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Editor(s):	Heesang Chung (ETRI)
Authors:	Heesang Chung (ETRI), Taesang Choi (ETRI), Youjun Choi (KATECH), Jiin Kim (Ktsat), Jung Ho Kim (SnetICT), Tak Ki Yu (SKT), Nicolas Cassiau (CEA), David Miras (CEA), Jean-Baptiste Doré (CEA), Guido Casati (FhG IIS), Marjorie Thary (TAS)
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Abstract

This deliverable was created as part of the project Work Package 5 “Prototyping, Validation and Demonstration” activities, and details the intercontinental trial and the results.

Keywords

5G ; Testbed ; Multi-Access ; Integration ; Testing ; Proof-of-Concept ; Inter-continental PoC

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Executive Summary

This document is the "integration and system level testing of proof-of-concept phase 2," which describes the final demonstration of the 5G-ALLSTAR. The European trial platform and the Korean trial platform are connected through the KREONET to showcase eMBB services over this intercontinental interoperability trial platform.

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List of Abbreviations

3GPP	3rd Generation Partnership Project
4G	4th Generation
5G	5th Generation
5G NR	5G New Radio
ACM	Adaptive Coding and Modulation
AMF	Access and Mobility management Function
AP	Access Point
ASM	Antenna Subsystem Module
ATDMA	Advanced Time Division Multiple Access
BSS	Broadcasting Satellite Service
CN	Core Network
DVB	Digital Video Broadcasting
DVB-S2	DVB 2nd Generation
DRU	Digital and Radio Unit
eMBB	Enhanced Mobile Broadband
FSS	Fixed Satellite Service
GEO	Geostationary Orbit Satellite
gNB	gNodeB
HMD	Head Mount Display
IPsec	Internet Protocol Security
KPI	Key Performance Indicators
KTP	Korean Trial Platform
LTE	Long-Term Evolution
mmWave	Millimeter Wave
NR	New Radio
NTN	None Terrestrial Network
OAI	Open Air Interface
PoC	Proof-of-Concept
PoP	Point of Presence
RAT	Radio Access Technology
SMF	Session Management Function
TB	Testbed
TC	Traffic Controller
TE	Terminal Equipment
UC	Use Case
UE	User Equipment
UPF	User Plane Function
USRP	Universal Software Radio Peripheral
Wi-Fi	Wireless Fidelity
WLAN	Wireless Local Area Network

1 Introduction

1.1 Background

Multiple radio access technologies (RATs) such as 5G NR (New Radio), 4G LTE (Long-Term Evolution), and WLAN (Wireless Local Area Network), which can be categorized as terrestrial access and non-terrestrial access like satellite can be combined to improve service availability and/or service continuity. In the 5G-ALLSTAR project, the 5G NR based cellular access and satellite access are two stems of the multiple RATs. The Europe and Korea had pursued unique designs and implementations on the multi-connectivity trial platforms depending on each consortium's view point, which will be explained in the following chapters.

Overall, the WP5 deals with "prototyping, validation and demonstration." There are four specific tasks, Task 5.1 – Task 5.4, in the WP5. Each task in the WP5 has its own goal to be accomplished. Task 5.1 – 5.3, as we'll see later in this section, are closely related to Task 5.4. The Task 5.4 utilizes the output of the former tasks, which deals with the European multi-connectivity trial platform and the Korean multi-connectivity trial platform. The trial platforms of Europe and Korea, integrated and validated independently in the phase 1, were put together for the intercontinental interoperability test scenario. With that our consortium showcased eMBB (enhanced Mobile Broad Band) services at the final demonstration or the phase 2 PoC (Proof-of-Concept) demonstration. Problems encountered during the phase 1 needed to be managed and resolved for the better use in the phase 2. The target service scenarios and KPIs (Key Performance Indicators) corresponding to the use case (UC) 1-3 defined in the WP2 had been addressed in the phase 1, and the UC 4 been addressed in the phase 2. In detail, task breakdown in the WP5 as well as the inputs from other work packages are shown in Figure 1.

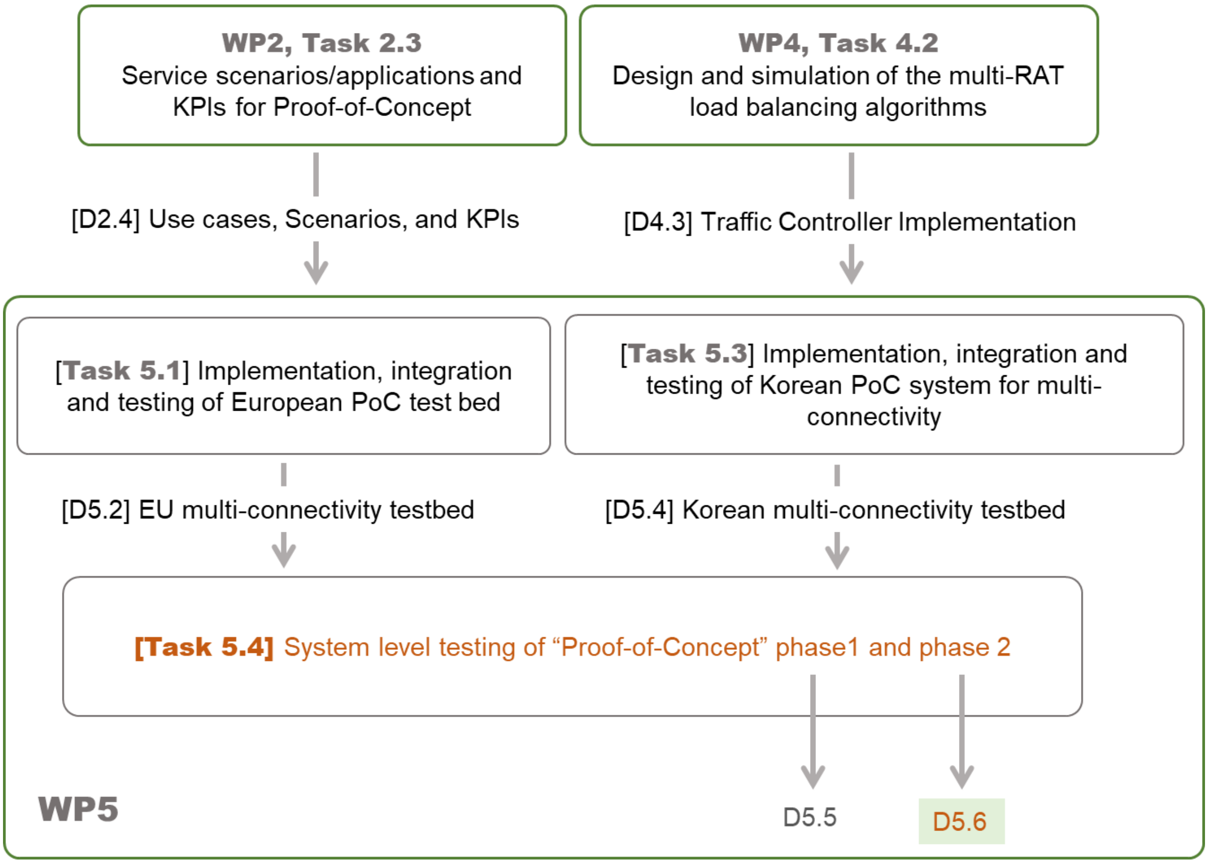

Figure 1. Inputs to the WP5 and the tasks in the WP5

1.2 Event for the final PoC

Originally, when the project was set up, the final demonstration of the 5G-ALLSTAR concepts was planned for May 2021, during the Roland Garros international tennis tournament. However, with the arrival of the Covid-19 epidemic and the difficulties in travelling, it appeared impossible to organise such a human and material move. A fallback plan was then organised with a demonstration planned during the Leti Days usually organised in May at the CEA in Grenoble. Once again, this plan had to be abandoned in the face of the new waves of the epidemic: the face-to-face exhibition was cancelled and the travel bans were extended. A new session of Leti Days was scheduled for October 2021, so it was decided to ask for a 4-month extension of the project and to carry out the demonstration at this edition. The exhibition did not take place but the plan was maintained: the European part of the final demonstration was held at CEA Grenoble, unfortunately without an audience.

