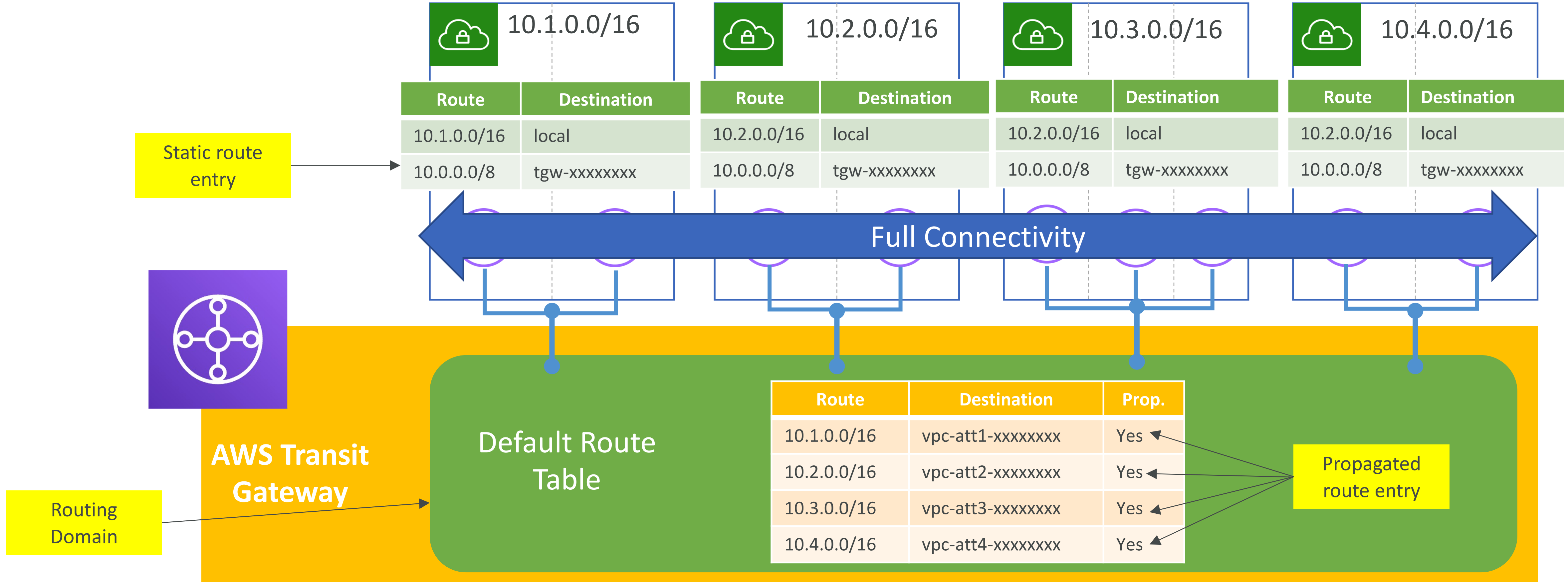
Region
VPC A
VPC
10.0.0.0/16
Public subnet
172.16.0.0
172.16.1.0
172.16.2.0
Jump host
Private subnet
172.16.0.0
172.16.1.0
172.16.2.0
A
att-a
att-a RT
10.1.0.0/16 via att-b
att-c RT
10.1.0.0/16 via att-b
att-c
VPC
10.2.0.0/16
Private subnet
172.16.0.0
172.16.1.0
172.16.2.0
C
VPC C
VPC
10.1.0.0/16
Private subnet
172.16.0.0
172.16.1.0
172.16.2.0
B
att-b
att-b RT
10.0.0.0/16 via att-a
10.2.0.0/16 via att-c
VPC B

Lab Steps

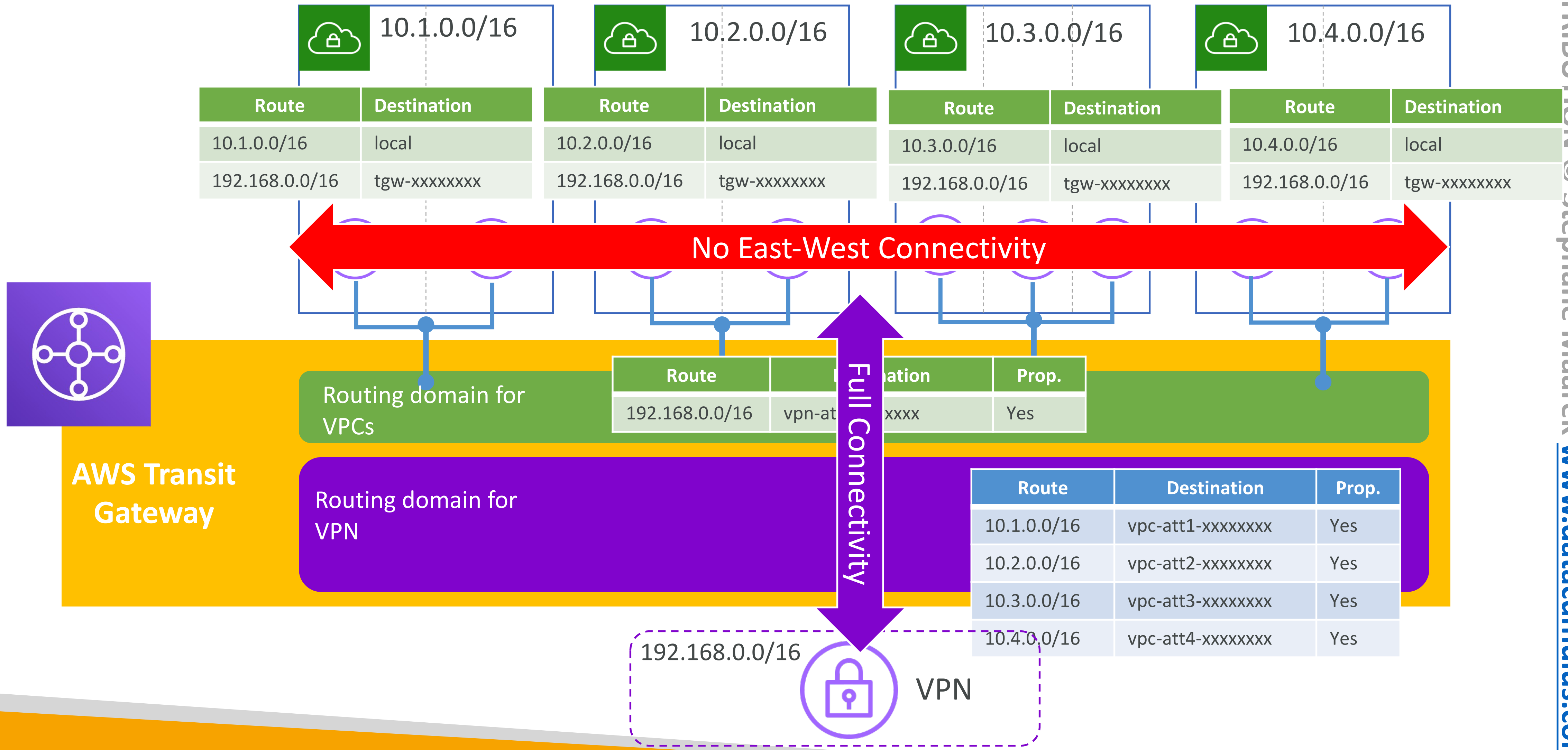
1. Create 3 VPCs and corresponding private subnets. For VPC A –additionally create a Public Subnet (we need that for jump host)
2. Create Transit Gateway (Do not enable default route table association and default route table propagation)
3. Create 3 Transit gateway VPC attachments for each VPC
4. Create 3 transit gateway route tables and associate each with corresponding VPC attachments.
5. For att-a route table add the route propagation for att-b
6. For att-b route table add the route propagation for att-a and att-c
7. For att-c route table add the route propagation for att-b
8. SSH to VPC A Jump host -> SSH to EC2-A -> Ping to EC2-B or EC2-C using a Private IP. Connectivity to EC2-B should work however EC2-C should be denied.
9. Similarly from EC2-B try to SSH/Ping to EC2-A and EC2-C. Connectivity to both the instances should be successful

Transit Gateway – VPC Network patterns

Flat network

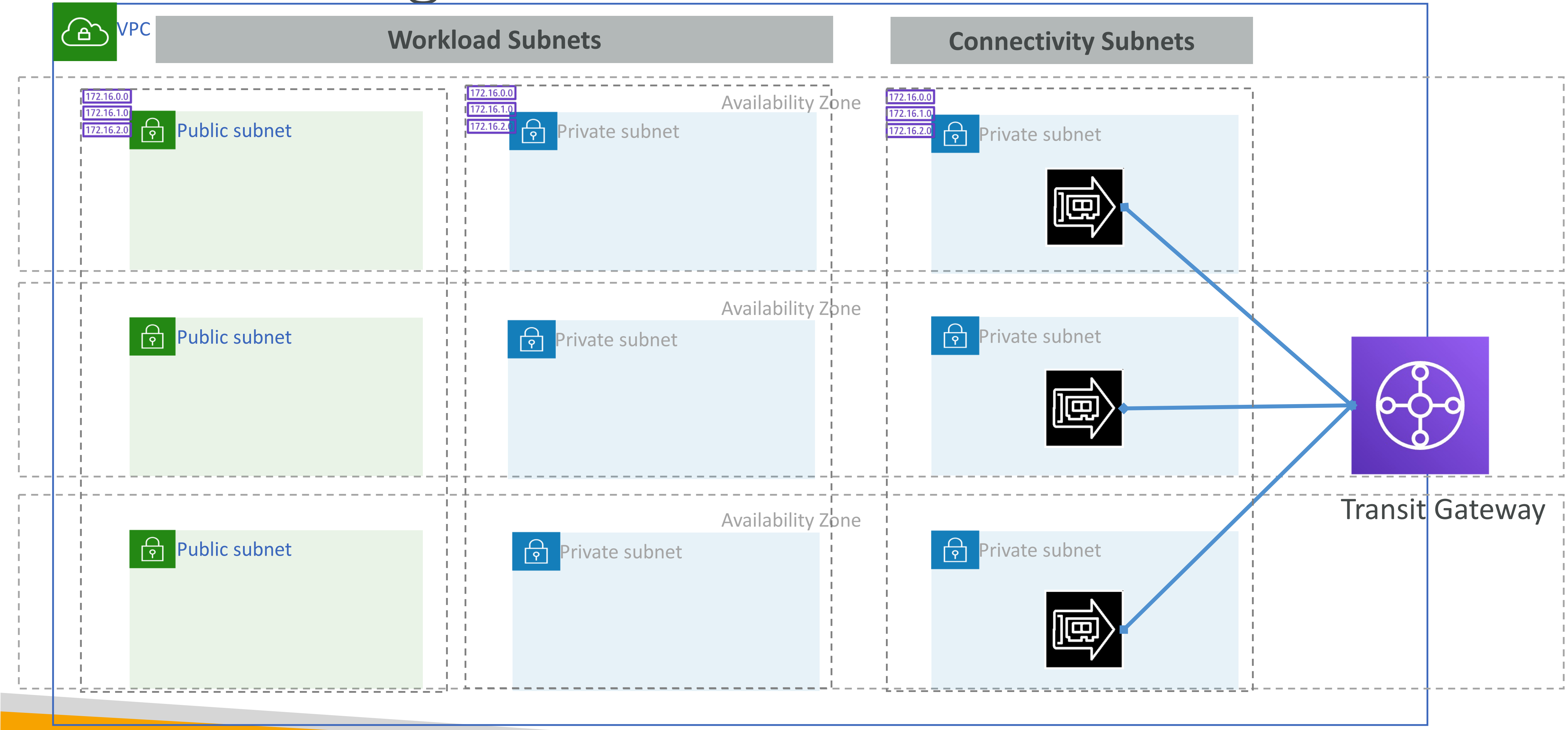


Segmented Network



VPC & Subnets design for Transit Gateway

VPC design for TGW

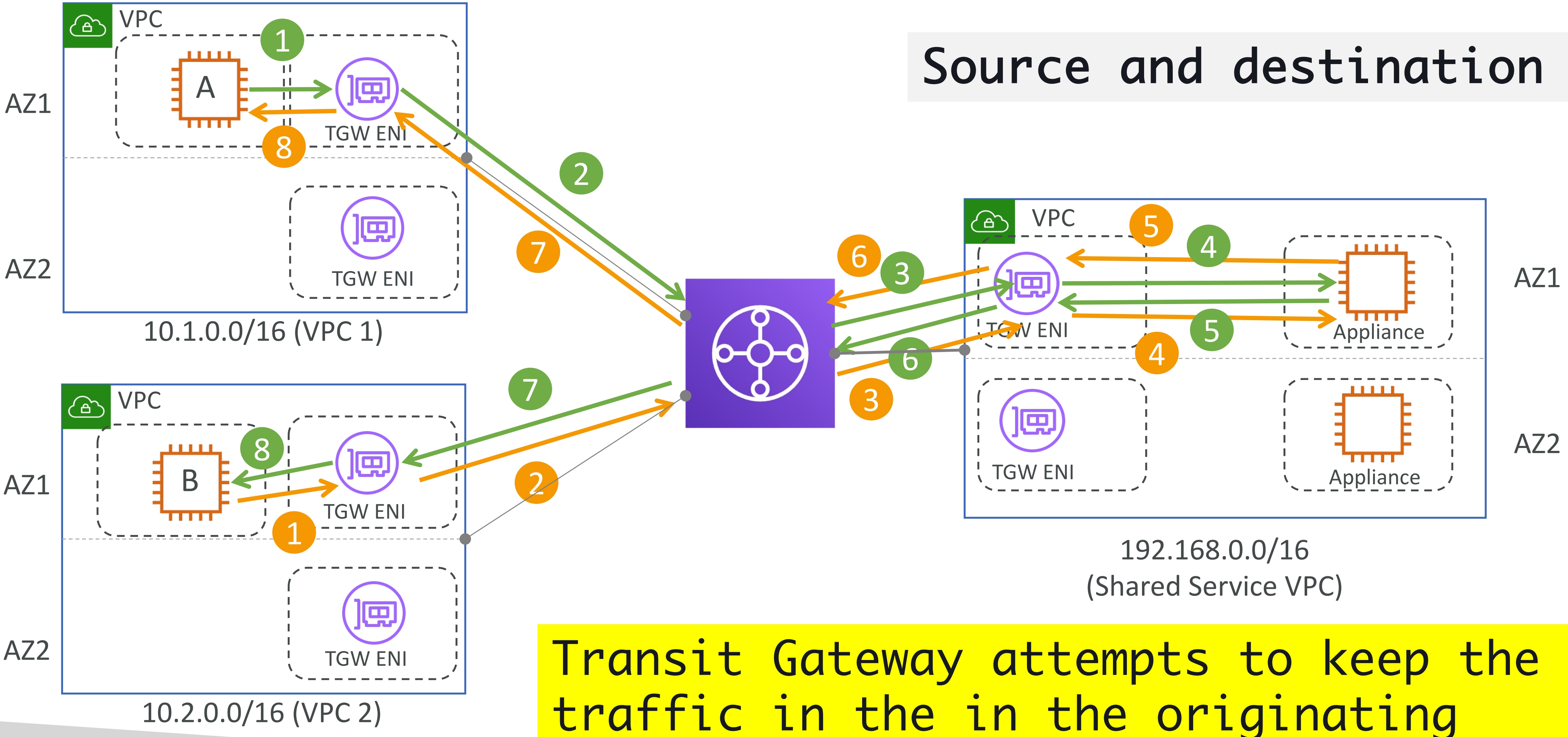


Availability zone considerations

- When you attach a VPC to a transit gateway, you must enable one or more Availability Zones to be used by the transit gateway to route traffic to resources in the VPC subnets
- To enable each Availability Zone, you specify exactly one subnet (typically /28 range to save IPs for workload subnets)
- The transit gateway places a network interface in that subnet using one IP address from the subnet
- After you enable an Availability Zone, traffic can be routed to all subnets in that zone, not just the specified subnet
- Resources that reside in Availability Zones where there is no transit gateway attachment cannot reach the transit gateway

Transit Gateway AZ affinity & Appliance mode

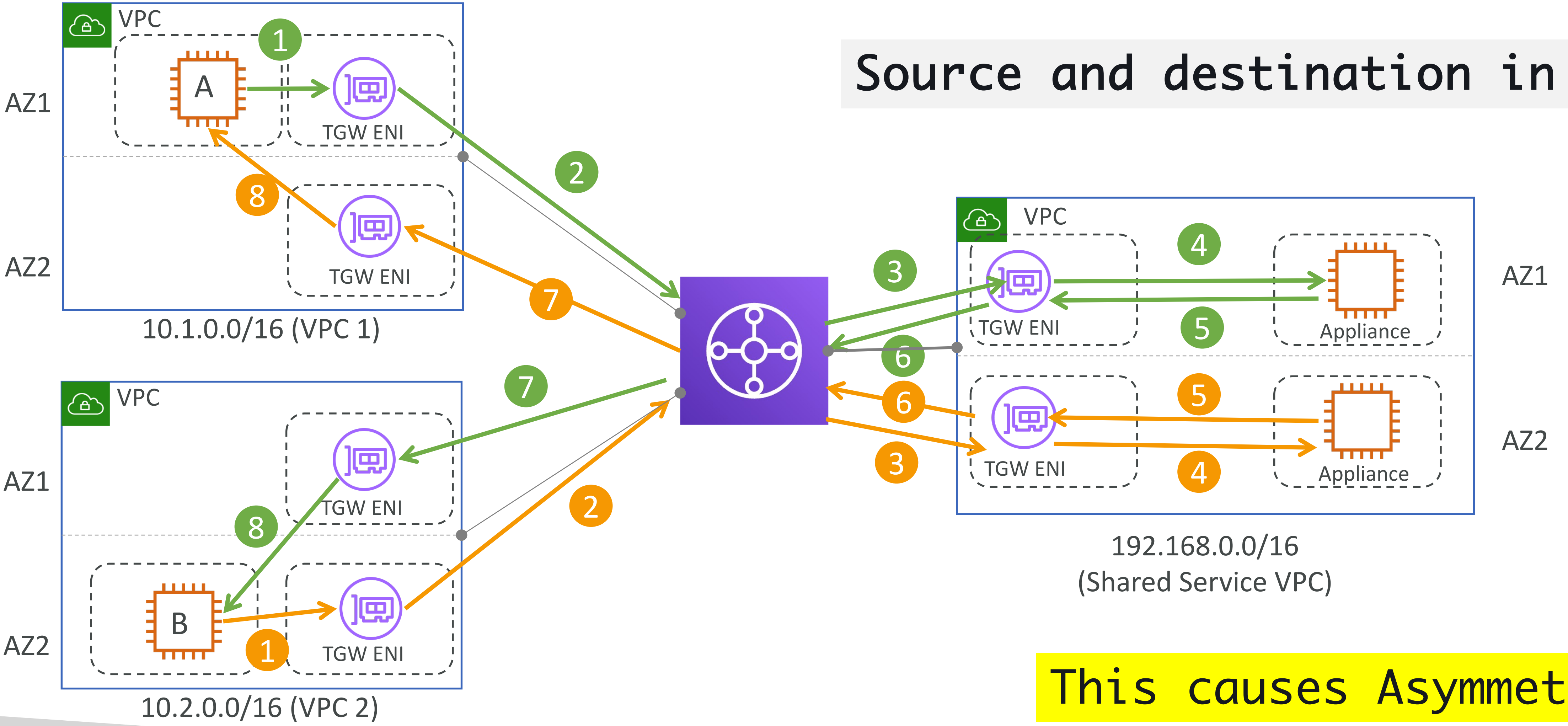
Transit Gateway – AZ Affinity



Source and destination in same

Transit Gateway attempts to keep the traffic in the in the originating Availability Zone until it reaches its destination

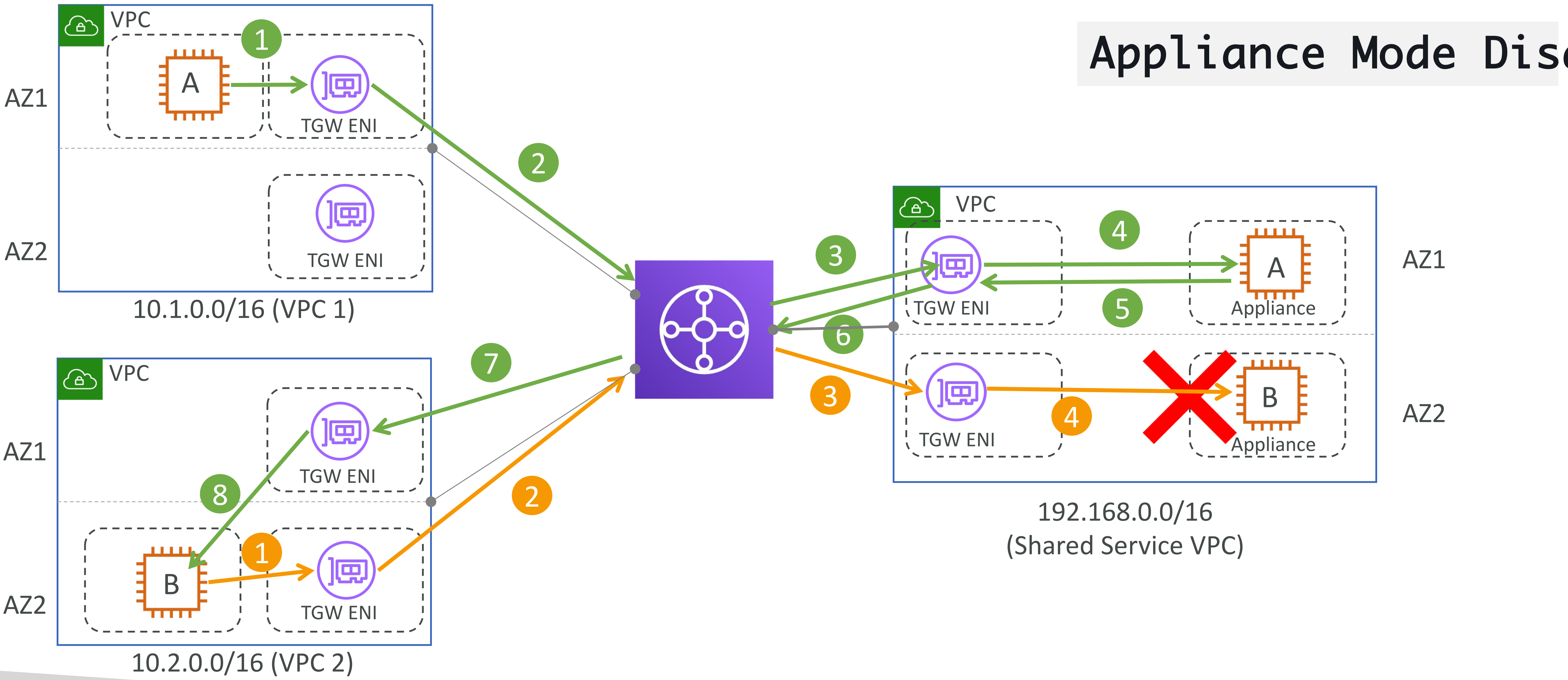
Transit Gateway – AZ Affinity



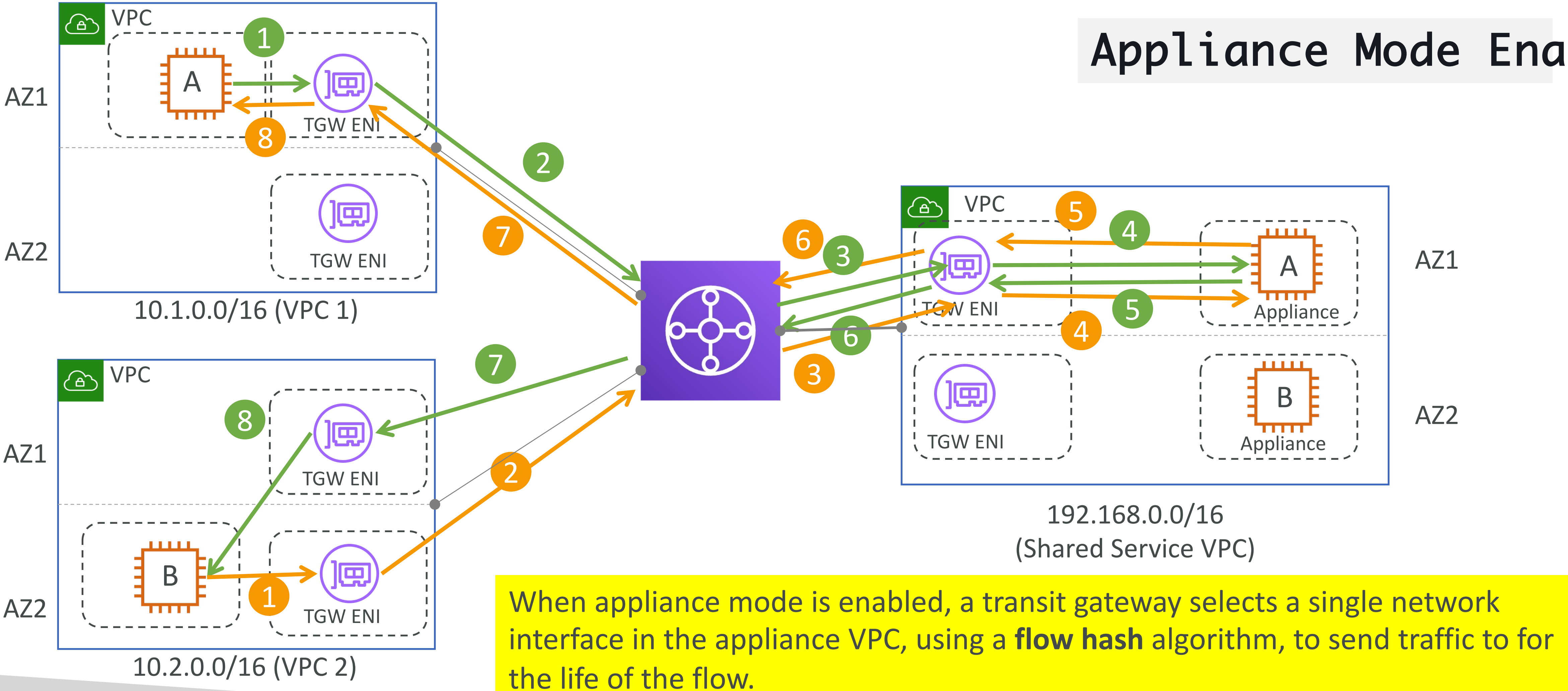
Source and destination in differ

This causes Asymmetric Rou

Transit Gateway – Stateful Appliance

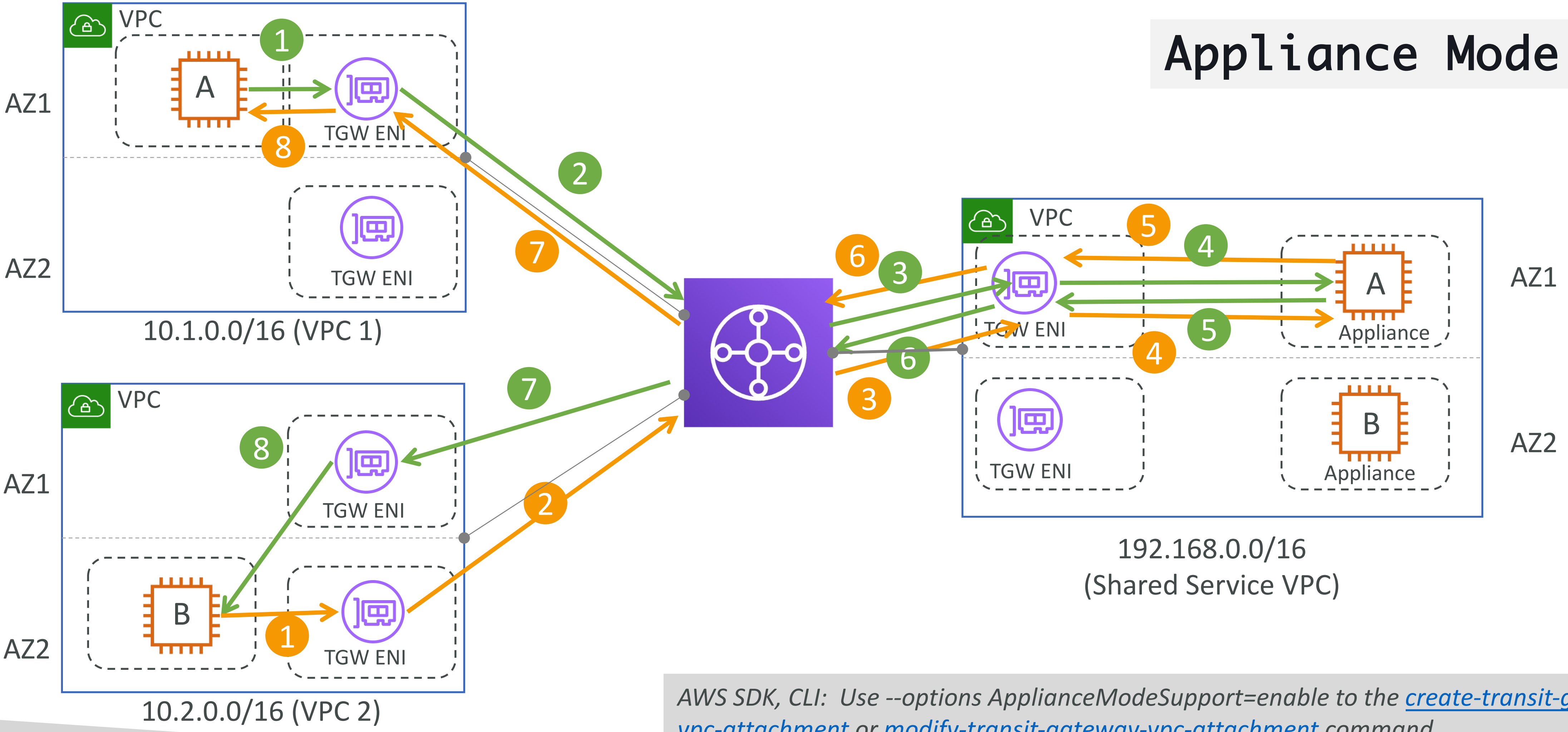


Transit Gateway – Stateful Appliance



When appliance mode is enabled, a transit gateway selects a single network interface in the appliance VPC, using a **flow hash** algorithm, to send traffic to for the life of the flow.

Transit Gateway – Stateful Appliance



AWS SDK, CLI: Use --options ApplianceModeSupport=enable to the [create-transit-gateway-vpc-attachment]() or [modify-transit-gateway-vpc-attachment]() command.

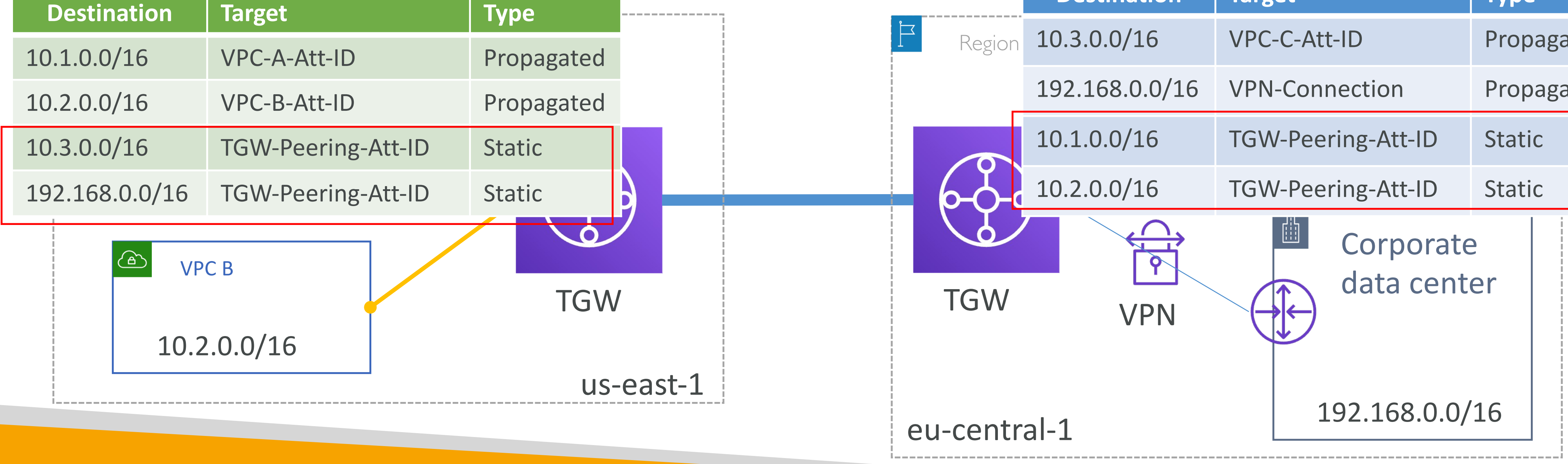
Transit Gateway Peering

Transit Gateway Peering

- Transit gateways are regional router which means you can connect VPCs from the same region
- For inter region network connectivity you can peer the transit gateways across the regions
- Static routes needs to be added for peering connection

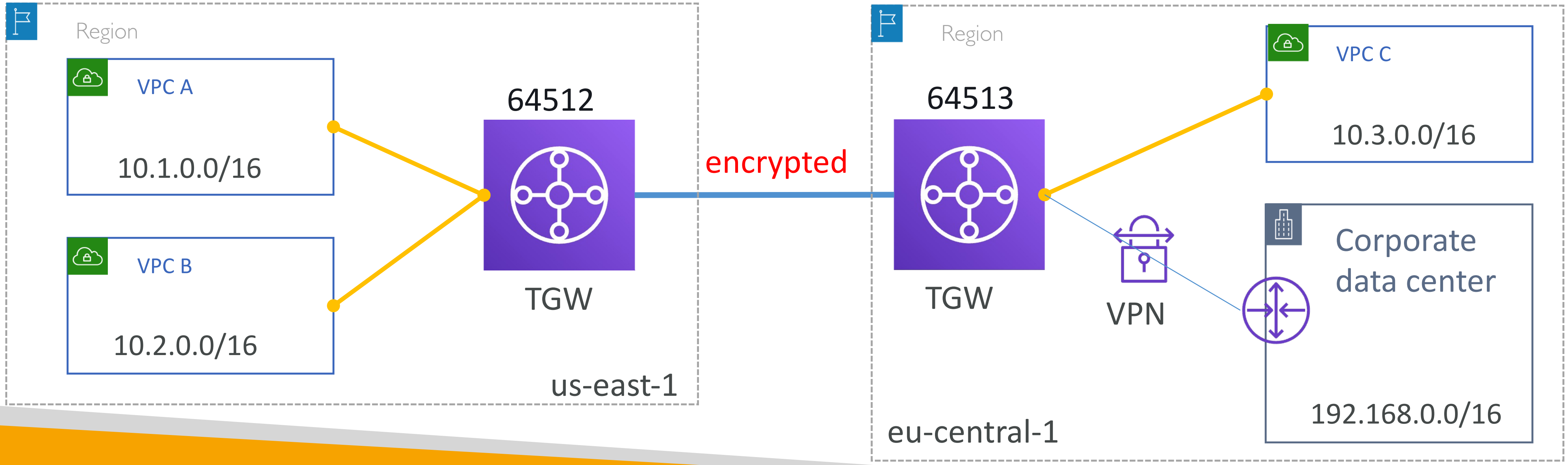
Destination	Target	Type
10.1.0.0/16	VPC-A-Att-ID	Propagated
10.2.0.0/16	VPC-B-Att-ID	Propagated
10.3.0.0/16	TGW-Peering-Att-ID	Static
192.168.0.0/16	TGW-Peering-Att-ID	Static

Destination	Target	Type
10.3.0.0/16	VPC-C-Att-ID	Propagated
192.168.0.0/16	VPN-Connection	Propagated
10.1.0.0/16	TGW-Peering-Att-ID	Static
10.2.0.0/16	TGW-Peering-Att-ID	Static



Transit Gateway Peering

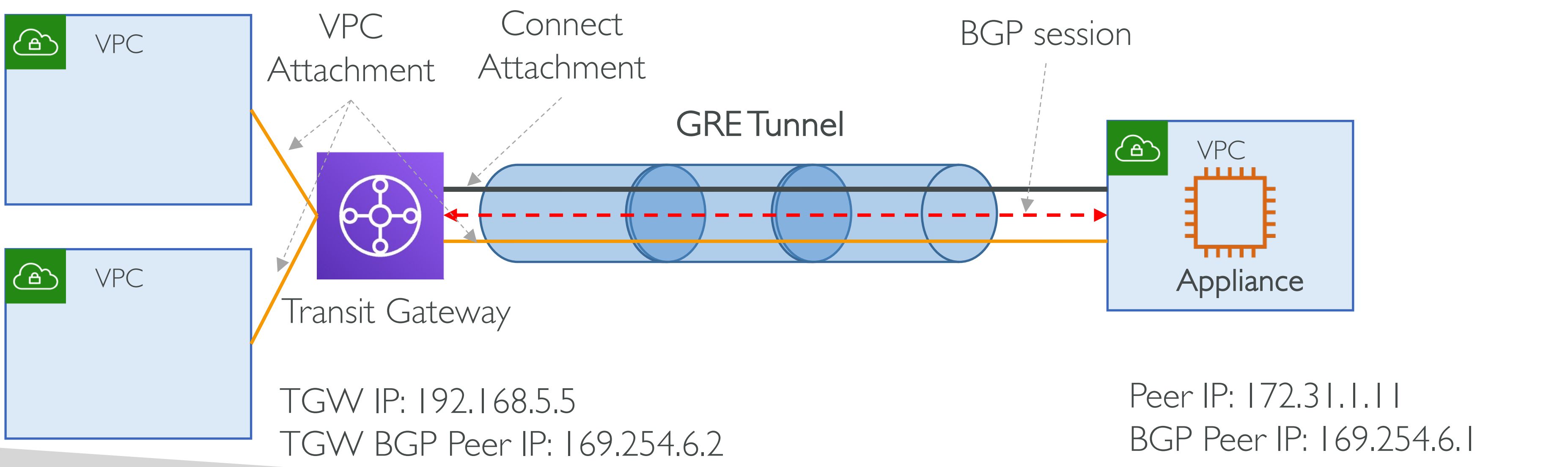
- Transit gateways are regional router which means you can connect VPCs from the same region
- For inter region network connectivity you can peer the transit gateways across the regions
- Static routes needs to be added for peering connection (No BGP)
- The inter-Region traffic is encrypted, traverses the AWS global network, and is not exposed to the public internet. Supports bandwidth up to 50 Gbps.
- Use unique ASNs for the peered transit gateways (as much possible)



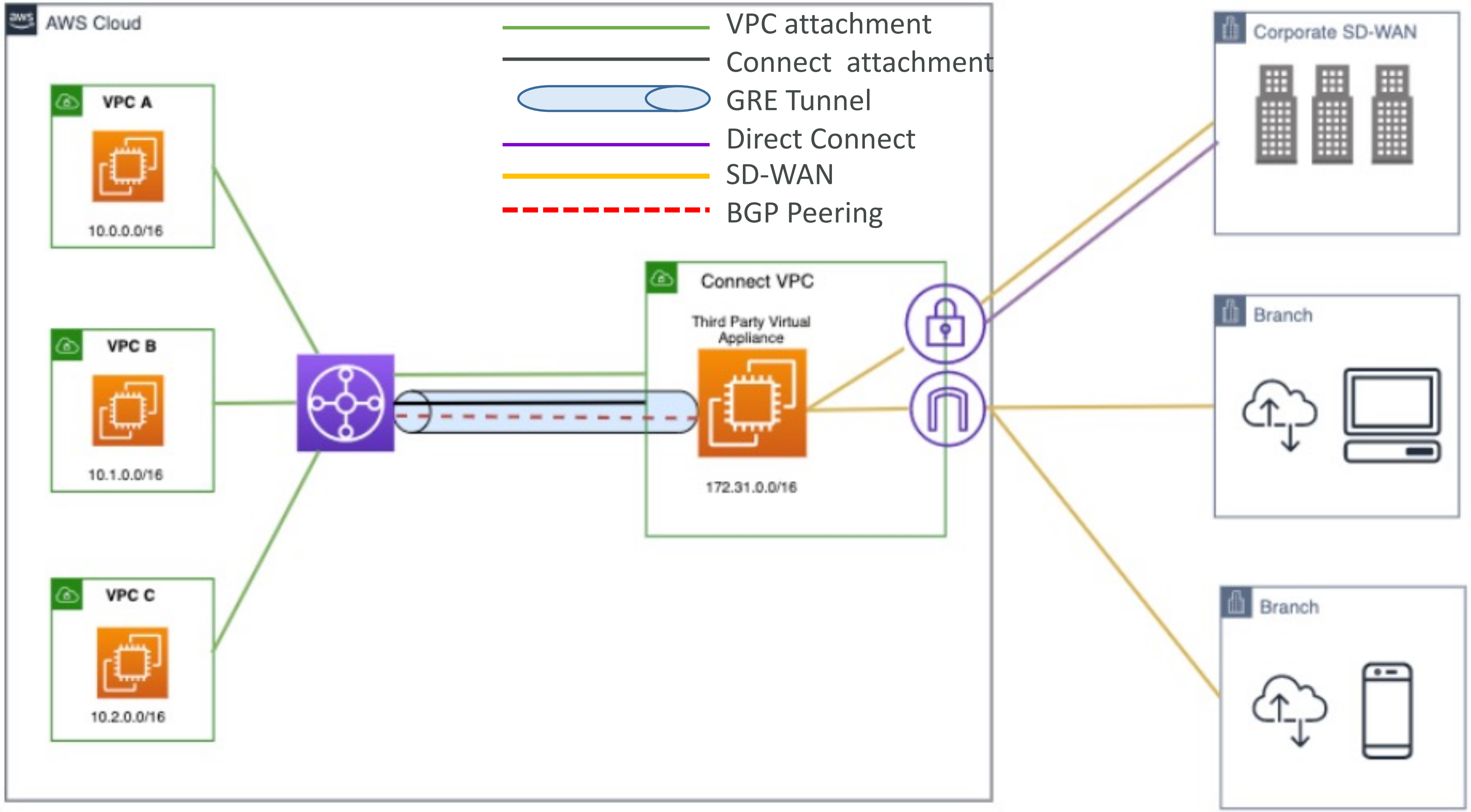
Transit Gateway Connect Attachment

Transit Gateway – Connect attachment

- You can create a transit gateway Connect attachment to establish a connection between a transit gateway and third-party virtual appliances (such as SD-WAN appliances) running in a VPC
- A Connect attachment uses an existing VPC or AWS Direct Connect attachment as the underlying transport mechanism.
- Supports Generic Routing Encapsulation (GRE) tunnel protocol for high performance, and Border Gateway Protocol (BGP) for dynamic routing.

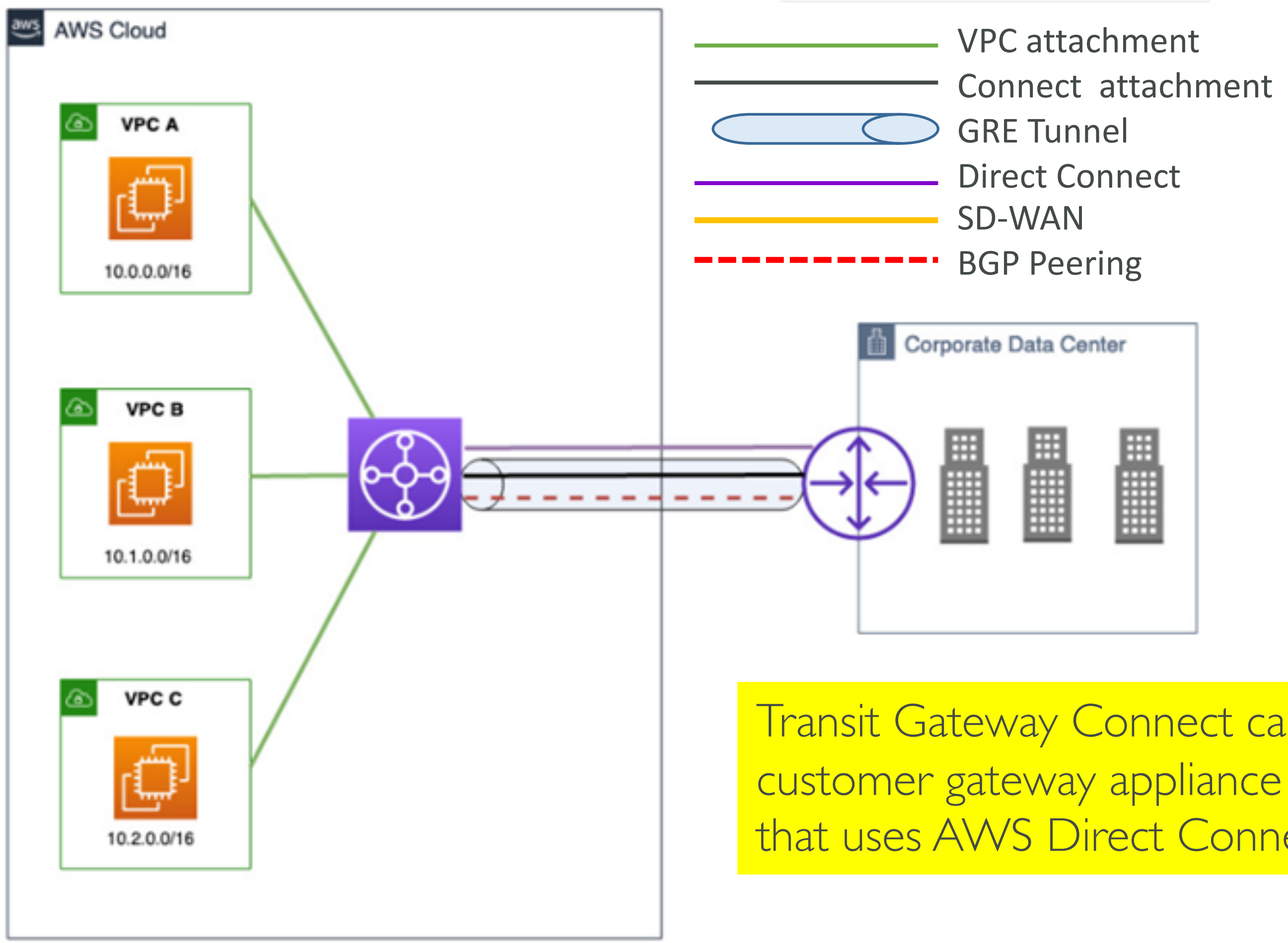


Transit Gateway Connect attachment over the VPC transport attachment



Source: [AWS documentation]

Transit Gateway Connect attachment over the DX transport attachment



Transit Gateway Connect can be used as a third-party branch or customer gateway appliance running in an on-premises network that uses AWS Direct Connect as transport.

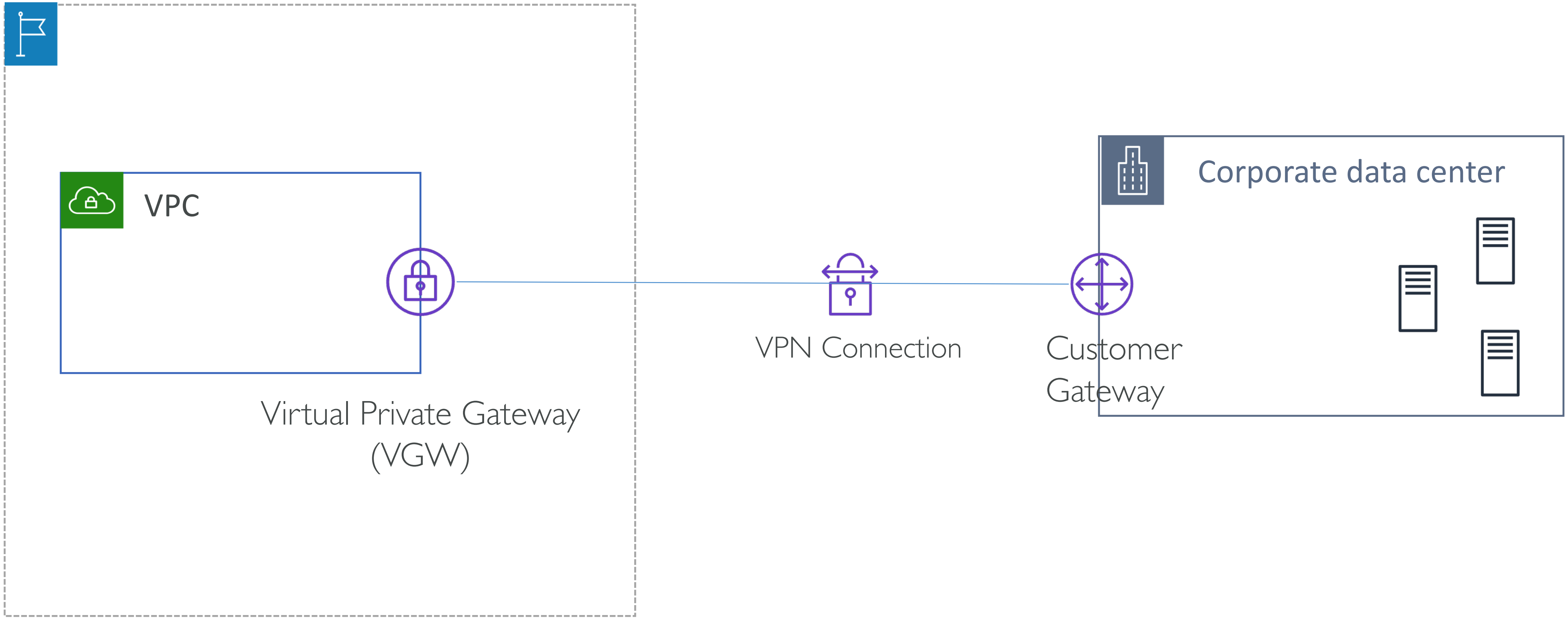
Source: AWS documentation

Transit Gateway Connect attachment

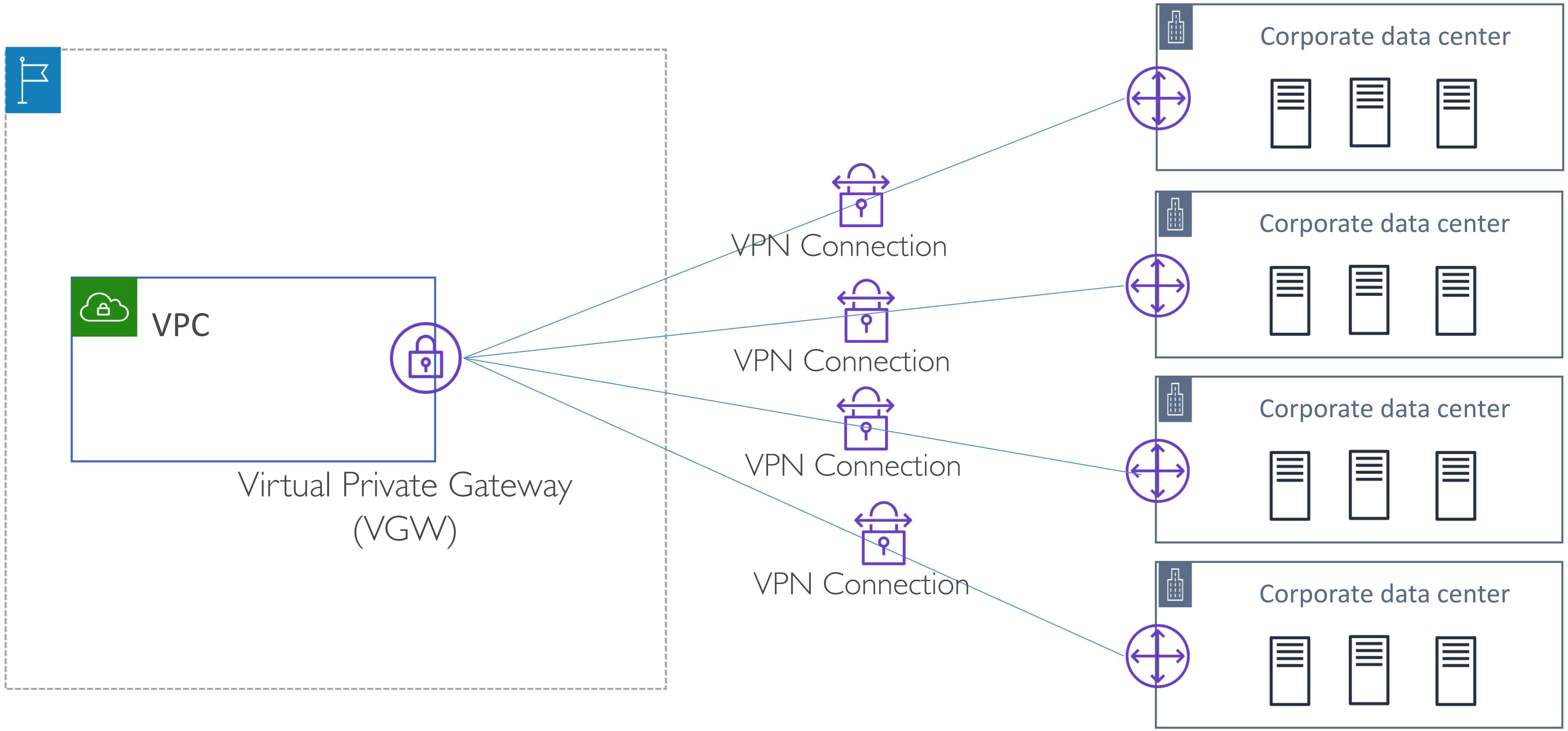
- Connect attachments do not support static routes. BGP is a minimum requirement for Transit Gateway Connect.
- Transit Gateway Connect supports a maximum bandwidth of 5 Gbps per GRE tunnel. Bandwidth above 5 Gbps is achieved by advertising the same prefixes across multiple Connect peer (GRE tunnel) for the same Connect attachment.
- A maximum of four Connect peers are supported for each Connect attachment there by providing total 20 Gbps bandwidth per connection

Transit Gateway with VPN

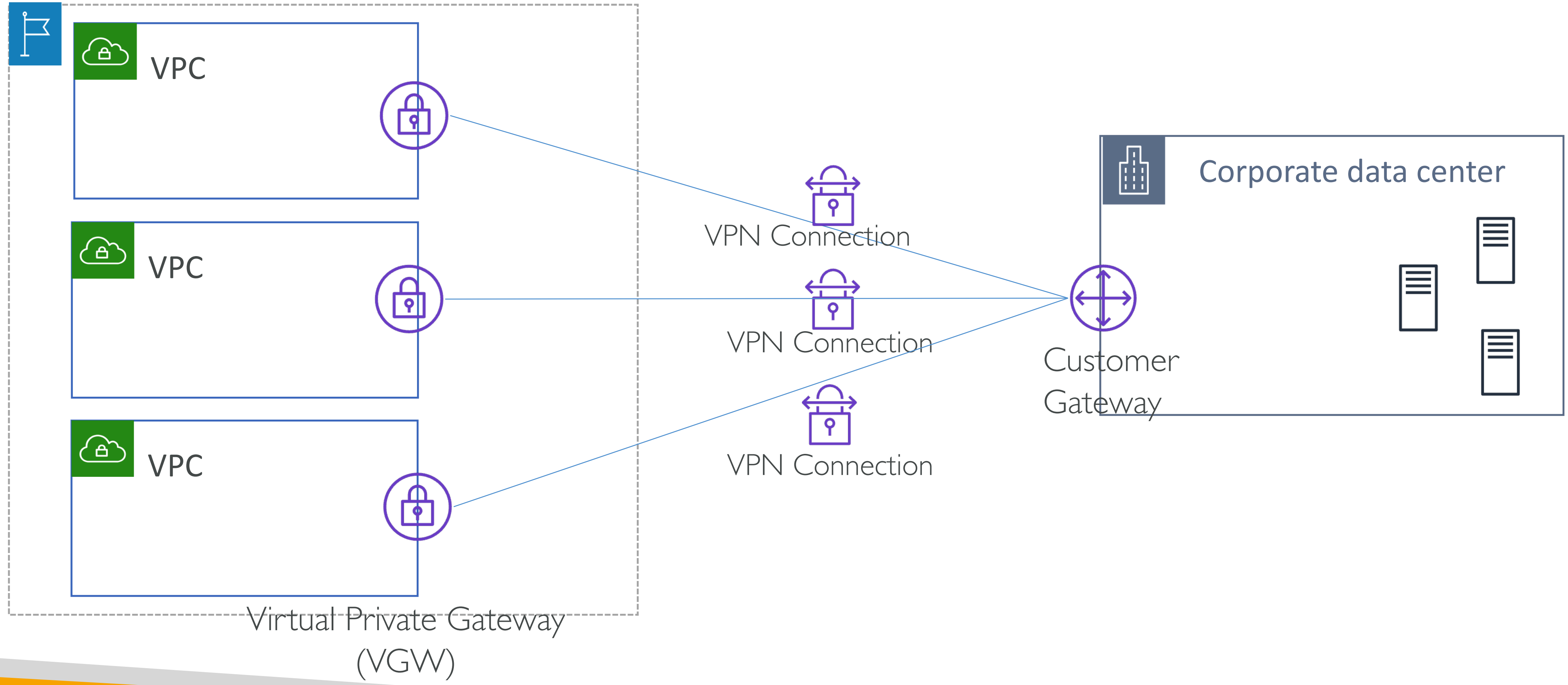
Single Site-to-Site VPN Connection over Virtual Private Gateway (VGW)



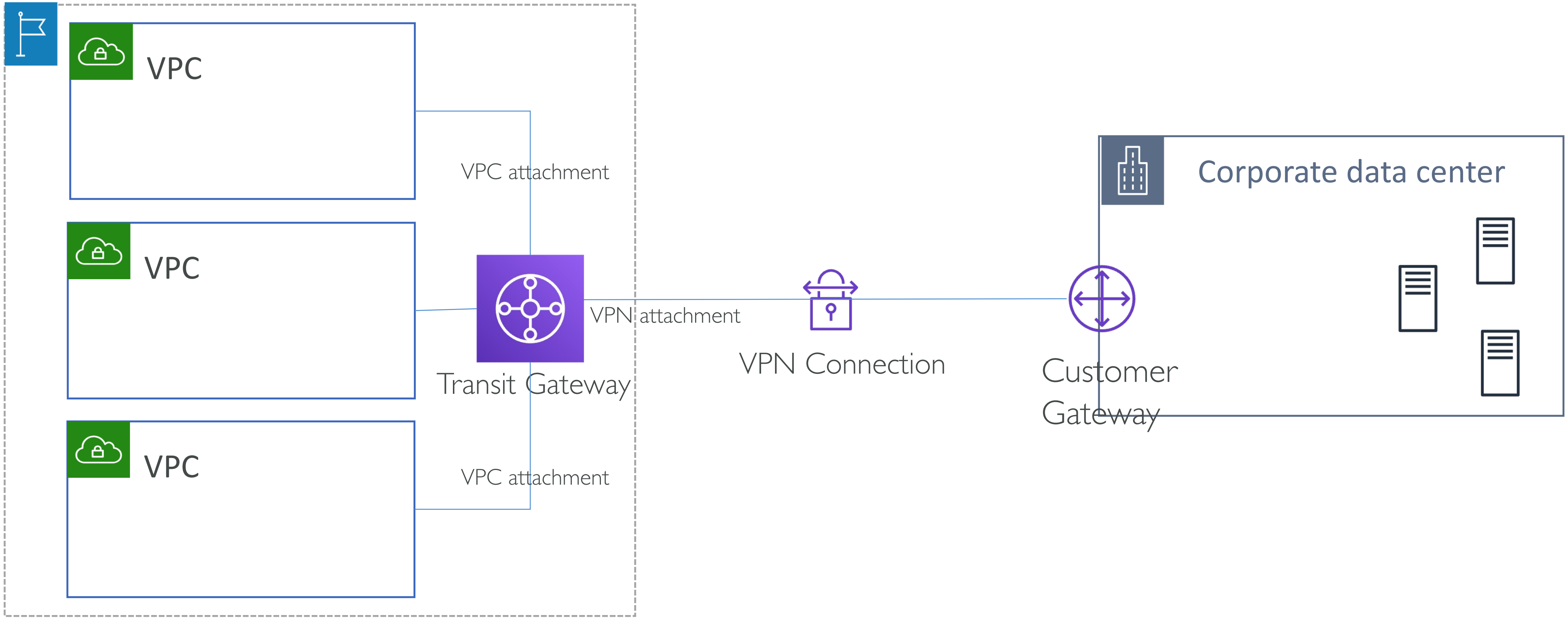
Connecting multiple branch offices over Site-to-Site VPN



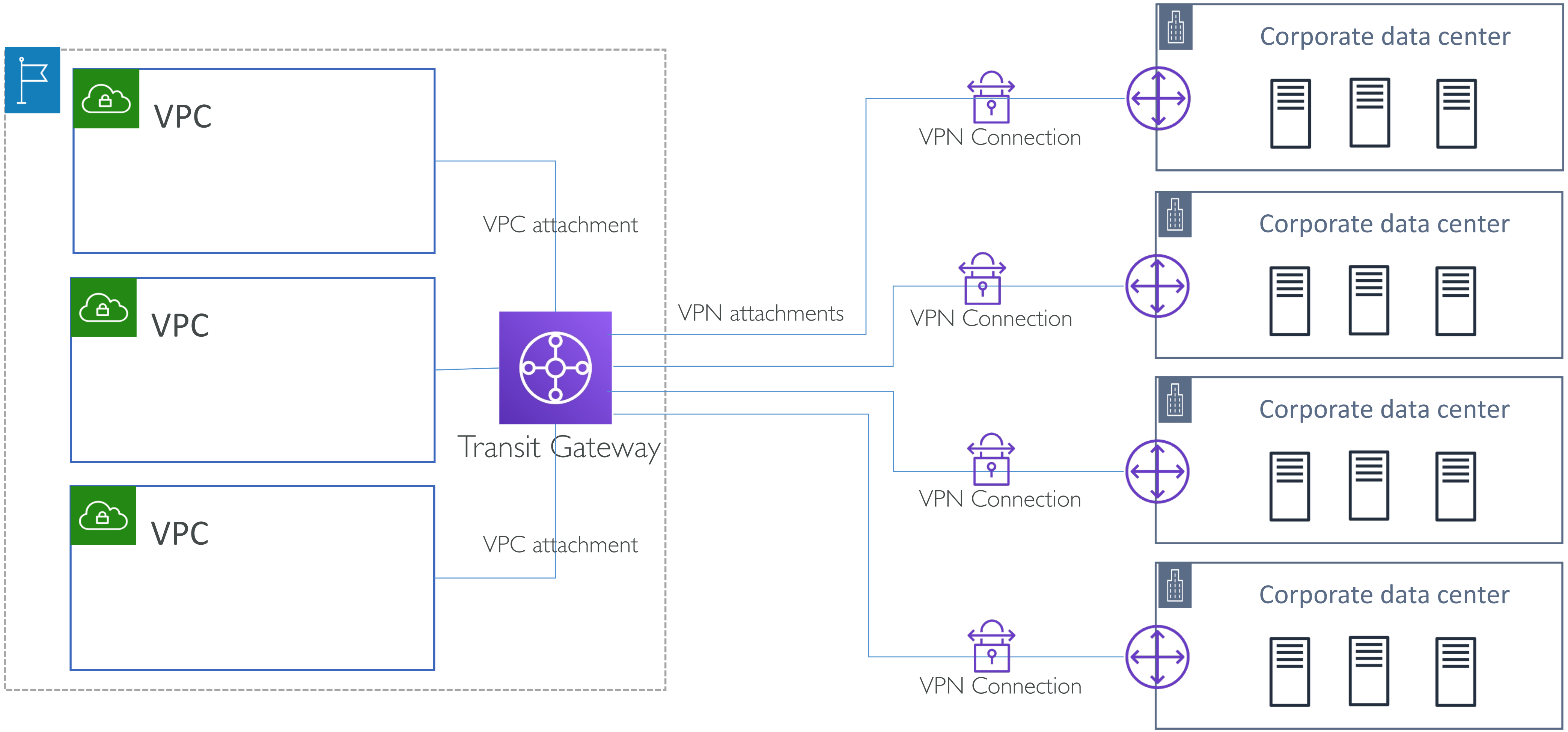
Connecting multiple VPCs over Site-to-Site VPN connections



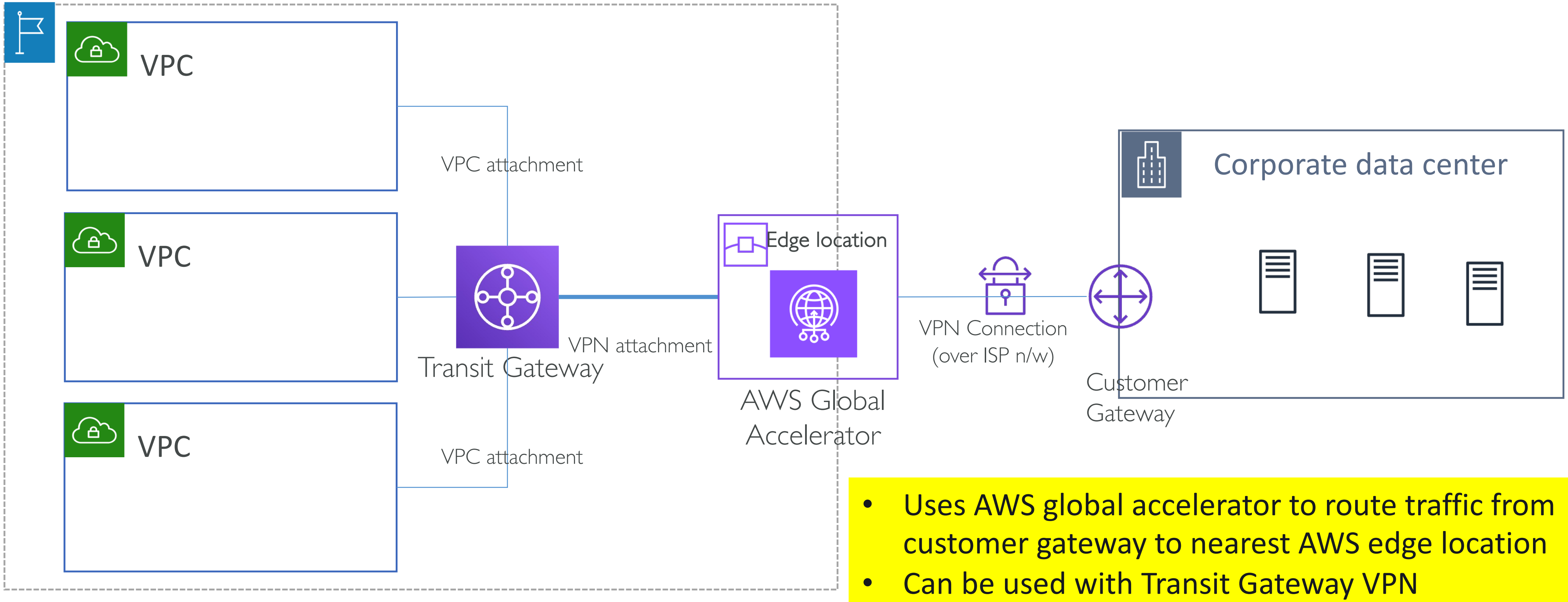
Simplify Site-to-Site VPN network with Transit Gateway



Simplify Site-to-Site VPN network with Transit Gateway

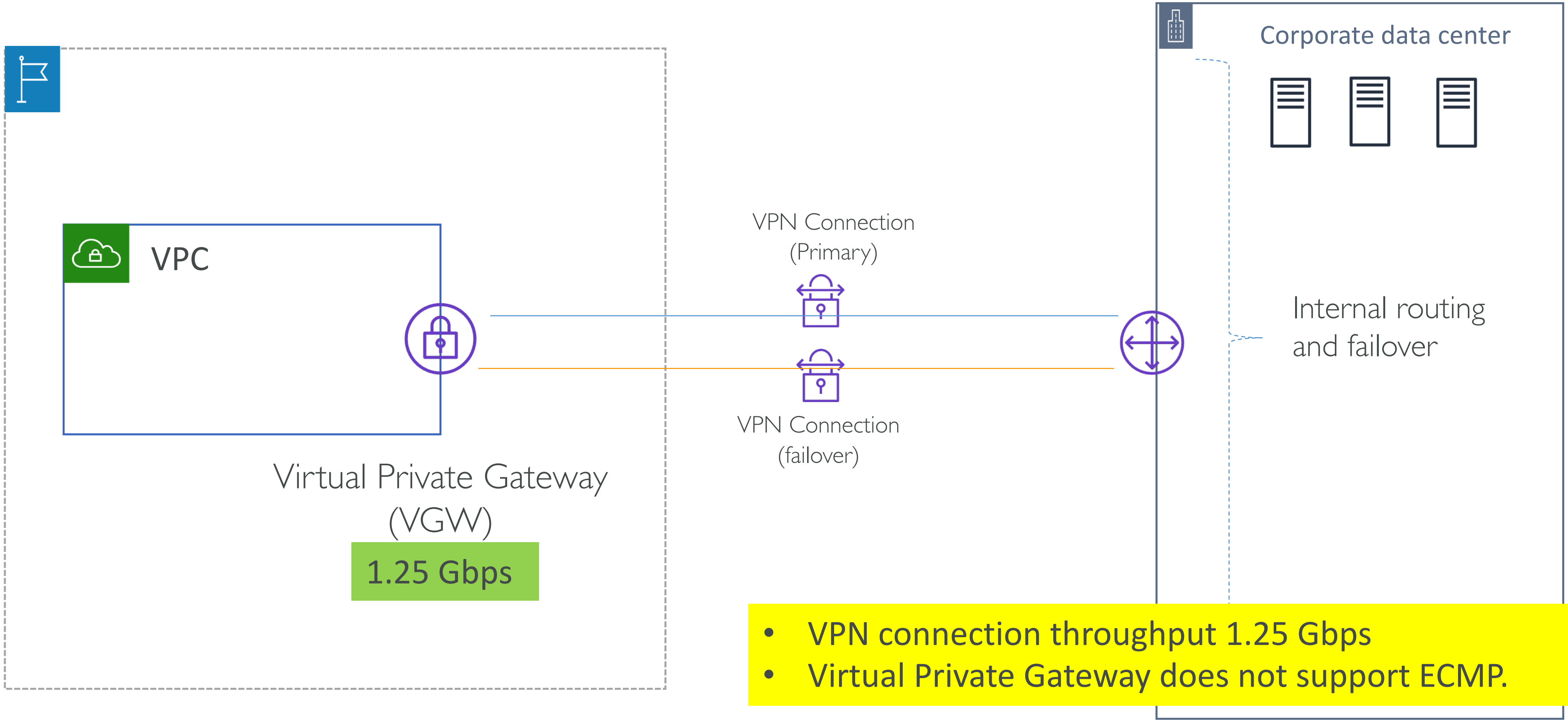


Accelerated Site-to-Site VPN network with Transit Gateway



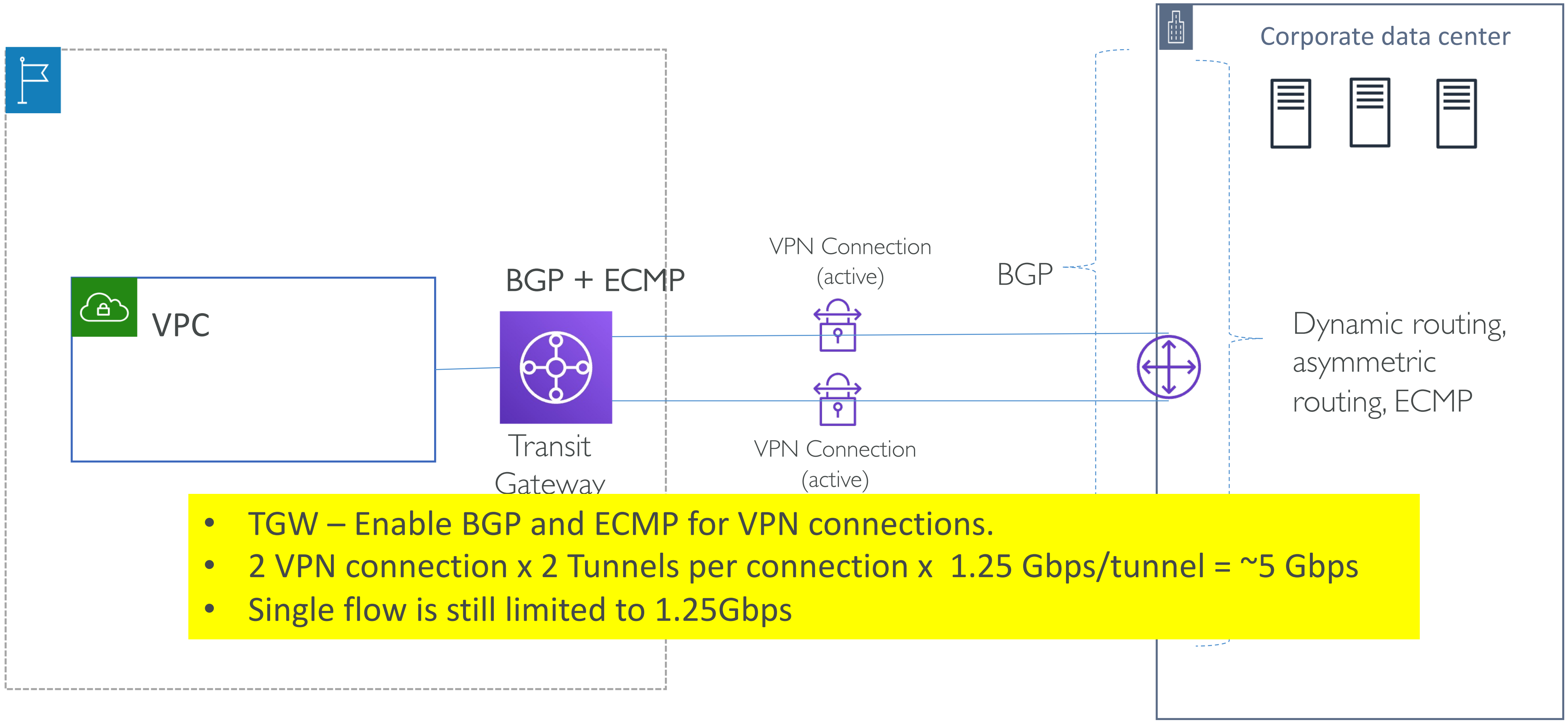
- Uses AWS global accelerator to route traffic from customer gateway to nearest AWS edge location
- Can be used with Transit Gateway VPN attachment only. Not supported with VGW.

Limited n/w throughput with multiple VPN Connections over VGW



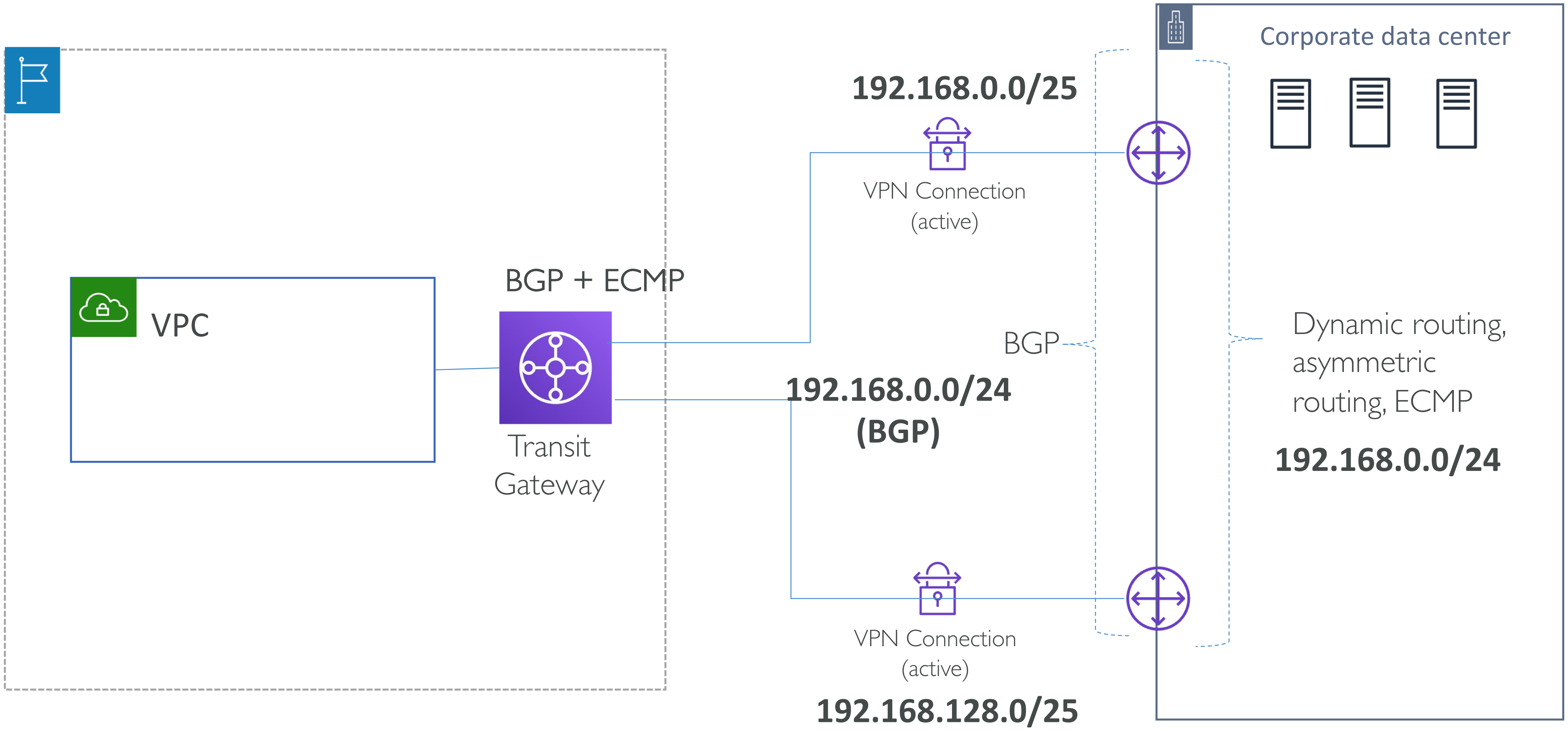
- VPN connection throughput 1.25 Gbps
- Virtual Private Gateway does not support ECMP.

ECMP over Transit Gateway & Site-to-Site VPN for higher aggregate throughput



- TGW – Enable BGP and ECMP for VPN connections.
- 2 VPN connection x 2 Tunnels per connection x 1.25 Gbps/tunnel = ~5 Gbps
- Single flow is still limited to 1.25Gbps

ECMP over Transit Gateway with dual VPN

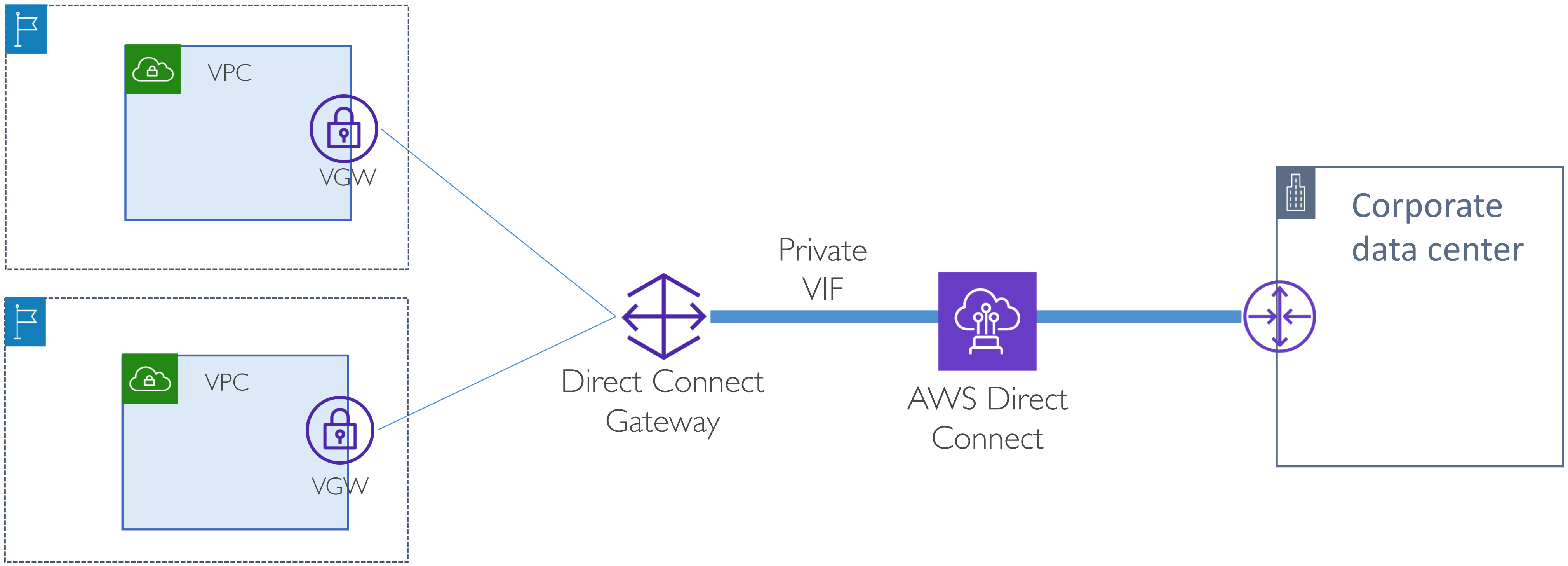


Transit Gateway with Direct Connect

Connecting without Transit Gateway

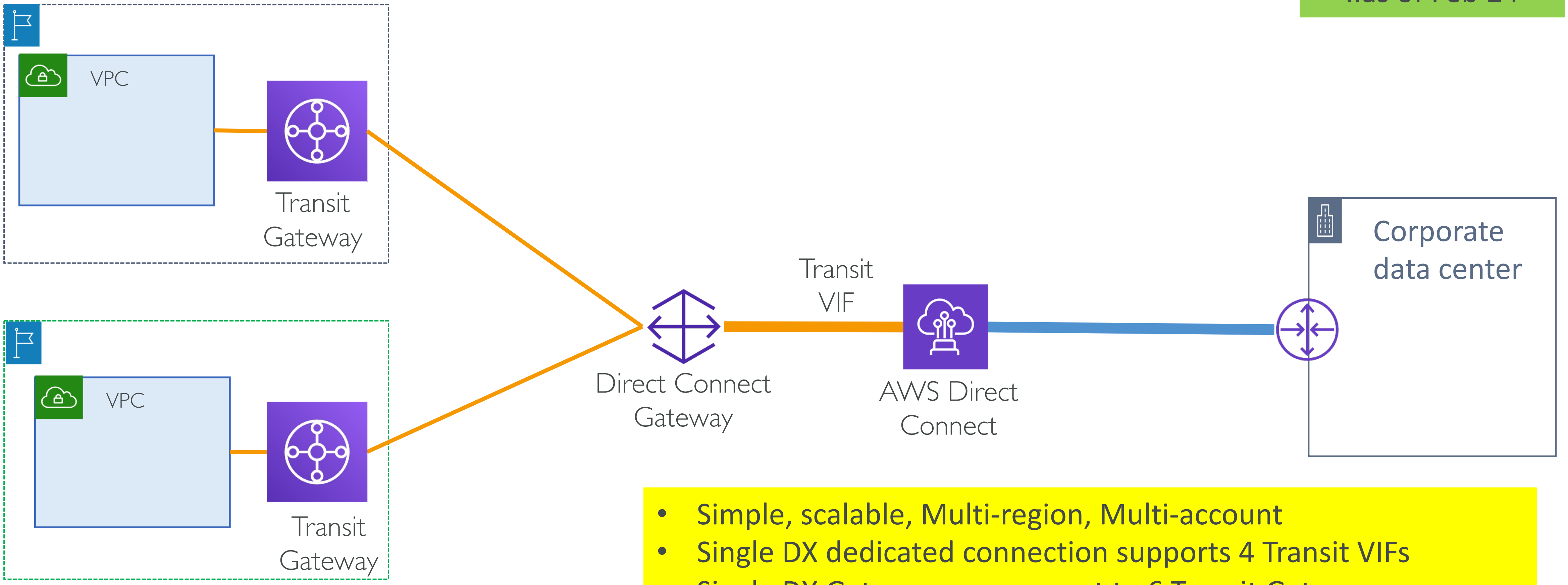
..as of Feb'24

- Using Direct Connect Gateway over a Private VIF
- Allows connecting maximum 10 VPCs



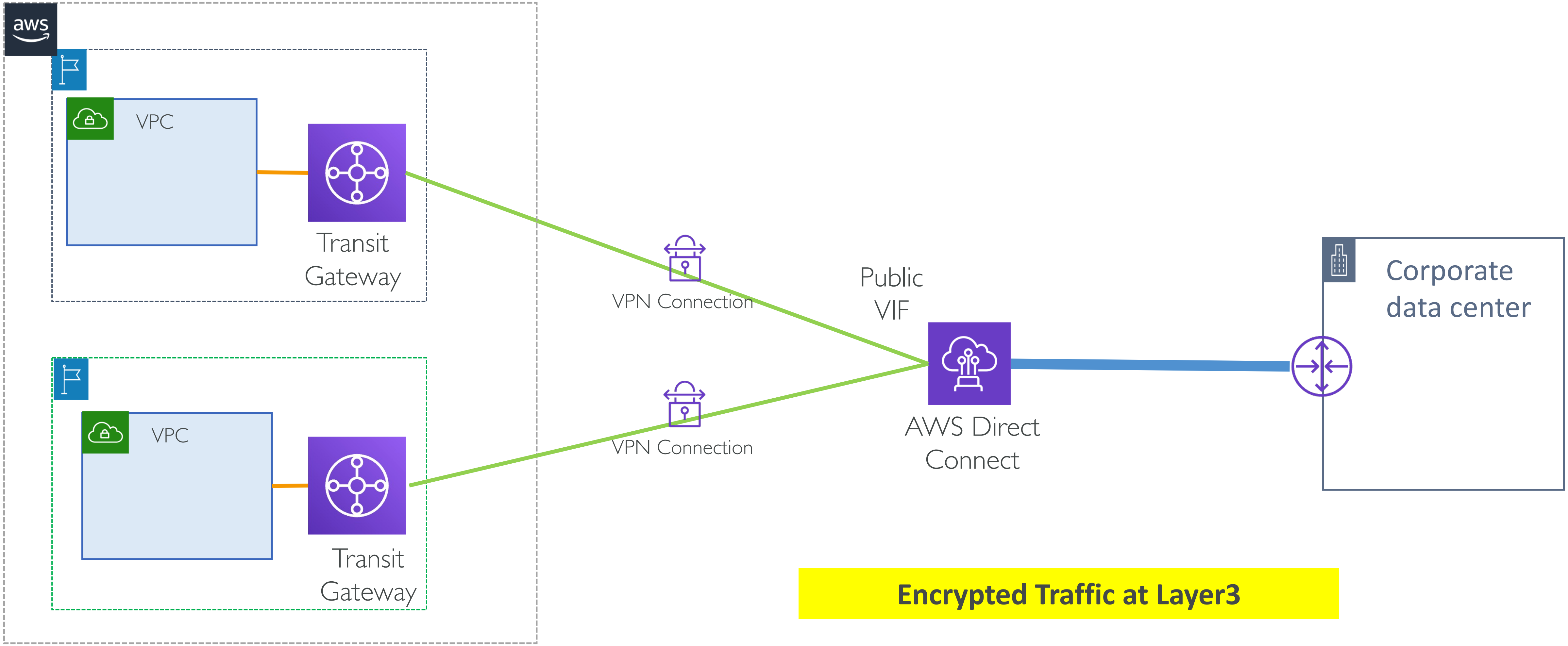
Direct Connect Gateway with Transit Gateway

..as of Feb'24



- Simple, scalable, Multi-region, Multi-account
- Single DX dedicated connection supports 4 Transit VIFs
- Single DX Gateway can connect to 6 Transit Gateways across AWS accounts or regions

IPSec VPN to Transit Gateway over Direct Connect

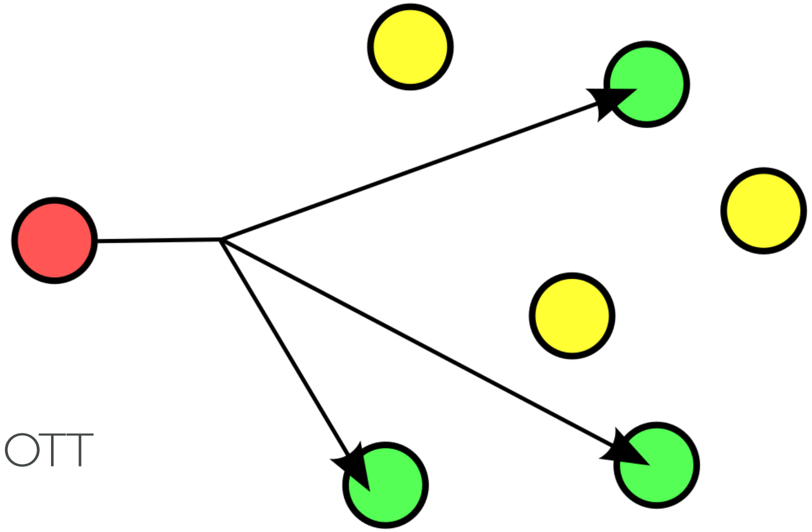


Encrypted Traffic at Layer3

Multicast with Transit Gateway

Multicast

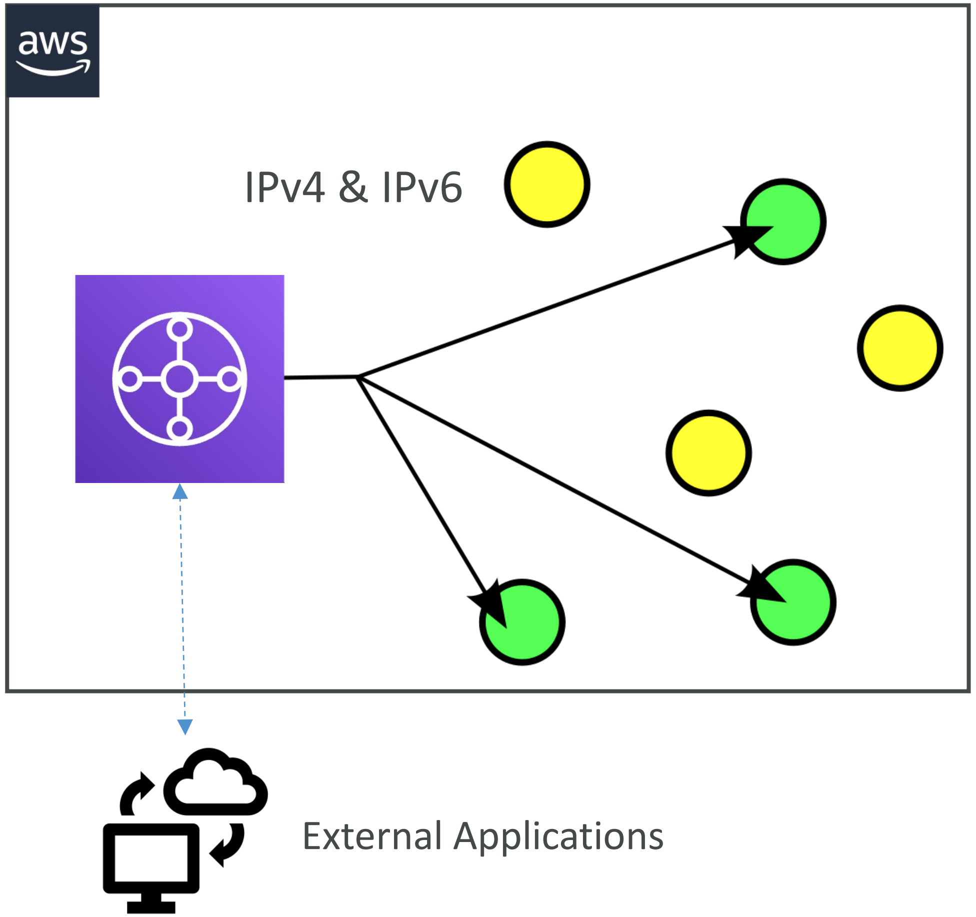
- Multicast is a communication protocol used for delivering a single stream of data to multiple receiving computers simultaneously.
- Single/multiple sources and destinations
- Destination is a multicast group address:
  - Class D - 224.0. 0.0 to 239.255. 255.255
- Connectionless UDP based transport
- One way communication
- Examples: Sending email to the email-list, Conference call / Group chat, OTT platforms / TV Media, Stock exchange transaction updates
- Multicast components
  - Multicast Domain
  - Multicast Group and member
  - Multicast source and receivers
  - Internet Group Management Protocol (IGMP)



https://en.wikipedia.org/wiki/Multicast

Multicast with Transit Gateway

- Enable Transit Gateway for Multicast services while creating the transit gateway
- Supports IPv4 & IPv6 IP addressing
- Supports hybrid integration with external applications
- Supports both static (API based) and Dynamic group membership through IGMP (supports IGMPv2)



Multicast considerations for TGW

- Transit Gateway supports routing multicast traffic between subnets of attached VPCs.
- A subnet can only be in one multicast domain.
- Hosts (ENIs) in the subnet can be part of one or more multicast groups within the Multicast domain.
- Multicast group membership is managed using the VPC Console or the AWS CLI, or IGMP.
- IGMPv2 support attribute determines how hosts join the multicast group. Members send JOIN or LEAVE IGMP message.
- Transit gateway issues an IGMPv2 QUERY message to all members every two minutes. Each member sends an IGMPv2 JOIN message in response, which is how the members renew their membership.
- Members that do not support IGMP must be added or removed from the group using the Amazon VPC console or the AWS CLI.
- Igmpv2Support attribute determines how group members join or leave a multicast group. When this attribute enabled, members can send JOIN or LEAVE messages.
- StaticSourcesSupport multicast domain attributes determine whether there are static multicast sources for the group.

Multicast considerations for TGW

- A non-Nitro instance cannot be a multicast sender. If you use a non-Nitro instance as a receiver, you must disable the Source/Destination check
- Multicast routing is not supported over AWS Direct Connect, Site-to-Site VPN, TGW peering attachments, or transit gateway Connect attachments.
- The source IP of these IGMP query packets is 0.0.0.0/32, destination IP is 224.0.0.1/32 and the protocol is IGMP(2).
- Security group configuration on the IGMP hosts (instances), and any ACLs configuration on the host subnets must allow these IGMP protocol messages.

NACL and Security Group for Multicast

NACL Inbound

Protocol	Source	Description
IGMP(2)	0.0.0.0/32	IGMP query sent to 224.0.0.1/32
UDP	Remote host sending multicast traffic	For inbound multicast traffic sent to multicast group IP

NACL Outbound

Protocol	Destination	Description
IGMP(2)	224.0.0.2/32	IGMP Leave
IGMP(2)	Multicast group IP address	IGMP Join
UDP	Multicast group IP address	For outbound multicast traffic

Security Group Inbound

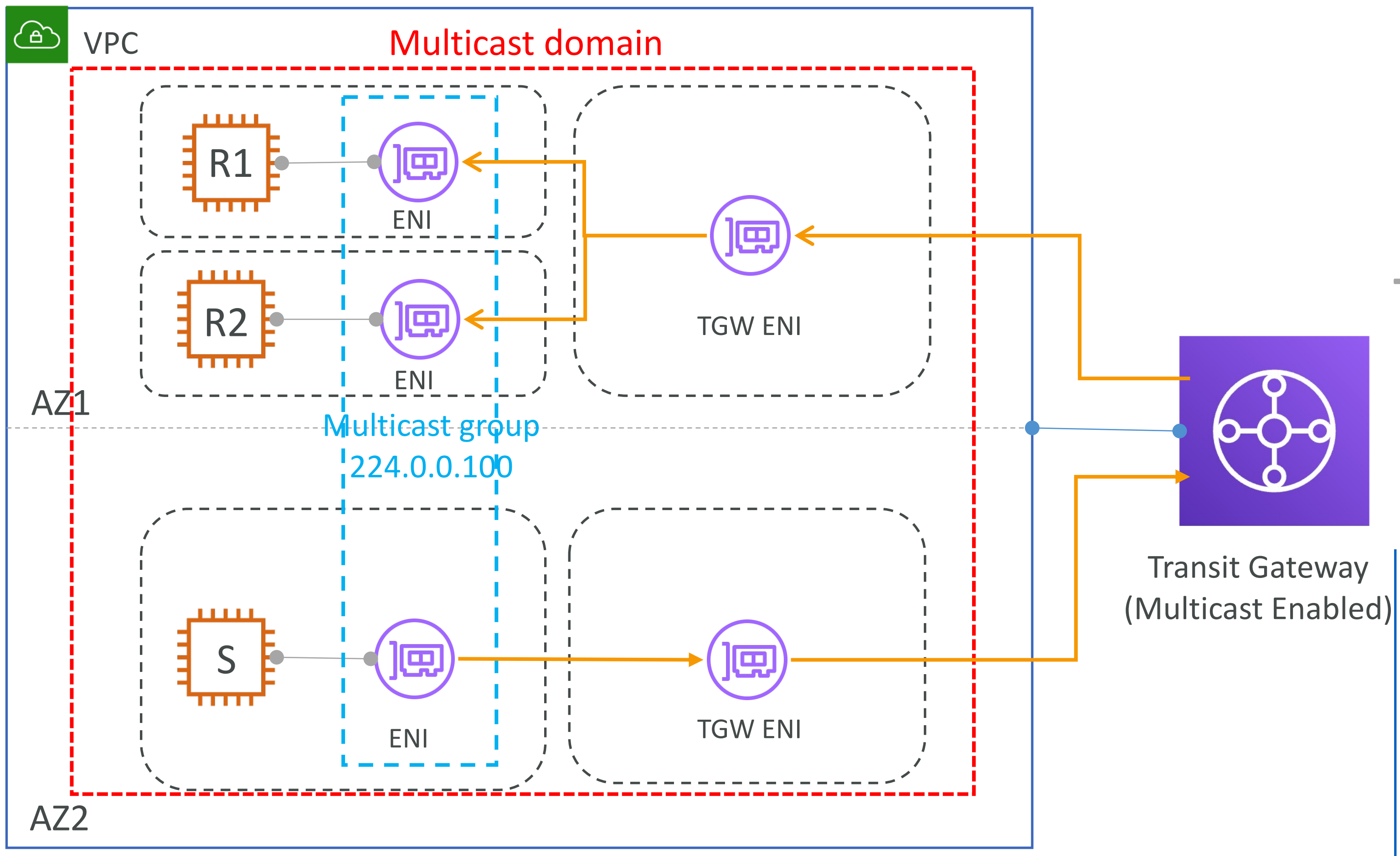
Protocol	Source	Description
IGMP(2)	0.0.0.0/32	IGMP query
UDP	Remote host sending multicast traffic	For inbound multicast traffic

Security Group Outbound

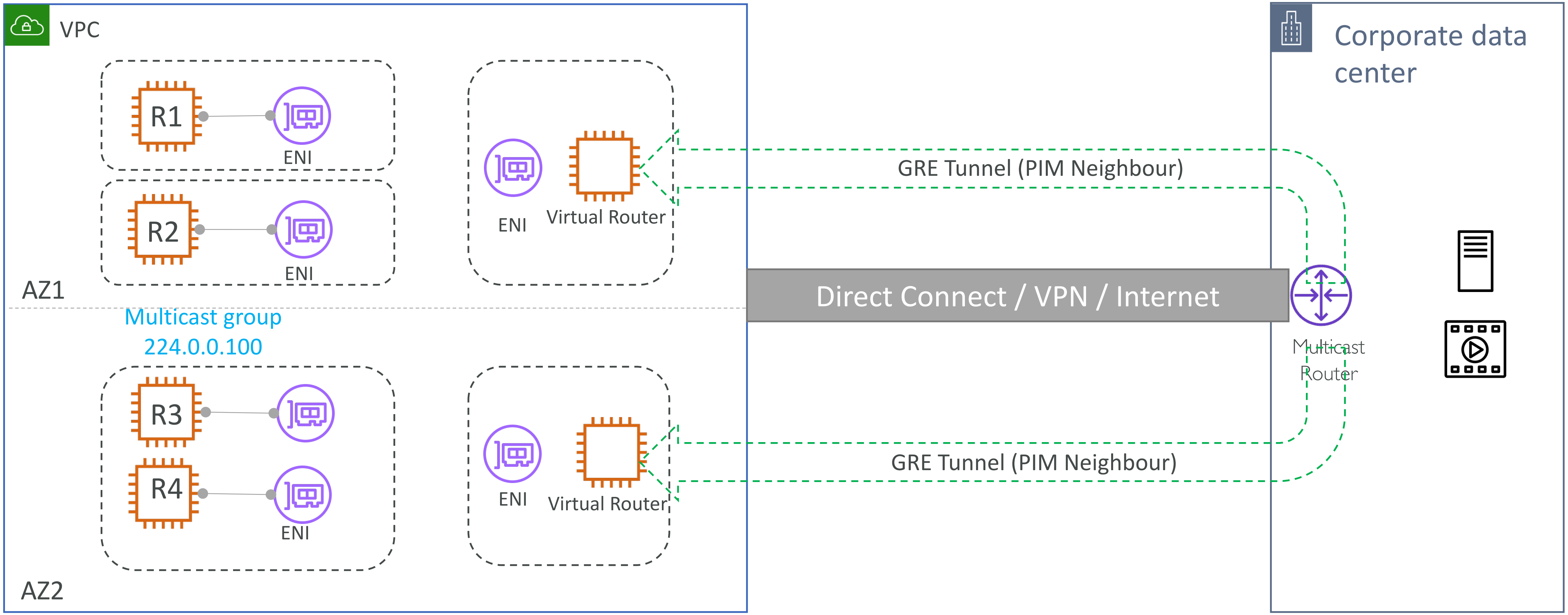
Protocol	Destination	Description
IGMP(2)	224.0.0.2/32	IGMP Leave
IGMP(2)	Multicast group IP address	IGMP Join
UDP	Multicast group IP address	For outbound multicast traffic

Multicast traffic in a VPC

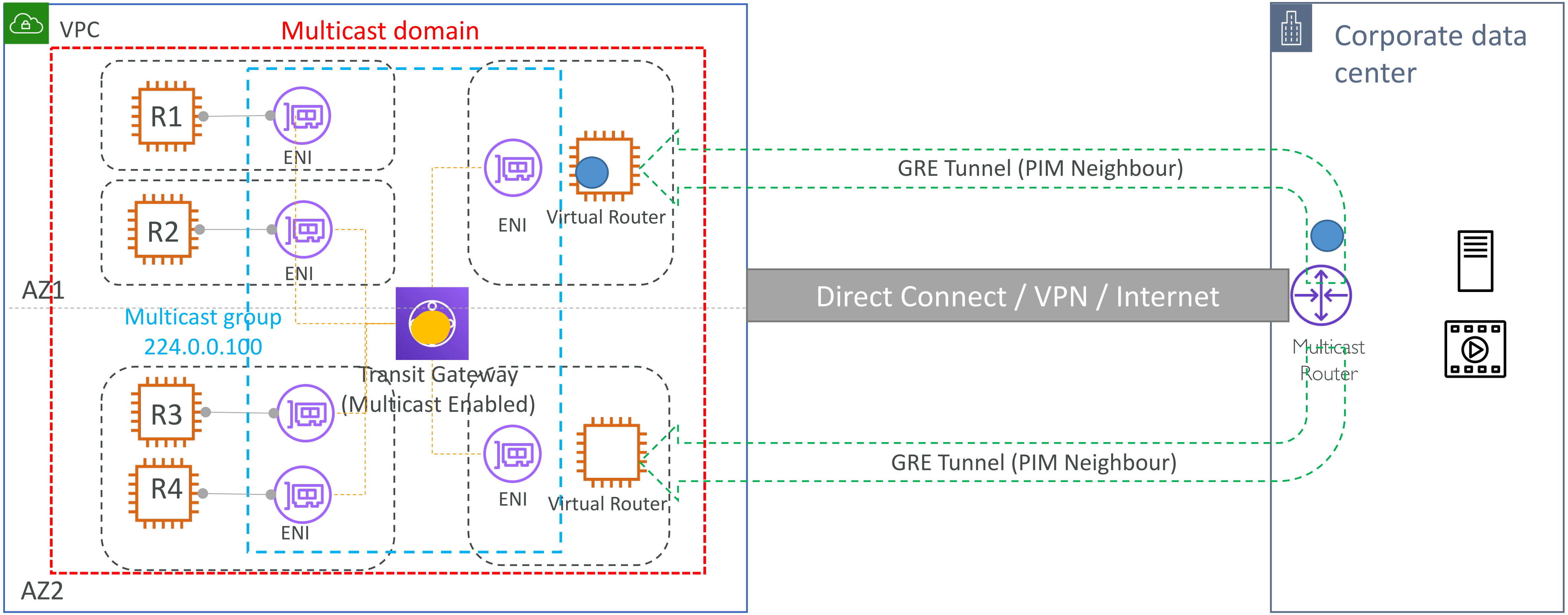
- Create multicast domain and add participating subnets
- Create multicast group and associate group membership IP (e.g. 224.0.0.100)
- Configure the group membership statically using CLI/SDK or dynamically using IGMPv2
- Send traffic from source to multicast group IP
- All members in the group receive the multicast traffic
- Similar network flow works in case of multi-vpc and multi-account architecture



Integrating external multicast services

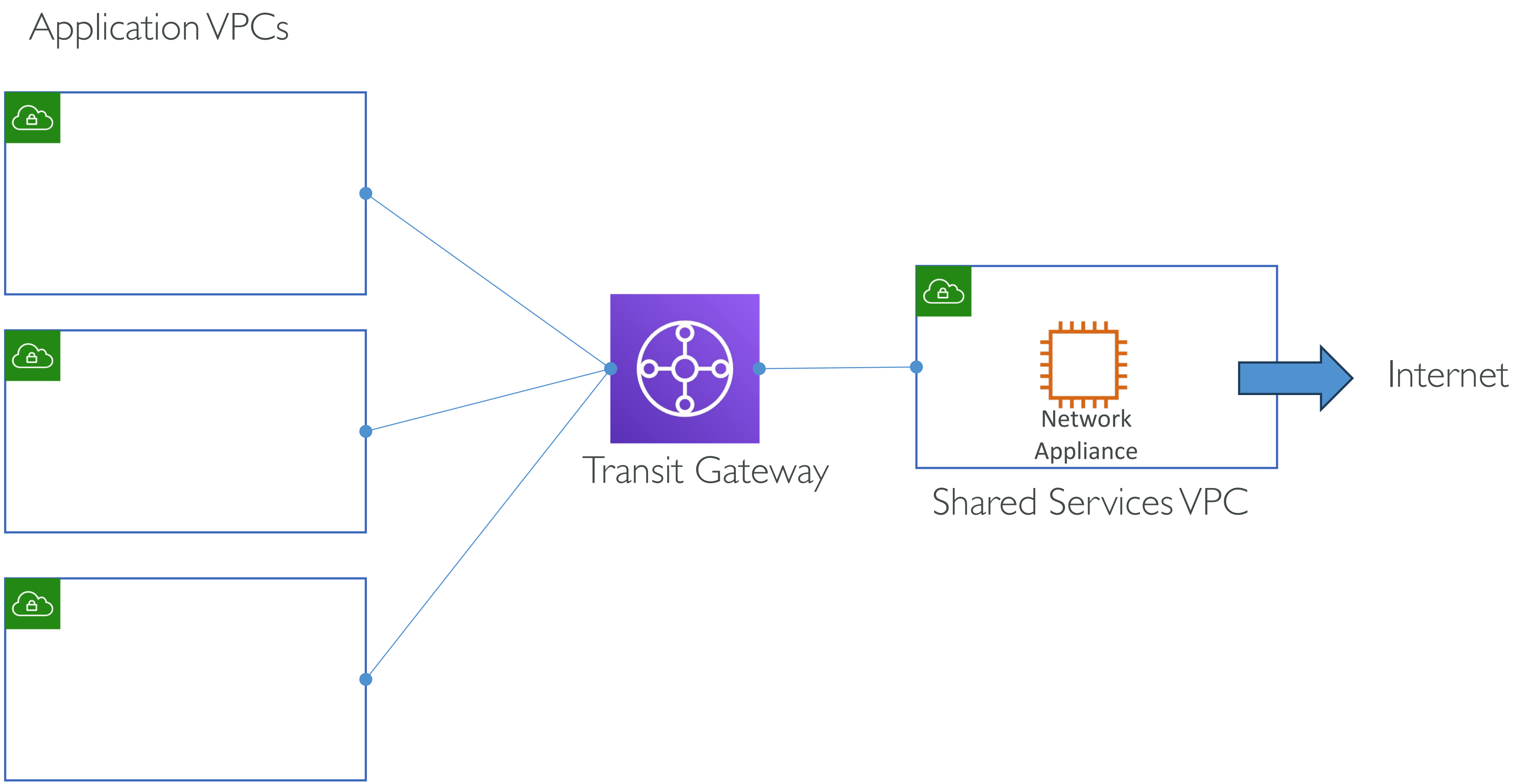


Integrating external multicast services

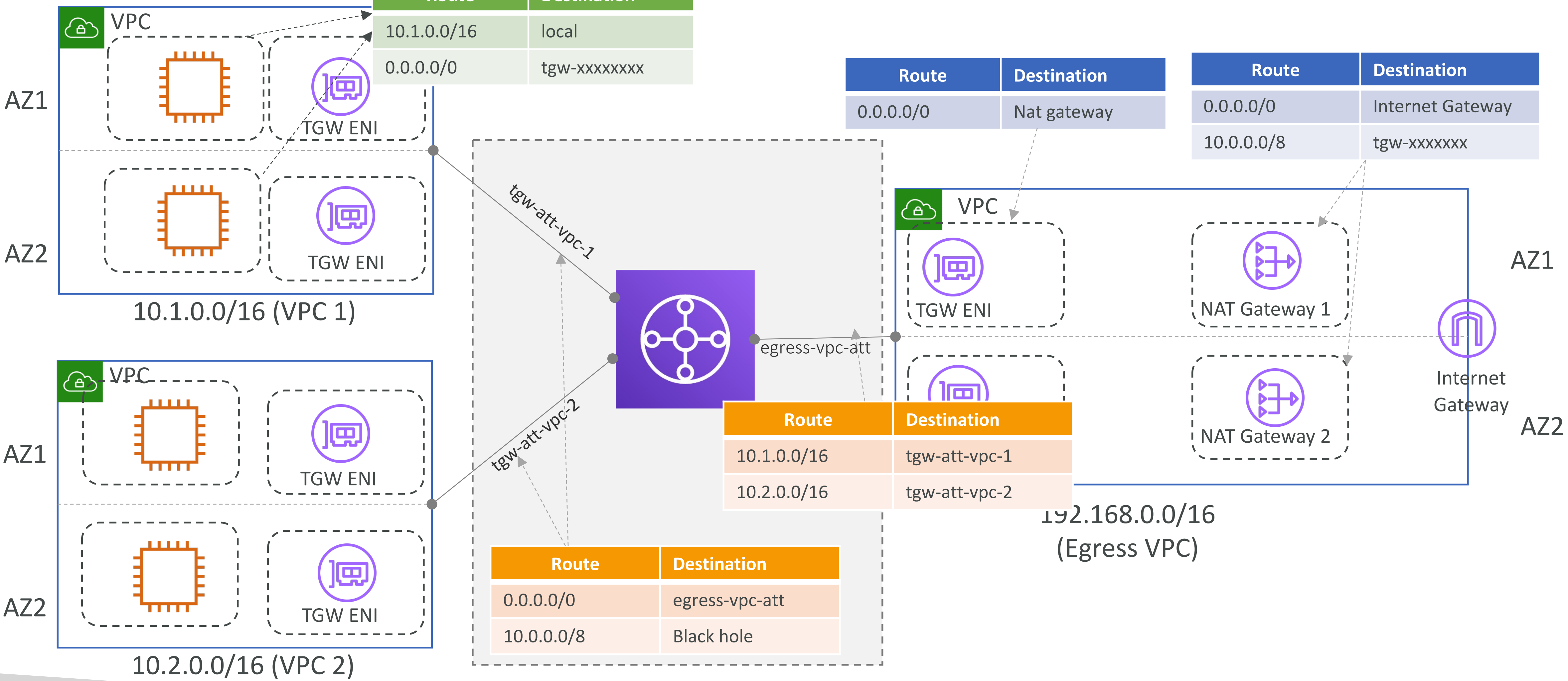


Transit Gateway - Centralized egress to internet

Centralized routing using Transit Gateway



Centralized egress to internet with NAT gateway



Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

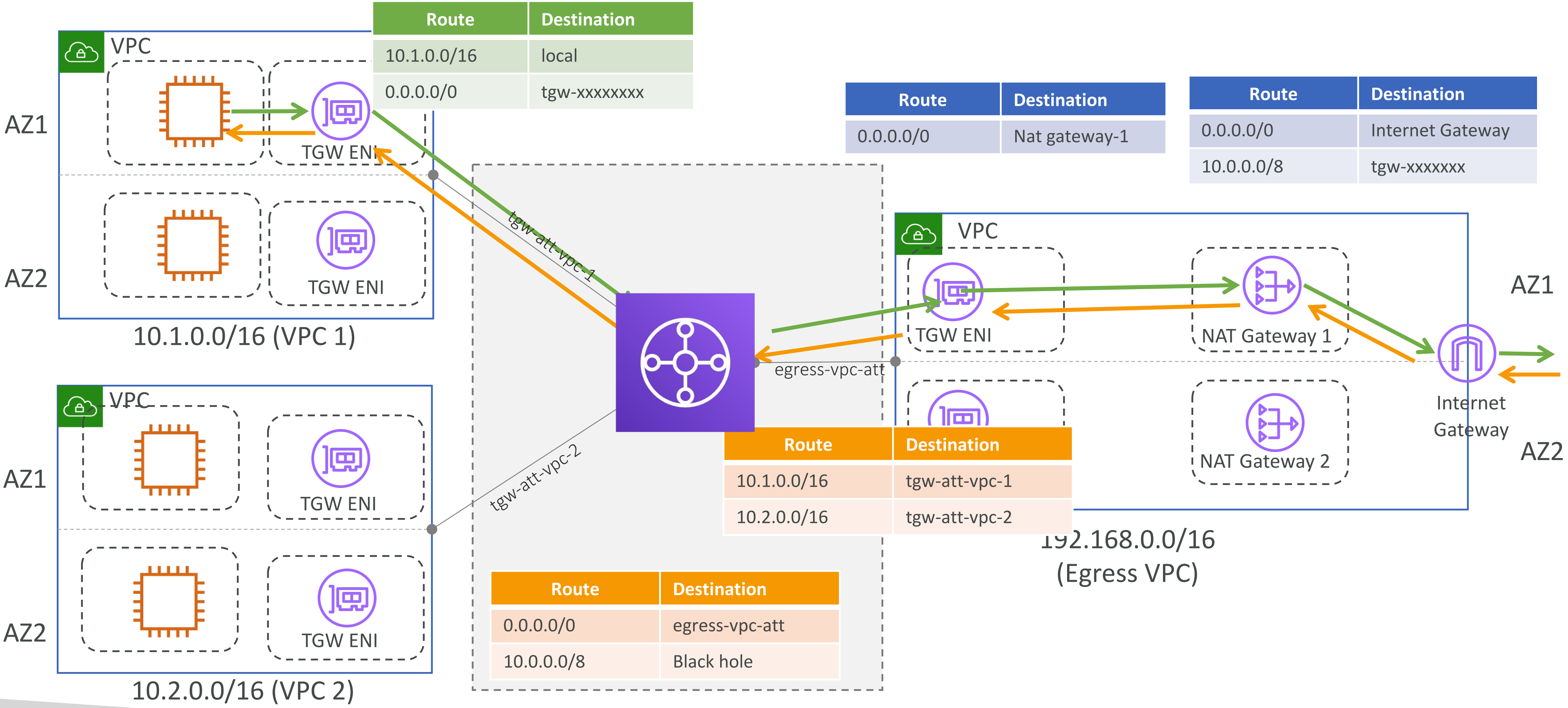
Route	Destination
0.0.0.0/0	Nat gateway

Route	Destination
0.0.0.0/0	Internet Gateway
10.0.0.0/8	tgw-xxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Route	Destination
0.0.0.0/0	egress-vpc-att
10.0.0.0/8	Black hole

Centralized egress to internet with NAT gateway



Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
0.0.0.0/0	Nat gateway-1

Route	Destination
0.0.0.0/0	Internet Gateway
10.0.0.0/8	tgw-xxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Route	Destination
0.0.0.0/0	egress-vpc-att
10.0.0.0/8	Black hole

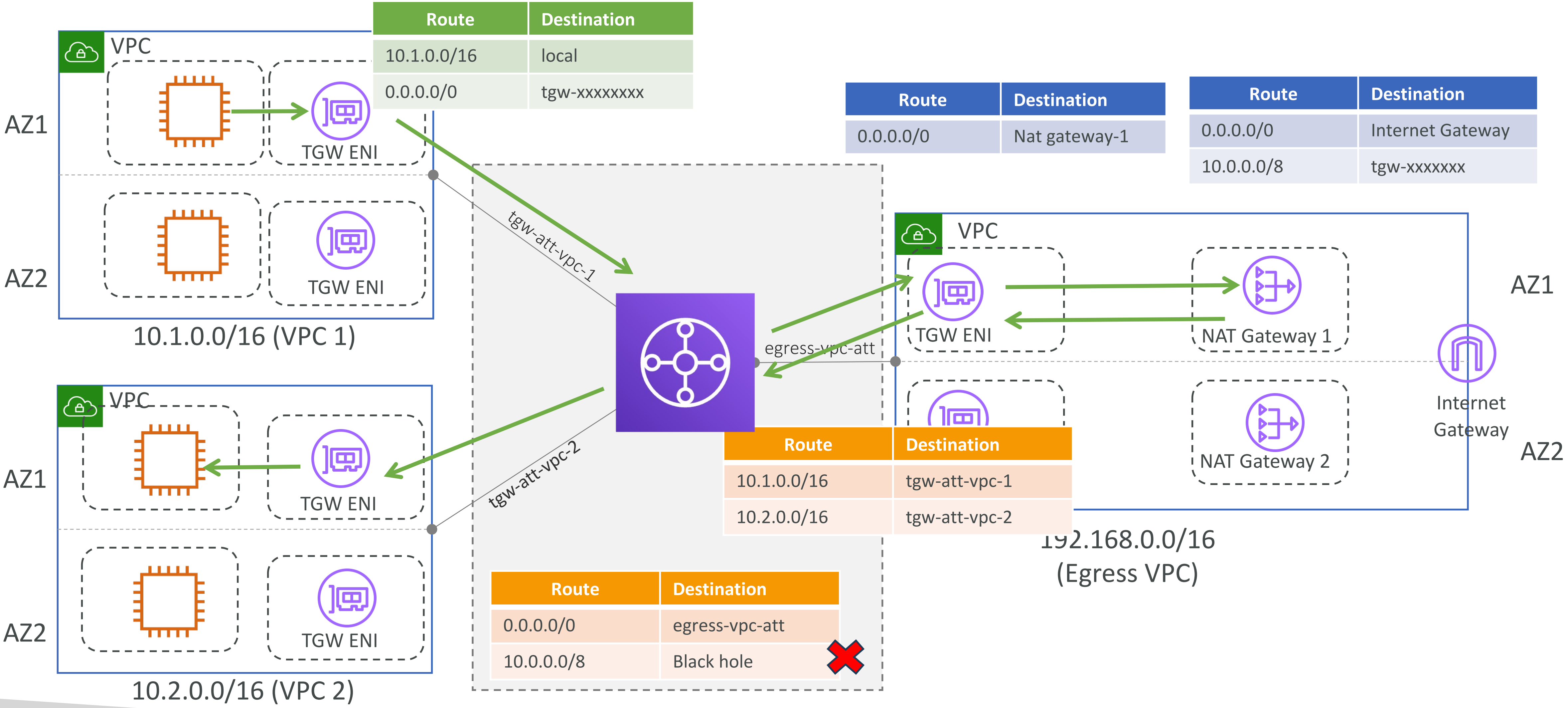
Centralized egress to internet with NAT gateway

..as of Feb'24

Important to know:

- Use NAT gateway's in each AZ for high availability and for saving inter-AZ data transfer cost.
- If one Availability Zone entirely fails, all traffic will flow via the Transit Gateway and NAT gateway endpoints in the other Availability Zone.
- A NAT gateway can support up to 55,000 simultaneous connections to each unique destination.
- NAT gateway can scale from 5 Gbps to 100 Gbps.
- Blackhole routes in the Transit Gateway route tables to restrict inter-VPC traffic

Centralized egress to internet with NAT gateway



Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

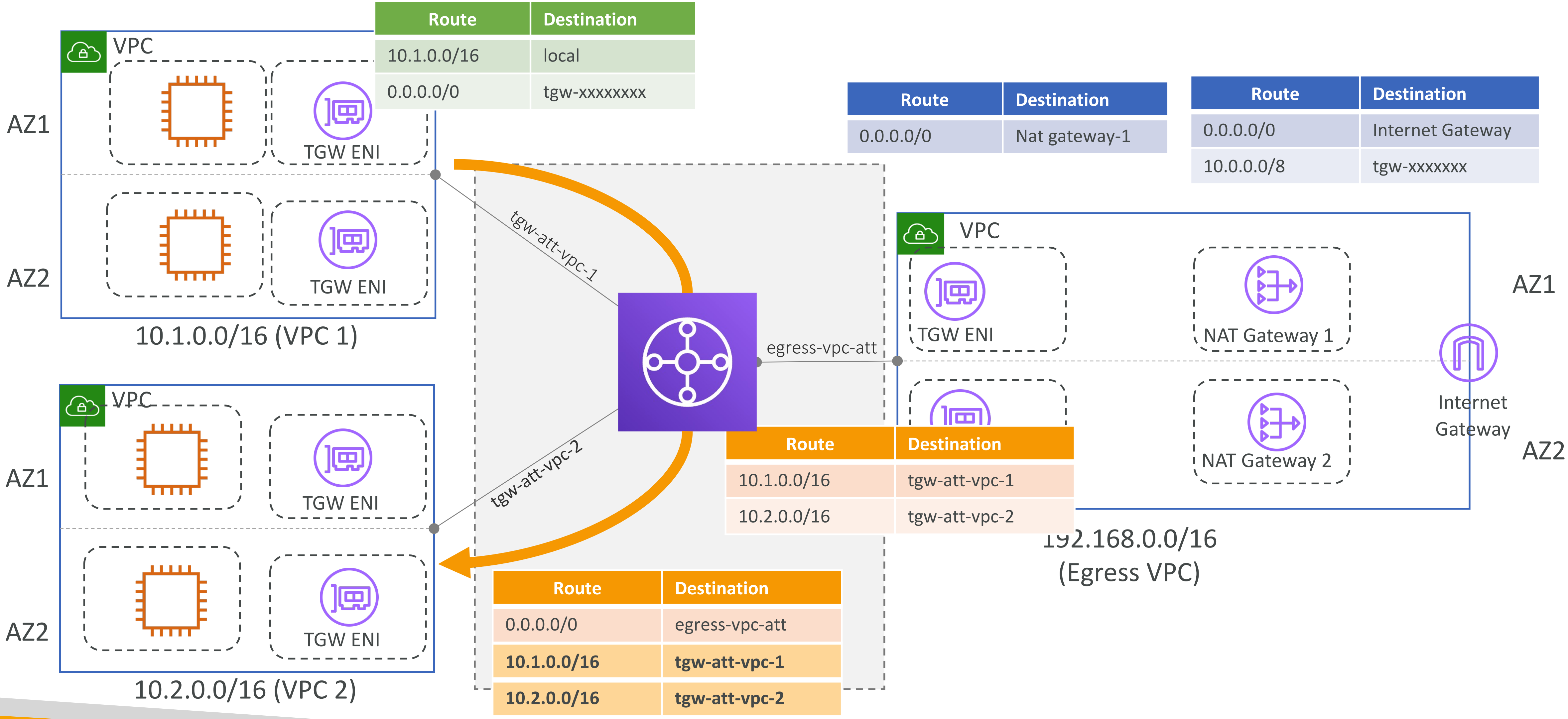
Route	Destination
0.0.0.0/0	Nat gateway-1

Route	Destination
0.0.0.0/0	Internet Gateway
10.0.0.0/8	tgw-xxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Route	Destination
0.0.0.0/0	egress-vpc-att
10.0.0.0/8	Black hole

Centralized egress to internet with NAT gateway



Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
0.0.0.0/0	Nat gateway-1

Route	Destination
0.0.0.0/0	Internet Gateway
10.0.0.0/8	tgw-xxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Route	Destination
0.0.0.0/0	egress-vpc-att
10.1.0.0/16	**tgw-att-vpc-1**
10.2.0.0/16	**tgw-att-vpc-2**

Centralized egress to internet with NAT gateway

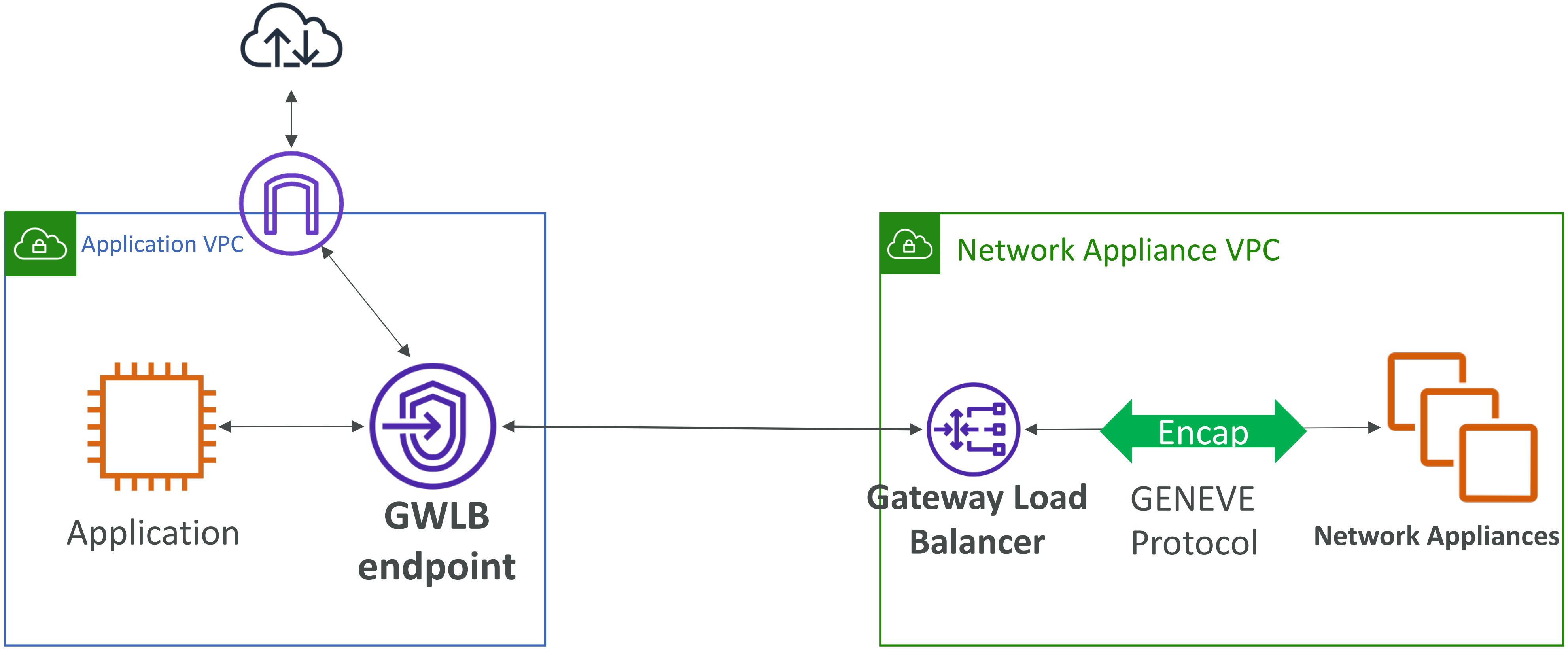
..as of Feb'24

Important to know:

- Use NAT gateway's in each AZ for high availability and for saving inter-AZ data transfer cost.
- If one Availability Zone entirely fails, all traffic will flow via the Transit Gateway and NAT gateway endpoints in the other Availability Zone.
- A NAT gateway can support up to 55,000 simultaneous connections to each unique destination.
- NAT gateway can scale from 5 Gbps to 100 Gbps.
- Blackhole routes in the Transit Gateway route tables to restrict inter-VPC traffic
- This architecture doesn't necessarily save the cost because instead of per VPC NAT Gateway charge (e.g. ~$0.045/hr + ~$0.045/GB) it adds Transit Gateway attachment & data processing charge (~$0.05/hr per VPC attachment + ~$0.02/GB)

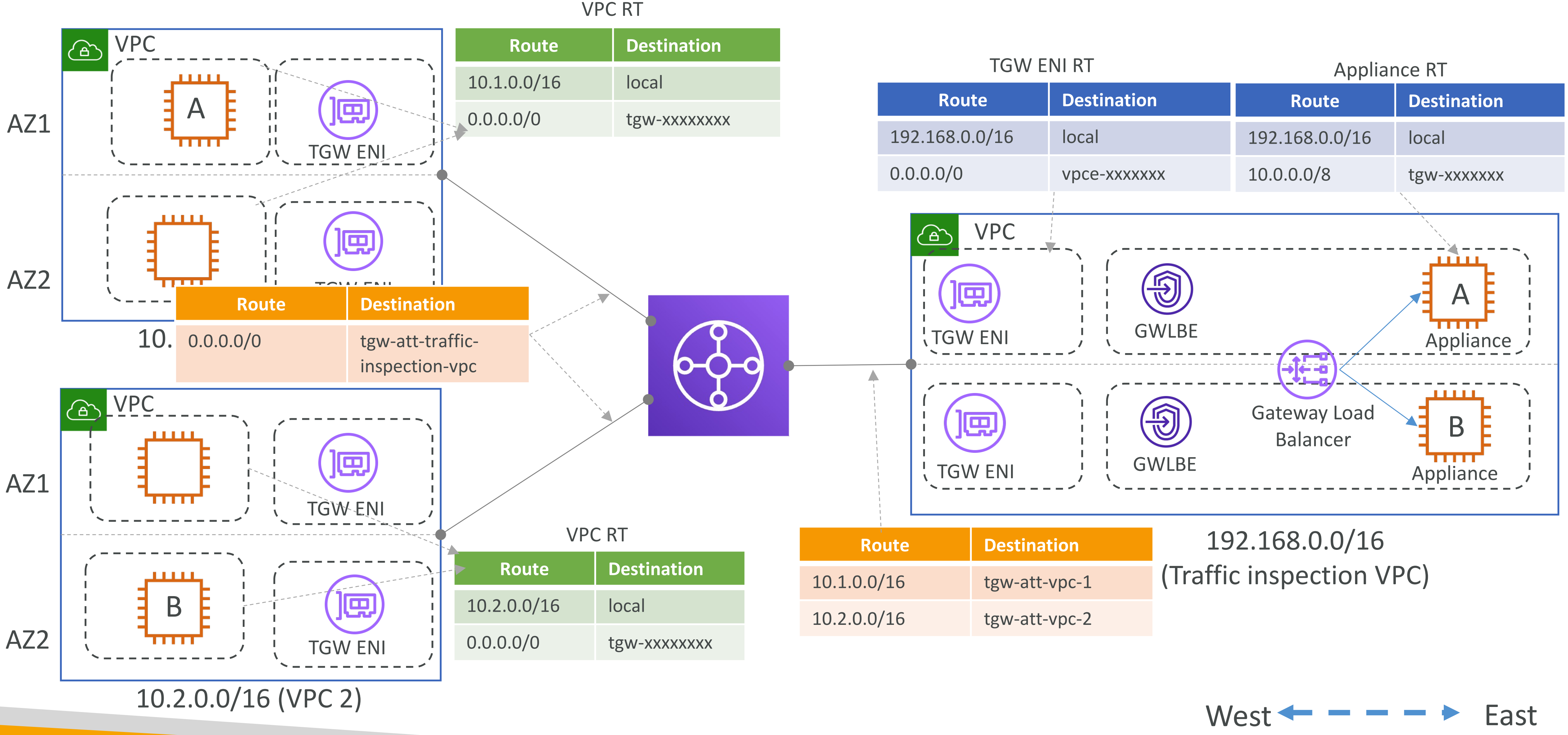
Transit Gateway – Centralized traffic inspection with Gateway Load Balancer & Network Appliances

Gateway Load Balancer



- Simple
- Low Latency
- Scalable
- Highly Available

Centralized inspection with AWS GWLB – Inter VPC traffic



VPC RT

Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
0.0.0.0/0	tgw-att-traffic-inspection-vpc

VPC RT

Route	Destination
10.2.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

TGW ENI RT

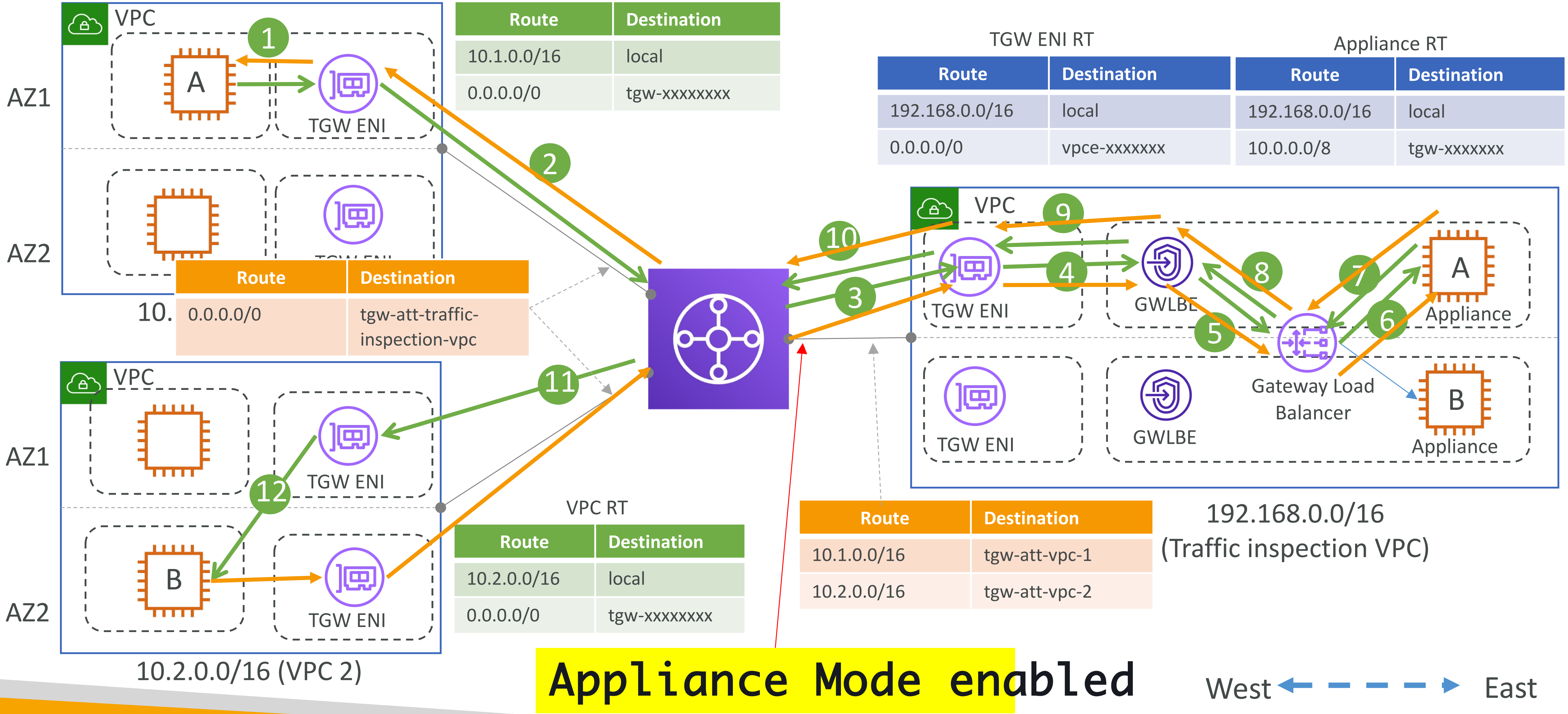
Route	Destination
192.168.0.0/16	local
0.0.0.0/0	vpce-xxxxxxx

Appliance RT

Route	Destination
192.168.0.0/16	local
10.0.0.0/8	tgw-xxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Centralized inspection with AWS GWLB – Inter VPC traffic



VPC RT

Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

TGW ENI RT

Route	Destination
192.168.0.0/16	local
0.0.0.0/0	vpce-xxxxxxx

Appliance RT

Route	Destination
192.168.0.0/16	local
10.0.0.0/8	tgw-xxxxxxx

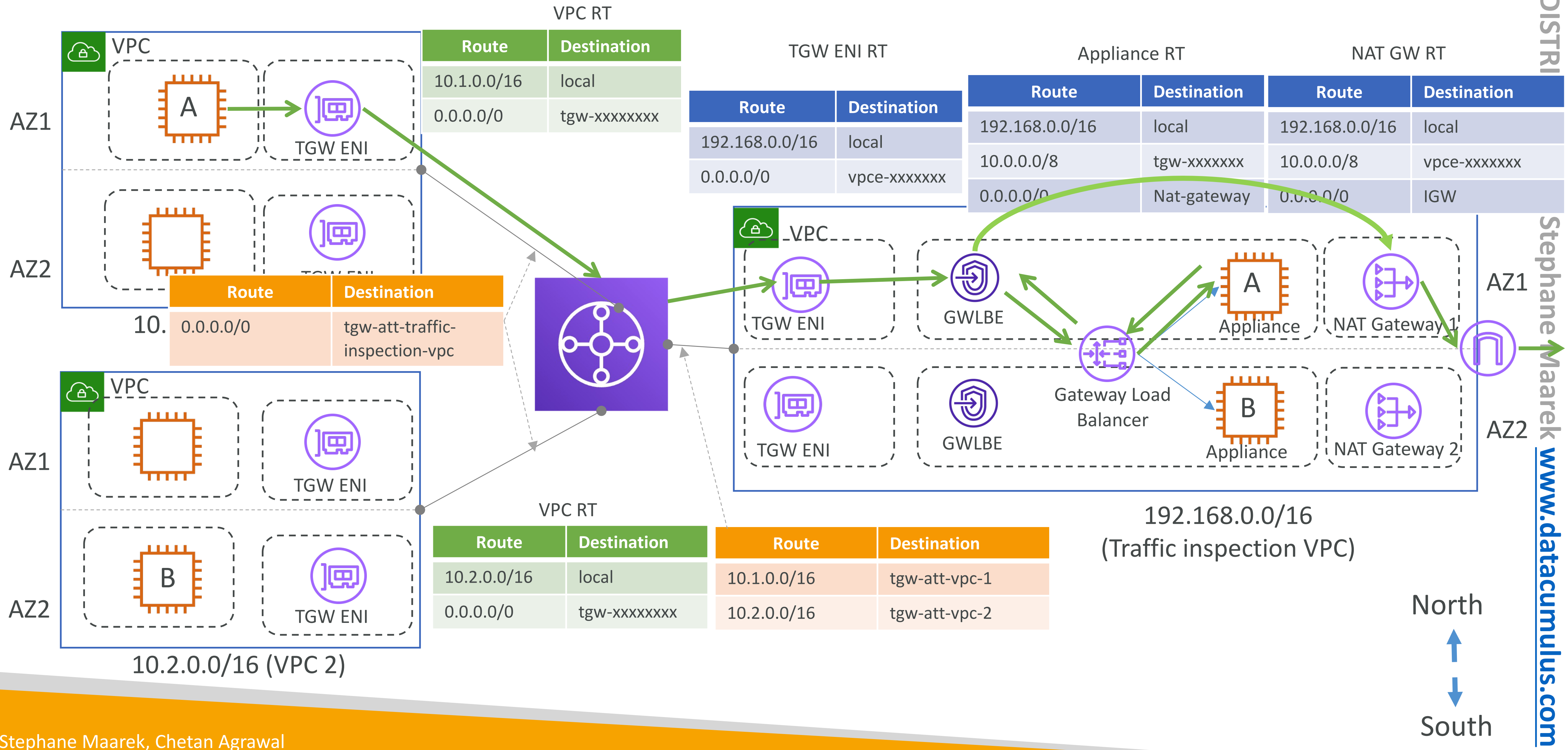
Route	Destination
0.0.0.0/0	tgw-att-traffic-inspection-vpc

VPC RT

Route	Destination
10.2.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Centralized inspection with AWS GWLB – internet traffic



VPC RT

Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
0.0.0.0/0	tgw-att-traffic-inspection-vpc

VPC RT

Route	Destination
10.2.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

TGW ENI RT

Route	Destination
192.168.0.0/16	local
0.0.0.0/0	vpce-xxxxxxx

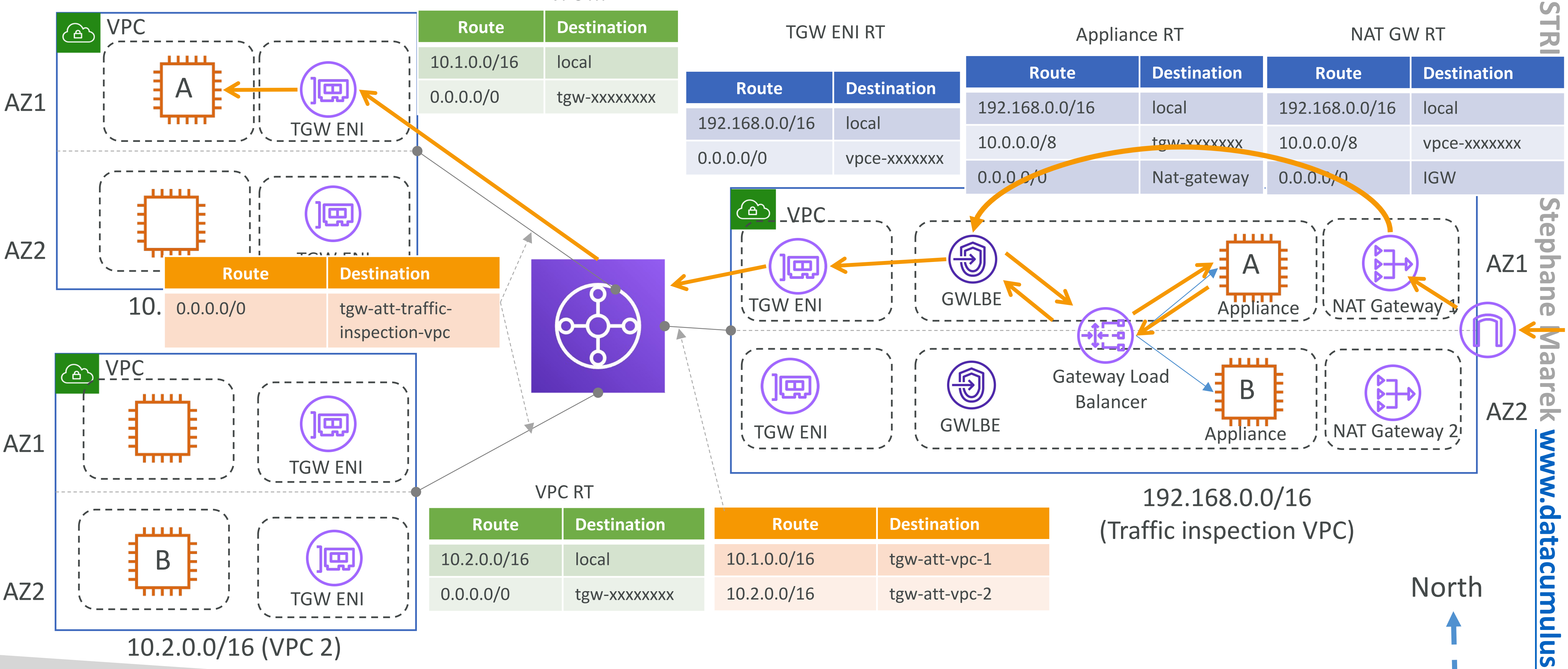
Appliance RT

Route	Destination
192.168.0.0/16	local
10.0.0.0/8	tgw-xxxxxxx
0.0.0.0/0	Nat-gateway

NAT GW RT

Route	Destination
192.168.0.0/16	local
10.0.0.0/8	vpce-xxxxxxx
0.0.0.0/0	IGW

Centralized inspection with AWS GWLB – internet traffic



VPC RT

Route	Destination
10.1.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

TGW ENI RT

Route	Destination
192.168.0.0/16	local
0.0.0.0/0	vpce-xxxxxxx

Appliance RT

Route	Destination
192.168.0.0/16	local
10.0.0.0/8	tgw-xxxxxxx
0.0.0.0/0	Nat-gateway

NAT GW RT

Route	Destination
192.168.0.0/16	local
10.0.0.0/8	vpce-xxxxxxx
0.0.0.0/0	IGW

Route	Destination
0.0.0.0/0	tgw-att-traffic-inspection-vpc

VPC RT

Route	Destination
10.2.0.0/16	local
0.0.0.0/0	tgw-xxxxxxxx

Route	Destination
10.1.0.0/16	tgw-att-vpc-1
10.2.0.0/16	tgw-att-vpc-2

Centralized inspection with AWS GWLB

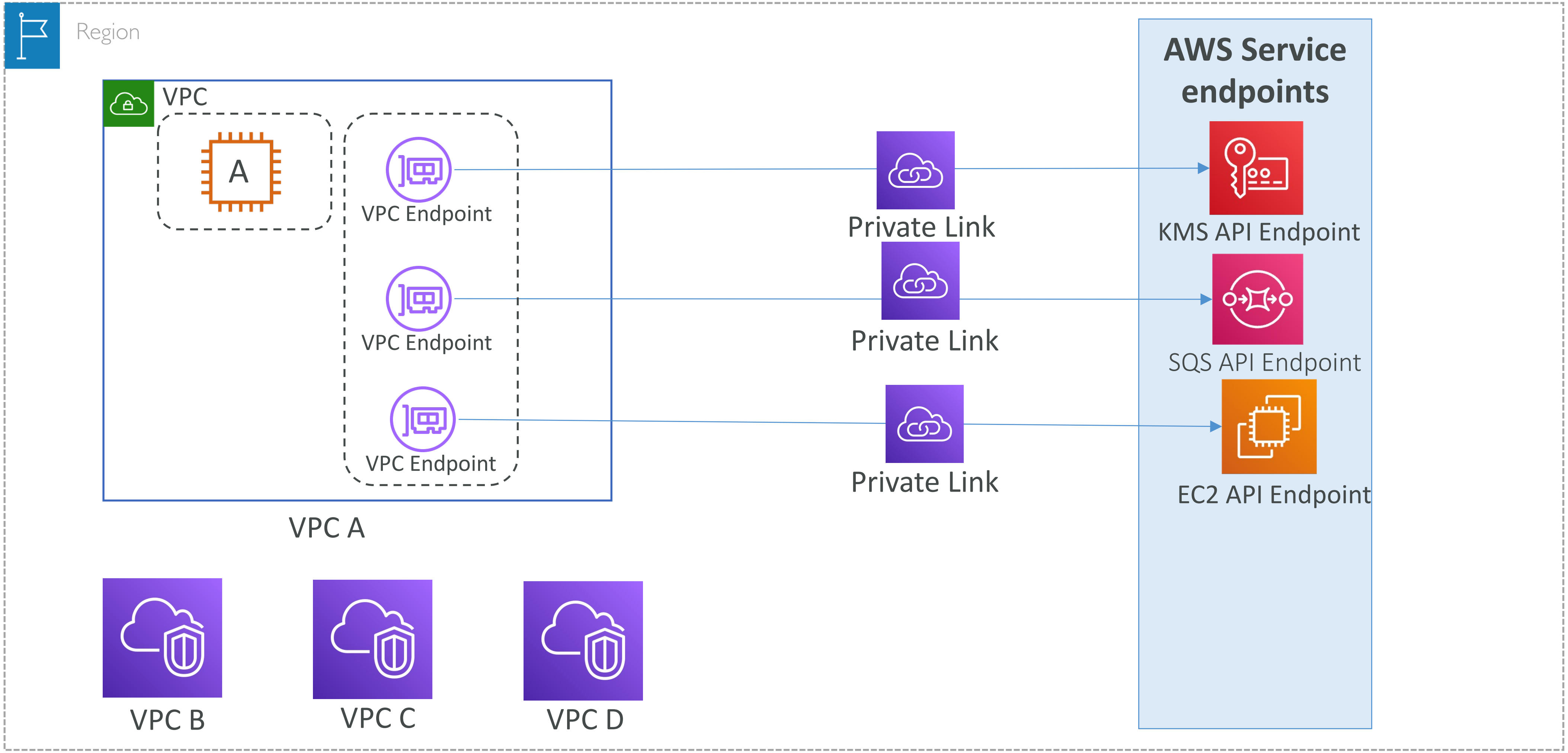
Important to know:

- Using AWS PrivateLink, GWLB Endpoint routes traffic to GWLB. Traffic is routed securely over Amazon network without any additional configuration.
- GWLB encapsulates the original IP traffic with a GENEVE header and forwards it to the network appliance over UDP port 6081.
- GWLB uses 5-tuples or 3-tuples of an IP packet to pick an appliance for the life of that flow. This creates session stickiness to an appliance for the life of a flow required for stateful appliances like firewalls.
- This combined with Transit Gateway Appliance mode, provides session stickiness irrespective of source and destination AZ.
- Refer to this blog for further details: https://aws.amazon.com/blogs/networking-and-content-delivery/centralized-inspection-architecture-with-aws-gateway-load-balancer-and-aws-transit-gateway/

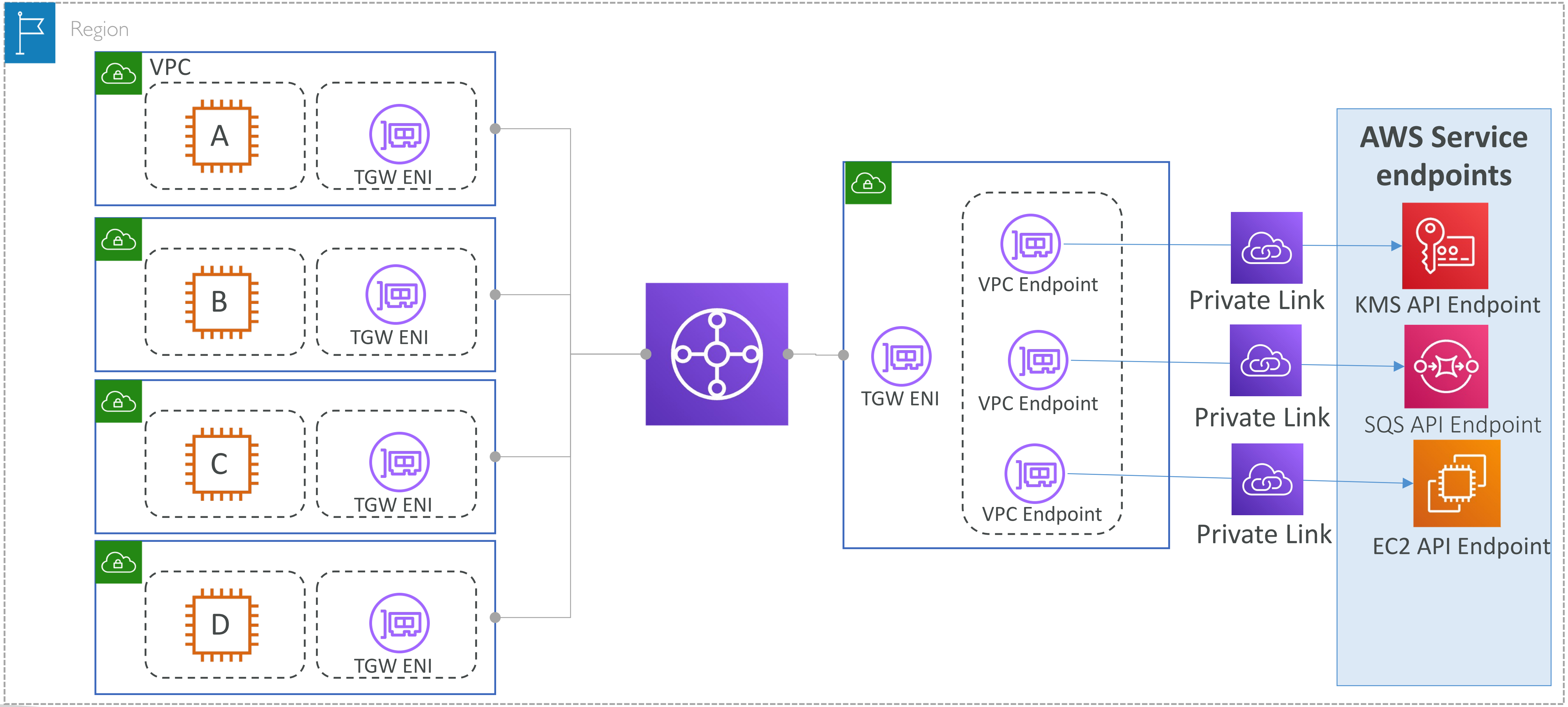
Transit Gateway – Centralized VPC interface endpoints

Transit Gateway – Centralized VPC interface endpoints

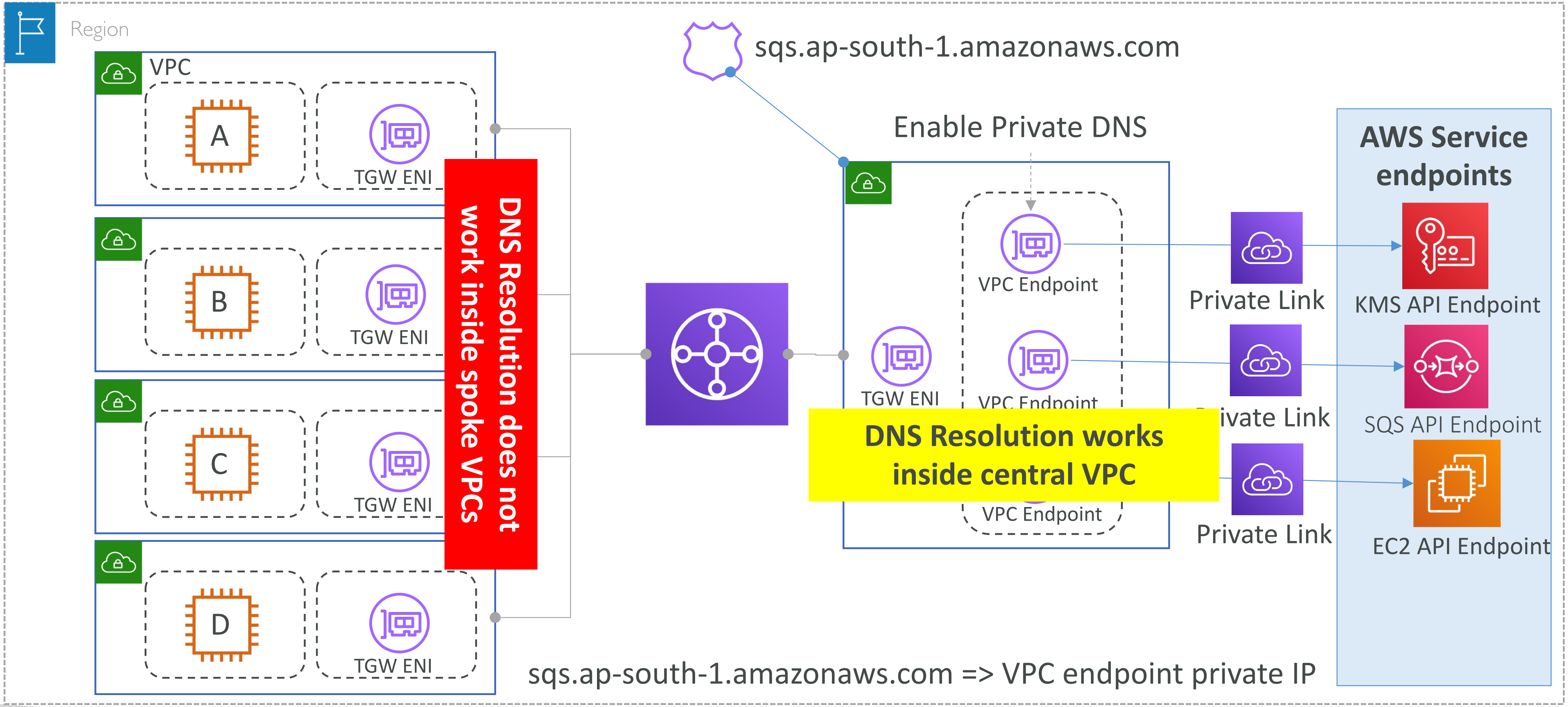
Interface endpoints



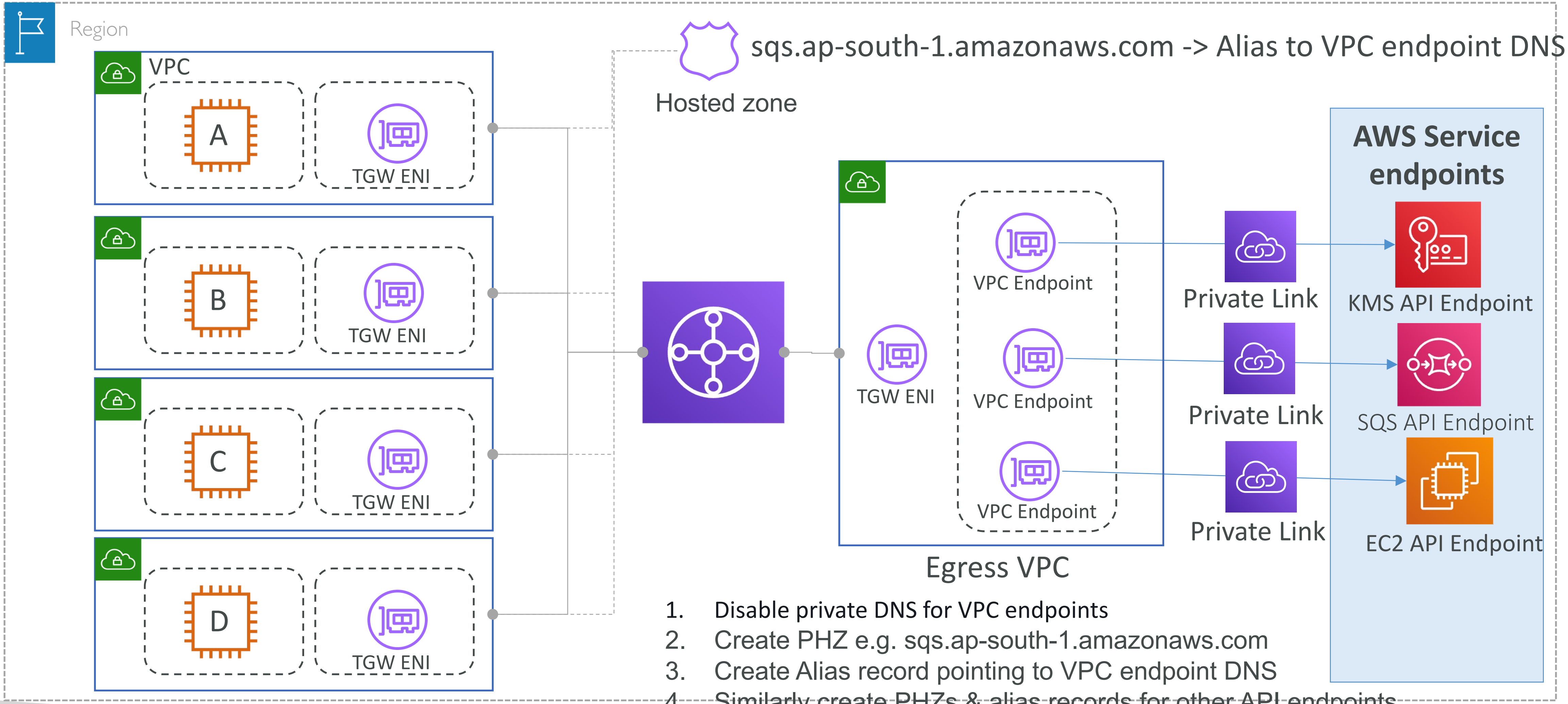
Centralized VPC interface endpoints



What about AWS service DNS resolution?



DNS resolution solution



1. Disable private DNS for VPC endpoints
2. Create PHZ e.g. sqs.ap-south-1.amazonaws.com
3. Create Alias record pointing to VPC endpoint DNS
4. Similarly create PHZs & alias records for other API endpoints
5. Associate PHZ with all the spoke VPCs

Centralized VPC interface endpoints

Important to know:

- VPC interface endpoints provides the regional and AZ level DNS endpoints
- The regional DNS endpoint will return the IP addresses for all the AZ endpoints
- In order to save the inter-AZ data transfer cost from Spoke VPC to Hub VPC, you can use the AZ specific DNS endpoints. Selection has to be done by the client.

```
[cloudshell-user@ip-10-0-112-90 ~]$ nslookup vpce-0b098a7d7394c553e-vzodek17.ec2.ap-south-1.vpce.amazonaws.com
Server:         127.0.0.1
Address:        127.0.0.1#53

Non-authoritative answer:
Name:   vpce-0b098a7d7394c553e-vzodek17.ec2.ap-south-1.vpce.amazonaws.com
Address: 10.10.1.230
Name:   vpce-0b098a7d7394c553e-vzodek17.ec2.ap-south-1.vpce.amazonaws.com
Address: 10.10.0.137
```

Centralized VPC interface endpoints

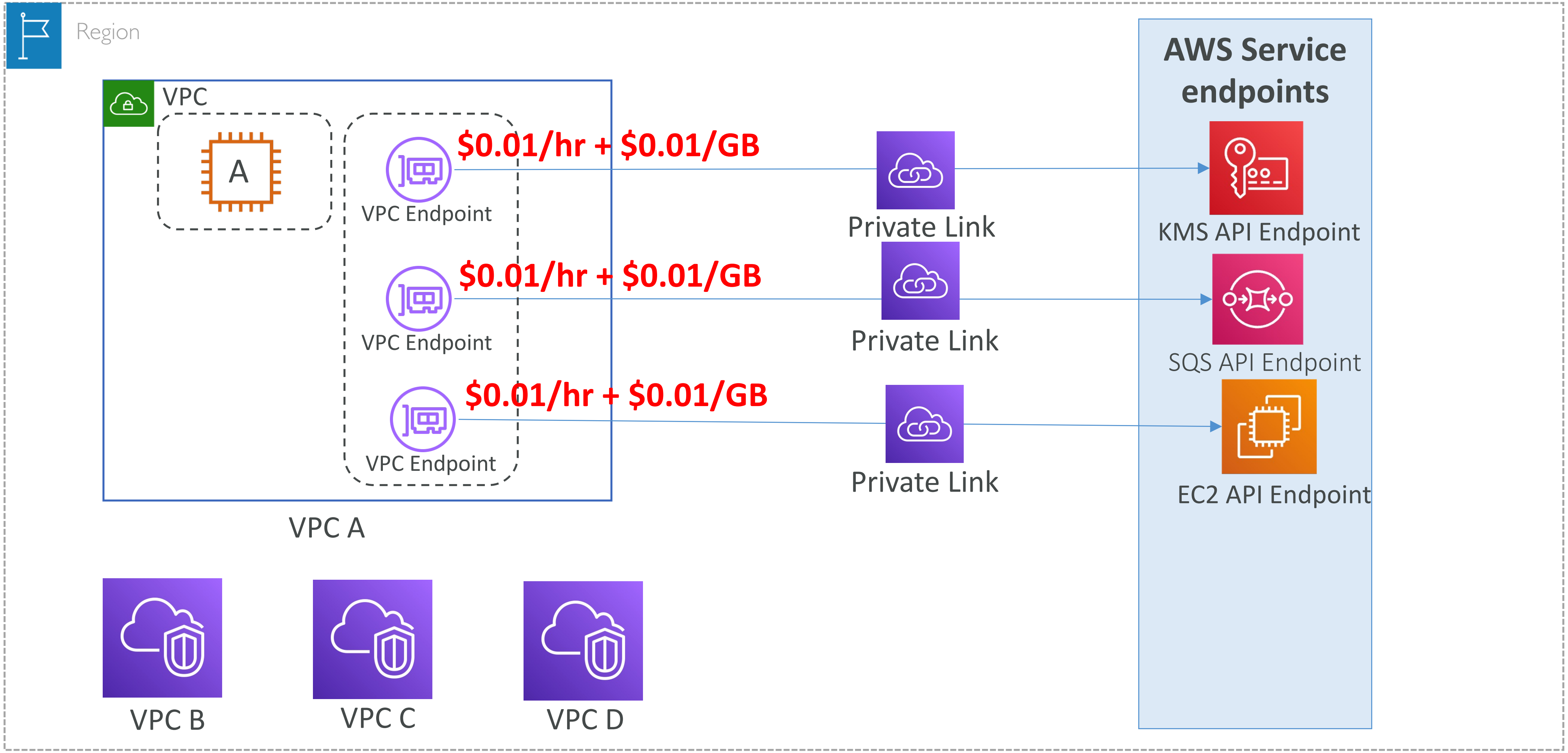
Important to know:

- VPC interface endpoints provides the regional and AZ level DNS endpoints
- The regional DNS endpoint will return the IP addresses for all the AZ endpoints
- In order to save the inter-AZ data transfer cost from Spoke VPC to Hub VPC, you can use the AZ specific DNS endpoints. Selection has to be done by the client.

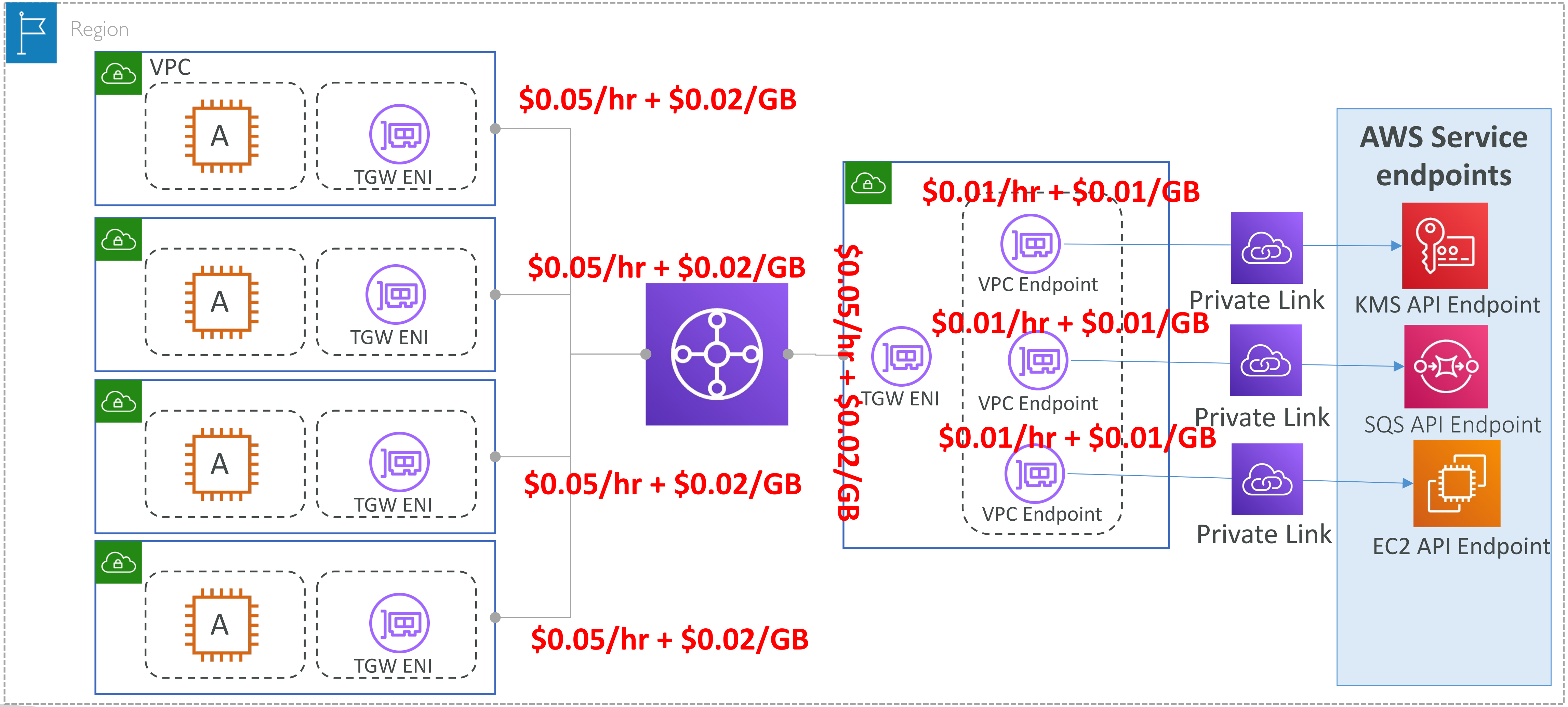
```
[cloudshell-user@ip-10-0-112-90 ~]$ nslookup vpce-0b098a7d7394c553e-vzodek17-ap-south-1a.ec2.ap-south-1.vpce.amazonaws.com
Server:         127.0.0.1
Address:        127.0.0.1#53

Non-authoritative answer:
Name:   vpce-0b098a7d7394c553e-vzodek17-ap-south-1a.ec2.ap-south-1.vpce.amazonaws.com
Address: 10.10.0.137
```

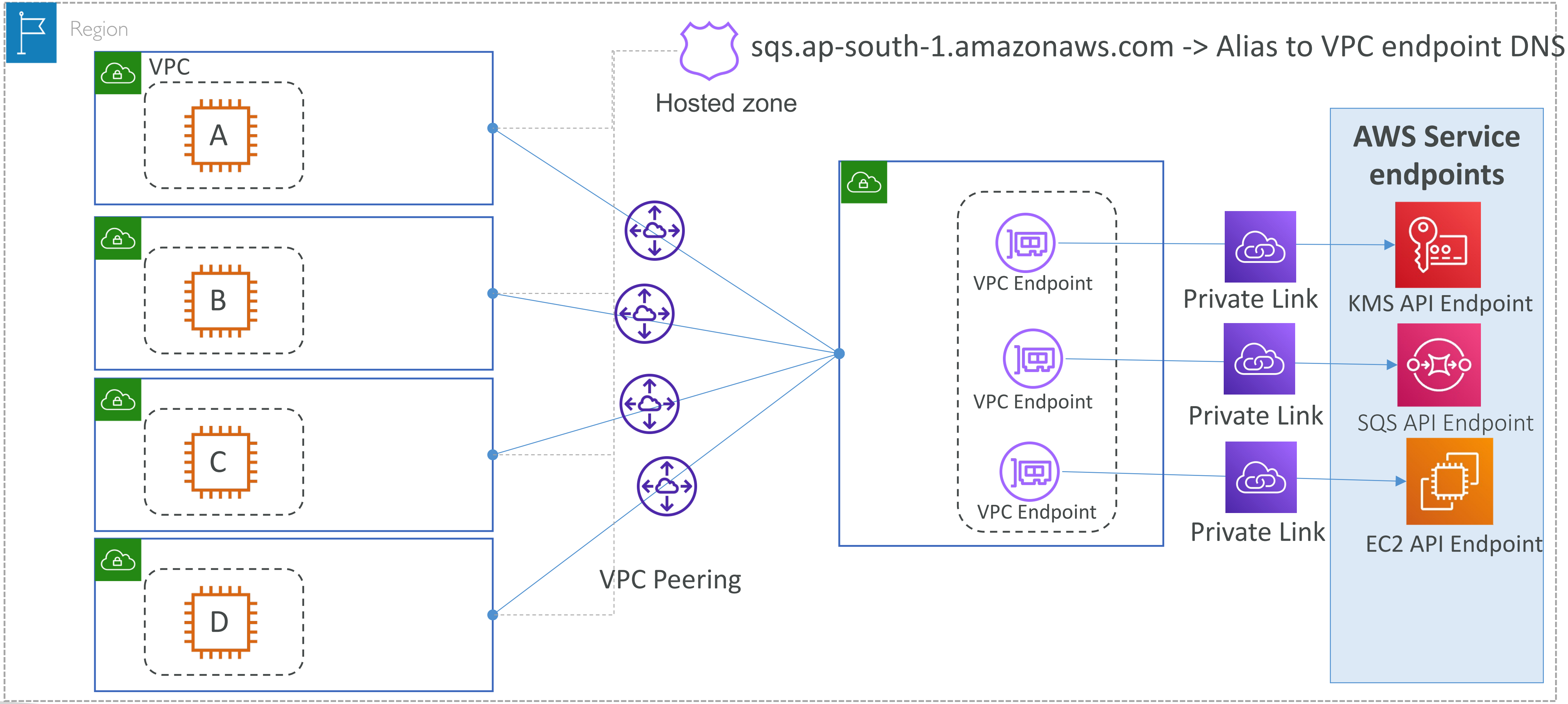
Let's apply the cost lens..



Cost of centralized VPC interface endpoints



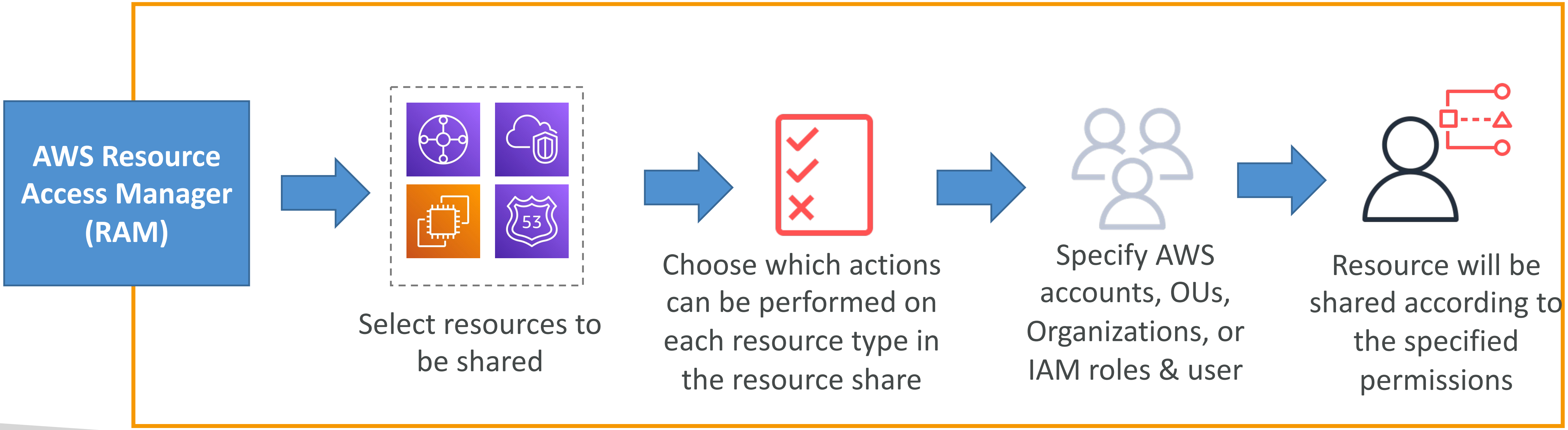
Using VPC peering instead of Transit Gateway



Transit Gateway Sharing

Sharing Transit Gateway

- Use AWS Resource Access Manager (RAM) to share a transit gateway for **VPC attachments** across accounts or across your organization in AWS Organizations



Important to know about shared transit gateway

- An AWS Site-to-Site VPN attachment must be created in the same AWS account that owns the transit gateway.
- An attachment to a Direct Connect gateway can be in the same AWS account as the Direct Connect gateway, or a different account from the Direct Connect gateway.
- When a transit gateway is shared with the AWS account, that AWS account cannot create, modify, or delete transit gateway route tables, or route table propagations and associations.
- When the transit gateway and the attachment entities are in different accounts, use the Availability Zone ID to uniquely and consistently identify the Availability Zone. For example, use1-az1 is an AZ ID for the us-east-1 Region and maps to the same location in every AWS account.

VPC Peering vs Transit Gateway

VPC Peering vs Transit Gateway

	VPC Peering	Transit Gateway
Architecture	One-One connection – Full Mesh	Hub and Spoke with multiple attachments
Hybrid Connectivity	Not supported	Supported hybrid connectivity via VPN and DX
Complexity	Simple for fewer VPCs, Complex as number of VPCs increase	Simple for any number of VPCs and hybrid network connectivity
Scale	125 peering / VPC	5000 attachments / TGW
Latency	Lowest	Additional Hop
Bandwidth	No limit	50 Gbps / attachment
Ref Security Group	Supported	Not supported
Subnet Connectivity	For all subnets across AZs	Only subnets within the same AZ in which TGW attachment is created
Transitive Routing e.g IGW access	Not supported	Supported
TCO	Lowest – Only Data transfer cost (free within same AZ, $0.01 across AZs in each direction, $0.02 across regions)	Per attachment cost + Data transfer cost (e.g N. Virginia: $0.05 per hour + $0.02 / GB)

TGW – Good to know

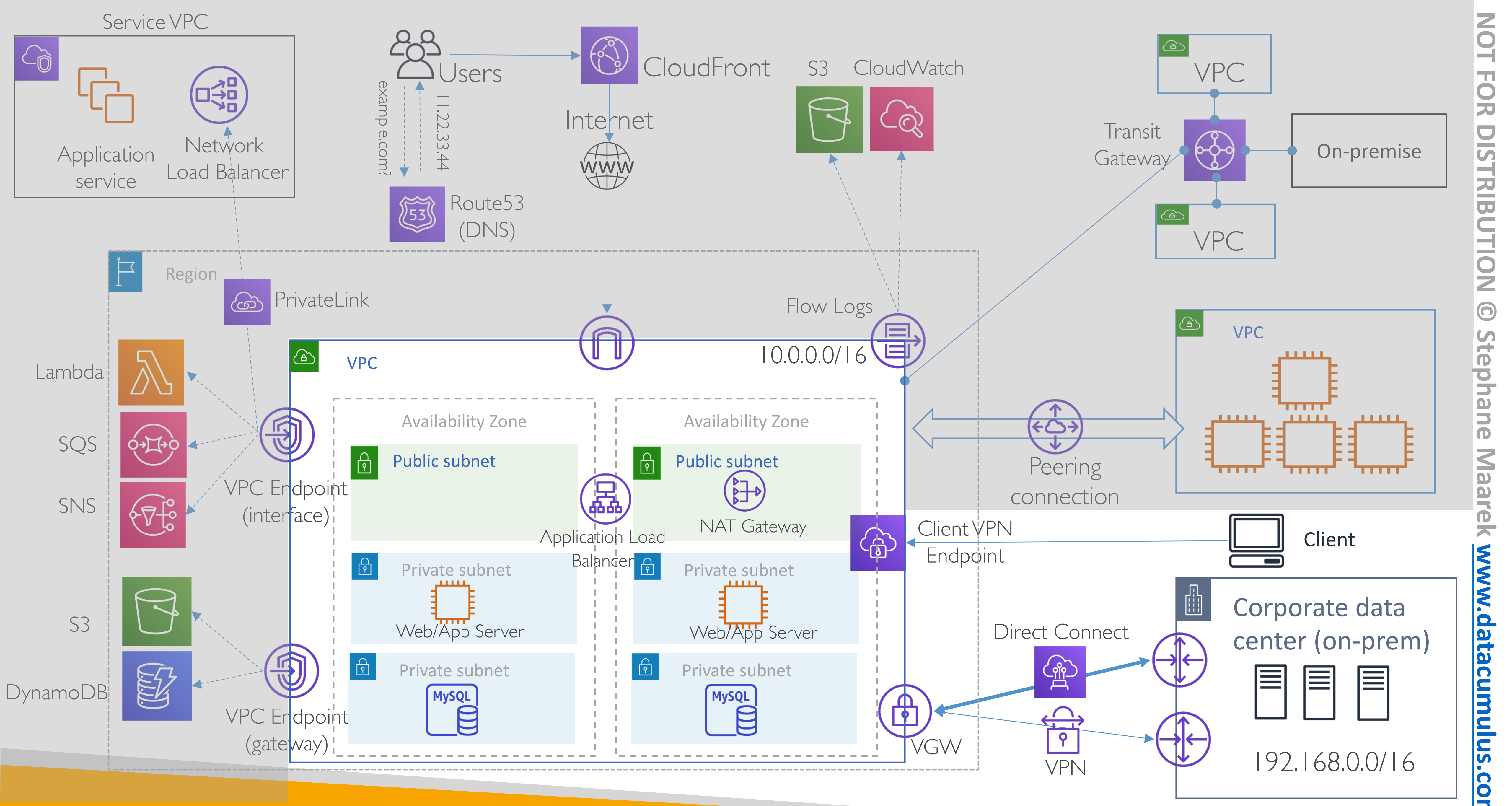
- DNS Resolution is supported for all VPC's attached to the TGW
- Supports resolving 'public' DNS names to Private IP's for EC2
- TGW can be shared using Resource Access Manager (RAM) across AWS accounts
- Billed per hour, per attachment
- Data processing charges apply for each gigabyte sent from an Amazon VPC or AWS Site-to-Site VPN to the AWS Transit Gateway
- Bandwidth at Transit Gateway is limited to 1.25 Gbps per VPN tunnel. With ECMP Transit Gateway can support up to 50 Gbps total VPN bandwidth

TGW – Good to know

- Transit Gateway supports up to 5000 attachments
- Transit gateway supports an MTU of 8500 bytes for traffic between VPCs, AWS Direct Connect, Transit Gateway Connect, and peering attachments
- Traffic over VPN connections can have an MTU of 1500 bytes.

Hybrid Network in AWS

AWS VPN and Direct Connect



Service VPC
Application service
Network Load Balancer
Users
example.com?
11.22.33.44
Route53 (DNS)
CloudFront
Internet
S3
CloudWatch
Transit Gateway
VPC
VPC
On-premise
Region
PrivateLink
Flow Logs
10.0.0.0/16
VPC
Lambda
SQS
SNS
VPC Endpoint (interface)
Availability Zone
Availability Zone
Public subnet
Public subnet
Application Load Balancer
NAT Gateway
Private subnet
Private subnet
Web/App Server
Web/App Server
Private subnet
Private subnet
MySQL
MySQL
S3
DynamoDB
VPC Endpoint (gateway)
VPC
Peering connection
Client VPN Endpoint
Client
Corporate data center (on-prem)
Direct Connect
VPN
VGW
192.168.0.0/16
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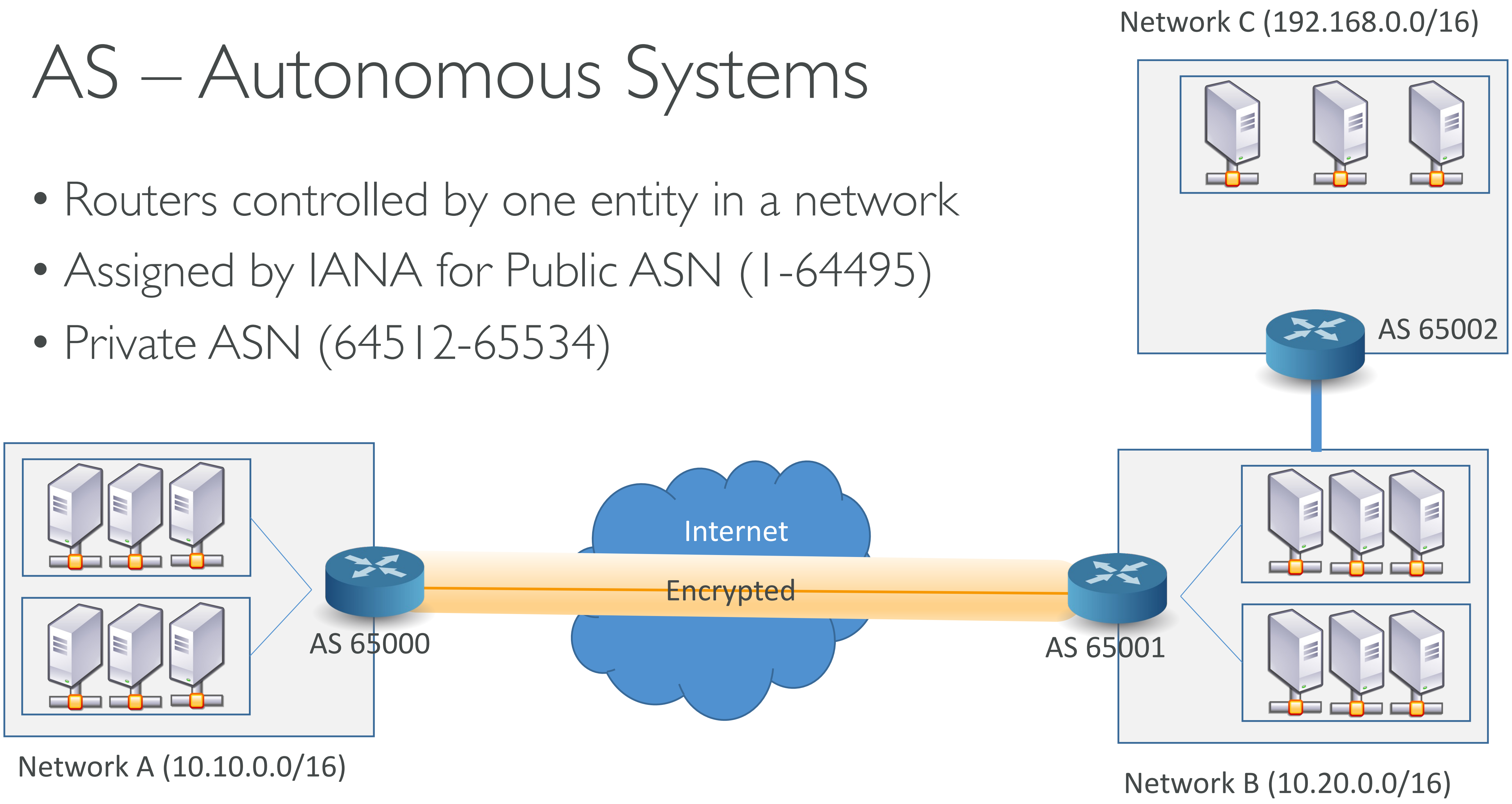
But before we dive deep..

- Static vs Dynamic Routing
- Border Gateway Protocol and how it works?
- BGP Route selection - ASPATH, LOCAL_PREF, MED

Routing – Static vs Dynamic

AS – Autonomous Systems

- Routers controlled by one entity in a network
- Assigned by IANA for Public ASN (1-64495)
- Private ASN (64512-65534)



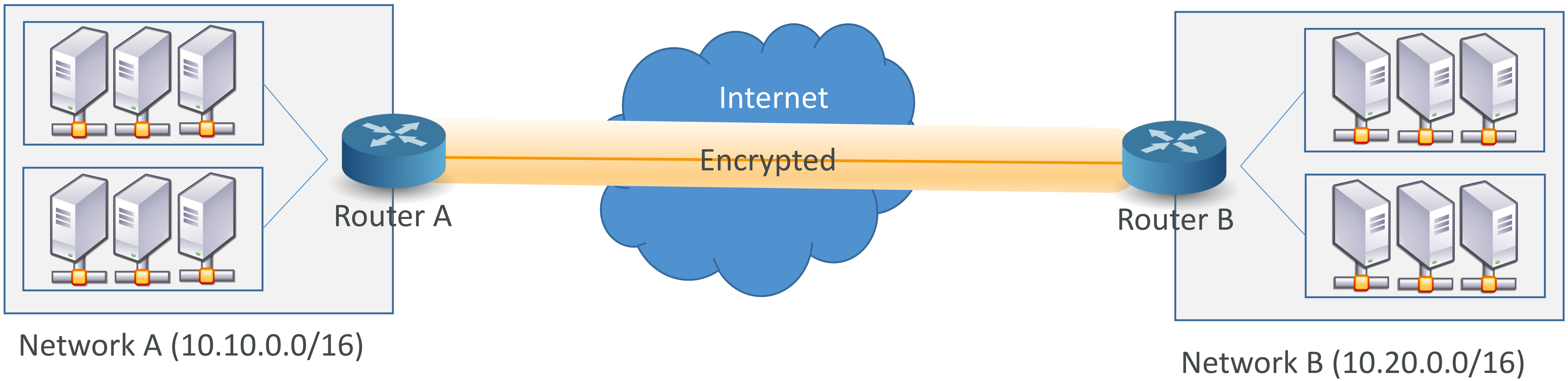
Static Routing

Network A

Destination	Target
10.10.0.0/16	Local
10.20.0.0/16	**Router B**

Network B

Destination	Target
10.20.0.0/16	Local
10.10.0.0/16	Router A



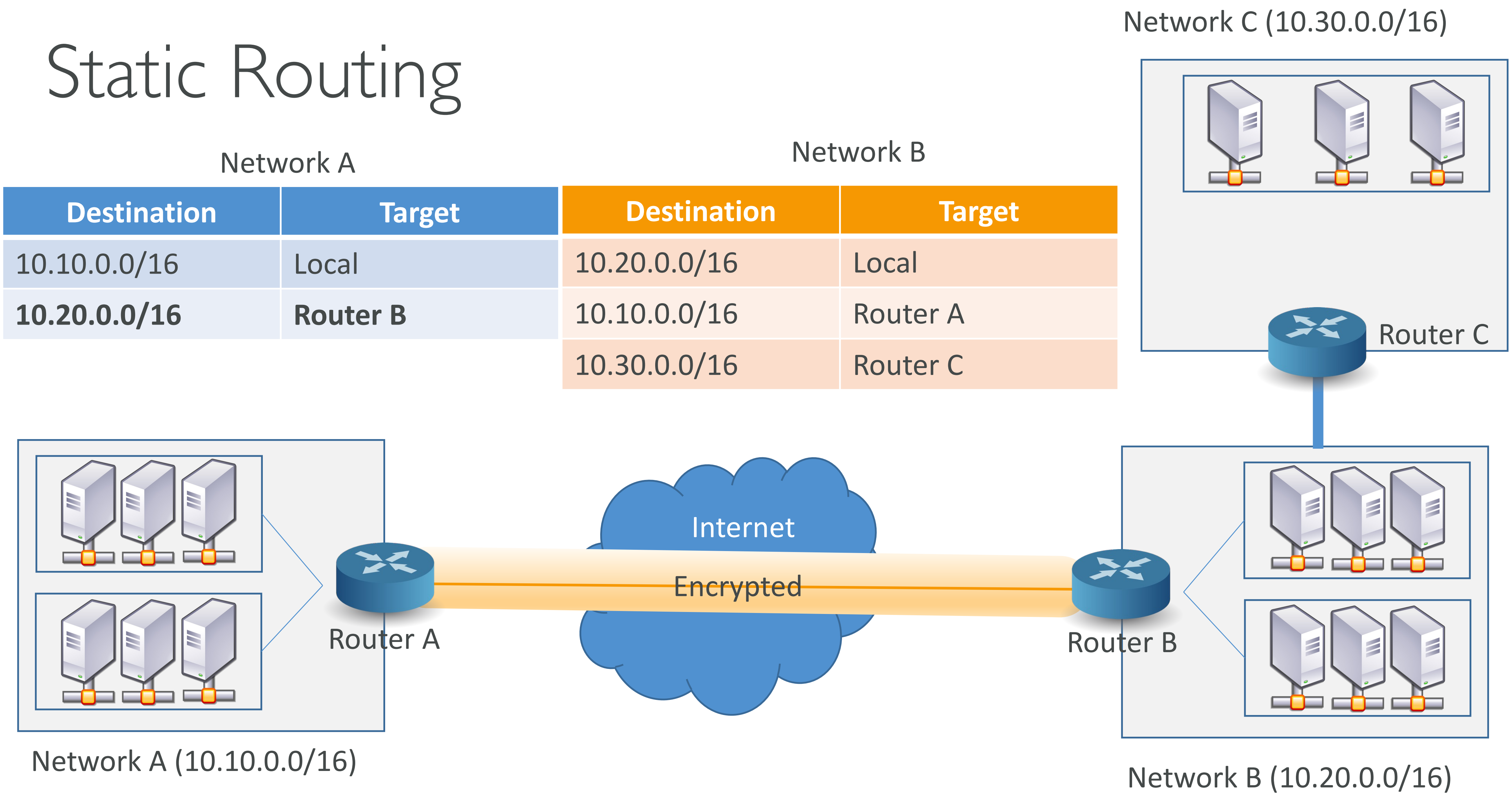
Static Routing

Network A

Destination	Target
10.10.0.0/16	Local
10.20.0.0/16	**Router B**

Network B

Destination	Target
10.20.0.0/16	Local
10.10.0.0/16	Router A
10.30.0.0/16	Router C

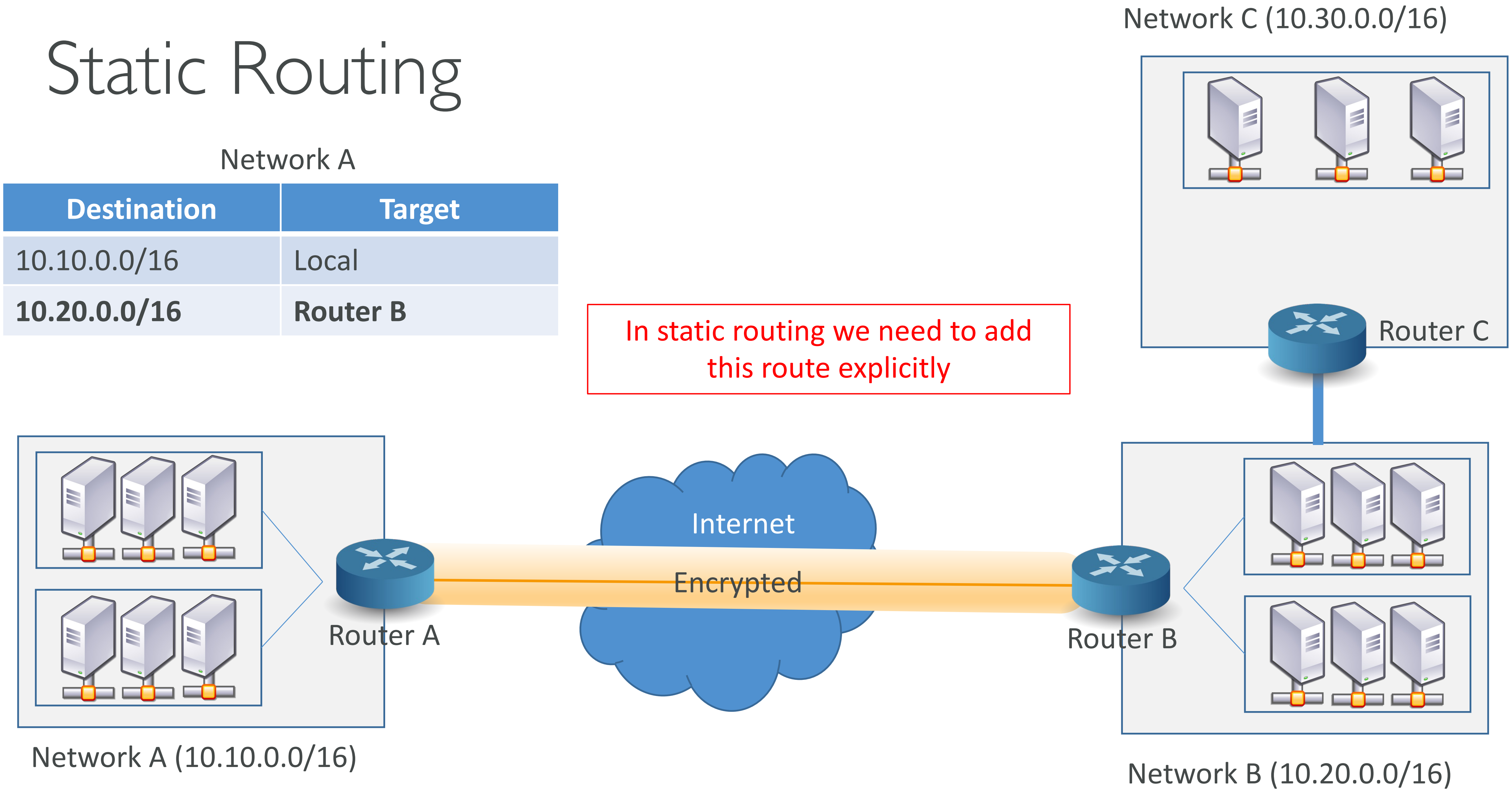


Static Routing

Network A

Destination	Target
10.10.0.0/16	Local
10.20.0.0/16	**Router B**

In static routing we need to add this route explicitly

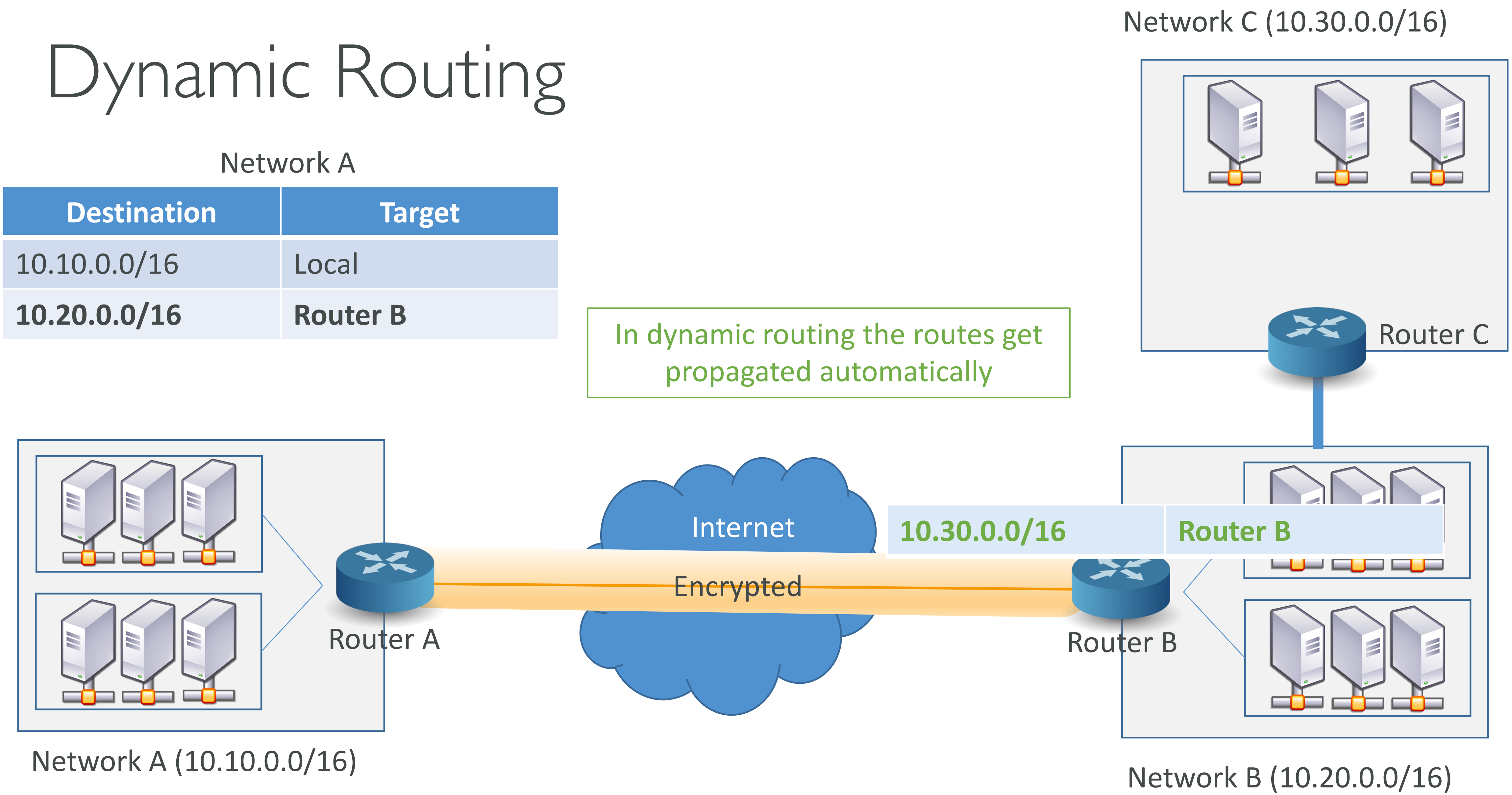


Dynamic Routing

Network A

Destination	Target
10.10.0.0/16	Local
10.20.0.0/16	**Router B**

In dynamic routing the routes get propagated automatically



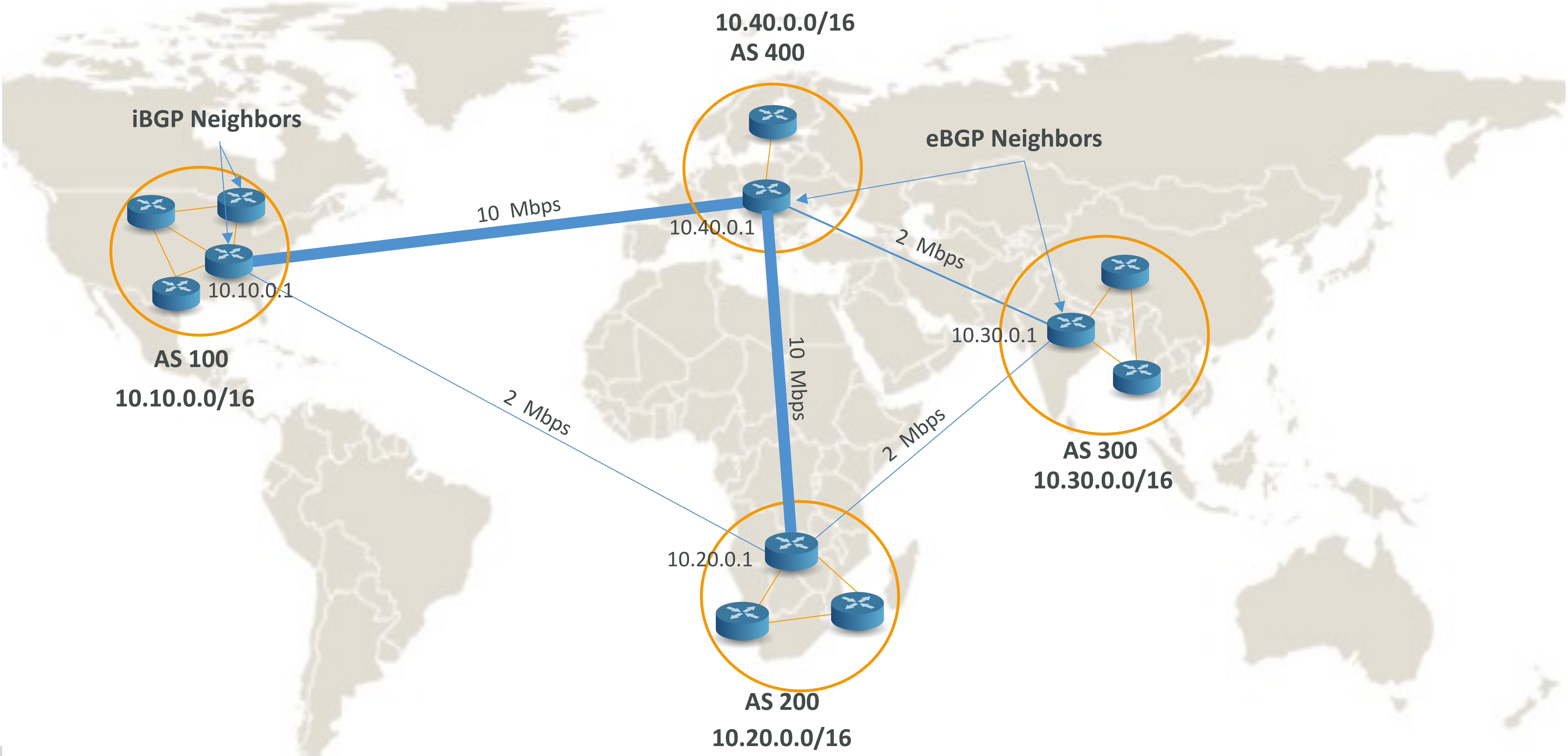
Dynamic Routing using Border Gateway Protocol (BGP)

BGP – Border Gateway Protocol

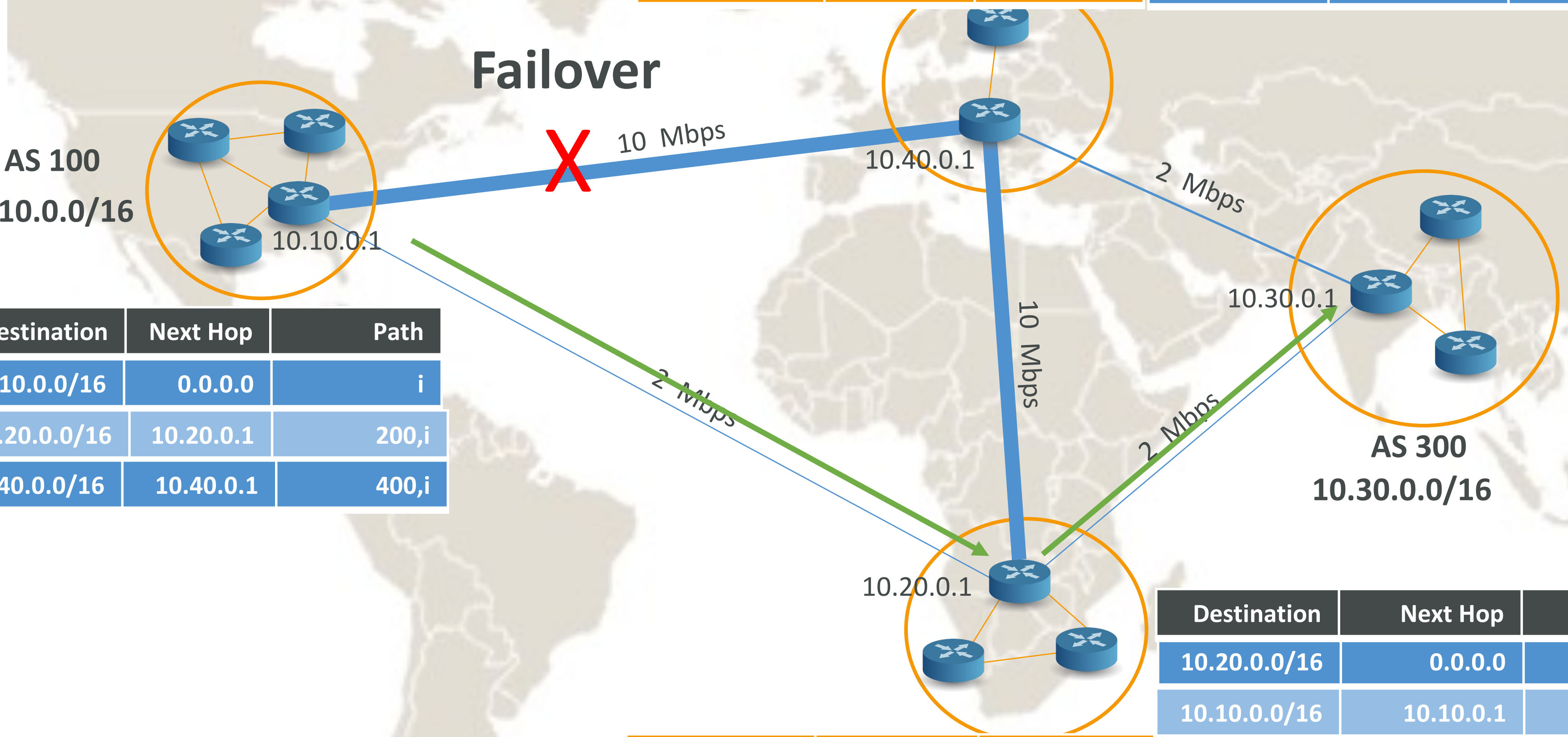
- Dynamic Routing using **Path-Vector** protocol where it exchanges the best path to a destination between peers or AS (ASPATH)
- iBGP – Routing within AS
- **eBGP – Routing between AS's**
- Routing decision is influenced by
  - Weight (Cisco routers specific – works within AS)
  - ASPATH – Series of AS's to traverse the path (Works between AS)
  - Local Preference LOCAL_PREF (Works within AS)
  - MED – Multi-Exit Discriminator (Works between AS)

The current version of BGP is version 4 (BGP4), which was published as [RFC 4271] in 2006

How BGP works



How BGP works



10.30.0.0/16	10.40.0.1	400,300,i

Destination	Next Hop	Path
10.40.0.0/16	0.0.0.0	i
10.10.0.0/16	10.10.0.1	100,i
10.20.0.0/16	10.20.0.1	200,i
10.30.0.0/16	10.30.0.1	300,i

Destination	Next Hop	Path
10.10.0.0/16	0.0.0.0	i
10.20.0.0/16	10.20.0.1	200,i
10.40.0.0/16	10.40.0.1	400,i

Destination	Next Hop	Path
10.30.0.0/16	0.0.0.0	i
10.40.0.0/16	10.40.0.1	400,i
10.20.0.0/16	10.20.0.1	200,i

10.30.0.0/16	10.20.0.1	200,300,i

Destination	Next Hop	Path
10.20.0.0/16	0.0.0.0	i
10.10.0.0/16	10.10.0.1	100,i
10.30.0.0/16	10.30.0.1	300,i
10.40.0.0/16	10.40.0.1	400,i

i => internal (Origin)

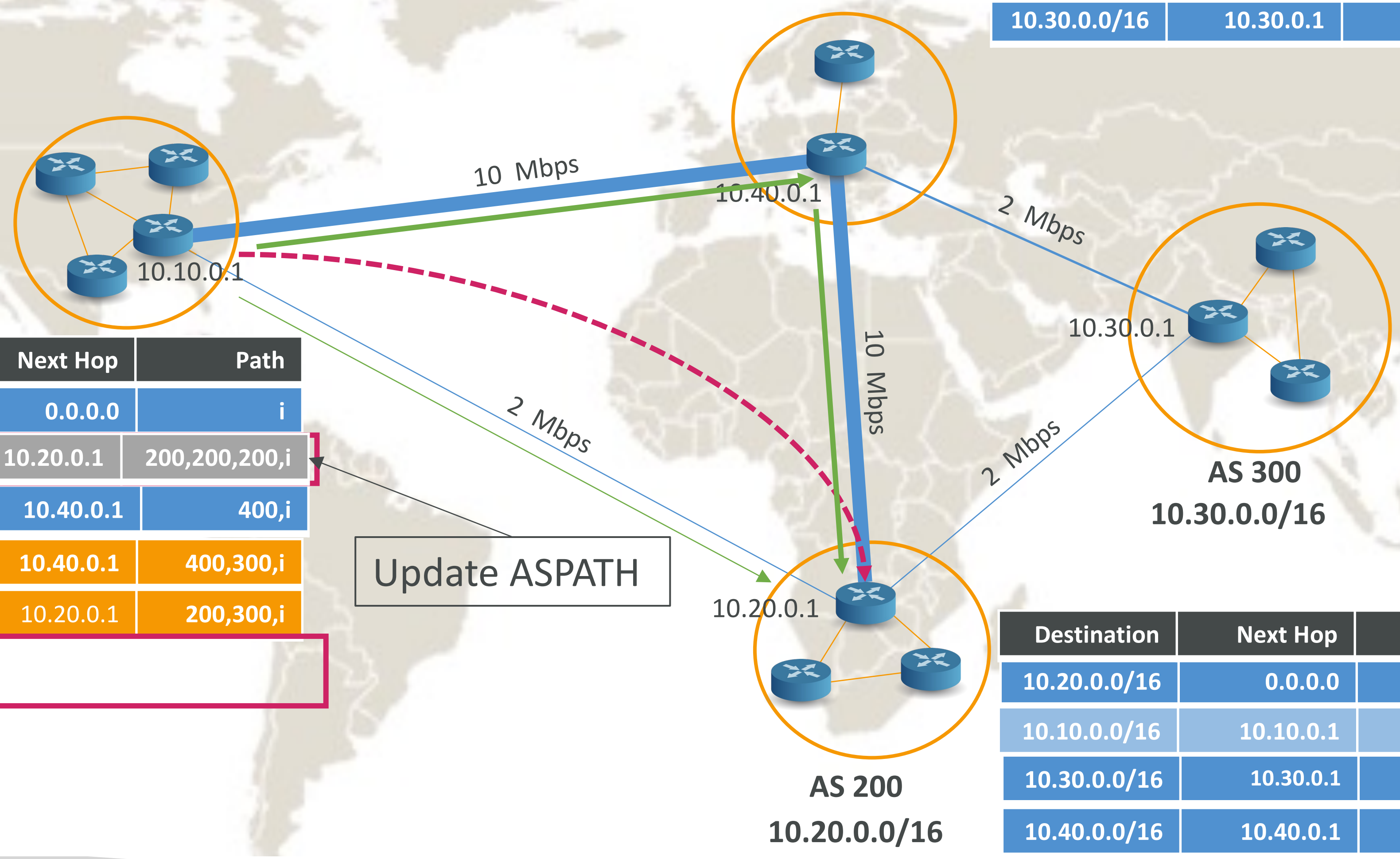
How BGP works

ASPATH

10.40.0.0/16

10.20.0.0/16	10.40.0.1	400,200,i

Destination	Next Hop	Path
10.40.0.0/16	0.0.0.0	i
10.10.0.0/16	10.10.0.1	100,i
10.20.0.0/16	10.20.0.1	200,i
10.30.0.0/16	10.30.0.1	300,i



Destination	Next Hop	Path
10.30.0.0/16	0.0.0.0	i
10.40.0.0/16	10.40.0.1	400,i
10.20.0.0/16	10.20.0.1	200,i

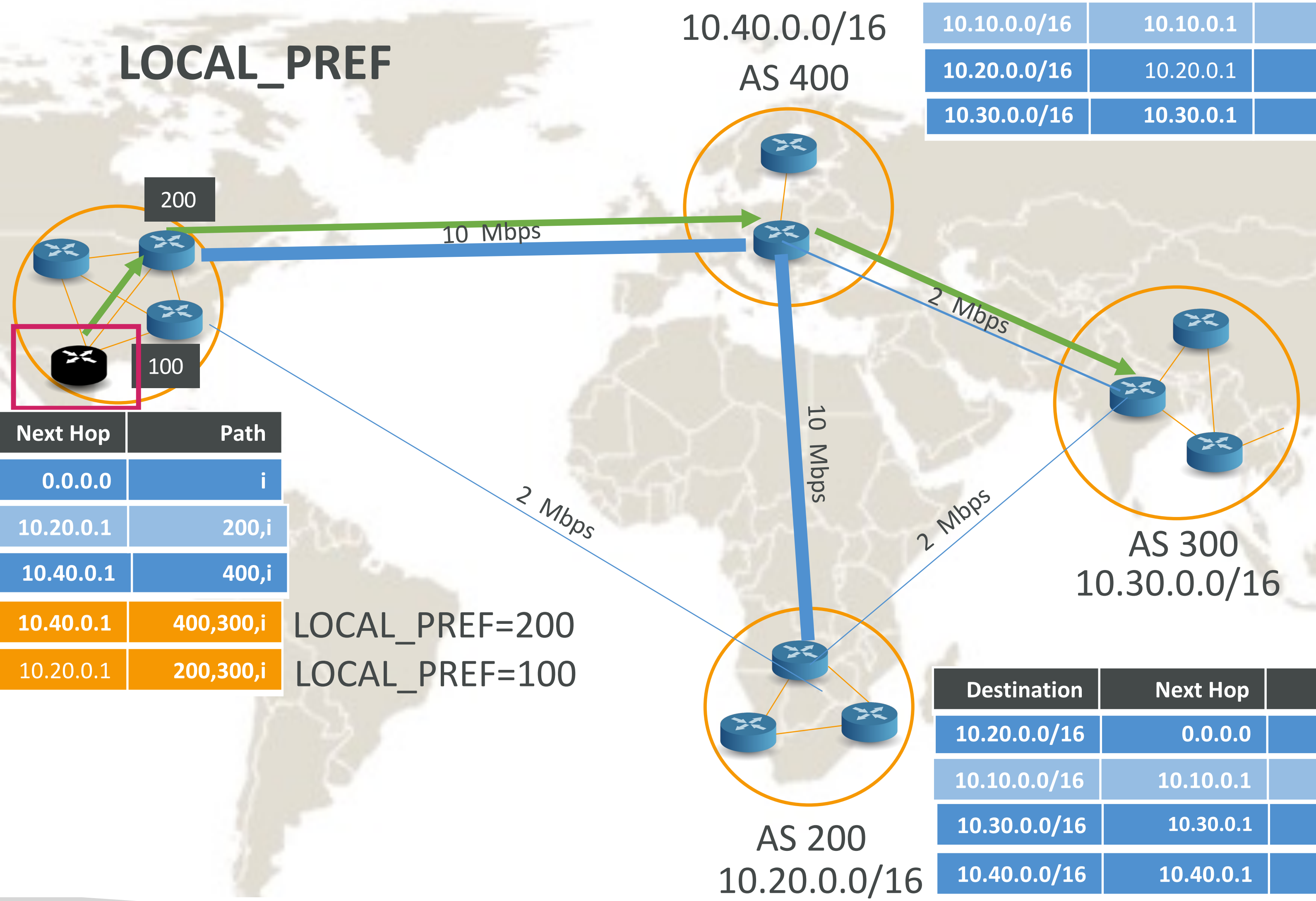
Destination	Next Hop	Path
10.10.0.0/16	0.0.0.0	i
10.20.0.0/16	10.20.0.1	200,200,200,i
10.40.0.0/16	10.40.0.1	400,i
10.30.0.0/16	10.40.0.1	400,300,i
10.30.0.0/16	10.20.0.1	200,300,i

Update ASPATH

Destination	Next Hop	Path
10.20.0.0/16	0.0.0.0	i
10.10.0.0/16	10.10.0.1	100,i
10.30.0.0/16	10.30.0.1	300,i
10.40.0.0/16	10.40.0.1	400,i

How BGP works

LOCAL_PREF



Destination	Next Hop	Path
10.40.0.0/16	0.0.0.0	i
10.10.0.0/16	10.10.0.1	100,i
10.20.0.0/16	10.20.0.1	200,i
10.30.0.0/16	10.30.0.1	300,i

Destination	Next Hop	Path
10.30.0.0/16	0.0.0.0	i
10.40.0.0/16	10.40.0.1	400,i
10.20.0.0/16	10.20.0.1	200,i

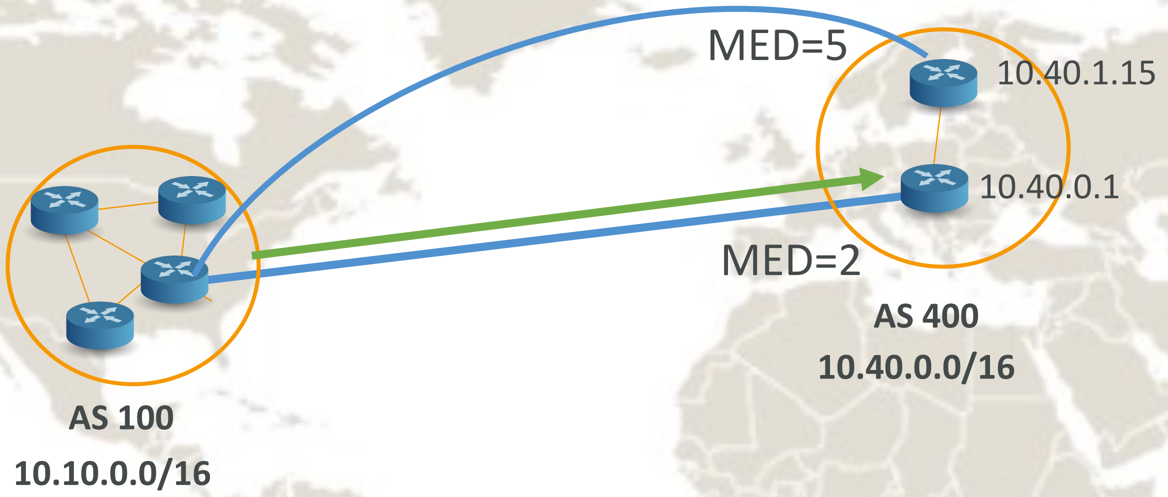
Destination	Next Hop	Path	
10.10.0.0/16	0.0.0.0	i	
10.20.0.0/16	10.20.0.1	200,i	
10.40.0.0/16	10.40.0.1	400,i	
10.30.0.0/16	10.40.0.1	400,300,i	LOCAL_PREF=200
10.30.0.0/16	10.20.0.1	200,300,i	LOCAL_PREF=100

Destination	Next Hop	Path
10.20.0.0/16	0.0.0.0	i
10.10.0.0/16	10.10.0.1	100,i
10.30.0.0/16	10.30.0.1	300,i
10.40.0.0/16	10.40.0.1	400,i

Default LOCAL_REF => 100

How BGP works

MED – Multi Exit Discriminator



Destination	Next Hop	PATH
10.10.0.0/16	0.0.0.0	i
10.40.0.0/16	10.40.1.15	400,i
10.40.0.0/16	10.40.0.1	400,i

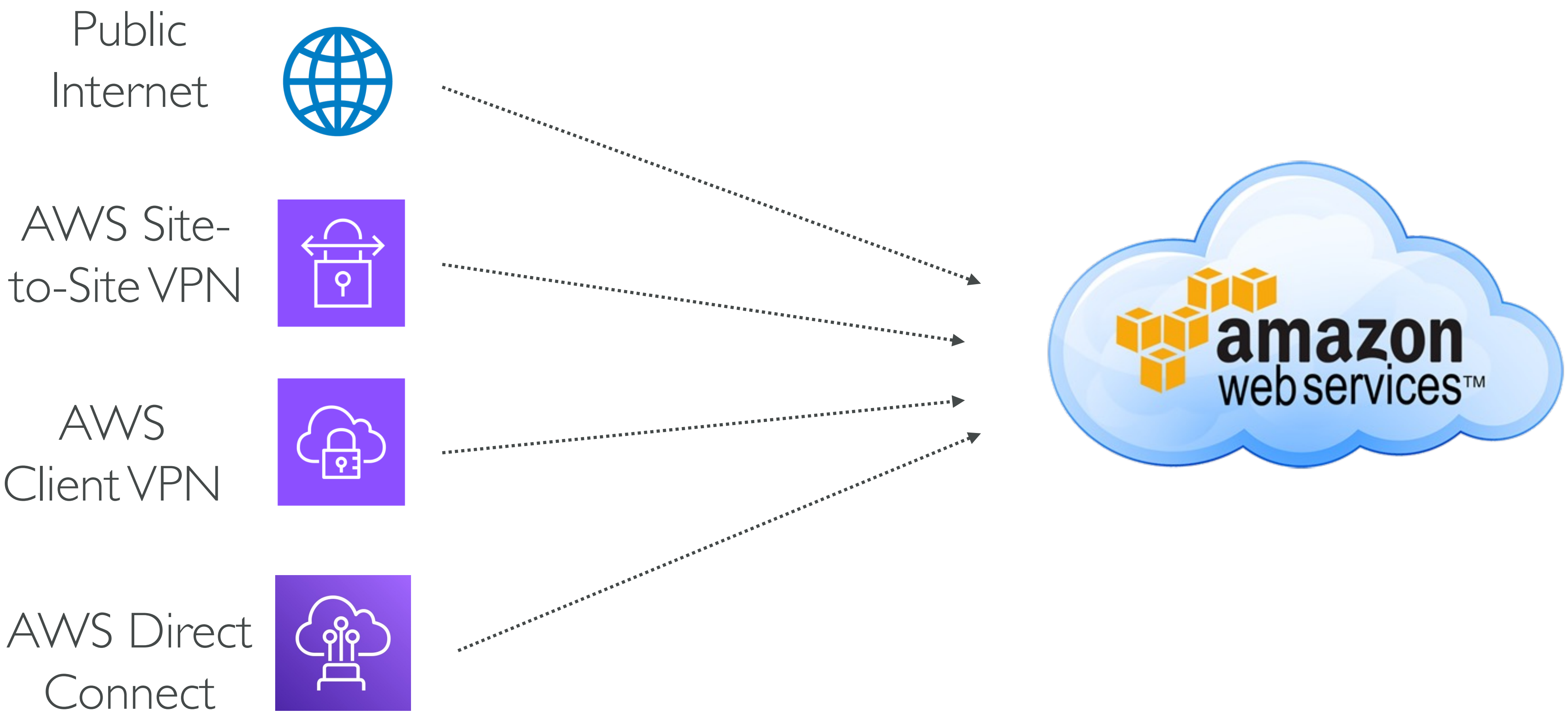
When:
- LOCAL_PREF is same
- AS_PATH is same
- Lowest MED = Highest Preference

Quick recap of BGP Route selection order and attributes

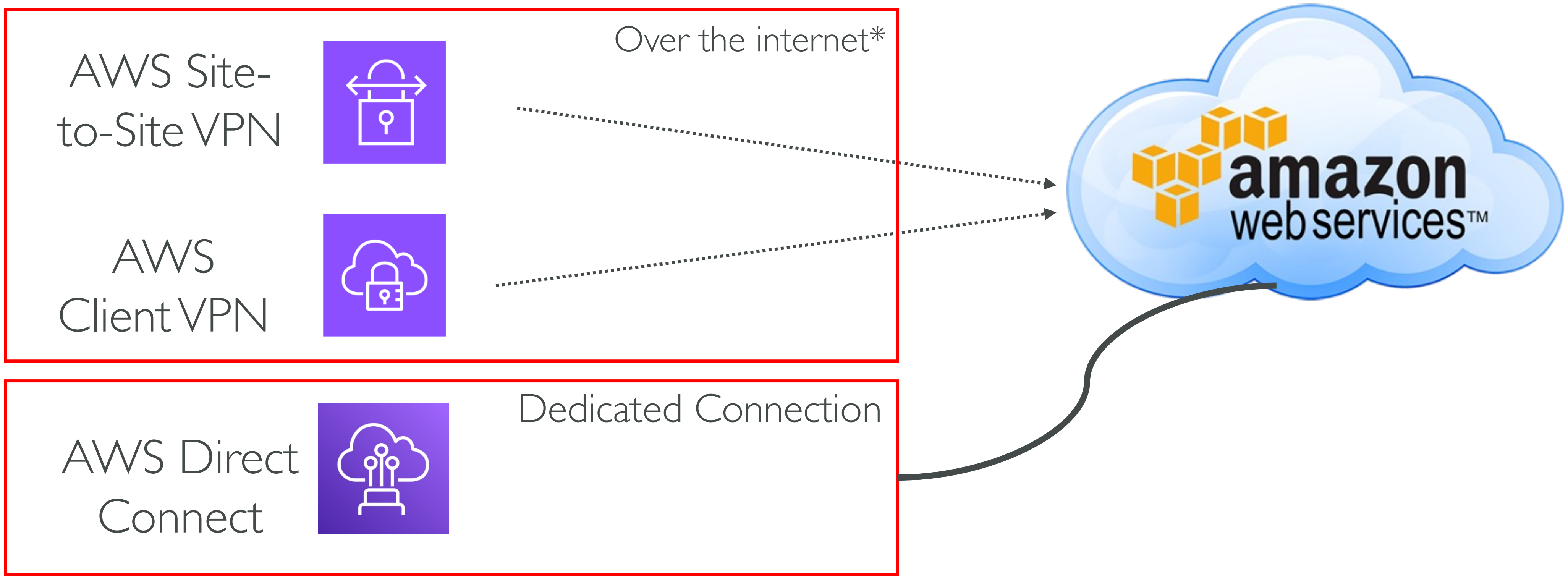
- Highest Weight
  - Cisco routers specific attribute
  - Works within the AS and set by the originating router
  - Not exchanged between external BGP routers
- Highest local preference
  - Choose the outbound external BGP path
  - Set by the local AS for internal BGP routers
  - Not exchanged between external BGP routers
  - Default value 100
- Shorted AS Path
  - AS Path can be modified using AS path prepend to make it appear longer
- Lowest Multi Exit Discriminator (MED)
  - Used when there are multiple paths between two AS's
  - MED is exchanged **between** autonomous systems

AWS Site-to-Site VPN

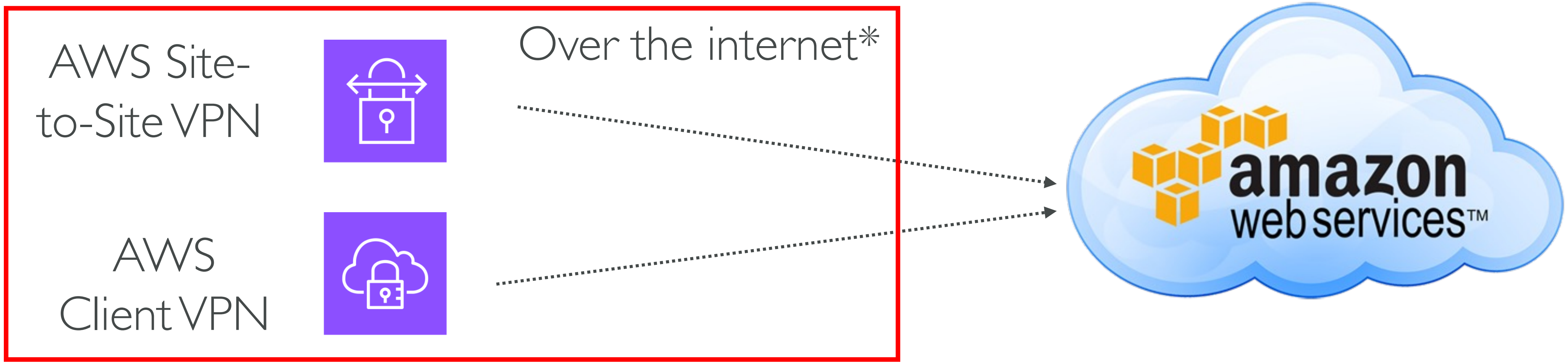
AWS Connectivity Options



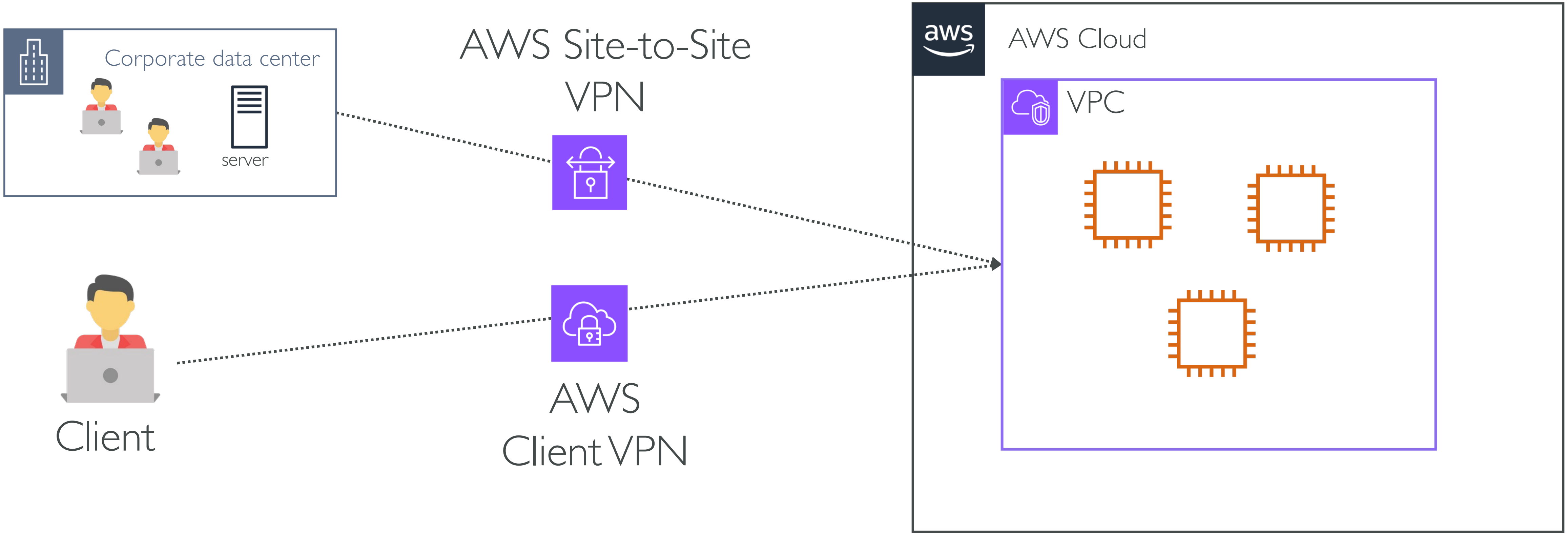
AWS Private Connectivity Options



AWS Private Connectivity Options

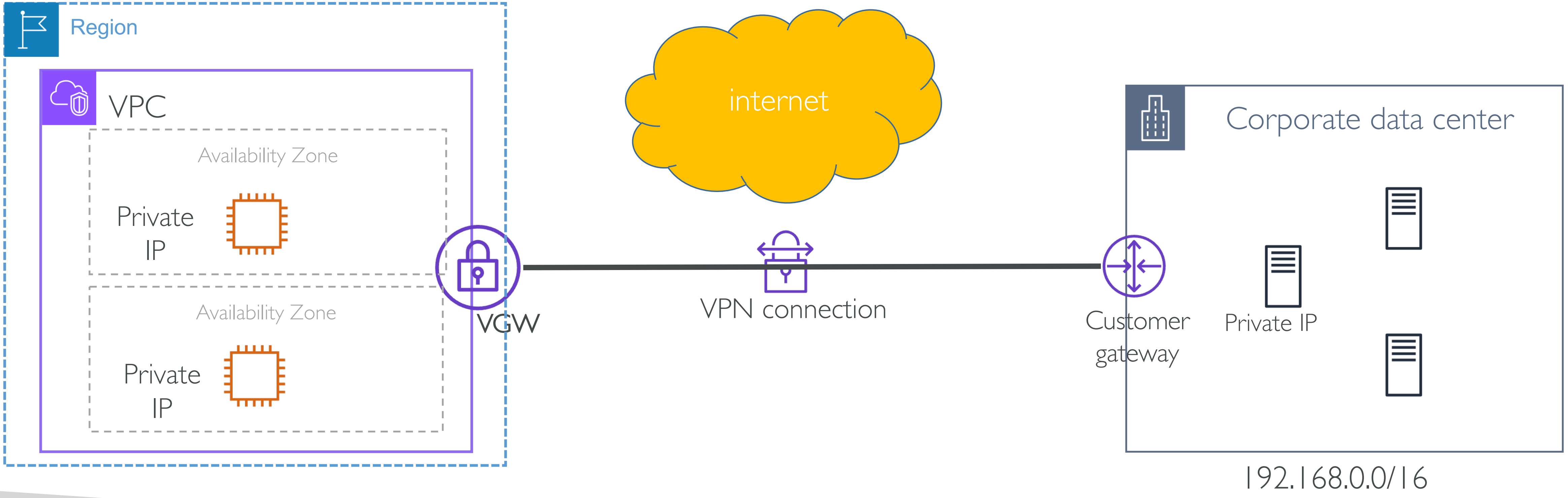


AWS VPN connectivity options



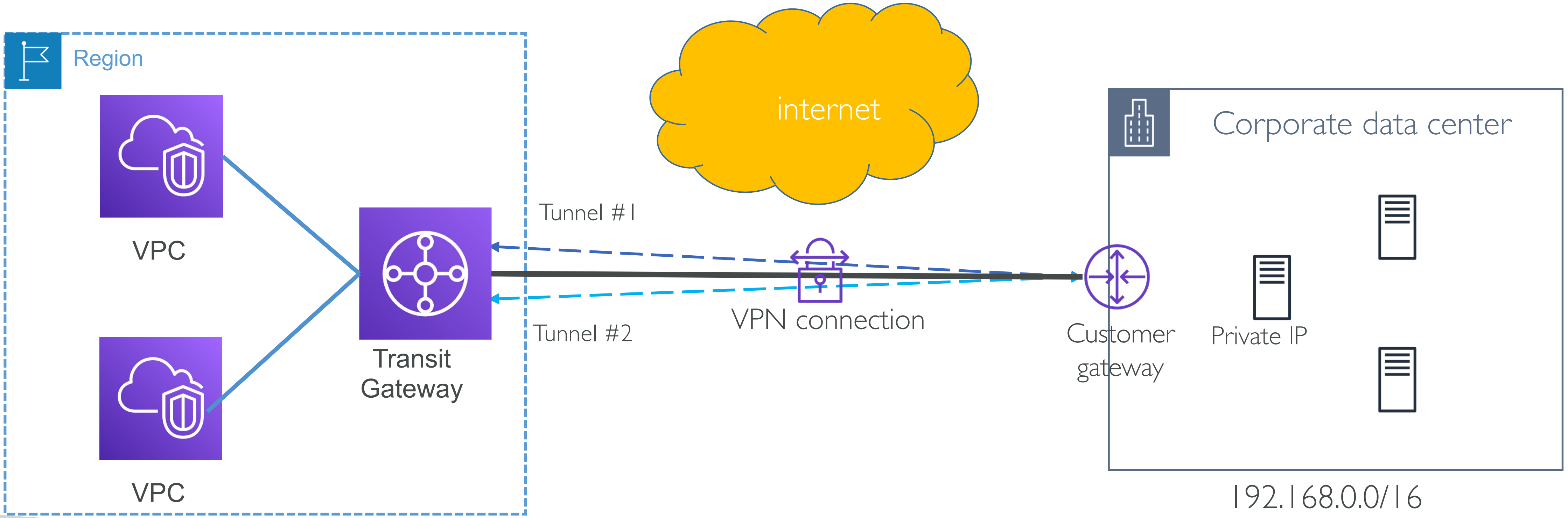
How Site-to-Site VPN works in AWS

- VPN connection is established between AWS network and Customer corporate network
- At AWS end, VPN can be terminated on Virtual Private Gateway (VGW) or AWS Transit Gateway



How Site-to-Site VPN works in AWS

- VPN connection is established between AWS network and Customer corporate network
- At AWS end, VPN can be terminated on Virtual Private Gateway (VGW) or AWS Transit Gateway
- Each AWS Site-to-Site VPN connection has 2 IP Security (IPSec) Tunnels for High Availability



AWS Site-to-Site VPN Fundamentals

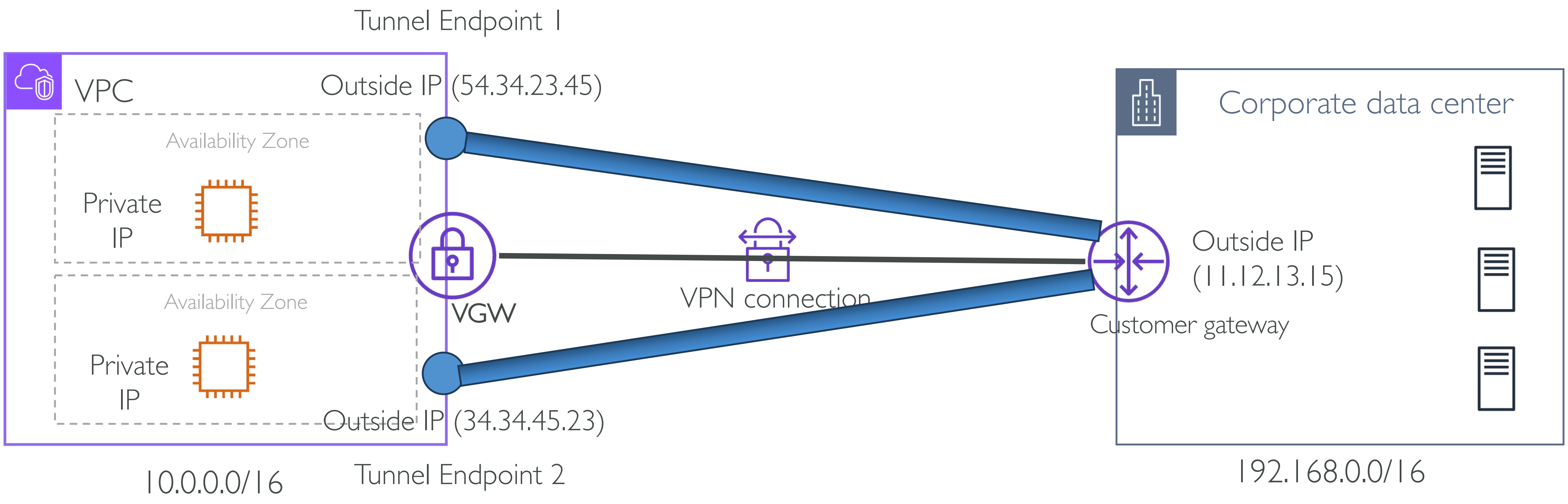
- VPN allows hosts to communicate privately over an untrusted intermediary network like internet, in **encrypted form**
- AWS supports Layer 3 VPN (not Layer 2)
- VPN has 2 forms – Site to Site VPN and Client to Site VPN
  - Site to Site VPN connects 2 different networks.
  - Client to Site VPN connects the client device like laptop to the private network
- VPN types
  - IPSec (IP Security) VPN which is supported by **AWS managed VPN**
  - Other VPNs like GRE and DMVPN are not supported by AWS managed VPN

AWS Site-to-Site VPN Fundamentals

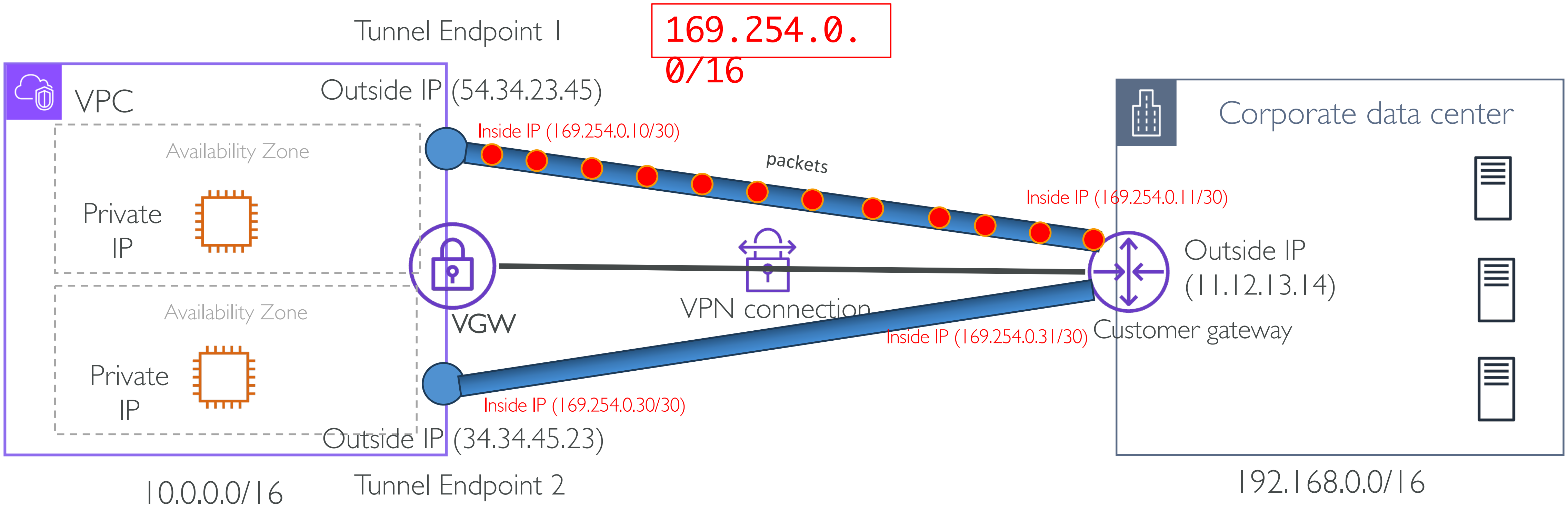
- VPN gateway or Virtual Private Gateway (VGW) is the managed gateway endpoint for the VPC
- Only one VGW can be attached to VPC at a time.
- Supports both Static Routing and Dynamic routing using Border gateway protocol (BGP)
- For BGP, you can assign the private ASN (Autonomous System Number) to VGW in the range of 64512 to 65534 (2-byte) or 1–2147483647 (4-byte)
- If you don't define ASN, AWS assigns default ASN **64512**
- You can use **pre-shared keys**, or **Private CA certificates** to authenticate Site-to-Site VPN tunnel endpoints.

