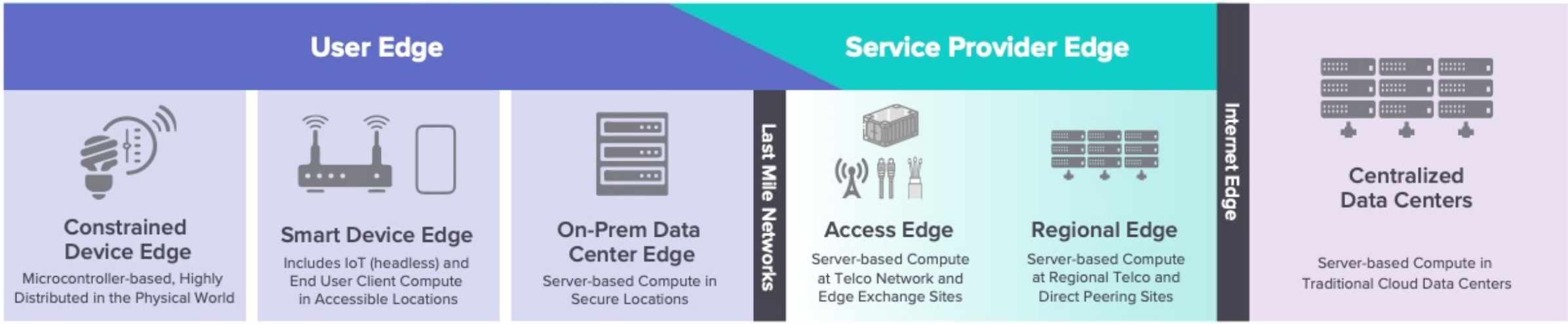
5G Super Blueprint

Use Case – Edge Site Selection and Placement



Increasing HW + SW customization, resource constraints and deployment scale

Typically owned and operated by users / enterprises but also SPs via CPE

Shared resources (XaaS), typically owned and operated by Service Providers (SPs)

Distributed in accessible to semi-secure locations

Inside secure data centers / Modular Data Centers (MDCs)