2 European Trial Platform

The purpose of the European platform was to prepare the final demonstration, i.e. to validate all the flows before the connection with Korea (see §**Erreur ! Source du renvoi introuvable.**). This preparation took place during the integration week of the European testbeds in Grenoble (see D5.5). The European partners therefore had to carry out this integration and the preparation for the final demonstration in a very short time.

2.1 Issues found in the phase 1

The only change from the original plan for the final demonstration on the European side concerns the satellite link. The original plan was to connect the PCs hosting the OpenAirInterface (OAI) physical layer to the USRP (Universal Software Radio Peripheral) boards performing the digital/analogue conversion and then, for the Forward Link (Satellite Service Down-Link) to the conversion boards at the target frequency (26 GHz) and to the CEA antennas. The Propsim F64 channel emulator had to be interfaced on each link to simulate the delay specific to geostationary satellites.

Although the satellite emulation platform made up by the OAI modems and the Propsim F64 set-up had been previously validated at Fraunhofer (see D5.2), it was not possible to reproduce it during the integration week in Grenoble due to missing the uplink synchronization. The reason behind this is that the OAI UE modem operating in NTN (None Terrestrial Network) mode need in input a timing advance value corresponding to the number of samples necessary to compensate the long delay introduced by the channel emulator. Also, the PROPSIM F64 introduces an extra hardware delay depending on the emulation scenario which adds up to the total delay. Finding the correct initial value of the timing advance is an iterative process that requires to add and remove samples until uplink synchronization is successfully achieved. This process can be very time-consuming, therefore, given the limited time available, it was decided for the sake of the final demo to dispense with the RF/wireless link and to connect the two USRPs directly to each other, with modem operating in RF simulation mode and the long delay corresponding to a GEO channel simulated by OAI.

2.2 Validation of EU platform

The platform for preparation of the final demonstration on the EU side is shown on Figure **2**. See §**Erreur ! Source du renvoi introuvable.** for the scenario. The flows that are exchanged are:

- From player 1 to/from the VR server on the internet, via the terrestrial links (over the air Forward Link).
- From player 2 to/from the VR server on the internet, via a Wi-Fi connection.
- From webcam 1 to screen 4 via the satellite link.
- From 8k video server to screen 5 via the terrestrial links (over the air Forward Link). Note that in the final demonstration, this flow may go to Korea while the 8k video displayed on screen 5 may come from Korea.

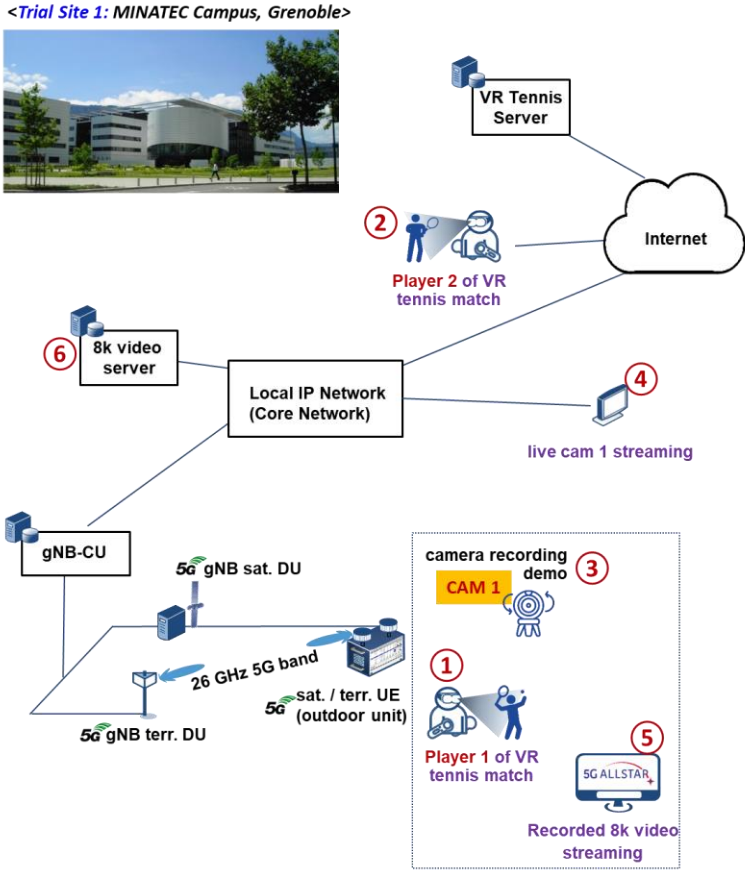

Figure 2. Setup of the European trial for demonstration preparation

Validations of the flows have been done qualitatively and/or quantitatively. Figure **3** shows the validation of the flow through the satellite link. The streaming of the webcam on the screen was smooth and appeared to be resilient to the large end-to-end round trip delay (250 ms due to each simulated GEO orbit bond) observed with iPerf tests.

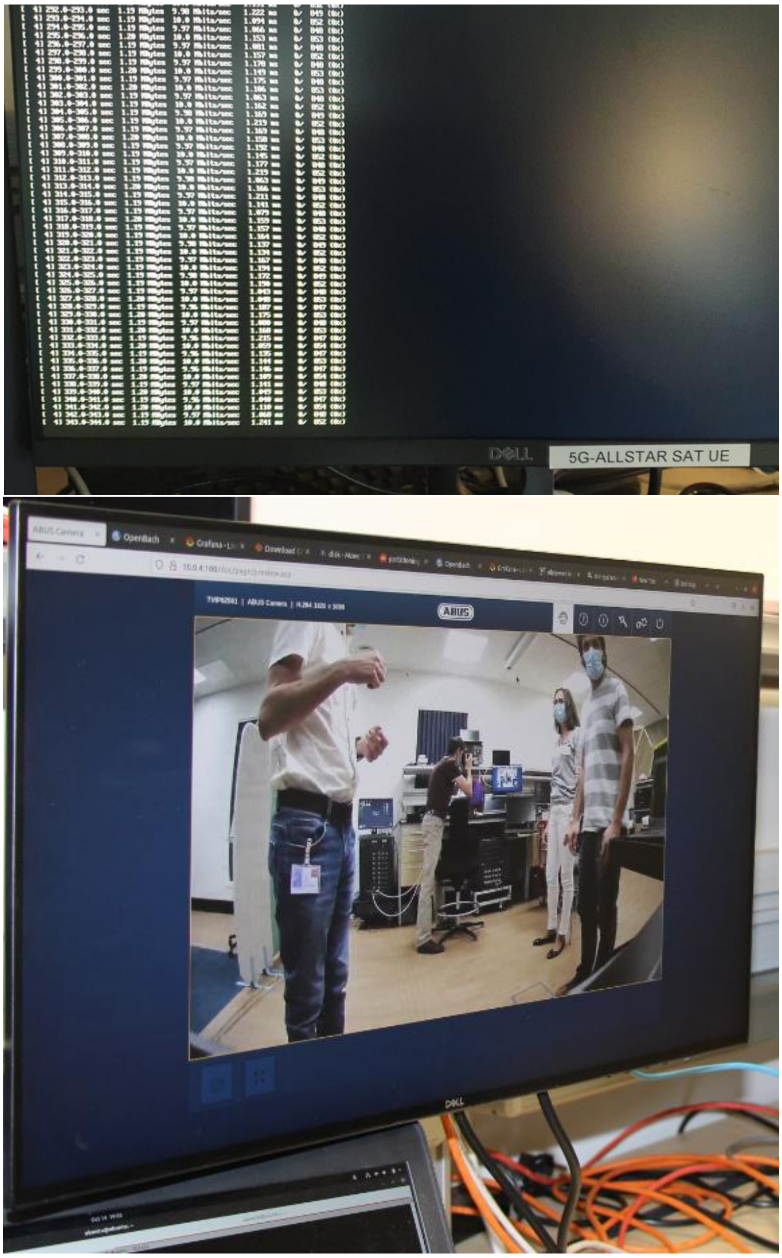

Figure 3. Satellite link validation. Top: data rate, bottom: webcam display

On Figure **4** bottom, the streaming of the 8k video through the over the air Forward terrestrial link can be seen. In the demonstration room, only a 4k screen was available: the streaming was demonstrated smooth. We have also shown that the throughput that can be reached by this link is more than enough to transmit and receive 8k video streams at the same time (see for example Figure **4** top where 180 Mb/s are demonstrated).

Figure 4. Top: throughput of the over the air link, bottom: 8k transmission validation (4k screen)

Finally, Figure **5** shows a picture of the two VR tennis players. The game was smooth, no delay was observed.

