Open5gs-k8s Overview

Purpose

Deploys the Open5GS core (3GPP R16 compliant) on Kubernetes.

Key Features

- **Microservices Architecture:** Each network function (NF) operates as an independent pod for modularity and scaling.
- **Network Slicing:** Configurable deployment supports two or more network slices.
- **Software-define Networking:** Leverages Open vSwitch and Multus CNI for software-defined networking, compatible with OpenFlow controllers (e.g., ONOS).
- **Extensive Testing:** Validated with open-source projects (UERANSIM, OpenAirInterface, srsRAN) and tested on real hardware, including SDRs and COTS UEs.

Deploying `open5gs-k8s`

Deployment involves 3 primary phases:

1. Core Deployment: Configure persistent storage and network attachment definitions. Deploy Open5GS core network functions in dedicated Kubernetes pods, along with the necessary services to facilitate inter-pod communication.

2. Subscriber Management: Add and manage subscribers through the Open5GS web-based GUI.

3. RAN Deployment: Deploy UERANSIM for simulated gNodeB and UE instances, facilitating end-to-end testing.

Before Starting Deployment

1. Navigate to the home directory

Use the `cd ~` command to ensure you're starting from your home directory.

2. Clone the `open5gs-k8s` repository

Use `git clone` to fetch the source code from the Monarch GitHub repository.

```
git clone https://github.com/niloysh/open5gs-k8s.git
cd open5gs-k8s
```

3. Set Up Your Testbed

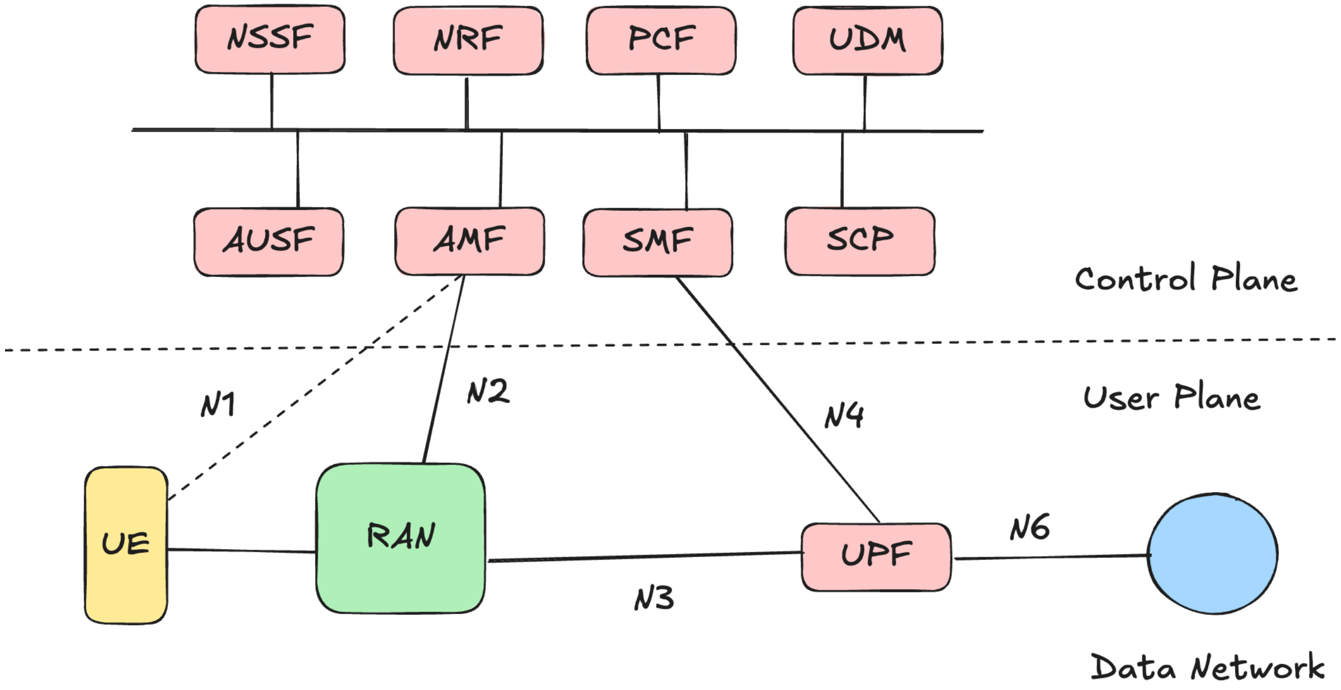
Make sure you've set up your testbed using the Testbed Automator. Verify that all pods are in the `RUNNING` state. You can quickly check the status of all pods with `kubectl get pods -A`.

