Task 17

Deploying Node.js App on Amazon EKS using Terraform

Umar Satti

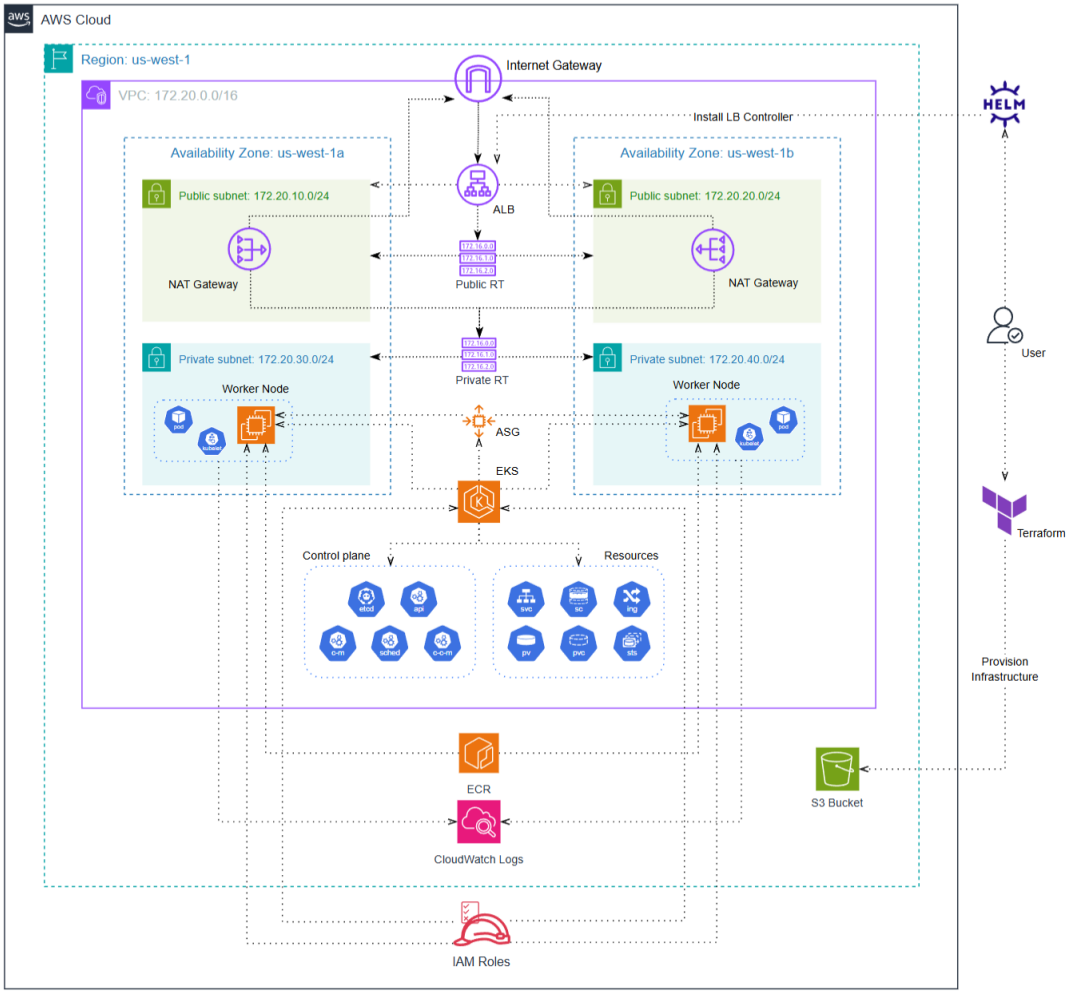
Table of Contents

1. Task Description

This project implements a fully automated AWS Kubernetes platform using Terraform and Amazon EKS. All core infrastructure components, including a custom VPC configuration, IAM roles and policies, and an EKS cluster with managed worker nodes, are provisioned using Terraform. EKS add-ons such as the AWS Load Balancer Controller, EBS CSI Driver, VPC CNI, and CloudWatch Observability are also configured.

A containerized Node.js application is deployed on the EKS cluster using Kubernetes manifests, including a StorageClass, StatefulSet, Service, and Ingress. Persistent storage is dynamically provisioned using Amazon EBS, while external access to the application is provided through an internet-facing Application Load Balancer managed by Kubernetes Ingress. CloudWatch Container Insights and log groups are used to collect metrics and logs from the cluster, nodes, and workloads, providing centralized observability.

2. Architecture Diagram



3. Project Structure

This project is organized into application source files and Terraform infrastructure code. The structure separates application logic, CI/CD configuration, and infrastructure provisioning for clarity and maintainability.

3.1 Application Files

These files define the Node.js application that is deployed on Worker node EC2s.

3.1.1 app.js

- Main application entry point.
- Uses Express to serve static files and provide a /health endpoint.
- Listens on port 3000 or the PORT environment variable.

3.1.2 package.json

- Defines application metadata, dependencies, and start scripts.
- Includes Express as a dependency.

3.1.3 index.html

- Static page served by the application.
- Confirms successful deployment.

3.1.4 Dockerfile

- Builds a lightweight Node.js container using the official Node 20 Alpine image.
- Installs dependencies, exposes port 3000, and starts the application.

3.2 Terraform Infrastructure Code

This directory contains Terraform configuration used to provision and manage all AWS infrastructure required for Jenkins, EC2, VPC, IAM, and CloudWatch. The setup follows a modular design to improve reusability and consistency.

3.2.1 Root Terraform Files

These files act as the entry point and orchestrate all infrastructure modules.

terraform.tf

- Defines required Terraform providers (AWS, Kubernetes, Helm).
- Configures remote encrypted S3 backend with state locking.
- Sets AWS region and configures Kubernetes and Helm providers.

main.tf

Serves as the central orchestration file and invokes the following Terraform modules:

- VPC: networking and security foundations
- IAM: roles and policies for EKS and add-ons
- ECR: container image repository
- EKS: Kubernetes cluster, node groups, and managed add-ons
- Add-ons: Helm-based Kubernetes controllers

variables.tf

- Declares all input variables required by the root module.
- Groups variables logically by service (VPC, IAM, ECR, EKS, Add-ons).
- Enables environment flexibility without modifying Terraform code.

terraform.tfvars

Supplies concrete values for all declared variables. Defines environment-specific configuration including:

- CIDR ranges and availability zones
- IAM role naming
- EKS version, node sizing, and add-on versions
- Allows reuse of the same code across environments.

3.2.2 Terraform Modules Directory

1. VPC Module

The VPC module provisions the complete networking layer for the EKS cluster.

- Creates a custom VPC with DNS support enabled.
- Provisions:
    - Two public subnets
    - Two private subnets
    - Internet Gateway
    - Two NAT Gateways (one per AZ)
    - Four route tables (one for each subnet)
- Configures public and private route tables for internet and outbound access.
- Defines a shared security group for EKS worker nodes allowing:
    - Full intra-node communication
    - Outbound internet access
- Tags resources to integrate seamlessly with the EKS cluster.

2. IAM Module

The IAM module provisions all roles and policies required by EKS, worker nodes, and cluster add-ons. This module also defines trust relationships for:

- EKS control plane
- EC2 worker nodes
- EKS Pod Identity

Creates IAM roles for:

- EKS cluster
- Managed node groups
- VPC CNI add-ons
- CloudWatch observability
- EBS CSI driver
- AWS Load Balancer Controller

3. ECR Module

The ECR module provisions a private container image repository.

- Creates an Amazon ECR repository for application images.
- Enables image tag mutability configuration.
- Configures encryption at rest using AES-256.
- Outputs repository URI for use in Kubernetes deployments.

4. EKS Module

The EKS module provisions the Kubernetes control plane, worker nodes, and managed add-ons.

eks/main.tf

Creates an Amazon EKS cluster with both public and private API access. Enables control plane logging for operational visibility. Deploys a managed node group in private subnets with autoscaling. Associates a node security group and SSH access key.

Installs core EKS add-ons:

- VPC CNI
- CoreDNS
- kube-proxy
- CloudWatch Observability
- EBS CSI Driver
- Pod Identity Agent
- Configures IAM Pod Identity associations for add-ons.

eks/variables.tf

Declares inputs for cluster configuration, networking, IAM roles, scaling, and add-on versions.

eks/outputs.tf

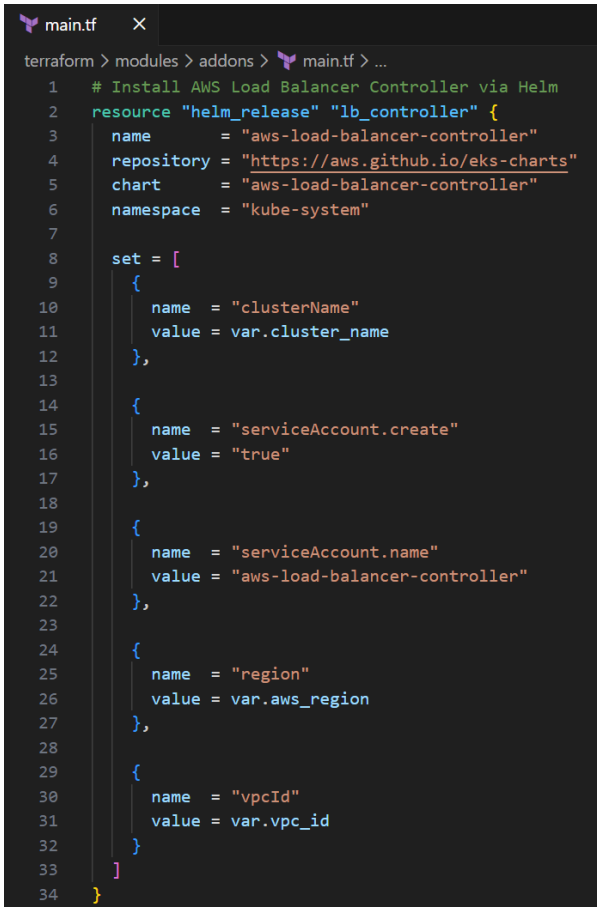
Exposes cluster name, endpoint, and certificate authority data.

5. Add-ons Module

The add-ons module installs Kubernetes controllers using Helm.

addons/main.tf

- Deploys the AWS Load Balancer Controller via Helm.
- Configures cluster name, region, and VPC integration.
- Uses a Kubernetes service account mapped to IAM Pod Identity.



addons/variables.tf

- Accepts cluster name, AWS region, and VPC ID.

variables.tf

terraform > modules > addons > variables.tf > ...

```
variable "cluster_name" {
  type = string
}

variable "aws_region" {
  type = string
}

variable "vpc_id" {
  type = string
}
```

3.2.3 Supporting Configuration

Load Balancer Controller IAM Policy (lbc-policy.json)

- The IAM policy for the AWS Load Balancer Controller is sourced directly from the official Kubernetes SIGs repository.
- Provides permissions required to manage Application Load Balancers, target groups, listeners, and security groups.
- Ensures alignment with supported controller versions and AWS best practices.

3.3 Terraform Commands

1. Terraform init

Initializes the Terraform working directory by downloading required providers and modules, configuring the remote backend, and preparing Terraform.

```
PS D:\Cloudelligent\Task-17\terraform> terraform init
Initializing the backend...
Initializing modules...
Initializing provider plugins...
- Reusing previous version of hashicorp/helm from the dependency lock file
- Reusing previous version of hashicorp/aws from the dependency lock file
- Reusing previous version of hashicorp/kubernetes from the dependency lock file
- Using previously-installed hashicorp/kubernetes v3.0.1
- Using previously-installed hashicorp/helm v3.1.1
- Using previously-installed hashicorp/aws v6.28.0

Terraform has been successfully initialized!

You may now begin working with Terraform. Try running "terraform plan" to see
any changes that are required for your infrastructure. All Terraform commands
should now work.

If you ever set or change modules or backend configuration for Terraform,
rerun this command to reinitialize your working directory. If you forget, other
commands will detect it and remind you to do so if necessary.
PS D:\Cloudelligent\Task-17\terraform>
```

2. Terraform validate

Checks the Terraform configuration for syntax and logical errors without creating resources, ensuring the configuration is valid and consistent.

```
PS D:\Cloudelligent\Task-14\terraform> terraform validate
Success! The configuration is valid.

PS D:\Cloudelligent\Task-14\terraform>
```

3. Terraform plan

Creates an execution plan that previews the AWS resources Terraform will create and any changes that will be applied, allowing review before deployment.

4. Terraform apply

The terraform apply command provisions the AWS infrastructure as defined in the Terraform configuration. Upon confirmation, Terraform creates all required resources defined in VPC, IAM, EKS, ECR and Add-on modules.

```
Apply complete! Resources: 49 added, 0 changed, 0 destroyed.
PS D:\Cloudelligent\Task-17\terraform>
```

4. Validate Infrastructure on AWS

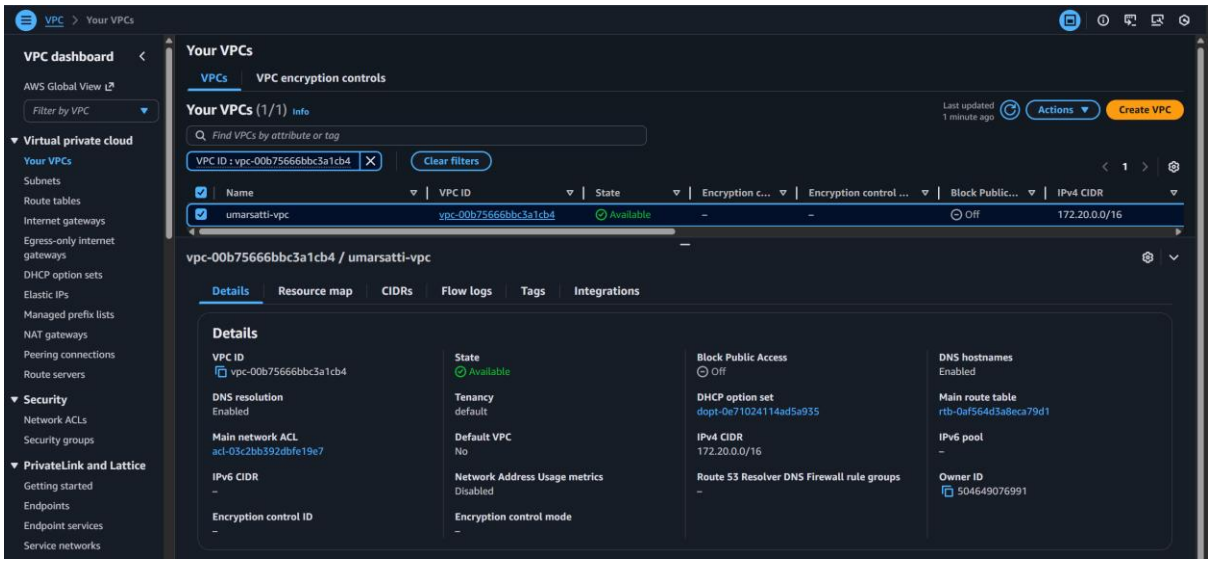
This section validates that all AWS resources created using Terraform are provisioned correctly and functioning as expected.