Figure 5. VR tennis game validation

3 Korean Trial Platform

The Korean trial platform (KTP) had been integrated and validated during the phase 1 PoC. In the process, a lot of local and system tests had been conducted for validating the integrated system and addressing the relevant scenarios and KPIs. In this chapter we explain two issues found in the phase 1, and describe the validation process.

3.1 Issues found in phase 1

During the phase 1 of the task 5.4, many errors in the KTP had been found and most of them been fixed. In particular, two questions had been raised on the platform and they were mainly in relation with making better service and interworking scenarios.

3.1.1 Trial site

We had considered two sites for the final demonstration. They were proving grounds in Yeonggwang and Cheonan. Each can provide appropriate test/channel environments except for KREONET connection, which is important for some interoperable services between EU and Korea. Meanwhile, since ETRI also can provide both of the testing ground and KREONET connection, which will be detailed in the following chapter, the final demonstration had been performed at ETRI. Figure 6 shows the outdoor testing ground of ETRI and some more details are described in D5.4.

Figure 6. Trial site in Korea

3.1.2 Interoperability

Interoperability[1] can be defined as a characteristic of a product or system, whose interfaces are completely understood, to work with other products or systems, at present or in the future, in either implementation or access, without any restrictions. In the 5G-ALLSTAR, however, the term can be defined rather differently from the general definition in consideration of specific goals of the project. In the 5G-ALLSTAR, "interoperability" can be considered according to which level we look into.

First, a low-level interoperability applies to subsystems like a satellite access subsystem or cellular access subsystem. Since these two subsystems need to be combined for the multi-connectivity trial system, the integration process should require appropriate interfaces between them, which we might name it interoperable if they work properly with the well-defined interfaces. Therefore, each consortium has to define appropriate interfaces among their component subsystems. In the EU trial platform, the cellular access and the satellite access follow a common 5G air interface whereas in the Korean platform, they don't share a common air interface. Thus, each consortium defines their own interfaces between the cellular and satellite access subsystems. This low-level interoperability in relation with each trial platform had been validated throughout the phase 1 PoC.

[1] Interoperability definition by Wikipedia, https://en.wikipedia.org/wiki/Interoperability

Second, a high-level interoperability applies to the connected intercontinental trial platform, which can be named as “intercontinental interoperability.” Unlike the low-level interoperability, it can be understood as an application-level or a service-level interoperability. Thus, the intercontinental interoperability in the 5G-ALLSTAR is closely related to the service scenarios of the final demonstration.

To be more specific, three eMBB services are considered in the intercontinental interoperability demonstration:

- live video streaming (High Definition Quality and 360°),
- 8K video streaming (not live),
- VR gaming (requiring low latency).

These services are main applications to showcase the validity of the intercontinentally connected trial platform as well as each local platform. In this regard, the final demonstration will focus on this high-level or service-level intercontinental interoperability test using these eMBB service scenarios.

3.2 Validation of Korean Platform

The overall architecture of the KTP is shown in Figure 7. It is the multi-connectivity system that encompasses the satellite access part and the cellular access part. Each component part had been accomplished in Task 5.2 and detailed in D5.3[i]. The multi-connectivity testbed had been completed in Task 5.3 and detailed in D5.4[ii]. Basically, the KTP equals the multi-connectivity testbed. In the figure below the contribution of each company of the Korean consortium is indicated. In the following subsections, main features of component and integrated testbeds are reviewed before dealing with the final PoC demonstration.

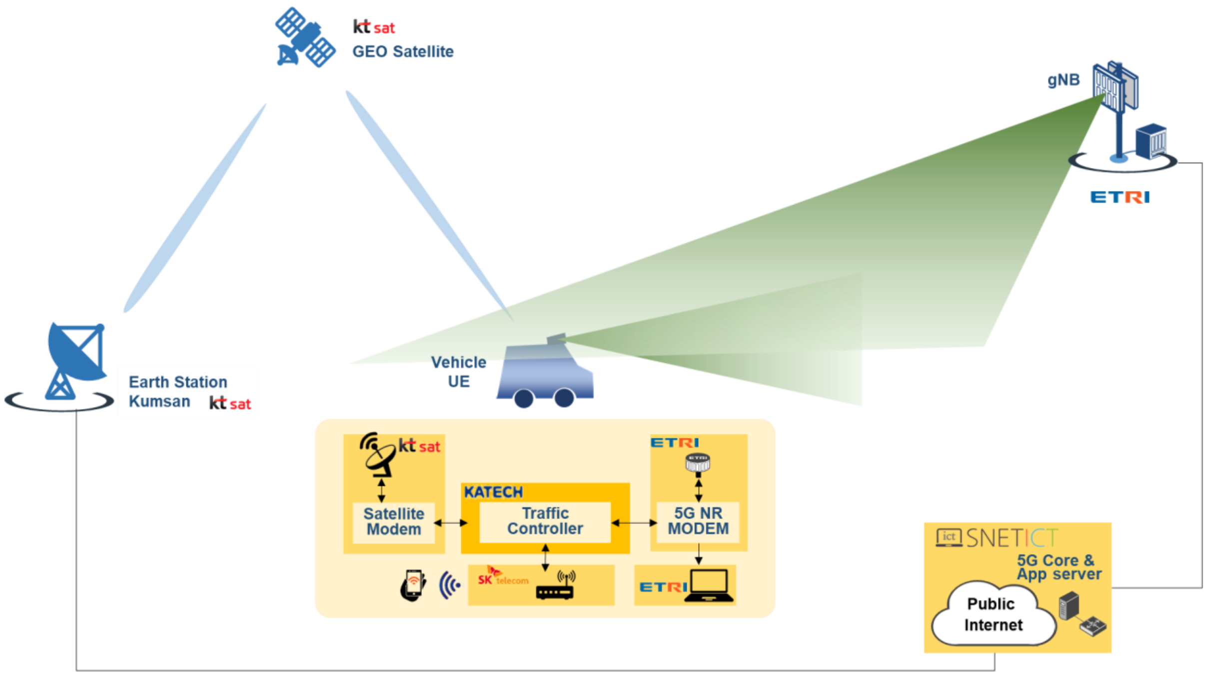

Figure 7. The architecture of the Korean trial platform

3.2.1 Validation of the 5G cellular access

The 5G cellular access is based on millimeter wave (mmWave) and 3GPP (3rd Generation Partnership Project) Rel-15 specifications. The 5G communication system consists of core network (CN) and access network. The CN is responsible for functions not related to the radio access but needed for providing a complete network. In the 5G cellular access testbed (TB), some limited functions had been implemented, which are user plane function (UPF), access and mobility management function (AMF), and session management function (SMF). The access network on the contrary is responsible for all radio-related functionality of the overall network such as radio resource control, ciphering/deciphering of data packets, retransmission protocols, scheduling, coding/decoding and multi-antenna transmissions. Here, the cellular access network has two important points to be differentiated from other networks. First of all, it uses mmWave of around 22.5 GHz to achieve a very large capacity. Next, it includes a transceiver for a vehicle named terminal equipment (TE). And, the TE is connected to a Wi-Fi access point (AP) so that the end users inside the vehicle or the passengers could access directly to the Wi-Fi AP instead of the TE. Figure 8 includes the pictures of the gNB hardware and the vehicle equipped with the cellular antenna and modem.

Figure 9 shows two pictures. The left picture shows several smartphones in the vehicle, which were used to measure Wi-Fi download speed and execute ping test with an App called Benchbee. Download speed of 578 Mbps and round-trip delay of 10.4ms are shown. With the smartphone, video contents in the video server can be selected and played as in the right side.

