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Scenarios, KPIs, use cases and baseline system evaluation

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List of Acronyms and Abbreviations

Acronym	Meaning
3GPP	Third Generation Partnership Project
5G	Fifth Generation
5GAA	5G Automotive Association
AAA	Authentication, Authorization and Accounting
AAS	Active Antenna System
AC	Alternate Current
ACLR	Adjacent Channel Leakage Ratio
ACS	Adjacent Channel Selectivity
ADM	Audio Definition Model
AR	Augmented Reality
ARQ	Automatic Repeat Request
BS	Base Station
BW	Bandwidth
C-plane	Control plane
CN	Core Network
CoMP	Coordinated Multi Point
CP	Cyclic Prefix
CPE	Customer Premises Equipment
CSI	Channel State Information
DASH	Dynamic Adaptive Streaming over HTTP
D2D	Device to device
DCI	Downlink Control Information
DL	Downlink
DMRS	Demodulation Reference Signal
DRB	Data Radio Bearers
DRX	Discontinuous Reception
E2E	End-to-end
ECC	Electronics Communications Code
eMBB	Enhanced Mobile Broadband
eNB	Enhanced NodeB
E-UTRA	Enhanced Universal Terrestrial Radio Access
EVM	Error Vector Magnitude
FCC	Federal Communications Commission

FDD	Frequency Division Duplex
FPV	First Person View
FTP	File Transfer Protocol
H2020	Horizon 2020
HAP	High Altitude Platform
HARQ	Hybrid Automatic Repeat Request
HBF	Hybrid Beamforming
HD	High Definition
HE	Homomorphic Encryption
HEVC	High Efficiency Video Coding
HTTP	Hyper-Text Transfer Protocol
IM	Interference Mitigation
IMSI	International Mobile Subscriber Identity
IoT	Internet of Things
IP	Internet Protocol
ISD	Inter-Site Distance
ITS	Intelligent Transportation Systems
ITU	International Telecommunications Union
KPI	Key Performance Indicator
KQI	Key Quality Indicator
LDPC	Low-Density Parity Check
LO	Local Oscillator
LTE	Long-Term Evolution
LTE-A	Long-Term Evolution – Advanced
MAC	Medium Access Control
MBB	Mobile Broadband
MBMS	Multicast Broadcast Multimedia Subsystem
MBSFN	Multicast Broadcast Single Frequency Network
MDA	Multi Dimensional Audio
MIMO	Multiple Input Multiple Output
mMIMO	Massive Multiple Input Multiple Output
mMTC	Massive Machine Type Communications
MPEG	Moving Pictures Expert Group
MTC	Machine Type Communications
NFV	Network Function Virtualization
NGC	Next Generation Core

NGMN	Next Generation Mobile Networks
NR	New Radio
NSA	Non Standalone
O2I	Outdoor to Indoor
OFDM	Orthogonal Frequency Division Multiplexing
OOB	Out of Band
OTA	Over-the-Air
PAPR	Peak to Average Ratio
PDCP	Packet Data Convergence Protocol
PDU	Protocol Data Unit
PLL	Phase Locked Loop
PMI	Precoding Matrix Indicator
PoC	Proof of Concept
PoP	Point of Presence
PRB	Physical Resource Block
QoE	Quality of Experience
QoS	Quality of Service
RACH	Random Access Channel
RAN	Radio Access Network
RAT	Radio Access Technology
RE	Resource Element
RF	Radio Frequency
RFC	Request For Comments
RLC	Radio Link Control
RRC	Radio Resource Control
RRH	Remote Radio Head
RRM	Radio Resource Management
RS	Reference Signal
RSU	Roadside Unit
RTCP	Real Time Control Protocol
RTP	Real-Time Protocol
RX	Receiver
SA	Standalone
SDO	Standards Development Organization
SI	System Information
SIM	Subscriber Identity Module

SIP	Session Initiation Protocol
SLA	Service Level Agreement
SON	Self-Organizing Network
SoTA	State of the Art
SPS	Semi-Persistent Scheduling
SRS	Sounding Reference Signal
SSL	Secure Sockets Layer
S/A	Sensor/Actuator
TCP	Transmission Control Protocol
TDD	Time Division Duplex
TLS	Transport Layer Security
TR	Technical Report
TRP	TX/RX Point
TS	Technical Specification
TTI	Time Transmission Interval
TX	Transmitter
U-plane	User plane
UCI	Uplink Control Indicator
UDP	User Datagram Protocol
UE	User Equipment
UHD	Ultra-High Definition
UICC	Universal Integrated Circuit Card
UL	Uplink
URLLC	Ultra-Reliable Low-Latency Communications
UTRAN	Universal Terrestrial Radio Access Network
V2X	Vehicle-to-X
VoIP	Voice over IP
VR	Virtual Reality
WP	Work Package
WRC	World Radiocommunications Conference

1 Executive Summary

The present deliverable describes the progress made in ONE5G project on the definition, characterization and quantitative analysis of a set of most promising use cases, and their corresponding services, that are identified for 5G beyond 3GPP Release 15. Strong focus has been put on the ability of 5G to address a variety of scenarios and verticals. Henceforth, views from Industry were taken into consideration prior to agreeing on the use cases.

