



5GMOBIX

5G for cooperative & connected automated
MOBility on X-border corridors

D3.3

Report on the 5G technologies integration and roll-out

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Control sheet

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ABBREVIATIONS

Abbreviation	Definition
3GPP	3rd Generation Partnership Project
5GAA	5G Automotive Association
5GC	5G Core
5GCN	5G Core Network
AAA	Authentication, Authorisation and Accounting
AF	Application Function
AMF	Access and Mobility Management Function
ANACOM	Autoridade Nacional de Comunicações
ASGH	Advanced Subscriber Group Handling
AV	Autonomous Vehicle
AVG	Average
CAM	Cooperative Awareness Message
CBAM	CloudBand Application Manager
CBC	Cross Border Corridor
CBIS	CloudBand Infrastructure Software
CCAM	Cooperative, Connected and Automated Mobility
CMG	Cloud Mobile Gateway
CMM	Cloud Mobility Manager
cmWave	centimetre wave
CN	Core Network
CNOM	Core Network Operation Manager
COTS	Commercial off the shelf
CP	Control Plane
CPM	Collective Perception Message

CPRI	Common Public Radio Interface
CRAN	Centralized RAN
C-SGN	Cellular IoT-Serving Gateway Node
CUDB	Centralized User Data Base
CUPS	Control User Plane Separation
C-V2X	Cellular Vehicle-to-Everything
CWDM	Coarse Wavelength Division Multiplexing
DDNS	Dynamic DNS
DENM	Decentralized Environmental Notification Message
DL	Down Link
DNN	Data Network Name
DNS	Domain Name System
DRAN	Distributed RAN
DSRC	Dedicated Short-Range Communication
DSS	Dynamic Spectrum Sharing
DWDM	Dense Wavelength Division Multiplexing
E2E	End to end
eCPRI	Enhanced Common Public Radio Interface
eMBB	Enhanced Mobile Broadband
eNB	E-UTRAN Node B
EN-DC	E-UTRAN Dual Connectivity
EPC	Evolved Packet Core
ePDG	Evolved Packet Data Gateway
ePLMN	Equivalent PLMN
ETSI	European Telecommunications Standards Institute
EU	European Union

E-UTRAN	Evolved Universal Terrestrial Radio Access Network
FDD	Frequency Division Duplex
FE	Front End
FTP	File Transfer Protocol
GGSN	Gateway GPRS Support Node
gNB	gNodeB
GNSS	Global Navigation Satellite System
GPRS	General Packet Radio Service
GRX	GPS Roaming Exchange
GTP	GPRS Tunnelling Protocol
HA	Home Agent
HAG	Hybrid Access Gateway
HO	Handover
HR	Home Routing
HSS	Home Subscriber Server
HTTP	Hypertext Transfer Protocol
IaaS	Infrastructure as a Service
IMSI	International Mobile Subscriber Identity
IoT	Internet of Things
IP	Internet Protocol
IPsec	Internet Protocol Security
ITS	Intelligent Transportation Systems
KPI	Key Performance Indicator
LBO	Local Breakout
LDNS	Local Domain Name Server
LEO	Low Earth Orbit

LTE	Long Term Evolution
LTE-V	LTE to Vehicle
MA	Multiple Access
MCM	Manoeuvre Coordination Message
MEC	Multi-access Edge Computing
MeNB	Master eNB
MIMO	Multiple-Input/Multiple-Output
MME	Mobility Management Entity
mmWave	millimetre wave
MNO	Mobile Network Operator
MOCN	Multi Operator Core Network
MPLS	Multiprotocol Label Switching
MQTT	Message Queuing Telemetry Transport
NAS	Network-Attached Storage
NAT	Network Address Translation
NB-IoT	Narrowband IoT
NDC	Network Data Center
NF	Network Function
NFV	Network Function Virtualization
NG-RAN	Next-Generation Radio Access Network
NR	New Radio
NRA	National Regulatory Authority
NRF	Network Repository Function
NSA	Non-Standalone
NSP	Network Service Platform
NSSF	Network Slice Selection Function

OAM	Operations, Administration, and Management
OBU	On-Board Unit
OSS	Operations Support System
OVS-DPDK	Open vSwitch Data Plane Development Kit
P ₂ P	Point to Point
PCF	Policy Control Function
PCI	Primary Cell ID
PCRF	Policy and Charging Rules Function
PDCP	Packet Data Convergence Protocol
PDU	Protocol Data Unit
PGW	Packet Gateway
PLMN	Public Land Mobile Network
PRACH	Physical Random-Access Channel
PTP	Precision Time Protocol
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RAN	Radio Access Network
RRC	Radio Resource Control
RSRP	Reference Signal Received Power
RSRQ	Reference Signal Received Quality
RSSI	Received Signal Strength Indicator
RSU	Roadside Unit
RTT	Round Trip Time
SA	Standalone
SAE	Society of Automotive Engineers
SDN	Software-Defined Networking

SgNB	Secondary gNB
SGSN-MME	Serving GPRS Support Node – Mobility Management Entity
SGW	Serving Gateway
SIM	Subscriber Identity Module
SINR	Signal to Interference and Noise Ration
SMF	Session Management Function
S-NSSAI	Single Network Slice Selection Assistance Information
SPGW	Combined PGW and SGW
SRI	Satellite Radio Interface
SRS	Sounding Reference Signal
SS	Synchronization Signal
SSC	Session and Service Continuity
SW	Software
TAC	Tracking Area Code
TC	Test Case
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TRP	Total Radiated Power
TS	Trial Site
TWAG	Trusted Wi-Fi Access Gateway
UC	Use Case
UCC	Use Case Category
UDM	Unified Data Management
UDP	User Datagram Protocol
UE	User Equipment
UICC	Universal Integrated Circuit Card

UL	Uplink
UP	User Plane
UPF	User Plane Function
uRLLC	Ultra-Reliable Low Latency Communication
US	User Story
V2I	Vehicle to Infrastructure
V2N	Vehicle to Network
V2P	Vehicle to Pedestrian
V2V	Vehicle to Vehicle
V2X	Vehicle-to-Everything
vCUDB	Virtual Centralized User Database
vEDA	Virtual Ericsson Dynamic Activation
vEPC	Virtual Evolved Packet Core
vEPG	Virtual Evolved Packet Gateway
vHSS-FE	Virtual Home Subscriber Server – Front End
VLAN	Virtual Local Area Network
VM	Virtual Machine
vMME	Virtual Mobility Management Entity
VNF	Virtual Network Function
VNFM	Virtual Network Function Manager
vUDM	Virtual Unified Data Management
WAN	Wide Area Network
WDM	Wavelength Division Multiplexing
WP	Work Package
X2AP	X2 Application Protocol
X-border	Cross-border

EXECUTIVE SUMMARY

The aim of this document is to report on the characteristics and delivery of the 5G network technologies to be used during the 5G-MOBIX trials, which will take place at the two cross border corridors (CBCs) of Spain-Portugal (ES-PT) and Greece-Turkey (GR-TR), as well as the local trial sites (TSs) in Finland (FI), France (FR), Germany (DE), the Netherlands (NL), South Korea (KR) and China (CN). Deliverable 3.3 provides a phased strategy for deployment/rollout of 5G networks, which is followed by a more detailed description of the activities that needs to be performed for radio access and core network deployment, integration and initial testing. Specific attention is paid to highlight the status of the advanced 5G technologies that are required for enabling cooperative, connected and automated mobility (CCAM) use cases at border crossings.

Corresponding to the physical/materialized work, done in line with the rollout strategy, the main focus of D3.3 is on those aspects of the deployed 5G networks such as the relevant architectures designed/chosen, the frequency ranges used, the technology choices made, and the network capabilities/features available for trialling. A comprehensive set of network tests that have been or will be performed at the CBCs and TSs in the remaining timeline of T3.3 beyond this deliverable are also described. D3.3 in its current version covers the first 18 months of work in T3.3, from M8 to M26 of 5G-MOBIX.

The deployments at the two CBCs, ES-PT and GR-TR, include a total of four networks with twelve gNBs covering locations at the two borders as well as testing sites further inland. At the Spanish-Portuguese border two bridges over the border river Miño form the designated cross-border testing area, where 5G coverage has been successfully deployed at the ES side, while deployment at the PT side is under way and expected to be completed by January 2021. The Greek-Turkish border testing site at the border crossing of the Ego/E84 near Kipoi/Ipsala has received 5G coverage from both sides and initial network testing has been performed. In both CBCs 5G NSA deployments were chosen and implemented.

The TSs have mostly completed the initial rollouts and are in the early stages of testing. Similar to the CBCs, many TSs feature multiple deployed networks, but often with more experimental deployments or a larger variance in characteristics or parameters compared to those at the CBCs. For instance, the TSs in DE, FR, NL and KR have or are planning to move towards 5G stand-alone (SA) deployments, while those in NL and KR include the use of mmWaves, as well.

A brief overview of the networks deployed in 5G-MOBIX is given in Table 1, with similar comparisons given on the aspects of RAN, core, network integration and the deployed technologies in Table 3.8, Table 4.14, Table 5.15, and Table 7.35, respectively. Figure 1 gives an overview of the technology deployed and tested per cross border corridor and trial site.

Finally, full testing of the networks is planned by all CBCs and TSs, having defined a common set of generic network tests as well as a per-CBC/TS set of specific tests. While most network testing is yet to be done, initial testing results are reported for the ES-PT and GR-TR CBCs.

Table 1: Overview of 5G-MOBIX networks.

CBC/ TS	Type	Commercial/ Test Components	Num. gNBs	Freq. Bands	Slicing
ES	NSA	Commercial: Transport network, 1x 4G RAN (MOCN) Test: 1x Core, 5G RAN, MEC	4	800 MHz (LTE B20), 1800 MHz (LTE B3) 2600 MHz (B7), 3.7 Hz (5G NR n78)	No
PT	NSA (SA)	Commercial: IP and Transport Network Test: 1x RAN, 1x Core, MEC	3	1800 MHz (LTE B3), 3700 MHz (5G NR n78)	After SA upgrade
GR	NSA	Commercial: IP and Transport Network Test: 1x RAN, 1x Core	1	LTE B7 (2600) 20MHz, NR n78F (3500-3600)	No
TR	NSA	Commercial: IP and Transport Network Test: 4x RAN, 1x Core	3 (+1)	LTE B7 (2600) 20MHz, NR n78G (3600-3700)	No
DE	NSA/SA	Commercial: 1x NSA Core + 1x RAN, MEC Test: 1x SA Core + 1x RAN, MEC	2	NSA: 2.1 GHz (5G NR n1) + 800 MHz (LTE B20), 900 MHz (LTE B8), 1800 MHz (LTE B3) 3.6 GHz (5G NR n78) + 1800 MHz (LTE B3), 2600 MHz (B7) SA: 3.7 - 3.8 GHz (n78)	No
FI	NSA/SA	Commercial: Test: 2xRAN, 2xCore, MEC	2	2600 MHz (B7), 3.5 GHz (n78)	Yes
FR	NSA	Commercial: 1x Core Test: 3x RAN + 2x Core, 2x MEC	3	700 MHz (4G), 800 MHz (4G), 1800 MHz (4G) 2100 MHz (3G/4G), 2600 MHz (4G) 3500 MHz (5G), 3700-3800 MHz (n77), 26 GHz	To be defined
NL	SA	Commercial: 1x 4G RAN (MOCN), 1x 4G transmission Test: 3x 5G RAN, 3x Core, 3x MEC	6	3.7 GHz (5G NR n78) 27 GHz (5G NR n258), LTE: 800 MHz (LTE B20), 1800 MHz (LTE B3)	Yes
CN	SA	Test	2	3.5GHz(n78), 4.9 GHz(n79) 2.6GHz(n41)	Yes
KR	NSA	Test	3	22-23.6 GHz	To be defined
Total			29		3(+3)

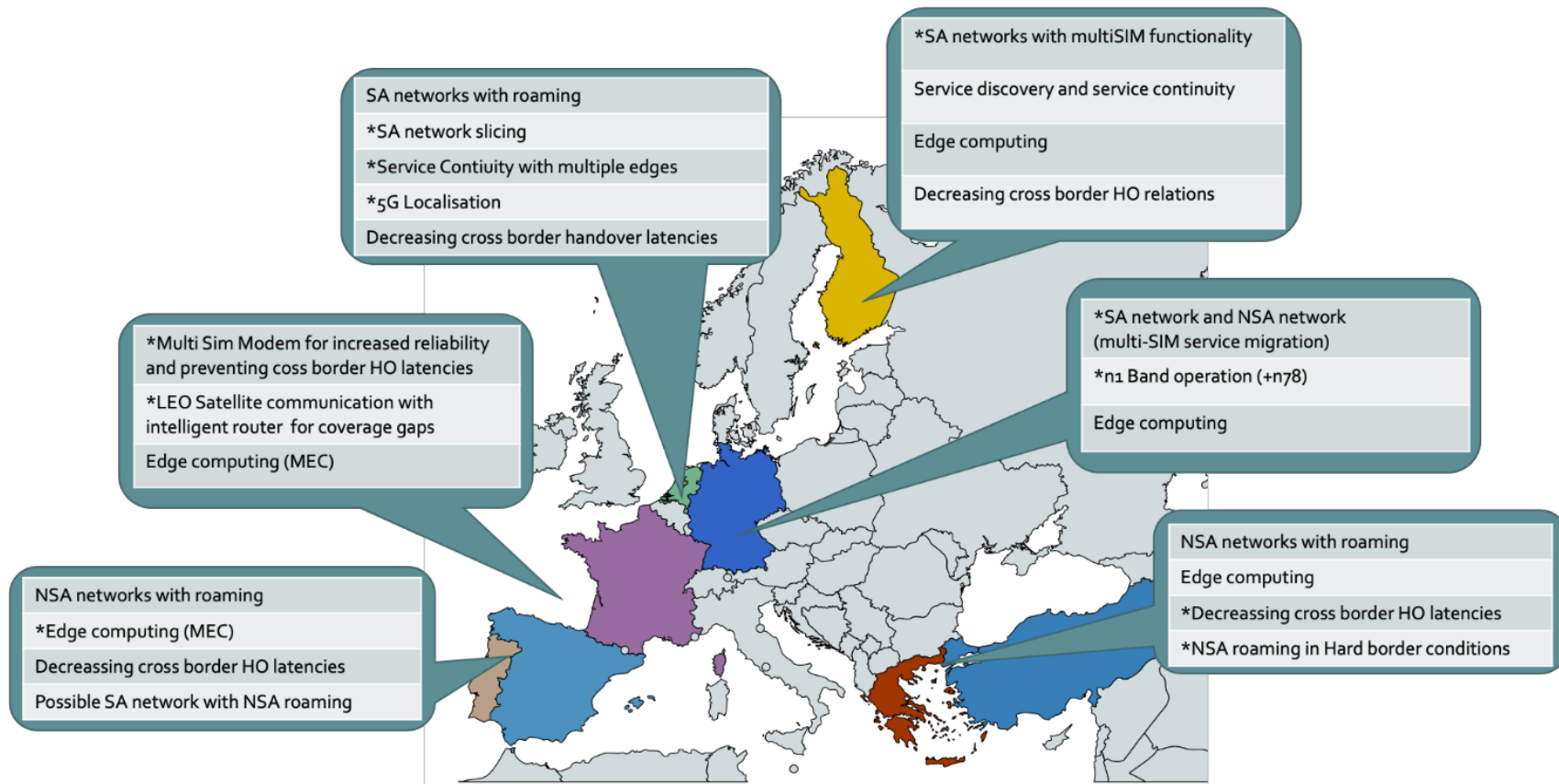


Figure 1: Technology overview per trial site (* indicates main differentiators).

1. INTRODUCTION

1.1 5G network deployment in 5G-MOBIX

5G-MOBIX aims to showcase the added value of 5G technology for advanced Cooperative, Connected and Automated Mobility (CCAM) use cases at cross-border setting and to validate the viability of the technology to bring automated driving to the next level of vehicle automation (SAE L4 and above). To do this, 5G-MOBIX plans to demonstrate the potential of different 5G features on real European roads and highways and create and use sustainable business models to develop 5G corridors. 5G-MOBIX also utilizes and upgrades existing key assets (infrastructure, vehicles, components), and ensures the smooth operation of 5G within a heterogeneous environment comprised of multiple incumbent technologies such as ITS-G5 and C-V2X.

Deployment of the 5G networks for the planned CCAM trials is executed under T3.3 within 5G-MOBIX. The main objectives are to integrate the 5G components and features needed for 5G network connectivity at the CBCs and TSs. T3.3 is in alignment with the specifications given in D2.2 [1] and 3GPP study on enhancement support for 5G V2X Services [2]. The 5G technology deployment and integration activities follow the 5-Phase rollout strategy developed in T3.1 [3]. In T3.3, phase 1 focuses on the network design issues, for both radio access network (RAN) and core network, defining a set of detailed deployment strategies at the TSs and CBCs. During phase 2, T3.3 activities included deployment of subsystems and components, procurement of the necessary frequency licenses and preparation of the core and RAN integration strategy as well as initiation of the core and RAN testing. Testing takes place during Phase 3, which integrates RAN and core elements, and performs end to end 5G network testing. In Phase 4, the networks will support the early trials, while carrying out in parallel the upgrades required to be able to support the full trials in Phase 5. T3.3 takes input from T2.1, T2.2, T2.3 and T3.1 and feeds T3.5, T3.6 and WP4.

This deliverable is prepared at the end of the Phase 2 and reports on the status of the 5G network deployment including preliminary test results. It further provides an overview of the networks deployed in 5G-MOBIX including their features and implementation, as shown in Table 1.

1.2 Purpose of the deliverable

This document is deliverable D3.3 "Report on the 5G technologies integration and roll-out". The scope of this deliverable is to provide an overview for the progress of the deployment and integration of the relevant 5G technologies at the CBCs. The purpose is to thoroughly document the rollout plans and deployment process including the major challenges faced. Documentation of network design, rollout plans, rollout for both RAN and core deployment and testing, and the 5G technologies deployed for CCAM at CBCs and TSs is available in detail in D3.3.

This deliverable focusses on the deployments in the two CBCs, reporting on their deployment strategies and network rollout as well as providing early testing results. The deliverable highlights the TS contributions to the evaluation of 5G for CCAM use cases, discussing the way they differ from the CBCs with respect to the network deployment setup used. It should be noted that in the interest of legibility detailed reports of all 5G networks rolled out in 5G-MOBIX are provided in separate annexes, while the main document focuses on the CBCs and specific TS contributions as well as the 5G technologies deployed.

1.3 Intended audience

The dissemination level of D3.3 is public (PU) and so it is addressed to any interested reader about the 5G networks deployed for and the 5G technologies to be used in the trials of 5G-MOBIX. However, this document is of special interest to 5G-MOBIX consortium members as it provides details about the process of 5G technology integration and the resulting 5G functionalities at the CBCs and TSs.

It may serve the further work in the project, especially the trials in WP4 and evaluation in WP5, but also the techno-economic studies in WP6 as input with regards to the available network functionality, connectivity and performance (WP4, WP5) as well as the chosen architectures, deployment enablers and recommendations for standardisation (WP6) and 5G technologies (WP4, WP6).

1.4 Structure of the document

As part of WP3, task T3.3 “5G Integration” follows the 5 Phase rollout plan defined in D3.1 [3]. This deliverable is divided into the following sections:

- Section 1, *Introduction*: Provides a brief introduction to the deployment of 5G networks in 5G-MOBIX, defines the purpose of the deliverable and its intended audience and outlines the structure of the deliverable.
- Section 2, *5G Deployment Strategy of 5G-MOBIX*: Gives detailed description of 5G network deployment plans for CCAM within 5G-MOBIX following the 5-Phase rollout strategy.
- Section 3, *Radio Access Network Solutions*: Documents the deployed 5G Radio Access Networks at each CBC. This section describes the process of obtaining frequency licenses, the acquisition of required hardware and software, as well as the installation and configuration processes.
- Section 4, *Core Network Solutions*: The core network deployment description includes architectures, features and attributes. This section, similarly, to Section 3, reports on the acquisition, installation and configuration of the relevant software and hardware as well as their integration into the 5G network.

- Section 5, *Network Integration*: Provides the planning and reports on the current status of the integration between RAN and core networks deployed as well as the status of cross-network integration at the CBCs.
- Section 6, *5G Network Testing and Results*: Provides the planning and selected test cases for testing of the 5G networks deployed and shows measured network performance.
- Section 7, *Advanced 5G Technology Deployment*: As 5G technologies are becoming available for the project, CBC and TS 5G networks continuously being upgraded with advanced 5G features. This section reports on the continuous activity running parallel with the initial testing and integration activities.
- Section 8, *5G Deployment Summary and Conclusions*: Summarizes the 5G network deployment and integration status within 5G-MOBIX, gives an outlook for the following tasks and challenges.
- Annexes A to F containing the deployment reports for each TS, summarizing their deployments following a similar structure as the main document body.
- Annex G provides the detailed test case reports for the initial measurements discussed in section 6.

1.5 Impact of Covid-19 on T3.3

The global Covid-19 pandemic arose during the execution of T3.3, specifically during Phase 2 of the of the global 5G-MOBIX deployment strategy in which T3.3 focussed on the 5G network deployment (see Figure 2.2 and Figure 2.3). The global pandemic resulted in restrictive measures ('lockdowns') being imposed by national governments and/or local or regional authorities, resulting in restrictions to regional, national and global travel, different levels of limitations to access to facilities and/or premises and restrictions to activity in public spaces. While these restrictions and their duration were and are highly country or region dependent and thus affect the work of the consortium partners in T3.3 in different ways, an overall impact of the global Covid-19 pandemic was observed. This impact is largely in the form of delays experienced in a) technology evaluation and integration due to restricted access to facilities and b) the 5G network rollouts due to restrictions to local and national travel and restrictions to activities in public spaces.

The revised 5-phase plan and corresponding timeline presented in the following section (especially Figure 2.2 and Figure 2.3) does account for delays due to Covid-19 encountered and foreseen at the time of its definition in mid-2020. Further delays may occur depending on the evolution of the global and national pandemic situations at the CBCs and TSs, especially where collaborative efforts are required for network integration or testing.

2. 5G DEPLOYMENT STRATEGY OF 5G-MOBIX

This chapter provides an overview, the timeline and the steps followed for the 5G deployments in 5G-MOBIX to be executed in T3.3. The relation of these plans to other tasks and work packages within the project is also presented.

2.1 Global deployment plan

In alignment with the specifications and designs in D2.2 [1] and global planning given by T3.1 [3], the 5G network deployment for all cross-border corridors and trial sites is structured in the following five main activities, as shown in Figure 2.2:

- 5G Network Design
- 5G Network Deployment
- 5G Integration and Testing
- 5G Network Operation and Trial Support
- 5G Technology Deployment and Integration

Each of these activities is described in more detail in the following section.

2.1.1 Global deployment timeline

A mapping of the main T3.3 activities and timeline to the 5-phase plan of T3.1 is shown in Figure 2.3, and a more detailed breakdown of the T3.3 activities is provided in Figure 2.2. The 5-phase plan runs from March 2019 to February 2022. Figure 2.2 further includes a label for all trial sites and cross-border corridors that will take a part in each phase/activity. Apart from the 'Satellite Deployment' sub-task in the 'Technology Deployment' activity, all trial sites and cross-border corridors are planned to partake in each phase of the T3.3 plan.

The creation of Network Design and Deployment Strategies maps to the phase 1 of T3.1, which involves Roll-out Planning and Readiness. During phase 2 of T3.1, TS-CBC Deployment & Integration, the core and RAN deployment was carried out in T3.3. Phase 3 T3.1 activities involve trial site and cross-border corridor testing and verification, while the RAN and core integration and testing are required in T3.3. Any technological updates and cross-border corridor integration of trial site contributions and support form part of phase 4, and therefore overlaps with the support for early trials and upgrades for full trials. The final phase for both T3.1 and T3.3 is maintenance and support for the ongoing full trials, which are expected to conclude in February 2022.

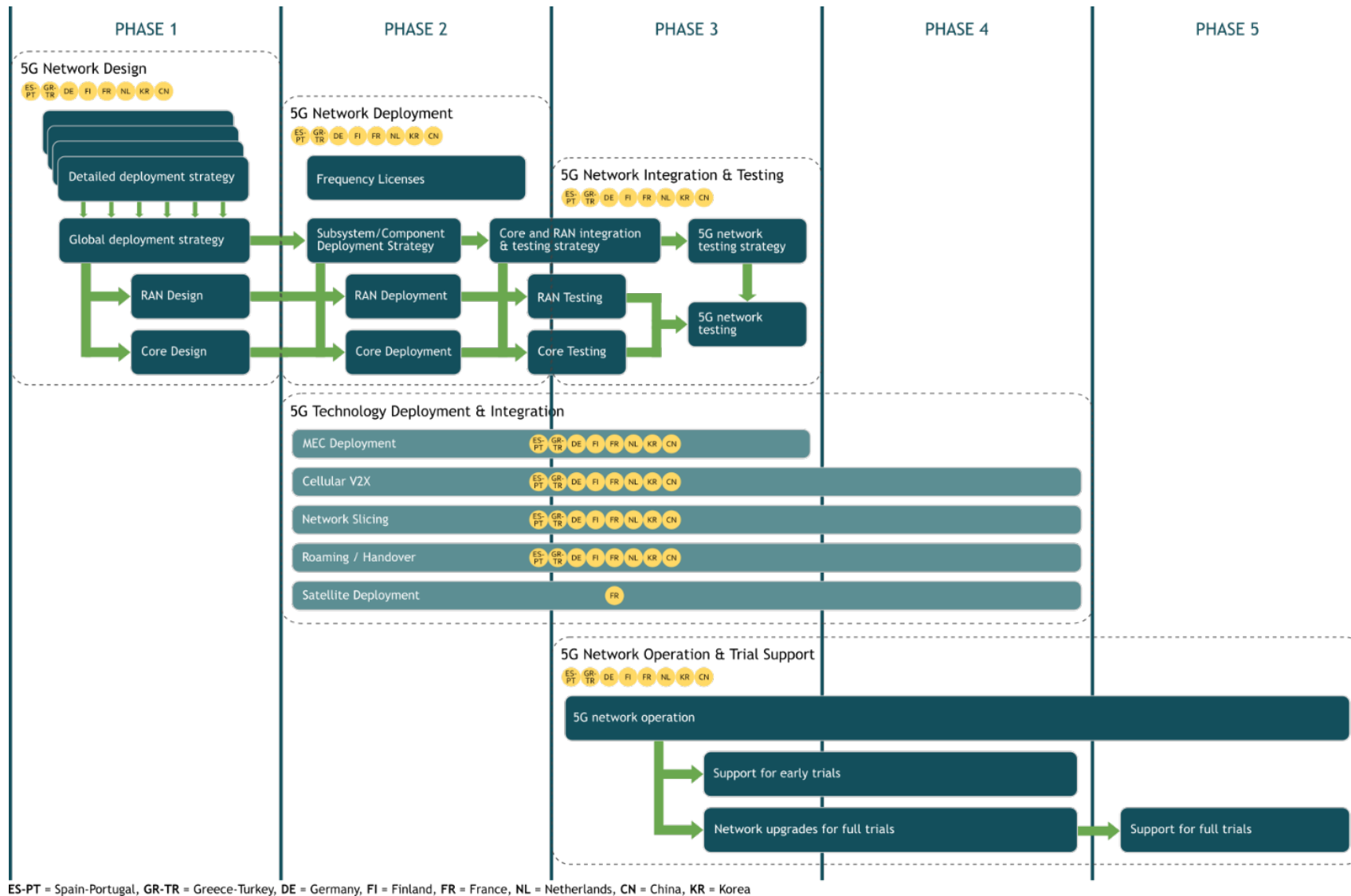


Figure 2.2: Global deployment strategy for 5G-MOBIX 5G networks, including deployment activities and alignment with the 5 phase plan.

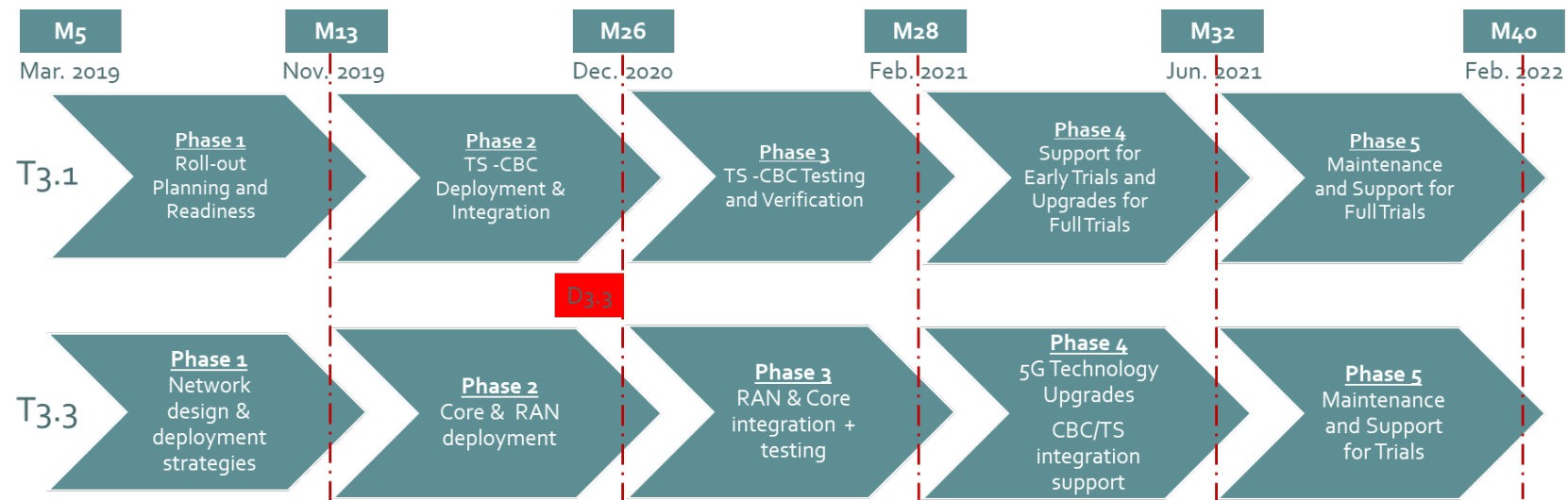


Figure 2.3: Mapping of T3.3 activity phases to T3.1 5-phase plan and timeline.

2.1.2 Deployment activities

This section describes the deployment activities of T3.3 shown in Figure 2.2 in more detail, including the specific timing.

2.1.2.1 5G network design (phase 1)

A 5G network includes two sub-systems, the Radio Access Network (RAN) and the core network. Phase 1 is described as the 5G Network Design stage, based on the specifications identified in T2.2 [1]. This phase focuses on the design issues related to the RAN and core sub-categories as well as their interconnection/integration, yielding a set of detailed deployment strategies for trial sites and cross-border corridors, which form part of the global deployment strategy.

The phase 1 design tasks involve overall network design, including detailed RAN and core network designs and their interconnecting interfaces. Both high- and low-level designs of the chosen network solutions are specified based on the requirements, preceding the preparation of implementation and test documentation during phase 2 and 3. Furthermore, identifying targeted deployment sites, frequency license and permission requirements, as well as selecting hardware and software components are included in the design activity of phase 1.

The RAN design segment requires planning network coverage, identifying targeted radio sites, selecting and acquiring licenses for frequency spectrum usage, and selecting or designing the radio equipment. The latter includes the front-end and backhauling architectures, as well.

The core network design includes both hardware and software design aspects. Selection and deployment planning of core network functions, identifying the required data network structure, and selecting any additional software and hardware components are important outputs for core network design.

Details regarding the design considerations, frequency requirements, and detailed deployment plans for the RAN at each cross-border corridor and trial site is available in section 3, whereas the core network specifications are elaborated on in section 4.

2.1.2.2 5G network deployment (phase 2)

The 5G Network Deployment activity involves deploying the planned subsystems and components from the 5G Network Design stage, frequency license acquisition, and detailing integration strategies for the RAN and core. This activity runs from November 2019 until December 2020 and is the main activity of T3.3 and is applicable to CBCs and TSs.

The detailed deployment strategies from phase 1 are utilized as a guide for deploying the components and subsystems at the specified sites. Testing and maintenance specifications for each of the deployed RAN and

core networks for both local and network wide usage is defined. The integration strategies for the RAN and core are also planned in phase 2.

The RAN deployment includes radio site survey and preparation, acquisition of hardware and software, as well as delivery, installation, and configuration of radio equipment. Front-and backhaul functionality should be confirmed as part of the RAN deployment phase.

The core network deployment involves a similar process of acquisition, installation and configuration of hardware and software components. Integration between hardware and software is required to achieve core network functionality. Depending on the network operation requirement, the core is set-up for either standalone (SA) or non-standalone (NSA) mode, as described in D2.2 [1]. The selection of SA or NSA is TS and CBC specific and based on the availability of existing technologies and support.

Details regarding deployment of the RAN at the CBCs and TSs are provided in section 3, whereas the core network deployment is elaborated on in Section 4.

2.1.2.3 5G network integration and testing (phase 3)

The RAN and core components and subsystems are integrated, and their functionality tested during the 5G Network Integration and Testing activity (phase 3), including inter-network integration and testing. This activity includes definition and execution of detailed test plans based on the D2.2 [1] specifications, the test and verification documents from phase 2, and the KPI's defined in D2.5 [4].

Network tests include end-to-end (E2E) testing of the fully deployed and integrated network, verifying the connectivity and coverage; however, prior tests should also be performed for verification of the functionality and existence of the communication links of the individual deployed nodes and inter-nodal integration, both in the core network and between RAN and core nodes. In the case of the CBC's and trial sites where multiple 5G networks are deployed, further interconnection testing from one network to the next is also required.

Details regarding network integration and testing of the RAN at the CBCs and TSs are provided in section 5 and section 6, respectively.

2.1.2.4 5G network operation and trial support (phase 3-5)

It is expected that the early trials will require support and that upgrades are also likely during this phase. The upgrades focus on being able to support the full trials during phase 5. Planned network upgrades are expected to fall within two categories: NSA-to-SA, and 5G technology upgrades. The latter is further discussed in the next section.

Network operation and trial support begins in phase 3, with completion of the network rollout and stretches through phases 4 and 5 in order to support both the early trials (phase 4) and – possibly after upgrading the network – the full trials (phase 5).

2.1.2.5 5G technology deployment and integration (phase 2-4)

This activity is focused on motivating and monitoring the deployment and integration of 5G-specific advanced technologies. The activity runs in parallel to deployment, testing and early integration of the network. The timeline shows that 5G Technology Deployment and Integration spans from the start of phase 2 until the end of phase 4, due to the current commercial availability of these 5G technologies and the high probability of required upgrades to fulfil the CBC and TS requirements.

As per D2.2 [1] and D3.1 [3], the CBC and TS 5G technologies to specifically be monitored as part of this activity are as follows:

- *MEC Solutions and Deployment:* Plan and monitor deployment of MEC solutions at different CBC and TS. This could be ETSI MEC deployments or regular edge computing and, depending on the CBC/TS needs or solution design, a single or multiple MECs may be deployed per operator.
- *Cellular V2X Variants:* Monitor the deployment, integration and use of the different V2X variants across the different CBCs and TSs. Cellular V2X is central to address the requirements from CCAM use cases and may be deployed in many variants, e.g., as direct/short-range vehicle to vehicle (V2V), as vehicle to network/long-range (V2N) or between vehicle and infrastructure (V2I).
- *5G Network Slicing:* Monitor the use of slicing at the different CBCs and TSs and the chosen solutions for both NSA deployments (e.g., using different access point names (APNs) or prescheduling and advanced subscriber group handling (ASGH)) as well as for SA deployments with 5G slicing (as per 3GPP Rel. 15). 5G Network Slicing is key to achieving guaranteed service level or quality of service or to deeply isolating traffic of different types or different priorities.
- *Roaming and Handover Solutions:* Monitor the deployment and integration of different solutions for roaming and handover at the different CBCs and TS and provide an overview of the selected roaming variant, e.g., home routed roaming or roaming with local breakout. Roaming and Handover choice is a key challenge at the CBC settings.
- *Satellite Network Deployment:* Track and monitor the integration of the satellite network with the 5G network at the FR TS.

In addition to monitoring the deployment of the above-mentioned technologies, this activity is also designed to provide an overview of the selected solutions and variants for each of these technologies, stimulating knowledge exchange and innovation about these activities between the CBCs and TSs.

Details regarding deployment and integration of 5G-specific advanced technologies for CBCs and TSs are provided in Section 7.

2.2 T3.3 position in 5G-MOBIX

The rollout of the 5G networks for 5G-MOBIX is closely related to a number of other tasks in the project either from which it takes input, for which it produces outputs or for which it forms the basis. These interrelations are shown in Figure 2.4 and described in the following.

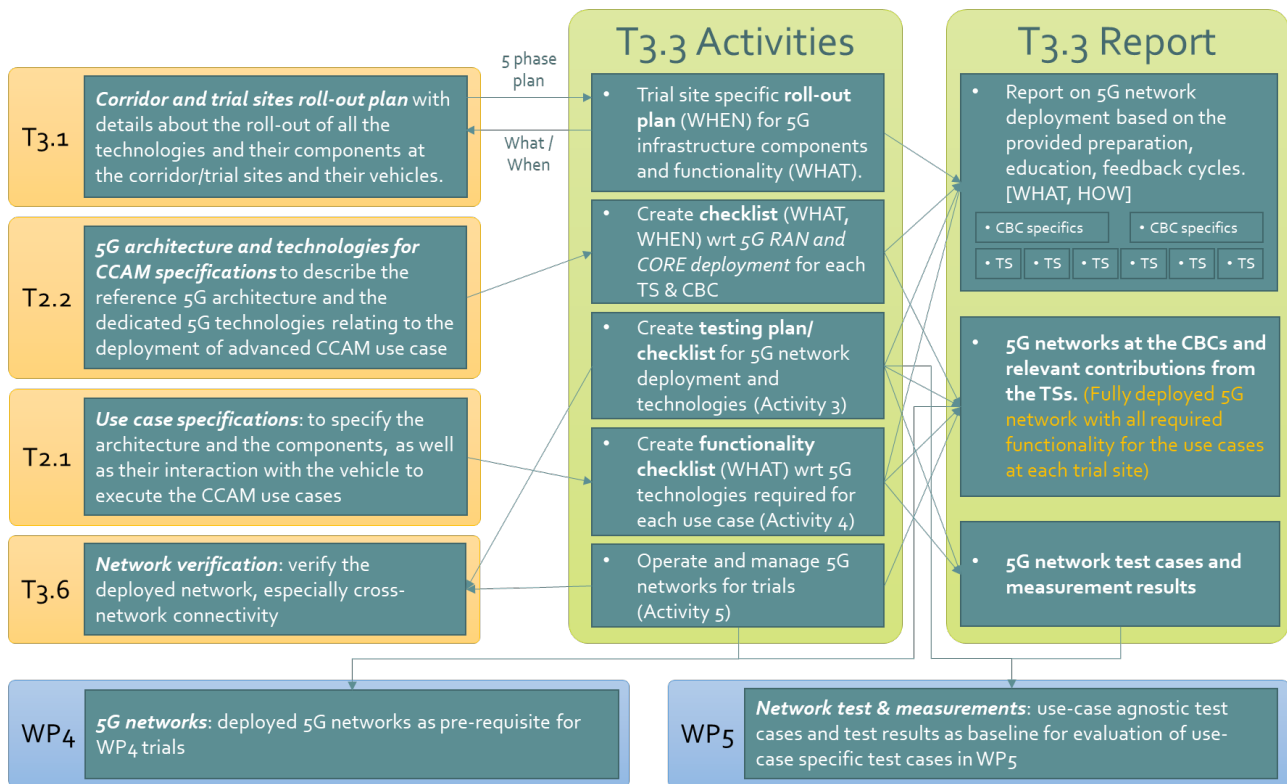


Figure 2.4: Positioning of T3.3 in 5G-MOBIX and relation of T3.3 activities to WP2, WP4, WP5 and other WP3 tasks.

2.2.1 Relation to WP2

The activities in T3.3 are largely preceded by the activities in WP2, with mainly T2.1 and T2.2 relevant to T3.3. In the 5G architectures and technologies for CCAM requirements and specifications are defined in T2.2 [1], resulting in the T3.3 activity of creating a checklist regarding the RAN and core deployment at each TS, as shown in Figure 2.4. They are further translated into detailed specifications and requirements for the 5G networks that affect the deployment plans and network designs for each CBC/TS.

Specifications regarding the use cases, created in T2.1 [5], are utilized to ensure the networks can support the required functionality and provide the expected performance. As such, the tasks of WP2 largely constitute an input to the work of T3.3.

2.2.2 Relation to other WP3 tasks

T3.3 relates closely to the other tasks in WP3, with the main relation being with T3.1 as the latter defined the 5 Phase plan and templates for rollout plans [3] and continuously monitors the progress of the rollouts, including of the 5G networks rolled out by T3.3. The relation to T3.1 is thus bidirectional.

Further relation exists with T3.6, as the latter is responsible for verification (e.g., of network interconnections) beyond the network testing performed in T3.3, i.e., it verifies some of the outputs of T3.3.

2.2.3 Relation to WP4

The 5G networks deployed are a required pre-requisite for execution of the trials in the tasks of WP4. As such, WP4 directly depends on the outputs of T3.3.

2.2.4 Relation to WP5

The evaluation performed in WP5 requires the outputs of T3.3, similar to WP4. Furthermore however, a closer relation exists between T5.2 and T3.3 in the definition of test cases and testing of the networks. T3.3 defines basic network testing (i.e., tests agnostic to the specific UCCs under consideration in the trials), which can to some extent serve as 'baseline' for the evaluation of the trials in T5.2. As such, the test cases in T3.3 are specified with the evaluation requirements of T5.2 in mind and designed to provide sufficient detail to allow the outcomes to serve the needs of T5.2 as far as UCC-agnostic, network-only testing is concerned.

3. RADIO ACCESS NETWORK SOLUTIONS

3.1 Overview

This section documents how, who and when the 5G Radio Access Networks have been deployed in the different Cross-Border Corridors (CBCs) and Trial Sites (TSs). This process of deployment has been built upon the five-phase roll-out plan shown in Figure 2.2, as follows:

- Phase 1: Every CBC and TS has developed its own detailed roll-out planning and deployment strategy.
- Phase 2: The actual deployment of radio components and subsystems takes place in this phase, putting special focus on frequency licenses.
- Phase 3: In this last deployment phase, integration testing and verification is performed to ensure the readiness of 5G communication at the RAN level.
- Phase 4: Maintenance effort oriented to adapt the infrastructure to the trials, changing antenna orientation and coverages, transmission power, etc.
- Phase 5: Maintenance effort oriented to support the running of the full trials, replacing or fixing assets that could be affected during the tests.

Due to the organisation of the 5G-MOBIX test sites into two main CBCs and a set of complementary TSs, having different designs and methodologies for 5G RAN deployment, it was decided to focus on the CBCs' RAN deployment in two main subsections, one for each CBC. Additionally, in a summarized fashion the TS RAN deployments are also covered, while their details are presented in the annexes.

3.2 ES-PT CBC RAN deployment

3.2.1 Overview

The ES-PT corridor is focused on the cross-border area between Spain and Portugal. The frontier is divided by the Miño river, which is crossed by two bridges, where the tests will take place. The RAN deployment not only provides coverages on these two bridges, but also in other important spots along the Vigo-Porto route, where the user stories will initially be tested. NOS in Portugal and Telefonica in Spain execute this deployment, with the technological solution provided by Nokia PT and Nokia ES, respectively.

The Portuguese network is completely dedicated for the project. NOS and Nokia PT will install the necessary nodes in Portugal to cover the test areas. On the other hand, Telefonica is using the existing 4G commercial network and the current sites of the BS to cover the test areas. For the interoperability between the two

different PLMNs, a Multi-Operator Core Network (MOCN) is configured to support both networks over the same RAN and frequency usage. The 5G nodes will be dedicated specifically for the pilot operation.

3.2.2 Frequency licensing

In the Spanish side of the corridor, Telefonica has a complete commercial RAN covering the test area with 4G coverage provided by Nokia and some of those nodes are used to provide the anchoring necessary in the 5G NSA architecture for 5G-MOBIX. The radio technology solution allows the implementation of a MOCN in all the bands that are present in the same site, so that, all the LTE frequency bands that Telefonica already use in the area are going to be configured for the anchoring in 5G-MOBIX.

Telefonica has three frequency bands commercially deployed to provide LTE coverage. In Table 3.2 the frequencies and available bandwidths for each of those bands and information about the NR spectrum are given in detail.

Table 3.2: Frequency licenses available on the ES side of the ES-PT CBC.

Frequency band	Bandwidth (MHz)	Frequency (MHz)	Valid until
LTE 800 (B20)	10 + 10	811 – 821 852 – 862	25/04/2031
LTE 1800 (B3)	20 + 20	1710.1 – 1730.1 1805.1 – 1825.1	31/12/2030
LTE 2600 (B7)	20 + 20	2500 – 2520 2620 – 2640	31/12/2030
NR 3500 (n78)	20 + 20 + 50	3440 – 3460 3540 – 3560 3750 – 3800	18/04/2030 18/04/2030 06/12/2038

For the 5G coverage, Telefonica has 90 MHz non-continuous bandwidth in the n78 band (3400 – 3800 MHz). The discontinuity in the spectrum allocation is due to the auction that occurred in two different phases by the Spanish regulatory body “Ministerio de Economía y Empresa” and is still pending a restructuring of the spectrum to create a continuous bandwidth for all operators. This restructuring was expected before 2021, but due to the impact of Covid-19, there is currently no official date.

The newly acquired 5G nodes, which provide coverage in all the test areas will work over the upper part of the n78 band, where Telefonica has 50MHz continuous (3750-3800 MHz). In case the restructuring of the band occurs, it might be necessary to change the frequency operation of these nodes in order to expand the bandwidth up to 90 MHz. However, there is no firm commitment from the authorities to do so at the moment.

The Autoridade Nacional de Comunicações (ANACOM) is the national regulatory authority (NRA) in Portugal for communications, and for the purposes of the law of the European Union (EU) and national legislation, it also inherits the assignments, powers and responsibilities of the Comissão de Planeamento de Emergência das Comunicações (Emergency Communications Planning Committee).

The 5G spectrum in Portugal is not yet allocated, but the auction is currently under way and expected to end in Q2 2021. ANACOM has already approved the regulation of the auction for allocation of frequency usage rights in the 700 MHz, 900 MHz, 1800 MHz, 2.1 GHz, 2.6 GHz and 3.6 GHz bands as presented in the table below.

Table 3.3: Frequency bands and lots for auction planned by ANACOM (PT).

Bands	Frequencies	Number of lots
700 MHz	703-733 MHz/ 758-788 MHz	6 lots of 2 x 5 MHz
900 MHz	880-885 MHz/ 925-930 MHz	1 lot of 2 x 5 MHz
900 MHz	895,1-898,1 MHz/ 940,1-943,1 MHz 914-915 MHz/ 959-960 MHz	4 lots of 2 x 1 MHz
1800 MHz	1770-1785 MHz/ 1865-1880 MHz	3 lots of 2 x 5 MHz
2.1 GHz	1954,9-1959,9 MHz/ 2144,9-2149,9 MHz	1 lot of 2 x 5 MHz
2.6 GHz	2500-2510 MHz/ 2620-2630 MHz	2 lots of 2 x 5 MHz
2.6 GHz	2595-2620 MHz	1 lot of 25 MHz
3.6 GHz	3400-3460 MHz (with restrictions up to 2025)	6 lots of 10 MHz
3.6 GHz	3460-3500 MHz (with restrictions up to 2025)	4 lots of 10 MHz
3.6 GHz	3500-3800 MHz	30 lots of 10 MHz

Given the project timeline availability of terminals, the initial deployment of cross border 5G network will be done in Non-Standalone option 3x (EN-DC NSA3x) with an LTE anchor layer on band n3 (FDD 1800 MHz) and 5G NR on band n78 (TDD 3700 MHz). The Standalone SA Option 2 is intended for a later stage, when 5GCN becomes available for deployment.

Until the 5G spectrum allocation process is completed by Portuguese regulator ANACOM, the 5G-MOBIX project will be using a test network that will be completely segregated from the commercial network. In the first phase of the project, the 5G radio access network is going to be deployed at 3700 MHz, with an LTE anchor layer at 1800 MHz, which will be granted temporarily for carrying out the technical trial. In a second phase, it will be possible to migrate the network to 5G commercial spectrum that will be held by NOS.

3.2.3 Implemented 3GPP architecture options

The ES-PT CBC are composed by two independent networks, one in the Spanish side and other in the Portuguese side, which are interconnected through a direct IP/MPLS through the edge site.

3.2.3.1 Spanish side (Nokia ES/Telefónica)

At the Spanish side, the architecture is based on the 3GPP non-standalone 3X option. A detailed description of the architecture in Spain is depicted in Figure 3.5.

The EPC is centrally located in Madrid, which is around 500km away from the test area. This large distance results in a high latency, therefore it is necessary to deploy an edge site with the MEC platform, where the most critical services can run closer to the final users. This edge site is located in Vigo, 20 km away from the border and it allows to drastically reduce the latency, from 25 - 30 ms at the core down to 15 - 20 ms at the MEC. All the nodes involved in the test will have direct connection to the MEC services through the transport network.

3.2.3.2 Portuguese side (Nokia PT/NOS)

At the Portuguese side a dedicated network is being built, independent from NOS commercial network. This network will initially operate based on NR NSA option 3x mode and is intended to be upgraded to NR SA option 2 mode at a later stage (depending on roadmap and resources availability).

There are two new axial sites deployed in Porto corridor at A28 (Corvo and Leça) whose main network deployment characteristics are listed in Table 3.4, and the hardware components as well their interconnections are displayed in Figure 3.6: Trial configuration for RAN at Corvo and Leça sites.

Table 3.4: Corvo, Leça and Valença RAN attributes.

	Corvo & Leça	Valença
Network deployment mode	EN-DC NSA3x, SA2 at later stage	EN-DC NSA3x, SA2 at later stage
Spectrum	5G NR on 3700 MHz (64T64R) and 4G anchor on 1800 MHz (4T4R)	5G NR on 3700 MHz (64T64R) and 4G anchor on 1800 MHz (4T4R)
Backhaul	10 Gbps P2P Fibre to IP WAN/MPLS	10 Gbps P2P Fibre to IP WAN/MPLS
Sync	GNSS and PTP T-GM G.8275.1	GNSS and PTP T-GM G.8275.1

There is also one additional new site with two locations deployed in PT side of ES-PT cross-border corridor. This is an axial site covering A3 motorway over the modern bridge, and two small cells that will provide dedicated coverage on the old train bridge. These locations will be remotely connected to the NOS baseband in Valença. The respective main network deployment characteristics are listed in Table 3.4, and the hardware components as well their interconnections in Figure 3.7.

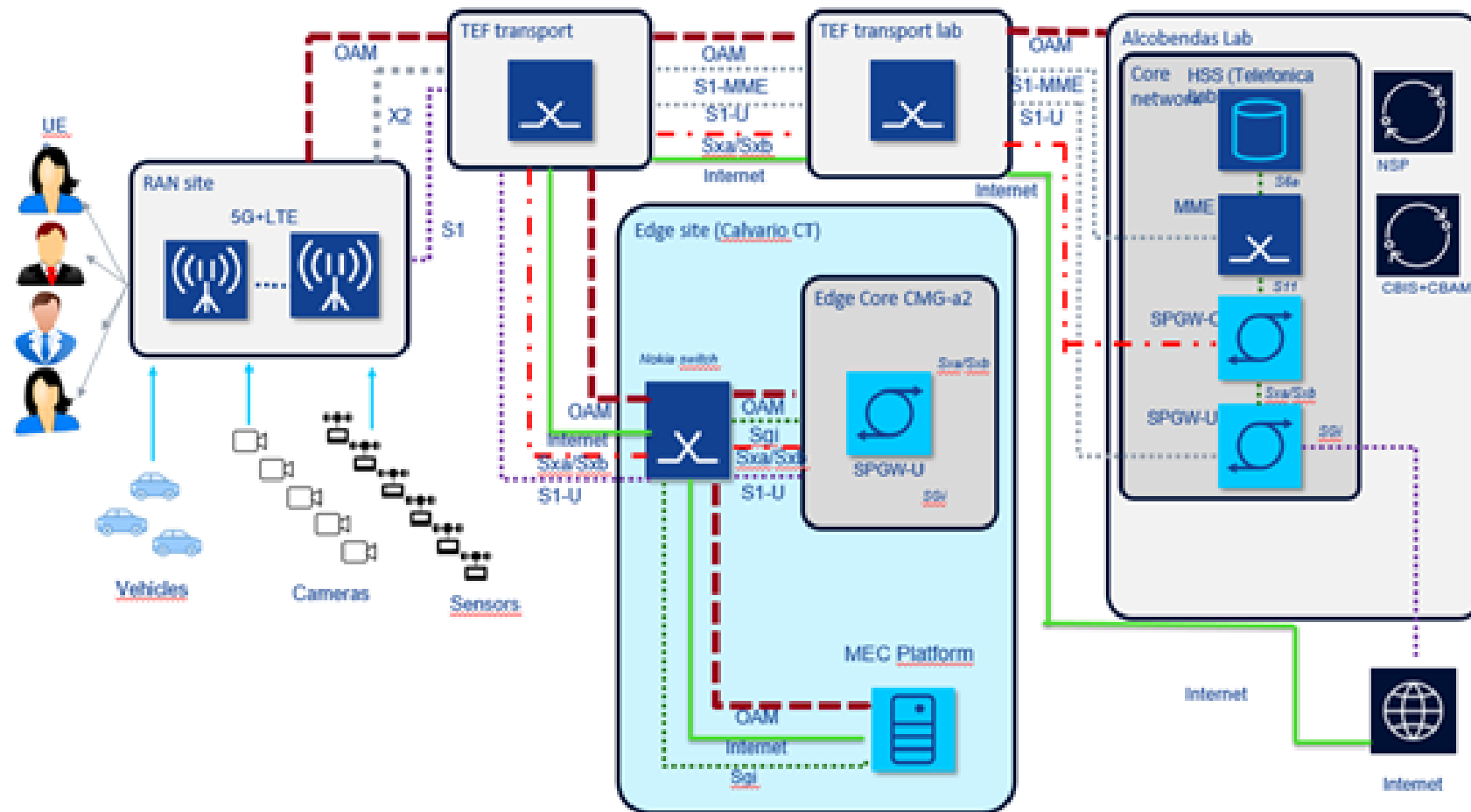


Figure 3.5: Deployed ES RAN architecture.

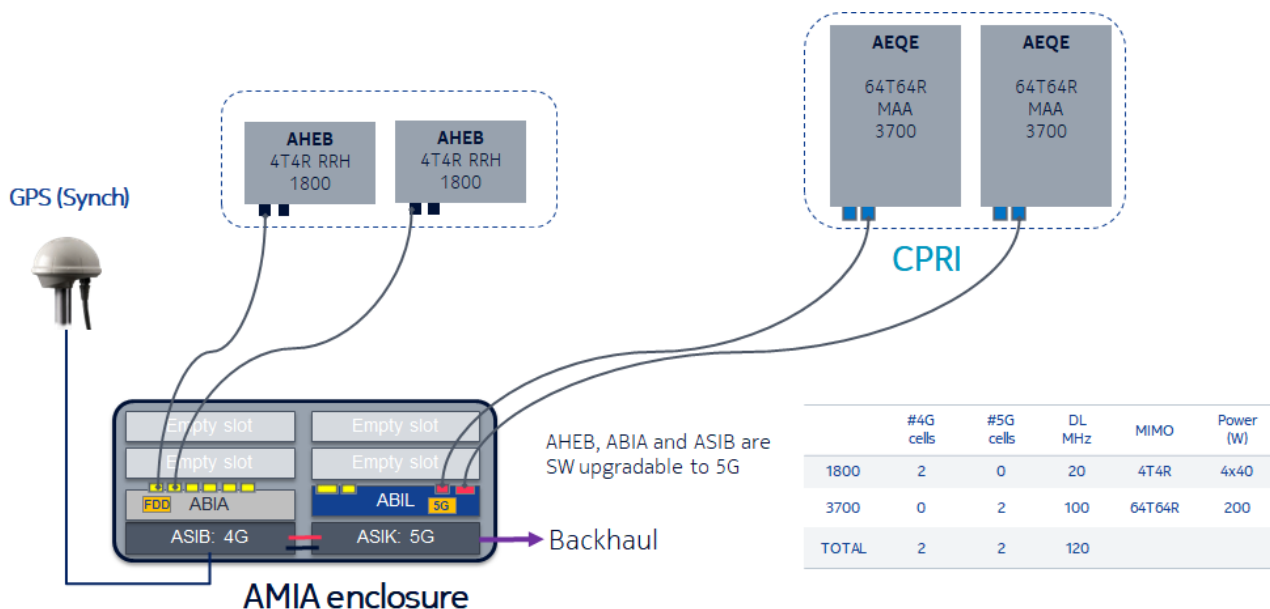


Figure 3.6: Trial configuration for RAN at Corvo and Leça sites.

Because of the restrictions imposed to the installation of additional radio units at the old bridge, which is a historical monument, while in NSA 3x, these will work in LTE (1800 MHz) only. 5G will be available at the old bridge once the network will be upgraded to SA2.

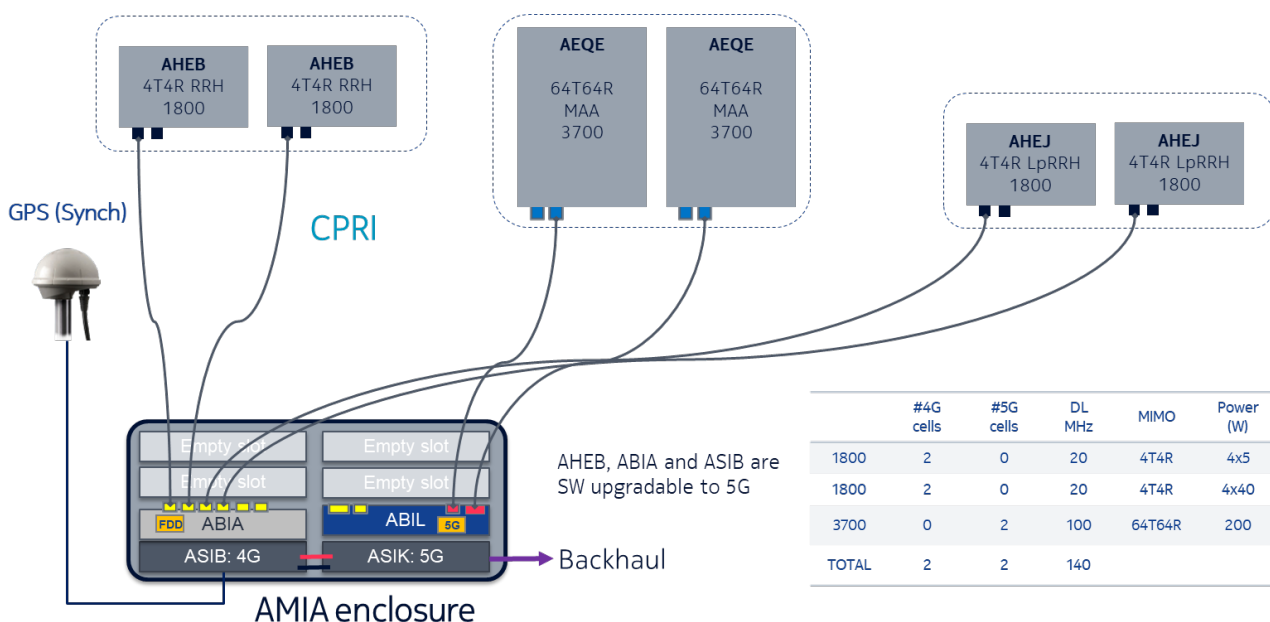


Figure 3.7: Trial configuration for RAN at Valença site (modern and old bridge).

3.2.4 Antenna locations and coverage

The Spanish RAN deployment provides coverage to three different locations, where the tests are going to be carried out. Since the selected architecture is the NSA 3X, it is necessary to evaluate the coverage both for 4G and 5G, using Reference Signal Received Power (RSRP) as a good indicator of the coverage. The RSRP measures have been taken along the different test areas by a drive test, obtaining the Primary Cell ID (PCI) of the sector to which the user is connected so that it can be depicted over a map to show the coverage of the serving cells.

The main test area in the frontier area is the new bridge highway and the old bridge, which are covered by two existing macro BS sites, “as bornetas” and “tui centro” respectively. After configuring the 5G nodes with the pilot PLMN, preliminary 5G coverage measurements have been carried out. In Figure 3.8 and Figure 3.9, 5G RSRP values can be seen. These values are scarce both in the new bridge with ≥ -90 dBm in the Spain-Portugal direction, ≥ -100 dBm in the Portugal-Spain direction and for the old bridge, where the coverage values obtained are ≥ -100 dBm in almost the entire road with some coverage gaps. These are the first values obtained with the pilot configuration. Further RAN optimization work is planned, and the signal strength for both bridges is expected to be improved by means of fine tuning of the RAN parameters.

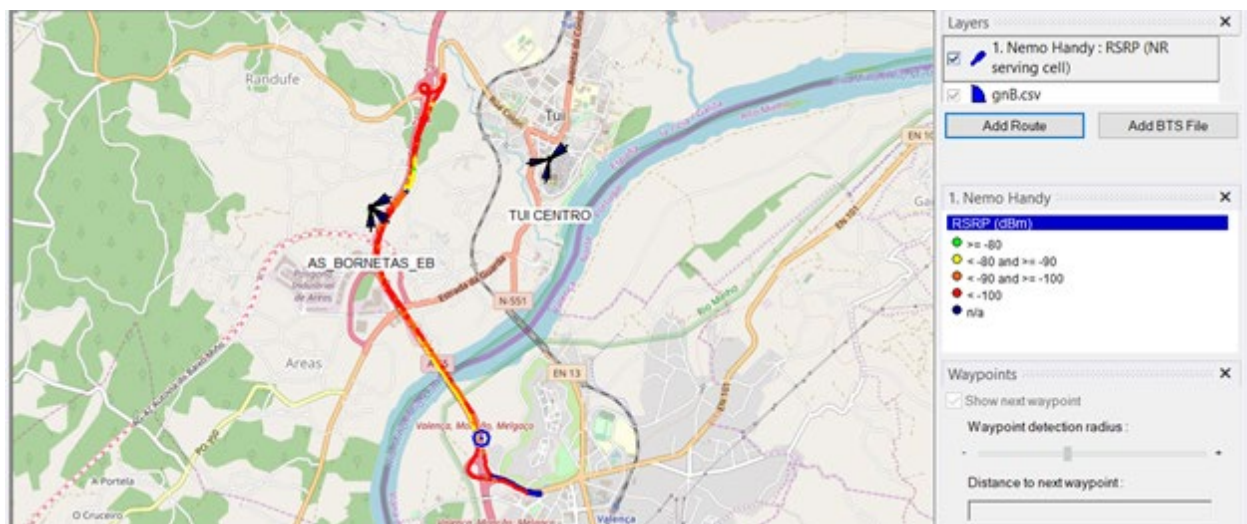


Figure 3.8: NR serving cell RSRP at cross-border new bridge.

Another test area is the A-55 road at km 17 for performing lane merge. This area is covered by a macro base station located at the south: “Porriño poligono”. In Figure 3.10, the LTE signal strength over the A-55 highway and the incorporation from the AP-9 road can be seen. In this area the LTE anchoring signal strength is good, with RSRP values mainly above -80 dBm in the test area.

Finally, several nodes have been deployed to cover the CTAG facilities (shown in Figure 3.11):

- Two micro RRH, one for 1800MHz LTE anchoring and another one for 5G coverage. These two micro RRHs cover the circuit, where the test is going to be placed.

- Eight pico RRHs (4 for anchoring in 4G and 4 for 5G) covering laboratories located inside the office building.



Figure 3.9: NR serving cell RSRP at cross-border old bridge.

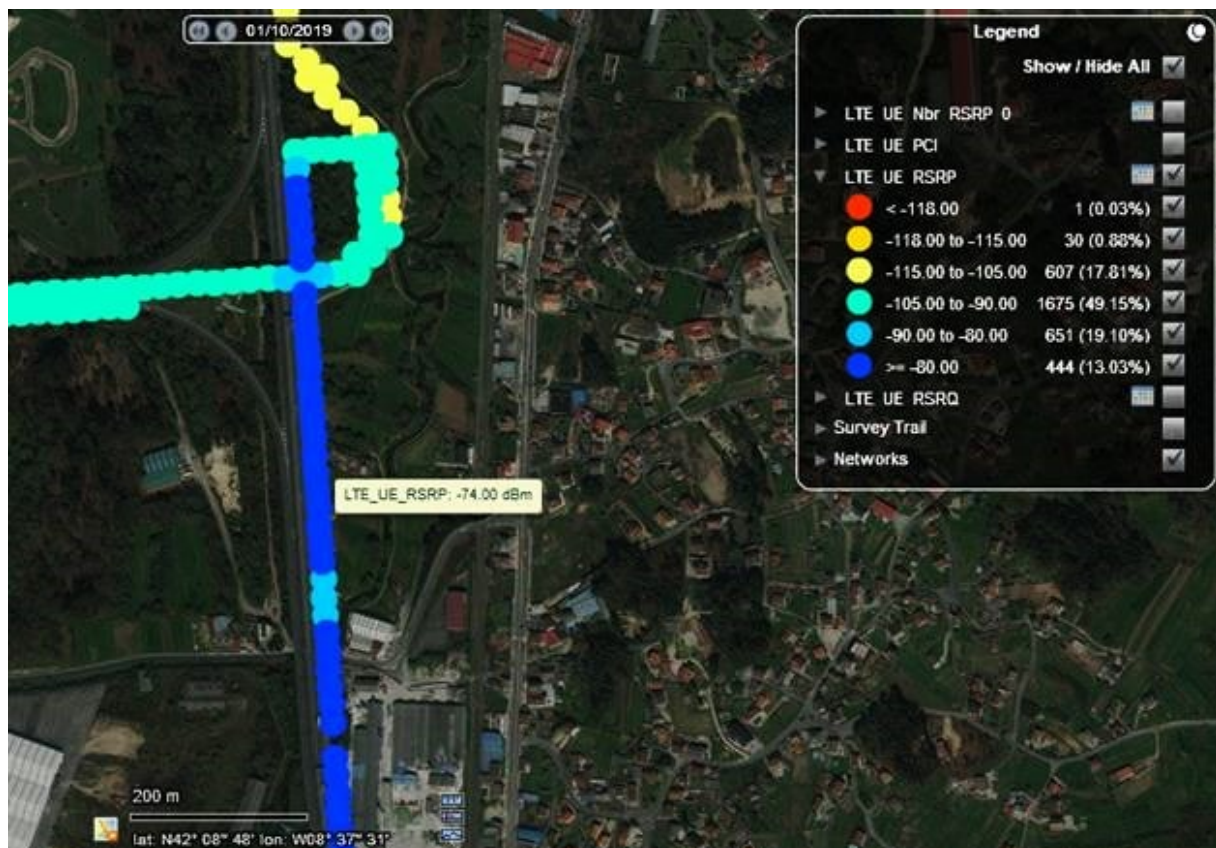


Figure 3.10: LTE RSRP over A-55 highway.