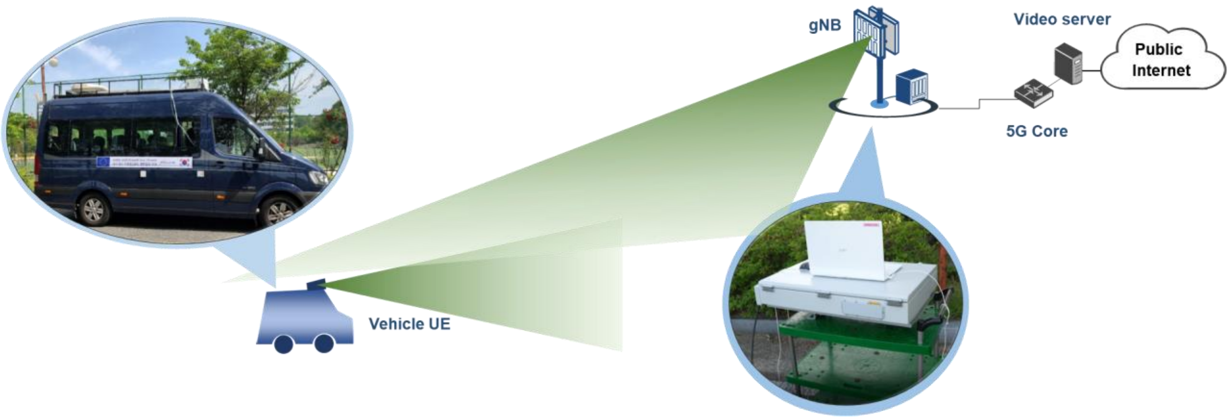

Figure 8. Korean 5G cellular access testbed

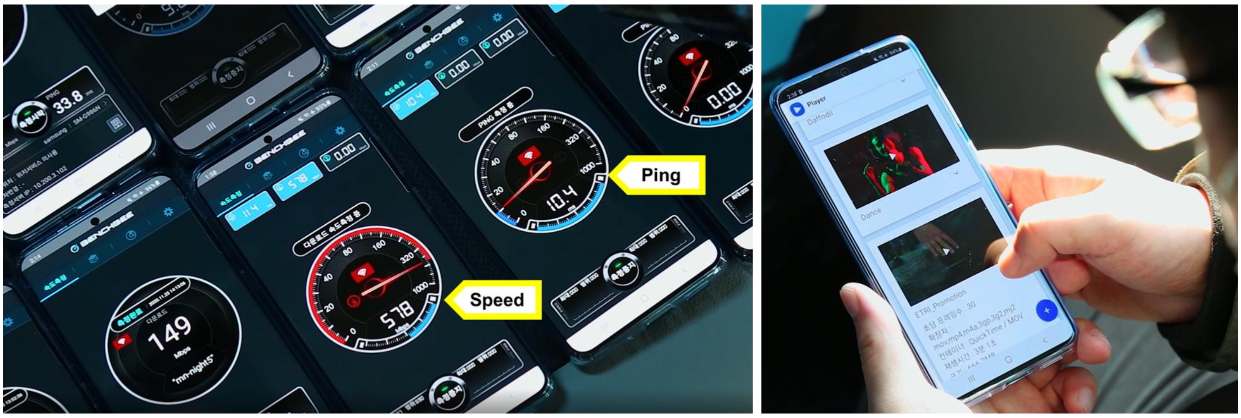

Figure 9. Testing with smartphones in the vehicle

3.2.2 Validation of the satellite access

The Koreasat-6 is a geostationary orbit satellite (GEO) operated by Ktsat. It has 24 FSS (Fixed Satellite Service) Ku-band transponders and 6 BSS (Broadcast Satellite Service) Ku-band transponders. The satellite generates 3.4 kilowatts of payload power and has a 15-year on-orbit mission life. Some of the specification of the Koreasat-6 is summarized in Table 1.

Table 1. The specification of the Koreasat-6

Parameter	Value
Number of Transponders	• FSS: 24x36MHz, BSS: 6x27MHz
Uplink/Downlink Frequencies (GHz)	• 14.0 – 14.5 / 12.25 – 12.75 • 14.5 – 14.8 / 11.7 – 12.0
Polarization	Linear (Horizontal or Vertical)
EIRP (Peak Value) (dBW)	62
G/T (dB/K)	12 - 20
Orbital Location (Longitude)	116°E
Geographic Coverage	Korea
Launch Date	30 Dec 2010
Manufacturer	Orbital Sciences Corporation

The hub system of the Koreasat-6 operates on a commercial iDirect evolution platform. The platform can be used to improve bandwidth efficiency with the application of DVB-S2 (DVB second generation), ACM (Adaptive Coding and Modulation) and ATDMA (Advanced Time Division Multiple Access). The hub can connect to any frequency bands for many kinds of satellite architecture, and automatically adjust to dynamic traffic demands depending on the changing network conditions as well. On the remote side, the commercial iDirect modem and Kymeta on-the-move antenna is used. The Kymeta antenna has a different design with phased array from those of other traditional parabolic antennas, and it does not require phase shifters and amplifiers to adjust the phase and/or amplitude of each antenna elements. A key component of the KyWay terminal is called Kymeta Antenna Subsystem Module (ASM), which includes a combined transmit and receive-capable aperture, control electronics assembly, mechanical enclosure system and software. Table 2 summarizes the specification of the Kymeta ASM.

Table 2. Kymeta antenna specification

Specification	Value
Band	Ku
Antenna type	Electronically scanned array
Polarization	Vertical and horizontal software defined
RX frequency range	11.3 – 12.3 GHz
RX gain	33.0 dB
RX G/T	9.5 dB/K
RX scan roll-off @60°(H-POL)	1.2
RX scan roll-off @60°(V-POL)	1.1
RX instantaneous bandwidth	>100 MHz
TX frequency range	13.75 – 14.5 GHz
TX gain	32.5 dB
TX G/T	9.5dB/K

TX scan roll-off @60°(H-POL)	1.4
TX scan roll-off @60°(V-POL) :	1.2
Antenna size	2.3cm(L)×22.21cm(D)×4.37cm(H)
Antenna weight	16.4 kg
Tracking rate	>20°/second
Scan angles	θ up to 75° off broadside and φ 360°
Tracking accuracy	<0.2°

Figure 10 shows three services that could be covered with the satellite TB in the phase 1 PoC.

Internet access Video conference VoIP

Figure 10. Three services over the satellite testbed

3.2.3 Validation of the multi-connectivity

One of the most important components of the Korean multi-connectivity trial platform is a traffic controller (TC), which has two input ports and one output port. The input ports are for the cellular access IP data and the satellite access IP data, respectively. The output port is connected to a Wi-Fi AP as shown in Figure 11.

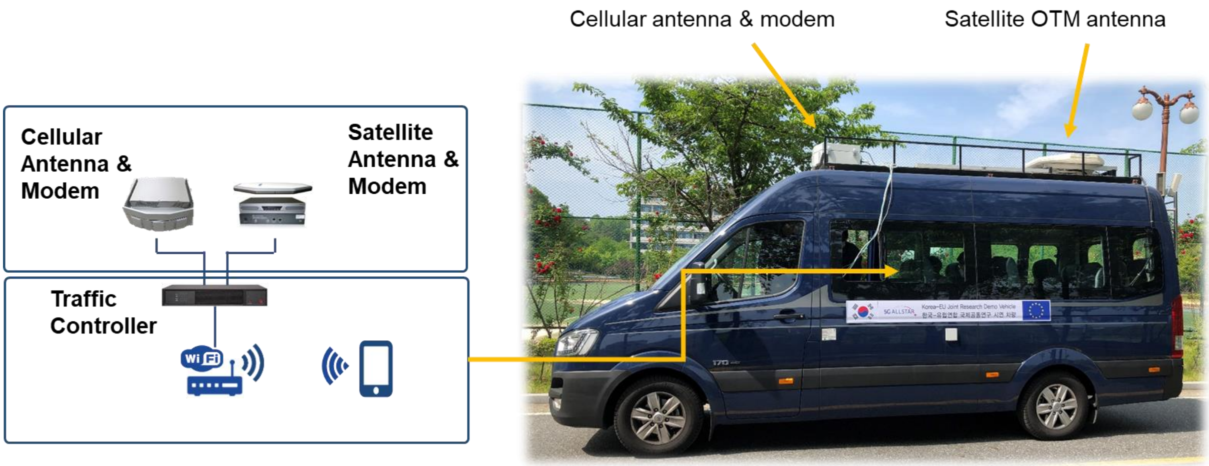

Figure 11. The vehicle for multi-connectivity with the TC

YouTube had been tried to validate the service continuity in the phase 1 PoC with the multi-connectivity platform. A smartphone, laptop, and TC had been arranged as shown in Figure 12. The picture was taken while a BBC live video was being played. The video could be played without delay or buffering for the cellular connection whereas it be played with rather short delay or buffering for the satellite connection. With this configuration, repeated testing had been made and proved the service continuity concept while the TC was functioning under the cellular channel blockage.

