Veydant Sharma D15C 50 Advanced Devops

Building and Managing Multi-Cloud Infrastructure

Deploying Node.js application using Terraform , S3 and Kubernetes

1. Introduction

- **Case Study Overview:**

  This case study centers on the development and management of multi-cloud infrastructure through the use of Terraform and Kubernetes on AWS. The goal is to automate the creation and management of resources, including an AWS S3 bucket and a Kubernetes cluster, utilizing Terraform scripts. Following this, a sample application will be deployed on the Kubernetes cluster to verify its operational capabilities.

- **Key features & Application**
  A key feature of this project is the seamless integration of multi-cloud infrastructure management using Terraform. This is achieved by automating the setup and management of both storage and computing resources, specifically AWS S3 and Kubernetes, across different cloud services. The project demonstrates how Terraform makes infrastructure management easier by treating it as code, allowing for consistent application deployment in various cloud environments.

- **Third year Project Integration (optional):**
  My third year project, ‘Saarthi’ aims to connect Nurses and care providers with patients and others who may require the services. Kubernetes deployment for the project will allow higher scalability leading to better customer reach. Also it will provide high availability, hence improving customer experience and reducing downtime. It can also help with load balancing and resource management. Furthermore it will allow CI/CD which will help with automated deployments/

2. Step by Step Explanation

1. Set Up Your Environment / Pre-requisites

- **Install Terraform**: Ensure Terraform is installed on your system.
- **Install AWS CLI**: Make sure the AWS CLI is set up and configured with your credentials.
- **Install Kubernetes Tools**

```
C:\Users\veyda>terraform -version
Terraform v1.9.8
on windows_amd64
```

```
C:\Users\veyda>aws --version
aws-cli/2.18.10 Python/3.12.6 Windows/10 exe/AMD64

C:\Users\veyda>kubectl version --client
Client Version: v1.29.2
Kustomize Version: v5.0.4-0.20230601165947-6ce0bf390ce3
```

