

Enterprise Private 5G

5G Hybrid Multicloud Demo Using Equinix Infra and Services

FiveG (5G) Optimized by Real Time Edge (FORTE)

July 2023

Enterprise 5G Fixed/Mobile Hybrid/Multi-Cloud Access

We will demonstrate the “Enterprise 5G Fixed/Mobile Hybrid/Multi-Cloud Access” use case:

- Simulated, open source based 5G Stand Alone network (including UPF, Control Plane, gNB and UE) is privately interconnected to multiple public clouds, an Edge Computing Cloud and the Internet using Equinix Fabric, Equinix Network Edge, Equinix Metal and Equinix Connect (Internet access) services.
- A fully automated infrastructure deployment using Infra-as-Code tooling (Terraform) of low latency virtual connectivity to AWS and Azure including L2 connections, IP addressing, BGP peering and end-to-end integration with AWS VPC/EC2 and Azure VNET/VM
- Deployment of an Equinix Metal bare metal server including its end-to-end connectivity to 5G and installation of a Kubernetes cluster, as well as low latency connectivity to the internet.
- Deployment of a cloud native IoT Gateway application on the Edge Computing cloud (on top of Kubernetes) and connectivity from the IoT client app running on the 5G UE to the IoT Gateway as well as private low latency connectivity from the UE to AWS, Azure, Equinix Metal and the Internet.
- All capabilities in the demo including the simulated 5G Sandbox and Terraform based automation will be based on Equinix production infrastructure and digital services.

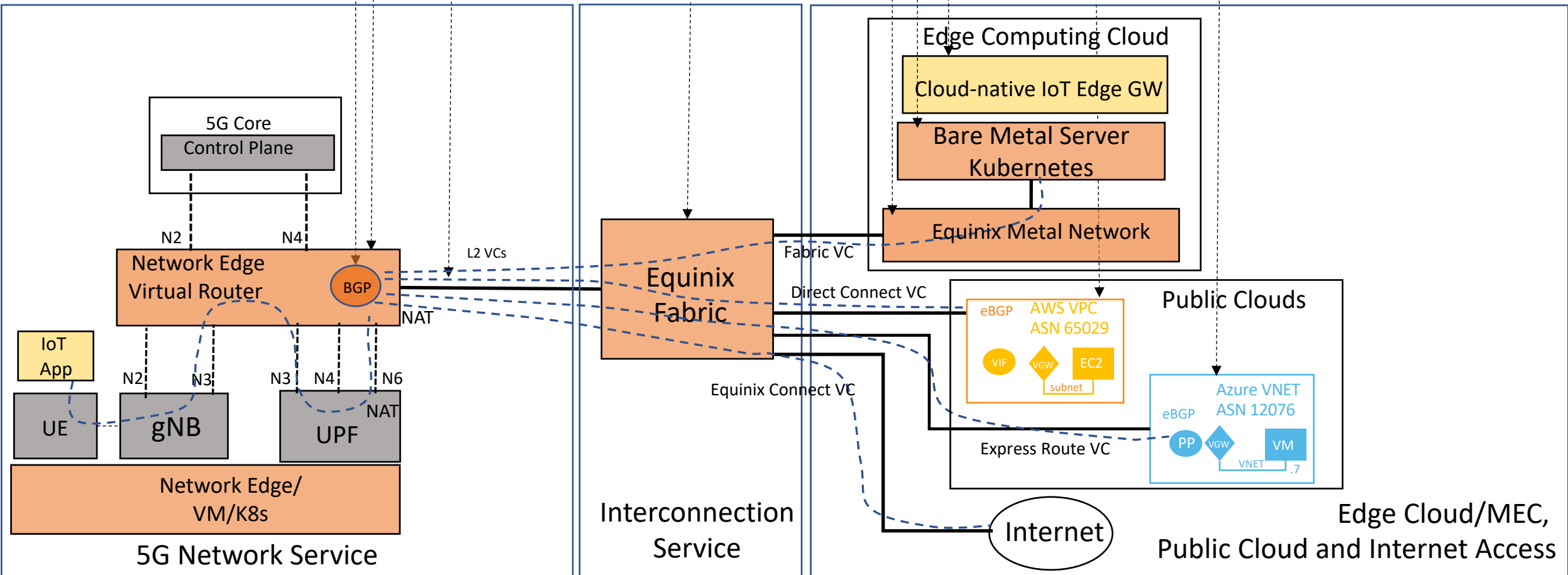
Use Case: Enterprise 5G Fixed/Mobile Hybrid/Multi Cloud Access

