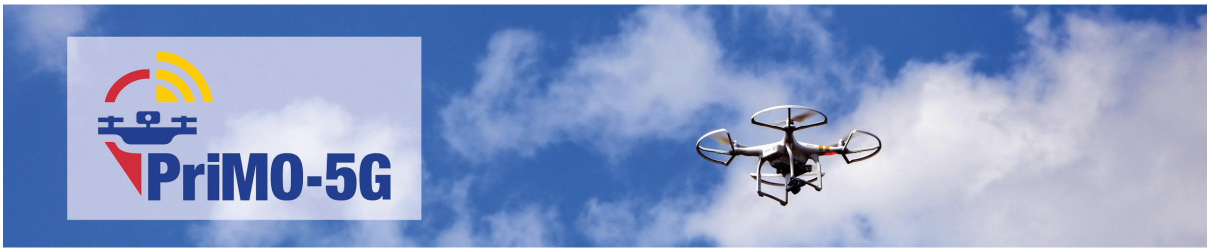

Project Title	Virtual Presence in Moving Objects through 5G
Project Acronym	PriMO-5G
Grant Agreement No	815191
Instrument	Research and Innovation Action
Topic	The PriMO-5G project addresses the area of “a) Focus on mmWave and super broadband services” in the call “EUK-02-2018: 5G” of the Horizon 2020 Work Program 2018-2020.
Start Date of Project	01.07.2018
Duration of Project	36 Months
Project Website	https://primo-5g.eu/

D2.5 - PRIMO-5G CORE INTEROPERABILITY REPORT

Work Package	WP2
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Due Date	30.04.2021
Date	
Version	

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Disclaimer

PriMO-5G has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 815191. The project is also supported by the Institute for Information & communications Technology Promotion (IITP) grant funded by the Korea government (MSIT) (No.2018-0-00170, Virtual Presence in Moving Objects through 5G). The dissemination of results herein reflects only the author's view, and the European Commission, IITP and MSIT are not responsible for any use that may be made of the information it contains.

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Executive Summary

The main aim of the PriMO-5G project is to demonstrate an end-to-end 5G system providing immersive video services for moving objects. For this, Work Package 2 (WP2) of the project strives to define and select the architecture for network slicing and multi-access edge computing as part of the new 5G Next Generation Core (NGC). This deliverable collects the final report on the interoperability of 5G core using different prototype implementations done by PriMO-5G partners.

List of Acronyms

Acronym	Definition
3GPP	Third Generation Partnership Project
5G	Fifth-Generation Mobile Network
5GC	5G Core
5G-PPP	5G Public-Private Partnership
AMF	Access and Mobility Management Function
BS	Base Station
CP	Control Plane
CU	Centralized Unit
DU	Distributed Unit
eNB	Evolved NodeB
gNB	Next Generation NodeB
IEC	International Electrotechnical Commission
IITP	Institute for Information & communications Technology Promotion
IoT	Internet of Things
ISO	International Organization for Standardization
MEC	Multi-access Edge Computing
MCU	Mobile Core Unit
NF	Network Function
NSA	Non-Standalone
QoS	Quality of Service
RAN	Radio Access Network
SA	Standalone
SBA	Service Based Architecture
SMF	Session Management Function
S/P-GW	Serving/Packet Gatewau
SW	Software
TRxP	Transmission Reception Point
UE	User Equipment

Acronym	Definition
UP	User Plane
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communications
WP	Work Package

1 Introduction

1.1 Purpose and Scope

The main aim of the PriMO-5G project is to demonstrate an end-to-end 5G system providing immersive video services for moving objects. For this, we design the architecture that will provide the required network resources to support the selected scenarios and use cases.

The PriMO-5G partners already performed initial interoperability tests reported in previous deliverable D2.2 and this deliverable includes the final 5G core interoperability results.

The objective of this deliverable is to collect the final interoperability tests of 5G core and RAN implementations from different partners. 5G SBA architecture is new, so the target is to ensure seamless integration of multi-vendor solution in the commercial deployments. This deliverable includes the results of different installations using Standalone (SA) mode of 5G Core and gNB. Considering the results were collected during 2H20 and 1H21, they are first deployments of such kind of 5G systems in SA mode.

1.2 Structure of the document

This deliverable is organized as follows. Section 2 provides a generic overview of the 5G architecture as baseline for the interoperability test cases. Section 3 describes the components contributed by the different partners to deploy the system used for the different test cases. Section 4 presents the interoperability use cases and the results collected after completing final installations using 5G SA packet core and gNBs.

2 5GC Architecture

This section describes the 3GPP mobile architecture for 5G Core network. The NSA version of the 5GC consists of 4G mobile core EPC where the user plane is using 5G network function UPF to deliver higher bandwidth and low latency. The NSA uses both eNB and gNB as RAN with EPC. The SA system uses only 5G RAN and 5GC so both signalling and user plane utilize 5G components.

3GPP released the specification on the 5G Core Network, in TS 23.501 [3GPP23.501], which follows the concept of Service Based Architecture (SBA). The principle of SBA is mainly higher flexibility where network functions provide services to each other. A control plane/user plane split allows independent scaling of control plane and user plane functions.

In SBA, the network functions communicate with each other via a logical communication bus and network functions can provide services to each other. A network function instance is registered to a Network Repository Function (NRF). Using the NRF, a network function instance can find other network function instances providing a certain service. The goal of such architecture is to get a higher flexibility in the overall system, and to make it easier to introduce new services.

In the 5G core, the Access and Mobility Management Function (AMF) provides the interfaces towards the Radio Access Network (RAN), the Session Management Function (SMF) keeps track of the ongoing sessions for a user, and the Unified Data Management (UDM) keeps the subscriber profiles. The User Plane Functions (UPFs) implement the user plane between the RAN and the Data Network (DN) (which can be the Internet, an operator services network or a 3rd party services network).

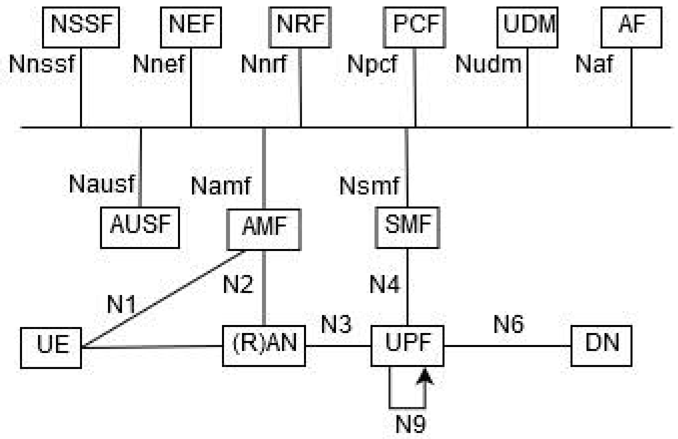

Figure 1. 5G Core Architecture, Source: 3GPP 23.501

3 PriMO-5G Core Interoperability Components

This section describes the components contributed by the different PriMO-5G partners for testing the 5G Core interoperability.

