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Deliverable D2.1

Vision, Scope and Goals

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Abstract

This deliverable has been created as part of the work in the project Work Package 2 (WP2) “Scenarios for Multiple Access in 5G”, and reports vision, scope and goals of the 5G-ALLSTAR project.
The main outcomes of the deliverable are the description of the possible use-cases of satellite/cellular multi-access, KPIs, and business models of 5G-ALLSTAR and the identification of the potential impact of 5G-ALLSTAR on the recently emerging and future 5G vertical markets.

Keywords

5G-ALLSTAR, Use case, Key Performance Indicator, Proof of Concept, Service scenario

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Executive Summary

This deliverable presents the vision, scope and goals of the 5G-ALLSTAR project mainly focusing on potential use cases and associated KPIs that can receive a great benefit from the technical achievements of the project. It provides a preliminary analysis on the use cases and KPIs targeting vertical markets, which is expected to give valuable insights into developing potential business models for vertical stakeholders. In addition, this deliverable summarizes the results of a preliminary study that has been conducted to investigate various service scenarios for the final PoC verification of 5G-ALLSTAR key enabling technologies. The service scenarios are categorized into three main types: European standalone service scenarios, Korean standalone service scenarios and global interoperable service scenario with two PoC systems respectively developed by European and Korean consortiums. Each service scenario and its target KPIs will be further clarified and the final service scenarios and target KPIs will be respectively included in D2.4 and D2.3. The final service scenarios and target KPIs will play a pivotal role in providing a baseline for defining the overall 5G-ALLSTAR system architecture including key components, key functionalities and required interfaces for the service scenarios.

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List of Abbreviations

2D	2 Dimensions / 2-Dimensional
3D	3 Dimensions / 3-Dimensional
3GPP	3rd Generation Partnership Project
5G	Fifth Generation
5G-ALLSTAR	5G AgiLe and fLexible integration of SaTellite And cellu-laR
AP	Access Point
BM	Business Model
BS	Base Station
CN	Core Network
DL	Downlink
eMBB	enhanced Mobile BroadBand
ETRI	Electronics and Telecommunications Research Institute
FACS	Flexible Access Common Spectrum
FPS	Frames per Second
GEO	Geostationary satellite
gNB	Next generation NodeB
HDR	High Dynamic Range
HST	High-Speed Train
IoT	Internet of things
ITU	International Telecommunication Union
KPI	Key Performance Indicator
LoS	Line of Sight
mmWave	Millimeter wave
mMTC	Massive Machine Type Communication
MHN	Mobile Hotspot Network
MN	Moving Network
MWB	Mobile Wireless Backhaul
NR	New Radio
NTN	Non-Terrestrial Network
PoC	Proof of Concept
QoS	Quality of Service

RAN	Radio Access Network
RAT	Radio Access Technology
RF	Radio Frequency
RTT	Round Trip Time
RU	Radio Unit
SA	System Aspects
TN	Terrestrial Network
TRL	Technology Readiness Level
UC	Use Case
UHD	Ultra High Definition
UE	User Equipment
UL	Uplink
URLLC	Ultra Reliable Low Latency Communication
V2X	Vehicle to Everything
VE	Vehicle Equipment
WiBro	Wireless Broadband
Wi-Fi	Wireless Fidelity
WP	Work Package

1 Introduction

1.1 Background

The advent of 5th generation (5G) mobile communications will bring a wide range of potential opportunities and challenges. 5G will enable the introduction of new services and markets and, at the same time, impose several unprecedented technical requirements. More specifically, support for the new services involves seamless connectivity across various vertical industries including multimedia, healthcare, internet-of-things (IoT), automotive, and manufacturing [1] . Such verticals services can be grouped into three main use cases, as follows:

- **Enhanced Mobile Broadband (eMBB)** originates from human-centric services requiring large amount of data rate such as internet browsing and multimedia streaming through smartphones, tablets, and so on. In addition to the high data rate, low latency and large coverage area are also matters of concern.
- **Massive Machine Type Communications (mMTC)** targets to support communications between machines such as sensor monitoring and asset tracking, which are typically low-cost and battery-operated devices. It also requires wireless connectivity among the massive number of deployed devices.
- **Ultra-Reliable Low-Latency Communications (URLLC)** refers to application scenarios with very tight requirements for the reliability and latency. Examples of this use case include industrial manufacturing control, remote surgery, and self-driving cars.

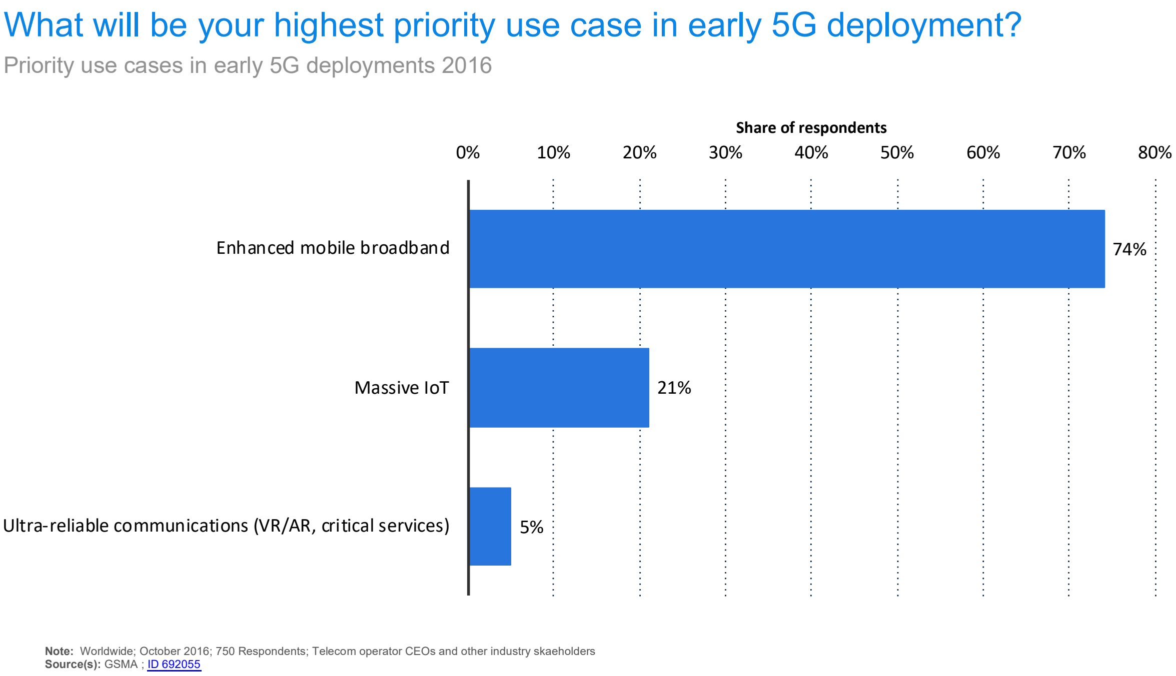

Figure 1: Use case priority (GSMA, 2016)[1]

[1] GSMA, (2017) The 5G era: Age of boundless connectivity and intelligent automation, page 19, available online at https://www.gsmaintelligence.com/research/2017/02/the-5g-era-age-of-boundless-connectivity-and-intelligent-automation/614/

Among the different use cases, telecom companies and industry stakeholders consider enhanced mobility broadband as their main priority for future 5G deployments (Figure 1). This reflects the increasing importance and diffusion of mobile Internet that has become the primary mean for internet access. For example, in 2018, more than 51% of all web pages were accessed through mobile devices[2]. While consumers awareness of 5G potentials remains focused on enhanced mobility broadband services, the ability of 5G to support different services on the base of the same network, opens to the development of services targeted at specific user groups and industries. "Therefore, 5G has the potential to change business models for network operators relative to the current marketplace, where network operators have offered largely standardised services and differentiation has been limited to pricing plans."[3] Additionally, automotive, energy, factories, health, media, public transportation and aeronautics industries may take the opportunity to provide services directly to the end consumers, implying the transformation of existing value chains.[4]

The three main use cases can be supported in various 5G deployment scenarios such as indoor, urban, rural, high speed trains, highways, etc. [2] . From scenario to scenario, deployment specific requirements are quite different [3] . For example, in the indoor hotspot scenario the focus is on achieving high user throughput with no or little mobility. Rural scenarios focus more on providing larger and continuous coverage rather than high throughput. The high speed train scenario targets to support very high mobility up to 500 km/h.

Efficient and reliable support for the above mentioned diverse use cases in various deployment scenarios can be further aided through the integration of multiple access technologies as specified in 3GPP TS 22.261 "Service requirements for next generation new services and markets"[5] (in clause 6.3). Providing tight interworking and integration between 5G and existing LTE networks or between 5G cellular and non-terrestrial (e.g., satellite) networks will be beneficial in terms of providing improved coverage and service continuity in a cost effective manner. Multiple access support is particularly useful for providing robust, seamless, and continuous wireless services for critical applications such as public safety and emergency case communications, i.e., when a cellular link fails due to an accident or a disaster, non-intermittent wireless services will be provided through a satellite access.

Therefore, the 5G-ALLSTAR project aims at developing a set of technologies enabling tight interworking and integration between cellular and satellite links supporting a heterogeneous environment with multi-access technology. Several use cases and deployment scenarios will be considered such as multimedia service (eMBB-type) to passengers on board train, bus, or ship, mMTC-type service for asset tracking and logistics, and public safety and emergency case communications requiring highly reliable QoS even in a disaster situation. After developing test beds based on selected 5G technologies, a demonstration involving interoperation/integration between cellular and satellite access will be provided either in Europe and/or in Korea.

1.2 KPI definition by ITU/3GPP

In order to satisfy the above three use cases (i.e., eMBB, mMTC, and URLLC), several key performance indicators (KPIs) were defined by ITU-R and 3GPP during their 5G standardization processes. Among the 5G KPIs developed by the ITU-R [4] , this section shows selected KPIs highly related to the 5G-ALLSTAR project.

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[2] StatCounter. (2018, April). Mobile internet traffic as percentage of total web traffic in April 2018, by region. In *Statista - The Statistics Portal*. Retrieved from https://www.statista.com/statistics/306528/share-of-mobile-internet-traffic-in-global-regions/

[3] DotEcon, Axon Partners Group (2018), Study on Implications of 5G Deployment on Future Business Models, page ii, Retrieved from https://berec.europa.eu/eng/document_register/subject_matter/berec/reports/8008-study-on-implications-of-5g-deployment-on-future-business-models

[4] 5GPPP (2018), 5G Innovations for New Business Opportunities, page 6, https://5g-ppp.eu/wp-content/uploads/2017/01/5GPPP-brochure-MWC17.pdf

[5] https://portal.3gpp.org/desktopmodules/Specifications/SpecificationDetails.aspx?specificationId=3107

1.2.1 Peak data rate

Peak data rate is the maximum achievable data rate under ideal conditions (in bit/s), which is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

The minimum requirements for peak data rate, for the purpose of evaluation in the eMBB usage scenario, are as follows:

- Downlink peak data rate is 20 Gbit/s.
- Uplink peak data rate is 10 Gbit/s.

1.2.2 Peak spectral efficiency

Peak spectral efficiency is the maximum data rate under ideal conditions normalized by channel bandwidth (in bit/s/Hz), where the maximum data rate is the received data bits assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times).

The minimum requirements for peak spectral efficiencies, for the purpose of evaluation in the eMBB usage scenario, are as follows:

- Downlink peak spectral efficiency is 30 bit/s/Hz (with eight spatial layers).
- Uplink peak spectral efficiency is 15 bit/s/Hz (with four spatial layers).

1.2.3 User experienced data rate

User experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time.

The target values for the user experienced data rate are as follows in the Dense Urban – eMBB test environment:

- Downlink user experienced data rate is 100 Mbit/s.
- Uplink user experienced data rate is 50 Mbit/s.

1.2.4 5th percentile user spectral efficiency

The 5th percentile user spectral efficiency is the 5% point of the CDF of the normalized user throughput. The normalized user throughput is defined as the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time, divided by the channel bandwidth and is measured in bit/s/Hz.

The minimum requirement for the 5th percentile user spectral efficiency for eMBB use case is defined for different test environments:

- Indoor Hotspot: 0.3 bit/s/Hz (downlink), 0.21 bit/s/Hz (uplink)
- Dense Urban: 0.225 bits/s/Hz (downlink), 0.15 bits/s/Hz (uplink)
- Rural: 0.12 bits/s/Hz (downlink), 0.045 bits/s/Hz (uplink)

1.2.5 Average spectral efficiency

Average spectral efficiency is the aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time) divided by the channel bandwidth of a specific band divided by the number of transmission reception points (TRxPs) and is measured in bit/s/Hz/TRxP.

The minimum requirement for the average spectral efficiency for eMBB use case is defined for different test environments:

- Indoor Hotspot: 9 bit/s/Hz/TRxP (downlink), 6.75 bit/s/Hz/TRxP (uplink)
- Dense Urban: 7.8 bits/s/Hz/TRxP (downlink), 5.4 bits/s/Hz/TRxP (uplink)
- Rural: 3.3 bits/s/Hz/TRxP (downlink), 1.6 bits/s/Hz/TRxP (uplink)

1.2.6 Area traffic capacity

Area traffic capacity is the total traffic throughput served per geographic area (in Mbit/s/m2). The throughput is the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time.

The target value for Area traffic capacity in downlink is 10 Mbit/s/m2 in the Indoor Hotspot – eMBB test environment.

1.2.7 Latency

User plane latency is the contribution of the radio network to the time from when the source sends a packet to when the destination receives it (in ms). It is defined as the one-way time it takes to successfully deliver an application layer packet/message from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface in either uplink or downlink in the network for a given service in unloaded conditions, assuming the mobile station is in the active state.

The minimum requirements for user plane latency are:

- 4 ms for eMBB
- 1 ms for URLLC

Control plane latency refers to the transition time from a most “battery efficient” state (e.g. Idle state) to the start of continuous data transfer (e.g. Active state).

The minimum requirement for control plane latency is 20 ms, for both eMBB and URLLC use cases.

1.2.8 Reliability

Reliability is the success probability of transmitting a layer 2/3 packet within a required maximum time, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface at a certain channel quality.

This requirement is defined for the purpose of evaluation in the URLLC usage scenario.

The minimum requirement for the reliability is $1\text{-}10^{-5}$ success probability of transmitting a layer 2 PDU (protocol data unit) of 32 bytes within 1 ms in channel quality of coverage edge for the Urban Macro-URLLC test environment, assuming small application data (e.g. 20 bytes application data + protocol overhead).

1.2.9 Mobility

Mobility is the maximum mobile station speed at which a defined QoS can be achieved (in km/h).

For the eMBB scenario, the following mobility requirement is defined at a given QoS level in terms of normalized traffic channel link data rate (bit/s/Hz).

- Indoor Hotspot: 1.5 bit/s/Hz at 10 km/h
- Dense Urban: 1.12 bits/s/Hz at 30 km/h
- Rural: 0.8 or 0.45 bits/s/Hz at 120 or 500 km/h

1.2.10 Mobility interruption time

Mobility interruption time is the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions.

The minimum requirement for mobility interruption time is 0 ms, for both eMBB and URLLC use cases.

1.3 Relevant research projects

The following EU and/or Korean research projects are quite relevant to the 5G-ALLSTAR project, where their outcomes and implications can be used.

Table 1. Research projects relevant to 5G-ALLSTAR

Project Name & Funding Program	Main Outcomes	Inputs to this project
H2020 5GCHAMPION 06/2016-05/2018	Feasibility demonstration of direct access of UE (handheld) via satellite.	Proposals for cellular radio protocols adaptations to operate via satellite. Efficient collaboration between European and Korean partners.
mmMAGIC 07/2015-07/2017 H2020	Suitability/requirements for cellular access and mmWave based back- and fronthaul in the whole frequency range from 10 GHz to 90 GHz. Channel models which can be parametrized from low to high mmWave bands.	Requirements for the 24-28 GHz band.
METIS/METIS II till 04/2015 - 07/2015-07/2017	5G radio access network design, evaluation of 5G radio access network concepts and regulatory and standardization actions.	Proposals for 5G radio access network design, coordination towards regulatory and standardization actions.
5GNOW 01/2012-02/2015 FP7	PHY and MAC layer solutions to enable non orthogonality and asynchronous operations.	Results related to the development/adaptation of waveforms for efficient usage in satellite communications with a particular interest on out-of-band leakage.
Fantastic5G 07/2015-09/2017 H2020	Development of a new multi-service air interface for below 6 GHz through a modular design. Key requirements are flexibility, scalability and efficiency.	Results related to the development/adaptation of waveforms for efficient usage in satellite communications.
FP7 CoRaSat 10/2012-12/2015	Feasibility demonstration of spectrum co-existence between Fixed service (Microwave) and Fixed Satellite Services	Proposals for spectrum sharing principles between cellular and satellite access technologies
FP7 BATS 10/2012-10/2015	Demonstration of IP based multi-link technology involving satellite and terrestrial links.	Proposals for smart routing principles between access links with unbalanced latency

Project Name & Funding Program	Main Outcomes	Inputs to this project
H2020 SAT5G 06/2017-11/2019	Satellite based solutions for 5G Backhaul service	Proposals for smart routing principles between transport network links with unbalanced latency
MHN 03/2012-02/2016 (Korea)	Develop mmWave wireless back-haul (1 Gbit/s support) technology. Feasibility study.	Results related to wireless backhaul and inter-face to core networks.
MHN-Enhanced 03/2016-02/2018 (Korea)	Development of mmWave wireless backhaul up to 5 Gbps at a high speed moving vehicle.	Results related to wireless backhaul and inter-face to core networks with mobility support.
BATS 10/2012-09/2015 FP7	Develop and demonstrate the con-cept of a fully integrated terrestrial and satellite communication sys-tem.	Results related to integration of terrestrial and GEO satellite links; out-of-band interference caused by nonlinearities (for spectrum sharing); input to business models.
MIMOSA 09/2010-12/2012 ESA Artes 5	Study the characteristics of fading from satellite systems taking into account MIMO technology with the goal to design and implement a software model of the satellite MIMO channel.	Input for the 5G-ALLSTAR channel model (measurement results, geometric model for mobile satellite channels)

1.4 Relevant standardisation activities

The 5G-ALLSTAR project focuses on the provision of novel technologies on the device, infra-structure and core network levels to enable multiple access 5G system in the context of shared spectrum in order to support critical communication services.