Equinix Infra-as-Code (Terraform) Orchestration

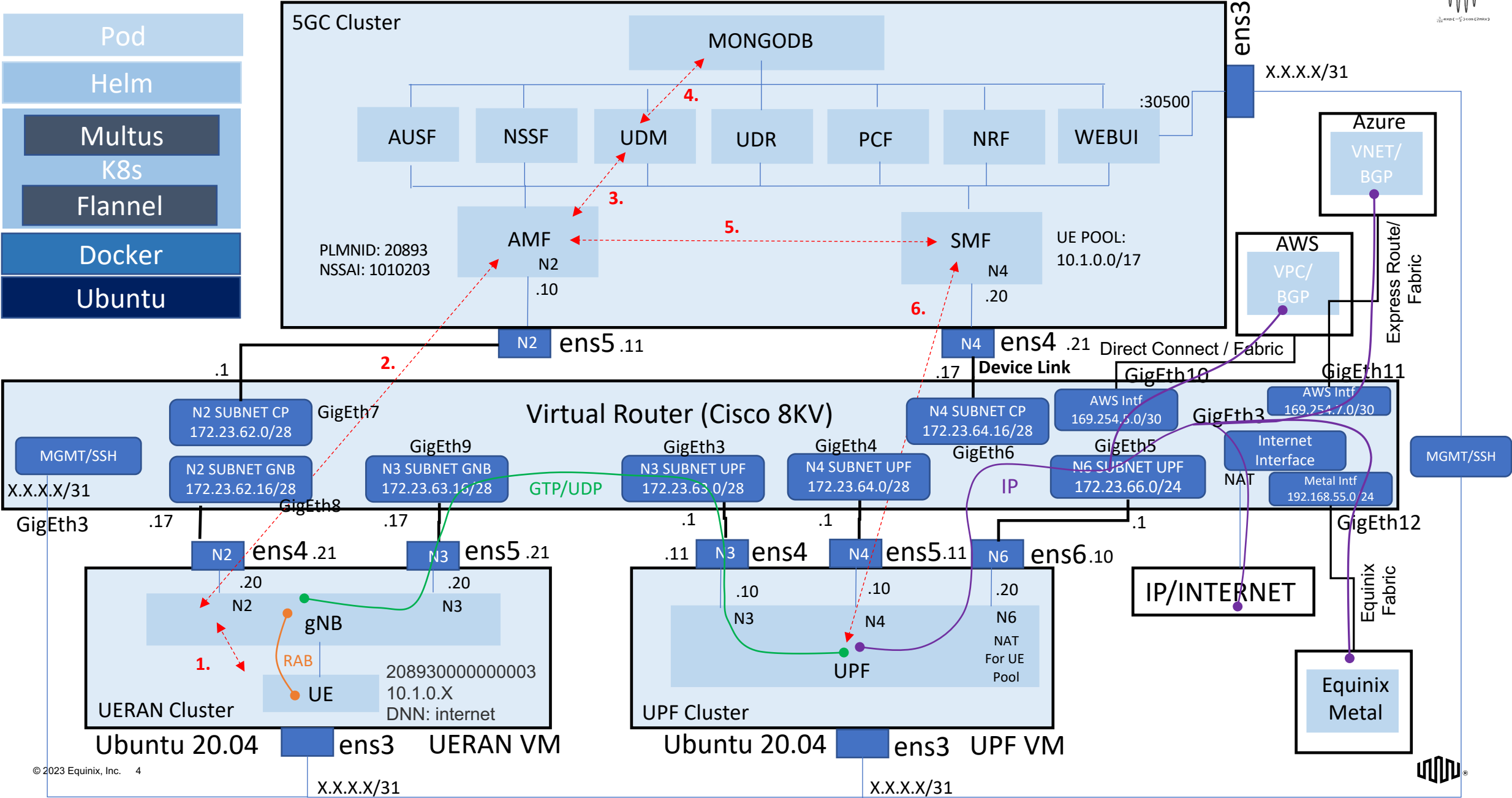
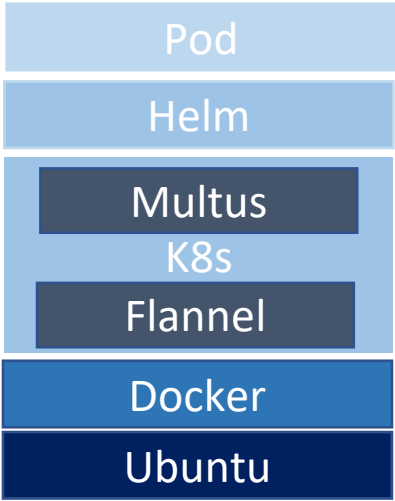
5G Operator Resources
(Simulated on Equinix NE, Silicon Valley, CA)