3.1 CMC 5G Core

Currently CMC has already implemented a prototype of 5G core architecture including AMF, SMF, UPF, NSSF and NRF based on micro-services as depicted in Figure 2. CMC core includes 4G and 5G network functions as well as NB-IOT and eMBMS components. The eMBMS is used in PriMO-5G to support the scenarios of media broadcast to mobile devices during firefighting scenarios.

The first objective is to test and validate the first implementations of the 5G core network functions between PriMO-5G partners. CMC contributes with the components described in Figure 2 for the 5G Core interoperability. The end-to-end interoperability will be also performed between 5G core from CMC and NG radio from other partners to ensure proper integration of early versions of both 5G core and radio components.

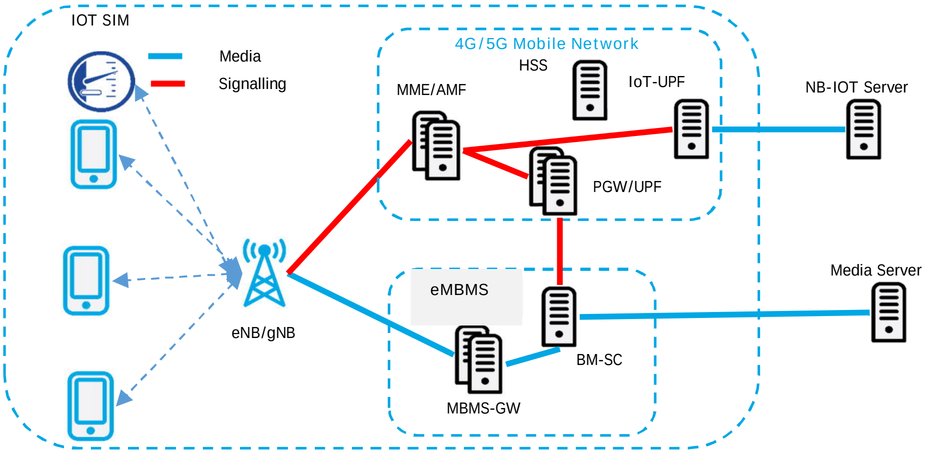

Figure 2. 5G network architecture of CMC

CMC packet core includes a graphical interface that allows to configure the RAN and monitor the status of the mobile devices and network elements. From the management UI shown in Figure 3 the operator can add subscribers, eNB/gNB and network functions.

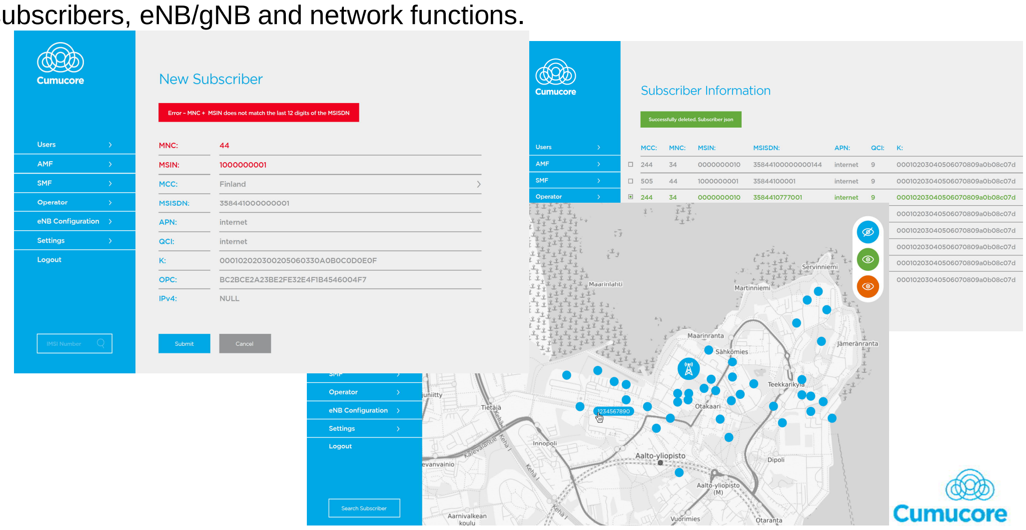

Figure 3. 5G network management interface of CMC

3.2 KT 5G Core

KT's transition to 5G network will be made based on EPC, in a way that minimize changes required in the core network. The KT's 5G network shown in Figure 4 and Figure 5 can be SW upgraded to reflect the updates/changes once 3GPP 5G standards are finalized in the future. It will be able to support both NSA and SA modes as being discussed in 3GPP. The network, consisting of EPC and base station will be composed of LTE base stations (eNBs) and 5G base stations. In this way, seamless interworking between LTE and 5G will be ensured.

