Research on Open 5GS and UERANSIM

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***Abstract*—Open5GS is an open-source implementation of the core network essential for 4G LTE and 5G systems. It adheres strictly to 3GPP standards, ensuring compatibility and interoperability with industry specifications. The platform's modular architecture supports both the Evolved Packet Core (EPC) for 4G LTE and the 5G Core (5GC) for standalone 5G networks, making it a versatile solution for various applications. Open5GS is designed to facilitate research, testing, and deployment of mobile core networks, offering a flexible and accessible approach for exploring and implementing next-generation wireless technologies in both academic and production environments.**

I. Introduction

Open5GS is a fully open-source software project that provides a comprehensive implementation of the core network essential for 4G LTE and 5G systems. It is designed to strictly comply with the 3GPP standards, ensuring seamless compatibility with industry specifications and enabling interoperability with various network components. This adherence to standards makes Open5GS a robust and versatile solution for building, testing, and deploying mobile core networks.

With its modular architecture, Open5GS supports both the Evolved Packet Core (EPC) for 4G LTE and the 5G Core (5GC) for standalone 5G networks. This dual compatibility allows it to cater to a wide range of use cases, including research and development, network testing, and even deployment in production environments. Open5GS is particularly valued for its accessibility and flexibility, making it an ideal choice for organizations and individuals exploring next-generation mobile network technologies.

II. Core Components of Open5GS

Open5GS comprises several critical functions, each mirroring the components specified in 3GPP standards:

A. 4G LTE (EPC) Components:

1) MME (Mobility Management Entity)::

- Responsible for signaling and session management between the mobile device (UE) and the network.
- Handles tasks like authentication, bearer management, handovers, and paging procedures.

2) SGW (Serving Gateway)::

- Manages data packet routing between the User Equipment (UE) and the PDN Gateway (PGW).
- Supports mobility for UEs as they move between eNodeBs.

3) PGW (PDN Gateway)::

- Provides connectivity between the LTE network and external packet data networks, such as the internet.
- Implements policies for QoS, packet filtering, and IP address allocation.

B. 5G Core (5GC) Components:

- AMF (Access and Mobility Management Function):– Centralizes mobility management tasks like registration, modification, and termination of PDU sessions.

  Allocates IP addresses to UEs and manages session QoS policies.
- UPF (User Plane Function):
  - Handles data forwarding and traffic routing on the user plane.
  - Optimized for high-throughput and low-latency applications.
- NRF (Network Repository Function), PCF (Policy Control Function), AUSF (Authentication Server Function), and others.

III. Features and Benefits

The 5G architecture is composed of various functions that work collaboratively to deliver advanced services:

- **3GPP Compliance:** Designed to meet the specifications of LTE (Release 8 and above) and 5G (Release 15+).
- **Modularity:** Each network function operates independently, allowing customized deployments.
- **Flexibility in Deployment:**
  - Supports both non-standalone (NSA) LTE deployments with EPC and standalone (SA) deployments with 5GC.
  - Usable with open-source RAN implementations like srsLTE or commercial RAN products.
- **Open and Extensible:** Written in C for high performance and is open-source, encouraging customization and extension by the community.
- **Cross-Platform Compatibility:** Runs on various platforms, including Linux distributions like Ubuntu and CentOS.

IV. UERANSIM :

UERANSIM (User Equipment and Radio Access Network Simulator) is an open-source tool designed to simulate critical aspects of a 5G network, specifically focusing on the **User Equipment (UE)** and the **Radio Access Network (RAN)**. It is an essential component in the 5G research and development ecosystem, enabling developers, researchers, and network engineers to experiment with and test 5G functionalities in a simulated environment.

A. Key Features of UERANSIM

1) UE Simulation::

- Simulates 5G mobile devices, including phones, IoT devices, and more.
- Performs crucial tasks such as:
  Registration: Establishes a connection with the 5G core network, simulating how a real device would connect to a live network.
  Session Management: Manages PDU (Packet Data Unit) sessions for data transfer.

