System Engineering Assignment

Requirement: write timestamp to DB when POST methods is issued to /app endpoint

curl -X POST http://avi-app-alb-638864777.eu-west-1.elb.amazonaws.com//app
curl -X POST http://52.18.161.254/app
curl -X POST http://52.17.154.97/app

A Records (IPs) for the service URL is highlighted below

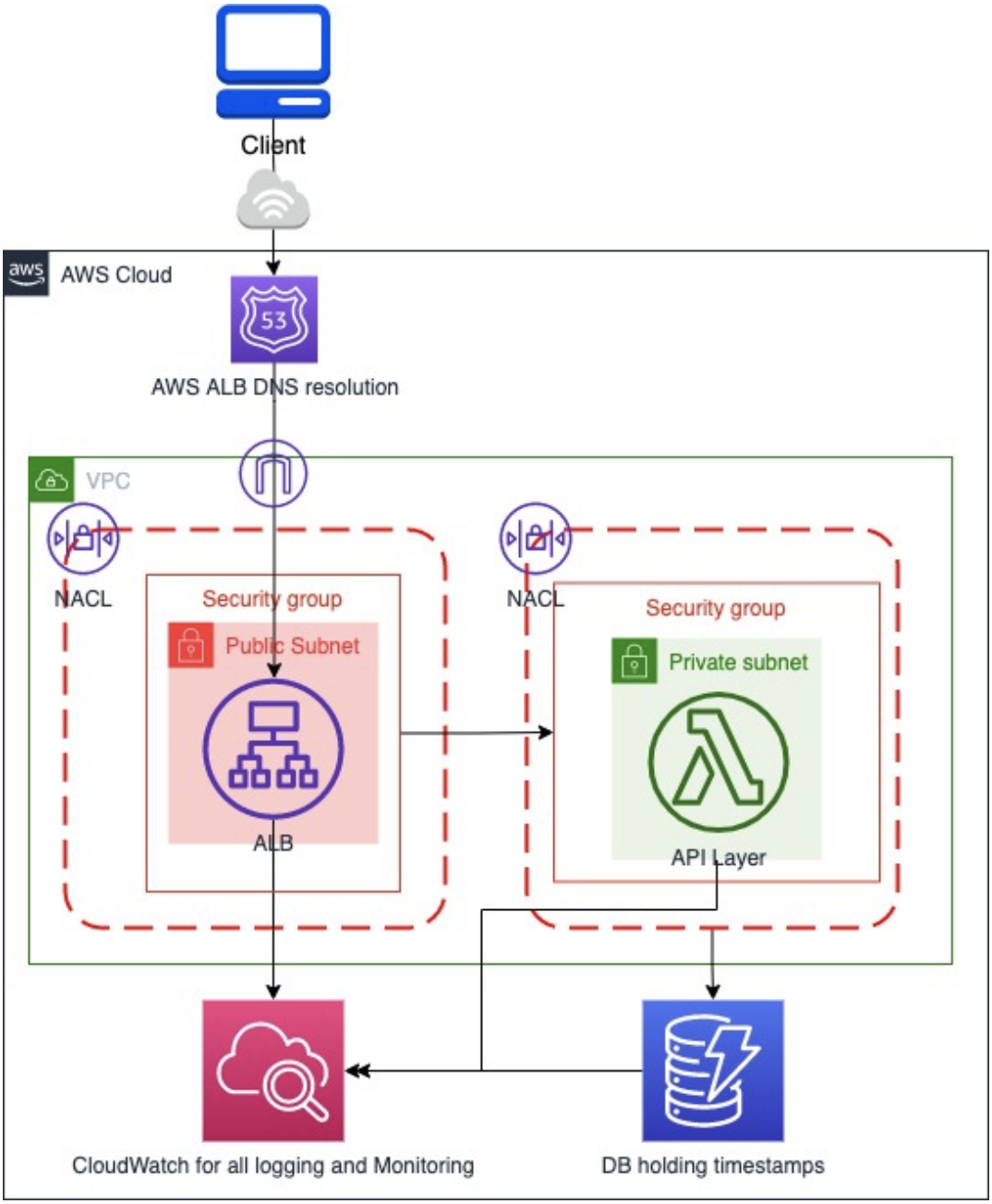
avi-app-alb-638864777.eu-west-1.elb.amazonaws.com. 60 IN A 52.18.161.254
avi-app-alb-638864777.eu-west-1.elb.amazonaws.com. 60 IN A 52.17.154.97

Index:

- High-level design
- Low-level design
- Deployment
- Technology consideration
- Few clarifications as asked
- Tech Debt
- Reference

Code base: https://github.com/asrivastava-github/writeDBAPI

High-Level design (As illustrated and explained below)



The solution consists of two major components:

1. API layer which is being served by AWS Application Load Balancer with AWS Lambda as it's target.
2. DB layer which is being served by AWS DynamoDB

When a client (Terminal, Browser etc) sends the request to API using AWS ALB external DNS or Public IP:

- The internet facing AWS Application Load Balancer receives it and based on the endpoint (path - /app in this case) passes it on to the respective target.
- Lambda is connected to target groups of ALB ready to serve the requests.
- Based on request Lambda executes the business logic (writing timestamp to DB in this case) and sends the response back to ALB which forwards it further to client.

Low-level design

An attempt to explain each component/function in detail covering below points

- Network
- Security
    - IAM
    - Network Security
        - Network Access Control Lists
        - Security Group
        - VPC endpoint
        - TLS
    - User Authentication
- API Layer
- DB Layer
- Logging and Monitoring

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1. Request goes to the internet looking for Address or IP mention.

2. ISP eventually finds where the requested DNS or IP needs to land, in this case Amazon Web Service, where Route 53 is ready to receive it.

3. Route53 routes the request to the Internet gateway (IGW) of VPC where solution (ALB + Lambda) has been deployed.

4. Now if connectivity and routing has been properly sorted, the request will be received by ALB as ALB sits in a Public Subnet which has routing enabled for internet → Internet gateway and local → Public Subnet. Public Subnet is attached to a NACL which allows

traffic from the internet on HTTP and HTTPS port. It allows outbound traffic on ephemeral ports as well **(Required for ALB to respond back).** Another layer of security on ALB, it's own security group allowing traffic only on HTTP and HTTPS ports.

5. ALB will analyse the request and based on the endpoint (path) mentioned in the request it will route it further to one of it's Target, which is nothing but Lambda. Lambda resides inside a Private subnet which has NACL allowing internal/local traffic on port 80 and 443, **along with Amazon's DynamoDB Service IP list for eu-west-*region on ephemeral ports required for DynamoDB to connect with Lambda which is deployed inside VPC.**

6. Lambda is a serverless compute ready to execute the code/business logic based on the request sent to it in the form of an Event. Lambda also carries its own security group rules to accept HTTP and HTTPS traffic from ALB security group only.

