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D2.2 - PRIMO-5G CORE INTEROPERABILITY REPORT

Work Package	WP2 5G Core Network
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Table of Contents

List of Figures

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 focuses on the interoperability of 5G core using different prototype implementations done by PriMO-5G partners. Therefore, this deliverable will ensure collaboration between Korean and European partners to guarantee end-to-end interoperability.

List of Acronyms

Acronym	Definition
3GPP	Third Generation Partnership Project
4G	Fourth-Generation Mobile Network
5G	Fifth-Generation Mobile Network
5GC	5G Core
5G-PPP	5G Public-Private Partnership
AMF	Access and Mobility Management Function
BS	Base Station
CMC	Cumucore
COTS	Commercial Off-the-Shelf
CP	Control Plane
CUPS	Control and User Plane Separation
eMBMS	Evolved Multimedia Broadcast Multicast Service
eNB	Evolved NodeB
EPC	Evolved Packet Core
FI	Finland
gNB	Next Generation NodeB
IEC	International Electrotechnical Commission
IITP	Institute for Information & communications Technology Promotion
IoT	Internet of Things
ISO	International Organization for Standardization
KCL	Kings College London
KR	Korea
KT	Korea Telecom
MEC	Multi-access Edge Computing
MCU	Mobile Core Unit
NB-IoT	Narrowband Internet of Things
NF	Network Function
NFV	Network Function Virtualisation

NSA	Non-Stand Alone
QoS	Quality of Service
RAN	Radio Access Network
SA	Stand Alone
SBA	Service Based Architecture
SMF	Session Management Function
TRxP	Transmission Reception Point
UE	User Equipment
UP	User Plane
UPF	User Plane Function
URLLC	Ultra-Reliable Low Latency Communications
VPN	Virtual Private Network
WP	Work Package
YU	Yonsei University

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.

However, as the first step for integrating different technologies such as network slicing or MEC we have to ensure the interoperability of 5G core (5GC) implementations. In order to achieve the objectives PriMO-5G partners will proceed incrementally by testing within the consortium first in order to reach certain level of maturity.

5G has introduced the new Service-Based Architecture (SBA) that provides higher flexibility in terms of deployments and dynamically adding new network functions (NFs) to the system. The 5GC, similar to 4G Control and User Plane Separation (CUPS) will facilitate among others inter-continental deployments where signaling components of the 5G core can run in a remote location while user plane can run close to the radio access network (RAN) and Data Network. However, the SBA is a new architecture introduced in 5G, which still needs to be validated and some interoperability issues between different vendors will arise.

The objective of this deliverable is to perform several interoperability tests of 5G core and RAN implementations from different PriMO-5G partners. The 5G SBA architecture is new so the target is to ensure seamless integration of multi-vendor solution in the commercial deployments.

Moreover, as the SBA promises high flexibility, in this deliverable we evaluate the feasibility to deploy 5G system across inter-continental links. Therefore, the PriMO-5G partners located in different continents will validate whether the SBA architecture can accommodate the deployment of network functions across different remote locations which will open up new use cases between mobile operators and service providers.

Thus, the deliverable defines the different deployment scenarios for testing interoperability of 5GC components implemented by PriMO-5G partners. The results of the PriMO-5G internal interoperability testing are released in this deliverable to highlight possible issues with the current 3GPP specifications. The deliverable includes findings for other vendors to check possible issues with new releases of the 5G core.

1.2 Structure of the document

This deliverable is organized as follows. Section 2 presents the current architecture proposed in 3GPP as SBA including all the nNFs required for deploying a 5G mobile network architecture. Section 3 describes the components contributed by the different PriMO-5G partners that will be used for testing 5GC interoperability. Section 4 presents the results including traffic samples and screenshots of end devices used for testing. Section 5 finally describes the remaining test scenarios to be included in the final deliverable.

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 use 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).

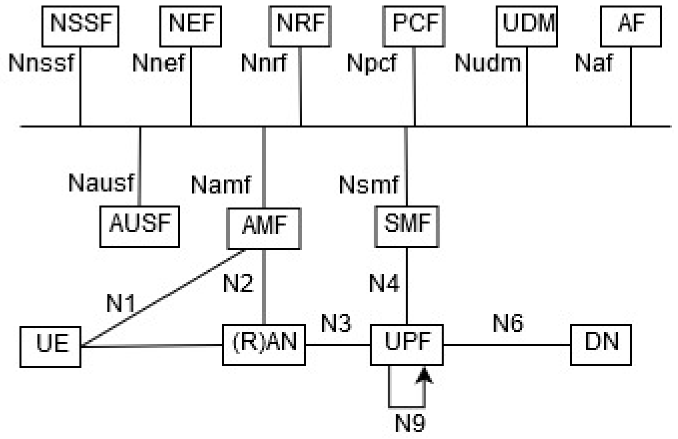

Figure 1. 5G Core Architecture (Source: 3GPP TS 23.501)

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 Narrowband Internet of Things (NB-IoT) and Evolved Multimedia Broadcast Multicast Service (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 RAN components.