Taxonomy for a number of vertical businesses is described first, and a set of six core use cases is presented followed by three additional associated use cases. The core use cases comprise those services that are considered most attractive for 5G and that will be technically covered in the project, by means of suitable analyses, simulations and Proof of Concepts (PoCs). The associated use cases comprise a collection of very interesting services, where some have recently gained traction within 3GPP. These will also be technically covered, although with a lower depth and without any related PoC. In parallel, a set of Key Performance Indicators (KPIs), suitable Key Quality Indicators (KQIs) are also introduced as a very convenient means to characterize the end-to-end performance. Further work will be conducted and presented in the deliverable D3.1 around the KQI concept.

A detailed quantitative characterization of the use cases is provided by means of a set of tables, containing the key parameters of the foreseen services and including the most relevant deployment and network characteristics. Wherever possible, widely recognized references, including 3GPP and NGMN, have been used to support the parameter values. The views from Industry and verticals have been considered through relevant White Papers, and the corresponding use cases and KPIs have been reviewed with the Advisory Board which gathers representatives from several of these verticals.

A basic framework for baseline system evaluations is also provided. This framework contains what is agreed upon in the Project to be the baseline for system-level evaluations, and includes the latest status in 3GPP Release 15 as well as the most relevant European Projects within the Horizon 2020 (H2020) ICT-Phase I program. A suitable methodology for system-level evaluations is also detailed, that will serve as a basis for the quantitative evaluations of the technical components that will be developed in ONE5G.

The key conclusions of this work can be highlighted in the following points:

- A significant number of use cases involve very stringent requirements, particularly in terms of **high reliability** and **low latency**.
- Some industries seem to require **more stringent values** for latency and reliability than the ones currently considered in 3GPP. Presenting suitable contributions to Standards is among the most important objectives of ONE5G, in order to ensure that the requirements set by vertical industries are sufficiently covered by Standards Development Organizations (SDOs).
- Further work is needed to properly characterize some of the selected use cases in terms of **traffic models**. Traditional traffic models for FTP, video, and multimedia sources cannot be applied to some of the described services, particularly those involving machines, factories and critical systems.
- Many of the identified use cases actually involve a **mixture** of enhanced Mobile Broadband – eMBB, massive Machine-Type Communications – mMTC and Ultra-Reliable Low-Latency Communications – URLLC service categories. The traditional division between the three categories proves to be unrealistic when it comes to the new and most advanced use cases, like e.g. time-critical processes or assisted, cooperated and tele-operated driving.
- Even if the current progress of New Radio in 3GPP Release 15 has been remarkable to date, most technical work has focused so far on eMBB with little support of other, less

traditional, use cases related to vertical industries. Hence there is an urgent need for presenting technical enablers to support these more stringent requirements of novel 5G use cases, which can influence standardization towards Release 16.

2 Introduction

This is the first public deliverable from the Work Package 2 (WP2) of the ONE5G project, where both quantitative and qualitative characterization of the identified use cases and the methodology for baseline system evaluation are presented. In the quantitative assessment of use cases, we evaluate the KPI values that need to be attained for each use case, through a number of well recognized references. These combinations of KPI values will be targeted in the project when developing the technical components and solutions in the two technical work packages WP3 and WP4. In the qualitative assessment, we look at how the use cases are related to the two main scenarios identified in the project (Megacities and Underserved Areas) and how the three service categories (eMBB, mMTC and URLLC) are captured within each use case. Also the qualitative assessment gives a notion of practical applicability of the use cases, which will make them relevant to a wider audience than in the wireless communications domain.

In use case categorization, we identify two sets: i) core use cases and ii) associate use cases. The core use cases will be studied from solution development, system level evaluation to the five proof of concepts as identified in the project proposal. The associated use cases will not have a related proof of concept in the project, but will be studied sufficiently through selected enablers aided with simulations. While the core use cases will cover the key targets set when the ONE5G project was formulated, the associated use cases give an opportunity to investigate emerging verticals which may become significant in the evolving 5G landscape.

The methodology for baseline system evaluation is also an important component in this D2.1. We identify the baseline as the current State of the Art (SoTA), at the time of developing this deliverable (M5 of the project). This is captured in terms of what is defined in the 3GPP release 15 (including the New Radio (NR) non stand-alone and stand-alone components), which will be frozen by mid 2018. We also look at the recently concluded 5GPPP phase I projects in the radio access area (FANTASTIC 5G, METIS II and mmMAGIC) to identify SoTA components that are not covered in 3GPP Release 15. The simulation methodology to capture such baseline systems is further detailed in this deliverable.

2.1 Objective of the document

The objective of this deliverable is the complete qualitative and quantitative characterization of the use cases for 5G evolution identified in ONE5G towards 3GPP Release 16.

