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TECHNOLOGY CENTER

**5G**

## **Setup Free5GC and UERANSIM Virtual Environment**



*This material is based upon work supported by the National Science Foundation under Grant No. 1700530. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.*



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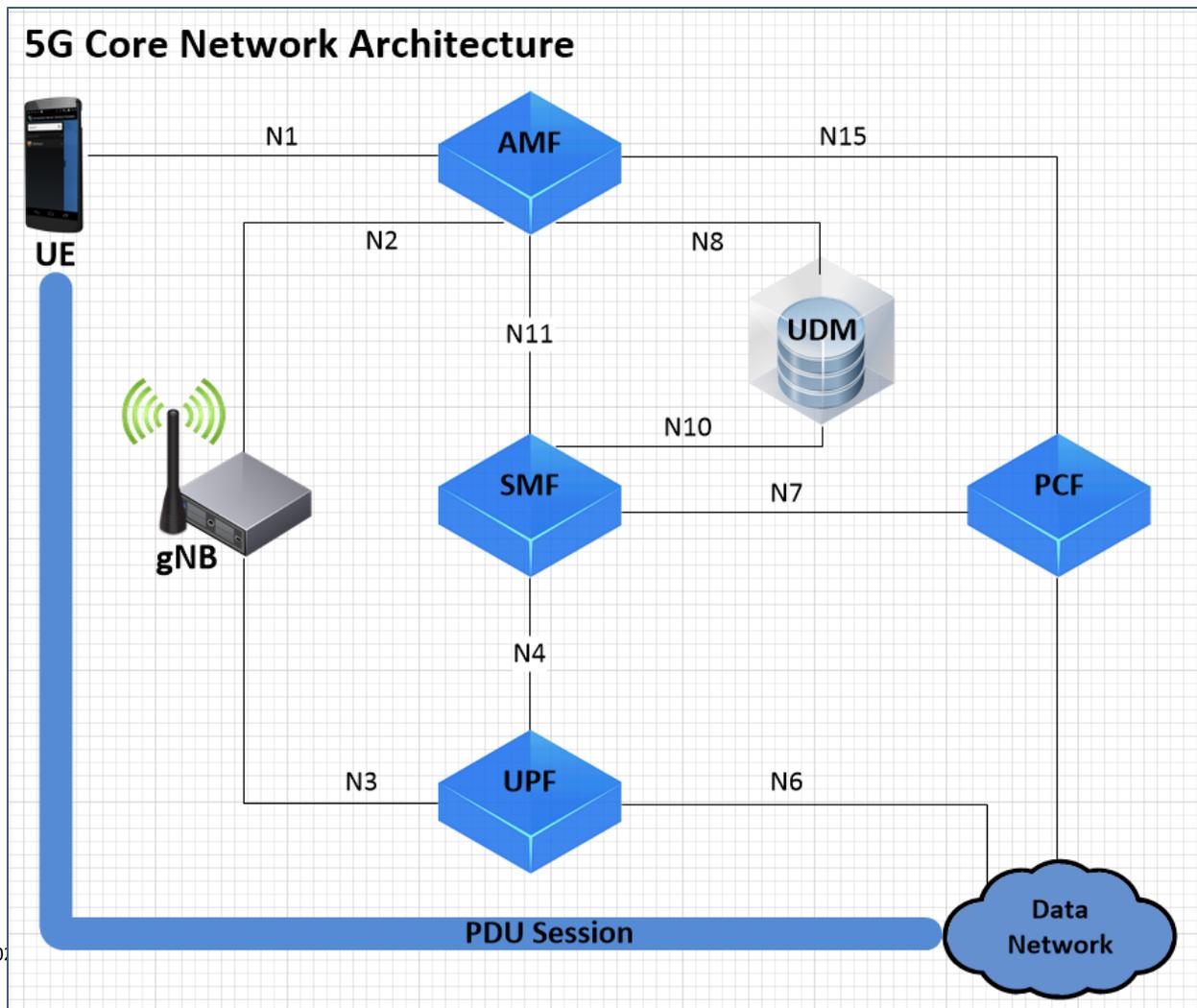
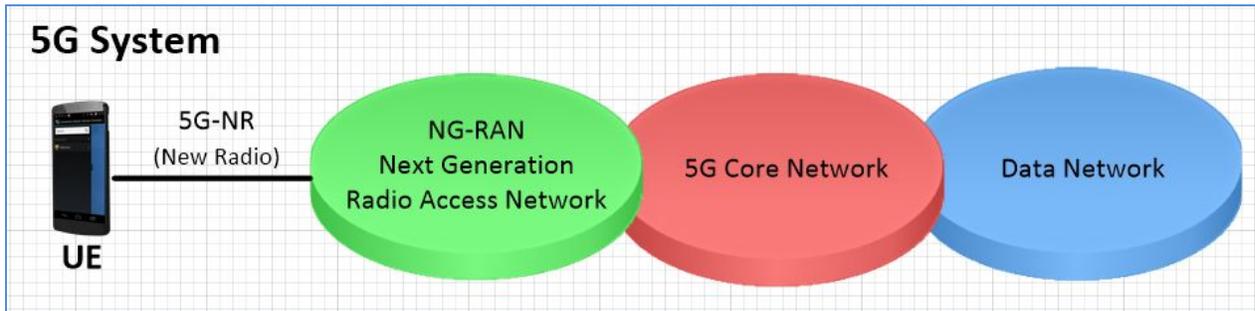
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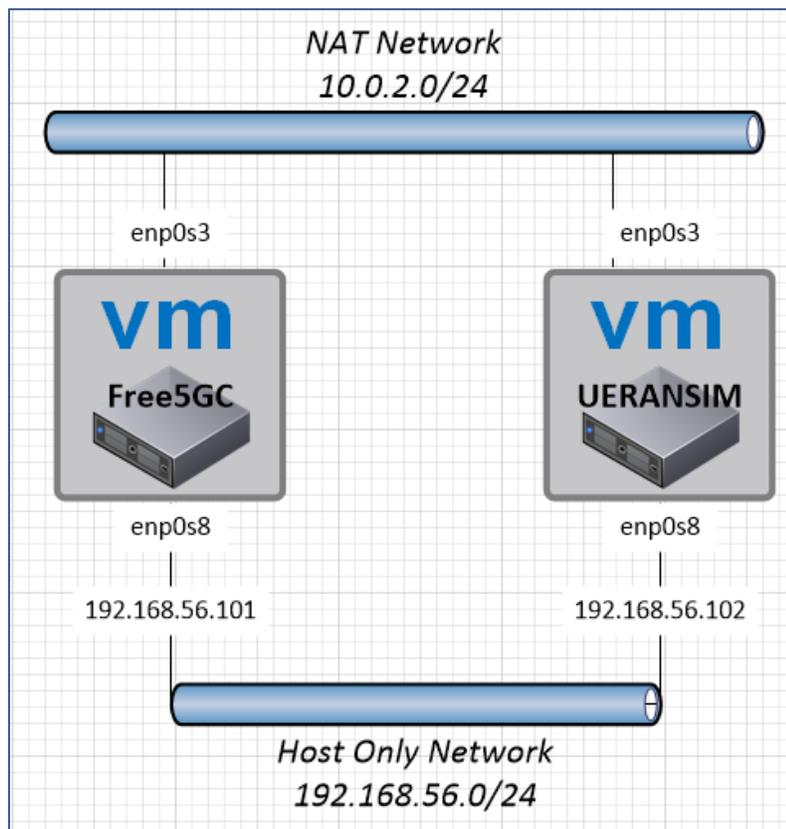
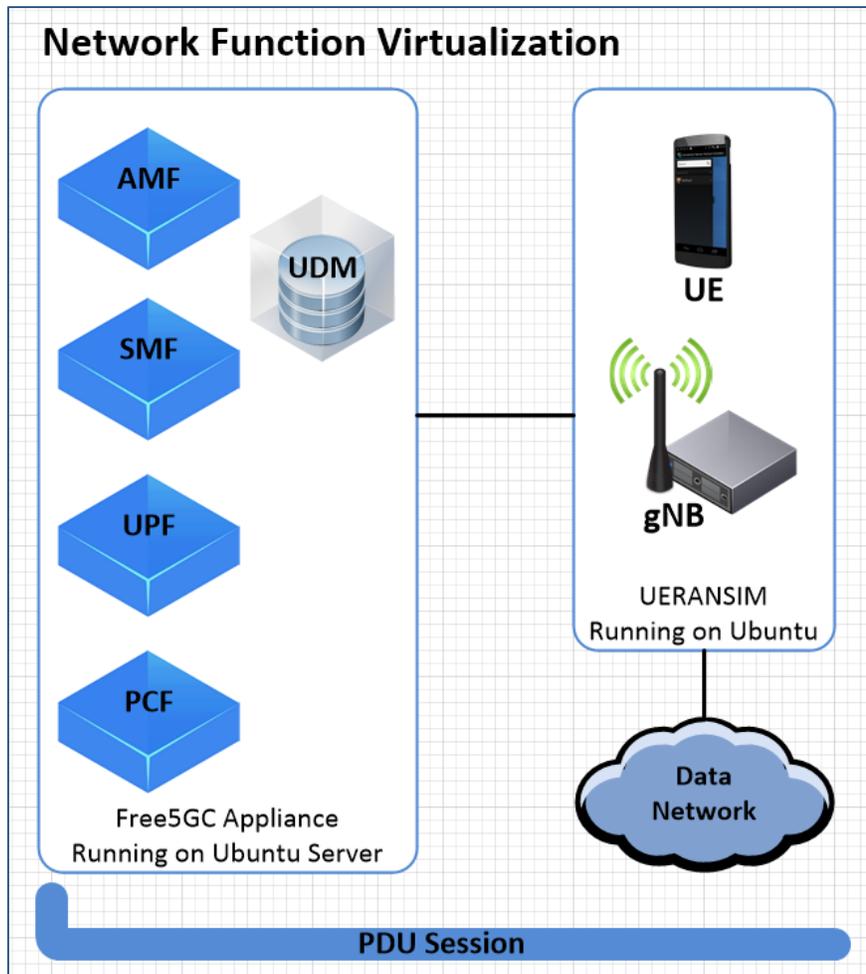
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## Introduction

As 5<sup>th</sup> Generation Mobile Core networks (5G) begin to be deployed, it will require a high level of support from the users, subscribers and developers. The free5GC appliance provides an open source implementation of the 5G Core Network (5GC) as defined in 3GPP Release 15 and beyond.

## Lab Topology





## 1 Prepare the 5G Virtual Environment

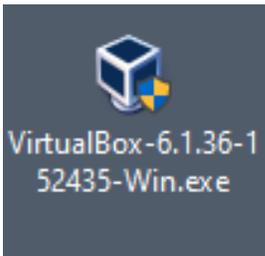
In this task, you will prepare the *Free5GC Core Simulator* and *UERANSIM* virtual machines.



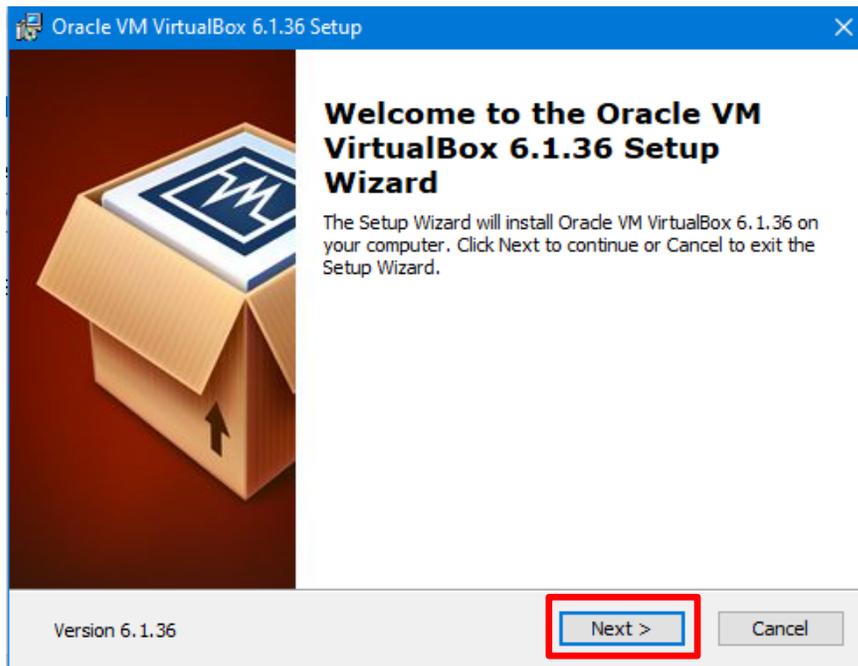
The following steps are written for Windows. If you using a Mac, the steps will be the same, but the screens will be different.

### 1.1 Install VirtualBox

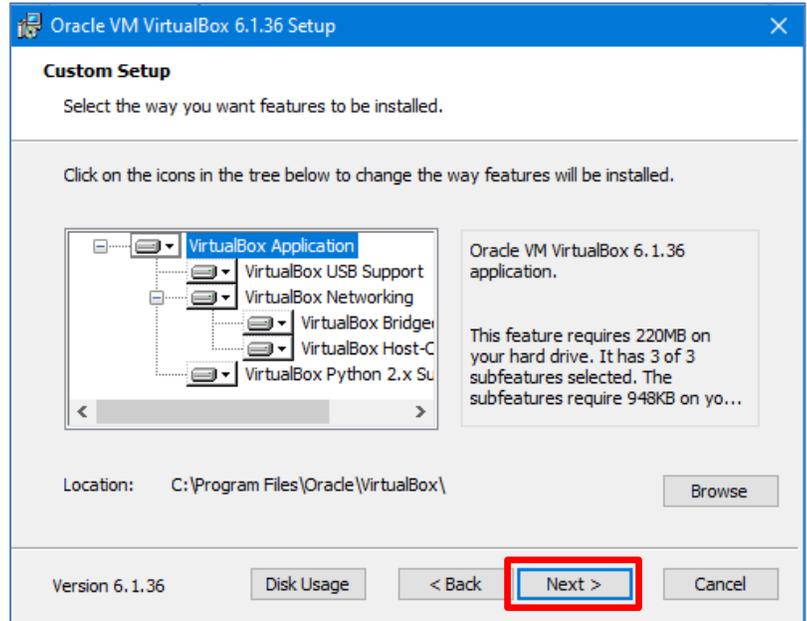
1. Copy the **VirtualBox** installer to your desktop:  
Windows: VirtualBox-6.1.36-152435-Win.exe  
MacOS: VirtualBox-6.1.36-152435-OSX.dmg
2. Double-click on the installer to start the installation.