Phase 1 - Core Deployment

5G Core Network

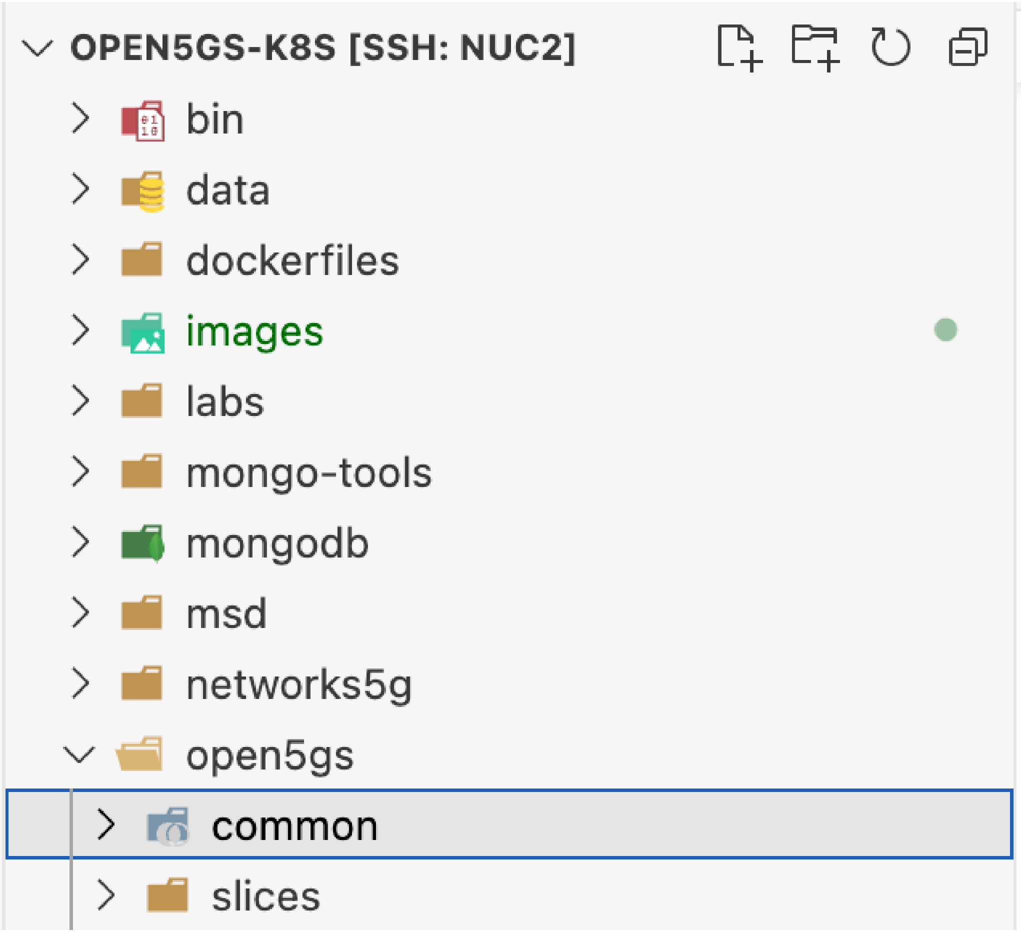
The 5G Core features a decomposed architecture, with each Network Function (NF) capable of registering for and subscribing to services offered by other NFs. **HTTP/2** is used as the primary communication protocol for these interactions.

The diagram below highlights key interfaces, including the `N2`, `N3`, and `N4` interfaces.



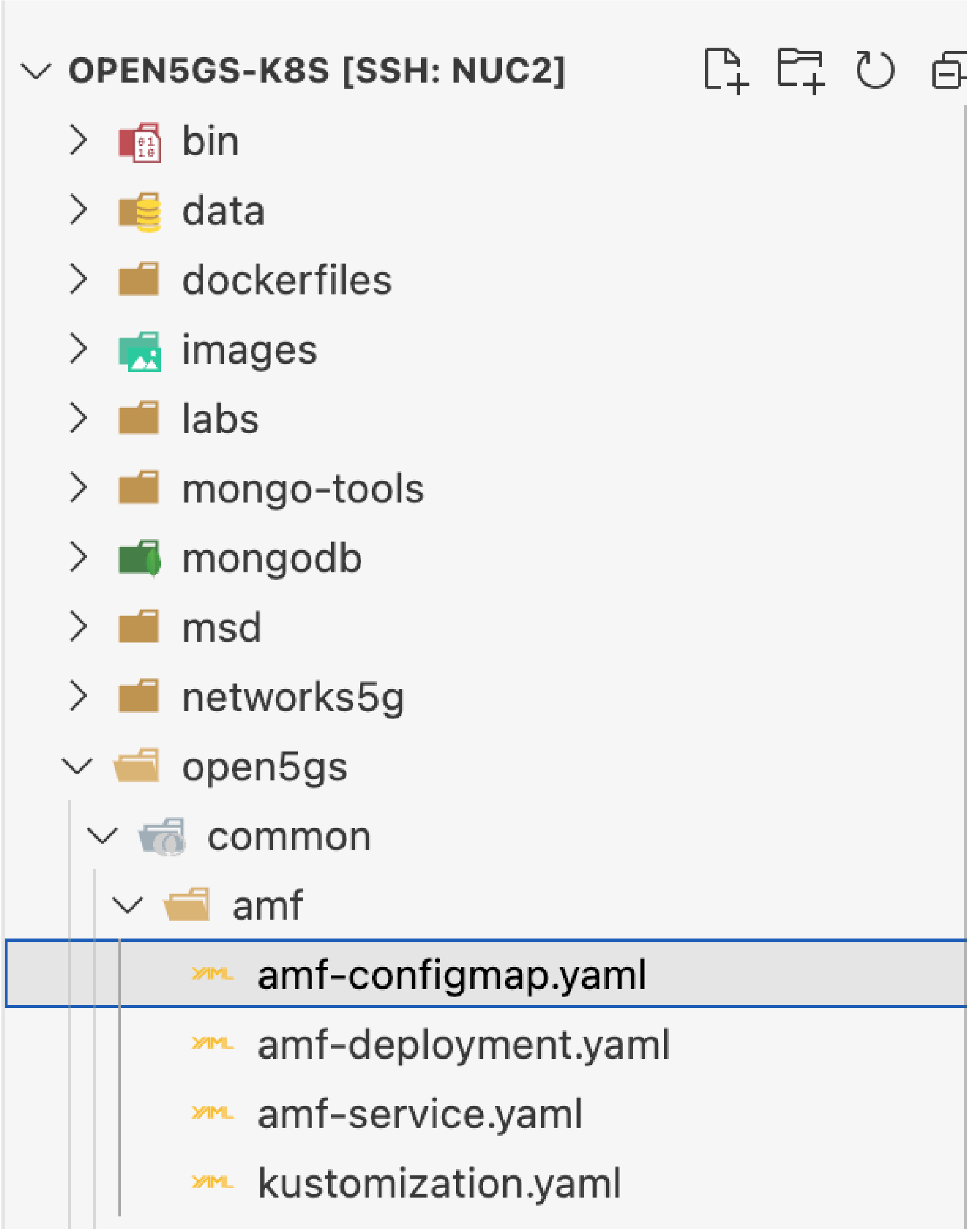
Core Deployment Configuration (1/6)