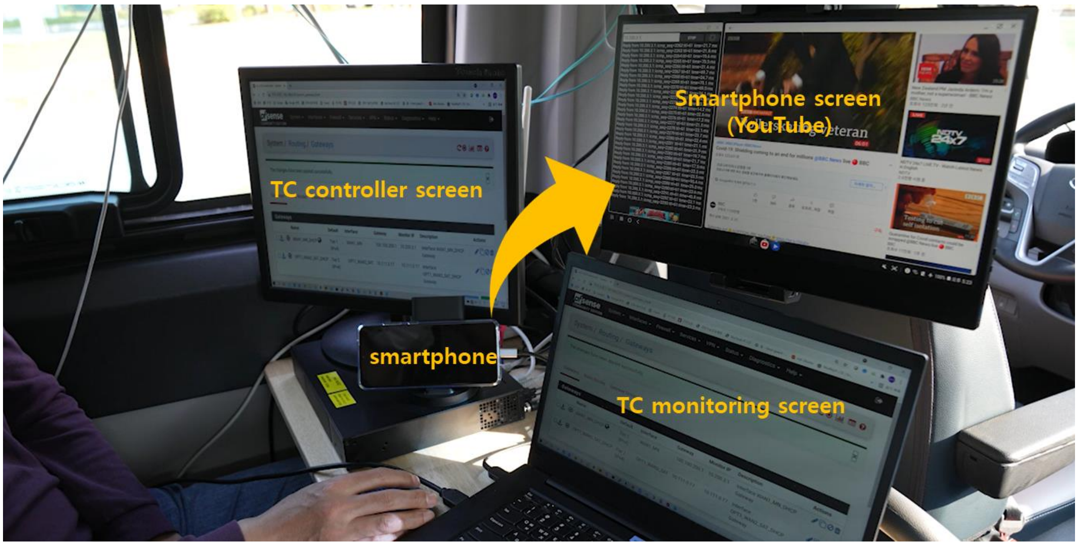

Figure 12. Video streaming with the multi-connectivity trial platform

4 PoC at the Final Event

Korean and European platforms, respectively in Daejeon and in Grenoble, have been connected through KREONET. For security reason that will be explained in the following subsection, the IPsec (Internet Protocol Security) tunnel had been laid over the KREONET.

4.1 Intercontinental Network Connections

Korean Side Connection

KREONET is a principal national Research & Education (R&E) network supported by the government, managed and operated by KISTI (Korea Institute of Science and Technology Information) since 1988. It uniquely provides production research network services for around 200 R&E organizations including non-profit research and educational organizations government research institutes, universities, public sectors, libraries, and so on, based on hybrid (IP and non-IP) network infrastructure with a total number of 21 network centers distributed among Korea (17), USA (2), China (1), and Netherlands (1). The network centers are divided into:

- 17 domestic regional GigaPoPs:
  - ✓ Based in Korea (Seoul, Daejeon, Gwangju, Busan, Changwon),
- international GigaPoPs:
  - ✓ Based in US (Chicago and Seattle), the Netherlands (Amsterdam) and Hong Kong.

KREONET can provide the following performance:

- KREONET backbone availability: [99.99]% in 2020,
- KREONet2/GLORIAD backbone availability: [99.90%] in 2020.

As shown in Figure 13, KREONET ensures a global connection of up to 10 Gbps between Daejeon PoP and Amsterdam PoP via Chicago PoP, which is sufficient to simultaneously demonstrate multiple broadband intercontinental interoperability services between KR and EU trial sites.

Figure 13. Map of KREONET in 2020

For intercontinental interoperability testing, the network of Korean side is configured as following.

1. The last mile is setup within ETRI. ETRI has a peering connection with KREONET. Figure 14 illustrates the configuration of the ETRI network.
2. KREONET then established a network connection with Amsterdam PoP.
3. KREONET is terminated at a building (B1) which is different location of our local network (B2). We had an optical connection from B1 to B2 in order to support KREONET connectivity.
4. To have secure connection with CEA, we installed cisco ASA5516-x IPsec device and established a IPsec tunnel between our local network and CEA local network over intercontinental connection over KRONET-GEANT-RENATER.

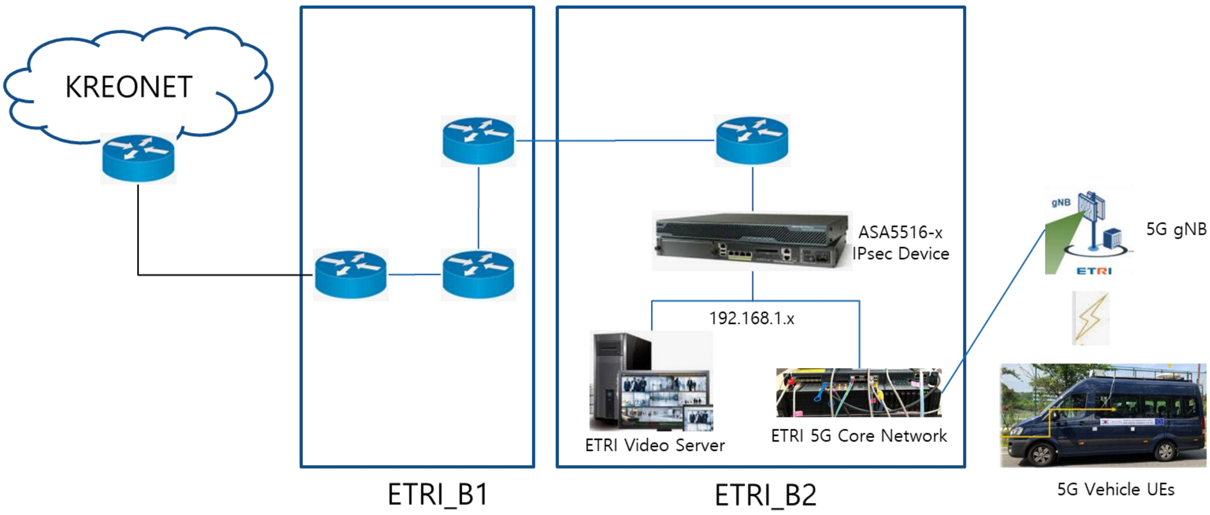

Figure 14. Configuration of the ETRI network

European Side Connection

The network of European side is configured as following, see Figure **15**.

1. In the demonstration room, in CEA Grenoble, a RJ45 plug is dedicated to the VPN connection.
2. The plug is connected to the ASA5516 IPsec device in the technical room in another building in CEA Grenoble.
3. The IPsec device is further connected to the RENATER network which in turn connects to the GEANT network.

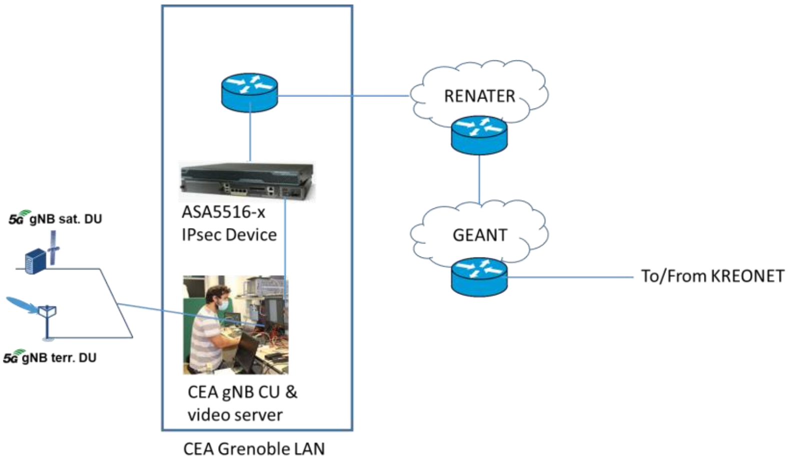

Figure 15. Configuration of the CEA network

RENATER (National telecommunications network for Technology, Education and Research) is the national research and education network in France. Deployed at the beginning of the 1990s, it provides a national and international connectivity via the pan-European GÉANT network, to more than 1,000 education and research sites in Metropolitan France and Overseas Departments and Territories. The RENATER network is an important and added value tool for research and education. It is connected to international networks through two nx10 Gbit/s links to GÉANT and directly to the Internet through four nx10 Gbit/s links, see Figure 16. RENATER supports IPv4 and IPv6. *(source: Wikipédia)*