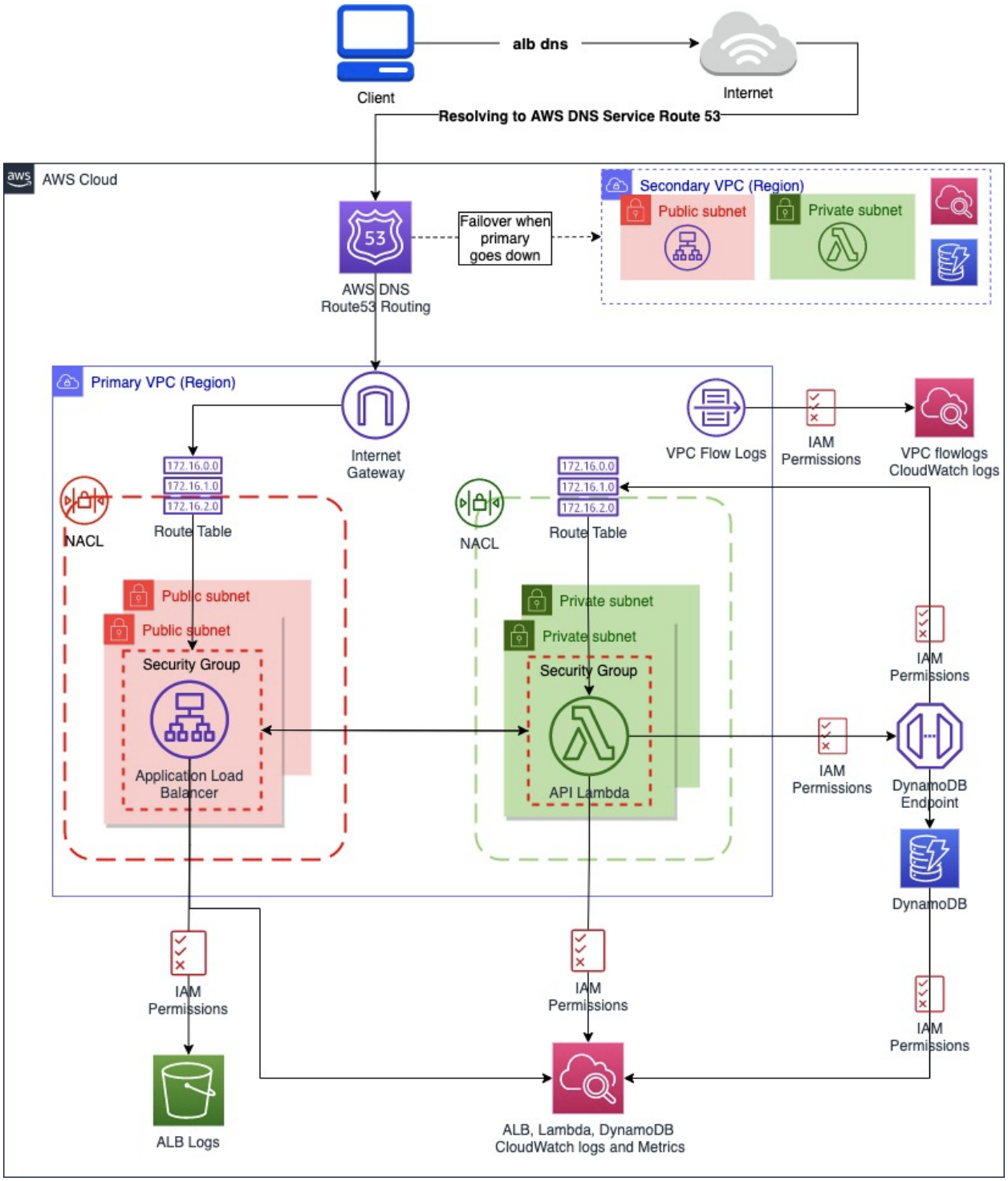
7. Post understanding the request, Lambda sends the response back to ALB in a specific format which ALB can understand and serve it further to the client, again if connectivity is properly sorted for outbound as well.
    a. Now it's worth explaining how the actual requirement is being served here. When Lambda receives the request where the **endpoint** (Path) is **"/app"** and the method is **POST**, it tries to connect to DB layer which is being served by AWS DynamoDB.
    b. Since Lambda is deployed under my/customer's VPC (NOT AWS own VPC), it cannot connect to AWS Managed Service DynamoDB straight away. Lambda will need a VPC endpoint created for DynamoDB which AWS facilitates free of cost but making it work is tricky, so ultimately a Secured Serverless compute has a way to connect to Serverless DynamoDB securely and internally (within AWS network, without going to internet)
    c. Post executing the business logic lambda responds to ALB and ALB takes care further.

8. HTTPS connectivity can be enabled by creating a certificate based on DNS and attaching it to the ALB HTTPS listener. This has not been covered here.

9. Additionally Lambda can easily be integrated with Cognito (AWS managed user authentication Server or IDP needs to be explored, Same is the case with DynamoDB).

10. Logging and Monitoring has been enabled at each level.
    a. Stating with vpc flow logs to capture all the request entering to VPC
    b. ALB logs being stored to s3 and AWS provided metrics
    c. Cloudwatch logs have been enabled for Lambda.
    d. Cloudwatch metric for DynamoDB

Below is the low level design touching each component.



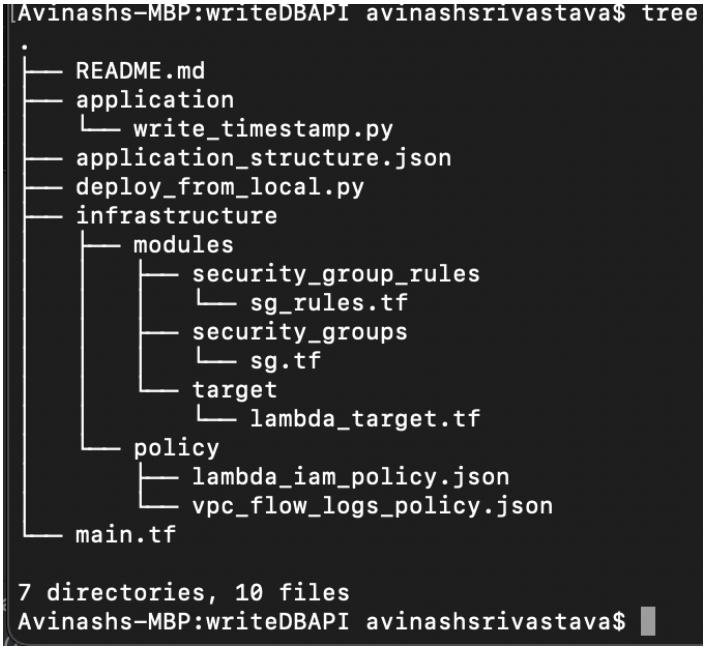
Deployment

Checkout below README for in depth detail

https://github.com/asrivastava-github/writeDBAPI/blob/main/README.md

- ## Directory Structure

    - Deployer file --> deploy_from_local.py
    - Business logic/API layer/Application -> ./application/write_timestamp.py
    - An attempt to design the application structure so that deployment can be controlled via config file --> application_structure.json
    - Infrastructure builder --> main.tf
        - Create security group rules
            --> ./infrastructure/modules/security_group_rules/sg_rules.tf
        - Create Security groups
            --> ./infrastructure/modules/security_groups/sg.tf
        - Configure the infrastructure of API layer e.g. Lambda and target groups etc.
            --> ./infrastructure/modules/target/lambda_target.tf



- Prerequisite:
    - Terraform version v0.13 or above must be installed. This project is build/tested using v0.14.2/0.15.4
    - Python version 3 (3.5 above) should be installed, This project is build/tested using Python 3.8.2
        - python3 -m pip install boto3 (pip Install boto3)
        - python3 -m pip install requests (pip Install requests)

    Avoiding file clutter else a requirements.txt will also be okay to define the required python packages. [Quickstart — Boto 3 Docs 1.9.42 documentation]

- AWS Configure
    - Create an Admin account on AWS which has access to provision the resources like ALB, Lambda, DynamoDB, CloudWatch, IAM etc
    - Install AWS CLI on your machine, Make sure you are able to connect to AWS post configuring AWS with "aws configure"
    - Default region used is eu-west-1

- Worth checking: Login to AWS console --> go to VPC --> Managed prefix lists, It should exist for s3 and DynamoDB or for either of them. If not, don't worry terraform wil created.