In order to accomplish this objective, the ONE5G Consortium has first identified a number of promising vertical businesses, trying to cover the main areas of interest according to the potential of 5G to address new attractive services. Then, a varying number of promising use cases are proposed for each vertical, each of them embracing one or more services pertaining to one or several service categories (see section 2.3). Each of the proposed services are then detailed in terms of KPIs, whose values are proposed after checking multiple references as highlighted in the Bibliography. Suitable connections with Key Quality Indicators (KQIs) is also advanced, although application to the selected use cases will only be accomplished in subsequent deliverables. Finally, a description of 3GPP status is provided that sets the stage for the baseline system evaluations that will be conducted in the project.

2.2 Structure of the document

The main structure of this deliverable can be summarized as follows:

- Chapter 2 contains the basic objective and structure of this deliverable, together with the terminology.
- Chapter 3 contains a general overview of the selected use cases.
- Chapter 4 describes the use cases in detail, pointing to Annex B for an extended list of KPIs.
- Chapter 5 describes the basic characteristics of the baseline system evaluation as considered in ONE5G.
- Chapter 6 contains the most relevant conclusions and prepares the technical work for the remaining of the project.
- Annex A contains further details of the 3GPP status for the baseline system evaluations.
- Annex B contains further details of selected use cases.

2.3 Terminology to be used in connection with the use cases

2.3.1 Scenarios

A scenario is defined by a particular environment where certain conditions are met in terms of existing urban furniture, orography, access to basic public infrastructure (like energy or transmission), density of users, and proximity to households. No further sub-scenarios will be defined, as this was considered too complex to be manageable at the requirements stage.

The project will use two deployment scenarios to structure its work. Covering both “Megacities” and “Underserved Areas” contributes to the objective of “true everywhere” coverage with at least 50 Mbps, as envisioned in the NGMN White Paper [NGMN15]. These two scenarios are quite “extreme”, in the sense that realistic scenarios will in most cases fall in an intermediate category. In the following we provide more details on these two opposing scenarios (Figure 1).

- **”Megacities”**: As the name indicates, the ”Megacities” scenario is a highly populated metropolitan area, encompassing districts of high interest for operators to provide 5G, as early as possible, as these districts are promising to be profitable right from the beginning (e.g. metropolitan areas with a high density of high-end customers – both individuals and business partners offering over-the-top services). Here, very high area throughputs and connection densities are of highest importance. In addition to persons with smartphones and other connected wearables, we anticipate that the ”Megacities” scenario in the near future will include large quantities of wireless connected machine type communication (MTC) devices, such as different sensors, utility control units (e.g. heating, water, and electricity control distribution), cameras, transportation systems, etc. The latter ranges from traffic control systems to minimize congestions on the roads to ultra-reliable low latency wireless communication support for driver-less subways, buses, trams or even for drones and robots.
- **”Underserved areas”**: To ensure 5G to be rolled-out in less populated areas as early as possible, the project will investigate a second scenario which we call “Underserved Areas”. Today more than 2 to 3 billion of inhabitants on earth still do not have access to Internet according to ITU. There are two reasons. The first one is because they live in regions that are not covered by traditional networks due to an insufficiently attractive business case, either because the population density is not high enough to provide sustainability for deploying and operating mobile networks infrastructure in these regions, or because of other challenging operational conditions (like unreliable AC power, abundance of natural disasters, etc.). The second reason is that there are many people under network coverage that cannot afford the price of end-user broadband and the price of voice/Internet connectivity offers. Addressing such underserved users is one of the goals of this scenario.
  Less extreme than the above (but equally relevant), there is a common situation in current networks where mobile voice/Internet access does exist, but is so basic in some regions that many advanced digital services simply cannot work. Improving mobile broadband connectivity in these areas is the other goal of the “Underserved Areas” scenario.

Table 1 summarizes the main characteristics and assumptions for both scenarios.

