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REGISTRATION #: 2023-BSE-061

COURSE: CLOUD COMPUTING

DEPARTMENT: BSE

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Assignment 2:

Advanced Terraform & Nginx Multi-Tier Architecture

Table of Content

1. Summary

This assignment focuses on the design and deployment of a production-ready, multi-tier web infrastructure using Terraform and Nginx on Amazon Web Services (AWS). The objective of the assignment is to demonstrate practical knowledge of Infrastructure as Code (IaC), cloud networking, security best practices, and high-availability web architectures. The deployed infrastructure consists of one Nginx server acting as a reverse proxy and load balancer, and three backend Apache web servers. Two backend servers operate as primary servers, while the third functions as a backup server that automatically serves traffic in case of failure of the primary servers. Terraform modules are used to ensure code reusability, scalability, and clean organization of infrastructure components. Advanced Nginx configurations have been implemented, including HTTPS with self-signed SSL certificates, HTTP to HTTPS redirection, response caching, security headers, and upstream load balancing. The system is designed to improve performance, enhance security, and ensure uninterrupted service availability. The assignment also includes comprehensive testing, such as load balancing verification, cache performance validation, high-availability failover testing, and security analysis. Proper documentation, screenshots, and cleanup of cloud resources have been carried out to meet academic and professional standards. This project provides hands-on experience with real-world cloud deployment scenarios and reinforces key concepts of cloud computing, DevOps practices, and secure system design.

2. Architecture Design

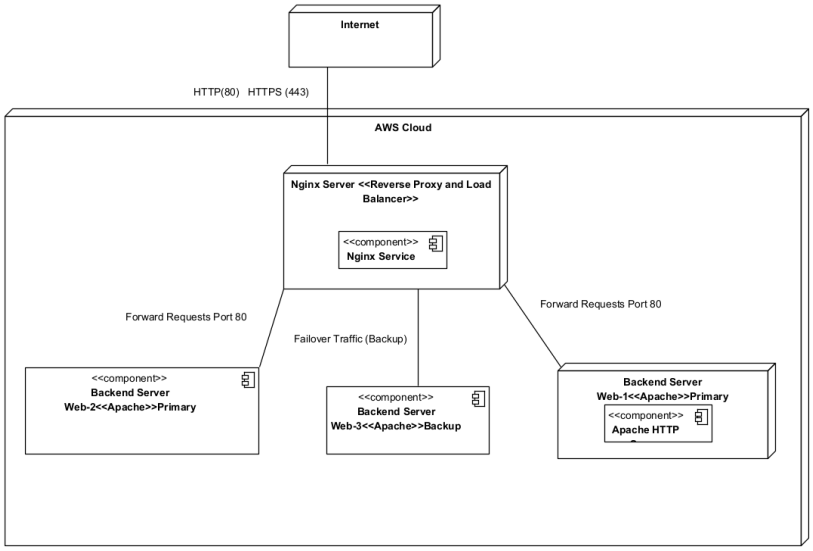
2.1 Architecture Overview

The architecture follows a multi-tier design where the application is divided into distinct layers to enhance scalability,

security, and maintainability. The front layer consists of an Nginx reverse proxy, which handles incoming client requests, while the backend layer consists of multiple Apache web servers responsible for serving application content. All resources are deployed within a custom AWS Virtual Private Cloud (VPC) using Terraform. The Nginx server acts as a single-entry point for users and distributes incoming traffic across backend servers using load balancing techniques.

2.2 Architecture Diagram

The diagram represents a multi-tier web architecture deployed on AWS, where incoming requests from the Internet are first handled by an Nginx server acting as a reverse proxy and load balancer. Nginx manages HTTP and HTTPS traffic, performs SSL termination, applies caching, and forwards requests to the backend layer. The backend consists of three Apache web servers, with Web-1 and Web-2 serving as primary nodes that handle normal traffic through load balancing, while Web-3 is configured as a backup server to ensure high availability during failures. This architecture enhances security, performance, scalability, and fault tolerance of the application.



2.3 System Components

The main components of the system are:

Terraform

Used as an Infrastructure as Code (IaC) tool to automate the provisioning and management of AWS resources.

Amazon VPC

A custom virtual network providing isolation and control over networking resources.

Public Subnet

Hosts the Nginx server and backend web servers with public IP addresses.

Nginx Server

Acts as a reverse proxy and load balancer, providing HTTPS access, caching, and security headers.

Apache Backend Servers (Web-1, Web-2, Web-3)

Serve dynamic HTML content. Web-3 is configured as a backup server.

Security Groups

Control inbound and outbound traffic based on the principle of least privilege.

2.4 Network Topology

The infrastructure is deployed in a single AWS availability zone for simplicity. The VPC contains one public subnet connected to the internet via an Internet Gateway. Routing rules allow external traffic to reach the Nginx server, while backend servers only accept traffic from the Nginx security group.

2.5 Security Design

Security has been implemented using AWS Security Groups:

Nginx Security Group

- Allows SSH (port 22) from the user's IP only
- Allows HTTP (80) and HTTPS (443) from anywhere
- Allows all outbound traffic

Backend Security Group

- Allows SSH (port 22) from the user's IP only

- Allows HTTP (80) traffic only from the Nginx security group
- Blocks all other inbound access
- This design ensures backend servers are not directly accessible from the internet, significantly improving system security.

3. Implementation Details

1. Infrastructure Setup (25 marks)

assignment_part1_project_structure

```
Syed@DESKTOP-S5OGK51 MINGW64 ~ (main)
$ mkdir -p Assignment2/modules/{networking,security,webserver}

Syed@DESKTOP-S5OGK51 MINGW64 ~ (main)
$ mkdir -p Assignment2/scripts

Syed@DESKTOP-S5OGK51 MINGW64 ~ (main)
$ cd Assignment2

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ touch main.tf variables.tf outputs.tf locals.tf terraform.tfvars README.md .gi
tignore

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ touch modules/networking/{main.tf,variables.tf,outputs.tf}

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ touch modules/security/{main.tf,variables.tf,outputs.tf}

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ touch modules/webserver/{main.tf,variables.tf,outputs.tf}

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ touch scripts/nginx-setup.sh scripts/apache-setup.sh

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ tree
bash: tree: command not found

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ ^C

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ ls -R
.:
README.md  main.tf   outputs.tf  terraform.tfvars
locals.tf  modules/  scripts/    variables.tf

./modules:
networking/  security/  webserver/

./modules/networking:
main.tf  outputs.tf  variables.tf

./modules/security:
main.tf  outputs.tf  variables.tf

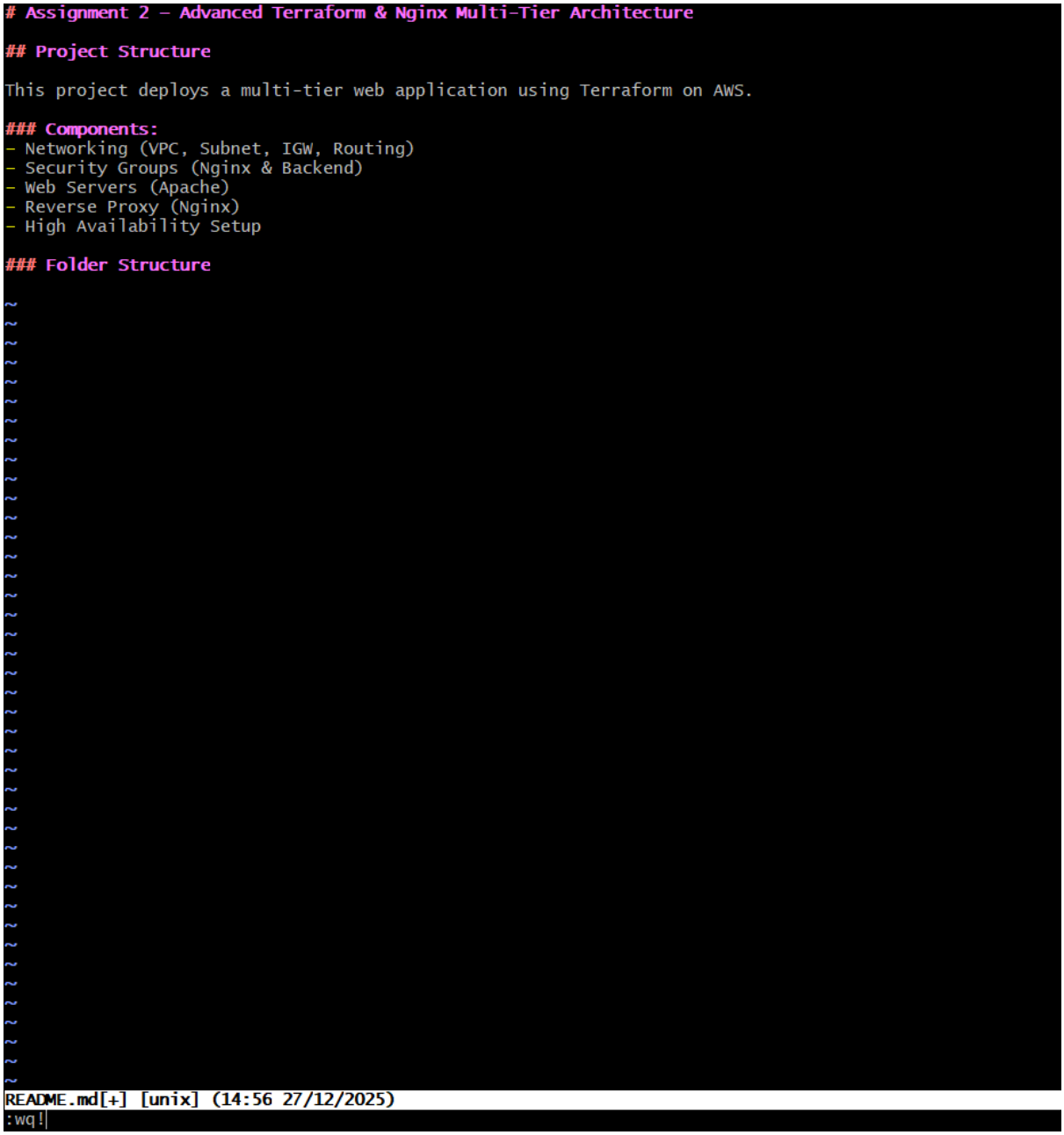
./modules/webserver:
main.tf  outputs.tf  variables.tf

./scripts:
apache-setup.sh  nginx-setup.sh

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$
```

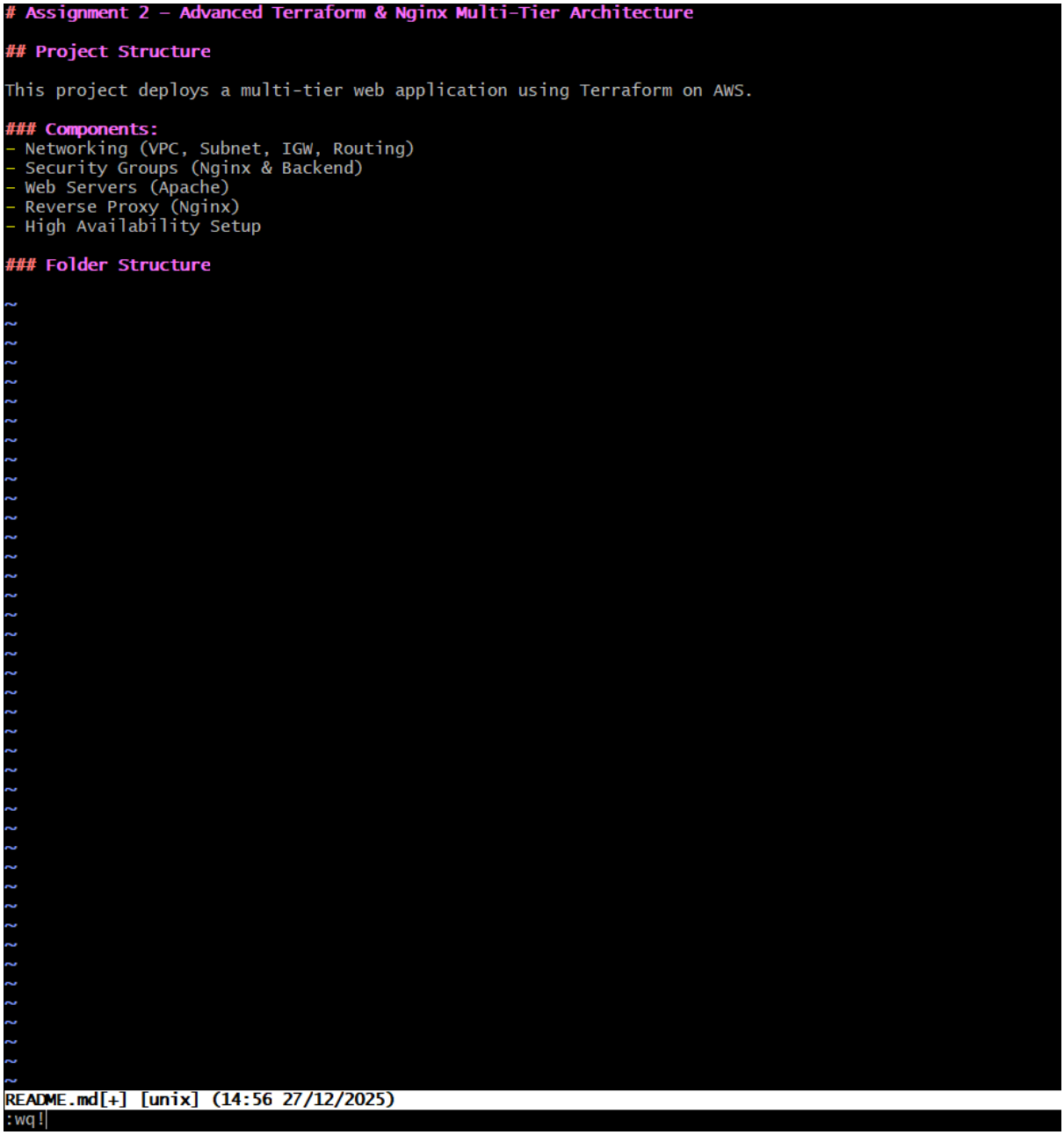
assignment_part1_gitignore


MINGW64:/c/Users/Syed/Assignment2
Terraform files
.terraform/
*.tfstate
.tfstate.
*.tfvars
.terraform.lock.hcl
SSH keys
*.pem
*.key
id_rsa
id_ed25519
OS files
.DS_Store
.gitignore[+] [unix] (14:56 27/12/2025)
:wq!



1.2 Variable Configuration (5 marks)

assignment_part1_variables_tf



assignment_part1_terraform_tfvars

```
vpc_cidr_block     = "10.0.0.0/16"
subnet_cidr_block = "10.0.10.0/24"
availability_zone = "me-central-1a"
env_prefix        = "prod"
instance_type     = "t3.micro"

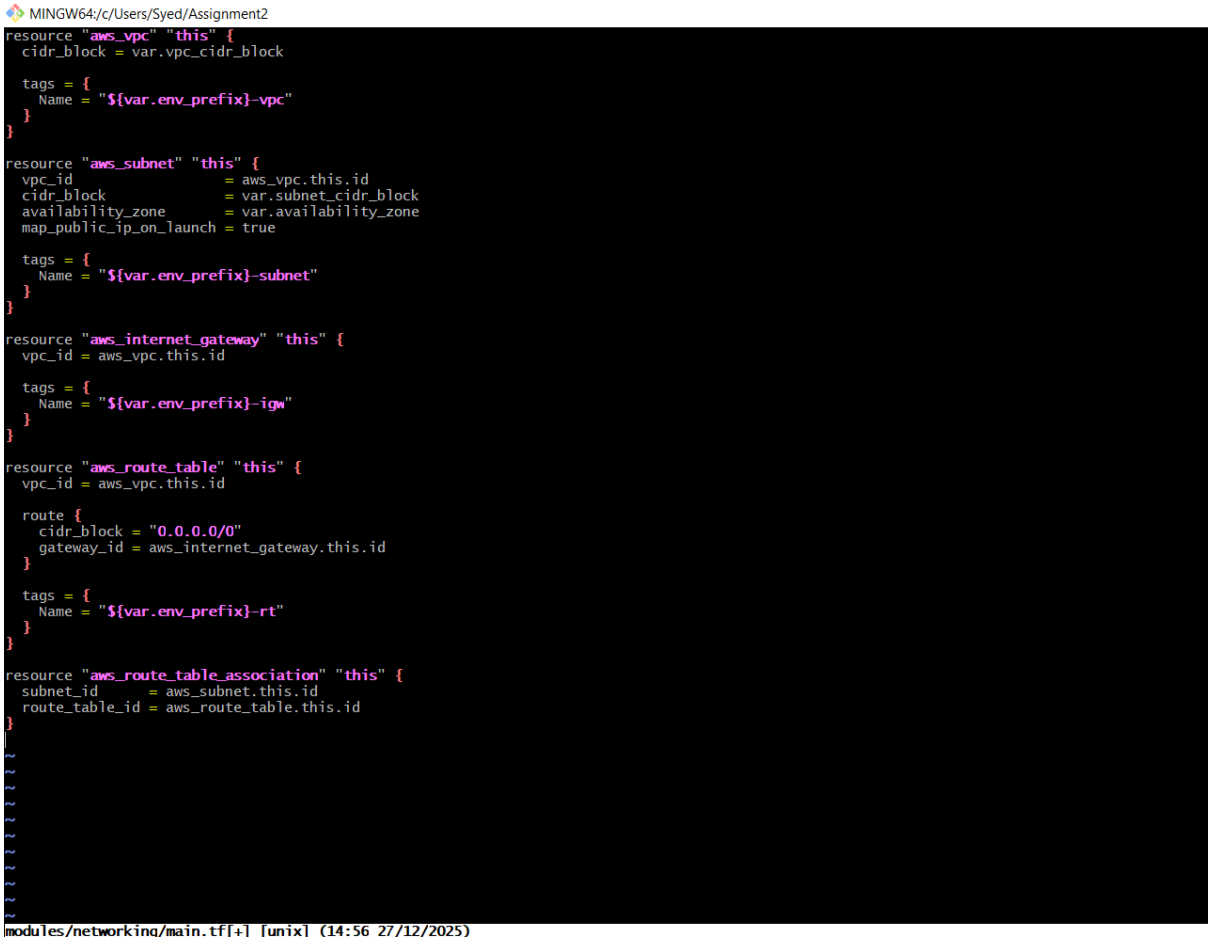
public_key  = "~/.ssh/id_ed25519.pub"
private_key = "~/.ssh/id_ed25519"

backend_servers = [
  {
    name        = "web-1"
    script_path = "./scripts/apache-setup.sh"
  },
  {
    name        = "web-2"
    script_path = "./scripts/apache-setup.sh"
  },
  {
    name        = "web-3"
    script_path = "./scripts/apache-setup.sh"
  }
]
```