Based on the recently developed 5G New Radio (NR) Release 15 specification, the 3rd Gen-eration Partnership Project (3GPP) plans to improve several features in the following releases, as seen in Figure 2. The 5G-ALLSTAR consortium partners are mainly involved in NR vehicle-to-everything (V2X) and NR non-terrestrial network (NTN) issues in 3GPP Radio Access Net-work (RAN) and System Architecture (SA) working groups.

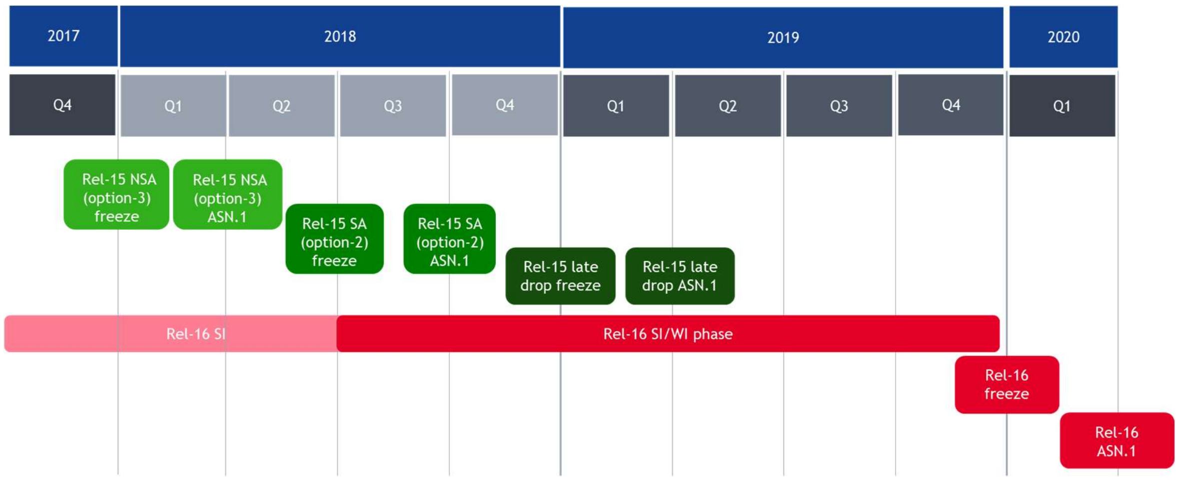

Figure 2: 3GPP 5G NR timeline for Releases 16

In the 3GPP RAN#80 plenary meeting, several new study and work items were approved, as seen in Figure 3. Some of them are closely related to the research in the 5G-ALLSTAR project, as follows:

- NR V2X SI: This study item targets standardization of 5G NR in the area of vehicle ap-plications. Identified use cases are vehicles platooning, extended sensors, advanced driving, and remote driving, and so on. Corresponding SI objectives includes sidelink design, Uu enhancements for advanced V2X (Vehicle to everything) use cases, Uu-based sidelink resource allocation/configuration, RAT/Interface selection for operation, QoS management, and Coexistence. This study item will be led by RAN1, RAN2, and RAN3. The 5G-ALLSTAR project also targets to support vehicle communications via cellular and satellite 5G NR links. Hence, the project results will be helpful in the NR V2X study and specification development.

- NR Non-Terrestrial SI: The scope of this study item is to identify solutions for physical layer control, random access, retransmission schemes from RAN1 perspective, and to study MAC (Medium Access Control), RLC (Radio Link Control), RRC (Radio Resource Control), handover impacts from RAN2 and RAN3 perspective. Since satellite support is the main research topic of 5G-ALLSTAR project, many contributions are expected to this study item. In addition, the study item results will be used for the design of PoC development of the project.

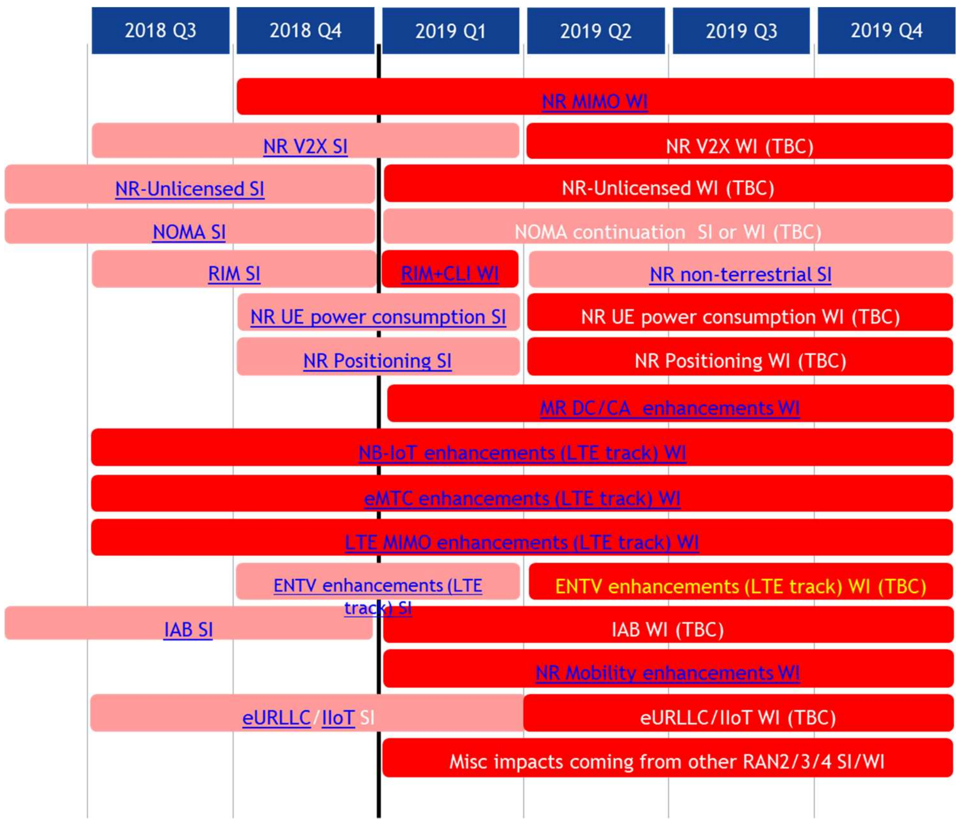

Figure 3: 3GPP Study and work items in release 16

2 5G-ALLSTAR ambitions

2.1 Vision

The development of key technologies for 5G communication networks has now reached a level of maturity that allows for extensive proof-of-concepts (PoCs). Although 5G standardisation has yet to be completed, 5G stakeholders have already converged on a consensus on key technologies, architecture and deployment scenarios for 5G networks. The 5G community now has the objective of transforming 5G use cases, vertical industry needs and ambitions to adopt 5G, into profitable business. The integration of various access technologies is however a prerequisite to the support of 5G new services and to a transparent connectivity across different verticals and multiple use cases. The vision of the 5G-ALLSTAR project is to design, to develop, to evaluate and to test via trials, multiple access based multi-connectivity: combination of satellite and cellular access technologies for support of seamless reliable and ubiquitous broadband services. In order to reach this goal, the following research areas will be explored:

1. Spectrum sharing and interference management. Means for decreasing out-of-band leakage of 5G waveforms will be investigated.
2. Multi-connectivity between heterogeneous access links. Link aggregation for data rate increase and traffic switching for improving reliability (e.g., fast radio link failure recovery) will be studied. Algorithm design and system integration will also be done.
3. Inter RAT spectrum sharing through Radio Resource Management. A new concept will be researched based on a dynamic coupling of both cellular and satellite access at radio resource management to ensure safe coexistence of both systems.
4. Testbed prototyping for 5G: 5G-ALLSTAR aims at validating system interoperability to supply global connectivity and to support mission critical applications of interest in both European and Korean regions. For this purpose, 5G-ALLSTAR will develop several PoCs implementing a set of technologies, for validation and demonstration, in heterogeneous real setup:
    - mmWave access in 5G cellular, in the aim of providing broadband and low-latency 5G services;
    - new radio (NR) based feasibility of satellite access for delivering broadband and reliable 5G services;
    - multi-connectivity support based on cellular and satellite access;
    - spectrum sharing between cellular and satellite access

5G-ALLSTAR not only aims at demonstrating technical feasibility of 5G NR multiple-access, the project will also actively contribute to global 5G standardization including 3GPP and ETSI focusing on multi-RAT interoperability and New Radio based satellite access and to the creation of a cross-regional lasting synergy for 5G research, innovation and commercialization through value proposition assessment for vertical industries.

2.2 Scope

5G networks are expected to provide combinations of diverse services/applications using interworking heterogeneous radio access technologies (RATs). The RATs include cellular-based access such as 5G NR, 4G LTE, and WLAN, and non-terrestrial access such as satellite, tightly interworking and coupled with the design of proper **resource sharing** algorithms.

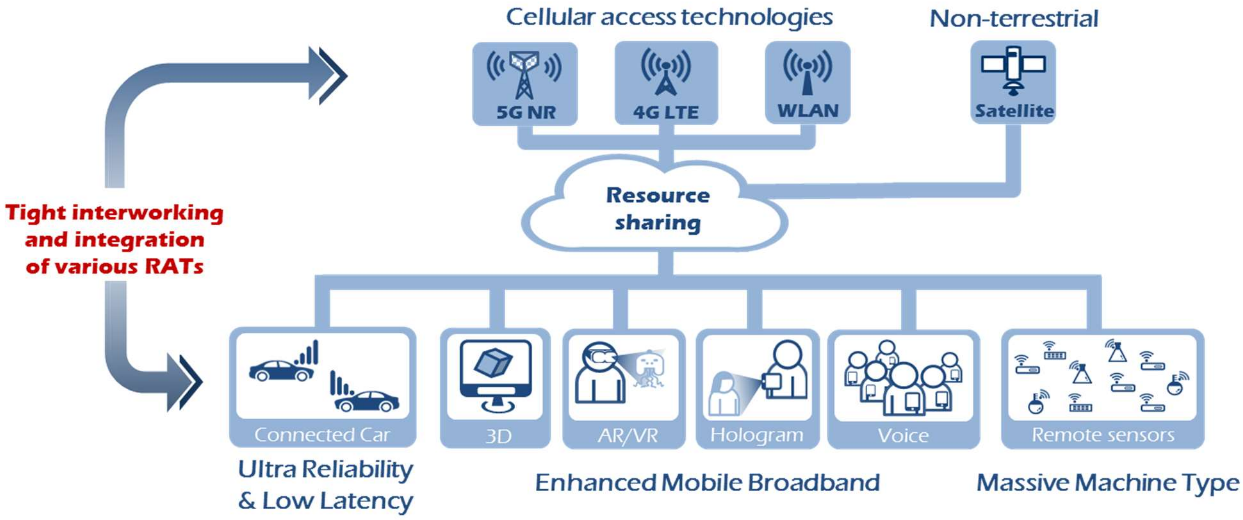

Figure 4: Overview of 5G radio access

The 5G-ALLSTAR project will analyse, design and implement **multi-RAT traffic steering algorithms** which will decide about the portion of the **traffic steering** that will be assigned to the available RATs according to their performances. These algorithms will be:

- **cognitive** (i.e. context-aware) since traffic steering algorithms are expected to take their decisions on the basis of the present performance in terms of the KPIs defined for the various use cases (e.g., latency, available bandwidth, link availability, etc.) measured in the candidate RATs; thus proper sensing (i.e. monitoring) functionalities able to provide real-time measurements on the present RAT status should be foreseen;
- **personalized** since traffic steering algorithms are expected to make their decisions aiming at satisfying the specific end-to-end Service/Application Requirements as well as the personalized QoE Requirements (these last being reduced by an ad-hoc **Personalization System**);
- **dynamic** since traffic steering algorithms are expected to vary in real-time their decisions depending on the present RAT status and on the dynamics of the traffic generated by the in-progress applications to be supported.

The decisions of the traffic steering algorithms will be made by adopting methodologies such as optimization techniques and learning algorithms. Such decisions will be investigated for being in line with link aggregation (i.e. the use of more than one RAT to support a specific flow aiming, for instance, to increase the flow throughput), traffic splitting for each flow among selected RATs according to proper percentages, triggering of vertical (inter-RAT) handovers interference-driven and/or traffic-driven, QoS requirements to be met by each underlying RAT for each specific flow and so on. The multi-connectivity principle is illustrated in Figure 5 and Figure 6.

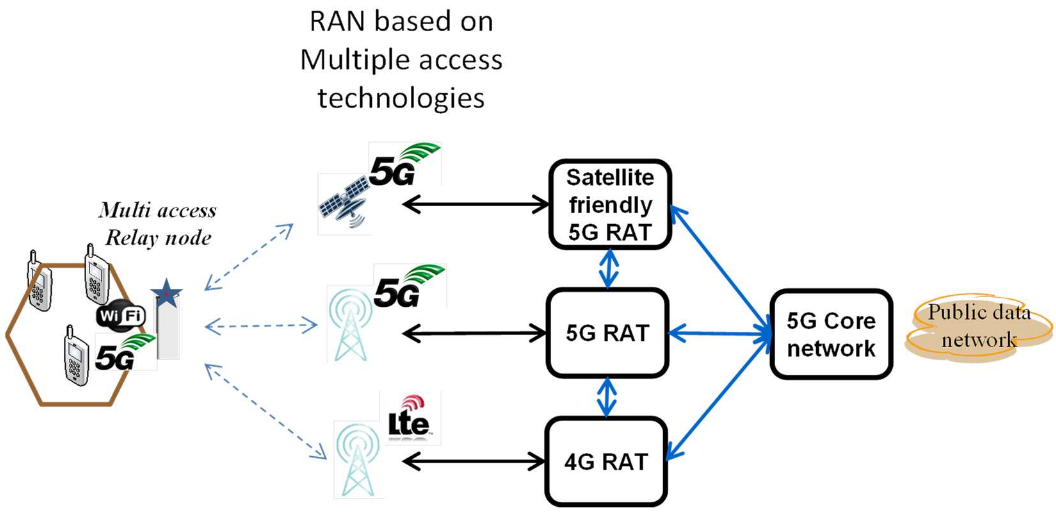

Figure 5: Multiple RATs in 5G context for robust communications

For example, Figure 5 shows a scenario in which there is interworking between cellular and satellite links. This can be used, for instance, to provide improved reliability, i.e., if one of the links fails the other link will be still available, thus enabling robust and continuous service. So, when an UE goes outside the terrestrial cellular coverage, it can still be supported by the satellite link, enabling continuous asset tracking and logistics. Multi connectivity by the combination of cellular and satellite links is particularly effective for public safety applications. Even though a cellular link fails due to a disaster event, satellite link will support essential wireless services.

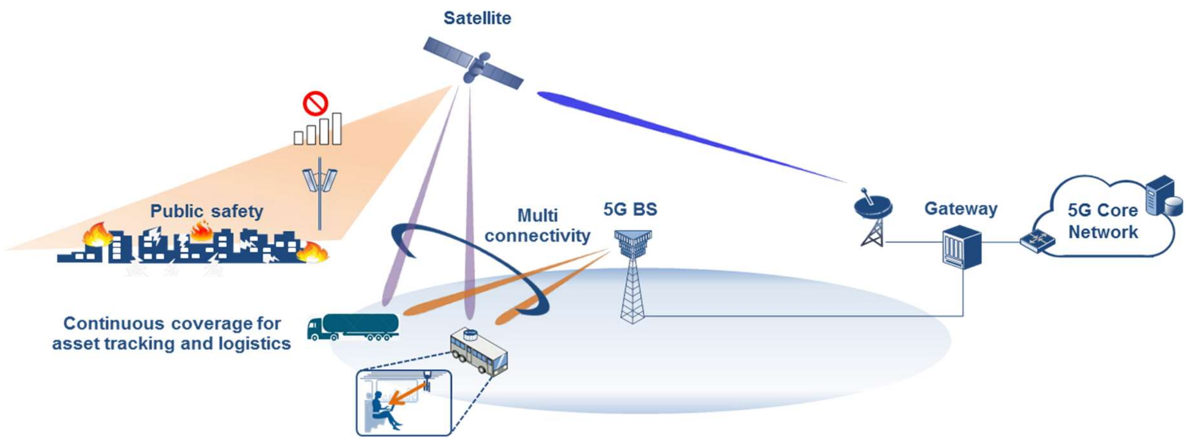

Figure 6: Multi connectivity applications and deployment scenarios

Overall, the resource sharing algorithms to be developed in the 5G-ALLSTAR project aim at maximizing resource exploitation of the integrated multi-RAT network, while satisfying the end-to-end Service/Application Requirement and the Personalized QoE Requirements of the in-progress applications. Oversimplifying, **the multi connectivity algorithms dynamically decide** (based on the status of the available RATs, on the specific end-to-end Service/Applications Requirements and on the Personalized QoE Requirements):

(i) the traffic flows (each flow can aggregate the traffic generated by several applications having similar QoS/QoE requirements) to be supported by the integrated multi-RAT network;

(ii) the most appropriate RAT(s) to support each flow (in case more than one RAT is selected, these algorithms have even to specify the flow portion to be supported by each of the selected RAT, i.e., traffic splitting) as well as the possible convenience of triggering inter-RAT handovers;

(iii) the QoS RAT requirements associated with each flow (i.e., the QoS RAT requirements that the selected supporting RAT(s) has/have to be met while supporting the flow in question).