Latency critical applications

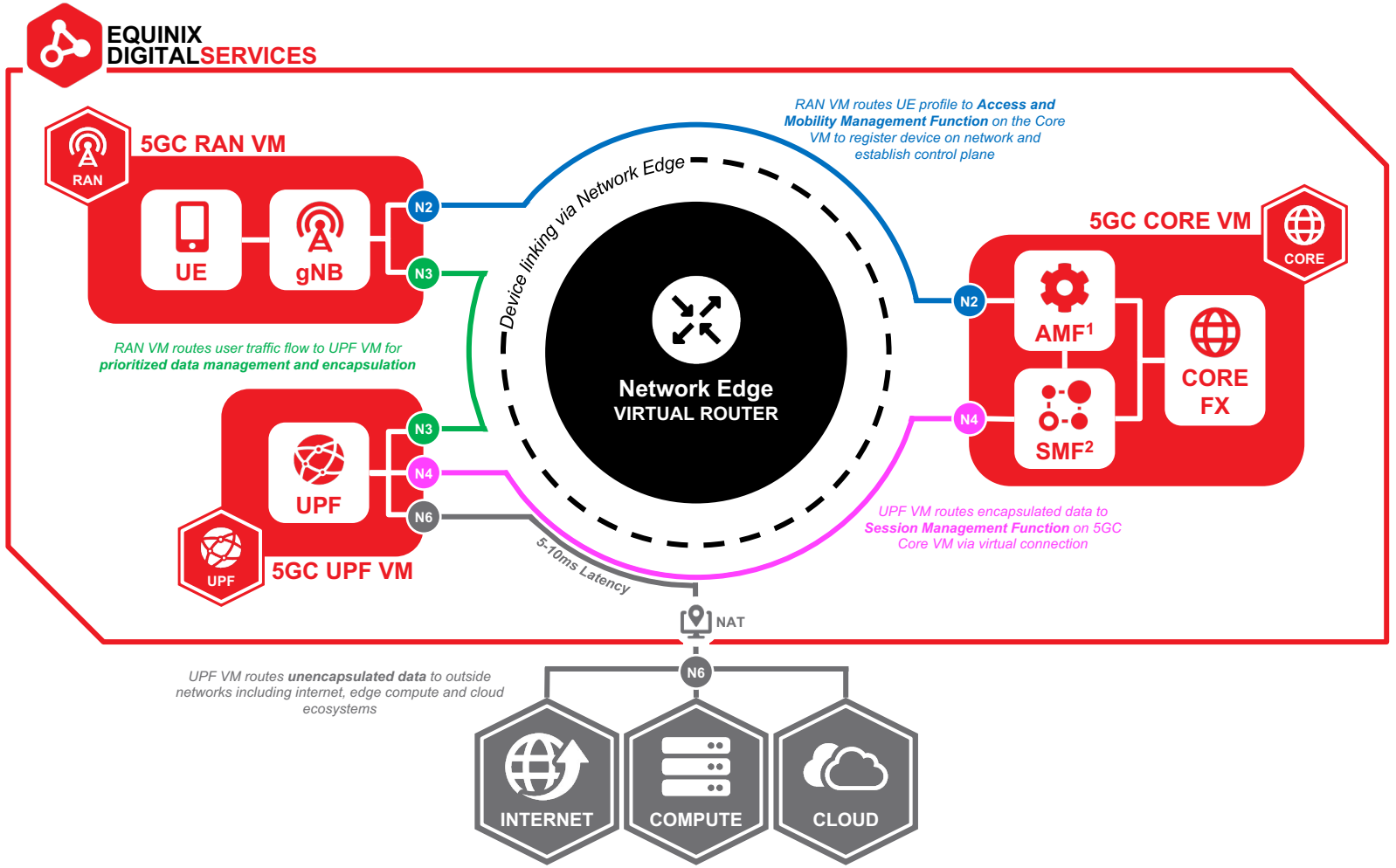
Latency sensitive applications

Embedded software

Increasing cloud-native development practices

The 5G Edge Developers Platform on Equinix

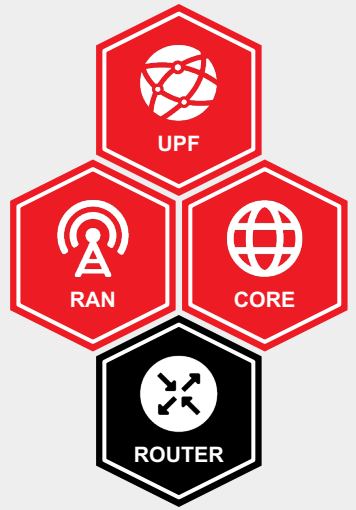
Free5GC-Enabled Solution for Application Developers Across All Ecosystems



1 **Access and Mobility Management Function (AMF)** is a control plane network function in a 5G core network managing registration, reachability, connection and mobility of the user's device to the network

2 **Session Management Function (SMF)** is a data plane network function in a 5G core network managing PDU sessions, IP address allocation, tunneling and downlink notifications

FOUR FUNCTIONS ONE PLATFORM



Test and run Applications and Frameworks in a real-world environment from a simulated User Edge to the Multi-Cloud hosted application with all the advanced features and functions of 5G Stand Alone

- **3 HOSTED VIRTUAL DEVICES SIMULATING 5G RAN, UPF & CORE**
- **1 VIRTUALIZED ROUTER TO DIRECT TRAFFIC FLOW ACROSS PLATFORM**
- **AVAILABLE TO BE SPUN UP ON DEMAND IN 28 GLOBAL METRO MARKETS**