Interconnection
Provider Resources
(Production Equinix Fabric)

Edge Cloud, Public Cloud, Internet Access Resources
(Production Equinix Metal, Equinix Internet Access, Azure, AWS, Silicon Valley, CA)

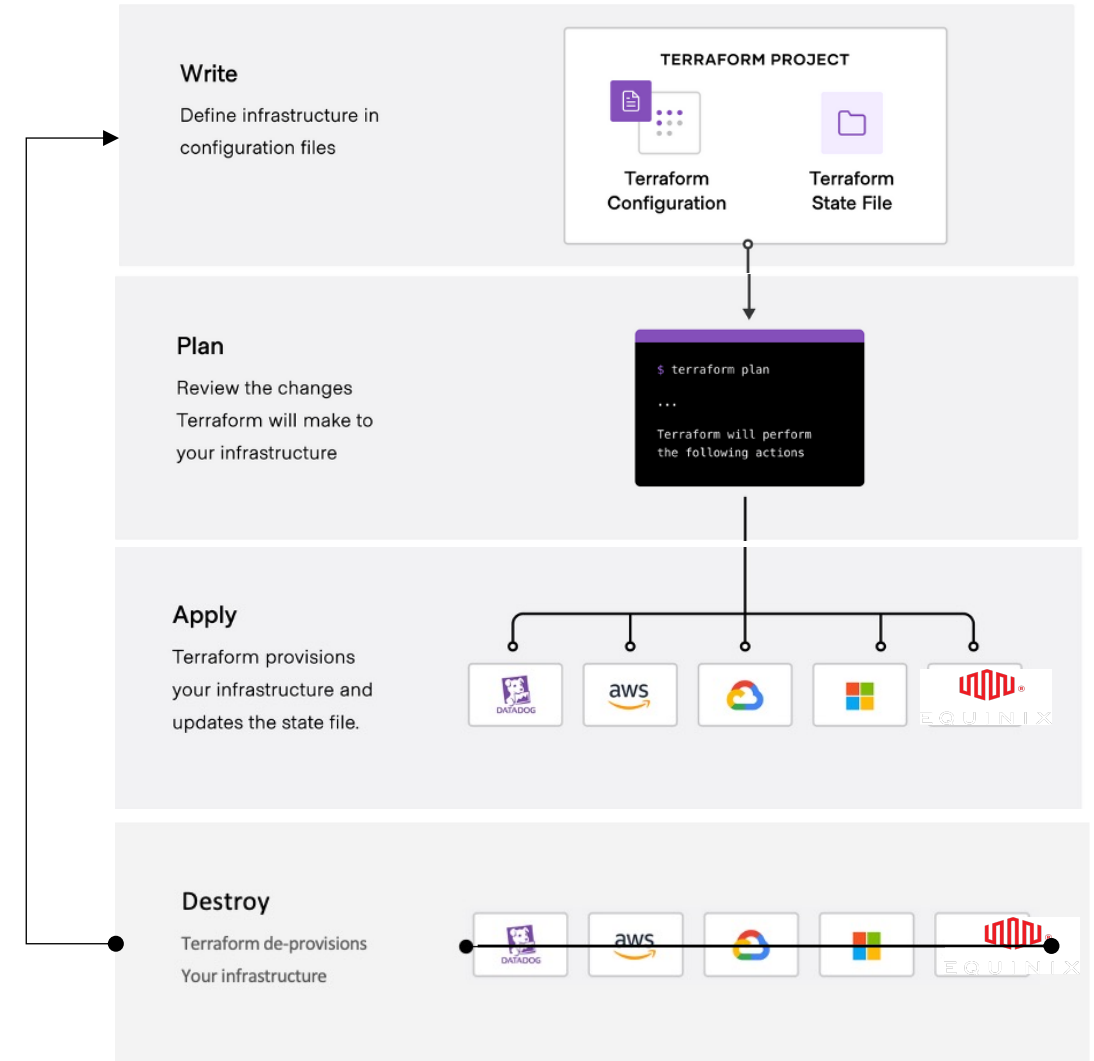


Free5GC Deployment on Equinix Network Edge



Overview of Infra-as-Code automation

- Terraform is an infrastructure as code tool that lets you define both cloud and edge resources in human-readable configuration files that you can version, reuse, and share.
- You can then use a consistent workflow to provision and manage all of your infrastructure throughout its lifecycle.
- Terraform can manage low-level components like compute, storage, and networking resources, as well as high-level components like Software as a Service (SaaS) features.



What does the use case do?