4.1 VPC and Networking Validation

1. Verify VPC

In the AWS Console, navigate to **VPC** service. Select **Your VPCs** and verify the following:

- VPC created by Terraform exists.
- Correct IPv4 CIDR block as defined in Terraform.
- DNS hostnames and DNS resolution are enabled.
- VPC name matches the Terraform configuration.
- The following shows the VPC configuration:
    - **Name:** umarsatti-vpc
    - **VPC ID:** vpc-00b75666bbc3a1cb4
    - **IPv4 CIDR:** 172.20.0.0/16



2. Verify Subnets

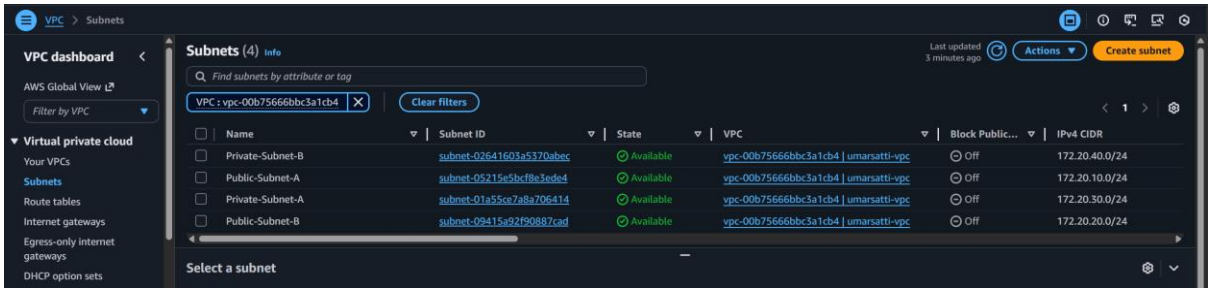
Navigate to **Subnets** section in the VPC console. Confirm creation of public and private subnets. The following shows the subnets configuration:

Public Subnets

- **Names:** Public-Subnet-A & Public-Subnet-B
- **IPv4 CIDRs:** 172.20.10.0/24 & 172.20.20.0/24
- **Subnet IDs:** subnet-05215e5bcf8e3ede4 & subnet-09415a92f90887cad

Private Subnets

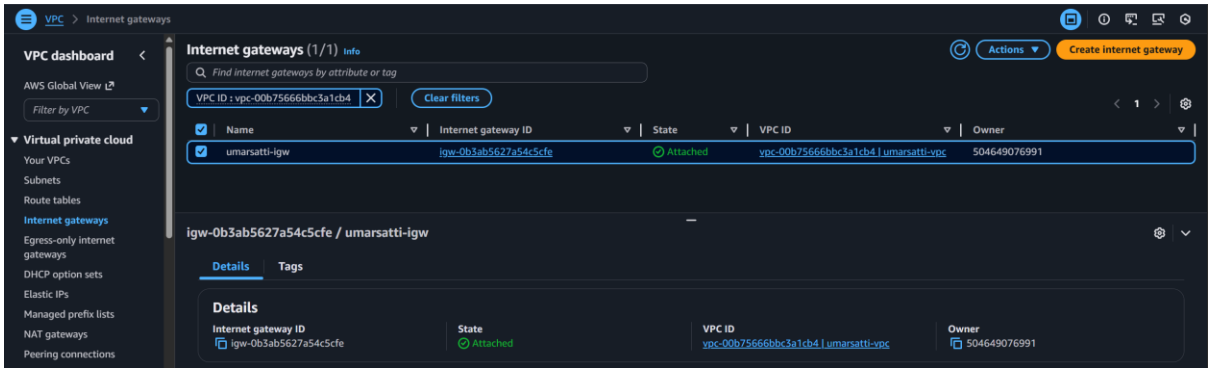
- **Names:** Private-Subnet-A & Private-Subnet-B
- **IPv4 CIDRs:** 172.20.30.0/24 & 172.20.40.0/24
- **Subnet IDs:** subnet-01a55ce7a8a706414 & subnet-02641603a5370abec



3. Verify Internet Gateway

Navigate to **Internet Gateways** in the VPC console.

- Confirm that Internet gateway exists and **attached** to VPC.
- The following shows the IGW configuration:
    - **Name:** umarsatti-igw
    - **Internet gateway ID:** igw-0b3ab5627a54c5cfe
    - **State:** Attached



4. Verify NAT Gateway

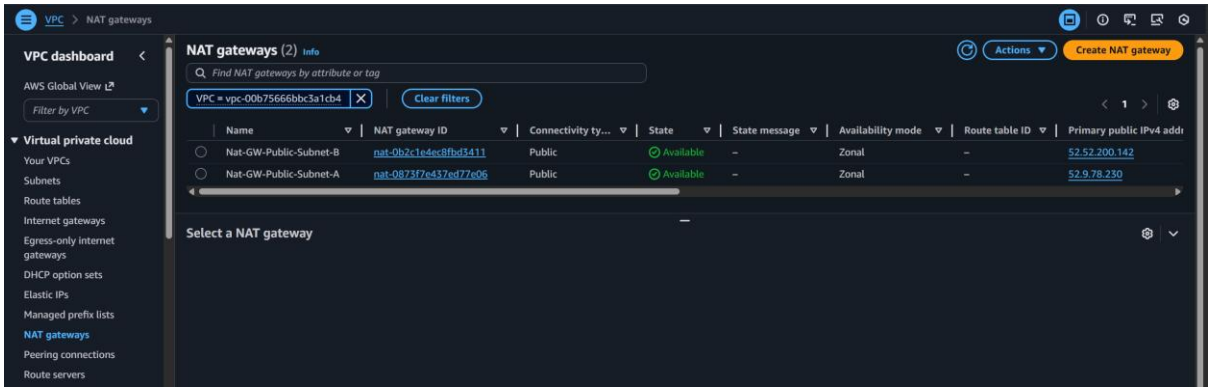
Navigate to **NAT gateways** in the VPC console. Confirm that NAT Gateways exist in their respective public subnets. The following shows the NAT gateway configuration:

NAT Gateway in Public subnet A:

- **Name:** Nat-EIP-Public-Subnet-A
- **Nat gateway ID:** nat-0873f7e437ed77e06
- **Elastic IP:** 52.9.78.230

NAT Gateway in Public subnet B:

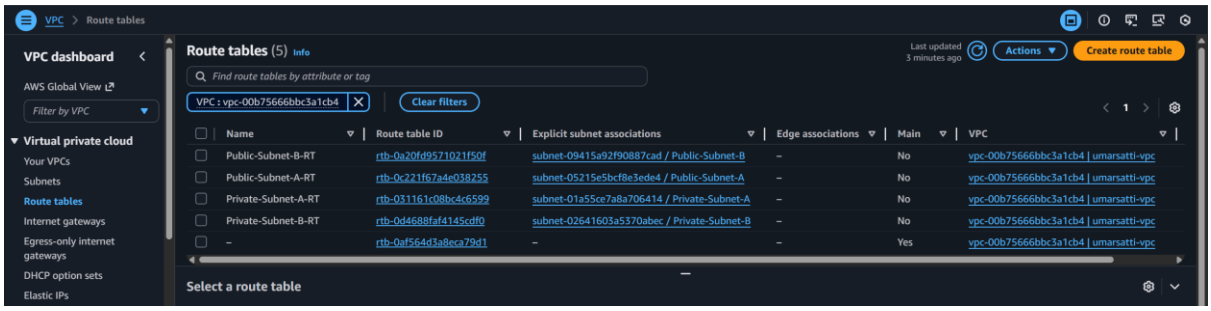
- **Name:** Nat-EIP-Public-Subnet-B
- **Nat gateway ID:** nat-0b2c1e4ec8fbd3411
- **Elastic IP:** 52.52.200.142



5. Route Tables

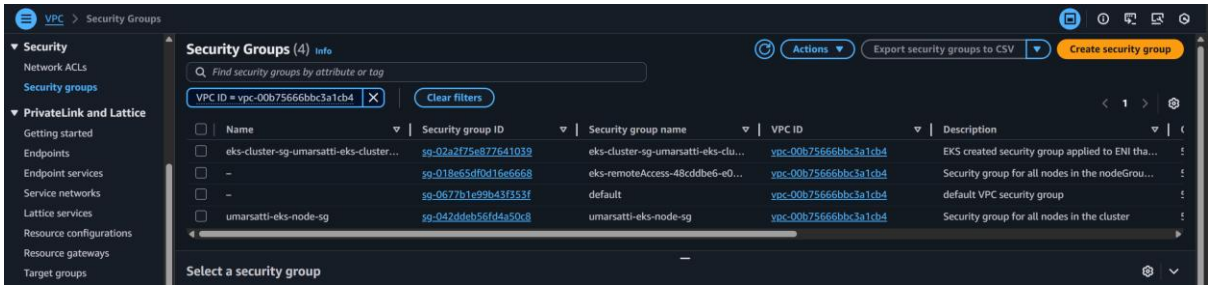
Navigate to **Route Tables** in the VPC console. Confirm that public and private route tables are created. The following shows the configuration:

- **Public route table names:** Public-Subnet-A-RT & Public-Subnet-B-RT
- **Private route table names:** Private-Subnet-A-RT & Private-Subnet-B-RT



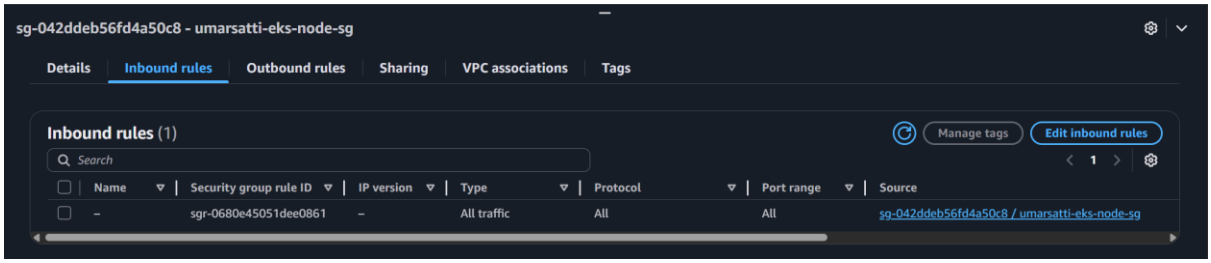
6. Security Groups

Navigate to **Security Groups** in the VPC console. Confirm that both the security groups are created. The following shows the security group configuration:



EKS worker node security group

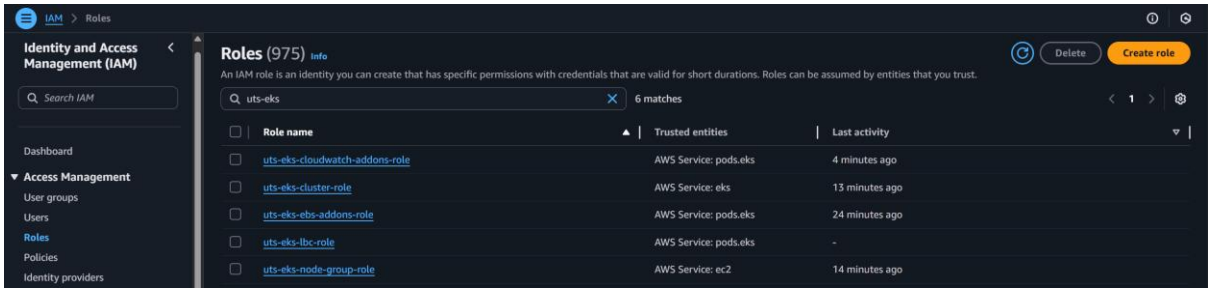
- **Name:** umarsatti-eks-node-sg
- **Inbound rules:** Traffic on Port 22, 80, and 3000.
- **Outbound rules:** All traffic allowed (0.0.0.0/0)



Note: Rest of the security groups were created automatically by EKS.

4.2 IAM Validation

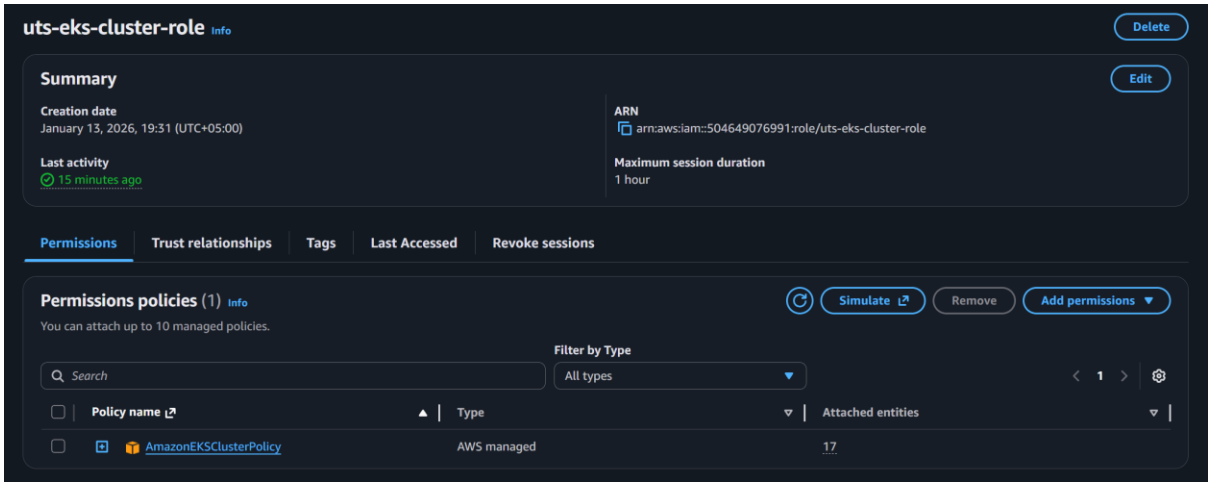
This section validates that all IAM roles required for the EKS cluster, worker nodes, and add-ons have been created and configured correctly.



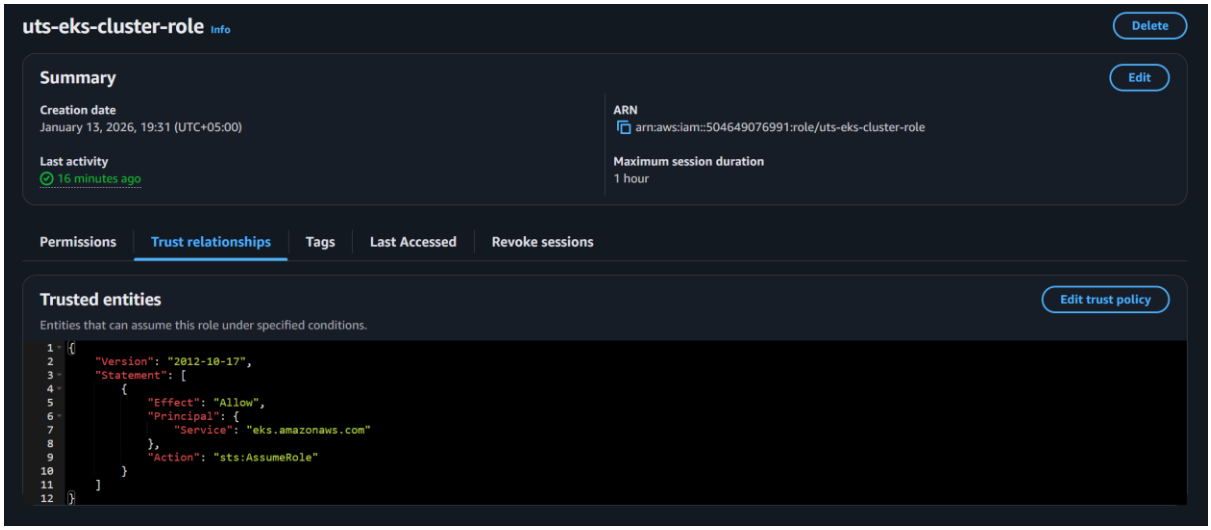
1. EKS Cluster IAM Role

Navigate to the **IAM** console and select **Roles**. Search for the role named **uts-eks-cluster-role**. Select this role and verify the following:

- The AWS managed policy **AmazonEKSClusterPolicy** is attached.
- The role is correctly referenced by the EKS cluster during creation.



This IAM Role should have trust relationship which allows the EKS service (**eks.amazonaws.com**) to assume the role.