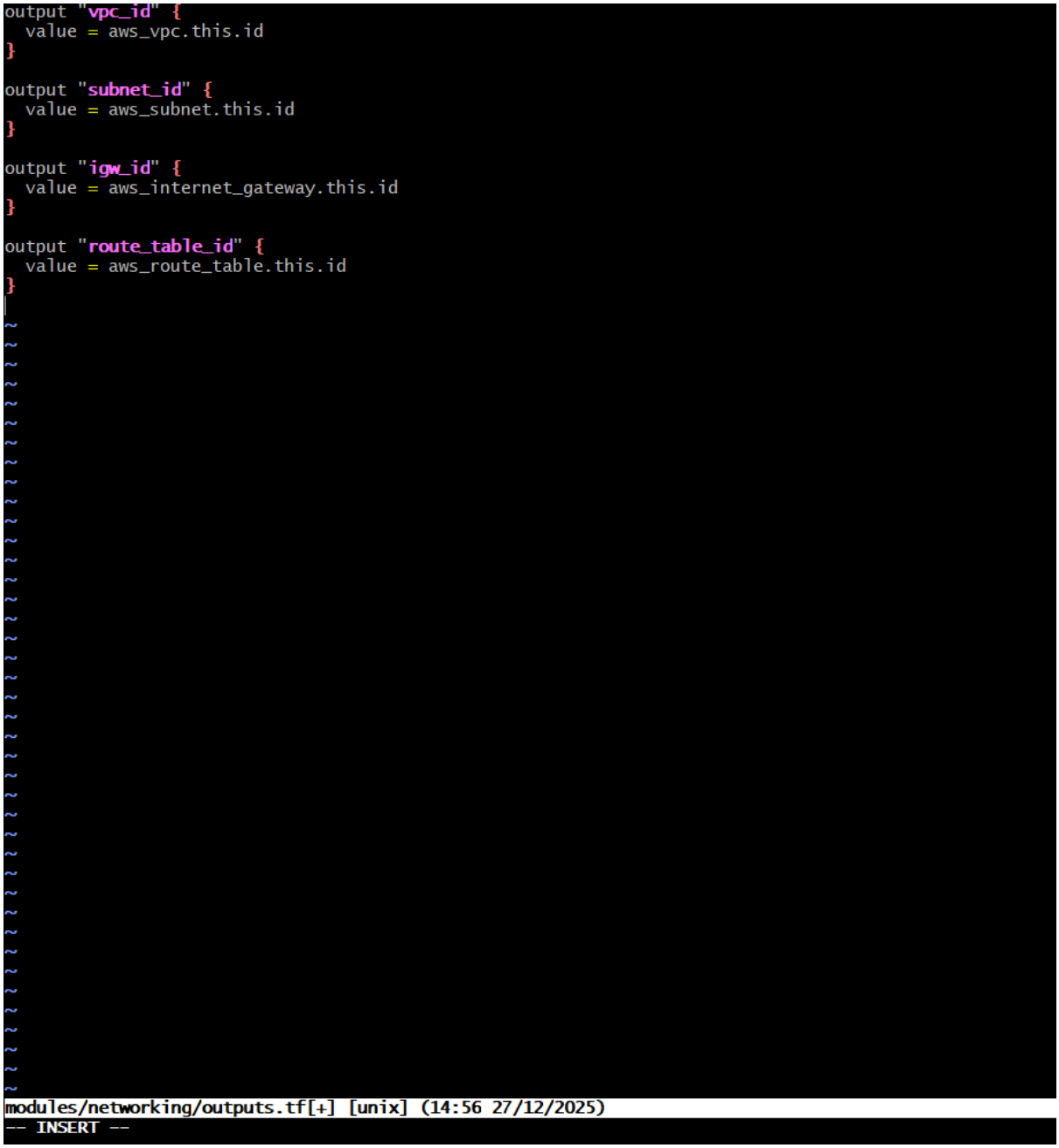
```
terraform.tfvars[+] [unix] (14:56 27/12/2025)
-- INSERT --
```

1.3 Networking Module (5 marks)

assignment_part1_networking_module_main



assignment_part1_networking_module_outputs



1.4 Security Module (5 marks)

assignment_part1_security_module

```
resource "aws_security_group" "nginx_sg" {
  name        = "${var.env_prefix}-nginx-sg"
  description = "Nginx Security Group"
  vpc_id      = var.vpc_id

  ingress {
    from_port   = 22
    to_port     = 22
    protocol    = "tcp"
    cidr_blocks = [var.my_ip]
  }

  ingress {
    from_port   = 80
    to_port     = 80
    protocol    = "tcp"
    cidr_blocks = ["0.0.0.0/0"]
  }

  ingress {
    from_port   = 443
    to_port     = 443
    protocol    = "tcp"
    cidr_blocks = ["0.0.0.0/0"]
  }

  egress {
    from_port   = 0
    to_port     = 0
    protocol    = "-1"
    cidr_blocks = ["0.0.0.0/0"]
  }

  tags = {
    Name = "${var.env_prefix}-nginx-sg"
  }
}

resource "aws_security_group" "backend_sg" {
  name   = "${var.env_prefix}-backend-sg"
  vpc_id = var.vpc_id

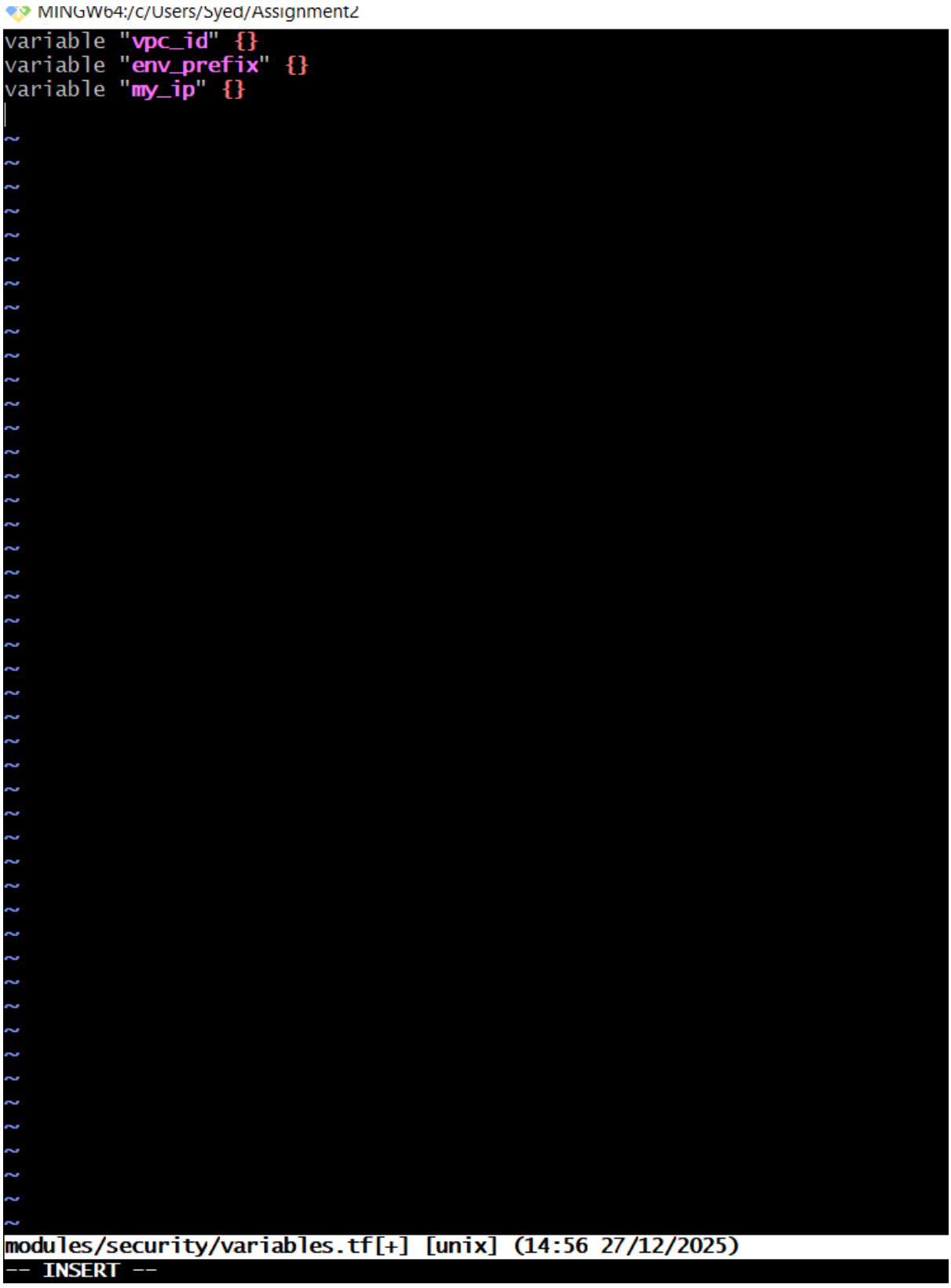
  ingress {
    from_port       = 22
    to_port         = 22
    protocol        = "tcp"
    cidr_blocks     = [var.my_ip]
  }

  ingress {
    from_port       = 80
    to_port         = 80
    protocol        = "tcp"
    security_groups = [aws_security_group.nginx_sg.id]
  }

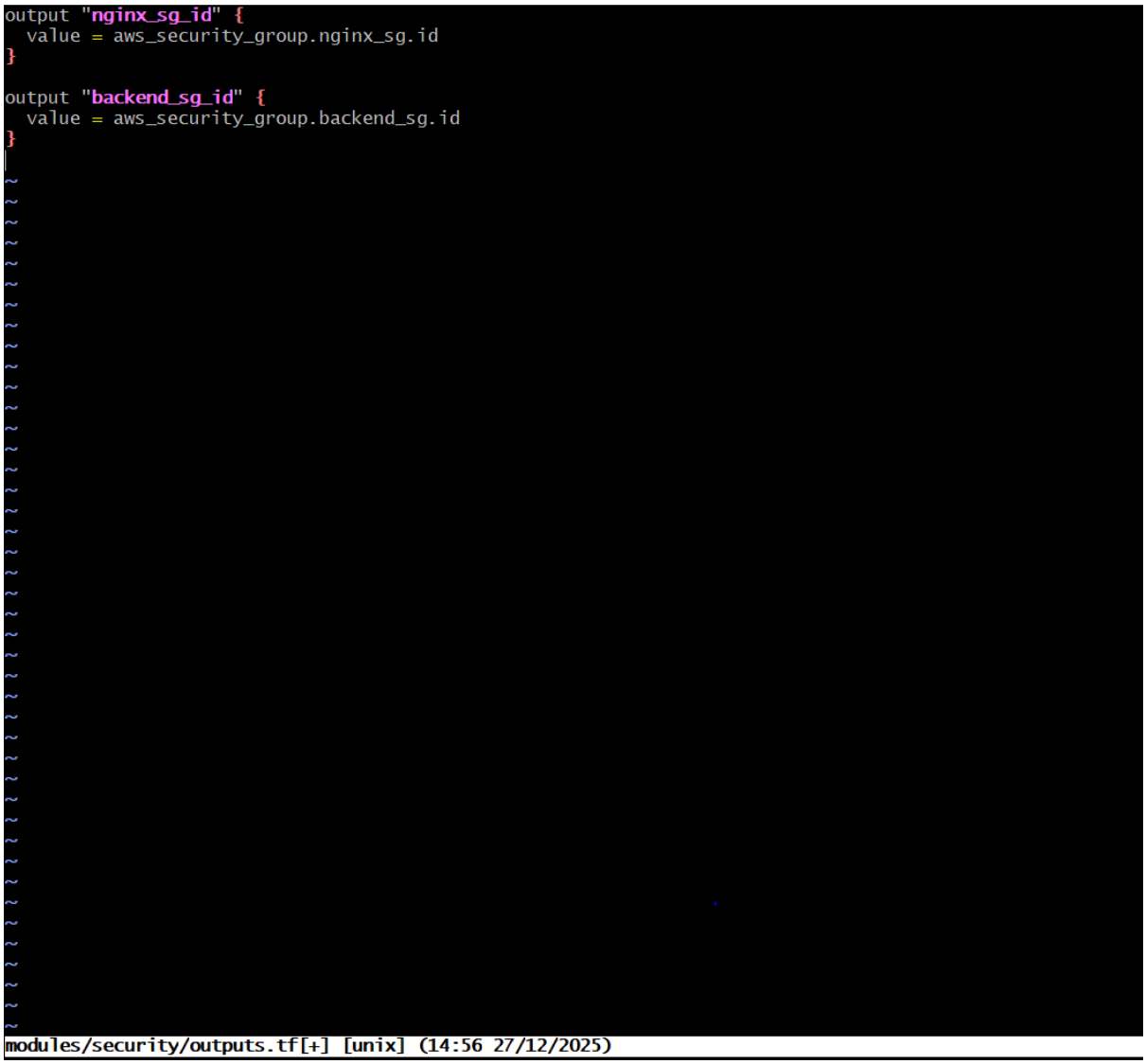
  egress {
    from_port   = 0
    to_port     = 0
    protocol    = "-1"
    cidr_blocks = ["0.0.0.0/0"]
  }

  tags = {
    Name = "${var.env_prefix}-backend-sg"
  }
}

~
modules/security/main.tf[+] [unix] (14:56 27/12/2025)
```

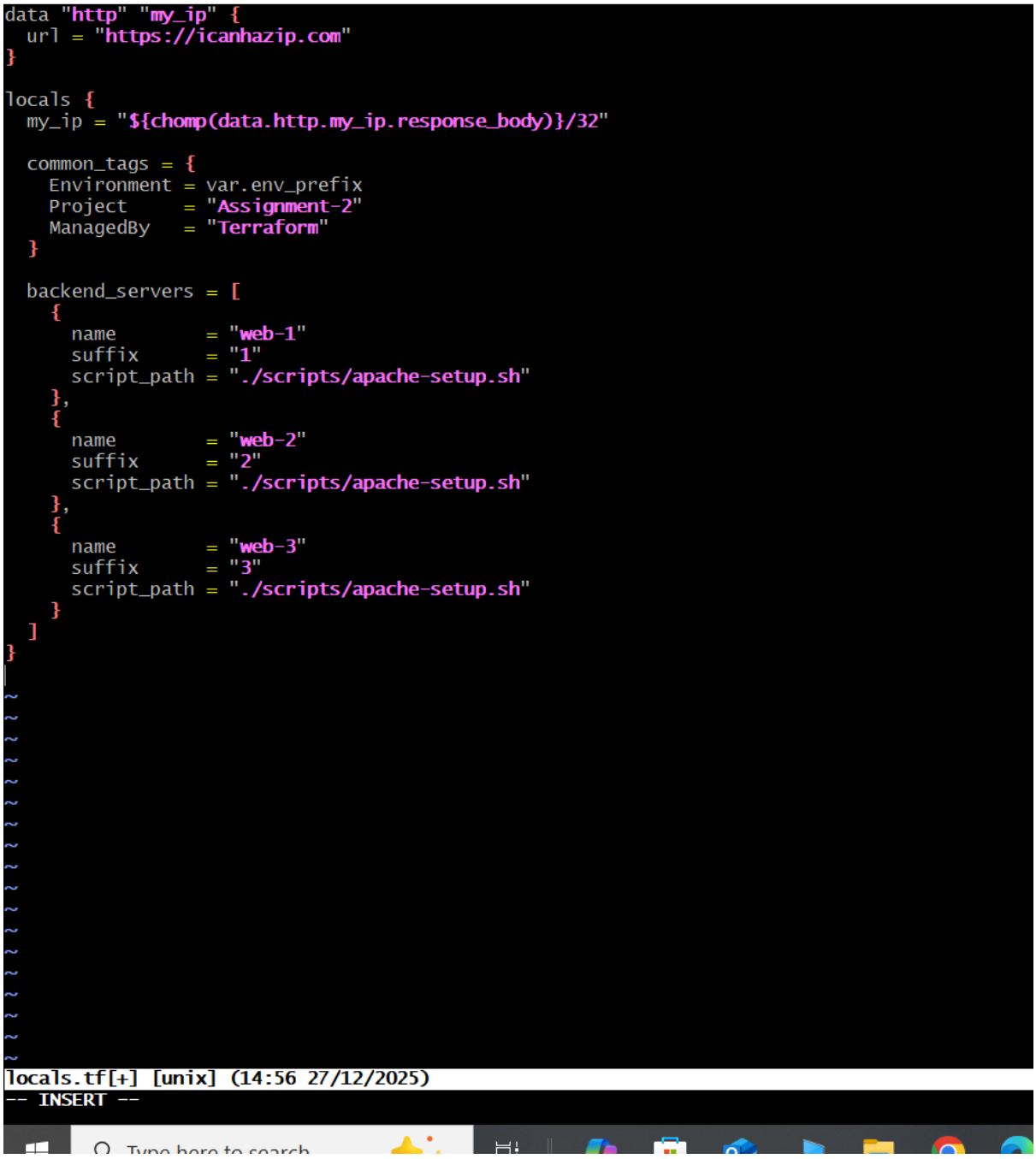


assignment_part1_security_groups_console



1.5 Locals Configuration (5 marks)

assignment_part1_locals_tf



2. Webserver Module (15 marks)

assignment_part2_webserver_module_variables

```
variable "env_prefix" {}
variable "instance_name" {}
variable "instance_type" {}
variable "availability_zone" {}
variable "vpc_id" {}
variable "subnet_id" {}
variable "security_group_id" {}
variable "public_key" {}
variable "script_path" {}
variable "instance_suffix" {}
variable "common_tags" {
  type = map(string)
}
```

assignment_part2_webserver_module_main

```
# Create AWS Key Pair
resource "aws_key_pair" "this" {
  key_name   = "${var.env_prefix}-${var.instance_suffix}-key"
  public_key = file(var.public_key)
}

# Create EC2 Instance
resource "aws_instance" "this" {
  ami                    = "ami-0c000000000000000" # Replace with latest Amazon Linux 2023 AMI in your region
  instance_type          = var.instance_type
  availability_zone      = var.availability_zone
  subnet_id              = var.subnet_id
  vpc_security_group_ids = [var.security_group_id]
  key_name               = aws_key_pair.this.key_name
  associate_public_ip_address = true
  user_data              = file(var.script_path)

  tags = merge(
    var.common_tags,
    {
      Name = "${var.instance_name}-${var.instance_suffix}"
    }
  )
}
modules/webserver/main.tf[+] [unix] (14:56 27/12/2025)
:wq!
```

assignment_part2_webserver_module_outputs

```
output "instance_id" {
  value = aws_instance.this.id
}

output "public_ip" {
  value = aws_instance.this.public_ip
}

output "private_ip" {
  value = aws_instance.this.private_ip
}
```

2.2 Module Usage (5 marks)

assignment_part2_main_tf_modules

```
module "nginx_server" {
  source            = "./modules/webserver"
  env_prefix        = var.env_prefix
  instance_name     = "nginx-proxy"
  instance_type     = var.instance_type
  availability_zone = var.availability_zone
  vpc_id            = module.networking.vpc_id
  subnet_id         = module.networking.subnet_id
  security_group_id = module.security.nginx_sg_id
  public_key        = var.public_key
  script_path       = "./scripts/nginx-setup.sh"
  instance_suffix   = "nginx"
  common_tags       = local.common_tags
}
module "backend_servers" {
  for_each = { for idx, server in local.backend_servers : server.name => server }

  source            = "./modules/webserver"
  env_prefix        = var.env_prefix
  instance_name     = each.value.name
  instance_type     = var.instance_type
  availability_zone = var.availability_zone
  vpc_id            = module.networking.vpc_id
  subnet_id         = module.networking.subnet_id
  security_group_id = module.security.backend_sg_id
  public_key        = var.public_key
  script_path       = each.value.script_path
  instance_suffix   = each.value.suffix
  common_tags       = local.common_tags
}
~
~
~
~
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~
~
~
~
~
~
~
~
~
~
~
~
~
main.tf[+] [unix] (14:56 27/12/2025)
-- INSERT --
```