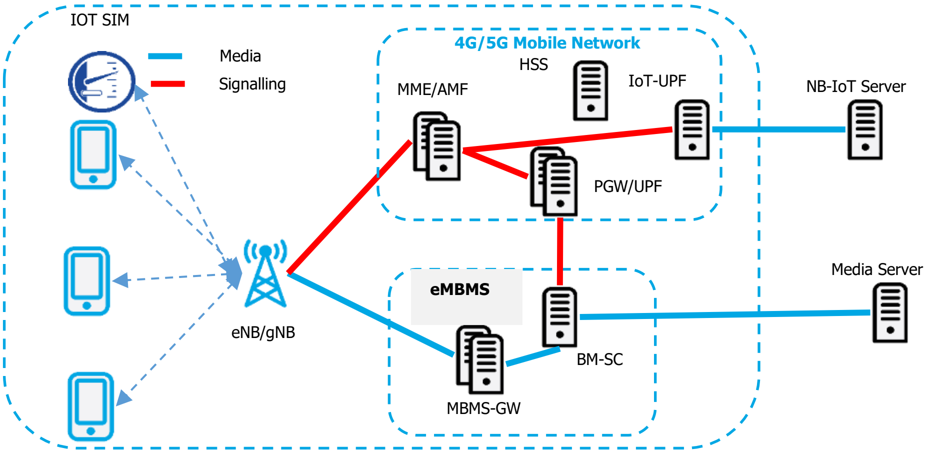

Figure 2. 5G network architecture of CMC

CMC packet core includes 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 3the operator can add subscribers, eNB/gNB and network functions.

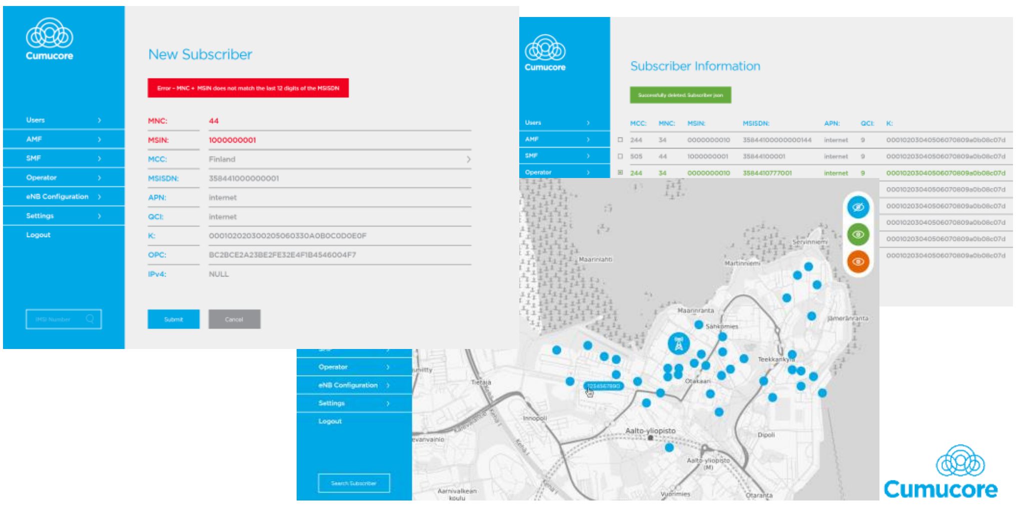

Figure 3. 5G network management interface of CMC

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 software 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, to be composed of LTE base stations (eNBs) and 5G base stations, will ensure seamless interworking between LTE and 5G.

