5G Networks

CITYMESH

Citymesh has been a key solution partner for business clients facing innovative challenges for nearly two decades. Since our establishment in 2006, we've specialized in providing both permanent and temporary connectivity solutions, harnessing advanced Wi-Fi, 0G, 4G, and 5G technologies.

Our approach is to layer high-tech solutions on top of our connectivity infrastructure, effectively turning connectivity into operational value.

This strategy has enabled us to serve a diverse range of sectors — industry, public services, offshore markets, education, healthcare, and smart cities. Additionally, we bring our expertise to various events and festivals, solidifying our position as a Techco powerhouse.

Our Solutions

Operator Solutions

Drone Solutions

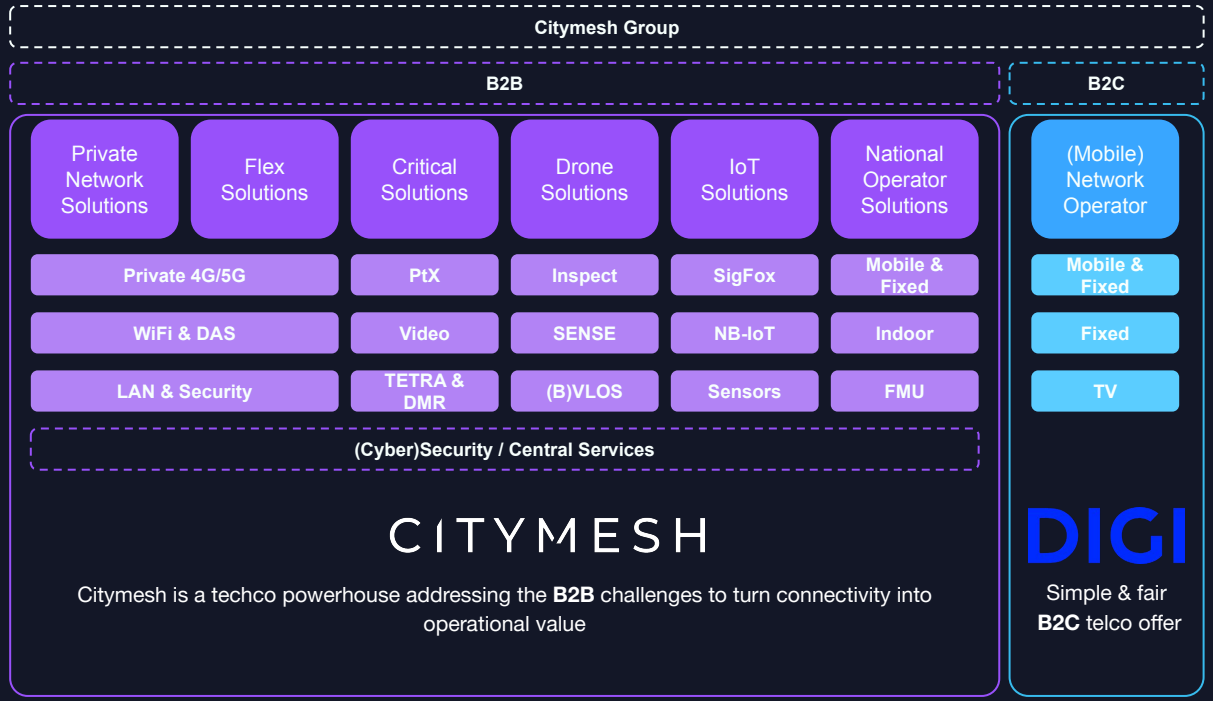
IT Integrator Solutions

IoT Solutions

Mission Critical Solutions

Temporary Solutions

Techco Powerhouse structure



From 0G to 5G

Emerged as a full-blown Techco entity, shifting from WiFi roots to a technology-centric identity.

We specialize in offering both permanent and temporary connectivity solutions, utilizing cutting-edge WiFi, IoT (0G), 4G, and 5G technologies **turning connectivity into operational value.**

DIGI will challenge & **redefine the B2C telco landscape in Belgium**


SAFETY DRONE

Difference between 4G and 5G

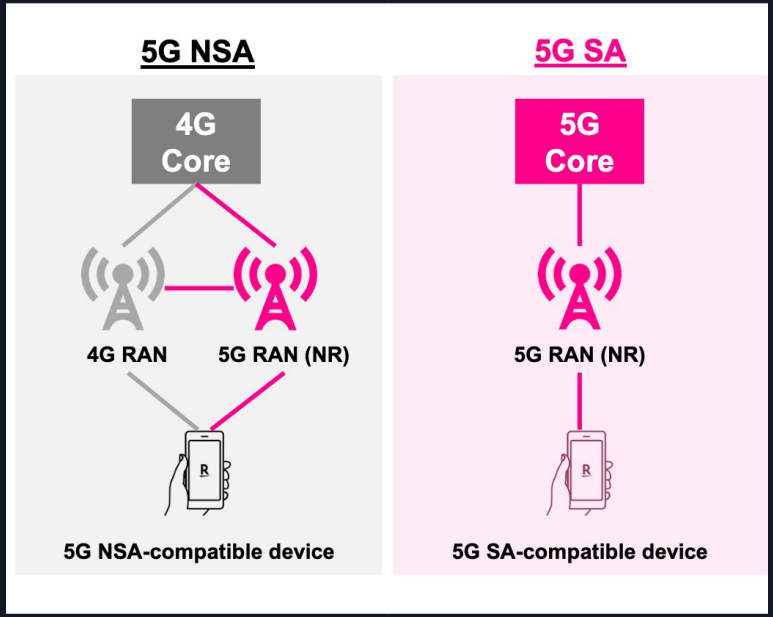
The key differences between **4G** and **5G** lie in their speed, latency, capacity, applications, deployment and the technology in general (frequency, bandwidth, modulation…).