Infrastructure Orchestration Stage (Equinix)

5G Operator (pre-built)

- Orchestrate Bare Metal
- Orchestrate K8s Install
- Orchestrate UPF install

Interconnect Provider

Create Connections:

- Public Clouds
- Internet
- Edge Computing Cloud

Edge Computing Cloud Provider

- Orchestrate Bare Metal
- Orchestrate K8s Install

Public Cloud IaaS and MEC Services/Applications Deployment Stage

Public Clouds

Create IaaS and Cloud Networking Configs

- Orchestrate AWS Direct Connect and Express Route
- Orchestrate private BGP Peering
- Orchestrate VNET and VPC integration

MEC App Provider

Orchestrate hybrid MEC IoT Application

- Orchestrate Azure IoT Edge GW on MEC Server
- Orchestrate Azure IaaS and IoT SaaS (IoT Hub)

End-to-end Application Operation Stage

5G UE

Register with 5G Network
Establish PDN Connection

IoT Client

Send Encoded
IoT Sensor data
(Temp, Humid, Pressure)

IoT Edge Gateway

Receive encoded data
Decode sensor data
Obtain location data
Send sensor and loc data to cloud

A large, faint, stylized logo, likely the Equinix logo, is positioned in the background of the slide. It consists of several vertical, interconnected shapes that form a larger, abstract figure.

Demo of Enterprise 5G Use Case (live)

Terraform Infra-as-Code Automation



AWS

```
tfaws - main.tf
tfaws main.tf
Project tfaws ~/workdir/tf/tfaws
  .terraform
    terraform.lock.hcl
    main.tf
    terraform.tf
    terraform.tfstate
    terraform.tfvars
    variables.tf
  External Libraries
  Scratches and Consoles
11 provider "equinix" {
12   client_id = var.equinix_client_id
13   client_secret = var.equinix_client_secret
14 }
15
16 provider "aws" {
17   access_key = var.aws_access_key
18   secret_key = var.aws_secret_key
19   region = var.aws_region
20   # aws_account_id = var.aws_account_id
21 }
22
23 data "equinix_ecx_l2_sellerprofile" "aws" {
24   name = "AWS Direct Connect"
25   organization_global_name = "AWS"
26 }
resource aws_dx_private_virtual_interface example
Termi... Local x + v
aws_dx_private_virtual_interface.example: Still creating... [4m50s elapsed]
aws_dx_private_virtual_interface.example: Still creating... [5m0s elapsed]
aws_dx_private_virtual_interface.example: Still creating... [5m10s elapsed]
aws_dx_private_virtual_interface.example: Still creating... [5m20s elapsed]
aws_dx_private_virtual_interface.example: Still creating... [5m30s elapsed]
aws_dx_private_virtual_interface.example: Still creating... [5m40s elapsed]
aws_dx_private_virtual_interface.example: Creation complete after 5m40s [id=dxvif-fgdcit5f]
Apply complete! Resources: 3 added, 0 changed, 0 destroyed.
```

Azure

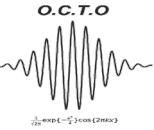
```
tfazr - main.tf
tfazr main.tf
Project tfazr ~/workdir/tf/tfazr
  .terraform
    providers
      registry.terraform.io
        equinix
        hashicorp
    terraform.lock.hcl
    main.tf
    terraform.tf
    terraform.tfstate
    terraform.tfvars
    variables.tf
  External Libraries
  Scratches and Consoles
1 provider "equinix" {
2   client_id = var.equinix_client_id
3   client_secret = var.equinix_client_secret
4 }
5
6 provider "azurerm" {
7   features {}
8
9   subscription_id = var.azure_subscription_id
10  tenant_id = var.azure_tenant_id
11  client_id = var.azure_client_id
12  client_secret = var.azure_client_secret
13 }
14
15 data "equinix_ecx_l2_sellerprofile" "azure" {
16   name = "Azure ExpressRoute"
17 }
provider azurerm client_id
Termi... Local x + v
the -compact-warnings option.
Warning: Values for undeclared variables
In addition to the other similar warnings shown, 4 other variable(s) defined without being declared.
Apply complete! Resources: 8 added, 0 changed, 0 destroyed.
```