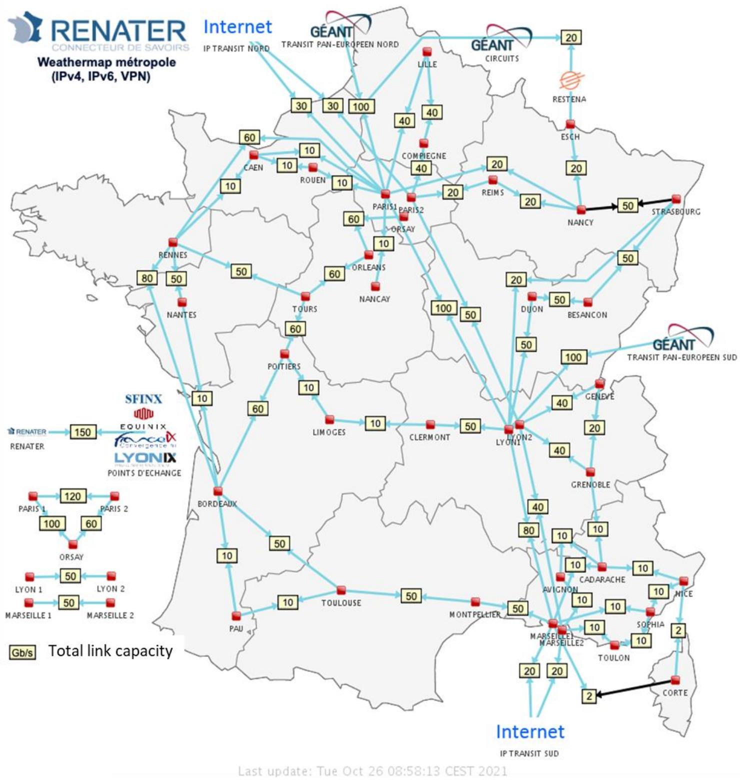

Figure 16. RENATER network

IPsec Tunnel

For intercontinental interconnection, we utilized IPsec connectivity due to the request made by CEA for its security policy. We established an IP level connectivity between ETRI 5G testbed and CEA 5G testbed first. Then, we setup an IPsec tunnel gateway at each testbed site. Table 3 describes the detailed configuration for IPsec tunnel between two testbeds.

Table 3. IPsec connectivity setting

Settings	Grenoble	Korean site
Gateway IP address (public)	194.254.181.17	134.75.238.100
Device Brand	Cisco	Cisco
Device Moduletype and Number	ASA5516-X	ASA5516-X
IKEV2 PropertiesIKE Session (IPSec Phase I)		
Authentication Mode	Preshared key	Preshared key
Authentication Algorithm	SHA256	SHA256
Transform Type (ESP/AH)	ESP	ESP
IKE Negotiation Mode	Main mode	Main mode
Encryption Algorithm	AES 256	AES 256
Perfect Forward Secrecy (PFS)	Diffie-Hellman Group 20	Diffie-Hellman Group 20
Rekey Time Interval	28800	28800
Preshared Key	*********	*********
IPSec Session (IPSec Phase II)		
Local Encryption Domain (IP address or range including the netmask)	10.0.0.0/21	192.168.0.x/24
Encapsulation	ESP	ESP
Hashing Algorithm	SHA256	SHA256
IPSec Mode	Tunnel	Tunnel
Encryption Algorithm	AES 256	AES 256
Rekey Time Interval (Life Time)	3600	3600
Rekey Data Interval (Life Size)	0	0
Perfect Forward Secrecy (PFS)	NO	NO

IPsec tunnel was successfully established and provided a securely connected 1 Gbps high bandwidth path between two local 5G/Satellite multi-access testbeds

End-to-end Connectivity

The following Figure 17 illustrates an end-to-end intercontinental network connection. The quality of connection was good enough to transmit 4K live video streams, 8K record video streams, 360-degree live cam streaming and VR tennis game playing.

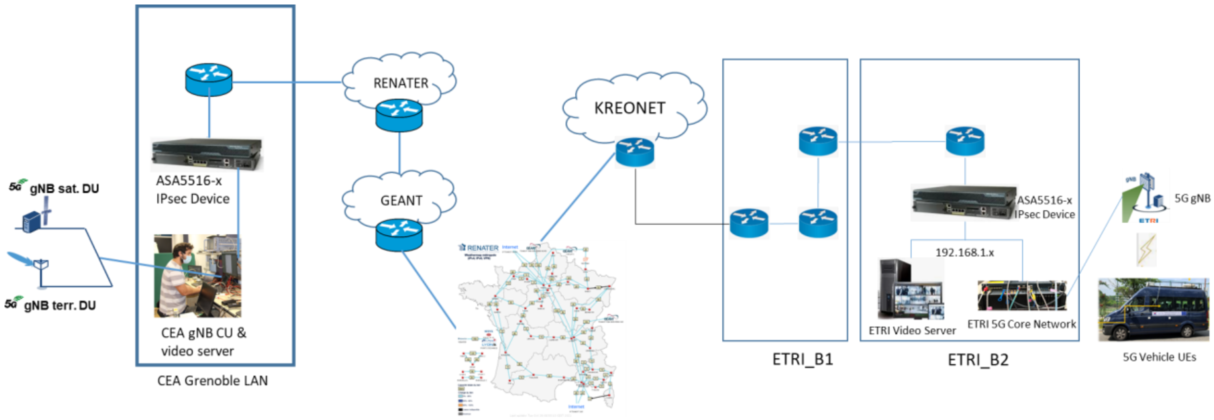

Figure 17. Configuration of end-to-end intercontinental network for 5G-ALLSTAR PoC

4.2 Service scenarios and test cases

Based on the intercontinental trial platforms, EU and Korea demonstrated a few services in each venue. Most services in a venue were closely related to the services in the other venue over the KREONET. EU and Korea services are described as follows.

The set-up for the intercontinental final 5G-ALLSTAR demonstration is provided on Figure 18. The scenario is the following:

- In Europe, a player of Virtual Reality (VR) tennis game ① is at home or on the move. He is equipped with a multi-connectivity 5G unit (UE), able to transmit/receive via a satellite link and a terrestrial link simultaneously.
- He plays with another player ② somewhere in the internet (flow goes through the terrestrial path).
- The player at home or on the move is filmed with a webcam ③ (flows goes through the satellite path).
- In Korea, people are in a bus equipped with satellite and 5G terrestrial receivers/transmitters. Some of them ⑨ are watching the VR tennis game from webcam ③, others are watching the game with VR goggles ⑩. These flows go through the best path between satellite and terrestrial.
- In the bus, people are filmed with a 360° camera ⑧. This stream is displayed in Europe ④ (through terrestrial path).
- Additionally, in order to demonstrate that high throughput can be reached, 8k videos are transmitted from Europe to Korea (via multi-connectivity receiver) ⑥⑨ and from Korea to Europe (via terrestrial path) ⑦⑤.