Navigate to the `~/open5gs-k8s/open5gs` directory, which contains two subdirectories: `common` and `slices`.



Core Deployment Configuration (2/6)

The `common` directory holds subdirectories for each network function (e.g., amf, smf). Each network function subdirectory (e.g., `amf`) contains a `deployment.yaml`, `service.yaml`, and `configmap.yaml`.



Core Deployment Configuration (3/6)

The `deployment.yaml` file defines the deployment for the network function, running the appropriate open5gs image.

```yaml
kind: Deployment
metadata:
  name: open5gs-amf  <==== name of the deployment
  labels:
    app: open5gs
    nf: amf
spec:
    ...
      containers:
      - image: ghcr.io/niloysh/open5gs:v2.6.4-aio  <==== container image
```

Core Deployment Configuration (4/6)

The `service.yaml` file configures the Kubernetes service for the network function, exposing the necessary ports, for example **port 80** for communication with other NFs over the service based interface (SBI).

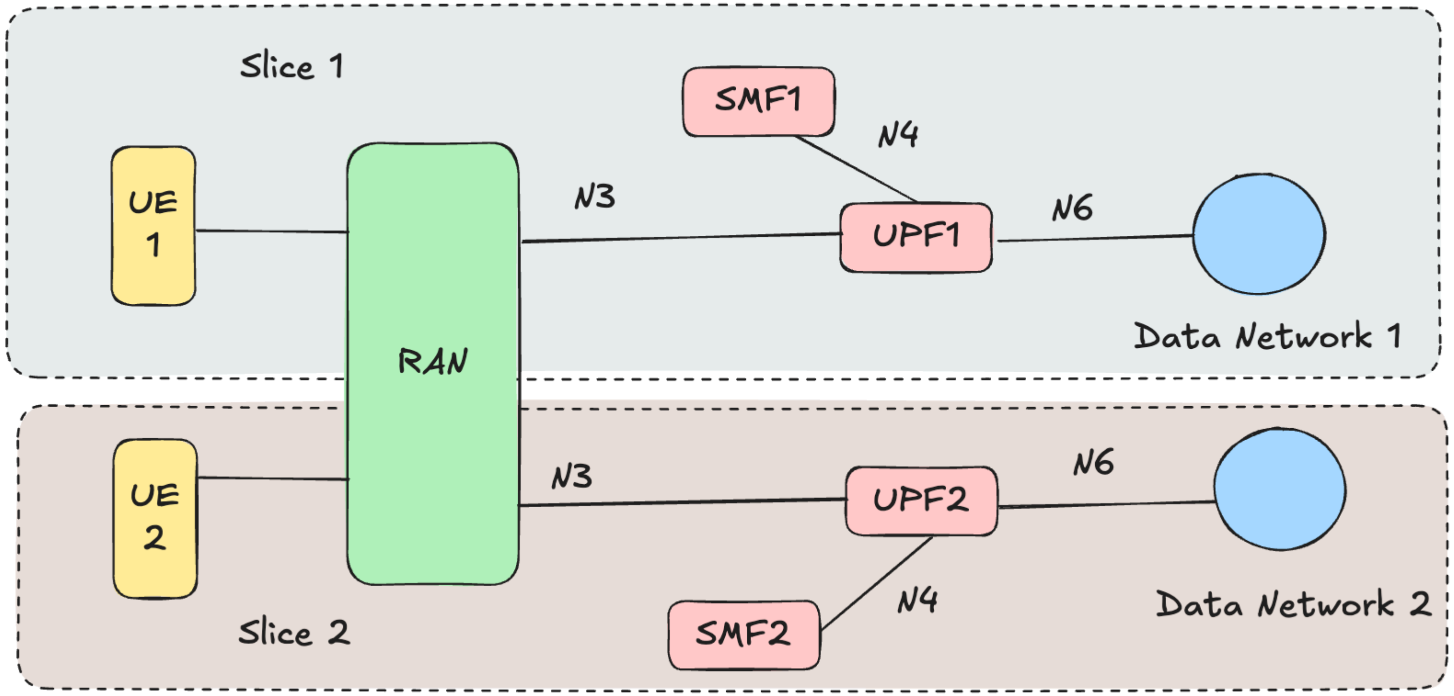
```
apiVersion: v1
kind: Service
metadata:
  name: amf-namf   <==== name of the service
  ...
spec:
  ports:
    - name: sbi
      port: 80    <==== exposed port
    ...
```