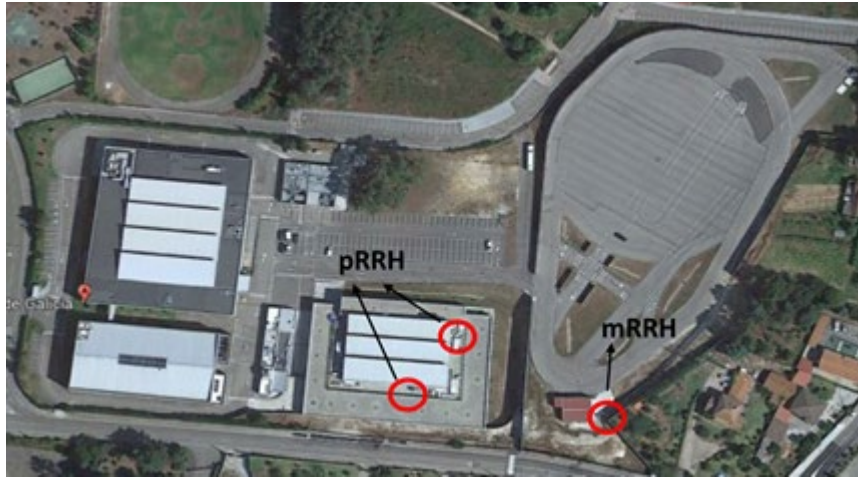


Figure 3.11: Antenna location at CTAG facilities.

The Portuguese RAN sites are deployed according to the details given in Table 3.5 and Figure 3.12.

Table 3.5: Antenna locations for Corvo, Leça and Valença sites.

SITE_NAME	SECTOR	TYPE	LATITUDE	LONGITUDE	AZIMUTH
NOS_CORVO	1	MACRO	41.23753	-8.69721	0
NOS_CORVO	2	MACRO	41.23753	-8.69721	180
NOS_LECA_IC1	1	MACRO	41.20396	-8.68908	190
NOS_LECA_IC1	2	MACRO	41.20396	-8.68908	350
VALENCA_NEW_BRIDGE	1	MACRO	42.02939	-8.65064	175
VALENCA_NEW_BRIDGE	2	MACRO	42.02939	-8.65064	330
VALENCA_OLD_BRIDGE_A	1	SMALL CELL	42.03507	-8.64525	80
VALENCA_OLD_BRIDGE_B	1	SMALL CELL	42.03507	-8.64525	260

3.2.5 Handover areas adjustments

One of the issues for the cross-border tests is the definition/identification of the exact point, where the user changes from the home network to the visited network. This is important to be able to measure the impact of the handover process when the connected vehicles are executing the manoeuvres of the different use cases. Even though the radio channel changes dynamically, it is possible to fine tune some RAN parameters to reduce the handover area as much as possible.

Different possibilities have been considered at each side of the border area. The Spanish network has some limitations, since the LTE radio is shared with Telefonica's commercial network through a MOCN. However, it is possible to adjust the parameters, which can be implemented independently for each PLMN of the RAN:

- Some of the threshold parameters involved in the handover process will be optimized: A₃, A₄, A₅, B₁-NR, B₂-NR.



Figure 3.12: Antenna implantation for Corvo, Leça and Valença sites.

For the Portuguese network more possibilities exist, since the network is completely dedicated to the project, and more parameters can be adjusted:

- BS output power
- Down tilt/orientation of the antennas
- SW parameters: A₃, A₄, A₅, B₁-NR, B₂-NR

3.3 GR-TR CBC RAN deployment

3.3.1 Overview

The GR-TR trials will take place on the most used border crossing between Greece and Turkey in the area of Kipoi (GR) - Ipsala (TR), where the Ego (GR) highway becomes the E84 (TR) highway when crossing into

Turkey. Figure 3.13 depicts the exact location the GR-TR cross-border trials and the route to be followed by the participating vehicles, covering a stretch of more than 10km for testing. Turkcell from Turkey and Cosmote from Greece are the respective MNOs providing their facilities. Ericsson will be the vendor for software and hardware deployment in Turkey and Greece.

Turkcell and Cosmote both already have commercial networks covering the test area with 4G, but new RAN equipment (baseband and air) was deployed for the 5G-MOBIX project to create an overlay network providing 5G coverage, with the existing/commercial L2600 band being utilized for 5G NSA anchoring.



Figure 3.13: GR-TR general view of CBC.

3.3.2 Frequency licensing

The NR NSA 5G-MOBIX 5G network will be use the 5G Mid Band, i.e., n78 in FR1 range. The details of the frequency bands that will be used in GR-TR for the 5G-MOBIX project are described in the following.

3.3.2.1 NR Frequencies

The NR frequencies that will be used for 5G-MOBIX are B78G for Turkey and B78F for Greece and are non-overlapping as shown in Figure 3.14. Selected bandwidths will be 100 MHz for both countries.

3.3.2.2 LTE Frequency

The LTE anchor carrier that will be used for 5G-MOBIX is B7 (2600 MHz) with 20MHz for GR and 5Mhz for TR of bandwidth. Both countries will use the same band for anchor cells, as indicated in Figure 3.15.

3.3.3 Implemented 3GPP architecture options

3.3.3.1 Deployment Strategy

The initial NR deployments are based on the NR NSA Option 3 with LTE anchoring. The LTE Node (eNodeB, eNB) handles control plane traffic (S1-C), while User Plane traffic (S1-U) can be handled by NR node or both. NSA means that a gNB is deployed together with an eNB. Functions are split between the eNB and the gNB. The deployment is referred to as dual connectivity.

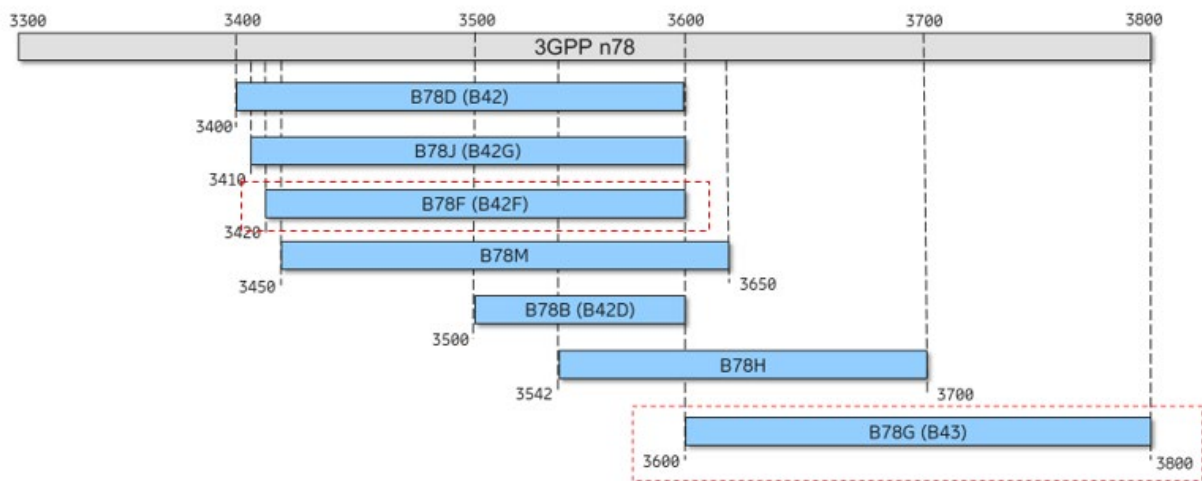


Figure 3.14: NR Frequency allocation for GR-TR.

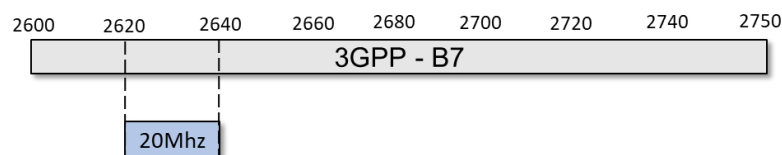


Figure 3.15: LTE Frequency allocation for GR-TR.

Figure 3.16 and Table 3.6 show the interfaces in an NR NSA (Option 3x) deployment. In an LTE deployment, the X2 interface is used between eNodeBs. In NR NSA, it is also used as the interface between the eNodeB and the NR Node for dual connectivity.

LTE eNodeB works as the MasterNode (MN), and NR gNodeB works as the Secondary Node (SN). LTE eNodeB terminates the S1 Control Signaling (S1-C) from the 5G EPC and the SignalingRadio Bearer (SRB) toward the EN-DC capable UE.

The user Data Bearer (DRB) can be set up as one of the following:

- MN-terminated Master Cell Group (MCG) DRB, this setup uses the following radio resource:
 - o Master Cell Group (MCG)

- SN-terminated split DRB, this setup can use following radio resources:
 - Secondary Cell Group (SCG)
 - Master Cell Group (MCG)

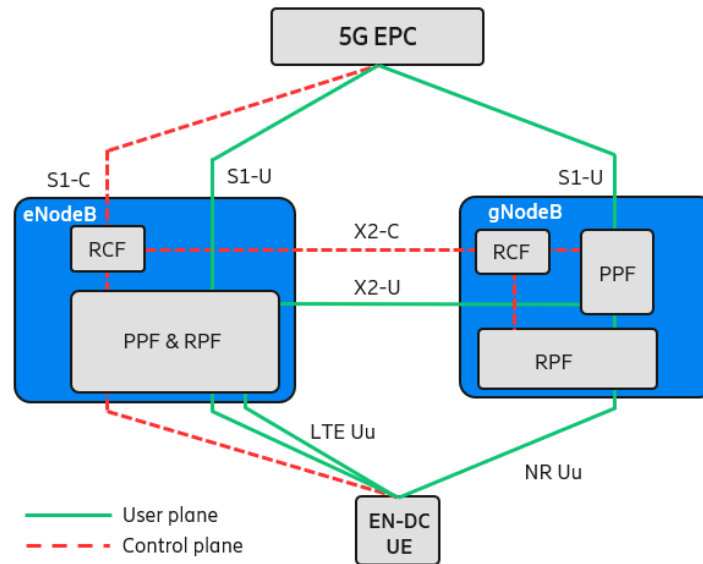


Figure 3.16: NR NSA Option 3x Architecture.

Table 3.6: Interfaces of NR NSA Option 3x Architecture.

Interface	Protocol	Description
S1-U	GTP/UDP/IP	S1 user plane, Backhaul Interface
S1-AP	S1AP/SCTP/IP	S1 control plane. Backhaul Interface
X2-U	GTP/UDP/IP	X2 user plane, packet forwarding interface
X2-AP	X2AP/SCTP/IP	X2 control plane, interworking interface
Uu		Interface between the eNodeB and the UE and between the NR Node and the UE

Figure 3.17 shows the route of data transmission for MN-terminated MCG DRB and SN-terminated split DRB. As gNodeB terminates the S1-U, the data traffic carried by MCG radio resource has to be forwarded from or to the PacketData Convergence Protocol (PDCP) layer of the gNodeB through the X2-U interface. The X2 interface carries a higher traffic load in 5G NR NSA networks compared to 4G LTE networks, therefore, this sets requirements on the transport network design for X2 interface.

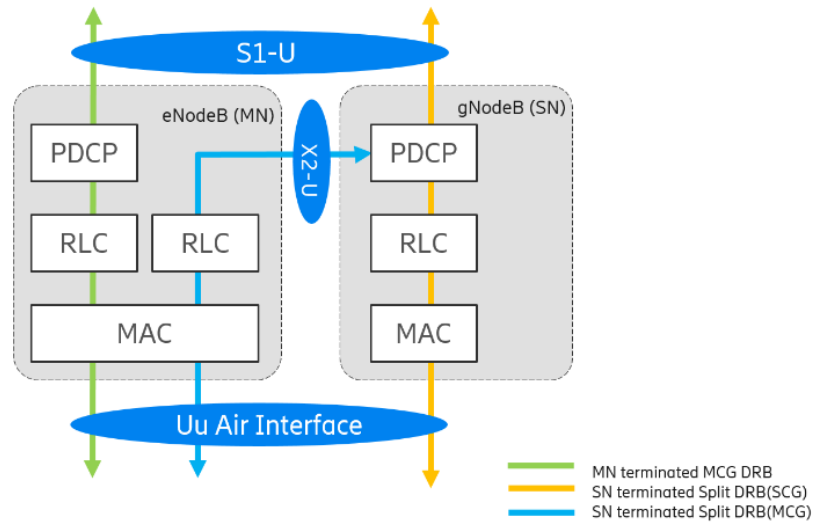


Figure 3.17: Data Transmission Flow of a Master Node Terminated DRB or Secondary Node Terminated Split DRB.

3.3.3.2 GR-TR CBC RAN Deployment

On the Turkish side 3 sites have been deployed with a total of 5 sectors while on the Greek side one site with one sector has been deployed for the 5G-MOBIX project. One additional 5G NSA site at the Ford Otosan plant in Eskişehir/Turkey is also made available for the testing of user stories. Figure 3.18 illustrates the NW topology. Core Nodes are located in Istanbul and Alexandroupolis, respectively.

Figure 3.19 illustrates the set of connections for the individual sites. (Router 6672 is an optional solution which is not necessary). Based on the architecture in Figure 3.19, the Ford Otosan site (Site Name: ESKIN) is deployed using the same equipment as the one at the actual cross border sites to create a comparable testing environment, where the RAN solution is again based on the 5G NR NSA Option 3x and connects to the identical dedicated core network in Istanbul. For the LTE-NR dual connectivity, NR carrier is on band n78, specifically between 3600-3800 MHz for Turkey and 3400-3600 MHz for Greece, where the LTE anchor carrier is chosen as B7 (2600 MHz) with 20MHz for Greece and 5Mhz for Turkey of bandwidth.

Internal trial sites of Turkcell other than the Ford Otosan plant such as the sites at Turkcell Kartal Plaza (Site Name: KRTOF) and Turkcell Maltepe Plaza (Site Name: SOGOF) in Istanbul are used for testing deployed equipment and configuration for 5G connectivity, and obtaining early performance results, which is a major contribution to the CBS trialling scenarios. It also helps performing OBU connectivity testing before the trials. Both sites are connected to 5G-MOBIX Core NW used same SW & HW version like border sites in Ipsala and trail site in Eskişehir Ford factory. Figure 3.20 illustrates the physical locations and configuration for internal trial sites.

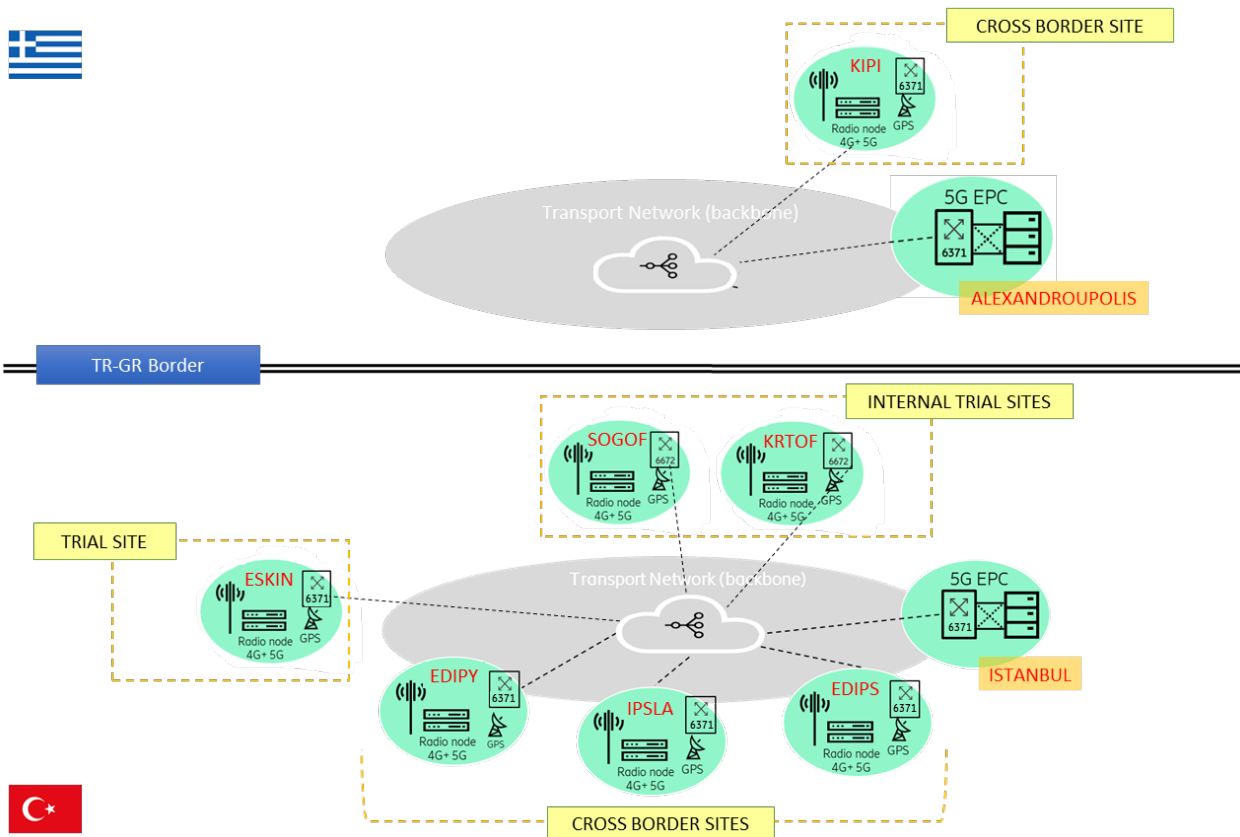


Figure 3.18: RAN deployment in the GR-TR CBC.

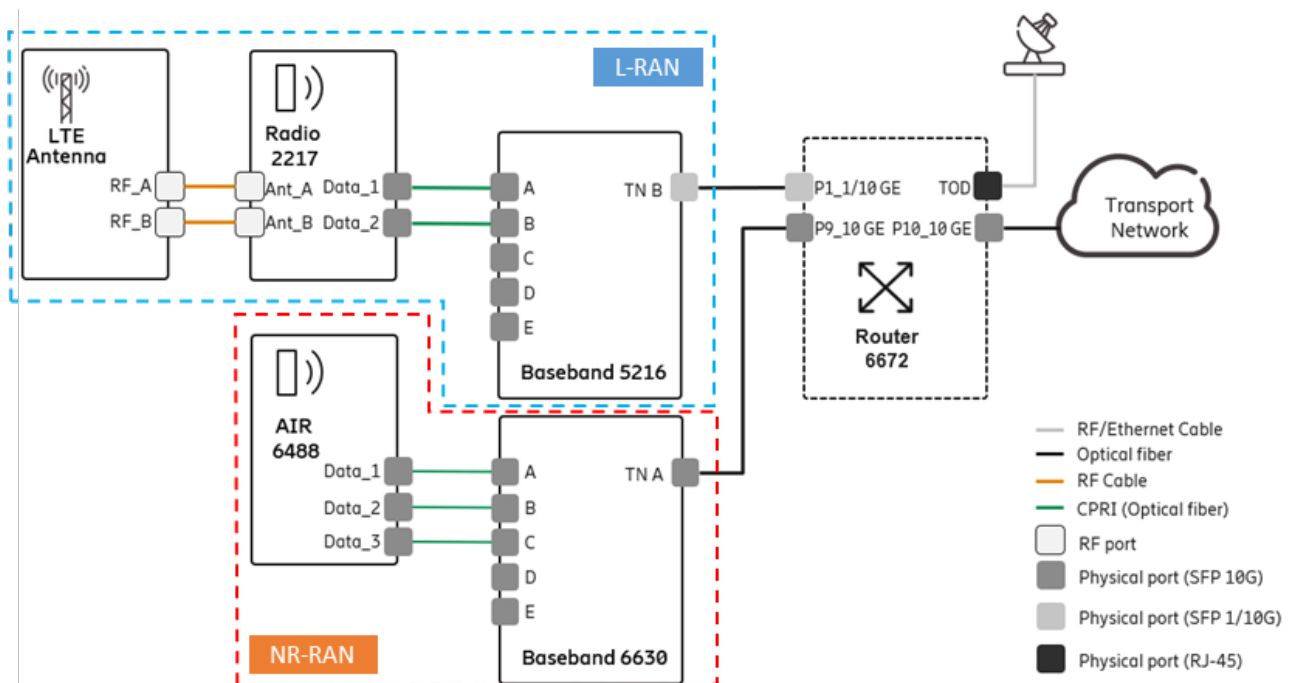


Figure 3.19: Single site connections.



Figure 3.20: Internal trail sites KRTOF and SOGOF.

3.3.4 Antenna locations and coverage

Network planning and design is an iterative process, encompassing topological design, network-synthesis and network-realization, and is aimed at ensuring that a new telecommunications network or service meets the needs of the subscriber and the operator. The process can be tailored according to each new technology or service.

In the beginning of the project, the existing LTE site locations were used to simulate via the planning tool the prospective coverage of an NSA network. The simulations give a rough idea about coverage and service quality expectations. The aim is to obtain/see a minimum -110dbm signal level at the handover region, ensuring no loss of signal before the roaming/handover takes place. L2600 is used for anchoring and the N78 band for NR frequencies in the simulations like in the actual trials. The existing site environment like antenna height, locations, directions were used. The results, presented in Figure 3.21, show that existing locations are able to provide enough coverage and quality level for the 5G-MOBIX trials. Also, it will be possible to demonstrate roaming/handover (i.e., there are no coverage gaps between the two operators). To avoid inter cell interference, some proposals for tuning the radio parameters are already planned and they will be verified during the initial tests.

For AIR6488, the macro pattern was used for predictions:

- Mechanical tilt (8°) applied to: IPSLA-1, EDIIP-2 and KIPI-1
- Mechanical tilt (4°) applied to: EDIPS-2
- 3dB less output power on: EDIIP-2

The antennas and baseband installations that have already been completed and deployed at the GR-TR CBC site, on the Turkish side, are illustrated below.

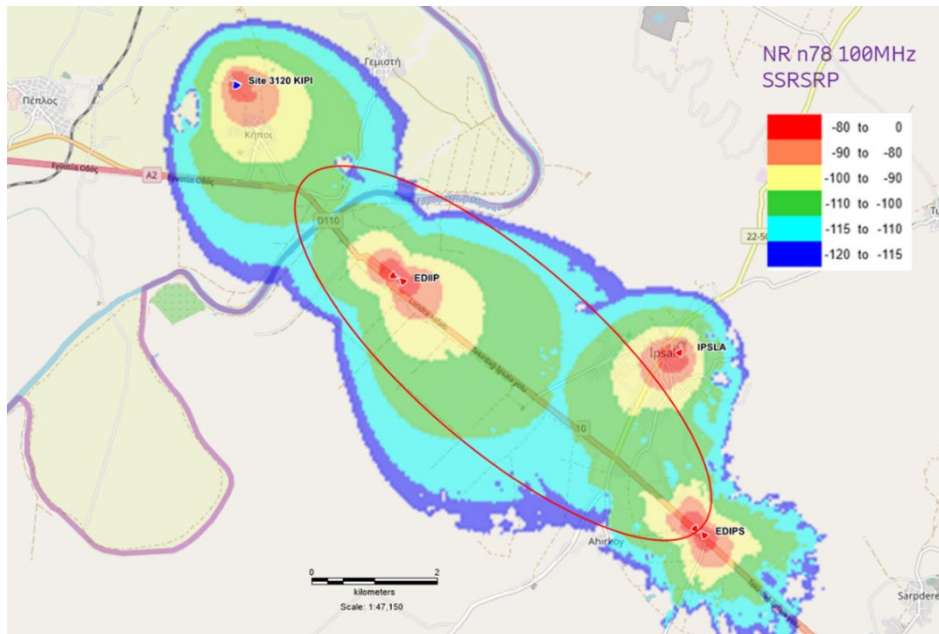


Figure 3.21: GR-TR CBC coverage map.

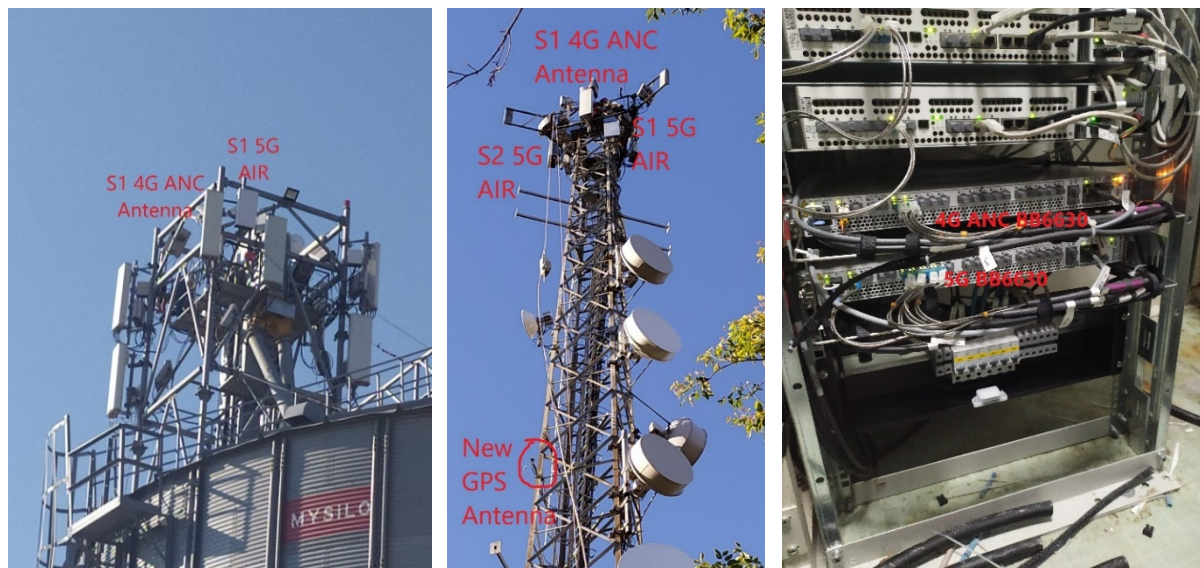


Figure 3.22: Sample antenna and baseband installations in Turkey.
Left: EDIPS Sector1, centre: IPSLA general view of the tower, right: IPSLA baseband installation.

3.3.5 Handover areas adjustments

Handover border adjustment is essential for the project success. In that purpose some of helpful parameters will be use in the Inter PLMN handover scenario. Listed parameter values are set as by default and may be

tuned if it is required to use during optimization process. It's also important for parameter exchange during network integration process. These parameters are illustrated in the Table 3.6. The RSRP thresholds expressed in dB, which are used in communication between the UE and the anchor eNodeB, determine when a handover shall take place.

Table 3.7: Handover parameters at GR-TR CBC.

	Cell 1 (Home) Turkcell	Cell 2 (Visiting) Cosmote
PLMN ID	28601	20201
Band	B7 for Anchor N78 for NR	B7 for Anchor N78 for NR
Cell ID	TBD	221 LTE 331 NR
EARFCN	2976 for LTE 646666 for NR	3050 for LTE 636666 for NR
a1ThresholdRsrpPrim	-105dB	-105dB
a2ThresholdRsrpPrim	-105dB	-105dB
a5Threshold1Rsrp	-105dB	-105dB
a5Threshold2Rsrp	-107dB	-113dB
Power	40.000 mw for LTE 200.000 mW for NR	80.000 mw for LTE 80.000 mw for NR
Bandwidth (MHz)	5MHz for LTE 100Mhz for NR	20MHz for LTE 100Mhz for NR

The area above the Meriç-Evros river bridge is usually the inter-PLMN handover location. To adjust the handover location during the 5G-MOBIX trials, the below parameters will be tuned:

- Power
- Tilt
- Event A1, EventA2, EventA5 (Event A1 = Serving cell becomes better than threshold, Event A2 = Serving cell becomes worse than threshold, Event A5 = Primary cell becomes worse than threshold1 and neighbour becomes better than threshold2)

Typically, the Event A1, A2 and A5 threshold 1 is configured with the same value and determine when a new cell shall be considered for handover. Event A5 threshold 2 is used to determine if a new cell has an adequate RSRP to be considered as a target for handover. By tuning these thresholds one can control under which conditions a handover occurs and approximately where it occurs.



Figure 3.23: GR-TR inter-PLMN handover area.

3.4 TS RAN deployments and contribution to CBCs

A summary comparison of the RAN deployments of 5G-MOBIX at the different CBCs and TSs is provided in Table 3.8. Note: detailed descriptions of TS deployments are found in the Annex.

Table 3.8: Summary of RAN deployments.

Test Site	NSA (op 3x)	SA (op 2)	Num gNB	Freq. bands	Bandwidth	Band Combinations	TDD Frame
ES	Yes	No	5	800 MHz (LTE B20) 1800 MHz (LTE B3) 2600 MHz (B7) 3.7 Hz (5G NR n78)	B20: 2x10 MHz B3: 2x20 MHz B7: 2x20 MHz n78: 50MHz	Depends on device	
PT	Yes	Tentative in 2021	3 (4 locations)	1800 MHz (LTE B3) 3700 MHz (5G NR n78)	B3: 20MHz n78: 100MHz	B3_n78	ULDLDataSlot Ratio: 1/4 frameStructureType: semiStatic basicBeamSet: beamSet_2

Test Site	NSA (op 3x)	SA (op 2)	Num gNB	Freq. bands	Bandwidth	Band Combinations	TDD Frame
GR	Yes	No	1	LTE B7 (2600) 20MHz NR n78F (3500-3600)	B7:20MHz n78F:100MHZ		TDD 4+2+4 (3:8:3)
TR	Yes	No	3 (+1 local)	LTE B7 (2600) 5MHz NR n78G (3600-3700)	B7:5MHz n78G:100MHZ		TDD 4+2+4 (3:8:3)
DE	Yes	SA research deployment in 2021	2	2.1 GHz (5G NR n1) 800 MHz (LTE B20) 900 MHz (LTE B8) 1800MHz (LTE B3) 3.6 GHz (5G NR n78) 1800MHz (LTE B3) 2600 MHz (LTE B7) 3.7 GHz (n78)	n1: 2 x 15 MHz LTE/5G in DSS-mode N78: 90MHz	Support depends on devices: NSA: B8_n1, B20_n1, B3_n1, B3_n78, B7_n78 SA: n78	
FI	Yes	No	2	2600 MHz (B7) 3.5 GHz (n78)	B7: 2x10MHz n78: 60MHz	B7_n78	Frame configuration: DDDSU (10:2:2) UL/DL logical data slot ratio 1/4 frameStructureType: semiStatic
FR	Yes	End of 2021	2	700 MHz (4G) 800 MHz (4G) 1800 MHz (4G) 2100 MHz (3G/4G) 2600 MHz (4G) 3500 MHz (5G) 3700-3800 MHz (n77)	100 MHz (at UTAC/CERAM site) 60 MHz (at Satory site with TDF)	B38_n42	UL/DL logical data slot ratio 1/4
NL	Yes	Yes	6	800 MHz (LTE B20) 1800 MHz (LTE B3) 700 MHz (5G NR n28) 3.7 GHz (5G NR n78) 27 GHz (5G NR n258)	B20: 2x10MHz B3: 2x20MHz B28: depending on auctions n78: 100MHz n258: 100MHz	Depending on devices. Minimum: B3_N78, B3_n28 or n78 only with SA.	DDDSU (10:2:2)

Test Site	NSA (op 3x)	SA (op 2)	Num gNB	Freq. bands	Bandwidth	Band Combinations	TDD Frame
CN	Yes	No	2	3.5GHz(n78) 4.9 GHz(n79) 2.6GHz(n41)	N/A	Depends on device	TDD with DL/UL ratio of 2:1
KR	No	Yes	3	22-23.6 GHz	N/A	22-23.6 GHz	TDD with DL/UL ratio of 7:1

4. CORE NETWORK SOLUTIONS

4.1 Overview

The deployment configuration or topology of the core networks serving the trial sites and their interconnection across borders is a key factor for the realisation and testing the cross-border CCAM UCCs/USs of 5G-MOBIX. The deployments should support the overriding requirements on service continuity and network performance (latency, throughput etc.) at cross-border areas. This Section provides a summary overview of the architecture, features and attributes of the core networks deployed (or being deployed) at the two CBCs (ES-PT, GR-TR) of the 5G-MOBIX project.

4.2 ES-PT CBC core network deployments

The core is a fundamental entity inside the 5G architecture, which manages numerous services to the UEs (User Equipment) that are interconnected by the access network. This 5G element provides flexibility, virtualization and programmability in the new generation of cellular networks.

4.2.1 Overview

The core deployment at a CBC presents a substantial challenge when the aim is to achieve seamless communication between the networks of two different countries. In the case of the ES-PT CBC, the implementation of the 5GC (5G Core) in each country is similar with minor differences.

4.2.2 ES side core network deployment

4.2.2.1 *Deployed core network architecture*

Telefónica Spain Core Network is a distributed core based on the 3GPP Rel. 15 NSA 3.x option. The 5G Core solution uses the NOKIA Cloud Mobile Gateway (CMG) as the SGW/PGW and the NOKIA Cloud Mobility Manager (CMM) as the MME of the 5G EPC in the NSA architecture.

An overall sight of the deployed 5G architecture in the project in the Spanish side was provided in Figure 3.5. The centralized 5G core is placed in Alcobendas (Madrid) where one CMM and one CMG (for User Plane and Control Plane) have been deployed, additionally a distributed CMG-A2 working as SGW/PGW, for the User Plane traffic, is located in the Calvario CT (Vigo, Galicia) edge site.

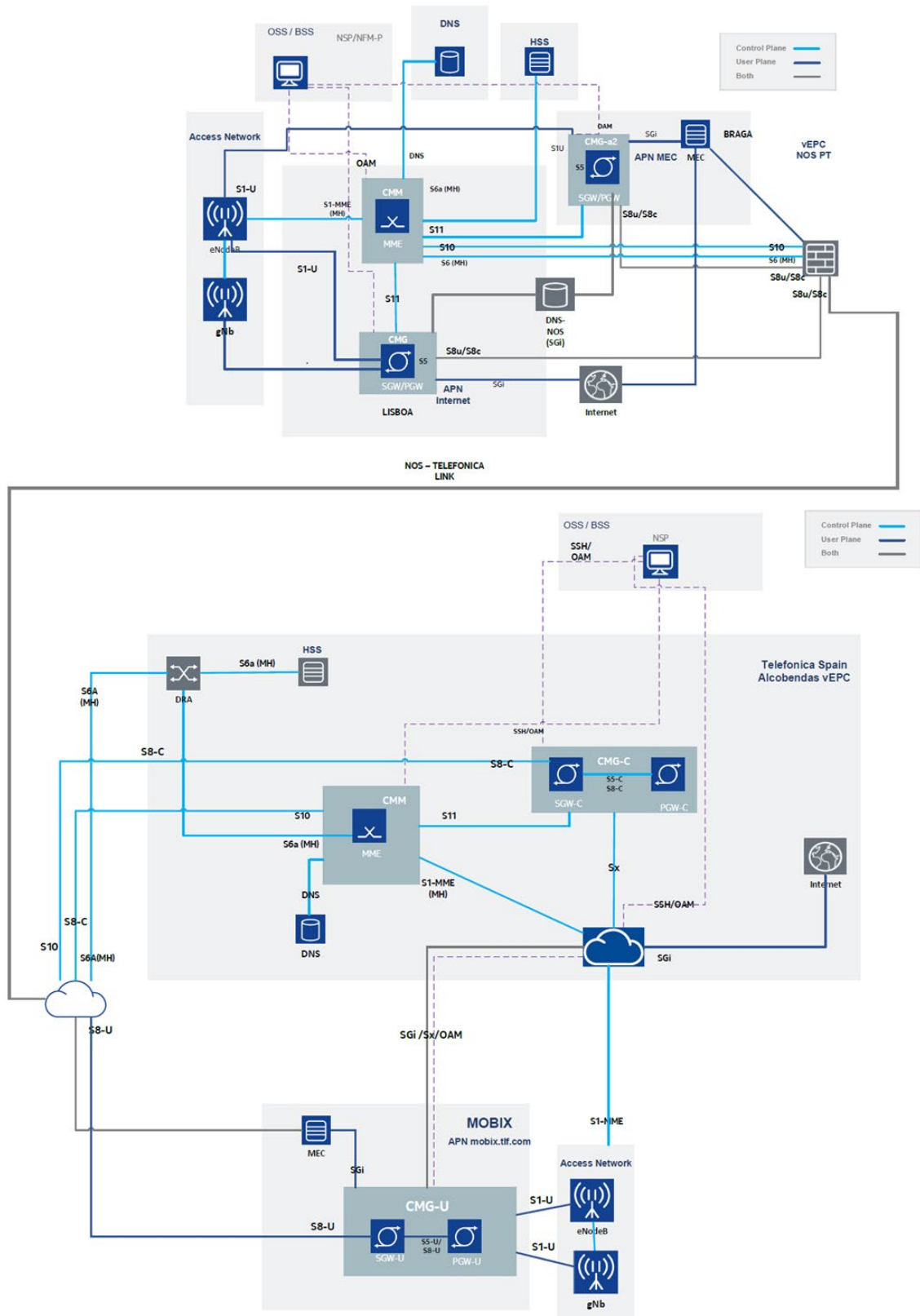


Figure 4.24: ES and PT Core Solution.

4.2.2.1.1 Cloud Mobility Manager (CMM)

The Nokia Cloud Mobility Manager (CMM) is a control plane function which performs virtualized MME functions within the packet core network in 5G NSA architecture. This entity helps to CCAM providing high performance, low latency and reliability required for this project and allows flexible configuration for traffic loads and networks designs; therefore, the network can be effectively adapted to the different user cases proposed in this project. Furthermore, this equipment is optimized for IoT (Internet of Things) and MTC (Massive Type Communications) services, hence, extended sensors user story leverages the features of this network element. This element provides MME functionalities through different virtual machines, as shown in Table 4.9. PAPS and IPPS VNF components are related to 2G/3G networks which are not relevant in this project.

Table 4.9: MME functionalities provided by the cloud mobility manager.

VNF Component	Description of functionality
Network Element Cluster Controller (NECC)	OAM
IP Director Service (IPDS)	Load balancing
Control Plane Processing Service (CPPS)	Handles 4G mobility and session management
Data Service (DBS)	Handles database services
Layer 3 Network Steering Service (L3NS)	Distributes MME signalling traffic (S1, M3, S11, and S11-U) and acts as a Layer 3 routing device toward the next-hop router for address advertisement.

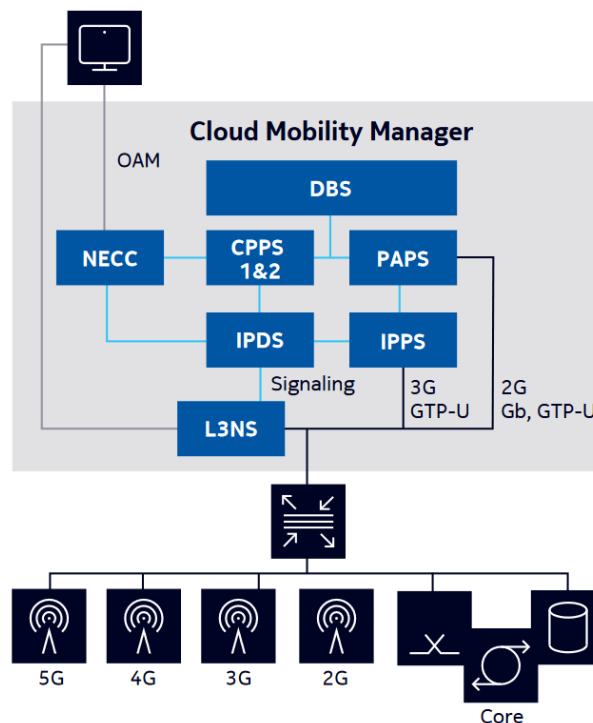


Figure 4.25: CMM architecture.

4.2.2.1.2 Cloud Mobile Gateway CMG

The Nokia Cloud Mobile Gateway (CMG) performs mobile gateway and related functions within the packet core as P-GW (Packing-Gateway) and S-GW (Serving-Gateway) functions in user plane within the packet core network in 5G NSA architecture. The use of this equipment provides a full range of mobile and IP services which CCAM takes advantage to implement the user stories of this project. CMG allows the network functions can be deployed as separate virtual instances or in combination providing maximum configuration flexibility, required aspect for this project. Moreover, the adjustment of control and data plane resources can be performed according to each user story requirements. This system supports enhanced mobile broadband (eMBB) data services and massive machine communication services (MTC) for 5G network, hence, remote driving, extended sensors and the rest of user stories will be benefited. CMG is comprised of a number of VMs shown in Figure 4.26.



Figure 4.26: CMG VNF implementation.

- The OAM-VM component performs control plane functions that include VNF and VNFC management, routing protocols and management interface.
- The LB-VM component provides network connectivity to the mobile gateway function and load distribution across the MG-VMs. It also forwards the GTP-C/GTP-U and UE addressed packets to the MG-VM. The LB-VM can provide a single common IP address for network interfacing elements (MME, eNodeB, S/P-GW).
- The MG-VM services include 3GPP call processing (Control and Data Plane), Policy and Charging Enforcement Function (PCEF), Application Assurance (PCEF enhanced with ADC for application detection and control and L7 service classification for policy charging control). The MG-VM supports all 3GPP gateway functions such as S-GW, P-GW, SAE-GW (S/P-GW).

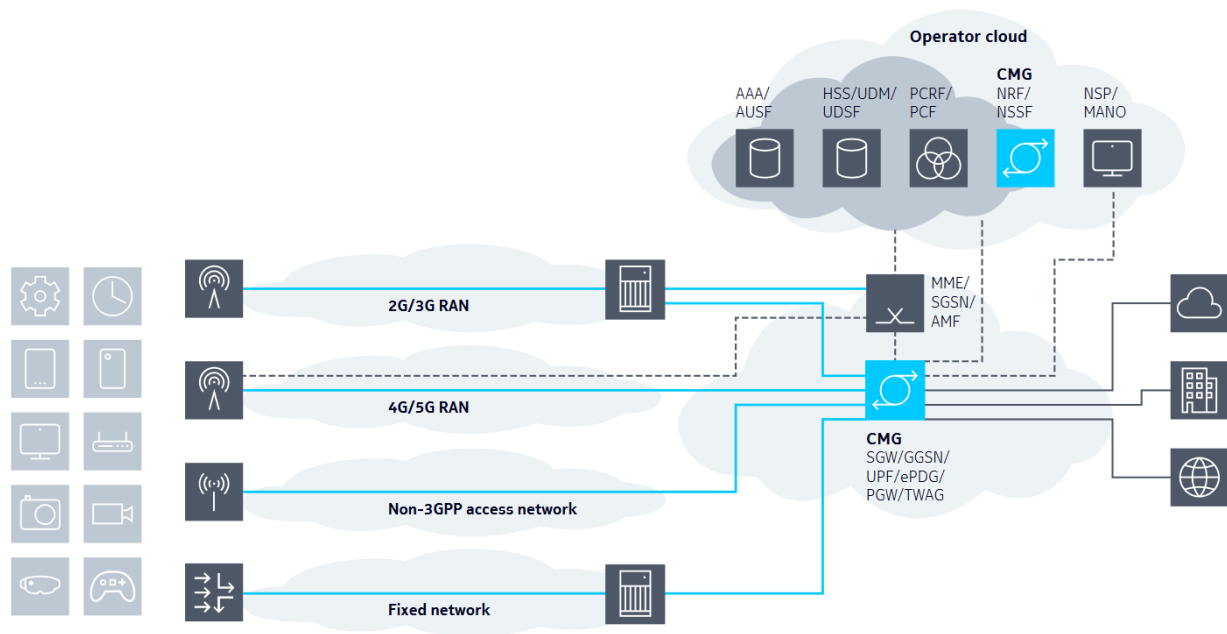


Figure 4.27: CMG localization inside a network.

4.2.2.2 Summary attributes

Attributes of the deployed core network architecture summarized in Table 4.10.

Table 4.10: Technical attributes of the core network deployed in ES.

ES core network deployment	
Vendor and operator	Nokia and Telefónica
Technology (EPC, 5GC etc.)	EPC 5G NSA 3x (Dual Connectivity) and CUPS
Deployed VNFs/functions/elements	HSS, MME, SPGW-C, SPGW-U (CMG-a2), NSP*, CBIS*+CBAM*
Supported 3GPP interfaces	S6a, S11, Sx, SGi, S10, S8, S1-U, S1-C, DNS
NFV infrastructure (NFVi)	CBIS*/CBAM*
Network slicing	N/A
Management and orchestration	CBIS* + CBAM*
Security features	3GPP 5G cyphering and integrity algorithms, VLAN traffic separation
Performance/KPI specs	User Plane and Control KPIs
Other attributes?	N/A

* Nokia solution.

4.2.3 PT side core network deployment

4.2.3.1 Deployed core network architecture

Figure 4.28 shows the centralized 5G core placed in Lisbon where one CMM and one CMG have been deployed, additionally a distributed CMGa-2 working as SGW/PGW is allocated in Riba de Ave, Braga. CMG's NOS Portugal have not been deployed in CUPS mode. However, CMG-a2 (SPGW) will be dedicated to 5G application services, all Control plane and User Plane traffic will be handled by such network element.

In addition to this, the 5GC is complemented with other 5G Nokia solutions such as the Network Services Platform (NSP), which helps to ensure maximum service performance and reliability for IP and optical networks. The core network in Lisbon (HSS, CMM, CMG, DNS) are provided by a Nokia integrated solution (miniEPC).

For the PT Core, there are two CMG deployed in combo mode (SGW/PGW together): One CMG in Lisbon is dedicated to a different APN, Internet Access only (SGW/PGW) and one CMG-a2 in Braga is dedicated to handle the Control and User Plane traffic (SGW/PGW) of 5G Applications. There is one CMM in the PT Core working as MME.

4.2.3.2 Summary attributes

Attributes of the deployed core network architecture summarized in Table 4.11.

Table 4.11: Technical attributes of the core network deployed in PT.

PT core network deployment	
Vendor and operator	Nokia and NOS Portugal
Technology (EPC, 5GC etc.)	EPC 5G NSA 3x, Dual Connectivity
Deployed VNFs/functions/elements	HSS, MME, SPGW, DNS (miniEPC), NSP* and CMG*-a2 (SPGW)
Supported 3GPP interfaces	S6a, S11, Sx, SGi, S10, S8, S1-U, S1-C, DNS.
NFV infrastructure (NFVi)	CBIS*/CBAM*
Network slicing	N/A
Management and orchestration	N/A
Security features	3GPP 5G cyphering and integrity algorithms, VLAN traffic separation, Firewall for external traffic.
Performance/KPI specs	User Plane and Control KPIs
Other attributes?	N/A

* Nokia solution.

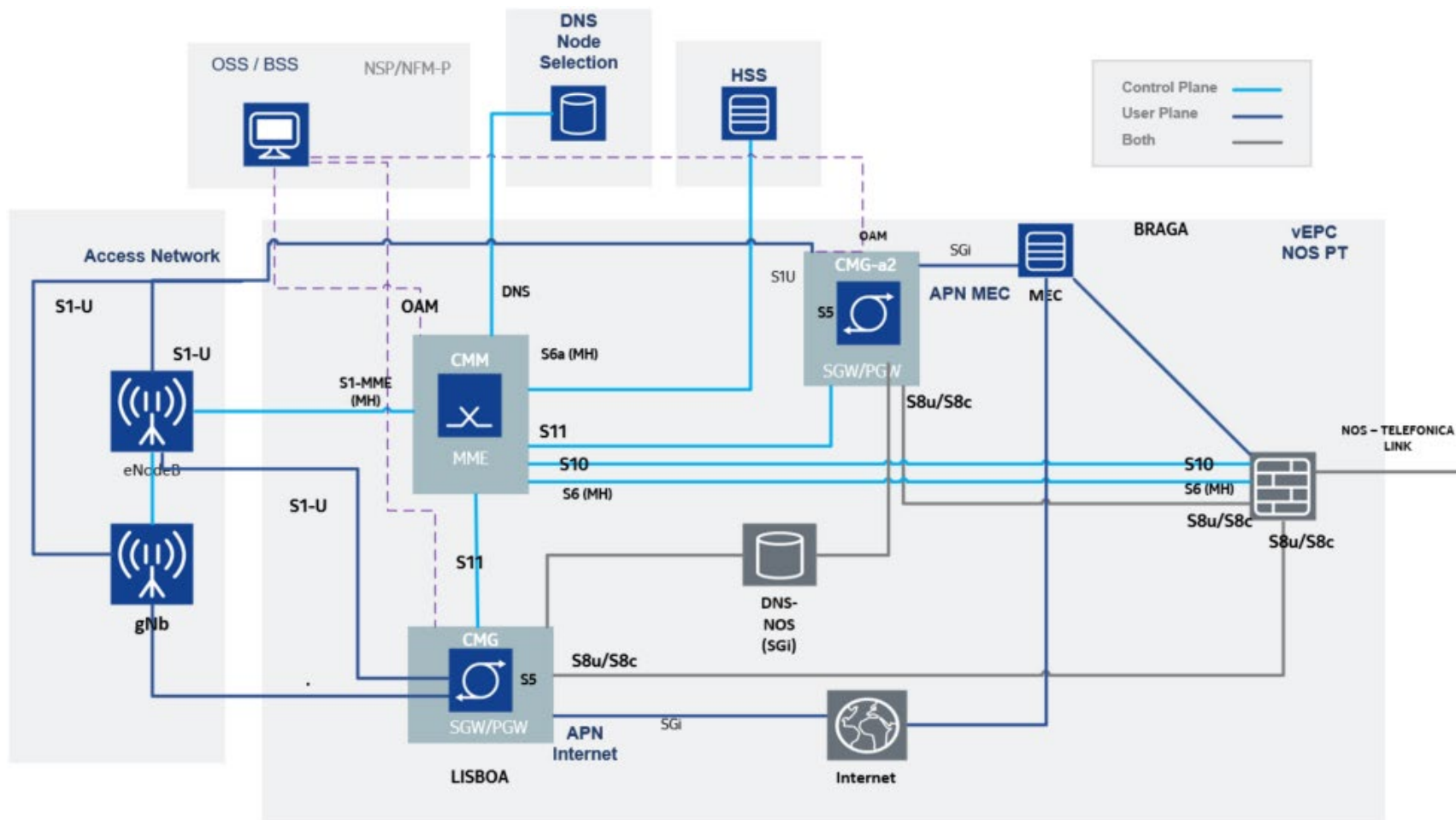


Figure 4.28: PT deployed core network architecture.

4.3 GR-TR CBC core network deployments

4.3.1 Overview

The criticality of latency for the GR-TR CCAM applications is taken into consideration and the location selection for the deployment of core components is made considering the shortest route of traffic as per the existing topology of operators. Thus, the core network solutions are deployed at the edge Data Centres (DCs), located close to the border' sides to fulfil the strict latency requirements imposed by the use case categories to be demonstrated at this cross-border corridor. The application servers will connect to the edge DCs, where the complete vEPC functionalities will be deployed, while the 5G UE – application servers' connectivity will be provided over the PGW SGi interface.

Both mobile network operators, Cosmote and Turkcell, are deploying overlay and dedicated networks based on the 5G EPC (NSA, opt. 3x) architecture, connected to dedicated 5G NR radio, creating thus a private 5G NR network. In fact, Ericsson's Enterprise Core solution, which consists of Evolved Packet Core (EPC) and User Data Consolidation (UDC) functionalities, is deployed.

Due to the fact that overlay and dedicated networks will be implemented for the trial, the 5GEPC infrastructure on both sites will include all mandatory functions required to realize the use cases. Those are:

- Serving GPRS Support Node – Mobility Management Entity (SGSN-MME)
- Evolved Packet Gateway (EPG), including the S-GW and P-GW nodes.
- User Data Consolidation (UDC), including the Front End (HSS-FE), the Centralized User Database (CUDb)
- Service Aware Policy Controller (SAPC)
- Core Network Operation Manager
- Ericsson Dynamic Activation (EDA), used as provisioning gateway.

The following sites are being deployed:

- Greece:
 - Alexandroupoli: 5G EPC Infrastructure & MEC Applications.
 - Athens: An OSS System will be installed for remote management and configuration of the equipment as well as KPI collection.
- Turkey:
 - Kartal EDGE: 5G EPC Infrastructure, OSS & MEC Applications.

The two edge sites will be connected over a direct/dedicated connection.

Providing service continuity when crossing a country border is a challenge, particularly for those applications which require a high speed, low latency network. For that reason, the S10 interface is planned to be implemented between MMEs in the two mobile networks operated by the different MNOs to enable cross-border radio handover in seamless operation. Interface S6a (authentication) and S8 (home routed user plane and control plane) are used in all tests as basic roaming interfaces.

4.3.2 GR side core network deployment

4.3.2.1 *Deployed core network architecture*

A compact trial configuration for the core network is selected to minimize the footprint of the solution at the edge site. A new overlay 5G network (NSA 3.x option) has been deployed by Cosmote, connected to dedicated RAN infrastructure deployed for the purpose of the 5G-MOBIX trial. The deployed solution consists of the Evolved Packet Core (EPC) and User Data Consolidation (UDC) functionalities as well as the supporting OSS infrastructure. The overlay core network will only handle critical type V2X traffic with low latency and high throughput requirements.

The edge application servers reside at the same edge DC where the new 5G EPC network is deployed, while the MEC servers' connectivity with the access network and the UEs will be provided over PGW SGi interface. The 5G compact NSA network consists of the following elements:

- Virtual Evolved Packet Gateway (vEPG)
- Virtual Mobility Management Entity (vMME)
- Virtual Centralized User Database (vCUDb)
- Virtual Ericsson Dynamic Activation (vEDA)
- Virtual Home Subscriber Server – Front End (vHSS-FE)
- Virtual Service Aware Policy Controller (SAPC)
- Virtual Core Network Operation Manager (CNOM)

The CNOM node provides support for performance management (PM), fault management (FM), reporting, health check and troubleshooting at network function level. In addition, the Ericsson Network Manager is deployed at a central DC in Athens in order to allow for remote operation (monitoring and configuration) of the nodes, as well as for collection of KPIs. The deployment model is aligned with the Multiple Access Edge Computing (MEC) with Distributed Virtual EPC Architecture.

4.3.2.2 *Summary attributes*

Attributes of the deployed core network architecture are summarized in Table 4.12.

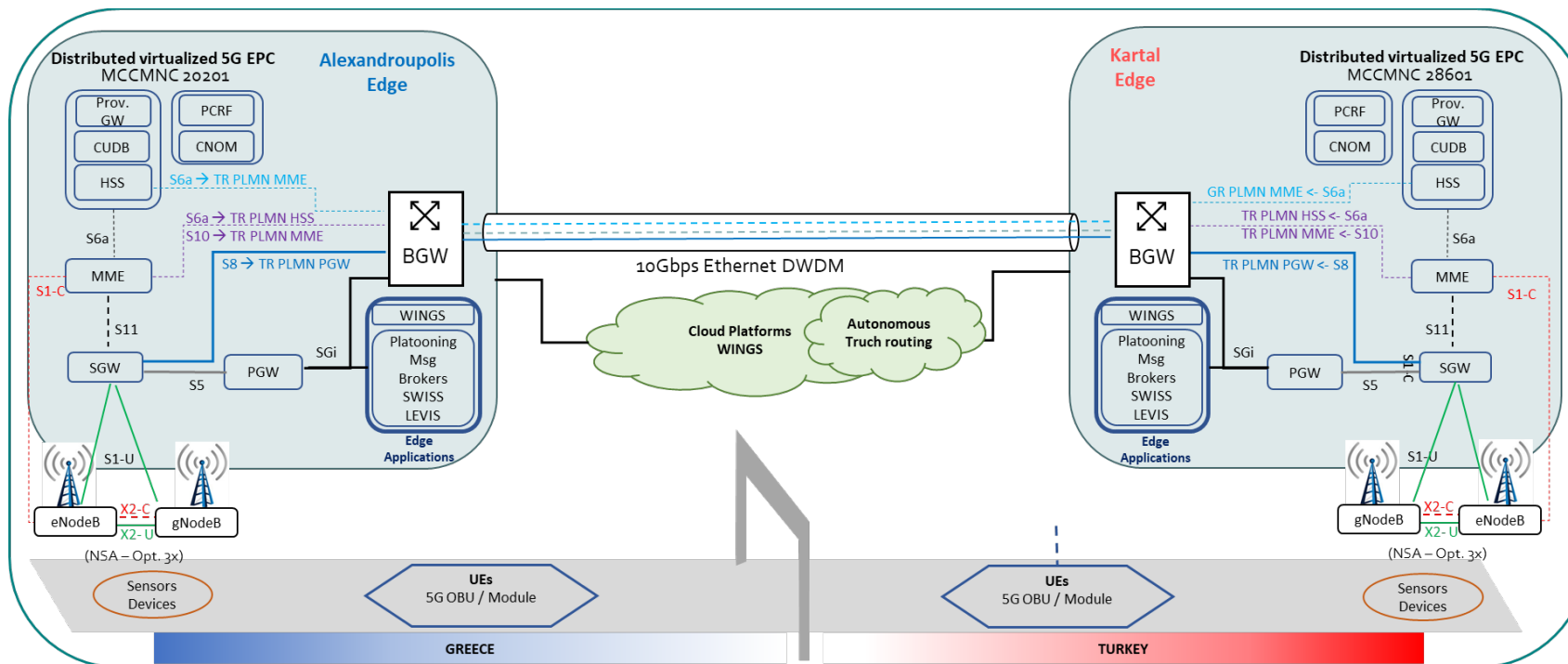


Figure 4.29: GR – TR deployed core network architecture.

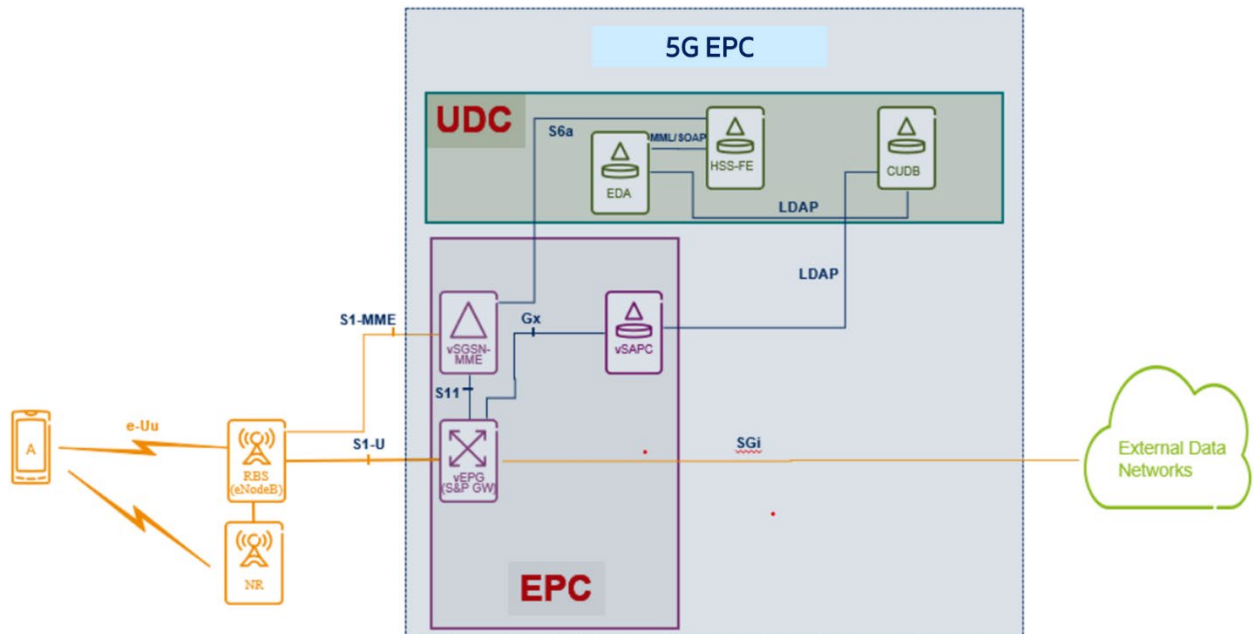


Figure 4.30: GR 5G EPC NSA deployment.

Table 4.12: Technical attributes of the core network deployed in GR.

GR core network deployment	
Vendor and operator	Ericsson 5G Infrastructure Network at Cosmote Edge Site
Technology (EPC, 5GC etc.)	5G EPC, NSA (Option 3.x)
Deployed VNFs/functions/elements	HSS, CUDB, MME, SGW, PGW, CNOM*, ENM*, EDA*
Supported 3GPP interfaces	S1-MME, S1-C, S1-U, S5/S8, S10, S11, S6a, S6d, SGi,
NFV infrastructure (NFVi)	Ericsson Cloud Execution Environment (Open Stack)
Network slicing	N/A
Management and orchestration	N/A
Security features	3GPP security features for authentication, integrity protection and encryption, VLAN separated interfaces, Node Hardening, ACLs
Performance/KPI specs	User Plane and control plane KPIs
Other attributes?	N/A

* Ericsson provisioning and operational supporting functions for the 5G NSA nodes.

4.3.3 TR side core network deployment

4.3.3.1 Deployed core network architecture

Ericsson installed all nodes at Turkcell Kartal DC, including vEPG-U, vEPG-C, vMME, vHSS-FE and vCUDBs. The CUPS feature is in the project scope and is already deployed. The solution deployed at the GR-TR

borders will accommodate the 5G EPC, the 5G NR Radio and the OSS, where the OSS is installed at the Turkcell DC in order to allow remote management and configuration of the equipment, and to collect KPIs. There will also be application servers to host the application logic of the platooning, see-what-I-see and assisted border crossing user stories.

Due to the fact that currently available 5G NSA technology uses LTE as the anchor, the established roaming agreements between Cosmote (MCCMNC 20201) and Turkcell (MCCMNC 28601) sufficiently cover the prerequisite for making handovers between the two operators.

Due to the use of the NSA architecture, the Home Routing roaming method will be used in order to enable session continuity. The local break out (LBO) option in NSA roaming scenario cannot provide session continuity and thus does not guarantee seamless operation of V2X applications. However, LBO will be considered as an option, in order to demonstrate application layer session continuity mechanisms.

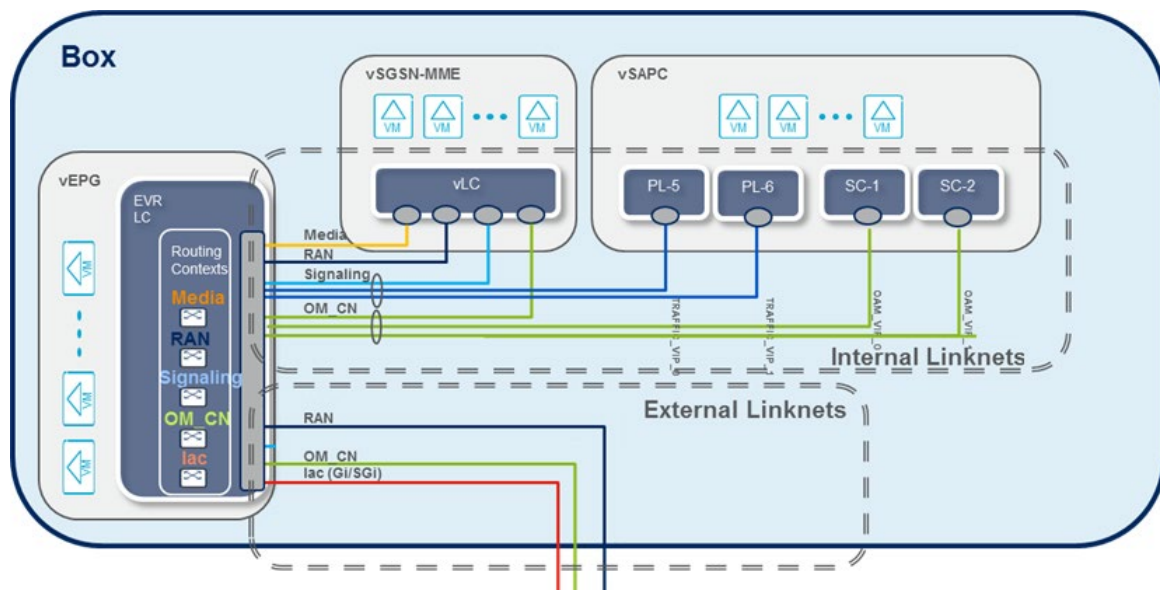


Figure 4.31: TR deployed core network architecture

4.3.3.2 Summary attributes

Attributes of the deployed core network architecture summarised in Table 4.13.

Table 4.13: Technical attributes of the core network deployed in TR.

TR core network deployment	
Vendor and operator	Ericsson Core network works on top of the Turkcell network
Technology (EPC, 5GC etc.)	5G NSA
Deployed VNFs/functions/elements	MME/SGW-C/SGW-U/PGW-C/PGW-U/ CNOM*
Supported 3GPP interfaces	S1-C/S1-U/S10/S5-S8/Sx/

TR core network deployment	
NFV infrastructure (NFVi)	CEEg-OpenStack
Network slicing	Dedicated Network for V2X Applications based on Distributed EPC infrastructure.
Management and orchestration	N/A
Security features	Security has been handled by Turkcell firewall and VPN server
Performance/KPI specs	User Plane and control plane KPIs
Other attributes?	NA

* Ericsson solution.

4.4 Cross-site core network deployments comparisons & core network deployment summary

A summary comparison of the core network solutions deployed for 5G-MOBIX at the different CBCs and TSs is provided in Table 4.14. Note: detailed descriptions of TS deployments are found in the Annex.

Table 4.14: Cross-site core network deployment comparison.