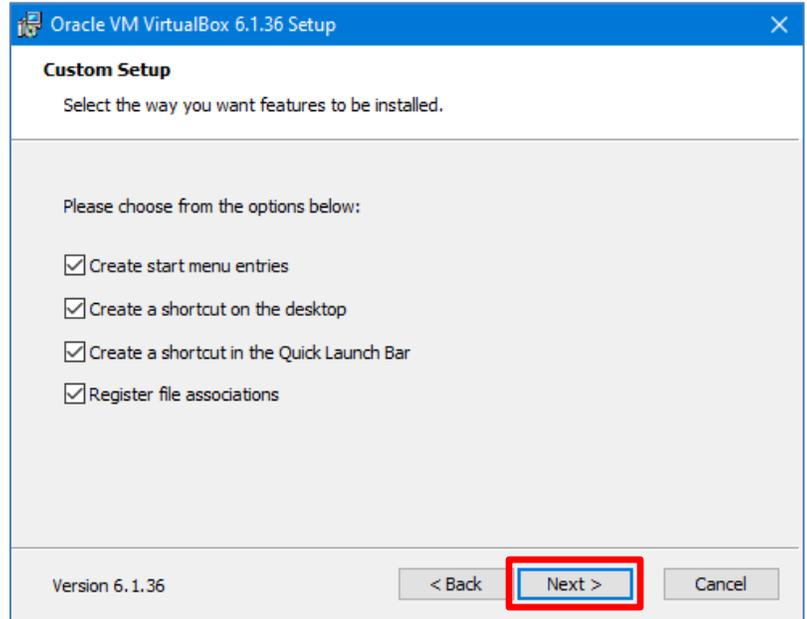
3. On the **Welcome** window, click **Next**



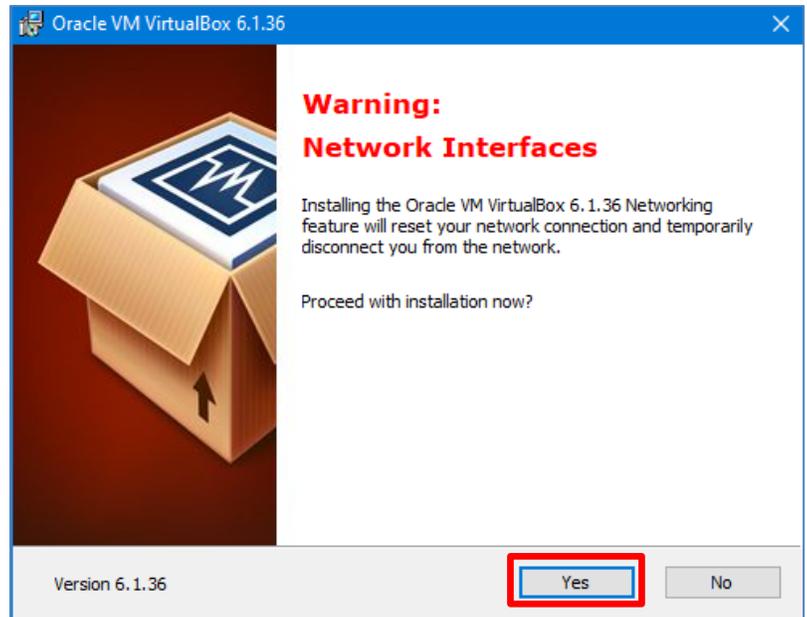
- 4. On the **Custom Setup / Install Features** window, accept the default settings and click **Next**



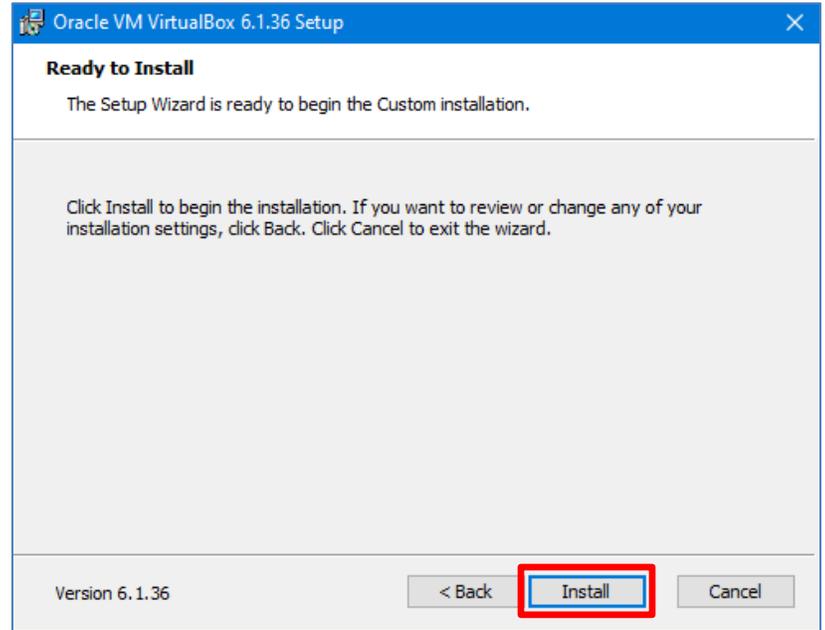
- 5. On the **Custom Setup / Options** window, accept the default settings and click **Next**



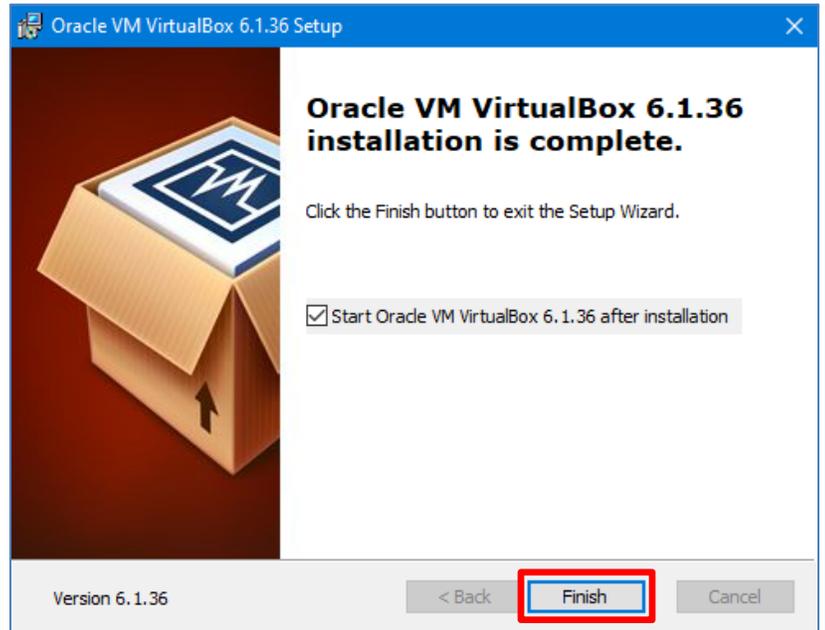
- 6. On the **Warning: Network Interfaces** window, click **Yes**.



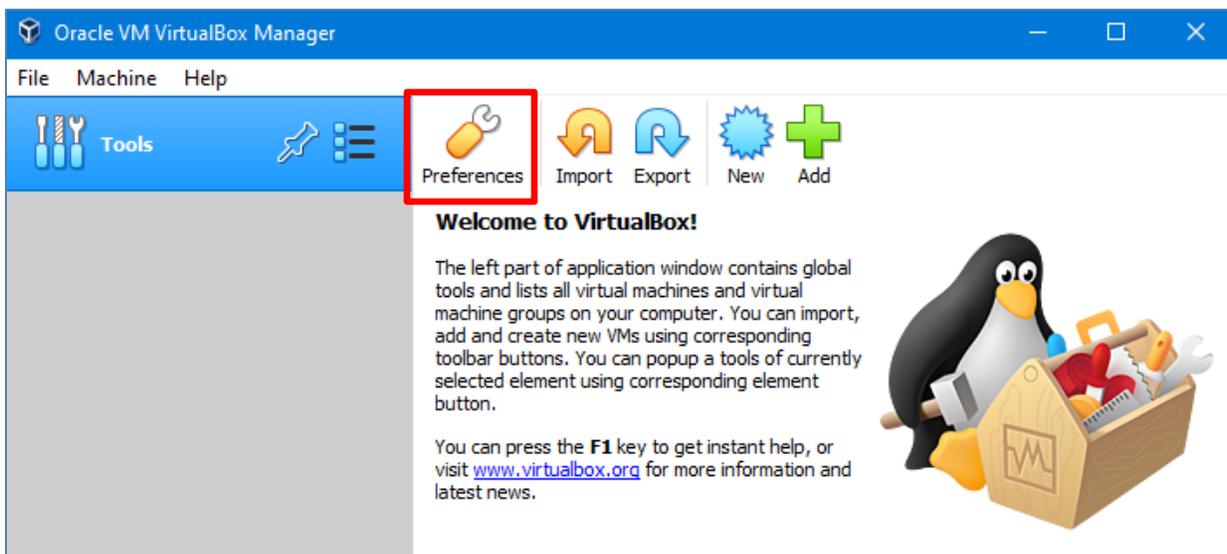
7. On the **Ready to Install** window, click **Install**.



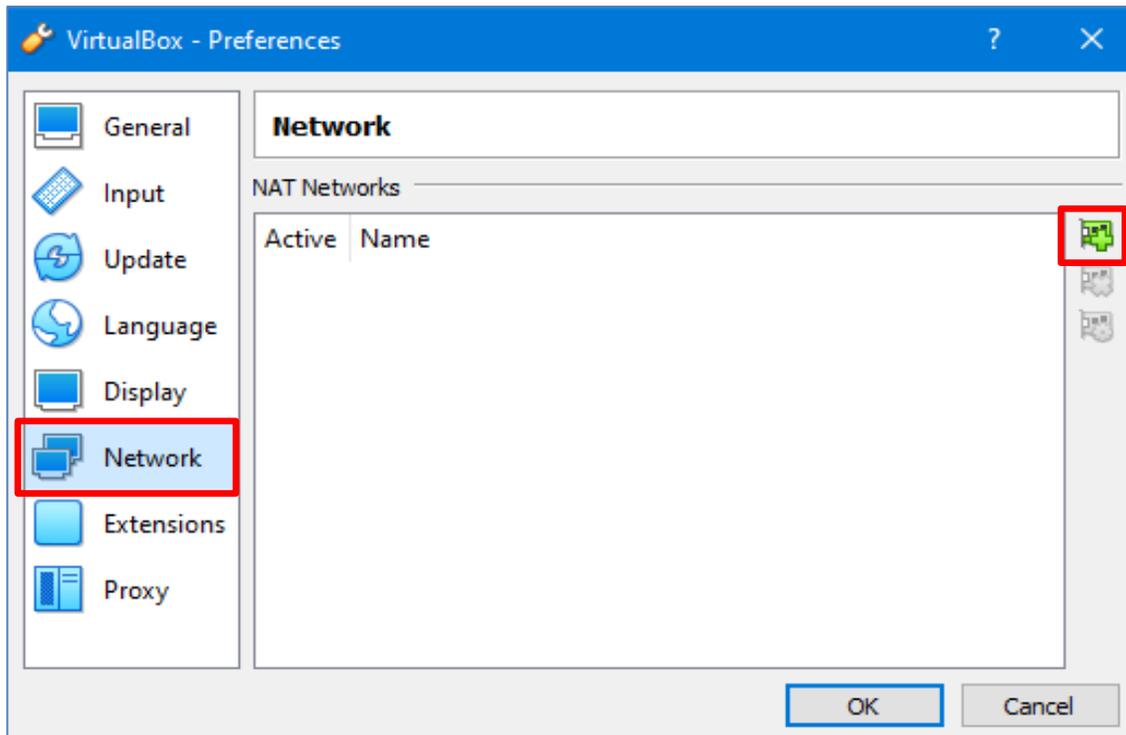
8. It will take several minutes to complete the installation. On the **VirtualBox Installation is Complete** window, make sure the **Start Oracle VM Virtualbox 6.1.36 After Installation box** is checked and click on **Finish**



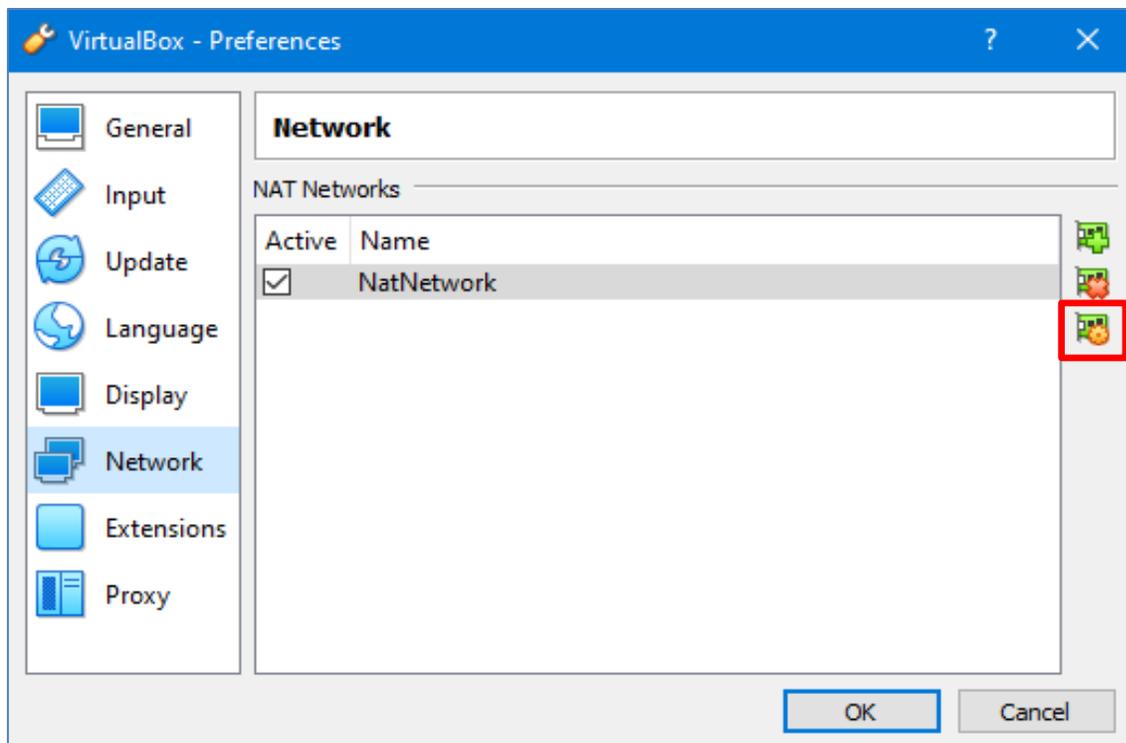
9. On the **Oracle VM VirtualBox Manager**, click the **Preferences** button:



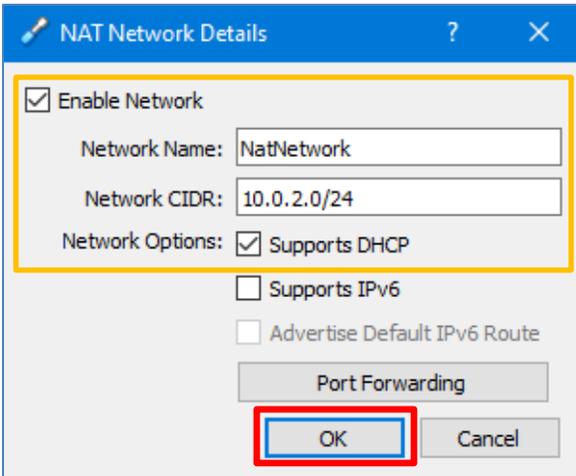
10. On the **VirtualBox – Preferences** window, click on **Network** on the left pane, then click the Adds New NAT Network icon on the right:



11. With the **NatNetwork** selected, click the **Edits Selected NAT Network** icon.



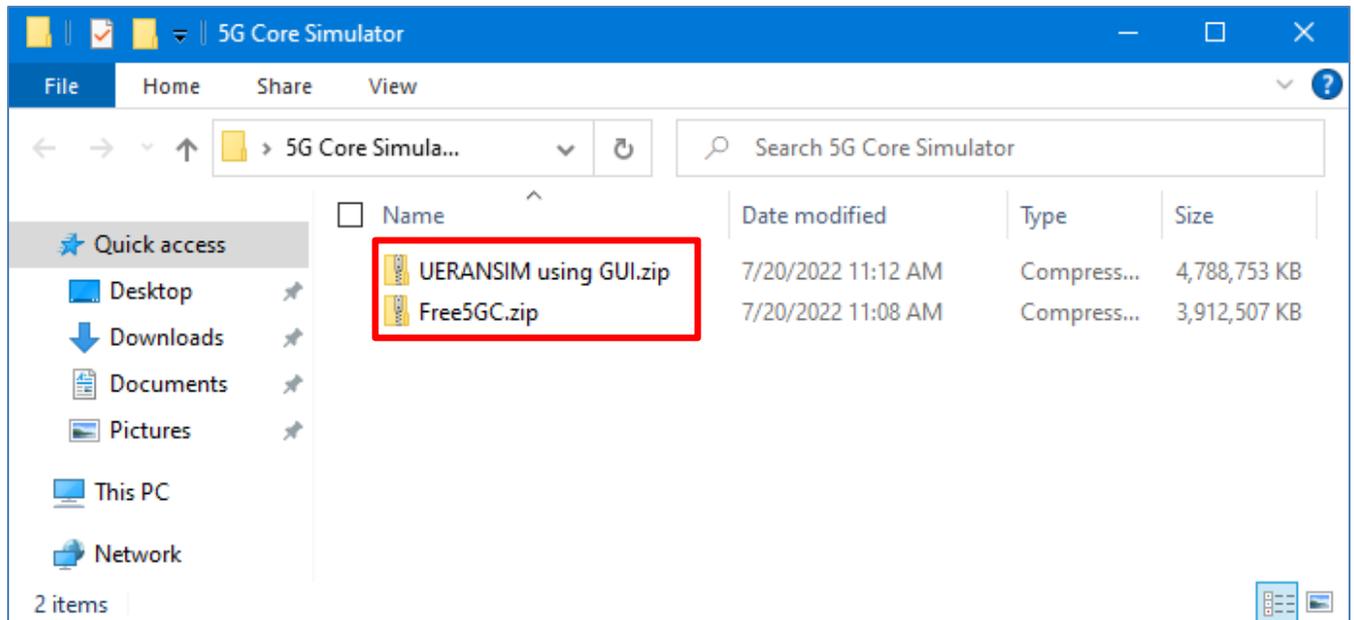
12. On the **NAT Network Details** window, confirm these settings and click **OK**.



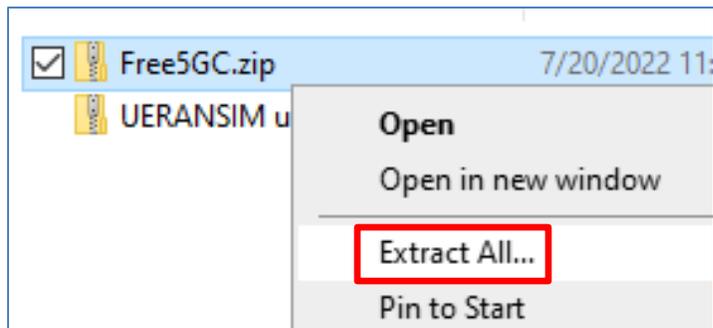
13. Back on the **VirtualBox – Preferences** window, click **OK**.

## 1.2 Get 5G Virtual Machine Images

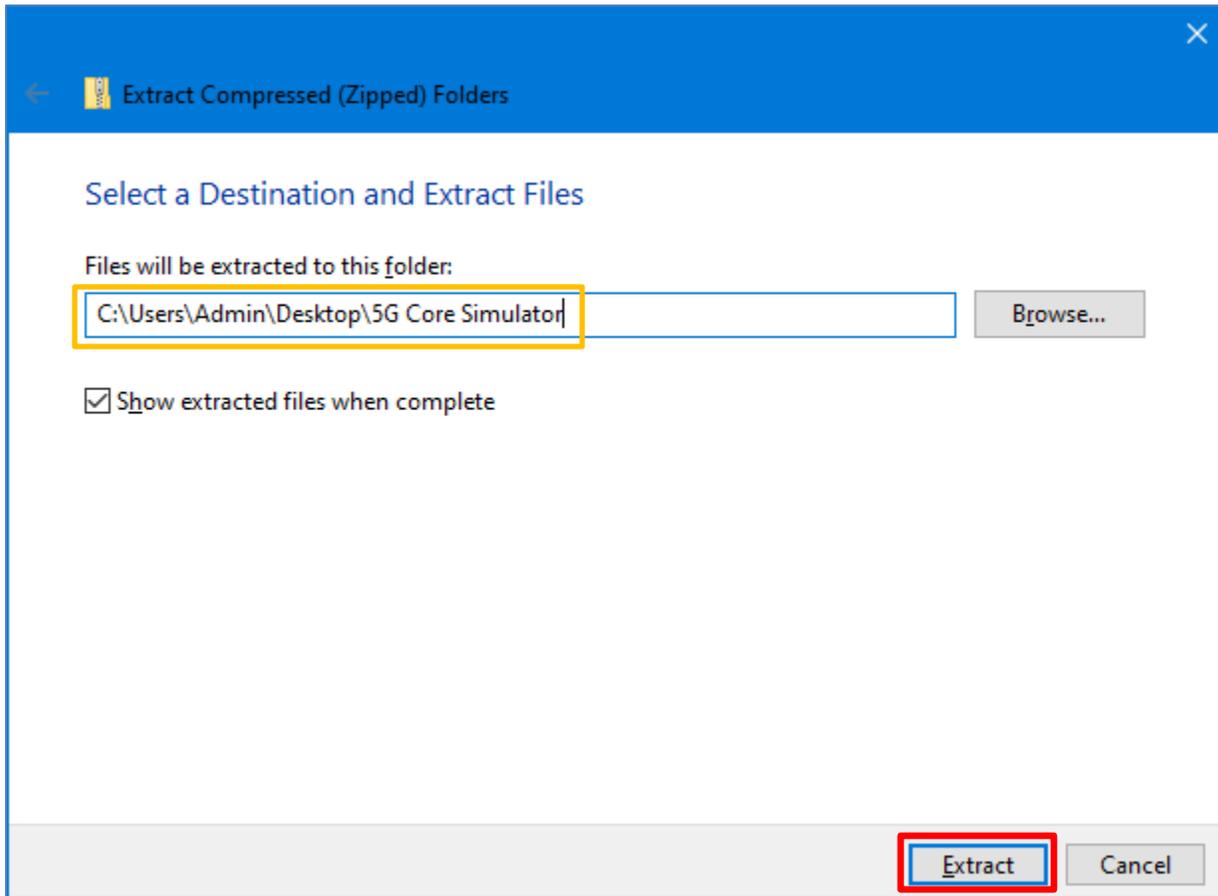
1. Create a folder on the desktop named **5G Core Simulator**
2. Copy the two 5G virtual machine ZIP files; **Free5GC.zip** and **UERANSIM.zip**, to the **5G Core Simulator** folder on the desktop.



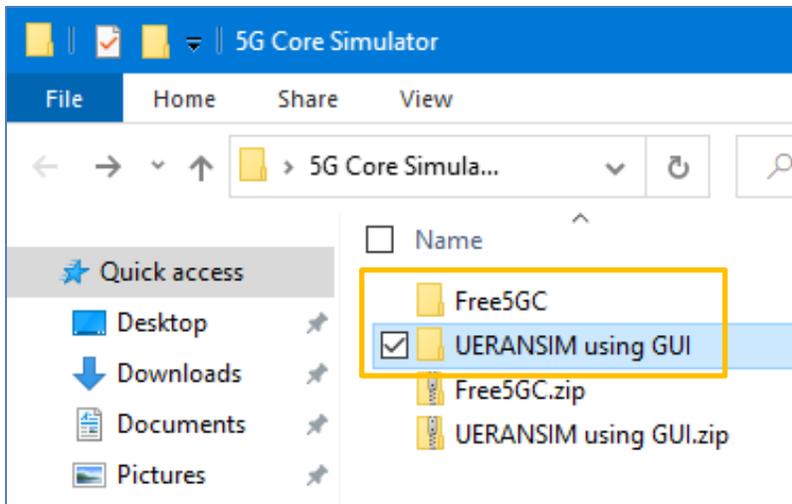
3. Extract the folders from the two ZIP files by right-clicking on the file and selecting **Extract All**



- In the **Select a Destination and Extract Files** entry box remove the last folder in the path (otherwise you'll get a double set of folders) and click the **Extract** button.

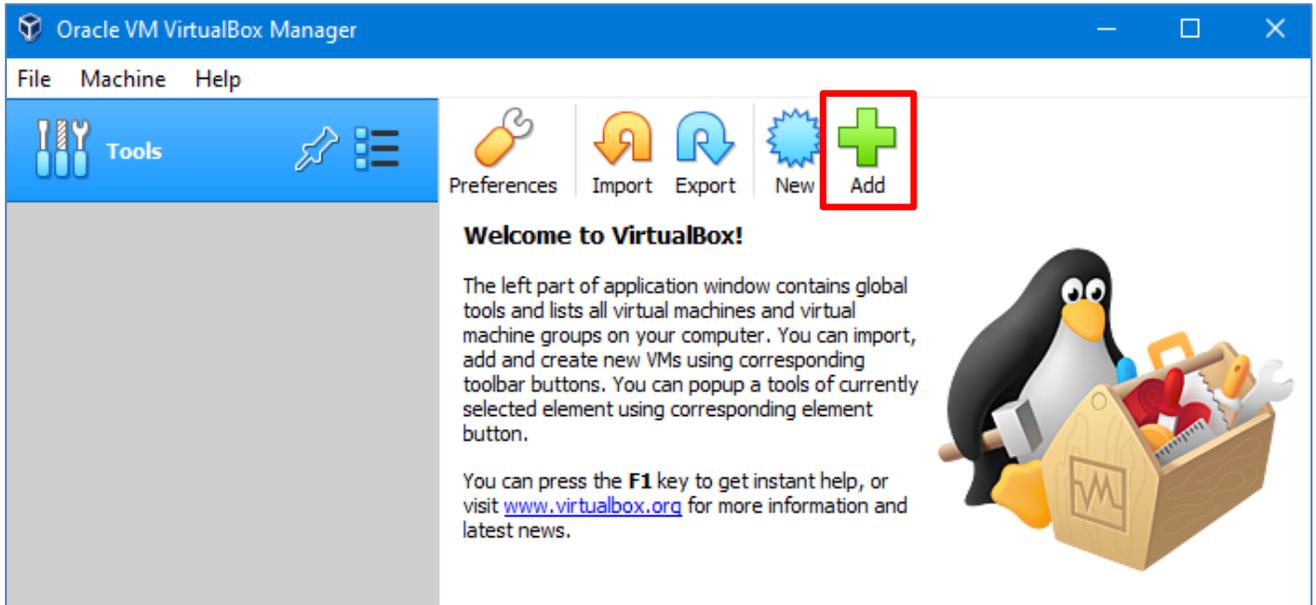


- You should now see the two VM folders in the File Explorer window.