Then, the spectrum sharing functionalities, managed by the RATs in a coordinate fashion, **aim at dynamically optimizing the usage of the available spectrum** in order to carry the flows which the multi connectivity has assigned to the RAT in question, by respecting the associated QoS flow requirements. **The 5G-ALLSTAR project will address several use cases such as targeted 5G verticals, for instance, in the area of transport (maritime, railway, bus) and public safety/emergency, by taking into account the related specific Service/Application Requirements, thus showing a highly interdisciplinary nature.** Participants with various expertise and background will cooperate during the project including system design, algorithm development, modem implementation, and testbed development. These interdisciplinary activities will be carefully managed in the 5G-ALLSTAR consortium. The technology readiness level (TRL) of the 5G-ALLSTAR project will be 4-6.

2.3 Goals

The 5G-ALLSTAR project aims to demonstrate novel 5G technologies for 5G cellular and satellite communications and multiple access comprising the cellular and satellite links, which is a key to ensure the availability of 5G performances and worldwide continuity of services to support not only broadband applications but also critical applications. In the project, the developed key enabling technologies will be implemented either on EU testbeds or on KR testbeds to validate end-to-end system performances encompassing innovative 5G radio-access, core-network and satellite technologies. In addition, the 5G-ALLSTAR plans to give a PoC demonstration of global interoperability service between the European and Korean trial testbeds during a relevant key event (e.g., a major sporting event like Roland Garros). More specifically, the 5G-ALLSTAR targets the following goals:

1. Develop key enabling technologies providing 5G performances including
   - ✓ User experienced data rate of minimum 50 Mbit/s in areas beyond dense urban areas in relation to 5GPPP targets
   - ✓ Average spectral efficiency of 3.3 bit/s/Hz in DL and 1.6 bit/s/Hz in UL in rural areas
   - ✓ Low perceived latency of 10 ms for high quality of experience over multiple access with unbalanced latency between the access links.
     i. For latency-sensitive traffic, user-plane latency of < 10 ms should be satisfied
   - ✓ Reliability of 99.999%
     i. Success probability of transmitting a layer 2/3 packet within a maximum time
2. Contribution to 5G global standardization on the multi connectivity, the multiple-access scheme and satellite friendly New Radio features as part of 3GPP release 16 and beyond
3. Demonstrate the affordability of multiple-access scheme for mission critical applications and for Bridging the Digital Divide through Business case assessment
4. Creating a long lasting EU-Korea synergy for 5G research, innovation and commercialization

5. Analyse and validate optimal spectrum sharing and interoperability techniques between cellular and satellite access technologies controlled by the same 5G radio access network.

In addition, considering the H2020 EUK-02-2018 call targets and the technical challenges of 5GPPP phase 3, the PoC of the 5G-ALLSTAR project has the following overall objectives:

1. Implement a 5G cellular mmWave radio access for providing broadband (50 Mbit/s user experience) and low-latency (10 ms) 5G services. 5G-ALLSTAR will deliver implementation, integration, interoperability and testing of 5G mmWave cellular access components in the joint PoC system across Europe and Korea.
2. Demonstrate feasibility of New Radio based mmWave satellite access for providing broadband and reliable 5G services. 5G-ALLSTAR PoC will verify that the defined 5G satellite access architecture as currently initially developed in the standardization organization 3GPP is working and that the various challenges coming from the mobility of satellite and propagation delay can be properly resolved.
3. Implement multi-connectivity support and integrate 5G cellular access and satellite access systems along with its function testing. 5G-ALLSTAR will conduct field trials to validate the hybrid PoC system operated through the interface for aggregation.
4. Demonstrate the PoC of multiple access systems in shared spectrum context supporting multi-connectivity at a key event. It will be verified that all specified service scenarios run free of errors. KPIs like user-experience data rate and latency will be evaluated.
5. Enable cellular and satellite access to share the same spectrum. 5G-ALLSTAR will provide the design and implementation of spectrum harmonization among the different access technologies. 5G-ALLSTAR will also partake the interference between access technologies, e.g., between cellular and satellite links, between cellular links, and so on.

Finally, the project will be constantly disseminating the technical achievements through various channels. The results will be published in international journals and conference presentations, and a special session will be organized at a key event to allow for stronger and long-term impact. We will also contribute to global 5G standardization. The 5G-ALLSTAR participants will contribute to the 5G standardization mainly in 3GPP and possibly in ETSI, focusing on multi-RAT interoperability. These efforts will be coordinated across Korean and European partners in order to approach standardization in a cooperative way, e.g. by proposing new study/work items. We firmly believe that all these efforts and achievements will create a long-lasting synergy for 5G research, innovation and commercialization. This includes:

1. Exchange of best practice and lesson learned in European and Korean prototyping, lab trials and proof of concept,
2. Joint development of solutions, techniques and components, architecture, interfaces and specific technological solutions that may have a direct impact on future business,
3. Establishing mutual understanding and trust among European and Korean academics, industry, telecom operators to promote future collaborations in 5G and future networks markets.

3 5G-ALLSTAR use cases and KPIs

3.1 Potential use cases analysis grid and selection for 5G-ALLSTAR

This section mainly investigates and identifies the various potential use cases and associated KPIs that receive benefits from the technologies to be developed in the 5G-ALLSTAR project. It also provides a preliminary techno-economic analysis on the use cases and KPIs targeting vertical markets, which is expected to give valuable insights into developing potential business models/markets for vertical stakeholders.

3.1.1 3GPP SA1 SMARTER use cases and applicability

3GPP TR 22.891 [1] was produced within the 3GPP SA1 Working Group and defines 74 different Use Cases, along with their service and operational requirements (see Table 2). Using [1] as input, the 3GPP SA1 Working Group have categorized these into four different use case groups named Services and Markets Technology Enablers (SMARTER) (see Figure 7 and Table 4):

- Massive Internet of Things
- Critical Communications
- Enhanced Mobile Broadband and
- Network Operation.

SatCom can serve many of the Use Cases identified in [1] and in particular, the 5G Use Case "5G Connectivity Using Satellites" (§5.72 of [1]) (see Table 3).

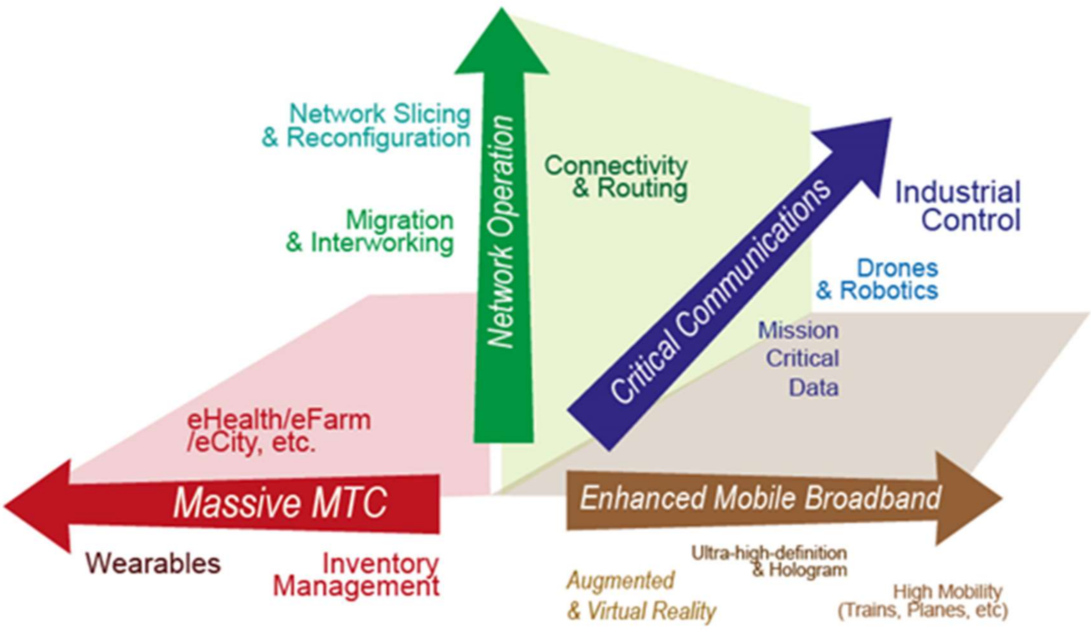

Figure 7. 3GPP Services and Markets Technology Enablers

The applicability of 3GPP SA1 5G Use cases, to 5G-ALLSTAR is discussed in Table 2.

Table 2. 5G Use cases according to TR 22.891 [1]

5	Use Case titles as defined in TR 22.891[1]	Applicability to 5G-ALLSTAR
5.1	Ultra-reliable communications	No, but reliability can be assessed for other services (e.g. eMBB)
5.2	Network Slicing	No, but FFS
5.3	Lifeline communications / natural disaster	No
5.4	Migration of Services from earlier generations	No
5.5	Mobile broadband for indoor scenario	No
5.6	Mobile broadband for hotspots scenario	Yes
5.7	On-demand Networking	No
5.8	Flexible application traffic routing	Yes
5.9	Flexibility and scalability	Yes
5.10	Mobile broadband services with seamless wide-area coverage	No. This Use case proposes a universal coverage.
5.11	Virtual presence	No
5.12	Connectivity for drones	No
5.13	Industrial Control	No
5.14	Tactile Internet	No
5.15	Localized real-time control	No
5.16	Coexistence with legacy systems	No
5.17	Extreme real-time communications and the tactile internet	No
5.18	Remote Control	No
5.19	Light weight device configuration	No
5.20	Wide area sensor monitoring and event driven alarms	No
5.21	IoT Device Initialization	No
5.22	Subscription security credentials update	No
5.23	Access from less trusted networks	No
5.24	Bio-connectivity	No
5.25	Wearable Device Communication	No
5.26	Best Connection per Traffic Type	Yes
5.27	Multi Access network integration	Yes
5.28	Multiple RAT connectivity and RAT selection	Yes
5.29	Higher User Mobility	Yes
5.30	Connectivity Everywhere	Yes
5.31	Temporary Service for Users of Other Operators in Emergency Case	Yes
5.32	Improvement of network capabilities for vehicular case	No
5.33	Connected vehicles	Yes (V2X services)
5.34	Mobility on demand	Yes: mobility (on demand) should be provided only to those devices and services that need it, not for all devices.
5.35	Context Awareness to support network elasticity	Yes
5.36	In-network and device caching	No, but relevant for Video streaming, generally speaking
5.37	Routing path optimization when server changes	No

5	Use Case titles as defined in TR 22.891[1]	Applicability to 5G-ALLSTAR
5.38	ICN (Information Centric Networks) Based Content Retrieval	No
5.39	Wireless Briefcase	No
5.40	Devices with variable data	No
5.41	Domestic Home Monitoring	No
5.42	Low mobility devices	No
5.43	Materials and inventory management and location tracking	No
5.44	Cloud Robotics	No
5.45	Industrial Factory Automation	No
5.46	Industrial Process Automation	No
5.47	SMARTER Service Continuity	Yes
5.48	Provision of essential services for very low-ARPU areas (Average Revenue Per User)	No
5.49	Network capability exposure	No
5.50	Low-delay speech and video coding	No
5.51	Network enhancements to support scalability and automation	Yes
5.52	Wireless Self-Backhauling	Yes
5.53	Vehicular Internet & Infotainment	Yes
5.54	Local UAV (Unmanned aerial vehicles) Collaboration	No
5.55	High Accuracy Enhanced Positioning (ePositioning)	No
5.56	Broadcasting Support	No
5.57	Ad-Hoc Broadcasting	No
5.58	Green Radio	No
5.59	Massive Internet of Things M2M and device identification	No
5.60	Light weight device communication	No
5.61	Fronthaul / Backhaul Network Sharing (sharing of fronthaul / backhaul network resources by several operators)	No
5.62	Device Theft Preventions / Stolen Device Recovery	No
5.63	Diversified Connectivity (A user can be connected via several devices)	No
5.64	User Multi-Connectivity across operators	No
5.65	Moving ambulance and bio-connectivity	No
5.66	Broadband Direct Air to Ground Communications (DA2GC)	No
5.67	Wearable Device Charging	No
5.68	Telemedicine Support	No
5.69	Network Slicing – Roaming	No, but FFS.
5.70	Broadcast/Multicast Services using a Dedicated Radio Carrier	Yes
5.71	Wireless Local Loop	No
5.72	5G Connectivity Using Satellites	Yes, in part.
5.73	Delivery Assurance for High Latency Tolerant Services	Yes
5.74	Priority, QoS and Policy Control	Yes

The applicability of SA1 SMARTER 5G Connectivity Using Satellites use cases to 5G-ALLSTAR is discussed in Table 3.

Table 3. 5G Connectivity Using Satellites according to TR 22.891 §5.72 [1] and applicability to 5G-ALLSTAR

List of Use cases using satellite according to §5.72 of [1]	Targeted markets	Applicability to 5G-ALLSTAR
Areas where it is not possible to deploy terrestrial towers: For example, maritime services, coverage on lakes, islands, mountains or other recreational areas that can only be covered by the satellites	Public, Transport	No
Disaster relief: During natural disasters or other unforeseen events that entirely disable the terrestrial network, satellites are the only option.	Public Safety	No
Emergency response: Besides wide scale natural disasters, there are specific emergency situations in areas where there is no terrestrial coverage. For example a public safety uses case of an accident in a power plant.	Public Safety	No
Secondary/backup connection (limited in capability) in the event of the primary connection failure or for connected cars	5G verticals, Network operation	No
Connectivity in rural areas that are hard to cover using terrestrial networks	Public	Yes, but extended to urban or rural areas where only very low throughputs are provided.
Connectivity for remotely deployed sensors, e.g. farms, substations, gas pipelines, digital signage, remote road alerts, etc.	5G Verticals	No
Low bit-rate broadcast services: Satellites can broadcast wide area emergency messages at a more efficient rate than terrestrial networks.	Public	Yes

The SMARTER as defined by 3GPP SA1, are reported into 4 Technical Reports [2], as described in Table 4. Their applicability to 5G-ALLSTAR is discussed in Table 4.

Table 4. 3GPP SA1 Reports related to SMARTER and applicability to 5G-ALLSTAR

3GPP Document	Description	Applicability to 5G-ALLSTAR
TR 22.861: FS_SMARTER – massive Internet of Things (mIoT)	Massive Internet of Things focuses on Use Cases with massive number of devices (e.g., sensors and wearables). This group of Use Cases is particularly relevant to the new vertical services, such as smart home and city, smart utilities, e-Health, and smart wearables. Note that mIoT is supported by mMTC.	No
TR 22.862: FS_SMARTER – Critical Communications	The main areas where improvements are needed for Critical Communications are latency, reliability, and availability to enable, for example, industrial control applications and tactile Internet. These requirements can be met with an improved radio interface, optimized architecture, and dedicated core and radio resources.	No
TR 22.863: FS_SMARTER – enhanced Mobile Broadband (eMBB)	Enhanced Mobile Broadband includes a number of different Use Case families related to higher data rates, higher density, deployment and coverage, higher user mobility, devices with highly variable user data rates, fixed mobile convergence, and small-cell deployments.	Yes
TR 22.864: FS_SMARTER – Network Operation (NEO):	The Use Case group Network Operation addresses the functional system requirements, including aspects such as: flexible functions and capabilities, new value creation, migration and interworking, optimizations and enhancements, and security.	Yes.

The applicability of SA1 SMARTER eMBB Use cases (3GPP TR 22.863) to 5G-ALLSTAR is discussed in Table 5 while the applicability of SA1 SMARTER Network Operation Use Cases (3GPP TR 22.864) is discussed in Table 6.