Core Deployment Configuration (5/6)

The `configmap.yaml` file contains configuration settings specific to the network function. For example, the AMF configmap contains the supported **PLMN**.

```yaml
kind: ConfigMap
metadata:
  name: amf-configmap
  ...
data:   <==== network function specific configuration
    ...
      plmn_support:
        - plmn_id:
            mcc: 001
            mnc: 01
 ...
```

Core Deployment Configuration (6/6)



The `slices` directory holds subdirectories for each slice. Each slice subdirectory in turn contains **UPF** and **SMF** NF subdirectories, consisting of `deployment`, `service`, and `configmap` files.

There are two slices defined, as shown in the figure.

Deploying the Core Network

1. Run the deployment script

```
./deploy-core.sh
```

This script will automatically perform the following tasks:

- **Setup persistent storage**: Deploy MongoDB and setup local persistence to store subscriber data and NF profile data.
- **Setup networking**: Deploy Multus network attachment definitions (NADs) for using OVS-CNI for the `N2`, `N3` and `N4` networks.
- **Deploy Kubernetes resources**: Deploy `deployments`, `configmaps`, and `services` for each network function in the core.

Verifying Core Deployment (1/2)

All `open5gs-k8s` components are deployed in the `open5gs` namespace. While the core is being deployed, you can use `kubectl get pods -n open5gs` with the `watch` command in a **new terminal** to see the progress.

```
watch kubectl get pods -n open5gs
```

```
Every 2.0s: kubectl get pods -n open5gs

NAME                              READY   STATUS    RESTARTS   AGE
mongodb-0                         1/1     Running   0          21m
open5gs-amf-777756df7f-m8vdx      1/1     Running   0          21m
open5gs-ausf-595c98fc96-sst6t     1/1     Running   0          21m
open5gs-bsf-585446f69b-wj45c      1/1     Running   0          21m
open5gs-nrf-7d55d67687-shlt5      1/1     Running   0          21m
open5gs-nssf-7dd8c874c5-g2hvp     1/1     Running   0          21m
```

It can take a while for all pods to reach the `RUNNING` stage.

Verifying Core Deployment (2/2)

Once all the pods are in the `RUNNING` stage, we can take a look at the logs.

For example, we can look at the AMF logs as follows:

```
kubectl logs deployments/open5gs-amf -n open5gs
```

```
11/14 04:56:14.187: [app] INFO: Configuration: '/open5gs/config/amfcfg.yaml' (../lib/app/ogs-i
11/14 04:56:14.187: [app] INFO: File Logging: '/open5gs/install/var/log/open5gs/amf.log' (../l
11/14 04:56:14.193: [metrics] INFO: metrics_server() [http://0.0.0.0]:9090 (../lib/metrics/pro
11/14 04:56:14.193: [sbi] INFO: NF Service [namf-comm] (../lib/sbi/context.c:1812)
11/14 04:56:14.194: [sbi] INFO: nghttp2_server() [http://10.244.0.122]:80 (../lib/sbi/nghttp2-
11/14 04:56:14.194: [amf] INFO: ngap_server() [10.10.3.200]:38412 (../src/amf/ngap-sctp.c:61)
11/14 04:56:14.194: [sctp] INFO: AMF initialize...done (../src/amf/app.c:33)
```