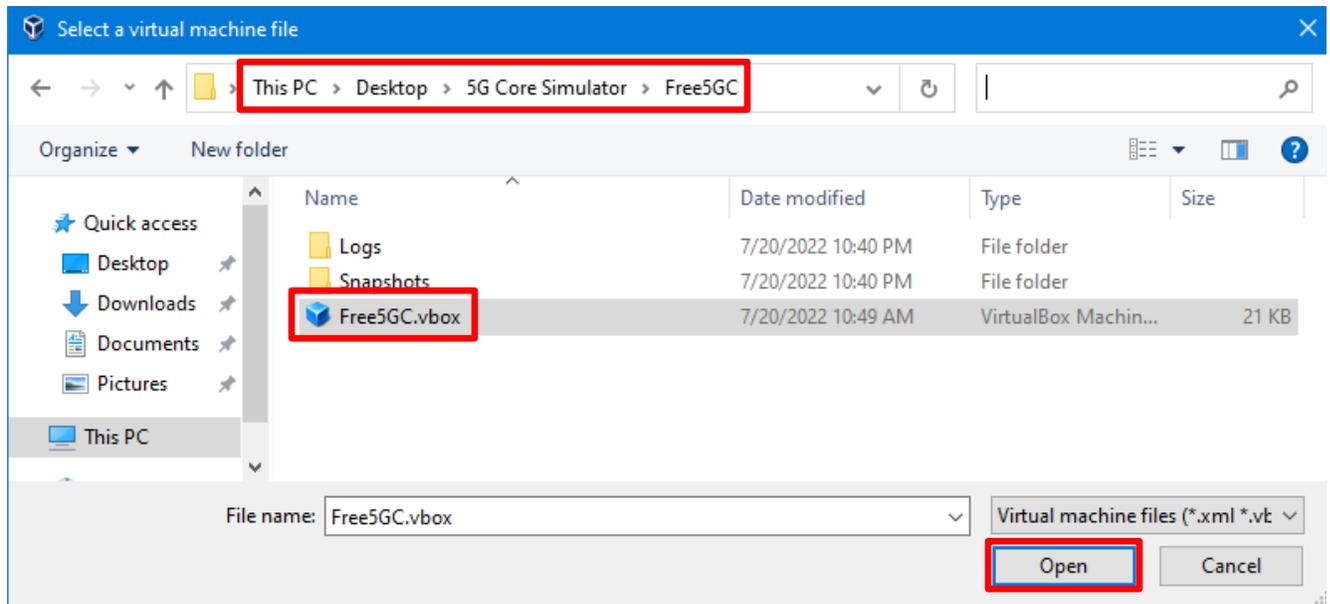


### 1.3 Adding the Free5GC and UERANSIM VMs to VirtualBox

1. On the **Oracle VM VirtualBox Manager**, click the **Add** button:

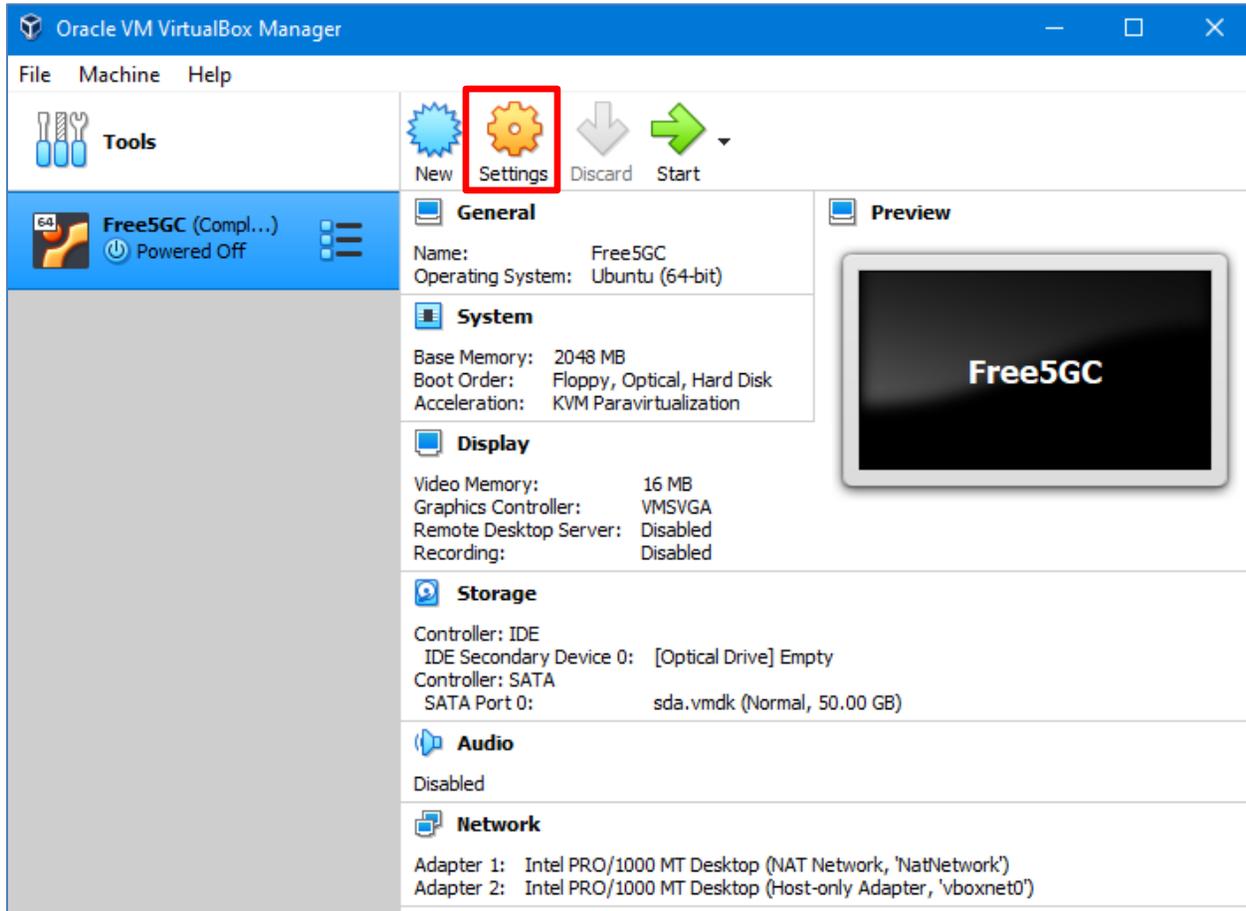


2. In the **Select a Virtual Machine File** window, navigate to **Desktop** → **5G Core Simulator** → **Free5GC**, click on **Free5GC.vbox** and click **Open**.

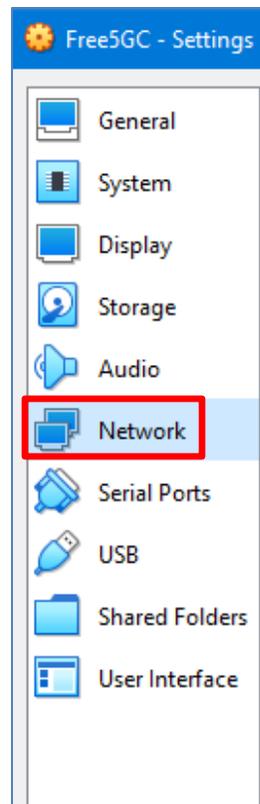


You will need to make some network settings adjustments before starting up the VM.

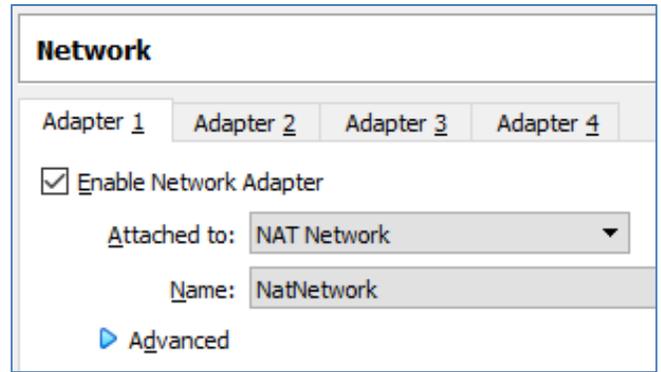
3. On the toolbar, click on the **Settings** tool icon



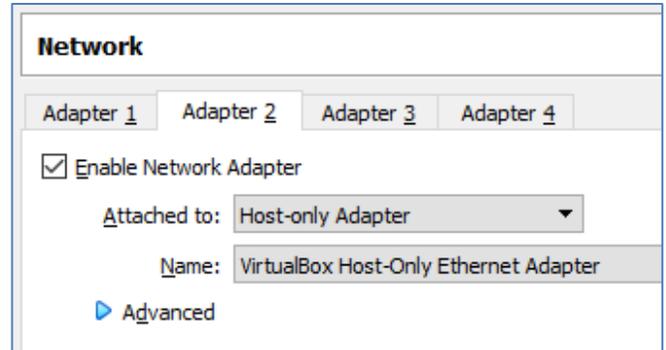
4. On the left side menu panel, click on **Network**



5. On the details panel on the right, confirm that the settings under the **Adapter 1** tab look like the image to the right.

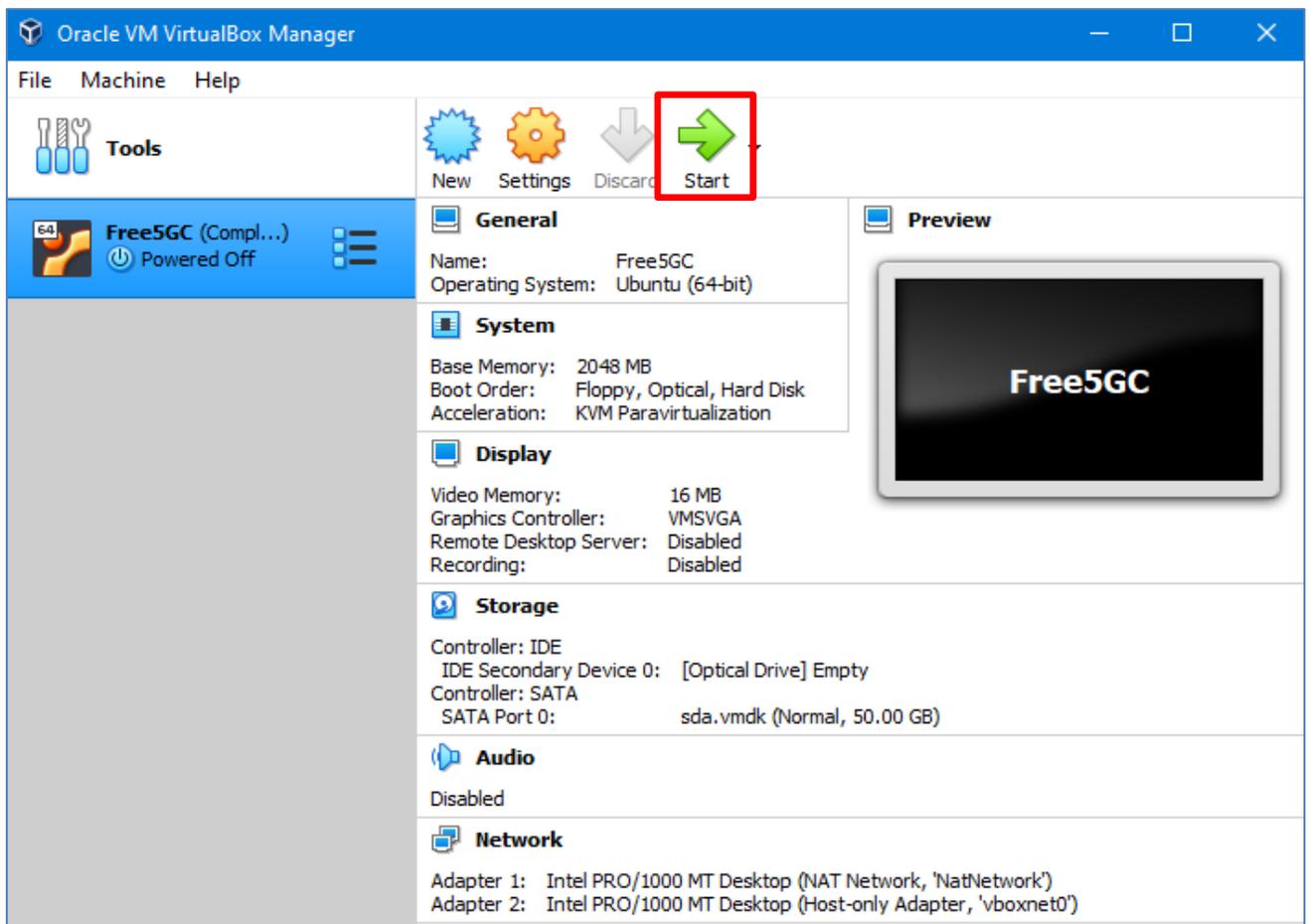


6. Click on the **Adapter2** tab and confirm the settings are the same as the image to the right.



7. If the two adapter's settings match, then click the **OK** button at the bottom of the window.

8. On the toolbar, click on the **Start** tool icon

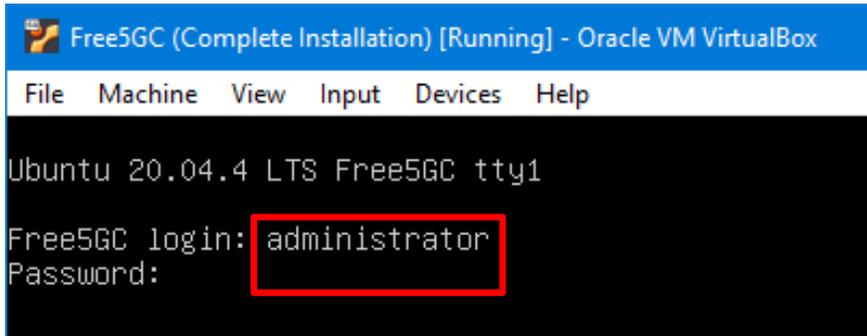


9. Repeat the steps in this task for the **UERANSIM VM**.
10. If you get a **VirtualBox – Information** pop up window saying the that the virtual machine will be switched to **Scale** mode, click the **Do not show this message again** checkbox and click the **Switch** button.