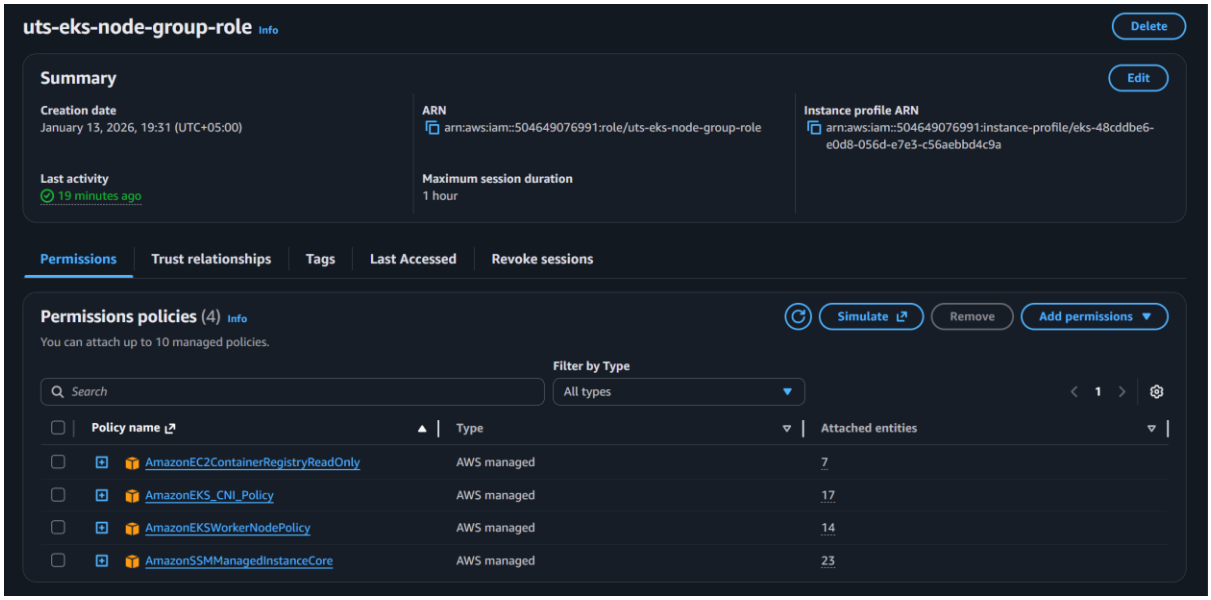


This confirms that the EKS control plane has the required permissions to manage cluster resources.

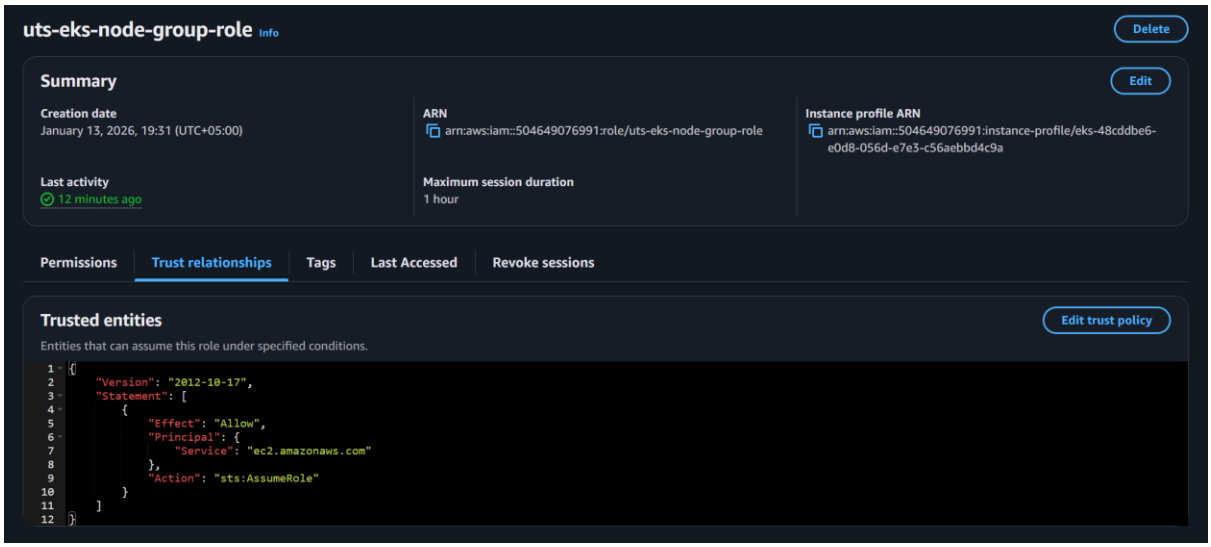
2. EKS Node Group IAM Role

In the **IAM** console, locate or search for the role named **uts-eks-node-group-role** and confirm the following.

- AWS managed policies are attached:
  - AmazonEC2ContainerRegistryReadOnly
  - AmazonEKS_CNI_Policy
  - AmazonEKSWorkerNodePolicy
  - AmazonSSMManagedInstanceCore
- The role is associated with the managed node group.



This IAM Role should have trust relationship which allows the EC2 service (**ec2.amazonaws.com**) to assume the role.

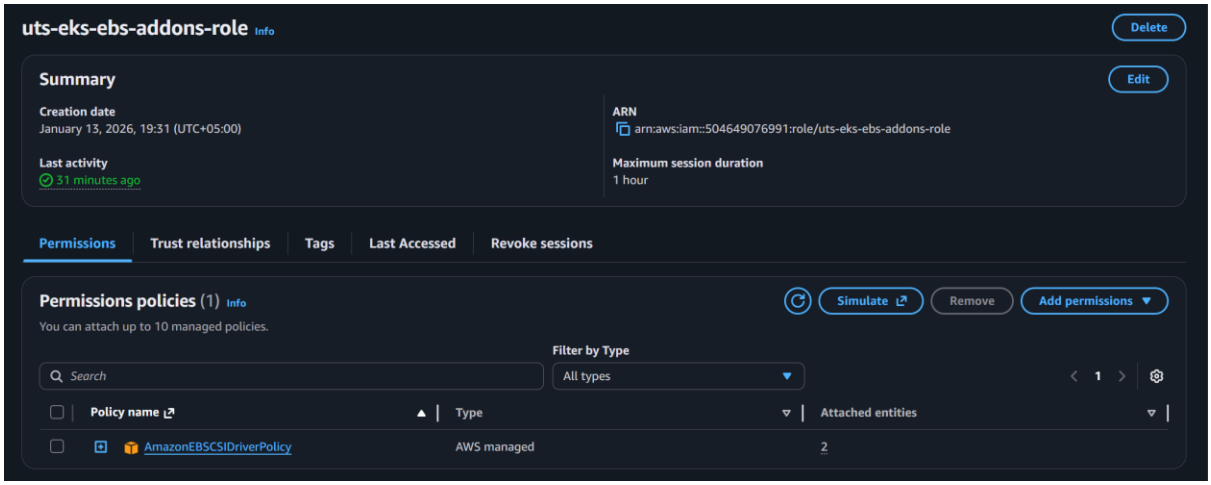


This validates that worker nodes can join the cluster, pull container images, manage networking, and be accessed via AWS Systems Manager.

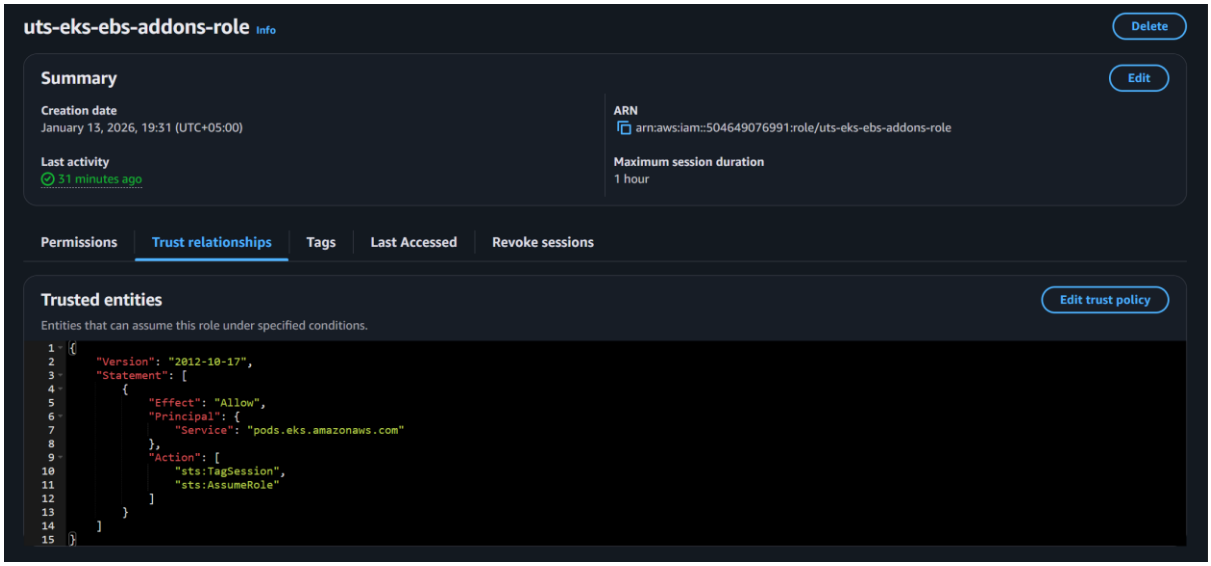
3. EBS CSI Driver IAM Role

Within the **IAM** console, search for **uts-eks-ebs-addons-role**. Verify the following:

- The AWS managed policy **AmazonEBSCSIDriverPolicy** is attached.
- The role is associated with the EBS CSI controller **service account**.



This IAM Role should have trust relationship which allows EKS pods (**pods.eks.amazonaws.com**) to assume the role.

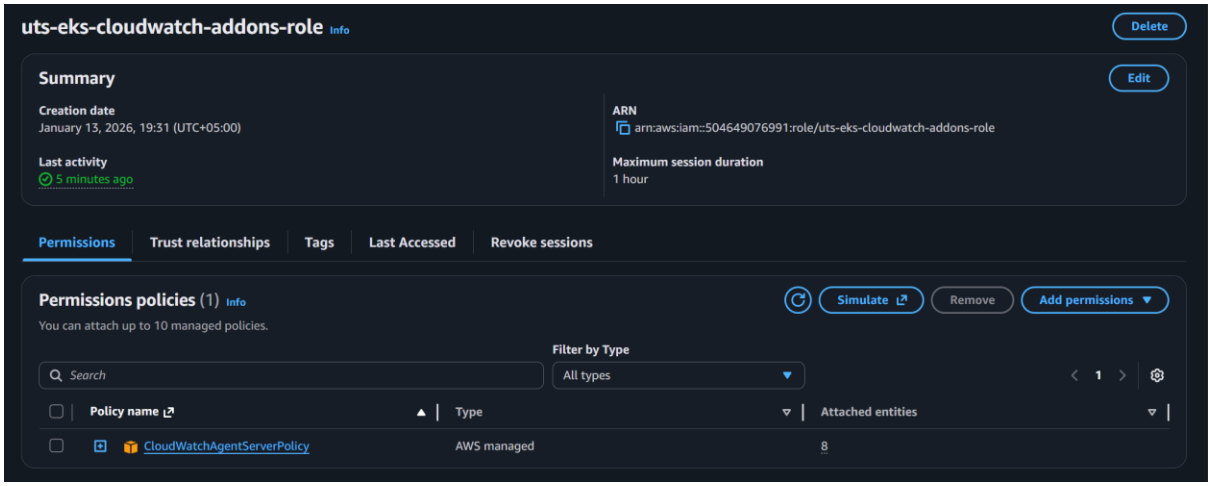


This ensures that Kubernetes workloads can dynamically provision and manage EBS volumes.

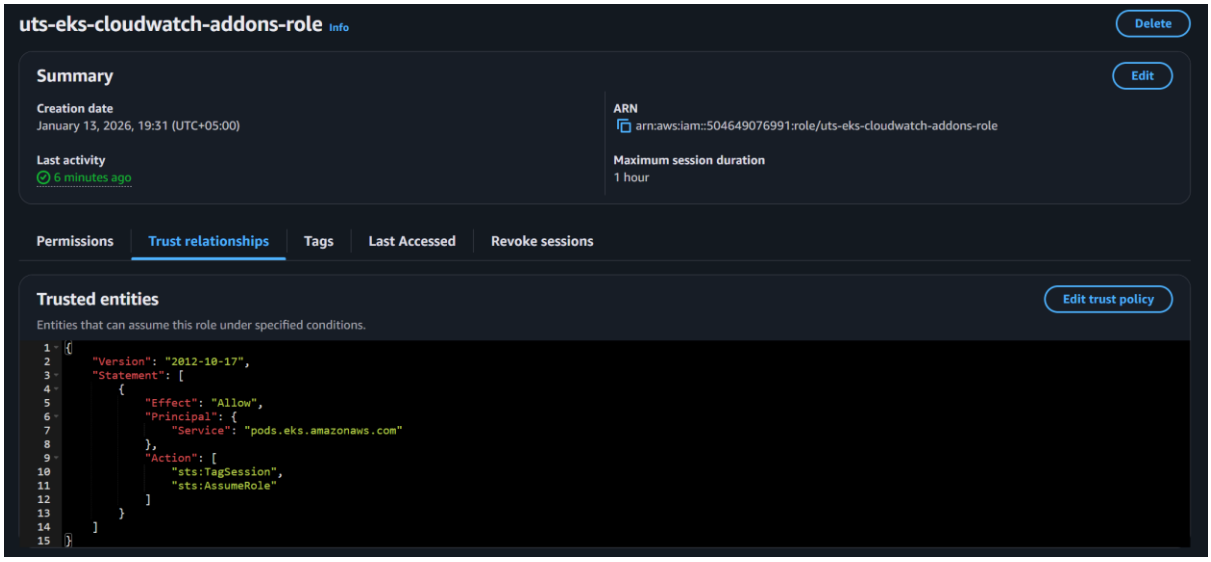
4. CloudWatch Observability IAM Role

Locate the IAM role named **uts-eks-cloudwatch-addons-role** and confirm:

- The **CloudWatchAgentServerPolicy** is attached.
- The role is linked to the CloudWatch observability add-on.



This IAM Role should have trust relationship which allows EKS pods (**pods.eks.amazonaws.com**) to assume the role.

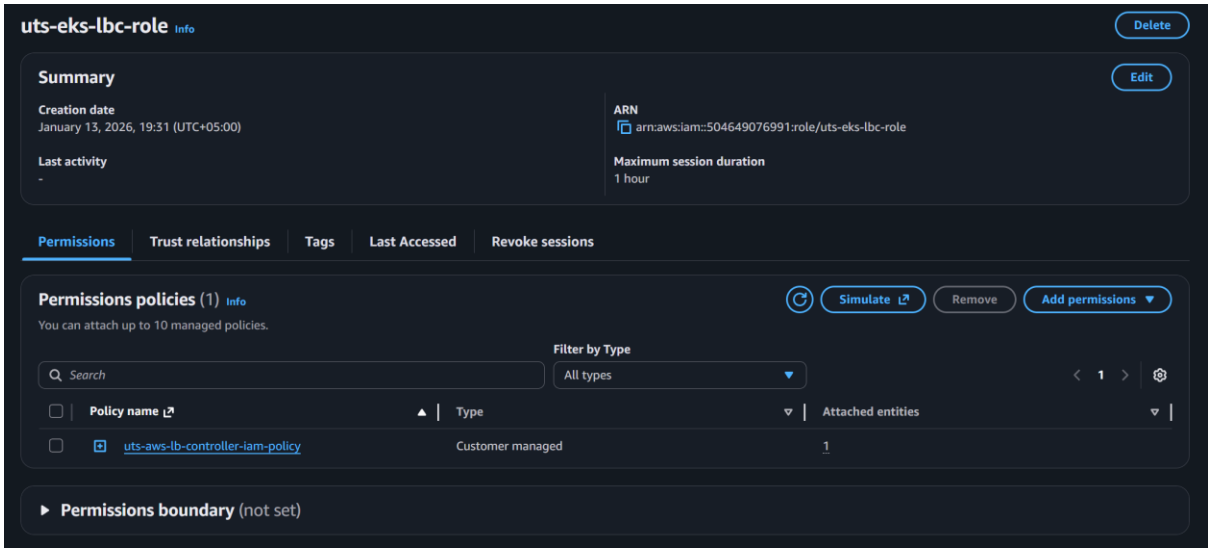


This validates that cluster and workload metrics and logs can be securely sent to Amazon CloudWatch.