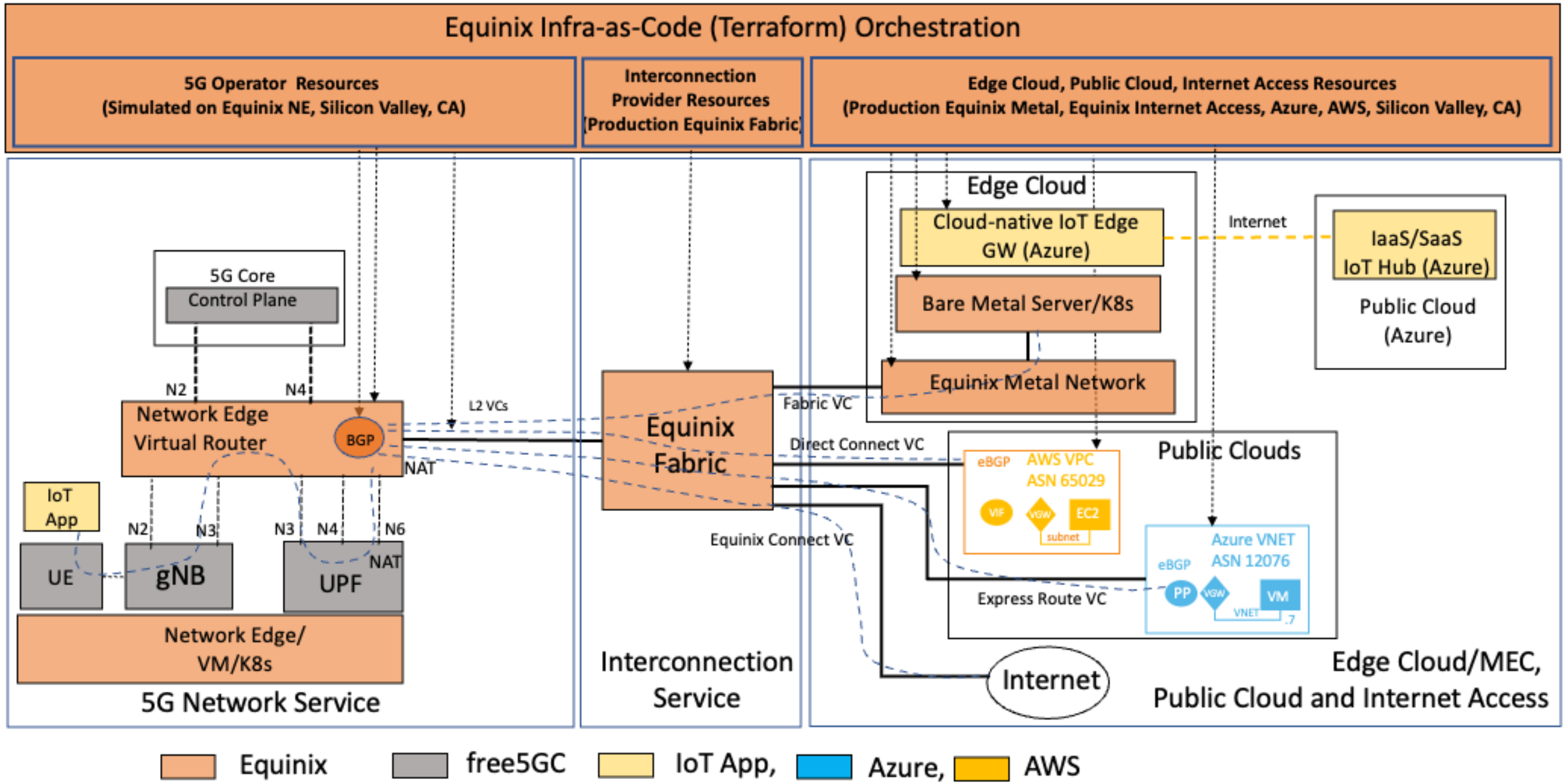
"The Slicing Must Go On" – Oleg Berzin, PhD.