Table 1: main characteristics of ONE5G scenarios

Feature	**"Megacities"**	**"Underserved Areas"**
Building structures	Highly heterogeneous. Large variety of building structures and transportation infrastructures. Dominated by multi-floor buildings of approximately 5-10 stories height, with some reaching heights of 20-50 floors (although less floors can also be characteristic of densely populated areas, depending on the country).	Mainly houses (1 or 2 stories), dispatched with potentially large open spaces and/or vegetation between houses or group of houses.
Transportation infrastructure	Public transportation systems such as underground subways, elevated subways, ground level busses and or trams.	Cars on roads and highways, trains, ground level buses
Open spaces	The scenario includes park areas with richer greenery (trees, bushes, small lakes), as well as open squares with less green vegetation	Open spaces, with or without vegetation, are largely dominant.
Human users	Time-variant and spatial non-uniform density of persons. Generally high density. (e.g. during work hours, high density of persons, slowly nomadic in office buildings) The public transportation systems are carrying larger groups of relative dense packed persons at medium to high speeds (approx 50-100 km/h).	Low to very low density of users, spatially non uniform Mobility of users can vary over a large scale: from pedestrian speed to high speeds (120 km/h)
Radio frequencies	Licensed operation from ~700 MHz to ~4 GHz as per WRC-2015. Unlicensed 5GHz band Options for higher frequency licensed usage as expected to come at WRC 2019 are not excluded.	Licensed operation from ~700 MHz to ~4 GHz as per WRC-2015. Unlicensed 5GHz band
Radio node density	Relatively high density of radio nodes. Mixture of indoor and outdoor nodes. Variable spatial density of nodes over the considered area.	Low density of radio nodes, mainly outdoor nodes. Spatial density of nodes is quite homogeneous.
Radio node power classes and antennas	From low power indoor nodes to high power outdoor macro cells. Small cell nodes are assumed to have moderate number of antennas, while larger outdoor nodes may have massive MIMO.	High power outdoor macro cells, mostly having omni-directional antennas.
RAN architecture	Areas with larger clusters of centralized RAN with radio nodes in the form of RRHs with dark fibers to centralized RAN entity. Other areas of the network include distributed RAN with traditional backhaul connections.	Mainly areas of the network include distributed RAN with traditional backhaul connections, or alternative backhaul connections (satellite ...) in remote areas). No fiber deployment for backhaul.
Radio links	Access links: Radio nodes and devices. Direct device to device links.	Access links: Radio nodes and devices. Wireless backhaul links

	Wireless backhaul links for some Radio nodes.	
Services	eMBB (e.g. from human carried devices and wearables) mMTC (e.g. sensors, control units, cameras, info boards) URLLC (e.g. com. for driver-less subways and busses, robots, drones, energy grid, alarm systems with remote action)	eMBB (e.g. from human carried devices and wearables) mMTC (e.g. agricultural / forest sensors) URLLC (e.g. control sensors on highways)

Figure 1: ONE5G concept: illustration of the two main scenarios covered by the project

2.3.2 Key Performance Indicators

Key Performance Indicators are the basic tool widely used for quantitative characterization of the use cases, in terms of a number of objective requirements for several fundamental parameters like throughput, latency, jitter, etc.

A major novelty in ONE5G will be to address the Radio Access Network taking into account the potential E2E performance. The E2E paradigm presents the mobile network as a single pipeline between the application running in the UE/device and the remote host. Performance assessed in an E2E fashion is close to the experience of the final user and reflects the behavior of the network and application as a whole, integrating the effects of various elements and configurations in the network over the E2E path, such as the RAN, core or external networks, interfaces, and the device/client itself.

2.3.3 Key Quality Indicators (KQIs)

Due to the presence of multiple inter-dependences across the entire E2E path described above, measuring the service quality is a non-trivial issue, even when it is limited to the objective quality rather than embracing subjective experience. The Key Quality Indicators (KQI), introduced by ETSI [102.250] and profiled by 3GPP [32.862, 26.944], offer a framework to reflect objectively the service performance and quality, inherently from an E2E perspective. Specifically, the KQIs in their general definition allow for measuring and effectively managing service quality while separating the quality assessment in well-defined phases or categories, thus measuring a specific aspect of the performance of the network or service levels. In the following the main KQI categories are defined:

- **Network Availability:** The probability of success that network functions can be performed over a specified period.
- **Network Accessibility:** The probability that the user requesting a service to the network receives the proceed to request within specified conditions.
- **Service Accessibility**: The ability of a service to be obtained, when requested by the user, within specified targets.
- **Service Integrity:** The degree to which a service is provided with acceptable quality, i.e. without major impairments, once obtained.
- **Service Retainability:** The probability that a service, once obtained, will continue to be provided under given conditions, i.e. without interruptions.

Each KQI category can then be constructed properly aggregating "lower-layer" KPIs, comprising of network and radio indicators, and therefore constrains the scope of the network/radio KPIs associated to the given KQI. It is worth noticing that, for simplicity, the current terminology considers an end-user service, however the definitions above could be adjusted slightly to accommodate machine type of communication and related services, which do not imply the presence of an end-user.

An additional observation is that the KQI categories help to identify network optimization potentials which will be helpful during the ONE5G technical work towards the E2E performance optimizations, as they pinpoint areas, which are responsible for quality degradations. Lastly, KQIs are also largely adopted in the industry as best practice, e.g. refer to NGMN [NGMN13] and TM Forum [GB 923].

The KQI concept will forge the foundation of the E2E performance modeling in ONE5G and will be adopted for the analysis of *selected* services and use cases in WP3/4/5, whenever KQI indicators are well defined in the industry. In fact, KQIs for eMBB are specified in detail in [32.862], see Table 2, whereas the definitions of KQIs for services belonging to new verticals appear still largely undefined in the industry, and may require further exploration of their availability. In general, although not well defined yet, KQIs for machine type communication may be more deterministic then user-based applications, therefore per-packet E2E QoS targets may suffice to a large extent.