3. Server Configuration Scripts (20 marks)

3.1 Apache Backend Server Script (10 marks)

assignment_part3_apache_script

```
#!/bin/bash
set -e

# Update system
yum update -y

# Install Apache
yum install httpd -y

# Start and enable Apache
systemctl start httpd
systemctl enable httpd

# Get metadata token (IMDSv2)
TOKEN=$(curl -s -X PUT "http://169.254.169.254/latest/api/token" \
  -H "X-aws-ec2-metadata-token-ttl-seconds: 21600")

# Get instance metadata
PRIVATE_IP=$(curl -s -H "X-aws-ec2-metadata-token: $TOKEN" \
  http://169.254.169.254/latest/meta-data/local-ipv4)
PUBLIC_IP=$(curl -s -H "X-aws-ec2-metadata-token: $TOKEN" \
  http://169.254.169.254/latest/meta-data/public-ipv4)
PUBLIC_DNS=$(curl -s -H "X-aws-ec2-metadata-token: $TOKEN" \
  http://169.254.169.254/latest/meta-data/public-hostname)
INSTANCE_ID=$(curl -s -H "X-aws-ec2-metadata-token: $TOKEN" \
  http://169.254.169.254/latest/meta-data/instance-id)

# Set hostname
hostnamectl set-hostname myapp-webserver

# Create custom HTML page
cat > /var/www/html/index.html <<EOF
<!DOCTYPE html>
<html>
<head>
    <title>Backend Web Server</title>
    <style>
        body {
            font-family: Arial, sans-serif;
            margin:  50px;
            background:  linear-gradient(135deg, #667eea 0%, #764ba2 100%);
            color: white;
        }
        .container {
            background: rgba(255, 255, 255, 0.1);
            padding: 30px;
            border-radius: 10px;
            box-shadow: 0 8px 32px 0 rgba(31, 38, 135, 0.37);
        }
        h1 { color: #fff; text-shadow: 2px 2px 4px rgba(0,0,0,0.3); }
        .info { margin: 15px 0; padding: 10px; background: rgba(255,255,255,0.2); border-radius: 5px; }
        .label { font-weight: bold; color: #ffd700; }
    </style>
</head>
<body>
    <div class="container">
        <h1>🚀 Backend Web Server - Assignment 2</h1>
        <div class="info"><span class="label">Hostname:</span> $(hostname)</div>
        <div class="info"><span class="label">Instance ID:</span> $INSTANCE_ID</div>
        <div class="info"><span class="label">Private IP:</span> $PRIVATE_IP</div>
        <div class="info"><span class="label">Public IP:</span> $PUBLIC_IP</div>
        <div class="info"><span class="label">Public DNS:</span> $PUBLIC_DNS</div>
        <div class="info"><span class="label">Deployed: </span> $(date)</div>
        <div class="info"><span class="label">Status:</span> ✅ Active and Running</div>
        <div class="info"><span class="label">Managed By:</span> Terraform</div>
    </div>
</body>
</html>
EOF

# Set permissions
chmod 644 /var/www/html/index.html

echo "Apache setup completed successfully!"
~
~
~
~
~
~
~
apache-setup.sh[+] [unix] (04:59 01/01/1970)
:wq!
```

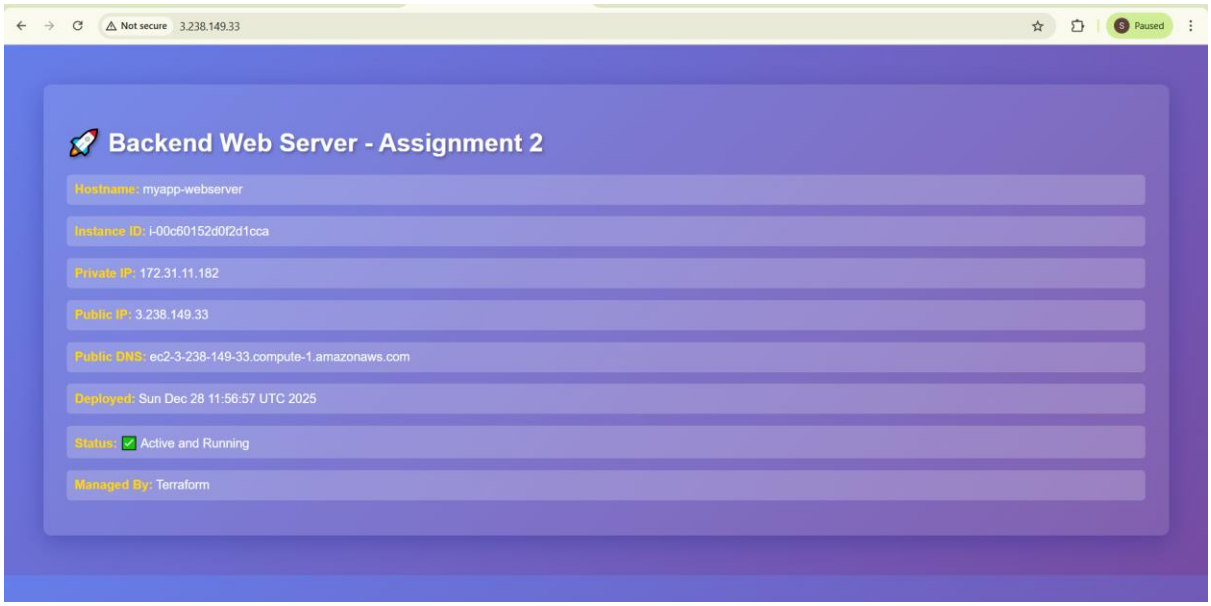
assignment_part3_apache_execution

```
[ec2-user@ip-172-31-11-182 scripts]$ sudo ./apache-setup.sh
Amazon Linux 2023 Kernel Livepatch repository                                   231 kB/s |  29 kB     00:00
Dependencies resolved.
Nothing to do.
Complete!
Last metadata expiration check: 0:00:02 ago on Sun Dec 28 11:56:52 2025.
Dependencies resolved.
================================================================================
 Package                 Architecture  Version                    Repository  Size
================================================================================
Installing:
 httpd                   x86_64        2.4.65-1.amzn2023.0.2      amazonlinux 47 k
Installing dependencies:
 apr                     x86_64        1.7.5-1.amzn2023.0.4       amazonlinux 129 k
 apr-util                x86_64        1.6.3-1.amzn2023.0.2       amazonlinux 97 k
 apr-util-lmdb           x86_64        1.6.3-1.amzn2023.0.2       amazonlinux 13 k
 generic-logos-httpd     noarch        18.0.0-12.amzn2023.0.3     amazonlinux 19 k
 httpd-core              x86_64        2.4.65-1.amzn2023.0.2      amazonlinux 1.4 M
 httpd-filesystem        noarch        2.4.65-1.amzn2023.0.2      amazonlinux 13 k
 httpd-tools             x86_64        2.4.65-1.amzn2023.0.2      amazonlinux 81 k
 libbrotli               x86_64        1.0.9-4.amzn2023.0.2       amazonlinux 315 k
 mailcap                 noarch        2.1.49-3.amzn2023.0.3      amazonlinux 33 k
Installing weak dependencies:
 apr-util-openssl        x86_64        1.6.3-1.amzn2023.0.2       amazonlinux 15 k
 mod_http2               x86_64        2.0.27-1.amzn2023.0.3      amazonlinux 166 k
 mod_lua                 x86_64        2.4.65-1.amzn2023.0.2      amazonlinux 60 k

Transaction Summary
================================================================================
Install  13 Packages

Total download size: 2.4 M
Installed size: 6.9 M
Downloading Packages:
(1/13): apr-1.7.5-1.amzn2023.0.4.x86_64.rpm                     3.3 MB/s | 129 kB     00:00
(2/13): apr-util-1.6.3-1.amzn2023.0.2.x86_64.rpm                2.2 MB/s |  97 kB     00:00
(3/13): apr-util-lmdb-1.6.3-1.amzn2023.0.2.x86_64.rpm           296 kB/s |  13 kB     00:00
(4/13): apr-util-openssl-1.6.3-1.amzn2023.0.2.x86_64.rpm        535 kB/s |  15 kB     00:00
(5/13): httpd-2.4.65-1.amzn2023.0.2.x86_64.rpm                  1.8 MB/s |  47 kB     00:00
(6/13): generic-logos-httpd-18.0.0-12.amzn2023.0.3.noarch.rpm   650 kB/s |  19 kB     00:00
(7/13): httpd-filesystem-2.4.65-1.amzn2023.0.2.noarch.rpm       487 kB/s |  13 kB     00:00
(8/13): httpd-core-2.4.65-1.amzn2023.0.2.x86_64.rpm              33 MB/s | 1.4 MB     00:00
(9/13): httpd-tools-2.4.65-1.amzn2023.0.2.x86_64.rpm            2.0 MB/s |  81 kB     00:00
(10/13): libbrotli-1.0.9-4.amzn2023.0.2.x86_64.rpm               12 MB/s | 315 kB     00:00
(11/13): mailcap-2.1.49-3.amzn2023.0.3.noarch.rpm               1.2 MB/s |  33 kB     00:00
(12/13): mod_http2-2.0.27-1.amzn2023.0.3.x86_64.rpm             4.8 MB/s | 166 kB     00:00
(13/13): mod_lua-2.4.65-1.amzn2023.0.2.x86_64.rpm               2.1 MB/s |  60 kB     00:00
--------------------------------------------------------------------------------
Total                                                            12 MB/s | 2.4 MB     00:00
Running transaction check
```

assignment_part3_backend_webpage



3.2 Nginx Server Setup Script (10 marks)

assignment_part3_nginx_script

ec2-user@ip-172-31-11-182:~/scripts

```
            proxy_cache my_cache;
            proxy_cache_valid 200 60m;
            proxy_cache_valid 404 10m;
            proxy_cache_key "$scheme$request_method$host$request_uri";
            proxy_cache_bypass $http_cache_control;
            add_header X-Cache-Status $upstream_cache_status;

            # Timeouts
            proxy_connect_timeout 60s;
            proxy_send_timeout 60s;
            proxy_read_timeout 60s;
        }

        # Health check endpoint
        location /health {
            access_log off;
            return 200 "Nginx is healthy\n";
            add_header Content-Type text/plain;
        }
    }

    # HTTP Server (redirect to HTTPS)
    server {
        listen 80;
        server_name _;

        location / {
            return 301 https://$host$request_uri;
        }

        # Allow health checks over HTTP
        location /health {
            access_log off;
            return 200 "Nginx is healthy\n";
            add_header Content-Type text/plain;
        }
    }
}
EOF

# Create cache directory
mkdir -p /var/cache/nginx
chown -R nginx:nginx /var/cache/nginx

# Test and restart Nginx
nginx -t && systemctl restart nginx

echo "Nginx setup completed successfully!"
:wq!
```

assignment_part3_nginx_default_page

4. Infrastructure Deployment (15 marks)

4.1 Initial Deployment (5 marks)

assignment_part4_ssh_keygen

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
$ cd ~/Assignment2

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ cd ~/Assignment2/terraform
bash: cd: /c/Users/Syed/Assignment2/terraform: No such file or directory

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ ls ~/.ssh/id_rsa.pub
ls: cannot access '/c/Users/Syed/.ssh/id_rsa.pub': No such file or directory

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ ssh-keygen -t rsa -b 4096 -f ~/.ssh/id_rsa -N ""
Generating public/private rsa key pair.
Your identification has been saved in /c/Users/Syed/.ssh/id_rsa
Your public key has been saved in /c/Users/Syed/.ssh/id_rsa.pub
The key fingerprint is:
SHA256:YGIylN8PMrHL2fmTp7ARvfEH6K/VuV36YslEg6A13BY Syed@DESKTOP-S5OGK51
The key's randomart image is:
+---[RSA 4096]----+
|  ..     . .E.   |
| .. .     = o    |
|  o.o+o  o + .   |
|   +=ooo..  . o  |
|   . *.+S .  . . |
|    + oo.+ o ..  |
|      o.o.o +o ..|
|       ++o.. o=o |
|      . o=. ..oo.|
+----[SHA256]-----+

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$
```

assignment_part4_terraform_init

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ terraform init
Initializing the backend...
Initializing modules...
Initializing provider plugins...
- Finding latest version of hashicorp/http...
- Finding latest version of hashicorp/aws...
- Installing hashicorp/http v3.5.0...
- Installed hashicorp/http v3.5.0 (signed by HashiCorp)
- Installing hashicorp/aws v6.27.0...
- Finding latest version of hashicorp/aws...
- Installing hashicorp/http v3.5.0...
- Installed hashicorp/aws v6.27.0 (signed by HashiCorp)
Terraform has created a lock file .terraform.lock.hcl to record the provider
selections it made above. Include this file in your version control repository
so that Terraform can guarantee to make the same selections by default when
you run "terraform init" in the future.

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.
```

assignment_part4_terraform_validate

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ terraform validate
Success! The configuration is valid.
```

assignment_part4_terraform_plan

```
$ terraform plan
var.ami_id
  AMI ID for EC2 instances

  Enter a value:

var.key_name
  Name of the EC2 key pair

  Enter a value: key

data.http.my_ip: Reading...
data.http.my_ip: Read complete after 0s [id=https://icanhazip.com]
data.aws_ssm_parameter.amzn2: Reading...
data.aws_ssm_parameter.amzn2: Read complete after 1s [id=/aws/service/ami-amazon
-linux-latest/amzn2-ami-hvm-x86_64-gp2]

Terraform used the selected providers to generate the following execution plan.
Resource actions are indicated with the following symbols:
  + create

Terraform will perform the following actions:

  # module.backend_servers["web-1"].aws_instance.backend[0] will be created
  + resource "aws_instance" "backend" {
      + ami                                  = (sensitive value)
      + arn                                  = (known after apply)
      + associate_public_ip_address          = (known after apply)
      + availability_zone                    = (known after apply)
      + disable_api_stop                     = (known after apply)
      + disable_api_termination              = (known after apply)
      + ebs_optimized                        = (known after apply)
      + enable_primary_ipv6                  = (known after apply)
      + force_destroy                        = false
      + get_password_data                    = false
      + host_id                              = (known after apply)
      + host_resource_group_arn              = (known after apply)
      + iam_instance_profile                 = (known after apply)
      + id                                   = (known after apply)
      + instance_initiated_shutdown_behavior = (known after apply)
      + instance_lifecycle                   = (known after apply)
      + instance_state                       = (known after apply)
      + instance_type                        = "t3.micro"
      + ipv6_address_count                   = (known after apply)
      + ipv6_addresses                       = (known after apply)
      + key_name                             = "key"
      + monitoring                           = (known after apply)
      + outpost_arn                          = (known after apply)
      + password_data                        = (known after apply)
      + placement_group                      = (known after apply)
      + placement_group_id                   = (known after apply)
      + placement_partition_number           = (known after apply)
      + primary_network_interface_id         = (known after apply)
      + private_dns                          = (known after apply)
      + private_ip                           = (known after apply)
      + public_dns                           = (known after apply)
      + public_ip                            = (known after apply)
```

assignment_part4_terraform_apply

```
$ terraform apply -auto-approve
var.ami_id
  AMI ID for EC2 instances

  Enter a value:

var.key_name
  Name of the EC2 key pair

  Enter a value: key

data.http.my_ip: Reading...
data.http.my_ip: Read complete after 0s [id=https://icanhazip.com]
data.aws_ssm_parameter.amzn2: Reading...
data.aws_ssm_parameter.amzn2: Read complete after 2s [id=/aws/service/ami-amazon-linux-latest/amzn2-ami-hvm-x86_64-gp2]

Terraform used the selected providers to generate the following execution plan. Resource actions are indicated with the following symbols:
  + create

Terraform will perform the following actions:

  # module.backend_servers["web-1"].aws_instance.backend[0] will be created
  + resource "aws_instance" "backend" {
      + ami                                  = (sensitive value)
      + arn                                  = (known after apply)
      + associate_public_ip_address          = (known after apply)
      + availability_zone                    = (known after apply)
      + disable_api_stop                     = (known after apply)
      + disable_api_termination              = (known after apply)
      + ebs_optimized                        = (known after apply)
      + enable_primary_ipv6                  = (known after apply)
      + force_destroy                        = false
      + get_password_data                    = false
      + host_id                              = (known after apply)
      + host_resource_group_arn              = (known after apply)
      + iam_instance_profile                 = (known after apply)
      + id                                   = (known after apply)
      + instance_initiated_shutdown_behavior = (known after apply)
      + instance_lifecycle                   = (known after apply)
      + instance_state                       = (known after apply)
      + instance_type                        = "t3.micro"
      + ipv6_address_count                   = (known after apply)
      + ipv6_addresses                       = (known after apply)
      + key_name                             = "key"
      + monitoring                           = (known after apply)
      + outpost_arn                          = (known after apply)
      + password_data                        = (known after apply)
      + placement_group                      = (known after apply)
      + placement_group_id                   = (known after apply)
      + placement_partition_number           = (known after apply)
```

4.2 Output Configuration (5 marks)

assignment_part4_terraform_output

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ terraform output
backend_servers_info = {
  "web-1" = {
    "instance_id" = [
      "i-08601a87b94e93fe8",
      "i-01a374de43288ab32",
      "i-047ef7dc11056549e",
    ]
    "private_ip" = [
      "10.0.10.243",
      "10.0.10.87",
      "10.0.10.183",
    ]
    "public_ip" = [
      "44.195.69.216",
      "98.86.148.130",
      "3.231.204.61",
    ]
  }
  "web-2" = {
    "instance_id" = [
      "i-049dfb0d3a79a8744",
      "i-00ddb751f17464a08",
      "i-0bb6fbc5dba72cdca",
    ]
    "private_ip" = [
      "10.0.10.33",
      "10.0.10.219",
      "10.0.10.253",
    ]
    "public_ip" = [
      "3.239.42.192",
      "34.236.243.157",
      "34.200.220.149",
    ]
  }
  "web-3" = {
    "instance_id" = [
      "i-0bfe5c3d42178e0c5",
      "i-0629846db90668695",
      "i-06f0bb724ced023a8",
    ]
    "private_ip" = [
      "10.0.10.89",
      "10.0.10.242",
      "10.0.10.73",
    ]
    "public_ip" = [
      "3.236.89.145",
      "18.207.111.59",
      "3.239.33.223",
    ]
  }
}
configuration_guide = <<EOT

====================================
```