IPv4 and IPv6 support

VPN outside and inside IP addresses



VPN outside and inside IP addresses



IPv4 and IPv6 traffic

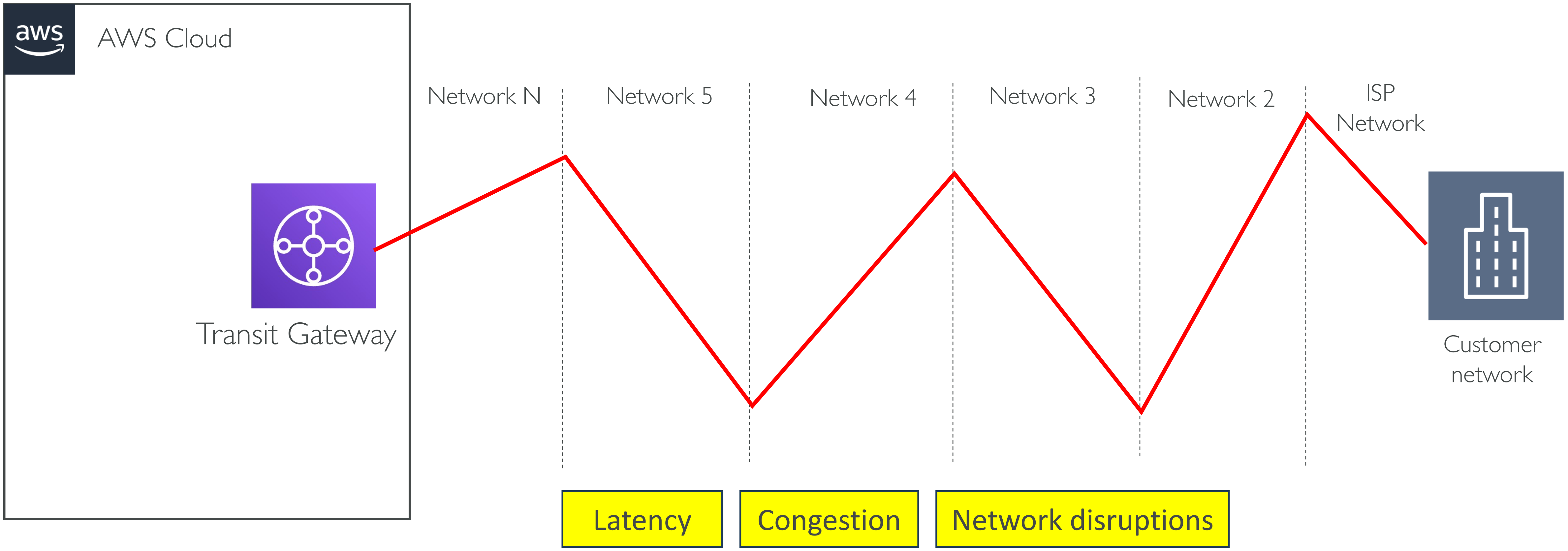
- **IPv4 outer tunnel with IPv4 inner packets** - Default configuration for IPv4 traffic, Supported for Virtual Private Gateway, Transit Gateway and Cloud WAN
- **IPv4 outer tunnel with IPv6 inner packets** – Allows IPv6 traffic within IPv4 VPN tunnels, Supported for Transit gateway and Cloud WAN
- **IPv6 outer tunnel with IPv6 inner packets** – Allows full IPv6 traffic and routing, Supported for Transit Gateway and Cloud WAN
- **IPv6 outer tunnel with IPv4 inner packets** - Allows IPv6 outer tunnel addressing while supporting legacy IPv4 applications within the tunnel. Supported for both Transit gateway and Cloud WAN.

A single Site-to-Site VPN connection cannot support both IPv4 and IPv6 traffic simultaneously. You need separate VPN connections to transport IPv4 and IPv6 packets.

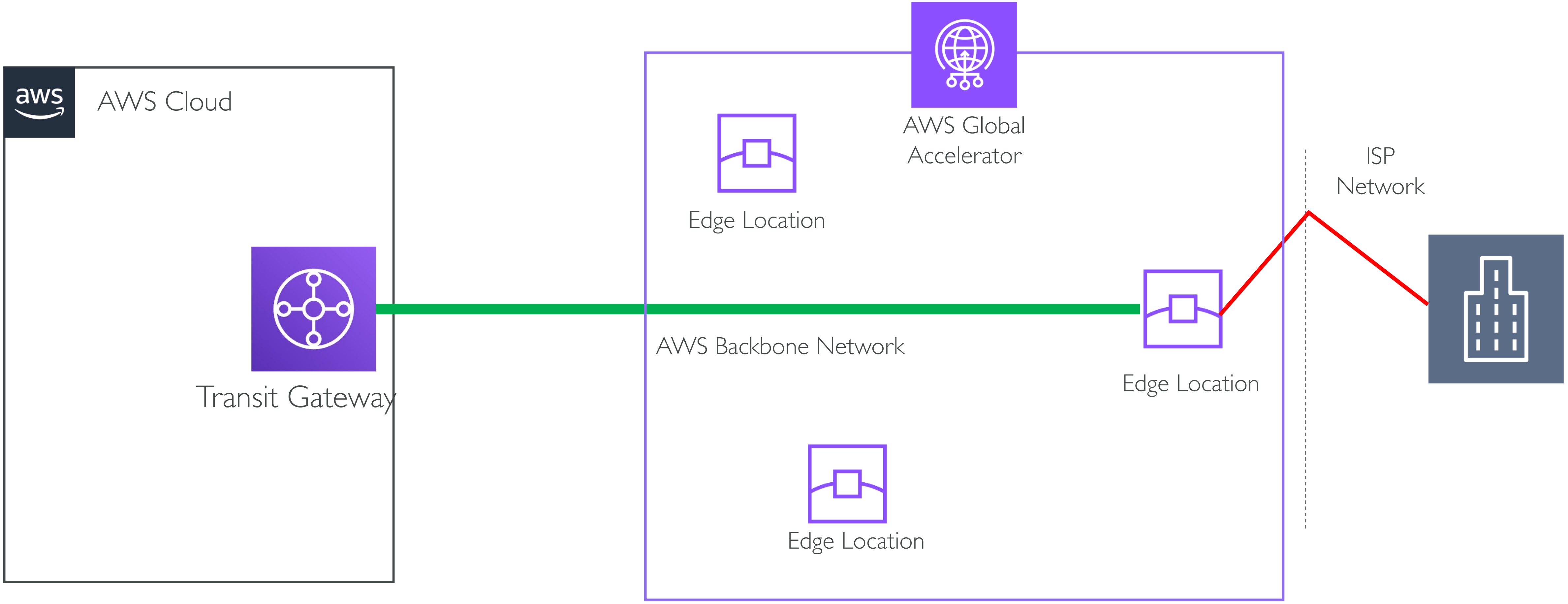
Accelerated Site-to-Site VPN

Using AWS Global Accelerator

Accelerated Site-to-Site VPN



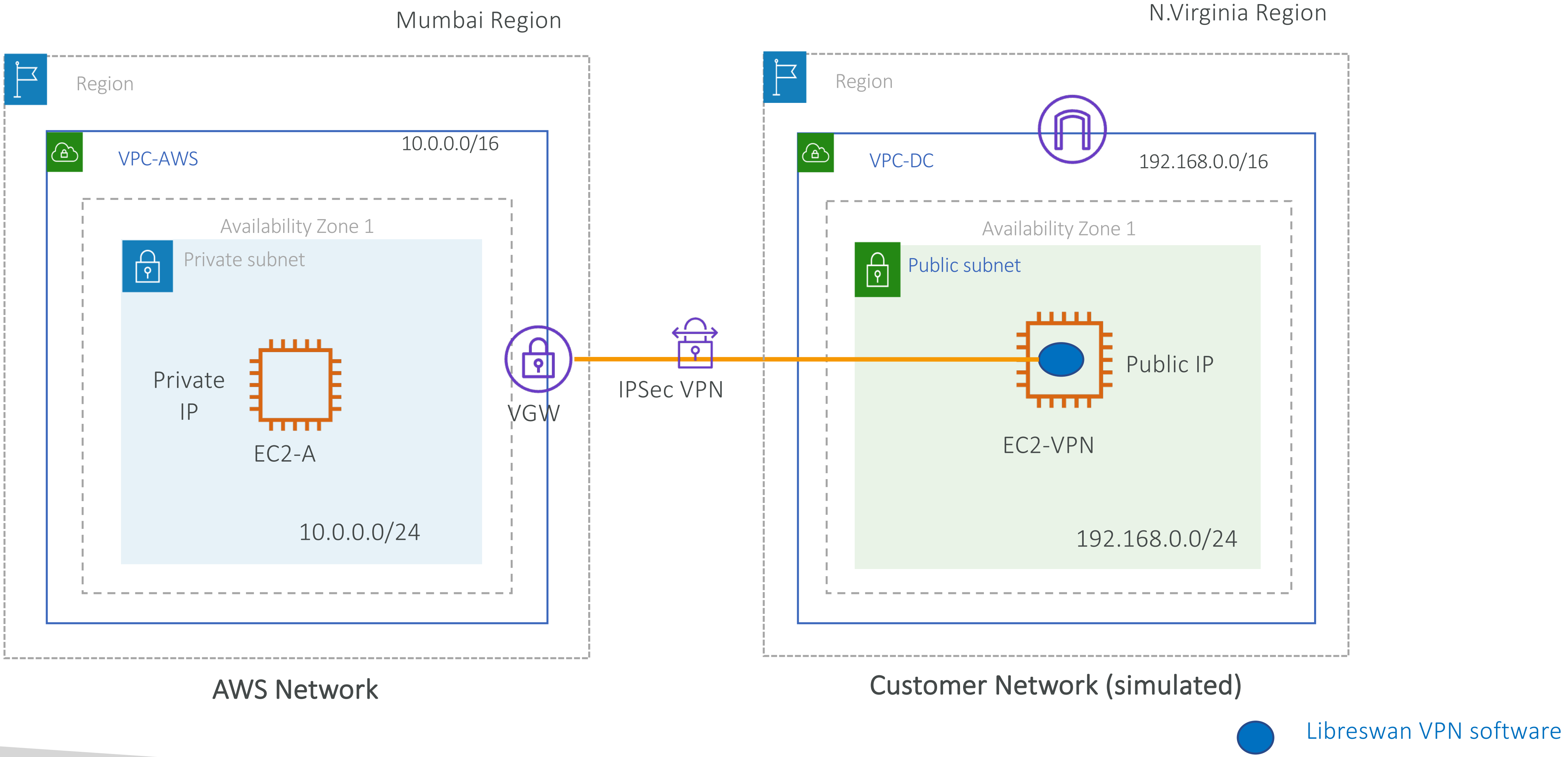
Accelerated Site-to-Site VPN



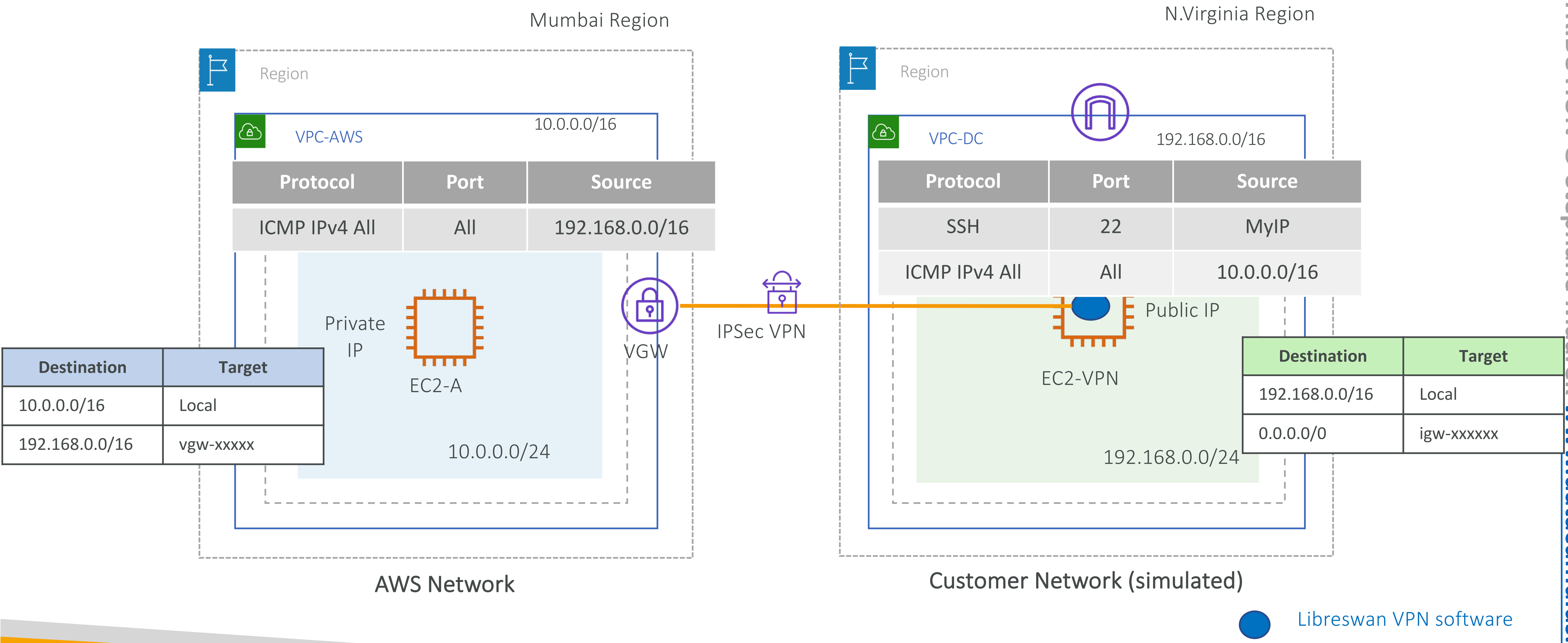
Accelerated Site-to-Site VPN – Important to know

- **Supported only for AWS Transit Gateway**. VPN terminating on VGW isn't supported.
- Can be enabled only when creating the new VPN connection. We can not enable the acceleration on the existing VPN connection.
- Provides the 2 Static anycast IPs which are different than VPN endpoint IPs
- NAT-traversal (NAT-T) must be enabled on customer gateway device as global accelerator does not support ESP 50
- IKE negotiation for the accelerated VPN tunnels must be initiated from the CGW
- Additional charge applied

Exercise – AWS Site-to-Site VPN



Exercise – AWS Site-to-Site VPN



Protocol	Port	Source
ICMP IPv4 All	All	192.168.0.0/16

Destination	Target
10.0.0.0/16	Local
192.168.0.0/16	vgw-xxxxx

Protocol	Port	Source
SSH	22	MyIP
ICMP IPv4 All	All	10.0.0.0/16

Destination	Target
192.168.0.0/16	Local
0.0.0.0/0	igw-xxxxxx

High level steps

1. Create VPCs in two different regions as shown in the diagram. One acts as an AWS network and other as a on-premises DC network.
2. Launch EC2 instances in both the VPCs. For VPC-DC, launch it using **Amazon Linux 2023 AMI** so that you can install Libreswan. In Security group for both EC2 instances allow ICMP traffic from the other network. EC2-VPN will have Public IP. You should also open SSH from MyIP or 0.0.0.0/0.
3. Create a Virtual Private Gateway (VGW) in Mumbai region and associate it with the VPC-AWS. Add route in VPC-AWS Private subnet route table to route all the traffic (0.0.0.0/0) via the VGW. Create Customer gateway using the EC2-VPN Public IP.
4. Create a VPN connection in Mumbai region. Use EC2-VPN Public IP with static routing with VPC-DC CIDR.
5. Download VPN configuration file for Openswan from VPN connection console.
6. Install Libreswan on EC2-VPN. You need to add Libreswan fedora repository. After you install libreswan follow the instructions in VPN configuration file. You need to replace values for various fields like IP and CIDR range as per your environment, start the IPSec VPN service.
7. Access the AWS side EC2-A instance Private IP from EC2-VPN. You should be able to.

Steps

Refer the PDF document provided with this lecture for the detailed steps.

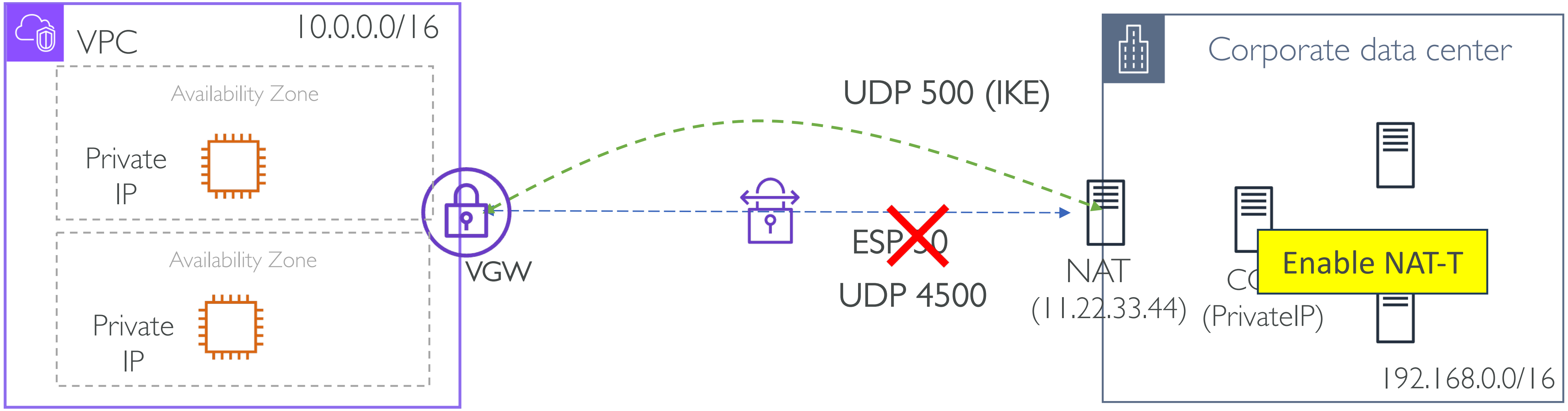
VPN NAT Traversal (NAT-T)

When Customer gateway is publicly reachable

Protocol	Port	Direction	Purpose
UDP	**500**	Inbound/Outbound	IKE (Internet Key Exchange) Phase 1 negotiation
Protocol 50 (ESP)	N/A	Inbound/Outbound	Encrypted IPsec payload (ESP packets)

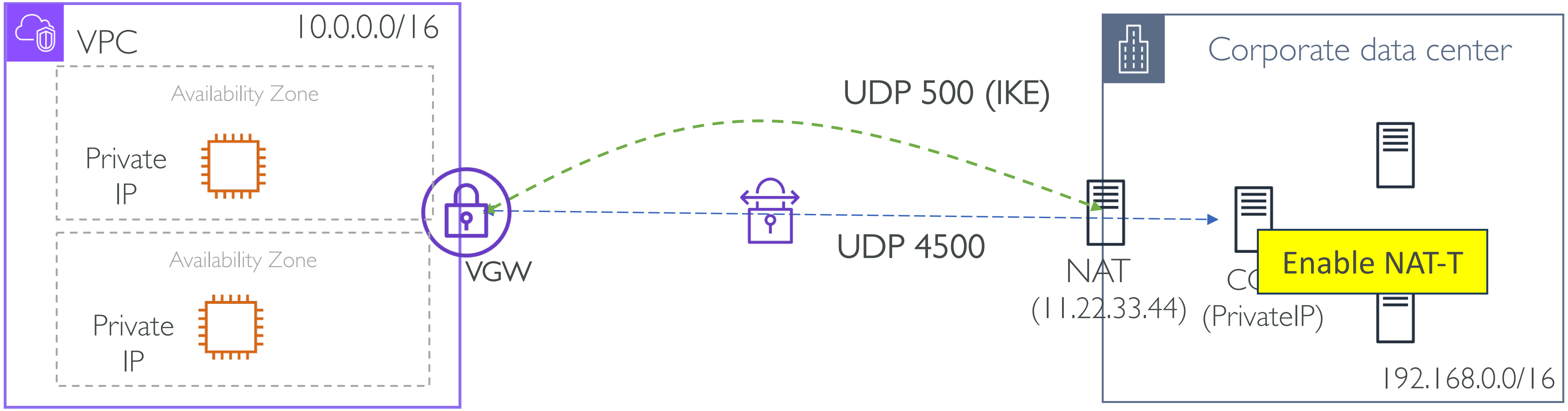
When Customer gateway is behind NAT

- NAT device can not handle ESP 50 protocol
- Hence ESP 50 needs to be further encapsulated inside UDP header



When Customer gateway is behind NAT

Protocol	Port	Direction	Purpose
UDP	**500**	Inbound/Outbound	IKE Phase 1 (initial handshake)
UDP	**4500**	Inbound/Outbound	IPsec NAT Traversal (encapsulated ESP in UDP)



NAT Traversal (NAT-T) – Important to know

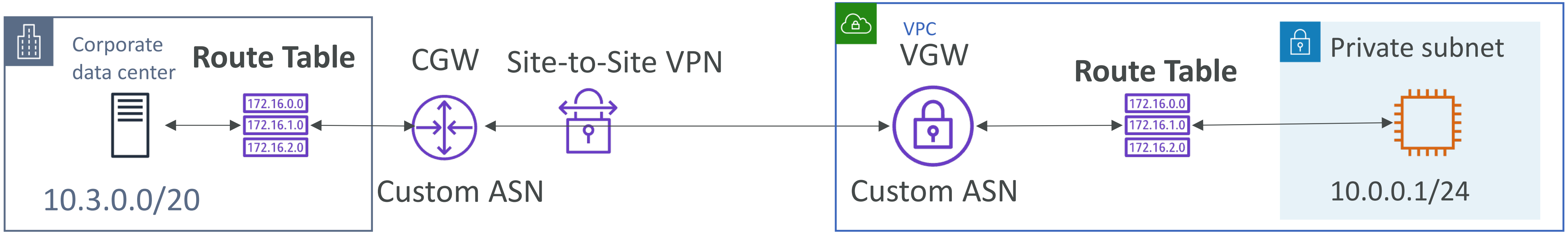
- AWS automatically detects NAT during IKE negotiation and switches to UDP 4500 (instead of ESP 50).
- For NAT-T, no configuration required on AWS side.
- On the **customer gateway side**:
  - When not using NAT: Allow inbound/outbound UDP 500, ESP 50
  - When using NAT: Allow inbound/outbound UDP500, UDP 4500
- Remember, for using Accelerated Site-to-Site VPN, NAT-T must be enabled on the customer gateway side because AWS Global accelerator does not support ESP 50 traffic

VPN Route Propagations

VPN Static and Dynamic routing

- In case of static routing, you must pre-define the CIDR ranges on both sides of the VPN connection. If you add new network ranges on either sides, the routing changes are not propagated automatically
- In case of Dynamic routing, both the ends learns the new network changes automatically. On AWS side, the new routes are automatically propagated in the route tables.
- **AWS route table can not have more than 100 propagated routes. Hence you need to make sure you don't publish more than 100 routes from on-premises network**
- To avoid this situation, you may think to consolidate network ranges into larger CIDR range

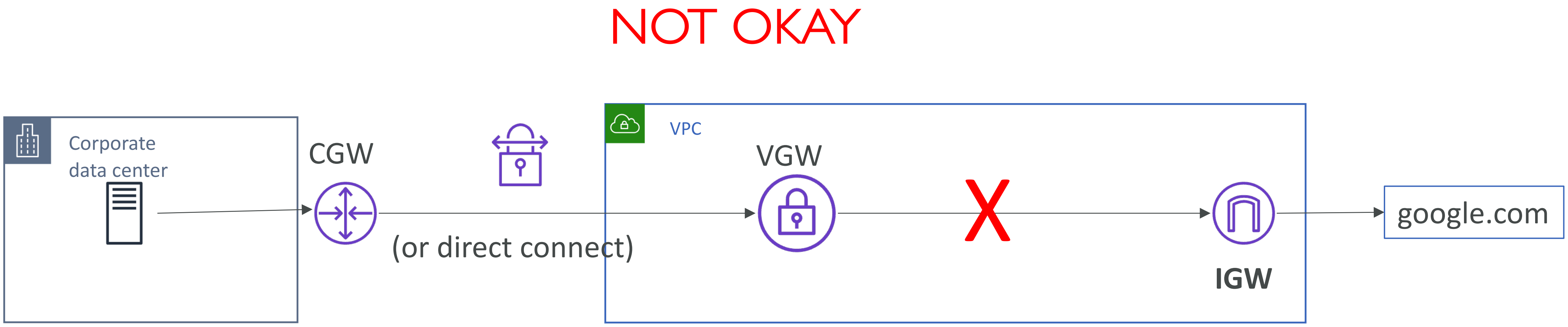
Route Propagation in Site-to-Site VPN



- 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

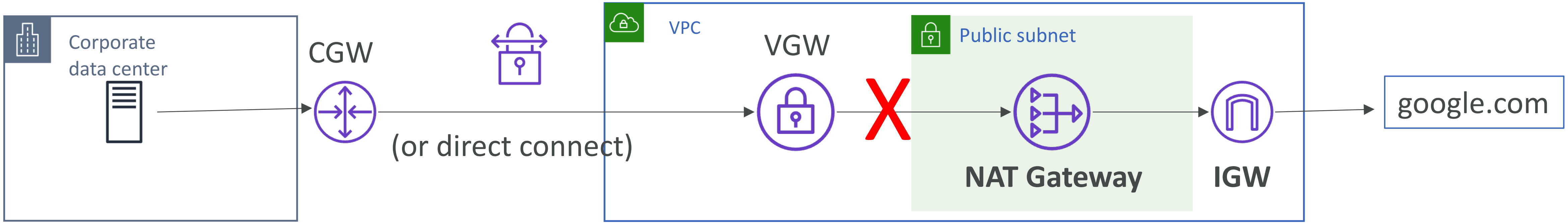
VPN Transitive Routing

Site to Site VPN and Internet Access



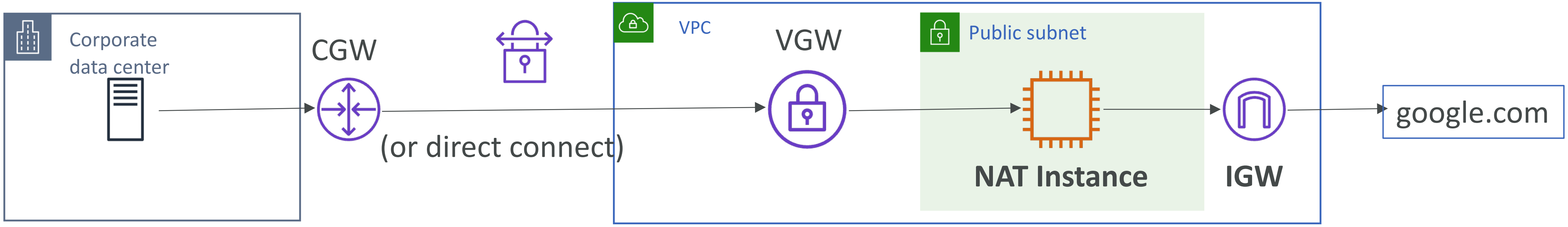
Site to Site VPN and Internet Access

NOT OKAY (blocked by NAT Gateway restrictions)

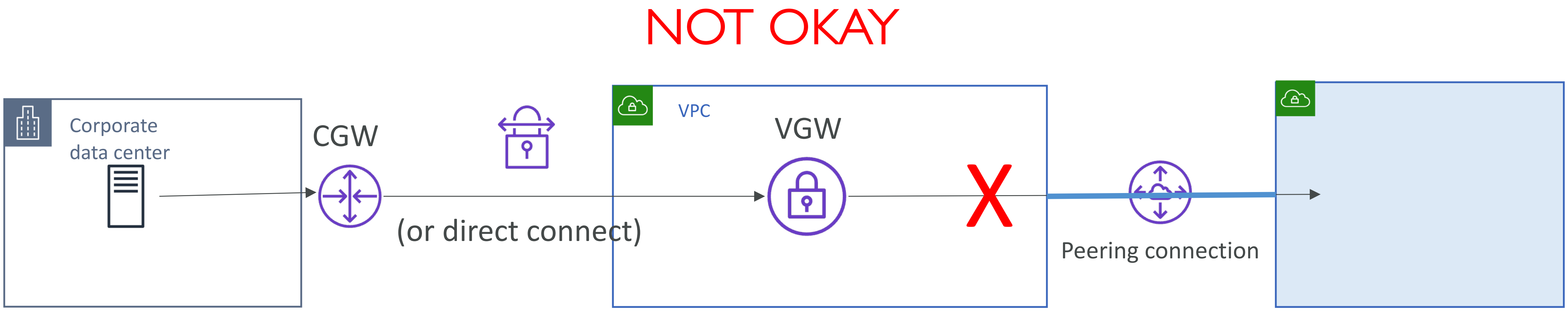


Site to Site VPN and Internet Access

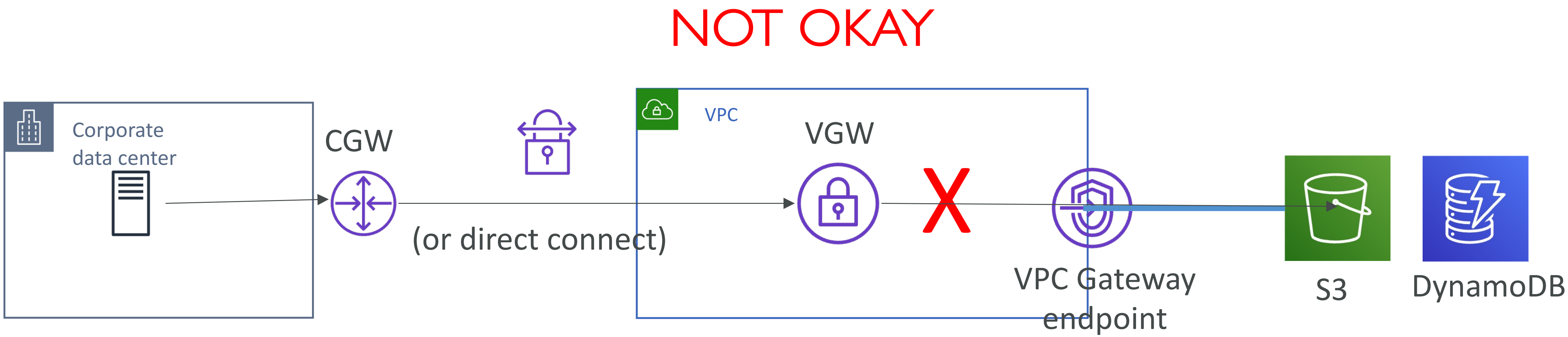
OKAY (self managed NAT Instance – more control)



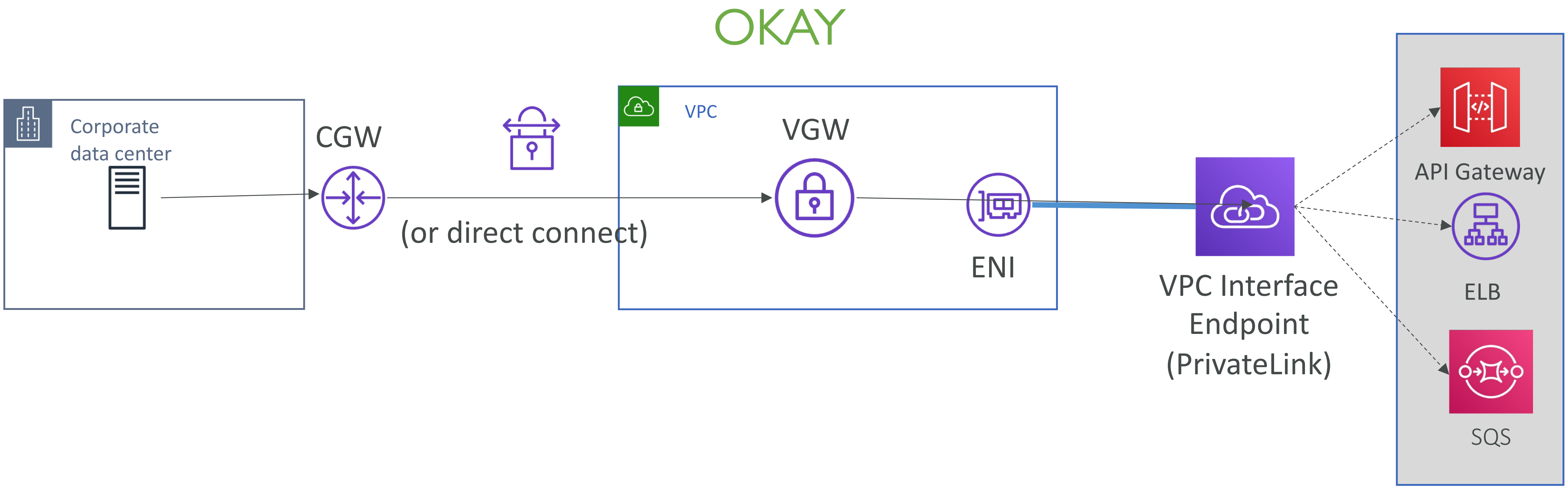
Site to Site VPN and VPC Peering



Site to Site VPN and VPC gateway endpoint

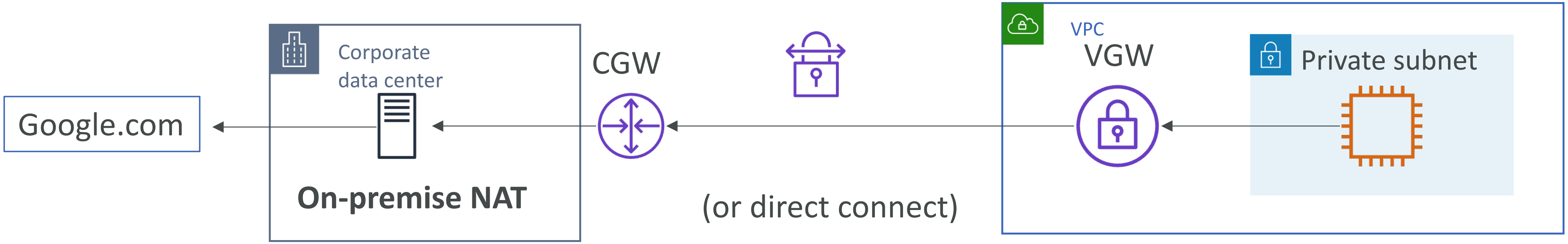


Site to Site VPN and VPC Interface endpoint



Site to Site VPN and on-premises Internet Access

OKAY (alternative to NAT Instances / Gateway)



Summary

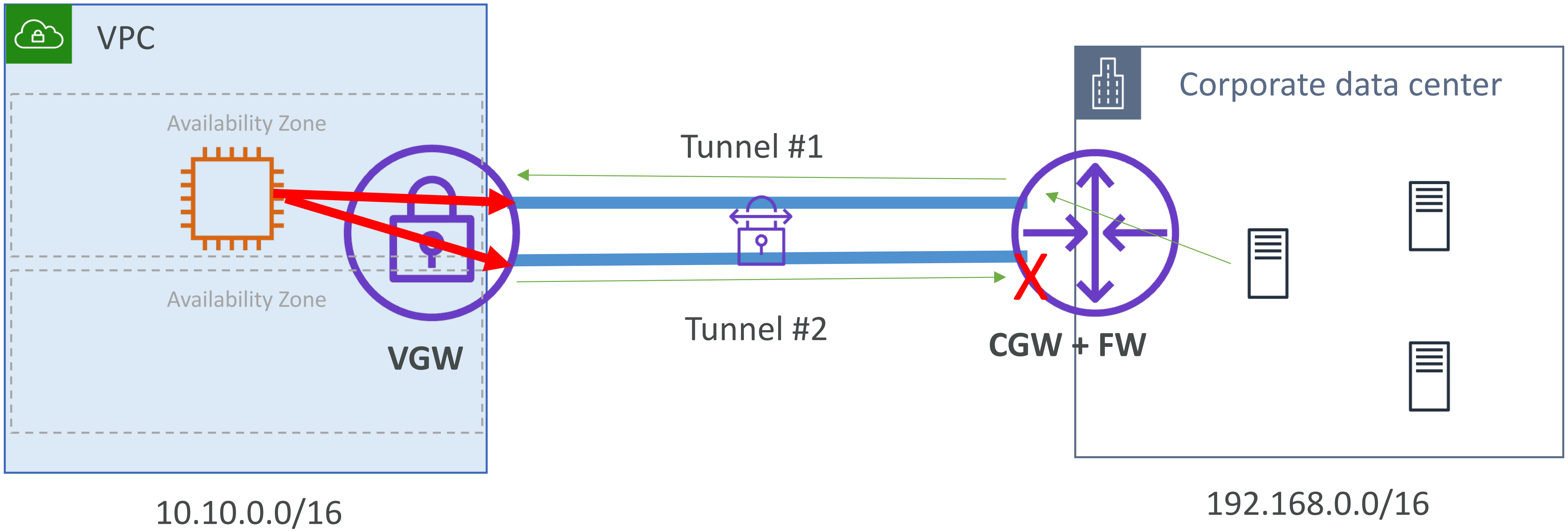
- From on-premises to AWS via Virtual Private Gateway:
  - You can not access Internet through VPC attached Internet Gateway
  - You can not access Internet through NAT Gateway in Public subnet
  - You can not access peered VPC resources through VPC peering connection via the AWS VGW
  - You can not access S3, DynamoDB via the VPC gateway endpoint
  - You can access AWS services endpoint e.g API gateway, SQS and customer endpoint services (powered by Privatelink) via VPC interface endpoint
  - You can access Internet through NAT EC2 instance in Public subnet
- From AWS to on-premises via customer gateway
  - You can access Internet and other network endpoints based on routing rules setup on CGW in on-premises network

VPN Tunnels and Routing

Active/Active and Active/Passive

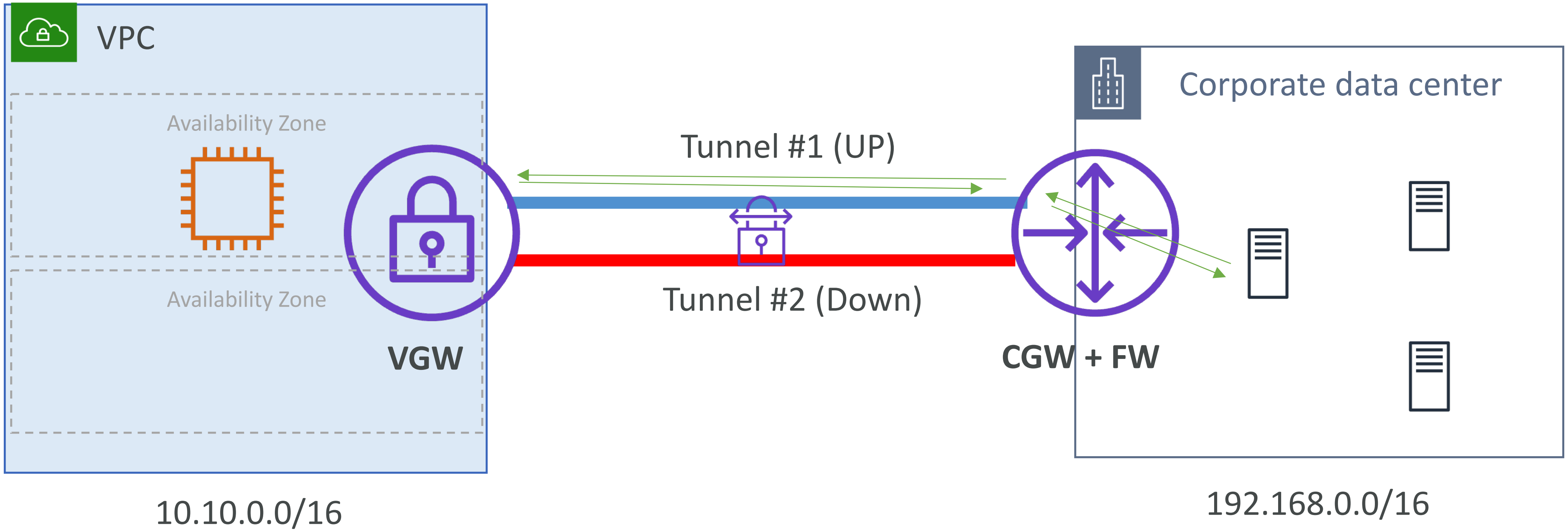
Static Routing - Active/Active Tunnels

- Active/Active tunnel may cause **Asymmetric routing** and Asymmetric routing should be enabled on the CGW
- For traffic originating from AWS, one of the tunnel is selected randomly



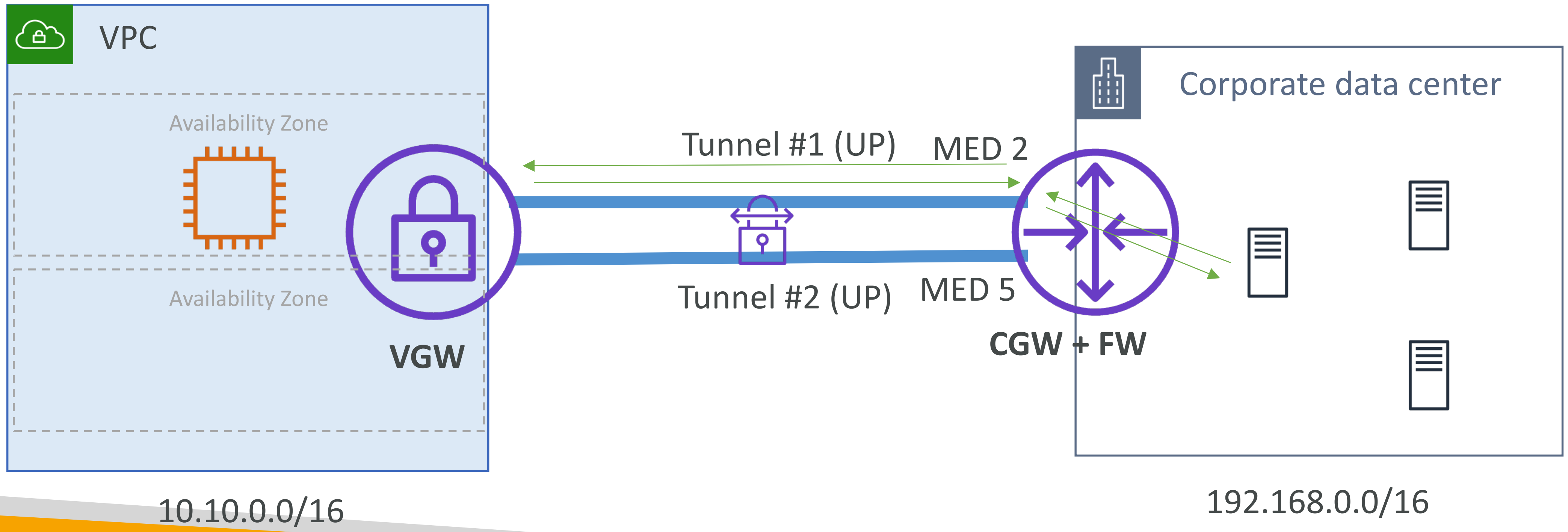
Static Routing - Active/Passive Tunnels

- When only one tunnel is UP, its used for traffic in both the directions
- In case one tunnel goes down, another tunnel should be brought up from CGW end



Dynamic Routing - Active/Active Tunnels

- Advertise a more specific prefix on the tunnel
- For matching prefixes where each VPN connection uses BGP, use ASPATH
- When the ASPATHs are the same length, use multi-exit discriminators (MEDs)
- The path with the lowest MED value is preferred.



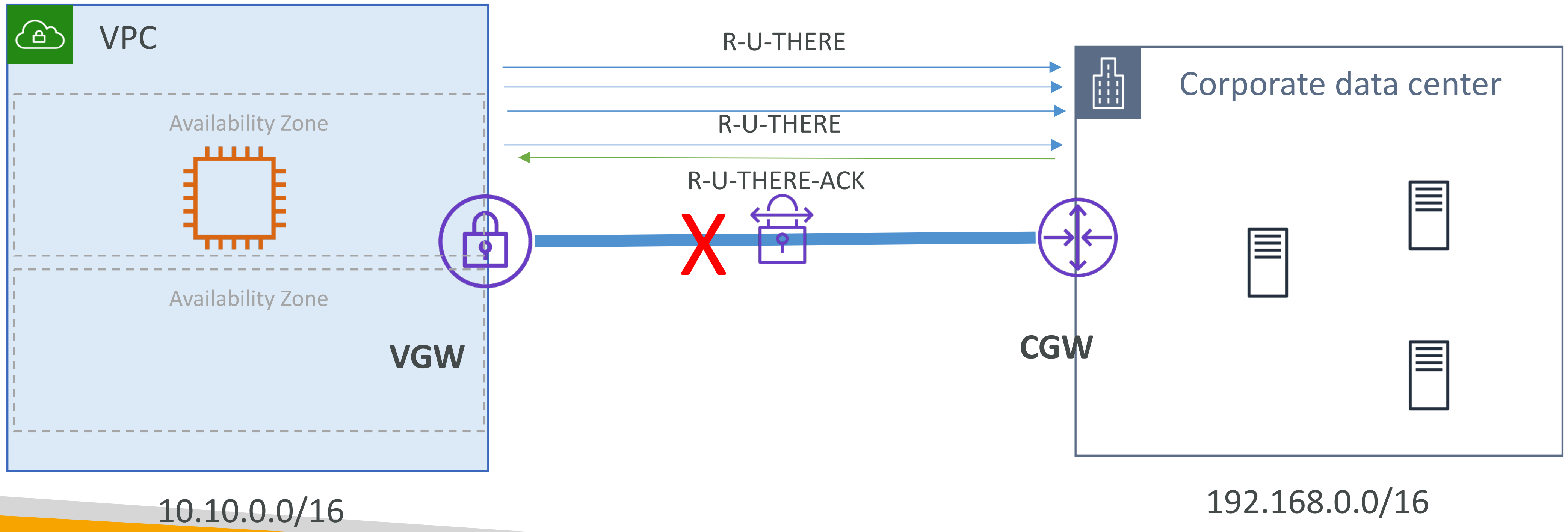
Summary

- In case of static routing active-active tunnel mode
  - AWS randomly select the tunnel for traffic originating from AWS.
  - Make sure that Asymmetric routing is enabled on CGW
- In case of static routing active-passive tunnel mode
  - The tunnel which is UP is used for the traffic in both the directions
- In case of dynamic routing (BGP) active-active tunnel mode you can influence the tunnel preference by
  - Advertising more specific prefix over preferred tunnel
  - Advertising shorter ASPATH over the preferred tunnel
  - Setting lower MED values over the preferred tunnel

VPN Dead Peer Detection (DPD)

Dead peer detection

- Dead Peer Detection (DPD) is a method to detect liveliness of IPSec VPN connection
- VPN peers can decide during "IKE Phase 1" if they want to use DPD
- If DPD is enabled AWS continuously (every 10 sec) sends DPD (R-U-THERE) message to customer gateway and waits for the R-U-THERE-ACK. If there is no response to consecutive 3 requests, then DPD times out.



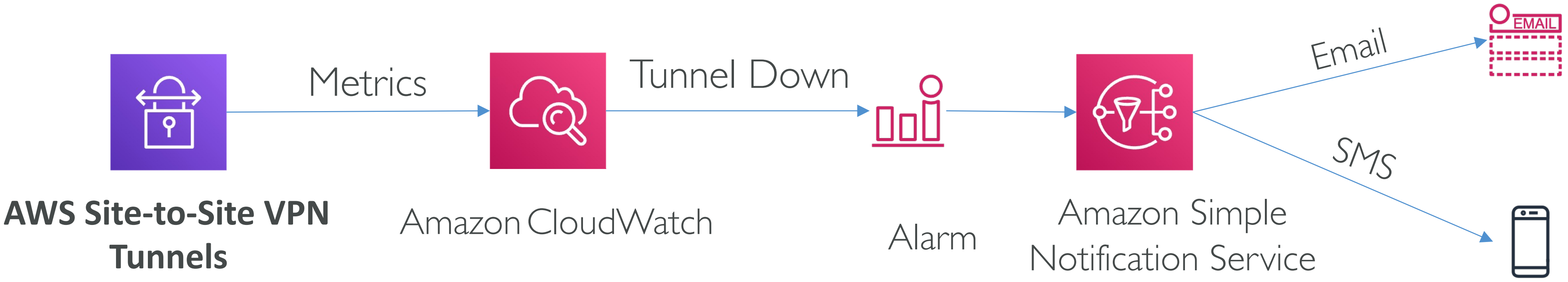
Dead Peer Detection

- By default, when DPD occurs, the gateways delete the security associations. During this process, the alternate IPsec tunnel is used if possible.
- Default DPD timeout value is 30 sec which can be set higher than 30 seconds.
- DPD uses UDP 500 or UDP 4500 to send DPD messages
- DPD timeout actions:
  - Clear (default action) - End the IPSec IKE session, stop the tunnel and clear the routes
  - Restart - AWS Restarts the IKE Phase 1
  - None – Take no action
- Customer router must support DPD when using Dynamic Routing (BGP)
- VPN tunnel can still be terminated due to inactivity or idle connection. You can set up appropriate idle timeout or setup a host which sends ICMP (ping) requests every say 5-10 seconds

VPN Monitoring

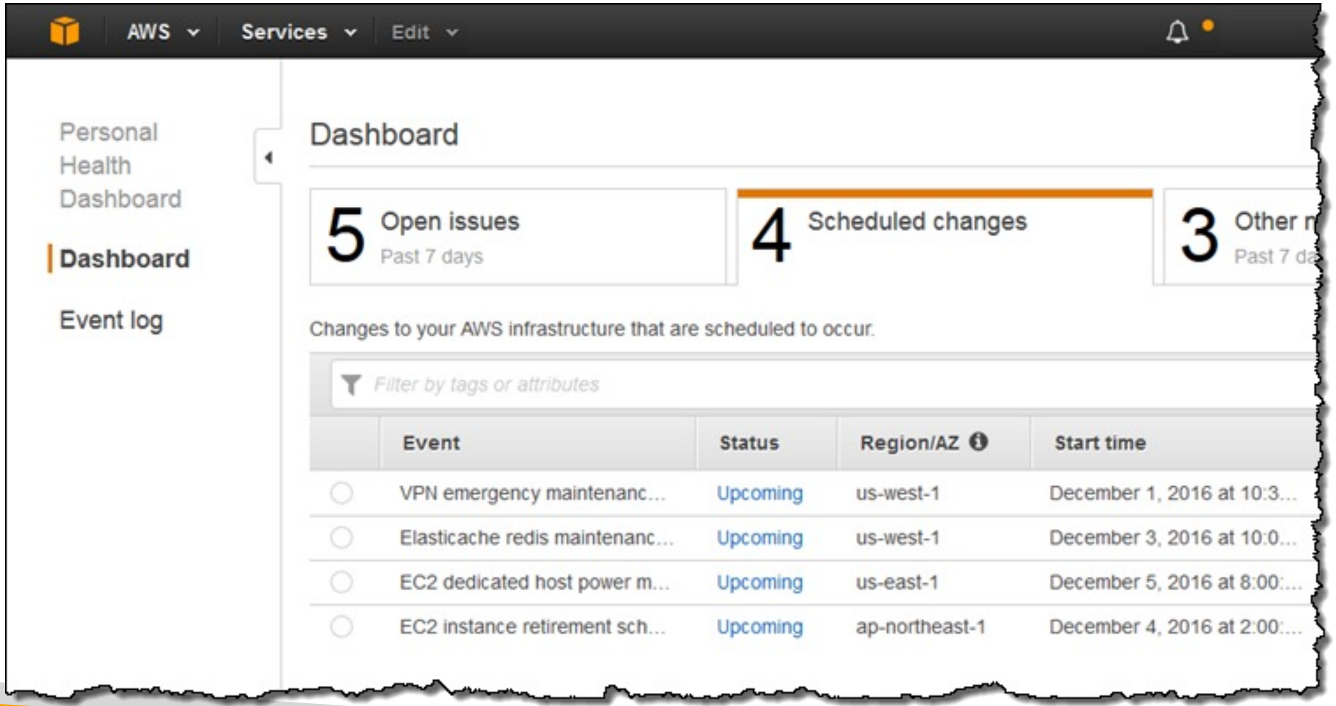
VPN Monitoring with CloudWatch

- **TunnelState:** The state of the tunnel. 0 indicates DOWN and 1 indicates UP. Value between 0 and 1 indicates that at least 1 tunnel is not UP.
- **TunnelDataIn:** The bytes received through the VPN tunnel
- **TunnelDataOut:** The bytes sent through the VPN tunnel



VPN Monitoring with Health Dashboard

- AWS Site-to-Site VPN automatically sends notifications to the AWS Personal Health Dashboard (PHD)
- Tunnel endpoint replacement notification
- Single Tunnel VPN notification (when one of the tunnel is down for more than one hour in a day)



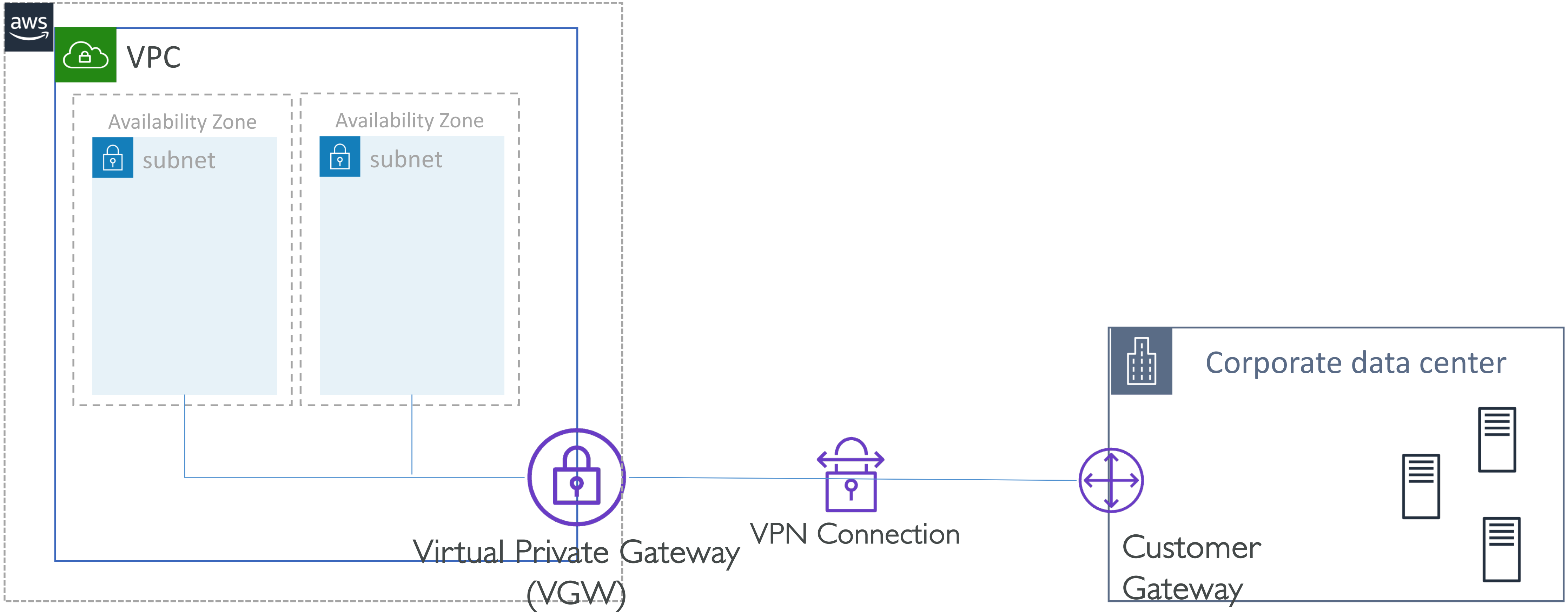
AWS Site-to-Site VPN architectures

AWS Site-to-Site VPN architectures

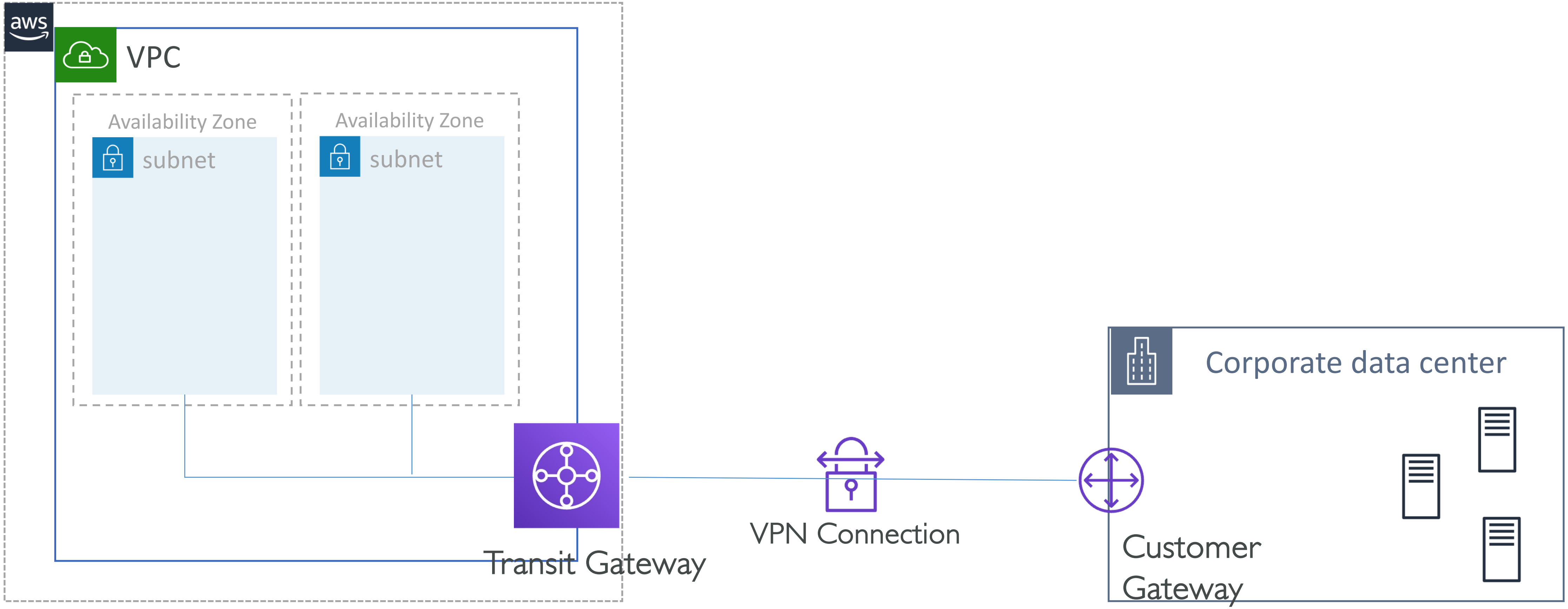
- Single Site-to-Site VPN connection
  - With Virtual Private Gateway (VGW)
  - With Transit Gateway (TGW)
- Multiple Site-to-Site VPN connections to branch offices
- Redundant VPN connections for High Availability

Refer: https://docs.aws.amazon.com/vpn/latest/s2svpn/s2s-vpn-user-guide.pdf

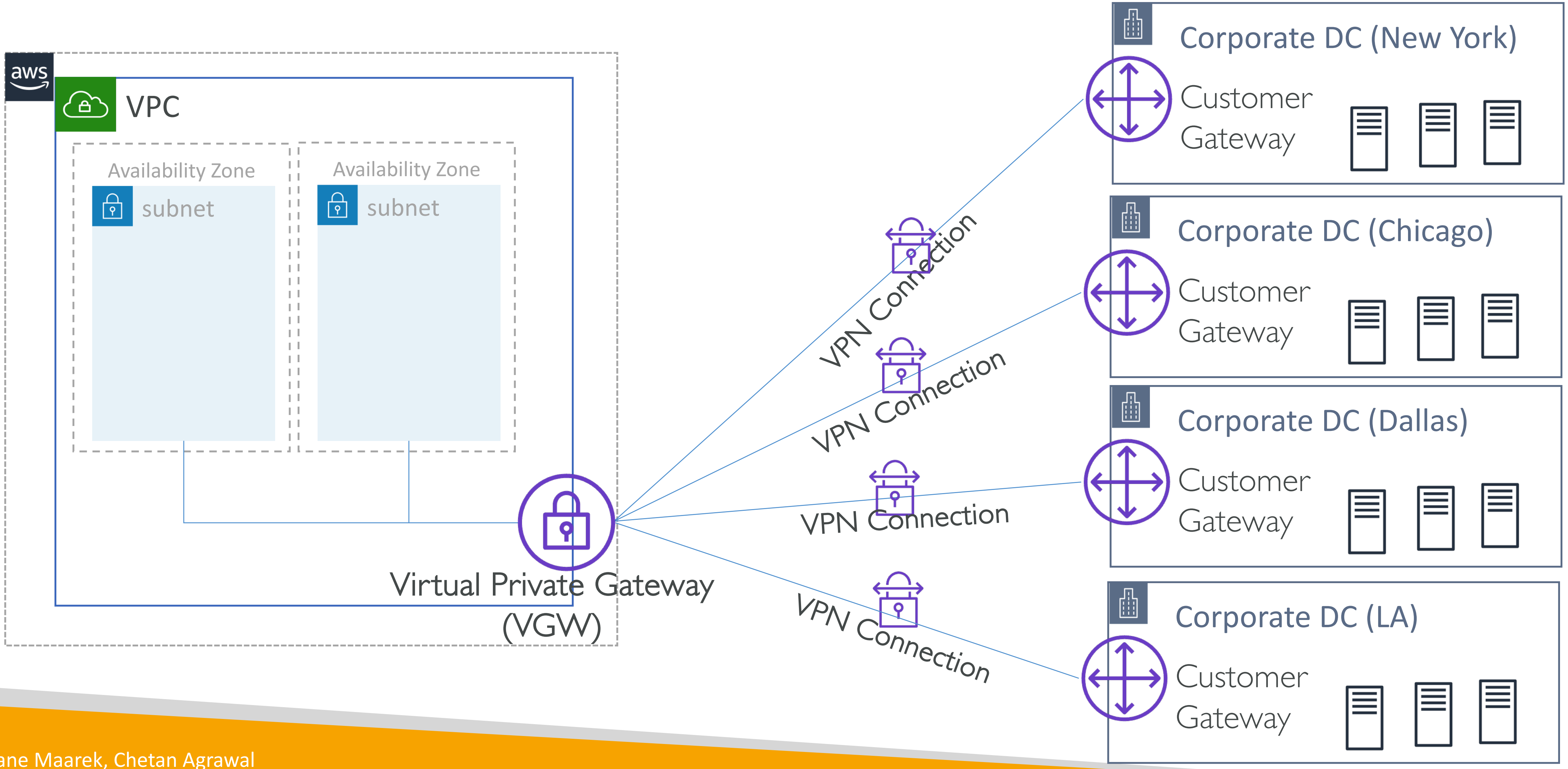
Single Site-to-Site VPN Connection using VGW



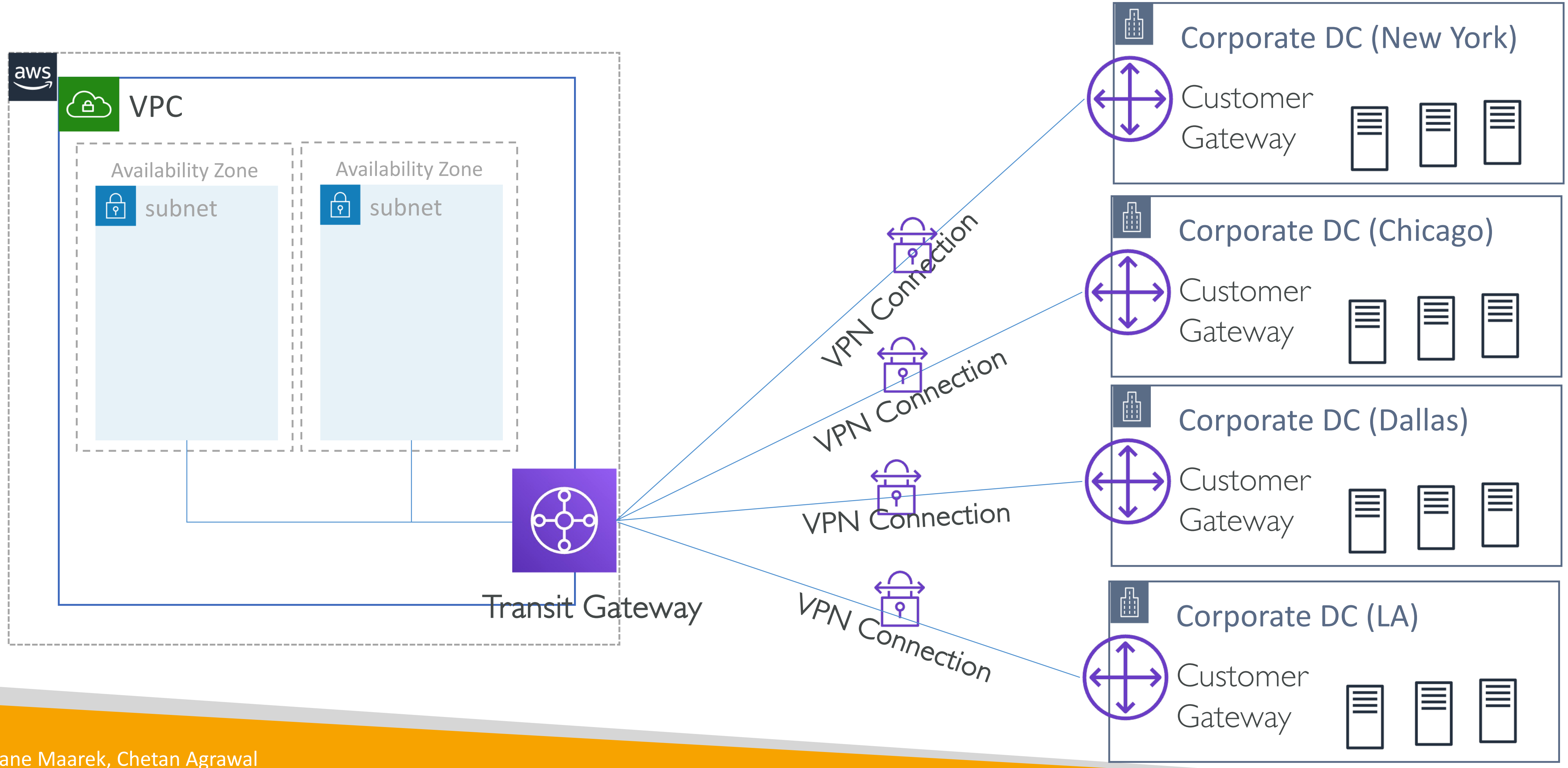
Single Site-to-Site VPN Connection using Transit Gateway (TGW)



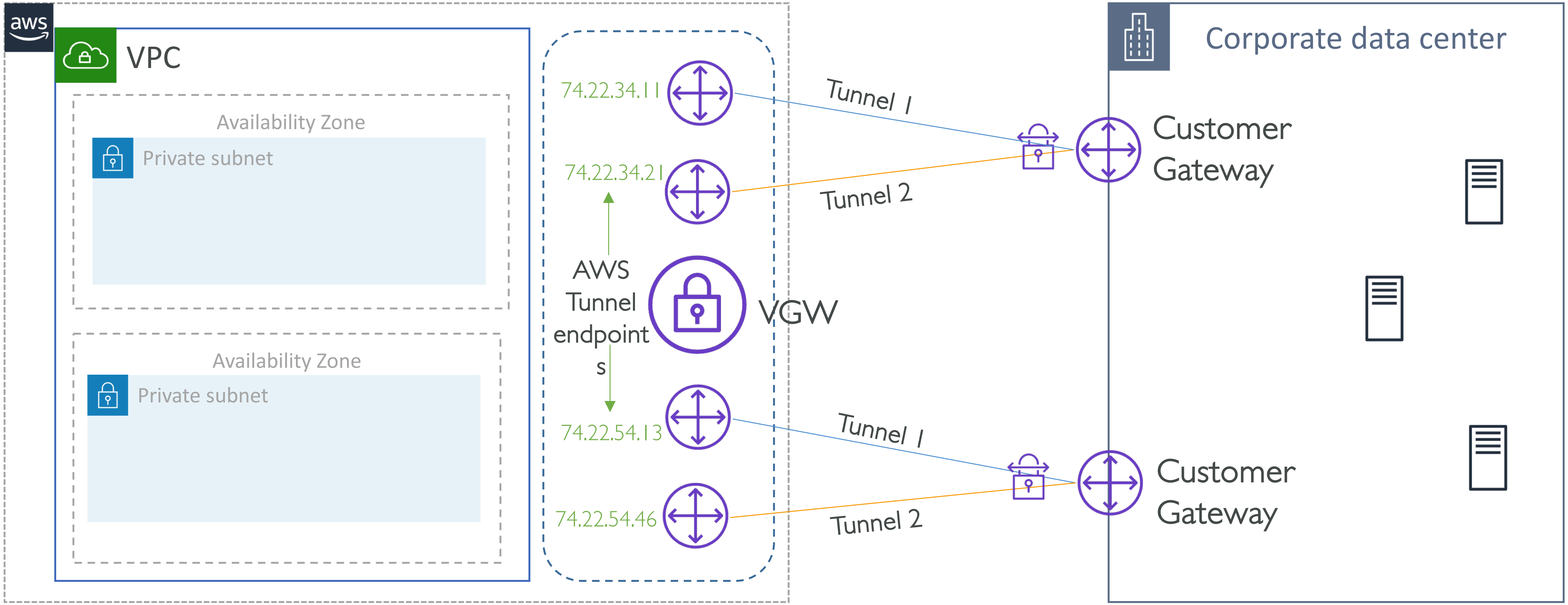
Multiple Site-to-Site VPN Connections using VGW



Multiple Site-to-Site VPN Connections using TGW

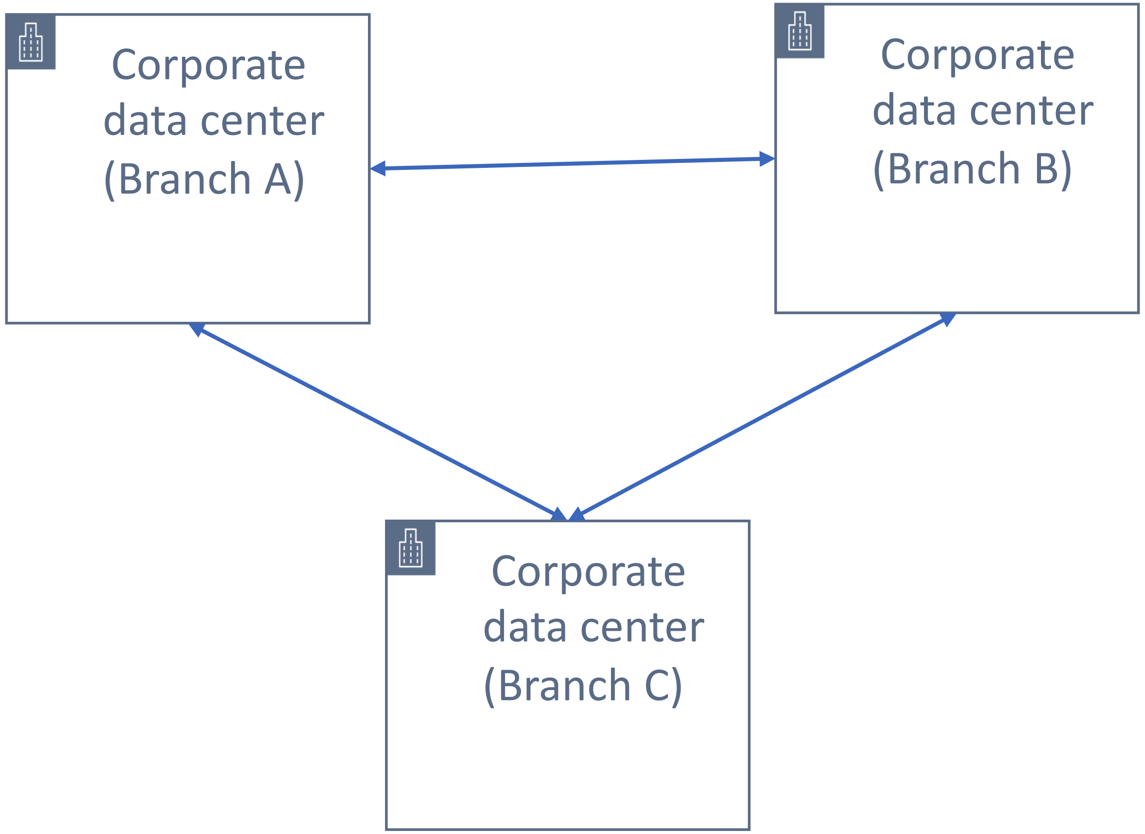


Redundant VPN connections for HA



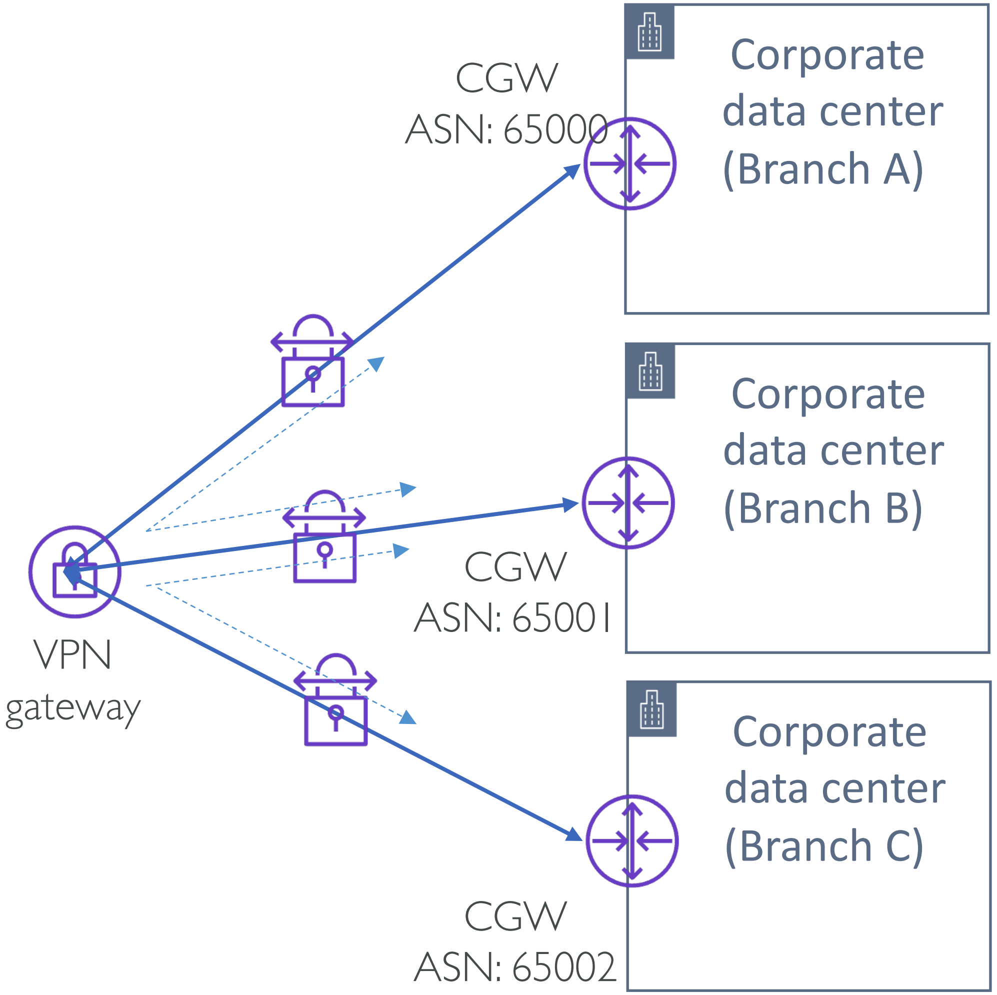
AWS Site-to-Site VPN Cloud Hub

VPN CloudHub – Routing between multiple customer sites



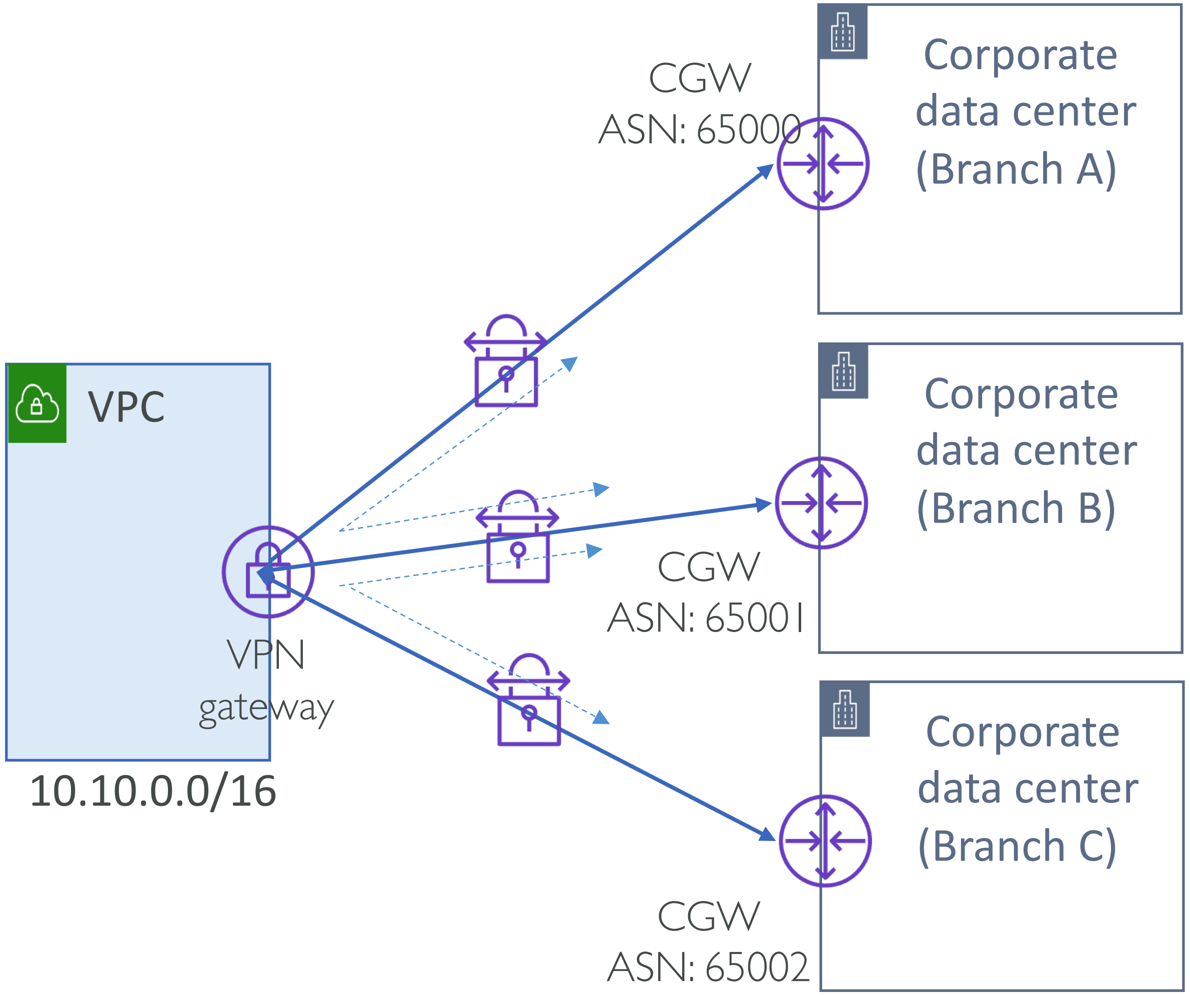
VPN CloudHub – Routing between multiple customer sites

- Using VPN Gateway in detached mode
- Each customer gateway must have unique BGP ASN with dynamic routing
- Sites must not have overlapping IP ranges
- Connect up to 10 Customer Gateways
- Can serve as failover connection between on-premises locations



VPN CloudHub – Routing between multiple customer sites

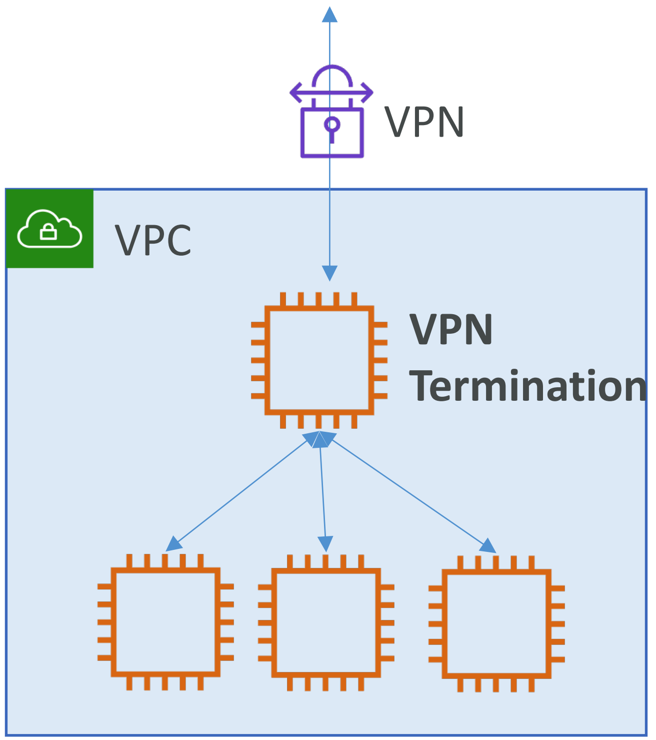
- VPN gateway can also be attached to VPC to enable communication



Amazon EC2 based VPN

VPN termination on EC2

EC2 based VPN



Why would you do that?

- You want to use different VPN protocol than IPSec e.g General Routing Encapsulation (GRE) or Dynamic MultiPoint VPN (DMVPN)
- You are using overlapping CIDRs
- You want to enable transitive routing on AWS side
- You want to have special features on VPN termination endpoints such as Advanced Threat Protection
- When bandwidth required > 1.25 Gbps

Considerations for EC2 based VPN

EC2 based VPN

- To enable routing of traffic, make sure that the **source/destination check is disabled on the VPN termination EC2 instance** and IP forwarding is enabled at the operating system level.
- In case of hardware failure, EC2 will be recovered automatically if EC2 auto recovery has been setup using CloudWatch status check
- Bandwidth limitations between EC2 instances:
  - Up to 5 Gbps outside VPC
- AWS does not provide or maintain third party software VPN appliances
  - Partner VPN Solutions on AWS Marketpalce: Cisco, Juniper, Palo Alto You may get a highly available & self-healing setup with their solution

Considerations for EC2 based VPN

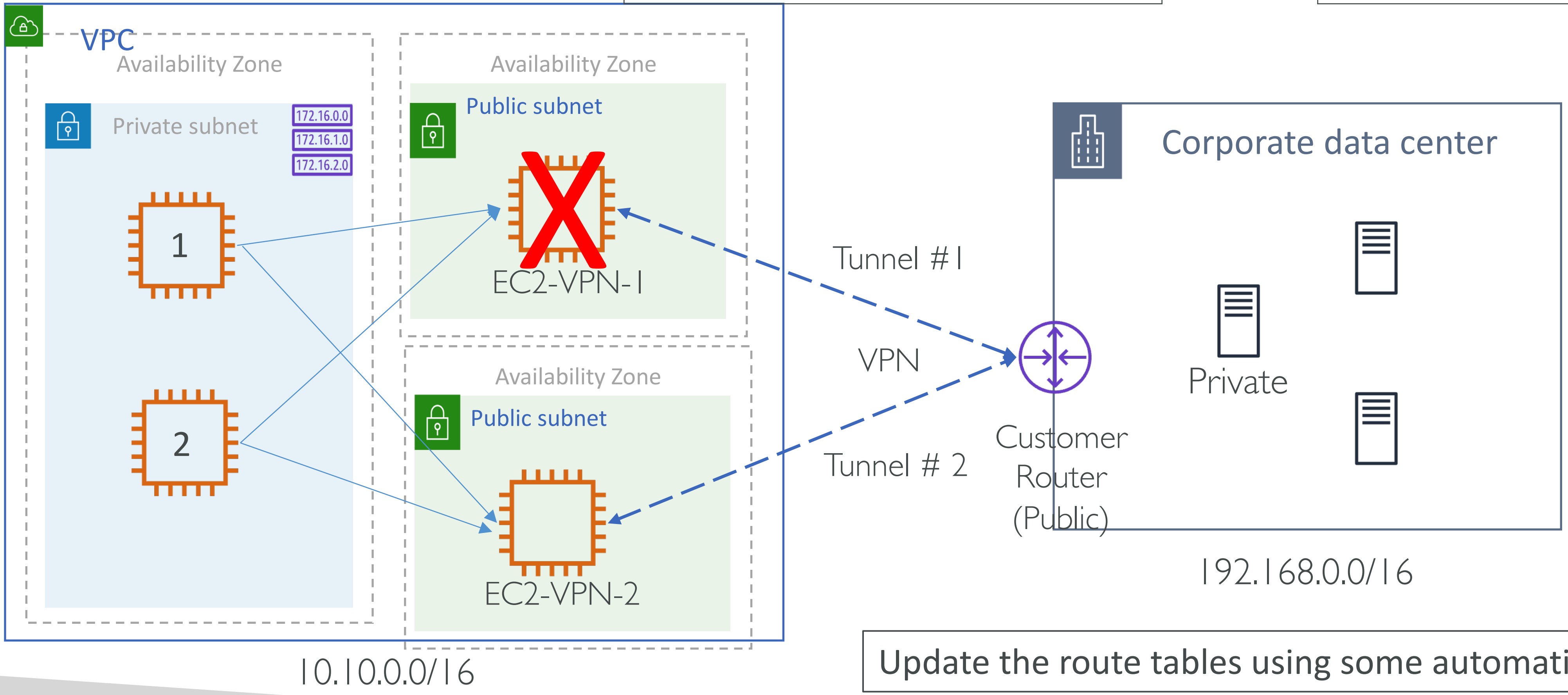
- Vertical scaling:
  - Increase instance size for increased performance
- Horizontal scaling
  - You can have the architecture which provides horizontal scaling

HA solution with EC2 based VPN

EC2 based VPN

Network	Next Hop
192.168.0.0/16	EC2-VPN-1

Network	Next Hop
192.168.0.0/16	EC2-VPN-2



Update the route tables using some automation

Considerations for EC2 based VPN

- Vertical scaling:
  - Increase instance size for increased performance
- Horizontal scaling
  - You can have the architecture which provides horizontal scaling
- IPsec as a protocol doesn't function through a Network Load Balancer due to non-Transmission Control Protocol (TCP) (IPSec protocol 50)

VPN scenarios

VPN design pattern scenarios

1. On-premises network needs to connect to AWS VPC with moderate throughput requirement (up to 1 Gbps)

Solution:

- Use AWS managed VPN (VGW)
- VGW supports bandwidth of 1.25 Gbps.
- Multiple VPN connections to the same Virtual Private Gateway are bound by an aggregate throughput limit of1.25 Gbps.
- For AWS Direct Connect connection on a Virtual Private Gateway, the throughput is bound by the Direct Connect physical port itself.

VPN design pattern scenarios

2. on-premises network needs to connect to AWS VPC with very high throughput requirement (> 2 Gbps)

Solutions:

1. Direct connect should be the first choice.
2. Terminate VPN on EC2 instance. You should also use multiple EC2 instances for high availability and aggregated throughput.

VPN design pattern scenarios

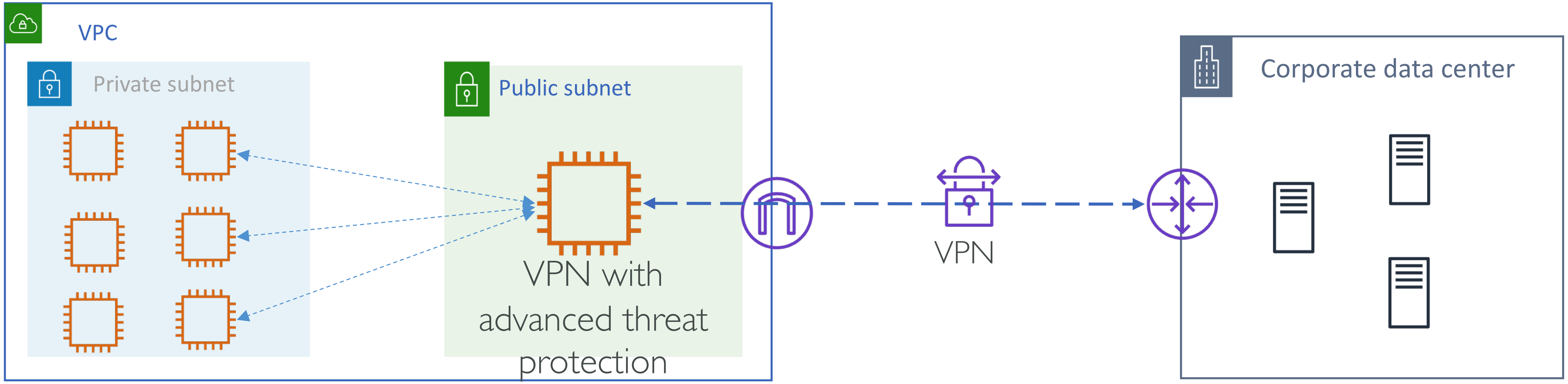
3. You want to configure VPN using non-IPSec protocol

Solution: Terminate VPN on EC2 instance as it would support all possible protocols like DMVPN and GRE.

VPN design pattern scenarios

4. You want to have advanced threat protection on your VPN termination endpoint

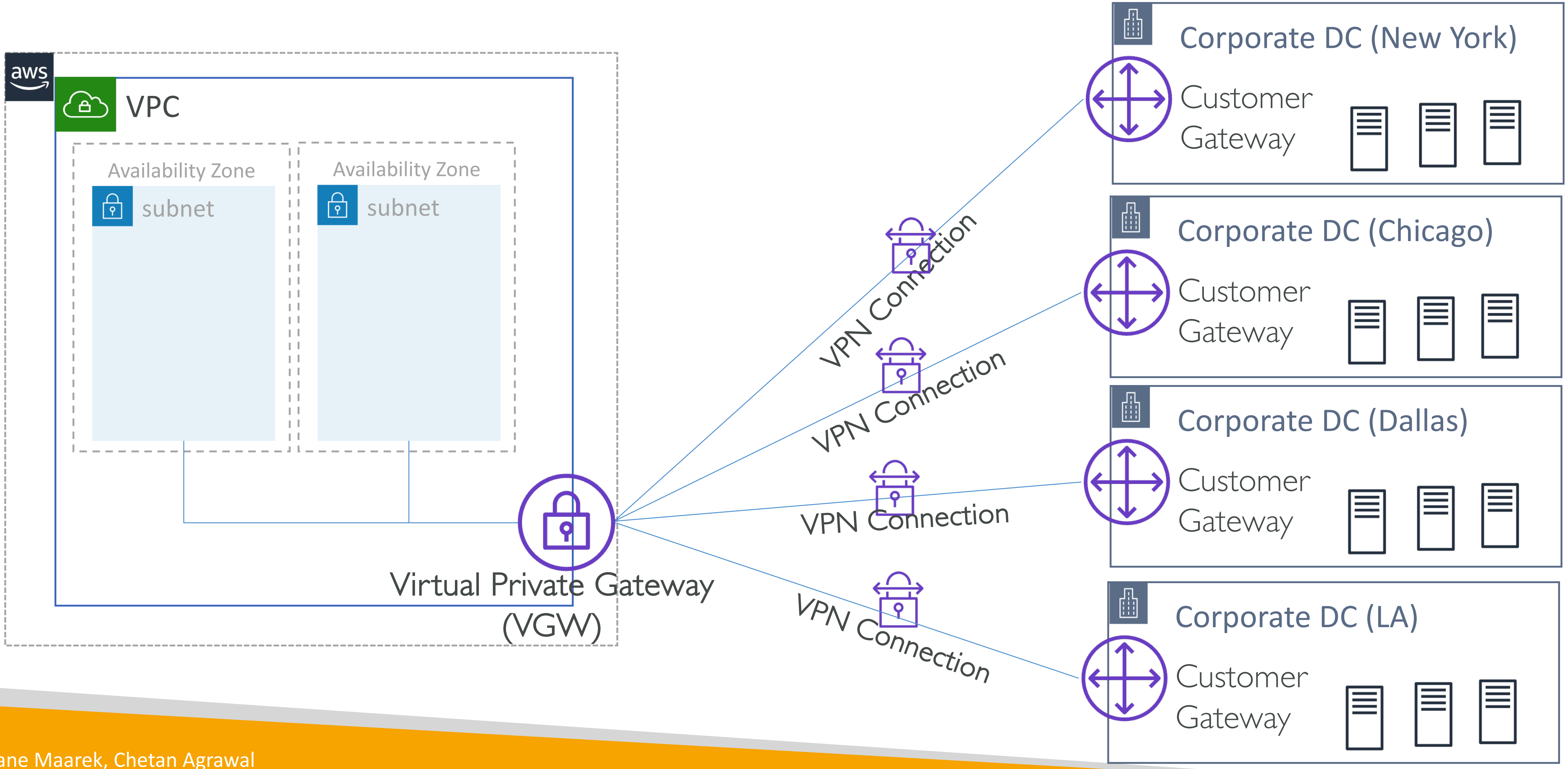
Solution: Terminate VPN on EC2 instance and install required threat protection software on EC2. You may also look at AWS Marketplace EC2 based solution.



Transit VPC

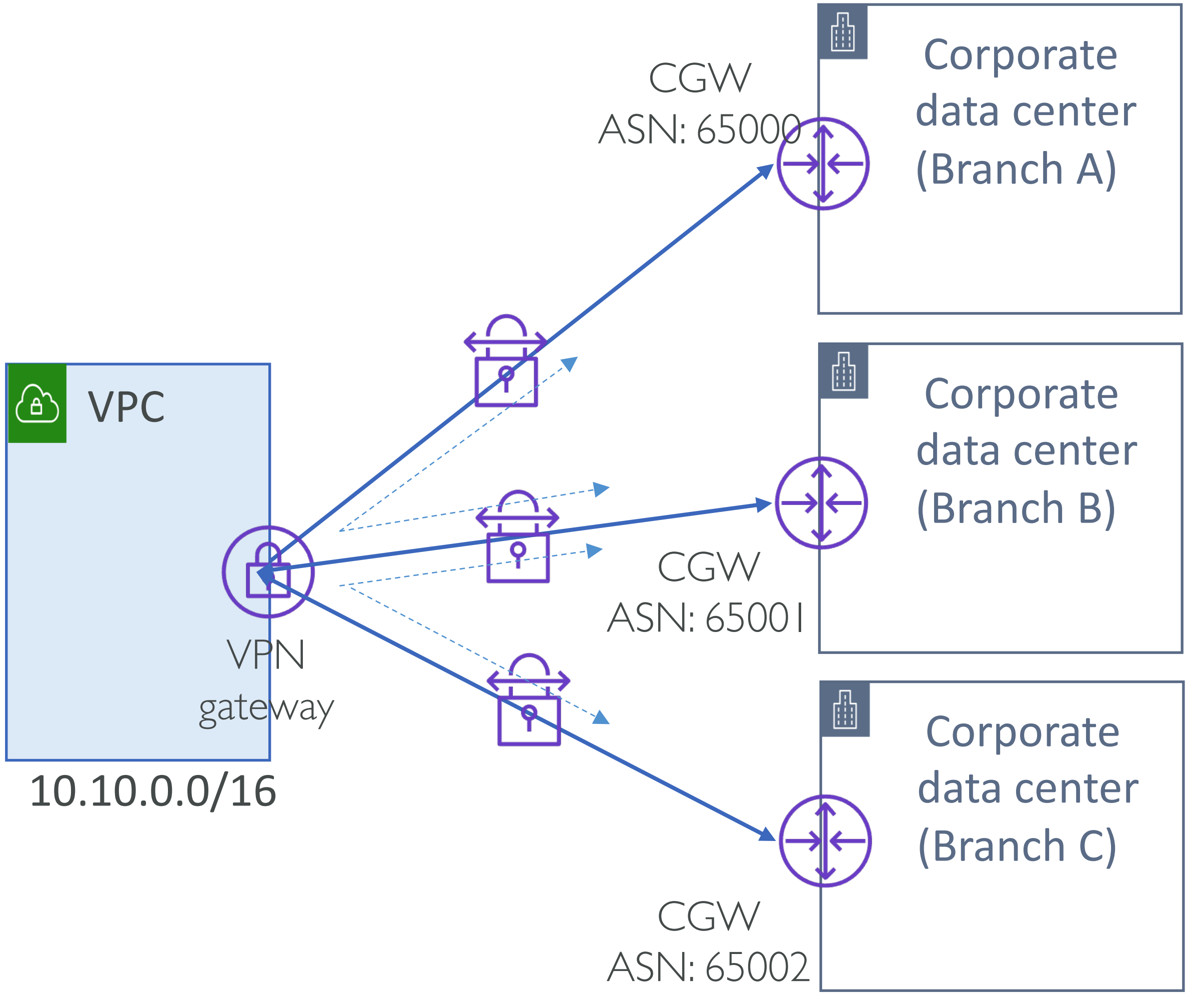
VPN architectures that we already looked at ..

Multiple Site-to-Site VPN Connections using VGW

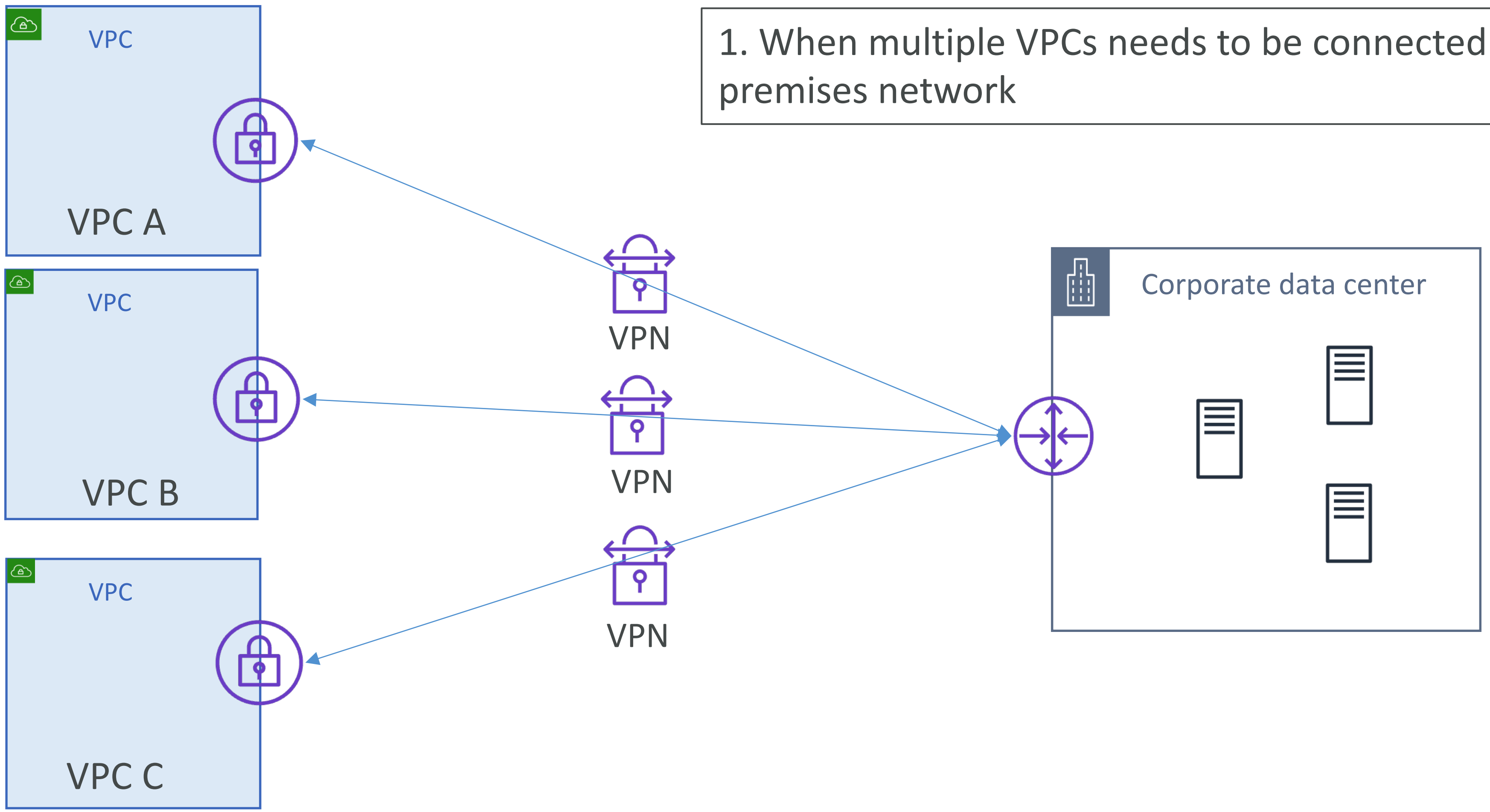


VPN CloudHub – Routing between multiple customer sites

- VPN gateway can also be attached to VPC to enable communication



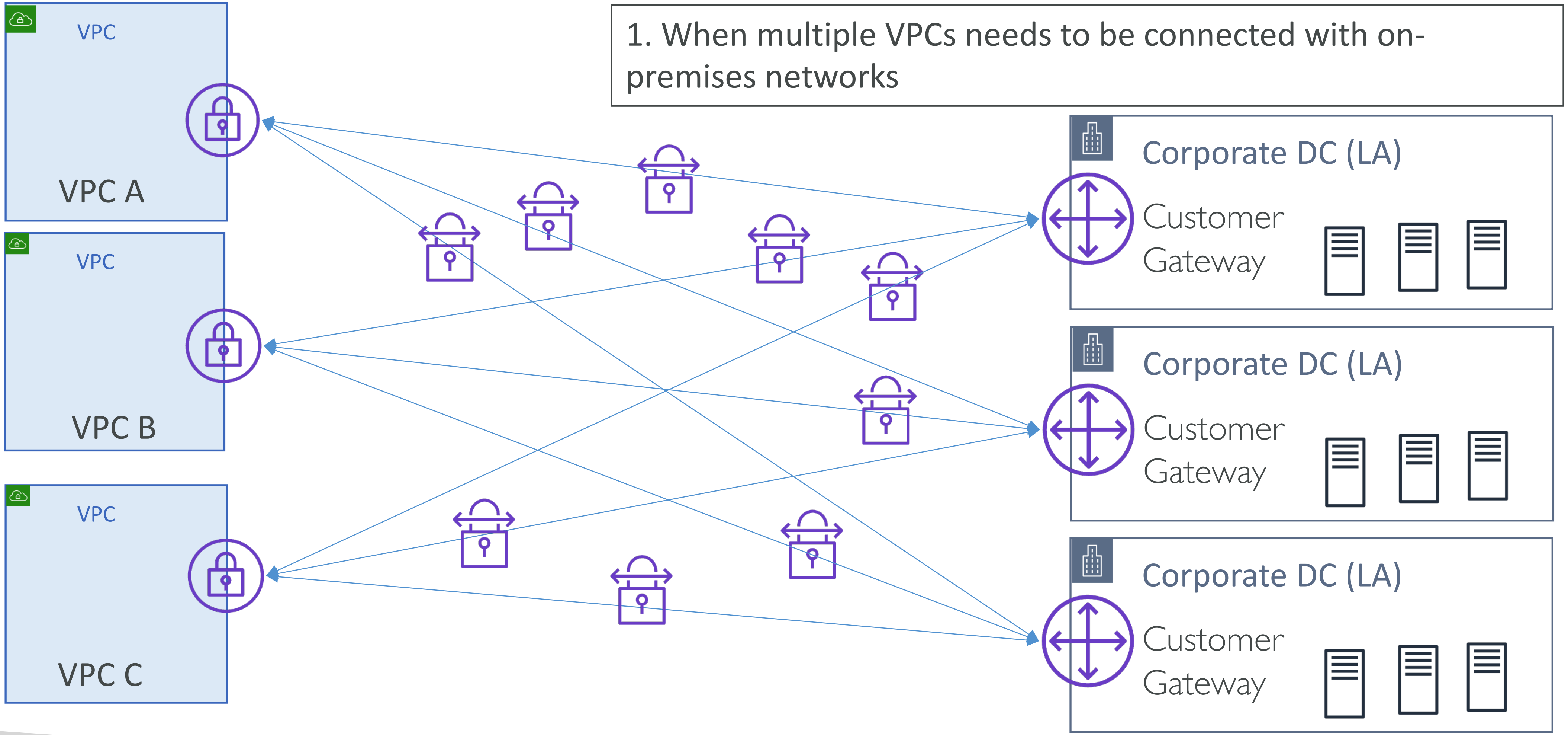
Transit VPC – What is it and why it is required?



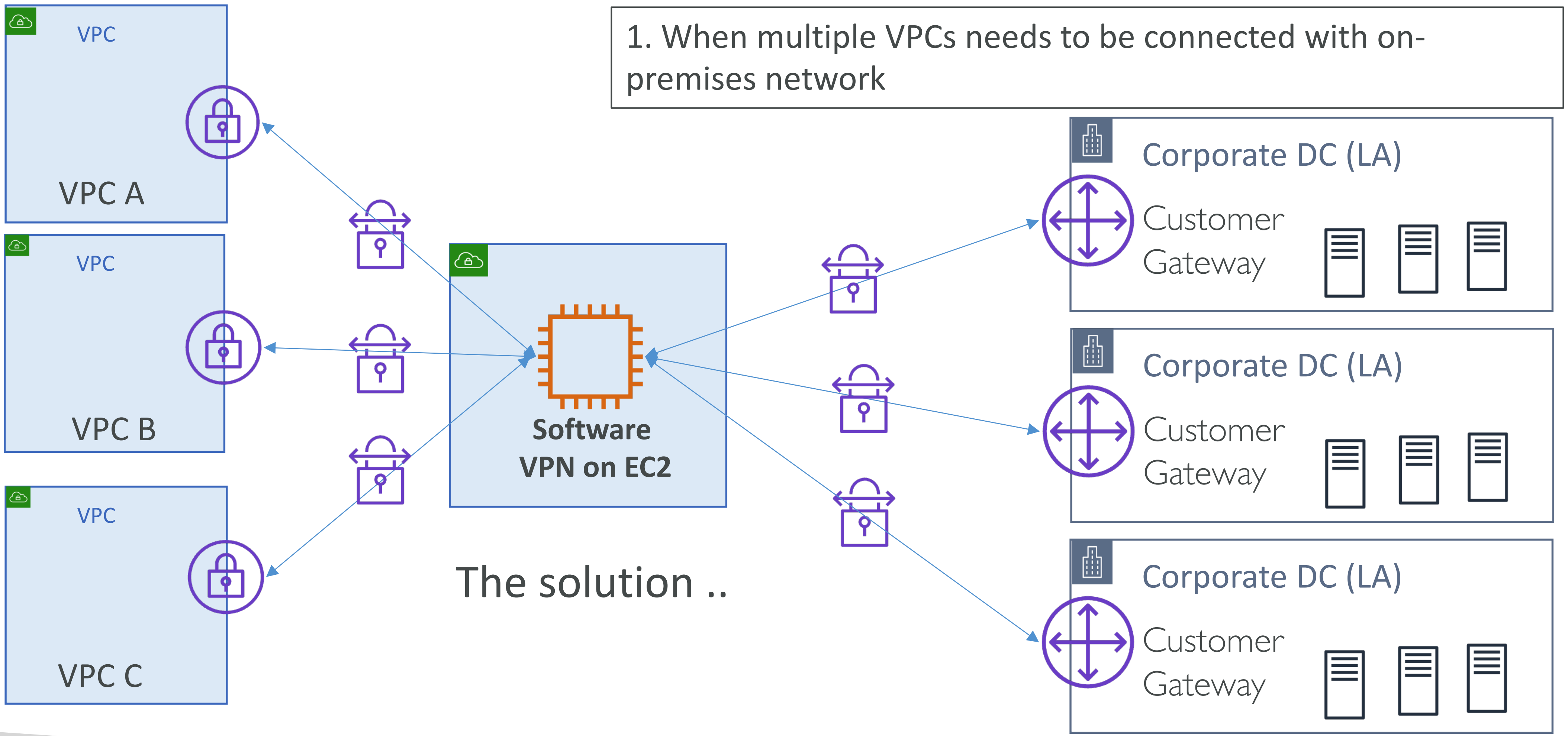
1. When multiple VPCs needs to be connected with on-premises network

Transit VPC – What is it and why it is required?

1. When multiple VPCs needs to be connected with on-premises networks



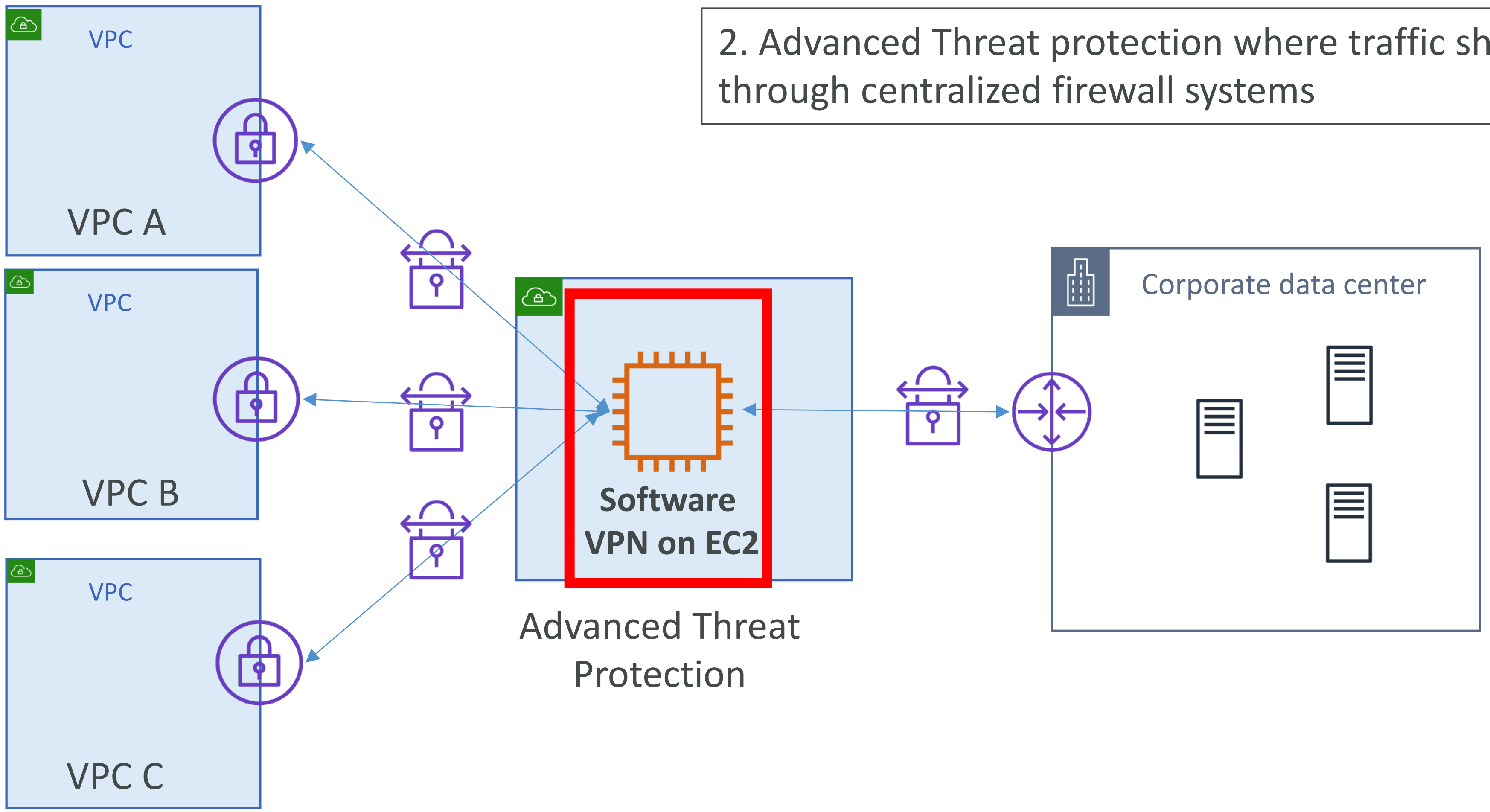
Transit VPC – What is it and why it is required?



The solution ..

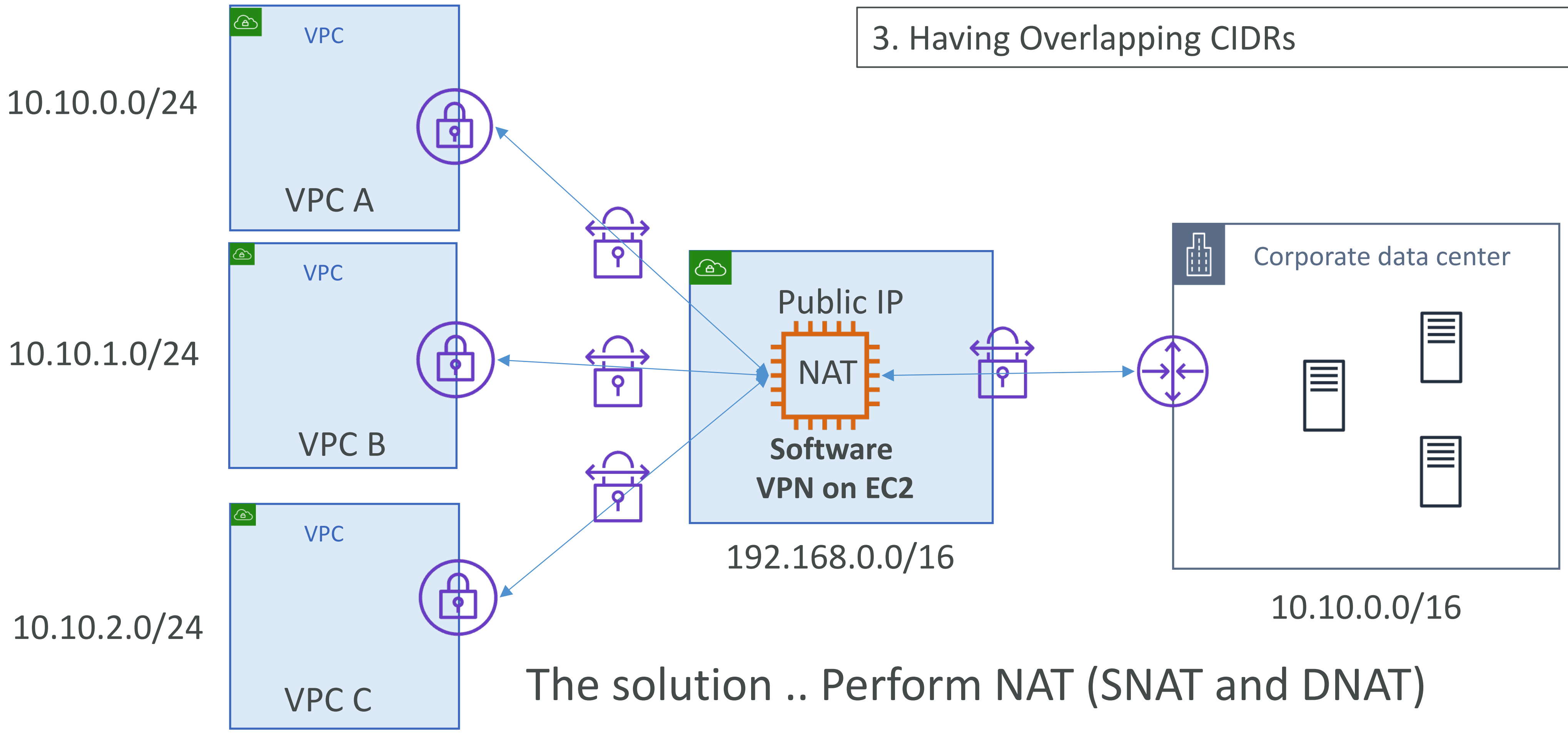
Transit VPC – What is it and why it is required?

2. Advanced Threat protection where traffic should be routed through centralized firewall systems



Transit VPC – What is it and why it is required?

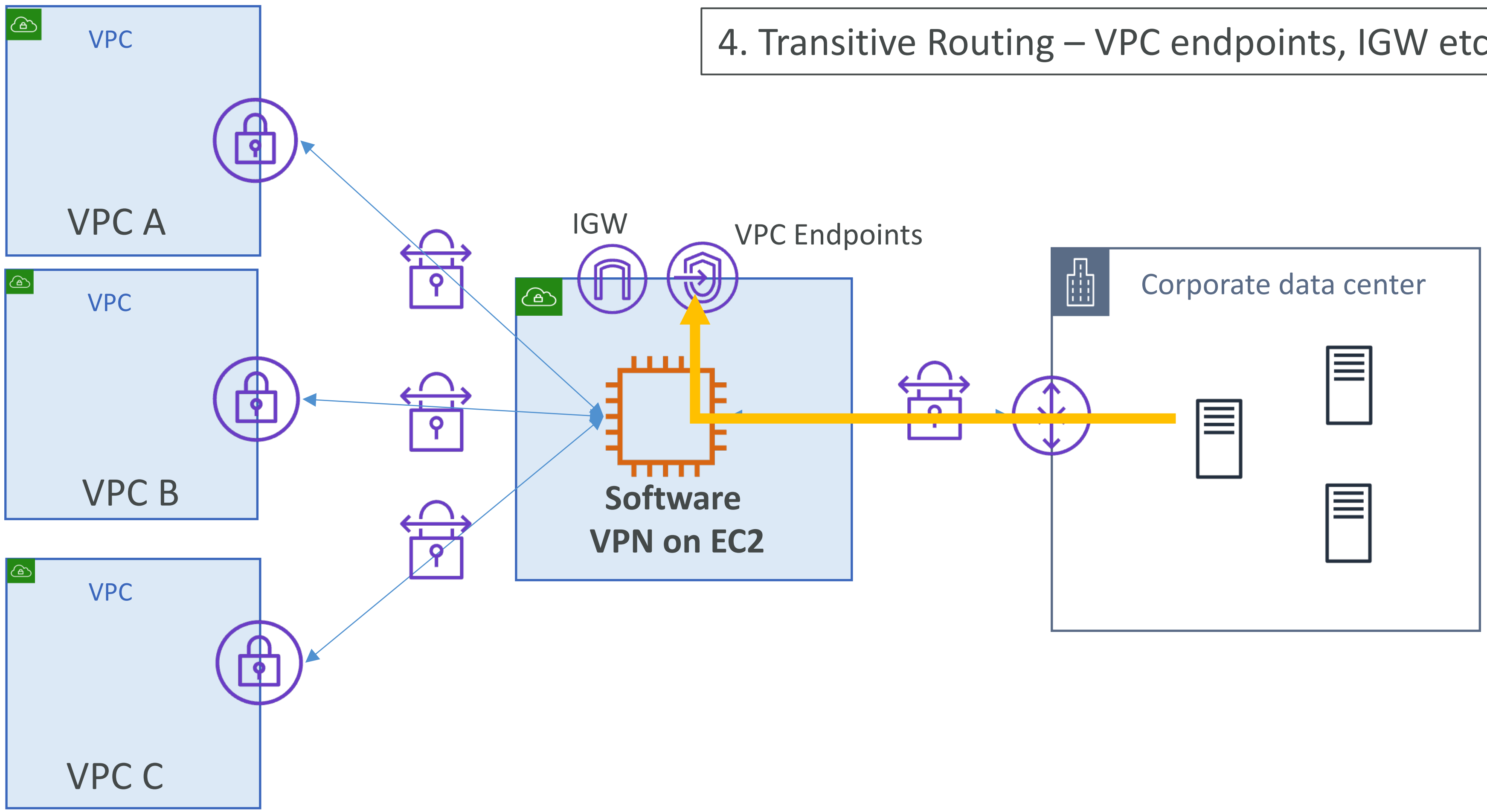
3. Having Overlapping CIDRs



The solution .. Perform NAT (SNAT and DNAT)

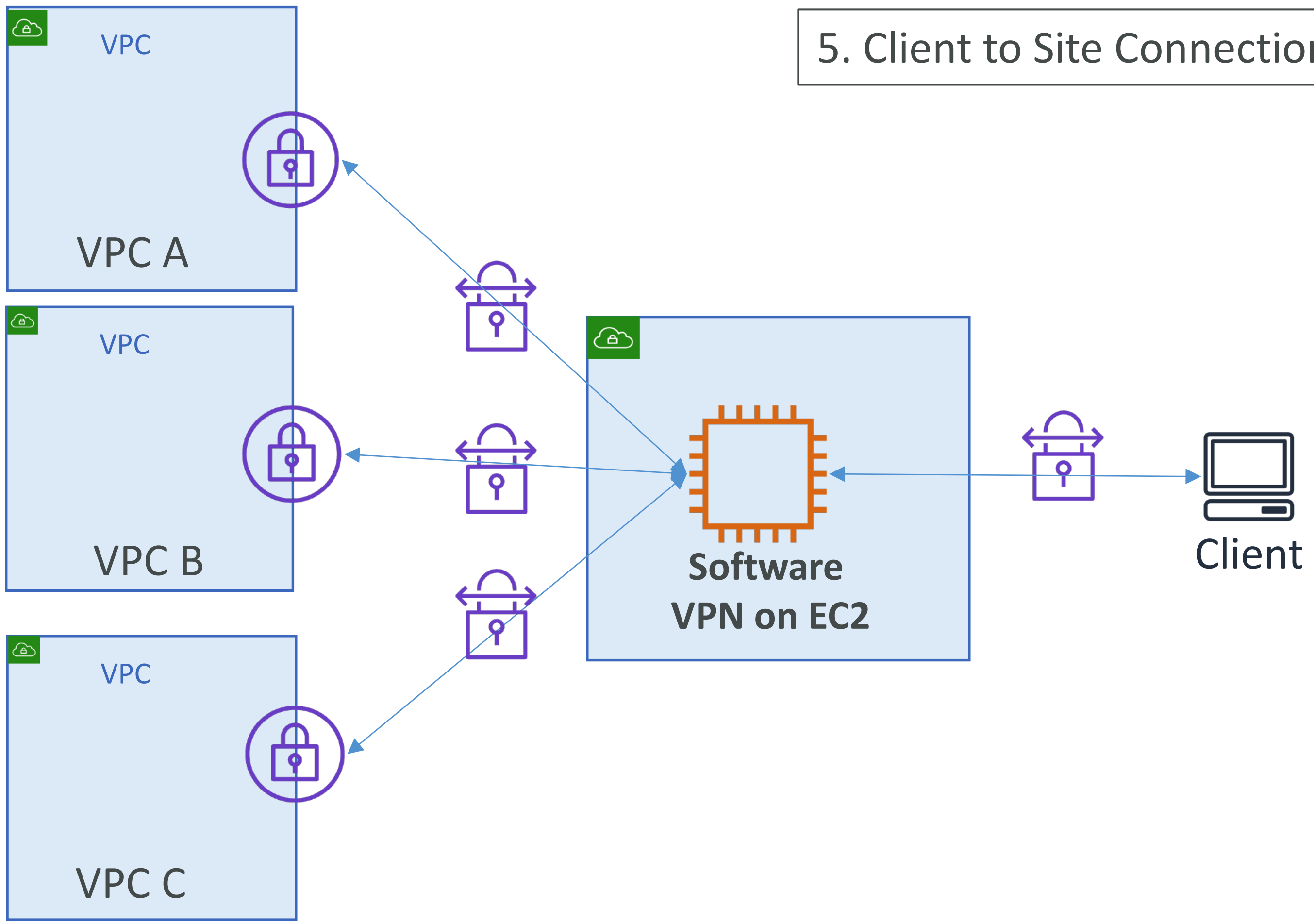
Transit VPC – What is it and why it is required?

4. Transitive Routing – VPC endpoints, IGW etc



Transit VPC – What is it and why it is required?

5. Client to Site Connection

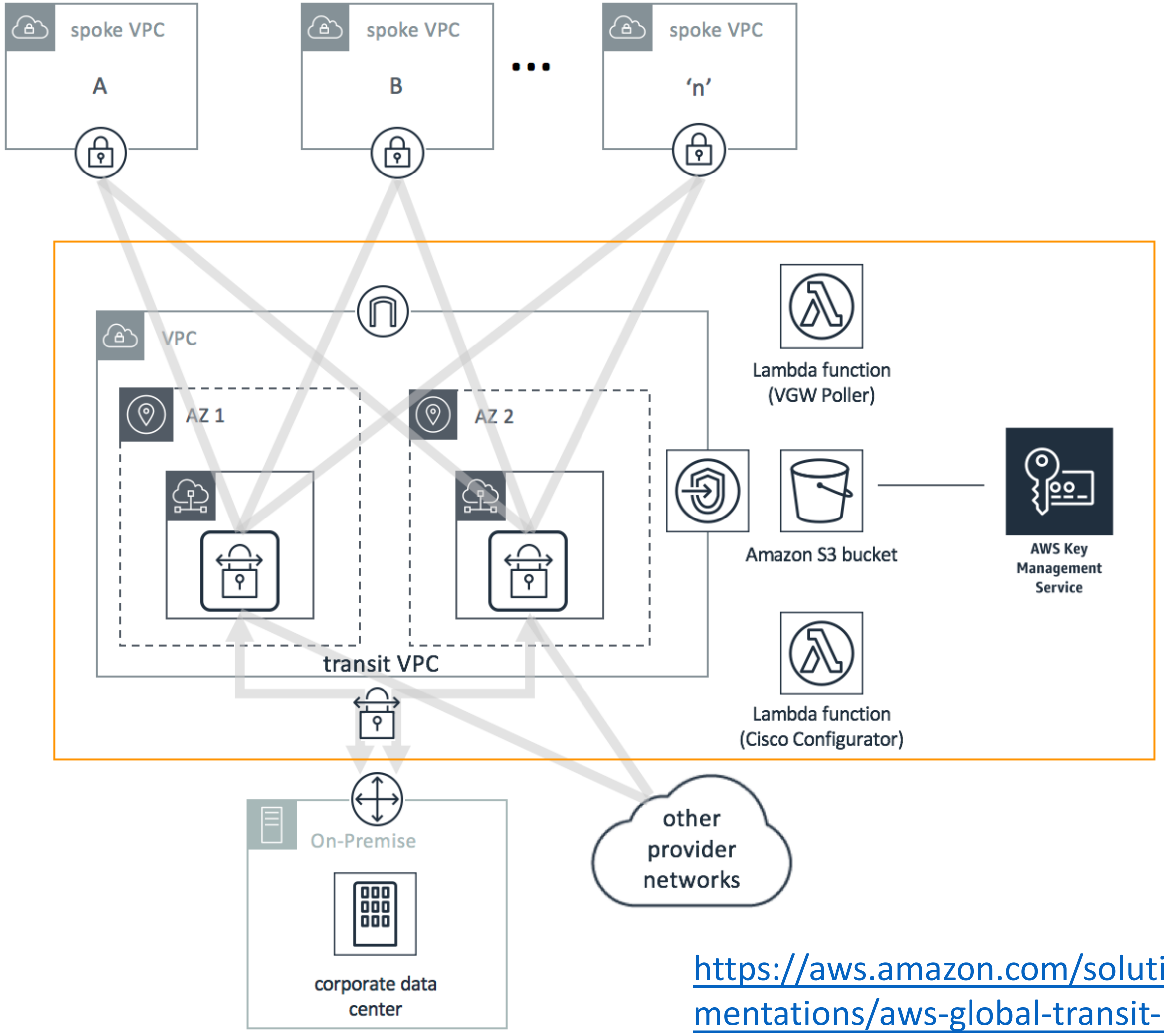


Transit VPC scenarios

1. When multiple VPCs needs to be connected with on-premises network
2. Advanced Threat protection where traffic should be routed through centralized firewall systems
3. When you want to connect to on-premises network having overlapping CIDRs. Transit VPC acts as a NAT translating IPs to different range to enable communication.
4. Allow access for remote networks (Spoke VPC or On-premise network) to endpoints hosted in Transit Hub VPC
5. Client-to-Site VPN where client devices can connect to the Transit VPC EC2 instance by establishing VPN connection

Transit VPC architecture for Transit Hub

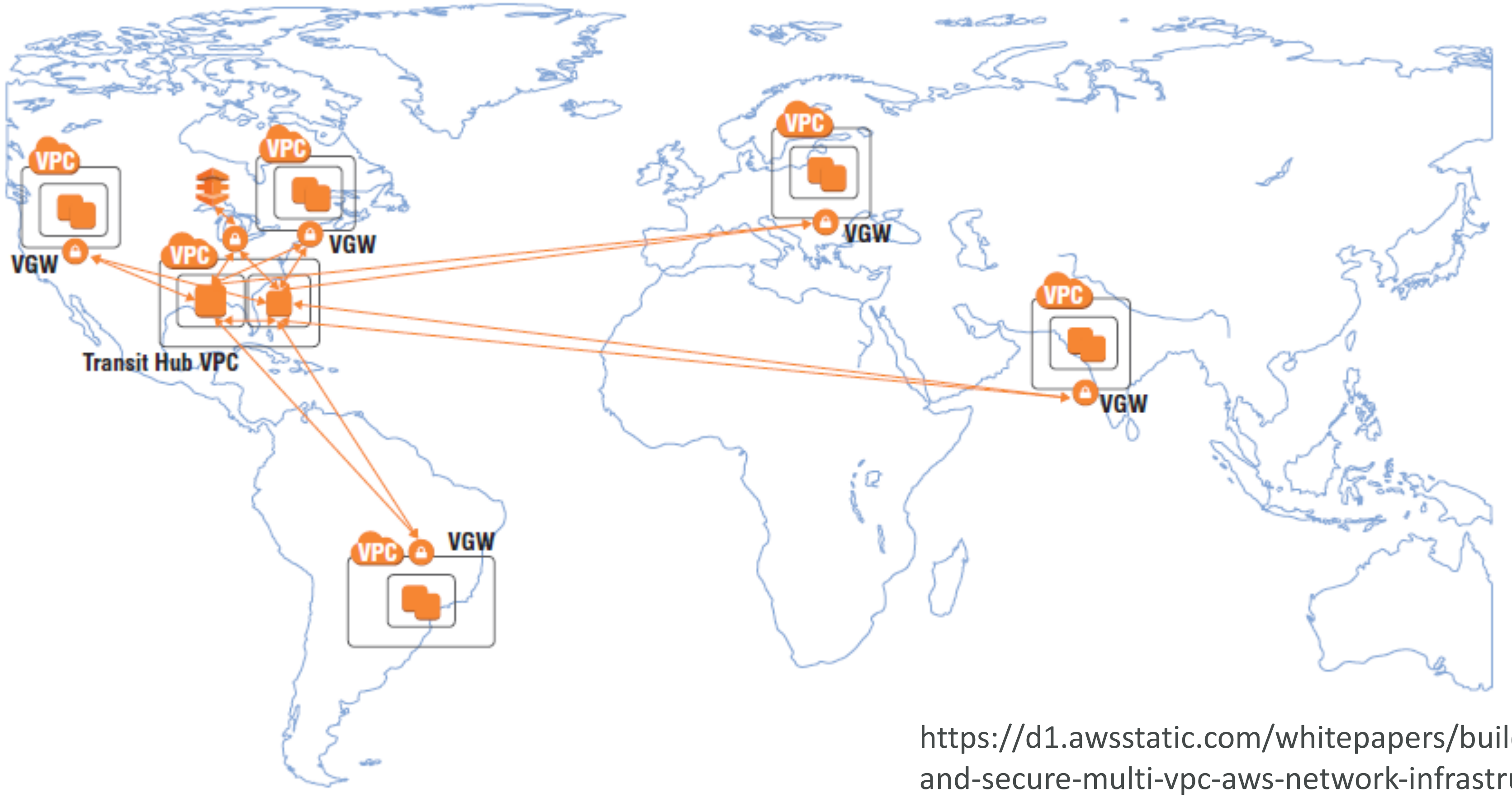
- **Hub/Transit VPC**: EC2 with VPN software (PaloAlto, Avitarix, CheckPoint etc), multi AZ for HA
- Each **Spoke VPC** has a VGW as their VPN termination
- On-premises establishes a VPN connection to the transit hub
- Possibility to use Direct Connect instead
- This architecture allows Full Mesh for communication between VPCs, On-premise VPN and AWS Direct Connect connection



https://aws.amazon.com/solutions/implementations/aws-global-transit-network/

Transit VPC scenarios

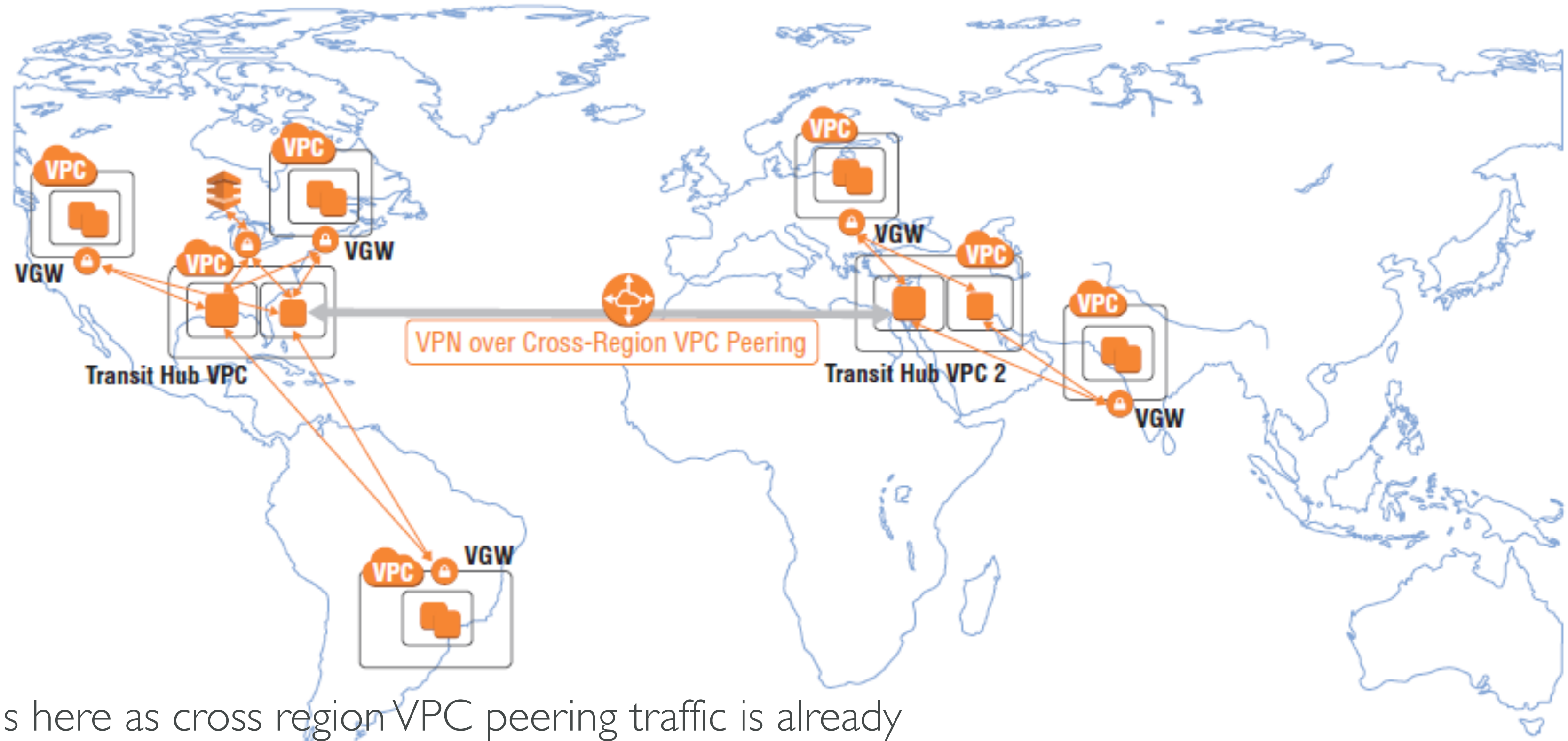
Global VPN infrastructure with single Transit Hub



https://d1.awsstatic.com/whitepapers/building-a-scalable-and-secure-multi-vpc-aws-network-infrastructure.pdf

Transit VPC scenarios

Global VPN infrastructure with Transit Hubs in each region

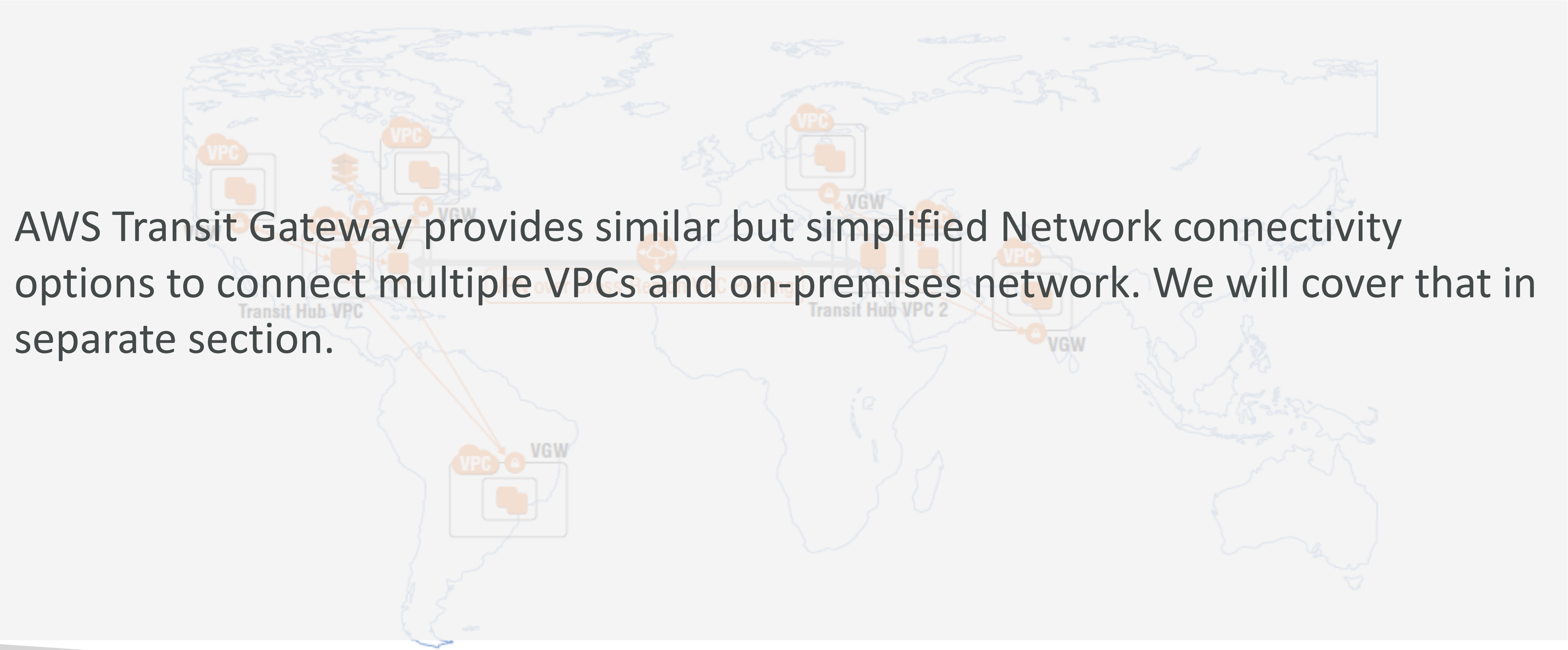


May use GRE tunnels here as cross region VPC peering traffic is already encrypted. GRE VPN is simpler and faster than IPSec.

https://d1.awsstatic.com/whitepapers/building-a-scalable-and-secure-multi-vpc-aws-network-infrastructure.pdf

Transit VPC scenarios

Global VPN infrastructure with Transit Hubs in each region



AWS Transit Gateway provides similar but simplified Network connectivity options to connect multiple VPCs and on-premises network. We will cover that in separate section.

Site to Site VPN Summary

- VPN comes into 2 categories – Site to Site and Client to Site
- AWS has fully managed VPN solution for Site-to-Site VPN. On AWS side, VPN terminates at Virtual Private Gateway (VGW)
- AWS supports IPSec Site-to-Site (S2S) VPN
- AWS S2S VPN creates 2 tunnels for high availability
- After successful VPN setup, the traffic should be initiated from the customer end. **VGW never initiates the traffic. (was true until Feb 2021)**
- The VGW has the aggregate bandwidth limit of 1.25 Gbps
- AWS S2S VPN supports static and dynamic routing using BGP
- You can not publish more than 100 routes towards VGW. You can consolidate CIDRs in case you are hitting the limit

Exam Essentials

- AWS managed VPN supports only IPSec protocol
- You can not create VPN connection between 2 VPCs using VGWs at both the end of the connection. This is because VGW never initiates the VPN traffic. Traffic should be initiated from customer side of VPN.
- You can monitor the tunnel status with AWS CloudWatch metrics like TunnelState, TunnelDataIn, TunnelDataOut
- AWS managed VPN does not support transitive routing
- For Client to Site VPN, you need to terminate VPN connection on EC2 (until 2018 when AWS released Managed Client to Site VPN service)
- There are many other scenarios for which you need to terminate the AWS side of the VPN connection on EC2 instance

AWS Site-to-Site VPN – Good to know

- IPv6 traffic is not supported for VPN connections with VGW however IPv6 is supported with VPN connection with Transit Gateway
- AWS managed VPN connection does not support Path MTU Discovery

AWS Site-to-Site VPN - Appendix

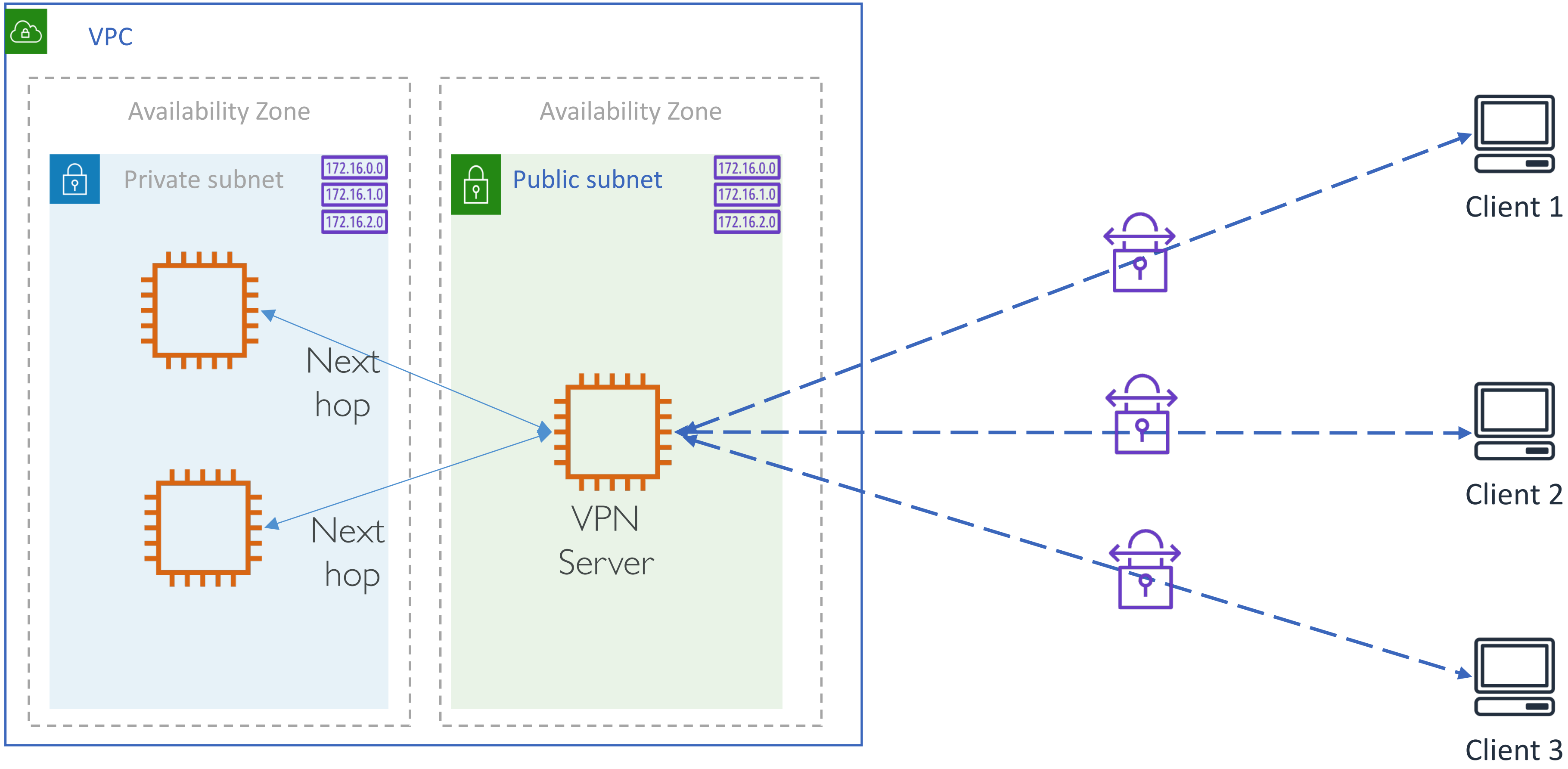
Which customer gateway you can use for VPN?

- Customer gateway devices supporting statically-routed VPN connections must be able to:
  - Establish IKE Security Association using Pre-Shared Keys
  - Establish IPsec Security Associations in Tunnel mode
  - Utilize the AES 128-bit, 256-bit, 128-bit-GCM-16, or 256-GCM-16 encryption function
  - Utilize the SHA-1, SHA-2 (256), SHA2 (384) or SHA2 (512) hashing function
  - Utilize Diffie-Hellman (DH) Perfect Forward Secrecy in "Group 2" mode, or one of the additional DH groups we support
  - Perform packet fragmentation prior to encryption
- In addition to the above capabilities, devices supporting dynamically-routed Site-to-Site VPN connections must be able to:
  - Establish Border Gateway Protocol (BGP) peering
  - Bind tunnels to logical interfaces (route-based VPN)
  - Utilize IPsec Dead Peer Detection

AWS Client VPN

AWS Client VPN

Client to Site VPN using EC2
(AWS Managed Client VPN was launched in Dec 2018)

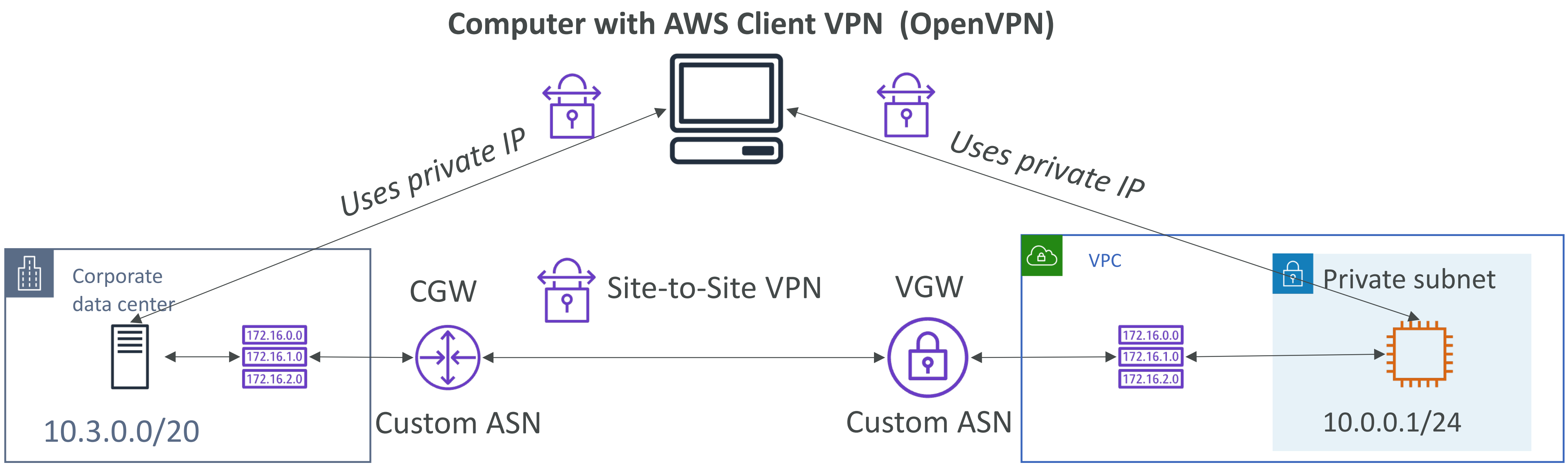


Client to Site VPN features

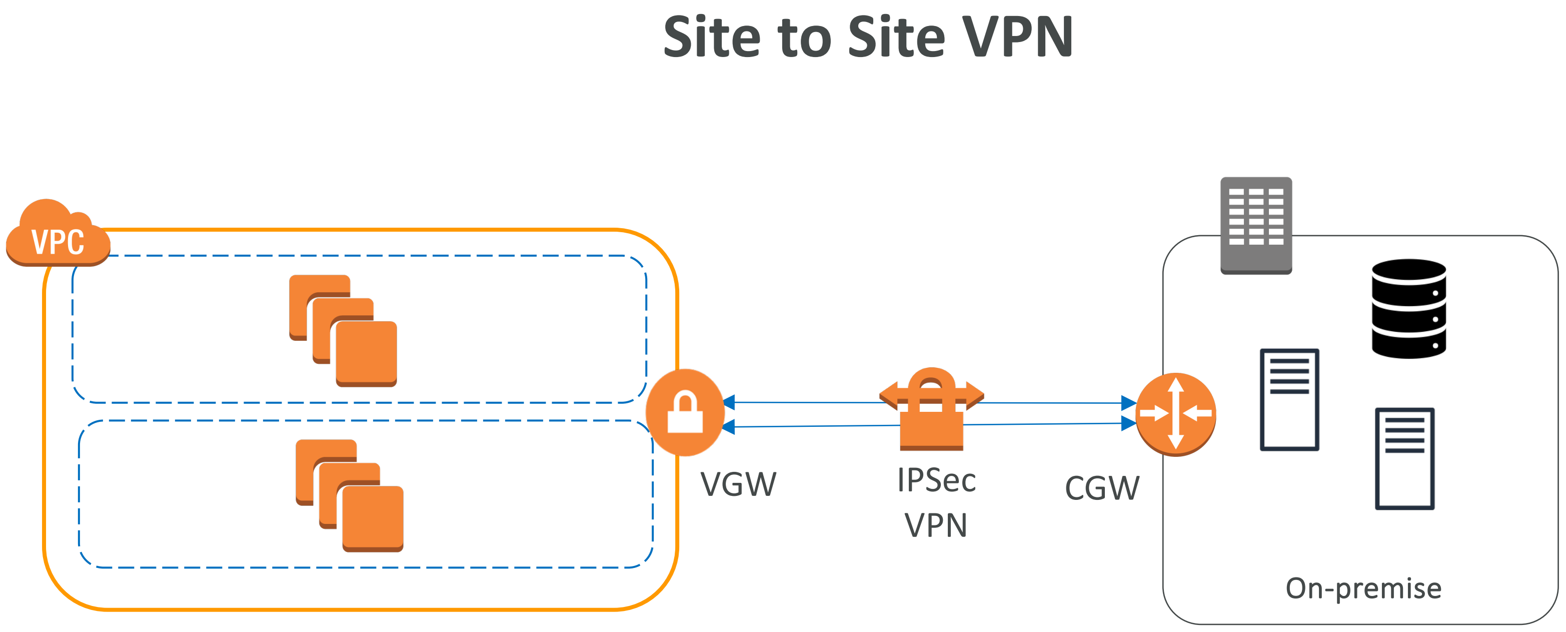
- AWS has a managed Client VPN (so far out of scope for the exam)
- Or setup Client VPN on EC2:
  - AWS Marketplace: Use pre-baked AMI with VPN software and license. Example vendors are Cisco, Aviatrix, Palo Alto, Sophos etc
  - Manual installation on EC2: OpenSwan, StrongSwan
- For high availability pointers:
  - Multiple EC2 instances with NLB
  - Optionally use DNS load balancing (client side) instead of NLB
- You may also have to implement Split tunneling at client side

AWS Client VPN

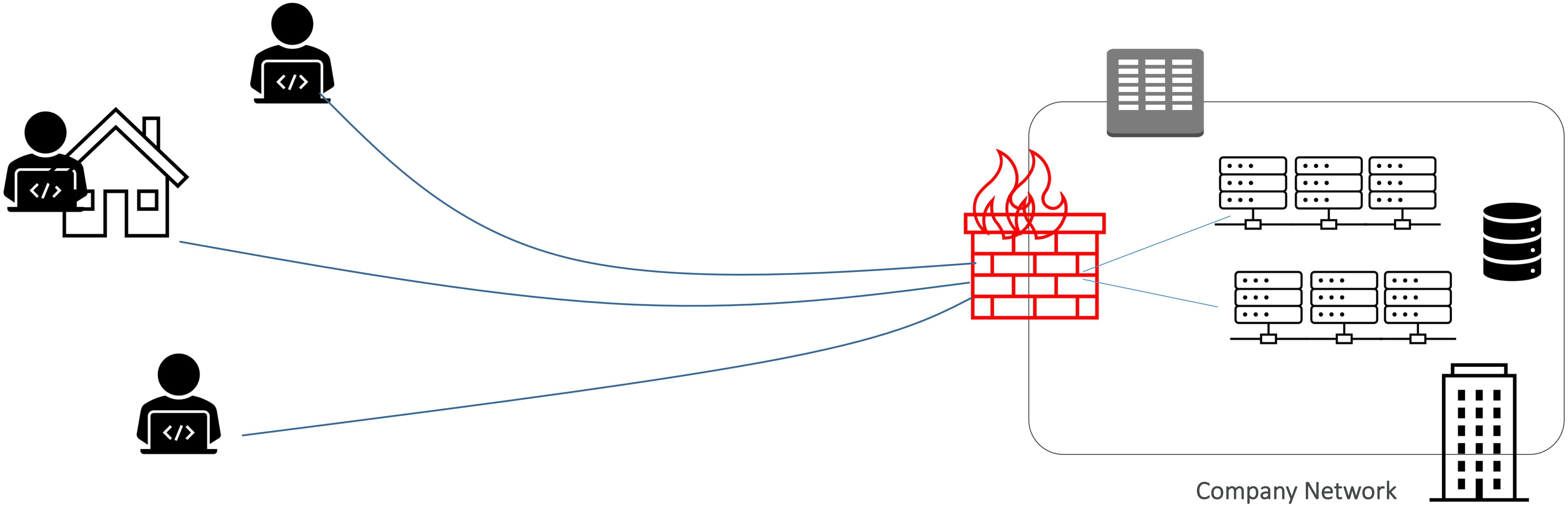
- Connect from your computer using OpenVPN to your private network in AWS and on-premise



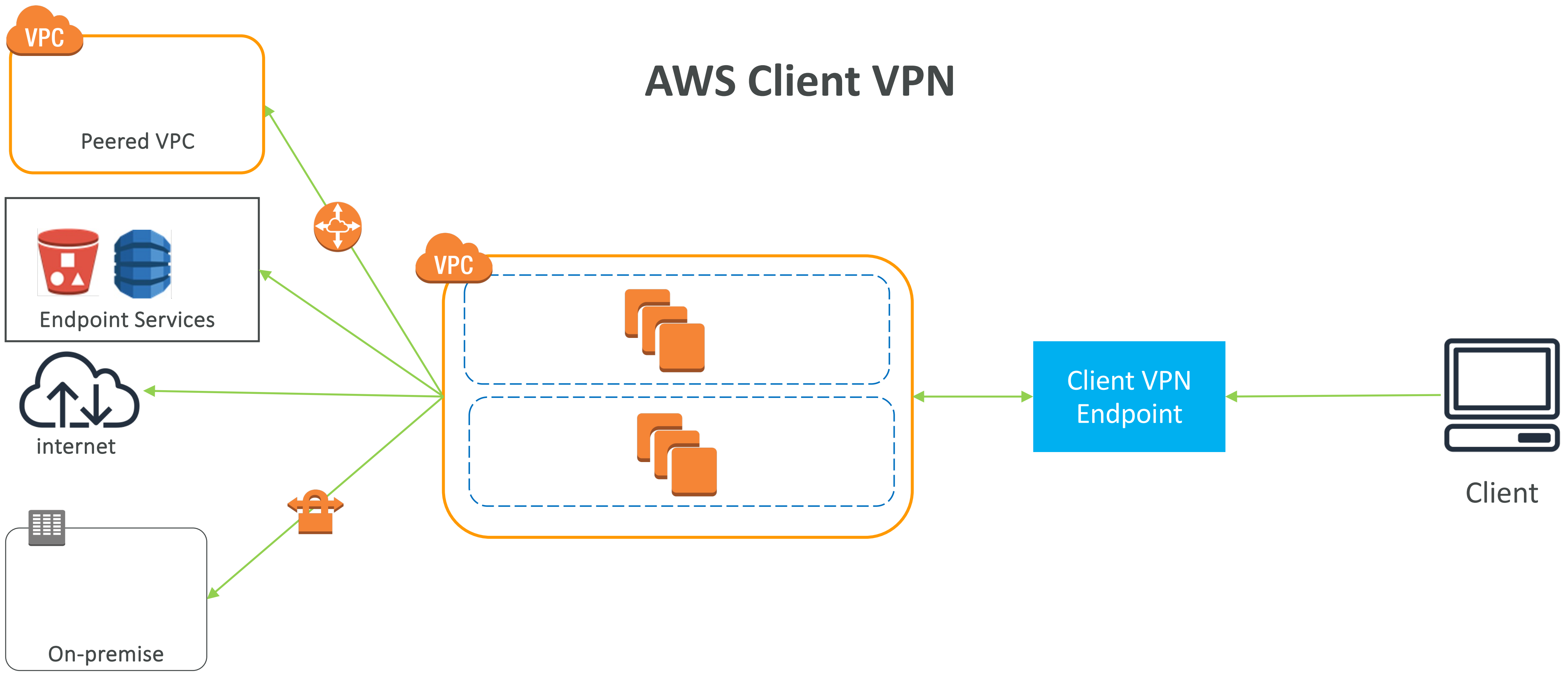
Site to Site VPN



Client to Site VPN



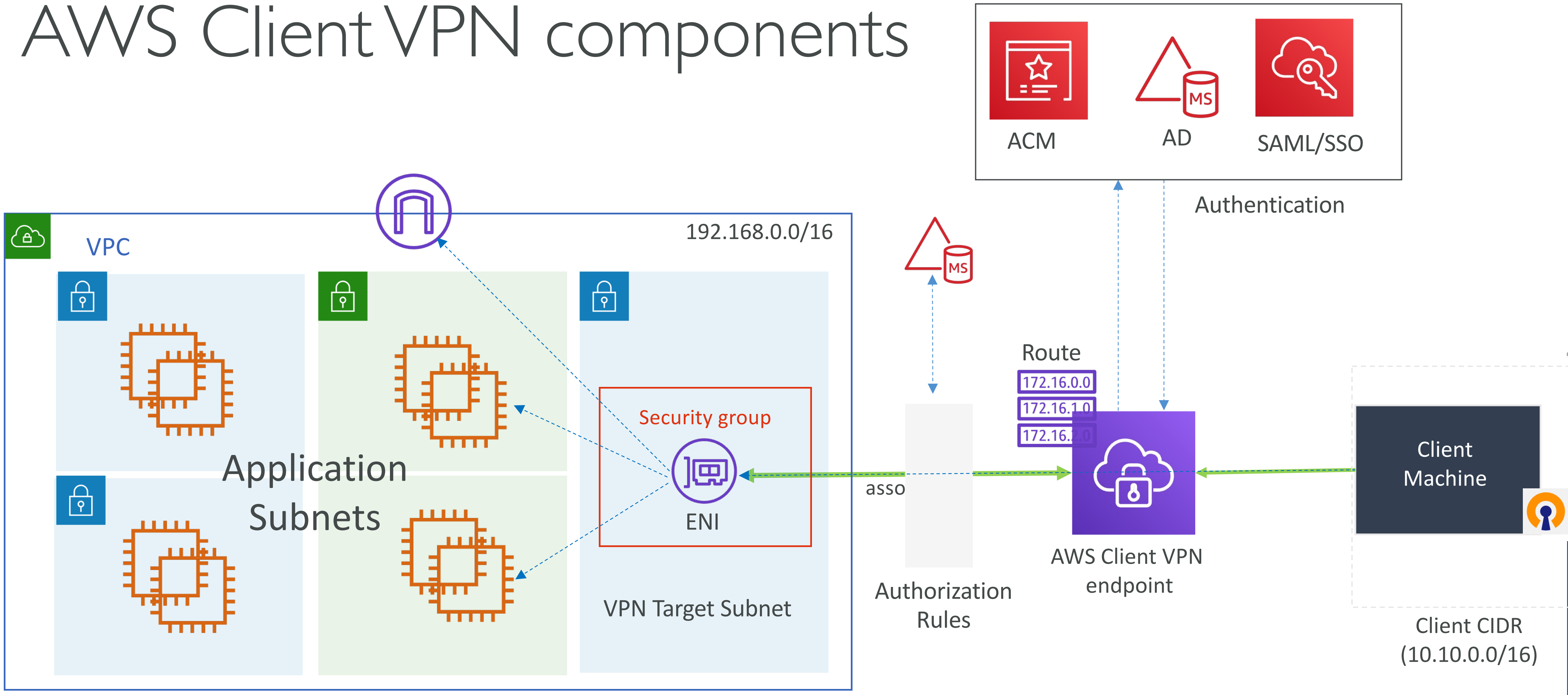
Client to site VPN



AWS Client VPN Components

- VPC
- Target Network Subent
- Client VPN Endpoint
- Route
- Authorization Rules
- Client CIDR range
- Client VPN Network Interfaces
- Authentication (Mutual, AD based, SAML based federated)
- Authorization (Security groups, Authorization groups)
- Client

AWS Client VPN components

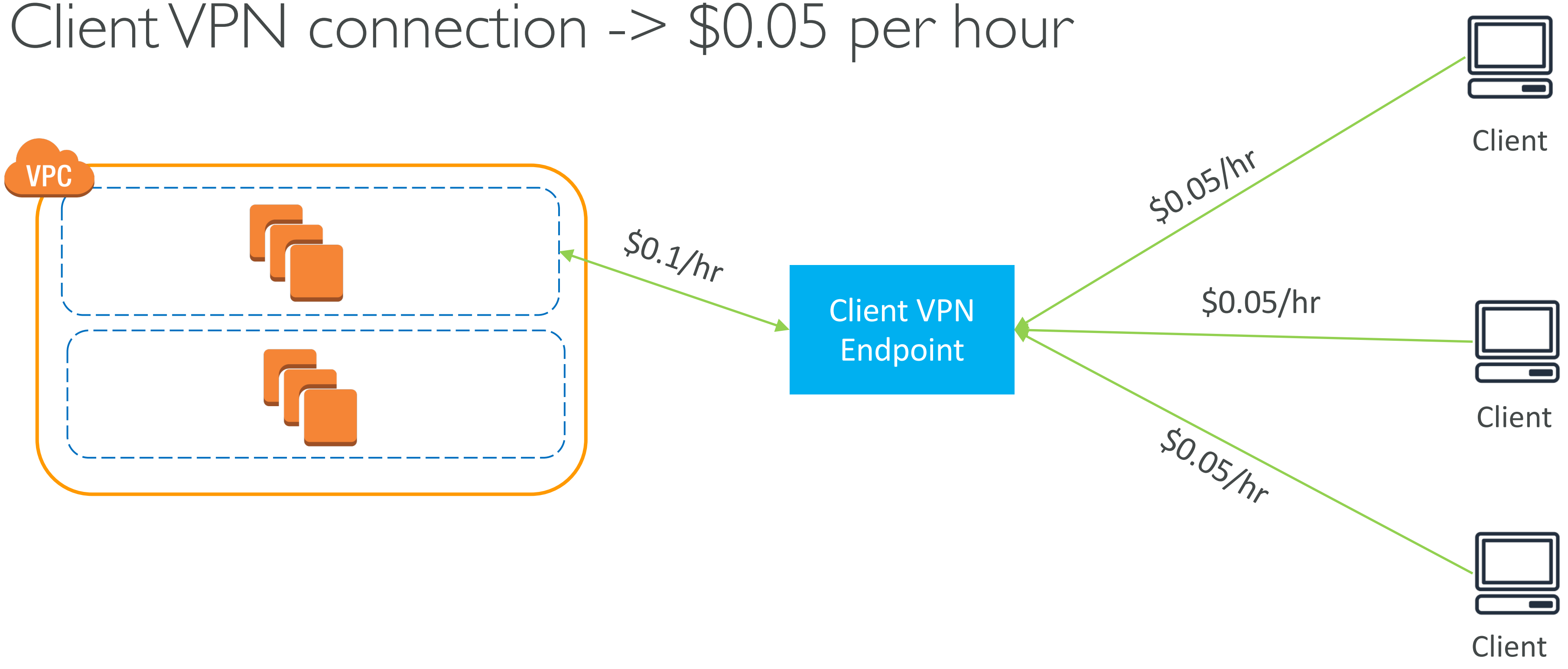


AWS Client VPN Limitations

- Client CIDR ranges cannot overlap with the local CIDR of the VPC in which the associated subnet is located
- Client CIDR ranges cannot overlap with any routes manually added to the Client VPN endpoint's route table
- Client CIDR ranges must have a block size between /22 and /12
- The client CIDR range cannot be changed after you create the Client VPN endpoint
- You cannot associate multiple subnets from the same Availability Zone with a Client VPN endpoint
- A Client VPN endpoint does not support subnet associations in a dedicated tenancy VPC
- Client VPN supports IPv4 traffic only

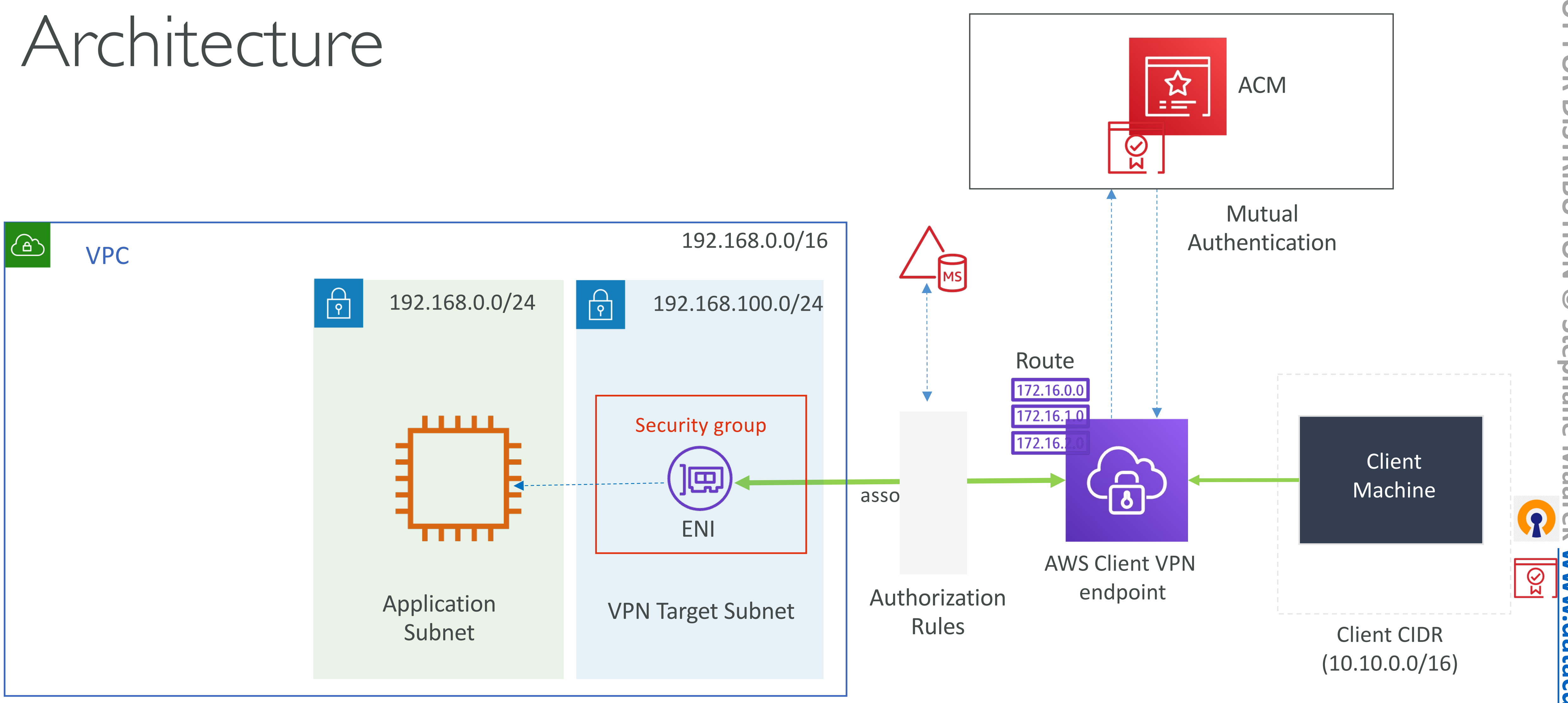
AWS Client VPN Pricing (N.Virginia region)

- AWS Client VPN endpoint association -> $0.10 per hour
- AWS Client VPN connection -> $0.05 per hour



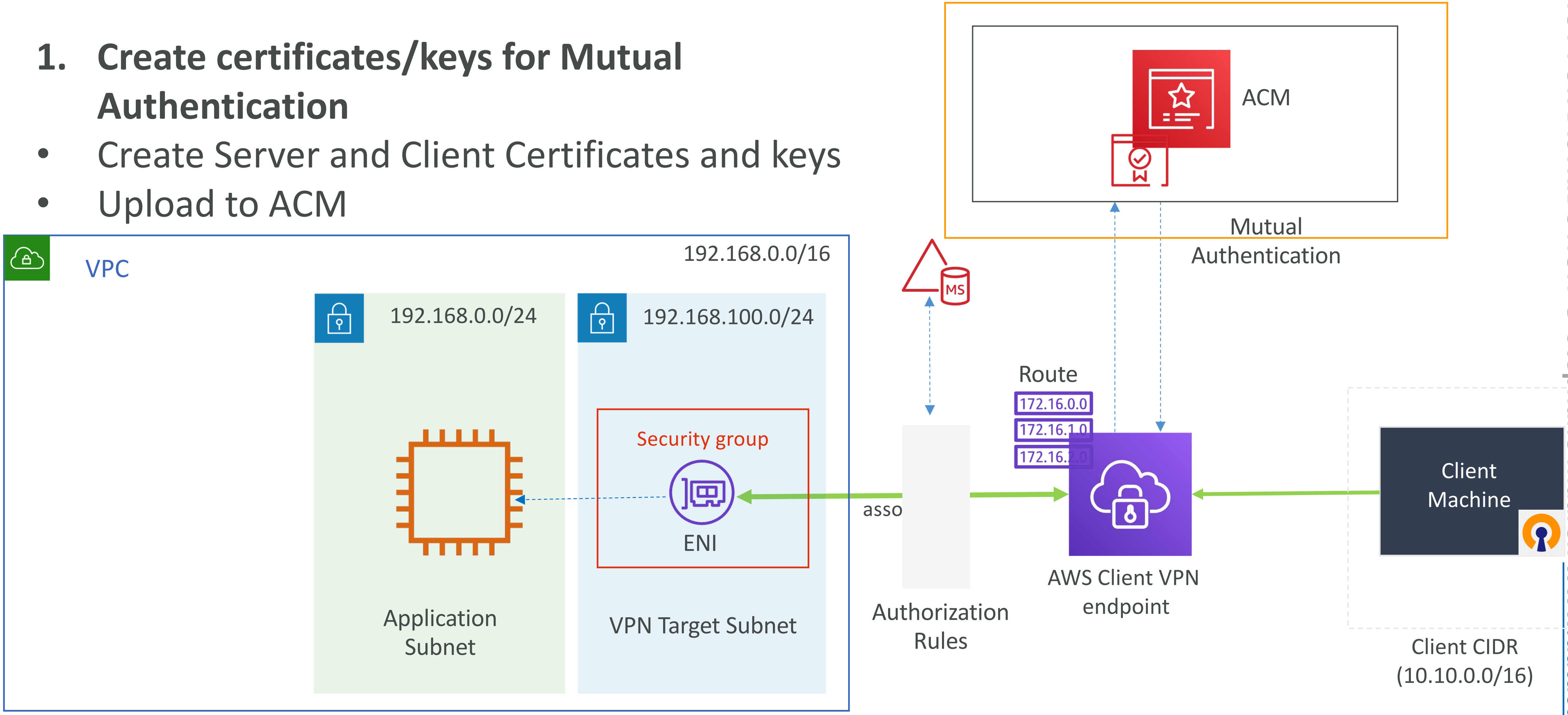
How to setup AWS Client VPN

Architecture



1. **Create certificates/keys for Mutual Authentication**

- Create Server and Client Certificates and keys
- Upload to ACM



https://docs.aws.amazon.com/vpn/latest/clientvpn-admin/client-authentication.html#mutual

Create Server and Client certificates and keys

Run below commands from your workstation (Should have AWS CLI)

1. Clone the easy-rsa repo

   $ git clone https://github.com/OpenVPN/easy-rsa.git
   $ cd easy-rsa/easyrsa3

2. Initialize PKI environment

   $ ./easyrsa init-pki

3. Create new Certification Authority (CA)

   $ ./easyrsa build-ca nopass

4. Generate the server certificate and key

   $ ./easyrsa build-server-full server nopass

Create Server and Client certificates and keys

5. Generate the client certificate and key

```
$ ./easyrsa build-client-full client1.domain.tld nopass
```

6. Copy server and client certificates and keys to one directory

```
$ mkdir ~/demo
$ cp pki/ca.crt ~/demo/
$ cp pki/issued/server.crt ~/demo/
$ cp pki/private/server.key ~/demo/
$ cp pki/issued/client1.domain.tld.crt ~/demo/
$ cp pki/private/client1.domain.tld.key ~/demo/
$ cd ~/demo
```

Create Server and Client certificates and keys

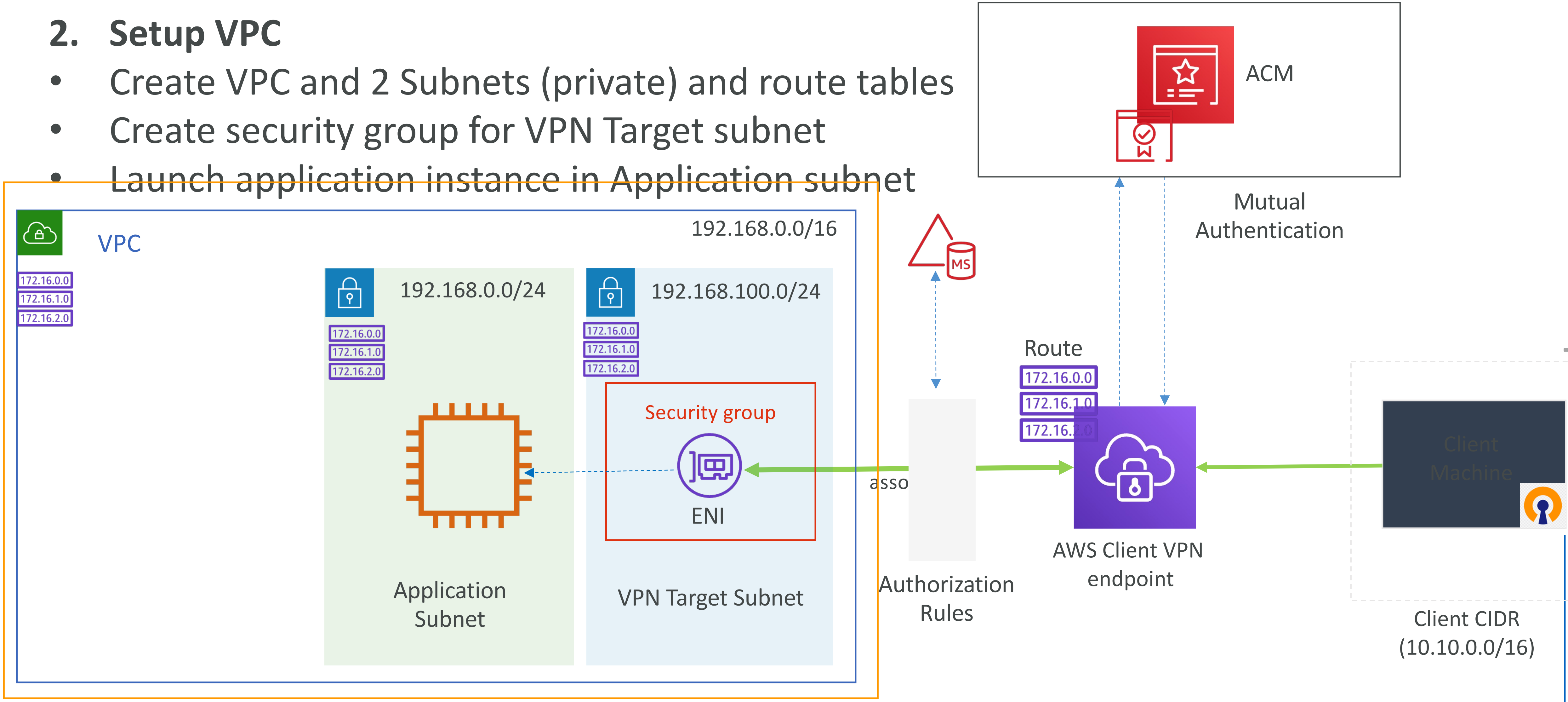
7. Upload the certificate and keys to ACM

$ aws acm import-certificate --certificate fileb://server.crt --private-key fileb://server.key --certificate-chain fileb://ca.crt --region ap-south-1

$ aws acm import-certificate --certificate fileb://client1.domain.tld.crt --private-key fileb://client1.domain.tld.key --certificate-chain fileb://ca.crt --region ap-south-1

2. Setup VPC

- Create VPC and 2 Subnets (private) and route tables
- Create security group for VPN Target subnet
- Launch application instance in Application subnet



Steps to setup VPC

1. Create VPC (name=demo) with CIDR 192.168.0.0/16
2. Create private subnet "demo-app-1" with CIDR 192.168.0.0/24
3. Create corresponding route table "demo-app-rt" with just a local route & associate with subnet "demo-app-1"
4. Create private subnet "demo-client-vpn-1" with CIDR 192.168.100.0/24
5. Create corresponding route table "demo-client-vpn-rt" with just a local route & associate with subnet "demo-client-vpn-1"
6. Create security group "demo-client-vpn-sg"
   - Do not add any inbound rules
   - All outbound should be allowed (All traffic – 0.0.0.0/0)

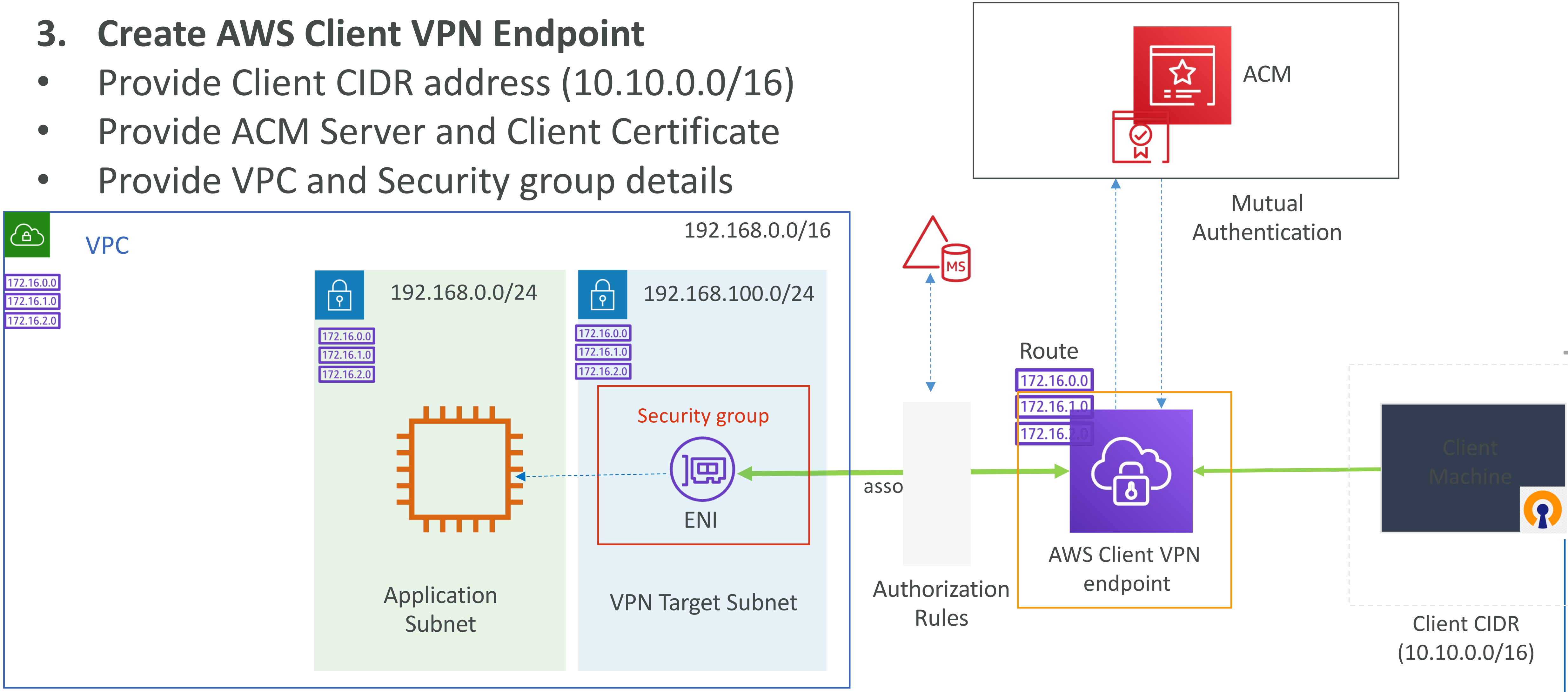
Steps to setup VPC

7. Launch application EC2 instance in "demo-app-1" subnet

   - Security group inbound rule should allow "All traffic" from security group "demo-client-vpn-sg" created in step 6

3. Create AWS Client VPN Endpoint

- Provide Client CIDR address (10.10.0.0/16)
- Provide ACM Server and Client Certificate
- Provide VPC and Security group details



Steps to create Client VPN endpoint

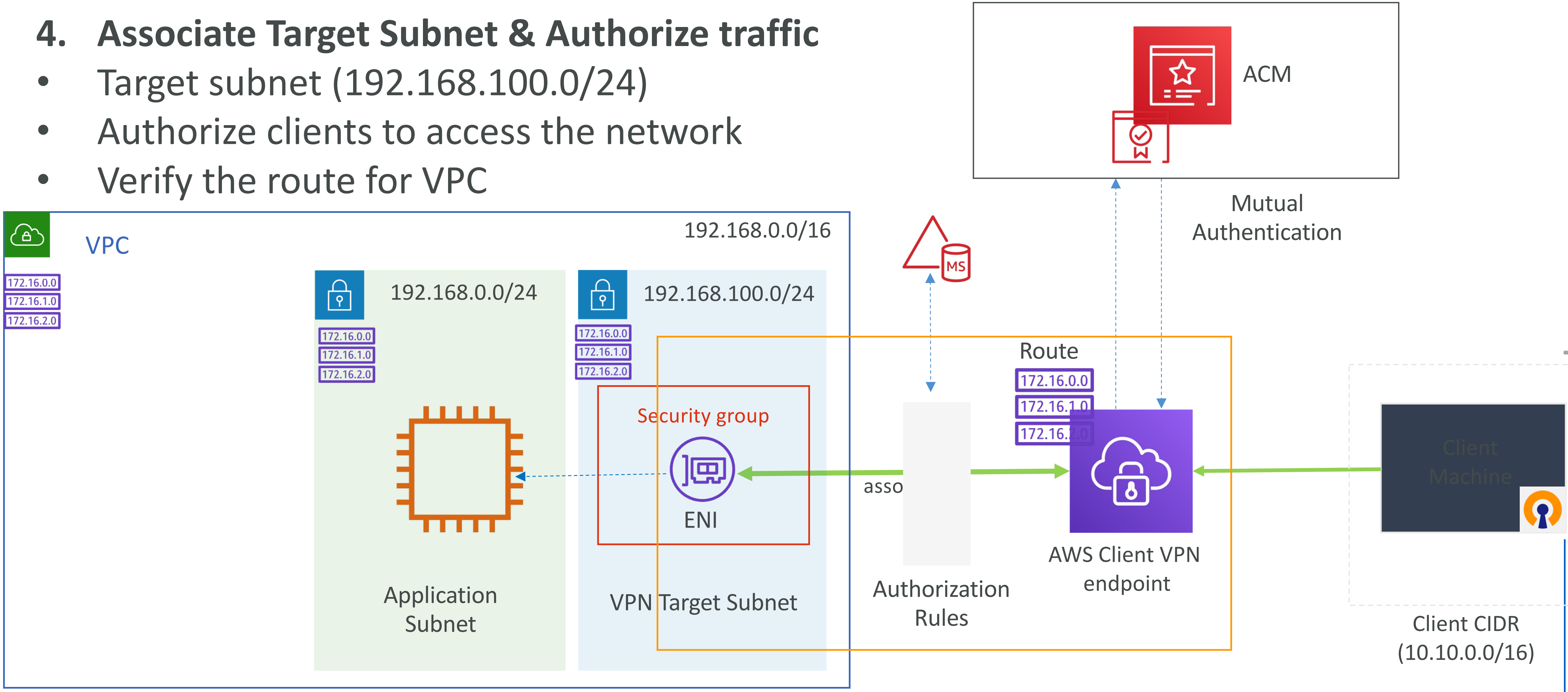
1. Provide name "demo-client-vpn-endpoint" and description
2. Client IPv4 CIDR: 10.10.0.0/16
3. Server Certificate ARN: Choose the Server Certificate created earlier
4. Authentication Options: Choose "Use Mutual Authentication"
5. Client certificate ARN: Choose the Client Certificate created earlier
6. Connection Logging: No
7. Transport Protocol: TCP
8. VPC ID: Choose "demo" VPC created in Step 2

Steps to create Client VPN endpoint

9. Security Group IDs: Select the "demo-client-vpn-sg" created earlier
10. VPN port: 443
11. Create Client VPN Endpoint

4. Associate Target Subnet & Authorize traffic

- Target subnet (192.168.100.0/24)
- Authorize clients to access the network
- Verify the route for VPC

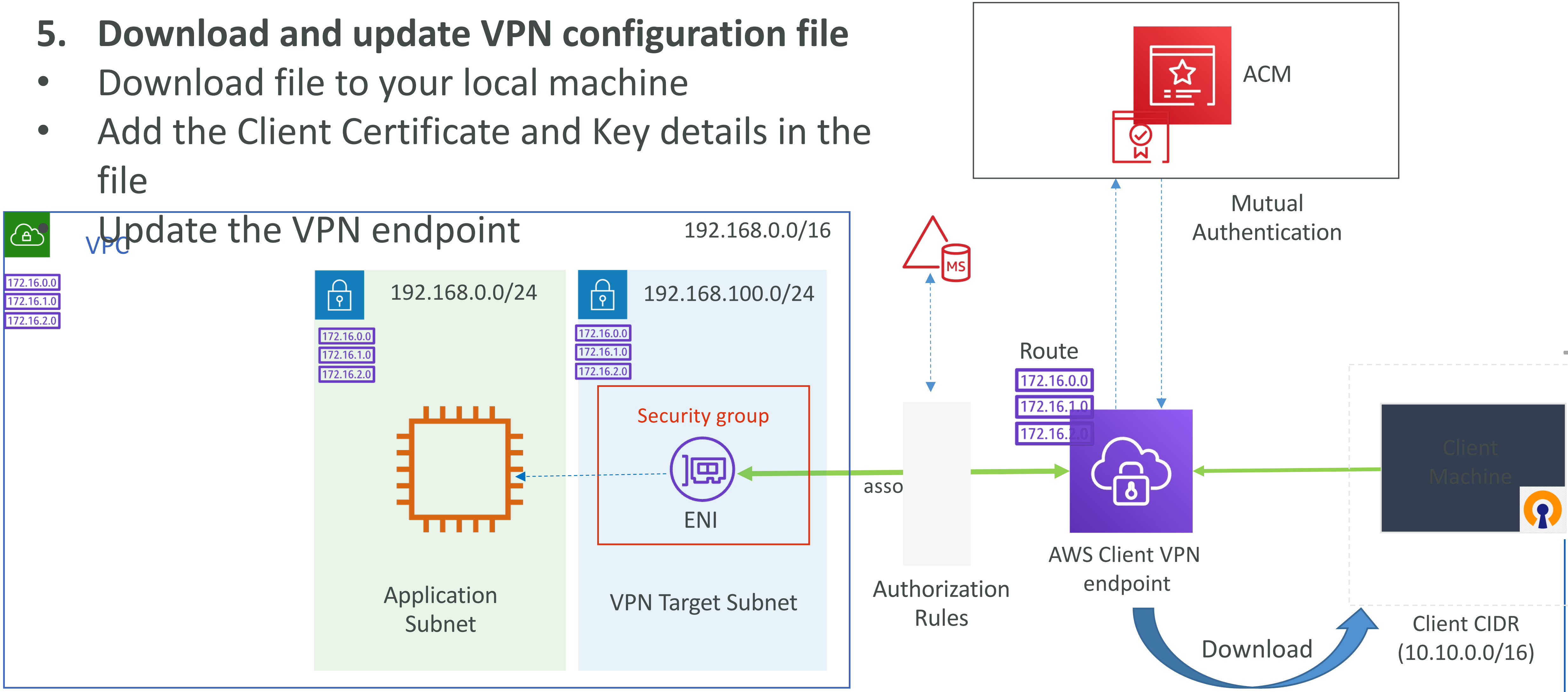


Steps to associate Target Subnet and Authorize traffic

- Select the Client VPN endpoint created earlier
- Go to Associations and associate the target subnet "demo-client-vpn-1"
- Go to Authorizations and choose Authorize Ingress
  - For Destination Networks to enable -> Enter the VPC IP address 192.168.0.0/16
  - Grant access to -> Choose "Allow access to all users"
- Add Authorization Rule

5. Download and update VPN configuration file

- Download file to your local machine
- Add the Client Certificate and Key details in the file
- Update the VPN endpoint



Steps to download and update VPN configuration file

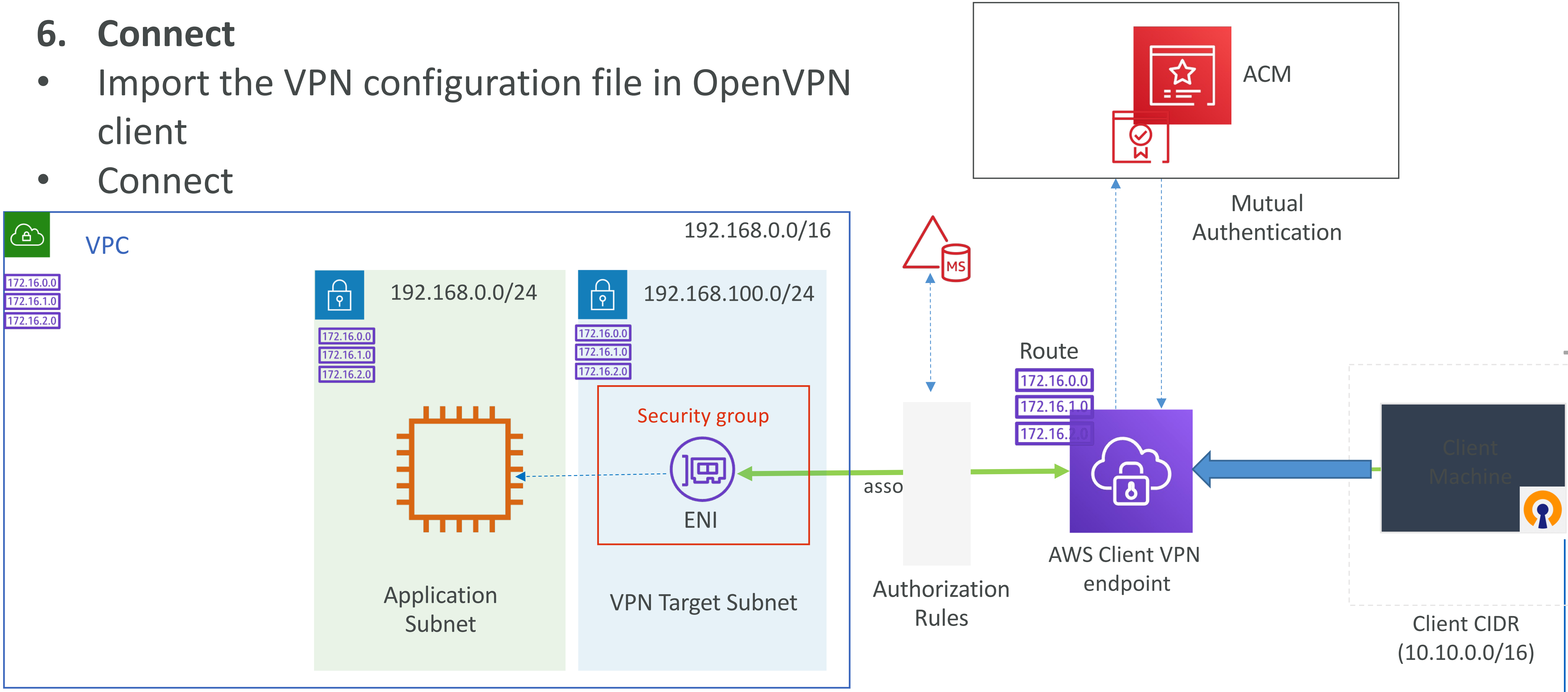
1. Select Client VPN endpoint and "Download Client Configuration" to your local workstation
2. Copy the client certificate and client key created in Step 1 to any folder in local workstation
3. Open the configuration file with any editor and add following lines
    1. cert /path/to/client1.domain.tld.crt
    2. key /path/to/client1.domain.tld.key

Steps to download and update VPN configuration file

4. Also, modify the endpoint dns name by adding random prefix
   1. **Original**: cvpn-endpoint-0102bc4c2eEXAMPLE.prod.clientvpn.us-west-2.amazonaws.com
   2. **Modified**: xxxxxx.cvpn-endpoint-0102bc4c2eEXAMPLE.prod.clientvpn.us-west-2.amazonaws.com

6. Connect

- Import the VPN configuration file in OpenVPN client
- Connect

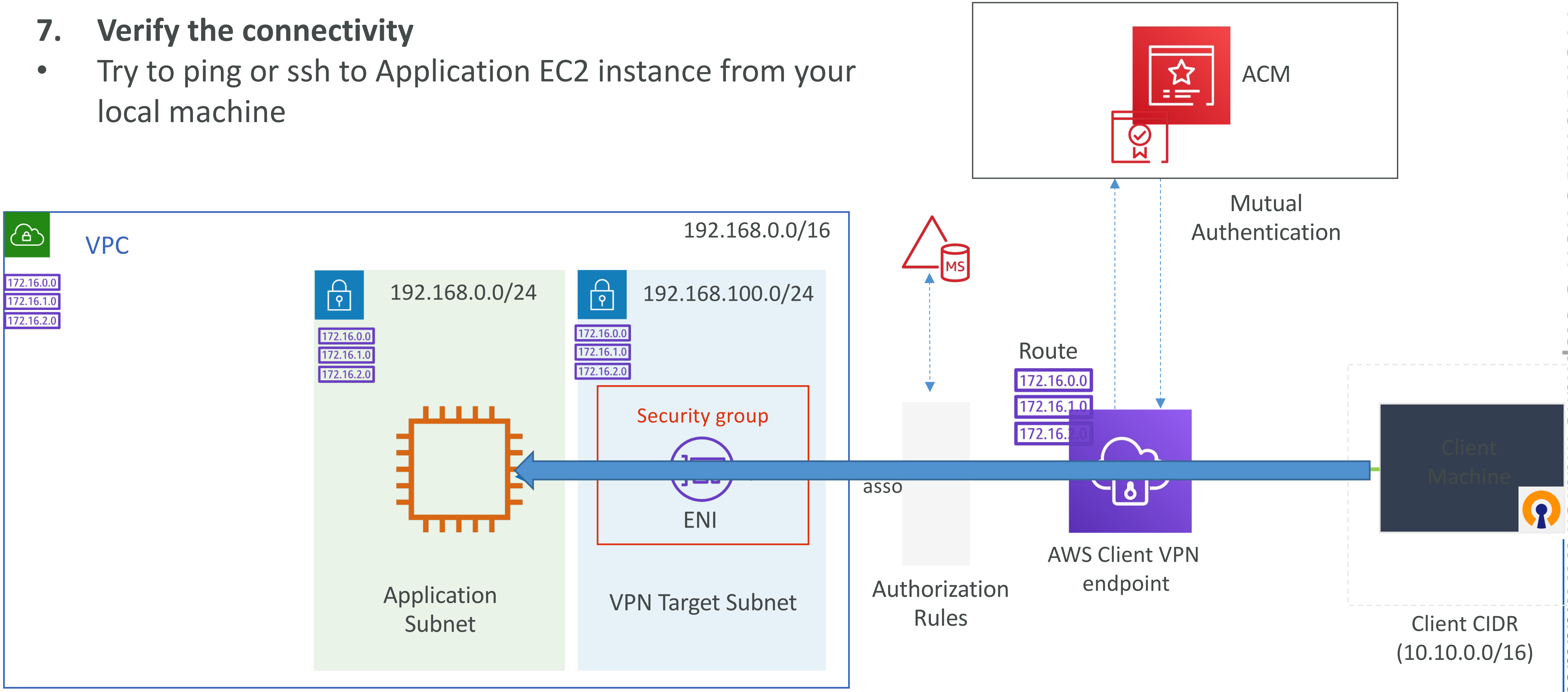


Steps to connect

- Pre-requisite: You should download and install OpenVPN client
  - https://openvpn.net/community-downloads/
- Import configuration file
- Connect

7. Verify the connectivity

- Try to ping or ssh to Application EC2 instance from your local machine

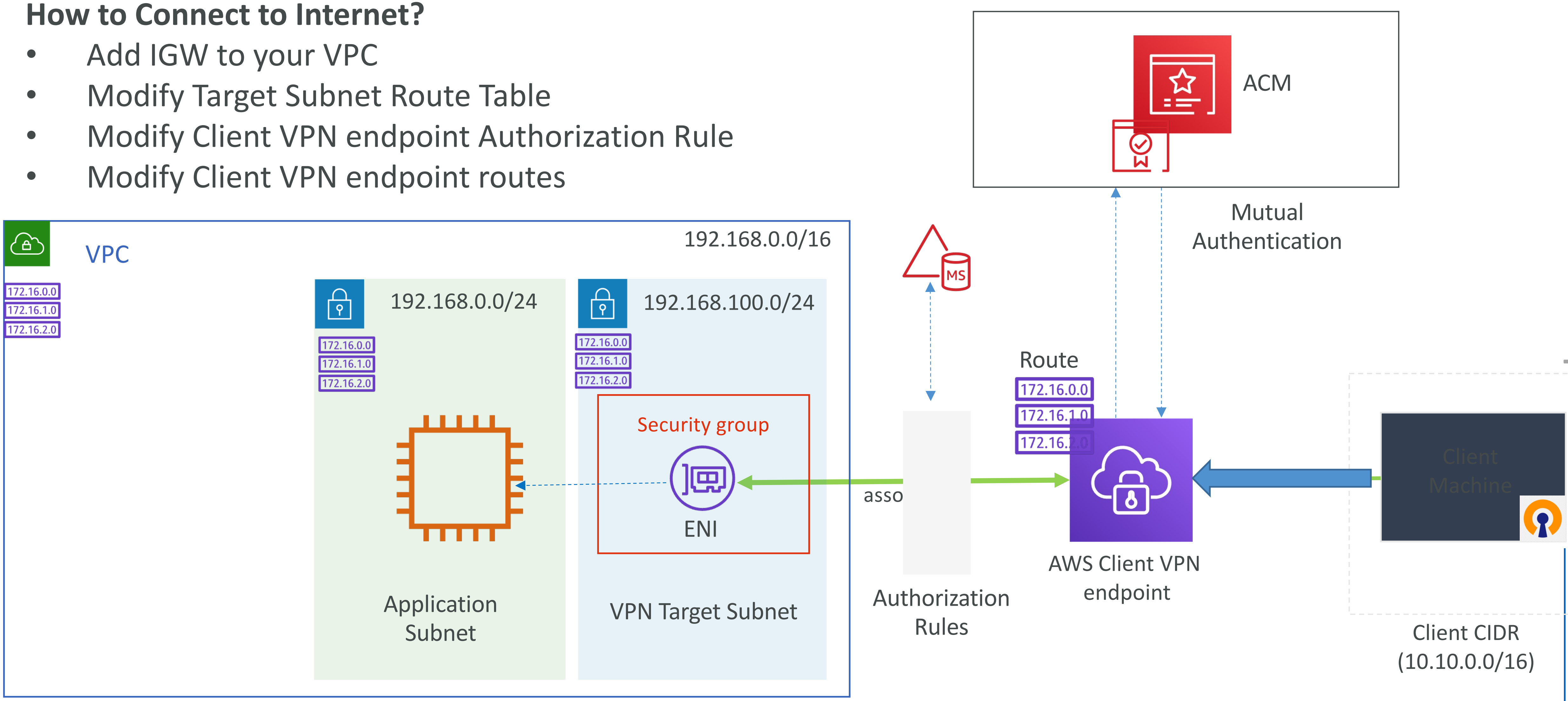


Steps to verify the VPN connection

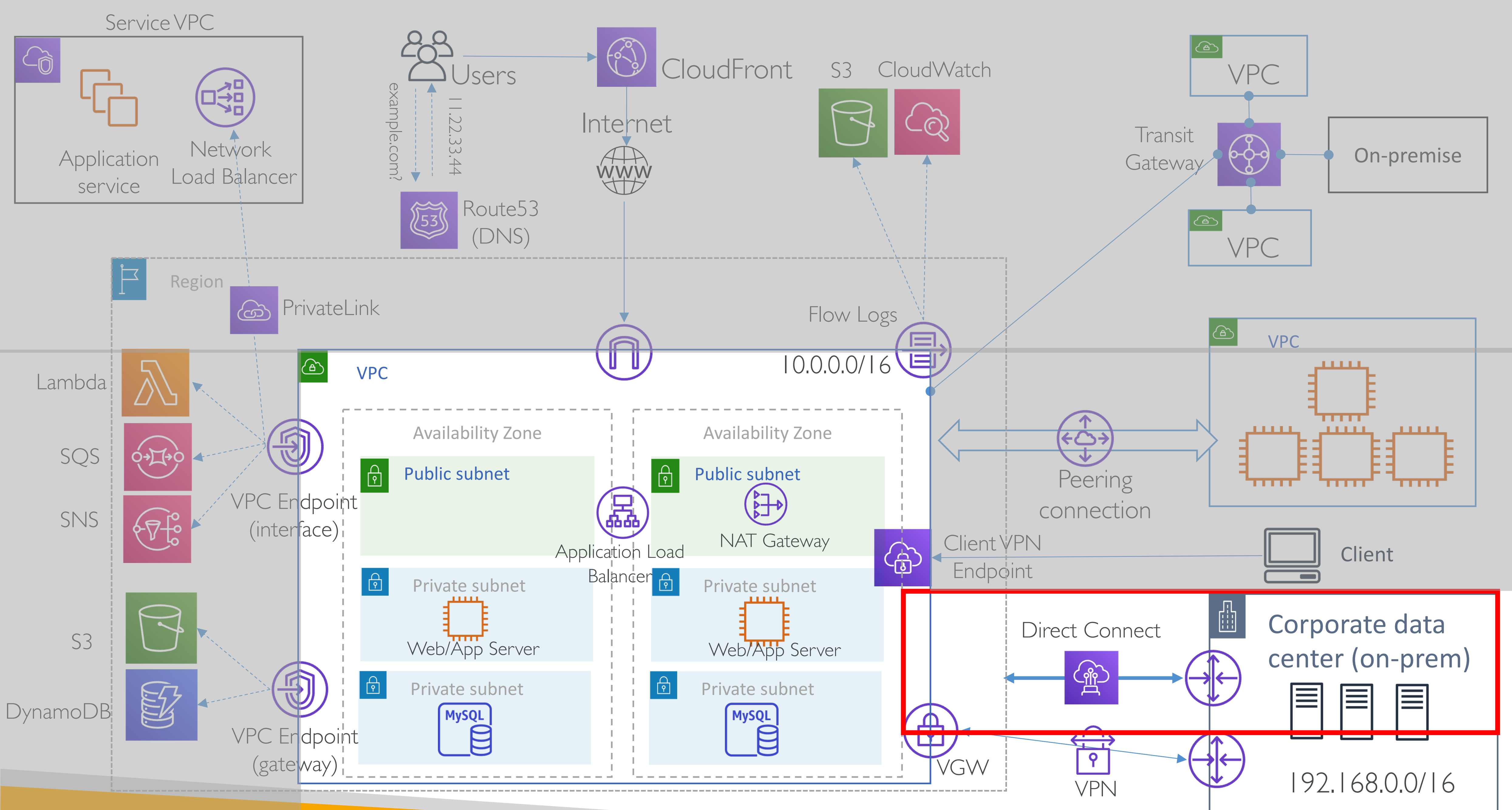
- Get the private IP address of Application EC2 instance say 192.168.0.55
- Open the command prompt from your local workstation
  - ping 192.168.0.55
- If you are using Windows workstation, also try to open SSH connection to Application instance
- Try to access now internet from your local workstation
  - Browse any website -> Does not work
  - ping amazon.com -> Does not work
- Why ?

How to Connect to Internet?

- Add IGW to your VPC
- Modify Target Subnet Route Table
- Modify Client VPN endpoint Authorization Rule
- Modify Client VPN endpoint routes



AWS Direct Connect (DX)


Service VPC
Application service
Network Load Balancer
Users
example.com?
11.22.33.44
Route53 (DNS)
CloudFront
Internet
S3
CloudWatch
VPC
Transit Gateway
On-premise
VPC
Region
PrivateLink
Flow Logs
10.0.0.0/16
VPC
Lambda
SQS
SNS
VPC Endpoint (interface)
Availability Zone
Availability Zone
Public subnet
Public subnet
Application Load Balancer
NAT Gateway
Private subnet
Web/App Server
Private subnet
Web/App Server
Private subnet
Private subnet
S3
DynamoDB
VPC Endpoint (gateway)
Peering connection
Client VPN Endpoint
Client
Direct Connect
Corporate data center (on-prem)
VGW
VPN
192.168.0.0/16

Direct Connect & OSI

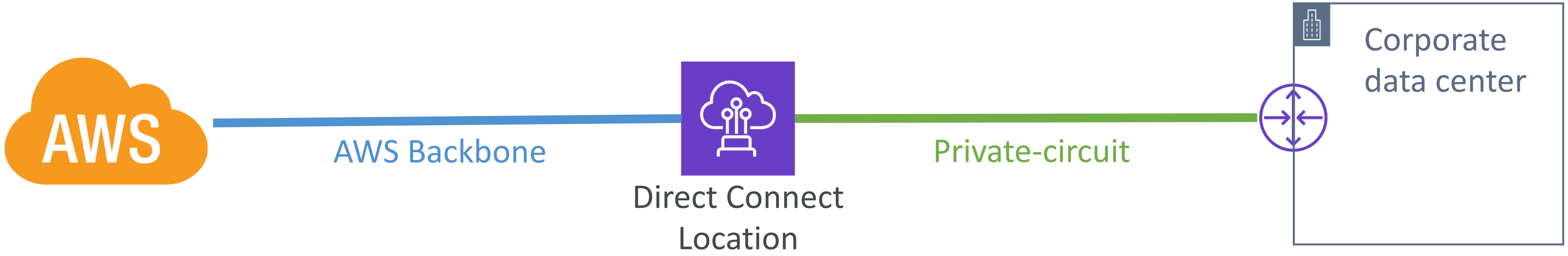
OSI Layer	Description	Direct Connect
Application	**End User Layer:** HTTP, FTP, SSH, DNS	BGP
Presentation	**Syntax Layer:** SSL, IMAP, MPEG, Encryption & Compression	
Session	**Synch & Send to Ports:** APIs, Sockets, WinSock	
Transport	**End to End Connections:** TCP, UDP	TCP (Port 179)
Network	**Packets:** IP, ICMP, IPSec	Peer and Amazon IP
Datalink	**Frames:** Ethernet, PPP, Switch, Bridge	Ethernet – 802.1Q LAN
Physical	**Physical Structure:** Coax, Fiber, Wirel	Single Mode Fiber – 1G or 10G or 100G

Direct Connect

What is Direct Connect?

AWS Direct Connect

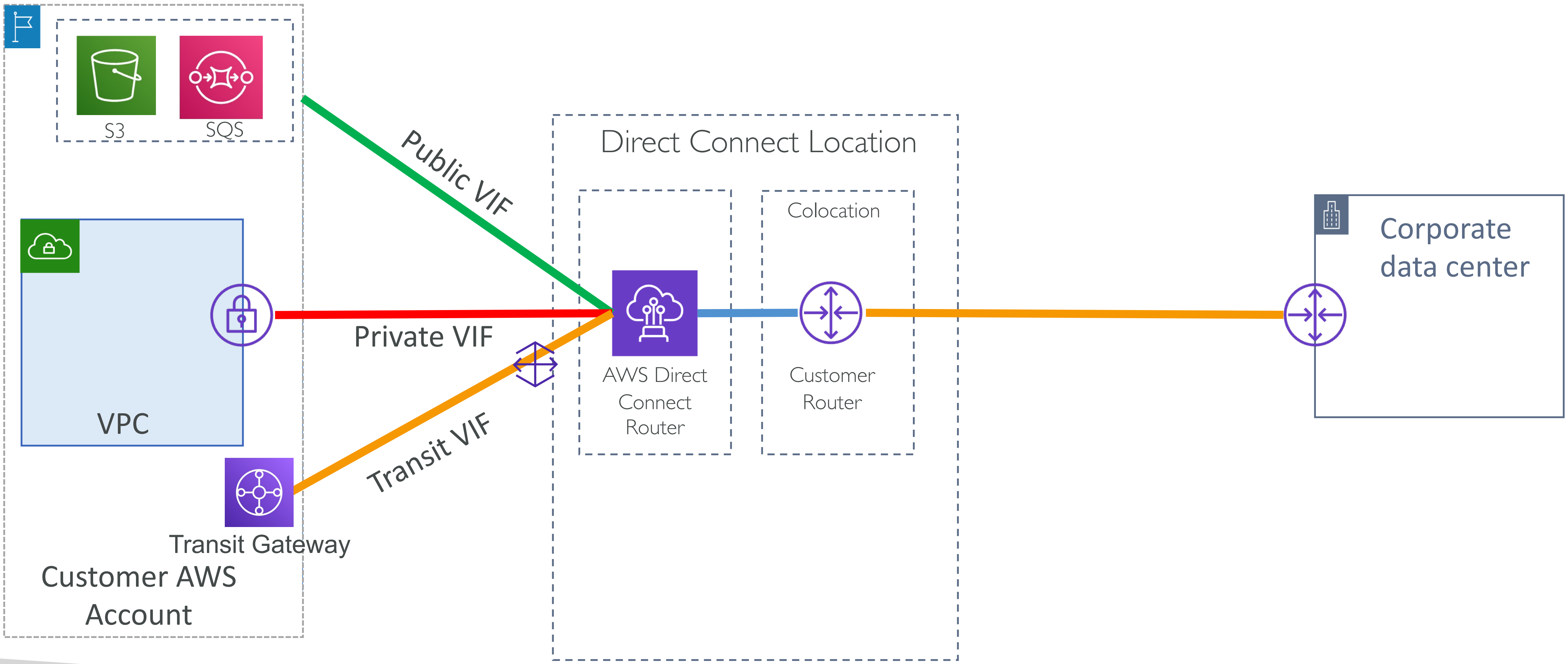
- A dedicated network connection from on-premises to AWS
- AWS <-> DirectConnect Location <-> On-premises Data Center
- Low latency and consistent bandwidth
- Lower data transfer cost
- Access AWS Private Network (VPC) and AWS public services endpoints (e.g S3, DynamoDB)



AWS Direct Connect

- Leverages AWS Global network backbone
- DX locations are provided by authoritative 3rd party providers.
- 115 DX locations across the world across 31 AWS regions (as of today)
- End to end provisioning time of 4-12 weeks
- Get bandwidth of 1, 10 or 100 Gbps with Dedicated connection
- Get sub-1 Gbps bandwidth (50/100/200/400/500 Mbps, 1,10 Gbps) by leveraging AWS Direct Connect APN partner

AWS Direct Connect

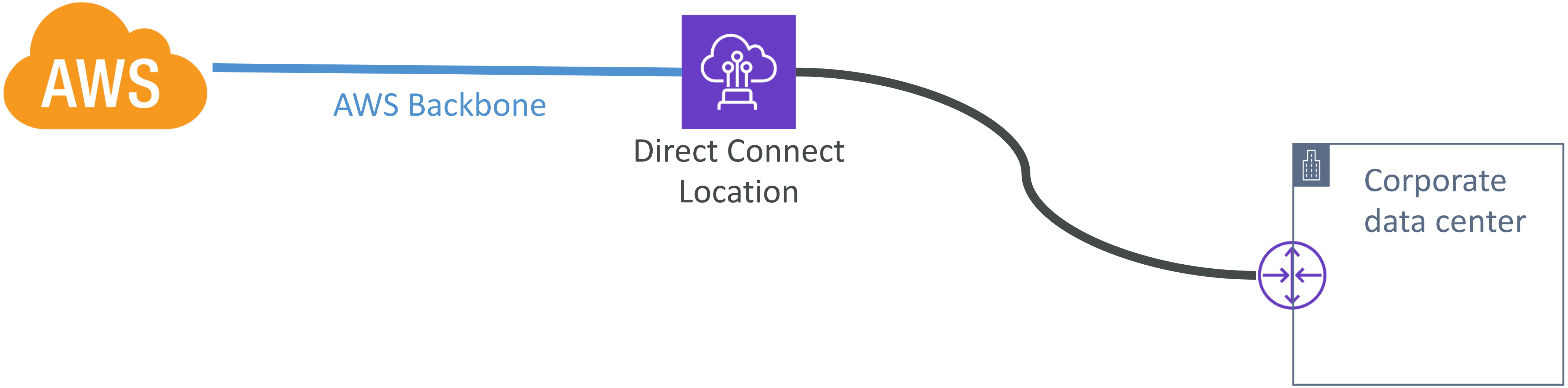


DX network requirement

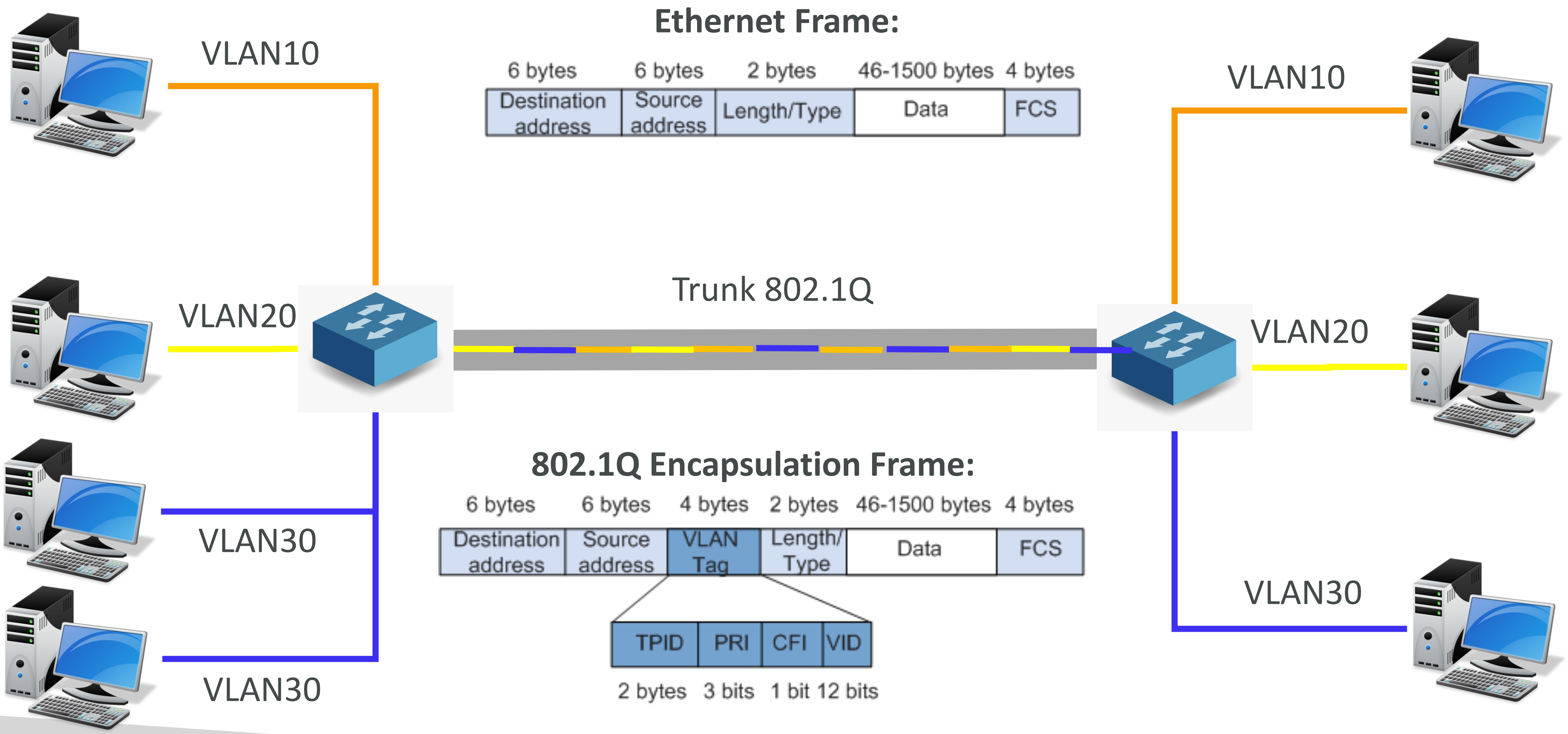
Direct Connect Network Requirements

- **Single-mode fiber**
  - 1000BASE-LX (1310 nm) transceiver for 1 G
  - 10GBASE-LR (1310 nm) transceiver for 10 G
  - 100GBASE-LR4 for 100 G
- **802.1Q VLAN** encapsulation must be supported
- Auto-negotiation for the port must be disabled for port speed of more than 1Gbps
- End Customer Router (on-premises) must support **Border Gateway Protocol** (BGP) and BGP MD5 authentication
- (optional) **Bidirectional Forwarding Detection**

Single-mode fiber



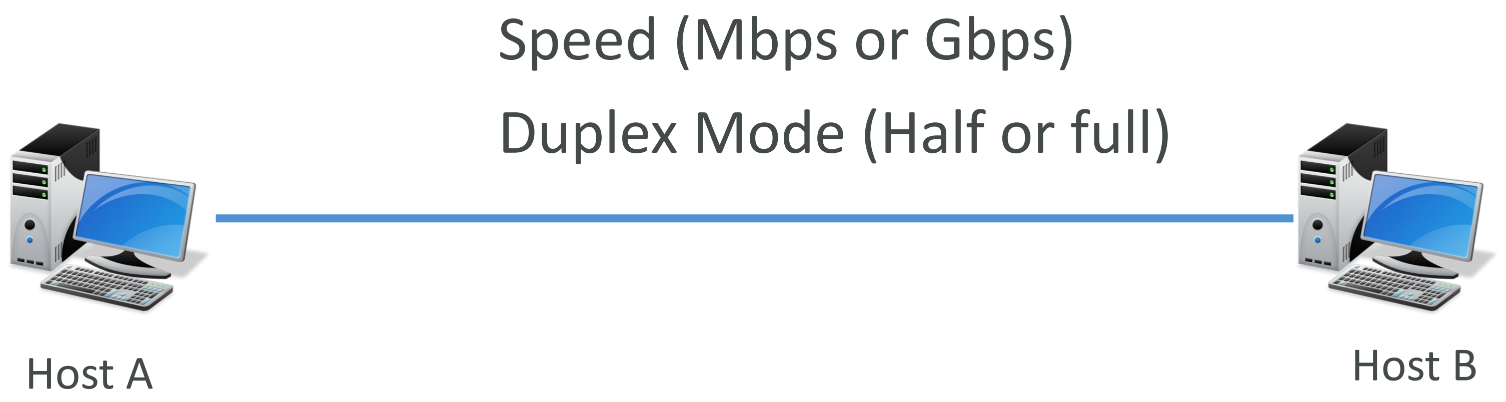
802.1Q VLAN



VLAN10
VLAN20
VLAN30
VLAN30
Ethernet Frame:
6 bytes 6 bytes 2 bytes 46-1500 bytes 4 bytes
Destination address
Source address
Length/Type
Data
FCS
Trunk 802.1Q
802.1Q Encapsulation Frame:
6 bytes 6 bytes 4 bytes 2 bytes 46-1500 bytes 4 bytes
Destination address
Source address
VLAN Tag
Length/Type
Data
FCS
TPID
PRI
CFI
VID
2 bytes 3 bits 1 bit 12 bits
VLAN10
VLAN20
VLAN30

Auto-negotiation of the ports

- Auto-negotiation is the ability of a network interface to automatically coordinate its own connection parameters (speed and duplex) with another network interface.