Table 2: Examples of KQIs for MBB services, source [32.862]

KQI category	**File transfer**	**Video Streaming**	**Web-browsing**
Service accessibility (KQI-A)	Initial File Transfer Delay (s)	Video Streaming Start delay (s)	Page Response Delay (s)
Service Integrity (KQI-I)	File Transfer avg throughput (Mbps) File Transfer delay (s)	Video Bit Rate (Mbps): Min/Average/Max (Assumes Adaptive Bit Rate)	Avg Page Throughput (Mbps) Page Download Time (s)
Service Retainability (KQI-R)	File Transfer Cut off ratio (-)	Video Streaming Stall: • Frequency (-) • Number (-) • Time (s) Streaming cut off ratio (-)	Page Transfer Cut-off Ratio (-)

Alignment of the KPIs associated to the proposed use cases, which are described in the later section, towards the KQI framework presented above, will be fine-tuned in the coming period as part of the technical Work Package 3 that will adopt the KQI concept.

2.3.4 Use cases

A use case will be a real life application that may support one or more service categories (eMBB, mMTC, URLLC – see below) through a clearly defined set of KPIs and belong to one or more verticals. The 'real life' aspect is highlighted in the use case description, as this helps the wider audience appreciate the real applications of the demanding technical KPIs we try to achieve in ONE5G. A use case may support diverse services from different service categories.

2.3.5 Services and service categories

A service represents an application that is provided within a use case and scenario, with particular characteristics in terms of KPIs. Examples are Augmented Reality (AR), Virtual Reality (VR), Ultra-High Definition (UHD) video, etc.

A service category represents a set of services that share some common characteristics in terms of connectivity. eMBB, mMTC and URLLC are examples of service categories. Services within each category may not have the same KPIs, but share some basic connectivity parameters, like e.g. the need to provide reliability and low latency in URLLC.

2.3.6 Vertical businesses

A vertical business (or vertical application) represents a set of services sharing some common characteristics, although not necessarily linked to connectivity. For example, the automotive vertical shares the common denominator of being related to vehicles, but actually can comprise services within all the three service categories: infotainment (eMBB), driving assistance (URLLC), and sensors within the car (mMTC). It will be key to identify, for the most interesting vertical businesses, which service categories will be necessary to address, and what will be the main characteristics of the services in each service category.

2.3.7 Context

Context means any associated information related to user/network that will help optimize the Quality of Service (QoS) / Quality of Experience (QoE), and different from the KPIs.

2.3.8 Deployment scenarios

Deployment scenarios are usually referenced in the use cases description (as per the 3GPP work), but are not directly related to the scope of the use cases in ONE5G. Some of these deployment scenarios can be matched to use cases, while others are out of scope for the project. The use cases descriptions are aligned with 3GPP whenever possible, but within the project scope.

3 General overview of the use cases

This section contains an overview of the core use cases and the associated use cases identified in ONE5G. It also contains a reference for the corresponding vertical businesses involved, the level of standards maturity with respect to 3GPP or other Standards bodies, and the service categories. An overview is provided in Table 3.

Table 3: summary of core and associated use cases considered in ONE5G

	No.	Use Case	Vertical business	Level of standards maturity w.r.t. 3GPP/other	Service categories	Scenario
Core use cases	1	Assisted, cooperative and tele-operated driving (between vehicles, and between them and infrastructure)	Automotive	High (TR 22.886)	all	Megacities, Underserved Areas
	2	Time-critical factory processes and logistics optimisation (industry and smart airports)	Factories, Transport and Logistics	High (TS 22.261)	all	Megacities
	3	Non time-critical processes and logistics (factories and smart cities)	Smart Cities and Energy	High (TR 45.820 and TR 38.913)	mMTC	Megacities, Underserved Areas
	4	Long range connectivity in remote areas with smart farming application	Agriculture	High (TR 38.913)	eMBB, mMTC	Underserved Areas
	5	Outdoor hotspots and smart offices with AR/VR and media applications	Media, Entertainment and eOffice	High (TR 38.913, TS 22.261, …)	eMBB	Megacities
	6	Live Event Experience	Media, Entertainment and eOffice	High (TS 23.246, TS 26.346, …)	eMBB	Megacities, Underserved Areas
Associated use cases	7	Health/wellness monitoring	eHealth and Wellness	Low	mMTC, UR(LL)C	Megacities, Underserved Areas
	8	Smart grid, connected lighting and energy infrastructure	Smart Cities and Energy	Med (eg: TR 45.820 and TR 38.913)	mMTC	Megacities, Underserved Areas
	9	Ad-hoc airborne platforms for disasters and emergencies	Disasters and Public Safety	High (Study Item on NR to support non-terrestrial networks)	eMBB/mMTC	Megacities, Underserved Areas

The core use cases identify the use cases that will be thoroughly studied in the project, with investigations of technical components and incorporation of a subset of these technical components in the PoC demonstrations. The associated use cases represent the ones that will be partially covered in ONE5G, with no support in the PoC, but with significant interest due to their connections to Industry and Standards.