- Clone Project repository writeDBAPI

  git clone https://github.com/asrivastava-github/writeDBAPI.git

- Deployment: plan --> apply --> visual test --> planDestroy --> destroy

  cd writeDBAPI

  Currently I am owning an avi-assignment-api-service bucket so if you are testing/deploying the solution, and getting a bucket exists error, let me know I will delete. Alternatively you can change the bucket name in application_structure.json as s3 bucket names are unique.

- Run below to plan the system infrastructure

  - python3 deploy_from_local.py -a plan -e poc

- Run below to provision the system infrastructure

  - python3 deploy_from_local.py -a apply -e poc

- Starting visual testing/Using the system

  1. You can hit http://<ALB DNS printed as output> in the browser to see the welcome page.

  2. Run the below curl command which will create the timestamp entry inside DynamoDB

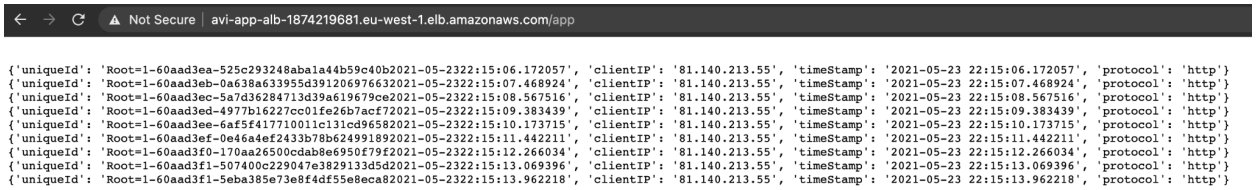
curl -X POST http://<ALB DNS printed as output>/app

3. Hit link http://<ALB DNS printed as output>/app in browser to see all the time stamps recorded.

```
Apply complete! Resources: 51 added, 0 changed, 0 destroyed.

Outputs:

albDNS = "avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com"
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:06.172057
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:07.468924
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:08.567516
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:09.383439
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:10.173715
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:11.442211
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:12.266034
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:13.069396
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-1874219681.eu-west-1.elb.amazonaws.com/app
2021-05-23 22:15:13.962218
Avinashs-MBP:writeDBAPI avinashsrivastava$
Avinashs-MBP:writeDBAPI avinashsrivastava$
```



- Destroy the system

1. Check what's being destroyed

   python3 deploy_from_local.py -a planDestroy -e poc

2. Finally destroy

   python3 deploy_from_local.py -a destroy -e poc

Deployment with AzureDevOps (CI/CD)

Pipeline:

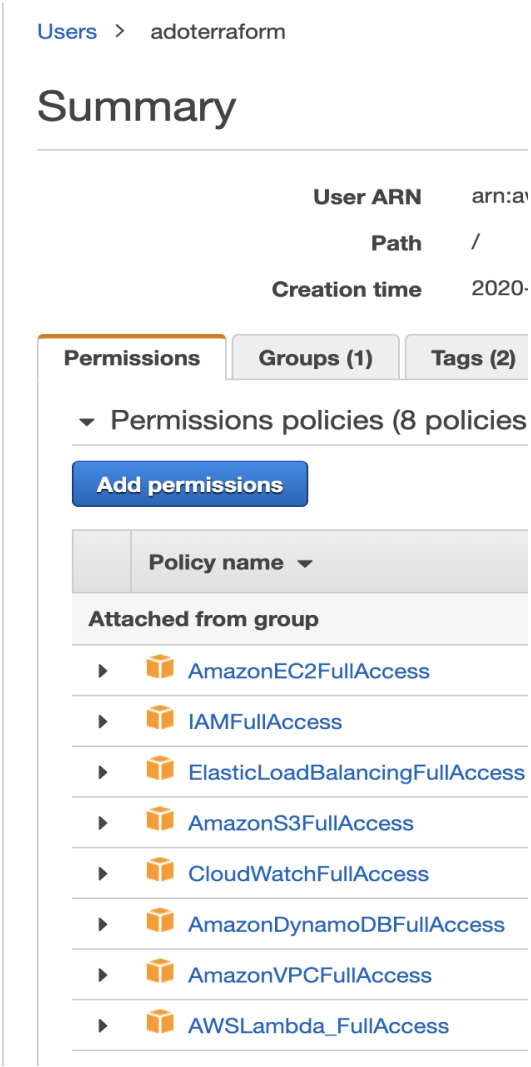
https://github.com/asrivastava-github/writeDBAPI/blob/release/v2/pipeline.yaml

Which uses python deployer script:

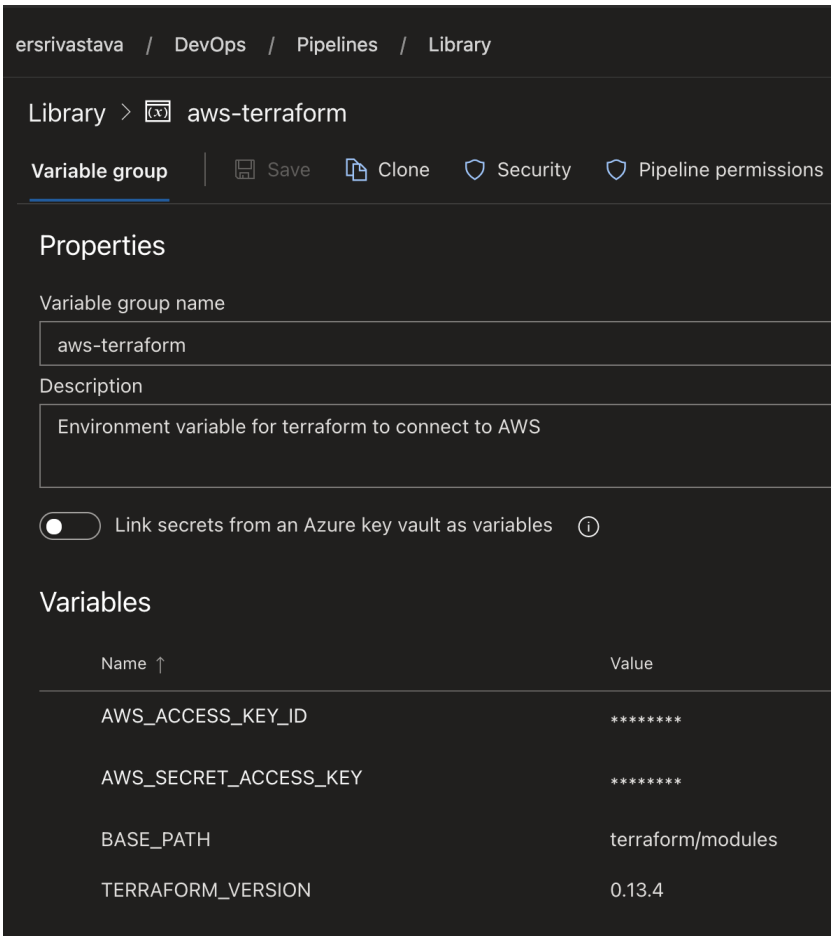
https://github.com/asrivastava-github/writeDBAPI/blob/release/v2/deployer.py