B. *gNodeB (Next Generation NodeB) Simulation:*

Represents the 5G Radio Access Network (RAN), responsible for:

- Interfacing with the UE: Simulates communication between user devices and the core network.
- Signal Processing: Emulates the functionality of gNodeB, such as signaling and data transmission, to establish realistic network conditions.

C. *Standards Compliance:*

- Adheres to **3GPP specifications** for 5G NR (New Radio) and network protocols, ensuring realistic simulations aligned with industry standards.

1) Interoperability::

- Designed to seamlessly connect with 5G core networks such as **Open5GS**, allowing for end-to-end 5G network simulation.
- Supports integration with other open-source tools and commercial systems for flexible and scalable deployments.

D. *Use Case*

Open5GS and UERANSIM are often used together to simulate complete end-to-end 5G networks. Open5GS acts as the core network, while UERANSIM simulates the user devices and the radio access interface, making them ideal for testing, research, and development of 5G technology.

V. Steps to Configure Open5GS and MongoDB

A. *A. System Update*

To ensure you have the latest system packages, update the system:

```
sudo apt-get update
sudo apt-get install -y gnupg wget curl
```

B. *B. Install MongoDB*

MongoDB is a prerequisite for Open5GS. Follow the steps below to install MongoDB:

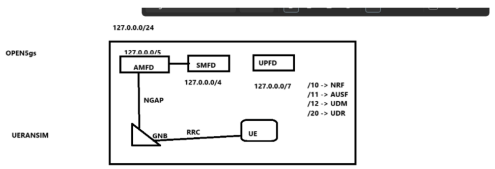
1) 1) Add MongoDB's Public Key: Download and add the MongoDB public key:

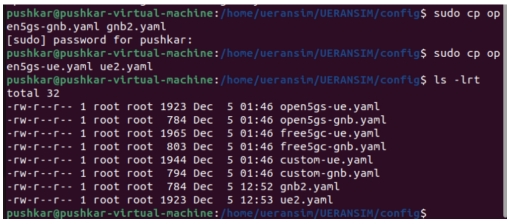
```
wget -qO - https://www.mongodb.org/static/pgp/
    server-6.0.asc | sudo apt-key add -
```

2) 2) Add MongoDB Repository: Add the MongoDB repository and update the package list:

```
echo "deb [arch=amd64,arm64] https://repo.
    mongodb.org/apt/ubuntu focal/mongodb-org
    /6.0 multiverse" | sudo tee /etc/apt/
    sources.list.d/mongodb-org-6.0.list
sudo apt update
```

3) 3) For Ubuntu 22.04: Handle `libssl1.1` Dependency: Since `libssl1.1` is not officially available for Ubuntu 22.04, use the following workaround:





a) a) Add the focal-security List for `libssl1.1`:

```
echo "deb http://security.ubuntu.com/ubuntu
    focal-security main" | sudo tee /etc/apt/
    sources.list.d/focal-security.list
sudo apt-get update && sudo apt-get install
    libssl1.1
```

b) b) Remove the focal-security List After Installation:

```
sudo rm /etc/apt/sources.list.d/focal-security
    .list
```

4) 4) Install MongoDB: Finally, install the MongoDB package:

```
sudo apt install -y mongodb-org mongodb-org-
    database
```

C. *C. Start and Enable MongoDB*

Start the MongoDB service and enable it to run on system startup:

```
sudo systemctl start mongod
sudo systemctl enable mongod
```

D. *FLOW DIAGRAM :*

VI. Seting up 2 Nodes in UERANSIM config :

A. *Build and Run gNodeB and UE in UERANSIM*

1) 1. Build UERANSIM:: Clone the UERANSIM repository and build the project on your system.