assignment_part4_outputs_json

```
========================================

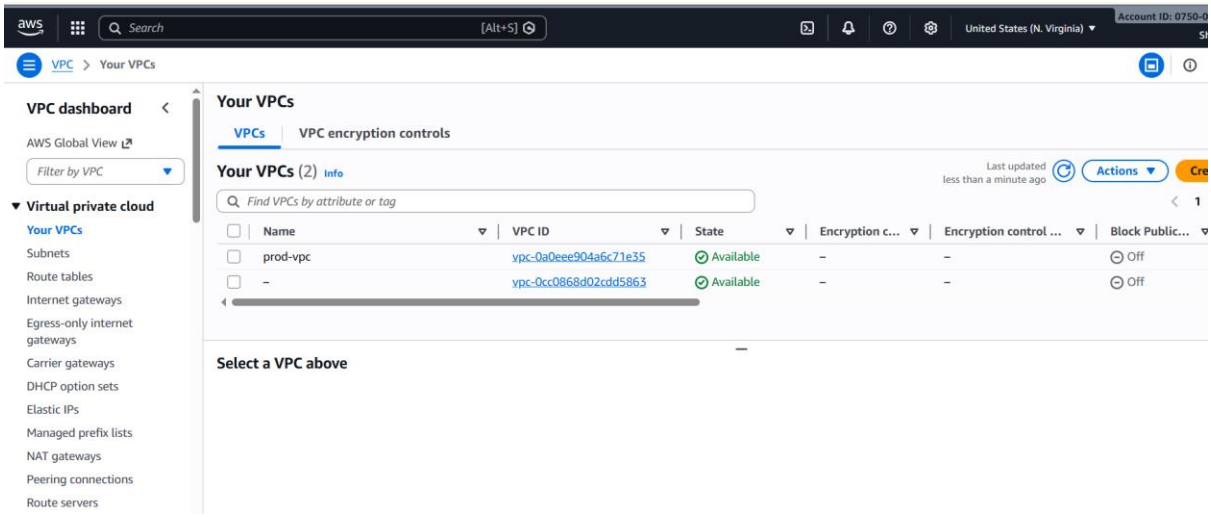
EOT
nginx_instance_id = "i-0824b01d8ce9cb1b6"
nginx_public_ip = "18.232.146.156"
subnet_id = "subnet-02f4b48141eb76975"
vpc_id = "vpc-0a0eee904a6c71e35"

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ terraform output -json > outputs.json

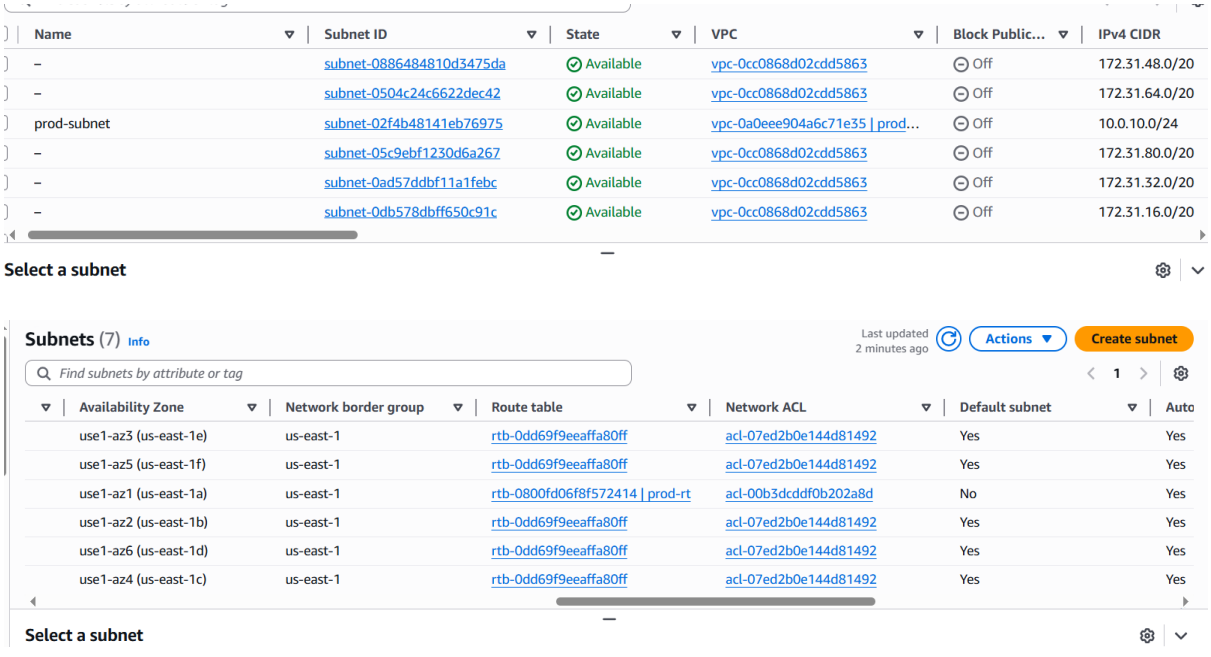
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$
```

4.3 AWS Console Verification (5 marks)

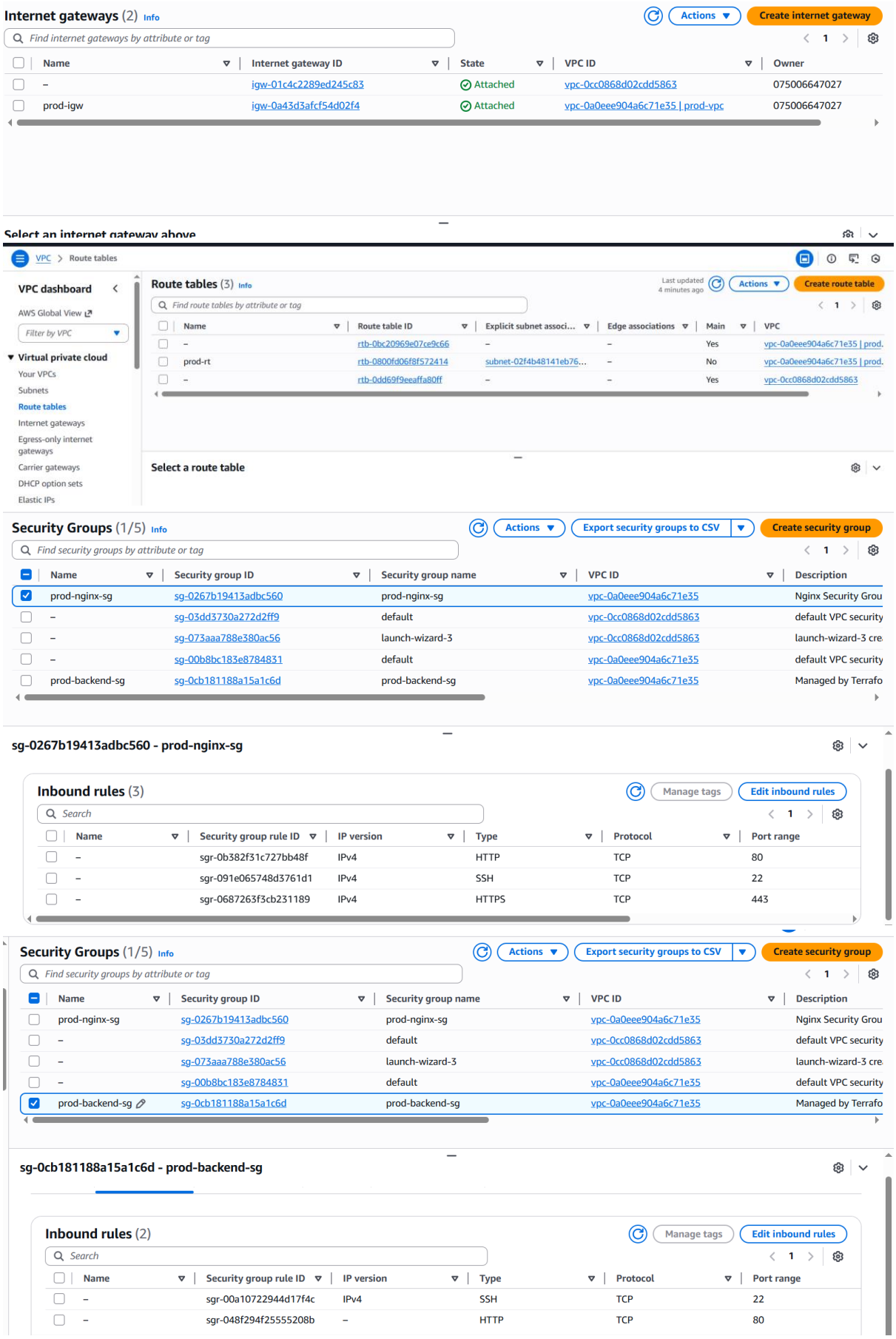
assignment_part4_aws_vpc



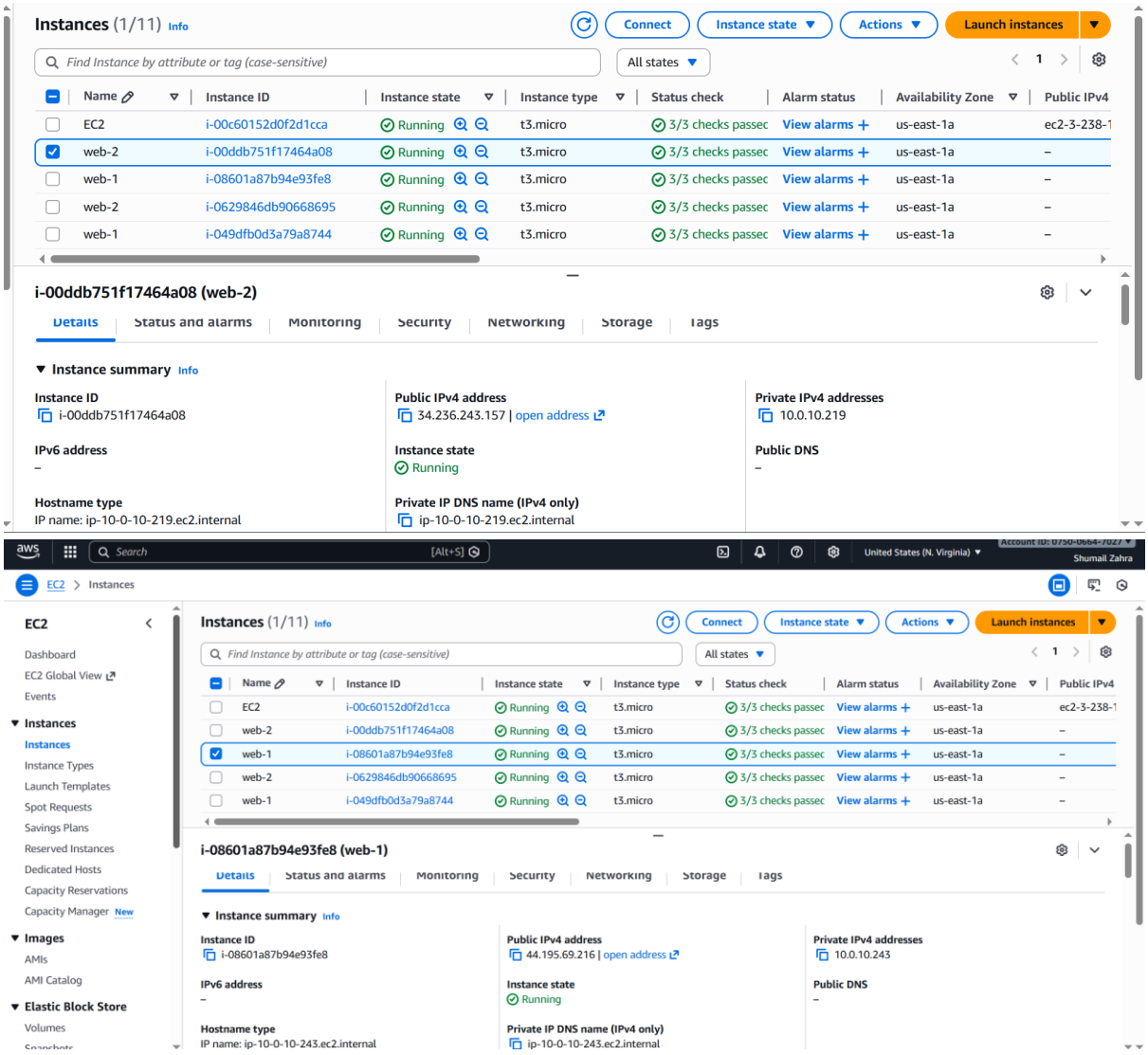
assignment_part4_aws_subnet

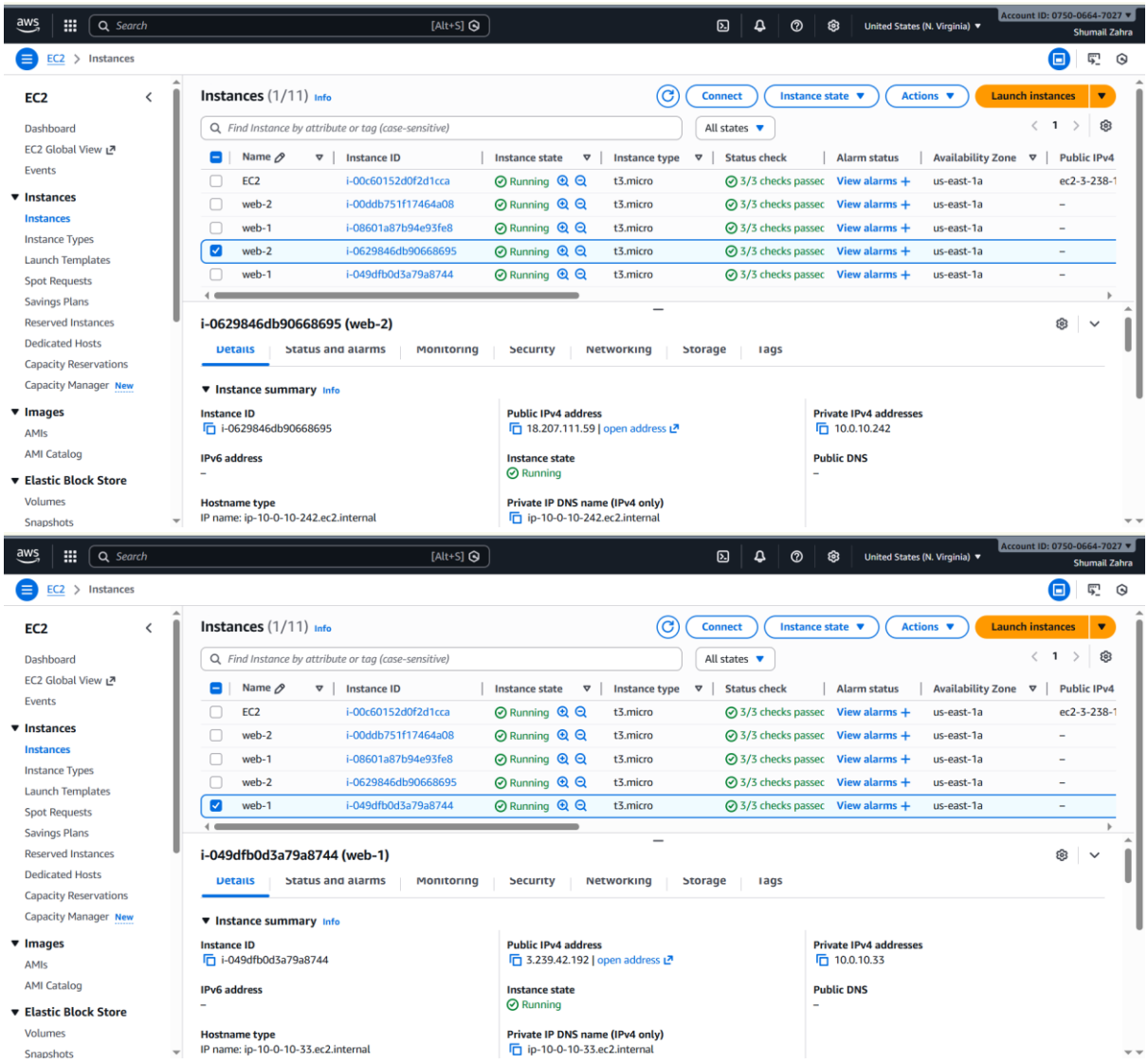


assignment_part4_aws_security_groups


Internet gateways (2) Info
Actions
Create internet gateway
Find internet gateways by attribute or tag
Name
Internet gateway ID
State
VPC ID
Owner
– igw-01c4c2289ed245c83 Attached vpc-0cc0868d02cdd5863 075006647027
prod-igw igw-0a43d3afcf54d02f4 Attached vpc-0a0eee904a6c71e35 | prod-vpc 075006647027
Select an internet gateway above
VPC > Route tables
VPC dashboard
AWS Global View
Filter by VPC
Virtual private cloud
Your VPCs
Subnets
Route tables
Internet gateways
Egress-only internet gateways
Carrier gateways
DHCP option sets
Elastic IPs
Route tables (3) Info
Last updated 4 minutes ago
Actions
Create route table
Find route tables by attribute or tag
Name
Route table ID
Explicit subnet associ...
Edge associations
Main
VPC
– rtb-0bc20969e07ce9c66 – – Yes vpc-0a0eee904a6c71e35 | prod.
prod-rt rtb-0800fd06f8f572414 subnet-02f4b48141eb76... – No vpc-0a0eee904a6c71e35 | prod.
– rtb-0dd69f9eeaffa80ff – – Yes vpc-0cc0868d02cdd5863
Select a route table
Security Groups (1/5) Info
Actions
Export security groups to CSV
Create security group
Find security groups by attribute or tag
Name
Security group ID
Security group name
VPC ID
Description
prod-nginx-sg sg-0267b19413adbc560 prod-nginx-sg vpc-0a0eee904a6c71e35 Nginx Security Grou
– sg-03dd3730a272d2ff9 default vpc-0cc0868d02cdd5863 default VPC security
– sg-073aaa788e380ac56 launch-wizard-3 vpc-0cc0868d02cdd5863 launch-wizard-3 cre
– sg-00b8bc183e8784831 default vpc-0a0eee904a6c71e35 default VPC security
prod-backend-sg sg-0cb181188a15a1c6d prod-backend-sg vpc-0a0eee904a6c71e35 Managed by Terrafo
sg-0267b19413adbc560 - prod-nginx-sg
Inbound rules (3)
Manage tags
Edit inbound rules
Search
Name
Security group rule ID
IP version
Type
Protocol
Port range
– sgr-0b382f31c727bb48f IPv4 HTTP TCP 80
– sgr-091e065748d3761d1 IPv4 SSH TCP 22
– sgr-0687263f3cb231189 IPv4 HTTPS TCP 443
Security Groups (1/5) Info
Actions
Export security groups to CSV
Create security group
Find security groups by attribute or tag
Name
Security group ID
Security group name
VPC ID
Description
prod-nginx-sg sg-0267b19413adbc560 prod-nginx-sg vpc-0a0eee904a6c71e35 Nginx Security Grou
– sg-03dd3730a272d2ff9 default vpc-0cc0868d02cdd5863 default VPC security
– sg-073aaa788e380ac56 launch-wizard-3 vpc-0cc0868d02cdd5863 launch-wizard-3 cre
– sg-00b8bc183e8784831 default vpc-0a0eee904a6c71e35 default VPC security
prod-backend-sg sg-0cb181188a15a1c6d prod-backend-sg vpc-0a0eee904a6c71e35 Managed by Terrafo
sg-0cb181188a15a1c6d - prod-backend-sg
Inbound rules (2)
Manage tags
Edit inbound rules
Search
Name
Security group rule ID
IP version
Type
Protocol
Port range
– sgr-00a10722944d17f4c IPv4 SSH TCP 22
– sgr-048f294f25555208b – HTTP TCP 80