Feature comparison: 4G vs 5G

Feature	4G	5G
Speed*	100 Mbps to 1 Gbps	
Latency*	30-50 milliseconds	
Device Density	Thousands of devices per km²	
Frequency	Below 6 GHz	
Applications	Mobile broadband, video streaming	
Energy Efficiency	Moderate	
Deployment	Centralized and Standalone	

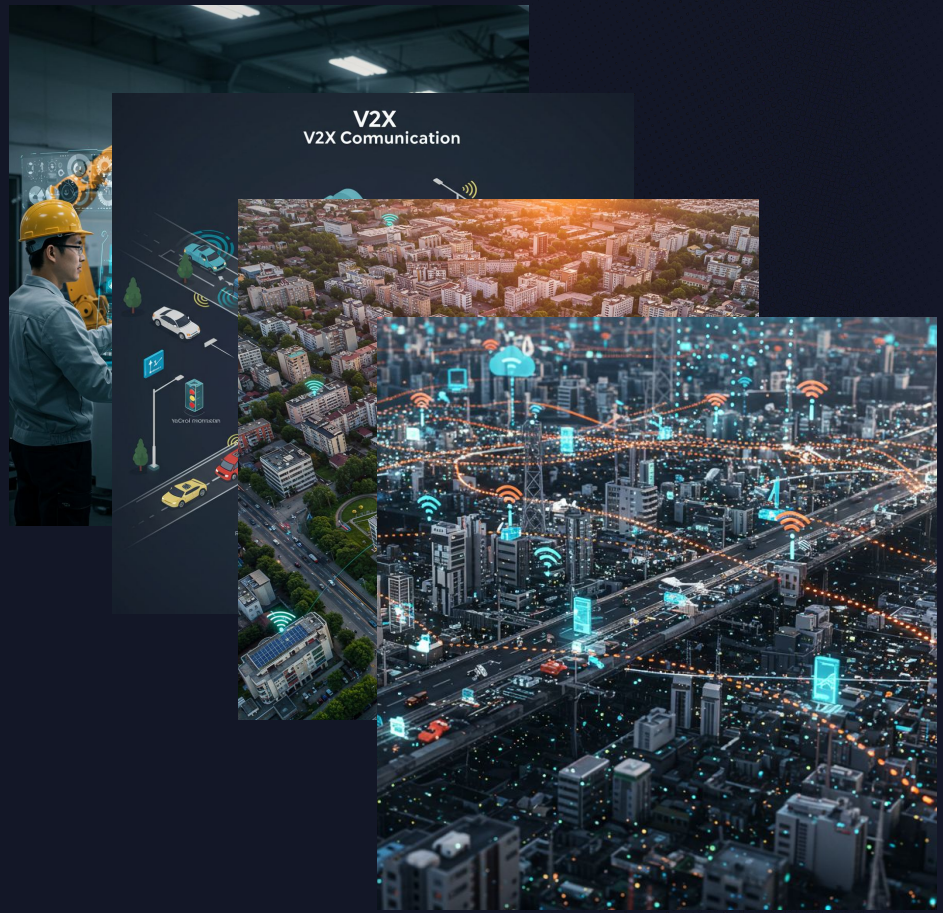
5G SA vs NSA

- 5G NSA or non-Standalone still uses the 4G Core in the background and depends on 4G RAN to establish the initial connection of the UE
- 5G SA (or Standalone) uses only 5G Core and 5G RAN
  - What are the advantages of this?



5G Use cases

- Industry 4.0
- V2x Communications
- Smart Cities
- Massive Machine Type Communications
- URLLC
- …



Why Private 5G?

- Full local Deployment with focus on sensitive data
- Guaranteed QoS
- Higher Signal power than WiFi:
  - 8 indoor WiFi APs = 1 5G Radio
  - 1 Outdoor 5G antenna reaches 5Km (depending on frequency, power…)
- Customized to client needs
  - Couples to LAN
  - Different Slices for different use cases (segmentation)
  - Decentralized setup
  - Modern equipment
  - …

Recent example of Private 5G…

Using a private 5G network to support coverage of the King's Coronation

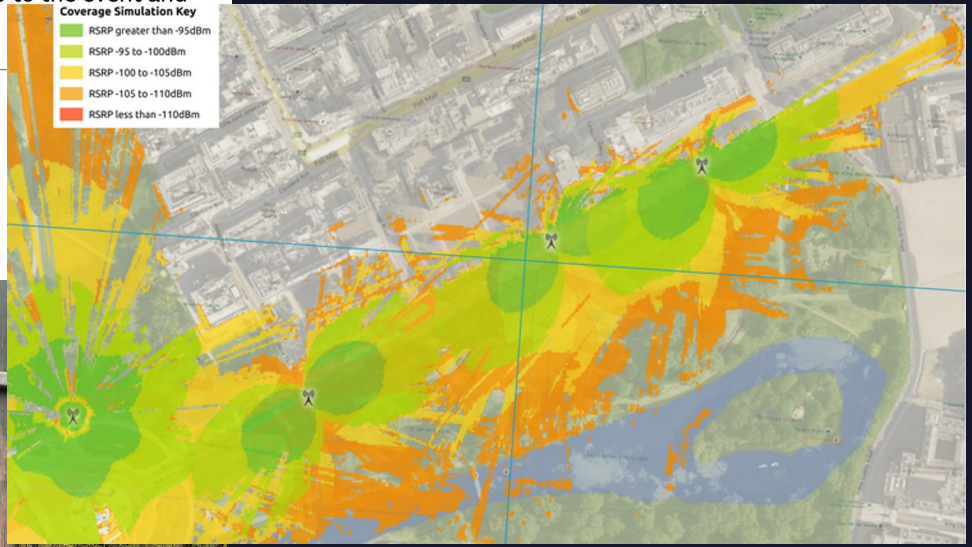
Could we provide a private 5G network that was available for the days leading up to the event and during the Coronation itself?

Ian Wagdin
Senior Technology Transfer Manager

Published: 5 May 2023

This week the world is focused on The Mall in central London for the **Coronation of King Charles III and Camilla, the Queen Consort**. afternoon the crowds are starting

Over recent years news crews hav heart of the action, they offer a gr truck or cable. This means that th anywhere you can get a mobile sig mobile networks can get saturate social media and **journalists comp**



Internship Project

Pepijn Algoedt & Kemp Dewulf

5G Project introduction

Questions

- How can we emit a **portable** indoor 5G signal
- How to determine **indoor 5G coverage** in a building
- How can we **determine** the number of indoor small cells?
- How can we adapt our solution to cover more use cases? (Extension to robotics…)

Solution

- Portable Indoor 5G emission
- Backend for data analysis
- Mobile Phone app for data collection