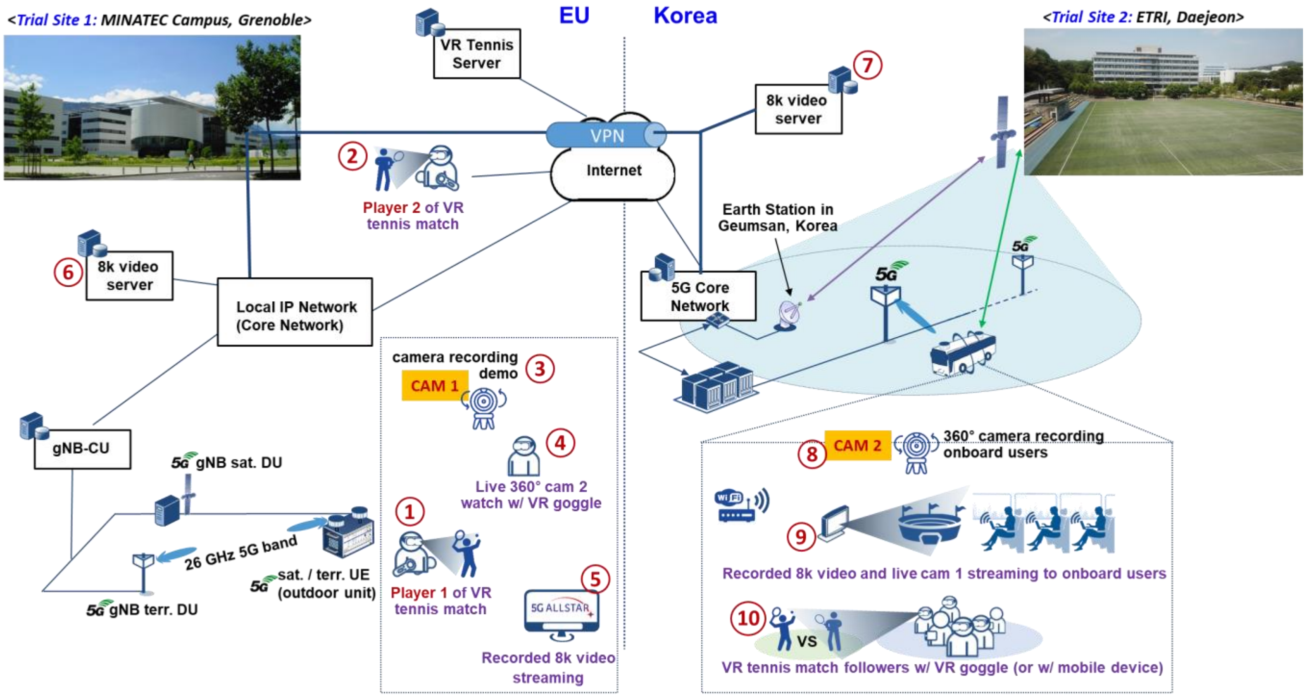

Figure 18. Final demonstration set-up

The final demonstration took place on Friday October 15th. The results are provided below.

4.2.1 Service scenarios and test cases at EU Venue

In the EU venue, 8k video streaming, VR tennis game, 360° camera and webcam streaming were demonstrated.

8k video streaming

The 8k video from Korean video server ⑦ was streamed in EU ⑤ through the VPN and through the 5G terrestrial over the air link of the EU platform in the 26 GHz band, see Figure 19. As demonstrated during the preparation phase, see §2.2, the throughput that can be reached by the terrestrial link is more than enough for streaming the highest video quality. Nevertheless, in the EU demonstration room, only a 4k screen was available. Video was displayed smoothly on this screen.

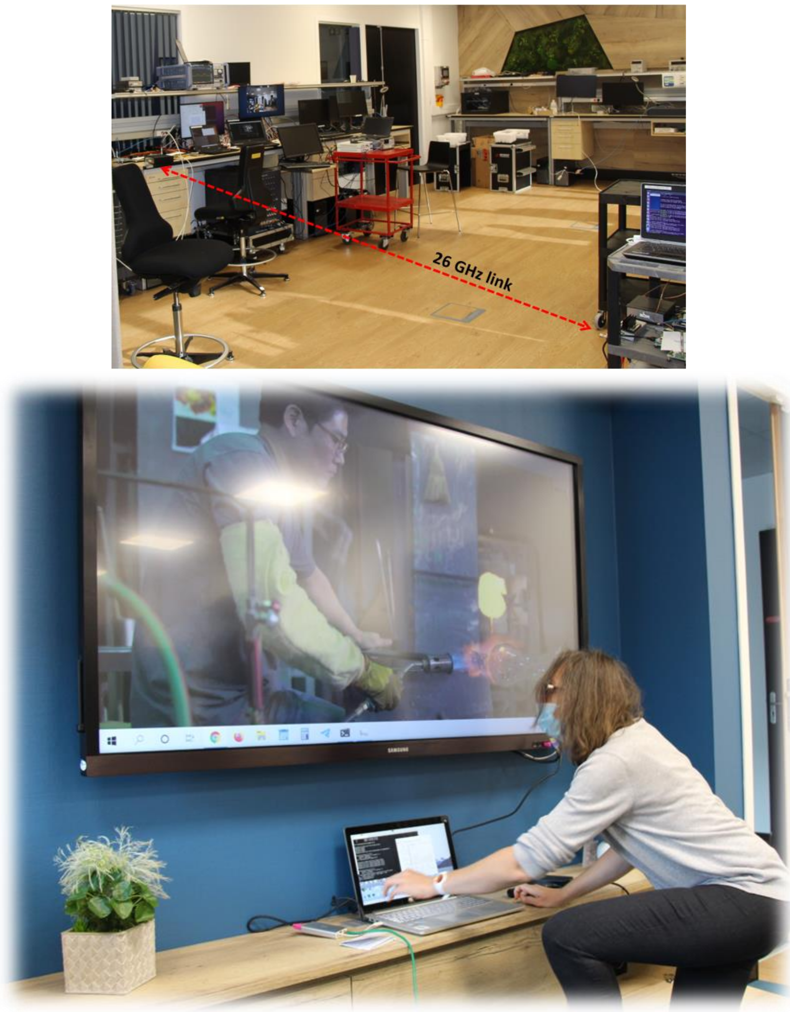

Figure 19. Top: over the air link. Bottom: streaming of the 8k Korean video in EU

Appnori VR tennis game

The game between the player connected via the terrestrial testbed and the player directly connected to the internet was validated during the preparation phase, see §2.2. During the demonstration, it was shown possible also for player 1 (Figure 20) to play with a player located inside the Korean test vehicle, see Figure 20 middle.

360° real-time Webcam

The 360-degree real-time webcam installed inside the KR test vehicle was watched on the EU side with VR goggles and also displayed on a screen. The transmission was realized through the over the air link, Figure 21.

Figure 20. Left: 360° camera watch with VR goggles. Middle: VR tennis player with Korea. Right: 360° camera display on the screen.

Webcam streaming

The EU platform was filmed with a webcam and streamed on YouTube, via the EU satellite emulated link, see §2.2. The Korean partners were then able to see what was happening in real-time in EU.

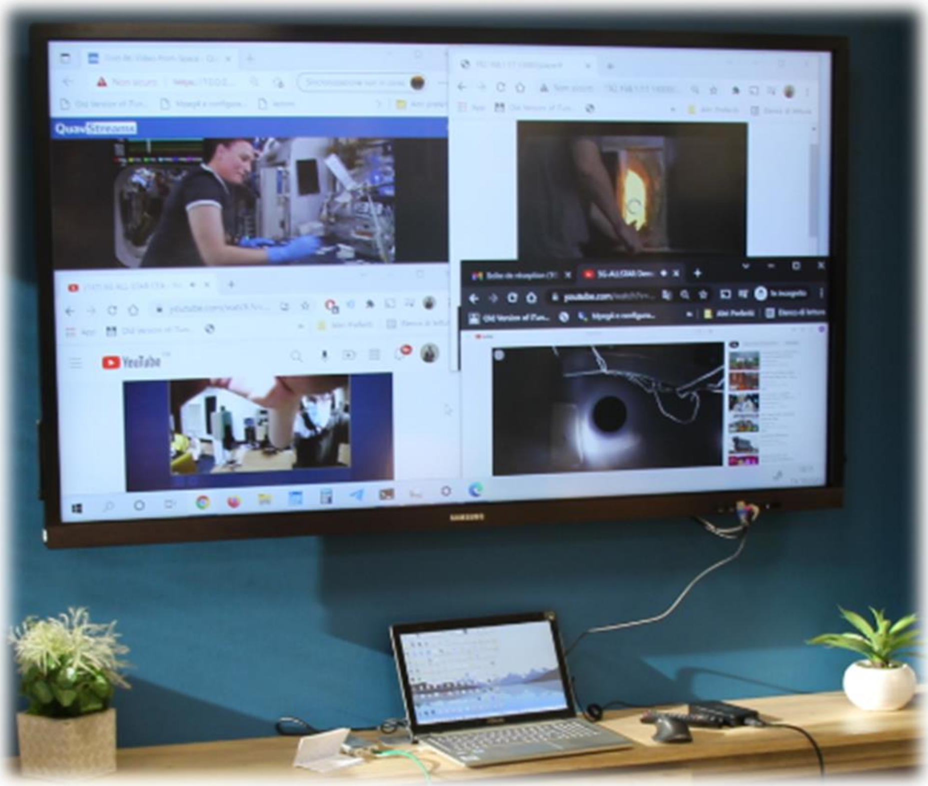

Figure 21. Display of all the flows: top-left: EU 8k video, top-right: Korean 8k video, bottom-left: EU webcam, bottom-right: 360° Korean camera.