It can be noticed that, apart from use cases 5 and 6 pertaining to the Media, Entertainment and eOffice vertical (i.e. closer to traditional MBB usage), the remaining use cases cope with new applications of 5G technology to the other verticals. Such new applications represent what the consortium considers are the most promising services to come. The advent of 5G in fields like smart farming, factories or eHealth will bring new and disruptive ways to improve people's lives by spreading the range of applications under reach of 5G.

A pictorial depiction of the core and associated use cases are presented in Figure 2 below.

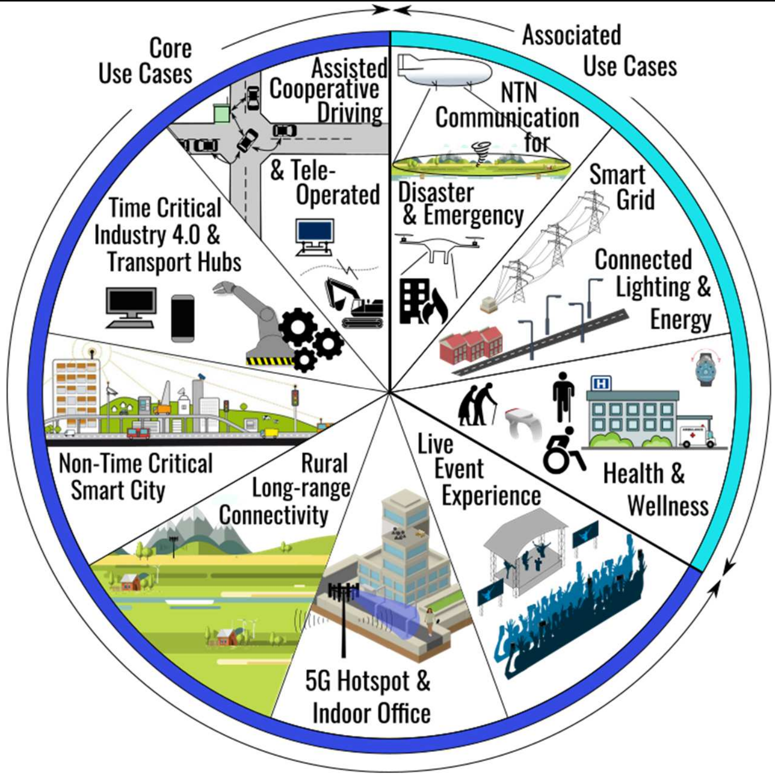

Figure 2: A pictorial view of the core and associated use cases of ONE5G

Further details of the use cases are described in section 4, including full quantitative parameterization in Annex B: full details of selected use cases.

4 Detailed characteristics, requirements, and KPIs of the use cases

Before looking at the detailed descriptions of the individual use cases, an overall view of the use cases and how they require key services combinations will be useful to the reader. A diagram to this effect is presented in Figure 3 below.