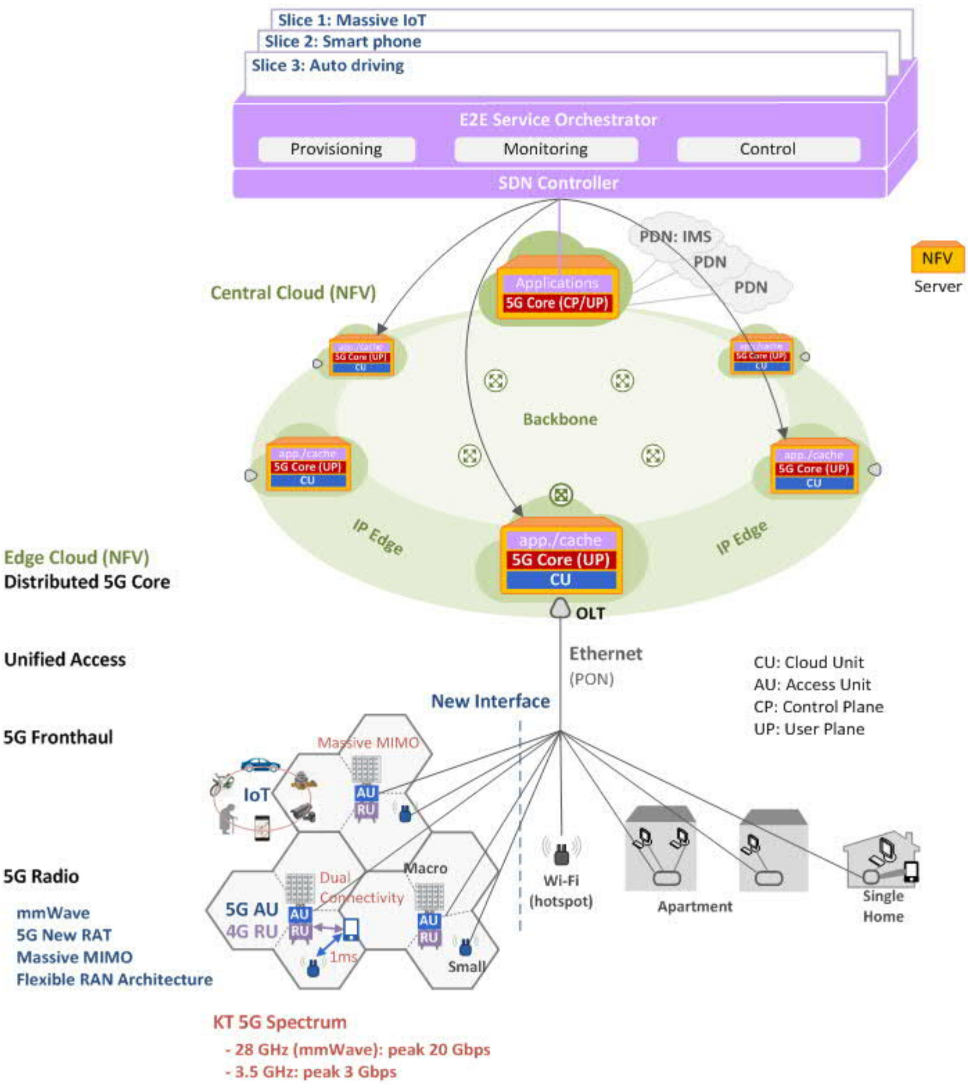

Figure 4. 5G network architecture of KT

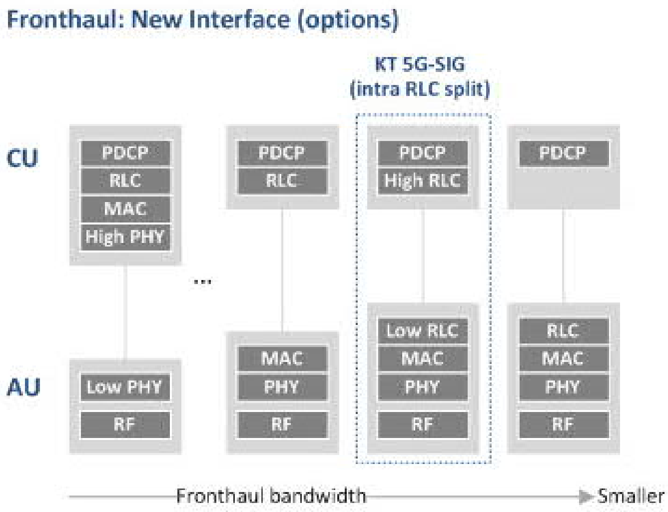

Figure 5. KT's AU-CU interface candidates

4G LTE network today can be divided into two parts: RAN (eNB) and core network (S/P-GW and MME), and the latter is in charge of mobility, authentication and charging. KT's plan for 5G is to distribute these core nodes to over tens of edge nodes that is operating across the nation. 5G core (or Mobile Core Unit (MCU)) is generally divided into MCU-UP (Core - User Plane) in charge of user plane traffic handling, and MCU-CP (Core - Control Plane) in charge of control functions. In addition, MCU-CP will stay where it is in the central cloud (NFV), but MCU-UP will be distributed to its tens of edge nodes nationwide and be installed in edge clouds (NFV) as shown in Figure 5.

5G will allow everyone to communicate at the speeds of 1 Gbps, and thus traffic generated from Radio Access Network will skyrocket. Once the core is distributed to local areas, and a variety of associated application servers are moved down along with it, backhaul traffic will significantly decrease, thereby bringing down backhaul investment costs as well.

5G network is supposed to be able to provide ultra-real time services. These types of services may cause much lesser traffic than video but require URLLC. These low delays can also be achieved by moving core functions/units closest to users and placing ultra-real time service servers right where the core functions/units are located.

Thus, MCU-CP and MCU-UP will stay in the central cloud, but MCU-UP will be distributed in edge clouds across the nation as well as shown in Figure 6.

3.3 KT gNB

KT gNB consists of Samsung, Ericson LG and Nokia. The composition and ratio are shown in the below table.

Table 1. KT gNB models

Update as of Nov. 17. 2019	Number of gNB		Radio Station
	Constructed gNB	Operating gNB	
Samsung	63,210	50,282	31,960
Ericsson LG	8,681	7,856	4,236
Nokia	5,822	5,680	3,196

Out of all the operating gNB, more than 50% of the gNB is densely located in the Seoul and capital area. Indoors that are difficult to reach sub-six 5G can utilize 5G service using additional small BS or repeaters. It is currently applied to 142 buildings.
So far, it is operating only in NSA only, and 5G SA service is in progress through firmware update later. Currently, “5G” maximum speed based on the terminal is 1.5Gbps, and “5G + LTE” maximum speed is 2.5Gbps. To commercialize mmWave-based 5G, KT is consistently discussing with Manufactures. However, the schedule for commercialization is not fixed.