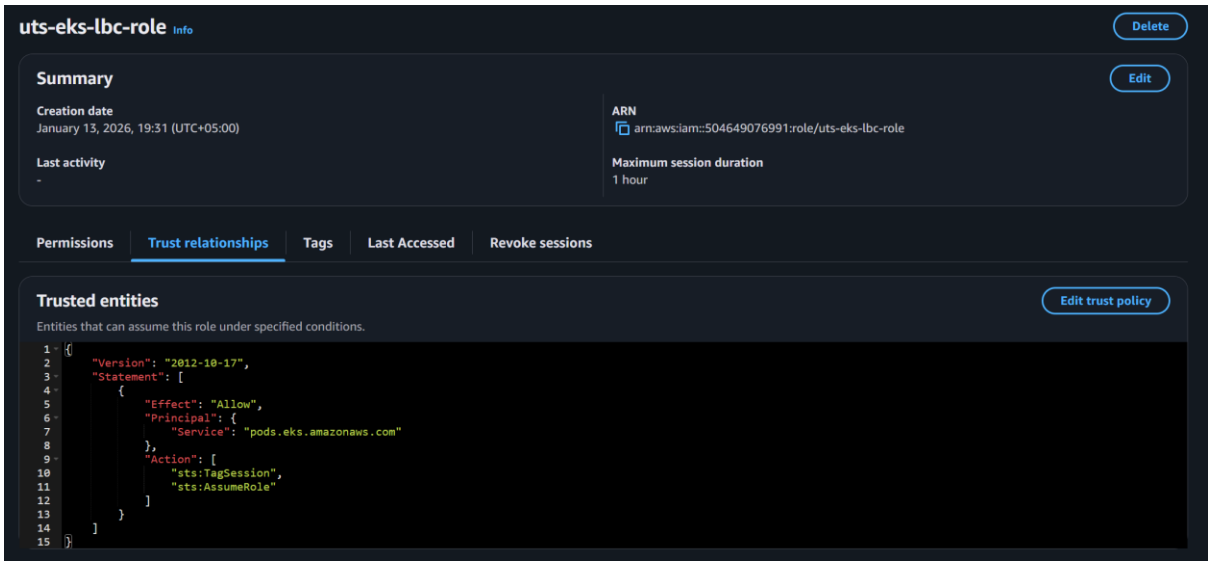
5. Load Balancer Controller IAM Role

In the IAM console, search for the role **uts-eks-lbc-role** and verify:

- A custom inline policy named uts-aws-lb-controller-iam-policy is attached.
- The policy grants permissions required to create and manage AWS Application Load Balancers.



This IAM Role should have trust relationship which allows EKS pods (**pods.eks.amazonaws.com**) to assume the role.

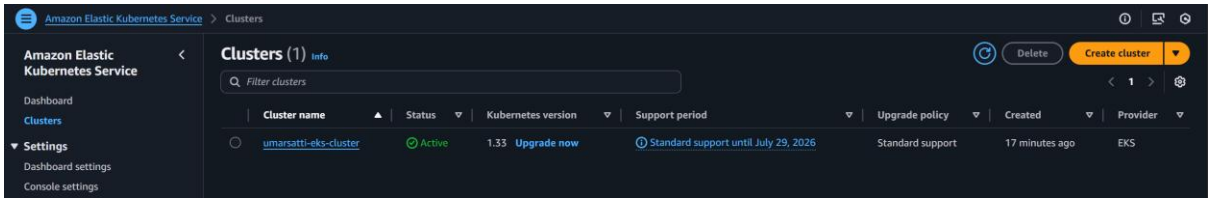


This confirms that the AWS Load Balancer Controller can provision and manage load balancers for Kubernetes services.

4.3 EKS Cluster Validation

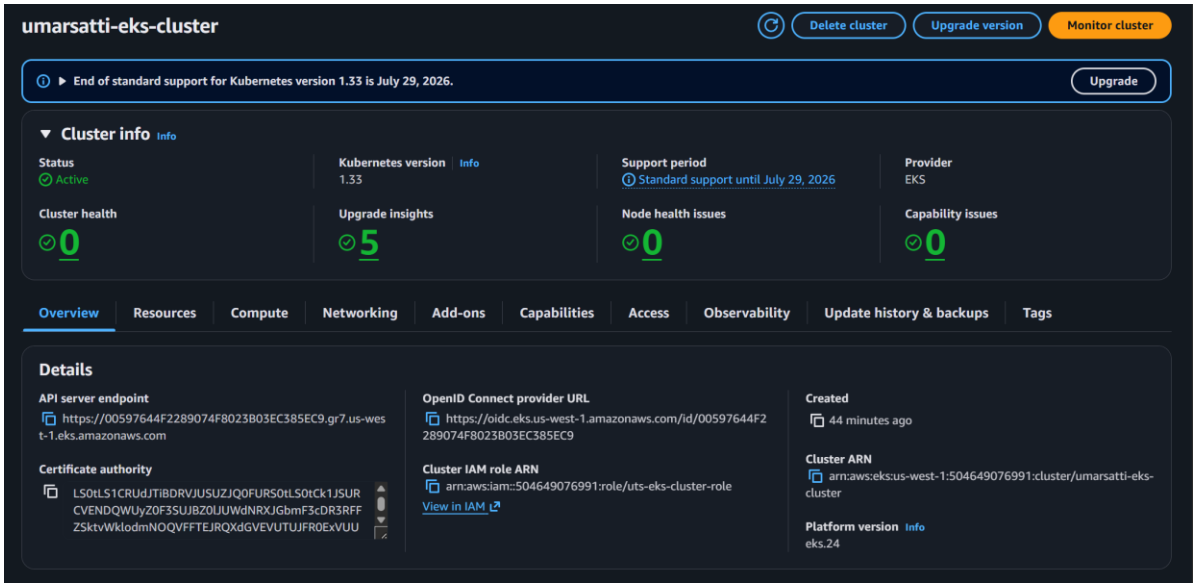
This section validates that the Amazon EKS cluster has been provisioned correctly, including compute, networking, add-ons, and observability.

1. EKS Cluster Status



Navigate to **Amazon EKS** within the **AWS Console.** Select **Clusters** located on the left navigation bar. Click on **umarsatti-eks-cluster**. Verify the following:

- **Status:** Active
- **Kubernetes version:** 1.33
- **Platform:** EKS managed
- **Cluster IAM role:** uts-eks-cluster-role
- **API endpoint:** Public and private access enabled (with URL)
- **OIDC provider URL:** Configured
- **Certificate authority:** Valid and defined
- **Support type:** Standard support

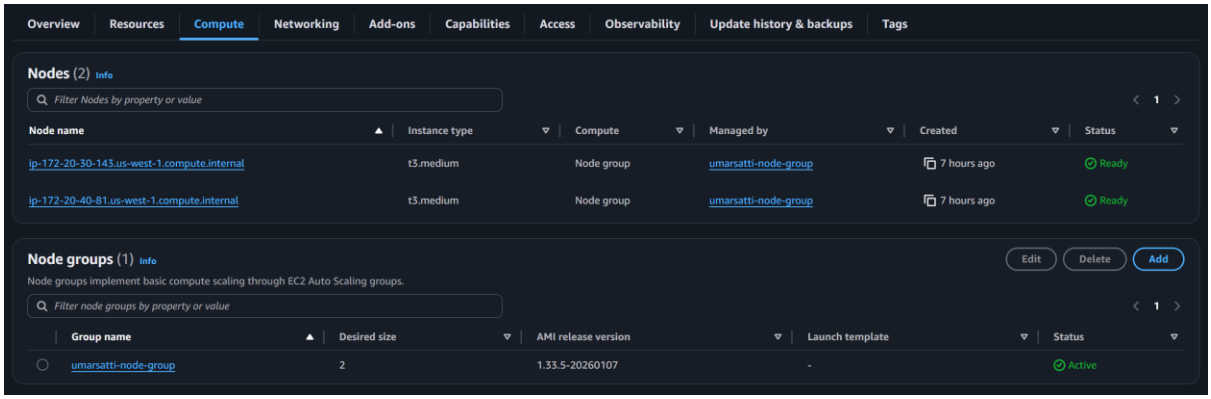


This confirms the EKS control plane is healthy and operational.

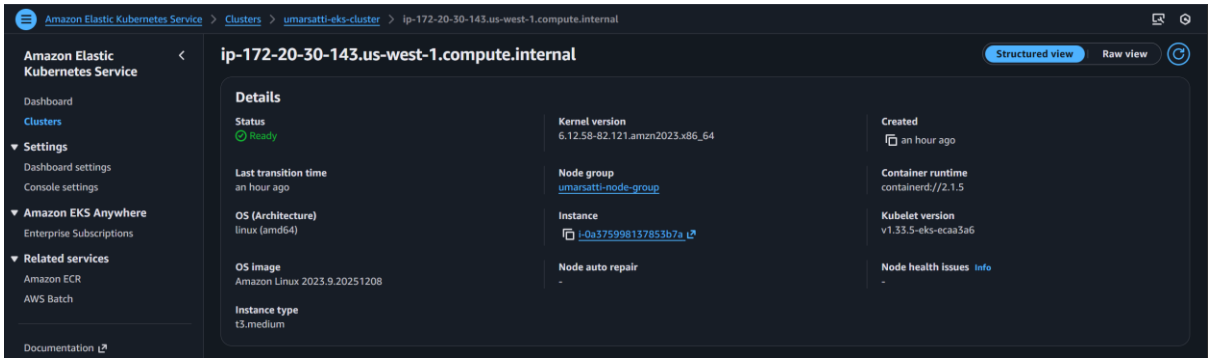
2. Managed Node Group Validation

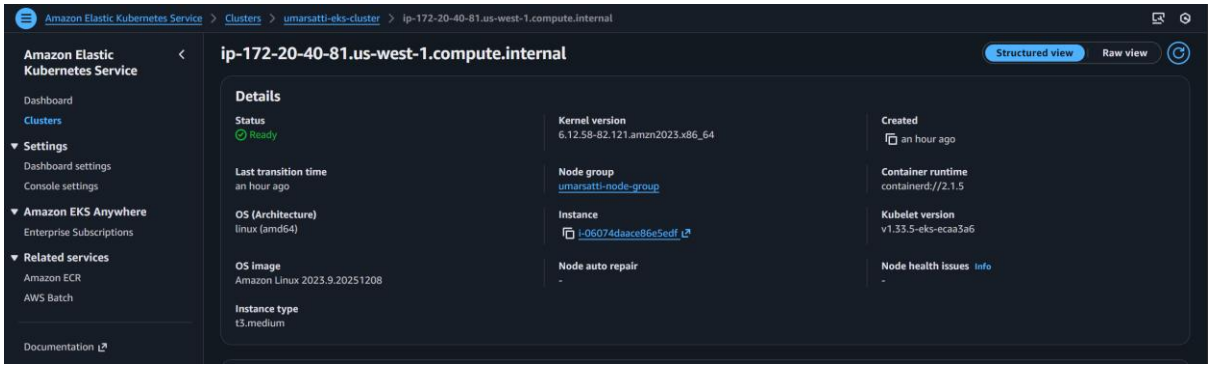
Navigate to **Cluster** within the EKS console. Click on **Compute** tab. Verify the following:

- Managed node group named **umarsatti-node-group**
- Two active worker nodes managed by the same node group
- **Status:** Ready
- **Instance type:** t3.medium
- **AMI:** Amazon Linux 2023
- **Subnets:** Private subnets in separate Availability Zones



Detailed view of Worker Nodes:



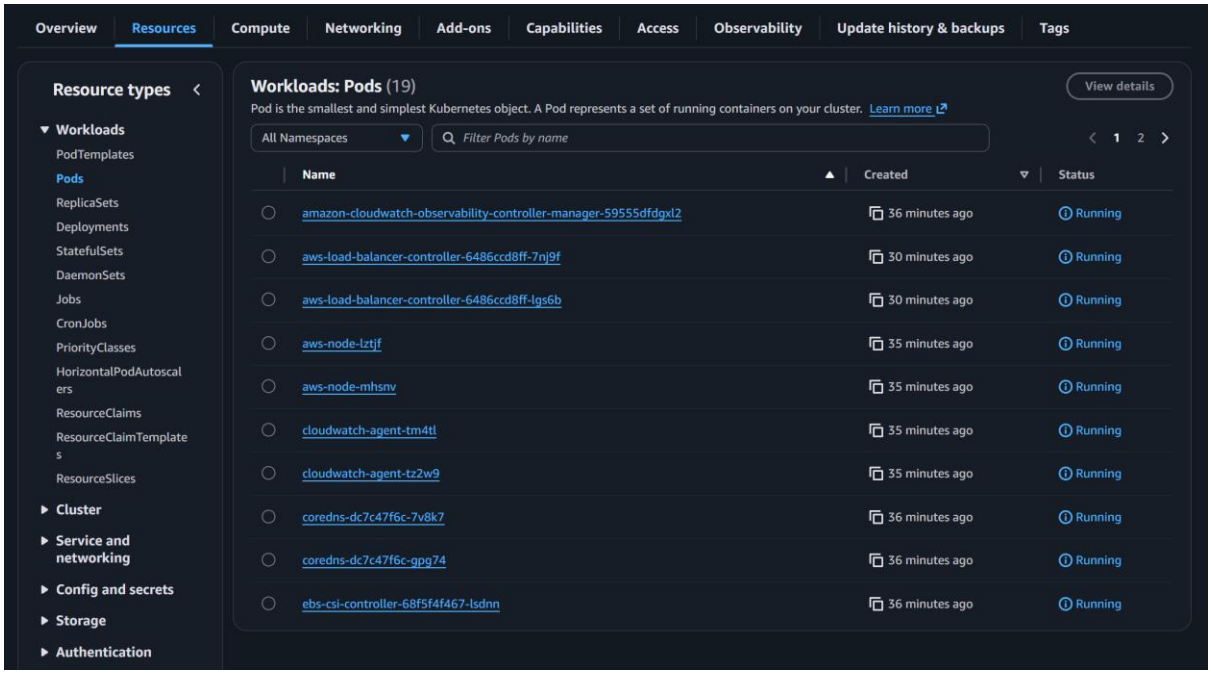


3. Workload and System Pod Validation

Navigate to **Cluster** within the EKS console. Click on **Resources** tab. Select Pods and verify that system pods are running in the following namespaces:

- **kube-system**:
  - CoreDNS
  - aws-node (VPC CNI)
  - kube-proxy
  - EBS CSI controller
  - AWS Load Balancer Controller

- **amazon-cloudwatch**
    - CloudWatch Agent

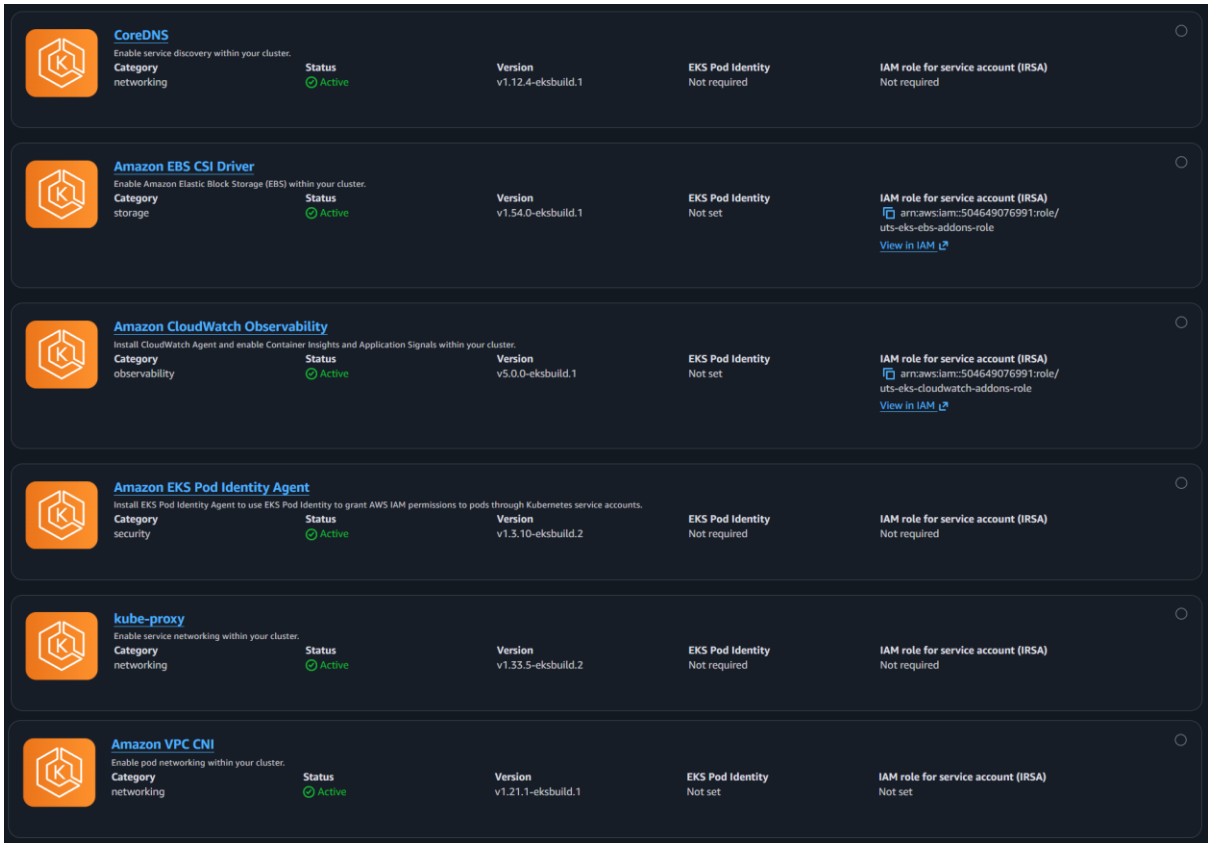


All pods should be in **Running** state, confirming normal cluster operations.