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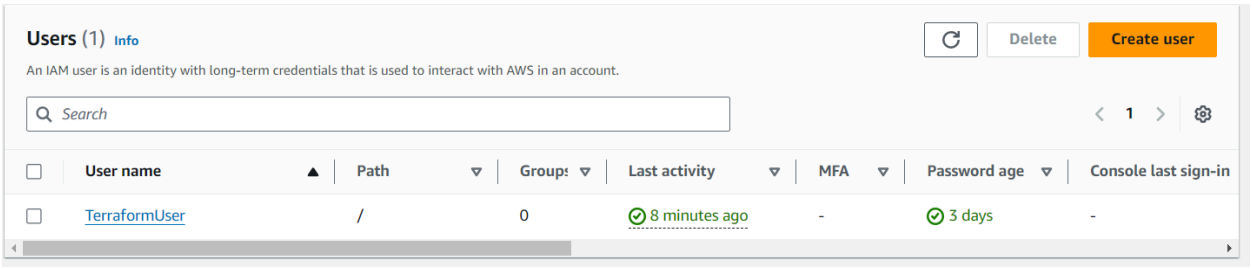
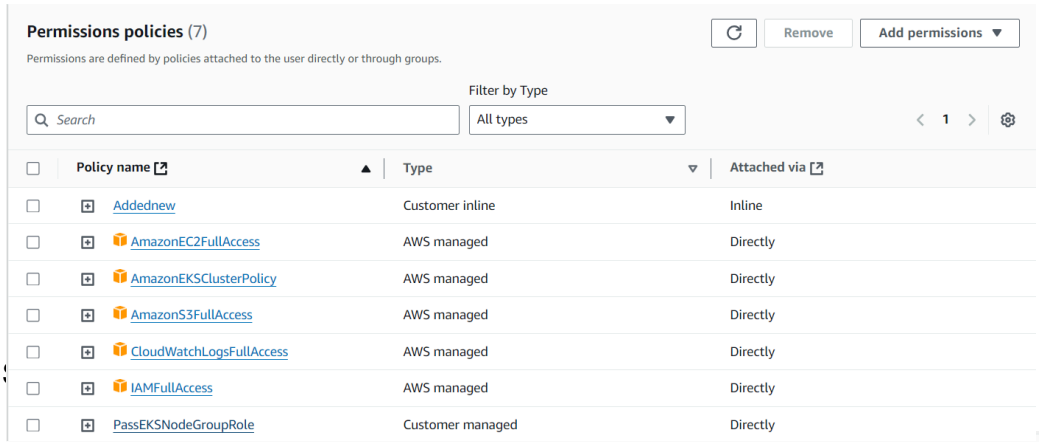
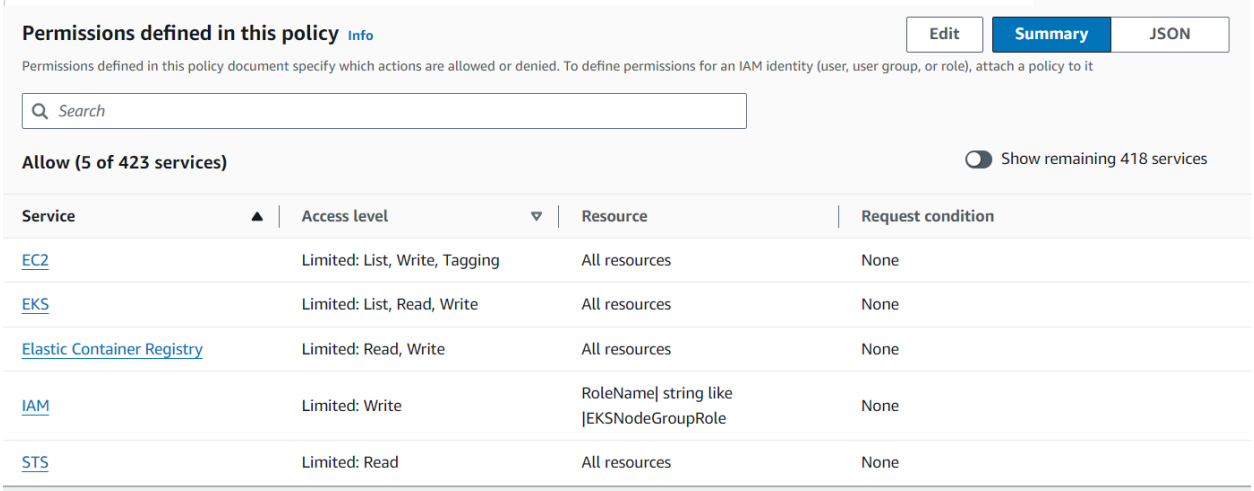
Add users and roles:

IAM User

I had Created a user called TerraformUser with the following permissions

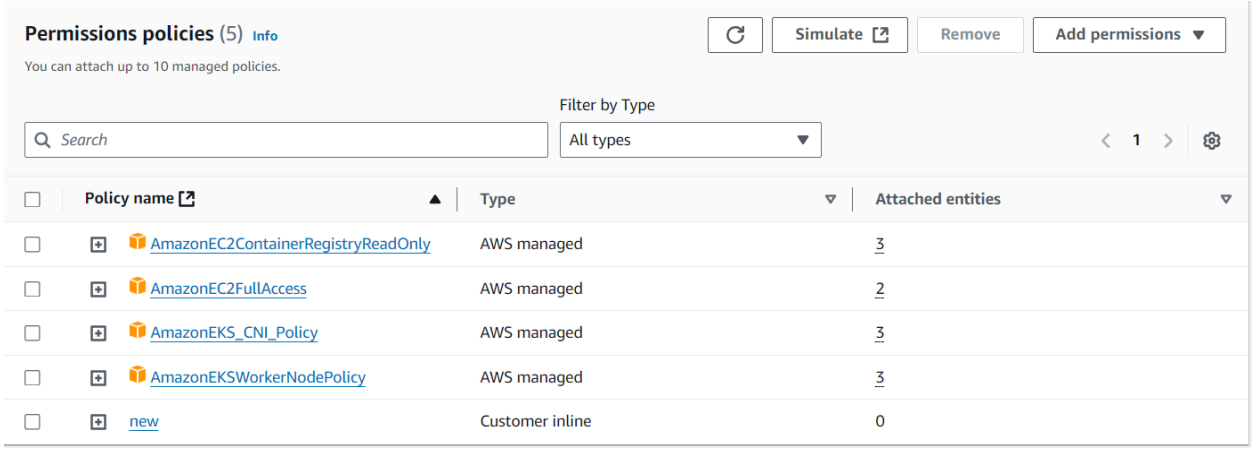






IAM Role: (Used for EKS)

I created a role called EKSNodeGroupRole with the following permissions



2. Create an S3 Bucket and Kubernetes Cluster using terraform

create a directory, I named mine terraform-multi-cloud, change your directory to the one you just created.

cd Desktop

mkdir terraform-multi-cloud

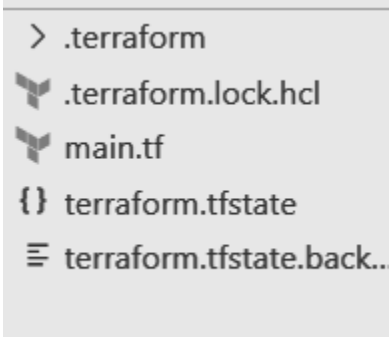
main.tf

```
terraform {
  required_providers {
    aws = {
      source  = "hashicorp/aws"
      version = "~> 5.0"
    }
    kubernetes = {
      source  = "hashicorp/kubernetes"
      version = "~> 2.0"
    }
  }
}

provider "aws" {
  region     = "eu-north-1"
  access_key = "AKIATQPD7SBWLD7OEY4X"
  secret_key = "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"
}

resource "aws_vpc" "my_vpc" {
  cidr_block = "10.0.0.0/16"
}

data "aws_availability_zones" "available" {}

resource "aws_subnet" "my_subnet" {
  count             = 2
  vpc_id            = aws_vpc.my_vpc.id
  cidr_block        = "10.0.${count.index}.0/24"
  availability_zone = element(data.aws_availability_zones.available.names, count.index)
}

```

```
module "eks" {
  source          = "terraform-aws-modules/eks/aws"
  cluster_name    = "my-cluster"
  cluster_version = "1.24"
  vpc_id          = aws_vpc.my_vpc.id
  subnet_ids      = aws_subnet.my_subnet[*].id

  tags = {
    Environment = "dev"
  }

  create_cloudwatch_log_group = false
}


data "aws_s3_bucket" "my_bucket" {
  bucket = "terraform-project-bucket-241533161580-oct2024"
}

output "s3_bucket_arn" {
  value = data.aws_s3_bucket.my_bucket.arn
}
```

After adding the code, open terminal and switch to the new directory, run the following commands

terraform init



terraform plan

```
C:\Users\veyda\Desktop\terraform-multi-cloud>terraform plan
module.eks.data.aws_caller_identity.current: Reading...
module.eks.module.kms.data.aws_caller_identity.current[0]: Reading...
module.eks.data.aws_partition.current: Reading...
data.aws_availability_zones.available: Reading...
data.aws_s3_bucket.my_bucket: Reading...
module.eks.module.kms.data.aws_partition.current[0]: Reading...
module.eks.data.aws_iam_policy_document.assume_role_policy[0]: Reading...
aws_vpc.my_vpc: Refreshing state... [id=vpc-09117ec96c191019d]
module.eks.data.aws_partition.current: Read complete after 0s [id=aws]
module.eks.module.kms.data.aws_partition.current[0]: Read complete after 0
module.eks.data.aws_iam_policy_document.assume_role_policy[0]: Read comple
module.eks.aws_iam_role.this[0]: Refreshing state... [id=my-cluster-cluste
```

Terraform apply When it prompts to enter a value, type ‘Yes’