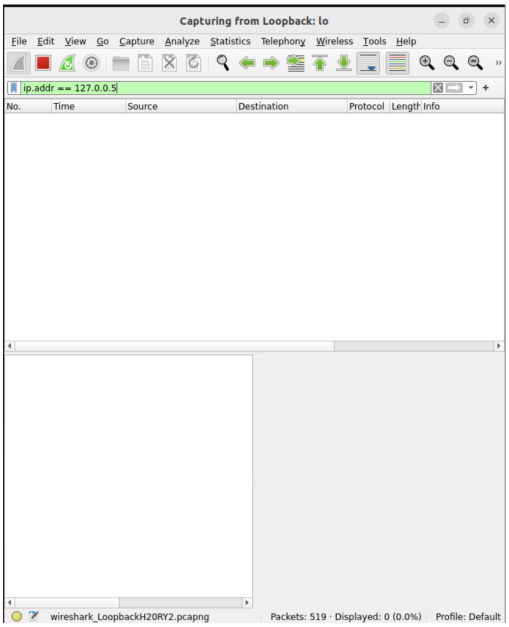
2) 2.Configure gNodeB: : in UERANSIM, you need to configure the gNodeB to connect to the AMF using NGAP over SCTP. Here's an example configuration file (gnb.yaml):

3) 3. Configure UE:: - The UE is also simulated using UERANSIM. Here is a sample configuration for the UE (ue.yaml):

- We will install some extension to add to wireshark and ue created will be simulator so it cant catch the packets send adding the extension will enable it.For thai we used RLS-wireshark-dissector.

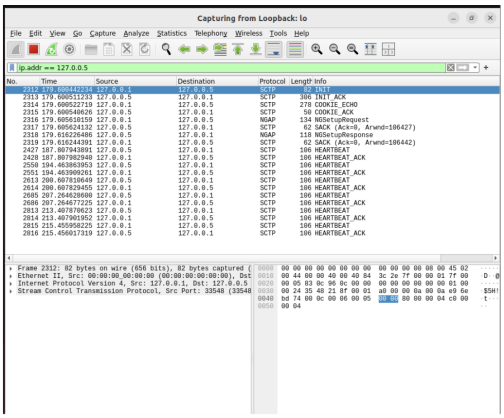
*gnb2.yaml [Read-Only]
/home/ueransim/UERANSIM/config

```yaml
mcc: '999'          # Mobile Country Code value
mnc: '70'           # 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: 127.0.0.5
    port: 38412

# List of supported S-NSSAIs by this gNB
slices:
  - sst: 1

# Indicates whether or not SCTP stream number errors should be ignored.
ignoreStreamIds: true
```



*ue2.yaml [Read-Only]
/home/ueransim/UERANSIM/config

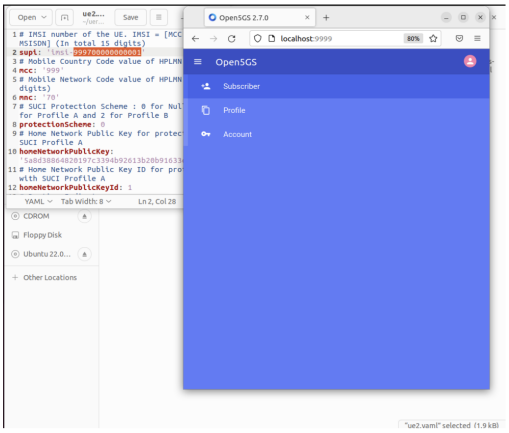
```yaml
# IMSI number of the UE. IMSI = [MCC|MNC|MSISDN] (In total 15 digits)
supi: 'imsi-999700000000001'
# Mobile Country Code value of HPLMN
mcc: '999'
# Mobile Network Code value of HPLMN (2 or 3 digits)
mnc: '70'
# SUCI Protection Scheme : 0 for Null-scheme, 1 for Profile A and 2 for Profile B
protectionScheme: 0
# Home Network Public Key for protecting with SUCI Profile A
homeNetworkPublicKey:
  '5a8d38864820197c3394b92613b20b91633cbd897119273bf8e4a6f4eec0a650'
# Home Network Public Key ID for protecting with SUCI Profile A
homeNetworkPublicKeyId: 1
# Routing Indicator
routingIndicator: '0000'

# Permanent subscription key
key: '465B5CE8B199B49FAA5F0A2EE238A6BC'
# Operator code (OP or OPC) of the UE
op: 'E8ED289DEBA952E4283B54E88E6183CA'
# This value specifies the OP type and it can be either 'OP' or 'OPC'
opType: 'OPC'
# Authentication Management Field (AMF) value
amf: '8000'
# IMEI number of the device. It is used if no SUPI is provided
imei: '3569380356543803'
# IMEISV number of the device. It is used if no SUPI and IMEI is provided
imeiSv: '4370816125816151'

# List of gNB IP addresses for Radio Link Simulation
gnbSearchList:
  - 127.0.0.1

# UAC Access Identities Configuration
uacAic:
  mps: false
  mcs: false

# UAC Access Control Class
uacAcc:
  normalClass: 0
```