Equinix Metal

```
tfmtl - main.tf
tfmtl main.tf
Project tfmtl ~/workdir/tf/tfmtl
  .terraform
    modules
      metalnodes
        cloud-config.cfg
        main.tf
        outputs.tf
        pre-cloud-config.sh
      ssh
        terraform.lock.hcl
        main.tf
        main.tf-old
        ssh-key-hyw2j
        terraform.tfstate
        terraform.tfvars
        variables.tf
  External Libraries
1 # define provider version and Metal Token
2 terraform {
3   required_providers {
4     equinix = {
5       source = "equinix/equinix"
6       version = "= 1.13.0"
7     }
8   }
9 }
10
11 provider "equinix" {
12   auth_token = var.auth_token
13 }
14
15 module metal_nodes {
16   eqx_metal_connection_service_token_type
17 }
Termi... Local x + v
module.metal_nodes.equinix_metal_device_network_type.metal_nodes: Still creating... [10s elapsed]
module.metal_nodes.equinix_metal_port.port[0]: Still creating... [10s elapsed]
module.metal_nodes.equinix_metal_port.port[0]: Still creating... [20s elapsed]
module.metal_nodes.equinix_metal_device_network_type.metal_nodes: Still creating... [20s elapsed]
module.metal_nodes.equinix_metal_device_network_type.metal_nodes: Still creating... [30s elapsed]
module.metal_nodes.equinix_metal_port.port[0]: Still creating... [30s elapsed]
module.metal_nodes.equinix_metal_port.port[0]: Creation complete after 33s [id=931cf34d-3c78-41fc-831b-
module.metal_nodes.equinix_metal_device_network_type.metal_nodes: Still creating... [40s elapsed]
module.metal_nodes.equinix_metal_device_network_type.metal_nodes: Creation complete after 41s [id=5cdc8
Apply complete! Resources: 10 added, 0 changed, 0 destroyed.
```



Demo Step 1: Enterprise 5G Fixed/Mobile Internet Access

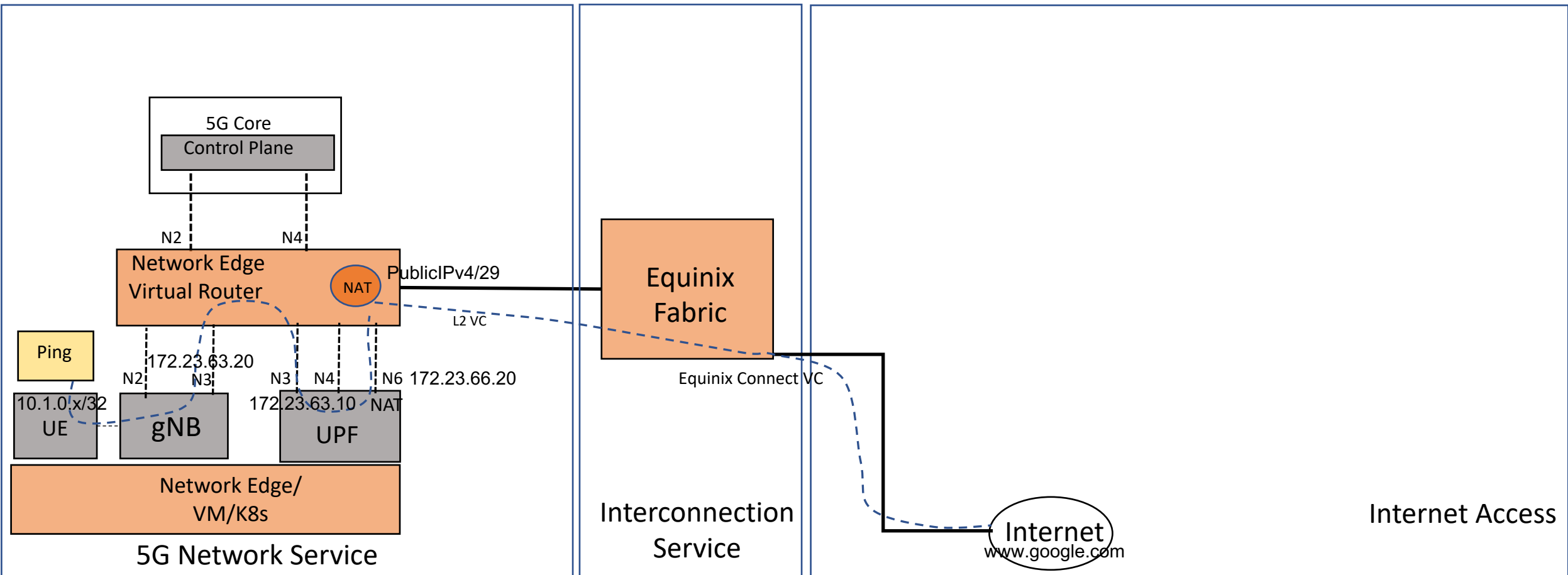


Equinix Infra-as-Code (Terraform) Orchestration

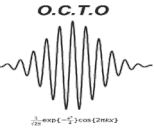
5G Operator Resources
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Interconnection
Provider Resources
(Production Equinix Fabric)

Edge Cloud, Public Cloud, Internet Access Resources
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Demo Step 2: Enterprise 5G Fixed/Mobile Edge Computing Cloud Access and MEC App Deployment