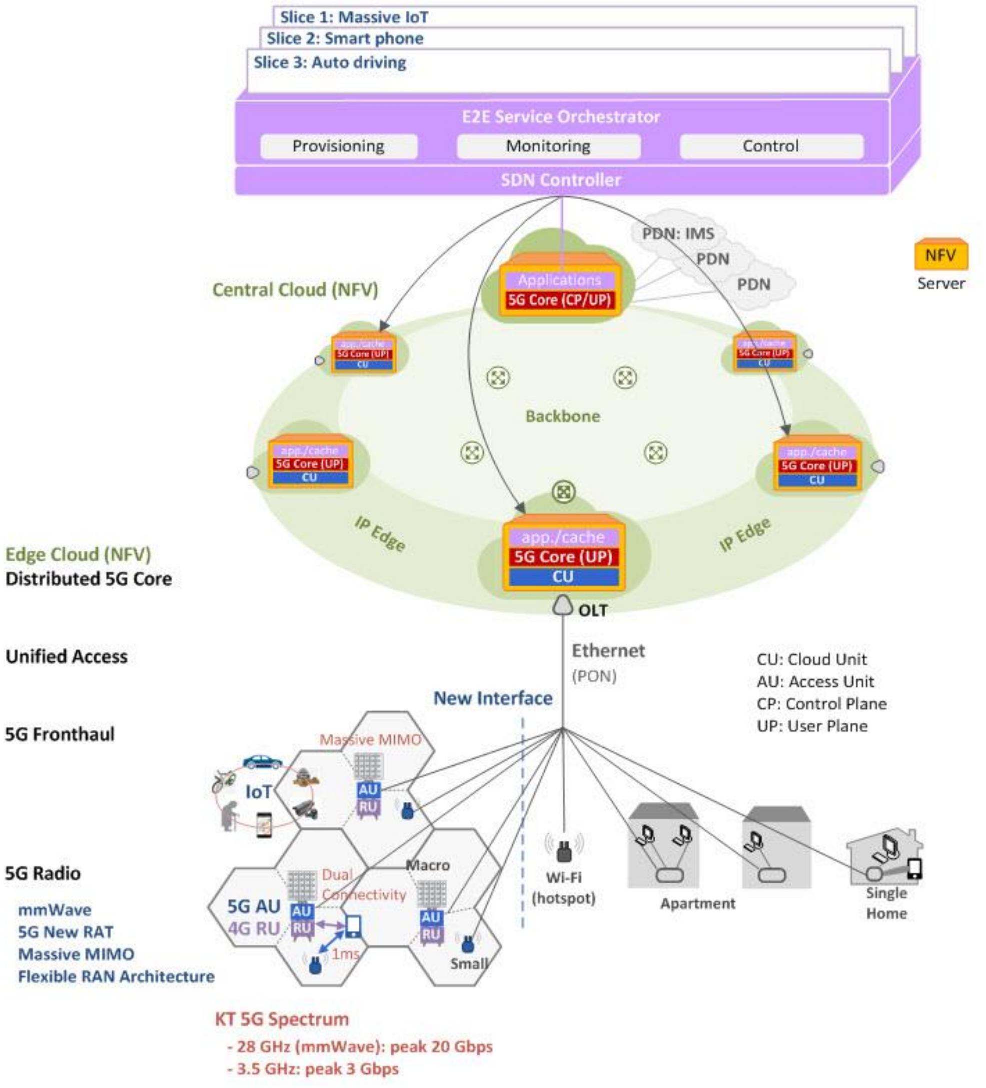

Figure 4. 5G network architecture of KT

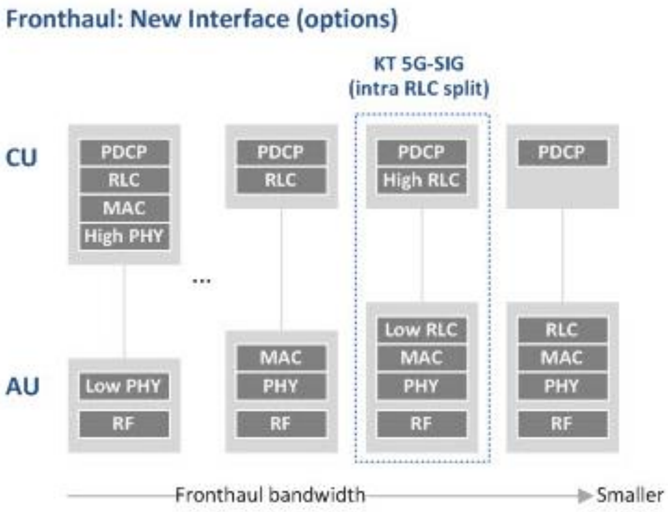

Figure 5. KT's AU-CU interface candidates

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.

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 as an 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 at the time of the intermediate release of this deliverable supports Non-Standalone NSA and is expected to be updated to SA for the second release of this deliverable. 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.

3.5 NI gNB

NI is working on the implementation of a SA gNB using mmWave frequencies. A first integration setup without PHY layer will be available by Q1/2020 so the interoperability testing will be added to the final release of this deliverable.

The NI gNB is based on NI's PXI platform and supports frequency bands n257 and n258. The gNB has interfaces to the 5G Core are based on 3GPP specifications.

Supported procedures are among others attach, radio bearer setup, radio resource management and mmWave beam management.

3.6 KCL gNB

KCL is using Open Air Interface (OAI) software based gNB but first integration is targeted for February next year so the interoperability testing will be added to the final release of this deliverable.

The gNB supports NSA functionality including a full software implementation of 4th generation mobile cellular systems compliant with 3GPP LTE standards.

4 PriMO-5G Core Intermediate Interoperability Setup

The interoperability test take place with components from PriMO-5G partners located either in Korea or Europe. A remote connectivity through Virtual Private Network (VPN) between Europe and Korea is established using GEANT infrastructure located in UK. The interoperability setup will include 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.

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

This test is conducted between CMC 5G core and Aalto gNB both located in Aalto campus. The CMC 5GC supports both NSA and SA, but in this first intermediate release only NSA is in use. The objective is to test basic interoperability between EPC using anchor eNB for the signalling and gNB for the user plane following NSA mode in this intermediate release and continue with SA after gNB is updated for the final release.