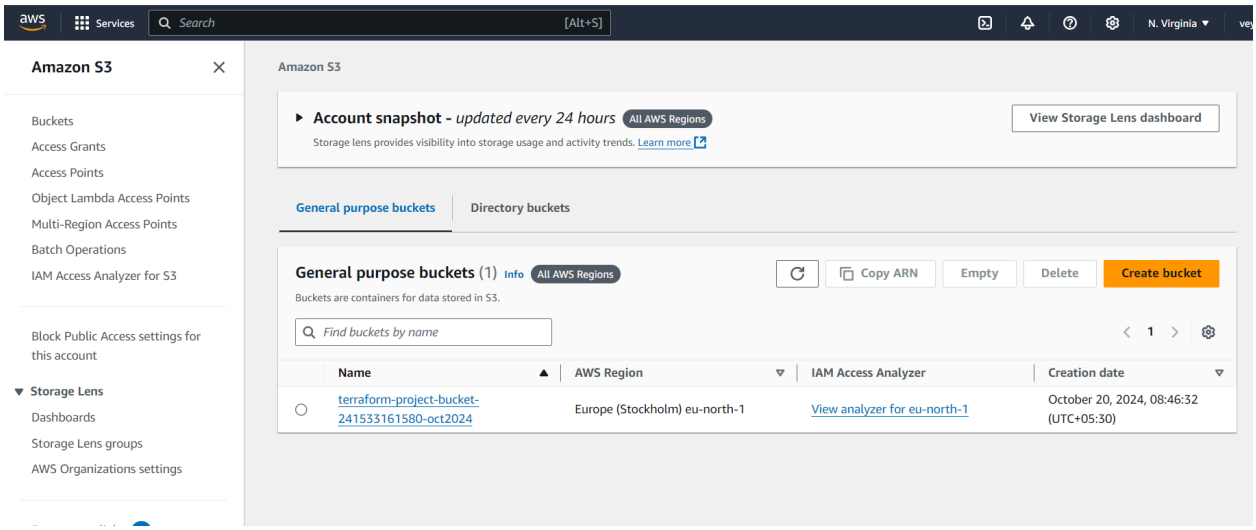
```
C:\Users\veyda\Desktop\terraform-multi-cloud>terraform apply
data.aws_availability_zones.available: Reading...
module.eks.data.aws_caller_identity.current: Reading...
data.aws_s3_bucket.my_bucket: Reading...
module.eks.data.aws_iam_policy_document.assume_role_policy[0]: Reading...
module.eks.data.aws_partition.current: Reading...
module.eks.module.kms.data.aws_caller_identity.current[0]: Reading...
module.eks.module.kms.data.aws_partition.current[0]: Reading...
aws_vpc.my_vpc: Refreshing state... [id=vpc-09117ec96c191019d]
```

If the command execute successfully you get the following output

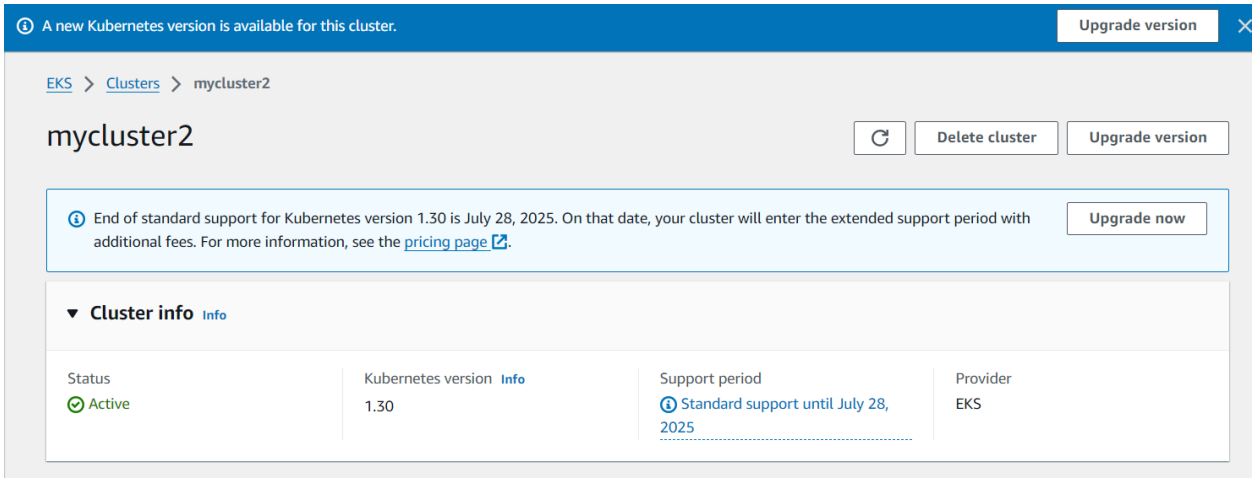
```
Apply complete! Resources: 4 added, 0 changed, 0 destroyed.

Outputs:

s3_bucket_arn = "arn:aws:s3:::terraform-project-bucket-241533161580-oct2024"
```