End Goal + challenges

End Goal

Determine an indoor coverage map

↓

To

↓

Know where to put 5G antennas indoors

↓

And

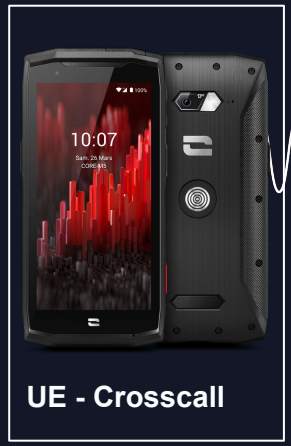
↓

Know how much we need to achieve a good signal

Challenges

- Indoor localisation without GPS
- Only 12 weeks of time

Our test setup / demo



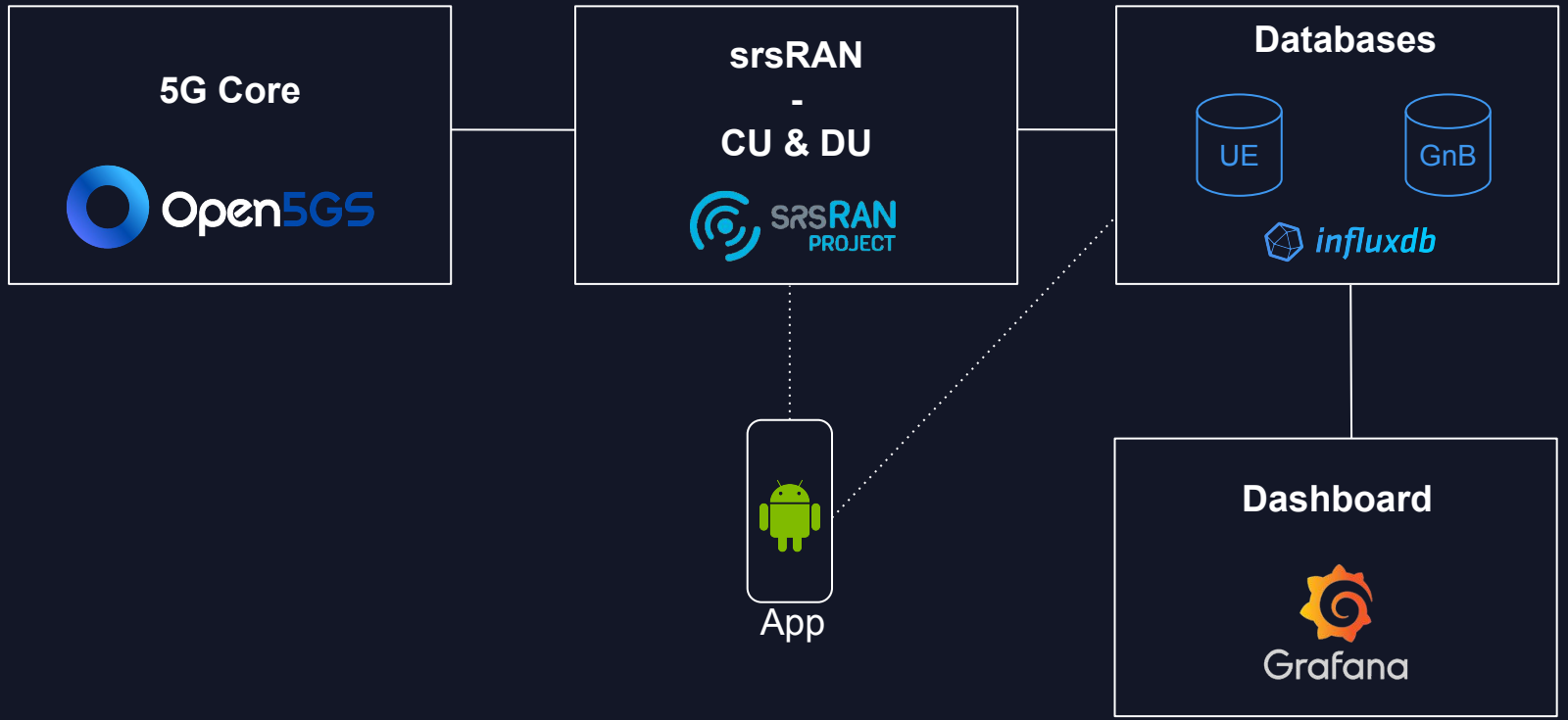
UE - Crosscall

gNB - Nokia Flexi Zone Small Cell

Core - Intel NUC

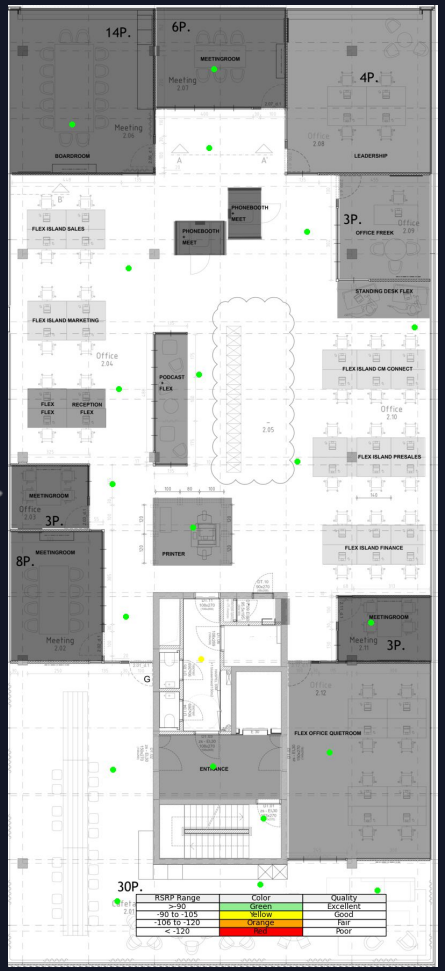
Powerstation

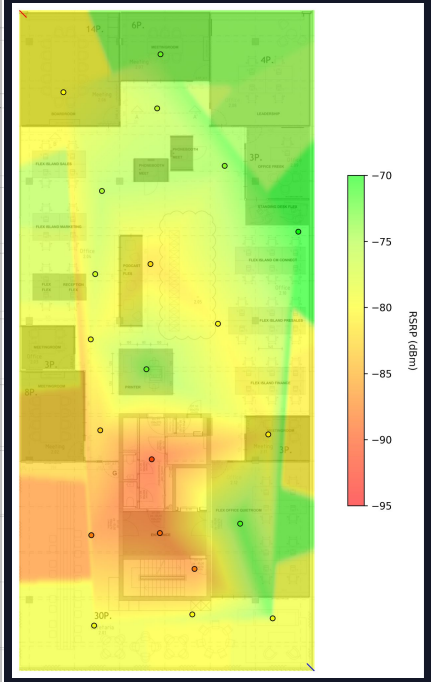
Process NUC


5G Core
Open5GS
srsRAN
-
CU & DU
SRSRAN PROJECT
Databases
UE
GnB
influxdb
App
Dashboard
Grafana