The setup consists of the 5GC located in Linux server, which is connected to the Aalto gNB manufactured by Nokia with NSA functionality. The gNB includes two radio heads that are installed in the roof of Väre building located in the centre of Aalto campus. The usage of two radio heads provides coverage to the two main roads in the campus as shown in the Figure 7 .

Figure 8 shows the setup used in the testing where the gNB is connected to CMC 5GC that includes both NSA and SA to support future updates in the gNB. The current test is using NSA functionality where the gNB connects to the 5GC using 4G signalling and the data plan connects to the 5GC for high throughput and low latency.

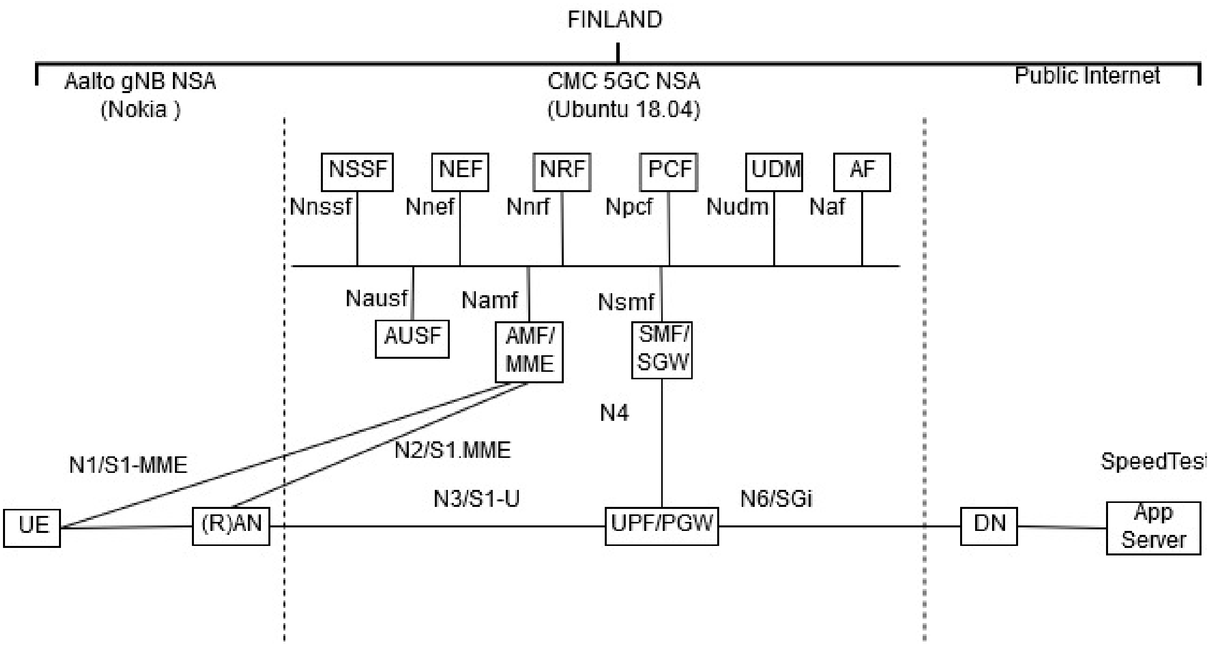

Figure 8. CMC 5GC- Aalto gNB testing setup.

The results are obtained for an application, i.e. Ookla's Speedtest[1], running in public Internet. The user plane is established from the gNB through the 5GC to the Data Network (DN) and the Speedtest server, which is located outside the campus network. The Figure 9 below shows a sample of the results where the throughput and latency varies in dependence on the number and kind of intermediate hops to connect to public Internet.

Figure 9. CMC 5GC- Aalto gNB testing results.

4.2 Local: CMC 5GC - KCL gNB NSA in UK

This test is done between CMC 5G core and KCL gNB. The aim is to test basic interoperability between 5G core and gNB.

The setup as shown in Figure 10 consists of the 5GC located in a Linux server and an OAI-based gNB with NSA functionality running on a Linux PC at KCL. The gNB is configured for FDD band 7.

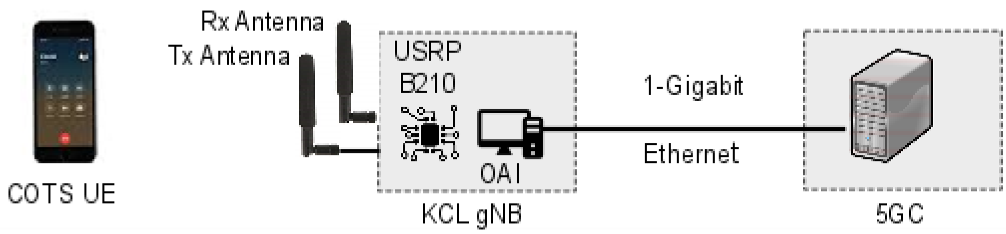

Figure 10. CMC 5GC- KCL gNB experimentation setup.