Attributes ↓/ Sites→	ES	PT	GR	TR	DE	FI	FR	NL	CN	KR
Vendor(s)	Nokia	Nokia	Ericsson	Ericsson	(not commercial)	CMC	Nokia, Ericsson	KPN: Ericsson	ZTE	Snet-ICT
Technology (EPC, 5GC etc.)	EPC (5G NSA)	EPC (5G NSA) 5GC (after upgrade to 5G SA)	5G EPC (NSA 3.x)	5G EPC (NSA 3.x)	Research 5GC	5GC EPC	5G EPC	5GC	5GC	5GC EPC (5G NSA)
Virtualised (Yes/No)	Yes	Yes	Yes	Yes	Yes	Yes	No	Yes	Yes	Yes
Network slicing (Yes/No)	No	Yes (after upgrade to 5G SA)	No	No	No	Yes	To be defined	Yes	Yes (Deployed by CMCC)	To be defined

Attributes ↓/ Sites→	ES	PT	GR	TR	DE	FI	FR	NL	CN	KR
Core interconnections (direct, GRX, IPX)	Direct	Direct	Direct	Direct	No	Direct	Direct	Direct	Direct	Direct
Roaming	NSA-NSA roaming relation with handover configured		NSA-NSA roaming relation with handover configured		No (emulated)	no	no	SA-SA roaming	SA-SA roaming	no

5. NETWORK INTEGRATION

5.1 Overview

This section documents how and when the 5G RAN components deployed at the different CBCs & TSs (described in Section 3) will be integrated with the core network solution implemented in the respective CBCs/TSs (Section 4), leading to an end-to-end (E2E) functional 5G network. The preparation of RAN and core integration strategy is part of Phase 2 of the 5-phase rollout plan for the 5G-MOBIX 5G networks, described in D3.1 and depicted on Figure 2.1, while the main integration process takes place in Phase 3.

Due to the focus of the ICT-18-2018 call on the cross-border corridors, the 5G-MOBIX trialling and test activities are organised into two main groups around the two CBCs, which are complemented by the TSs. Based on the need to look more deeply into the CBCs, the network integration part of the deliverable D3.3 has this outline: Since each operator has a different strategy for 5G network deployment and RAN-core integration, there will be one sub-section focused on the network integration per each side of the CBC, and another sub-section focused on the cross-network interconnection of the two MNOs across the borders. In addition, the network integration process adopted by each TS will be presented in a summary table, keeping the detailed description of each TS network integration solutions to the annexes.

5.2 5G RAN & core network integration

This section provides an overview of the 5G NR and core network integration strategy followed by each side of the CBCs. The specific key points that are highlighted are the mobile backhaul solution, 5G network synchronisation solution, interfaces deployed between the 5G NR and core network (providing also dimensioning guidelines, if feasible), network programmability, etc.

5.2.1 ES-PT CBC Network Integration

5.2.1.1 ES side RAN & core Network Integration

For this European project, the Spanish 5G end-to-end network architecture is built according to the 3GPP NSA 3x option configuration. The Spanish RAN is comprised of four sites, (1) Porriño/CTAG, which covers CTAG's headquarters, (2) Tui Centro and (3) As Bornetas, which cover both bridges in the CBC and (4) Porriño/Polígono EB, which serves the motorway near CTAG. Currently, all these nodes work under the pilot PLMN 21438 of Telefonica except Porriño/Polígono site which works in commercial PLMN (21407).

Each RAN site is connected to Telefónica's transport network by means of X2 and S1 interfaces. In addition to this, OAM (Operations, Administration and Maintenance) services of the network are set up end-to-end to provide essential processes, activities and tools to verify the proper operation of the NR deployment.

The primary functional elements of the 5G RAN such as the Remote Radio Unit (RRU), Control Unit/Distribution Unit (CU/DU) are logically mapped to the transport network, giving rise to two segments of the transport network, namely the fronthaul and the backhaul. The fronthaul is based on local fibre connection between the CU/DU and the RRUs around a length of some tens of meters while the backhaul (connection between the CU/DU and the 5GC) is built on fibre. This implementation handles a distributed baseband deployment, called Distributed RAN (DRAN), where the interface between the RAN and the core network is located at the radio site, enabling quick rollout, ease of deployment and standard IP-based connectivity. All RAN interfaces used in 5G-MOBIX by Telefónica have a capacity of 10 Gbps by default and, for instance, are used between eNBs and gNBs.

Telefónica's transport network provides connectivity to the edge site, located in Calvario CT (Vigo). Several connections arrive to the Nokia switch at the edge site, including the previously mentioned OAM connection, connection to access to the Internet, the Sxa/Sxb interfaces to connect to the internet, the Sxa/Sxb interfaces to connect to the SGW/PGW user and control plane as well as the S1-u interface owing to the user plane functionality hosted at the Edge core. This transport network also links through Telefónica's transport network to the laboratory sited in Alcobendas (Madrid), where the 5G Core is located. This connection supplies OAM services, S1-MME and S1-U interfaces and access to the Internet.

Furthermore, a highly accurate time synchronization is needed almost everywhere in the network. Hence, the synchronization requirements are extremely demanding in the deployment of a 5G network. At the Spanish border, as was mentioned previously, the n78 (3.5 GHz) band is Time Division Duplex (TDD), requiring much tighter time and phase synchronization to ensure against the interference between the uplink and downlink compared to Frequency Division Duplex (FDD), so for this project GNSS synchronization is installed at all RAN sites.

5.2.1.2 PT side RAN & core Network Integration

The 5G spectrum is not yet allocated in Portugal thus 5GMOBIX network is separated from NOS commercial network. Until the 5G spectrum allocation process is completed by Portuguese regulator ANACOM the 5G-MOBIX project will be installed on a test network that will be completely segregated from the commercial network. In the first phase of the project, the 5G radio access network is going to be deployed at 3700 MHz, with an LTE anchor layer at 1800 MHz, which will be granted temporarily for carrying out the technical trial. In a second phase, it will be possible to migrate the network to 5G commercial spectrum that will be held by NOS.

The RAN equipment is installed on NOS existing radio sites and the Core equipment is housed in Lisbon and Riba d'Ave Datacenters. The Core network nodes are connected through NOS WDM IP Network backbone and the RAN backhaul is connected to Core over 10 Gbps Ethernet fibre links. For Roaming and MEC interconnection it was deployed a direct interconnection between Telefonica and NOS to minimize latency of C-V2X applicational traffic and S6, S10 and S8 signalling interfaces.

The distributed Core architecture allows the breakout of user plane traffic on Edge to the MEC which is also interconnected with Spanish MEC.

5.2.2 GR-TR CBC Network Integration

5.2.2.1 GR side RAN & core Network Integration

As described in section 3.3, the RAN equipment provided by Ericsson can realize the Centralized RAN (CRAN) concept, since Ericsson's Baseband Unit (BBU) 6630 can support up to 15 CPRI ports. In fact, the BBU 6630 is connected to the antenna unit via CPRI interface (fronthaul). However, given that only one gNB is deployed at the Greek side for the needs of the 5G-MOBIX project, it was logically decided to install the baseband unit and the antennas at the same site of KIPOI area, following a "DRAN-like" concept, where the transport between the RAN and the core network (CN) uses an S1 interface. Specifically, given that there is no fibre connectivity to the site at KIPOI area, which is a rural one, the gNB is connected via a microwave link of 2Gbps capacity to the first aggregation point of Cosmote's transport network. Via the commercial transport network of Cosmote, which is Packet-based Optical Network (DWDM with Ethernet Capabilities), the vEPC at Alexandroupoli site is reached (Figure 5.32).

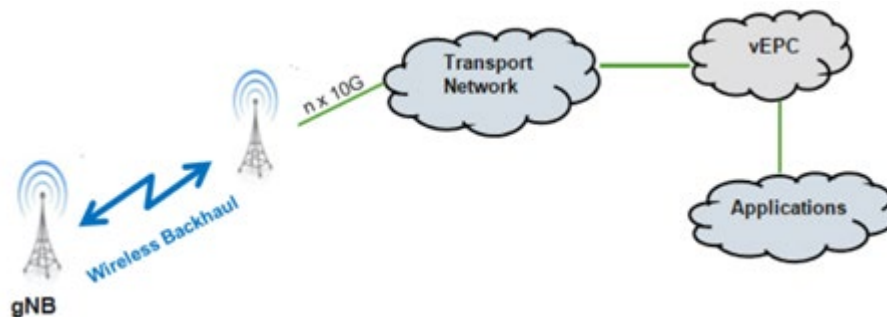


Figure 5.32: GR RAN & Core Network Integration Diagram.

Given that an overlay RAN and core network is deployed for the needs of the 5G MOBIX project, decoupled from Cosmote's production network, it has been decided to use GNSS for carrier frame synchronisation in order to have a minimum impact in the transport network. In addition, an NTP server has been deployed by Ericsson at the core network, which is used as a reference for the Packet Core network as well as the application servers located at the edge.

5.2.2.2 TR side RAN & core Network Integration

The 5G sites in Turkey are installed with a distributed RAN architecture, where each site has its own baseband unit (BBU) installed. The baseband units host both Central Unit (CU) and Distributed Unit (DU) functions. The active antenna units are connected to the BBUs with fiberoptic cables, which carry eCPRI traffic.

EDIPY site has 2Gbps Radio Link (RL) as backhaul and EDIPS site has 1.2Gbps RL backhaul. Both sites are aggregated on the IPSLA site, which is using a 10Gbps CTAN backhaul. The aggregated traffic is transported to a Turkcell Network Data Center (NDC) in Çorlu. From Çorlu, the backhaul traffic is transported to the Turkcell Lab in İstanbul (i.e., the Captive Lab) via a DWDM transport network and is connected to the vEPC.

All three sites have phase and time synchronization enabled and also have a GPS solution installed, which acts as a backup in case of a phase synchronization failure. The captive lab is synchronized via an NTP server located in the lab, which is a stratum 1 server, meaning that the NTP is synchronized directly from a GPS server.

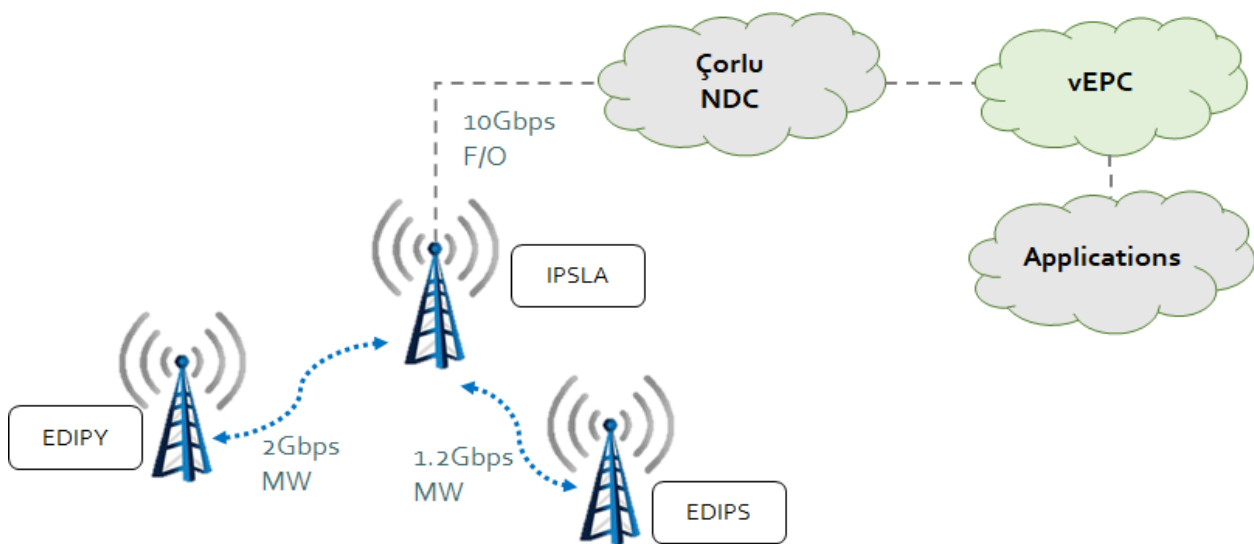


Figure 5.33: TR RAN & Core Network Integration Diagram.

5.2.3 5G RAN & core Network Integration Summary

A summary for the comparison of the network integration solutions deployed in 5G-MOBIX at the different CBCs and TSs is provided in Table 5.15. Note: A detailed descriptions of the TS deployments are found in the Annex.

Table 5.15: Cross-site network integration comparison.

Attributes ↓/ Sites →	ES	PT	GR	TR	DE	FI	FR	NL	CN	KR
DRAN / CRAN option	DRAN	DRAN	DRAN	DRAN	DRAN	DRAN	DRAN	DRAN	DRAN	DRAN
Fronthaul (Yes/No)	Yes	Yes	No	No	Yes	Yes	No	No	No	No

Attributes ↓/ Sites →	ES	PT	GR	TR	DE	FI	FR	NL	CN	KR
Midhaul (Yes/No)	No	No	No	No	No	No	No	No	No	Yes
Fibre to the Site/ MW link	Fibre	Fibre	MW link	Fibre & MW	Fibre	Fibre	Fibre	Fibre	Fibre	Fibre
Backhaul Techno- logy	Fibre	Ethern et	DWD M + Ethern et capabi lities	DWD M	CWD M	Ethern et (CWD M and DWD M possib le)	Ethern et	Ethern et (direct ly conne cted)	Ethern et	Ethern et
Programm ability (Yes/No)	No	No	No	No	No	No	No	No	No	Yes
Network Synchroniz ation (GNSS/PTP /...)	GNSS & PTP	GNSS & PTP (T-GM G.827 5.1)	GNSS NTP	GNSS & PTP	GNSS & NTP	PTP	NTP	GNSS	GNSS PTP	NTP

5.3 CBCs Cross-Network Integration

This section presents an overview of how the 5G networks deployed by the two MNOs of each CBC are interconnected aiming to fulfil the requirements imposed by the use cases to be demonstrated at the specific CBC. Key focus points discussed in this section are the following: direct interconnection/partial GRX use (for CP functionalities), cross-network synchronisation.

5.3.1 ES-PT CBC cross-network Integration

In the ES-PT cross-border corridor the solution implemented for the cross-network integration is by the use of a dedicated fibre, which interconnects both networks, reducing the transport latency to the minimum possible because it is the shortest way considering the existing transport network infrastructure.

The point of interconnection selected is an IP/MPLS point of presence of NOS in Vigo where the Spanish MEC is also located. This point of presence is connected through fibre to the aggregation point of Telefonica's transport network, which provides connectivity to the MEC and EPC. This link is being designed

to support the different interfaces needed to implement the roaming capabilities using different VLANs: S6a, S10, S8-u, S8-c and a dedicated interface for inter-MEC communication at the application level.

5.3.2 GR-TR CBC cross-network Integration

In order to fulfil the strict latency requirements imposed by the use cases to be supported at the GR-TR cross-border trials, both MNOs (Cosmote and Turkcell) decided to interconnect their networks directly and leased a 10Gbps Ethernet unprotected DWDM circuit by OTEGLOBE¹.

Via this leased line, Cosmote's network will interconnect with Turkcell in Ipsala, since this is the terminating point of OTEGLOBE's network. From Ipsala, Turkcell will pass the interconnect traffic to CTAN ring. The traffic is transported to Turkcell Network Data Center (NDC) in Çorlu. From Çorlu the interconnect traffic is transported to the Turkcell Lab in İstanbul via a DWDM transport network and connected to the 5G vEPC.

¹ OTEGLOBE, headquartered in Athens-Greece, is the international wholesale arm of OTE Group and the leading wholesale carrier in S.E. Europe with global reach, delivering a complete portfolio of voice and data services.

6. 5G NETWORK TESTING & RESULTS

6.1 Overview

This section documents the 5G network test cases planned to be performed by all CBCs and TSs, as part of Phase 3 of the 5-phase rollout plan of the 5G-MOBIX networks, aiming to ensure the readiness of the 5G communication in an end-to-end level. It should be stressed here that the test cases mentioned in Section 6.2 are equivalent to agnostic test cases of D5.1 [6]. In addition, preliminary results of the first tests performed by the CBC/TS by the end of November 2020 are reported in section 6.3.

6.2 5G Network Testing

This section documents the 5G network-related test cases of the 5G-MOBIX project, focused on ensuring reliable and functional end-to-end communication of the deployed 5G networks. In fact, Section 6.2.1 describes the generic test cases agreed to be performed by each CBC and TS, while Section 6.2.2 presents the specific network testing items planned to be tested by each CBC/TS taking into account the special characteristics of their deployed network topologies.

6.2.1 Generic Network Testing

This section presents the generic test cases which are relevant for the 5G networks of 5G-MOBIX CBCs/TSs in order to ensure reliability and functionality of the deployed 5G networks. Table 6.16 presents the generic test cases that will be performed by the CBCs/TSs.

Table 6.16: Generic Test Cases – to be performed by each CBC/TS.

Test Case Category	Test Case (TC) ID	TC Name	GR-TR	ES-PT	DE	FI	FR	NL	CN	KR
Single User Throughput	TCA-GEN-01_TCP_DL TCA-GEN-01_UDP_DL	Peak DL TCP/UDP Data Throughput of Single User (stationary use)	√	√	√			√	√	
	TCA-GEN-02_TCP_UL TCA-GEN-02_UDP_UL	Peak UL TCP/UDP Data Throughput of Single User (stationary use)	√	√	√			√	√	
	TCA-GEN-03_TCP_DL_No load	User Average DL Data Throughput in Mobile Use (Average Speed) - Unloaded conditions	√	√	√	√	√		√	
	TCA-GEN-04_TCP_UL_No load	User Average UL Data Throughput in Mobile Use (Average Speed) - Unloaded conditions	√	√	√	√	√		√	

Test Case Category	Test Case (TC) ID	TC Name	GR-TR	ES-PT	DE	FI	FR	NL	CN	KR
	TCA-GEN-05_TCP_DL_x% load	User Average DL Data Throughput in Mobile Use (Average Speed) - Loaded conditions	√	√			√		√	
	TCA-GEN-06_TCP_UL_x% load	User Average UL Data Throughput in Mobile Use (Average Speed) - Loaded conditions	√	√			√		√	
	TCA-GEN-07_TCP_DL_No load	User Average DL Data Throughput in Mobile Use (High Speed) - Unloaded conditions	√	√	√	√	√	√	√	
	TCA-GEN-08_TCP_UL_No load	User Average UL Data Throughput in Mobile Use (High Speed) - Unloaded conditions	√	√	√	√	√	√	√	
	TCA-GEN-09_TCP_DL_x% load	User Average DL Data Throughput in Mobile Use (High Speed) - Loaded conditions	√	√			√	√	√	
	TCA-GEN-10_TCP_UL_x% load	User Average UL Data Throughput in Mobile Use (High Speed) - Loaded conditions	√	√			√	√	√	
	TCA-GEN-11_TCP_DL_x% load TCA-GEN-11_TCP_UL_x% load	User Average Data Throughput at the cell edge	√	√	√		√	√	√	
Network Performance	TCA-GEN-12_TCP_DL_No Load	TCP DL Use case route performance		√		√		√	√	
	TCA-GEN-13_TCP_UL_No Load	UL TCP Use case route performance		√		√		√	√	
	TCA-GEN-14_TCP_DL_Loaded	DL TCP Data Throughput along use case route with several users		√				√	√	
	TCA-GEN-15_TCP_UL_Loaded	UL UDP Data Throughput along use case route with several users		√				√	√	
	TCA-GEN-16_DL_Cell Capacity	DL Cell Capacity	√						√	
	TCA-GEN-17_UL_Cell Capacity	UL Cell Capacity	√	√					√	
Latency	TCA-GEN-18_PING_No load_MTU size	User Plane Latency in Unloaded Cell (e2e)	√	√	√	√	√	√	√	
	TCA-GEN-19_PING_x% load_MTU size	User Plane Latency in Loaded Cell (e2e)	√	√				√	√	

Test Case Category	Test Case (TC) ID	TC Name	GR-TR	ES-PT	DE	FI	FR	NL	CN	KR
	TCA-GEN-20_CP Latency	Control Plane Latency (NR RRC Idle -> NR Connected)	√	√		√			√	
	TCA-GEN-21_CP Latency_UE triggered	Control Plane Latency (NR RRC_INACTIVE -> NR RRC_CONNECTED, UE triggered)							√	
	TCA-GEN-22_CP Latency_Network triggered	Control Plane Latency (NR RRC_INACTIVE -> NR RRC_CONNECTED, Network triggered)							√	
NSA Mobility (EN-DC, opt. 3/3a/3x)	TCA-GEN-23_TCP_DL_speed TCA-GEN-23_TCP_UL_speed TCA-GEN-23_TCP_DL&UL_speed	Intra-cell mobility (at different speed ranges)	√	√	√					
	TCA-GEN-24_TCP_DL TCA-GEN-24_TCP_UL TCA-GEN-24_TCP_DL&UL	Intra MeNB mobility: MeNB same, SgNB different	√	√	√					
	TCA-GEN-25_Handover	Inter-MeNB handover without SgNB change triggered by MeNB	√	√						
	TCA-GEN-26_Handover	Inter-MeNB handover no SgNB scenario	√	√						
SA Mobility	TCA-GEN-27_UDP_DL_speed TCA-GEN-27_TCP_DL_speed TCA-GEN-27_UDP_UL_speed TCA-GEN-27_TCP_UL_speed TCA-GEN-27_UDP_DL&UL_speed TCA-GEN-27_TCP_DL&UL_speed	Intra-cell mobility (at different speed ranges)							√	
	TCA-GEN-28_UDP_DL_speed TCA-GEN-28_TCP_DL_speed TCA-GEN-28_UDP_UL_speed TCA-GEN-28_TCP_UL_speed TCA-GEN-28_UDP_DL&UL_speed TCA-GEN-28_TCP_DL&UL_speed	Inter-cell mobility: intra-gNB handover (without CU-DU split)							√	
	TCA-GEN-29_UDP_DL_speed TCA-GEN-29_TCP_DL_speed TCA-GEN-29_UDP_UL_speed TCA-GEN-29_TCP_UL_speed TCA-GEN-29_UDP_DL&UL_speed TCA-GEN-29_TCP_DL&UL_speed	Inter-gNB handover (without CU-DU split)							√	
	TCA-GEN-30_UDP_DL_speed TCA-GEN-30_TCP_DL_speed TCA-GEN-30_UDP_UL_speed TCA-GEN-30_TCP_UL_speed TCA-GEN-30_UDP_DL&UL_speed TCA-GEN-30_TCP_DL&UL_speed	Intra Distributed Unit (DU) handover							√	
	TCA-GEN-31_UDP_DL_speed TCA-GEN-31_TCP_DL_speed TCA-GEN-31_UDP_UL_speed TCA-GEN-31_TCP_UL_speed	Intra Central Unit (CU) inter DU handover							√	

Test Case Category	Test Case (TC) ID	TC Name	GR-TR	ES-PT	DE	FI	FR	NL	CN	KR
	TCA-GEN-31_UDP_DL&UL_speed TCA-GEN-31_TCP_DL&UL_speed									
	TCA-GEN-32_UDP_DL_speed TCA-GEN-32_TCP_DL_speed TCA-GEN-32_UDP_UL_speed TCA-GEN-32_TCP_UL_speed TCA-GEN-32_UDP_DL&UL_speed TCA-GEN-32_TCP_DL&UL_speed	Inter CU handover						√	√	
Roaming	TCA-GEN-33_InterPLMN_HO_HR_TCP_DL TCA-GEN-33_InterPLMN_HO_HR_TCP_UL TCA-GEN-33_InterPLMN_HO_HR_UDP_DL TCA-GEN-33_InterPLMN_HO_HR_UDP_UL TCA-GEN-33_InterPLMN_HO_HR_TCP_DL&UL TCA-GEN-33_InterPLMN_HO_HR_UDP_DL&UL	5G NR Inter-PLMN HO (HR support)	√	√				√		
	TCA-GEN-34_InterPLMN_HO_LBO_TCP_DL TCA-GEN-34_InterPLMN_HO_LBO_TCP_UL TCA-GEN-34_InterPLMN_HO_LBO_UDP_DL TCA-GEN-34_InterPLMN_HO_LBO_UDP_UL TCA-GEN-34_InterPLMN_HO_LBO_TCP_DL&UL TCA-GEN-34_InterPLMN_HO_LBO_UDP_DL&UL	5G NR Inter-PLMN HO (LBO support)	√	√				√		
	TCA-GEN-35_InterPLMN_HO_TCP_DL_speed TCA-GEN-35_InterPLMN_HO_TCP_UL_speed TCA-GEN-35_InterPLMN_HO_UDP_DL_speed TCA-GEN-35_InterPLMN_HO_UDP_UL_speed TCA-GEN-35_InterPLMN_HO_TCP_DL&UL_speed TCA-GEN-35_InterPLMN_HO_UDP_DL&UL_speed	5G NR Inter-PLMN HO at various vehicular speeds		√						
Reliability	TCA-GEN-36_DL_Reliability	DL Reliability measurements	N/A	√	√			√		

Test Case Category	Test Case (TC) ID	TC Name	GR-TR	ES-PT	DE	FI	FR	NL	CN	KR
	TCA-GEN-37_UL_Reliability	UL Reliability measurements	N/A	√	√			√		

Based on Table 6.16, the generic test cases are grouped into the following categories:

I. Test Case Category: Single User Throughput

The test cases of this category are applicable to all CBCs and TSs, independent of the deployed architecture option (5G NSA or SA).

Table 6.17: Generic Test Cases – Single User Throughput Category.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-01_TCP_DL TCA-GEN-01_UDP_DL	Peak DL TCP/UDP Data Throughput of Single User (stationary use)	Measure the Peak Downlink TCP/UDP User Data Throughput of Single User	Perform a 5G data call in an empty cell under best RF conditions. TCA-GEN-01_TCP-DL: Start TCP DL data transfer and measure received DL throughput over 1 minute TCA-GEN-01_UDP-DL: Start UDP DL data transfer at x data rate and measure UDP throughput over 1 minute. x data rate will be defined e.g., 20% over the result obtained in TCA-GEN-01_TCP-DL
TCA-GEN-02_TCP_UL TCA-GEN-02_UDP_UL	Peak UL TCP/UDP Data Throughput of Single User (stationary use)	Measure the Peak Uplink TCP/UDP User Data Throughput of Single User	Perform a 5G data call in an empty cell under best RF conditions. TCA-GEN-02_TCP-UL: Start TCP UL data transfer and measure received UL throughput over 1 minute TCA-GEN-02_UDP-UL: Start UDP UL data transfer at x data rate and measure UDP throughput over 1 minute. x data rate will be defined e.g., 20% over the result obtained in TCA-GEN-02_TCP-UL
TCA-GEN-03_TCP_DL_No load	User Average DL Data Throughput in Mobile Use (Average Speed) - Unloaded conditions	Observe the user average data throughput performance when a user has an active DL TCP session and is moving along a predefined drive route at an average speed of x km/h (depending on vehicle type).	Selected drive test route should cover radio link conditions with SINR in the range from Excellent RF conditions value to Bad RF conditions value. Initiate a continuous DL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route.
TCA-GEN-04_TCP_UL_No load	User Average UL Data Throughput in Mobile Use (Average Speed) - Unloaded conditions	Observe the user average data throughput performance when a user has an active UL TCP session and is moving along a predefined drive route at an average speed of x km/h (depending on vehicle type).	Selected drive test route should cover radio link conditions with SINR in the range from Excellent RF conditions value to Bad RF conditions value. Initiate a continuous UL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route.
TCA-GEN-05_TCP_DL_x% load	User Average DL Data Throughput in Mobile Use	Observe the user average data throughput performance under loaded conditions when a user	Selected drive test route should cover radio link conditions with SINR in the range from Excellent RF conditions value to Bad RF conditions value.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
	(Average Speed) - Loaded conditions	has an active DL TCP session and is moving along a predefined drive route at an average speed of x km/h (depending on vehicle type).	Under loaded conditions, initiate a continuous DL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route.
TCA-GEN-o6_TCP_UL_x% load	User Average UL Data Throughput in Mobile Use (Average Speed) - Loaded conditions	Observe the user average data throughput performance under loaded conditions when a user has an active UL TCP session and is moving along a predefined drive route at an average speed of x km/h (depending on vehicle type).	Selected drive test route should cover radio link conditions with SINR in the range from Excellent RF conditions value to Bad RF conditions value. Under loaded conditions, initiate a continuous UL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route.
TCA-GEN-o7_TCP_DL_No load	User Average DL Data Throughput in Mobile Use (High Speed) - Unloaded conditions	Measure User average DL TCP Data Throughput in moving high speed (x km/h) user	All logs are started in UE before the call set up. Initiate a continuous DL TCP session on the reference UE while simulating moving at high speed (x km/h, depending on vehicle type). Get the average DL TCP throughput and related SINR.
TCA-GEN-o8_TCP_UL_No load	User Average UL Data Throughput in Mobile Use (High Speed) - Unloaded conditions	Measure User average UL TCP Data Throughput in moving high speed (x km/h) user	All logs are started in UE before the call set up. Initiate a continuous UL TCP session on the reference UE while simulating moving at high speed (x km/h, depending on vehicle type). Get the average UL TCP throughput.
TCA-GEN-o9_TCP_DL_x% load	User Average DL Data Throughput in Mobile Use (High Speed) - Loaded conditions	Measure User average DL TCP Data Throughput in moving high speed (x km/h) user under loaded conditions	All logs are started in UE before the call set up. Under loaded conditions, initiate a continuous DL TCP session on the reference UE while simulating moving at high speed (x km/h, depending on vehicle type). Get the average DL TCP throughput and related SINR.
TCA-GEN-10_TCP_UL_x% load	User Average UL Data Throughput in Mobile Use (High Speed) - Loaded conditions	Measure User average UL TCP Data Throughput in moving high speed (x km/h) user	All logs are started in UE before the call set up. Under loaded conditions, initiate a continuous UL TCP session on the reference UE while simulating moving at high speed (x km/h, depending on vehicle type). Get the average UL TCP throughput.
TCA-GEN-11_TCP_DL_x% load TCA-GEN-11_TCP_UL_x% load	User Average Data Throughput at the cell edge	Observe user average TCP data throughput at the cell edge	Load the neighbour interfering cell by configuring two mobile devices to transmit TCP sessions at maximum data rate in that neighbour cell. Select the test point in the serving cell edge area. After successful channel setup, start DLTCP data transfer and trace for 30s. Get the average DL TCP throughput and record RSRP, RSRQ, SINR, MIMO mode. Disconnect the UEs and save the logs. Repeat the procedure for 3 times and average the DL TCP throughput. Repeat the TC for UL.

II. Test Case category: Network Performance

The test cases of this category are applicable to all CBCs and TSs, independent of the deployed architecture option (5G NSA or SA).

Table 6.18: Generic Test Cases – Network Performance Category.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-12_TCP_DL_No Load	TCP DL Use case route performance	Measure coverage, DL Throughput and cell mobility in a UCC/US route	Select most relevant UC drive test routes. Initiate a continuous DL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route. Establish as many TCP connections as required (i.e., 8) to saturate the link (maximum DL throughput provided by the network). Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell IDs. Identify NAS and RRC procedures along the route to identify cell mobility (handover success rate, etc.)
TCA-GEN-13_TCP_UL_No Load	UL TCP Use case route performance	Measure coverage, UL Throughput and cell mobility in a UCC/US route	Select most relevant UC drive test routes. Initiate a continuous UL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route. Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell IDs. Identify NAS and RRC procedures along the route to identify cell mobility (handover success rate, etc.)
TCA-GEN-14_TCP_DL_Loaded	DL TCP Data Throughput along use case route with several "n" users	Measure DL Throughput and cell mobility in a UCC/US route with TCP protocol in the case of several users	Select most relevant UC drive test routes. Initiate a continuous DL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route. Configure "n" number of additional mobile devices to transmit DL TCP sessions at maximum data rate. Measure throughput and cell mobility along the route.
TCA-GEN-15_TCP_UL_Loaded	UL TCP Data Throughput along use case route with several "n" users	Measure coverage, UL Throughput and cell mobility in a UCC/US route with TCP protocol in the case of several users	Select most relevant UC drive test routes. Initiate a continuous UL TCP session on the reference UE, which moves at an average speed of x km/h. Configure "n" number of additional mobile devices to transmit DL TCP sessions at same data rate. Measure throughput and cell mobility along the route.
TCA-GEN-16_DL_Cell Capacity	DL Cell Capacity	Get the value of the Cell downlink throughput and	Unload the interfering cell. One UE successfully setups the channel and starts downlink TCP data transfer. Make other 3 UEs access the

Test Case ID	Test Case (TC) Name	Purpose	TC Description
		analyse the downlink capability in a single cell	target cell and start downlink TCP data transfer one by one. Observe the user throughput and RB occupied number change between before and after the fourth UE accesses the target cell. The three UEs (i.e., the initial UE and the two others) will occupy all RB resources, and the throughput of the former three UEs become lower after the fourth UE access and download. Keep the downlink services for 3 minutes, observe each UE TCP throughput, SINR/RSRP and compute the peak and average cell throughput in the downlink. Save the logs and disconnect the UEs.
TCA-GEN-17_UL_Cell Capacity	UL Cell Capacity	Get the value of the Cell uplink throughput and analyse the uplink capability in a single cell	Unload the interfering cell. One UE successfully setups the channel and starts uplink TCP data transfer. Make other 3 UEs access the target cell and start uplink TCP data transfer one by one. Keep the uplink services for 3 minutes, observe each UE TCP throughput, SINR/RSRP and compute the peak and average cell throughput in the uplink. Save the logs and disconnect the UEs.

III. Test Case Category: Latency

Taking into account that each CBC/TS deployed either the 5G NSA or the 5G SA architecture option, all of the test cases are prepared to be applicable to both deployed architecture options (5G NSA and SA), whereas the last two test cases of Table 6.19, referring to Test Case IDs “TCA-GEN-21_CP Latency_UE triggered” and “TCA-GEN-22_CP Latency_Network triggered”, are valid only for the SA deployment option.

Table 6.19: Generic Test Cases – Latency Category.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-18_PING_No load_MTU size	User Plane Latency in Unloaded Cell (e2e)	Measure the U-Plane latency (e2e) for various x-bytes ping in unloaded network	User is located near to the gNB so that it operates under good RF conditions. Start trace logs in the UE and the S1 interface. Perform ping of size 32 bytes with at least 50 echo requests. Target address for the ping is the application server: ping -32 50 <AS IP-address>. Record the maximum, minimum and average value. Disconnect the UE and save the logs. Repeat the test case for 1400 bytes ping.
TCA-GEN-19_PING_x% load_MTU size	User Plane Latency in Loaded Cell (e2e)	Measure the U-Plane latency (e2e) for various x-bytes ping in loaded network	User is located near the gNB so that it operates under good RF conditions. Start trace logs in the UE and the S1 interface. Perform ping of size 32 bytes with at least 50 echo requests. Target address for the ping is the application server: ping -32 50 <AS IP-address>. Record the maximum, minimum and average value. Disconnect the UE and save the logs. Repeat the test case for 1400 bytes ping.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-20_CP Latency	Control Plane Latency (NR RRC Idle -> NR Connected)	Measure the state transition latency (NR RRC Idle -> NR Connected)	In the serving cell, start UE trace and UE power cycle. Core Network initiates UE Context Release Command messages, and then UE transmits idle state. Ping a server on the Core Network to trigger a service request from the UE. Stop UE trace. Based on the UE log, evaluate the transition time (Transition time at UE side = Time of last "RRC reconfiguration complete" – Time of "RRC Setup Request"). Repeat the above-mentioned steps n times.
TCA-GEN-21_CP Latency_UE triggered	Control Plane Latency (NR RRC_INACTIVE -> NR RRC_CONNECTED, UE triggered)	Measure the state transition latency (NR RRC_INACTIVE -> NR RRC_CONNECTED, UE triggered)	In the serving cell, ensure UE is in Inactive State and moved from its last Serving gNB to under the coverage of another gNB (actual). Start UE and gNB traces. Ping a server on the 5G Core Network to trigger a service request from the UE. Stop traces. Based on the UE and gNB logs, evaluate the transition time: (Transition time = "Path Switch Request Response" at g-NodeB – Time of "RRC Connection Resume Request" at UE side). Repeat the previous steps n times.
TCA-GEN-22_CP Latency_Network triggered	Control Plane Latency (NR RRC_INACTIVE -> NR RRC_CONNECTED, Network triggered)	Measure the state transition latency (NR RRC_INACTIVE -> NR RRC_CONNECTED, Network triggered)	In the serving cell, ensure UE is in Inactive State. Start UE and gNB traces. Trigger a RAN paging event (e.g., in initiating an incoming DL user plane). Observe that the UE switches to Connected mode. Stop the UE trace. Based on the UE and gNB logs, evaluate the transition time: (Transition time = Time of "Resuming from RRC Inactive" – "Paging UE Message"). Repeat previous steps n times.

IV. Test Case Category: Mobility

Taking into account that each CBC/TS deployed either the 5G NSA or the 5G SA architecture option depending on its current plans, only one of the mobility test case sets will be applied, grouped as in Table 6.19 and Table 6.20 for the 5G NSA and the SA networks, respectively.

Table 6.20: Generic Test Cases – NSA Mobility.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-23_TCP_DL_speed TCA-GEN-23_TCP_UL_speed TCA-GEN-23_TCP_DL&UL_speed	Intra-cell mobility (at different speed ranges)	Verify the impact of vehicular speed on intra-cell mobility	A UE is successfully attached to the 5G network and starts uploading/downloading data (e.g., from an FTP server.) The UE starts moving following a selected route (between two specific measurement points of a cell). The speed should remain the same during the testing. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Repeat the test case with different vehicular speeds.
TCA-GEN-24_TCP_DL TCA-GEN-24_TCP_UL TCA-GEN-24_TCP_DL&UL	Intra MeNB mobility: MeNB same, SgNB different	Evaluate possible mobility interruption time	A UE is under the coverage of SgNB1 and starts uploading/downloading data (e.g., from an FTP server.) The UE starts moving away from gNB1 until it is served under the coverage of gNB2. Both gNB1 and gNB2 should have the same MeNB. The speed should remain the same

Test Case ID	Test Case (TC) Name	Purpose	TC Description
			during the testing. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR.
TCA-GEN-25_Handover	Inter-MeNB handover without SgNB change triggered by MeNB	Measure the user plane handover interruption time.	Perform an EN-DC call using an LTE cell that has configured LTE neighbour cells. Both LTE cells have EN-DC neighbours from the same gNB. Start DL and UL data transfer. Perform an LTE inter-eNB HO. The target eNB is sending an SgNB addition request to the gNB including the gNB UE X2 AP ID as reference to the UE context in the gNB. Measure the user plane handover interruption time.
TCA-GEN-26_Handover	Inter-MeNB handover no SgNB scenario	Measure the user plane handover interruption time.	Perform an EN-DC call using an LTE cell that has configured LTE neighbour cells. Both LTE cells have EN-DC neighbours from the same gNB. Start DL and UL data transfer. Perform an LTE inter-eNB HO. The target eNB is sending a SgNB addition request to the gNB including the gNB UE X2 AP ID as reference to the UE context in the gNB. Measure the user plane handover interruption time.

Table 6.21: Generic Test Cases – SA Mobility.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-27_UDP_DL_speed TCA-GEN-27_TCP_DL_speed TCA-GEN-27_UDP_UL_speed TCA-GEN-27_TCP_UL_speed TCA-GEN-27_UDP_DL&UL_speed TCA-GEN-27_TCP_DL&UL_speed	Intra-cell mobility (at different speed ranges)	Verify the impact of vehicular speed on intra-cell mobility	A UE is successfully attached to the 5G network and starts uploading/ downloading data (e.g., from an FTP server.) The UE starts moving following a selected route (between two specific measurement points of a cell). The speed should remain the same during the testing. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Repeat the test case with different vehicular speeds.
TCA-GEN-28_UDP_DL_speed TCA-GEN-28_TCP_DL_speed TCA-GEN-28_UDP_UL_speed TCA-GEN-28_TCP_UL_speed TCA-GEN-28_UDP_DL&UL_speed TCA-GEN-28_TCP_DL&UL_speed	Inter-cell mobility: intra-gNB handover (without CU-DU split)	Evaluate inter-cell mobility & measure possible interruption time	A UE is successfully attached to the 5G network and starts uploading/ downloading data (e.g., from an FTP server.) The UE starts moving from Cell 1 to Cell 2 at different vehicular speed ranges. Cell 1 and Cell 2 are in the same gNB. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR.
TCA-GEN-29_UDP_DL_speed TCA-GEN-29_TCP_DL_speed TCA-GEN-29_UDP_UL_speed TCA-GEN-29_TCP_UL_speed TCA-GEN-29_UDP_DL&UL_speed TCA-GEN-29_TCP_DL&UL_speed	Inter-gNB handover (without CU-DU split)	Evaluate the successful handover & measure possible interruption time	A UE is successfully attached to the 5G network and starts uploading/ downloading data (e.g., from an FTP server.) The UE starts moving from Cell 1 to Cell 2 at different vehicular speed ranges. Cell 1 and Cell 2 are in different gNBs. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR.
TCA-GEN-30_UDP_DL_speed TCA-GEN-30_TCP_DL_speed TCA-GEN-30_UDP_UL_speed TCA-GEN-30_TCP_UL_speed TCA-GEN-30_UDP_DL&UL_speed TCA-GEN-30_TCP_DL&UL_speed	Intra Distributed Unit (DU) handover	Evaluate the successful handover & measure possible interruption time	A UE is successfully attached to the 5G network and starts uploading/ downloading data (e.g., from an FTP server.) The UE starts moving from Cell 1 to Cell 2 at different vehicular speed ranges. Cell 1 and Cell 2 are in same the DU. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-31_UDP_DL_speed TCA-GEN-31_TCP_DL_speed TCA-GEN-31_UDP_UL_speed TCA-GEN-31_TCP_UL_speed TCA-GEN-31_UDP_DL&UL_speed TCA-GEN-31_TCP_DL&UL_speed	Intra Central Unit (CU) inter DU handover	Evaluate the successful handover & measure possible interruption time	A UE is successfully attached to the 5G network and starts uploading/ downloading data (e.g., from an FTP server.) The UE starts moving from Cell 1 to Cell 2 at different vehicular speed ranges. Cell 1 and Cell 2 are under the same CU but different DUs. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR.
TCA-GEN-32_UDP_DL_speed TCA-GEN-32_TCP_DL_speed TCA-GEN-32_UDP_UL_speed TCA-GEN-32_TCP_UL_speed TCA-GEN-32_UDP_DL&UL_speed TCA-GEN-32_TCP_DL&UL_speed	Inter CU handover	Evaluate the successful handover & measure possible interruption time	A UE is successfully attached to the 5G network and starts uploading/ downloading data (e.g., from an FTP server.) The UE starts moving from Cell 1 to Cell 2 at different vehicular speed ranges. Cell 1 and Cell 2 are in different CUs. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR.

V. Test Case Category: Roaming

The test cases of this category are applicable to all CBCs and TSs, independent of the deployed architecture option (5G NSA or SA).

Table 6.22: Generic Test Cases – Roaming Category.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-33_InterPLMN_HO_HR_TCP_DL TCA-GEN-33_InterPLMN_HO_HR_TCP_UL TCA-GEN-33_InterPLMN_HO_HR_UDP_DL TCA-GEN-33_InterPLMN_HO_HR_UDP_UL TCA-GEN-33_InterPLMN_HO_HR_TCP_DL&UL TCA-GEN-33_InterPLMN_HO_HR_UDP_DL&UL	5G NR Inter-PLMN HO (HR support)	Measure the handover interruption time (e.g., i. via GRX, ii. Direct interconnection)	HR is supported by both H-PLMN & V-PLMN. A UE close to the border has a DL and/or UL 5G data session at its H-PLMN. It follows a specific drive route in order to roam into the 5G network of V-PLMN, while having the DL/UL session. Verify whether there is a service discontinuity and measure possible service interruption time. The TC is repeated from V-PLMN to H-PLMN following the same route. The vehicular speed should be the same in both directions. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Perform the test case with SIM cards from H-PLMN and V-PLMN.
TCA-GEN-34_InterPLMN_HO_LBO_TCP_DL TCA-GEN-34_InterPLMN_HO_LBO_TCP_UL TCA-GEN-34_InterPLMN_HO_LBO_UDP_DL TCA-GEN-34_InterPLMN_HO_LBO_UDP_UL TCA-GEN-34_InterPLMN_HO_LBO_TCP_DL&UL TCA-GEN-34_InterPLMN_HO_LBO_UDP_DL&UL	5G NR Inter-PLMN HO (LBO support)	Measure the handover interruption time (e.g., i. via GRX, ii. Direct interconnection)	LBO is configured by both H-PLMN & V-PLMN. A UE close to the border has a DL and/or UL 5G data session at its H-PLMN. It follows a specific drive route in order to roam into the 5G network of V-PLMN, while having the DL/UL session. Verify whether there is a service discontinuity and measure possible service interruption time. The TC is repeated from V-PLMN to H-PLMN following the same route. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Perform the test case with SIM cards from H-PLMN and V-PLMN.
TCA-GEN-35_InterPLMN_HO_TCP_DL_speed TCA-GEN-35_InterPLMN_HO_TCP_UL_speed TCA-GEN-	5G NR Inter-PLMN HO at various	Analyse the impact of vehicular speed on roaming	A UE close to the border has a DL 5G data session at its H-PLMN. It follows a specific drive route in order to roam into the 5G network of V-PLMN, while having the DL session. Verify whether there is a service

Test Case ID	Test Case (TC) Name	Purpose	TC Description
35_InterPLMN_HO_UDP_DL_speed TCA-GEN- 35_InterPLMN_HO_UDP_UL_speed TCA-GEN- 35_InterPLMN_HO_TCP_DL&UL_spe ed TCA-GEN- 35_InterPLMN_HO_UDP_DL&UL_sp eed	vehicular speeds (HR and /or LBO support)		discontinuity and measure possible service interruption time. The TC is repeated for various speed ranges and from V-PLMN to H-PLMN following the same route. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Repeat the TC for an UL 5G data session. Perform the test case with SIM cards from H-PLMN and V-PLMN.

VI. Test Case Category: Reliability

The test cases of this category are applicable to all CBCs and TSs, independent of the deployed architecture option (5G NSA or SA).

Table 6.23: Generic Test Cases – Reliability Category.

Test Case ID	Test Case (TC) Name	Purpose	TC Description
TCA-GEN-36_DL_Reliability	DL Reliability measurements	Measure DL packet loss rates at different data rates	Select the most relevant UC drive test routes. Perform a continuous DL UDP transmission. Measure packet loss along the route. Measurement repeated at several data rates (i.e., 200 Mbps, 150 Mbps, 100 Mbps, 50 Mbps)
TCA-GEN-37_UL_Reliability	UL Reliability measurements	Measure UL packet loss rates at different data rates	Select the most relevant UC drive test routes. Perform a continuous UL UDP transmission. Measure packet loss along the route. Measurement repeated at several data rates (i.e., 20 Mbps, 15 Mbps, 10 Mbps, 5 Mbps)

6.2.2 Specific Network Testing

This section incorporates the specific network testing items planned to be tested by each CBC/TS taking into account the special characteristics of their deployed network topologies.

6.2.2.1 ES-PT CBC Specific Network Testing

Table 6.24: ES-PT CBC Specific Test Cases.

Test Case Category	Test case ID	Test Case (TC) Name	Purpose	TC Description
Roaming	TCA-ES-PT-01	Hybrid Roaming Latency analysis (if PT is able to upgrade to SA) to select the best option (LBO, HR)	Measuring the roaming latency to select the best roaming option (LBO, HR) between a 5G SA network and 5G NSA network.	Obtaining latency value to assess the best roaming option (LBO, HR) between a 5G SA network and 5G NSA network. LBO & HR are both options to be considered per user story.
	TCA-ES-PT-02	Impact of the distance on Home Routed (if possible) analysis	Analysing the impact of the distance on Home Routed roaming type.	Obtaining roaming latency values at different locations (distance1, distance2, distance3...) and evaluating the impact

Test Case Category	Test case ID	Test Case (TC) Name	Purpose	TC Description
				of the distance on the Home routed roaming latency.
Handover	TCA-ES-PT-03	Impact of grey areas on handover	Measuring the handover features in grey areas	Measuring the handover features in grey areas. Throughput continuity and latency will be evaluated.
Inter-MEC Connectivity	TCA-ES-PT-04	IP transition between MECs analysis	Evaluating Inter-MEC connectivity	User traffic will be forwarded from one MEC to another and the latency will be measured.
Performance	TCA-ES-PT-05	Network performance under stress conditions	Evaluating performance continuity	Evaluating throughput continuity in stressing conditions (including more users per cell, tests in cell edge, etc).
	TCA-ES-PT-06	DL UDP Performance of Single User across a route	Measure the UDP Throughput, latency and packet loss of Single User the network is able to provide across a route in DL	Perform a continuous DL UDP transmission. Establish a UDP traffic session transmitting continuously data at a speed slightly above the peak throughput measured during the TCP session Measure DL throughput along the route. This TC can be run together with TCA-GEN-36_DL_Reliability.
	TCA-ES-PT-07	UL UDP Performance of Single User across a route	Measure the UDP Throughput, latency and packet loss of Single User the network is able to provide across a route in UL	Perform a continuous UL UDP transmission. Establish a UDP traffic session transmitting continuously data at a speed slightly above the peak throughput measured during the TCP session. Measure UL throughput, latency and packet loss along the route. This TC can be run together with TCA-GEN-37_UL_Reliability
	TCA-ES-PT-08	DL UDP Performance across a route, several users	Measure the UDP Throughput, latency and packet loss the network is able to provide across a route in DL with several users	Same as TCA-ES-PT-06, but after user starts transmitting DL data, other users (i.e., 2 devices) also start downloading data (TCP protocol)
	TCA-ES-PT-09	UL UDP Performance across a route, several users	Measure the UDP Throughput, latency and packet loss the network is able to provide across a route in UL with several users	Same as TCA-ES-PT-07, but after user starts transmitting UL data, other users (i.e., 2 devices) also start uploading data (TCP protocol)

6.2.2.2 GR-TR CBC Specific Network Testing

Table 6.25: GR-TR CBC Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
NSA Mobility	TCA-GR-TR-01_Handover	Inter-MeNB handover with SgNB change triggered by MeNB	Evaluate possible mobility interruption time	LTE HO with SN change.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
	TCA-GR-TR-02_Handover	NSA Inter-RAT Mobility: Secondary Node Addition	Evaluate possible mobility interruption time. See service continuity.	Perform a data call using an LTE cell that has configured LTE neighbour cells. The target LTE cell does have an EN-DC neighbour. Start DL and UL data transfer. Perform an LTE HO. As part of the LTE HO procedure the target eNB will trigger the SgNB addition procedure.
	TCA-GR-TR-03_Handover	NSA Inter-RAT Mobility: Secondary Node Release	Measure the user plane handover interruption time. See service continuity.	Perform an EN-DC call using an LTE cell that has configured LTE neighbour cells. The target LTE cell does not have an EN-DC neighbour. Start DL and UL data transfer. Perform an LTE inter-eNB HO. As part of the LTE HO procedure the SgNB will be released. The SgNB release procedure will be triggered by the MeNB in the initial phase of the intra-LTE HO. Verify that there is service continuity
Roaming	TCA-GR-TR-06_InterPLMN_HO_HR	HR without Session continuity	Verify possible service degradation and measure the handover interruption time	Perform an inter-PLMN HO for a 5G NR UE. HR deployment is configured. No equivalent PLMN configuration on MMEs.
	TCA-GR-TR-07_InterPLMN_HO_HR	HR with session release and redirect	Verify possible service degradation and measure the handover interruption time	Perform an inter-PLMN HO for a 5G NR UE. HR deployment is configured, neighbouring PLMNs (roaming partner) are configured as Equivalent PLMNs (ePLMN) on MME. In the feature "Release with Redirect" the ePLMNs are used both by the eNodeB and the UE.
	TCA-GR-TR-08_InterPLMN_HO_LBO	LBO without Session continuity	Verify possible service degradation and measure the handover interruption time	Perform an inter-PLMN HO for a 5G NR UE. LBO deployment is configured. No equivalent PLMN configuration on MMEs.
	TCA-GR-TR-09_InterPLMN_HO_LBO	LBO with session release and redirect	Verify possible service degradation and measure the handover interruption time	Perform an inter-PLMN HO for a 5G NR UE. LBO deployment is configured, while neighbouring PLMNs (roaming partner) are configured as Equivalent PLMNs (ePLMN) on MME. In the feature "Release with Redirect" the ePLMNs are used both by the eNodeB and the UE.

6.2.2.3 DE TS Specific Network Testing

Table 6.26: DE TS Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Network Performance	TCA-DE-01	User Average Data UL/DL Throughput with max. number of users in the DE-TS	Observe the user average data throughput performance when several users have an active TCP session within the same cell	Perform an iperf3 test simultaneously from various UEs in an empty cell under best RF conditions with reverse option activated (-R) to test in both directions. Deploy an iperf3 server near to the TS.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Handover	TCA-DE-02	Handover disconnection time NSA-SA	Measuring the time of disconnection when a handover procedure between NSA-SA networks is done	Download file from the application server and measure time of disconnection when handover procedure happens between two 5G networks (NSA <-> SA)
	TCA-DE-03	Impact of speed on handover	Measuring the handover latency when the vehicle is driven supporting different speeds.	Obtaining handover latency values at different speeds (speed1, speed2, speed3...) and evaluating the impact of the speed on roaming.

6.2.2.4 FI TS Specific Network Testing

Table 6.27: FI TS Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Multi-SIM	TCA-FI-01	Inter-PLMN HO performance	Measurement of roaming latency between two PLMNs (5G NSA or SA networks) using multi-SIM OBU	Perform an inter-PLMN HO between two PLMNs using multi-SIM OBU based on performance-related preconfigured handover criteria. Measurements focus on observing the experienced throughput, latency, packet loss for the OBU before/during/after HO executed.
	TCA-FI-02	Multi-PLMN redundancy performance	Measurement performance achieved when multi-SIM connection is simultaneously active over 2 PLMNs	Test performance experienced when simultaneously connected to two PLMNs using multi-SIM OBU. Measurements focus on observing the experienced throughput, latency, and packet loss for the OBU throughout the test route, also identifying segments with single and dual PLMN connectivity.

6.2.2.5 FR TS Specific Network Testing

Table 6.28: FR TS Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Handover	TCA-FR-01	Inter-PLMN (5G cmWave to 5G cmWave) HO Success rate	Analyse Inter-PLMN (5G cmWave to 5G cmWave) HO Success Rate by calculating the number of successful HO procedures among all triggered HO	TEQMO Centre contains a predefined drive test route that traverses overlapped coverage areas of two cmWave 5G PLMNs. A connected vehicle initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
				overlapping zone, the vehicle will trigger a HO to the target gNB.
	TCA-FR-02	Inter-PLMN (5G cmWave to 5G mmWave) HO Success Rate	Analyse Inter-PLMN (5G cmWave to 5G mmWave) HO Success Rate by calculating the number of successful HO procedures among all triggered HOs.	TEQMO Centre contains a predefined drive test route that traverses overlapped coverage areas of a cmWave and a mmWave 5G PLMN. A connected vehicle initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the overlapping zone, the vehicle will trigger a HO to the target gNB.
	TCA-FR-03	Inter-PLMN (5G cmWave to 5G mmWave) HO Success Rate	Analyse Inter-PLMN (5G cmWave to 5G mmWave) HO Success Rate by calculating the number of successful HO procedures among all triggered HOs.	Satory site contains a predefined drive test route that traverses overlapped coverage areas of a cmWave and a mmWave 5G PLMN. A connected vehicle initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the overlapping zone, the vehicle will trigger a HO to the target gNB.
	TCA-FR-04	Inter-PLMN (5G mmWave to 5G cmWave) HO Success Rate	Analyse Inter-PLMN (5G mmWave to 5G cmWave) HO Success Rate by calculating the number of successful HO procedures among all triggered HO	Satory site contains a predefined drive test route that traverses overlapped coverage areas of a cmWave and a mmWave 5G PLMN. A connected vehicle initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the overlapping zone, the vehicle will trigger a HO to the target gNB.
	TCA-FR-05	Inter-PLMN (5G NSA to 4G) HO Success Rate	Analyse Inter-PLMN (5G NSA to 4G) HO Success Rate by calculating the number of successful HO procedures among all triggered HOs	TEQMO Centre contains a predefined drive test route that traverses overlapped coverage areas of two PLMNs (5G NSA and 4G). A connected vehicle attached to 5G NSA gNB initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the overlapping zone, the vehicle will trigger a HO to the target eNB.
	TCA-FR-06	Inter-PLMN (4G to 5G NSA) HO Success Rate	Analyse Inter-PLMN (4G to 5G NSA) HO Success Rate by calculating the number of successful HO procedures among all triggered HOs	TEQMO Centre and Satory site contain predefined drive test routes that traverse overlapped coverage areas of two PLMNs (5G NSA and 4G). A connected vehicle attached to 4G eNB initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the overlapping zone, the vehicle will trigger a HO to the target gNB.
	TCA-FR-07	Inter-PLMN (5G mmWave to 4G) HO Success Rate	Analyse Inter-PLMN (5G mmWave to 4G) HO Success Rate by calculating the number of successful HO procedures among all triggered HOs	Satory site contains a predefined drive test route that traverses overlapped coverage areas of two PLMNs (5G NSA and 4G). A connected vehicle attached to 4G eNB initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the overlapping zone, the vehicle will trigger a HO to the target eNB.
Inter-system Handover	TCA-FR-08	5G terrestrial to sat technology (5G to satellite)	Analyse 5G terrestrial to sat technology (5G to satellite) HO Success Rate	TEQMO Centre and Satory site contain predefined drive test routes that traverses the covered area of 5G NSA PLMN. A connected vehicle attached to

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
		HO Success Rate	by calculating the number of successful HO procedures among all triggered HOs	5G eNB initiates a continuous UL TCP/UDP session while moving at an average speed of ~50 km/h (speed limit on the selected road). When arriving to the 5G coverage edge, the vehicle will scan the available technologies in order to find a target one. The satellite coverage is large scale and is almost omnipresent. This technology can be used when there is a coverage gap.
Multi-SIM	TCA-FR-09_MultiSIM	Redundant connection using Multi-SIM (5G mmWave and 4G)	Evaluate redundant connection simultaneous availability using Multi-SIM (5G mmWave and 4G) communications from the vehicle	The vehicle is equipped with dual SIM (5G mmWave and 4G). Redundant connection is ensured by simultaneous attachment to both of networks
Service Continuity	TCA-FR-10	Inter-MEC service continuity	Analyse service continuity by measuring the service interruption time when AV is changing the serving MEC when carrying out the HO.	Each MNO of the test sites has its own MEC. When the vehicle executes inter PLMN HO, it quits the serving area of the first MEC. MEC application status and context shall be transferred to the next serving MEC.
MEC processing	TCA-FR-11	Real-time MEC Multi-tier processing	Analyse real-time data processing performances (processing time, CPU load) for bare metal MEC and cloud-MEC installations. Load balancing between the Edge MEC and cloud servers can also be tested.	In addition to the MEC deployed at the edge, cloud servers can also be used in case of huge data processing (if the EDGE MEC CPU reaches a certain threshold). This can offload the edge MEC and provide more resources for the processing.

6.2.2.6 NL TS Specific Network Testing

Table 6.29: NL TS Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Slicing	TCA-NL-01	Slice Isolation	Verify slices can be isolated from each other	Analyse 1) impact of large throughput in one slice on the latency in the other slice, 2) impact of large number of low-latency messages in one slice on bandwidth of the other slice.
	TCA-NL-02	Slicing Overhead	Analyse impact/overhead of slicing on overall bandwidth	Analyse overhead of slicing by comparing the overall bandwidth used without slicing and with different slice configurations.

6.2.2.7 CN TS Specific Network Testing

Table 6.30: CN TS Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Network Performance	TCA-CN-01	Data rate of OBU and MEC with different communication technologies (4G/5G/DSRC)	Analyse the experienced data rate of the use case with variations in the communications technology (4G/5G/DSRC).	Measure the data rate of the OBU and the MEC in test cases by deploying different communication technologies (4G/5G/DSRC) to compare their performance.
Mobility	TCA-CN-02	Uplink and downlink of cross-network (4G to 5G SA) handover	A vehicle moves from area 1 covered by 5G to area 2 covered by LTE-V without 5G to achieve cross-network handover. Process the uplink and downlink data.	The vehicle connected to 5G SA will initiate a continuous UL TCP/UDP session while moving at an average speed of ~60km/h to another area covered by 4G. Record and analyse the uplink and downlink data when the vehicle is in the handover process.
Roaming	TCA-CN-03	Uplink and downlink of cross-network (5G with different MNO) handover	A vehicle moves from area 1 covered by 5G to area 2 covered 5G to achieve cross-network handover. Process the uplink and downlink data.	The vehicle connected to 5G SA will initiate a continuous UL TCP/UDP session while moving at an average speed of ~60km/h to another area covered by different 5G MNO. Record and analyse the uplink and downlink data when the vehicle is in the cross-network process.
Latency	TCA-CN-04	Latency between OBUs in platoon under different communication technologies (4G/5G/DSRC)	Analyse end to end latency between an OBU and another in the same platoon, depending on the communications technology used (4G/5G/DSRC).	Measure the end-to-end latency of an OBU and another one in the test cases for cloud-assisted platoon, where different communication technologies (4G/5G/DSRC) are deployed and compare their performance.
	TCA-CN-05	Latency between OBU and MEC in a platoon under different communication technologies (4G/5G/DSRC)	Analyse end to end latency between an OBU and a MEC in platoon, depending on the communications technology used (4G/5G/DSRC).	Measure the end-to-end latency of an OBU and a MEC in the test cases for cloud-assisted platoon, where different communication technologies are (4G/5G/DSRC) deployed and compare their performance.

6.2.2.8 KR TS Specific Network Testing

Table 6.31: KR TS Specific Test Cases.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
Throughput	TCA-KR-01	Per-vehicle data rate	Verify the maximum data rate achieved at a vehicle	Per-vehicle data rate measurement is done by displaying data rate on a diagnostic monitor connected to the vehicle terminal. Per-vehicle data rate can be used to show the ability of supporting high data rate service to passengers in a vehicle.
	TCA-KR-02	Per-RSU data rate	Verify the maximum data rate achieved at an RSU	Per-RSU data rate measurement is done by summing per-vehicle data rates displayed at each vehicle. Per-RSU data rate can be used to show the ability of supporting high data rate wireless backhaul links to vehicles.

Test Case Category	Test Case ID	Test Case (TC) Name	Purpose	TC Description
			supporting multiple vehicles	
Latency	TCA-KR-03	User plane latency	Verify the time to successfully deliver an application layer packet	User plane latency measurement is done by displaying user plane latency on a terminal controller connected to a vehicle terminal. User plane latency can be used to show the latency related QoS when supporting Tethering via Vehicle use case to vehicle passengers.
	TCA-KR-04	Control plane latency	Verify the time the state of a vehicle UE is moved from an idle state to an active state	Control plane latency measurement is done by displaying control plane latency on a terminal controller connected to a vehicle terminal. Control plane latency can be used to show the latency related QoS when supporting Tethering via Vehicle use case to vehicle passengers.
Handover	TCA-KR-05	Handover latency	Verify the time during which the wireless service at a vehicle is interrupted due to handover	Handover latency measurement is done by displaying handover interruption time on a terminal controller connected to a vehicle terminal.

6.3 5G Network Testing Results

This section presents the initial test results of the 5G network test cases performed by the CBCs. At the time of D3.3 submission, network testing is ongoing at most CBCs & TSs according to the five-phase plan and availability of test results is limited to initial and partial results. A full set of test results will be available after the completion of phase three and will be reported in D3.7 and included in the evaluation studies of WP5.

6.3.1 ES-PT CBC Results

A set of preliminary measurements have been performed at the ES-PT CBC and at one (local) ES-PT site with 5G coverage to get an estimation of the 5G network performance at the cross-border area and to compare it with the performance of 5G at other locations.

6.3.1.1 ES side Results

Several test cases have been performed at the local ES site Malaga TechPark area, see Figure 6.34, where a 5G network is available. Test cases include UDP and TCP protocols, and tests have been performed in both the downlink (DL) and the uplink (UL) directions. The main objective of the test cases was to measure the performance of the network in terms of throughput, and also to obtain the first latency and reliability measurements at the predefined drive routes, where the use cases will be trialled.

Test cases have been performed in two different sessions: August 2020 and September 2020. The summary of the results is compiled in Table 6.32. Information on the individual test cases with the relevant results can be found in Annex G, specifically in Table G.46 through Table G.52.



Figure 6.34: Malaga TechPark test locations and general view of test area (left); Testing drive route at DEKRA testing track (right)

Table 6.32: Summary of the test results on the ES side (August and September 2020).

Test Case ID	Test Case (TC) Name	Stationary/ Mobility TC	TC Result ²
TCA-GEN-01_TCP_DL	Peak DL TCP/UDP Data Throughput of Single User (stationary use)	Stationary	429.5 Mbps
TCA-GEN-02_TCP_UL	Peak UL TCP/UDP Data Throughput of Single User (stationary use)	Stationary	27.6 Mbps
TCA-GEN-12_TCP_DL_No Load	TCP DL Use case route performance	Mobility	Average DL: 197.7 Mbps
TCA-GEN-13_TCP_UL_No Load	UL TCP Use case route performance	Mobility	Average UL: 23.4 Mbps
TCA-GEN-18_PING_No load_MTU size	User Plane Latency in Unloaded Cell (e2e)	Stationary	Min RTT (ms): 23 ms
TCA-GEN-20_CP Latency	Control Plane Latency (NR RRC Idle - > NR Connected)	Stationary	1.343s
TCA-GEN-37_UDP_UL	UL Reliability and latency measurements	Mobility	Packet Loss Rate: 0.01 (at 5Mbps)

6.3.1.2 ES-PT cross border area Results

A set of measurements were taken in late February 2020. At that stage, the 5G Spanish side network had just been deployed and the configuration of the network was not completely fine-tuned. It was assumed at that time that the performance results would not be very good, but the tests would show the issues to be solved.

² Maximum throughput values (Mbps) are shown in the summary table. Additional measurements results are depicted in the individual test case tables in Annex G.

The network tests were performed at the old bridge and the new bridge (highway) that link Tui (Spain) and Valença (Portugal) locations as shown in Figure 6.35. Some measurements were also obtained at the highway in Porriño, where there is also 5G network coverage. It should be noted that PT network was not used for these test cases. In fact, all test cases were performed using ES PLMN ID. The table below lists the preliminary test cases executed at the ES-PT CBC. The results obtained in each of these test cases are shown in Table G.53 to Table G.57 of Annex G.



Figure 6.35: ES-PT Test locations and a general view of the test area.

Table 6.33: ES-PT CBC TC results.

Test Case ID	Test Case (TC) Name	TC Location	TC Result
TCA-GEN-12_TCP_DL_No Load	TCP DL Use case route performance	Old bridge New bridge	AVG DL TCP (Old Bridge): 58.5 Mbps AVG DL TCP (New Bridge): 12.5 Mbps Please check Table G.53 & Table G.54
TCA-GEN-13_TCP_UL_No Load	UL TCP Use case route performance	Porriño	AVG UL TCP: 11.9 Mbps Please check Table G.55
TCA-GEN-23_TCP_DL_speed	Intra-cell mobility (at different speed ranges)	Old bridge New bridge	Please check Table G.56 & Table G.57

6.3.2 GR-TR CBC Results

6.3.2.1 GR side Results

No test results from the GR side are available as of this moment. Test results from the GR side will be reported in D3.7 after the completion of phase 3 of the roll-out plan.