4. EKS Add-ons Validation

Navigate to **Cluster** within the EKS console. Click on **Add-ons** tab and verify that the following add-ons are installed and in **Active** state:

- CoreDNS
- VPC CNI
- kube-proxy
- Amazon EBS CSI Driver
- Amazon CloudWatch Observability
- EKS Pod Identity Agent

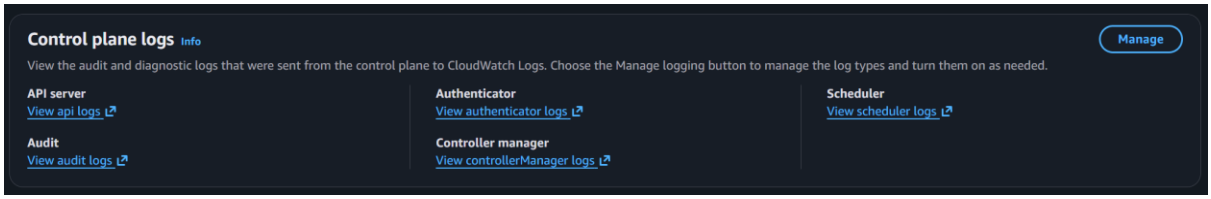


Confirm IAM roles are associated with add-ons that require AWS permissions such as **EBS CSI Driver** and **CloudWatch Observability**.

5. Control Plane Logging

Navigate to **Cluster** within the EKS console. Click on **Observability** tab. Under **Control plane logs,** it should display the following log types enabled:

- API server
- Audit
- Authenticator
- Controller manager
- Scheduler



This confirms that control plane logs are being sent to Amazon CloudWatch.

Note: Click the link under each log type to view them in CloudWatch console.

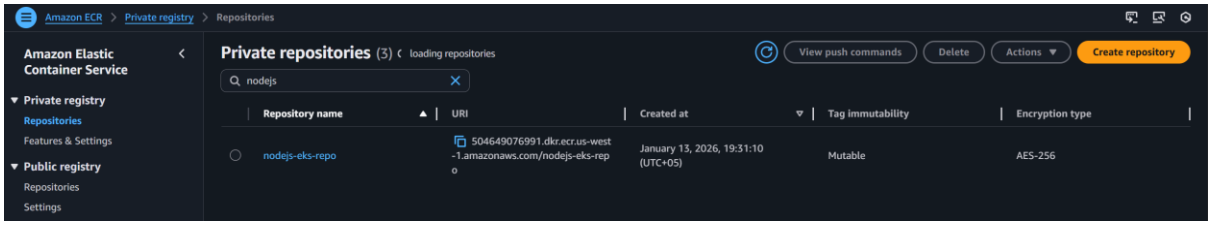
Validation Summary

- EKS cluster is **Active** and **healthy**
- Node group is **highly available** and **private**
- All system workloads and add-ons are **running**
- IAM, logging, and networking are correctly configured

4.4 Amazon ECR Validation

Navigate to **Amazon ECR** and click **Repositories** under **Private registry.** Select **nodejs-eks-repo**. Verify the following:

- **Repository type:** Private
- **Region:** us-west-1
- **Encryption:** AES-256 (AWS managed)
- **Tag mutability:** Mutable



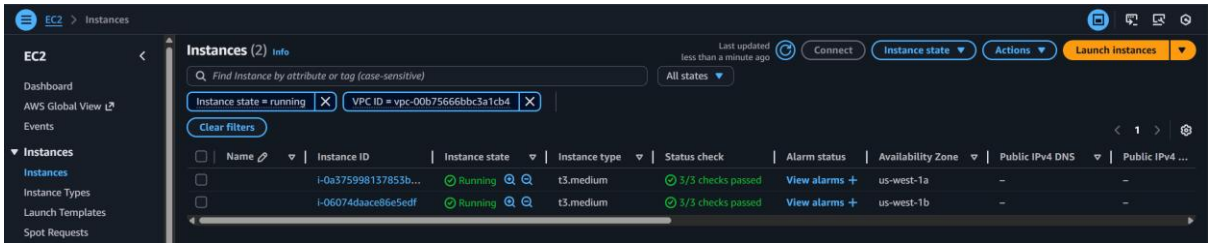
This repository is used to store Docker images for the Node.js application.
EKS worker nodes can pull images using the IAM role **uts-eks-node-group-role** with the **AmazonEC2ContainerRegistryReadOnly** policy.

4.5 EC2 Instances (EKS Worker Nodes) Validation

Navigate to **EC2 console** and click **Instances.** Filter by the EKS cluster or node group or VPC ID.

Verify the following:

- **Total instances:** 2
- **Instance type:** t3.medium
- **State:** Running
- **Subnets:** Private subnets across two Availability Zones
- **Public IP:** None assigned
- **IAM role:** uts-eks-node-group-role
- **Security groups:** umarsatti-eks-node-sg & EKS-managed SGs



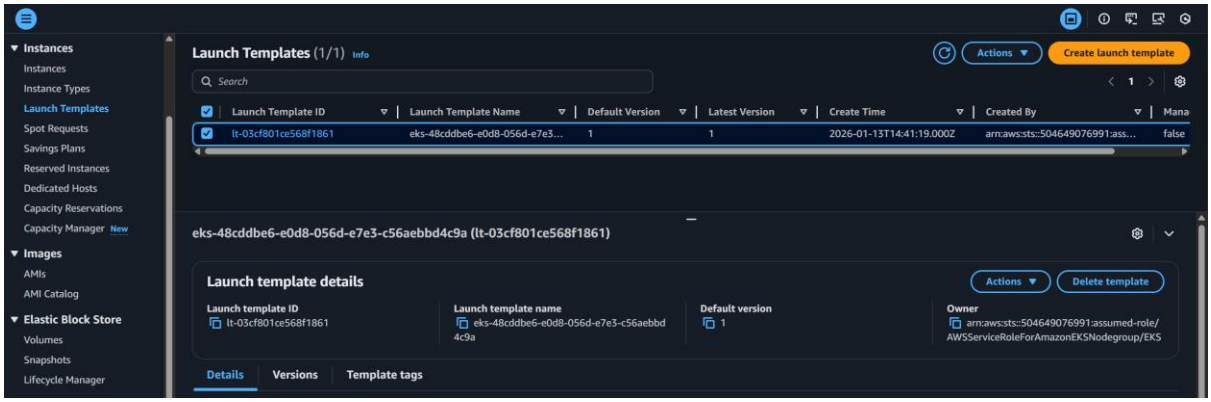
This confirms worker nodes are privately deployed, healthy, and managed by EKS.

4.6 Launch Template Validation

Navigate to **EC2 console** and click **Launch Templates**. Select the template associated with the node group.

Verify the following:

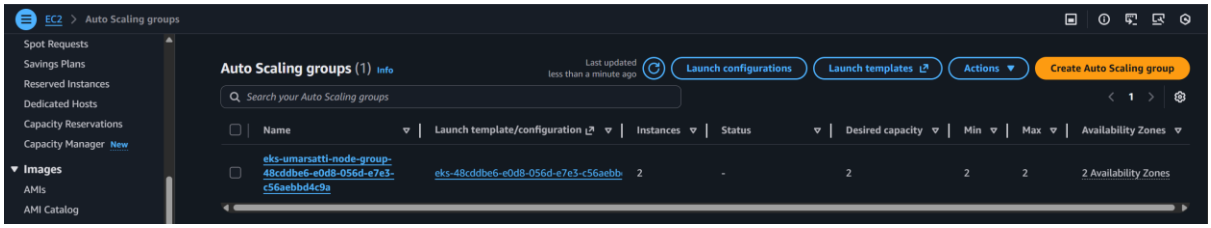
- **Launch template name:** eks-*
- **AMI:** Amazon Linux 2023
- **Instance type:** t3.medium
- **IAM instance profile:** uts-eks-node-group-role
- **Security groups:** EKS-managed SGs + custom node SG
- **Public IP:** Disabled



The launch template ensures all worker nodes are launched with a consistent and secure configuration.

4.7 Auto Scaling Group Validation

Navigate to **EC2** console and click **Auto Scaling Groups**. Select the EKS-managed Auto Scaling Group.

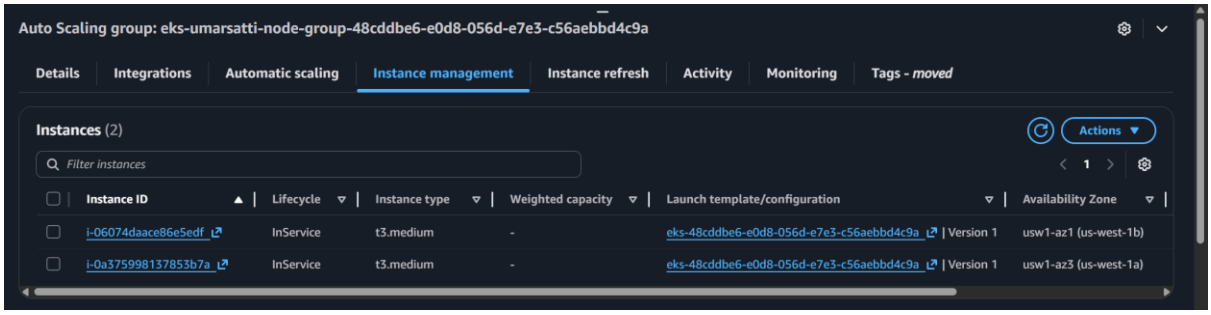


Verify the following:

- **Desired / Min / Max capacity:** 2 / 2 / 2
- **Running instances:** 2
- **Availability Zones:** us-west-1a and us-west-1b
- **Health status:** Healthy
- **Launch template:** Correct version attached

Navigate to the **Instance management** tab and confirm:

- All instances are **InService**
- Unhealthy instances would be automatically replaced



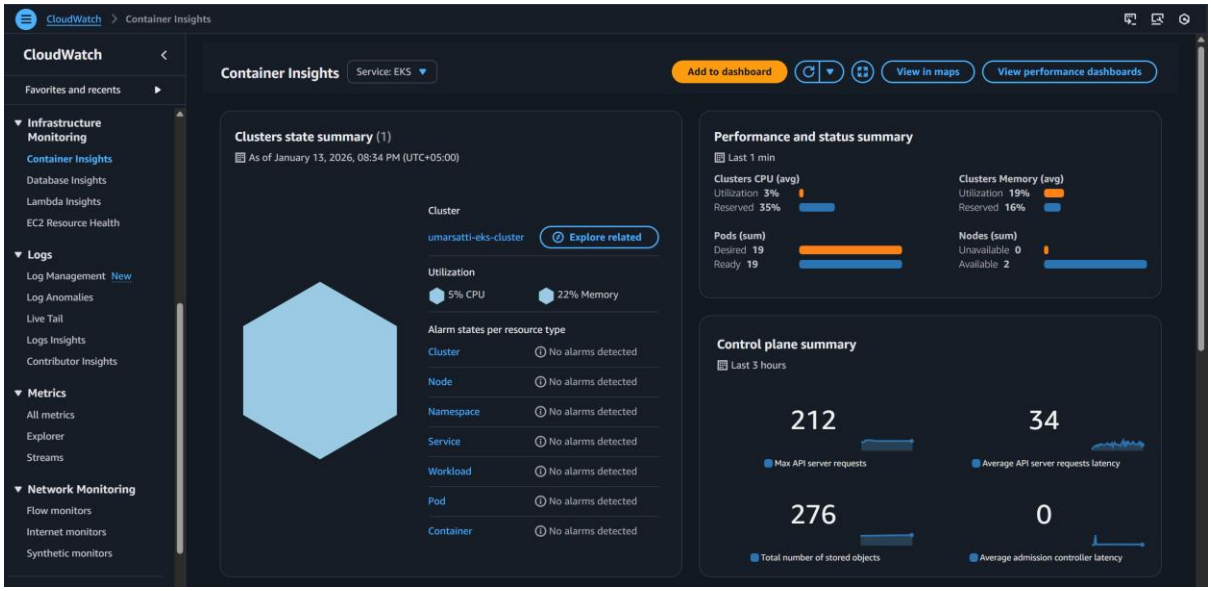
This validates automatic lifecycle management and high availability of worker nodes.

4.8 CloudWatch Validation

4.8.1 CloudWatch Container Insights

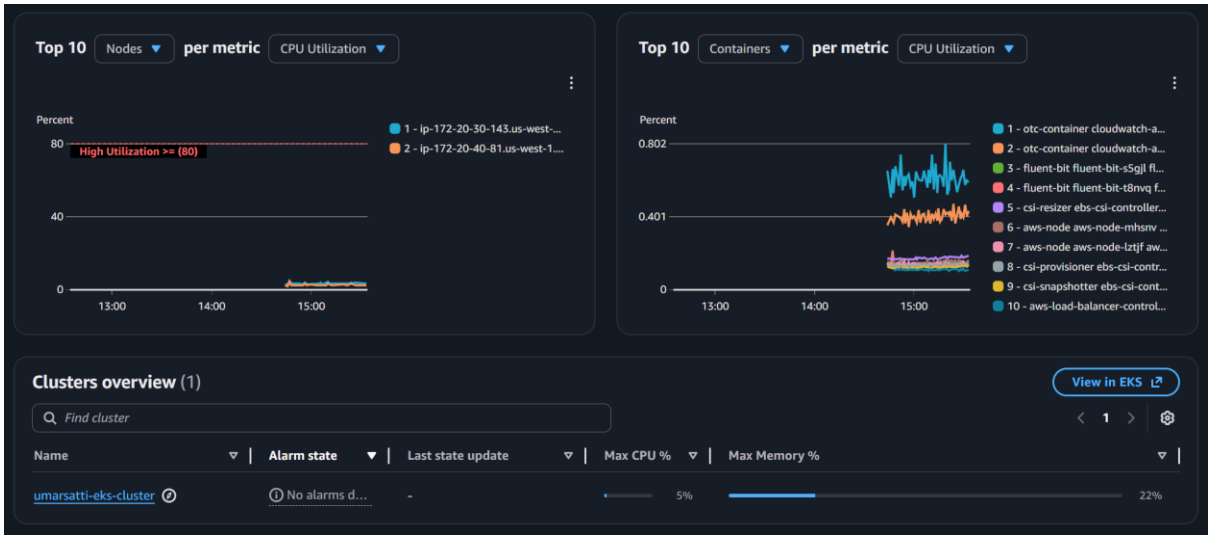
Navigate to **CloudWatch console** and click **Container Insights** under Infrastructure Monitoring. Select the EKS cluster **umarsatti-eks-cluster**.