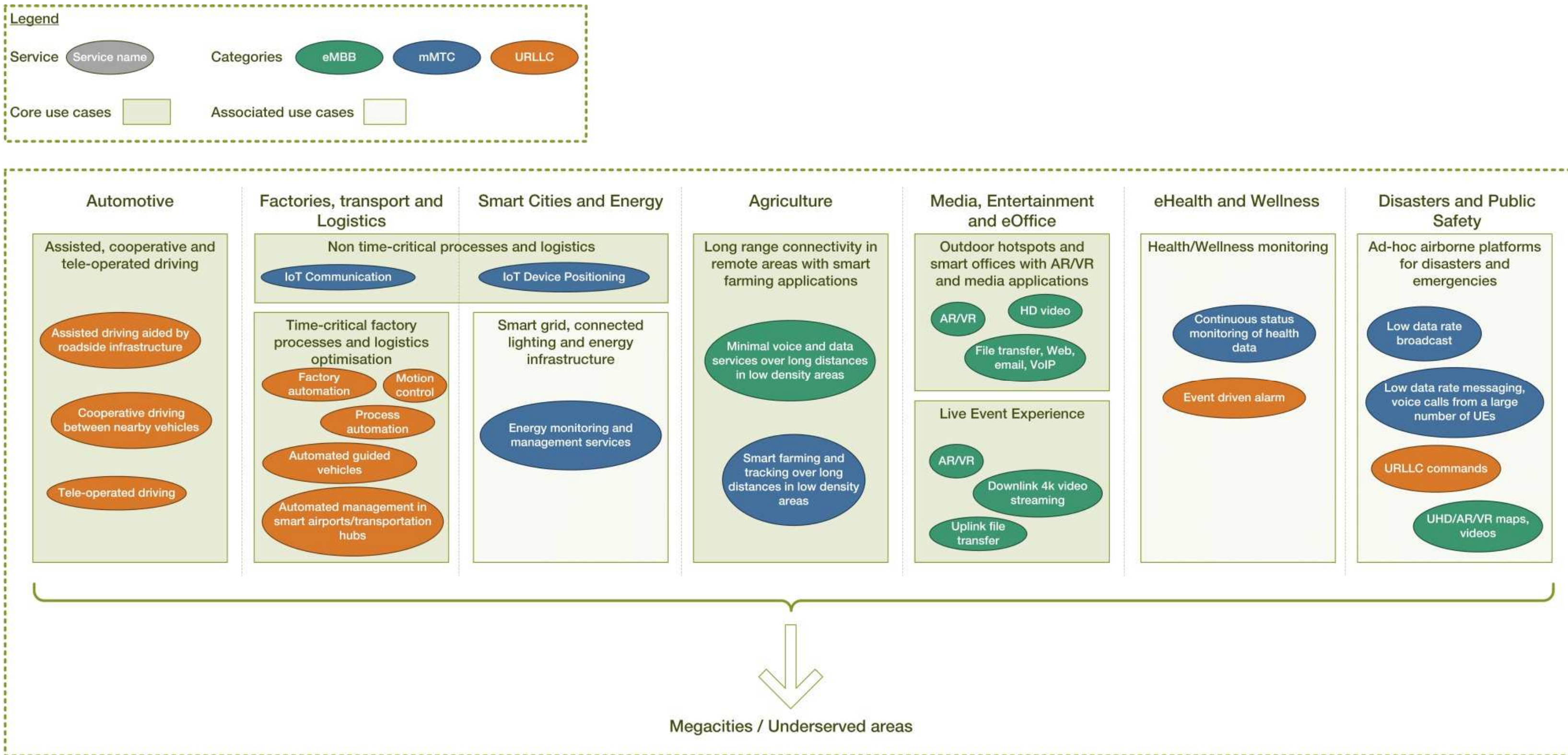

Figure 3: Detailed view of the use cases, with service components

4.1 Assisted, cooperative and tele-operated driving

4.1.1 Description

A vehicle is driving in a road in presence of other vehicles. Assisted/cooperative driving use case enables vehicles to interact with each other, as well as with the network infrastructure and any available roadside unit (RSU), in order to avoid potential collisions and improve driving safety.

Tele-operated driving involves a human driver physically located outside of the vehicle. When routes are predictable, such as in public transportation, driving based on cloud computing can be considered. Access to cloud-based back-end service platform can also be taken into account. High reliability and short latencies are the main requirements in this case [22.886].

3GPP SA1 defines RSU as a logical entity that combines V2X application logic with the functionality of an eNB (referred to as eNB-type RSU) or UE (referred to as UE-type RSU). Therefore, a RSU can communicate with vehicles via D2D link or cellular DL/UL [38.913]. Roadside units may comprise any roadside element with connection capabilities towards other vehicles and/or the cellular network (Figure 4).

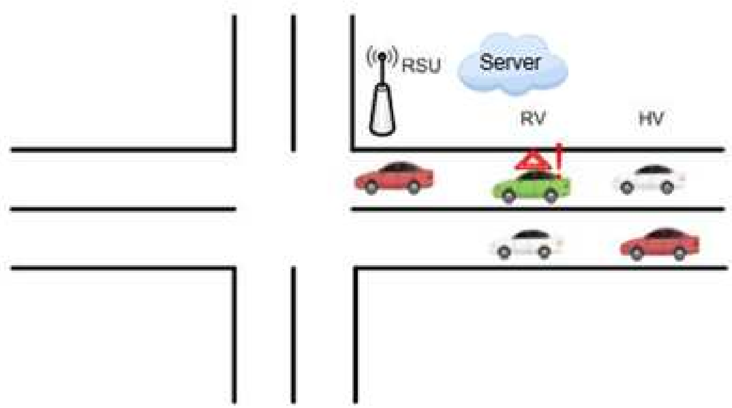

Figure 4: Schematic scenario for assisted, cooperative and tele-operated driving use case. In this context, "RV" stands for Remote Vehicle and "HV" means Home Vehicle.

The scenarios for applicability of this use case are both Megacities and Underserved areas. In the former case, "Urban grid for connected car" is the applicable scenario from 3GPP, while in the latter case "Highway scenario" is the closest one, both described in [38.913]. Roadside units may or may not be present.

All the three service categories (eMBB, URLLC, mMTC) are present in this use case.

4.1.2 Services

1. **Assisted driving aided by roadside infrastructure**. This service assumes the presence of RSUs as an enabler for improved coverage and very low-latencies. The network infrastructure is generally present, but car-to-car communication should be possible even in the absence of network coverage. An example (taken from the 5G Automotive Association, 5GAA) is provided in Figure 4.
2. **Cooperative driving between nearby vehicles**. In this service, RSUs are not present and communication is purely car-to-car based, with the aid of the network infrastructure (wherever available). Car-to-car communication should be possible even in the absence of network coverage.
3. **Tele-operated driving**. This service requires the cellular communication providing URLLC for the control data transmission in the downlink as well as reliable and low-latency video (plus other sensor data) transmission in the uplink.