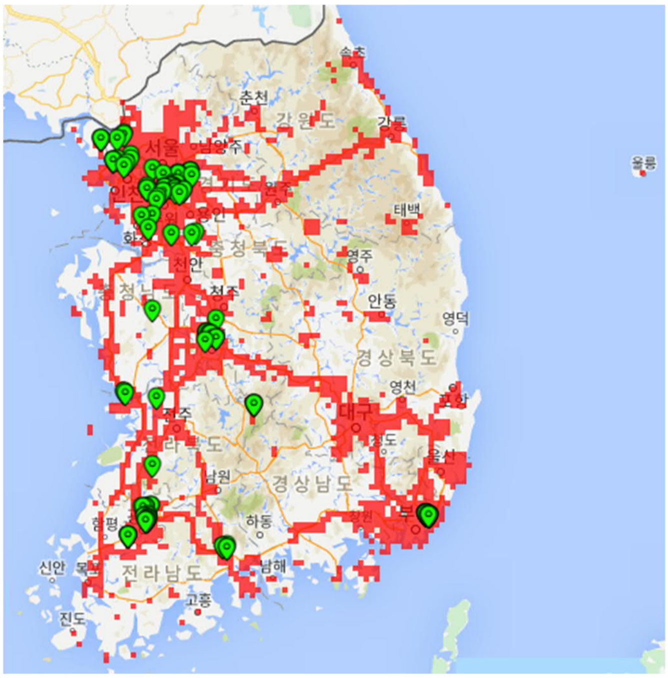

Figure 6. KT 5G coverage map

3.4 Aalto gNB

Aalto gNB is based on commercial release from Nokia and includes two radio heads installed in the roof of building at Aalto University campus as shown in Figure 7. The Aalto gNB is then connected to a baseband unit installed in a separate building from where it connects to local network running CMC core or it connects to remote sites running different instances of the 5G core. The current version of the gNB has been updated to support both NSA and SA modes at the time of reporting in this final report. As shown in the figure below with the installation the gNB is connected together with eNB that acts as the anchor node to the gNB.

Figure 7. Aalto gNB installation in Väre building.

The Aalto campus has been extended with the installation of a new site in a different location of the campus as shown in Figure 8. This installation is currently configured as SA mode and is integrated with a different instance of the 5G Core including a different PLMN 244 53. With this second installation Aalto is operating two independent mobile networks in order to test roaming functionality and mobility across mobile operators.

Figure 8. Aalto gNB installation in Otakaari 5 building.

3.5 NI gNB

NI contributes with a gNB provided by the third-party vendor Radisys. The Radisys 5GNR CU and DU can be operated in sub-6 GHz and mmWave as well as in Standalone (SA) and Non-Standalone (NSA) mode. For NI's PriMO-5G activities the gNB is used in the mmWave frequency range and in SA mode.

The Radisys components used by NI comply with 3GPP TS 24.501 in version 15.2.0 for the NAS layer, TS 38.413 v.15.3.0 for the Next Gen Application Protocol and TS 38.415 v.15.1.0 for the PDU Session User Plane Protocol. For a reference setup NI uses a simple core network and a UE Simulator, both provided by Radisys, too. These components are considered as demonstration tools for the operation of the gNB and thus may take a few shortcuts. The physical layer and RF between the gNB and the UE is omitted in this software stack and replaced by a physical abstraction layer (PAL).

First tests with this gNB, the simple core network and the UE Simulator have been performed in Q1/2020. Afterwards, NI and CMC worked on the interoperability of the CMC 5G Core network and the gNB and UE Simulator to enable the testing of these components.

4 PriMO-5G Core Final Interoperability Setup

The interoperability test took place with components from PriMO-5G partners located either in Korea or Europe. A remote connectivity through VPN between Europe and Korea is established using GEANT infrastructure located in UK. The interoperability setup includes the following test cases where some local tests will be done using direct connection between RAN and 5GC while intercontinental tests are done using remote connection between RAN and 5GC through e.g. GEANT infrastructure.

The final interoperability setup will include new components not available during the intermediate interoperability testing. These new components will include gNBs which supports standalone mode operation as well as mmWave frequencies but are not completed for the intermediate deliverable. The final test setup will integrate components from PriMO-5G partners located either in Korea or Europe. This test will utilize the same remote connection through VPN connection between Europe and Korea, which is established using GEANT infrastructure located in UK. The final interoperability setup will include the following test cases.

4.1 Local: CMC 5GC - Aalto gNB SA in FI

This test is an extension of similar one performed for the intermediate deliverable with the difference that an additional gNB has been configured in Standalone mode. CMC is using Aalto gNB integrated with CMC 5G SA packet core. The end-to-end system is deployed at CMC laboratory located in Aalto campus to perform local interoperability tests while keeping the outdoors deployment in NSA mode. The CMC 5G and Aalto gNB are configured to work with eMBB and MIoT but current devices only support eMBB slice type so all the measurements are done using default eMBB slice.

The setup is show in following Figure 9, On the right, there is the Aalto gNB, which consists of BBU and two indoor pico radio heads and CMC 5G SA core is running in black Supermicro server on the left.

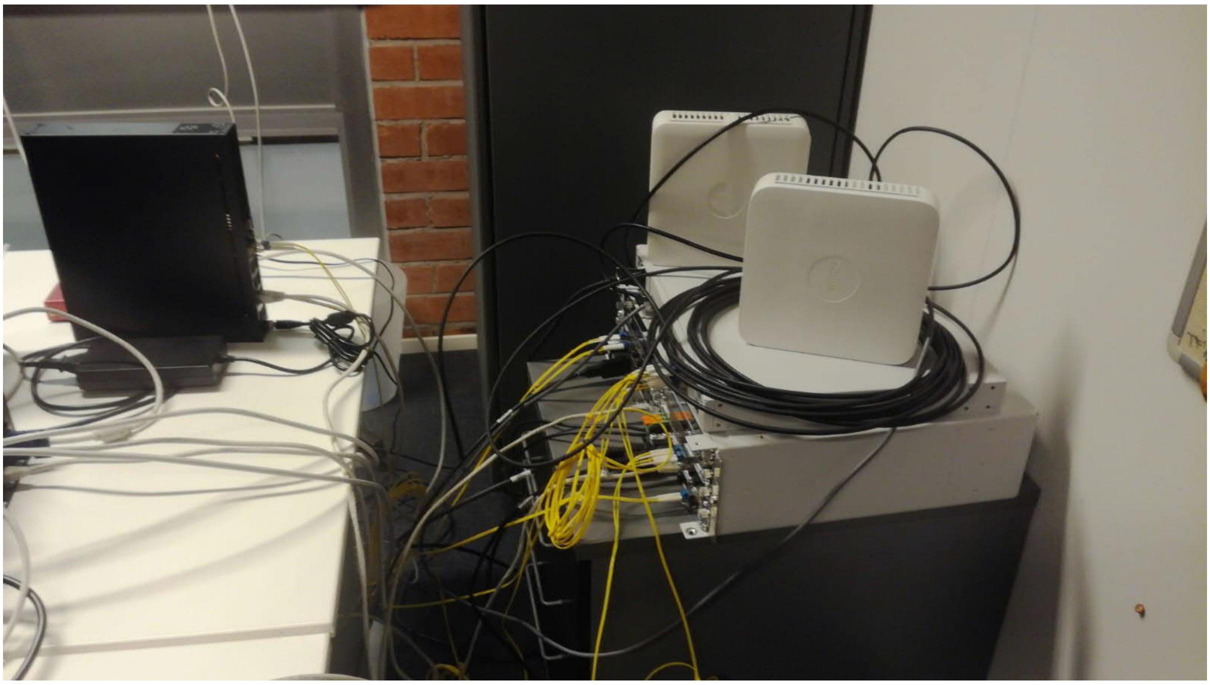

Figure 9. CMC 5GC and Aalto gNB SA installation in CMC laboratory.