4.2.2 Service scenarios and test cases at Korean Venue

In the Korean venue, three services, 8K video streaming, Appnori VR tennis game, and 360° real-time Webcam had been demonstrated.

8K Video Streaming

Transmitting high quality video streaming needs high data rates according to the video qualities and encoding methods. For example, Table 7-1 of D4.3 lists bitrates corresponding to level 1-6 of encoding settings. It represents that the level 6 corresponds to 8K video encoding with the resolution of 7,680x4,320 and frame rate of 25, and this requires 30Mbps of bitrate. The required bitrate can be changed with the encoding method and the frame rate for the same resolution. Meanwhile, Figure 22 shows the video server web page where a 8K video shows 114 Mbps of requested data rate. In the intercontinental PoC, the video had been transmitted through KRE-ONET connection.

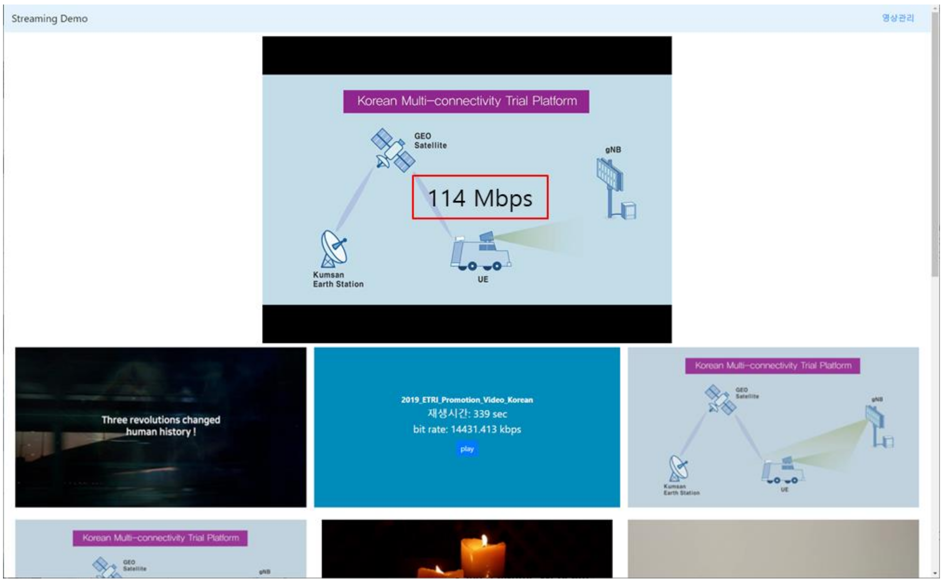

Figure 22. KR Video server manager

Figure 23 illustrates a KR side network configuration for setting up 5G core and video server over the IPSec equipment (Cisco ASA 5516-X). Without KREONET, high quality videos should be transmitted through the public Internet, which mostly accompanies severe buffering. With the help of the KREONET connection, the video streaming service had been performed smoothly.

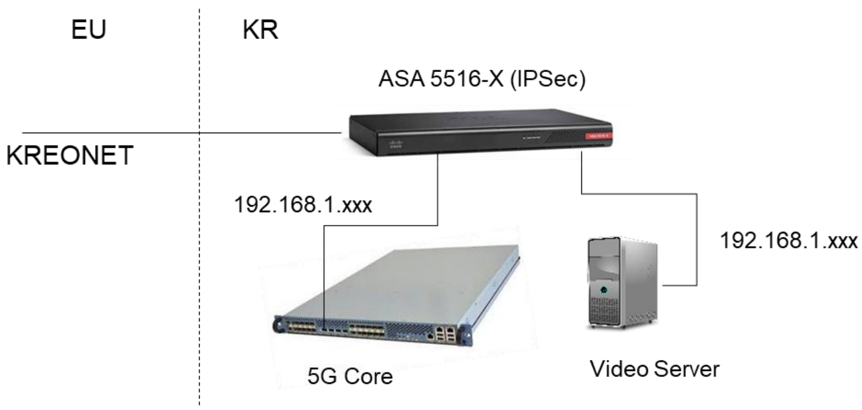

Figure 23. KR network configuration for 8K video streaming

Figure 24 shows a laptop playing 8K video in the KR test vehicle. The video server is located at CEA-Leti, and the video is streaming through the KREONET.

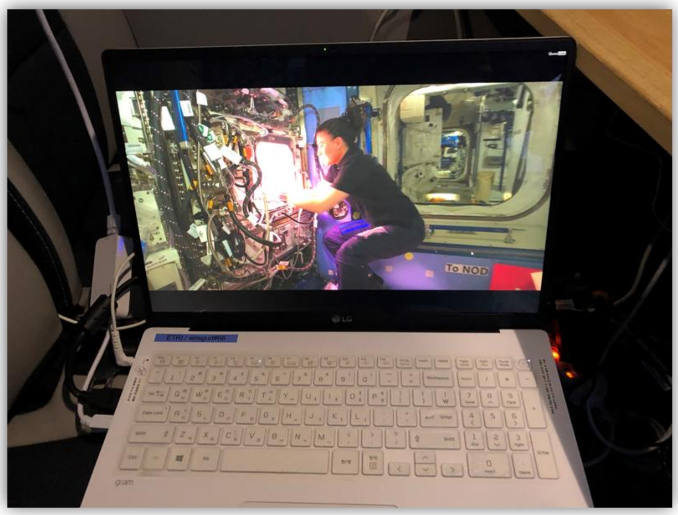

Figure 24. Watching EU 8K video in the KR test vehicle

Appnori VR tennis game

As described in D5.5, Appnori VR tennis gaming provides two kinds of mode; player mode and audience mode. In the final demonstration, both sides of EU and KR connected to a game server in EU. KR participants tried the audience mode while the EU participants were playing the VR tennis match. They also tried the payer mode with the remote player as in Figure 25. The participant in the left is in the vehicle. A laptop screen is displaying a EU participant that is playing the game.

Figure 25. Appnori VR tennis match between KR and EU

360° real-time Webcam

A 360-degree real-time webcam was installed inside the KR test vehicle as in Figure 26. The webcam was connected to the Wi-Fi AP, transmitted captured data to a broadcasting server so that other connected devices such as laptop or HMD (Head Mount Display) can watch the uploaded video in real time.

Figure 26. 360-degree webcam inside KR test vehicle

5 Conclusion

European and Korea partners had integrated and validated each trial platform before they connected them through KREONET at the final demonstration.

During the preparation period, they had found some issues and settled them down.

On the Korean side, there had been considerations on the final trial site for better test/channel environments for the satellite and terrestrial networks. Eventually, however, it was connectivity to the KREONET that impacted the final decision. ETRI was decided as the Korean trial site because of the connectivity to the KREONET.

On the European side, considerations on the satellite channel had been taken in the trial platform phase. Instead of a satellite modem connection through Propsim F64, a direct modem connection without the channel emulator had been adopted, which had not affected the service scenarios of the final demonstration. It should be noted that the connection with the Propsim F64 had been proved already at a local test.

Another big barrier was about the KREONET connection that was a key part for the intercontinental trial. For security reason, the IPsec tunnelling between CEA-Leti and ETRI had been requested. It took quite a long time even until the final demonstration day to achieve the IPsec tunnel between each testbed.

In the final demonstration, three services for each trial site had been showcased.

First, the EU trial platform provided a 8K video server so that the participants in the Korean test vehicle could enjoy 8K video streaming through the wireless and intercontinental network connections. There was also a 8K video server placed in the Korean network side, whose contents were accessible to the EU participants.

Second, both sides had provided 360-degree real-time webcam and broadcasted online status of each trial site. Each side users could watch the other site in real time with a monitor screen or HMD.

Third, the Appnori VR tennis gaming had been tried with participation from both sides. According to the story telling, EU players tried some matches among them and Korean participants could watch the games in audience mode. Furthermore, some international match between one player in the EU and another in the Korea had been tried and done nicely without much delay in spite of latency due to the long-haul intercontinental connection. All of these services had been provided on top of each trial platform and the intercontinental connection, and had proved high-level (or service level) interoperability concepts successfully.

6 References

[i] D5.3, “Integration and system level testing for Korean testbeds of 5G cellular and satellite access networks,” delivered in 30 Aug., 2020.
[ii] D5.4, “Integration and system level testing for Korean multi-connectivity,” delivered in 30 Jun., 2021.