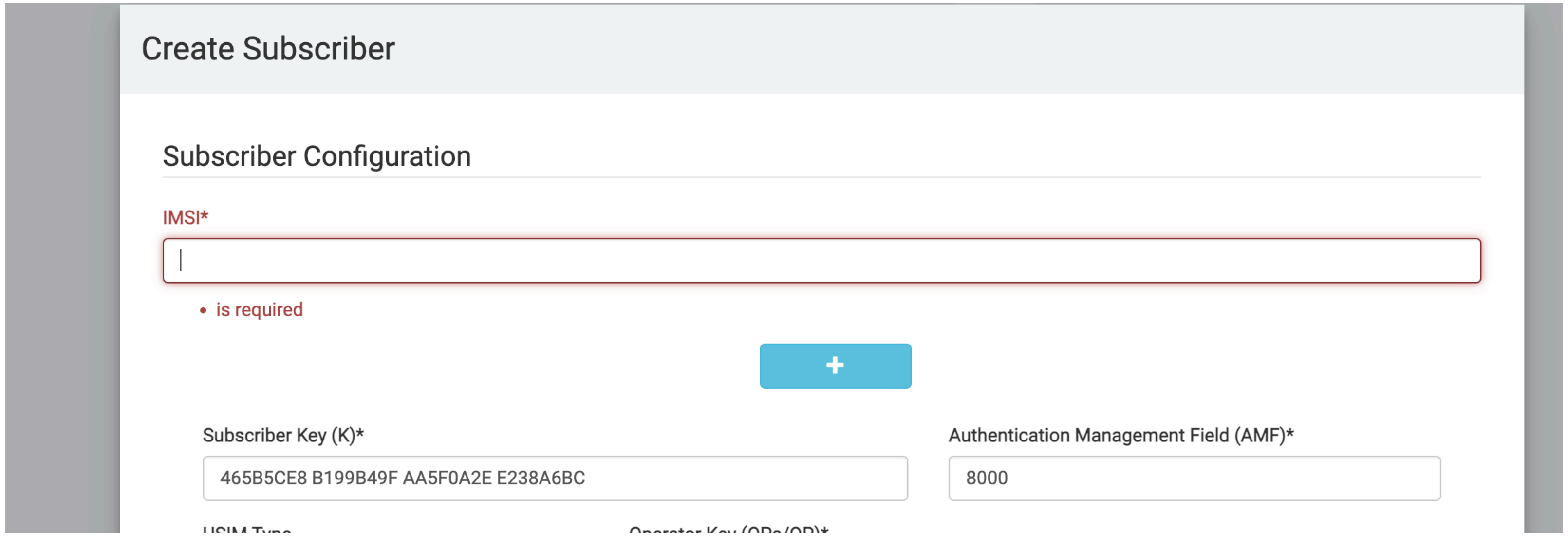
You should see logs similar to those seen above, e.g., stating `AMF initialize done`.

Phase 2 - Subscriber Management

Adding Subscribers using the Open5GS GUI (1/4)

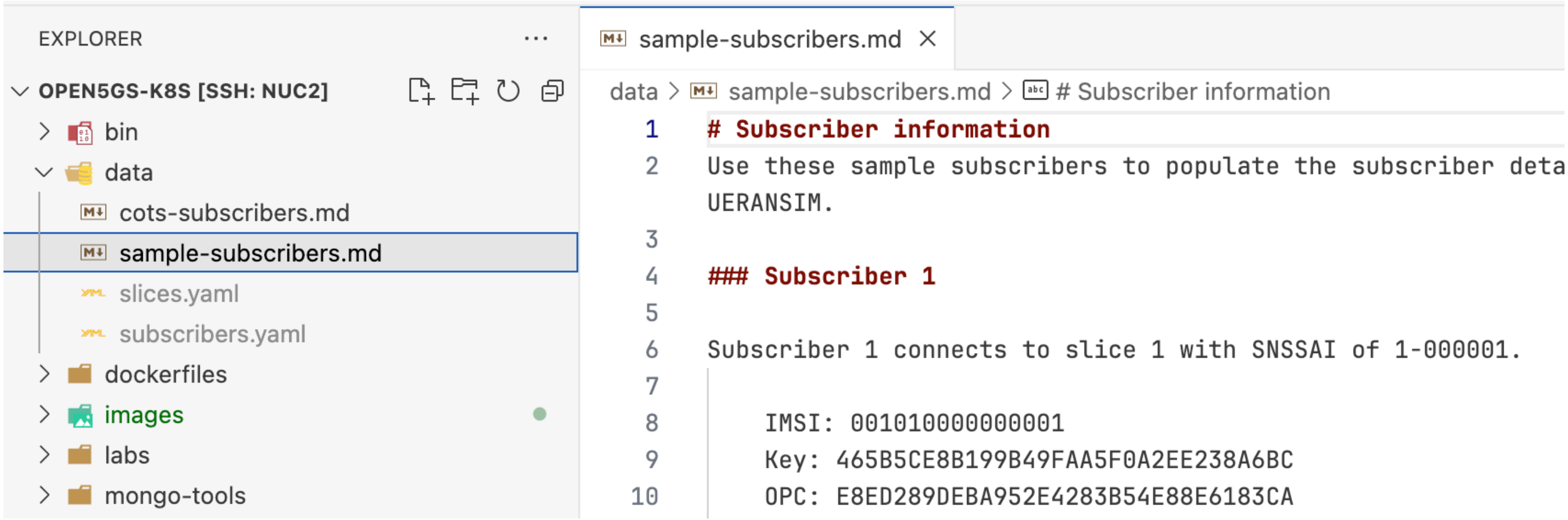
Now that our core has been deployed, let's add some subscribers using the Open5GS GUI.

Navigate to http://localhost:30300/ and login with credentials: **username:** `admin` and **password:** `1423`. We can now add subscribers as shown.