## 2 Establishing a PDU Session in the 5G Virtual Environment

### 2.1 Use the Free5GC WebConsole to Add an UE

1. Set the focus to the **Free5GC** virtual machine and login as **administrator** with the password **Password1**



```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
Ubuntu 20.04.4 LTS Free5GC tty1
Free5GC login: administrator
Password:
```

2. Start **mongodb** by typing the following command:

```
sudo systemctl start mongodb
```

If asked for the **[sudo] password** for sysadmin: type **Password1**

```
administrator@Free5GC:~$ sudo systemctl start mongodb
[sudo] password for administrator:
```

3. Start the **Free5GC WebConsole** server to add the **UE** (User Equipment) configuration by typing:

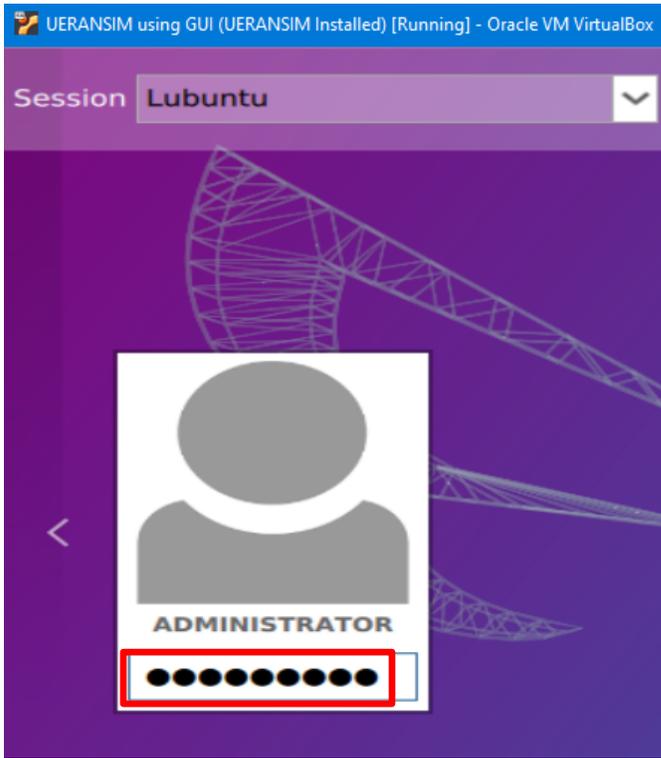
```
cd ~/free5gc/webconsole
go run server.go
```

```
administrator@Free5GC:~$ cd ~/free5gc/webconsole
administrator@Free5GC:~/free5gc/webconsole$ go run server.go_
```

It will take about 2 minutes for the web server to load. The output will show the listening port is 5000.

```
[GIN-debug] Listening and serving HTTP on :5000
```

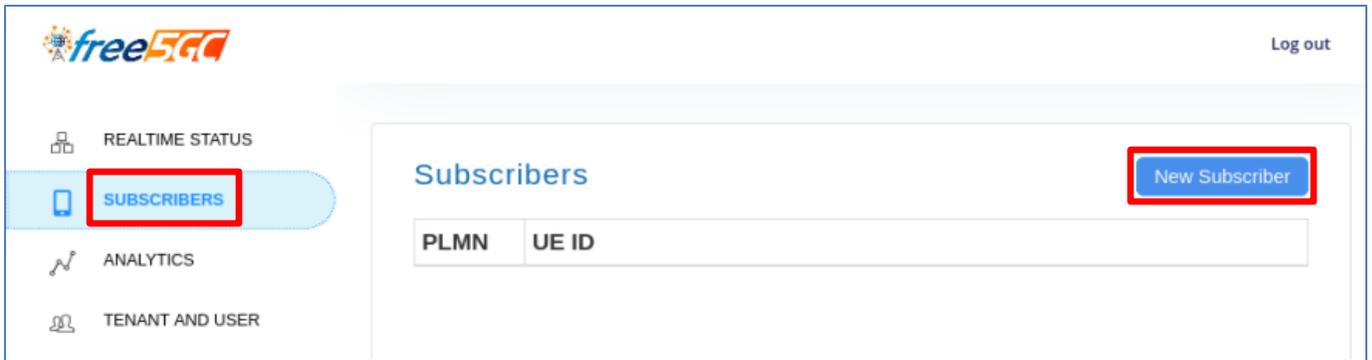
4. Set the focus to the **UERANSIM** virtual machine and login to the administrator account with the password **Password1**.



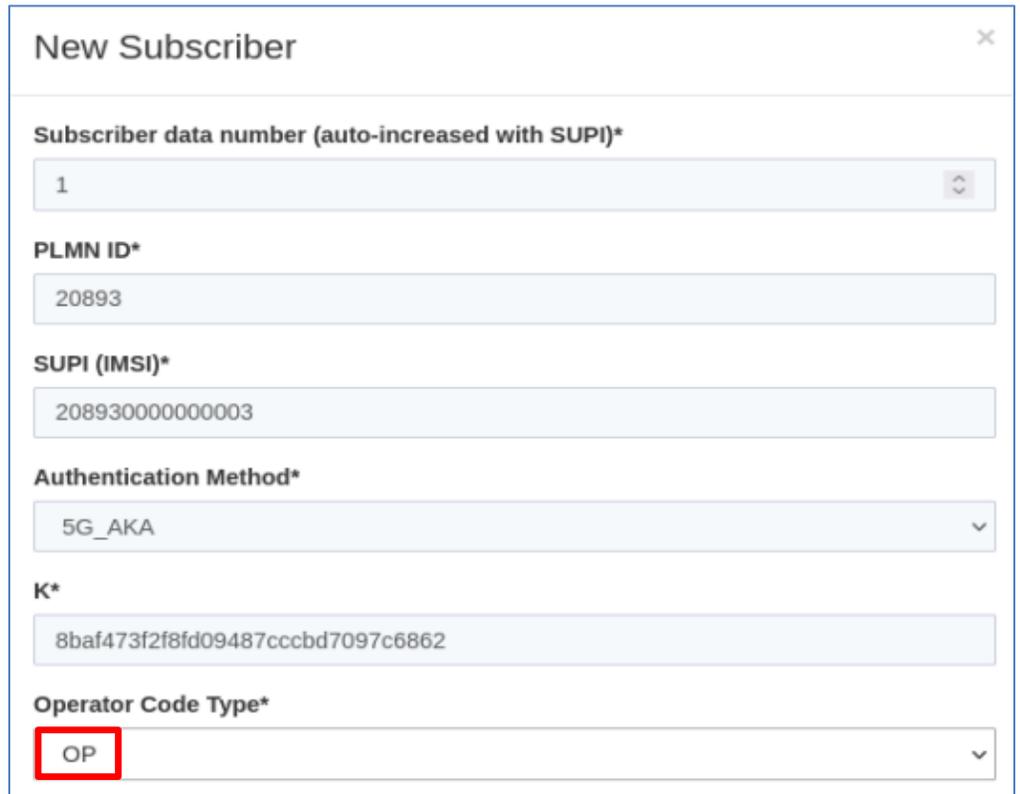
5. Open the **Firefox** web browser and type the URL **http://192.168.56.101:5000**
6. On the login page, type the username **admin** and the password **free5gc** (case sensitive) and click the **Login** button.



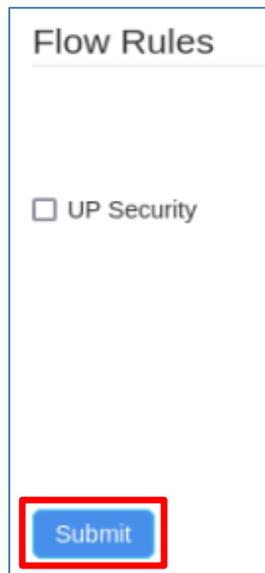
- 7. On the left side of the window, click on **SUBSCRIBERS** and then on the right side, click on the **New Subscriber** button.



- 8. On the New Subscriber page, click the list arrow on the right of the Operator Code Type and change it to **OP**.



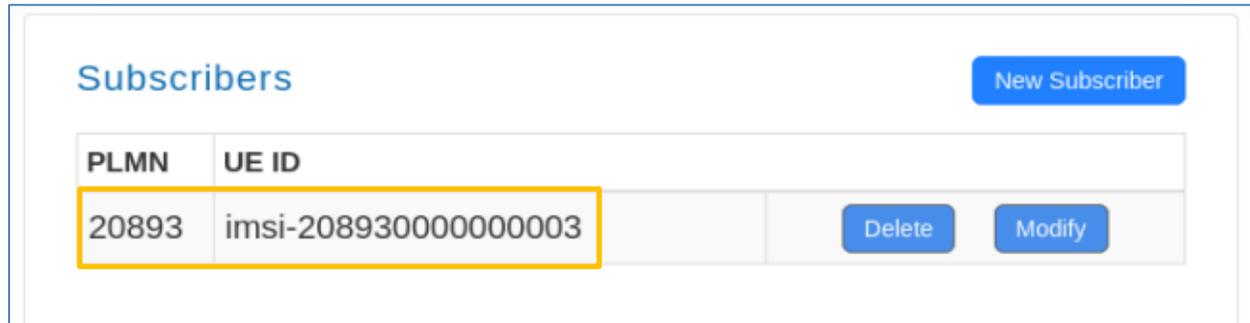
- 9. Leave all of the remaining fields with their default values, scroll to the bottom of the window and click the **Submit** button.



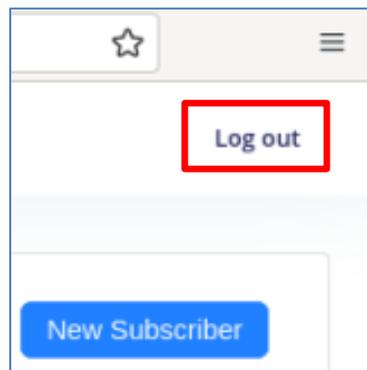
You should make note of the settings for the New Subscriber.

You will need to confirm these settings in the configuration file later in the lab.

10. Confirm that the New Subscriber has been added



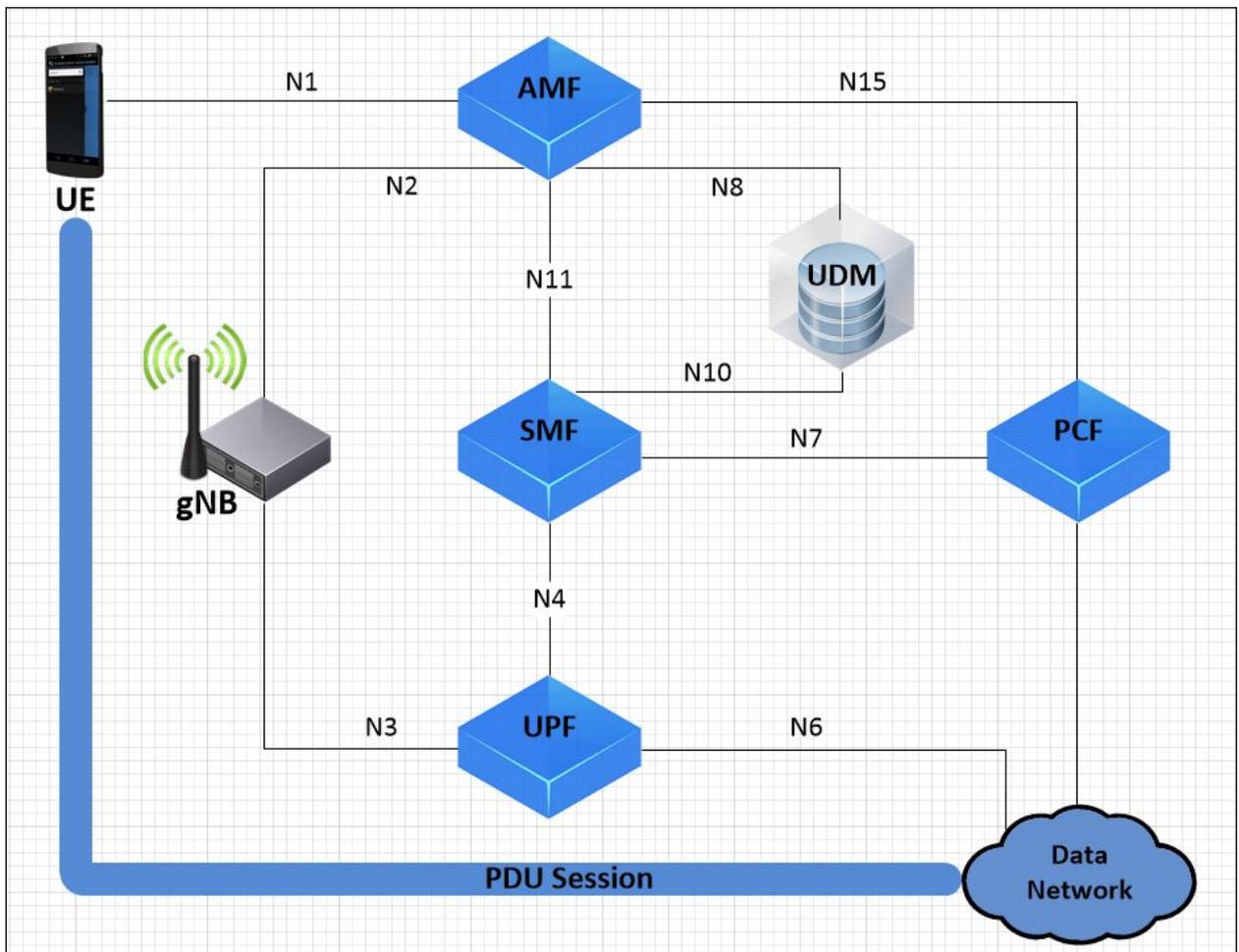
11. Click **Log Out** on the right side of the window and close the web browser.



12. Set the focus back to the **Free5GC** virtual machine and press **Ctrl+C** to quit **WebConsole**.

## 2.2 Setting Free5GC and UERANSIM Parameters

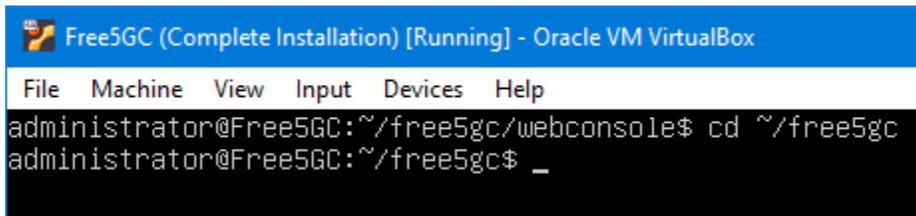
In the discussion of the 5G Core Infrastructure, the *AMF*, *SMF*, *UPF*, *PCF* and *UDM* are virtualized services that run on a single host server, in this case, the *Free5GC* appliance.



Each of the services has an associated configuration file that will need to have the parameters set for the appropriate IP Addresses.