The test should show a successful attachment procedure of COTS UE to 5GC through KCL gNB. Furthermore, the test should show a successful establishment of user data by performing uplink/downlink transmission.

[1] https://www.speedtest.net/

4.3 Intercontinental: CMC 5G in KR - Aalto gNB NSA in FI

This test has been taking place between CMC 5G core running in Korea and Aalto gNB running in Finland. The objective is to test basic interoperability between 5G core signalling with local breakout in anchor eNB and gNB located in Aalto premises. This test will validate the functionality of SBA architecture that enables the deployment of network functions in different locations.

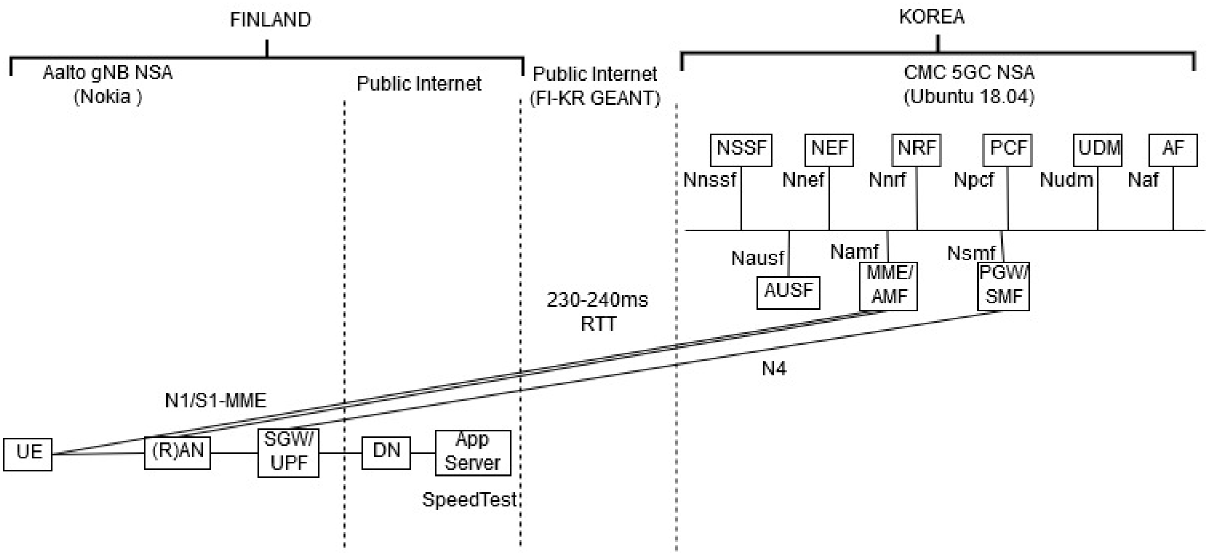

Figure 11. Intercontinental test setup 5GC in KR and gNB in FI.

The connectivity between RAN in Aalto premises and the 5GC in Korea had an average delay of 230-240 ms. The following Figures 11-13 shows the signalling messages exchanged between the anchor eNB in Aalto and the 5GC in Korea. Figure 11 shows traffic log with the mobile device attach message that is sent from the anchor eNB with the country code 244 for Finland and the operator code 52.

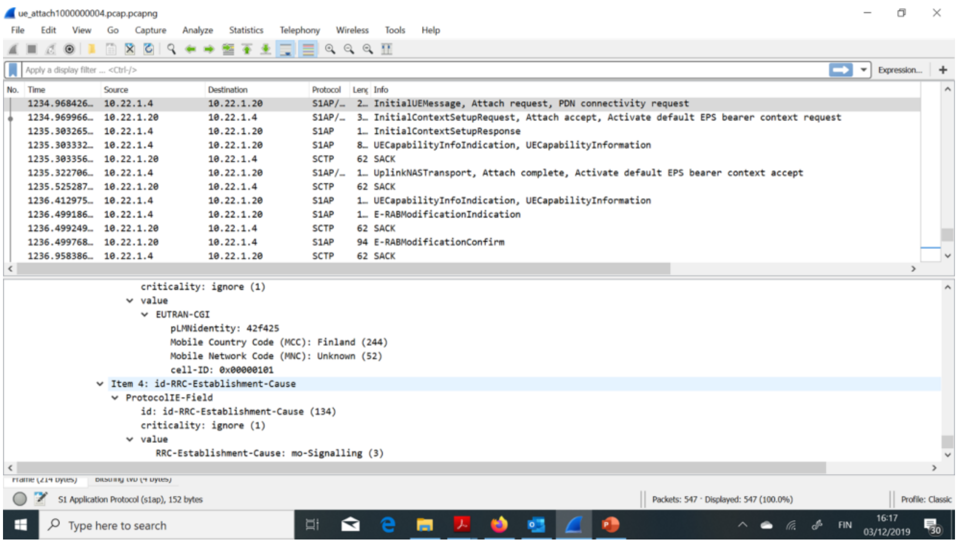

Figure 12. Attach request message from 5G capable mobile device sent from anchor eNB in Aalto to EPC in Korea through the intercontinental connection.