Table 5. SA1 SMARTER eMBB Use Cases series and applicability to 5G-ALLSTAR

Use case	Description	Applicability to 5G-ALLSTAR
Higher Data Rates (TR 22.863 [8] , §5.1	This Use Case series focus on identifying key Scenarios from which eMBB primary data rate requirements for peak, experienced, downlink, uplink, etc. data rates can be derived, as well as associated requirements pertaining to latency when applicable with UEs relative speed to ground up to 10 km/h (pedestrian).	Yes
Higher Density (TR 22.863 [8], §5.2	This Use Case series cover Scenarios with system requirement for the transport of high volume of data traffic per area (traffic density) or transport of data for high number of connections (devices density or connection density) with UEs relative speed to ground up to 60 km/h (pedestrian or users moving on urban vehicle).	Yes. The project will address how to serve more devices in a given area, thanks to Multi-access and interference mitigation.
Deployment and Coverage (TR 22.863 [8], §5.3	This Use Case series cover Scenarios with system requirement considering the deployment and coverage scenario e.g. indoor/outdoor, local area connectivity, wide area connectivity, with UEs relative speed to ground up to [120] km/h.	Yes but with restrictions: Local Area Connectivity is supported by the Cellular Access and Wide Area Connectivity, by the Satellite Access. This UE speed is not a target.
Higher User Mobility (TR 22.863 [8], §5.4)	This Use Case series focus on identifying key Scenarios from which eMBB mobility requirements can be derived, with UEs relative speed to ground up to 1000 km/h. It supports eMBB for rapidly moving devices, for example the provision of internet to road vehicles / trains / airplanes and its use for on-board entertainment and infotainment.	No
Area Devices with highly variable data rates (TR 22.863 [8], §5.5):	This Use Case series focus on identifying key Scenarios from which eMBB requirements can be derived, for UEs having multiple applications which exchange small amount of data and large amount of data.	No
Fixed Mobile Convergence (TR 22.863 [8], §5.6):	This Use Case family focuses on identifying key Scenarios for leveraging the 5G network characteristics defined in TR22.863 SMARTER eMBB (high data rates, low latency, high density, wide area coverage & low mobility) and TR22.864 SMARTER NEO (network slicing, efficient data plane & content delivery, broadcast/multicast, policy control & charging, high availability and security) to enable combined use of fixed broadband (e.g. FTTx/xDSL) access and Next Generation Radio access network.	No
Femtocell deployments (TR 22.863 [8], §5.7	This Use Case series focus on identifying key Scenarios for leveraging the 5G network characteristics defined in TR22.863 SMARTER eMBB (high data rates, low latency, high density, wide area coverage & low mobility) and TR22.864 SMARTER NEO (network slicing, efficient data plane & content delivery, broadcast/multicast, policy control & charging, high availability and security) to enable use of fixed broadband (e.g. FTTx/xDSL) access and Next Generation Radio access network for femtocell deployments. The overall aim is to deliver a seamless user experience to end users accessing operator services across any access network, including macrocellular as well as femtocell access over fixed broadband networks.	No

Table 6. SA1 SMARTER Network Operation Use Cases series and applicability to 5G-ALLSTAR

Use case	Description	Applicability to 5G-ALLSTAR
System flexibility (TR 22.864 [9] ,	This series cover the Use Cases for building the network in a flexible manner per diverse scenario demand, e.g., slicing the	Yes, but with restrictions:

Use case	Description	Applicability to 5G-ALLSTAR
§5.1)	network for variant market segments and verticals.	-flexibility may be based on coordinated and dynamic cellular / satellite Radio resource Managers (RRMs). These topics are relevant. -Network slicing: No. It is FFS.
Scalability (TR 22.864 [9], §5.2)	This series cover the Use Cases for enabling the operators to support an elastic and scalable network.	Yes. -scalability may come from the use of Multi-access and dynamic RRM. These topics are relevant.
Mobility support (TR 22.864 [9], §5.3)	This series cover the Use Cases for optimizing use of mobility management for diverse scenarios.	Yes.
Efficient content delivery (TR 22.864 [9], §5.4)	This series cover the Uses Cases to support efficient content delivery.	No. For example: in-network caching mechanisms via broadcast.
Self-backhauling (TR 22.864 [9], §5.5)	This series cover the Use Cases for wireless self-backhauling.	No. NR RAN backhauling, combined to cellular / satellite multi-access is already addressed.
Access (TR 22.864 [9], §5.6)	This series cover access related Use Cases including selection of the most appropriate access for user traffic.	Yes
Migration and interworking (TR 22.864 [9], §5.7)	This series cover the coexistence of the FS_SMARTER system with the legacy systems and the migration of services from early generations.	No
Security (TR 22.864 [9], §5.8)	This series cover security requirements that are common to all building blocks as well as the ones that are specific to network operation.	No

3.1.2 3GPP RAN use cases according to 3GPP TR 38.811 and applicability

3GPP TR 38.811 [10] was produced within the 3GPP RAN1 Working Group and defines different Use Cases, categorized into:

- 3GPP RAN 5G use cases for Satellite access networks
- 3GPP RAN 5G use cases for Aerial access networks

The Aerial access networks are not addressed in 5G-ALLSTAR.

The tables below respectively identify for each of the 5G service enablers, the use cases wherein Non-Terrestrial Network components have a role to play.

- 5G service enablers refer to eMBB (enhanced Mobile Broadband), and mMTC (massive Machine Type Communications).
- 5G use cases correspond to the interactions between a stakeholder (user, operator, service provider) and the 5G system, to achieve a specific goal.
- The services enabled by the Non-Terrestrial Network component in the 5G system to support the use case.

- 3GPP reference documents are provided in which the use cases are mentioned.

We have added the targeted markets, to this classification, in this section. The applicability to 5G-ALLSTAR is also discussed.

For the Table 7, the 5G service enabler is eMBB.

Table 7. 3GPP 5G RAN eMBB use cases for Satellite access networks and applicability to 5G-ALLSTAR

5G Use case	Description	Satellite service	Targeted Market	3GPP references	Applicability to 5G-ALLSTAR
Multi connectivity	Split into several ones.		Public	TR 22.864, TR 22.863, TS 22.261	The use case has been split into several ones.
MC1	Users in underserved areas (home or in Small Offices, Big events in ad-hoc built-up facilities) are connected to the 5G network via multiple network technologies and benefit from 50 Mbps+.	Broadband connectivity to cells or relay node in underserved areas in combination with terrestrial wireless/cellular or wire line access featuring limited user throughput.			Yes with restrictions: 5G-ALLSTAR focuses on cellular /satellite Multi-access, not any wireless access network. 50 Mbps is for DL.
MC2: extension of MC1 for Handset UE	Users in underserved areas (home or in Small Offices, Big events in ad-hoc built-up facilities) are connected to the 5G network via multiple network technologies.	Connectivity to UE in underserved areas in combination with terrestrial wireless/cellular or wire line access featuring limited user throughput.			Yes with restrictions : 5G-ALLSTAR focuses on cellular /satellite Multi-access. The throughput of the UE is lower.
MC3	Delay sensitive traffic may be routed over short latency links while less delay sensitive traffic can be routed over the long latency links.				Yes
Fixed cell connectivity	Split into several ones.			TR 22.863,	No
FCC1	Users in isolated villages access 5G services and benefit from 50 Mbps+.	Broadband connectivity between the core network and the cells in un-served areas (isolated areas).	Public		No
FCC2	Industry premises (Mining, off shore platform) access 5G services and benefit from 50 Mbps+.	Broadband connectivity between the core network and the cells in un-served areas (isolated areas).	5G verticals		No
Mobile cell connectivity	Split into several ones.		Transport	TR 22.863, TS 22.261	No

5G Use case	Description	Satellite service	Targeted Market	3GPP references	Applicability to 5G-ALLSTAR
MCC1	Passengers on board vessels access 5G services and benefit from 50 Mbps+.	Broadband connectivity between the core network and the cells on board a moving platform.			No
MCC2	Passengers on aircraft access 5G services and benefit from 50 Mbps+.	Broadband connectivity between the core network and the cells on board a moving platform.			No
Extension to bus, as moving platform: MCC3 (not in TR 38.811)	Passengers on bus access 5G services and benefit from 50 Mbps+.	Broadband connectivity between the core network and the cells on board a moving platform.			Yes
Network resilience	Some critical network links requires high availability which can be achieved through the aggregation of two or several network connections in parallel. The intent is to prevent complete network connection outage.	Secondary/backup connection (although potentially limited in capability compared to the primary network connection).	Not a market but Network Operation	TR 22.862, TS 22.261	Yes, in a multi-access context. Each access protects the other one. The wording “protected link” is more appropriate than “secondary link”, in a SATCOM context.
Trunking	A network operator may want to deploy or restore (disaster relief) 5G service in an isolated area (not connected to public data network). A network operator may want to interconnect various 5G local access network islands not otherwise connected	Broadband connectivity between the public data network and a mobile network anchor point or between the anchor points of two mobile networks.	Not a market but Network Operation	TR 22.863	No Interwork between 2 CN is not related to RAN.

5G Use case	Description	Satellite service	Targeted Market	3GPP references	Applicability to 5G-ALLSTAR
Edge network Delivery	The intent is to off load popular content from the mobile network infrastructure (especially at backhaul level). Media and entertainment content such as live broadcasts, ad-hoc broadcast/multicast streams, group communications, Mobile Edge Computing's Virtual Network Function updates are transmitted in multicast mode to a RAN equipment at the network edge where it may be stored in a local cache or further distributed to the User Equipment. The intent is to off load popular content from the mobile network infrastructure (especially at backhaul level).	Broadcast channel to support Multicast delivery to 5G network edges.	Not a market but Network Operation	TR 22.864, TS 22.261	Not a Radio Resource Management issue but relevant at system level. Close to Efficient Content Delivery SMARTER Network Operation use case as defined by SA2 (TR 22.864 [9], §5.4)
Mobile cell hybrid connectivity	Split into several ones. Passengers on board public transport vehicles (e.g. high speed/regular trains, buses, river boats) access reliable 5G services. They are served by a base station which is connected by a hybrid cellular/satellite connection. The cellular connectivity may be intermittent and/or support limited user throughput.	Broadband connectivity combined with terrestrial cellular access to connect a cell/group of cells or relay node(s) on board moving platforms (Indirect UE Access case).	Public, Transport	TR 22.863, TR 22.862, TS 22.261	Yes
MCH1	The cellular connectivity is intermittent.				Yes. It is very close to the "Network resilience" use case. The UE should switch to the available access.
MCH2	The cellular connectivity is permanent.				Yes. It is very close to the "Multi-Access connectivity" use case.
Direct To Node broadcast	Split into several ones.		Public, Transport	TR 22.864, TS 22.261	No
DNC1	TV or multimedia service delivery to home premises	Broadcast/Multicast service to access points in homes.	Public		No

5G Use case	Description	Satellite service	Targeted Market	3GPP references	Applicability to 5G-ALLSTAR
DNC2	TV or multimedia service delivery to on board moving platform	Broadcast/Multicast service to access points on board moving platforms.	Transport		Yes
Direct to mobile broadcast	Split into several ones.			TR 22.864, TR 22.862, TS 22.261	No
DMB1	Public safety authorities want to be able to instantaneously alert/warn the public (or specific subsets thereof) of catastrophic events and provide guidance to them during the disaster relief while the terrestrial network might be down.	Broadcast/Multicast service directly to User Equipment whether handheld or vehicle mounted.	Public safety		No
DMB2	Media and entertainment industry can provide entertainment services in vehicles (cars, buses, trucks).	Broadcast/Multicast service directly to User Equipment whether handheld or vehicle mounted.	Infotainment		No
Wide area public safety	Emergency responders, such as police, fire brigade and medical personnel can exchange messaging and voice services in outdoor conditions anywhere they are and achieve continuity of service whatever mobility scenarios.	Access to User Equipment (handset or vehicle mounted).	Public safety,	TR 22.862, TS 22.261	Yes Applicable for multi-connectivity but public safety KPIs might be too stringent to be demonstrated on 5G All-Star)
Local area public safety	Emergency responders, such as police, fire brigade, and medical personnel can set up a tactical cell wherever they need to operate. This cell can be connected to the 5G system via satellite to exchange data, voice and video based services between the public safety users within a tactical cell or with the remote coordination centre.	Broadband connectivity between the core network and the tactical cells.	Public safety	TR 22.862, TS 22.261	Yes Applicable for multi-connectivity but public safety KPIs might be too stringent to be demonstrated on 5G All-Star)
Hot spot on demand	Users in un/underserved areas (big events) are connected to the 5G network and benefit from 50 Mbps+.	Broadband connectivity to cells or relay node in un/underserved areas.	Public	TR 22.863, TS 22.261	No

5G Use case	Description	Satellite service	Targeted Market	3GPP references	Applicability to 5G-ALLSTAR
Regional area public safety	Emergency responders, such as police, fire brigades, and medical personnel can exchange messaging, voice and video services in indoor/outdoor conditions anywhere they are and whatever mobility scenarios.	Access to User Equipment (handset or vehicle mounted). Ad-hoc connectivity between two cells	Public safety	TR 22.862, TS 22.261	Yes
Fixed cell connectivity	Users in isolated villages or industry premises (Mining, off shore platform) access 5G services and benefit from 50 Mbps+.	Broadband connectivity between the core network and the cells in un-served areas (isolated areas).	Public, 5G Verticals	TS 22.261, TR 22.863,	No

For the Table 8 below, the 5G service enabler is mMTC.

Table 8 5G mMTC use cases for Satellite access networks and applicability to 5G-ALLSTAR

5G Use case	Description	Satellite service	Targeted Market	3GPP references	Applicability to 5G-ALLSTAR
Wide area IoT service	Global continuity of service for telematic applications based on a group of sensors/actuators (IoT devices, battery activated or not) scattered over or moving around a wide area and reporting information to or controlled by a central server.	Connectivity between IoT devices (battery activated sensors/actuators or not) and spaceborne platform. Continuity of service across spaceborne platforms and terrestrial base stations is needed.	5G Verticals	TR 22.861, TR 22.864, TR 22.862, TS 22.261	No
Local area IoT service	Group of sensors that collect local information, connect to each other and report to a central point. The central point may also command a set of actuators to take local actions such as on-off activities or far more complex actions. The sensors/actuators served by a local area network may be located in a smart grid subsystem (Advanced Metering) or on board a moving platform (e.g. container on board a vessel, a truck or a train).	Connectivity between mobile core network and base station serving IoT devices in a cell or a group of cells.	5G Verticals	TR 22.863, TS 22.261	No

3.2 Use case series 1: Multi-connectivity

3.2.1 Overview, use cases categories and KPIs

The 5G RAN will lead to the democratization of TelCo innovations because of its highly efficient and low cost transport network (5GPPP, 2018). In this sense, 5G satellite connectivity allows the emergence of scenarios where satellites enable direct and complementary connections.

Among the possible use cases categories, already explored in literature (see for example Sat5G project), one can find:

- Backhauling and tower feed, where satellites are used to complement the existing infrastructure;
- Mobile backhauling, where satellites complement or directly support communications on moving platforms such as trains, ships, planes or cars;
- Hybrid, where satellites complement existing terrestrial broadband services.

The use cases aim at developing and demonstrated a set of technologies enabling tight interworking and integration between cellular and satellite Radio Access Networks. They address multiple access systems in shared spectrum through Radio Resource Management, in the context of multi-connectivity support.

In order to define use cases categories and relevant multi-connectivity use cases for 5G-ALLSTAR, the following 3GPP documents have been analysed:

- 5G Use cases according to TR 22.891 [1]
- 5G Connectivity Using Satellites according to TR 22.891 §5.72 [1]
- 3GPP SA1 SMARTER eMBB Use Cases series [8]
- 3GPP SA1 SMARTER Network Operation Use Cases series [9]
- 3GPP 5G RAN eMBB use cases for Satellite access networks wrt to TR 38.811 [10] with extensions to support multiple access, when needed.
- 3GPP TR 23.793, Study on Access Traffic Steering, Switching and Splitting support in the 5G system architecture", Release 16 [12]

Several use case categories are foreseen, below, mapped to the multi-connectivity use cases while scenarios are discussed in section 4.1.

Table 9 Use case categories mapped to the multi-connectivity use cases

Use case category	Use case	Use cases series 1 of 5G-ALLSTAR	Examples of supported services
Backhauling for eMBB and narrowband services	Providing efficient multicast, broadcast services delivery to : - fixed platforms (such as small home / small office) - moving platforms.	UC1-2/UC1-3: Simultaneous Video TV streaming and other stringent QoS services delivery to UE / a platform UC1-3/UC1-4: Simultaneous Satellite Over The Air services and other stringent QoS services delivery to UE / a platform	Messaging, Data transfer, Voice, Video.
Communication on the move, for eMBB and narrowband services	Multi-connectivity cellular / satellite to serve moving platforms such as high speed trains/buses and other road vehicles, to ensure service reliability.	UC1-2/UC1-3: Simultaneous Video TV streaming and other stringent QoS services delivery to UE / a platform (moving cases) UC1-3/UC1-4: Simultaneous Satellite Over The Air services and other stringent QoS services delivery to UE / a platform (moving cases)	Messaging, Data transfer, Voice.
Hybrid Multi-play, for eMBB and narrowband services	Multi-Connectivity cellular / satellite to serve broadband & narrowband services to - fixed platforms (such as small home / small office) - moving platforms	UC1-1: Simultaneous cellular / satellite access with enhanced total throughput	Messaging, Data transfer, Voice.
Network resilience, for Network Operation and/or Public Safety	In a multi-access cellular / satellite context, each access attempts to protect the other one.	UC1-6: Network resilience for critical links, UC1-8: Mobile cell hybrid connectivity – Predictable connectivity release	Messaging, Data transfer, Voice and Video.
ATSSS functions, flexibility and scalability	Access Traffic Steering, Splitting and Switching related use cases and Scalability and flexibility can be demonstrated by ATSSS functions.	UC1-7: Mobile cell hybrid connectivity – Unpredictable connectivity release with-out any protection, UC1-9: Traffic Steering over appropriate Access Networks, UC1-10: Traffic Splitting over appropriate Access Networks - Flexibility and scalability UC1-8: Mobile cell hybrid connectivity – Predictable connectivity release	Messaging, Data transfer, Voice and Video.

According to the analysis grid of 5G use cases in section 3.1, the following potential use cases, for multi-access connectivity, are foreseen, for 5G-ALLSTAR:

- UC1-1: Simultaneous cellular / satellite access with enhanced total throughput
- UC1-2: Simultaneous Video TV streaming and other stringent QoS services delivery to UE
- UC1-3: Simultaneous Video TV streaming and other stringent QoS services delivery to a platform
- UC1-4: Simultaneous Satellite Over The Air services and other stringent QoS services delivery to UE
- UC1-5: Simultaneous Satellite Over The Air services and other stringent QoS services delivery to a platform
- UC1-6: Network resilience for critical links

- UC1-7: Mobile cell hybrid connectivity – Unpredictable connectivity release without any protection
- UC1-8: Mobile cell hybrid connectivity – Predictable connectivity release
- UC1-9: Traffic Steering over appropriate Access Networks
- UC1-10: Traffic Splitting over appropriate Access Networks - Flexibility and scalability

The following KPIs are discussed, per use case. Only the relevant KPI are kept, for a given use case. Some KPI are additional regarding section 1.2 and described in section 4.1.3. Regarding the throughput KPI, the throughput can be summed up when both access links are active or equal to the active access link capacity. Regarding the latency KPI: it is the minimum latency of both access links due to smart routing of delay sensitive traffic over low latency access link and non-delay sensitive traffic over the long latency access link. The maximum latency is due to satellite access, typically 50 ms with LEO and 600 ms via GEO.