assignment_part4_aws_instances





5. Nginx Configuration & Testing (25 marks)

5.1 Update Nginx Backend Configuration (5 marks)

assignment_part5_ssh_nginx

```
Syed@DESKTOP-S5OGK51 MINGW64 ~ (main)
$ cd ~/Assignment2

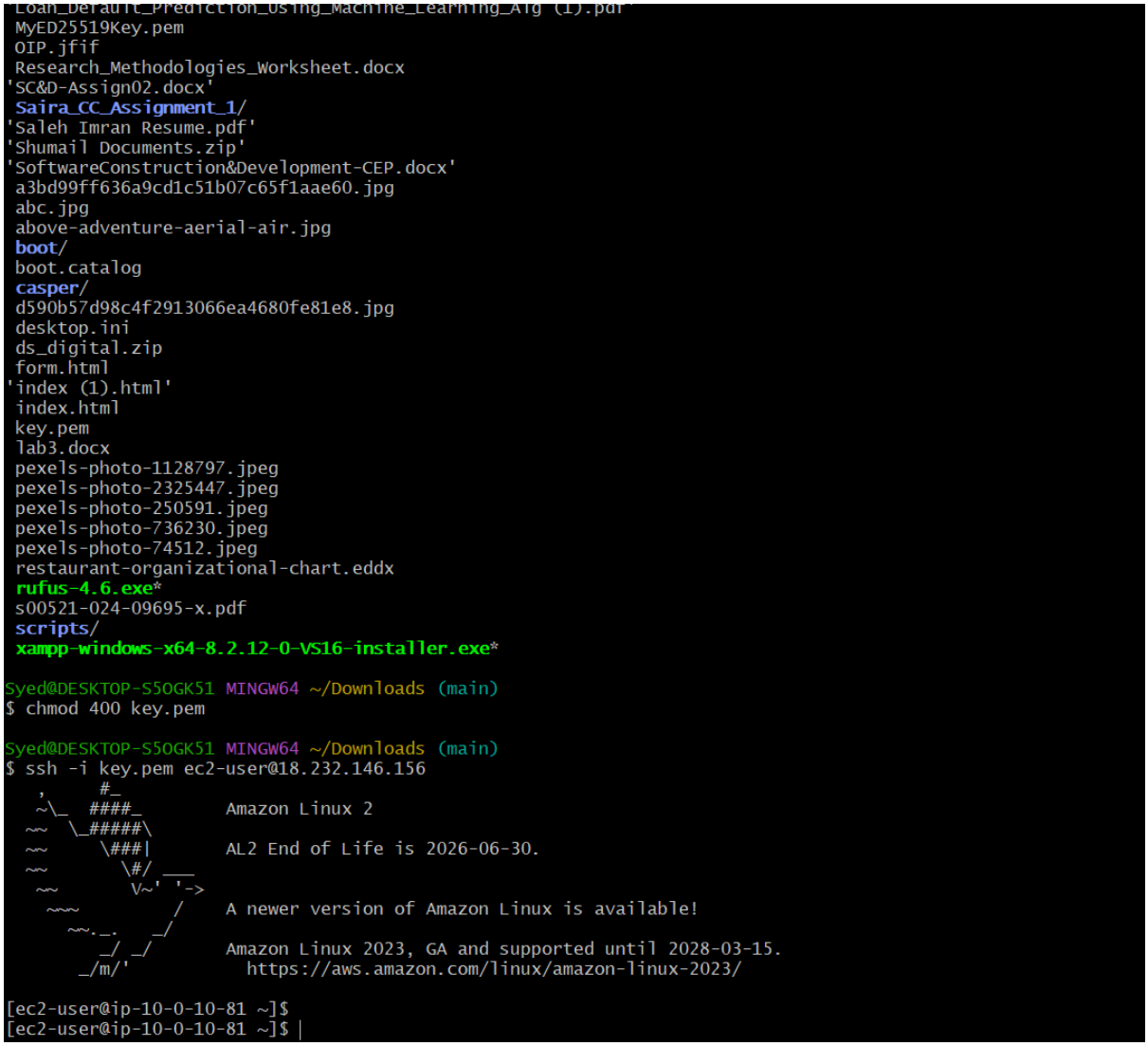
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ $ ssh ec2-user@18.232.146.156
bash: $: command not found

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ ssh ec2-user@18.232.146.156
ssh: connect to host 18.232.146.156 port 22: Connection timed out

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ ssh ec2-user@18.232.146.156
The authenticity of host '18.232.146.156 (18.232.146.156)' can't be established.
ED25519 key fingerprint is SHA256:8sE31yR2EZOKzFBNM7lRv1czRoMznVAhA9grESOj6fI.
This key is not known by any other names.
Are you sure you want to continue connecting (yes/no/[fingerprint])? yes
Warning: Permanently added '18.232.146.156' (ED25519) to the list of known hosts
.
ec2-user@18.232.146.156: Permission denied (publickey,gssapi-keyex,gssapi-with-m
ic).

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ cd /c/Users/Syed/Downloads

Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
$ ls
'3716895.3717020 new.pdf'
 52b356b3c4412c6e2c77554bd53bb24e.jpg
 682b604d466185e1a2368aadd85c09cc.jpg
'AI_Assignment_Shumail (1).ipynb'
 AI_Assignment_Shumail.ipynb
 ANN.pdf
 AWSCLIV2.msi
'Acknowledgement for EE Personal Information Sharing.docx'
 Admin_credentials.csv
 AnyDesk.exe*
'Assignment # 1 (1).pdf'
 Assignment-1.zip
 Assignment1.md
'CONFLUENT HEALTH EMPLOYEE FOUNDATION.pdf'
'ChatGPT Image Oct 13, 2025, 09_45_35 AM.png'
'Confluent - Web flyer.pdf'
 CyberGhostVPNSetup.exe*
'DAA_Lec_04_BSE_V (1).pptx'
 Documents/
 EFI/
 Form_I-9_08-08-2023.pdf
'Healthcare+and+Insurance+Systems (1).pdf'
 Healthcare+and+Insurance+Systems.pdf
 Lab3.md
```



assignment_part5_nginx_conf_updated

```
# For more information on configuration, see:
#   * Official English Documentation: http://nginx.org/en/docs/
#   * Official Russian Documentation: http://nginx.org/ru/docs/

user nginx;
worker_processes auto;
error_log /var/log/nginx/error.log;
pid /run/nginx.pid;

# Load dynamic modules. See /usr/share/doc/nginx/README.dynamic.
include /usr/share/nginx/modules/*.conf;

events {
    worker_connections 1024;
}

http {
       upstream backend_servers {
            server 10.0.10.89:80;
            server 10.0.10.87:80;
            server 10.0.10.253:80 backup;
        }
    log_format  main  '$remote_addr - $remote_user [$time_local] "$request" '
                      '$status $body_bytes_sent "$http_referer" '
                      '"$http_user_agent" "$http_x_forwarded_for"';

    access_log  /var/log/nginx/access.log  main;

    sendfile            on;
    tcp_nopush          on;
    tcp_nodelay         on;
    keepalive_timeout   65;
    types_hash_max_size 4096;

    include             /etc/nginx/mime.types;
    default_type        application/octet-stream;

    # Load modular configuration files from the /etc/nginx/conf.d directory.
    # See http://nginx.org/en/docs/ngx_core_module.html#include
    # for more information.
    include /etc/nginx/conf.d/*.conf;

    server {
        listen       80;
        listen       [::]:80;
        server_name  _;
        root         /usr/share/nginx/html;

        # Load configuration files for the default server block.
        include /etc/nginx/default.d/*.conf;

:wq!
```

assignment_part5_nginx_test

```
[ec2-user@ip-10-0-10-81 ~]$ sudo nginx -t
nginx: the configuration file /etc/nginx/nginx.conf syntax is ok
nginx: configuration file /etc/nginx/nginx.conf test is successful
```

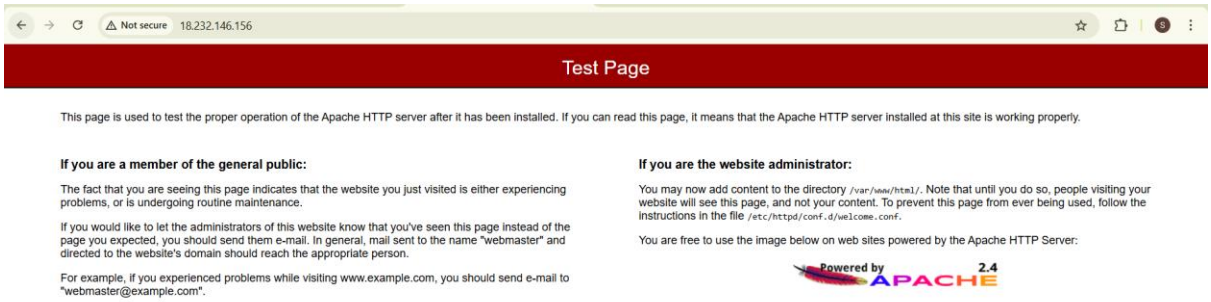
assignment_part5_nginx_restart

```
[ec2-user@ip-10-0-10-81 ~]$ sudo systemctl restart nginx
[ec2-user@ip-10-0-10-81 ~]$ sudo systemctl status nginx
● nginx.service - The nginx HTTP and reverse proxy server
   Loaded: loaded (/usr/lib/systemd/system/nginx.service; enabled; vendor preset: disabled)
   Active: active (running) since Mon 2025-12-29 08:32:10 UTC; 51s ago
  Process: 2301 ExecStart=/usr/sbin/nginx (code=exited, status=0/SUCCESS)
  Process: 2298 ExecStartPre=/usr/sbin/nginx -t (code=exited, status=0/SUCCESS)
  Process: 2296 ExecStartPre=/usr/bin/rm -f /run/nginx.pid (code=exited, status=0/SUCCESS)
 Main PID: 2304 (nginx)
   CGroup: /system.slice/nginx.service
           ├─2304 nginx: master process /usr/sbin/nginx
           ├─2306 nginx: worker process
           └─2307 nginx: worker process

Dec 29 08:32:10 ip-10-0-10-81.ec2.internal systemd[1]: Starting The nginx HTTP and reverse proxy server...
Dec 29 08:32:10 ip-10-0-10-81.ec2.internal nginx[2298]: nginx: the configuration file /etc/nginx/nginx.conf syntax is ok
Dec 29 08:32:10 ip-10-0-10-81.ec2.internal nginx[2298]: nginx: configuration file /etc/nginx/nginx.conf test is successful
Dec 29 08:32:10 ip-10-0-10-81.ec2.internal systemd[1]: Started The nginx HTTP and reverse proxy server.
[ec2-user@ip-10-0-10-81 ~]$
```

5.2 Test Load Balancing (5 marks)

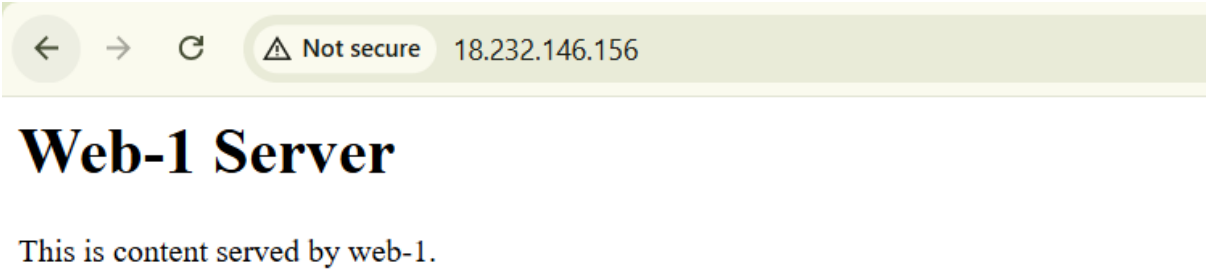
assignment_part5_ssl_warning



assignment_part5_web1_response

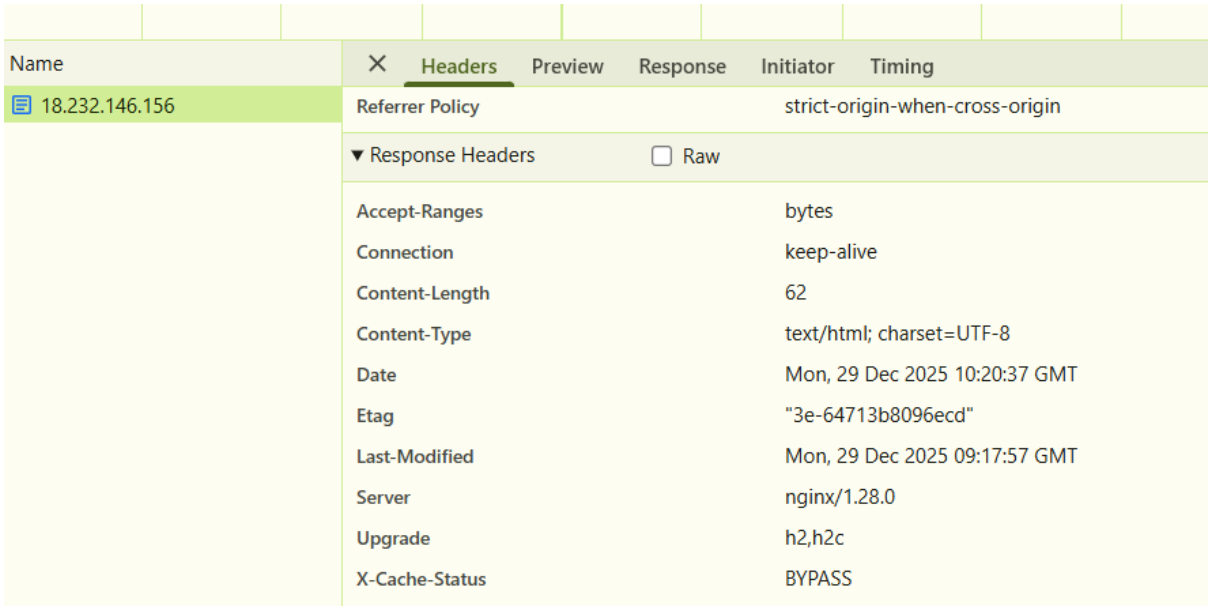
assignment_part5_web2_response

assignment_part5_load_balancing_demo

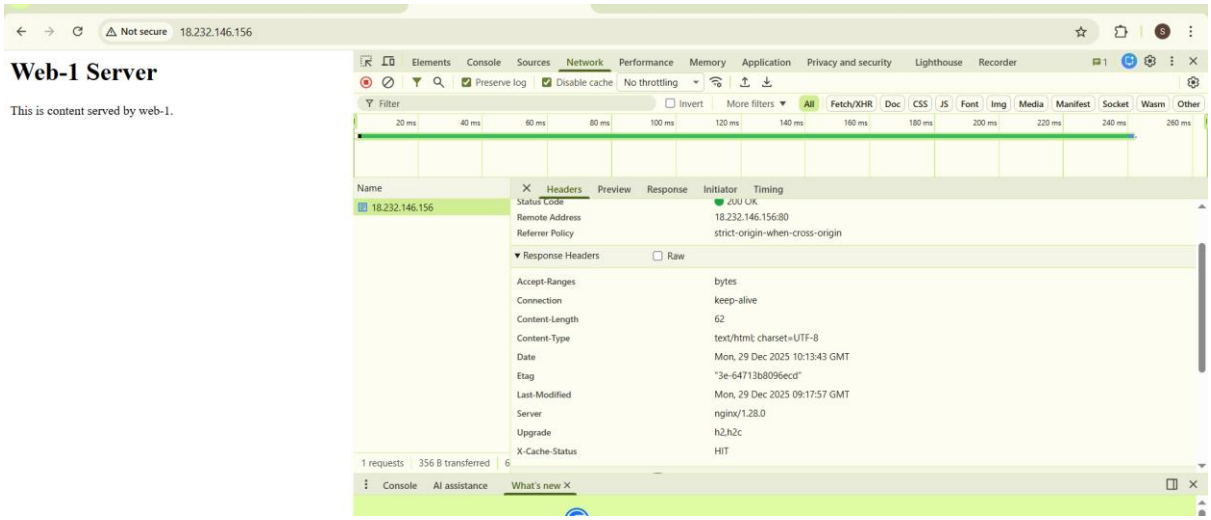


5.3 Test Cache Functionality (5 marks)

assignment_part5_cache_miss



assignment_part5_cache_hit



assignment_part5_cache_directory

```
[ec2-user@ip-10-0-10-81 ~]$ sudo ls -la /var/cache/nginx/
total 0
drwx------ 2 nginx root  6 Dec 29 09:55 .
drwxr-xr-x 7 root  root 76 Dec 29 09:55 ..
[ec2-user@ip-10-0-10-81 ~]$
[ec2-user@ip-10-0-10-81 ~]$
```

assignment_part5_access_log_cache

```
drwxr-xr-x 7 root  root  76 Dec 29 09:55 ..
drwx------ 3 nginx nginx 16 Dec 29 10:12 f
[ec2-user@ip-10-0-10-81 ~]$ sudo systemctl stop nginx
[ec2-user@ip-10-0-10-81 ~]$ sudo rm -rf /var/cache/nginx/*
[ec2-user@ip-10-0-10-81 ~]$ sudo systemctl start nginx
[ec2-user@ip-10-0-10-81 ~]$
[ec2-user@ip-10-0-10-81 ~]$ sudo grep "Cache:" /var/log/nginx/access.log | tail -20
[ec2-user@ip-10-0-10-81 ~]$
```