- For DX the Auto-negotiation for the port must be disabled for port speed more than 1 Gbps

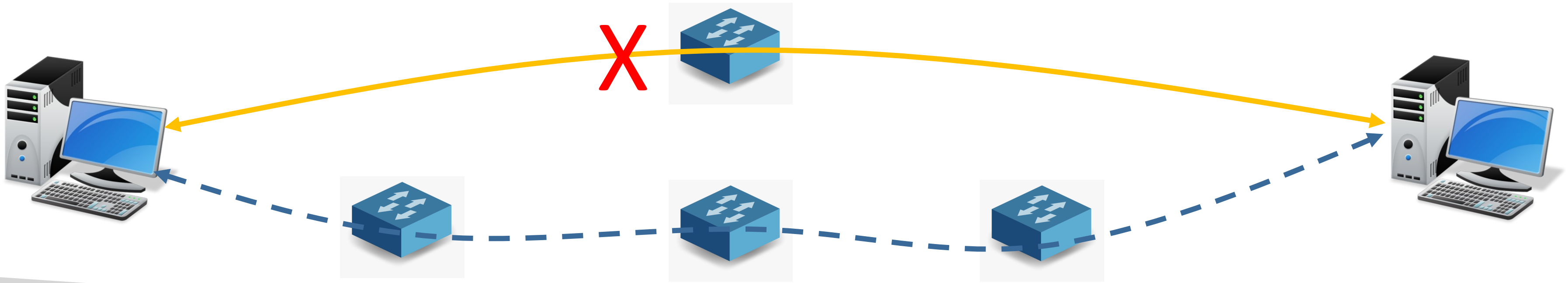
BGP – Border Gateway Protocol

- Dynamic Routing using **Path-Vector** protocol where it exchanges the best path to a destination between peers or AS
- TCP based protocol on port 179
- iBGP – Routing within AS
- eBGP – Routing between AS's
- Network path selection decision is influenced by BGP routing parameters
  - ASPATH – Series of AS's to traverse the path (works between AS)
  - Local Preference LOCAL_PREF (works within AS)
  - MED – Multi-Exit Discriminator (works between AS)

The current version of BGP is version 4 (BGP4), which was published as RFC 4271 in 2006

BFD – Bidirectional Forwarding Detection (Optional)

- It's a simple Hello Network Protocol
- Lowers the network failure detection time between the neighboring peers
- Provides the detection time less than 1 sec



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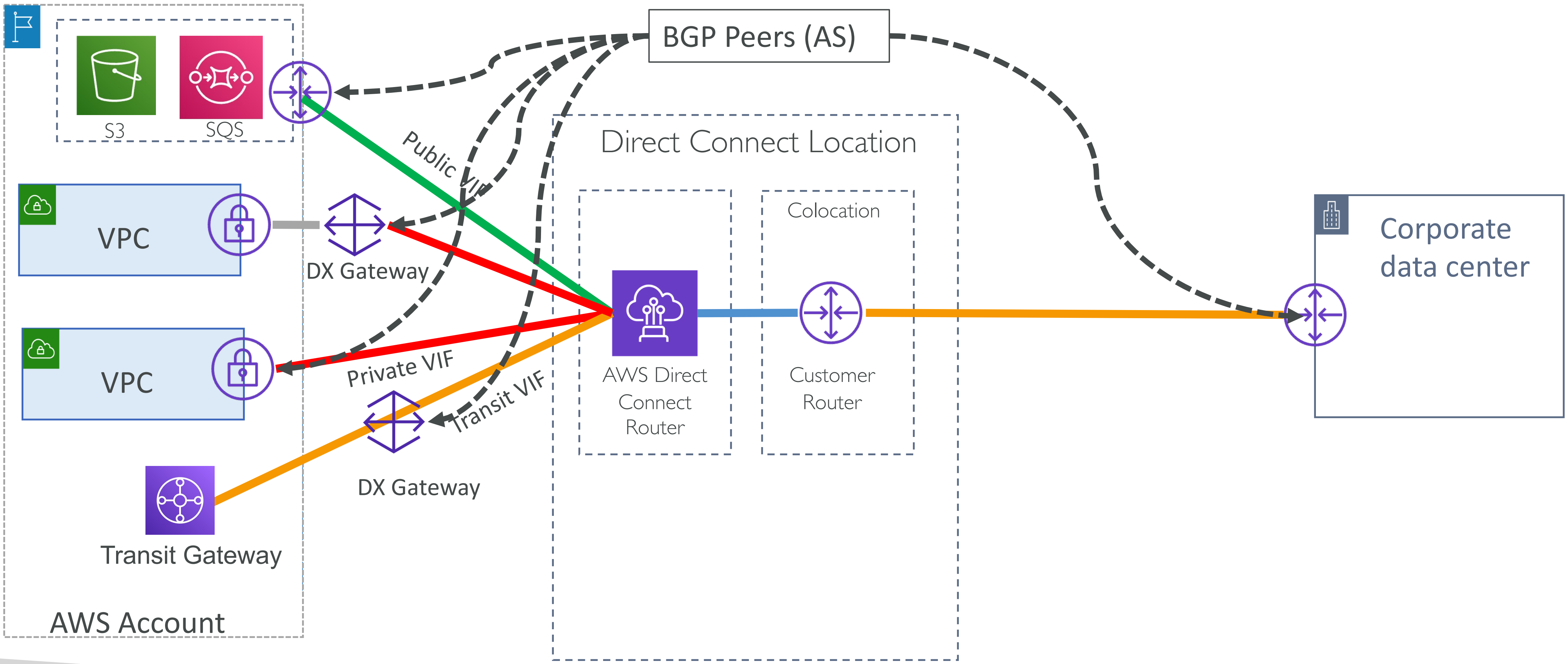
BGP AS and ASN

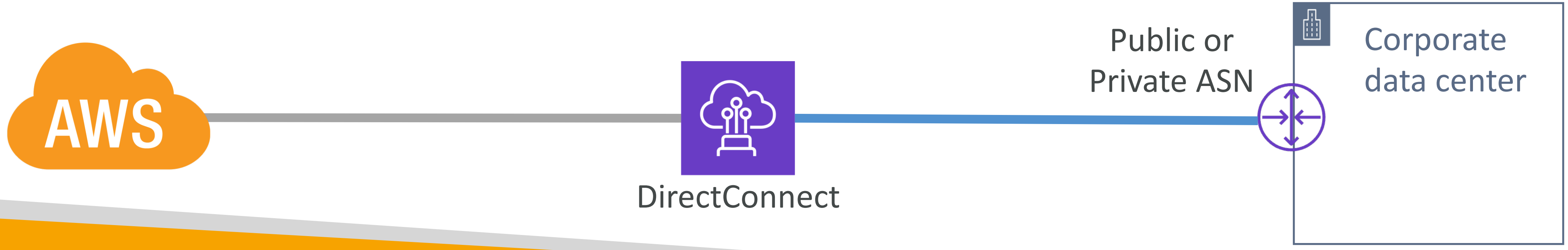
BGP Peers



BGP Peers (AS)
S3
SQS
Public VIF
VPC
DX Gateway
VPC
Private VIF
Transit VIF
DX Gateway
Transit Gateway
AWS Account
Direct Connect Location
Colocation
AWS Direct Connect Router
Customer Router
Corporate data center

ASN – Autonomous System Number

- Public and Private ASN
  - Public ASNs are assigned by IANA via Regional Internet Registries (RIRs)
  - You need to use the Public ASN if you are exchanging routes over a public internet
  - You can use private ASN for **private** connection between two AS
- 2 Byte (16 bit) ASN (0-65535)
  - Public ASN is assigned by IANA in the range of 1 to 64495
  - Private ASN can be assigned in the range of **64512 to 65534**
- 4 Byte (32 bit) ASN (0 to 4294967295)
  - Public ASN is assigned by IANA in the range1 to 2147483647
  - Private ASN can be assigned in the range of **4200000000 to 4294967294**

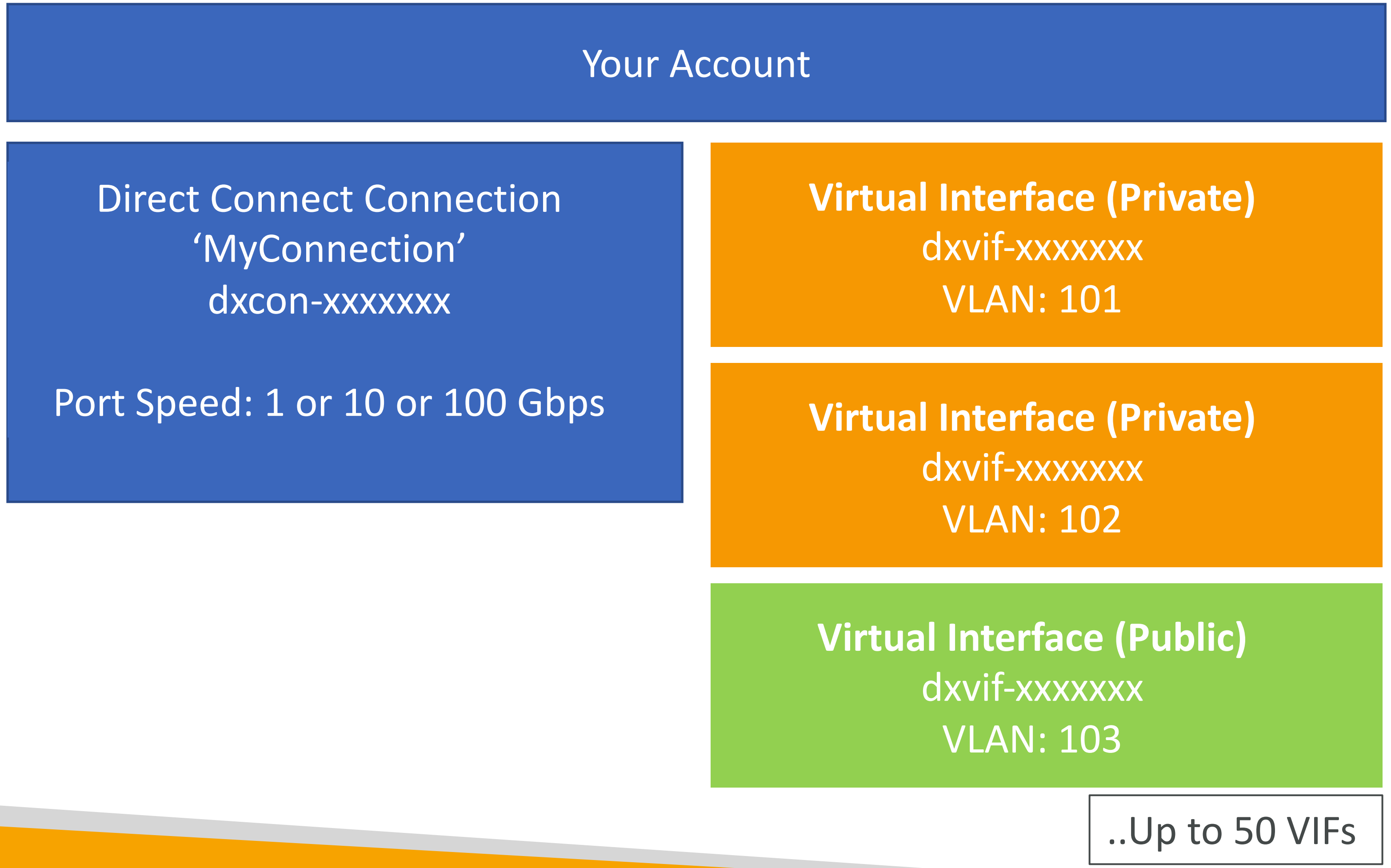


DX Connection Types

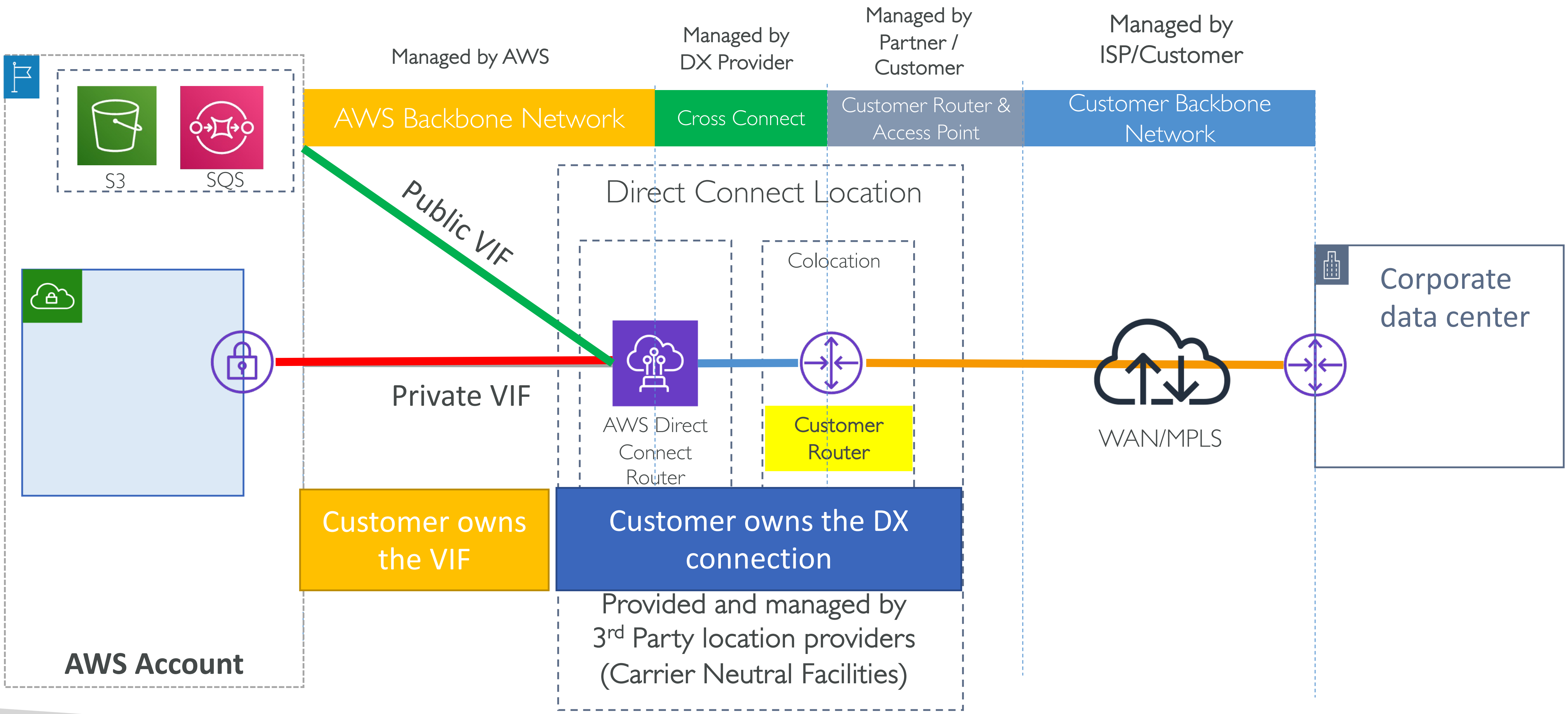
Direct Connect – Connection Types

- **Dedicated Connections:** 1Gbps, 10 Gbps and 100 Gbps capacity
  - Physical ethernet port dedicated to a customer
  - Request made to AWS first, then completed by AWS Direct Connect Partners
  - Can be either setup by your Network Provider or AWS Direct Connect Partner
- **Hosted Connections:**
  - 50, 100, 200, 300, 400, 500 Mbps and 1 Gbps, 2 Gbps, 5 Gbps, 10 Gbps
  - Connection requests are made via AWS Direct Connect Partners
  - 1, 2, 5, 10 Gbps available at select AWS Direct Connect Partners
  - AWS uses traffic policing on hosted connections – excess traffic is dropped

Dedicated connection – AWS account



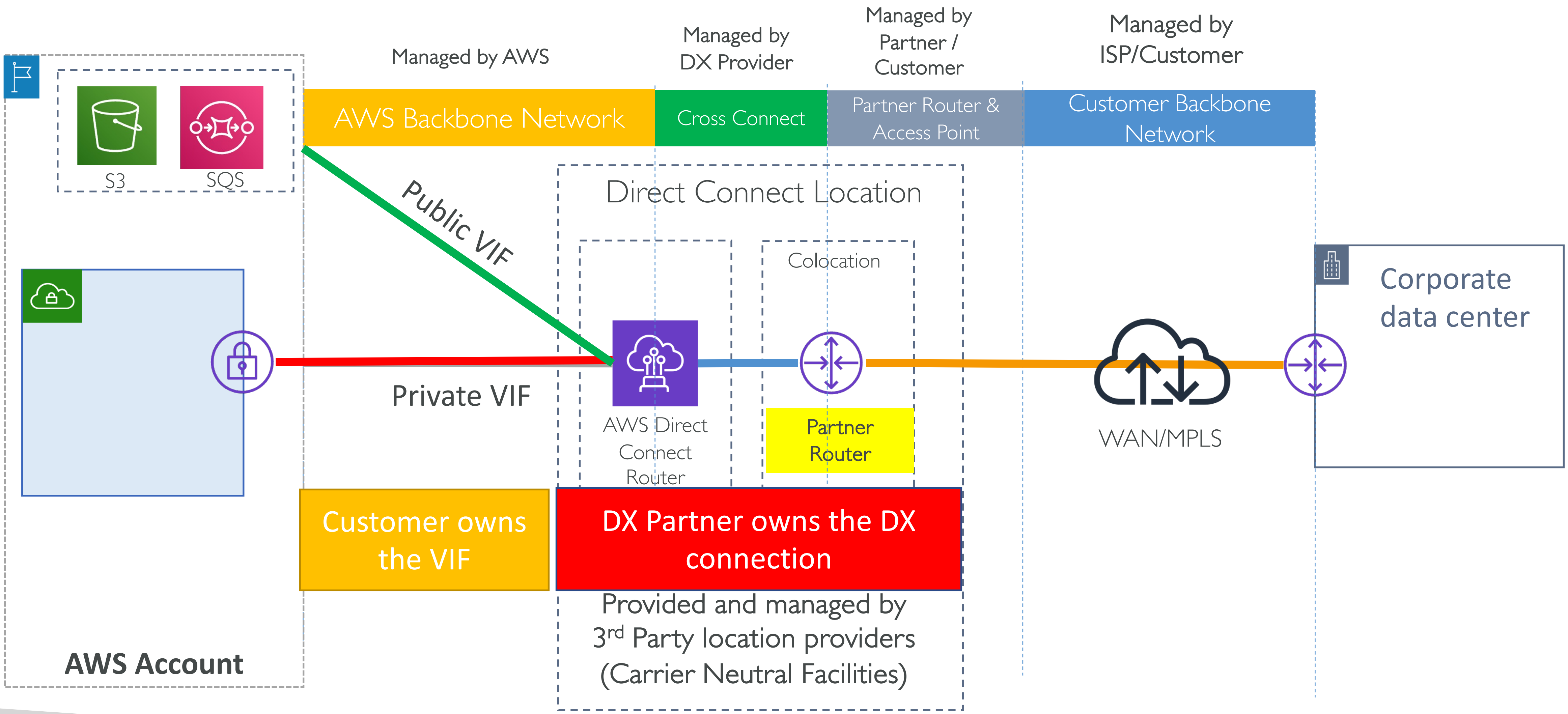
Dedicated connection



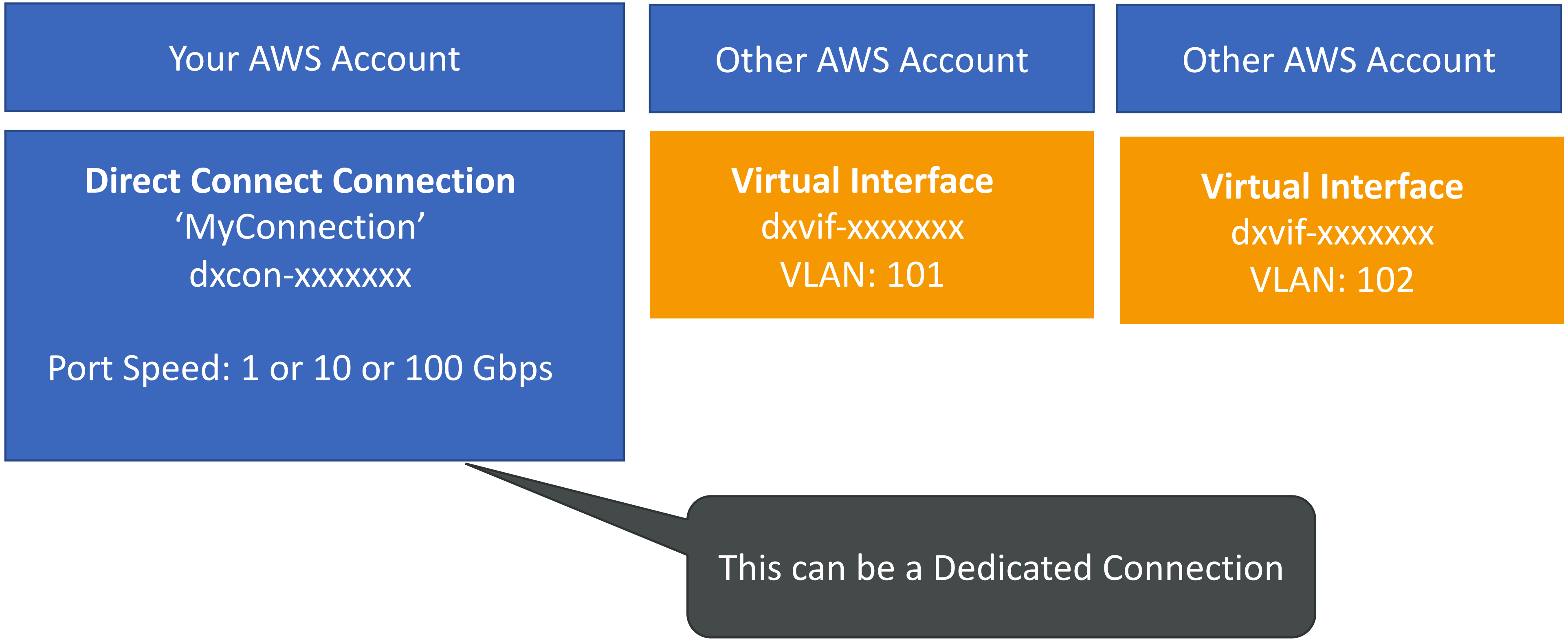
Hosted connection – AWS account

Partner AWS Account	Your AWS Account	
Interconnect	**Hosted Connection** 'MyConnection1' dxcon-xxxxxxx VLAN: 101 Port Speed: 50-500 Mbps	**Virtual Interface** dxvif-xxxxxxx VLAN: 101
One Hosted Connection = 1 VIF	**Hosted Connection** 'MyConnection2' dxcon-xxxxxxx VLAN: 102 Port Speed: 50-500 Mbps	**Virtual Interface** dxvif-xxxxxxx VLAN: 102

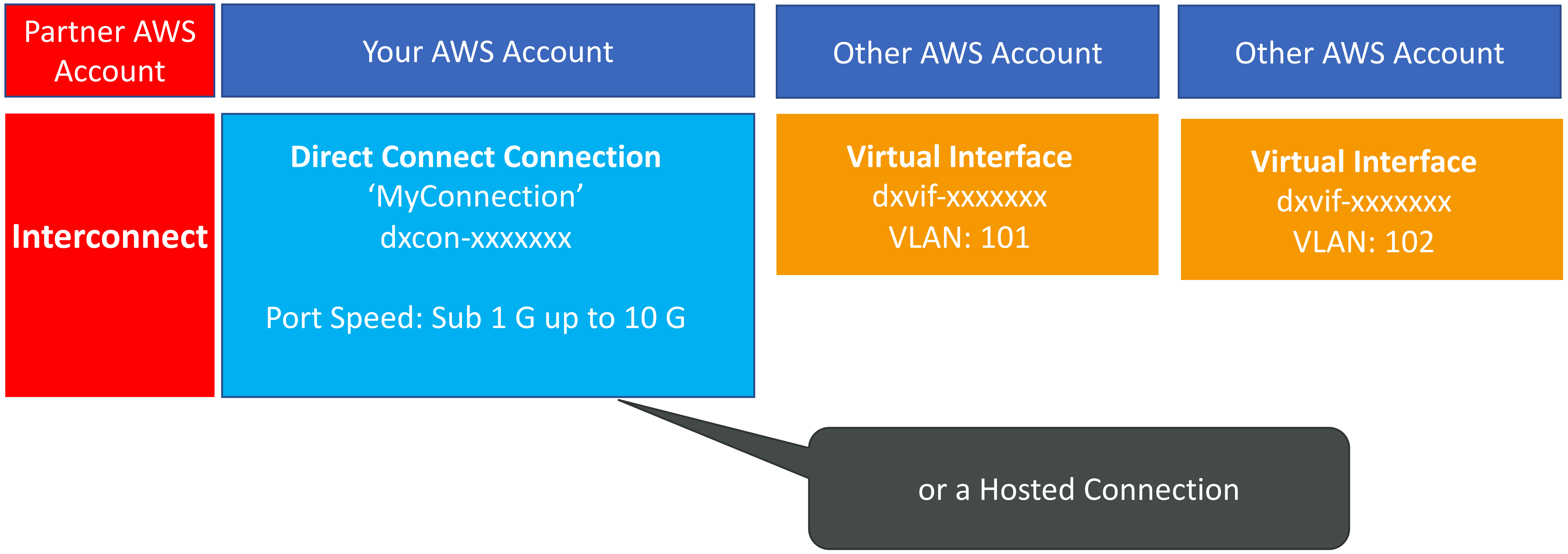
Hosted connection



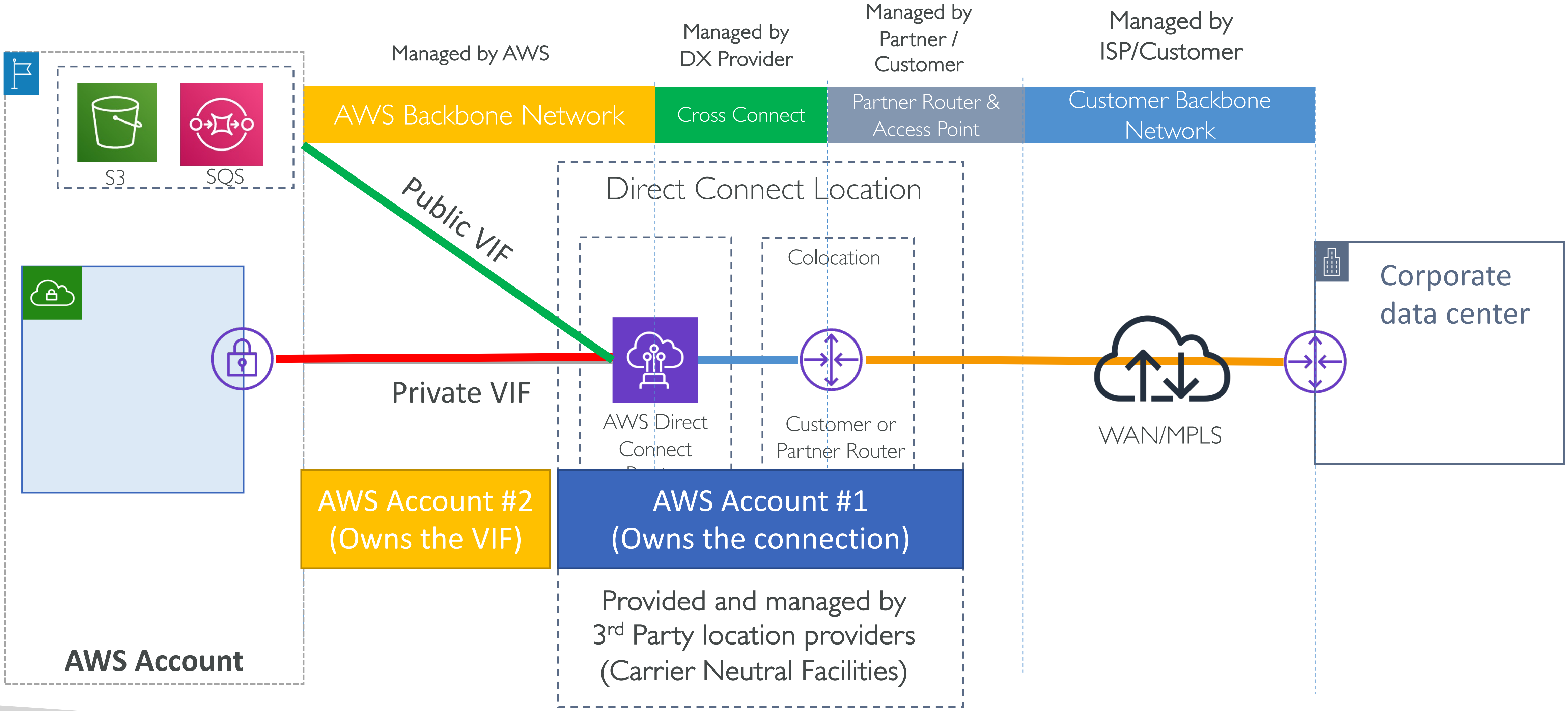
Hosted VIF – AWS account



Hosted VIF – AWS account



Hosted VIF



S3
SQS
Managed by AWS
Managed by
DX Provider
Managed by
Partner /
Customer
Managed by
ISP/Customer
AWS Backbone Network
Cross Connect
Partner Router &
Access Point
Customer Backbone
Network
Public VIF
Direct Connect Location
Colocation
Corporate
data center
Private VIF
AWS Direct
Connect
Customer or
Partner Router
WAN/MPLS
AWS Account #2
(Owns the VIF)
AWS Account #1
(Owns the connection)
Provided and managed by
3rd Party location providers
(Carrier Neutral Facilities)
AWS Account

Steps to setup Direct Connect connections

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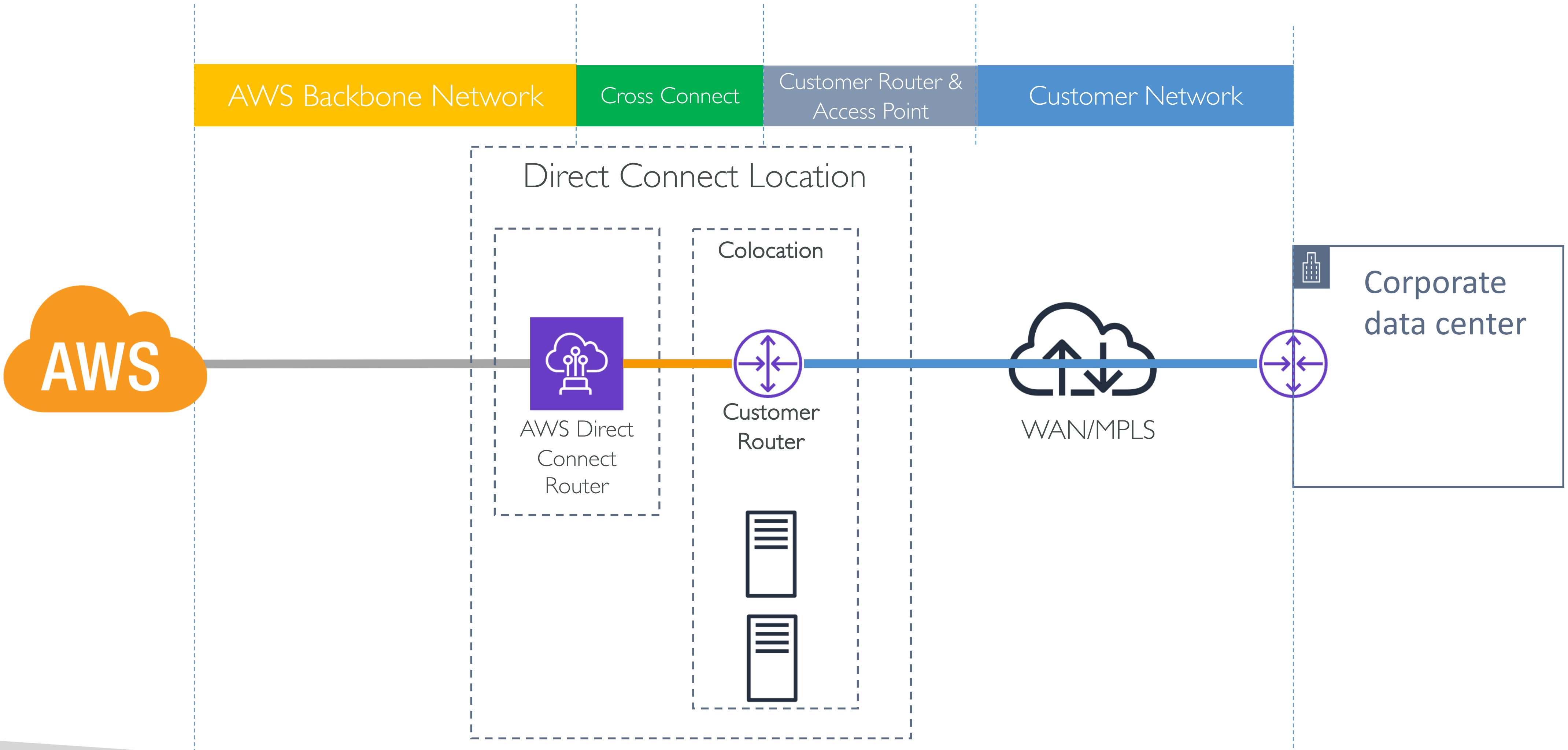
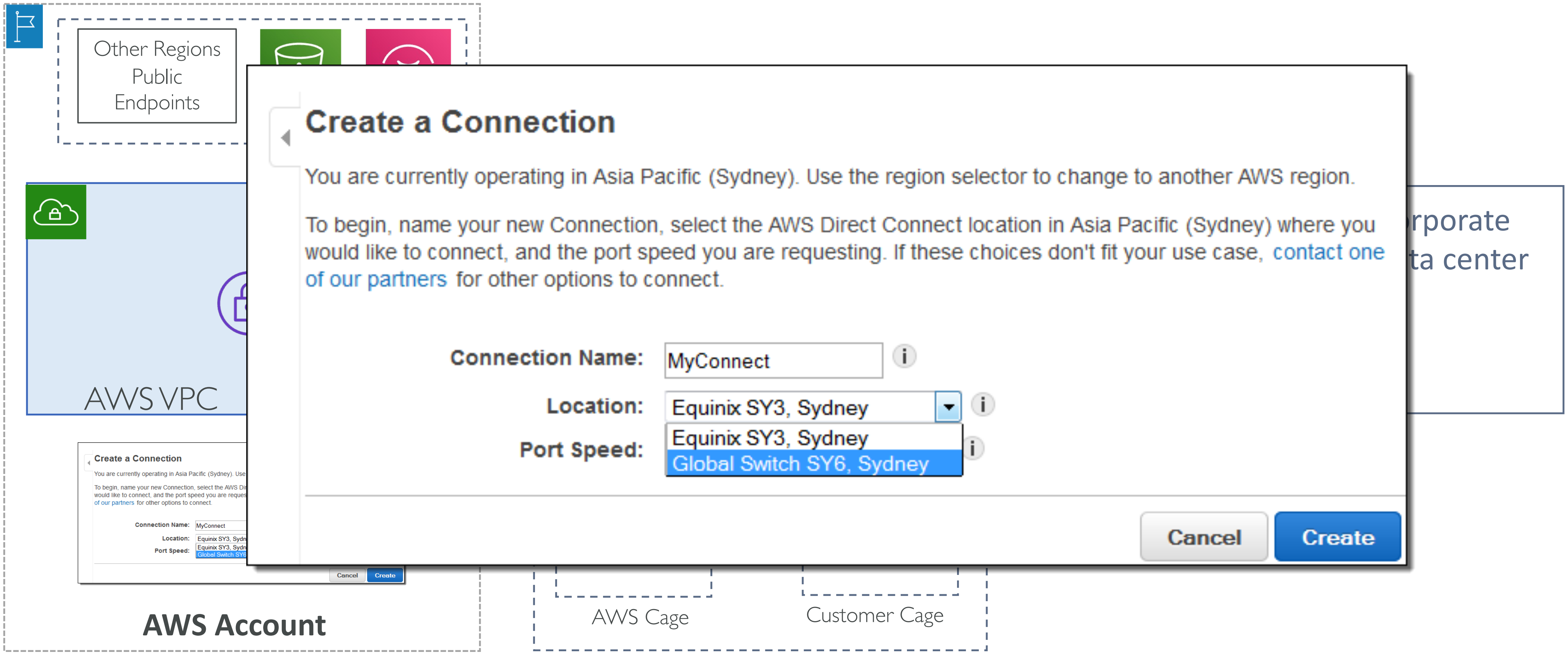
Dedicated Connection



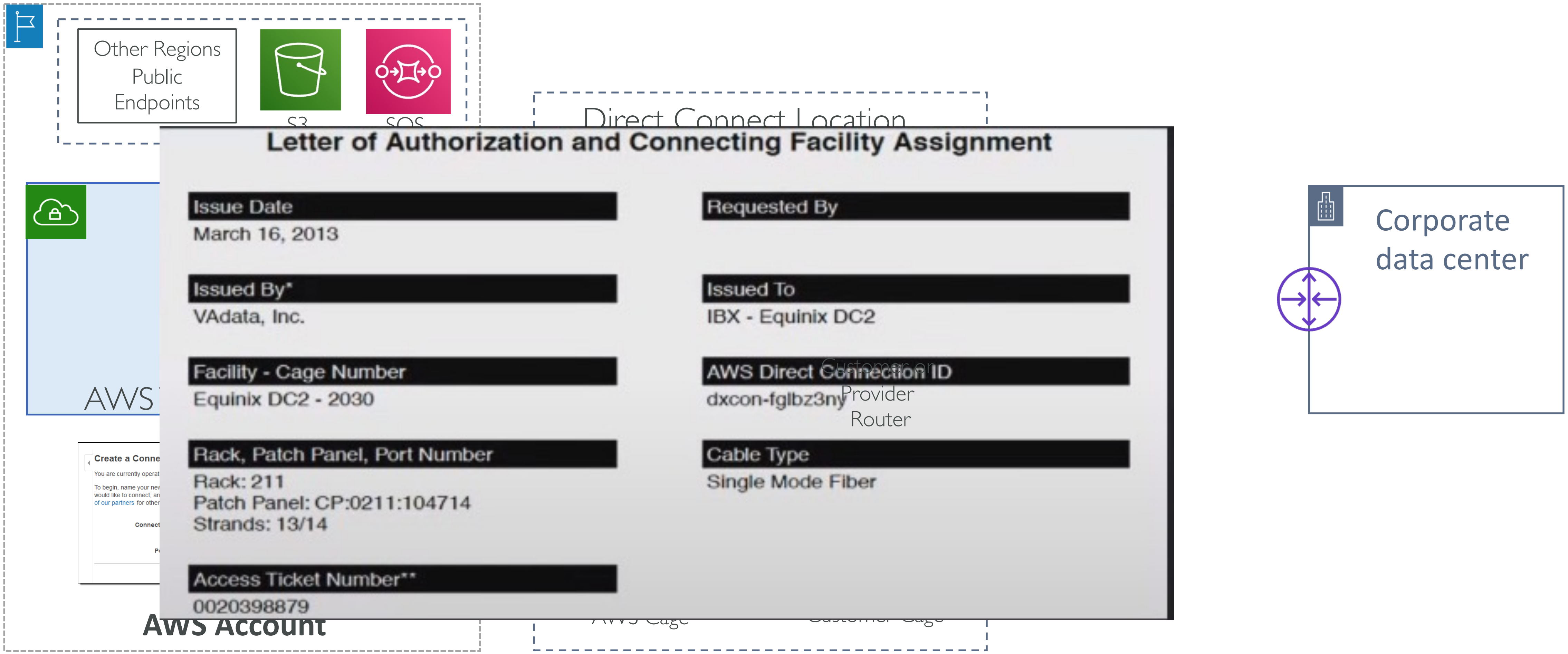
Dedicated connection – Sequence of events

1. You select the AWS region, DX location and submit the connection request via AWS console or CLI or API
2. AWS provisions your port within 72 hrs and provide you with the LOA-CFA (Letter of Authorization – Connection facility assignment)
3. LOA contains the demarcation details of assigned port within the facility
4. If your organization has physical presence in DX location, then you can request for cross-connect within the facility to connect to AWS device
5. If not, you provide the copy of LOA to DX APN partner and partner places the order for cross-connect
6. After connection is up, you receive Tx/Rx optical signal at your equipment
7. Now, you can create Private or Public Virtual Interfaces to connect to your VPC or public AWS services

Steps to setup DX Dedicated connection



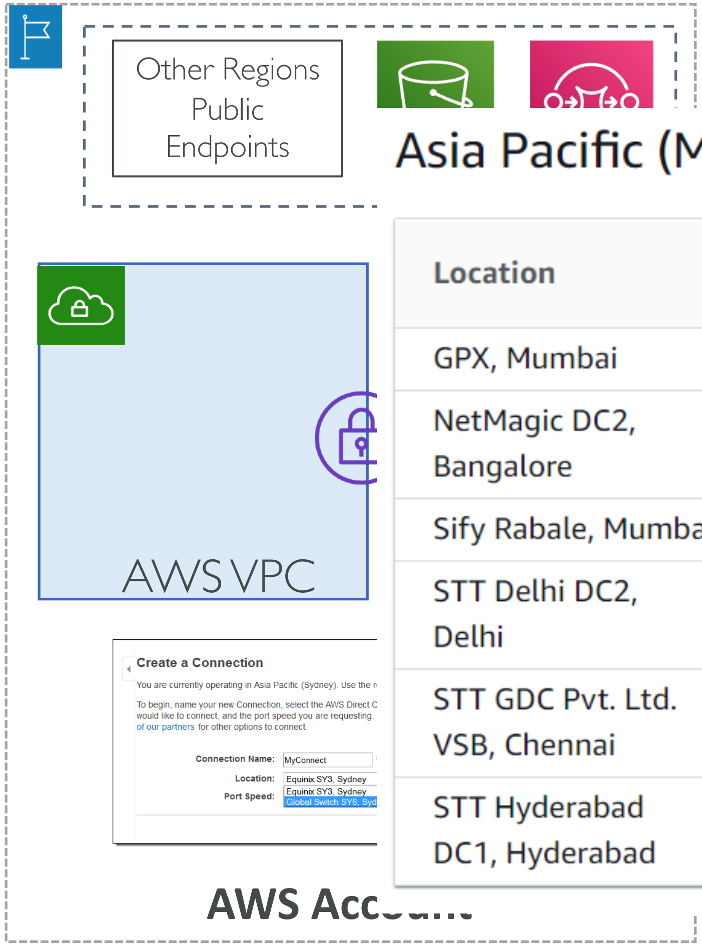
Steps to setup DX Dedicated connection



Letter of Authorization and Connecting Facility Assignment

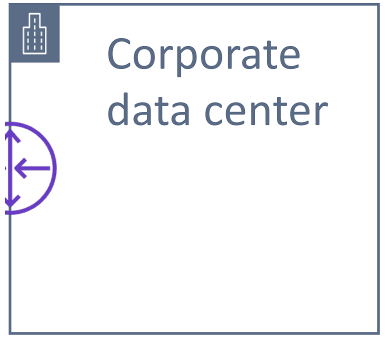
Issue Date	March 16, 2013
Requested By	
Issued By*	VAdata, Inc.
Issued To	IBX - Equinix DC2
Facility - Cage Number	Equinix DC2 - 2030
AWS Direct Connection ID	dxcon-fglbz3ny
Rack, Patch Panel, Port Number	Rack: 211 Patch Panel: CP:0211:104714 Strands: 13/14
Cable Type	Single Mode Fiber
Access Ticket Number**	0020398879

Steps to setup DX Dedicated connection

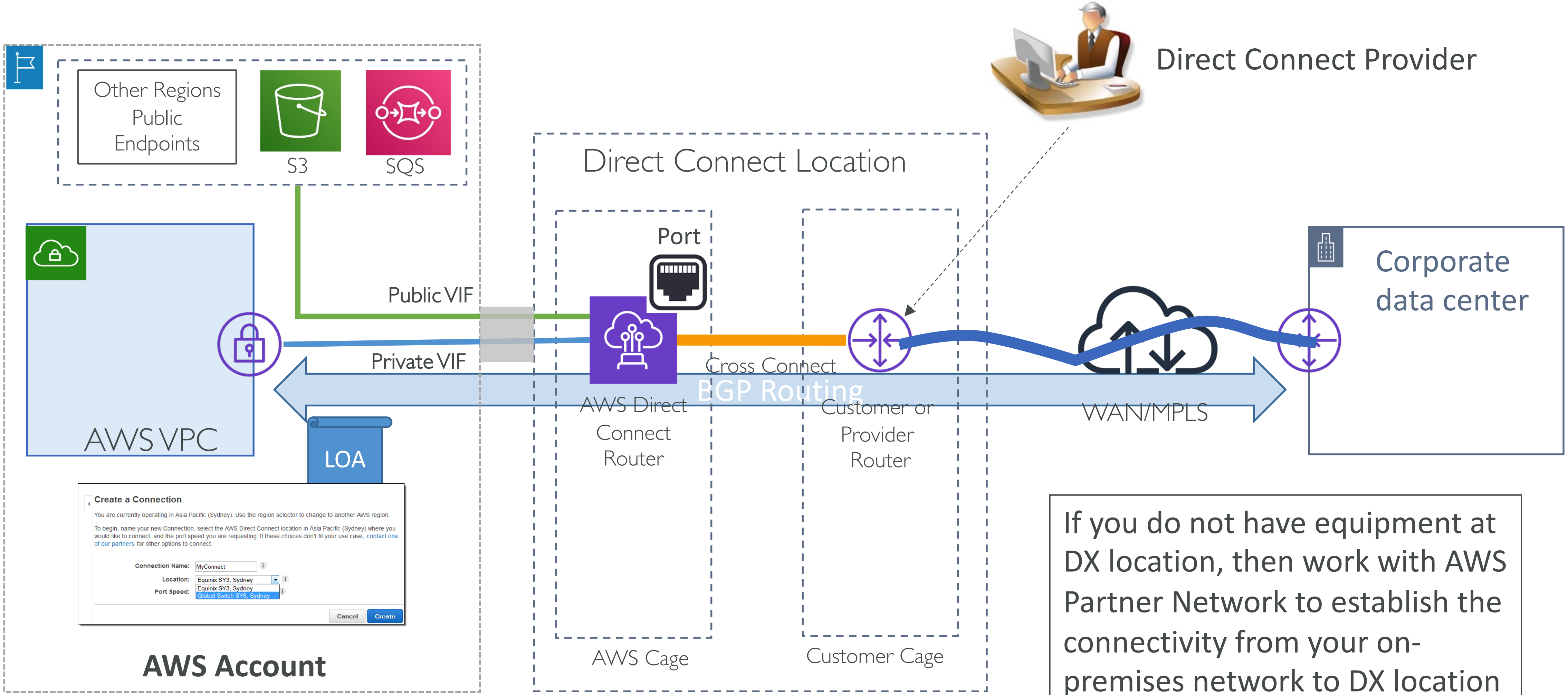


Asia Pacific (Mumbai)

Location	How to request a connection
GPX, Mumbai	Contact GPX at nkankane@gpxglobal.net.
NetMagic DC2, Bangalore	Contact NetMagic Sales and Marketing toll-free at 18001033130 or at marketing@netmagicsolutions.com.
Sify Rabale, Mumbai	Contact Sify at aws.directconnect@sifycorp.com.
STT Delhi DC2, Delhi	Contact STT at enquiry.AWSDX@sttelemediagdc.in.
STT GDC Pvt. Ltd. VSB, Chennai	Contact STT at enquiry.AWSDX@sttelemediagdc.in.
STT Hyderabad DC1, Hyderabad	Contact STT at enquiry.AWSDX@sttelemediagdc.in.

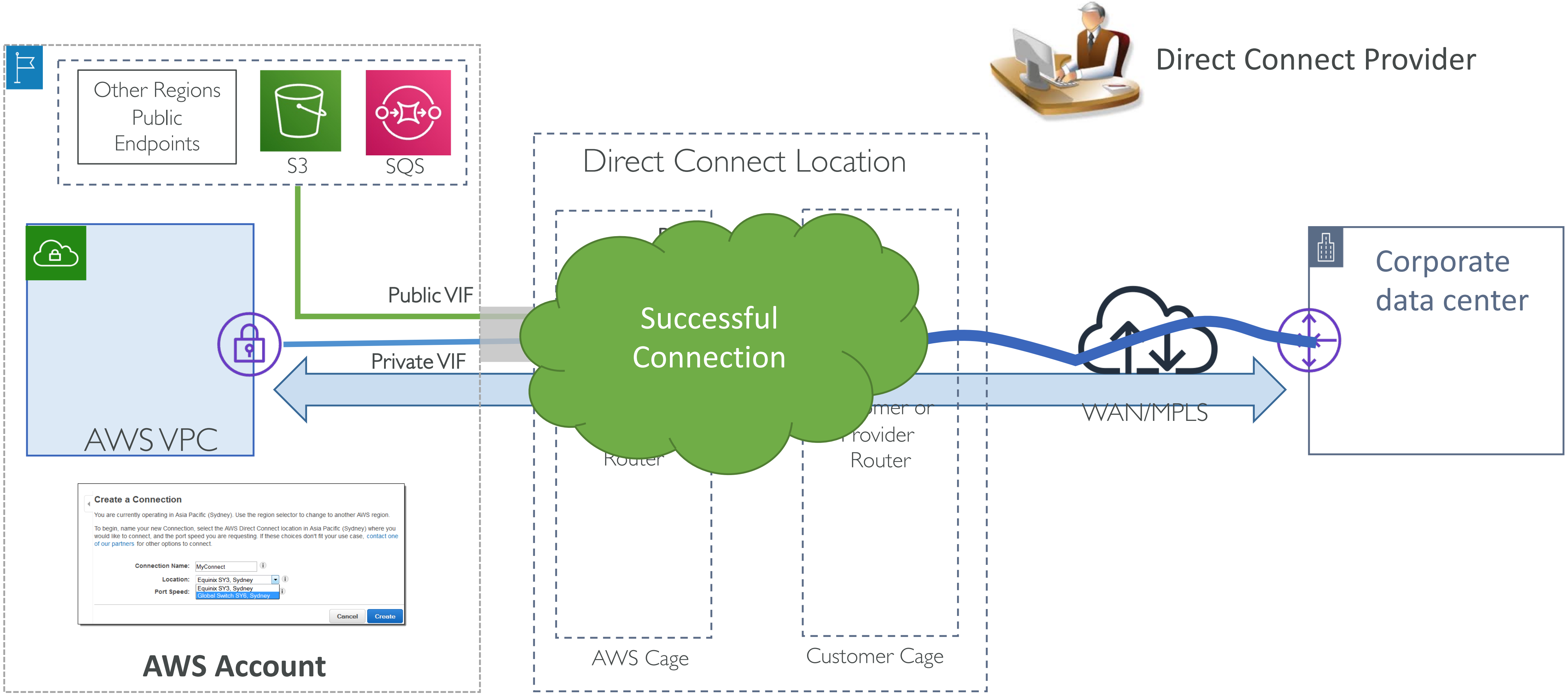


Steps to setup DX Dedicated connection

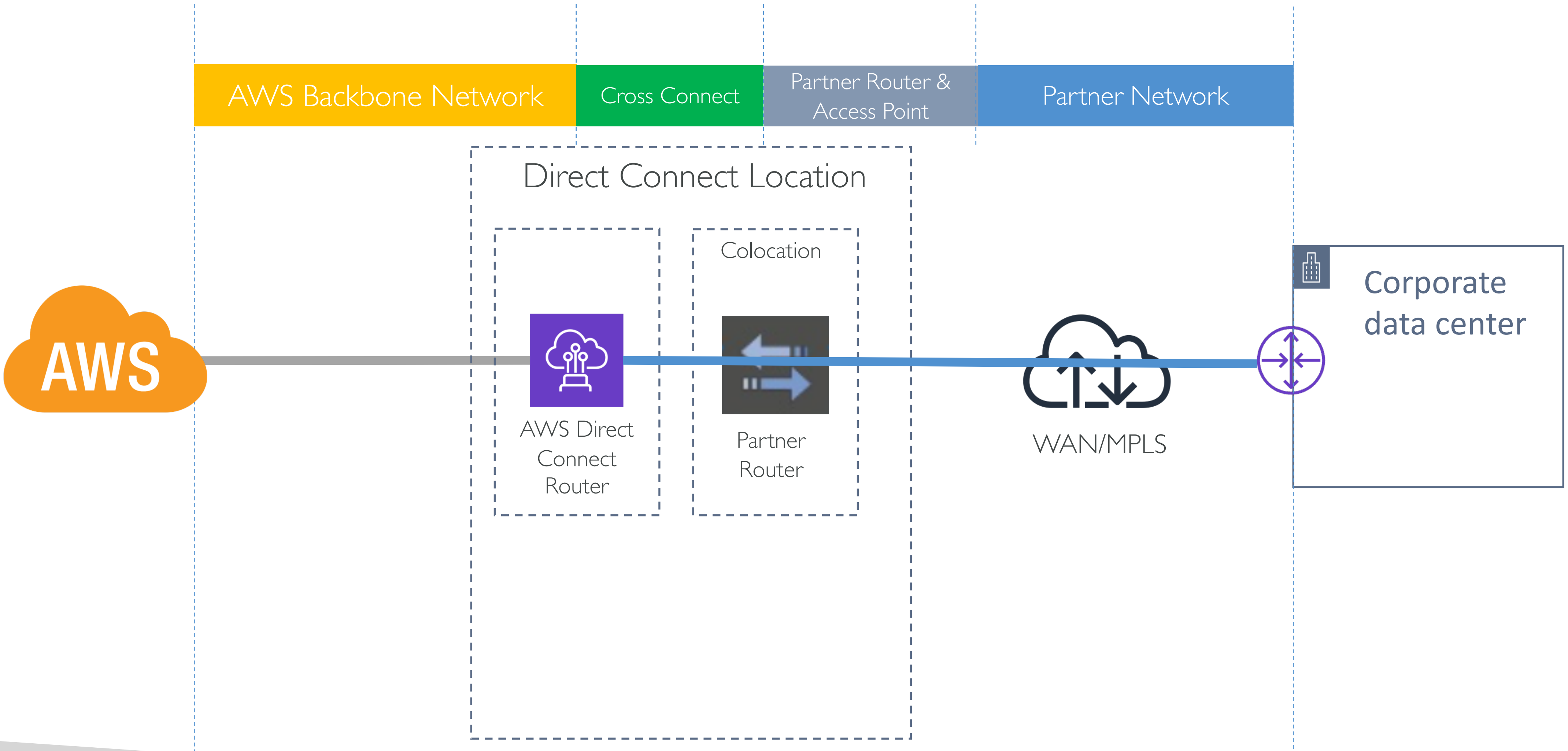


If you do not have equipment at DX location, then work with AWS Partner Network to establish the connectivity from your on-premises network to DX location

Steps to setup DX Dedicated connection



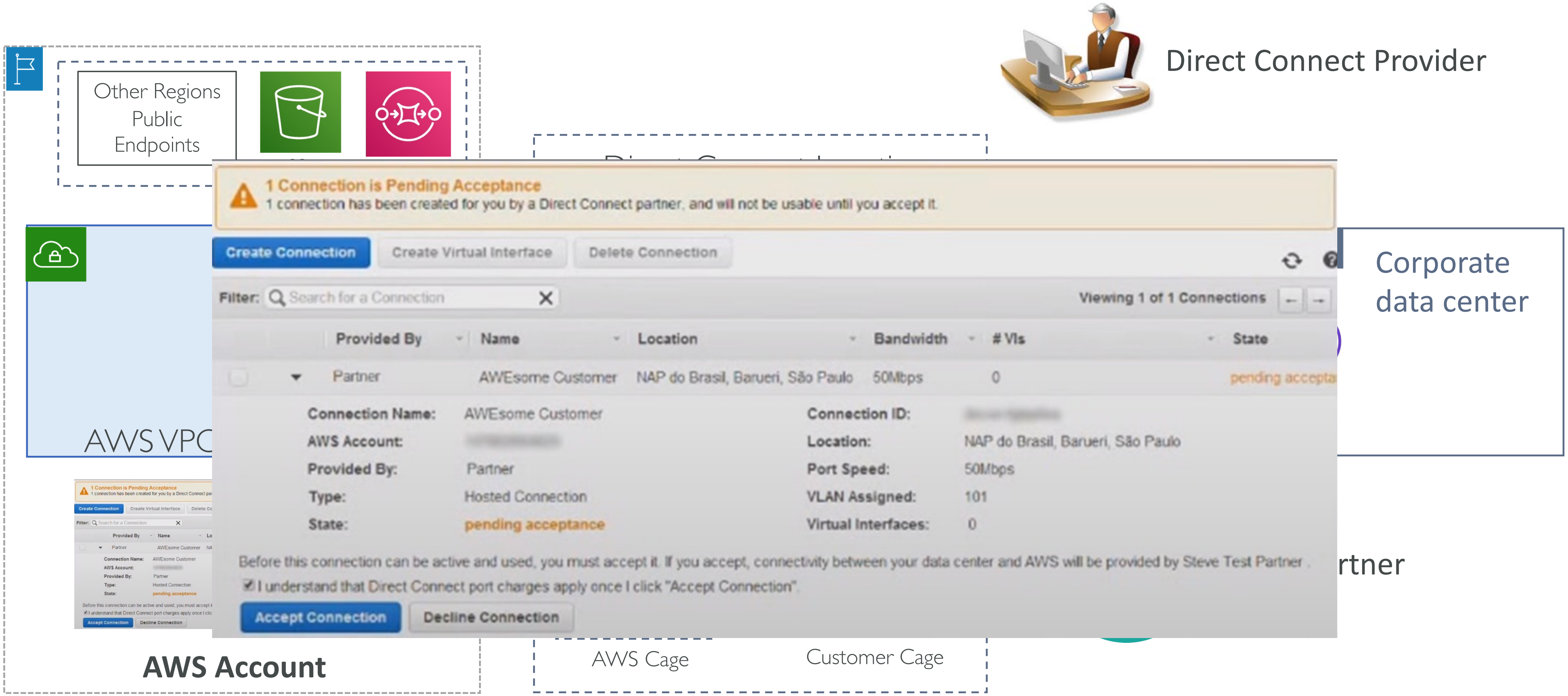
Hosted Connection



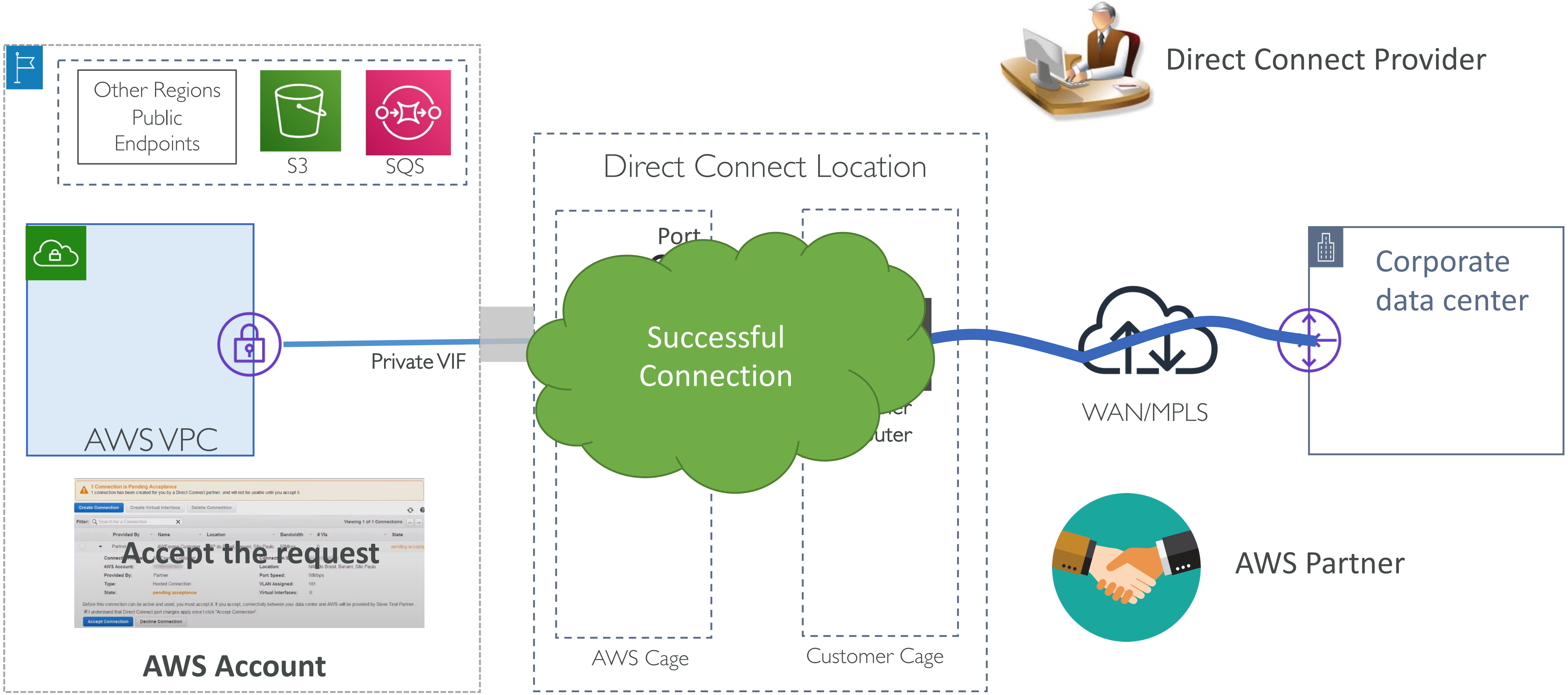
Hosted connection – Sequence of events

- To order Hosted connection, you don't need to get LOA. You can directly contact a **Direct Connect Partner** to order the connection
- You provide your 12-digit AWS account number to the partner
- Partner will setup the hosted connection and this connection will be available in your account (in the given region) to accept it
- Once you accept the connection, it enables the billing for associated port hours and data transfer charges

Steps to setup DX Hosted connection



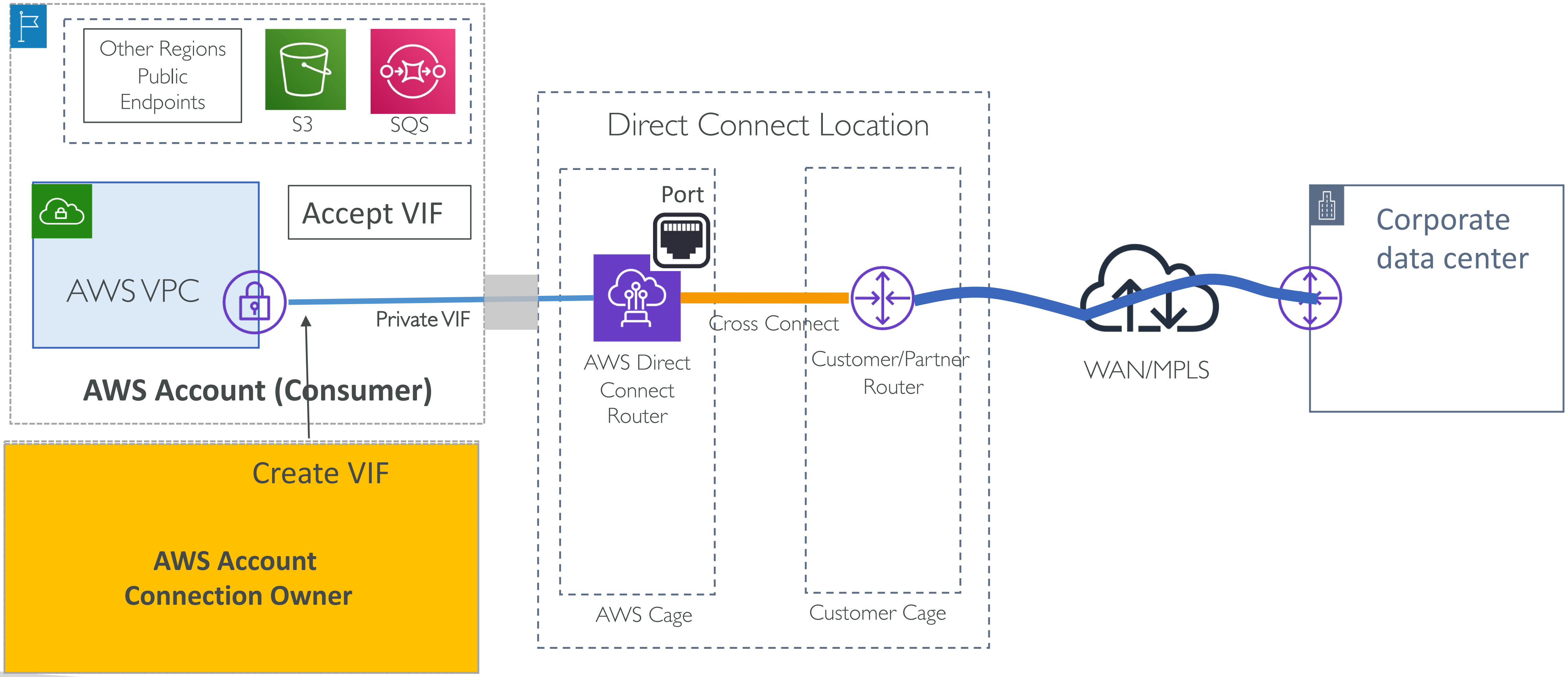
Steps to setup DX Hosted connection



Hosted VIF

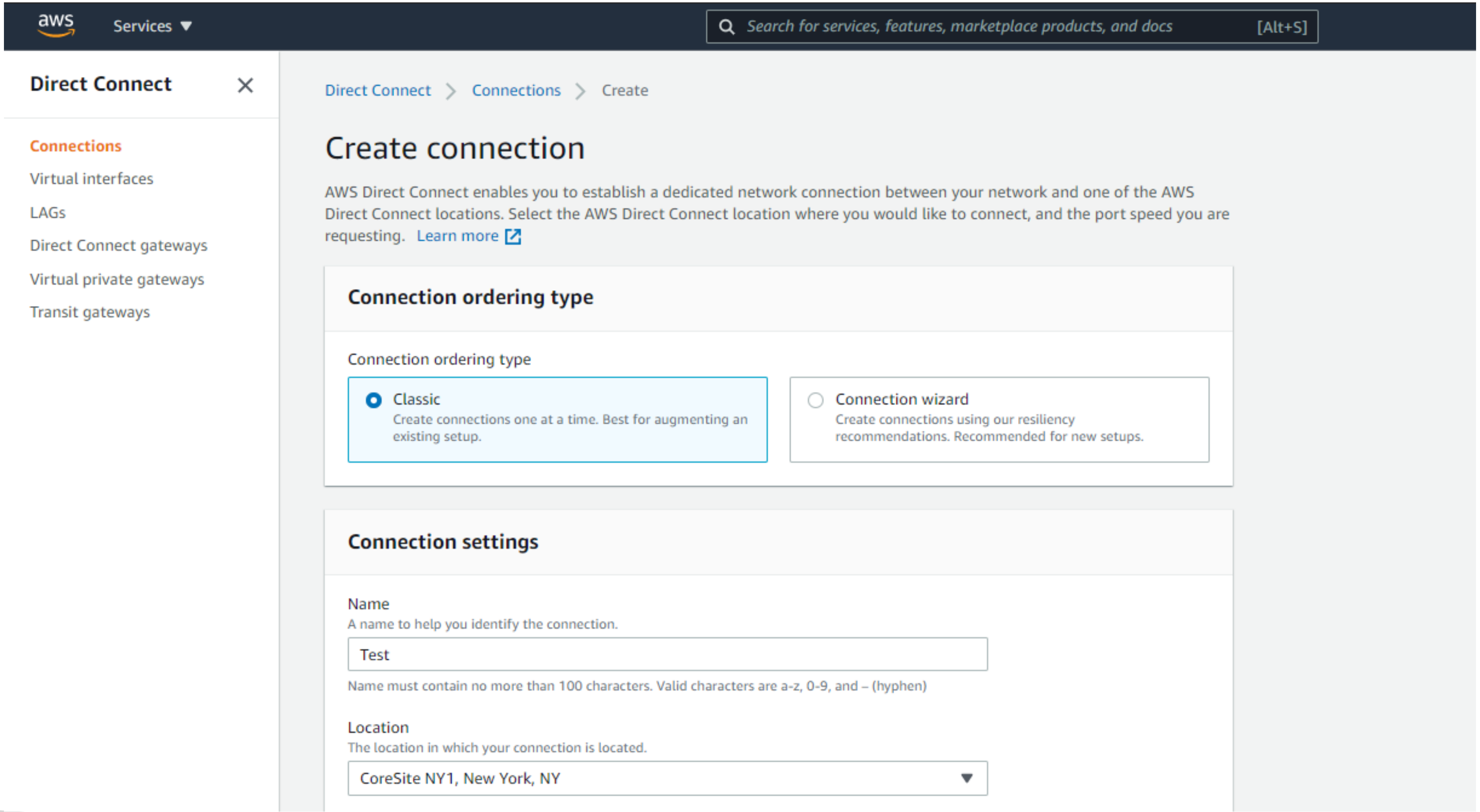
- Don't get confused with Hosted Connection
- When creating a VIF you may choose "Another AWS account"
- You are still the owner of the Direct connect Connection however the VIF is created in another AWS account who must accept it
- For Private VIF, the other account should also associate it with VGW
- A connection of less than 1 Gbps supports only one virtual interface.
- Typically used in a scenario where centralized network team manages the DX connection and provisions VIFs for business accounts

Steps to create Hosted VIF



DX Connection creation steps walkthrough

Demo

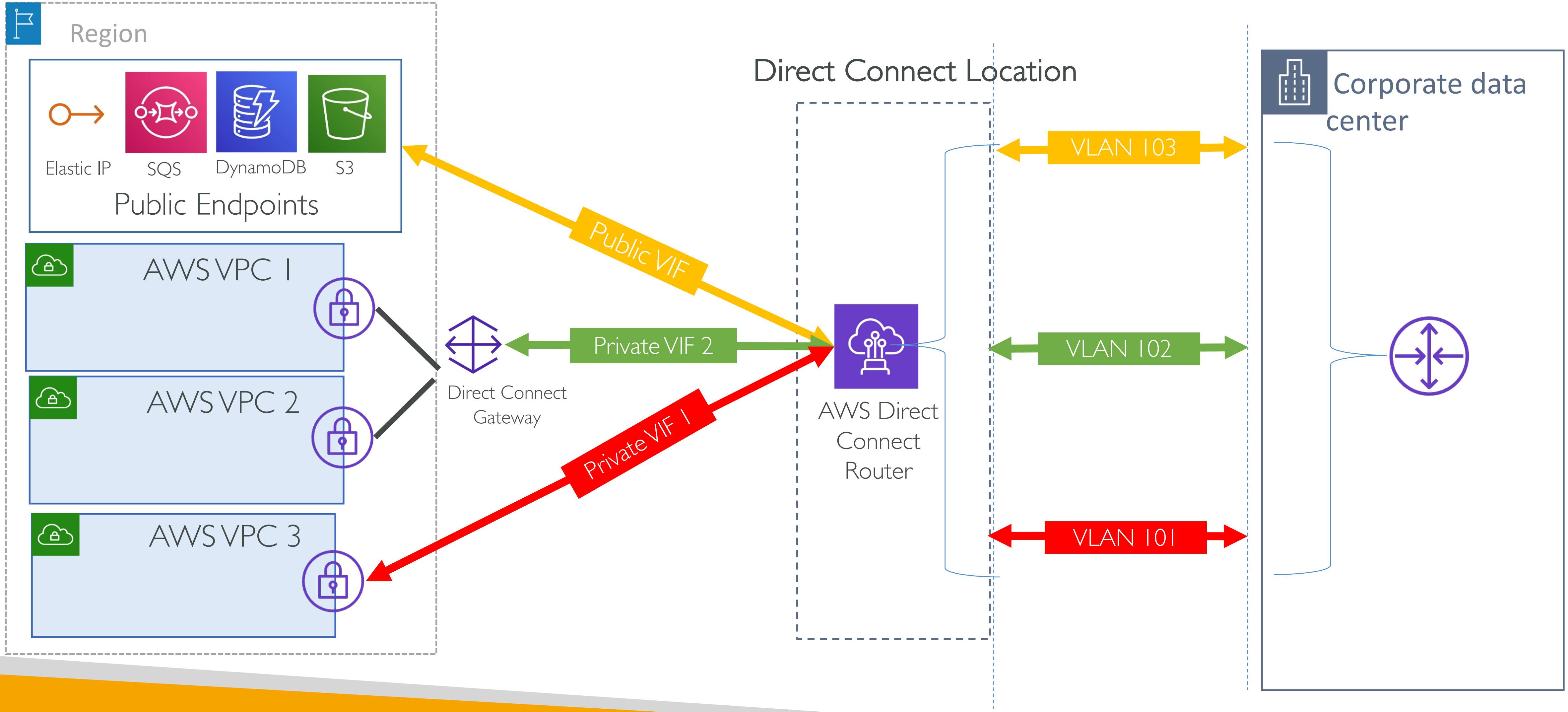

aws
Services
Search for services, features, marketplace products, and docs
[Alt+S]
Direct Connect
Connections
Virtual interfaces
LAGs
Direct Connect gateways
Virtual private gateways
Transit gateways
Direct Connect > Connections > Create
Create connection
AWS Direct Connect enables you to establish a dedicated network connection between your network and one of the AWS Direct Connect locations. Select the AWS Direct Connect location where you would like to connect, and the port speed you are requesting. Learn more
Connection ordering type
Connection ordering type
Classic
Create connections one at a time. Best for augmenting an existing setup.
Connection wizard
Create connections using our resiliency recommendations. Recommended for new setups.
Connection settings
Name
A name to help you identify the connection.
Test
Name must contain no more than 100 characters. Valid characters are a-z, 0-9, and – (hyphen)
Location
The location in which your connection is located.
CoreSite NY1, New York, NY

DX Virtual Interfaces

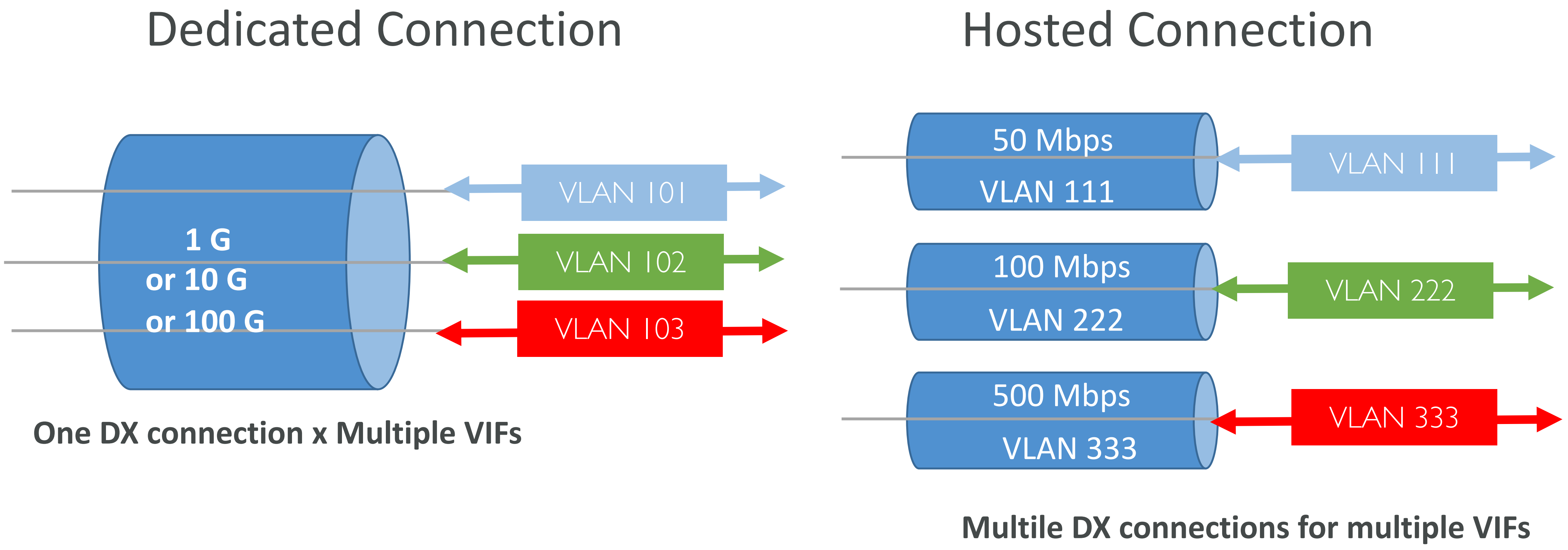
Virtual Interfaces – VIF (Logical connectivity)

- In order to use the DX connection you must provision the Virtual Interfaces
- A VIF is a configuration consisting primarily of an 802.1Q VLAN
- There are 3 types of the VIFs
  - Public VIF - Enables the connectivity to all AWS public IP addresses
  - Private VIF - Enables the connectivity to VPC via Virtual Private Gateway or Direct Connect Gateway
  - Transit VIF – Enables the connectivity to Transit Gateways via Direct Connect gateway

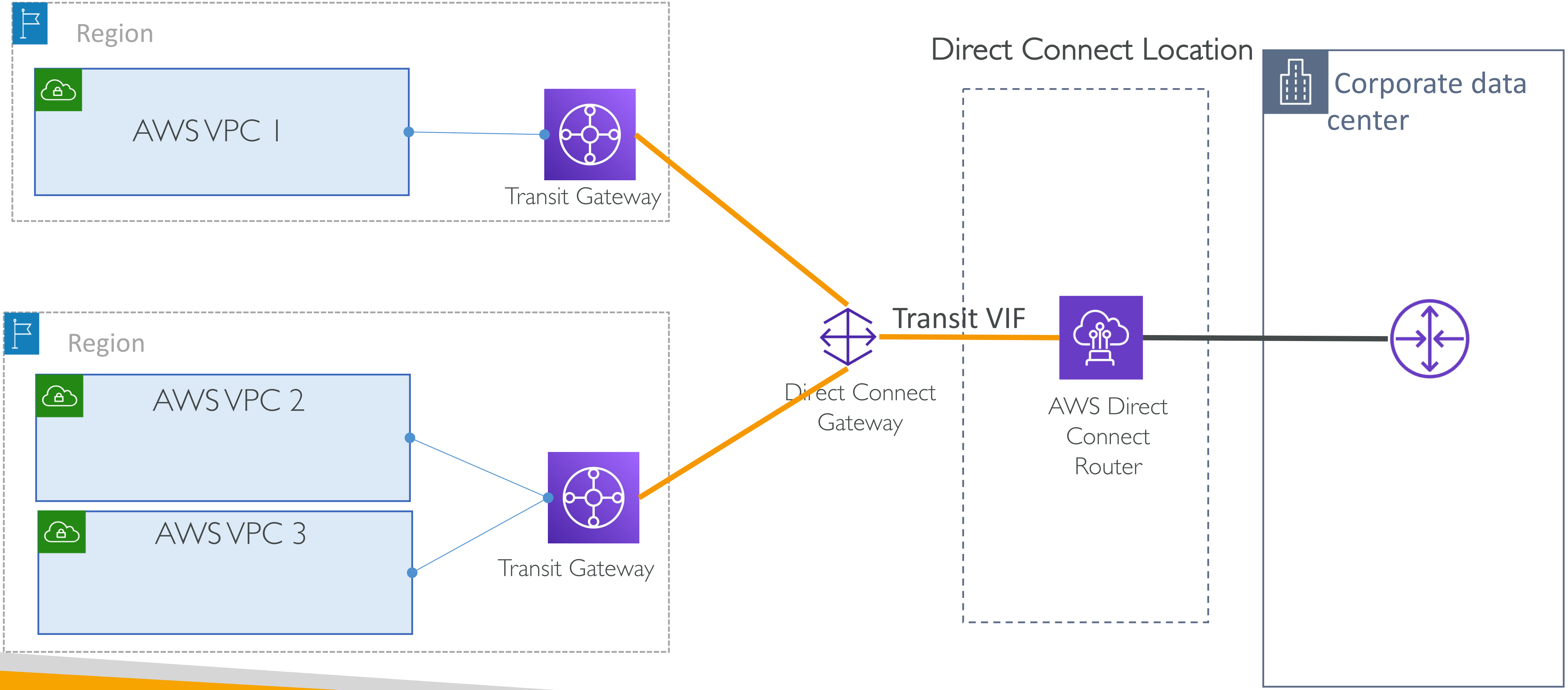
Public and Private VIFs



VIFs for Dedicated vs Hosted Connection



Transit VIF



Region
AWS VPC 1
Transit Gateway
Region
AWS VPC 2
AWS VPC 3
Transit Gateway
Direct Connect Location
Transit VIF
Direct Connect Gateway
AWS Direct Connect Router
Corporate data center

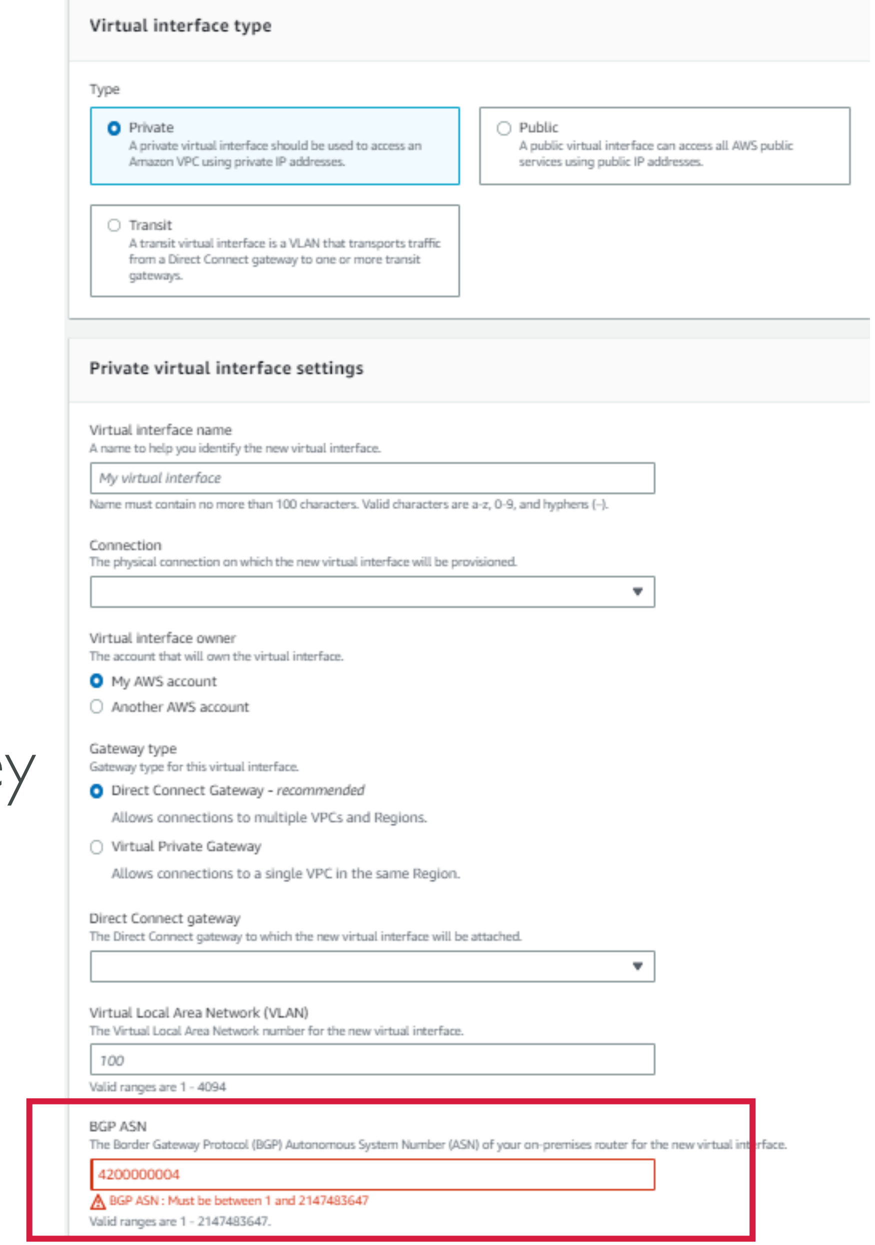
VIF Parameters

VIF parameters

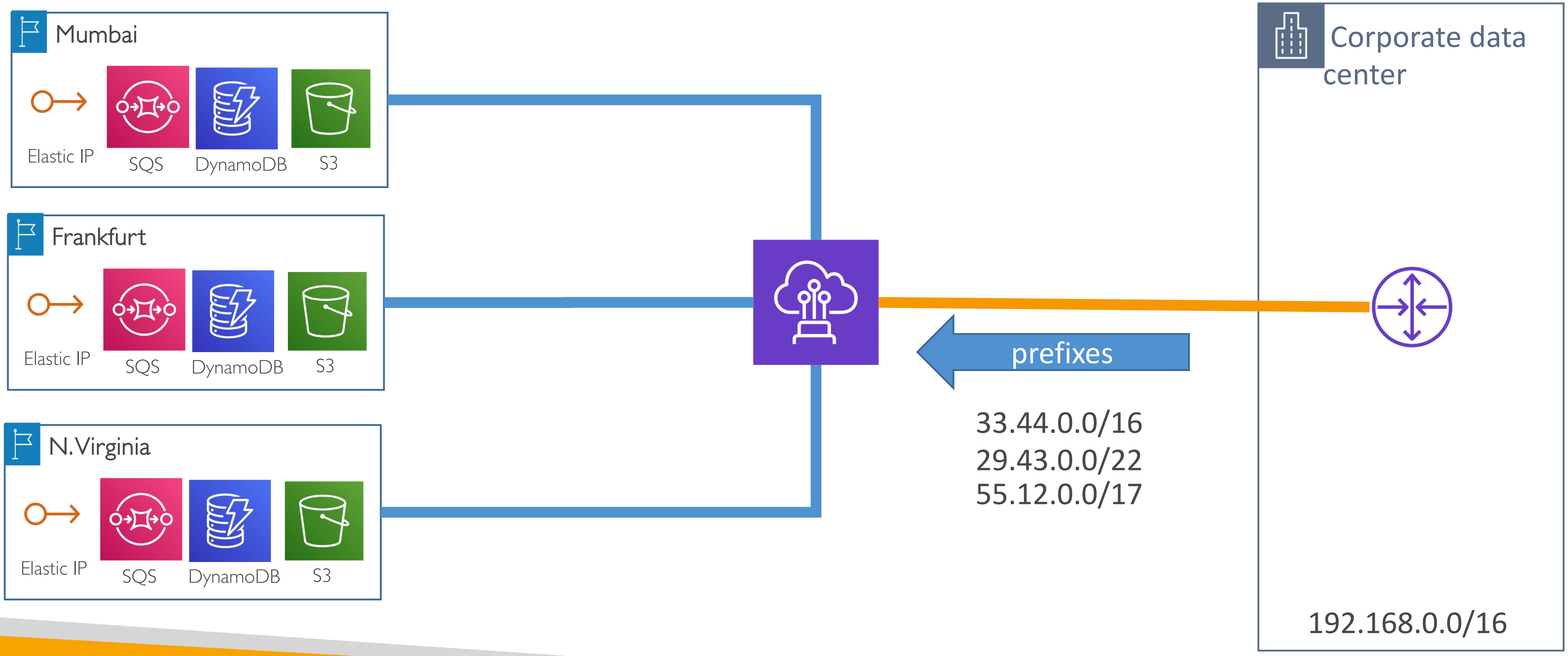
- Connection: AWS DX connection or a LAG
- VIF Type: Public or Private or Transit
- VIF Name: Anything
- VIF Owner: Your AWS account or other AWS account (hosted VIF)
- Gateway Type (Private VIF only)
  - Virtual Private Gateway
  - Direct Connect Gateway
- VLAN
  - Not duplicated on same DX connection (1-4094)
  - For hosted connection VLAN ID is already configured by the partner
- BGP address Family – IPv4 or IPv6
- BGP Peer IP Addresses
  - Public VIF (IPv4) - Public IPs (/30) allocated by you for the BGP session. Request to AWS if you don't have it.
  - Private VIF (IPv4) - Specify private IPs in the range 169.254.0.0/16. By default AWS provides address space.
  - IPv6: Amazon automatically allocates you a /125 IPv6 CIDR. You cannot specify your own peer IPv6 addresses.

VIF parameters

- BGP ASN
  - Public or Private BGP ASN
  - Public ASN must be owned by the customer and assigned by IANA
  - Private ASN can be set by you and must be between **64512 to 65534 (16-bit) or 1 to 2147483647 (32-bit)**
- BGP MD5 authentication key. If not provides, AWS generates authentication key
- Prefixes to be advertises (Public VIF only)
  - Public IPv4 routes or IPv6 routes to advertise over a BGP



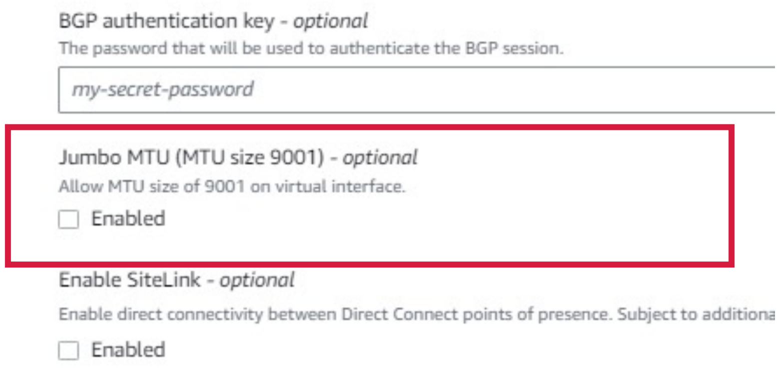
Advertising prefixes over a public VIF



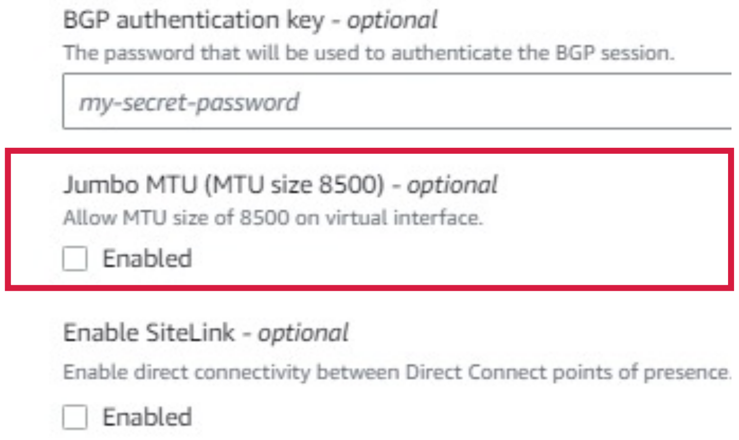
VIF parameters

- BGP ASN
  - Public or Private BGP ASN
  - Public ASN must be owned by the customer and assigned by IANA
  - Private ASN can be set by you and must be between **64512 to 65534 (16-bit) or 1 to 2147483647 range (32-bit)**
- BGP MD5 authentication key. If not provides, AWS generates authentication key
- Prefixes to be advertises (Public VIF only)
  - Public IPv4 routes or IPv6 routes to advertise over BGP
- Jumbo Frames (Private and Transit VIF only)
  - Private VIF: 9001 MTU supported for propagated routes only (Default is 1500 MTU)
  - Transit VIF: 8500 MTU supported

Private VIF

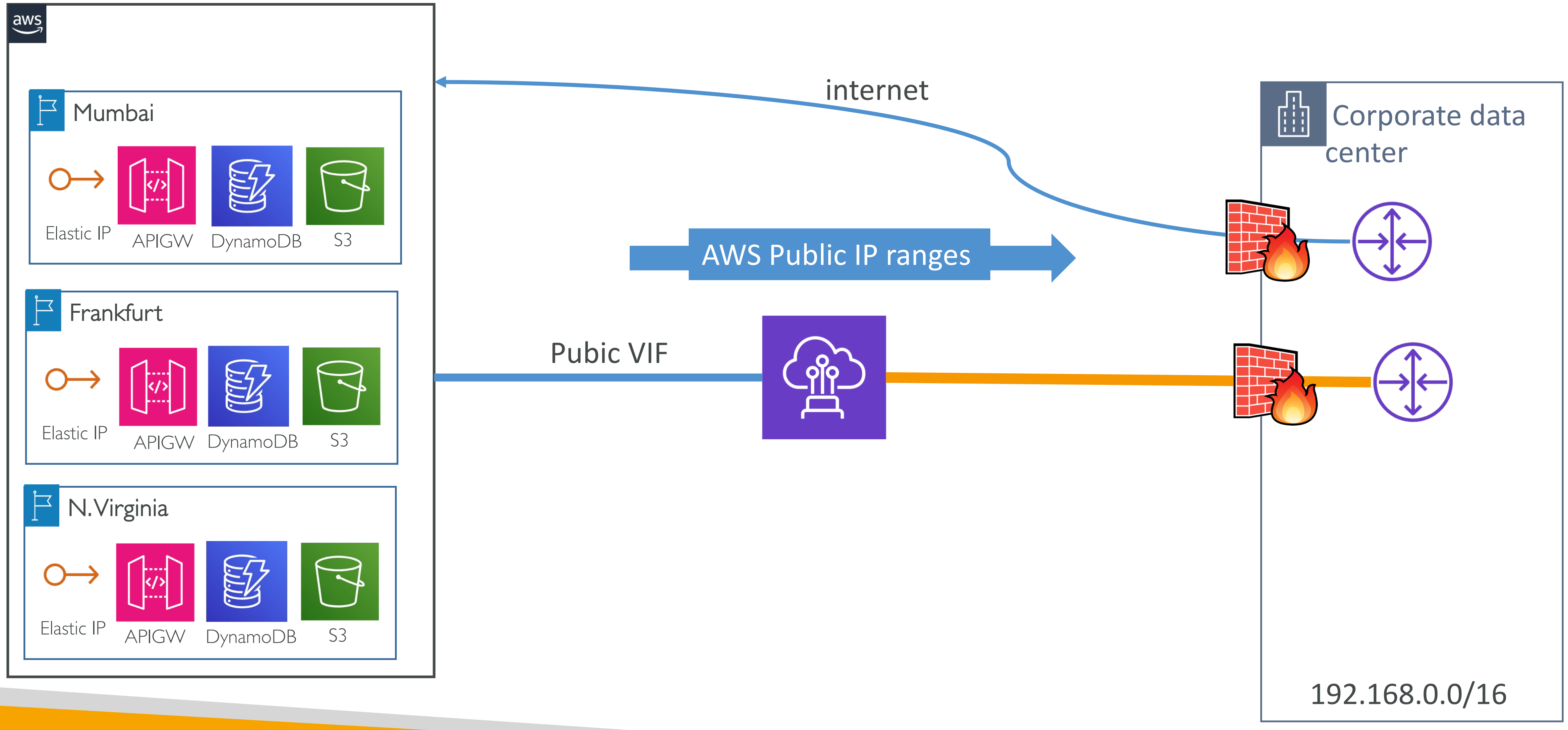


Transit VIF



ip-ranges.json

Public VIF



aws
Mumbai
Elastic IP
APIGW
DynamoDB
S3
Frankfurt
Elastic IP
APIGW
DynamoDB
S3
N.Virginia
Elastic IP
APIGW
DynamoDB
S3
internet
AWS Public IP ranges
Pubic VIF
Corporate data center
192.168.0.0/16

AWS IP Ranges - ip-ranges.json

- AWS Publishes all its **current** public IP addresses in JSON format
- Download json: https://ip-ranges.amazonaws.com/ip-ranges.json
- You can filter the IP addresses by Region, AWS Service, IPv4 or IPv6
- Useful when you want to restrict access to only AWS services public IPs
- Get notified by subscribing to AWS SNS topic in N.Virginia region
  - Topic Name: AmazonIpSpaceChanged
  - Topic ARN: arn:aws:sns:us-east-1:806199016981:AmazonIpSpaceChanged

AWS IP Ranges: ip-ranges.json

The syntax of ip-ranges.json:

```
{
  "syncToken": "0123456789",
  "createDate": "yyyy-mm-dd-hh-mm-ss",
  "prefixes": [
    {
      "ip_prefix": "cidr",
      "region": "region",
      "network_border_group": "network_border_group",
      "service": "subset"
    }
  ],
  "ipv6_prefixes": [
    {
      "ipv6_prefix": "cidr",
      "region": "region",
      "network_border_group": "network_border_group",
      "service": "subset"
    }
  ]
}
```

S3

```
{
  "ip_prefix": "3.5.140.0/22",
  "region": "ap-northeast-2",
  "service": "S3",
  "network_border_group": "ap-northeast-2"
},
{
  "ip_prefix": "52.219.170.0/23",
  "region": "eu-central-1",
  "service": "S3",
  "network_border_group": "eu-central-1"
},
```

EC2

```
{
  "ip_prefix": "15.181.232.0/21",
  "region": "us-east-1",
  "service": "EC2",
  "network_border_group": "us-east-1-iah-1"
},
{
  "ip_prefix": "142.4.160.136/29",
  "region": "us-east-1",
  "service": "EC2",
  "network_border_group": "us-east-1-msp-1"
},
```

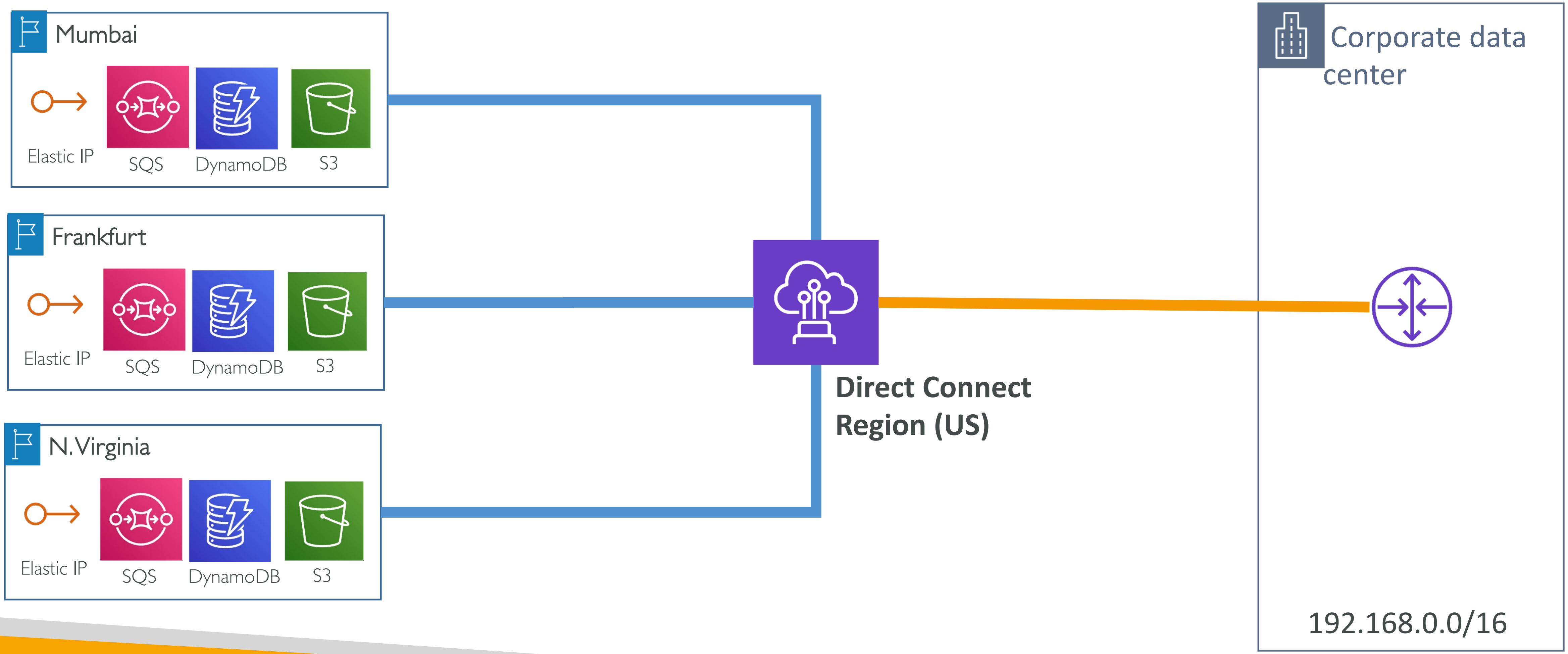
AWS Services: AMAZON | AMAZON_APPFLOW | AMAZON_CONNECT | API_GATEWAY | CHIME_MEETINGS | CHIME_VOICECONNECTOR | CLOUD9 | CLOUDFRONT | CODEBUILD | DYNAMODB | EBS | EC2 | EC2_INSTANCE_CONNECT | GLOBALACCELERATOR | KINESIS_VIDEO_STREAMS | ROUTE53 | ROUTE53_HEALTHCHECKS | S3 | WORKSPACES_GATEWAYS

Public VIF

Public VIF

- Enables your network to connect to all AWS Public IPs **globally**

Access to all global regions via Public VIF



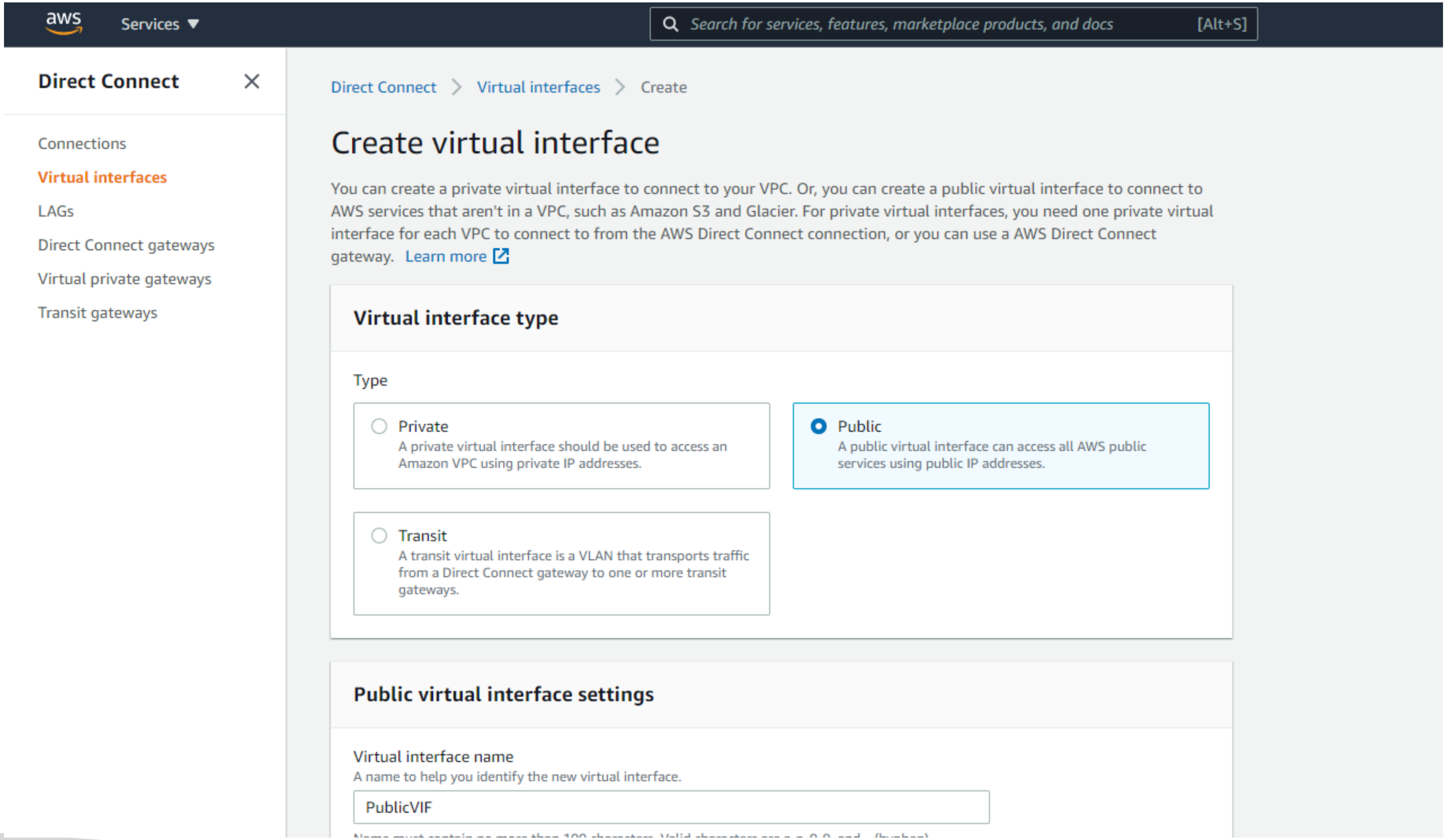
Public VIF

- Enables your network to connect to all AWS Public IPs **globally**
- You can access services outside VPC e.g S3, SQS, DynamoDB and other public endpoints like AWS managed VPN (VGW) Public IPs
- To create a public VIF with IPv4 addresses, you need to provide both the AWS router public IPs and your side of the router public IPs with /30 CIDR
- In case you don't have your own Public IPs for peering, raise a support case to get it from AWS owned IP ranges (AWS provides /31 range)
- You must also specify the IPv4 address prefixes you want to advertise
- AWS verifies with Internet registries that these IP prefixes are owned by you and you are authorized to advertise those prefixes

Public VIF

- AWS advertises all Amazon prefixes over a BGP session. These includes prefixes for AWS services like EC2, S3 and Amazon.com
- No access to non-amazon prefixes
- Refer ip-ranges.json for current list of Amazon prefixes
- At customer router the firewall can be use to restrict access to and from specific Amazon prefixes
- From customer router to AWS maximum 1000 route prefixes can be advertised per Border Gateway Protocol (BGP) session

Public VIF creation walkthrough



Remember

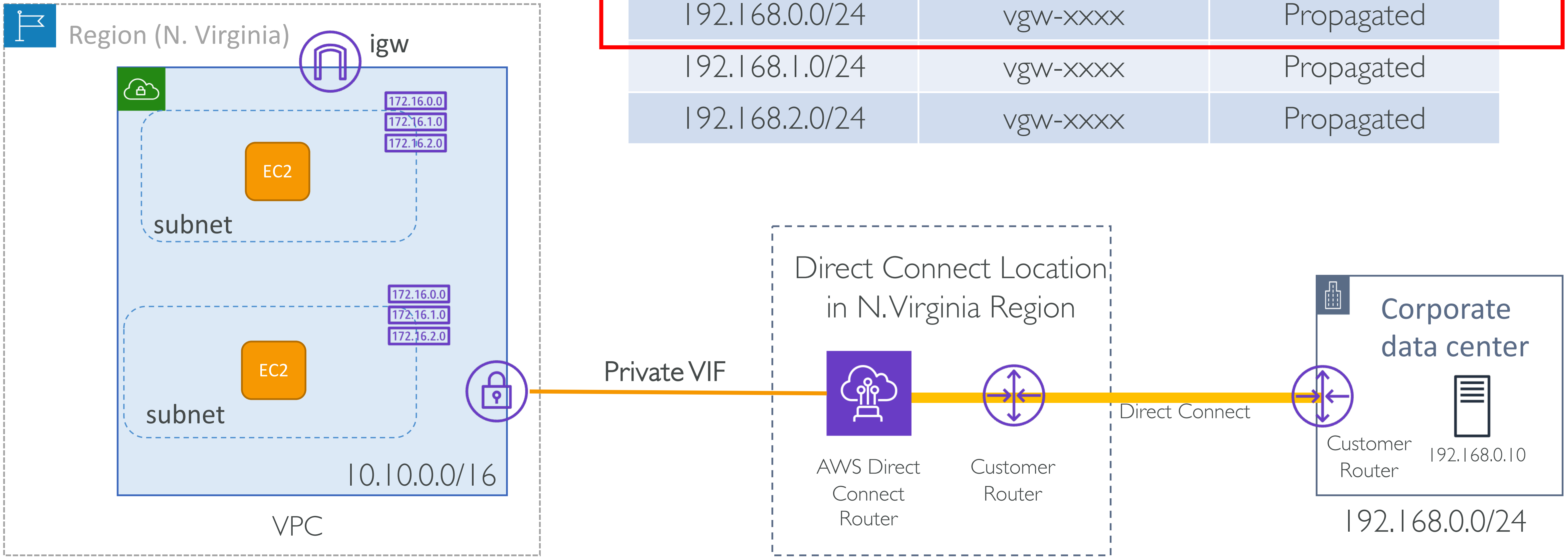
- Public VIF enables your network to connect to all AWS Public IPs **globally**
- To create a public VIF with IPv4 addresses, you need to provide both the AWS router public IPs and your side of the router public IPs with /30 CIDR
- From customer router to AWS maximum 1000 route prefixes can be advertised per Border Gateway Protocol (BGP) session

Private VIF

Private VIF

- Enables your network to connect to resources inside VPC using Private IPs for resources like EC2, RDS, Redshift over Private IPs
- You must attach your VPC to VGW and associate VGW with Private VIF
- **Private VIF and VGW must be in the same AWS Region**
- On BGP session, customer router will receive all the prefixes of VPC
- You can announce a maximum of 100 prefixes to AWS. These routes can be automatically be propagated into subnet route tables
- In order to advertise more than 100 prefixes, you should summarize the prefixes into larger range to reduce number of prefixes
- The propagated routes will take precedence over default route to internet via IGW

Destination	Target	Route Type
10.10.0.0/16	Local	Static
0.0.0.0/0	igw-xxxx	Static
192.168.0.0/24	vgw-xxxx	Propagated
192.168.1.0/24	vgw-xxxx	Propagated
192.168.2.0/24	vgw-xxxx	Propagated

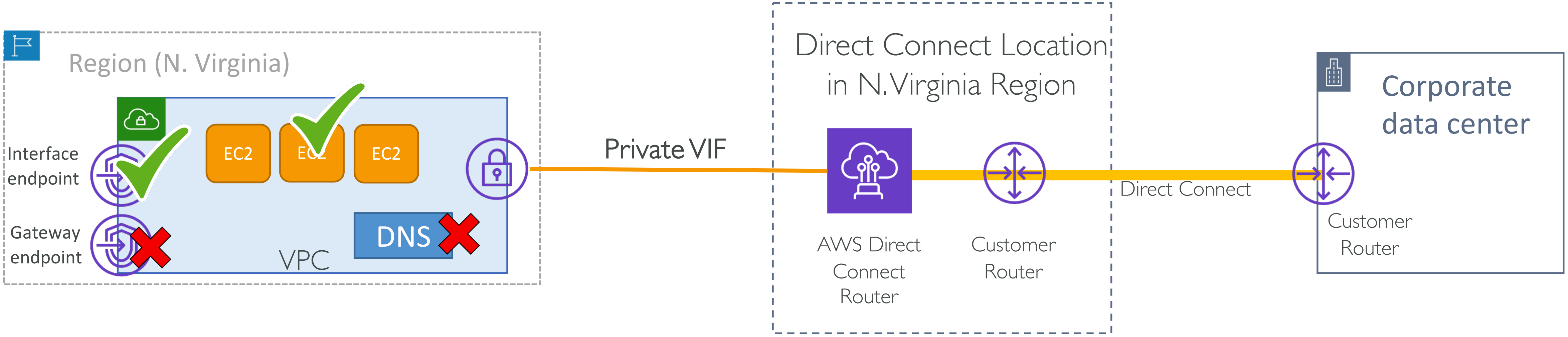


Private VIF

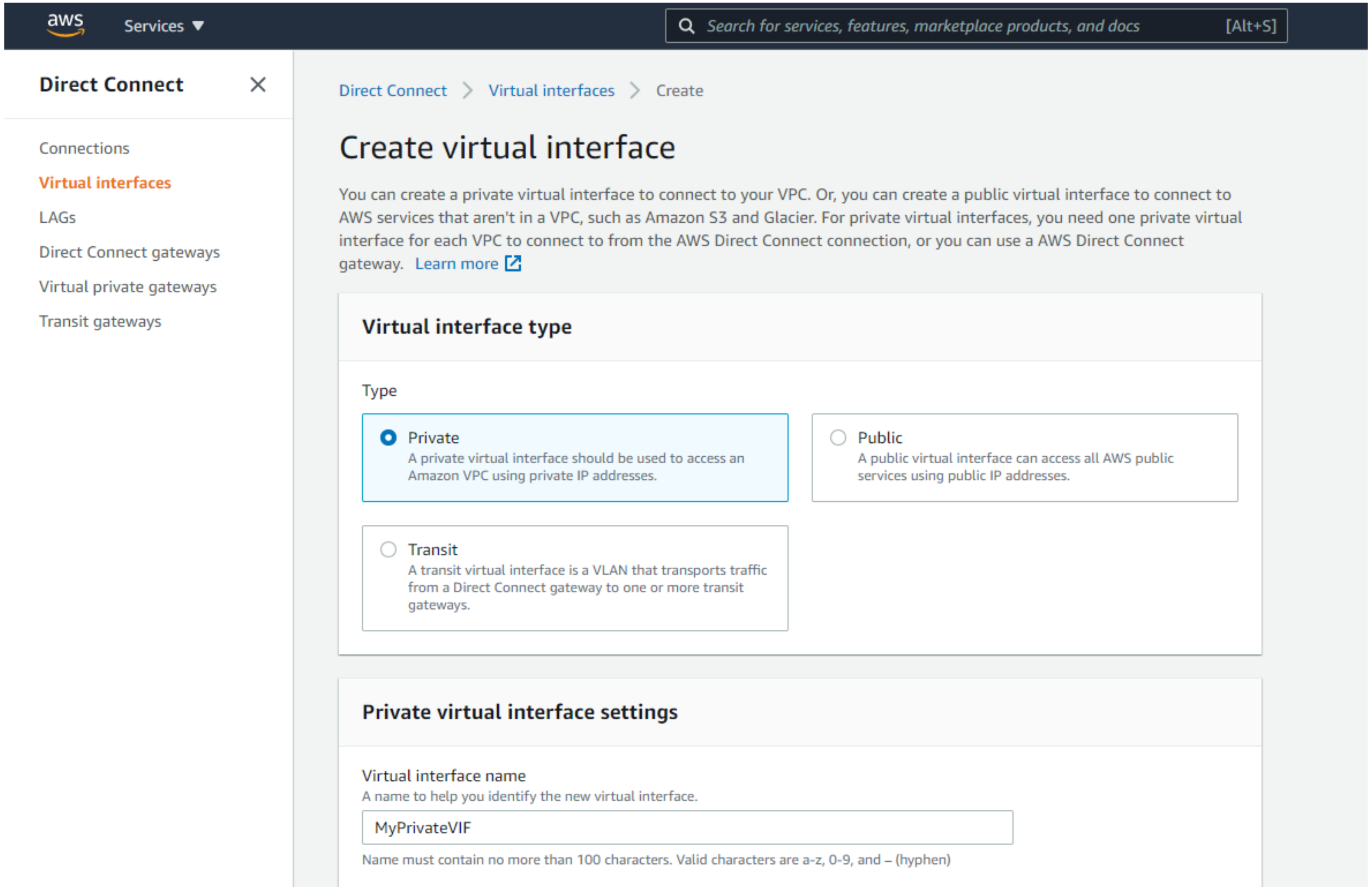
- Supports MTU of 1500 (default) and 9001 for propagated routes

Private VIF - What you can't access inside VPC?

- Does not provide access to VPC DNS resolver at Base + 2
- Does not provide access to VPC Gateway endpoints



Private VIF creation walkthrough



Remember

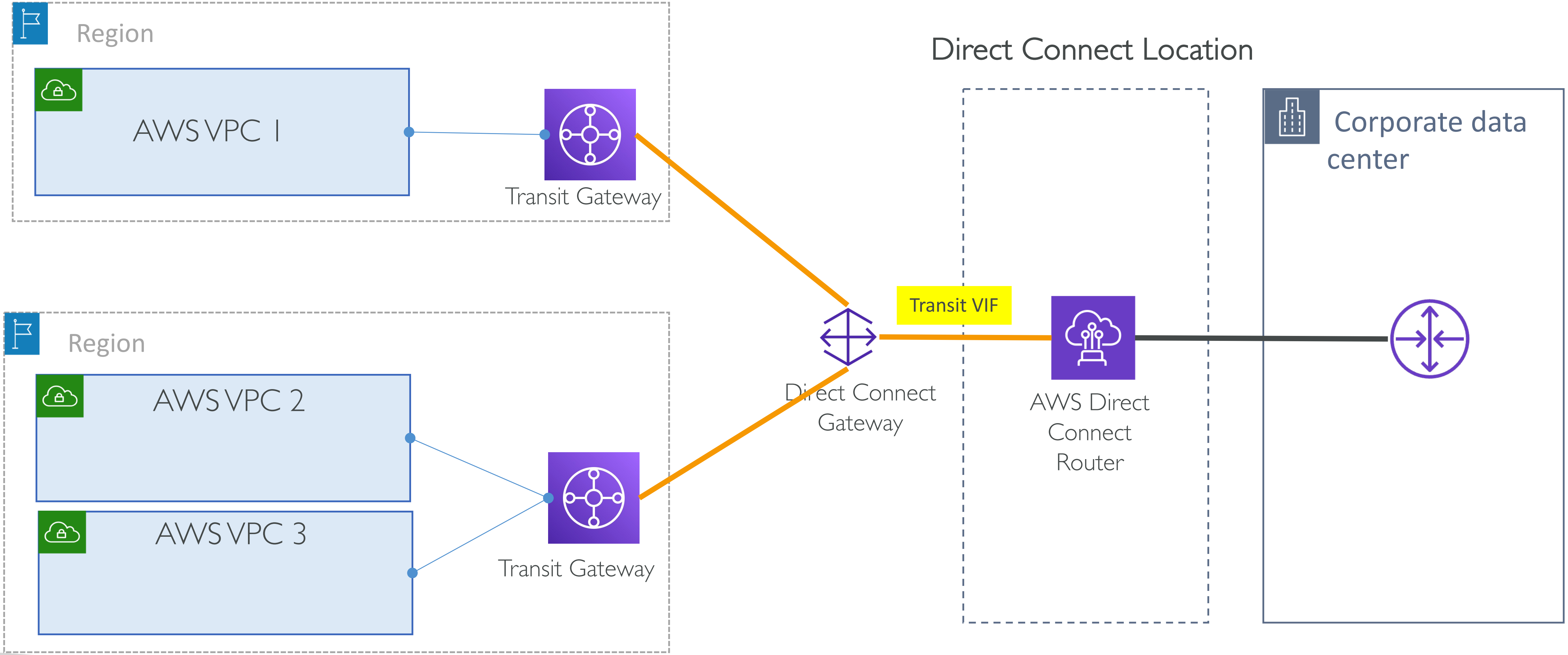
- Private VIF enables your network to connect to resources inside VPC using Private IPs for resources like EC2, RDS, Redshift **over Private IPs**
- You can announce a maximum of **100** prefixes to AWS

Transit VIF

Transit VIF

- Enables the connection between Direct Connect and Transit Gateway
- Transit VIF is connected to Direct Connect Gateway and Direct Connect Gateway connects to Transit Gateway
- Support MTU of 1500 and 8500 (Jumbo Frames)
- You can attach multiple Transit Gateways to a single DX Gateway

Transit VIF

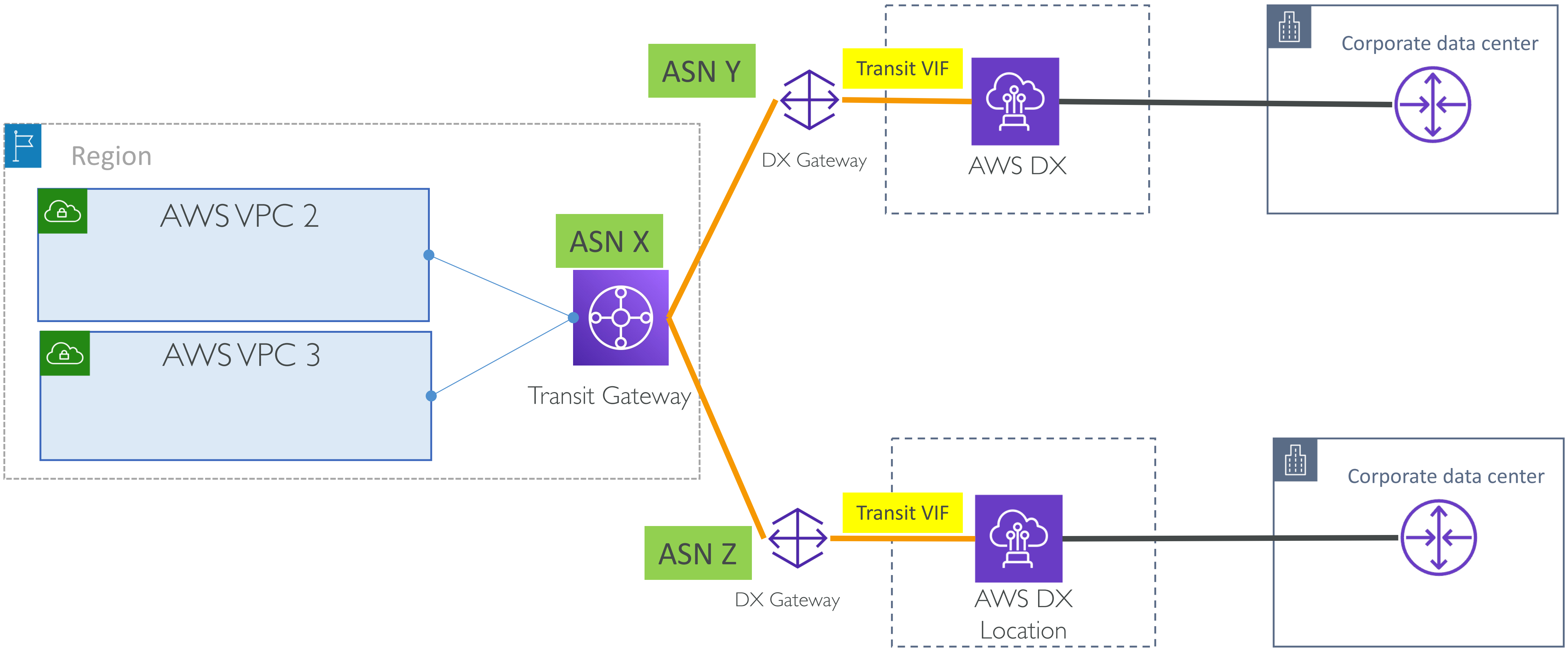


Region
AWS VPC 1
Transit Gateway
Region
AWS VPC 2
AWS VPC 3
Transit Gateway
Direct Connect Location
Transit VIF
Direct Connect Gateway
AWS Direct Connect Router
Corporate data center

Transit VIF

- Enables the connection between Direct Connect and Transit Gateway
- Transit VIF is connected to Direct Connect Gateway and Direct Connect Gateway connects to Transit Gateway
- Support MTU of 1500 and 8500 (Jumbo Frames)
- You can attach multiple Transit Gateways to a single DX Gateway
- You can attach multiple DX Gateways to a single Transit Gateway
- The ASN for DX Gateway and Transit Gateway must be different. If you use the default ASN (64512) for both of them then the association fails.

Transit VIF



Region
AWS VPC 2
AWS VPC 3
ASN X
Transit Gateway
ASN Y
DX Gateway
Transit VIF
AWS DX
Corporate data center
ASN Z
DX Gateway
Transit VIF
AWS DX
Location
Corporate data center

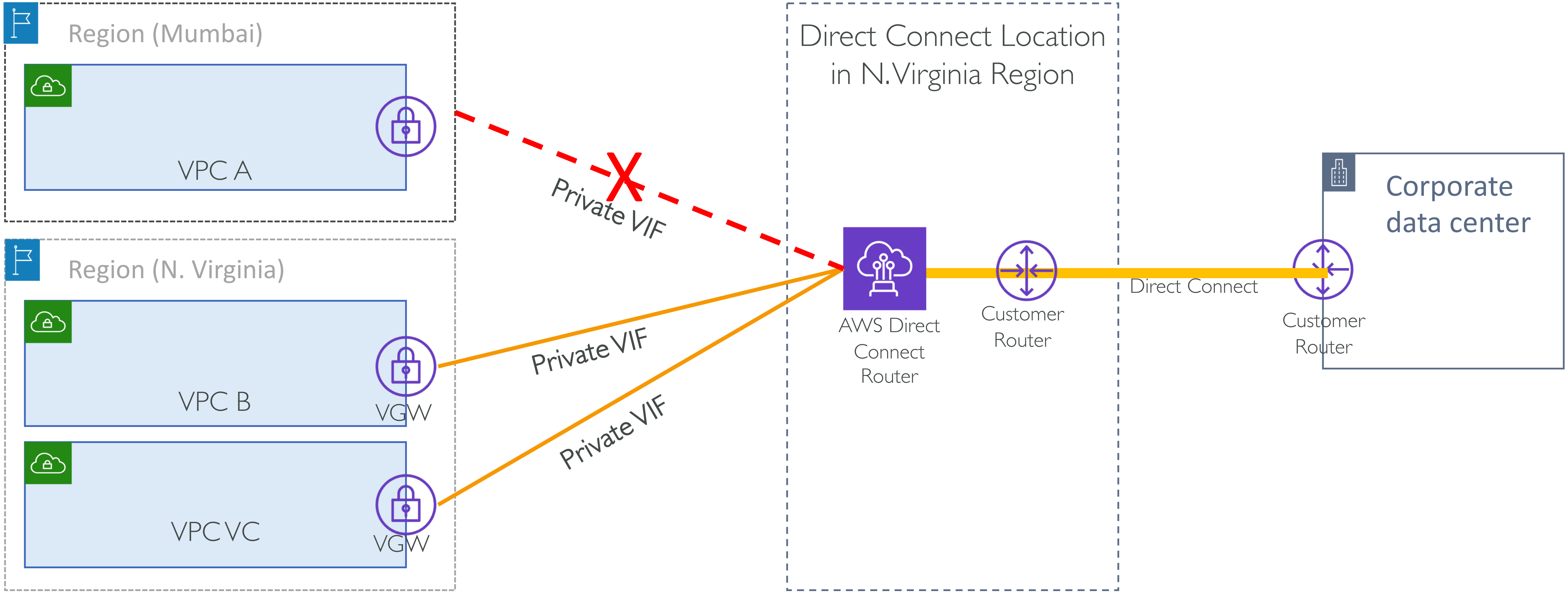
DX Gateway with Private VIF and Virtual Private Gateway

Why Direct Connect Gateway?

- Problem: I want to access multiple VPCs over a same Direct Connect connection
- Solution: Use AWS Direct Connect Gateway

A single direct connect gateway can be connected to multiple VPCs in the **same or different** AWS regions and in the **same or different AWS accounts** using Virtual Private Gateway (VGW) or Transit Gateway (TGW)

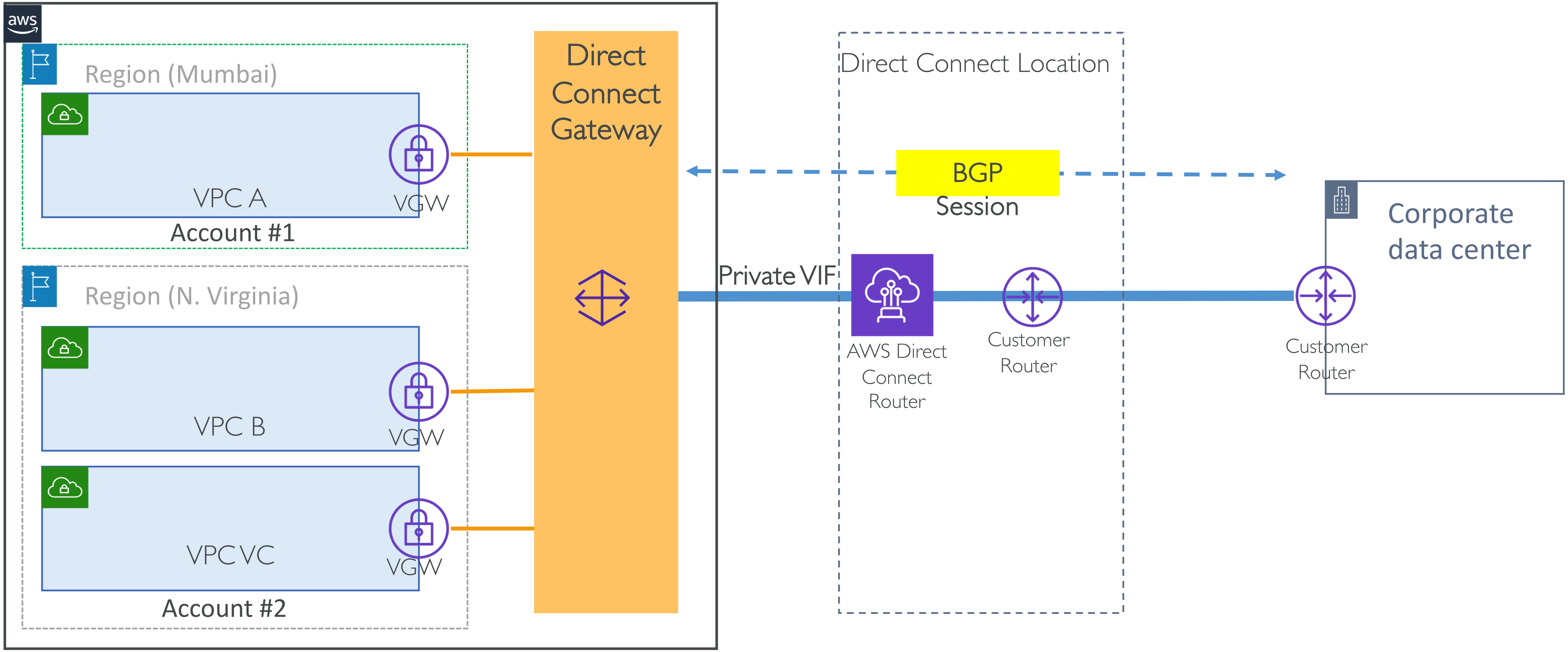
Connecting VPCs outside of home region using Private VIF



Direct Connect Gateway

- Global network device – Accessible in all regions
- Direct Connect integrates via a private VIF or a transit VIF

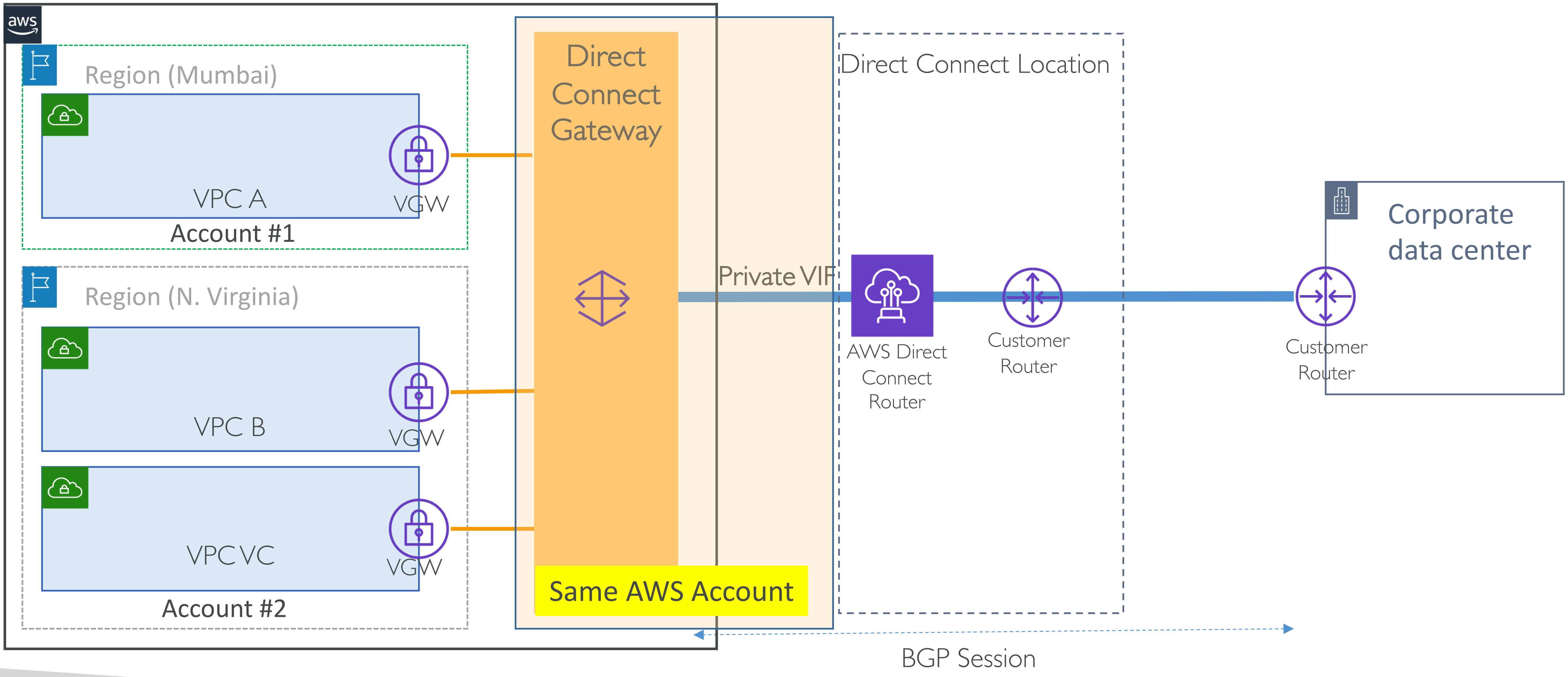
Direct Connect Gateway



Direct Connect Gateway

- Global network device – Accessible in all regions
- Direct Connect integrates via a private VIF or a transit VIF
- DX Gateway is used for VPC <-> On-premise connectivity and can not be used for Public endpoint connectivity
- The Private VIF or Transit VIF and Direct Connect gateway must be owned by same AWS account however VPCs (VGWs) or Transit Gateways can be from same or different AWS accounts

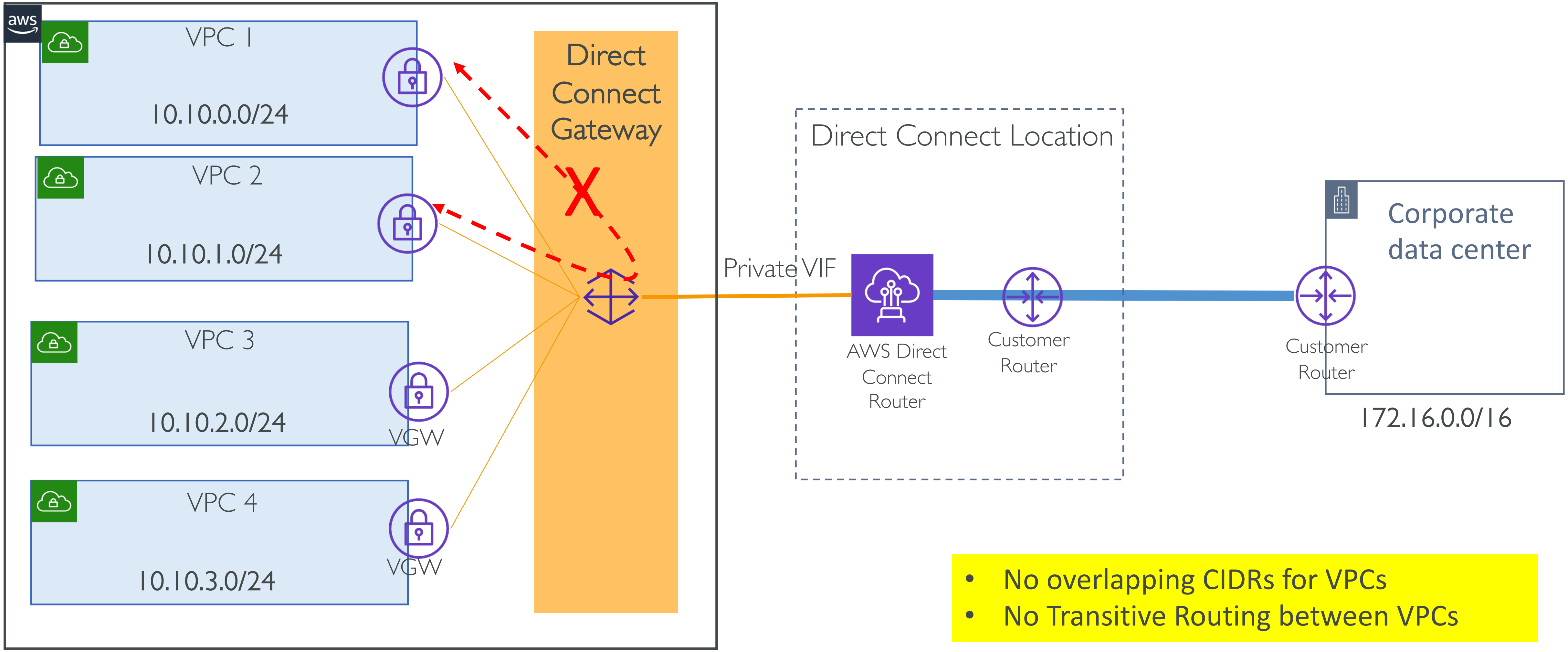
Direct Connect Gateway



Direct Connect Gateway

- Overlapping CIDRs for VPCs are not allowed
- VPC to VPC communication is **not** allowed via DX Gateway

Direct Connect Gateway - Routing

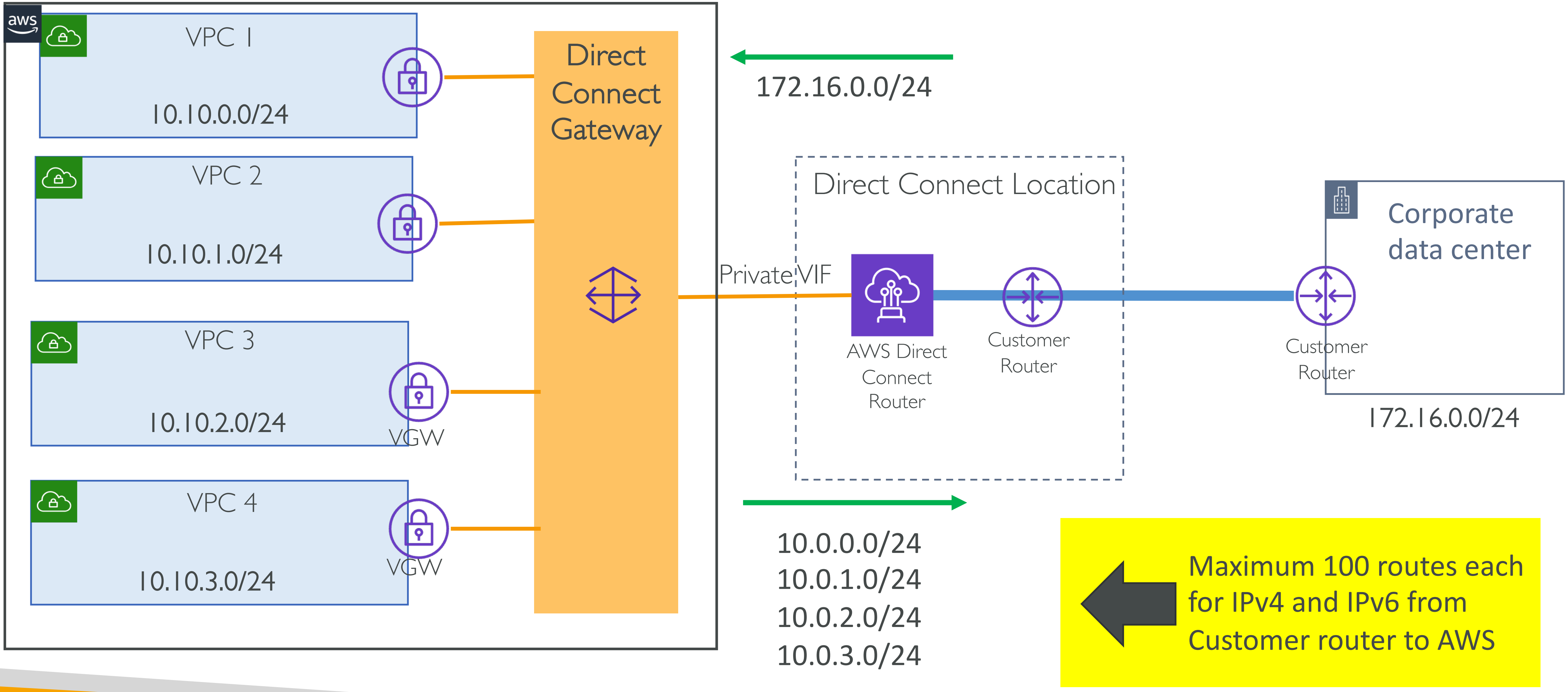


- No overlapping CIDRs for VPCs
- No Transitive Routing between VPCs

Direct Connect Gateway

- Maximum 100 routes each for IPv4 and IPv6 can be advertised from on-premises to AWS (same as Private VIF and Transit VIF limit)

Direct Connect Gateway - Routes



Direct Connect Gateway # VPC limits

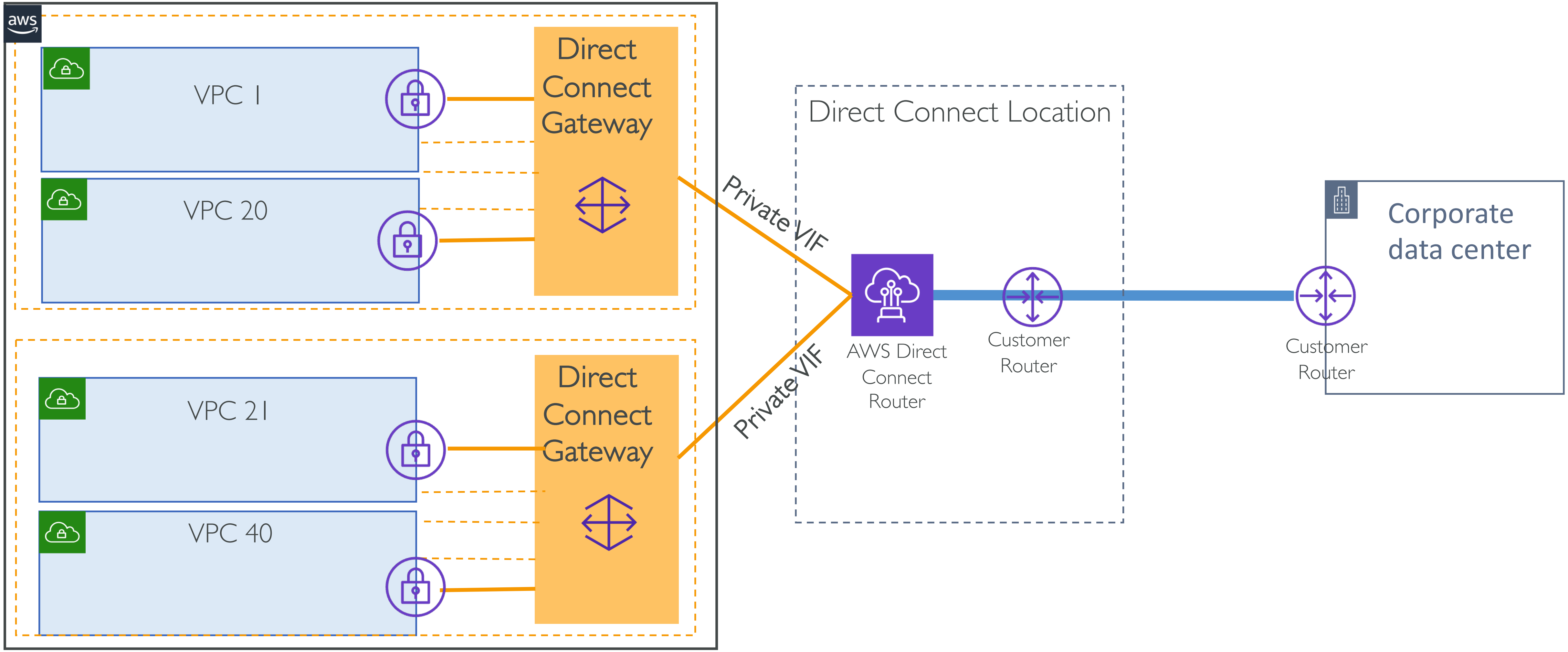
- Single Direct Connect Gateway can connect to 20 VGWs (VPCs) and this limit may increase in the future

Always refer AWS documentation for latest limits:
https://docs.aws.amazon.com/directconnect/latest/UserGuide/limits.html

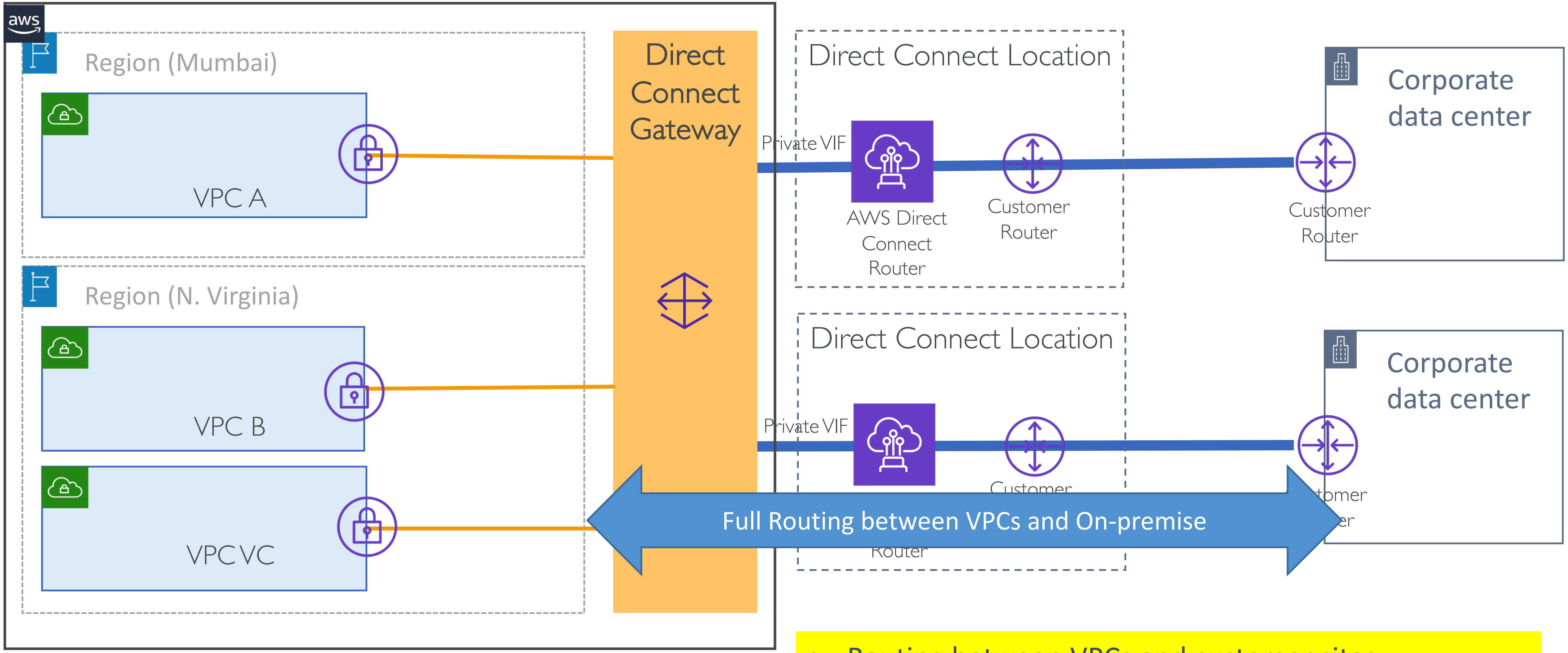
Creating DX Gateway Walkthrough

DX Gateway architectures

Multiple Direct Connect Gateways

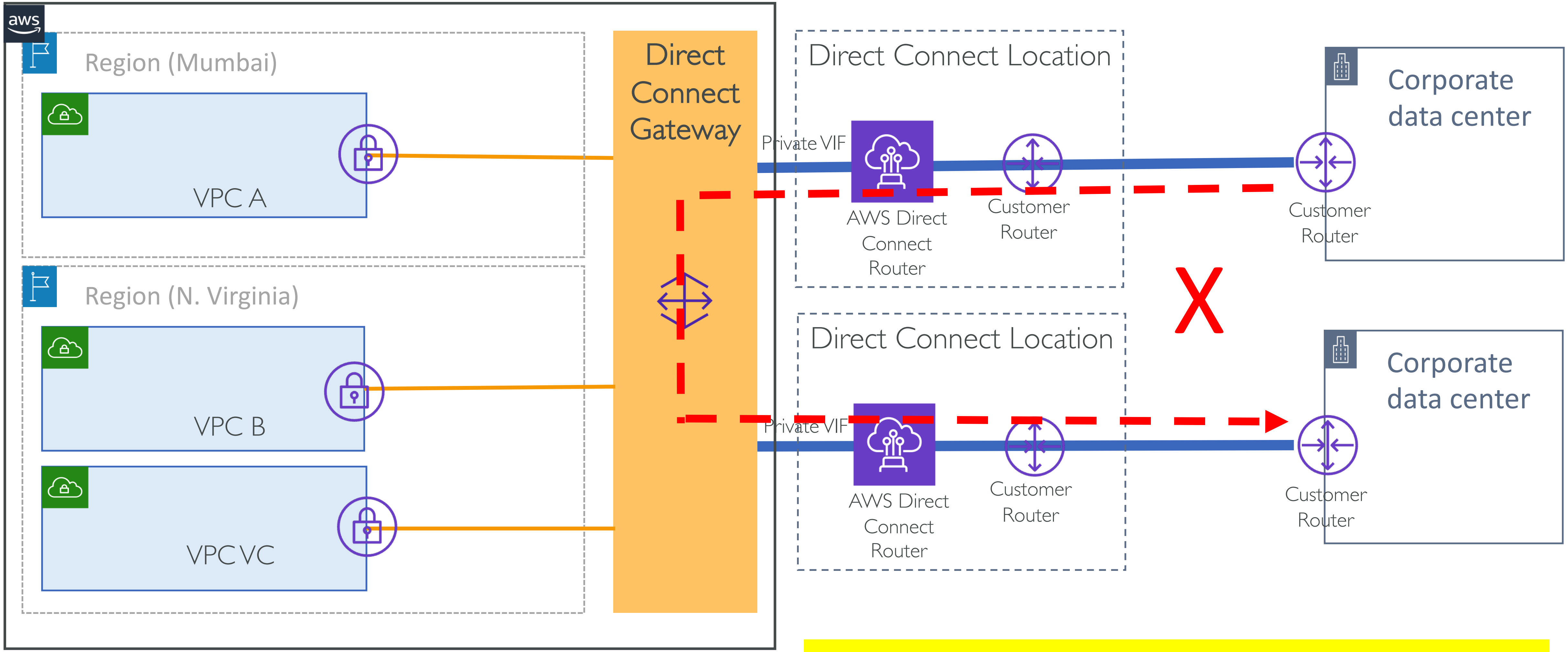


DX Gateway and multiple customer sites



- Routing between VPCs and customer sites

DX Gateway and multiple customer sites



- No routing between customer sites

Direct Connect Gateway + Private VIF summary

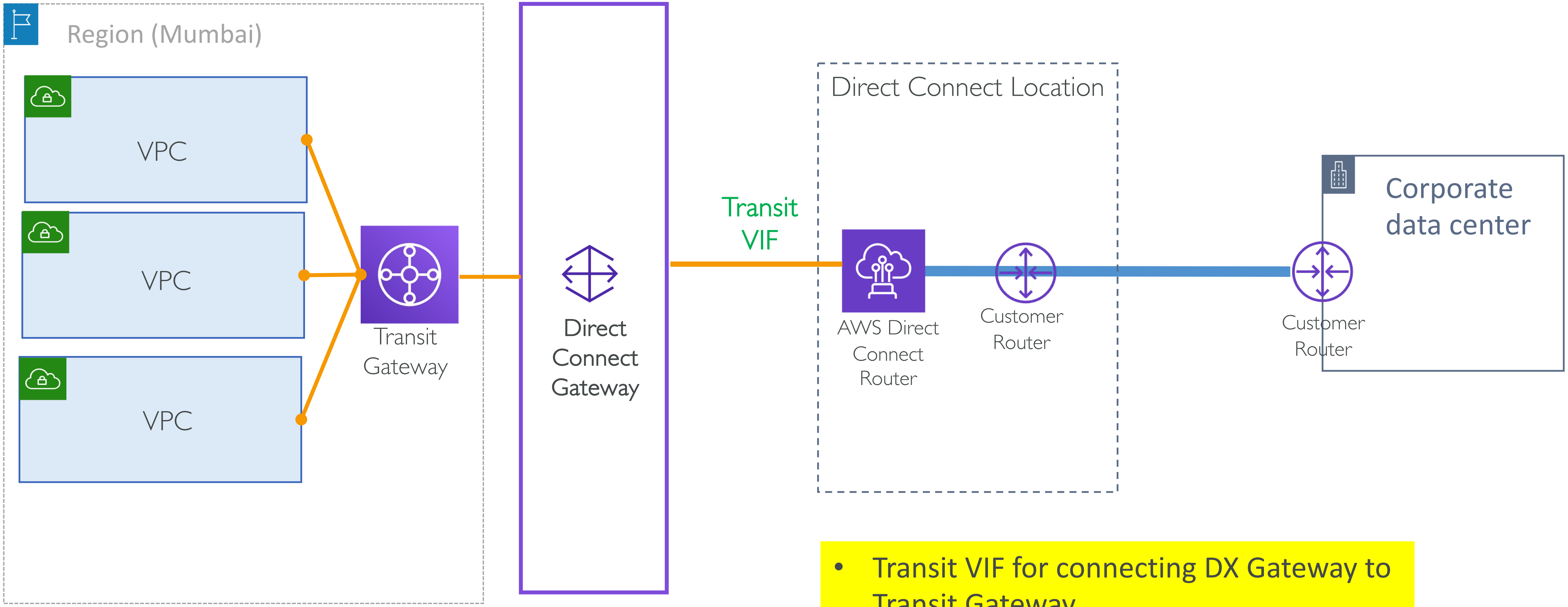
- Globally accessible
- Enables private connectivity between on-premises network and AWS VPCs
- Can connect to up to 20 VGWs (VPCs) across AWS regions and across AWS accounts [This limit may change. Refer AWS docs]
- VPC CIDRs should not be overlapping
- VPC-to-VPC communication is not allowed via the DX gateway.
- DX Gateway and Private VIF should be created in the same AWS account

Direct Connect Gateway + Private VIF summary

- There are **no charges** for using a Direct Connect gateway.
- You will pay applicable egress data charges based on the source remote AWS Region and DX port hour charges

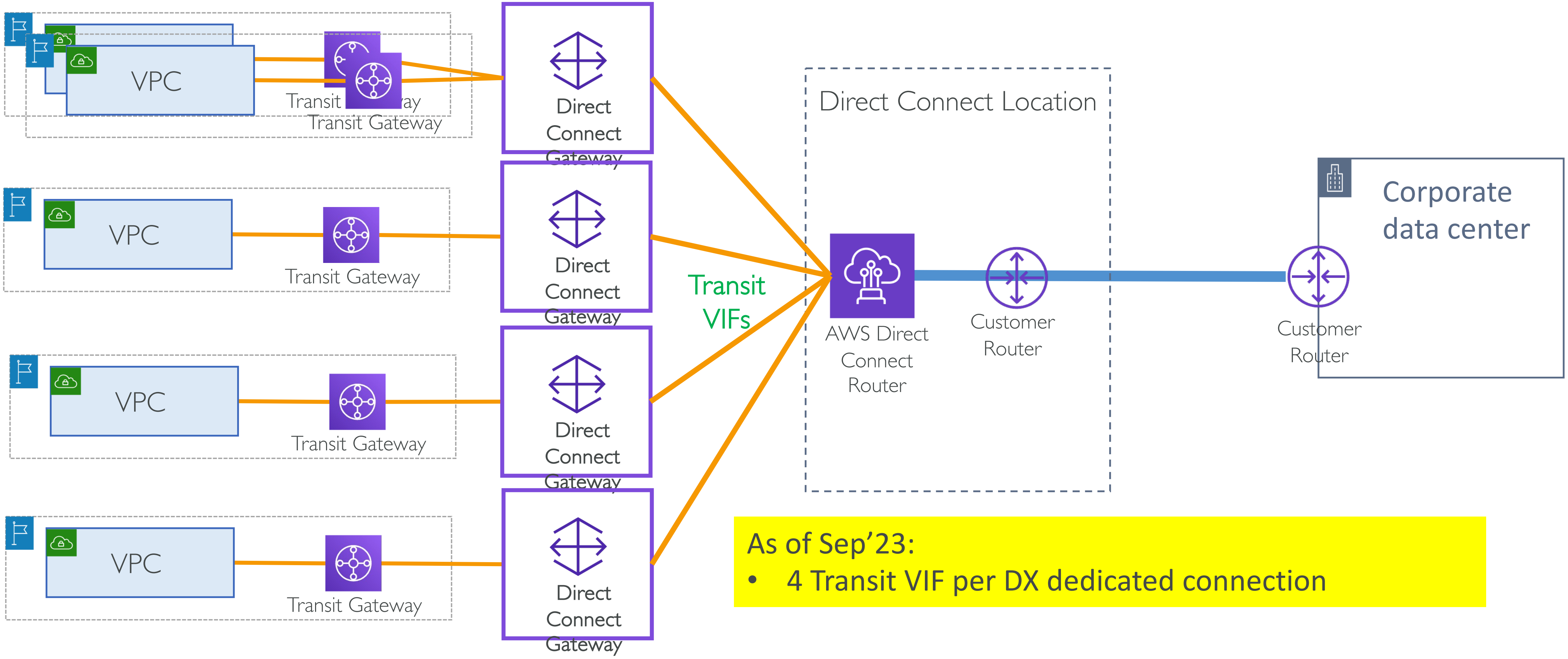
DX Gateway with Transit VIF and Transit Gateway

DX Gateway with TGW



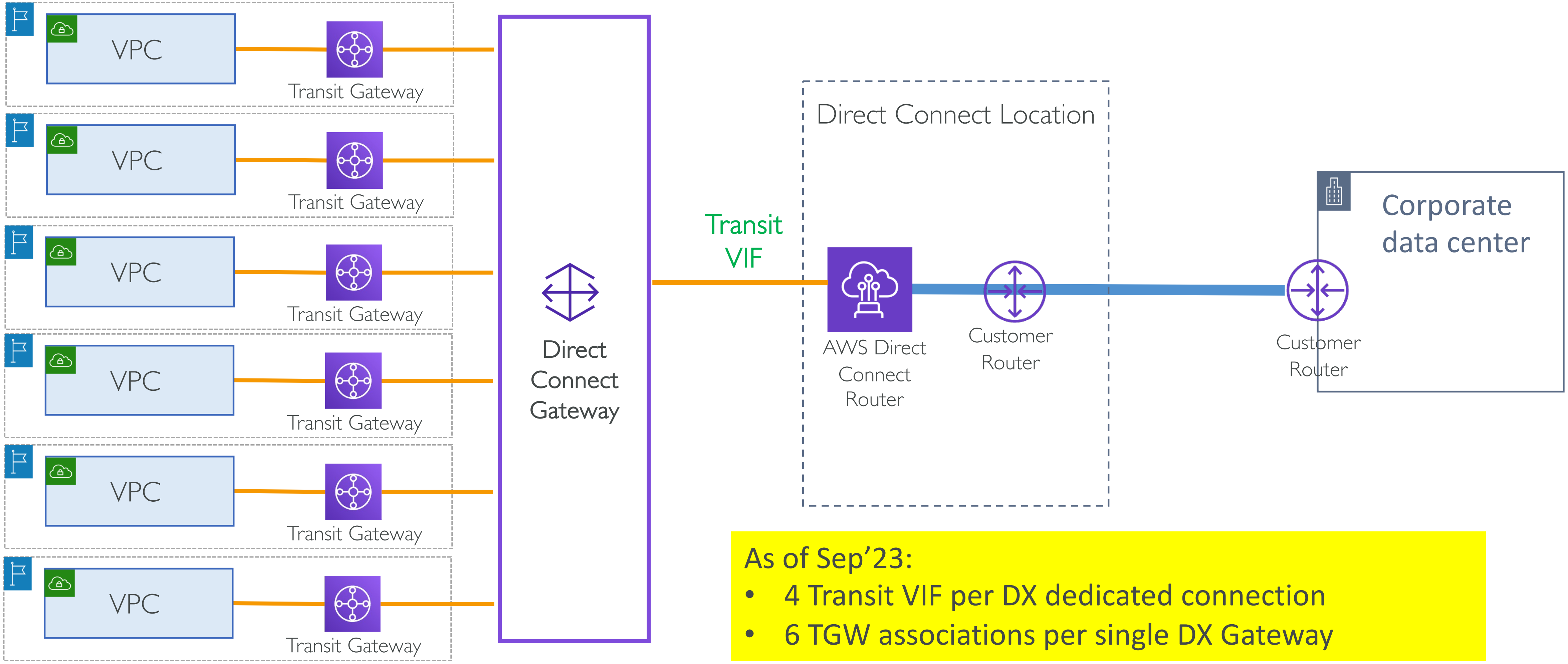
- Transit VIF for connecting DX Gateway to Transit Gateway

Multiple Transit VIFs



As of Sep'23:
- 4 Transit VIF per DX dedicated connection

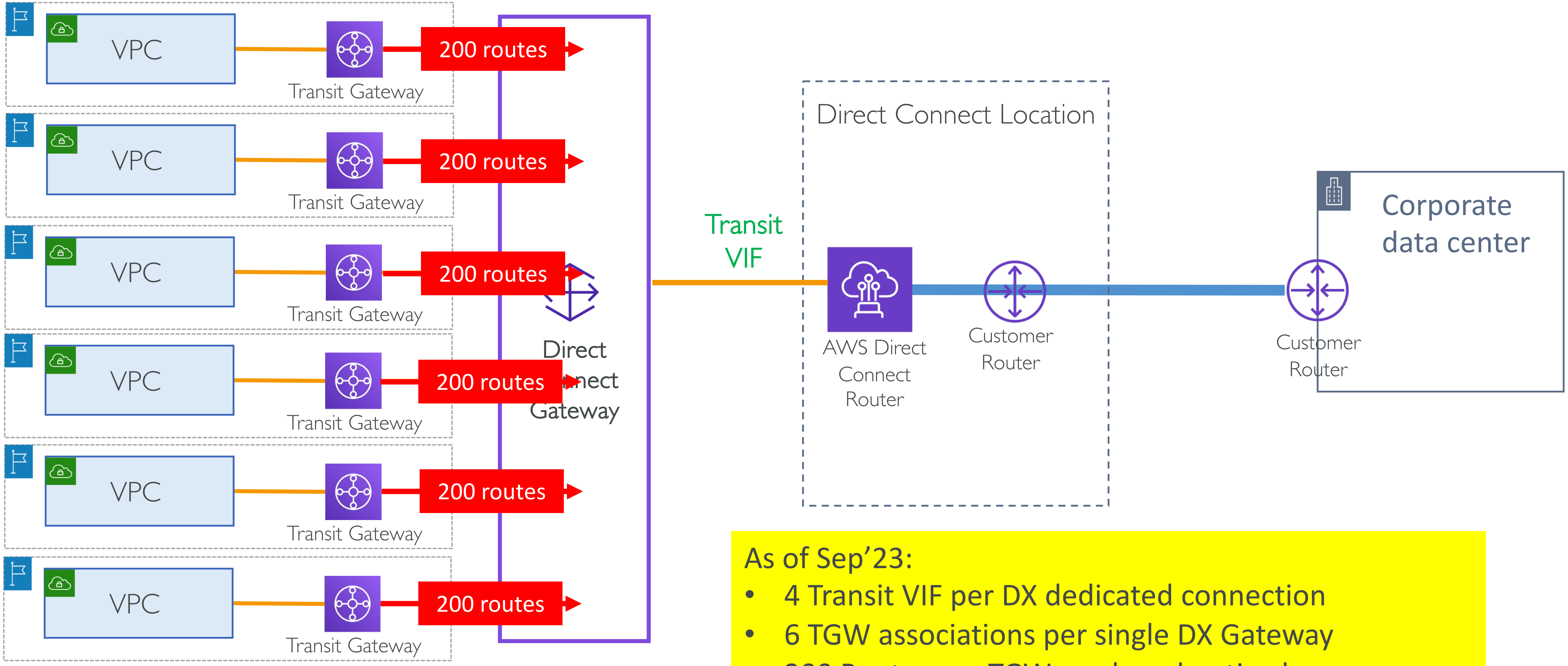
DX Gateway with multiple TGWs



As of Sep'23:

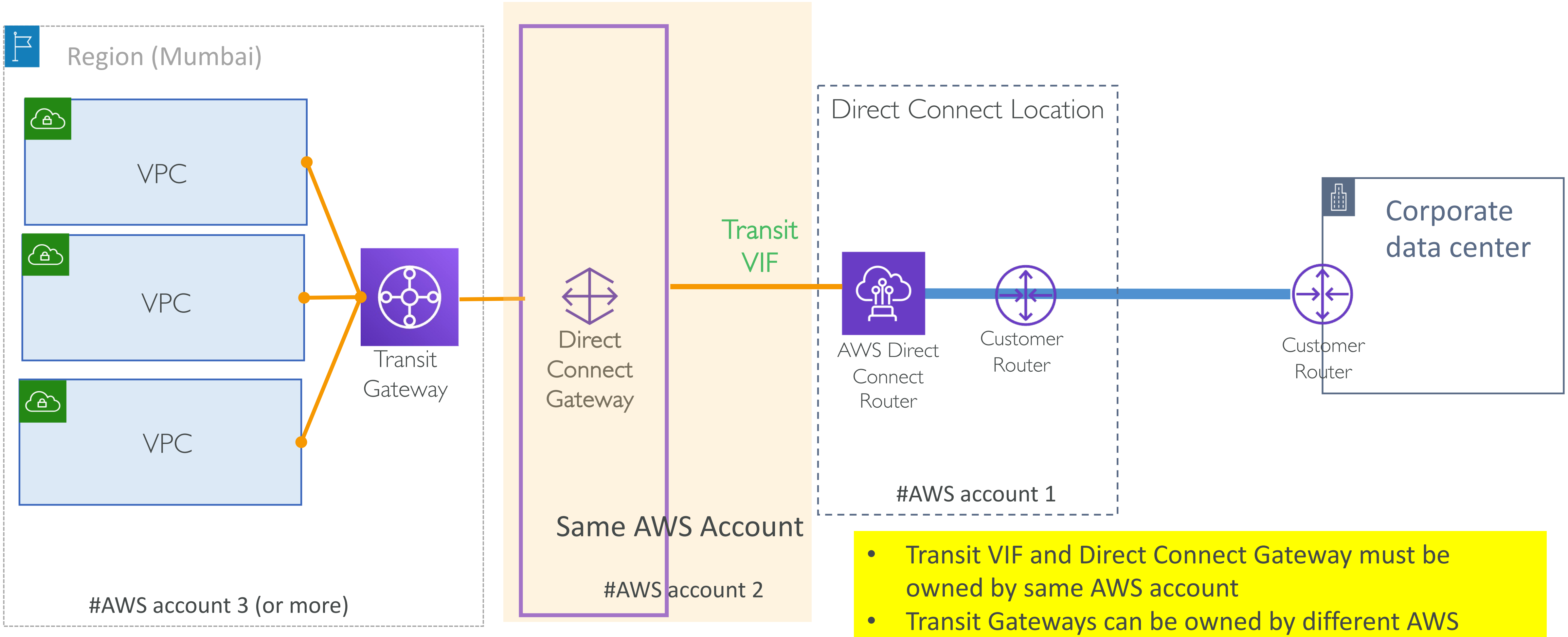
- 4 Transit VIF per DX dedicated connection
- 6 TGW associations per single DX Gateway

TGW routes advertisement



As of Sep'23:
- 4 Transit VIF per DX dedicated connection
- 6 TGW associations per single DX Gateway
- 200 Routes per TGW can be advertised

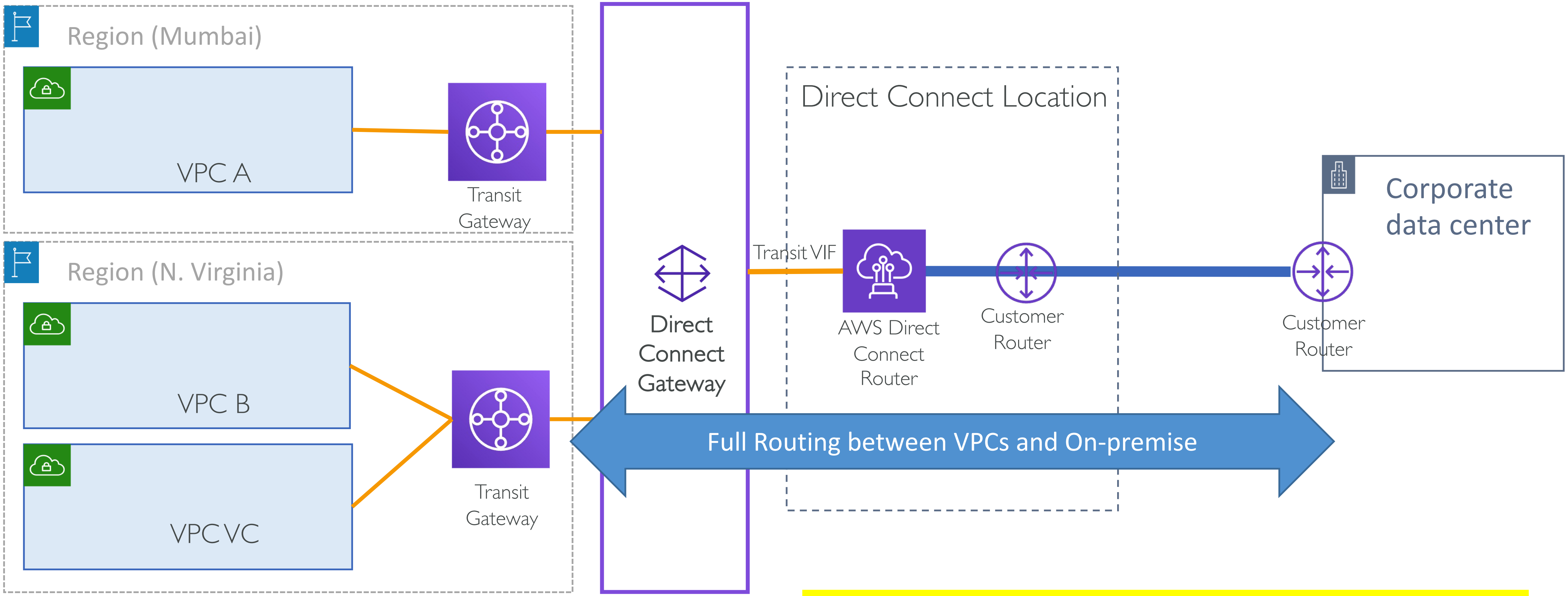
AWS account ownership



- Transit VIF and Direct Connect Gateway must be owned by same AWS account
- Transit Gateways can be owned by different AWS accounts

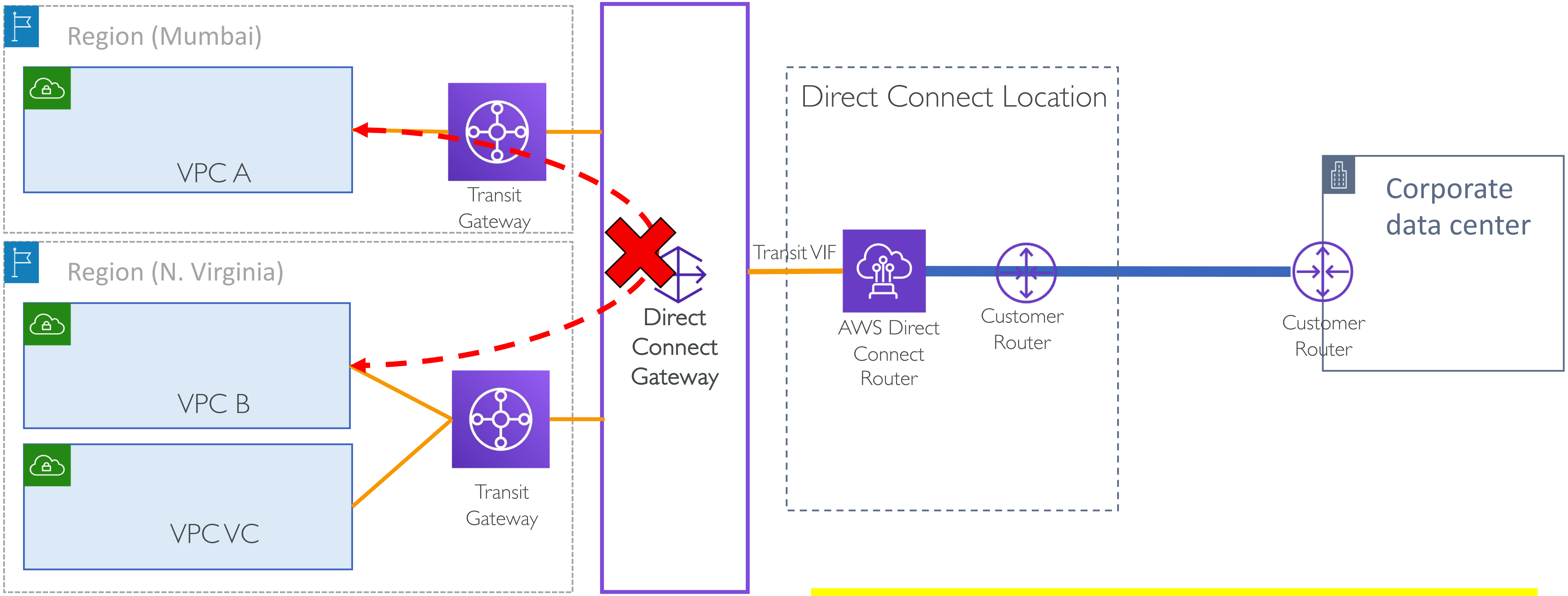
Let's look at some architectural patterns

Routing between VPCs and On-premises



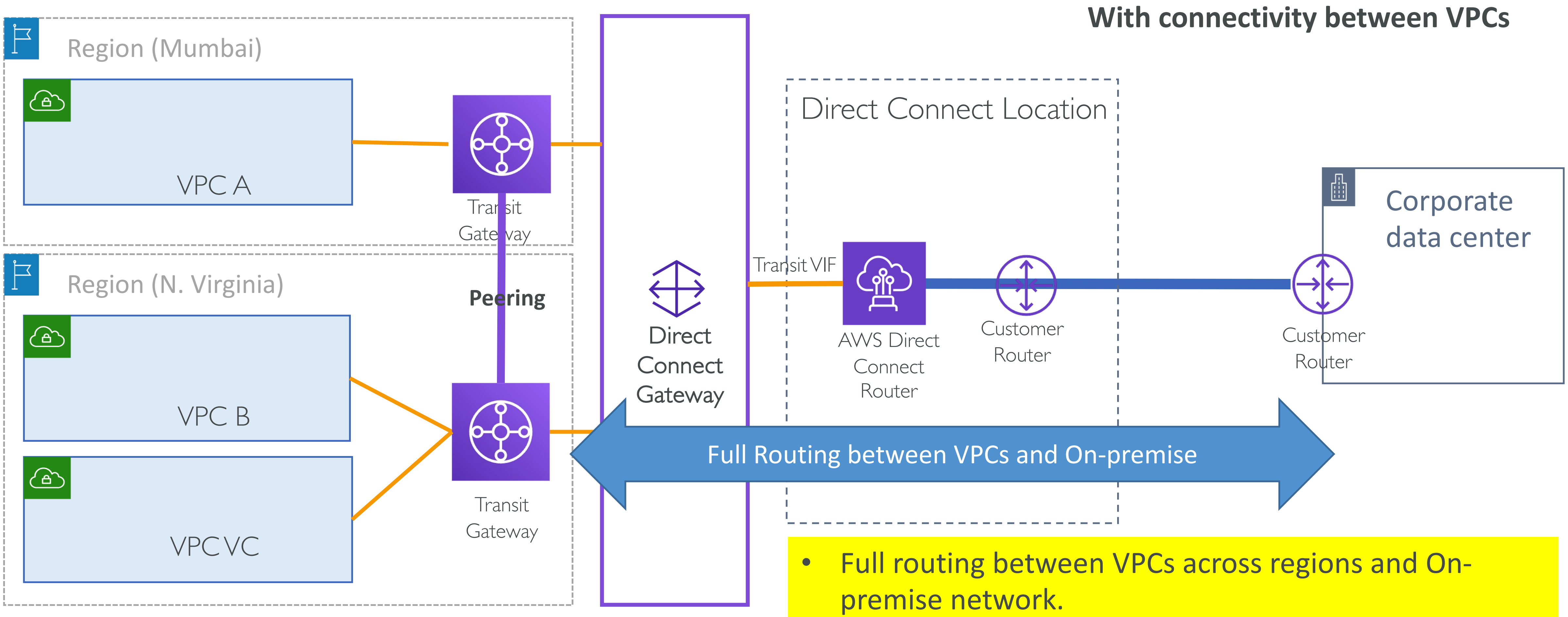
- Routing between VPCs and On-premise network

Routing between VPCs ?



- No Transitive Routing between VPCs

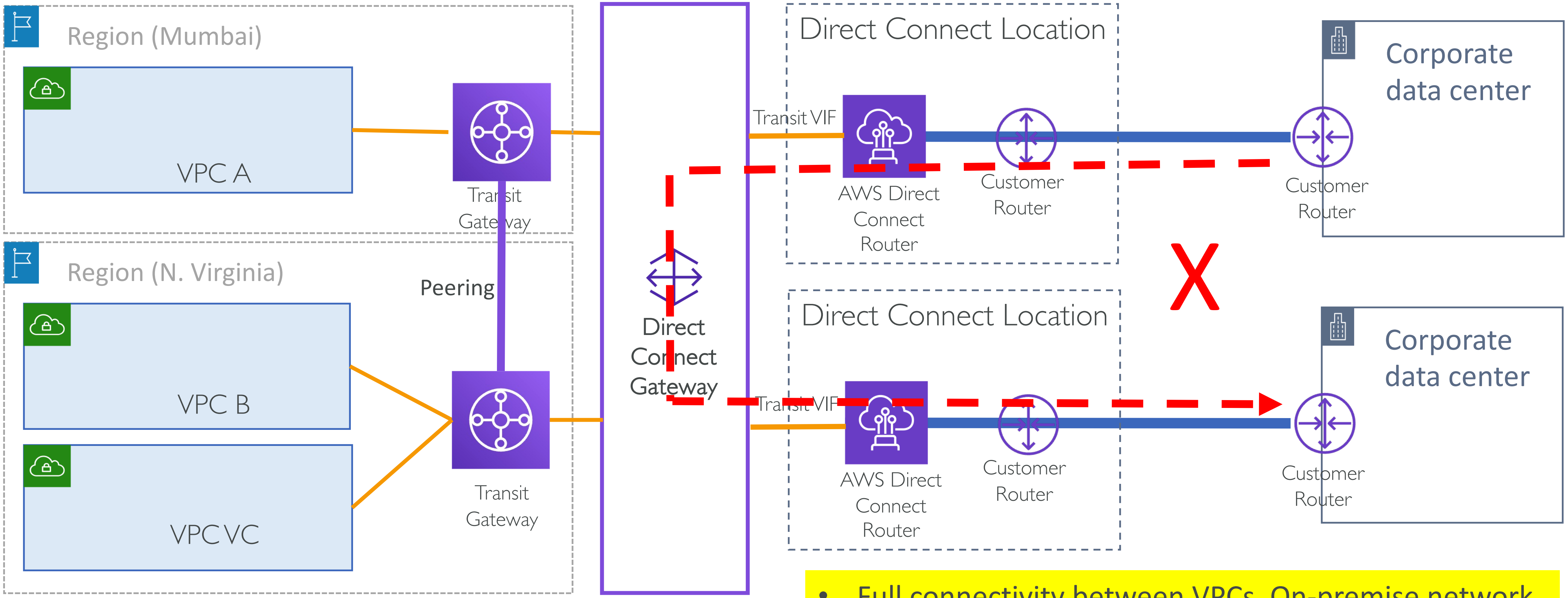
Routing between VPCs



- Full routing between VPCs across regions and On-premise network.
- Routing between VPCs using Transit Gateway peering

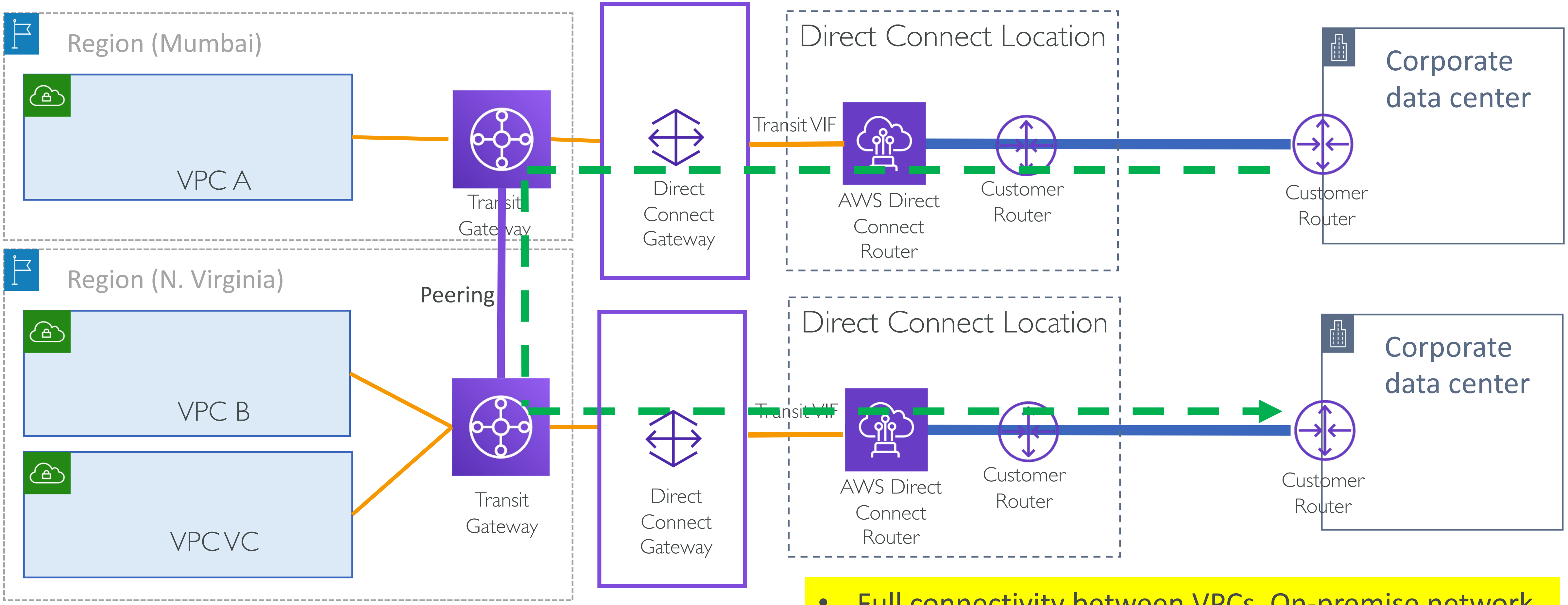
Routing between customer sites

Multiple customer sites & routing



- Full connectivity between VPCs, On-premise network
- No connectivity between customer sites because DX Gateway does not support transitive routing

Multiple customer sites & routing



- Full connectivity between VPCs, On-premise network
- Site to Site Connectivity

DX Gateway with TGW - Summary

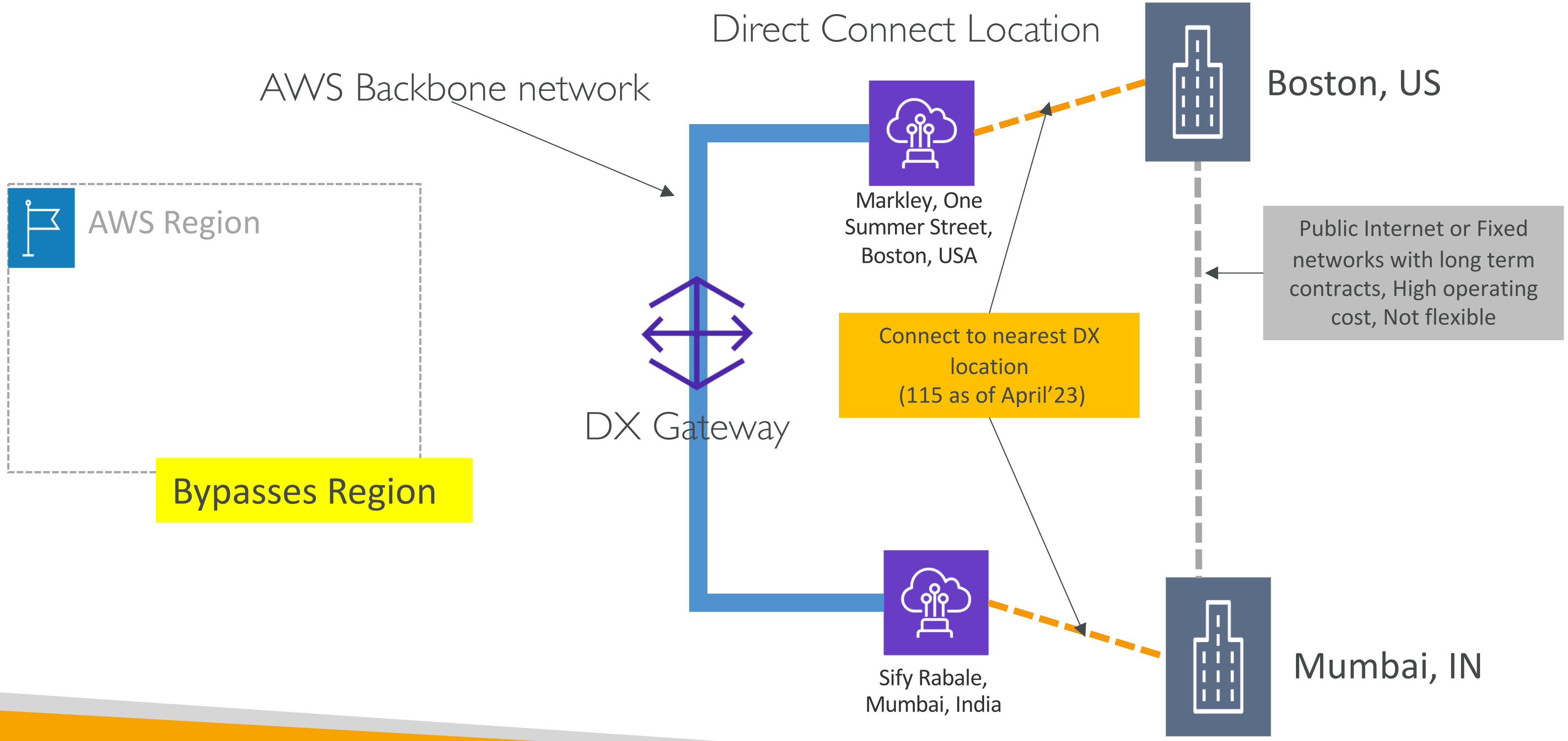
- 4 Transit VIF per Direct Connect dedicated connection.
- 1 Transit VIF per Direct Connect hosted connection
- TGW is associated with the Direct Connect Gateway
- 6 TGW's can be attached per Direct Connect Gateway
- TGW's can be peered across AWS Regions to enable inter VPC communication

Sep'23

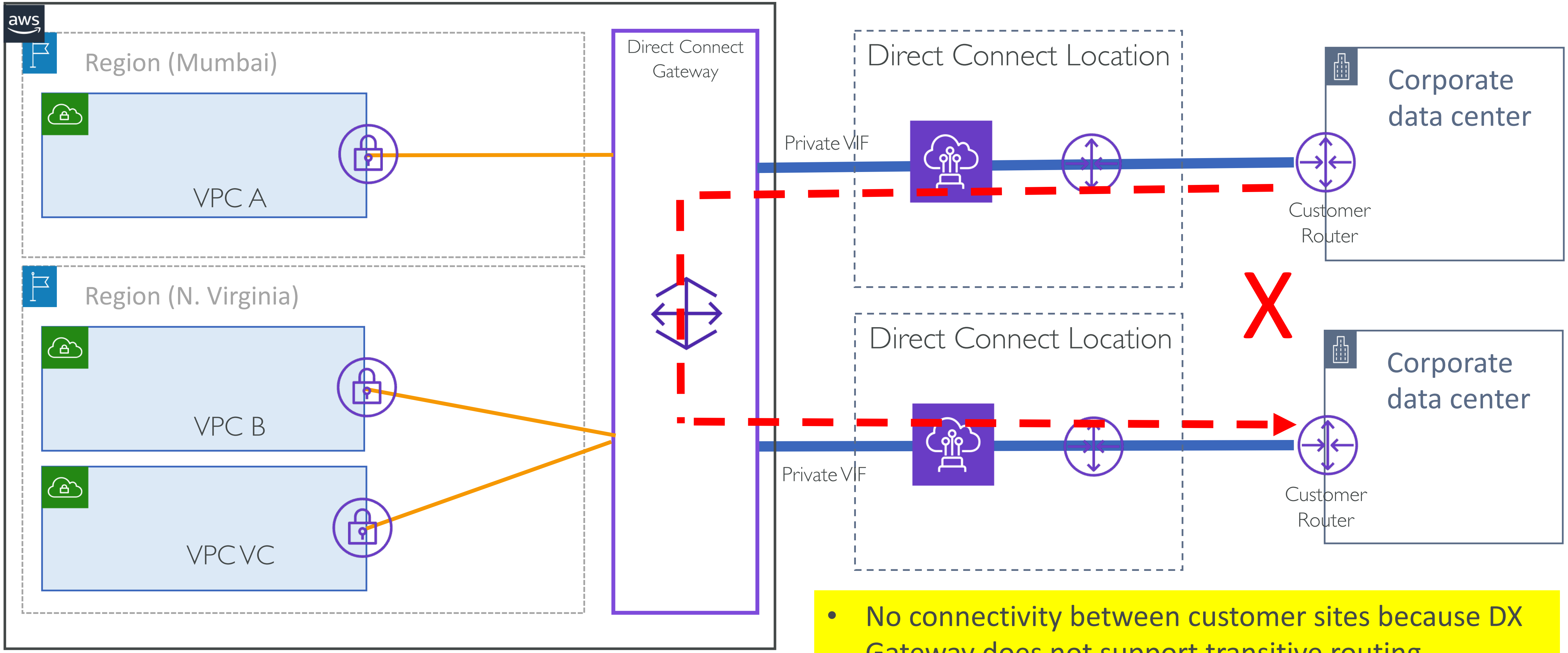
AWS Direct Connect – SiteLink

What is AWS Direct Connect **SiteLink**?

Connects on-premises networks through the AWS global network backbone

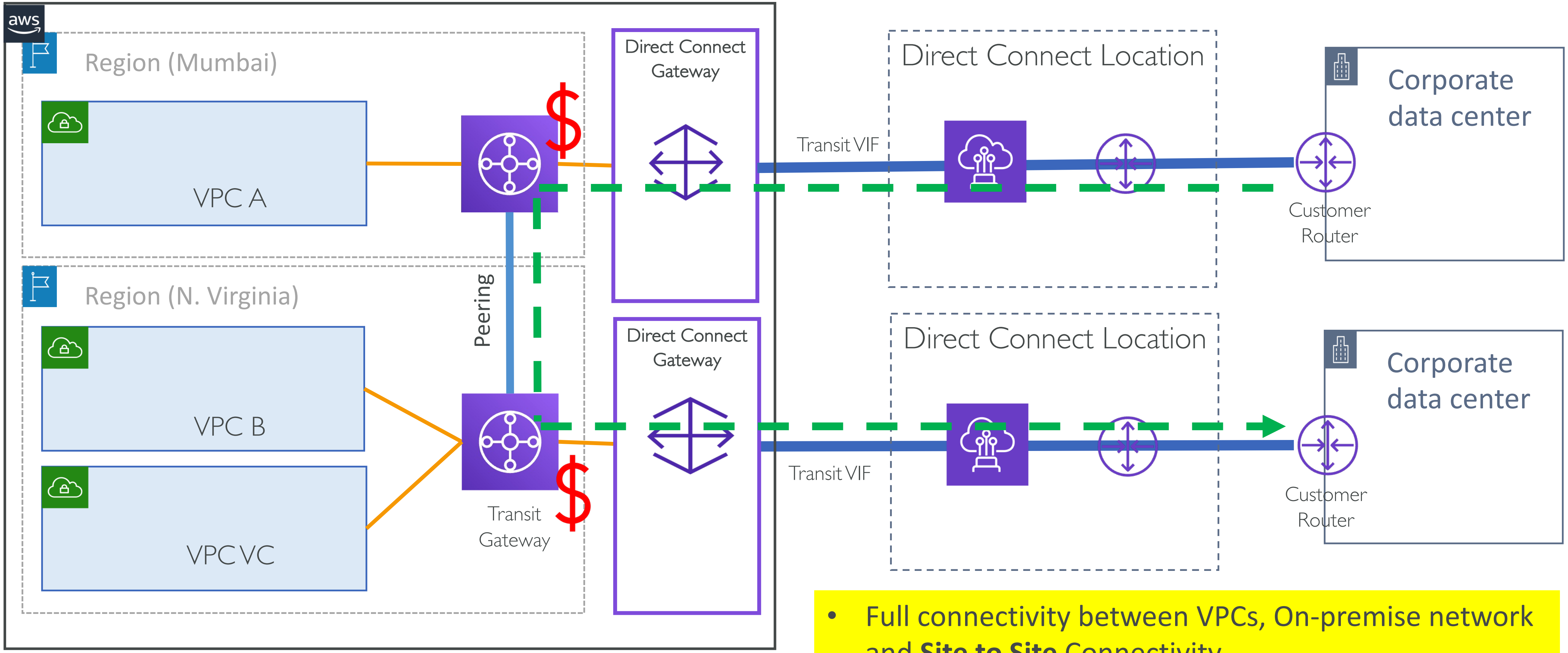


Without SiteLink - Routing between customer sites



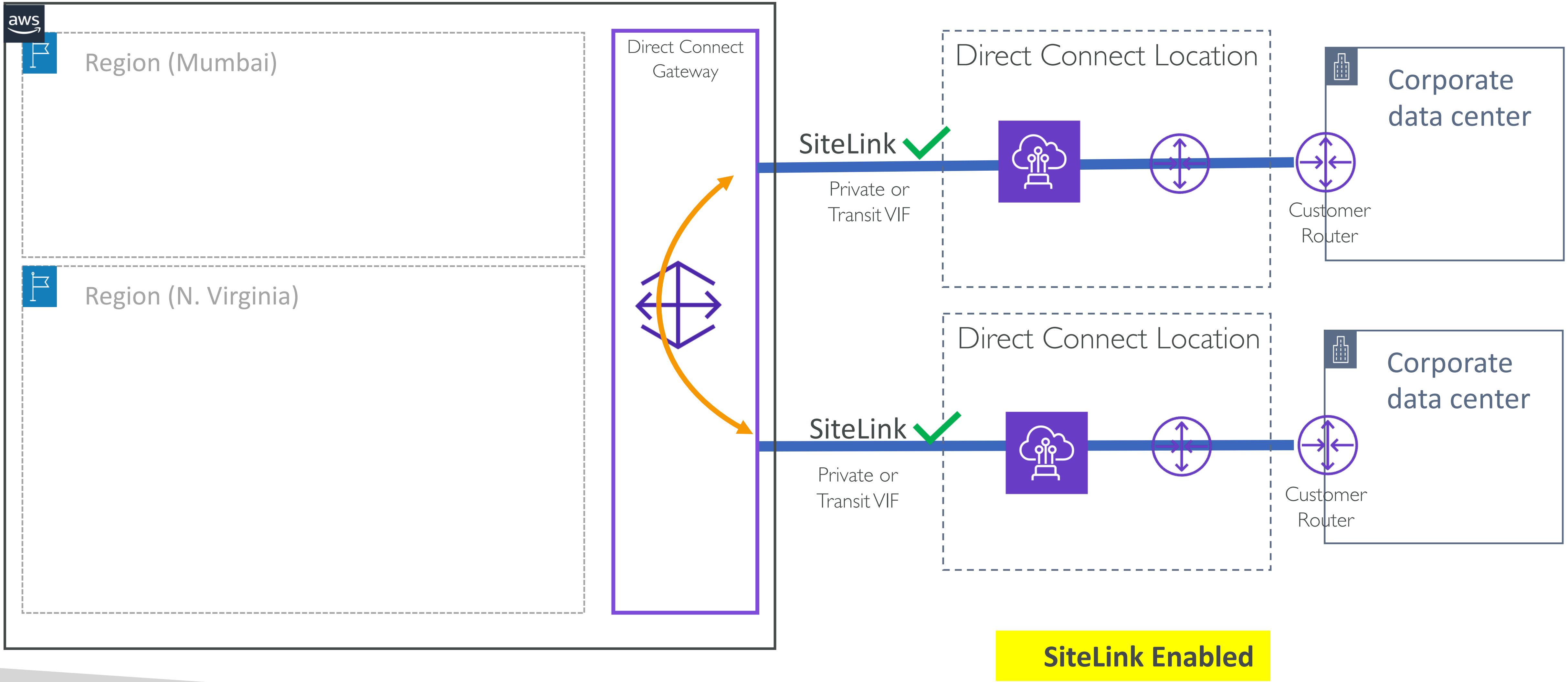
- No connectivity between customer sites because DX Gateway does not support transitive routing

Without SiteLink - Routing between customer sites



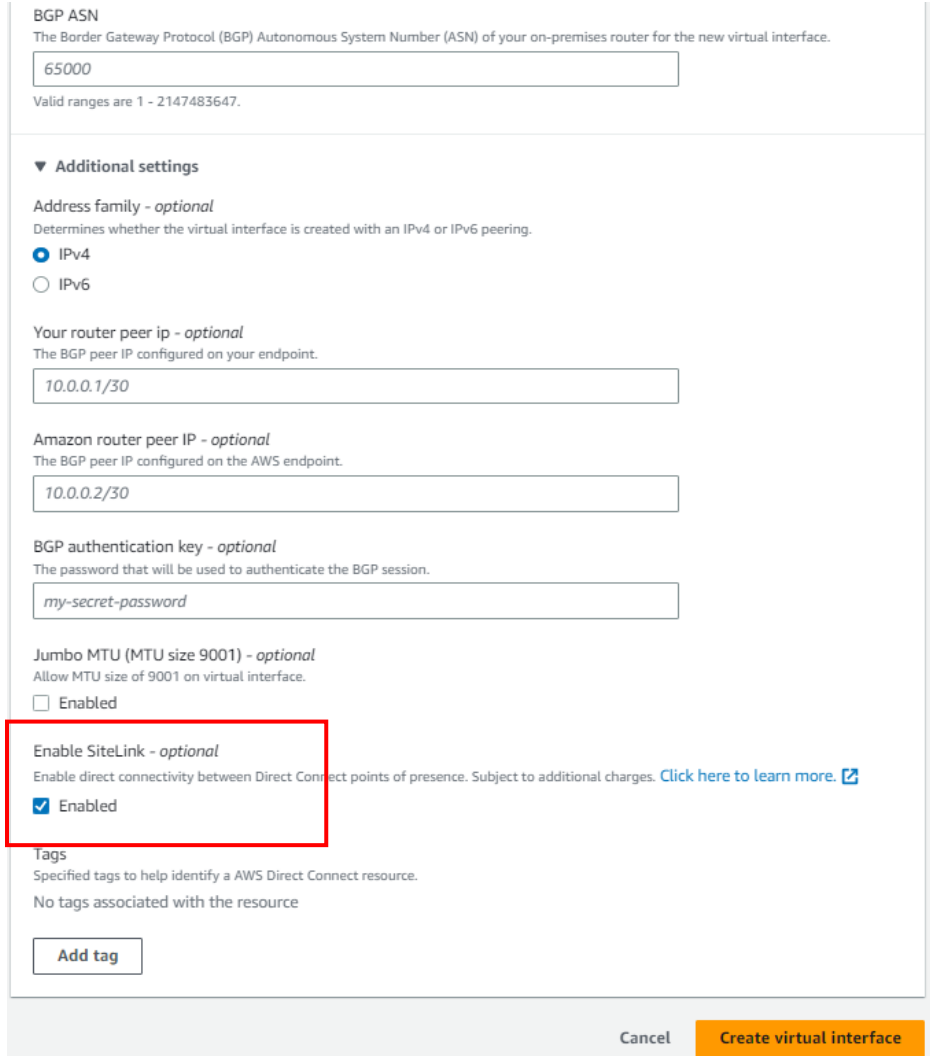
- Full connectivity between VPCs, On-premise network and **Site to Site** Connectivity
- Extra cost, extra hop and latency

With SiteLink - Routing between customer sites

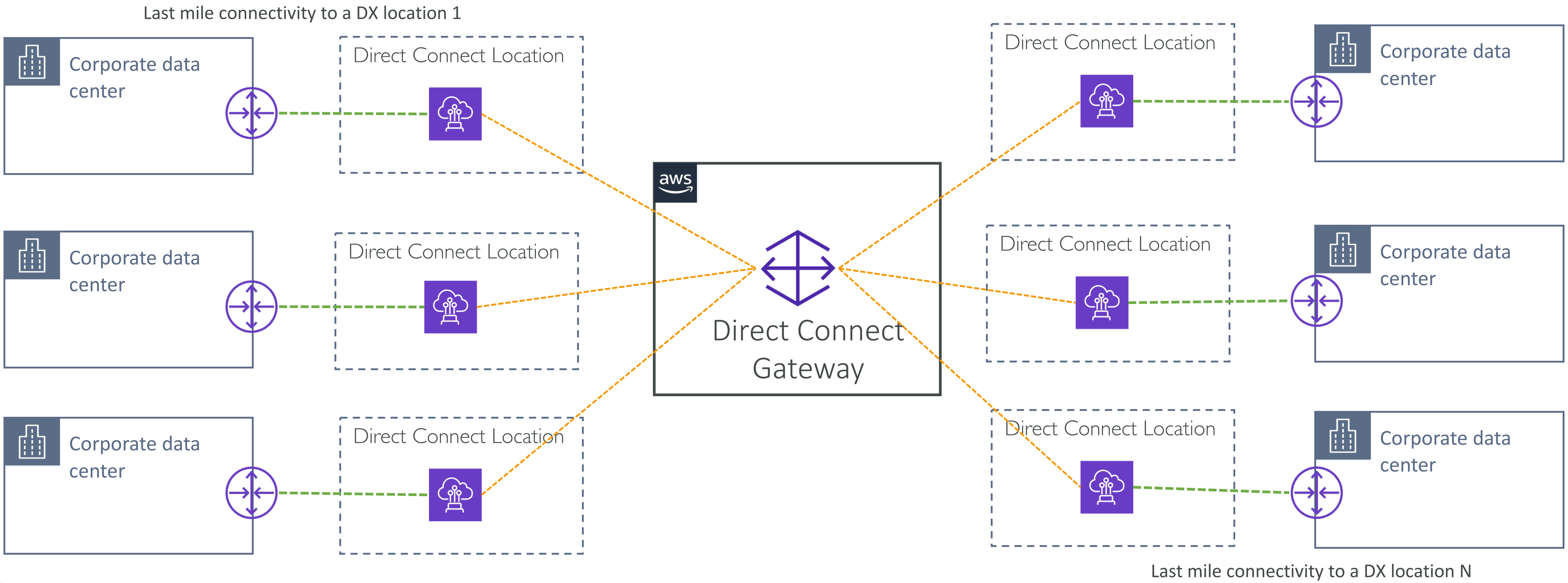


AWS Direct Connect SiteLink

- SiteLink can be enabled for a Private VIF or a Transit VIF
- Supported on any combination of a dedicated or a hosted DX connection with different port speeds
- Takes the shortest path for the traffic sent over AWS global network
- Turn SiteLink on or off in minutes
- Supports both IPv4 and IPv6 routing prefixes and traffic
- Full mesh or isolated network connections between customer locations

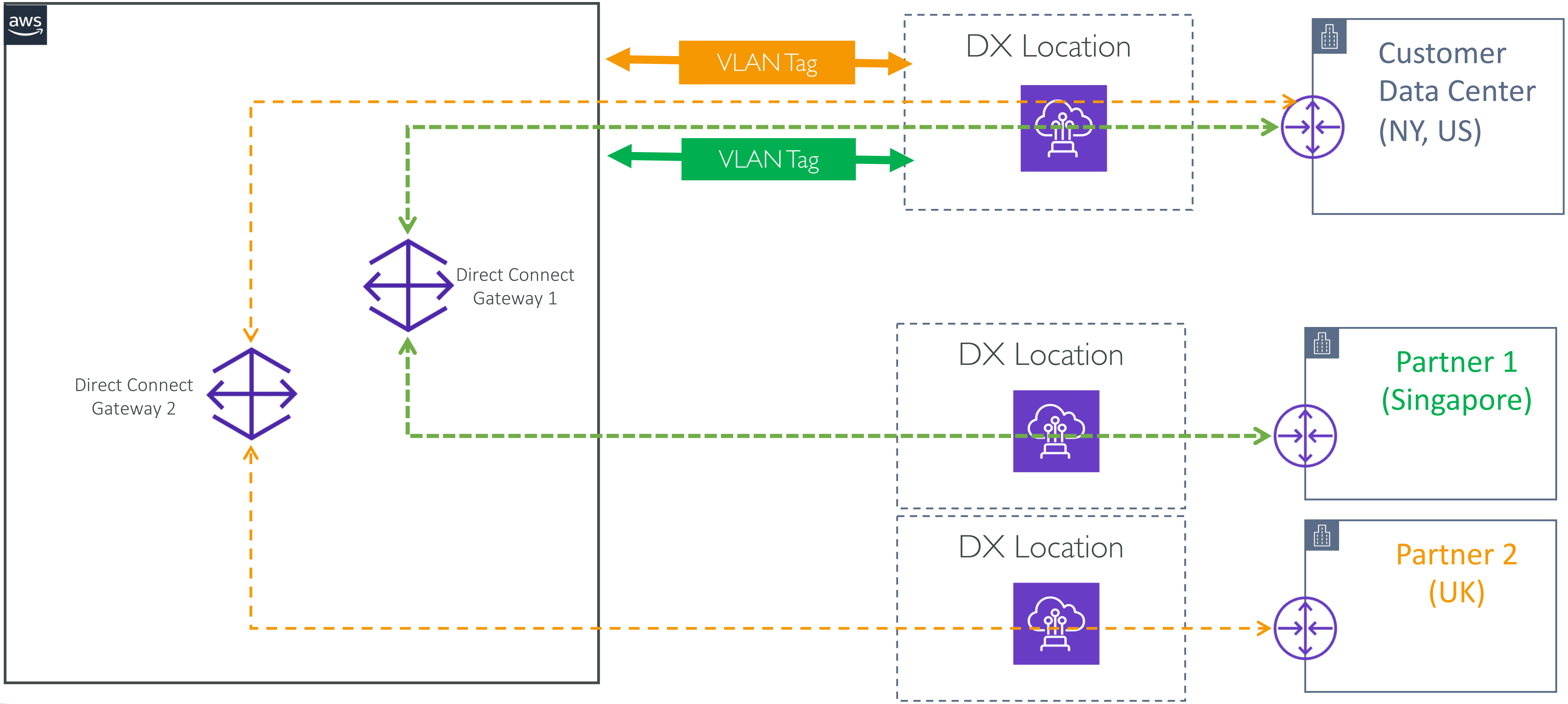


Full mesh connectivity



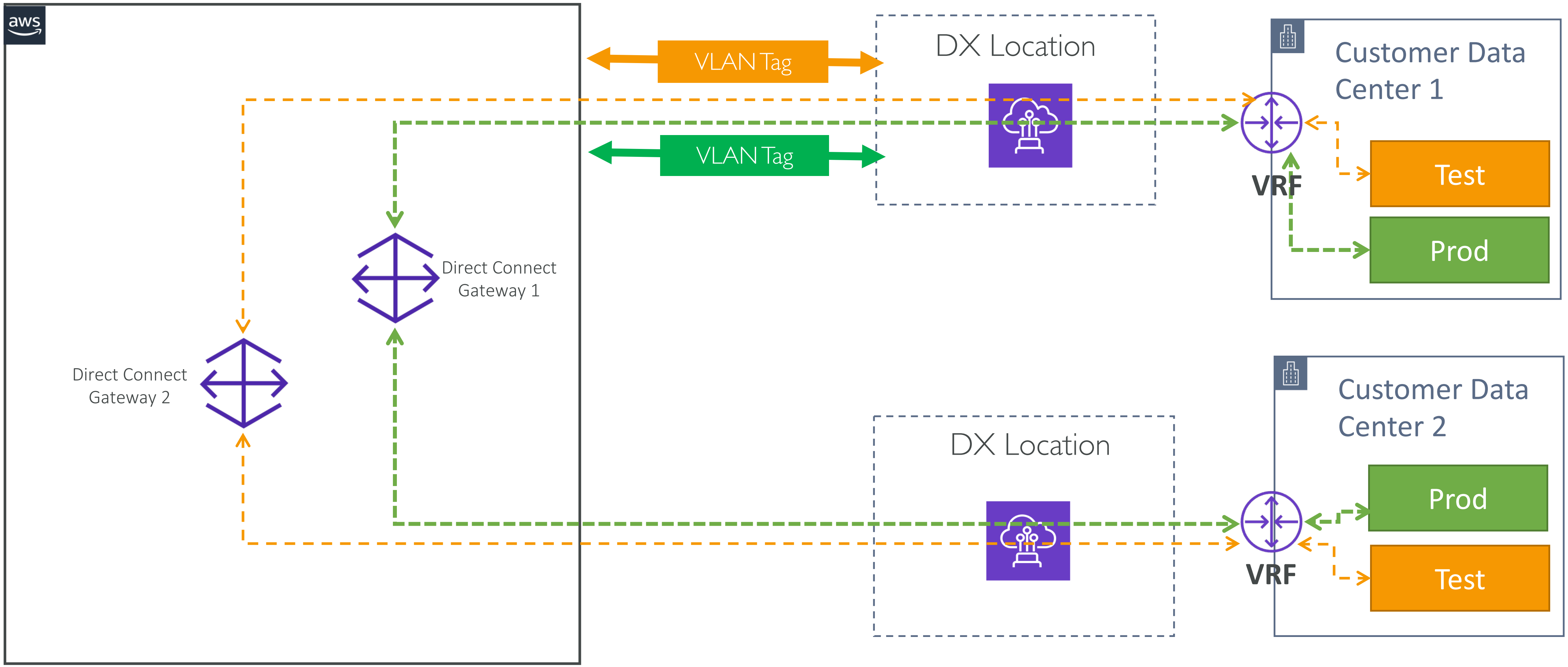
SiteLink Enabled

Isolated connectivity – Pattern 1



SiteLink Enabled

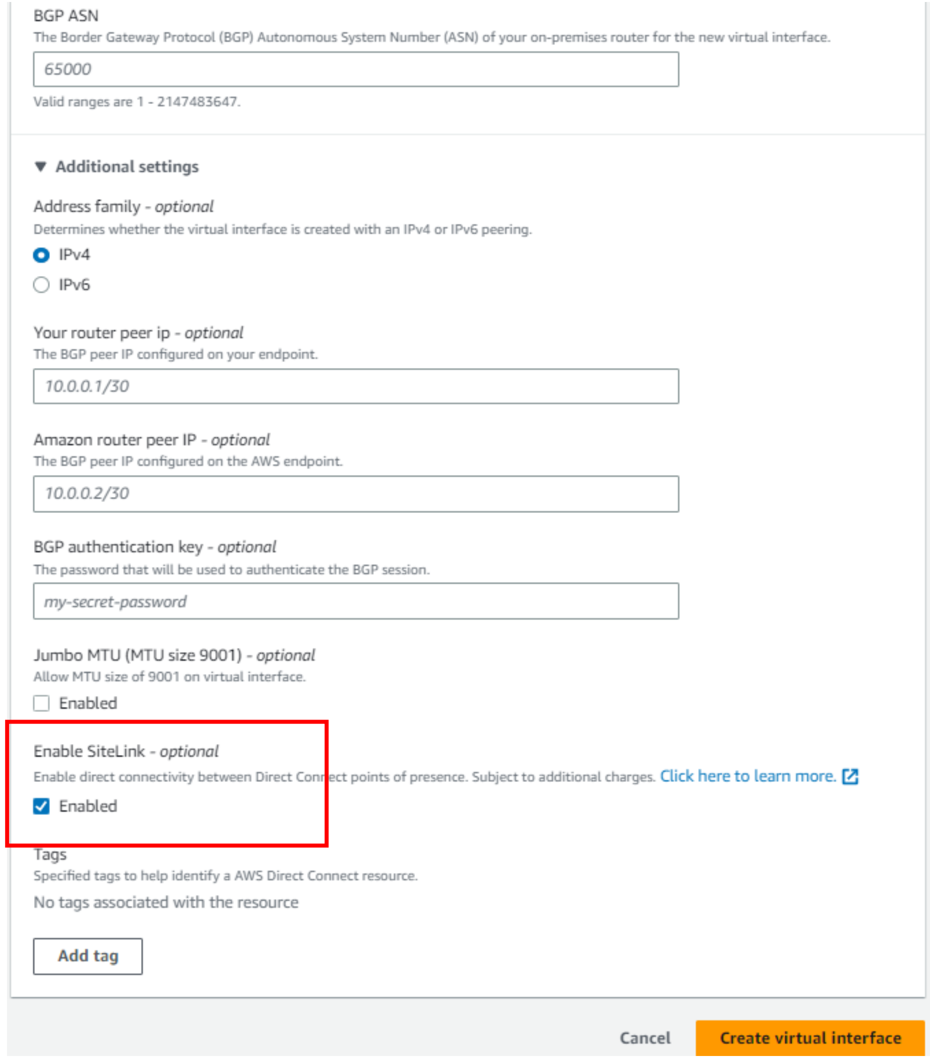
Isolated connectivity – Pattern 2



SiteLink Enabled

AWS Direct Connect SiteLink

- SiteLink can be enabled for a Private VIF or a Transit VIF
- Supported on any combination of a dedicated or a hosted DX connection with different port speeds
- Takes the shortest path for the traffic sent over AWS global network
- Turn SiteLink on or off in minutes
- Supports both IPv4 and IPv6 routing prefixes and traffic
- Full mesh or isolated network connections between customer locations
- Cost: $0.50/hr + Data transfer cost



Direct Connect Routing Policies and BGP Communities

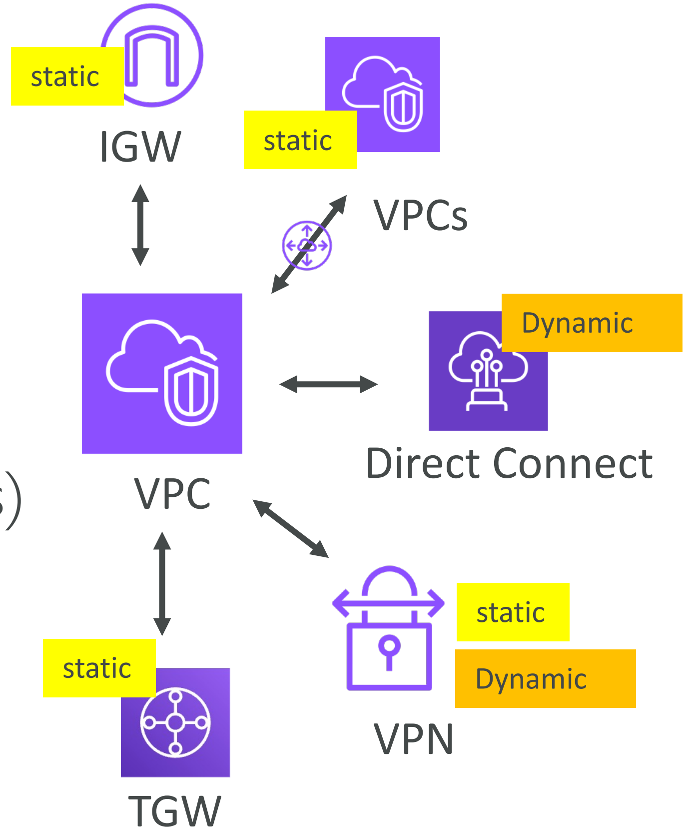
Routing Priority & Path selection

Routing priority out of the VPC

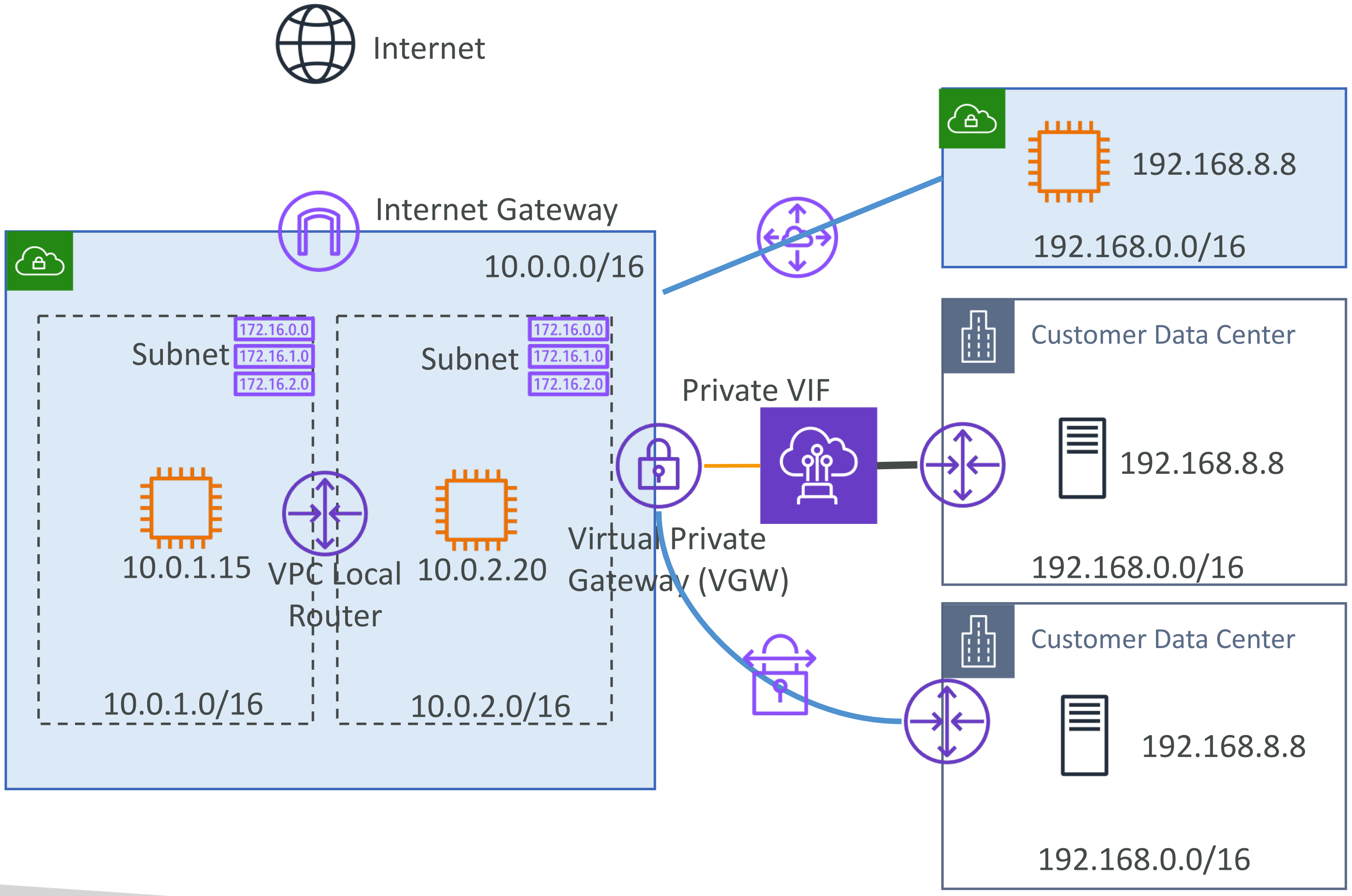
1. Longest prefix match first

   e.g. 10.10.2.15/32 has priority over 10.10.2.0/24

2. Static routes over propagated routes
3. Propagated routes
   1. Direct Connect BGP routes (Dynamic routes)
   2. VPN Static routes
   3. VPN BGP routes (Dynamic routes)

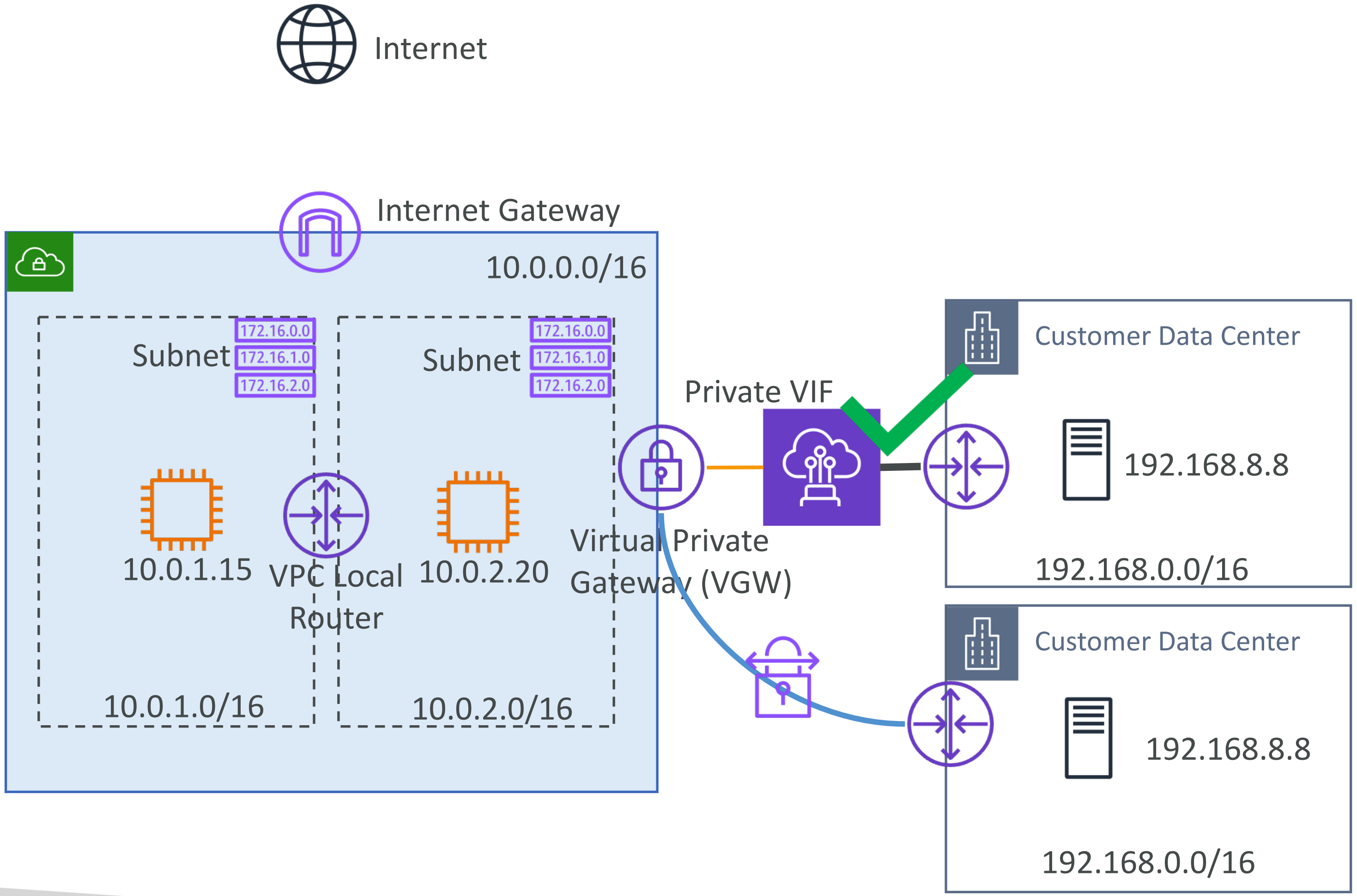


Routing preference for VPC



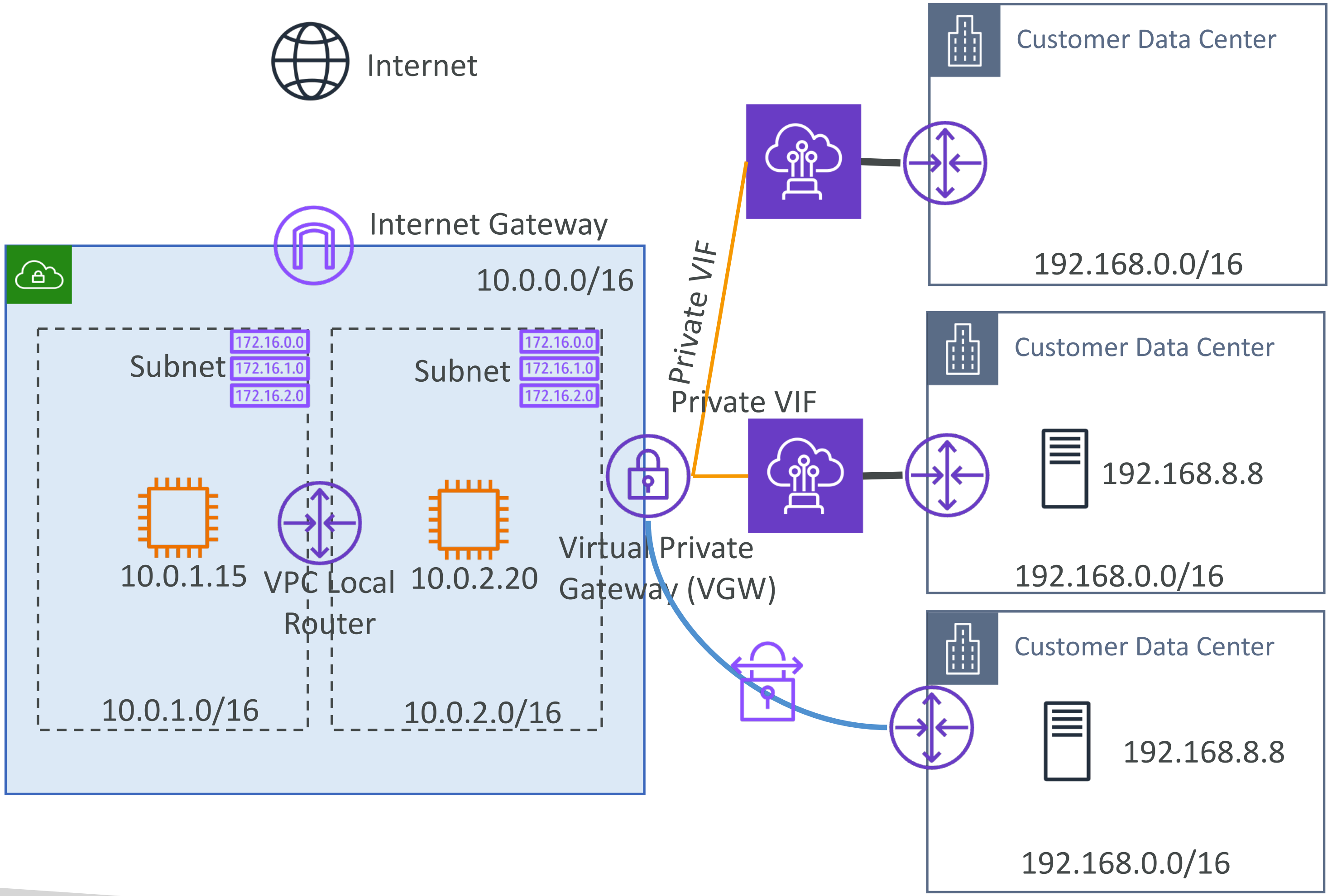
Destination	Target	Propagated
10.0.0.0/16	Local	No
192.168.0.0/16	vpc-peering	No ✓
192.168.0.0/16	vgw	Yes
0.0.0.0/0	Internet-gw	No

Routing preference for VPC



Destination	Target	Propagated
10.0.0.0/16	Local	No
~~192.168.0.0/16~~	~~vpc-peering~~	~~No~~
192.168.0.0/16	vgw	Yes
0.0.0.0/0	Internet-gw	No

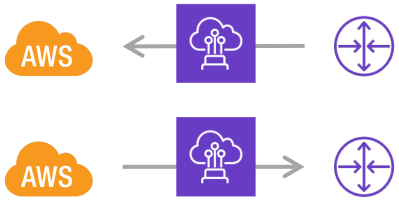
Routing preference for VPC



BGP Routing policies and BGP Community Tags are used to influence the routing decision

DX Routing Policies and BGP communities

- Routing policies influence the routing decision when traffic flows through Direct Connect connections.
- **Inbound routing Policies** - from on-premises to AWS
- **Outbound routing Policies** - from AWS to on-premises
- Routing policies and BGP communities work differently for Public VIF and Private /Transit VIFs



Public VIF & Private/Transit VIF Routing

Public VIF

Private or Transit VIF

- For path selection (route priority) use BGP attributes:
  - Longest prefix
  - AS_PATH
- For route propagation scope, use BGP community tags
  - Inbound: 7224:9100, 7224:9200, 7224:9300
  - Outbound: 7224:8100, 7224:8200, No tag
  - NO_EXPORT

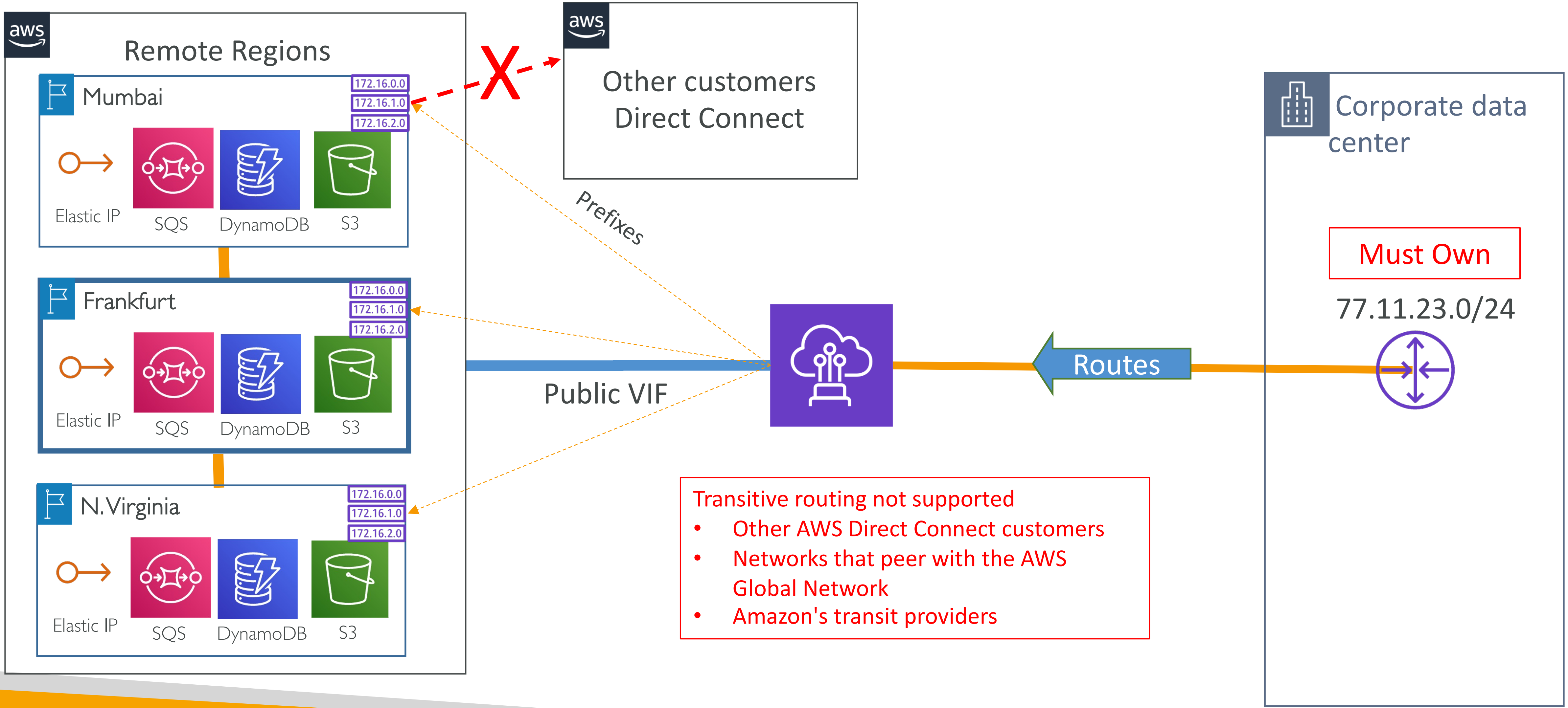
- For path selection (route priority) use BGP attributes:
  - Longest prefix
  - AS_PATH
  - Local preference BGP community Tags:
    - 7224:7100 (Low)
    - 7224:7200 (Medium)
    - 7224:7300 (High)

Public VIF Routing Policies

Public VIF Routing policies - **Inbound**

- You must specify the public IPv4 prefixes or IPv6 prefixes to advertise over BGP .
- You must own the public prefixes (Regional Internet Registry).
- Traffic must be destined to Amazon public prefixes.
- Transitive routing between connections is not supported.
- AWS Direct Connect performs inbound packet filtering

Public VIF Routing policies - Inbound



Transitive routing not supported

- Other AWS Direct Connect customers
- Networks that peer with the AWS Global Network
- Amazon's transit providers

Public VIF Routing policies - **Outbound**

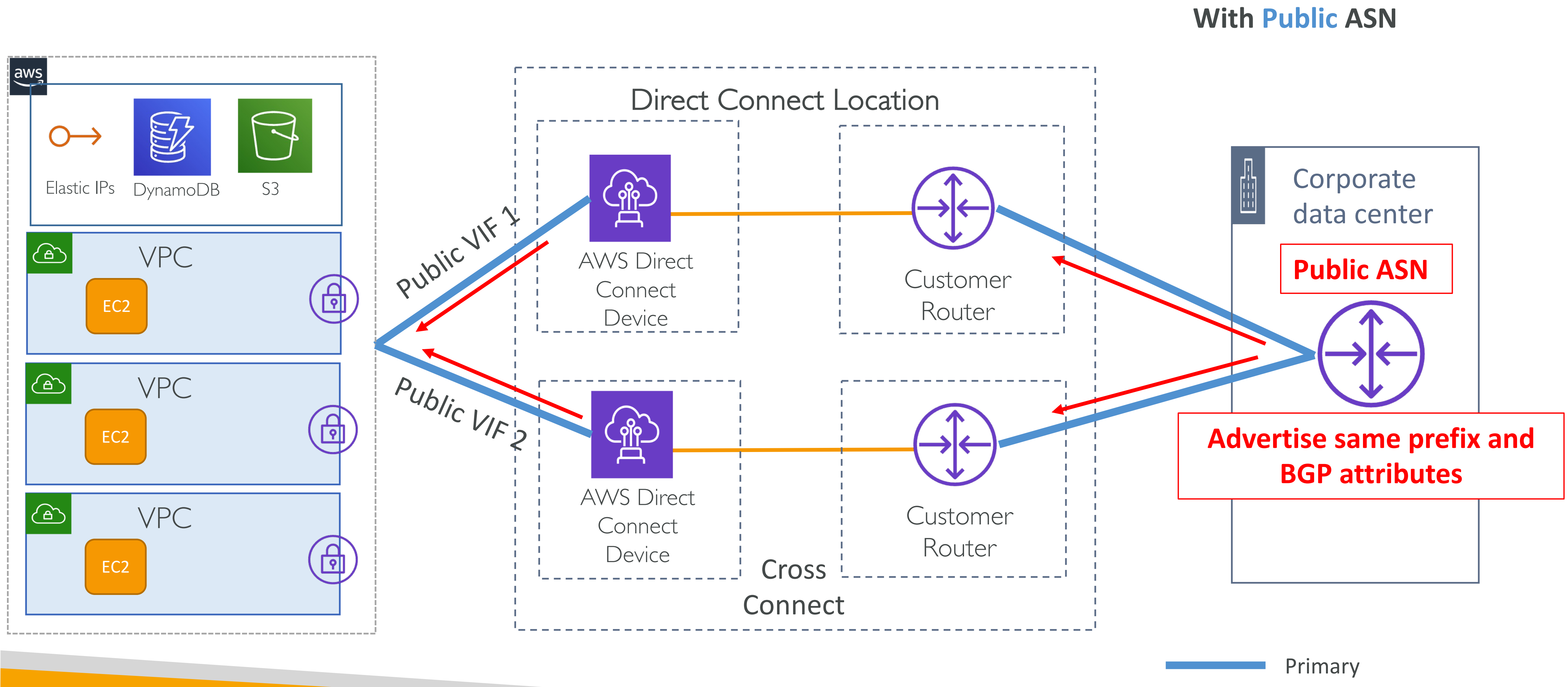
- Longest Prefix Match and AS_PATH can be used to influence the routing
- AWS Direct Connect advertises all local and remote AWS Region prefixes
- Advertises all public prefixes with NO_EXPORT BGP community tag.
- Additionally AWS advertises 7224:8100 and 7224:8200 BGP community tags.
- The prefixes advertised by AWS Direct Connect must not be advertised beyond the network boundaries of your connection
- In case of multiple AWS DX connections, you can adjust the **load-sharing** of traffic by advertising prefixes with similar path attributes (ECMP)

Multiple DX connections traffic routing scenarios using Routing policies for Public VIF

Active-Active connection using Public VIF

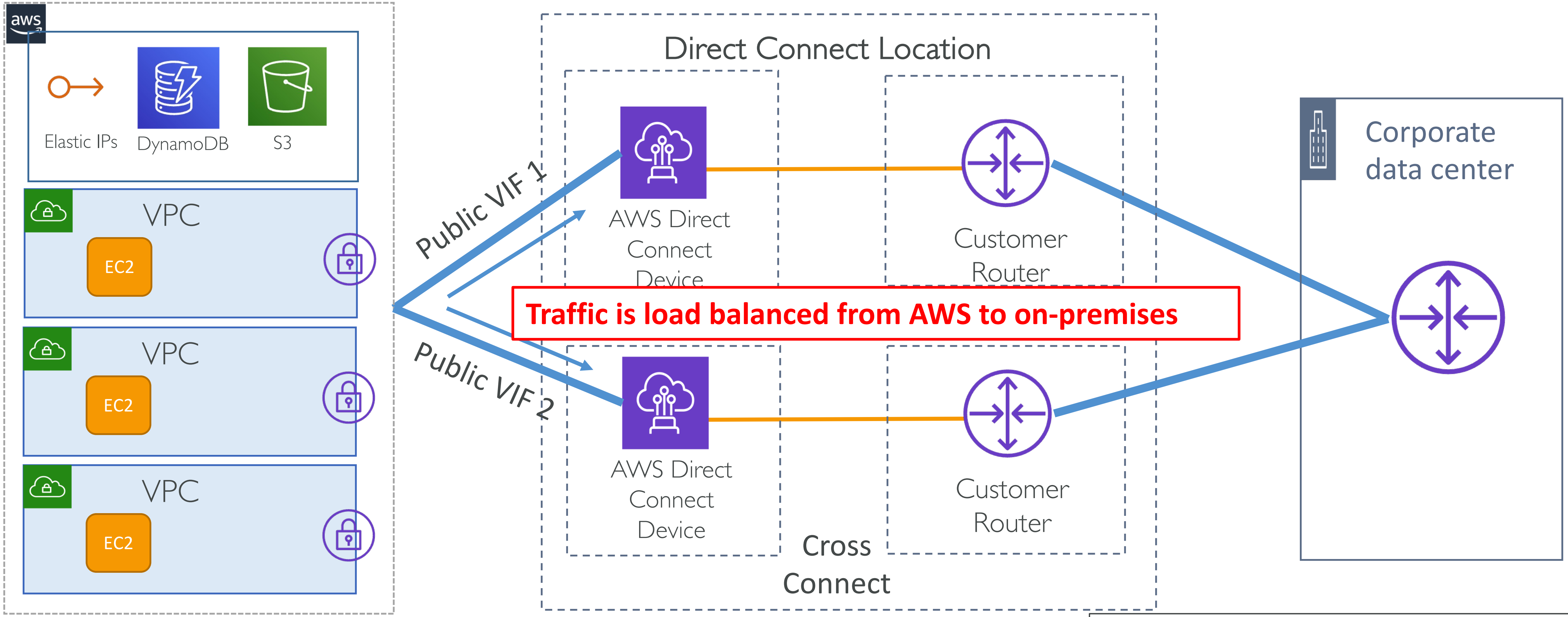
- If using a public ASN:
  - Customer gateway to advertise the same prefix with the same Border Gateway Protocol (BGP) attributes on both public virtual interfaces.
  - This configuration load balances traffic over both public virtual interfaces.
- If using a private ASN
  - Load balancing on a public virtual interface is not supported.