6.3.2.2 TR side Results

A set of preliminary test cases has been performed during September 2020 on the TR side, and specifically in the area close to the Ford Otosan Eskisehir-Inonu factory, which is not close to the border area. In fact, a 2-sector trial site has been installed covering the testing route, which consists of the D650 highway and the Ford Otosan plant test area. A general view of the test area is depicted in Figure 6.37: Test locations and general view of the test area for the Ford Otosan plant site.



Figure 6.36: General view of the NR site location serving the Ford Otosan plant (TR)



Figure 6.37: Test locations and general view of the test area for the Ford Otosan plant site

The table below shows the test cases performed and the average value of the test cases' results, where applicable. It should be noted that for all test cases, the Oppo Find X2 smartphone (UE category 19) and Accuver XCAL drive testing tool were used. Detailed information about the test cases performed and the results obtained can be found in Section G2.1 of the Annex.

Table 6.34: TR side TC Results

Test Case ID	Test Case (TC) Name	Stationary/Mobility TC	Test Case Result
TCA-GEN-01_TCP_DL	Peak DL TCP/UDP Data Throughput of Single User (stationary use)	Stationary	DL TCP: 712.1 Mbps
TCA-GEN-01_UDP_DL			DL UDP: 712.5 Mbps
TCA-GEN-02_TCP_UL	Peak UL TCP/UDP Data Throughput of Single User (stationary use)	Stationary	UL TCP: 75.56 Mbps
TCA-GEN-02_UDP_UL			UL UDP: 93.07 Mbps
TCA-GEN-03_UDP (Avg)	User Average Data Throughput in Mobile Use (Average Speed)	Mobility	DL UDP: 418,7 Mbps
TCA-GEN-03_UDP (Max)			DL UDP: 638,1 Mbps
TCA-GEN-11_UDP_DL	User Average Data Throughput at the cell edge (<i>NO LOAD</i>)	Mobility	DL UDP: 16.73Mbps
TCA-GEN-11_UDP_UL			UL UDP: 13.1 Mbps
TCA-GEN-16_DL_Cell Capacity	DL Cell Capacity	Stationary	Please check Table G.63
TCA-GEN-17_UL_Cell Capacity	UL Cell Capacity	Stationary	Please check Table G.64
TCA-GEN-18_PING_No load_MTU size	User Plane Latency in Unloaded Cell (RAN & e2e)	Mobility	AVG = 53.99 msec
TCA-GEN-20_CP Latency	Control Plane Latency (NR RRC Idle -> NR Connected)	Mobility	AVG = 435.3 msec

6.3.2.3 GR-TR Cross-Network Results

No cross-network test results from the GR-TR CBC are available as of this moment. Cross-network test results from the GR-TR CBC will be reported in D3.7 after the completion of phase 3 of the roll-out plan.

6.3.3 TS Network Testing Results

No TS network test results are available as of this moment. Network test results from the TSs will be reported in D3.7 after the completion of phase 3 of the rollout plan.

7. ADVANCED 5G TECHNOLOGY DEPLOYMENT

7.1 Overview

The 5G-MOBIX project takes advantage of the advanced technologies made available by 5G networks. These technologies play a key role for supporting CCAM applications at cross-border settings by providing essential features such as low-latency communications and service continuity, which are particularly important for inter-PLMN handover scenarios and during roaming. Thus, this section provides an overview of the several 5G technologies deployed in the context of the project, focusing on the ES-PT and GR-TR cross-border corridors, but also describing the contributions of the different trial sites or some particular type of deployment not present in the CBCs.

7.2 5G Technology 1: Cellular V2X

7.2.1 Overview

Cellular vehicle-to-everything (C-V2X) is a foundational technology developed within the 3GPP and designed to operate in both vehicle-to-vehicle and vehicle-to-network modes. It was initially standardized under Releases 14 based on an adaptation of LTE for vehicular scenarios, providing an alternative to 802.11p, the IEEE specified standard for V2V and other forms of V2X communications with direct links between communicating entities. C-V2X is currently the most prominent technology that can achieve the V2X requirements in an efficient manner, paving the way to connected and automated driving. It allows vehicles to communicate with each other and nearly everything around them, helping achieve 360° non-line-of-sight awareness and improved predictability for enhanced road safety and autonomous driving.

C-V2X, which comprises both LTE-V2X and 5G-V2X, is designed to operate in two modes:

- Side link interface (PC5): This is Vehicle-to-Vehicle (V2V), Vehicle-to-Roadside Infrastructure (V2I) and Vehicle-to-Pedestrian (V2P) direct communication without necessarily relying on network involvement for scheduling.
- Device-to-network (Uu interface): This is Vehicle-to-Network (V2N) communication, which uses the traditional cellular links to enable cloud or MEC services to be part of the end-to-end solution.

7.2.2 CBC ES-PT deployment

In the ES-PT CBC, 3GPP Release 15-based 5G communications is used to exchange CCAM messages through the Uu interface as in V2N. Outside the regions with 5G coverage, 3GPP Release 14 cellular links (standard LTE) and the PC5 interface are employed for direct communications among vehicles.

7.2.3 CBC GR-TR deployment

C-V2X communications based on the 3GPP Release 15 specifications are utilized in the GR-TR CBC to exchange messages in all different user stories. In order to provide redundancy, the PC5 interface is also exploited, as this functionality is provided by IMEC in its OBU module operating according to the 3GPP Release 14 specifications. A performance comparison will be conducted between the 5G-V2N (Uu interface) and the LTE side link (PC5 interface) for the platooning user story at the cross-border corridor, thanks to The OBUs and RSUs developed by IMEC, which offer a C-V2X PC5 module (Cohda MK6c) that may be used for the platooning use case for direct communication between the trucks involved in the platoon.

7.3 5G Technology 2: MEC Deployment

7.3.1 Overview

An edge computing solution is implemented at different cross border corridors and trial sites. These solutions are implemented based on either standards-compliant or proprietary solutions (1) from vendors such as Ericsson and Nokia or (2) are of experimental nature. In most cases this is based on an implementation with OpenStack for hosting the VM-based or containerized applications. This implementation is carrier grade, facilitating both runtime applications and core components. Core components are based on the 3GPP Release 15. A local breakout is based on either PGW-U or an UPF, depending on an NSA or SA-based 5G Core implementation, respectively.

The selected edge locations are close to the gNBs in order to satisfy the strict latency requirements of the user stories. The main focus of 5G-MOBIX is to analyse crossing of borders from a cellular network mobility point of view. Given the lack of standards to define the related 3GPP/MEC mobility concepts, deployment of a unified edge computing platform was not considered feasible and of priority as discussed at the project set-up phase.

Several use cases make use of edge computing to minimize end-to-end latencies for information exchange between the vehicles connected to the same 5G mobile network or to different networks. Among the challenges identified to support the various MEC deployment options such as session management, lawful interception, charging, security and MEC platform subscribers' identification, mobility management is especially critical as it affects the service continuity. Different scenarios are evaluated on service continuity, i.e., Intra-MEC mobility (the UE moves from one eNodeB to another but is still in the coverage of the same serving MEC host), Inter-MEC mobility/MEC hand-over (the UE moves out of the coverage area of the source MEC host to enter the coverage area of a target MEC) and MEC-interconnection between multi-MNOs. Two different technologies are considered to enable service continuity with inter-MEC mobility:

1. DNS based approach (section 7.3.2.1)
2. SSC mode 2 and 3 based approach (section 7.3.4)

An evaluation of these different approaches should give more insight in the performance benefits and complexity of both technologies.

For Extended Sensors and Advanced Driving use cases, geo-messaging distribution servers (ETSI ITS messages such as CAM, DENM, CPM, MCM) are deployed in the MEC nodes, using V2N2V connections to serve vehicles, road-side units and other devices.

7.3.2 CBC ES-PT deployment

In the ES-PT cross-border corridor, partners use the NOKIA Edge computing solution, both on the Spanish and Portuguese sides. This is an edge-optimized cloud infrastructure CSP for high performance requirements, with support for real-time software optimizations and hardware accelerators. It can provide flexible scalability from single server (Edge Cloud) to multi-rack with SDN (Centralized Cloud). This hybrid infrastructure enables hosting and running containerized or/and virtualized applications, supporting smooth evolution towards microservices and 3rd party VNFs. It is also an open and interoperable solution.

The MEC is configured with an OpenStack-based solution (MicroStack), supporting continuous delivery with no dependencies to commercial distributions. It also provides carrier grade high availability and auto-recovery. The deployment and update/upgrade automation are enabled with remote capability, runtime configuration management and open APIs.

On the Spanish side, Telefonica deployed the MEC in a distributed site where the traffic from several radio sites is received in the commercial network. This Telefonica site is used to aggregate radio traffic from several radio sites and redirect this traffic to the Core network. The distributed 5G EPC infrastructure is deployed on this site, and the Local Break Out traffic from the PGW-U is sent to this Edge infrastructure. The Edge and the distributed Core are deployed on a virtualized infrastructure.

In Portugal, Nokia deployed the Edge infrastructure near the radio sites at NOS data centre in Riba d'Ave (Figure 7.38), where a trial dedicated miniEPC infrastructure is also deployed, as NOS commercial network will not be used for this project. The virtualized infrastructure is configured in the same way as the Spanish MEC.

COTS hardware based on X86 Servers, OPNFV and OpenStack are used for the MEC deployment. The OPNFV is a source carrier grade NFV reference platform hosted by Linux Foundation. The aim is to speed up development and deployment of NFV and this option accelerates the transformation of service provider and enterprise networks. This option follows closely OpenStack cycle, with whole community integrating and testing the open-source components (Figure 7.39).

The MEC hosts vertical applications for CCAM and for Remote Driving developed by third parties. These applications take advantage of a Real-time Kernel and Hypervisor optimization with accelerated Virtual switch OVS-DPDK. The enhanced platform awareness and support for hardware accelerators will be critical as the hybrid infrastructure running containerized or/and virtualized applications.

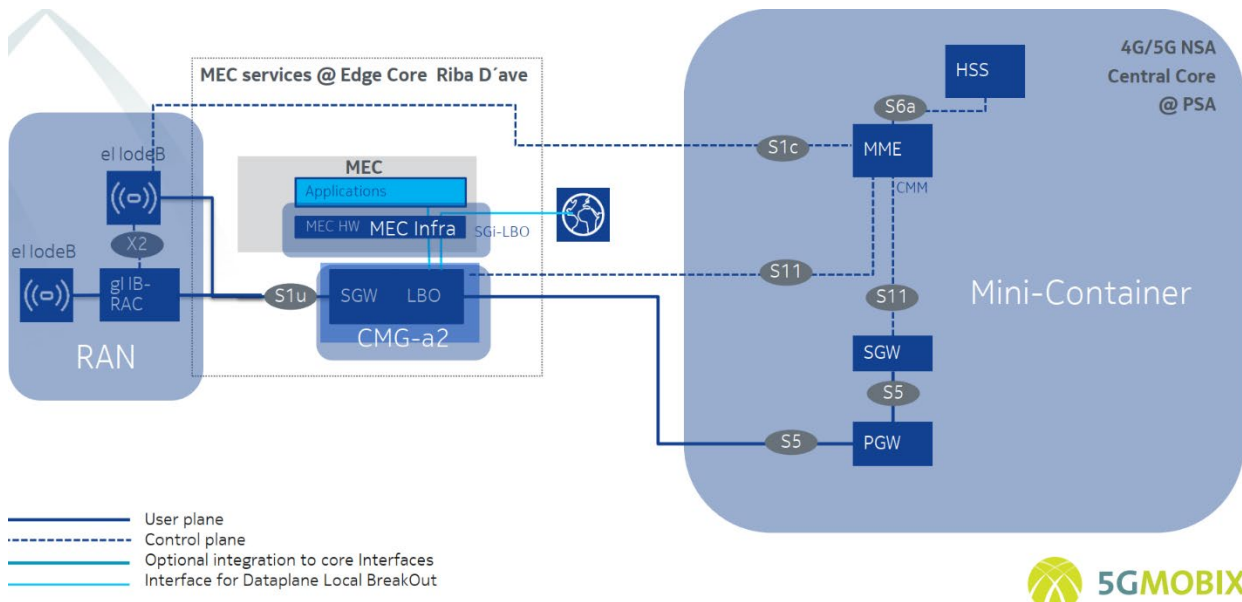


Figure 7.38: MEC deployment at Riba d'Ave (PT side).

These applications benefit from a carrier and telco grade (X.731 compliant) HA, a sub-second reaction time in the case of failures with proper recovery action (auto-evacuation) and on-demand system health check.

The Single Node Cloud (distributed edge clouds) and the Multitrack DataCenter scalability with SDN and native L3 fabric, or the Scale-in/out of compute and storage nodes allows to the applications VMs being deployable on each cloud server.

7.3.2.1 TS FI contribution

FI provides the service discovery mechanism in the CBC ES-PT to help the UE find the IP address of the MEC. The system is built on top of DNS to ensure the compatibility with existing applications, i.e., the edge platform in Spain and Portugal.

The assumption of the service discovery mechanism is as follows: 1) The UE connects to a MEC via its public/private IP address. 2) The UE can connect to a MEC via its public IP address from anywhere on the Internet. 3) The UE can connect to the MEC via its private IP address if it is inside the same 5GC as the MEC or it is roaming to the MEC's 5GC. 4) Each 5GC has a dedicated IP subnet so that a public server can distinguish which 5GC a UE belongs to by matching its source IP address, which may be behind a NAT, in a predefined database.

The architecture of the service discovery system is shown in Figure 7.40. The MECs register themselves in a cloud-located coordinator, which instructs the DNS server on how to reply to different domain names. The LDNS deployed at the 5GC is a resolver for relaying and caching the DNS queries in the local network. Its job is to accelerate the DNS query process and the response is purely decided by the cloud-located DNS server.

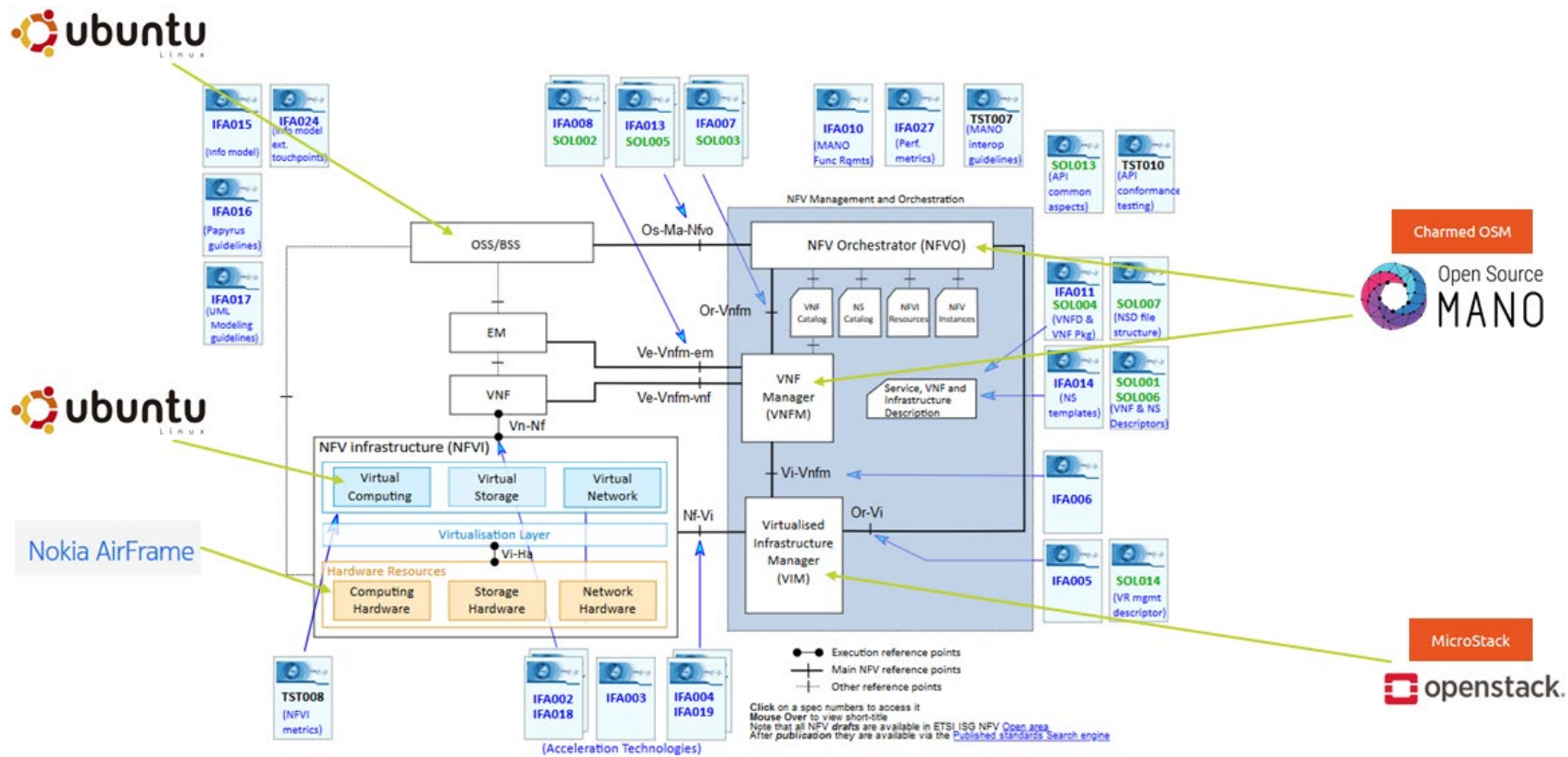


Figure 7.39: MEC Virtualization Platform in the ES-PT CBC.

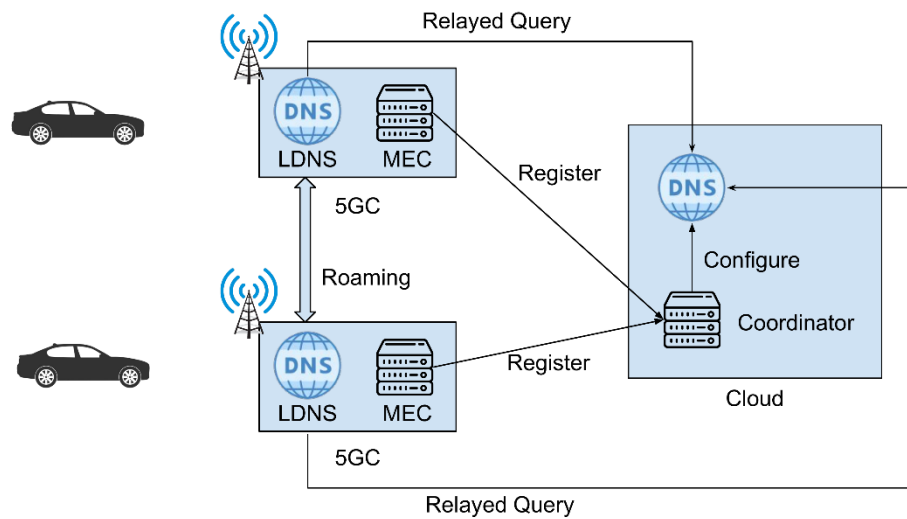


Figure 7.40: Service Discovery in the ES-PT CBC.

The UE can get the IP address of the MEC inside the same 5GC by sending a DNS query to the LDNS, which is further relayed to the cloud-based DNS server. The DNS server matches the UE's IP address with the registration information of the MECs to find which MEC is inside the same 5GC as the UE. Then, the private IP address and the public IP address (if applicable) of the MEC are returned to the UE.

The service discovery mechanism supports service migration. The UE needs to use a DNS query to find the IP of the MEC whenever its connected gNB changed or its IP address is changed. If the newly found MEC is different from the previous one, the UE can migrate from the old MEC to the new one. During the stage of migration, the UE has access to both the old and the new MECs so that it can implement application-specific logic for data transfer, e.g., move its user data from the old MEC to the new MEC.

7.3.3 CBC GR-TR deployment

In the GR-TR Gross Border trial, partners will use their own EDGE computing infrastructure build on virtualization technology. In the current context of the project, the underlying Mobile Networks are based on 3GPP Release 15 in a complete/standalone 5G EPC infrastructure, deployed as an edge node, with Local Break Out (PGW-U) to the Application servers at the EDGE as well as Internet access to the Cloud. The edge position selected are close to the gNBs in order to satisfy the strict delays.

Ericsson, Turkcell and Cosmote are using two different versions of a distributed 5G infrastructure. In GR site a full-fledged 5G EPC infrastructure is deployed as an EDGE node on Open Stack offering LBO (PGW-U). In TR a distributed 5G EPC infrastructure is used with Local Break Out at the EDGE (PGW-U). Both systems are deployed on a virtualized infrastructure. The Ericsson infrastructure is deployed based on the Ericsson NFVI Blueprint using COTS infrastructure and Open Stack as virtualized infrastructure.

For the Platooning case, the 4K video streaming from the leading truck to the follower trucks will be processed via the application server at the edge, to minimize video latency. For the “Zero-touch” border crossing, the data fusion and post-processing from the truck and environmental sensors may take place both in the cloud and at the edge, benchmarking the difference in performance as the autonomous driving commands sent from the server to the trucks need extremely low latency. As part of this use case, autonomous breaking of the truck takes place based on commands from the application server in order to avoid accidents within the customs area.

The Cosmote GR edge will consist of a compact 5G EPC Infrastructure (UDM, vEPC) located inside the edge site providing Local Break Out access to application server. Moreover, the “See-what-I-see” streaming application and the “Zero-touch” border crossing application (data ingestion, fusion, post-processing and intelligence) will be both hosted at the edge.

7.3.4 TS NL deployment

In the Dutch trial site three edges will be deployed, currently two are already deployed. One edge in the TNO network and one in the KPN network. Both edges are interconnected to be able to exchange information without much latency. To also be able to test different schemes of service continuity a third edge will be deployed at the KPN network. This will happen in order to test how the vehicle can stay connected to the relevant services when traversing through different regions, served with different edges. Without extra measures, by default the UE will anchor to a UPF in the network and stay anchored to that UPF, even if there is a UPF and edge closer by. To have the network re-anchor the UE to a new UPF closer by a mechanism called SSC (Session and Service Continuity is proposed). Using SSC two new options are given to re-anchor the UE to a new UPF:

- Mode 2: Break before make,
- Mode 3: Make before break.

Using mode 3 in theory the application can continue to function without any interruption. Only the current commercial network solutions and UE’s don’t support this feature yet. If this feature would be supported, it is unclear how the application can be made aware that an action is needed to connect to a new edge services closer by. For these reasons a scheme is proposed to test SSC without needing the actual function in the control domain. It is proposed to setup a central control function that will coordinate when the application needs to reconnect to a closer by edge. The central control function can use an application function to get information on mobility events. It is interesting to see if we can get a better performing system using this scheme and see if the better performance will justify the extra complexity. The Finish trial site will test a simpler scheme using only DNS queries to detect a connection to a new edge. Comparing the two schemes will be of value to the 5G-MOBIX project.

We will use a two-step approach to implement this function:

1. Implement the central control function in the vehicle (currently the commercial network software does not support yet the Notification requests from the Application function via the NEF). The central control function will use the information from the modem to detect the mobility event.
2. Move the central control function to the 5G network and use the mobility events coming from the NEF.

This functionality is also highly depending on the modems capable of setting up multiple PDU sessions. These functions need to be tested still but are expected to become available.

7.4 5G Technology 3: Network Slicing

7.4.1 Overview

5G enables the slicing of a single physical network into multiple virtual networks that can support different radio access networks (RANs), or different service types running across a single RAN. Network slicing will maximise the flexibility of 5G networks, optimising both the utilisation of the infrastructure and the allocation of resources. Each virtual network (network slice) comprises an independent set of logical network functions that support the requirements of the particular use case, which will be optimised to provide the resources and network topology for the specific service and traffic that will use the slice.

It is expected that network slicing will play an important role in CCAM scenarios, for instance to differentiate network provision of very different use cases, such as safety applications or streaming services. However, in the initial stage of 5G-MOBIX project, both cross-border corridors only support 5G NSA setups, which impedes the implementation of E2E network slicing, being that planned for a later moment in time. Some trial sites like Finland and the Netherlands have deployed a 5G SA setup with slicing configurations, which will allow the comparison of some metrics, such as E2E latency, against the setups deployed in the CBCs with no network slicing capabilities, thus highlighting the importance of the complementary local trials.

7.4.2 CBC ES-PT deployment

During the first phase of the project (NSA (option 3x)), slicing will not be utilized on the ES-PT CBC. Depending on the technology availability and stakeholder's deployment roadmap, slicing will be available when 3GPP SA (option 2) is deployed at the ES-PT CBC, at a later phase of the project.

7.4.3 CBC GR-TR deployment

In this initial stage of the project, a private 4G/5G network is used to process V2X traffic, providing RAN traffic isolation by planning a separate IMSI series for the V2X use cases. The V2X specified subscribers are restricted to access predefined Location Areas and Geographical Areas. This can be considered as a basic network slicing mechanism by creating 2 separate networks to handle different applications, i.e., a commercial network for mobile broadband use cases and the private 4G/5G network for V2X applications.

The frequency bands exclusively allocated to V2X applications are the B7 (2600 MHz) with 20 MHz bandwidth for the overlay 4G cell, which is used as NR anchor band, and the n78 (3420-3600 MHz) with 100 MHz bandwidth for 5G.

7.4.4 TS FI deployment

The FI trial site uses APNs for network slicing for the 5G NSA configuration. As per the 5G standard, at the time of UE registration, the UE needs to inform the Slice Management Function (SMF) which APN to use and the SMF will assign a UPF to the UE according to the UE's request. This process can also happen after a UE is connected: the UE can notify the SMF of switching APN at any time and the SMF should decide whether to assign a new UPF to the UE. In this way, network slicing is achieved by assigning different UPFs to different type of UEs. And the UPF can be further optimized for different types of applications.

In FI trial site, two APNs are used: 'internet' for general use and 'fastinternet' for edge computing. These two APNs are assigned to different UPFs. MECs are deployed only to the 'fastinternet' UPF, which means UEs can connect to the MEC if and only if it sets the APN to 'fastinternet'. To that end, the gNBs in SA mode are configured with two slices, where, the AMF will check with the Network Slice Selection Function (NSSF) to confirm the device is allowed to use one of the slices. Currently the gNB uses Network Slice Selection Assistance Information (NSSAI) values 1 and 2 for the slices associated with the two different APNs.

7.4.5 TS NL deployment

At the Dutch trial site two of the three 5G Core networks have been enabled for slicing. These are the core networks from both KPN and TNO. This functionality is still to be tested with devices capable of slicing, modem suppliers have indicated that they will support this in Q4 2020 / Q1 2021 with firmware updates.

To support the different use cases, we plan to use three slices:

1. Generic internet services
2. V2X services and vehicle control traffic
3. Video traffic

Traffic associated to the V2X slice will be connected to a local User Plane Function (UPF) deployed at the edge of the network (physically located to the base station) whereas regular Internet traffic will go via the central UPF (physically located at central servers). The UE will need to support the establishment of multiple (three) PDU sessions, each session associated to a specific Single Network Slice Selection Assistance Information (S-NSSAI) value. At the 5G core (SA), the Network Slice Selection Function (NSSF) will use the different S-NSSAI values to map each PDU session to specific deployment options: UPF at the edge or UPF at the central servers. Alternatively, in case S-NSSAI is not supported by the UE chipset or by the core, three PDU sessions will be established by the UE with different Data Network Names (DNNs), where each DNN would be mapped to either the central or edge servers. It is unclear at this moment if we are able to support

slicing in the RAN. This will depend on the supplier roadmap. When possible, we will implement and test RAN slicing at the gNB deployed. Therefore, it might be the case that no radio prioritization capability will be available for each slice (i.e., no E2E slicing). In any case we will be able to differentiate between traffic going to the central core and traffic that stays at the edge.

7.5 5G Technology 4: Roaming

7.5.1 Overview

The mobile service continuity in country borders has been a challenge in each of the technologies that have been part of mobile communications throughout history and 5G network will be no less. This aspect must be considered in user stories like complex manoeuvres, remote driving, platooning and see-through functionality, since the loss of service at the borders between countries would provoke an unsafe experience for autonomous driving owing to the demanding requirements of high speeds and ultra-low latency.

7.5.2 CBC ES-PT deployment

The ES-PT CBC 5G deployment is based on Non-Stand-Alone technology, hence, the adopted technical solution for Roaming is applicable to 4G with LTE as anchor technology. The assumed configuration is EN-DC (E-UTRAN New Radio Dual Connectivity), hence the network reselection occurs on 4G LTE due to this technology in this kind of setup manages the control plane functions of the network and NR connectivity is re-established subsequently.

MNOs leverage different strategies based on the current 3GPP standards, which are adopted as roaming procedure in the ES-PT CBC like Roaming with New Registration or local breakout (LBO) and Roaming with MME relocation (Idle mode mobility) or home routed. The connectivity between the mobile networks use a direct fibre interconnection among the Cores. In addition, there will be an additional link through the interconnection for communication between MEC applications to facilitate the transfer of the session at the application level.

The Home Routed alternative is based on the configuration of a threshold from controlling RAN which determines when a UE should start being considered for release i.e., while still proper connection exists. The controlling RAN provides information about available target frequency bands to allow the UE to immediately tune to a new carrier (without the need to scan the spectrum), providing a reduction of the latency in this phase. When UE knows the new network where it will connect an additional roaming interface is created between MMEs (S10). This interface allows the MME in the Visited PLMN to fetch the UE context from the source MME. In addition to this, the user plane will be re-established with help of the previous interface. This option provides a better service continuity; however, latency potentially increases with distance from the border.

In the local breakout (LBO), the roaming case from Spain to Portugal is considered, the MME (Mobility Management Entity) in Portuguese network contacts the Spanish HSS (Home Subscribers System) to obtain subscriber data through the interface S6a. When the Portuguese network accepts the subscriber, the user plane is established to the PGW (Packet Data Gateway) in the Spanish network using S8 interface where the subscriber IP address is anchored, and “Internet” access provided. The procedure in reverse direction is similar. In this case the latency is not affected, albeit the service is interrupted in a period to be quantified.

7.5.2.1 TS FR contribution

In the presence of a multi PLMN environment and with roaming and hard-handover solutions, users may experience a disconnected period, which can be too long for some applications. Indeed, CCAM applications such as remote driving and advanced driving are extremely sensitive to service disconnection due to potential safety risks. 3GPP has approved a work item in its Rel. 17 in order to standardize the support of Multi-SIM users, which is to ensure service continuity by allowing UEs to be simultaneously connected to different PLMNs. 3GPP TSG RAN 3GPP RP-193263 [5] and SA2 3GPP SP-190248 [6] are studying the impact of multi-SIM devices on the overall system and the potential enhancements within Rel. 17 specifications. This contribution provides the implementation of seamless handover between available technologies at the corridor: 5G to 5G, 5G to 4G or 4G to 5G using a dual-SIM solution.

FR TS will use an intelligent router solution, connected to its OBU, which allows the UE to keep multi-SIM connections with PLMNs ensuring continuity and communication quality between the application endpoints. Specifically, it performs link aggregation and load balancing across different PLMN connections and use these connections in a combined manner. At the CBC, the intelligent router will be configured to make a seamless handover from one PLMN to another PLMN using multiple-SIM cards according to the different criteria defined for individual applications, including wireless link reliability, latency, or available bandwidth. Particularly the solution will allow simultaneous multi-PLMN connections that are bonded together using Speed Fusion solution, which allows service continuity, better reliability, larger bandwidth, and increased wireless coverage comparing to the hard handover/roaming solutions. The speed fusion box is a proprietary solution from Peplink [7] that allows to create seamless bonding of VPN communication bearers over VPN. At the reception, a software module, so-called aggregator receives the packets transmitted over the different PLMNs. The module applies the operations, particularly packet reordering and removal of duplicate packets and provides the aggregated data to the target application.

7.5.3 CBC GR-TR deployment

Providing service continuity when crossing a country border is a challenge particularly in the “Platooning with the See What I See” user story where it is a high requirement to enforce high speed, low latency network. For that reason, S10 interface is implemented between MMEs in the two mobile networks operated by the different MNOs to enable cross-border radio handover in seamless operation. Interface S6a (authentication) and S8 (home routed user plane and control plane) are used in all tests as basic roaming interfaces. Two Roaming models are considered:

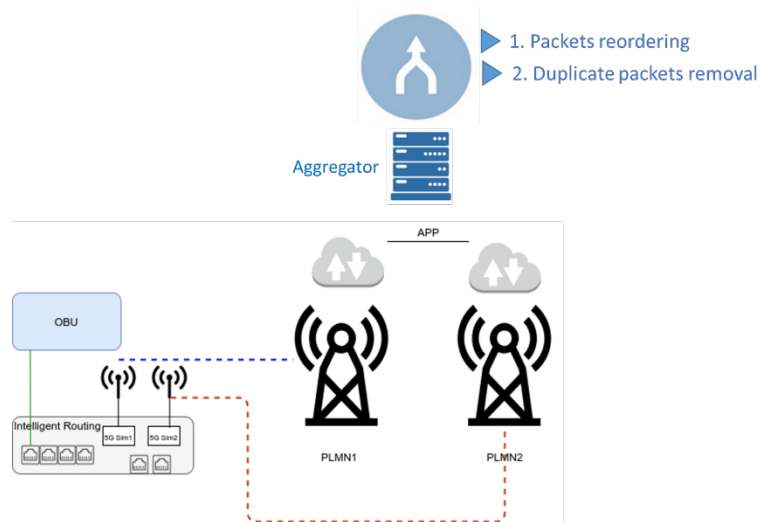


Figure 7.41: Multi-SIM solution for seamless handover using intelligent router.

- The home routed roaming model, where the end-user's data traffic is serviced by their home network.
- The local breakout architecture model, where the subscriber's data is serviced by the network they are visiting, delivers more efficient routing in terms of bandwidth and latency. The visited network has complete control over the packet gateway (PGW). In the case of LBO, the visitor network controls the roaming customer and has role in delivering services to them.

The following are the reference points for Inter PLMN Handover:

- S1-MME: Reference point for the control plane protocol between E-UTRAN/NG-RAN and MME.
- S1-U: Reference point between E-UTRAN and Serving GW for the per bearer user plane tunnelling and inter eNodeB path switching during handover. S1-U does not apply to the Control Plane CIoT EPS Optimisation.
- S6a: It enables transfer of subscription and authentication data for authenticating/authorizing user access to the evolved system (AAA interface) between MME and HSS.
- S8: Inter-PLMN reference point providing user and control plane between the Serving GW in the VPLMN and the PDN GW in the HPLMN. S8 is the inter PLMN variant of S5.
- S10: Reference point between MMEs for MME relocation and MME to MME information transfer. This reference point can be used intra-PLMN or inter-PLMN (e.g. in the case of Inter-PLMN HO).
- S11: Reference point providing control plane between MME and Serving GW, the S11-U reference point provides user plane between MME and Serving GW.

- SGi: It is the reference point between the PDN GW and the packet data network. Packet data network may be an operator external public or private packet data network. This reference point corresponds to Gi for 3GPP accesses.

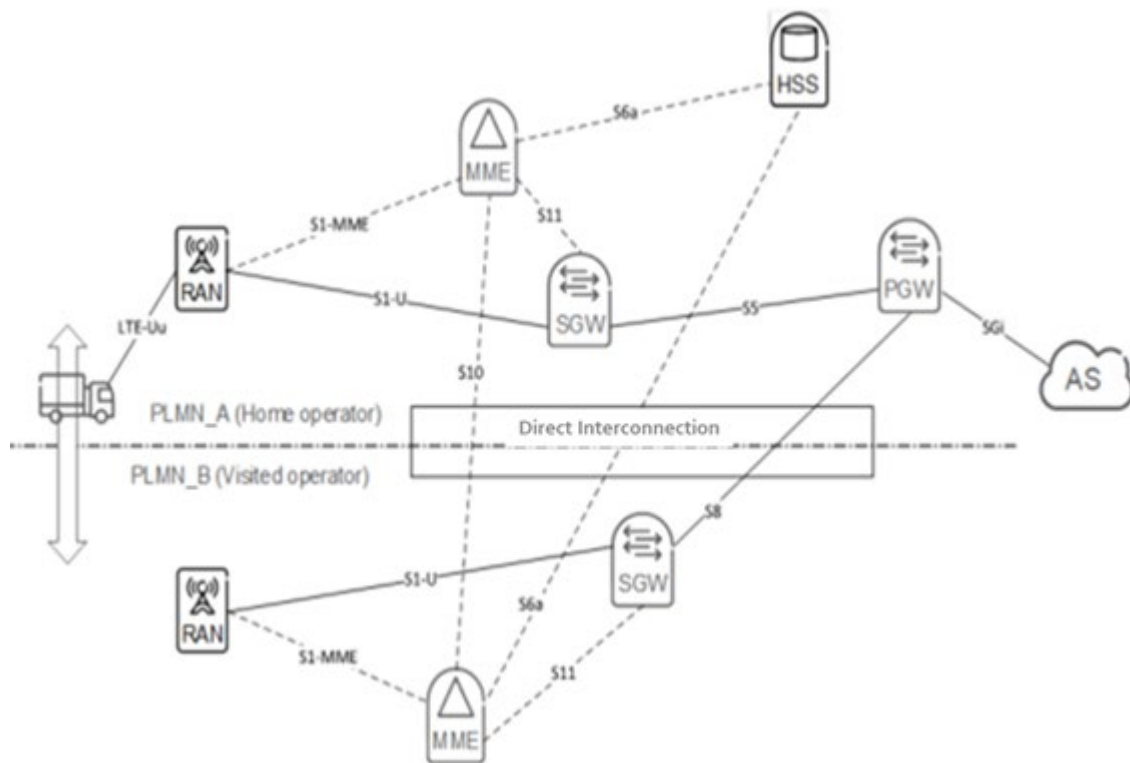


Figure 7.42: GR – TR (Home Routed) Roaming Architecture with Session Continuity.

7.5.3.1 Inter PLMN Handover Configuration

“Release with Redirect” or “S1 Handover” feature on RAN for the S10 reference points must be supported as roaming interfaces. The UE and RAN will also be configured with information about neighbouring PLMNs also called equivalent PLMNs. The UE and RAN will then handle the visited PLMNs same as the serving PLMN. The RAN is configured to use the “Release with Redirect” or “S1 Handover” feature. The two main concepts to be implemented on MME to support a smooth steer of the UE into selecting a visitor PLMN network at cell selection and cell reselection are:

- Equivalent PLMN
- Static IMSI PGW selection

7.5.3.1.1 Equivalent PLMN

An Equivalent PLMN List (EPL) is a list of Public Land Mobile Networks (PLMNs) which can be used to steer the UE into selecting a preferred PLMN during Attach and Tracking Area Update (TAU) procedures at cell selection and cell reselection. The MME sends an EPL to the User Equipment (UE) containing a configurable

number of equivalent PLMN IDs. Several unique EPLs can be set up in the SGSN-MME and one of these lists is selected by the SGSN-MME. An EPL can be made more selective for each subscriber, by basing the selection of an equivalent PLMN on the International Mobile Subscriber Identity (IMSI) number of the subscriber.

The E-PLMN list can be signalled to the UE as part of the location area update, tracking area update or attach procedures. It is not signalled on the broadcast channel. Specifically, it can be included in the Location Updating Accept, Tracking Area Updating Accept and Attach Accept messages. On Turkcell's MME, EPLMN must be implemented for Cosmote PLMN 20201. Here, Turkcell is a provider of the network. On Cosmote's MME, EPLMN must be implemented for Turkcell PLMN 28601. Here, Cosmote is a provider of the network.

7.5.3.1.2 Static IMSI PGW selection

When the UE attaches to the network, PGW Selection is based on the information provided to the MME as we are not using Gn DNS. The address of the P-GW needs to be configured on the MME. PGW selection is performed by the MME at initial attach or PDN connection establishment. On MME, a node function "StaticGwSelection" is present to make the IMSI based static PGW selection work. In case of Home routed roaming, the VPLMN IMSI has to be statically pointed to the home PGW address on the vMME, whereas in case of Local Breakout roaming, the VPLMN IMSI has to be statically pointed to the visitor PGW address on the vMME.

7.5.3.2 Home routed (HR) roaming

In the scenario, Cosmote subscriber attaches on Turkcell network. On Turkcell MME, the PGW IP address of Cosmote will be configured, the Cosmote IMSI will be statically pointed to Cosmote PGW IP address, hence when Cosmote subscriber attaches on Turkcell MME, it will be directed to Cosmote PGW during PDN connection establishment.

Similarly, in the scenario where Turkcell subscriber attaches on Cosmote network. On Cosmote MME, the PGW IP address of Turkcell will be configured, the Turkcell IMSI will be statically pointed to Turkcell PGW IP address, hence when Turkcell subscriber attaches on Cosmote MME, it will be directed to Turkcell PGW during PDN connection establishment.

7.5.3.3 Local Breakout (LBO) roaming

In the scenario, Cosmote subscriber attaches on Turkcell network. On Turkcell MME, the Cosmote IMSI will be statically pointed to Turkcell PGW IP address, hence when Cosmote subscriber attaches on Turkcell MME, it will be directed to Turkcell PGW during PDN connection establishment.

Similarly, in the scenario where Turkcell subscriber attaches on Cosmote network. On Cosmote MME, the Turkcell IMSI will be statically pointed to Cosmote PGW IP address, hence when Turkcell subscriber attaches on Cosmote MME, it will be directed to Cosmote PGW during PDN connection establishment.

In case of LBO, the call for a roamer should flow in the same manner as it does for the home subscriber. Using IMSI based Static GW selection the PLMN of roamer will be statically directed to the home PGW. So, here in LBO solution, TR subscriber roaming in GR will be using GR PGW & GR subscriber roaming in TR will be using TR PGW.

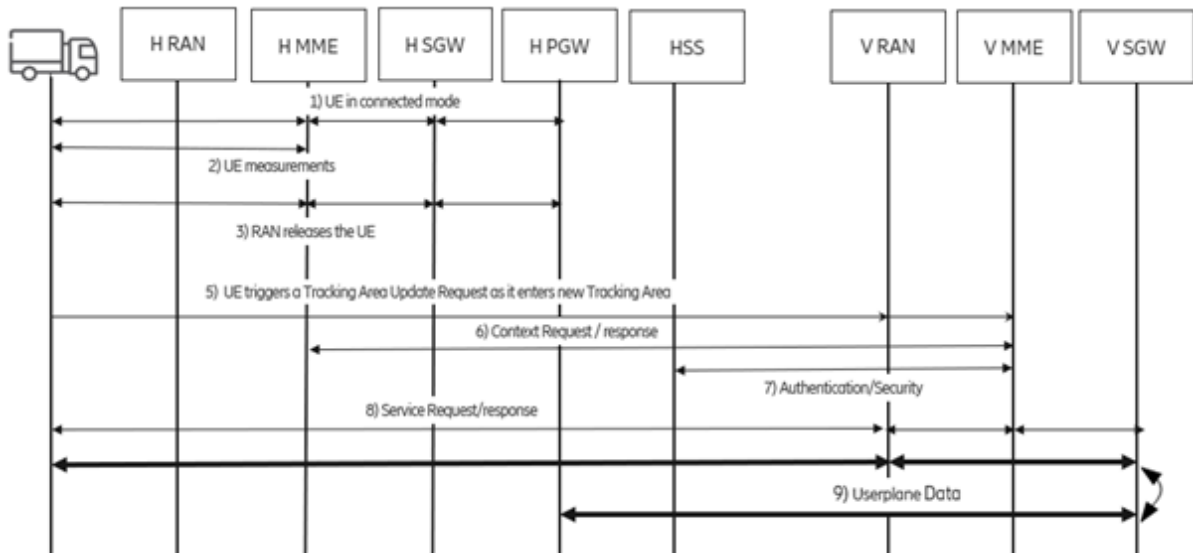


Figure 7.43: HR roaming call flow.

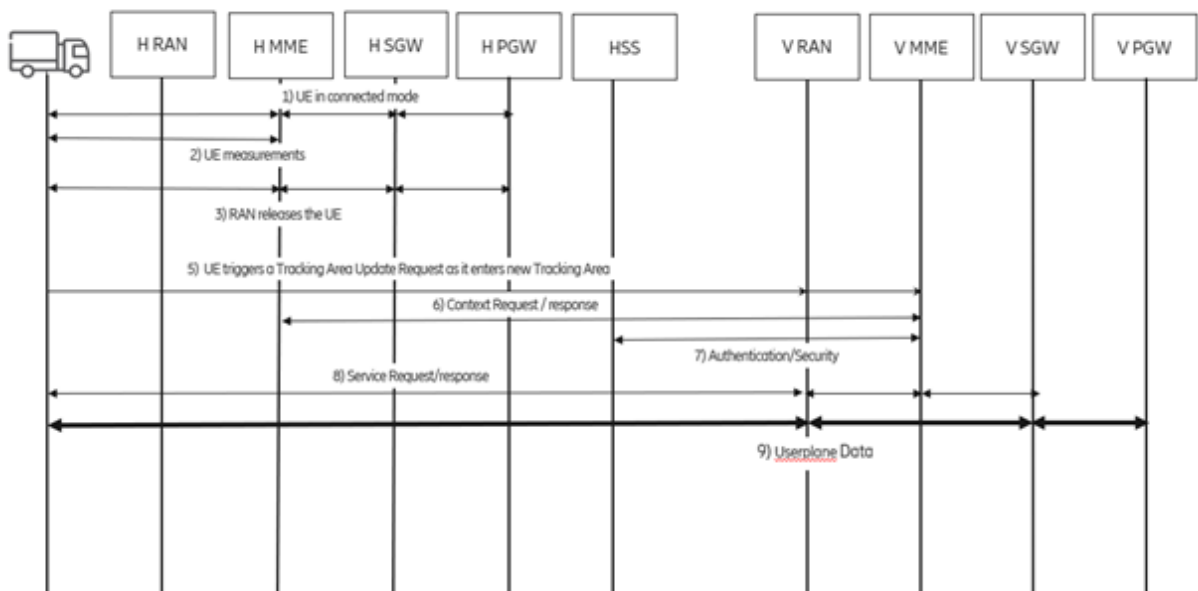


Figure 7.44: LBO roaming call flow.

7.5.4 NL TS development and deployment of SA roaming

Roaming in the NL TS will be based on 5G Stand Alone roaming, i.e. without use of 4G components and protocols, see Figure 7.45. The reason for this focus on 5G SA is that the trial must provide insight in how session continuity can be achieved for CCAM services that rely on:

- 5G slicing in the radio network and core network, and on
- 5G control plane mechanisms to setup the connectivity to local edges.

Resorting to 4G-based roaming mechanisms (as in 5G NSA) would mean that these two 5G technology components could not be trialled.

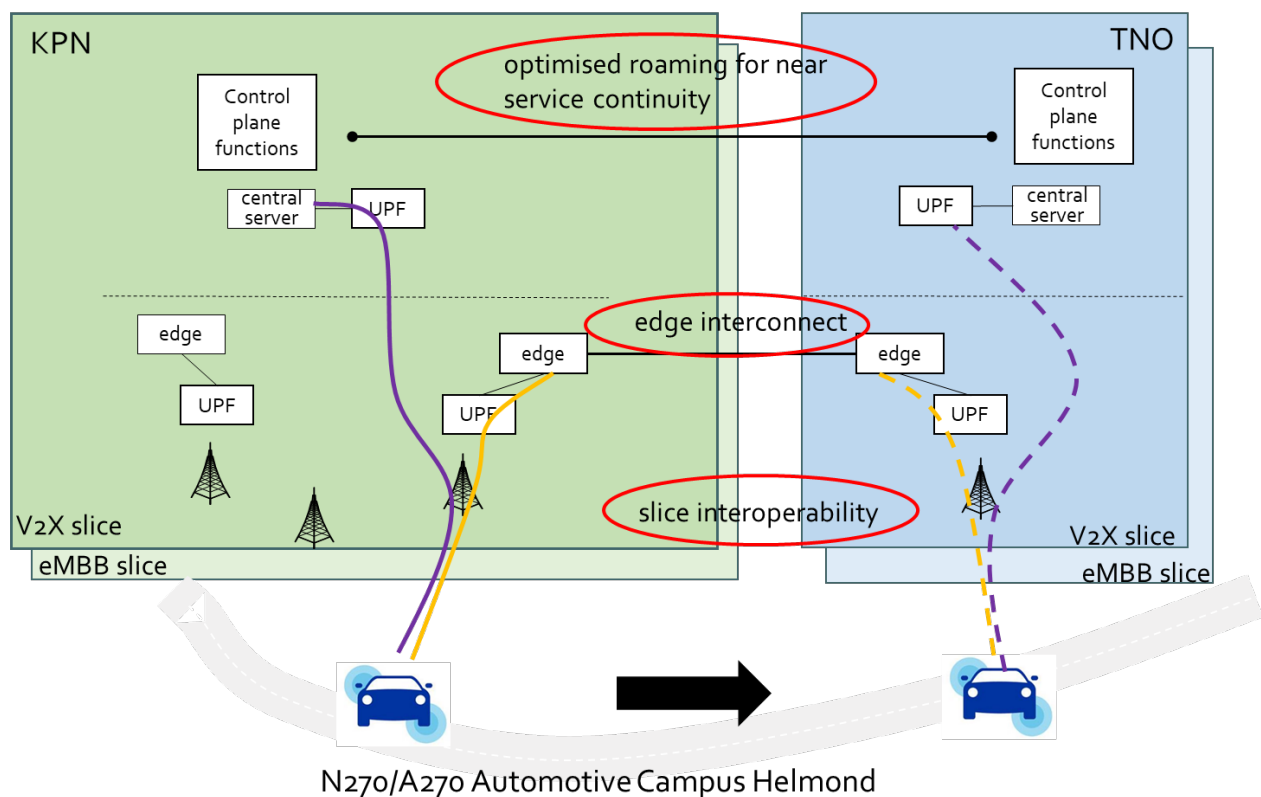


Figure 7.45: SA roaming in NL TS is aimed at continuity across networks of CCAM services based on local edges and 5G slices.

The focus on 5G SA roaming does introduces a challenge for the trial, as 5G SA roaming is still under development. The vendor software release that support for 5G SA basic roaming is expected to be available Q4 2021 for the NL trial. With this release, we can trial the mechanisms to find and transfer to the correct 5G V2X slice in the visited network and the determination of the optimal local edge in that slice.

However, basic roaming means that there is no handover or session continuity across borders. There is likely to be an interruption of at least many seconds. This is unacceptable for the extended sensor applications in the trial. As a fallback solution, it is planned to use a 5G SA dual modem approach. The vehicle will be

equipped with two modems, both with SIMs from the same MNO, so that a new connection in the visited network can be set up while the existing connection in the home network still exists. In this way, the 5G slicing and 5G control plane mechanisms for edge selection can be trialled as they would work with optimised 5G SA roaming. In the long term, as the optimised 5G SA roaming becomes available, a vehicle equipped with a single modem/SIM can use the same mechanisms.

7.5.5 FI TS development and deployment of SA roaming

The network setup in the FI TS includes two PLMNs, with PLMN one taking role of Home Network (Home PLMN) covering test road area where the vehicle began its trajectory and the Visited Network (Visited PLMN) where the vehicle completes its trajectory. Each of these PLMNs are deployed 4G and 5G cores that enable them to be alternatively configured in NSA and SA mode (further details of the testbed setup are provided in Annex C). The core network implementations in FI TS are based on virtualised and open experimental platforms which allows for early prototyping and testing core network features, such as, roaming mechanisms, which may still be under specification in 3GPP or yet to be adopted in commercial deployments. Moreover, the fact that both core networks are deployed and managed by same operating entity (AALTO) provides a convenient means for implementation of interconnections between the networks.

To that end, the FI TS is targeting implementation and testing of 5G roaming in SA mode, whereby, 5GCs using 3GPP-compliant SBA (Service-Based Architecture) are utilised by both the Home Network and Visited Network. Specifically, this 5G SA roaming will be implemented based on the 5G SA roaming Local Breakout (LBO) architecture following GSMA guidelines that are derived from 3GPP standards [8]. The interfaces in the roaming architecture are depicted the Figure 7.46, whereby, in the roaming phase the UE will setup a new PDU session in the visited network. Furthermore, in the visited network the AMF will authenticate the UE by accessing the home Unified Data Management (UDM) via the N8 interface and the SMF will access UE profile from home UDM N10 interface through the Security Edge Protection Proxy (SEPP). At the current time of reporting, the development work for this 5G SA roaming is ongoing with extensive testing implemented, before inclusion of the roaming feature upgrade in future iteration of FI trials in 2H 2021.

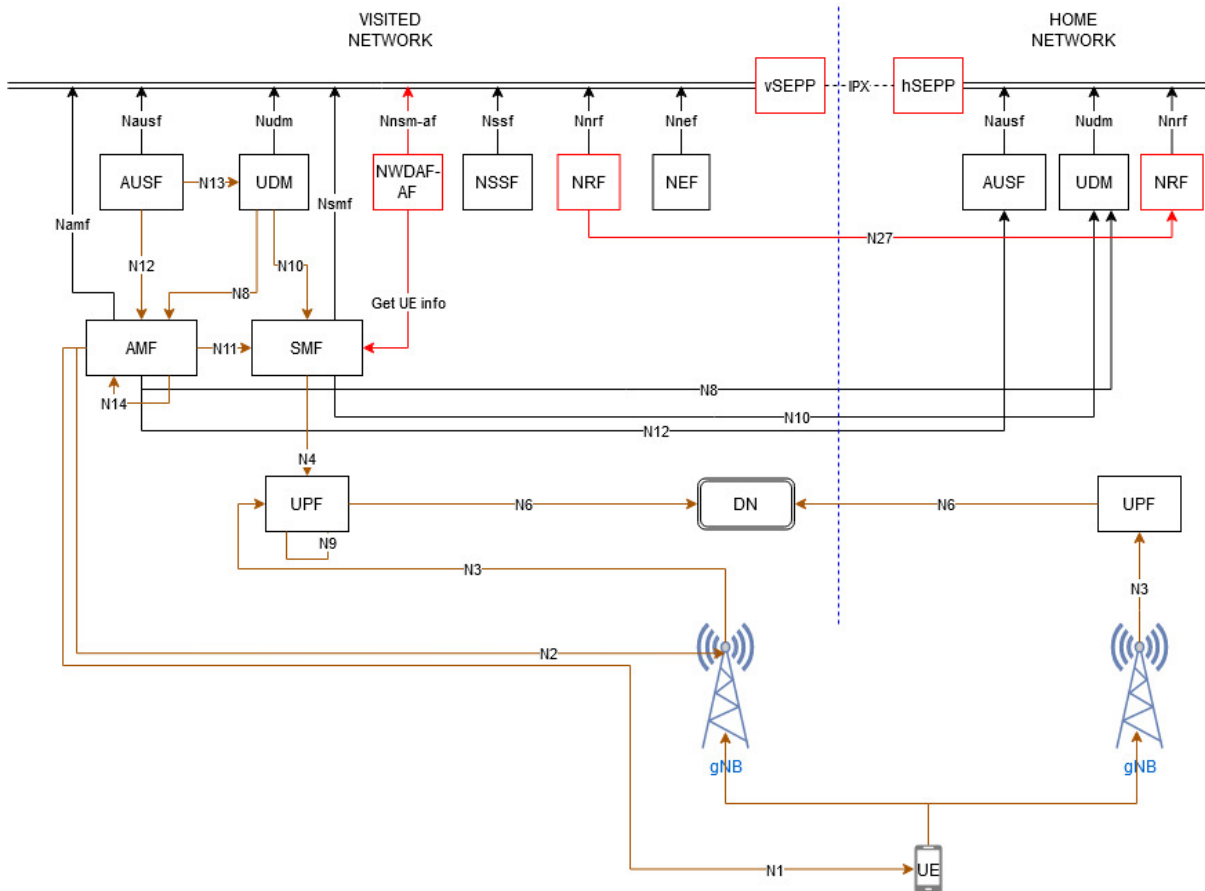


Figure 7.46: 5G SA roaming architecture targeted in the FI TS.

7.6 5G Technology 5: Satellite Deployment

7.6.1 Overview

Coverage and network dimensioning issues in under-served areas, as well as across cross border corridors, where the terrestrial 5G infrastructure is unable to satisfy the connectivity requirements, impose the utilization of additional communication bearers, associated with satellite communication networks. It is worth noting that the gaps in terrestrial coverage do not arise from the technical limitations of 5G NR but from the operational and commercial balance that have correctly guided commercial terrestrial operators in their deployment. Coverage of sparsely or uninhabited areas will continue to be sporadic since there is little opportunity to recover large investment costs. Satellite communication systems provide a good alternative solution to address these scenarios especially when there is no terrestrial technology available at the border, provided that they are seamlessly integrated into the 5G architecture so that the optimum efficiency can be achieved through technological interactions between 5G mobile and Satcom systems [9]. Recognising this opportunity, industry standard bodies ETSI 3GPP, European Space Agency (ESA), satellite

and terrestrial stakeholders have joined forces over the last five years to realise the convergence of satellite and terrestrial communication within 5G.

In this section the main architectures and interfaces required to integrate LEO satellite communications within an underlying 5G infrastructure are presented. These are technologies that consist architectural solutions to the use cases presented in 3GPP TR.22.822 [10] and TR 23.737 [11], where among others, refer to hybrid connectivity, satellite backhauling and inter PLMN coverage. Some of these solutions are also demonstrated in [3], however the resolutions to various issues/use cases will be adapted and applied appropriately to the French trial site 5G CCAM development. Satellite Applications Catapult (SAC) is closely collaborating with the FR-TS leader for the implementation of at least one of the state-of-the art solutions identified for future standards (Release 16 and Release 17), as well as additional architectures that can act complementary on the existing studies.

To clarify and thoroughly describe the various satellite -5G integration aspects for CCAM applications development, the remainder of this section focuses on the following use cases and respective solutions:

- IP based seamless satellite-5G connectivity
- Satellite as a 5G backhauling solution with local MEC break-out
- Satellite-5G integration through non-3GPP access
- MA-PDU for multiple access of both 3GPP and satellite bearers through the 5G Core
- Satellite-5G integration through 3GPP access (Satellite NR)

7.6.2 IP based Satellite-5G Connectivity

In the French test site (FR-TS) the On-Board Unit (OBU) will have access to both terrestrial and non-terrestrial radio bearers through an intelligent routing device. As mentioned previously, CCAM applications require reliable and seamless connectivity irrespectively of the vehicle's location and availability of terrestrial communications. Therefore, the routing engine will automatically determine the most appropriate bearer based on signal strength, communications statistics, connectivity predictions and preferred mode of connectivity. For instance, this would mean using the satellite bearer for critical traffic, whenever the terrestrial 5GNR is unable to satisfy the connectivity requirement (e.g., due to unavailability, signal degradation, etc). Such conditions will be covered during the trials as part of WP4.

Despite the bearer selection process, another capability of the intelligent routing device, is bonding of 5G and satellite bearers. This fulfils the requirement of seamless connectivity, since maintaining two active communication channels at any time allows for connectivity persistence in the case that one channels drops. For instance, when terrestrial coverage becomes unavailable, the communication between the OBU and the

platform hosting the CCAM application will remain uninterrupted. The end-to-end hybrid 5G-satellite architecture to be deployed, in the FR-TS is illustrated in Figure 7.47.

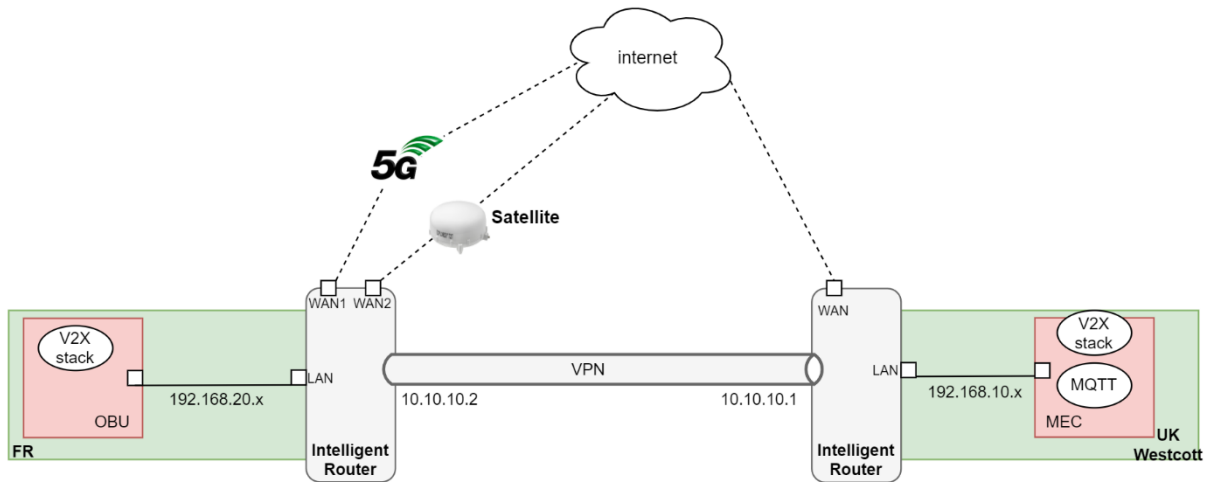


Figure 7.47: Hybrid 5G-satellite intelligent routing-based deployment at the French test site.

As shown in Figure 7.47, a Commercial Off the Shelf (COTS) routing device equipped with mode switching and RAT bonding capabilities, will be integrated with the OBU. The OBU is connected through the router's LAN interface and the router is configured with two wide area network (WAN) interfaces, one dedicated to terrestrial 5G connectivity and another to satellite Low Earth Orbit (LEO) connectivity.

To terminate the VPN connection and benefit from the seamless connectivity provided by the device, another intelligent router is required at the server site, where the CCAM application is installed. In this example, the server site is located at Catapult's 5G step out centre facility, in Oxfordshire, UK. A similar configuration will be followed for the deployment on the FR-TS.

The server site hosts the Vedecom CCAM application and required MQTT broker that communicates with both the OBU and the application on a Kubernetes cluster engine configured on a R440 DELL server. To enable communication with the Kubernetes API and provide enhanced security and efficiency, containerized version of the CCAM application and MQTT broker has been installed.

The CCAM application and the MQTT broker that communicates with both the OBU and the application, are configured in the form of Docker containers (Kubernetes pods), to enable communication with the Kubernetes API. In addition, intra-cluster and external communication are enabled by exposing the cluster-IP and NodePort Kubernetes services manifests, respectively. It is worth mentioning that the WAN IP addresses shown in the figure are exemplary; however, it is crucial that a static WAN IP address will be configured on the terminating device to create the VPN tunnel. Alternatively, the configuration can be achieved by public Dynamic DNS servers (DDNS); however, the former provides a more stable solution.

The part of satellite connectivity is attained by using the LEO land-mobile Thales MissionLink terminal [12]. The selection of the terminal is based on its capabilities to provide LEO satellite services and thus achieving the minimum possible latency among all satellite communication alternatives. In fact, FR T S is utilizing the best LEO land-mobile satellite terminal available in the market. There have been measurements of terminal to terminal where the LEO latencies are 35 ms and less [13]. In the case of Iridium terminal, we are utilizing the link through Iridium's earth station that introduce more latency than a terminal-to-terminal solution. Furthermore, the terminal can be easily deployed on the vehicle and it does comprise an electronically steerable phased array antenna, capable of tracking the Iridium Certus LEO satellite constellation. Based on the availability the terminal can provide speeds from 180 up to 700 Kbps, sufficient for the transfer of critical CCAM messages between the OBU and the on-site CCAM application.

7.6.3 Satellite Backhaul with Local MEC Breakout

One of the most promising applications of satellite communications in 5G is the backhaul solution, where satellite bearers transfer the N₁, N₂ and N₃ interfaces from UE to 5G Core network using satellite channels. This is quite useful when terrestrial backhauling solutions are expensive or challenging to be installed on site (i.e., in rural areas, or in CBC scenarios). An enhancement proposed in the current study is the separation of control plane (N₁/N₂/N₄) over satellite and the deployment of a User plane MEC breakout at the edge, to reduce latency and increase reliability of the CCAM applications.

A similar architecture is issued and resolved in [11], where a network function at the edge (edge NF) is capable of storing content files (e.g., video segments in HTTP-based video streaming applications) through a satellite link and making them available at the edge cache. In this scenario satellite is employed for both control plane and caching. To enhance this scenario, we propose the deployment of a user plane function at the edge, associated with a Kubernetes Infrastructure as a Service (IaaS) platform described in the previous paragraph. This platform could potentially host the required CCAM related.

In the proposed architecture user plane functionality is exploited through a 5G RAN node directly connected to the UPF through the N₃ interface. It is worth mentioning that implementation of this use-case and the respective solution depends on the flexibility and the resources available to the partners responsible for the deployment of on-site 5G infrastructure.

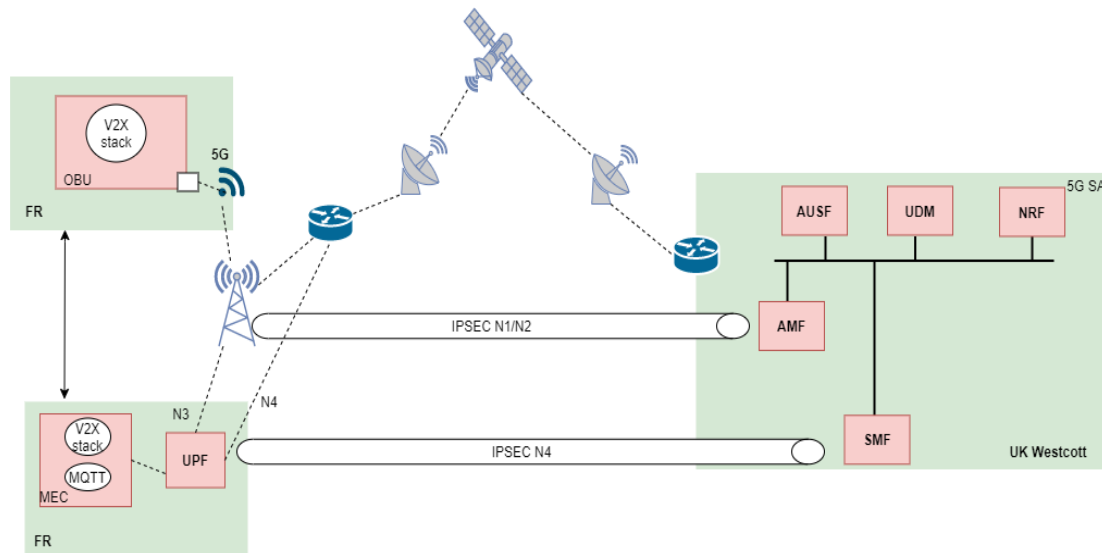


Figure 7.48: Satellite Backhauling with user plane/MEC breakout.