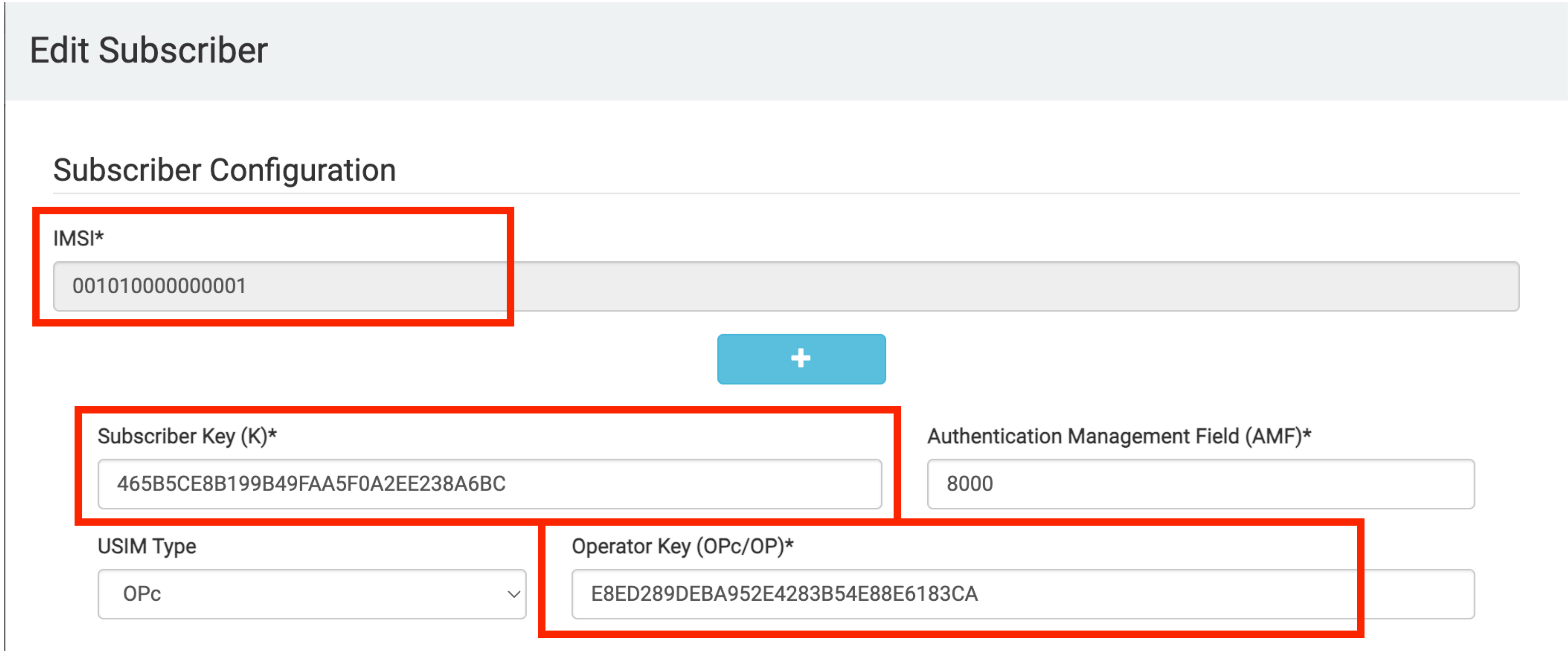
Adding Subscribers using the Open5GS GUI (2/4)

Navigate to `data/sample-subscribers.md` in VSCode. You should see two subscribers, `Subscriber 1` and `Subscriber 2`, one for each slice.



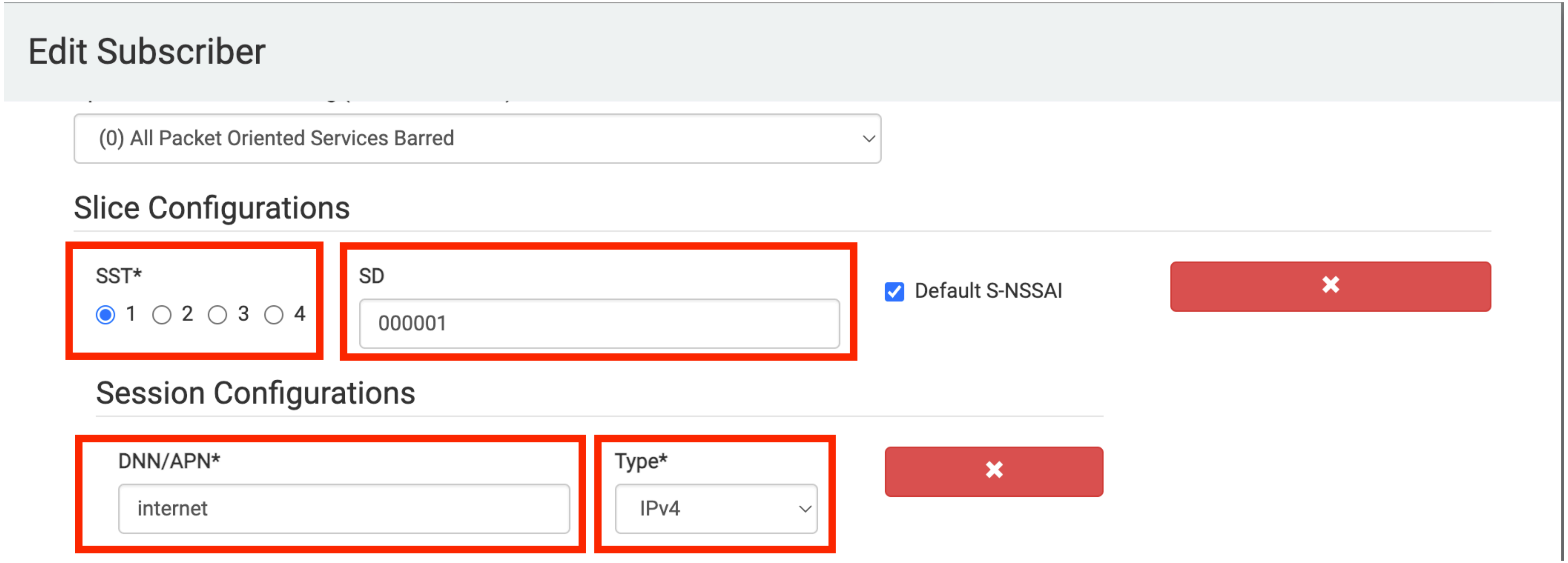
Adding Subscribers using the Open5GS GUI (3/4)