Active-Active Connection using Public VIF



Active-Active Connection using Public VIF

With Public ASN



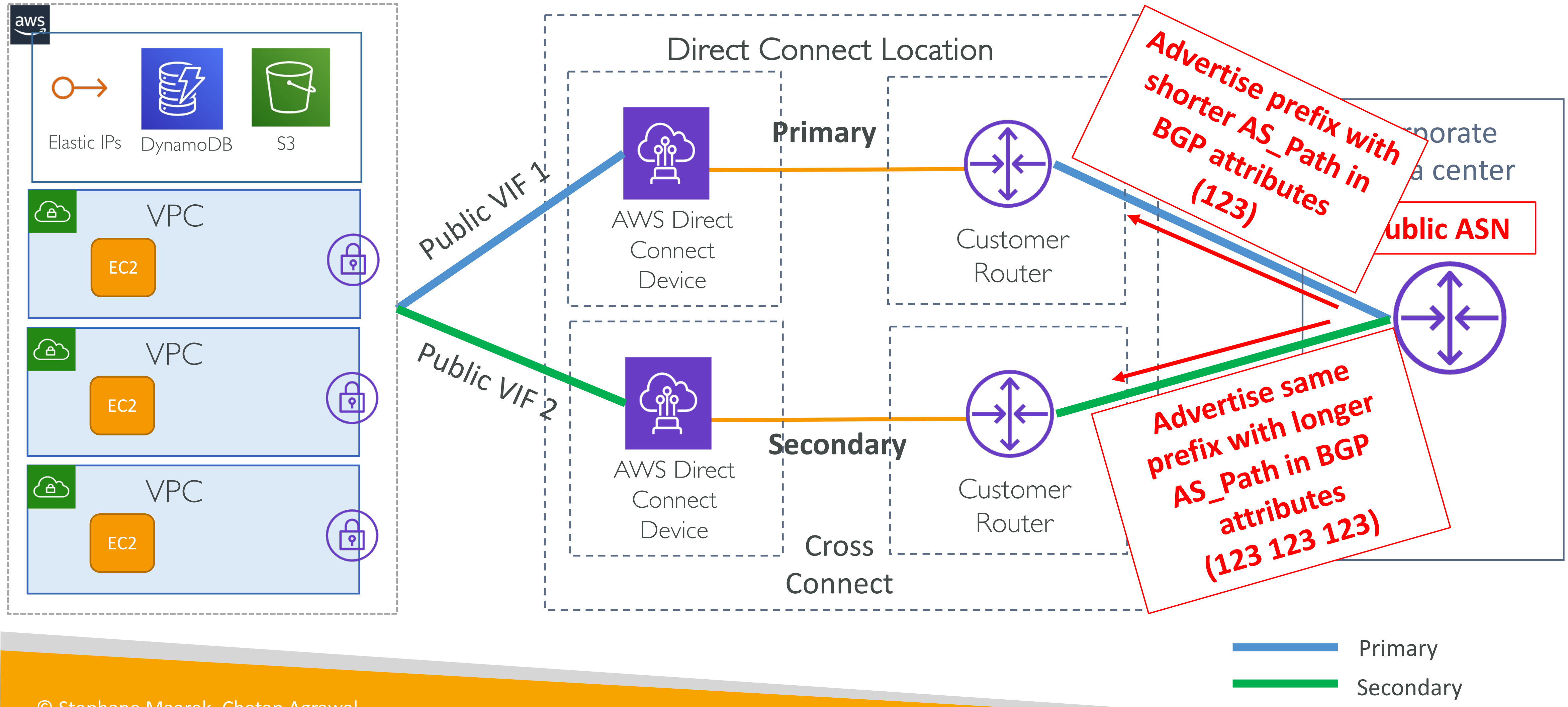
- Uses Equal cost multi-path (ECMP)
- Not possible with **private** ASN

Active-Passive Connection using Public VIF

- If using a public ASN:
  - Customer gateway to advertising the same prefix (public IP or network that you own) on both BGP sessions.
  - Start advertising the on-premises public prefixes with additional AS_Path prepends in the BGP attributes for Secondary connection.
  - Increase the Local Preference (local-pref) to be sure that the on-premises router always chooses the correct path for sending traffic to AWS.
- If using a private ASN:
  - Use longer prefixes on primary connection.
  - Example: two prefixes (X.X.X.0/25 and X.X.X.128/25) on your primary connection and X.X.X.0/24 on secondary connection

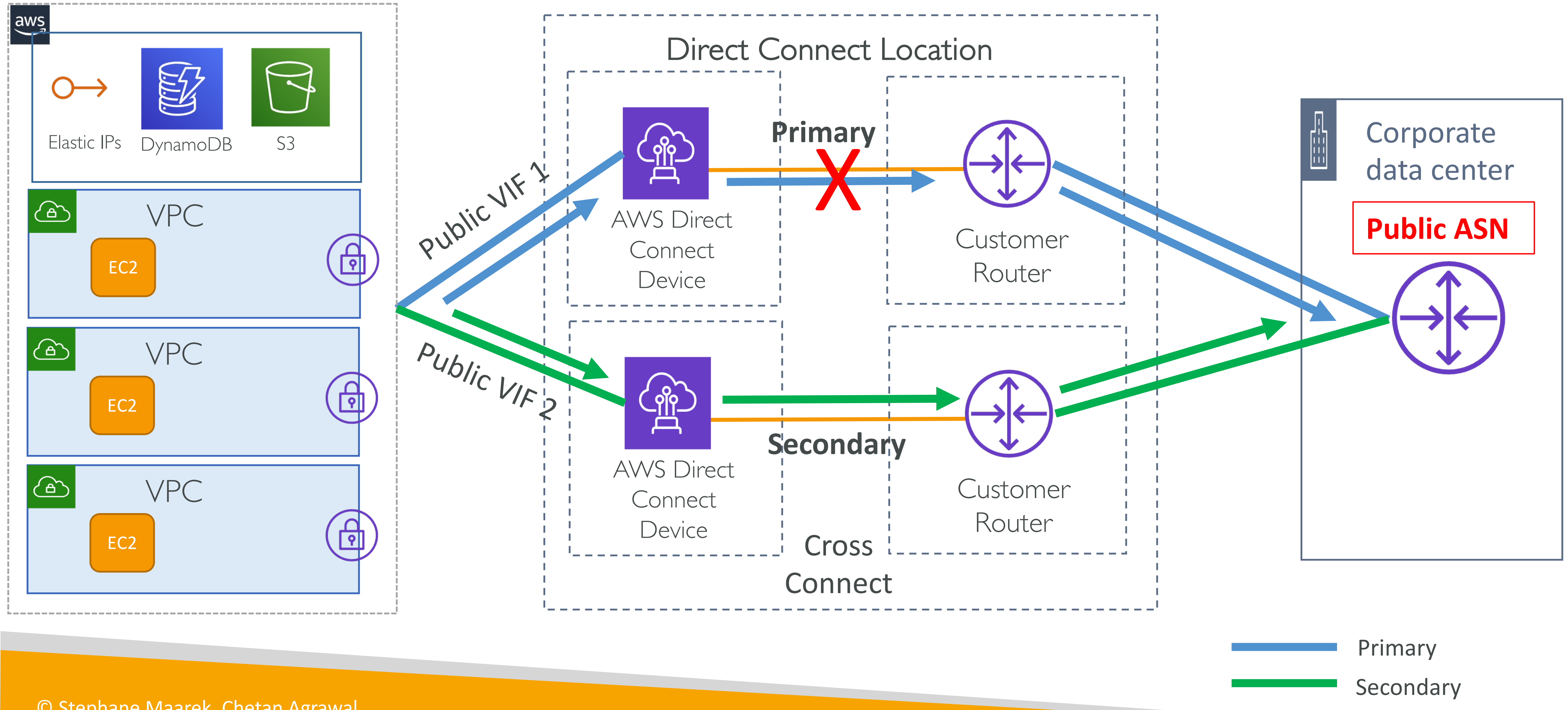
Active-Passive Connection using Public VIF

With Public ASN



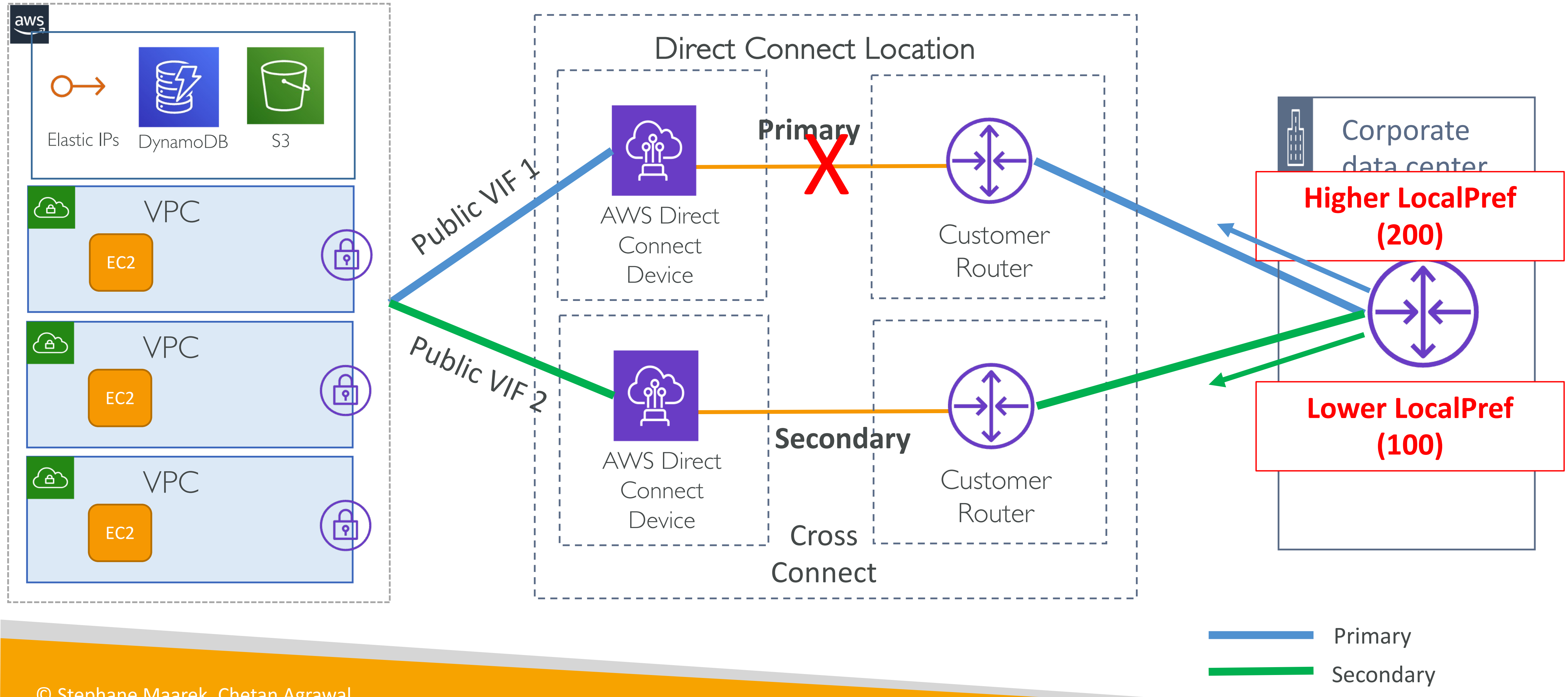
Active-Passive Connection using Public VIF

With Public ASN



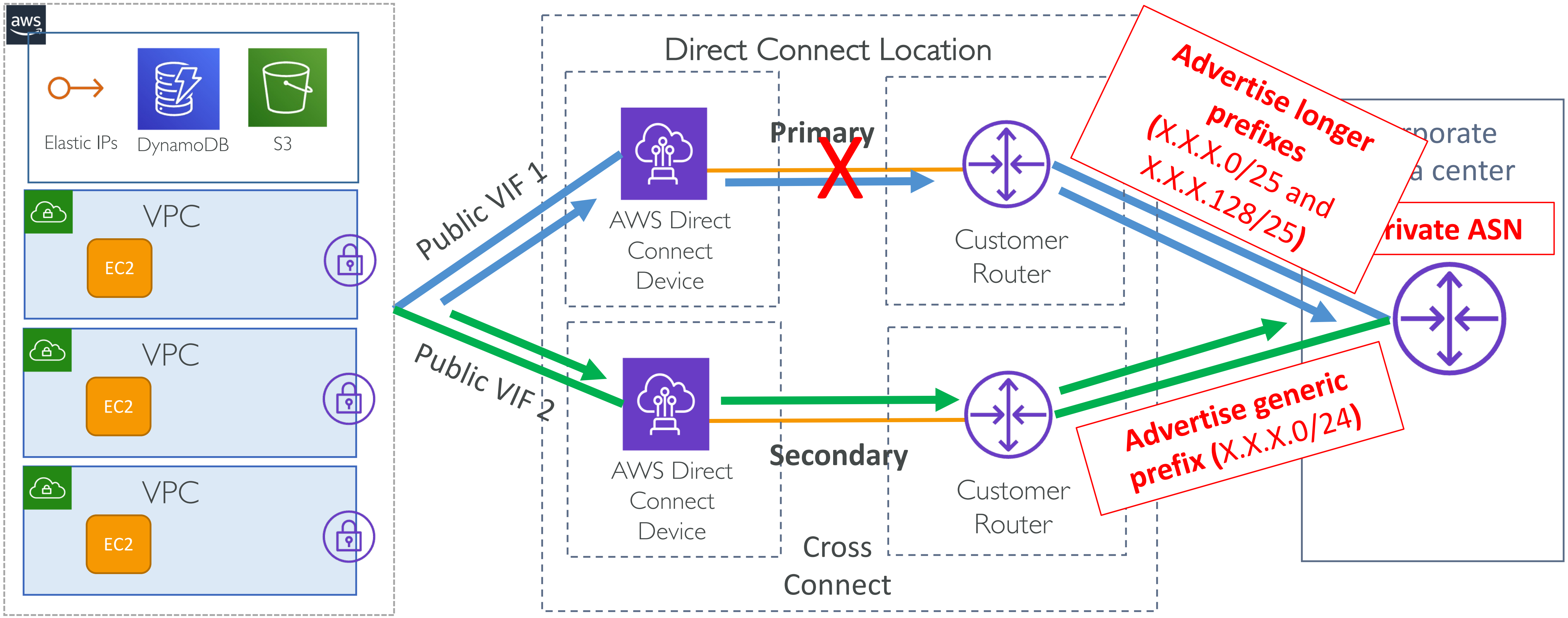
Active-Passive Connection using Public VIF

With Public ASN



Active-Passive Connection using Public VIF

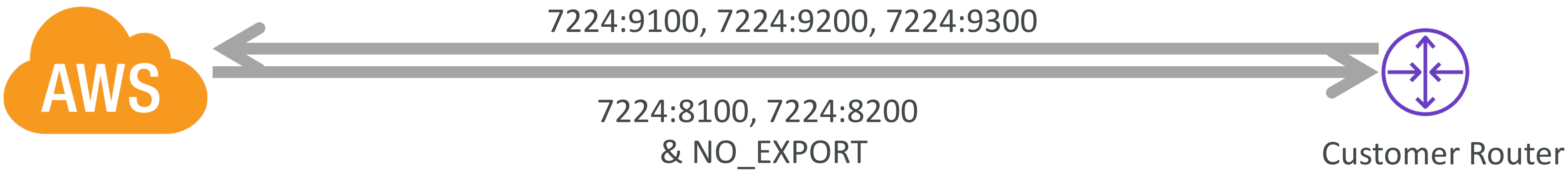
With Private ASN



DX route advertisement scenarios for Public VIF using BGP communities

Public VIF – BGP Communities

- BGP Community tags help control the scope for the advertisement of the prefixes (Regional or global)
- Supports scope BGP community tags
  - Inbound 7224:9100, 7224:9200, 7224:9300
  - Outbound 7224:8100, 7224:8200
- Supports NO_EXPORT BGP community tag



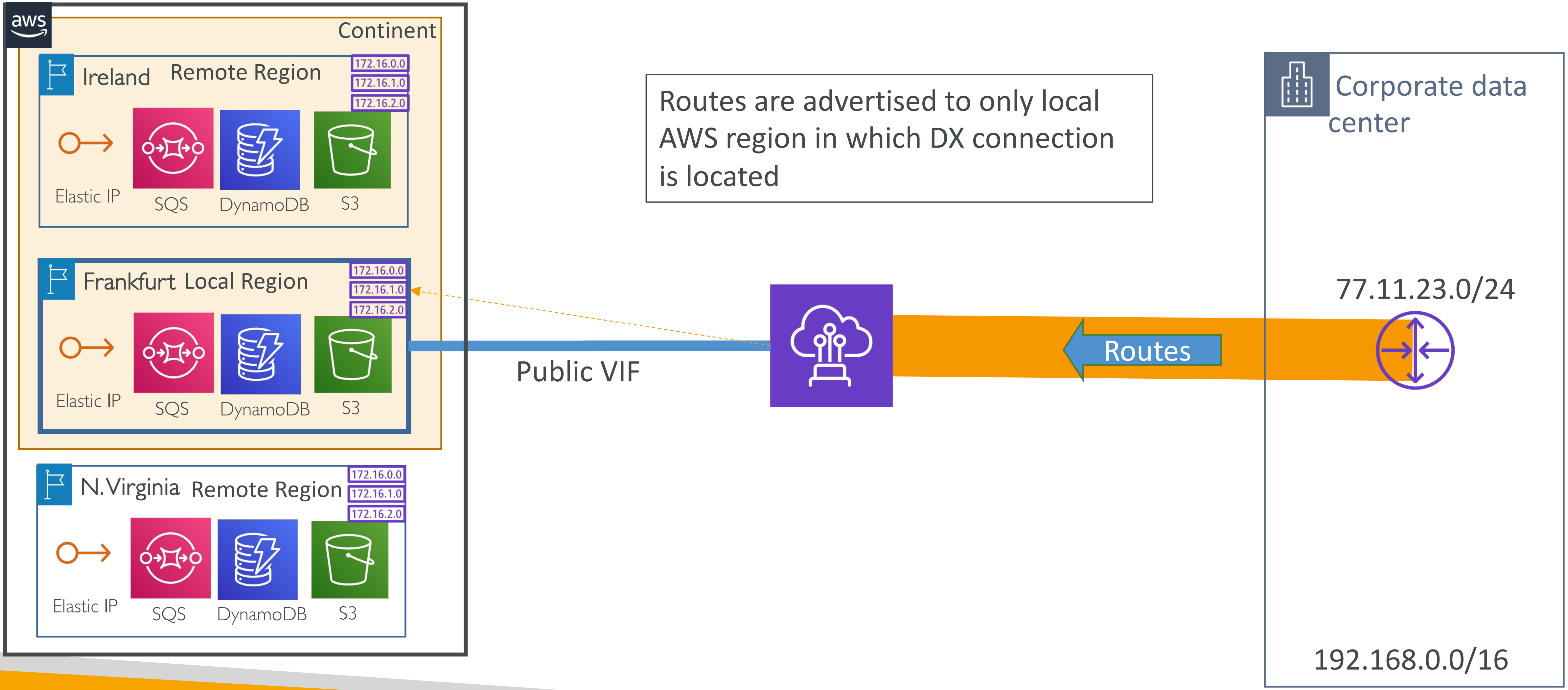
Public VIF BGP Communities - Inbound

The prefixes received from customer on Public VIFs are advertised within AWS as per below BGP community tags

- 7224:9100—Local AWS Region
- 7224:9200—All AWS Regions for a continent
  - North America–wide
  - Asia Pacific
  - Europe, the Middle East and Africa
- 7224:9300—Global (all public AWS Regions)

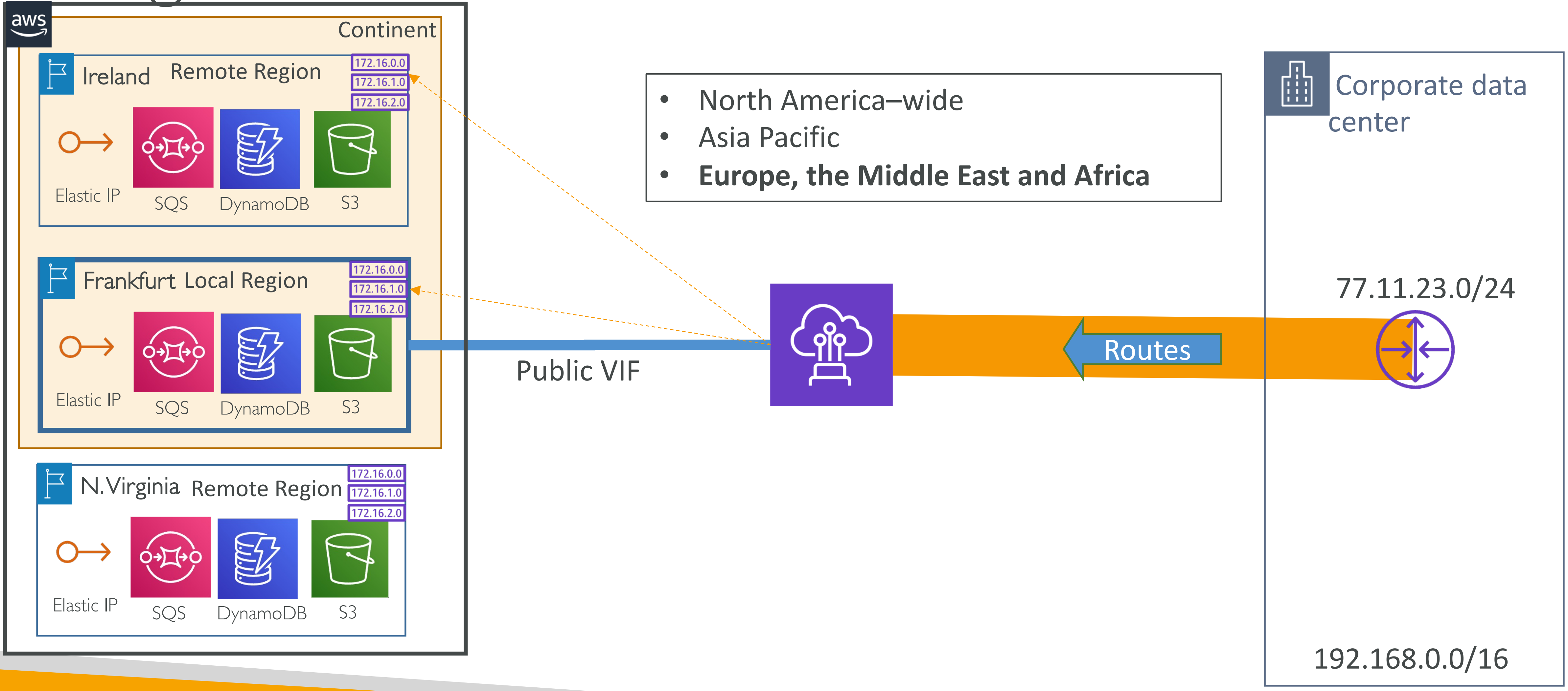
Default

Public VIF BGP Communities Inbound – Local 7224:9100



Routes are advertised to only local AWS region in which DX connection is located

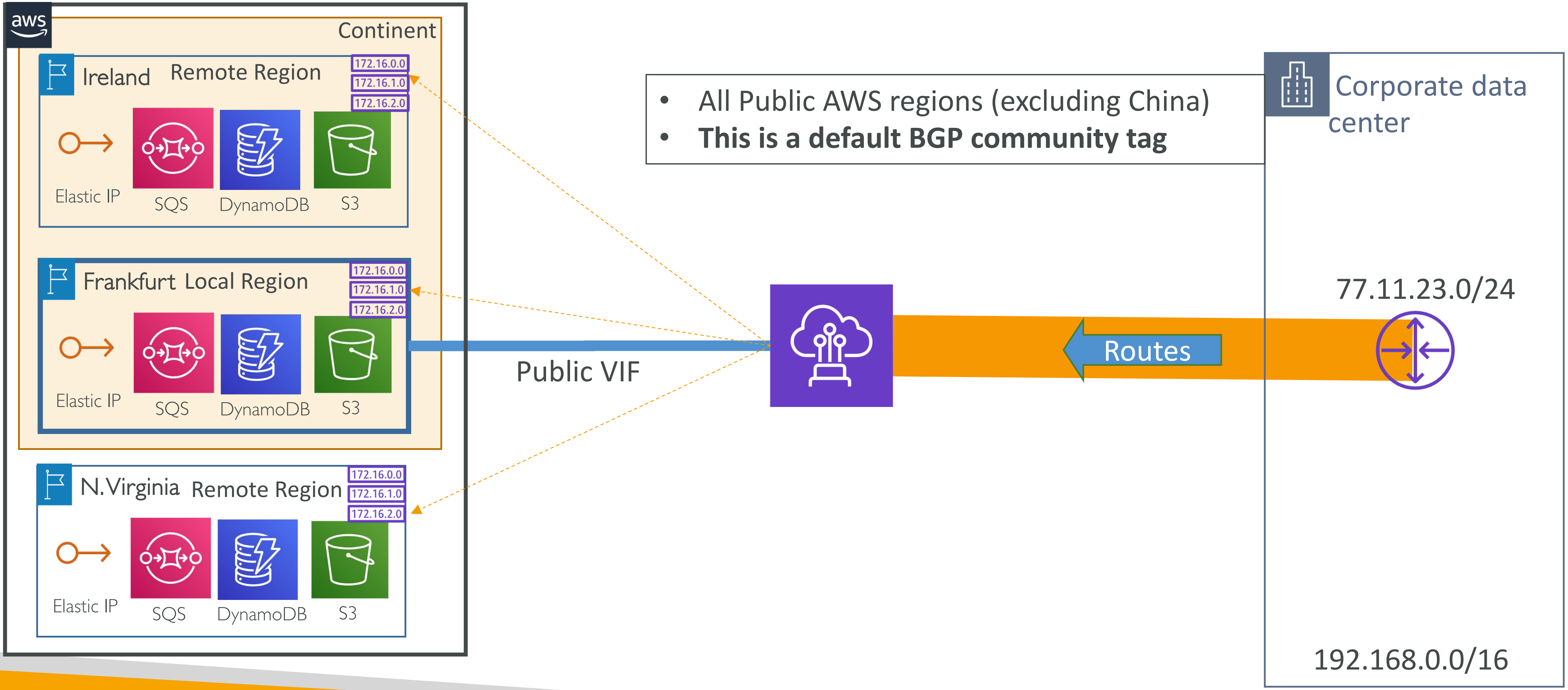
Public VIF BGP Communities Inbound - All AWS regions for a continent 7224:9200



- North America–wide
- Asia Pacific
- **Europe, the Middle East and Africa**

Public VIF BGP Communities Inbound – Global 7224:9300

- All Public AWS regions (excluding China)
- **This is a default BGP community tag**

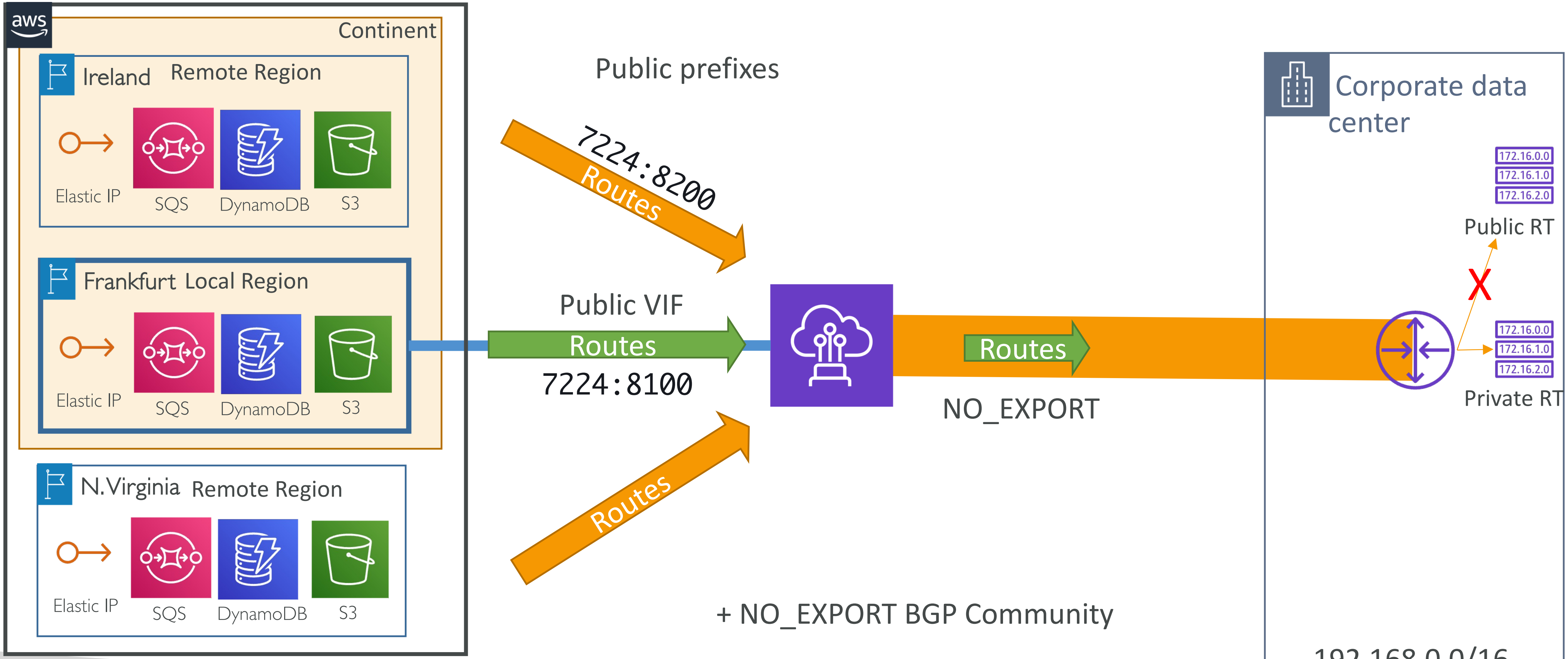


Public VIF BGP Communities - Outbound

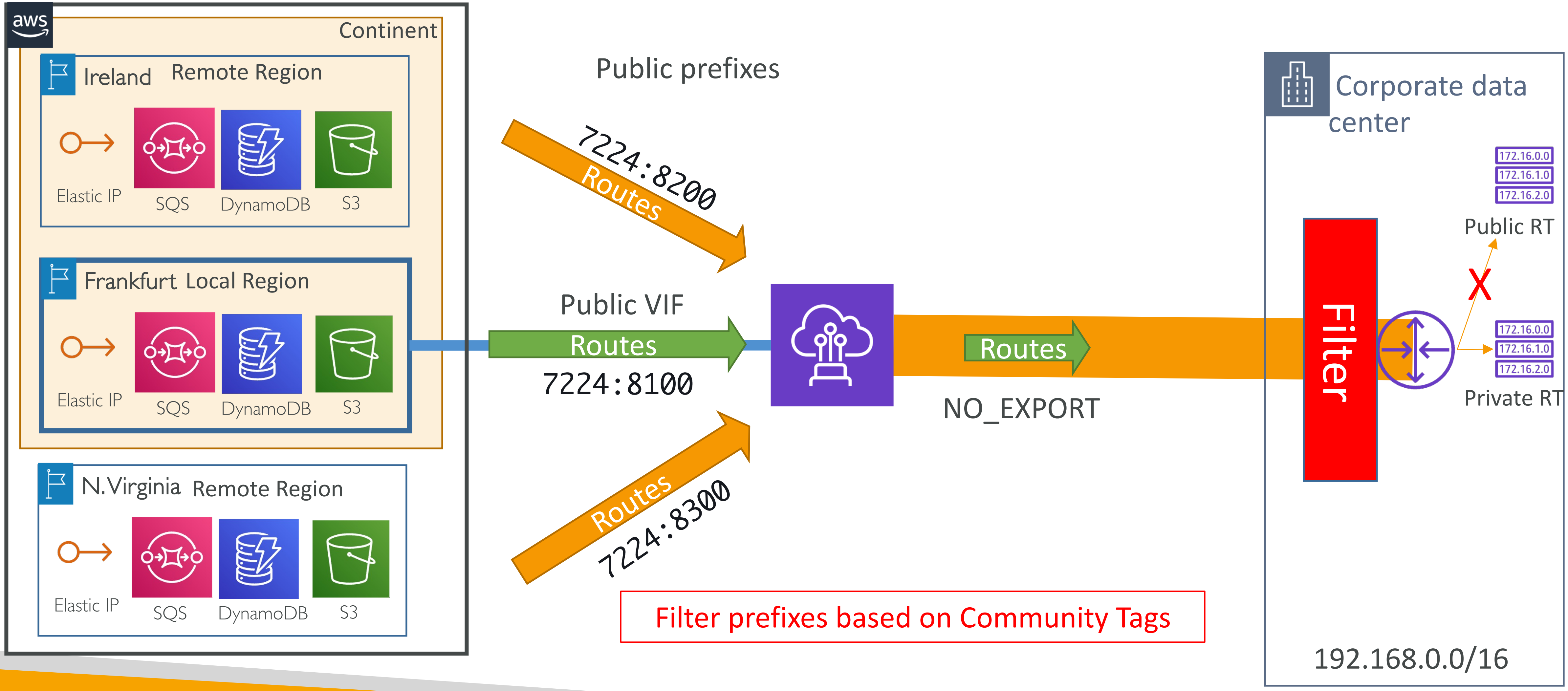
AWS applies following BGP community tags on the prefixes advertised based on the origin of the traffic at AWS end

- 7224:8100—Routes that originate from the same AWS Region in which the AWS Direct Connect point of presence is associated.
- 7224:8200—Routes that originate from the same continent with which the AWS Direct Connect point of presence is associated.
- No tag—Global (all public AWS Regions)
- Apart from above Tags, AWS Direct Connect also advertises NO_EXPORT community tag for all routes
- Customer router can choose which prefixes to accept by filtering the routes based on BGP communities associates with the routes

Public VIF BGP Communities Outbound



Public VIF – Route filtering



Filter prefixes based on Community Tags

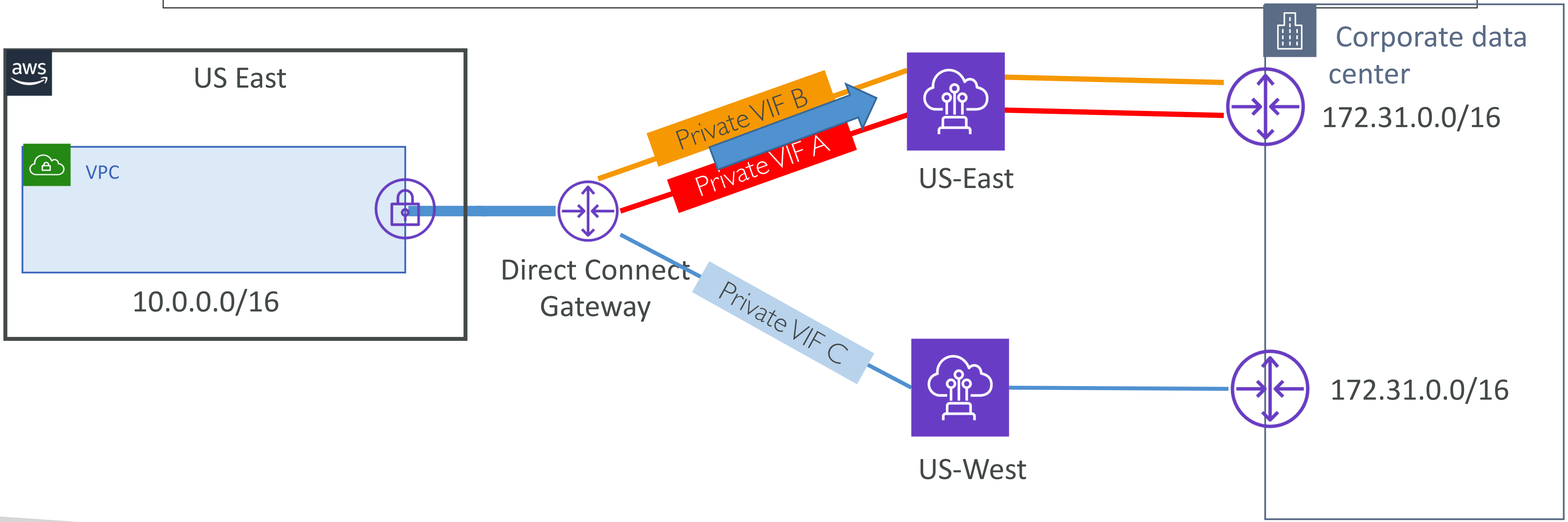
Private VIF Routing Policies & BGP communities

Private VIF Routing Policies

- AWS evaluates the longest prefix match first
- If prefix is same, AWS uses the distance from the local Region to the AWS Direct Connect location to determine the virtual (or transit) interface for routing.
- This behavior can be modified by assigning local preference BGP communities (7224:7300 > 7224:7200 > 7224:7100)
- In case of multiple virtual interfaces in a same local region, Set the AS_PATH attribute to prioritize which interface AWS uses to route the traffic.

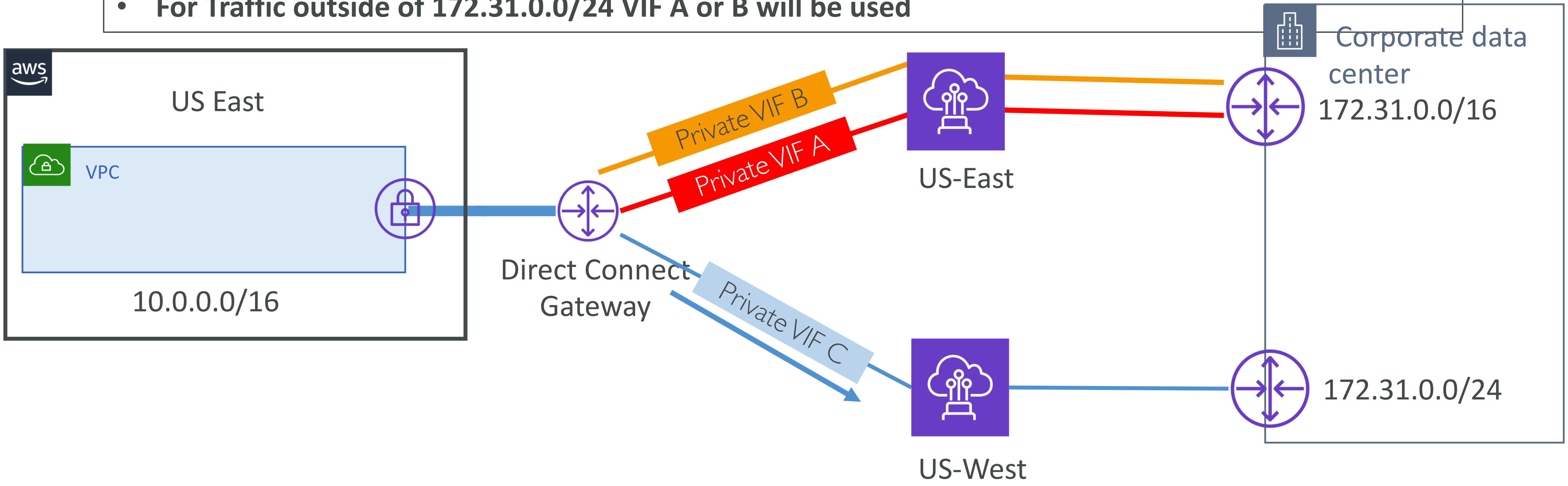
Private VIF Routing policies – Home/Local region

- All VIFs advertises same Prefix – 172.31.0.0/16
- **US-East VIF A or B** will be used for the traffic originated or return traffic as distance is minimum
- The lower network cost takes the precedence



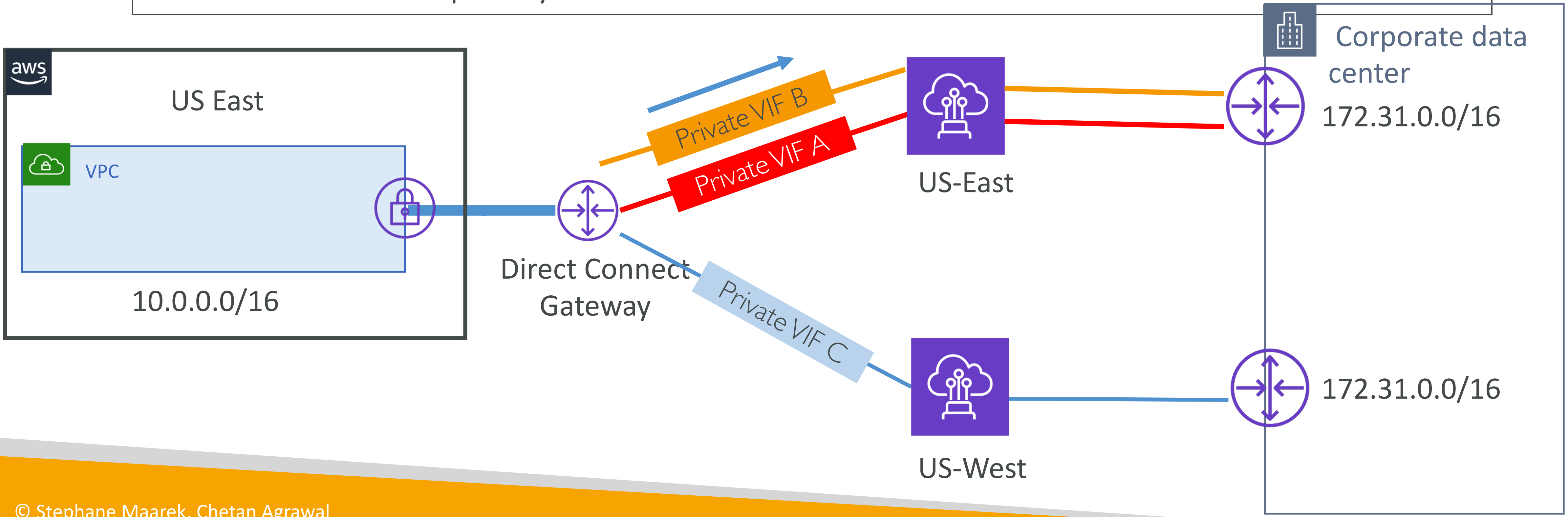
Private VIF Routing policies – Longest Prefix

- VIFs A & B advertises same Prefix – 172.31.0.0/16
- VIF C advertises 172.31.0.0/24
- **VIF C will be used for the traffic originated or return traffic for destination 172.31.0.0/24**
- **For Traffic outside of 172.31.0.0/24 VIF A or B will be used**



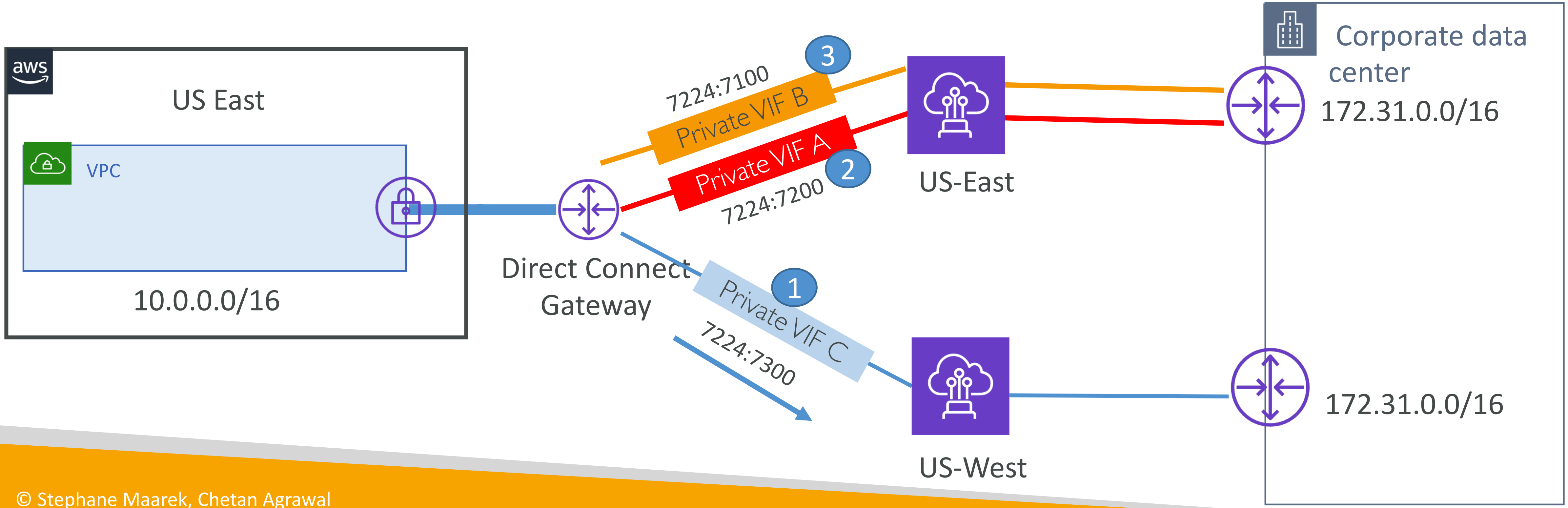
Private VIF Routing policies – AS_PATH

- All VIFs advertises same Prefix – 172.31.0.0/16
- **AS_Path is in effect if the Direct Connect location is same**
- VIF A AS_PATH attribute of 65001, 65001, 65001 VIF B: AS_PATH attribute of 65001, 65001 and VIF C: AS_PATH attribute of 65001
- Because US-East network cost is lower than US-West DX location – the VIF A or VIF B will be used
- VIF B will be used as primary interface. If VIF B is down then VIF A will be used



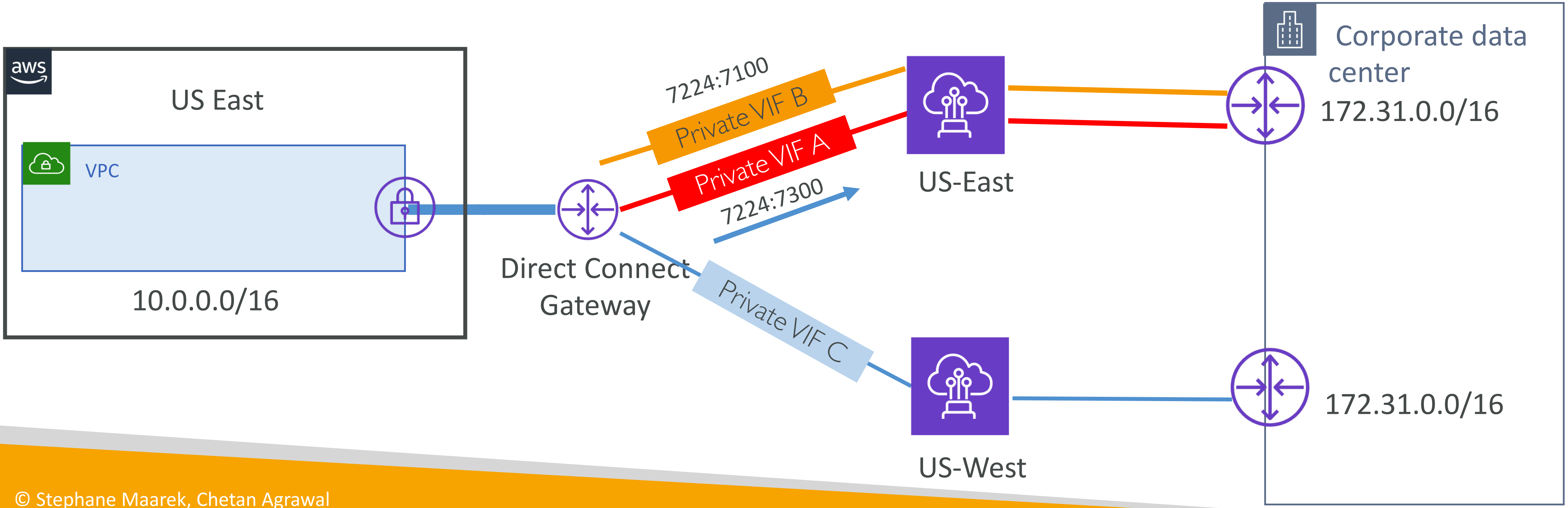
Private VIF Routing policies – Local Preference BGP Community

- All VIFs advertises same Prefix – 172.31.0.0/16
- **You can set Local preference BGP community tags.**
- 7224:7100—Low preference, 7224:7200—Medium preference, 7224:7300—High preference
- Local preference community tags are evaluated before AS_PATH



Private VIF Routing policies – Local Preference BGP communitues for Active/Passive traffic

- All VIFs advertises same Prefix – 172.31.0.0/16
- **VIF B: 7224:7100 (low preference), VIF A – 7224:7300 (high preference)**
- VIF A will be used as primary interface. If VIF A is down then VIF B will be used



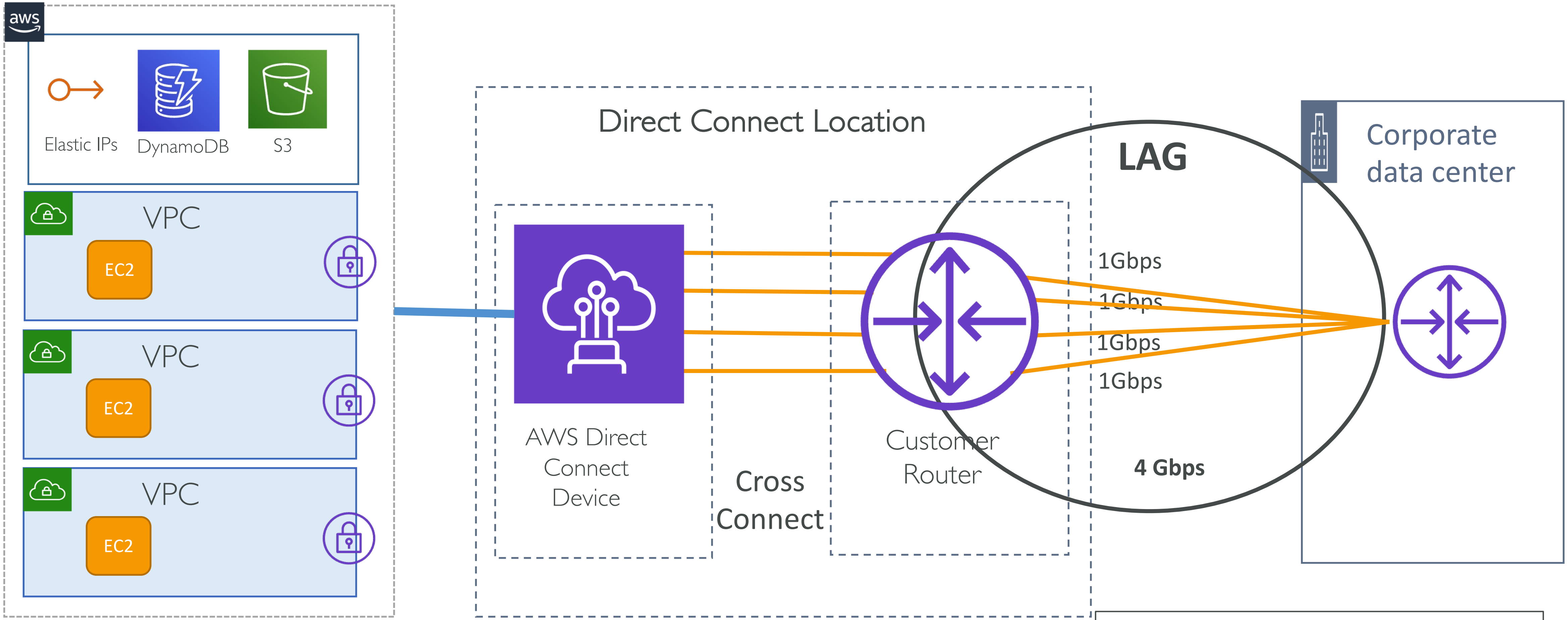
Link Aggregation Groups (LAGs)

Direct Connect Link Aggregation Groups (LAG)

- Get **increased bandwidth** and **failover** by aggregating multiple Direct Connect connections into a **single logical connection**
- Uses Link Aggregation Control Protocol (LACP)
- All connections must be dedicated connections and have a port speed of 1 Gbps, 10 Gbps, or 100 Gbps.
- Can aggregate up to 4 connections (active-active mode)
- Can use existing connection or add new connections to the LAG
- **All connections in the LAG must have the same bandwidth**
- **All connections in the LAG must terminate at the same AWS Direct Connect Endpoint**
- Supports all virtual interface types - public, private, and transit

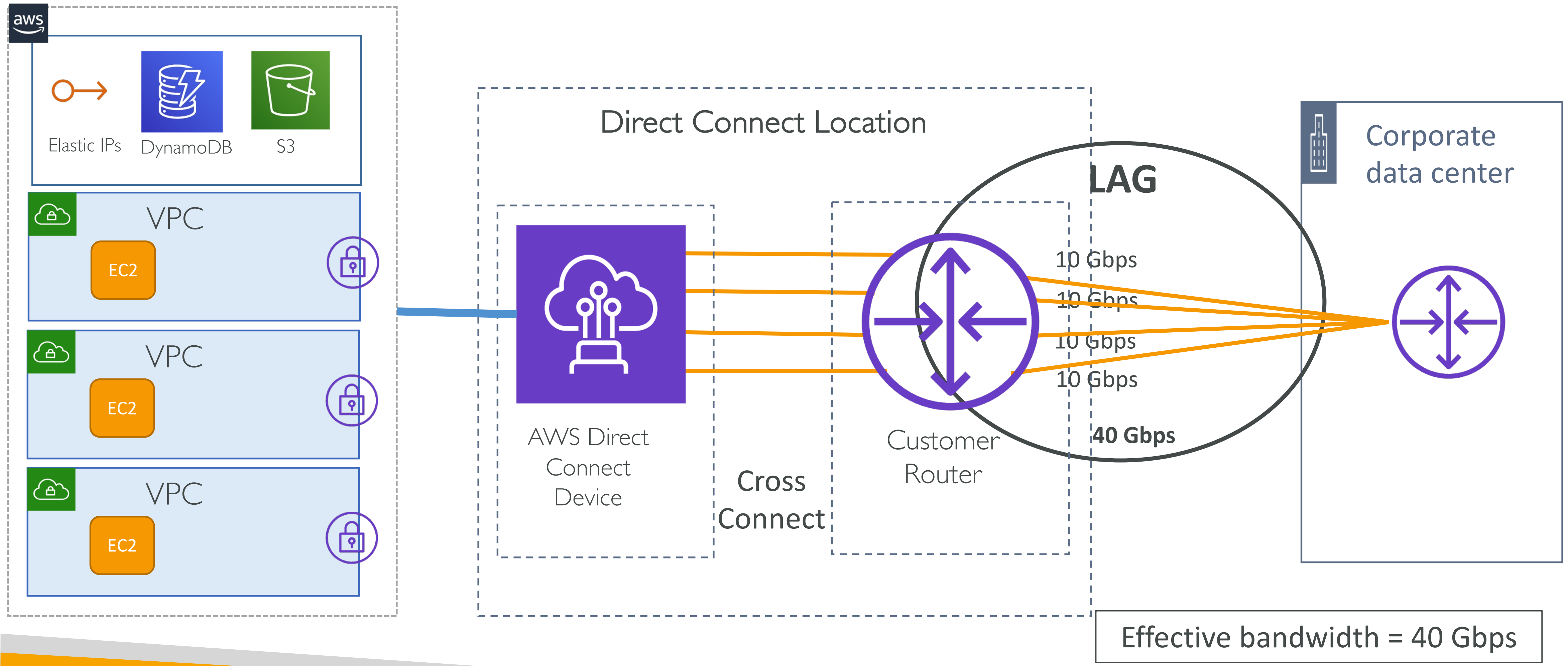
https://docs.aws.amazon.com/directconnect/latest/UserGuide/lags.html

LAG with 1 Gbps dedicated connections

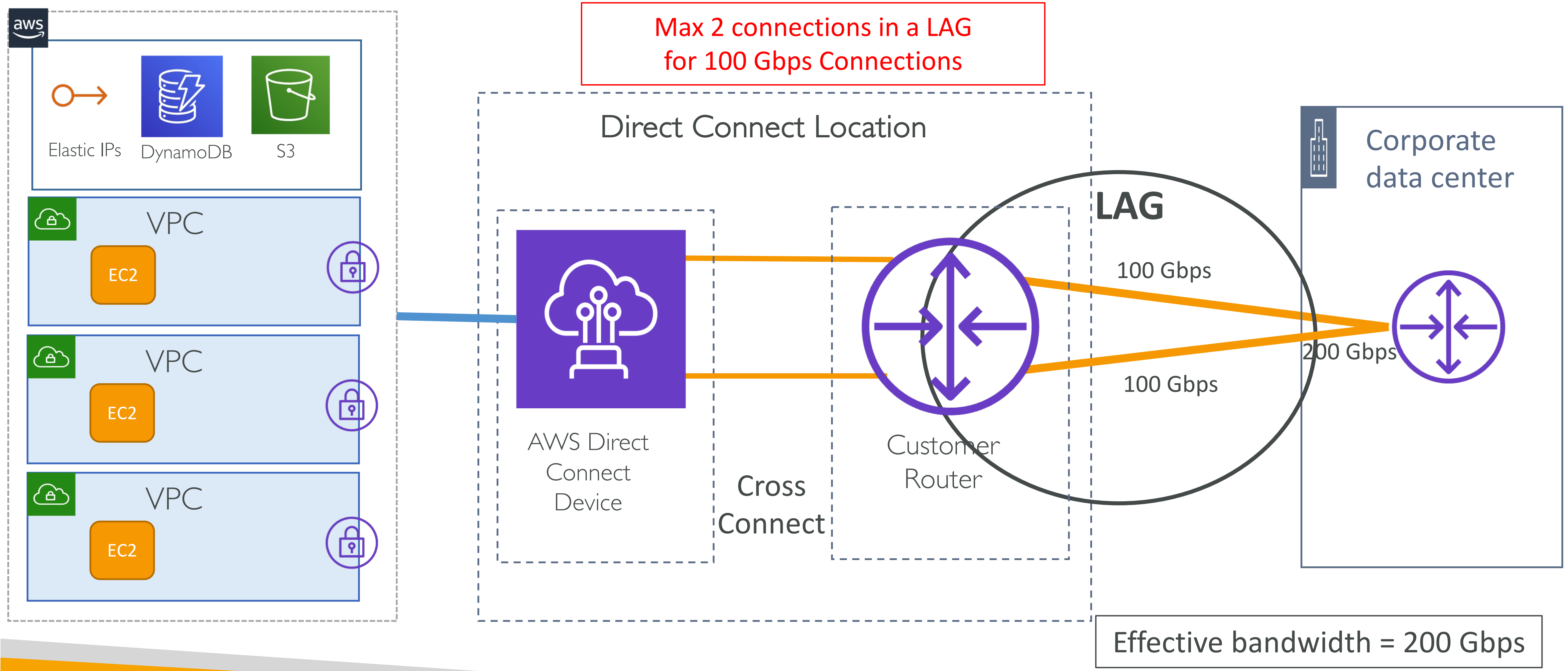


Effective bandwidth = 4 Gbps

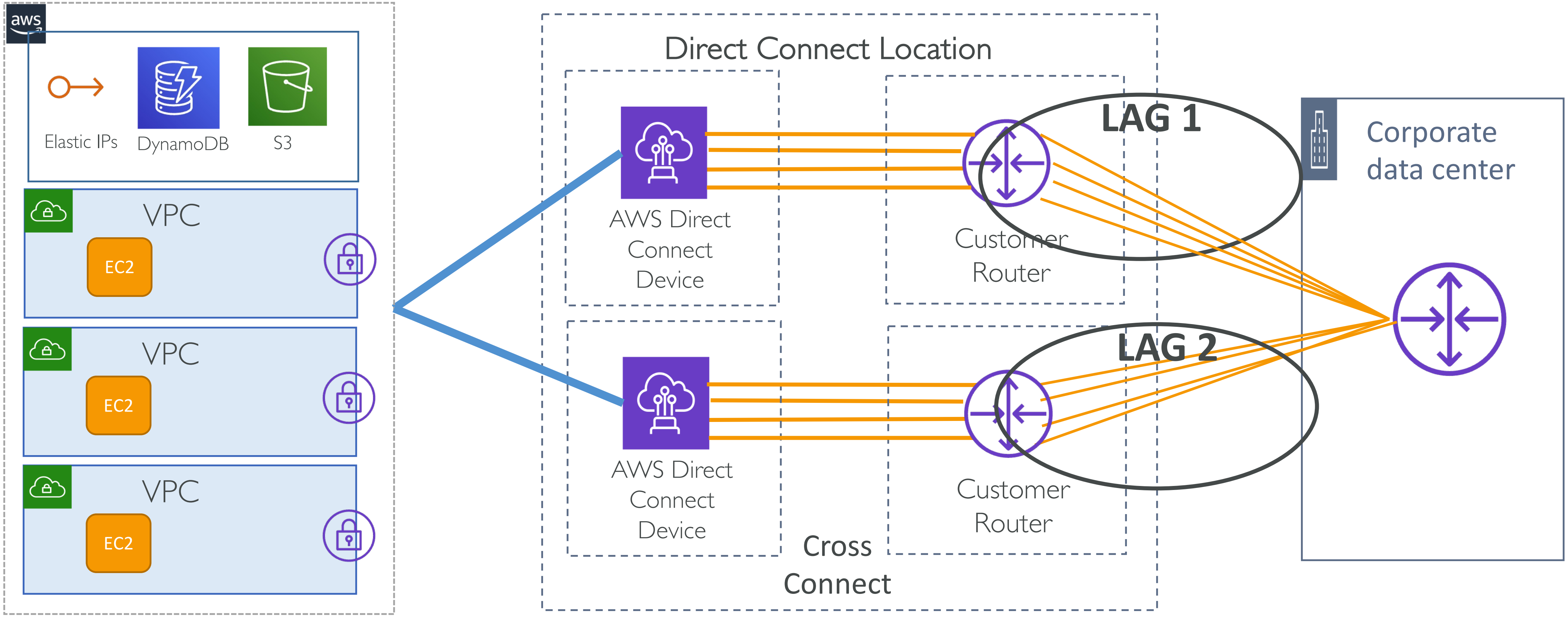
LAG with 10 Gbps dedicated connections



LAG with 100 Gbps dedicated connections



LAG High Availability



LAG operational status

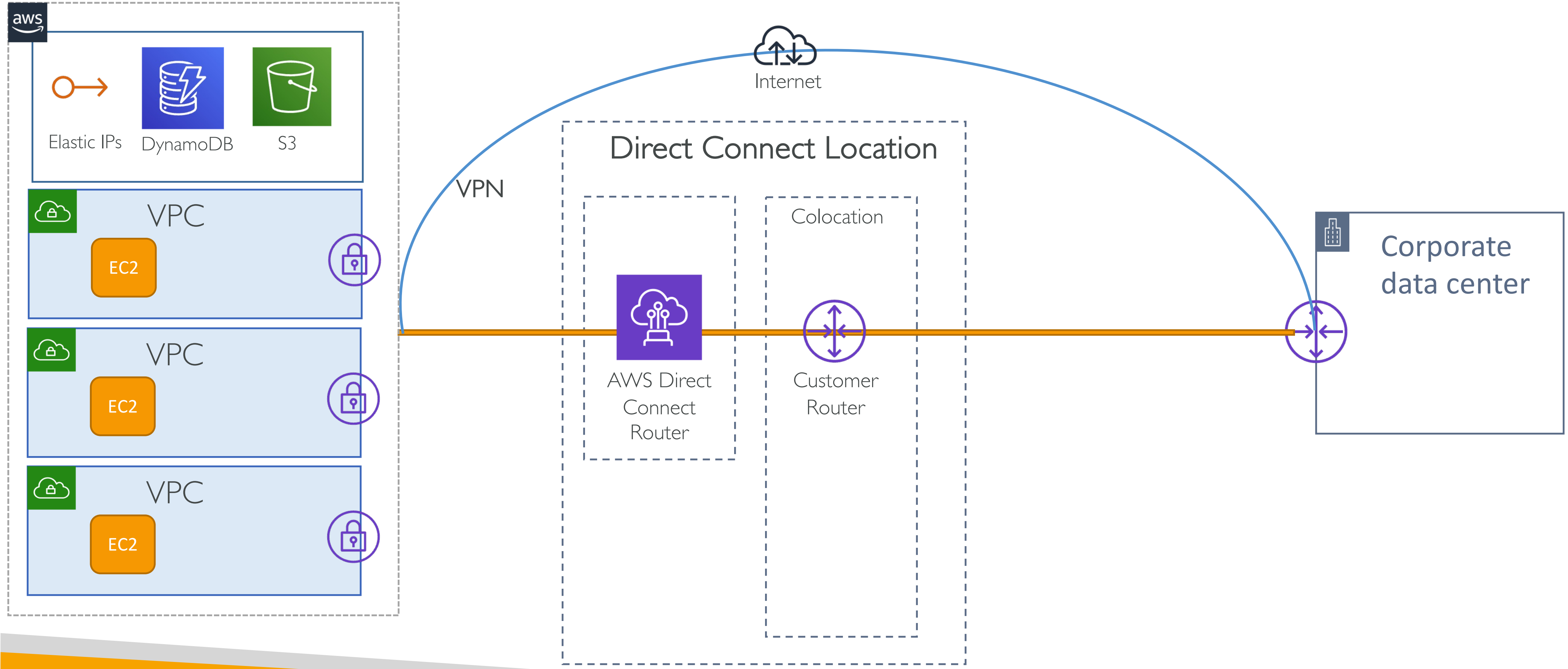
- All LAG connections operate in Active/Active mode
- LAG supports attribute to define minimum number of operational connections for the LAG to function (Default value = 0)
  - If there are say 4 connections in the LAG and operational connection attribute value = 1 then LAG will be **operational** even if 3 connections are down
  - If there are say 4 connections in the LAG and operational connection attribute value = 3 then LAG will be **non-operational** if 2 or more connections are down
- This attribute prevents over-utilization of active LAG connections in case of failures in other connections.

MACSec with LAGs

- We can enable MACsec for the LAGs
- MACsec uses MACsec secret key which is generated using Connection Key Name (CKN) and Connectivity Association Key (CAK)
- For existing connections with MACsec, the MACsec key is disassociated with the connection and LAG MACsec security key is associated with the connection after connection is added to the LAG
- LAG MACsec key is associated with all the member connections

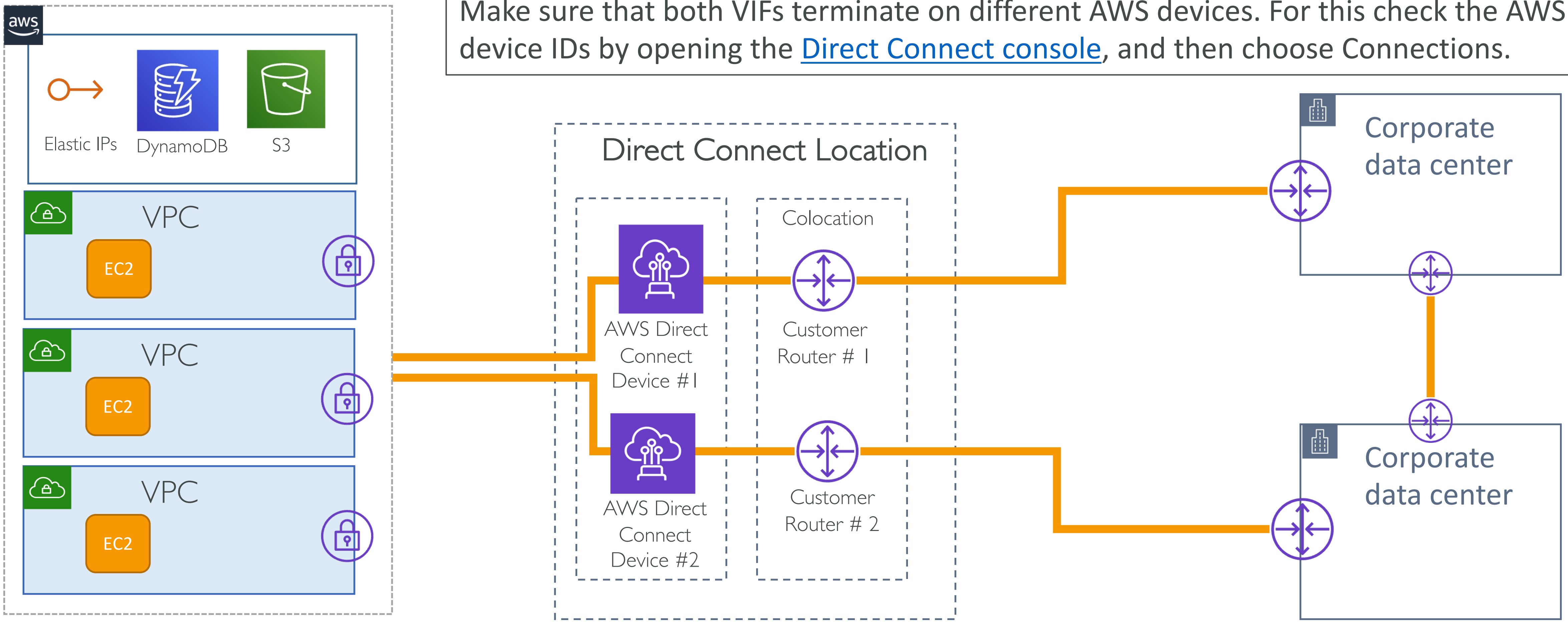
Resilient DX Connections

Single DX Connection: VPN as a backup



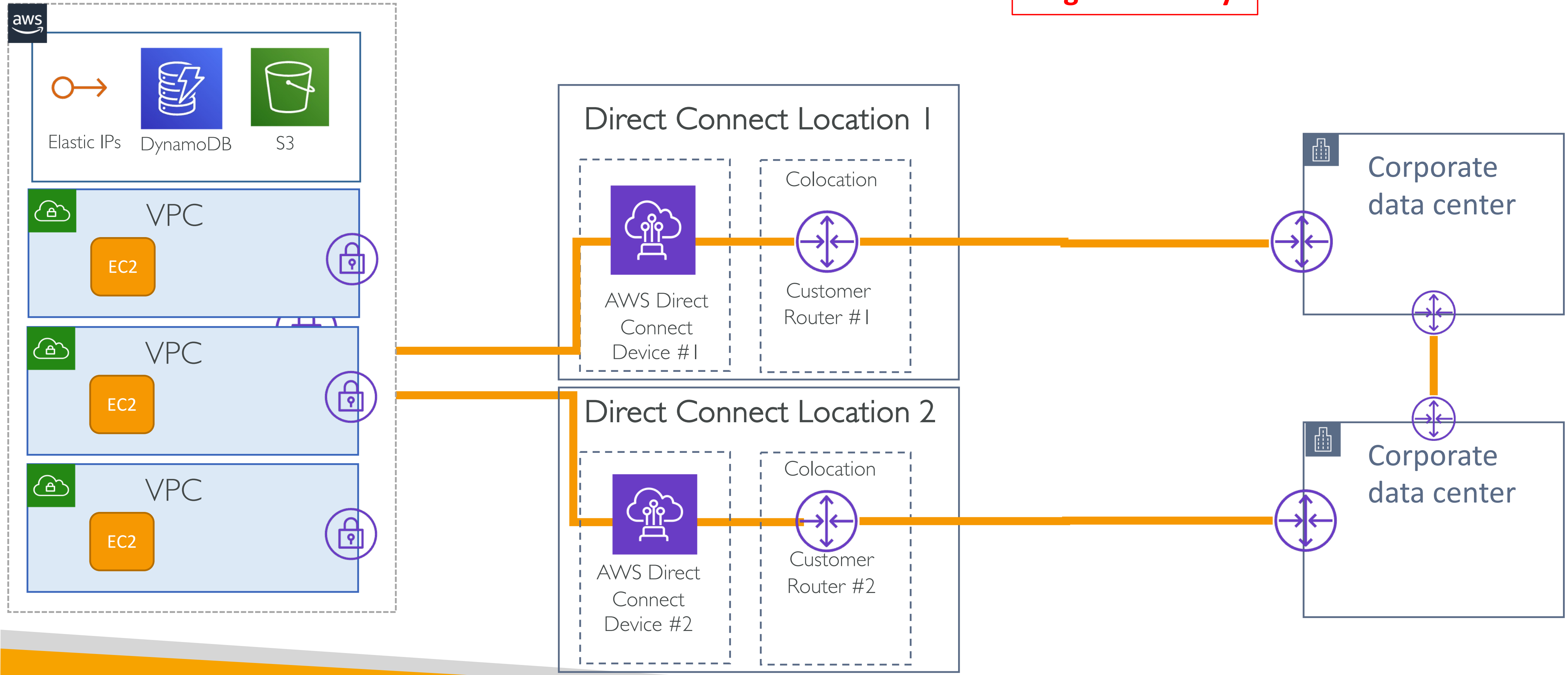
Dual DX Connections – Dual devices

Make sure that both VIFs terminate on different AWS devices. For this check the AWS device IDs by opening the [Direct Connect console](), and then choose Connections.

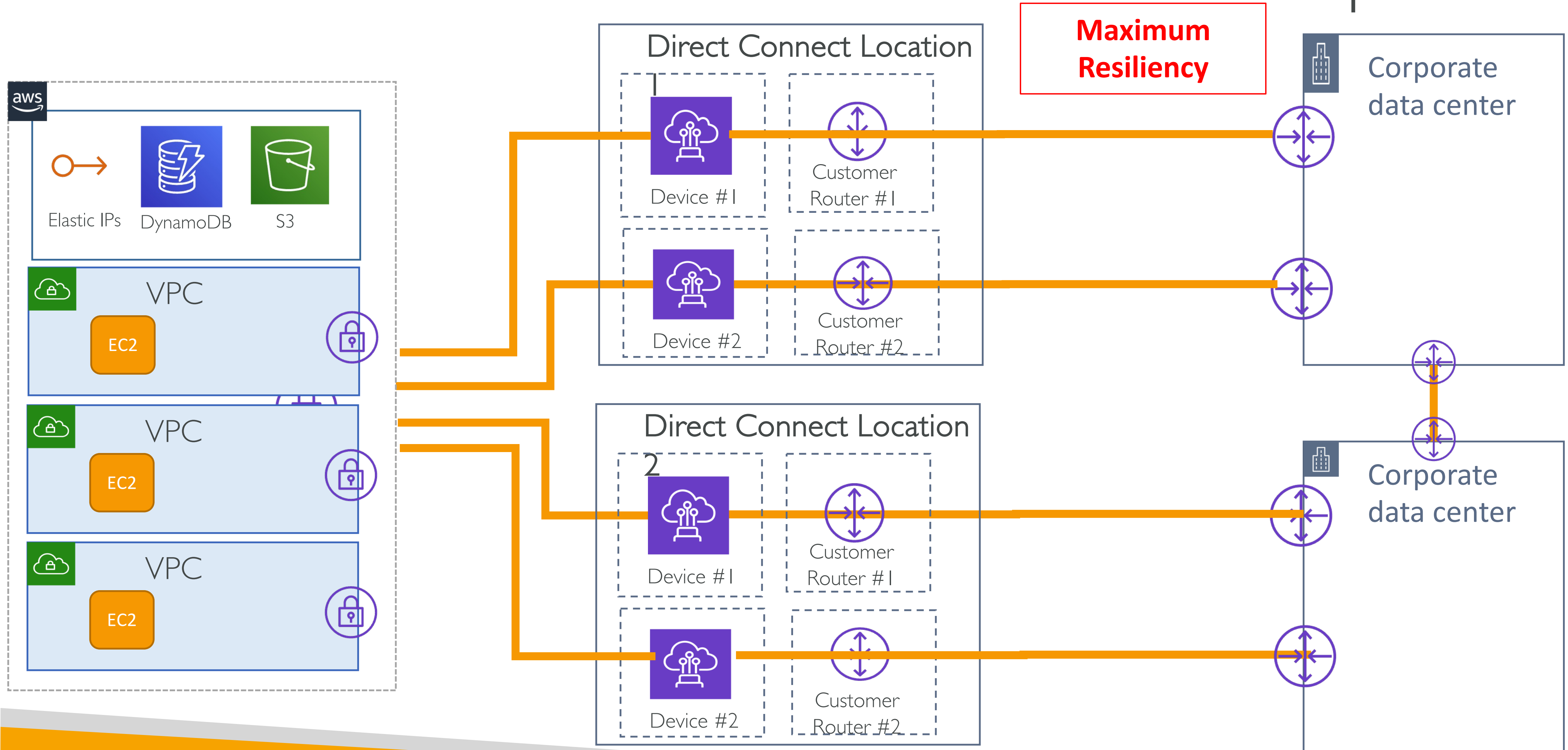


Dual DX Connections – Dual locations

High Resiliency

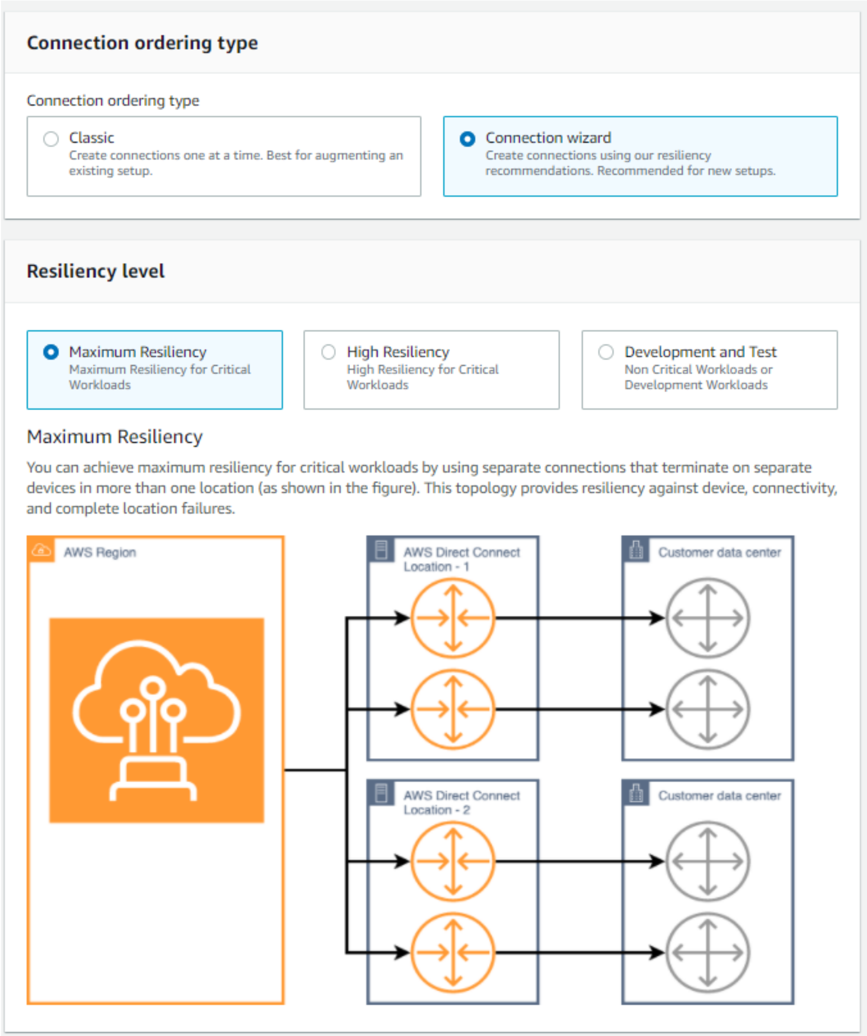


Dual locations with DX connection backup



Using DX console for Resiliency

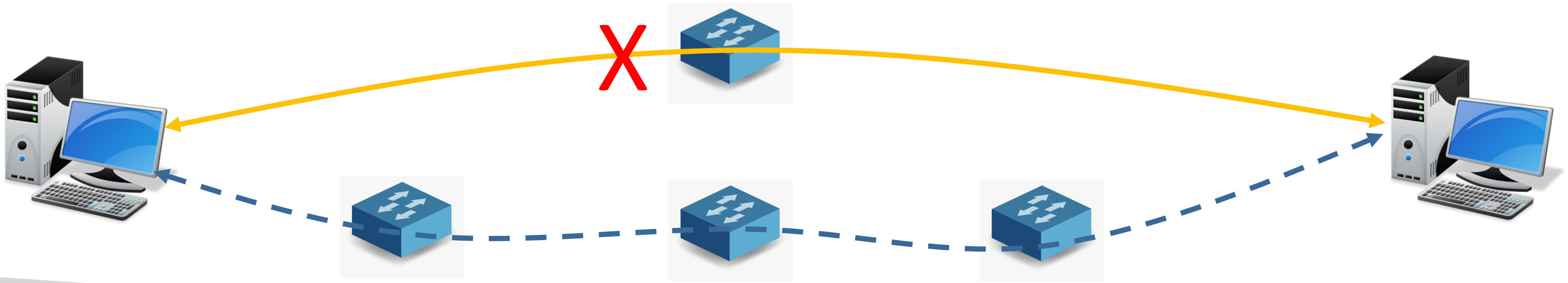
- Use AWS DirectConnect console to choose between Classic or Connection Wizard
- Classic allows you to create a single connection
- Connection Wizard allows to choose from three types of resiliency options
  - Maximum Resiliency
  - High Resiliency
  - Development and Test



DirectConnect fast failover using BFD

BFD – Bidirectional Forwarding Detection

- It's a simple Hello Network Protocol
- Lowers the network failure detection time between the neighboring peers
- BFD control packets are transmitted and received periodically between the BFD peers (Asynchronous mode)
- Neighbors can use dynamic routing protocol or static routes (BGP/OSPF)
- Provides the detection time less than 1 sec



Using BFD with Direct Connect

- While using multiple DX connections or using VPN backup, its important to have fast failover to redundant connection
- By default, BGP waits for three keep-alives to fail at a hold-down time of **90 seconds**.
- AWS enables BFD by default on DX connections. However BFD should be configured on customer side of the router
- AWS sets the BFD liveness detection interval to **300 ms** and BFD liveness detection count to 3 which results in **failover under 1 second**
- Cisco Router example:

  bfd interval 300 min_rx 300 multiplier 3

DirectConnect Security

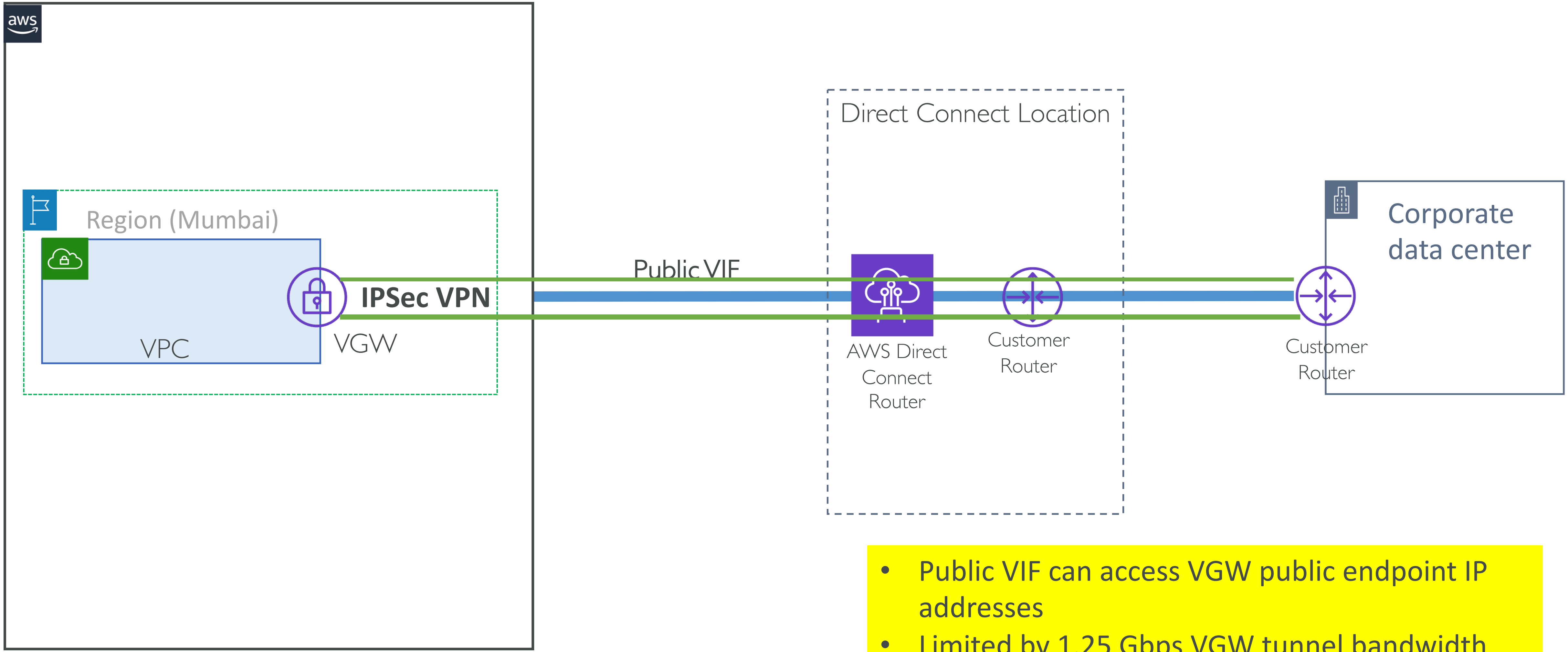
DX network traffic security

- Layer3 VPN over a Direct Connect connection
- Layer2 encryption using MACSec

Encrypting DX traffic

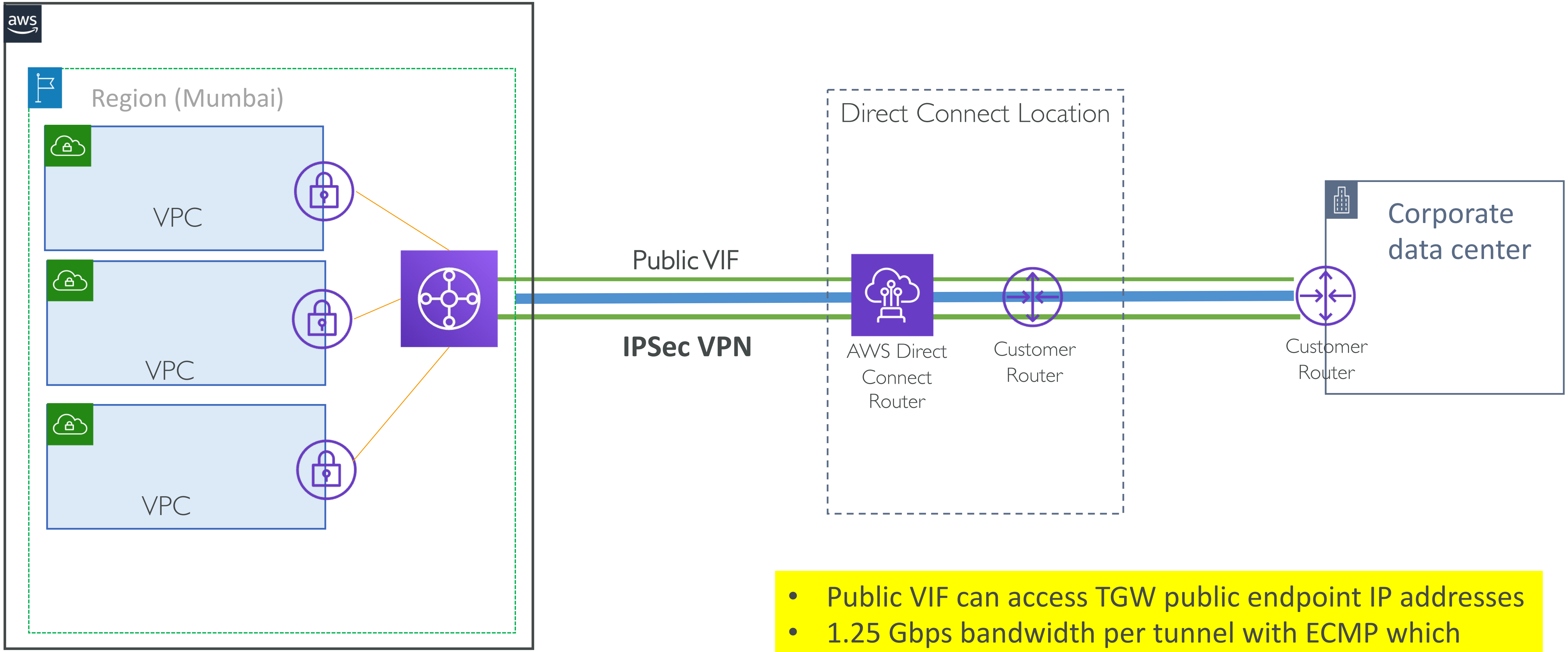
- **DirectConnect traffic is not encrypted**
- Ideal way to have the traffic encrypted is to have layer 4 (TLS) encryption between hosts communicating over Direct Connect
- If its still required to have Layer 3 encryption, set up a VPN over Direct Connect connection using Public VIF
- AWS publishes Public IPs which also includes the Public IPs of AWS managed VPN (VGW) and Transit Gateways (TGW)
- Set up IPSec tunnels using Public IPs of VGW or TGW on AWS end and customer router Public IP on the other end

VPN over a DX using VGW (Layer3)



- Public VIF can access VGW public endpoint IP addresses
- Limited by 1.25 Gbps VGW tunnel bandwidth

VPN over a DX using TGW (Layer3)



- Public VIF can access TGW public endpoint IP addresses
- 1.25 Gbps bandwidth per tunnel with ECMP which allows bandwidth aggregation

MAC Security (MACSec) – Layer2

- Mac Security (MACSec) is an IEEE 802.1 Layer 2 standard that provides data confidentiality, data integrity, and data origin authenticity
- MACSec provides Layer2 security for Dedicated connection.
- MACSec is available for certain Direct Connect partners only. Currently its not supported by all Direct connect partners.
- Make sure that you have a device on your end of the connection that supports MACSec
- When you configure your connection, you can specify one of the following values: MACSec – should_encrypt, must_encrypt, no_encrypt

[Read more about MACSec]

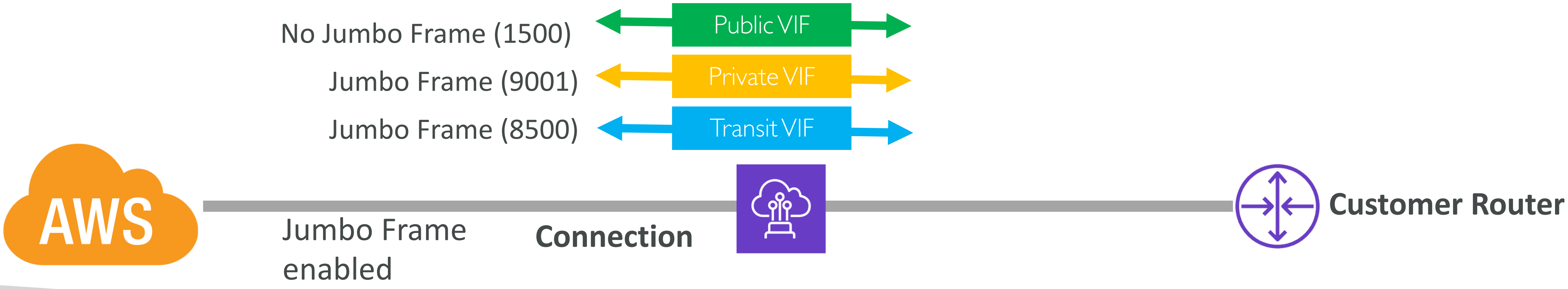
DirectConnct MTU & Jumbo frames

MTU and Jumbo Frames

- MTU Recap: The size in bytes of the largest permissible packet that can be passed over the connection.
- Until Oct 2018, Direct connect used to support MTU of 1500 bytes
- Now Direct connect supports MTU up to 9001 bytes i.e. Jumbo Frames

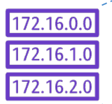
MTU and Jumbo Frames

- Public VIFs don't support Jumbo Frames
- Transit VIFs support MTU 1500 or 8500
- Private VIFs support MTU 9001
- For supporting jumbo frames the Direct connect connection or a LAG must be jumbo frame capable



MTU and Jumbo Frames

- Jumbo frames apply only to propagated routes from DX (traffic routed through the static routes is sent using 1500 MTU)

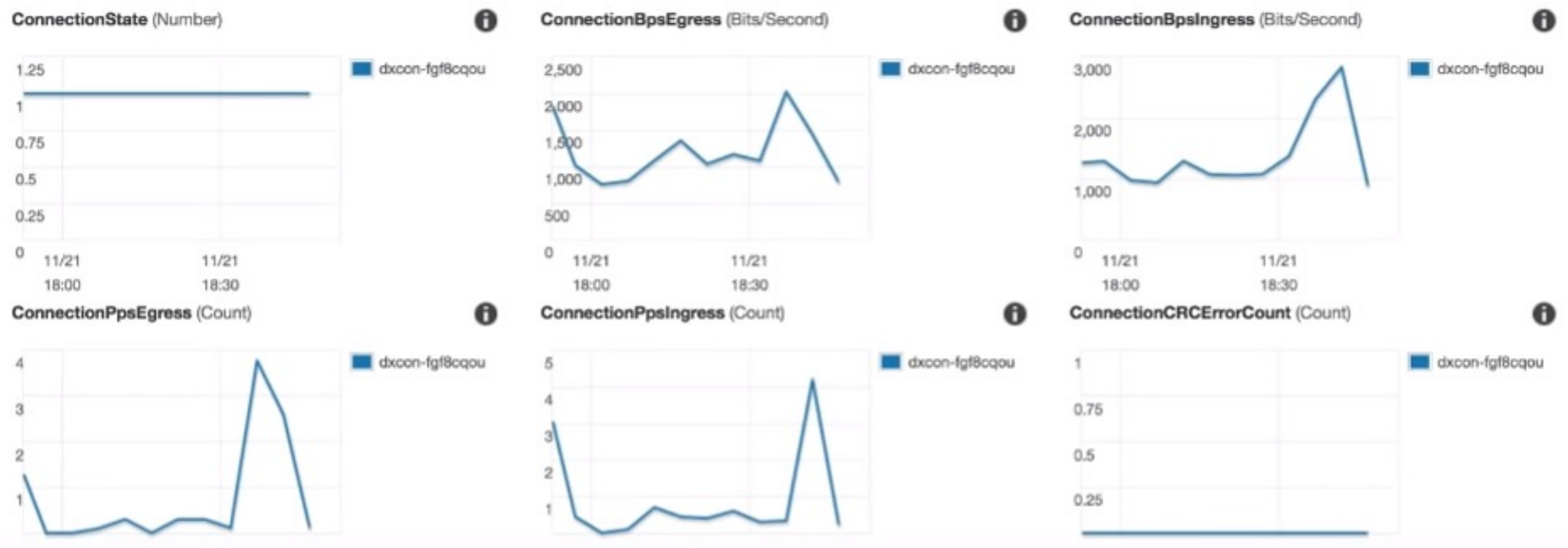


Destination	Target	Route Type
10.10.0.0/16	Local	Static
0.0.0.0/0	igw-xxxx	Static
192.168.0.0/24	vgw-xxxx	Propagated
192.168.1.0/24	vgw-xxxx	Propagated
192.168.2.0/24	vgw-xxxx	Propagated

DirectConnect Monitoring

Monitoring

• CloudWatch monitors DX connection and Virtual interfaces



DX Connection CW Metrics

ConnectionState	1 indicates the connection is up and 0 indicates down
ConnectionBpsEgress	Bitrate for outbound data from the AWS side
ConnectionBpsIngress	Bitrate for inbound data into the AWS
ConnectionPpsEgress	Packet rate for outbound data from the AWS side
ConnectionPpsIngress	Packet rate for inbound data into the AWS
ConnectionErrorCount	The total error count for all types on the AWS device
ConnectionLightLevelTx	Health of the fiber connection for outbound (egress) from AWS
ConnectionLightLevelRx	Health of the fiber connection for inbound (ingress) traffic to AWS
ConnectionEncryptionState	1 indicates the encryption is up and 0 indicates down (MACSec)

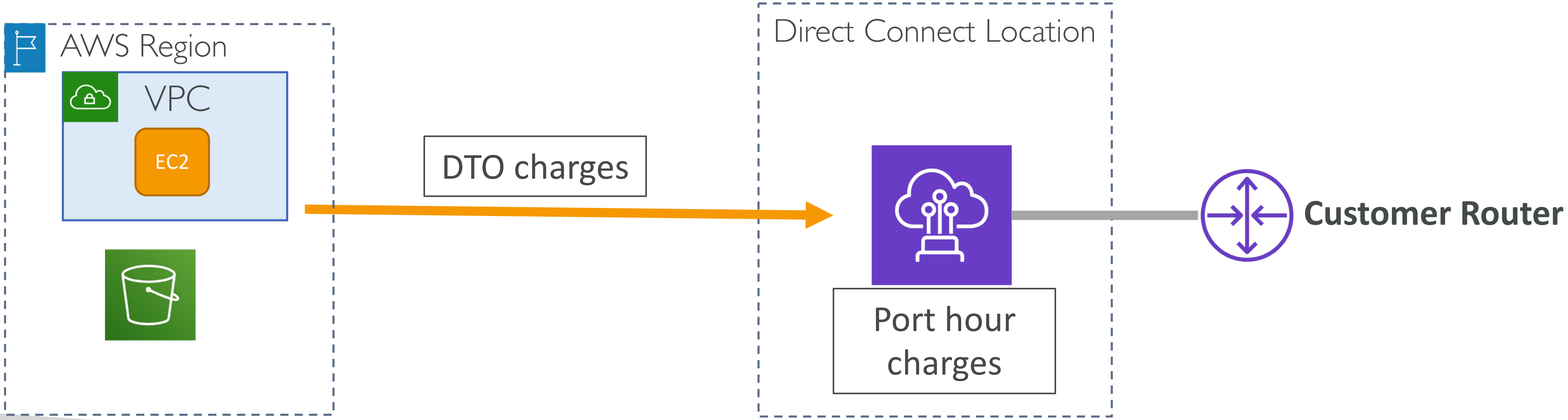
DX Virtual Interface CW Metrics

VirtualInterfaceBpsEgress	Bitrate for outbound data from the AWS side of the virtual interface
VirtualInterfaceBpsIngress	Bitrate for inbound data to the AWS side of the virtual interface
VirtualInterfacePpsEgress	Packet rate for outbound data from the AWS side of the virtual interface
VirtualInterfacePpsIngress	Packet rate for inbound data to the AWS side of the virtual interface

Direct Connect Billing

Direct Connect Billing

- Port hour charges as per the DX connection type & capacity
  - Dedicated Connection
  - Hosted Connection
- Data transfer out charges – per GB depending on the DX location and source AWS region



Port hour charges for Dedicated Connection

- Consistent across all DX locations (except Japan)

Capacity	Port-Hour rate (All AWS Direct Connect locations except in Japan)	Port-hour rate in Japan
1G	$0.30/hour	$0.285/hour
10G	$2.25/hour	$2.142/hour
100G	$22.50/hour	$22.50/hour

Port hour charges for Hosted Connection

Capacity	Port-Hour rate (All AWS Direct Connect locations except in Japan)	Port-hour rate in Japan
50M	$0.03/hour	$0.029/hour
100M	$0.06/hour	$0.057/hour
200M	$0.08/hour	$0.076/hour
300M	$0.12/hour	$0.114/hour
400M	$0.16/hour	$0.152/hour
500M	$0.20/hour	$0.190/hour
1G*	$0.33/hour	$0.314/hour
2G*	$0.66/hour	$0.627/hour
5G*	$1.65/hour	$1.568/hour
10G*	$2.48/hour	$2.361/hour

Data Transfer charges

- Data Transfer IN - $0 per GB (free)
- Data Transfer OUT – Depends on DX location and Source AWS Region

Data transfer from AWS region

	US East (Ohio), US East (Virginia), US West (Northern California), US West (Oregon), AWS GovCloud (US-East), AWS GovCloud (US-West)	Canada (Central)	From EU (Frankfurt), EU (Stockholm), EU (Ireland), EU (London), EU (Paris), EU (Milan)	Asia Pacific (Tokyo), Asia Pacific (Osaka)	From Asia Pacific (Seoul), Asia Pacific (Singapore), Asia Pacific (Hong Kong)	Asia Pacific (Mumbai)	South America (Sao Paulo)	Asia Pacific (Sydney)	Middle East (Bahrain)	Africa (Cape Town)
AWS Direct Connect location in:										
United States	$0.0200	$0.0200	$0.0282	$0.0900	$0.0900	$0.0850	$0.1500	$0.1300	$0.1100	$0.1100
Canada	$0.0200	$0.0200	$0.0300	$0.0900	$0.0900	$0.0850	$0.1500	$0.1300	$0.1100	$0.1100
Europe	$0.0200	$0.0300	$0.0200	$0.0600	$0.0900	$0.0850	$0.1107	$0.1300	$0.1000	$0.1100
Japan	$0.0491	$0.0500	$0.0600	$0.0410	$0.0420	$0.1132	$0.1700	$0.1132	$0.1500	$0.1700
Hong Kong SAR, Malaysia, S.Korea, Singapore & Taiwan	$0.0491	$0.0500	$0.0600	$0.0410	$0.0410	$0.1000	$0.1700	$0.1107	$0.1500	$0.1600
India	$0.0600	$0.0600	$0.0625	$0.1132	$0.1107	$0.0450	$0.1800	$0.1400	$0.1030	$0.1400

Examples of DX port & DTO charges

Data Transfer OUT

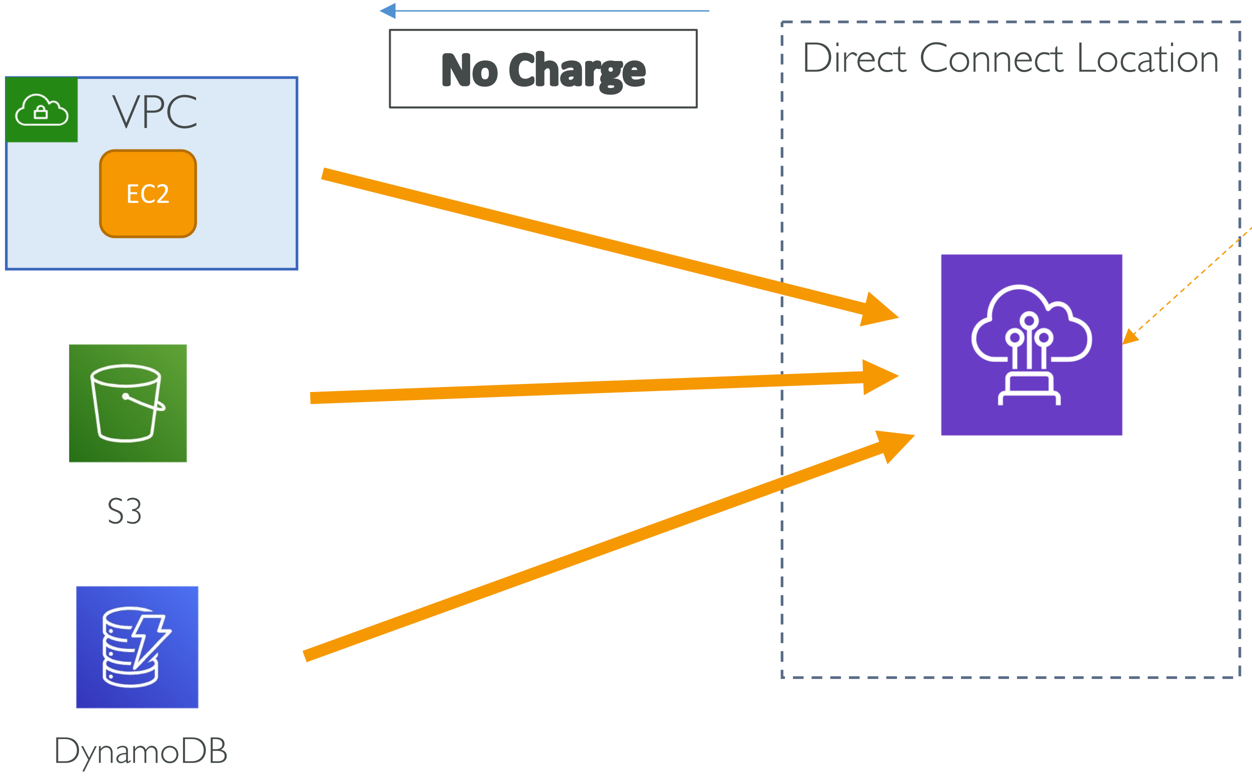
Source Region:
N. Virginia

Dest. DX location:
Switch SUPERNAP
Las Vegas

$0.0200 / GB Out

Data Transfer IN

No Charge



DX Port charges

1G = $0.30 /hour
10G = $2.25 /hour
100G= $22.5 /hour
***All locations except Japan**

Dedicated Connections

Examples of DX port & DTO charges

Data Transfer OUT

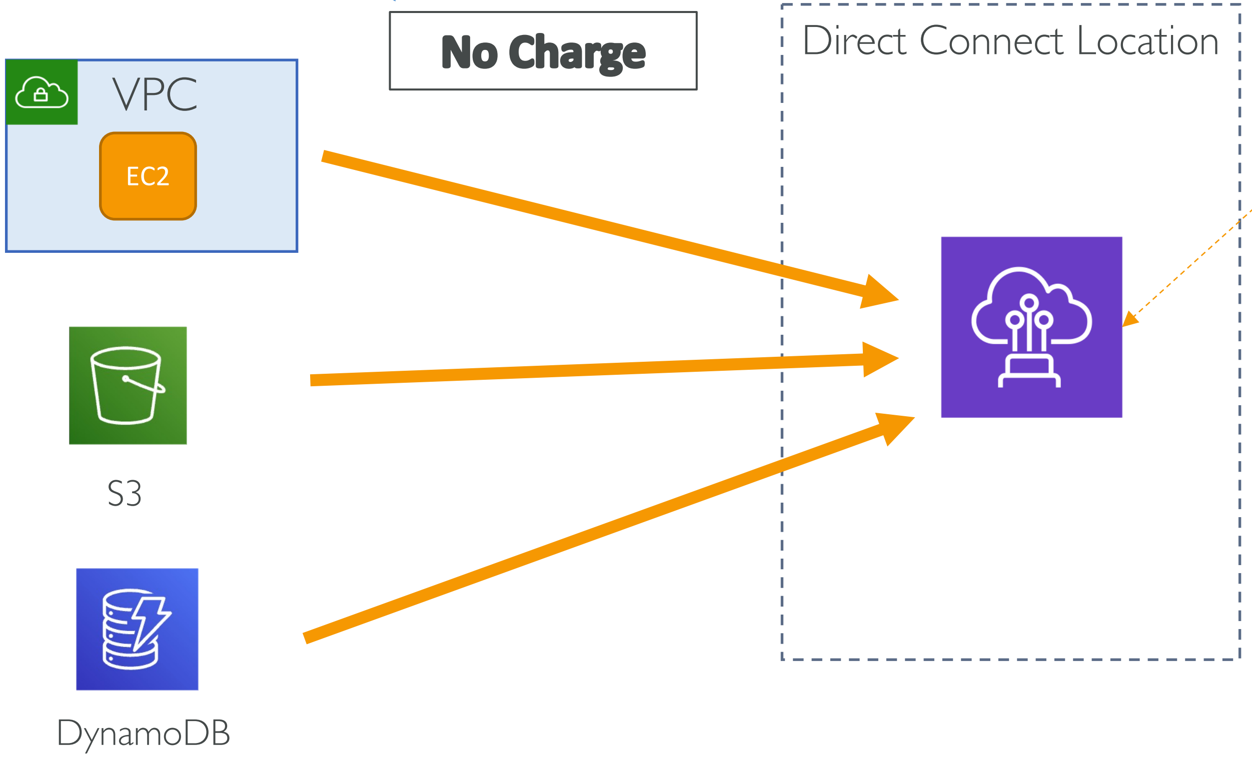
Data Transfer IN

No Charge

DX Port charges

1G = $0.30 /hour
10G = $2.25 /hour
100G= $22.5 /hour
***All locations except Japan**

Source Region:
N. Virginia



Dest. DX location:
GPX, Mumbai, India

$0.0600 / GB Out

Dedicated Connections

Who pays for the DX charges?

Port hour charges

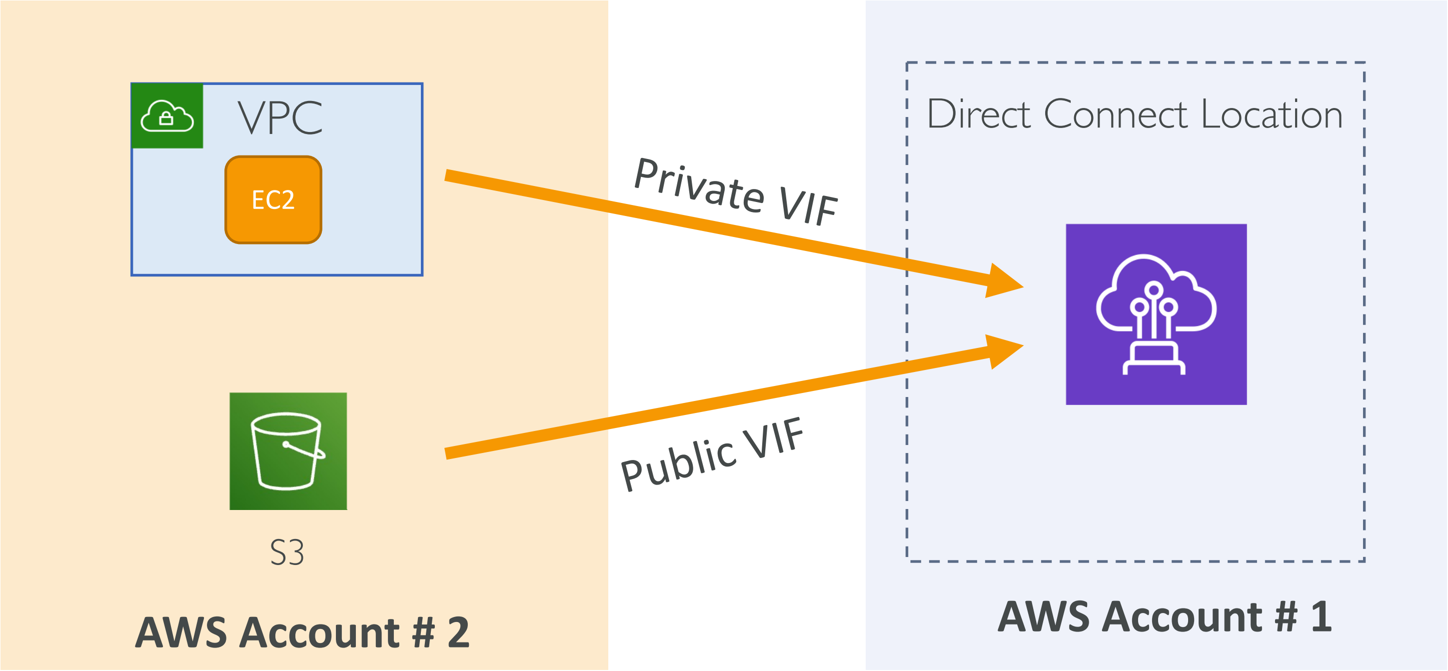
- **The account that owns the Direct Connect connection i.e the account which requested the connection**
- For Dedicated connection Port-hour charges are applied from the moment the connection is available. After ordering the DX connection, even if you don't proceed with connection setup process then it's billed post 90 days of connection requested
- For Hosted connections port-hours are billed once you have accepted the Hosted Connection

Billing for port-hours stops when the dedicated connection or hosted connection is **deleted** from your AWS account. Being in a "down" state does not cause the charges to stop.

Data Transfer Out charges

Data Transfer out charges are usually allocated to the account that owns the resource sending the traffic

Account #2 pays DTO



- For Public/Private/Transit VIFs the resource owner (EC2, S3, VPC etc) pays for DTO
- For S3 you can enable billing option of "Requester Pays"

DTO while using Transit Gateway

- In case the traffic is sent through an AWS Transit Gateway:
  - Data Transfer out is allocated to the **owner of the last resource** to send traffic before traffic hits the Direct Connect VIF
- If the owner of a Direct Connect connection and the owner of the resource sending traffic are in different AWS Organizations, Data Transfer out costs are allocated to the owner of the resource sending traffic, and charged the internet Data Transfer rate for the specific service they are using (not the Direct Connect DTO rate)

Summary of the DX Billing

- Port hour charges & Data Transfer Out (DTO) charges
- Port hour charges depend on the DX capacity
- The AWS account which created the DX connection pays for the Port hour charges
- Data Transfer out charges are usually allocated to the account that owns the resource sending the traffic (with exception of TGW)
- In case of multi account setup where owner of Connection and AWS resources are in different AWS organizations, the DTO is charged to Resource owner account based on standard AWS service DTO rate and not the DX DTO rate

Knowledge check

- Who pays for the charges for Hosted VIF?
- Answer:
  - Port hour charges will be billed to AWS account owning the connection wether it's a dedicated connection or a hosted connection
  - Data transfer out charges will be billed to the AWS account which contains the resource sending the traffic over the Hosted VIF

Ask 2 questions: Who owns the connection and Who sends the traffic, Simple?

Troubleshooting DX issues

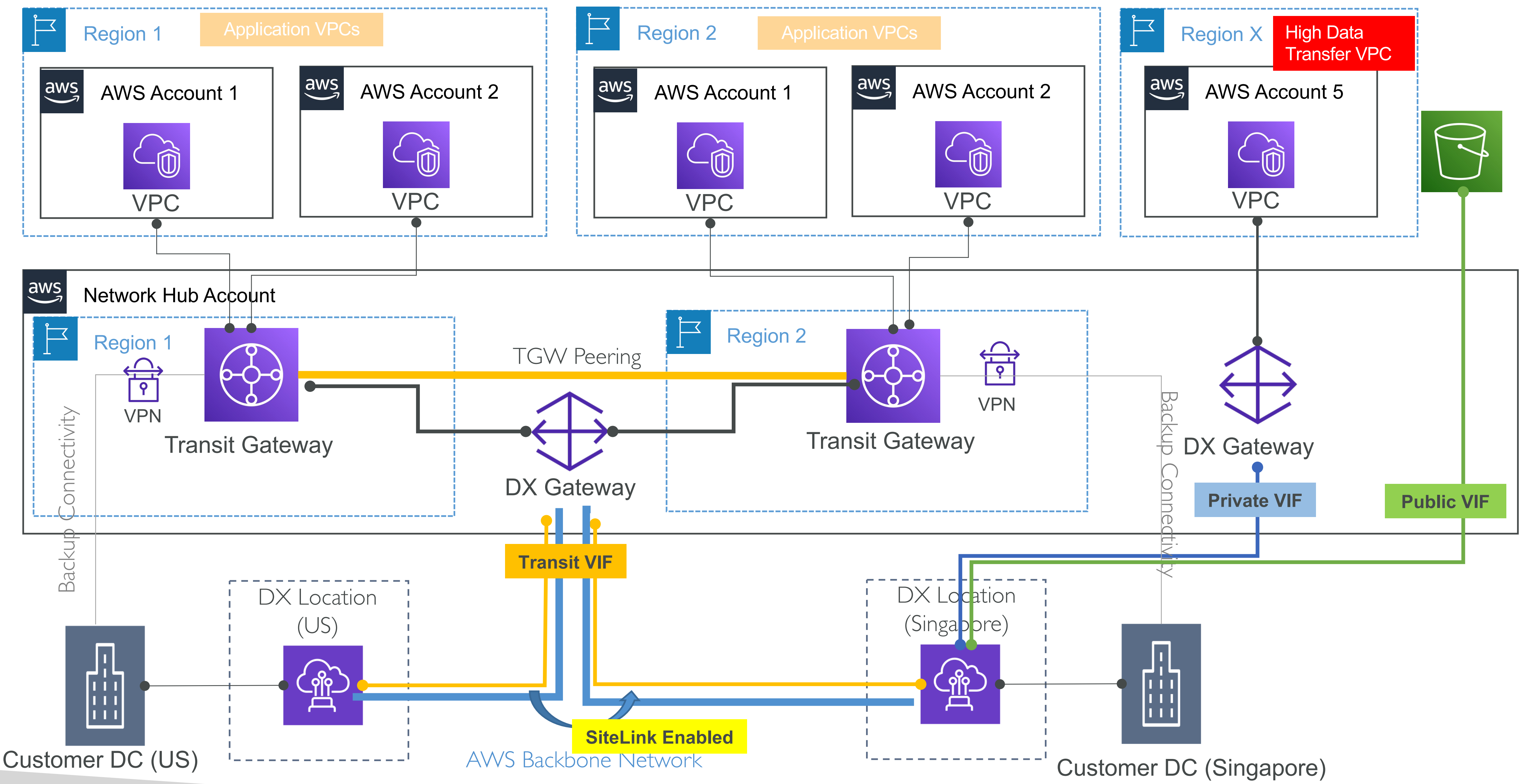
Troubleshooting with DirectConnect

When no physical connectivity	When VIF is down	When BGP session is down	When not able to reach destination
1. Cross Connect is complete 2. Ports are correct 3. Routers are powered ON 4. Tx/Rx optical signals are receiving (CW) 5. Contact colocation provider & get report for Tx/Rx signals 6. CW Metrics for Physical error count 7. Contact AWS support	1. IP addresses are correct 2. VLAN IDs are correct 3. Router MAC address in ARP table 4. Try clearing ARP table 5. VLAN truncing enabled at intermediate devices 6. Contact AWS Support	1. Both Ends BGP ASN 2. Peer IPs are correct 3. MD5 Auth key – no spaces or extra chars 4. <= 100 prefixes for Private VIF 5. < = 1000 prefixes for Public VIF 6. Firewall not blocking TCP 179 port 7. BGP logs 8. Contact AWS Support	1. Advertising routes for on-premises prefixes 2. For Public VIF, it should be publicly routable prefixes 3. Security group and NACL 4. VPC Route table
Layer 1 Issues	**Layer 2 Issues**	**Layer 3/4 Issues**	**BGP/Routing issues**

Troubleshooting with DirectConnect

- [Troubleshooting layer 1 (physical) issues]
- [Troubleshooting layer 2 (data link) issues]
- [Troubleshooting layer 3/4 (Network/Transport) issues]
- [Troubleshooting routing issues]
- https://aws.amazon.com/premiumsupport/knowledge-center/troubleshoot-bgp-dx/

AWS Direct Connect Architecture – Putting in together



Region 1
Application VPCs
AWS Account 1
VPC
AWS Account 2
VPC
Region 2
Application VPCs
AWS Account 1
VPC
AWS Account 2
VPC
Region X
High Data Transfer VPC
AWS Account 5
VPC
Network Hub Account
Region 1
VPN
Transit Gateway
TGW Peering
DX Gateway
Region 2
Transit Gateway
VPN
DX Gateway
Private VIF
Public VIF
Backup Connectivity
Backup Connectivity
Transit VIF
DX Location (US)
DX Location (Singapore)
Customer DC (US)
Customer DC (Singapore)
SiteLink Enabled
AWS Backbone Network

Direct Connect Summary

Summary

- Understand various parties involved in DX e.g DX location provider, Direct connect partner, Network provider for connectivity back to your data center
- Understand various segments involved in DX connection e.g AWS device/router, Customer router, Cross connect, Virtual Interfaces
- Dedicated Connection and Hosted connection
- Public VIF, Private VIF and Transit VIF
- Transit Gateway integration with DirectConnect Gateway
- Routing Policies and BGP communities for Public and Private VIF

Summary

- Link Aggregation Group (LAG)
- Bidirectional Forwarding Detection (BFD)
- DX HA architectures
- DX encryption – VPN over DX, MacSec
- DX MTU and Jumbo frames
- DX billing - Port hour and Data transfer Out charges
- DX Troubleshooting

Exam Essentials

- AWS Direct connect provides 1 or 10 or 100 Gbps dedicated connection or sub-1 Gbps Hosted connections
- BGP protocol is used to exchange routes
- 802.1Q VLANs tags are used to separate virtual interfaces on the same connection
- Public VIF provides global connectivity to public AWS resources
- Private VIF provides connectivity to resources inside VPC
- Hosted connection allows a single VIF per connection
- Parameters required for creating DX connection
- Parameters required for creating Public/Private/Transit VIFs
- BGP path selection/failover parameters (AS_PATH, Routes etc)

Exam Essentials

- VIF Routing policies and BGP Communities
- Link Aggregation Group (LAG) for higher aggregated DX bandwidth
- BFD can be used to increase the speed at which connection failures are detected and cause failover to alternative routes (1 sec)
- DX HA options – Dual device, Dual Location, VPN backup etc
- Public VIF includes Hardware VPN IP addresses. Can use for VPN over a DX connection
- 100 routes can be published for Private VIFs and 1000 for Public VIF from customer end to AWS

AWS Cloud WAN

What is AWS Cloud WAN?

- A managed wide-area networking (WAN) service to build, manage, and monitor a global network across AWS and on-premises network
- Simple network policies to configure and automate network management
- Provides a central dashboard (through AWS Network Manager)

AWS Cloud WAN

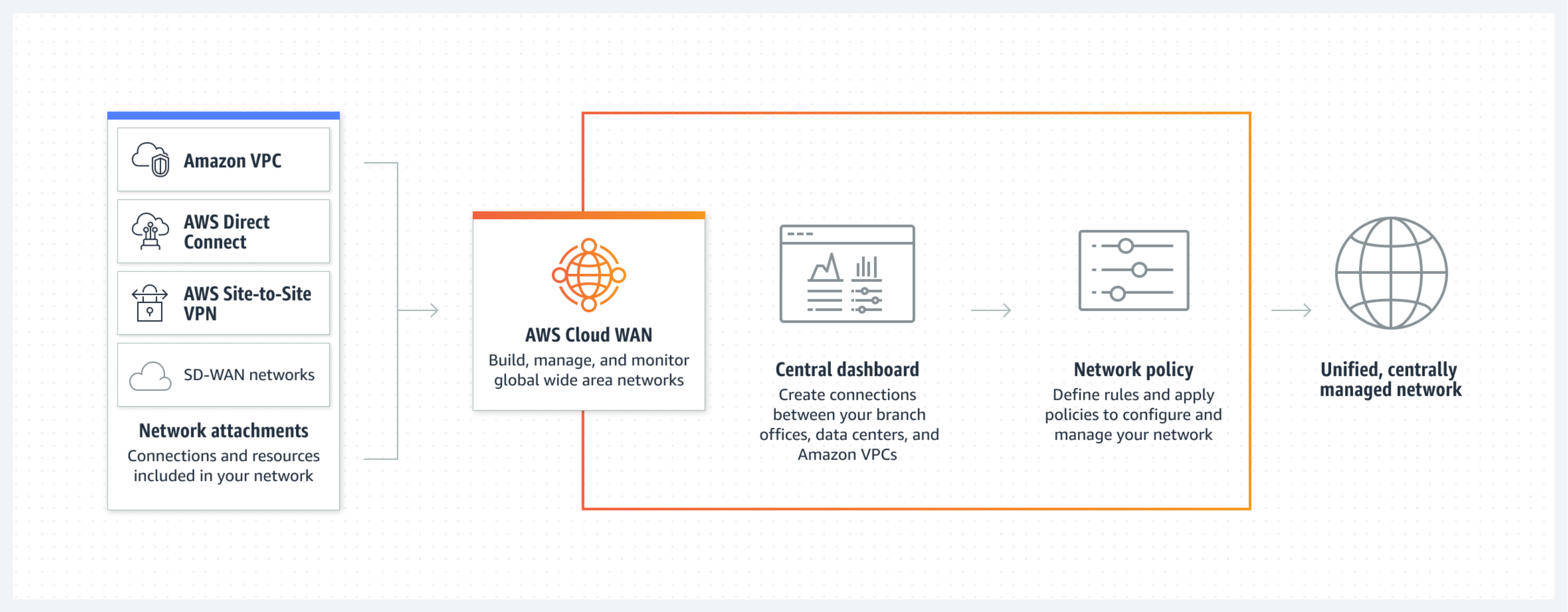
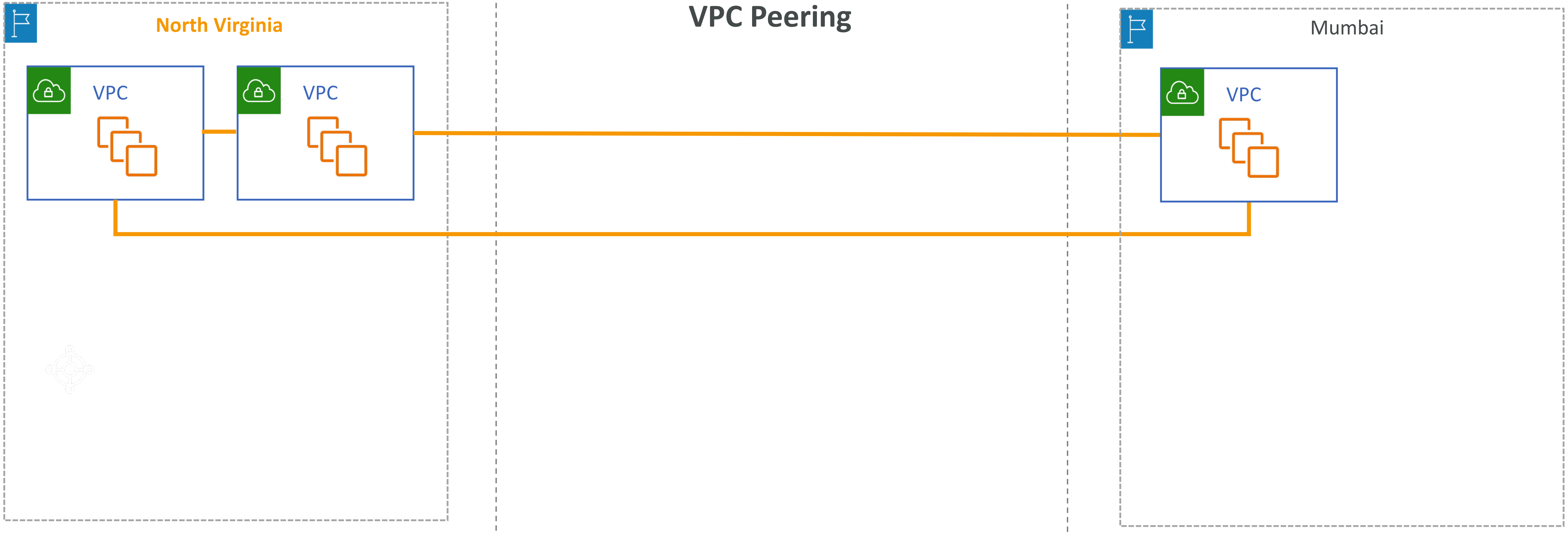
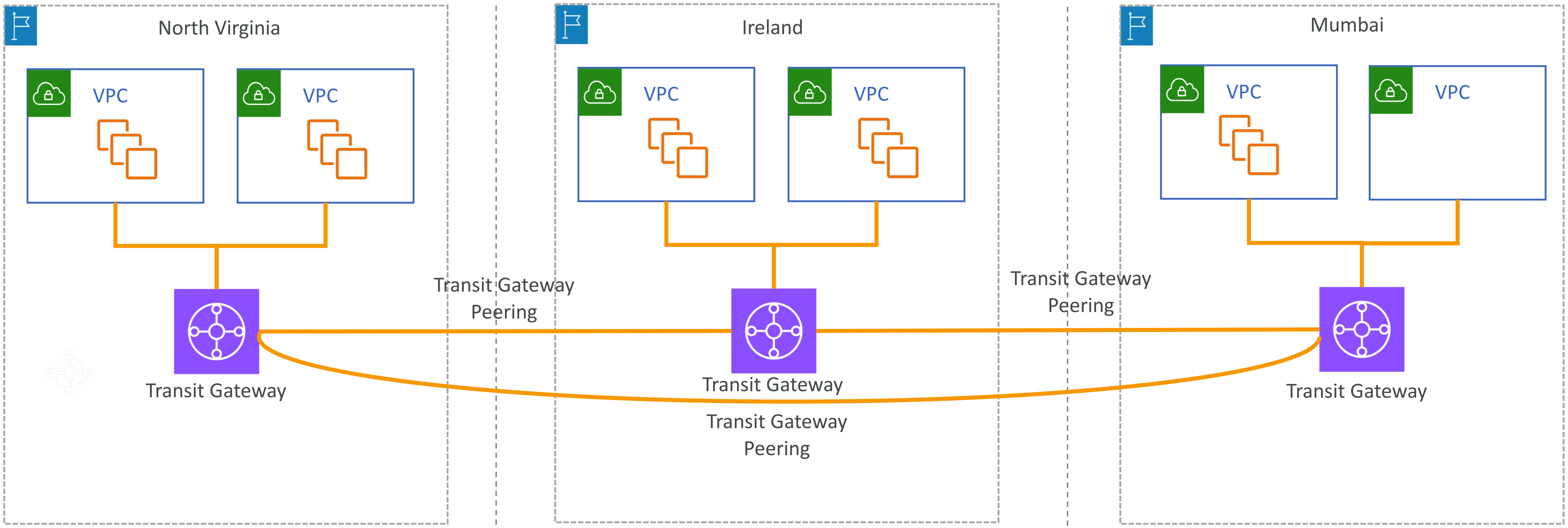
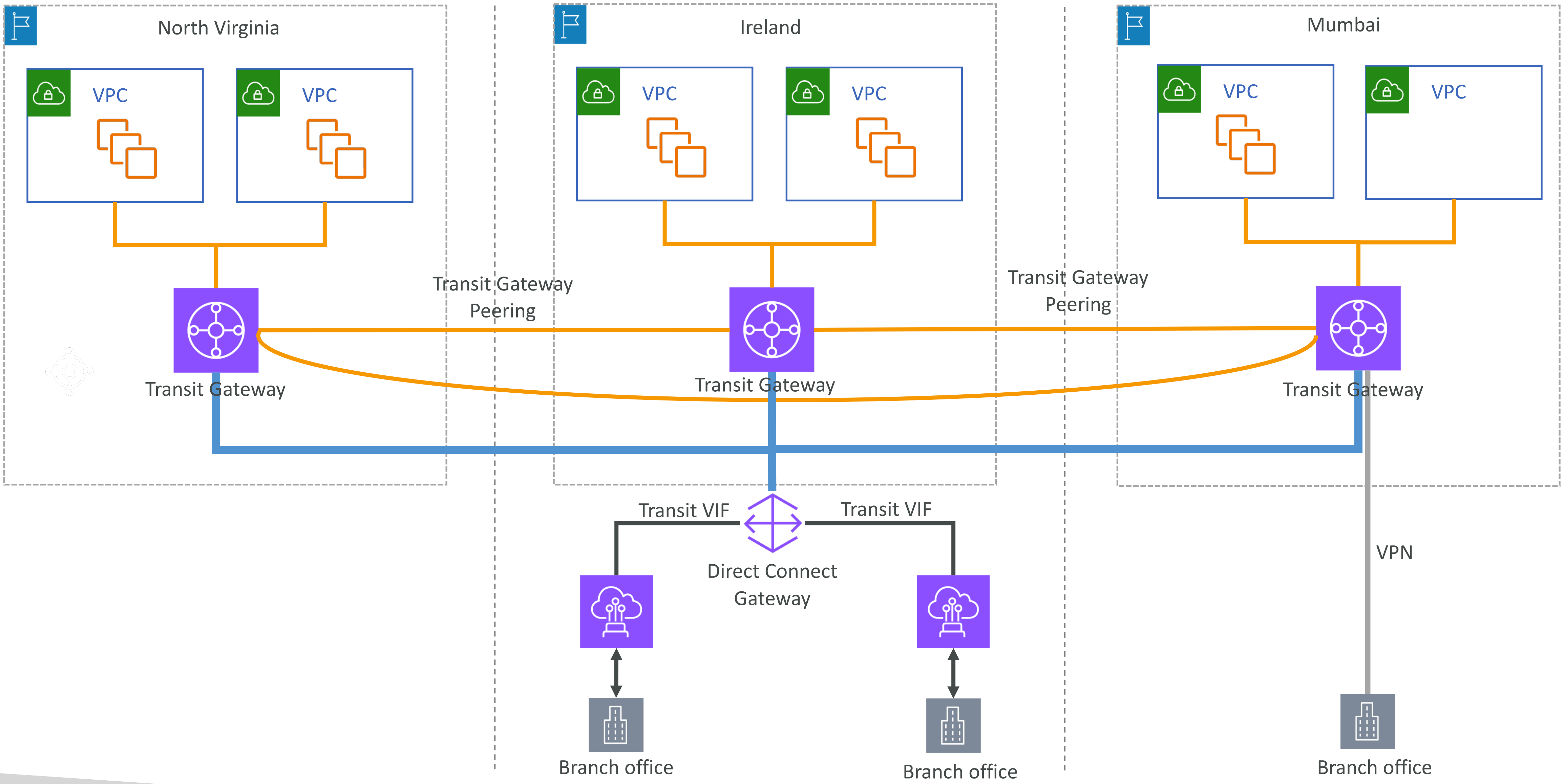


Image source: https://aws.amazon.com/cloud-wan/

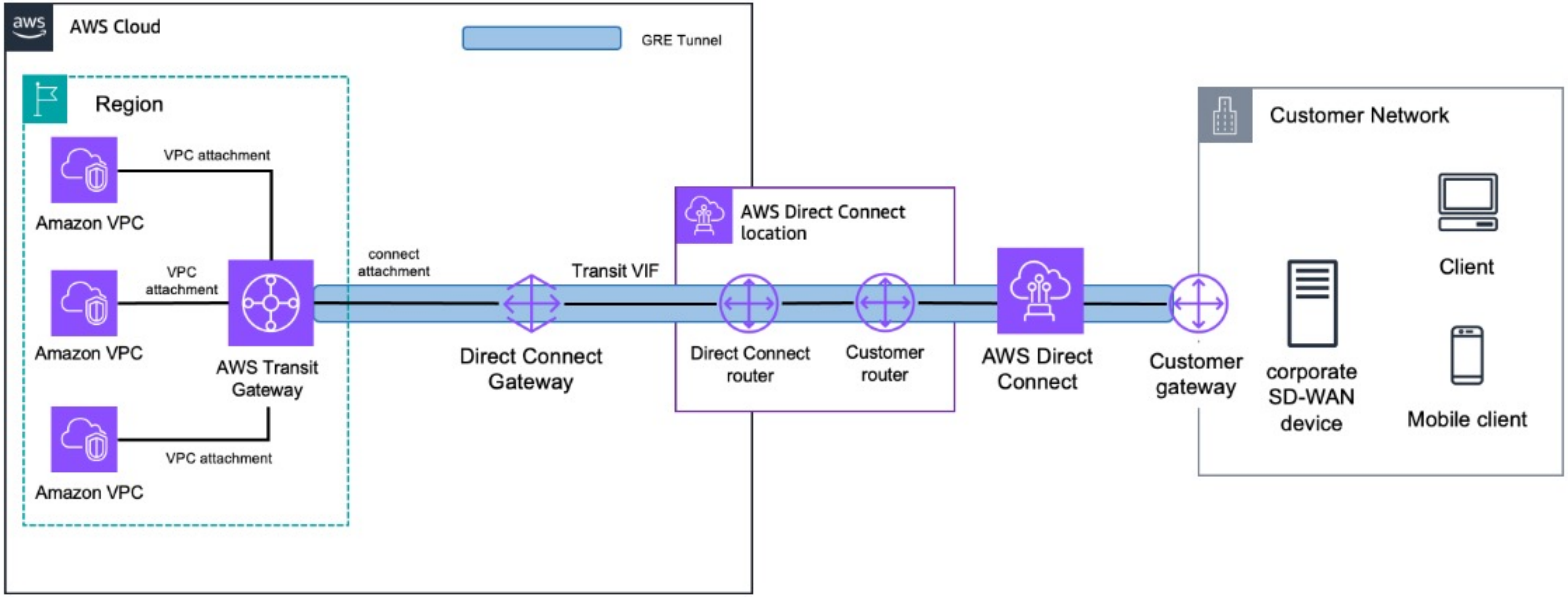
VPC Peering

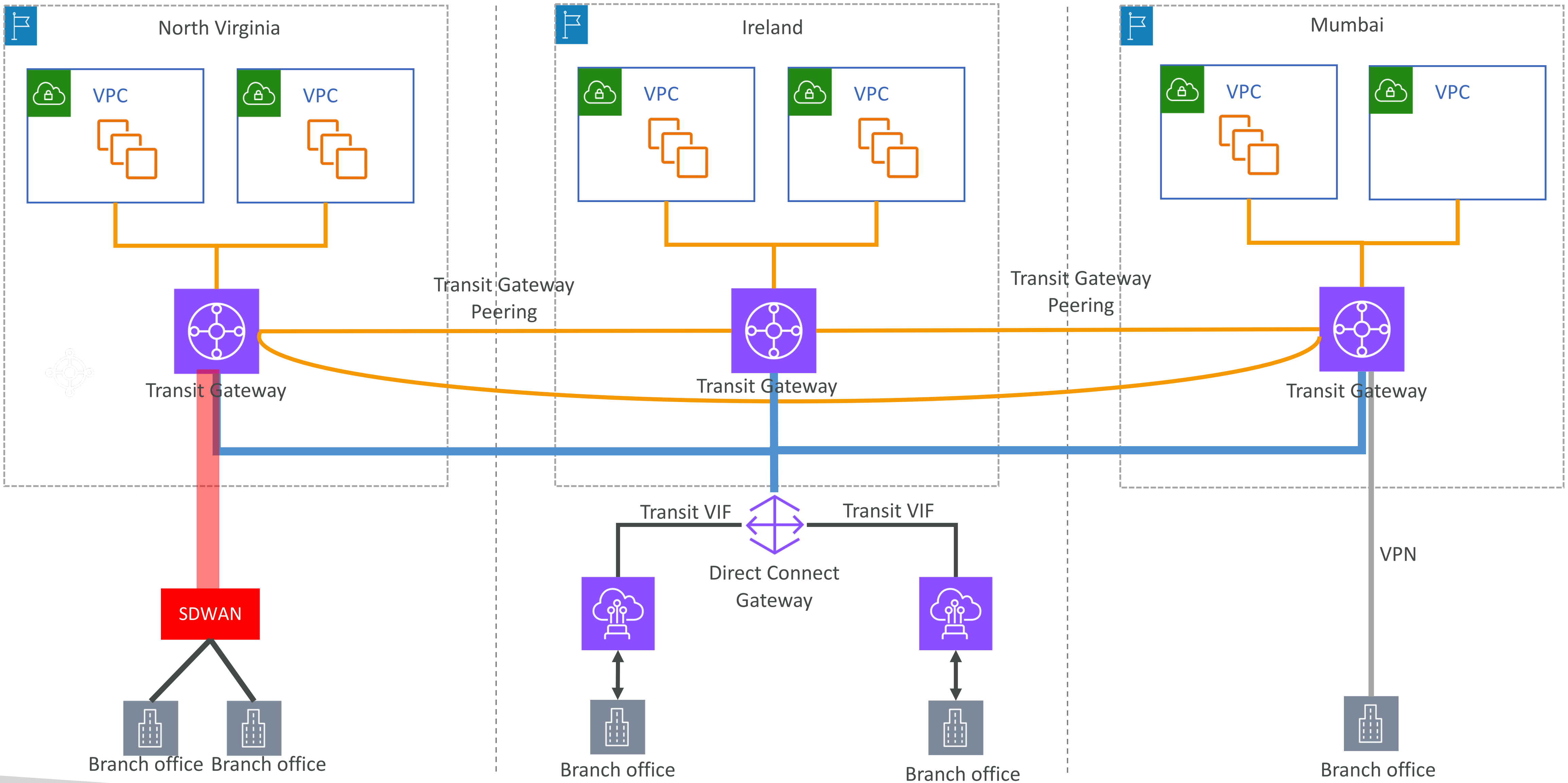


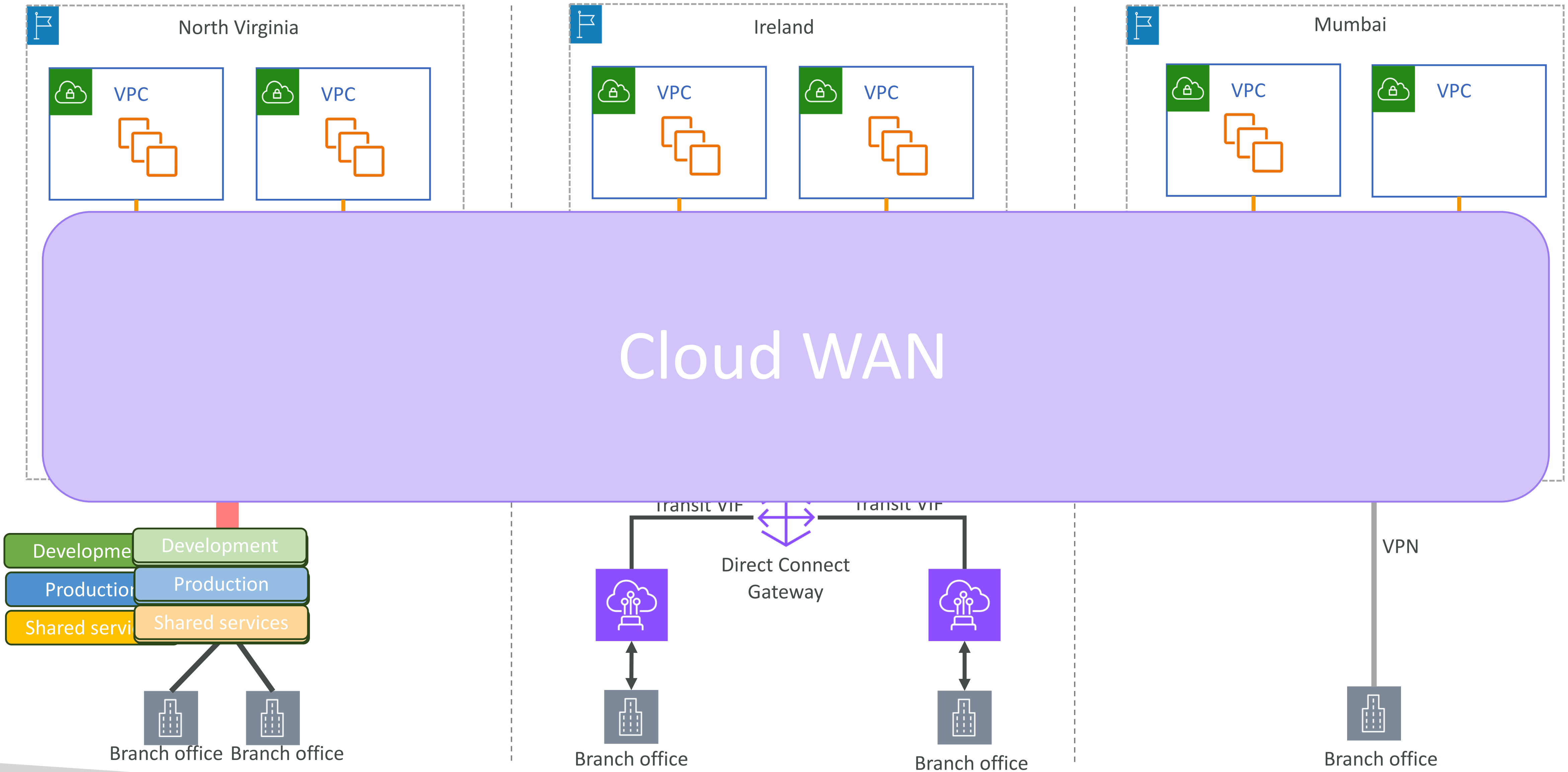

North Virginia
Ireland
Mumbai
VPC
VPC
VPC
VPC
VPC
VPC
Transit Gateway
Transit Gateway
Transit Gateway
Transit Gateway Peering
Transit Gateway Peering
Transit Gateway Peering


North Virginia
VPC
VPC
Ireland
VPC
VPC
Mumbai
VPC
VPC
Transit Gateway Peering
Transit Gateway Peering
Transit Gateway
Transit Gateway
Transit Gateway
Transit VIF
Transit VIF
Direct Connect Gateway
VPN
Branch office
Branch office
Branch office

SD-WAN with Transit Gateway Connect




North Virginia
Ireland
Mumbai
VPC
VPC
VPC
VPC
VPC
VPC
Transit Gateway Peering
Transit Gateway Peering
Transit Gateway
Transit Gateway
Transit Gateway
Transit VIF
Transit VIF
Direct Connect Gateway
VPN
SDWAN
Branch office
Branch office
Branch office
Branch office
Branch office

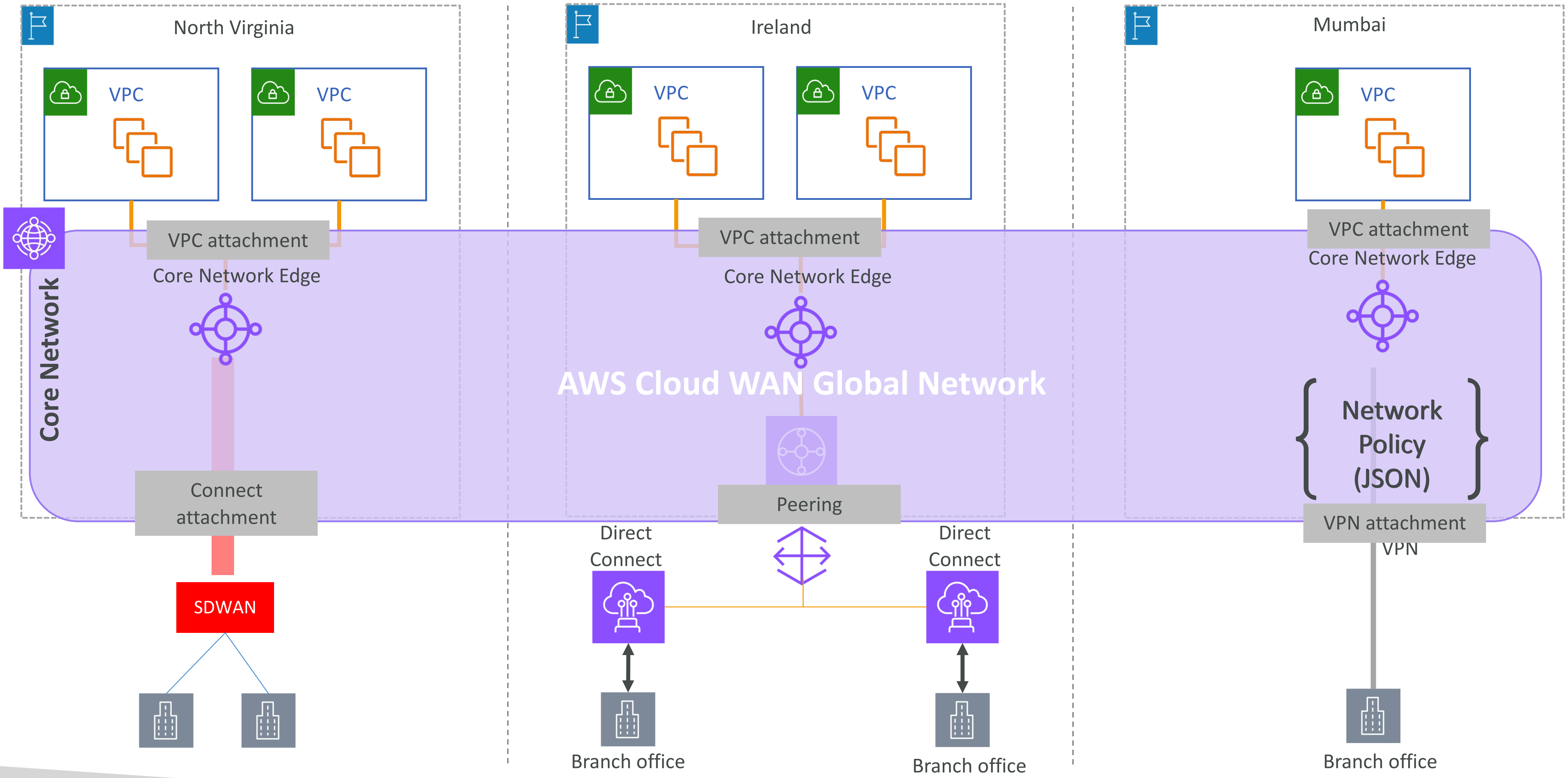

North Virginia
VPC
VPC
Ireland
VPC
VPC
Mumbai
VPC
VPC
Cloud WAN
Transit VIF
Transit VIF
Direct Connect
Gateway
VPN
Developme
Development
Productio
Production
Shared servi
Shared services
Branch office
Branch office
Branch office
Branch office
Branch office

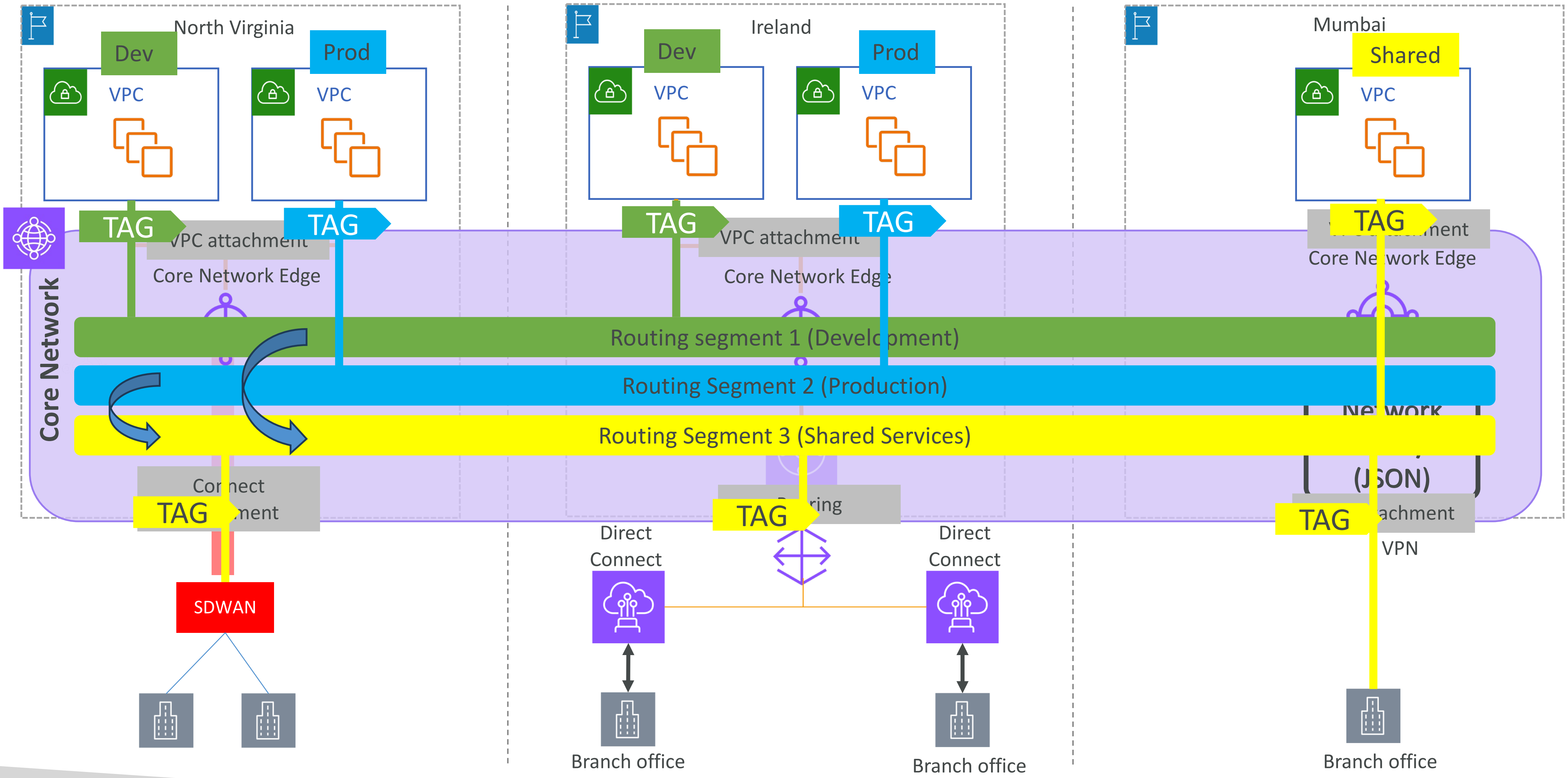
AWS Cloud WAN components

- Global Network – Core Networks + Transit Gateway Network
- Core Network
  - Core Network Edge
  - Core Network Policy
- Network Segments
  - Segment actions
- Attachments
  - Attachment policies
- Peering

Home Region for storing data

Oregon (us-west-2)


North Virginia
Ireland
Mumbai
VPC
VPC
VPC
VPC
VPC
VPC attachment
VPC attachment
VPC attachment
Core Network Edge
Core Network Edge
Core Network Edge
Core Network
AWS Cloud WAN Global Network
Network Policy (JSON)
Connect attachment
Peering
VPN attachment
VPN
SDWAN
Direct Connect
Direct Connect
Branch office
Branch office
Branch office



North Virginia
Dev
Prod
VPC
VPC
TAG
TAG
VPC attachment
Core Network Edge
Ireland
Dev
Prod
VPC
VPC
TAG
TAG
VPC attachment
Core Network Edge
Mumbai
Shared
VPC
TAG
Core Network Edge
Core Network
Routing segment 1 (Development)
Routing Segment 2 (Production)
Routing Segment 3 (Shared Services)
(JSON)
Connect
TAG
TAG
TAG
Direct
Connect
Direct
Connect
VPN
SDWAN
Branch office
Branch office
Branch office

Core Network Policy

Core Network Policy

- Network configurations
  - ASN ranges
  - Regions (Core Network Edge)
- Segments
  - Name
  - Regions
  - Require acceptance
  - Sharing between segments
  - Static routes
- Attachment policies
  - Rules
  - Associate the attachments to the segments
  - Require Acceptance

```
{
    "version": "2021.12",
    "core-network-configuration": {
        "asn-ranges": ["64512-65534"],
        "edge-locations": [
            {"location": "us-east-1"}
        ]
    },
    "segments": [
        {
            "name": "mynetwork",
            "require-attachment-acceptance": false
        }
    ],
    "attachment-policies": [
    {
        "rule-number": 100,
        "condition-logic": "and",
        "conditions": [{ "type": "any" }],
        "action": {
            "association-method": "constant",
            "segment": "mynetwork"
            }
        }
    ]
}
```

Image source: AWS documentation

Core Network Policy

- Network configurations
  - ASN ranges
    - 64512-65534
    - 4200000000-4294967294
  - Edge locations (Regions)
  - Inside CIDR blocks
    - For Transit Gateway Connect tunnels
    - Can be defined per region
  - ECMP support


```json
{
    "version": "2021.12",
    "core-network-configuration": {
        "asn-ranges": ["64512-65534"],
        "inside-cidr-blocks": ["100.65.0.0/16"],
        "edge-locations": [
            {"location": "eu-central-1"},
            {"location": "us-west-2"},
            {"location": "us-east-1"},
            {"location": "eu-west-1"}
        ]
    },
    "segments": [
        {"name": "sales"},
        {"name": "testing"},
        {
        "name": "iot",
        "isolate-attachments": true
        },
        {"name": "internet"},
        {"name": "engineering"}
    ],
```


Image source: AWS documentation

Segments

- Name
- Edge locations
  - Subset of Core Network edges
- Isolate attachments (default: False)
  - If True, attachment routes are not shared automatically
  - Routes can be shared through Share segment action or by adding static routes
- Require attachment acceptance (default: True)
- Filters
  - allow or deny routes sharing between segments
- Segment Actions
  - Share segments
  - Create static routes

```
"segments": [
    {
        "name": "development",
        "isolate-attachments": true,
        "require-attachment-acceptance": false
    },
    {"name": "hybrid"}
],
"segment-actions": [
    {
        "action": "share",
        "mode": "attachment-route",
        "segment": "development",
        "share-with": ["hybrid"]
    },
    {
        "action": "create-route",
        "destination-cidr-blocks": ["0.0.0.0/0"],
        "segment": "development",
        "destinations": ["attachment-12355678901234567"
    }
],
```

Image source: AWS documentation

Attachments

- VPC
- VPN
- Connect & Connect Peer
  - Connects to 3rd party virtual appliances hosted inside VPC
  - Supports both GRE and Tunnel-less protocols
  - BGP for Dynamic routing (two BGP sessions for redundancy)
- Transit Gateway Route table

Attachment policies

- Rule numbers
  - 1-65535
  - Lower number takes priority
  - Rule evaluation stops after first match
- Require acceptance
  - In effect only when Segment require acceptance is false
- Logical conditions: AND or OR
  - AWS Account
  - Region
  - TagKey, TagValue
  - Resource ID (e.g. VPC ID/ VPN ID)
- Association-method
  - Constant or Tag
  - If "Constant" then provide the segment name

```
{
  "rule-number": 200,
  "condition-logic": "or",
  "conditions": [],
  "action": {
    "association-method": "constant",
    "segment": "TestingSegment",
    "require-acceptance": true
  }
},
{
  "rule-number": 300,
  "condition-logic": "and",
  "conditions": [
    {
      "type": "region",
      "operator": "equals",
      "value": "us-east-2"
    },
    {
      "type": "attachment-type",
      "operator": "equals",
      "value": "vpc"
    }
  ],
  "action": {
    "association-method": "constant",
    "segment": "ProductionSegment",
    "require-acceptance": true
  }
}
```

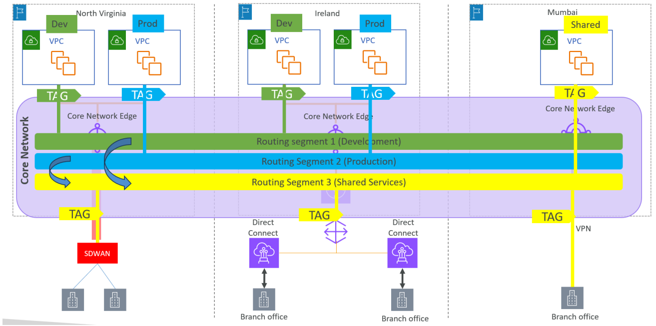
Process to make changes to the Network Policy

V1 → V2 → V2 (LATEST)

Generate new Policy version
(Visual editor or json mode)

Change Set
- AWS regions
- Core network edges
- Attachments
- Segments
- Add/delete/change

Validate changes and Apply



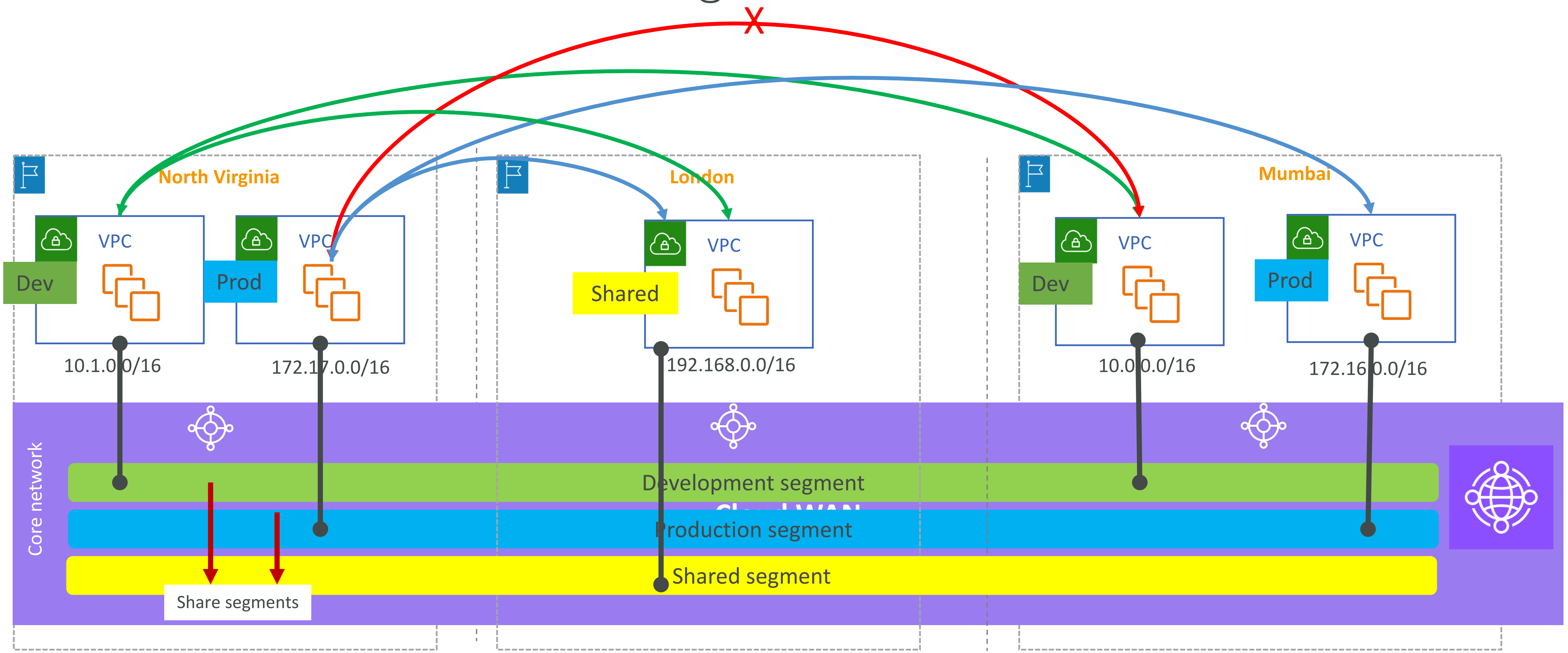
Execute Policy

Policy state changes: Pending generation → Ready to execute → Execution Succeeded

Pending generation → Failed generation

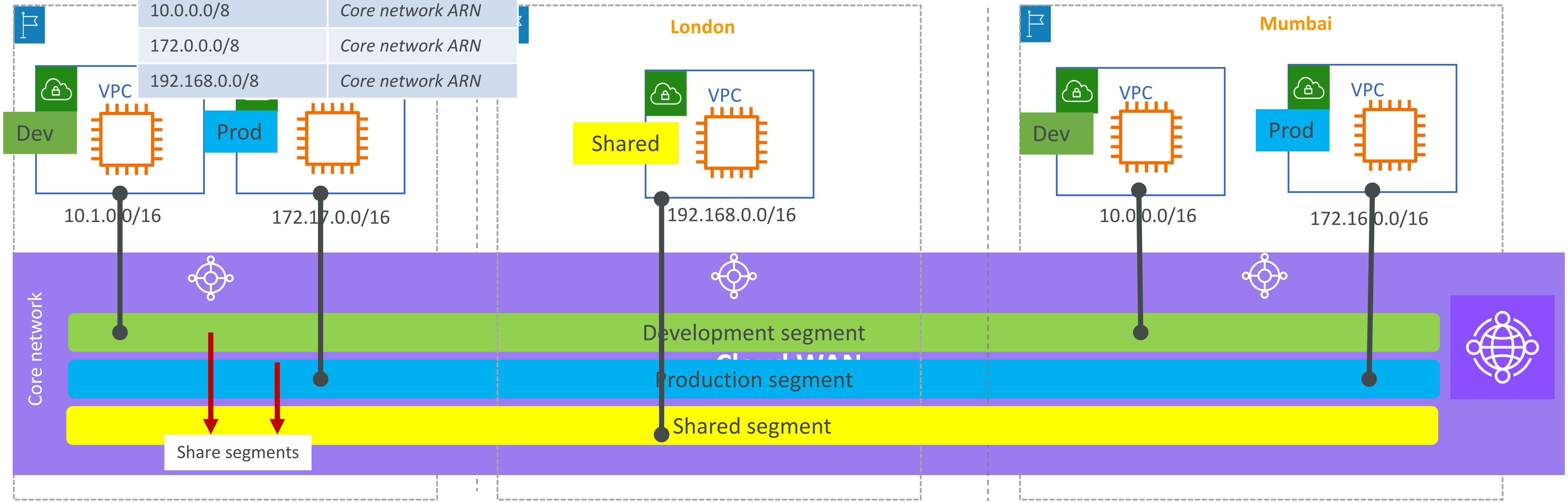
AWS Cloud WAN walkthrough

AWS Cloud WAN Walkthrough



AWS Cloud WAN Walkthrough

Route table	
10.1.0.0/16	local
0.0.0.0/0	igw-id
10.0.0.0/8	*Core network ARN*
172.0.0.0/8	*Core network ARN*
192.168.0.0/8	*Core network ARN*



Process to set up Cloud WAN

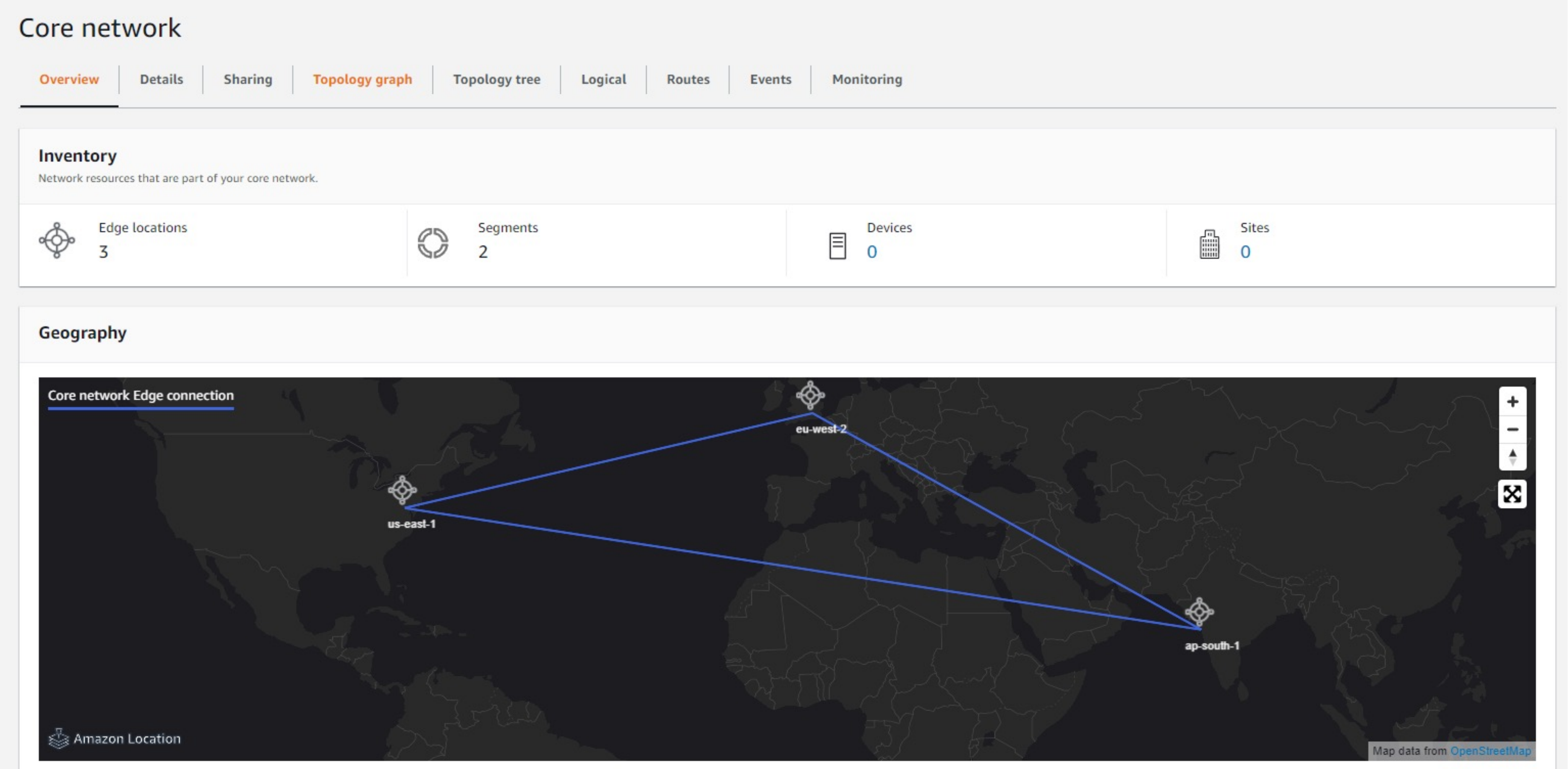
- Create 5 VPCs across 3 AWS regions (as shown in the diagram)
  - Create one public subnet in each VPC
  - Launch one EC2 instance each in every VPC (Public subnet) with Public IP.
  - Security Group to Allow SSH from your IP, ICMP (IPv4) ping from 0.0.0.0/0.
- Create a Global Network and Core network
  - ASN Ranges: 64512-65334
  - Enable 3 edge locations (Mumbai, London & N.Virginia)
  - Create default segment – Shared segment
  - Wait for Core network to be created
- Go to Core network Policy and edit the latest version of the policy
  - Go to segments
    - Create 2 more segments i.e. Development & Production
  - Apply the policy changes and wait for the execution to complete

Process to set up Cloud WAN

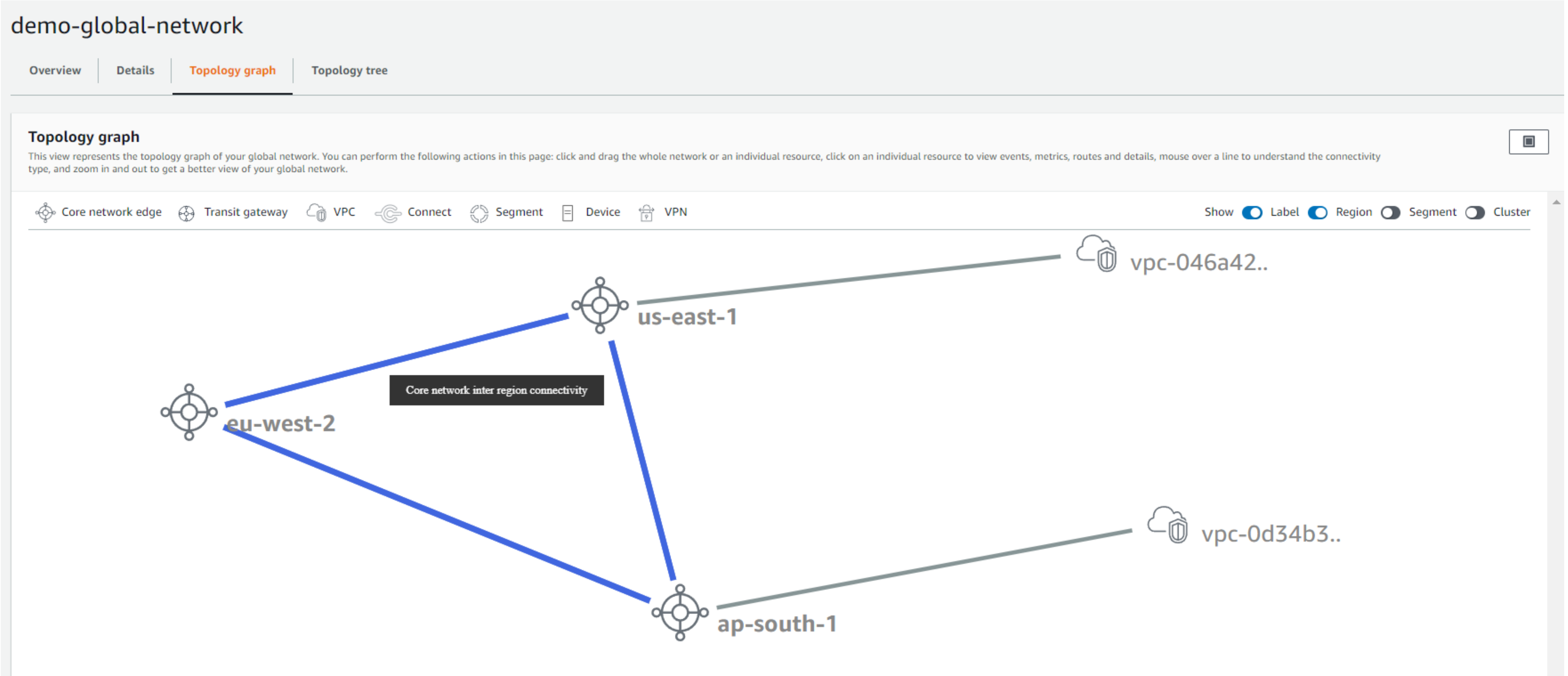
- Again edit the new version of the policy and go to Segments
  - Go to Segments
    - For Development segment add Shared segment in the Allow list
    - For Production segment add Shared segment in the Allow list
    - For Shared segment – Allow All (We want Development & Production Segments to access Shared Segment)
  - Go to Segment Actions
    - Share "Shared" Segment with both Development & Production segments
  - Go to Attachment policies and create 3 policies (rules)
    - Development attachment policy - with rule for tag Environment = Development
    - Production attachment policy - with rule for tag Environment = Production
    - Shared attachment policy – with rule for Any
  - Verify the change set and apply network policy.
  - Wait for the policy execution to be completed
- Create VPC attachments for all 5 VPCs (select right Edge location, VPC ID and provide Environment Tags & value)
- Update VPC route tables and add corresponding routes for other VPC network CIDR destination
  - Route entry should point to the **Core-network ARN** as Target
- Verify the Core Network routes for all the attachments (should see propagated routes)
- Login to EC2 instances over SSH from your machine and verify the connectivity by pinging to private IP of target EC2
  - Should connect: Dev to Dev, Prod to Prod, Dev to Shared, Prod to Shared
  - Should not connect: Dev to Prod or Prod to Dev

DELETE EVERYTHING AFTER THE EXERCISE

CloudWAN Visualization with Network Manager

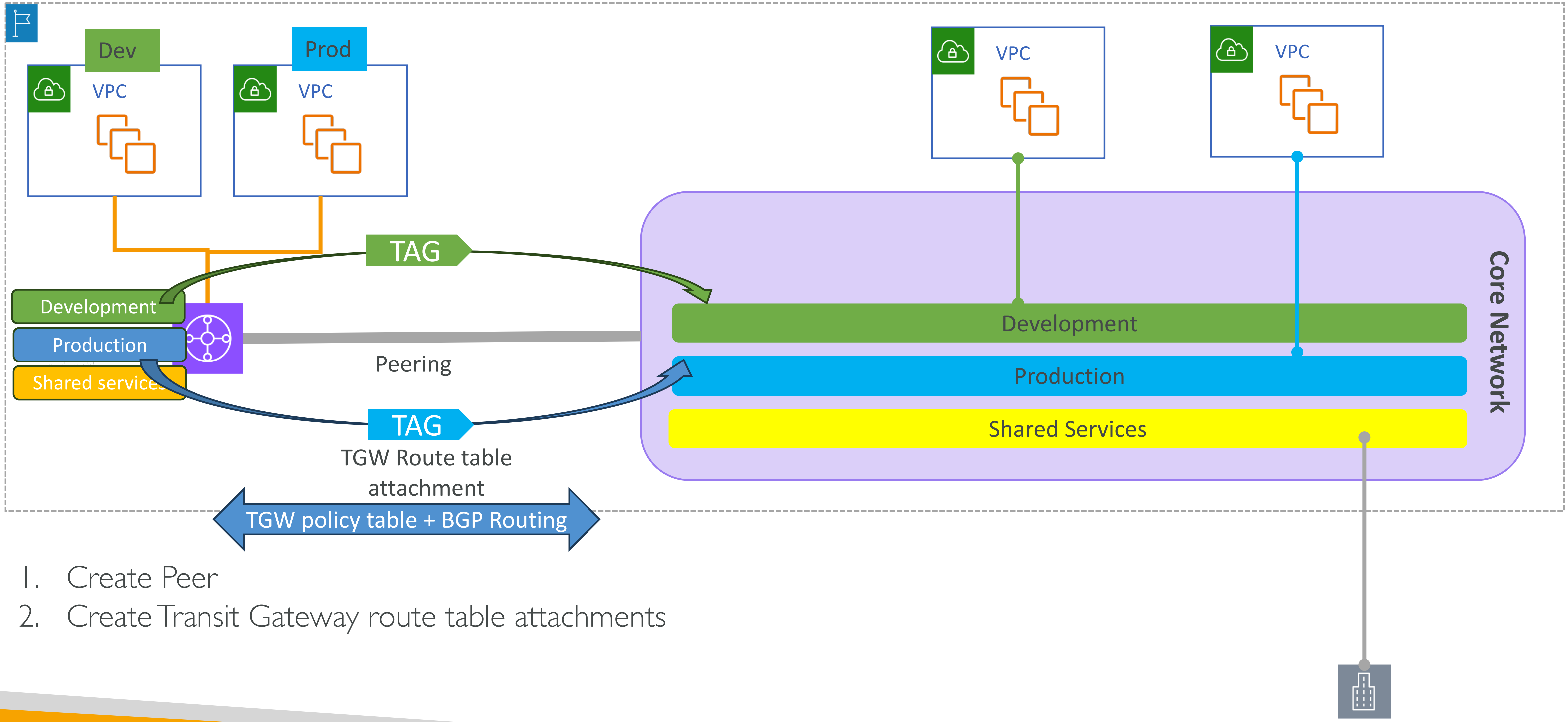


CloudWAN Visualization with Network Manager



AWS Cloud WAN + Transit Gateway & Direct Connect

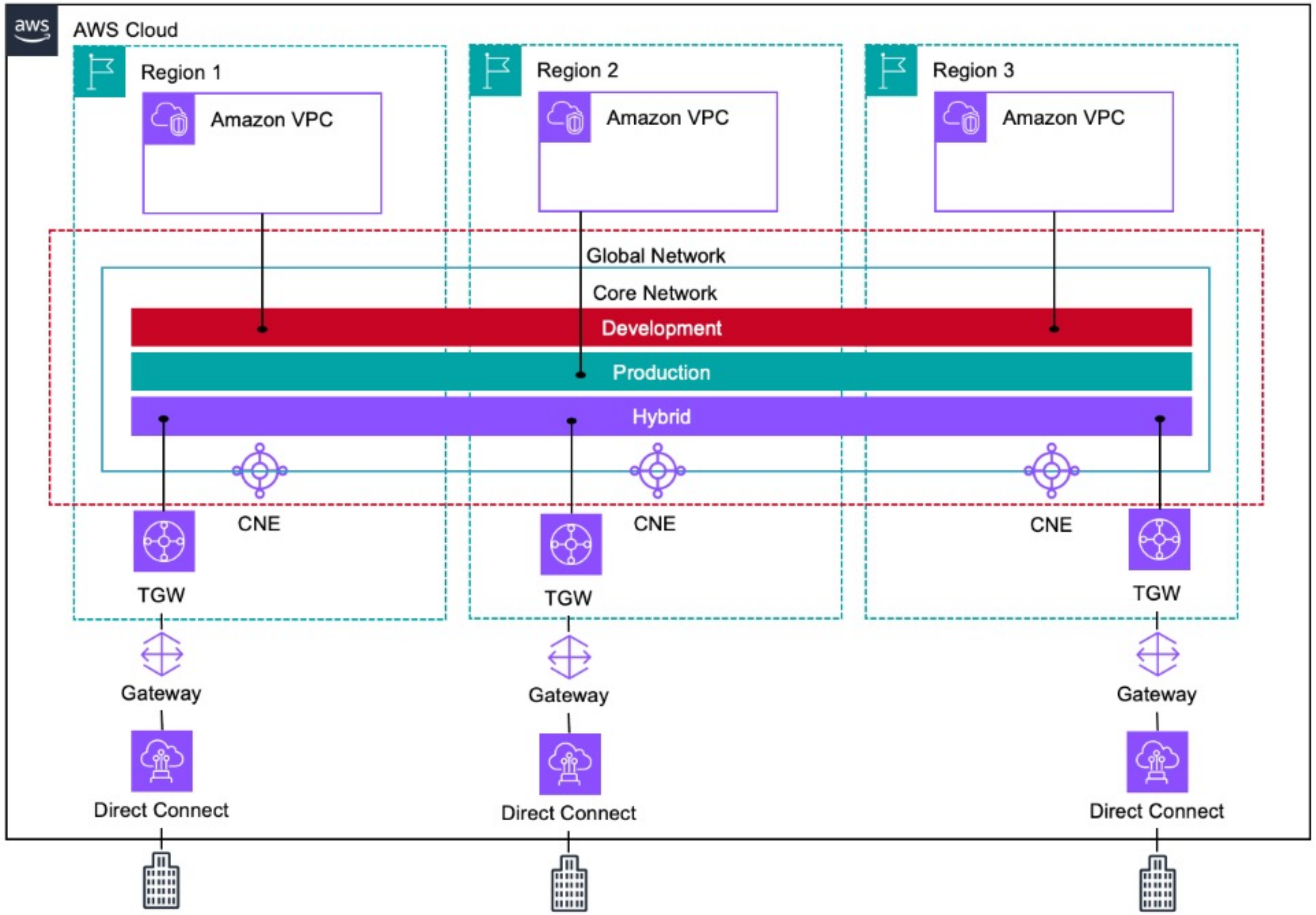
AWS Cloud WAN and Transit Gateway



1. Create Peer
2. Create Transit Gateway route table attachments

AWS Cloud WAN with Direct Connect

- Connect Direct Connect to Transit Gateway over a Transit VIF & DX Gateway
- Create Cloud WAN peering with Transit Gateway
- Create Transit Gateway route table attachments connecting to Cloud WAN segments



AWS Cloud WAN Summary

AWS Cloud WAN Summary

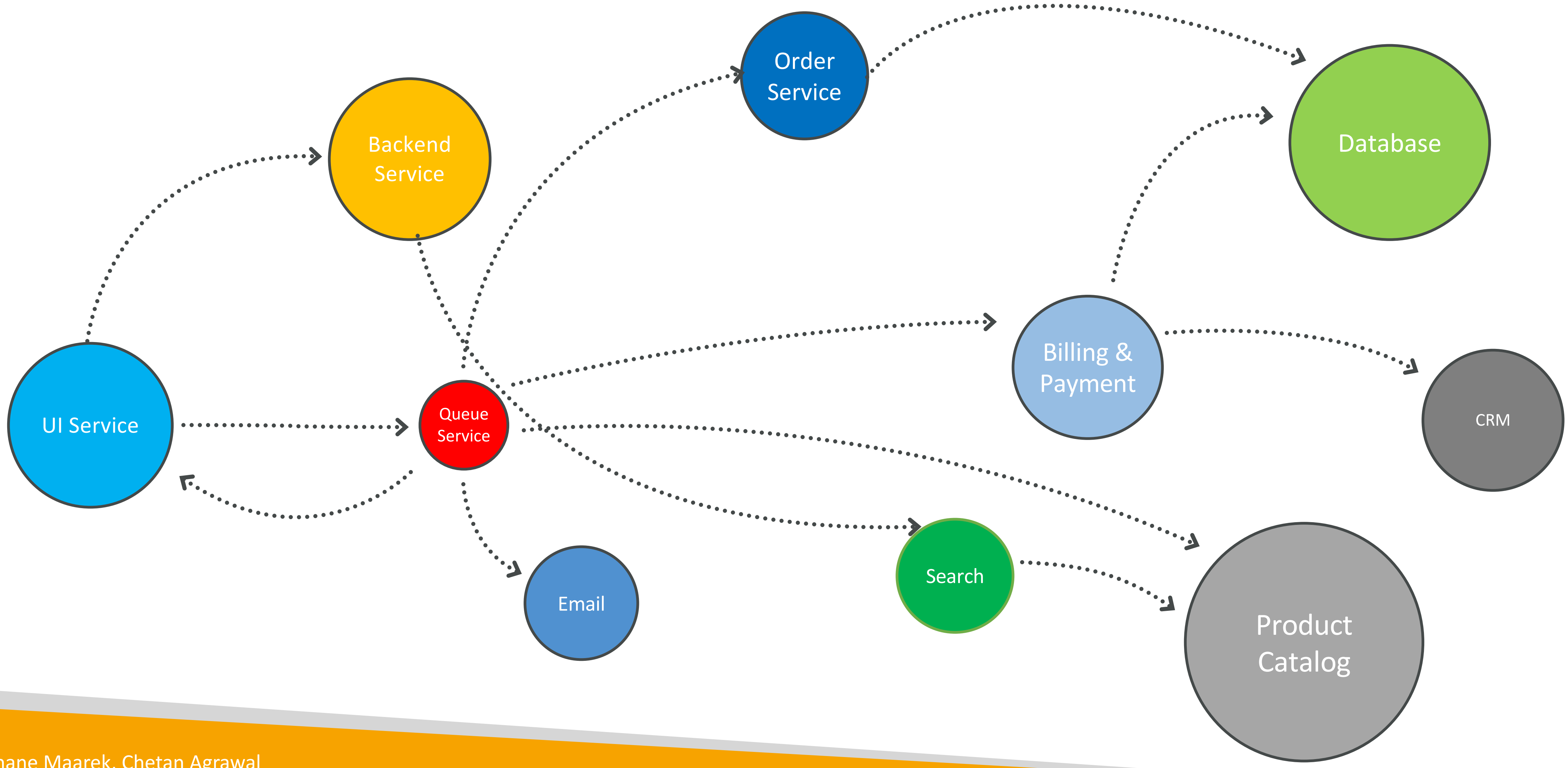
- A managed wide-area networking (WAN) service
- AWS Network Manager provides a central dashboard
- Uses simple network policies to centrally configure and automate network management
- Segments to segregate network traffic (like VRF)
- Core network can be shared across AWS accounts using Resource Access Manager
- Supports attachments such as VPC, Site-to-Site VPN, Connect (SDWAN), Transit Gateway route table (for connecting existing Transit Gateways)
- Connect attachments support GRE and Tunnel-less protocols
- Direct Connect attachment is currently not supported. You can connect DX gateway through the Transit Gateway.

VPC Lattice

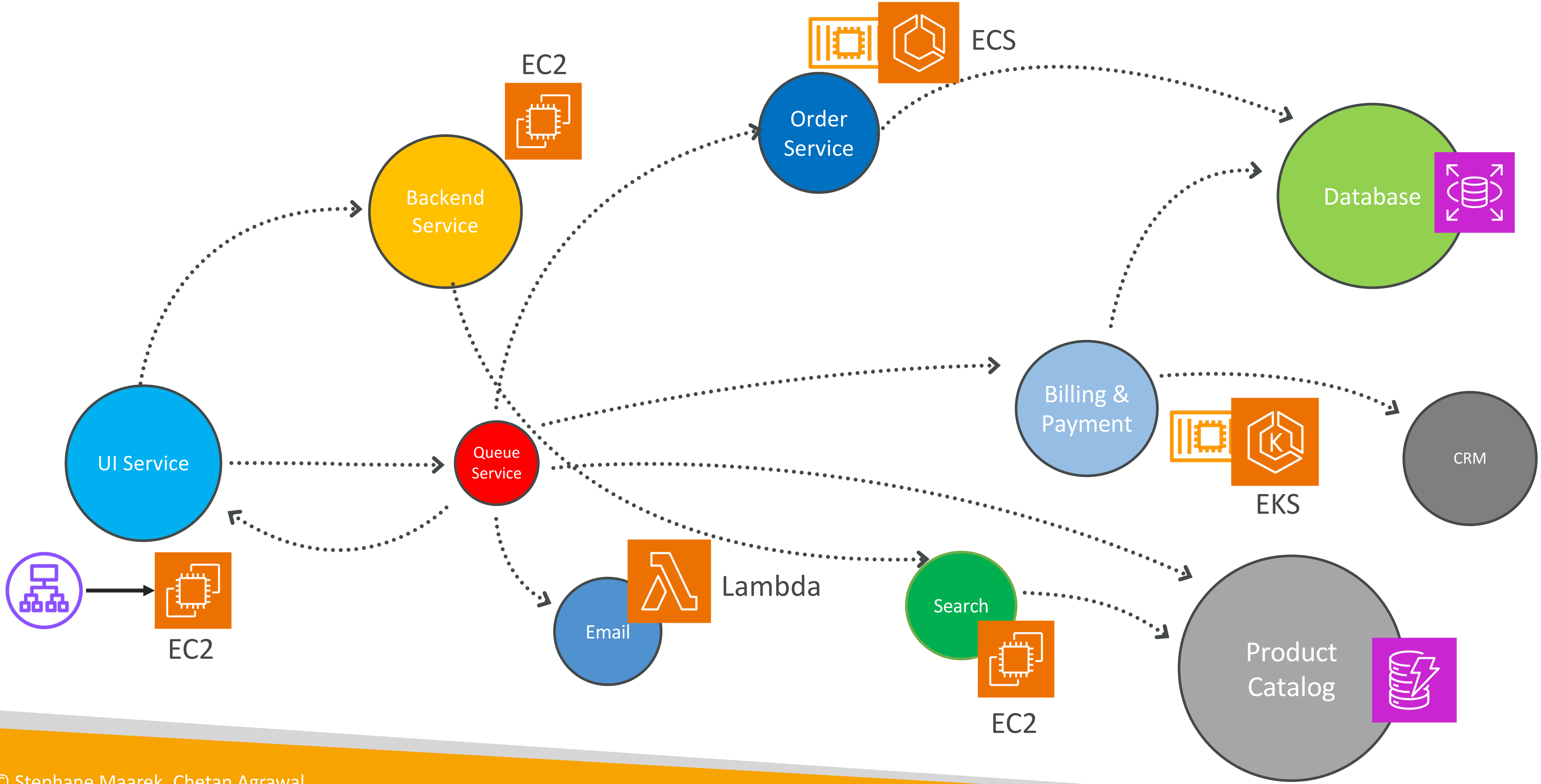
VPC Lattice

- Simplifies service-to-service (application to application) communication
- Enables secure, consistent connectivity without needing complex network peering like VPC peering or Transit Gateways
- Provides Service discovery and dynamic routing capabilities
- Supports **Zero Trust** architectures with centralized access controls, IAM authentication, and context-specific authorization

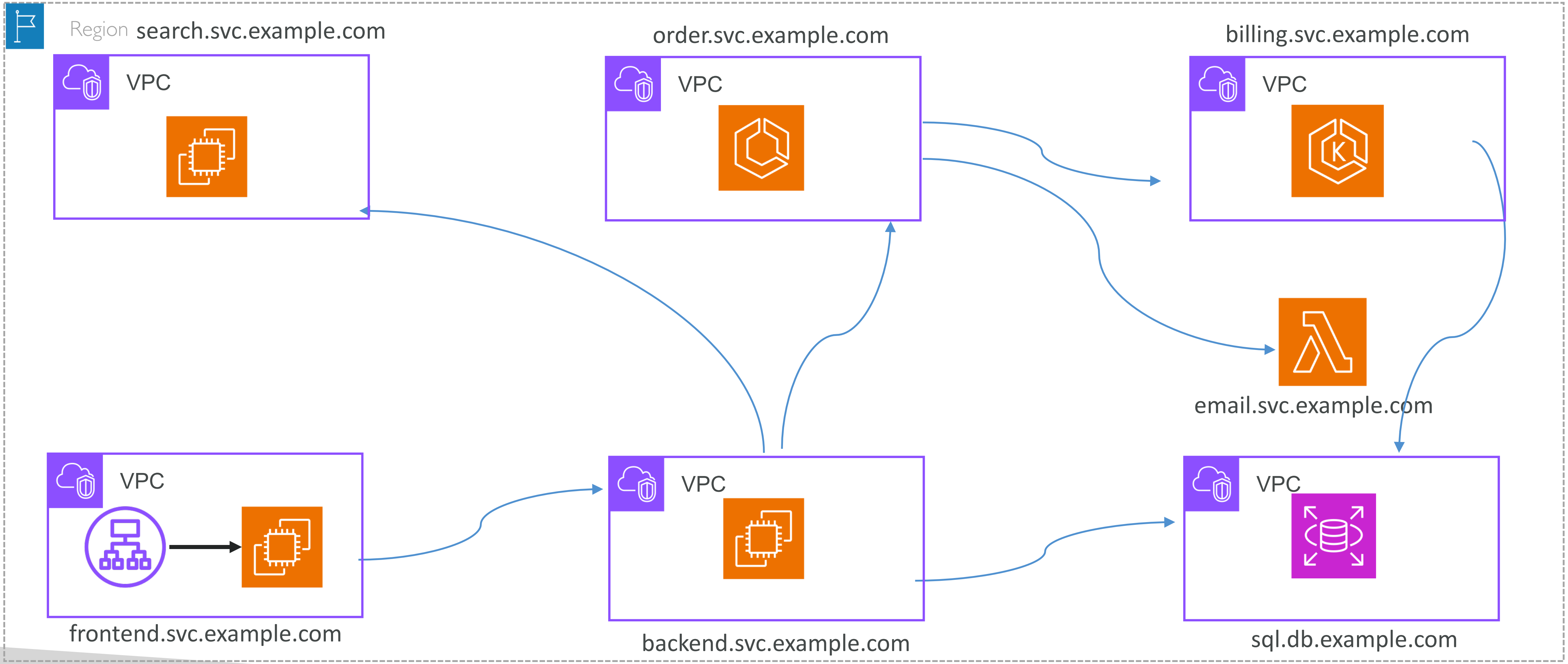
Microservices application architecture



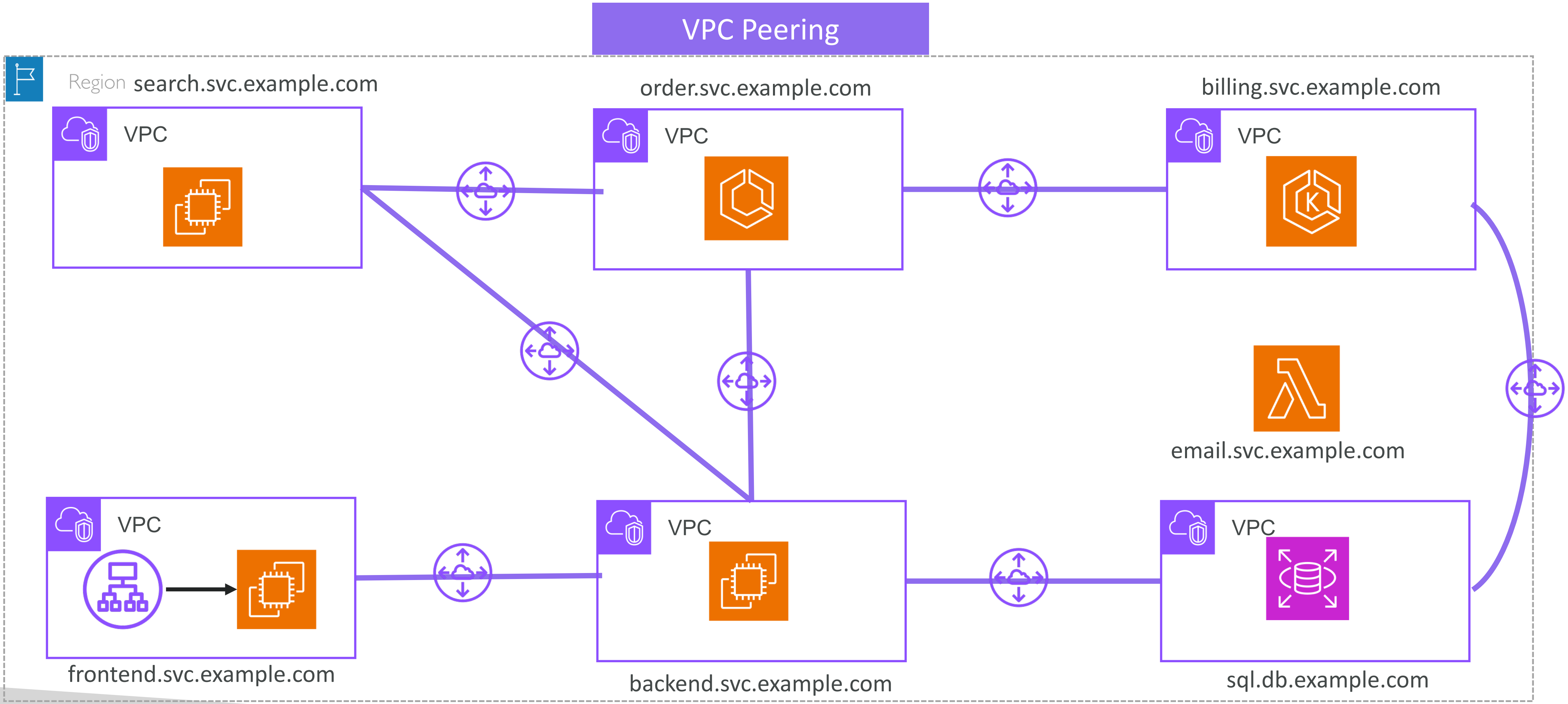
Microservices application architecture



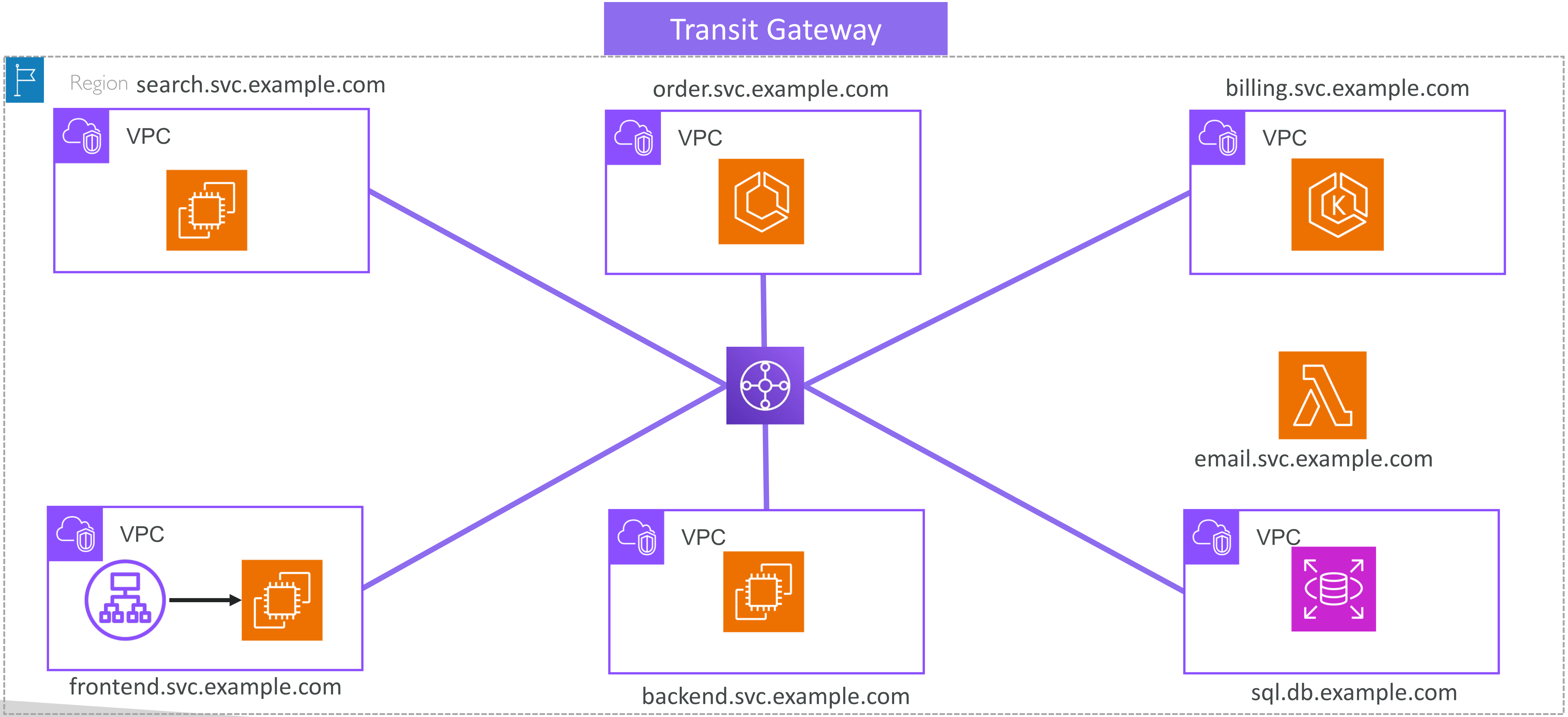
Without VPC Lattice.. Inter-services communication



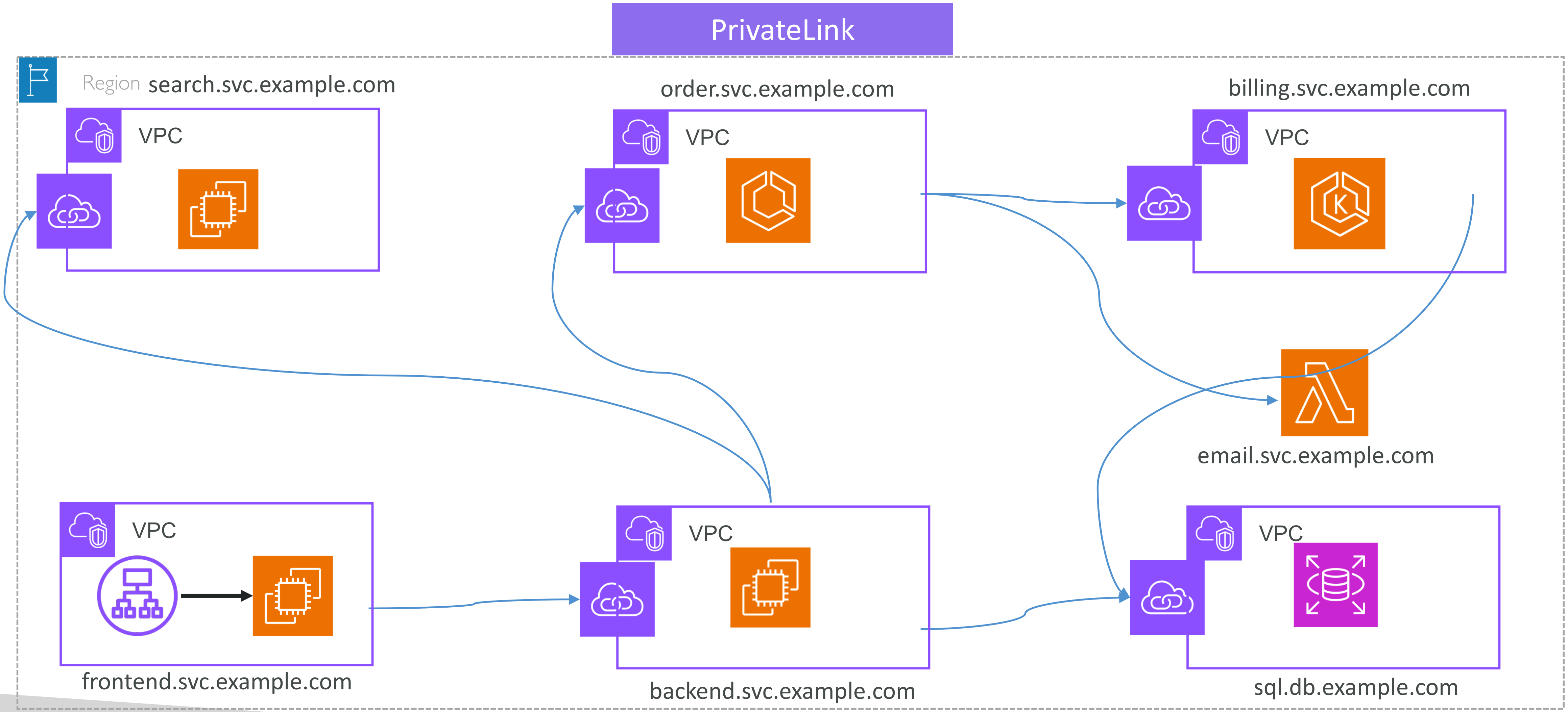
Without VPC Lattice.. Inter-services communication



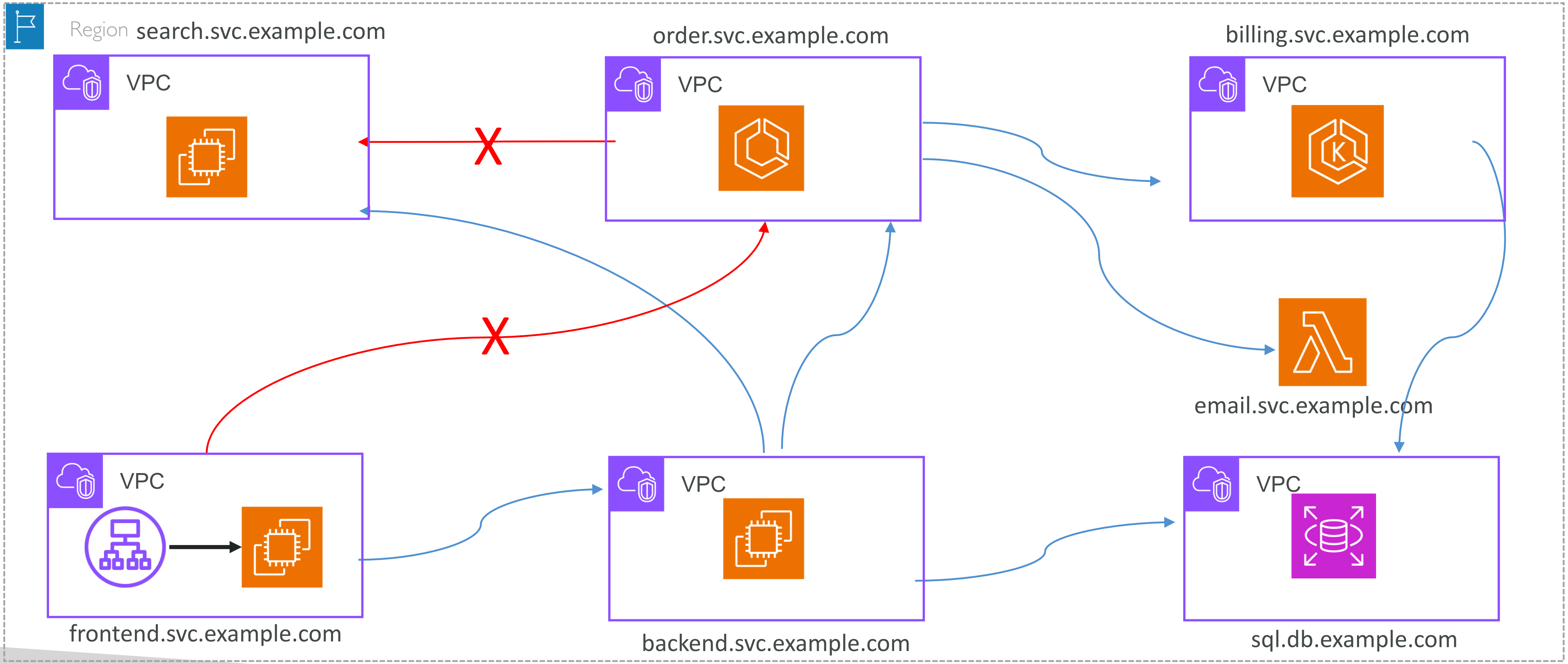
Without VPC Lattice.. Inter-services communication



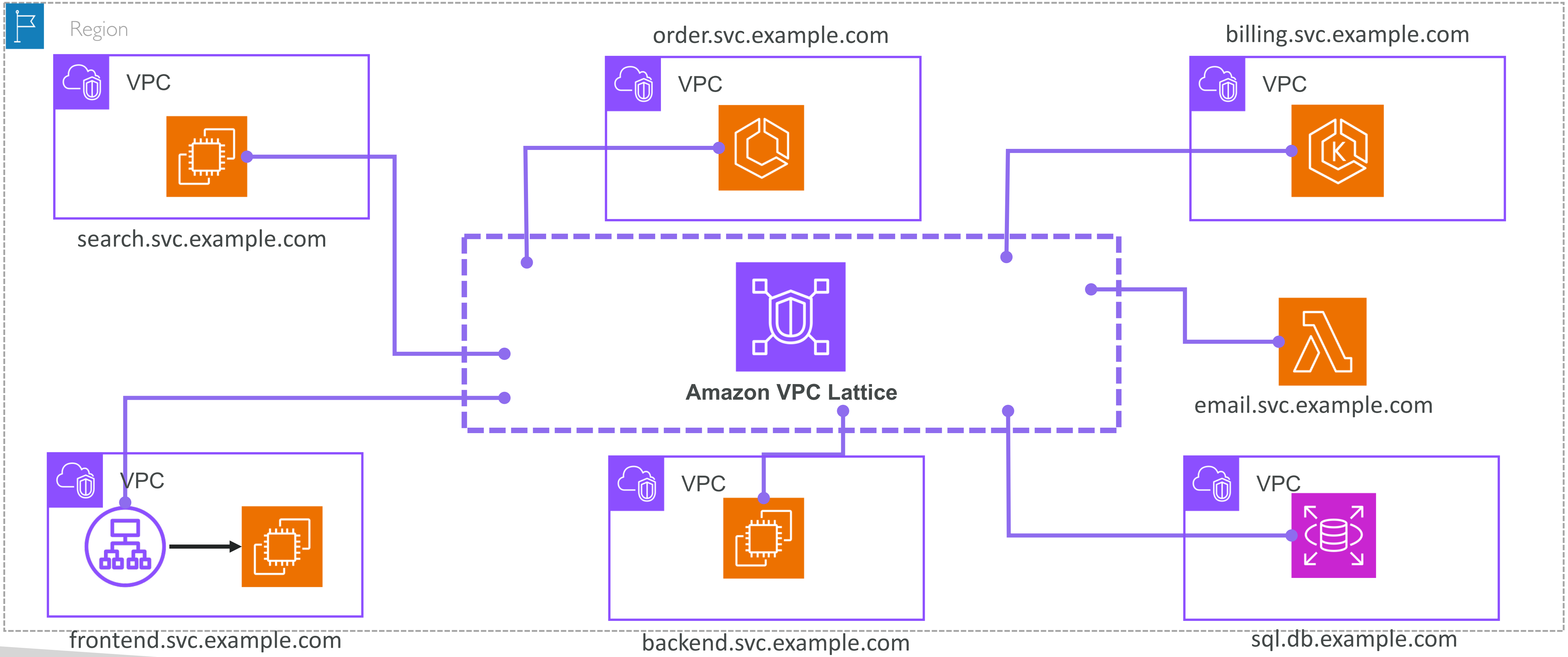
Without VPC Lattice.. Inter-services communication



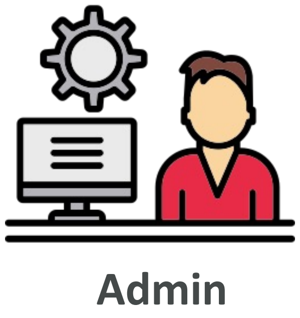
Without VPC Lattice.. Inter-services communication



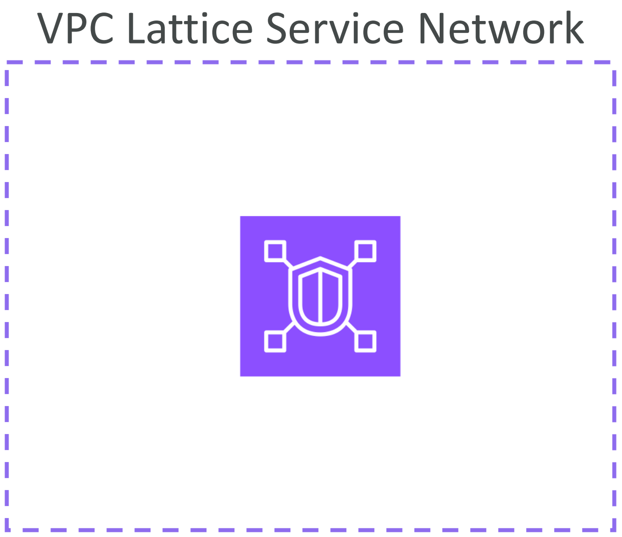
With VPC Lattice



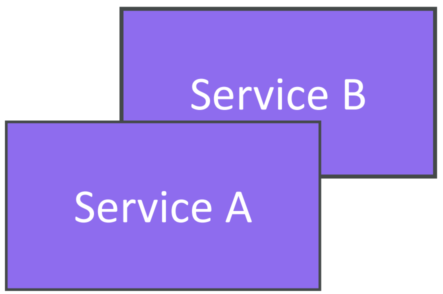
VPC Lattice responsibilities



- Create Service Network
- Define Access Control
- Associate Service Network to VPCs



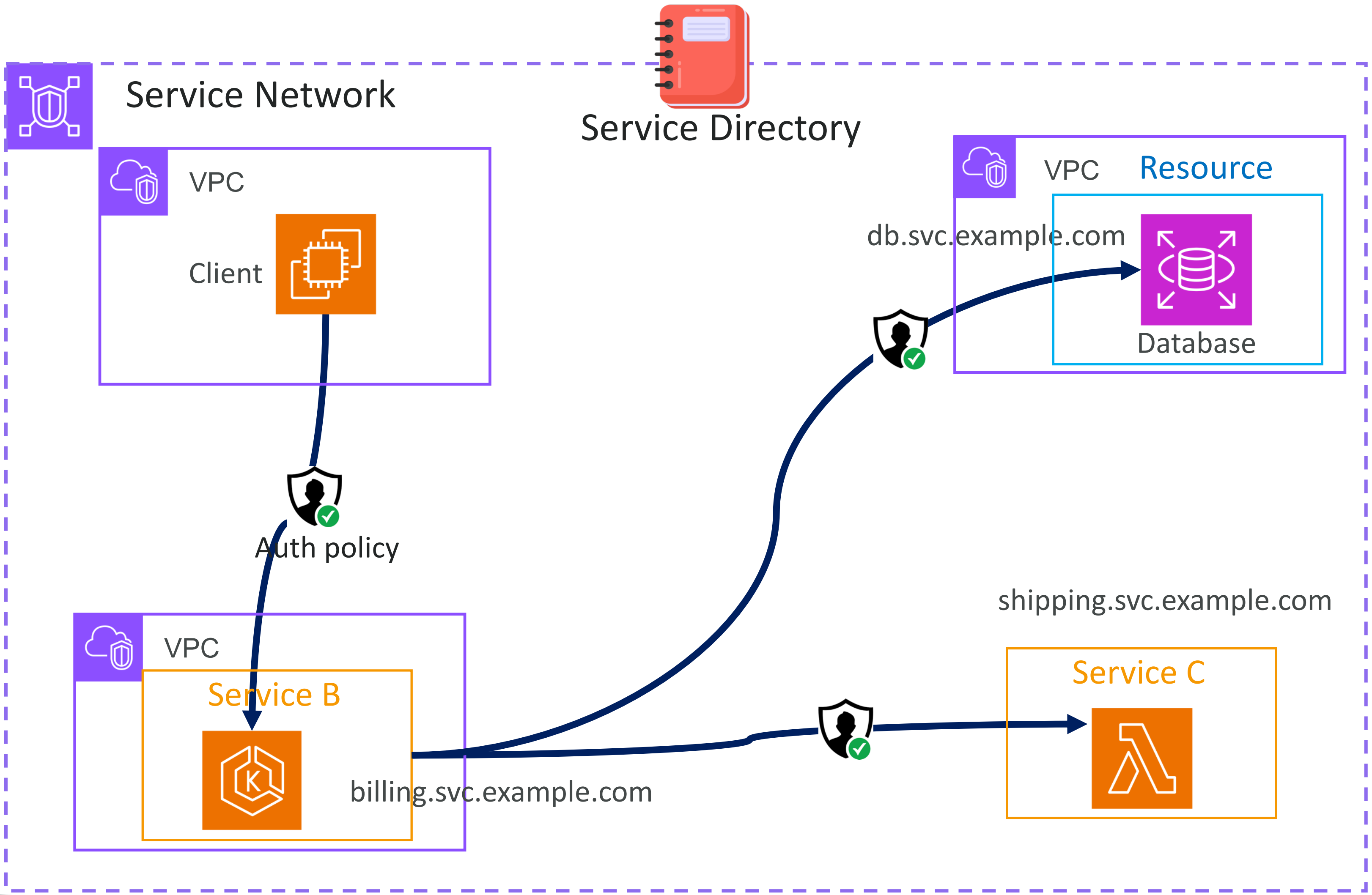
- Create Services
- Define traffic routing and authorization
- Associate Services to Service network



VPC Lattice components

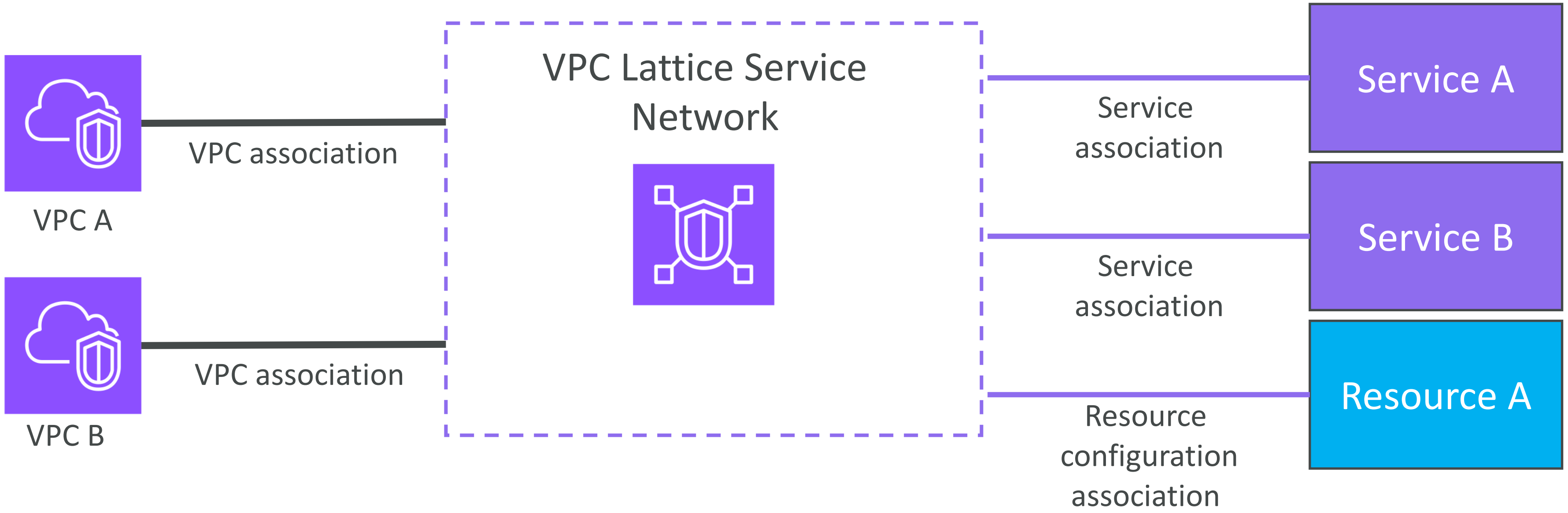
VPC Lattice components

- Service Network
- Service
- Resource
- Service Directory
- Auth Policies



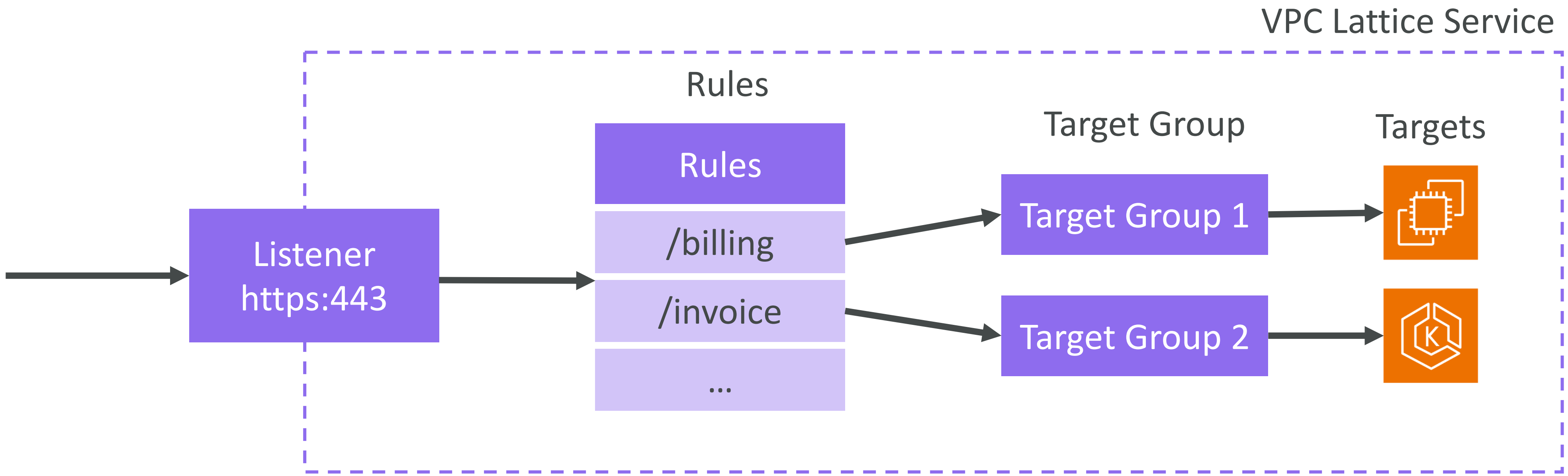
VPC Lattice - Service Network

A service network is a logical boundary for a collection of services and resource configurations.