The interoperability tests were performed with two types of devices shown in next Figure 10. The device on the left consists of Quectel modem connected to small server to establish the connection with the 5GC and run iperf client. The iperf server was running in the 5GC to focus on the measurements between the device and the 5GC. The second device on the right consists of another server which had embedded 5G modems and was also running iperf client to perform the measurements with the iperf server running in the 5GC.

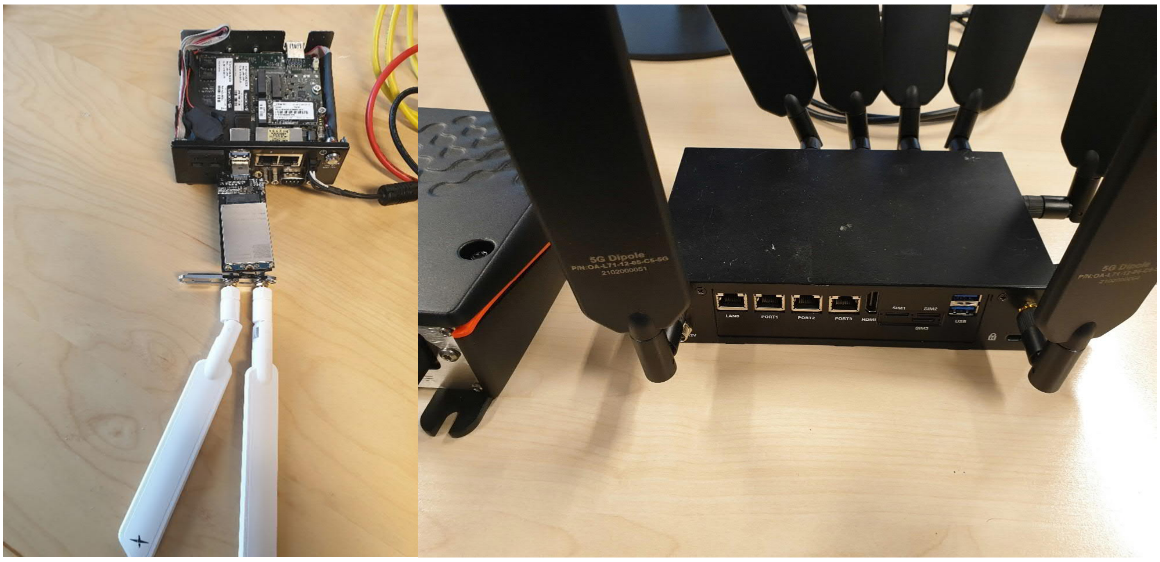

Figure 10. Devices for the Interoperability testing 5GC and Aalto gNB SA.

Table 2. Device performance 5G SA

Device	Transport:UDP	Transport: TCP
Quectel	Uplink: 5.25Mbps	Uplink: 79.7Mbps
	Downlink: 5.26Mbps	Downlink: 95Mbps
Router	Uplink: 100Mbps	Uplink: 100Mbps
	Downlink: 650Mpbs	Downlink: 495Mbps

4.2 Local: CMC 5GC - NI gNB SA in DE

This test has been deployed in Germany and consists of the CMC 5GC and a gNB and UE Simulator designed for mmWave frequencies in SA mode. Due to minor version mismatches in the NAS and the PDU Session User Plane Protocol specifications used by 5G core network, gNB and UE and because the original purpose of the UE Simulator is to demonstrate the operation of the Radisys gNB together with their simple core network, adaptions both at the CMC Core network and the UE Simulator were necessary and thus done by CMC and NI respectively.

The interoperability test was executed in a simplified environment, where the actual PHY Layer and RF is replaced by a PHY Abstraction Layer (PAL). Figure 11 shows this setup: The CMC 5G Core network is located on a Linux server, the gNB is split into Centralized Unit (CU) and Distributed Unit (DU) which are both on individual Linux computers, too. The UE Simulator shares the computer with the DU. All computers are connected via 10Gbps ethernet interfaces. For the tests, the connection between core and gNB has been replaced with a 1Gbps connection. Furthermore, tests were executed with DPDK connections and socket-based connections between the individual computers. For the tests conducted however the socket-based approach was used as this proved to be simpler and without performance penalties.

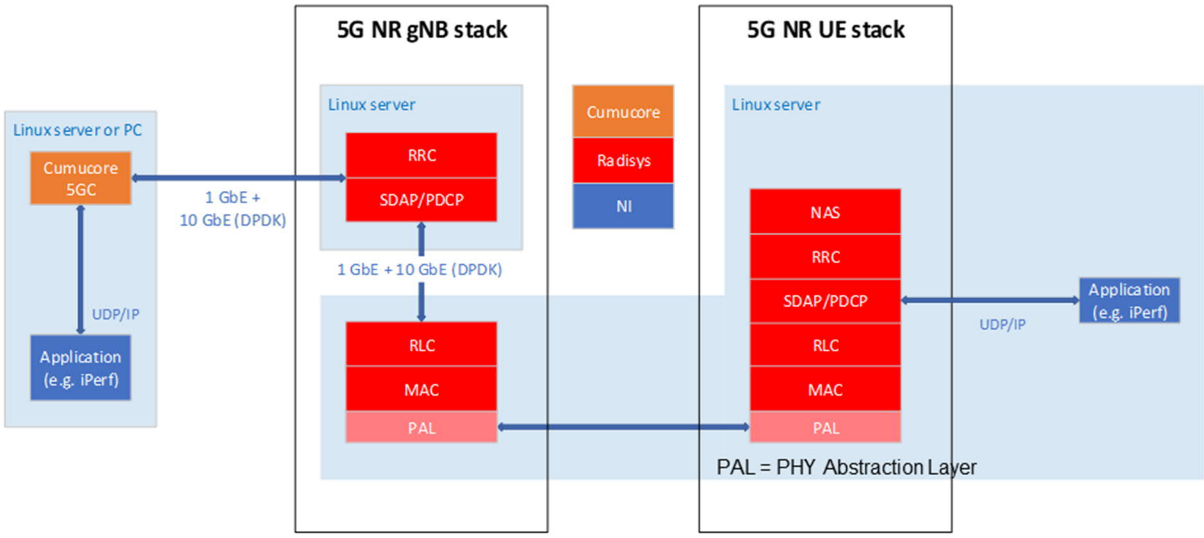

Figure 11: Setup used for interoperability tests performed by NI

The maximum data rate in uplink and downlink is measured with iperf server and client on core network and UE machine. The data rate and packet loss can be observed in the iperf server output.