1. Set the focus back to the **Free5GC** virtual machine, if it is not already set.
2. Change to the **free5gc** folder by typing the following command:

```
cd ~/free5gc
```



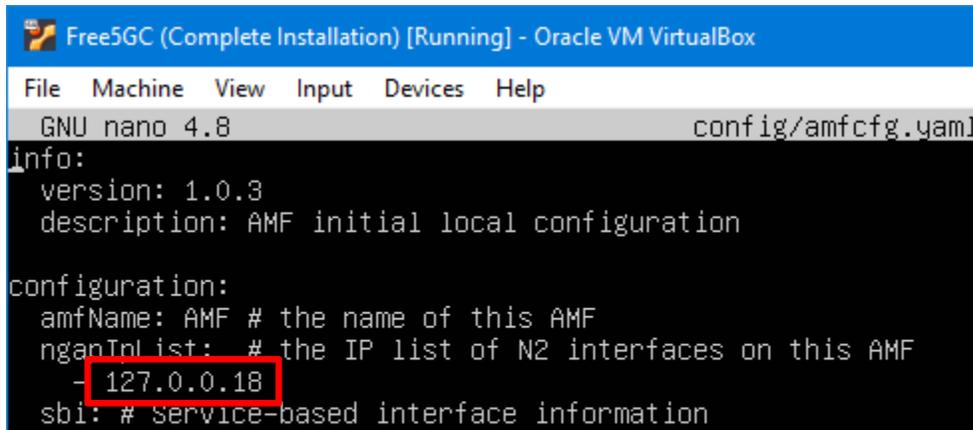
First, set the IP Address of the AMF (Access and Mobility Management Function):

3. Edit the **AMF** configuration file by entering the following command:

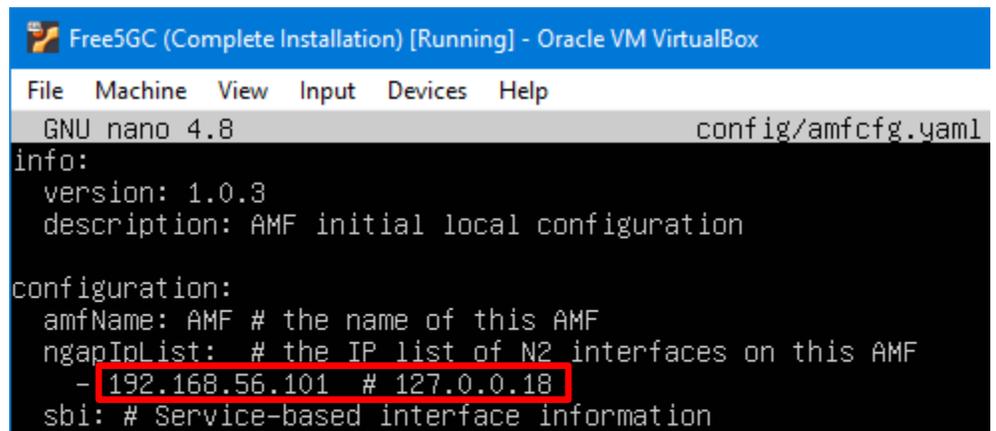
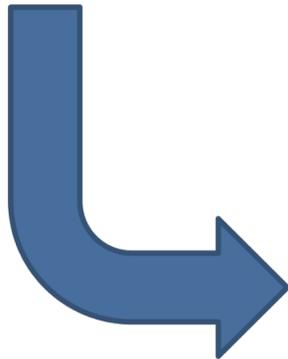
```
sudo nano config/amfcfg.yaml
```

if asked for the **[sudo]password**: type **Password1**

4. Change **ngapIpList** IP from 127.0.0.1 to **192.168.56.101**

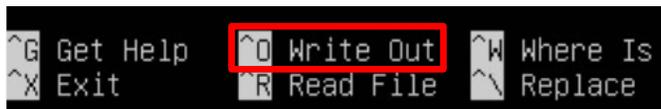


```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
GNU nano 4.8 config/amfcfg.yaml
info:
version: 1.0.3
description: AMF initial local configuration
configuration:
amfName: AMF # the name of this AMF
ngapIpList: # the IP list of N2 interfaces on this AMF
- 127.0.0.18
sbi: # Service-based interface information
```



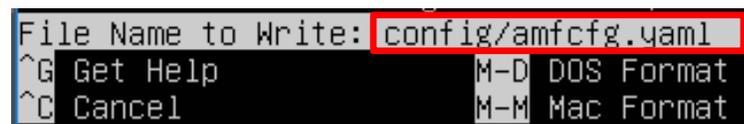
```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
GNU nano 4.8 config/amfcfg.yaml
info:
version: 1.0.3
description: AMF initial local configuration
configuration:
amfName: AMF # the name of this AMF
ngapIpList: # the IP list of N2 interfaces on this AMF
- 192.168.56.101 # 127.0.0.18
sbi: # Service-based interface information
```

5. When finished, press **Ctrl+O** to write the file.



```
^G Get Help      ^O Write Out    ^W Where Is
^X Exit          ^R Read File    ^_ Replace
```

6. Press **Enter** to confirm the file name **config/amfcfg.yaml**.



```
File Name to Write: config/amfcfg.yaml
^G Get Help      M-D DOS Format
^C Cancel        M-M Mac Format
```

7. Press **Ctrl+X** to exit.



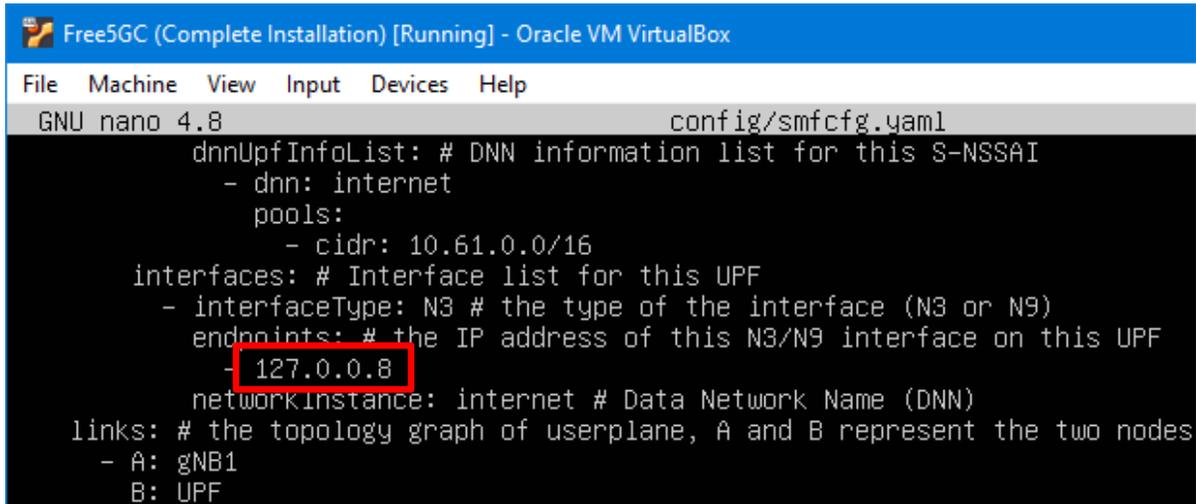
```
^G Get Help      ^O Write Out    ^W Where Is
^X Exit          ^R Read File    ^_ Replace
```

Next, set the IP Address of the SMF (Session Management Function):

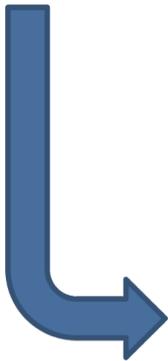
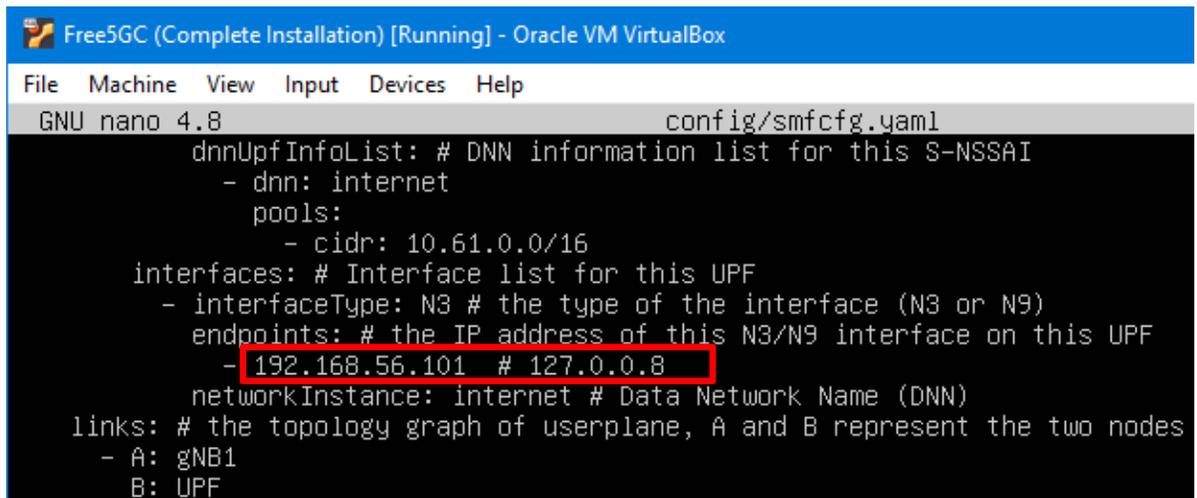
8. Edit the **SMF** configuration file by entering the following command:

```
sudo nano config/smfcfg.yaml
```

9. In the entry inside **userplane\_information / up\_nodes / UPF / interfaces / endpoints**, change the IP from 127.0.0.8 to **192.168.56.101**

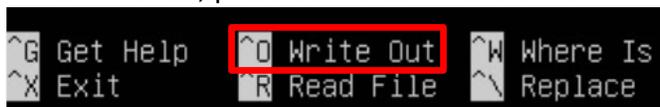


```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
GNU nano 4.8 config/smfcfg.yaml
dnnUpfInfoList: # DNN information list for this S-NSSAI
- dnn: internet
  pools:
  - cidr: 10.61.0.0/16
interfaces: # Interface list for this UPF
- interfaceType: N3 # the type of the interface (N3 or N9)
  endpoints: # the IP address of this N3/N9 interface on this UPF
  - 127.0.0.8
networkInstance: internet # Data Network Name (DNN)
links: # the topology graph of userplane, A and B represent the two nodes
- A: gNB1
  B: UPF
```

```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
GNU nano 4.8 config/smfcfg.yaml
dnnUpfInfoList: # DNN information list for this S-NSSAI
- dnn: internet
  pools:
  - cidr: 10.61.0.0/16
interfaces: # Interface list for this UPF
- interfaceType: N3 # the type of the interface (N3 or N9)
  endpoints: # the IP address of this N3/N9 interface on this UPF
  - 192.168.56.101 # 127.0.0.8
networkInstance: internet # Data Network Name (DNN)
links: # the topology graph of userplane, A and B represent the two nodes
- A: gNB1
  B: UPF
```

10. When finished, press **Ctrl+O** to write the file.



```
^G Get Help      ^O Write Out    ^W Where Is
^X Exit          ^R Read File   ^\ Replace
```

11. Press **Enter** to confirm the file name **config/smfcfg.yaml**.



```
File Name to Write: config/smfcfg.yaml
^G Get Help      M-D DOS Format
^C Cancel        M-M Mac Format
```

12. Press **Ctrl+X** to exit.



```
^G Get Help      ^O Write Out    ^W Where Is
^X Exit          ^R Read File   ^\ Replace
```

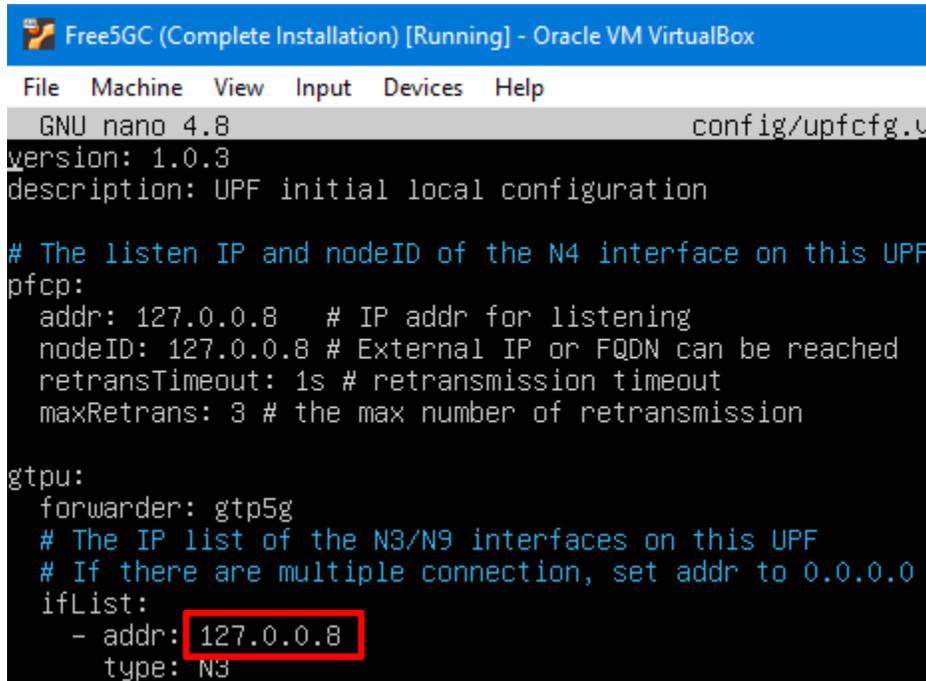
Finally, set the IP Address of the UPF (User Plane Function):