Use case: Bolster

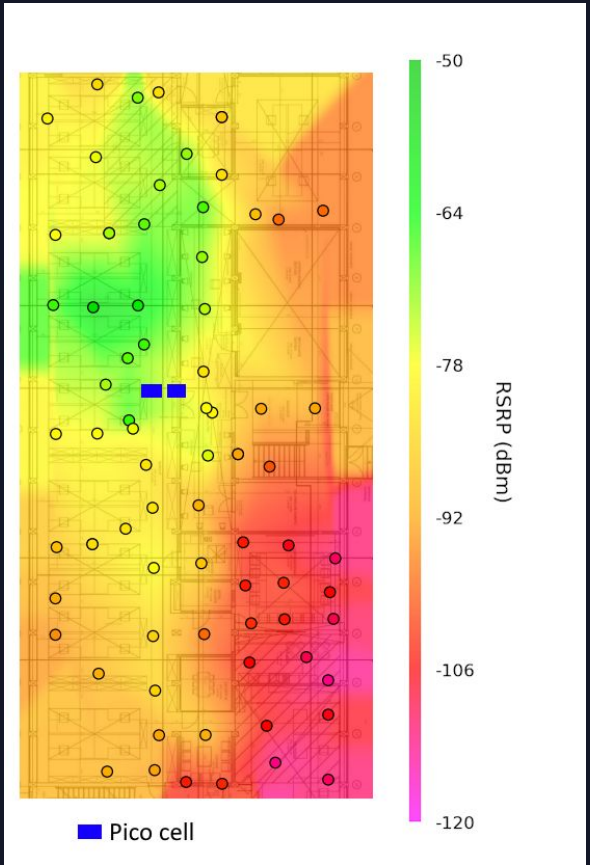
UE - Crosscall

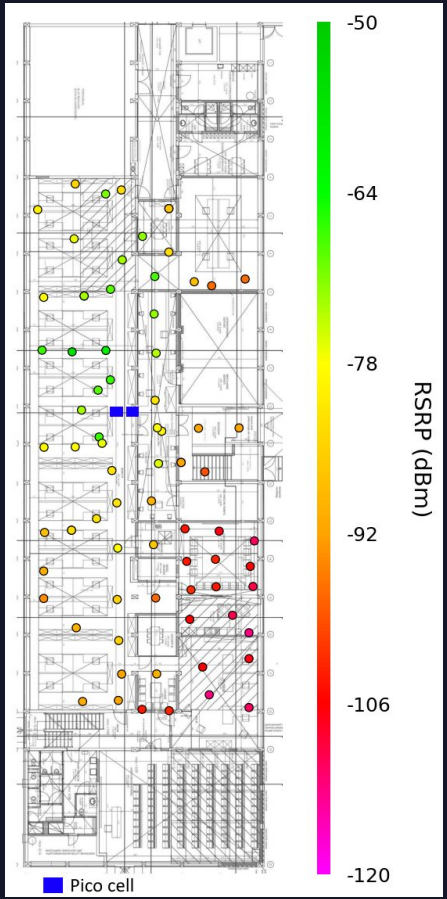




Use case: Hogent

Use case: Hogent



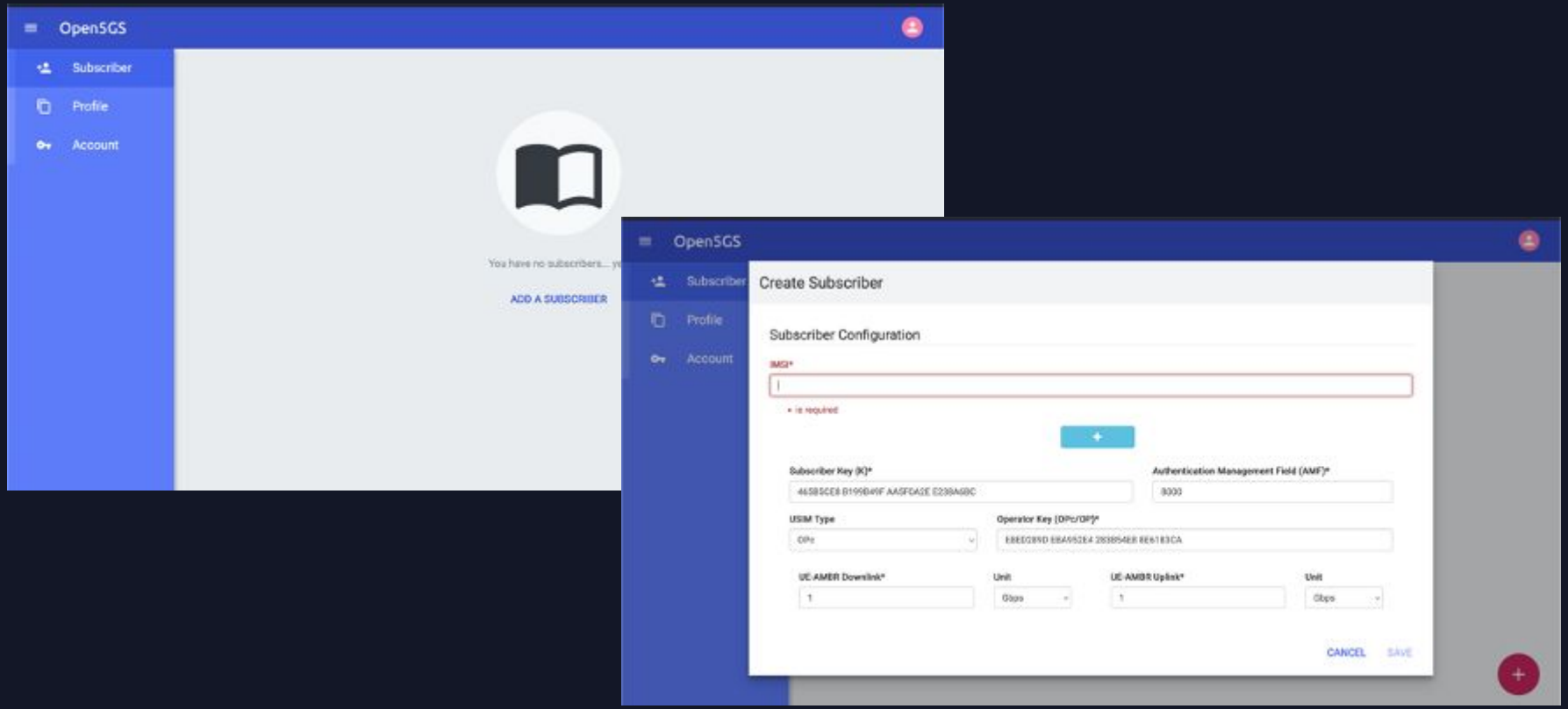


DEMO!
+ Coffee

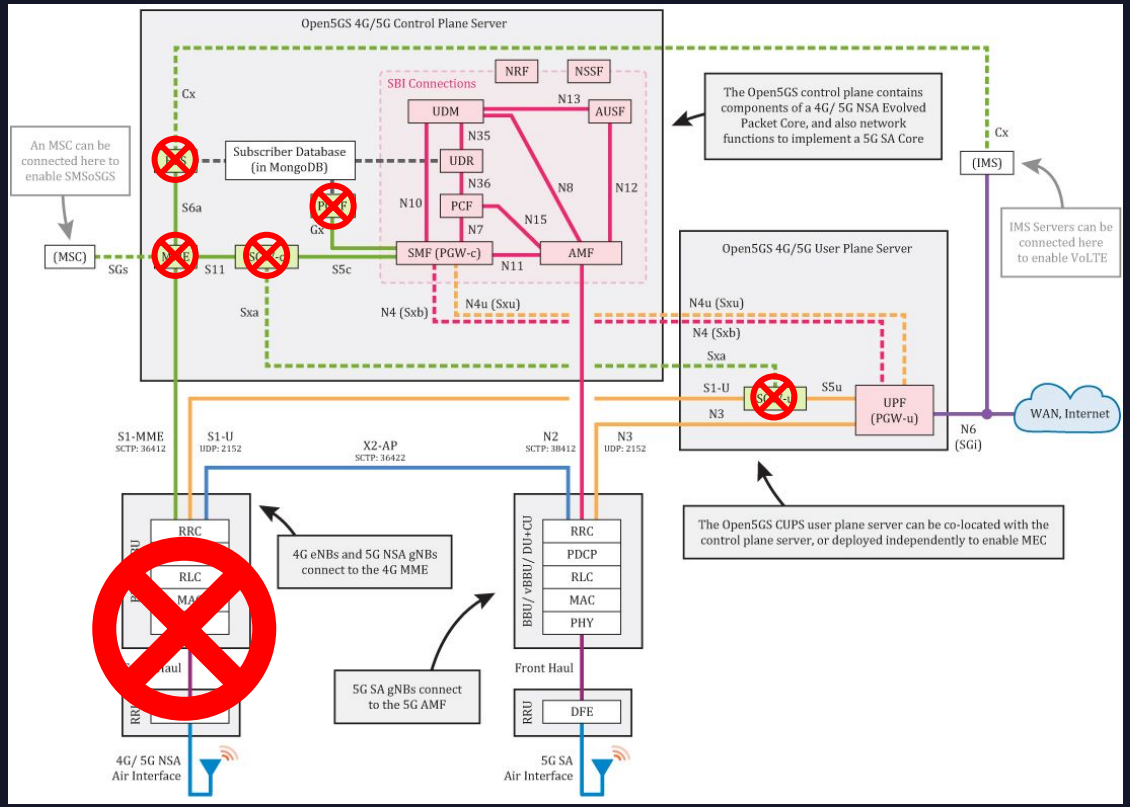
Live demo results

5G Internals

Open5GS



Open5GS


Open5GS 4G/5G Control Plane Server
SBI Connections
NRF
NSSF
UDM
AUSF
UDR
PCF
SMF (PGW-c)
AMF
N13
N35
N36
N8
N12
N10
N15
N7
N11
Cx
S6a
Gx
S11
S5c
Sxa
N4 (Sxb)
N4u (Sxu)
Subscriber Database (in MongoDB)
An MSC can be connected here to enable SMSoSGS
(MSC)
SGs
The Open5GS control plane contains components of a 4G/ 5G NSA Evolved Packet Core, and also network functions to implement a 5G SA Core
(IMS)
IMS Servers can be connected here to enable VoLTE
Open5GS 4G/5G User Plane Server
S1-U
S5u
N3
UPF (PGW-u)
N6 (SGi)
WAN, Internet
S1-MME
SCTP: 36412
S1-U
UDP: 2152
X2-AP