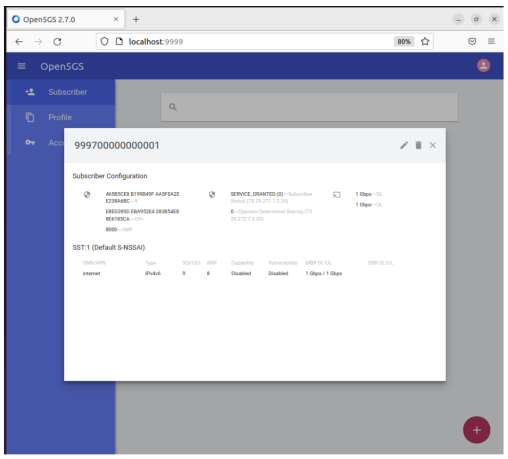


amf.yaml
/etc/open5gs

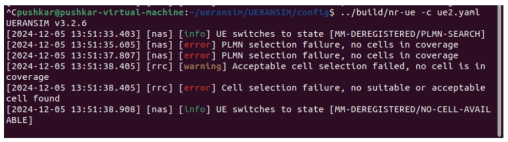
```yaml
logger:
  file:
    path: /var/log/open5gs/amf.log
#  level: info   # fatal|error|warn|info(default)|debug|trace

global:
  max:
    ue: 1024  # The number of UE can be increased depending on memory size.
#    peer: 64

amf:
  sbi:
    server:
      - address: 127.0.0.5
        port: 7777
    client:
#      nrf:
#        - uri: http://127.0.0.10:7777
      scp:
        - uri: http://127.0.0.200:7777
  ngap:
    server:
      - address: 127.0.0.5
  metrics:
    server:
      - address: 127.0.0.5
        port: 9090
  guami:
    - plmn_id:
        mcc: 999
        mnc: 70
      amf_id:
        region: 2
        set: 1
  tai:
    - plmn_id:
        mcc: 999
        mnc: 70
      tac: 1
  plmn_support:
    - plmn_id:
        mcc: 999
```

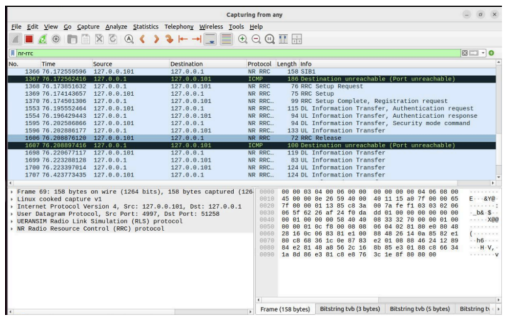
YAML Tab Width: 8 Ln 1, Col 1 INS





Adding Subscriber using MSI number.





Since I am interrupting, there are some errors messages receiving.

So I am using the commands as an administrator -¿ sudo ../build/nr-ue -c ue2.yaml

No with sudo call it will world smoothly and no error See the call flow after second request

VII. Conclusion

The successful implementation and simulation of Open5GS and UERANSIM provide a comprehensive understanding of the core components and functionalities of 5G networks. Open5GS offers a robust, standards-compliant core network implementation, while UERANSIM effectively simulates User Equipment (UE) and Radio Access Network (RAN) functionalities. Together, they enable the creation of an end-to-end 5G environment suitable for research, testing, and development.

This project serves as a foundation for further research and development in 5G networks, including optimization of Quality of Service (QoS), integration with IoT devices, and real-world deployment scenarios. It highlights the potential of open-source tools in advancing telecommunication technologies and their accessibility for educational and experimental purposes.