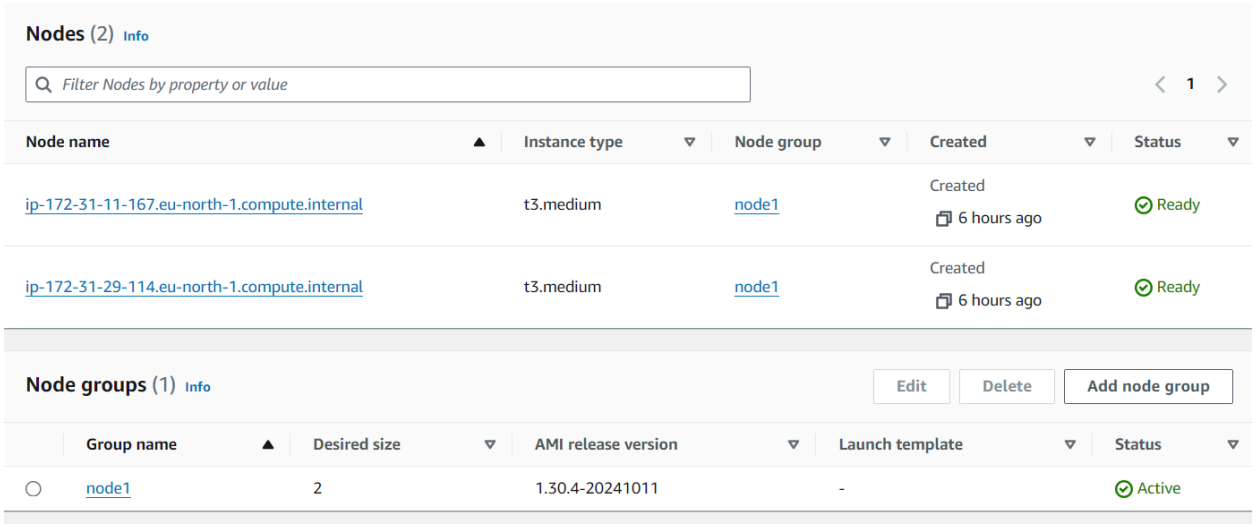
3. Kubernetes EKS Cluster & S3 Bucket

Successfully created a S3 bucket



I created a cluster called mycluster2 Assigned role of EKS group custom role Then created a node group with the same role