The diagram for the solution of the presented use case is depicted in Figure 7.48. As shown, the OBU is first authenticated by backhauling control plane traffic to the remote 5G Core, through the satellite network. When authentication is accomplished, SMF and UPF directly exchange N4 traffic through the satellite backhaul to establish the PDU session. To ensure security among remote 5GCore and on-site breakout platform, two IPsec tunnels are formed, one for the N1 and N2 interfaces and another for the N4 interface. Thereafter, the OBU can directly communicate related CCAM messages with the local MEC platform via the N3 interface connecting the gNB to the UPF.

7.6.4 Non 3GPP Satellite Access

This use case addresses the issue where a certain area is under-served or unserved by 5G infrastructure, however the 5G MNO provides 5G Core access to the OBU, through a satellite network provider. The collaborative discussions as well as the agreements that need to take place for this scenario is out of the scope of this document and we are only focusing on the technical solution of this issue.

The following requirements shall be met for this solution:

- The satellite terminal shall utilize the necessary protocols for N1 (NAS 5GS), N2 (NGAP) interfaces for the authentication between the terminal and the 5G Core
- The satellite network shall allow transport of the 5G control plane to the 5G Core through the satellite network. Therefore, an approach should exist that allows the UE to be first authenticated by the satellite network. After initial attachment, the N1, N2 interfaces should be transferred from the satellite network data plane to N3IWF

- If the above requirement cannot be implemented, N3IWF shall be deployed in the satellite network and all control/user traffic shall be transferred to 5G Core from this NF, so that authentication takes place in the 5G Core.

The main functions of N3IWF are defined within the context of TS 23.501 [14] and includes the following:

- Support of IPsec tunnel establishment with the UE: The N3IWF terminates the IKEv2/IPsec protocols with the UE over NWu and relays over N2 the information needed to authenticate the UE and authorize its access to the 5G Core Network.
- Termination of N2 and N3 interfaces to 5G Core Network for control - plane and user-plane, respectively.
- Relaying uplink and downlink control-plane NAS (N1) signalling between the UE and AMF
- Handling of N2 signalling from SMF (relayed by AMF) related to PDU Sessions and QoS.
- De-capsulation/ encapsulation of packets for IPsec and N3 tunnelling
- Support AMF selection

The configuration for the configuration of non-3GPP satellite access is demonstrated in Figure 7.49.

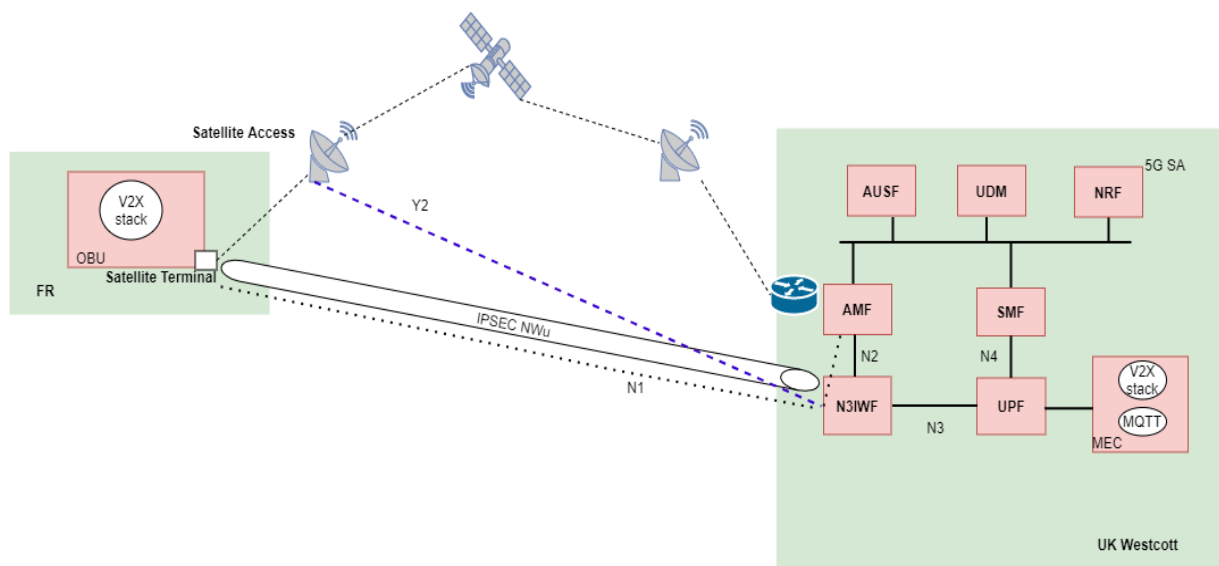


Figure 7.49: Non 3GPP Satellite access.

In the figure above, these functionalities are clearly illustrated. Furthermore, there are two additional interfaces that need to be interlinked to the reference points of the 5G Core. The Y2 and the NWu interface. The former is the reference point between the untrusted non-3GPP access and the N3IWF for the transport of NWu traffic. The latter is the interface between the UE and N3IWF for establishing secure tunnel(s)

between the UE and N3IWF so that control-plane and user-plane exchanged between the UE and the 5G Core Network is transferred securely over untrusted non-3GPP access.

It is worth mentioning that when a UE is connected via a NG-RAN and via a standalone non-3GPP access, multiple N1 instances shall exist for the UE (i.e., there shall be one N1 instance over NG-RAN and one N1 instance over non-3GPP access). Further details for UE attachment to 5G Core Network over untrusted non-3GPP access are described in clause 4.12.2 in TS 23.502 [15].

7.6.5 Hybrid Communication through 5G Core (MA-PDU)

In 4G networks, it is possible to have coordinated transmissions from two neighbouring evolved eNBs at the same time. The idea was that by utilizing this technique at the cell edge, signal reception becomes more reliable, increasing thus the quality of service. In this approach, the UE maintains connection to both eNBs, where the same content was split to achieve resource sharing among the eNBs. One of the main additions in 5G, is the integration of simultaneous 3GPP and non-3GPP technologies accessing the 5G Core.

The multiple link access is thoroughly investigated in TR 32.793 [7] where new architectures for simultaneous 3GPP and non-3GPP access are documented. This study is mostly focusing on how the 5G System (5G UE and CN) can be extended to support Access Traffic Steering, Switching and Splitting (ATSSS) between 3GPP and non-3GPP access network.

This solution supports Multi-Access (MA PDU) based on ATSSS. A MA PDU is a type of PDU session that allows application to send/receive traffic either over 3GPP access, or non-3GPP access, or both accesses simultaneously. A MA PDU session comprises a PDU session over 3GPP access and a "linked" PDU session over non-3GPP access, or vice versa. Each of the PDU sessions may have its own set of UPFs, but both PDU sessions share a common PDU session anchor (PSA) as shown in Figure 7.50. For MA PDU session, applications in UE and the N6 host server are not aware of traffic split across multiple accesses.

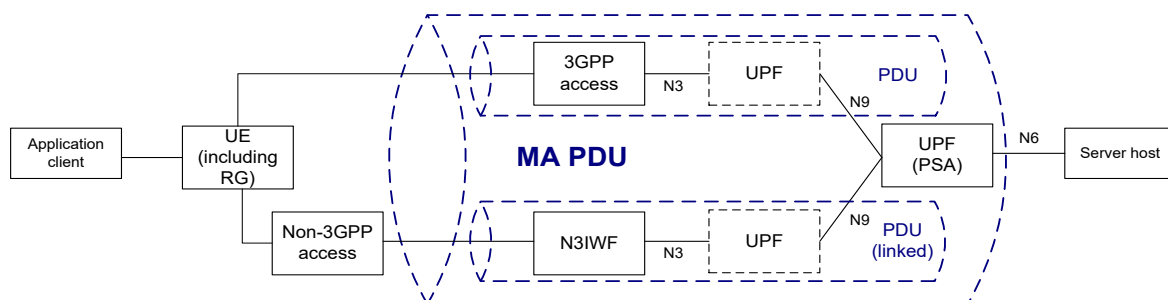


Figure 7.50: MA PDU Session [source: [16]].

7.6.6 NR over Satellite

Direct 5G UE access with NR implies a satellite link on the RAN using the native 5G radio access technology. Therefore, additional functions for secure authentications are not required. However, a direct

implementation of the 5G NR protocols and schemes using the 3GPP specifications/standards may be problematic due to the differences in the propagation channel between the terrestrial link and the satellite link. For example, propagation delays and Doppler shifts at satellite links can be 300 times and 126 times larger than at terrestrial links, respectively. The characteristics of the network layout can also be significantly different such as the maximum cell size and the mobility of the infrastructure's transmission equipment. To this end, a modification to the 3GPP 5G NR specifications/standards with respect to the satellite links will be required. The impacted areas requiring modification include mainly the network architecture, the physical and MAC layer procedures [17].

There are two main architectures for direct 5G NR access over satellite. The first is illustrated in Figure 7.51, where the satellite is transparent, the NR signals are generated from gNBs from a satellite enabled NR-RAN that are located on ground. The satellite is equivalent to a Radio Frequency (RF) Remote Unit, and is full transparent to the New Radio protocols, including the physical layer.

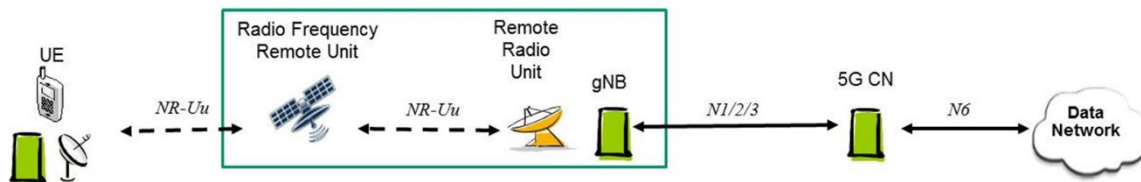


Figure 7.51: 5G System with transparent satellite enabled NR-RAN [source: [11]].

The second architecture is shown in Figure 7.52, relates to a regenerative satellite. The satellite payload implements a full gNB supporting a satellite enabled NR-RAN. A Satellite Radio Interface (SRI) transports the N1/N2/N3 interfaces between the on-ground 5G CN and the on-board gNB [11].

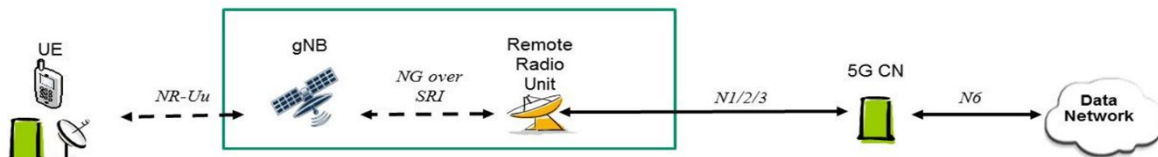


Figure 7.52: 5G System with regenerative satellite enabled NR-RAN and on-board gNB [source: [11]].

There are other intermediate options where the satellite payload implements a gNB-Distributed Unit (DU) as part of a satellite enabled NR-RAN. Some of the protocols of the NR are processed by the satellite and the satellite Radio Interface (SRI) transports the F1 protocol between the on-ground centralized unit and the on-board DU.

7.7 5G Technology deployment summary

Table 7.35 provides a summary comparison of the advanced 5G technologies deployed in the different CBCs and TSs of the 5G-MOBIX project. Figure 1 gives an overview of the technology deployed and tested per cross border corridor and trial site.

Table 7.35: Advanced 5G technologies deployment comparison.

Technology ↓/ Site→	ES-PT	GR-TR	DE	FI	FR	NL	CN	KR
C-V2X	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X (PC5 support)	5G-V2X
MEC Deploy- ment	Yes, Nokia solution	Yes, Ericsson solution	Yes, Near Edge	Yes, MEC Service Discover y	Yes, Far/ Cloud Edge	Yes, MEC Discover y SSC M3	Yes, ZTE solution	No
Network Slicing	No	No	No	Yes	To be defined	Yes	Yes	To be defined
Roaming	Cross- border	Cross- border	Multi- SIM in NSA/SA	Multi- SIM in SA	Multi- SIM in NSA	Virtual cross- border	Natio- nal	No
Satellite Deploymen t	No	No	No	No	Yes	No	No	No

8. 5G DEPLOYMENT SUMMARY AND CONCLUSIONS

This document reports on the 5G networks of 5G-MOBIX, providing the deployment strategies and timelines, describing the radio access and core network deployments as well as the integration and planned testing, along with the initial testing results, with respect to the individual CBCs and the local TSs. It further reports on the deployment of a set of 5G technologies at the CBCs and TSs and their relevance to the cross-border CCAM use cases.

The document is structured following the main timeline of the deployments and the main parts of the network, namely first describing the deployment strategies and activities, then separately the actual deployment of the radio access and core network, before describing their integration as well as the integration between the networks at the CBCs, followed by testing plans and results. It finally includes a section on 5G technologies that spans across large parts of the deployment timeline, focussing instead on how these advanced 5G technologies relate to and enable the cross-border CCAM use cases.

The deployments at the two CBCs, ES-PT and GR-TR, include a total of four networks with twelve gNBs covering locations at the two borders as well as testing sites further inland. At the Spanish-Portuguese border two bridges over the border river Miño form the designated cross-border testing area, and 5G coverage has been successfully deployed at the ES side, while deployment at the PT side is under way and expected to be completed by January 2021. The Greek-Turkish border testing site at the border crossing of the Ego/E84 near Kipoi/Ipsala has received 5G coverage from both sides and initial network testing has been performed. In both CBCs 5G NSA deployments were chosen and implemented.

The TSs have mostly completed the initial rollouts and are in the early stages of testing. Similar to the CBCs, many TSs feature multiple 5G networks, but often with more experimental deployments or a larger variance in characteristics or parameters. For instance, the TSs in DE, FR, NL and KR have or are planning to go to 5G SA deployments, while those in NL and KR include the use of mmWaves.

Testing of the networks is planned by all CBCs and TSs, having defined a common set of generic network tests as well as a per-CBC/TS set of specific tests. While most network testing is yet to be done, initial testing results are reported for the ES-PT and GR-TR CBCs.

A number of advanced 5G technologies is analysed and their deployment at the CBCs and TSs described in relation to their use for the CCAM use cases of 5G-MOBIX. 5G vehicular communications (5G V2X) is used at all CBCs and TSs, as is edge computing in different flavours and covering various edge placements and strategies for service discovery. Network slicing is used at the FI, NL and CN TSs and foreseen as an option for the DE and FR TSs, highlighting the contribution of the local TSs, as slicing is considered key to achieve isolation of different traffic types or use cases and thus to guarantee performance and quality of service or quality of experience. Roaming or seamless multi-SIM switching are implemented at all CBCs and TSs in

different forms, allowing the project to compare between strategies and implementations. Finally, the FR TS includes the use of satellite technology.

Overall, D3.3 reports on the successful deployment of 5G networks at all CBCs and TSs, forming a key part of the project and setting the basis for the network testing and upgrades to be performed in the remainder of the T3.3 timeline and providing the background required for full specification of the further cross-party testing and verification in T3.6. As such, E2E testing on the network level will be the immediate focus of T3.3 to complete network testing and allow for the verification planned in T3.6.

Finally, D3.3 documents a major step towards the completion of the 5G networks of 5G-MOBIX, fulfilling a pre-requisite for the trials and evaluation to be performed in WP4 and WP5 respectively. T3.3 will support the early and full trials, as foreseen in its activities and timeline, by taking care of network maintenance, providing fixes where needed and seeking to upgrade the deployed networks at the CBCs and TSs as technology becomes as available and as indicated in the respective CBC and TS plans. Notably, this includes the possible upgrade to SA, as considered by some CBCs and TSs as indicated in section~4.

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ANNEXES

The following annexes provide additional detail of the CBC deployments and deployment reports from the TSs.

A. DEPLOYMENT REPORT FOR THE DE TS

A.1 Overview

In this Annex, the main characteristics of the two distinct 5G network infrastructures that are utilized in the DE-TS are briefly described. It should be noted that the DE TS consortium does not have a mobile network operator who is also a direct consortium member in 5G-Mobix. However, instead of a project partner creating its dedicated 5G network, the DE TS partners with Deutsche Telekom, who has upgraded its commercial deployment to feature 5G coverage over the trial site area. Furthermore, the DE TS uses of the non-commercial 5G test deployment at the TUB campus area, available to us as the second 5G network. In the following section, we describe in detail the characteristics of the prevalent 5G networks for the German trial site location in the urban centre of Berlin.

A.2 Specific deployment plan and strategy

In order to enable the evaluation of CCAM use cases, the DE-TS has access to two different 5G network deployments. For this reason, the UEs employed in the use cases will be able to change from one network to another, allowing for the assessment of the performance of experiments in the context of an “emulated roaming” scenario. Following this roaming scenario, we can simulate a border-crossing between two countries in terms of cellular connectivity, where the vehicles move across the 5G coverage areas of two different MNOs, while remaining in the same city. In this context, the focus is not on a handover from one base station to another of the same operator, instead the UE leaves the coverage area of one operator and then attaches to the other operator to establish a new data connection on the other network. We refer to this setting as the “inter-MNO service handover” or simply “inter-MNO handover” experiment in the rest of the text.

Depending on a set of parameters the UE connects to the first or to the second 5G network. The first 5G network present in the DE-TS is the commercial 5G network provided by the Deutsche Telekom, the second is a research-focused 5G test deployment that is hosted on the campus of TUB. In order to realize the “inter-MNO handover” experiments, a dedicated SIM card for each of the networks is required.

A.3 RAN deployment

As stated in the overview section, the DE-TS is not in charge of setting up a RAN deployment as it makes use of 5G networks that are already deployed and that provide 5G coverage within the area of the trial site. In the following we describe the relevant RAN parameters that define the characteristics of the 5G deployment at the DE-TS. General network deployment features are also summarized in Table A.36.

Table A.36: Overview of the 5G networks deployment at the DE TS.

5G Networks	Operated by	Type	Commercial / Test	Freq. Bands	Num. gNBs
Network 1	Deutsche Telekom	NSA	Commercial	Full covered TS: 2.1 GHz (5G NR n1) + 800 MHz (LTE B20), 900 MHz (LTE B8), 1800MHz (LTE B3) anchor bands Partial coverage TS: 3.6 GHz (5G NR n78) + 1800MHz (LTE B3), 2600 MHz (LTE B7) anchor bands	TBC: X -Available: 5 -Deployed during 2021: 15
Network 2	TUB	SA	Test	3.7 - 3.8 GHz (5G NR n78)	1

A.3.1 Site overview

In Figure X, the relevant base stations present in the DE-TS are presented. They are mostly property of the Deutsche Telekom, except of one marked in purple, which represent the 5G tower that is used for testing with SA networks in the TU Berlin campus. The towers represented in black are LTE eNBs and the towers represented in pink are EN-DC capable LTE eNBs that may be used as anchor base stations for the 5G gNBs in Telekom's NSA network. Due to confidentiality agreements with Deutsche Telekom, it is not possible to release the specific deployment of the 5G gNBs.

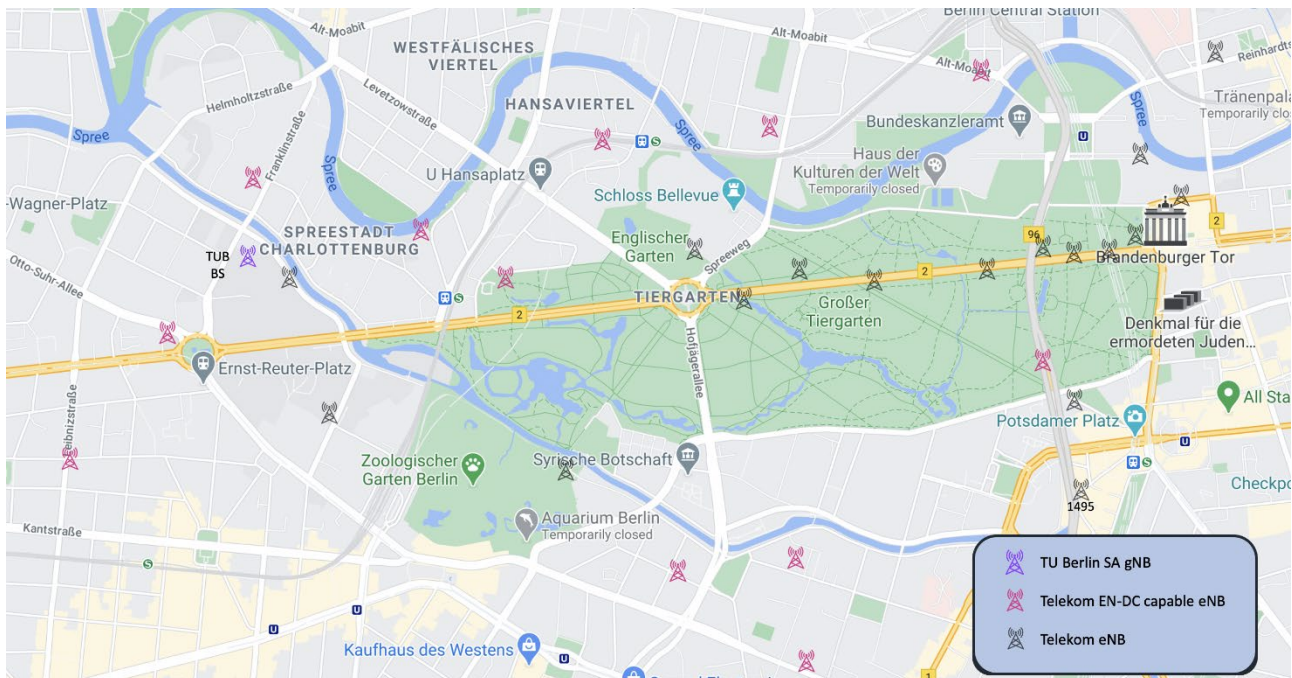


Figure A.53: Base Stations distribution at the DE-TS.

In the case of the Deutsche Telekom, the area of TUB main campus and the trial site located in the city centre of Berlin is fully covered with a 5G network operated in Non-Standalone Mode (NSA) on a frequency of 2.1 GHz (n1 band), as shown in Figure A.54. In addition to this full-area coverage, the trial site is also partly covered by base stations that are using the 3.6GHz frequency range (n78b). At this point in time the coverage in n78 is limited, however, Deutsche Telekom plans to have new base station locations for the n78 band operational as early as beginning of 2021. For this reason, we assume to be able to deploy some additional road infrastructure in the coverage of n78 base stations or even perform some trialling in the coverage area with higher bandwidth than the one provided by the n1 band. However, it should be noted that already the available data rates of up to 225 Mbit/s that are theoretically achievable in the n1 band are more than sufficient for the DE-TS use cases. The anchoring LTE frequencies utilized by Deutsche Telekom for the 5G n1 band are the 800 (B20), 900 (B8) and 1800 (B3) MHz LTE bands, and for the 5G n78 band, the 1800 (B3) MHz and 2600 MHz (B7) LTE bands. From July 2021 the used bandwidth on the n1 frequency band will increase from 15MHz to 20 MHz, using the spectrum previously allocated for UMTS for 5G in this case.

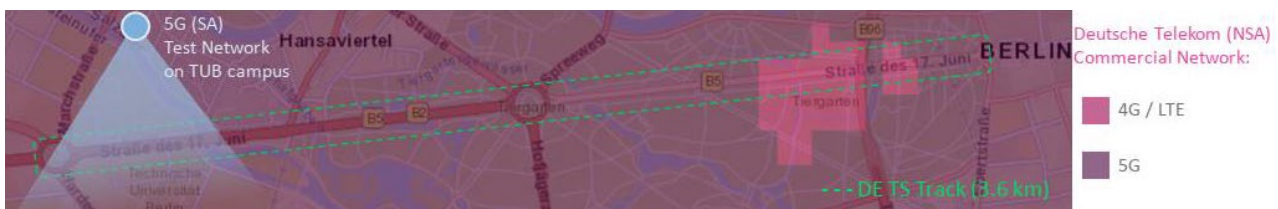


Figure A.54: 5G Network coverage at the DE TS.

The Deutsche Telekom also makes use of the advantages from Dynamic Spectrum Sharing (DSS), where in principle the same antenna is shared for 4G and 5G purposes in the same frequency band. This is possible by determining how much of the bandwidth should be used for each standard in real-time, and by allocating dynamically the available spectrum regarding the needs of 4G and 5G users. This technology allows to make use of 5G capabilities with already existing deployments, saving in costs and in time.

Another interesting feature from the Deutsche Telekom NSA network is the novel application of the inter-site anchoring concept. Normally a 5G user connected to a gNB should use as anchor LTE cell the one that is in the same location as the gNB where it is camping. With the use of inter-site anchoring, the 5G user can use as anchor any LTE cell that overlaps its coverage with the gNB's coverage, without the need of being necessarily the LTE cell where the gNB is located. This fact allows to make a better use of the gNBs coverage, as it is different from the LTE's coverage due to the different frequencies that are being used. Inter-site anchoring requires that all base stations are synchronized, in order to prevent timeouts of signalling events, for example.

The graphic showing the 5G coverage by Deutsche Telekom in Figure A.54 is based on the map publicly made available³ by Deutsche Telekom itself. As can be seen there is currently only a small coverage hole

³ <https://www.telekom.de/netz/mobilfunk-netzausbau>

where Deutsche Telekom cannot offer 5G at this point in time, however, this gap is supposed to be closed by the end of Q4 2020.

In Figure A.55 and Figure A.56, the Telekom LTE base stations that can perform in EN-DC mode and act as an anchor for the 5G base stations are represented. In these figures, also the relevant Tracking Area Codes (TAC) covering the DE-TS area and the coverage area of the EN-DC capable LTE cells that are pointing in the TS direction have been represented. The used LTE band anchor and the respective cell IDs are written inside of the covered areas from the relevant eNBs. Also, the eNB's ID is written next to each tower. In Figure X2, only the areas covered by the LTE cells that can act as an anchor for the 5G n1 band, and are oriented in the TS's direction, are represented. In Figure X3, only the areas covered by the LTE cells that can act as an anchor for the 5G n78 band, and are oriented in the TS's direction, are represented.

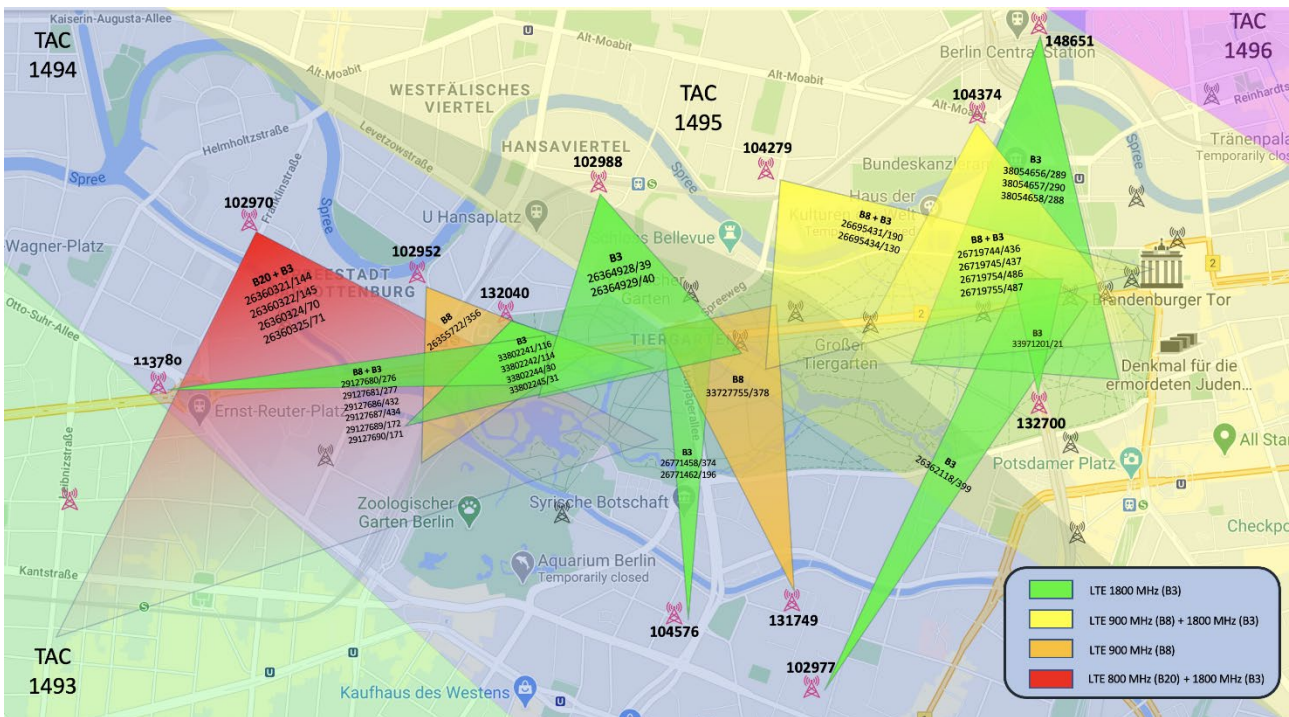


Figure A.55: Telekom's LTE eNBs that are EN-DC capable for anchoring in the n1 band.

Regarding the research standalone base station to be used for the inter-MNO handover experiments, it provides 5G access via the n78 band on the frequency band reserved for experimental use in Germany (3.7-3.8 GHz). It is deployed on the rooftop of a building located on the northern end of the TU Berlin campus, also covering a partial area of the DE TS as illustrated in blue in the picture above.



The Deutsche Telekom 5G network operates on its commercially licensed frequencies for Germany (n1, n78b), the research deployment utilizes a 5G Campus frequency license (3.7-3.8 GHz) that was approved by the German agency that handles experimental licenses (Bundesnetzagentur).

The core deployment used in the DE TS is provided by the Deutsche Telekom and for now, being an NSA network, the LTE EPC core is used to enable 5G data connections. Since the Core Network is the commercially used one, no research interaction or interference with the operations or procedures for measurements or experiments are possible. The research 5G deployment on TUB campus utilizes an experimental core network with reduced functionality, as the focus of research on the gNB is on wireless aspects.

The RSUs and OBUs utilized by the DE TS for experiments are equipped with 5G modems from Quectel. At the time of writing the available hardware has only limited support for all 5G combinations of NSA and SA operational modes and frequency bands. The models which are based on Qualcomm X55 chipsets are the RM500Q-GL and RG500Q-EA modules to access the two different 5G networks that give coverage to the DE TS. In addition to the user equipment and access networks described above, the DE TS has secured

access to the near edge MEC infrastructure that is operated and managed by a subsidiary of Deutsche Telekom called MobileEdgeX. The DE TS utilizes the datacentre location operated in Berlin to deploy Kubernetes containers that exploit the low latency and the logical location of the communication exchanged with UEs inside of the Deutsche Telekom mobile network control domain.

A.6 Network integration and testing

At the time of writing the integration testing of 5G Modems by Quectel with the 5G networks is an ongoing activity, mainly due to the aforementioned compatibility issues of the chipsets with the particular frequency combinations of LTE anchoring frequencies in NSA mode (EN-DC), and the bleeding edge testing of Standalone Mode with the research 5G base station.

Upload and download throughput tests have been realized along the DE TS using the Dekra Tool and a 5G capable smartphone, in order to have a first quick view of the network performance. More than ten tests were accomplished but only the result of one test for each type, download and upload, are included in Figure A.57, as they were similar. The duration of the tests were 15 seconds and the maximum data rate was set to 1 Gbps, in order to reach the maximum throughput allowed by the network. As it is a commercial network, the values vary depending on the traffic at that moment of the day. The maximum throughput in this test was close to 300 Mbps but in other cases peaks of more than 500 Mbps were already reached.

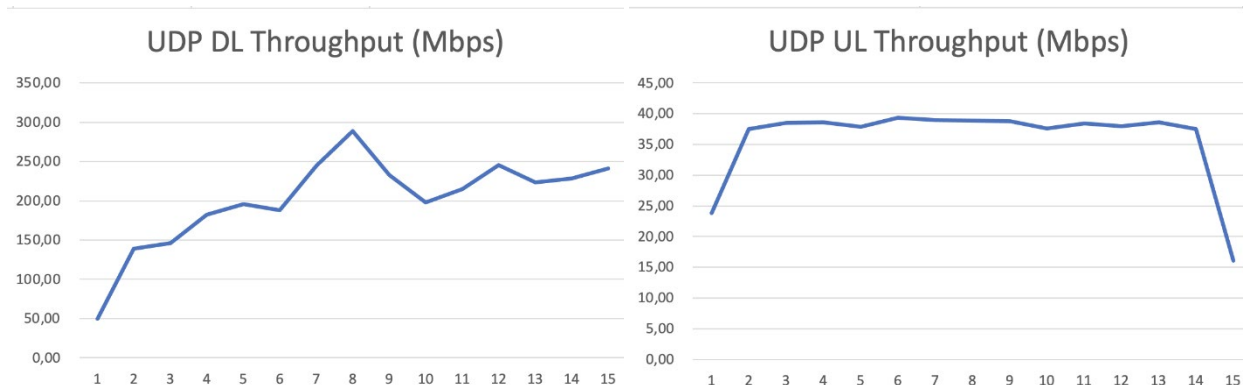


Figure A.57: UDP down- and upload throughput in the DE TS.

A.7 Summary

The deployment report presented above compiles all the information on 5G infrastructure and networks that is being exploited for the DE TS activities within the scope of 5G-MOBIX. The information provided resembles the status at the end of 2020 and is bound to change in the near future based on the availability of 5G chipsets with improved compatibility.

B. DEPLOYMENT REPORT FOR THE FR TS

B.1 Overview

FR TS 5G deployment targets a multi-PLMN environment to emulate the cross-border conditions. To this end, FR TS will use two different sites for 5G network related functionalities trials.

In the first site (UTAC/CERAM), there are two 5G networks already deployed respectively by Orange and Bouygues MNOs. These will be used specially to test seamless Handover between two PLMNs which will then be transferred to CBC as a FR TS contribution.

The second site is located at Satory and will use mmWave technology. The deployment of 5G network infrastructure with the help of a private network provider (TDF) is in progress. This trial site will be used for preliminary functions testing (command control, message dissemination, etc).

B.2 Deployment plan and strategy

1. The deployment of 5G networks at UTAC/CERAM site is already completed.
2. The deployment of 5G network at Satory site is still in progress. The different steps for 5G network deployment at Satory site as well as their status are summarized below:
 - Frequency license acquisition: completed
 - Preparation for installation of 5G NSA option: in progress
 - Discussions with network provider (TDF) for 5G NSA deployment: in progress
 - SA option will probably be available in 2021 (To be confirmed)

B.3 RAN deployment

5G network deployment at France trial site will firstly be based on NSA option. The radio access network consists of 5G base stations (gNB) deployed as follows:

- At Satory, one gNB will be installed using mmWave (26 GHz frequency).
- In TECMO trial site, each 5G MNO has deployed one gNB (3 sectors).

B.3.1 Site overview

Figure B.58 provides an overview of the TEMCO FR trial site.



Figure B.58: TECMO FR trial site overview.

B.3.2 Frequency licences

The National Frequency Agency (ANFR) manages all radio frequencies in France. In the framework of an agreement that has been renewed every year since 1998, the ANFR prepares the frequency use authorisations (AUF) issued by the ARCEP (France's Electronic Communications, Postal and Print media distribution Regulatory Authority). In this matter, it manages some parts of the spectrum assigned to the ARCEP and examines, prepares and sends the authorisations that are under ARCEP jurisdiction in specific bands. In April 2020, ARCEP announced that France's four mobile network operators – Bouygues Telecom, Free Mobile, Orange and SFR – had qualified to participate in the 3.4 – 3.8 GHz band frequency awards. Each had made the commitments that enabled them to obtain a block of 50 MHz. On October 2020, frequency auction was organized by ARCEP to award the remaining 11 blocks of 10 MHz in the 3.4 – 3.8 GHz band.

As a result of the auctions, Orange and Bouygues operators have obtained the frequency bands listed in Table B.37. At Satory trial site, the obtained frequency is used only for test purposes.

Table B.37: Frequencies used in the FR TS.

Site	MNO	Frequency band	Bandwidth (MHz)
TECMO trial site	Orange	LTE 700 (B28)	2 x 30 MHz (FDD)
		NR 3500 (n78)	90 (TDD)
	Bouygues	700 MHz (n28) 800 MHz (n20) 1800 MHz (n3) 2100 MHz (n1) 2600 MHz (n7)	2 x 30 MHz
		NR 3500 (n78)	70 (TDD)
Satory trial site	TDF	NR 26 GHz	100 (TDD)

B.4 Core deployment

At Satory trial site, the core network will be deployed following two phases:

- Phase 1: 4G Core (Evolved Packet core) will be firstly deployed for NSA option by June 2020
- Phase 2: 5G Core will be deployed during 2021 for 5G SA option

At TECMO trial site, Orange is already deploying its trial 4G core network (NSA option). For Bouygues PLMN, we will use the commercial 4G core network. Both MNOs are planning to migrate to 5G core network (SA option) as a next step. Figure B.59 describes the overall architecture at TECMO trial site.

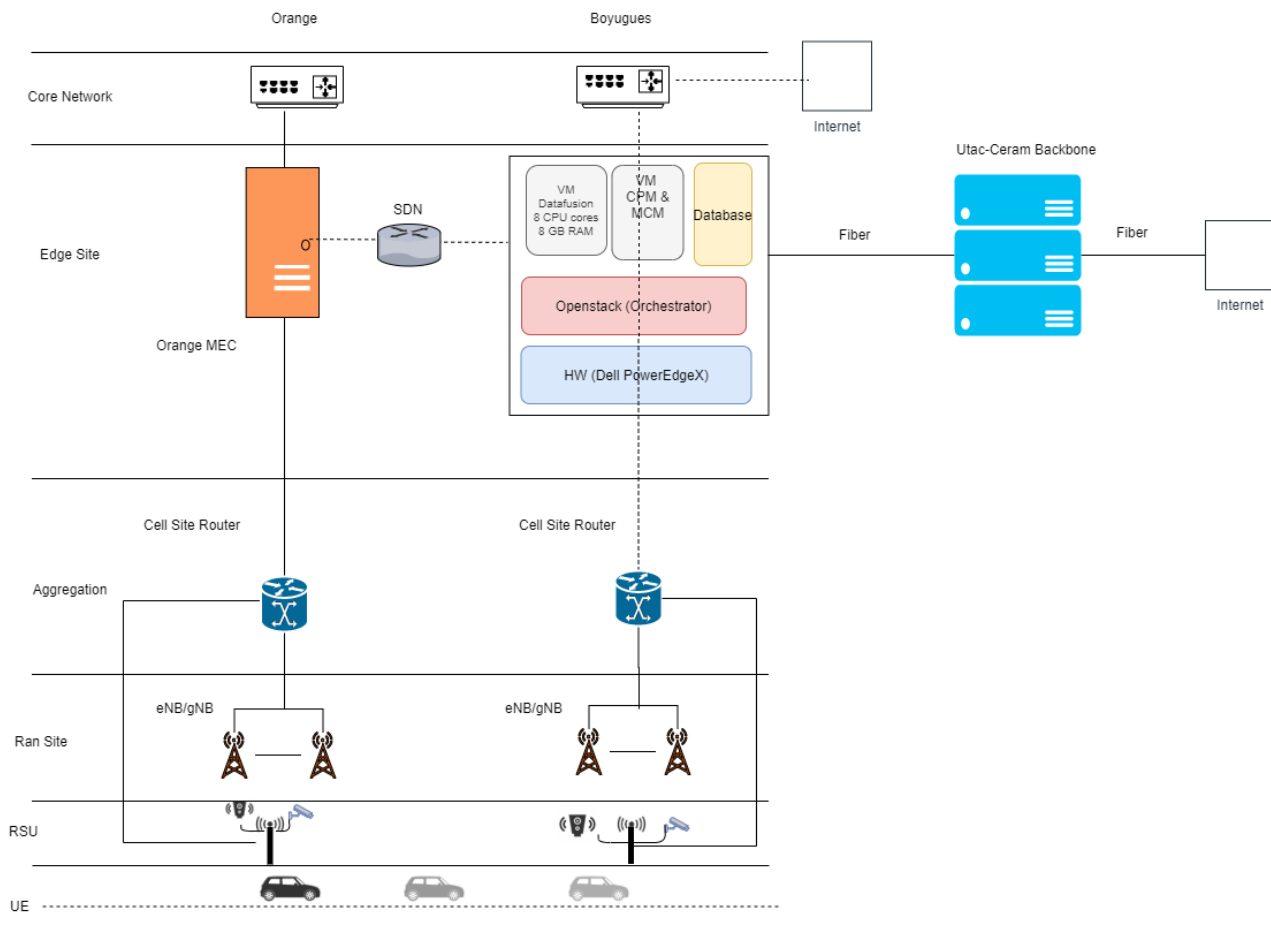


Figure B.59: 5G network architecture at TECMO FR trial site.

B.5 5G Technology deployment

NSA option: mmWave in RAN part, eMBB, URLLC, dual connectivity, Edge computing (MEC).

SA option: Network slicing (during 2021, to be confirmed).

FR TS will deploy the following 5G technologies:

1. Development and test of V2X Application Server and Control Function specified in 3GPP TS 24.386. The key roles of these functions are to ensure authorization and authentication of vehicle UEs and enable efficient distribution of safety and traffic related information that are primordial for CCAM applications. FR TS demonstrates that thanks to these functions, AVs will be informed of the presence of AD-prohibited zone and the contextual speed limit of the route.
2. QoS control support for eMBB and URLLC applications: this will be respectively achieved by APN selection for NSA option and network slicing for SA option.

3. Testing different MEC deployment options in 5G network: shared MEC (as specified by ETSI and 5GAA for multi-tenancy), non-shared but cooperative MEC approaches. These deployment strategies are relevant for cross-borders scenarios (ES-PT, GR-TR).

B.6 Network integration & testing

Some preliminary tests have been carried out in TECMO trial site. The figure below represents 5G drive test of Bouygues network average throughput performed at TECMO trial site.

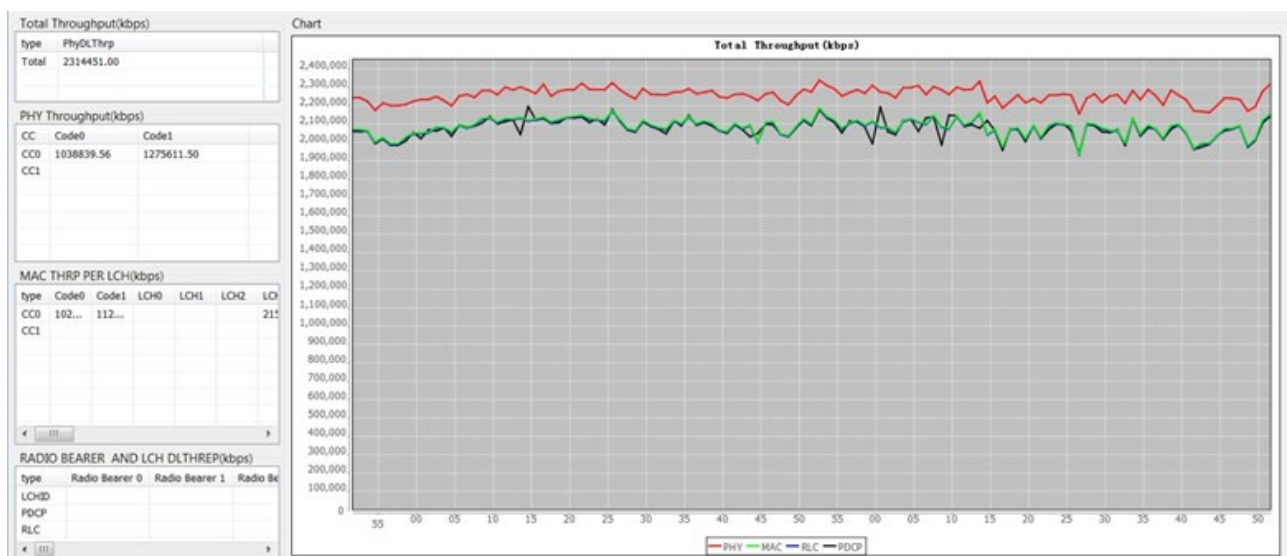


Figure B.6o: 5G drive test results at TECMO FR trial site.

B.7 Summary

This Section provided an overview of the completed and ongoing 5G multi-PLMN deployments for the French trial sites. The initially planned deployment schedule has been impacted by Covid-19 measures in France.

C. DEPLOYMENT REPORT FOR THE FI TS

C.1 Overview

The Finland trial site is located within the Otaniemi area of Aalto University campus. To that end, the 5G-MOBIX project leverages 4G/5G testbeds deployed in the Otaniemi area that are continuously being enhanced/upgraded for use in 5G-MOBIX and other local and international research projects. All the networks utilise standards-compliant commercial equipment and are self-operated by AALTO. In the case of 5G-MOBIX, the priority is to have network deployments that provide coverage on roads targeted for the 5G-MOBIX trials and a surrounding environment includes features (buildings, vegetation etc.) that impact radio propagation.

C.2 Specific deployment plan and strategy

The network deployment in the FI TS targets a multi-PLMN environment (with two PLMNs) to support remote driving and cooperative perception user stories. The intention of this two PLMN deployment is to emulate network environments encountered in cross-border areas. This provides a useful environment for studying behaviour of CCAM applications when transitioning between cross-border networks. For instance, in the remote driving user story, multi-PLMN arrangement could be used to provide connectivity redundancy for an L₄ vehicle, demonstrating the potential benefits of having the vehicle maintain its services when it loses connectivity to one of the two PLMNs it is attached to. Moreover, this provides an environment for comparison to the conventional scenario whereby a vehicle roams or hands over from one PLMN to another.

The fact that both PLMNs considered above are research networks operated by AALTO, provides an opportunity for testing relatively new technology features or configurations that would otherwise be difficult or unfeasible to execute in commercial production networks.

C.3 RAN deployment

The radio equipment deployed in Finland were initially shipped supporting only 5G NSA mode, but a software upgrade was later applied to allow also for support for SA mode. 5G SA. The radio access network consists of two base station sites (Väre and Otakaari 5), with each site representing a single PLMN as it is associated to a distinct core network and assigned a unique PLMN-ID (see Figure C.61). The site selection considered the availability of necessary site facilities (grid power, fibre backhauling cables etc.) and a coverage footprint that allows for overlap in coverage between the two PLMNs to enable testing of multi-PLMN connectivity.



The environment and radio equipment deployment for the Väre and Otakaari 5G sites are shown in Figure C.62 and Figure C.63, respectively. It is noted that both sites are rooftop deployments to ensure line of sight visibility on significant portions of the test road (Otakaari road shown previously in Figure C.61). The Otakaari 5G site and Väre sites are 33 m and 30 m above sea level, respectively (or 27 m and 27 m above ground level, respectively). Furthermore, both sites utilise 5G radio equipment from Nokia with RRH consisting of 64Tx64R massive MIMO active antennas. The Väre site has two RRHs (two cells), whereas, the Otakaari 5G site has one RRH. Both sites also include 4G radio equipment (4Tx4R passive antennas) to serve as the 5G NSA anchor. In all cases the 4G and 5G BBUs are deployed remotely at the Aalto Data Centre (indicated in map of Figure C.61) with multi Gbps fibre connectivity to each site. At the time of reporting, the Väre site was fully operational whilst the Otakaari 5G site was awaiting installation of fibre cables to the site prior to site commissioning.



Figure C.62: Radio network equipment deployment at Väre site.



Figure C.63: Radio network equipment shipment and deployment at the Otakaari 5 site.

Table C.38: Location and heights of antenna at the two FI sites

Site	Location	Antenna height (above ground)	Antenna height (above sea level)
Otakaari 5	60°11'23"N 24°49'54"E	33 m	27 m
Väre	60°11'09"N	30 m	27 m

Site	Location	Antenna height (above ground)	Antenna height (above sea level)
	24°49'26"E		

C.3.2 Frequency licences

In the FI TS, AALTO as the operator of the 4G and 5G campus test networks has spectrum licenses granted by the Finnish regulator, TRAFICOMM. This is made possible by the fact that TRAFICOMM in addition to granting national spectrum licenses to commercial operators, also has an arrangement for granting local test spectrum licenses to research institutions, mobile equipment vendors, and other industry verticals maintaining local test networks. It also noted that TRAFICOMM serves in the advisory board of 5G-MOBIX. The spectrum licenses available for use in the FI TS are shown in Table C.39.

Table C.39: Frequency licenses available at the FI TS.

Frequency band	Bandwidth (MHz)	Frequency (MHz)	Valid until
LTE 2600 (B7)	10 + 10 (FDD)	2660 – 2670 (UL) 2680 – 2690 (DL)	Renewed annually
NR 3500 (n78)	60 (TDD)	3640 – 3700	Renewed annually

C.4 Core deployment

The multi-PLMN environment in FI TS is enabled by the deployment and usage of multiple virtualised 4G/5G core networks. This configuration enables switching between NSA and SA modes via the network management interface. The virtualised core networks provide the necessary level of deployment flexibility and sharing of cloud infrastructure as shown in Figure C.64 (note for simplicity only 5GC network functions are shown). AALTO possesses multiple PLMN IDs and SIM programming capabilities to create multiple PLMN instances is required for different research purposes, even in cases where common infrastructure is leveraged. Specifically, Aalto University has access to ten PLMN IDs (244 50 to 244 59) assigned by the local regulator, TRAFICOM. For the two PLMNs used for 5G-MOBIX trials, the PLMN IDs 244 52 and 244 53 are allocated to the PLMN-1 and PLMN-2 based on the Väre and Otakaari 5 sites, respectively (see Figure C.64).



The figure consists of two side-by-side satellite images illustrating network deployment scenarios. The left image, titled 'PLMN 244 52 DEPLOYED LOCALLY', shows a local deployment where two sites are connected by optical fiber. Each site contains individual core networks (AMF, SMF, UPF) producing two PLMNs. The right image, titled 'PLMN 244 53 DEPLOYED REMOTELY', shows a remote deployment where two sites are connected by a 1500 km link. One site contains AMF and SMF components, while the other site contains the UPF component. Both images are sourced from Google Earth.

Figure C.65: Placement of 5GC network functions for PLMN-1 (left) and PLMN-2 (right)

C.5 5G technology deployment

The FI TS network deployments provide opportunity for deployment of additional advanced 5G technology feature or concepts to support the remote driving and extended sensor user stories. To that end, two notable developments deployed and validated in the FI TS include:

- MEC services discovery to enable migration of MEC applications when vehicles move from one PLMN to another (this was described in more detail previously in section 7.3.2.1)
- Network slicing approach to provide isolation of edge computing traffic from general traffic (this was previously described in more detail in section 7.4.4)

C.6 Network integration and testing

The 5G network integration and testing for the FI TS has been conducted gradually as each radio base station site becomes live and is integrated to the 5GC. The preliminary testing results are currently only available for the Väre site which became active at around M12 of the project. A sample of tests results were generated from a 5G measurement campaign with Keysight Nemo outdoor drive test tools. As noted previously, the Väre site has two cells with cell IDs PCI-10 and PCI-20. Some of the observations from the measurements:

- Best servers for the two cells (PCI-10 and PCI-20) of the Väre site (see Figure C.66)
- Coverage measurements (in terms of SS-RSRP) on test roads from the Väre site (see Figure C.67)
- Signal quality (in terms of SS-SINR) achieved from the two serving cells of the Väre site (see Figure C.68)

At the time of reporting, the Otakaari 5 site installation is still ongoing with fibre cabling installation work and preliminary test results for this site might be available for the final version of this report. Apart from the understanding the performance of the Otakaari 5 site, this will also enable to observe overlapping coverage areas of each PLMN and potential handover/roaming points.

C.7 Summary

This Section provided an overview of the completed and ongoing 5G multi-PLMN deployments for the FI TS. The deployment schedule has been impacted for Covid-19 measures, as well as, some unforeseen disruptions. For instance, one of the planned test roads was closed for a long period of time to allow for construction work for a parallel light rail track. This also necessitated the transfer for the second PLMN site to the current Otakaari 5 location. Additional site changes or reconfigurations may become necessary after another extended drive test campaign to optimise performance and ensure multi-PLMN coverage scenarios that support the FI TS user stories.



Figure C.66: Best server for the two cells of the Väre site.

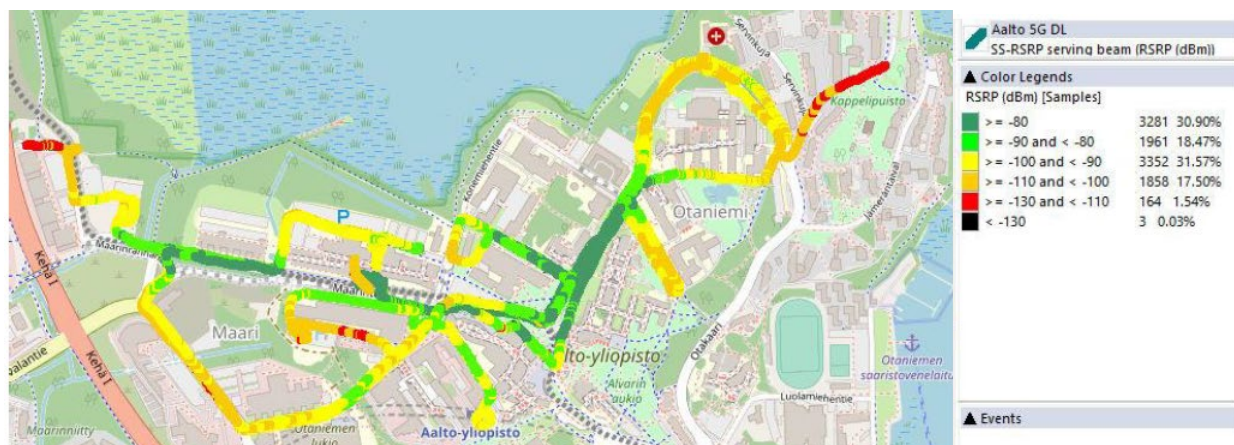


Figure C.67: Coverage measurements for the Väre site.

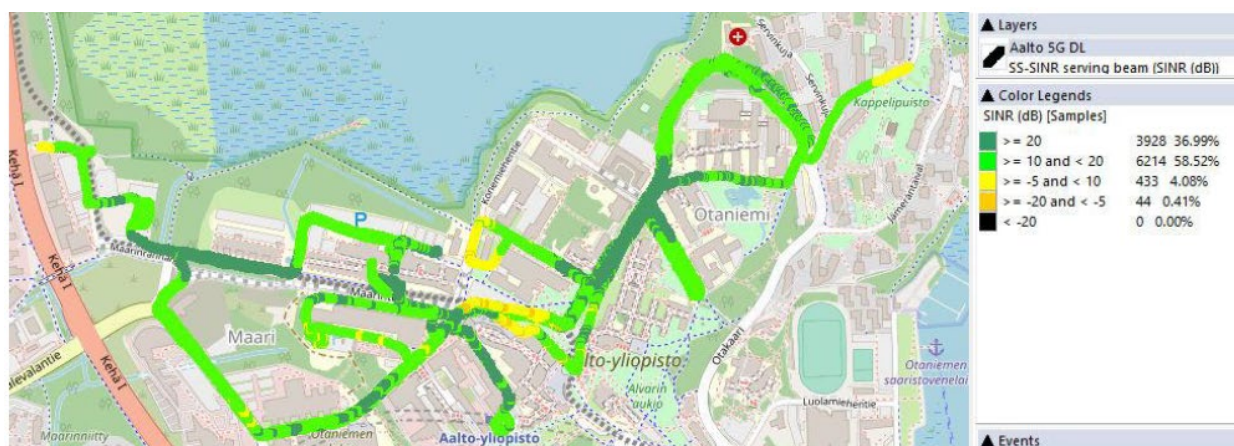


Figure C.68: Signal quality achieved from the Väre site.

D. DEPLOYMENT REPORT FOR THE NL TS

D.1 Overview

The NL trial site consists of three different 5G networks. The TUE network focuses on mmWave localisation. The KPN and TNO networks focus on handovers and service continuity. For this reason, a cross border is simulated between the KPN and TNO network to be able to test different technologies and scenarios.

D.2 Specific deployment plan and strategy

Both the KPN and TNO networks have a SA Core setup, deployment option 2. TUE has deployed a mmWave setup with custom configuration emulating a SA setup, focussing on the user plane and with minimal core implementation. In total three sites have been set up and three more at the TUE will be build.

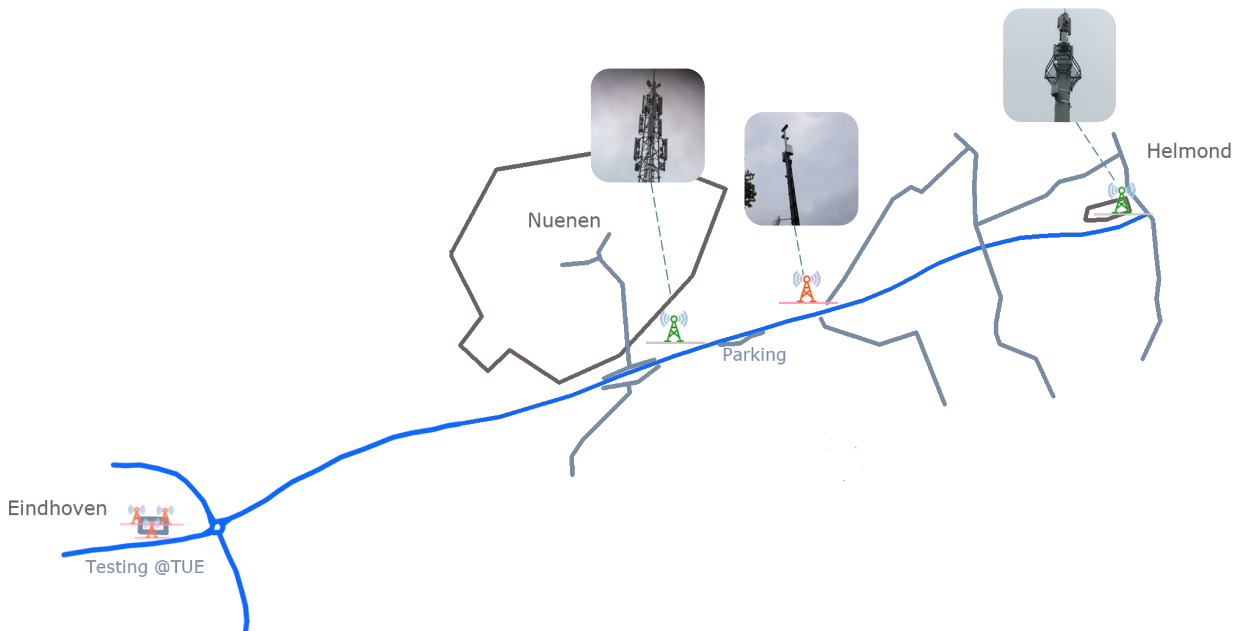


Figure D.6g: Overview map of NL deployment.

D.3 RAN deployment

D.3.1 Site overview

Table D.40: Sites in the NL deployment.

Site	Partner network	Frequency band
Helmond – automotive Campus	KPN	3,5GHz NR

Site	Partner network	Frequency band
Intersection Neervoortsedreef / Europaweg at A270	TNO	3,5GHz NR
Nuenen	KPN	3,5GHz NR
Flux parking lot - 1	TUE	27GHz NR
Flux parking lot - 2	TUE	27GHz NR
Flux parking lot - 3	TUE	27GHz NR

8.1.1.1 *Helmond – automotive Campus*

The 3,5 GHz site at the automotive campus covers part of the campus and N270.

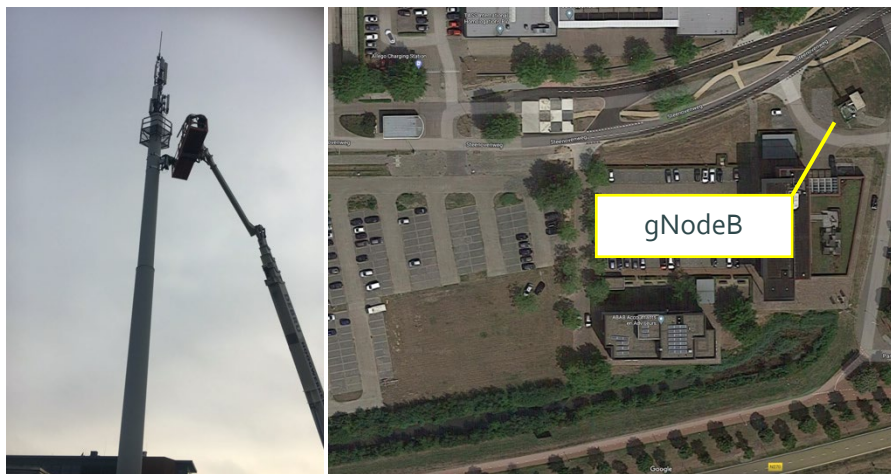


Figure D.70: Photograph of the Helmond – automotive Campus site.

8.1.1.2 *Intersection Neervoortsedreef / Europaweg at A270*

TNO has deployed a 5G base station (gNB) at the intersection between Europaweg and Neervoortsedreef in the A270 highway in The Netherlands, shown in Figure D.71. It consists of two directional antennas mounted on top of a camera pole, radio units supporting both 5G and 4G frequency bands, GPS and baseband unit.

8.1.1.3 *Site at Nuenen*

The Site at Nuenen (shown in Figure D.72) has two cells and covers the A270 in two directions. This includes the parking across the A270 where some tests are planned (this parking can be closed off).

8.1.1.4 *TU/e campus*

Three mm-wave radio sites will be deployed by Q2 2021 on TU/e campus around the parking lot and access road to the Flux building. Each site is provided with a direct fibre connection. The custom RAN equipment of TU/e is currently under test in the laboratories and expected to be deployed on campus in early 2021.

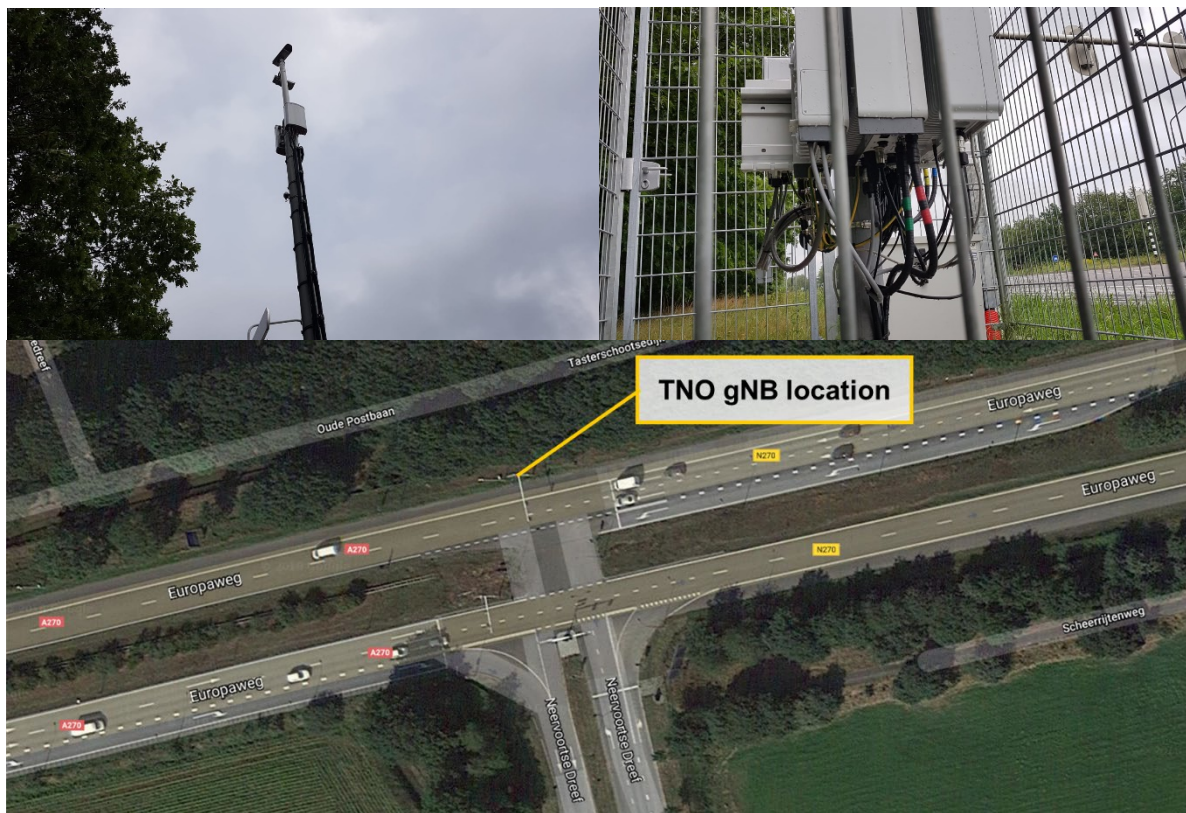


Figure D.71: TNO gNB deployment on the A270.



Figure D.72: Deployment at Nuenen.

D.3.2 Frequency licences

Agentschap Telecom (the Dutch regulator) has awarded test licenses to KPN, TNO and TU/e for tests to be performed in 5G-MOBIX. The specifics of the awarded licenses are as shown in Table D.41.

Table D.41: Frequency licenses of KPN, TNO and TU/e for the NL TS.

	KPN	TNO	TU/e
License Start Date	9 October 2019	15 October 2019	23 January 2019
License End Date	7 October 2021	15 October 2021	1 June 2021
Frequency Band	3500-3600 MHz	3650 – 3750 MHz	27 GHz
Transmit Power	23 dBW e.r.p.	22 dBW e.r.p	26 dBW e.r.p
Bandwidth	100 MHz	100 MHz	800 MHz
Antenna Height	20-24 m	7 m	5-25 m

D.4 Core deployment

For the Dutch trial sites a set of core services/functions have been deployed, as shown in Table D.42. Additionally, a number of interconnections between the deployments of the three NL TS partners have been implemented or are planned, as shown in Table D.43.

Table D.42: Core services/functions deployed in the networks of the NL TS.

Service/Function	KPN	TNO	TU/e
<i>AMF</i>	Implemented	Implemented	Minimal
<i>SMF</i>	Implemented	Implemented	Minimal
<i>Central UPF</i>	Implemented	Implemented	Implemented
<i>Local UPF</i>	Planned	Implemented	N/A
<i>Edge Computing</i>	Implemented	Implemented	Planned
<i>UDR</i>	Implemented	Implemented	N/A
<i>UDM</i>	Implemented	Implemented	N/A
<i>AUSF</i>	Implemented	Implemented	N/A
<i>NRF</i>	Implemented		N/A
<i>PCF</i>	Implemented	Planned	Minimal
<i>NSSF</i>	Planned	Planned	N/A
<i>AF for Service Continuity</i>	Considered		N/A

Table D.43: Interconnection between the partners in the NL TS.