5.4 Test High Availability (Backup Server) (5 marks)

assignment_part5_web1_stopped

```
$ ssh -i key.pem ec2-user@3.236.89.145
Last login: Mon Dec 29 09:17:16 2025 from 59.103.199.30
   ,     #_
   ~\_  ####_        Amazon Linux 2
  ~~  \_#####\
  ~~     \###|       AL2 End of Life is 2026-06-30.
  ~~       \#/ ___
   ~~       V~' '->
    ~~~         /    A newer version of Amazon Linux is available!
      ~~._.   _/
         _/ _/       Amazon Linux 2023, GA and supported until 2028-03-15.
       _/m/'           https://aws.amazon.com/linux/amazon-linux-2023/

[ec2-user@ip-10-0-10-89 ~]$ sudo systemctl stop httpd

[ec2-user@ip-10-0-10-89 ~]$
[ec2-user@ip-10-0-10-89 ~]$ sudo systemctl status httpd
● httpd.service - The Apache HTTP Server
   Loaded: loaded (/usr/lib/systemd/system/httpd.service; enabled; vendor preset: disabled)
   Active: inactive (dead) since Mon 2025-12-29 10:24:10 UTC; 6s ago
     Docs: man:httpd.service(8)
  Process: 2145 ExecStart=/usr/sbin/httpd $OPTIONS -DFOREGROUND (code=exited, status=0/SUCCESS)
 Main PID: 2145 (code=exited, status=0/SUCCESS)
   Status: "Total requests: 27; Idle/Busy workers 100/0;Requests/sec: 0.0047; Bytes served/sec:   8 B/sec"

Dec 29 08:48:15 ip-10-0-10-89.ec2.internal systemd[1]: Starting The Apache HTTP Server...
Dec 29 08:48:15 ip-10-0-10-89.ec2.internal systemd[1]: Started The Apache HTTP Server.
Dec 29 10:24:09 ip-10-0-10-89.ec2.internal systemd[1]: Stopping The Apache HTTP Server...
Dec 29 10:24:10 ip-10-0-10-89.ec2.internal systemd[1]: Stopped The Apache HTTP Server.
[ec2-user@ip-10-0-10-89 ~]$
```

assignment_part5_web2_stopped

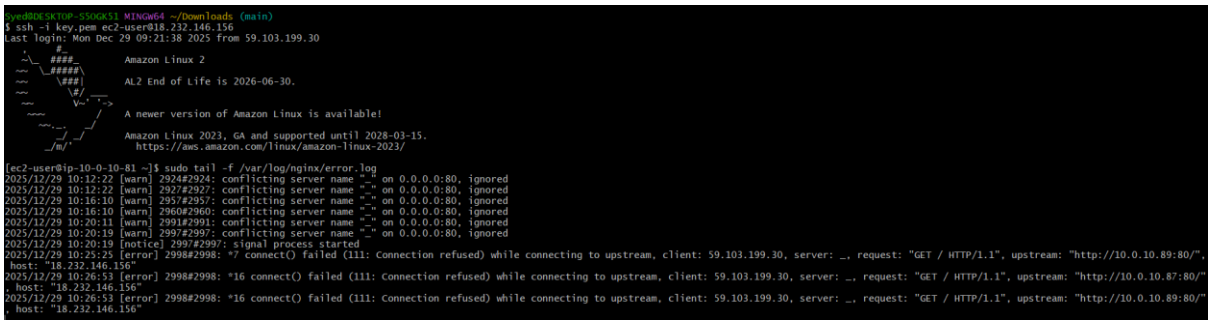
```
$ ssh -i key.pem ec2-user@98.86.148.130
Last login: Mon Dec 29 09:18:41 2025 from 59.103.199.30
   ,     #_
   ~\_  ####_        Amazon Linux 2
  ~~  \_#####\
  ~~     \###|       AL2 End of Life is 2026-06-30.
  ~~       \#/ ___
   ~~       V~' '->
    ~~~         /    A newer version of Amazon Linux is available!
      ~~._.   _/
         _/ _/       Amazon Linux 2023, GA and supported until 2028-03-15.
       _/m/'           https://aws.amazon.com/linux/amazon-linux-2023/

[ec2-user@ip-10-0-10-87 ~]$ sudo systemctl stop httpd
[ec2-user@ip-10-0-10-87 ~]$ sudo systemctl status httpd
● httpd.service - The Apache HTTP Server
   Loaded: loaded (/usr/lib/systemd/system/httpd.service; enabled; vendor preset: disabled)
   Active: inactive (dead) since Mon 2025-12-29 10:26:10 UTC; 8s ago
     Docs: man:httpd.service(8)
  Process: 2168 ExecStart=/usr/sbin/httpd $OPTIONS -DFOREGROUND (code=exited, status=0/SUCCESS)
 Main PID: 2168 (code=exited, status=0/SUCCESS)
   Status: "Total requests: 26; Idle/Busy workers 100/0;Requests/sec: 0.00453; Bytes served/sec:   8 B/sec"

Dec 29 08:50:19 ip-10-0-10-87.ec2.internal systemd[1]: Starting The Apache HTTP Server...
Dec 29 08:50:19 ip-10-0-10-87.ec2.internal systemd[1]: Started The Apache HTTP Server.
Dec 29 10:26:09 ip-10-0-10-87.ec2.internal systemd[1]: Stopping The Apache HTTP Server...
Dec 29 10:26:10 ip-10-0-10-87.ec2.internal systemd[1]: Stopped The Apache HTTP Server.
[ec2-user@ip-10-0-10-87 ~]$
```

assignment_part5_backup_activated

assignment_part5_nginx_error_log



assignment_part5_services_restored

5.5 Security & Performance Analysis (5 marks)

assignment_part5_ssl_certificate

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
$ openssl s_client -connect 18.232.146.156:443 -showcerts
Connecting to 18.232.146.156
CONNECTED(00000158)
Can't use SSL_get_servername
depth=0 C=PK, L=Karachi, O=MyCompany, OU=IT, CN=18.232.146.156
verify error:num=18:self-signed certificate
verify return:1
depth=0 C=PK, L=Karachi, O=MyCompany, OU=IT, CN=18.232.146.156
verify return:1
---
Certificate chain
 0 s:C=PK, L=Karachi, O=MyCompany, OU=IT, CN=18.232.146.156
   i:C=PK, L=Karachi, O=MyCompany, OU=IT, CN=18.232.146.156
   a:PKEY: RSA, 2048 (bit); sigalg: sha256WithRSAEncryption
   v:NotBefore: Dec 29 10:36:55 2025 GMT; NotAfter: Dec 29 10:36:55 2026 GMT
-----BEGIN CERTIFICATE-----
MIIDhTCCAm2gAwIBAgIJAOXwGdW3HT2xMA0GCSqGSIb3DQEBCwUAMFkxCzAJBgNV
BAYTAlBLMRAwDgYDVQQHDAdLYXJhY2hpMRIwEAYDVQQKDAlNeUNvbXBhbnkxCzAJ
BgNVBAsMAklUMRcwFQYDVQQDDA4xOC4yMzIuMTQ2LjE1NjAeFw0yNTEyMjkxMDM2
NTVaFw0yNjEyMjkxMDM2NTVaMFkxCzAJBgNVBAYTAlBLMRAwDgYDVQQHDAdLYXJh
Y2hpMRIwEAYDVQQKDAlNeUNvbXBhbnkxCzAJBgNVBAsMAklUMRcwFQYDVQQDDA4x
OC4yMzIuMTQ2LjE1NjCCASIwDQYJKoZIhvcNAQEBBQADggEPADCCAQoCggEBAL7e
zRrz8PK5DUQN9SccONADJrDWnfMRV6Eby3ZKBWsoiXOfmobk5kqhYYhsjW5S2O/k
OQ69FDfy3sSMZzNwC/Ut3+Bw3CXBg1EICWVLJSqV/kRGY3KIvDmdHCvD+btL6d+3
aHxzvGjIeBB1I8pHjgiB2Gkyga1mOJURgQxAwrFEEgOyPmWTrsFjryzFhZBYQeHm
4egQt6kDNROTZD4e8xGakgT2iv/998aRi/9GkoZkDHX1aXiOIpozVKn53xxRYFIc
PgaRFpcP1W8UGuFQHUia7eO4yKVyJ58EV2SGqnUsuGz3Q5AnHWbrSXUxhfksOWYI
swXDYXodckn+AE7qIp8CAwEAAaNQME4wHQYDVR0OBBYEFGkQr4ol7UBWq9QKgao/
NUsEpYtwMB8GA1UdIwQYMBaAFGkQr4ol7UBWq9QKgao/NUsEpYtwMAwGA1UdEwQF
MAMBAf8wDQYJKoZIhvcNAQELBQADggEBACnj3yvc4ev71xqAw/s97IPb7j/N47Z3
WvEkaO5TDL8khNkEVKzyz1Voev5SUjyXCVdyAG2CJprakeZy3Xjz3UnHHCaQ1JgR
Yop6IKIL1oXmsHdzir0yEIbY3iYpBZSnW3yZWOAqI1VTAfByxYzAtaGAe3VtAoaP
JmGAQmmzwIKl/3wVMrYjywAHXt4CLRS9Y2WSoTq47U1+aF/m+ujVzm+E+2yT8qpZ
mQgYx95FvRsGfoah+nlylXfJg5IUp3N3O1tSuQO/3tsX/x+8dar/YmxJ7E7B+sl5
FIuz9gctKJ/Li6E1MygZXDJNGbPwMLrjgHjLyVSRlNhnowViC8t3r+k=
-----END CERTIFICATE-----
---
Server certificate
subject=C=PK, L=Karachi, O=MyCompany, OU=IT, CN=18.232.146.156
issuer=C=PK, L=Karachi, O=MyCompany, OU=IT, CN=18.232.146.156
---
No client certificate CA names sent
Peer signing digest: SHA256
Peer signature type: rsa_pss_rsae_sha256
Peer Temp Key: X25519, 253 bits
---
SSL handshake has read 1461 bytes and written 1611 bytes
Verification error: self-signed certificate
---
New, TLSv1.3, Cipher is TLS_AES_256_GCM_SHA384
Protocol: TLSv1.3
Server public key is 2048 bit
This TLS version forbids renegotiation.
Compression: NONE
Expansion: NONE
No ALPN negotiated
Early data was not sent
Verify return code: 18 (self-signed certificate)
---
---
Post-Handshake New Session Ticket arrived:
SSL-Session:
    Protocol  : TLSv1.3
```

```
    PSK identity: None
    PSK identity hint: None
    SRP username: None
    TLS session ticket lifetime hint: 300 (seconds)
    TLS session ticket:
    0000 - 0b 28 bb 29 8c 2c e2 8c-8f e2 b2 da d9 01 ef 24   .(.).,.........$
    0010 - 32 6b 2b a2 f3 46 5a af-ff 1d 62 be e5 ec 16 1b   2k+..FZ...b.....
    0020 - 60 25 ed 31 ac 65 42 e0-d8 6f 66 04 06 9d eb 88   `%.1.eB..of.....
    0030 - 3c fd 55 9d db 22 74 42-6d 1b 83 11 7f a0 6d 14   <.U.."tBm.....m.
    0040 - 8d e7 f9 f4 b3 09 00 68-65 ff d3 e8 1c 1b 2f d4   .......he...../.
    0050 - 88 ad b1 7e 0e 93 6a ae-41 70 92 43 55 2f f2 98   ...~..j.Ap.CU/..
    0060 - de 10 9e d9 56 09 6d 92-3a 48 a2 24 53 ab 17 09   ....V.m.:H.$S...
    0070 - 4f d5 87 3b 83 cf 0a 9c-c1 6a 83 7a 24 1f d3 e1   O..;.....j.z$...
    0080 - a5 59 e0 ca 7f 10 ee bc-11 0f c5 fb d6 fb 2a 9c   .Y............*.
    0090 - ab 98 bb 45 f1 be d2 61-f2 b1 cb 85 9d 97 b8 54   ...E...a.......T
    00a0 - bc 7b fa cd 98 79 e8 c5-3c 5b 03 b0 1e 20 7f fa   .{...y..<[... ..
    00b0 - 37 67 4a 90 44 cc 63 0f-e3 27 d4 5c 4c 75 95 36   7gJ.D.c..'.\Lu.6
    00c0 - 3e f1 0b 18 6f a6 54 26-09 c3 9c 84 3d c9 51 f1   >...o.T&....=.Q.
    00d0 - e5 9a 66 3b b0 c7 ec 07-5e 82 a2 4e 13 f1 0e 63   ..f;....^..N...c

    Start Time: 1767004884
    Timeout   : 7200 (sec)
    Verify return code: 18 (self-signed certificate)
    Extended master secret: no
    Max Early Data: 0
---
read R BLOCK
---
Post-Handshake New Session Ticket arrived:
SSL-Session:
    Protocol  : TLSv1.3
    Cipher    : TLS_AES_256_GCM_SHA384
    Session-ID: 695EE9030EA807B46E4EE0115DAD229C7F39862716B7F8FAE1771E9723269E65
    Session-ID-ctx:
    Resumption PSK: 8A612767C3454A163668C47DBC7606D3180175506A532FE7183FB16EEBD11B069808BC6F74A11C1E646ED9D8EA6E7D1F
    PSK identity: None
    PSK identity hint: None
    SRP username: None
    TLS session ticket lifetime hint: 300 (seconds)
    TLS session ticket:
    0000 - 0b 28 bb 29 8c 2c e2 8c-8f e2 b2 da d9 01 ef 24   .(.).,.........$
    0010 - ad a4 d6 aa 93 46 1f 5b-9d 76 8f aa 53 0c bb 24   .....F.[.v..S..$
    0020 - dd 5d c8 db 98 90 97 70-9d 62 39 55 0c 67 7b 4a   .].....p.b9U.g{J
    0030 - 0b e5 d2 cc 9d 99 c7 fa-8b a2 87 6b 58 80 7d 46   ...........kX.}F
    0040 - 4c 59 7a 60 22 52 17 18-46 1b 05 99 d4 0f 9d de   LYz`"R..F.......
    0050 - 6e 69 37 f3 2f 43 0d 60-50 28 6d dc c3 c8 52 73   ni7./C.`P(m...Rs
    0060 - 4e e8 34 3f 03 16 30 4a-aa 7a 6a 9a cf de 43 96   N.4?..0J.zj...C.
    0070 - 51 4c 23 c5 de 13 ab 4a-cf f7 13 c3 23 7e 30 5e   QL#....J....#~0^
    0080 - e5 0e b4 94 24 ff 1b 00-34 6e 38 93 7f d6 90 9d   ....$...4n8.....
    0090 - 81 67 3d 80 d6 57 50 e8-6f aa 2f c3 ec 3b eb 56   .g=..WP.o./..;.V
    00a0 - f1 f0 76 3d 35 0d cd 3d-92 d0 2a 40 3e e3 c6 a2   ..v=5..=..*@>...
    00b0 - 4f 89 92 7e a3 e1 7a 72-f6 9c ae 5a 9d e5 10 b6   O..~..zr...Z....
    00c0 - 3b b2 53 5d 92 eb de ee-79 98 28 56 3e e0 4c 8f   ;.S]....y.(V>.L.
    00d0 - 95 1b 10 fe d7 2f 39 e1-45 9c 53 68 0f fb 3f 66   ...../9.E.Sh..?f

    Start Time: 1767004884
    Timeout   : 7200 (sec)
    Verify return code: 18 (self-signed certificate)
    Extended master secret: no
    Max Early Data: 0
---
read R BLOCK
closed

Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
```

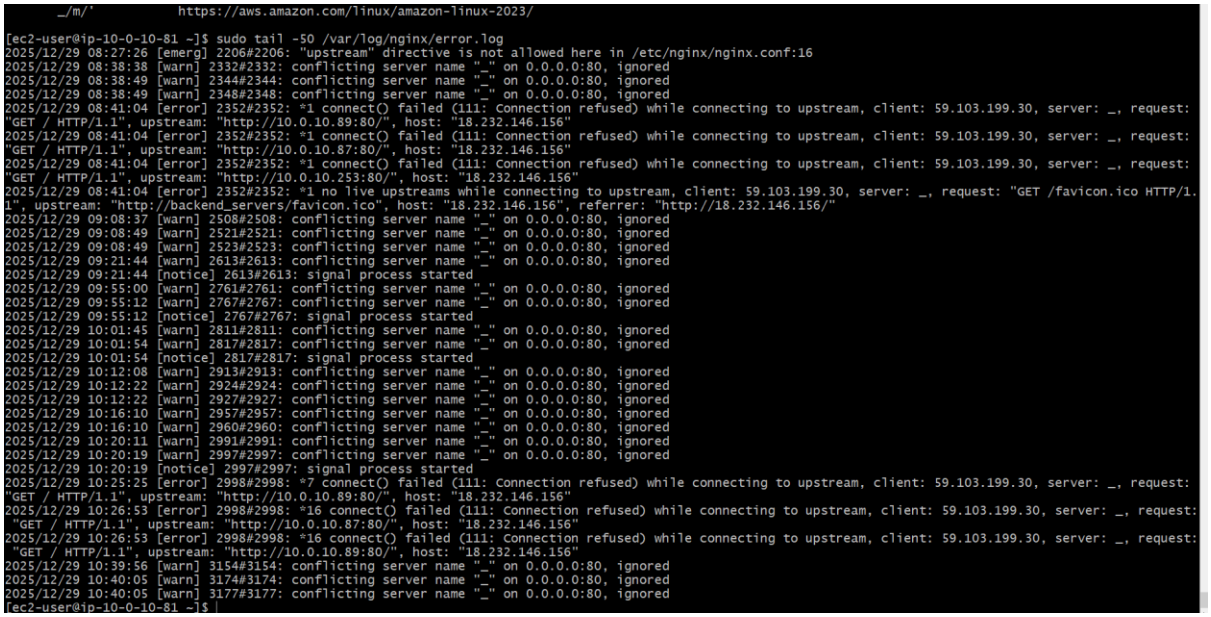
assignment_part5_security_headers

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
$ curl -I -k https://18.232.146.156
HTTP/1.1 200 OK
Server: nginx/1.28.0
Date: Mon, 29 Dec 2025 10:44:01 GMT
Content-Type: text/html; charset=UTF-8
Content-Length: 62
Connection: keep-alive
Upgrade: h2,h2c
Last-Modified: Mon, 29 Dec 2025 09:19:28 GMT
ETag: "3e-64713bd754fee"
X-Cache-Status: HIT
Accept-Ranges: bytes
```

assignment_part5_http_redirect

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
$ curl -I http://18.232.146.156
HTTP/1.1 301 Moved Permanently
Server: nginx/1.28.0
Date: Mon, 29 Dec 2025 10:44:12 GMT
Content-Type: text/html
Content-Length: 169
Connection: keep-alive
Location: https://18.232.146.156/
```

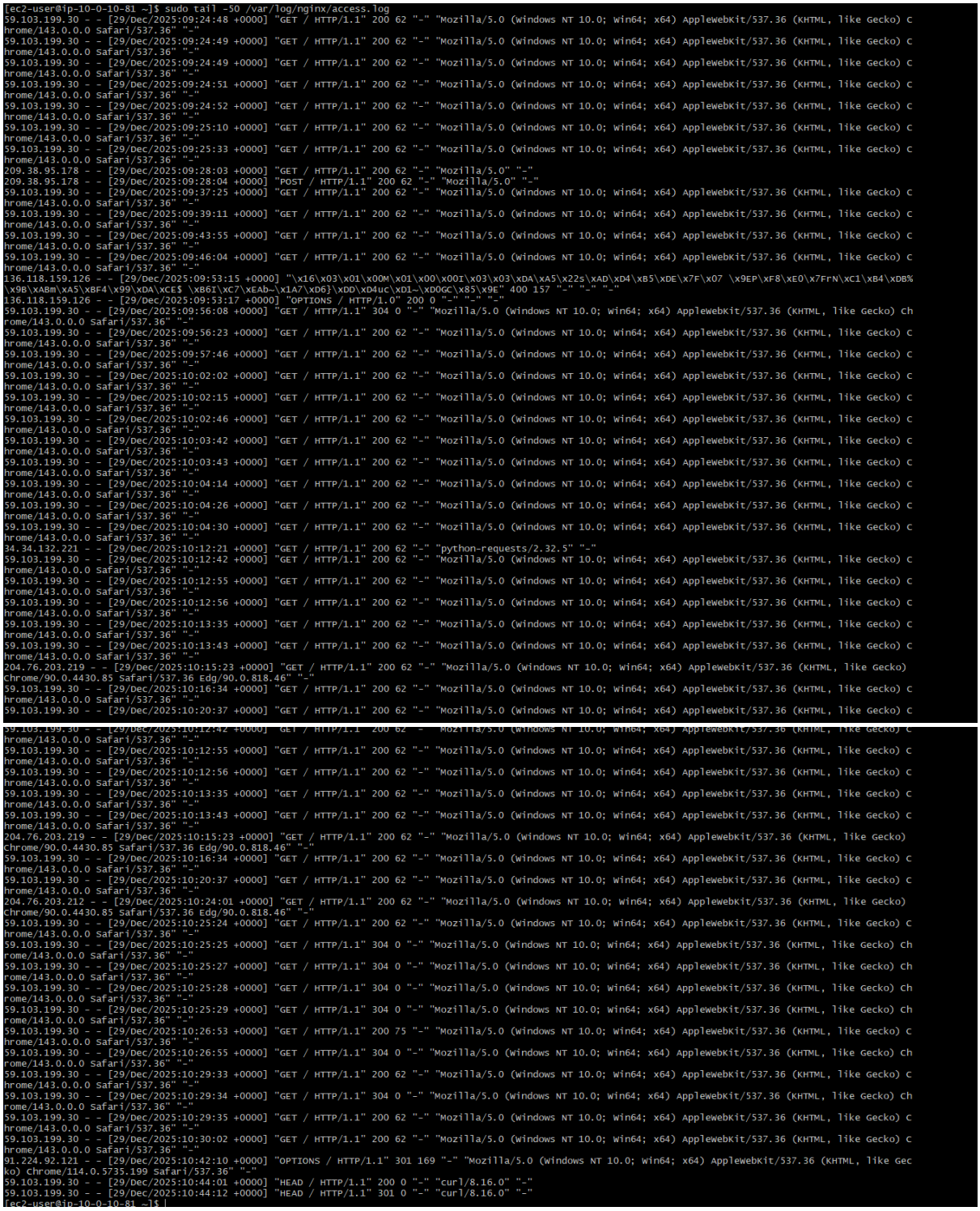
assignment_part5_error_log_analysis