Figure 12 shows the attach accept message sent from the 5GC in Korea to the anchor eNB indicating the supported maximum uplink and downlink throughput (indicated in the signalling UE-AMBR-UL and UE-AMBR-DLparameters).

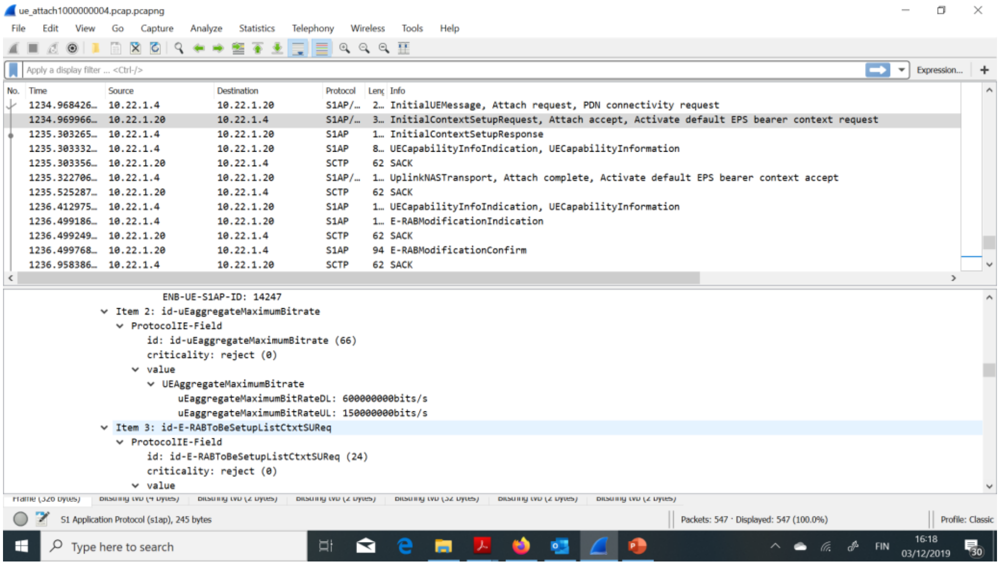

Figure 13. Attach accept message from EPC in Korea sent back to the anchor eNB in Aalto premises.

Next Figure 13 shows that, after the attach is completed, a change is initiated with the mobile device to start using the gNB that can support the requested throughput. After this radio change is completed, the user data plane will go through the gNB.

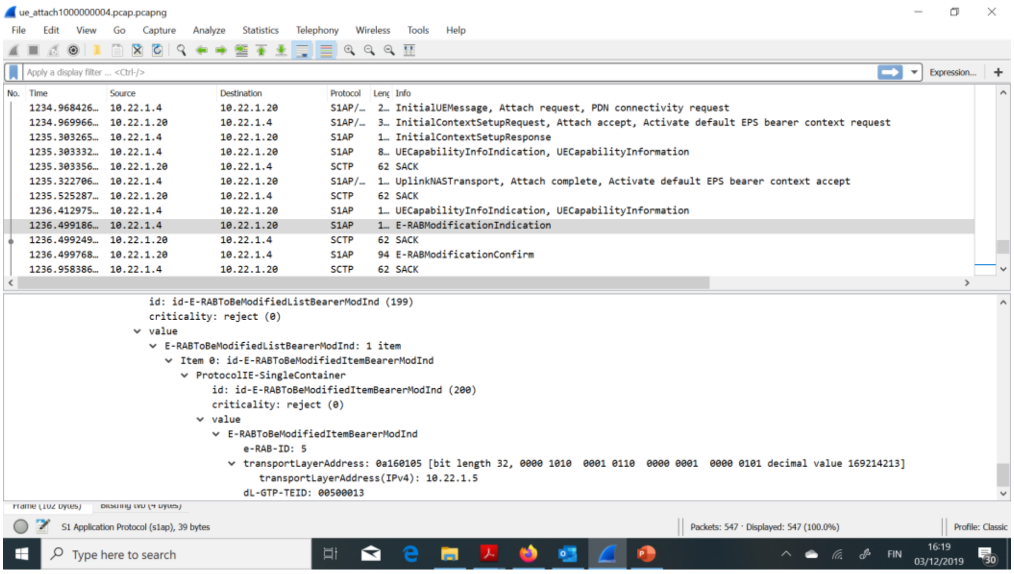

Figure 14. Attach accept message from 5GC in Korea sent back to the anchor eNB in Aalto premises.

Figure 14 shows the performance in terms of latency and throughput measured directly in the 5G mobile device (model Huawei 20X 5G). The results show throughput and latency numbers achieved for the connection of the SpeedTest application running in the mobile device with a server in the public internet.