SCTP: 36422
N2
SCTP: 38412
N3
UDP: 2152
RRC
RLC
MAC
PHY
PDCP
BBU/ vBBU/ DU+CU
Front Haul
RRU
DFE
4G eNBs and 5G NSA gNBs connect to the 4G MME
5G SA gNBs connect to the 5G AMF
The Open5GS CUPS user plane server can be co-located with the control plane server, or deployed independently to enable MEC
4G/ 5G NSA Air Interface
5G SA Air Interface

Open5GS

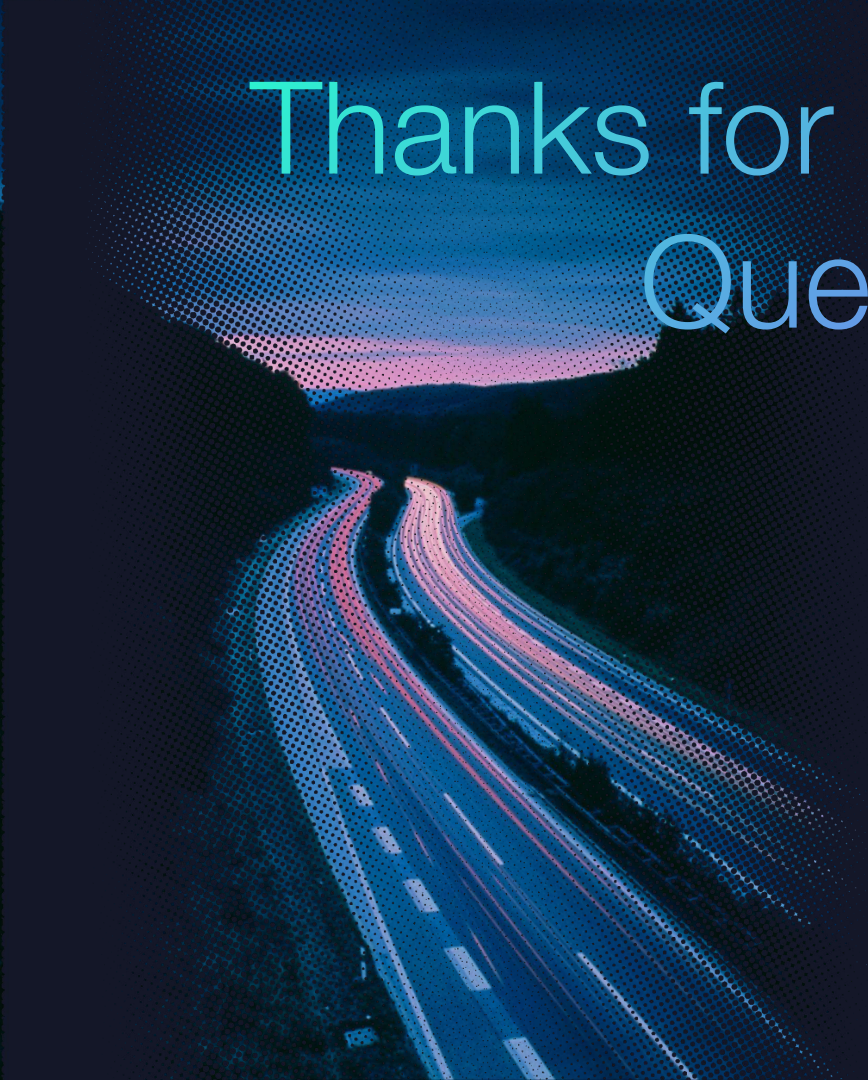
- **Supported Features**
  - Release-17 compliant
  - AES, Snow3G, ZUC algorithms for encryption
  - Support of USIM cards using Milenage
  - IPv6 support
  - Multiple PDU session
  - Handover(5GC Xn/N2 and EPC S1/X2)
  - CSFB(Circuit Switched Fall Back) and SMSoS(SMS Over SGs)
  - VoLTE(Voice over LTE) with HSS-Cx interface
  - VoNR(Voice over NR)
  - 5G Roaming
- **Known Limitations**
  - No Interworking with EPC
  - No NB-IoT
  - No OCS/OFCS
  - No eMBMS
  - No SRVCC
  - No Emergency Call