```
      _/m/'           https://aws.amazon.com/linux/amazon-linux-2023/

[ec2-user@ip-10-0-10-81 ~]$ sudo tail -50 /var/log/nginx/error.log
2025/12/29 08:27:26 [emerg] 2206#2206: "upstream" directive is not allowed here in /etc/nginx/nginx.conf:16
2025/12/29 08:38:38 [warn] 2332#2332: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 08:38:49 [warn] 2344#2344: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 08:38:49 [warn] 2348#2348: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 08:41:04 [error] 2352#2352: *1 connect() failed (111: Connection refused) while connecting to upstream, client: 59.103.199.30, server: _, request:
"GET / HTTP/1.1", upstream: "http://10.0.10.89:80/", host: "18.232.146.156"
2025/12/29 08:41:04 [error] 2352#2352: *1 connect() failed (111: Connection refused) while connecting to upstream, client: 59.103.199.30, server: _, request:
"GET / HTTP/1.1", upstream: "http://10.0.10.87:80/", host: "18.232.146.156"
2025/12/29 08:41:04 [error] 2352#2352: *1 connect() failed (111: Connection refused) while connecting to upstream, client: 59.103.199.30, server: _, request:
"GET / HTTP/1.1", upstream: "http://10.0.10.253:80/", host: "18.232.146.156"
2025/12/29 08:41:04 [error] 2352#2352: *1 no live upstreams while connecting to upstream, client: 59.103.199.30, server: _, request: "GET /favicon.ico HTTP/1.
1", upstream: "http://backend_servers/favicon.ico", host: "18.232.146.156", referrer: "http://18.232.146.156/"
2025/12/29 09:08:37 [warn] 2508#2508: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 09:08:49 [warn] 2521#2521: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 09:08:49 [warn] 2523#2523: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 09:21:44 [warn] 2613#2613: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 09:21:44 [notice] 2613#2613: signal process started
2025/12/29 09:55:00 [warn] 2761#2761: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 09:55:12 [warn] 2767#2767: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 09:55:12 [notice] 2767#2767: signal process started
2025/12/29 10:01:45 [warn] 2811#2811: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:01:54 [warn] 2817#2817: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:01:54 [notice] 2817#2817: signal process started
2025/12/29 10:12:08 [warn] 2913#2913: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:12:22 [warn] 2924#2924: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:12:22 [warn] 2927#2927: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:16:10 [warn] 2957#2957: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:16:10 [warn] 2960#2960: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:20:11 [warn] 2991#2991: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:20:19 [warn] 2997#2997: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:20:19 [notice] 2997#2997: signal process started
2025/12/29 10:25:25 [error] 2998#2998: *7 connect() failed (111: Connection refused) while connecting to upstream, client: 59.103.199.30, server: _, request:
"GET / HTTP/1.1", upstream: "http://10.0.10.89:80/", host: "18.232.146.156"
2025/12/29 10:26:53 [error] 2998#2998: *16 connect() failed (111: Connection refused) while connecting to upstream, client: 59.103.199.30, server: _, request:
 "GET / HTTP/1.1", upstream: "http://10.0.10.87:80/", host: "18.232.146.156"
2025/12/29 10:26:53 [error] 2998#2998: *16 connect() failed (111: Connection refused) while connecting to upstream, client: 59.103.199.30, server: _, request:
 "GET / HTTP/1.1", upstream: "http://10.0.10.89:80/", host: "18.232.146.156"
2025/12/29 10:39:56 [warn] 3154#3154: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:40:05 [warn] 3174#3174: conflicting server name "_" on 0.0.0.0:80, ignored
2025/12/29 10:40:05 [warn] 3177#3177: conflicting server name "_" on 0.0.0.0:80, ignored
[ec2-user@ip-10-0-10-81 ~]$
```

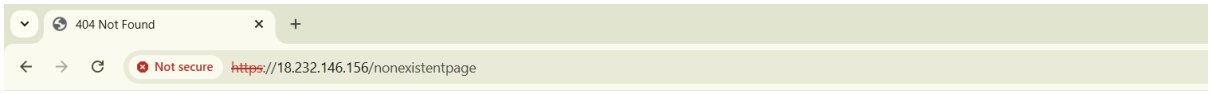
assignment_part5_access_log_analysis



Bonus Tasks (10 marks extra credit)

Bonus 1: Custom Error Pages (3 marks)

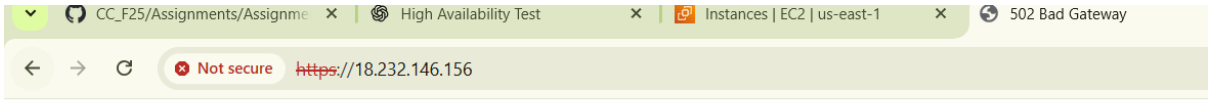
bonus1_custom_404



Not Found

The requested URL was not found on this server.

bonus1_custom_502



502

Bad Gateway! The server received an invalid response.

Bonus 2: Implement Rate Limiting (3 marks)

bonus2_rate_limit_config

ec2-user@ip-10-0-10-81:~

```
# Upstream backend servers
upstream backend_servers {
    server 10.0.10.89;
    server 10.0.10.87;
    server 10.0.10.253;
}

# Rate limiting
limit_req_zone $binary_remote_addr zone=mylimit:10m rate=10r/s;

# HTTP server: redirects all traffic to HTTPS
server {
    listen 80;
    server_name _;

    # Redirect all HTTP requests to HTTPS
    return 301 https://$host$request_uri;
}

# HTTPS server: handles traffic, caching, and security headers
server {
    # Custom error pages
    error_page 404 /errors/404.html;
    error_page 502 /errors/502.html;
    error_page 503 /errors/503.html;

    location = /errors/404.html { internal; }
    location = /errors/502.html { internal; }
    location = /errors/503.html { internal; }

    listen 443 ssl;
    server_name _;

    # SSL certificate
    ssl_certificate /etc/ssl/certs/selfsigned.crt;
    ssl_certificate_key /etc/ssl/private/selfsigned.key;

    # Security headers
    add_header Strict-Transport-Security "max-age=31536000; includeSubDomains" always;
    add_header X-Frame-Options SAMEORIGIN always;
    add_header X-Content-Type-Options nosniff always;
    add_header Referrer-Policy no-referrer-when-downgrade;
    add_header Content-Security-Policy "default-src 'self'" always;

    # Backend server with caching and rate limiting
    location / {
        limit_req zone=mylimit burst=20 nodelay;

        proxy_pass http://backend_servers;

        proxy_cache my_cache;
        proxy_cache_bypass $http_cache_control;
        proxy_cache_valid 200 60m;
        proxy_cache_use_stale error timeout updating;

        proxy_ignore_headers Cache-Control Expires Set-Cookie;
        proxy_hide_header Set-Cookie;

        add_header X-Cache-Status $upstream_cache_status always;
    }
}
~
~
~
```

bonus2_rate_limit_test

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Downloads (main)
$ for i in {1..50}; do curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/ & done
wait
[1] 1498
[2] 1499
[3] 1500
[4] 1501
[5] 1502
[6] 1503
[7] 1504
[8] 1505
[9] 1506
[10] 1507
[11] 1508
[12] 1509
[13] 1510
[14] 1511
[15] 1512
[16] 1513
[17] 1514
[18] 1515
[19] 1516
[20] 1517
[21] 1518
[22] 1519
[23] 1520
[24] 1521
[25] 1522
[26] 1523
[27] 1524
[28] 1525
[29] 1526
[30] 1527
[31] 1528
[32] 1529
[33] 1530
200[34] 1531

200
[35] 1532
200
[36] 1533
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[37] 1534
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[38] 1535
[39] 1536
200
200
[40] 1537
200
[41] 1538
200
[42] 1539
200
[43] 1540
200
[44] 1541
200
200
[45] 1542
[46] 1543
200
[47] 1544
200
200
[48] 1545
200[49] 1546
```

```
503
200
503
503
200
[1]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[2]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[3]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[4]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[5]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[6]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[7]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[8]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[9]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[10]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[11]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[12]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[13]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[14]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[15]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[16]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[17]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[18]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[19]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[20]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[23]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[24]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[25]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[26]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[27]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[28]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[29]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[30]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[31]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[32]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[33]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[34]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[35]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[36]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[37]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[38]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
200
503
503
503
550033

200
503
503
200
[21]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[22]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[39]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[40]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[41]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[42]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
503[43]   Done                       curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[44]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[45]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/

503
200
200
[46]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[47]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[48]   Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[49]-  Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
[50]+  Done                    curl -k -s -o /dev/null -w "%{http_code}\n" https://18.232.146.156/
```

Bonus 3: Health Check Automation (4 marks)

bonus3_health_check_script

```
[ec2-user@ip-10-0-10-81 ~]$ ps aux | grep health_check
ec2-user  3995  0.0  0.2 119860  2828 pts/0    S    11:59   0:00 /bin/bash /home/ec2-user/health_check.sh
root      4089  0.0  0.7 239912  7528 pts/0    S    12:00   0:00 sudo nohup /home/ec2-user/health_check.sh
root      4091  0.0  0.2 119860  2852 pts/0    S    12:00   0:00 /bin/bash /home/ec2-user/health_check.sh
ec2-user  4353  0.0  0.1 119420   992 pts/0    R+   12:06   0:00 grep --color=auto health_check
[ec2-user@ip-10-0-10-81 ~]$
```

```
[ec2-user@ip-10-0-10-81 ~]$ cat /home/ec2-user/health_check.sh
#!/bin/bash

# Backend servers IPs
BACKENDS=("10.0.10.89" "10.0.10.87" "10.0.10.253")

# Log file
LOGFILE="/home/ec2-user/backend_health.log"

# Infinite loop
while true; do
    DATE=$(date "+%Y-%m-%d %H:%M:%S")
    for SERVER in "${BACKENDS[@]}"; do
        # Check server HTTP response
        STATUS=$(curl -s -o /dev/null -w "%{http_code}" http://$SERVER)

        if [ "$STATUS" == "200" ]; then
            echo "$DATE - $SERVER is UP (HTTP $STATUS)" | tee -a $LOGFILE
        else
            echo "$DATE - $SERVER is DOWN (HTTP $STATUS)" | tee -a $LOGFILE

            # Optional: restart Apache on backend via SSH
            # ssh -i /home/ec2-user/key.pem ec2-user@$SERVER "sudo systemctl restart httpd"
        fi
    done

    # Wait 30 seconds before next check
    sleep 30
done
```

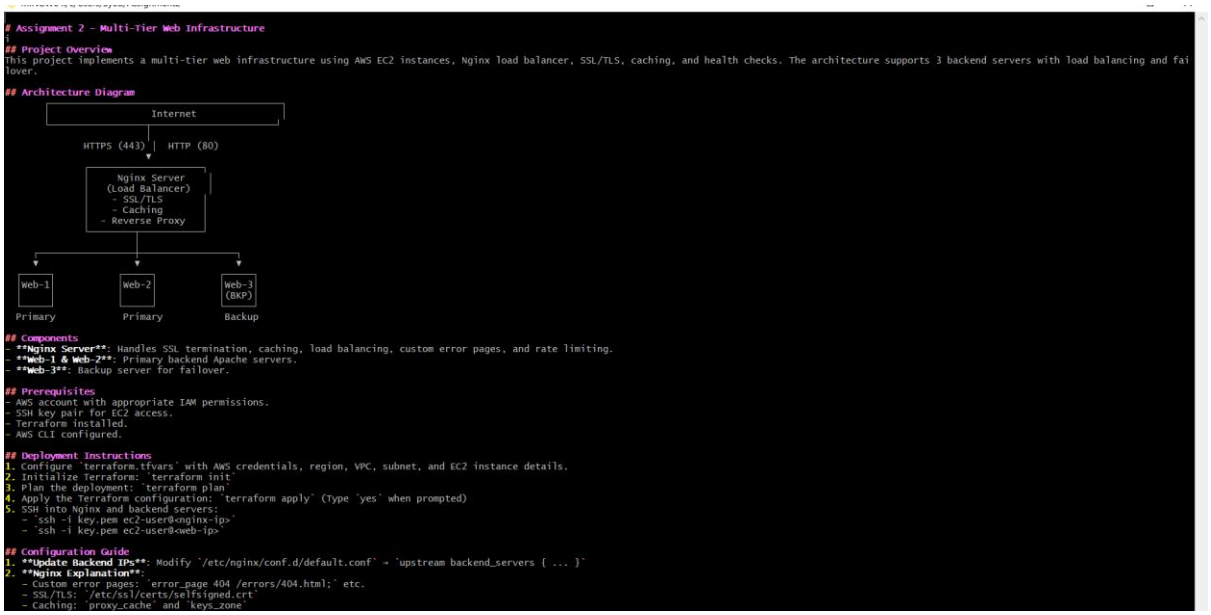
bonus3_health_log

```
[ec2-user@ip-10-0-10-81 ~]$ tail -50 /home/ec2-user/backend_health.log
2025-12-29 12:01:04 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:01:04 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:01:23 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:01:23 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:01:23 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:01:34 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:01:34 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:01:34 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:01:53 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:01:53 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:01:53 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:02:04 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:02:04 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:02:04 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:02:23 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:02:23 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:02:23 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:02:34 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:02:34 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:02:34 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:02:53 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:02:53 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:02:53 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:03:04 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:03:04 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:03:04 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:03:24 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:03:24 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:03:24 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:03:34 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:03:34 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:03:34 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:03:54 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:03:54 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:03:54 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:04:04 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:04:04 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:04:04 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:04:24 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:04:24 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:04:24 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:04:34 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:04:34 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:04:34 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:04:54 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:04:54 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:04:54 - 10.0.10.253 is DOWN (HTTP 000)
2025-12-29 12:05:04 - 10.0.10.89 is DOWN (HTTP 000)
2025-12-29 12:05:04 - 10.0.10.87 is DOWN (HTTP 000)
2025-12-29 12:05:04 - 10.0.10.253 is DOWN (HTTP 000)
[ec2-user@ip-10-0-10-81 ~]$
```