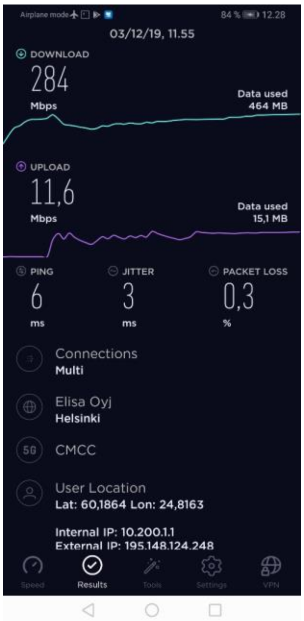

Figure 15. Speedtest showing the latency and throughput measured in the 5G capable mobile device.

5 PriMO-5G Core Final Interoperability Setup

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.

5.1 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 both CMC 5GC and Aalto gNB will be functioning in SA mode as shown in Figure 16.

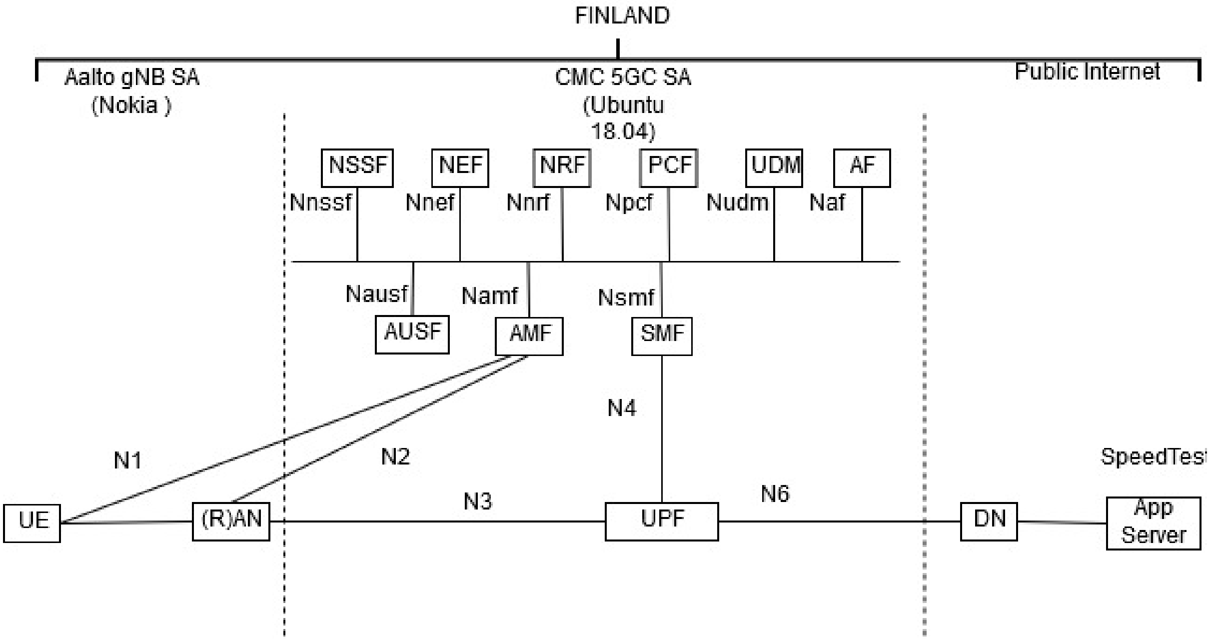

Figure 16. Local test setup with 5GC and gNB SA mode.

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

This test will be deployed in Germany and consist of CMC 5GC and NI gNB and NI 5G UE designed for mmWave frequencies in SA mode. The interoperability test will be executed in a simplified environment, where the actual PHY Layer and RF is replaced by a PHY Abstraction Layer (PAL).

5.3 Local: CMC 5GC - KT gNB NSA in KR

This test will be run locally in KR using CMC 5GC deployed in dedicated system by KT in their premises to test the interoperability with a gNB from different vendor.

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

This test will be taking place between CMC 5G core in Finland and the gNB in UK, both in Europe but remotely connected. The objective is to test basic interoperability between 5G core and one gNB located at KCL.

5.5 Intercontinental: CMC/KT 5G in KR - Aalto gNB SA in FI

This test is similar to the one performed for the intermediate deliverable, but both 5GC and gNB are running in SA mode.

5.6 Intercontinental: CMC/KT 5GC in KR - Aalto gNB in FI SA with SBA

This scenario will test the SBA using Network Repository Function (NRF) and Network Slice Selection Function (NSSF) for AMF re-registration from remote AMF in KR to local AMF in FI after discovering it includes MEC functionality as shown in Figure 17.