One scenario that this project wants to cover is the firefighting scenario: A fire is spreading; fire fighters arrive and need to get an overview. For this they launch drones which stream video data to the incident commander. This requires high throughput and low latency to steer the drones. To achieve this, 5G technology is used because here network functions can be distributed according to special needs. Figure 12 shows how this scenario could look like.

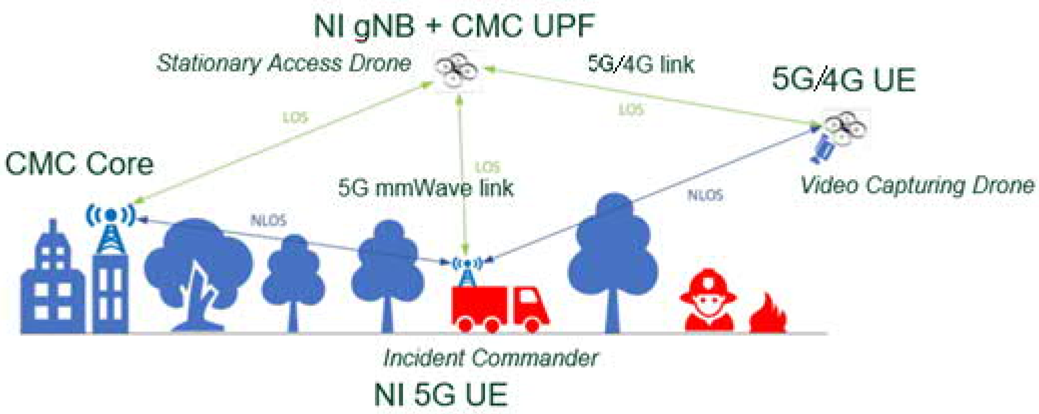

Figure 12: Firefighting scenario in PriMO-5G

To achieve better performance compared to “general purpose” 5G setups, dedicated gNB and UPF are installed close to the incident. Possible options are having these components at the incident commander truck or at the stationary access drone to overcome issues in non-line-of-sight environments. In the interoperability tests these scenarios with close gNB and UPF were covered as seen in Table 3.

Table 3. Test scenarios for CMC - NI interoperability tests.

Scenario name	Setup
Baseline: General purpose 5G setup	- UPF, SMF, AMF on virtual machine in different subnet than other components, connected to gNB via 1Gbps ethernet - gNB distributed to CU machine and DU machine connected via 10Gbps link - UE Simulator running on the DU machine
Local UPF: Dedicated user plane function for video streams	- Like baseline but UPF on separate machine connected via 10Gbps ethernet
Distant Core: Simulate very far away core	- Like baseline but added 300ms delay between core and gNB machines to emulate a great geographical distance between them. According to https://wondernetwork.com/pings this delay is an average value between Seoul and several European cities.
Distant Core w/ Local UPF: Test the influence of distant core if UPF is close	- Like “Distant Core” but UPF on separate machine connected via 10Gbps ethernet

For assessing and comparing the performance of these scenarios, the (maximum) data rate, jitter, CPU load and round-trip time were measured.

The maximum data rate is measured by using iperf in UDP mode and by increasing the desired data rate until packet loss occurs. When this happens the data rate is decreased again in small steps until no packet loss can be seen anymore. To judge the impact of the data rate on the other measures the tests were repeated at 10Mbps. High data rates are important for high quality video data.

The jitter is measured with iperf. While the throughput measurements are running iperf reports the jitter in an own column. In the end these values are averaged to get one value per scenario. With low jitter values, the jitter buffer can be smaller and the delay in the video stream is smaller.

The CPU consumption of the individual components is measured by letting iperf run for a while and watching the overall CPU utilization in the ‘top’ command which is 0 if the machines are idle. By not looking at the load of a single process but at the overall load we cover any side-effects caused in other processes. A low CPU load relates to lower energy consumption which is especially helpful in mobile devices like drones.

The round-trip time (RTT) is measured using ping –f option and setting a big packet size (-s 65507). The last column in the output of ping reports the RTT. This is done while no other traffic is flowing.

For all measurements except the RTT, the length of the UDP packets was decreased from 1400 bytes (default for all measurements) to 100 bytes to check which impact this has on the measurements. Smaller packets may be used in mobile communications as in case of transmission errors the portions to retransmit can be smaller, too. It was noticed that these very small packets caused much more CPU load, therefore some measurements had to be performed separately for downlink and uplink instead of together. **Error! Reference source not found.** shows the measurement results.

Table 4. Measurements with CMC 5G Core and Radisys gNB + UE Simulator performed by NI

Scenario	Measurement	Packet length Bytes	Data rate DL/UL Mbps	Jitter DL/UL µs	CPU load Core/CU/DU+UESIM
Baseline RTT: 7.251ms	Max Throughput	1400	160/237	93/83	1.20/0.13/2.90
	10Mbps DL+UL	1400	10/10	112/872	0.10/0.10/2.80
	Max Throughput	100	9.96/36.3	115/126	1.50/0.50/2.70
Local UPF RTT: 5.361ms	Max Throughput	1400	1220/240	11/75	0.00/1.30/4.00
	10Mbps DL+UL	1400	10/10	89/874	0.00/0.00/3.10
	Max Throughput, individual UL/DL	100	152/56	2/61	0.00/2.80/11.50 DL 0.00/0.60/3.5 UL
Distant Core (300ms delay) RTT: 307ms	Max Throughput	1400	37.1/238	111/194	0.10/0.60/2.90
	10Mbps DL+UL	1400	10/10	137/878	0.00/0.00/0.50
	Max Throughput, individual UL/DL	100	3/64	58/34	0.00/0.00/1.60 DL 0.00/1.50/4.00 UL
Distant Core (300ms delay), w/ local UPF RTT: 5.322ms	Max Throughput	1400	1220/240	6/78	0.00/1.00/4.20
	10Mbps DL+UL	1400	10/10	89/889	0.00/0.00/0.40
	Max Throughput	100	153/56.6	2/102	0.00/2.80/8.30 DL 0.00/0.40/2.90 UL

From the measurement the following conclusions can be drawn:

1. As expected, a close and well connected UPF improves the overall performance: The data rate is improved and the RTT is lower. Therefore, in the firefighting scenario it makes sense to have the gNB and the UPF located close-by to support the reliable video transmission from the drones.
2. This is even unaffected by the large delay that was introduced towards AMF and SMF. So even if the authentication and session management are badly connected, the video streams from the drones and the control of the drones are not impacted.