Connection	Status
Edge KPN <-> TNO	Implemented
Edge KPN <-> TUE	Implemented
Core interconnect for Home Routing KPN <-> TNO	Planned for 1H 2022
Core interconnect for Local Breakout Routing KPN <-> TNO	Planned for 1H 2022

D.4.1 KPN 5G network overview

KPN has both the 4G production RAN and a dedicated 5G test network connected to a dual core setup. There are two edges with both their own UPF to allow the traffic to connect to the closest edge. The Central Core network is located in Aachen at Ericsson. This setup will provide for logically separated edges for testing purposes. In reality both edges will be hosted in the same Metro Core location in Helmond. The production RAN is connected to the test core using RAN sharing. This way we can test with the 4G technology providing the same services as the 5G SA setup. In the future we also hope to use our shared production RAN to provide for 5G SA services. It is not clear yet if this can be done within the 5G-MOBIX timelines.

To reach the final setup as described above with multiple UPF's and edges we use a phased approach. This means that we already have a 5G SA network running but without the local UPF's and without the multiple edges. Currently the 5G SA Core is running at Ericsson Rijen. The final setup using the dual core in Aachen is expected to be finished in Q1-2021. An overview of the KPN deployment is provided in Figure D.73.

D.4.2 TNO 5G network overview

TNO 5G core SA deployment is split between edge and central networks. At the edge network (Helmond), a local User Plane Function (UPF) is deployed close to the TNO edge service. This service is inter-connected with the KPN edge service running at KPN's edge network. An overview of the TNO deployment is provided in Figure D.74.

D.5 5G technology deployment

The NL TS deploys a range of 5G technologies in support of its 5G-MOBIX use cases. The NL TS deployments of MEC with service continuity and 5G slicing were described in the corresponding parts of section 7 (section 7.3.4 and section 7.4.5, respectively).



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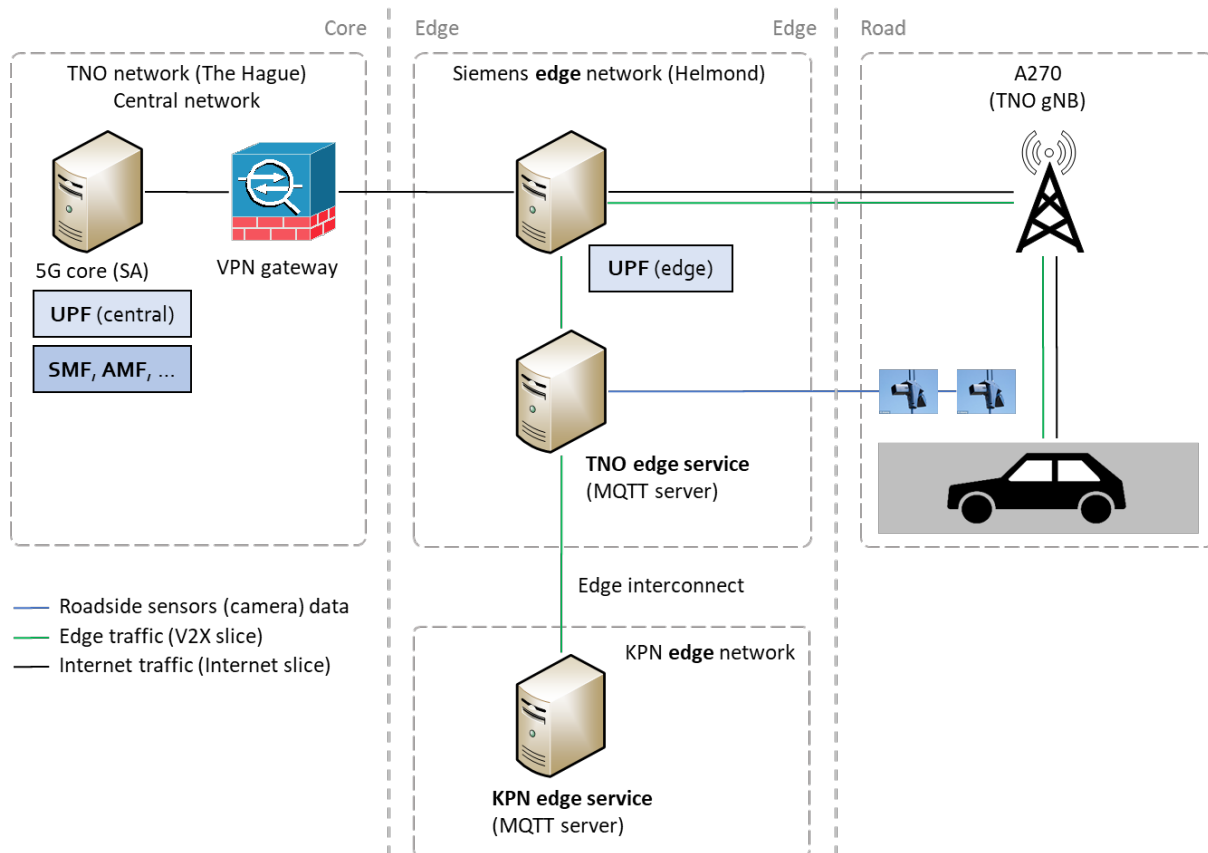


Figure D.74: TNO 5G core and edge infrastructure and services deployment in Helmond.

D.6 Summary

This annex D provided a brief deployment report and overview over the 5G networks of the 5G-MOBIX NL TS. At the Dutch TS three networks are deployed by KPN, TNO and TU/e, where the first two focus on the 3.5 GHz band with and stand-alone deployment, while the latter is an experimental deployment at mmWave with only a minimal core.

Three sites have been deployed at the Automotive Campus in Helmond, on the A270 at the intersection of Neervoortsedreef and Europaweg and close to the A270 in Nuenen. Through the combination of these three sites, the planned trial areas are covered, except for TU/e campus which will be covered by the mmWave network once the three planned sites there are deployed.

A number of connections between the networks are planned, including connections between the edge of KPN and those of TNO and TU/e respectively which were successfully implemented already.

E. DEPLOYMENT REPORT FOR THE KR TS

E.1 Overview

The representative user stories to be showcased at Korean trial site (KR TS) are *remote driving using mmWave communication* and *tethering via vehicle using mmWave communication*, which are categorized into use case category, *Remote Driving* and *Vehicle QoS Support*, respectively. Both of them are tightly related to the 5G use cases of eMBB and URLLC. For the remote driving user story, broadband uplink connectivity that enables delivery of the high-quality video from driver's perspective and information collected by sensors to the remote operating centre and ultra-reliable and low-latency connectivity to cope with fast-changing driving situations and environments need to be supported. For the tethering user story, broadband mobile wireless backhaul needs to be supported in order to support data demanding in-vehicle applications such as entertainment and infotainment services (e.g., video streaming, virtual reality (VR), and augmented reality (AR)).

KR TS is an urban-type-proving ground that is located in Yeonggwang, South Korea, the construction of which was completed at the end of 2019, and it provides various type of test roads. In the KR TS, a PoC platform for mmWave-band 5G NR-based vehicular communication system will be deployed to demonstrate the two user stories. Along with the demonstration of user stories, we also plan to conduct a demonstration of core technologies for the realization of the user stories. The core technologies include mmWave-band vehicular communication system supporting NR Rel-15 specifications, multi-antenna transmission, multiple access, fast and seamless handover dedicated for vehicular communications, and fast beam switching. The details are explained in the following subsections.

E.2 Specific deployment plan and strategy

The status of 5G network deployment at KR TS is summarized below:

- Frequency license acquisition: in progress,
- Implementation of mmWave-band 5G NR vehicular communication system: integration of system components and its preliminary system-level testing have been completed, and an additional functional testing and system stabilization are now underway and expected to be completed by the end of 2020,
- Preparation for installation of mmWave-band 5G NR vehicular communication system: in progress.

Please note that all the following subsections are related to deployment activities at KR TS.

E.3 RAN deployment

As briefly mentioned in the previous subsection, a PoC platform for mmWave-band 5G NR-based vehicular communication system will be deployed at the KR TS. The platform mainly consists of 5G core network, RAN (i.e., gNB), and V-UE. To support the cloud RAN functionality, the RAN is implemented to have a CU connected with multiple DUs as illustrated in Figure E.75. The number of DUs will be one or two, but the exact number is yet to be decided. In this network structure, baseband and RF/antenna modules are distributed to each DU that will be deployed along the trackside, and the other higher-layer system components (L2/L3) are located at the CU. The CU is connected with 5G core network, and both CU and 5G core network will be located in a laboratory of a building in the KR TS. The vehicle UE (V-UE) will be installed on top of a demo vehicle and it serves as a mobile relay that provides broadband Wi-Fi connectivity to passengers in the vehicle by communicating with the RAN over mmWave-band 5G NR vehicular communication links. In addition, it is also responsible for delivering the high-quality video from driver's perspective and information collected by sensors in the vehicle to the remote operating centre.

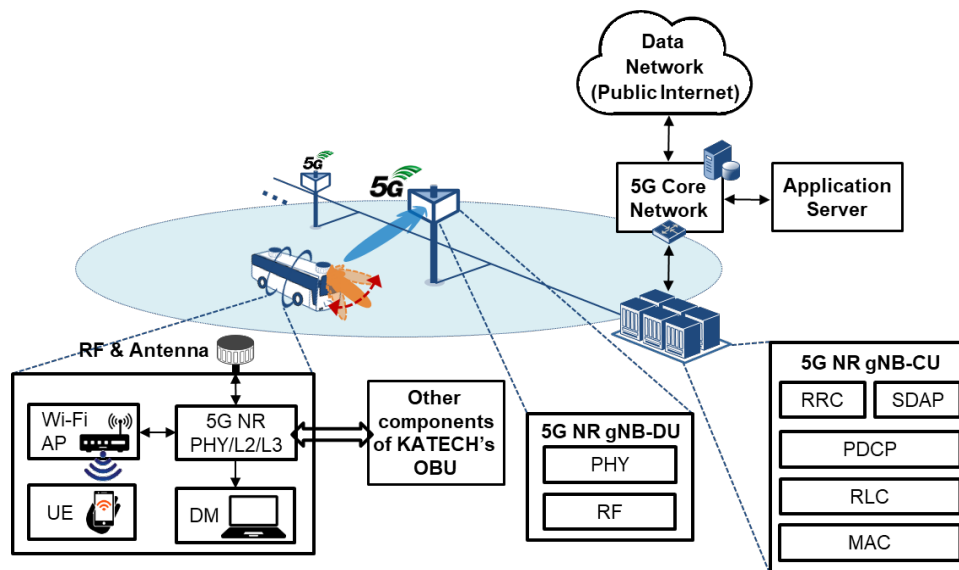


Figure E.75: High-level architecture of the PoC platform in KR TS.

E.3.1 Site overview

Figure E.76 illustrates KR TS, which is an urban-type-proving ground that is located in Yeonggwang, South Korea. The construction of KR TS was completed at the end of 2019, and it provides various type of test roads such as intersection, pebble road, test hills, circular road. In the KR TS, mmWave-band 5G NR-based vehicular communication networks are deployed, and a vehicle equipped with real time monitoring system and V-UE that communications with the vehicular networks is used to demonstrate our two user stories, remote driving using mmWave communication and tethering via vehicle using mmWave communication.



Figure E.76: Illustration of KR TS.

E.3.2 Frequency licences

In south Korea, an unlicensed band called Flexible Access Common Spectrum (FACS) is allocated by Korean government. FACS ranges from 22 ~ 23.6 GHz, and to use the band, it is mandatory to comply with the Effective Isotropic Radiated Power (EIRP) requirement regulated by the KR government where the maximum allowable RF power emitted by the TX antenna is 36 dBm. The PoC platform in KR TS is designed to operate in the FACS, and as illustrated in Figure E.77, we plan to apply for permission to use part of its band, 22.1 - 23.1 GHz.

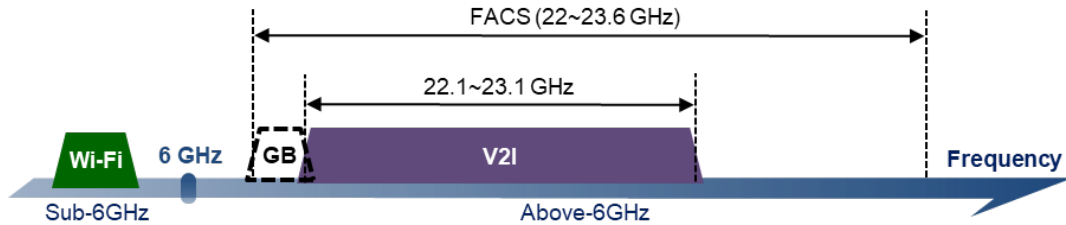


Figure E.77: Frequency band used in KR TS.

E.4 Core deployment

5G core network for 5G SA option, which is a system component of the PoC platform, will be deployed in KR TS, and its implementation, integration with the other system components, and system-level testing are now underway. As mentioned in the previous subsection, as soon as the integration and system-level testing are completed, 5G core network will be located in a laboratory of a building in the KR TS for the demonstration of two target user stories.

E.5 5G technology deployment

The core technologies implemented on the PoC platform for the demonstration in KR TS are listed as follows:

- mmWave-band vehicular communication system supporting NR Rel-15 specifications:

- ✓ By taking advantage of a vast amount of spectrum underutilized in FACS, high data rate transmission between RSU and V-UE can be achieved. More specifically, KR PoC platform is designed to support the maximum bandwidth of 600 MHz through Carrier Aggregation (CA) of 6 Component Carriers (CCs).
- ✓ Since KR PoC platform is designed to operate in the FACS that is close to FR2 band in NR, numerology of $\mu = 2$ is supported to combat large Doppler frequency spread.
- Multi-antenna transmission:
 - ✓ RF array beamforming is used to deal with serious propagation loss in mmWave-band communications.
 - ✓ A polarization-based multi-antenna scheme will be used since it is particularly effective in a Line-of-Sight (LoS) dominant channel environment like in mmWave-band communications. With the polarization antenna, two spatial layers transmission is supported.
- Multiple access: it allows multiple vehicles in a cell covered by an MNS-RAS to simultaneously receive MWB links for broadband Wi-Fi services. In addition, by effectively scheduling radio resources to vehicles in the coverage, multiple access technique is able to offer increased system throughput.
- Fast and seamless handover dedicated for vehicular communications: it provides seamless handover to minimize the communication interruption time when a vehicle crosses a cell edge.
- Fast beam switching: it is responsible for aligning TX/RX beam in the best direction in order to maximize received signal quality and to combat unexpected signal blockage by the motion of the vehicle and/or surrounding.
- ✓ Figure E.78 shows the three beam-based beam switching technique (beam sweeping and beam selection) that is implemented on the PoC platform.

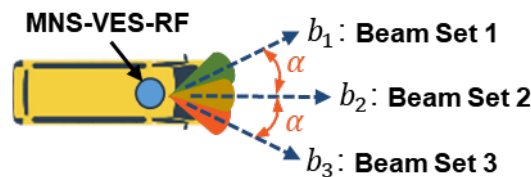


Figure E.78: Three beam-based beam switching technique.

- ✓ Beam sweeping is performed at a specific period by measuring the received power of Channel State Information Reference Signal (CSI-RS) and/or synchronization signal.
- ✓ The beam selection for Tx or Rx at each time instance (e.g. slot) can be done by

$$b^* = \underset{b \in B}{\operatorname{argmax}}(P_{\text{RSRP},b}), \text{ where } B = \{b_1, b_2, b_3\},$$

where $P_{\text{RSRP},b}$ represents RSRP of b -th beam.

E.6 Network integration and testing

After the implementation of system components was completed, a preliminary system-level testing was conducted. First, we conducted a PHY-to-PHY communication test both in indoor and outdoor environments. For the indoor testing, the maximum downlink throughput of 3 Gbps and the maximum uplink throughput of 200 Mbps were verified, and as shown in Figure E.79 and Figure E.80, for the outdoor testing that was carried out in an urban road in Daejeon city, south Korea, the maximum downlink data rate of up to 2.5 Gbps was validated using the beam switching techniques described in the previous subsection.

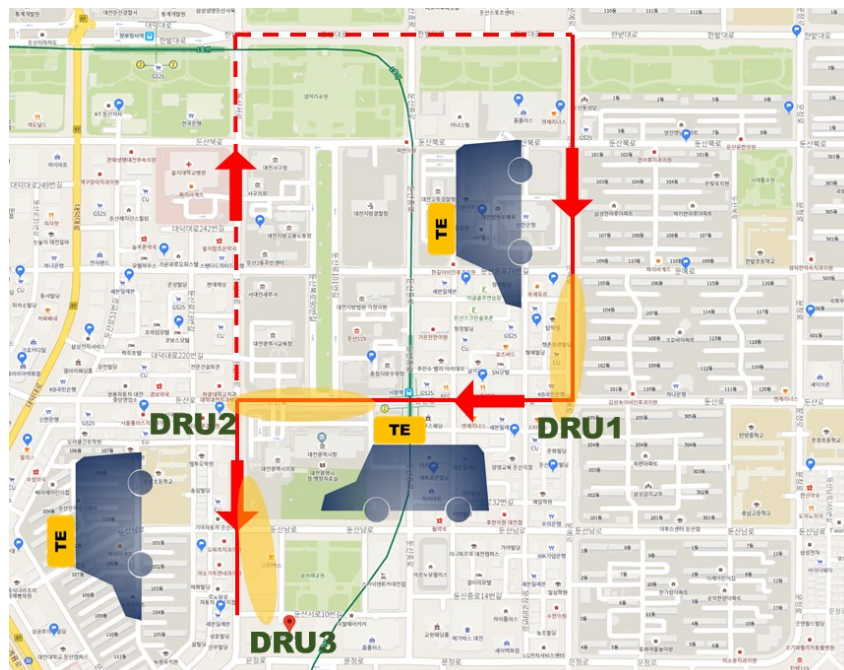


Figure E.79: PHY-to-PHY communication test setup.

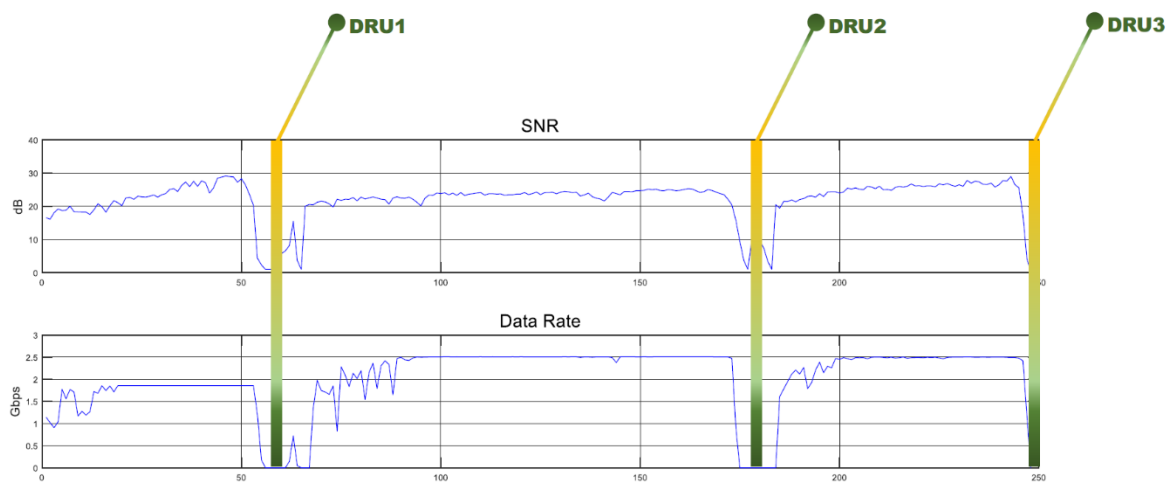


Figure E.80: Received SNR and downlink data rate.

After the test, physical layer is integrated with L2/L3 and 5G core network, and their software interfaces and higher-layer functionalities were tested in a laboratory. Through the test, we successfully demonstrated YouTube video streaming services with smartphones. After the indoor system-level integration testing, the PoC platform is deployed at ETRI premise for outdoor demonstration. We deployed one RSU as shown in Figure E.81, and V-UE is installed on top of the demo vehicle. Through the outdoor demonstration, we provided passengers with a broadband Wi-Fi service. The passengers inside the vehicle used smart phones to connect onboard Wi-Fi and access YouTube for high-quality video streaming. While the vehicle is moving, video streaming was very stable, and no interruption was observed. In addition, by using Internet speed testing application called BenchBee, it was estimated that onboard Wi-Fi connection is capable of providing download speeds of up to 400 Mbps. The functionalities verified at this stage include cell search, random access, channel sounding, control/data modulation/demodulation, registration/deregistration, and uplink timing adjustment using both PRACH and SRS. Currently, we are working on the verification of additional functionalities such as downlink and uplink link adaptation based on the reported CQI and channel sounding and seamless handover.



Figure E.81: An example of beam switching with three available beams.

E.7 Summary

As the construction of KR TS was completed, the implementation, integration, and system-level testing of system components of the PoC platform is now actively underway. We have completed the first preliminary testing of the PoC platform for mmWave-band 5G NR-based vehicular communications and observed reasonable performance while the demo vehicle is moving. We'll continue to work on the additional functional testing and system stabilization, and once completed, the PoC platform will be deployed at KR TS where we'll showcase the two representative user stories, remote driving and tethering via vehicle.

F. DEPLOYMENT REPORT FOR THE CN TS

F.1 Overview

The representative user stories to be enabled at the China trial site (CN TS) are cloud-assisted advanced driving, cloud-assisted platooning, and remote driving with data ownership focus. All of them are related to the 5G use cases of eMBB and URLLC. The cloud-assisted advanced driving aims to improve the safety and efficiency in the urban road scenario with the help of the assisted cloud. In the test case of the cloud-assisted platooning, we will test the fleet communication through LTE-V or 5G and compare the different communication technology on the platoon's performance. The data ownership focus in the remote driving scene will also consider the latency and information safety with 5G.

The CN TS is located in Jinan city, Shandong province, provided by Shandong Hi-speed company (SDHS) and Institute of Automation, Shandong Academy of Sciences (SDIA). The SDHS has installed a 2-kilometer road with 5G infrastructure with other roadside infrastructures. Another partner, SDIA, has completed three 5G base stations in the east zone for remote driving tests. We will test the seamless switching on the heterogeneous network provided by MNOs and different devices in the future.

F.2 Specific deployment plan and strategy

To enable the evaluation of CCAM use cases, the CN-TS has access to two different 5G network deployments provided by China Unicom and China Mobile. Thus, we can realize the test stories of our plan, especially of the test case of remote driving with data ownership focus. In our plan, we mainly focus on the performance of remote driving under different MNO or networks. Firstly, we will test the cross-network handover from area 1 covered by LTE-V without 5G to area 2 covered by 5G. We will record the critical parameter of remote driving performance and improve the system capacity. Secondly, we will enable the cross-network handover test scenario from area 1 covered by 5G to area 2 covered by another 5G, provided by China Mobile and China Unicom. We will test the performance of remote driving when switching to different MNO in this scenario. Meanwhile, the deployed 5G network will also be applied to other scenarios for testing.

According to our plan, we have deployed the 5G SA NR in CN TS. The spectrum of the deployed 5G SA network is 2.6Ghz(n41), provided by China Mobile. In the future, we will accomplish the whole network deployment and realize the heterogeneous network.

F.3 RAN deployment

As shown in the Figure F.82, RAN was deployed by China Mobile in the CN-TS. Figure F.82 shows the framework of RAN, and we had described the relevant RAN parameters that defined the characteristics of the 5G deployment.

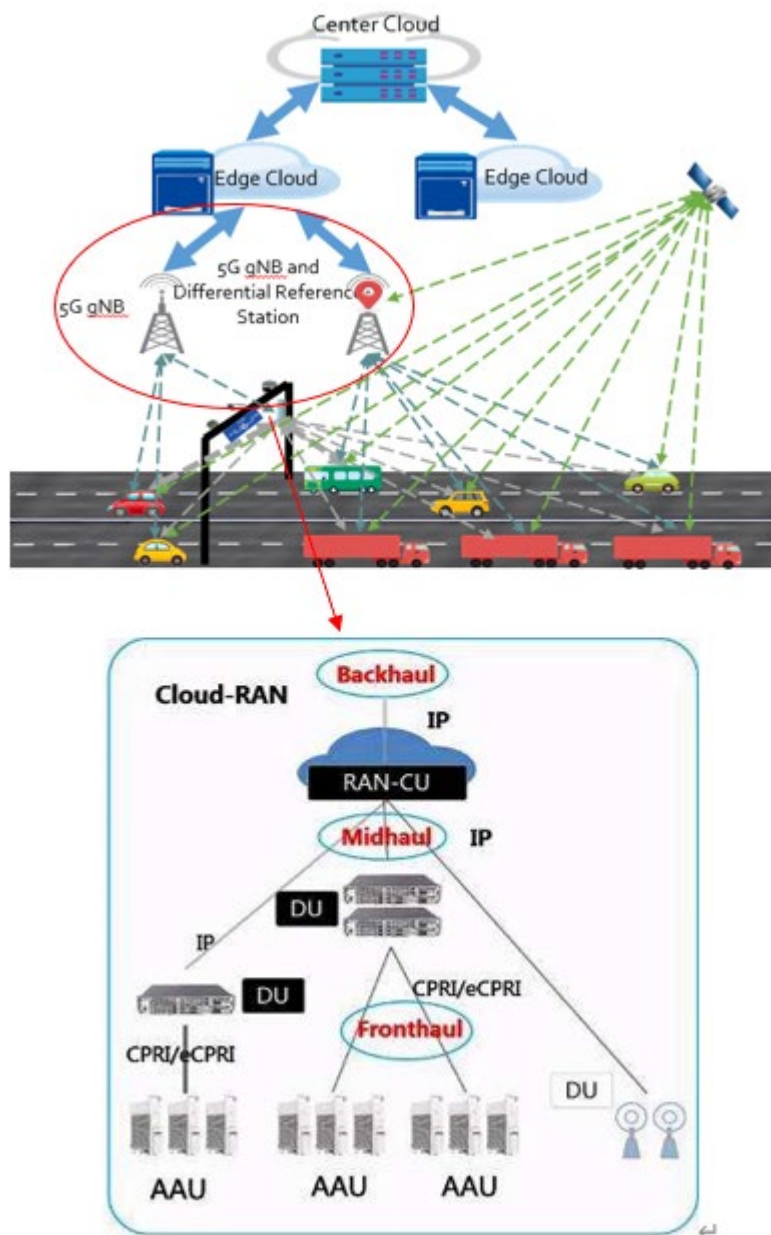


Figure F.82: The framework of RAN in CN TS.

F.4 Site overview

Figure F.83 illustrates an urban trial site located in Jinan, China, which provides various types of test roads such as intersection, pebble road, test hills, and circular road. Now, the highway test site has installed a 2-kilometer road with 5G infrastructure. In the CN TS, 5G NR-based vehicular communication networks were deployed. The vehicles were equipped with real-time monitoring system and 5G OBUs. In our three USs, remote driving employs 5G communications while advanced driving and platoon employ C-V2X PC5.

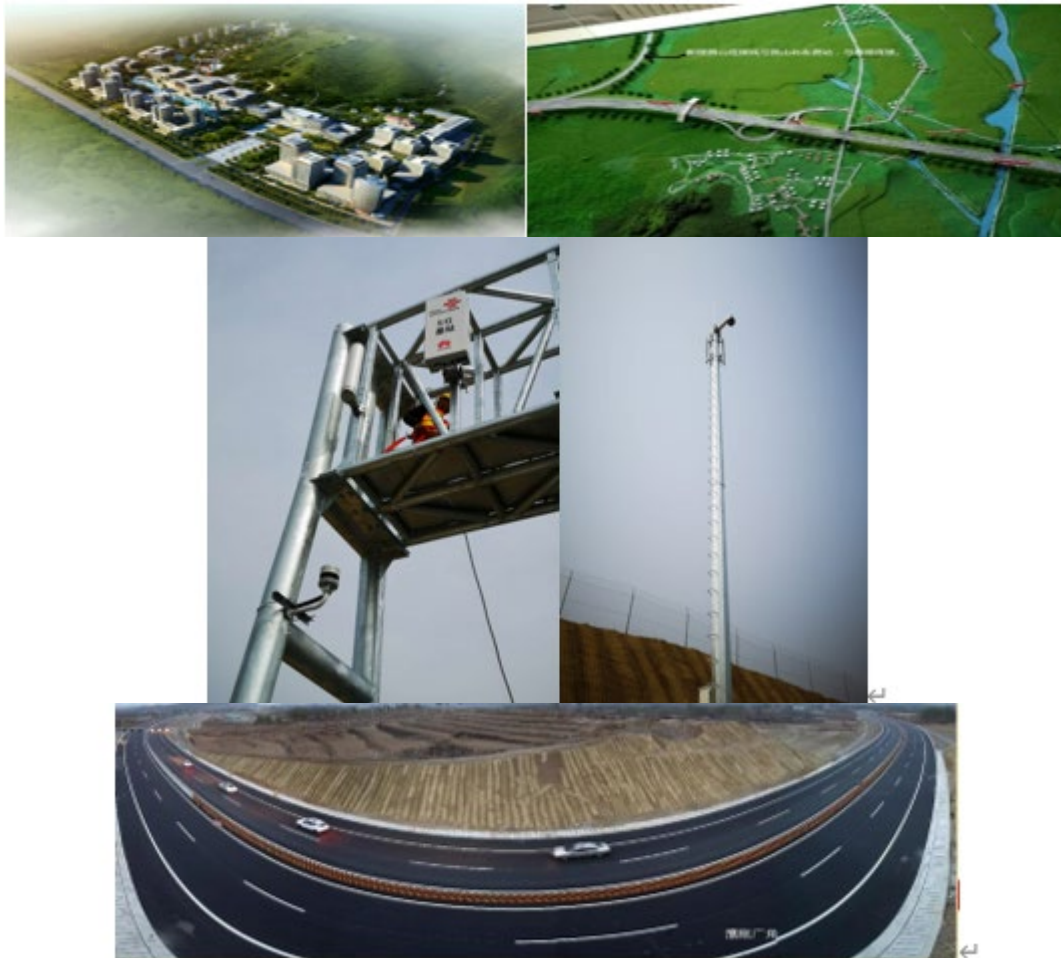


Figure F.83: Illustration of CN TS.

F.5 Frequency licenses

China Mobile Communications Group 5G network operates on 4.9GHz and 2.6GHz, and China Unicom 5G network operates on 3.5GHz. The CN deployment utilizes 5G Campus frequency licenses approved by the China agency that handles experimental licenses.

F.6 Core deployment

China Mobile provided the core deployment used in the CN TS, where NSA is currently used. SA is still in the experimental stage and will be the final choice for 5G with more technical advantages. China Mobile will finally provide the core network service of SA for CN TS when they finish their experiments, which will improve the performance of our system.

F.7 5G technology deployment

In the CN TS, 5G technology deployment support three use stories in 5G-Mobix, advanced driving, remote driving and cloud-assisted platooning. China Unicom and China Mobile provide the 5G New Radio bands (n78 and n41). Additionally, SIM8200EA-M2, 5G base stations and others (Cohda, ZTE, QUECTEL) will be used to establish communication between the test vehicle and the system. The SIM8200EA-M2 is a multi-band 5G NR/LTE-FDD/LTE-TDD/HSPA+ module solution that supports R15 5G NSA/SA data transmission 4.0 Gbps. The V2X deployment supported RSU to communicate with up to 200 UEs by V2I and V2V. The MEC and 5G Network Slicing (eMBB, uRLLC) are Implemented to achieve transmission of HD video and low latency.

F.8 Network integration and testing

The CN TS's integration test of the 5G network is in progress. The picture below is the 5G module used in SDIA and SDHS. The SIM8200EA-M2 is Multi-Band 5G NR/LTE-FDD/LTE-TDD/HSPA+ module solution in an M.2 type, which supports R15 5g NSA/SA up to 4.0 Gbps data transfer, as shown in Figure D.75. We have used network performance test tools like Iperf3, to test the rate and TCP/UDP performance of 5G modules, including uplink and downlink rates, delay, bandwidth, and connection reliability. We plan to conduct connection tests on the networks of different MNOs.

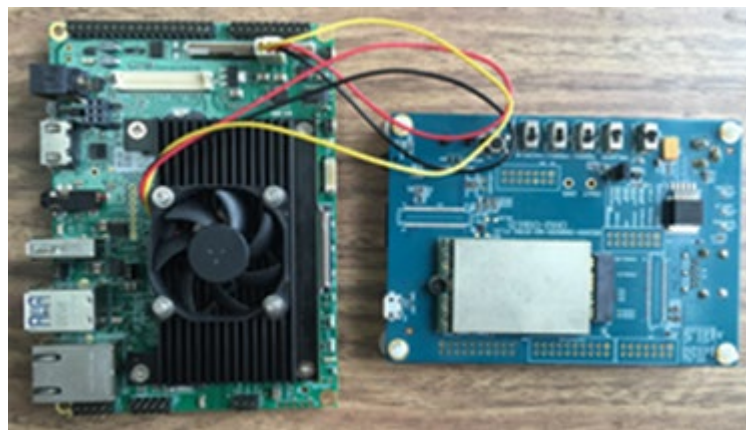


Figure F.84: The SIM8200EA-M2 5G module.

F.9 Overview

The CN trial site is located within the SDHS and the SDIA. To that end, the 5G-MOBIX project leverages 4G/5G testbeds deployed in the SDHS that is continuously being enhanced/upgraded for use in 5G-MOBIX. All the networks will utilize standards-compliant commercial equipment which are self-operated by China Mobile. In the case of 5G-MOBIX, the priority is to deploy 5G network that provide coverage on roads targeted for the 5G-MOBIX trials.

G. TEST RESULT REPORTS

The following sections provide information regarding the test cases performed at the CBC/TS by November 2020, while details of preliminary test cases' results can be found below.

G.1 ES-PT CBC Results

G.1.1 ES side Results

The tables below summarize the test results obtained during the test sessions performed from August to September 2020.

Peak DL TCP/UDP Data Throughput of Single User (stationary use)

Table G.44: TCA-GEN-1_TCP_DL test case results.

Test Location	DEKRA test track	Test Case (TC) ID	TCA-GEN-1_TCP_DL
Test Case (TC) Name	Peak DL TCP/UDP Data Throughput of Single User (stationary use)		
Test Case Purpose	Measure the Peak Downlink TCP/UDP User Data Throughput of Single User		
Stationary / Mobility TC	Stationary		
Test environment	DEKRA test track, PTA Málaga.		
Test setup ID	ES-PT-UsAg-TCP_DL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	214 07		
Initial Conditions			
-DEKRA TACS ₄ Performance Testing Platform. 8 TCP connections established to get maximum throughput			
Test Case Description			
Perform a 5G data call in an empty cell under best RF conditions. TCA-GEN-01_TCP-DL: Start TCP DL data transfer and measure received DL throughput over 1 minute			
Test UE Info			
UE Type: Mobile Phone (LG V50) with TACS ₄ Mobile app UE SW version: Build PKQ1.190321.001			
Test Variables			
- Live NW traffic on the transmission link			
Expected TC Result			

Obtain maximum DL throughput. Values above 300 Mbps should be obtained				
TC Results Report				
Number of repetitions	3 (with NR)			
TC comments	-			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Peak DL Throughput (Mbps)	271.4	373.4	429.5	Throughput
TC Responsible	DEKRA			
Date	19/11/2020			

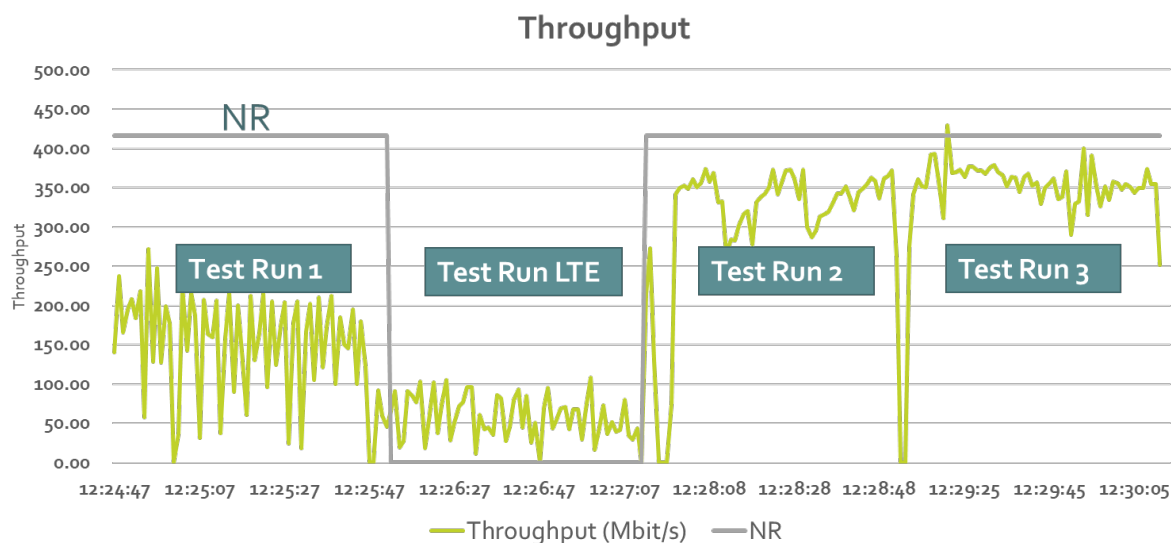


Figure G.85: TCA-GEN-1_TCP_DL – DL Throughput.

Peak UL TCP/UDP Data Throughput of Single User (stationary use)

Table G.45: TCA-GEN-2_TCP_UL test case results.

Test Location	DEKRA test track	Test Case (TC) ID	TCA-GEN-2_TCP_UL
Test Case (TC) Name	Peak UL TCP/UDP Data Throughput of Single User (stationary use)		
Test Case Purpose	Measure the Peak Uplink TCP/UDP User Data Throughput of Single User		
Stationary / Mobility TC	Stationary		
Test environment	DEKRA test track, PTA Málaga.		
Test setup ID	ES-PT-UsAg-TCP_UL		

5G Deployment Option	NSA (option 3x)			
PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
-DEKRA TACS ₄ Performance Testing Platform. 8 TCP connections established to get maximum throughput				
Test Case Description				
Perform a 5G data call in an empty cell under best RF conditions. TCA-GEN-02_TCP-UL: Start TCP UL data transfer and measure received UL throughput over 1 minute				
Test UE Info				
UE Type: Mobile Phone (LG V50) with TACS ₄ Mobile app UE SW version: Build PKQ1.190321.001				
Test Variables				
- Live NW traffic on the transmission link				
Expected TC Result				
Obtain maximum UL throughput. Values above 30 Mbps should be obtained				
TC Results Report				
Number of repetitions	3 (with NR)			
TC comments	-			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Peak UL Throughput (Mbps)	26	27.6	26.2	Throughput
TC Responsible	DEKRA			
Date	19/11/2020			

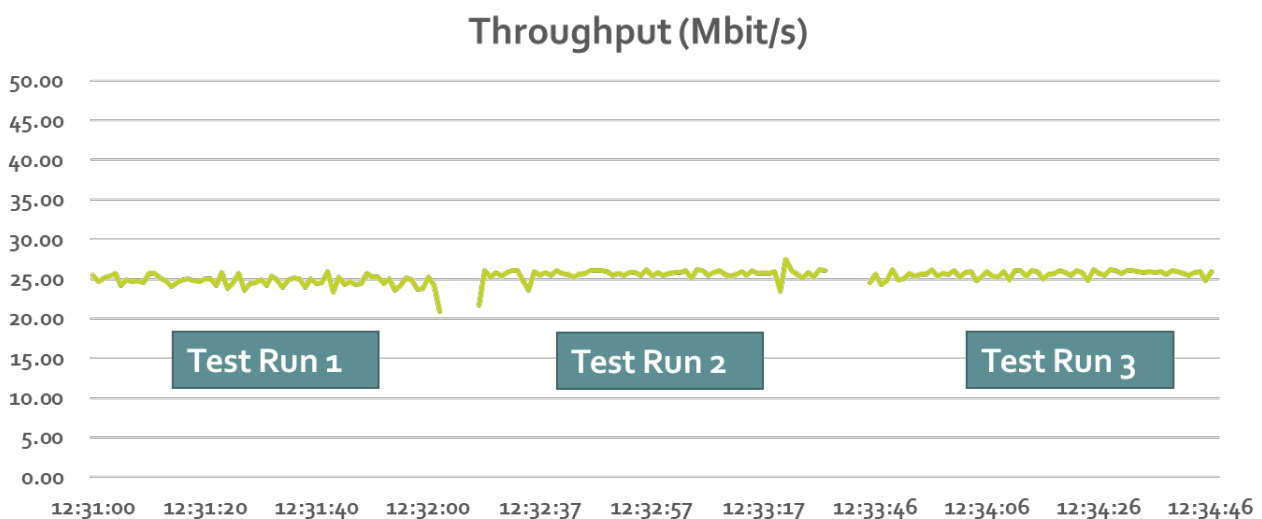


Figure G.86: TCA-GEN-2_TCP_UL – UL Throughput.

TCP DL Use case route performance

Table G.46: TCA-GEN-12_TCP_DL_No Load test case results.

Test Location	DEKRA test track	Test Case (TC) ID	TCA-GEN-12_TCP_DL_No Load	
Test Case (TC) Name	TCP DL Use case route performance			
Test Case Purpose	Measure coverage, DL Throughput and cell mobility in a UCC/US route			
Stationary / Mobility TC	Mobility			
Test environment	DEKRA test track, PTA Málaga.			
Test setup ID	ES-PT-UsAg-TCP_DL			
5G Deployment Option	NSA (option 3x)			
PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
DEKRA TACS ₄ Performance Testing Platform. 8 TCP connections established to get maximum throughput				
Test Case Description				
Select most relevant UC drive test routes. Initiate a continuous DL TCP session on the reference UE, which moves at an average speed of 40 km/h (depending on vehicle type) along the predefined drive route. Establish as many TCP connections as required (i.e. 8) to saturate the link (maximum DL throughput provided by the network). Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell ids. Identify NAS and RRC procedures along the route to identify cell mobility, handover successful rate, etc.)				
Test UE Info				
UE Type: Mobile Phone (LG V50) with TACS ₄ Mobile app UE SW version: Build PKQ1.190321.001 UE speed: 30 km/h				
Test Variables				
Live NW traffic on the transmission link; Moving vehicles				
Expected TC Result				
Values above 300 Mbps expected.				
TC Results Report				
Number of repetitions	3			
TC comments				
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Max DL Throughput (Mbps)	465.7	425.1	149.7	Throughput Throughput map
Average DL Throughput (Mbps)	177.3	197.7	81	

LTE RSRP range (dBm)	-80 / -118	-68 / -98	-78 / -90.4	LTE PCI map RAT map
RAT	LTE, NR			
ARFCN	2850			
LTE eNBID	290255, 290636			
LTE PCI	36,38,501,502			
TC Responsible	DEKRA			
Date	14/08/2020 - 17/09/2020			

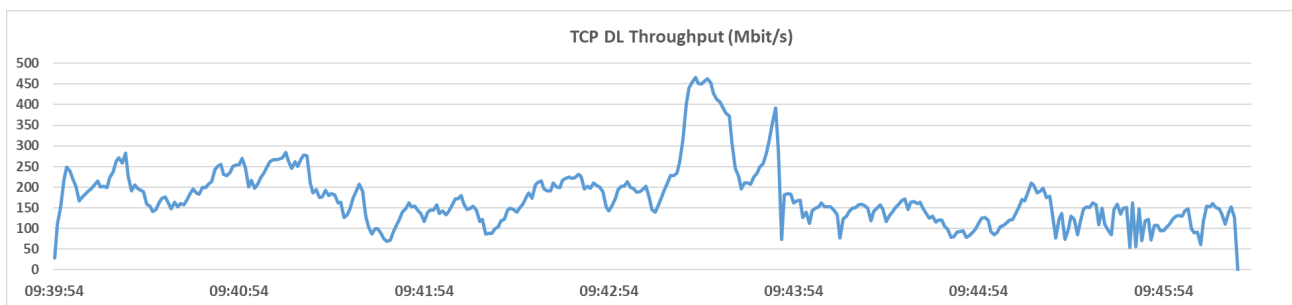


Figure G.87: TCA-GEN-12_TCP_DL_No Load Iteration 1 – DL Throughput.

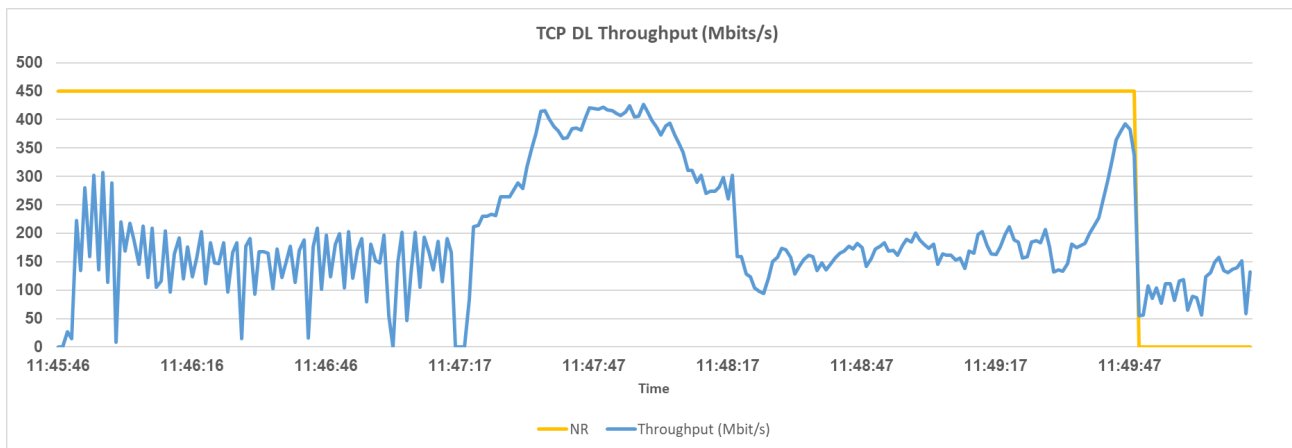


Figure G.88: TCA-GEN-12_TCP_DL_No Load Iteration 2 – DL Throughput.

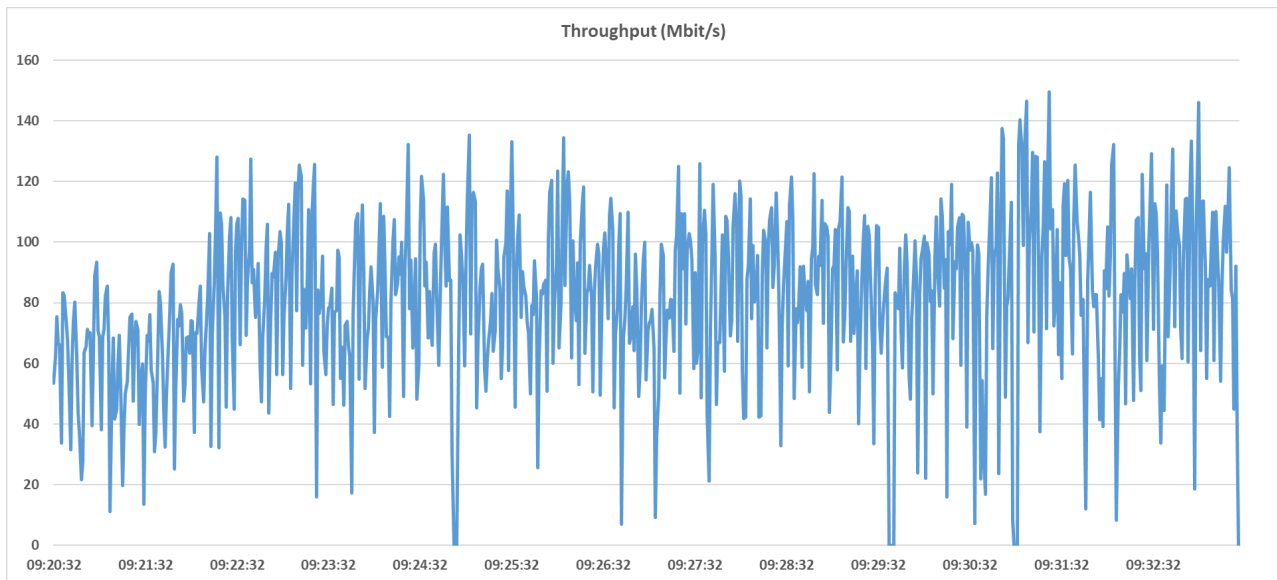


Figure G.89: TCA-GEN-12_TCP_DL_No Load Iteration 3 – DL Throughput.

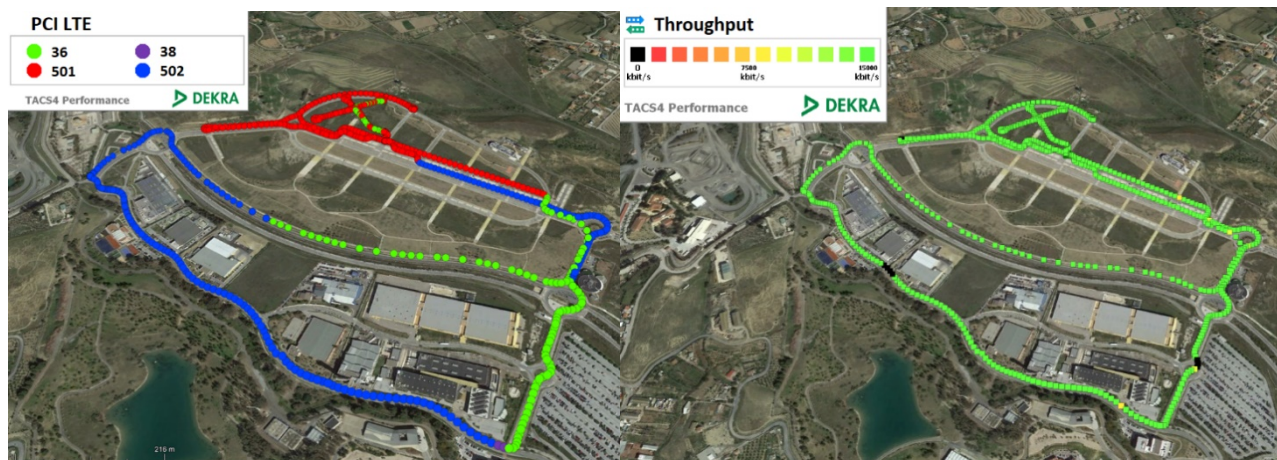


Figure G.90: LTE PCI & Throughput Map (Iteration 3).

TCP UL Use case route performance

Table G.47: TCA-GEN-13_TCP_UL_No Load test case results.

Test Location	Porriño	Test Case (TC) ID	TCA-GEN-13_TCP_UL_No Load
Test Case (TC) Name	TCP UL Use case route performance		
Test Case Purpose	Measure coverage, UL Throughput and cell mobility in a UCC/US route		
Stationary / Mobility TC	Mobility		
Test environment	DEKRA test track, PTA Málaga.		
Test setup ID	ES-PT-UsAg-TCP_UL		
5G Deployment Option	NSA (option 3x)		

PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
DEKRA TACS ₄ Performance Testing Platform.				
Test Case Description				
Select most relevant UC drive test routes. Initiate a continuous UL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route. Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell IDs. Identify NAS and RRC procedures along the route to identify cell mobility, handover successful rate, etc.)				
Test UE Info				
UE Type: Mobile Phone (LG V50) with TACS ₄ Mobile app UE SW version: Build PKQ1.190321.001 UE speed: 30 km/h				
Test Variables				
Live NW traffic on the transmission link; Moving vehicles				
Expected TC Result				
Values above 30 Mbps expected.				
TC Results Report				
Number of repetitions	3			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams Throughput Throughput map LTE PCI map
Max UL Throughput (Mbps)	21.7	57.9	58.2	
Average UL Throughput (Mbps)	8.32	40.3	23.4	
RAT	NR	LTE, NR	LTE, NR	
ARFCN	2850	2850	2850	
LTE eNBID	290255, 290636			
LTE PCI	36, 501			
TC Responsible	DEKRA			
Date	27/08/2020, 17/09/2020, 19/11/2020			

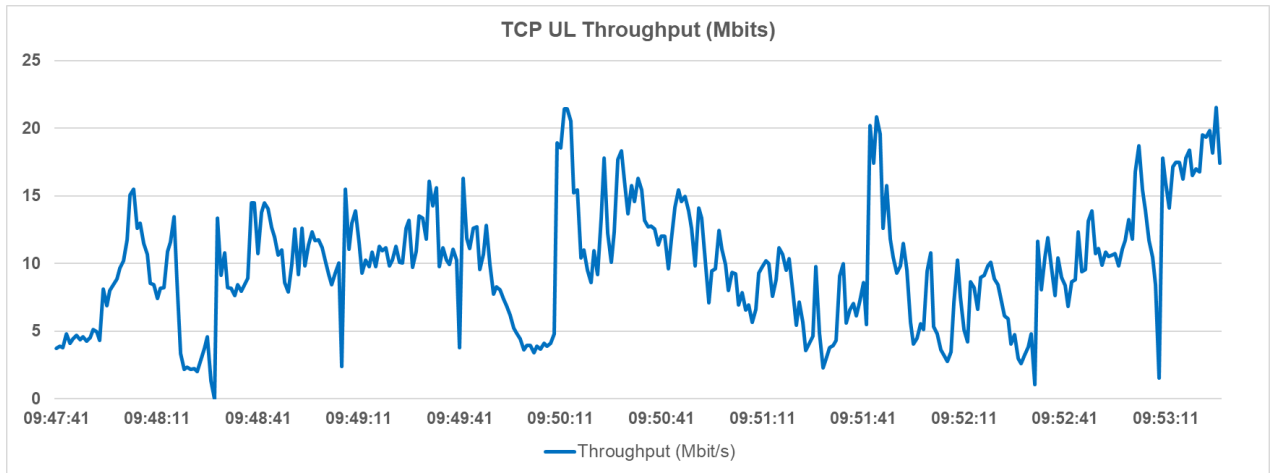


Figure G.91: TCA-GEN-13_TCP_UL_No Load Iteration 1 – UL Throughput.

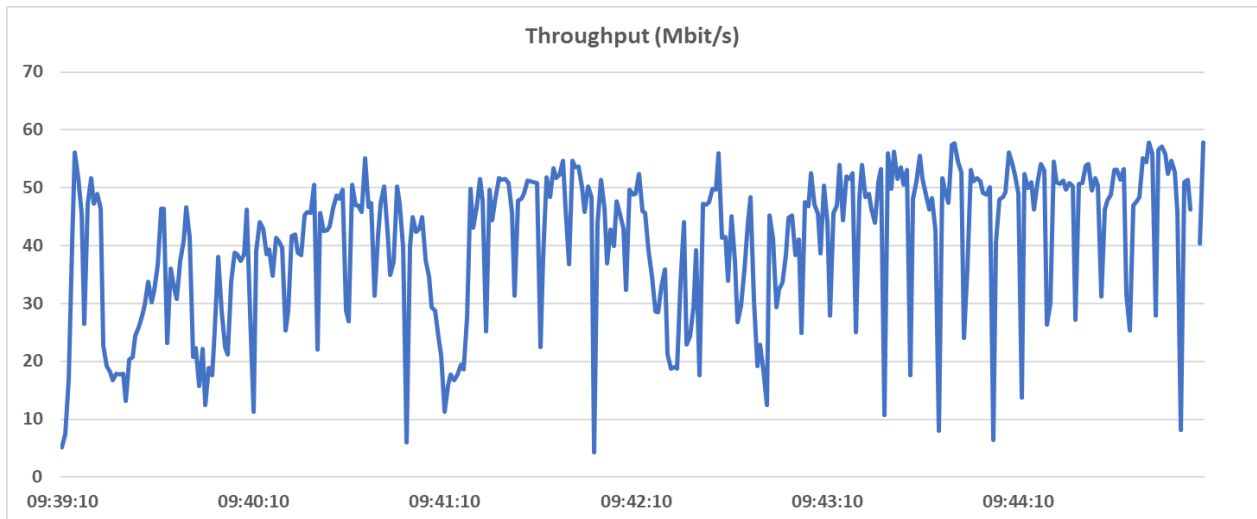


Figure G.92: TCA-GEN-13_TCP_UL_No Load Iteration 2 – UL Throughput.

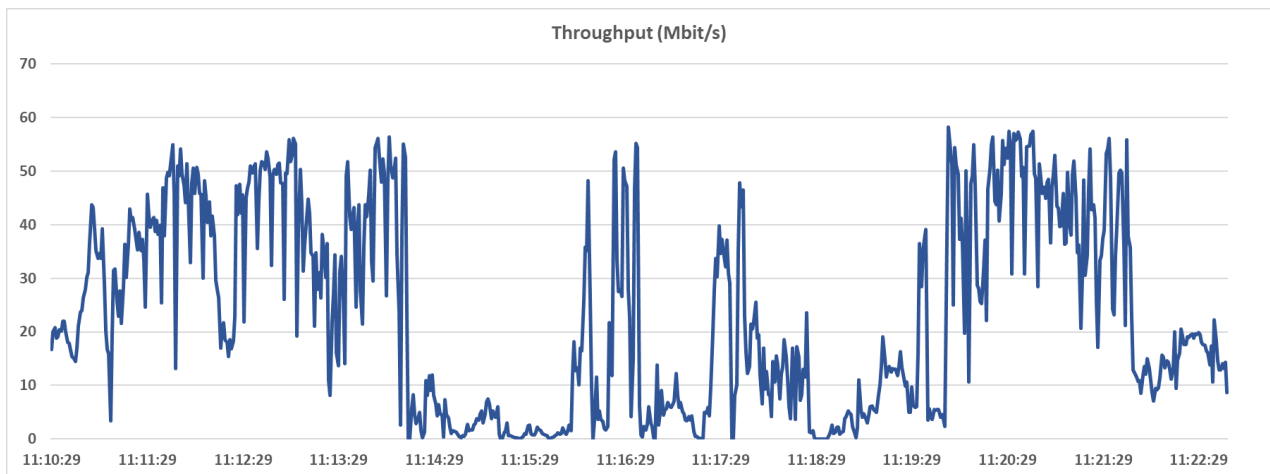


Figure G.93: TCA-GEN-13_TCP_UL_No Load Iteration 3 – UL Throughput.

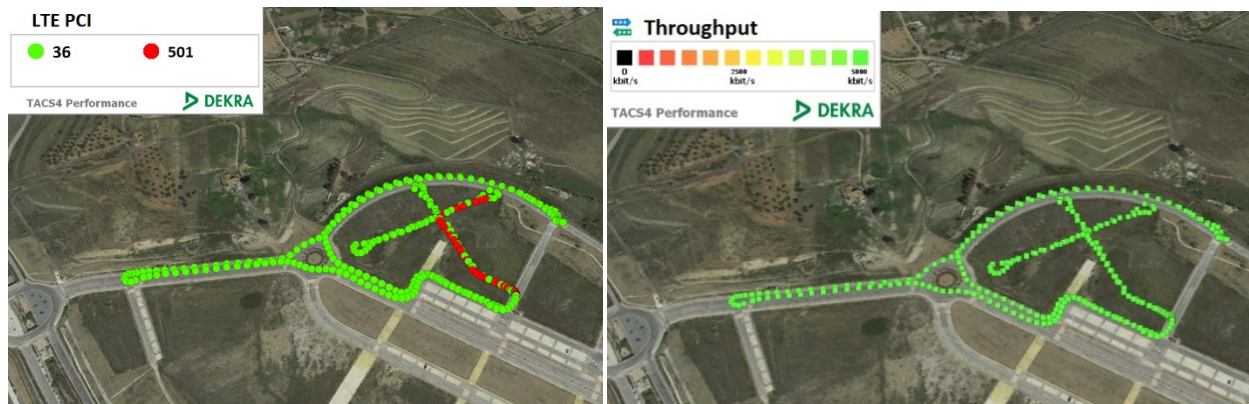


Figure G.94: LTE PCI & Throughput Map (Iteration 2).

User Plane Latency in Unloaded Cell (E2E)

Table G.48: TCA-GEN-18_PING_No load_MTU size test case results.

Test Location	DEKRA test track	Test Case (TC) ID	TCA-GEN-18_PING_No load_MTU size
Test Case (TC) Name	User Plane Latency in Unloaded Cell (e2e)		
Test Case Purpose	Measure coverage, DL Throughput and cell mobility in a UCC/US route		
Stationary / Mobility TC	Stationary		
Test environment	DEKRA test track, PTA Málaga.		
Test setup ID	ES-PT-UsAg-Ping		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	214 07		
Initial Conditions			
-DEKRA TACS4 Performance Testing Platform.			
Test Case Description			
User is located near to the gNB so that it operates under good RF conditions. Start trace logs in the UE and S1 interface. Perform ping of size n bytes with at least 50 echo requests. Target address for the ping is the application server: ping -n 50 <AS IP-address>. Record the maximum, minimum and average value. Disconnect the UE and save the logs. Repeat the test case for y bytes ping.			
Test UE Info			
UE Type: Mobile Phone (LG V50) with TACS4 Mobile app UE SW version: Build PKQ1.190321.001			
Test Variables			
- Live NW traffic on the transmission link			

Expected TC Result				
No timeouts happen. Store RTT				
TC Results Report				
Number of repetitions	2 (one with 24 bytes size, one with 1500 byte size)			
TC comments	-			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams RTT (ms) Iteration 1: size 24 bytes Iteration 2: size 1500 bytes
Max RTT (ms)	70	201		
Average RTT (ms)	45	76		
Min RTT (ms)	23	31		
Ping Timeout (%)	0	26%		
Average retransmissions	6%	2%		
TC Responsible	DEKRA			
Date	19/11/2020			

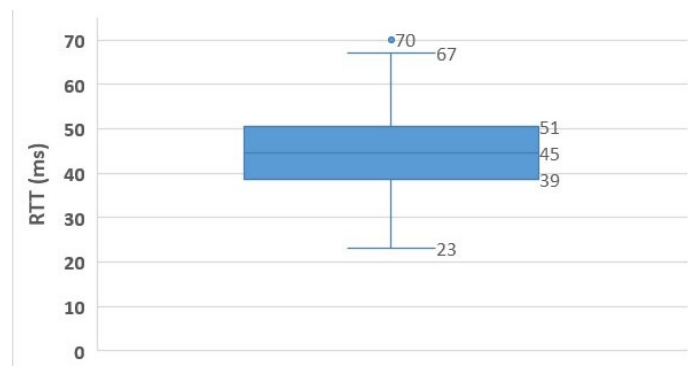


Figure G.95: TCA-GEN- 18_PING_No load 24 bytes boxplot (50 packets).

Control Plane Latency (NR RRC Idle -> NR Connected)

Table G.49: TCA-GEN-20_CP Latency test case results.

Test Location	DEKRA test track	Test Case (TC) ID	TCA-GEN-20_CP Latency
Test Case (TC) Name	Control Plane Latency (NR RRC Idle -> NR Connected)		
Test Case Purpose	Measure coverage, DL Throughput and cell mobility in a UCC/US route		
Stationary / Mobility TC	Stationary		
Test environment	DEKRA test track, PTA Málaga.		
Test setup ID	ES-PT-UsAg-CPL		
5G Deployment Option	NSA (option 3x)		

Layer	Protocol Procedure	System Procedure	Result	Extra Info	Start Procedure	End Procedure
RRC	Connection Establishment		OK	{"Establishment Cause": "highPriorityAccess"}	2020-11-19 11:30:53.884	2020-11-19 11:30:53.987
EMM	Service Request		OK	{}	2020-11-19 11:30:53.884	2020-11-19 11:30:53.987
RRC	Connection Reconfiguration	Radio Bearer Configuration	OK	{"Measurement ID": [1, 2, 4, 7, 17], "EARFCN": 2850, "DRB Id": 1}	2020-11-19 11:30:54.010	2020-11-19 11:30:54.076
RRC	Connection Reconfiguration	CA SCell Addition	OK	{"Measurement ID": [3], "SCell Index": [1], "SCell PCI": [3], "SCell Bandwidth": 100}	2020-11-19 11:30:54.125	2020-11-19 11:30:54.137
RRC	Connection Reconfiguration	NR RRC Reconfiguration. RB 1	OK	{"DRB Identity": 4, "NR Config": "setup", "EN-DC ReleaseAndAdd": false}	2020-11-19 11:30:54.888	2020-11-19 11:30:54.933
RRC	Connection Reconfiguration	NR RRC Reconfiguration	OK	{"NR Config": "setup", "EN-DC ReleaseAndAdd": false, "NR Security": "setup"}	2020-11-19 11:30:55.216	2020-11-19 11:30:55.243
RRC	Connection Reconfiguration		OK	{}	2020-11-19 11:30:56.408	2020-11-19 11:30:56.414
RRC	Connection Release		OK	{"Release Cause": "other"}	2020-11-19 11:32:18.728	2020-11-19 11:32:18.728
RRC	Connection Establishment		OK	{"Establishment Cause": "highPriorityAccess"}	2020-11-19 11:32:22.067	2020-11-19 11:32:22.122
EMM	Service Request		OK	{}	2020-11-19 11:32:22.067	2020-11-19 11:32:22.122
RRC	Connection Reconfiguration	Radio Bearer Configuration	OK	{"Measurement ID": [1, 2, 4, 7, 17], "EARFCN": 2850, "DRB Id": 1}	2020-11-19 11:32:22.144	2020-11-19 11:32:22.179
RRC	Connection Reconfiguration	CA SCell Addition	OK	{"Measurement ID": [3], "SCell Index": [1], "SCell PCI": [3], "SCell Bandwidth": 100}	2020-11-19 11:32:22.227	2020-11-19 11:32:22.254
RRC	Connection Reconfiguration	NR RRC Reconfiguration. RB 0	OK	{"DRB Identity": 4, "NR Config": "setup", "EN-DC ReleaseAndAdd": false}	2020-11-19 11:32:22.968	2020-11-19 11:32:23.087
RRC	Connection Reconfiguration	NR RRC Reconfiguration	OK	{"NR Config": "setup", "EN-DC ReleaseAndAdd": false, "NR Security": "setup"}	2020-11-19 11:32:23.376	2020-11-19 11:32:23.384

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DL Reliability and latency measurements

Table G.50: TCA-GEN-36_UDP_DL test case results.