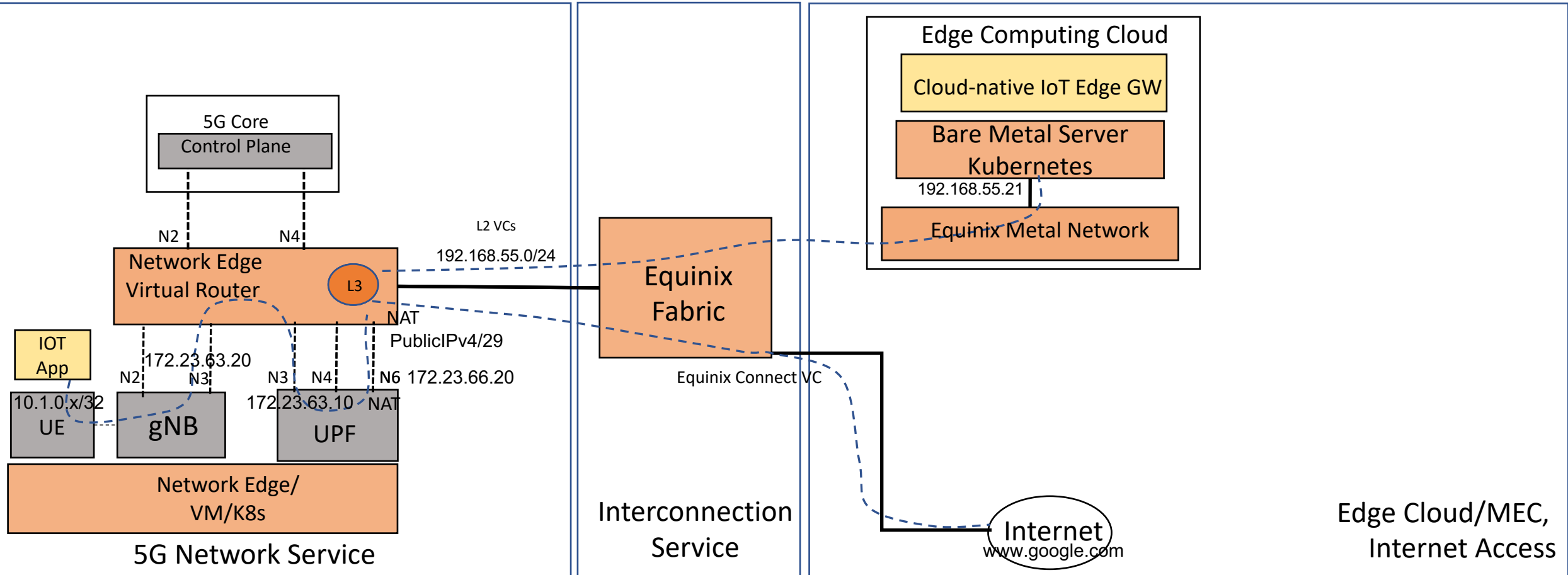


Equinix Infra-as-Code (Terraform) Orchestration

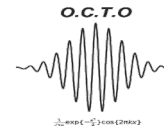
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Demo Step 3: Enterprise 5G Fixed/Mobile Multi Cloud Access