3. The jitter is mainly affected by the data rate: If the system is operated close to its limits the jitter decreases. In high throughput scenarios like videos from the drones this is a plus. The exact impact on real-time video streams, however, might be subject of further research.
4. Small packet sizes cause a large overhead on all components and therefore might not be the best choice for high throughput applications as in PriMO-5G's firefighting scenario. Especially in the battery-powered drones this causes an unwanted higher energy consumption.

The tests show that deploying an own gNB with an own UPF close to the incident, either on the incident commander truck or at the stationary access drone can support getting an overview with the help of drones in the PriMO-5G firefighting scenario. While having the gNB at the ground and not moving would be a classic approach, installing it on the stationary access drone could improve the connection towards the core network.

4.3 Local: CMC EPC – EUCAST PTT in CMC

This test case aims at showing the cooperation between partners to confirm interoperability between different products. In this scenario the Push to Talk (PTT) application from EUCAST is installed and tested with CMC EPC mobile packet core. The usage of the PTT is required for critical communications in emergency situations. Therefore, this test case validates the integration of multi-vendor products to deliver end to end system including mobile infrastructure and communication services such as PTT. Figure below shows the setup where off the shelf eNB from Nokia operating in 2.6GHz is connected to CMC EPC running in the small portable server in the blue box which is then connected to Supermicro where PTT is running.

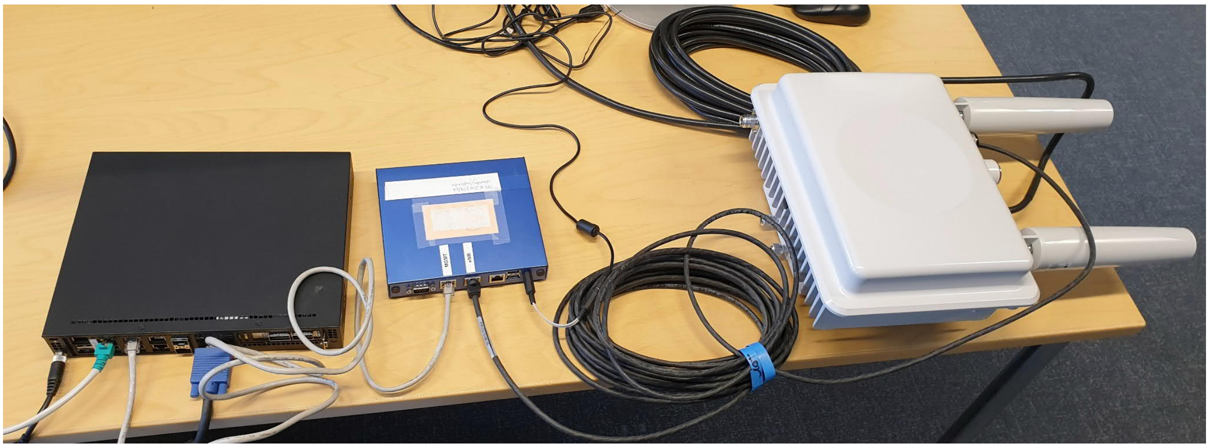

Figure 13: PTT integration with CMC EPC

The PTT service deployed as shown in previous figure is used from an application running in Android devices as shown in next figure.

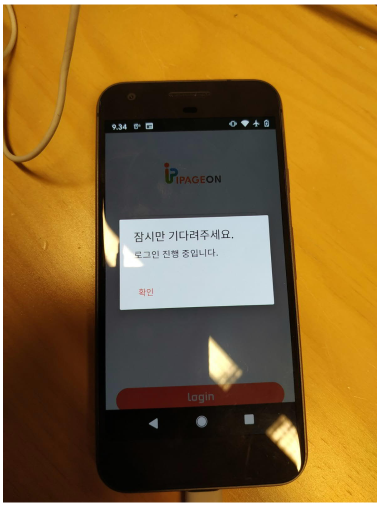

Figure 14: PTT application in Android mobile

The PTT application deployed in CMC was tested with successful configuration of the system and establishment of PTT session as shown in Figure 15 showing the message flow.