Preparation:

1. Create an IAM User in AWS for terraform running on Azure DevOps to connect



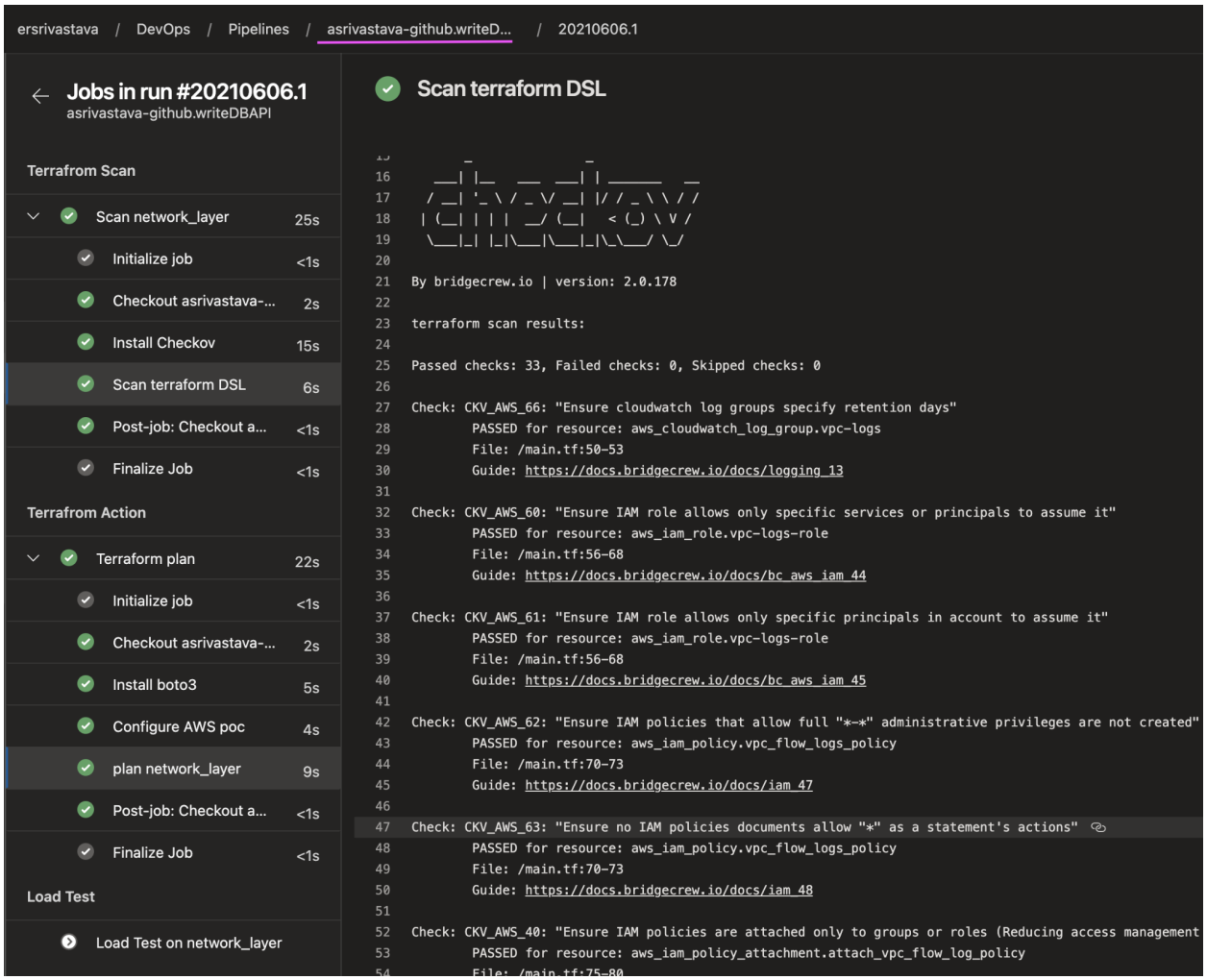
2. Either you can create a service connection or create a variable group to store the credential as secret (a sensitive variable which ADO will not expose). You can use Azure vault as well.



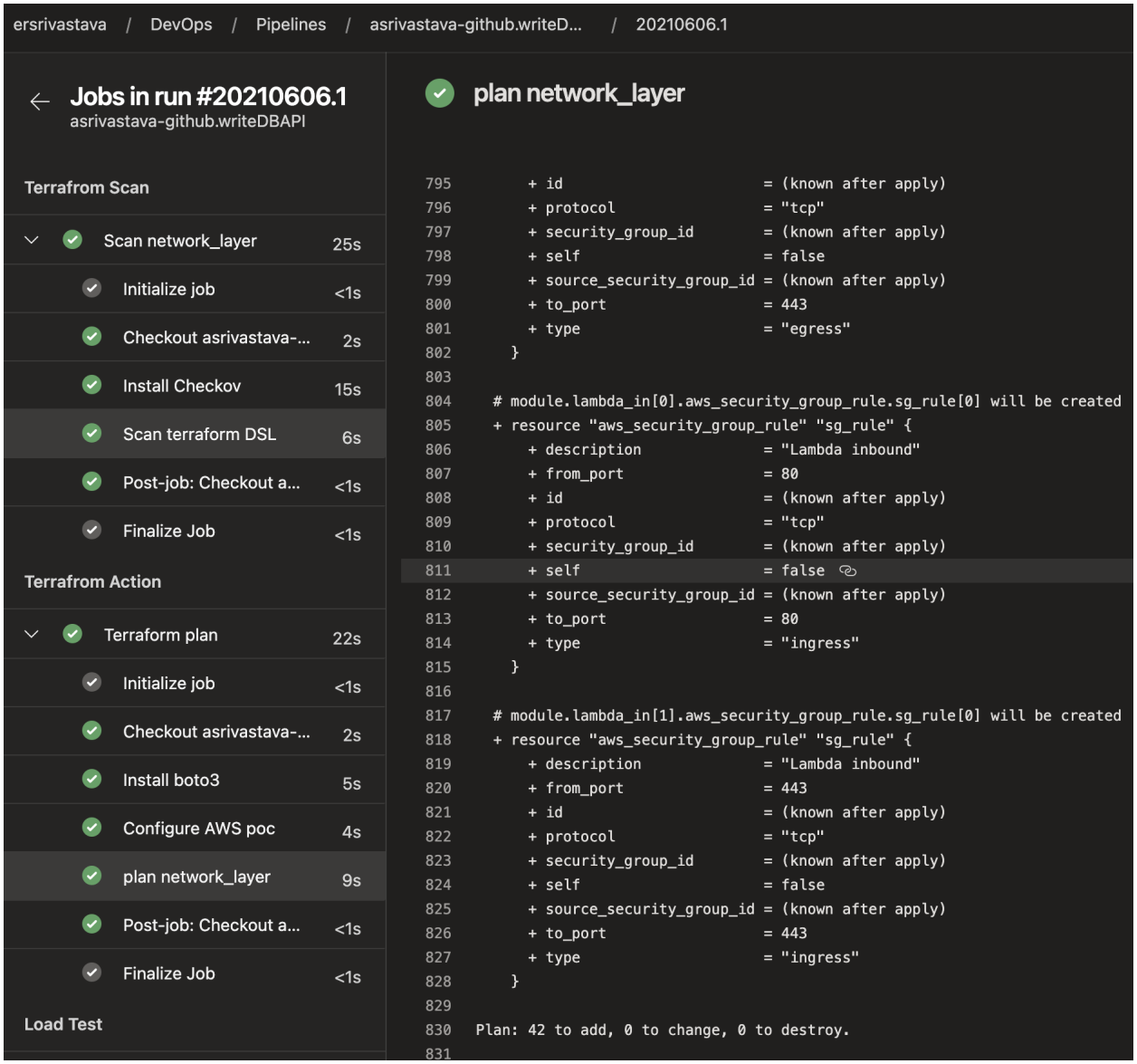
This is all We need to connect from Azure DevOps to AWS over the internet. It will be recommended to have a self hosted Azure agent (installed inside your premises cloud or DC) and have connectivity to AWS cloud.