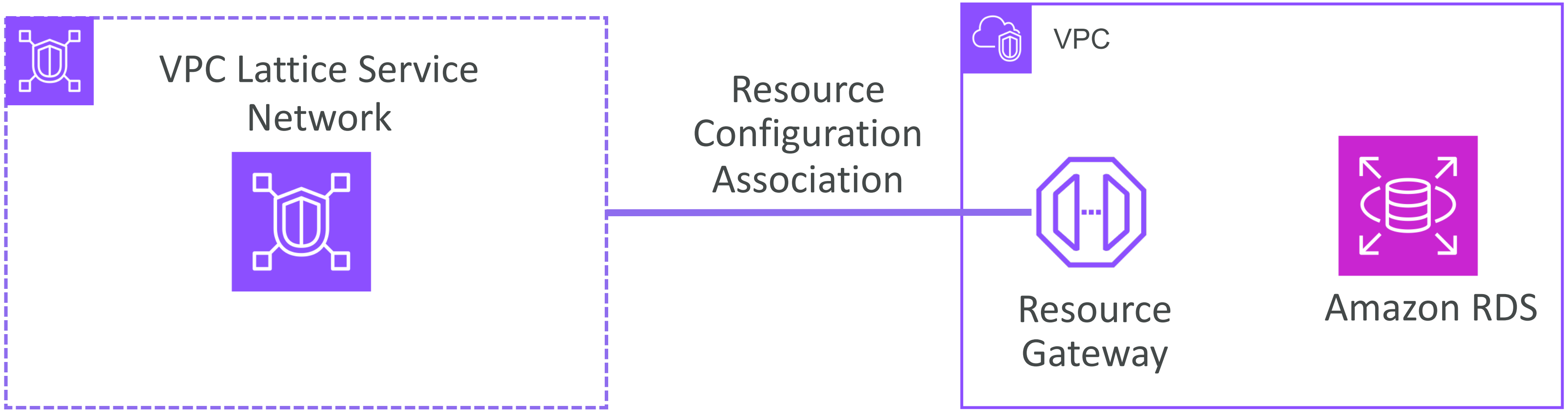
VPC Lattice - Service

- An independently deployable unit of software that delivers a specific task or function.
- A service can run on EC2 instances, ALB, ECS/EKS/Fargate containers, Lambda functions or IP address
- VPC Lattice service has target groups, listeners, and rules
- Target groups can have weights and Rules can have priorities and conditions like header match, method match or path match



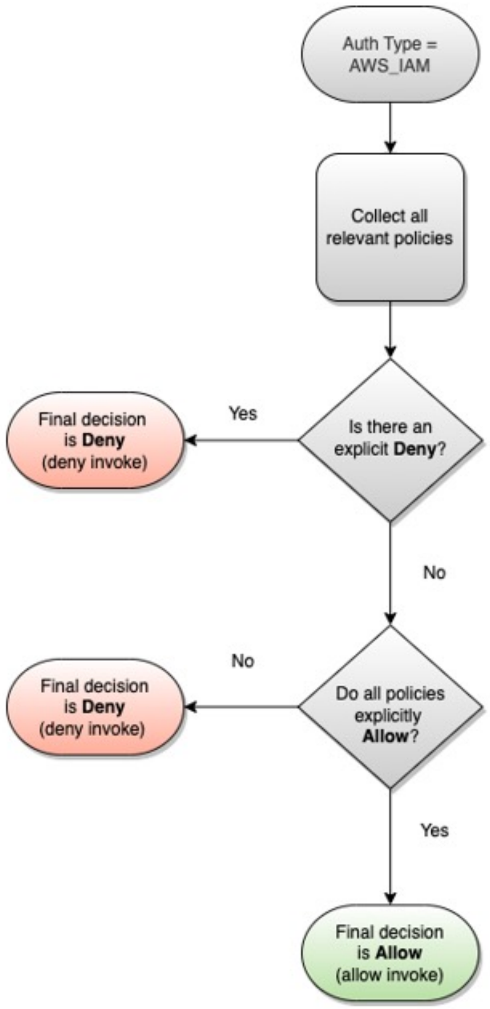
VPC Lattice – Resource

- A resource is an entity such as an Amazon RDS database, a cluster of nodes, an instance, an application endpoint, a domain-name target, or an IP address.
- Resource gateway is a point of ingress in which resources reside



VPC Lattice Auth policies

- Fine-grained authorization policies that can be used to define access to services.
- Auth policy can be attached to individual services or to the service network.
- Auth type can be None or AWS_IAM
- By default, all requests are implicitly denied when auth is AWS_IAM
- Authorization evaluation
  - Collect all IAM identity-based policies and auth policies
  - Requestor should have IAM allow permissions in their identity-based policy in their AWS account (IAM User, Role).
  - VPC lattice service network auth policy and/or VPC lattice service auth policy should have explicit allow for the principal or None to allow the access



example auth policies

Allow access only from within AWS organization

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Principal": "*",
            "Action": "vpc-lattice-svcs:Invoke",
            "Resource": "*",
            "Condition": {
                "StringEquals": {
                    "aws:PrincipalOrgID": [
                        "o-123456example"
                    ]
                }
            }
        }
    ]
}
```

Allow only GET method access for a particular VPC lattice service to a particular IAM role

```
{
   "Version":"2012-10-17",
   "Statement":[
      {
         "Effect": "Allow",
         "Principal": {
            "AWS": [
               "arn:aws:iam::123456789012:role/rates-client"
            ]
         },
         "Action": "vpc-lattice-svcs:Invoke",
         "Resource": [
            "arn:aws:vpc-lattice:us-west-2:123456789012:service/svc-0123456789abcdef0/*"
         ],
         "Condition": {
            "StringEquals": {
               "vpc-lattice-svcs:RequestMethod": "GET"
            }
         }
      }
   ]
}
```

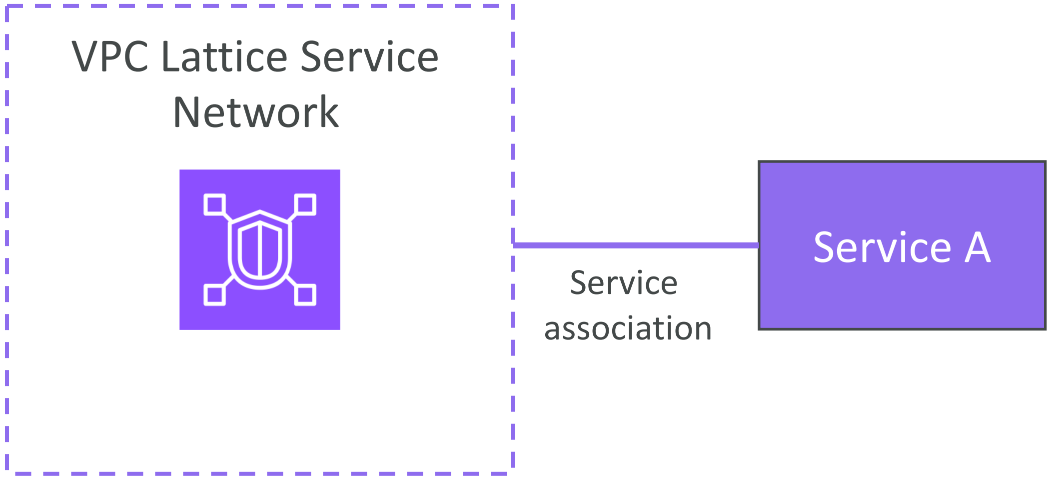
VPC Lattice network associations

VPC Lattice network associations

- Service association
- Resource Configuration association
- VPC association
- VPC endpoint association

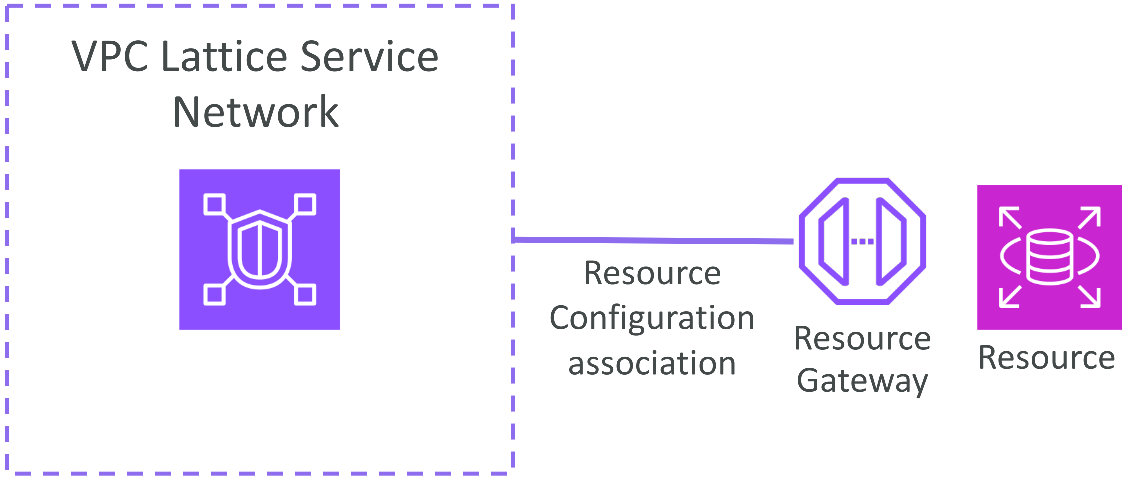
Service association

- Service is discoverable and reachable from VPC Lattice network when you associate a service with the VPC lattice network
- Service can be in the same AWS account or can be shared using RAM from another AWS account



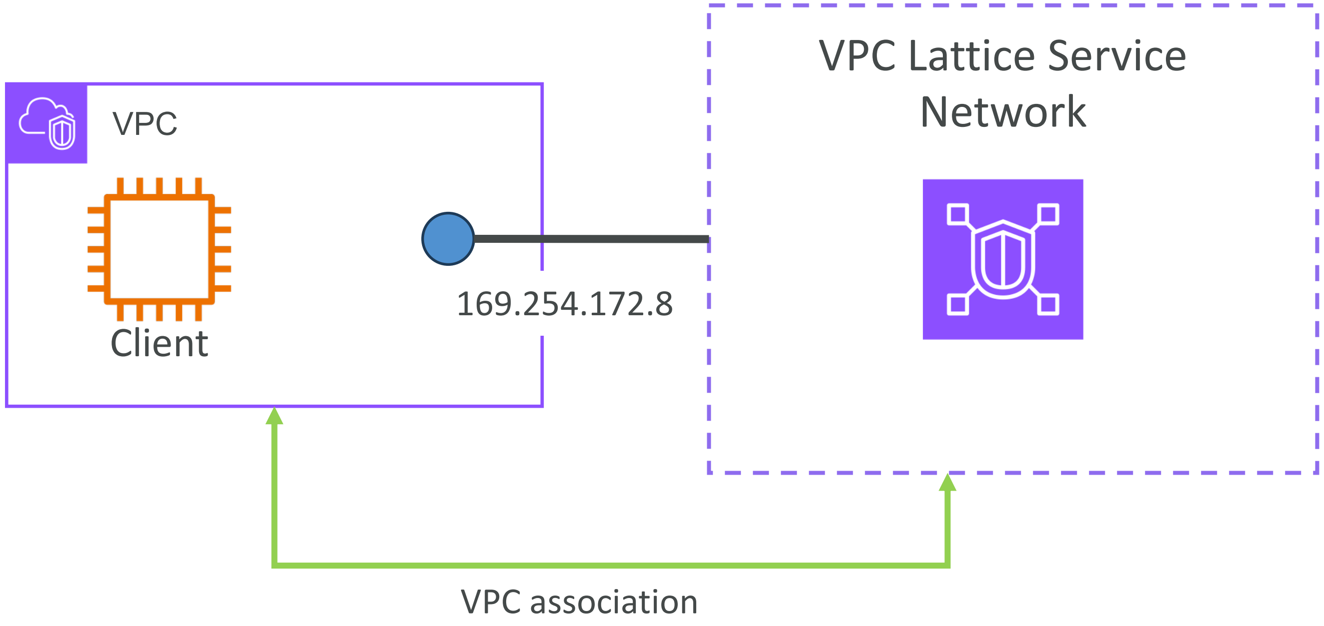
Resource configuration association

- Resource is discoverable and reachable from VPC Lattice network when you associate a resource configuration with the VPC lattice network
- Resource configuration can be in the same AWS account or can be shared using RAM from another AWS account



VPC association

- Clients in the consumer VPC can access the VPC Lattice network over the link-local address 169.254.171.x



VPC association

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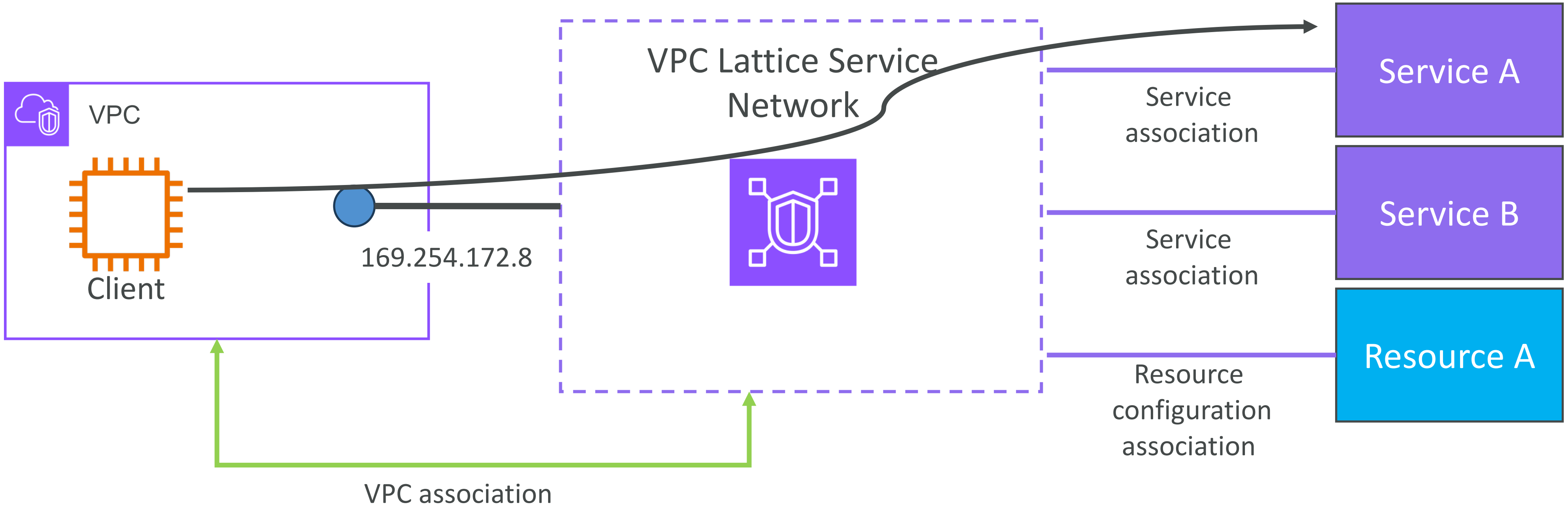
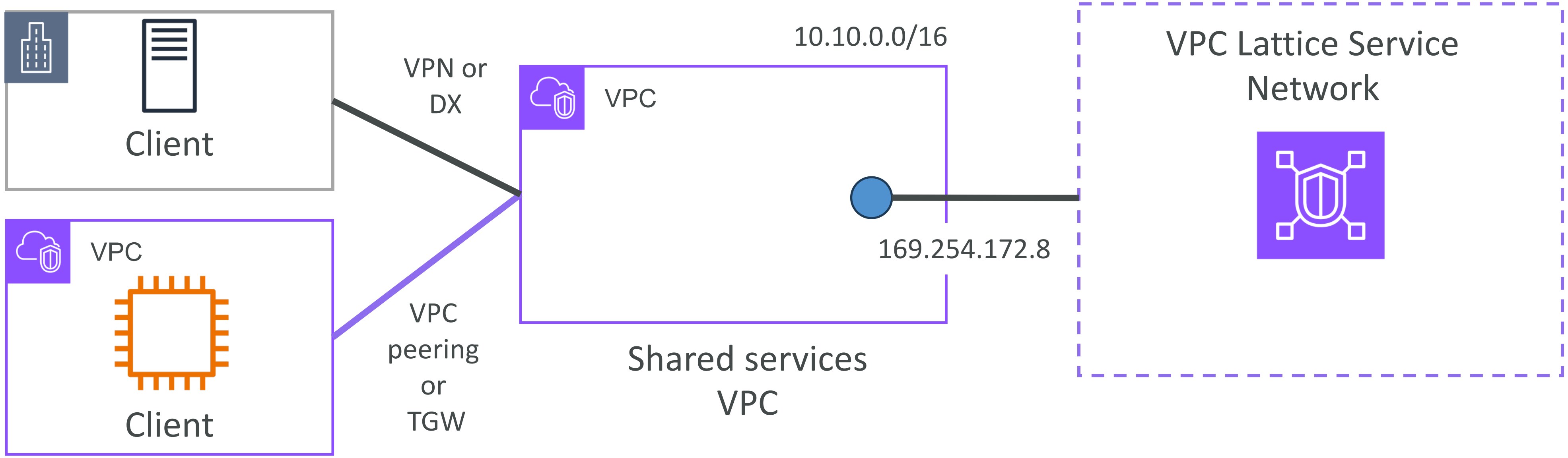
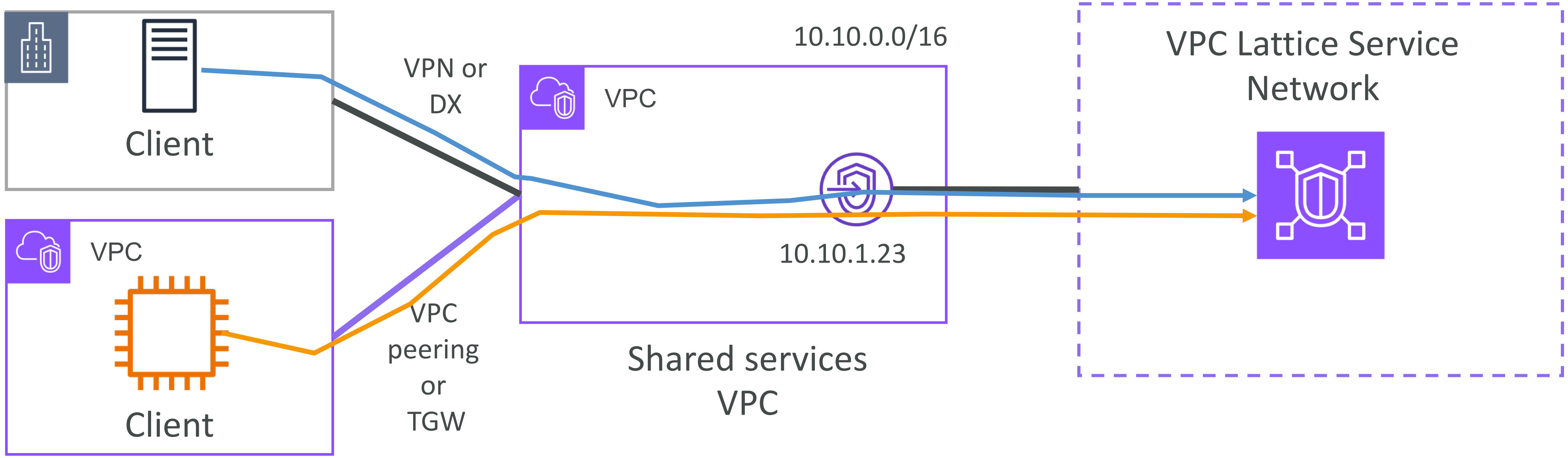


VPC endpoint association

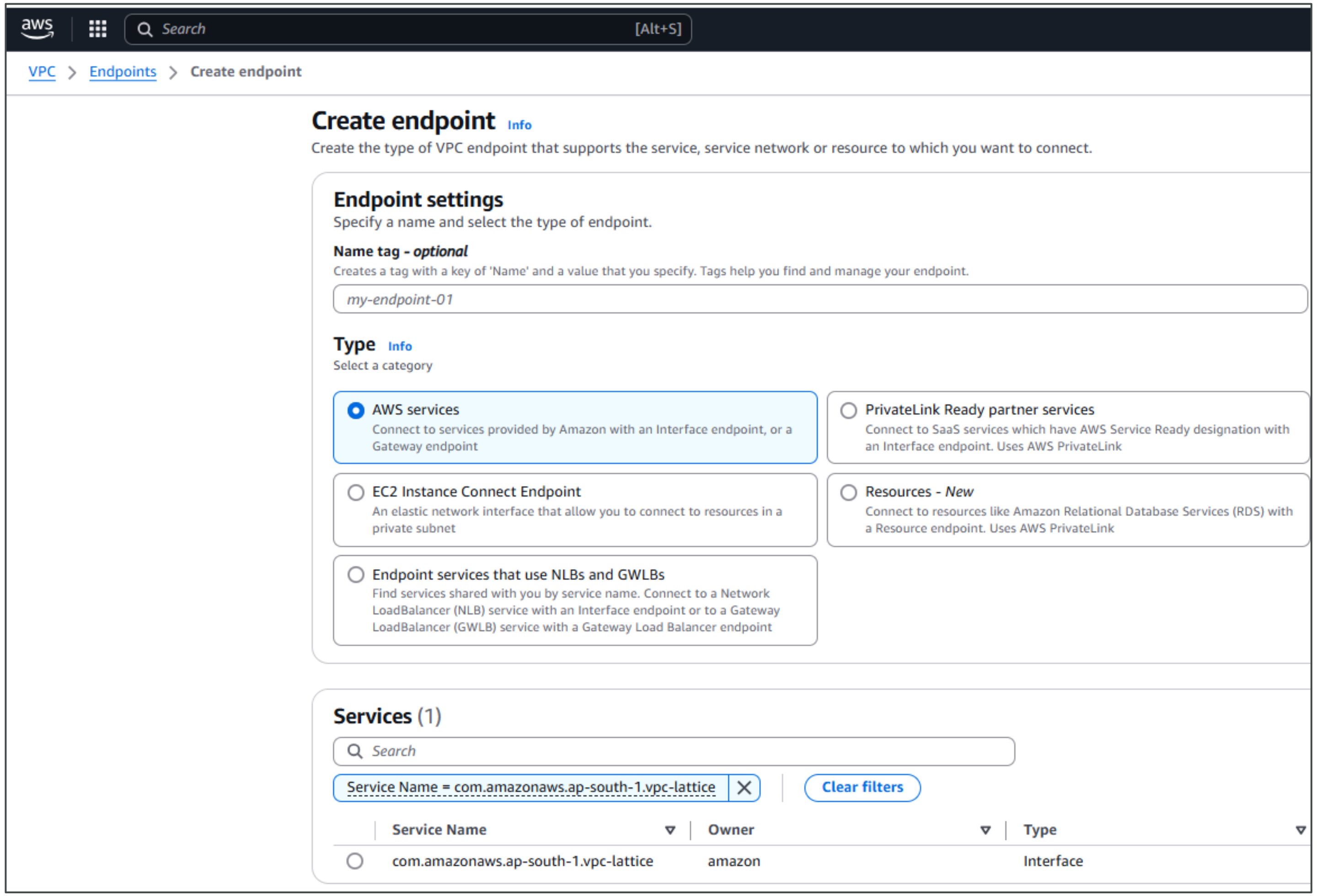


VPC endpoint association

- A VPC endpoint of type **service network** connects a VPC to a service network.
- Client traffic that comes from outside the VPC over a VPC peering connection, Transit Gateway, Direct Connect, or VPN can use the VPC endpoint to reach lattice services.
- When you create a VPC endpoint in a VPC, IPs from the VPC (and not link local IPs) are used to establish connectivity to the service network.

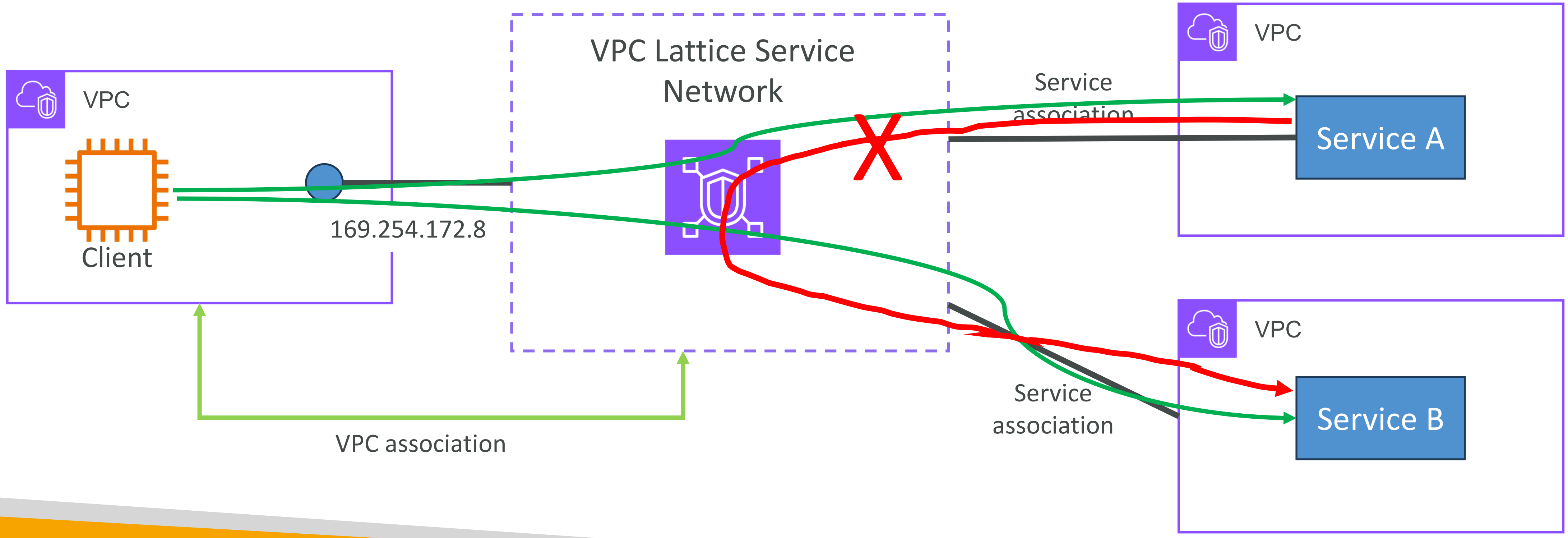


VPC endpoint for lattice service network



Note

- If the VPC in which Service is hosted is not associated with the Service network over VPC association, then that Service can not initiate the request for other Service. It can only respond to the requests.



Note

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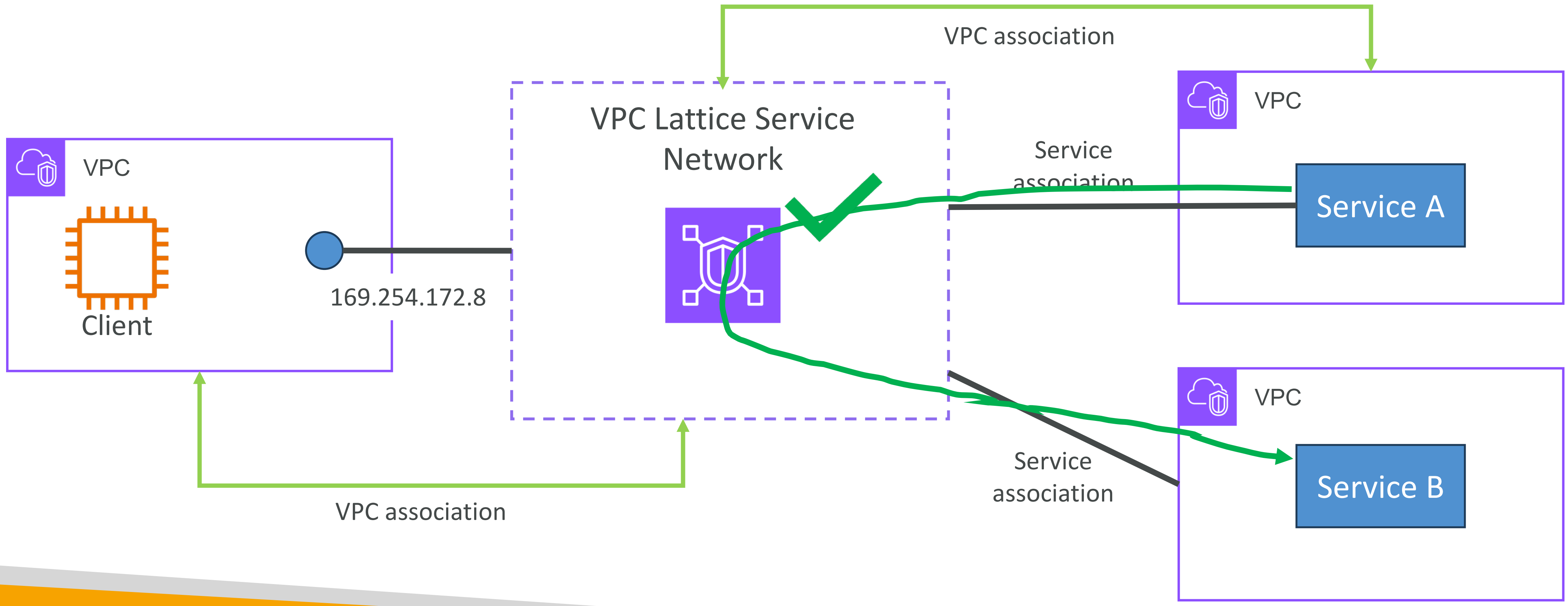
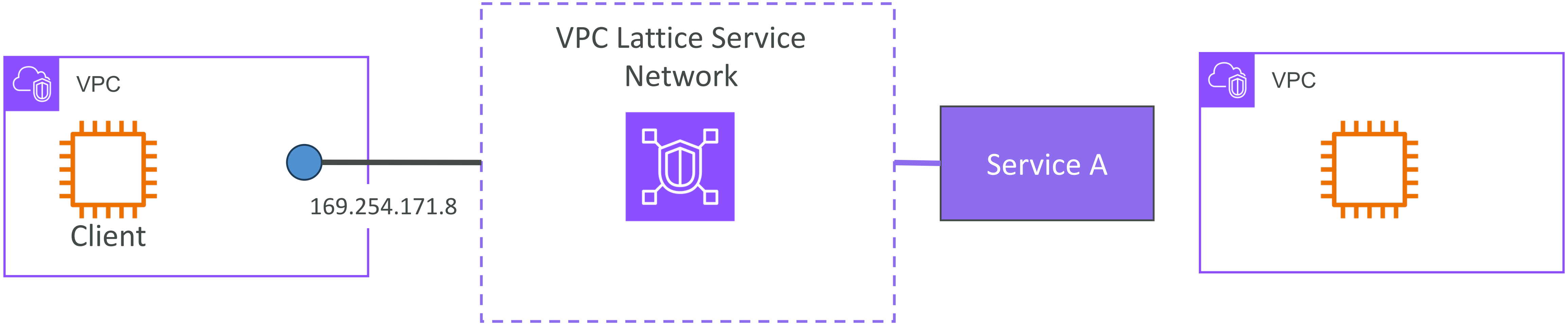


VPC Lattice traffic flow

VPC Lattice traffic flow

1 DNS query

- DNS query for VPC lattice service DNS or DNS query to Route53 for custom DNS
- Returns link-local address 169.254.171.x (This address is only accessible from within the VPC)

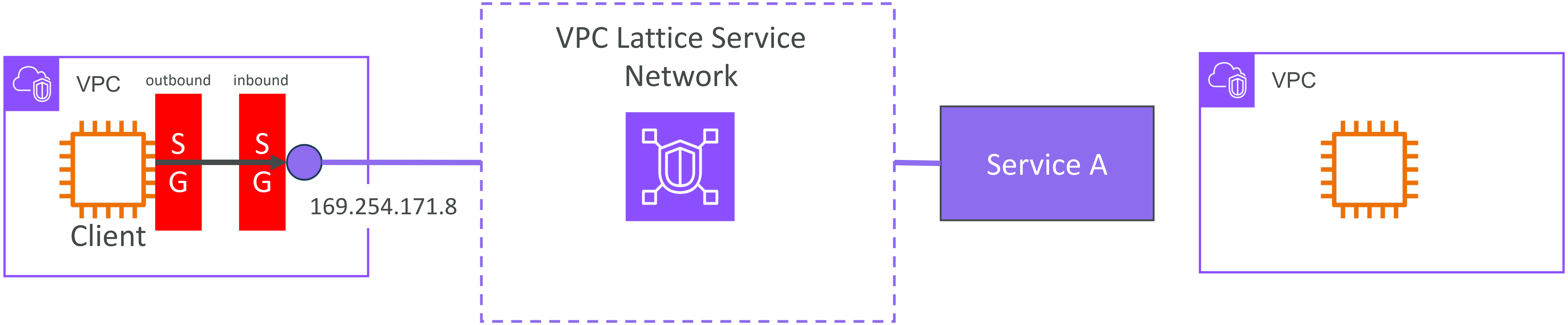


- **VPC Lattice service DNS:** servicea.xxx.xxx.vpc-lattice.svcs.ap-south-1.on.aws
- **Custom domain name:** servicea.example.com

VPC Lattice traffic flow

2 **Check Security groups**

- Outbound security group for EC2 to allow traffic for VPC lattice prefix list or 0.0.0.0/0
- Inbound security group for VPC lattice VPC association to allow traffic from EC2 instance Private IP

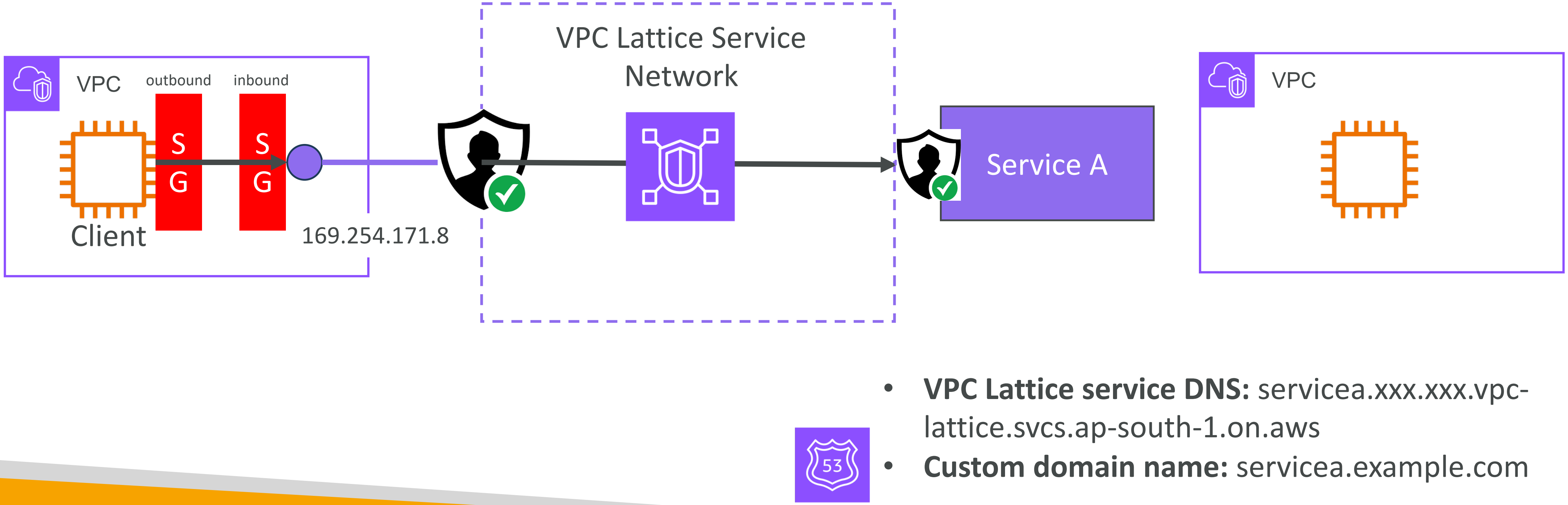


- **VPC Lattice service DNS:** servicea.xxx.xxx.vpc-lattice.svcs.ap-south-1.on.aws
- **Custom domain name:** servicea.example.com

VPC Lattice traffic flow

3 **Check VPC Lattice Auth policy for Service Network and Service**

- Validate if traffic is allowed based on service network auth policy and Service auth policy
- If auth policy is disabled (None) then the traffic is allowed by default.

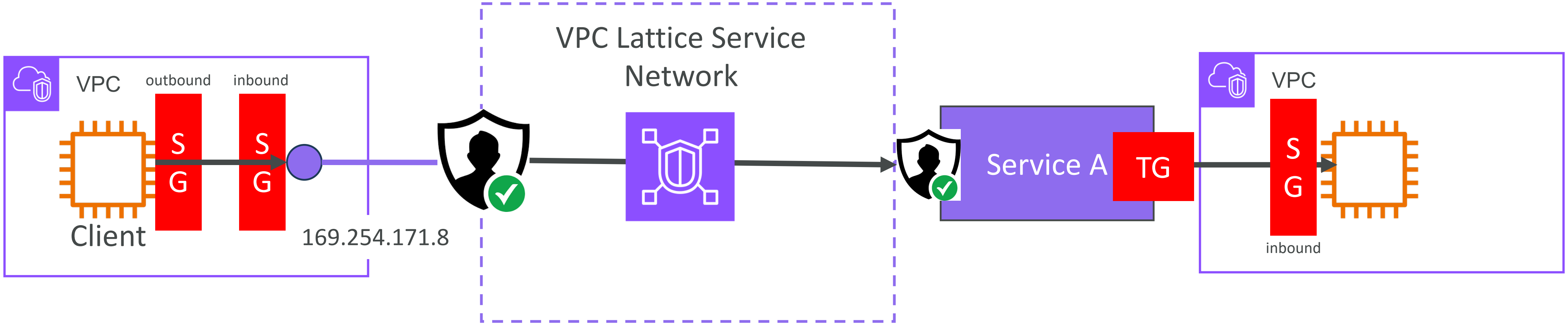


- **VPC Lattice service DNS:** servicea.xxx.xxx.vpc-lattice.svcs.ap-south-1.on.aws
- **Custom domain name:** servicea.example.com

VPC Lattice traffic flow

4 **Check Security group for the target to allow the incoming traffic**

- If the target is EC2 instance, ALB (EKS/ECS) then inbound security group rule should allow the traffic from link local address (169.254.x.x) or VPC Lattice Managed Prefix list

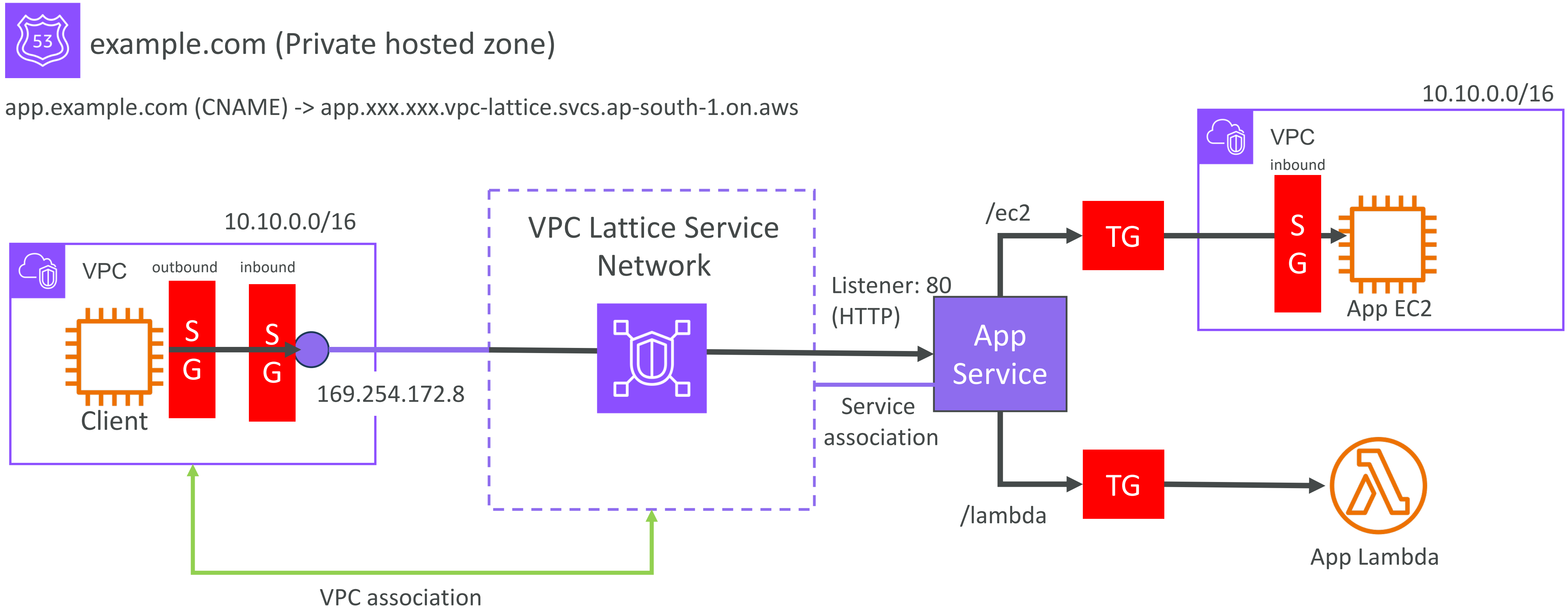


NO ROUTE TABLES CHANGES

- **VPC Lattice service DNS:** servicea.xxx.xxx.vpc-lattice.svcs.ap-south-1.on.aws
- **Custom domain name:** servicea.example.com

VPC Lattice exercise

VPC Lattice exercise



VPC Lattice exercise steps

1. Create client VPC 10.0.0.0/16 and a Public subnet
2. Create an application VPC 10.0.0.0/16 and a Public subnet
3. Create a Route53 Private Hosted zone example.com and associate it with client VPC. Enable DNS settings for the client VPC.
4. Launch client EC2 instance in client VPC. SG to allow SSH from anywhere.
5. Launch App EC2 instance in the application VPC. SG to allow SSH, HTTP from anywhere.
6. Configure App EC2 instance by installing a web server (port 80). Test web server and remove HTTP rule from the security group (we want to treat this instance as a private instance)
7. Create an App lambda function with default code to return "hello" message.
8. Create a Lattice target group and add ec2 instance as a target
9. Create another lattice target group and add lambda function as a target

VPC Lattice exercise steps

10. Create VPC lattice service with a custom domain name (app.example.com), add listener (80), add one rule for /lambda pointing to lambda target group and default rule to forward the traffic to ec2 target group.
11. Create security group in client VPC for VPC lattice VPC association. Allow inbound HTTP(80) from client VPC CIDR (10.0.0.0/16)
12. Create VPC lattice network
    - Add VPC lattice service that you just created
    - Add VPC association for client VPC, use the security group created above for VPC association.
13. Update App EC2 instance security group to allow inbound HTTP(80) from VPC lattice managed prefix list (pay attention for IPv4 and IPv6 prefix lists)
14. SSH into client EC2 instance and try accessing VPC lattice service using service default DNS endpoint -> Should work
15. In Route53 PHZ create a record app.example.com CNAME pointing to VPC lattice service DNS
16. From client EC2 instance try access app.example.com/ -> Should work

Try this on your own

See if you access lattice service from the App EC2 instance

- At this point from App EC2 instance you cannot access VPC lattice services. This is because application VPC is not associated with the VPC lattice network.
- To allow this communication, create a new Security Group in the application VPC to allow HTTP(80) from VPC CIDR (10.0.0.0/16) and create a new VPC association for this VPC in the VPC lattice network. After this, from App EC2 instance you should be able to access VPC lattice service using VPC lattice service DNS.
- Further you can also associate R53 PHZ with the application VPC and then you should be able to access VPC lattice service with custom domain name i.e. app.example.com

Cleanup

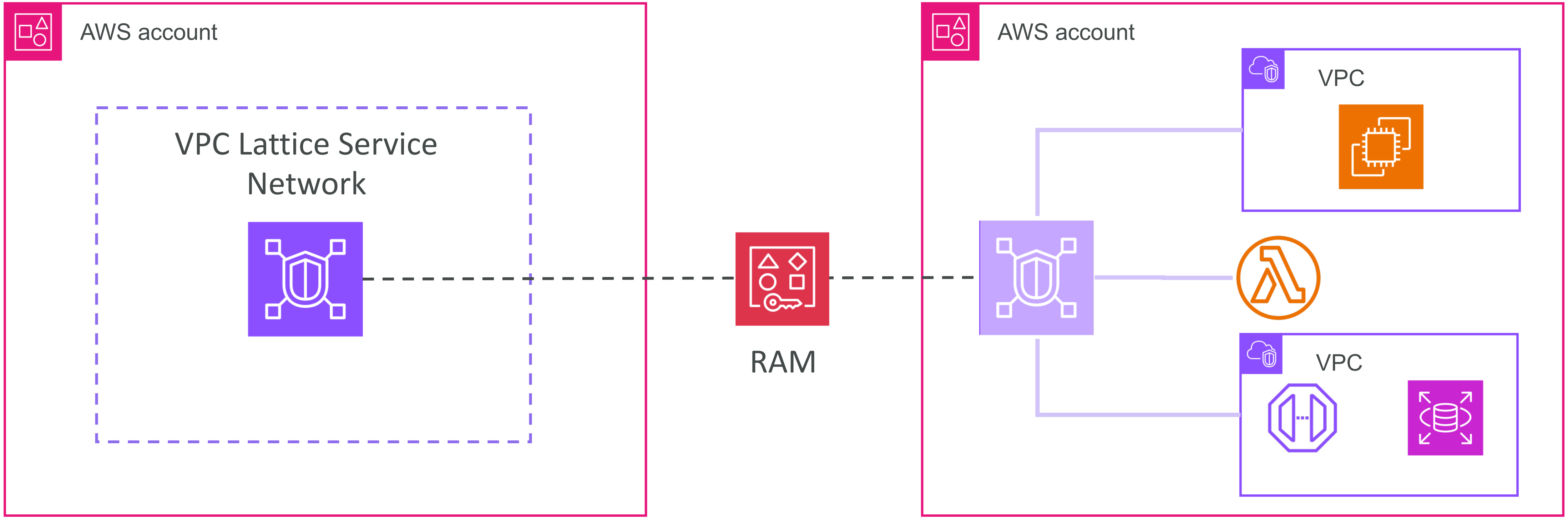
1. Terminate both the EC2 instances.
2. Delete the Lambda function.
3. In the VPC lattice network - Delete the Service association and VPC associations.
4. Delete VPC lattice service
5. Delete VPC lattice network
6. Delete VPC lattice target groups
7. Delete both the VPCs
8. Delete Route53 Private Hosted Zone

VPC Lattice features

- Connectivity – Cross VPCs and Cross AWS Accounts
- Protocols – HTTP, HTTPS, gRPC for lattice services and TCP/TLS for VPC lattice resources
- Request routing – Path based, Method, Weighted
- Security – IAM authorization, Security groups
- Targets – EC2 instances, Lambda functions, IP address, ALB/NLB
  - EKS services can be registered with AWS Gateway API controller
  - ECS services can be registered using ALB/NLB
- VPC lattice service, resource and network sharing with RAM
- NAT and NAT64 for supporting overlapping CIDR and IPv4 ⟷ IPv6 traffic

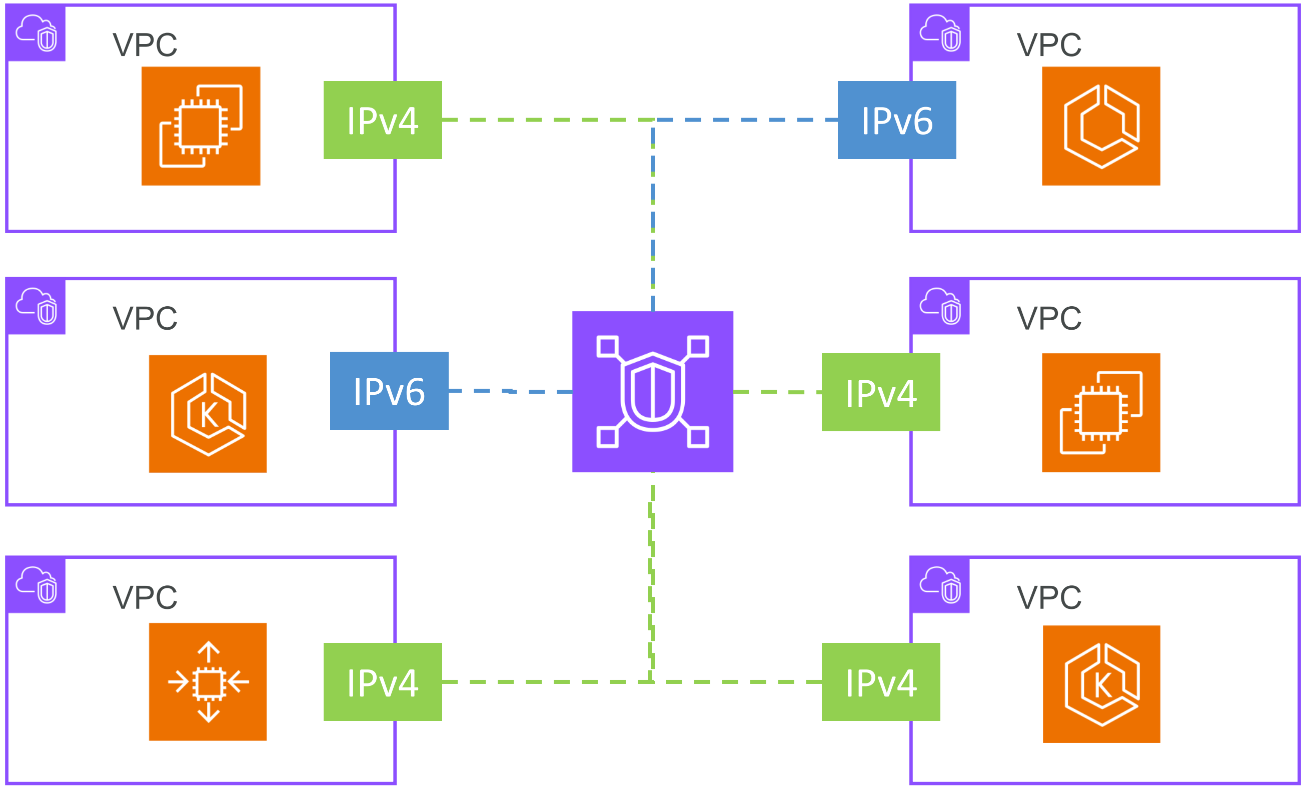
VPC Lattice – Sharing with RAM

AWS Resource Access Manager (RAM) : Share Service networks, services, and resource configurations



VPC Lattice – Overlapping CIDRs, IPv6

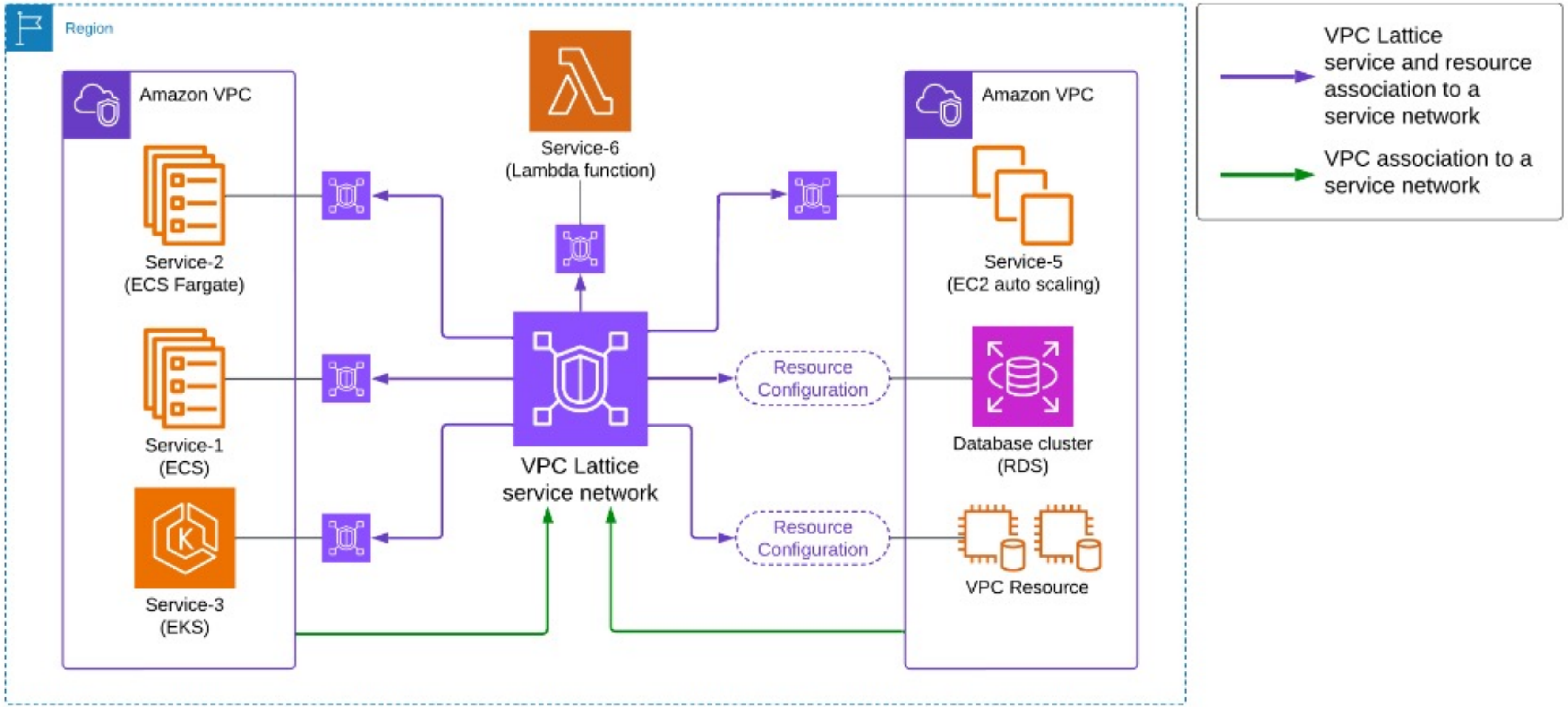
- VPCs can have overlapping CIDRs
- Supports IPv4 and IPv6 traffic
- VPC lattice performs the NAT/NAT64 to allow
  - Overlapping CIDRs
  - IPv4 to IPv6 traffic
  - IPv6 to IPv4 traffic



VPC Lattice common architectures

VPC Lattice common architecture patterns

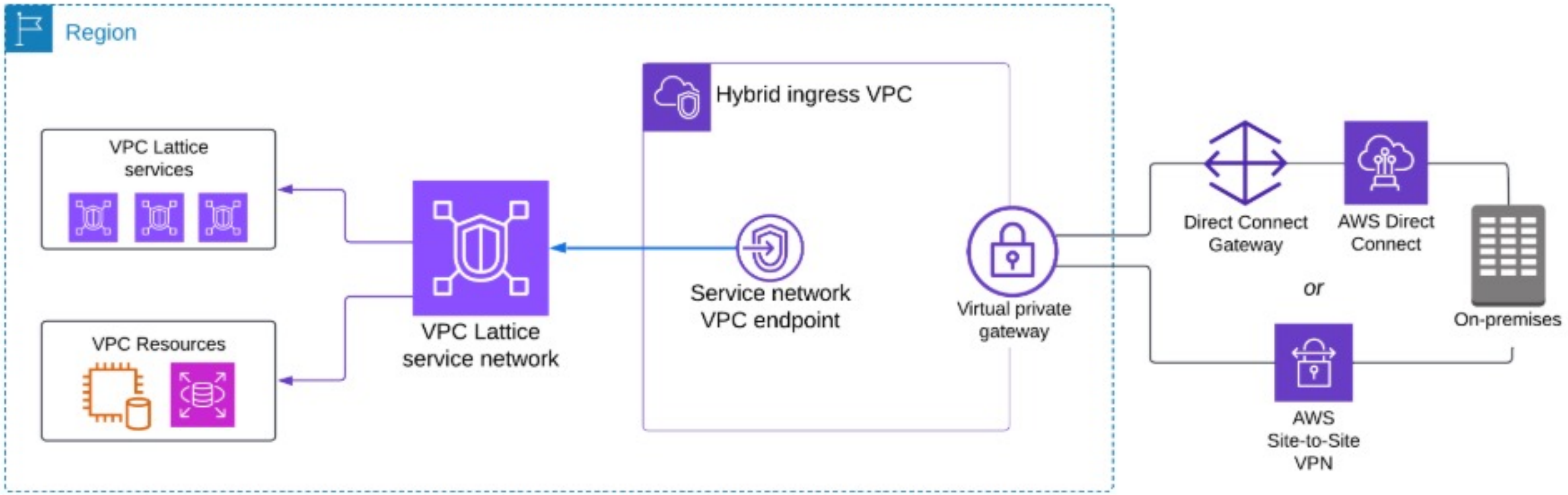
- Connectivity between applications within the VPC



Reference: https://aws.amazon.com/blogs/networking-and-content-delivery/amazon-vpc-vattice-modernize-and-simplify-your-enterprise-network-architectures/

VPC Lattice common architecture patterns

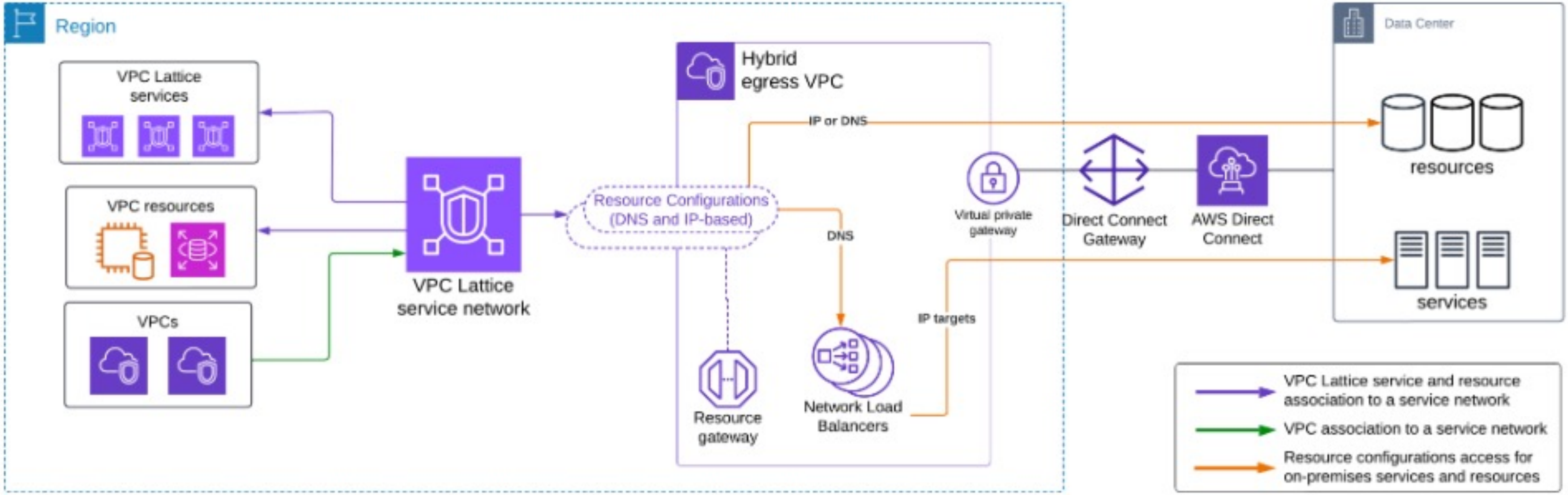
- Connectivity for accessing VPC lattice service in AWS from on-premises network



Reference: https://aws.amazon.com/blogs/networking-and-content-delivery/amazon-vpc-vattice-modernize-and-simplify-your-enterprise-network-architectures/

VPC Lattice common architecture patterns

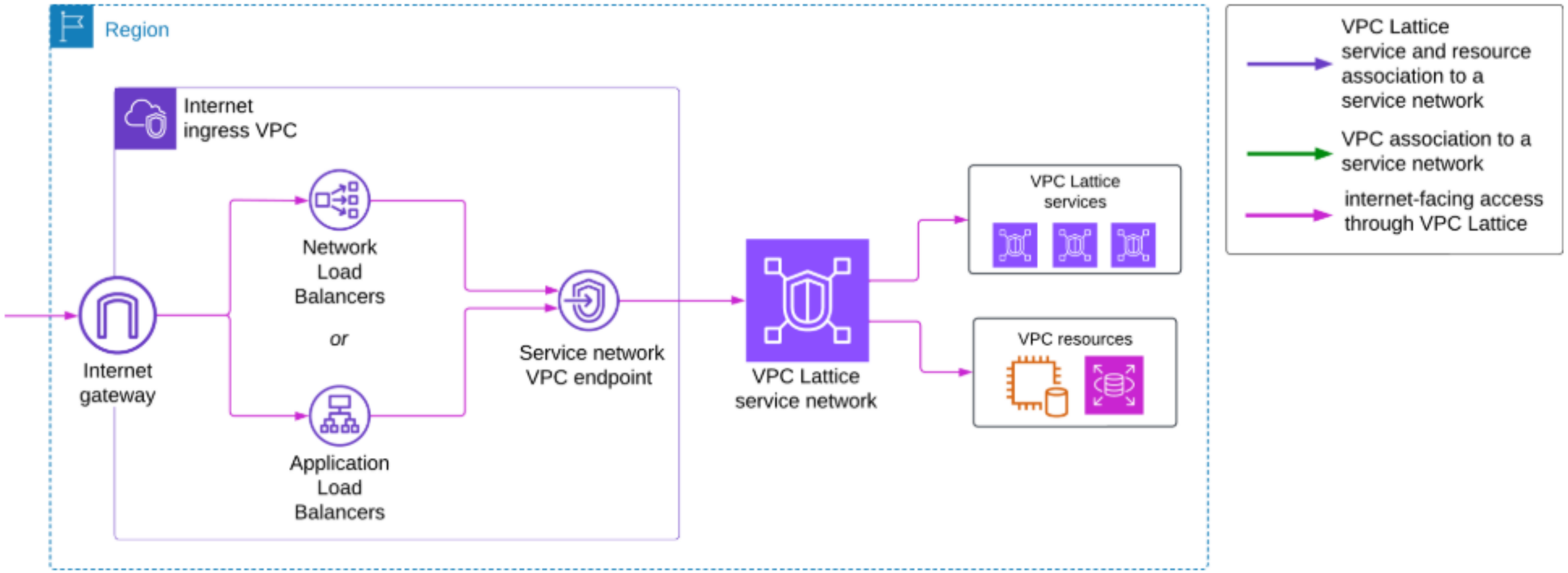
- Connectivity for accessing on-premises application from AWS



Reference: https://aws.amazon.com/blogs/networking-and-content-delivery/amazon-vpc-vattice-modernize-and-simplify-your-enterprise-network-architectures/

VPC Lattice common architecture patterns

- Connectivity for accessing VPC lattice application from Internet



Reference: https://aws.amazon.com/blogs/networking-and-content-delivery/amazon-vpc-vattice-modernize-and-simplify-your-enterprise-network-architectures/

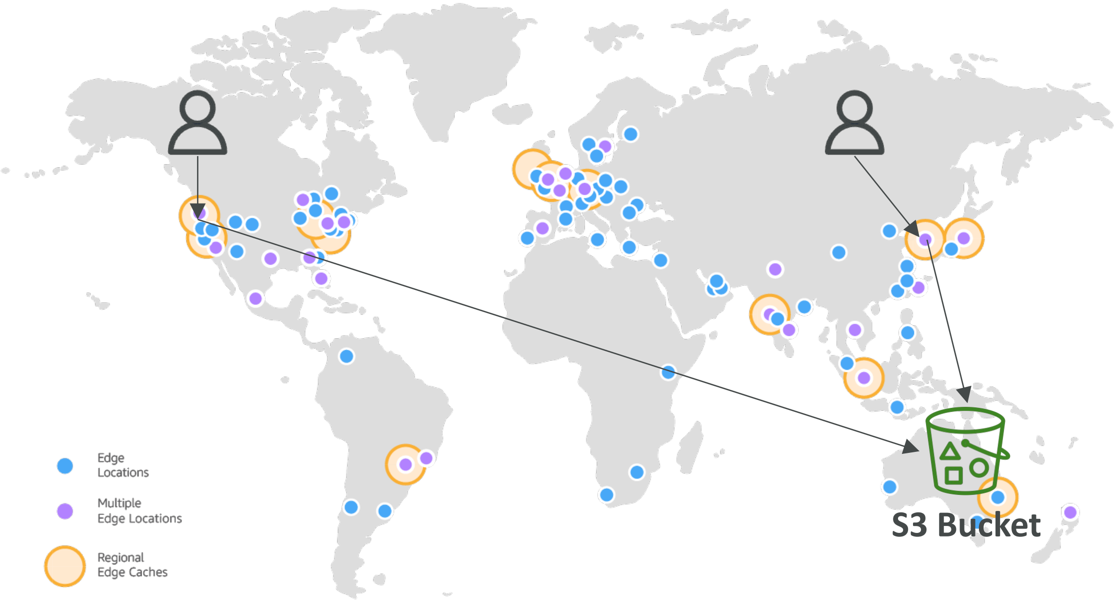
VPC Lattice - Summary

- Enables service-to-service communication across multiple VPCs and AWS accounts, eliminating the need for complex network configurations like peering or transit gateway.
- Supports targets such as EC2, IP, EKS/ECS, ALB/NLB, Lambda
- Dynamic routing rules allow traffic to be directed to specific service instances or groups based on HTTP headers, paths, or other conditions.
- Services registered in VPC Lattice can be accessed using custom DNS names which simplifies endpoint management and service discovery.
- Integration with **VPC endpoints** allows services outside the service network to securely connect to VPC Lattice, enabling hybrid cloud use cases and on-premises access.
- Utilizes AWS **IAM policies** to enforce fine-grained access controls for communication between services within the network (None & AWS_IAM)

AWS CloudFront – CDN Service

AWS CloudFront

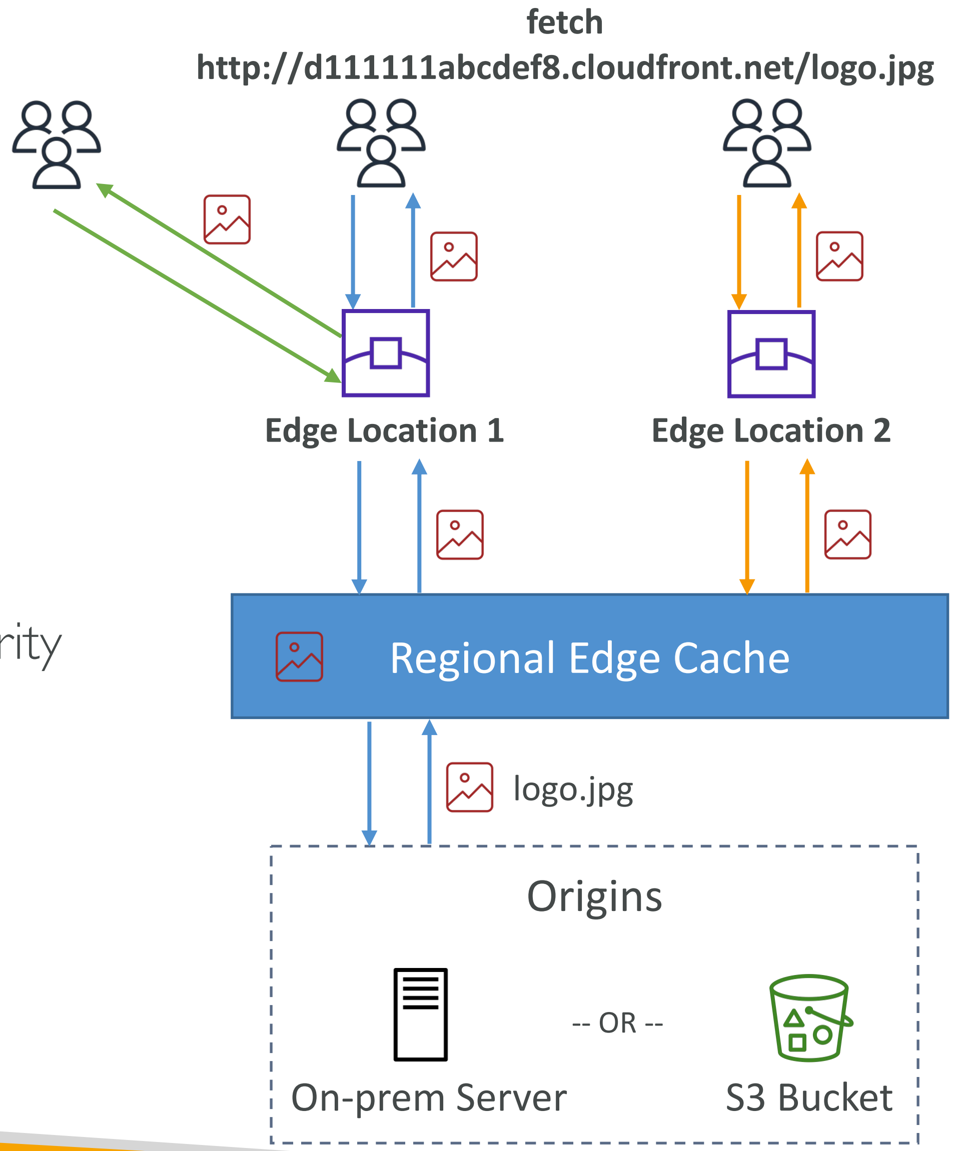
- Content Delivery Network (CDN)
- Improves read performance, content is cached at the edge
- 225+ Point of Presence globally (215+ Edge Locations & 13 Regional Edge Caches)
- Protect against Network and Application layer attacks (e.g., DDoS attacks)
- Integration with AWS Shield, AWS WAF, and Route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



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

Edge Locations & Regional Edge Caches

- Edge Locations
  - Serve content quickly/directly to users
  - Cache more popular content
- Regional Edge Caches
  - Serve content to Edge Locations
  - Cache less popular content that might suddenly find popularity
  - Larger cache than Edge Location (objects remain longer)
  - Improve performance, reduce the load on your origins
  - Dynamic content doesn't pass through it (directly to origin)



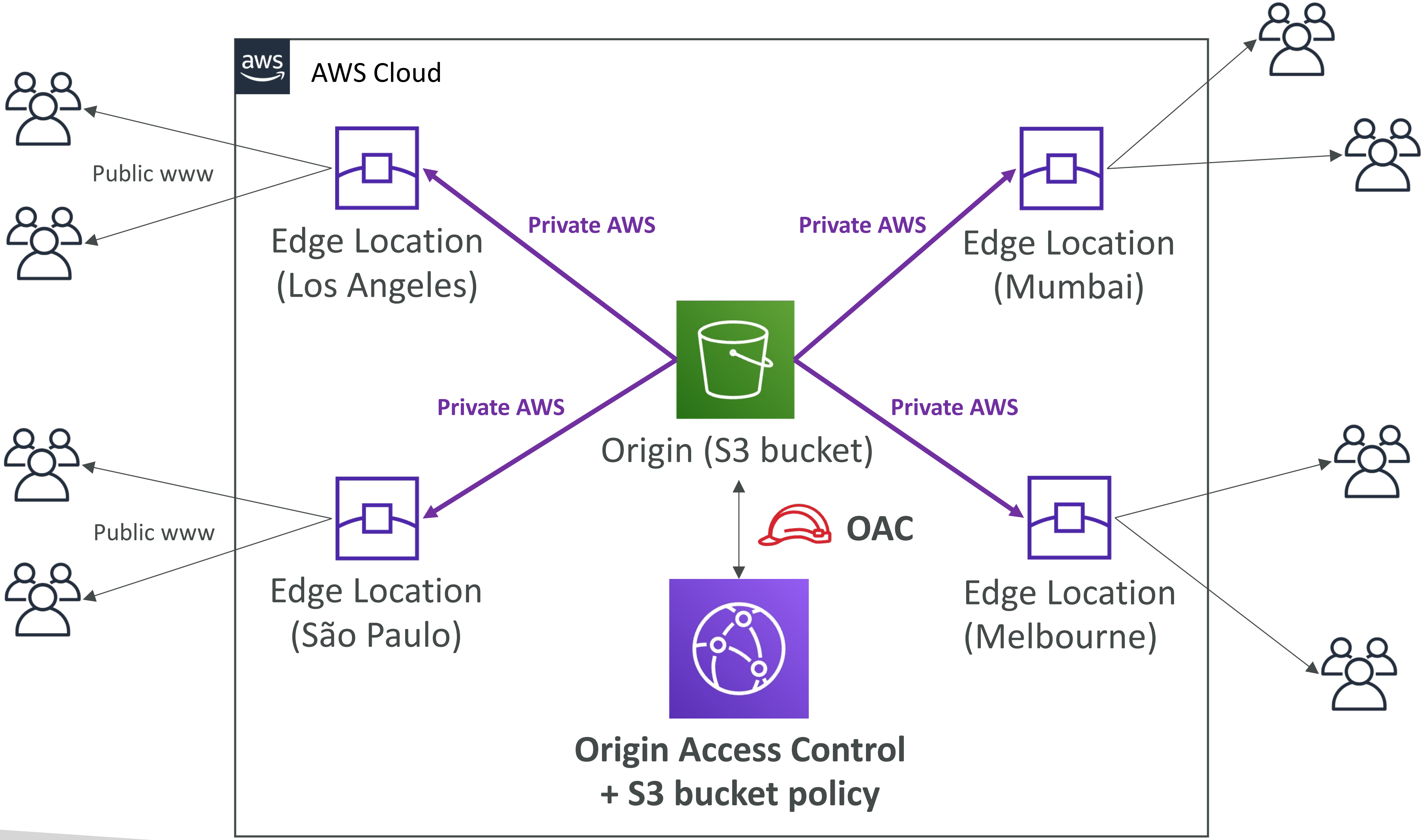
CloudFront Components

- Distribution
  - Identified by a domain (e.g., d111111abcdef8.cloudfront.net)
  - You can use this distribution domain name to access the website
  - You can also use Route53 CNAME (non-root) or Alias (root & non-root) which points to distribution's domain name
- Origin
  - Where actual contents resides (S3 Bucket, ALB, HTTP Server, API Gateway, etc.)
- Cache Behavior
  - Cache configurations (e.g., Object Expiration, TTL, Cache invalidations)

CloudFront – Origins

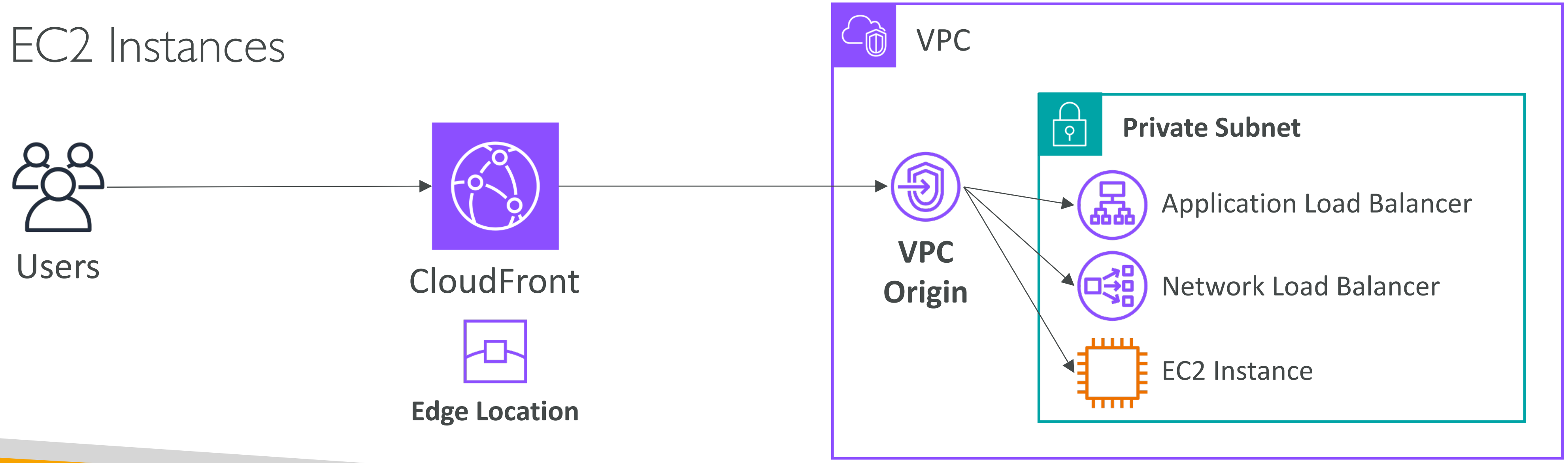
- S3 Bucket
  - For distributing files
  - For uploading files to S3 (using CloudFront as an ingres)
  - Enhanced security with CloudFront **Origin Access Control (OAC)**
- MediaStore Container & MediaPackage Endpoint
  - To deliver Video On Demand (VOD) or live streaming video using AWS Media Services
- VPC Origin
  - For applications hosted in VPC private subnets
  - Application Load Balancer / Network Load Balancer / EC2 Instances
- Custom Origin (HTTP)
  - API Gateway (for more control… otherwise use API Gateway Edge)
  - S3 Bucket configured as a website (enable Static Website hosting)
  - Any HTTP backend you want

CloudFront Origins – S3 as an Origin

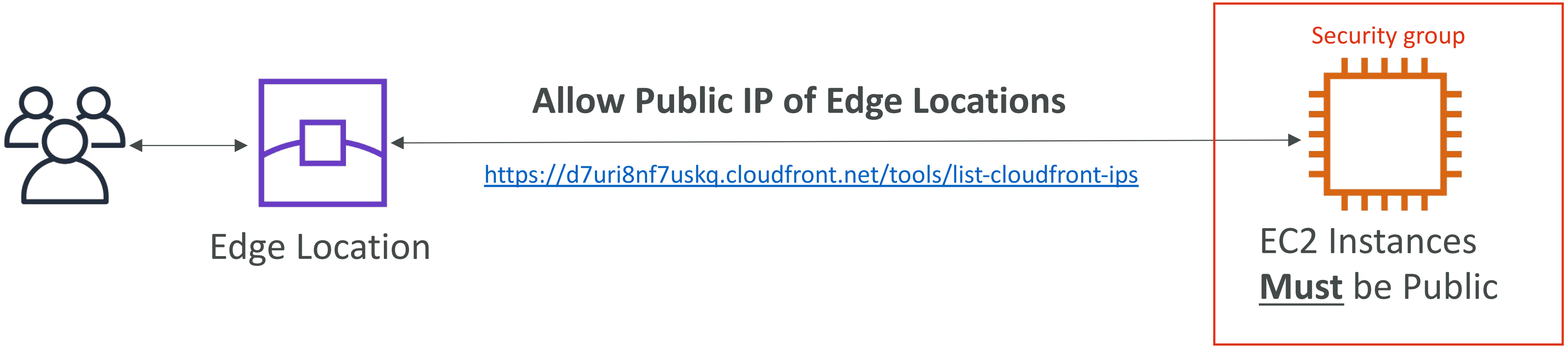


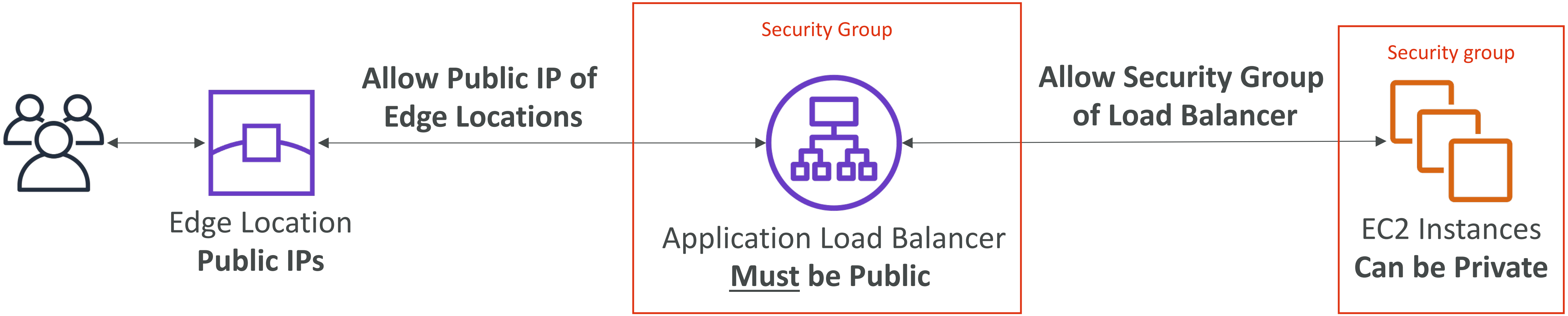
CloudFront – ALB or EC2 as an origin Using VPC Origins

- Allows you to deliver content from your applications hosted in your VPC private subnets (no need to expose them on the Internet)
- Deliver traffic to **private**:
  - Application Load Balancer
  - Network Load Balancer
  - EC2 Instances



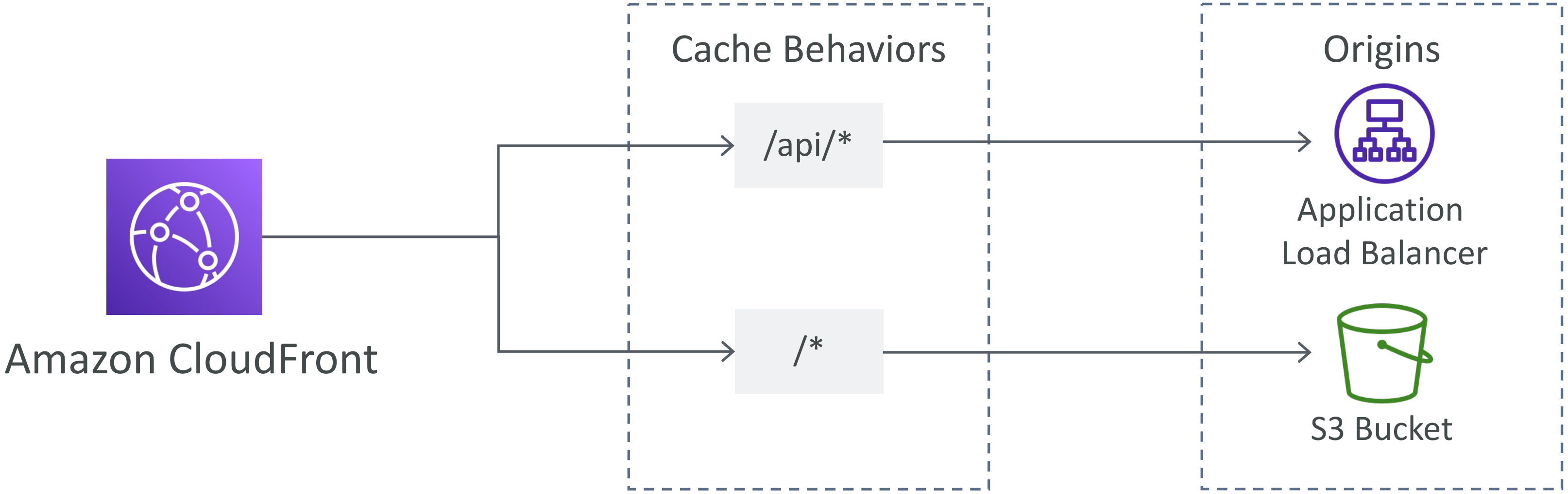
CloudFront Origins – ALB or EC2 as an origin





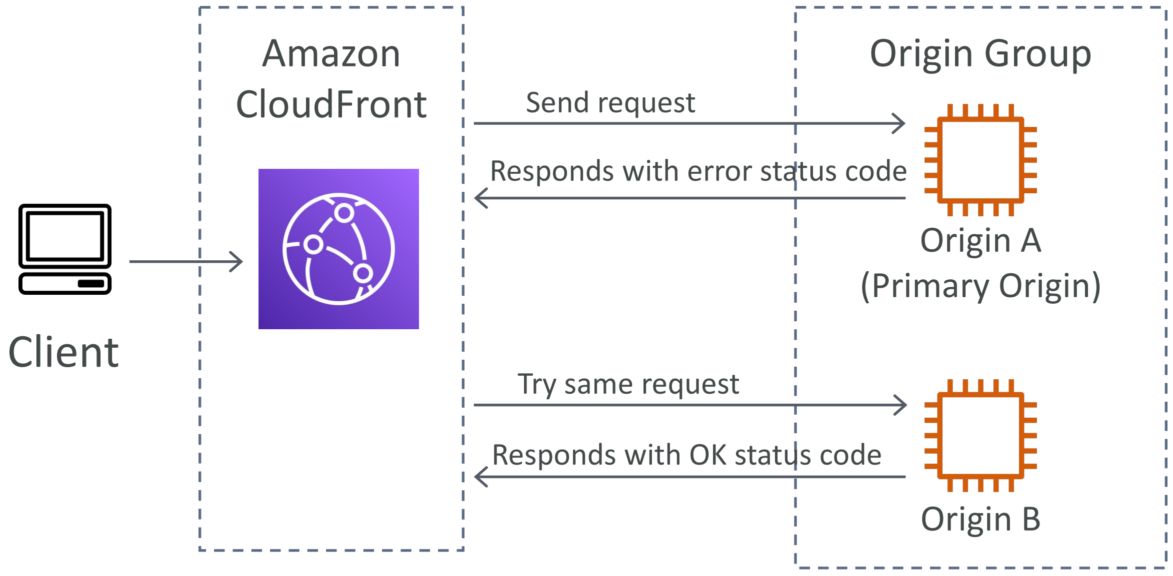
CloudFront – Multiple Origin

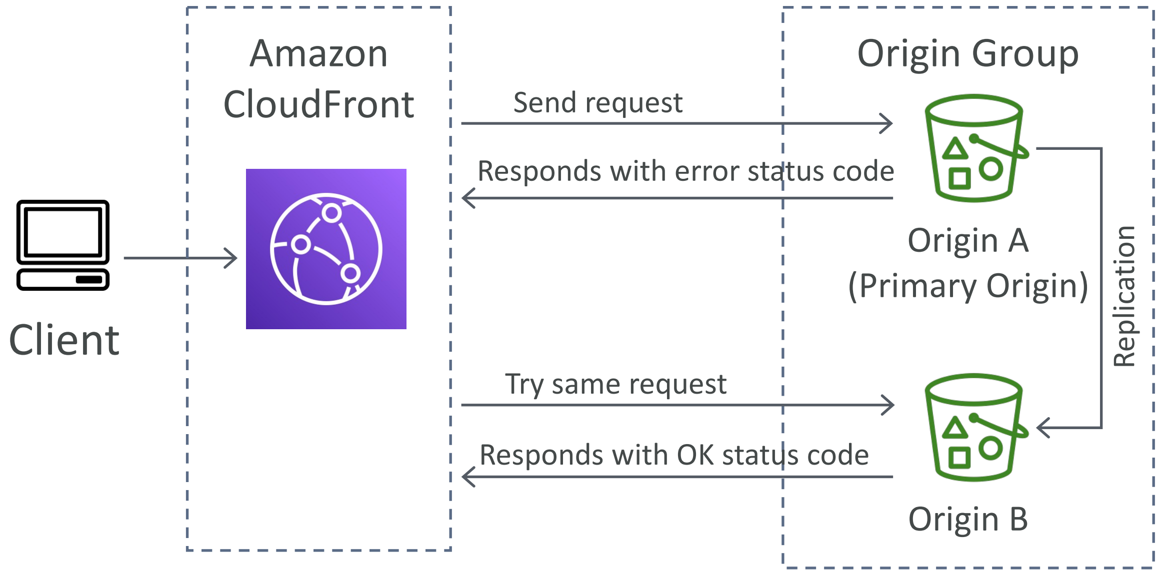
- To route to different kind of origins based on the content type
- Based on path pattern:
  - /images/*
  - /api/*
  - /*



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

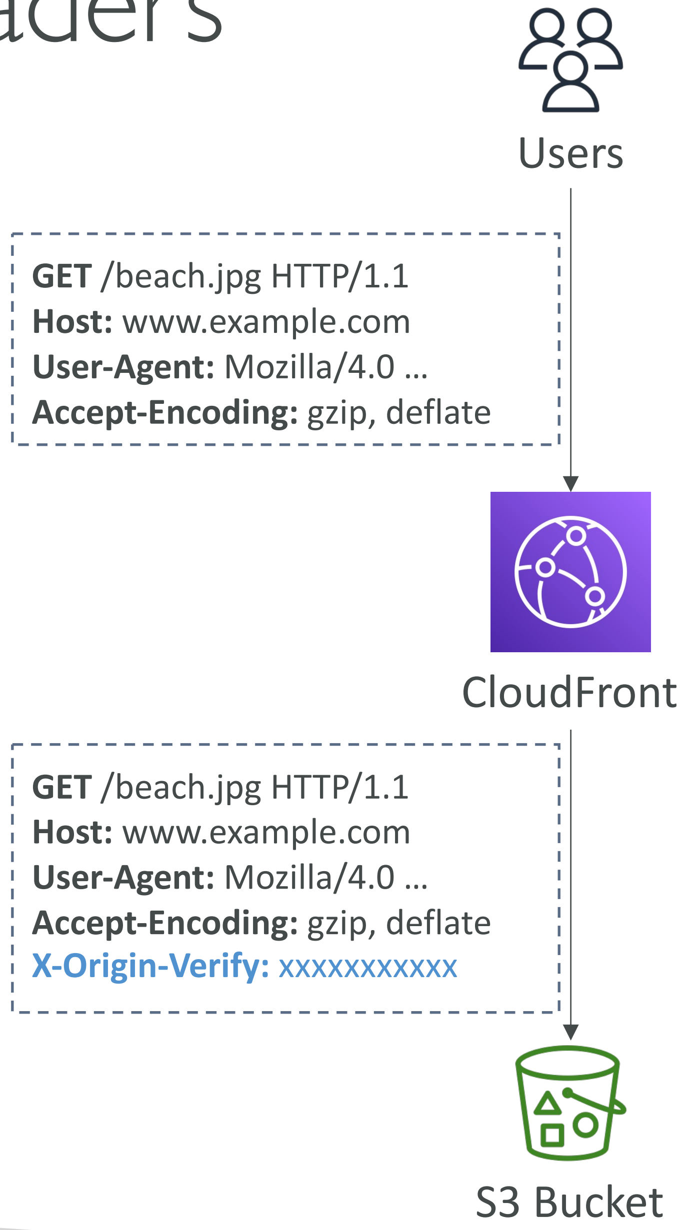




S3 + CloudFront – Region-level High Availability

CloudFront – Origin Custom Headers

- Add custom headers to requests CloudFront sends to your origin
- Can be customized for each origin
- Supports custom and S3 origins
- Use cases:
  - Identify which requests coming from CloudFront or a particular distribution
  - Control access to content (configure origin to respond to requests only when they include a custom header)



CloudFront HTTP Headers

- Specific HTTP headers added based on the viewer request

- **Viewer's Device Type Headers** (based on User-Agent)
  - CloudFront-Is-(Android/Desktop/IOS/Mobile/SmartTV/Tablet)-Viewer
- **Viewer's Location Headers** (based on viewer's IP address)
  - CloudFront-Viewer-(City/Country/Latitude/Longitude, …)
- **Viewer's Request Protocol & HTTP Version**
  - CloudFront-Forwarded-Proto & CloudFront-Viewer-Http-Version

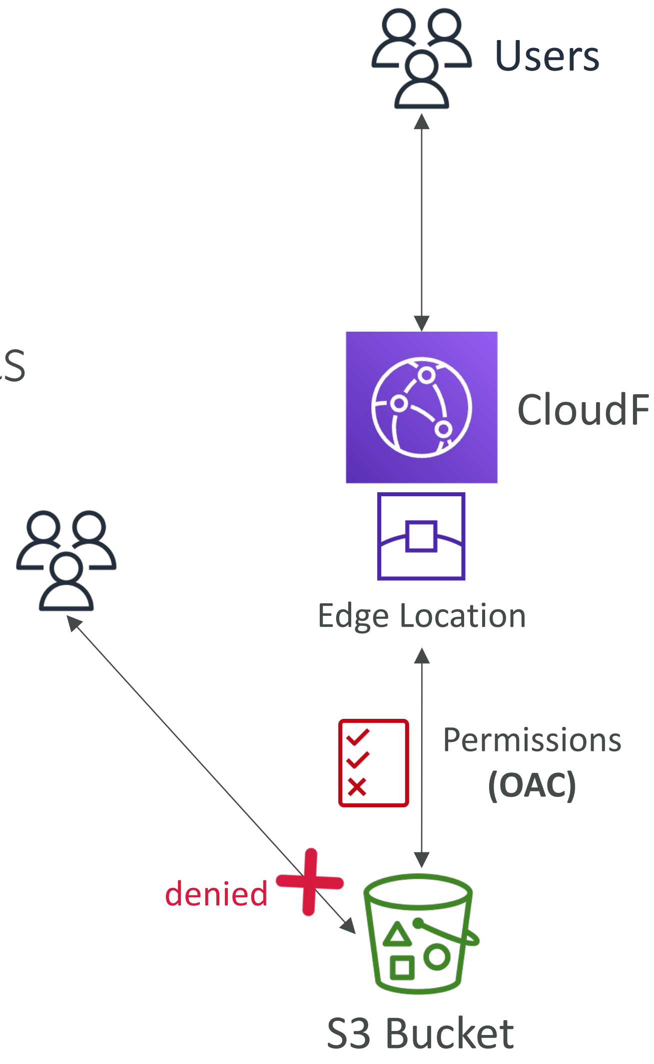
- You can include them in the Cache Key (using **Legacy Cache Settings** or **Cache Policies**) or receive them at your origin (using **Origin Request Policies**)

CloudFront – Restrict Access to S3 Buckets

- Prevent direct access to files in your S3 buckets (only access through CloudFront)
- First, create an **Origin Access Control** and associate it with your distribution (previously known as OAI)
- Second, edit your **S3 bucket policy** so that only OAC has permission

Bucket Policy