Table 10 KPI of multi-connectivity

Target KPI	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Reliability	To be measured, DL and UL
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following Inter-RAT Handover (see §4.1.3)	To be measured, if possible
Interruption Time, per given service type (or classes of services : 5QI PER, delay), following a link failure (see §4.1.3)	To be measured, if possible
Access Traffic Steering, Splitting and Switching related KPIs (see §4.1.3)	To be measured, if possible
Multi Access PDU session (see §4.1.3)	To be tested
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

In the use cases, it is expected study and demonstrate that KPI can be enhanced (see NOTE 1) in:

- Switching unused Radio Resource from a RRM to another one, based on coordination between RRMs. The system should avoid localized underutilization of resources.
- Mitigating interferences, also based on coordination between RRMs,

NOTE 1: As examples: Increasing User throughput, mitigating service discontinuity, avoiding radio access network congestion, increasing the user traffic density.

3.2.2 UC1-1: Simultaneous cellular / satellite access with enhanced total throughput

The objective of this use case is to

- demonstrate how UE can benefit from a simultaneous (dual) multi access based NR and
- study resource allocation methods within RRMs and interference mitigation mechanisms, under these conditions

In outdoor, UE are simultaneously connected to 5G networks: cellular RAN and satellite RAN via cellular and satellite network technologies and benefit from an aggregate throughput, greater or equal than 50 Mbps (Direct UE multiple access). This <u>Direct UE multiple access</u> may lie on:

- Case 1: Direct UE access to satellite combined with Direct UE access to cellular RAN
  - Case 1.1: the services are delivered to fixed UE
  - Case 1.2: the services are delivered to moving UE

Additional use cases are foreseen. They provide dual connectivity to an outdoor UE Relay. The UE that are served by this UE Relay indirectly benefit from the satellite user link. This <u>Indirect UE multiple access</u> may lie on:

- Case 2: Indirect UE access to satellite combined with Indirect UE access to cellular RAN
  - Case 2.1: the services are delivered to fixed UE Relay
  - Case 2.2: the services are delivered to moving UE Relay
- Case 3: Indirect UE access to satellite combined with Direct UE access to cellular RAN.
  - Case 3.1: the services are delivered to fixed UE Relay
  - Case 3.2: the services are delivered to moving UE Relay

<u>Foreseen KPI for Direct UE access (respectively Indirect UE access):</u>

Table 11 KPI of UC1-1

Main KPIs	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of	To be measured, DL and UL

services) (see §4.1.3)	
- Fixed UE	
- Mobile UE	
Secondary KPIs	**Value**
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following Inter-RAT Handover (see §4.1.3)	To be measured, if possible
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.3 UC1-2: Simultaneous video TV streaming and other stringent QoS services delivery to UE

The objective of this use case is to study resource allocation methods within RRMs and interference mitigation mechanisms, with multi access based NR, under stringent QoS constraints, such as delay and with TV Broadcast service delivery to UE. The TV broadcast is delivered to the UE via the satellite access, while Real Time QoS stringent service(s) are delivered to the UE by the cellular access, such as VoIP service. This use case is a kind of Direct UE multiple access and is split into:

- Case 1: the services are delivered to fixed UE
- Case 2: the services are delivered to moving UE

Table 12 KPI of UC1-2

Main KPIs	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak

	data rate.
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following Inter-RAT Handover (see §4.1.3)	To be measured, if possible
Secondary KPIs	**Value**
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.4 UC1-3: Simultaneous video TV streaming and other stringent QoS services delivery to a platform

The objective of this use case is to study resource allocation methods within RRMs and interference mitigation mechanisms, with multi access based NR, under stringent QoS constraints such as delay and with TV broadcast service delivery, to a moving platform.

The TV broadcast is delivered via the satellite access, to a moving UE relay, which relays it to the UE within the moving vehicle, while other QoS stringent service(s) are delivered by the cellular access, such as VoIP service.

The objective of this use case is to study the impacts on RRM and interference mitigation mechanisms, with multi access based NR.

This use case is a kind of Indirect UE multiple access and is split into:

- Case 1: the QoS stringent services are directly delivered by the cellular RAN to the UE (Direct UE cellular access)
  - The UE is fixed
  - The UE is moving
- Case 2: the QoS stringent services are delivered to the UE relay(i.e. the platform), then to the UE (Indirect UE cellular access)
  - The UE Relay is fixed
  - The UE Relay is moving

Table 13 KPI of UC1-3

Main KPIs	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	

Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following Inter-RAT Handover (see §4.1.3)	To be measured, if possible
Secondary KPIs	**Value**
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.5 UC1-4: Simultaneous satellite Over The Air services and other stringent QoS services delivery to UE

The objective of this use case is to study resource allocation methods within RRMs and interference mitigation mechanisms, with multi access based NR, under stringent QoS constraints, such as delay and with OTA (Over The Air) service delivery to UE. QoS stringent service(s), such as VoIP service, are provided by the cellular access to the UE, while Over The Air service(s) (alerts, warning, real-time traffic, weather, and early warning broadcasts, Points of Interests) are sent to the UE via the satellite access.

An additional OTA service to assess is the UE Location Service: the UE periodically send its location to a remote server, via the satellite access (UE tracking over a wide area), while other QoS stringent services are provided by the cellular RAN.

This use case is a kind of Direct UE multiple access and is split into:

- Case 1: the services are delivered to fixed UE
- Case 2: the services are delivered to moving UE

Table 14 KPI of UC1-4

Main KPIs	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	

- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following Inter-RAT Handover (see §4.1.3)	To be measured, if possible
Secondary KPIs	**Value**
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.6 UC1-5: Simultaneous satellite Over The Air services and other stringent QoS services delivery to a platform

The objective of this use case is to study resource allocation methods within RRMs and interference mitigation mechanisms, with multi access based NR, under stringent QoS constraints, such as delay and with OTA (Over The Air) service delivery to a moving platform.

Over The Air service(s) (such as alerts, warning, real-time traffic, weather, and early warning broadcasts, Points of Interests) are delivered via the satellite access, to a moving UE relay, which relays it to the UE within the moving vehicle, while other QoS stringent service(s) are delivered by the cellular access, such as VoIP service.

This use case is a kind of Indirect UE multiple access and is split into:

- Case 1: the QoS stringent services are directly delivered by the cellular RAN to the UE (Direct UE cellular access)
    - The UE is fixed
    - The UE is moving
- Case 2: the QoS stringent services are delivered to the UE relay (i.e. the platform), then to the UE (Indirect UE cellular access)
    - The UE Relay is fixed
    - The UE Relay is moving

Table 15 KPI of UC1-5

Main KPIs	**Value**
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	

Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following Inter-RAT Handover (see §4.1.3)	To be measured, if possible
Secondary KPIs	**Value**
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.7 UC1-6: Network resilience for critical links

The objective of this use case is to:

- demonstrate that UE can benefit from a protection scheme (protecting link), with multi access based NR, when unpredictable release occur, with provisioning of protecting radio resource and,
- study resource allocation methods within RRMs and interference mitigation mechanisms, under these conditions

Some critical network links requires high availability which can be achieved through the aggregation of two or several network connections in parallel.

The objective of the network resilience is to prevent complete network connection outage.

This use case is a kind of Direct UE multiple access and is split into:

- Case 1: the satellite access protects the cellular access, following a cellular connectivity failure. The services and traffic are switched on the satellite access.
- Case 2: the cellular access protects the satellite access, following a satellite connectivity failure. The services and traffic are switched on cellular accesses.

Each access protects the other one.

Table 16 KPI of UC1-6

Main KPIs	**Value**

Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Reliability	To be measured, DL and UL
Access Traffic Steering, Splitting and Switching related KPIs (see §4.1.3)	To be measured, if possible
Multi Access PDU session (see §4.1.3)	To be tested
Interruption Time, per given service type (or classes of services : 5QI PER, delay), following a link failure (see §4.1.3)	To be measured, if possible
Secondary KPIs	**Value**
Service Minimum Duration, per connected service types (see §4.1.3)	To be measured, per service types
Service Set up time, per given service types (see §4.1.3)	To be measured, per service types
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.8 UC1-7: Mobile cell hybrid connectivity – Unpredictable connectivity release without any protection

The objective of this use case is to:

- demonstrate that mobile UE can benefit from Access Traffic Switching and Splitting functions, with multi access based NR, when unpredictable radio resource are requested and
- study resource allocation methods within RRMs and interference mitigation mechanisms, under these conditions

We assume that the cellular connectivity (respectively the satellite connectivity) is intermittent and the release of this connectivity is unpredictable.

The objective is to restore connectivity, but on another link, after a connectivity release/failure has occurred and to minimize the time outage.

This use case is a kind of Direct UE multiple access and is split into:

- Case 1: the services and traffic of the cellular access are switched to the satellite access, following a cellular connectivity release,
- Case 2: the services and traffic of the satellite access are switched to cellular access(es), following a satellite connectivity release.

Table 17 KPI of UC1-7

Main KPIs	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Reliability	To be measured, DL and UL
Service Minimum Duration, per connected service types (see §4.1.3) after switching	To be measured, per service types
Service Set up time, per given service types (see §4.1.3) during switching	To be measured, per service types
Interruption Time, per given service type (or classes of services : 5QI PER, delay), following a link failure (see §4.1.3)	To be measured, if possible
Access Traffic Steering, Splitting and Switching related KPIs (see §4.1.3)	To be measured, if possible
Multi Access PDU session (see §4.1.3)	To be tested
Secondary KPIs	**Value**
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.9 UC1-8: Mobile cell hybrid connectivity – Predictable connectivity release

The objective of this use case is to:

- demonstrate that a mobile UE can benefit from inter and intra RAT-handovers mechanisms (respectively Access Traffic Switching function) with multi access based NR, when predictable radio resource are requested and
- to study resource allocation methods within RRMs and interference mitigation mechanisms, under these conditions

We assume that the cellular connectivity (respectively the satellite connectivity) is intermittent and the release of the connectivity is predictable.

The objective is to kept connectivity based handover mechanisms, from cellular RAN to satellite RAN and in the opposite direction as well, and to minimize the Handover Interruption time.

This use case is a kind of Direct UE multiple access and is split into:

- Case 1: the services and traffic provided by the cellular access is switched to the satellite access, following a mobility event,
- Case 2: the services and traffic provided by the satellite access is switched to cellular access(es), following a mobility event.

Two additional uses cases are foreseen:

- An access is maintained when moving from indoor (small cell) to outdoor (satellite access) and ensures continuity of services.
- An access is maintained when moving from outdoor (satellite access) to indoor (small cell) and ensures continuity of services.

Table 18 KPI of UC1-8

Main KPIs	**Value**
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Reliability	To be measured, DL and UL
Service Minimum Duration, per connected service types (see §4.1.3) after Handover	To be measured, per service types
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (see §4.1.3) (intra-RAT handover type)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following cellular / satellite Handover (Inter-RAT Handover type) (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following cellular Handover (intra-RAT Handover type) (see §4.1.3)	To be measured, if possible
Access Traffic Steering, Splitting and Switching related KPIs (see §4.1.3)	To be measured, if possible
Multi Access PDU session (see §4.1.3)	To be tested
Secondary KPIs	**Value**
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.10 UC1-9: Traffic steering over appropriate access networks

The objective of this use case is to:

- demonstrate that UE can benefit from a traffic steering function and with multi access based NR and
- study resource allocation methods within RRMs and interference mitigation mechanisms, under these conditions

Delay sensitive traffic are forwarded / routed over short latency links, namely to/from the cellular RAN, while less delay sensitive traffic are forwarded / routed over the long latency links, namely to/from satellite RAN. In other words, the use case study how to select the best Connection per Traffic Type.

This use case is a kind of Direct UE multiple access and is split into:

- Case 1: the services are delivered to a fixed UE
- Case 2: the services are delivered to a moving UE

Table 19 KPI of UC1-9

Main KPIs	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms
Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Reliability	To be measured, DL and UL
Access Traffic Steering, Splitting and Switching related KPIs (see §4.1.3)	To be measured, if possible
Multi Access PDU session (see §4.1.3)	To be tested
Service Minimum Duration, per connected service types (see §4.1.3) after traffic steering commitment	To be measured, per service types
Secondary KPIs	**Value**
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (intra-RAT handover type) (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : 5QI PER, delay), following cellular Handover (intra-RAT handover type) (see §4.1.3)	To be measured, if possible
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.11 UC1-10: Traffic splitting over appropriate access networks – Flexibility and scalability

The objective of this use case is to:

- demonstrate the benefits of the Traffic Splitting over appropriate Access Networks of coordinated Access Networks (cellular / satellite) and
- study the coordination of RRMs, in the control plane and interference mitigation mechanisms, under these conditions

Since traffic varies depending on the time of the day and on the day of the week, radio access network deployment decisions / sizing based on peak traffic profiles cause waste of radio resources. In addition, traffic may also vary depending on location.

Traffic may move from a location to another, in a way, while the total amount of traffic in a wider area is less changed. Therefore, it is important that the overall system can flexibly scale with various levels of control and user-plane demand in order to avoid localized underutilization of resources.

Moreover, the number of UE connections requests may also vary and can reach the maximum threshold, provisioned by the operator. This latter case is an issue of scalability in terms of number of UE.

Cellular RAN(s) and satellite RAN may work together in order to provide a global answer to traffic increase and UE connection requests increase, over the set of served areas.

Flexibility and scalability may be supported, in part, by coordinated cellular / satellite RRMs:

- Unused Radio Resource, may be switched from some cellular RAN(s) to the satellite RAN in order to support other cellular RAN(s) traffic increase,
- Unused Radio Resource, may be switched from the satellite RAN to cellular RAN(s) in order to support traffic increase in these cellular RANs,
- Unused Radio Resource, may be switched from cellular RAN(s) in order to support traffic increase in the satellite RAN.

This use case is split into:

- Case 1: the traffic increase is predictable,
- Case 2: the traffic increase is unpredictable.

Table 20 KPI of UC1-10

Main KPI	Value
Peak Data Rate per UE	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Guaranteed Data Rate, per service types (or Classes of services) (see §4.1.3)	To be measured, DL and UL
- Fixed UE	
- Mobile UE	
Latency	
- User-plane latency	Expected value: < 4 ms
- Control-plane latency	Expected value: < 10 ms

Service Coverage (see §4.1.3)	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate.
Reliability	To be measured, DL and UL
Service Minimum Duration, per connected service types (see §4.1.3) after traffic splitting commitment	To be measured, per service types
Access Traffic Steering, Splitting and Switching related KPIs (see §4.1.3)	To be measured, if possible
Multi Access PDU session (see §4.1.3)	To be tested
Secondary KPIs	**Value**
Mobility Interruption Time, per given service types (or classes of services 5QI PER, delay), following Satellite Beam Handover (intra-RAT handover type) (see §4.1.3)	To be measured, if possible
Mobility Interruption Time, per given service types (or classes of services : PER, delay), following cellular Handover (intra-RAT handover type) (see §4.1.3)	To be measured, if possible
5th percentile user spectral efficiency	To be measured, if possible
Average spectral efficiency	To be measured, if possible
Area traffic capacity	To be measured, if possible
Density of connected devices (UE), per service type (see §4.1.3)	To be measured, if possible

3.2.12 Potential business models

Below is the summary of the potential business models of the use cases of multi-connectivity:

- Provide a worldwide availability of the network through satellite connection: both free and paid access are possible. TelCo providers may offer new services like frequent flyers program
- Provide requested network access to remote areas: new markets will thus be available: in case of disaster, better access to the network to NGOs, victims, companies … could help to overcome crises
- Develop the Internet of Things as every objects, wherever their location, could be connected
- Create new nodes – both human and digital –, therefore new business and new actors/activity because of the increase of the networks
- In terms of new industrial practices: the use of robots through the multi-connectivity will highly increase as it will replace manpower in case of danger, poor human efficiency …
- Forecast of new start-ups – for instance in ehealth – which will compete with large companies because of the ubiquitous connectivity and better reliability and validity
- Examples of new services: improved security, better traceability, new ways of travelling, tactile Internet, virtual reality, multi-person video call …

3.3 Use case series 2: Vehicular communications

3.3.1 Overview, use cases categories and KPIs

5G aims to satisfy a diverse set of communication requirements of various stakeholders. Among the stakeholders, automotive industry, in particular, will greatly benefit from 5G at both the systems and applications since vehicles have become an indispensable part of our lives and vehicles with the 5G technologies has the potential to provide the various applications, for example:

- Road safety improvement,
  - Road situation monitoring and sharing with other vehicles
  - Prevention of traffic accidents through cellular and satellite links
  - Real-time video streaming of vehicles for the purpose of traffic enforcement
- Traffic efficiency optimization,
- Connected car (e.g., automated driving),
- Ubiquitous Internet access on vehicles and so on.

For this reason, in recent years, vehicular communications have attracted more and more attention from both industry and academia owing to their potential to satisfy growing demand for the various applications.