Test Location	Old bridge	Test Case (TC) ID	TCA-GEN-36_UDP_DL_Reliability_Latency	
Test Case (TC) Name	DL Reliability and latency measurements			
Test Case Purpose	Measure DL latency and packet loss rates at different data rates			
Stationary / Mobility TC	Mobility			
Test environment	DEKRA test track, PTA Málaga.			
Test setup ID	ES-PT-UsAg-UDP_DL			
5G Deployment Option	NSA (option 3x)			
PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
DEKRA TACS4 Performance Testing Platform. UDP rates:200 Mbps, 1 Mbps				
Test Case Description				
Select most relevant UC drive test routes. Perform a continuous DL UDP transmission. Measure one-way delay and packet loss along the route. Measurement repeated at several data rates (i.e. 200 Mbps, 150 Mbps, 100 Mbps, 50 Mbps)				
Test UE Info				
UE Type: Mobile Phone (LG V50) with TACS4 Mobile app, UE SW version: Build PKQ1.190321.001, UE speed: 30 km/h				
Test Variables				
Live NW traffic on the transmission link; Moving vehicles				
Expected TC Result				
Average throughput very close to configured UDP rate.				
TC Results Report				
Number of repetitions	2 (first UDP 200 Mbps; second UDP 1 Mbps)			
Tools used	DEKRA TACS4 PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Max DL Throughput (Mbps)	244.6	1.2		Throughput Throughput map NR available map LTE PCI map
Aver. DL Throughput (Mbps)	121.6	1		
LTE RSRP range (dBm)	-70 / -103			
RAT	LTE, NR			
ARFCN	2850, 6400			
LTE eNBID	290255, 290305, 290636, 290565			
LTE PCI	36,38,501,502			
TC Responsible	DEKRA			
Date	27/08/2020 - 17/09/2020			



Figure G.97: NR Available Map (Iteration 2).



Figure G.98: LTE PCI Map (Iteration 2).

UL Reliability and latency measurements

Table G.51: TCA-GEN-37_UDP_UL_5Mbps test case results.

Test Location	Old bridge	Test Case (TC) ID	TCA-GEN-37_UDP_UL_Reliability_Latency	
Test Case (TC) Name	UL Reliability and latency measurements			
Test Case Purpose	Measure UL latency and packet loss rates at different data rates			
Stationary / Mobility TC	Mobility			
Test environment	DEKRA test track, PTA Málaga.			
Test setup ID	ES-PT-UsAg-UDP_UL			
5G Deployment Option	NSA (option 3x)			
PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
DEKRA TACS4 Performance Testing Platform. UDP rate: 5 Mbps				
Test Case Description				
Select most relevant UC drive test routes. Perform a continuous UL UDP transmission. Measure one-way delay and packet loss along the route. Measurement repeated at several data rates (i.e 200 Mbps, 150 Mbps, 100 Mbps, 50 Mbps)				
Test UE Info				
UE Type: Mobile Phone (LG V50) with TACS4 Mobile app UE SW version: Build PKQ1.190321.001 UE speed: 30 km/h				
Test Variables				
Live NW traffic on the transmission link; Moving vehicles				
Expected TC Result				
Average throughput very close to configured UDP rate.				
TC Results Report				
Number of repetitions	1			
TC comments	Check mobility through old bridge route			
Tools used	DEKRA TACS4 PERFORMANCE TESTING PLATFORM			
Test Results	Average	Min	Max	Descriptions/Diagrams
One-way-delay (ms)	43.3	19	1165	UDP UL Jitter vs One-Way Delay UDP UL One-Way Delay (ms) vs Jitter (ms) vs Packet error rate (%) UDP UL Throughput (Mbps)
Jitter (ms)	2.4	1	3	
Packet Loss Rate	0.01	0.8	0	
Throughput (Mbps)	5	1.6	8.3	
TC Responsible	DEKRA			
Date	14/08/2020			

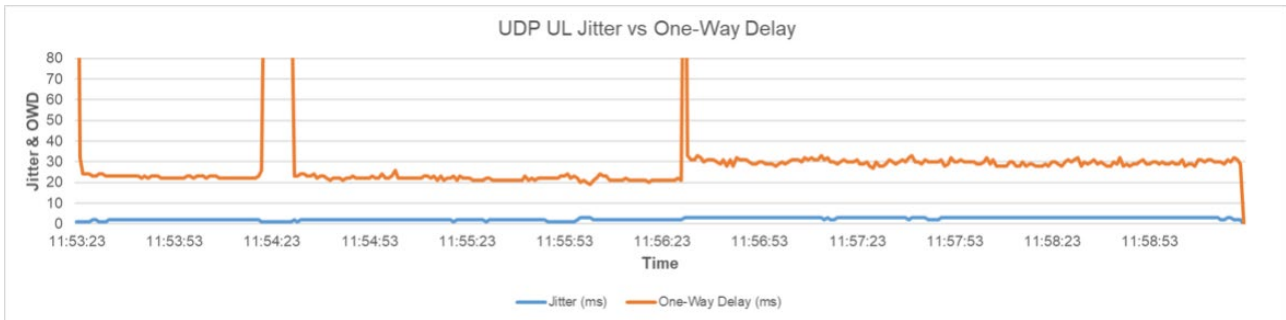


Figure G.99: UDP UL Jitter vs One-Way Delay

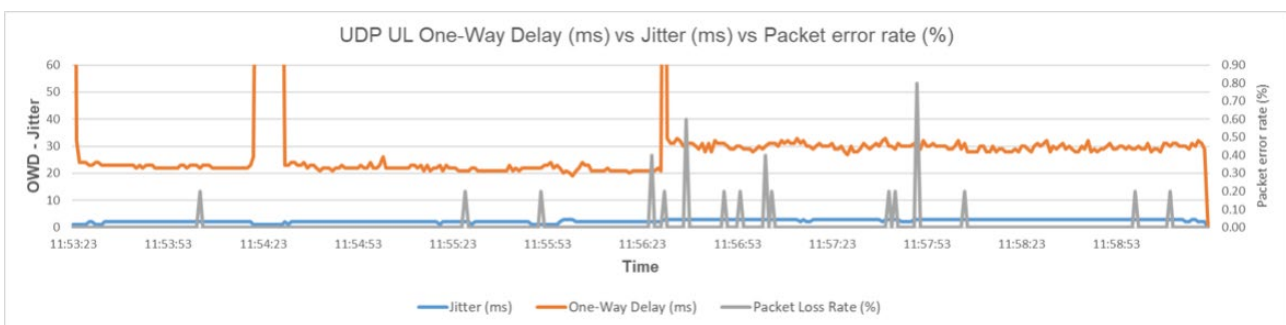


Figure G.100: UDP UL One-Way Delay (ms) vs Jitter (ms) vs Packet error rate (%)

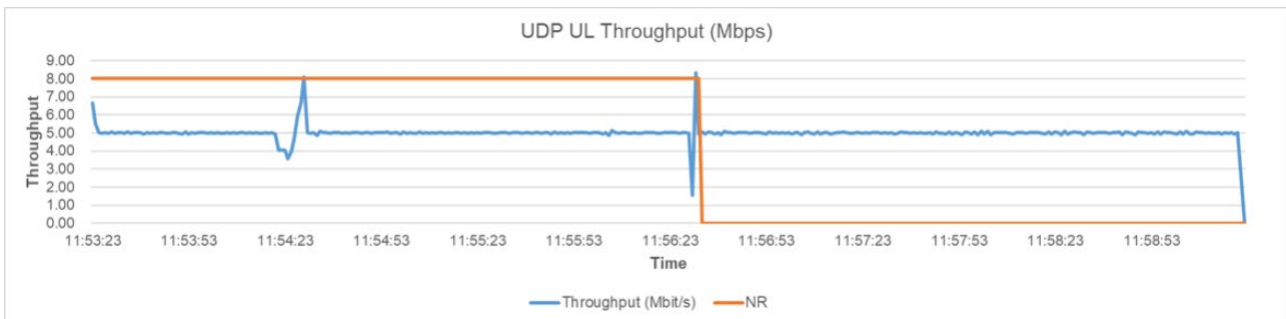


Figure G.101: UDP UL Throughput (Mbps)

Table G.52: TCA-GEN-37_UDP_UL_1Mbps test case results.

Test Location	Old bridge	Test Case (TC) ID	TCA-GEN-37_UDP_UL_Reliability_Latency
Test Case (TC) Name	UL Reliability and latency measurements		
Test Case Purpose	Measure UL latency and packet loss rates at different data rates		
Stationary / Mobility TC	Mobility		
Test environment	DEKRA test track, PTA Málaga.		
Test setup ID	ES-PT-UsAg-UDP_UL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	214 07		

Initial Conditions				
DEKRA TACS ₄ Performance Testing Platform. UDP rate: 1 Mbps				
Test Case Description				
Select most relevant UC drive test routes. Perform a continuous DL UDP transmission. Measure one way delay and packet loss along the route. Measurement repeated at several data rates (i.e. 200 Mbps, 150 Mbps, 100 Mbps, 50 Mbps)				
Test UE Info				
UE Type: Mobile Phone (LG V50) with TACS ₄ Mobile app UE SW version: Build PKQ1.190321.001 UE speed: 30 km/h				
Test Variables				
Live NW traffic on the transmission link; Moving vehicles				
Expected TC Result				
Average throughput very close to configured UDP rate.				
TC Results Report				
Number of repetitions	1			
TC comments	Check mobility through old bridge route			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Max UL Throughput (Mbps)	2.1			Throughput RSRP map
Aver. UL Throughput (Mbps)	1			
LTE RSRP range (dBm)	-57 / -106			
RAT	LTE, NR			
ARFCN	2850, 6400			
LTE eNBID	290255, 290305, 290636, 290565			
LTE PCI	401, 501, 502, 503,...			
TC Responsible	DEKRA			
Date	17/09/2020			



Figure G.102: UDP UL Throughput (Mbps).

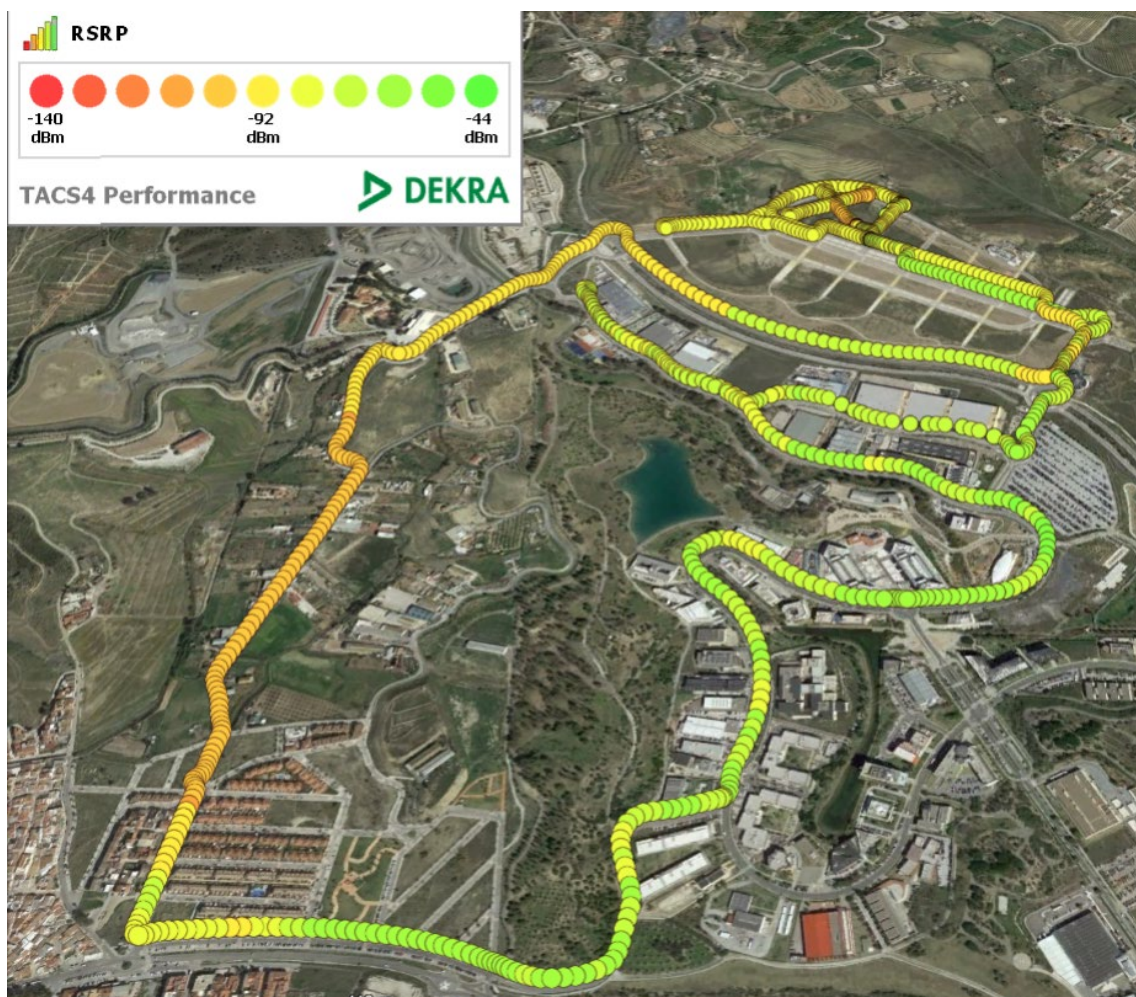


Figure G.103: RSRP Map.

G.1.2 ES-PT cross border area Results

The tables below summarize the test results obtained during the test sessions performed in August and September 2020 in the ES-PT CBC, connected to ES network -Telefónica. PT network is not used during testing.

TCP DL Use case route performance

Table G.53: TCA-GEN-12_TCP_DL_No Load (Old bridge).

Test Location	Old bridge	Test Case (TC) ID	TCA-GEN-12_TCP_DL_No Load
Test Case (TC) Name	TCP DL Use case route performance		
Test Case Purpose	Measure coverage, DL Throughput and cell mobility in a UCC/US route		
Stationary / Mobility TC	Mobility		
Test environment	ES-PT CBC Old bridge		
Test setup ID	ES-PT-UsAg-TCP_DL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	214 07		
Initial Conditions			
<div>- Mobile network is at early deployment stage and not properly configured</div> <div>- DEKRA TACS₄ M19Performance Testing Platform. 8 TCP connections established to get maximum throughput</div>			
Test Case Description			
Select most relevant UC drive test routes. Initiate a continuous DL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route. Establish as many TCP connections as required (i.e. 8) to saturate the link (maximum DL throughput provided by the network). Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell IDs. Identify NAS and RRC procedures along the route to identify cell mobility, handover successful rate, etc.)			
Test UE Info			
UE Type: Mobile Phone (Xiaomi MiMix3) with TACS ₄ Mobile app; UE SW version: Build PKQ1.190223.001 UE speed: 20 km/h			
Test Variables			
Live NW traffic on the transmission link; Moving vehicles			
Expected TC Result			
The test is performed to collect current network performance. Due to the lack of maturity of the network configuration status at measurement time, results above 100 Mbps are good enough.			
TC Results Report			
Number of repetitions	1		

Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Max Total DL Throughput	143.5 Mbps			Throughput vs PCI Throughput vs RSRP LTE RSRP vs NR SS-RSRP Throughput map
Aver. Total DL Throughput	58.5 Mbps			
Max NR DL Throughput	99.1 Mbps			
Aver. NR DL Throughput	40.6 Mbps			
Max LTE DL Throughput	61.4 Mbps			
Aver. LTE DL Throughput	24.4 Mbps			
LTE RSRP range (dBm)	-87 / -114			
NR SS-RSRP range (dBm)	-82 /NA			
RAT	LTE, NR			
LTE eNBID	360103,360133,360149,360150			
LTE PCI	67,196,207,221			
NR PCI	168,446			
TC Responsible	DEKRA, NOKIA			
Date	27/02/2020			

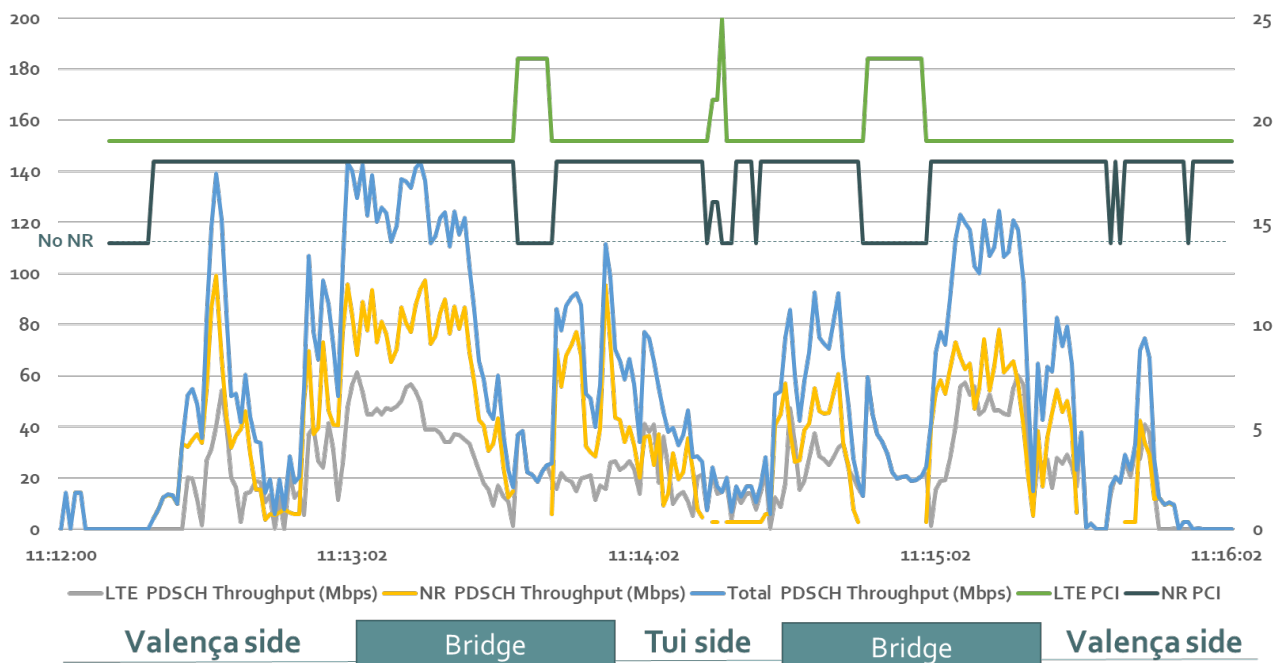


Figure G.104: DL Throughput vs PCI (Old Bridge).

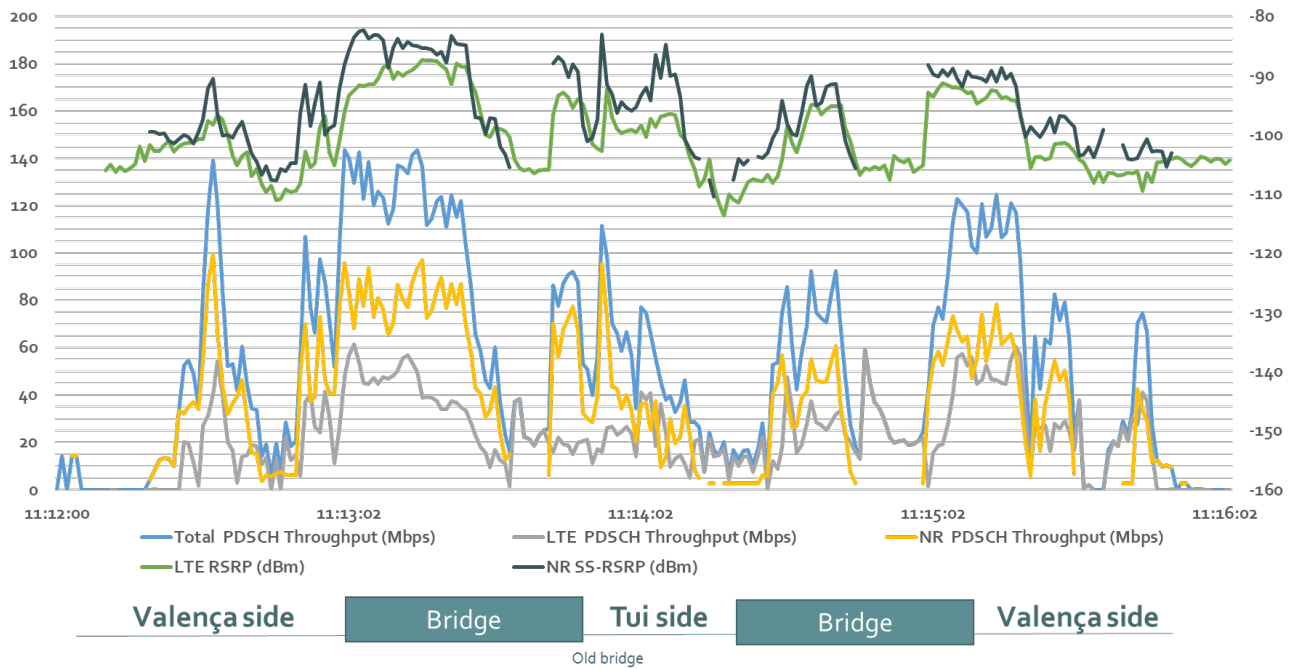


Figure G.105: DL Throughput vs RSRP (Old Bridge).

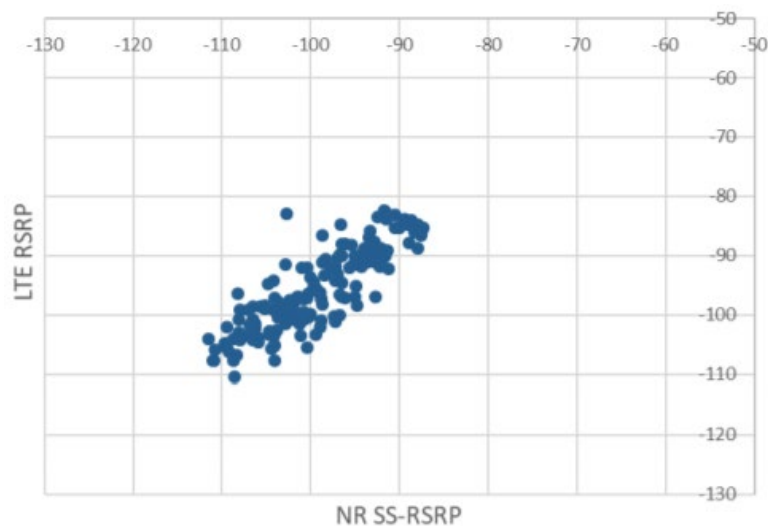


Figure G.106: LTE RSRP vs NR SS-RSRP.

Table G.54: TCA-GEN-12_TCP_DL_No Load (New bridge).

Test Location	New bridge	Test Case (TC) ID	TCA-GEN-12_TCP_DL_No Load
Test Case (TC) Name	TCP DL Use case route performance		
Test Case Purpose	Measure coverage, DL Throughput and cell mobility in a UCC/US route		
Stationary / Mobility TC	Mobility		
Test environment	ES-PT CBC New bridge		
Test setup ID	ES-PT-UsAg-TCP_DL		

5G Deployment Option	NSA (option 3x)			
PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
<div>- Mobile network is at early deployment stage and not properly configured</div> <div>- DEKRA TACS4 M19Performance Testing Platform. 8 TCP connections established to get maximum throughput</div>				
Test Case Description				
Select most relevant UC drive test routes. Initiate a continuous DL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route. Establish as many TCP connections as required (i.e. 8) to saturate the link (maximum DL throughput provided by the network). Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell ids. Identify NAS and RRC procedures along the route to identity cell mobility, handover successful rate, etc.)				
Test UE Info				
UE Type: Mobile Phone (Xiaomi MiMix3) with TACS4 Mobile app; UE SW version: Build PKQ1.190321.001 UE speed: 80 km/h				
Test Variables				
Live NW traffic on the transmission link; moving vehicles				
Expected TC Result				
The test is performed to collect current network performance. Due to the lack of maturity of the network configuration status at measurement time, results above 100 Mbps are good enough.				
TC Results Report				
Number of repetitions	1			
Tools used	DEKRA TACS4 PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
Max Total DL Throughput	94.7 Mbps			Throughput vs PCI Throughput vs RSRP LTE RSRP vs NR SS-RSRP Throughput map
Aver. Total DL Throughput	12.5 Mbps			
Max NR DL Throughput	53.7 Mbps			
Aver. NR DL Throughput	7.1 Mbps			
Max LTE DL Throughput	60.1 Mbps			
Aver. LTE DL Throughput	11.2 Mbps			
LTE RSRP range (dBm)	-80 / -118			
NR SS-RSRP range (dBm)	-82.7 /NA			
RAT	LTE, NR			
LTE eNBID	360102, 360103, 360136, 360149, 360150, 360173, 360191			
LTE PCI	11,42,106,110,1201,125,133,138,142,197,207,209			

NR PCI	168,283,446			
TC Responsible	DEKRA, NOKIA			
Date	27/02/2020			

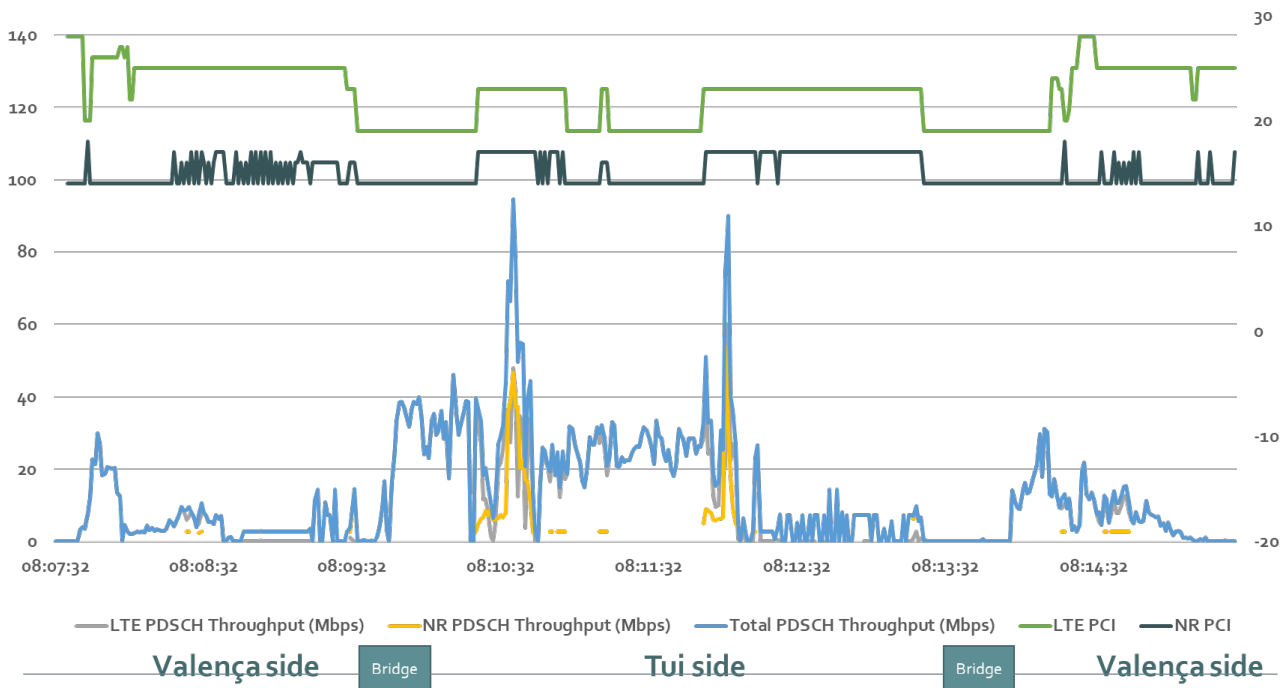


Figure G.107: DL Throughput vs PCI (New Bridge).

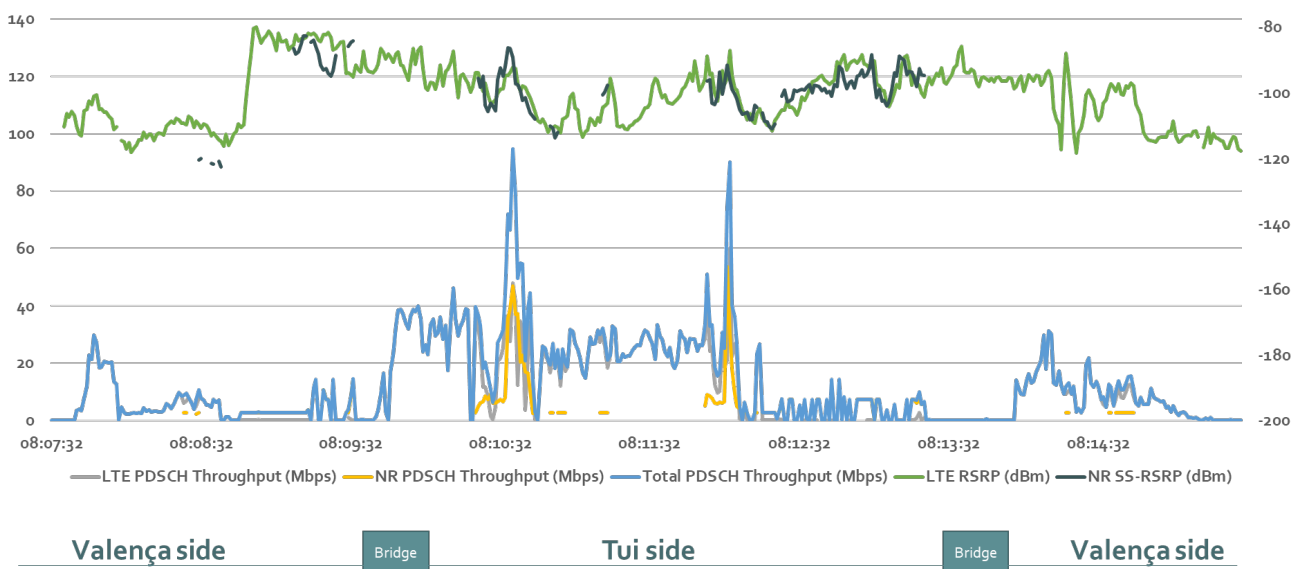


Figure G.108: DL Throughput vs RSRP (New Bridge).

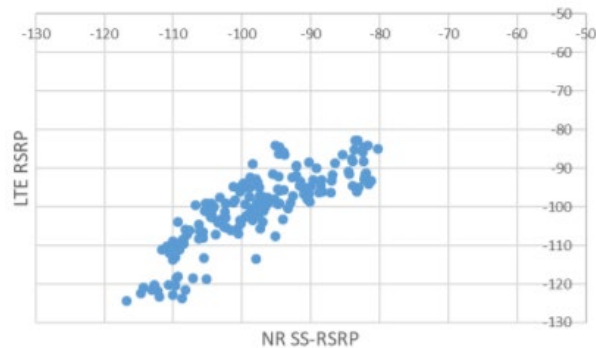


Figure G.109: LTE RSRP vs NR SS-RSRP.

TCP UL Use case route performance

Table G.55: TCA-GEN-13_TCP_UL_20.

Test Location	Porriño	Test Case (TC) ID	TCA-GEN-12_TCP_UL_No Load
Test Case (TC) Name	TCP UL Use case route performance		
Test Case Purpose	Measure coverage, UL Throughput and cell mobility in a UCC/US route		
Stationary / Mobility TC	Mobility		
Test environment	Highway Porriño		
Test setup ID	ES-PT-UsAg-TCP_UL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	214 07		
Initial Conditions			
<div>- Mobile network is at early deployment stage and not properly configured</div> <div>- DEKRA TACS4 M19Performance Testing Platform.</div>			
Test Case Description			
<div>Select most relevant UC drive test routes. Initiate a continuous UL TCP session on the reference UE, which moves at an average speed of x km/h (depending on vehicle type) along the predefined drive route.</div> <div>Measure throughput (LTE, NR and total) and obtain average, maximum and minimum values. Obtain RSRP, SS-RSRP, RSRQ, SS-RSRQ, PCIs, eNBs, cell ids. Identify NAS and RRC procedures along the route to identity cell mobility, handover successful rate, etc.)</div>			
Test UE Info			
<div>UE Type: Mobile Phone (Xiaomi MiMix3) with TACS4 Mobile app</div> <div>UE SW version: Build PKQ1.190223.001</div> <div>UE speed: 80 km/h</div>			
Test Variables			
Live NW traffic on the transmission link; moving vehicles			
Expected TC Result			

The test is performed to collect current performance. Due to the lack of maturity of the network configuration status at measurement time, results above 10 Mbps are good enough.

TC Results Report				
Number of repetitions	1			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	#2	#3	Descriptions/Diagrams
Max UL Throughput	27.0 Mbps			Throughput vs PCI Throughput vs RSRP LTE RSRP vs NR SS-RSRP Throughput map
Average UL Throughput	11.9 Mbps			
LTE RSRP range (dBm)	-80 / -118			
NR SS-RSRP range (dBm)	-82.7 / NA			
RAT	LTE, NR			
LTE eNBID	360125,360136,360141,360155,360226			
LTE PCI	25,45,51,52,53,79,80, 176			
NR PCI	146			
TC Responsible	DEKRA, NOKIA			
Date	27/02/2020			

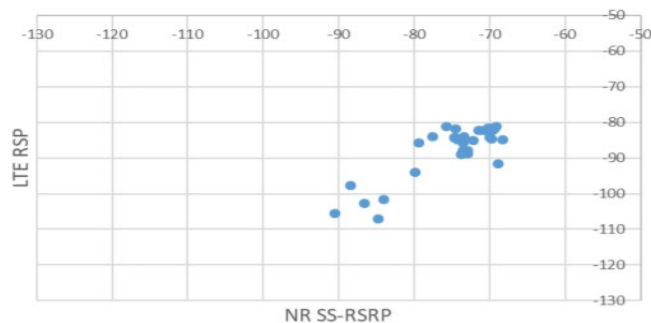


Figure G.110: LTE RSRP vs NR SS-RSRP

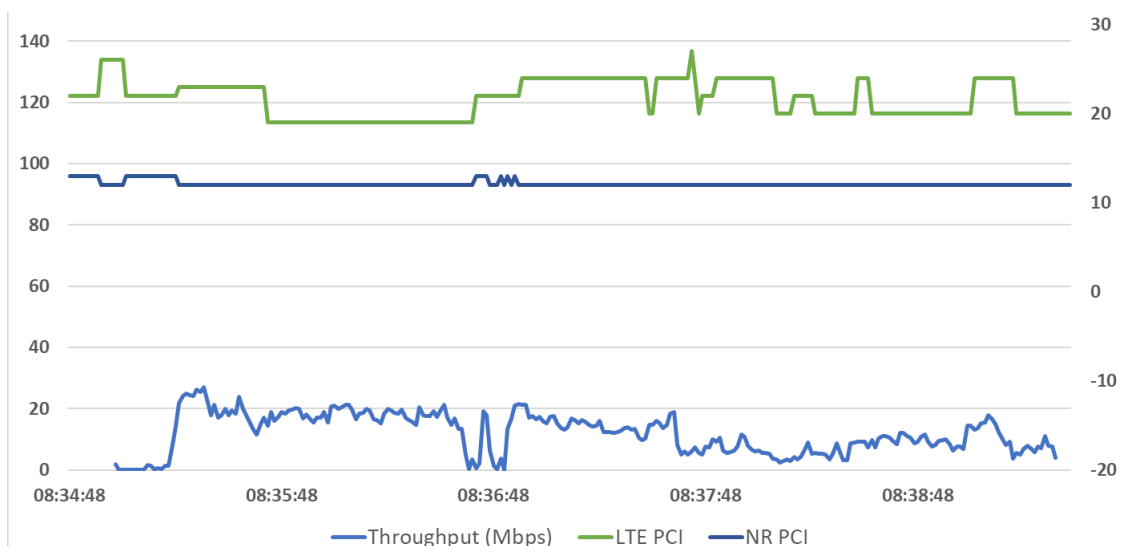


Figure G.111: UL Throughput vs PCI

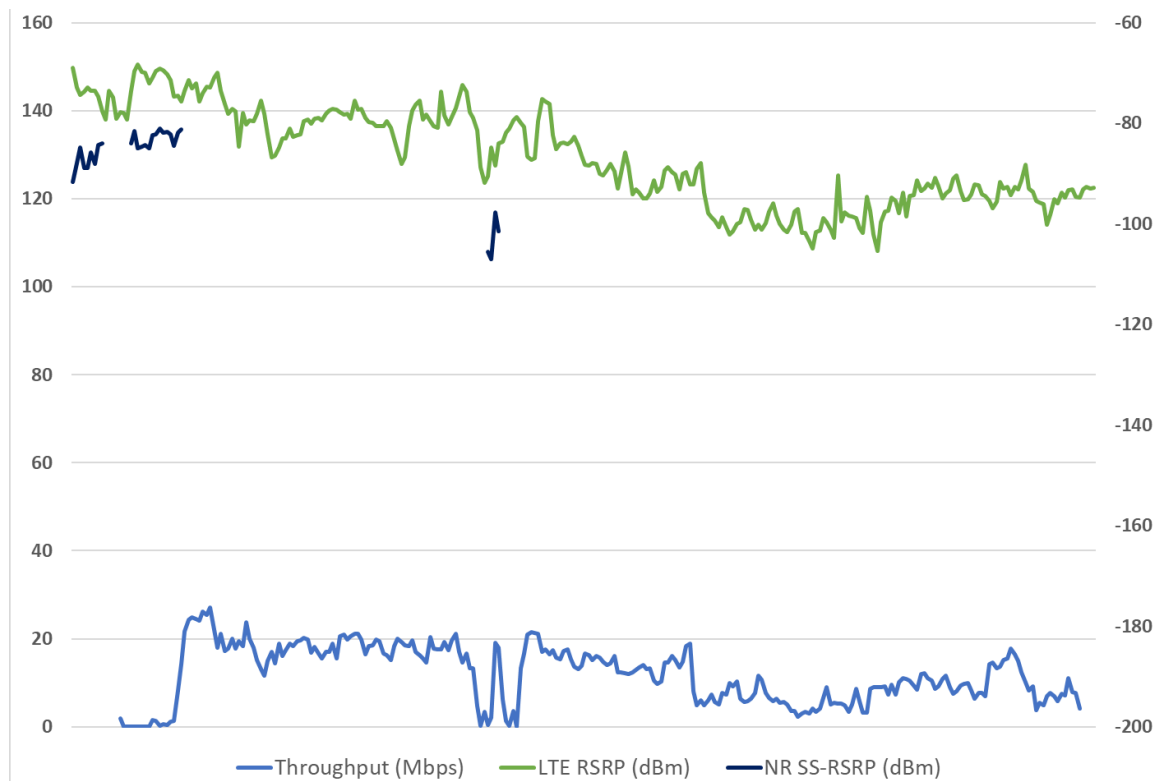


Figure G.112: UL Throughput vs RSRP (New Bridge)



Figure G.113: UL Throughput Map

Intra-cell mobility (at different speed ranges)

Table G.56: TCA-GEN-23_TCP_DL_20 (Old bridge).

Test Location	Old bridge	Test Case (TC) ID	TCA-GEN-23_TCP_DL_20	
Test Case (TC) Name	Intra-cell mobility (at different speed ranges)			
Test Case Purpose	Verify the impact of vehicular speed on intra-cell mobility			
Stationary / Mobility TC	Mobility			
Test environment	ES-PT CBC Old bridge			
Test setup ID	ES-PT-UsAg-TCP_DL			
5G Deployment Option	NSA (option 3x)			
PLMN ID (MCC + MNC)	214 07			
Initial Conditions				
<div>- Mobile network is at early deployment stage and not properly configured</div> <div>- DEKRA TACS₄ M19Performance Testing Platform. 8 TCP connections established to get maximum throughput</div>				
Test Case Description				
A UE is successfully attached to the 5G network and starts uploading/downloading data (e.g. from a FTP server.) The UE starts moving following a selected route (between two specific measurement points of a cell). The speed should remain the same during the testing. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Repeat the test case with different vehicular speeds. Verify the impact of vehicular speed on intra-cell mobility				
Test UE Info				
UE Type: Mobile Phone (Xiaomi MiMix3) with TACS ₄ Mobile app UE SW version: Build PKQ1.190223.001 UE speed: 20 km/h				
Test Variables				
Live NW traffic on the transmission link. Moving vehicles				
Expected TC Result				
Annotate cell mobility between two selected locations during the test				
TC Results Report				
Number of repetitions	1			
Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
RAT	LTE, NR			LTE PCI changes: 221 to 196; 196 to 67; 67 to 221; 221 to 207; 207 to 221
LTE eNBID	360103,360149,360150			
LTE PCI	67,196,207,221			

NR PCI	168,446			NR PCI changes: 446 to 168; 168 to 446. Occasional Loss of NR coverage
TC Responsible	DEKRA, NOKIA			
Date	27/02/2020			

Table G.57: TCA-GEN-23_TCP_DL_80 (New bridge).

Test Location	New bridge	Test Case (TC) ID	TCA-GEN-23_TCP_DL_80
Test Case (TC) Name	Intra-cell mobility (at different speed ranges)		
Test Case Purpose	Verify the impact of vehicular speed on intra-cell mobility		
Stationary / Mobility TC	Mobility		
Test environment	ES-PT CBC New bridge		
Test setup ID	ES-PT-UsAg-TCP_DL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	214 07		
Initial Conditions			
<div>- Mobile network is at early deployment stage and not properly configured</div> <div>- DEKRA TACS4 M19Performance Testing Platform. 8 TCP connections established to get maximum throughput</div>			
Test Case Description			
A UE is successfully attached to the 5G network and starts uploading/downloading data (e.g. from a FTP server.) The UE starts moving following a selected route (between two specific measurement points of a cell). The speed should remain the same during the testing. Continuously monitor DL/UL throughput, latency, packet loss and RSRP/RSRQ/SINR. Repeat the test case with different vehicular speeds. Verify the impact of vehicular speed on intra-cell mobility			
Test UE Info			
UE Type: Mobile Phone (Xiaomi MiMix3) with TACS4 Mobile app UE SW version: Build PKQ1.190223.001 UE speed: 80 km/h			
Test Variables			
<div>- Live NW traffic on the transmission link. Moving vehicles</div>			
Expected TC Result			
Annotate cell mobility between two selected locations during the test			
TC Results Report			
Number of repetitions	1		

Tools used	DEKRA TACS ₄ PERFORMANCE TESTING PLATFORM			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
RAT	LTE, NR			LTE PCI changes: 142 to 120; 120 to 11; 11 to 120; 120 to 11; 11 to 120; 120 to 11; 11 to 120; NR PCI changes: continuous changes between 168 and 283 and loss of NR coverage
LTE eNBID	360103			
LTE PCI	11,120,142			
NR PCI	168,283			
TC Responsible	DEKRA, NOKIA			
Date	27/02/2020			

G.2 GR-TR CBC Results

G.2.1 TR side Results

The tables below summarize the test results obtained during the test sessions performed in September 2020 at Eskisehir (TR side) and specifically close to the Ford-Eskisehir factory, which is not close to the GR-TR borders. Eskisehir Ford factory site location is far from GR-TR border. Its integrated and tested for Ford internal tests. The site critically important for identifying any problem before GR-TR CBC tests.

Peak DL Throughput

Table G.58: TCA-GEN-01_TCP_DL & TCA-GEN-01_UDP_DL

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-01_TCP_DL TCA-GEN-01_UDP_DL
Test Case (TC) Name	Peak DL TCP/UDP Data Throughput of Single User (stationary use)		
Test Case Purpose	Measure the Peak Downlink TCP/UDP User Data Throughput of Single User		
Stationary / Mobility TC	Stationary TC		
Test environment	Stationary TC Location depicted on Figure G.114		
Test setup ID	GR-TR-UsAg-TCP_DL, GR-TR-UsAg-UDP_DL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			

- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W
- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.
- Accuver XCAL Drive Testing has been used during drive test.
- Core NW was deployed different city.
- Transmission backbone supporting 900Mbps and carrying live traffic.
- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.
- UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored.
- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.
- DDSU-11:3:0 was used as TDD pattern.

Test Case Description

Perform a 5G data call in an empty cell under best RF conditions.

TC01-1: Start UDP DL data transfer and measure received DL throughput over 1 minute

TC01-2: Start TCP DL data transfer and measure TCP throughput over 1 minute

Test UE Info

UE Type: Oppo Find X2

UE category: Cat19

UE SW version: CPH2023EU_11.A.22_0720_202006121628

UE: Max 90 kmph, Average:50 kmph

Test Variables

- Live NW traffic on the transmission link

- Moving vehicles

Expected TC Result

DL throughput exceeded 700Mbps which is acceptable value for 900Mbps supported transmission backbone.

TC Results Report

Number of repetitions 3

TC comments

DL throughput exceeded 700Mbps which is acceptable level when consider transport capacity. Periodic deeps related to UDP test methodology. Measured deeps are related to NW behaviour and vehicle traffic for TCP Test. UDP/TCP results close to each other because of link capacity is fully loaded but there is some room for higher throughput.

Tools used

Accuver XCAL Drive Testing Tool

Test Results

Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
712.8	711.7	713.2	Figure G.115 and Figure G.116 are illustrating MAC DL throughput which is closest level of the physical Layer.
712.3	712.3	711.7	
UDP: 712,5 Mbps, TCP: 712,1			

TC Responsible

Ericsson TR, TURKCELL

Date

6/11/2020

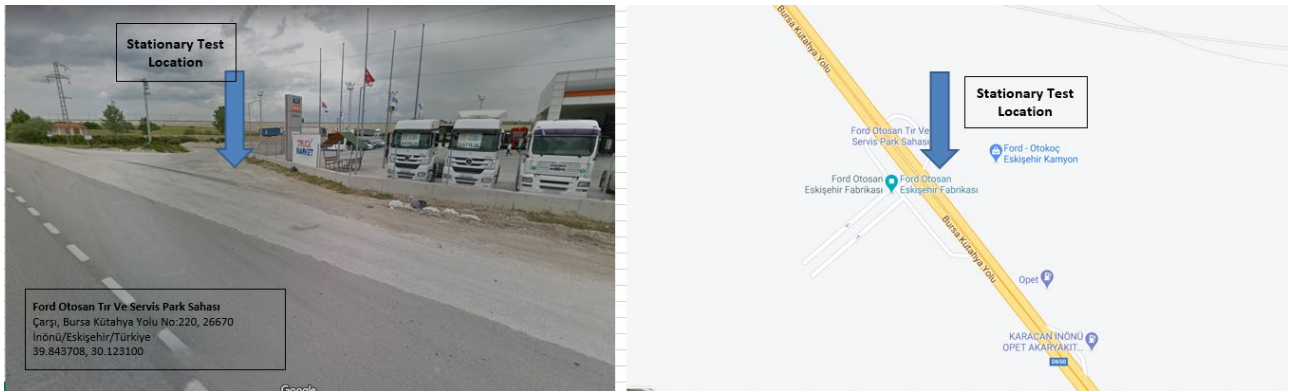


Figure G.114: Stationary test location

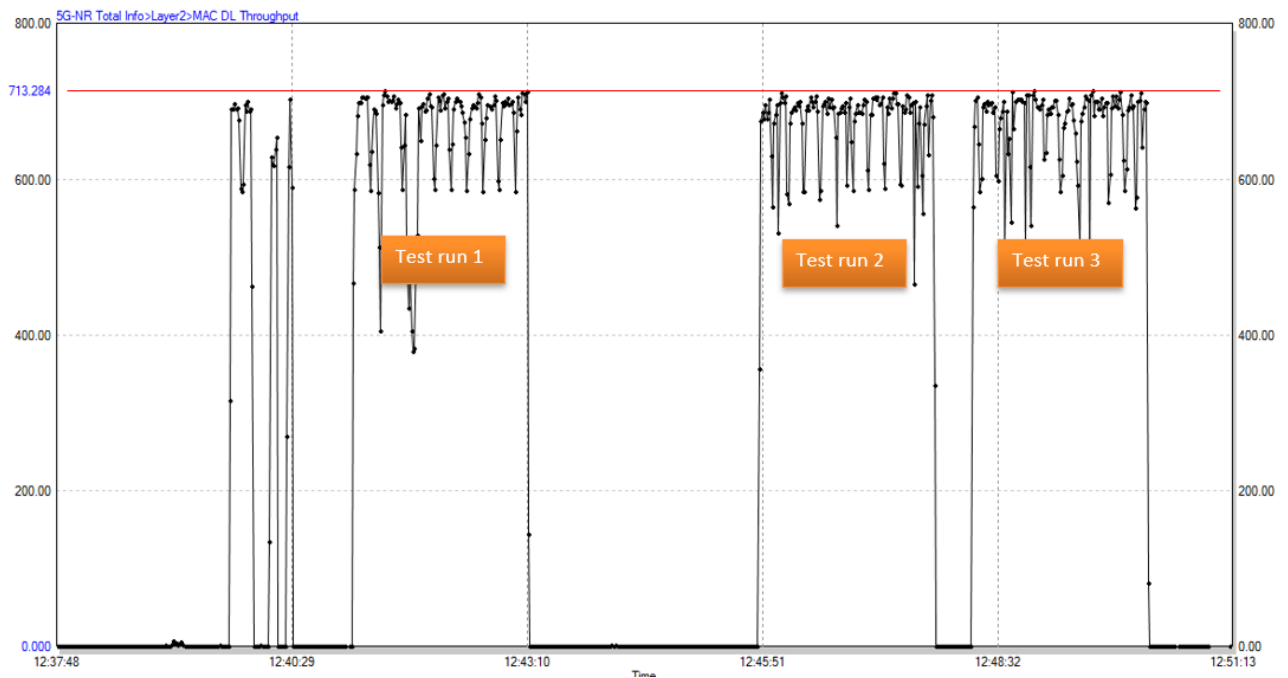


Figure G.115: UDP DL Throughput.

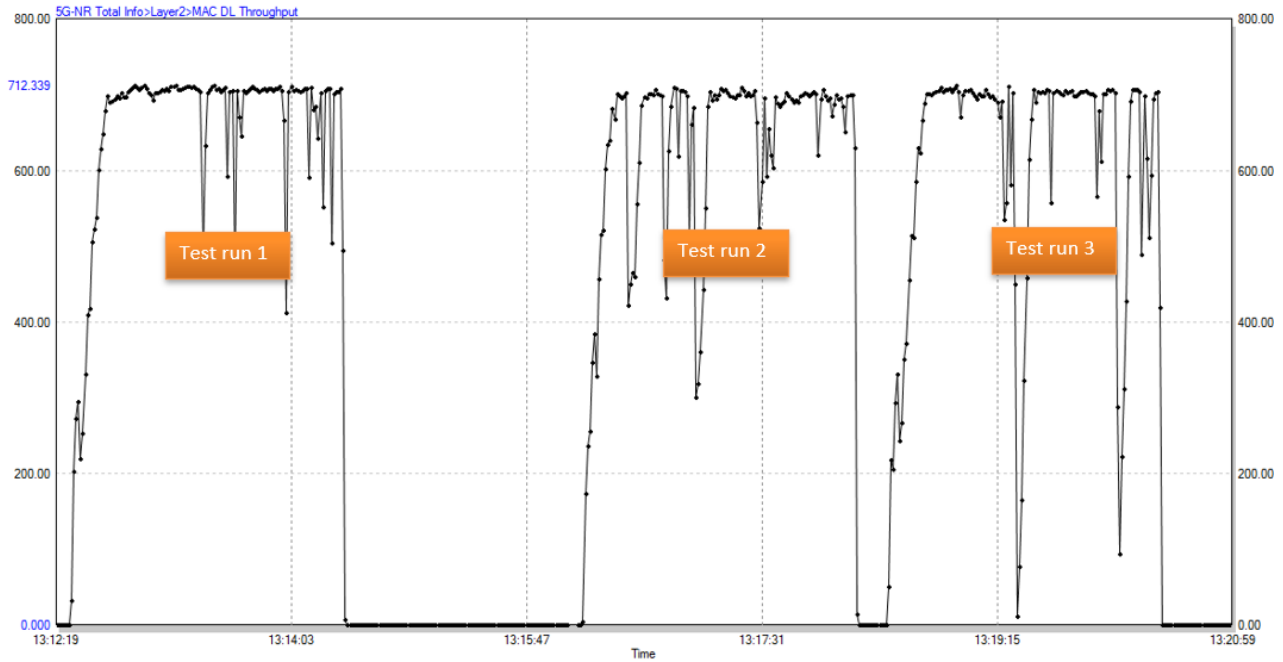


Figure G.116:TCP DL Throughput.

Peak UL Throughput

Table G.59: TCA-GEN-02_TCP_UL & TCA-GEN-02_UDP_UL

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-02_TCP_UL TCA-GEN-02_UDP_UL
Test Case (TC) Name	Peak UL TCP/UDP Data Throughput of Single User (stationary use)		
Test Case Purpose	Measure the Peak Uplink TCP/UDP User Data Throughput of Single User		
Stationary / Mobility TC	Stationary TC		
Test environment	Stationary TC Location depicted on Figure G.114		
Test setup ID	GR-TR-UsAg-TCP_UL, GR-TR-UsAg-UDP_UL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			

- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W
- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.
- Accuver XCAL Drive Testing has been used during drive test.
- Core NW was deployed different city.
- Transmission backbone supporting 900Mbps and carrying live traffic.
- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.
- UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored.
- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.
- DDSU-11:3:0 was used as TDD pattern.

Test Case Description

Perform a 5G data call in an empty cell under best RF conditions.

TC02-1: Start UDP UL data transfer and measure received DL throughput over 1 minute

TC02-2: Start TCP UL data transfer and measure TCP throughput over 1 minute

Test UE Info

UE Type: Oppo Find X2

UE category: Cat19

UE SW version: CPH2023EU_11.A.22_0720_202006121628

UE: Max 90 kmph, Average:50 kmph

Test Variables

- Live NW traffic on the transmission link
- Moving vehicles

Expected TC Result

Lab tests UL throughput reached up to 100Mbps. In the field test reached a peak of 97 Mbps UDP UL and 80 Mbps TCP UL which is acceptable level.

TC Results Report

Number of repetitions	3			
TC comments	UL throughput reached up to 97Mbps which is very close to the lab results. Measurement deeps are related to NW behaviour and vehicle traffic.			
Tools used	Accuver XCAL Drive Testing Tool			
Test Results	Iteratio n #1	Iteratio n #2	Iteratio n #3	Descriptions/Diagrams
TCA-GEN-02-UDP	97.24	88.9		
TCA-GEN-02-TCP	80.13	72.16	74.4	
<Average Metric measured>	UDP: 93,07 Mbps, TCP: 75,56			
TC Responsible	Ericsson TR, TURKCELL			
Date	6/11/2020			

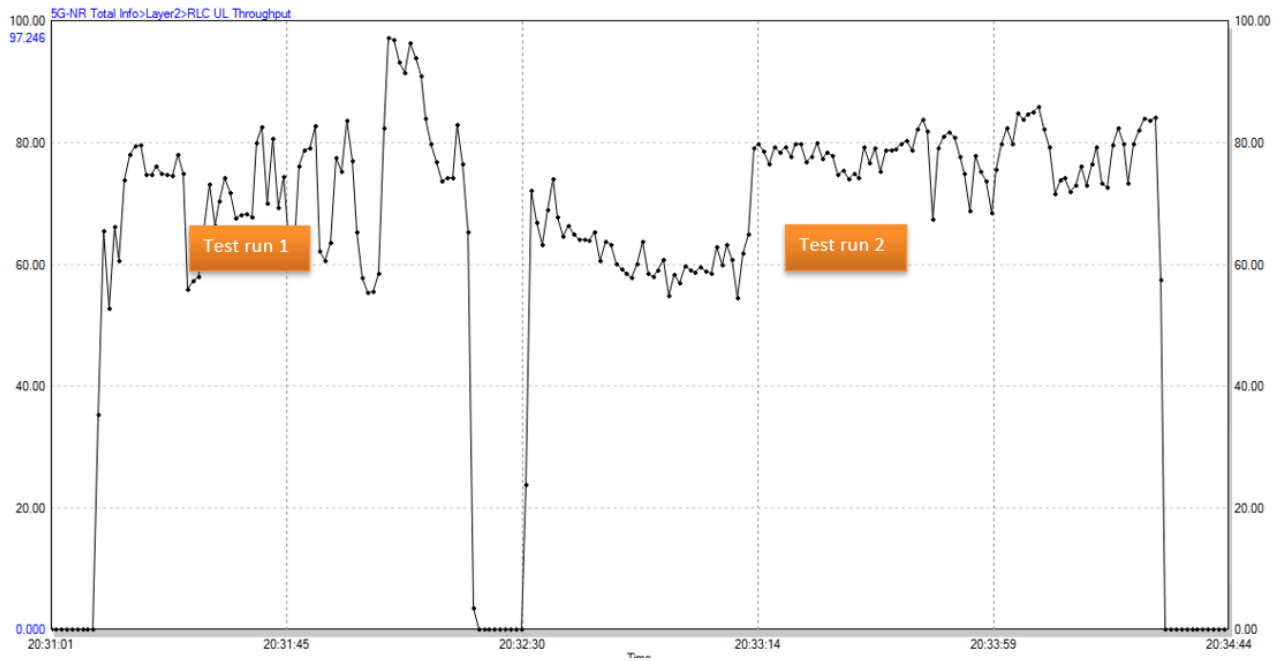


Figure G.117: UDP UL Throughput.

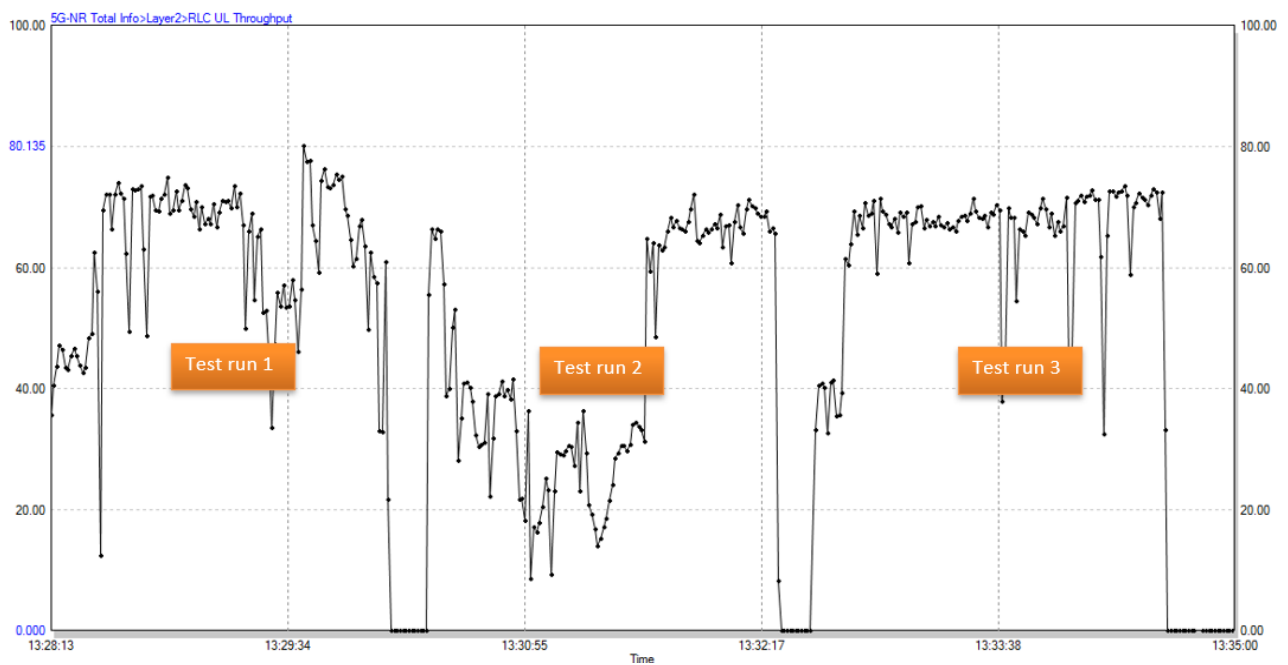


Figure G.118: TCP UL Throughput.

User Average Data Throughput in Mobile Use (Average Speed)

Table G.6o: TCA-GEN-03_UDP_DL.

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-03_UDP_DL_Avg Speed
Test Case (TC) Name	User Average Data Throughput in Mobile Use (Average Speed)		
Test Case Purpose	Observe the user average data throughput performance when a user has an active TCP/UDP session and is moving along a predefined drive route at an average speed of ~50 km/h (depending on vehicle type).		
Stationary / Mobility TC	Mobility TC		
Test environment	Depicted on Figure 6.37: Test locations and general view of the test area for the Ford Otosan plant site		
Test setup ID	GR-TR-UsAg-UDP_DL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			
<div>- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W</div> <div>- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.</div> <div>- Accuver XCAL Drive Testing has been used during drive test.</div> <div>- Core NW was deployed different city.</div> <div>- Transmission backbone supporting 900Mbps and carrying live traffic.</div> <div>- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.</div> <div>- UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored.</div> <div>- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.</div> <div>- DDSU-11:3:0 was used as TDD pattern.</div>			
Test Case Description			
<div>Selected drive test route should cover radio link conditions with SINR in the range from Excellent RF conditions value to Bad RF conditions value. Initiate a continuous DL TCP/UDP session on the reference UE, which moves at an average speed of ~50 km/h (depending on vehicle type) along the predefined drive route. Repeat the test under loaded conditions.</div> <div>Repeat the TC for UL.</div>			
Test UE Info			
<div>UE Type: Oppo Find X2</div> <div>UE category: Cat19</div> <div>UE SW version: CPH2023EU_11.A.22_0720_202006121628</div> <div>UE: Max 90 kmph, Average:50 kmph</div>			
Test Variables			
<div>- Live NW traffic on the transmission link</div> <div>- Moving vehicles</div>			

Expected TC Result

- Get better DL throughput close to site location.

TC Results Report

Number of repetitions	1			
TC comments	The site has configured as two sector and using same LTE/NR frequencies. Its aimed to see no drop during Intra gNB / Intra Frequency HO procedure, get good UDP/TCP throughput. UDP UL-TCP DL and TCP UL test was not performed.			
Tools used	Accuver XCAL Drive Testing Tool			
TC Logs	See TCA-GEN-03-UDP <Logs> sheet			
Test Results	Iteratio n #1	Iteratio n #2	Iteratio n #3	Descriptions/Diagrams Figure G.119 illustrates MAC DL Throughput during mobility. Figure G.120 illustrates SINR distribution during mobility test. Figure G.121 showing mobility decision points during handover procedure.
TCA-GEN-03-UDP (Avg)	418.7			
TCA-GEN-03-UDP (Max)	638.1			
<Average Metric measured>				
TC Responsible	Ericsson TR, TURKCELL			
Date	6/11/2020			

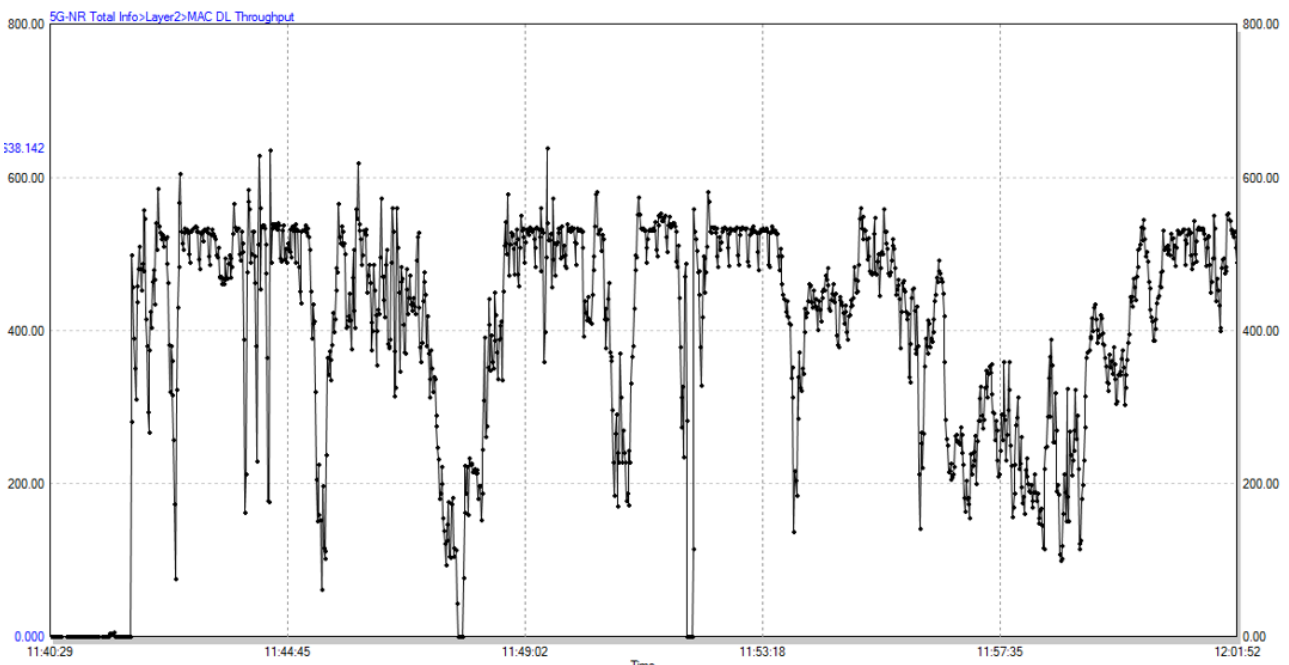


Figure G.119: MAC DL TCP Throughput.