Tools and Demo

Aarna Networks – AES Demo

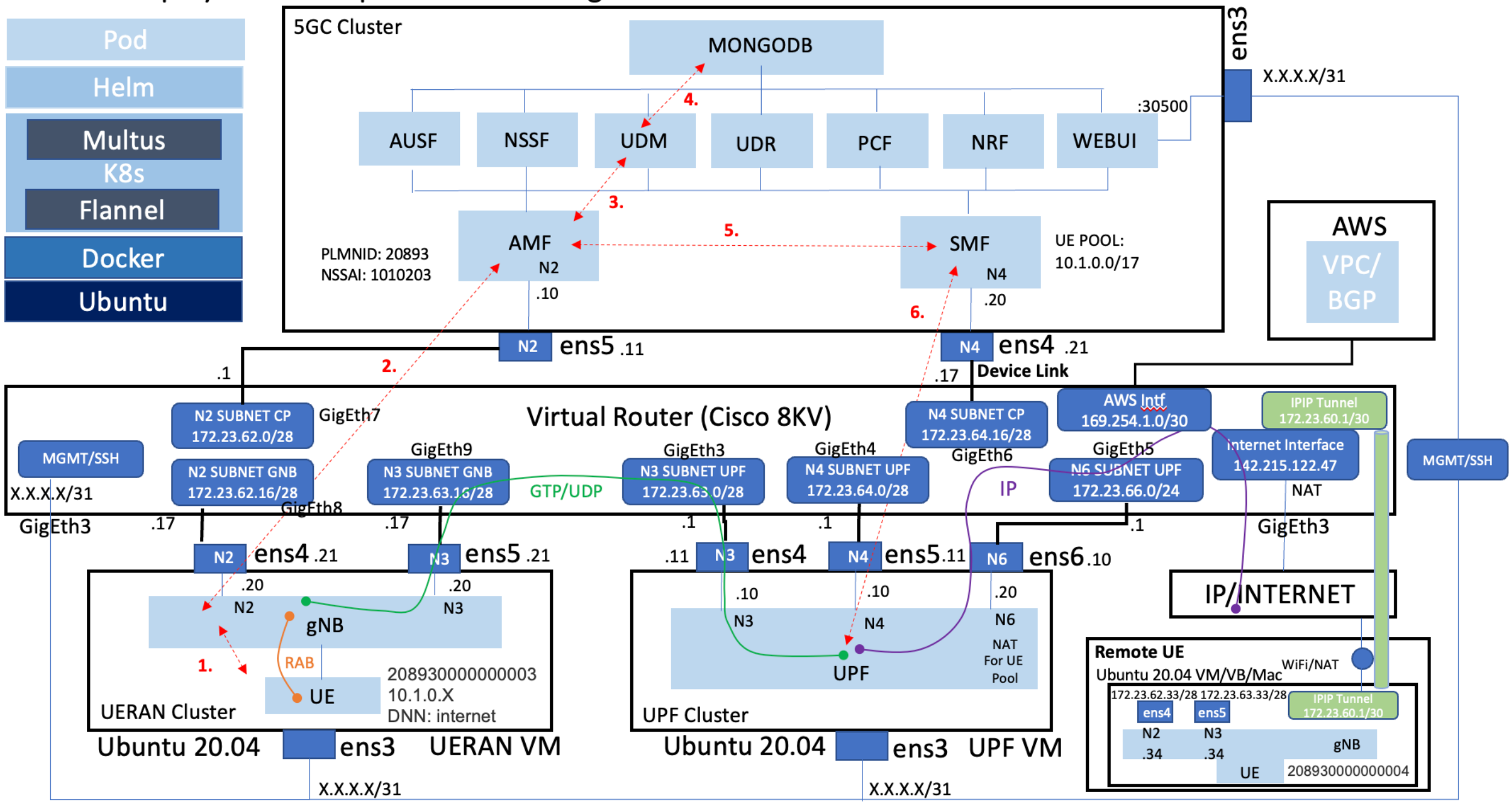
Equinix Terraform Orchestration

Use Case: **Enterprise 5G Fixed/Mobile Hybrid/Multi Cloud Access**

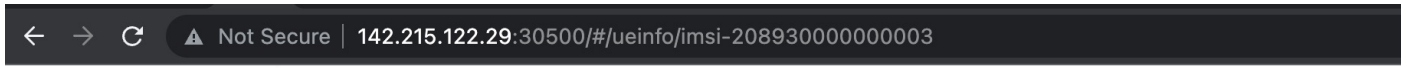


Free5GC Deployment on Equinix Network Edge – L3

5GC VM Ubuntu 20.04



Free5GC WebUI



free5GC

REALTIME STATUS

SUBSCRIBERS

ANALYTICS

AMF Information [SUPI:imsi-208930000000003]