Cluster Dashboard Validation



Verify the following from the **EKS Cluster dashboard**:

- **Cluster status:** Active
- **Nodes available:** Displays the expected number of worker nodes
- **Pods ready:** All or most pods should be in a *Running* and *Ready* state
- **CPU utilization:** Dashboard should display cluster CPU usage metrics
- **Memory utilization:** Dashboard should display cluster memory usage metrics



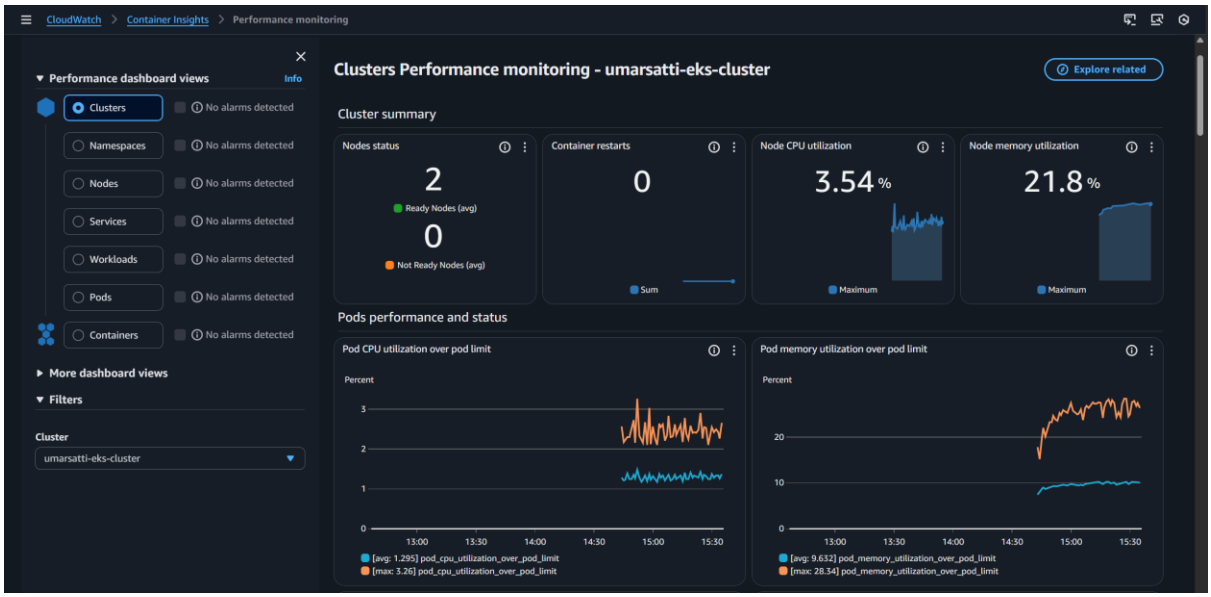
The presence of live CPU and memory metrics with no active alarms indicates normal cluster operation and sufficient capacity.

Performance Monitoring

In the **Container Insights** dashboard, click **Performance monitoring** button on the top right and review the following:

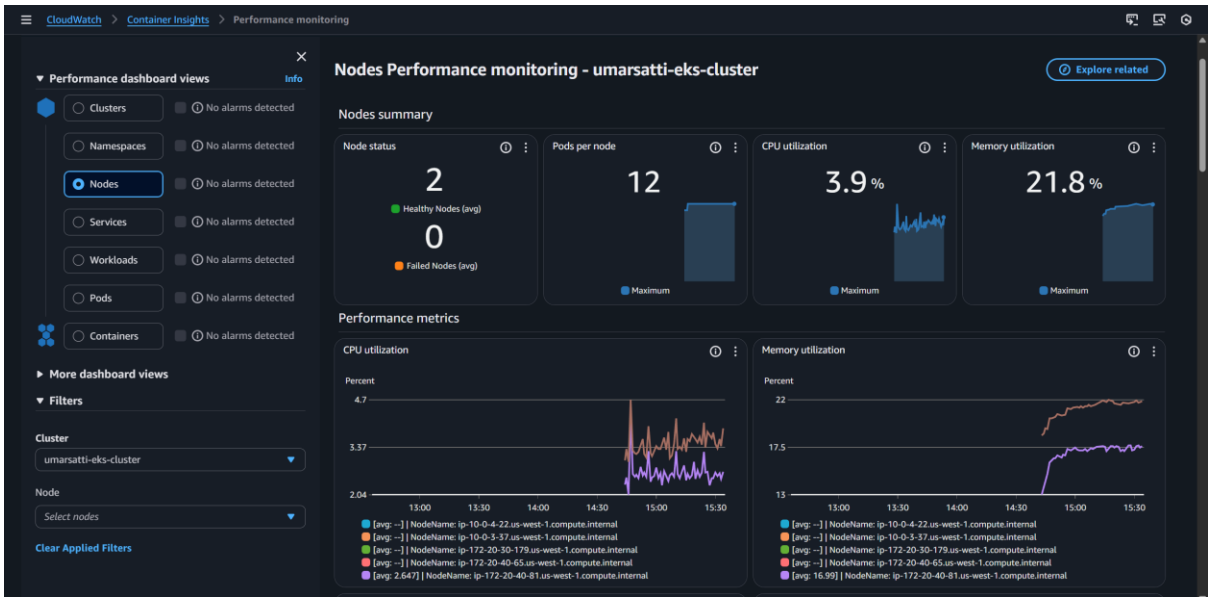
Clusters View

- Ready node count is visible
- Container restart metrics are displayed
- CPU and memory utilization charts are populated



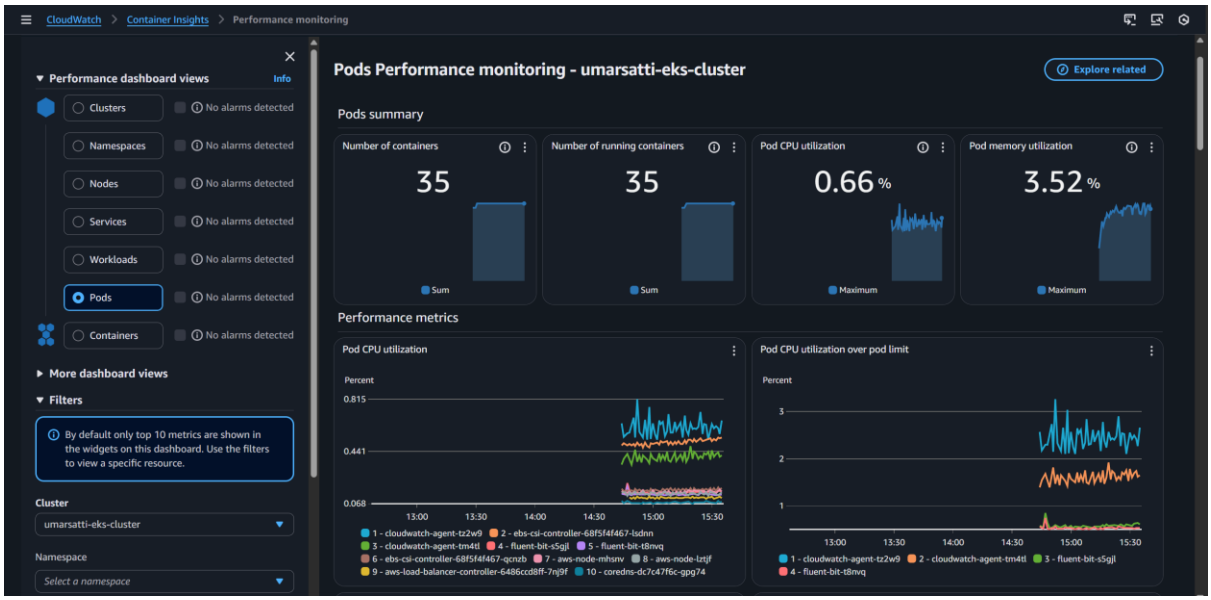
Nodes View

- All nodes report a *Healthy* status
- Pod distribution across nodes is visible
- Node-level CPU and memory metrics are displayed



Pods View

- All containers are in a **Running** state
- Pod-level CPU and memory utilization metrics are visible
- Resource usage appears within configured limits



These dashboards confirm that monitoring is functioning correctly and that cluster, node, and pod performance metrics are being collected.

4.8.2 CloudWatch Log Groups

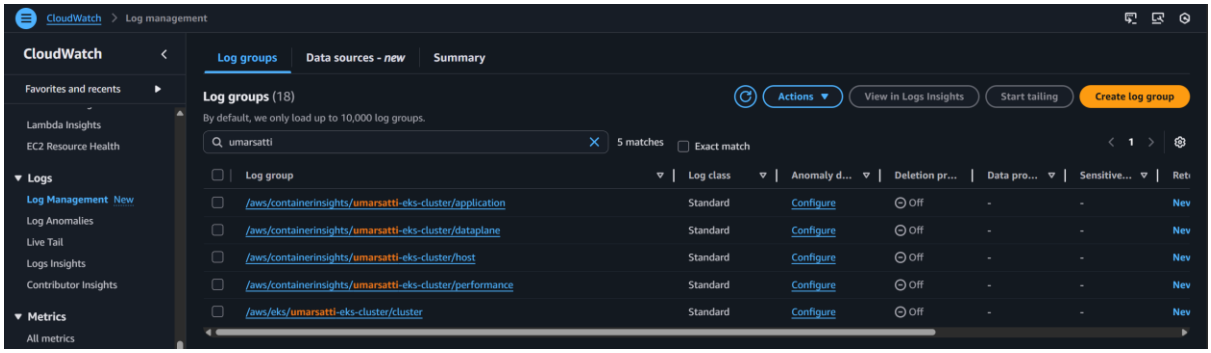
In the **CloudWatch console,** click **Log Management** under Logs**.** Search for **umarsatti-eks-cluster** log groups.

Log Groups Validation

Verify the following log groups exist and are receiving logs:

1. **/aws/eks/umarsatti-eks-cluster/cluster**
    - EKS control plane logs (API server, scheduler, controllers, authenticator)
2. **/aws/containerinsights/umarsatti-eks-cluster/performance**
    - Cluster, node, pod, and container performance metrics
3. **/aws/containerinsights/umarsatti-eks-cluster/application**
    - Application container stdout/stderr logs (via Fluent Bit)
4. **/aws/containerinsights/umarsatti-eks-cluster/dataplane**
    - Kubelet, container runtime, and CNI logs

5. **/aws/containerinsights/umarsatti-eks-cluster/host**
    - EC2 worker node system and OS logs



All log groups are:

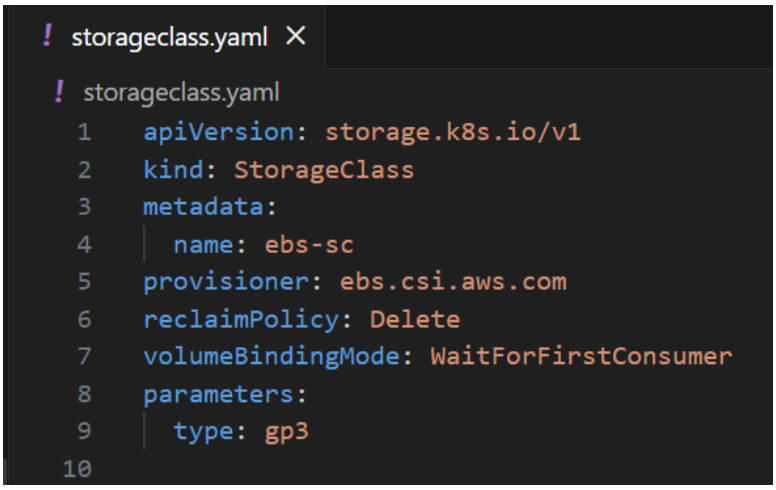
- **Log class:** Standard
- **Retention:** Never expire
- **Status:** Actively receiving logs

5. Kubernetes Manifest and Configuration

This section documents the Kubernetes YAML manifest files used to deploy the application on Amazon EKS. Each manifest defines a specific Kubernetes resource and its intended behavior. Screenshots of these files are captured to demonstrate configuration correctness prior to deployment.

5.1 StorageClass Configuration (storageclass.yaml)

The StorageClass defines how persistent storage is dynamically provisioned for the application using Amazon EBS.



Key Configuration:

- Provisioner: ebs.csi.aws.com (AWS EBS CSI Driver)
- Volume Type: gp3
- Reclaim Policy: Delete
- Volume Binding Mode: WaitForFirstConsumer

Purpose:

- Enables dynamic provisioning of Amazon EBS volumes
- Ensures volumes are created only after pods are scheduled, aligning storage with availability zones
- Automatically deletes EBS volumes when their PersistentVolumeClaims (PVCs) are removed

This **StorageClass** is later referenced by the **StatefulSet** to provide persistent storage for each pod.

5.2 StatefulSet Definition (statefulset.yaml)

The StatefulSet manages the deployment of the Node.js application pods with stable identities and persistent storage.

```yaml
apiVersion: apps/v1
kind: StatefulSet
metadata:
  name: node-app
spec:
  serviceName: node-app
  replicas: 2
  selector:
    matchLabels:
      app: node-app
  template:
    metadata:
      labels:
        app: node-app
    spec:
      topologySpreadConstraints:
      - maxSkew: 1
        topologyKey: topology.kubernetes.io/zone
        whenUnsatisfiable: DoNotSchedule
        labelSelector:
          matchLabels:
            app: node-app
      containers:
      - name: node-app
        image: 504649076991.dkr.ecr.us-west-1.amazonaws.com/nodejs-eks-repo:latest
        ports:
        - containerPort: 3000
        volumeMounts:
        - name: data
          mountPath: /usr/src/app/data
  volumeClaimTemplates:
  - metadata:
      name: data
    spec:
      accessModes: ["ReadWriteOnce"]
      storageClassName: ebs-sc
      resources:
        requests:
          storage: 4Gi
```

Key Configuration:

- Replicas: 2
- Pod Naming: node-app-0, node-app-1
- Container Image: Stored in Amazon ECR
- Container Port: 3000
- Topology Spread Constraints: Evenly distributes pods across availability zones
- Volume Mount: /usr/src/app/data

Persistent Storage:

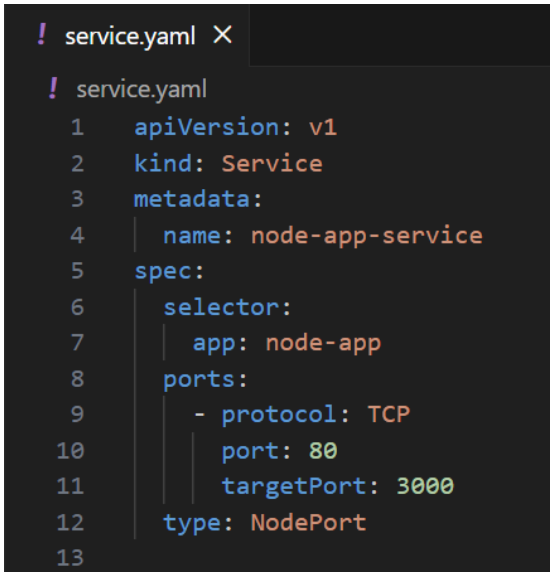
- Each pod defines a volumeClaimTemplate
- Requests 4 GiB of storage per pod
- Uses the ebs-sc StorageClass
- Access mode: ReadWriteOnce

Purpose:

- Provides stable pod identities and ordered startup
- Automatically creates PersistentVolumeClaims (PVCs) for each pod
- Triggers dynamic provisioning of PersistentVolumes (PVs) backed by Amazon EBS
- Ensures data persistence across pod restarts and rescheduling

5.3 Service Configuration (service.yaml)

The Service provides stable internal networking and exposes the application to other Kubernetes components.