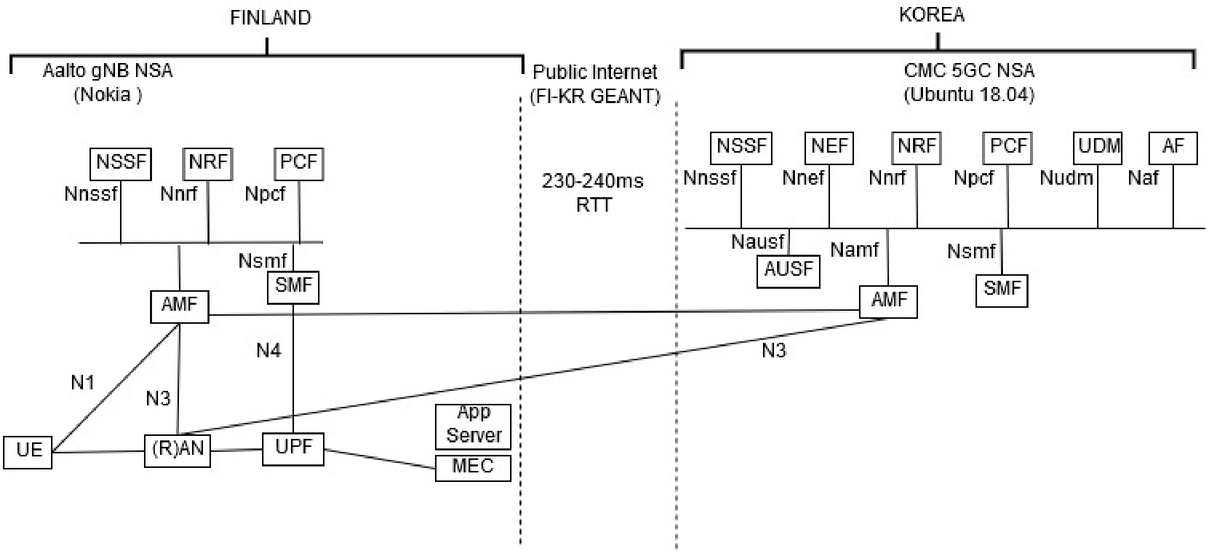

Figure 17. Intercontinental test setup with 5GC in KR and gNB in FI SA mode with SBA functionality.

5.7 Intercontinental: CMC/KT 5G FI - YU gNB KR SA with SBA

This scenario will test the 5G core interoperability with YU gNB and the SBA that uses NRF and NSSF to locate optimal AMF with UPF including MEC functionality as shown in Figure 18.

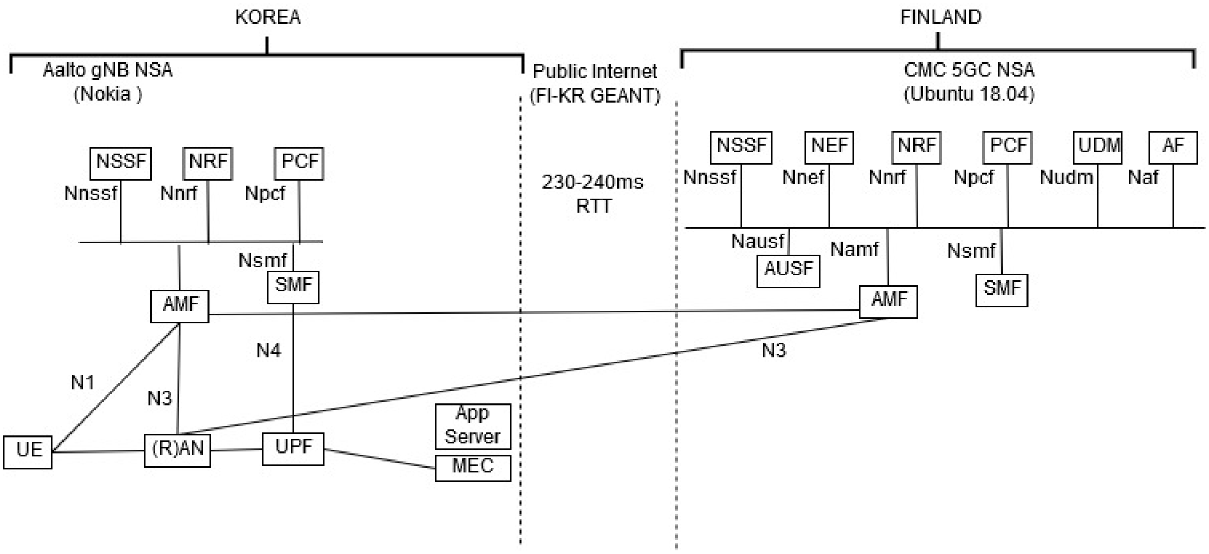

Figure 18. Intercontinental test setup with 5GC in FI and gNB in KR SA mode with SBA functionality.

6 Conclusions

The main objective of this deliverable is to describe initial interoperability testing of 5GC between PriMO-5G partners. This first 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 Release 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 Release 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.