Vehicular communications, also known as V2X (vehicle-to-everything) communication is a communication technology that allows a vehicle to exchange various information (e.g., traffic information, map data) with other entities (e.g., other vehicles, network). More specifically, the V2X communication incorporates various types of communications such as V2V (vehicle-to-vehicle), V2P (vehicle-to-pedestrian) and V2I/N (vehicle-to-infrastructure/network). As an example of V2X communication, automobiles within a certain range communicate their position / speed information and surrounding traffic situation information through V2V or V2I/N communication, thereby preventing sudden traffic accidents. Through V2V link, vehicles platooning service can be provided which enables the vehicles to dynamically form a group travelling together on a highway. In addition, V2I / N communication provides a high-speed wireless connectivity to the vehicle, which not only allows users in the vehicle to use broadband Internet service, but also enables the remote driving of the vehicle.

Meanwhile, 3GPP SA1 has identified 25 use cases for advanced V2X services that can be categorized into four use case groups as shown in Figure 8. These use cases are also the potential use cases that can benefit from the 5G-ALLSTAR technologies and the detailed description of each use case group is provided in the following subsections.

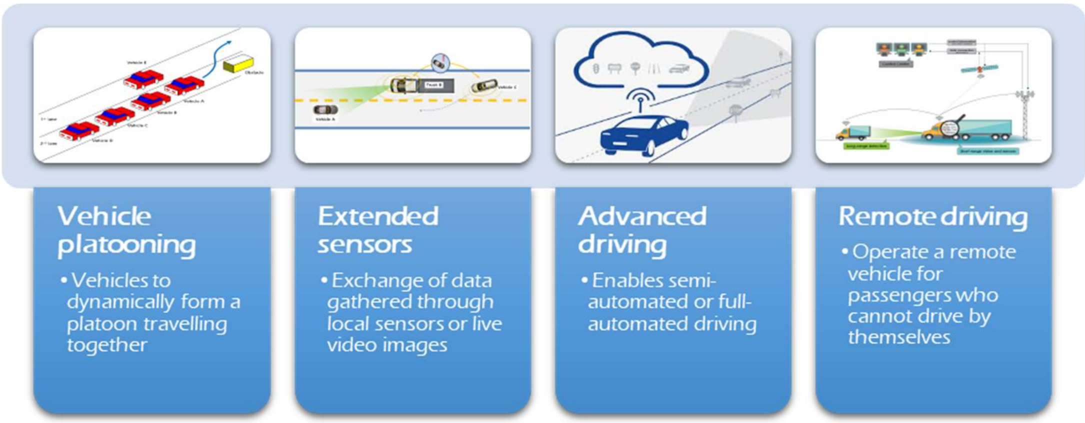

Figure 8 3GPP eV2X service

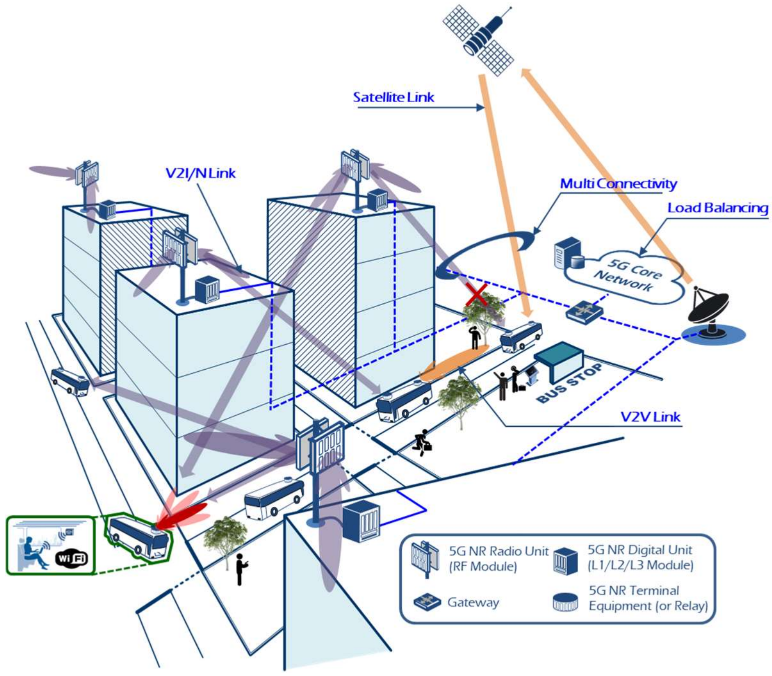

Figure 9 Vehicular communications

In addition, recently, due to the emergence of various new multimedia services, and proliferation of portable smart devices such as mobile phones and tablets, mobile data traffic even on the public transportations has been explosively increasing, which requires the same communication quality as the wired or wireless Internet quality at home. For example, 6 out of 10 people prefer online video platforms to live TV (Think with Google, 2016). A survey conducted by the Korea Internet and Security Agency (KISA) in 2015 [5] also reported that Internet access through Wi-Fi while "on the move" (e.g., on buses, trains, subways) are the second most often locations after home. What illustrated the best this phenomenon is the percentage of worldwide YouTube users accessing the service on mobile devices: approximatively 70% (YouTube press, 2018). *De facto*, the development of 5G will involve the increase of Wi-Fi hotspots worldwide to 542 million in 2021 (Cisco Systems, 2018).

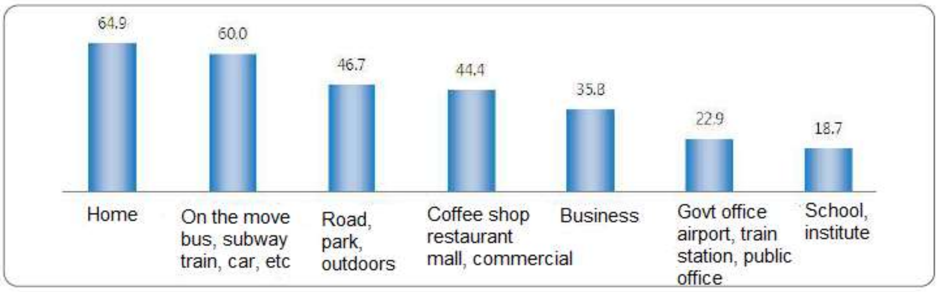

Figure 10 Wi-Fi usage locations in Korea

Moreover, considering that in South Korea, the average monthly communication expenditure per household of two or more people is approximately KRW144,000, which accounts for about 4.3% of household spending, a considerable amount of spending is expected to be caused by the use of mobile Internet outside, especially "on the move (on public transportation)". However, most public transportations in Korea do not provide free Wi-Fi services, and even if they do, Wi-Fi service quality in general is very poor (data rate is only a few Mbps). Therefore, in spite of expensive telecommunication charges, most Korean citizens are using mobile Internet services through a cellular network.

Meanwhile, Seoul Metro, which is a public corporation owned by Seoul Metropolitan Government, and one of the two major operators of Seoul Metropolitan Subway with Korail, plans to provide a free Wi-Fi service on subway by deploying the Mobile Hotspot Network (MHN) system operating in the FACS (Flexible Access Common Spectrum) from Seoul subway line 1 to line 9. The MHN system developed by ETRI can provide HST with a broadband MWB of 100 times faster than the MWB of WiBro in Korea. ETRI also successfully gave its demonstration both in Seoul subway line 8 and during PyeongChang Winter Olympics in Feb. 2018.

However, the MHN system was originally designed for HST communications where only one or two VEs need to be served. Therefore, it is not desirable to directly apply the MHN system to a general vehicular communications environment in which a number of VEs in one cell must be served at the same time. Moreover, in highway and urban road environments, LoS is often not secured due to an unexpected blockage by the vehicles or/and various structures (e.g., building) around the transceiver, which causes a very lethal performance degradation in the high frequency band communication environment. More serious performance degradation can occur when the vehicle is changing lanes or turning a curve in this case.

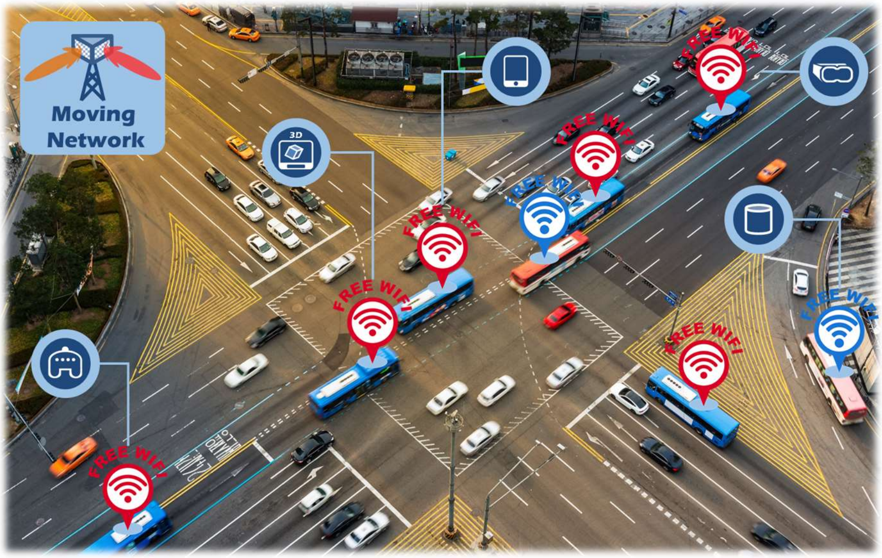

Figure 11 Concept of broadband moving hotspot network use case

For these reasons, 5G-ALLSTAR aims to develop a system called moving network (MN) capable of providing broadband Wi-Fi service on city buses and express bus as illustrated in Figure 11. In addition, the MN system will be designed to operate in the unlicensed band newly allocated by Korean government called FACS (22 ~ 23.6 GHz) to allow onboard passengers to use the Gigabit Wi-Fi for free. Ultimately, it is expected to provide a broadband wireless connection to any kind of vehicles allowing users to use broadband and reliable on-board mobile Internet service. However, this level of connectivity, and besides the increasing richness of car-entertainment requested by customers, it is the entire automobile sector that could be revolutionized. Indeed, 5G is seen as the critical element supporting self-driving and autonomous vehicles resulting in a reduction of car accidents and better traffic management (ARCEP, 2017).

And again, new service leads to new business opportunities as the Wi-Fi could be implemented and managed by different actors: the municipality, the transportation company, the TelCo, and so on.

In addition to the above use case, 5G-ALLSTAR technologies are applicable to a variety of V2X services related to road safety. Therefore, we expect the technologies to be applicable to the following use cases:

To summarize, the following potential five potential use case series relevant to vehicular communications are expected to receive benefit from 5G-ALLSTAR:

- UC2-1: Broadband mobile wireless backhaul (MWB) for public transportations,
- UC2-2: Vehicles platooning,
- UC2-3: Advanced driving,
- UC2-4: Extended sensors,
- UC2-5: Remote driving,

and as shown in Table 21, it can be categorized into broadband MWB use case and 3GPP eV2X service.

The general requirements of the four eV2X services are defined in TR 22.186 [16] , which is the beyond the scope of the 5G-ALLSTAR targets.

- May support group management (based on requests from application layer)
- Shall support relative lateral position accuracy of 0.1m between UEs
- Shall support 'high connection density' for congested traffic
  - e.g., 3,100~4,300 cars per km2 for worst case in US (3 intersecting highways of 10 lanes each)
- Shall support network access via relay
- RSU shall be able to communicate with up to 200 UEs

Table 21 summarizes the KPIs of the use case series of vehicular communications, where the requirements of the four 3GPP eV2X services are defined in TR 22.186 [16] and compare them with the potential KPIs of 5G-ALLSTAR technologies. From the table, we observed that most of the requirements can be met by 5G-ALLSTAR, so most of use cases series 2 can be realized with 5G-ALLSTAR technologies.

Table 21 KPIs of UC2

	Broadband MWB (UC2-1)	3GPP eV2X Service ([16])				5G-ALLSTAR
		Vehicles Platooning (UC2-2)	Advanced Driving (UC2-3)	Extended Sensors (UC2-4)	Remote Driving (UC2-5)	
Average BS throughput	DL: 5 Gbps	-	-	-	-	DL: 5 Gbps
Data rate (UE/vehicle)	UL: 125 Mbps DL: 1 Gbps	70 kbps~65 Mbps	60 kbps~53 Mbps	120 kbps~1000 Mbps	UL: 25 Mbps DL: 1 Mbps	UL: 125 Mbps DL: 1 Gbps
Max. E2E Latency	< 4 ms (U-plane latency)	10~25 ms	3~100 ms	3~100 ms	5 ms	< 4 ms (U-plane latency)
Reliability	-	90~99.99 %	90~99.999 %	90~99.999 %	99.999 %	99.999 % (limited to specific sce-narios)
Coverage	500 ~ 1000 m	80 ~ 350 m	360 ~ 700 m	50 ~ 1000 m	-	500 ~ 1000 m
Mobility (absolute speed)	< 120 km/h	-	-	-	250 km/h	< 120 km/h
Note 1: KPI of 5G-ALLSTAR is a value that does not take the V2V link into consideration.						

3.3.2 UC2-1: Broadband mobile wireless backhaul for public transportations

This use case is one of the primary use cases of the 5G-ALLSTAR that aims to provide a millimeter-wave (mmWave)-band broadband mobile wireless backhaul (MWB) to public transportation (e.g., city buses, express buses), enabling onboard Gigabit Wi-Fi service. Since this use case utilizes the unlicensed band newly allocated by Korean government called FACS, it will allow passengers on the public transportation to use the Gigabit Wi-Fi for free.

<u>Potential KPIs:</u>

Table 22 KPIs of UC2-1

Target KPI	Value

Average gNB throughput		Downlink: 5 Gbps
Average throughput per bus		Downlink: 1 Gbps
Average user-experienced throughput		Downlink: < 100 Mbps
Latency	User-plane latency	< 4 ms
	Control-plane latency	< 10 ms
Handover latency		< 2 ms

3.3.3 UC2-2: Vehicles platooning

Vehicles Platooning enables the vehicles to dynamically form a group travelling together. All the vehicles in the platoon receive periodic data from the leading vehicle, in order to carry on platoon operations. This information allows the distance between vehicles to become extremely small, i.e., the gap distance translated to time can be very low (sub second). Platooning applications may allow the vehicles following to be autonomously driven.

Potential KPIs:

Table 23 KPI of UC2-2 (vehicles platooning, [16])

Communication scenario description		Payload (Bytes)	Tx rate (Message/ Sec)	Max end-to-end latency (ms)	Reliability (%) (NOTE 5)	Data rate (Mbps)	Min required communication range (meters) (NOTE 6)
Scenario	**Degree**						
Cooperative driving for vehicle platooning Information exchange between a group of UEs supporting V2X application.	Lowest degree of automation	300-400 (NOTE 2)	30	25	90		
	Low degree of automation	6500 (NOTE 3)	50	20			350
	Highest degree of automation	50-1200 (NOTE 4)	30	10	99.99		80
	High degree of automation			20		65 (NOTE 3)	180
Reporting needed for platooning between UEs supporting V2X application and between a UE supporting V2X application and RSU.	N/A	50-1200	2	500			
Information sharing for platooning between UE supporting V2X application and RSU.	Lower degree of automation	6000 (NOTE 3)	50	20			350
	Higher degree of automation			20		50 (NOTE 3)	180

NOTE 2: This value is applicable for both triggered and periodic transmission of data packets.

NOTE 3: The data that is considered in this V2X scenario includes both cooperative manoeuvres and cooperative perception data that could be exchanged using two separate messages within the same period of time (e.g., required latency 20ms).

NOTE 4: This value does not including security related messages component.

NOTE 5: Sufficient reliability should be provided even for cells having no value in this table

NOTE 6: This is obtained considering UE speed of 130km/h. All vehicles in a platoon are driving in the same direction.

3.3.4 UC2-3: Advanced driving

Advanced Driving enables semi-automated or fully-automated driving. Longer inter-vehicle distance is assumed. Each vehicle and/or RSU shares data obtained from its local sensors with vehicles in proximity, thus allowing vehicles to coordinate their trajectories or maneuvers. In addition, each vehicle shares its driving intention with vehicles in proximity. The benefits of this use case group are safer traveling, collision avoidance, and improved traffic efficiency.

Potential KPIs:

Table 24 KPI of UC2-3 (advanced driving, [16])

Communication scenario description: Scenario	Communication scenario description: Degree	Payload (Bytes)	Tx rate (Message/Sec)	Max end-to-end latency (ms)	Reliability (%) (NOTE3)	Data rate (Mbps)	Min required Communication range (meters) (NOTE 4)
Cooperative collision avoidance between UEs supporting V2X applications.		2000 (NOTE 5)	100 (NOTE 5)	10	99.99	10 (NOTE 1)	
Information sharing for automated driving between UEs supporting V2X application.	Lower degree of automation	6500 (NOTE 1)	10	100			700
	Higher degree of automation			100		53 (NOTE 1)	360
Information sharing for automated driving between UE supporting V2X application and RSU	Lower degree of automation	6000 (NOTE 1)	10	100			700
	Higher degree of automation			100		50 (NOTE 1)	360
Emergency trajectory alignment between UEs supporting V2X application.		2000 (NOTE 5)		3	99.999	30	500
Intersection safety information between an RSU and UEs supporting V2X application.		UL: 450	UL: 50			UL: 0. 25 DL: 50 (NOTE 2)	
Cooperative lane change between UEs supporting V2X applications.	Lower degree of automation	300-400		25	90		
	Higher degree of automation	12000		10	99.99		
Video sharing between a UE supporting V2X application and a V2X application server.						UL: 10	

NOTE 1: This includes both cooperative manoeuvers and cooperative perception data that could be exchanged using two separate messages within the same period of time (e.g., required latency 100ms).
NOTE 2: This value is referring to a maximum number of 200 UEs. The value of 50 Mbps DL is applicable to broadcast or is the maximum aggregated bitrate of the all UEs for unicast.
NOTE 3: Sufficient reliability should be provided even for cells having no values in this table
NOTE 4: This is obtained considering UE speed of 130km/h. Vehicles may move in different directions.
NOTE 5: These values are based on calculations for cooperative maneuvers only.