Open5GS

- NRF - NF Repository Function
- SCP - Service Communication Proxy
- SEPP - Security Edge Protection Proxy
- **AMF - Access and Mobility Management Function**
- **SMF - Session Management Function**
- **UPF - User Plane Function**
- AUSF - Authentication Server Function
- UDM - Unified Data Management
- **UDR - Unified Data Repository**
- PCF - Policy and Charging Function
- **NSSF - Network Slice Selection Function**
- BSF - Binding Support Function

srsRAN & UERANSIM

- Real CU DU and supports integration with a real radio and real UE
- Emulated CU, DU and the UE



Thanks for your attention!
Questions?

CITYMESH

Open5GS

- MongoDB = 127.0.0.1 (subscriber data) - http://localhost:9999
- SMF-gtpc = 127.0.0.4 :2123 for S5c
- SMF-gtpu = 127.0.0.4 :2152 for N4u (Sxu)
- SMF-pfcp = 127.0.0.4 :8805 for N4 (Sxb)
- SMF-frDi = 127.0.0.4 :3868 for Gx auth
- SMF-sbi = 127.0.0.4 :7777 for 5G SBI (N7,N10,N11)
- **AMF-ngap = 127.0.0.5 :38412 for N2**
- AMF-sbi = 127.0.0.5 :7777 for 5G SBI (N8,N12,N11)
- UPF-pfcp = 127.0.0.7 :8805 for N4 (Sxb)
- **UPF-gtpu = 127.0.0.7 :2152 for S5u, N3, N4u (Sxu)**
- NRF-sbi = 127.0.0.10:7777 for 5G SBI
- SCP-sbi = 127.0.0.200:7777 for 5G SBI
- SEPP-sbi = 127.0.0.250:7777 for 5G SBI
- SEPP-n32 = 127.0.0.251:7777 for 5G N32
- SEPP-n32f = 127.0.0.252:7777 for 5G N32-f
- AUSF-sbi = 127.0.0.11:7777 for 5G SBI
- UDM-sbi = 127.0.0.12:7777 for 5G SBI
- PCF-sbi = 127.0.0.13:7777 for 5G SBI
- NSSF-sbi = 127.0.0.14:7777 for 5G SBI
- BSF-sbi = 127.0.0.15:7777 for 5G SBI
- UDR-sbi = 127.0.0.20:7777 for 5G SBI

Open5GS

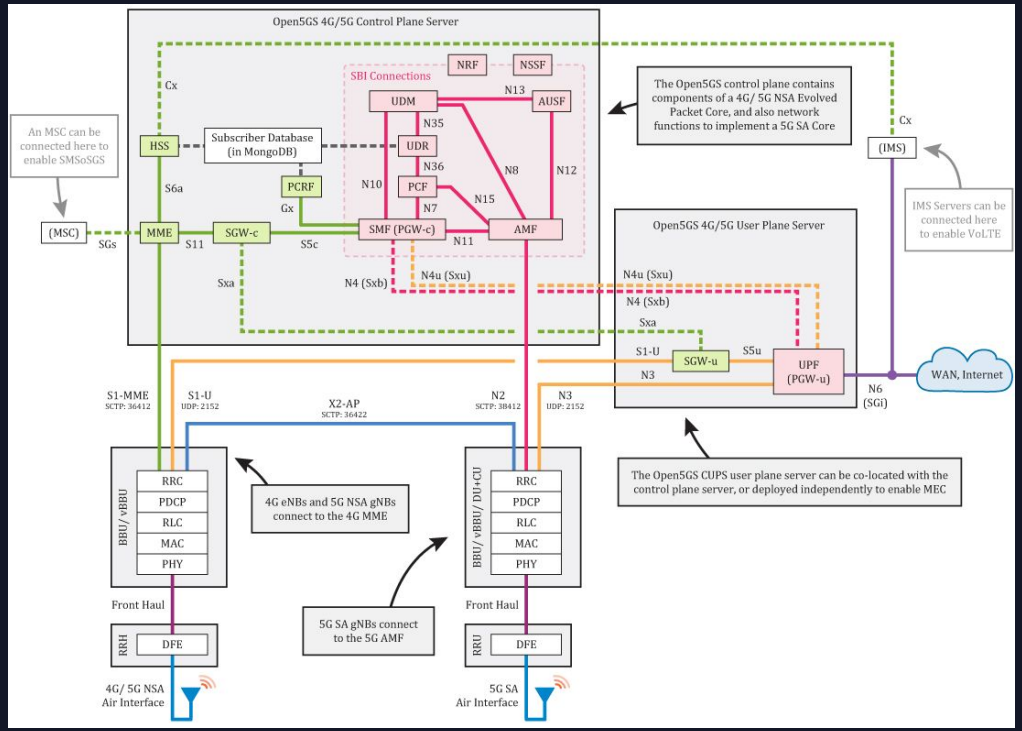
- Each one has its own VM
- Complete the configuration by changing the PLMN-ID of the network to MNC=01, MCC=001 and slicing to SST=1, SD=1 (/etc/open5gs/{amf.yaml,nssf.yaml})
- And also change the /usr/lib/node_modules/open5gs/server/index.js file to listen on o.o.o.o instead of “localhost”
- Sudo systemctl restart open5gs-webui
- You should be able to access a WebUI to register your UEs on your VM IP port 9999 (http://<VM_IP>:9999) with user admin and password 1423

Now to the Technical side of things...