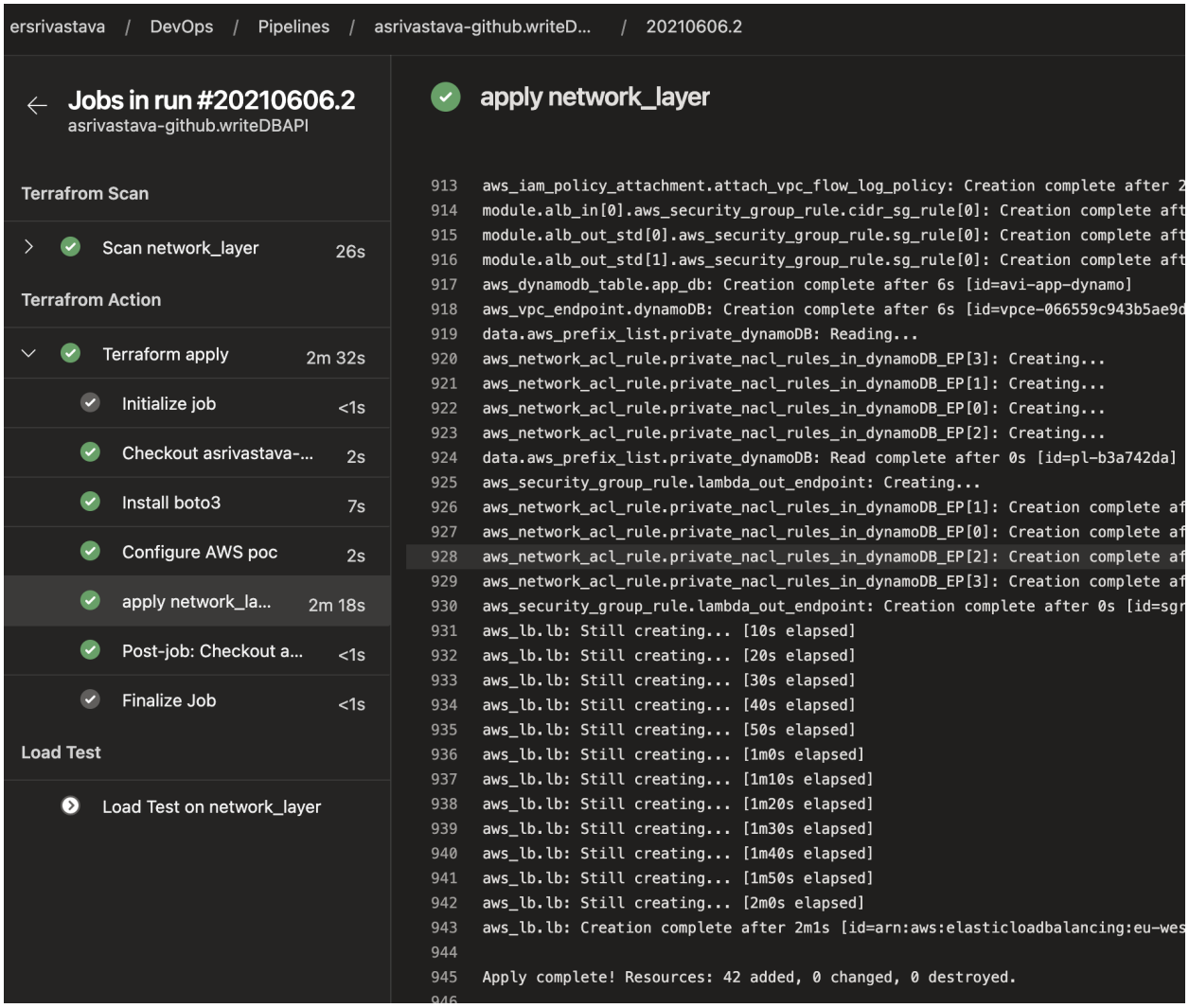
Now coming to deployment, It has 3 major steps to perform:

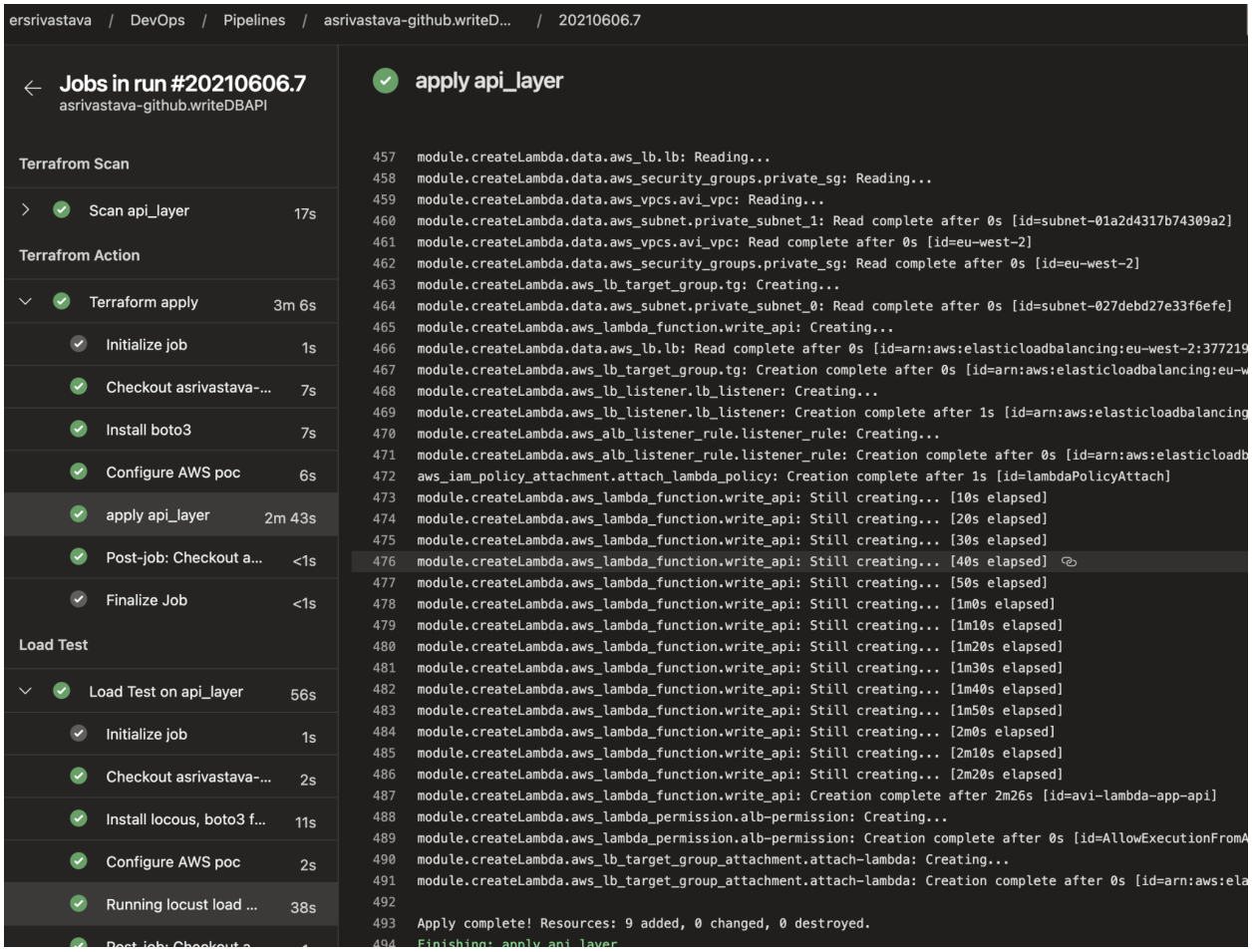
1. Scan terraform code using checkov



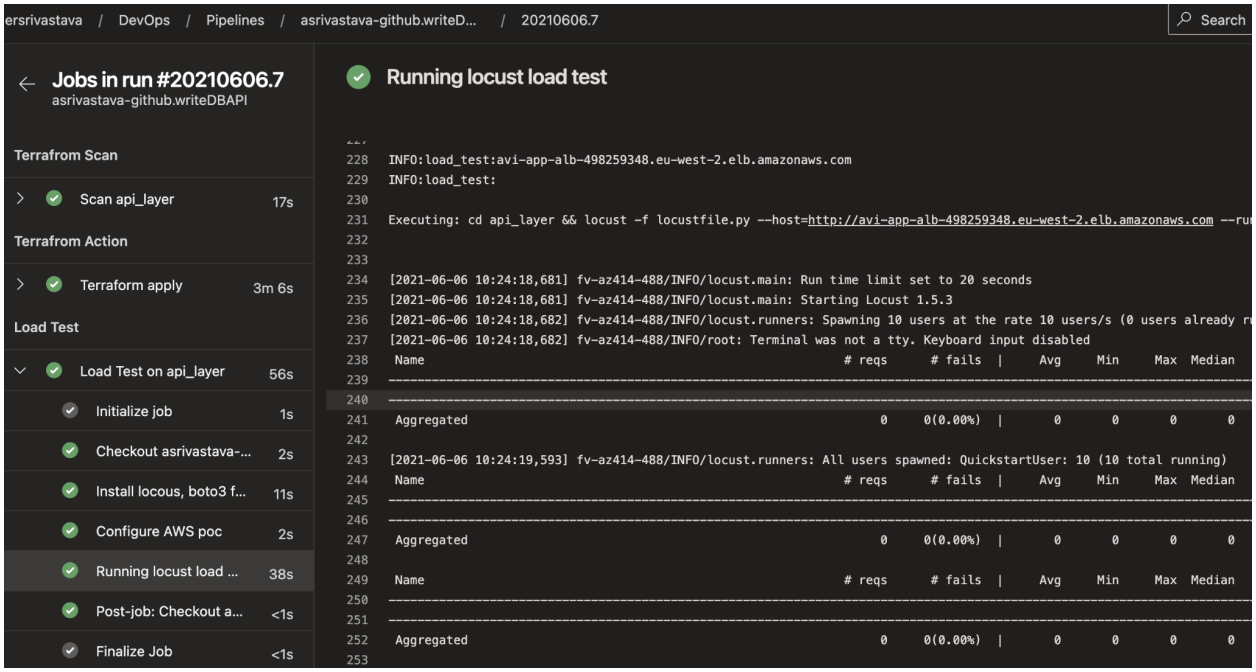
2. Perform Terraform deployment

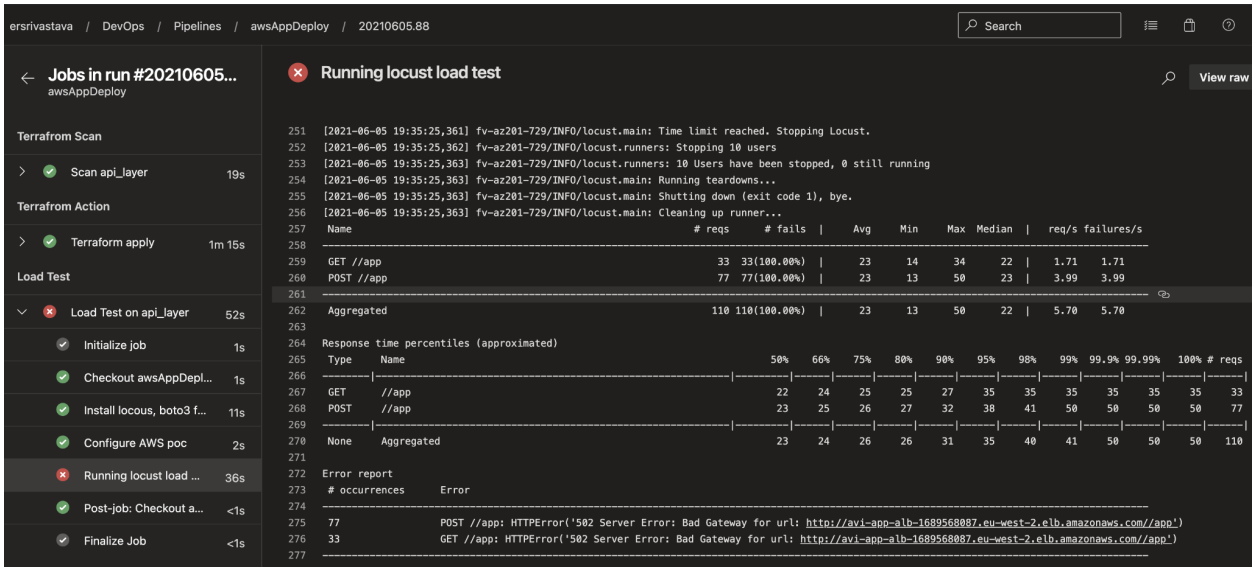



ersrivastava / DevOps / Pipelines / asrivastava-github.writeD... / 20210606.2
Jobs in run #20210606.2
asrivastava-github.writeDBAPI
Terrafrom Scan
Scan network_layer 26s
Terrafrom Action
Terraform apply 2m 32s
Initialize job <1s
Checkout asrivastava-... 2s
Install boto3 7s
Configure AWS poc 2s
apply network_la... 2m 18s
Post-job: Checkout a... <1s
Finalize Job <1s
Load Test
Load Test on network_layer
apply network_layer
913 aws_iam_policy_attachment.attach_vpc_flow_log_policy: Creation complete after 2
914 module.alb_in[0].aws_security_group_rule.cidr_sg_rule[0]: Creation complete aft
915 module.alb_out_std[0].aws_security_group_rule.sg_rule[0]: Creation complete aft
916 module.alb_out_std[1].aws_security_group_rule.sg_rule[0]: Creation complete aft
917 aws_dynamodb_table.app_db: Creation complete after 6s [id=avi-app-dynamo]
918 aws_vpc_endpoint.dynamoDB: Creation complete after 6s [id=vpce-066559c943b5ae9d
919 data.aws_prefix_list.private_dynamoDB: Reading...
920 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[3]: Creating...
921 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[1]: Creating...
922 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[0]: Creating...
923 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[2]: Creating...
924 data.aws_prefix_list.private_dynamoDB: Read complete after 0s [id=pl-b3a742da]
925 aws_security_group_rule.lambda_out_endpoint: Creating...
926 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[1]: Creation complete af
927 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[0]: Creation complete af
928 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[2]: Creation complete af
929 aws_network_acl_rule.private_nacl_rules_in_dynamoDB_EP[3]: Creation complete af
930 aws_security_group_rule.lambda_out_endpoint: Creation complete after 0s [id=sgr
931 aws_lb.lb: Still creating... [10s elapsed]
932 aws_lb.lb: Still creating... [20s elapsed]
933 aws_lb.lb: Still creating... [30s elapsed]
934 aws_lb.lb: Still creating... [40s elapsed]
935 aws_lb.lb: Still creating... [50s elapsed]
936 aws_lb.lb: Still creating... [1m0s elapsed]
937 aws_lb.lb: Still creating... [1m10s elapsed]
938 aws_lb.lb: Still creating... [1m20s elapsed]
939 aws_lb.lb: Still creating... [1m30s elapsed]
940 aws_lb.lb: Still creating... [1m40s elapsed]
941 aws_lb.lb: Still creating... [1m50s elapsed]
942 aws_lb.lb: Still creating... [2m0s elapsed]
943 aws_lb.lb: Creation complete after 2m1s [id=arn:aws:elasticloadbalancing:eu-wes
944
945 Apply complete! Resources: 42 added, 0 changed, 0 destroyed.



3. Perform load test using locust in case the api layer is deployed. (Need to work on DB connectivity) will complete the refactoring post discussion.