```
{
    "Version": "2012-10-17",
    "Statement": [
        {
            "Effect": "Allow",
            "Principal": {
                "service": "cloudfront.amazonaws.com"
            },
            "Action": "s3:GetObject",
            "Resource": "arn:aws:s3:::mybucket/*",
            "Condition": {
                "StringEquals": {
                    "AWS:SourceArn": "arn:aws:cloudfront::ACCOUNT_ID:distribution/EDFDVBD6EXAMPLE"
                }
            }
        }
    ]
}
```

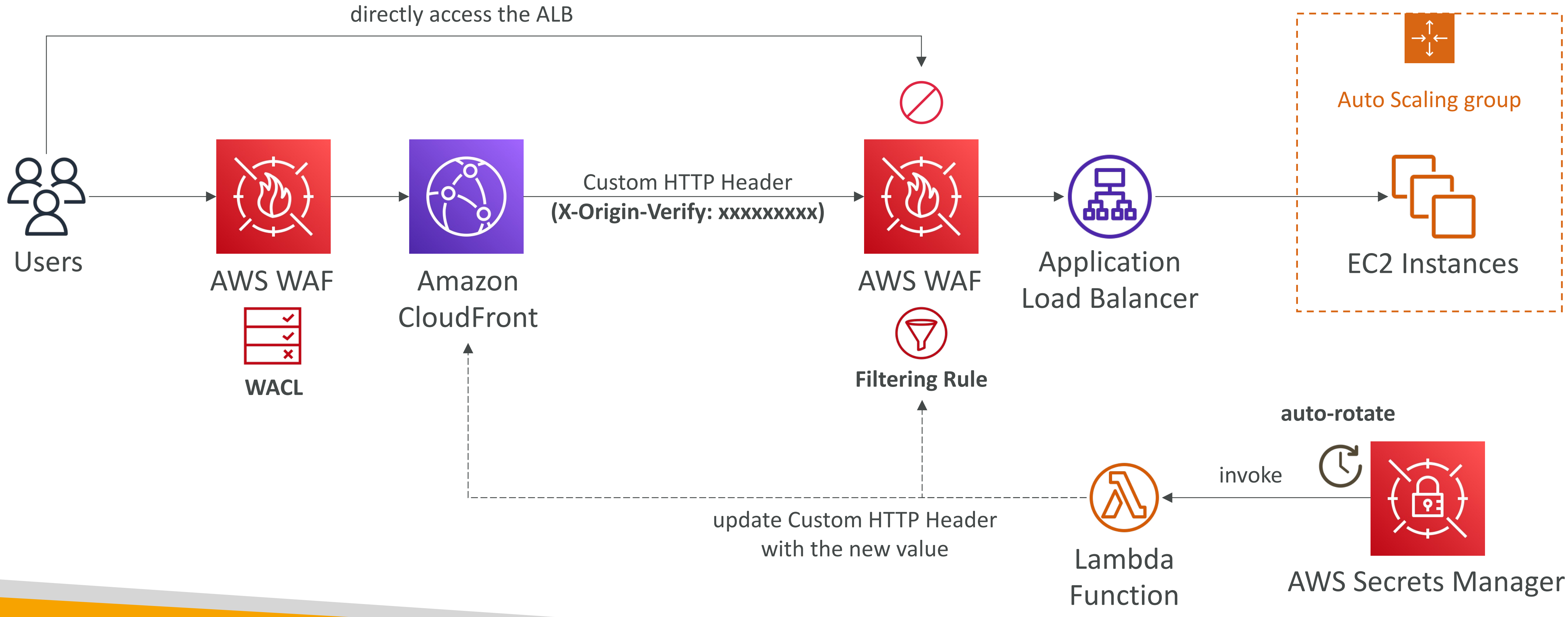


CloudFront – Restrict Access to Application Load Balancers and Custom Origins

- 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!**

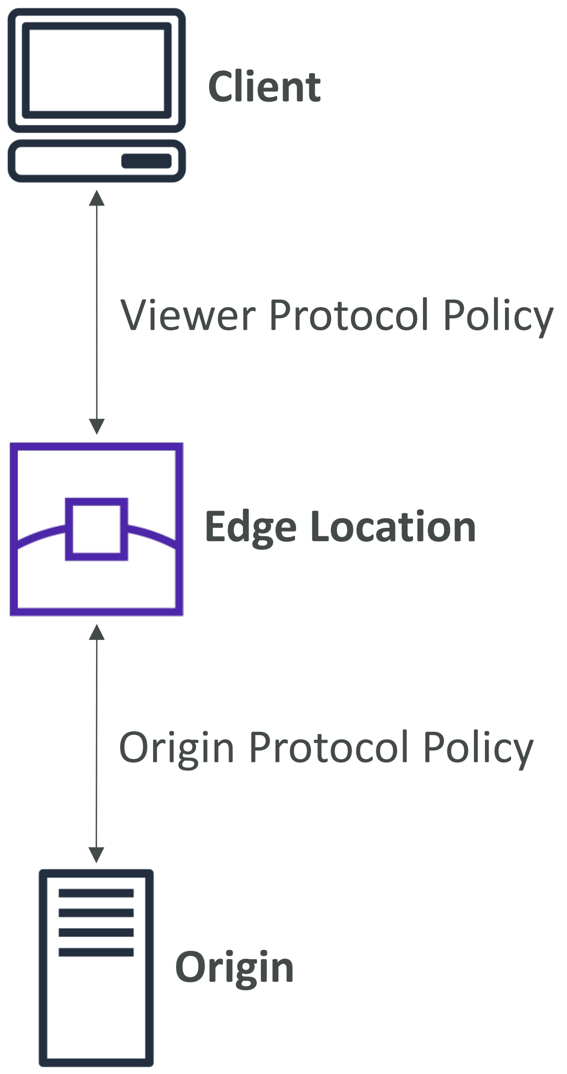
You can also restrict access to CloudFront Public IP addresses ONLY
https://d7uri8nf7uskq.cloudfront.net/tools/list-cloudfront-ips

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



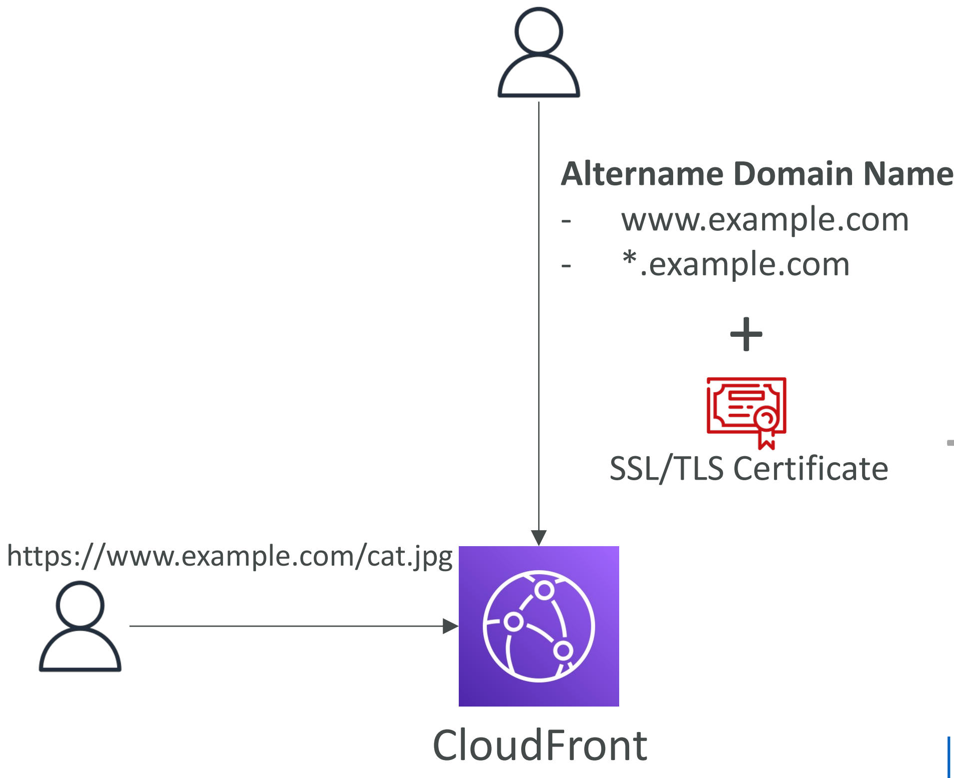
CloudFront and HTTPS

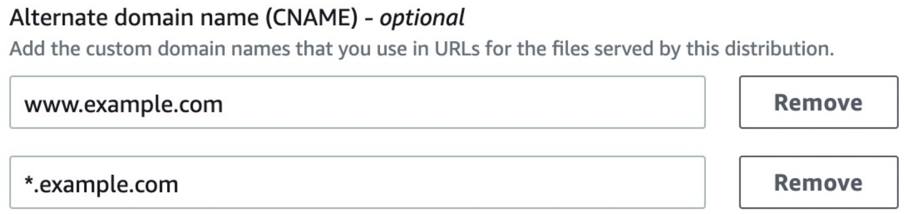
- Viewer Protocol Policy:
  - HTTP and HTTPS
  - Redirect HTTP to HTTPS
  - HTTPS Only
- Origin Protocol Policy (HTTP or S3):
  - HTTP Only (default for S3 Static Website)
  - HTTPS Only
  - Or Match Viewer
    (HTTP => HTTP & HTTPS => HTTPS)
- Note:
  - S3 bucket "static websites" don't support HTTPS
  - You must use a valid SSL/TLS certificate between CloudFront and your origin (can't use self-signed certificates)



Alternate Domain Names

- Use your own domain name instead of the domain assigned by CloudFront to your distribution
- Example: http://d111111abcdef8.cloudfront.net/cat.jpg => http://www.example.com/cat.jpg
- You **must** have a valid SSL/TLS Certificate from an authorized CA that covers:
  - Your domain name
  - All Alternate Domain Names you added to your distribution
- You can use wildcards in Alternate Domain Names (e.g., *.example.com)



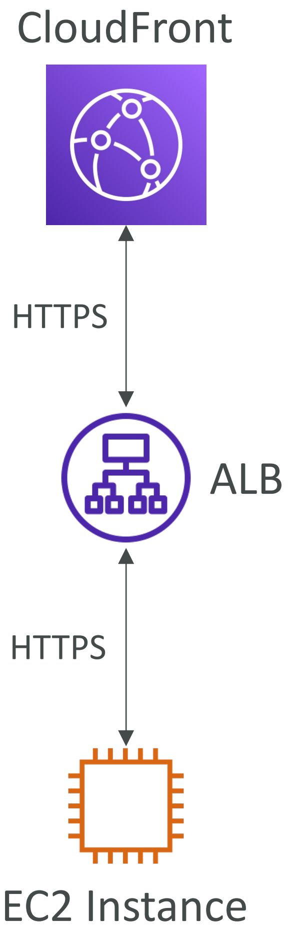


CloudFront – SSL Certificates

- Default CloudFront Certificate (*.cloudfront.net)
  - Used with default CloudFront domain names assigned to your distribution
    - https://d111111abcdef8.cloudfront.net/cat.jpg
- Custom SSL Certificate
  - When using your own domain name – **Alternate Domain Names** (e.g., https://www.example.com)
  - CloudFront can serve HTTPS requests using:
    - Server Name Indication (SNI) – Recommended
    - Dedicated IP Address in Each Edge Location (expensive)
  - You can use
    - Certificates provided by ACM
    - 3rd party certificates uploaded to ACM or IAM Certificate Store (manually rotate when expired)
  - Certificate must be created/imported in US East (N.Virginia) Region

- Ability to specify a Security Policy (min. SSL/TLS protocol & ciphers to use)

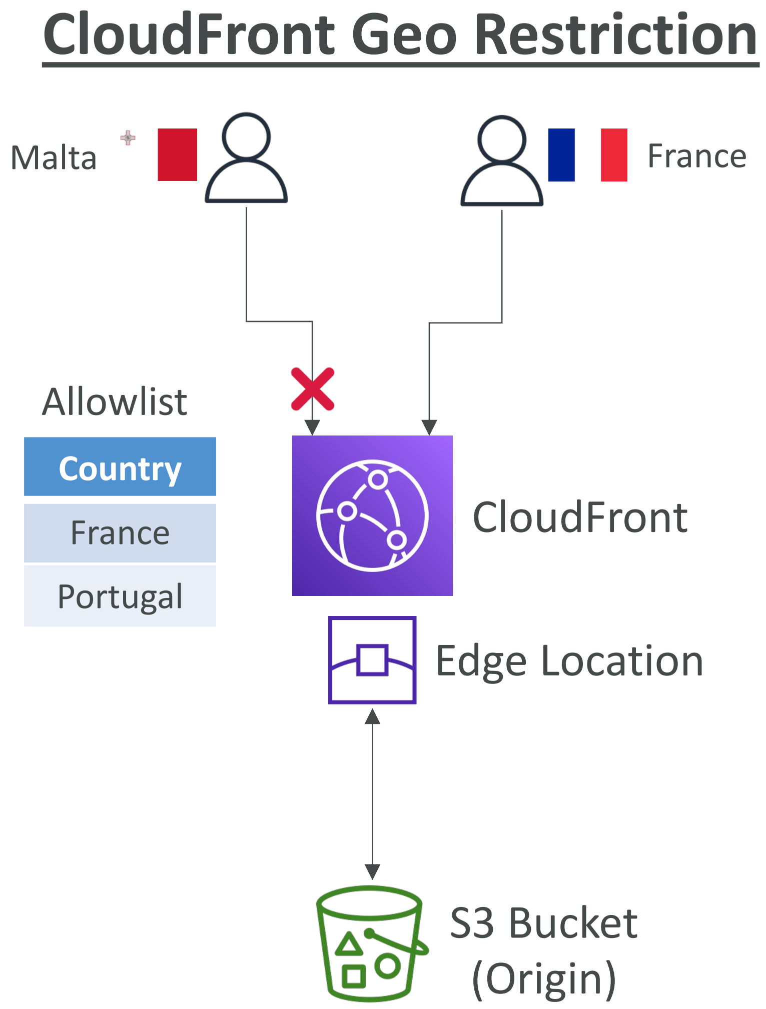
End-to-End Encryption: CloudFront, ALB, EC2



- CloudFront
  - Origin protocol policy: HTTPS Only
  - Install an SSL / TLS certificate on your custom origin
  - The origin certificate must include either the Origin domain field (configured in CloudFront) or the domain in the "Host" header if it's forwarded to Origin
  - Does not work with self-signed certificate
- Application Load Balancer
  - Use a certificate provided by AWS Certificate Manager or imported into ACM
- EC2 Instance
  - ACM is not supported on EC2
  - Can use a third-party SSL certificate (any domain name)
  - Can use a self-signed certificate (ALB does not verify the certificate itself)

CloudFront – Restrict Content Geographically

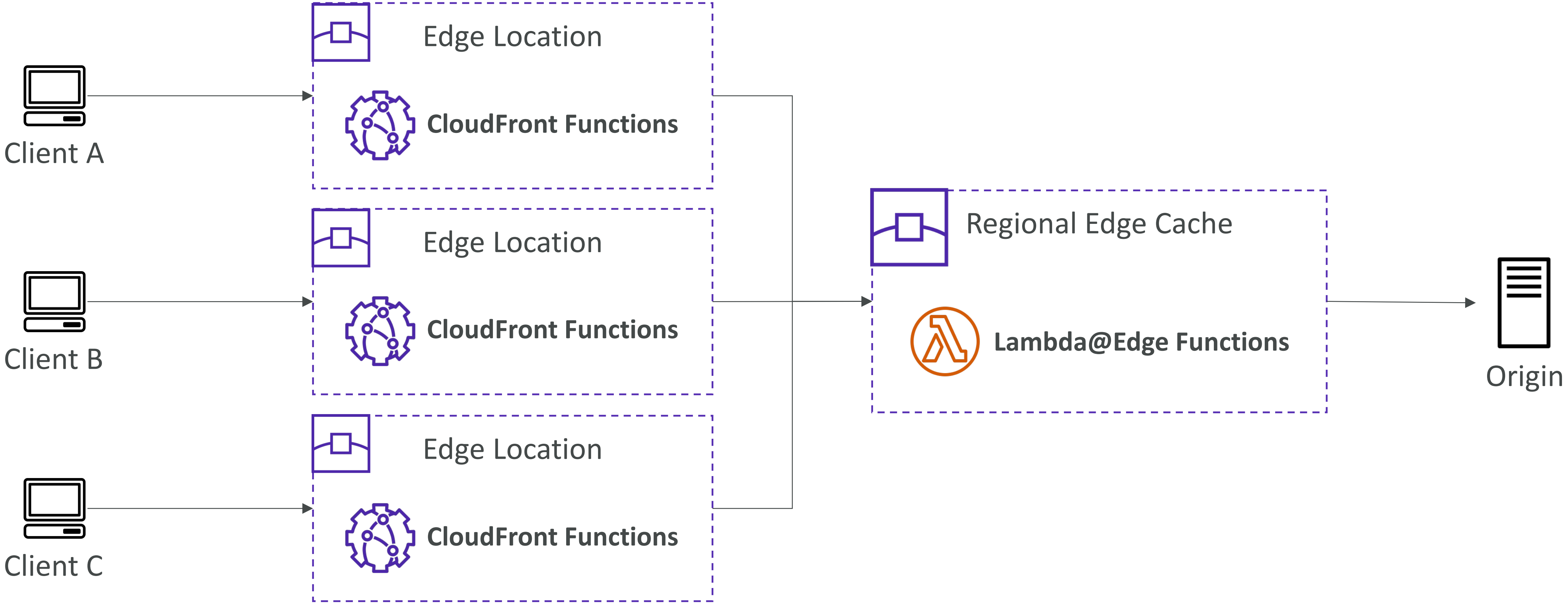
- Prevent users in specific locations from accessing your content/distribution
- CloudFront Geo Restriction
  - Restrict access at the country level (country determined using a 3rd party GeoIP database)
  - Allow list – allow access only if is from one of the approved countries
  - Block list – prevent access if users in one of the countries on a blacklist of banned countries
  - Applied to an entire CloudFront distribution
- Use case: Copyright Laws to control access to content



CloudFront – Customization At The Edge

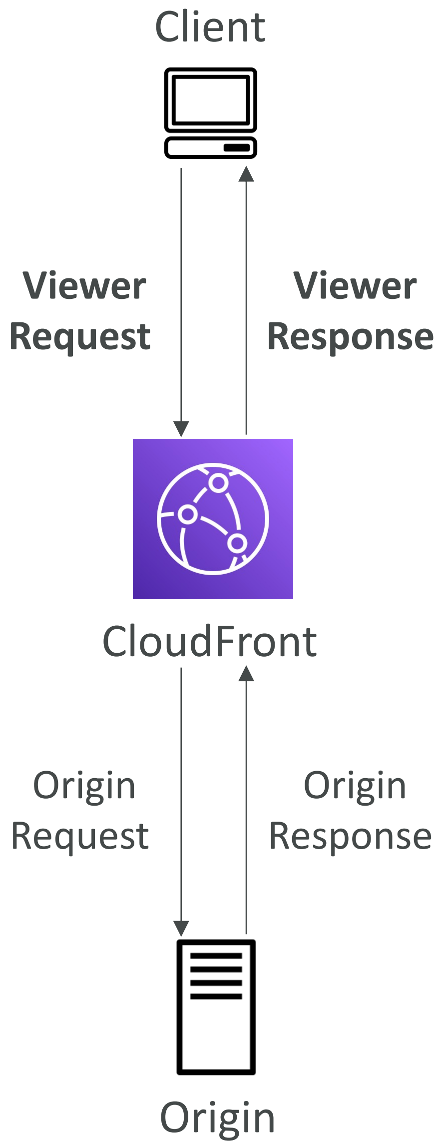
- Many modern applications execute some form of the logic at the edge
- **Edge Function:**
  - A code that you write and attach to CloudFront distributions
  - Runs close to your users to minimize latency
  - Doesn't have any cache, only to change requests/responses
  - CloudFront provides two types: **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



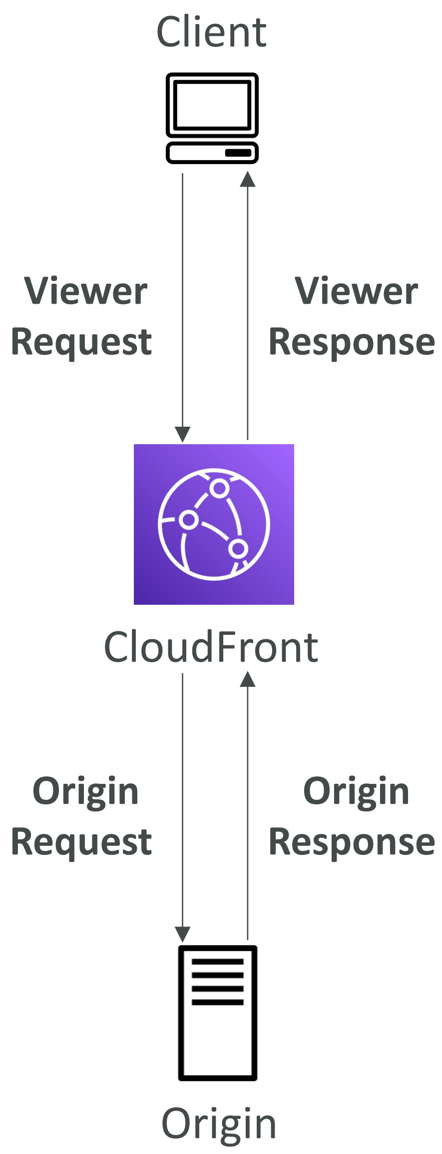
CloudFront – CloudFront Functions

- 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)



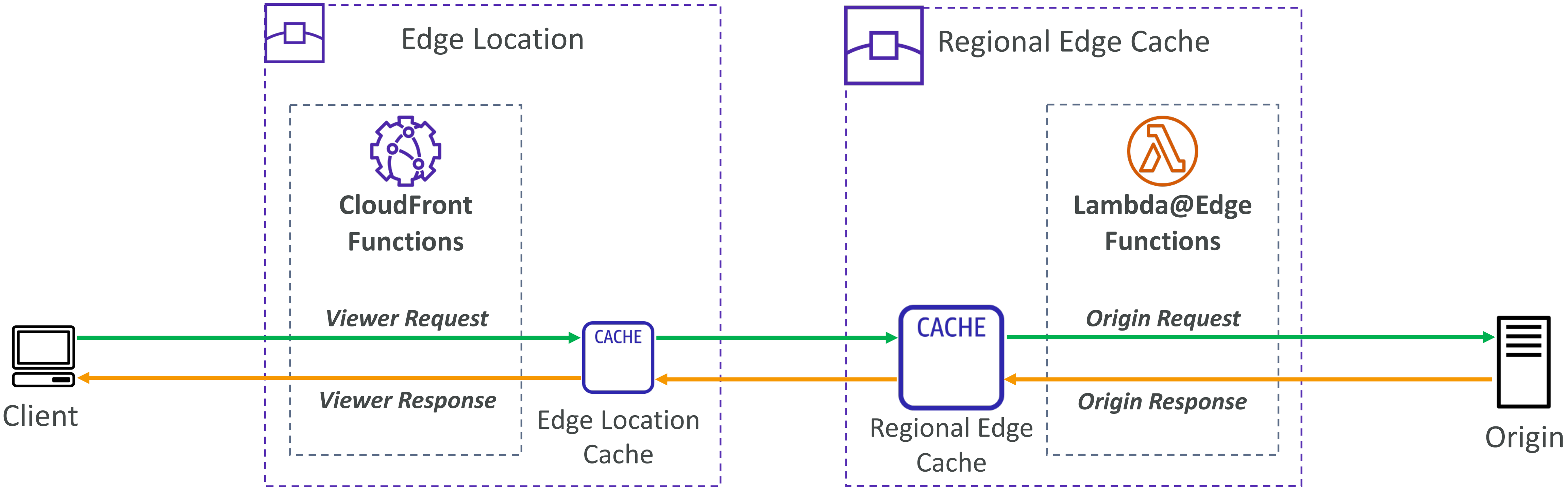
CloudFront – Lambda@Edge

- 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

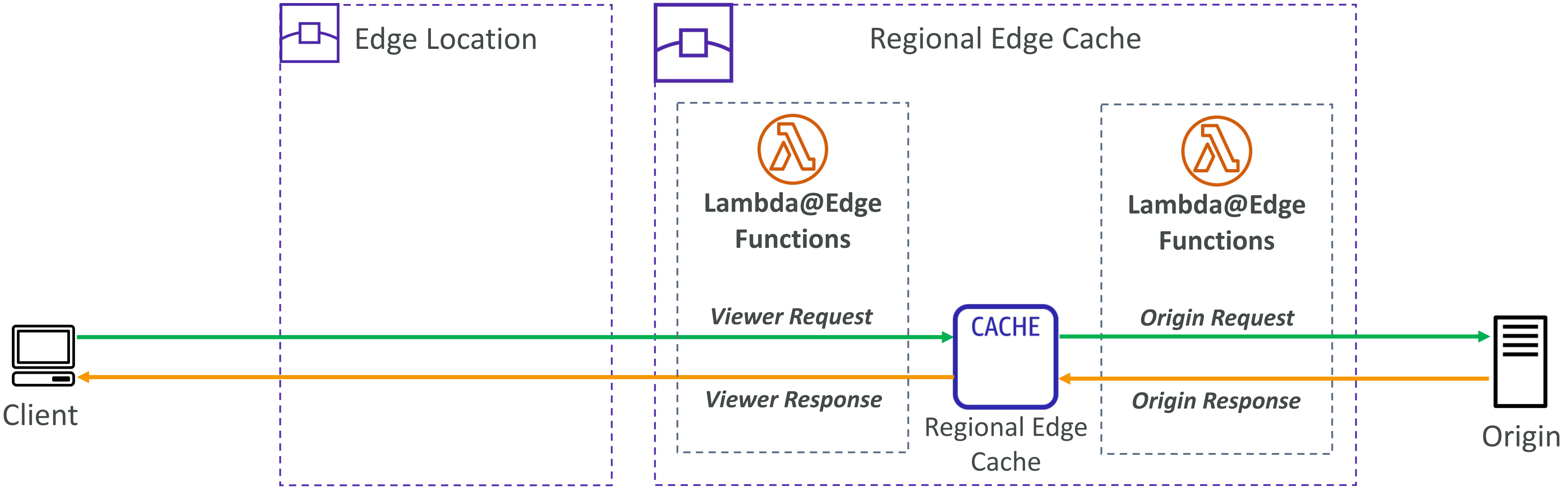
CloudFront Functions and **Lambda@Edge** can be used together



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, 1/6th price of @Edge	No free tier, charged per request & duration

CloudFront Functions vs. Lambda@Edge – Use Cases

CloudFront Functions

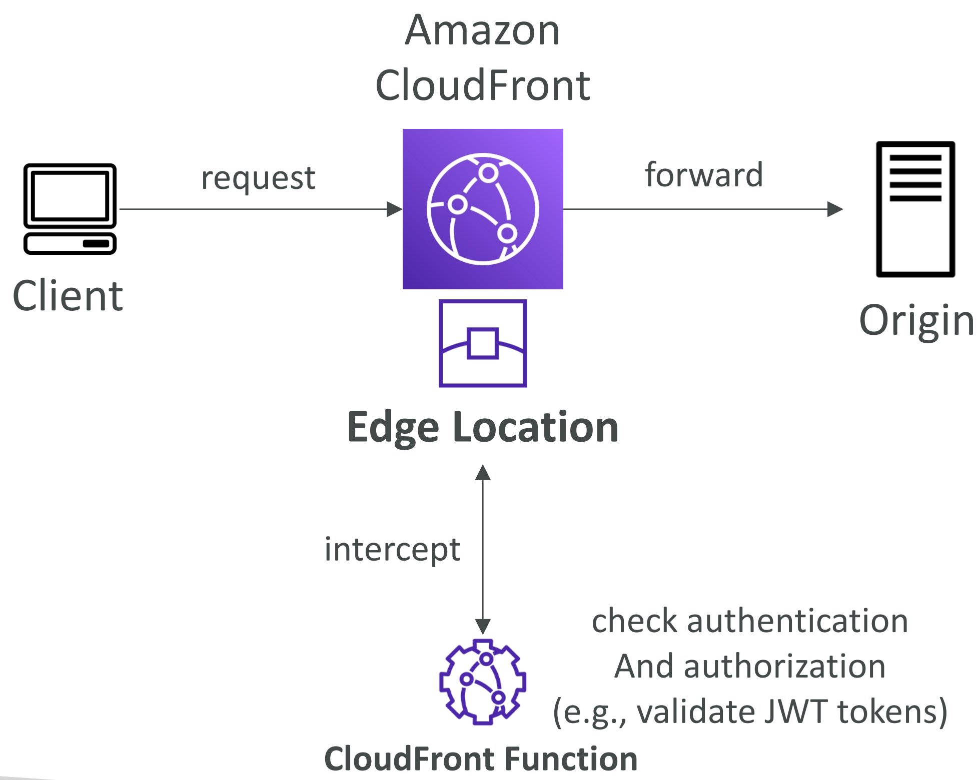
- Cache key normalization
  - Transform request attributes (headers, cookies, query strings, URL) to create an optimal Cache Key
- Header manipulation
  - Insert/modify/delete HTTP headers in the request or response
- URL rewrites or redirects
- Request authentication & authorization
  - Create and validate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

Lambda@Edge

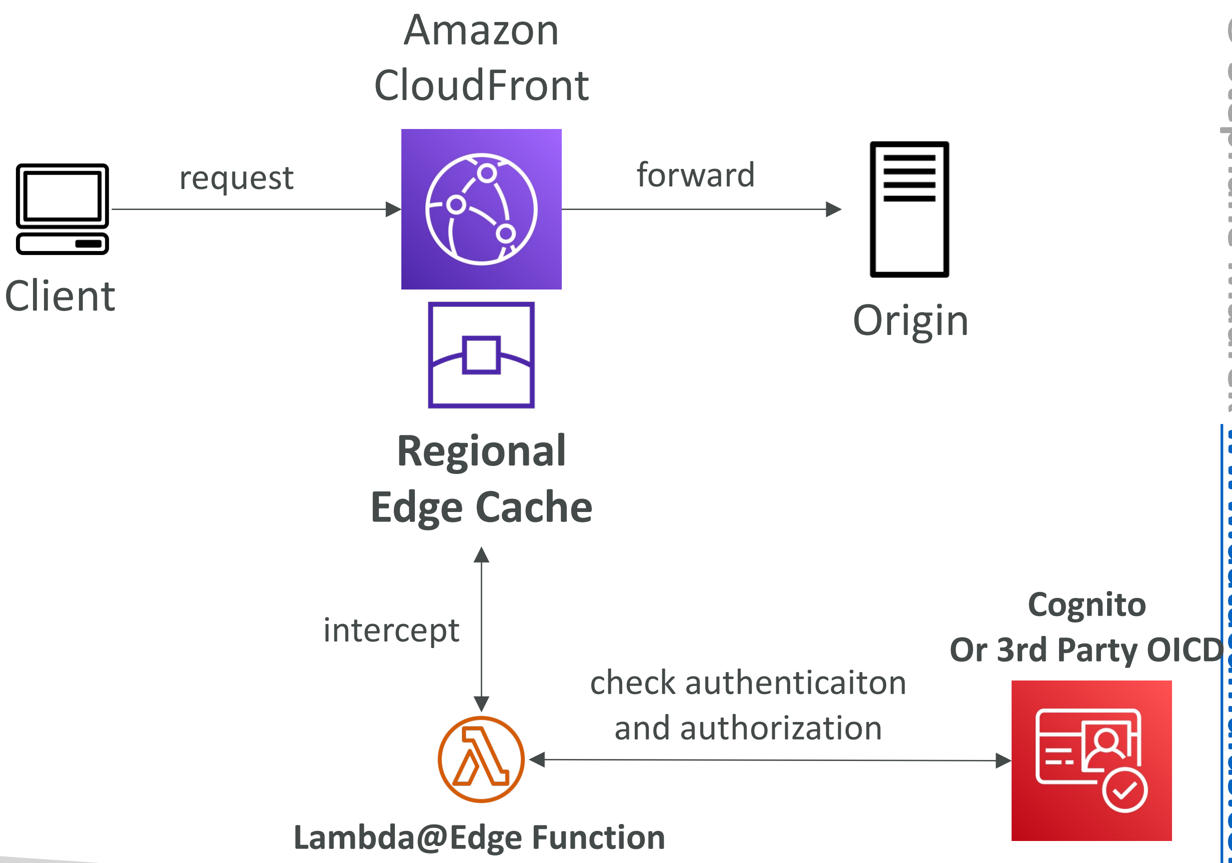
- Longer execution time (several ms)
- Adjustable CPU or memory
- Your code depends on a 3rd libraries (e.g., AWS SDK to access other AWS services)
- Network access to use external services for processing
- File system access or access to the body of HTTP requests

CloudFront Functions vs. Lambda@Edge – Authentication and Authorization

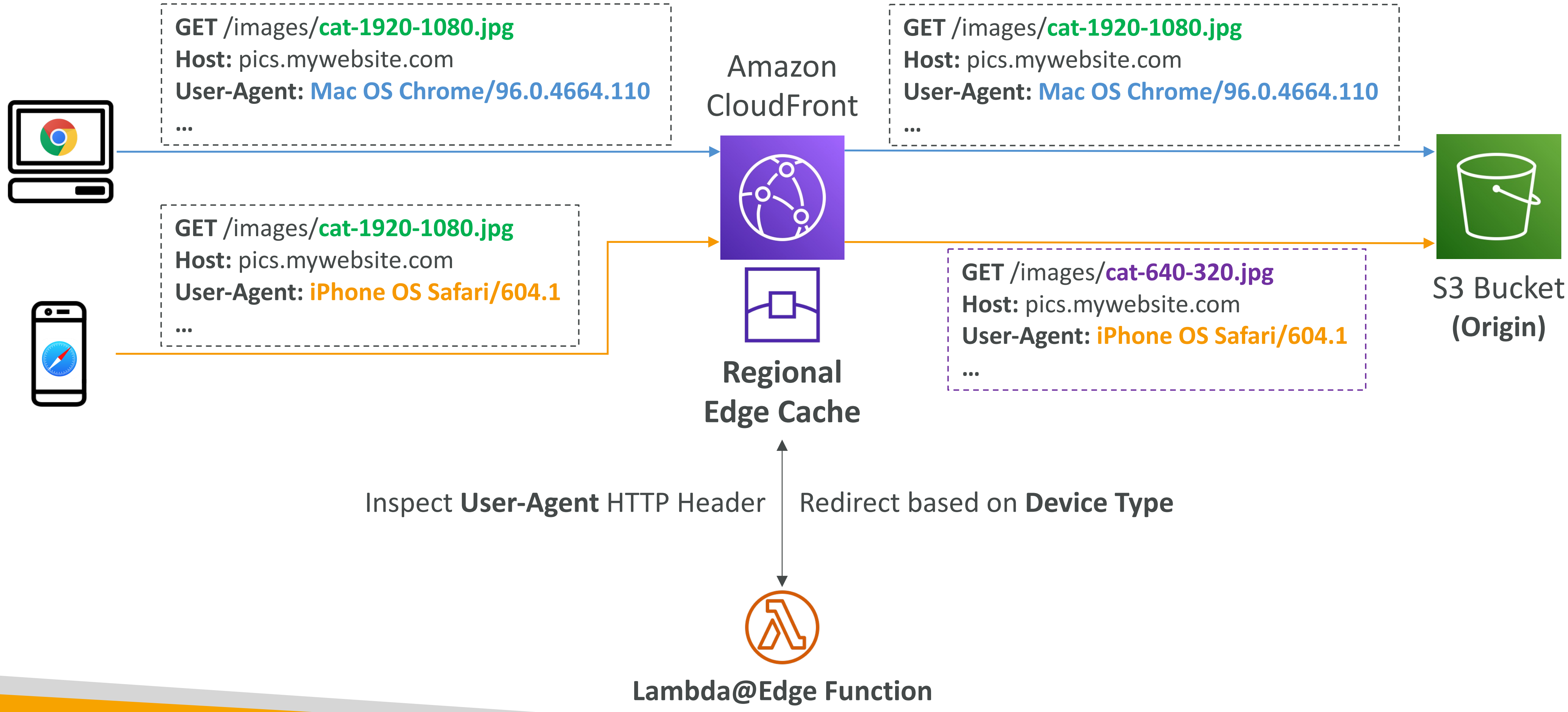
CloudFront Functions



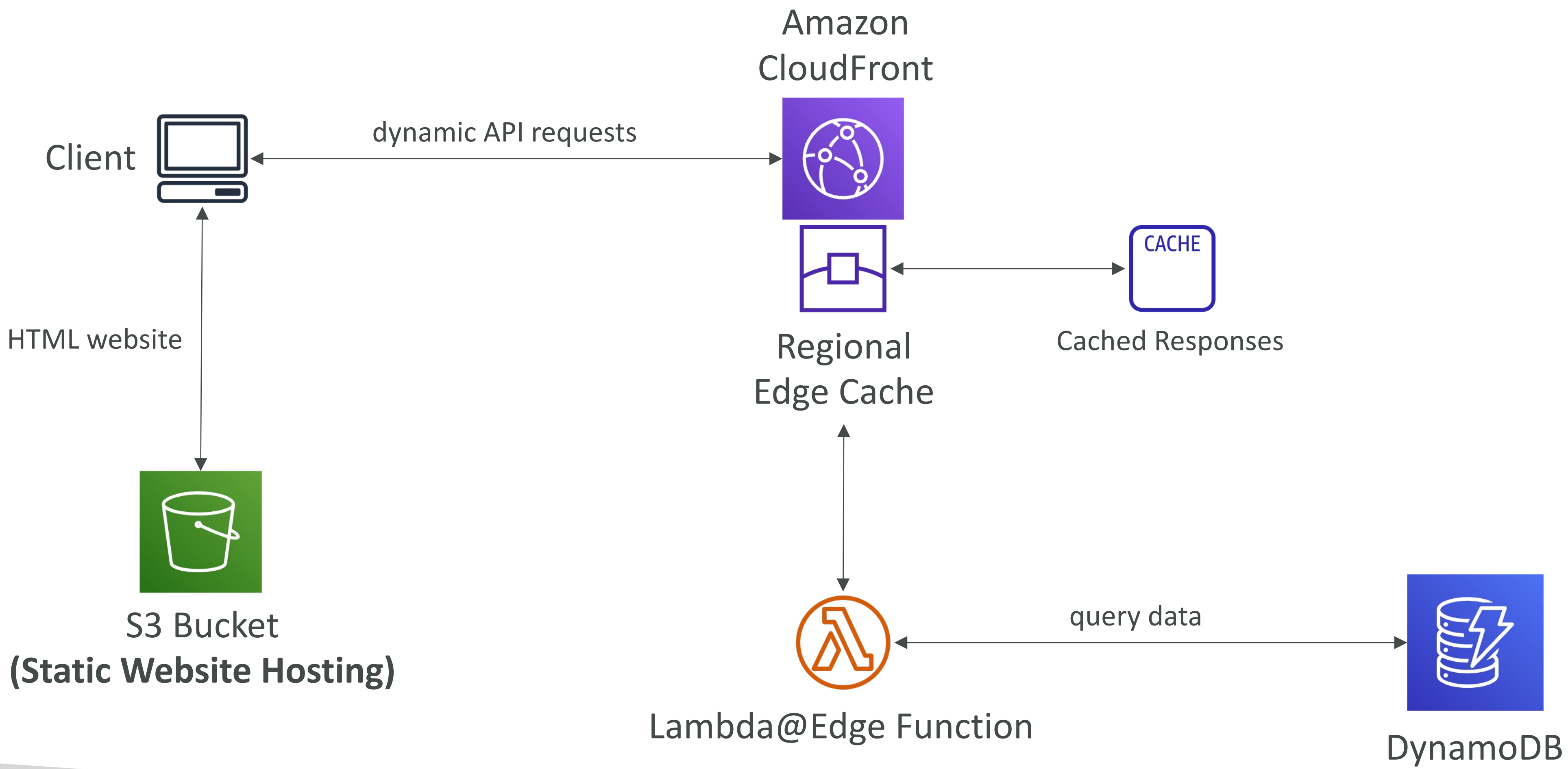
Lambda@Edge



Lambda@Edge: Loading content based on User-Agent

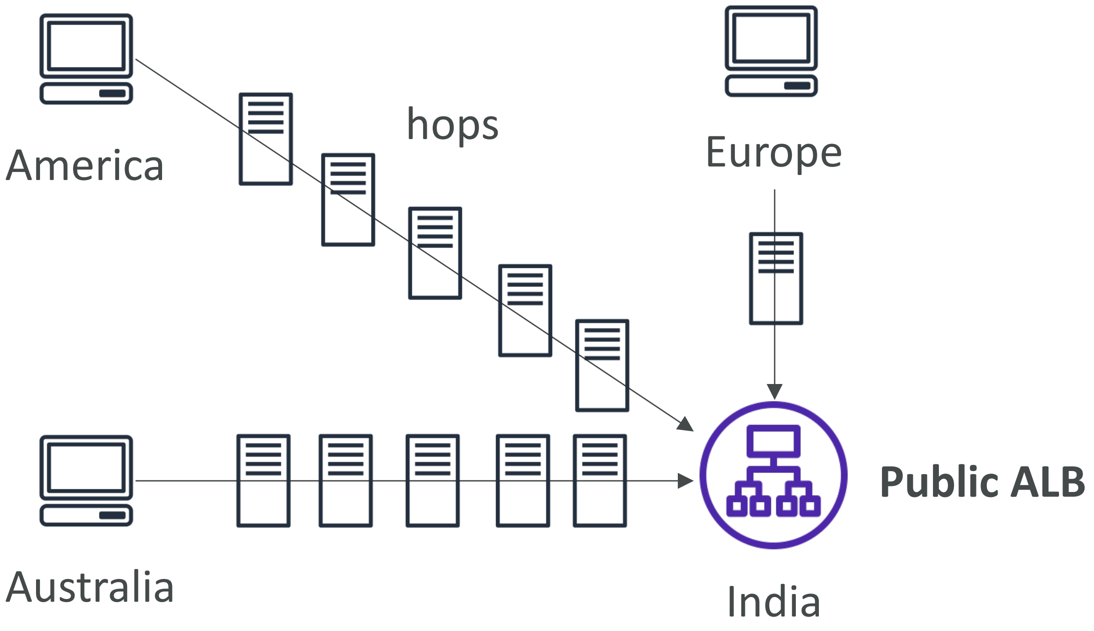


Lambda@Edge – Global Application



Global users for our application

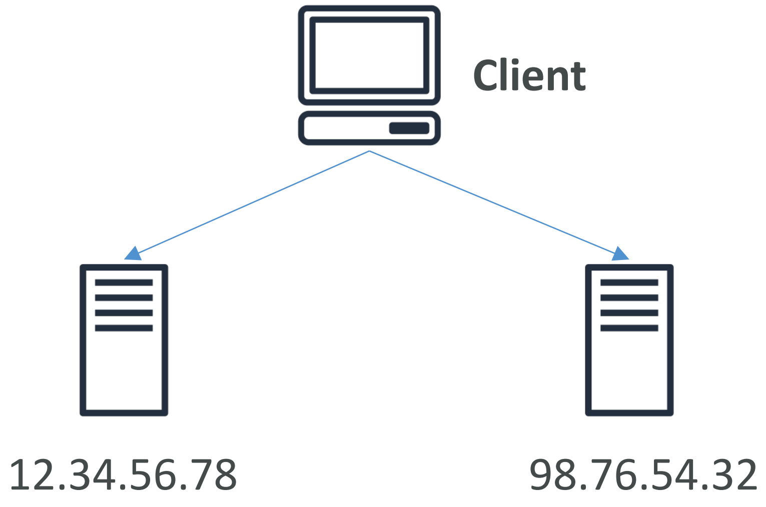
- You have deployed an application and have global users who want to access it directly
- They go over the public internet, which can add a lot of latency due to many hops
- We wish to go as fast as possible through AWS network to minimize latency

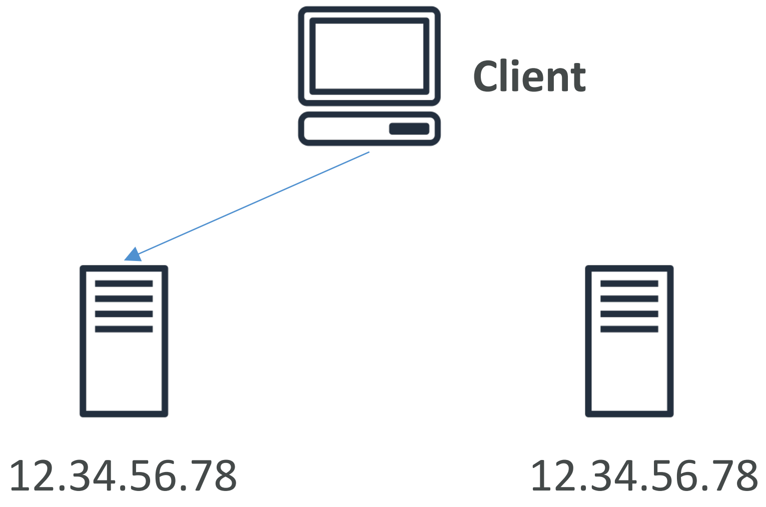


Unicast IP vs Anycast IP

- **Unicast IP:** one server holds one IP address

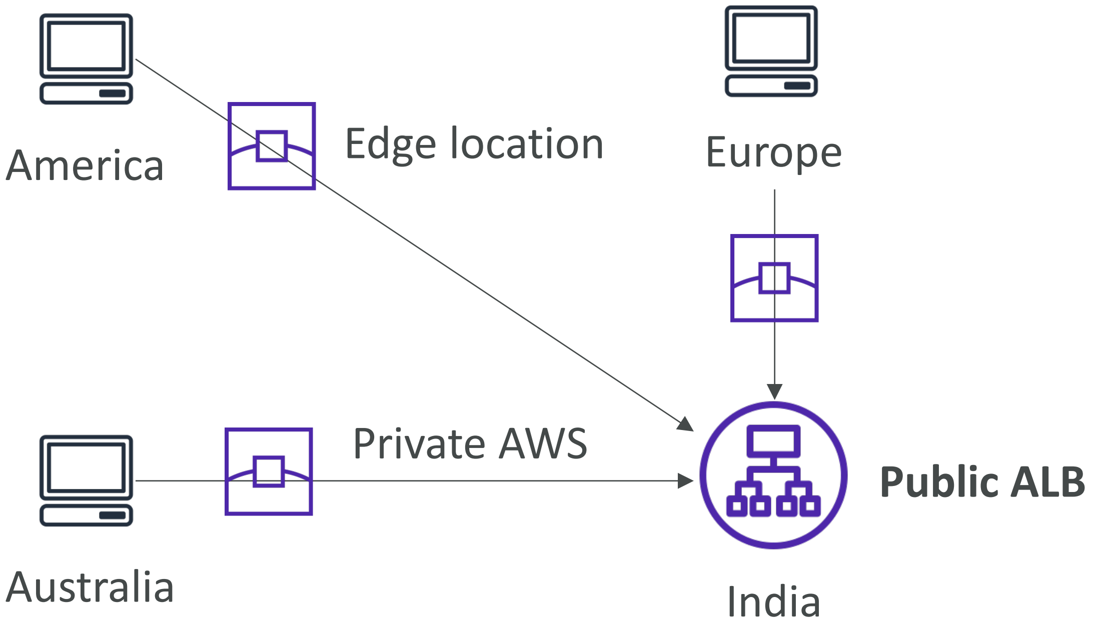
- **Anycast IP:** all servers hold the same IP address and the client is routed to the nearest one





AWS Global Accelerator

- 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**
- 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.

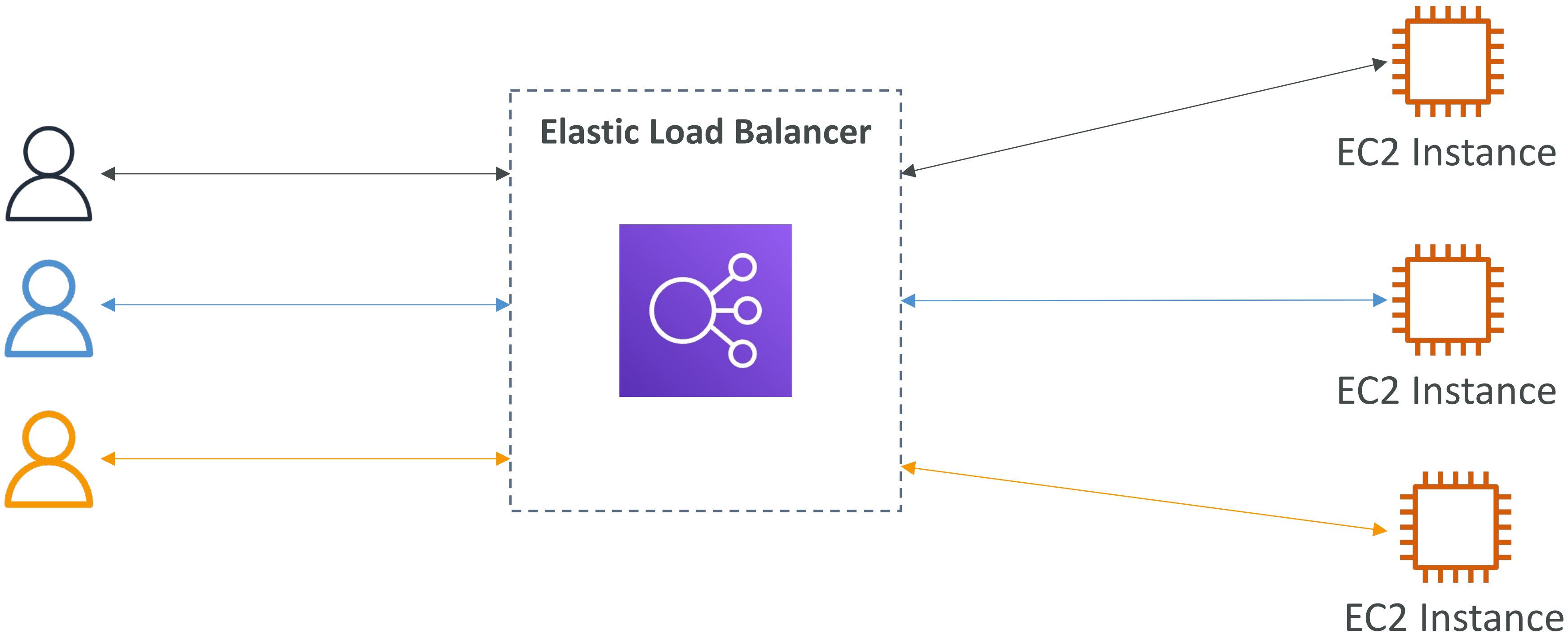
- CloudFront
  - Improves performance for both cacheable content (such as images and videos)
  - Dynamic content (such as API acceleration and dynamic site delivery)
  - Content is served at the edge

- 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

AWS Elastic Load Balancer

What is load balancing?

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



Why use a load balancer?

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

Why use an Elastic Load Balancer?

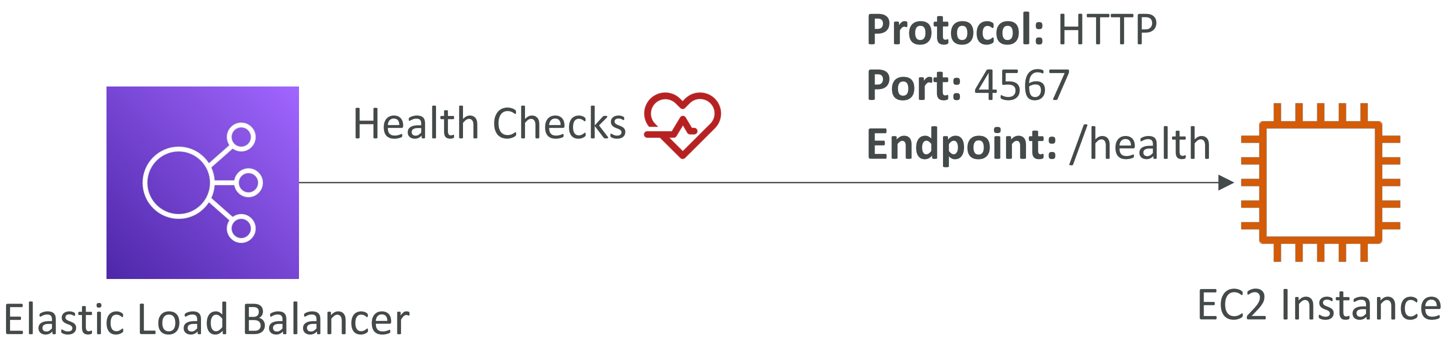
- An Elastic Load Balancer is a managed load balancer
  - AWS guarantees that it will be working
  - AWS takes care of upgrades, maintenance, high availability
  - AWS provides only a few configuration knobs

- It costs less to setup your own load balancer but it will be a lot more effort on your end

- It is integrated with many AWS offerings / services
  - EC2, EC2 Auto Scaling Groups, Amazon ECS
  - AWS Certificate Manager (ACM), CloudWatch
  - Route 53, AWS WAF, AWS Global Accelerator

Health Checks

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

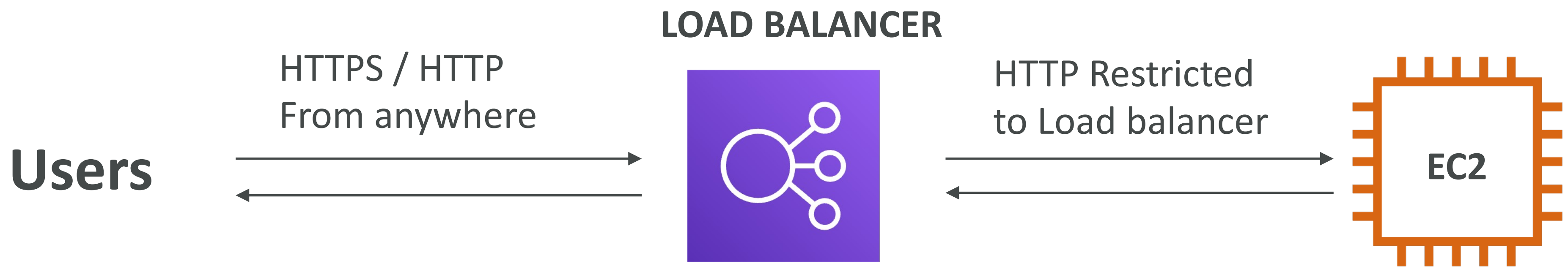


Types of load balancer on AWS

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

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

Load Balancer Security Groups



Load Balancer Security Group:

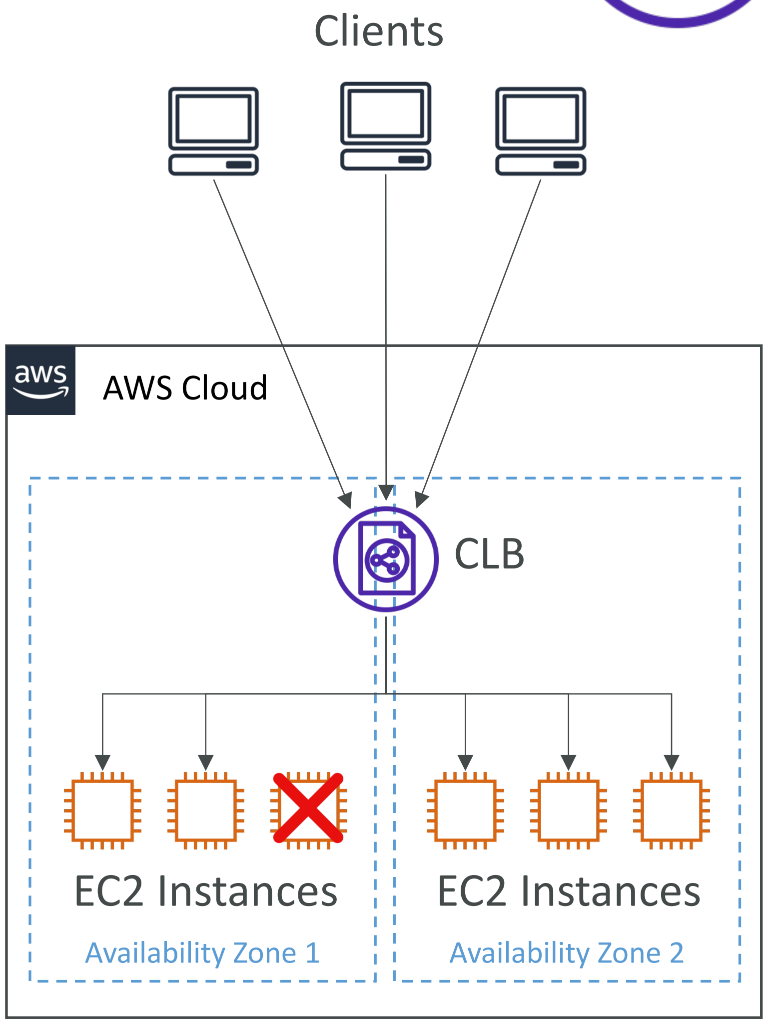
Type	Protocol	Port Range	Source	Description
HTTP	TCP	80	0.0.0.0/0	Allow HTTP from an...
HTTPS	TCP	443	0.0.0.0/0	Allow HTTPS from a...

Application Security Group: Allow traffic only from Load Balancer

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

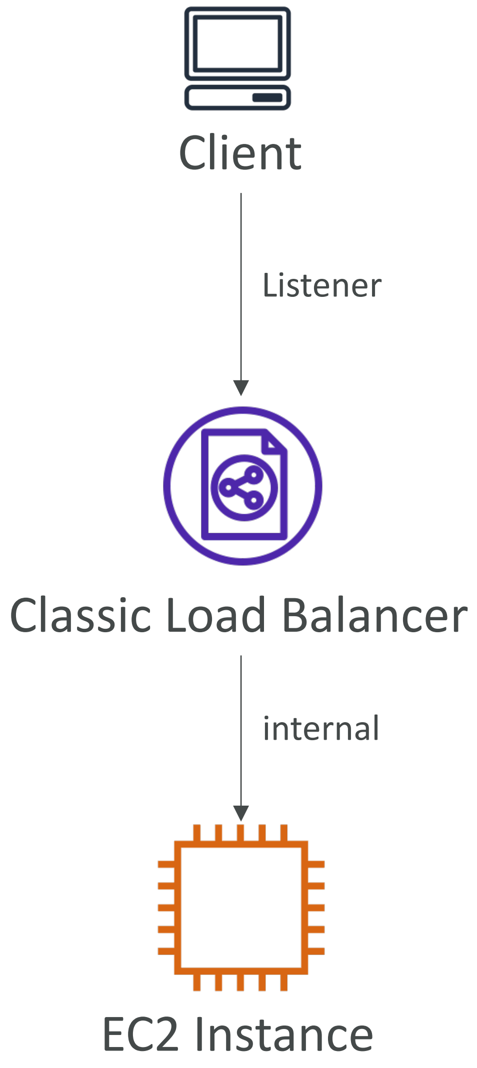
Classic Load Balancer

- Operates at layer 4 and layer 7
- Supported protocols HTTP, HTTPS, TCP, and SSL/TLS
- EC2 instances registered directly with the CLB (no Target Groups)
- Health Checks can be HTTP, HTTPS, or TCP
- Supports EC2-Classic networks



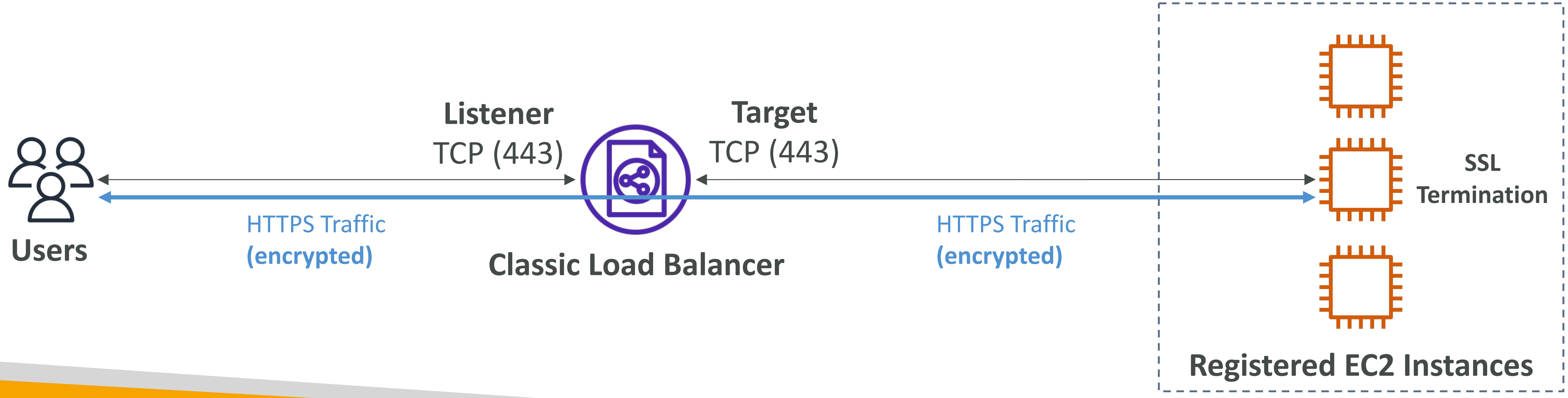
Classic Load Balancer

Listener	Internal
HTTP (L7)	HTTP or HTTPS (Must install certificate on EC2)
HTTPS (L7) – SSL Termination (Must install certificate on CLB)	HTTP or HTTPS (Must install certificate on EC2)
TCP (L4)	TCP or SSL (Must install certificate on EC2)
SSL (L4) (Must install certificate on CLB)	TCP or SSL (Must install certificate on EC2)



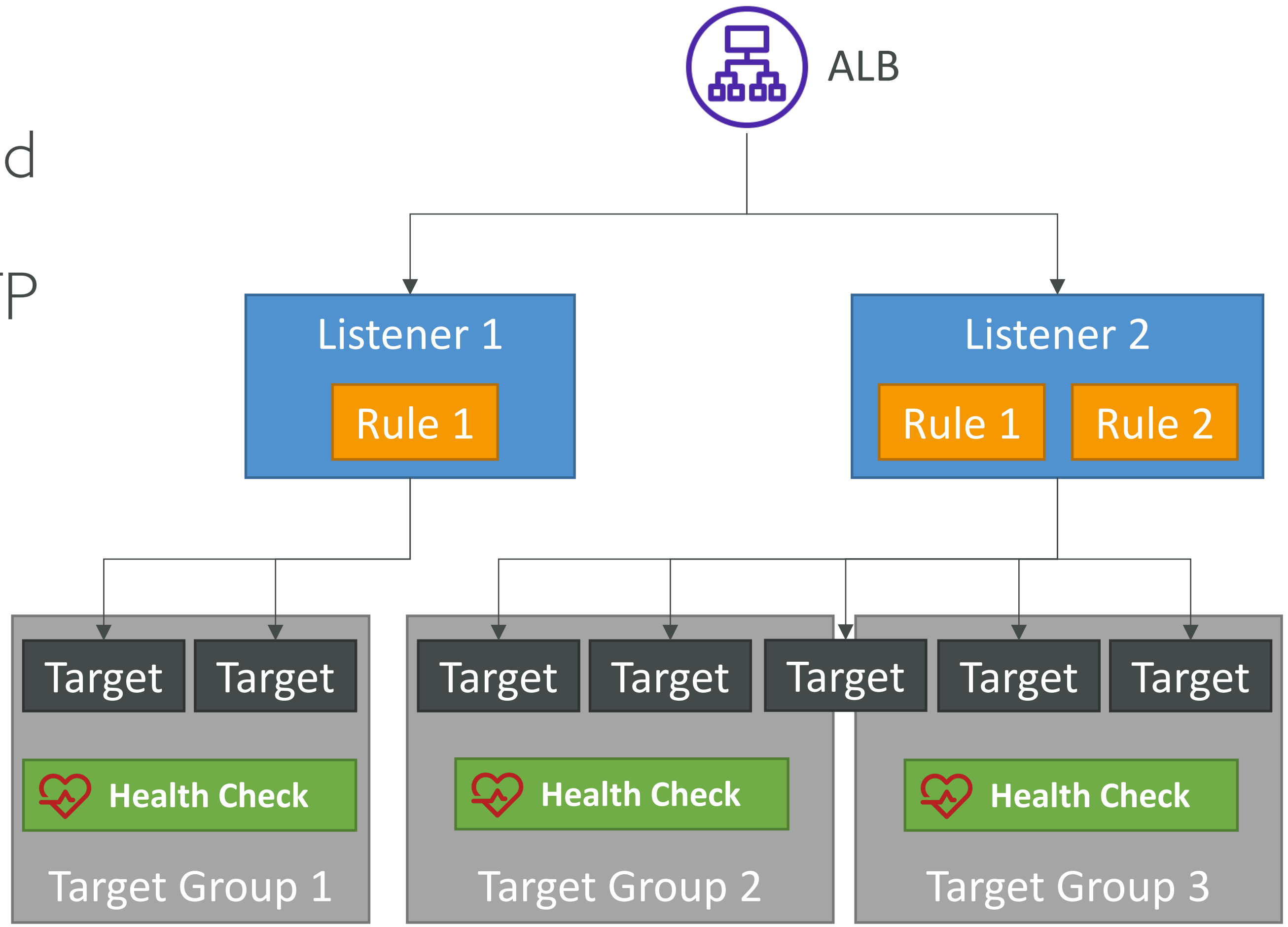
Classic Load Balancer – SSL considerations

- Enabling HTTPS or SSL on EC2 instances is called **"Backend Authentication"** (between the CLB and the backend EC2 instances)
- TCP => TCP passes all the traffic to the EC2 instance (no termination):
  - The only way to do **2-way Mutual SSL Authentication**



Application Load Balancer

- Operates at Layer 7 (HTTP…)
- Supported protocols HTTP, HTTPS, WebSocket, HTTP/2 and gRPC
- Load balancing to multiple HTTP applications across machines (Target Groups)
- Load balancing to multiple applications/ports on the same server (e.g., containers)
- Support for returning custom HTTP responses
- Supports redirects (e.g., from HTTP to HTTPS)



Application Load Balancer

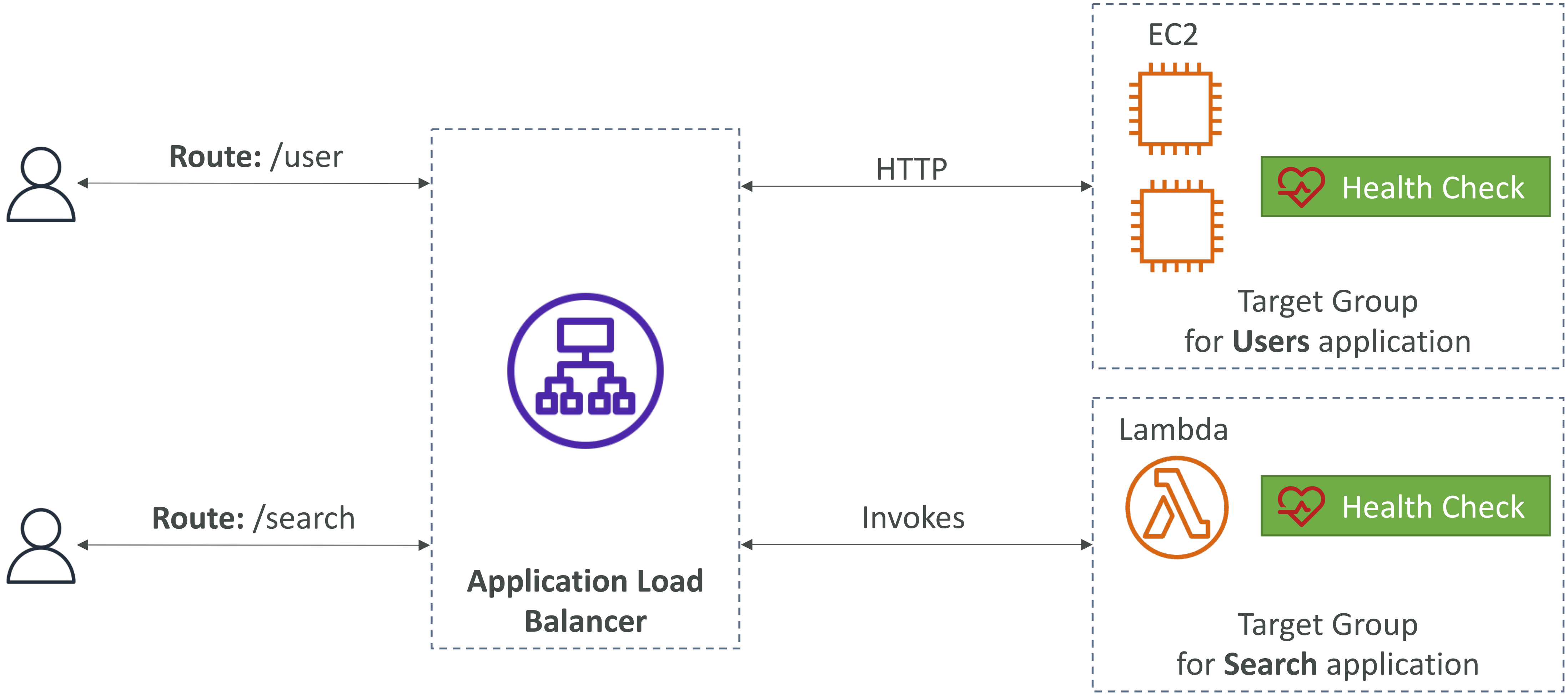
- Target Groups
  - **EC2 Instances** (can be managed by an ASG) – HTTP
  - **ECS Tasks** (managed by ECS itself) – HTTP
  - **Lambda functions** – HTTP request is translated into a JSON event
  - **IP Addresses** – must be private IP addresses (e.g., EC2 instances in peered VPC, on-premises servers accessed over AWS Direct Connect or VPN connection)
- Supports Weighted Target Groups
  - Example: multiple versions of your application, blue/green deployment
- Health Checks can be HTTP or HTTPS (WebSocket is not supported)
- Each subnet must have a min of /27 and 8 free IP addresses
- Across all subnets, a maximum of 100 IP addresses will be used per ALB

Application Load Balancer

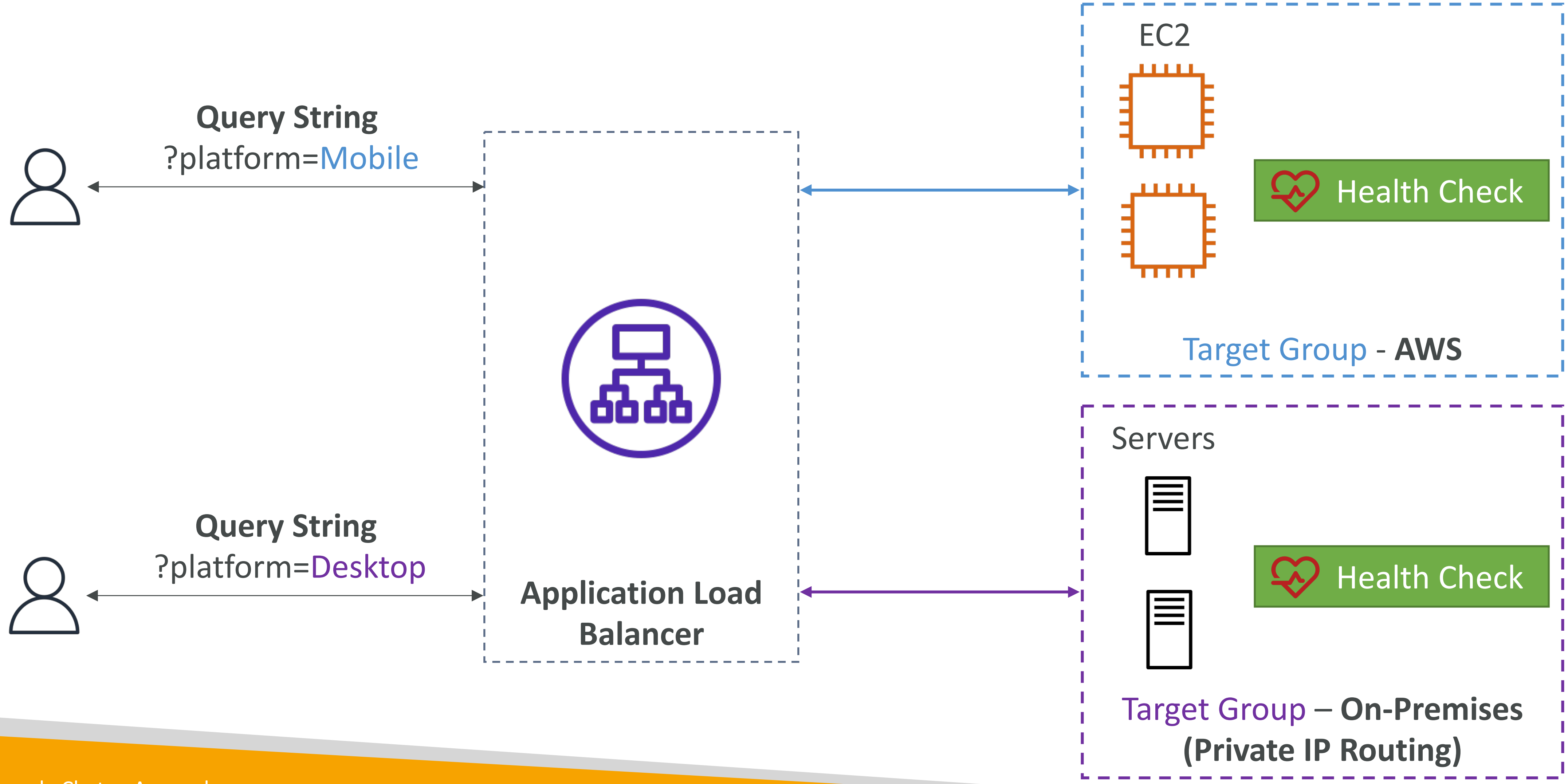
- Routing to different target groups
  - Routing based on **URL Path** (example.com/users, example.com/posts)
  - Routing based on **Hostname**
    - one.example.com, other.example.com
    - *.example.com, example.com
  - Routing based on **Query String, HTTP Headers, Source IP Address** (example.com/users?id=123&order=false)

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

Application Load Balancer
Path-based Routing



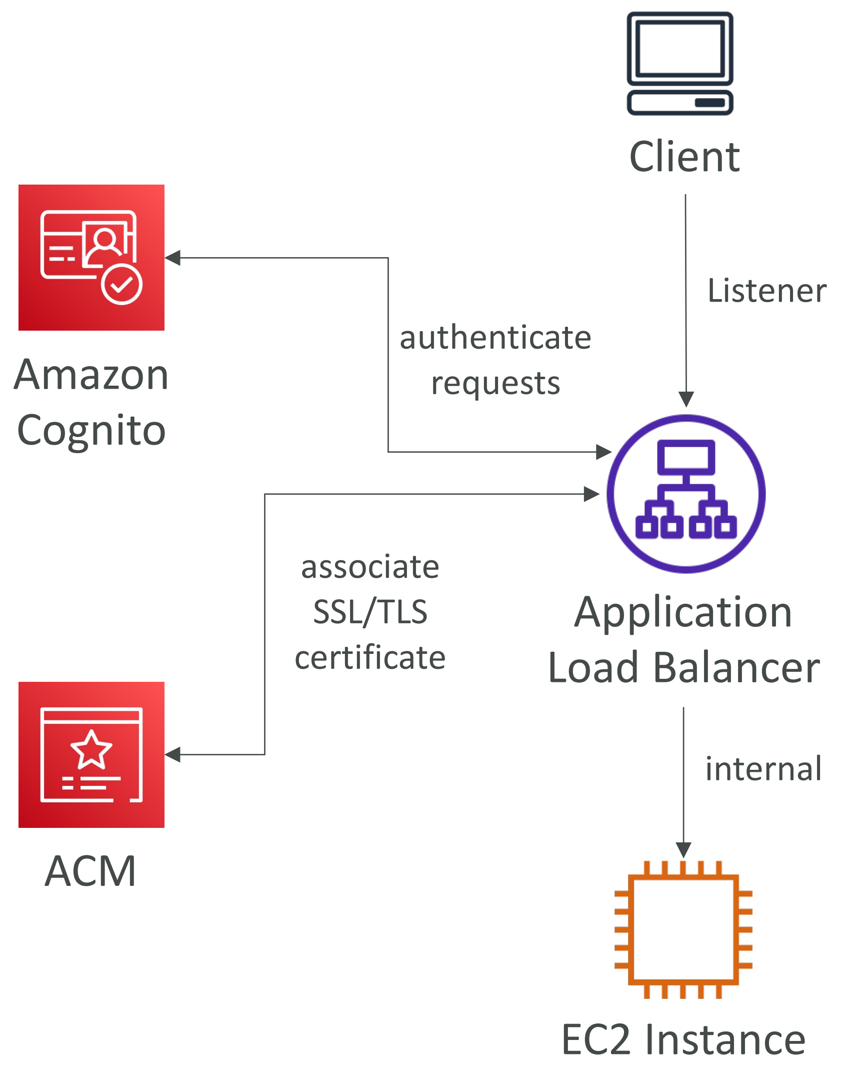
Application Load Balancer
Query String/Parameters Routing



Application Load Balancer

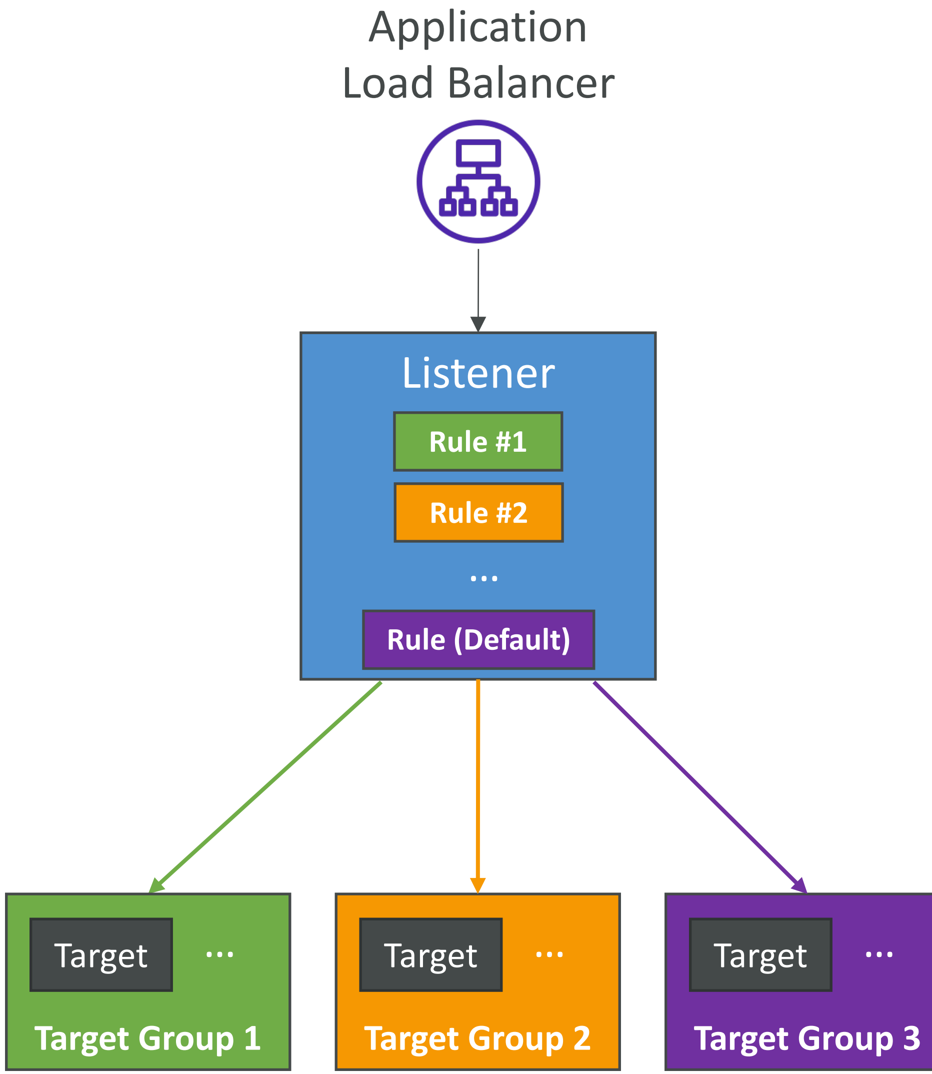
- Ability to authenticate users before routing requests to registered targets
  - Amazon Cognito User Pools and Identity Providers
  - Microsoft Active Directory, OIDC, SAML, LDAP, OpenID
  - Social Identity Providers such as Amazon, Facebook, Google
- TLS Certificates (multiple listeners & SNI)

Listener	Internal
HTTP	HTTP or HTTPS (Must install certificate on target)
HTTPS – SSL Termination (ACM)	HTTP or HTTPS (Must install certificate on target)



ALB – Listener Rules

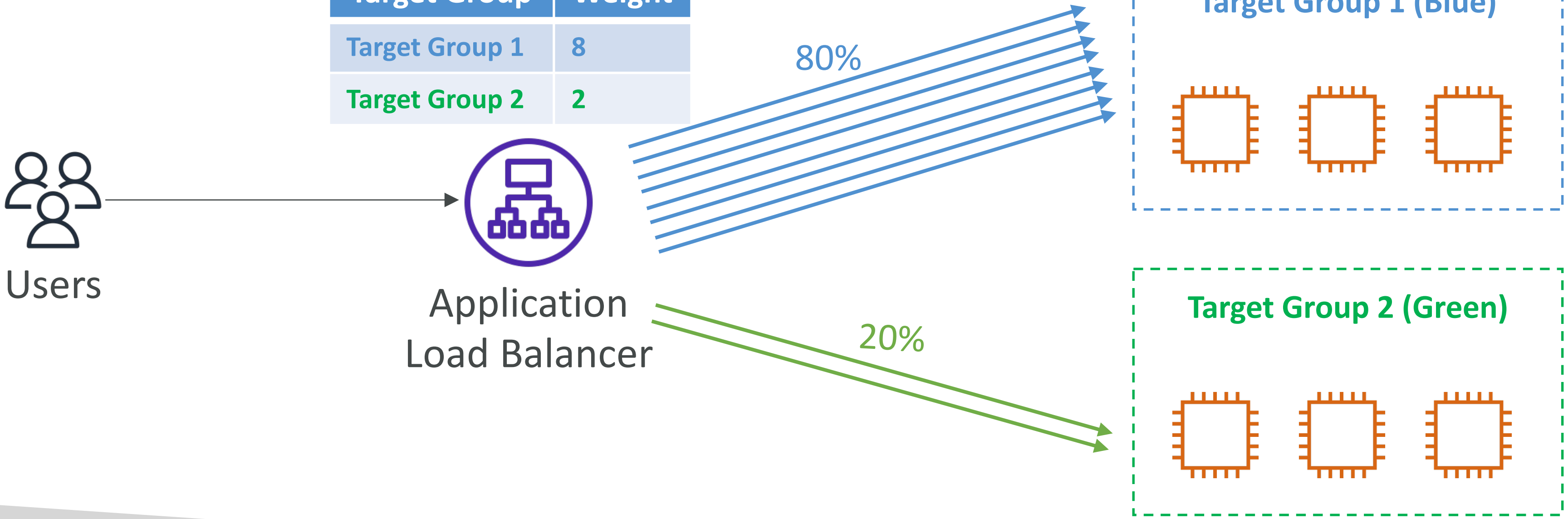
- Processed in order (last is Default Rule)
- Supported Actions (forward, redirect, fixed-response)
- Rule Conditions:
  - host-header
  - http-request-method
  - path-pattern
  - source-ip
  - http-header
  - query-string



Target Group Weighting

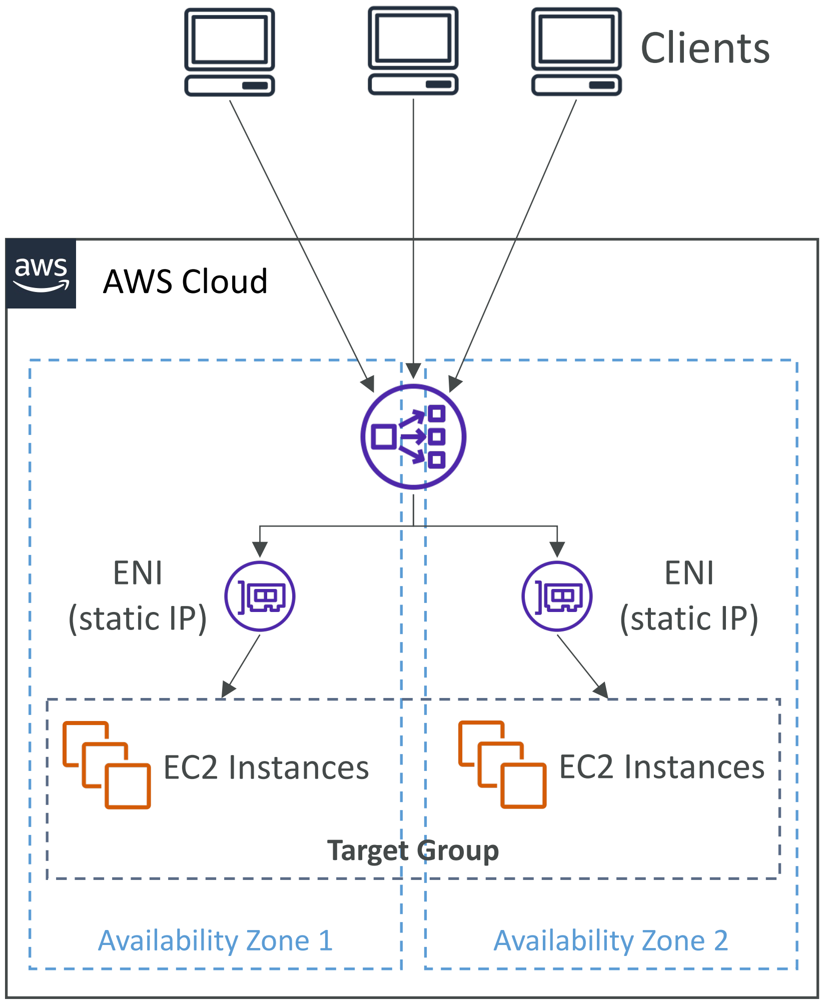
- Specify weight for each Target Group on a single Rule
- Example: multiple versions of your app, blue/green deployment
- Allows you to control the distribution of the traffic to your applications

Target Group	Weight
Target Group 1	8
Target Group 2	2



Network Load Balancer

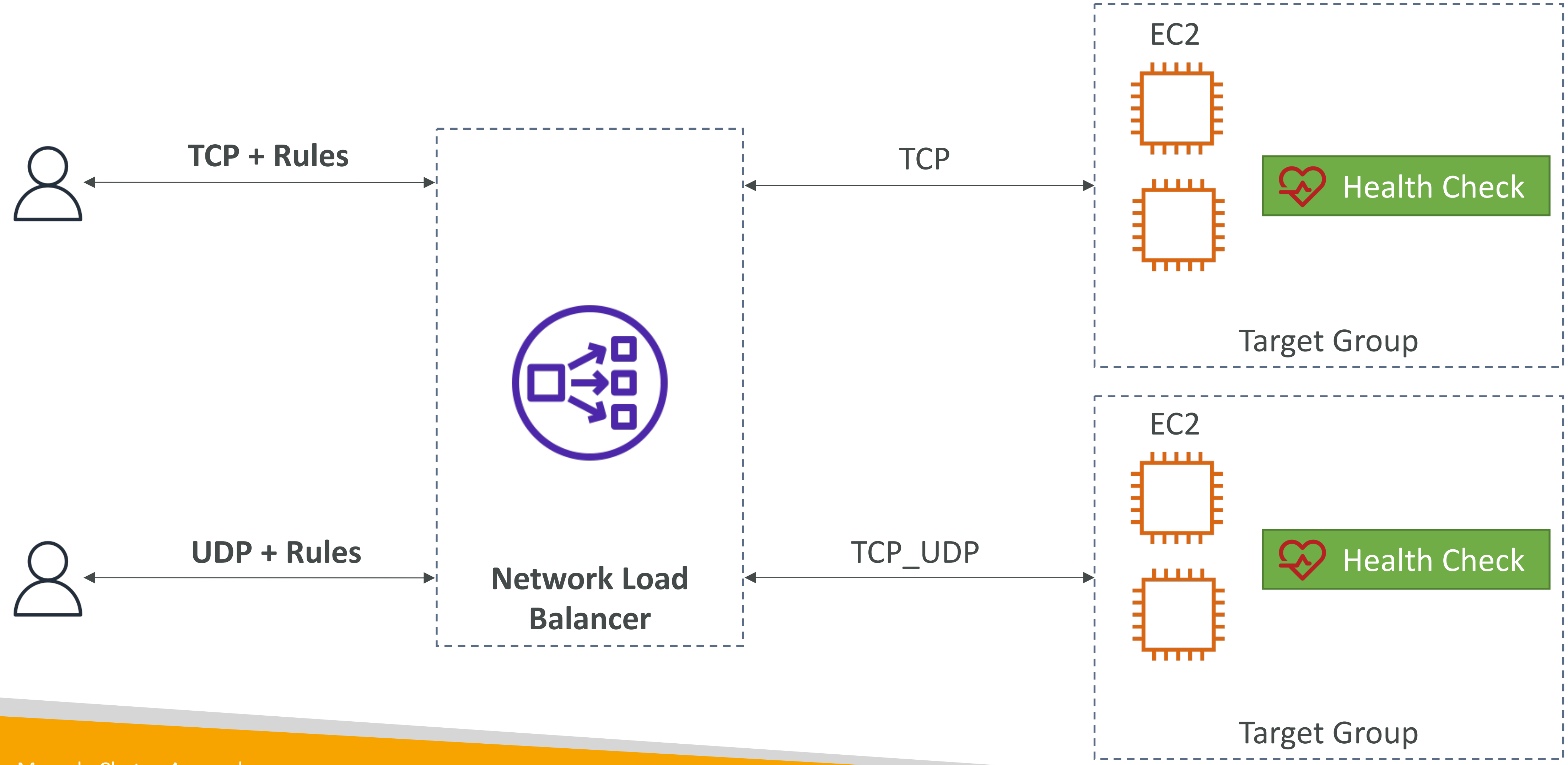
- Operates at Layer 4
- Supported protocols TCP, UDP, and TLS
- Handle millions of requests per second
- NLB has one static IP per AZ, and supports assigning Elastic IP (Internet-facing NLB) (helpful for whitelisting specific IP addresses)
- Load balancing to multiple applications/ports on the same machine (e.g., containers, Amazon ECS)
- Less latency ~100 ms (vs. 400 ms for ALB)
- Supports WebSocket protocol
- Network Load Balancers are mostly used:
  - For extreme performance, TCP or UDP traffic
  - With AWS PrivateLink: privately expose an internal service



Network Load Balancer

- Target Groups
  - **EC2 Instances** – can be managed by an ASG
  - **ECS Tasks** – (managed by ECS itself)
  - **IP Addresses**
    - must be private IP addresses, TCP listeners only (on-premises servers over AWS DX or VPN)
    - can be inter-region peered VPC
- You can't register EC2 instances by instance ID if these EC2 instances are in another VPC (even if peered with NLB VPC)
  - Register by IP address instead
- Health Checks
  - Supported protocols HTTP, HTTPS, and TCP
  - **Active Health Check** – periodically sends a request to registered targets
  - **Passive Health Check** – observe how targets respond to connections. Detect unhealthy targets before Active Health Checks (can't be disabled or configured)

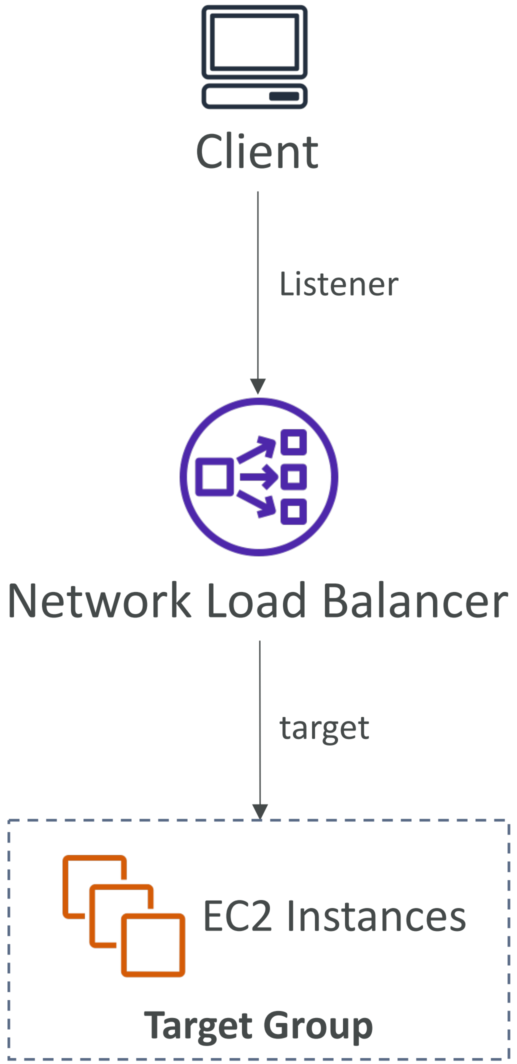
Network Load Balancer TCP & UDP -based Traffic



Network Load Balancer

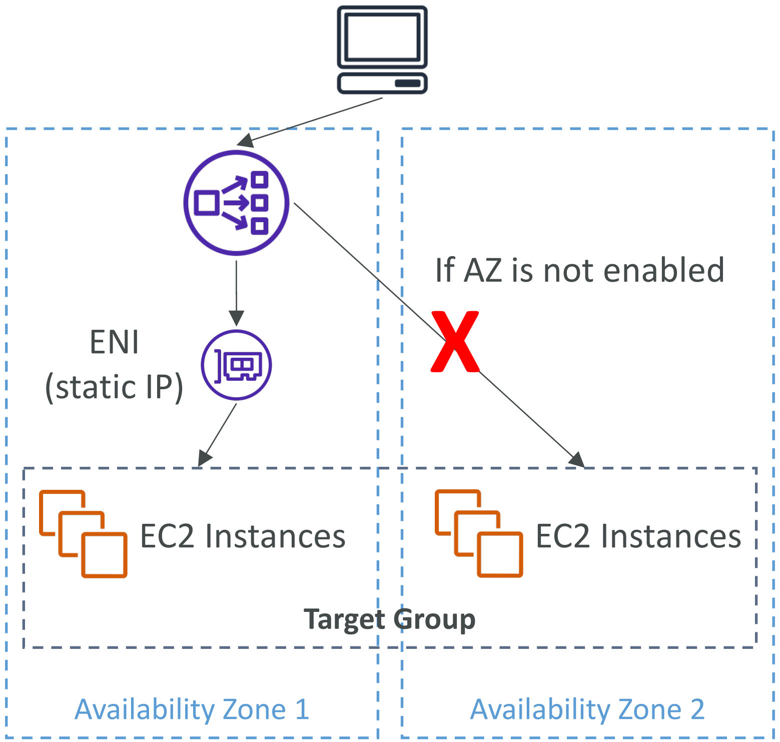
- **Client IP Preservation:** client IP is forwarded to targets
  - Targets by instance ID / ECS Tasks: Enabled
  - Targets by IP address **TCP & TLS**: Disabled by default
  - Targets by IP address **UDP & TCP_UDP**: Enabled by default
- When disabled, use **Proxy Protocol v2 (will add headers)**

Listener	Target
TCP	TCP or TCP_UDP
TLS – SSL Termination (Must install certificate on NLB)	TCP or TLS (Must install certificate on targets)
UDP	UDP or TCP_UDP
TCP_UDP	TCP_UDP

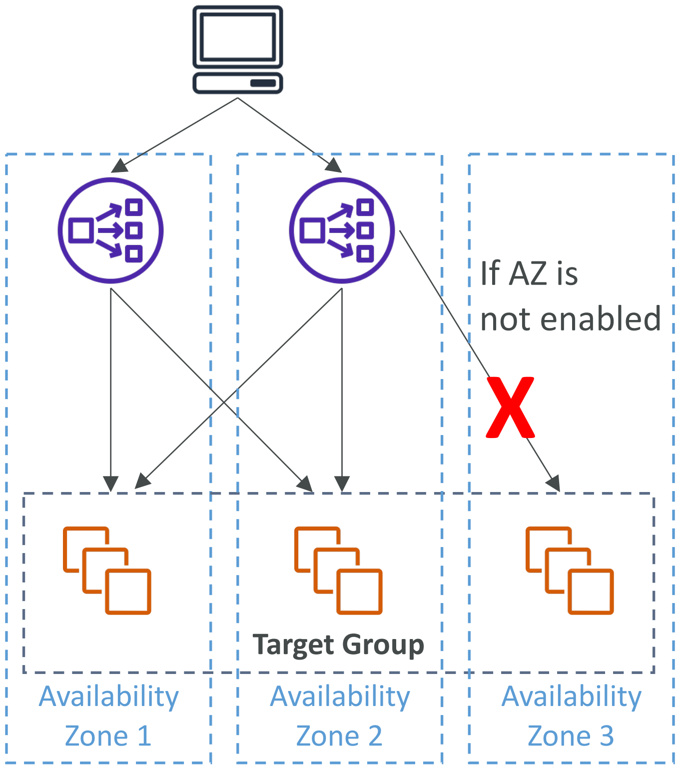


Network Load Balancer – Availability Zones

- You must enable an AZ before traffic is sent to that AZ (**can be added after NLB creation**)
- You cannot remove an AZ after it is enabled

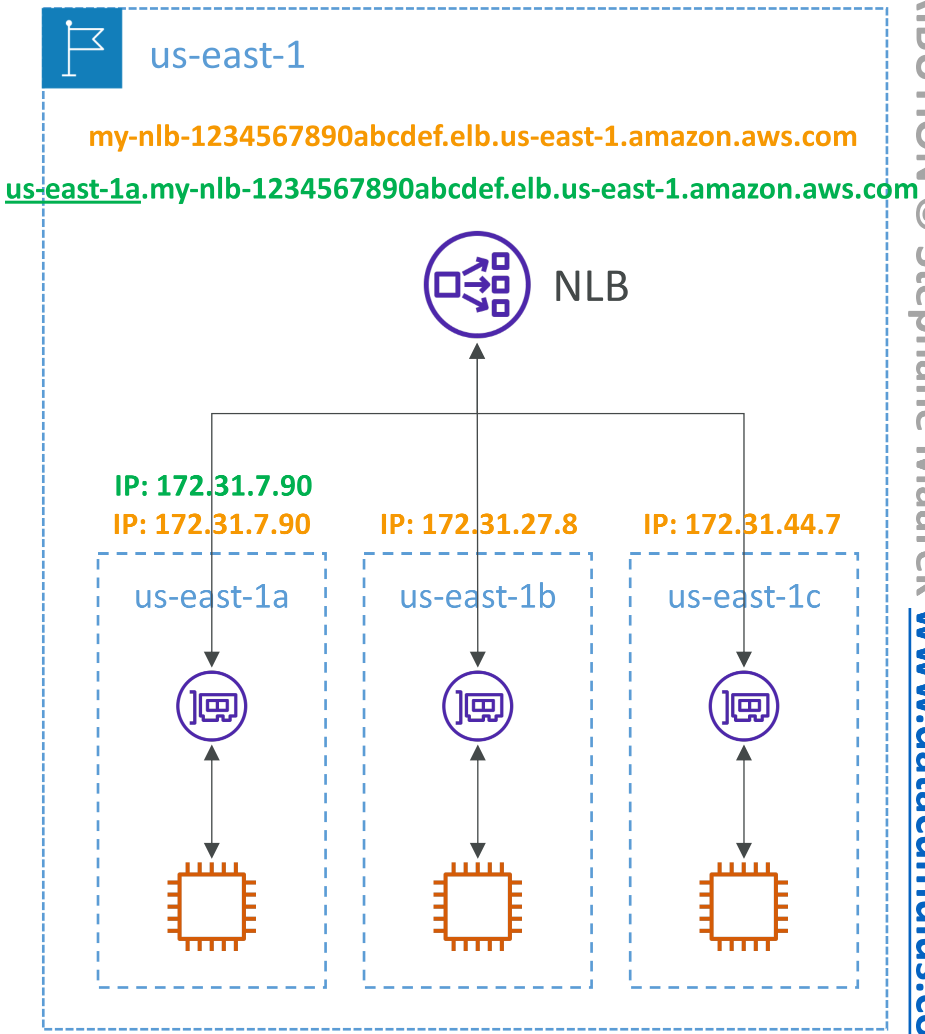


- Cross Zones Load Balancing only works for the availability zones that are enabled on the NLB



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.amazon.aws.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.amazon.aws.com
  - Used to minimize latency and data transfer costs
  - You need to implement app specific logic



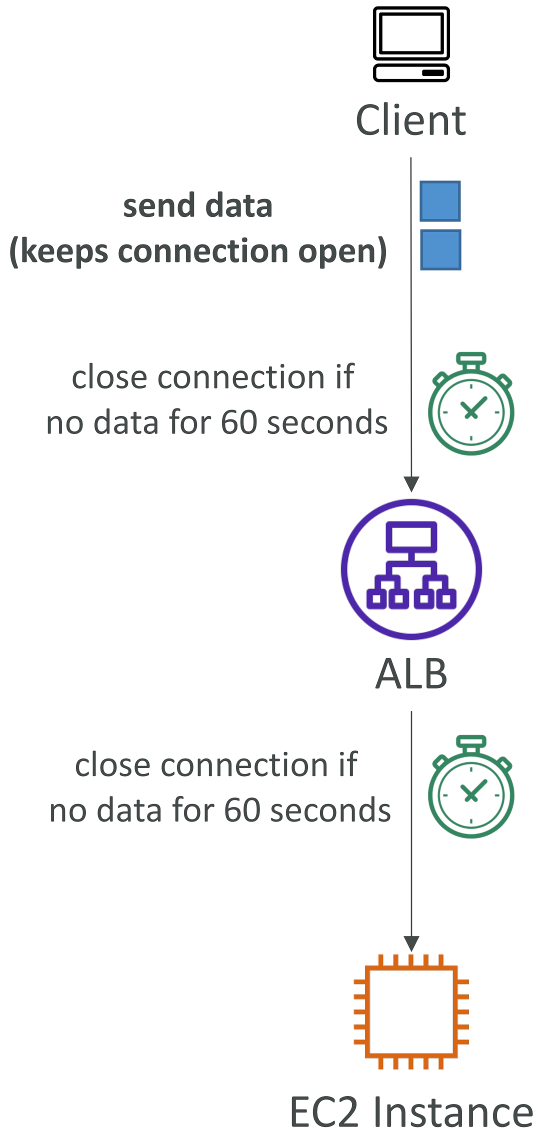
Network Load Balancer – Good To Know

- You can't disable/remove an AZ after you create it
- You can't modify ENIs created for the NLB in each AZ (view only)
- You can't change EIPs and private IPv4 addresses attached to the ENIs after you create the load balancer
- Supports 440,000 simultaneous connections/minute per target
  - If exceeded, you'll receive **port allocation errors**
  - Solution: add more targets to the target group
- For internet-facing load balancers, the subnets that you specify must have at least 8 available IP addresses (e.g. min /28). For internal load balancers, this is only required if you let AWS select a private IPv4 address from the subnet.

Connection Idle Timeout

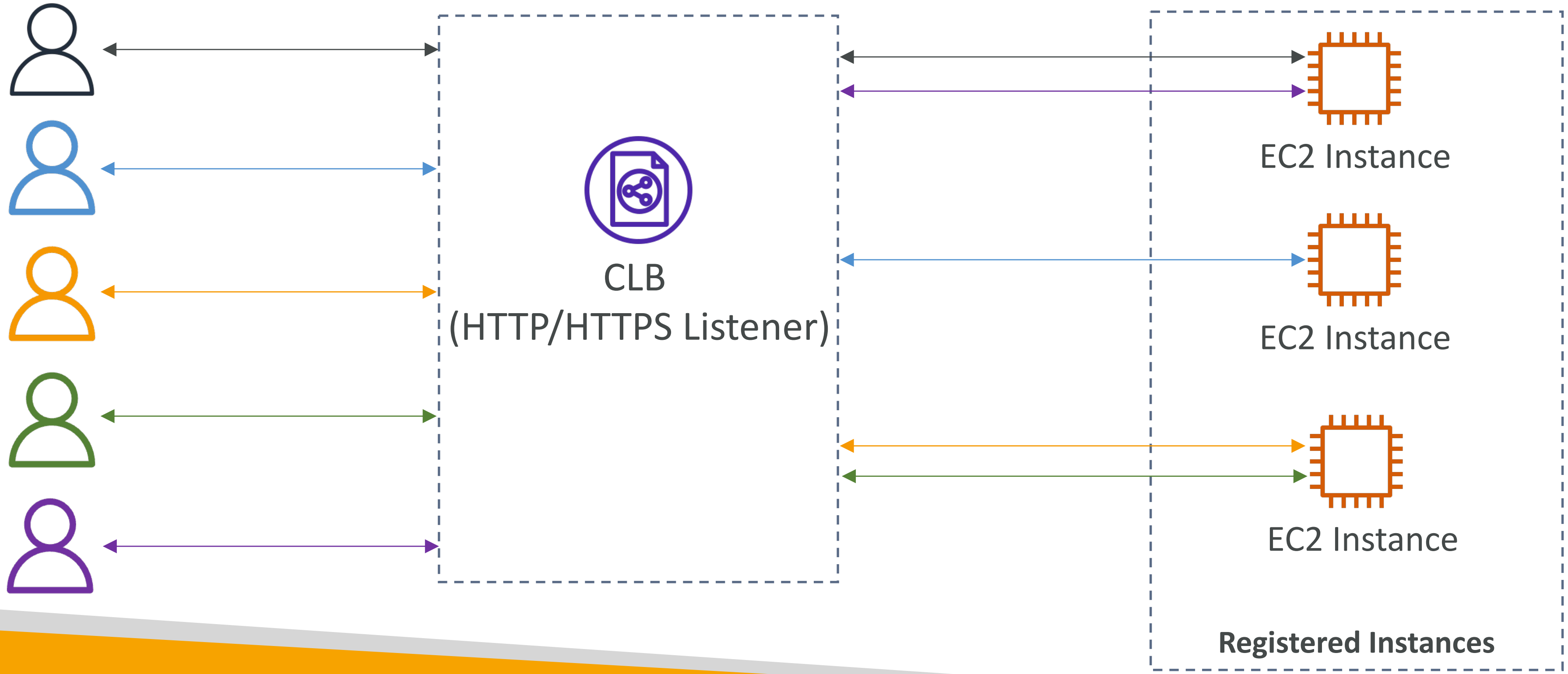
- Idle Timeout period for ELB's connections (client-ELB connection & ELB-target connection)
  - Connection closed if no data has been sent/received during that period
  - Opened if at least 1 byte is sent before that timeout period elapses
- Supported for CLB, ALB, and NLB
- Can be configured for CLB & ALB (default 60 seconds)
- Can't be configured for NLB (350 sec. for TCP, 120 sec. for UDP)
- Usage: avoid timeouts while uploading files

- Recommended to enable HTTP keep-alive in the web server settings for your EC2 instances, thus makes the ELB reuse the backend connections until the keep-alive timeout expires



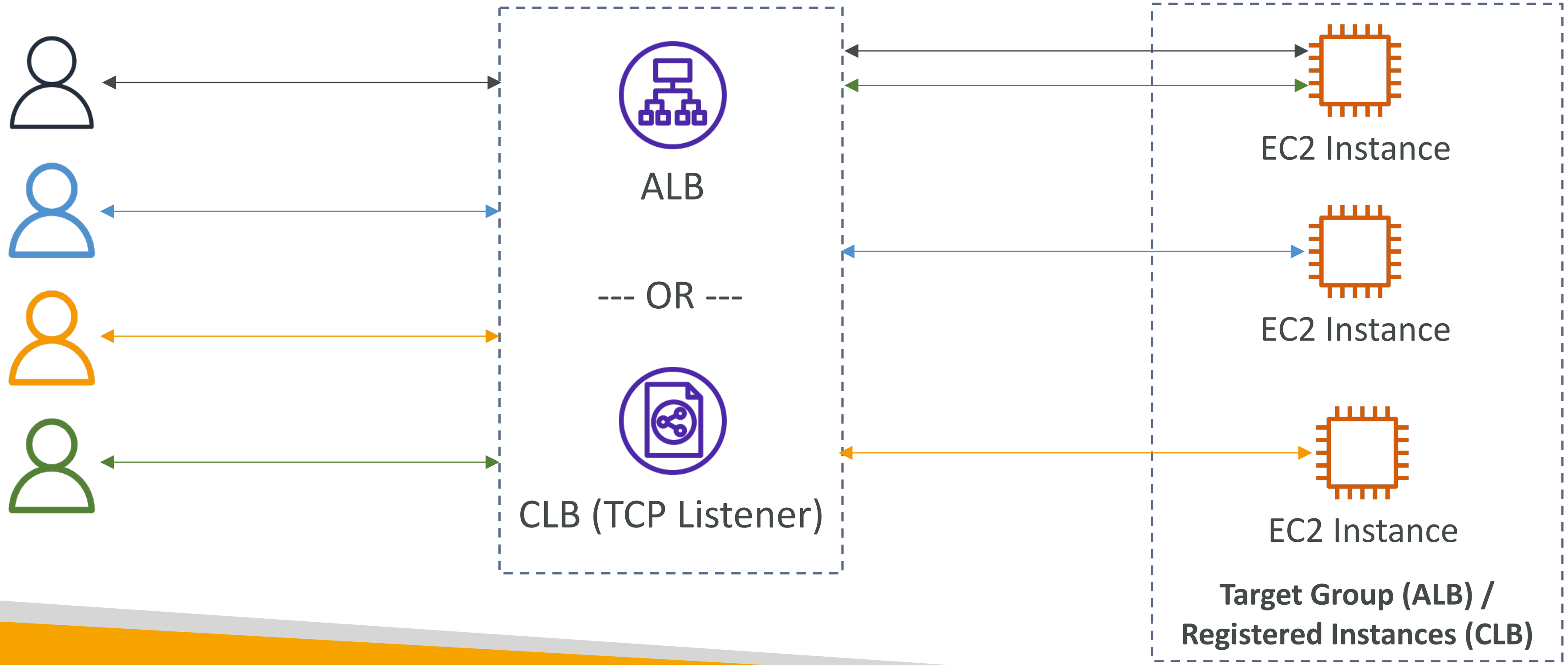
Request Routing Algorithms – Least Outstanding Requests

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



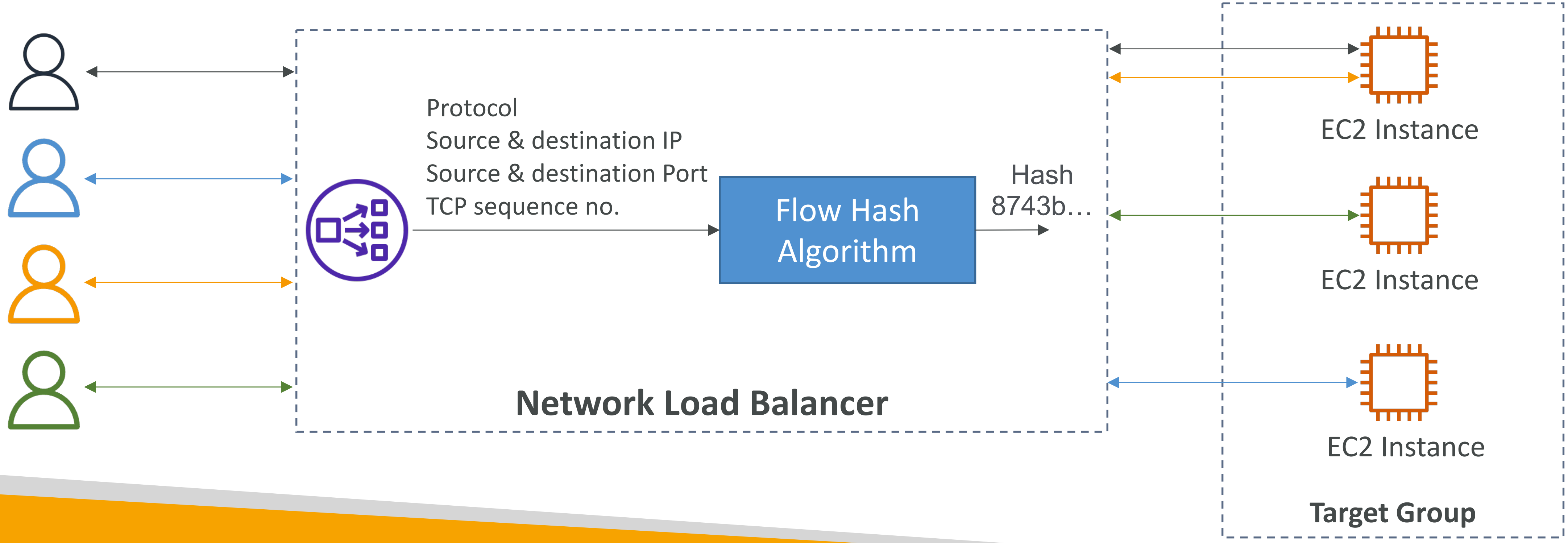
Request Routing Algorithms – Round Robin

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



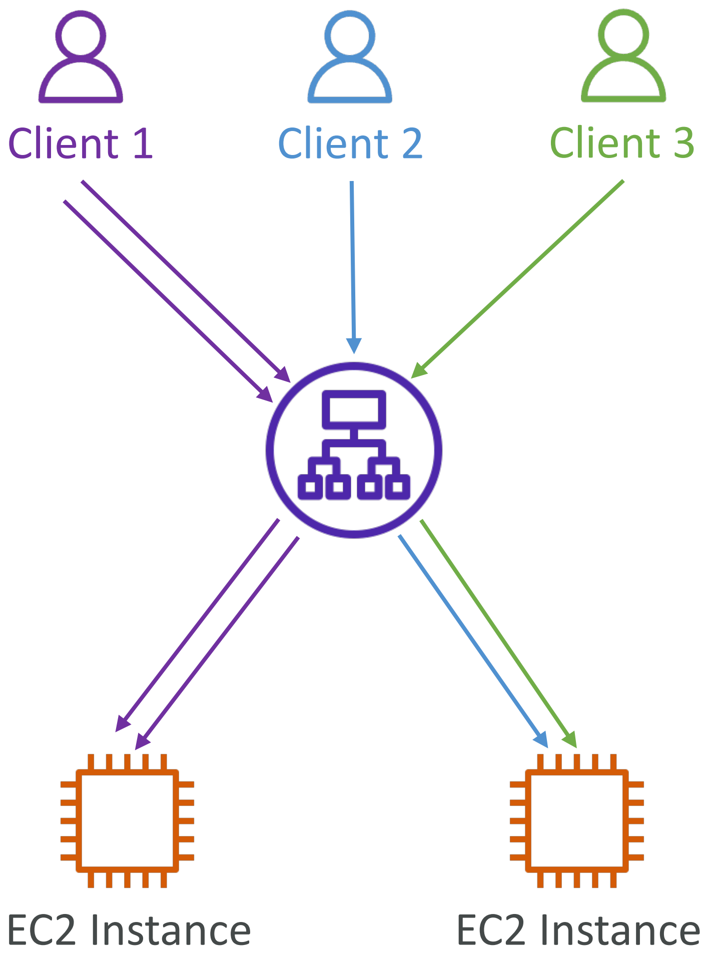
Request Routing Algorithms – Flow Hash

- 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**



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 Balancer, Application Load Balancer, and Network Load Balancer**
- For both CLB & ALB, the "cookie" used for stickiness has an expiration date you control
- Use case: make sure the user doesn't lose his session data
- Enabling stickiness may bring imbalance to the load over the backend EC2 instances



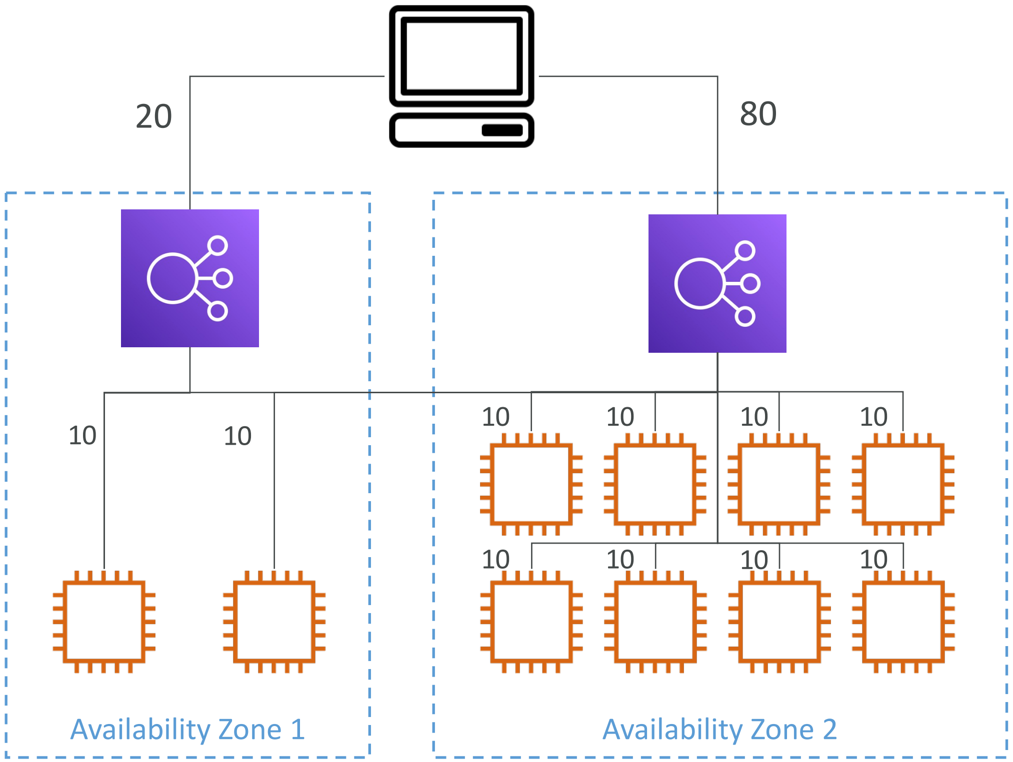
Sticky Sessions – Cookie Names

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

Cross-Zone Load Balancing

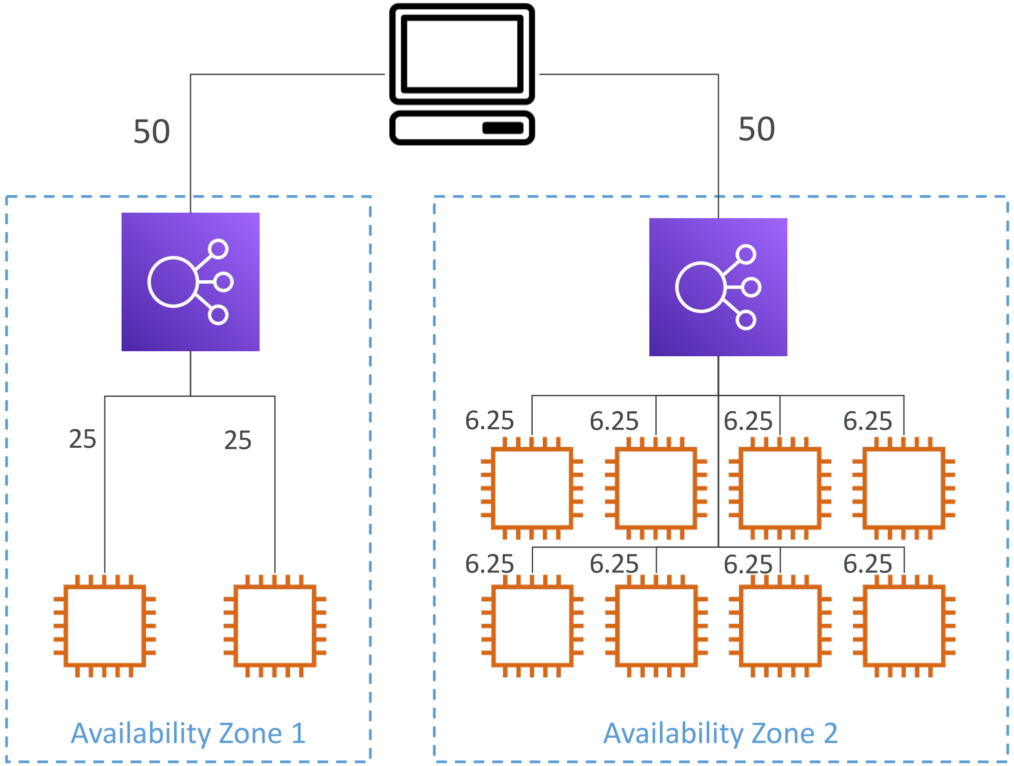
With Cross Zone Load Balancing

Requests are distributed evenly across all registered instances in all AZ



Without Cross Zone Load Balancing

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



Cross-Zone Load Balancing

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

SSL/TLS - Basics

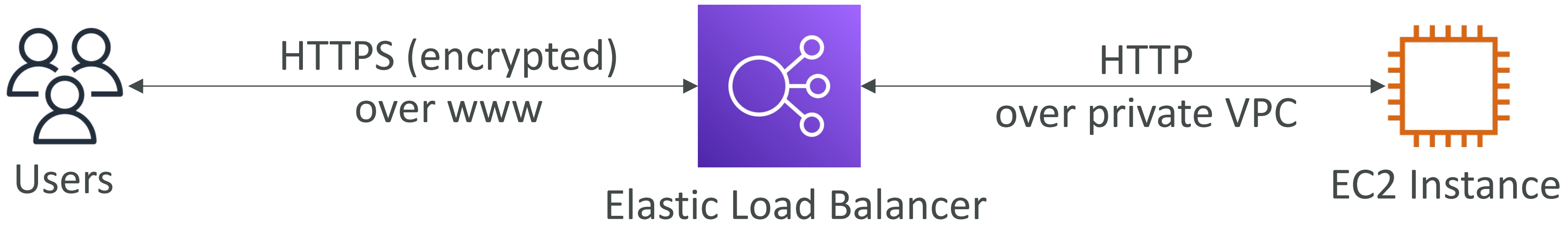
- An SSL Certificate allows traffic between your clients and your load balancer to be encrypted in transit (in-flight encryption)

- **SSL** refers to Secure Socket 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, Let's Encrypt, …

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

Elastic Load Balancer – SSL Certificates

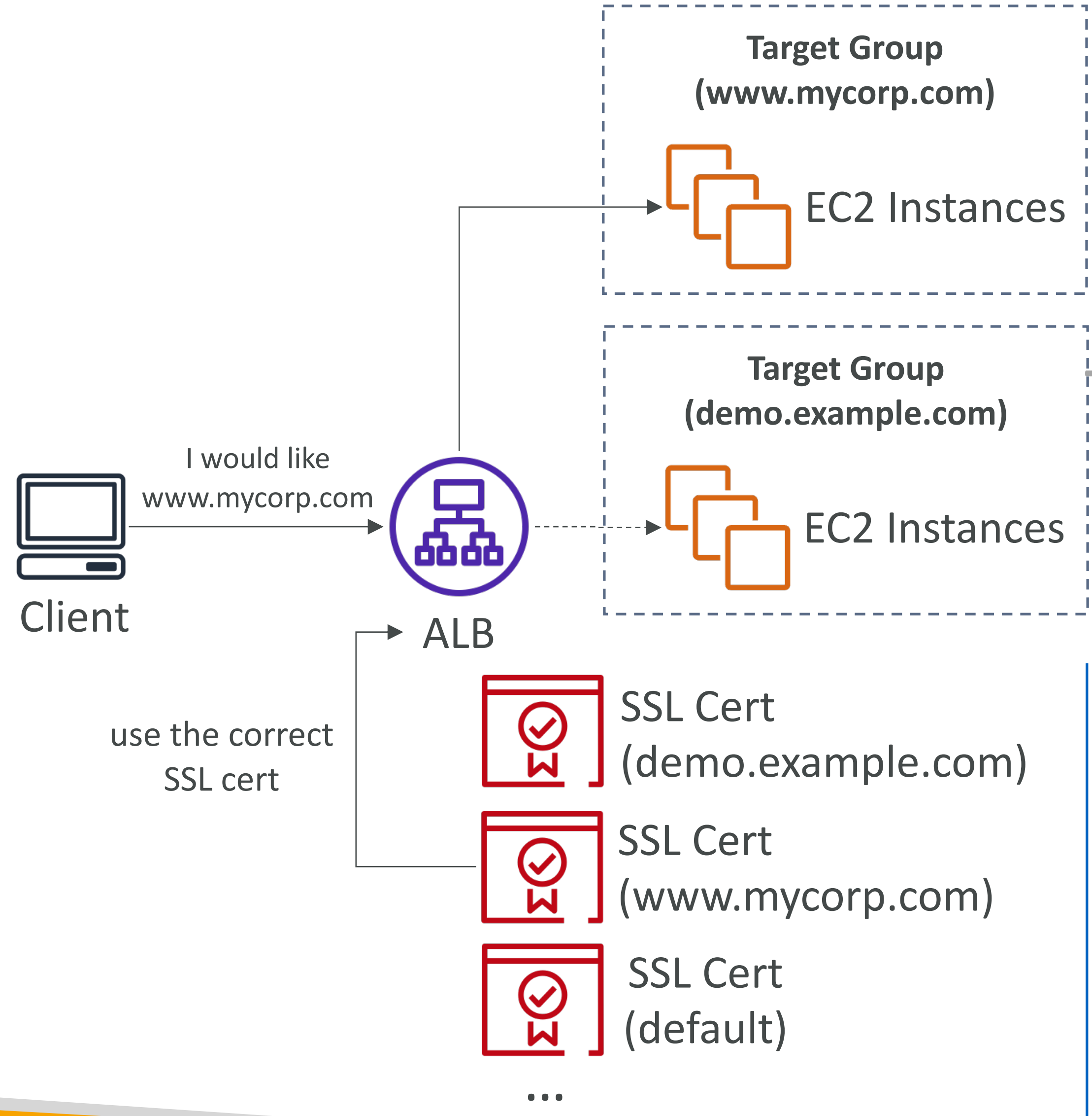


- The load balancer uses an X.509 certificate (SSL/TLS server certificate)
- You can manage certificates using ACM (AWS Certificate Manager)
- You can create upload your own certificates alternatively
- HTTPS listener:
  - You must specify a default certificate
  - You can add an optional list of certs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

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 hostname in the initial SSL handshake
- The server will then find the correct certificate, or return the default one

- Only works for ALB & NLB



Elastic Load Balancers – SSL Certificates

- Classic Load Balancer
  - Supports only one SSL certificate
  - The SSL certificate can have many Subject Alternate Name (SAN), but the SSL certificate must be changed anytime a SAN is added / edited / removed
  - Must use multiple CLB for multiple hostnames with multiple SSL certificates
  - Better to use ALB with Server Name Indication (SNI) if possible

- Application Load Balancer
  - Supports multiple listeners with multiple SSL certificates
  - Uses Server Name Indication (SNI) to make it work

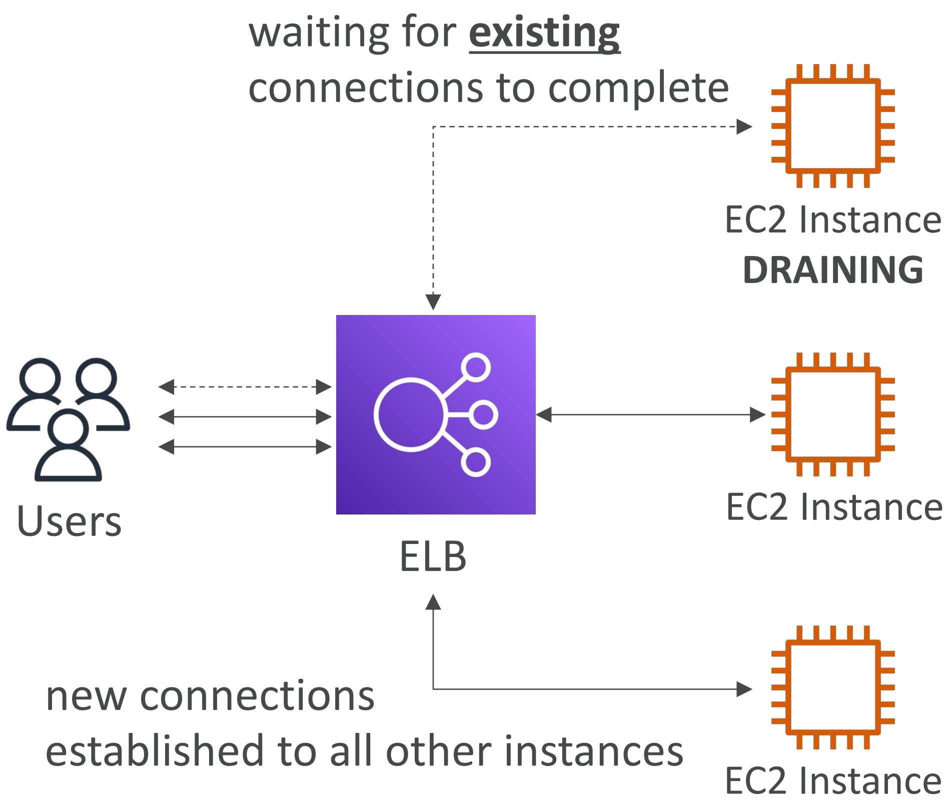
- Network Load Balancer
  - Supports multiple listeners with multiple SSL certificates
  - Uses Server Name Indication (SNI) to make it work

HTTPS/SSL Listener – Security Policy

- A combination of SSL protocols, SSL ciphers, and Server Order Preference option supported during SSL negotiations
- Predefined Security Policies (e.g., ELBSecurityPolicy-2016-08)
- For **ALB and NLB**
  - Frontend connections, you can use a predefined Security Policy
  - Backend connections, **ELBSecurityPolicy-2016-08** Security Policy is always used
- Use **ELBSecurityPolicy-TLS** policies
  - To meet compliance and security standards that require certain TLS protocol version
  - To support older versions of SSL/TLS (legacy clients)
- Use **ELBSecurityPolicy-FS** policies, if you require **Forward Secrecy**
  - Provides additional safeguards against the eavesdropping of encrypted data
  - Using a unique random session key

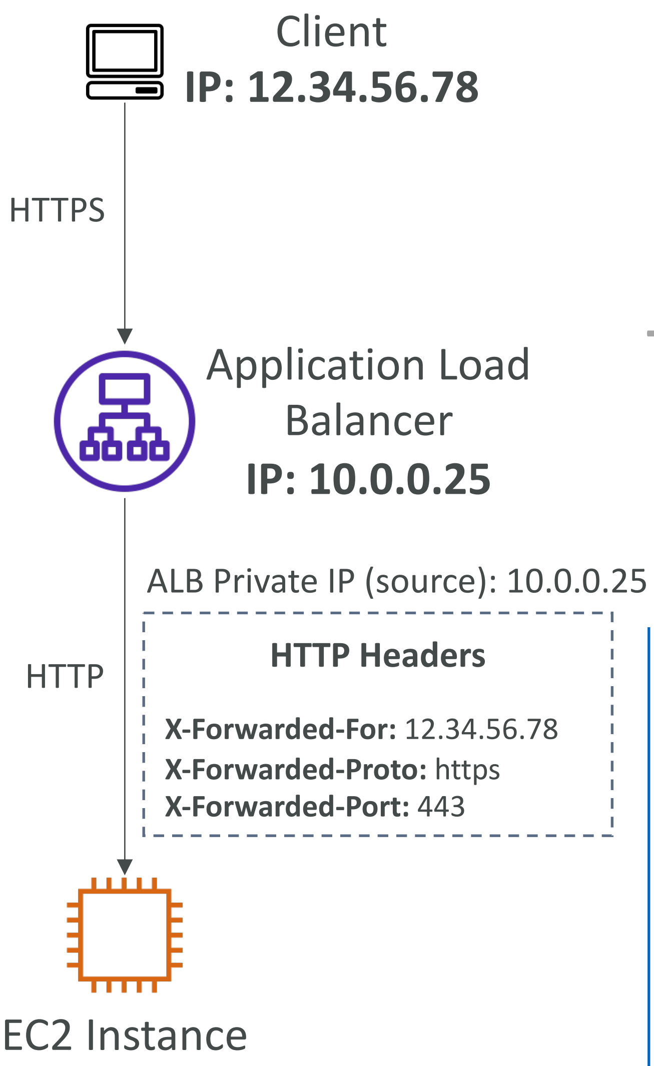
Connection Draining

- Feature naming
  - Connection Draining – for CLB
  - Deregistration Delay – for ALB & NLB
- Time to complete "in-flight requests" while the instance is de-registering or unhealthy
- Stops sending new requests to the EC2 instance which is de-registering
- Between 1 to 3600 seconds (default: 300 seconds)
- Can be disabled (set value to 0)
- Set to a low value if your requests are short



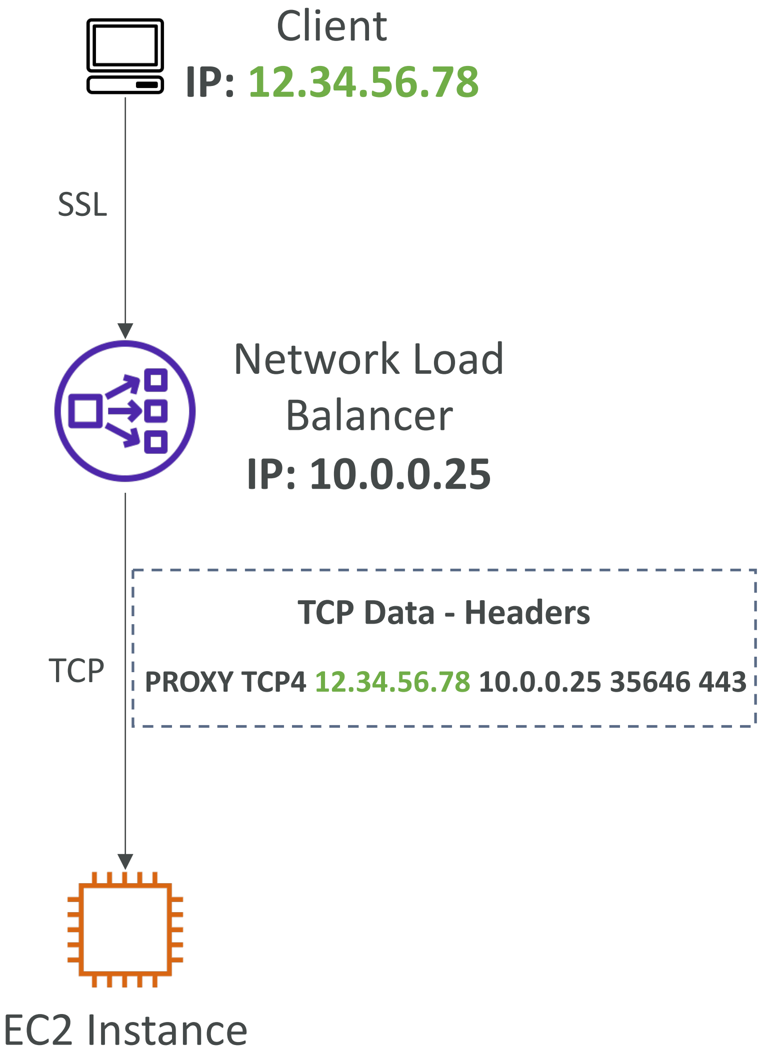
X-Forwarded Headers (HTTP)

- Non-standard HTTP headers that have an **X-Forwarded** prefix
- Used by ELB to forward client information to the targets (e.g., client IP address)
- You can use to log client requests on your server
- Supported by **Classic Load Balancer (HTTP/HTTPS)** and **Application Load Balancer**
- X-Forwarded-For
  - Contains the IP address of the client
  - May contain comma-separated list of multiple IP addresses, such as proxies (left-most is the client IP address)
- X-Forwarded-Proto – the protocol used between client and the ELB (HTTP/HTTPS)
- X-Forwarded-Port – the destination port the client used to connect to the ELB



Proxy Protocol

- An Internet protocol used to carry information from the source (requesting the connection) to the destination (where connection was requested)
- If the LB terminates the connection, the source IP address of the client cannot be preserved
- We use the Proxy Protocol to pass the source/destination IP address and port numbers
- The load balancer prepends a proxy protocol header to the TCP data
- Available for both Classic Load Balancer (TCP/SSL) and Network Load Balancer

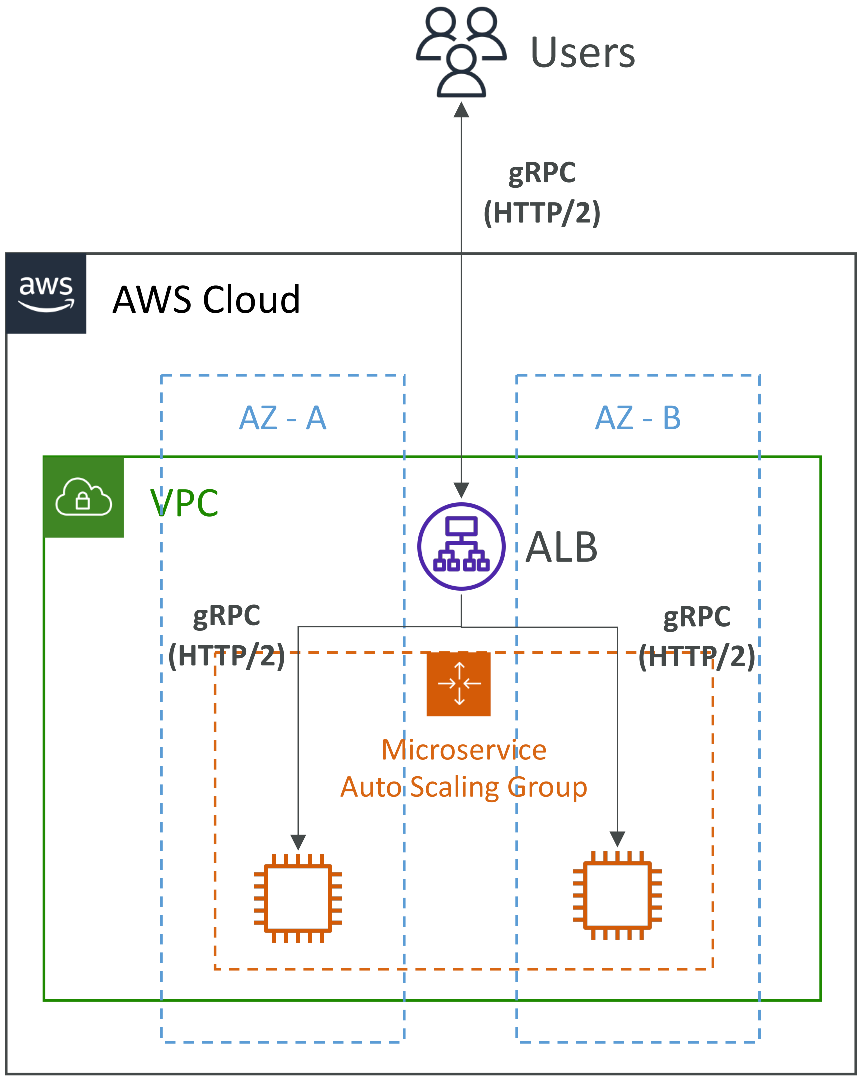


Proxy Protocol

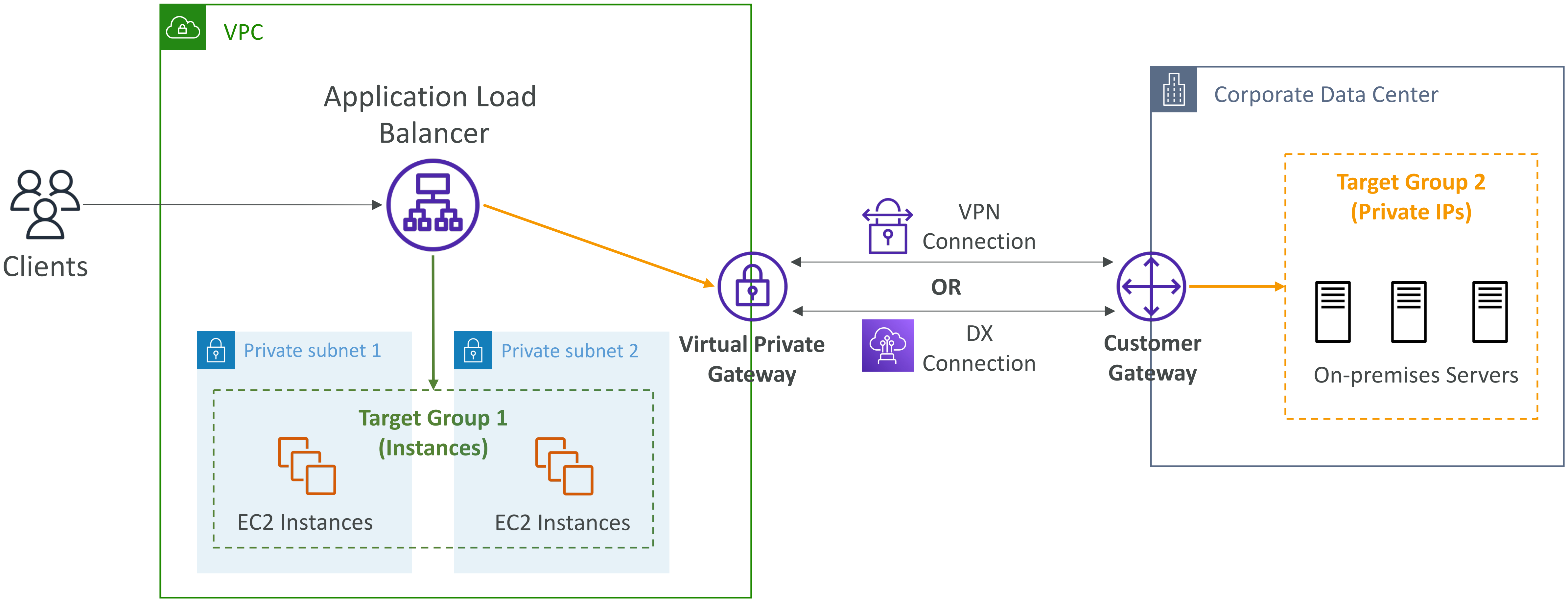
- **CLB** uses Proxy Protocol version 1 & **NLB** uses Proxy Protocol version 2
- For Network Load Balancer
  - **Target with Instance ID and ECS Tasks:** the source IP of the client is preserved
  - **Target with IP Address:**
    - **TCP & TLS:** the source IP of the client isn't preserved, enable Proxy Protocol
    - **UDP & TCP_UDP:** the source IP of the client is preserved
- Load balancer should not be behind proxy server, otherwise backend may receive duplicate configuration information resulting in error
- Proxy protocol is not needed when using an Application Load Balancer, as ALB already inserts **HTTP X-Forwarded-For** headers

Application Load Balancer & gRPC

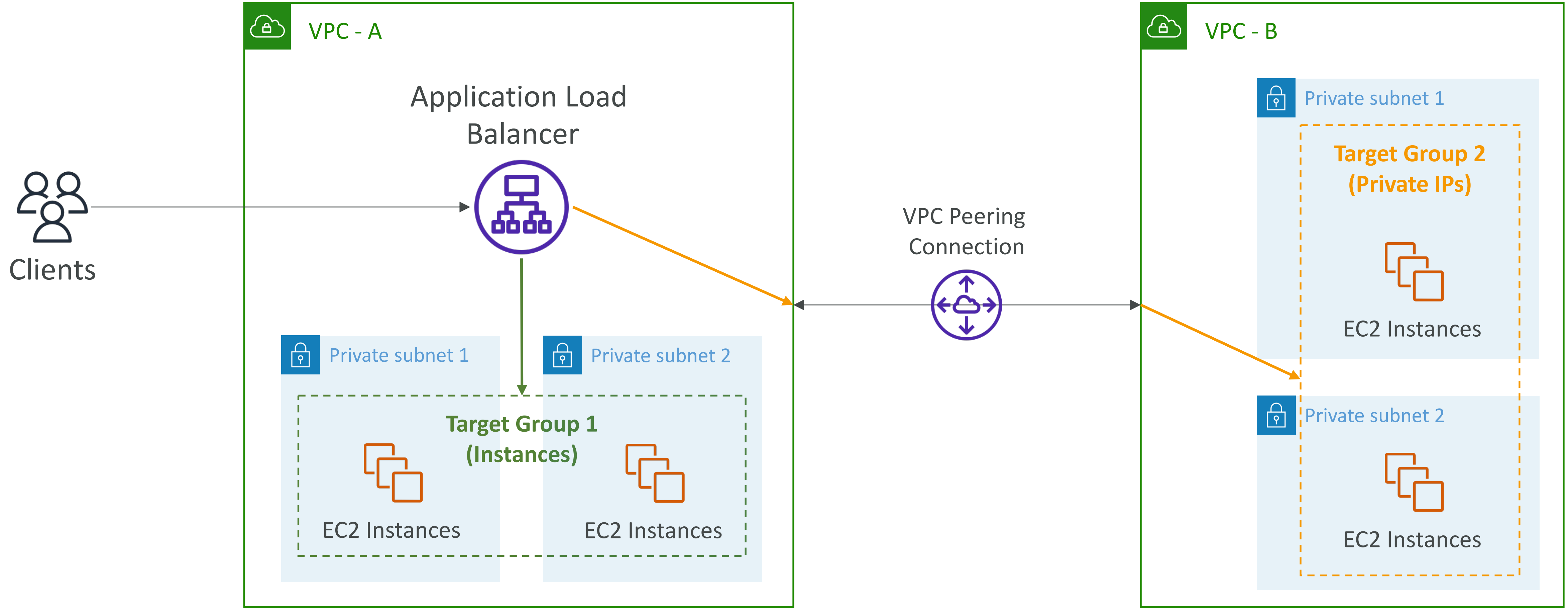
- gRPC is a popular choice for microservice integrations using HTTP/2
- The **Application Load Balancer** fully supports gRPC
  - Supports gRPC health checks from target group
  - Content based routing feature to route to the appropriate service
  - Supports all kind of gRPC communication (including bidirectional streaming)
  - Listener protocol is HTTPS
- *Note: gRPC would work with NLB but you wouldn't have any "HTTP-specific" features*



Load Balancing across on-premises servers



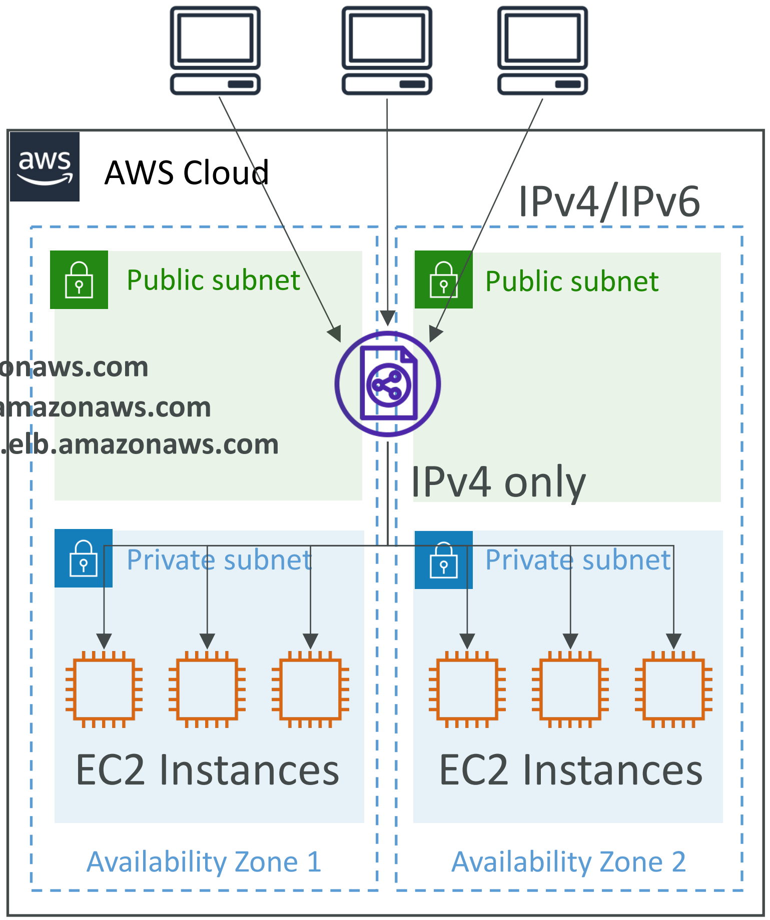
Load Balancing across Peered VPCs



Internet-facing vs. Internal Load Balancer

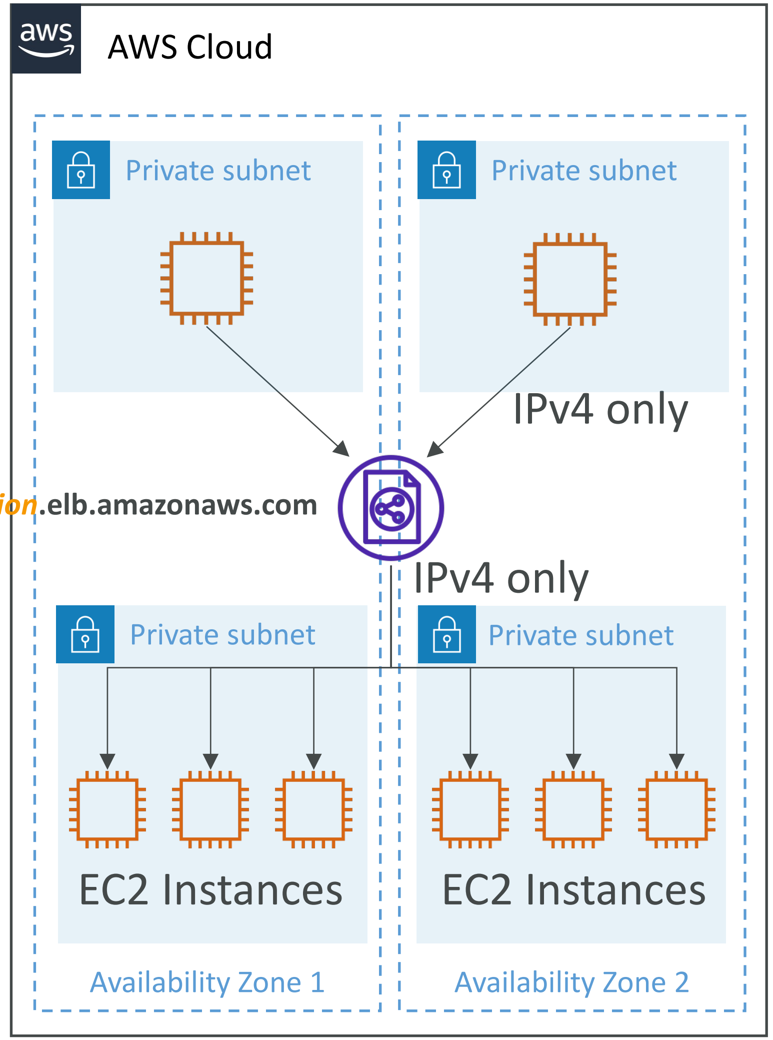
Internet-facing ELB (IPv4 or Dualstack)

name-1234567890.region.elb.amazonaws.com
ipv6.***name-1234567890.region***.elb.amazonaws.com
dualstack.***name-1234567890.region***.elb.amazonaws.com



Internal ELB (IPv4)

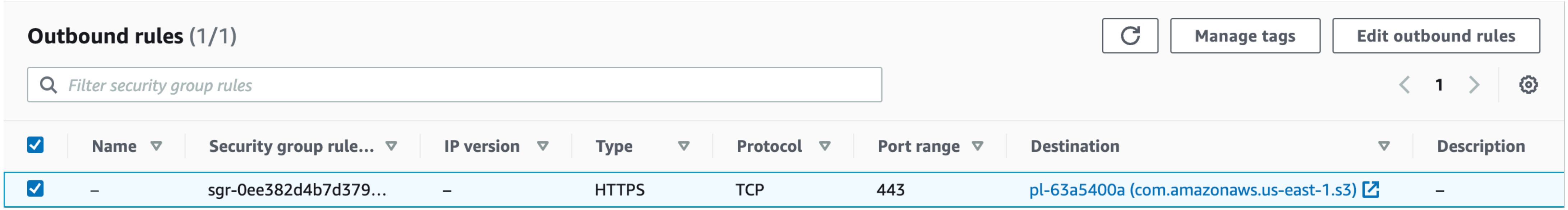
internal-***name-1234567890.region***.elb.amazonaws.com



NOTE: ELB connects to backend instances using Private IP address only

Security Groups – Outbound Rules

- Default is allowed **0.0.0.0/0** anywhere
- But we can remove and just allow specific prefixes



Outbound rules (1/1)

Manage tags | Edit outbound rules

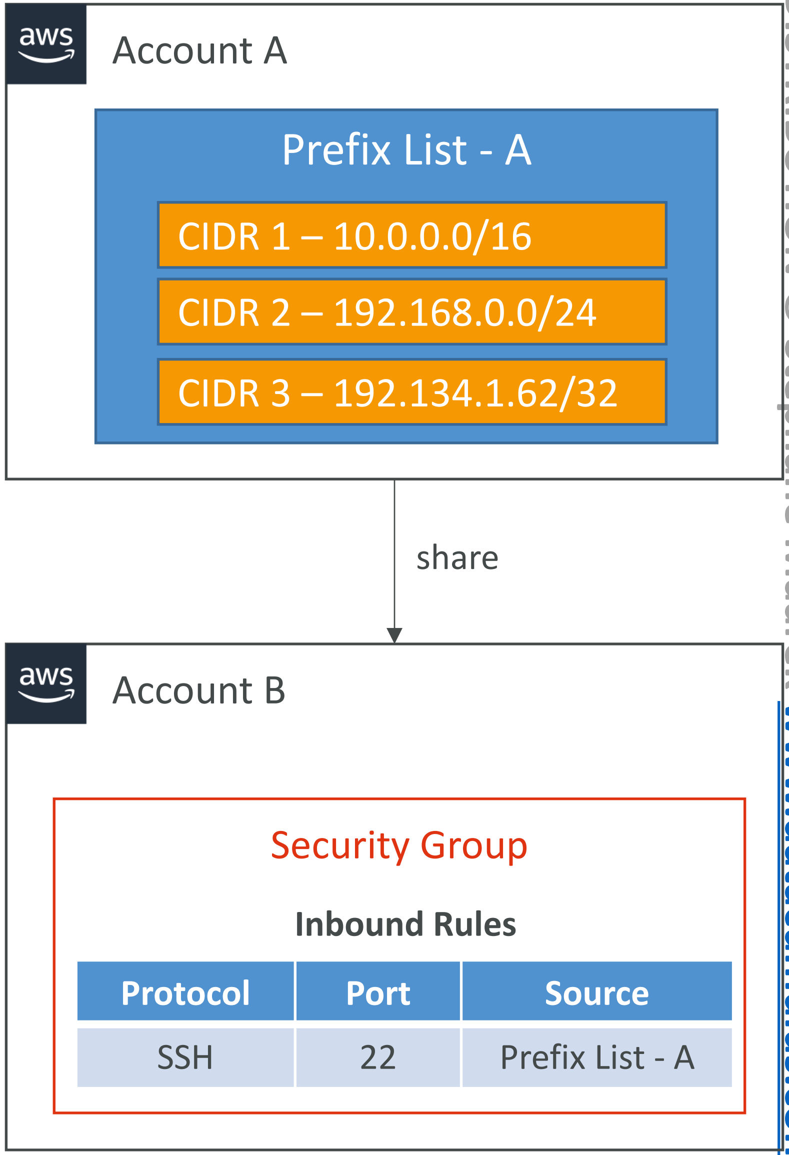
Filter security group rules

Name	Security group rule...	IP version	Type	Protocol	Port range	Destination	Description
–	sgr-0ee382d4b7d379...	–	HTTPS	TCP	443	pl-63a5400a (com.amazonaws.us-east-1.s3)	–

Allow Outbound traffic over port 443 to Amazon S3

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 managed 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
  - S3, CloudFront, DynamoDB, Ground Station…



Q1

Your company has deployed a bursty web application to AWS and would like to improve the user experience. It is important for only the web host to have the private key for Transport Layer Security (TLS), so the Classic Load Balancer has a listener on Transmission Control Protocol (TCP) port 443. What are some approaches that you can use to reduce latency and improve the scale-out process for the application?

1. Use an Application Load Balancer in front of the application, enabling better utilization of multiple target groups with different HTTP paths and hosts.
2. Configure enhanced networking on the Classic Load Balancer for lower latency load balancing.
3. Use Amazon Certificate Manager (ACM) to distribute new certificates to Amazon CloudFront to accomplish handling content at the edge.
4. **Use a Network Load Balancer in front of your application to increase network performance.**

Q2

Why is referencing the Application Load Balancer or Classic Load Balancer by its DNS CNAME recommended?

1. IP addresses may change as the load balancers scale.
2. DNS CNAMEs provide a lower latency than IP addresses.
3. You want to preserve the source IP of the client.
4. IP addresses are public and open to the Internet.

Amazon Route 53

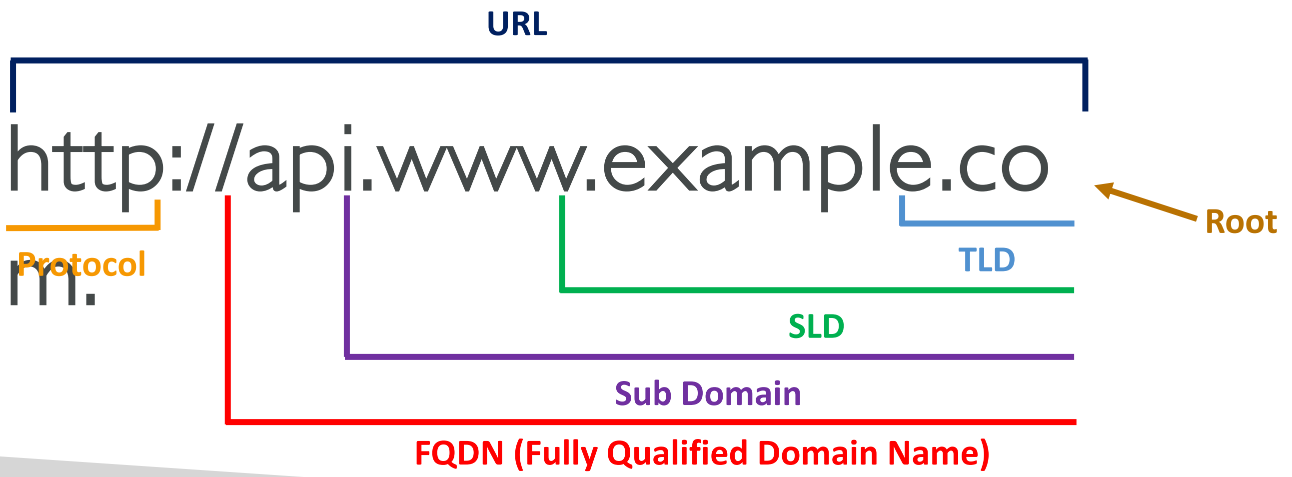
What is DNS?

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

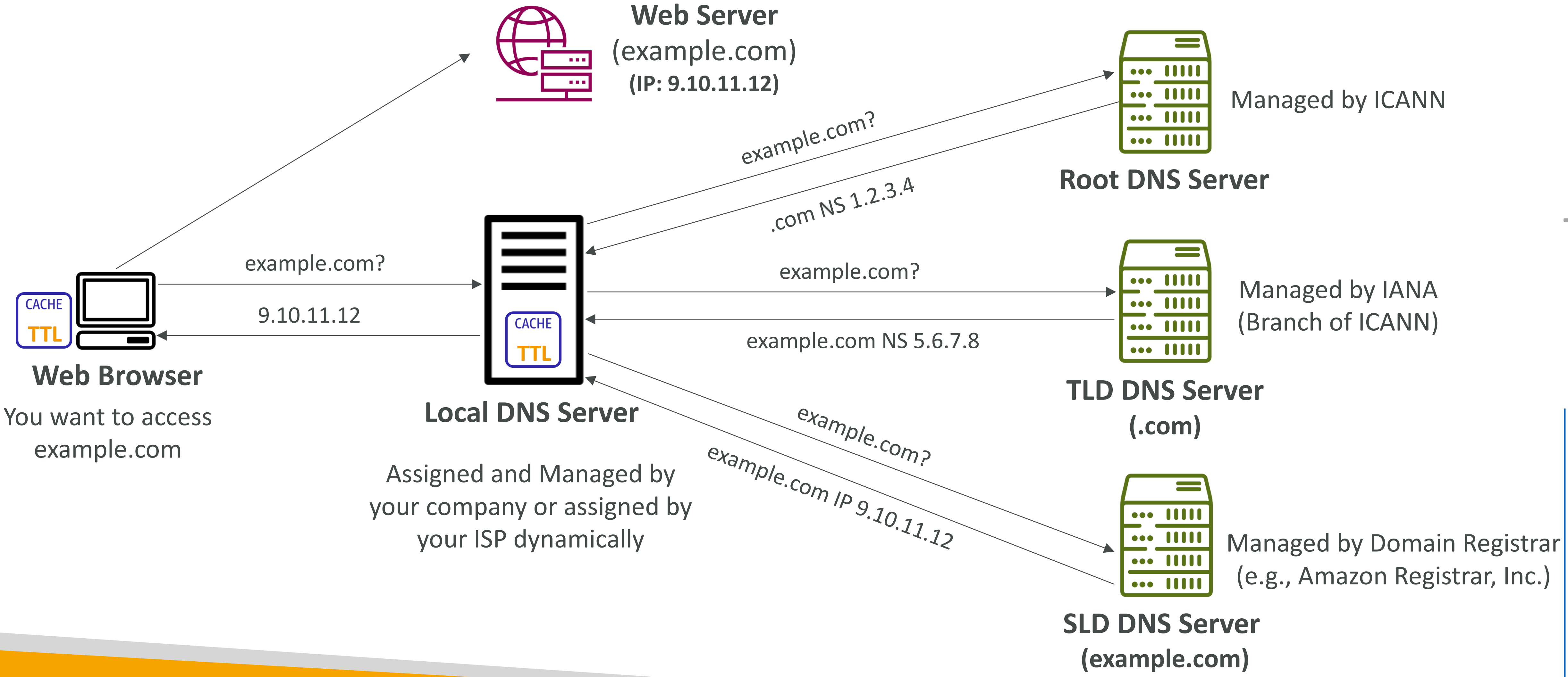
.com
example.com
www.example.com
api.example.com

DNS Terminologies

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

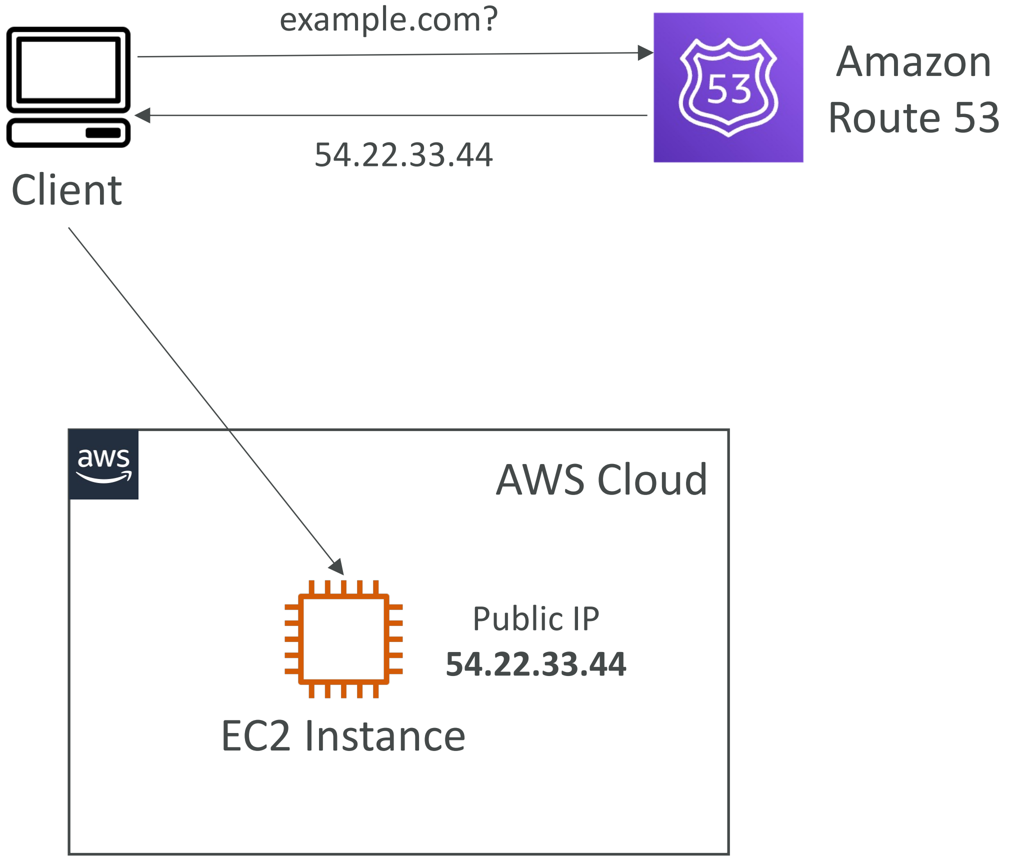


How DNS Works



Amazon Route 53

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



Route 53 – Records

- How you want to route traffic for a domain
- Each record contains:
  - **Domain/subdomain Name** – e.g., example.com
  - **Record Type** – e.g., A or AAAA
  - **Value** – e.g., 123.456.789.123
  - **Routing Policy** – how Route 53 responds to queries
  - **TTL** – amount of time the record cached at DNS Resolvers
- Route 53 supports the following DNS record types:
  - (must know) A / AAAA / CNAME / NS
  - (advanced) CAA / DS / MX / NAPTR / PTR / SOA / TXT / SPF / SRV

Route 53 – Record Types

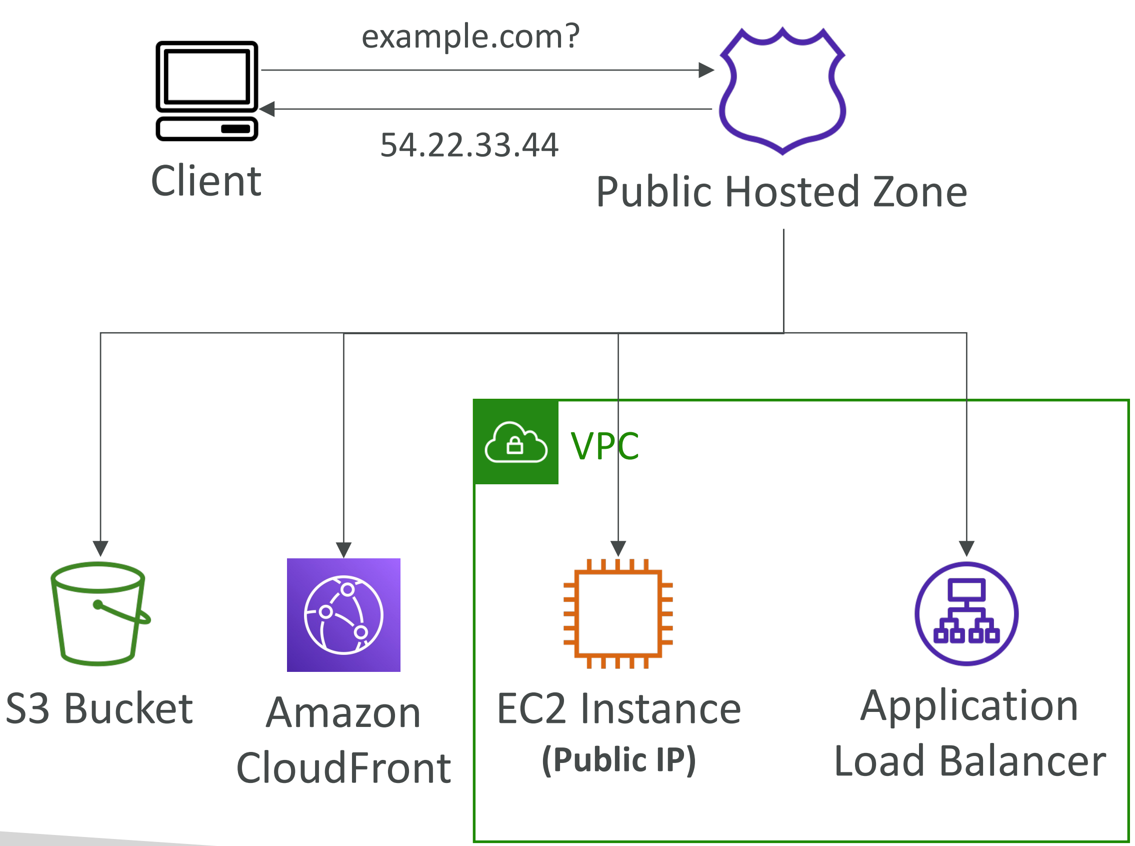
- A – maps a hostname to IPv4
- AAAA – maps a hostname to IPv6
- CNAME – maps a hostname to another hostname
  - The target is a domain name which must have an A or AAAA record
  - Can't create a CNAME record for the top node of a DNS namespace (Zone Apex)
  - Example: you can't create for example.com,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

Route 53 – Hosted Zones

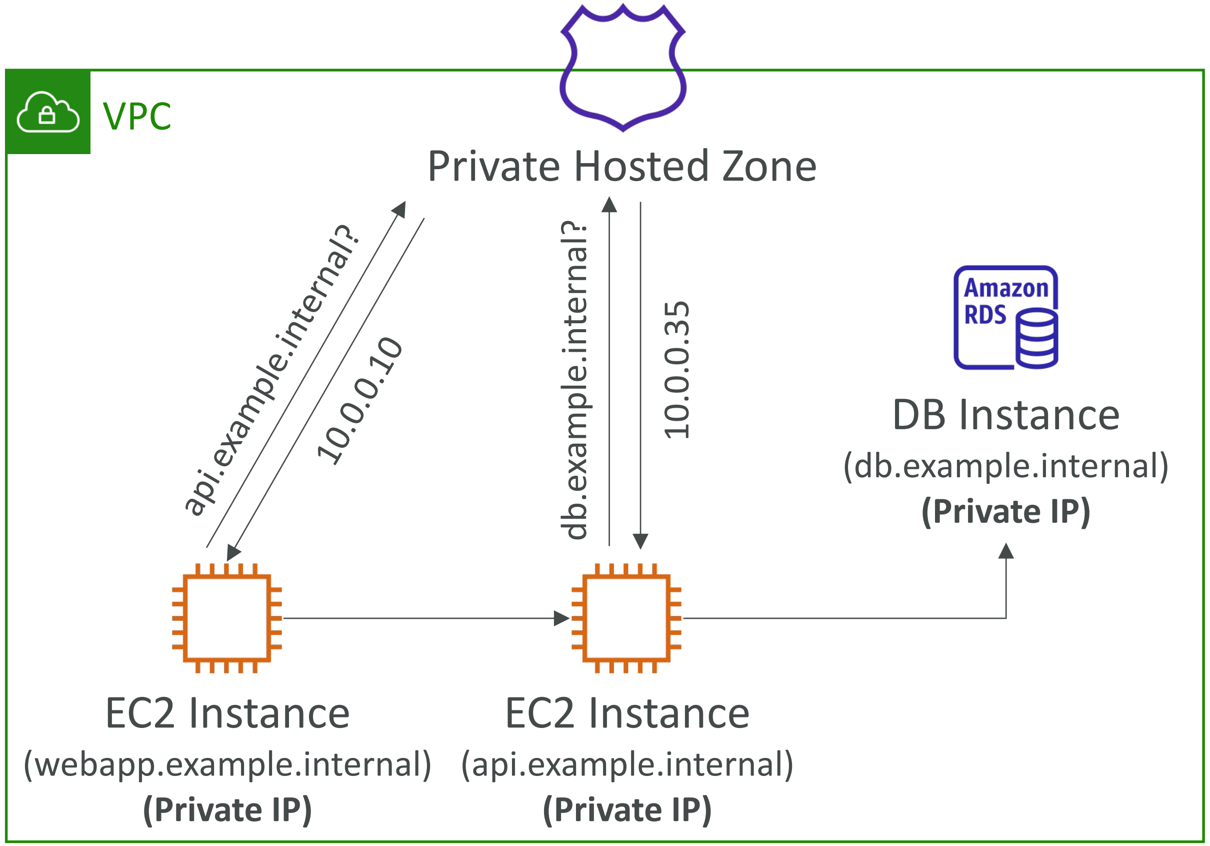
- A container for records that define how to route traffic to a domain and its subdomains
- **Public Hosted Zones** – contains records that specify how to route traffic on the Internet (public domain names) application1.mypublicdomain.com
- **Private Hosted Zones** – contain records that specify how you route traffic within one or more VPCs (private domain names) application1.company.internal
- You pay $0.50 per month per hosted zone

Route 53 – Public vs. Private Hosted Zones

Public Hosted Zone



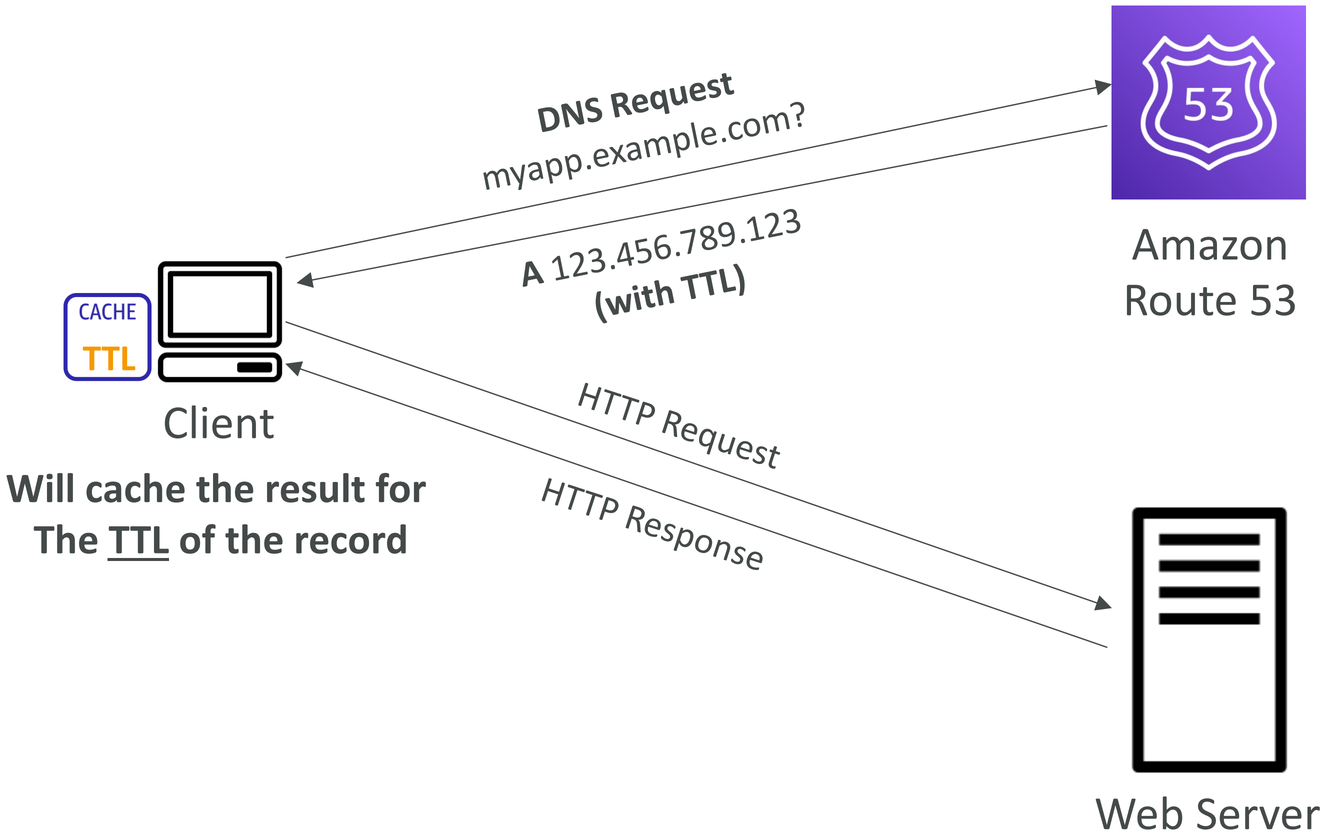
Private Hosted Zone



Route 53 – Records TTL (Time To Live)

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

- Except for Alias records, TTL is mandatory for each DNS record



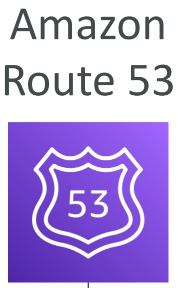
CNAME vs Alias

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

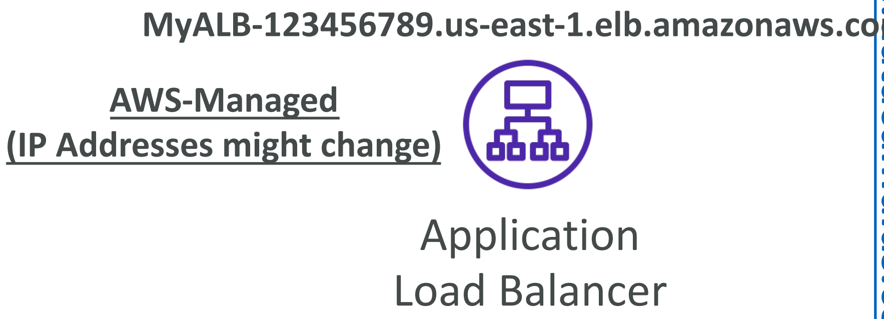
- CNAME:
  - Points a hostname to any other hostname. (app.mydomain.com => blabla.anything.com)
  - <u>ONLY FOR NON ROOT DOMAIN (aka. something.mydomain.com)</u>
- Alias:
  - Points a hostname to an AWS Resource (app.mydomain.com => blabla.amazonaws.com)
  - <u>Works for ROOT DOMAIN and NON ROOT DOMAIN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

Route 53 – Alias Records

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



Record Name	Type	Value
example.com	A	MyALB-123456789.us-east-1.elb.amazonaws.com



Route 53 – Alias Records Targets

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

Elastic Load Balancer

Amazon CloudFront

Amazon API Gateway

Elastic Beanstalk

S3 Websites

VPC Interface Endpoints

Global Accelerator

Route 53 Record (same Hosted Zone)

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

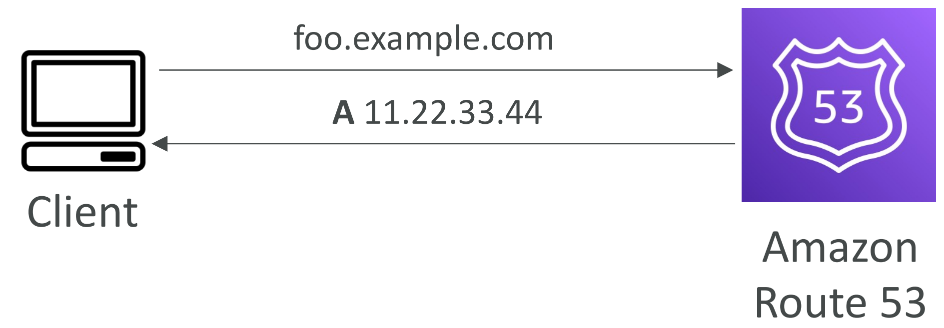
Route 53 – Routing Policies

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

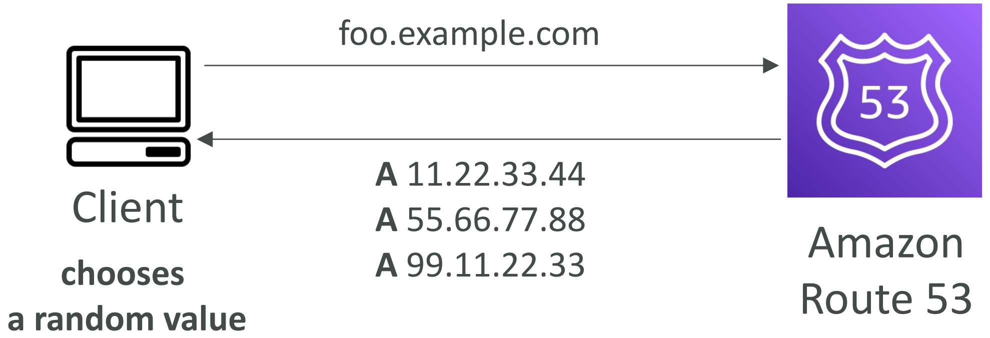
Routing Policies – Simple

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

<u>Single Value</u>

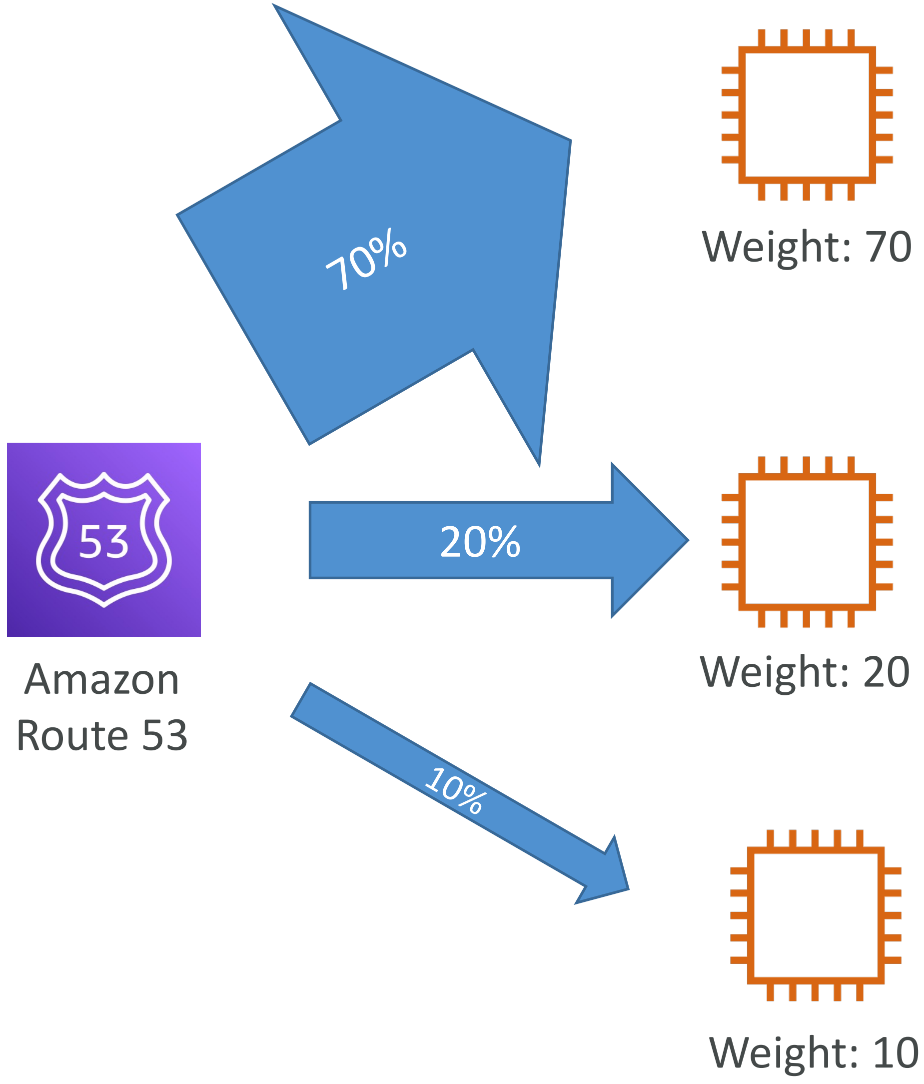


<u>Multiple Value</u>



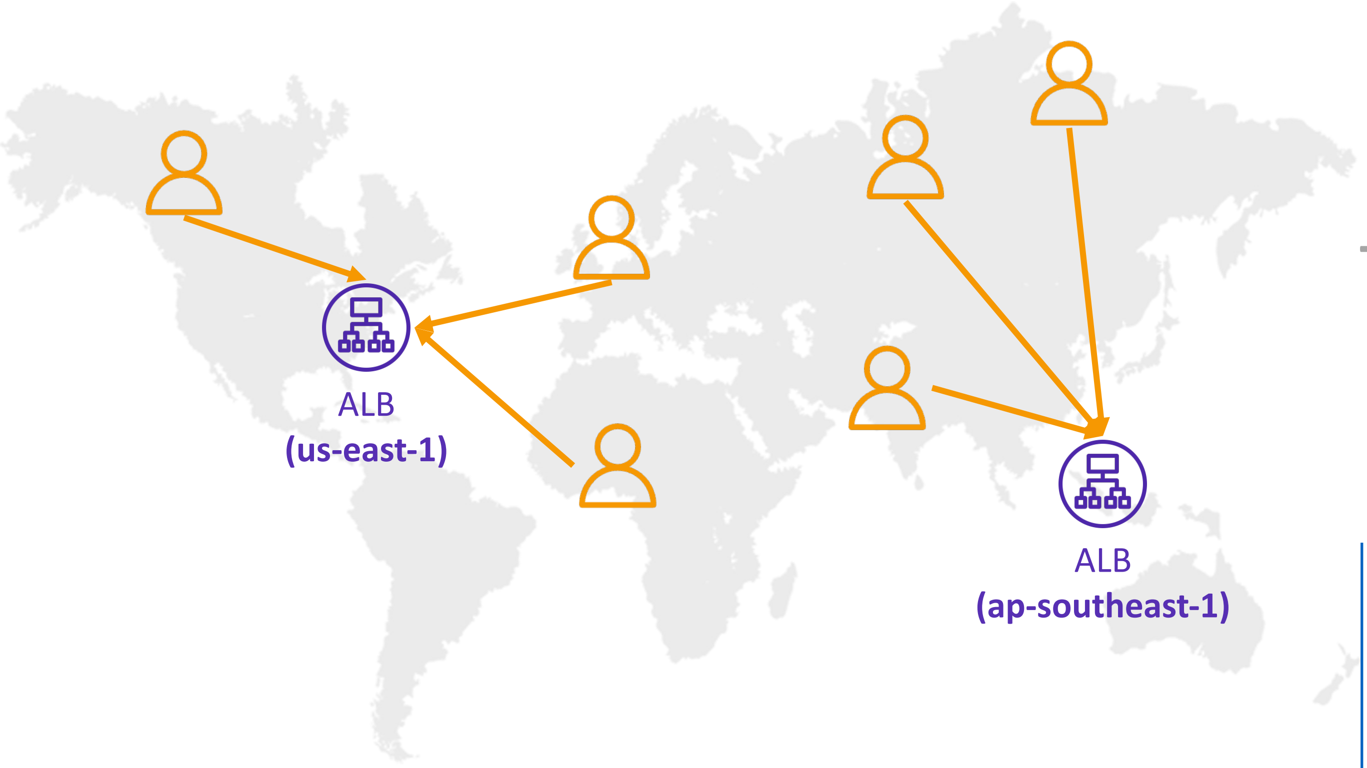
Routing Policies – Weighted

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



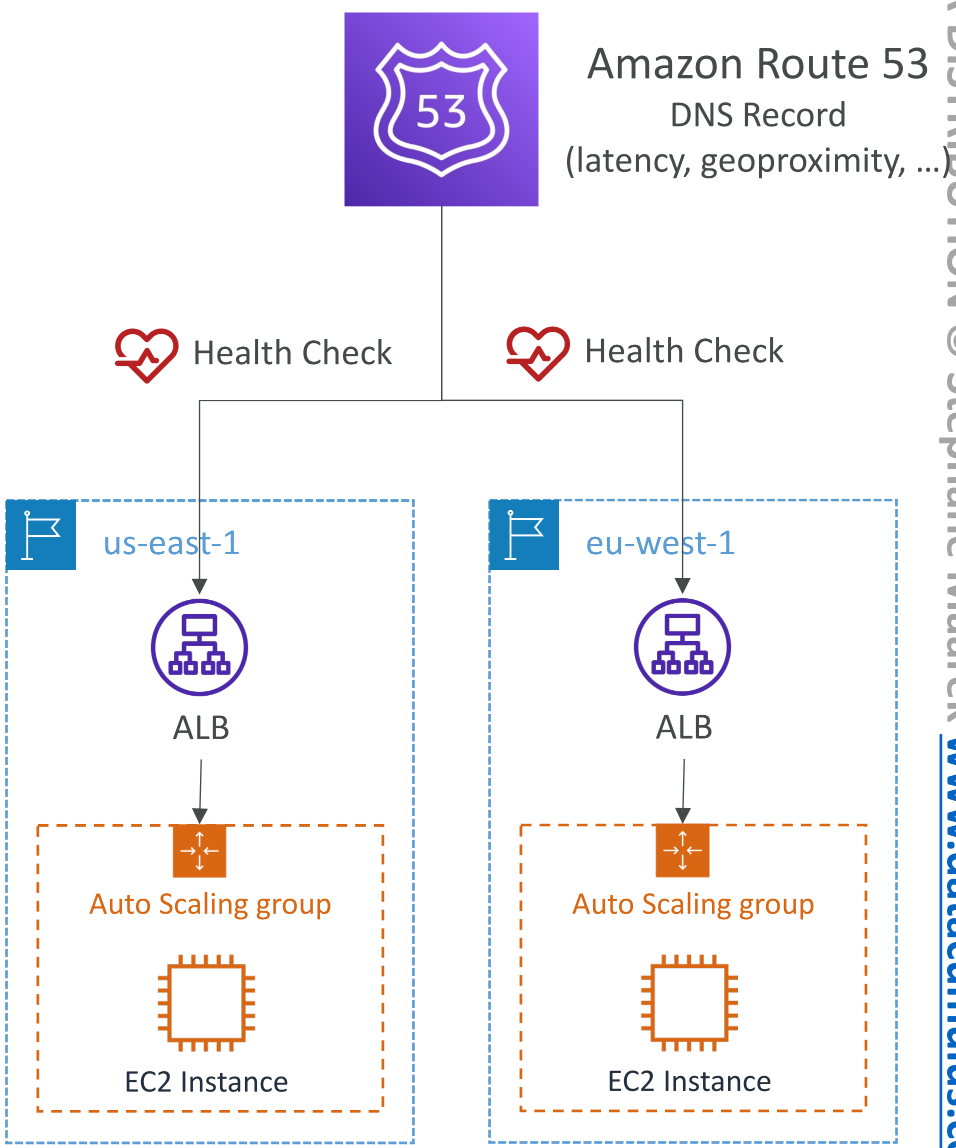
Routing Policies – Latency-based

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



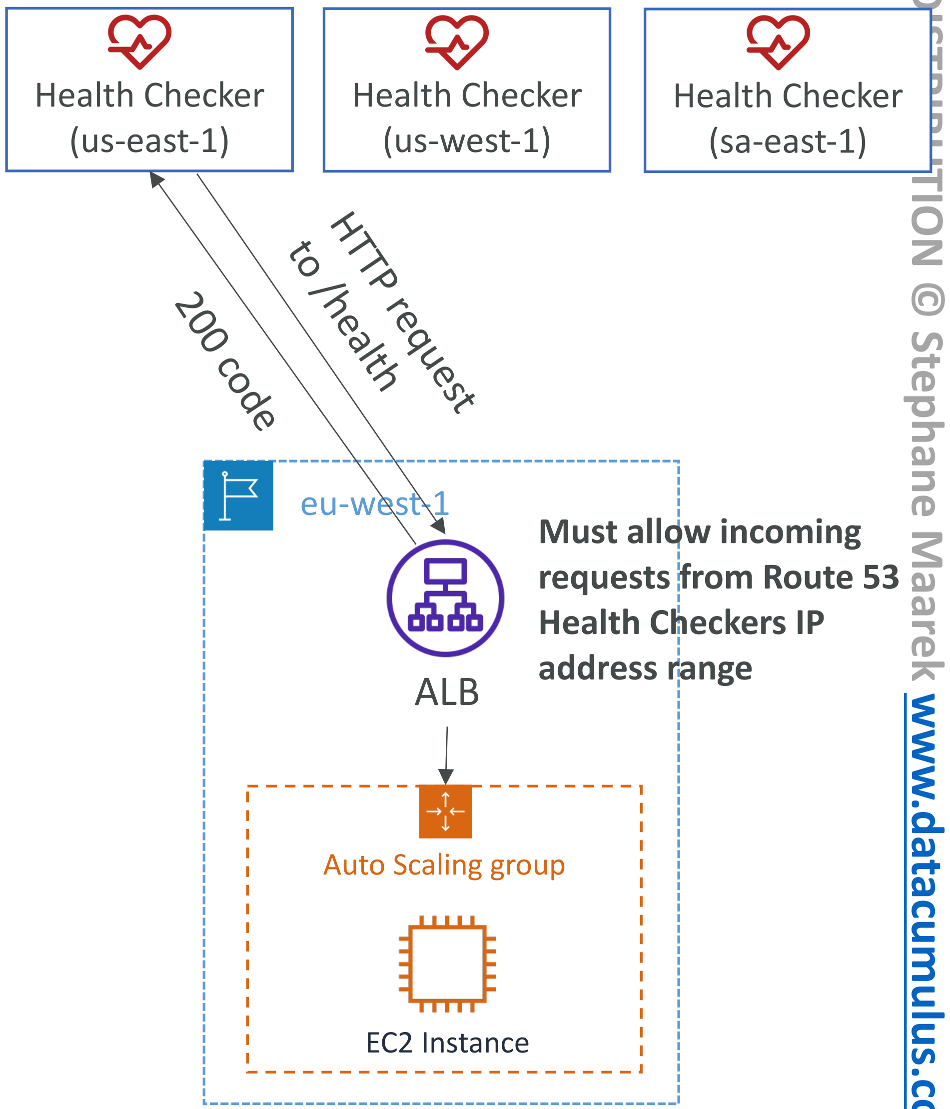
Route 53 – Health Checks

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



Health Checks – Monitor an Endpoint

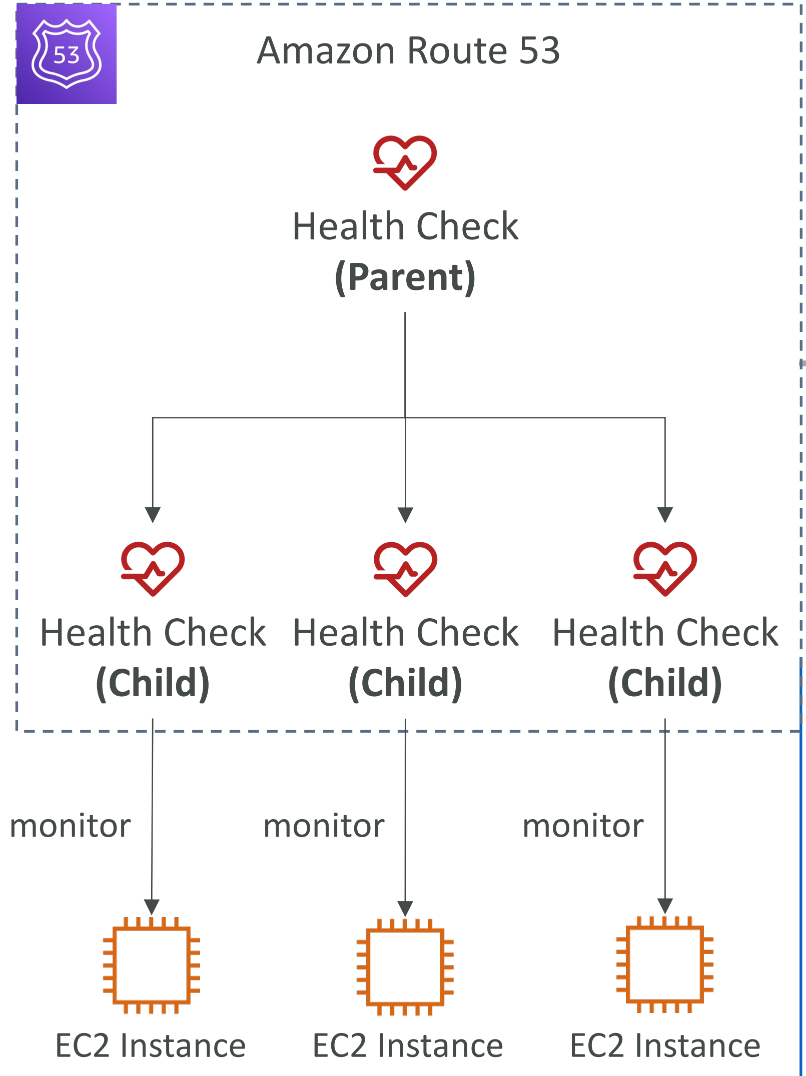
- About 15 global health checkers will check the endpoint health
  - Healthy/Unhealthy Threshold – 3 (default)
  - Interval – 30 sec (can set to 10 sec – higher cost)
  - Supported protocol: HTTP, HTTPS and TCP
  - If > 18% of health checkers report the endpoint is healthy, Route 53 considers it **Healthy**.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



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

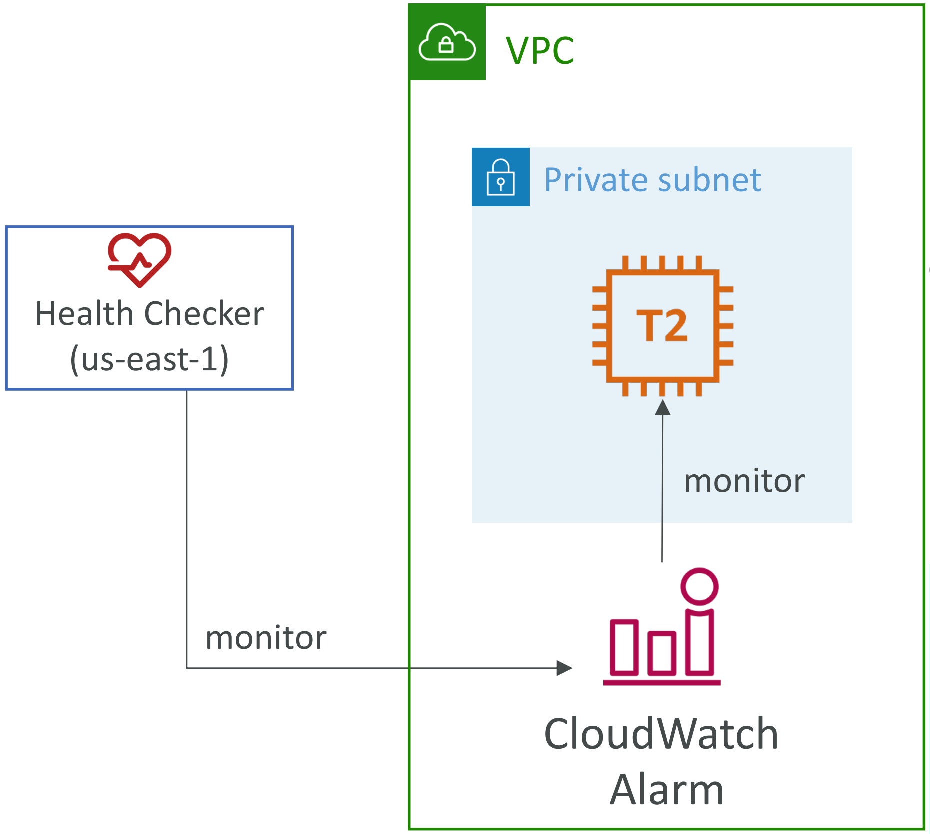
Route 53 – Calculated Health Checks

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

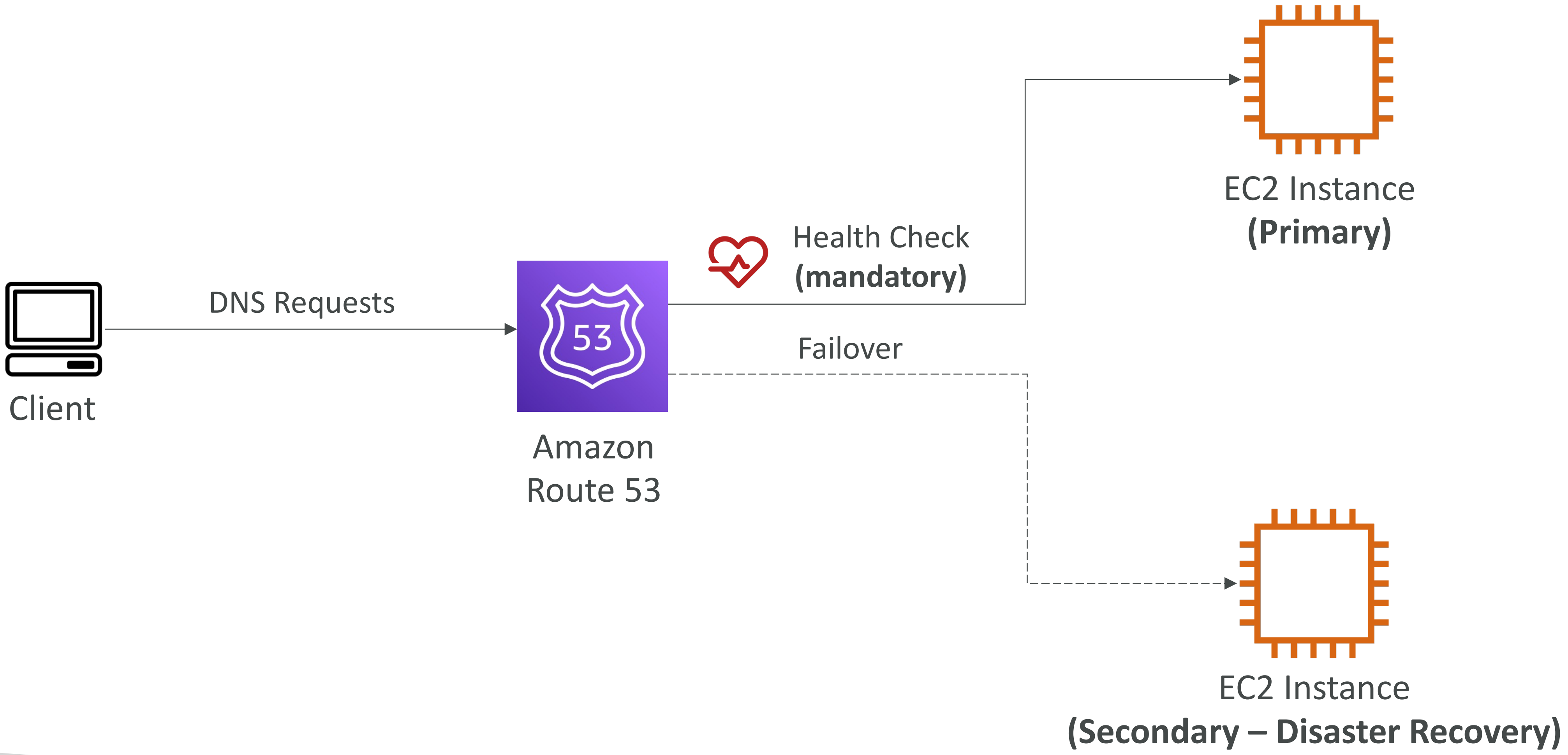


Health Checks – Private Hosted Zones

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

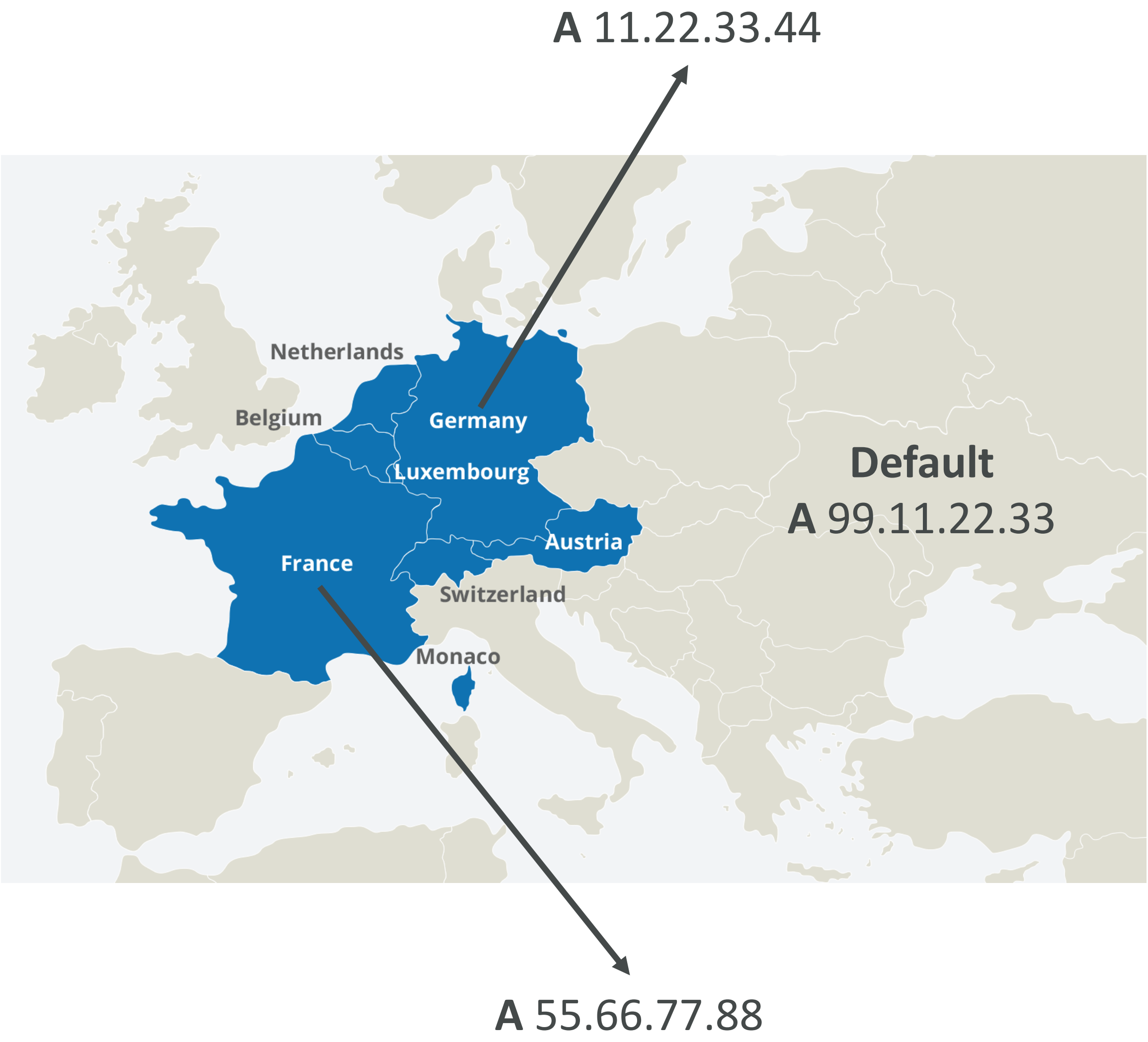


Routing Policies – Failover (Active-Passive)



Routing Policies – Geolocation

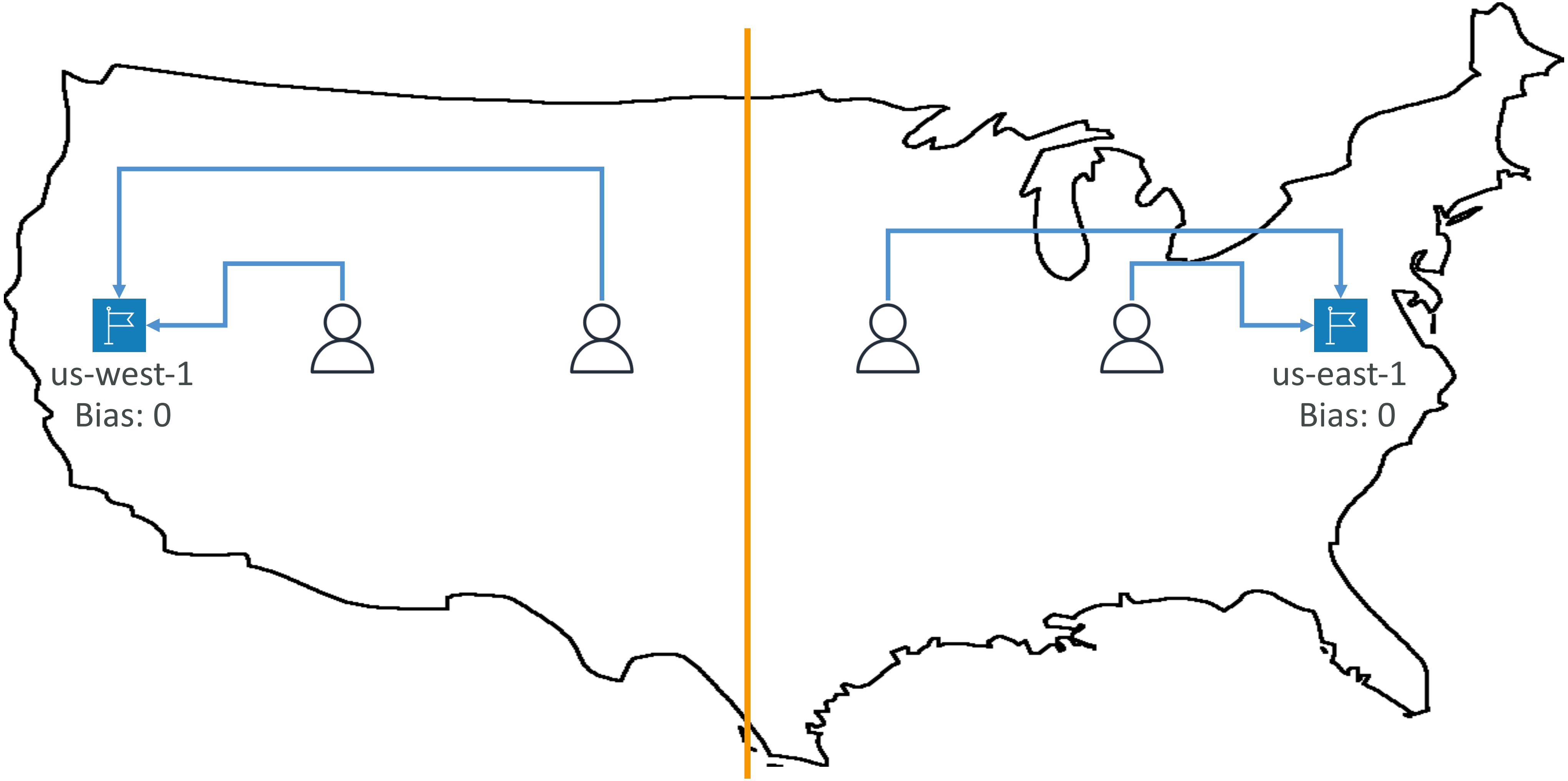
- Different from Latency-based!
- **This routing is based on user location**
- Specify location by Continent, Country or by US State (if there's overlapping, most precise location selected)
- Should create a **"Default"** record (in case there's no match on location)
- Use cases: website localization,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



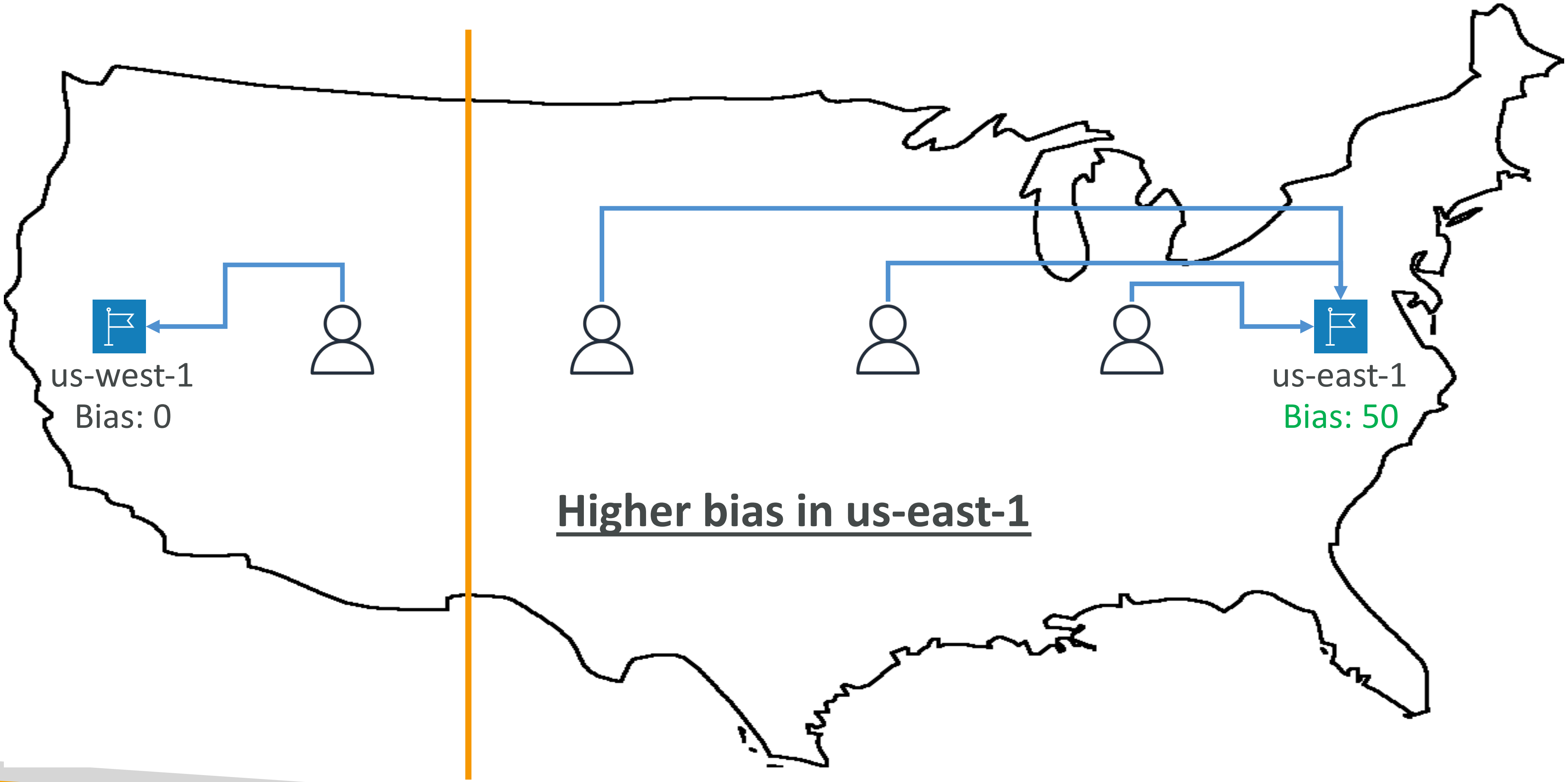
Routing Policies – Geoproximity

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

Routing Policies – Geoproximity

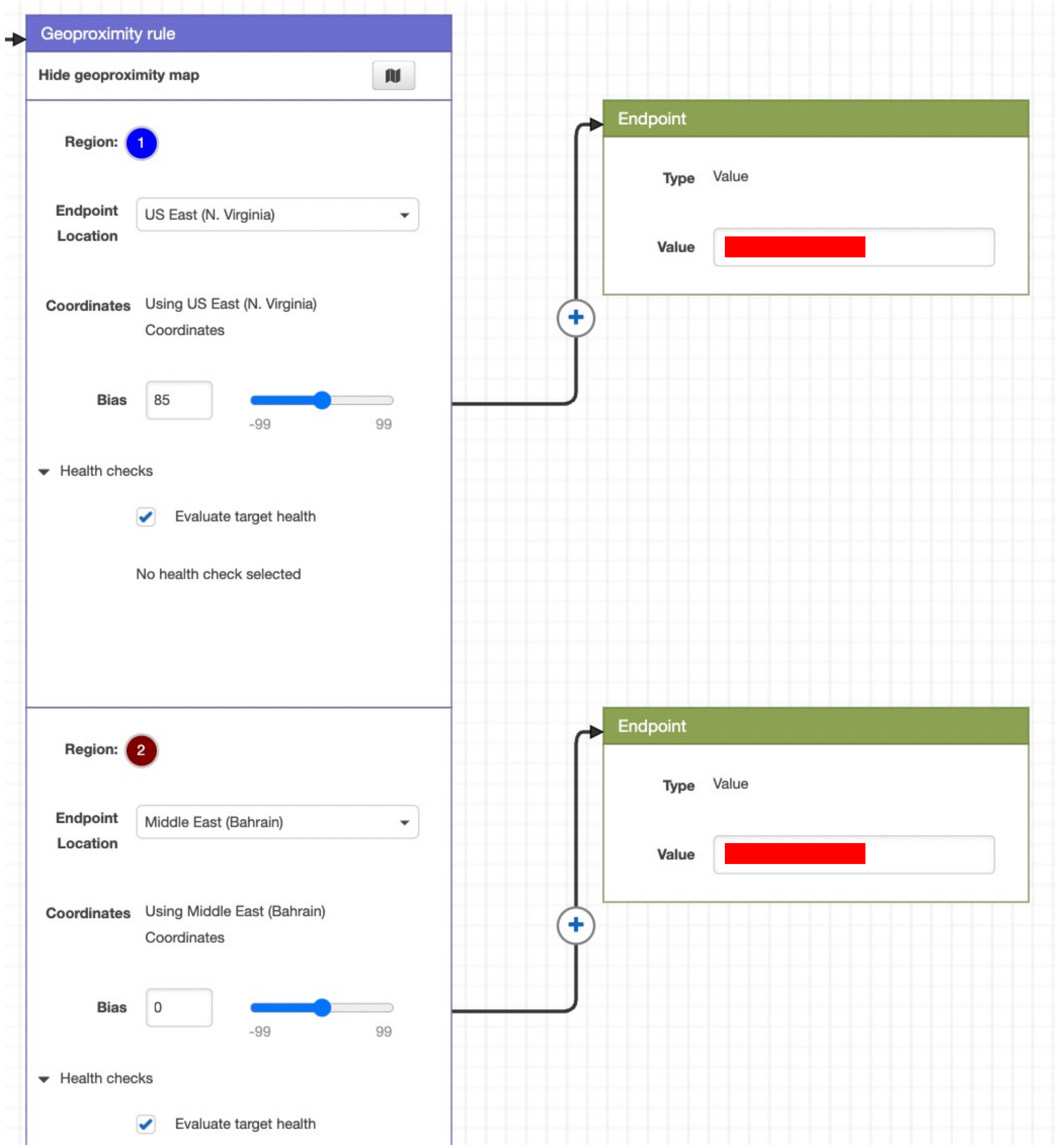


Routing Policies – Geoproximity



Route 53 – Traffic flow

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



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

CIDR Collection

Locations	CIDR blocks
location-1	203.0.113.0/24
location-2	200.5.4.0/24

Records

Record Name	Value	IP-based
example.com	1.2.3.4	location-1
example.com	5.6.7.8	location-2

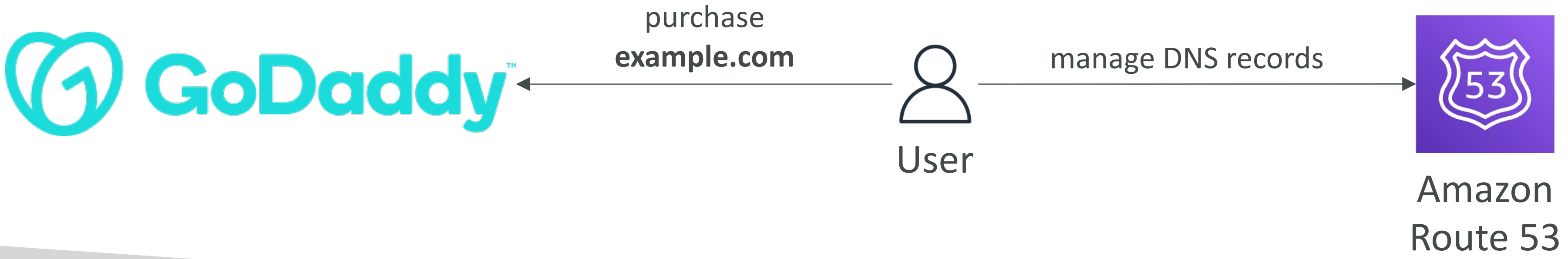
Routing Policies – Multi-Value

- 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

Domain Registar vs. DNS Service

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



GoDaddy as Registrar & Route 53 as DNS Service

GoDaddy

Records

We can't display your DNS information because your nameservers aren't managed by us.

Nameservers

Using custom nameservers **Change**

Nameserver
ns-1083.awsdns-07.org
ns-932.awsdns-52.net
ns-1911.awsdns-46.co.uk
ns-481.awsdns-60.com

Amazon Route 53

Public Hosted Zone
stephanetheteacher.com

Hosted zone details Edit hosted zone

Hosted zone ID
Z30IUJCCWPKZUV

Description
HostedZone created by Route53 Registrar

Query log
-

Type
Public hosted zone

Record count
22

Name servers
ns-252.awsdns-31.com
ns-1468.awsdns-55.org
ns-633.awsdns-15.net
ns-1800.awsdns-33.co.uk

3rd Party Registrar with Amazon Route 53

- If you buy your domain on a 3rd party registrar, you can still use Route 53 as the DNS Service provider

1. Create a Hosted Zone in Route 53
2. Update NS Records on 3rd party website to use Route 53 **Name Servers**

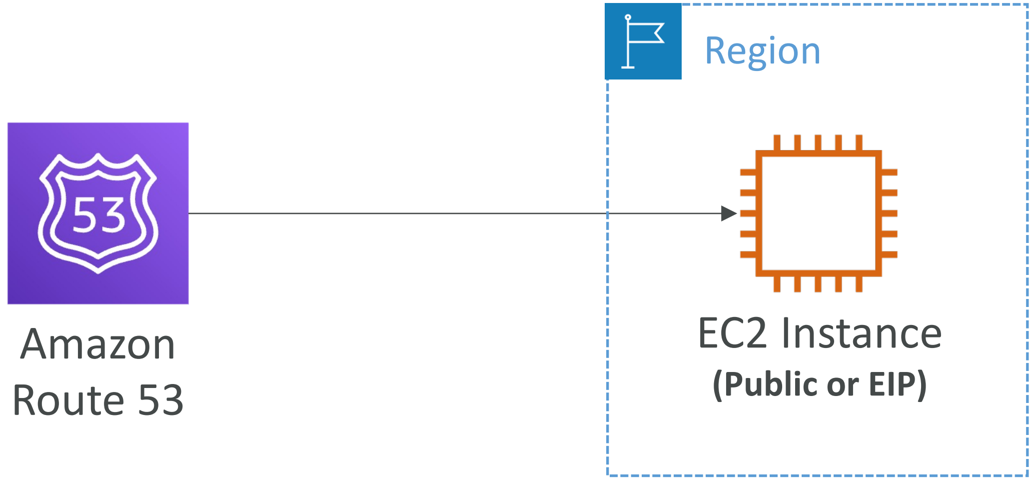
- **Domain Registrar != DNS Service**
- But every Domain Registrar usually comes with some DNS features

Making Route 53 the DNS service for a domain that is in use (users are accessing it)

1. Get the current DNS configuration (records to duplicate)
2. Create a **public** hosted zone in Route 53
3. Create all records in the newly created zone
4. Lower TTL settings of NS record to 15 minutes (to roll back in case)
5. Wait two days to ensure the new NS record TTL has propagated
6. Update the NS record to use the Route 53 name servers
7. Monitor traffic for the domain
8. Change NS record TTL on Route 53 to a higher value (two days)
9. Transfer domain registration to Amazon Route 53 (optional)

Route 53 Scenarios – EC2 Instance

- Your domain points to an EC2 instances with public or Elastic IP
- Example:
  - example.com => 54.55.56.57 (A)



Route 53 Scenarios – EC2 DNS name

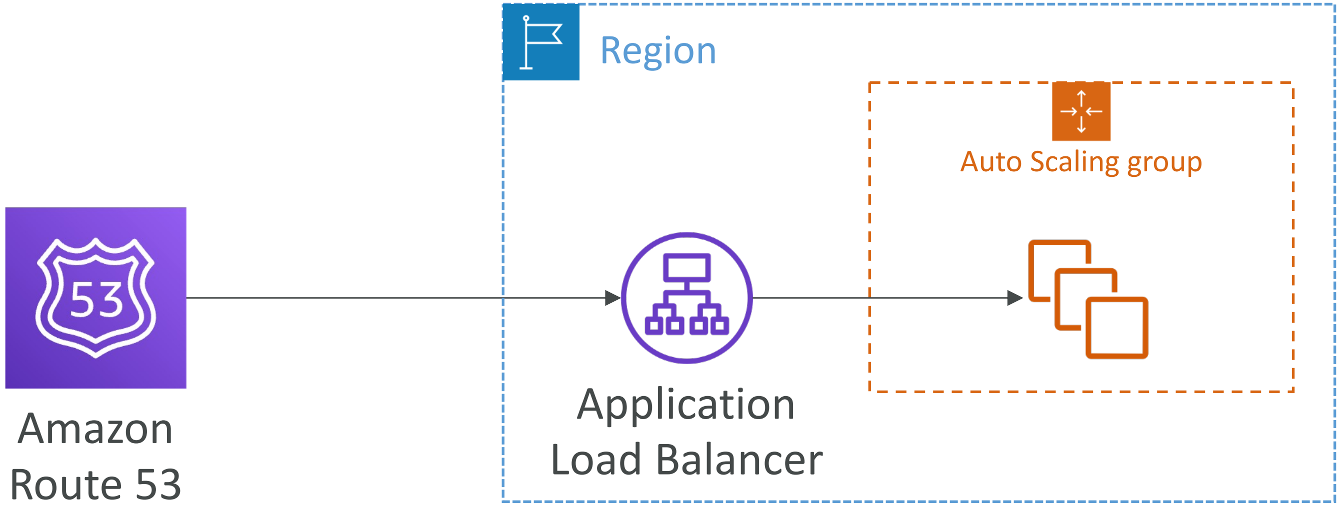
- Example:
  - app.example.com => ec2-12-34-56-78.us-west-2.compute.amazonaws.com (CNAME)

Record Name	Type	Value
app.example.com	CNAME	ec2-12-34-56-78.us-west-2.compute.amazonaws.com

Instance Details	
Public DNS name	ec2-12-34-56-78.us-west-2.compute.amazonaws.com
Public IPv4	12.34.56.78
Private IPv4	10.0.10.71

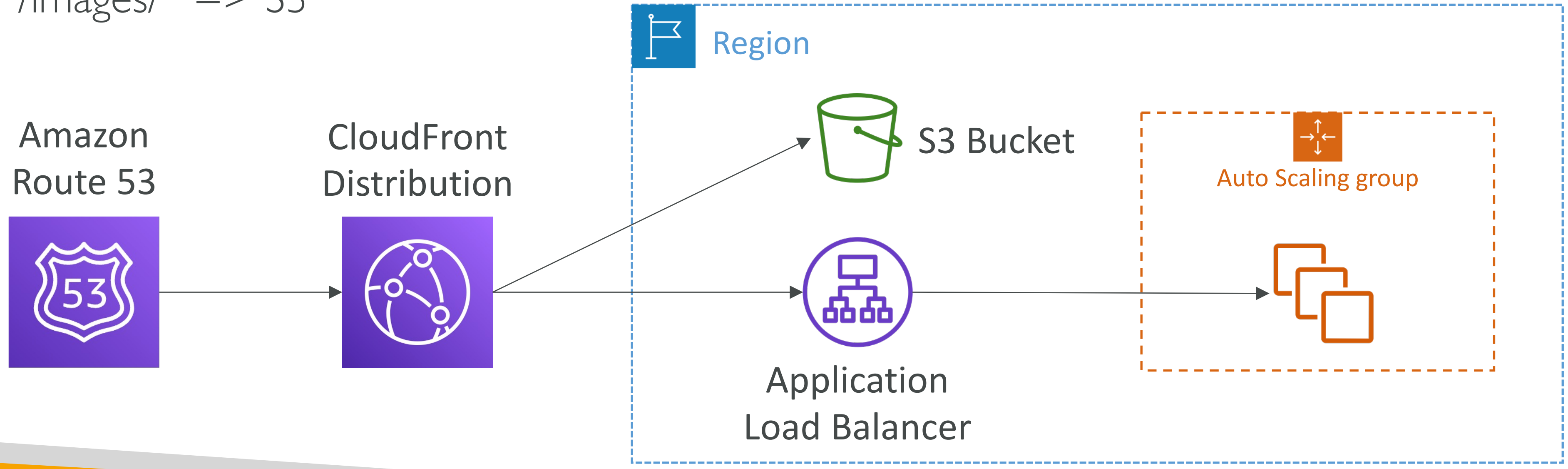
Route 53 Scenarios – Application Load Balancer

- Your domain points to AWS provided ALB DNS name
- Example:
  - example.com => my-load-balancer-1234567890.us-west-2.elb.amazonaws.com (Alias)
  - lb.example.com => my-load-balancer-1234567890.us-west-2.elb.amazonaws.com (Alias or CNAME)



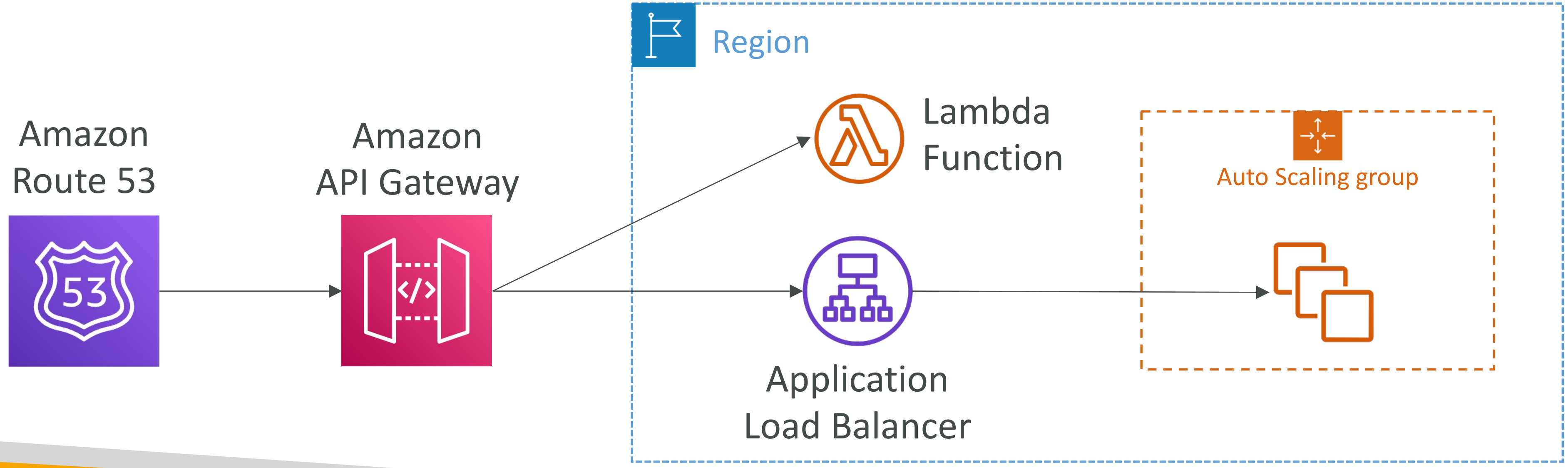
Route 53 Scenarios – CloudFront Distribution

- Example:
  - example.com => d2222222abcdef8.cloudfront.net (Alias)
  - cdn.example.com => d2222222abcdef8.cloudfront.net (Alias or CNAME)
- CloudFront internally connects to multiple origins
  - /application/ => ELB
  - /images/* => S3



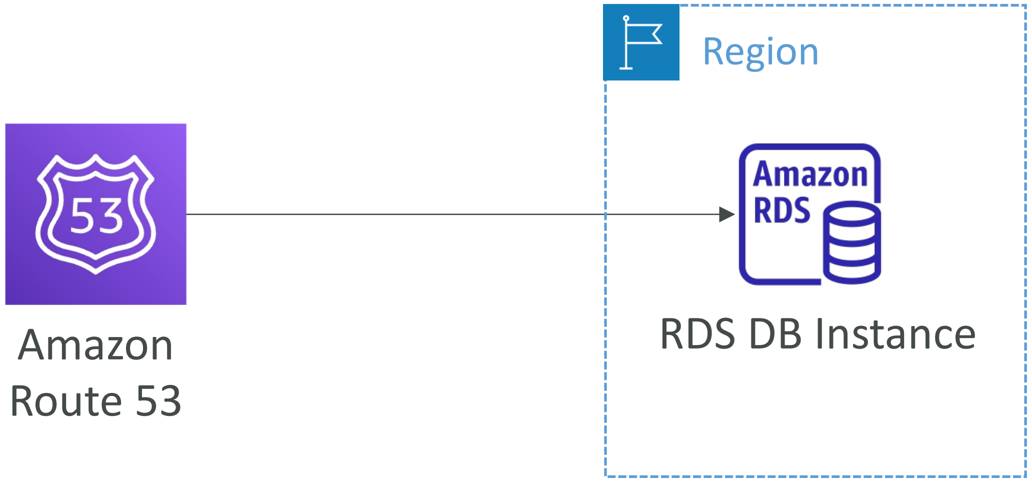
Route 53 Scenarios – API Gateway

- Points to API Gateway Regional/Edge Optimized DNS name
- Example:
  - example.com => b123abcde4.execute-api.us-west-2.amazonaws.com (Alias)



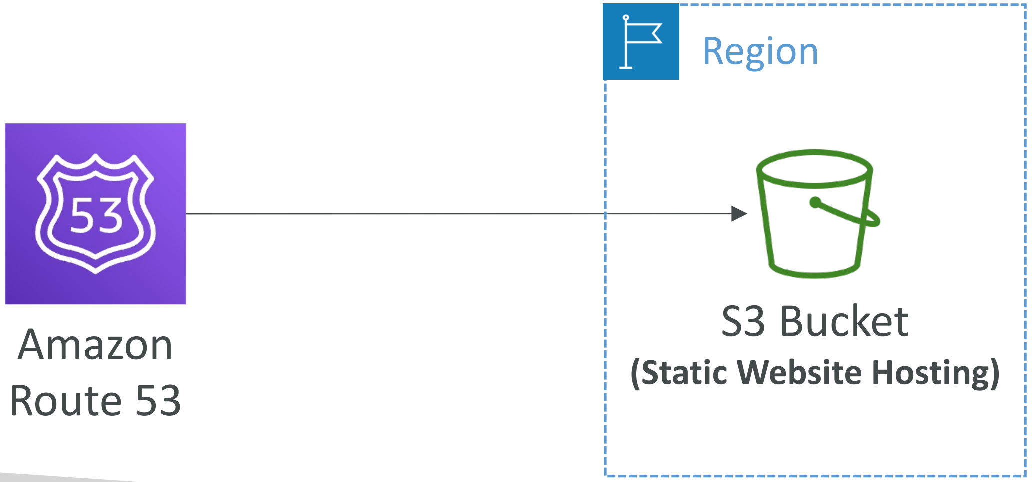
Route 53 Scenarios – RDS DB Instance

- Your domain name points to RDS DB instance DNS name
- You must create a **CNAME** record (other record types are not supported)
- Example:
  - db.example.com => myexampledb.a1b2c3d4wxyz.us-west-2.rds.amazonaws.com (CNAME)



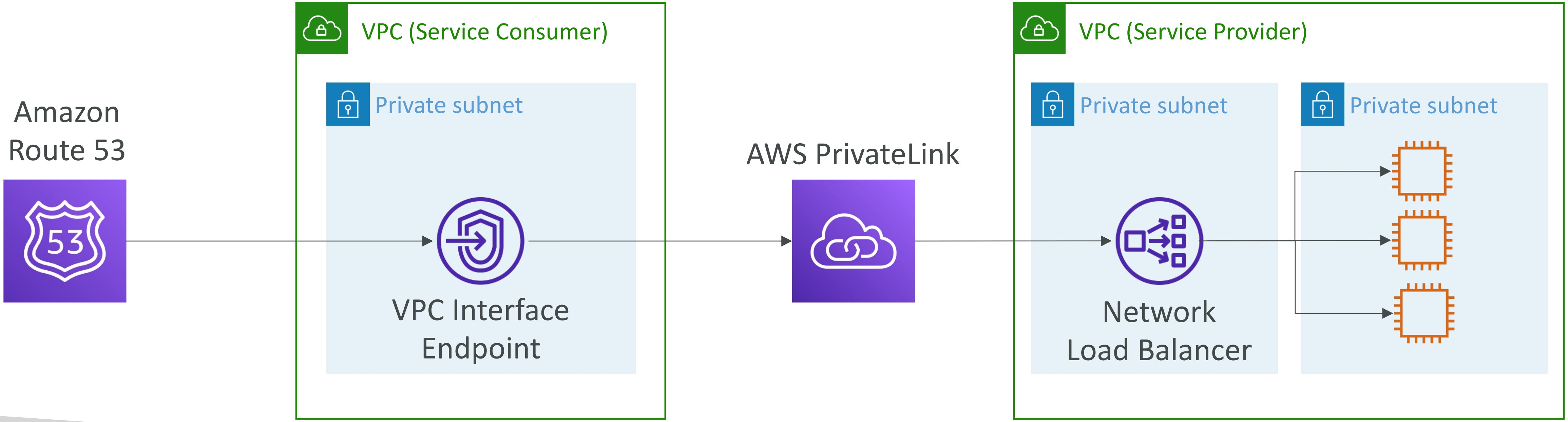
Route 53 Scenarios – S3 Bucket

- Your domain name points to S3 website endpoint
- You must create an Alias record for S3 endpoints
- **Bucket name must be the same as domain name**
- Example:
    - example.com => s3-website-us-west-2.amazonaws.com (Alias)



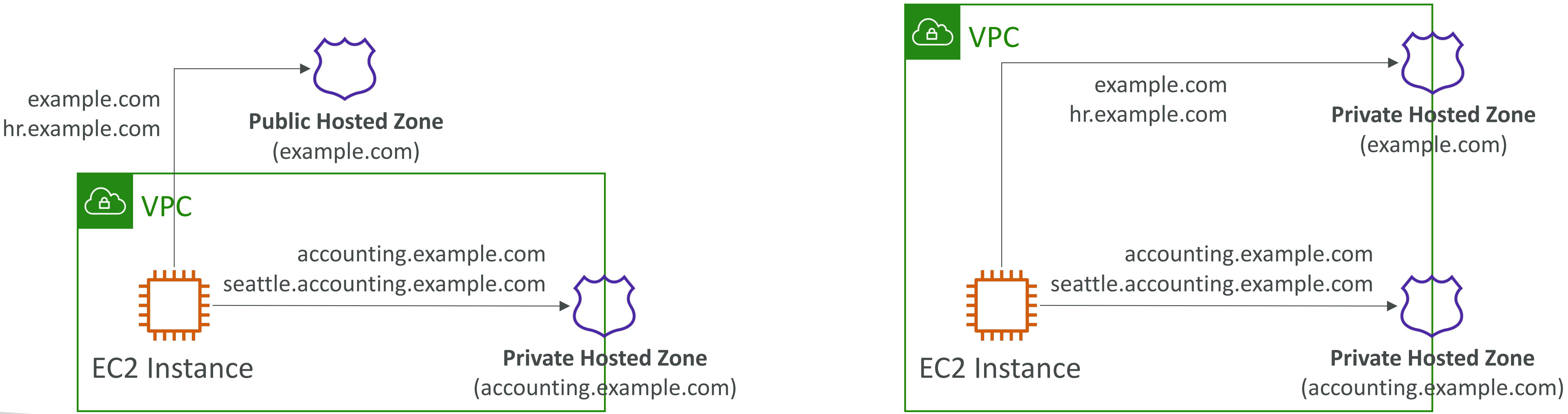
Route 53 Scenarios – VPC Interface Endpoint

- Your domain name points to a VPC Interface Endpoint (AWS PrivateLink)
- Example:
  - example.com => vpce-1234-abcdev-us-east-1.vpce-svc-123345.us-east-1.vpce.amazonaws.com (Alias)



Route 53 – Hosted Zones

- Route 53 automatically creates NS and SOA records
- For public/private and private Hosted Zones that have overlapping namespaces, Route 53 Resolvers routes traffic to the **most specific match**



Route 53 – Routing Traffic For Subdomains

- Create a Hosted Zone for the Subdomain
- Known as, either:
  - "Delegation Responsibility for a Subdomain to a Hosted Zone"
  - "Delegating a Subdomain to Another Name Servers"
- Use cases:
  - different subdomains managed by different teams
  - Restrict access using IAM Permissions (you can't use IAM to control access to Route 53 records)

Hosted Zone
(example.com)

Record Name	Type	Value
example.com	NS	…
acme.example.com	NS	- *ns2048.awsdns-64.com* - *ns-2049.awsdns-65.net* - *ns-2050.awsdns-66.org* - *ns-2051.awsdns-67.co.uk*

Hosted Zone
(acme.example.com)

Record Name	Type	Value
acme.example.com	NS	- *ns2048.awsdns-64.com* - *ns-2049.awsdns-65.net* - *ns-2050.awsdns-66.org* - *ns-2051.awsdns-67.co.uk*

Using Route 53 as the DNS Service for a Subdomain without Migrating the Parent Domain

Amazon Route 53

Subdomain Hosted Zone
(acme.example.com)

Record Name	Type	Value
acme.example.com	NS	- *ns2048.awsdns-64.com* - *ns-2049.awsdns-65.net* - *ns-2050.awsdns-66.org* - *ns-2051.awsdns-67.co.uk*

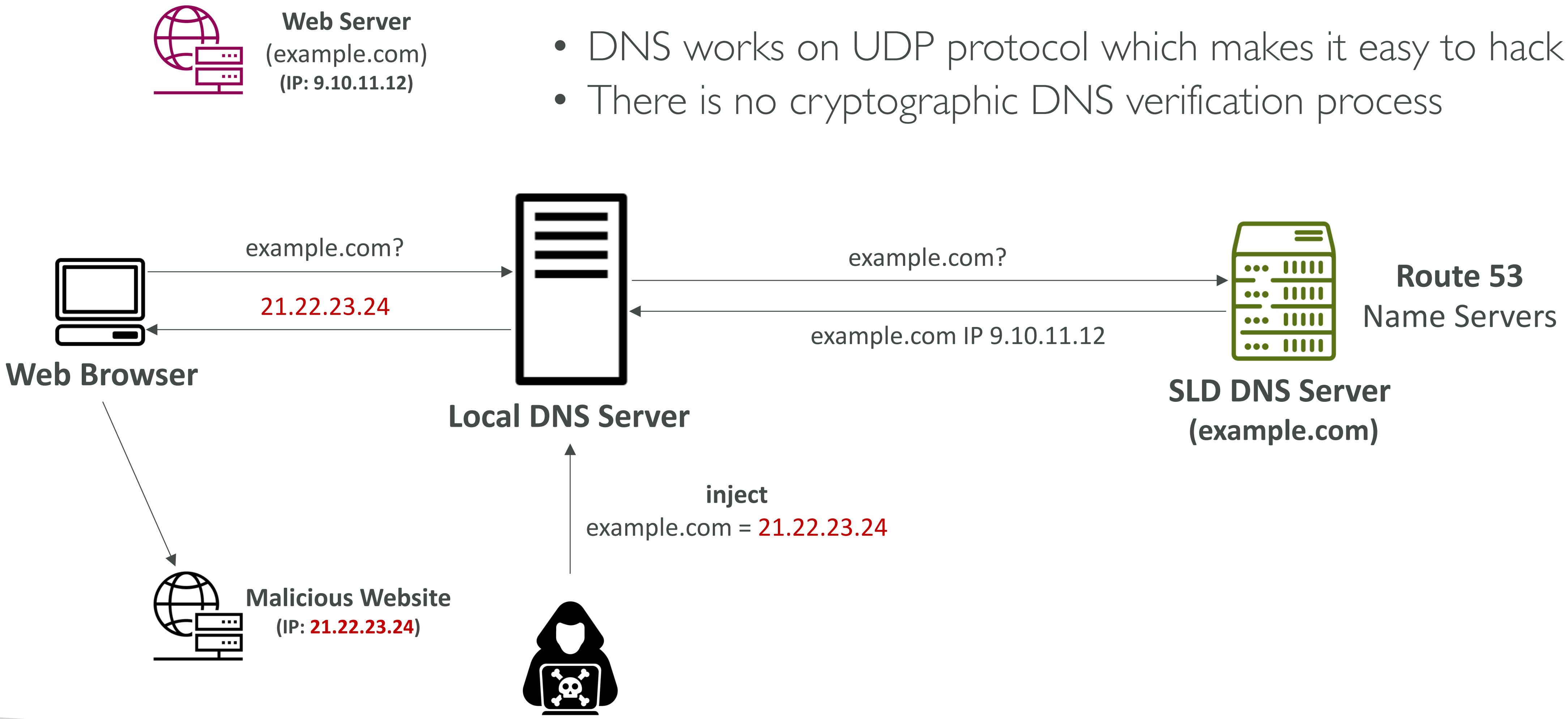
3rd Party DNS Service

Parent Domain
(example.com)

Record Name	Type	Value
example.com	NS	…
acme.example.com	NS	- *ns2048.awsdns-64.com* - *ns-2049.awsdns-65.net* - *ns-2050.awsdns-66.org* - *ns-2051.awsdns-67.co.uk*

DNS Poisoning (Spoofing)

- DNS works on UDP protocol which makes it easy to hack
- There is no cryptographic DNS verification process



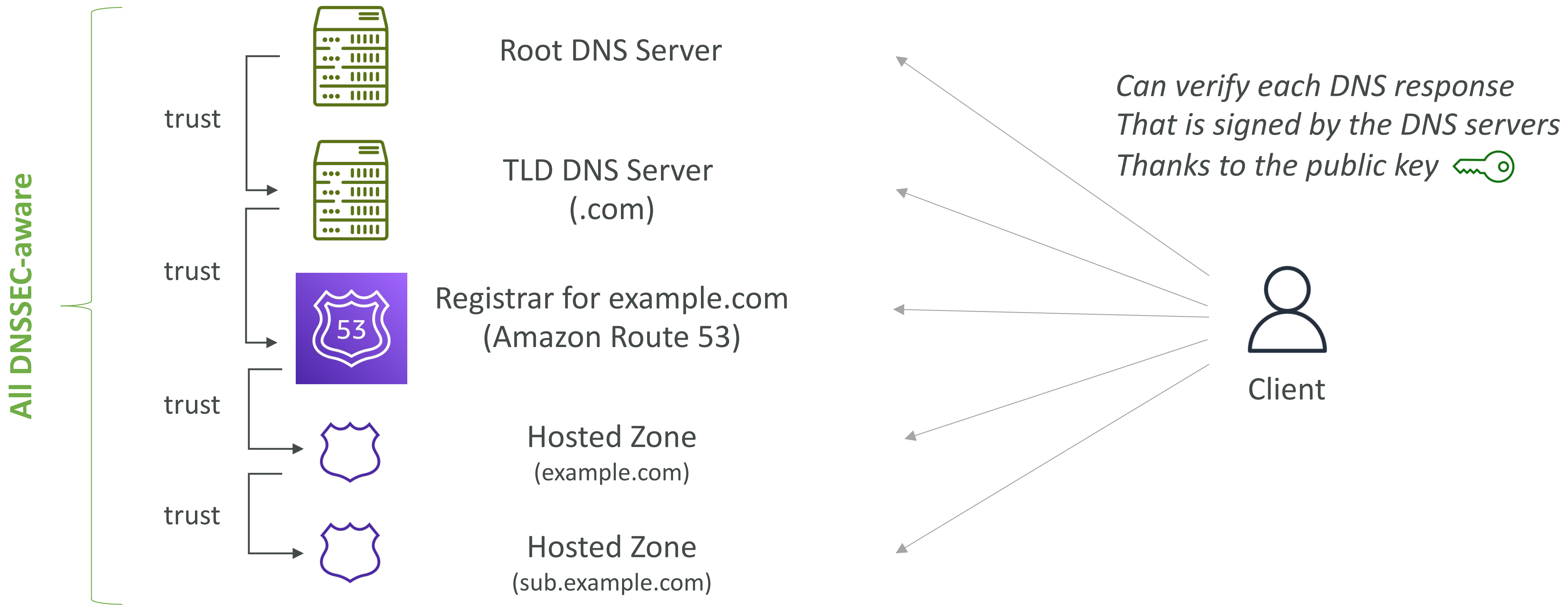
Route 53 – DNS Security Extensions (DNSSEC)

- A protocol for securing DNS traffic, verifies DNS data integrity and origin
- Works only with **Public Hosted Zones**
- Route 53 supports both DNSSEC for Domain Registration and Signing
- **DNSSEC Signing**
  - Validate that a DNS response came from Route 53 and has not been tampered with
  - Route 53 cryptographically signs each record in the Hosted Zone
  - Two Keys:
    - Managed by you: **Key-signing Key (KSK)** – based on an asymmetric CMK in AWS KMS
    - Managed by AWS: **Zone-signing Key (ZSK)**
- When enabled, Route 53 enforces a TTL of one week for all records in the Hosted Zone (records that have TTL less than one week are not affected)

Route 53 – Enable DNSSEC on a hosted zone

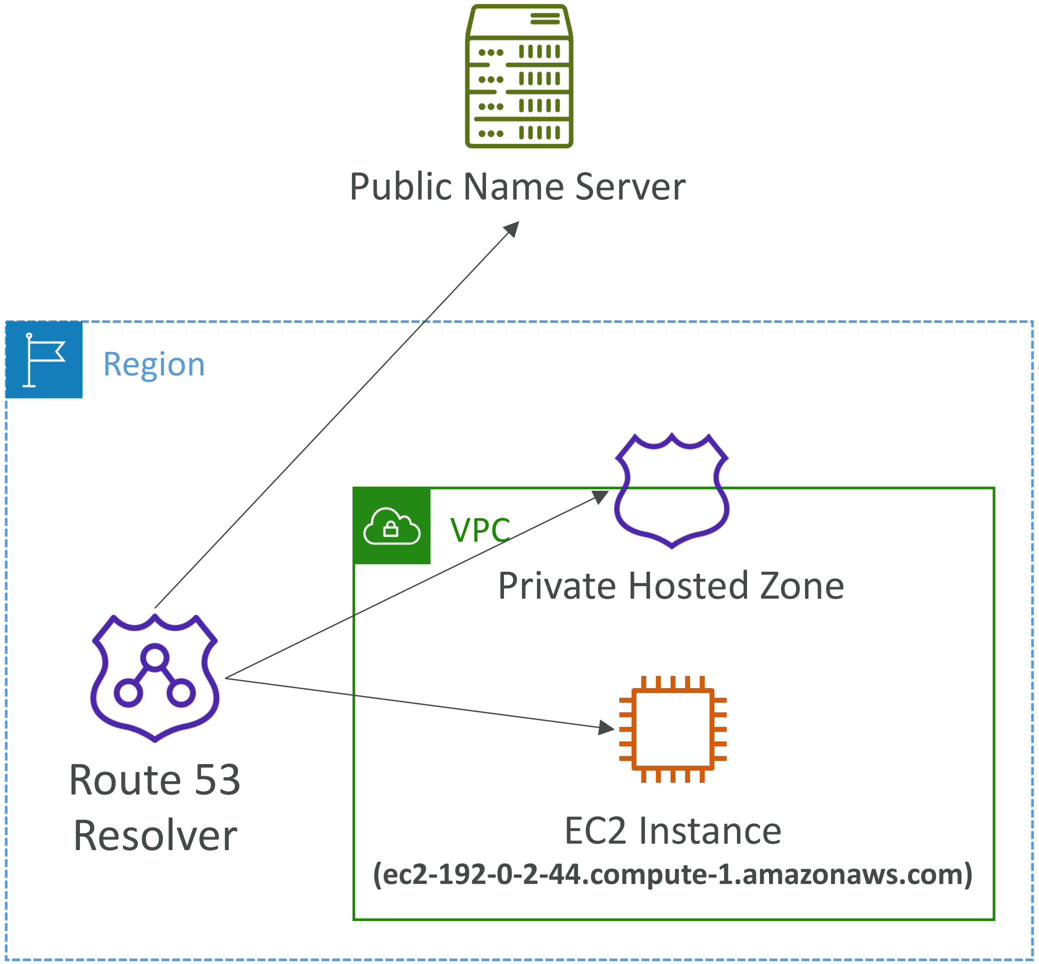
- Step 1 – Prepare for DNSSEC signing
  - Monitor zone availibility (through customer feedback)
  - Lower TTL for records (recommended 1 hour)
  - Lower SOA minimum for 5 minutes
- Step 2 – Enable DNSSEC signing and create a KSK
  - Enable DNSSEC in Route 53 for your hosted zone (Console or CLI)
  - **Make Route 53 create a KSK in the console and link it to a Customer managed CMK**
- Step 3 – Establish chain of trust
  - Create a chain of trust between the hosted zone and the **parent** hosted zone
  - **By creating a Delegation Signer (DS) record in the parent zone**
  - It contains a hash of the public key used to sign DNS records
  - Your registrar can be Route 53 or a 3rd party registrar
- Step 4 – (good to have) Monitor for errors using CloudWatch Alarms
  - Create CloudWatch alarms for *DNSSECInternalFailure* and *DNSSECKeySigningKeysNeedingAction*

DNSSEC – Chain of Trust



Route 53 – Hybrid DNS

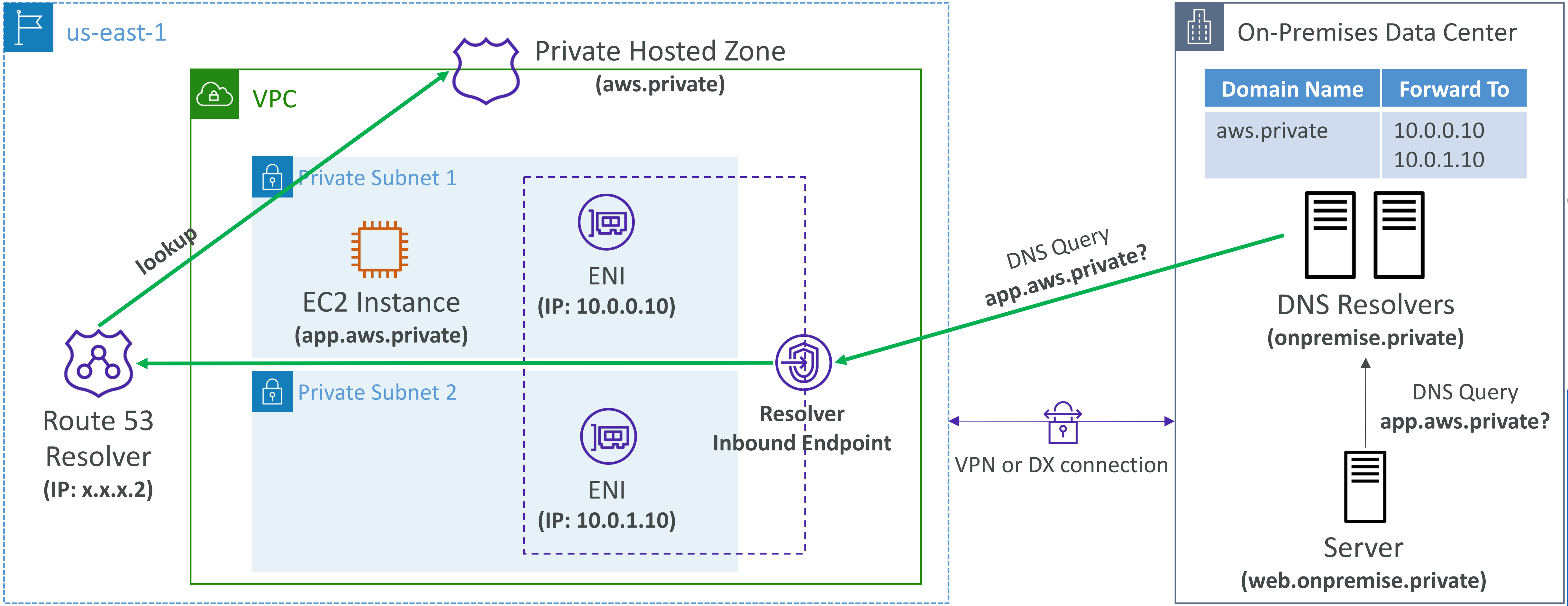
- By default, Route 53 Resolver automatically answers DNS queries for:
  - Local domain names for EC2 instances
  - Records in Private Hosted Zones
  - Records in public Name Servers
- **Hybrid DNS** – resolving DNS queries between VPC (Route 53 Resolver) and your networks (other DNS Resolvers)
- Networks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



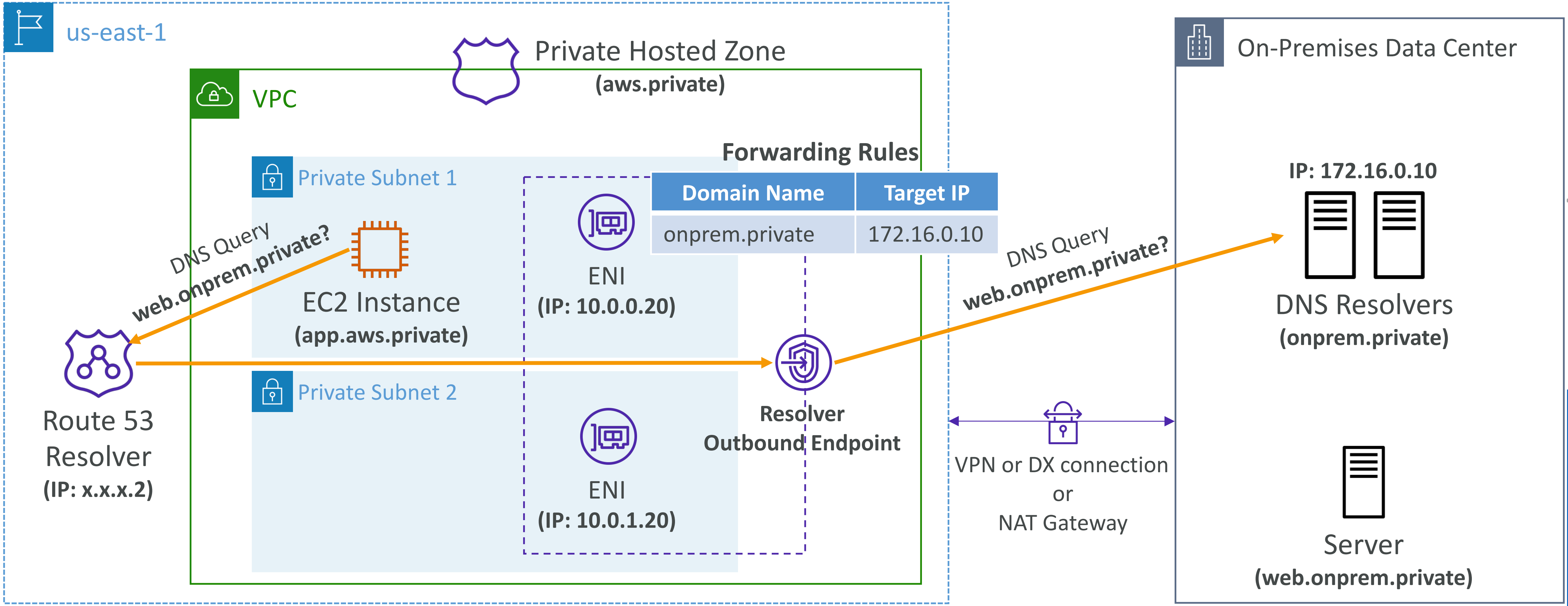
Route 53 – Resolver Endpoints

- 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



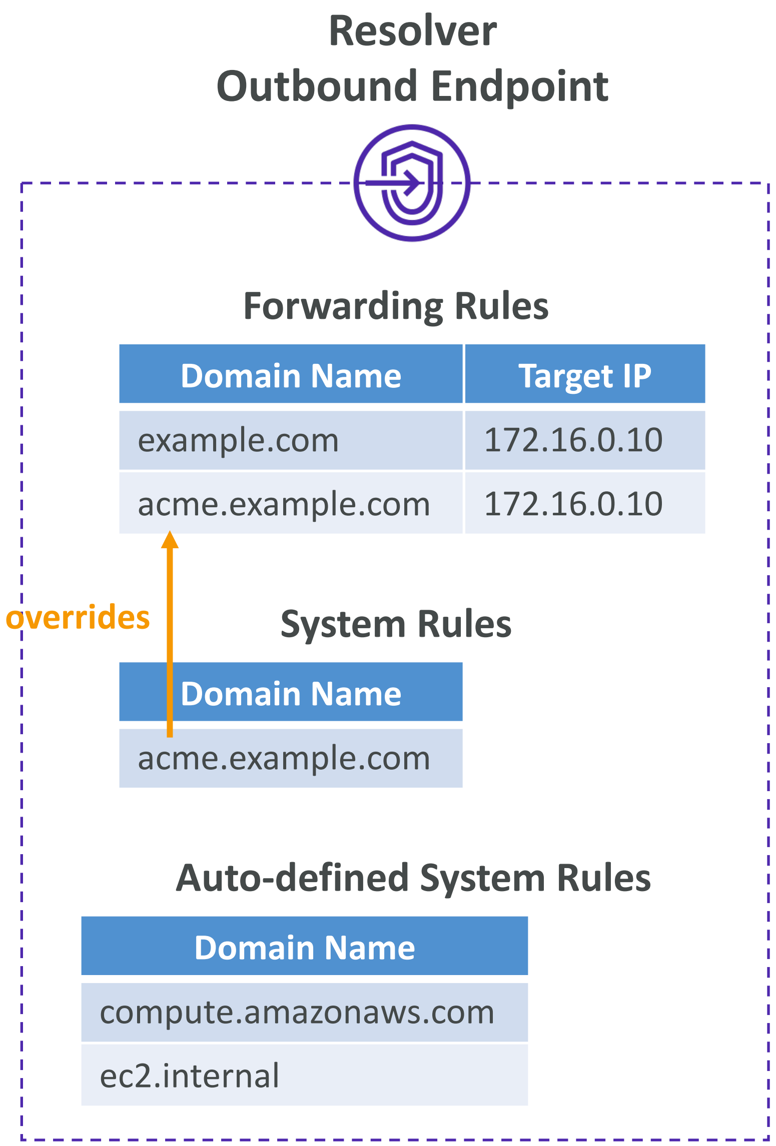
Route 53 – Resolver Outbound Endpoints



Domain Name	Target IP
onprem.private	172.16.0.10

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, Privated 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



Route 53 – DNS Query Logging

- Log information about **public** DNS queries Route 53 Resolver receives
- Only for **Public Hosted Zones**
- Can send logs to CloudWatch Logs (can export to S3)

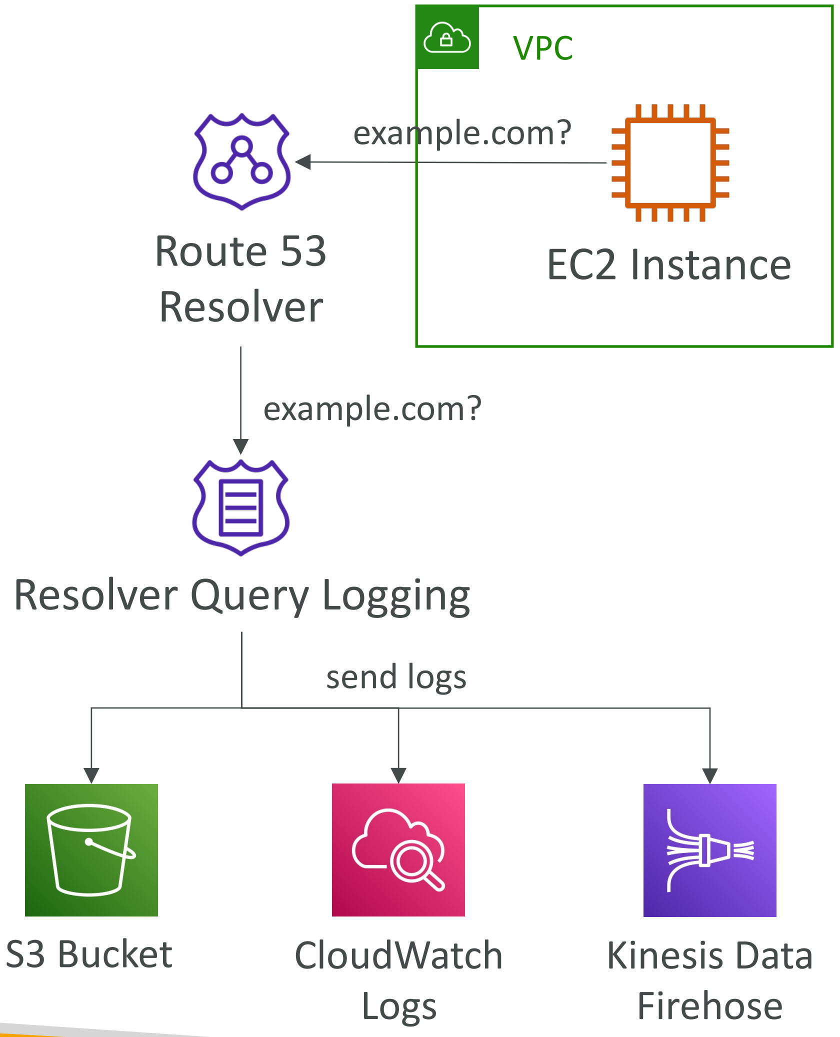
Log Format Version | Hosted Zone ID | Query Type | Query Protocol | Resolver IP Address

```
1.0 2017-12-13T08:16:02.130Z Z123412341234 example.com A NOERROR UDP FRA6 192.168.1.1 -
1.0 2017-12-13T08:15:50.235Z Z123412341234 example.com AAAA NOERROR TCP IAD12 192.168.3.1 192.168.222.0/24
1.0 2017-12-13T08:16:03.983Z Z123412341234 example.com ANY NOERROR UDP FRA6 2001:db8::1234 2001:db8:abcd::/48
1.0 2017-12-13T08:15:50.342Z Z123412341234 bad.example.com A NXDOMAIN UDP IAD12 192.168.3.1 192.168.111.0/24
1.0 2017-12-13T08:16:05.744Z Z123412341234 txt.example.com TXT NOERROR UDP JFK5 192.168.1.2 -
```

Query Timestamp | Query Name | Response Code | Edge Location | EDNS Clinet Subnet

Route 53 – Resolver Query Logging

- Logs all DNS queries made by resources within a VPC
  - Private Hosted Zones
  - Resolver Inbound & Outbound Endpoints
  - Resolver DNS Firewall
- Can send logs to CloudWatch Logs, S3 bucket, or Kinesis Data Firehose
- Configurations can be shared with other AWS Accounts using AWS Resource Access Manager (AWS RAM)

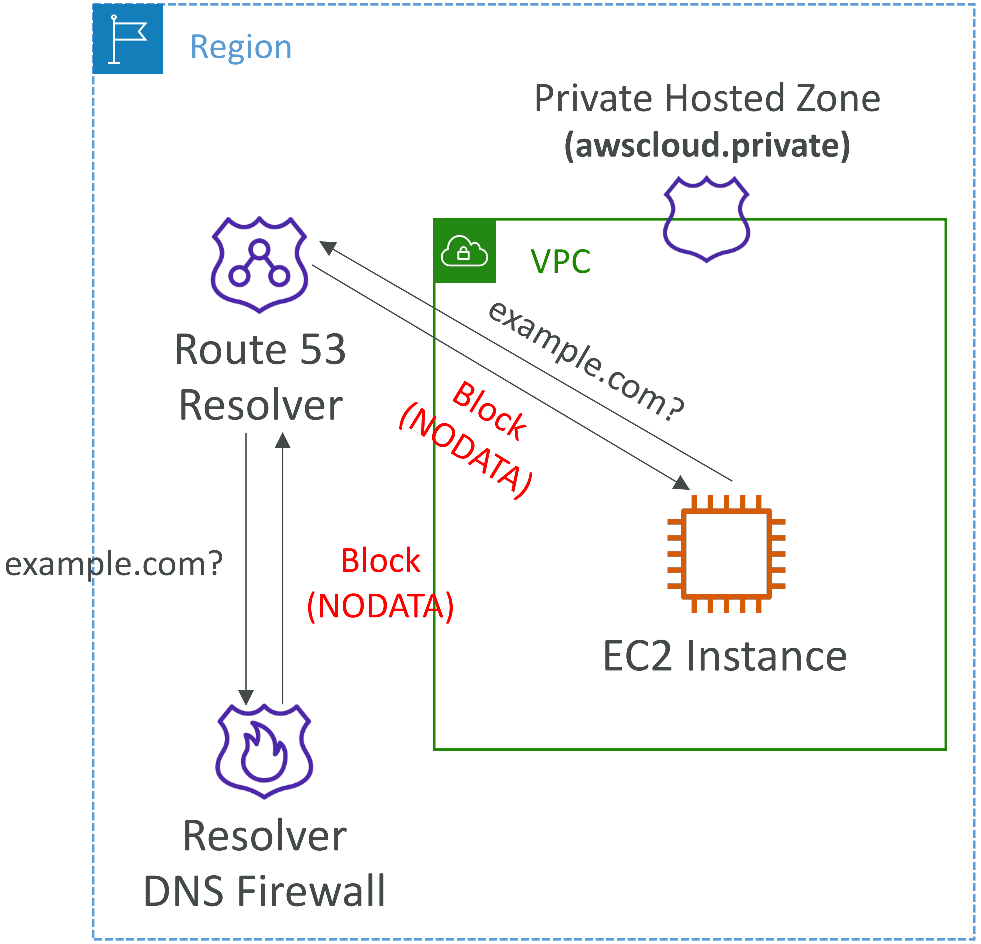


Route 53 – Resolver Query Logging


```json
{
    "srcaddr": "4.5.64.102",
    "vpc_id": "vpc-7example",
    "answers": [
        {
            "Rdata": "203.0.113.9",
            "Type": "PTR",
            "Class": "IN"
        }
    ],
    "firewall_rule_group_id": "rslvr-frg-01234567890abcdef",
    "firewall_rule_action": "BLOCK",
    "query_name": "15.3.4.32.in-addr.arpa.",
    "firewall_domain_list_id": "rslvr-fdl-01234567890abcdef",
    "query_class": "IN",
    "srcids": {
        "instance": "i-0d15cd0d3example"
    },
    "rcode": "NOERROR",
    "query_type": "PTR",
    "transport": "UDP",
    "version": "1.100000",
    "account_id": "111122223333",
    "srcport": "56067",
    "query_timestamp": "2021-02-04T17:51:55Z",
    "region": "us-east-1"
}
```

Route 53 – Resolver DNS Firewall

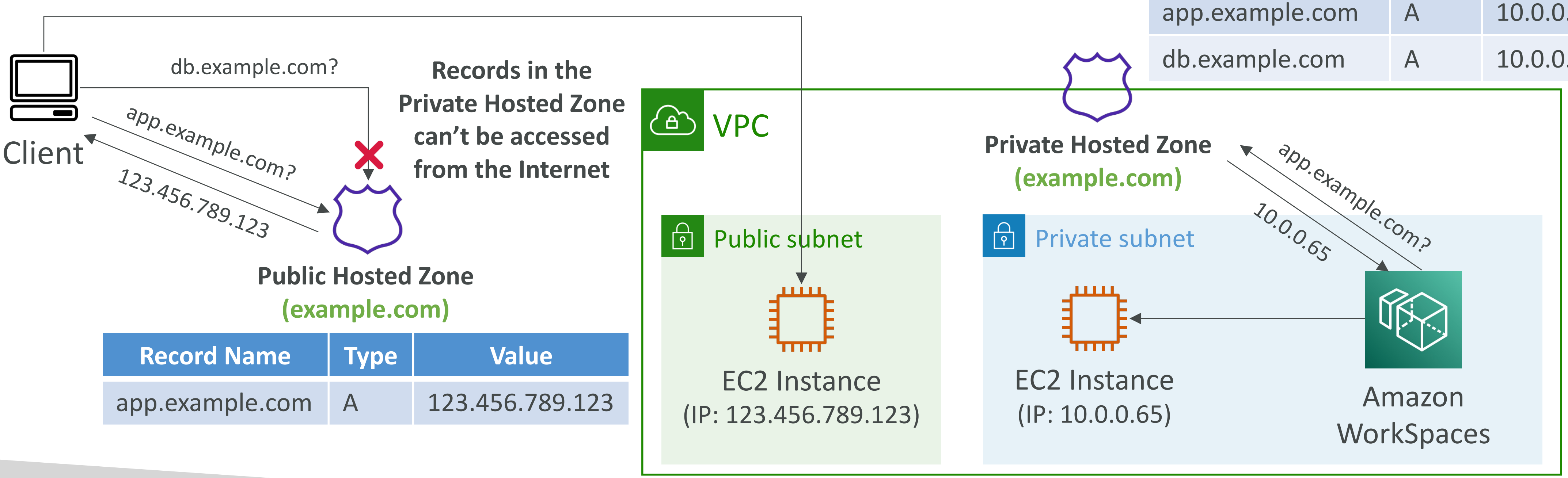
- A managed firewall enables you to filter outbound DNS requests going out through Route 53 Resolver from your VPC
- Blacklist malicious domains or Whitelist trusted domains
- This is to prevent a compromised application within your VPC to send data out through DNS (to a malicious domain) – also called DNS exfiltration
- Can be managed/configured from AWS Firewall Manager
- Integrated with CloudWatch Logs and Route 53 Resolver Query Logs
- Fail-close vs Fail-Open (DNS Firewall Configuration):
  - **Fail-close:** Resolver blocks query if no response from DNS Firewall (security over availability)
  - **Fail-open:** Resolver allows query if no response from DNS firewall (availability over security)



Route 53 Solution Architecture
Split-View DNS (Split-Horizon)

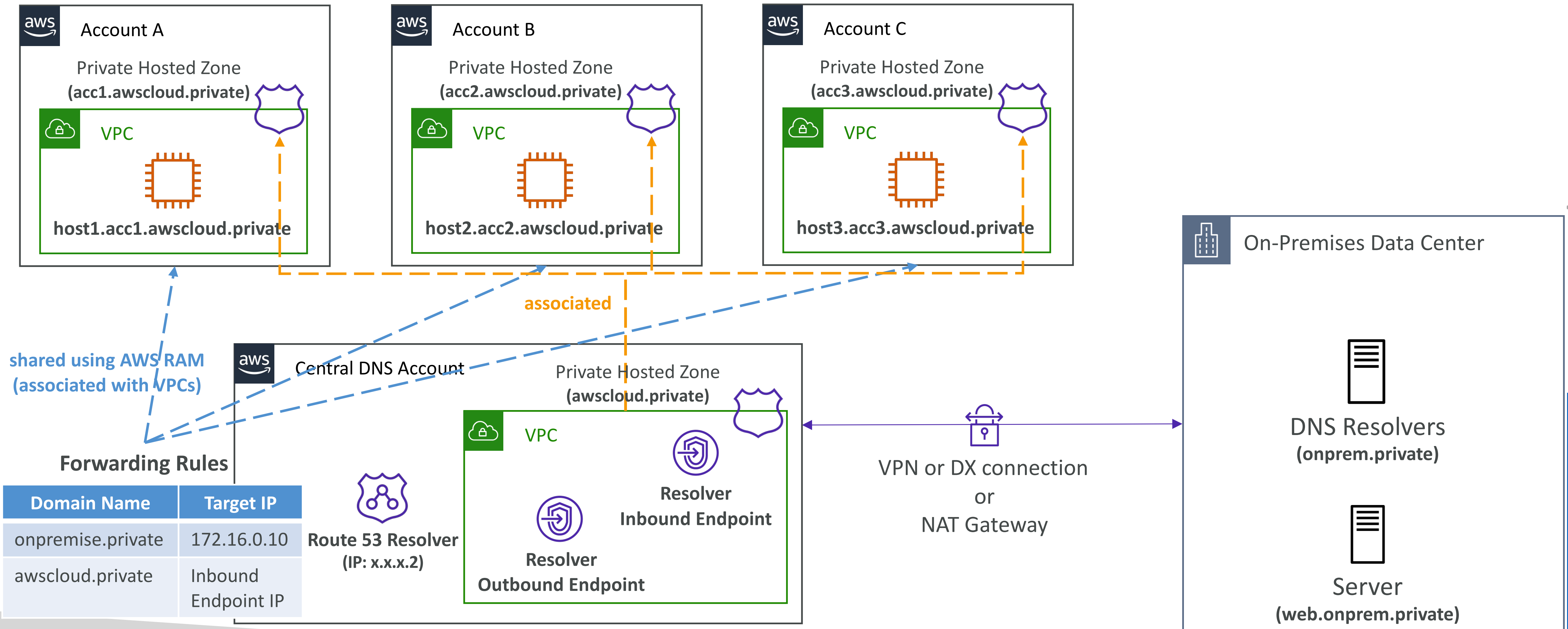
- Use the same domain for internal and external uses
- Public and Private hosted zones will have the same name (e.g., example.com)
- Use case: serve different content, require different authentication for internal and external users, …

Record Name	Type	Value
app.example.com	A	10.0.0.65
db.example.com	A	10.0.0.90



Record Name	Type	Value
app.example.com	A	123.456.789.123

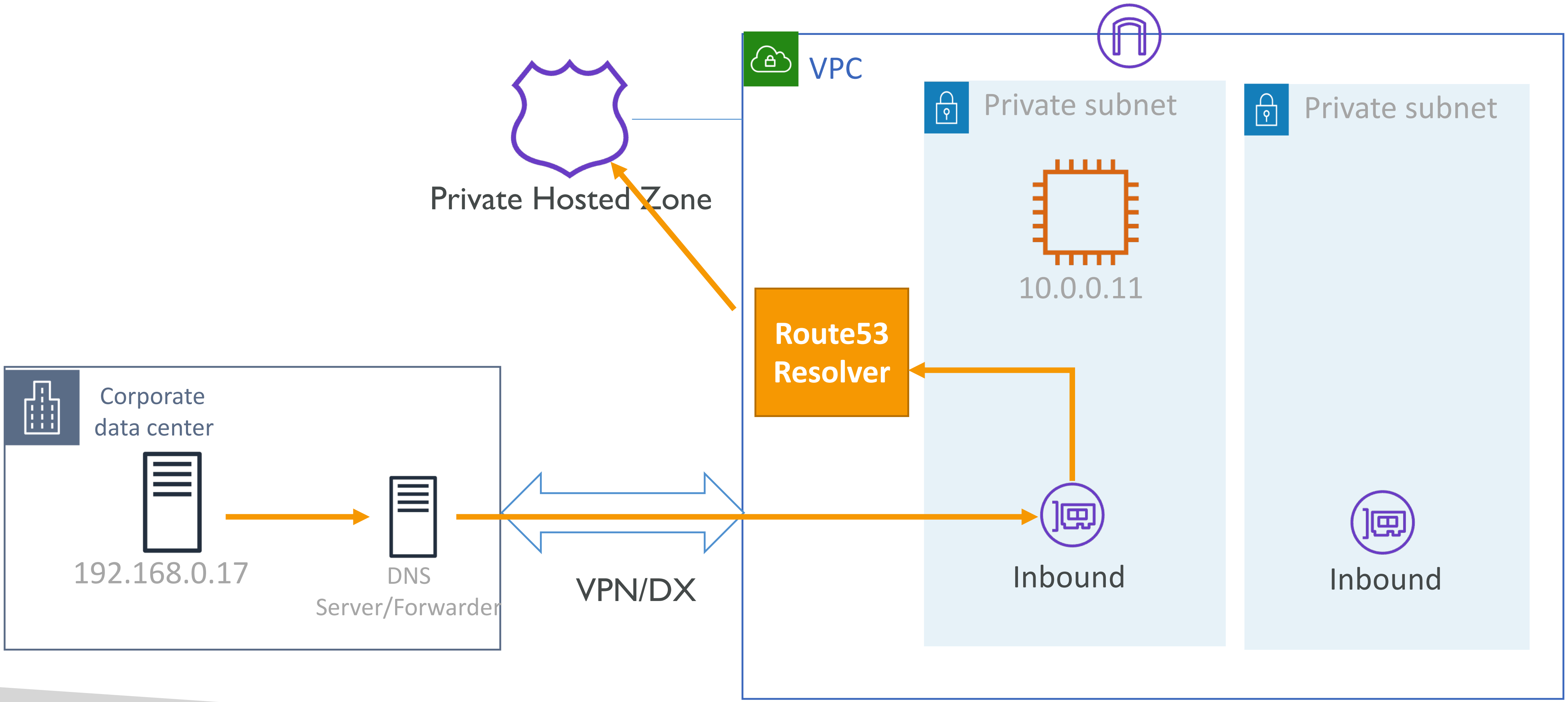
Solution Architecture – Multi-Account DNS Management with Route 53 Resolver



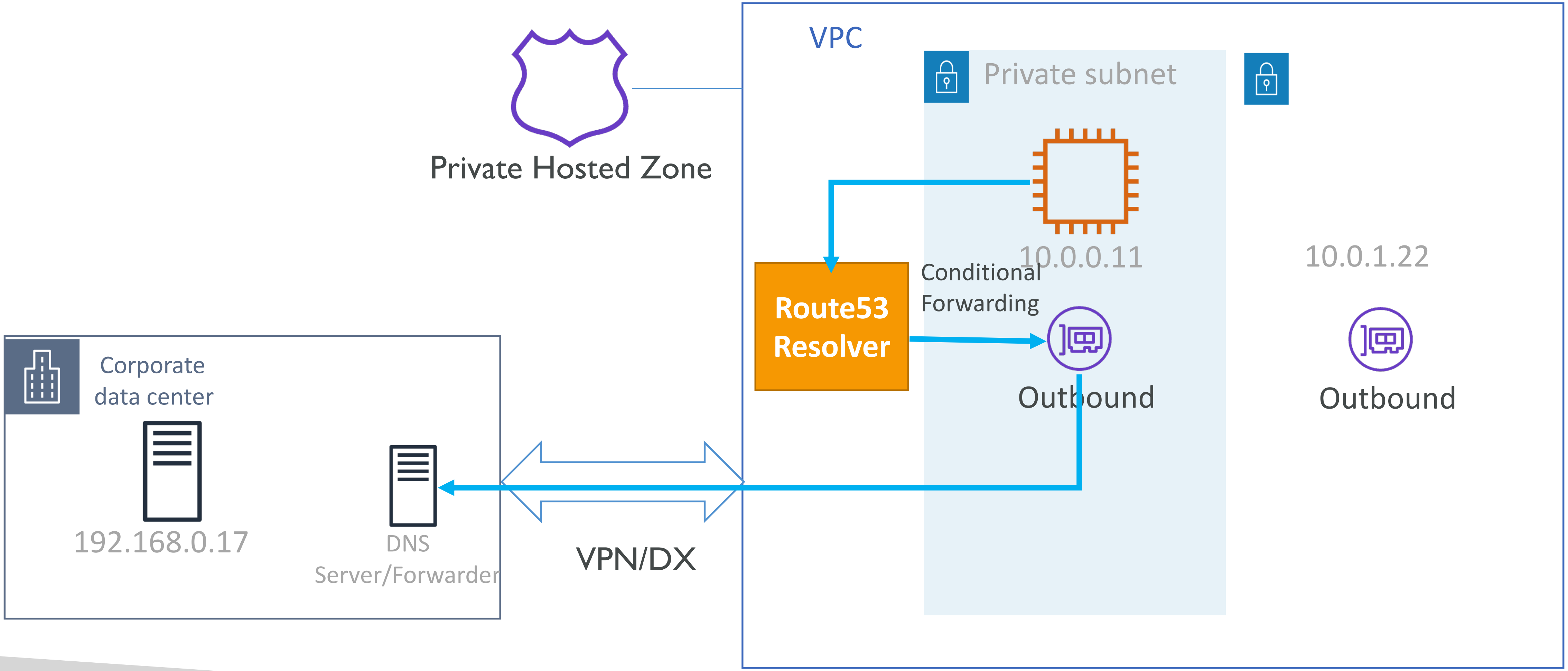
Domain Name	Target IP
onpremise.private	172.16.0.10
awscloud.private	Inbound Endpoint IP

Hands On: Route53 Hybrid DNS

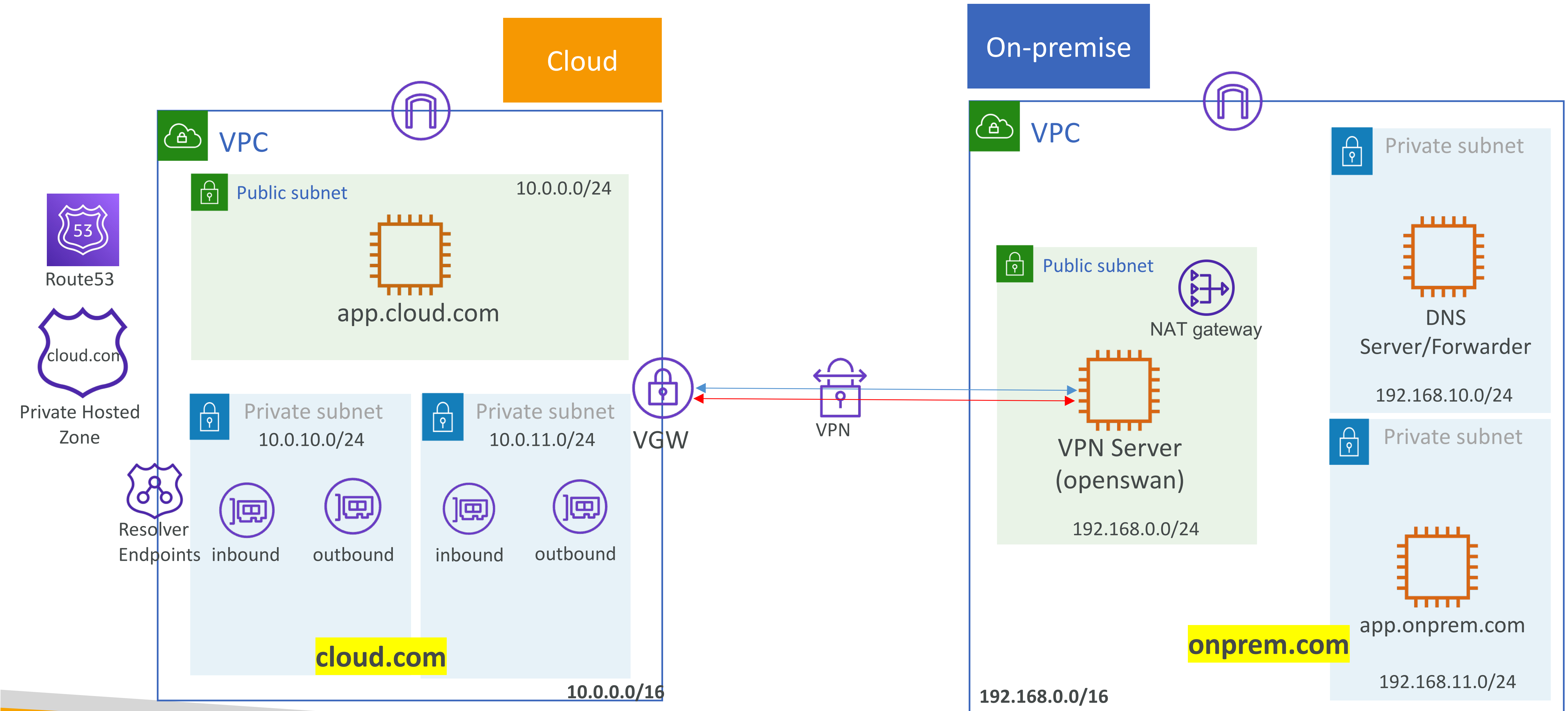
Route53 Resolver Endpoint - Inbound



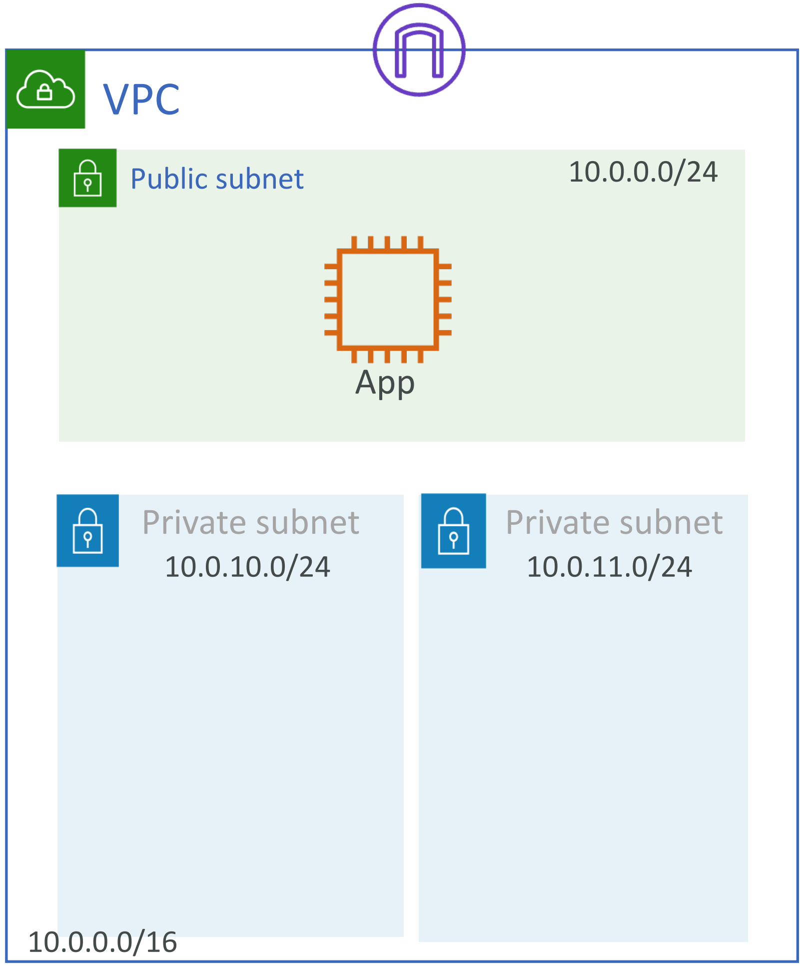
Route53 Resolver Endpoint - Outbound



Lab Architecture



Step 1a – Setup basic cloud VPC network and app server



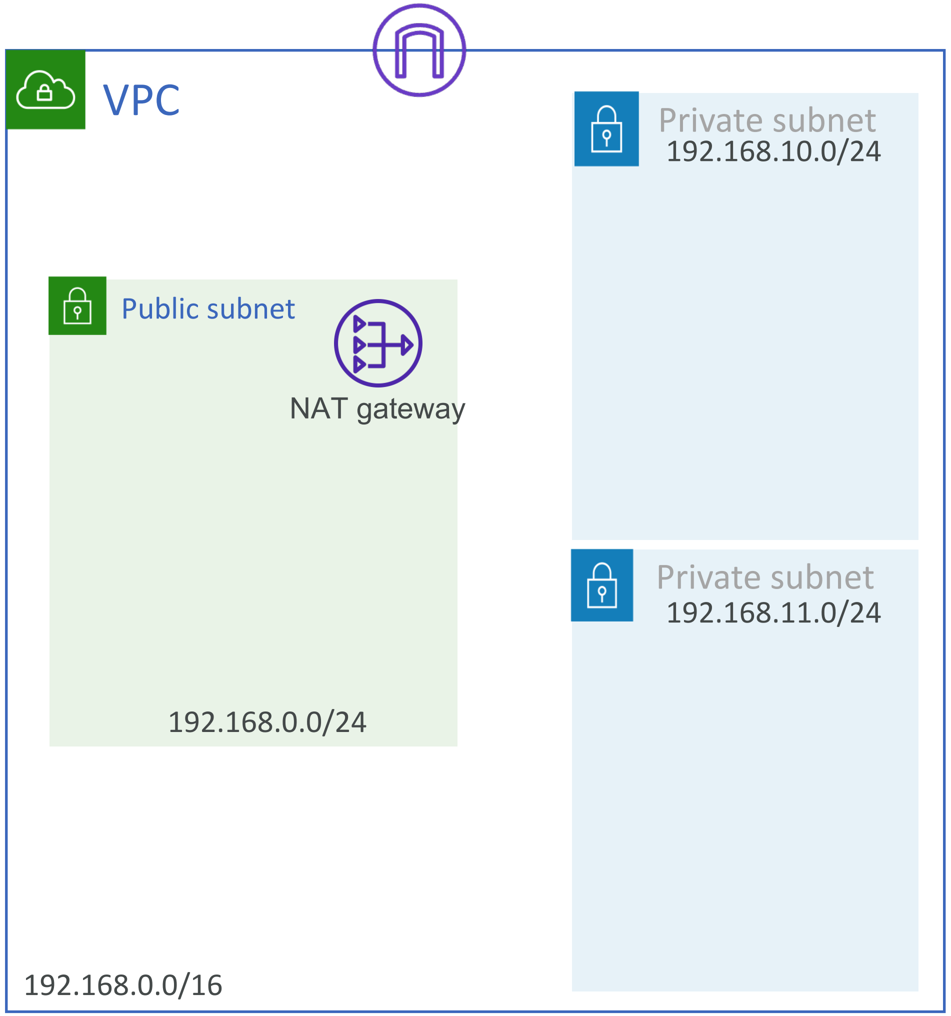
1. Create VPC (10.0.0.0/16), Internet Gateway, 1 Public subnet and 2 private subnets as shown
2. Create route tables for Public and Private subnets.
3. Launch App EC2 instance in a public subnet
4. Security group of App EC2 instance to allow
   1. SSH from 0.0.0.0/0 (to connect and configure)
   2. ICMP IPv4 from 192.168.0.0/16 (Ping from on-premises)

Pre-created to save some time

Step 1b – Setup on-premise network

1. Create VPC (192.168.0.0/16), Internet Gateway, 1 Public subnet and 2 private subnets as shown
2. Create NAT gateway in Public subnet
3. Create route tables for Public and Private subnets.
4. Update private subnet Route table to route traffic for 0.0.0.0/0 through the NAT gateway.

Pre-created to save some time

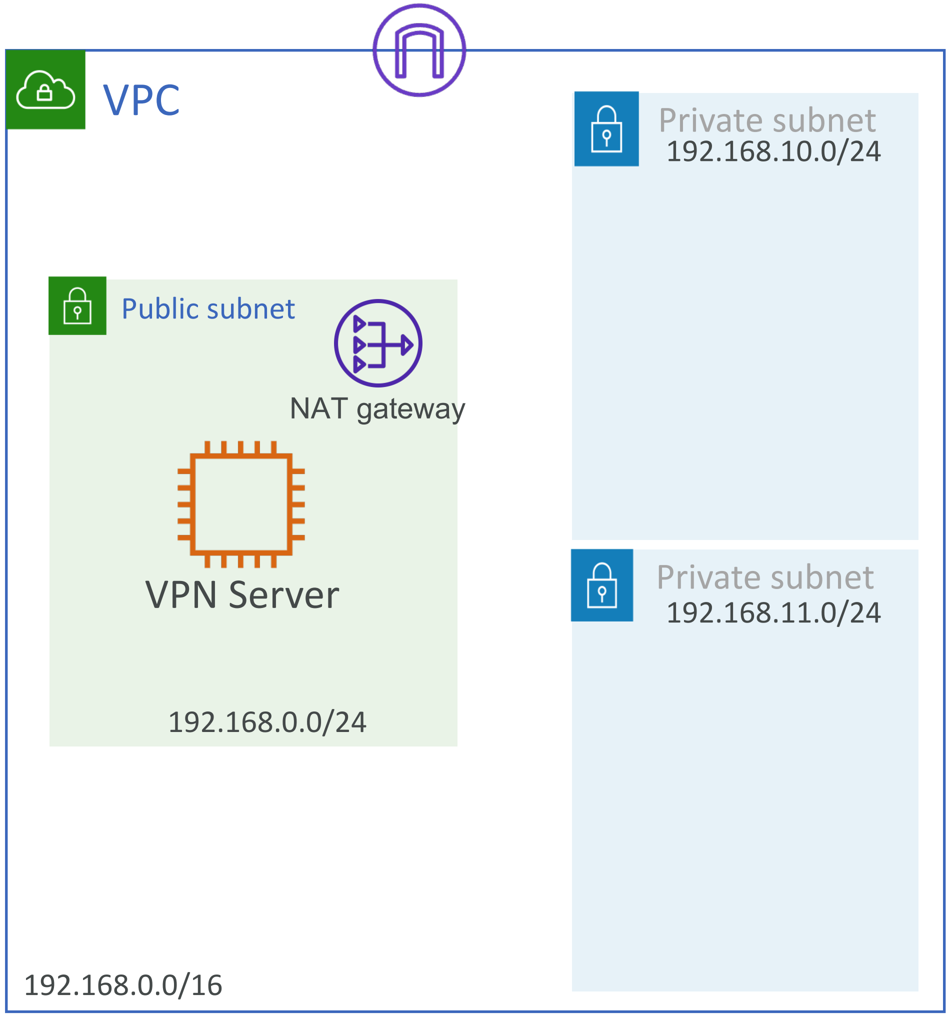


Step 2a – Create on-premise VPN server

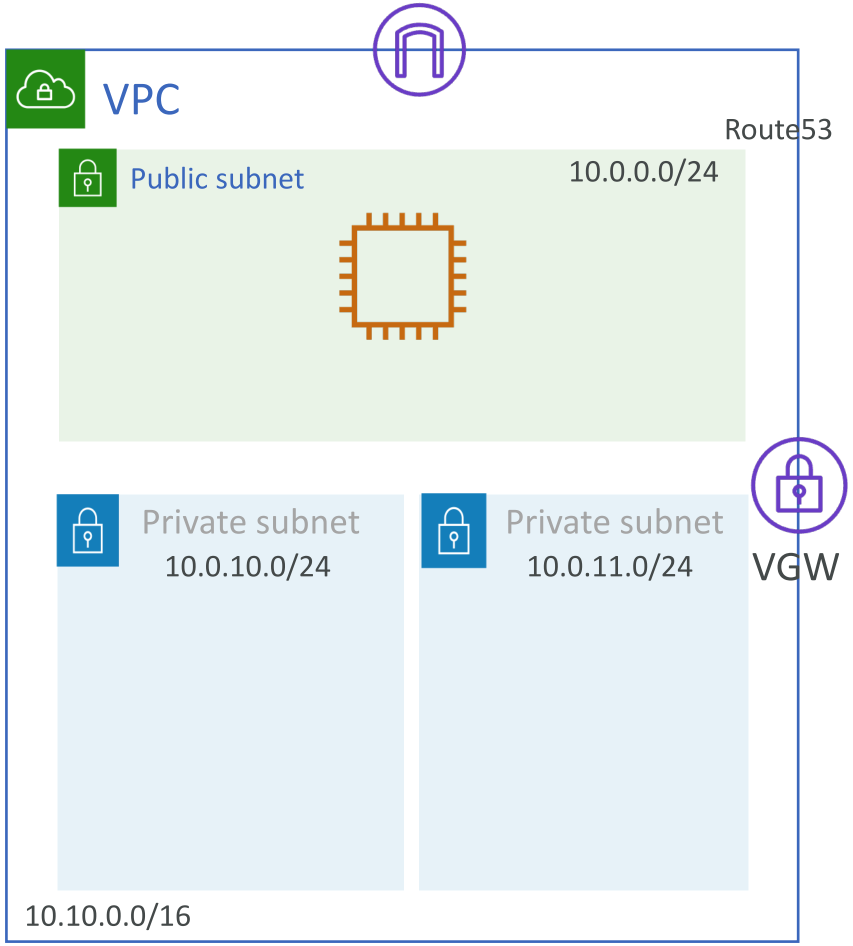
1. Launch EC2 instance in a public subnet (VPN server)
2. Security group of VPN server to allow
   1. SSH from 0.0.0.0/0 (to connect and configure)
   2. ICMP IPv4 from 192.168.0.0/16 (VPN server acts as router)
   3. DNS UDP 53 from 192.168.0.0/16 (VPN server acts as router)
3. Get new EIP and attach EIP to the VPN server

Note: If VPN handshake is initiated from the other end, then you should have following inbound rules in VPN server firewall. In our case, it's initiated by Openswan server and SG by default has outbound traffic allowed. Due to SG's statefulness, we don't need to open these ports for inbound traffic. Return traffic is allowed.

1. *Custom Protocol 50 (ESP) from VGW Public IPs*
2. *UDP 500 from VGW Public IPs*
3. *UDP 4500 from VGW Public Ips if VPN server is behind NAT*



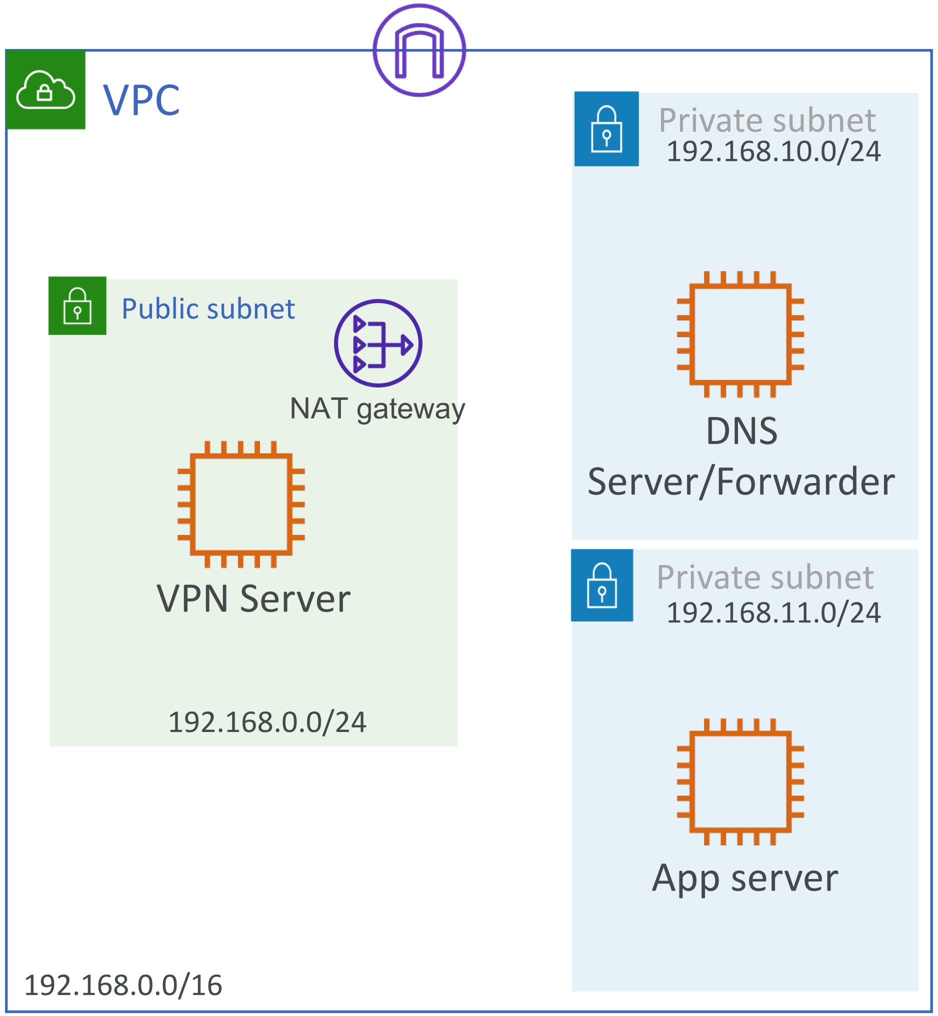
Step 2b – Create VPN Connection



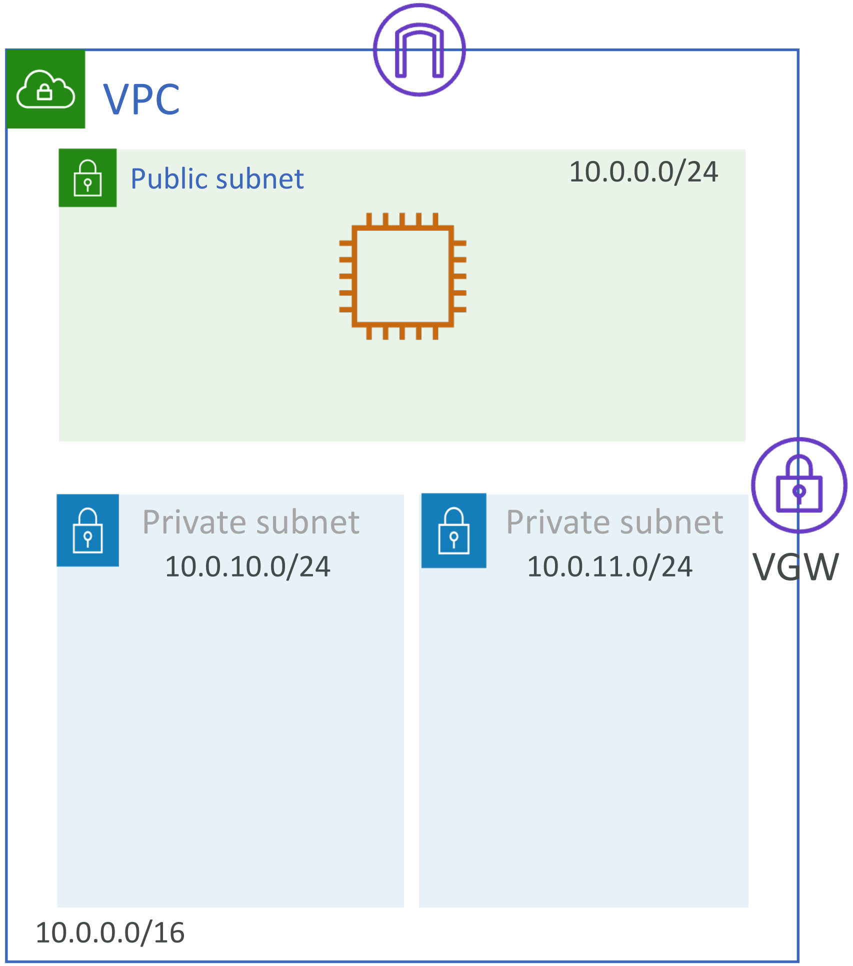
1. Create Virtual Private Gateway and attach to Cloud VPC
2. Create Customer gateway
   1. Use on-premise VPN server EIP
3. Create Site-to-Site VPN connection
   1. Use VGW and CGW created above
   2. Use static routing with IP prefixes – 192.168.0.0/16
   3. Use local IPv4 CIDR as 192.168.0.0/16 (on-prem side) and Remote IPv4 CIDR as 10.0.0.0/16 (Cloud side)
4. Create VPN connection
5. Wait for few minutes and download VPN configuration file for Openswan vendor.

Step 2c – Configure on-premise VPN server

1. SSH into the VPN server
2. Install openswan: *sudo yum install openswan -y*
3. Open the VPN configuration file you downloaded and follow the instructions in the file to setup **Tunnel 1**
   - ✓ Make sure you remove auth=esp from the configuration
   - ✓ Make sure you change:
     - phase2alg=aes_gcm
     - ike=aes256-sha1;modp1024
4. Start the IPSec service: *sudo service ipsec start*
5. Check status of IPSec service: *sudo service ipsec status*
6. Go back to AWS console and check the VPN tunnel status – Tunnel 1 should be UP (and Tunnel 2 should be down)
7. Disable Source/Destination check for VPN server

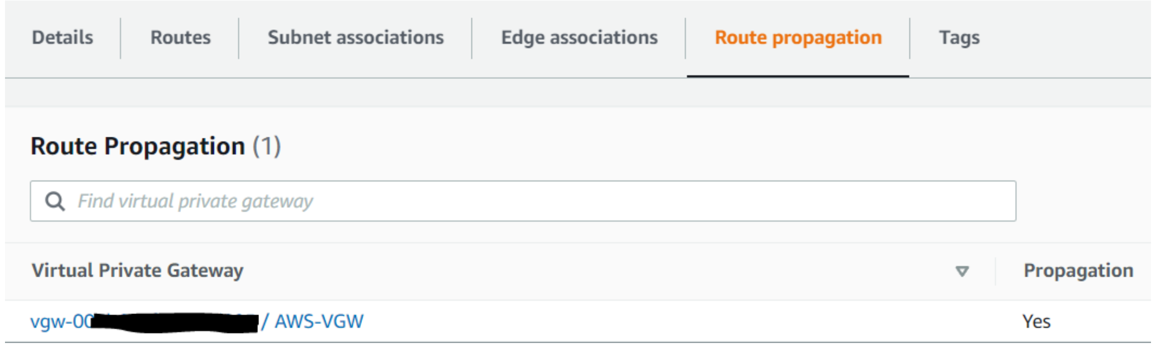


Step 2d – Configure routes for cloud vpc to route VPN traffic through VPN connection



1. Update the Public and Private Subnets route table to propagate routes from the VGW

(This should automatically add a route to the route table for destination 192.168.0.0/16)



On-premise

Step 2e – Configure routes for on-premise network to route VPN traffic through VPN server

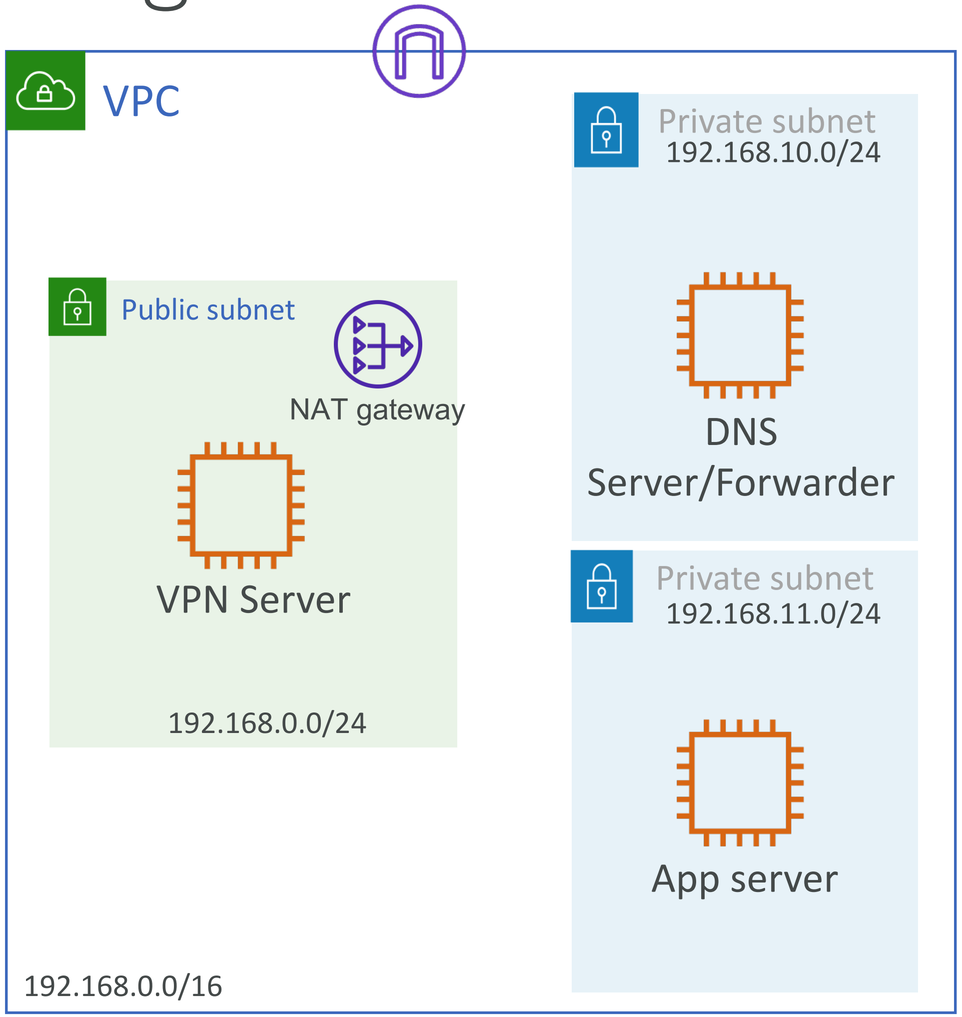
1. Update the private subnet route table to route the traffic to 10.0.0.0/16 through the VPN server eni.

Routes (2)

Filter routes

Destination	Target
0.0.0.0/0	eni-0f[redacted]
192.168.0.0/16	local

Note: Both private subnets are using the same route table.



Cloud

On-premise

Step 2f – Verify that VPN is working

- From Cloud EC2 instance – Ping to on-premises App server private IP

Cloud EC2 -> VGW -> VPN Tunnel 1 -> VPN server -> App server

- Login to on-premises App server (via SSH into VPN server first and then SSH to app server) – Ping to Cloud EC2 instance private IP

On-prem App server -> On-prem VPN router -> VPN tunnel 1 -> VGW -> Cloud EC2

- From on-premises App server ping public website e.g. google.com. Should be able to reach. This traffic goes out through the NAT gateway.

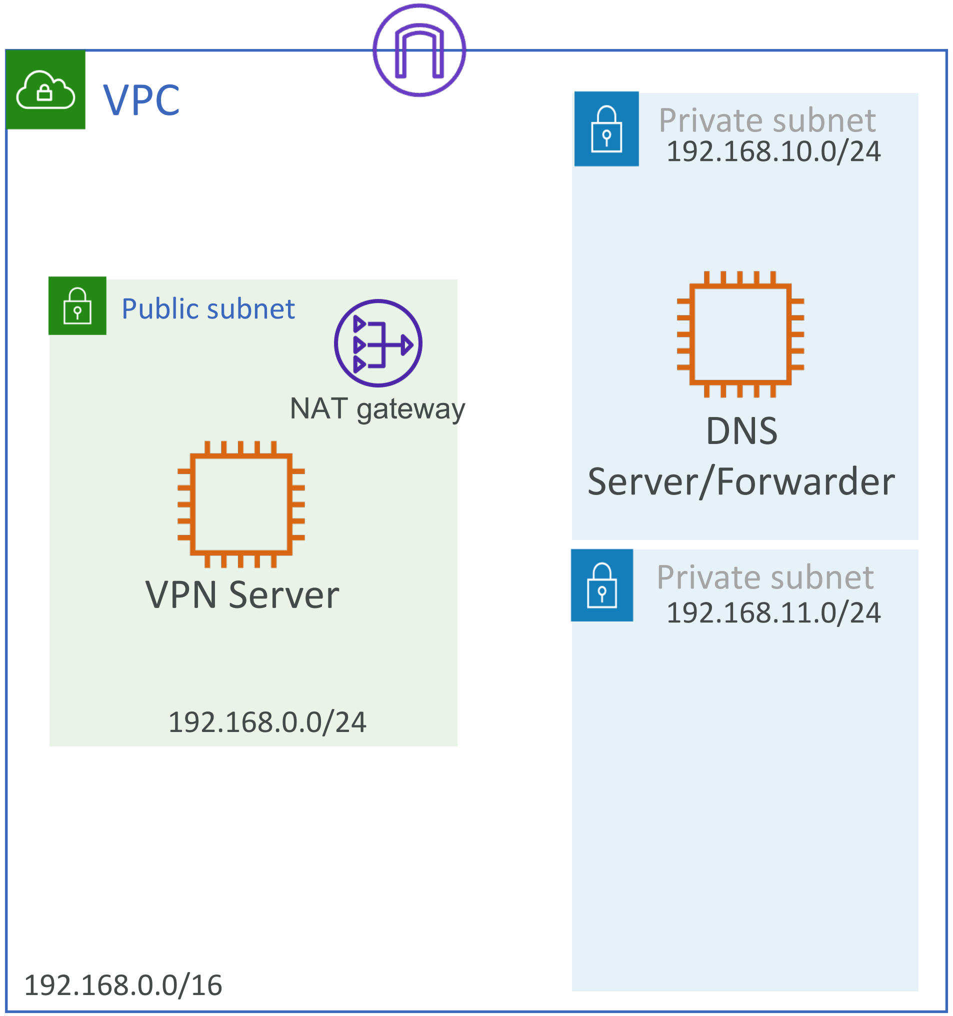
On-prem App server -> NAT gateway -> public website

Well done. VPN working fine.

Step 3a – Setup on-premise DNS server

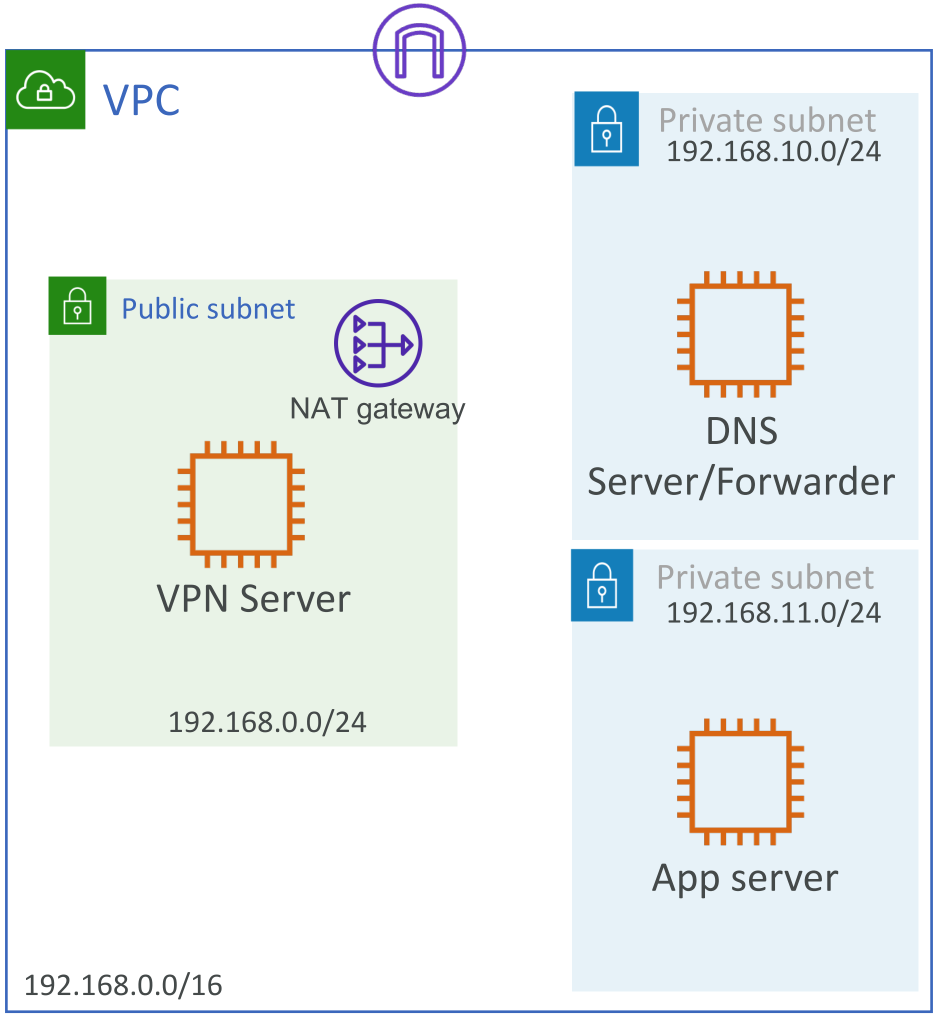
On-premise

1. Launch EC2 instance in one of the private subnet
2. Security group of DNS server to allow
    1. SSH (TCP 22) from 192.168.0.0/16 (to connect and configure)
    2. DNS (UDP 53) from 192.168.0.0/16 (to receive DNS queries from within same VPC on-premise servers)
    3. DNS (UDP 53) from 10.0.0.0/16 (to receive DNS queries from cloud servers)



Step 3b – Setup on-premise App server

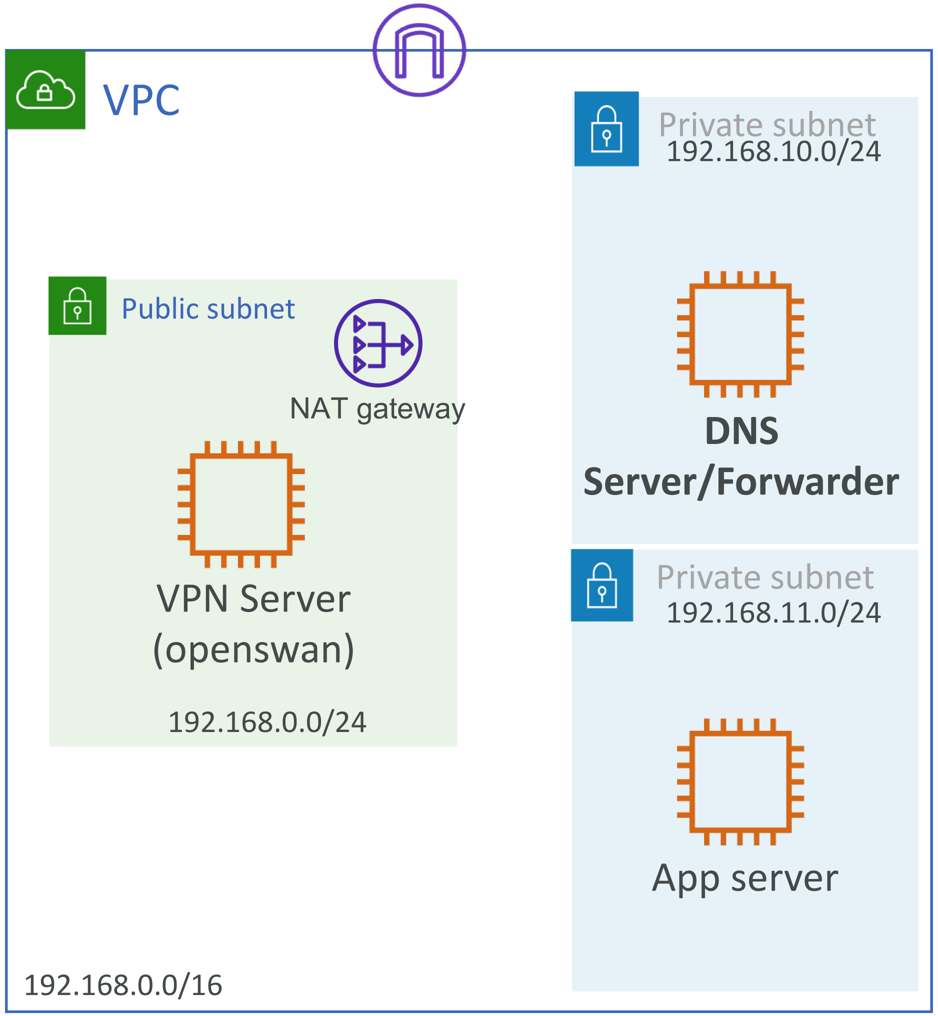
1. Launch an EC2 instance in another private subnet
2. Security group of App server to allow
   1. SSH (TCP 22) from 192.168.0.0/16 (to connect and configure)
   2. ICMP IPv4 from 10.0.0.0/16



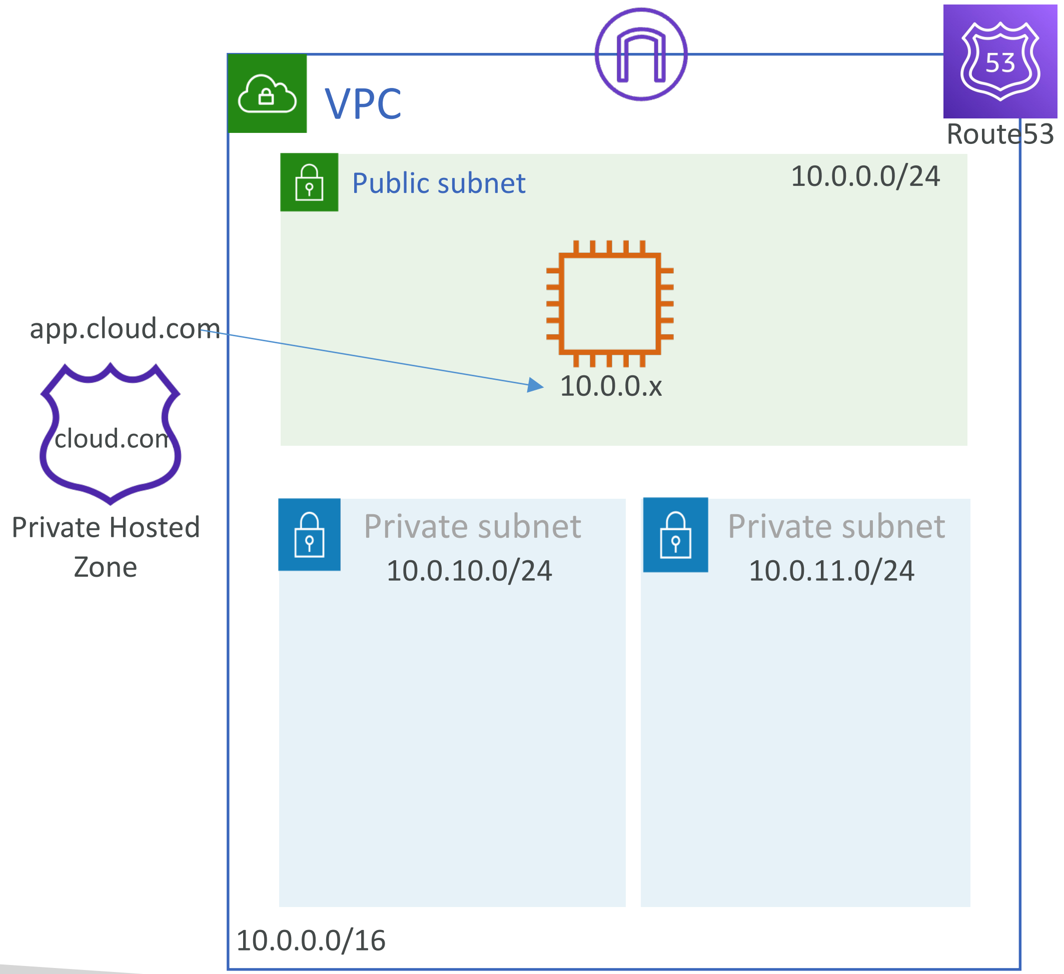
On-premise

Step 4 – Configure Cloud and on-premise DNS servers

We will now configure the DNS Server for both cloud and on-premises network



Step 4a – Setup cloud DNS using Route53 Private hosted zone



1. For Cloud VPC – **Enable DNS resolution and Enable DNS hostname** (required to use Private hosted zone)
2. Create a Private Hosted Zone (cloud.com) and attach to the Cloud VPC
3. Create A record with name app.cloud.com with Cloud EC2 instance private IP address
4. Login to Cloud EC2 instance and verify if the domain name app.cloud.com is resolving to private IP of itself

$nslookup app.cloud.com

(may have to wait for couple of minutes)

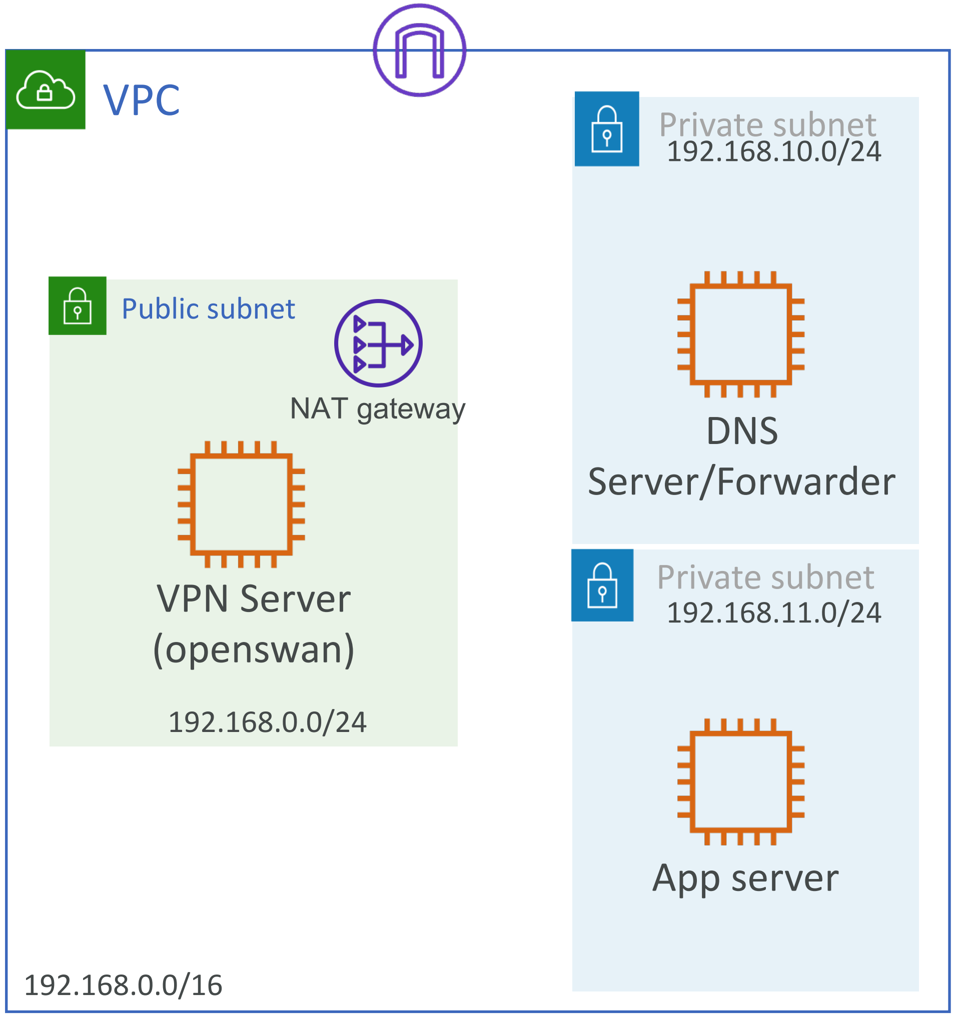
Step 4b – Setup on-premise DNS server

1. Login to on-premise DNS server (via SSH into VPN server first)
2. Install DNS server packages

   $sudo su

   $yum update –y

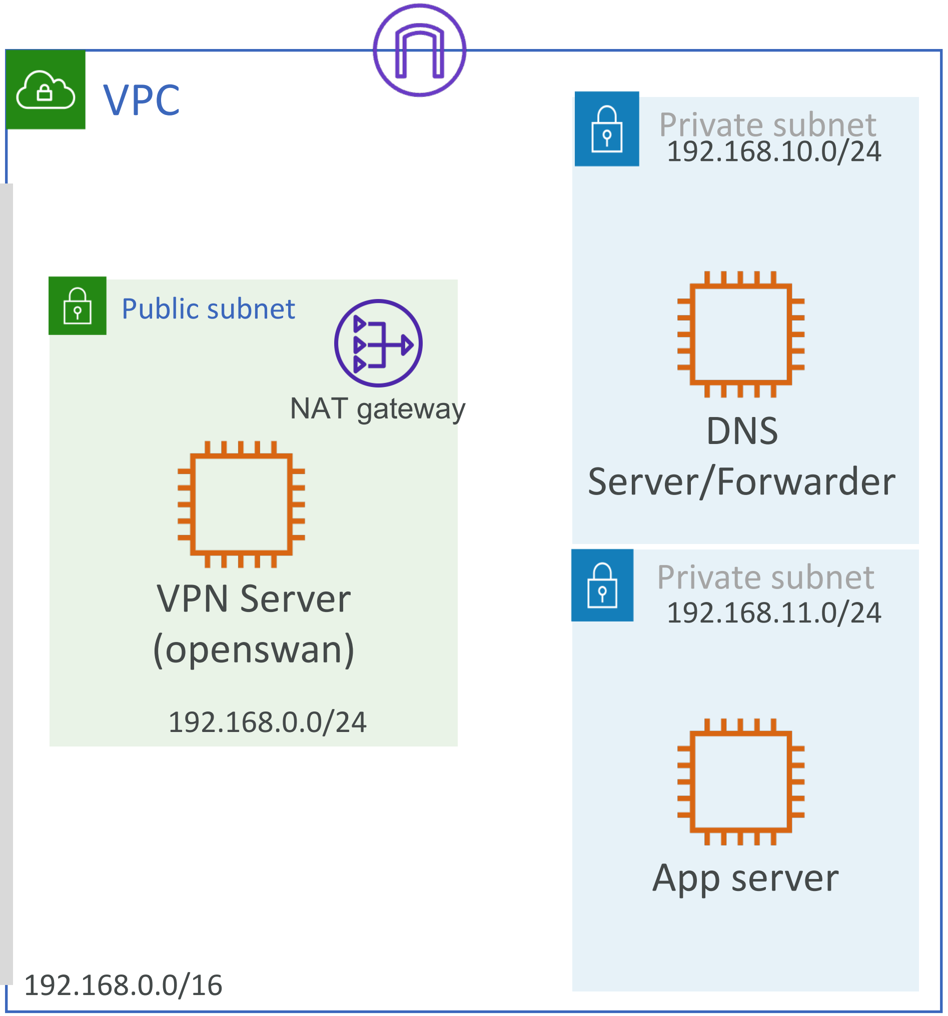
   $yum install bind bind-utils –y



Step 4b – Configure on-premise DNS server

3. Create file /var/named/onprem.com.zone [Replace X.X with your App server IP]

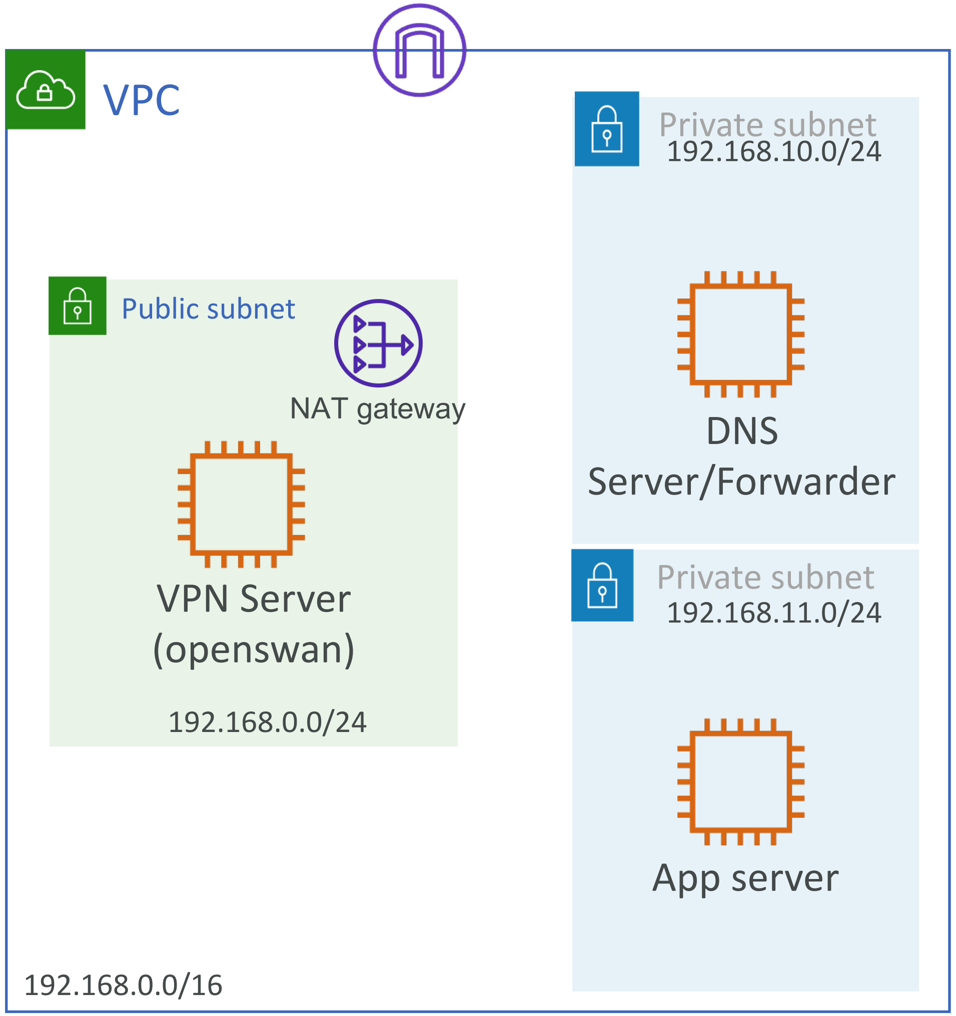
```
$TTL 86400
@
IN  SOA     ns1.onprem.com. root.onprem.com. (
2013042201  ;Serial
3600        ;Refresh
1800        ;Retry
604800      ;Expire
86400       ;Minimum TTL
)
; Specify our two nameservers
IN  NS    dnsA.onprem.com.
IN  NS    dnsB.onprem.com.
; Resolve nameserver hostnames to IP, replace with your two droplet IP addresses.
dnsA
IN  A   1.1.1.1
dnsB
IN  A   8.8.8.8
; Define hostname -> IP pairs which you wish to resolve
@
IN  A   192.168.X.X
app   IN
A   192.168.X.X
```



Step 4b – Configure on-premise DNS server

4. Create file /etc/named.conf [Replace X.X with your DNS server IP]

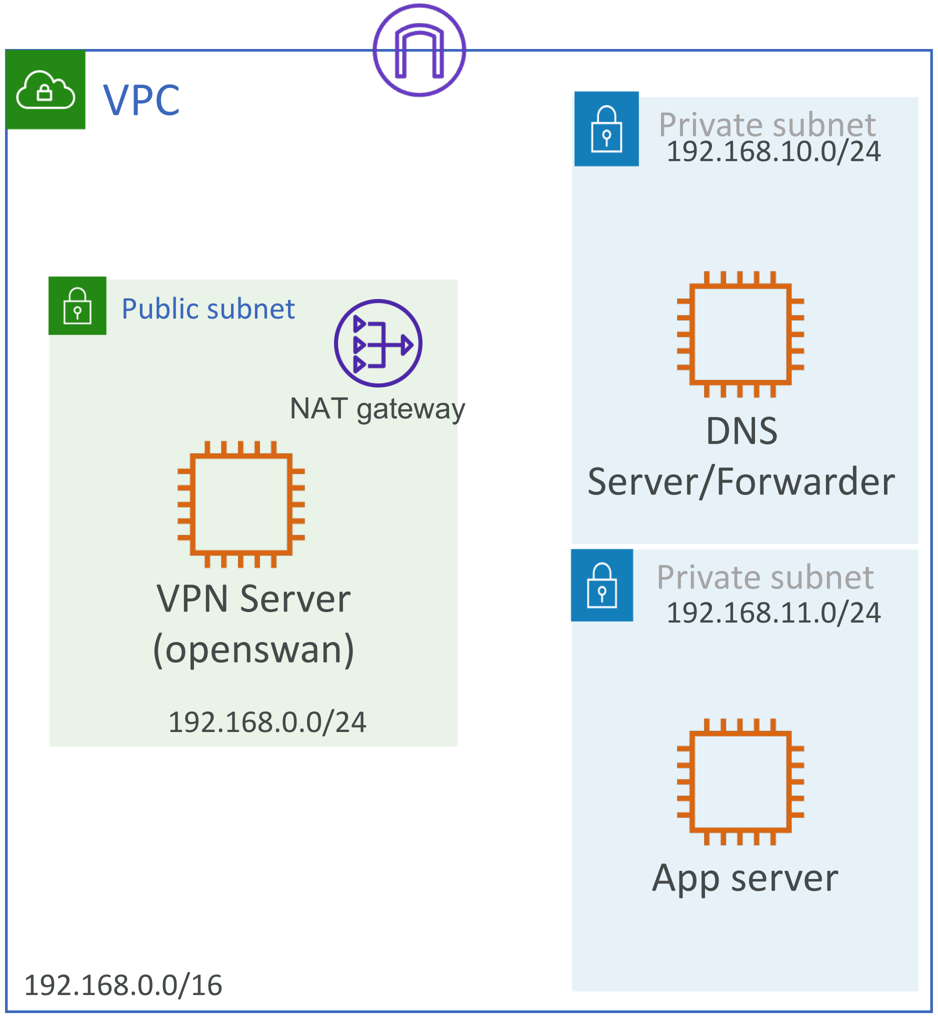
```
options {
  directory "/var/named";
  dump-file "/var/named/data/cache_dump.db";
  statistics-file "/var/named/data/named_stats.txt";
  memstatistics-file "/var/named/data/named_mem_stats.txt";
  allow-query { any; };
  allow-transfer     { localhost; 192.168.X.X; };
  recursion yes;
  forward first;
  forwarders {
    192.168.0.2;
  };
  dnssec-enable yes;
  dnssec-validation yes;
  dnssec-lookaside auto;
  /* Path to ISC DLV key */
  bindkeys-file "/etc/named.iscdlv.key";
  managed-keys-directory "/var/named/dynamic";
};
zone "onprem.com" IN {
    type master;
    file "onprem.com.zone";
    allow-update { none; };
};
```



Step 4b – Configure on-premise DNS server

5. Restart **named** service

$service named restart
$chkconfig named on



Step 4c – Configure App server to send all DNS requests to DNS server

On-premise

You e need to configure the App server to send the DNS queries to you DNS server

1. Add the DNS server details to /etc/sysconfig/network-scripts/ifcfg-eth0

DNS1=<IP address of on-premise DNS server>

2. Reboot App server

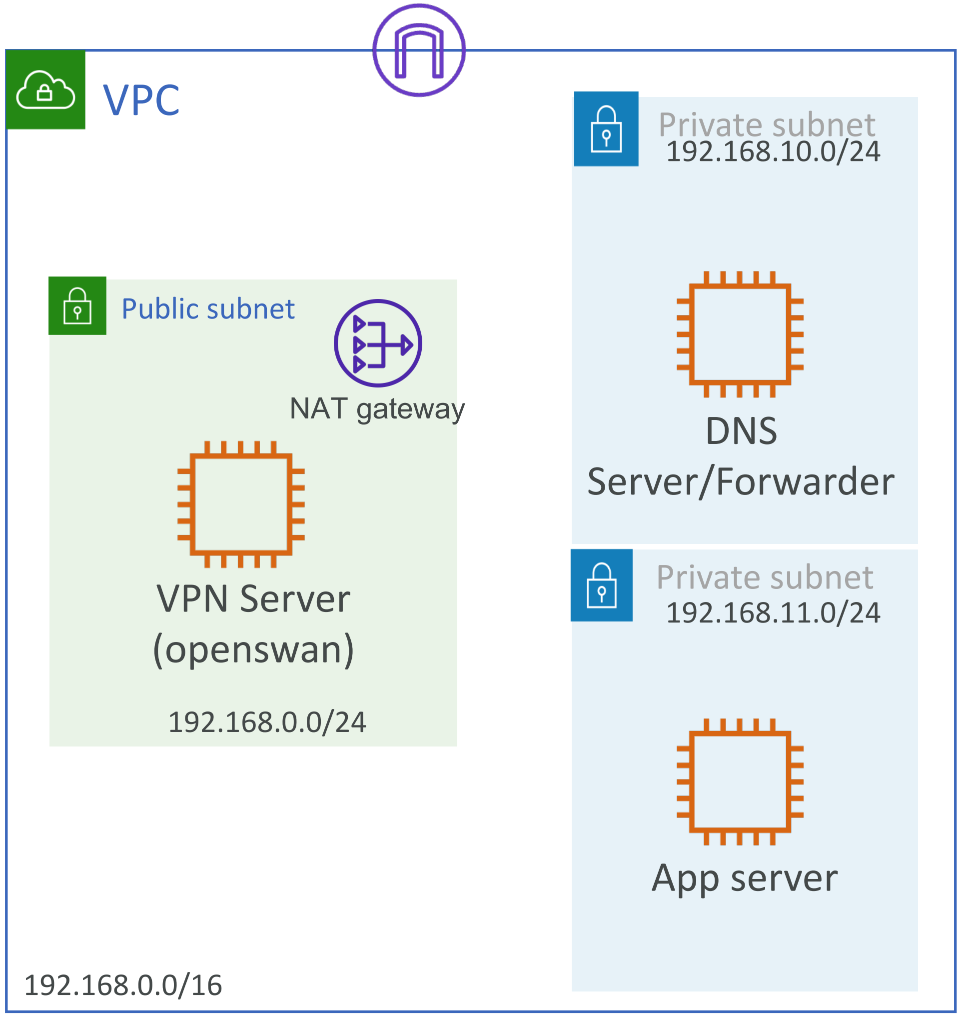
$sudo reboot

3. Login to App server again and verify that you are able to ping to app.onprem.com

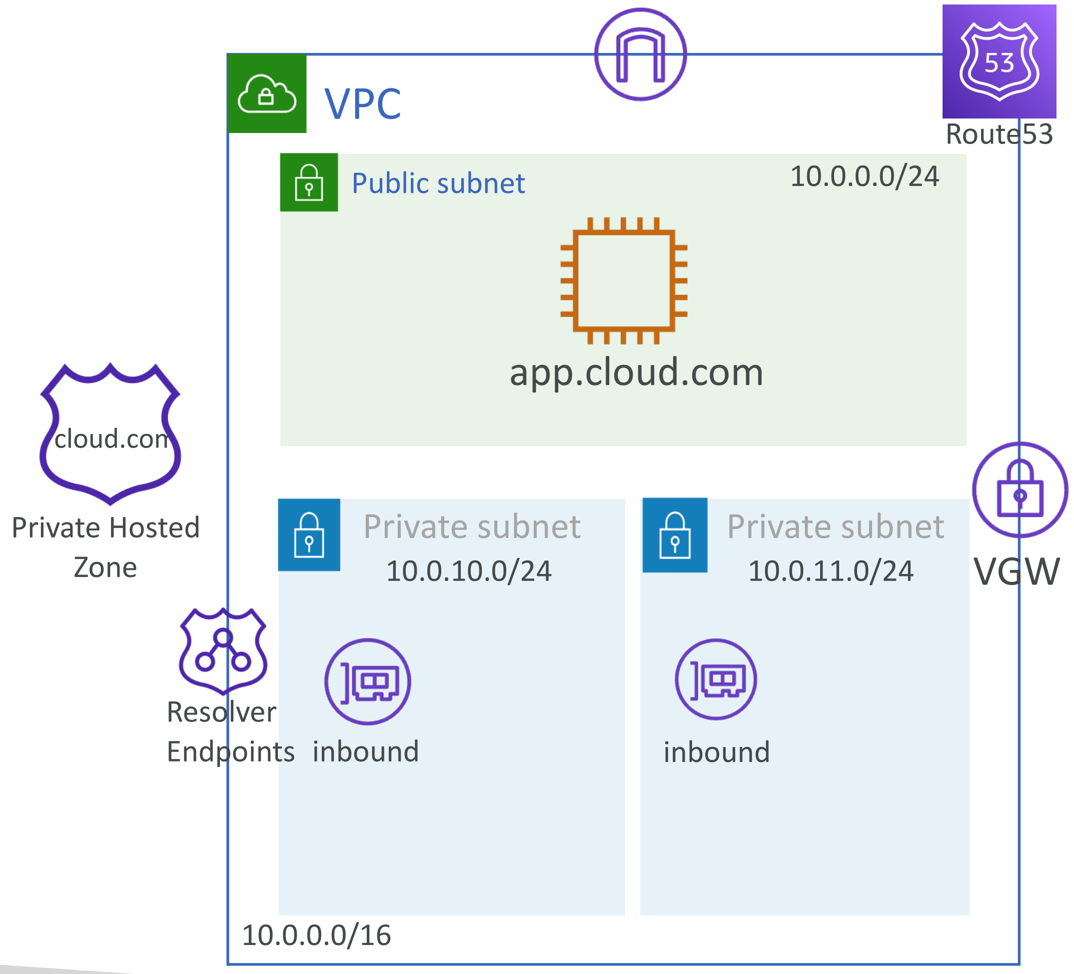
$ping app.onprem.com

*[At this moment, you **can not** ping to app.cloud.com from on-premise app server and vise-a-versa for obvious reason that we haven't configured hybrid DNS so far]*

Well done. Separate DNS configurations done for Cloud and On-premises environments.



Step 5a – Hybrid DNS – From on-premises to AWS



Create Route53 Resolver inbound endpoint

1. Create a Security group for Route53 resolver inbound endpoint
   - Allow DNS (UDP 53) from on-premise network 192.168.0.0/16
2. Create Route53 Resolver inbound endpoint
   1. Make sure you choose same region
   2. Select Cloud VPC
   3. Select 2 private subnets (across 2 AZs) created earlier.

Step 5b – Hybrid DNS – From on-premises to AWS

On-premise

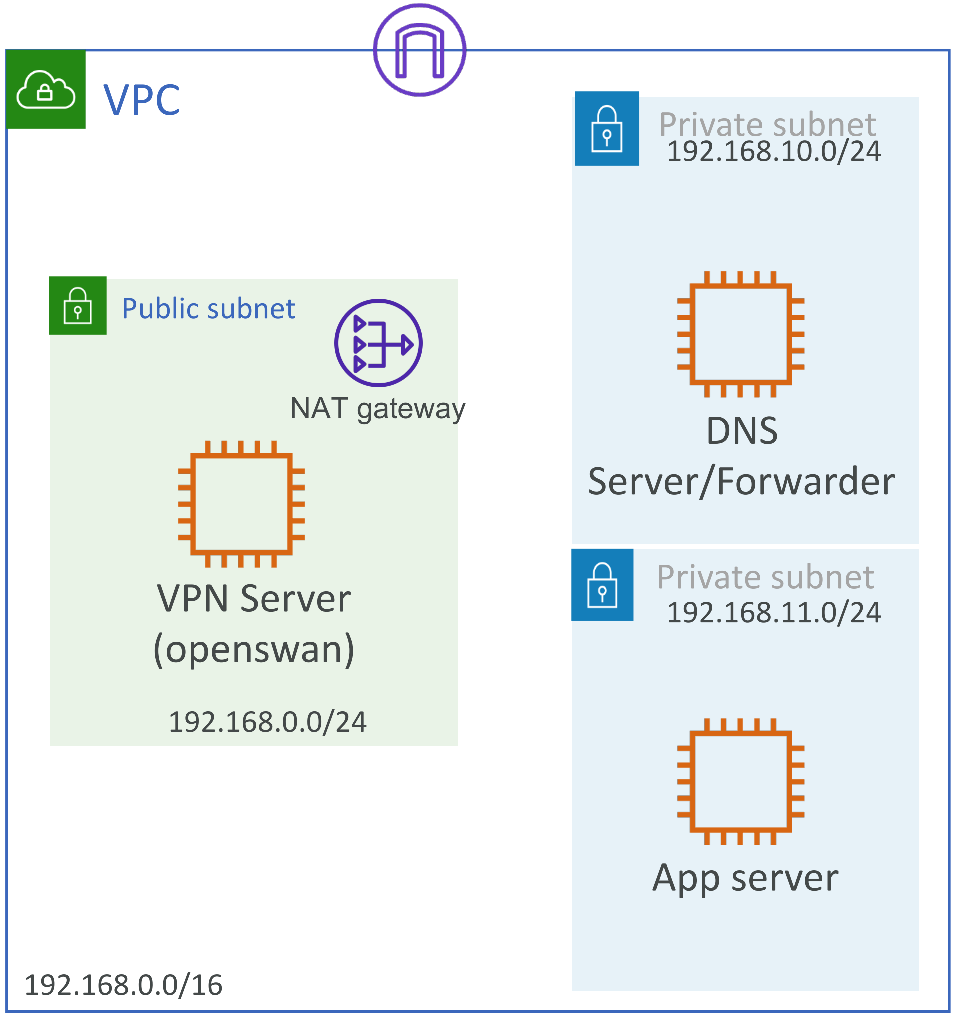
Configure on-premise DNS server to forward DNS queries for cloud.com to Route53 inbound resolver endpoint IPs

1. Add following to /etc/named.conf. Replace ENDPOINT IPs with Route53 inbound resolver IPs.