3.3.5 UC2-4: Extended sensors

Extended Sensors enables the exchange of raw or processed data gathered through local sensors or live video data among vehicles, RSUs, devices of pedestrians and V2X application servers. The vehicles can enhance the perception of their environment beyond what their own sensors can detect and have a more holistic view of the local situation.

Potential KPIs:

Table 25 KPI of UC2-4 (extended sensors, [16])

Communication scenario description: Scenario	Communication scenario description: Degree	Payload (Bytes)	Tx rate (Message /Sec)	Max end-to-end latency (ms)	Reliability (%)	Data rate (Mbps)	Min required communication range (meters)
Sensor information sharing between UEs supporting V2X application	Lower degree of automation	1600	10	100	99		1000
	Higher degree of automation			10	95	25 (NOTE 1)	
				3	99.999	50	200
				10	99.99	25	500
				50	99	10	1000
				10	99.99	1000	50
Video sharing between UEs supporting V2X application	Lower degree of automation			50	90	10	100
	Higher degree of automation			10	99.99	700	200
				10	99.99	90	400
NOTE 1: This is peak data rate. NOTE 2: This is for imminent collision scenario.							

3.3.6 UC2-5: Remote driving

Remote Driving enables a remote driver or a V2X application to operate a remote vehicle for those passengers who cannot drive themselves or a remote vehicle located in dangerous environments. For a case where variation is limited and routes are predictable, such as public transportation, driving based on cloud computing can be used. In addition, access to cloud-based back-end service platform can be considered for this use case group.

Potential KPIs:

Table 26 KPI of UC2-5 (remote driving, [16])

Communication scenario description	Max end-to-end latency (ms)	Reliability (%)	Data rate (Mbps)
Information exchange between a UE supporting V2X application and a V2X Application Server	5	99.999	UL: 25 DL: 1

3.3.7 Potential business models

Below is the summary of the potential business models of the use cases of vehicular communications:

- Provide a free broadband Wi-Fi service on public transportation (e.g., city buses, express buses, and train) using unlicensed bands (e.g., FACS in Korea), which improves quality of service in transportation for customers while reducing their public communication costs
- Possible to adopt the technologies to an infrastructure for road-safety V2X and advanced V2X systems, for example:
  - Improving safety and traffic control with bus video streaming
  - Connected cars, C-ITS, autonomous driving
- Possible to support relevant small / medium enterprises for domestic and overseas commercialization
- Contributes to revitalization of 5G-related industry such as development/manufacturing of mmWave RF, antenna, modem
- Possible to create new business models related to mmWave-based broadband vehicular communications (e.g., V2X)

4 Preliminary study on 5G-ALLSTAR service scenarios and KPIs

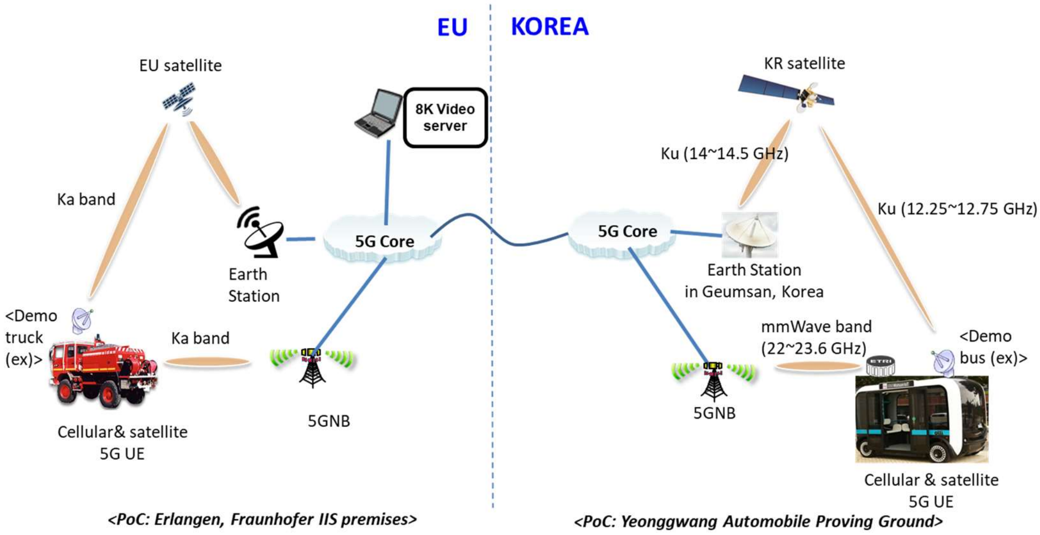

Figure 12 The overall architecture of 5G-ALLSTAR PoC demonstration

The overall 5G-ALLSTAR system architecture for PoC demonstration is depicted in Figure 12, and it mainly consists of two different implementations of 5G networks that will be respectively developed in Europe and Korea. Europe and Korea aim to independently integrate their potential access networks (e.g., satellite access, cellular access based on 5G NR or 4G) under a common core network (e.g., 5G core network), and conduct a global interoperability demonstration by connecting two different integrated systems across regions.

Table 27 presents the overall KPIs and the corresponding target performance requirements to be validated through PoC demonstration in the project. The performance values are basically referred to the ITU-R M2410 "Minimum requirements related to technical performance for IMT-2020 radio interface(s)". These KPIs will be mainly validated with respect to the multi-connectivity technologies (multiple access of cellular and satellite links). In the table, the way the KPIs will be validated is also indicated.

Table 27 Overall target KPIs verification during the 5G-ALLSTAR PoC stage

KPI	Target performance	Demonstration of KPIs through		
		Simulation	Testbeds	Field trial
User experienced data rate	Downlink: 50 Mbps Uplink: 10 Mbps	○	○	○
User plane latency	< 10 ms for delay sensitive traffic	○	○	○
Control plane latency	< 20 ms	○	○	
Reliability	99.999 % success probability of transmission	○	○	
Service continuity	No service interruption (verifying zero service interruption when one of a link (e.g., cellular) fails abruptly or disappears due to mobility e.g. in rural areas)			○

In the following subsections, we identify the preliminary service scenarios for PoC demonstrations/field trials that are suitable for verifying the overall KPIs defined in Table 27, and define detailed KPIs for each service scenario.

4.1 Service scenario 1: Multi-connectivity

4.1.1 Scenarios definition

Several scenarios are proposed below, for multiple access, namely A_{ma}, B_{ma}, C_{ma}, D_{ma}, which are extensions of A, B, C, D scenarios as defined in 3GPP TR 38.821 [11] :

The scenarios A_{ma}, B_{ma}, C_{ma}, D_{ma} will assess multi-access use cases as defined in section 3.2.

Table 28 Definition of multi-connectivity service scenarios

	Transparent satellite	**Regenerative satellite**	**Mapping to KR test bed**	**Mapping to EU test bed**
GEO based non-terrestrial access network	Extended Scenario A_{ma}: Scenario A + Multi-RAT Dual connectivity cellular / NTN Scenario A [11] : Standalone NTN	Extended Scenario B_{ma}: Scenario B + Multi-RAT Dual connectivity cellular / NTN. Scenario B [11] : Standalone NTN	Transparent GEO satellite	Transparent emulated GEO satellite with satellite friendly 5G L1/MAC.
LEO based non-terrestrial access network	Scenario C [11] : Standalone NTN Extended Scenario C_{ma}: Scenario C + Multi-RAT Dual connectivity cellular / NTN. Scenario C [11] : Standalone NTN	Extended Scenario D_{ma}: Scenario D + Multi-RAT Dual connectivity cellular / NTN. Scenario D [11] : Standalone NTN	NA.	Transparent emulated LEO satellite with satellite friendly 5G L1/MAC, No ISL.

4.1.2 Input parameters of the scenarios

According to [10] and [11] , the main input parameters of scenarios to set up are following:

- Satellite orbit and altitude
- Carrier Frequency on the service link, between satellite and UE (or UE Relay)
- Beam pattern:
  - Maximum foot print size at NADIR
  - Earth fixed beams vs. Earth moving beams
  - Multi-satellite beam vs. single satellite beam
- Duplexing mode: FDD / TDD
- Channel Bandwidth, on the service link (DL + UL)
- NTN RAN architecture options, w.r.t. to the payload type:
  - Transparent satellite based,
  - Regenerative satellite based with on board gNB, with/without Xn interface over ISL (Inter Satellite Link)
- Minimum Elevation angle for satellite-gateway

- Minimum elevation angle for satellite-UE
  - Knowing the elevation angle and the altitude, the slot range (distance between the UE and the satellite) and the Maximum Round Trip Delay can be deduced.
- Maximum delay variation within a beam (earth fixed UE)
- Max differential delay within a beam
- Maximum Doppler shift (earth fixed UE)
- Max Doppler shift variation (earth fixed UE)
- UE Direct Access to satellite vs. UE Indirect Access to satellite, via an UE Relay
- UE type or UE Relay type (or NTN Terminal type)
- UE or UE Relay (or NTN terminal) Distribution
- UE or UE Relay (or NTN terminal) speed (motion) on earth
- UE or UE Relay antenna types: Omnidirectional vs. Directive
- UE or UE Relay Transmission power
- UE or UE Relay Noise figure of merits (dB)
- Waveform used on the Service link: 3GPP defined NR
- Waveform used on the feeder link: 3GPP defined NR or non-3GPP defined Radio interface

The NTN architecture option is an input parameter for any scenario:

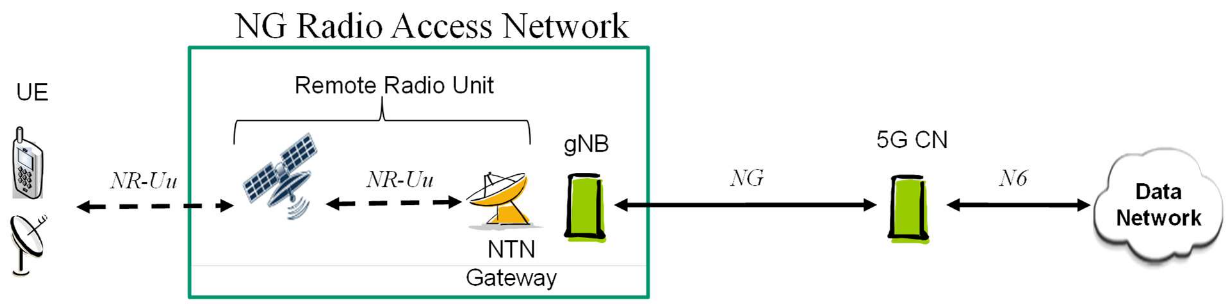

Figure 13. Non-Terrestrial Access Network with transparent satellite

The transparent satellite model based architecture may be used for the study of Interference mitigation and the study of resource allocation methods within of RRMs, in the case of coordination between cellular gNB/NTN Gateway-gNB.

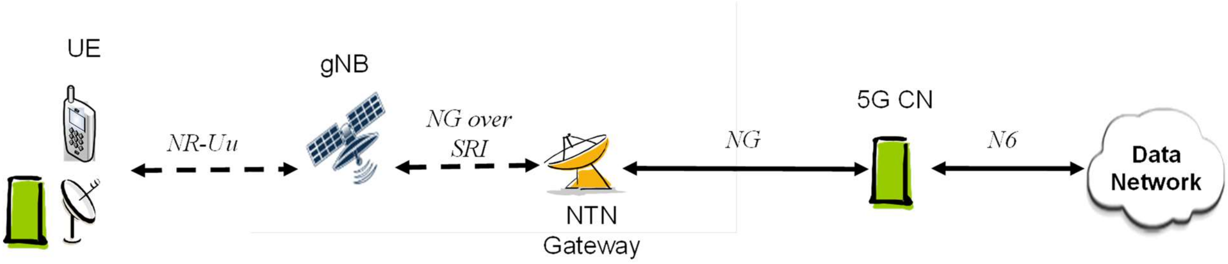

Figure 14. Non-Terrestrial Access Network with a regenerative satellite

The Regenerative satellite model based architecture may also be used for the study of Interference mitigation and the study of resource allocation methods within RRMs, in the case of coordination between:

- cellular gNB / satellite gNB and satellite gNB / satellite gNB, with and without Xn interface over ISL (Inter Satellite Link)

According to [10] , the parameters for the space channel model are following:

- Platform orbit and altitude
- Carrier Frequency on the link between Air / space-borne platform and UE
- Maximum Channel Bandwidth (DL + UL)
- UE (or UE Relay) antenna pattern + polarisation
- UE type or UE Relay type (or NTN Terminal type)
- Satellite antenna pattern modelling + polarisation
- Doppler cause
- O2I (Outdoor-to-Indoor) penetration loss
- Atmospheric absorption
- Rain attenuation
- Cloud attenuation
- Scintillation
- Link level model
- Shadowing model

4.1.3 Target KPI per scenario

The KPI are described per scenario. Additional scenarios are used.

As defined in section 4.1.1:

- Scenario A: Transparent GEO satellite
- Scenario B: Regenerative GEO Satellite
- Scenario C: Transparent LEO satellite
- Scenario D: Regenerative LEO Satellite

- Scenario Ama: Transparent GEO satellite (like scenario A) with cellular / terrestrial multi-access
- Scenario Bma: Regenerative GEO satellite (like scenario B) with cellular / terrestrial multi-access
- Scenario Cma: Transparent LEO satellite (like scenario C) with cellular / terrestrial multi-access
- Scenario Dma: Regenerative LEO satellite (like scenario D) with cellular / terrestrial multi-access

Referenced notes within the following table:

NOTE 1: Reliability relates to the capability of transmitting a given amount of traffic within a predetermined time duration with high success probability. (IMT-2020). It is applicable to eMBB services, not only URLLC.

The measurands could be, for both directions:

- (NTx – NTx) / NTx ratio

with: NTx: number transmitted data (frames if L2 data, packets if L3 data), NRx: number of received L2/L3 data

NOTE 2:

- The measurements on standalone satellite access are 1st processed and stored. Then cellular access is re-established, measurements are done and compared to the previous ones.
- In the reverse logic as well: The measurements on standalone cellular access are 1st processed and stored. Then satellite access is re-established, measurements are done and compared to the previous ones.

NOTE 3: The service should not be interrupted, below a given threshold duration and ideally, should never be aborted by the system.

NOTE 4: According to 3GPP TR 23.793 [12] “Access Traffic Steering, Switching and Splitting” (ATSSS) for the different multi-connectivity supports.

For each type of support, following measurements are proposed:

- For given access and QoS:
    - Ratios and amount of successfully, unsuccessfully transported data (frames if L2 data, packets if L3 data)
    - Used bandwidth / Unused Bandwidth of given Radio Bearers or any other radios of given transport containers
    - Traffic Steering, Switching and Splitting times

Inputs parameters could be:

- ratios or amounts of traffic to Steer, Switch or Split (SSS), per class of services, class of users or any other class to be defined,
- ratios or amount of volumes to SSS per class,

- ratios or amount of allocated Radio (Block size or PRB – Physical Resource Blocks) per class.

NOTE 5: 5% point of the CDF of the normalized user throughput (throughput divided by the channel Bandwidth).

NOTE 6: Aggregate throughput of all users, divided by the channel Bandwidth.

NOTE 7: Total traffic throughput served per geographic area (in Mbit/s/m2). This KPI may be split in Traffic throughput per (classes of) services per geographic area (in services types group / Mbits/s/m2).

NOTE 8: Number of connected devices served per geographic area (in Mbit/s/m2). This KPI may be split in Number of connected services per service type (respectively Radio Access Bearers per RAB type), per geographic area (in services types/ Mbits/s/m2) (respectively RAB types/ Mbits/s/m2).

Table 29 Target KPIs of service scenario 1

KPI	Additional KPI ?	Cellular Access	Satellite Access only: Scenarios A, B	Satellite Access only: Scenarios C, D	Multiple Access: Scenarios A_{ma}, B_{ma}	Mutiple Access: Scenarios C_{ma}, D_{ma}
Peak data rate per user based on user spectral efficiency: Case 1: Fixed UE Case 2: Mobile UE	Yes. But values and conditions are different. 3 data rates are defined.	Typically up to 20 Gbps over short range (<100 m)	Typically up to 200 Mbps in downlink and 20 Mbps on uplink with High Throughput Satellites At least: 50 Mbps in DL and 10 Mbps in UL.	Same as for scenarios A, B.	Sum up of the throughput, with / without contention. Without contention, combining both access technologies will enable to achieve a higher aggregate throughput.	Same as for scenarios A_{ma}, B_{ma}.
Latency For Both cases: - User plane - Control plane	Yes. But values are different.	User plane: Typically less than 10 ms (for 4G and beyond) Control plane: < 20ms	Typically 600 ms via GEO	Typically 50 ms with LEO without ISL (Scenario C)	The minimum latency of both access links due to smart routing of delay sensitive traffic over low latency access link and non-delay sensitive traffic over the long latency access link	Same as for scenarios A_{ma}, B_{ma}.