Information Entity	Value
AccessType	3GPP_ACCESS
CmState	CONNECTED
Guti	20893cafe0000000001
Mcc	208
Mnc	93
Supi	imsi-208930000000003
Tac	000001
Dnn	internet
PduSessionId	1
Sd	010203
SmContextRef	urn:uuid:35f130c7-88c3-4132-8bb2-b4ed45e20453
Sst	1

SMF Information [SUPI:imsi-208930000000003]

Information Entity	Value
AnType	3GPP_ACCESS
Dnn	internet
LocalSEID	
PDUAddress	10.1.0.1
PDUSessionID	1
RemoteSEID	
Sd	010203
Sst	1

UE and gNB - simulated

```
onaplab@f5gc-ueran:~$ kubectl -n f5gc exec -it f5gc-ueran-ueransim-ue-95b9f89b4-6tp45 /bin/bash
kubectl exec [POD] [COMMAND] is DEPRECATED and will be removed in a future version. Use kubectl exec [POD] -- [COMMAND] instead.
root@f5gc-ueran-ueransim-ue-95b9f89b4-6tp45:/ueransim/build# ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
3: eth0@if20: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 8900 qdisc noqueue state UP group default
    link/ether 92:d4:37:8d:02:f6 brd ff:ff:ff:ff:ff:ff link-netnsid 0
    inet 10.244.0.13/24 brd 10.244.0.255 scope global eth0
       valid_lft forever preferred_lft forever
4: uesimtun0: <POINTOPOINT,PROMISC,NOTRAILERS,UP,LOWER_UP> mtu 1400 qdisc fq_codel state UNKNOWN group default qlen 500
    link/none
    inet 10.1.0.1/32 scope global uesimtun0
       valid_lft forever preferred_lft forever
root@f5gc-ueran-ueransim-ue-95b9f89b4-6tp45:/ueransim/build#
```

UE container with established mobile link/interface

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-6tp45:/ueransim/build# ping www.google.com -I uesimtun0
PING www.google.com (142.251.46.228) from 10.1.0.1 uesimtun0: 56(84) bytes of data.
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=1 ttl=118 time=3.20 ms
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=2 ttl=118 time=2.60 ms
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=3 ttl=118 time=2.59 ms
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=4 ttl=118 time=2.53 ms
```

Ping from UE to Google.com (goes through UPF and VR)

```
onaplab@f5gc-ueran:~$ kubectl get pods --all-namespaces
NAMESPACE      NAME                                      READY   STATUS    RESTARTS   AGE
f5gc           f5gc-ueran-ueransim-gnb-7f4b9fc9f-w2gc9   1/1     Running   0          50m
f5gc           f5gc-ueran-ueransim-ue-95b9f89b4-6tp45    1/1     Running   0          50m
kube-flannel   kube-flannel-ds-mwg2z                     1/1     Running   0          4d1h
kube-system    coredns-74ff55c5b-bszpp                   1/1     Running   0          4d1h
kube-system    coredns-74ff55c5b-jmzr7                   1/1     Running   0          4d1h
kube-system    etcd-f5gc-ueran                           1/1     Running   0          4d1h
kube-system    kube-apiserver-f5gc-ueran                 1/1     Running   89         4d1h
kube-system    kube-controller-manager-f5gc-ueran        1/1     Running   1          4d1h
kube-system    kube-multus-ds-rrk8x                      1/1     Running   0          54m
kube-system    kube-proxy-6g8mr                          1/1     Running   0          4d1h
kube-system    kube-scheduler-f5gc-ueran                 1/1     Running   1          4d1h
onaplab@f5gc-ueran:~$
```

UE and GNB Kubernetes Pods On UERAN VM

UPF