5G Core

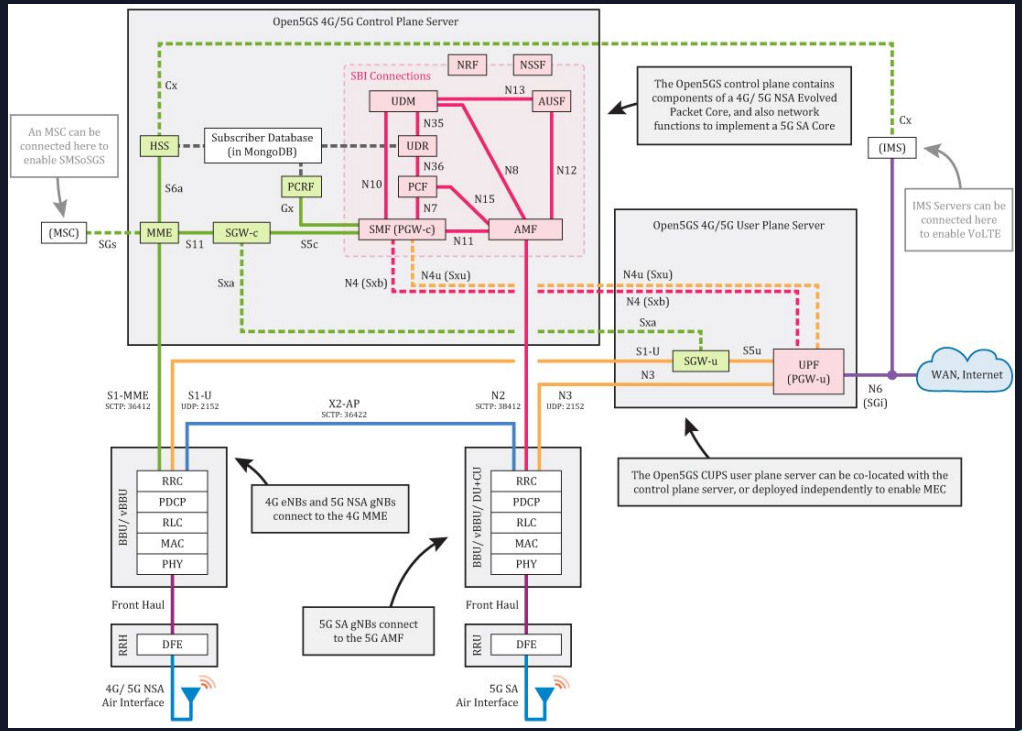
Core network

- Brains of the network
- Different from the radio, in the core we can already see IP Packets instead of IQ samples.
- Authentication, Security, Routing, Accounting, QoS…
- In 4G we focused on packet switching and mobility
- In 5G we focus on Applications and Services, using what is called a Service based architecture and Service based Interface (SBI), with high levels of decentralization and scalability
    - API Based (RESTful + HTTP/2)



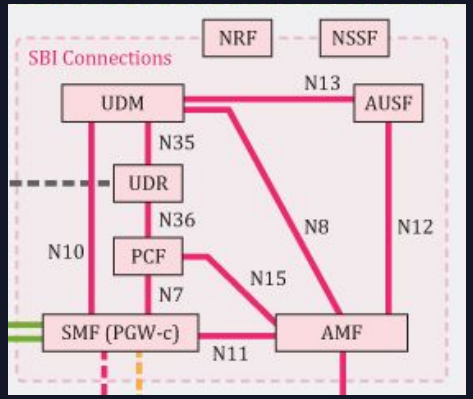
5G SA Core Functions

- AMF - Access and Mobility Management Function
- AUSF - Authentication Server Function
- UDM - Unified Data Management
- UDR - Unified Data Repository
- NRF - NF Repository Function
- SCP - Service Communication Proxy
- SMF - Session Management Function
- UPF - User Plane Function
- NSSF - Network Slice Selection Function
- PCF - Policy and Charging Function
- BSF - Binding Support Function
- SEPP - Security Edge Protection Proxy
- And more to come



5G Core and Interoperability

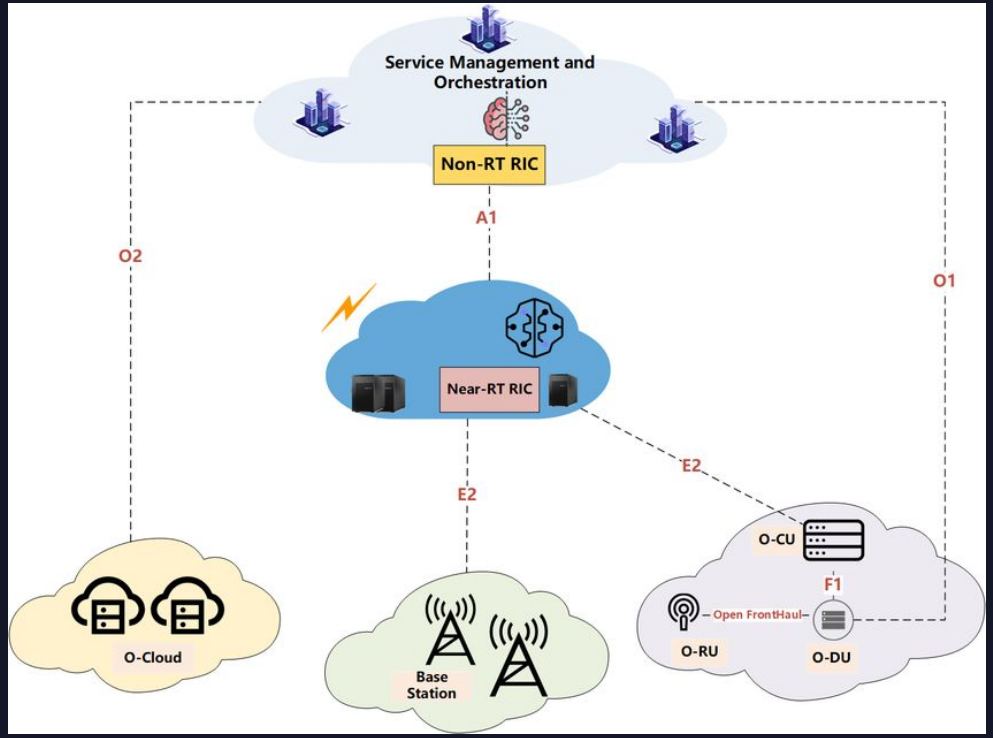
- The 5G Core was designed for interoperability, meaning that we can possibly use different vendor for different functions. This means that we left a "black box" approach from 3G and 4G, where the functions belong to only one vendor, to a white box approach.
- You can select certain functions from one vendor and connect them to other functions of different vendors to try and achieve the best possible combination for your network
- This also breaks vendor lock in and allows for better development in the Open Source world.