```
zone "cloud.com" {
  type forward;
  forward only;
  forwarders { INBOUND_ENDPOINT_IP1; INBOUND_ENDPOINT_IP2; };
};
```

2. Restart named service

$service named restart



On-premise

Step 5c – Verify DNS resolution

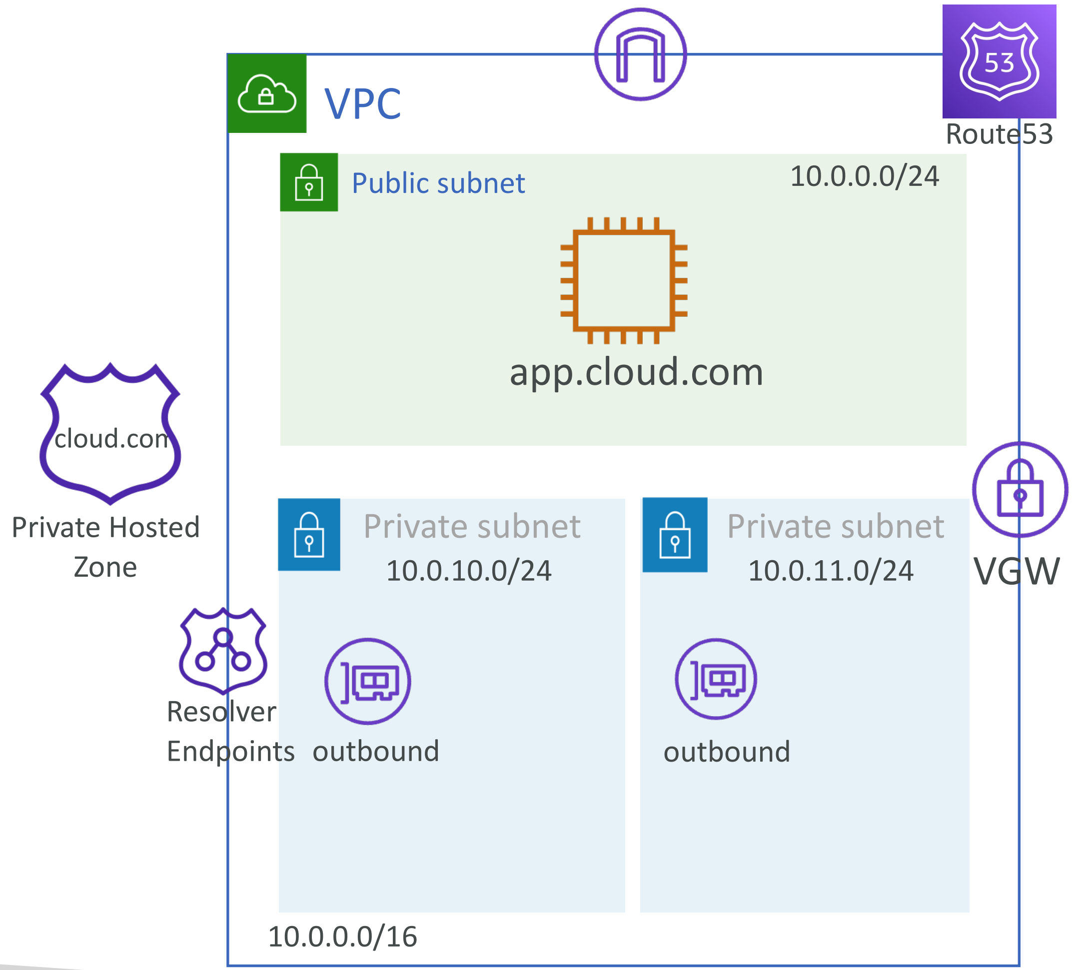
You should be able to resolve app.cloud.com from the on-premise App Server

1. From on-premise App Server

$nslookup app.cloud.com
$ping app.cloud.com

Well done ! On-premises to AWS DNS resolution working as expected.

Step 6a – Hybrid DNS – From cloud to on-premises (outbound)



Create Route53 Resolver outbound endpoint

1. Create a Security group for Route53 resolver outbound endpoint
   - Outbound Rule: Allow DNS (UDP 53) to on-premise network 192.168.0.0/16
2. Create Route53 Resolver outbound endpoint
   1. Make sure you choose same region
   2. Select Cloud VPC
   3. Select 2 private subnets (across 2 AZs) created earlier.
3. Create Outbound Rule to forward the DNS requests for onprem.com to DNS server IP
   1. Domain name as onprem.com
   2. Select Cloud VPC
   3. Target IP address of on-premises DNS server IP (192.168.X.X)

Step 6b – Verify DNS resolution

You should be able to resolve app.onprem.com from the Cloud EC2 instance

1. From Cloud EC2 instance

$nslookup app.onprem.com
$ping app.onprem.com

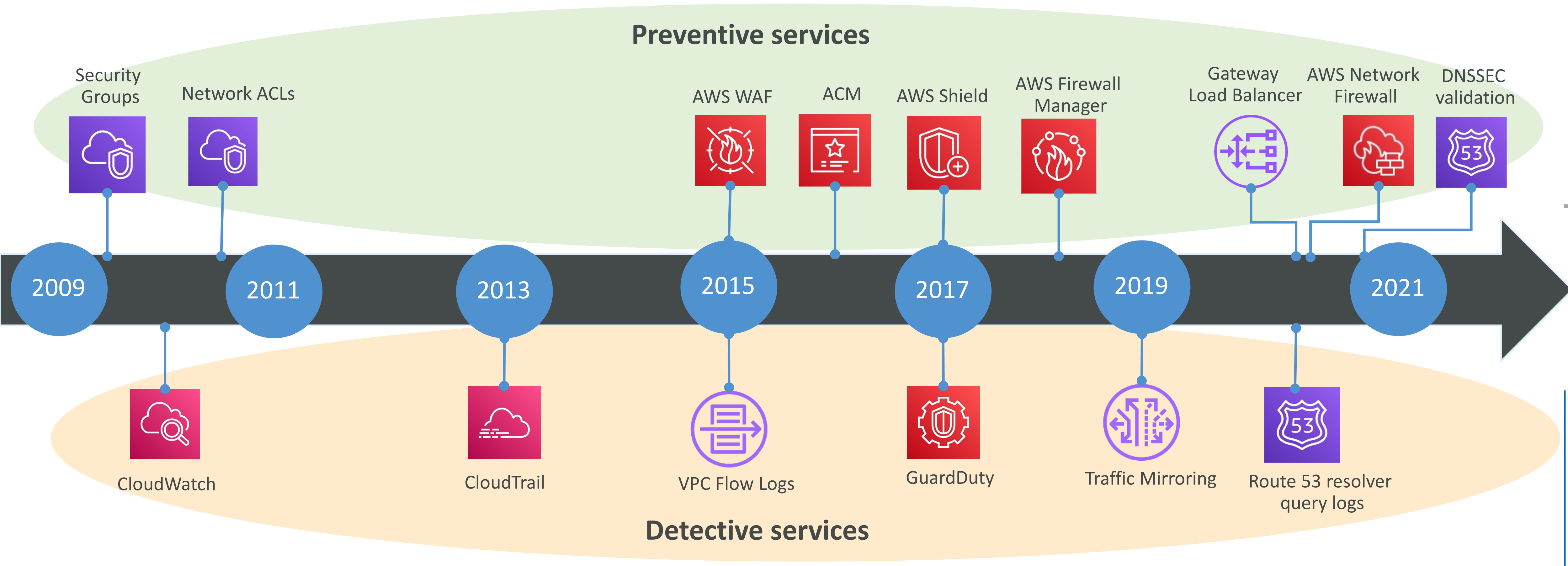
Amazing ! AWS to on-premises DNS resolution is also working!

Step 7 - Cleanup

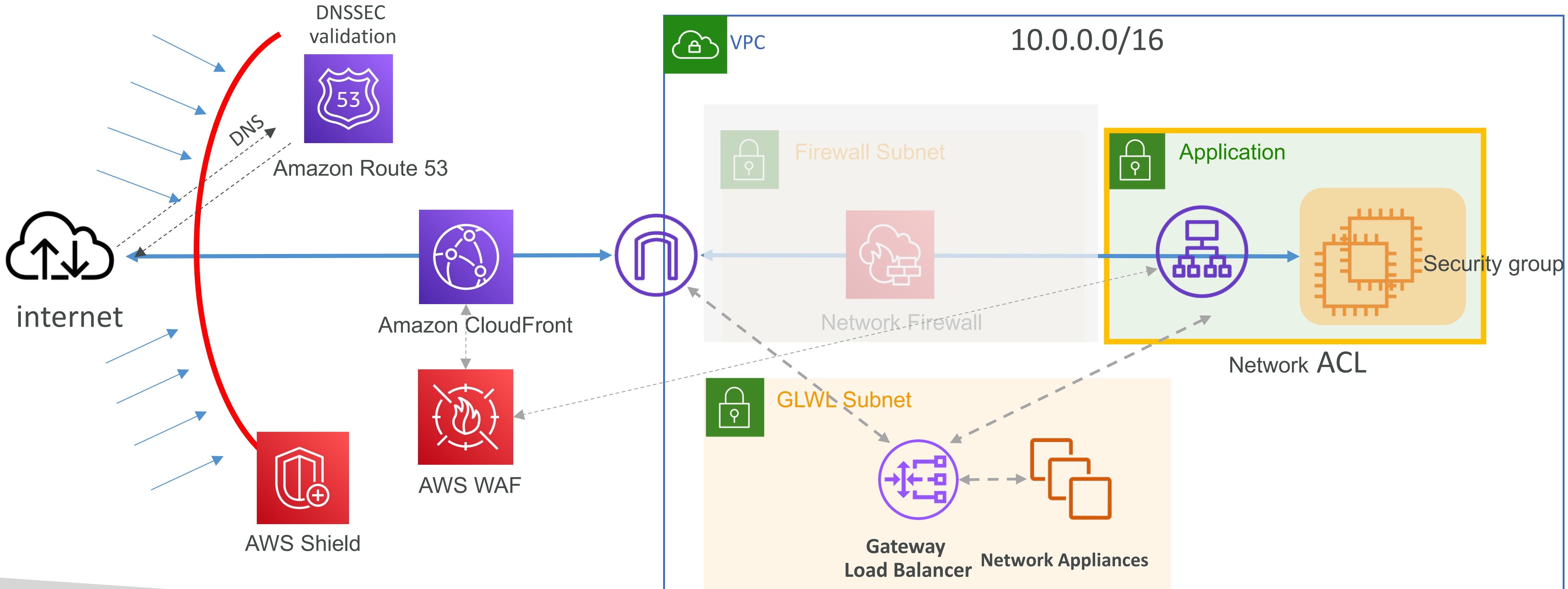
- Terminate all EC2 instances created in this lab.
- Delete VPN Connection, VGW and CGW
- Delete NAT Gateway
- Delete Route53 resolver rules followed by resolver endpoints
- Delete Route53 A record followed by a private hosted zone
- Delete both VPCs

AWS Network Security

AWS Network Security services



Security at different layers

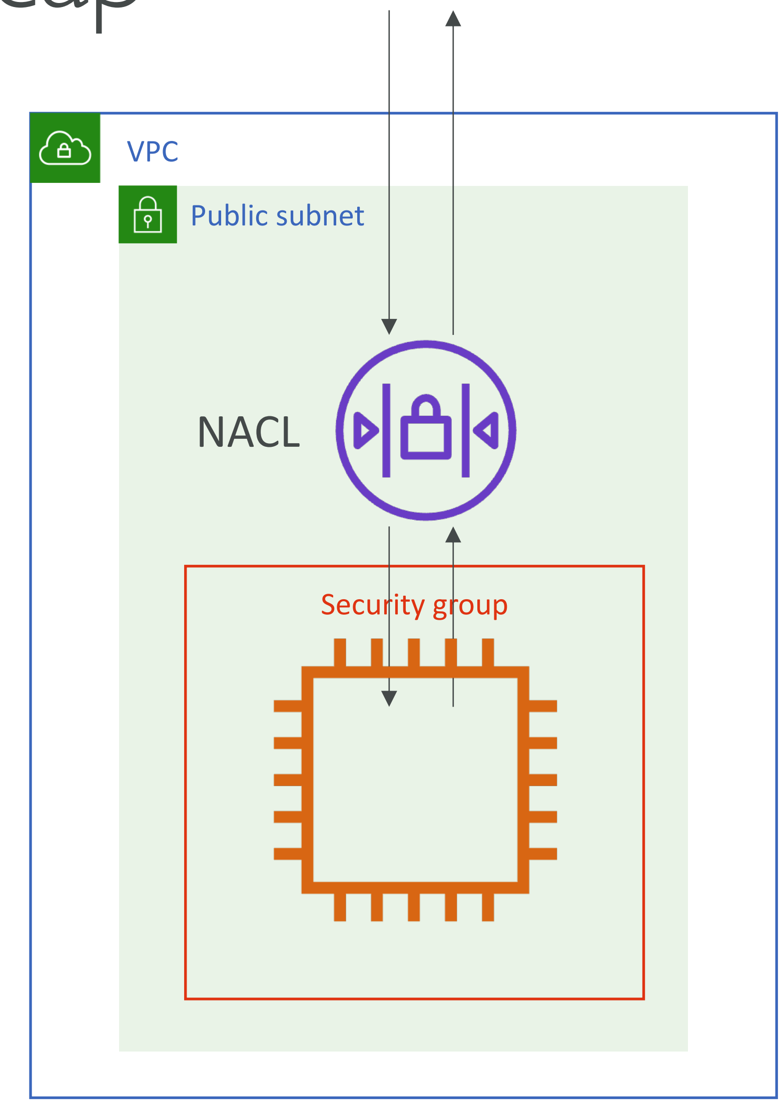


AWS Firewall services

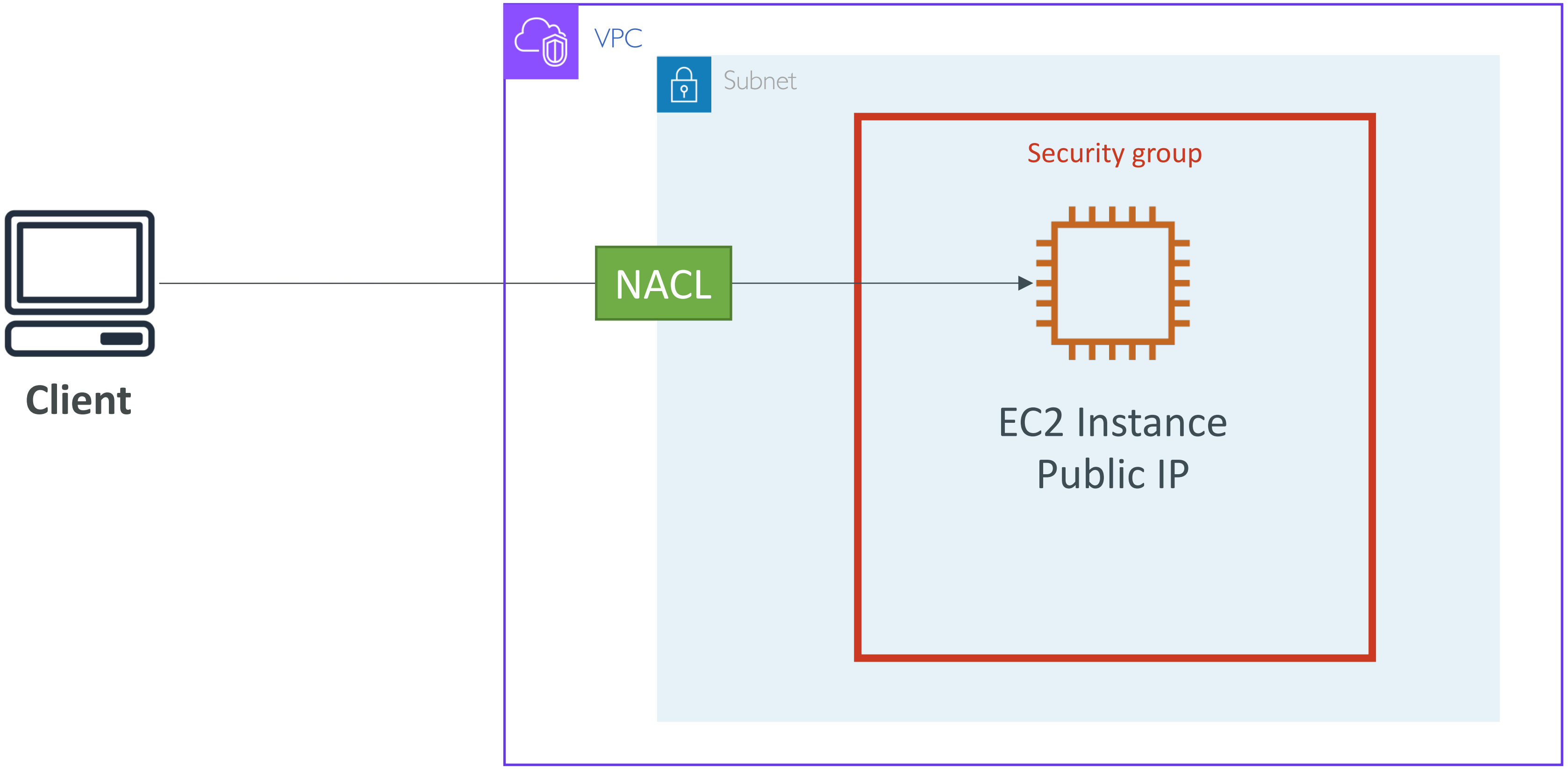
Recap – Security Group and Network ACL

Security Group and NACL recap

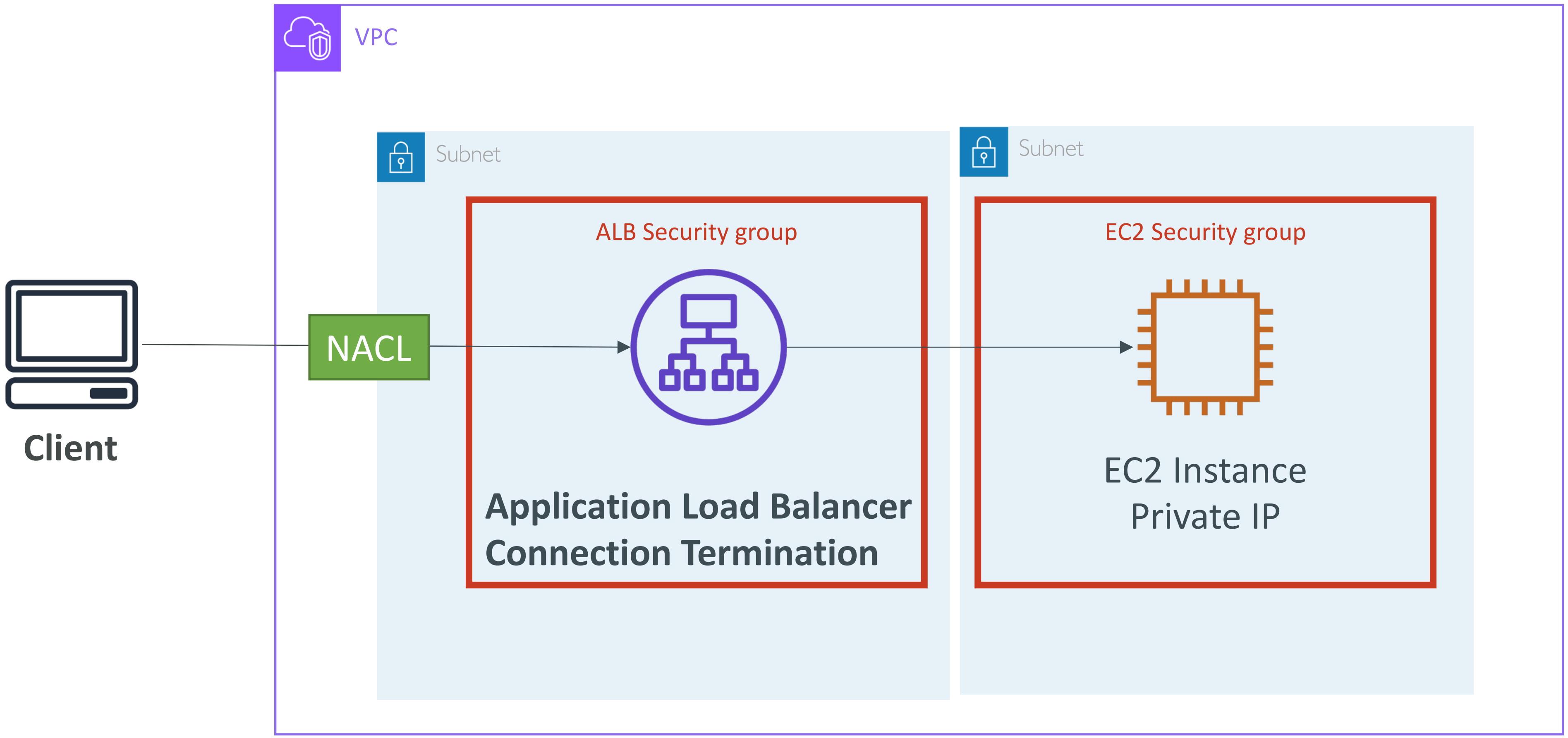
- Security Groups
  - Attached to ENI (Elastic Network Interfaces) – EC2, RDS, Lambda in VPC, etc
  - Are stateful (any traffic in is allowed to go out, any traffic out can go back in)
  - Can reference by CIDR and security group id
  - Supports security group references for VPC peering
  - Default: inbound denied, outbound all allowed
- NACL (Network ACL):
  - Attached at the subnet level
  - Are stateless (inbound and outbound rules apply for all traffic)
  - Can only reference a CIDR range (no hostname)
  - Default: denies all inbound, denies all outbound



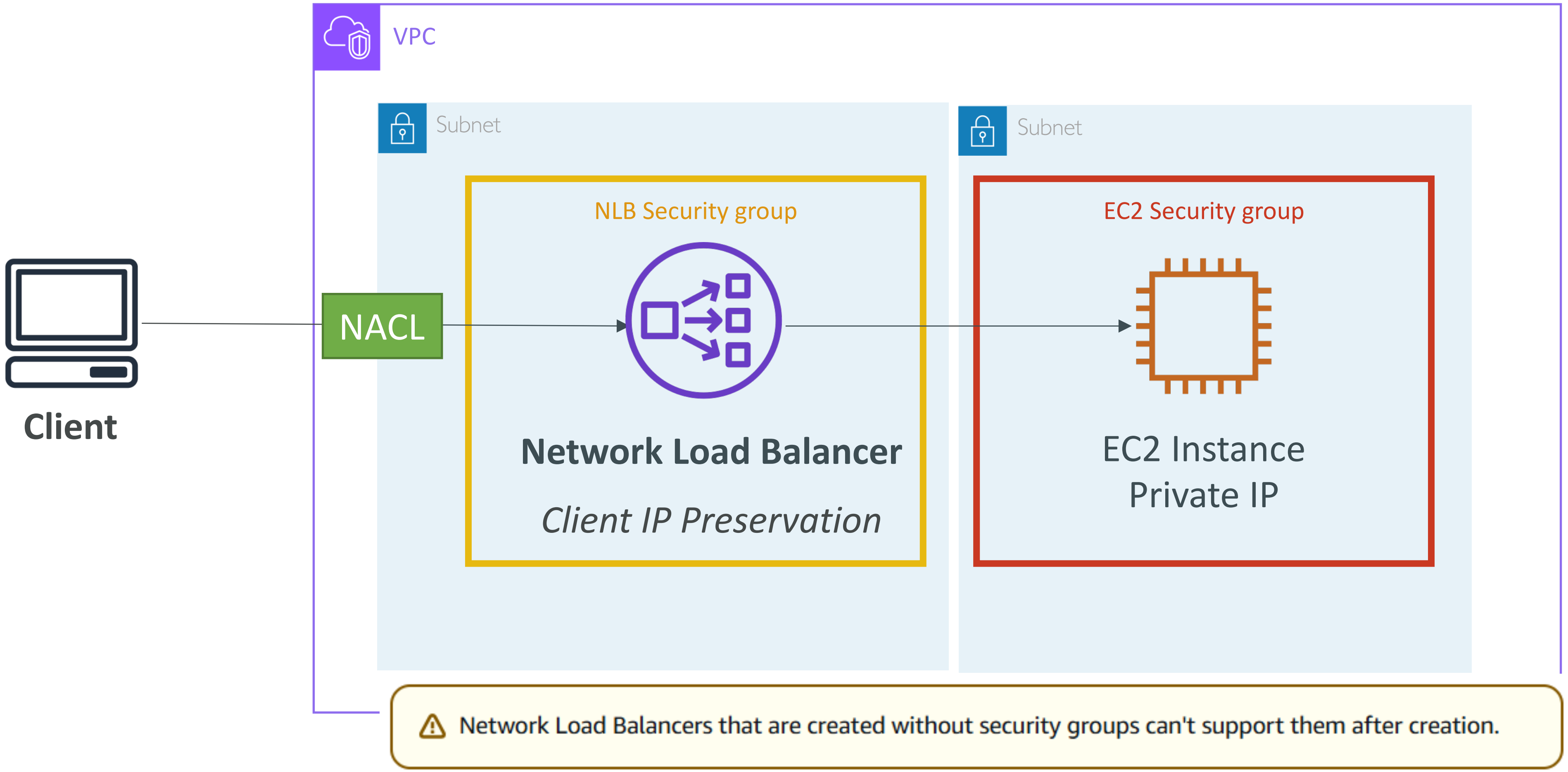
Blocking an IP address



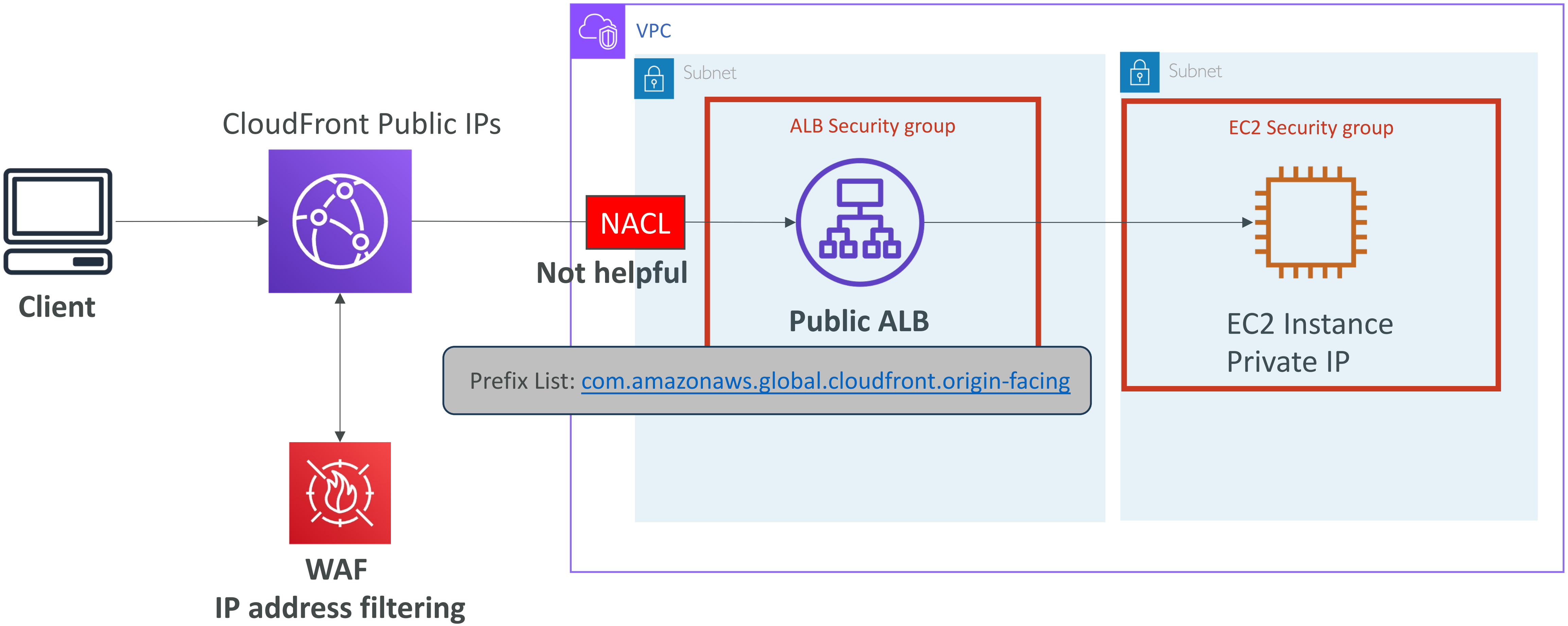
Blocking an IP address – with an ALB



Blocking an IP address – with NLB

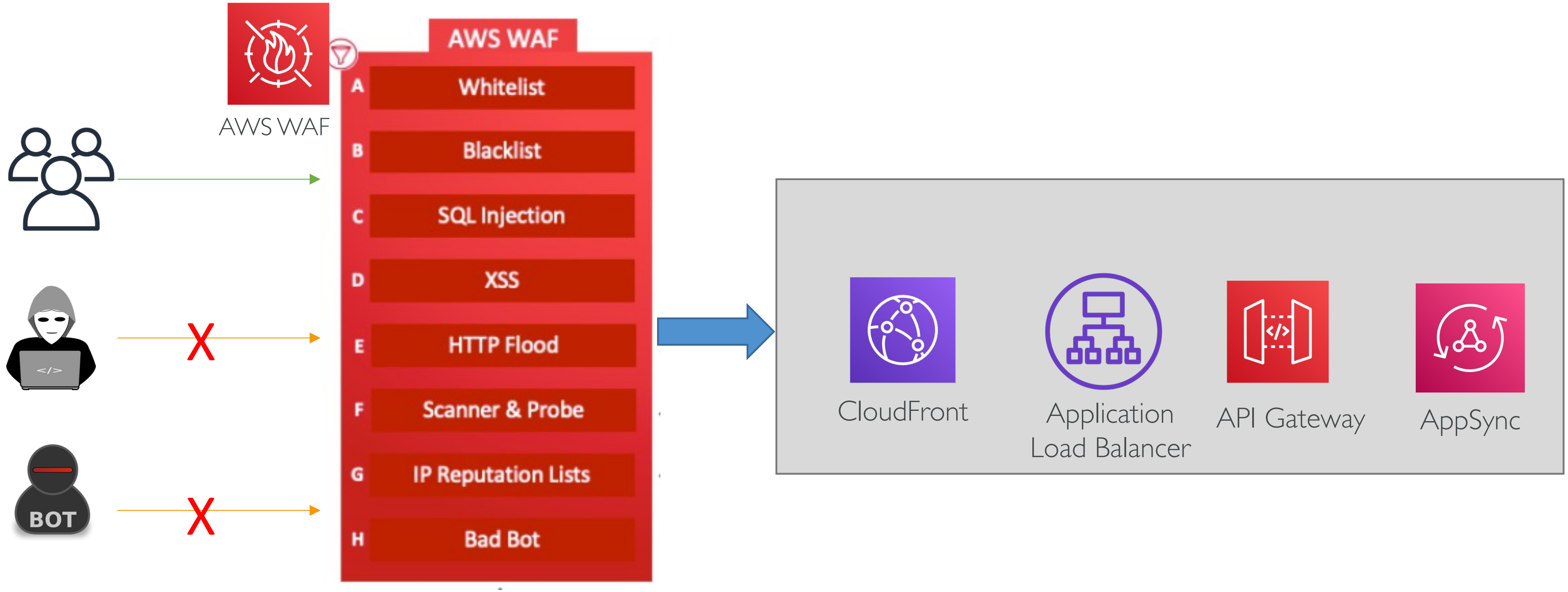


Blocking an IP address - CloudFront



Web Application Firewall (WAF)

Amazon Web Application Firewall (WAF)



AWS WAF – Web Application Firewall

- Protects web applications from common web exploits (Layer 7)
- Deploy on **Application Load Balancer, API Gateway** or **AppSync** GraphQL APIs and **CloudFront** (rules running globally on edge locations)
- Define Web ACL (Web Access Control List) with which you can allow, block or monitor web requests by inspecting IP addresses, HTTP headers, HTTP body, or URI strings, Size constraints, Geo match, String match etc.
- Web ACLs also support Rate-based rules (to count occurrences of events)
- When you evaluate the body of a request, only the first 8,192 bytes (8KB) are inspected.
- On blocking the malicious traffic WAF returns HTTP 403 status code (Forbidden)
- It takes less than a minute for the WAF rules to propagate worldwide

Amazon Web Application Firewall (WAF)

Web ACL regular rules support following conditions

1. **Cross-site Scripting (xss)** : Searched in HTTP method, header, query string, Uniform Resource Identifier (URI), or body
2. **IP addresses**: Allows you to match IPv4 and IPv6 addresses
3. **Size**: Allows you to match request on basis of length for common parts of request data
4. **SQL Injection (SQLi)**: Can be applied on common parts of request data.
5. **Geographic match**: Allow or block requests based on the country from which the request originates
6. **String/Regex match**: Allows to match common parts of request data based on string content including regular expression

WAF Labs – XSS example

1. Deploy simple application which is susceptible to the XSS attack
   - Launch an EC2 instance and install httpd ($sudo yum install httpd –y)
   - Install git ($sudo yum install git –y)
   - Clone the xss-example repo & copy the content into /var/www/html/ dir
     - $git clone https://github.com/academind/xss-example.git
   - Start the web server ($sudo service httpd start)
   - Open the web browser and connect to EC2 Public IP.
   - In the image field enter something like:

example.com/any-image.jpg" onerror="alert('This computer is hacked')"

WAF Labs – Use WAF to prevent XSS

1. Use the existing EC2 instance but this time we will have simple hello web page
2. Just backup the existing index.html file under /var/www/html dir and create another index.html file with simple HTML text
3. Create ALB and add attach EC2 instance in the target group. Make sure instance shows healthy.
4. Create WAF Web ACL and enable the core rules. Associate with ALB.
5. Now try to access the website using EC2 Public IP followed by some XSS script

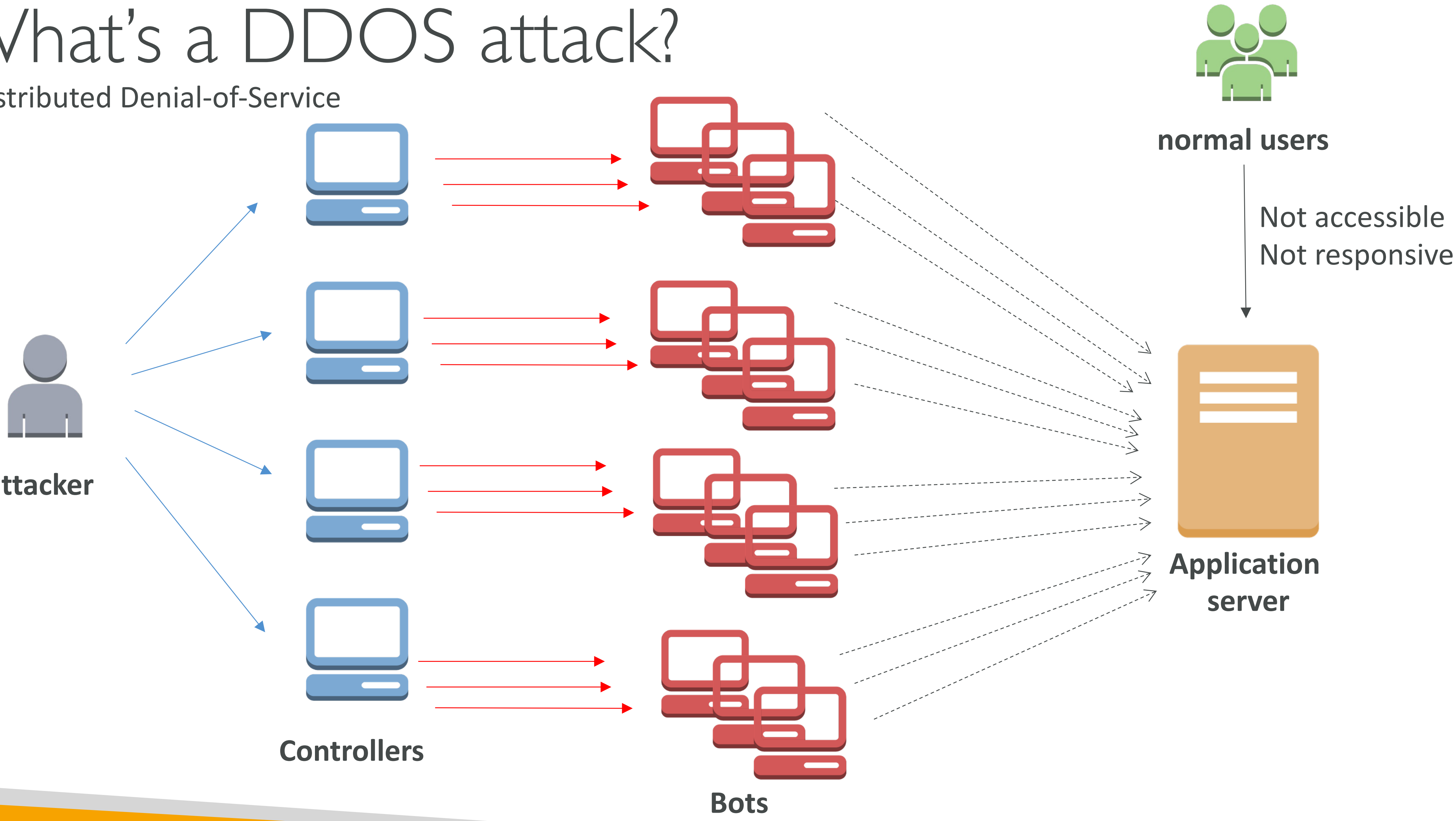
   http://x.x.x.x/<script>alert('Hacked')</script>

6. You should get 403 Forbidden error. Also check the WAF console, it should show the matched rule for XSS.

AWS Shield

What's a DDOS attack?

*Distributed Denial-of-Service



Common DDoS attacks

#	Layer	Unit	Description	Vector examples
7	Application	Data	Network process to application	HTTP floods, DNS query floods
6	Presentation	Data	Data representation and encryption	Transport Layer Security (TLS) abuse
5	Session	Data	Interhost communication	N/A
4	Transport	Segments	End-to-end connections and reliability	Synchronize (SYN) floods
3	Network	Packets	Path determination and logical addressing	User Datagram Protocol (UDP) reflection attacks
2	Data Link	Frames	Physical addressing	N/A
1	Physical	Bits	Media, signal, and binary transmission	N/A

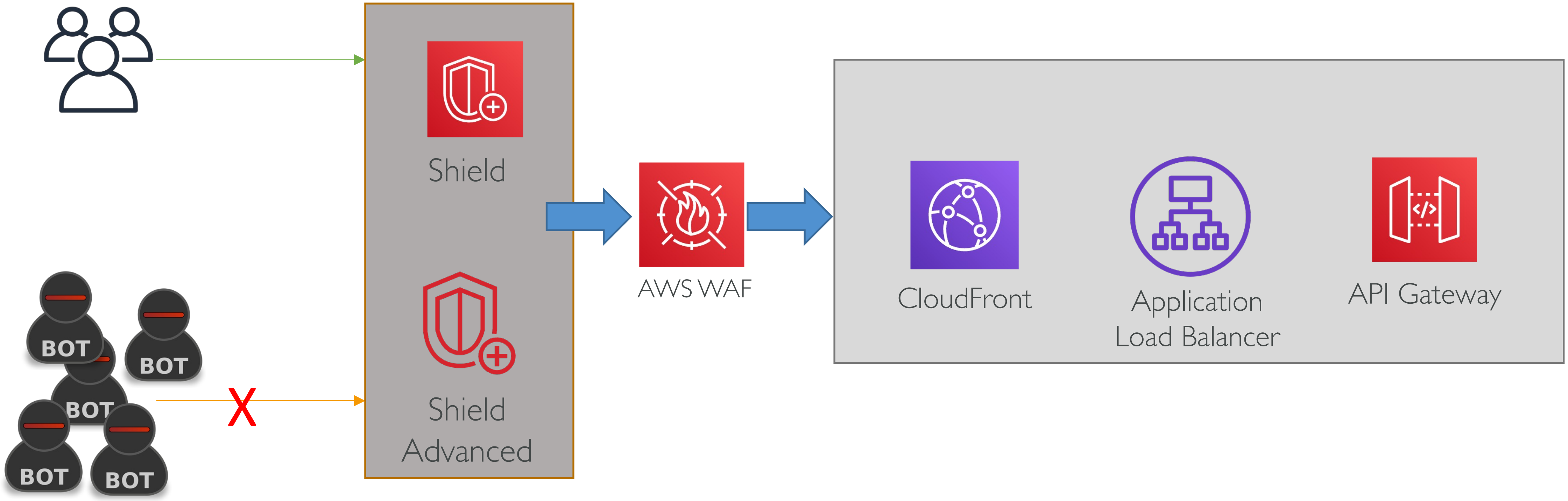
Application Layer attacks

Infrastructure Layer attacks

Common DDoS attacks

- SYN Flood attack: Too many half open TCP connections
- UDP Flood attack: Too many UDP requests
- UDP Reflection attack: Spoof the victim server IP as a source for UDP packet. Victim server receives the unexpected responses.
- DNS Flood attack: Overwhelm the DNS so legitimate users can't find the site
- Slow Loris attack (Layer7): A lot of HTTP connections are opened and maintained

AWS Shield & AWS Shield Advanced



AWS Shield & AWS Shield Advanced

- AWS Shield Standard (Free service)
  - 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
  - Enabled automatically for ELB, CloudFront and Route53
- AWS Shield Advanced (Paid service)
  - 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, and Route 53
  - 24/7 access to AWS Shield Response Team (SRT). The SRT will help triage the incidents, identify root causes, and apply mitigations on your behalf.
  - Protection against higher Service usage fees during usage spikes due to DDoS.

AWS Shield Advanced

- Provides protection against large and more sophisticated DDoS attacks
- Supports AWS resources AWS Route53, CloudFront, ELB, Global Accelerator and resources attached to Elastic IPs like EC2, NAT
- Customers subscribed to Business or Enterprise support plan can engage 24/7 with Shield Response Team (SRT)
- SRT team also helps to identify layer 7 attacks/patterns and deploys Web ACL rules on WAF (you must grant IAM role to SRT team)
- Customer receives attack forensic report from SRT
- Get AWS credits* against Route53, CloudFront, ELB and EC2 in case of billing spike due to DDoS

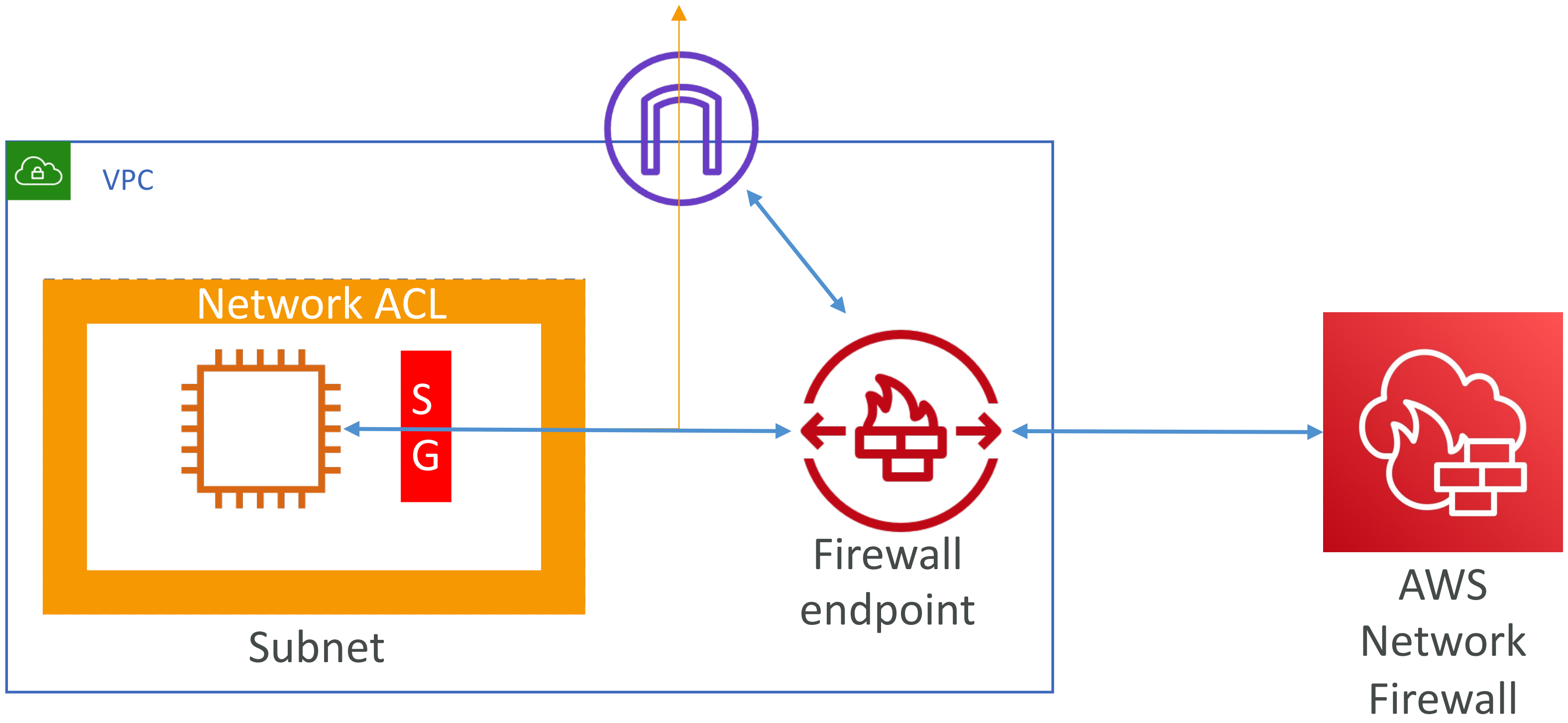
Best practices for DDoS protection

- Read the whitepaper: https://docs.aws.amazon.com/whitepapers/latest/aws-best-practices-ddos-resiliency/best-practices-for-ddos-mitigation.html

AWS Network Firewall

What is AWS Network Firewall?

A stateful network firewall and intrusion detection and prevention service for VPC



SG, NACL, WAF … so why this new service?

	Security Group	Network ACL	WAF	AWS Network Firewall
Protection at	EC2 instance level	Subnet level	Endpoint level (ALB, CloudFront etc)	VPC level based on routes
Stateful or Stateless	Stateful	Stateless	Stateless	Both
OSI layer	Layer3/4	Layer3/4	Layer7	Layer3-7
Features	IP, Port, Protocol filtering	IP, Port, Protocol filtering	Application layer filtering	Stateless/ACL L3 rules, stateful/L4 rules, IPS-IDS/L7 rules, FQDN filtering, Protocol detection, Large IP block/allow lists
Flows	All ingress/egress flows at instance level	All ingress/egress flows at subnet level	Ingress only from internet to API Gateway, ALB, CloudFront	All ingress/egress flows at perimeter of VPC (e.g. IGW, VGW, DX, VPN, VPC-VPC)

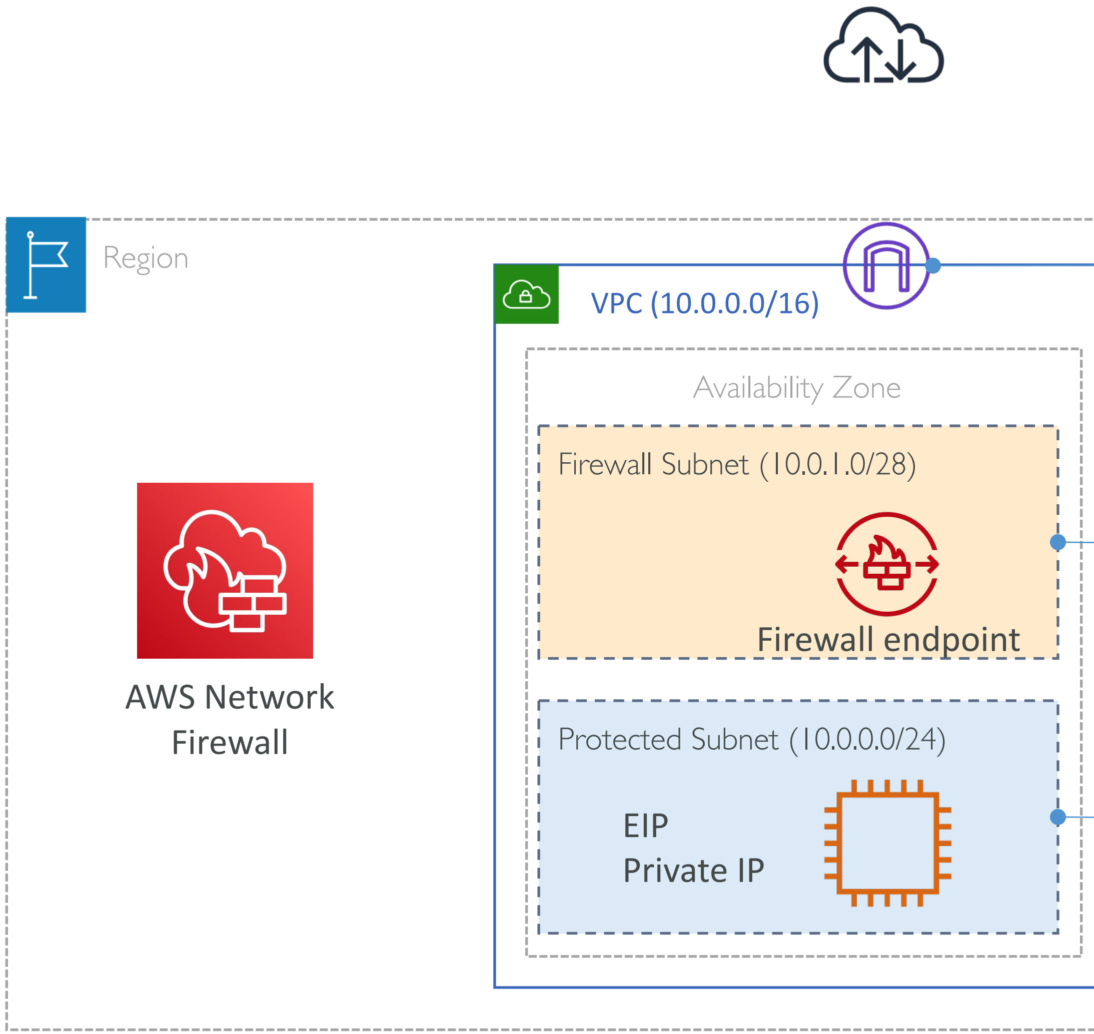
Stateful vs Stateless firewalls

- Stateful Firewalls
  - Filters traffic based on network packet context and connection state
  - Context involves metadata of the packet including IP addresses, ports, packet length, information about reassembly and defragmentation, flags, TCP sequence number etc
  - State refers to the state of the connection e.g for TCP connection the state of connection is SYN, ACK, FIN and RST
- Stateless Firewalls
  - Inspects each packet in isolation
  - Performs well in case of heavy traffic

AWS Network Firewall

- Filters traffic at the perimeter of the VPC such as traffic going to or coming from internet gateway, NAT gateway, over VPN or Direct connect
- Uses the Suricata for stateful inspection
- Suricata is an open source-based intrusion detection system and intrusion prevention system developed by the Open Information Security Foundation
- Allows domain name filtering e.g only AWS service endpoints
- Block access to bad domains and limit the types of domain names
- Deep packet inspection on traffic entering or leaving your VPC
- Stateful protocol detection to filter protocols like HTTPS (independent of the port used)

Network firewall traffic flow - Inbound



IGW ingress Route Table

10.0.0.0/16	local
10.0.0.0/24	vpce-xxxxx

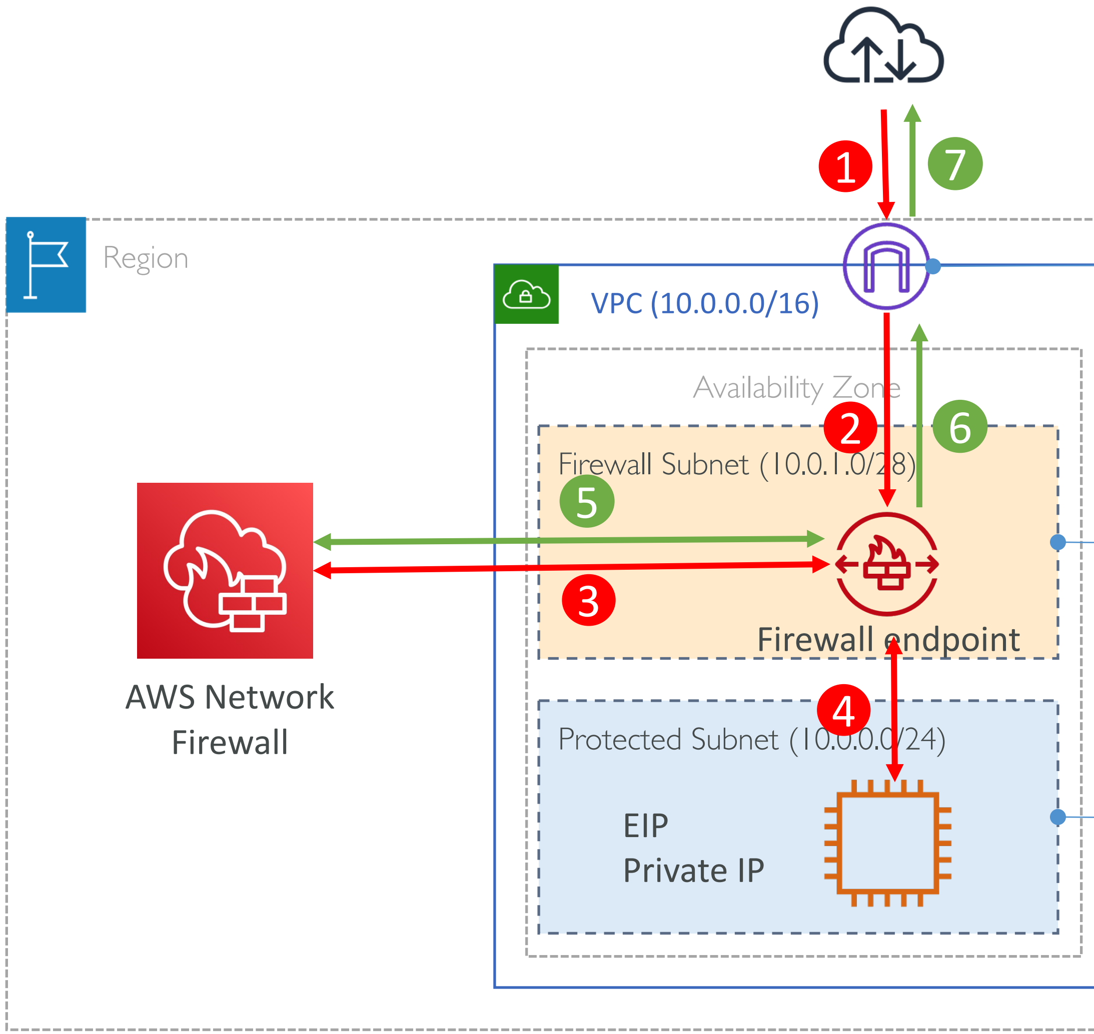
Firewall Subnet Route Table

10.0.0.0/16	local
0.0.0.0/0	igw-xxxxx

Protected Subnet Route Table

10.0.0.0/16	local
0.0.0.0/0	vpce-xxxxx

Network firewall traffic flow - Inbound

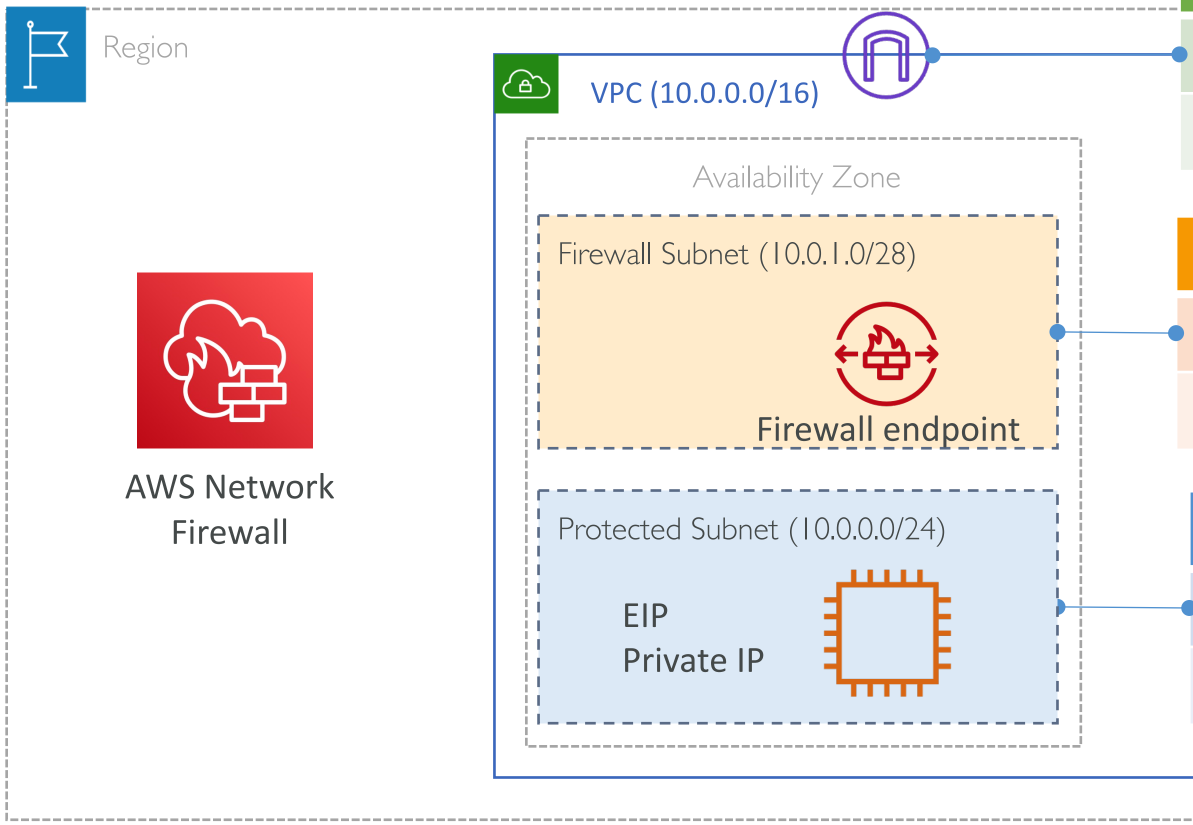


IGW ingress Route Table	
10.0.0.0/16	local
10.0.0.0/24	vpce-xxxxx

Firewall Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	igw-xxxxx

Protected Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	vpce-xxxxx

Network firewall traffic flow - Outbound



IGW ingress Route Table	
10.0.0.0/16	local
10.0.0.0/24	vpce-xxxxx

Firewall Subnet Route Table	
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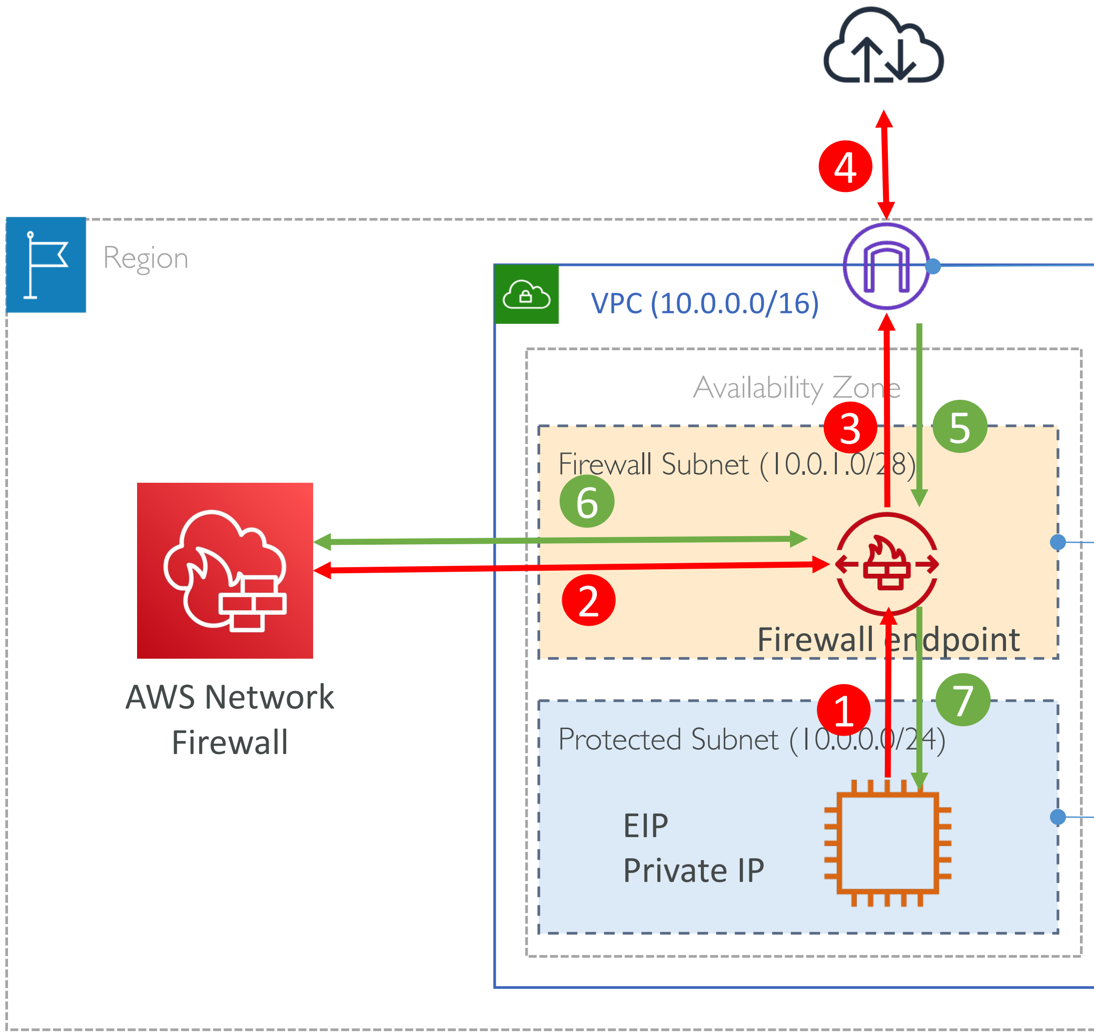
0.0.0.0/0	igw-xxxxx

Protected Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	vpce-xxxxx

Network firewall traffic flow - Outbound



IGW ingress Route Table	
10.0.0.0/16	local
10.0.0.0/24	vpce-xxxxx

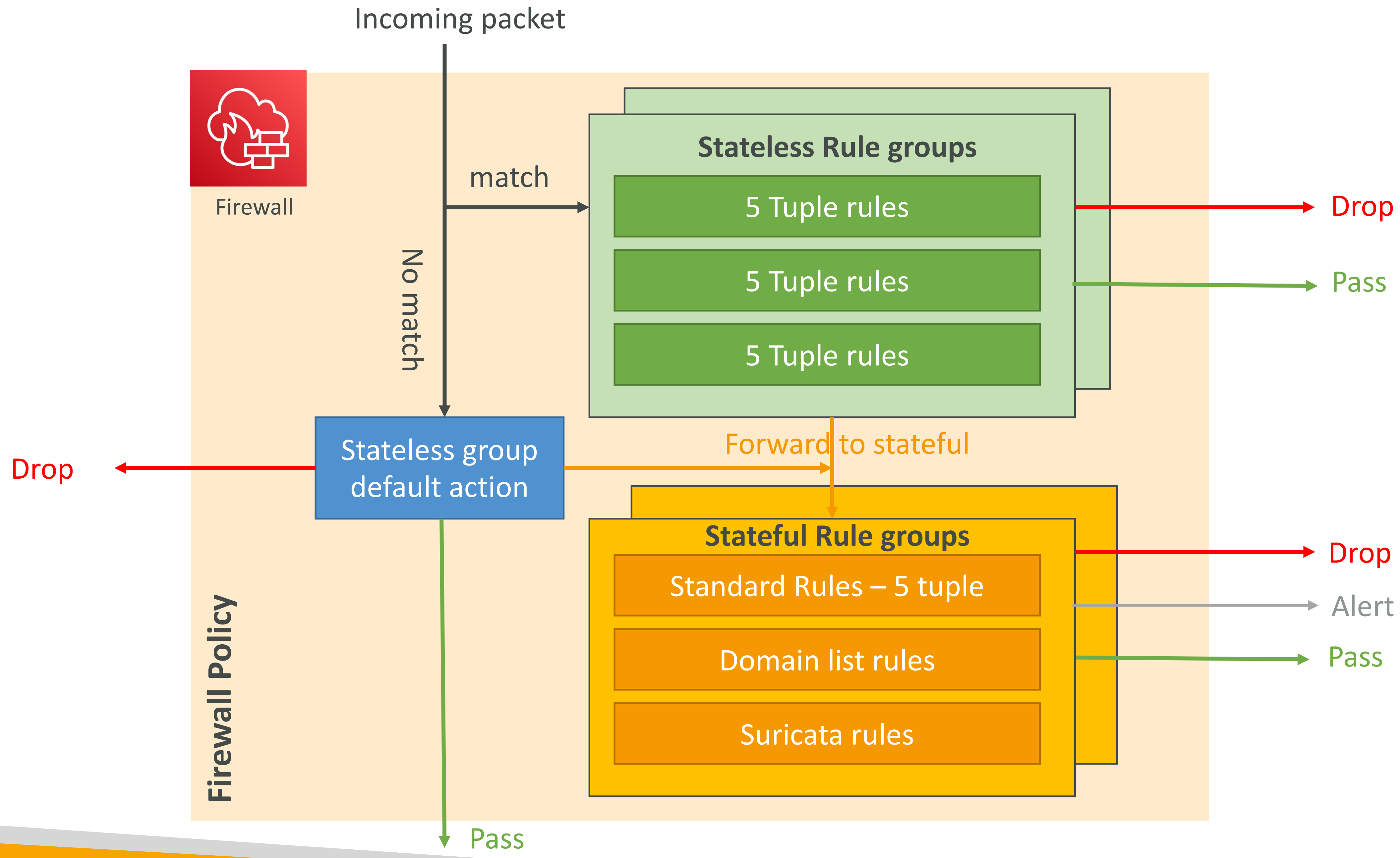
Firewall Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	igw-xxxxx

Protected Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	vpce-xxxxx

Network Firewall components – Firewall policy and Rule groups

AWS Network Firewall components

- Firewall
  - A firewall connects the VPC that you want to protect to the protection behavior that's defined in a firewall policy.
- Firewall policy
  - Defines the behavior of the firewall in a collection of stateless and stateful rule groups and other settings.
  - You can associate each firewall with only one firewall policy, but you can use a firewall policy for more than one firewall.
- Rule group
  - A rule group is a collection of **stateless** or **stateful** rules that define how to inspect and handle network traffic.


Incoming packet
Firewall
match
No match
Stateless Rule groups
5 Tuple rules
5 Tuple rules
5 Tuple rules
Drop
Pass
Stateless group default action
Drop
Forward to stateful
Stateful Rule groups
Standard Rules – 5 tuple
Domain list rules
Suricata rules
Drop
Alert
Pass
Firewall Policy
Pass

Stateless Rule groups

- Inspects each packet in isolation
- Does not take into consideration factors such as the direction of traffic, or whether the packet is part of an existing, approved connection
- Standard 5-tuple connection criteria – Protocol, Source IP range, Source port range, destination IP range, destination port range
- Process rules in the order that you prioritize them and stops processing when it finds a match
- Actions: pass, drop, and forward to stateless (or allows custom action)
- Similar in behavior and use to Amazon VPC network access control lists (ACLs)

Stateless Rules – 5-Tuple

- Priority – Lower the number higher the priority
- Action – Pass, Drop and Forward to stateful
- Rule match settings
    - Protocol – ALL or TCP, UDP and other protocols.
    - Source – List of IP address CIDRs
    - Source Port range – Port and port ranges
    - Destination – List of IP address CIDRs
    - Destination Port range – Port and port ranges
    - (Optional) TCP Flags

Stateful Rule groups

- Inspect packets in the context of their traffic flow and direction of the traffic
- Support rules compatible with Suricata (an open source IPS)
- Supports Standard rule, Suricata compatible rules and Domain list rule
- Processes rules in the order of their action setting, with pass rules processed first, then drop, then alert and then stops processing when it finds a match
- Similar in behavior and use to Security Groups
- By default, the stateful rules engine allows traffic to pass, while the security groups default is to deny traffic.

Stateful rule – Domain list rule

- Supports Allow list and Deny list for domain names
- Action
  - Allow – If doesn't match the domain specifications then traffic is denied
  - Deny
- Match settings
  - Domain list (e.g example.com or a wildcard like .example.com)
  - Protocols – HTTP and HTTPS
- For HTTPS traffic, Network Firewall uses the Server Name Indication (SNI) extension in the TLS handshake to determine the hostname, or domain name.
- For HTTP traffic, Network Firewall uses the HTTP host header to get the name.

Stateful rule - Suricata rule/signature

- The signature of the rule consists of
  - Action – defines what happens when the signature matches
  - Header – defines the protocol, IP addresses, ports and direction of traffic
  - Options – defines specifics of the rule

Action

Header

Options

```
drop tcp $HOME_NET any -> $EXTERNAL_NET any (msg:"ET TROJAN Likely Bot Nick in IRC (USA +..)";
flow:established,to_server; flowbits:isset,is_proto_irc; content:"NICK "; pcre:"/NICK .*USA.*[0-9]{3,}/i";
reference:url,doc.emergingthreats.net/2008124; classtype:trojan-activity; sid:2008124; rev:2;)
```

protocol

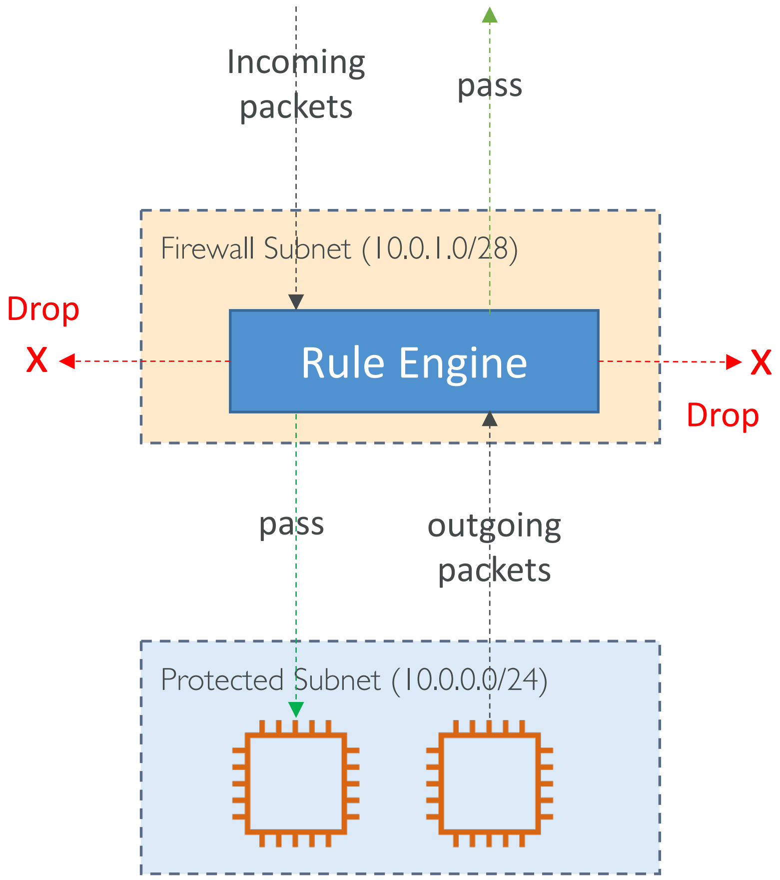
variables

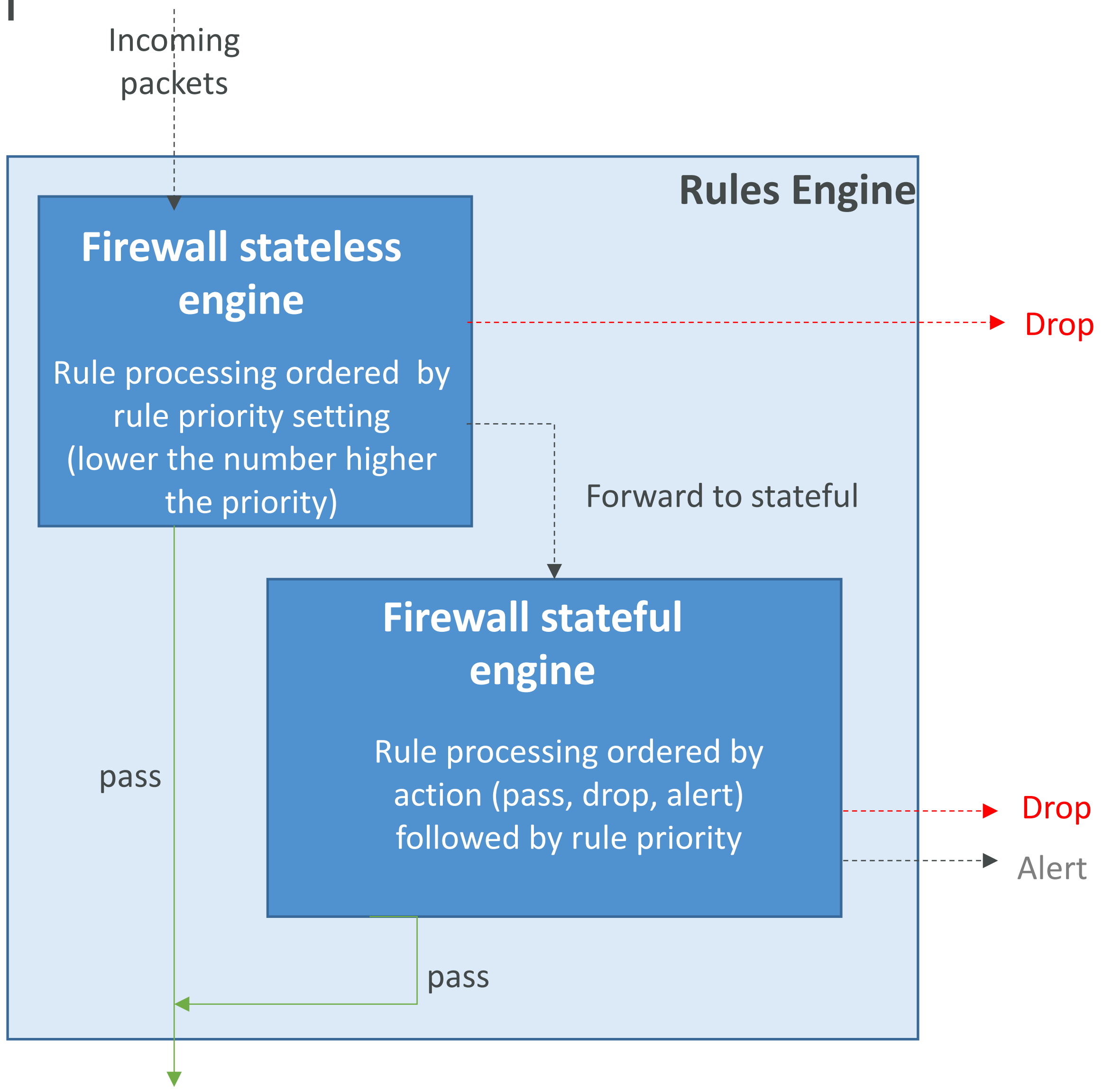
ports

Direction
-> or <>

https://suricata.readthedocs.io/en/suricata-5.0.0/rules/intro.html

Rules evaluation order





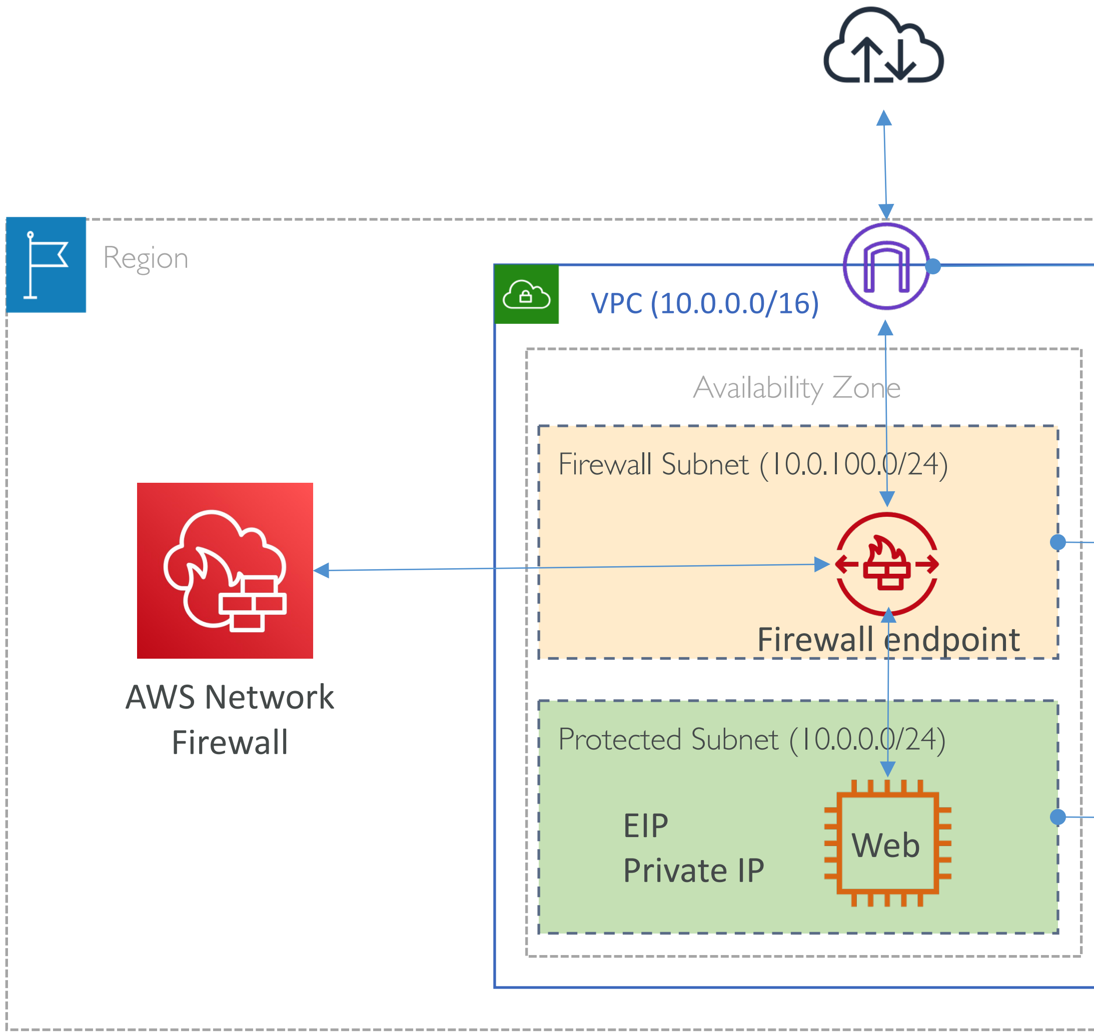
Lab: AWS Network Firewall

Lab: AWS Network Firewall

- What do we want to achieve?
  - Launch the simple webserver running on EC2 instance
  - Stateless rule to block the inbound ICPM (ping request) traffic to the web server
  - Stateful rule to allow outbound traffic from the webserver to a particular domain name e.g aws.amazon.com over TLS and block all other outgoing traffic

https://aws.amazon.com/blogs/security/hands-on-walkthrough-of-the-aws-network-firewall-flexible-rules-engine/

Lab: Architecture



IGW ingress Route Table	
10.0.0.0/16	local
10.0.0.0/24	vpce-xxxxx

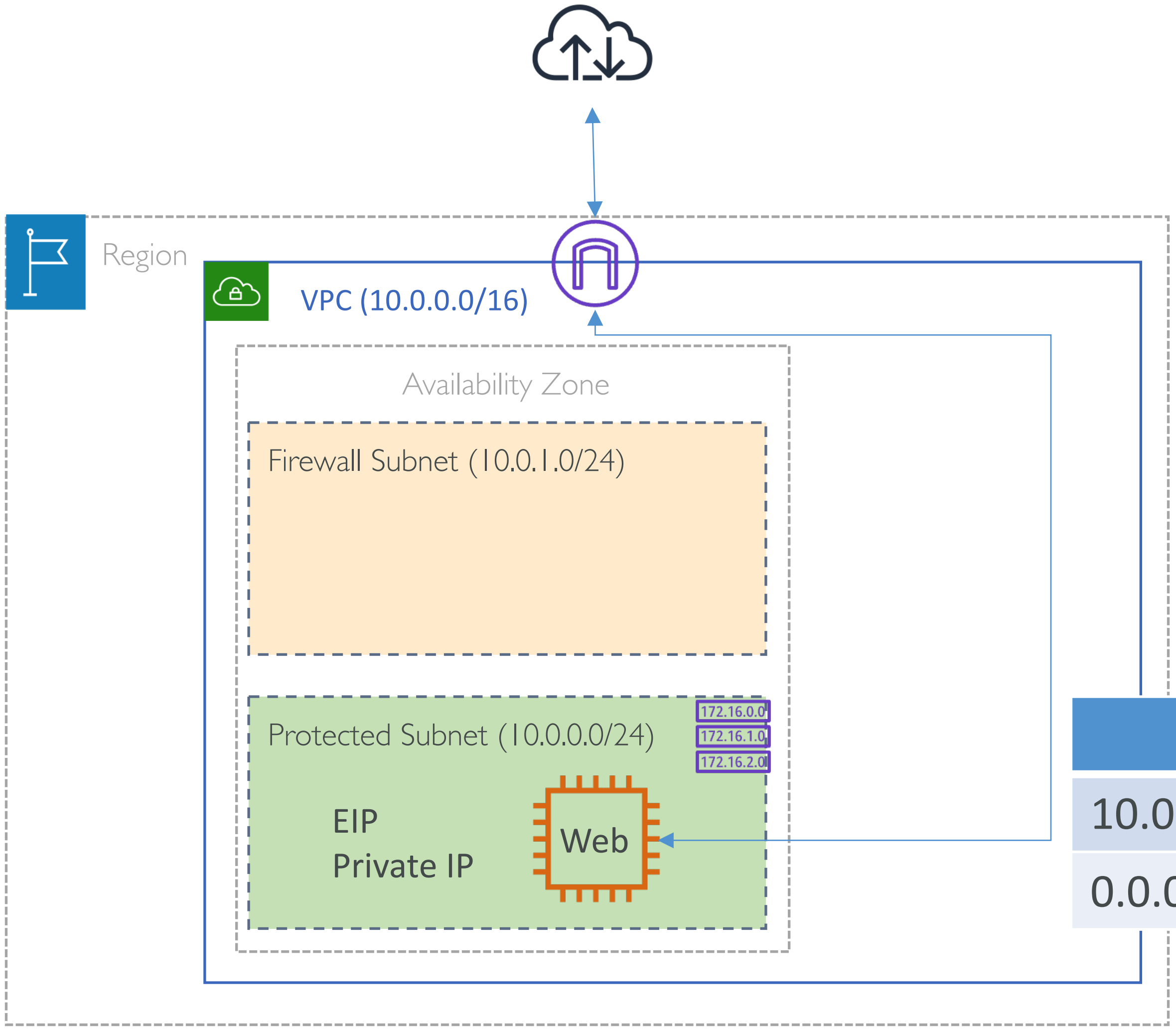
Firewall Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	igw-xxxxx

Protected Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	vpce-xxxxx

Lab: Firewall rules

- Stateless Rules
  1. Drop all ICMP traffic from 0.0.0.0/0 to 0.0.0.0/0 (priority 10)
  2. Forward all other traffic to Stateful rule group (priority 20)
- Stateful Rules
  1. pass tcp any any -> any 22 (msg:"Allow TCP 22"; sid:1000001; rev:1;)
  2. pass http any any -> any any (http.host; dotprefix; content:".amazonaws.com"; endswith; msg:"Permit HTTP access to the web server"; sid:1000002; rev:1;)
  3. pass tls any any -> any any (tls.sni; content:"aws.amazon.com"; startswith; nocase; endswith; msg:"Permit HTTPS access to aws.amazon.com"; sid:1000003; rev:1;)
  4. drop tcp any any -> any any (flow:established,to_server; msg:"Deny all other TCP traffic"; sid: 1000004; rev:1;)

Lab: Initial Architecture to start with



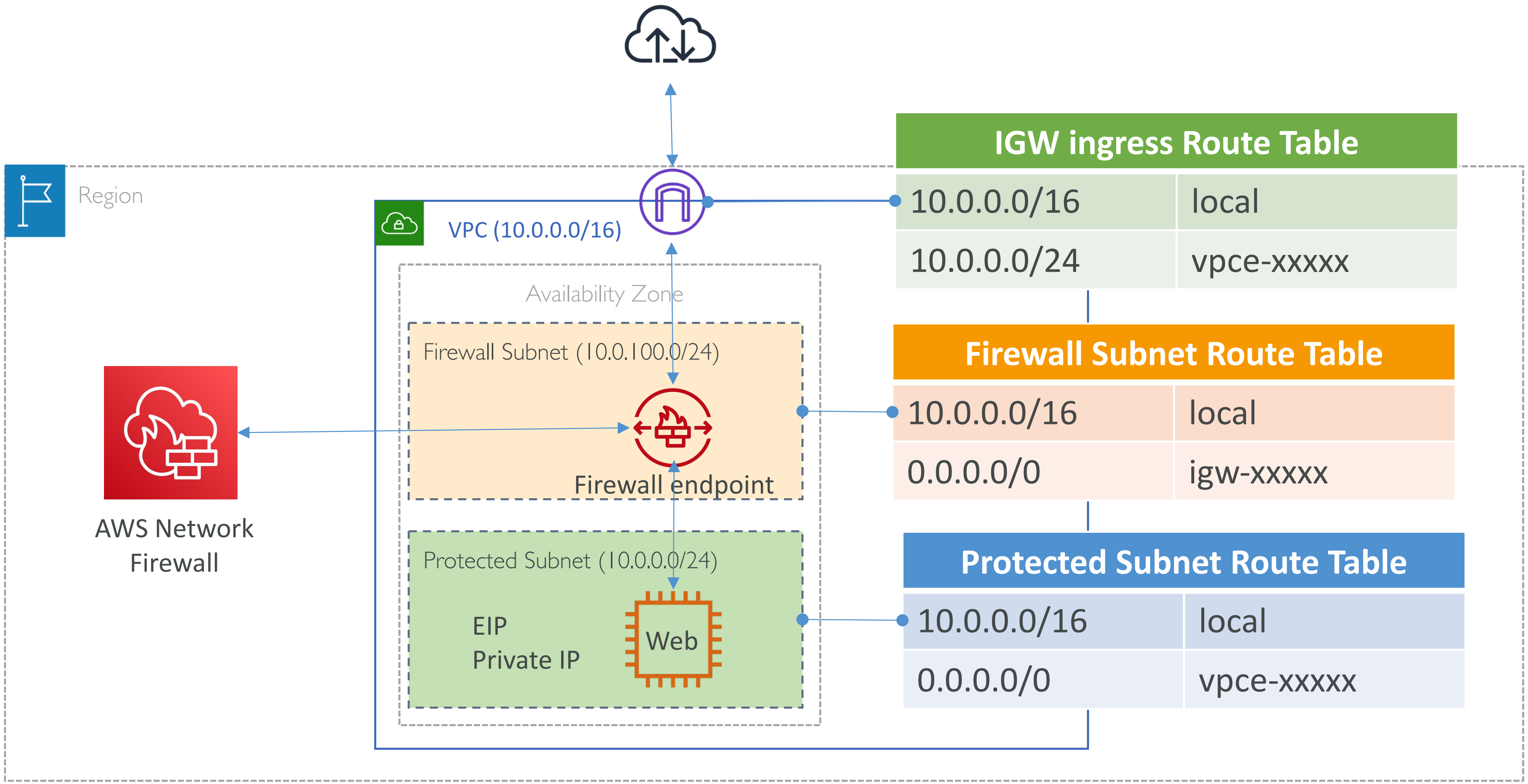
Enable DNS Hostname
Enable DNS Resolution

Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	Igw-xxxxx

Lab: Next steps

- SSH to EC2 instance and install HTTPD web server (In security group allow SSH, HTTP and ICMP traffic from anywhere 0.0.0.0/0)
- Verify that you are able to access the web server over a browser using EC2 instances public IP or public DNS
- Verify that you are able to ping to EC2 instance from your workstation
- Now create AWS Network Firewall in the Firewall subnet and create firewall policy and rules as shown earlier
- Modify route tables for both the subnets and internet gateway
- Test connectivity
  - Ping to webserver should not work
  - SSH to webserver and from webserver you should only be able to download content from https://aws.amazon.com. All other traffic should be blocked.

Lab: Route tables

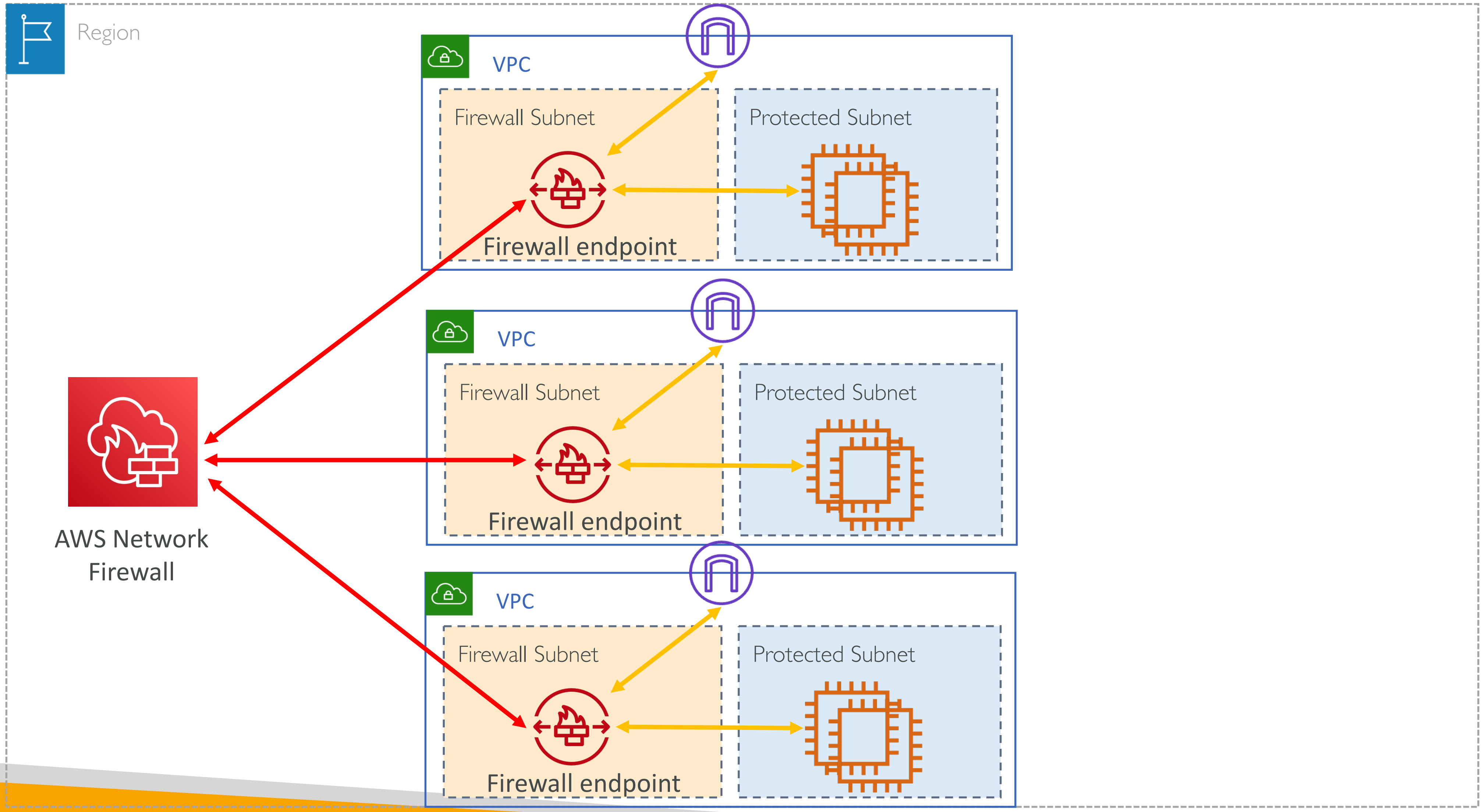


IGW ingress Route Table	
10.0.0.0/16	local
10.0.0.0/24	vpce-xxxxx

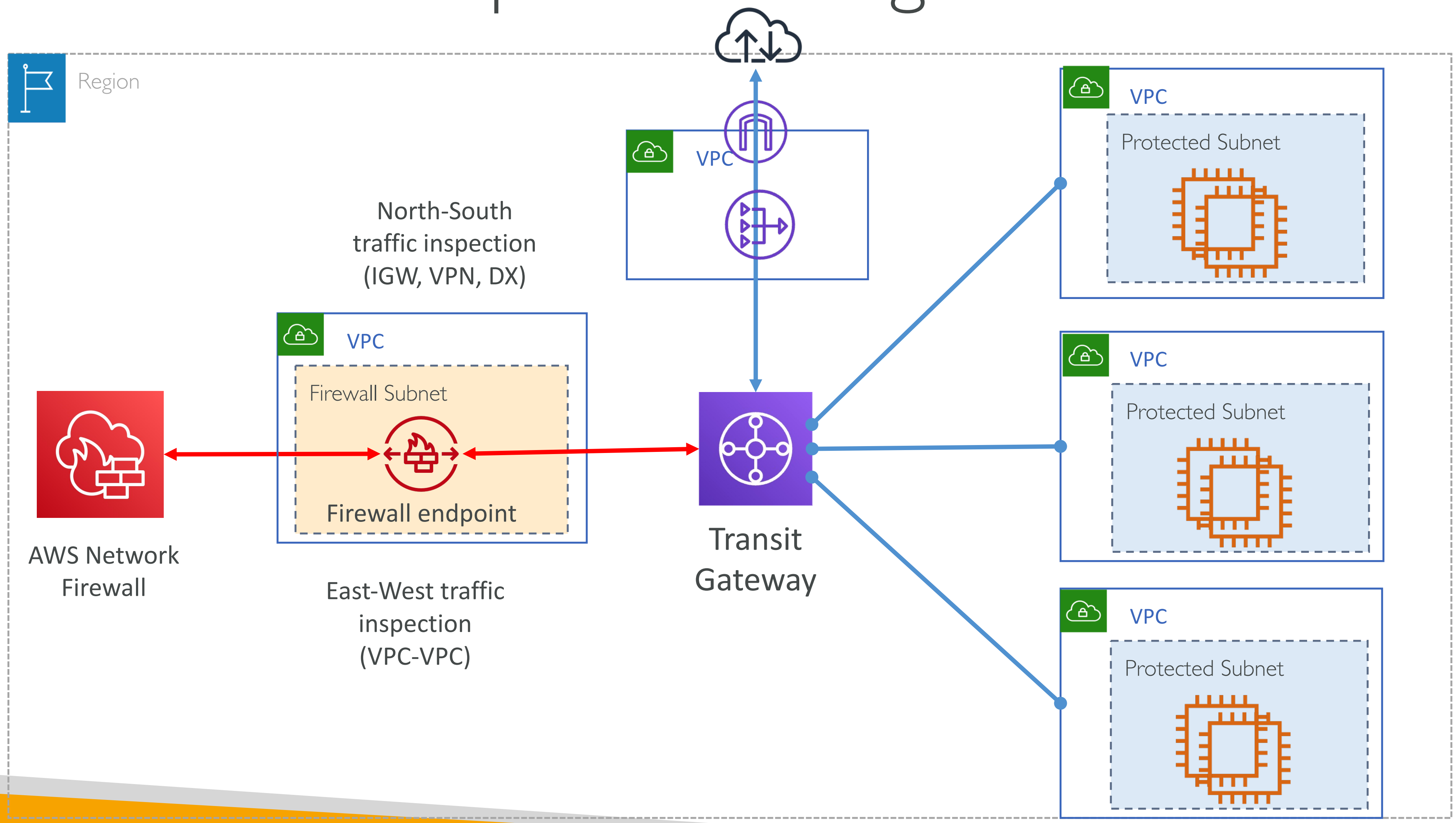
Firewall Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	igw-xxxxx

Protected Subnet Route Table	
10.0.0.0/16	local
0.0.0.0/0	vpce-xxxxx

Distributed Inspection



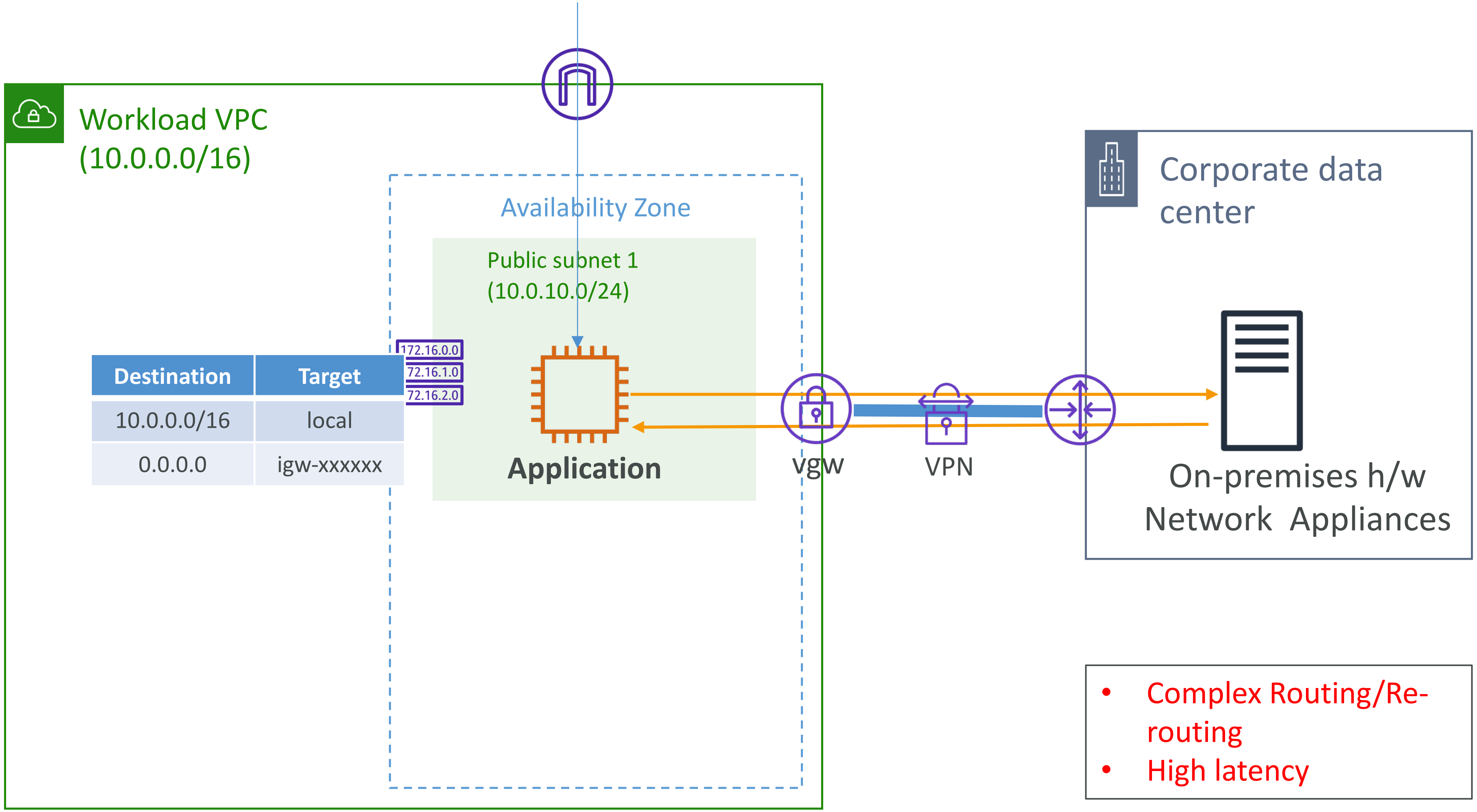
Centralized Inspection using TGW



Gateway Load Balancers

Gateway Load Balancer

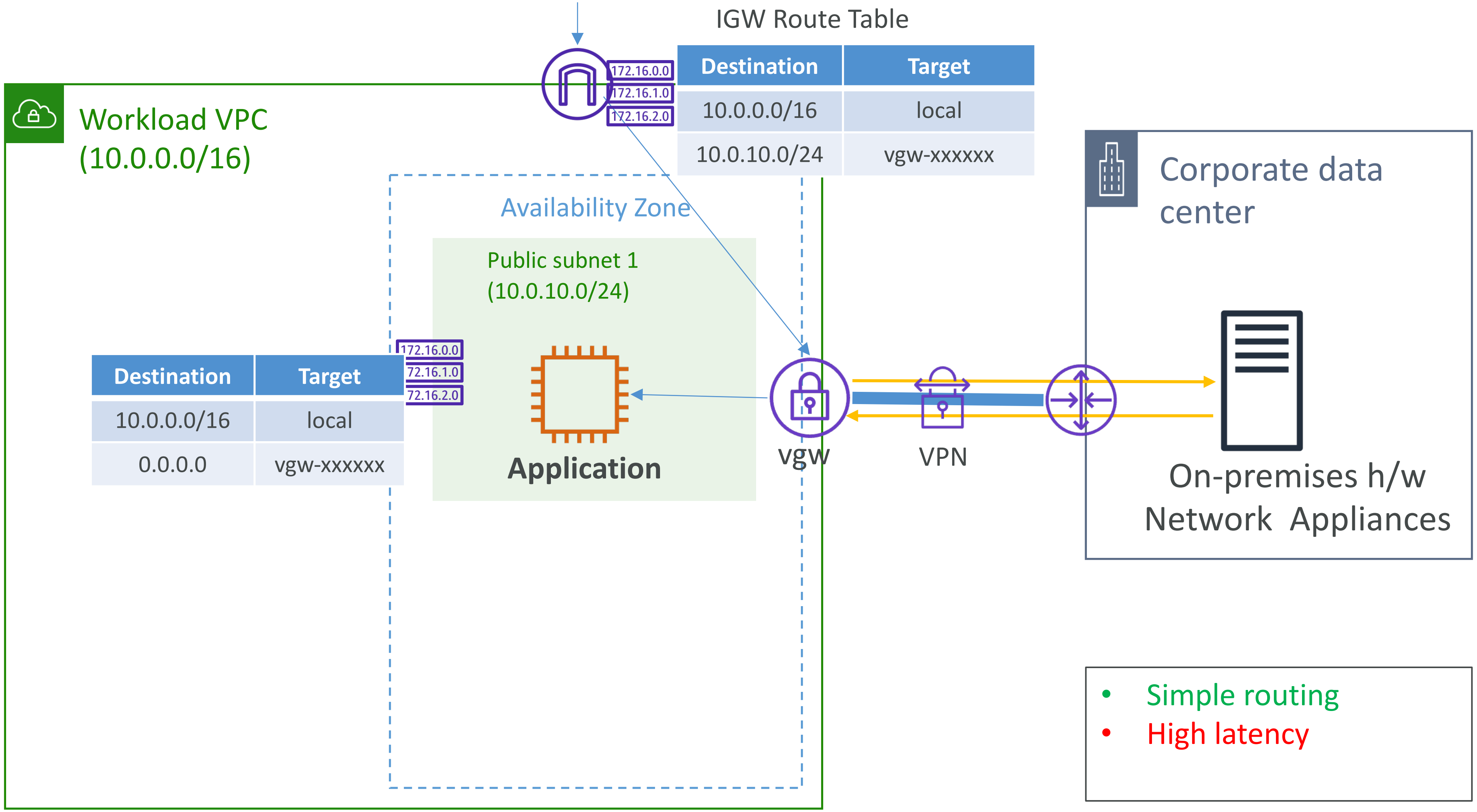
Network appliances – Hardware based



Destination	Target
10.0.0.0/16	local
0.0.0.0	igw-xxxxxx

- Complex Routing/Re-routing
- High latency

Network appliances – VPC ingress routing



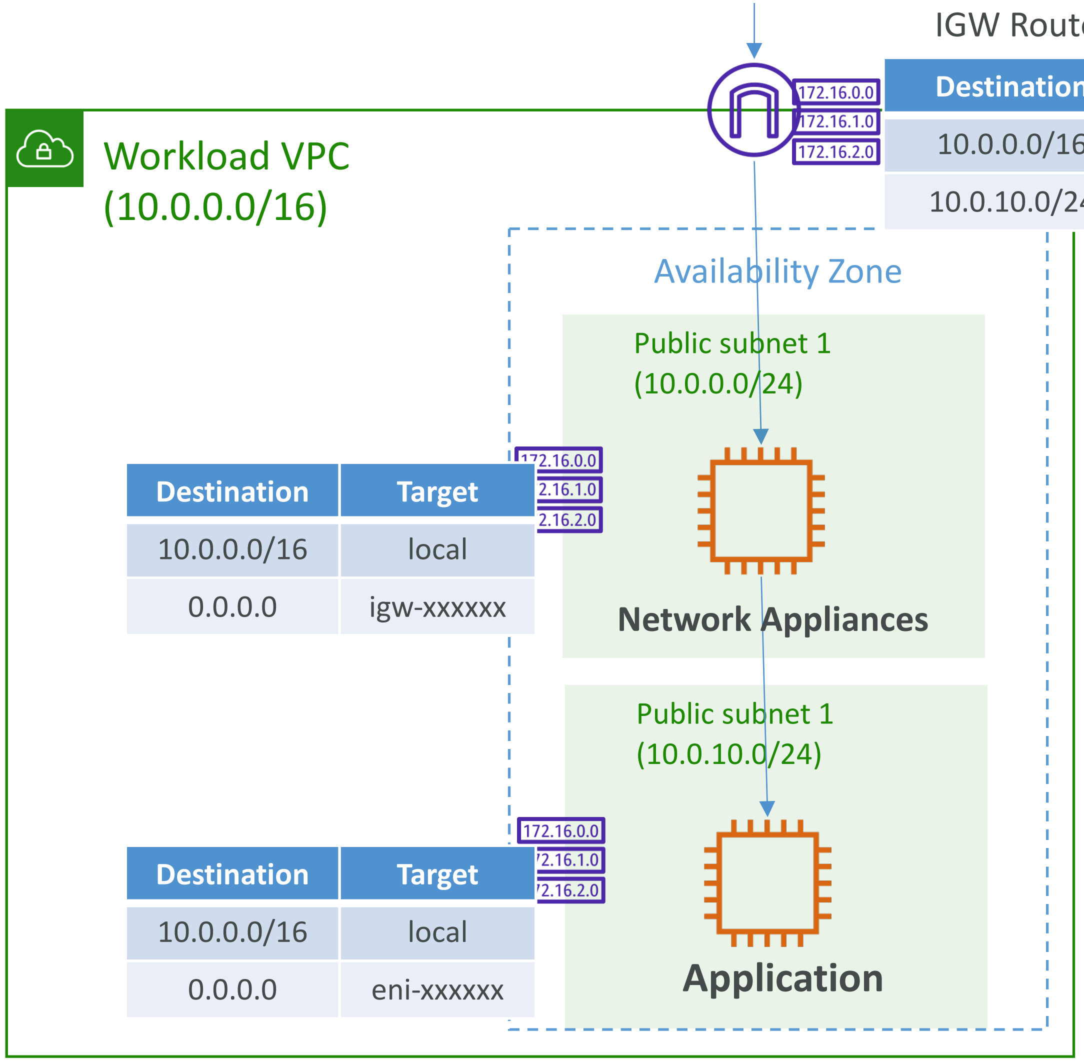
IGW Route Table

Destination	Target
10.0.0.0/16	local
10.0.10.0/24	vgw-xxxxxx

Destination	Target
10.0.0.0/16	local
0.0.0.0	vgw-xxxxxx

- Simple routing
- High latency

Network appliances – Virtual Appliance



IGW Route Table

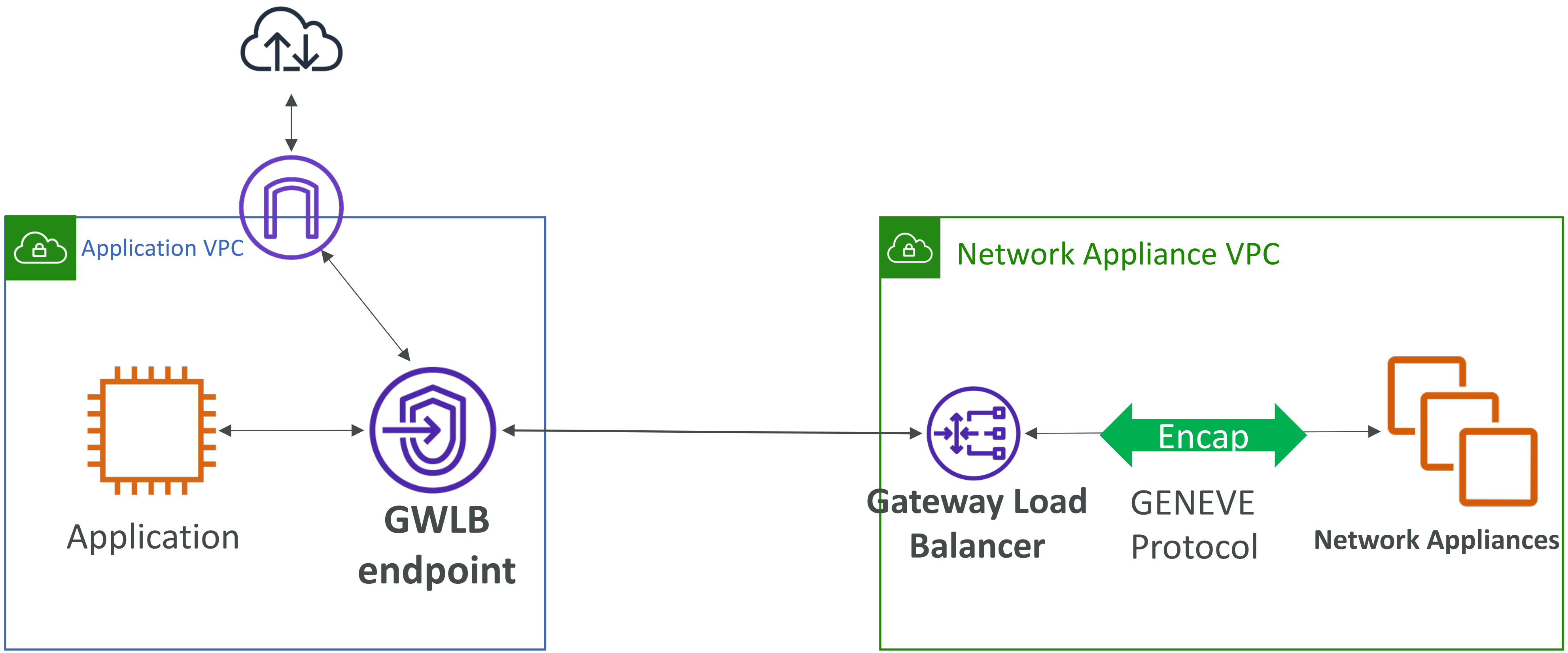
Destination	Target
10.0.0.0/16	local
10.0.10.0/24	eni-xxxxxx

Destination	Target
10.0.0.0/16	local
0.0.0.0	igw-xxxxxx

Destination	Target
10.0.0.0/16	local
0.0.0.0	eni-xxxxxx

- Simple
- Low Latency
- Non-scalable
- Non-HA

Gateway Load Balancer



- Simple
- Low Latency
- Scalable
- HA

Gateway Load Balancer – How It Works

IGW Route Table

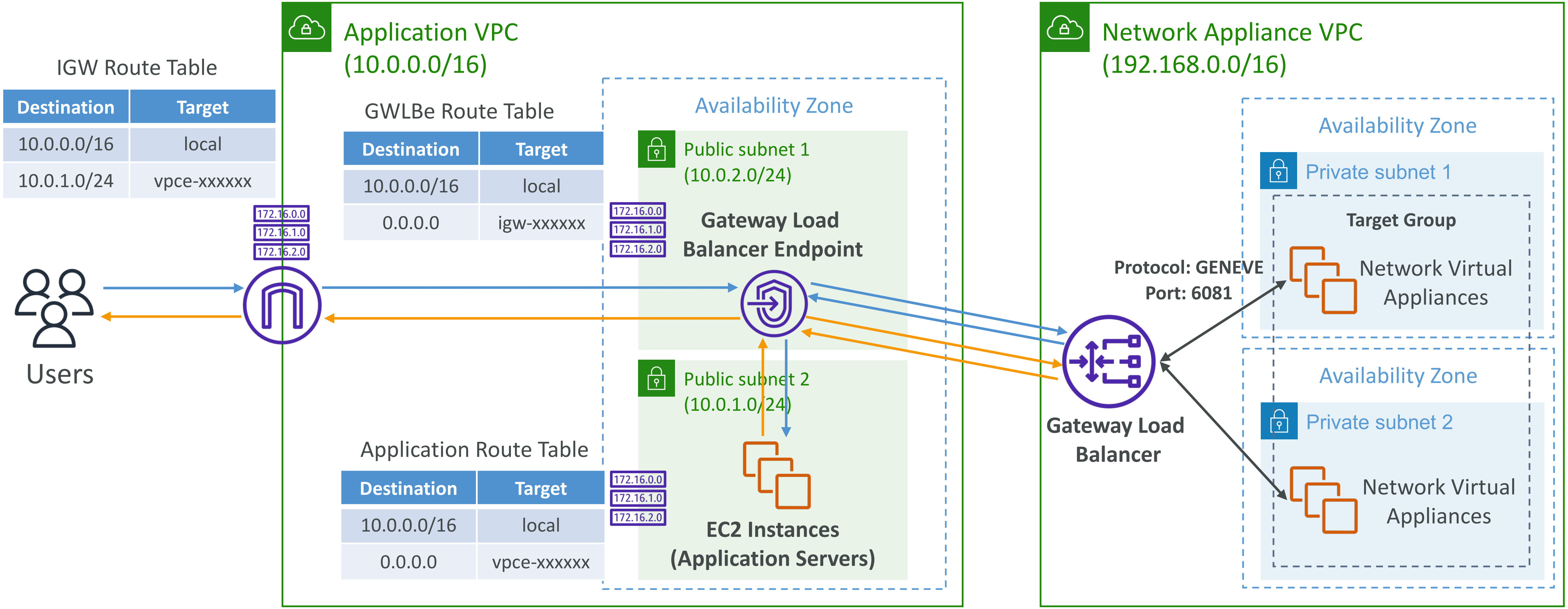
Destination	Target
10.0.0.0/16	local
10.0.1.0/24	vpce-xxxxxx

GWLBe Route Table

Destination	Target
10.0.0.0/16	local
0.0.0.0	igw-xxxxxx

Application Route Table

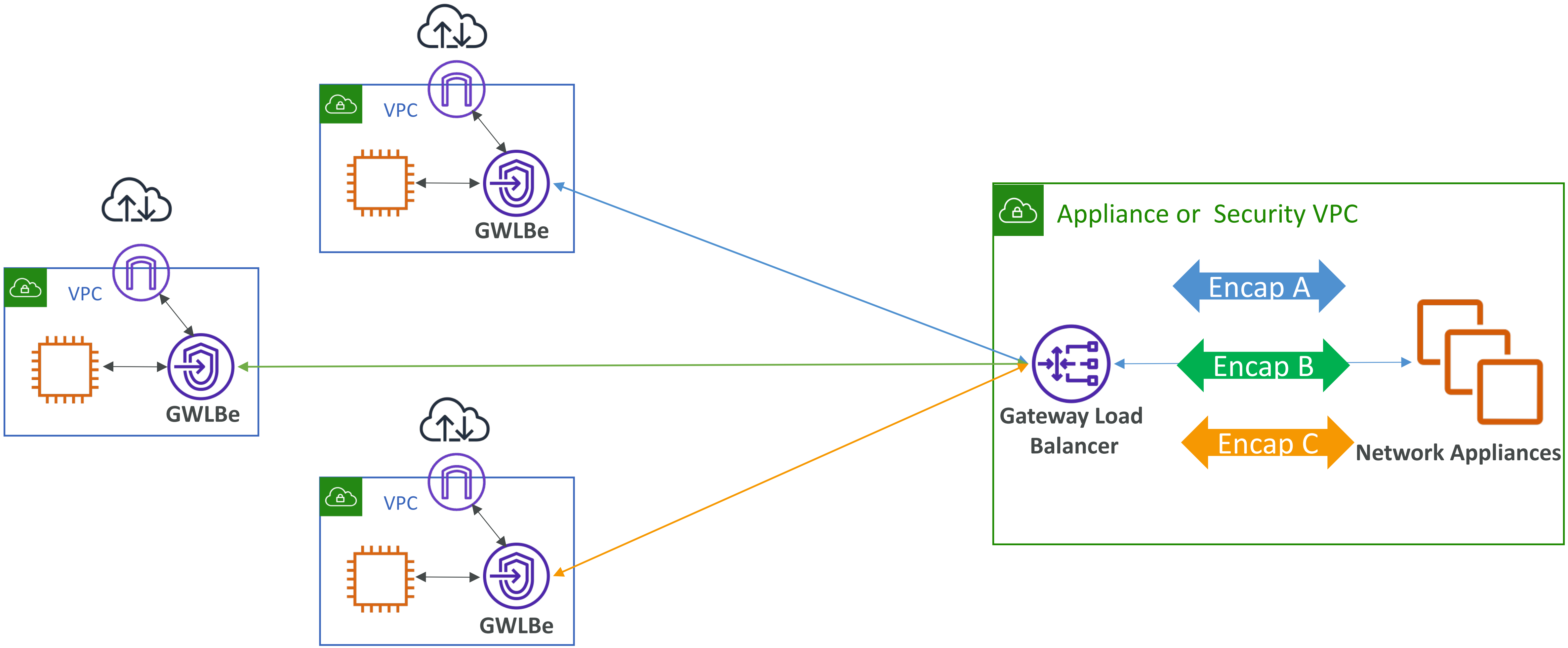
Destination	Target
10.0.0.0/16	local
0.0.0.0	vpce-xxxxxx



NOTE: GWLBE and Application Servers must be in different subnets

Gateway Load Balancer Architectures

Centralized Inspection using GWLB



Summary

- GWLB is used to deploy, scale, and manage a fleet of 3rd party network appliances in AWS.
- Example: Firewalls, Intrusion Detection and Preventions Systems, Deep Packet Inspection Systems, payload manipulation etc.
- GWLB operates at Layer 3 (Network Layer) – As opposed to ALB (Layer7) and NLB (Layer4)
- It's a transparent network gateway which acts as single entry and exit point for all traffic
- Load balances the traffic and scales virtual appliances on demand
- GWLB integrates with industry leading partners Aviatrix, Cisco Systems, Fortinet, Palo Alto Networks, …
  - https://aws.amazon.com/elasticloadbalancing/partners

Exam Essentials

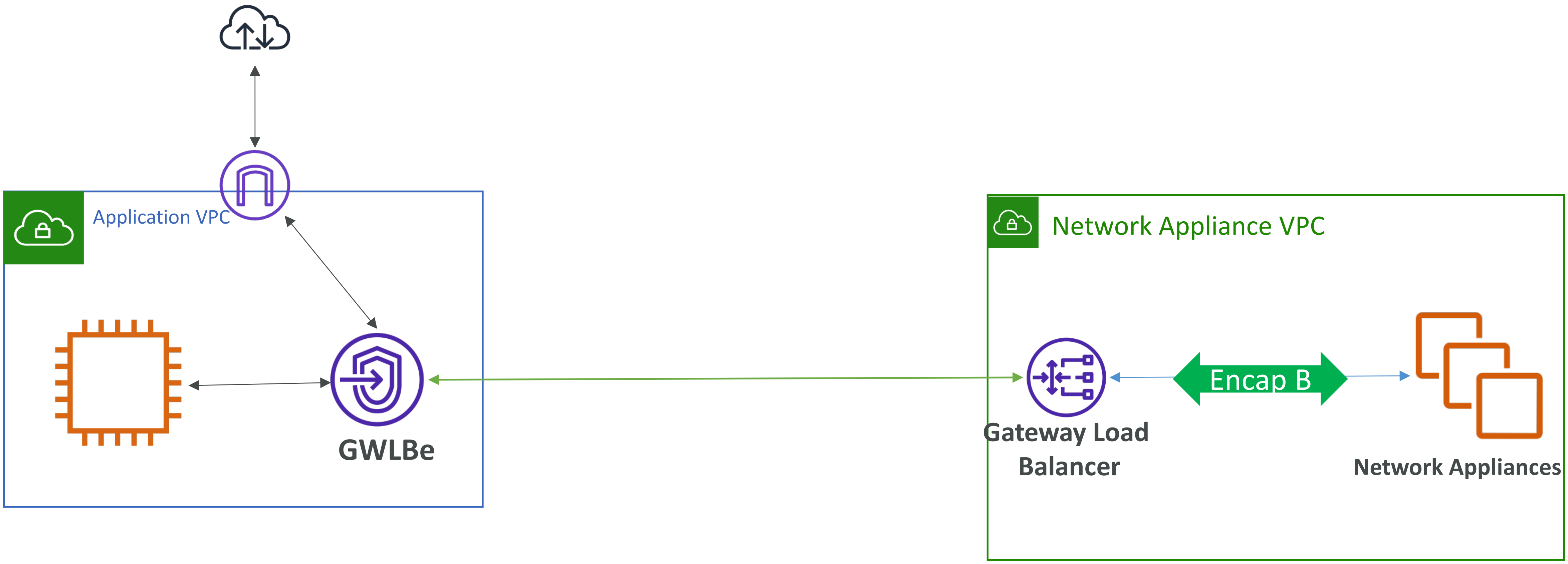
- GWLB Listener
  - Listen for all IP packets across all ports (can't specify a protocol or port)
  - You only specify a rule for routing requests to target groups
  - Can't be deleted
- Target Groups
  - **EC2 Instances** – can be managed by an ASG
  - **IP Addresses** – Private IP only
- Traffic between GWLB and its targets exchanged using the **GENEVE protocol** on UDP **port 6081**
- It maintains stickiness of flows to a specific target appliance using 5-tuple (for TCP/UDP flows) or 3-tuple (for non-TCP/UDP flows)
- Health Checks supported protocols HTTP, HTTPS, and TCP

Exam Essentials

- Doesn't support public GWLB (internal only, no public DNS)
- Doesn't support dual stack mode (IPv4 only)
- You can't associate security groups to GWLBs (SGs associated with targets must use IP addresses to allow traffic from GWLB)
- Supports MTU size of 8500 bytes

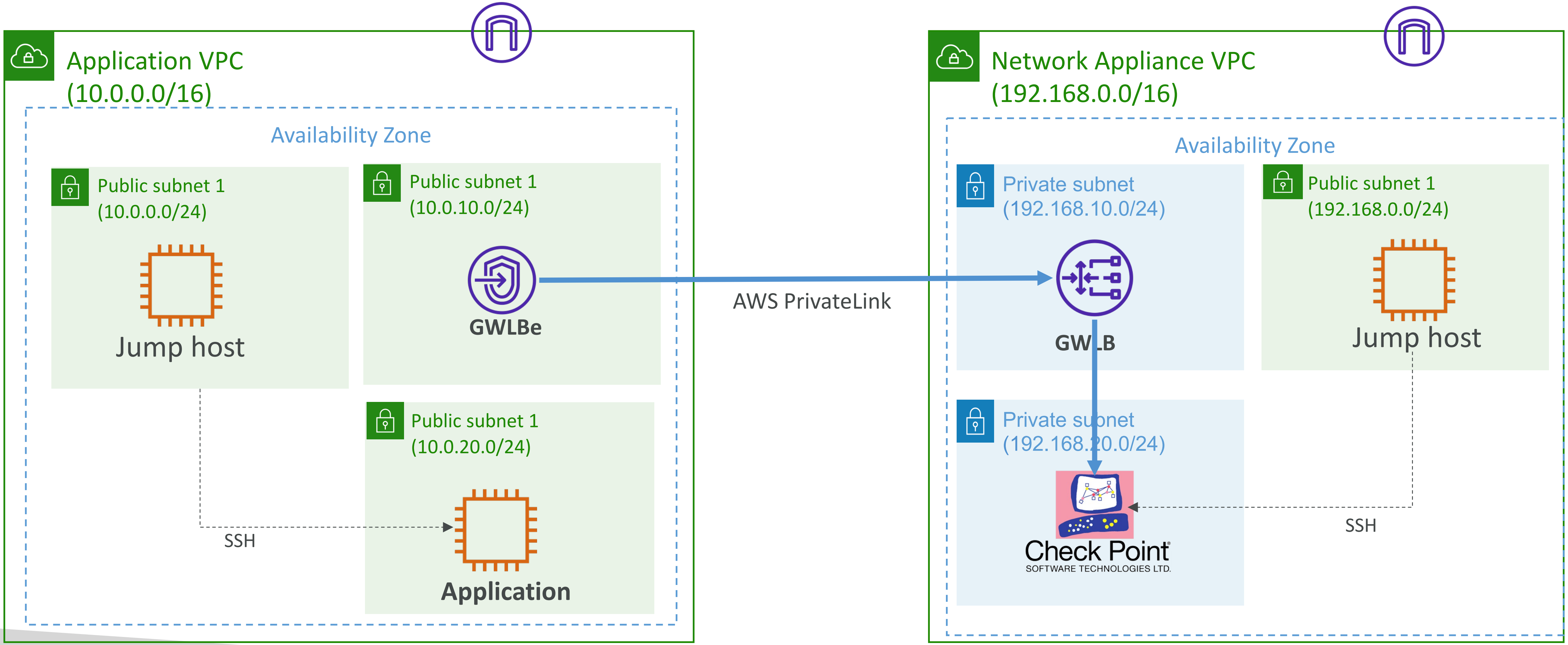
Lab: Gateway Load Balancer

Lab setup

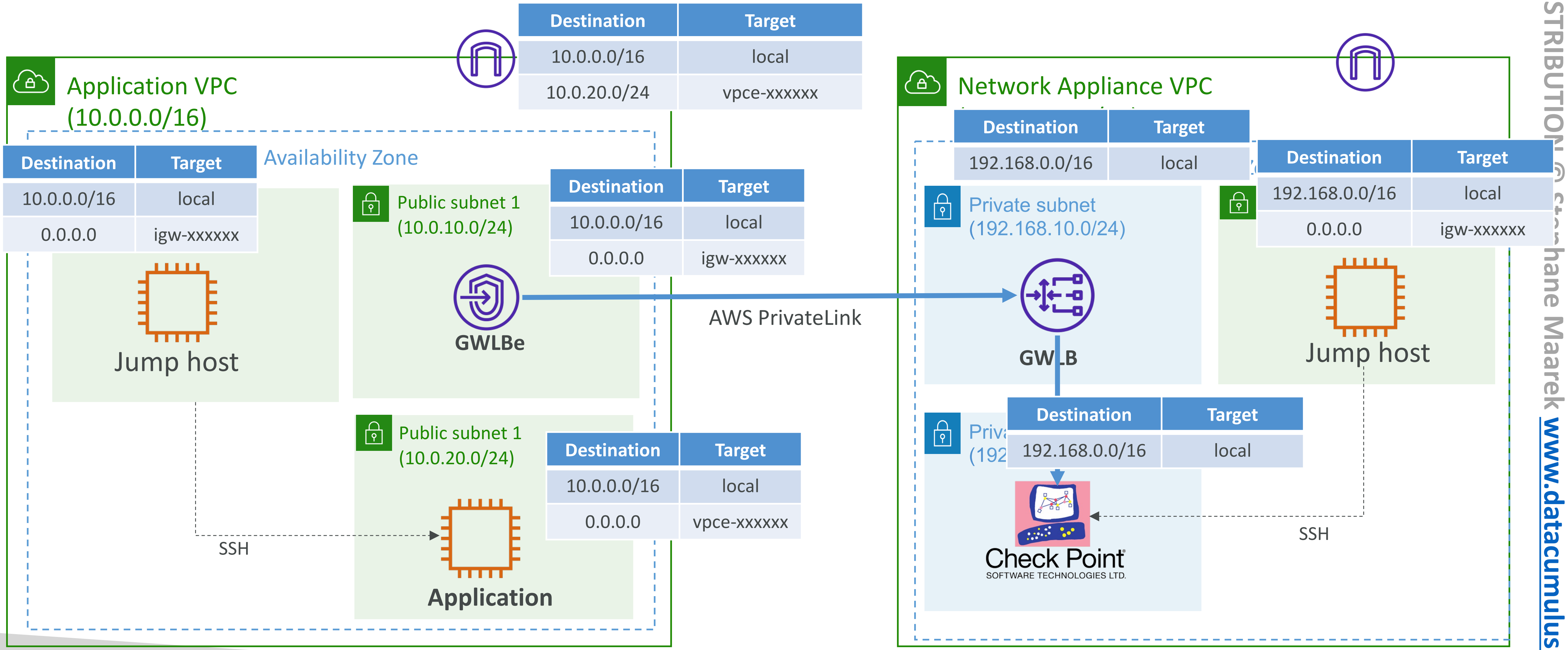


Application VPC
GWLBe
Network Appliance VPC
Encap B
Gateway Load Balancer
Network Appliances

Lab: Network architecture



Lab: Network setup



Steps - I

1. Create 2 VPCs – Application VPC and Network Appliance VPC
2. Create 3 subnets and corresponding 3 route tables in Application VPC
    1. Public subnet for jump host instance
    2. Public subnet for Application instance
    3. Public subnet for Gateway load balancer endpoint
3. Create 3 subnets and corresponding 3 route tables in Network VPC
    1. Public subnet for Jump host instance
    2. Private subnet for Gateway load balancer (ideally we should use multiple AZs)
    3. Private subnet for the Network appliance instance (ideally we should have multiple appliance instances across multiple AZs)

Steps - 2

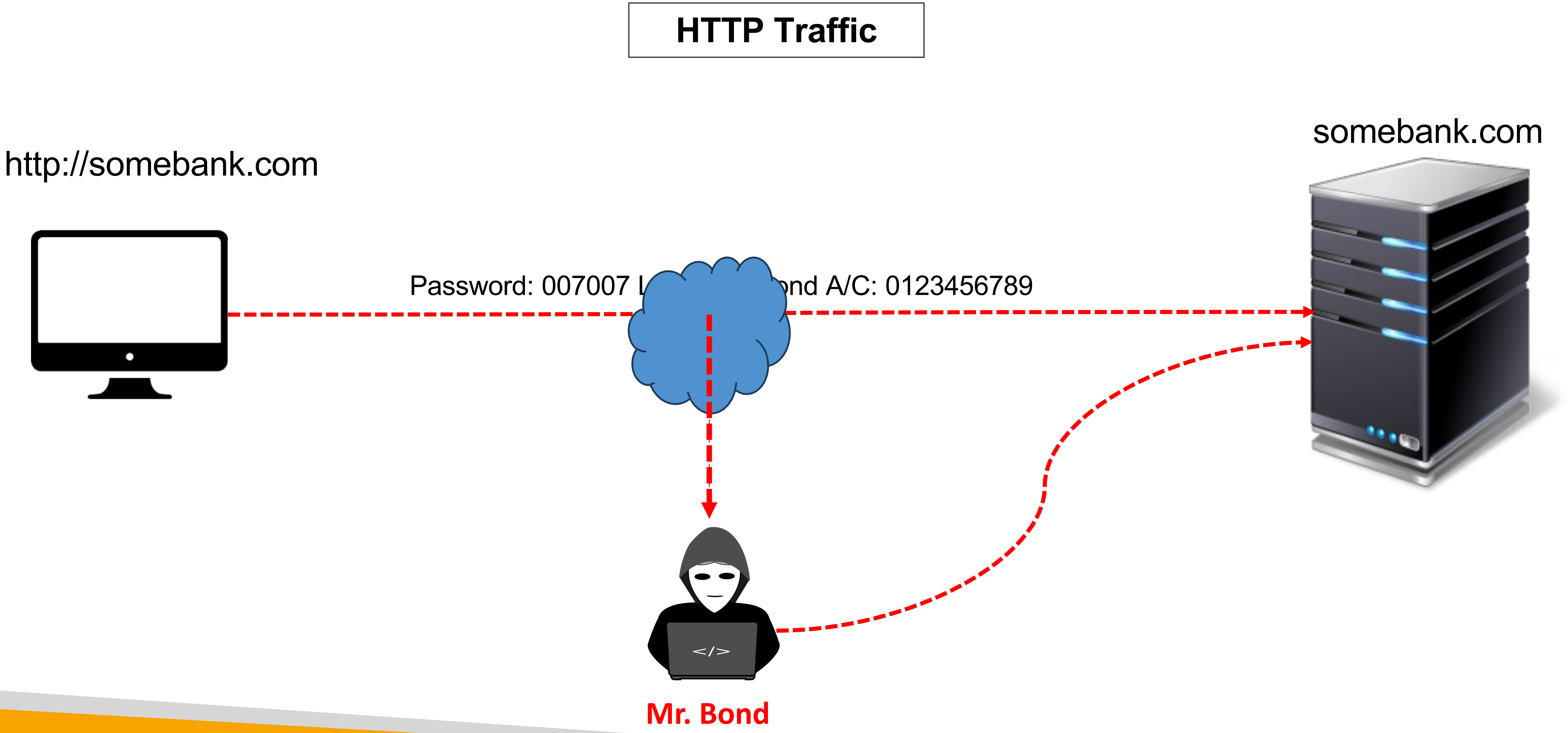
4. Launch jumps hosts in both the VPCs public subnets
5. Launch an Application host in the Application VPC public subnet
6. Launch Checkpoint CloudGuard instance in Network Appliance VPC
    1. For this you need to first subscribe to the AWS marketplace AMI.
    2. SG should allow Traffic on GENEVE port 6081 from the GWLB IPs (192.168.10.0/24)
7. Create GWLB and Target group
    1. Add the Checkpoint instance as a target with healthcheck on TCP port 443
8. Create VPC endpoint service in Network Appliance VPC using GWLB
9. Create VPC endpoint in Application VPC for the GWLB service created above
10. Configure all the route tables as shown in the network diagram

Steps - 3

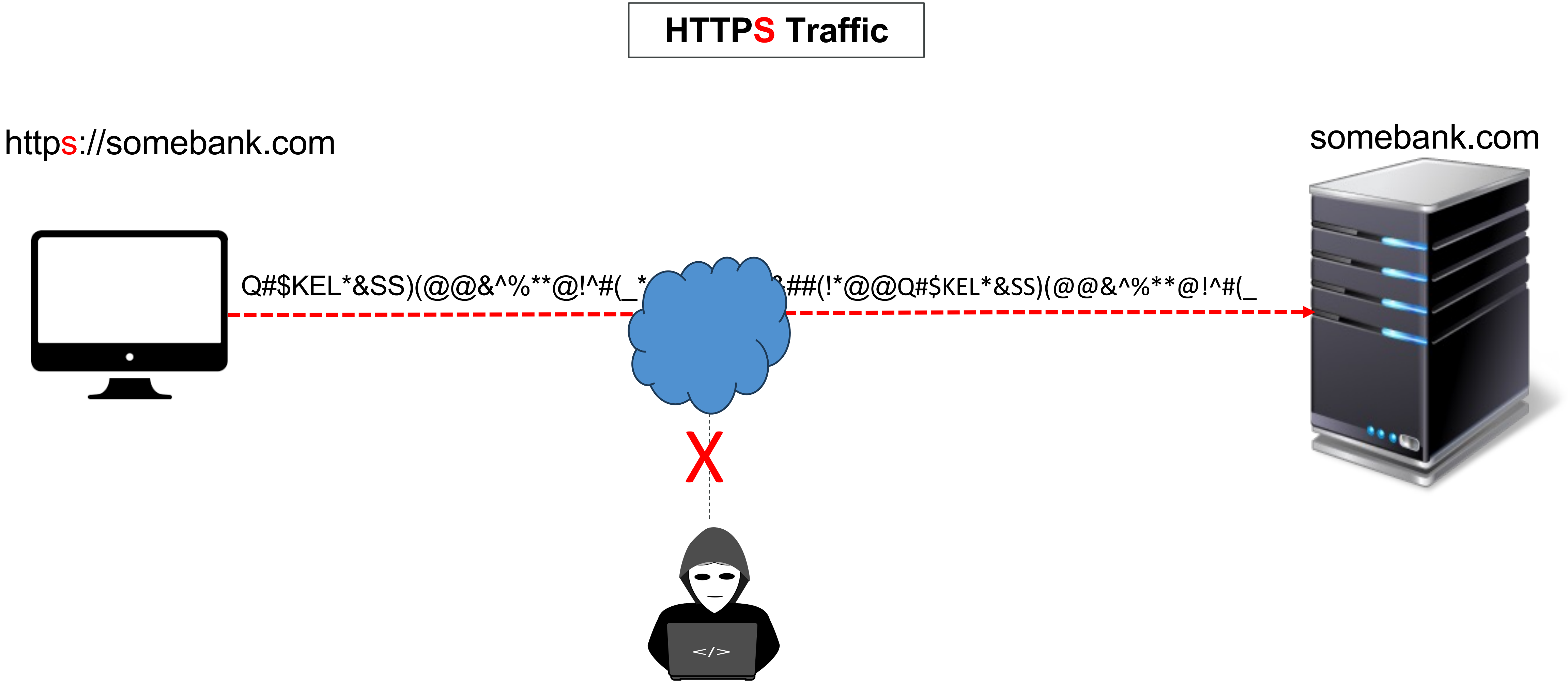
10. SSH to jump host in Network Appliance VPC and from there SSH to Checkpoint instance (use the username: admin)
    - Get into the Expert mode: $expert
    - Run the tcpdump command: $tcpdump –nvv 'port 6081'
11. SSH to jump host in Application VPC and from there SSH to application host
    - From Application host: $ping www.amazon.com
12. You should see the ICMP traffic captured in the checkpoint instance tcpdump

AWS Certificate Manager (ACM)

Why HTTPS?


HTTP Traffic
http://somebank.com
somebank.com
Password: 007007 L
ond A/C: 0123456789
</>
Mr. Bond

Why HTTPS?

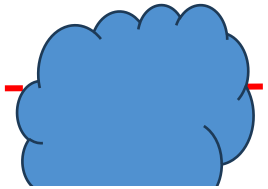

HTTPS Traffic
https://somebank.com
somebank.com
Q#$KEL*&SS)(@@&^%**@!^#(_*
##(!*@@Q#$KEL*&SS)(@@&^%**@!^#(_
X
</>

Why HTTPS?

HTTPS Traffic

Certificate Authority (CA)

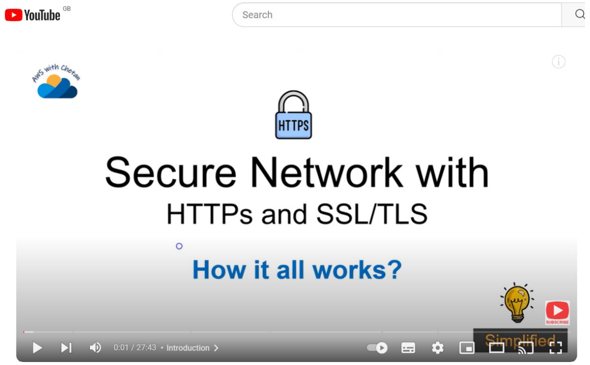
https://somebank.com



somebank.com

Public Key

Private Key



https://youtu.be/cLYv4uSFJA8

How to get SSL/TLS certificate?

GlobalSign by GMO

GoDaddy

HOSTINGER

DOMAIN.COM

Amazon Route 53

Buy a public domain name → Create Public/Private Key and create CSR → Submit CSR to CA → CA verifies the CSR (Domain validation) → Certificate is Issued

example.com

Certificate Authority

SSL

AWS Certificate Manager

CLOUDFLARE

namecheap

How to issue certificate using ACM?

GlobalSign by GMO

GoDaddy

HOSTINGER

DOMAIN.COM

Amazon Route 53

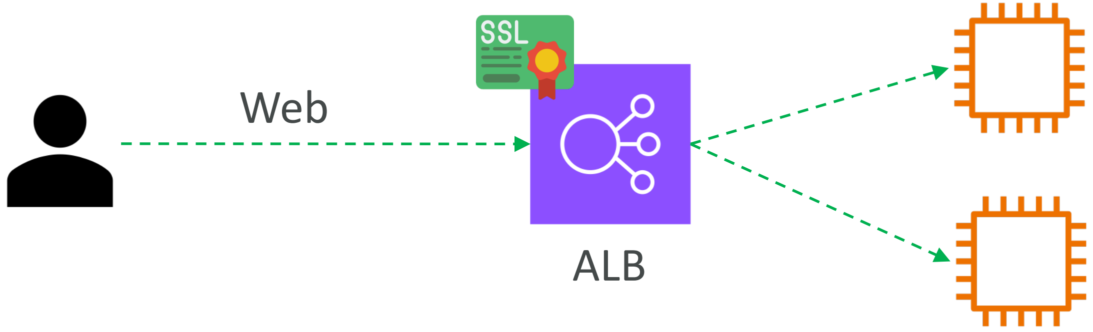
Buy a public domain name → Request a Pubic Certificate → Validate Domain ownership → Certificate is Issued

example.com

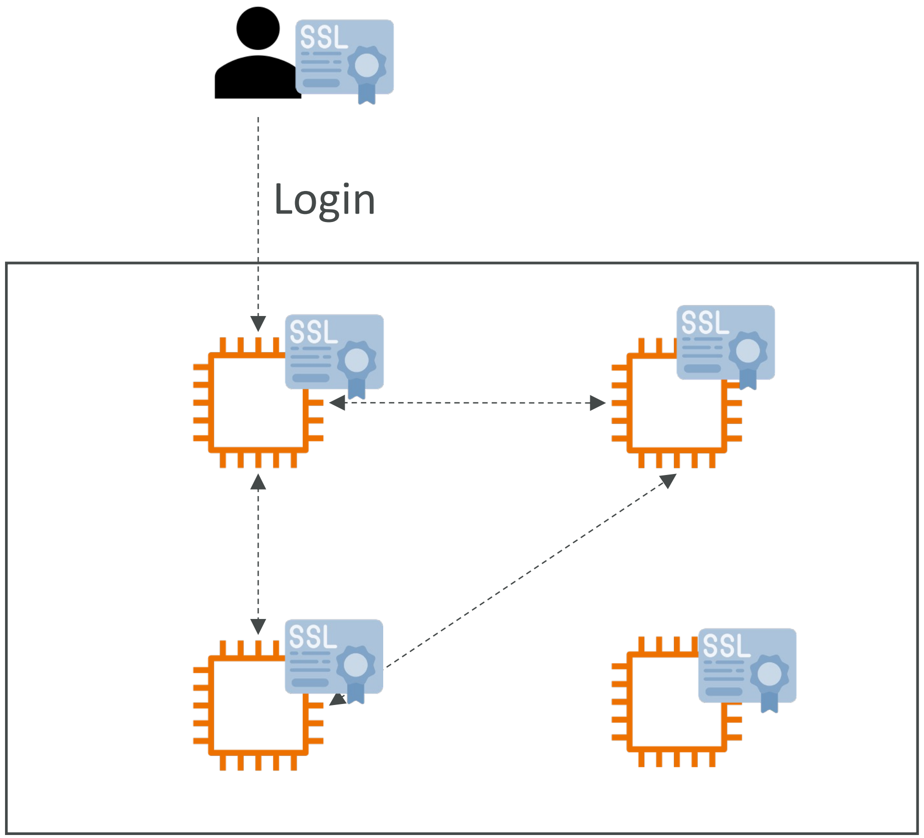
AWS Certificate Manager

AWS Certificate Manager

- AWS Certificate Manager (ACM)
- AWS Private CA

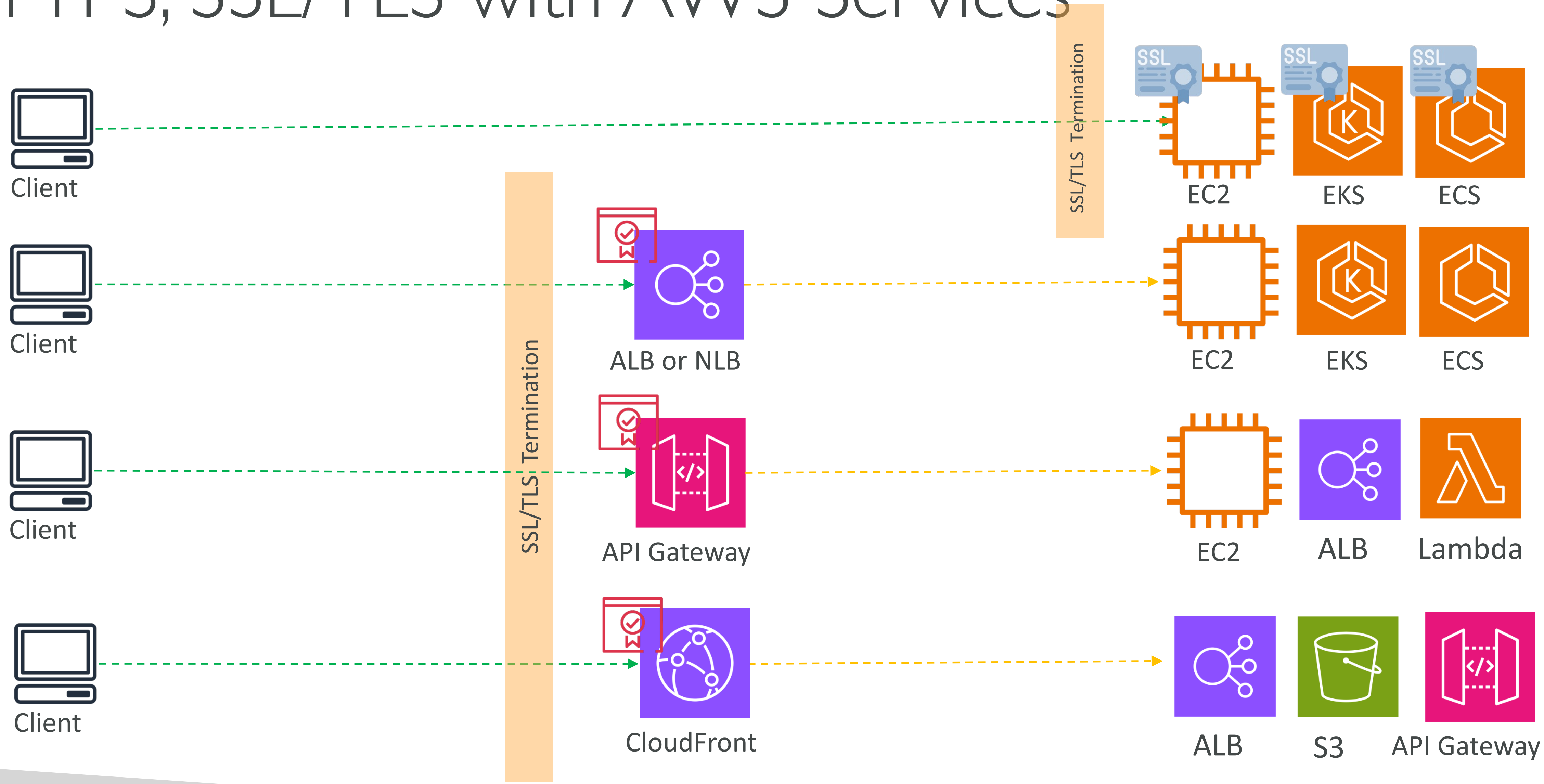


AWS Certificate Manager (ACM)



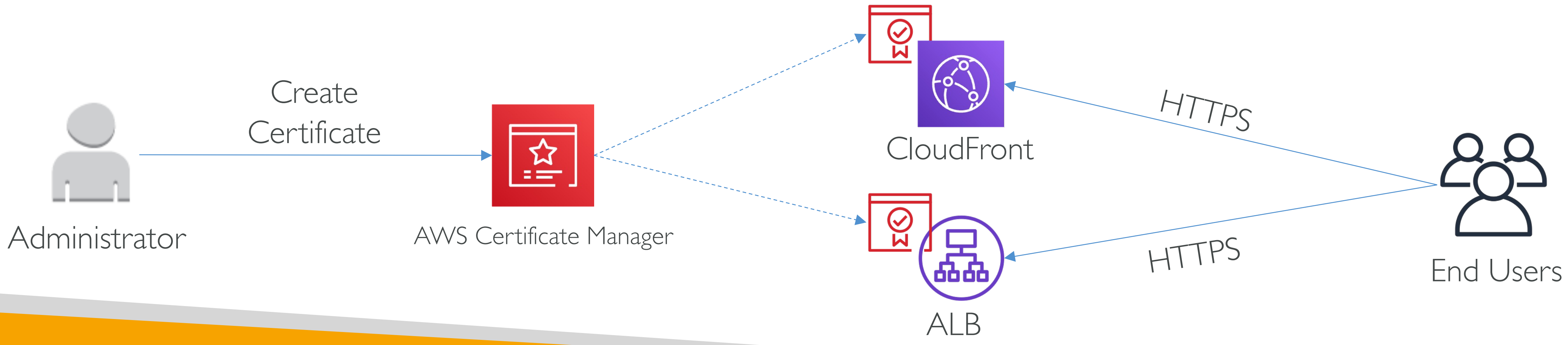
AWS Private CA

HTTPS, SSL/TLS with AWS Services



AWS Certificate Manager (ACM)

- Provides the free SSL/TLS X.509 Certificate which you can deploy on CloudFront, ELB, ElasticBeanstalk, API Gateway
- You can also request wildcard certificate e.g. *.example.com
- ACM is a regional service and you need to generate certificate in each region. However for **CloudFront** you must request certificate in **us-east-1** i.e. North Virginia region.

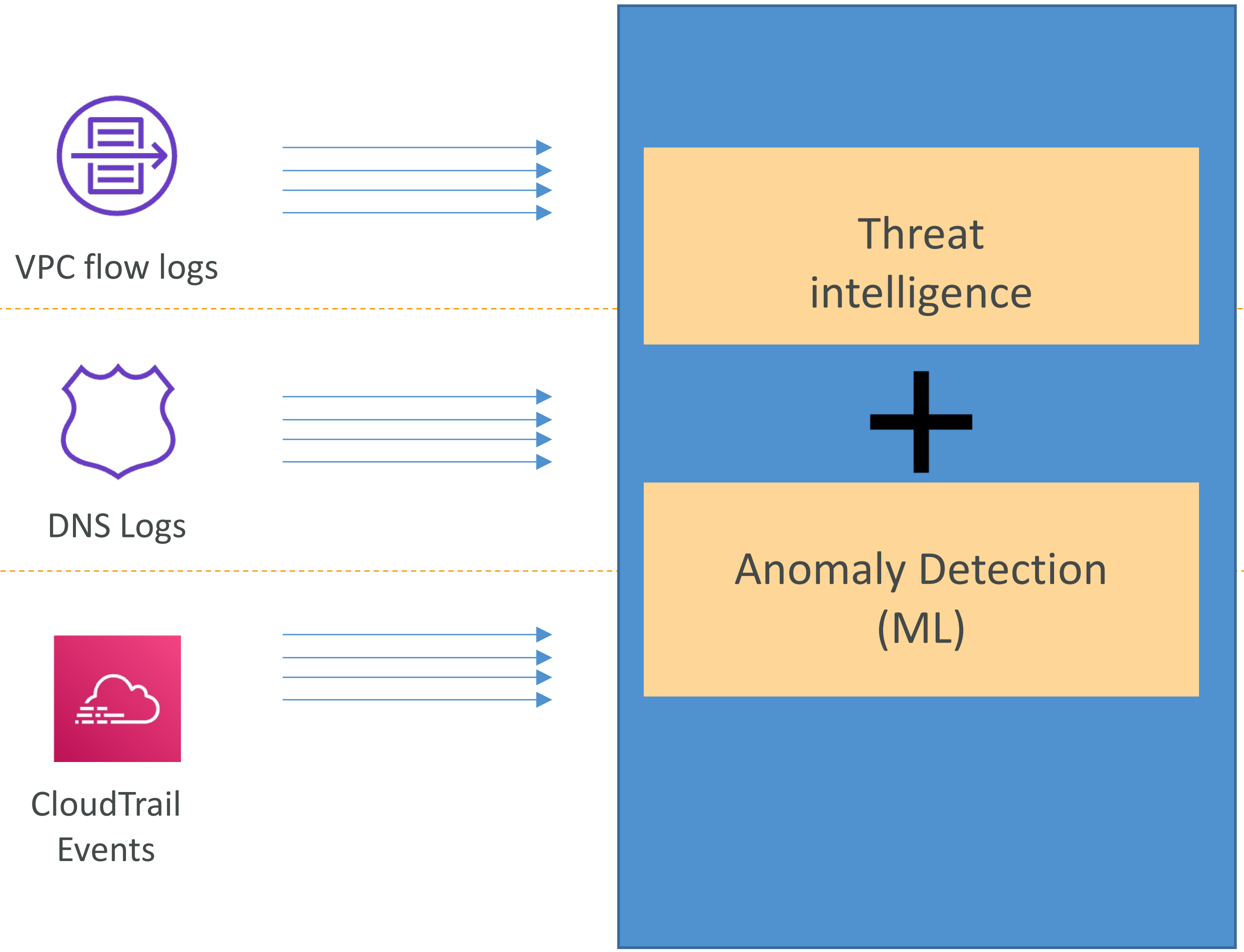


AWS Certificate Manager (ACM)

- You can not have wildcard in the middle of the domain name
  - Example: app.*.example.com is **not allowed**
  - Example: *.app.example.com is allowed
- Public certificates that you request through ACM are obtained from [Amazon Trust Services]() which is an Amazon managed public [certificate authority (CA)]()
- Public certificates issued through ACM are valid for 13 months (395 days) However, with private CA you may chose the certificate validity period
- ACM automatically renews the Certificates which are domain validated
- You can import your own Certificate into ACM. You have to renew imported certificates.

Amazon GuardDuty

Amazon GuardDuty



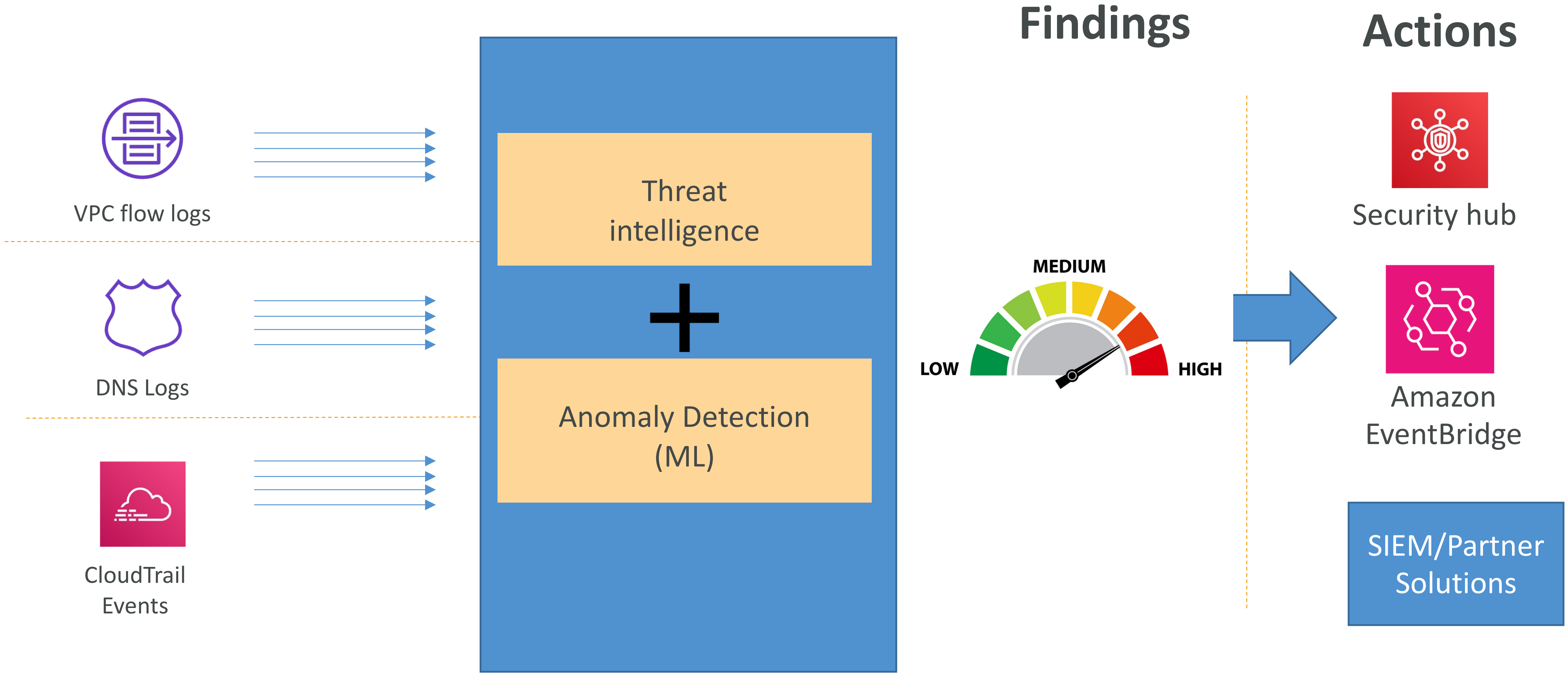
Threat and anomaly detection checks

EC2: C&C, DoS, Spambot,
EC2: Unusual Network Port, Traffic Volume
EC2: Bitcoin, Portscan, RDP/SSH Brute force

EC2: C&C DNS, Bitcoin DNS, Abused domain, Phishing domain
EC2: DGADomain Request, DNS data Exfiltration

IAM: Anomalous Behavior (GetPasswordData, StopLogging etc)
IAM: Kali/Parrot/Pentoo Linux
IAM: Root Credential usage,
S3: Malicious IP caller, Tor IP caller, Unusual object read,
S3: Bucket anonymous access granted, Block public access disabled,

Amazon GuardDuty



Amazon GuardDuty

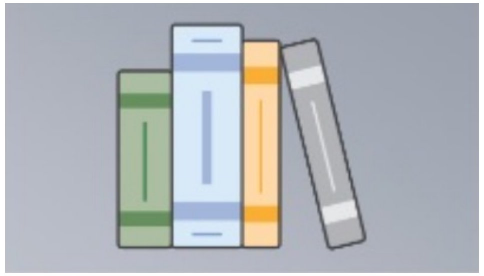
- Intelligent threat detection service
- GuardDuty analyzes billions of events from AWS CloudTrail Management event logs, VPC Flow Logs, and DNS Logs. Additionally, AWS CloudTrail data events (S3, EBS, EKS, ECS, EC2 runtime, RDS login etc.)
- There are no agents, sensors, or network appliances to deploy and absolutely no footprint in your AWS account
- There is no risk of performance or availability impact to existing workloads
- When a threat is detected, GuardDuty delivers a detailed security finding to the console and AWS Eventbridge making alerts actionable

Amazon Inspector

AWS Inspector

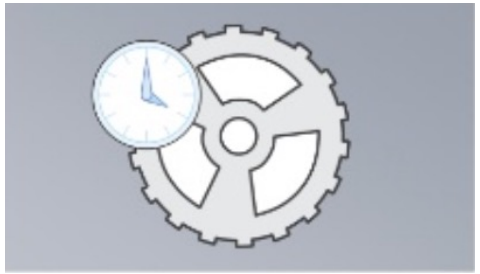
Assessment Template

Assessment Targets



Rules Packages

Inspector Agent



Triggers and Rules

Findings and Reports

AWS Inspector

- Simple Vulnerability Assessment for EC2 instances & Container images
- Common Vulnerability and Exposures (CVE)
- Center of Internet Security (CIS) Benchmark
- Security Best Practices
- Network Reachability
- The CVEs, Vulnerability rules and security best practices are automatically updated over the time
- Supports Agent based (through Systems Manager) and Agentless scanning (using EC2 snapshot)

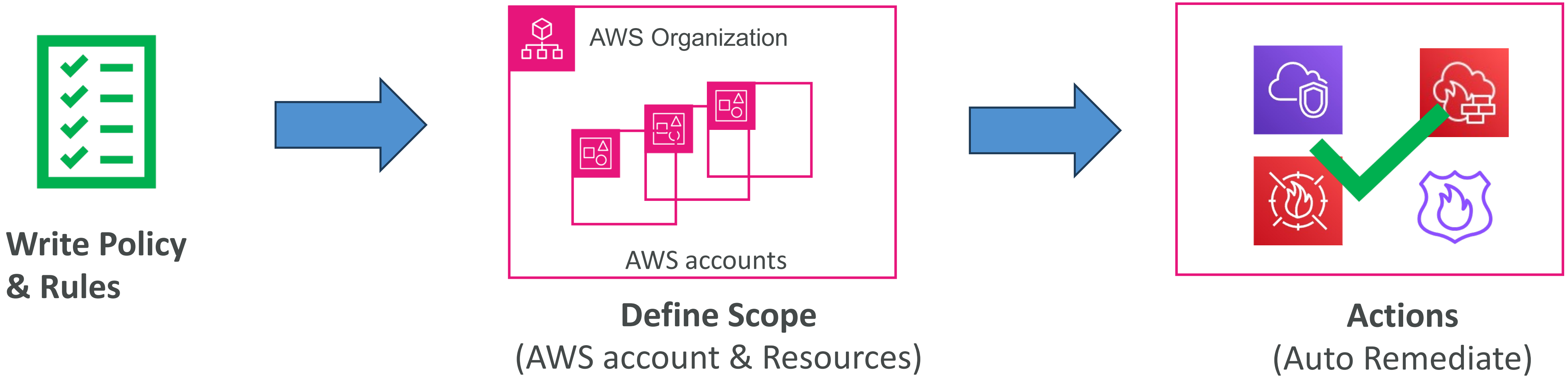
AWS Firewall Manager

AWS Firewall Manager

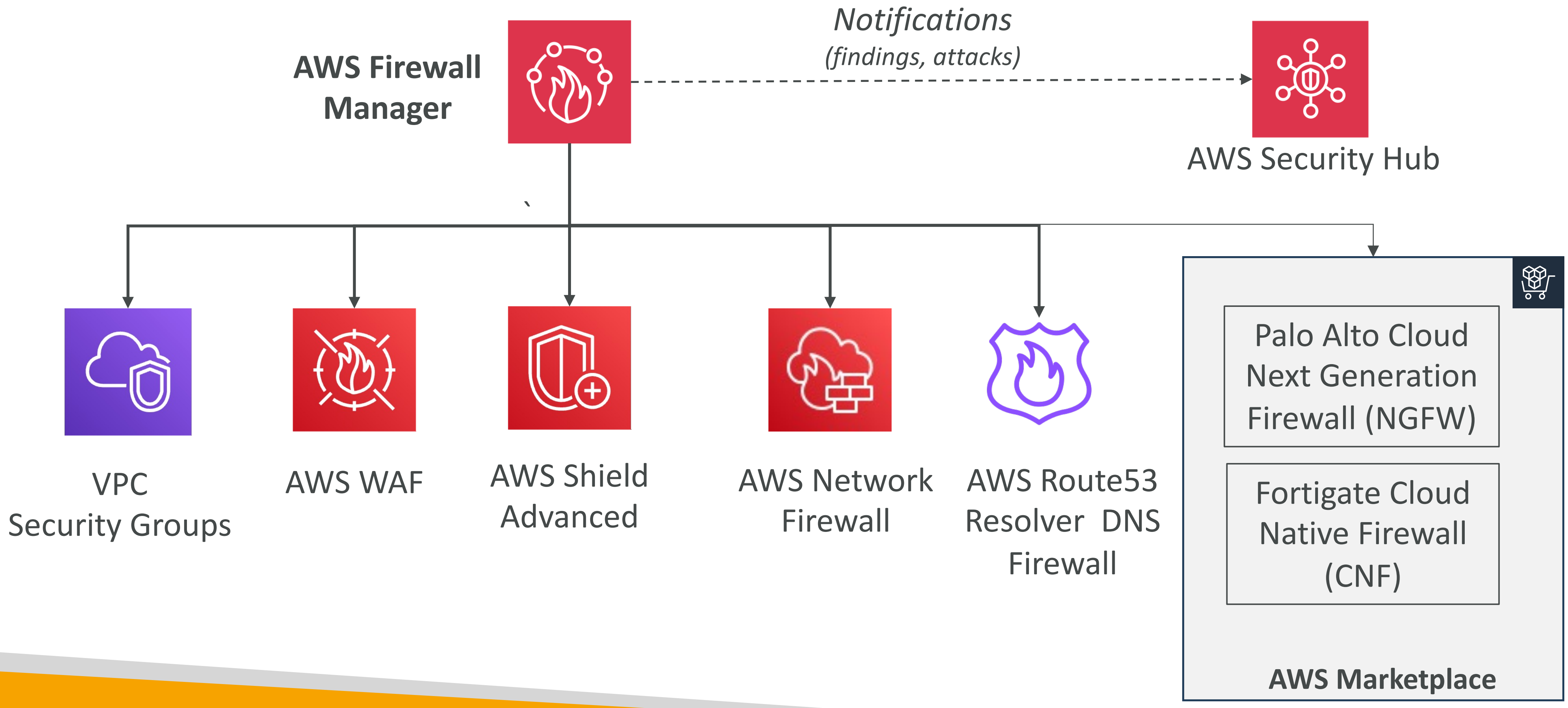
- Security management tool which simplifies security administration and maintenance tasks **across multiple AWS accounts** and **resources**
- Manages the rules for AWS WAF, AWS Shield Advanced, Amazon VPC security groups, AWS Network Firewall, and Amazon Route 53 Resolver DNS Firewall
- New accounts added under the AWS Organizations are automatically protected
- Provides centralized monitoring of DDoS attacks across AWS organization

Pre-requisites for Firewall Manager

- Enable AWS Organization (full features)
- Enable AWS Config
- Enable AWS Resource Access Manager (RAM)



AWS Firewall Manager



When to use what?

Need an easy and quick to deploy firewall for protecting Web applications from Layer7 attacks?	AWS Web Application Firewall (WAF)
Need to have protection against DDoS with support from AWS to handle the attack?	AWS Shield Advanced
Need more sophisticated managed firewall (IPS/IDS) for all the traffic flowing in/out of VPC resources?	AWS Network Firewall
Need sophisticated 3rd party firewall (IPS/IDS) or network monitoring for all the traffic flowing in/out of VPC resources?	AWS Gateway Load Balancer
Need the centralized governance for managing the firewall protections across accounts?	AWS Firewall Manager
These services are not mutually exclusive. Ex. You can use WAF, Shield and AWS Firewall manager together.	

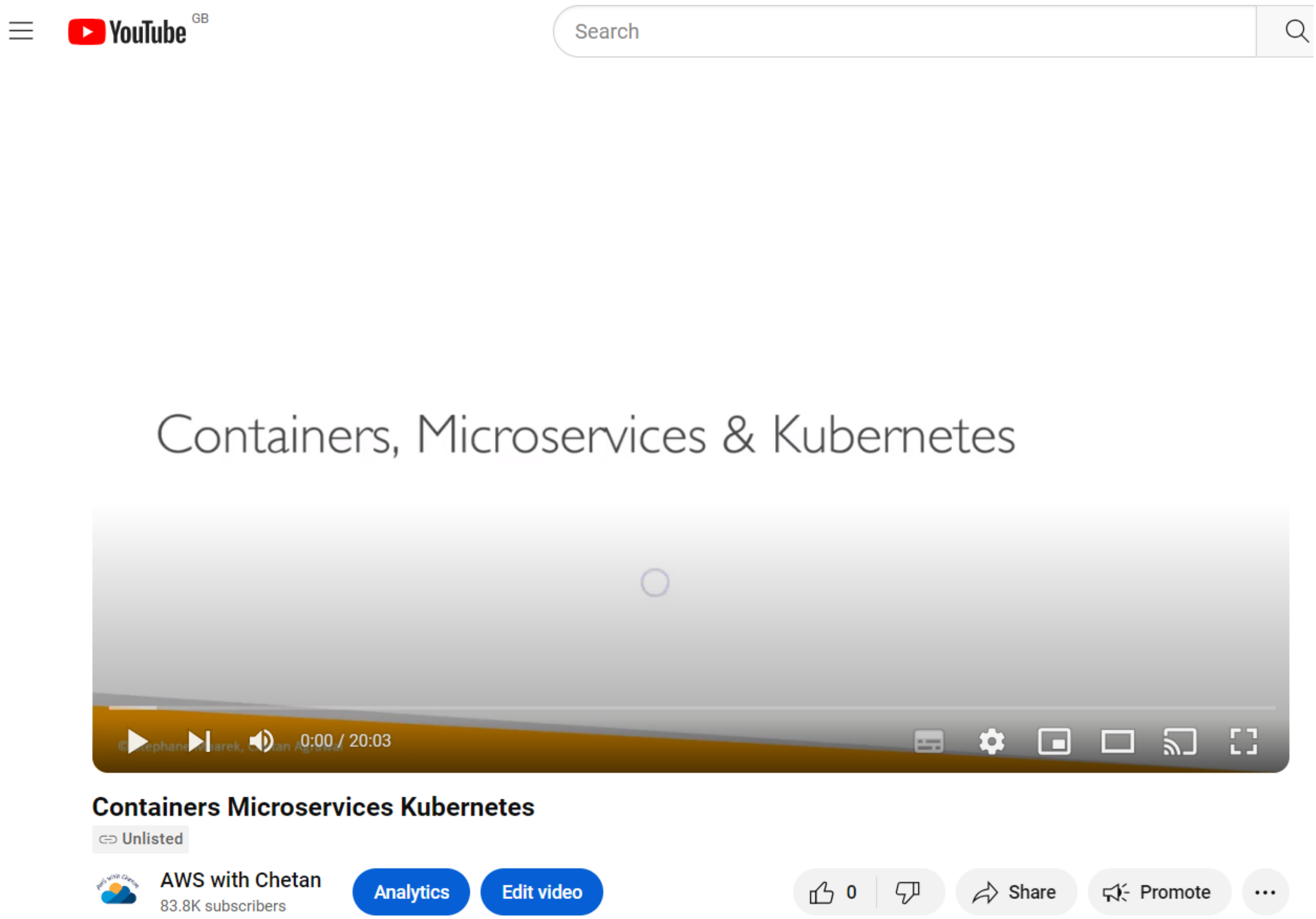
Amazon EKS Networking

In this section..

- Expected to know: What are containers, microservices and Kubernetes
- Kubernetes (opensource) Architecture
- Amazon Elastic Kubernetes Service (EKS)
  - EKS Architecture – Control plane & Data plane
  - EKS Cluster Networking
  - EKS Pod Networking
  - Using Security Groups with EKS Pods
  - Exposing EKS services using Load Balancers (CLB/ALB/NLB)
  - EKS Custom Networking
  - EKS Networking Summary

What are containers, microservices and Kubernetes?

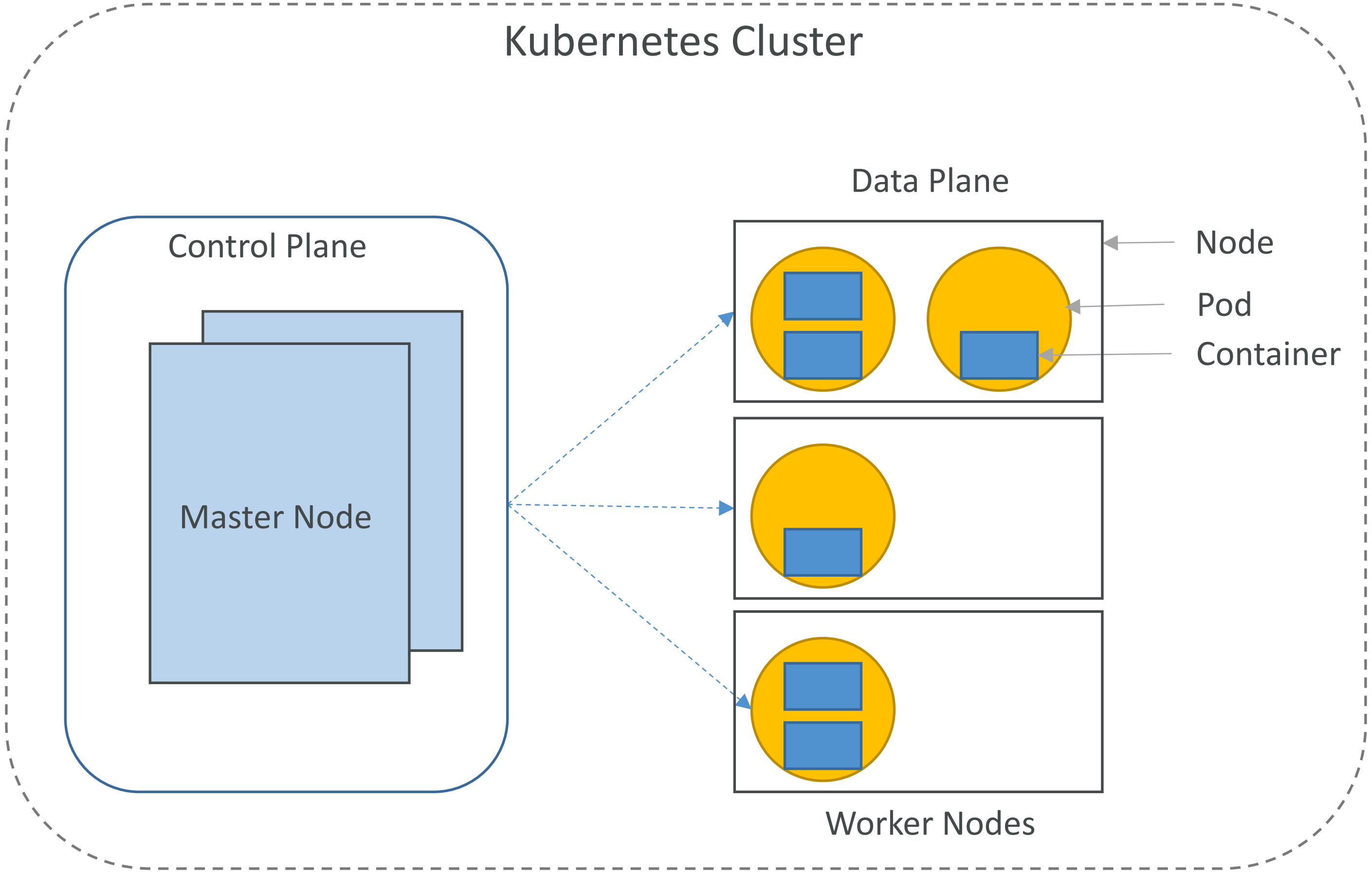
https://youtu.be/QekQLFWbkuM



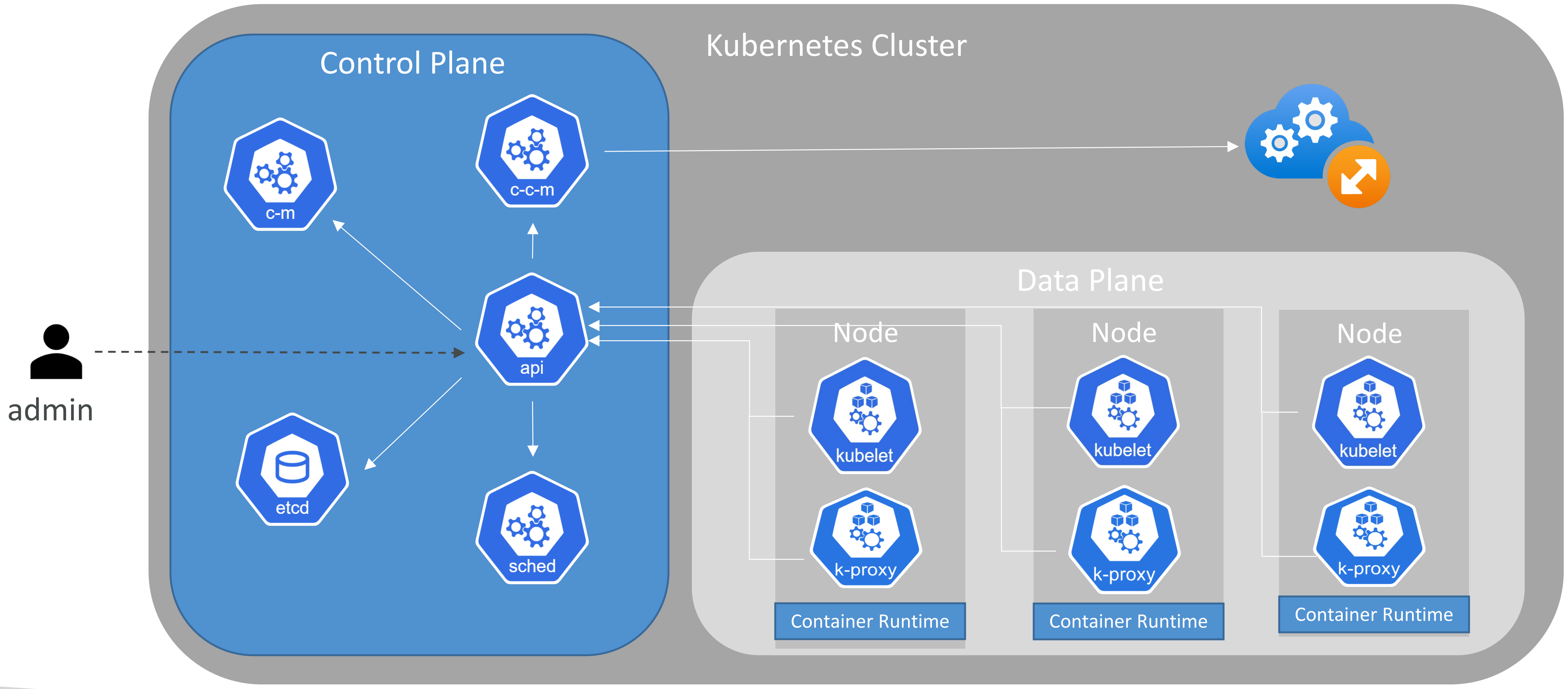
Kubernetes Architecture

Kubernetes building blocks

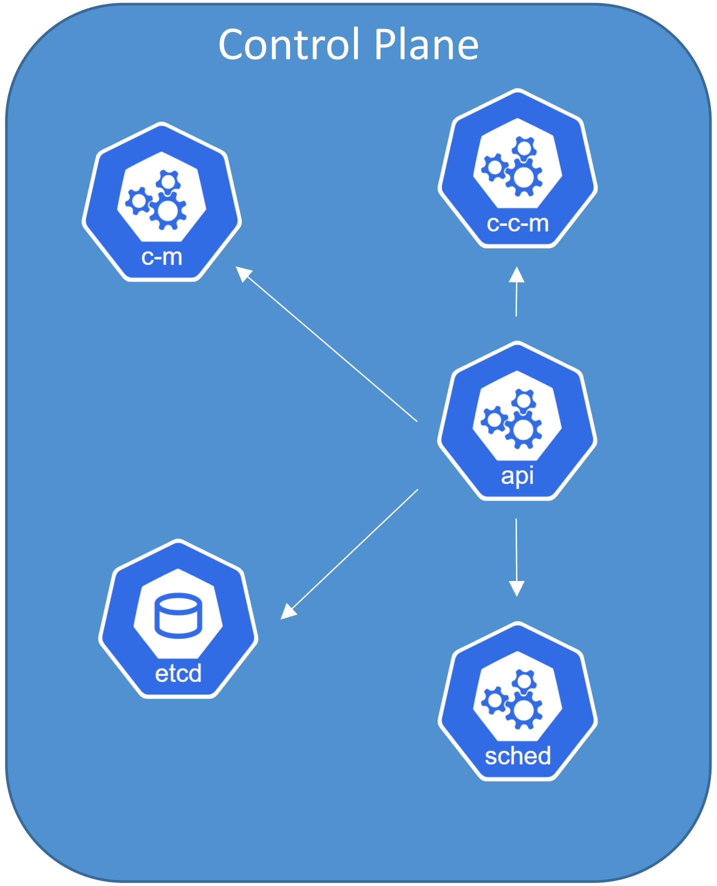
- Kubernetes Cluster consists of Control Plane and Data Plane
- Control plane consists of set of control processes hosted on master nodes
- Data plane consist of set of worker nodes called Nodes
- Nodes host the Pods
- A Pod represents a group of **one or more application containers**



Kubernetes architecture

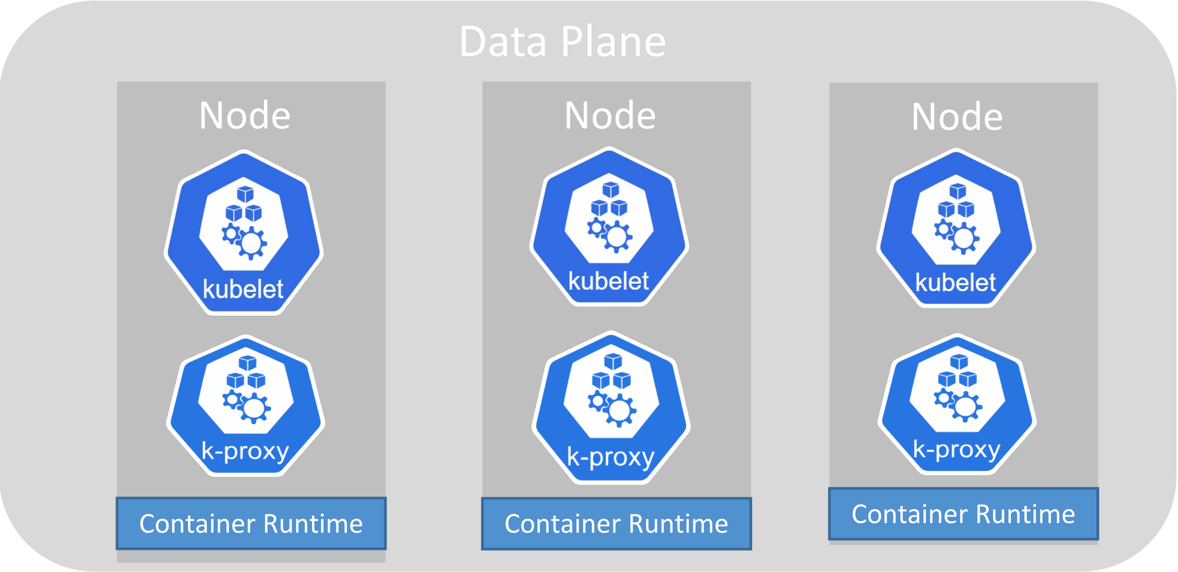


Control Plane Components



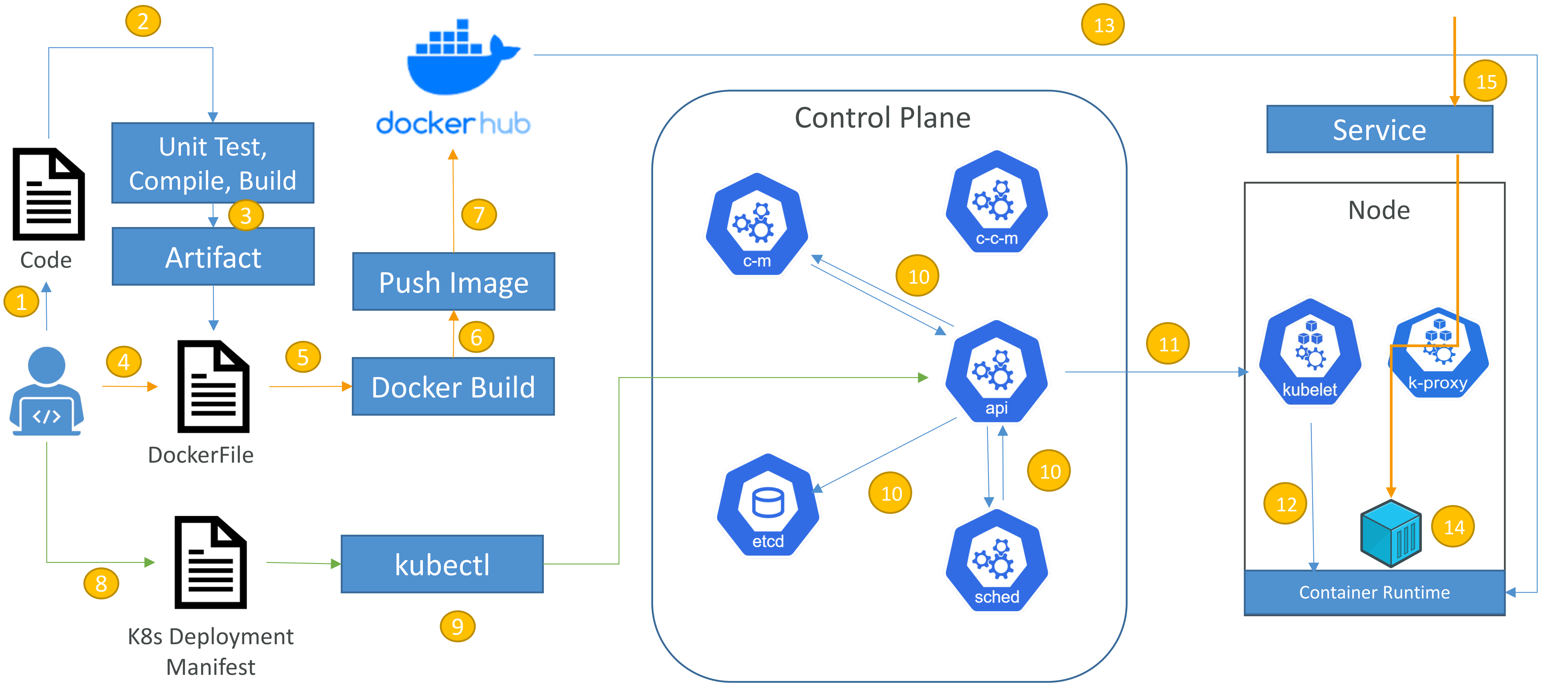
- kube-apiserver
  - Exposes Kubernetes APIs. It's a frontend for the Kubernetes control plane.
- etcd
  - Key-value store used as Kubernetes backing store for all cluster data.
- kube-scheduler
  - Watches for newly created Pods with no assigned node, and selects a node for them to run on.
- kube-controller-manager
  - Runs controller processes such as Node controller, Replication controller, Namespace controller, Job Controller, EndpointSlice controller etc.
- cloud-controller-manager
  - Links Kubernetes cluster into cloud provider's API such as Node controller for determining if node (instance) is deleted in the cloud, Service controller for cloud load balancer etc.

Kubernetes Data plane components



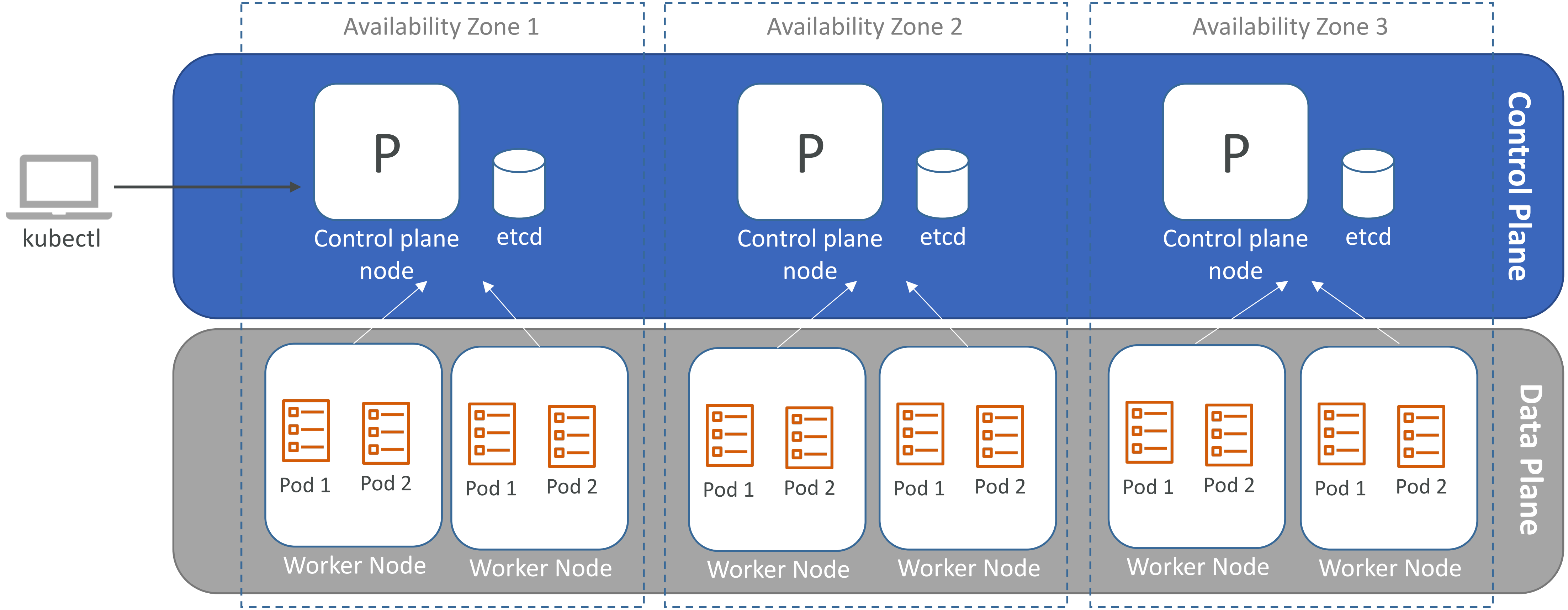
- Node
  - hosts the pods (applications)
- kubelet
  - An agent that runs on each node in the cluster. It makes sure that containers are running in a Pod.
- kube-proxy
  - Enables network communication to Pods from network sessions inside or outside of your cluster
- Container Runtime
  - Responsible for running containers. Kubernetes supports container runtimes such as containerd, CRI-O, and any other implementation of the Kubernetes CRI

Application deployment to Kubernetes

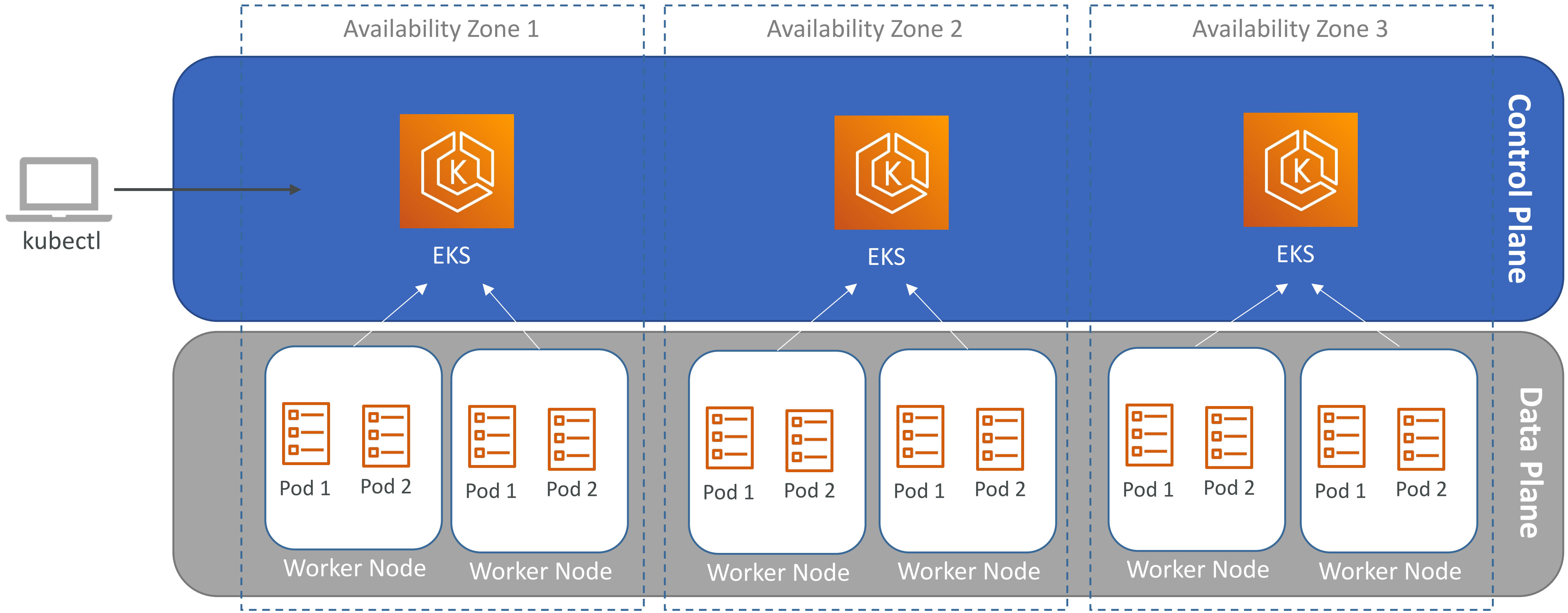


Amazon EKS Architecture

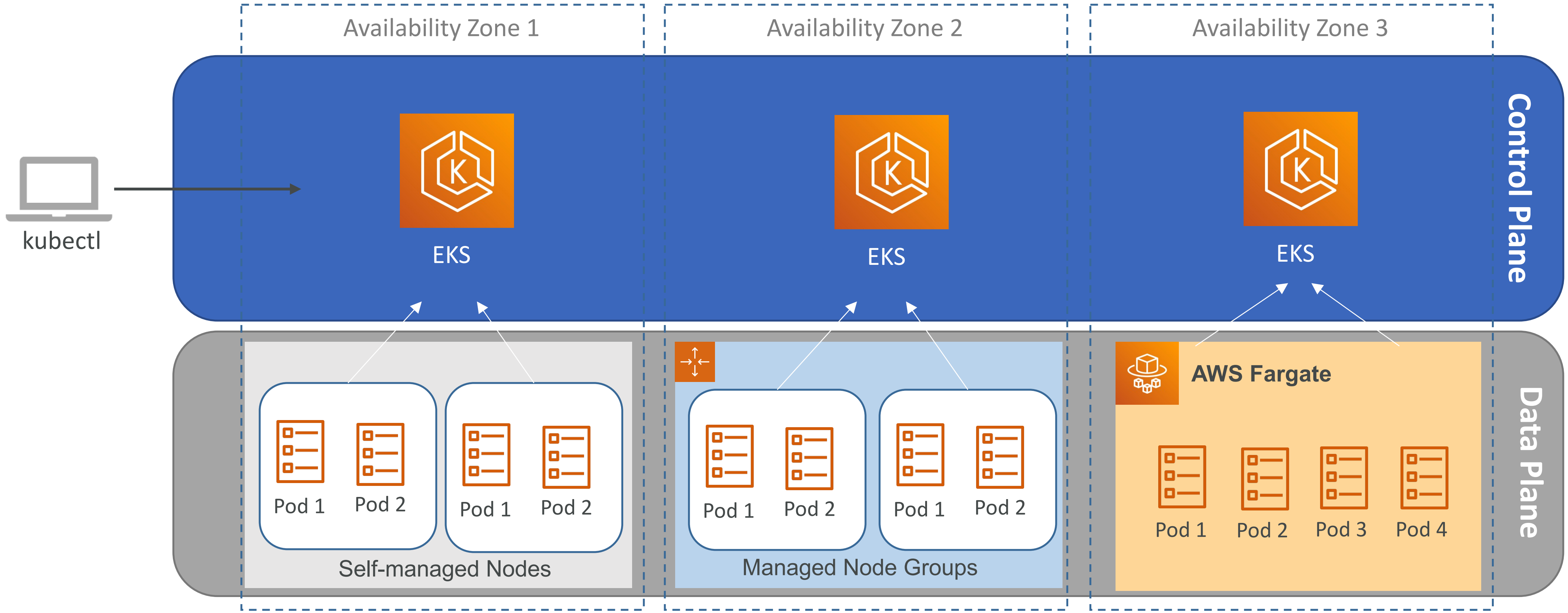
Kubernetes Control plane & data plane in AWS



EKS Control plane & data plane



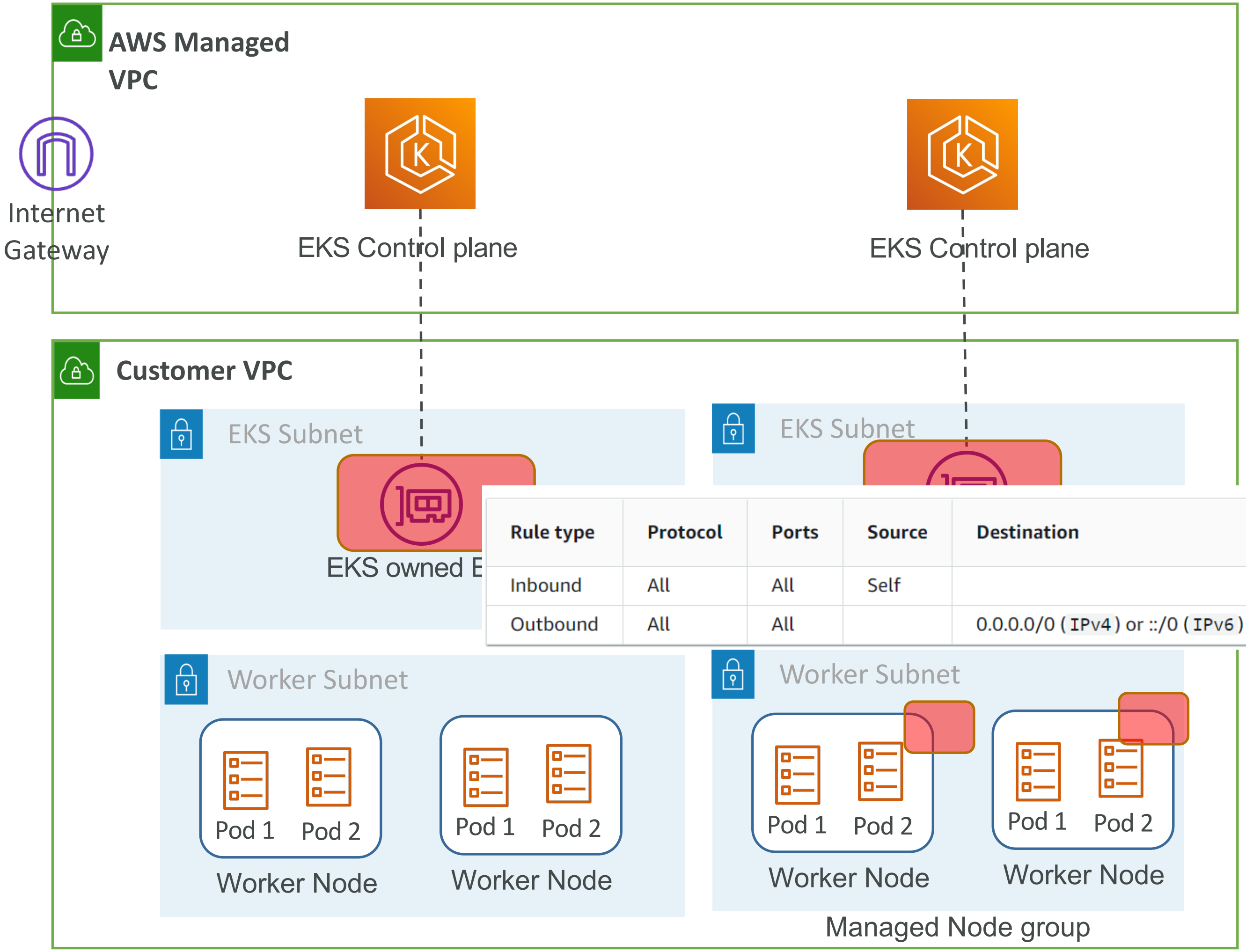
EKS – Data plane hosting options



Amazon EKS Cluster Networking

EKS Networking

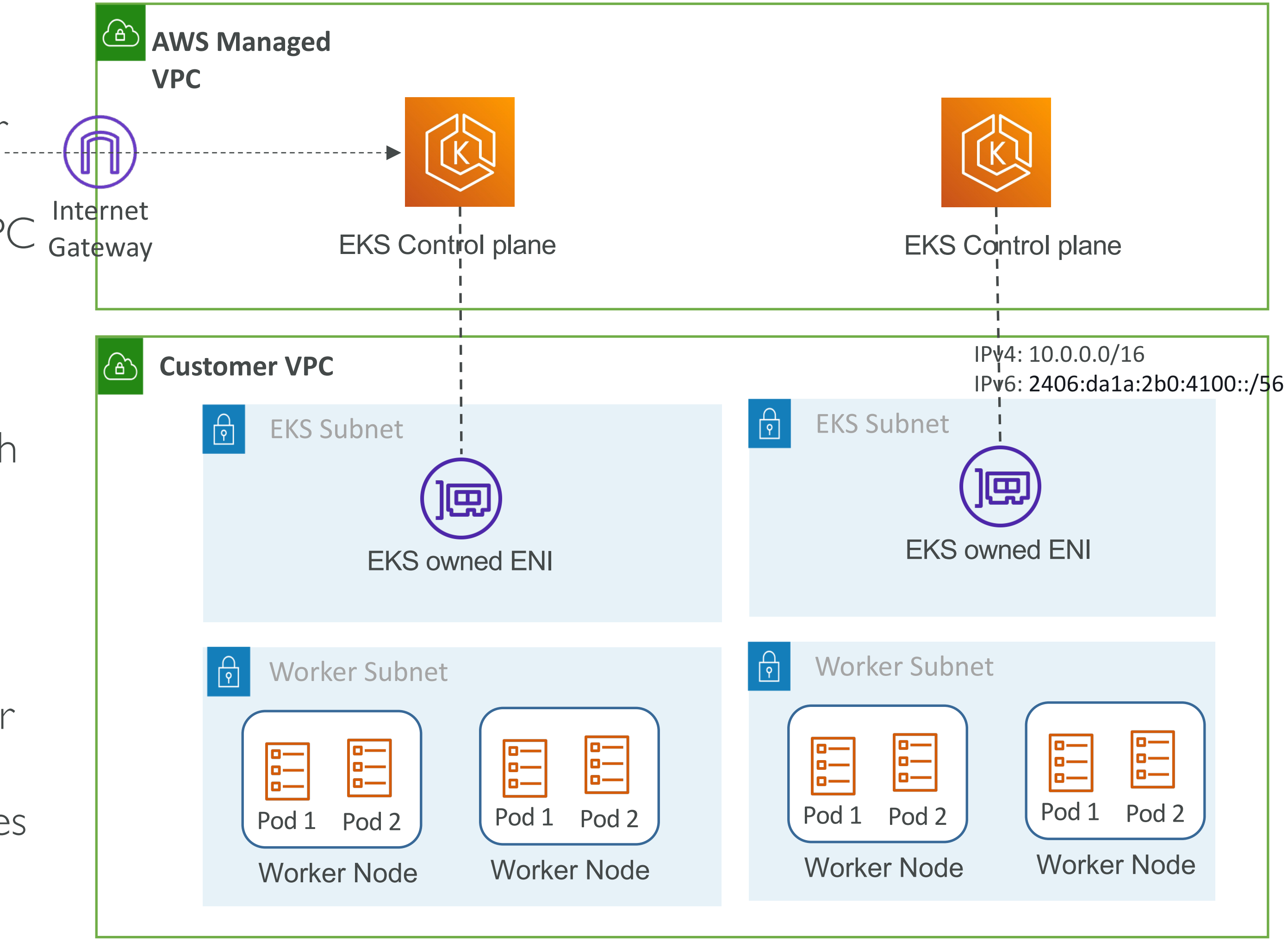
- EKS Control Plane is launched in the AWS managed account & VPC
- Data plane nodes are launched in Customer account & VPC
- EKS provisions 2-4 ENIs in the Customer VPC to enable the communication between Control plane and VPC.
- It's recommended to have separate subnets for EKS ENIs. EKS needs at least 6 IPs in each subnet (16 recommended)
- EKS creates and associates SG to these EKS owned ENIs (and also to Managed Group Nodes).



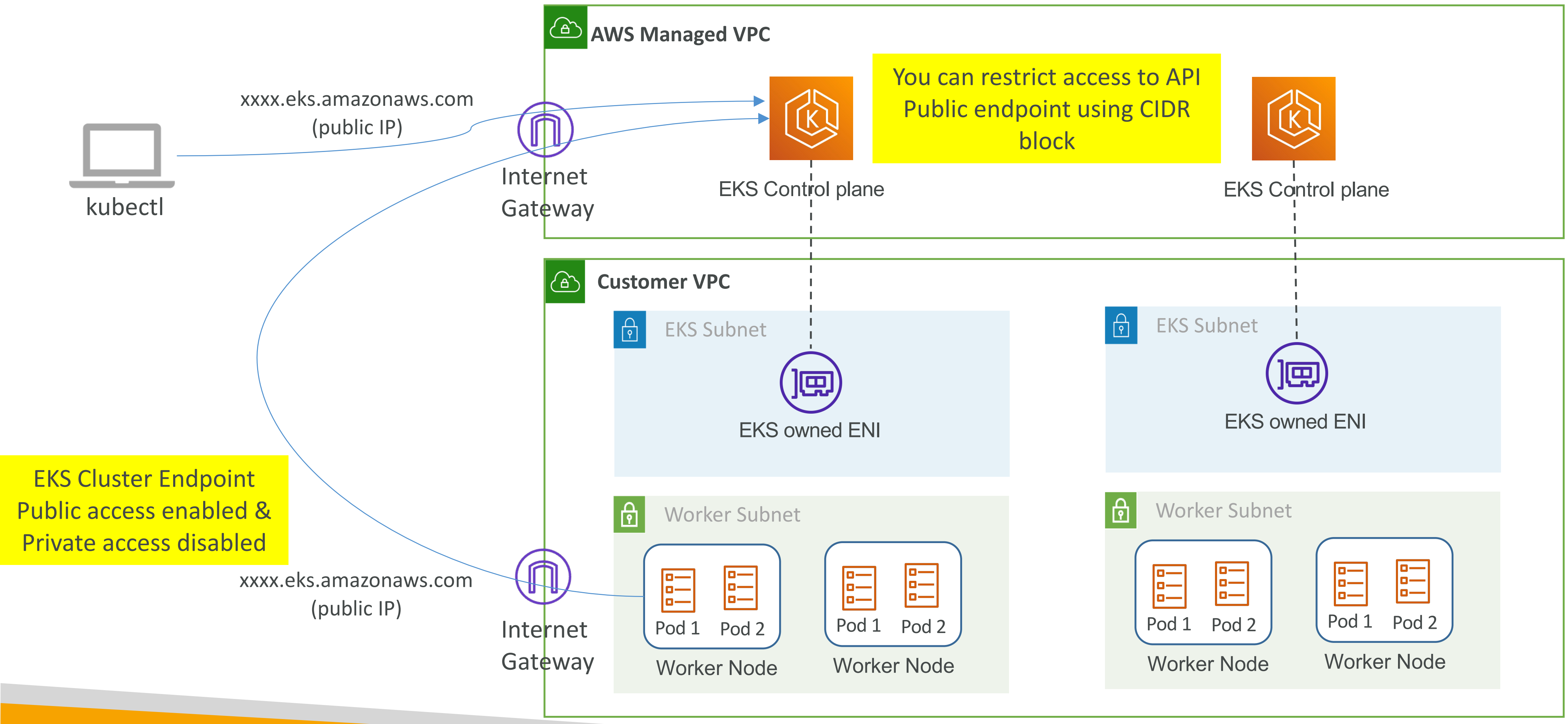
Rule type	Protocol	Ports	Source	Destination
Inbound	All	All	Self	
Outbound	All	All		0.0.0.0/0 (IPv4) or ::/0 (IPv6)

EKS Networking

- EKS Control Plane is launched in the AWS managed account & VPC
- Data plane nodes are launched in Customer account and VPC
- EKS provisions 2-4 ENIs in the Customer VPC to enable the communication between Control plane and VPC.
- It's recommended to have separate subnets for EKS ENIs. EKS needs at least 6 IPs in each subnet (16 recommended)
- EKS creates and associates SG to these EKS owned ENIs (and also to Managed Group Nodes).
- Kubernetes API Server can be accessed over the internet (by default)
- EKS allows assigning IPv4 or IPv6 IP addresses to Pods (but not in dualstack mode)

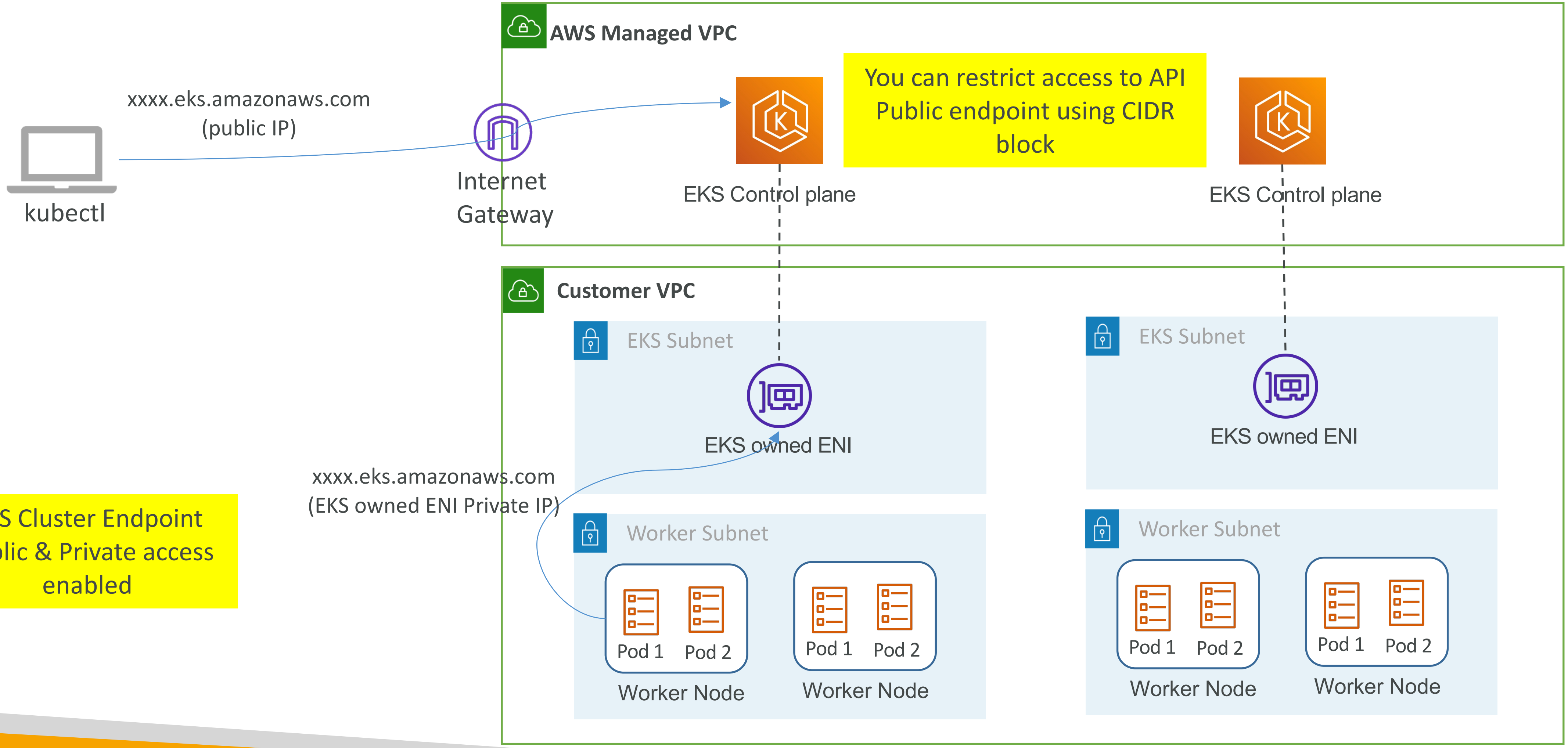


EKS cluster endpoint access – Public (default)



Worker Node

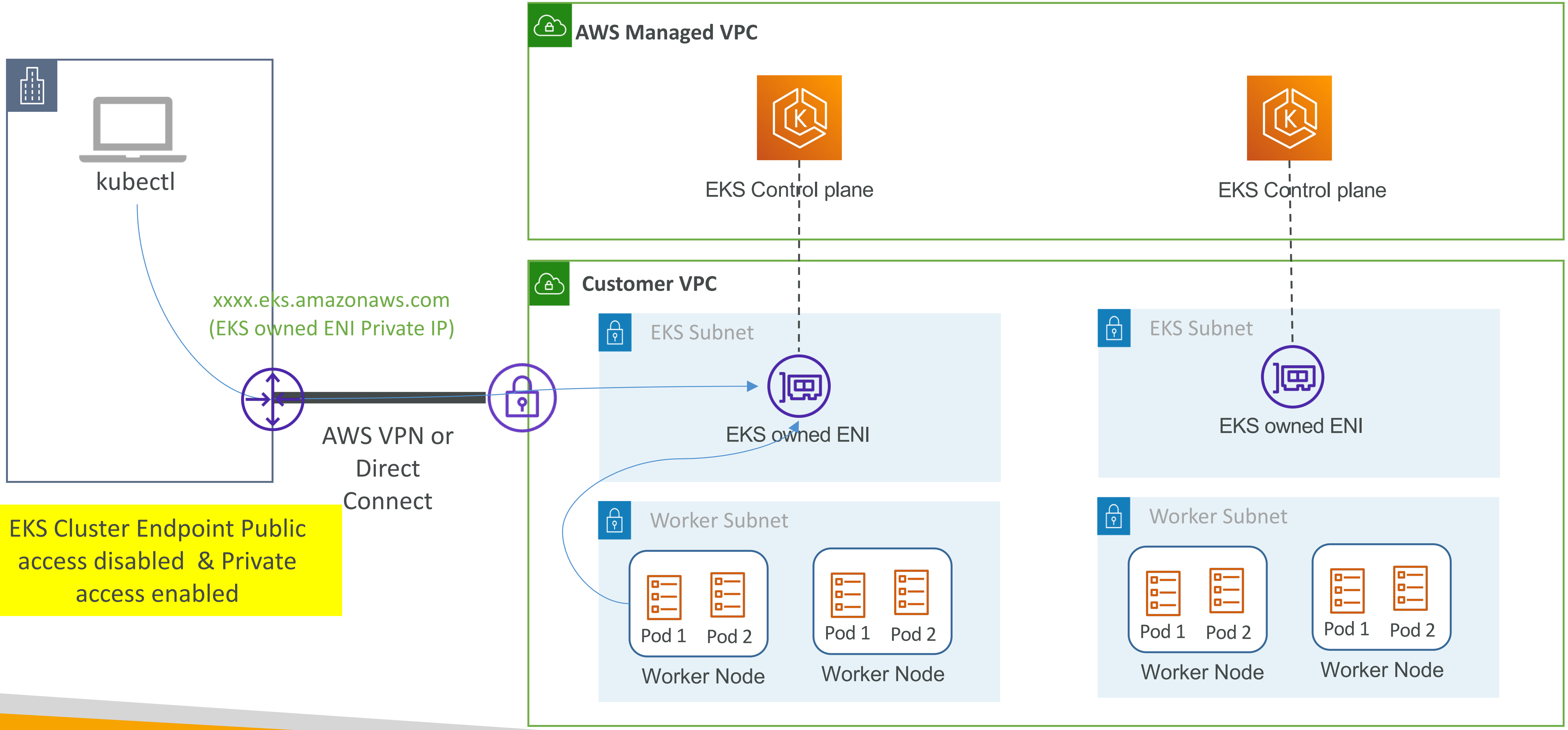
EKS cluster endpoint access – Public & Private



EKS Cluster Endpoint Public & Private access enabled

Worker Node

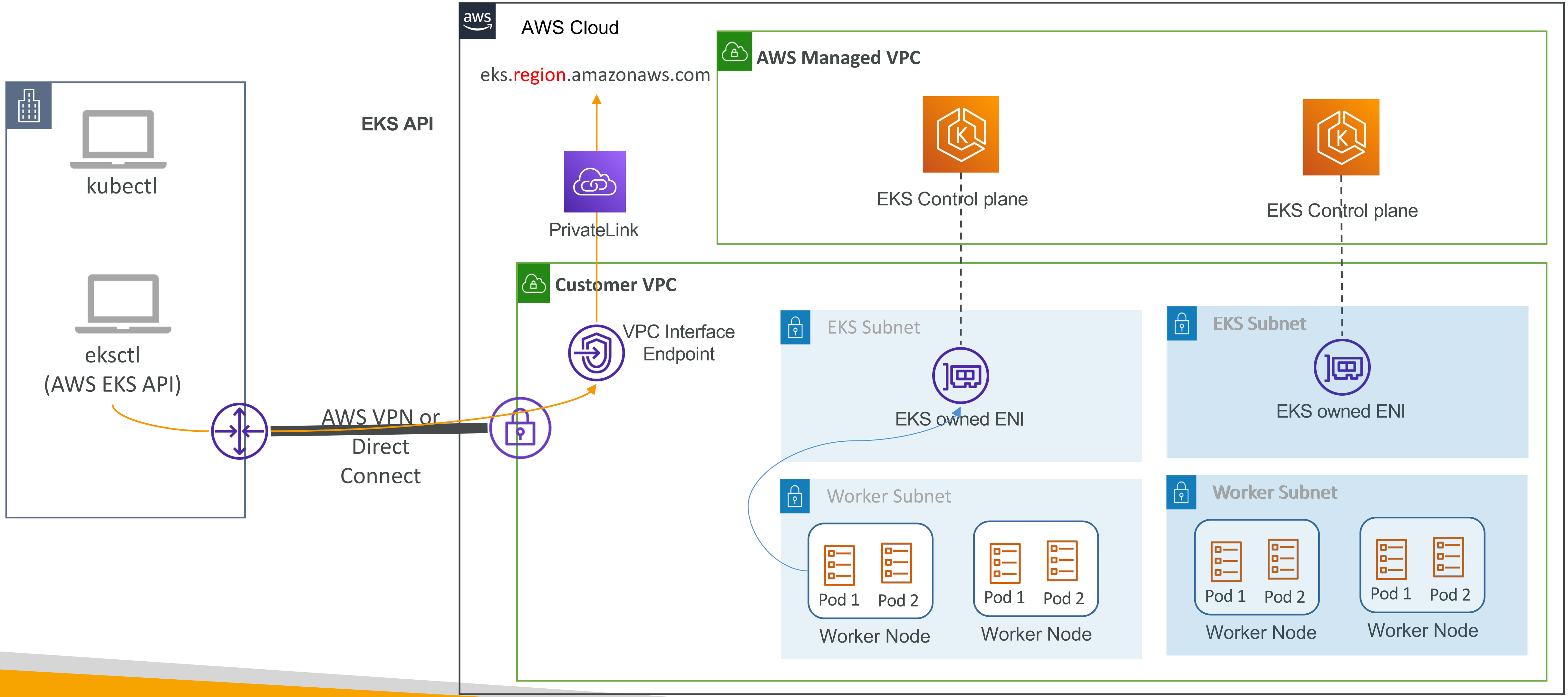
EKS cluster endpoint access – Private only



EKS Cluster Endpoint Public access disabled & Private access enabled

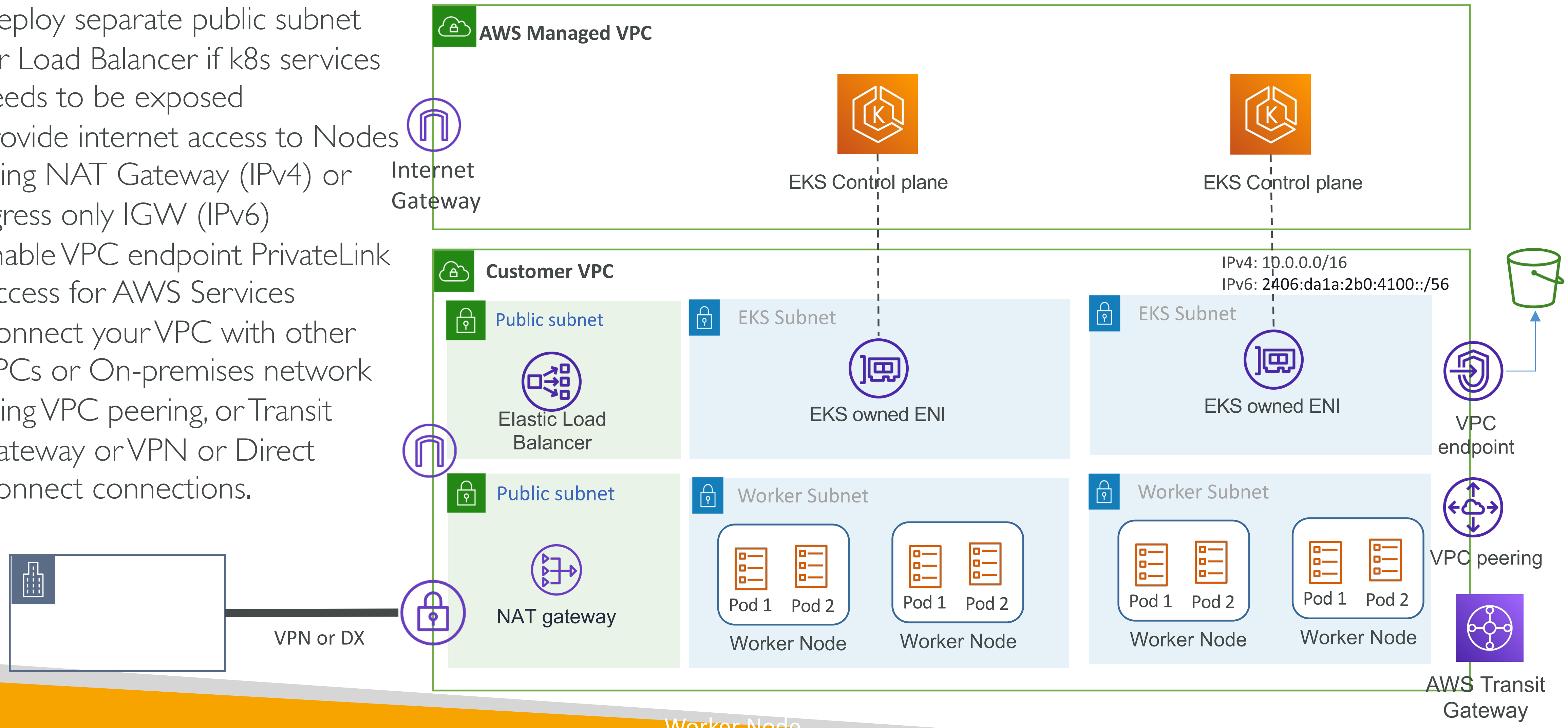
Worker Node

EKS API Private access through PrivateLink



EKS VPC extended connectivity

- Deploy separate public subnet for Load Balancer if k8s services needs to be exposed
- Provide internet access to Nodes using NAT Gateway (IPv4) or Egress only IGW (IPv6)
- Enable VPC endpoint PrivateLink Access for AWS Services
- Connect your VPC with other VPCs or On-premises network using VPC peering, or Transit Gateway or VPN or Direct Connect connections.



Amazon EKS Pod Networking - CNI

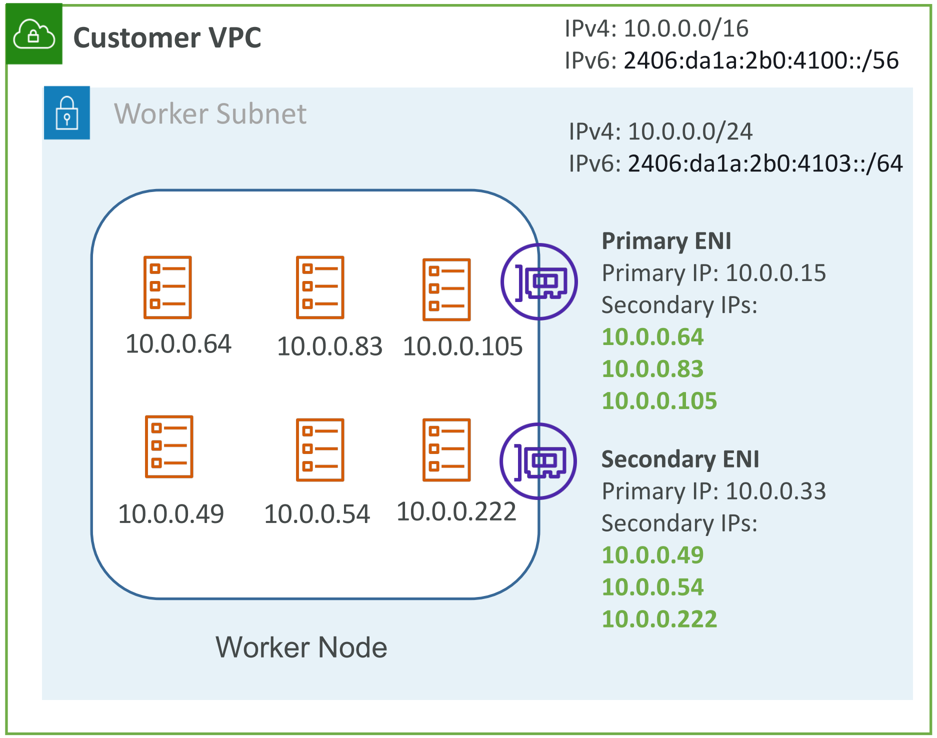
Kubernetes Network Model

CNCF networking specifications

- Every pod gets its own IP address
- Containers in the same Pod share the network IP address
- All pods can communicate with all other pods without using network address translation (NAT).
- All nodes can communicate with all pods without NAT.
- The IP that a pod sees itself as is the same IP that other see it as.

CNI

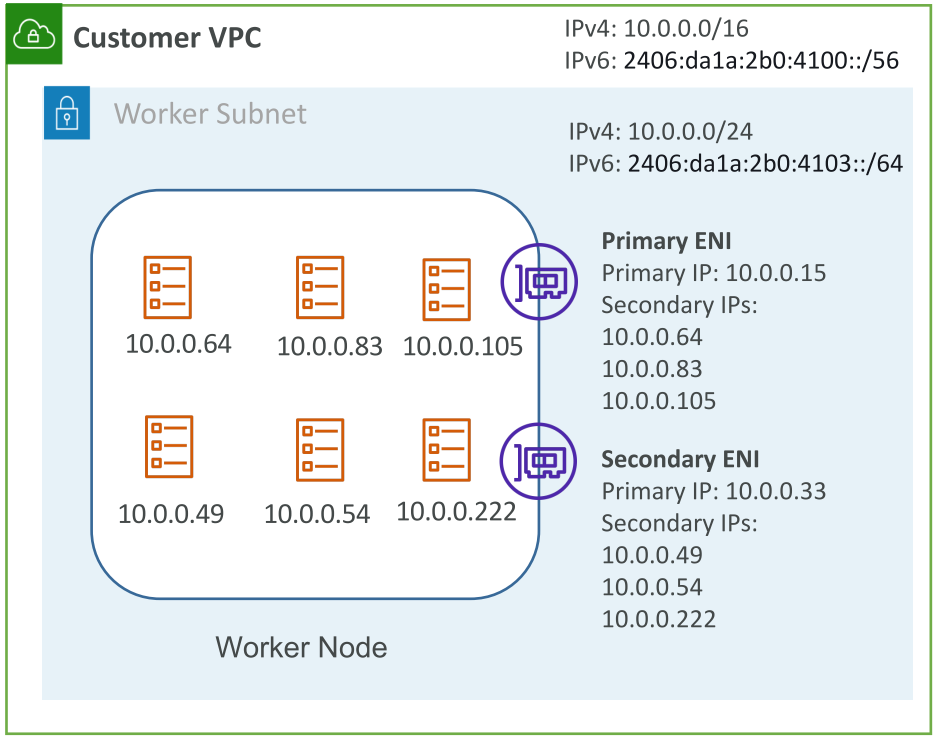
Amazon VPC CNI plugin



- Amazon VPC Container Network Interface (CNI) plugin:
  - Creates and attaches ENIs to worker nodes
  - Assigns ENI secondary IP addresses to Pods
- Amazon EKS officially supports the Amazon VPC CNI plugin for Kubernetes
- Alternate compatible CNI plugins:

Partner	Product
Tigera	Calico
Isovalent	Cilium
Weaveworks	Weave Net
VMware	Antrea

Maximum Pods per node



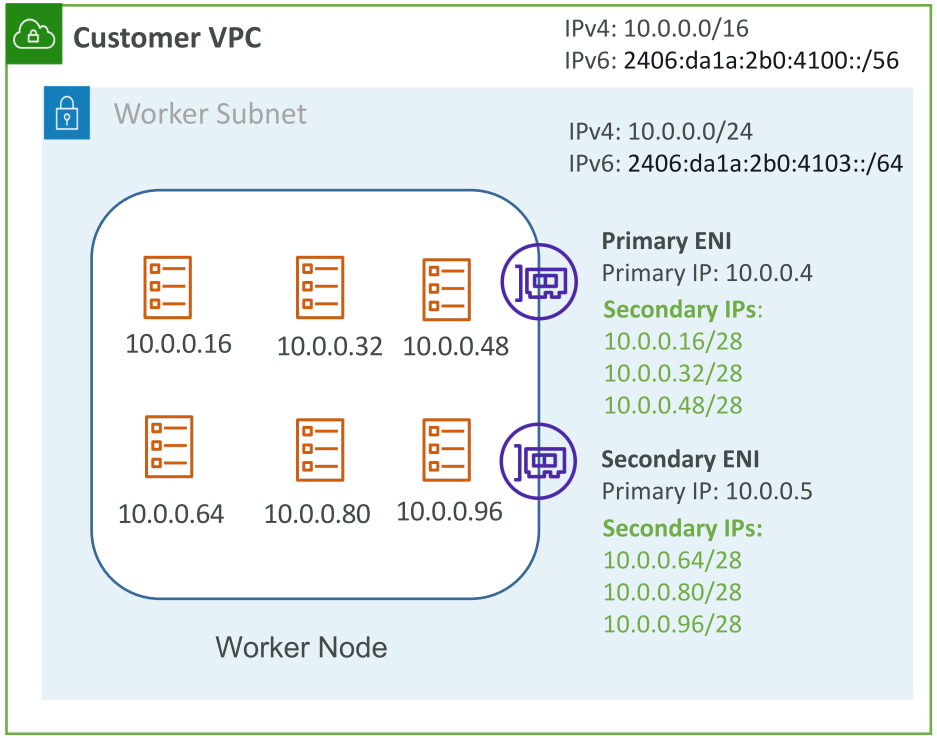
IP addresses per network interface per instance type

Instance type	Maximum network interfaces	Private IPv4 addresses per interface	IPv6 addresses per interface
m5.large	3	10	10
m5.xlarge	4	15	15
m5.2xlarge	4	15	15
m5.4xlarge	8	30	30

Max Pods = (Total number of network interfaces)x (Maximum IPs per network interface - 1) + 2

Example (m5.large with IPv4 address):
Max Pods = 3 x (10-1) + 2 = 29

Increased available IP addresses for Pods



Only AWS Nitro-based nodes use this capability

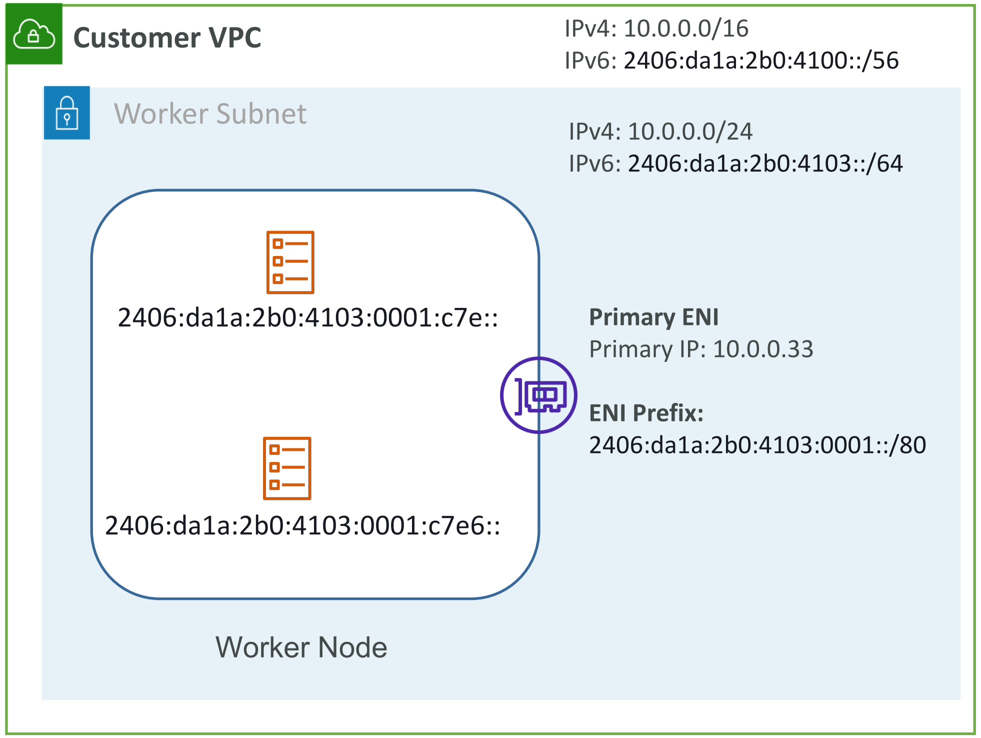
Prefix delegation:
Assign a prefix to EC2 ENI
- /28 block for IPv4 (x16)
- /80 block for IPv6 (x280 trillion)

Max Pods = (Total number of network interfaces)x (Maximum IPs per network interface - 1) + 2

Example (m5.large with IPv4 address):
Max Pods = 3 x (10-1)x16 + 2 = 434

Max Pods (recommended) = 110

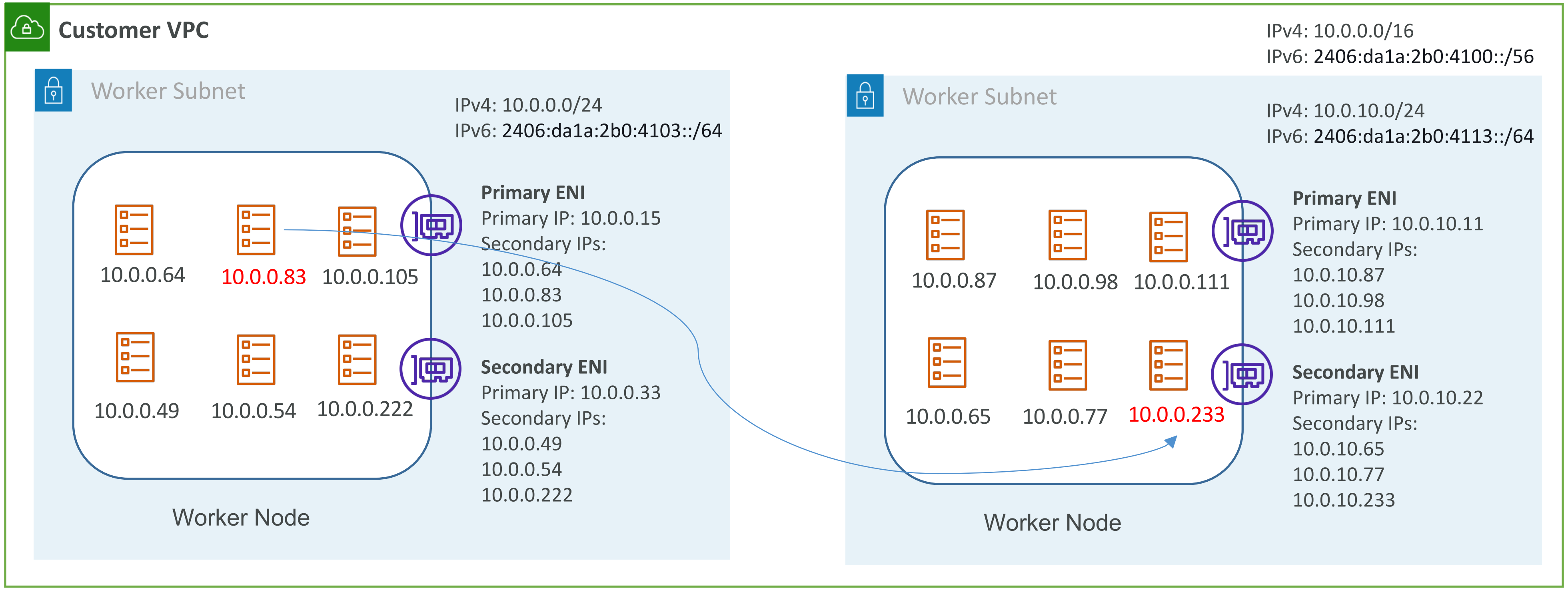
Assigning IPv6 addresses to pods and services



Supported with AWS Nitro-based instances & Fargate

- By default, Kubernetes assigns IPv4 addresses to pods and services but we can also configure cluster with IPv6 addresses.
- EKS doesn't support dual-stack pods or services.
- For Amazon EC2 nodes, you must configure the Amazon VPC CNI add-on with IP prefix delegation and IPv6.
- You must also assign IPv4 address to VPC and subnets as VPC does require IPv4 addresses to function.
- Subnets must have auto-assign IPv6 address enabled.
- Not supported for Windows pods and services.

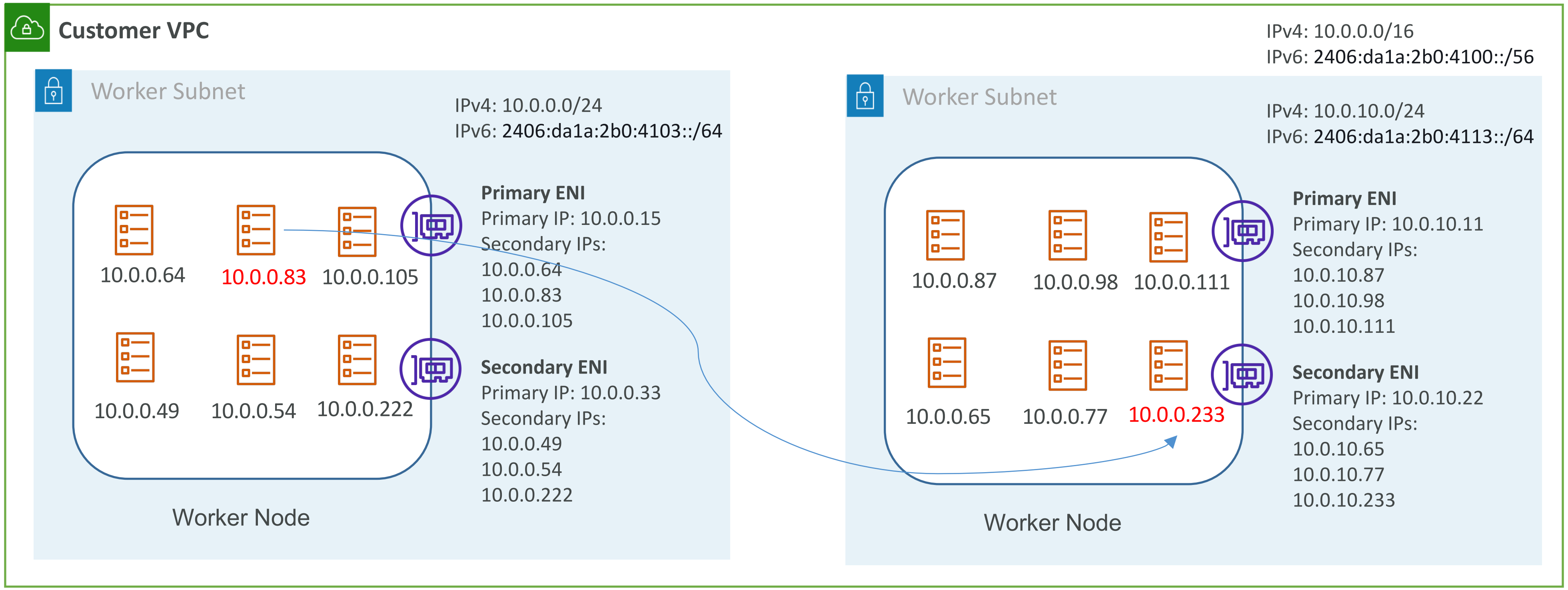
Pod to Pod communication



Pods within the same VPC can communicate directly using Pod IP address

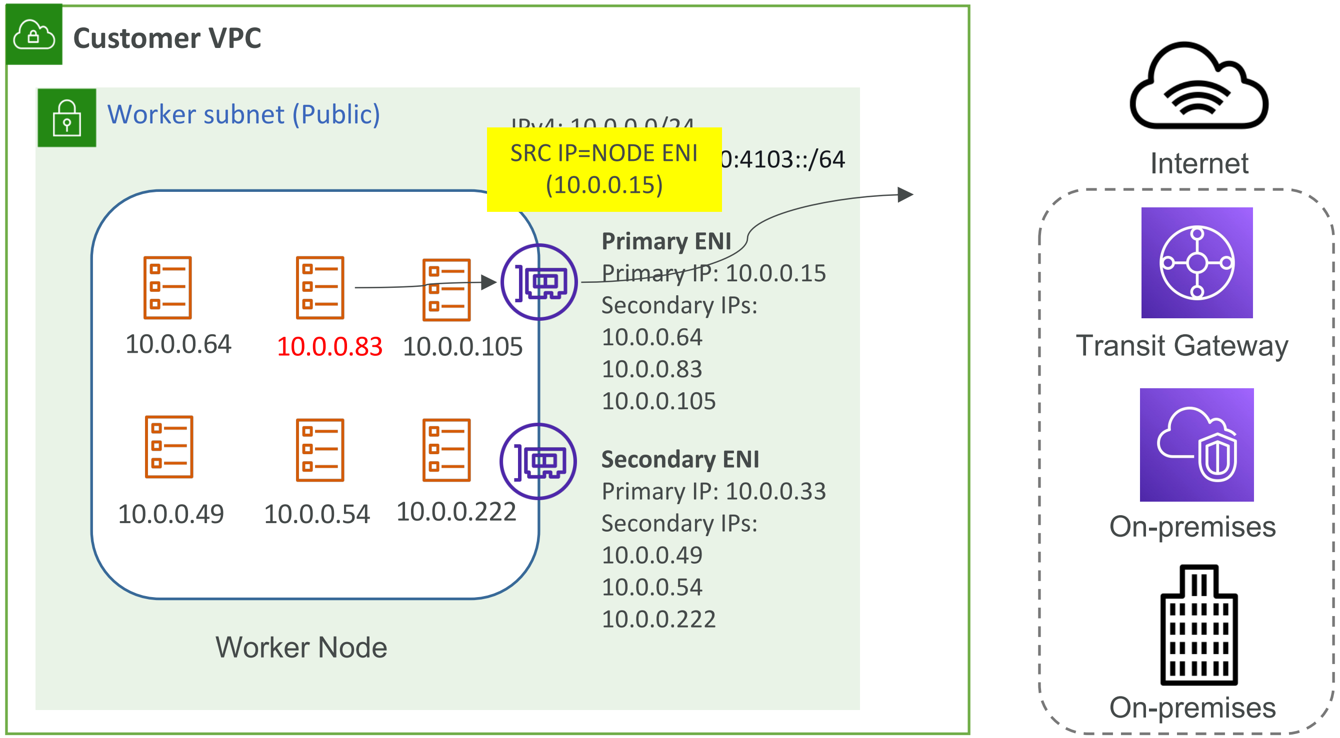
Amazon EKS Pod Networking – traffic between Pod and external network

Recap - Pod to Pod communication



Pods within the same VPC can communicate directly using Pod IP address

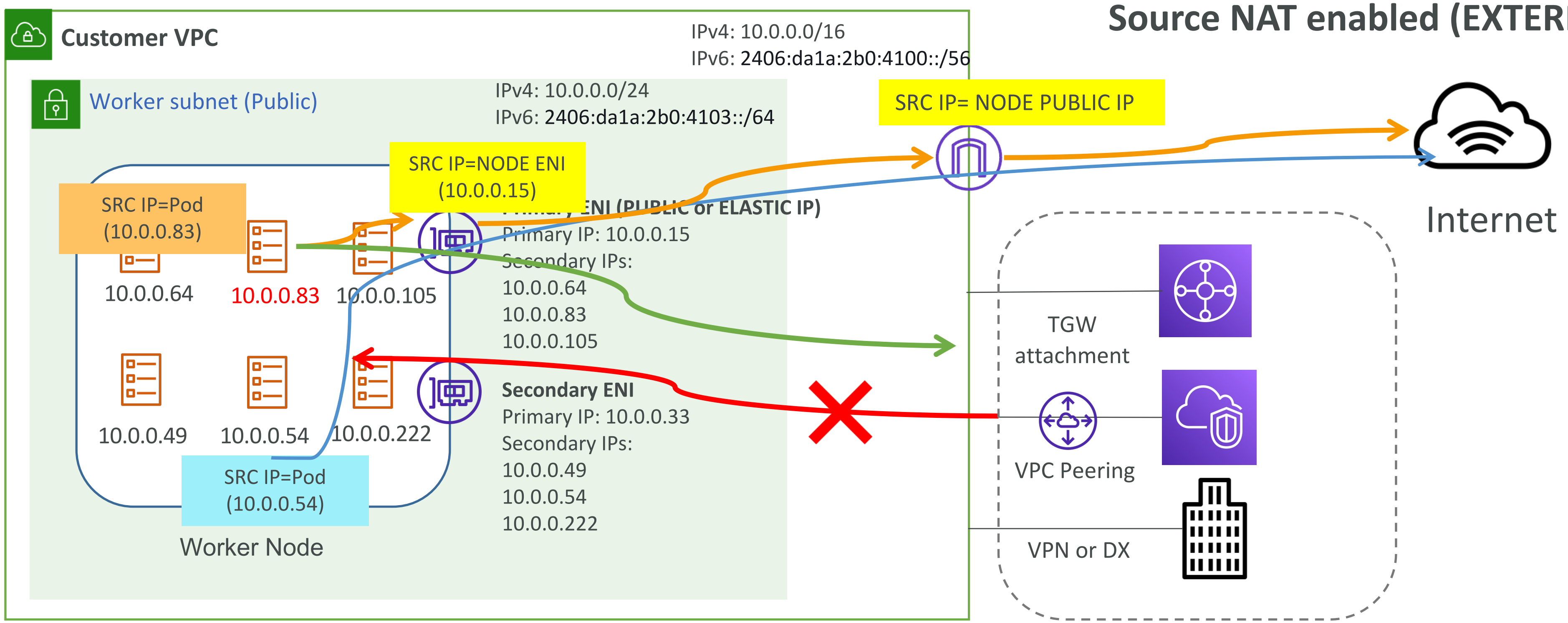
Pod to external network communication



- When a pod communicates to any IPv4 address that isn't within a CIDR block of VPC, the Amazon VPC CNI plugin translates the pod's IPv4 address to the **primary private IPv4 address of the primary ENI** of the node that the pod is running on
- For IPv6 address family, this isn't applicable, because IPv6 addresses are not network translated.

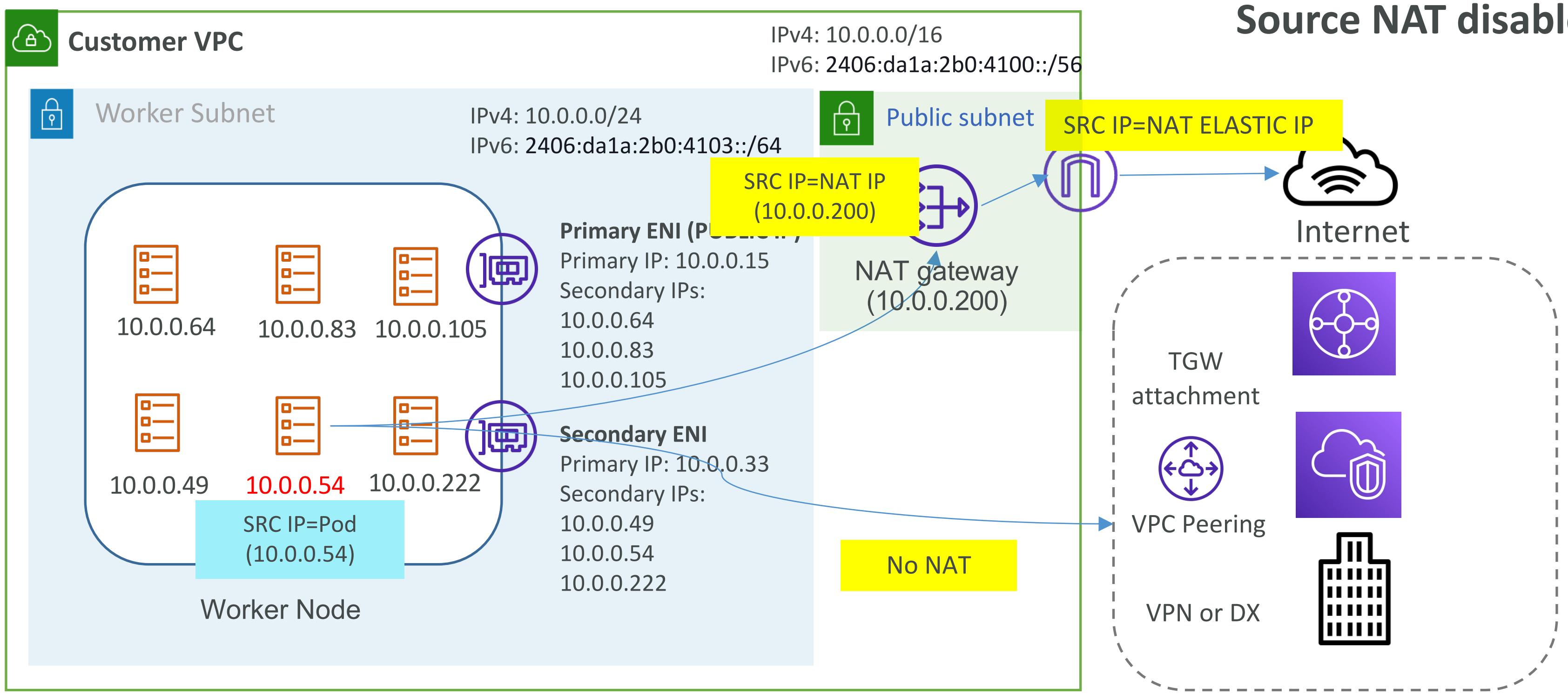
Pod to external network communication - Node in Public Subnet

Source NAT enabled (EXTERNALSNAT=false)



kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_EXTERNALSNAT=false

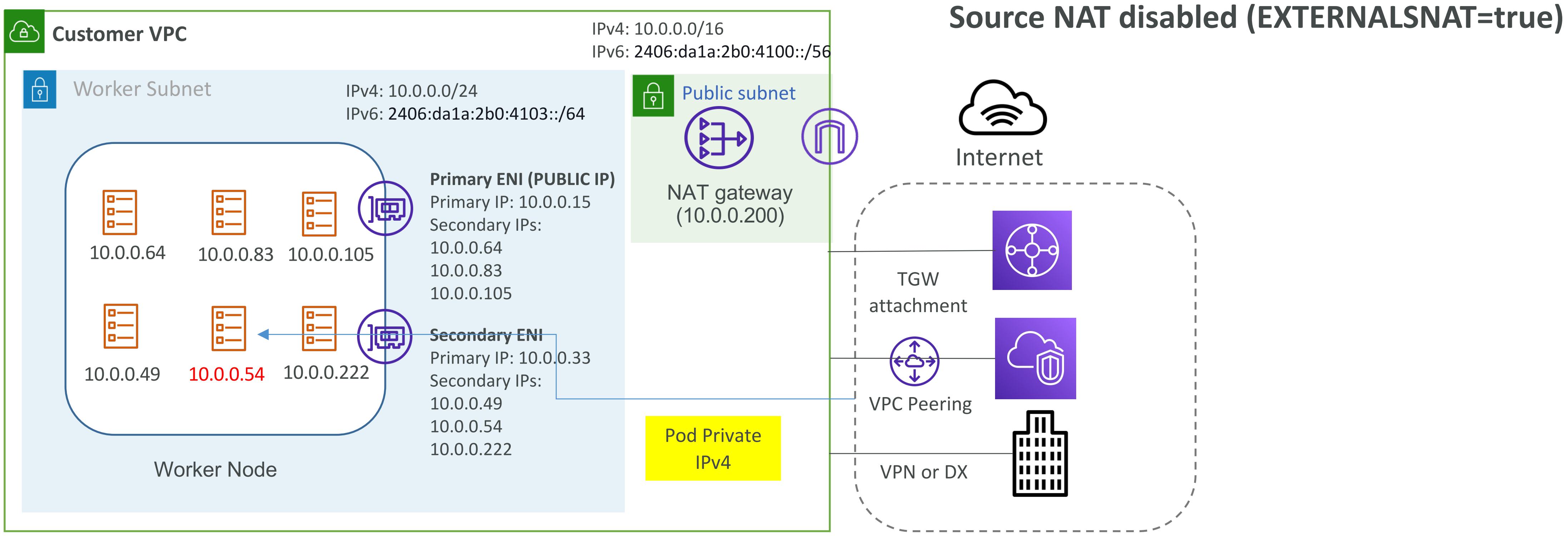
Pod to external network communication – Node in Private Subnet



Source NAT disabled (EXTERNALSNAT=true)

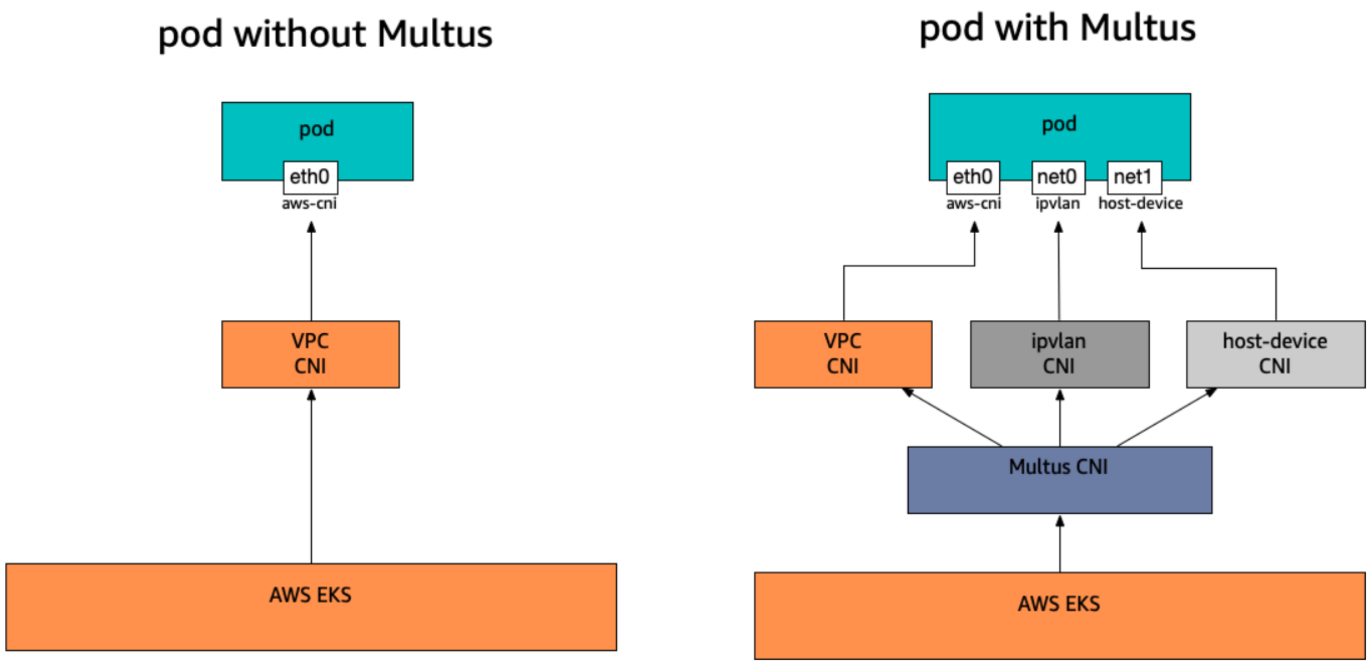
kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_EXTERNALSNAT=true

External network to Pod communication



kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_EXTERNALSNAT=true

Multi-homed Pods with **Multus CNI**



- Enables attaching multiple interfaces to pods
- With Multus, you can create a multi-homed pod that has multiple interfaces
- AWS support for Multus comes with VPC CNI

https://github.com/aws-samples/eks-install-guide-for-multus/blob/main/README.md

Security Groups in EKS

EKS Cluster Security group

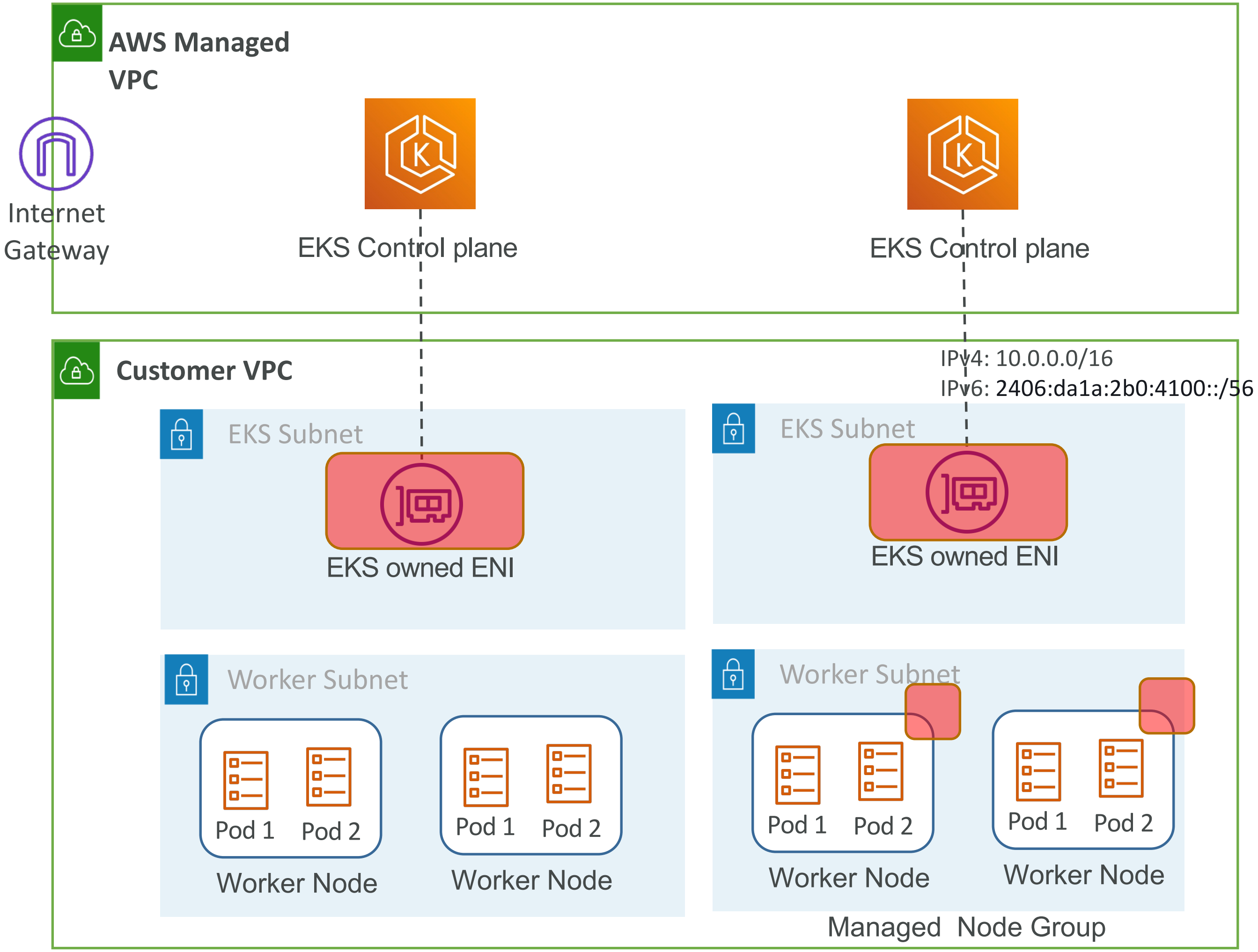
- When you create EKS Cluster, it creates and associates SG with following rules:

Rule type	Protocol	Ports	Source	Destination
Inbound	All	All	Self	
Outbound	All	All		0.0.0.0/0 (IPv4) or ::/0 (IPv6)

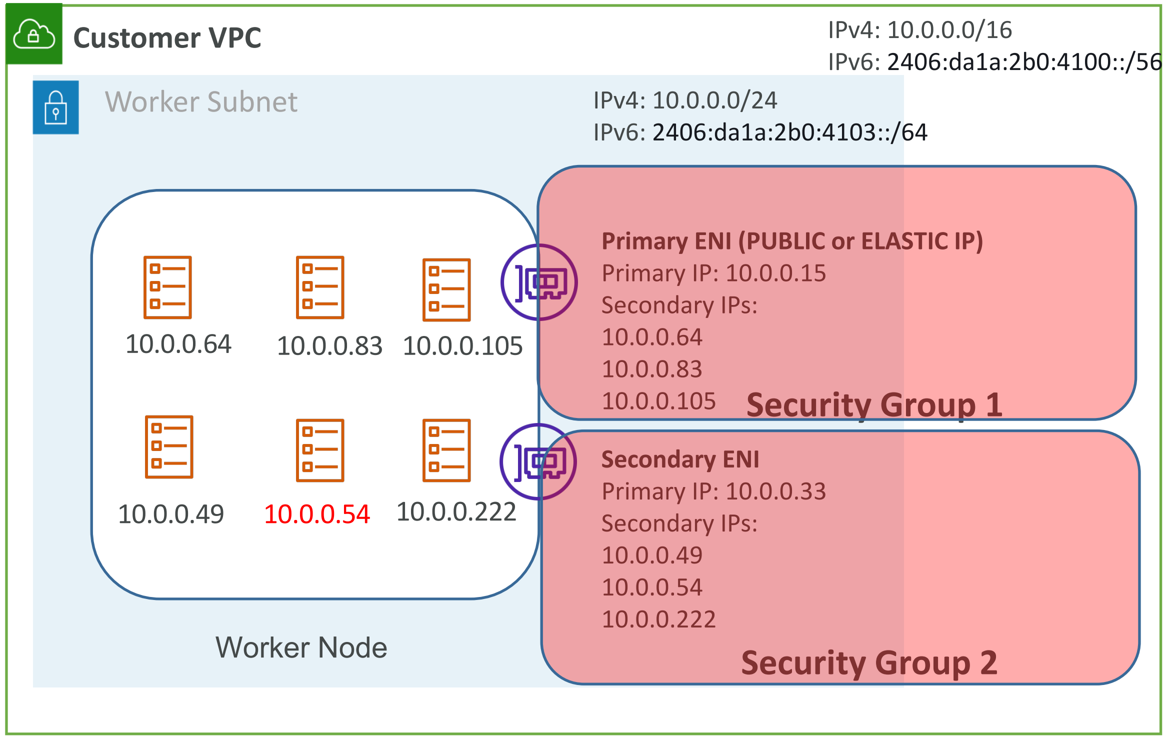
- EKS associates this SG with:
  - ENIs created by EKS in Customer VPC
  - ENIs of the nodes in Managed Node group

- At minimum following Outbound rules are required:

Rule type	Protocol	Port	Destination
Outbound	TCP	443	Cluster security group
Outbound	TCP	10250	Cluster security group
Outbound (DNS)	TCP and UDP	53	Cluster security group

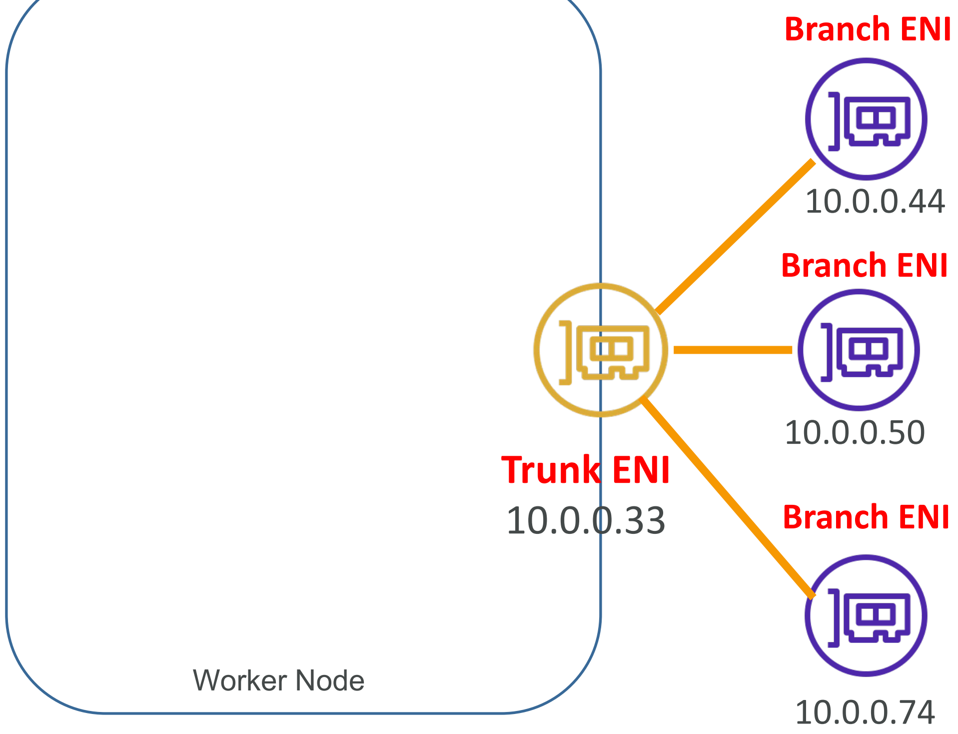


Pod Security groups – The problem



- SG is assigned to Node ENIs and hence all Pods having secondary IPs from the same ENI will use the same SG
- This is a drawback if you need different security groups for different Pods
- One of the option is to use Network policy engine like Calico which provides network security policies to restrict inter pod traffic using iptables
- EKS native option is to use Trunk and Branch ENIs

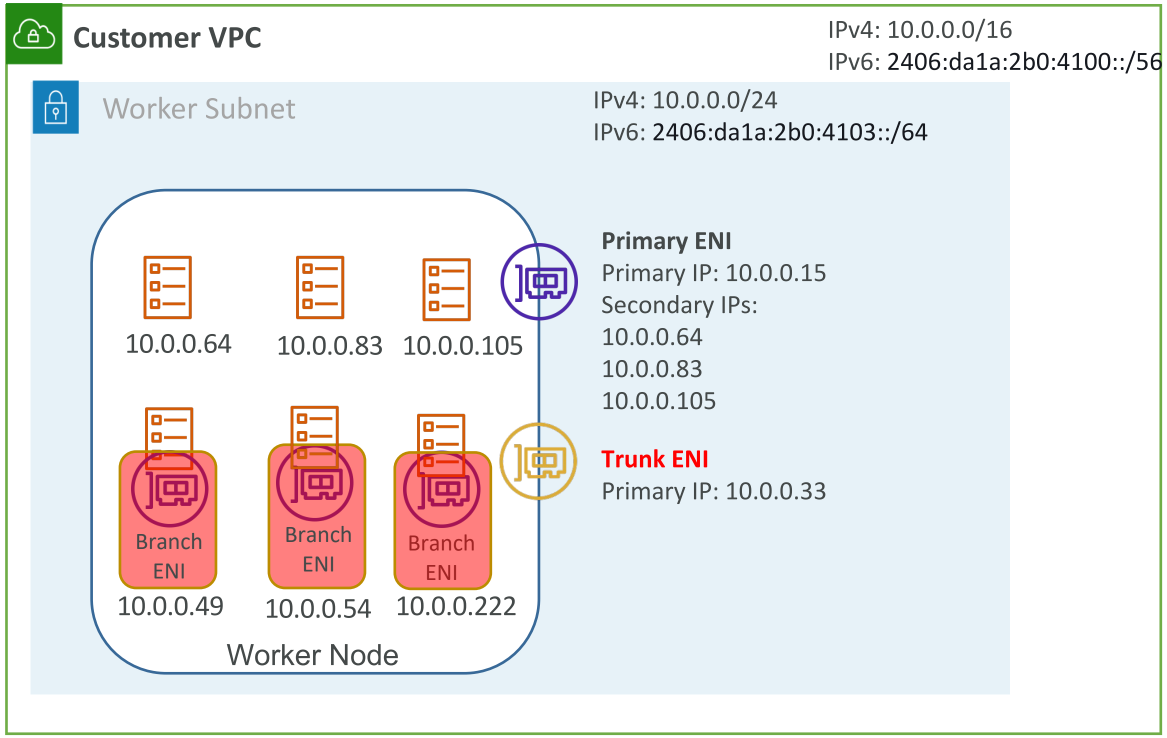
Pod Security groups – The solution Trunk and Branch ENIs



- Amazon EKS and ECS supports Trunk & Branch ENI feature
- A VPC resource controller add-on named "amazon-vpc-resource-controller-k8s" manages Trunk & Branch Network Interfaces
- When ENABLE_POD_ENI=true, VPC resource controller creates special network interface called a trunk network interface with description "aws-k8s-trunk-eni" and attaches it to the node
- The controller also creates branch interfaces with description "aws-k8s-branch-eni" and associates them with the trunk interface.