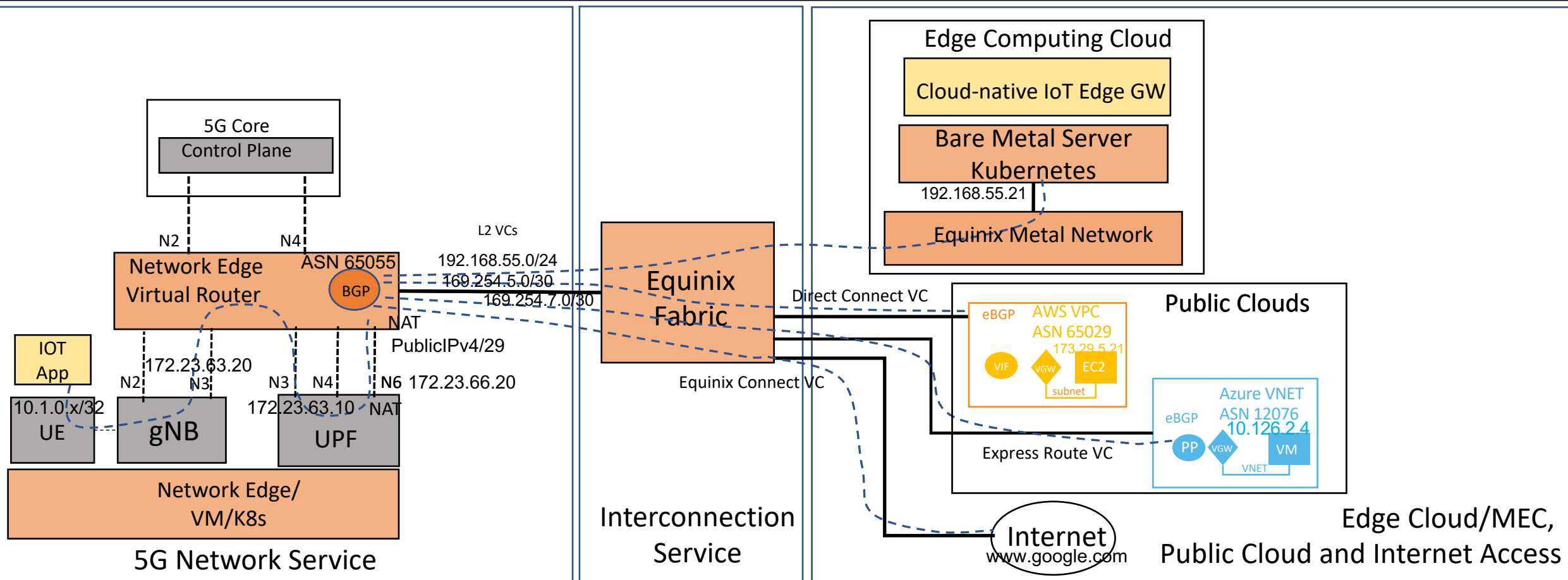


Equinix Infra-as-Code (Terraform) Orchestration

5G Operator Resources
(Simulated on Equinix NE, Silicon Valley, CA)

Interconnection
Provider Resources
(Production Equinix Fabric)

Edge Cloud, Public Cloud, Internet Access Resources
(Production Equinix Metal, Equinix Internet Access, Azure, AWS, Silicon Valley, CA)



Demo stats

UE PDN Connection

```
[2023-06-14 16:09:38.474] [nas] [debug] Sending Initial Registration
[2023-06-14 16:09:38.474] [nas] [info] UE switches to state [MM-REGISTER-INITIATED]
[2023-06-14 16:09:38.474] [rrc] [debug] Sending RRC Setup Request
[2023-06-14 16:09:38.474] [rrc] [info] RRC connection established
[2023-06-14 16:09:38.474] [rrc] [info] UE switches to state [RRC-CONNECTED]
[2023-06-14 16:09:38.474] [nas] [info] UE switches to state [CM-CONNECTED]
[2023-06-14 16:09:38.604] [nas] [debug] Authentication Request received
[2023-06-14 16:09:38.611] [nas] [debug] Security Mode Command received
[2023-06-14 16:09:38.611] [nas] [debug] Selected integrity[2] ciphering[0]
[2023-06-14 16:09:39.103] [nas] [debug] Registration accept received
[2023-06-14 16:09:39.103] [nas] [info] UE switches to state [MM-REGISTERED/NORMAL-SERVICE]
[2023-06-14 16:09:39.103] [nas] [debug] Sending Registration Complete
[2023-06-14 16:09:39.103] [nas] [info] Initial Registration is successful
[2023-06-14 16:09:39.103] [nas] [debug] Sending PDU Session Establishment Request
[2023-06-14 16:09:39.103] [nas] [debug] UAC access attempt is allowed for identity[0], category[MO_sig]
[2023-06-14 16:09:39.908] [nas] [debug] PDU Session Establishment Accept received
[2023-06-14 16:09:39.908] [nas] [info] PDU Session establishment is successful PSI[1]
[2023-06-14 16:09:39.919] [app] [info] Connection setup for PDU session[1] is successful, TUN interface[uesimtun0, 10.1.0.6] is up.
```

UE PDN IP Address

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-htf4x:/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
2: eth0@if42: <BROADCAST,MULTICAST,UP,LOWER_UP> mtu 8900 qdisc noqueue state UP group default
    link/ether f6:9a:9e:3b:13:66 brd ff:ff:ff:ff:ff:ff link-netnsid 0
    inet 10.244.0.228/24 brd 10.244.0.255 scope global eth0
        valid_lft forever preferred_lft forever
6: uesimtun0: <POINTOPOINT,PROMISC,NOTRAILERS,UP,LOWER_UP> mtu 1400 qdisc fq_codel state UNKNOWN group default qlen 500
    link/none
    inet 10.1.0.6/32 scope global uesimtun0
        valid_lft forever preferred_lft forever
```

IOT Edge GW Log – decoded message