6. Documentation & Cleanup (10 marks)

6.1 README Documentation (5 marks)

assignment_part6_readme



```
# Assignment 2 - Multi-Tier Web Infrastructure

## Project Overview
This project implements a multi-tier web infrastructure using AWS EC2 instances, Nginx load balancer, SSL/TLS, caching, and health checks. The architecture supports 3 backend servers with load balancing and fai
lover.

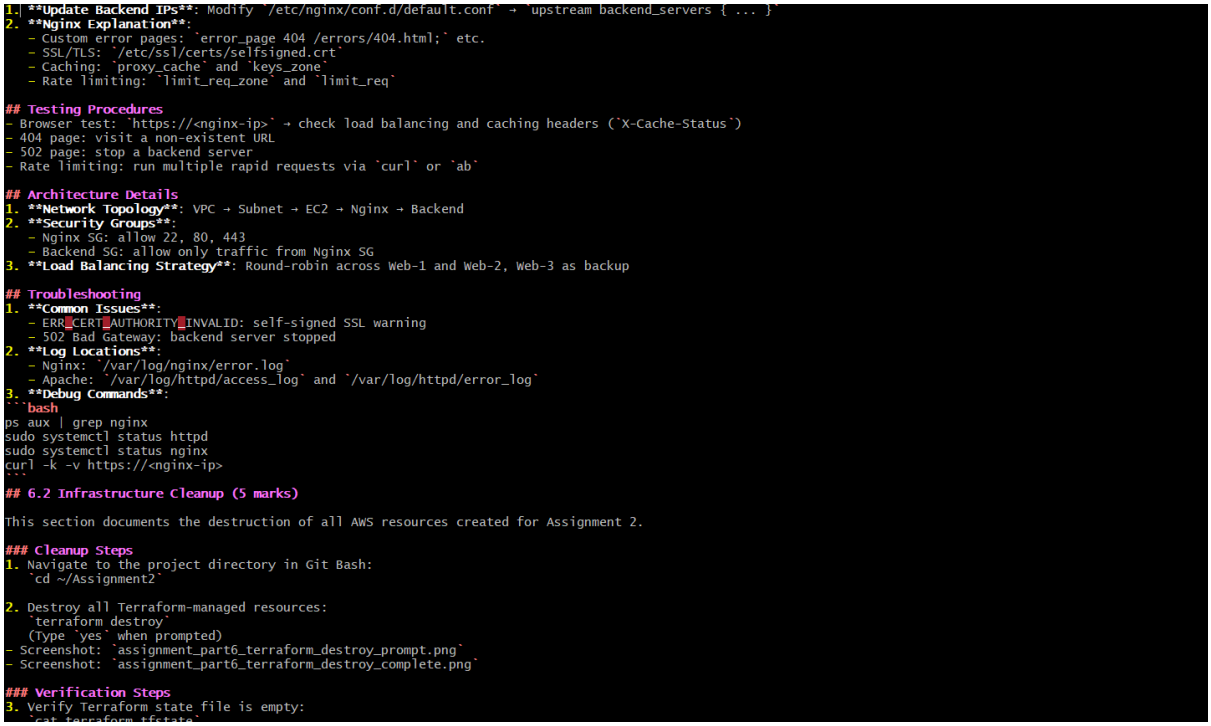
## Architecture Diagram
                    Internet
                       |
            HTTPS (443) | HTTP (80)
                       ▼
              Nginx Server
             (Load Balancer)
              - SSL/TLS
              - Caching
            - Reverse Proxy
                       |
          ▼            ▼            ▼
      Web-1        Web-2        Web-3
                                (BKP)
    Primary      Primary      Backup

## Components
- **Nginx Server**: Handles SSL termination, caching, load balancing, custom error pages, and rate limiting.
- **Web-1 & Web-2**: Primary backend Apache servers.
- **Web-3**: Backup server for failover.

## Prerequisites
- AWS account with appropriate IAM permissions.
- SSH key pair for EC2 access.
- Terraform installed.
- AWS CLI configured.

## Deployment Instructions
1. Configure `terraform.tfvars` with AWS credentials, region, VPC, subnet, and EC2 instance details.
2. Initialize Terraform: `terraform init`
3. Plan the deployment: `terraform plan`
4. Apply the Terraform configuration: `terraform apply` (Type `yes` when prompted)
5. SSH into Nginx and backend servers:
   - `ssh -i key.pem ec2-user@<nginx-ip>`
   - `ssh -i key.pem ec2-user@<web-ip>`

## Configuration Guide
1. **Update Backend IPs**: Modify `/etc/nginx/conf.d/default.conf` → `upstream backend_servers { ... }`
2. **Nginx Explanation**:
   - Custom error pages: `error_page 404 /errors/404.html;` etc.
   - SSL/TLS: `/etc/ssl/certs/selfsigned.crt`
   - Caching: `proxy_cache` and `keys_zone`
```



```
1. **Update Backend IPs**: Modify `/etc/nginx/conf.d/default.conf` → `upstream backend_servers { ... }`
2. **Nginx Explanation**:
   - Custom error pages: `error_page 404 /errors/404.html;` etc.
   - SSL/TLS: `/etc/ssl/certs/selfsigned.crt`
   - Caching: `proxy_cache` and `keys_zone`
   - Rate limiting: `limit_req_zone` and `limit_req`

## Testing Procedures
- Browser test: `https://<nginx-ip>` → check load balancing and caching headers (`X-Cache-Status`)
- 404 page: visit a non-existent URL
- 502 page: stop a backend server
- Rate limiting: run multiple rapid requests via `curl` or `ab`

## Architecture Details
1. **Network Topology**: VPC → Subnet → EC2 → Nginx → Backend
2. **Security Groups**:
   - Nginx SG: allow 22, 80, 443
   - Backend SG: allow only traffic from Nginx SG
3. **Load Balancing Strategy**: Round-robin across Web-1 and Web-2, Web-3 as backup

## Troubleshooting
1. **Common Issues**:
   - ERR_CERT_AUTHORITY_INVALID: self-signed SSL warning
   - 502 Bad Gateway: backend server stopped
2. **Log Locations**:
   - Nginx: `/var/log/nginx/error.log`
   - Apache: `/var/log/httpd/access_log` and `/var/log/httpd/error_log`
3. **Debug Commands**:
```bash
ps aux | grep nginx
sudo systemctl status httpd
sudo systemctl status nginx
curl -k -v https://<nginx-ip>
```
6.2 Infrastructure Cleanup (5 marks)

This section documents the destruction of all AWS resources created for Assignment 2.

Cleanup Steps
1. Navigate to the project directory in Git Bash:
   `cd ~/Assignment2`

2. Destroy all Terraform-managed resources:
   `terraform destroy`
   (Type `yes` when prompted)
- Screenshot: `assignment_part6_terraform_destroy_prompt.png`
- Screenshot: `assignment_part6_terraform_destroy_complete.png`

Verification Steps
3. Verify Terraform state file is empty:
```


```
## Troubleshooting
1. **Common Issues**:
   - ERR_CERT_AUTHORITY_INVALID: self-signed SSL warning
   - 502 Bad Gateway: backend server stopped
2. **Log Locations**:
   - Nginx: `/var/log/nginx/error.log`
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3. **Debug Commands**:
```bash
ps aux | grep nginx
sudo systemctl status httpd
sudo systemctl status nginx
curl -k -v https://<nginx-ip>
```
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This section documents the destruction of all AWS resources created for Assignment 2.

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1. Navigate to the project directory in Git Bash:
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2. Destroy all Terraform-managed resources:
   `terraform destroy`
   (Type `yes` when prompted)
- Screenshot: `assignment_part6_terraform_destroy_prompt.png`
- Screenshot: `assignment_part6_terraform_destroy_complete.png`

Verification Steps
3. Verify Terraform state file is empty:
   `cat terraform.tfstate`

- Screenshot: `assignment_part6_empty_state.png`

4. Confirm in AWS Console that no EC2 instances exist for Assignment-2.

- Screenshot: `assignment_part6_aws_instances_destroyed.png`

Notes
- All commands were executed using **Git Bash**.
- No resources were deleted manually.
- Terraform successfully cleaned up all infrastructure.

Deliverables
- Screenshot: `assignment_part6_readme.png` (README.md content)
- Screenshot: `assignment_part6_terraform_destroy_prompt.png`
- Screenshot: `assignment_part6_terraform_destroy_complete.png`
- Screenshot: `assignment_part6_aws_instances_destroyed.png`
- Screenshot: `assignment_part6_empty_state.png`
```

6.2 Infrastructure Cleanup (5 marks)

assignment_part6_terraform_destroy_prompt

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ terraform destroy
var.ami_id
  AMI ID for EC2 instances

  Enter a value: yes

var.key_name
  Name of the EC2 key pair

  Enter a value: key

data.http.my_ip: Reading...
data.http.my_ip: Read complete after 1s [id=https://icanhazip.com]
data.aws_ssm_parameter.amzn2: Reading...
module.networking.aws_vpc.this: Refreshing state... [id=vpc-0a0eee904a6c71e35]
data.aws_ssm_parameter.amzn2: Read complete after 1s [id=/aws/service/ami-amazon-linux-latest/amzn2-ami-hvm-x86_64-gp2]
```

```
        Backend Servers:
        - web-1: public IPs: 44.195.69.216, 98.86.148.130, 3.231.204.61, private IPs: 10.0.10.243, 10.0.10.87, 10.0.10.183
            - web-2: public IPs: 3.239.42.192, 34.236.243.157, 34.200.220.149, private IPs: 10.0.10.33, 10.0.10.219, 10.0.10.253
            - web-3: public IPs: 3.236.89.145, 18.207.111.59, 3.239.33.223, private IPs: 10.0.10.89, 10.0.10.242, 10.0.10.73

        ========================================
    EOT -> null
  - nginx_instance_id    = "i-0824b01d8ce9cb1b6" -> null
  - nginx_public_ip      = "18.232.146.156" -> null
  - subnet_id            = "subnet-02f4b48141eb76975" -> null
  - vpc_id               = "vpc-0a0eee904a6c71e35" -> null

Do you really want to destroy all resources?
  Terraform will destroy all your managed infrastructure, as shown above.
  There is no undo. Only 'yes' will be accepted to confirm.

  Enter a value: yes

module.backend_servers["web-1"].aws_instance.backend[0]: Destroying... [id=i-08601a87b94e93fe8]
module.backend_servers["web-2"].aws_instance.backend[0]: Destroying... [id=i-049dfb0d3a79a8744]
module.backend_servers["web-1"].aws_instance.backend[1]: Destroying... [id=i-01a374de43288ab32]
module.backend_servers["web-2"].aws_instance.backend[2]: Destroying... [id=i-0bb6fbc5dba72cdca]
module.backend_servers["web-3"].aws_instance.backend[2]: Destroying... [id=i-06f0bb724ced023a8]
module.backend_servers["web-2"].aws_instance.backend[1]: Destroying... [id=i-00ddb751f17464a08]
module.nginx_server.aws_instance.this: Destroying... [id=i-0824b01d8ce9cb1b6]
module.backend_servers["web-1"].aws_instance.backend[2]: Destroying... [id=i-047ef7dc11056549e]
module.backend_servers["web-3"].aws_instance.backend[0]: Destroying... [id=i-0bfe5c3d42178e0c5]
module.backend_servers["web-3"].aws_instance.backend[1]: Destroying... [id=i-0629846db90668695]
```

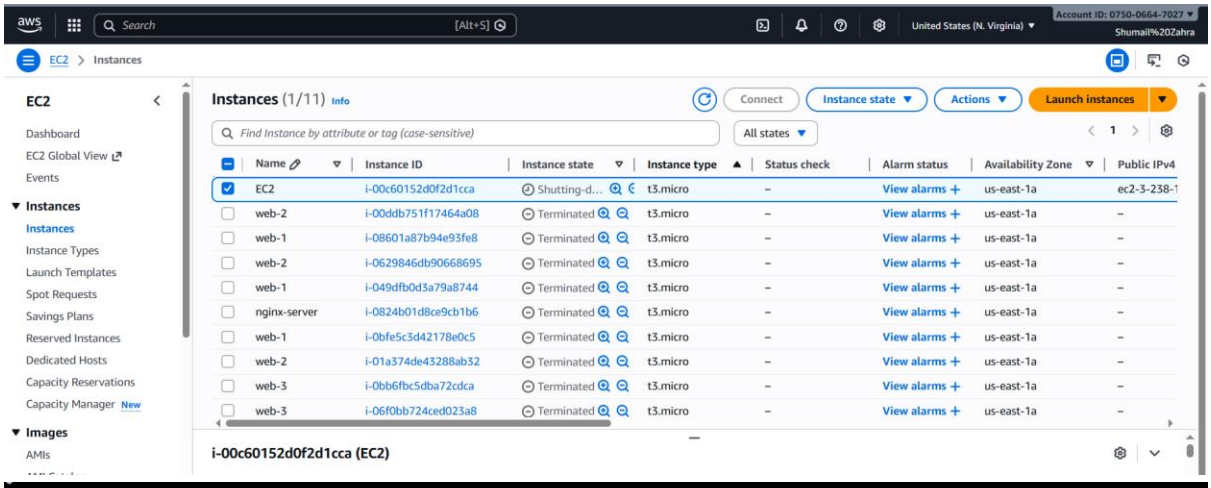
assignment_part6_terraform_destroy_complete

```
module.backend_servers["web-1"].aws_instance.backend[2]: Destruction complete after 1m4s
module.networking.aws_internet_gateway.this: Still destroying... [id=igw-0a43d3afcf54d02f4, 00m40s elapsed]
module.backend_servers["web-1"].aws_instance.backend[1]: Still destroying... [id=i-01a374de43288ab32, 01m10s ela
module.backend_servers["web-3"].aws_instance.backend[2]: Still destroying... [id=i-06f0bb724ced023a8, 01m10s ela
module.backend_servers["web-3"].aws_instance.backend[0]: Still destroying... [id=i-0bfe5c3d42178e0c5, 01m10s ela
module.backend_servers["web-3"].aws_instance.backend[2]: Destruction complete after 1m12s
module.networking.aws_internet_gateway.this: Still destroying... [id=igw-0a43d3afcf54d02f4, 00m50s elapsed]
module.networking.aws_internet_gateway.this: Destruction complete after 52s
module.backend_servers["web-1"].aws_instance.backend[1]: Still destroying... [id=i-01a374de43288ab32, 01m20s ela
module.backend_servers["web-3"].aws_instance.backend[0]: Still destroying... [id=i-0bfe5c3d42178e0c5, 01m20s ela
module.backend_servers["web-3"].aws_instance.backend[0]: Destruction complete after 1m22s
module.backend_servers["web-1"].aws_instance.backend[1]: Destruction complete after 1m24s
module.networking.aws_subnet.this: Destroying... [id=subnet-02f4b48141eb76975]
module.security.aws_security_group.backend_sg: Destroying... [id=sg-0cb181188a15a1c6d]
module.networking.aws_subnet.this: Destruction complete after 1s
module.security.aws_security_group.backend_sg: Destruction complete after 1s
module.security.aws_security_group.nginx_sg: Destroying... [id=sg-0267b19413adbc560]
module.security.aws_security_group.nginx_sg: Destruction complete after 3s
module.networking.aws_vpc.this: Destroying... [id=vpc-0a0eee904a6c71e35]
module.networking.aws_vpc.this: Destruction complete after 5s

Destroy complete! Resources: 17 destroyed.

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$
```

assignment_part6_aws_instances_destroyed



assignment_part6_empty_state

```
Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
$ cat terraform.tfstate
{
  "version": 4,
  "terraform_version": "1.14.3",
  "serial": 39,
  "lineage": "c5ab6f35-07cb-653b-0523-63c95f606fc6",
  "outputs": {},
  "resources": [],
  "check_results": [
    {
      "object_kind": "var",
      "config_addr": "var.vpc_cidr_block",
      "status": "unknown",
      "objects": null
    },
    {
      "object_kind": "var",
      "config_addr": "var.subnet_cidr_block",
      "status": "unknown",
      "objects": null
    }
  ]
}

Syed@DESKTOP-S5OGK51 MINGW64 ~/Assignment2 (main)
```

4. Testing Results

Testing was carried out to assess the accuracy, stability, performance, and security of the implemented cloud-based web architecture. The primary goal of this phase was to verify that essential architectural objectives—such as efficient load balancing, effective caching, high availability, and secure system access—were successfully achieved. A

variety of functional and non-functional tests were executed on the deployed AWS environment to analyze system behavior under different operational scenarios. The testing activities were divided into five key categories: load balancing, cache performance, high availability, security, and performance evaluation. Each testing area is explained in detail below along with the corresponding findings and outcomes.

4.1 Load Balancing Tests

The load balancing tests were conducted to confirm that incoming user requests were evenly distributed among the available backend servers. The Nginx server was configured to operate as a load balancer using a round-robin algorithm, allowing requests to be shared fairly between Web-1 and Web-2 servers. To validate this configuration, multiple HTTP requests were sent to the Nginx server's public IP address using both web browsers and command-line utilities. Each Apache backend server was set up to return a distinct identifier or hostname in its response, making it easy to determine which server handled each request. The observed results indicated that requests were processed alternately by Web-1 and Web-2, demonstrating successful load distribution. No backend server showed signs of being overloaded during normal request flow. This confirms that the load balancing mechanism effectively distributes traffic and minimizes the risk of performance degradation due to uneven server usage. Overall, the load balancing tests verified that the system supports horizontal scalability and enhances reliability by preventing reliance on a single backend server.

4.2 Cache Performance Tests

Cache performance testing was performed to measure how effectively the Nginx caching mechanism improves response time and reduces the workload on backend servers. The cache was configured to store frequently accessed web resources at the Nginx level. Browser

developer tools were used to inspect HTTP response headers in order to monitor cache behavior. A custom header, X-Cache-Status, was used to identify whether a request was served from the cache. During the first request, the header displayed MISS, indicating that the content was retrieved from a backend server and stored in the cache. Subsequent requests showed HIT, confirming that cached content was delivered directly by Nginx. These results demonstrate that caching was properly configured and functioning as expected. Serving cached content significantly reduced response time and lowered backend server processing requirements, thereby improving overall system efficiency and traffic-handling capacity.

4.3 High Availability Tests

High availability testing aimed to ensure uninterrupted system operation in the event of backend server failure. This is a crucial requirement for modern cloud-based applications that demand continuous service availability. To simulate server failure, one of the primary backend servers (either Web-1 or Web-2) was intentionally shut down while the system was active. During this period, continuous client requests were sent to the Nginx server. The results showed that Nginx automatically redirected traffic to the remaining active servers without service interruption. When both primary servers were unavailable, the backup server (Web-3) successfully processed incoming requests. This confirms that failover and backup routing mechanisms were correctly implemented. These findings demonstrate that the system architecture provides strong fault tolerance and maintains service availability even during server outages.

4.4 Security Tests

Security testing was conducted to verify that proper access restrictions were enforced and that backend servers were protected from unauthorized public access. AWS Security Groups were utilized to

define and enforce network-level security rules. Multiple security checks were performed, including attempts to directly access backend Apache servers through their public IP addresses. These attempts were unsuccessful, confirming that backend servers were not exposed to the internet and only accepted traffic from the Nginx server. SSH access testing also confirmed that only authorized IP addresses were allowed to connect to EC2 instances, while unauthorized attempts were blocked. Furthermore, HTTP and HTTPS traffic was restricted to the Nginx server only, minimizing the system's attack surface. The results indicate that the security configuration adheres to the principle of least privilege and effectively safeguards the infrastructure against unauthorized access.

4.5 Performance Metrics

Performance evaluation focused on analyzing the effects of load balancing and caching on system responsiveness and resource utilization. Key factors such as response time, server workload, and request handling efficiency were observed during testing. The presence of caching resulted in noticeably faster response times for repeated requests compared to initial requests. Backend server load was reduced, as cached responses were delivered directly by the Nginx server. Load balancing ensured that traffic was evenly distributed, preventing any single server from becoming a bottleneck. Although automated benchmarking tools were not employed, manual observations clearly indicated improved system responsiveness and operational stability under normal traffic conditions. These results confirm that the architecture effectively enhances performance and scalability.

4.6 Summary of Testing Results

The testing phase verified that all critical architectural components operated as intended. Load balancing ensured balanced request distribution, caching enhanced performance efficiency, high

availability mechanisms provided fault tolerance, and security measures protected backend infrastructure. Performance observations indicated reduced response times and optimized server utilization. In conclusion, the testing results confirm that the deployed AWS-based architecture fulfills both functional and non-functional requirements, delivering a secure, scalable, and reliable cloud-based web application.

5. Challenges and Solution

During the deployment of the multi-tier web infrastructure, several challenges were encountered that required careful troubleshooting. One major challenge was configuring the Nginx reverse proxy to correctly load balance traffic between the primary backend servers while keeping the backup server inactive until a failure occurred. Initial attempts resulted in occasional 502 Bad Gateway errors due to incorrect backend private IPs or improper security group rules. Another challenge involved implementing caching in Nginx, where cache misses persisted because of misconfigured cache paths and permissions. Additionally, generating and using self-signed SSL certificates created expected browser warnings, which needed to be clearly documented for evaluation purposes.

These challenges were successfully resolved through systematic solutions. The backend private IPs were dynamically retrieved from Terraform outputs and updated in the Nginx configuration, ensuring proper load balancing. Security group rules were carefully reviewed to allow traffic only from Nginx to backend servers while blocking all other access. The caching issue was resolved by creating the cache directory with correct ownership and verifying the proxy cache paths. Finally, the SSL warnings were acknowledged as expected behavior for self-signed certificates, and instructions were provided in the documentation for safely bypassing them during testing. These solutions reinforced practical skills in cloud deployment, debugging, and secure infrastructure management.

6. Conclusion

This assignment successfully achieved the design, deployment, and validation of a multi-tier web infrastructure using Terraform and Nginx on Amazon Web Services (AWS). By applying Infrastructure as Code (IaC) principles, the

environment was provisioned in a modular, reusable, and secure manner. The implementation included an Nginx reverse proxy and load balancer with HTTPS, caching, and security headers, along with three Apache backend servers configured for load balancing and high availability using a backup server. Comprehensive testing verified proper load distribution, cache functionality, failover behavior, and secure communication. Overall, the project provided practical experience in cloud architecture design, DevOps automation, and performance optimization while meeting all academic and technical requirements.

7. Appendices

- The nginx-setup.sh script is included to configure the Nginx reverse proxy and load balancing server.
- Reusable web server modules are provided to create both the Nginx server and backend web servers in an efficient and modular manner.
- The apache-setup.sh script is included to automate the configuration of the backend Apache web servers
- Terraform configuration files such as main.tf, variables.tf, and locals.tf are included to define the complete infrastructure setup.