```
kubectl set env daemonset aws-node -n kube-system
ENABLE_POD_ENI=true
```

Pod Security groups – The solution Trunk and Branch ENIs



- Each Pod gets dedicated ENI (branch ENI) mapped to trunk ENI
- Independent Security group per Pod

Note

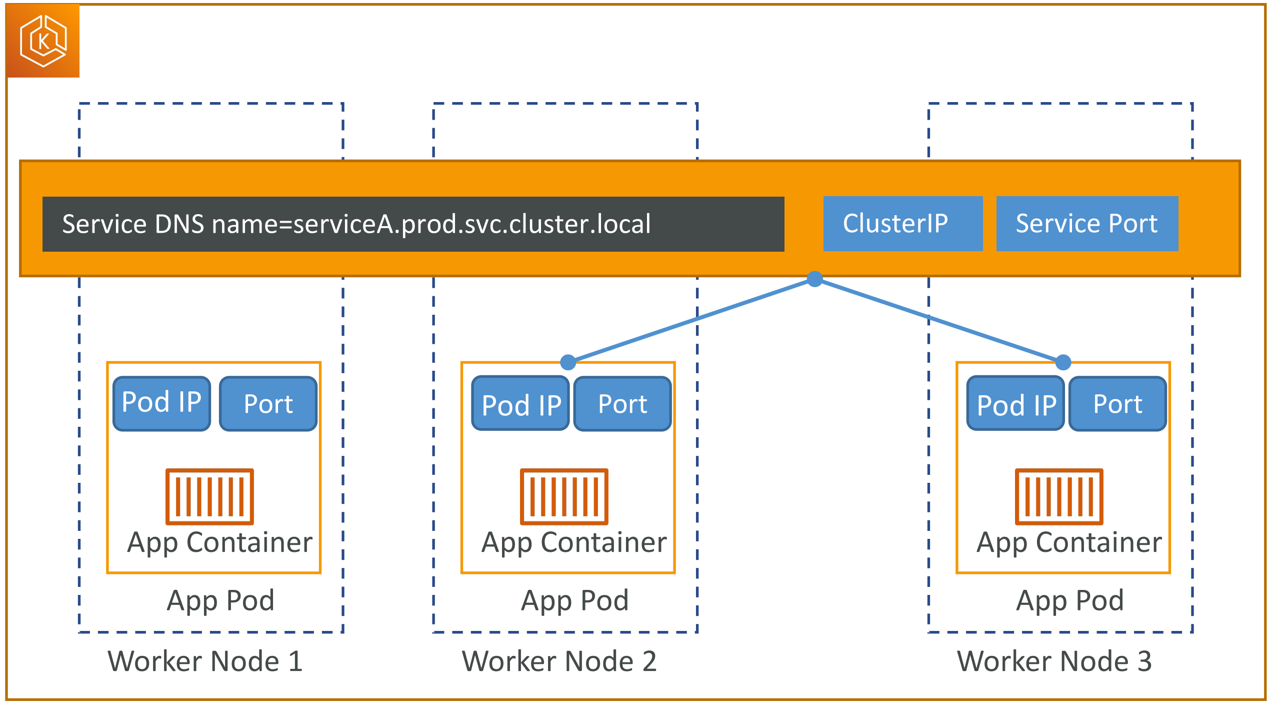
- Security groups for pods can't be used with Windows nodes
- If cluster is using IPv6 address family then this feature only works with Fargate nodes
- Supported by most Nitro based system (t instance family is not supported)
- The Node instances should be listed in limits.go file with IsTrunkingCompatible: true

Exposing EKS services

Kubernetes Service

- Accessing applications by their Pod's IPs is usually an anti-pattern because
  - Pods are non-permanent objects
  - Pods may be created and destroyed
  - Pods move between the cluster's nodes due to a scaling event, a node replacement, or a configuration change.
- Kubernetes Service is a way to expose an application running on a set of Pods as a network service
- Kubernetes & EKS Supports following Service Types:
  - ClusterIP (access services from inside EKS cluster using Virtual IP)
  - NodePort (access services externally using Node static port)
  - LoadBalancer (Network load balancing, access services externally using CLB/NLB Layer4)
  - Ingress (Application load balancing, access services externally using ALB Layer7)

ClusterIP

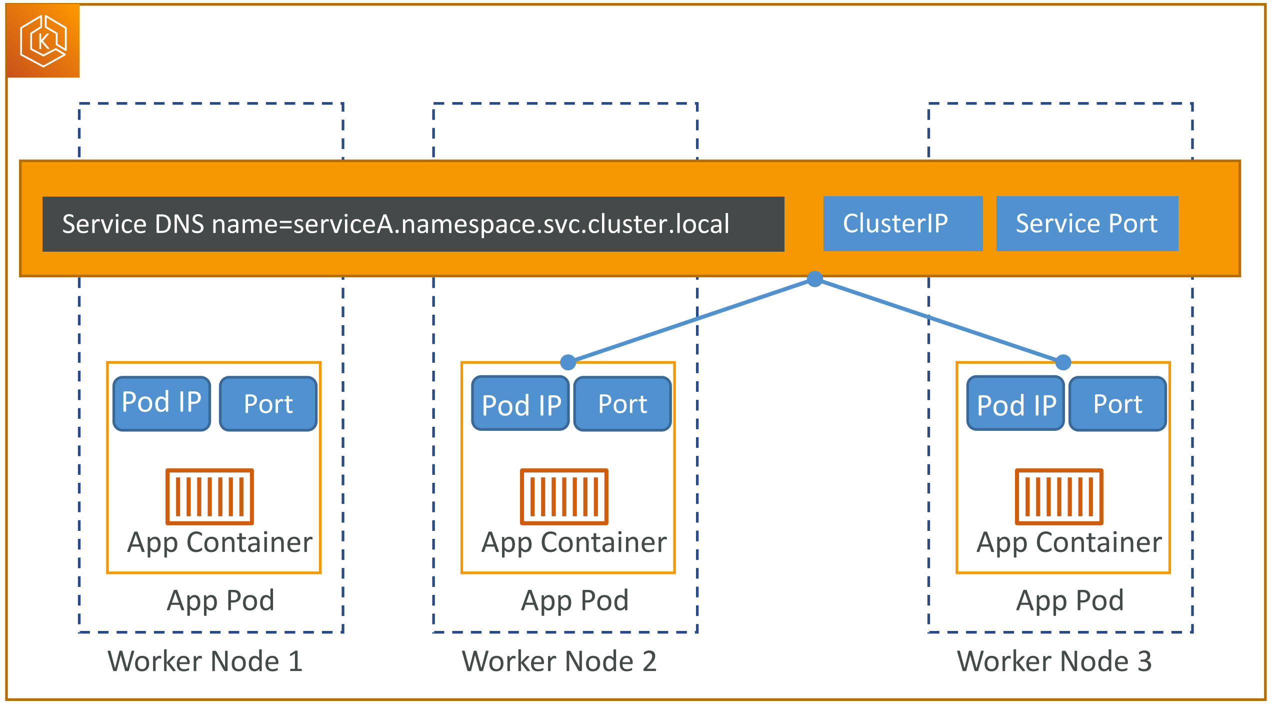


- ClusterIP is the default service type
- Makes the service reachable/accessible **only from within the cluster**
- Service is exposed on a virtual IP on each node. This IP is not exposed outside of a cluster.
- The service virtual IP is assigned from a pool which is configured by setting following parameter in kube-apiserver:

    --service-cluster-ip-range

- If not configured explicitly then Amazon EKS provisions either 10.100.0.0/16 or 172.20.0.0/16 for this Virtual IP.
- A kube-proxy daemon on each cluster node defines the ClusterIP to Pod IP mapping in iptables rules
- Service is accessible with private DNS <service-name>.<namespace-name>.svc.cluster.local

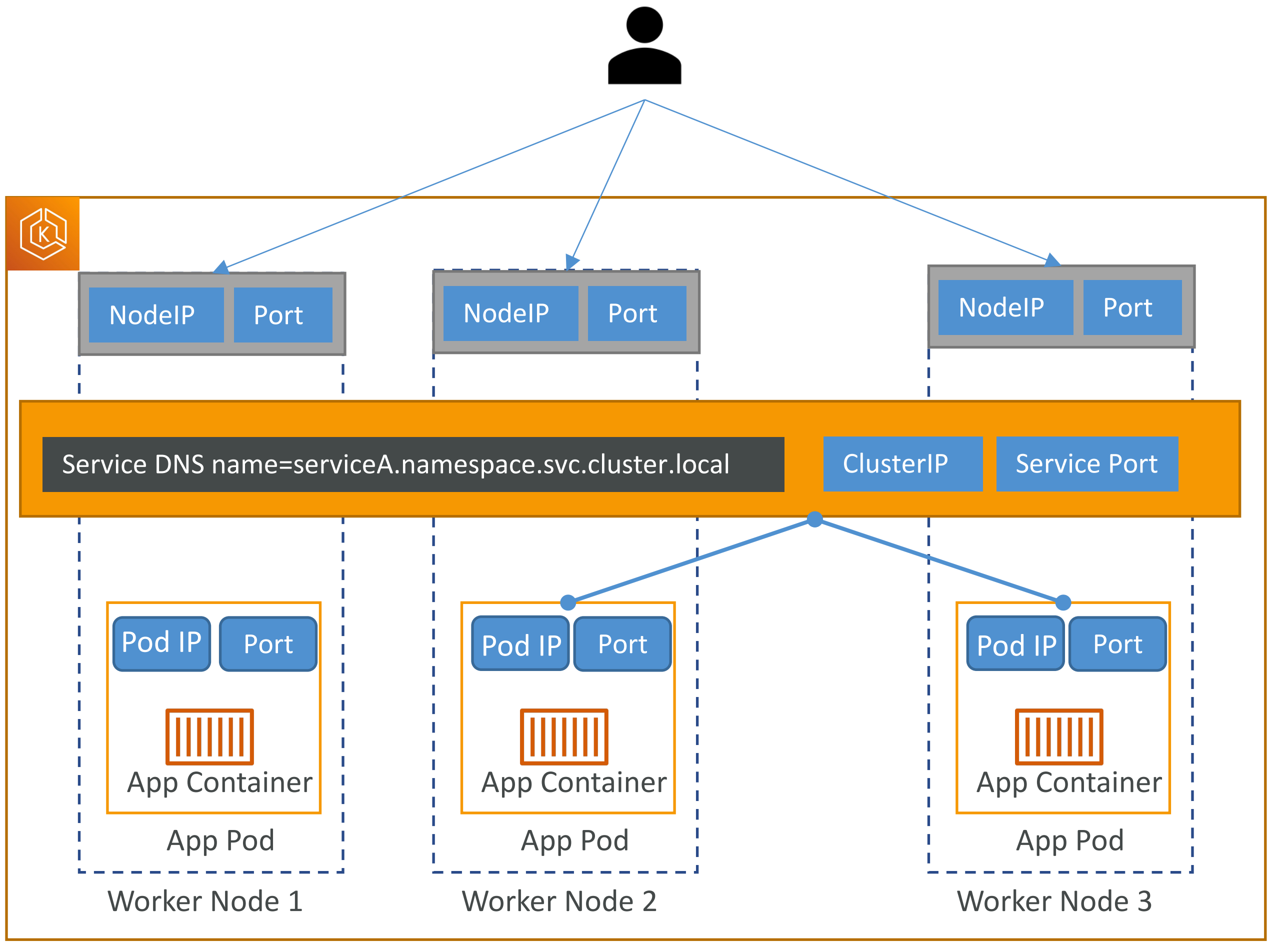
ClusterIP



YAML

```yaml
apiVersion: v1
kind: Service
metadata:
  name: some-service
  namespace: some-namespace
spec:
  type: ClusterIP
  selector:
    app.kubernetes.io/name: some-app
  ports:
    - name: svc-port
      port: 80
      targetPort: app-port
      protocol: TCP
---
apiVersion: apps/v1
kind: Deployment
metadata:
  name: some-deployment
  namespace: some-namespace
spec:
  replicas: 1
  selector:
    matchLabels:
      app.kubernetes.io/name: some-app
  template:
    metadata:
      labels:
        app.kubernetes.io/name: some-app
    spec:
      containers:
        - name: nginx
          image: public.ecr.aws/nginx/nginx
          ports:
            - name: app-port
              containerPort: 80
```

NodePort

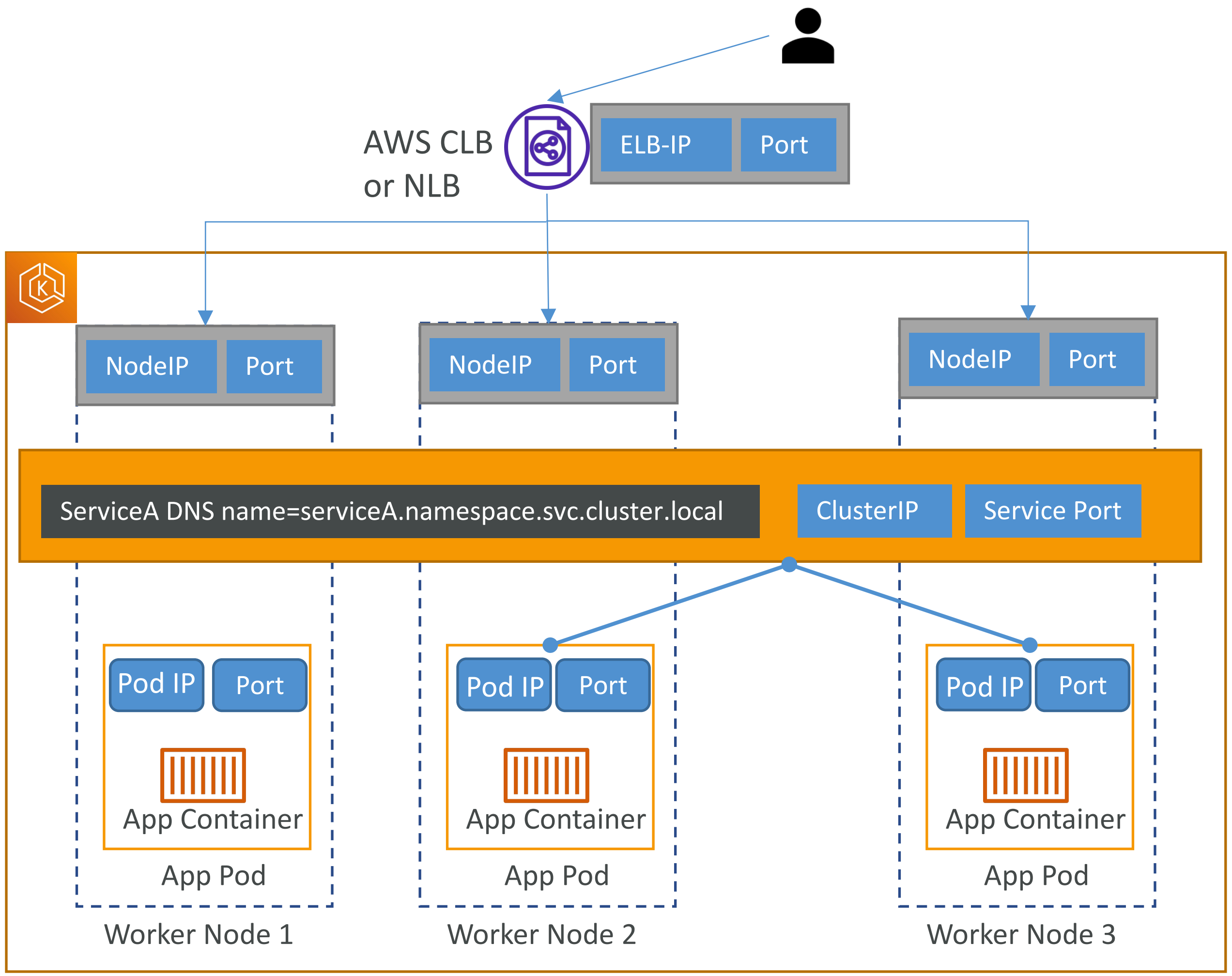


- NodePort is used to make a Kubernetes service accessible from outside the cluster
- Exposes the service on each worker node's IP at a static port, called the NodePort
- One Node port per Service
- Port range: 30000-32767
- NodePort internally uses ClusterIP to route the NodeIP/Port requests to ClusterIP service
- Client needs to keep track of Node IPs and any IP changes over the time
- Not a feasible option to expose services to the outside world

EKS Network & Application Load Balancing

- ServiceType=LoadBalancer
  - Handled by Kubernetes Controller Manager (in-tree cloud controller)
  - Deploys AWS CLB (default) or NLB in instance mode
  - Layer 4 with NLB and Layer 4/7 with CLB
  - Now also supported by newer controller called AWS Load Balancer Controller
- ServiceType=Ingress
  - Handed by AWS Load Balancer Controller (formerly AWS ALB Ingress controller)
  - Deploys ALB in Instance & IP mode for ingress resource
  - Layer 7

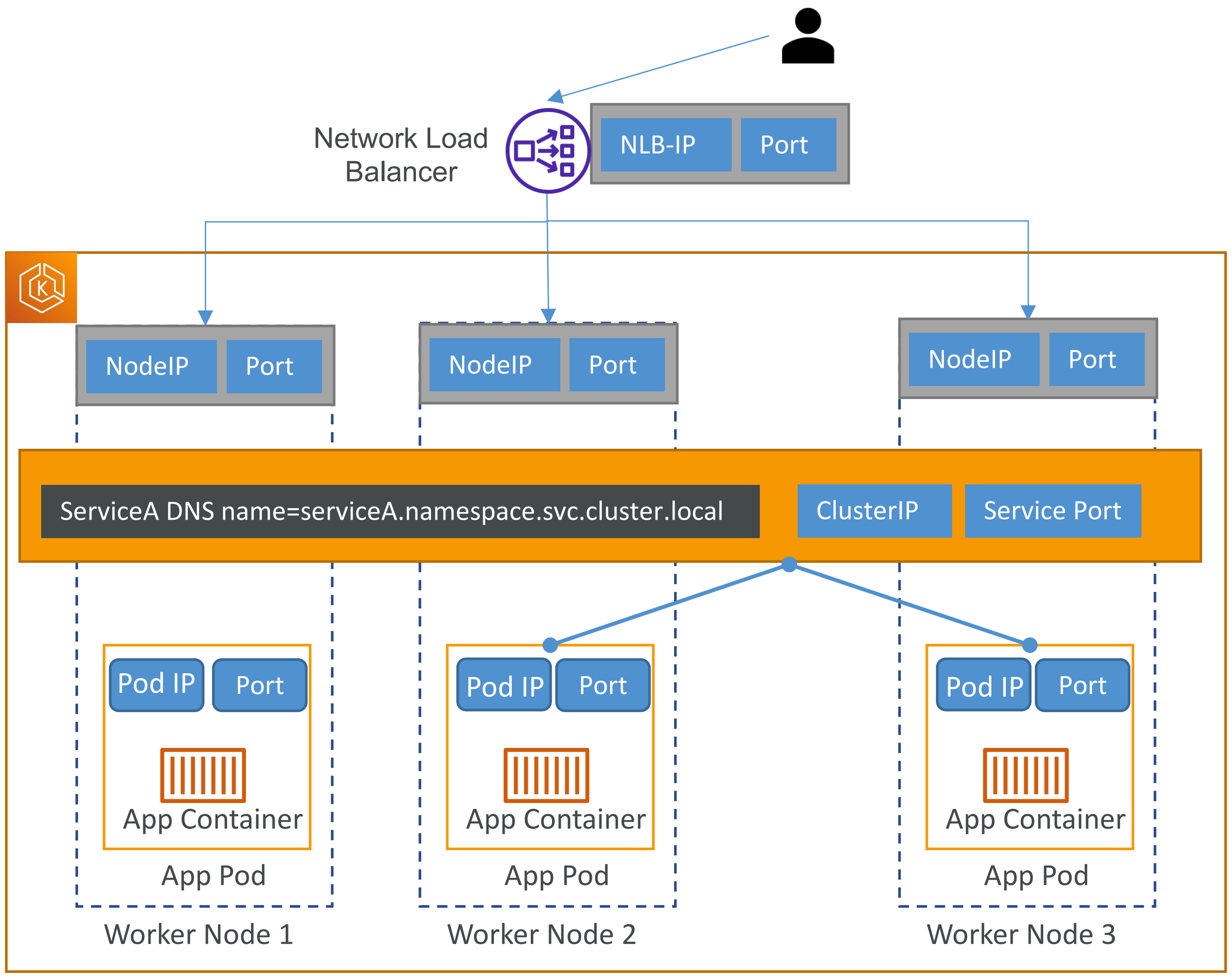
LoadBalancer Service (with legacy controller)



- Exposes services to the client outside of the cluster
- LoadBalancer service is built on top of NodePort service
- Supports:
  - Classic Load Balancer (CLB)
    - Layer 4/Layer 7 traffic (TCP, SSL/TLS, HTTP, HTTPS)
  - Network Load Balancer (NLB)
    - Layer4 traffic (TCP, UDP, TLS)
    - Instance mode only

Legacy controller

LoadBalancer Service (with newer controller)



- Recommended to use **AWS Load Balancer Controller**
- For target as IP (for EC2 or Fargate) use:

```
service.beta.kubernetes.io/aws-load-balancer-type: "external"
service.beta.kubernetes.io/aws-load-balancer-nlb-target-type: "ip"
```

- For target as Instance (for EC2) use:

```
service.beta.kubernetes.io/aws-load-balancer-type: "external"
service.beta.kubernetes.io/aws-load-balancer-nlb-target-type: "instance"
```

- Each service needs a dedicated NLB
- Scaling & management is a challenge when number of services grows

Kubernetes Ingress

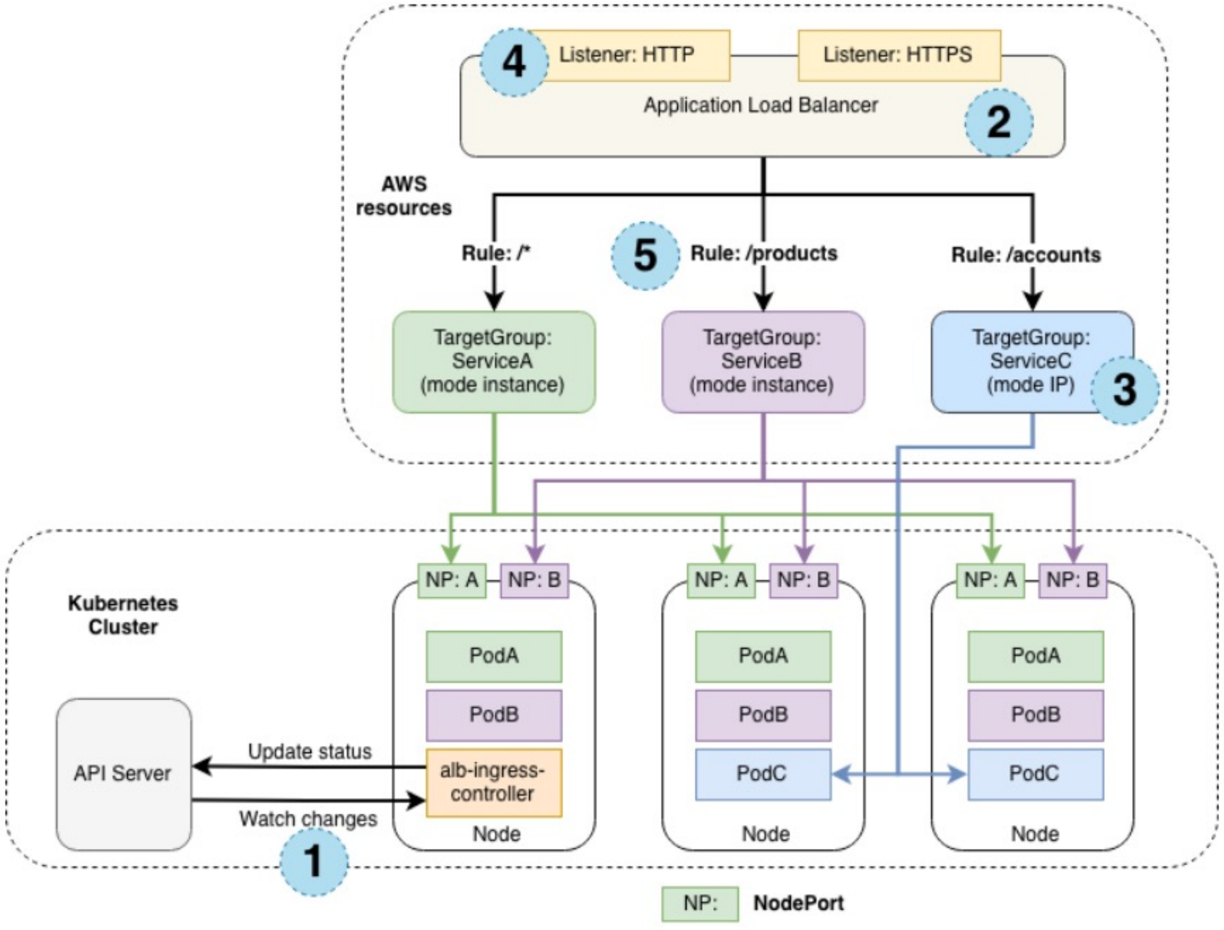


Diagram: https://kubernetes-sigs.github.io/aws-load-balancer-controller/v2.4/how-it-works/

- Exposes services to the client outside of the cluster
- Ingress exposes HTTP and HTTPS routes from outside the cluster to services within the cluster.
- Traffic routing is controlled by rules defined on the Ingress resource.
- Saves cost and complexity as multiple services can be added behind a single ALB using ALB target groups.
- EKS uses **AWS Load Balancer Controller** for provisioning load balancer resources

AWS Load Balancer Controller

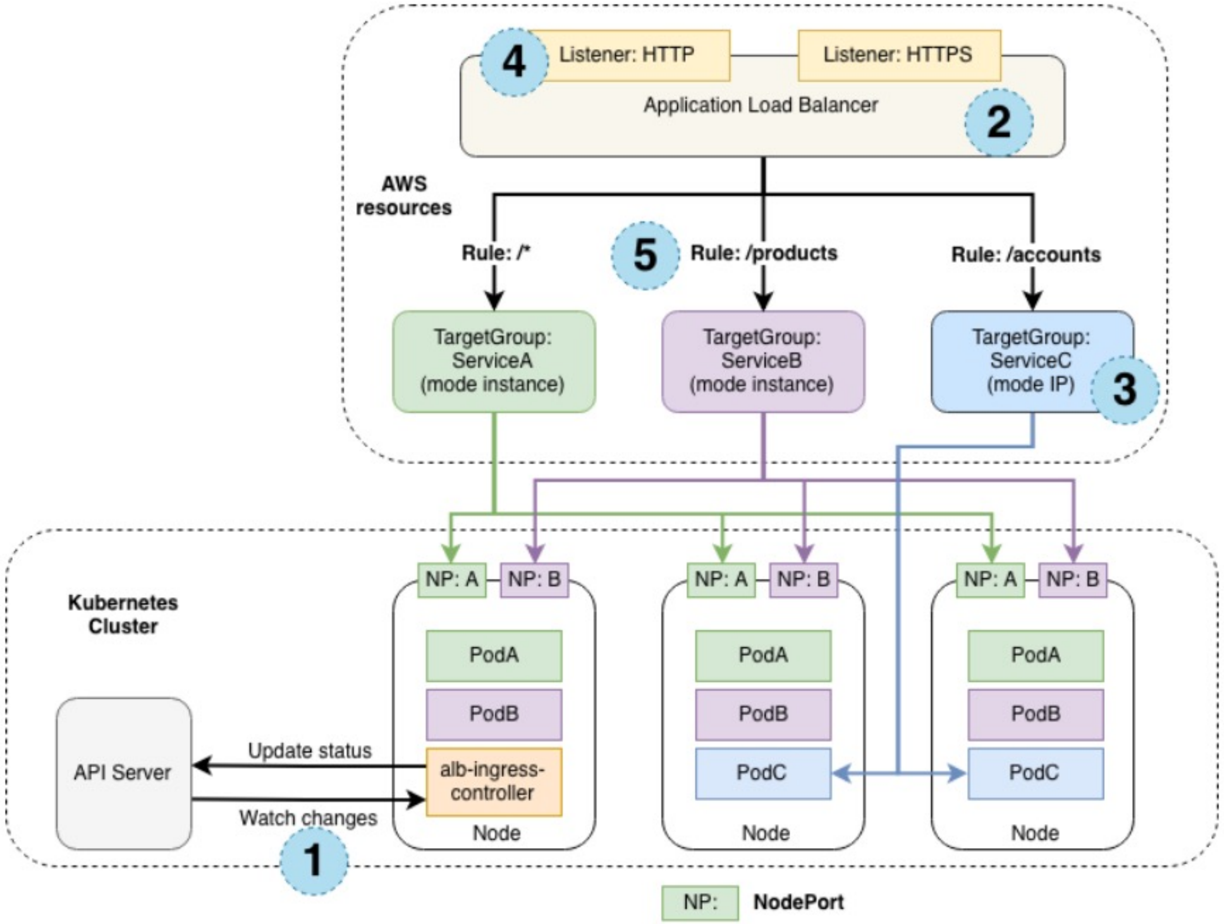


Diagram: https://kubernetes-sigs.github.io/aws-load-balancer-controller/v2.4/how-it-works/

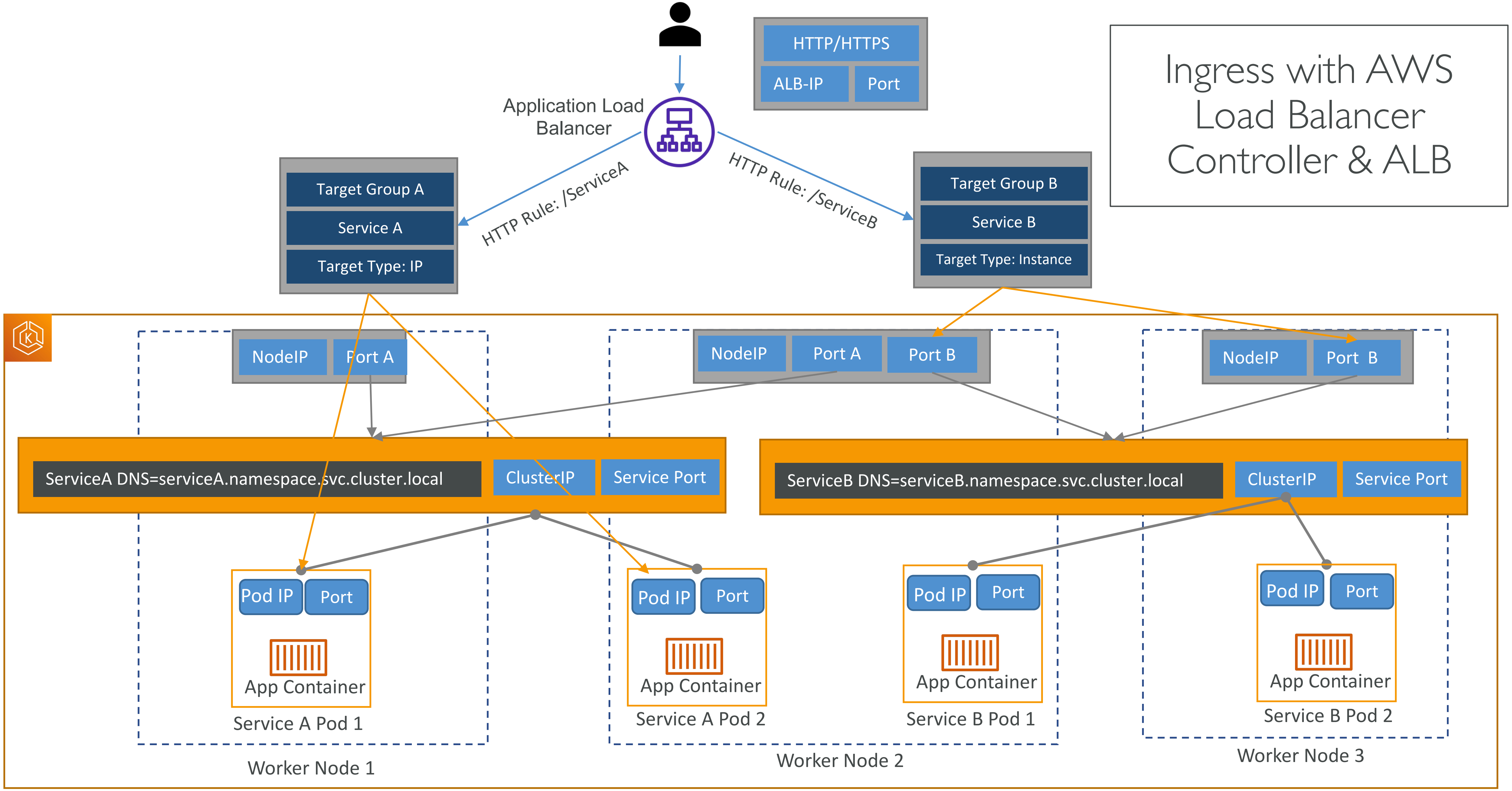
- The AWS implementation for Ingress controller
- Translates the Ingress rules, parameters, and annotations into the ALB configuration, creating listeners and target groups and connecting their targets to the backend Services.
- Supports target as Instance or Pod IP.
- Annotation used:

  `kubernetes.io/ingress.class: alb`
- Share ALB with multiple services by using annotation:

  `alb.ingress.kubernetes.io/group.name: my-group`
- Traffic for IPv6 is supported for IP targets only. Use annotation:

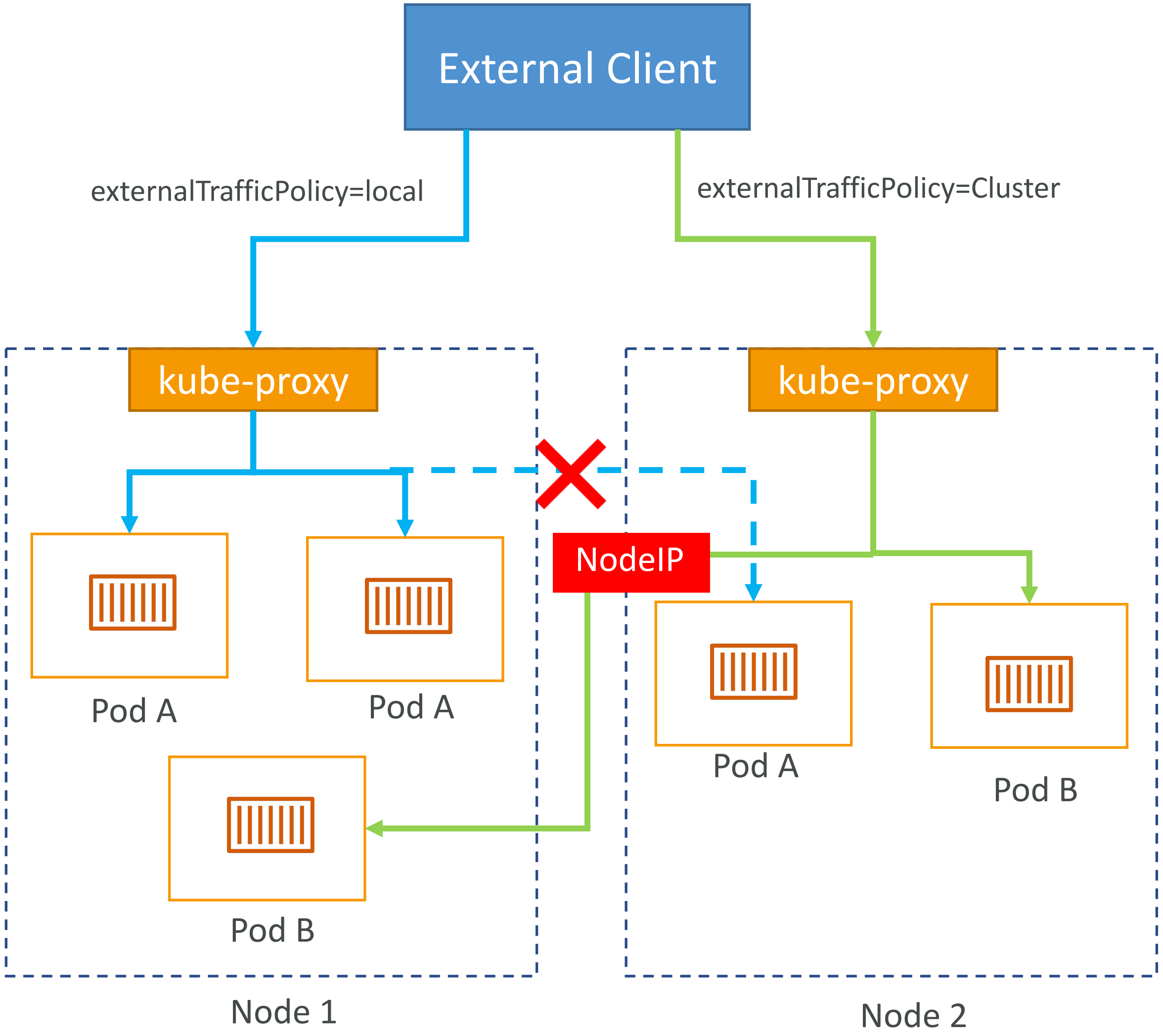
  `alb.ingress.kubernetes.io/ip-address-type: dualstack`

Ingress with AWS Load Balancer Controller & ALB



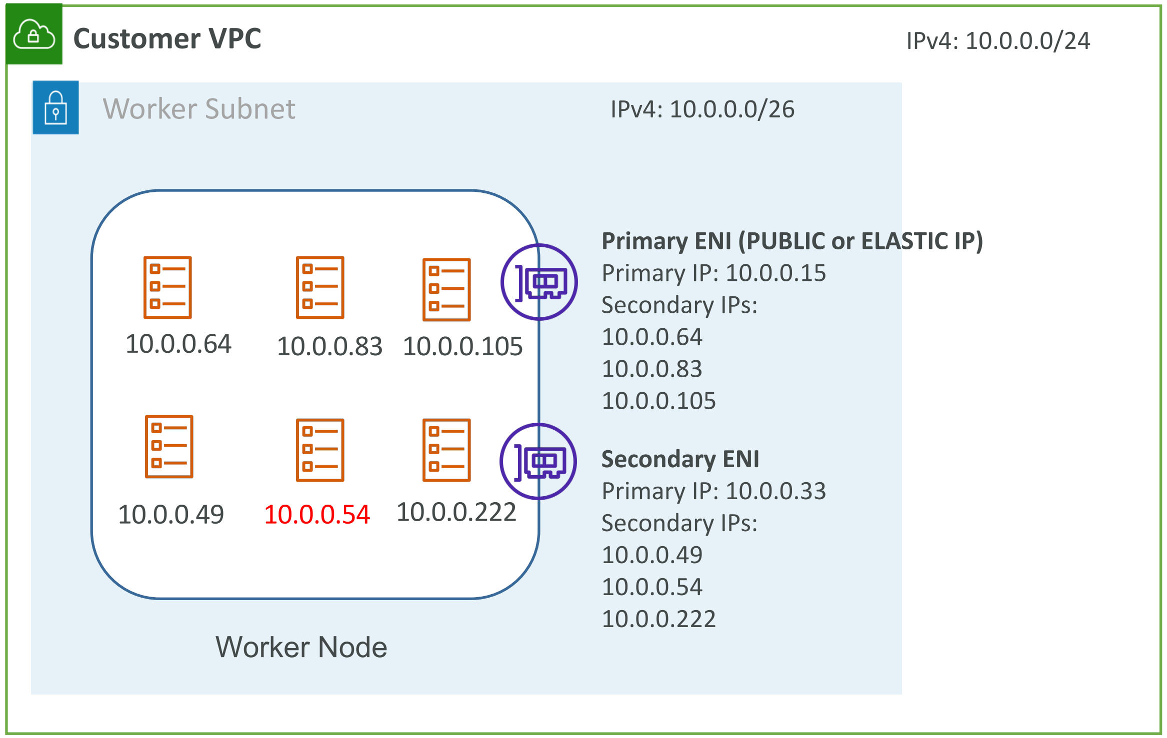
Preserving Client IP

- For NLB with LoadBalancer service:
  - **externalTrafficPolicy** service spec defines how load-balancing happens in the cluster.
  - If **externalTrafficPolicy=Cluster**, the traffic may be sent to another node and source IP is changed to node's IP address thereby Client IP is not preserved. However load is evenly spread across the nodes.
  - By setting **externalTrafficPolicy=Local**, traffic is not routed outside of the node and client IP addresses is propagated to the end Pods. This could result in uneven distribution of traffic.
- For ALB Ingress service:
  - HTTP header X-Forwarded-For is used to get the Client IP.



EKS Custom Networking

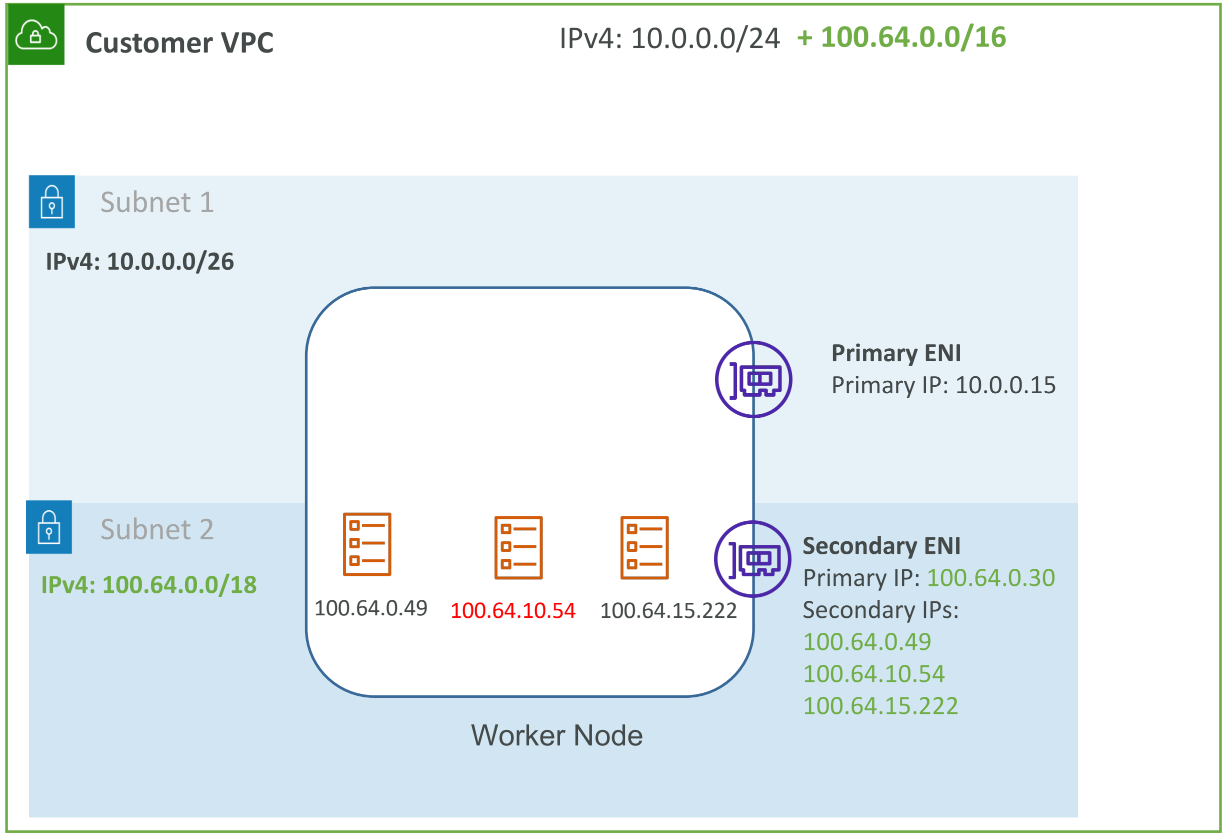
Pod Network – Custom networking (IPv4)



Problem

- If you have limited IP space, it will constraint the number of Pods
- /24 CIDR will have 251 unique IPv4 addresses

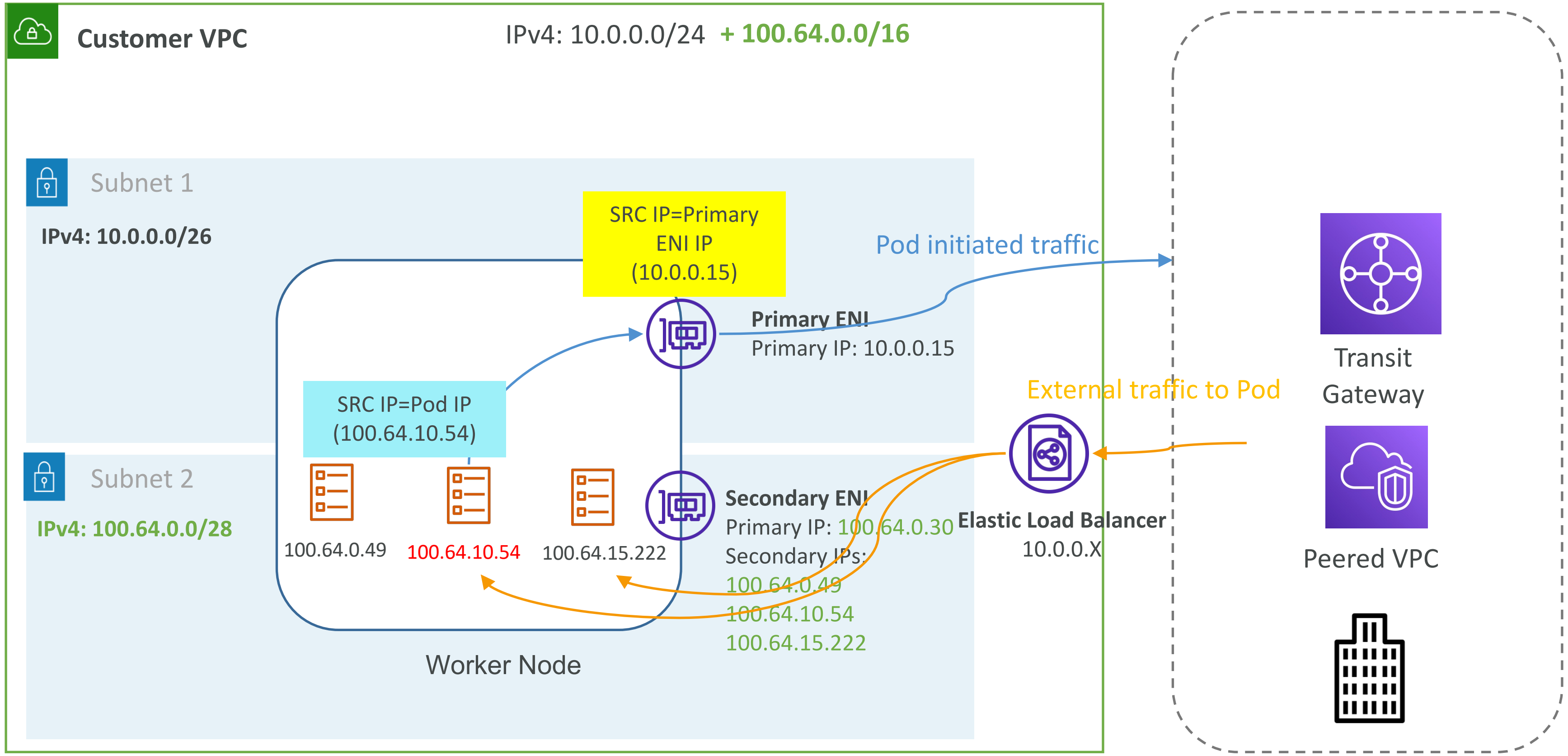
Pod Network – Custom networking



- Add Secondary VPC CIDR in the range 100.64.0.0/16 (~65000 IPs) to the VPC
- This CIDR IP addresses are routable only within the VPC
- Enable VPC CNI Custom Networking
- VPC CNI plugin creates Secondary ENI in the separate subnet
- Only IPs from Secondary ENI are assigned to Pods
- Custom Networking can be combined with SNAT

kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_CUSTOM_NETWORK_CFG=true
kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_EXTERNALSNAT=false

Pod Network – Custom networking



kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_CUSTOM_NETWORK_CFG=true
kubectl set env daemonset aws-node -n kube-system AWS_VPC_K8S_CNI_EXTERNALSNAT=false

EKS Networking Summary

EKS Networking Summary

- EKS control plane is launched in AWS managed VPC and EKS data plane (worker nodes) is launched in customer VPC.
- EKS provisions ENIs into customer VPC to enable communication between EKS control plane and data plane
- EKS cluster API endpoint is publicly accessible by default but can be configured as a private in which case it can be accessed from customer VPC via the EKS owned ENI
- EKS uses Amazon VPC Container Network Interface (CNI) plugin for Pod networking.
- CNI allocates IPs to each Pod from available **Secondary IPs**
- Maximum number of Pods per node depends on number of ENIs and number of IP addresses per ENI
- For supported Nitro based instance types, Pod per node limit can be increased using Prefix delegation (/28 for IPv4 and /80 for IPv6)
- Custom Networking enables associating secondary VPC CIDR (100.64.0.0/16) and when combined with SNAT enables much larger IPv4 private IPs for Pods.
- CNI allows Nodes to enable/disable SNAT to allow outbound internet access to Pods through the Internet gateway or NAT gateway respectively.

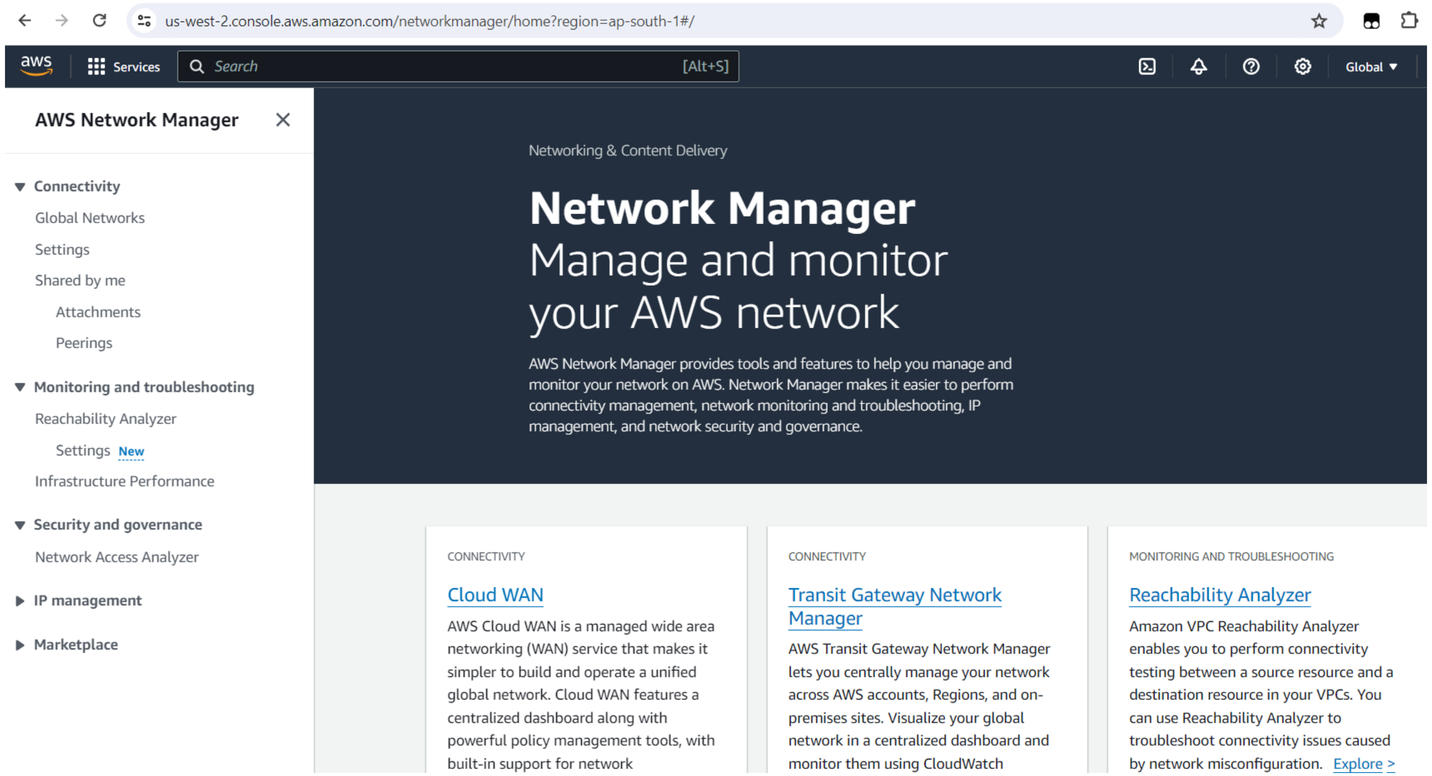
EKS Networking Summary

- By default, ENI security group is assigned to all the Pods which have been allocated secondary IPs for that ENI
- Pods specific security group can be assigned using Trunk & Branch ENI feature for selected Nitro system based instances.
- Pod services can be configured using ClusterIP, NodePort, LoadBalancer and Ingress resources.
- ClusterIP allows accessing services from within the cluster only.
- NodePort allows accessing services externally using Node IP and static port
- LoadBalancer service can be configured to use CLB or NLB in instance mode.
- Ingress service can be configured to use ALB in instance or IP mode.
- AWS Load Balancer Controller can be used for LoadBalancer (with NLB IP mode) and Ingress service (with ALB) configurations.
- externalTrafficPolicy=Local allows NLB in instance mode to preserve client IP address by disabling kube-proxy to send traffic to other nodes.

Management & Governance

AWS Network Manager

- Connectivity
  - Global Networks
  - Cloud WAN
- Monitoring & troubleshooting
  - Reachability Analyzer
- Security & Governance
  - Network Access Analyzer
- IP Management – IPAM



AWS Management & Governance services

AWS Organizations

AWS Control Tower

AWS Personal Health Dashboard

AWS Cost & Usage Report

AWS OpsWorks

AWS Systems Manager

AWS CloudFormation

AWS Service Catalog

AWS Config

AWS CloudTrail

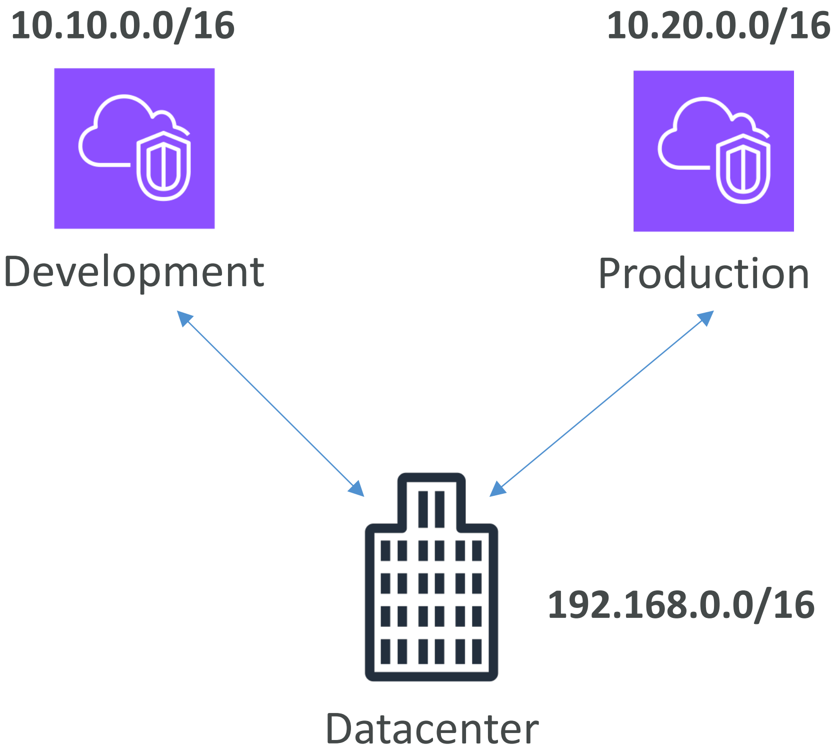
Amazon CloudWatch

IPAM – IP Address Management

Amazon VPC IP Address Management (IPAM)

- What's the problem with managing IP addresses?
- Amazon VPC IP Address Management (IPAM)
- IPAM Pools and rules
- Quick walkthrough – How it works
- Tracking & Monitoring IP addresses with IPAM
- Summary

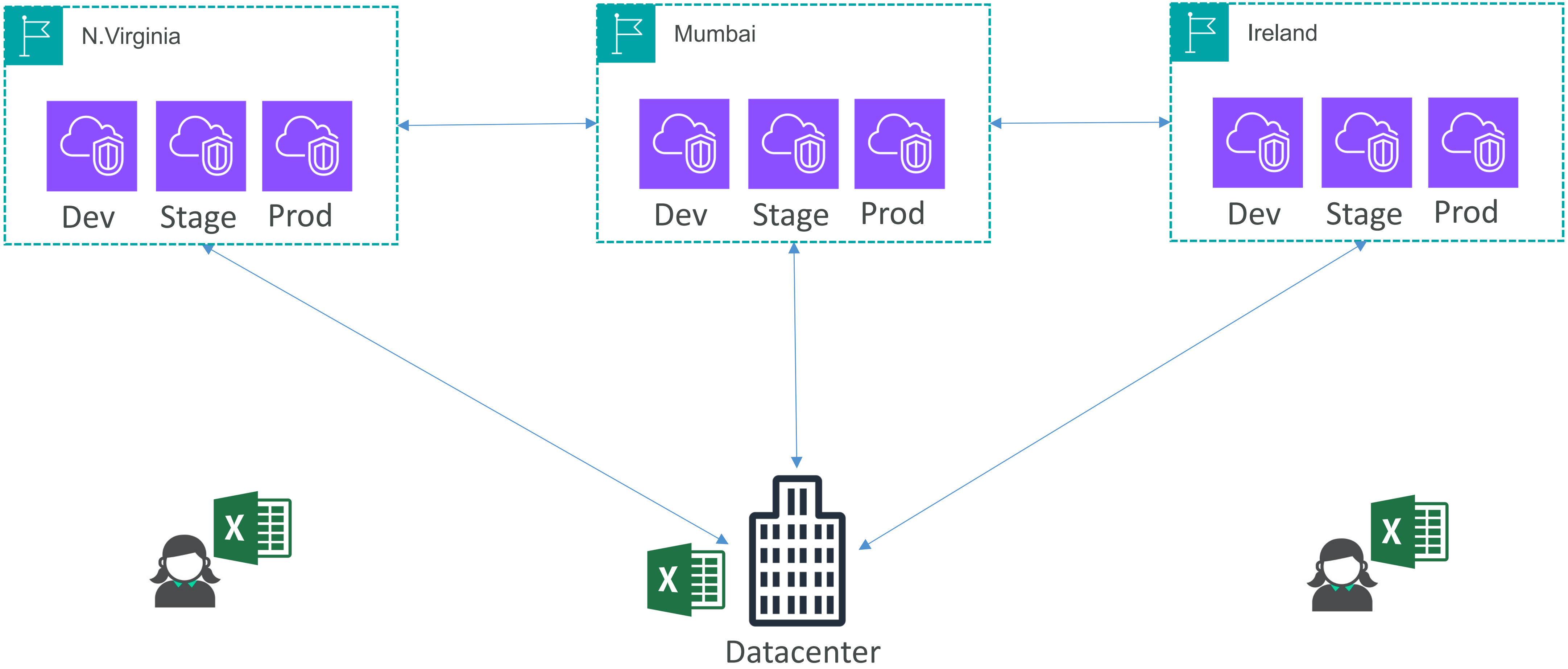
In the beginning..



- Allocate CIDRs to VPCs
- Set up Route tables
- Set up Security groups
- Set up VPN connection
- Set up VPC peering etc.

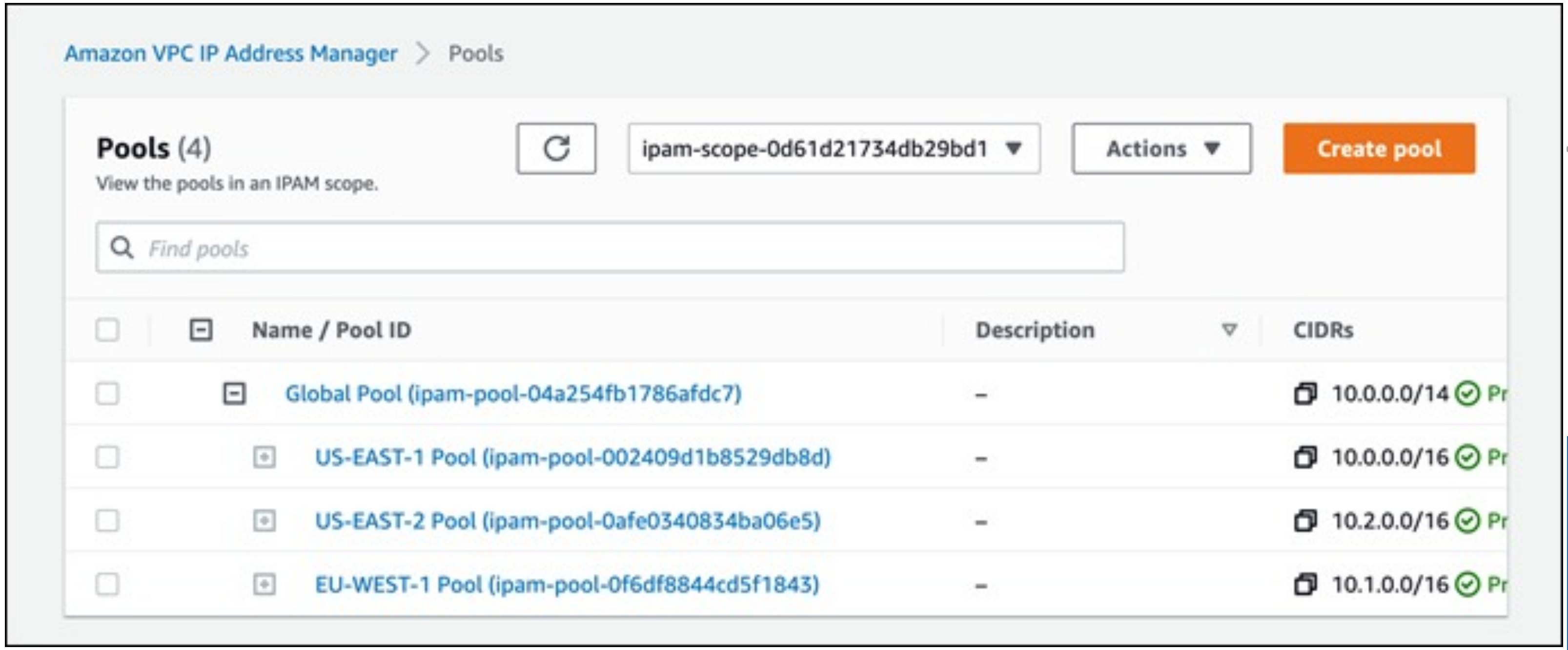
Region N.Virginia (us-east-1)
    Development x.x.x.x
    Production x.x.x.x
    Testing x.x.x.x
Region Mumbai (ap-south-1)
    Development x.x.x.x
    Production x.x.x.x
    Testing x.x.x.x

Over the time..

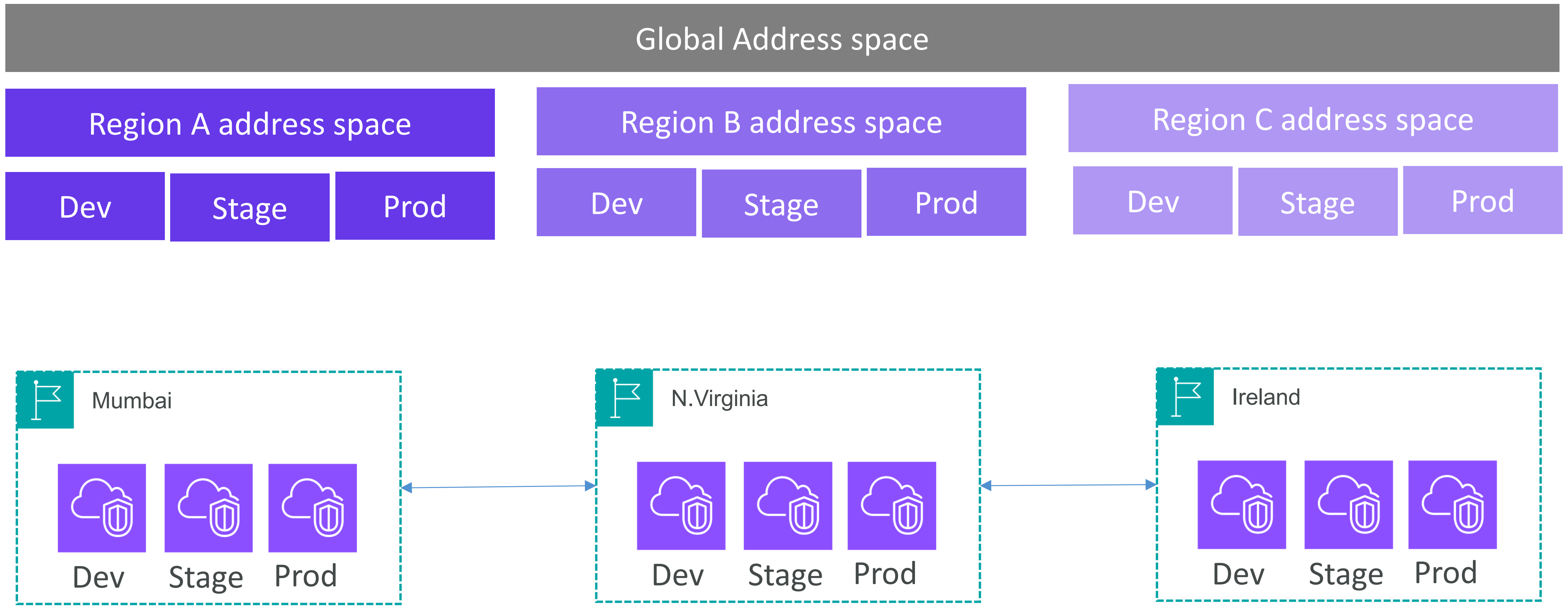


AWS IP Address Management - IPAM

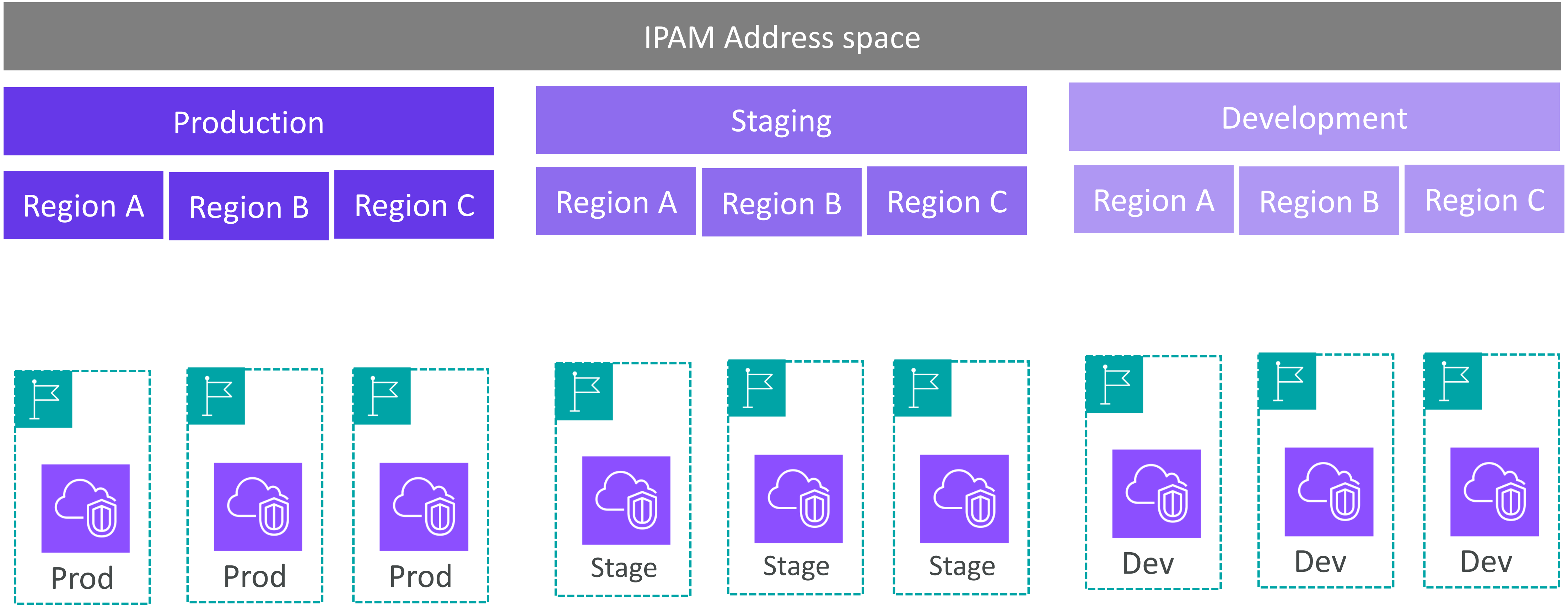
- IPAM
  - Scope (Public or Private)
    - Pools
      - Sub-pools
        - VPCs
- AWS account level
- AWS organization level



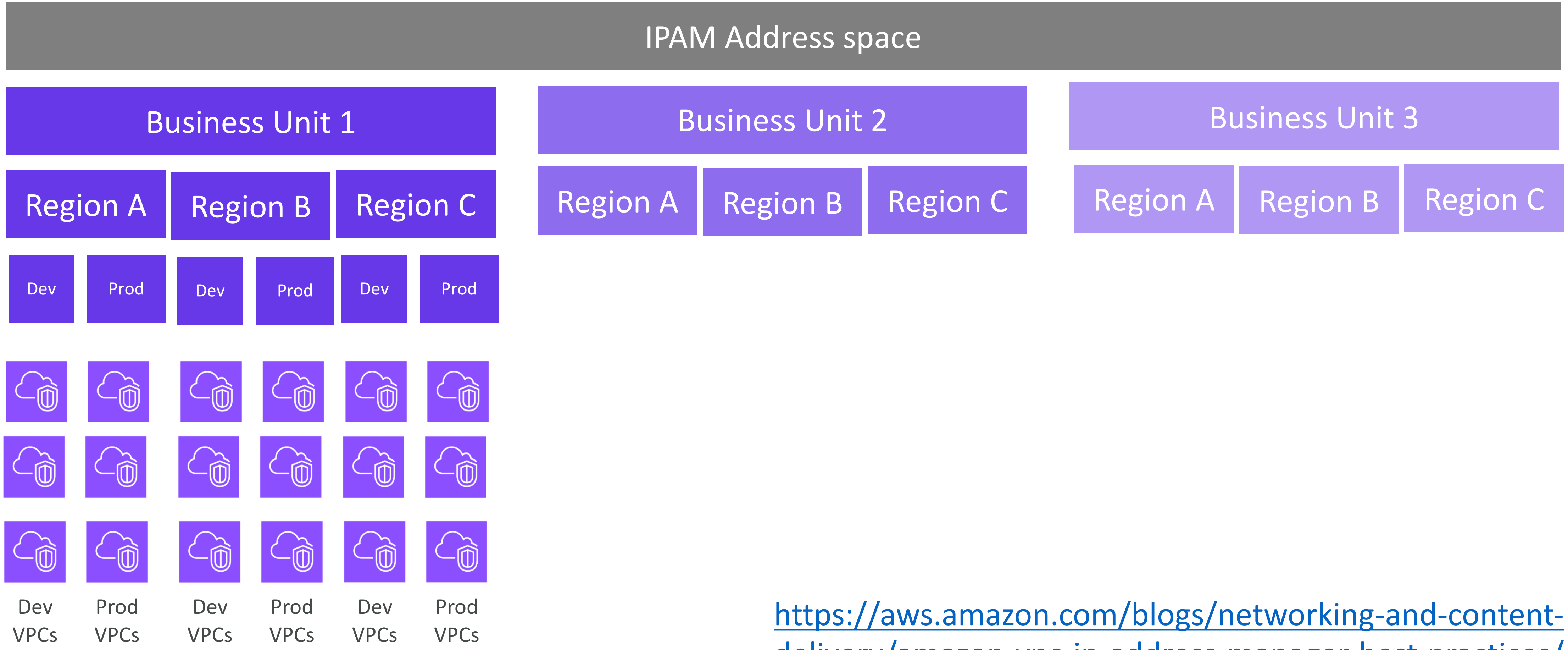
IPAM - Pools


Global Address space
Region A address space
Dev
Stage
Prod
Region B address space
Dev
Stage
Prod
Region C address space
Dev
Stage
Prod
Mumbai
Dev
Stage
Prod
N.Virginia
Dev
Stage
Prod
Ireland
Dev
Stage
Prod

IPAM Pools - Example



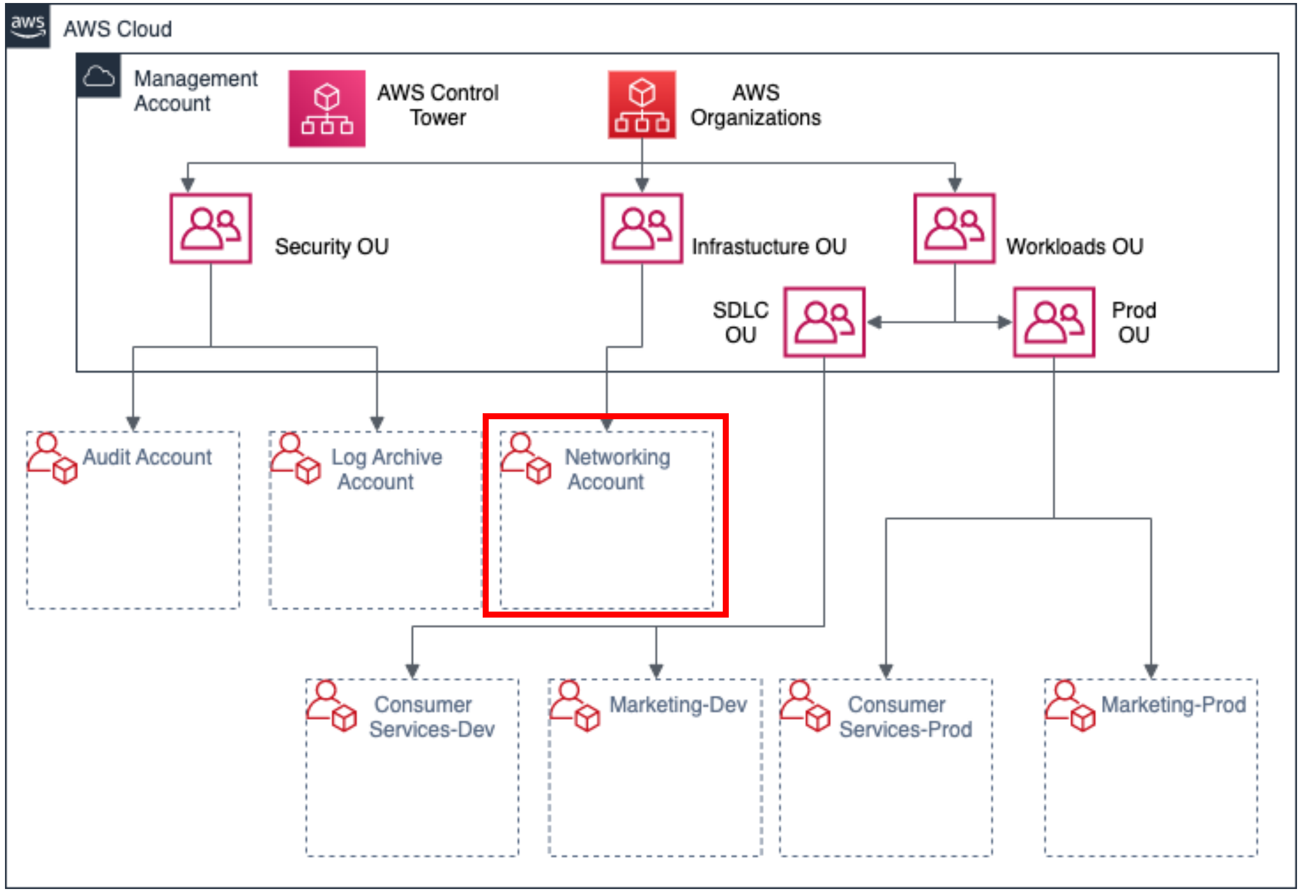
IPAM Pools - Example



https://aws.amazon.com/blogs/networking-and-content-delivery/amazon-vpc-ip-address-manager-best-practices/

IPAM with AWS Organization

- Amazon VPC IPAM can be integrated with your organization's structure.
- Create an IPAM-administrator account for your Organization.
- This account must be a member of the Organization

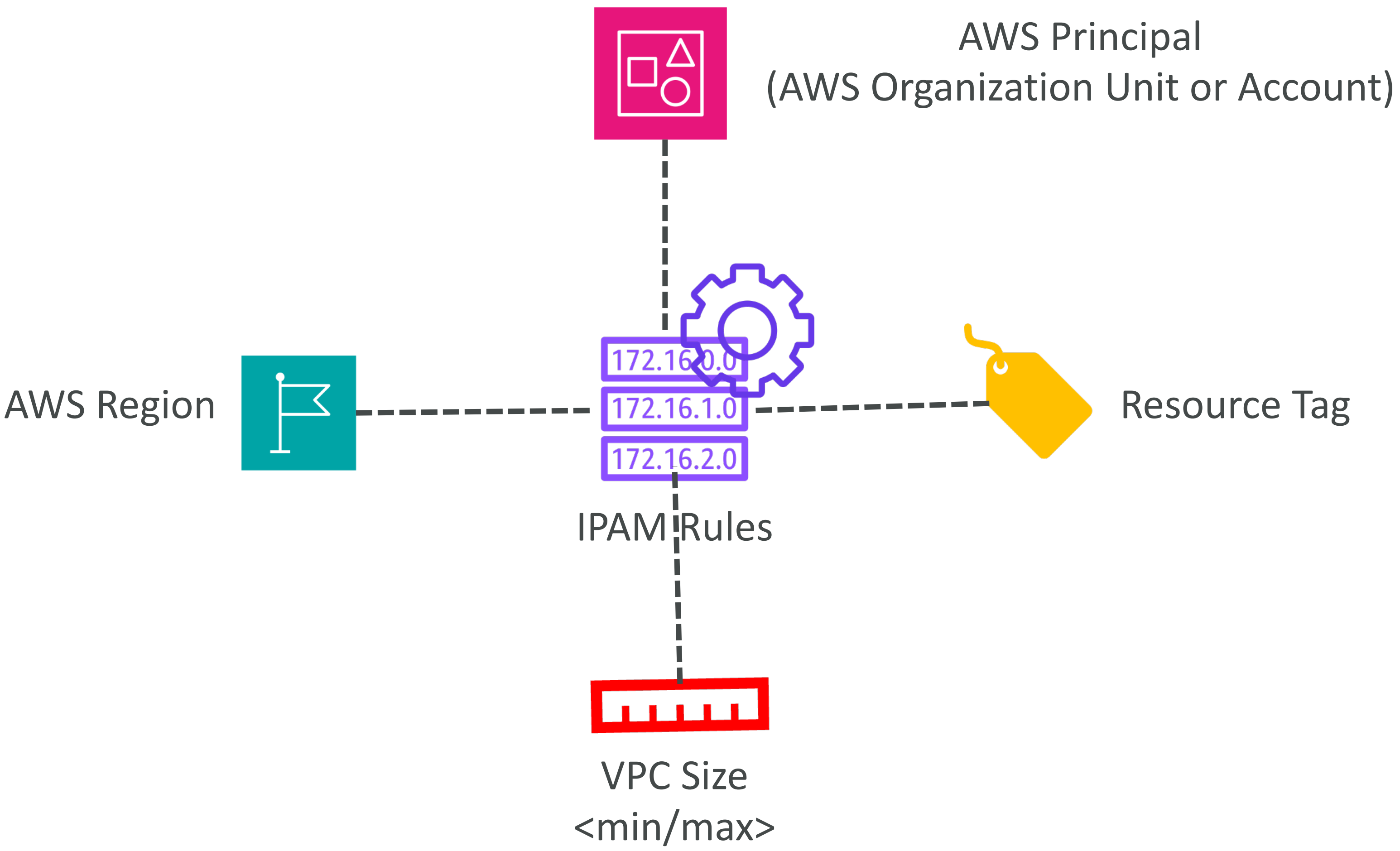


IPAM with AWS Organization

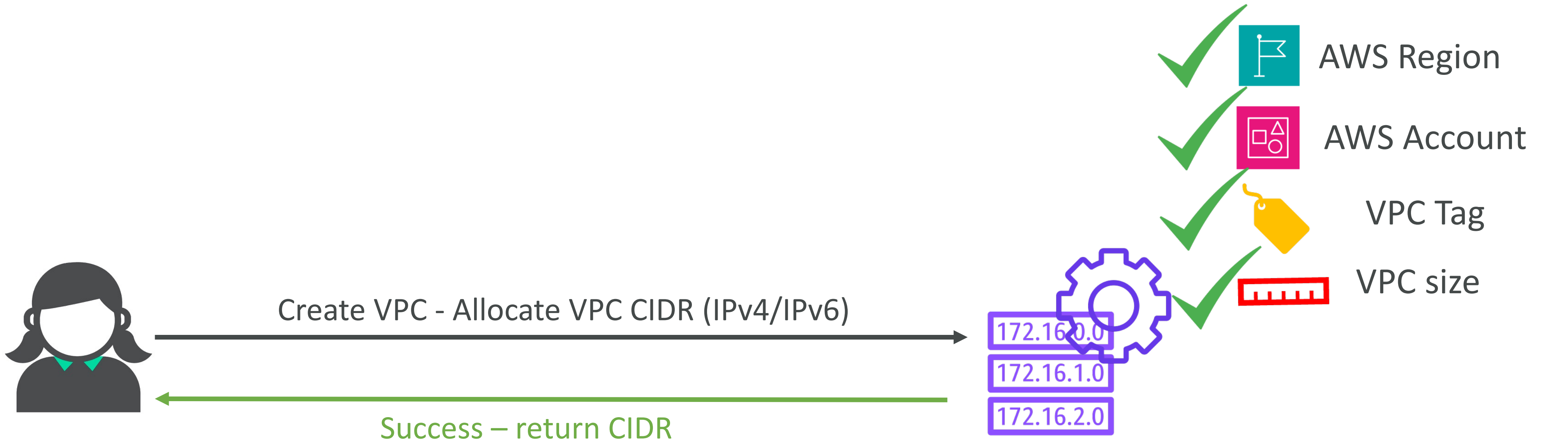
- AWS Organization Service control policy (SCP) to enforce CIDR allocation through IPAM while creating VPCs
- Enforce using specific IPAM pools
- Enforce specific IPAM pools to specific OUs

```
{
    "Version": "2012-10-17",
    "Statement": [{
      "Effect": "Deny",
       "Action": ["ec2:CreateVpc", "ec2:AssociateVpcCidrBlock"],
       "Resource": "arn:aws:ec2:*:*:vpc/*",
       "Condition": {
           "Null": {
               "ec2:Ipv4IpamPoolId": "true"
           }
       }
     }]
}
```

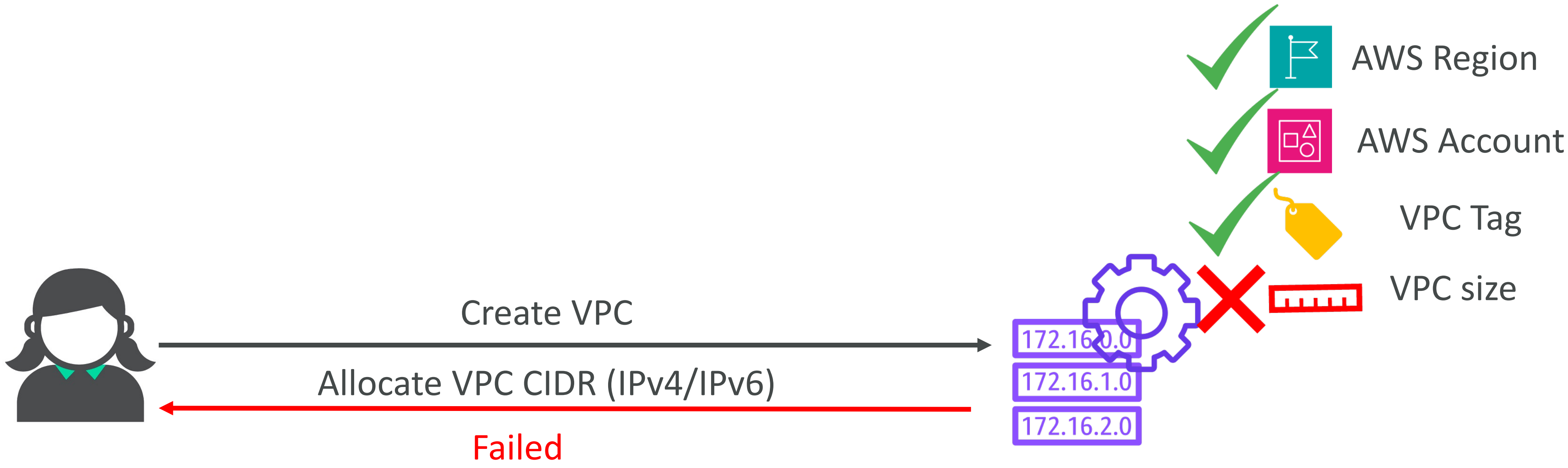
Apply rules for IP allocation



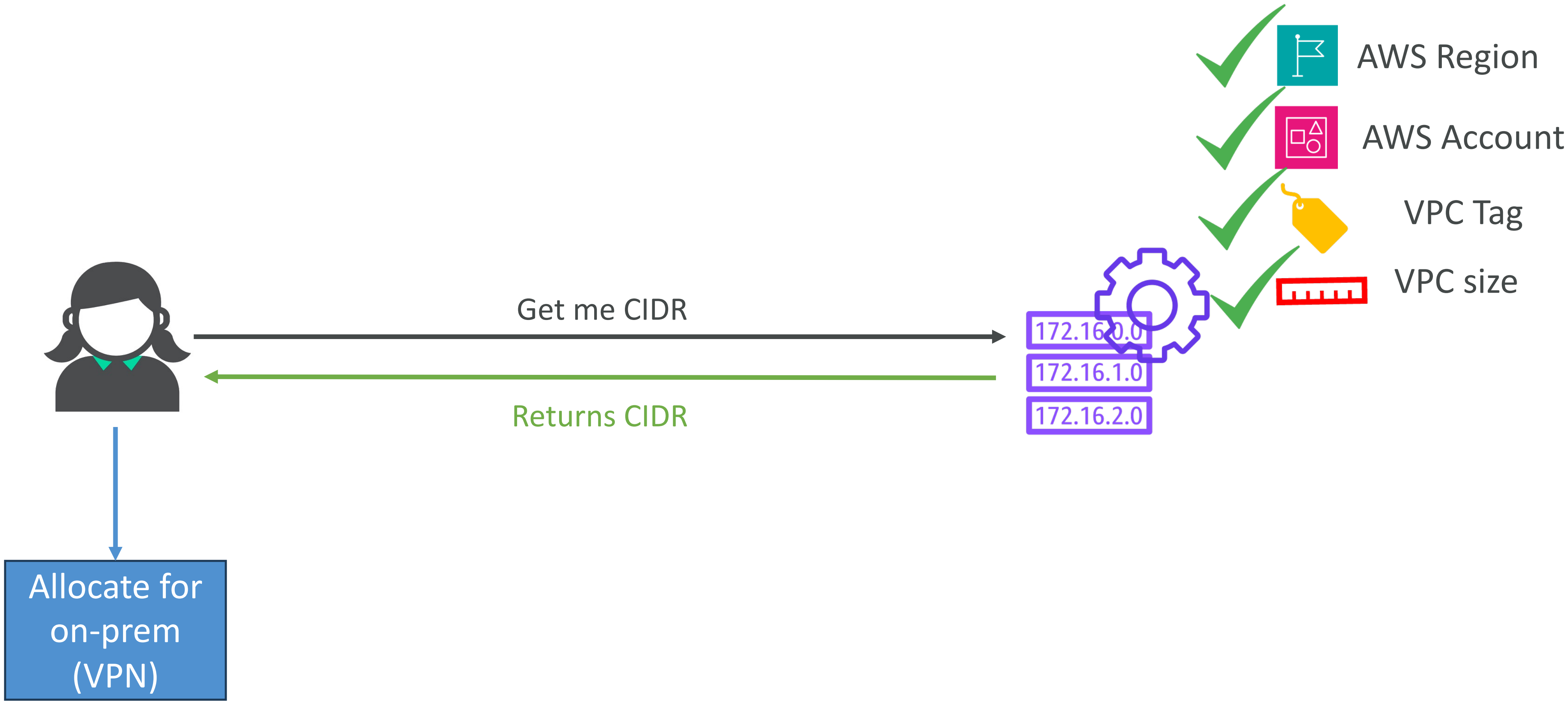
Apply rules for IP allocation



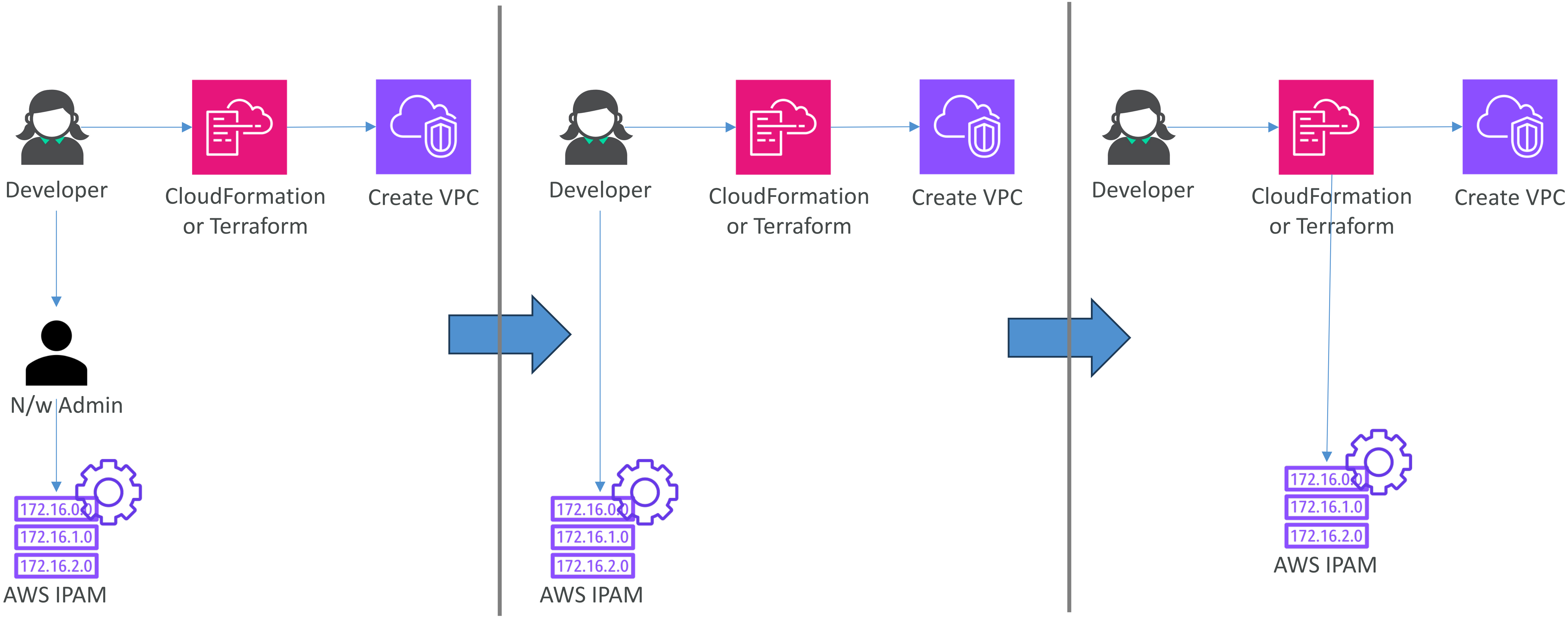
Apply rules for IP allocation



Request CIDR for non-VPC resources



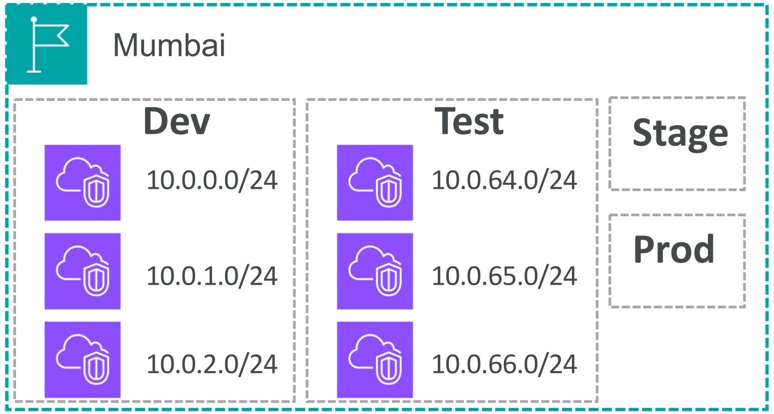
IPAM integration with AWS tools



IPAM Pools – Quick walkthrough

Global: 10.0.0.0/12 (1,048,576 IPs)

Mumbai: 10.0.0.0/16 (65,536 IPs)	N.Virginia: 10.1.0.0/16 (65,536 IPs)	Ireland: 10.2.0.0/16 (65,536 IPs)
Dev 10.0.0.0/18 (16,384)	Dev 10.1.0.0/18 (16,384)	Dev 10.2.0.0/18 (16,384)
Test 10.0.64.0/18 (16,384)	Test 10.1.64.0/18 (16,384)	Test 10.2.64.0/18 (16,384)
Stage 10.0.128.0/18 (16,384)	Stage 10.1.128.0/18 (16,384)	Stage 10.2.128.0/18 (16,384)
Prod 10.0.192.0/18 (16,384)	Prod 10.1.192.0/18 (16,384)	Prod 10.2.192.0/18 (16,384)



Tracking & Monitoring IP addresses with IPAM

- Monitor CIDR usage with IPAM Dashboard
- Monitor CIDR usage by resource
- Monitor IPAM with Amazon CloudWatch
- View IP address history
- View public IP insights

IP & CIDR monitoring with IPAM

Resources (4) Info

View the resources in an IPAM scope.

Input a CIDR - IPs | Actions ▼

Filter resources

Resource ID	Compliance status	Overlap status	IP usage	CIDR
vpc-00a58edb2cd4b145e	Compliant	Nonoverlapping	100%	10.0.3.0/24
vpc-0c1326b497308dc1e	Compliant	Overlapping	25%	10.0.1.0/24
vpc-0e071cfbee110ab5e	Compliant	Nonoverlapping	0%	10.0.2.0/24
vpc-0e557ac8bedfff3c2	Compliant	Overlapping	13%	10.0.0.0/24

Image source: https://aws.amazon.com/blogs/aws/network-address-management-and-auditing-at-scale-with-amazon-vpc-ip-address-manager/

IP Address History

- VPCs
- VPC subnets
- Elastic IP addresses
- EC2 instances
- EC2 network interfaces attached to instances

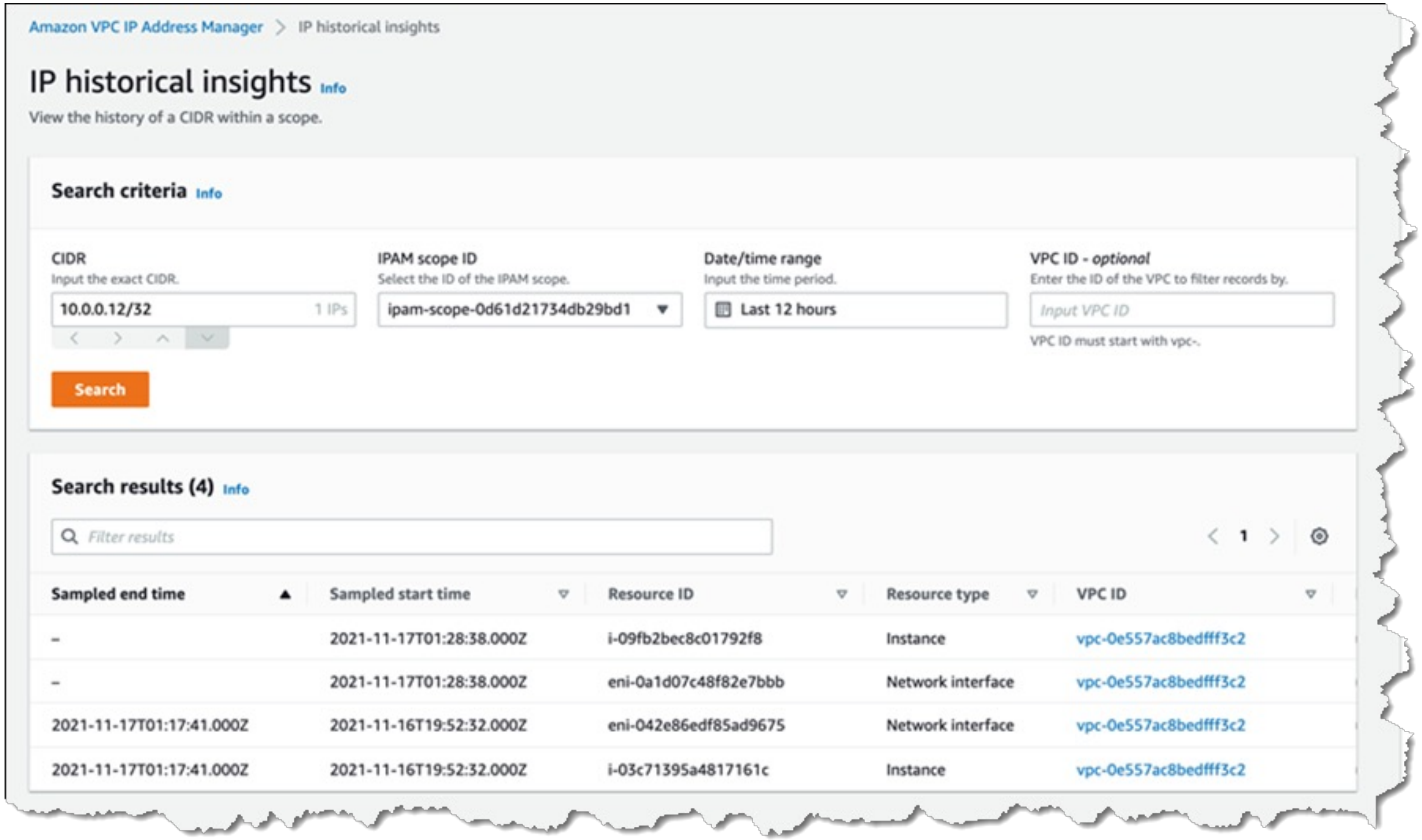


Image source: https://aws.amazon.com/blogs/aws/network-address-management-and-auditing-at-scale-with-amazon-vpc-ip-address-manager/

IP Pool monitoring with CloudWatch

- IPAM automatically stores metrics related to IP address usage in **AWS/IPAM** CloudWatch namespace
- Use these metrics to create alarms for IPAM pools
  - To notify if the address pools are nearing exhaustion
  - Resources fail to comply with allocation rules set on a pool
- IPAM publishes IP utilization metrics for resources that the IPAM manages. These resources include:
  - VPCs (IPv4 and IPv6)
  - Subnets (IPv4)
  - Public IPv4 pools

Image source: https://aws.amazon.com/blogs/aws/network-address-management-and-auditing-at-scale-with-amazon-vpc-ip-address-manager/

Public IP insights

Note: Starting 1st Feb 2024, AWS will be charging for Public IPv4 addresses associated with running instances and Elastic IPs. (~$3.65/month)

Insights for:

- Elastic IP addresses (EIPs)
- EC2 Public IPv4 addresses
- BYOIPv4 addresses
- Service-managed IPv4 addresses
- Provides view of all Public IPs in your AWS account or AWS Organization across all the regions
- Provides view of unassociated Elastic IPs

IPAM Summary

- Organize IP address space into separate domains (e.g. Business/ security/ environments etc.)
- Automatically allocate CIDRs to VPCs using specific business rules
- Monitor IP address space that's in use and monitor resources that are using IP space against business rules
- View the history of IP address assignments
- Enable cross-region and cross-account sharing of your Bring Your Own IP (BYOIP) addresses
- IPAM provides Free tier and Advanced tier pricing. Free tier allows Public IP pools and BYOIP.
- Caution about IPAM Advance tier pricing : $0.00027 per hour per active IP

AWS CloudFormation

Infrastructure as a Code

- If you have been doing a lot of manual work for deployment of the infrastructure in AWS e.g. creating VPC, Subnets, EC2 instances, VPN connection etc. …
- All this manual work will be very tough to reproduce:
  - In another region
  - in another AWS account
  - Within the same region if everything was deleted
- Wouldn't it be great, if all our infrastructure was… code?

AWS CloudFormation

- CloudFormation is a declarative way of outlining your AWS Infrastructure, for any resources (most of them are supported).
- For example, within a CloudFormation template, you say:
  - I want a VPC and Subnets
  - I want an internet gateway and attach it to the VPC
  - I want a security group
  - I want two EC2 machines using this security group in the subnet just created
- Then CloudFormation creates those for you, in the **right order**, with the exact configuration that you specify

Benefits of AWS CloudFormation

Infrastructure as code

- No resources are manually created, hence no manual errors
- The code can be version controlled for example using git
- Changes to the infrastructure are reviewed through code

Cost

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

Benefits of AWS CloudFormation

Productivity

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

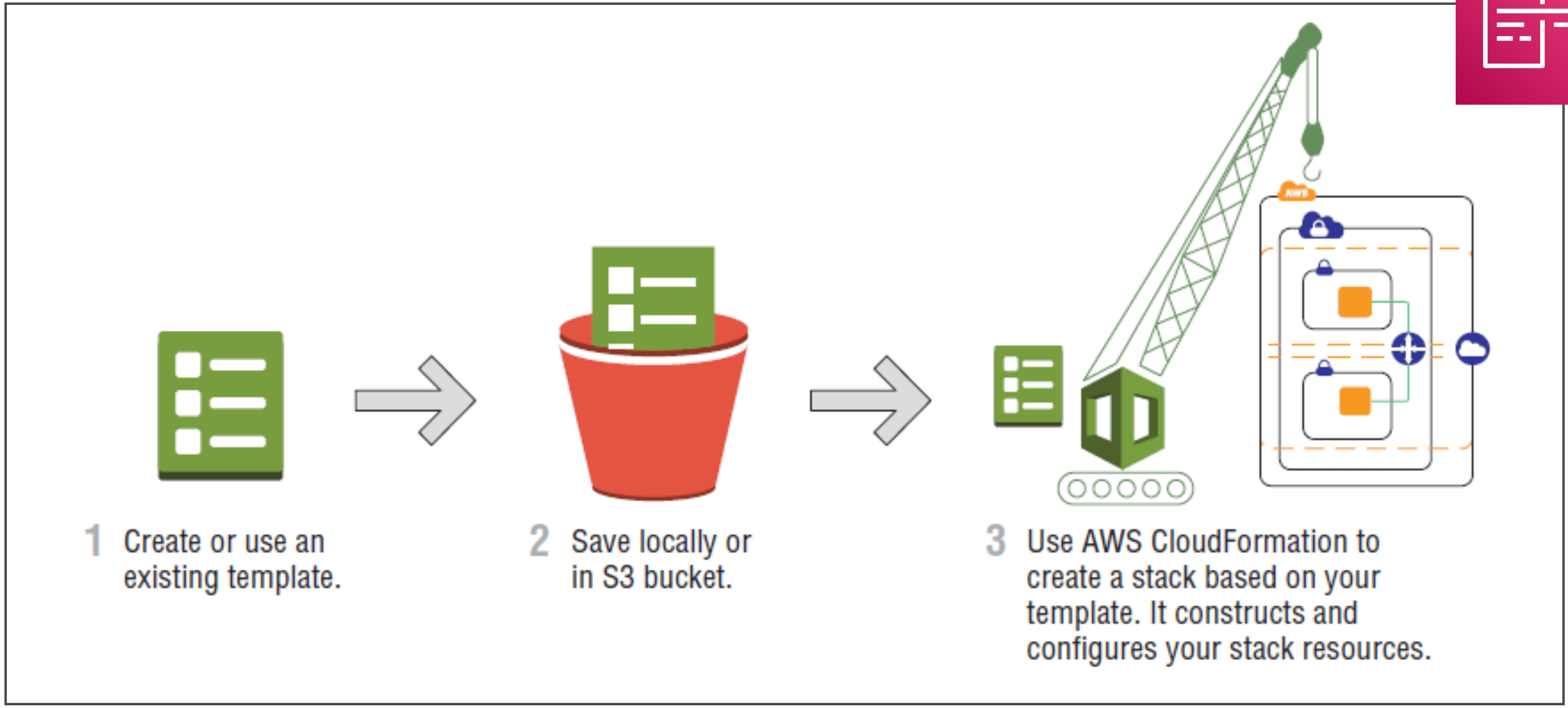
Separation of concern: create many stacks for many apps, and many layers. Ex:

- Network stacks
- App stacks

Don't re-invent the wheel

- Leverage existing templates on the web!
- Leverage the documentation

AWS CloudFormation



CloudFormation template examples

```
{
"Type": "AWS::EC2::VPCPeeringConnection",
"Properties": {
            "VpcId": String,
            "PeerVpcId": String
 }
```

VPC peering in the same account, same region

```
{
  "Type" : "AWS::EC2::VPCPeeringConnection",
  "Properties" : {
      "PeerOwnerId" : String,
      "PeerRegion" : String,
      "PeerRoleArn" : String,
      "PeerVpcId" : String,
      "Tags" : [ Tag, ... ],
      "VpcId" : String
    }
}
```

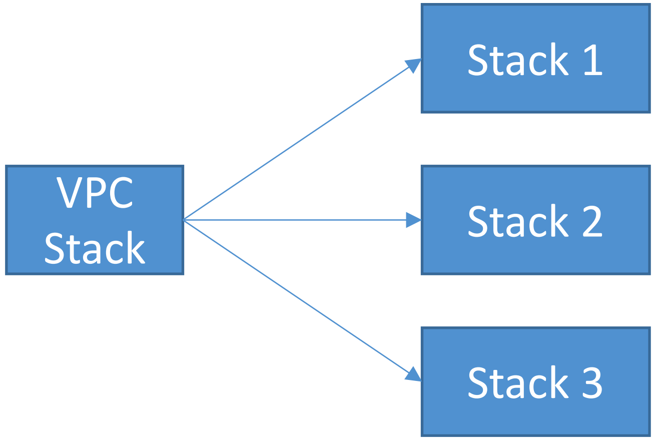
VPC peering cross account cross region

CloudFormation – Feature & Components

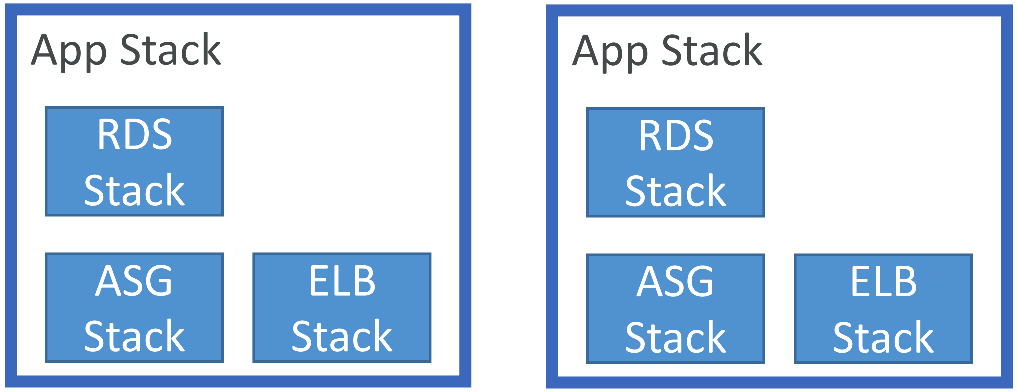
- CloudFormation Designer
  - A graphical tool for creating, viewing, and modifying AWS CloudFormation templates
- ChangeSets
  - Generate & Preview the CloudFormation changes before they get applied
- StackSets
  - Deploy a CloudFormation stack across multiple accounts and regions
- Stack Policies
  - Prevent accidental updates / deletes to stack resources

CloudFormation – Feature & Components

- Cross Stacks
  - Helpful when stacks have different lifecycles
  - Use Outputs Export and Fn::ImportValue
  - When you need to pass export values to many stacks (VPC Id, etc…)



- Nested Stacks
  - Nested stacks are stacks created as part of other stacks using the AWS::CloudFormation::Stack resource.
  - Helpful when components must be re-used
  - Ex: re-use how to properly configure an Application Load Balancer
  - The nested stacks are not shared.



CloudFormation – manage resource dependencies

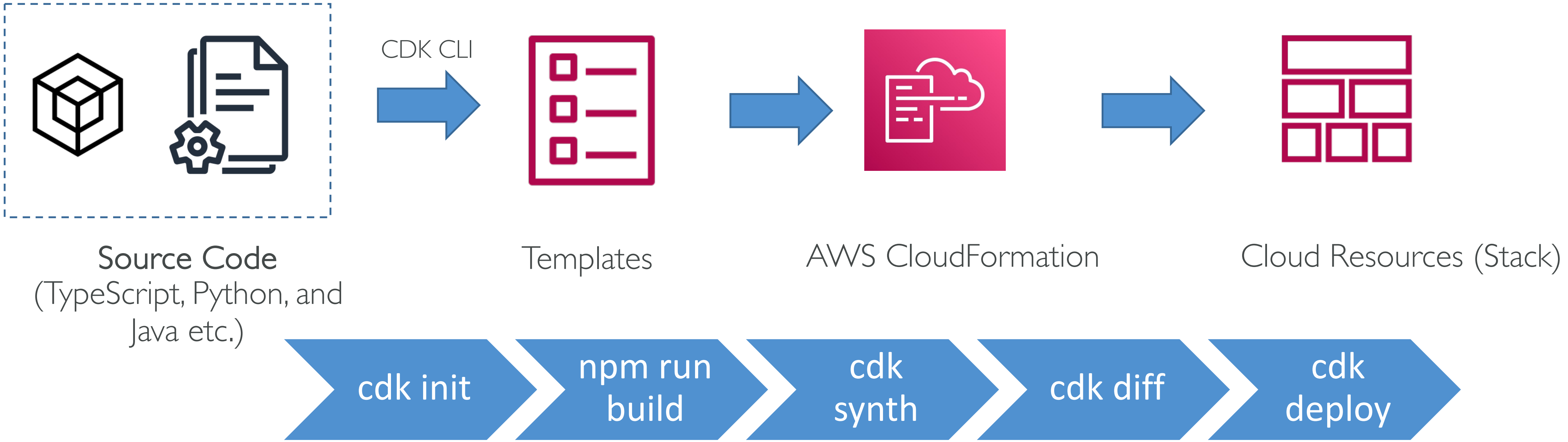
- DependsOn
  - Control the order of the resource creation. DependsOn will force the resource creation wait until the resource specified by "DependsOn" is created successfully.
  - Example:
    - If you reference a VPN gateway that is in the same template as your VPN gateway route propagation, you must explicitly declare a dependency on the VPN gateway attachment.
    - The AWS::EC2::VPNGatewayRoutePropagation resource cannot use the VPN gateway until it has successfully attached to the VPC.
    - Add a DependsOn Attribute in the AWS::EC2::VPNGatewayRoutePropagation resource to explicitly declare a dependency on the VPN gateway attachment.

CloudFormation – manage resource dependencies

- WaitCondition
  - To coordinate stack resource creation with configuration actions that are external to the stack creation.
  - Waits until the success/failure signal received or timeout occurs
  - For the resources to respond to the wait condition, they must have an access to the cloudformation specific S3 bucket presigned URL where they can send the response signal
  - WaitCondition itself can DependsOn the underlying resource
  - Examples:
    - Create a WaitCondition which DependsOn EC2 instance.
    - The WaitHandler will wait for the signal to be received.
    - EC2 bootstrap action will send the Success signal to the wait condition.

AWS Cloud Development Kit (CDK)

- An open-source software development framework to define your cloud application resources using familiar programming languages.

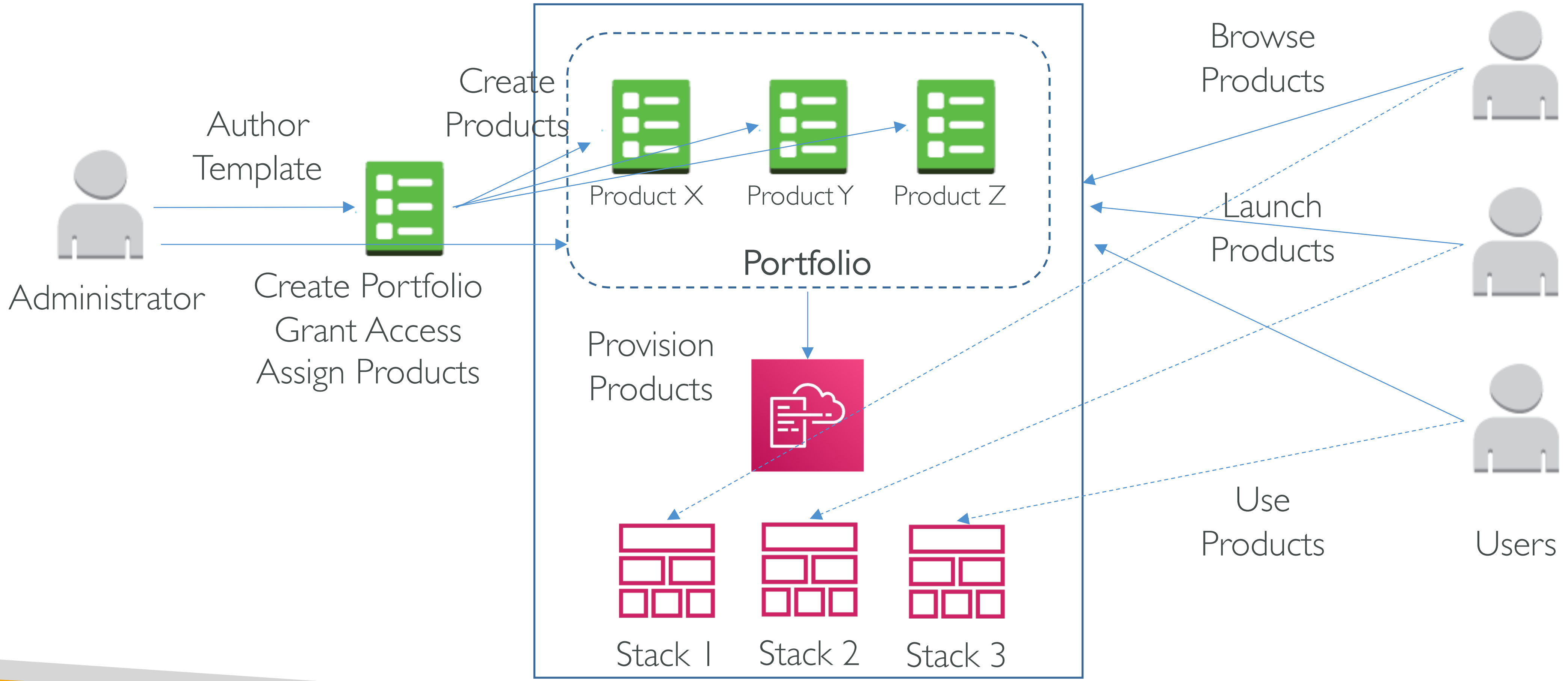


AWS Service Catalog

AWS Service Catalog

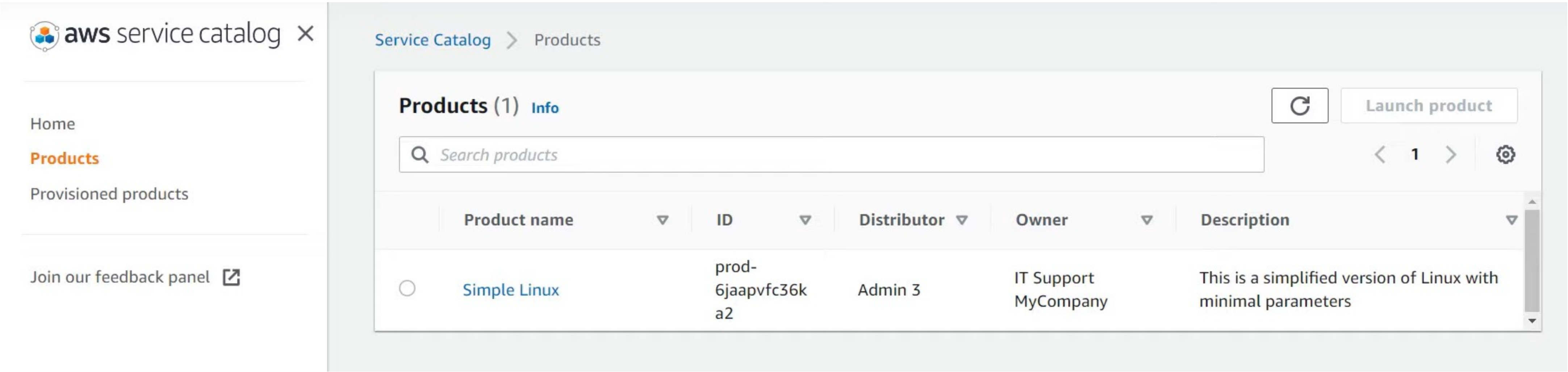
- Allow users to launch group of approved IT resources as a Product in a self-service manner
- It uses CloudFormation templates to launch the related resources / architecture / software / servers.
- Products can be versioned and can be shared across AWS organization, Organization Units (OU) or AWS accounts
- It uses user's IAM permissions or a launch constraints for launching the products
- Users can optionally provide the parameters.
- Administrator can also provide details like support email
- Output of the CloudFormation can also be part of the launch output e.g. Website URL etc.

AWS Service Catalog



AWS Service Catalog

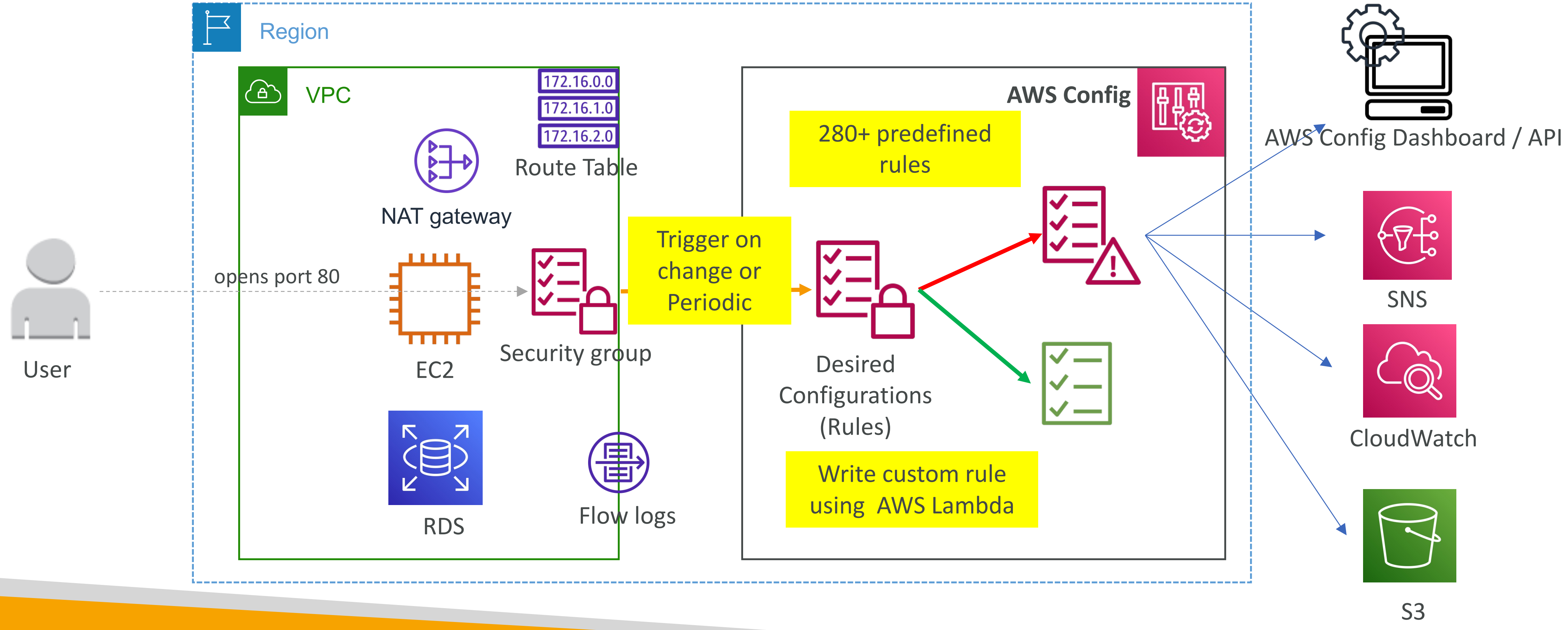
- User browse the products listed in AWS Service catalog
- User selects the product
- User launches the product



AWS Config

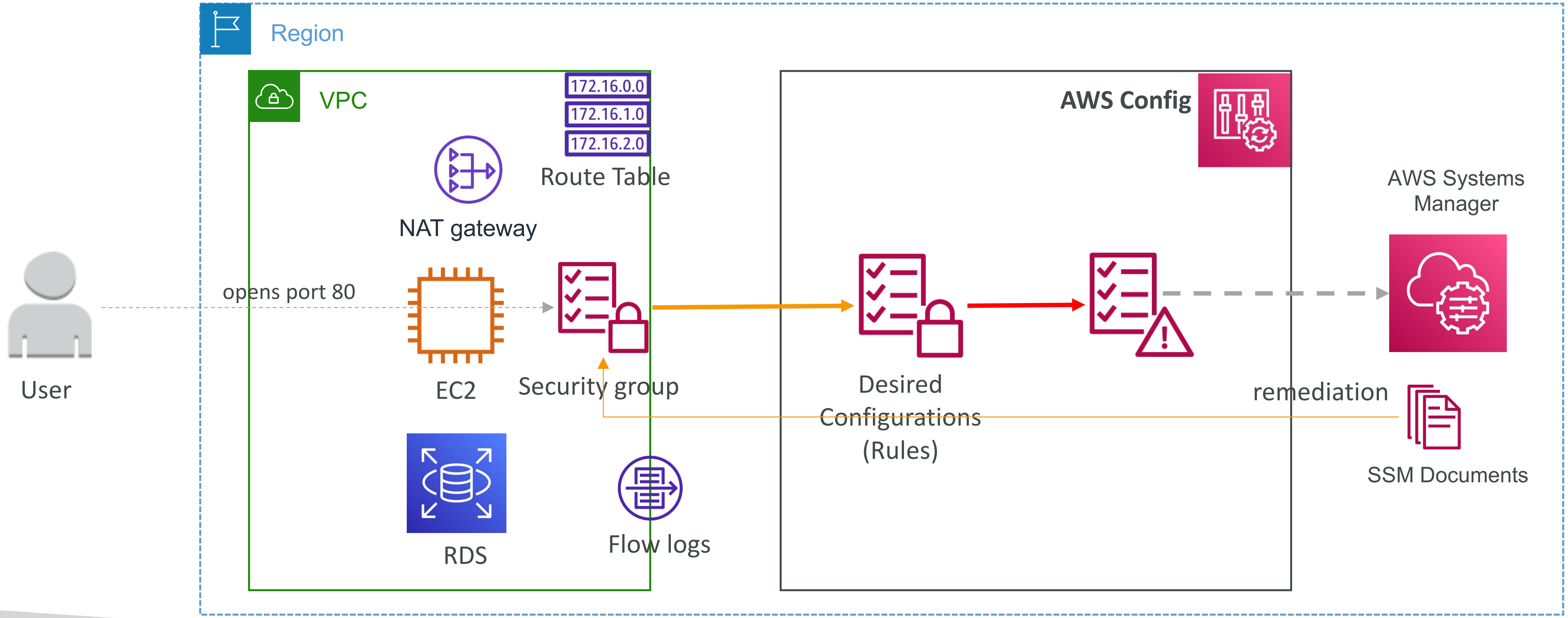
AWS Config

Assess, Audit and Evaluate the configuration of your AWS resources



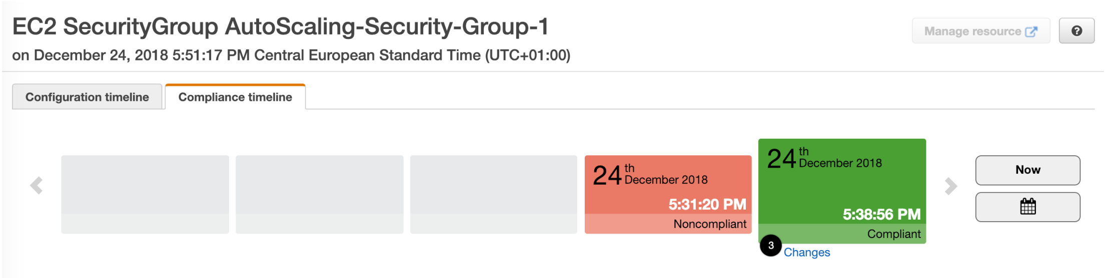
AWS Config - Remediation

Auto remediation using Systems Manager SSM documents

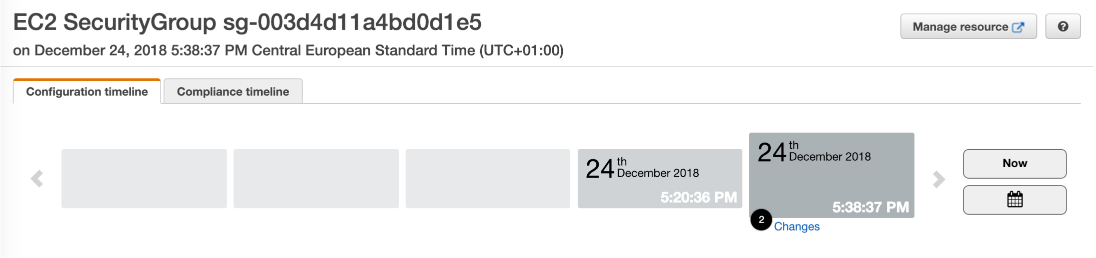


AWS Config Resource

- View compliance of a resource over time



- View configuration of a resource over time



- View CloudTrail API calls if enabled

AWS Config summary

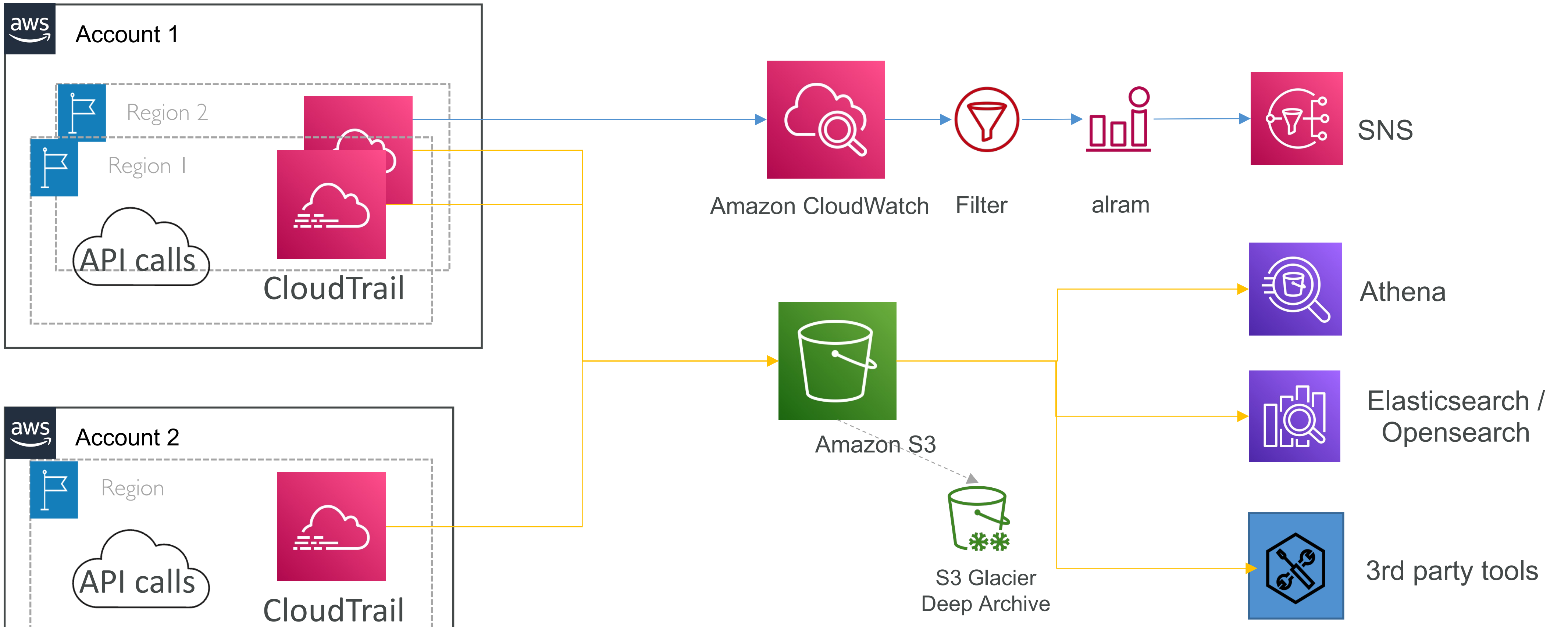
- Helps record configurations and changes over time
- **AWS Config Rule does not prevent actions from happening (no deny)**
- Questions that can be solved by AWS Config:
  - Is there unrestricted SSH access to my security groups?
  - Do my buckets have any public access?
  - How my ALB configuration has changed over time?
- Can make custom config rules (must be defined in AWS Lambda)
  - Example 1: Evaluate if each EBS disk is of type gp2
  - Example 2: Evaluate if each EC2 instance is t2.micro
- AWS Config is a regional service however can aggregate data across multiple regions and accounts

AWS CloudTrail

AWS CloudTrail

- Provides audit for your AWS Account activities by logging all the API calls
- CloudTrail is enabled by default!
- Get an history of events / API calls made within your AWS Account by:
  - Console
  - SDK
  - CLI
  - AWS Services
- If a resource is deleted in AWS, look into CloudTrail first!
- CloudTrail console shows the past 90 days of activity. Optionally, you can persist the CloudTrail logs into CloudWatch or S3
- Can be region specific or global & include global events (e.g. IAM)

CloudTrail Trail



cloudtrail-bucket/account-A
cloudtrail-bucket/account-B
cloudtrail-bucket/account-C…

Sample event


```
{
    "eventVersion": "1.08",
    "userIdentity": {
        "type": "IAMUser",
        "principalId": “xxxxxxxxxxxxxxxxxx",
        "arn": "arn:aws:iam::xxxxxxxxx:user/admin",
        "accountId": “xxxxxxxxxxx",
        "accessKeyId": “xxxxxxxxxxxxxxxxxx",
        "userName": "admin",
        …
        }
    },
    "eventTime": "2022-07-22T02:02:13Z",
    "eventSource": "ec2.amazonaws.com",
    "eventName": "TerminateInstances",
    "awsRegion": "ap-south-1",
    "sourceIPAddress": "AWS Internal",
    "userAgent": "AWS Internal",
    "requestParameters": {
        "instancesSet": {
            "items": [
                {
                    "instanceId": "i-xxxxxxxxxxxxx"
                }
            ]
        }
    }
}
```


User

Event time

Action

Resource

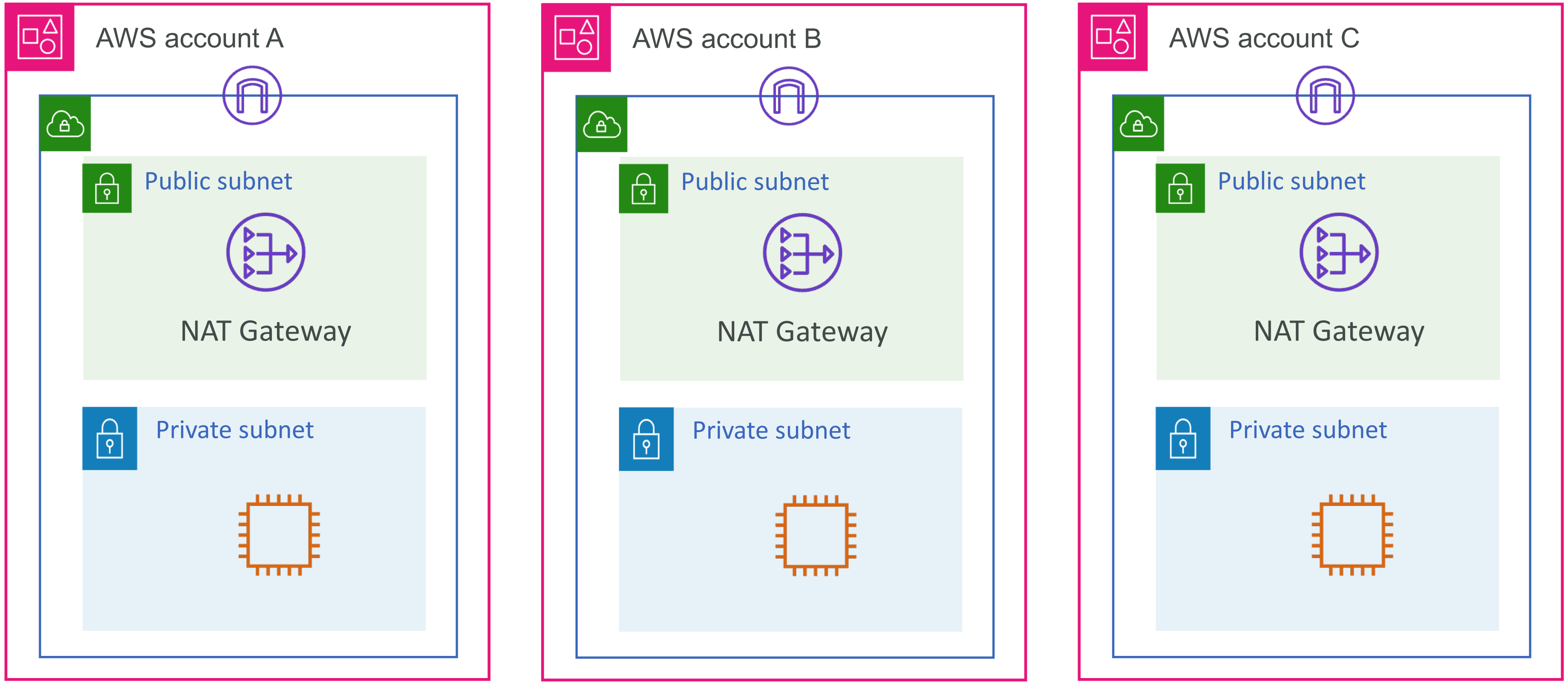
Additional Topics

VPC Sharing

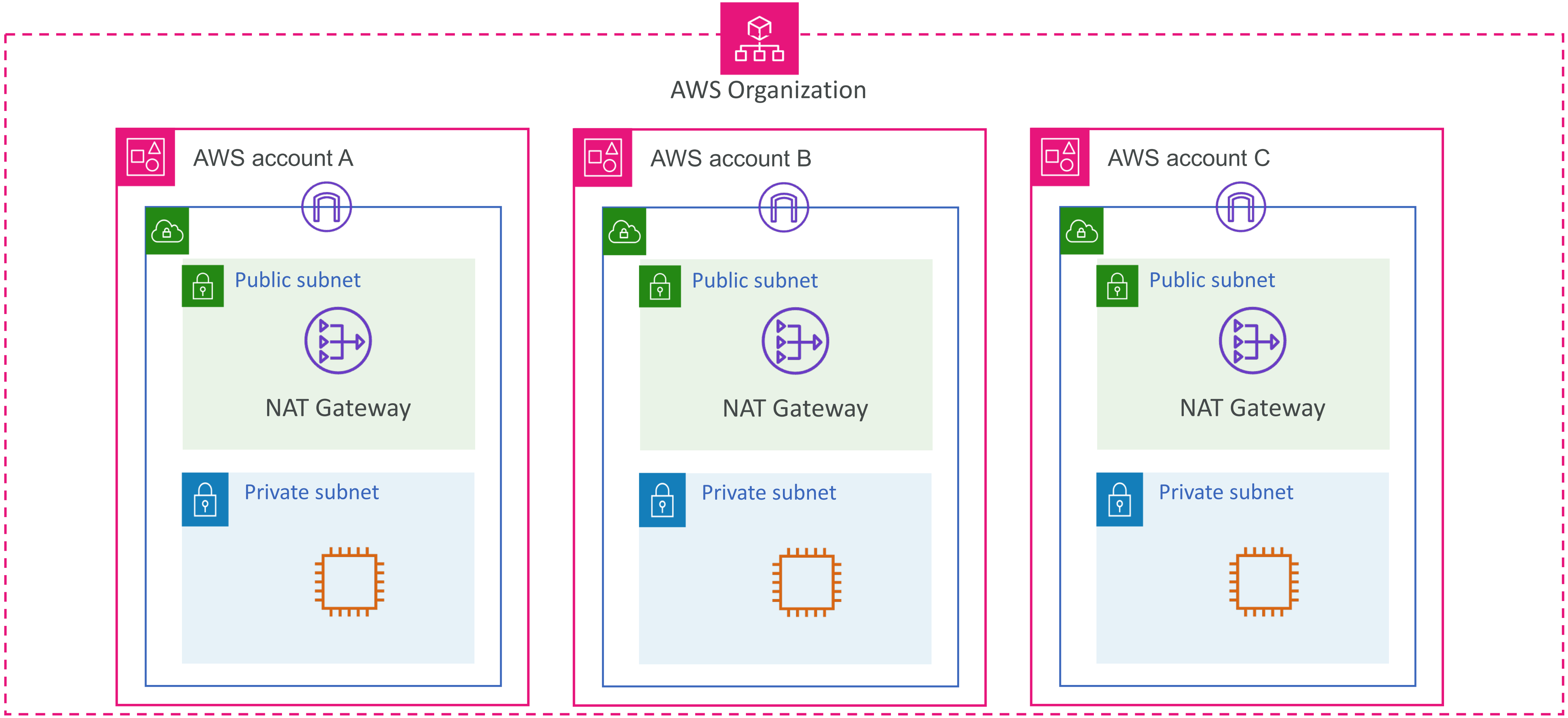
VPC Sharing

- Multiple AWS accounts in an AWS organization can share a VPC to launch their resources(e.g. EC2 instances, RDS database etc.)
- Account that owns the VPC (owner) shares one or more subnets with other accounts (participant)
- Must enable resource sharing from the management account for the AWS organization.
- Resource Share should be created for the subnet to be shared. It can be shared with AWS accounts, organizational units, or an entire organization.
- VPC owners can't share subnets that are in a default VPC.

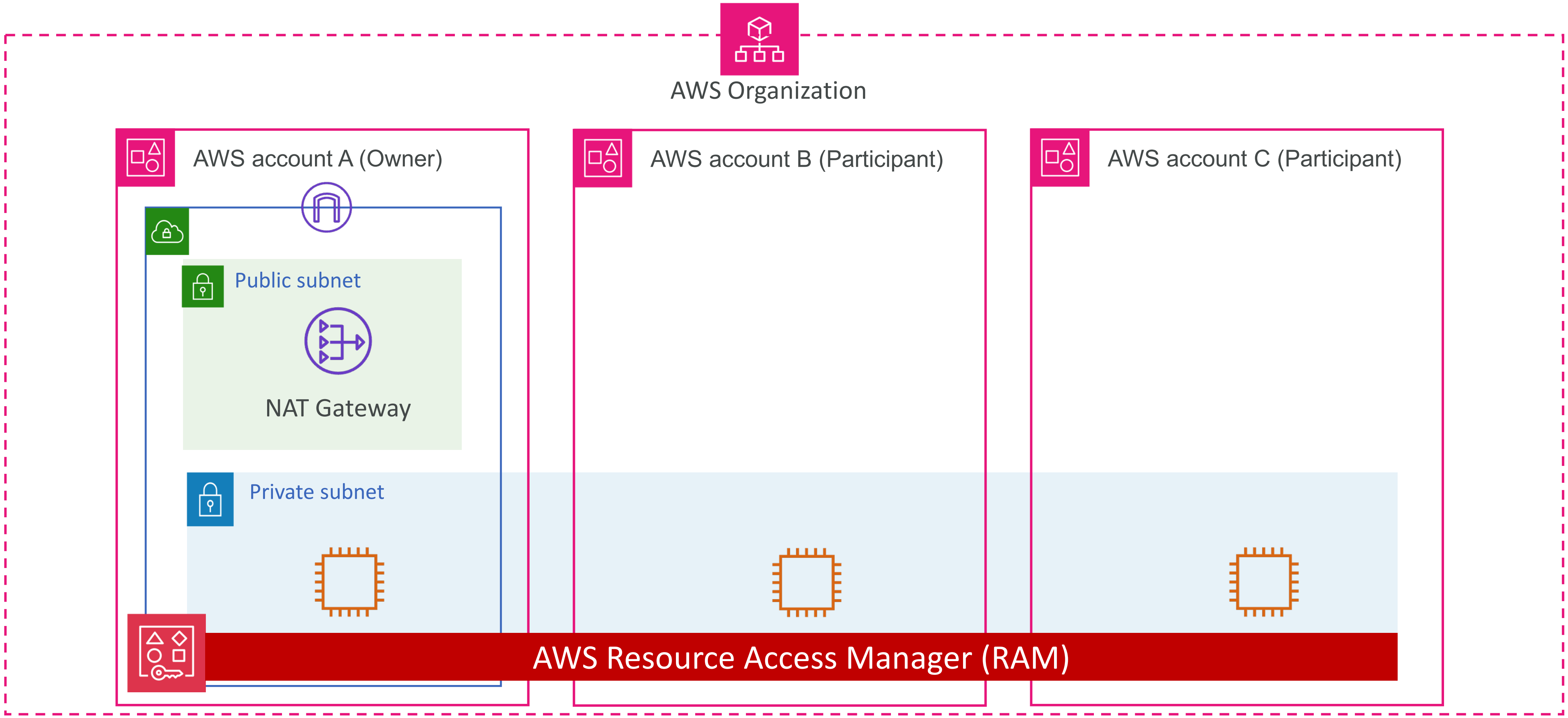
VPC and AWS accounts



VPC and AWS accounts



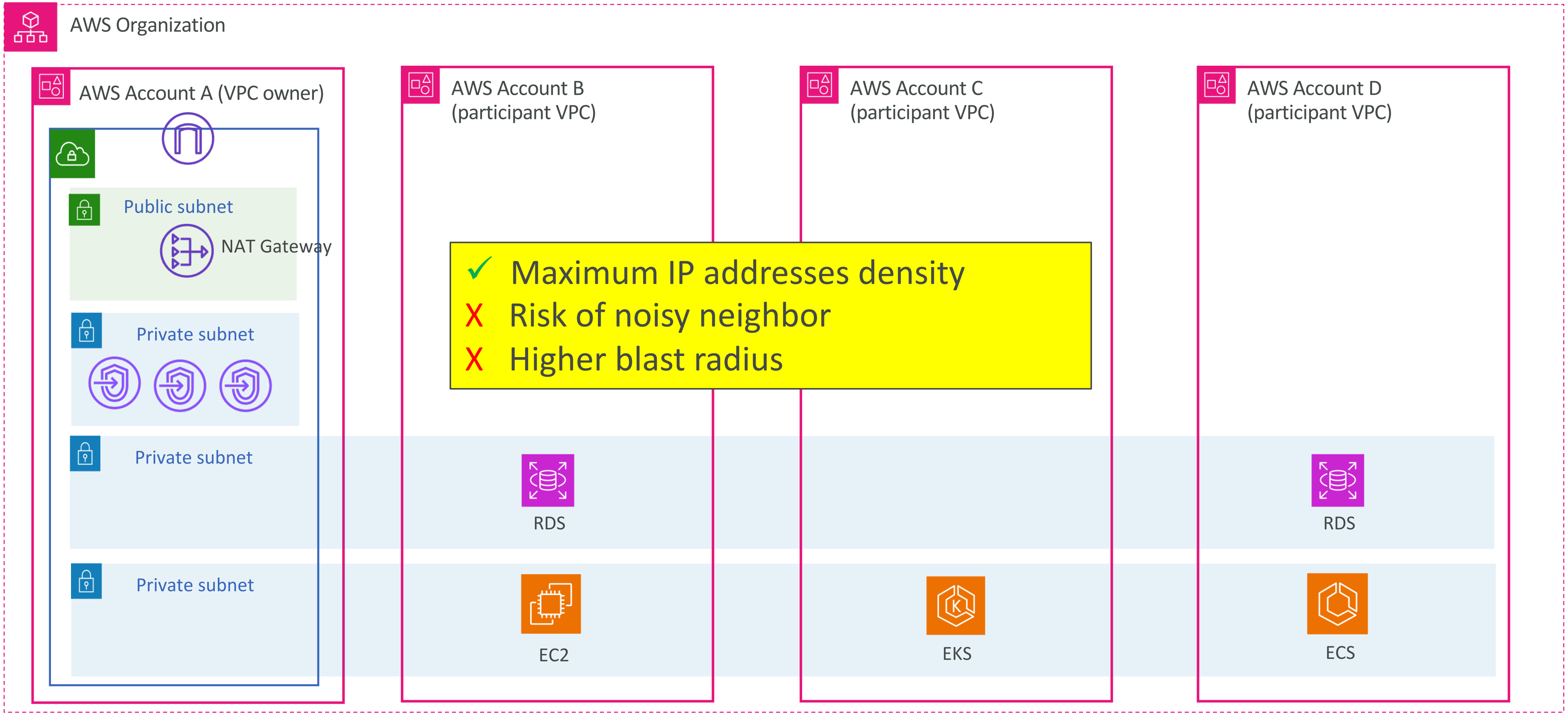
Sharing VPC across AWS accounts



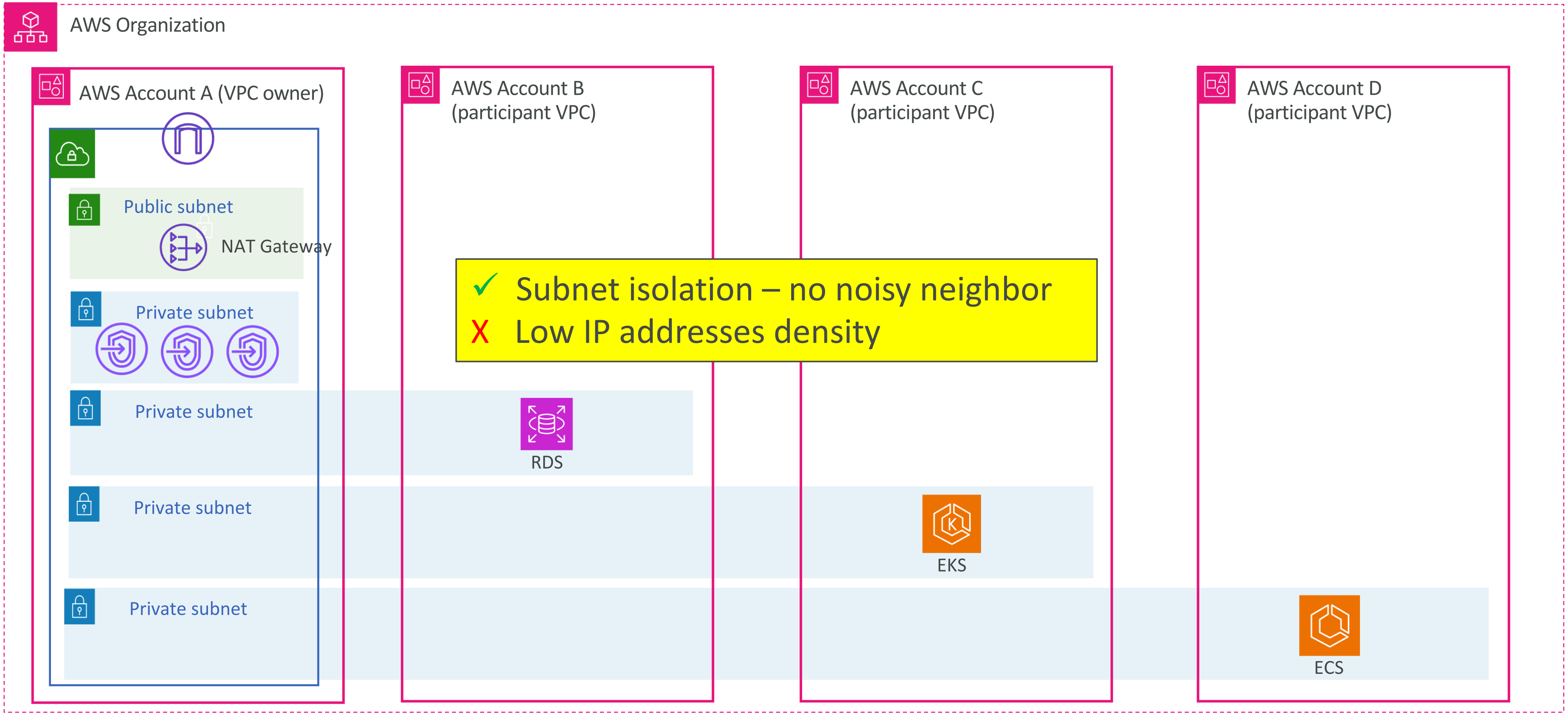
Benefits of Sharing VPCs

- Simplified design — no complexity around inter-VPC connectivity
- Fewer managed VPCs
- Avoidance of the problem of CIDR overlap that is encountered with multiple VPCs
- Segregation of duties between network teams and application owners
- Better IPv4 address utilization
- **Reuse of network address translation (NAT) gateways, VPC interface endpoints etc.**
- No data transfer charges between instances belonging to different accounts within the same Availability Zone

Shared VPC architectures – Shared subnets across all accounts



Shared VPC architectures – Dedicated subnets per account



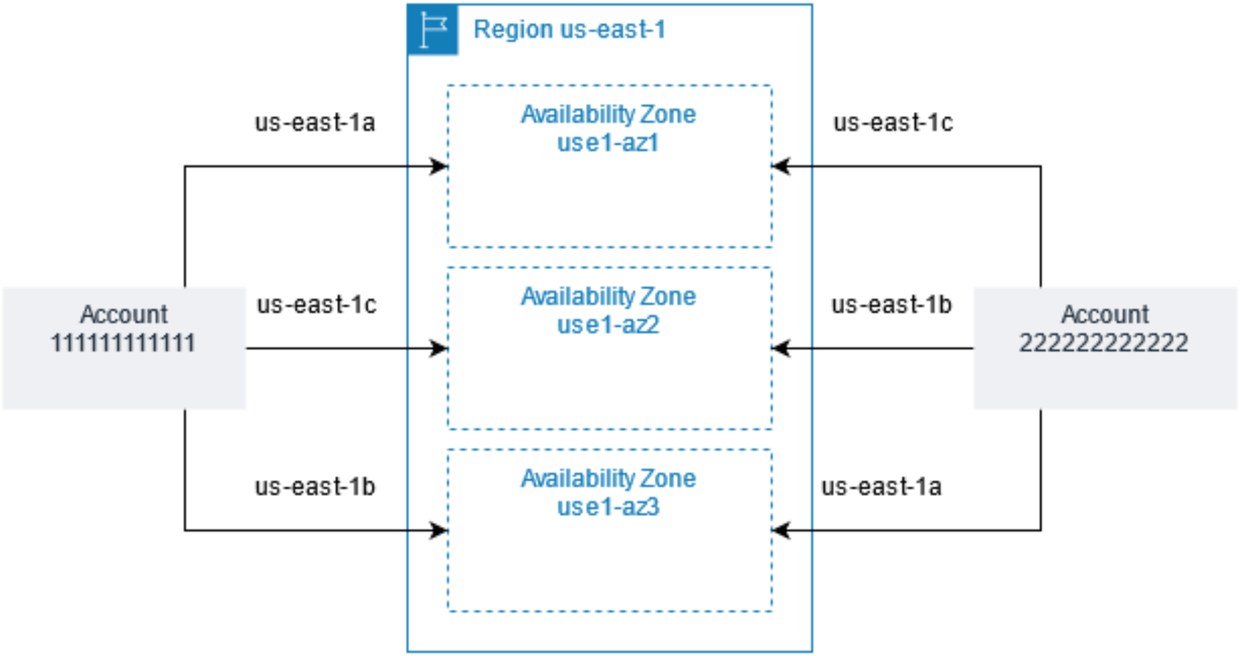
✓ Subnet isolation – no noisy neighbor
X Low IP addresses density

Availability Zone consideration

- AWS maps AZ names independently to different AWS accounts

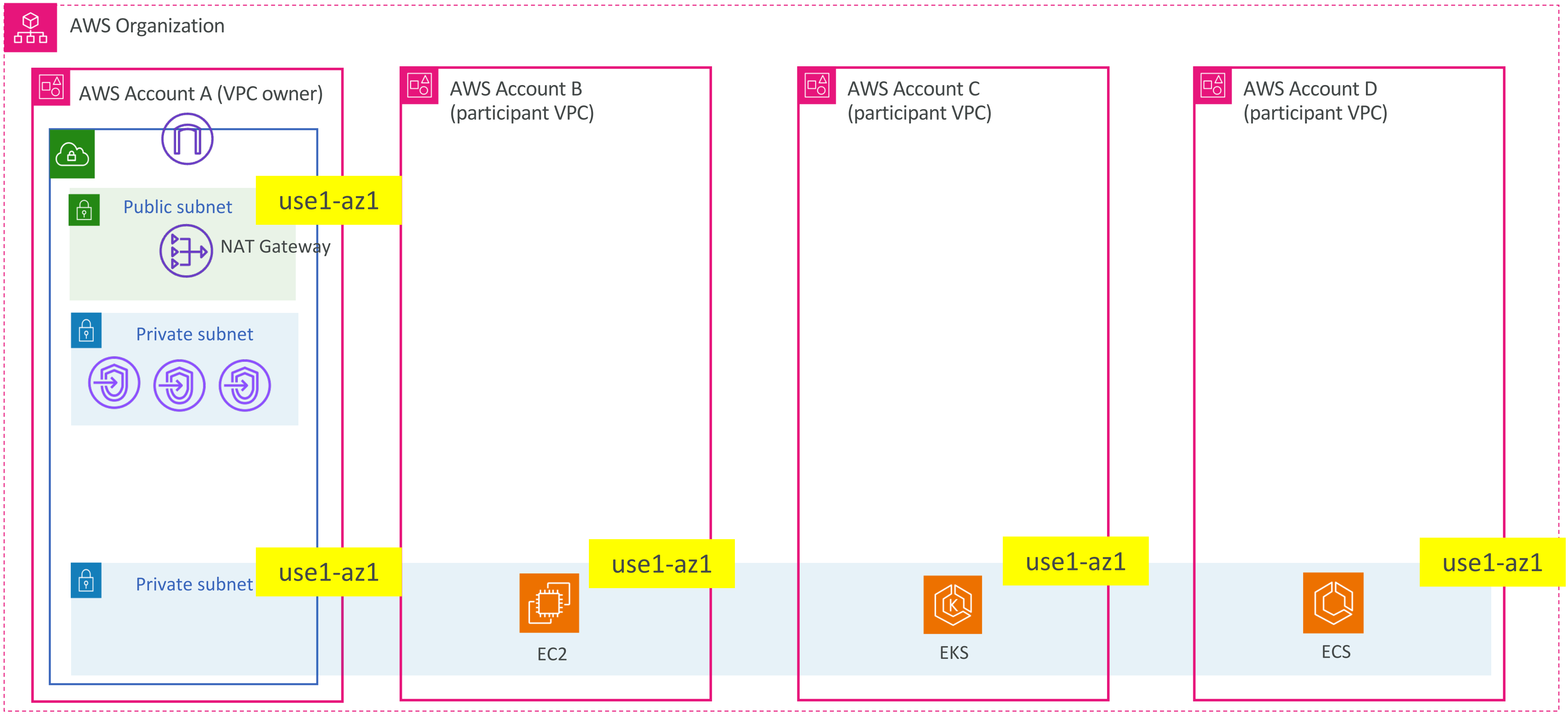
Example:

- us-east-1a in Account A may not be same AZ in Account B



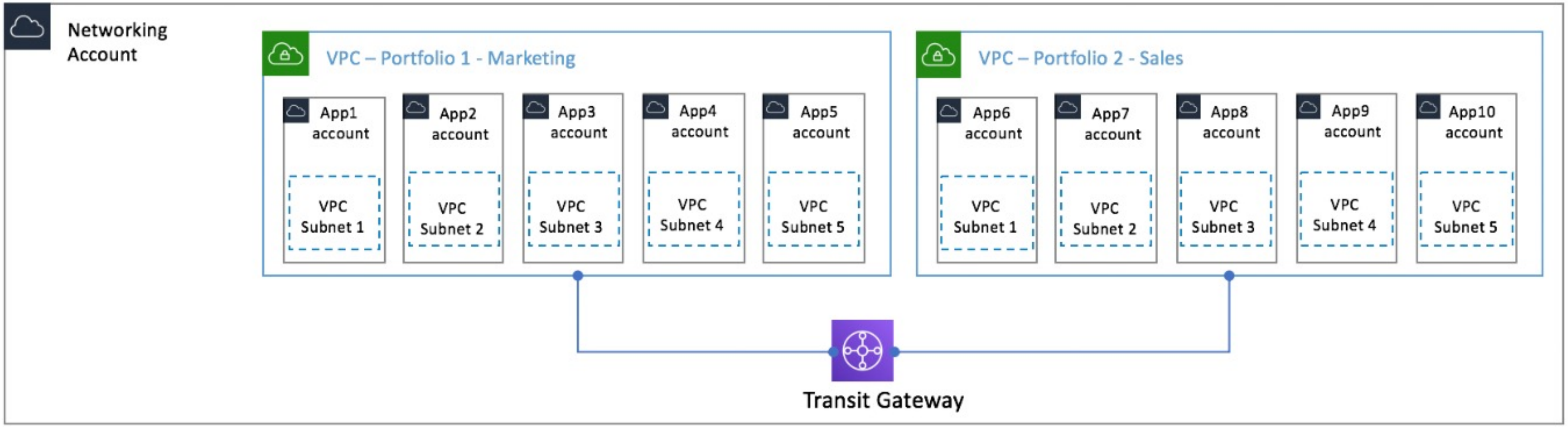
To coordinate Availability Zones across accounts for VPC sharing, you must use an AZ ID e.g. **use1-az1**

Shared VPC architectures – Shared subnets across all accounts



VPC sharing and Transit Gateway

- We can use VPC sharing to enable subnet sharing within the same project/business unit across different teams and Transit Gateway to connect these VPCs for centralized routing, firewall and on-premises connectivity.



Permissions for VPC Owner and Participants

- VPC participants cannot create, delete, or describe flow logs in a shared VPC subnet that they do not own.
- VPC participants can only enable VPC Flow Logs for ENIs they own.
- VPC owners cannot describe or delete flow logs created by a participant.
- VPC participants cannot create, attach, or delete NAT gateways, internet gateways and egress-only internet gateways in a shared VPC subnet.
- VPC participants cannot create, delete, or replace Route tables or NACLs in a shared VPC subnet.
- VPC participants can work with security groups that they own in a shared VPC subnet. Participants cannot work with security groups created by VPC owners in any way including default Security group.
- VPC participants can't launch instances using security groups that are owned by the VPC owner or other participants.
- DNS Query logs and DNS resolution e.g. DHCP Option set, Route53 Resolver endpoints etc. is controlled by the VPC owner.

https://docs.aws.amazon.com/vpc/latest/userguide/vpc-sharing.html

Billing for VPC Owner and Participants

- VPC participant pays for their application resources including EC2 instances, RDS databases, Redshift clusters, Lambda functions etc.
- VPC participant pays for data transfer charges associated with inter-Availability Zone data transfer, data transfer over VPC peering connections and across AWS Direct Connect gateways.
- VPC owner pays hourly charges for VPC resources, data processing and data transfer charges across NAT gateways, virtual private gateways, transit gateways, AWS VPC endpoints.
- Data transfer within the same Availability Zone (uniquely identified using the AZ-ID) is free irrespective of account ownership of the communicating resources.

https://docs.aws.amazon.com/vpc/latest/userguide/vpc-sharing.html

VPC sharing best practices

- Have a dedicated subnets for shared AWS infrastructure components such as VPC interface endpoints, firewall endpoints, and NAT gateways.
- These subnets should not be shared and only used within the VPC owner AWS account.
- Deny Resource Access Manager (RAM) sharing for AWS accounts which shouldn't share VPC subnets.
- Deny ability to deploy services such as Client VPN and VPC endpoints for VPC participants using Service Control Policies (SCP)
- Deny Private Hosted Zone creation for participant accounts. If required, participant account can create their own PHZ and share it with VPC owner account to associate it with the shared VPC.

Private NAT Gateway

Problems with Private IPs

- Limited by Private IP ranges defined by RFC1918
- Need to have separate Private IP range for different business units
- Microservices architecture require services to have their own Private IPs thereby requiring more and more Private IPs
- This causes..

Difficulty to establish connectivity between the business units with overlapping CIDRs

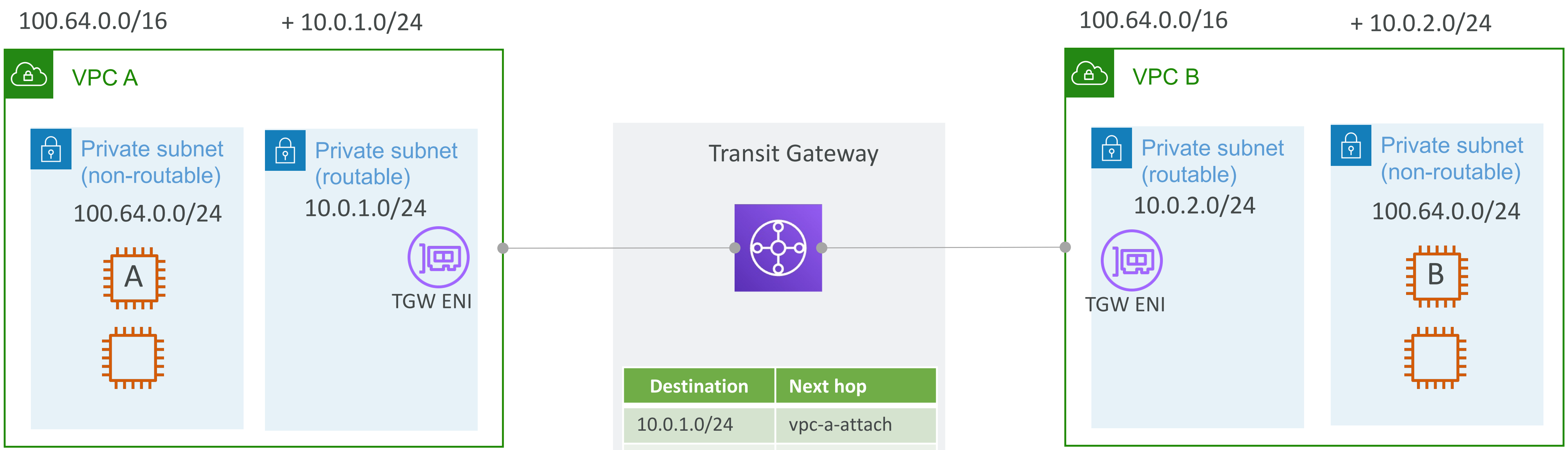
Possible solutions for overlapping IP ranges

- Using AWS PrivateLink
- Using IPv6 addresses
- Using self managed NAT'ing appliances
  - Additional appliances to manage
  - Operational overhead

Private NAT Gateway

- Allows communication between VPCs or VPC and on-premises network having the overlapping CIDRs
- Networks could be connected over Virtual Private Gateway (VGW) or Transit Gateway
- Private NAT performs the Private IP network address translation
- For deploying Private NAT you would often need to divide your address space in routable and non-routable (overlapping) address space and then configure the routing such that there is a communication between non-routable address range via the routable IP addresses

Solution Architecture :VPC A -> VPC B



Destination	Next hop
10.0.1.0/24	vpc-a-attach
10.0.2.0/24	vpc-b-attach

Business Unit 1

Route	Target
10.0.1.0/24	local
100.64.0.0/16	local

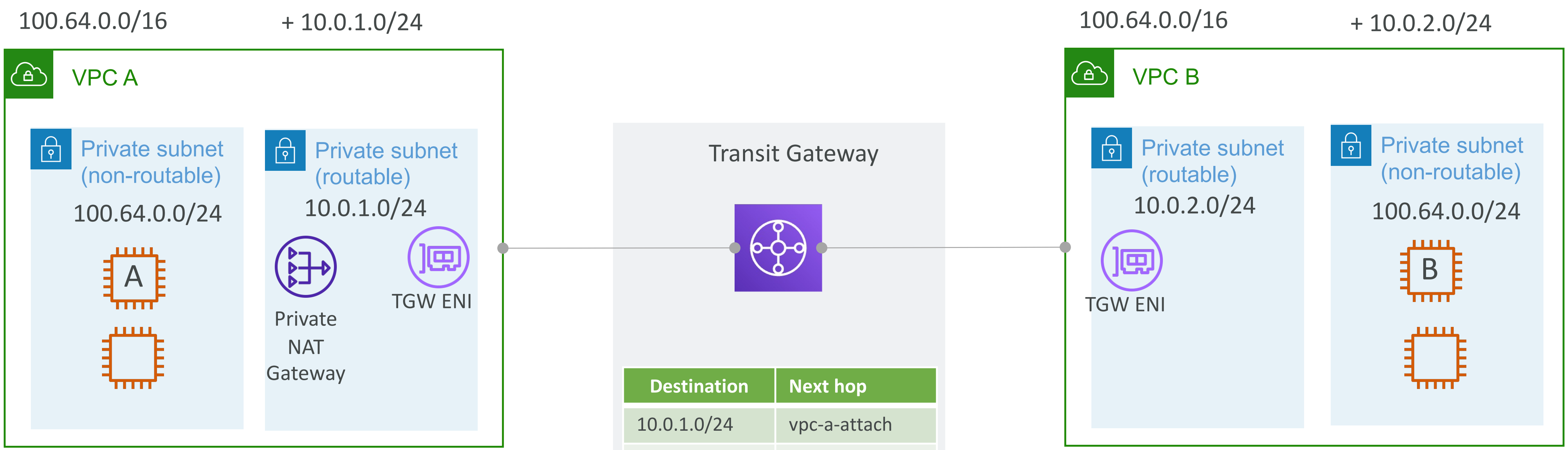
Route	Target
10.0.1.0/24	local
100.64.0.0/16	local

Business Unit 2

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local

Solution Architecture :VPC A -> VPC B



Destination	Next hop
10.0.1.0/24	vpc-a-attach
10.0.2.0/24	vpc-b-attach

Business Unit 1

Route	Target
10.0.1.0/24	local
100.64.0.0/16	local
10.0.2.0/24	nat-xxx

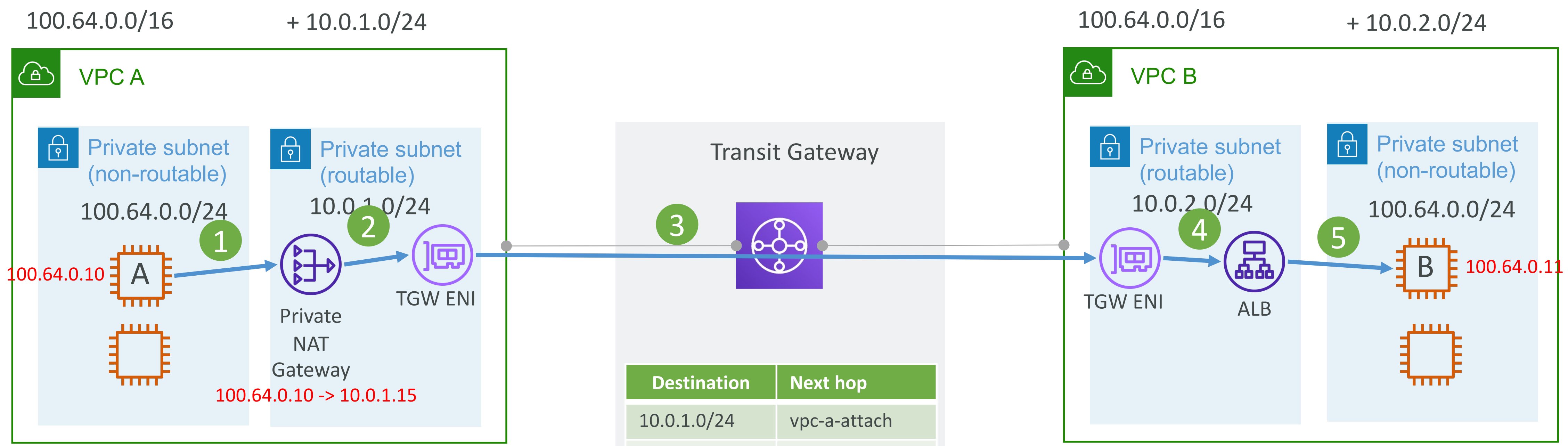
Route	Target
10.0.1.0/24	local
100.64.0.0/16	local
10.0.2.0/24	tgw-xxx

Business Unit 2

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local
10.0.1.0/24	tgw-xxx

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local

Solution Architecture: VPC A -> VPC B



Destination	Next hop
10.0.1.0/24	vpc-a-attach
10.0.2.0/24	vpc-b-attach

Business Unit 1

Route	Target
10.0.1.0/24	local
100.64.0.0/16	local
10.0.2.0/24	nat-xxx

Route	Target
10.0.1.0/24	local
100.64.0.0/16	local
10.0.2.0/24	tgw-xxx

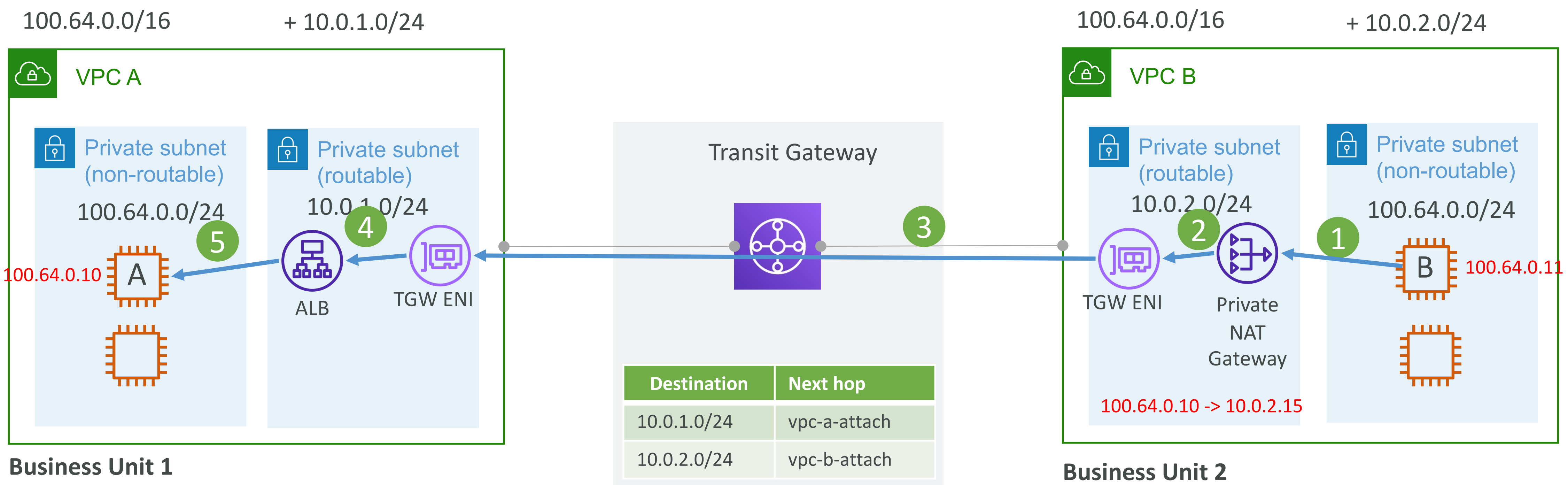
Instance A -> ALB DNS
100.64.0.10 -> 10.0.2.10

Business Unit 2

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local
10.0.1.0/24	tgw-xxx

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local

Solution Architecture –VPC B -> VPC A



Destination	Next hop
10.0.1.0/24	vpc-a-attach
10.0.2.0/24	vpc-b-attach

Instance B -> ALB DNS
100.64.0.11 -> 10.0.1.10

Business Unit 1

Route	Target
10.0.1.0/24	local
100.64.0.0/16	local

Route	Target
10.0.1.0/24	local
100.64.0.0/16	local
10.0.2.0/24	tgw-xxx

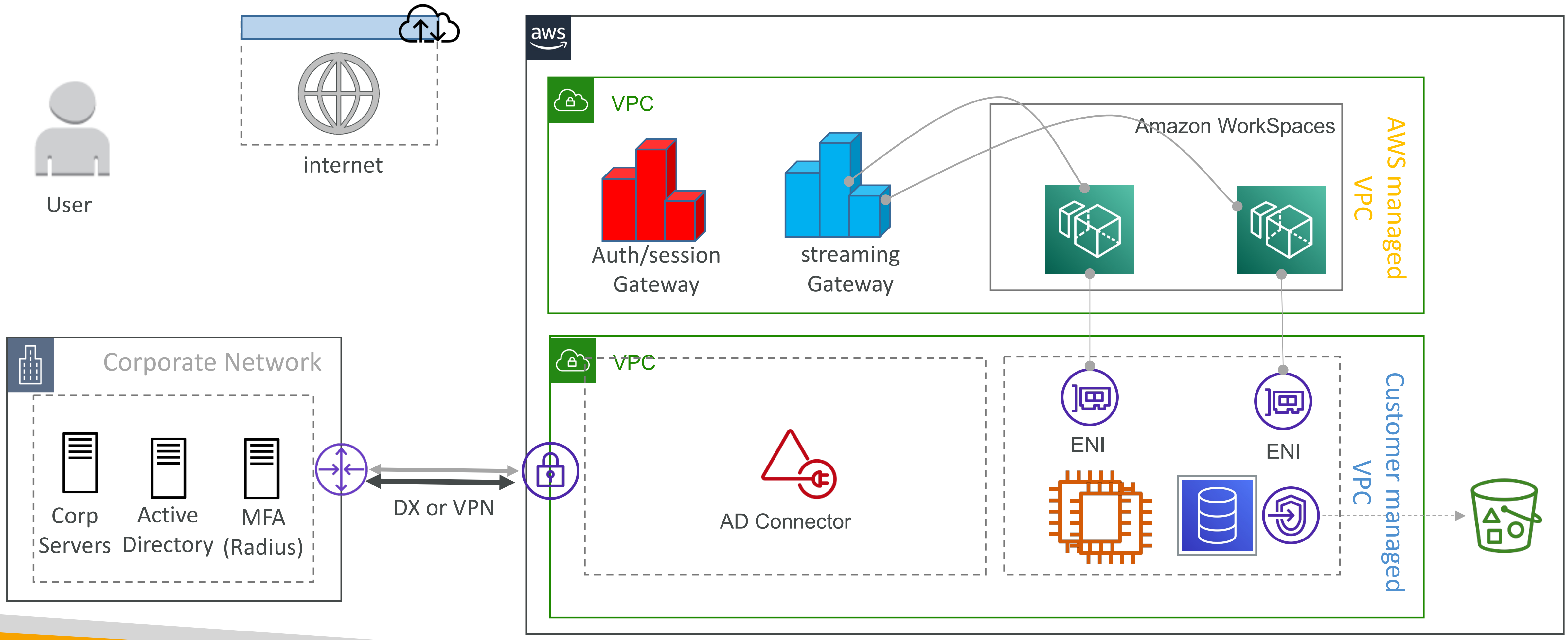
Business Unit 2

Route	Target
10.0.2.0/24	local
100.64.0.0/16	local
10.0.1.0/24	tgw-xxx

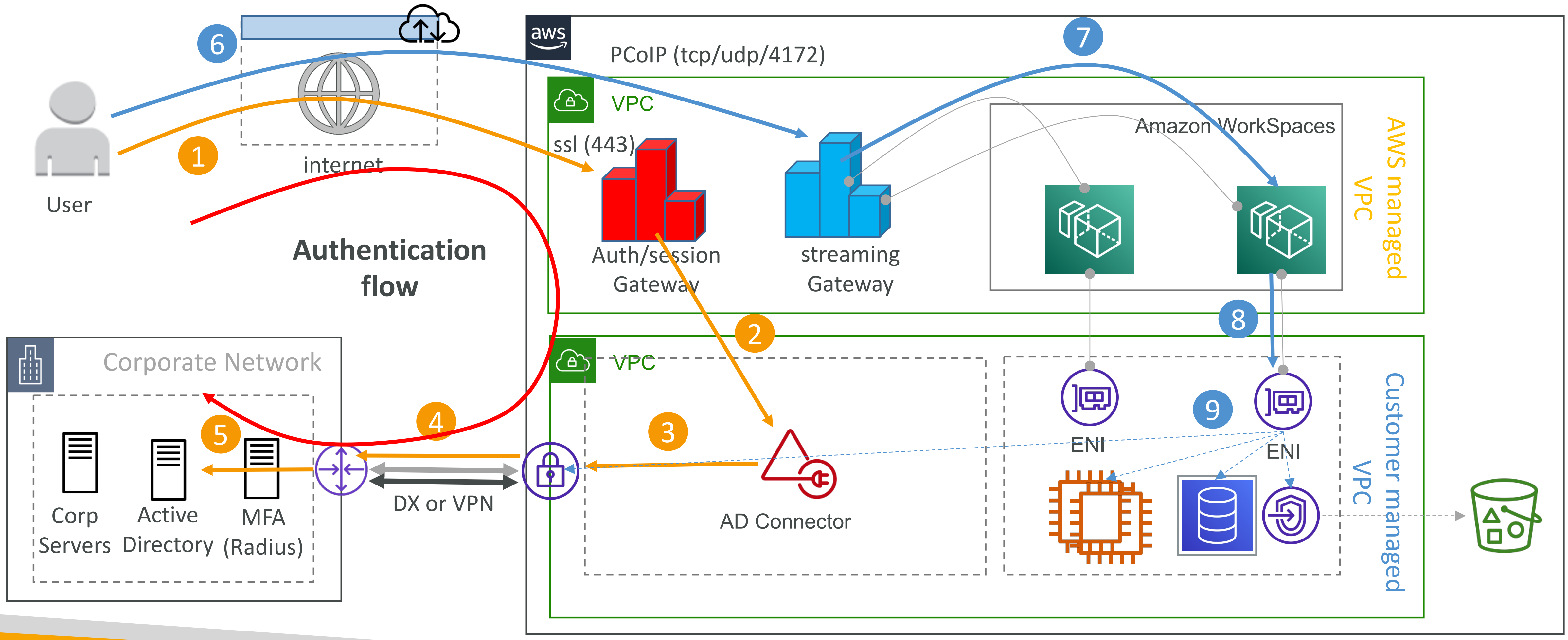
Route	Target
10.0.2.0/24	local
100.64.0.0/16	local
10.0.1.0/24	nat-xxx

VPC resource access for Amazon Workspaces & Appstream2.0

Amazon Workspaces/Appstream networking

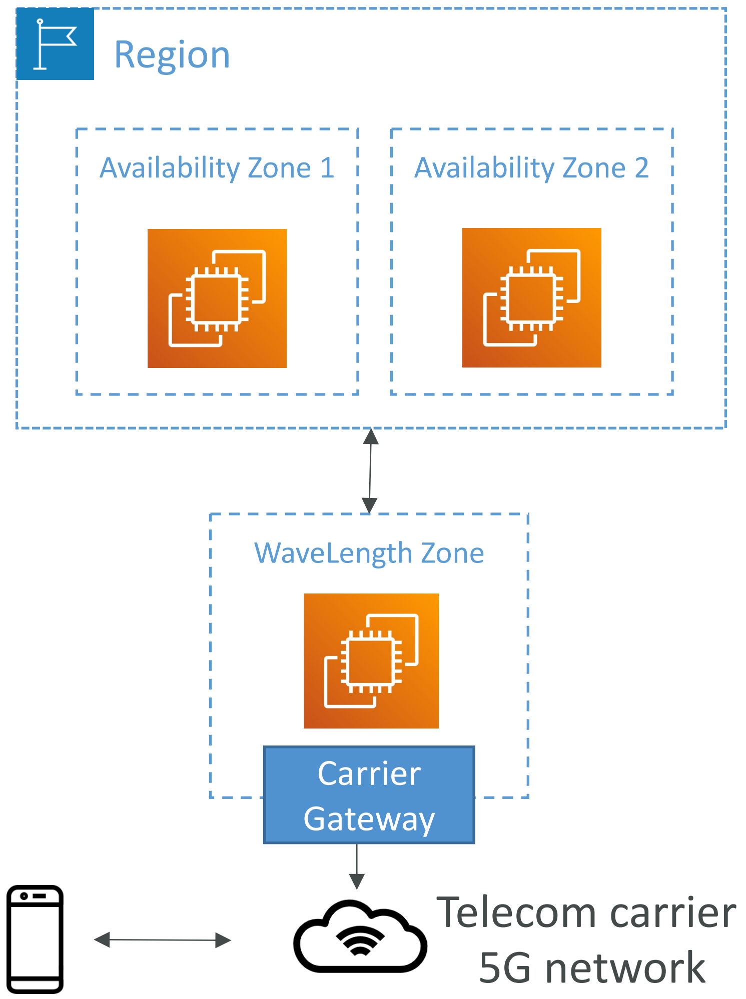


Amazon Workspaces/Appstream networking



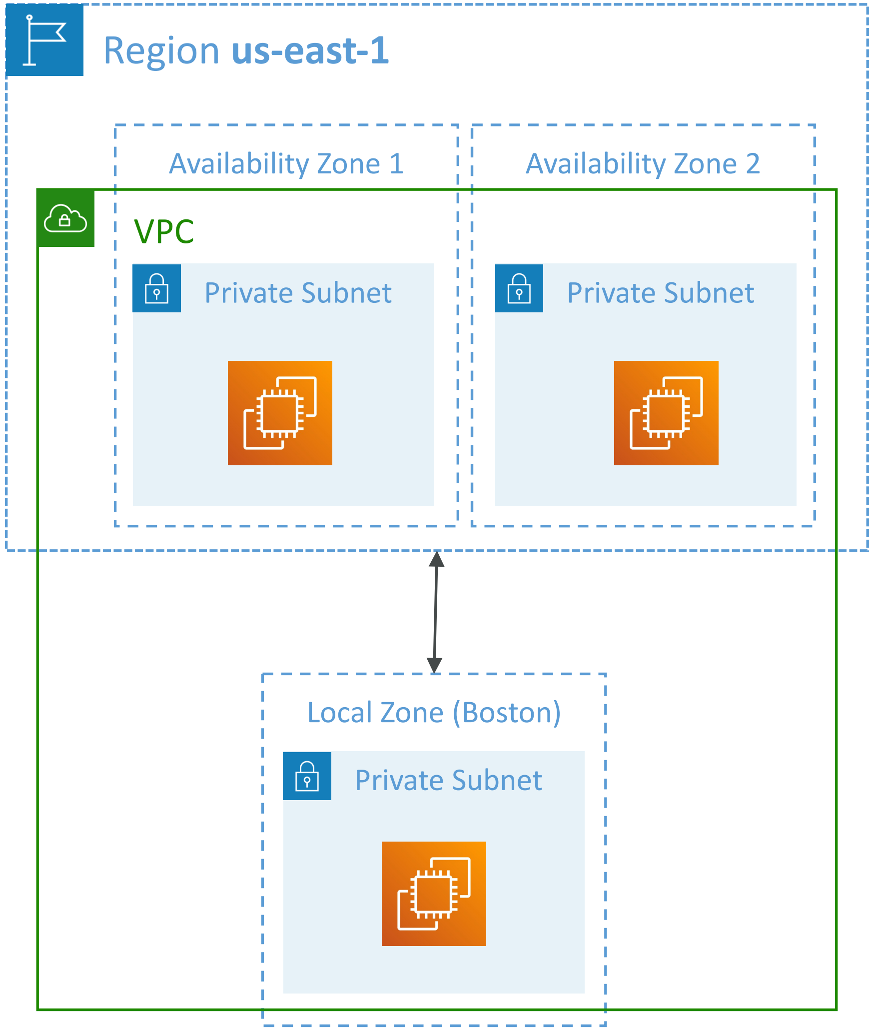
AWS WaveLength

- **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, …



Congratulations

Your AWS Certification journey

Foundational

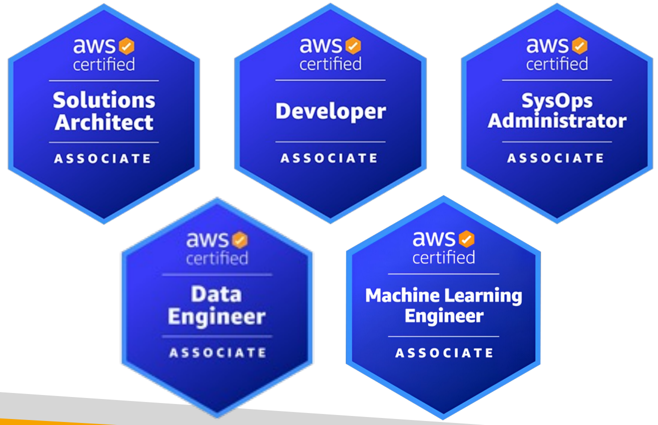
Knowledge-based certification for
foundational understanding of AWS Cloud.
No prior experience needed.

Professional

Role-based certifications that validate advanced skills
and knowledge required to design secure, optimized,
and modernized applications and to automate processes on AWS.
2 years of prior AWS Cloud experience recommended.

Associate

Role-based certifications that showcase your knowledge
and skills on AWS and build your credibility as an AWS Cloud professional.
Prior cloud and/or strong on-premises IT experience recommended.



Specialty

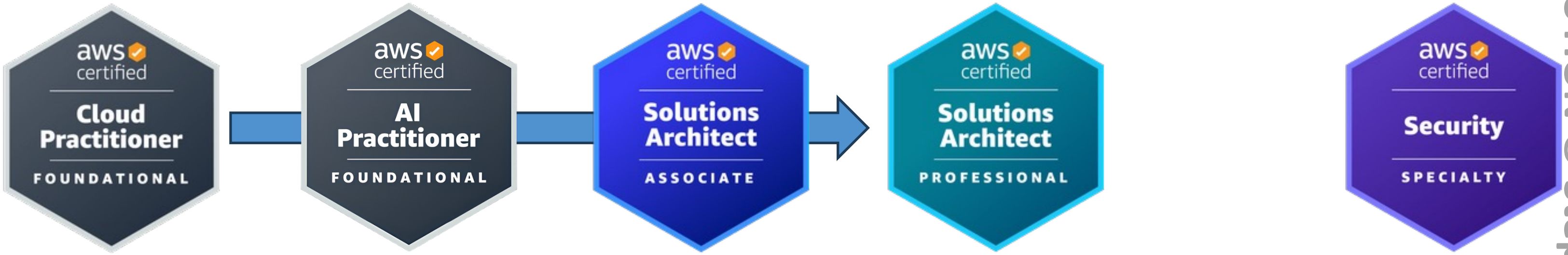
Dive deeper and position yourself as a trusted advisor to your
stakeholders and/or customers in these strategic areas.
Refer to the exam guides on the exam pages for recommended experience.

AWS Certification Paths – Architecture

Architecture

Solutions Architect

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



optional for IT/ cloud professionals

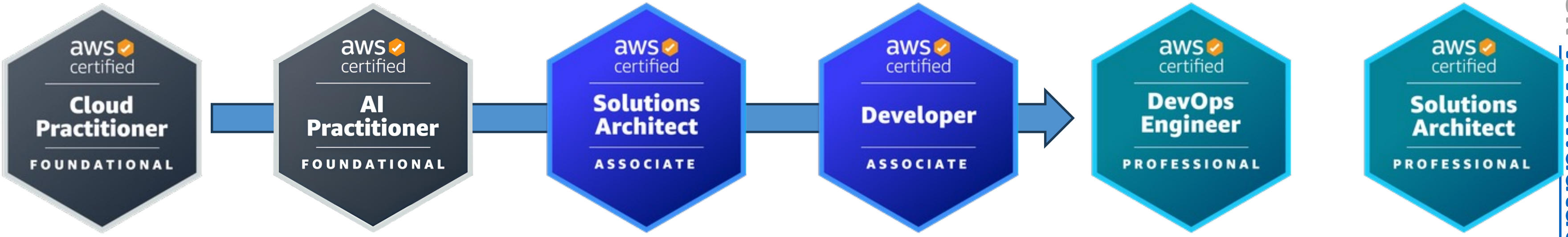
recommended for IT/cloud professionals to leverage AI

Dive Deep

Architecture

Application Architect

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



optional for IT/ cloud professionals

recommended for IT/cloud professionals to leverage AI

Dive Deep

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

optional for IT/ cloud professionals

Dive Deep

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

optional for IT/ cloud professionals

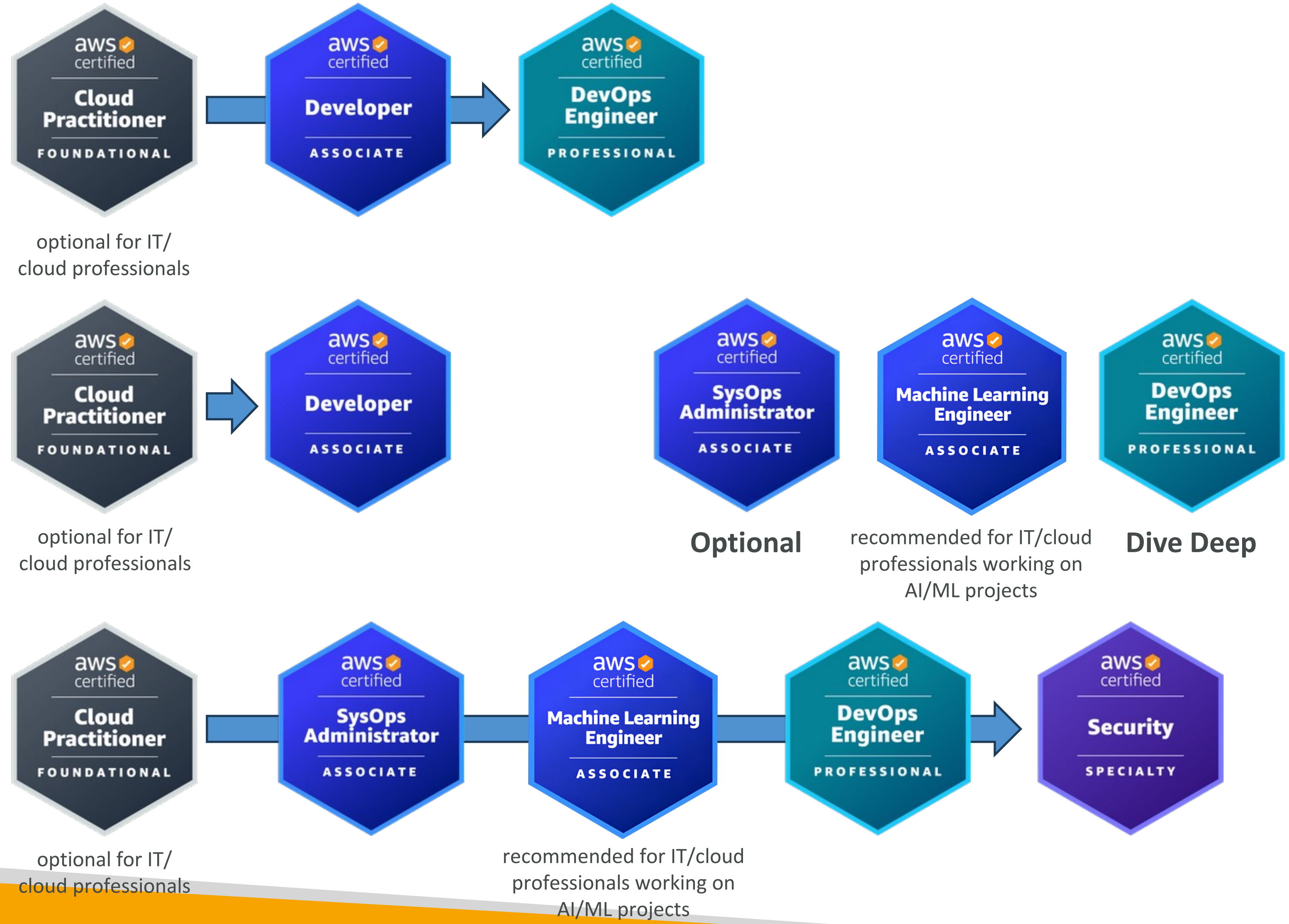
Dive Deep

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

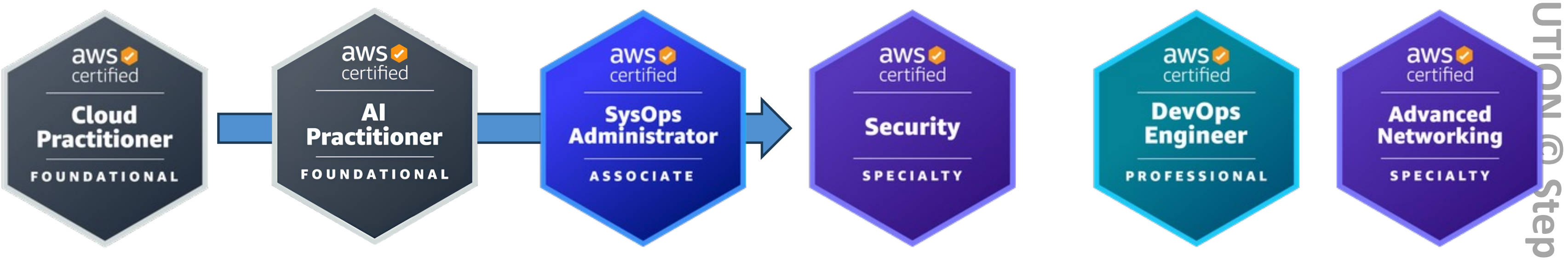


AWS Certification Paths – Security

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



optional for IT/ cloud professionals

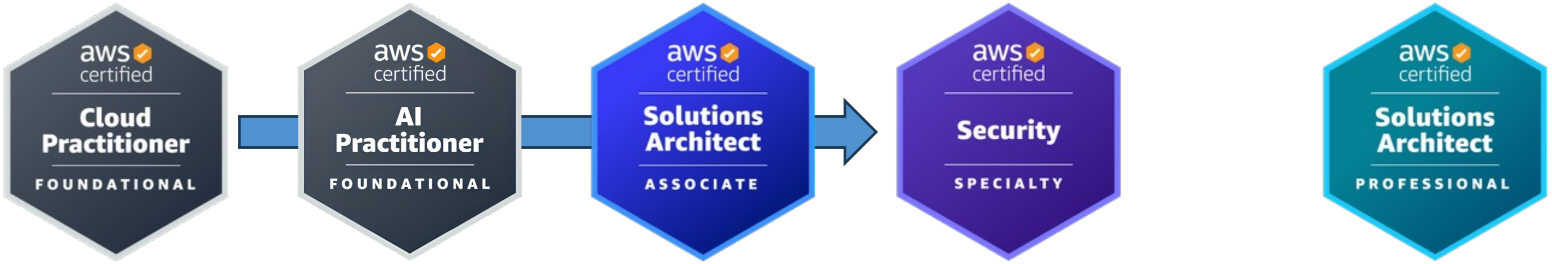
recommended for IT/cloud professionals to secure AI/ML systems

Dive Deep

Security

Cloud Security Architect

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



optional for IT/ cloud professionals

recommended for IT/cloud professionals to secure AI/ML systems

Dive Deep

AWS Certification Paths – Development & Networking

Development

Software Development Engineer

Develop, construct, and maintain software across platforms and devices

optional for IT/ cloud professionals

recommended for IT/cloud professionals to leverage AI

Networking

Network Engineer

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

optional for IT/ cloud professionals

Dive Deep

AWS Certification Paths – Data Analytics & AI/ML

Data Analytics

Cloud Data Engineer

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

optional for IT/ cloud professionals

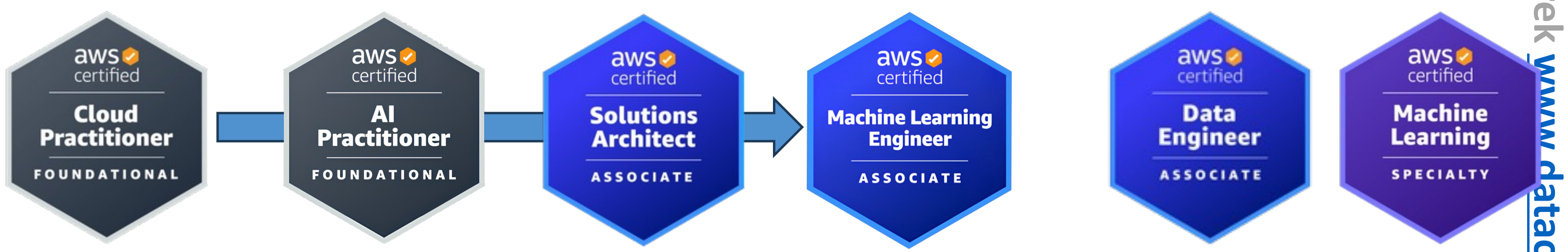
recommended for IT/cloud professionals working on AI/ML projects

Dive Deep

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



optional for IT/ cloud professionals

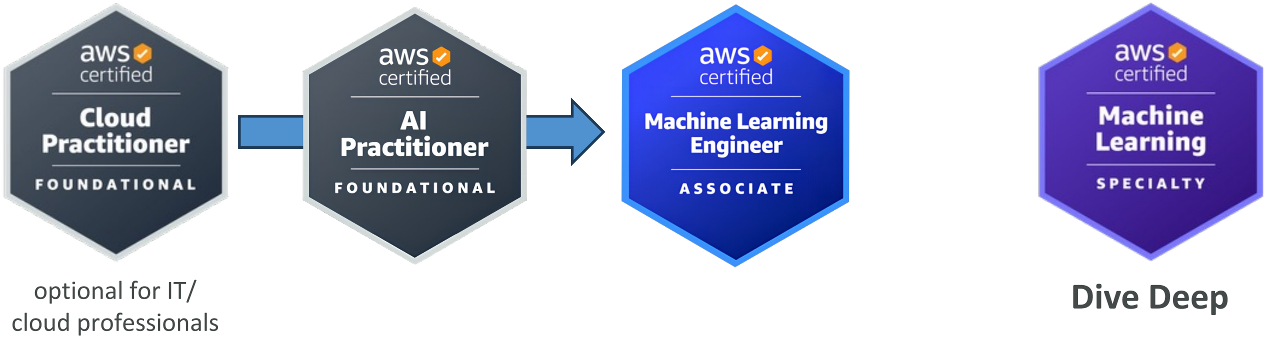
optional for AI/ML professionals

Dive Deep

AWS Certification Paths – AI/ML

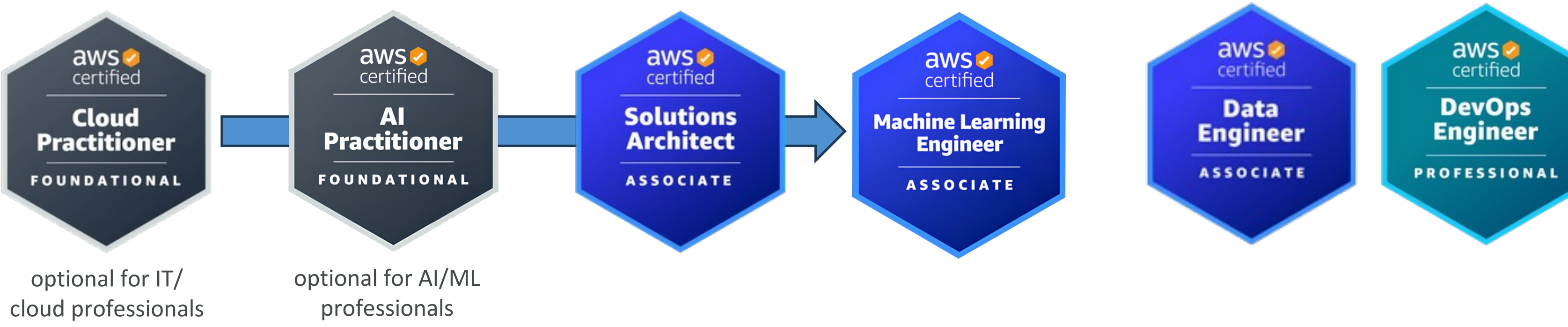
AI/ML
Prompt Engineer

Design, test, and refine text prompts to optimize the performance of AI language models



AI/ML
Machine Learning Ops Engineer

Build and maintain AI and ML platforms and infrastructure. Design, implement, and operationally support AI/ML model activity and deployment infrastructure



AI/ML
Data Scientist

Develop and maintain AI/ML models to solve business problems. Train and fine tune models and evaluate their performance