Key Configuration:

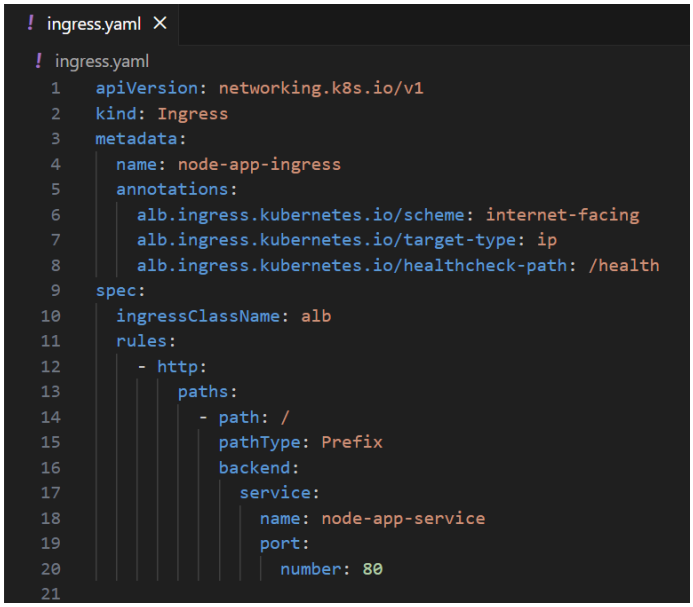
- Type: NodePort
- Service Port: 80
- Target Port: 3000
- Selector: Matches pods labeled app: node-app

Purpose:

- Enables internal traffic routing to StatefulSet pods
- Exposes the application on a static port on each worker node
- Acts as the backend service for the Ingress and Application Load Balancer

5.4 Ingress Configuration (ingress.yaml)

The Ingress resource integrates with the AWS Load Balancer Controller to expose the application externally.



Key Configuration:

- Ingress Class: alb
- Scheme: Internet-facing
- Target Type: IP
- Health Check Path: /health
- Routing: Forwards traffic from / to node-app-service on port 80

Purpose:

- Automatically provisions an AWS Application Load Balancer (ALB)
- Routes external HTTP traffic to the NodePort service
- Enables scalable and highly available access to the application

5.5 Resource Creation Summary

When these manifests are applied, Kubernetes automatically creates the following resources:

- Pods: Two application pods managed by the StatefulSet
- PersistentVolumeClaims (PVCs): One PVC per pod
- PersistentVolumes (PVs): Dynamically provisioned EBS volumes via CSI
- Service: Internal and NodePort-based traffic routing
- Ingress & ALB: External access via AWS Application Load Balancer

This layered resource creation ensures a fully functional, scalable, and persistent application architecture on EKS.

6. Post-Provisioning Kubernetes Deployment

This section validates the successful deployment of a Node.js application on the EKS cluster after infrastructure provisioning. It covers cluster access, node readiness, storage configuration, container image management, workload deployment, networking, and external access through an AWS Application Load Balancer.

6.1 Cluster Access and Initial Validation

1. Configure kubectl Access

Before interacting with the cluster, the local kubeconfig is updated to include the EKS cluster endpoint and authentication details.

- *aws eks update-kubeconfig --region us-west-1 --name umarsatti-eks-cluster*

This command retrieves cluster metadata from AWS and configures **kubectl** to authenticate using AWS IAM credentials.

```
PS D:\Cloudelligent\Task-17> aws eks update-kubeconfig --region us-west-1 --name umarsatti-eks-cluster
Updated context arn:aws:eks:us-west-1:504649076991:cluster/umarsatti-eks-cluster in C:\Users\umars\.kube\config
PS D:\Cloudelligent\Task-17>
```

Validation:

- kubeconfig updated successfully
- kubectl context set to umarsatti-eks-cluster
- The cluster is accessible for management operations.

2. Verify Worker Nodes

- *kubectl get nodes -o wide*

```
PS D:\Cloudelligent\Task-17> kubectl get nodes -o wide
NAME                                          STATUS   ROLES    AGE   VERSION               INTERNAL-IP     EXTERNAL-IP   OS-IMAGE                        KERNEL-VERSION                  CONTAINER-RUNTIME
ip-172-20-30-143.us-west-1.compute.internal   Ready    <none>   87m   v1.33.5-eks-ecaa3a6   172.20.30.143   <none>        Amazon Linux 2023.9.20251208   6.12.58-82.121.amzn2023.x86_64   containerd://2.1.5
ip-172-20-40-81.us-west-1.compute.internal    Ready    <none>   87m   v1.33.5-eks-ecaa3a6   172.20.40.81    <none>        Amazon Linux 2023.9.20251208   6.12.58-82.121.amzn2023.x86_64   containerd://2.1.5
PS D:\Cloudelligent\Task-17>
```

Validation Checks:

- All worker nodes appear in the output
- Node status is **Ready**
- Nodes have no public IPs (private subnet deployment)
- Nodes report the expected Kubernetes version and container runtime

This confirms that the managed node group has successfully joined the cluster and is ready to schedule workloads.

6.2 Core System Components Validation

1. Verify DaemonSets

- *kubectl get daemonsets -A*

DaemonSets ensure critical services run on every worker node. The following must be running with desired replicas equal to available replicas:

- **aws-node**: VPC CNI for pod networking
- **kube-proxy**: Service networking and routing
- **ebs-csi-node**: EBS volume attachment
- **cloudwatch-agent**: Metrics collection
- **fluent-bit**: Log forwarding
- **eks-pod-identity-agent**: IAM role assumption for pods

```
PS D:\Cloudelligent\Task-17> kubectl get daemonsets -A
NAMESPACE           NAME                                        DESIRED   CURRENT   READY   UP-TO-DATE   AVAILABLE   NODE SELECTOR              AGE
amazon-cloudwatch   cloudwatch-agent                            2         2         2       2            2           kubernetes.io/os=linux     86m
amazon-cloudwatch   cloudwatch-agent-windows                    0         0         0       0            0           kubernetes.io/os=windows   86m
amazon-cloudwatch   cloudwatch-agent-windows-container-insights 0         0         0       0            0           kubernetes.io/os=windows   86m
amazon-cloudwatch   dcgm-exporter                               0         0         0       0            0           kubernetes.io/os=linux     86m
amazon-cloudwatch   fluent-bit                                  2         2         2       2            2           kubernetes.io/os=linux     87m
amazon-cloudwatch   fluent-bit-windows                          0         0         0       0            0           kubernetes.io/os=windows   87m
amazon-cloudwatch   neuron-monitor                              0         0         0       0            0           kubernetes.io/os=linux     86m
kube-system         aws-node                                    2         2         2       2            2           <none>                     89m
kube-system         ebs-csi-node                                2         2         2       2            2           kubernetes.io/os=linux     87m
kube-system         ebs-csi-node-windows                        0         0         0       0            0           kubernetes.io/os=windows   87m
kube-system         eks-pod-identity-agent                      2         2         2       2            2           <none>                     87m
kube-system         kube-proxy                                  2         2         2       2            2           <none>                     89m
PS D:\Cloudelligent\Task-17>
```

Validation:
All required DaemonSets are running on both nodes with no missing pods. Node-level services are functioning correctly.

2. Verify System Pods

- *kubectl get pods -n kube-system*

Key Observations:

- All pods are in **Running** state
- No container restarts observed
- High availability achieved for critical components (CoreDNS, EBS CSI controller, Load Balancer Controller)

```
PS D:\Cloudelligent\Task-17> kubectl get pods -n kube-system
NAME                                          READY   STATUS    RESTARTS   AGE
aws-load-balancer-controller-6486ccd8ff-7nj9f   1/1     Running   0          79m
aws-load-balancer-controller-6486ccd8ff-lgs6b   1/1     Running   0          79m
aws-node-lztjf                                2/2     Running   0          84m
aws-node-mhsnv                                2/2     Running   0          84m
coredns-dc7c47f6c-7v8k7                       1/1     Running   0          85m
coredns-dc7c47f6c-gpg74                       1/1     Running   0          85m
ebs-csi-controller-68f5f4f467-lsdnn           6/6     Running   0          85m
ebs-csi-controller-68f5f4f467-qcnzb           6/6     Running   0          85m
ebs-csi-node-qjxvs                            3/3     Running   0          84m
ebs-csi-node-ztnkt                            3/3     Running   0          84m
eks-pod-identity-agent-djnxt                  1/1     Running   0          84m
eks-pod-identity-agent-lrfcp                  1/1     Running   0          84m
kube-proxy-cdg6z                              1/1     Running   0          84m
kube-proxy-krm25                              1/1     Running   0          84m
PS D:\Cloudelligent\Task-17>
```

This confirms cluster stability and readiness for application workloads.

6.3 Storage Configuration

Create and Validate StorageClass

- *kubectl apply -f storageclass.yaml*
- *kubectl get sc*

StorageClass Highlights:

- Uses **EBS CSI driver**
- Volumes provisioned dynamically
- **WaitForFirstConsumer** ensures volumes are created in the correct AZ

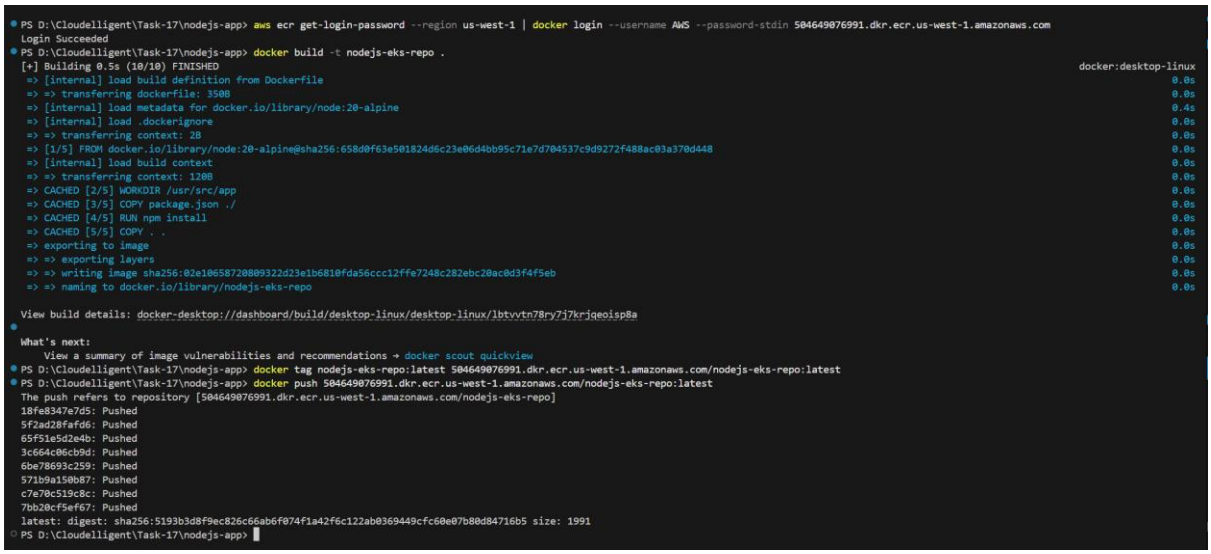
```
PS D:\Cloudelligent\Task-17> kubectl apply -f storageclass.yaml
storageclass.storage.k8s.io/ebs-sc created
PS D:\Cloudelligent\Task-17> kubectl get sc
NAME     PROVISIONER             RECLAIMPOLICY   VOLUMEBINDINGMODE      ALLOWVOLUMEEXPANSION   AGE
ebs-sc   ebs.csi.aws.com         Delete          WaitForFirstConsumer   false                  8s
gp2      kubernetes.io/aws-ebs   Delete          WaitForFirstConsumer   false                  69m
PS D:\Cloudelligent\Task-17>
```

This StorageClass is used by StatefulSets to provision persistent EBS volumes automatically.

6.4 Container Image Management

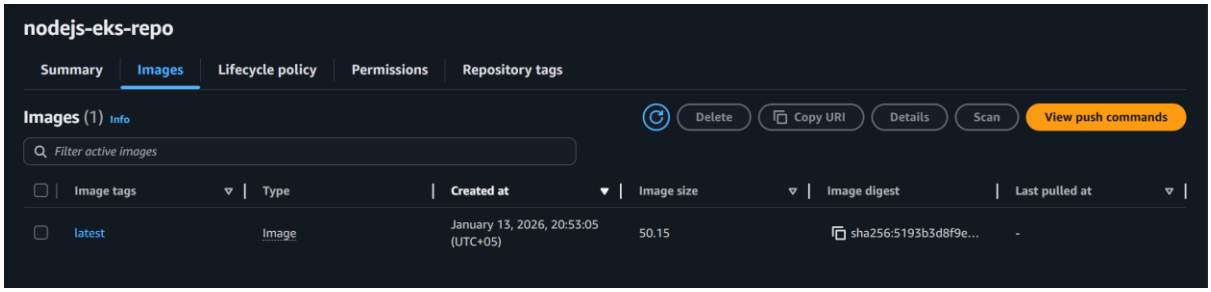
Build and Push Application Image to ECR

The Node.js application image is built locally and pushed to Amazon ECR using repository-specific push commands.



Validation Steps:

- Docker authentication to ECR succeeds
- Image build completes without errors
- Image appears in the ECR repository with the expected tag (latest)



This ensures the EKS worker nodes can securely pull the application image during deployment.

6.5 Application Deployment

1. Deploy StatefulSet

- *kubectl apply -f statefulset.yaml*
- *kubectl get pods*

StatefulSet Validation:

- Desired replicas are running
- Pods start sequentially
- Each pod reaches **Ready** state

- No restarts detected

```
PS D:\Cloudelligent\Task-17> kubectl apply -f statefulset.yaml
statefulset.apps/node-app created
PS D:\Cloudelligent\Task-17> kubectl get pods
NAME          READY   STATUS    RESTARTS   AGE
node-app-0    1/1     Running   0          75s
node-app-1    1/1     Running   0          58s
PS D:\Cloudelligent\Task-17>
```

StatefulSet is used to provide stable pod identities and persistent storage.

2. Verify Persistent Volumes

- *kubectl get pv*
- *kubectl get pvc*

Observations:

- One PVC created per pod
- PVCs are bound to dynamically provisioned EBS volumes
- Volumes persist independently of pod lifecycle

```
PS D:\Cloudelligent\Task-17> kubectl get pv
NAME                                       CAPACITY   ACCESS MODES   RECLAIM POLICY   STATUS   CLAIM                       STORAGECLASS   VOLUMEATTRIBUTESCLASS   REASON   AGE
pvc-1bf555ca-0cc2-45d8-91ce-cbd7f875a2a9   4Gi        RWO            Delete           Bound    default/data-node-app-0     ebs-sc         <unset>                          3m44s
pvc-3a9dc6db-9b34-4323-b91d-9e488489f8ac   4Gi        RWO            Delete           Bound    default/data-node-app-1     ebs-sc         <unset>                          3m27s
PS D:\Cloudelligent\Task-17> kubectl get pvc
NAME              STATUS   VOLUME                                     CAPACITY   ACCESS MODES   STORAGECLASS   VOLUMEATTRIBUTESCLASS   AGE
data-node-app-0   Bound    pvc-1bf555ca-0cc2-45d8-91ce-cbd7f875a2a9   4Gi        RWO            ebs-sc         <unset>                 3m54s
data-node-app-1   Bound    pvc-3a9dc6db-9b34-4323-b91d-9e488489f8ac   4Gi        RWO            ebs-sc         <unset>                 3m37s
PS D:\Cloudelligent\Task-17>
```

This confirms correct integration between Kubernetes storage and AWS EBS.

6.6 Service Configuration

Deploy Kubernetes Service

- *kubectl apply -f service.yaml*
- *kubectl get svc*

Service Characteristics:

- Type: NodePort
- Provides stable internal access to pods
- Acts as the backend for the Ingress resource

```
PS D:\Cloudelligent\Task-17> kubectl apply -f service.yaml
service/node-app-service created
PS D:\Cloudelligent\Task-17> kubectl get svc
NAME               TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)        AGE
kubernetes         ClusterIP   10.100.0.1      <none>        443/TCP        78m
node-app-service   NodePort    10.100.41.218   <none>        80:31777/TCP   8s
PS D:\Cloudelligent\Task-17>
```

This service enables traffic routing from the load balancer to application pods.