```
Listening
Connection address: ('10.244.0.1', 10108)
received data: b'\n  "ack": "false", \n  "channel": 6, \n  "datarate": 3, \n  "devClass": "A", \n  "devEui": "0004A30B001BA\nAAA", \n  "freq": 903.5, \n  "gwEui": "00250C00010003A9", \n  "joinId": 90, \n  "pdu": "007321E7016700dc026866", \n  "port":\n  3, \n  "rssi": -39, \n  "seqno": 60782, \n  "snr": 10.75, \n  "txtime": "2023-06-12T17:00:36-47"\n}'
{'ack': 'false', 'channel': 6, 'datarate': 3, 'devClass': 'A', 'devEui': '0004A30B001BA', 'freq': 903.5, 'gwEui': '00250C00010\n003A9', 'joinId': 90, 'pdu': '007321E7016700dc026866', 'port': 3, 'rssi': -39, 'seqno': 60782, 'snr': 10.75, 'txtime': '2023-06-1\n2T17:00:36-47'}
007321E7016700dc026866
00dc
66
21E7
{"TIMESTAMP": "2023-06-12T17:00:36-47", "Device EUI": "0004A30B001BAAAA", "Temperature": 71.6, "Humidity": 51.0, "Pressure": 867.\n9}
Listening
```

Ping from UE to Internet (~3msec RTT)

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-htf4x:/ueransim/build# ping www.google.com -I uesimtun0
PING www.google.com (142.251.46.228) from 10.1.0.6 uesimtun0: 56(84) bytes of data.
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=1 ttl=118 time=3.36 ms
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=2 ttl=118 time=2.61 ms
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=3 ttl=118 time=2.60 ms
64 bytes from sfo03s27-in-f4.1e100.net (142.251.46.228): icmp_seq=4 ttl=118 time=2.57 ms
```

Ping from UE to AWS (~4msec RTT)

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-htf4x:/ueransim/build# ping 173.29.5.21 -I uesimtun0
PING 173.29.5.21 (173.29.5.21) from 10.1.0.6 uesimtun0: 56(84) bytes of data.
64 bytes from 173.29.5.21: icmp_seq=1 ttl=61 time=3.50 ms
64 bytes from 173.29.5.21: icmp_seq=2 ttl=61 time=3.27 ms
64 bytes from 173.29.5.21: icmp_seq=3 ttl=61 time=3.20 ms
64 bytes from 173.29.5.21: icmp_seq=4 ttl=61 time=3.53 ms
```

Ping from UE to Equinix Metal (~3msec RTT)

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-htf4x:/ueransim/build# ping 192.168.55.21 -I uesimtun0
PING 192.168.55.21 (192.168.55.21) from 10.1.0.7 uesimtun0: 56(84) bytes of data.
64 bytes from 192.168.55.21: icmp_seq=1 ttl=62 time=2.98 ms
64 bytes from 192.168.55.21: icmp_seq=2 ttl=62 time=2.68 ms
64 bytes from 192.168.55.21: icmp_seq=3 ttl=62 time=3.02 ms
64 bytes from 192.168.55.21: icmp_seq=4 ttl=62 time=2.56 ms
```

Ping from UE to Azure (~5msec RTT)

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-htf4x:/ueransim/build# ping 10.126.2.4 -I uesimtun0
PING 10.126.2.4 (10.126.2.4) from 10.1.0.6 uesimtun0: 56(84) bytes of data.
64 bytes from 10.126.2.4: icmp_seq=1 ttl=61 time=4.33 ms
64 bytes from 10.126.2.4: icmp_seq=2 ttl=61 time=4.69 ms
64 bytes from 10.126.2.4: icmp_seq=3 ttl=61 time=4.19 ms
64 bytes from 10.126.2.4: icmp_seq=4 ttl=61 time=4.20 ms
```

UE IOT Client Log – encoded message

```
root@f5gc-ueran-ueransim-ue-95b9f89b4-htf4x:/ueransim/build# python iotclient.py
ENTER SERVER IPv4: "192.168.55.21"
192.168.55.21
ENTER SERVER PORT: 30808
30808
SENDING...
Source IP = 10.1.0.6
Start socket bind
End socket bind

2023-06-14T20:08:52-33
e6
62
21
##### COUNT: 1
{u'txtime': u'2023-06-14T20:08:52-33', u'datarate': 3, u'ack': u'false', u'seqno': 60782, u'pdu': u'007321E7016700e6026862', u'devClass': u'A',
u'snr': 10.75, u'devEui': u'0004A30B001BAAAA', u'rssi': -39, u'gwEui': u'00250C00010003A9', u'joinId': 90, u'freq': 903.5, u'port': 3, u'chann
el': 6}
```



EQUINIX