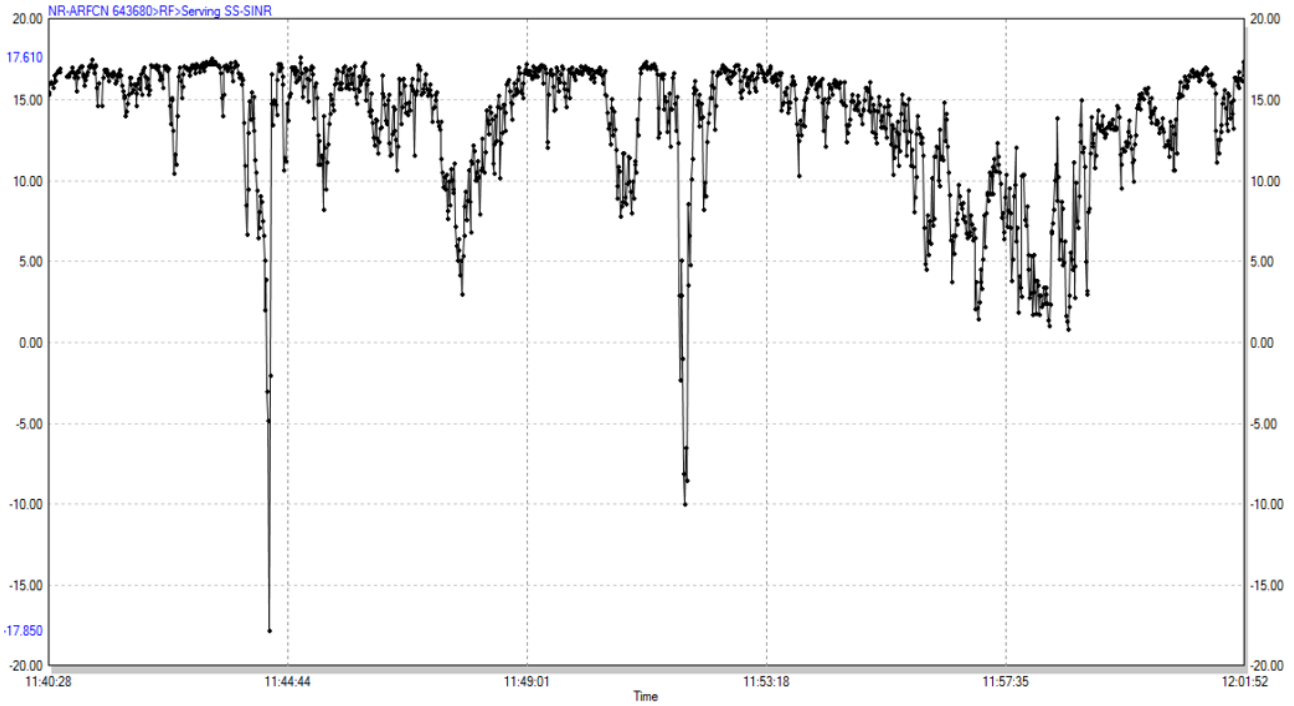
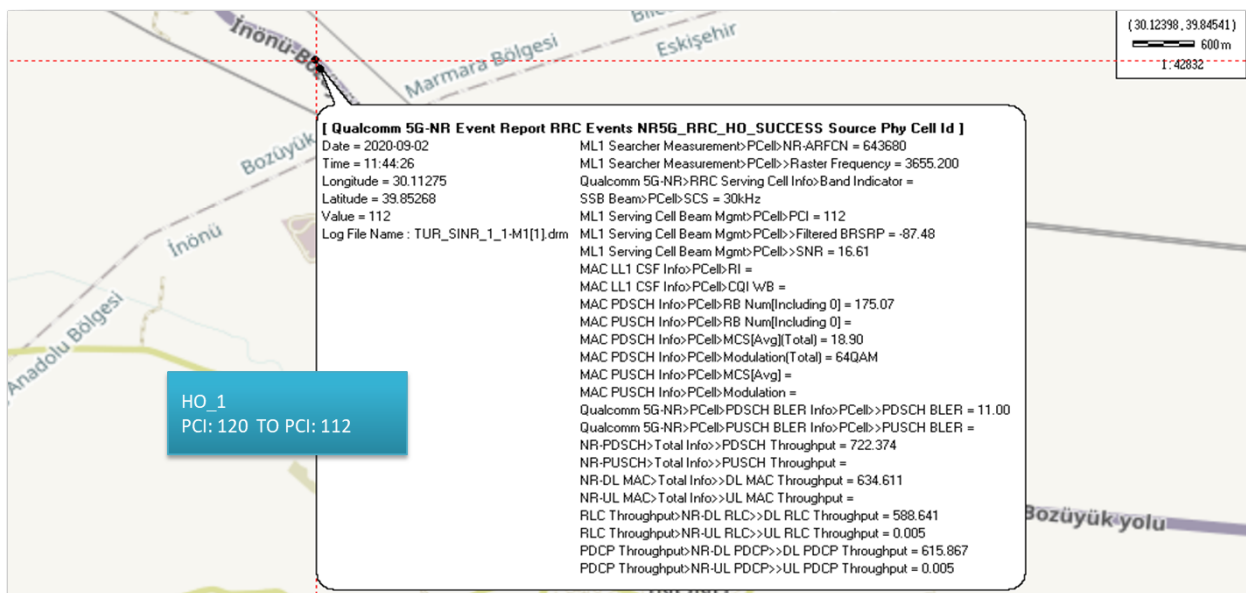


Figure G.120: SINR Distribution.

Table G.61: Handover positions and timing for the TCA-GEN-03_UDP_DL test.

TIME_STAMP	Lon	Lat	5G-NR RRC Events NR5G_RRC_HO_SUCCESS Source NR-ARFCN
2020-09-02 11:44:26.902636	30.1127	39.8527	643680
2020-09-02 11:51:54.133598	30.1132	39.8521	643680



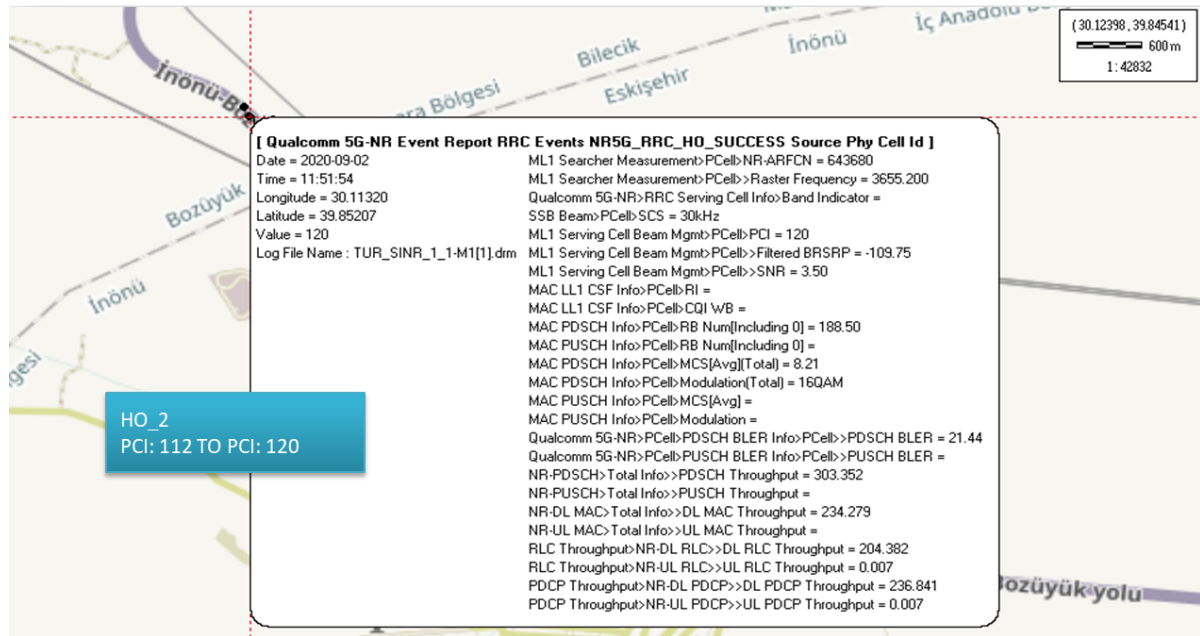


Figure G.121: Handover locations.

User Average Data Throughput at the cell edge

Table G.62: TCA-GEN-11_UDP_DL_70% load.

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-11_UDP_DL_70% load TCA-GEN-11_UDP_UL_70% load
Test Case (TC) Name	User Average Data Throughput at the cell edge		
Test Case Purpose	Observe user average TCP/UDP data throughput at the cell edge		
Stationary / Mobility TC	Mobility TC		
Test environment	Depicted on Figure 6.37: Test locations and general view of the test area for the Ford Otosan plant site		
Test setup ID	GR-TR-UsAg-UDP_DL , GR-TR-UsAg-UDP_UL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			

- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W
- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.
- Accuver XCAL Drive Testing has been used during drive test.
- Core NW was deployed different city.
- Transmission backbone supporting 900Mbps and carrying live traffic.
- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.
- UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored.
- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.
- DDSU-11:3:0 was used as TDD pattern.

Test Case Description

Load the interfering cell with 70% load. Select the test point in the serving cell edge area. After successful channel setup, start downlink TCP/UDP data transfer and trace for 30s. Get the average DL TCP/UDP throughput and record RSRP, RSRQ, SINR, MIMO mode. Disconnect the UEs and save the logs. Repeat the procedure for n times and average the DL TCP/UDP throughput.
Repeat the TC for UL.

Test UE Info

UE Type: Oppo Find X2
UE category: Cat19
UE SW version: CPH2023EU_11.A.22_0720_202006121628
UE: Max 90 kmph, Average:50 kmph

Test Variables

- Live NW traffic on the transmission link
- Moving vehicles

Expected TC Result

- Reach acceptable DL/UL throughput levels to maintain UL/DL real traffic.

TC Results Report

Number of repetitions	1			
TC comments	<div>- Testing methodology not the same as described test scenario.</div> <div>- Mobility log is used for reporting. In the border tests stationary log will be use.</div> <div>- Cell not loaded %70 during test.</div>			
Tools used	Accuver XCAL Drive Testing Tool			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
TCA-GEN-05-UDP_DL	16.73			
TCA-GEN-05-UDP_UL	13.1			
<Average Metric measured>				

TC Responsible	Ericsson TR, TURKCELL
Date	11/6/2020

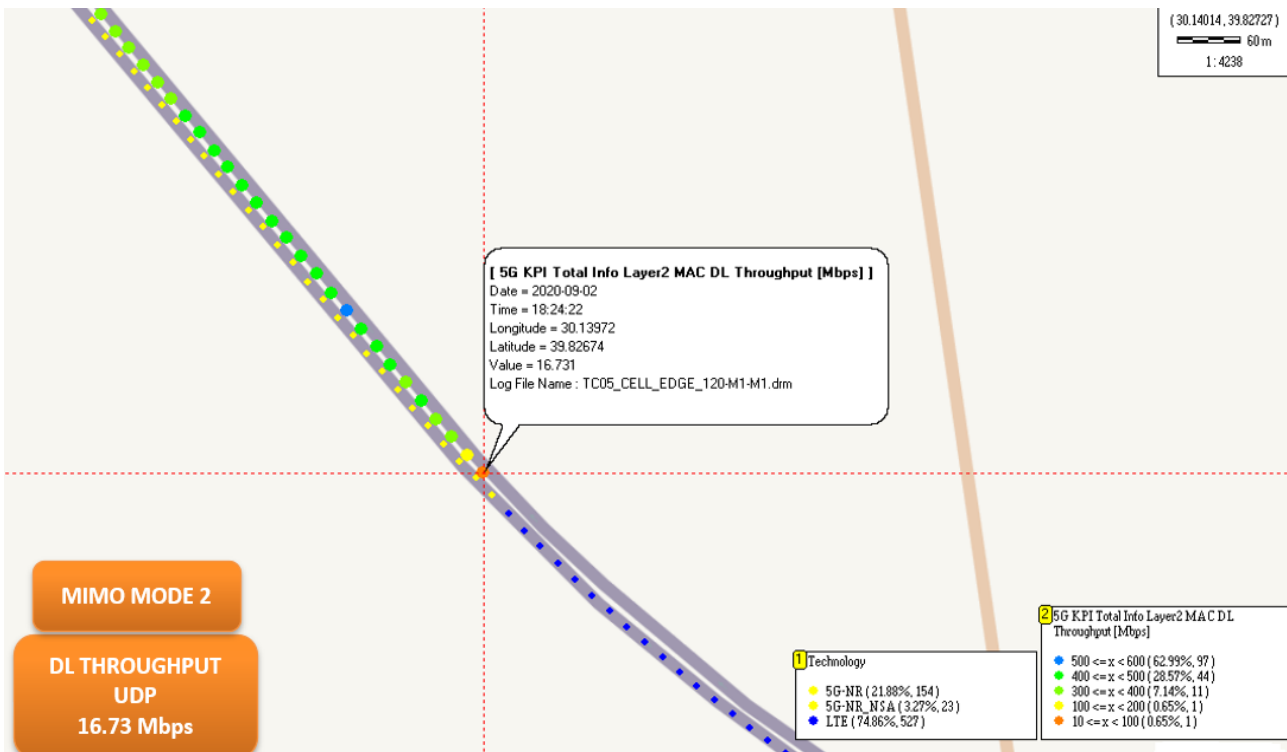


Figure G.122: MAC DL Cell Edge Throughput (UDP Test Scenario).

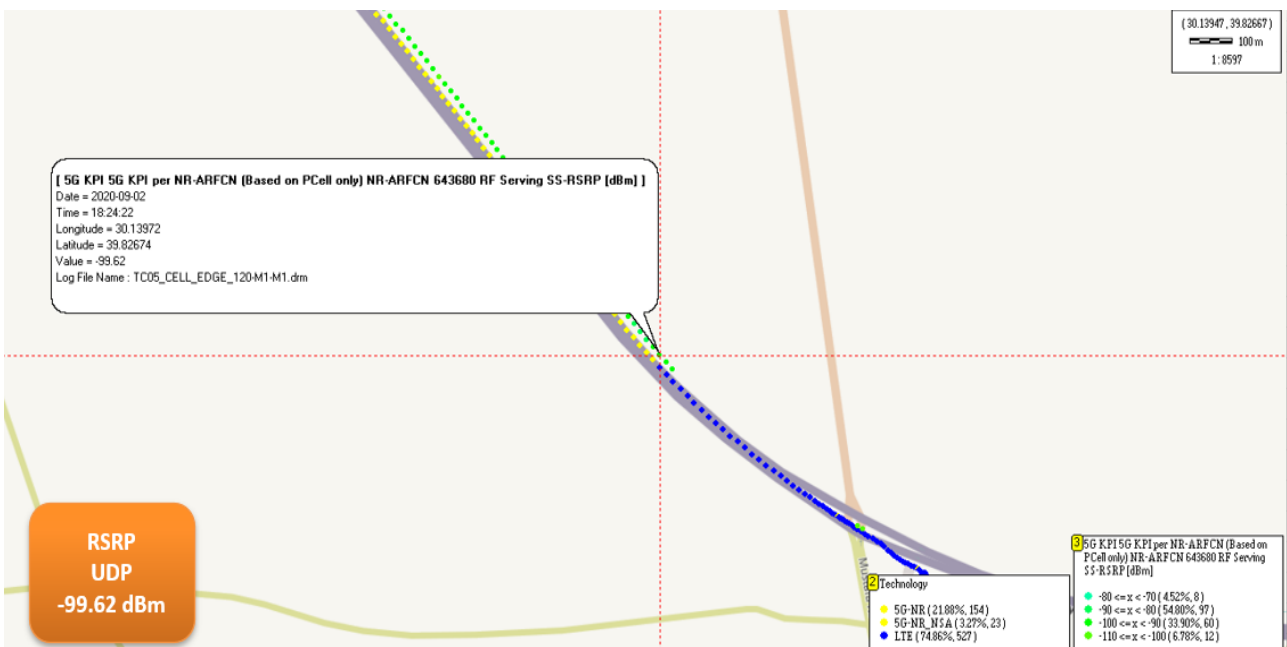


Figure G.123: RSRP at Cell Edge (DL).

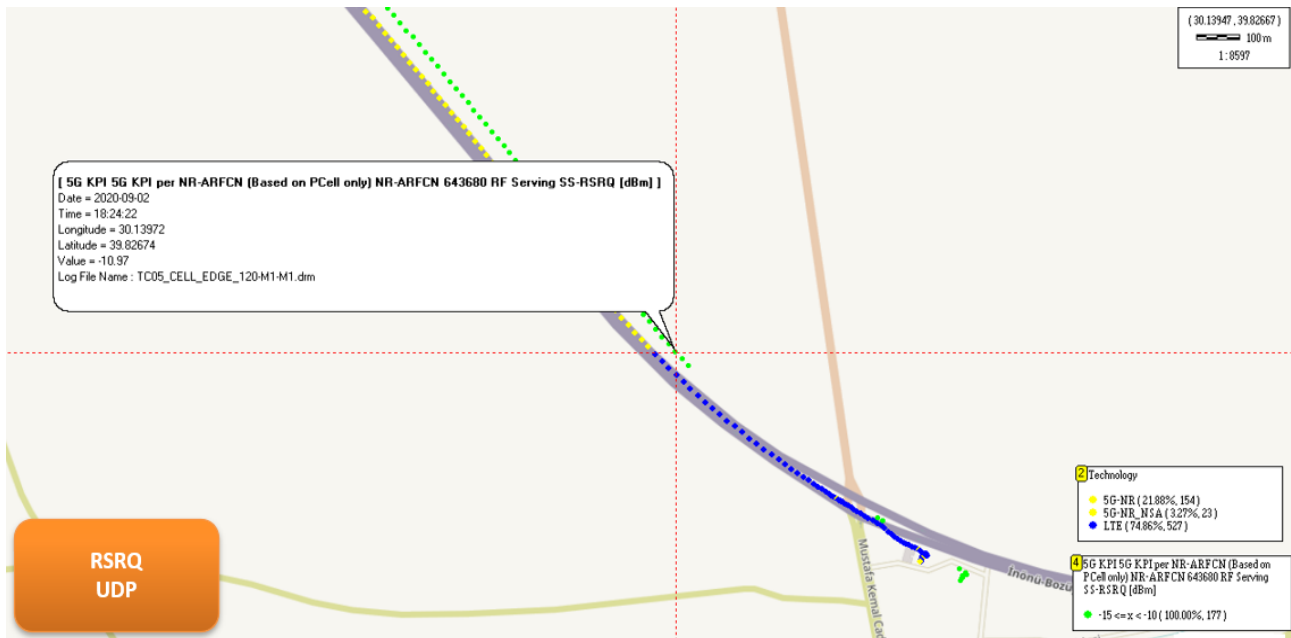


Figure G.124: RSRQ at Cell Edge (DL).



Figure G.125: SINR at Cell Edge (DL).

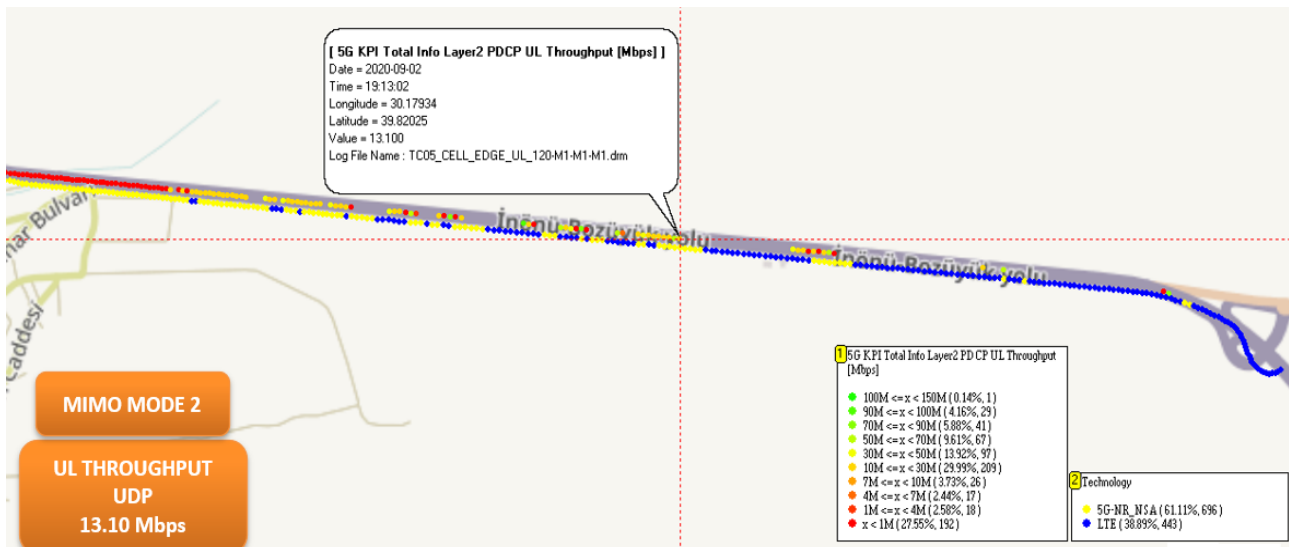


Figure G.126: PDCP UL Cell Edge Throughput (UDP Test Scenario).

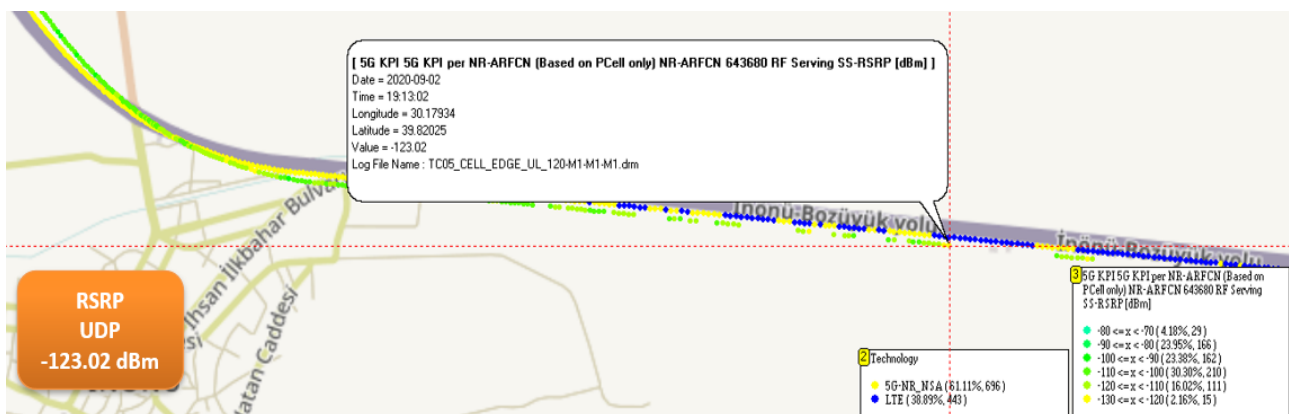


Figure G.127: RSRP at Cell Edge (UL).

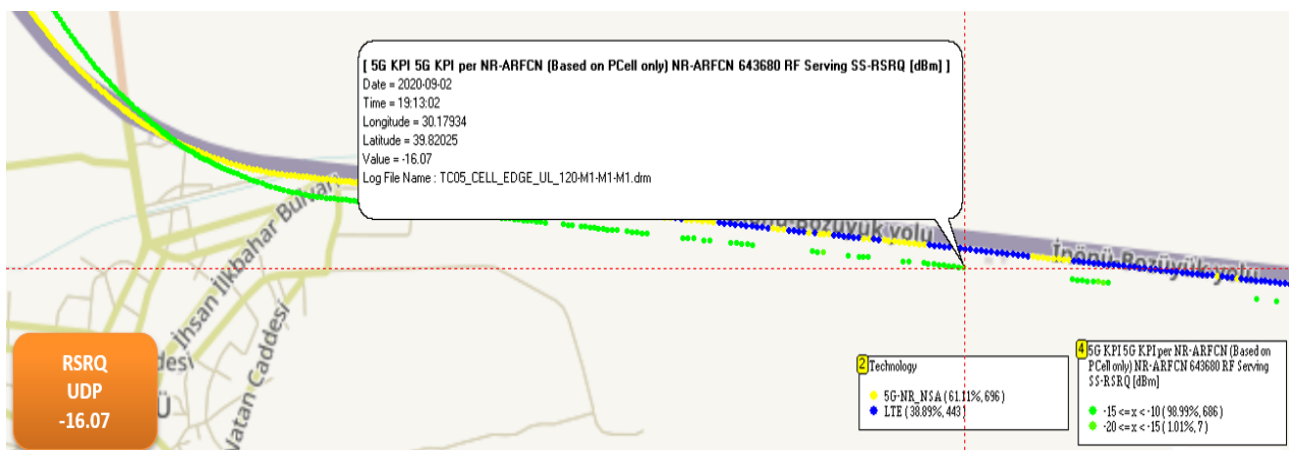


Figure G.128: RSRQ at Cell Edge (UL).

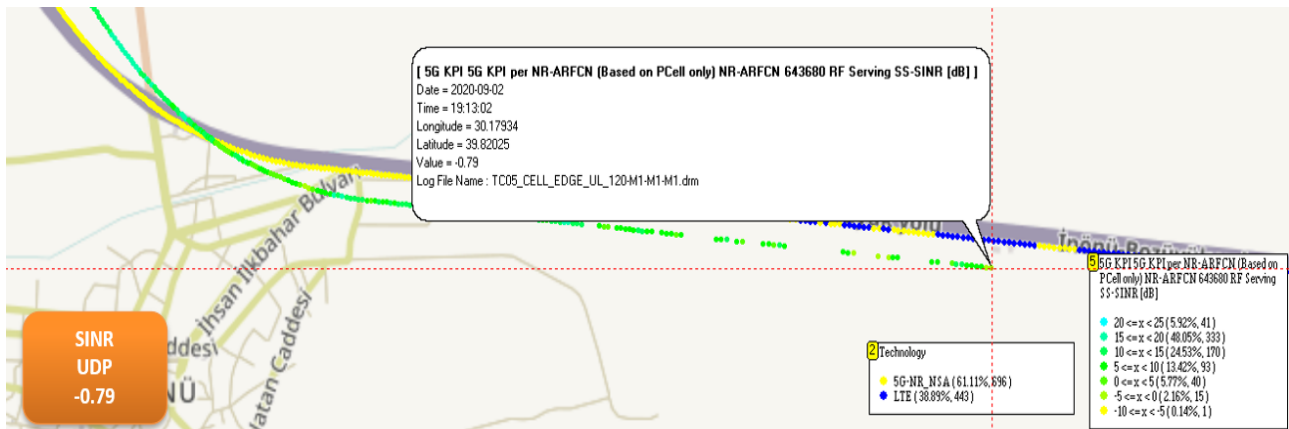


Figure G.129: SINR at Cell Edge (UL).

DL Cell Capacity

Table G.63: TCA-GEN-16_DL_Cell Capacity.

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-16_DL_Cell Capacity
Test Case (TC) Name	DL Cell Capacity		
Test Case Purpose	Get the value of the Cell downlink throughput and analyse the downlink capability in a single cell		
Stationary / Mobility TC	Stationary TC		
Test environment	Stationary TC Location depicted in Figure G.114		
Test setup ID	GR-TR-UsAg-TCP_DL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			
<ul style="list-style-type: none">- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.- Accuver XCAL Drive Testing has been used during drive test.- Core NW was deployed different city.- Transmission backbone supporting 900Mbps and carrying live traffic.- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.- UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored.- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.- DDSU-11:3:0 was used as TDD pattern.			
Test Case Description			

Unload the interfering cell. One UE successfully setups the channel and starts downlink TCP/UDP data transfer. Make other y UEs access the target cell and start downlink TCP/UDP data transfer one by one. Observe the user throughput and RB occupied number change between before and after the fourth UE accesses the target cell. It can be observed that three UEs will occupy all RB resources, and the throughput of the former three UEs become lower after the fourth UE access and download. Keep the downlink services for x minutes, observe each UE TCP/UDP throughput, SINR/RSRP and compute the peak and average cell throughput in the downlink. Save the logs and disconnect the UEs.				
Test UE Info				
UE Type: Oppo Find X2 UE category: Cat19 UE SW version: CPH2023EU_11.A.22_0720_202006121628 UE: Max 90 kmph, Average:50 kmph				
Test Variables				
<div>- Live NW traffic on the transmission link</div> <div>- Moving vehicles</div> <div>- Adding new UEs in test setup</div>				
Expected TC Result				
See DL Throughput and PRB usage change after each UE start data application.				
TC Results Report				
Number of repetitions	1			
TC comments	<div>- Scheduling algorithm adjust PRB usage of UEs. UE1 used 203 DL PRB for single TCP DL test which is enough to reach 700Mbps.</div> <div>- Total PRB usage can be reach 273 [MAX] if the transmission link is allowed.</div> <div>- 2UE test shows one UE can take 130 PRB and if other UE also possible to use 130 PRB at the same time.</div>			
Tools used	Accuver XCAL Drive Testing Tool			
Test Results	Iteratio n #1	Iteratio n #2	Iteratio n #3	Descriptions/Diagrams
TCA-GEN-16-UDP_DL				Figure G.130 to Figure G.134 illustrate measured values of test and radio condition. This is functionality test and no exact level of measurement reported.
<Average Metric measured>				
TC Responsible	Ericsson TR, TURKCELL			
Date	6/11/2020			

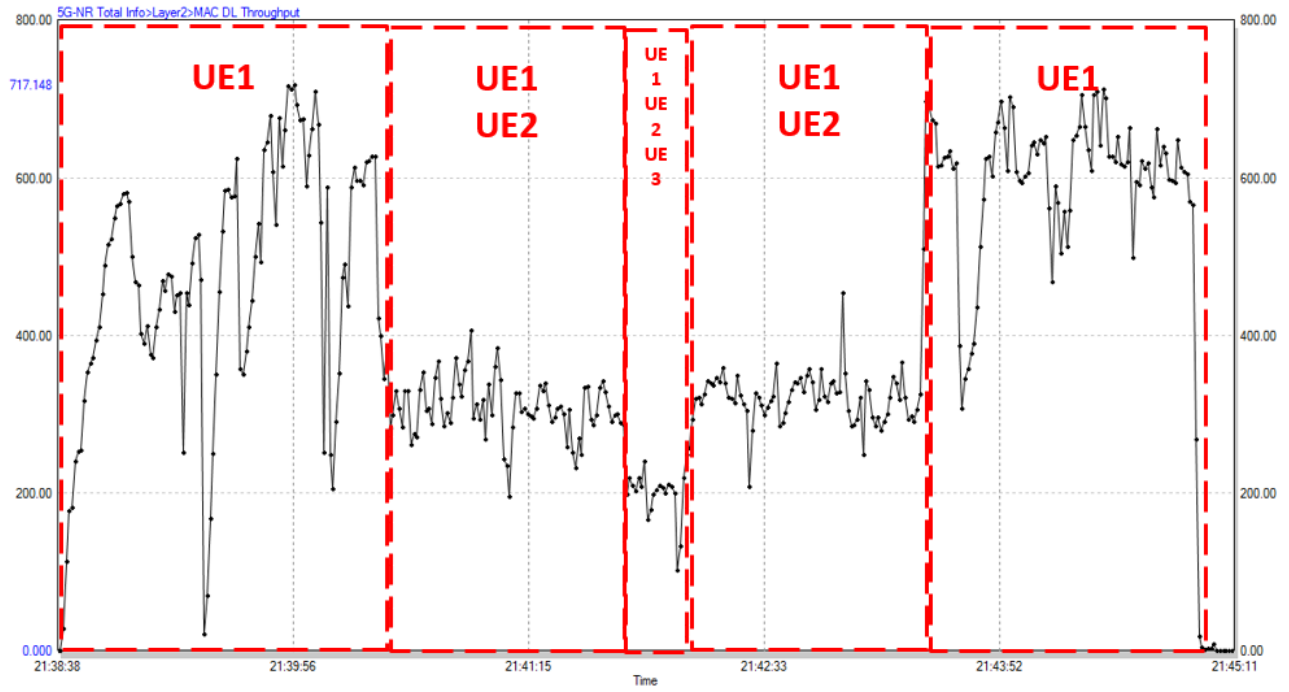


Figure G.130: MAC DL Throughput.

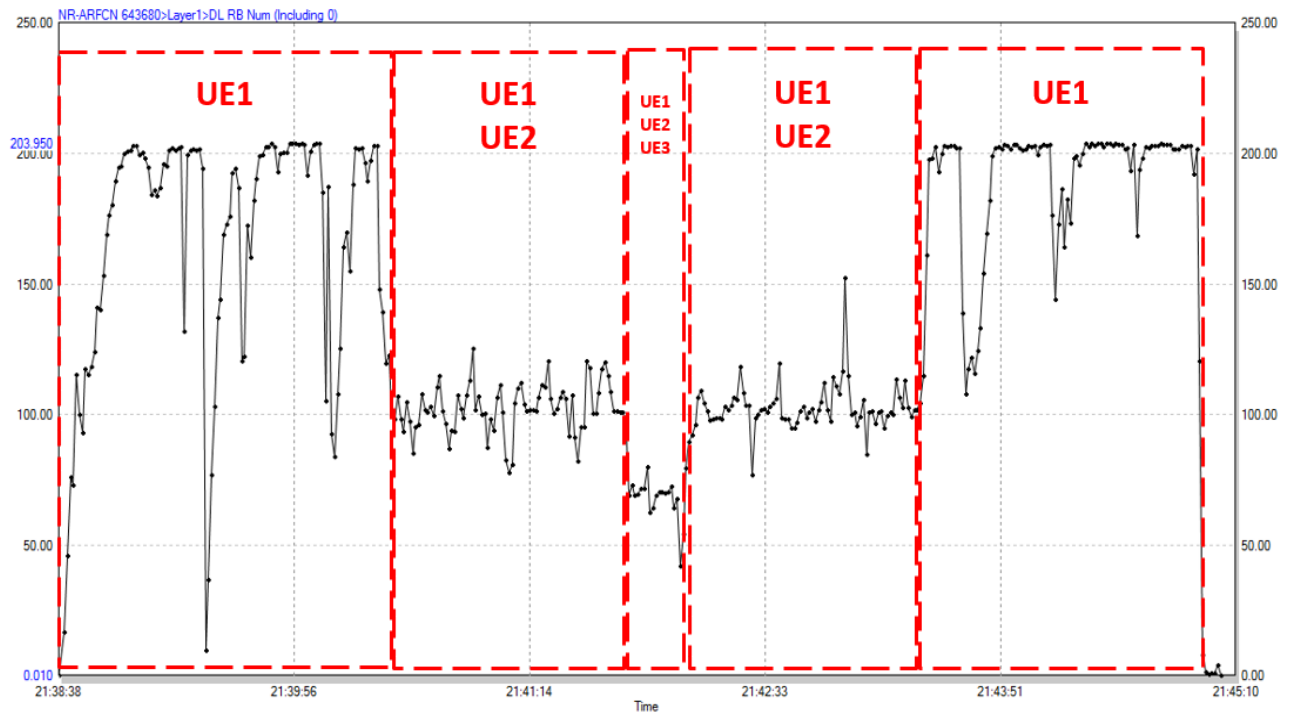


Figure G.131: RB Utilization.

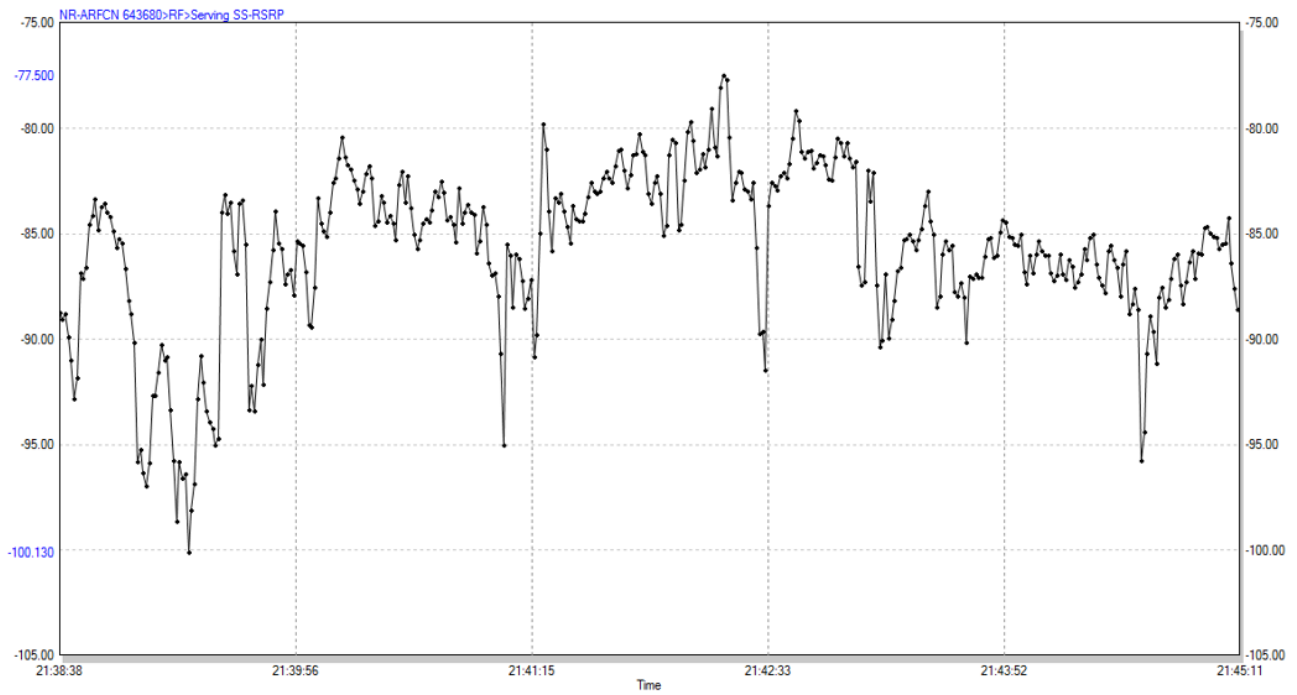


Figure G.132: RSRP Distribution.

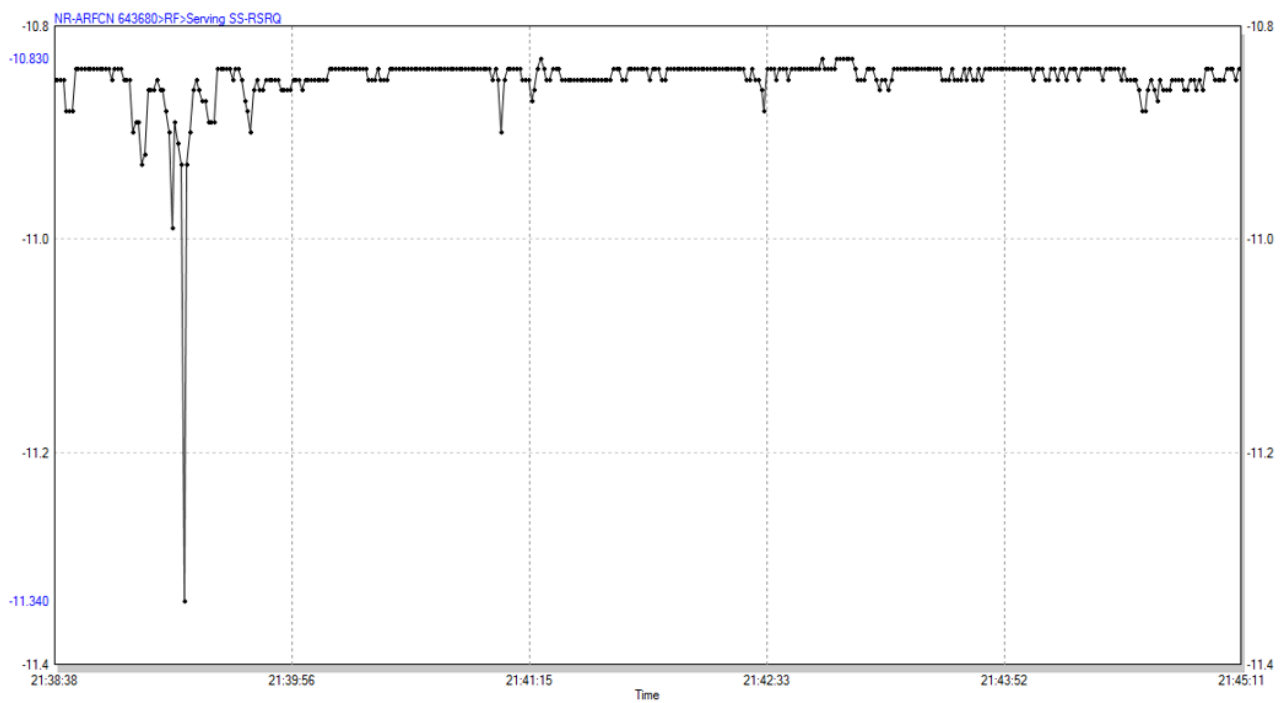


Figure G.133: RSRQ Distribution.

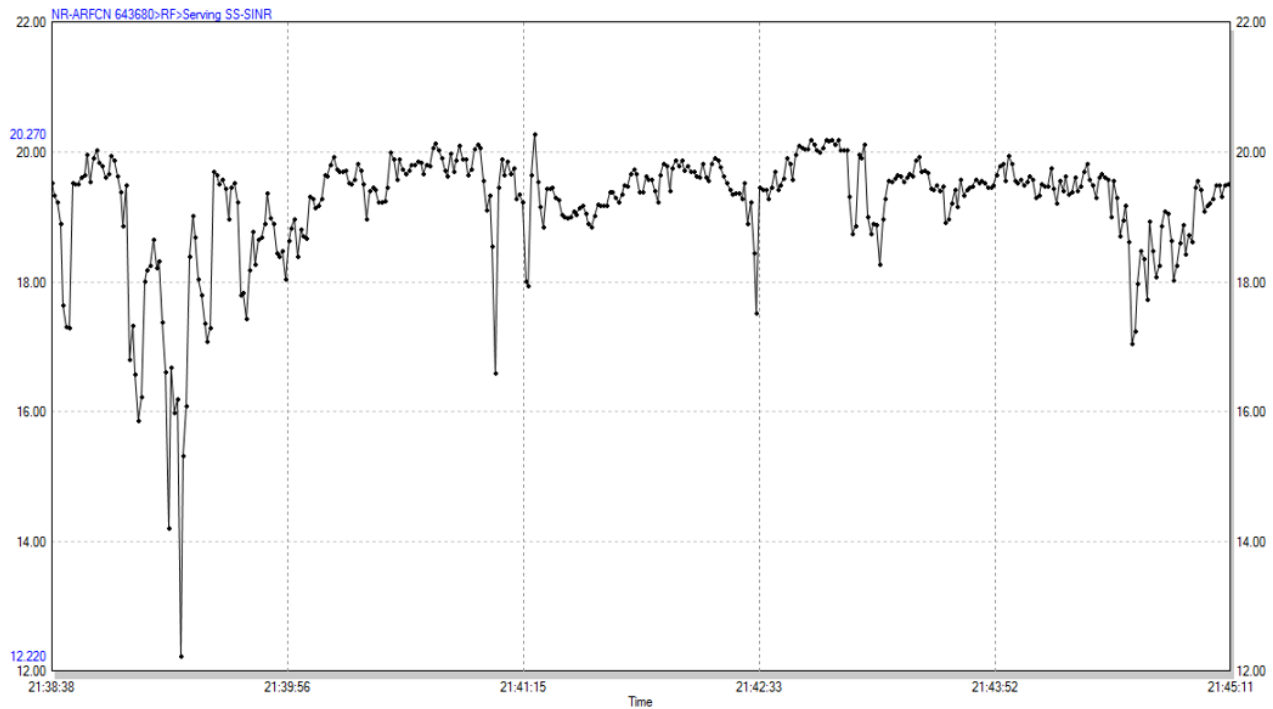


Figure G.134: SINR Distribution.

UL Cell Capacity

Table G.64: TCA-GEN-17_UL_Cell Capacity.

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-17_UL_Cell Capacity
Test Case (TC) Name	UL Cell Capacity		
Test Case Purpose	Get the value of the Cell uplink throughput and analyse the uplink capability in a single cell		
Stationary / Mobility TC	Stationary TC		
Test environment	Stationary TC Location depicted on Figure G.114		
Test setup ID	GR-TR-UsAg-TCP_UL		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			

- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W
- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.
- Accuver XCAL Drive Testing has been used during drive test.
- Core NW was deployed different city.
- Transmission backbone supporting 900Mbps and carrying live traffic.
- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.
- UL Modulation vary between 16QAM and 64 QAM. Mainly 64 QAM was monitored.
- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.
- DDSU-11:3:0 was used as TDD pattern.

Test Case Description

Unload the interfering cell. One UE successfully setups the channel and starts uplink TCP/UDP data transfer. Make other y UEs access the target cell and start uplink TCP/UDP data transfer one by one. Keep the uplink services for x minutes, observe each UE TCP/UDP throughput, SINR/RSRP and compute the peak and average cell throughput in the uplink. Save the logs and disconnect the UEs.

Test UE Info

UE Type: Oppo Find X2
 UE category : Cat19
 UE SW version : CPH2023EU_11.A.22_0720_202006121628
 UE : Max 90 kmph, Average:50 kmph

Test Variables

- Live NW traffic on the transmission link
- Moving vehicles
- Adding new UEs in test setup

Expected TC Result

See UL Throughput and PRB usage change after each UE start data application.

TC Results Report

Number of repetitions	1			
TC comments	<ul style="list-style-type: none"> - Scheduling algorithm adjust PRB usage of UEs. UE1 used 16 avg UL PRB for single TCP UL test which is enough to reach 86Mbps. - Total PRB usage can be reach 273 [MAX] if the transmission link is allowed. - UL Cell throughput can support 100Mbps if radio conditions well enough. 			
Tools used	Accuver XCAL Drive Testing Tool			
Test Results	Iteratio n #1	Iteratio n #2	Iteratio n #3	Descriptions/Diagrams
TCA-GEN-17-UDP_UL				Figure G.135 to Figure G.138 illustrate measured values of test and radio condition. This is functionality test and no exact level of measurement reported.
<Average Metric measured>				

TC Responsible	Ericsson TR, TURKCELL
Date	6/11/2020

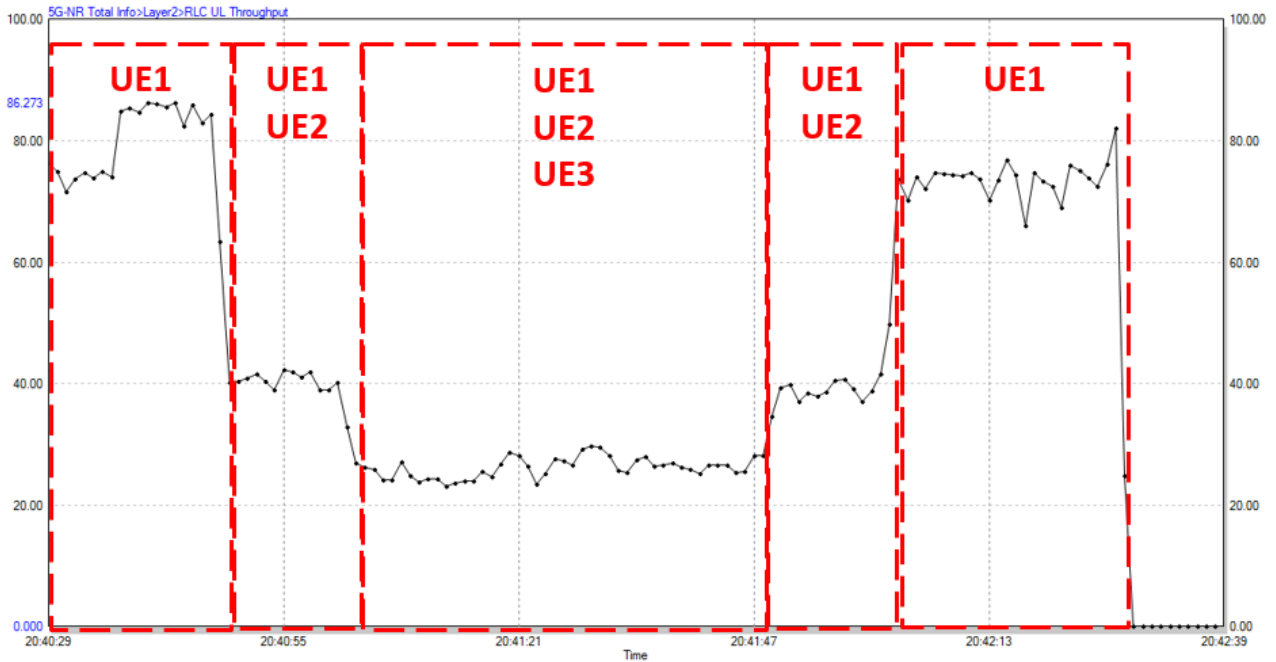


Figure G.135: RLC UL Throughput.

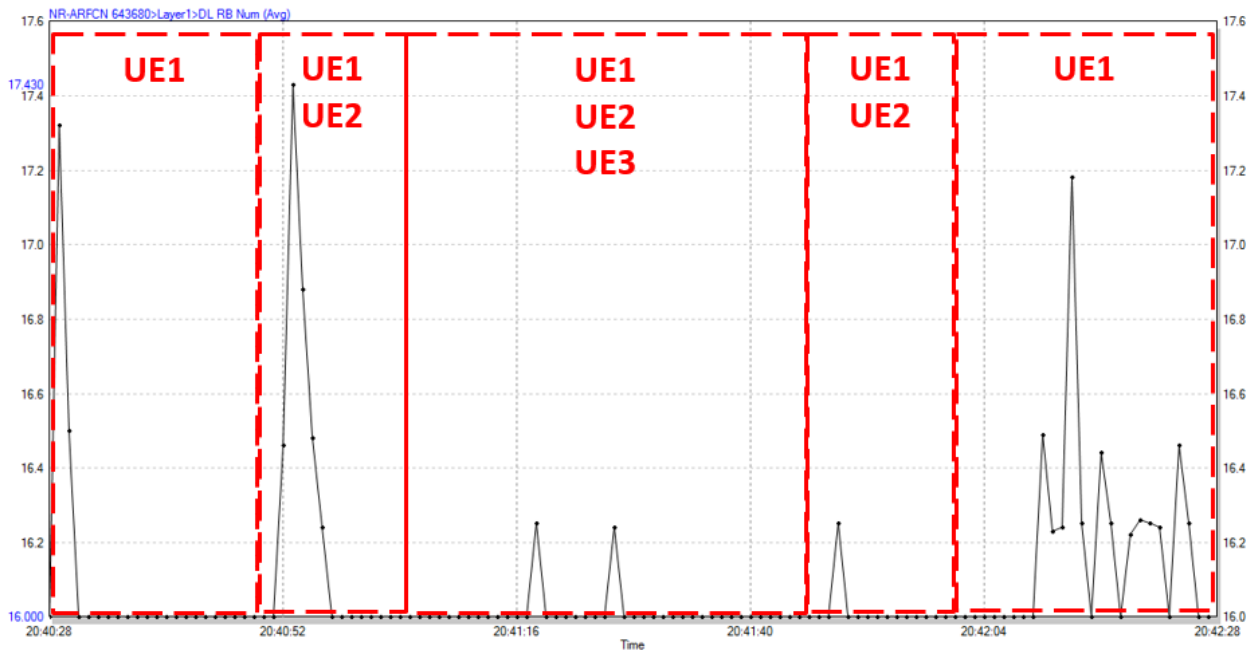


Figure G.136: RB Utilization.

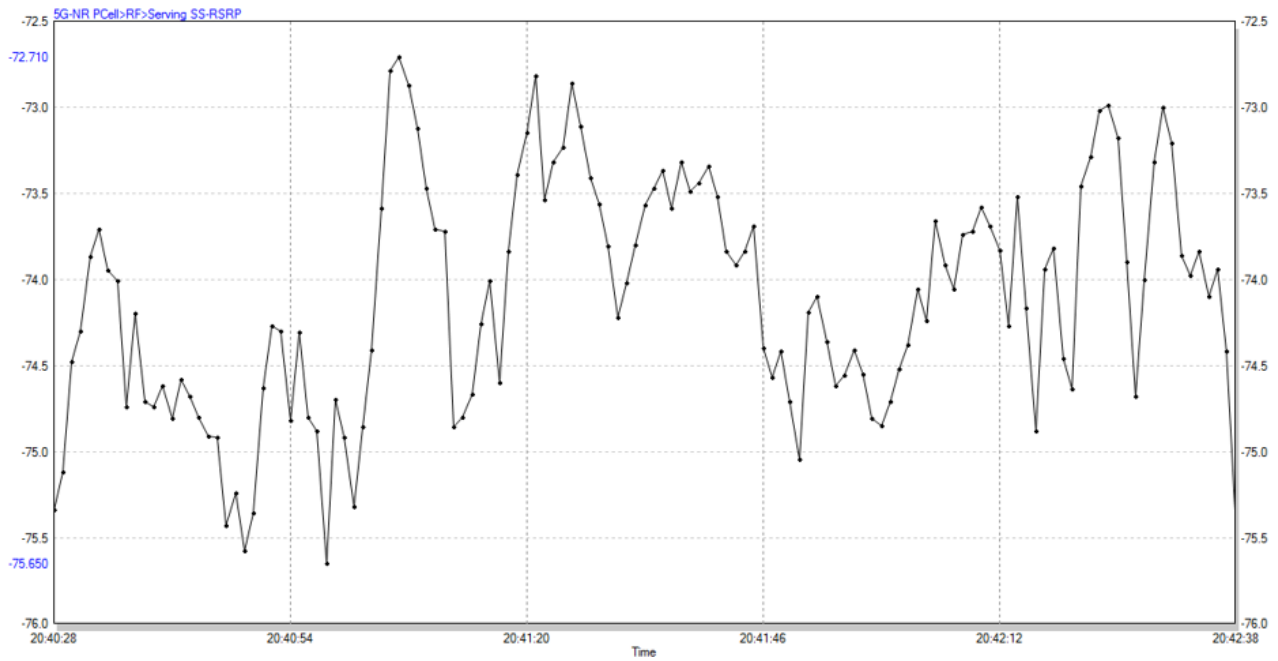


Figure G.137: RSRP Distribution.

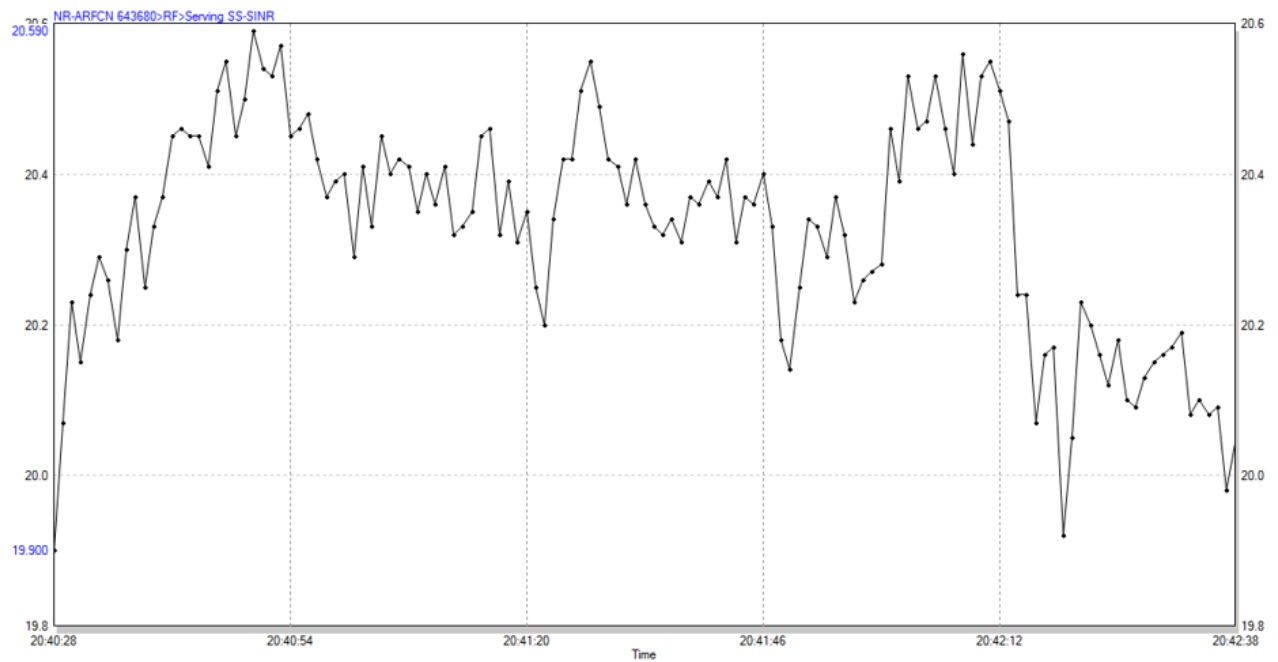


Figure G.138: SINR Distribution.

User Plane (UP) Latency

Table G.65: TCA-GEN-18_PING_No load.

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-18_PING_No load_MTU size
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Test Case (TC) Name	User Plane Latency in Unloaded Cell (RAN & e2e)
Test Case Purpose	Measure the U-Plane latency (e2e & RAN) for various x-bytes ping in unloaded network
Stationary / Mobility TC	Stationary TC
Test setup ID	GR-TR-UsAg-PING
5G Deployment Option	NSA (option 3x)
PLMN ID (MCC + MNC)	286-01
Initial Conditions	
<ul style="list-style-type: none"> - ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W - IPERF server used for synthetic traffic. It wasn't direct connection to the PGW. - Accuver XCAL Drive Testing has been used during drive test. - Core NW was deployed different city. - Transmission backbone supporting 900Mbps and carrying live traffic. - Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used. - UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored. - DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored. - DDSU-11:3:0 was used as TDD pattern. 	
Test Case Description	
<p>User is located near to the gNB so that it operates under good RF conditions. Start trace logs in the UE and S1 interface. Perform ping of size 32 bytes with at least 50 echo requests. Target address for the ping is the application server: ping -n 50 <AS IP-address>. Record the maximum, minimum and average value. Disconnect the UE and save the logs.</p> <p>Repeat the test case for 1500 bytes ping.</p>	
Test UE Info	
<p>UE Type: Oppo Find X2 UE category : Cat19 UE SW version : CPH2023EU_11.A.22_0720_202006121628 UE : Max 90 kmph, Average:50 kmph</p>	
Test Variables	
<ul style="list-style-type: none"> - Live NW traffic on the transmission link - Moving vehicles 	
Expected TC Result	
To see ping variation when test UE moving.	
TC Results Report	
Number of repetitions	1

TC comments	<ul style="list-style-type: none">- Stationary log is corrupted and not able to use- Mobility log is used for reporting.- In the border tests stationary log will be perform.- One of peak latency level is not true.- Min: 16msec latency has been measured.- All collected measured values were included, even at a distance of more than 10km from site, leading to very high value of observed max latency. However, it should be noted that measured latency values in serving area vary from 16msec to 30msec.			
Tools used	Accuver XCAL Drive Testing Tool			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
TCA-GEN-18 (Min)	16 msec			
TCA-GEN-18 (Max)	1230 msec (this value was collected at a distance value of 10km from site and was affected by physical obstacles)			
<Average Metric measured>	53,99msec			
TC Responsible	Ericsson TR, TURKCELL			
Date	6/11/2020			

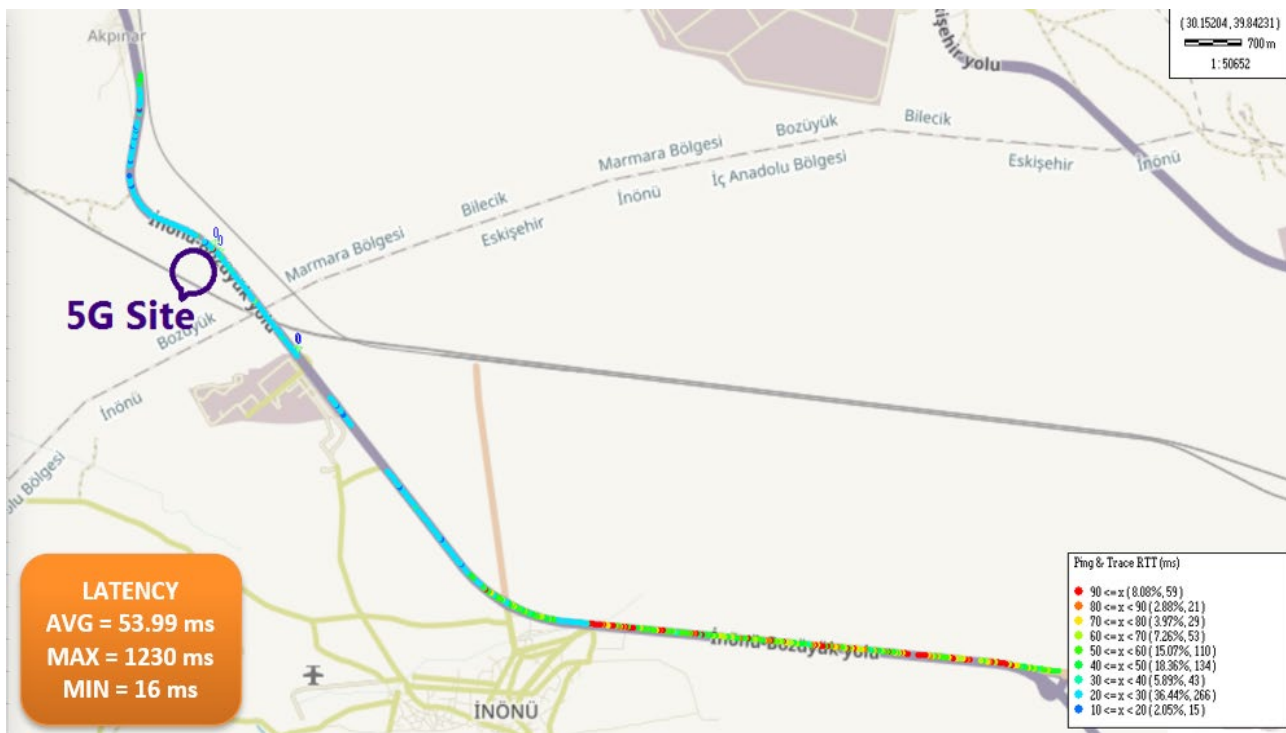


Figure G.139: Ping & Trace RTT results (UP).

Control Plane Latency (NR RRC Idle -> NR Connected)

Table G.66: TCA-GEN-20_CP Latency.

Test Location	ESKISEHIR/Turkey	Test Case (TC) ID	TCA-GEN-20_CP Latency
Test Case (TC) Name	Control Plane Latency (NR RRC Idle -> NR Connected)		
Test Case Purpose	Measure the state transition latency (NR RRC Idle -> NR Connected)		
Stationary / Mobility TC	Stationary TC		
Test setup ID	GR-TR-UsAg-PING		
5G Deployment Option	NSA (option 3x)		
PLMN ID (MCC + MNC)	286-01		
Initial Conditions			
<div>- ESKIN site has been deployed close to the Ford-Eskisehir factory. Site has planned for two sector and L2600MHz [5MhzBW] was anchor cell and NR3500 [100Mhz BW] used 5G service. Output powers were for LTE 40W and NR 200W</div> <div>- IPERF server used for synthetic traffic. It wasn't direct connection to the PGW.</div> <div>- Accuver XCAL Drive Testing has been used during drive test.</div> <div>- Core NW was deployed different city.</div> <div>- Transmission backbone supporting 900Mbps and carrying live traffic.</div> <div>- Depends on radio conditions MIMO mode vary between RI:1 to RI4 but mainly RI4 was used.</div> <div>- UL Modulation vary between 16QAM and 64 QAM. Mainly 64QAM was monitored.</div> <div>- DL Modulation vary between 64QAM and 256QAM. Mainly 256QAM was monitored.</div> <div>- DDSU-11:3:0 was used as TDD pattern.</div>			
Test Case Description			
In the serving cell, start UE trace and UE power cycle. Core Network initiates UE Context Release Command messages, and then UE transmits Idle state. Ping a server on the Core Network to trigger a service request from UE. Stop UE trace. Based on UE log, evaluate the transition time (i. For NSA case -> Transition time at UE side = Time of last "RRC reconfiguration complete" – Time of "RACH preamble transmission", ii. For SA case -> Transition time at UE side = Time of last "RRC reconfiguration complete" – Time of "RRC Setup Request"). Repeat the above-mentioned steps n times.			
Test UE Info			
UE Type: Oppo Find X2 UE category : Cat19 UE SW version : CPH2023EU_11.A.22_0720_202006121628 UE : Max 90 kmph, Average:50 kmph			
Test Variables			
<div>- Live NW traffic on the transmission link</div> <div>- Moving vehicles</div>			
Expected TC Result			
To see successfully complete IDLE - ACTIVE transition based on 3GPP standards.			

TC Results Report				
Number of repetitions	1			
TC comments	- Check Idle - Active transition time difference. - RA Procedure is not visible in the tool. It has been checked via other samples and takes about 20sec.			
Tools used	Accuver XCAL Drive Testing Tool			
Test Results	Iteration #1	Iteration #2	Iteration #3	Descriptions/Diagrams
TCA-GEN-20-CP_LAT	434msec	425msec	447msec	
<Average Metric measured>	435,3msec			
TC Responsible	Ericsson TR, TURKCELL			
Date	6/11/2020			

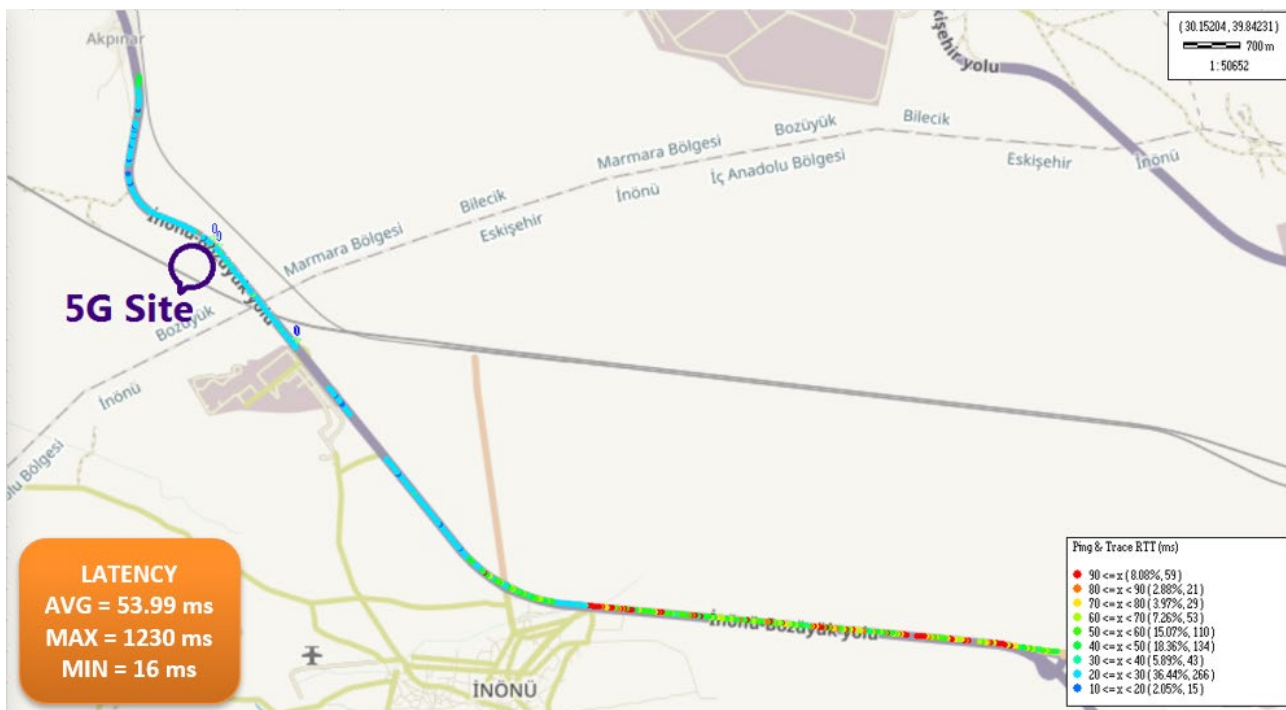


Figure G.140: Ping & Trace RTT results (CP).

G.2.2 GR side Results

Test results for the GR site at the GR-TR borders are not yet available. First tests are expected to take place by December 2020 and full test results will be available after the end of phase 3 and will be reported in D3.7.