6.7 Ingress and Load Balancer Configuration

Deploy Ingress Resource

- *kubectl apply -f ingress.yaml*
- *kubectl get ingress*

Ingress Validation:

- AWS Load Balancer Controller detects the resource
- Application Load Balancer is provisioned automatically
- ALB DNS name is assigned

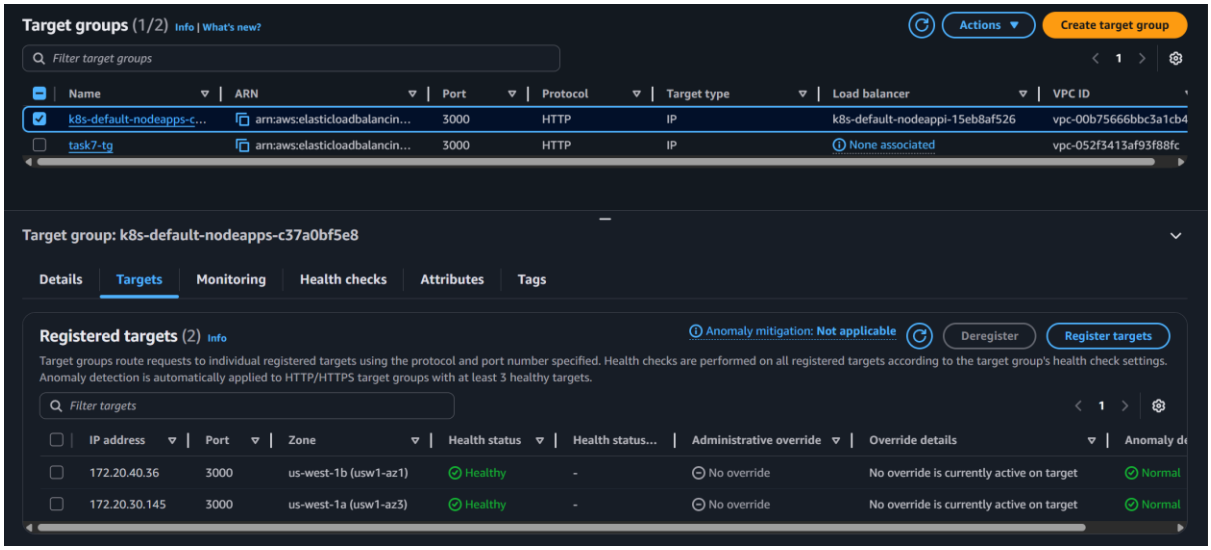
```
PS D:\Cloudelligent\Task-17> kubectl apply -f ingress.yaml
ingress.networking.k8s.io/node-app-ingress created
PS D:\Cloudelligent\Task-17> kubectl get ingress
NAME              CLASS   HOSTS   ADDRESS                                                                  PORTS   AGE
node-app-ingress  alb     *       k8s-default-nodeappi-15eb8af526-1755730335.us-west-1.elb.amazonaws.com   80      9s
PS D:\Cloudelligent\Task-17>
```

Traffic flow: Client → ALB → NodePort → Service → Pods

6.8 Load Balancer Validation

1. Target Group Validation

Navigate to **EC2** console. Select **Target Groups** located in the left navigation bar.

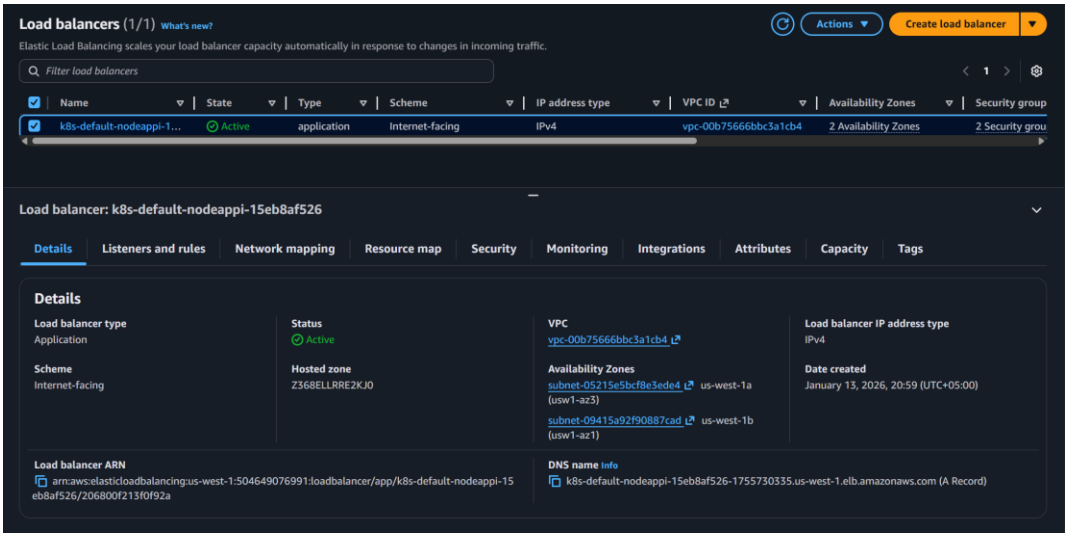


Checks:

- Worker node IPs registered
- All targets marked **Healthy**
- Health checks passing

2. Application Load Balancer Validation

Navigate to **EC2** console. Select **Load Balancers** located in the left navigation bar.



Checks:

- Load balancer is Active
- Internet-facing
- Deployed across multiple AZs
- Listener configured on port 80

This confirms high availability and fault tolerance.

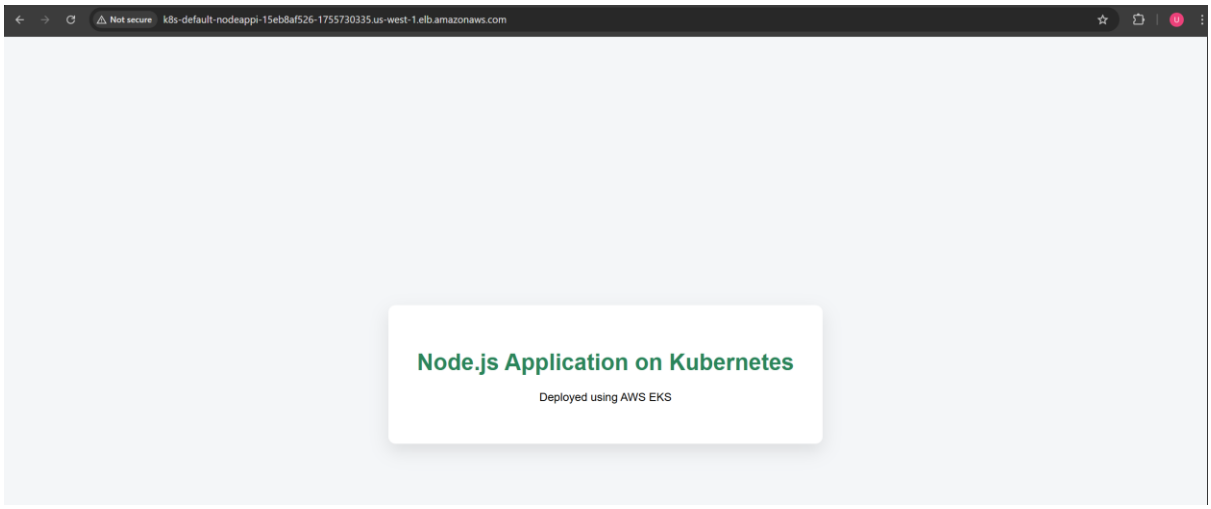
6.9 Application Access Verification

Access Application

Using the ALB DNS name in a browser:

Validation Outcome:

- Application loads successfully
- Requests are served without errors
- Traffic is balanced across multiple pods



As shown above, the application is accessible using ALB DNS name.

Overall Post-Provisioning Summary

- EKS cluster accessible and stable
- Nodes, system components, and storage validated
- Application image managed via ECR
- Stateful application deployed with persistent storage
- External access enabled using AWS ALB

7. Clean Up

This section documents the removal of all Kubernetes workloads and AWS infrastructure resources created during the project. Performing a clean-up ensures that no unused resources remain running and prevents unnecessary AWS costs.

7.1 Delete Ingress Resource

The Ingress resource is removed first to ensure that the Application Load Balancer is deprovisioned correctly.

- *kubectl get ingress*

Ingress Resource Details:

- **Ingress name:** node-app-ingress
- **Port:** 80
- ALB address assigned
- **Hosts:** *

Delete command:

- *kubectl delete ingress node-app-ingress*

```
PS D:\Cloudelligent\Task-17> kubectl get ingress
NAME               CLASS   HOSTS   ADDRESS                                                          PORTS   AGE
node-app-ingress   alb     *       k8s-default-nodeappi-15eb8af526-1755730335.us-west-1.elb.amazonaws.com   80      7h36m
PS D:\Cloudelligent\Task-17> kubectl delete ingress node-app-ingress
ingress.networking.k8s.io "node-app-ingress" deleted
PS D:\Cloudelligent\Task-17>
```

Result:

The Ingress resource is successfully deleted, triggering the cleanup of the associated AWS Application Load Balancer.

7.2 Delete Service

The Kubernetes Service is deleted after the Ingress to cleanly remove backend routing.

- *kubectl get service*

Service Resource Details:

- **Service name:** node-app-service
- **Type:** NodePort
- Cluster IP assigned
- No external IP

- **Port mapping:** 80:31777/TCP

Delete command:

- *kubectl delete service node-app-service*

```
PS D:\Cloudelligent\Task-17> kubectl get service
NAME               TYPE        CLUSTER-IP      EXTERNAL-IP   PORT(S)        AGE
kubernetes         ClusterIP   10.100.0.1      <none>        443/TCP        8h
node-app-service   NodePort    10.100.41.218   <none>        80:31777/TCP   7h39m
PS D:\Cloudelligent\Task-17> kubectl delete service node-app-service
service "node-app-service" deleted
PS D:\Cloudelligent\Task-17>
```

Result:

The NodePort service is removed and no longer exposes the application internally.

7.3 Delete StatefulSet

The application StatefulSet is deleted to terminate running pods and detach associated volumes.

- *kubectl get statefulset*

StatefulSet Resource Details:

- StatefulSet name: node-app
- READY: 2/2

Delete command:

- *kubectl delete statefulset node-app*

```
PS D:\Cloudelligent\Task-17> kubectl get statefulset
NAME       READY   AGE
node-app   2/2     7h43m
PS D:\Cloudelligent\Task-17> kubectl delete statefulset node-app
statefulset.apps "node-app" deleted
PS D:\Cloudelligent\Task-17>
```

Result:

All application pods are terminated in an orderly manner.

7.4 Delete StorageClass

The custom StorageClass is deleted after application workloads are removed.

- *kubectl get storageclass*

StorageClass Resource Details:

- StorageClass name: ebs-sc
- Provisioner: ebs.csi.aws.com
- Reclaim policy: Delete
- Volume binding mode: WaitForFirstConsumer

Delete Command:

- *kubectl delete storageclass ebs-sc*

```
PS D:\Cloudelligent\Task-17> kubectl get storageclass
NAME     PROVISIONER             RECLAIMPOLICY   VOLUMEBINDINGMODE      ALLOWVOLUMEEXPANSION   AGE
ebs-sc   ebs.csi.aws.com         Delete          WaitForFirstConsumer   false                  7h49m
gp2      kubernetes.io/aws-ebs   Delete          WaitForFirstConsumer   false                  8h
PS D:\Cloudelligent\Task-17> kubectl delete storageclass ebs-sc
storageclass.storage.k8s.io "ebs-sc" deleted
PS D:\Cloudelligent\Task-17>
```

Result:

The StorageClass is removed. Any dynamically provisioned EBS volumes are cleaned up according to the reclaim policy.

7.5 Destroy Terraform Infrastructure

After all Kubernetes resources are removed, the underlying AWS infrastructure is destroyed using Terraform.

- *terraform destroy -auto-approve*

Result:

- Terraform successfully destroyed all managed resources
- Total resources destroyed: **49**

```
Destroy complete! Resources: 49 destroyed.
PS D:\Cloudelligent\Task-17\terraform>
```

This confirms that the EKS cluster, networking components, IAM roles, add-ons, and supporting AWS services have been fully removed.

8. Troubleshooting

The following issues were encountered during the Amazon EKS cluster provisioning, add-on configuration, IAM Pod Identity integration, application deployment, and load balancer setup. Each issue documents the observed problem, root cause, and the corrective action taken.

Issue 1: AWS Load Balancer Controller fails with IMDSv2 metadata timeout

Problem Description
The AWS Load Balancer Controller failed to start with the following error:

"unable to initialize AWS cloud","error":"failed to get VPC ID: failed to fetch VPC ID from instance metadata... context deadline exceeded"

Root Cause
Modern EKS worker nodes enforce **IMDSv2**, which limits metadata access using hop count restrictions. The controller pod runs multiple network hops away from the node's hardware, preventing it from accessing instance metadata such as VPC ID and region.

Solution
Explicitly provided the **VPC ID** and **region** during Helm installation so the controller no longer relied on instance metadata.

Issue 2: Missing Service Account causing "Unauthorized" errors

Problem Description
The controller failed to start with the following errors:

serviceaccounts "aws-load-balancer-controller" not found
"error":"Unauthorized"

Root Cause
The Helm installation was configured with serviceAccount.create=false, but the service account was not created manually. As a result, the controller pod had no Kubernetes or AWS identity.

Solution
Re-ran the Helm upgrade with:

serviceAccount.create=true

This created the service account and linked it to the IAM role using **EKS Pod Identity Association**.

Issue 3: Pod Identity Association already exists

Problem Description
Attempting to create a Pod Identity Association failed with an error indicating the association already existed.

Root Cause
The association had already been created in AWS and could not be duplicated.

Solution
Confirmed the existing association and executed:

kubectl rollout restart

This forced the pods to reload and successfully assume the existing IAM role.

Issue 4: Ingress creation fails with YAML unmarshalling error

Problem Description
Applying the Ingress manifest resulted in:

BadRequest: cannot unmarshal object into Go struct

Root Cause
The ingress.yaml file was missing a list indicator (-) under the paths section, violating Kubernetes API schema rules.

Solution
Corrected the YAML indentation and added the required list markers, then re-applied the manifest.

Issue 5: Target group registration limited to a single Availability Zone

Problem Description
Application Load Balancer target groups registered pods only from one private subnet.

Root Cause
EBS volumes are **Availability Zone–locked**. When using a Deployment with persistent storage, Kubernetes was forced to schedule all pods in the same AZ where the volume existed.

Solution
Migrated to a **StatefulSet**, which provisions one EBS volume per pod, allowing pods to be evenly distributed across multiple Availability Zones.
Alternatively, EFS CSI Driver could be used for multi-AZ storage.

Issue 6: Worker nodes created but not joining the cluster

Problem Description
Worker nodes were launched, but CoreDNS and CloudWatch add-ons showed a ***Degraded*** status. Kubernetes access errors indicated insufficient permissions.

Root Cause
The current IAM principal did not have Kubernetes RBAC permissions and was not mapped in the cluster authentication configuration.

Solution
Updated cluster authentication to grant the IAM principal access to Kubernetes resources, allowing worker nodes and system add-ons to initialize correctly.

Issue 7: AmazonEBSCSIDriverPolicy ARN does not exist

Problem Description
Terraform failed when referencing:

arn:aws:iam::aws:policy/AmazonEBSCSIDriverPolicy

Root Cause
The policy exists under the **service-role** path, not the root managed policy path.

Solution
Updated the ARN to:

arn:aws:iam::aws:policy/service-role/AmazonEBSCSIDriverPolicy

Issue 8: Managed Node Group creation fails due to VPC CNI add-on configuration

Problem Description
Managed Node Group creation failed, and VPC networking logs showed:

NetworkPluginNotReady
cni plugin not initialized

Root Cause
A Pod Identity IAM role was incorrectly attached to the **VPC CNI add-on**, which does not support **Pod Identity**.

Solution
Removed the Pod Identity role from the VPC CNI add-on. Once corrected, node groups were created successfully and networking initialized properly.

Issue 10: CloudWatch Container Insights active but metrics unavailable

Problem Description
CloudWatch Container Insights console returned:

Log group '/aws/containerinsights/umarsatti-eks-cluster/performance' does not exist

No log groups were created despite the add-on being active.

Root Cause
The CloudWatch Observability add-on creates a service account (cloudwatch-agent) in the amazon-cloudwatch namespace. While an IAM role was provided, no **Pod Identity Association** existed for this service account.

Solution
Created a Pod Identity Association linking:

- Service Account: cloudwatch-agent
- Namespace: amazon-cloudwatch
- IAM Role: CloudWatch permissions role

After applying the association, log groups and metrics were created successfully.