Technology consideration

Tools:

1. Terraform as Infrastructure as Code (Iac)
2. Git for version control (github)
3. Python for automation

AWS Platform:

- Route 53
- Internet Gateway
- Virtual Private Cloud (VPC) and Subnets
- Route Tables, NACL and Security Groups.
- VPC Endpoint for DynamoDB Service
- Application Load Balancer
- Lambda
- DynamoDB
- CloudWatch
- S3
- And other services like IAM, ALB listeners, Target groups etc

Amazon Web Service's Serverless platforms is suitable for such requirement's solution, because:

1. I can avoid platform maintenance overhead in terms of

    a. Patching
    b. Scanning
    c. Upgrade and updates
    d. Life cycle management
    e. From pay as you go to pay when it runs (in milliseconds.)

2. HIghly scalable and AWS managed service.

3. Flexibility in terms of scalability and elasticity.

Choosing NoSQL DB for this requirement because it's not asking to follow a strict schema to maintain and We are looking to perform any relational activity among tables hence NoSQL is suitable as it can scale.

Few clarifications as asked:

1. Provide details of your web API that will be used to submit a curl command (curl -X POST http:// <someip> /app) that will insert the DateTime stamp into your database. The api code should be well documented.

    curl -X POST http://avi-app-alb-859748445.eu-west-1.elb.amazonaws.com/app

Or

curl -X POST http://**34.240.221.237**/app

Or

curl -X POST http://**108.128.135.54**/app

A Records (IPs) for the service URL is highlighted below

avi-app-alb-859748445.eu-west-1.elb.amazonaws.com. 60 IN A **34.240.221.237**
avi-app-alb-859748445.eu-west-1.elb.amazonaws.com. 60 IN A **108.128.135.54**

```
Outputs:

albDNS = "avi-app-alb-859748445.eu-west-1.elb.amazonaws.com"
Avinashs-MBP:writeDBAPI avinashsrivastava$ dig avi-app-alb-859748445.eu-west-1.elb.amazonaws.com

; <<>> DiG 9.10.6 <<>> avi-app-alb-859748445.eu-west-1.elb.amazonaws.com
;; global options: +cmd
;; Got answer:
;; ->>HEADER<<- opcode: QUERY, status: NOERROR, id: 64355
;; flags: qr rd ra; QUERY: 1, ANSWER: 2, AUTHORITY: 0, ADDITIONAL: 1

;; OPT PSEUDOSECTION:
; EDNS: version: 0, flags:; udp: 512
;; QUESTION SECTION:
;avi-app-alb-859748445.eu-west-1.elb.amazonaws.com. IN A

;; ANSWER SECTION:
avi-app-alb-859748445.eu-west-1.elb.amazonaws.com. 60 IN A 34.240.221.237
avi-app-alb-859748445.eu-west-1.elb.amazonaws.com. 60 IN A 108.128.135.54

;; Query time: 32 msec
;; SERVER: 192.168.1.254#53(192.168.1.254)
;; WHEN: Wed May 26 07:18:21 BST 2021
;; MSG SIZE  rcvd: 110

Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://avi-app-alb-859748445.eu-west-1.elb.amazonaws.com/app
2021-05-26 06:21:45.660429
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://34.240.221.237/app
2021-05-26 06:22:08.074466
Avinashs-MBP:writeDBAPI avinashsrivastava$ curl -X POST http://108.128.135.54/app
2021-05-26 06:22:17.135785
Avinashs-MBP:writeDBAPI avinashsrivastava$
```