<table>
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<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57730 [ACK] Seq=1 Ack=378 Win=30080 Len=1348 TSval=357876614 TSecr=180715363 [T</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57730 [ACK] Seq=1349 Ack=378 Win=30080 Len=1348 TSval=357876614 TSecr=180715363</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57730 [ACK] Seq=2697 Ack=378 Win=30080 Len=1348 TSval=357876614 TSecr=180715363</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57730 [ACK] Seq=4045 Ack=378 Win=30080 Len=1348 TSval=357876614 TSecr=180715363</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <HTTP></td><td>934</td><td>HTTP/1.1 200 (application/vnd.3gpp.mcptt-user-profile+xml)</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.2</td><td>192.168.9.8</td><td>GTP <HTTP></td><td>483</td><td>GET /org.3gpp.mcptt.service-config/users/9990001003/service-config HTTP/1.1</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>102</td><td>9090 → 57732 [ACK] Seq=1 Ack=382 Win=30080 Len=0 TSval=357876836 TSecr=180715603</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57732 [ACK] Seq=1 Ack=382 Win=30080 Len=1348 TSval=357876859 TSecr=180715603 [T</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <HTTP></td><td>173</td><td>HTTP/1.1 200 (application/vnd.3gpp.mcptt-service-config+xml)</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.2</td><td>192.168.9.8</td><td>GTP <HTTP></td><td>483</td><td>GET /org.openmobilealliance.groups/global/byGroupID/tel:0000010001 HTTP/1.1</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>102</td><td>9090 → 57734 [ACK] Seq=1 Ack=382 Win=30080 Len=0 TSval=357876956 TSecr=180715733</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57734 [ACK] Seq=1 Ack=382 Win=30080 Len=1348 TSval=357876974 TSecr=180715733 [T</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57734 [ACK] Seq=1349 Ack=382 Win=30080 Len=1348 TSval=357876974 TSecr=180715733</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57734 [ACK] Seq=2697 Ack=382 Win=30080 Len=1348 TSval=357876974 TSecr=180715733</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57734 [ACK] Seq=4045 Ack=382 Win=30080 Len=1348 TSval=357876974 TSecr=180715733</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57734 [ACK] Seq=5393 Ack=382 Win=30080 Len=1348 TSval=357876974 TSecr=180715733</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <TCP></td><td>1450</td><td>9090 → 57734 [ACK] Seq=6741 Ack=382 Win=30080 Len=1348 TSval=357876974 TSecr=180715733</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.2</td><td>GTP <HTTP/XML></td><td>116</td><td>HTTP/1.1 200</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <SIP></td><td>1065</td><td>Request: REGISTER sip:mcptt.kete.co.kr (1 binding) |</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.3</td><td>GTP <SIP></td><td>704</td><td>Status: 200 OK (1 binding) |</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <IPv4></td><td>1486</td><td>Fragmented IP protocol (proto=UDP 17, off=0, ID=b378) [Reassembled in #452]</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <SIP/SDP></td><td>1190</td><td>Request: INVITE sip:mcptt1_opf_psi@mcptt.kete.co.kr |</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.3</td><td>GTP <SIP></td><td>702</td><td>Status: 100 Trying |</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.3</td><td>GTP <IPv4></td><td>1502</td><td>Fragmented IP protocol (proto=UDP 17, off=0, ID=efcf) [Reassembled in #455]</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.3</td><td>GTP <SIP/SDP></td><td>734</td><td>Status: 200 OK |</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <SIP></td><td>1017</td><td>Request: SUBSCRIBE sip:subscription_proxy@mcptt.kete.co.kr |</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.3</td><td>GTP <SIP></td><td>534</td><td>Status: 200 OK |</td></tr>
<tr><td>2021-04-19…</td><td>192.168.9.8</td><td>10.200.0.3</td><td>GTP <SIP></td><td>787</td><td>Request: NOTIFY sip:9990001002@10.200.0.3:4221 |</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <SIP></td><td>613</td><td>Request: ACK sip:9990001002@192.168.9.8:6060;transport=udp |</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <UDP></td><td>102</td><td>26744 → 20400 Len=24</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <STUN></td><td>106</td><td>Binding Request</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <RTCP></td><td>106</td><td>13997 → 20397 Len=28</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <STUN></td><td>106</td><td>Binding Request</td></tr>
<tr><td>2021-04-19…</td><td>10.200.0.3</td><td>192.168.9.8</td><td>GTP <RTCP></td><td>106</td><td>16057 → 20399 Len=28</td></tr>
</table>

Figure 15: PTT message flow.

4.4 Intercontinental: CMC 5GC in FI - KCL gNB NSA in UK

This setup consists of 5G core by CMC running in KCL premises connected to Aalto gNB running in Finland through international connection provided by GENAT. The objective is to test an architecture where network functions are deployed in different locations. The gNB installed in AALTO campus communicates with the CMC core network components (AMF, SMF, UPF) at remote site through the intercontinental connection. After the gNB connects to the default AMF running in another server located in KCL, then the AMF will allocate a suitable UPF that is located close to the gNB. The figure below shows the connectivity (i.e. ping with RTT around 175ms) between the 5GC located at KCL and the gNB in Aalto premises. In the middle of the figure are the logs of the CMC 5G running at KCL and on the right-hand side the Speedtest results (i.e. 141Mbps DL, 3Mbps UL and 13ms delay) are shown when the mobile is connected to the gNB in Aalto and local UPF is assigned for local breakout.

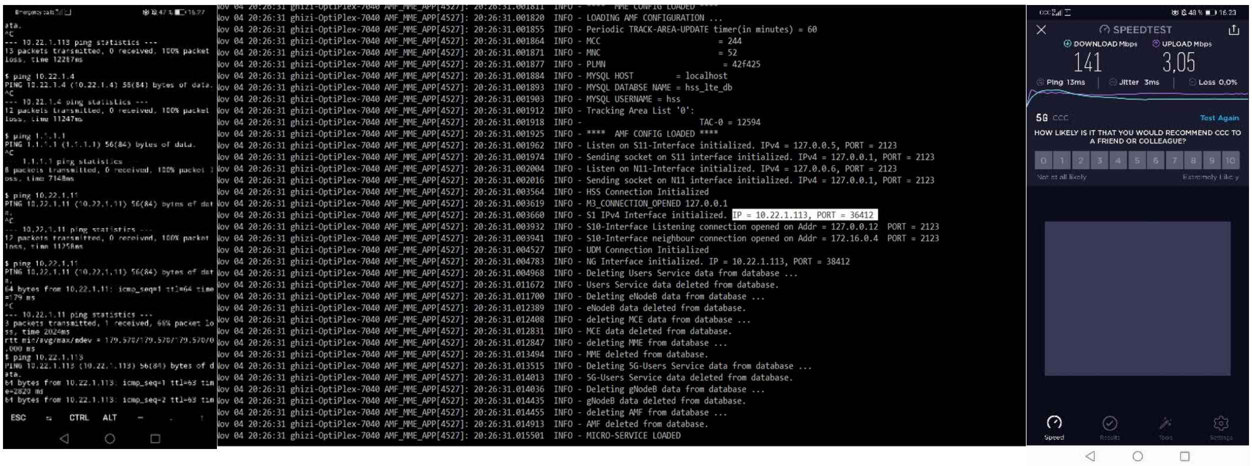

Figure 16: Interoperability results CMC-KCL

5 Conclusions

The main objective of this deliverable is to describe initial interoperability testing of 5GC between PriMO-5G partners. This deliverable includes the results of first interoperability tests run locally on-premises but also intercontinental testing being one of the first international tests of 5G system with local breakout on different continents. This shows the impact of having 5G system running in remote locations, but user plane managed locally for low latency applications like firefighting. The test scenarios to be addressed in the final release have been delayed due to lack of equipment including Rel 16 features like gNB standalone (SA) and network functions required for the SBA system. Moreover, WP2 is integrating MEC with network slicing as part of 5G architecture which has not been considered in detail during last 3GPP releases of standards. Therefore, discovery of UPF with MEC support is not considered and would be part of work item in the next 3GPP Rel 17. Thus, PriMO-5G might be able to contribute to this work item based on the initial design and prototype of SBA with MEC support.