```
onaplab@f5gc-upf:~$ kubectl get pods --all-namespaces
NAMESPACE      NAME                                        READY   STATUS    RESTARTS   AGE
f5gc           f5gc-upf-free5gc-upf-upf-55ccffffcc-j9s8d   1/1     Running   0          66m
kube-flannel   kube-flannel-ds-7dxmt                       1/1     Running   0          128m
kube-system    coredns-74ff55c5b-5cjqn                     1/1     Running   0          128m
kube-system    coredns-74ff55c5b-qxgvc                     1/1     Running   0          128m
kube-system    etcd-f5gc-upf                               1/1     Running   0          128m
kube-system    kube-apiserver-f5gc-upf                     1/1     Running   0          128m
kube-system    kube-controller-manager-f5gc-upf            1/1     Running   0          128m
kube-system    kube-multus-ds-b4c59                        1/1     Running   0          127m
kube-system    kube-proxy-x2jk9                            1/1     Running   0          128m
kube-system    kube-scheduler-f5gc-upf                     1/1     Running   0          128m
onaplab@f5gc-upf:~$
```

UPF Pod on UPF VM

```
onaplab@f5gc-upf:~$ kubectl -n f5gc exec -it f5gc-upf-free5gc-upf-upf-55ccffffcc-j9s8d /bin/bash
kubectl exec [POD] [COMMAND] is DEPRECATED and will be removed in a future version. Use kubectl exec [POD] -- [COMMAND] instead.
root@f5gc-upf-free5gc-upf-upf-55ccffffcc-j9s8d:/free5gc/free5gc-upfd# ip a
1: lo: <LOOPBACK,UP,LOWER_UP> mtu 65536 qdisc noqueue state UNKNOWN group default qlen 1000
    link/loopback 00:00:00:00:00:00 brd 00:00:00:00:00:00
    inet 127.0.0.1/8 scope host lo
       valid_lft forever preferred_lft forever
3: eth0@if25: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 8900 qdisc noqueue state UP group default
    link/ether 4e:fe:5e:e3:09:7b brd ff:ff:ff:ff:ff:ff link-netnsid 0
    inet 10.244.0.15/24 brd 10.244.0.255 scope global eth0
       valid_lft forever preferred_lft forever
4: n3@eth0: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 8950 qdisc noqueue state UNKNOWN group default
    link/ether fa:16:3e:f0:c1:09 brd ff:ff:ff:ff:ff:ff
    inet 172.23.63.10/28 brd 172.23.63.15 scope global n3
       valid_lft forever preferred_lft forever
5: n6: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 8950 qdisc noqueue state UNKNOWN group default
    link/ether fa:16:3e:ea:28:b4 brd ff:ff:ff:ff:ff:ff
    inet 172.23.66.20/24 brd 172.23.66.255 scope global n6
       valid_lft forever preferred_lft forever
6: n4@n3: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 8950 qdisc noqueue state UNKNOWN group default
    link/ether fa:16:3e:5a:c3:0a brd ff:ff:ff:ff:ff:ff
    inet 172.23.64.10/28 brd 172.23.64.15 scope global n4
       valid_lft forever preferred_lft forever
7: upfgtp: <POINTOPOINT,MULTICAST,NOARP,UP,LOWER_UP> mtu 1500 qdisc noqueue state UNKNOWN group default qlen 1000
    link/none
```

Inside UPF container

```
root@f5gc-upf-free5gc-upf-upf-55ccffffcc-j9s8d:/free5gc/free5gc-upfd# ip r
default via 10.244.0.1 dev eth0
10.0.0.0/8 via 172.23.66.1 dev n6
10.1.0.0/17 dev upfgtp proto static
10.244.0.0/24 dev eth0 proto kernel scope link src 10.244.0.15
10.244.0.0/16 via 10.244.0.1 dev eth0
172.23.63.0/28 dev n3 proto kernel scope link src 172.23.63.10
172.23.63.16/28 via 172.23.63.1 dev n3
172.23.64.0/28 dev n4 proto kernel scope link src 172.23.64.10
172.23.64.16/28 via 172.23.64.1 dev n4
172.23.66.0/24 dev n6 proto kernel scope link src 172.23.66.20
```

```
root@f5gc-upf-free5gc-upf-upf-55ccffffcc-j9s8d:/free5gc/free5gc-upfd# tcpdump -n -i n3 udp
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on n3, link-type EN10MB (Ethernet), capture size 262144 bytes
19:54:22.225715 IP 172.23.63.20.2152 > 172.23.63.10.2152: UDP, length 100
19:54:22.227474 IP 172.23.63.10.2152 > 172.23.63.20.2152: UDP, length 100
19:54:23.227596 IP 172.23.63.20.2152 > 172.23.63.10.2152: UDP, length 100
```

Traffic on UPF N3 interface