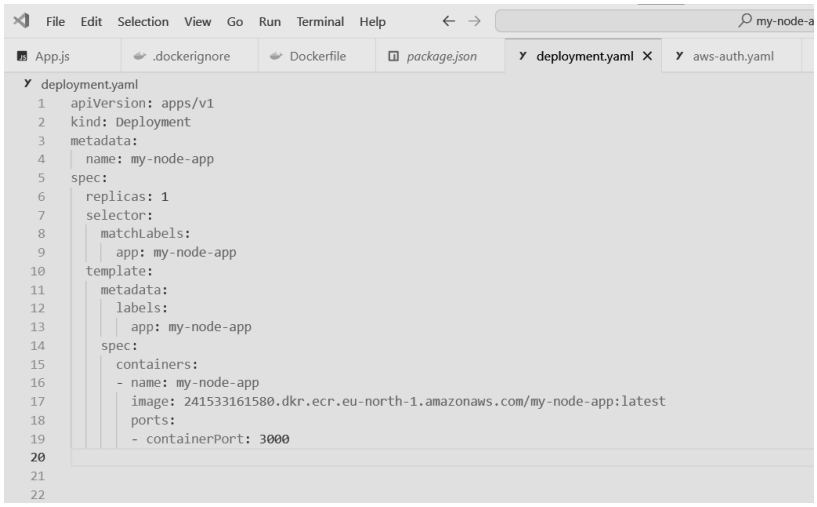
Now create Node.js Application

4. Create Node.js Application

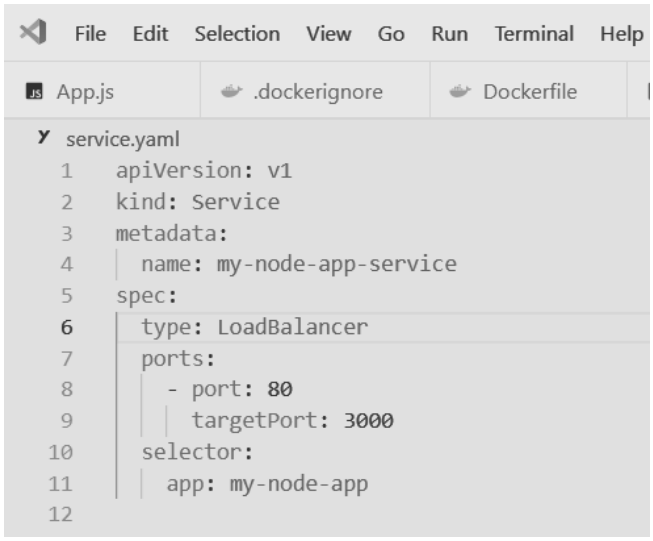
App.js

```
App.js > ...
1   const express = require('express');
2   const app = express();
3   const port = process.env.PORT || 3000;
4
5   app.get('/', (req, res) => {
6       res.send('Hello, World!');
7   });
8
9   app.listen(port, () => {
10      console.log(`Server running on port ${port}`);
11  });
12
```

deployment.yaml



Service.yaml



Create service and deployment yaml files, these files are necessary for the deployment

5. Approach: Adding Docker image to Amazon Elastic Container Registry:

Login to AWS ECR:

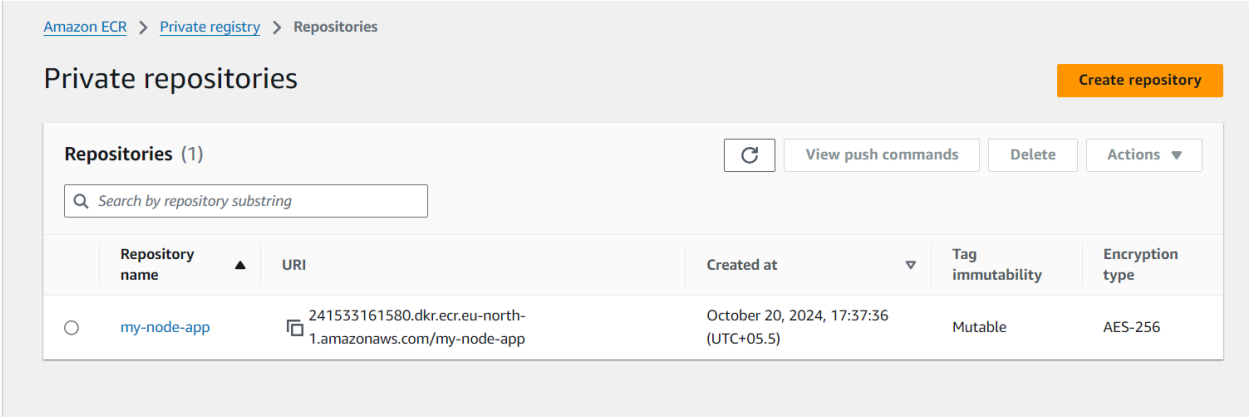
```
C:\Users\veyda\Desktop\my-node-app>docker login --username AWS --password-stdin 241533161580.dkr.ecr.eu-north-1.amazonaw
s.com < pass.txt
Login Succeeded
```