13. Edit the **UPF** configuration file by entering the following command:

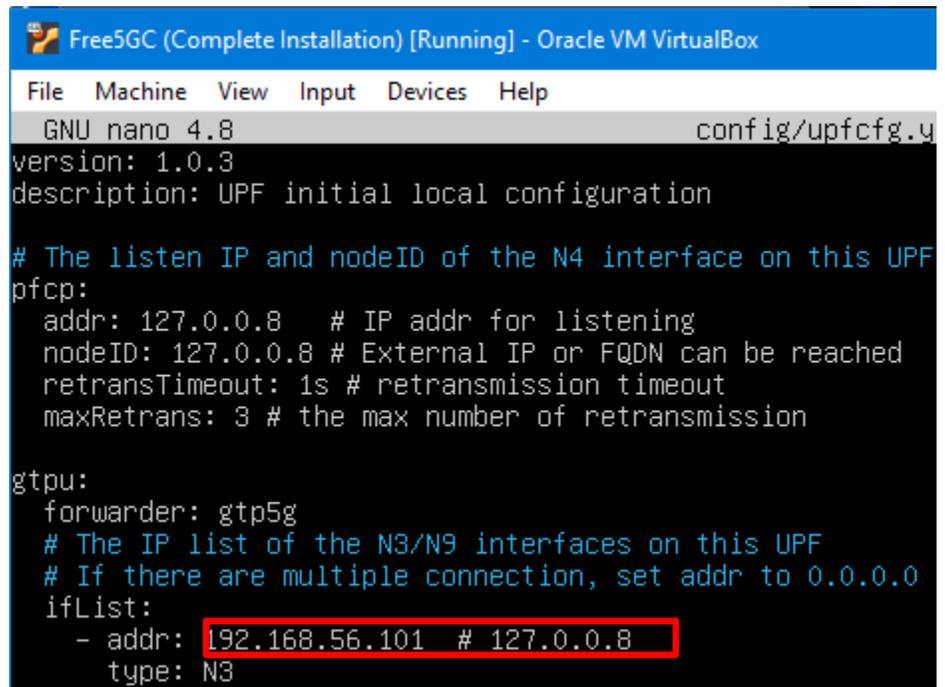
```
sudo nano config/upfcfg.yaml
```

if asked for the **[sudo]password**: type **Password1**

14. Change **gtpu IP** from 127.0.0.8 into **192.168.56.101**

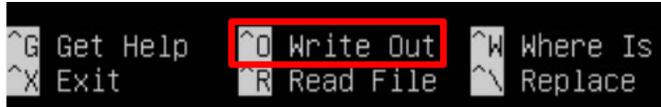


```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
GNU nano 4.8 config/upfcfg.y
version: 1.0.3
description: UPF initial local configuration
# The listen IP and nodeID of the N4 interface on this UPF
pfcfg:
  addr: 127.0.0.8 # IP addr for listening
  nodeID: 127.0.0.8 # External IP or FQDN can be reached
  retransTimeout: 1s # retransmission timeout
  maxRetrans: 3 # the max number of retransmission
gtpu:
  forwarder: gtp5g
  # The IP list of the N3/N9 interfaces on this UPF
  # If there are multiple connection, set addr to 0.0.0.0
  ifList:
    - addr: 127.0.0.8
      type: N3
```

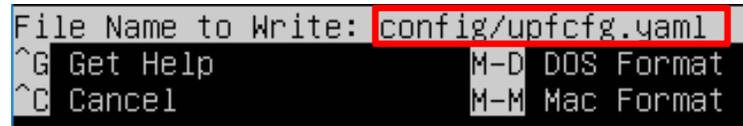


```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
GNU nano 4.8 config/upfcfg.y
version: 1.0.3
description: UPF initial local configuration
# The listen IP and nodeID of the N4 interface on this UPF
pfcfg:
  addr: 127.0.0.8 # IP addr for listening
  nodeID: 127.0.0.8 # External IP or FQDN can be reached
  retransTimeout: 1s # retransmission timeout
  maxRetrans: 3 # the max number of retransmission
gtpu:
  forwarder: gtp5g
  # The IP list of the N3/N9 interfaces on this UPF
  # If there are multiple connection, set addr to 0.0.0.0
  ifList:
    - addr: 192.168.56.101 # 127.0.0.8
      type: N3
```

15. When finished, press **Ctrl+O** to write the file.



16. Press Enter to confirm the file name **config/upfcfg.yaml**.



17. Press **Ctrl+X** to exit.



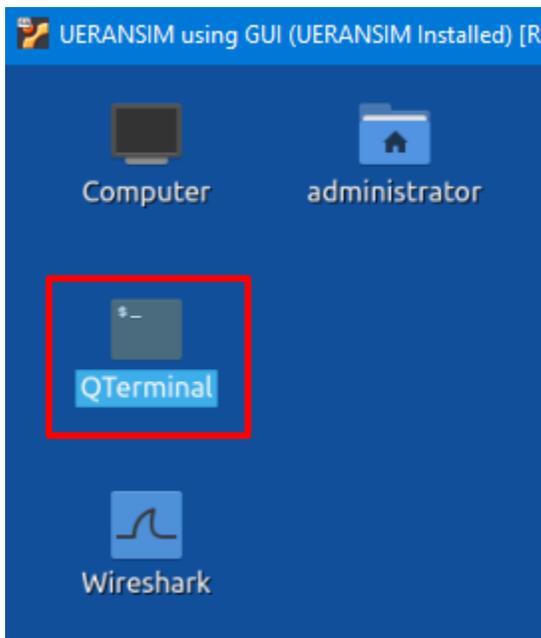
In the *UERANSIM* virtual machine, there are two files that are needed to establish a connection with the *Free5GC* Core services:

- ~/UERANSIM/config/free5gc-gnb.yaml
- ~/UERANSIM/config/free5gc-ue.yaml

The second file is for the *UE* (User Equipment), which we don't have to change since the data inside should be consistent with the (default) registration data that was set using *WebConsole* in the previous task.

18. Set the focus on the **UERANSIM** virtual machine.

19. Double-click on the **QTerminal** icon on the desktop to open a terminal session



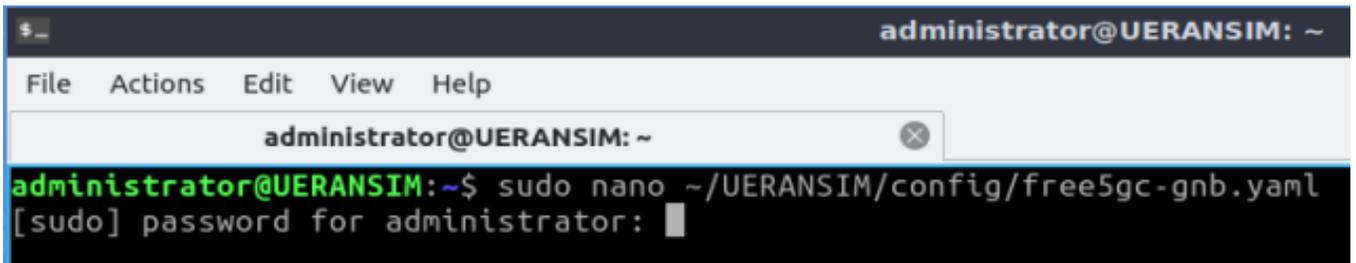
The *UERANSIM* appliance is the simulator for both the User Equipment and the Radio Area Network. This includes the *gNB* which is the 5G wireless base stations that transmit and receive communications between the user equipment and the mobile network.

The *gNB* configuration file will need to be edited to add the IP Addresses of the *gNB* and the 5G Core server. the file `~/UERANSIM/config/free5gc-gnb.yaml`.

20. Edit the **gNB** configuration file by entering the following command:

```
sudo nano ~/UERANSIM/config/free5gc-gnb.yaml
```

if asked for the **[sudo]password**: type **Password1**



A terminal window screenshot showing the execution of the command to edit the gNB configuration file. The terminal title is 'administrator@UERANSIM: ~'. The command prompt shows the user typing 'sudo nano ~/UERANSIM/config/free5gc-gnb.yaml'. The terminal output shows the command being executed and the prompt changing to '[sudo] password for administrator:'. The user has entered the password 'Password1'.

21. Make the following changes:

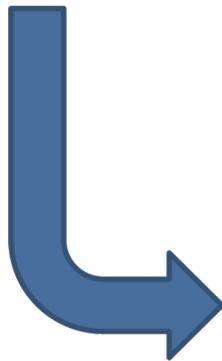
- Change the **ngapIp IP**, as well as the **gtpIp IP**, from 127.0.0.1 to **192.168.56.102**
- Change the IP in **amfConfigs** into **192.168.56.101**

```
GNU nano 4.8 /home/administrator/UERANSIM/config/free5gc-gnb.yaml
mcc: '208' # Mobile Country Code value
mnc: '93' # Mobile Network Code value (2 or 3 digits)

nci: '0x000000010' # NR Cell Identity (36-bit)
idLength: 32 # NR gNB ID length in bits [22...32]
tac: 1 # Tracking Area Code

linkIp: 127.0.0.1 # gNB's local IP address for Radio Link Simulation (Usually same with local IP)
ngapIp: 127.0.0.1 # gNB's local IP address for N2 Interface (Usually same with local IP)
gtpIp: 127.0.0.1 # gNB's local IP address for N3 Interface (Usually same with local IP)

# List of AMF address information
amfConfigs:
- address: 127.0.0.1
  port: 38412
```



```
GNU nano 4.8 /home/adminis
mcc: '208' # Mobile Country Code valu
mnc: '93' # Mobile Network Code valu

nci: '0x000000010' # NR Cell Identity (36-bit)
idLength: 32 # NR gNB ID length in bits
tac: 1 # Tracking Area Code

linkIp: 127.0.0.1 # gNB's local IP address f
ngapIp: 192.168.56.102 # 127.0.0.1 # gNB's
gtpIp: 192.168.56.102 # 127.0.0.1 # gNB's

# List of AMF address information
amfConfigs:
- address: 192.168.56.101 # 127.0.0.1
  port: 38412

# List of supported S-NSSAIs by this gNB
slices:
- sst: 0x1
  sd: 0x010203
```

22. When finished, press **Ctrl+O** to write the file.

```

^G Get Help      ^O Write Out    ^W Where Is
^X Exit          ^R Read File    ^_ Replace
  
```

23. Press Enter to confirm the file name **config/upfcfg.yaml**.

```

File Name to Write: /home/administrator/UERANSIM/config/free5gc-gnb.yaml
^G Get Help          M-D DOS Format      M-A Append
^C Cancel            M-M Mac Format      M-P Prepend
  
```

24. Press **Ctrl+X** to exit.

```

^G Get Help      ^O Write Out    ^W Where Is
^X Exit          ^R Read File    ^_ Replace
  
```

25. Next examine the file `~/UERANSIM/config/free5gc-ue.yaml` (use `cat` to display the file or `nano` to open it in an editor)

Confirm the settings are consistent with those in **free5GC** (via **WebConsole**), for example,

```

# IMSI number of the UE. IMSI = [MCC|MNC|MSISDN] (In total 15 or 16 digits)
supi: 'imsi-208930000000003'
# Mobile Country Code value
mcc: '208'
# Mobile Network Code value (2 or 3 digits)
mnc: '93'

# Permanent subscription key
key: '8baf473f2f8fd09487cccbd7097c6862'
# Operator code (OP or OPC) of the UE
op: '8e27b6af0e692e750f32667a3b14605d'
# This value specifies the OP type and it can be either 'OP' or 'OPC'
opType: 'OP'

...

# Initial PDU sessions to be established
sessions:
- type: 'IPv4'
  apn: 'internet'
  slice:
    sst: 0x01
    sd: 0x010203

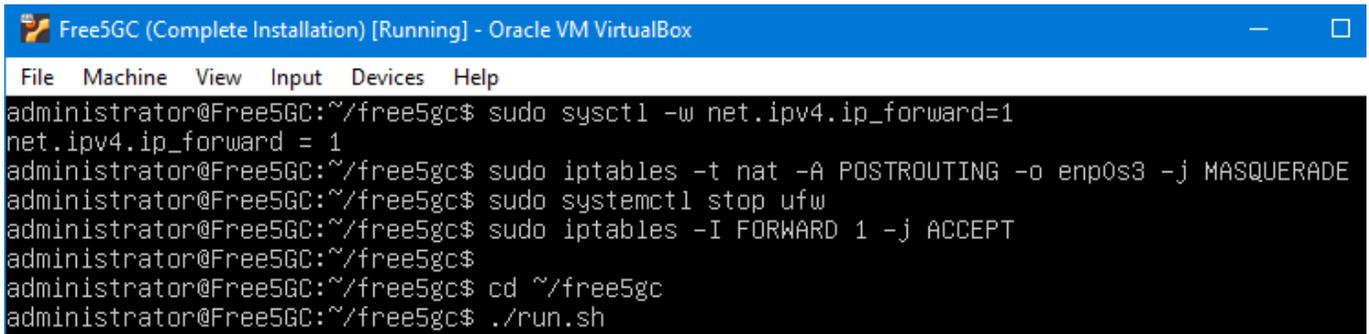
# List of requested S-NSSAs by this UE
slices:
- sst: 0x01
  sd: 0x010203
  
```

## 2.3 Establish a PDU Session

1. Set the focus to the **Free5GC** virtual machine.
2. Configure the **IP Tables** and **Firewall** settings by typing the following commands:

```
sudo sysctl -w net.ipv4.ip_forward=1
sudo iptables -t nat -A POSTROUTING -o enp0s3 -j MASQUERADE
sudo systemctl stop ufw
sudo iptables -I FORWARD 1 -j ACCEPT
cd ~/free5gc
./run.sh
```

if asked for the **[sudo]password**: type **Password1**



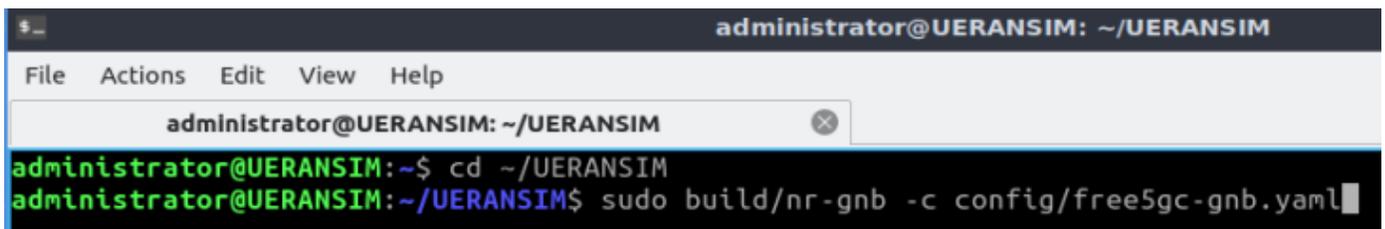
```
Free5GC (Complete Installation) [Running] - Oracle VM VirtualBox
File Machine View Input Devices Help
administrator@Free5GC:~/free5gc$ sudo sysctl -w net.ipv4.ip_forward=1
net.ipv4.ip_forward = 1
administrator@Free5GC:~/free5gc$ sudo iptables -t nat -A POSTROUTING -o enp0s3 -j MASQUERADE
administrator@Free5GC:~/free5gc$ sudo systemctl stop ufw
administrator@Free5GC:~/free5gc$ sudo iptables -I FORWARD 1 -j ACCEPT
administrator@Free5GC:~/free5gc$
administrator@Free5GC:~/free5gc$ cd ~/free5gc
administrator@Free5GC:~/free5gc$ ./run.sh
```

This will start the *5G Core services* on the *Free5GC appliance*.