```
root@f5gc-upf-free5gc-upf-upf-55ccffffcc-j9s8d:/free5gc/free5gc-upfd# tcpdump -n -i n6 icmp
tcpdump: verbose output suppressed, use -v or -vv for full protocol decode
listening on n6, link-type EN10MB (Ethernet), capture size 262144 bytes
19:55:17.304565 IP 172.23.66.20 > 142.250.189.196: ICMP echo request, id 17, seq 91, length 64
19:55:17.306288 IP 142.250.189.196 > 172.23.66.20: ICMP echo reply, id 17, seq 91, length 64
19:55:18.306206 IP 172.23.66.20 > 142.250.189.196: ICMP echo request, id 17, seq 92, length 64
19:55:18.307936 IP 142.250.189.196 > 172.23.66.20: ICMP echo reply, id 17, seq 92, length 64
```

Traffic on UPF N6 interface

Control Plane

```
onaplab@f5gc-cp:~$ kubectl get pods --all-namespaces
NAMESPACE      NAME                                      READY   STATUS    RESTARTS   AGE
f5gc           f5gc-amf-free5gc-amf-amf-7b96c6d797-mkh2z         1/1     Running   0          106m
f5gc           f5gc-ausf-free5gc-ausf-ausf-6595d76d8c-26rn8      1/1     Running   0          106m
f5gc           f5gc-nrf-free5gc-nrf-nrf-864954486-7fr5v          1/1     Running   0          106m
f5gc           f5gc-nssf-free5gc-nssf-nssf-857985f7bf-g2nzq      1/1     Running   0          106m
f5gc           f5gc-pcf-free5gc-pcf-pcf-74545f4869-tzvgz         1/1     Running   0          106m
f5gc           f5gc-smf-free5gc-smf-smf-74b7d7866d-wx4bv         1/1     Running   0          78m
f5gc           f5gc-udm-free5gc-udm-udm-74469f57c5-hh47m         1/1     Running   0          106m
f5gc           f5gc-udr-free5gc-udr-udr-94d6b67ff-c45b8          1/1     Running   0          106m
f5gc           f5gc-webui-free5gc-webui-webui-57bd79bf6d-6sjwj   1/1     Running   0          106m
f5gc           mongodb-0                                 1/1     Running   0          106m
kube-flannel   kube-flannel-ds-mgxw9                     1/1     Running   0          4d2h
kube-system    coredns-74ff55c5b-8hhdg                   1/1     Running   0          4d2h
kube-system    coredns-74ff55c5b-r69jt                   1/1     Running   0          4d2h
kube-system    etcd-f5gc-cp                              1/1     Running   0          4d2h
kube-system    kube-apiserver-f5gc-cp                    1/1     Running   90         4d2h
kube-system    kube-controller-manager-f5gc-cp           1/1     Running   1          4d2h
kube-system    kube-multus-ds-m4rc5                      1/1     Running   0          107m
kube-system    kube-proxy-s9rdt                          1/1     Running   0          4d2h
kube-system    kube-scheduler-f5gc-cp                    1/1     Running   1          4d2h
onaplab@f5gc-cp:~$
```

5G SA Control Plane Kubernetes Pods On CP VM