Use the GUI to **fill out the fields** given in `data/sample-subscribers.md` for each subscriber, leaving other fields at their default values.



Adding Subscribers using the Open5GS GUI (4/4)

You can scroll down to get to `SST`, `SD` etc. Don't forget to set `Type` to `ipv4`.



Note: Do the same for Subscriber 2.

Phase 3 - RAN Deployment

Deploying the RAN

1. Run the deployment script

```
./deploy-ran.sh
```

This script will automatically perform the following tasks:

- **Deploy the UERANSIM gNB**: Deploy the `deployment`, `service` and `configmap` for the UERANSIM gNodeB.
- **Deploy the UERANSIM UEs**: Deploy two simulated UEs, one for each slice. These UEs have been pre-configured with the subscriber information you added earlier.

Verifying the RAN Deployment (1/3)

In your terminal where the `kubectl get pods -n open5gs` command is running, you should observe a new pods for UERANSIM as shown below:

```
ueransim-gnb-64679ddbb7-9pzv5    1/1    Running   0          21s
ueransim-ue1-5c865d4878-vhkb6    1/1    Running   0          15s
ueransim-ue2-579fdd8555-fc6t2    1/1    Running   0          15s
```

We can also check the AMF logs again. You should see `Number of AMF-Sessions is now 2` indicating 2 UEs connected.

```
INFO: [imsi-001010000000001] Registration complete (../src/amf/gmm-sm.c:2146)
INFO: [imsi-001010000000001] Configuration update command (../src/amf/nas-path.c:612)
INFO:     UTC [2024-11-14T05:38:24] Timezone[0]/DST[0] (../src/amf/gmm-build.c:559)
INFO:     LOCAL [2024-11-14T05:38:24] Timezone[0]/DST[0] (../src/amf/gmm-build.c:564)
INFO: [Added] Number of AMF-Sessions is now 2 (../src/amf/context.c:2571)
INFO: UE SUPI[imsi-001010000000001] DNN[internet] S_NSSAI[SST:1 SD:0x1] smContextRef [
INFO: SMF Instance [c9272e86-a244-41ef-8097-1372dade42f7] (../src/amf/gmm-handler.c:12
INFO: [imsi-001010000000001:1:11][0:0:NULL] /nsmf-pdusession/v1/sm-contexts/{smContext
```

Verifying the RAN Deployment (2/3)

Next, let's look at the gNodeB logs.

```
kubectl logs deployments/ueransim-gnb -n open5gs
```

Scroll to the top. You should see a successful `NG setup procedure` when the gNodeB connects to the AMF.

```
[sctp] [info] Trying to establish SCTP connection... (10.10.3.200:38412)
[sctp] [info] SCTP connection established (10.10.3.200:38412)
[sctp] [debug] SCTP association setup ascId[14742]
[ngap] [debug] Sending NG Setup Request
[ngap] [debug] NG Setup Response received
[ngap] [info] NG Setup procedure is successful
```

Verifying the RAN Deployment (3/3)

To verify the RAN deployment, check the UE logs:

1. View Logs: Use the following command to view the logs for the ue1 pod:

```
kubectl logs deployments/ueransim-ue1 -n open5gs
```

2. Check for PDU Session: Look for a successful `PDU Session Establishment` message in the logs. You should also see the `TUN` interface being set up.

```
[debug] Sending PDU Session Establishment Request
[debug] UAC access attempt is allowed for identity[0], category[MO_sig]
[debug] Configuration Update Command received
[debug] PDU Session Establishment Accept received
[info] PDU Session establishment is successful PSI[1]
[info] Connection setup for PDU session[1] is successful, TUN interface[uesimtun0, 10.41.0.3] is up.
```