KPI	Additional KPI ?	Cellular Access	Satellite Access only: Scenarios A, B	Satellite Access only: Scenarios C, D	Multiple Access: Scenarios A_{ma}, B_{ma}	Mutiple Access: Scenarios C_{ma}, D_{ma}
Service coverage (Better / Ubiquitous coverage)	New KPI Or Input parameter of a scenario	Typically cell range is maximum 100 m for 20 Gbps peak data rate and maximum 100 km for 1 Mbps peak data rate	Typically cell (beam foot print) is between 100 and 1000 km diameter) Max beam foot print diameter at nadir: 500 Km	Typically cell (beam foot print) is between 100 and 1000 km diameter). Max beam foot print diameter at nadir: 200 Km	Continuous coverage including both satellite and cellular access coverages to be assessed: Beyond cellular coverage, assess that the satellite should provide the access.	Same as for scenarios A_{ma}, B_{ma}.
Reliability (See NOTE 1)	Yes, but the definition is different.	Up to 99.999% but typically over very short range especially in mmW bands	Up to 99.999% but with large link margin requirements for the satellite mmW access link	Same as for scenarios A, B.	Combining both access technologies will enable to achieve the targeted reliability performance optimizing link margin and extending service coverage (see **NOTE 2**).	Same as for scenarios A_{ma}, B_{ma}.
Service Minimum Duration, for connected mode. (see NOTE 3)	New	Better or same as in LTE-A	To characterize.	To characterize.	To characterize.	To characterize.
Service Set up time, per given classes of services	Yes	Lower than in LTE-A.	To characterize. GEO measurements should be compared to LEO ones.	To characterize. LEO measurements should be compared to GEO ones.	Same as for scenarios A, B.	Same as for scenarios C_{ma}, D_{ma}.
Guaranteed (Minimum) data rate per	Yes	To characterize over short range (<100 m),	To characterize over the served area, both for	To characterize over the served area, both	Combining both access technologies will lead	Same as for scenarios A_{ma}, B_{ma}.

KPI	Additional KPI ?	Cellular Access	Satellite Access only: Scenarios A, B	Satellite Access only: Scenarios C, D	Multiple Access: Scenarios A_{ma}, B_{ma}	Mutiple Access: Scenarios C_{ma}, D_{ma}
user based on user spectral efficiency: Use case 1: Fixed UE Use Case 2: mobile UE		both for downlink and uplink cases. Measurements should be better than for LTE-A.	downlink and uplink cases.	for downlink and uplink cases.	to better support GBR services. To characterize.	
Energy Consumption, Energy saving, UE Battery lifetime	Yes	Lower than in LTE-A.	To characterize, at terminal side.	To characterize, at terminal side.	Combining both access technologies will lead to less consume. To characterize.	Same as for scenarios A_{ma}, B_{ma}.
Mobility Interruption Time, per given (classes of) services (5QI: PER, delay), following Satellite Beam Handover	Per given (classes of) services.	NA	Intra satellite Beam HO	Intra satellite beam HO. Scenario D: Inter satellite beam HO, with ISL.	Same as for scenarios A, B.	Same as for scenarios C, D.
Mobility Interruption Time, per given (classes of) services (5QI: PER, delay), following Inter-RAT Handover	Per given (classes of) services.	To compare to standalone LTE-A	GEO SAT -> Cellular, Cellular -> GEO SAT	LEO SAT -> Cellular, Cellular -> LEO SAT	From Multiple Access to standalone GEO SAT. From standalone GEO SAT to Multiple access, w.r.t. to the available coverage.	Same as for scenarios A_{ma}, B_{ma}.

KPI	Additional KPI ?	Cellular Access	Satellite Access only: Scenarios A, B	Satellite Access only: Scenarios C, D	Multiple Access: Scenarios A_{ma}, B_{ma}	Mutiple Access: Scenarios C_{ma}, D_{ma}
Mobility Interrup-tion Time, per given (classes of) services (5QI: PER, delay), fol-lowing a link failure	Per given (classes of) services.	NA	NA	Scenario D: An ISL fails –> the route to the UE / the 5GC is restored through another route, over other ISL(s)	When the Satellite access fails, an access is recovered by the cellular system, w.r.t. to the coverage. When the cellular ac-cess fails, an access is recovered by the satel-lite system, w.r.t. to the coverage.	Same as for A_{ma}, B_{ma}. And D.
Multi-connectivity support across cellular / Satellite access : 1: Access Traffic Steering (see NOTE 4)	Yes	NA	NA	NA	To characterize.	To characterize.
2: Access Traffic Switching support (e.g. for Cellular RAN Offloading) (see NOTE 4)	Yes	NA	NA	NA	To characterize.	To characterize.
3: Access Traffic Splitting (e.g. for load balancing) (see NOTE 4)	Yes	NA	NA	NA	To characterize.	To characterize.

KPI	Additional KPI ?	Cellular Access	Satellite Access only: Scenarios A, B	Satellite Access only: Scenarios C, D	Multiple Access: Scenarios A_{ma}, B_{ma}	Mutiple Access: Scenarios C_{ma}, D_{ma}
4 : Multi-Access PDU session (see NOTE 4)	Yes	NA	NA	NA	To characterize.	To characterize.
5th percentile user spectral efficiency (see NOTE 5)		Yes	Yes	Yes	Yes	Yes
Average spectral efficiency (see NOTE 6)		Yes	Yes	Yes	Yes	Yes
Area traffic capaci-ty (see NOTE 7)		Yes	Yes	Yes	Yes	Yes
Density of con-nected devices (UE), per service type (see NOTE 8)	KPI or Input Parameter.	Higher than in LTE-A	To characterize, for the given served area.	To characterize, for the given served area.	Combining both access technologies will ena-ble to achieve a higher density, to character-ize.	Same as for scenarios A_{ma}, B_{ma}.

4.2 Service scenario 2: Broadband moving hotspot network

4.2.1 Scenarios definition

This service scenario gives a PoC demonstration of a system developed to provide broadband MWB links between base stations and vehicles utilizing the high-frequency unlicensed band called FACS (22 ~ 23.6 GHz) that was newly allocated in January 2018 as part of the Korean government's supply of frequencies for the 4th industrial revolution. By providing the broad-band MWB, providing passengers inside the car (bus) with high-speed Wi-Fi service through Giga-Wi-Fi AP will be demonstrated.

Unlike the below-6GHz band used in conventional cellular communications, a vast amount of frequency resources can be utilized in the FACS, thereby enabling high-speed data transmis-sion. However, as mentioned in the previous section, in highway and urban road environ-ments, there are various technical challenges that need to be solved. For example, LoS is often not secured due to an unexpected blockage by the vehicles or/and various structures (e.g., building) around the transceiver, which causes a very lethal performance degradation in the high frequency band communication environment. Therefore, 5G-ALLSTAR will demon-strate the feasibility of the key technologies by showing both high-quality video streaming ser-vice on bus and broadband onboard Wi-Fi service either in highway scenario or in urban road scenario as illustrated in Figure 15. These demonstrations will, in a first term,only involve ter-restrial infrastructures, but could also make use, in a second term of satellite complementary resources, highlighting this way the benefits of satellite systems integration within larger 5G networks.

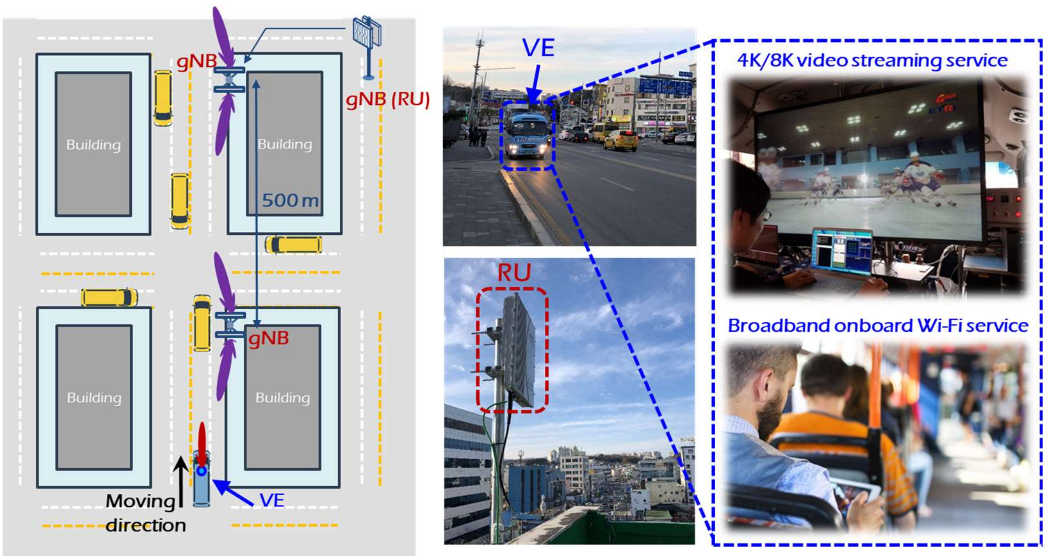

Figure 15 A preliminary plan for demonstration of service scenario 2

Key enabling technologies to be demonstrated:

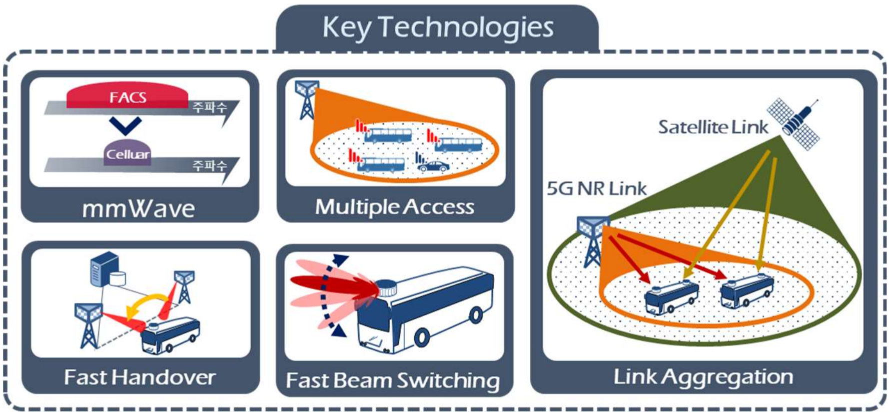

Figure 16 Key enabling technologies to be demonstrated

- mmWave-based vehicular communications: by taking advantage of a vast amount of spectrum underutilized, mmWave enables high data rate transmission
- Multiple access: a technology that allows multiple vehicles in a cell covered by a RU 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 handover: a key technology to provide seamless handover to minimize the communication interruption time when a vehicle crosses cell edge.
- Fast beam switching: a technology to combat unexpected signal blockage and increase received signal quality.
- Link aggregation: a technique to improve link reliability and potentially other service KPIs by integrating cellular link and satellite link either simultaneously or selectively in a seamless way from user standpoint.

4.2.2 Target KPI

Table 30 summarizes the target KPIs to be shown through the service scenario.

Table 30 Target KPIs of service scenario 2

Target KPI		Value
Average throughput per bus		Downlink: 500 Mbps
Average user-experienced throughput		Downlink: < 50 Mbps
Latency	User-plane latency	< 4 ms
	Control-plane latency	< 10 ms
Handover latency		< 2 ms

4.3 Service scenario 3: UHD video streaming through interoperable networks

4.3.1 Scenarios definition

This service scenario will be implemented as PoC demonstration of global interoperability between the single European and Korean PoCs. It will be eventually demonstrated during a joint EU-KR event, which might be a major sport event (e.g. Roland Garros). The demonstration will prove the feasibility of two basic 5G NR capabilities, that is multi-connectivity and satellite access, by providing multimedia services (eMBB-type) for use cases such as urban mobility (e.g. car or bus transportation).

A possible implementation of the scenario is depicted in the following picture:

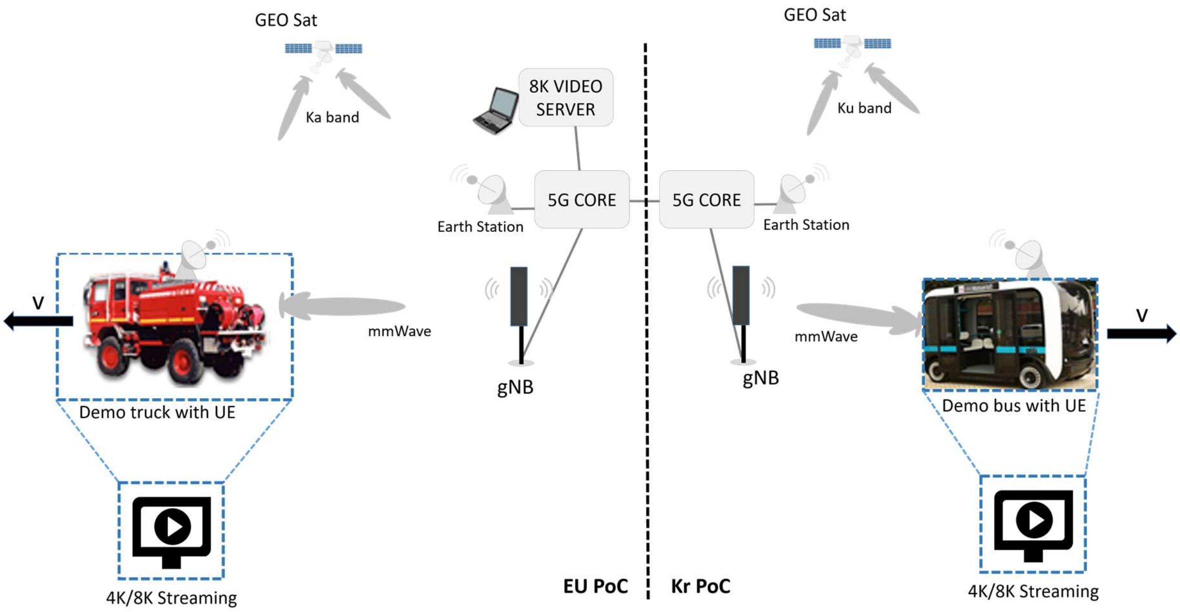

Figure 17 Possible implementation of service scenario 3

The interoperable system represents a joint EU-KR PoC made up by the single European and Korean trial platforms. Multi connectivity is achieved through multiple access combining cellular and satellite access technologies in shared mmW spectrum (Ka band at European side and Ku Band at Korean side).

At both sides of the joint system, a moving vehicle (e.g. truck, bus) equipped with 5G enabled UEs and RF equipment (e.g. on-the-roof VSAT, dish antennas) has access to the shared radio spectrum either via gNB and satellite. A 4K/8K video server (part of the European trial platform) is accessed by both UEs through public data network (VPN tunnelling) and a 4K/8K video streaming is provided. UEs are under vehicular mobility conditions (from 10 km/h to 120 km/h as defined in [4]).

4.3.2 Target KPI

The following table summarizes some possible target KPIs based on [4], [13] and NGMN technical documentation (e.g. [14], "broadcast-like services" scenarios):

Table 31 Target KPIs of service scenario 3

Target KPI		Value
Average user-experienced throughput		> 50 Mbps DL < 10 Mbps UL
Latency	U-plane end-to-end terrestrial	< 10 ms
	U-plane end-to-end satellite	< 600 ms
Service continuity		No service interruptions

The data rates of the 8K video streaming provided in the 5G-ALLSTAR demo will be likely in the range of 40-100 Mbps per video stream. In case of transmission over satellite, the available bandwidth will be a critical parameter of the system.

The following table shows approximate values for the required bitrates of video-streaming services with various qualities of transmission:

Resolution	FPS	Codec	HDR	Bitrate (kbps)
4320p (8K)	60	H.265 / VP9	yes	91000
	60	H.265 / VP9	no	78500
	30	H.265 / VP9	no	52000
2160p (4K)	60	H.265 / VP9	yes	28500
	60	H.265 / VP9	no	25000
	30	H.265 / VP9	no	16000
1440p	60	H.265 / VP9	yes	16000
	60	H.265 / VP9	no	11800
	30	H.265 / VP9	no	7600
1080p	60	H.265 / VP9	yes	6800
	60	H.265 / VP9	no	4000
	60	H.264	no	5100
	30	H.265 / VP9	no	2500
	30	H.264	no	3300
720p	60	H.265 / VP9	yes	4500
	60	H.265 / VP9	no	2400
	60	H.264	no	3000
	30	H.265 / VP9	no	1400
	30	H.264	no	1900

Assuming that state-of-the-art video and audio coding technologies are applied to the 8K video signal with 80 Mbps data rate, a minimum bandwidth of up to 40 MHz is expected to be necessary (e.g. [15]).

As per [10], two-way latency depends on the communication path and the RATs involved. As each GEO bentpipe satellite hop adds end-to-end latency in the order of 285 ms, RTT amount to up more than 0.5 s. Therefore, delay-sensitive traffic shall be routed over terrestrial access which can offer performance of the order of few milliseconds.

Typically, user-plane latency for broadband video streaming services is required to be limited to up to 1-5 s. For specific verticals (e.g. health, smart cities) the requirement for video streaming can be lowered down to 100 ms end-to-end.

5 Conclusions

This deliverable provides an overview of the vision, scope and goals of the 5G-ALLSTAR project under a variety of technical backgrounds. It also investigated and identified the various potential use cases and associated KPIs that can receive benefits from the technologies to be developed in the 5G-ALLSTAR project. It also provided a preliminary analysis on the use cases and KPIs targeting vertical markets, which is expected to give valuable insights into developing potential business models/markets for vertical stakeholders. Furthermore, we identified the preliminary service scenarios for PoC demonstrations/field trials that are suitable for verifying the overall KPIs defined, and defined detailed KPIs for each service scenario. The service scenarios and target KPIs defined in the deliverable will be further clarified and finalized in the future deliverables of WP2 (D2.3 and D2.4). With the target scenarios, WP2 will develop the overall 5G-ALLSTAR system architecture including key components, key functionalities and required interfaces and key enabling technologies will be developed by the other technical WPs. Finally, WP5 will be able to carry out a wide range of experimentations and PoC demonstrations with testbeds implemented by several key enabling technologies developed by the other technical WPs (WP3, WP4) and validate technical feasibilities of them, especially the multi-connectivity and the global interoperability.

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