Then execute the following commands to build docker image , make sure Docker Desktop is running

```
C:\Users\veyda\Desktop\my-node-app>docker build -t my-node-app .
[+] Building 3.6s (11/11) FINISHED                                                                    docker:desktop-linux
 => [internal] load build definition from Dockerfile                                                                  0.1s
 => => transferring dockerfile: 408B                                                                                  0.0s
 => [internal] load metadata for docker.io/library/node:14                                                            2.6s
 => [auth] library/node:pull token for registry-1.docker.io                                                           0.0s
 => [internal] load .dockerignore                                                                                     0.1s
 => => transferring context: 69B                                                                                      0.0s
 => [1/5] FROM docker.io/library/node:14@sha256:a158d3b9b4e3fa813fa6c8c590b8f0a860e015ad4e59bbce5744d2f6fd8461aa      0.0s
 => [internal] load build context                                                                                     0.1s
 => => transferring context: 2.15kB                                                                                   0.0s
 => CACHED [2/5] WORKDIR /usr/src/app                                                                                 0.0s
 => CACHED [3/5] COPY package*.json ./                                                                                0.0s
 => CACHED [4/5] RUN npm install                                                                                      0.0s
 => [5/5] COPY . .                                                                                                    0.2s
 => exporting to image                                                                                                0.2s
 => => exporting layers                                                                                               0.1s
 => => writing image sha256:ef10af7d4e1b77f7ac85e3dcfbbe801ff5881323efa791b7b0f0e056f2afd2ad                          0.0s
 => => naming to docker.io/library/my-node-app                                                                        0.0s

What's next:
    View a summary of image vulnerabilities and recommendations → docker scout quickview

C:\Users\veyda\Desktop\my-node-app>docker tag my-node-app:latest 241533161580.dkr.ecr.eu-north-1.amazonaws.com/my-node-a
pp:latest
```

Then Push the image to ECR:

```
C:\Users\veyda\Desktop\my-node-app>docker push 241533161580.dkr.ecr.eu-north-1.amazonaws.com/my-node-app:latest
The push refers to repository [241533161580.dkr.ecr.eu-north-1.amazonaws.com/my-node-app]
672a4d37395a: Pushed
b77a097565ee: Layer already exists
2cbfd73256b4: Layer already exists
9d8eca4ec15e: Layer already exists
0d5f5a015e5d: Layer already exists
3c777d951de2: Layer already exists
f8a91dd5fc84: Layer already exists
cb81227abde5: Layer already exists
e01a454893a9: Layer already exists
c45660adde37: Layer already exists
fe0fb3ab4a0f: Layer already exists
f1186e5061f2: Layer already exists
b2dba7477754: Layer already exists
latest: digest: sha256:102604de5635009bdecfbb83c4982b01a36ffbd4c09eac3d206e9748776e1489 size: 3050

C:\Users\veyda\Desktop\my-node-app>
```



6. Kubernetes deployment

In a command prompt, switch to the directory where you created the node.js app and deployment and service files.

kubectl apply -f deployment.yaml

```
C:\Users\veyda\Desktop\my-node-app>kubectl apply -f deployment.yaml
error: error validating "deployment.yaml": error validating data: failed to download openapi: Get "https://127.0.0.1:49
98/openapi/v2?timeout=32s": dial tcp 127.0.0.1:49698: connectex: No connection could be made because the target machine
actively refused it.; if you choose to ignore these errors, turn validation off with --validate=false
```

Here we encountered an error due to the kubeconfig context, i.e it is located on minikube instead of cluster.