3. Check IP Address: The `10.41.X.X` IP address displayed in the logs is the IP assigned to the UE.

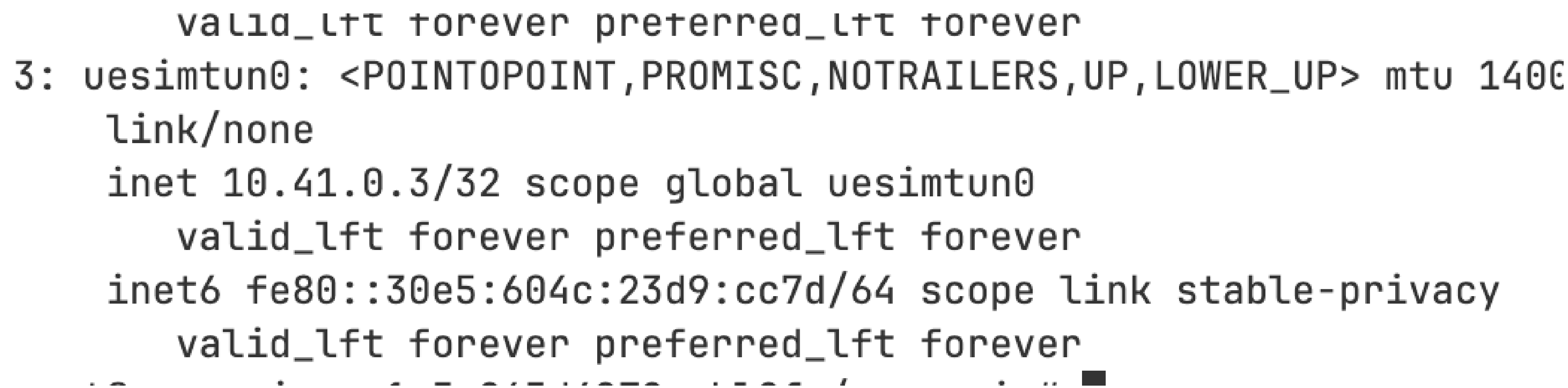
Sending Traffic through the Slices (1/3)

With the RAN deployment complete, it's time to send traffic through the slices.

1. Access UE Pod: Open a shell on the `ue1` pod with the following command:

```
kubectl exec -it deployments/ueransim-ue1 -n open5gs -- /bin/bash
```

2. Verify Interface: Inside the pod, run `ip a` to check the interfaces. Look for the `uesimtun0` interface, which indicates the active PDU session and connection to the 5G network.



```
        valid_lft forever preferred_lft forever
3: uesimtun0: <POINTOPOINT,PROMISC,NOTRAILERS,UP,LOWER_UP> mtu 140
    link/none
    inet 10.41.0.3/32 scope global uesimtun0
       valid_lft forever preferred_lft forever
    inet6 fe80::30e5:604c:23d9:cc7d/64 scope link stable-privacy
       valid_lft forever preferred_lft forever
```

Sending Traffic through the Slices (2/3)

To send traffic through the slice, perform a ping test to `google.ca` using the `uesimtun0` interface:

```
ping -I uesimtun0 www.google.ca
```

You should see output similar to the screenshot below, indicating successful traffic transmission through the slice.

```
root@ueransim-ue1-5c865d4878-qbl8f:/ueransim# ping -I uesimtun0 www.google.ca
PING www.google.ca (142.251.32.67) from 10.41.0.3 uesimtun0: 56(84) bytes of data.
64 bytes from yyz12s07-in-f3.1e100.net (142.251.32.67): icmp_seq=1 ttl=47 time=6.67 ms
64 bytes from yyz12s07-in-f3.1e100.net (142.251.32.67): icmp_seq=2 ttl=47 time=6.41 ms
64 bytes from yyz12s07-in-f3.1e100.net (142.251.32.67): icmp_seq=3 ttl=47 time=6.27 ms
64 bytes from yyz12s07-in-f3.1e100.net (142.251.32.67): icmp_seq=4 ttl=47 time=6.61 ms
64 bytes from yyz12s07-in-f3.1e100.net (142.251.32.67): icmp_seq=5 ttl=47 time=6.87 ms
```

Sending Traffic through the Slices (3/3)

To confirm the pings are routed through the 5G network, follow these steps:

1. Access UPF1: In a **new terminal**, open a shell on the UPF1 pod (connected to slice1):

```
kubectl exec -it deployments/open5gs-upf1 -n open5gs -- /bin/bash
```

2. Check Interfaces: Run `ip a` to see the tunnel interface representing the N3 GTP-U endpoint. Look for the `ogstun` interface with an IP address (e.g., 10.41.0.1/16).

3. Capture Traffic: Use `tcpdump` to capture packets on the tunnel interface:

```
tcpdump -i ogstun
```

You should see ping traffic like this:

```
18:34:29.550600 IP vpn-uw-ft-10-41-0-2 > yyz10s17-in-f3.1e100.net: ICMP echo request
```

Next Steps

Congratulations!

You've successfully done the following:

- Completed the deployment of 5G core on Kubernetes.
- Learned how to add subscribers to the core network.
- Connected simulated gNodeB and UEs to network slices and sent traffic through them.

What's Next?

Dive deeper into the core configuration by continuing to Lab 1.