5G RAN

5G RAN: Components

- Centralized Unit (CU): High layer, not time sensitive functions.
  - SDAP
  - PDCP
  - RRC
- Decentralized Unit (DU): Lower layer functions, more real time
  - RLC
  - MAC
  - Part of PHY
- Radio Unit (RU): "The antenna side", sends and receives radio signals and its responsible for the initial processing of the signals depending on the Function split in this network (See next slide)
- RAN Intelligent controller (RIC): based on feedback loops it can control, optimize, collect metrics and reconfigure the RAN side of the network.

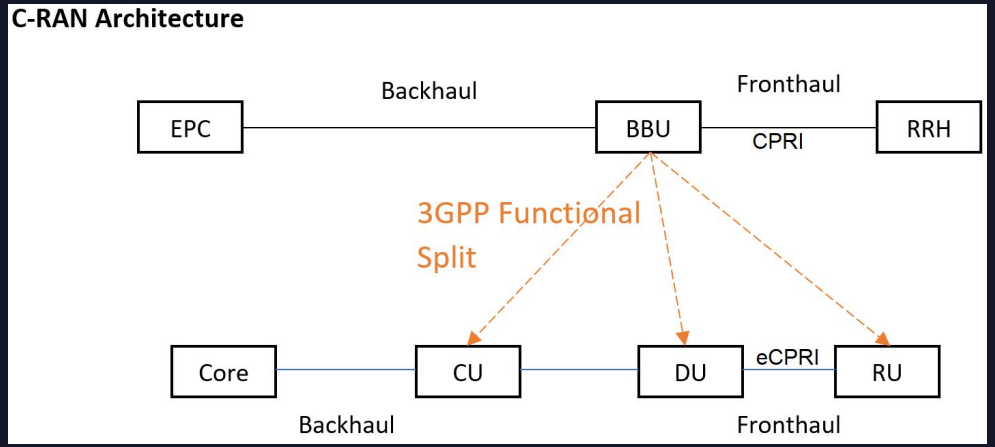


Source: https://www.researchgate.net/publication/373665710_Resource_allocation_based_on_Radio_Intelligence_Controller_for_Open_RAN_towards_6G

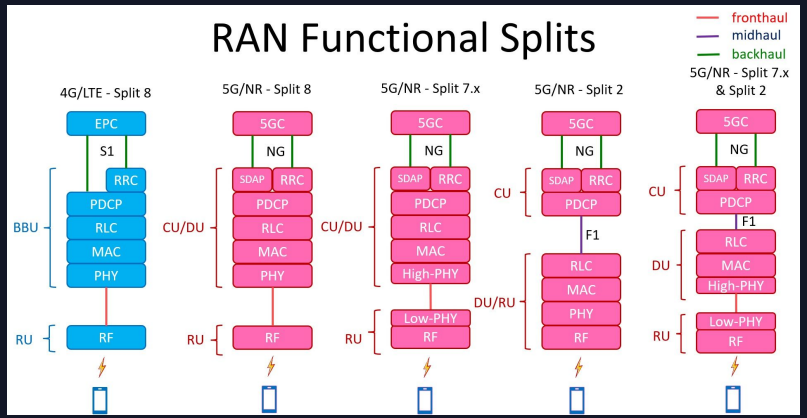
1 CU ↔ x DU ↔ x RU

5G RAN and Virtualization

- 5G RAN was made to be decentralized
  - Again, 5G premise of breaking vendor lock in!
- Using 3GPP Functional Splits:
  - 7: CU + DU + RU, all decentralized. Divides further: 7.1, 7.2, 7.3 according to which functionalities are delegated to which component
  - 8: CU + DU combined, with separated RU
- Due to the nature of 5G, you can virtualize more components and combine multiple vendors:
  - vCU + vDU + RU
  - vCU + Physical DU + RU
  - CU + vDU + RU
  - ...

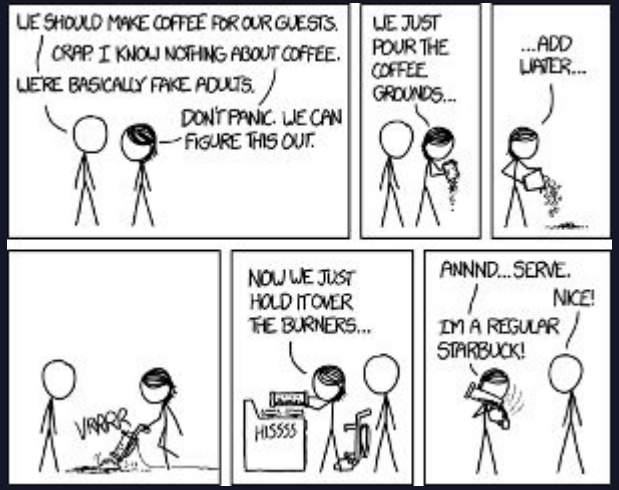


Source: https://www.nctatechnicalpapers.com/Paper/2019/2019-5g-backhaul-fronthaul-opportunities-and-challenges



Source: https://blog.3g4g.co.uk/2021/03/5g-ran-functional-splits.html

Coffee Break



UERANSIM

UERANSIM

- **Interfaces**
  - There are 3 main interface in UE/RAN perspective:
    - Control Interface (between RAN and AMF)
    - User Interface (between RAN and UPF)
    - Radio Interface (between UE and RAN)
- **Control Plane**
  - Control Plane has 2 interfaces:
    - NAS is in control of UE
    - NGAP is in control of RAN.
- **NAS Features**
  - Following features are implemented in NAS layer:
  - Primary Authentication and Key Agreement
  - Security Mode Control
  - Identification
  - Generic UE Configuration Update
  - Initial and Periodic Registration
  - UE and Network initiated De-registration
  - UE initiated PDU session establishment
  - UE and Network initiated PDU session release
  - Service Request
  - Paging
- **NGAP Features**
  - Following features are implemented in NGAP layer:
    - PDU Session Resource Setup
    - PDU Session Resource Release
    - Initial Context Setup
    - UE Context Release (NG-RAN node initiated and AMF initiated)
    - UE Context Modification
    - Initial UE Message
    - Paging
    - Downlink NAS Transport
    - Uplink NAS Transport
    - NAS Non Delivery Indication
    - Reroute NAS Request
    - NG Setup
    - Error Indication
- **User Plane**
  - Our RAN implements GTP protocol for user plane. **And Currently only IPv4 is supported.**

UERANSIM

UERANSIM does not implement 5G radio protocols below the RRC layer. And 5G radio is partially simulated over UDP protocol over port-4997. So, PHY, MAC, RLC, PDCP is not implemented in UERANSIM. However main RRC procedures are available in UERANSIM.

UERANSIM


```
git clone https://github.com/aligungr/UERANSIM ~/UERANSIM
sudo apt install make gcc g++ libsctp-dev lksctp-tools iproute2
sudo snap install cmake --classic
cd UERANSIM
make
```