kubectl config current-context

```
C:\Users\veyda\Desktop\my-node-app>kubectl config get-contexts
CURRENT   NAME                                                CLUSTER
          AUTHINFO                                            NAMESPACE
          arn:aws:eks:eu-north-1:241533161580:cluster/my-cluster   arn:aws:eks:eu-north-1:241533161580:cluster/my-clust
r   arn:aws:eks:eu-north-1:241533161580:cluster/my-cluster
          arn:aws:eks:eu-north-1:241533161580:cluster/mycluster2   arn:aws:eks:eu-north-1:241533161580:cluster/mycluste
2   arn:aws:eks:eu-north-1:241533161580:cluster/mycluster2
*         minikube                                            minikube
          minikube                                            default
```

We update the context to our cluster using the eks command for updating the kubeconfig

kubectl config use-context arn:aws:eks:eu-north-1:241533161580:cluster/mycluster2

```
C:\Users\veyda\Desktop\my-node-app>aws eks update-kubeconfig --name mycluster2 --region eu-north-1
Updated context arn:aws:eks:eu-north-1:241533161580:cluster/mycluster2 in C:\Users\veyda\.kube\config
```

The error occurs with deployment.yaml not being accepted by EKS Cluster and also a failure to fetch the pods

kubectl get pods

```
C:\Users\veyda\Desktop\my-node-app>kubectl get pods
E1022 18:25:23.435792   14632 memcache.go:265] "Unhandled Error" err="couldn't get current server API group list: the se
rver has asked for the client to provide credentials"
E1022 18:25:25.929634   14632 memcache.go:265] "Unhandled Error" err="couldn't get current server API group list: the se
rver has asked for the client to provide credentials"
^C
C:\Users\veyda\Desktop\my-node-app>Exception ignored in: <_io.TextIOWrapper name='<stdout>' mode='w' encoding='cp1252'>
OSError: [Errno 22] Invalid argument
```

Apply the Deployment and Service:

Run the following commands:

kubectl apply -f deployment.yaml

kubectl apply -f service.yaml

Our configuration files get accepted

7. Verify the Deployment

Check the Service Status: Use the following command to retrieve details about your service:

kubectl get svc hello-world-node-service

Find the External IP: In the output, locate the `EXTERNAL-IP` column. Note that it might take a few minutes for the external IP to be assigned.

Access Your Application: Once the external IP is available, open a web browser and enter the URL:

http://<EXTERNAL-IP>/

You should see a "Hello, World!" message displayed.

8. Clean Up Resources

After testing, you may want to remove the resources to avoid incurring charges.

Use the following commands to destroy a particular resource

```
C:\Users\veyda\Desktop\terraform-multi-cloud>del *.tfstate

C:\Users\veyda\Desktop\terraform-multi-cloud>del *.tfstate.backup
```

Run Terraform Destroy:

```
C:\Users\veyda\Desktop\terraform-multi-cloud>terraform destroy

No changes. No objects need to be destroyed.

Either you have not created any objects yet or the existing objects were already deleted outside of Terraform.

Destroy complete! Resources: 0 destroyed.

C:\Users\veyda\Desktop\terraform-multi-cloud>
```

Conclusion:

This project demonstrated how we leveraged Terraform to automate the setup and management of multi-cloud resources, specifically on AWS. Our approach included creating an S3 bucket for data storage and establishing a Kubernetes cluster on AWS to handle container orchestration. By deploying a sample application, like a Node.js app, on the Kubernetes cluster, we highlighted the effective integration of infrastructure and applications across cloud environments.

Key insights from this project include:

1. Flexibility of Terraform: Terraform streamlines infrastructure management by allowing us to define resources as code, enabling efficient deployment, management, and scaling of services.
2. Kubernetes Scalability: The Kubernetes cluster created an optimal environment for deploying and scaling applications, ensuring consistent and reliable performance.
3. Cloud-native Storage with S3: The AWS S3 bucket provided a scalable and durable solution for storing data, meeting the needs of the deployed application.
4. Error Resolution in Cluster Creation: We also learned how to troubleshoot and resolve errors encountered during the creation of the cluster.
5. Amazon ECR: We also worked and learnt about Amazon ECR service that allows to upload docker images for project, and can be used for further deployment.

We also learned about various Permission policies and their effect on Terraform, EKS, and ECR.