```
time="2023-01-13T19:53:19Z" level=info msg="Handle Uplink Nas Transport" category=NGAP component=AMF ran_addr="172.23.62.20:49618"
time="2023-01-13T19:53:19Z" level=info msg="Uplink NAS Transport (RAN UE NGAP ID: 1)" amf_ue_ngap_id="AMF_UE_NGAP_ID:1" category=N
GAP component=AMF ran_addr="172.23.62.20:49618"
time="2023-01-13T19:53:19Z" level=info msg="Handle Registration Request" amf_ue_ngap_id="AMF_UE_NGAP_ID:1" category=GMM component=
AMF supi="SUPI:imsi-208930000000003"
time="2023-01-13T19:53:19Z" level=info msg="Authentication procedure" amf_ue_ngap_id="AMF_UE_NGAP_ID:1" category=GMM component=AMF
 supi="SUPI:imsi-208930000000003"
time="2023-01-13T19:53:19Z" level=info msg="Handle MobilityAndPeriodicRegistrationUpdating" amf_ue_ngap_id="AMF_UE_NGAP_ID:1" cate
gory=GMM component=AMF supi="SUPI:imsi-208930000000003"
time="2023-01-13T19:53:19Z" level=info msg="RequestedNssai - ServingSnssai: &{Sst:1 Sd:010203}, HomeSnssai: <nil>" amf_ue_ngap_id=
"AMF_UE_NGAP_ID:1" category=GMM component=AMF supi="SUPI:imsi-208930000000003"
time="2023-01-13T19:53:19Z" level=info msg="RequestedNssai - ServingSnssai: &{Sst:1 Sd:010203}, HomeSnssai: <nil>" amf_ue_ngap_id=
"AMF_UE_NGAP_ID:1" category=GMM component=AMF supi="SUPI:imsi-208930000000003"
time="2023-01-13T19:53:19Z" level=info msg="Send Downlink Nas Transport" amf_ue_ngap_id="AMF_UE_NGAP_ID:1" category=NGAP component
=AMF ran_addr="172.23.62.20:49618"
```

AMF Log

```
time="2023-01-13T18:38:18Z" level=info msg="Listen on 172.23.64.20:8805" category=PFCP component=SMF
time="2023-01-13T18:38:18Z" level=info msg="Send PFCP Association Request to UPF[172.23.64.10]\n" category=App component=SMF
time="2023-01-13T18:38:18Z" level=info msg="In HandlePfcpAssociationSetupResponse" category=PFCP component=SMF
time="2023-01-13T18:38:18Z" level=info msg="Remove Request Transaction [1]\n" category=PFCP component=LIB
time="2023-01-13T18:38:18Z" level=info msg="Handle PFCP Association Setup Response with NodeID[172.23.64.10]" category=PFCP compon
ent=SMF
time="2023-01-13T18:38:18Z" level=info msg="UPF(172.23.64.10)[internet] setup association" category=PFCP component=SMF
time="2023-01-13T18:53:19Z" level=info msg="Recieve Create SM Context Request" category=PduSess component=SMF
time="2023-01-13T18:53:19Z" level=info msg="In HandlePDUSessionSMContextCreate" category=PduSess component=SMF
time="2023-01-13T18:53:19Z" level=info msg="Send NF Discovery Serving UDM Successfully" category=PduSess component=SMF
time="2023-01-13T18:53:19Z" level=info msg="Allocated UE IP address: 10.1.0.1" category=CTX component=SMF
time="2023-01-13T18:53:19Z" level=info msg="Selected UPF: UPF" category=CTX component=SMF
time="2023-01-13T18:53:19Z" level=info msg="UE[imsi-208930000000003] PDUSessionID[1] IP[10.1.0.1]" category=PduSess component=SMF
```

SMF Log

Non-Public Networks at Metro Edge

WHAT IS A NON-PUBLIC NETWORK?

Non-Public Networks (NPN), such as Private 5G and similar initiatives, allow non-network customers (enterprises, governments, etc.) to **create and operate their own self-contained wireless network**.

OPTIMIZE YOUR NPN AT EQUINIX

- FLEXIBLE HOSTING OF MEC AND DU/CU INFRASTRUCTURE VIA COLO OR METAL
- INTELLIGENT MANAGEMENT OF DEPLOYED RAN ASSETS FROM A CENTRALIZED POINT OF CONTROL
- HOSTED UPF AT EQUINIX TO DELIVER LOW LATENCY CLOSEST TO CRITICAL PARTNERS & ECOSYSTEMS
- ON-DEMAND, AUTOMATED INTERCONNECTION TO DEPLOYED INFRASTRUCTURE & ECOSYSTEMS
- NPN INVESTMENT AT EQUINIX DRIVES OPEX SPEND WHILE LOWERING COSTS & MAXIMIZING MARGIN