3. Set the focus to the **UERANSIM** virtual machine.
4. If a terminal session is not open, double-click on the **QTerminal** icon on the desktop.
5. The first step in the **PDU Session** establishment is to start the **gNB** by typing the following:

```
cd ~/UERANSIM
sudo build/nr-gnb -c config/free5gc-gnb.yaml
```

if asked for the **[sudo]password**: type **Password1**



```
administrator@UERANSIM: ~/UERANSIM
File Actions Edit View Help
administrator@UERANSIM: ~/UERANSIM
administrator@UERANSIM:~$ cd ~/UERANSIM
administrator@UERANSIM:~/UERANSIM$ sudo build/nr-gnb -c config/free5gc-gnb.yaml
```

You will see the first phase of the **UDP Session Establishment** steps (these messages will also show up a Wireshark packet capture).

```

administrator@UERANSIM: ~/UERANSIM
File Actions Edit View Help
administrator@UERANSIM: ~/UERANSIM
administrator@UERANSIM:~$ cd ~/UERANSIM
administrator@UERANSIM:~/UERANSIM$ sudo build/nr-gnb -c config/free5gc-gnb.yaml
UERANSIM v3.1.0
[2022-07-21 15:11:06.008] [sctp] [info] Trying to establish SCTP connection... (192.168.56.101:38412)
[2022-07-21 15:11:06.372] [sctp] [info] SCTP connection established (192.168.56.101:38412)
[2022-07-21 15:11:06.373] [sctp] [debug] SCTP association setup ascId[3]
[2022-07-21 15:11:06.373] [ngap] [debug] Sending NG Setup Request
[2022-07-21 15:11:06.562] [ngap] [debug] NG Setup Response received
[2022-07-21 15:11:06.562] [ngap] [info] NG Setup procedure is successful

```



If you have arranged the two virtual machine windows in order to see both screens, you can see the session establishment process on the Free5GC screen.

6. Open a second **Terminal** session, by clicking on **File → New Tab**

```

administrator@UERANSIM: ~/UERANSIM
File Actions Edit View Help
+ New Tab Ctrl+Shift+T
New Tab From Preset >
- Close Tab Ctrl+Shift+W
New Window Ctrl+Shift+N
Preferences...
Quit
[2022-07-21 15:11:06.562] [ngap]
[2022-07-21 15:11:06.562] [ngap]

```

7. The next step in the **PDU Session establishment** is to start the **UE** by typing the following:

```
cd ~/UERANSIM
sudo build/nr-ue -c config/free5gc-ue.yaml
```

if asked for the **[sudo]password:** type **Password1**

```

administrator@UERANSIM: ~/UERANSIM
File Actions Edit View Help
administrator@UERANSIM: ~/UERANSIM administrator@UERANSIM:
administrator@UERANSIM:~$ cd ~/UERANSIM
administrator@UERANSIM:~/UERANSIM$ sudo build/nr-ue -c config/free5gc-ue.yaml

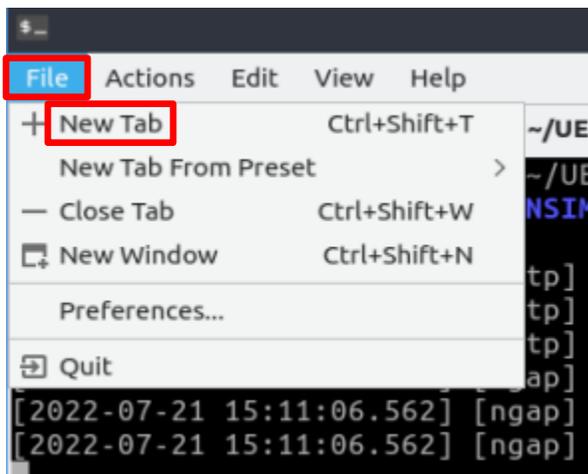
```

You will see the second phase of the **UDP Session Establishment**

```

administrator@UERANSIM: ~/UERANSIM
File Actions Edit View Help
administrator@UERANSIM: ~/UERANSIM administrator@UERANSIM: ~/UERANSIM
administrator@UERANSIM:~/UERANSIM$ sudo build/nr-ue -c config/free5gc-ue.yaml
UERANSIM v3.1.0
[2022-07-21 15:26:42.371] [nas] [debug] NAS layer started
[2022-07-21 15:26:42.373] [rrc] [debug] RRC layer started
[2022-07-21 15:26:42.376] [nas] [info] UE switches to state: MM-DEREGISTERED/PLMN-SEARCH
[2022-07-21 15:26:42.381] [nas] [info] UE connected to gNB
[2022-07-21 15:26:42.382] [nas] [info] UE switches to state: MM-DEREGISTERED/NORMAL-SERVICE
[2022-07-21 15:26:42.382] [nas] [info] UE switches to state: MM-REGISTERED-INITIATED/NA
[2022-07-21 15:26:42.437] [rrc] [debug] Sending RRC Setup Request
[2022-07-21 15:26:42.459] [rrc] [info] RRC connection established
[2022-07-21 15:26:42.459] [nas] [info] UE switches to state: CM-CONNECTED
[2022-07-21 15:26:43.516] [nas] [debug] Received rand[86B92E51BC15C43EE0EFC7D7C661D267] autn[9F239CD41FF6800CACF72E34D8323CD]
[2022-07-21 15:26:43.516] [nas] [debug] Calculated res[D2B603CA506727D8] ck[0C32CECB11A6673F6B518C9E31D6151C] ik[339E2356A323B2FEE8D0E709F2F8C416] ak[89D02F231034] mac_a[CACF72E34D8323CD]
[2022-07-21 15:26:43.516] [nas] [debug] Used snn[5G:mnc093.mcc208.3gppnetwork.org] sqn[16F3B3F70FC2]
[2022-07-21 15:26:43.516] [nas] [debug] Derived kSeaf[3A7E0A4CEE87AD917FE2BE73D6936F1F1015E7D0043ADB3334C6C93EDAA68609] kAUSF[1FF865FF42D3FEEAADCAE26D0DC3A4A1E0D39B0D8CF1DE3B8384730F051E96C4] kAmf[12044F05CDFBD969C0A1CF16C9F189A1895454D1567673A29DEC57474B768A55]
[2022-07-21 15:26:43.953] [nas] [debug] Derived kNasEnc[136AF613AABF03D5148B8278301476C4] kNasInt[AAECB7D6908EC5AFA19AA6693203581]
[2022-07-21 15:26:43.953] [nas] [debug] Selected integrity[2] ciphering[0]
[2022-07-21 15:26:46.631] [nas] [debug] T3512 started with int[3600]
[2022-07-21 15:26:46.631] [nas] [info] UE switches to state: MM-REGISTERED/NORMAL-SERVICE
[2022-07-21 15:26:46.631] [nas] [info] Initial Registration is successful
[2022-07-21 15:26:46.631] [nas] [info] Initial PDU sessions are establishing [1#]
[2022-07-21 15:26:46.631] [nas] [debug] Sending PDU session establishment request
[2022-07-21 15:26:48.506] [nas] [info] PDU Session establishment is successful PSI[1]
[2022-07-21 15:26:49.332] [app] [info] Connection setup for PDU session[1] is successful, TUN interface[uesimtun0,10.60.0.1] is up.
    
```

- Open a third **Terminal** session, by clicking on **File → New Tab**



9. Run a **ping** to **192.168.56.101** to see *free5gc* is alive. Then, use **ifconfig** to see if the tunnel **uesimtun0** has been created (by *nr-ue*):

```
ping 192.168.56.101 -c4
```

```
File  Actions  Edit  View  Help
:RANSIM  administrator@UERANSIM: ~/UERANSIM
administrator@UERANSIM:~$ ping 192.168.56.101 -c4
PING 192.168.56.101 (192.168.56.101) 56(84) bytes of data.
64 bytes from 192.168.56.101: icmp_seq=1 ttl=64 time=37.8 ms
64 bytes from 192.168.56.101: icmp_seq=2 ttl=64 time=147 ms
64 bytes from 192.168.56.101: icmp_seq=3 ttl=64 time=5.28 ms
64 bytes from 192.168.56.101: icmp_seq=4 ttl=64 time=4.23 ms

--- 192.168.56.101 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3008ms
rtt min/avg/max/mdev = 4.228/48.498/146.720/58.288 ms
administrator@UERANSIM:~$
```

10. Confirm that the tunnel **uesimtun0** (this is the UDP Session tunnel) has been created by **nr-ue** by typing **ifconfig**.

```
ifconfig
```

```
uesimtun0: flags=4305<UP,POINTOPOINT,RUNNING,NOARP,MULTICAST> mtu 1500
inet 10.60.0.1 netmask 255.255.255.255 destination 10.60.0.1
inet6 fe80::7c38:fea9:310f:3492 prefixlen 64 scopeid 0x20<link>
unspec 00-00-00-00-00-00-00-00-00-00-00-00-00-00-00-00 txqueuelen 500 (UNSPEC)
RX packets 0 bytes 0 (0.0 B)
RX errors 0 dropped 0 overruns 0 frame 0
TX packets 8 bytes 384 (384.0 B)
TX errors 0 dropped 0 overruns 0 carrier 0 collisions 0
```

11. Finally, **ping** a web site using the **uesimtun0** PDU session by typing the following command:

```
ping -I uesimtun0 google.com -c4
```

```
administrator@UERANSIM: ~
File  Actions  Edit  View  Help
:RANSIM  administrator@UERANSIM: ~/UERANSIM  administrator@
administrator@UERANSIM:~$ ping -I uesimtun0 google.com -c4
PING google.com (142.250.188.238) from 10.60.0.1 uesimtun0: 56(84) bytes of data.
64 bytes from lax31s15-in-f14.1e100.net (142.250.188.238): icmp_seq=1 ttl=126 time=53.4 ms
64 bytes from lax31s15-in-f14.1e100.net (142.250.188.238): icmp_seq=2 ttl=126 time=28.9 ms
64 bytes from lax31s15-in-f14.1e100.net (142.250.188.238): icmp_seq=3 ttl=126 time=46.9 ms
64 bytes from lax31s15-in-f14.1e100.net (142.250.188.238): icmp_seq=4 ttl=126 time=37.6 ms

--- google.com ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3010ms
rtt min/avg/max/mdev = 28.886/41.692/53.387/9.293 ms
```

12. Check the current routing table to see if there are routing rules for the two network interfaces, **enp0s3** and **enp0s8** by typing the following command:

```
route -n
```

```

administrator@UERANSIM: ~
File Actions Edit View Help
administrator@UERANSIM: ~/UERANSIM
administrator@UERANSIM:~$ route -n
Kernel IP routing table
Destination      Gateway         Genmask         Flags Metric Ref    Use Iface
0.0.0.0          10.0.2.1       0.0.0.0         UG    100    0      0 enp0s3
10.0.2.0         0.0.0.0        255.255.255.0   U     100    0      0 enp0s3
192.168.56.0     0.0.0.0        255.255.255.0   U     101    0      0 enp0s8

```

13. The network **10.0.2.0/24** using interface **enp0s3** are part of the *VirtualBox* NAT. Bring down the interface by entering the command:

```
sudo ifconfig enp0s3 down
route -n
```

```

administrator@UERANSIM:~$ sudo ifconfig enp0s3 down
administrator@UERANSIM:~$ route -n
Kernel IP routing table
Destination      Gateway         Genmask         Flags Metric Ref    Use Iface
192.168.56.0     0.0.0.0        255.255.255.0   U     101    0      0 enp0s8

```

14. Looking at the routing table above, the only network still available is the **Host-Only** network **192.168.56.0/24** on **enp0s8**. Confirm by trying to ping an address on the internet:

```
ping 8.8.8.8
```

```

administrator@UERANSIM:~$ ping 8.8.8.8
ping: connect: Network is unreachable

```

... but you can ping through the tunnel

```
ping -I uesimtun0 8.8.8.8 -c4
```

```

administrator@UERANSIM:~$ ping -I uesimtun0 8.8.8.8 -c4
PING 8.8.8.8 (8.8.8.8) from 10.60.0.1 uesimtun0: 56(84) bytes of data.
64 bytes from 8.8.8.8: icmp_seq=1 ttl=126 time=69.9 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=126 time=28.8 ms
64 bytes from 8.8.8.8: icmp_seq=3 ttl=126 time=30.0 ms
64 bytes from 8.8.8.8: icmp_seq=4 ttl=126 time=37.0 ms

--- 8.8.8.8 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3012ms
rtt min/avg/max/mdev = 28.797/41.426/69.876/16.724 ms

```

15. To be able to send all traffic through the PDU Session tunnel, you will need to change the default gateway to the **uesimtun0** interface by entering the following command:

```
sudo ip r add default dev uesimtun0
```

```
administrator@UERANSIM:~$ sudo ip r add default dev uesimtun0
```

16. Then, check the routing table:

```
route -n
```

```
administrator@UERANSIM:~$ route -n
Kernel IP routing table
Destination      Gateway          Genmask         Flags Metric Ref    Use Iface
0.0.0.0          0.0.0.0         0.0.0.0         U        0     0      0 uesimtun0
192.168.56.0     0.0.0.0         255.255.255.0   U        101    0      0 enp0s8
```

17. Now, **ping 8.8.8.8** again without using the **UDP Session** tunnel:

```
ping 8.8.8.8 -c4
```

```
administrator@UERANSIM:~$ ping 8.8.8.8 -c4
PING 8.8.8.8 (8.8.8.8) 56(84) bytes of data:
64 bytes from 8.8.8.8: icmp_seq=1 ttl=126 time=34.9 ms
64 bytes from 8.8.8.8: icmp_seq=2 ttl=126 time=38.9 ms
64 bytes from 8.8.8.8: icmp_seq=3 ttl=126 time=27.8 ms
64 bytes from 8.8.8.8: icmp_seq=4 ttl=126 time=26.2 ms

--- 8.8.8.8 ping statistics ---
4 packets transmitted, 4 received, 0% packet loss, time 3006ms
rtt min/avg/max/mdev = 26.164/31.932/38.870/5.172 ms
```