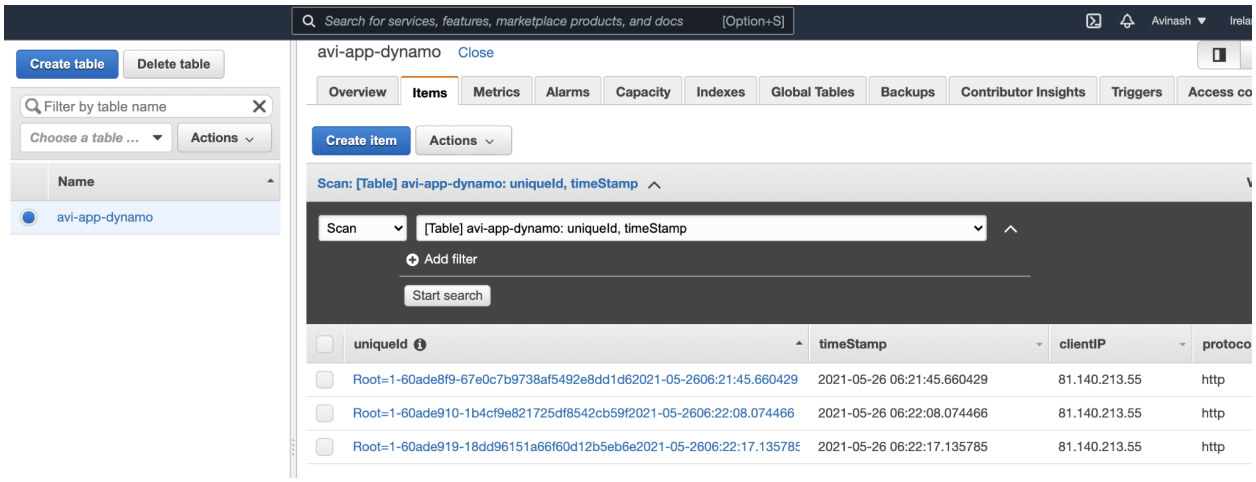
2. In addition, provide any automation for your backup/restore process you would implement.

   With AWS DynamoDB, which is AWS managed services We get feature of replication and backup as well, It can be easily enabled (Commented out in my code base at https://github.com/asrivastava-github/writeDBAPI/blob/main/main.tf#L298-L303). Additionally with the help of this feature in case of primary region failure once route 53 will start routing request to secondary region (Which is not part of code because of absence of hosted zone and domain for now) the secondary region API layer will be able to consume the replica/backup DynamoDB (We have chosen same region for DynamoDB replica and route 53 failover region for API layer)

3. Provide details of your Persistence Layer, with details of your cluster setup and configuration.

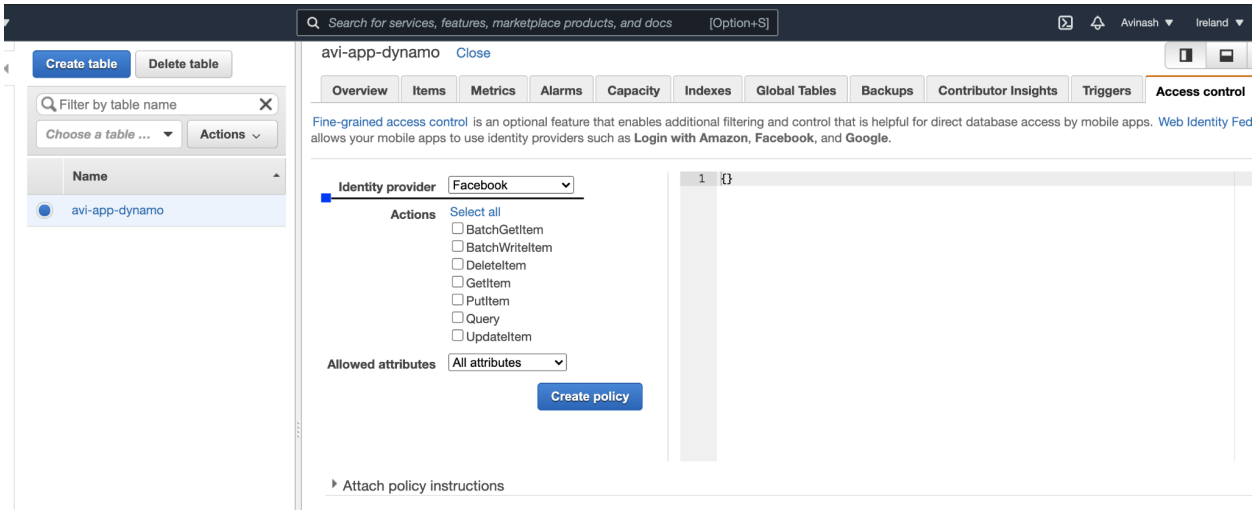
   AWS provides great compatibility between Lambda and DynamoDB. At the API layer (Lambda) I need to just mention the DynamoDB table name and DynamoDB endpoint while creating the client (Needed when Lambda is inside VPC and I would recommend it for security reasons) and voila a secure connectivity is established. There is AWS resource level trust defined between Lambda and DynamoDB using IAM policy for authentication, Hence I don't need to manage any credential (another plus). You can access DynamoDB tables with login to the AWS management console.

   Table and entries inside DynamoDB screen shots:



   Additionally you can have External authentication enabled using IDP but that is not applicable in this case.

   Identity Provider Screenshot:



4. Please explain how elastic your service is, what would be trigger points and how the scale up or down would actually work.

    - At API layer, for an Initial burst of traffic, Lambda function's concurrency (number of requests being served at any given time) can reach an initial level of between 500 to 3000 (varies per region)

    - After the initial burst, your function's **concurrency** can scale by an **additional 500** instances **each minute.** This continues until there are enough instances to serve all the requests, or a concurrency limit is reached.

      We can opt for Reserved Concurrency (guarantees the maximum number of concurrent instances) or Provisioned Concurrency (prepares number of execution environment for all requests)

Limitations

Serverless compute can not be suitable for all kinds of systems. The system design pattern largely varies based on use case.

If system has not be thoroughly understood and not designed adequately then Serverless Systems can face challenges like:

- Lambda throttling (If there is not enough concurrency to server all the requests, then additional requests will be throttled and will be retried)

- Function timeouts, dependent AWS resources/services might face throttling.
- Detailed Telemetry.

Useful link to refer:
https://docs.aws.amazon.com/lambda/latest/dg/gettingstarted-limits.html

Technical Debt

1. Segregation of Standard Network terraform (e.g. VPC, Endpoints, Route Tables, NACLs, ALB etc) and Application specific Infrastructure (ALB Target Groups, Lambda, DynamoDB etc)
2. Flexibility to deploy the additional endpoint which is dependent on the above point.
3. Creation of a pipeline on Azure DevOps for portability.
4. Demonstration of additional regional deployment which will require a hosted zone with the specific domain.
5. Test Automation

References

- https://docs.aws.amazon.com/vpc/latest/userguide/managed-prefix-lists.html
- https://docs.aws.amazon.com/general/latest/gr/rande.html
- https://docs.aws.amazon.com/lambda/latest/dg/configuration-vpc.html
- https://aws.amazon.com/blogs/aws/new-vpc-endpoints-for-dynamodb/
- https://docs.amazonaws.cn/en_us/amazondynamodb/latest/developerguide/vpc-endpoints-dynamodb.html
- https://docs.aws.amazon.com/amazondynamodb/latest/developerguide/vpc-endpoints-dynamodb-tutorial.html
- https://aws.amazon.com/blogs/networking-and-content-delivery/lambda-functions-as-targets-for-application-load-balancers/
- https://docs.aws.amazon.com/lambda/latest/dg/monitoring-functions-access-metrics.html
- https://docs.aws.amazon.com/lambda/latest/dg/runtimes-extensions-api.html
- https://docs.aws.amazon.com/amazondynamodb/latest/developerguide/GettingStarted.Python.03.html

- https://boto3.amazonaws.com/v1/documentation/api/latest/reference/services/dynamodb.html#service-resource
- https://docs.aws.amazon.com/general/latest/gr/aws-ip-ranges.html