4.1.3 Relevant KPIs

Among the most relevant KPIs, the following ones are highlighted in the tables below.

4.1.3.1 Network and UE deployment KPIs

Network and UE deployment KPIs	Service 1	Service 2	Service 3	Comments
Layout and layers	Macro grid, with presence of RSU	Macro grid, with no RSUs	Macro grid, with optional presence of RSU	RSUs may be deployed in an opportunistic way, i.e. any location can be valid for testing this use case. [38.913] defines some possible layouts.
Inter-site distance (ISD, m)	500m (urban), 1732m (highways). Eventual presence of RSUs in e.g. street intersections or semaphores. Inter-RSU distance = 50/100 m for highways.	500m (urban), 1732m (highways).	500m (urban), 1732m (highways), with optional presence of RSUs at convenient locations	As per [38.913].
Carrier frequency	Below 6 GHz (e.g. ETSI ITS band) for vehicle to vehicle/RSU. Any licensed band <6 GHz for connection to base station.			As per [38.913]. ETSI ITS band includes 30 MHz in 5.875 – 5.925 GHz. Other options might appear in the future.
Aggregated system bandwidth	Up to 200 MHz (DL+UL) for connection to base station. Up to 100 MHz (SL) for connection to vehicle to vehicle/RSUs.			Total bandwidth typically assumed to derive the values for some KPIs, such as area traffic capacity and user experienced data rate [38.913]. Might start with a lower value (10/20 MHz) and extend to 100/200 MHz when new ITS bands are available.
BS / UE transmit power (dBm)	BS: +46 dBm (+49 dBm in Underserved Areas) UE: +23 dBm RSU: +23 dBm			20 MHz BW assumed. Actual values may change as per the system BW. Transmit power is assumed larger for

		Underserved areas, but Transmit power + antenna gain should not exceed the max. EIRP.
# BS antennas	Up to 256 TX/RX	As per [38.913]
# UE antennas	Up to 8 TX/RX	As per [38.913]
Maximum # UEs	1000 vehicles	Number of UEs attached to base station
Maximum / Average # Active UEs	Max: 200 active UEs. Avg: 50 active UEs	An RSU shall be able to communicate with up to 200 UEs supporting a V2X application [22.886]. A lower value is taken for the average #connections
UE speed	Up to 250 km/h	As per [22.886].
Connection density	1000 veh. / km^2 (Megacities), 85 veh. / km^2 (Underserved areas)	Obtained with ISD = 500/1732 m and 200 active UEs, assuming omni-directional coverage. Higher densities may appear in e.g. parking lots, with densely packed cars e.g. outside a stadium.

4.1.3.2 Service KPIs

Service KPIs	**Service 1**	**Service 2**	**Service 3**	**Comments**
U-plane maximum UL/DL radio latency (ms)	0.5 ms	0.1 ms	2 ms	Taken as 1/10th of the end-to-end maximum latency. Radio protocol layer in which it is measured should be specified.
U-plane maximum E2E latency (ms)	5 ms	1 ms	20 ms	Taken from [22.886].
C-plane maximum UL/DL radio latency (ms)	10 ms	2 ms	10 ms	Max. time for C-plane state transition to “connected state”. Taken from [38.913], reduced for Service #2.
U-plane maximum DL/UL radio packet loss (%)	0.001%	0.001%	0.001% or lower	Taken as (100 - reliability)%

U-plane reliability	99.999%	99.999%	99.999 % or higher, up to 250 km/h.	Probability that IP packets are correctly received within the latency time. Taken from [22.886].

4.2 Time-critical factory processes and logistics optimization (industry and smart airports)

4.2.1 Description

The focus on this use case is primarily on use of URLLC in factories-of-the-future and smart-transportation verticals for both closed- and open-loop control and monitoring of critical processes. In regard to the latter, the use case also involves eMBB for enhanced monitoring and offering new services, and mMTC for the connection of multiple sensors and related machinery.

The common characteristic of the services from this use cases is that they concern in-door deployment. The required levels of reliability and tolerated latency depend on the service; notably, the required levels of reliability and latency as foreseen by 3GPP [22.261] are typically less demanding in comparison to what is expected by some industrial players [SIEMENS] or telecom vendors [EBR15].

4.2.2 Services

1. **Motion control**

Motion control pertains to industrial setups in which controllers periodically issue control-commands to actuators, typically machines with moving parts, like machine tools, printing machines, paper mills and textile machines. The communications in this serviceare assumed to be isochronous. The cycle times (i.e., the time from execution of the command until the feedback from the actuator is received, which includes all processing and latencies on the air interface and actuation times) are of the order of milliseconds, putting extreme requirements on the communications in terms of latency. Moreover, the controlled processes may incur risks to the factory personnel or overall production, which puts extreme requirements on reliability and availability of communications (six nines or more).

Figure 5, taken from [22.261] illustrates a service of motion control within factory premises.

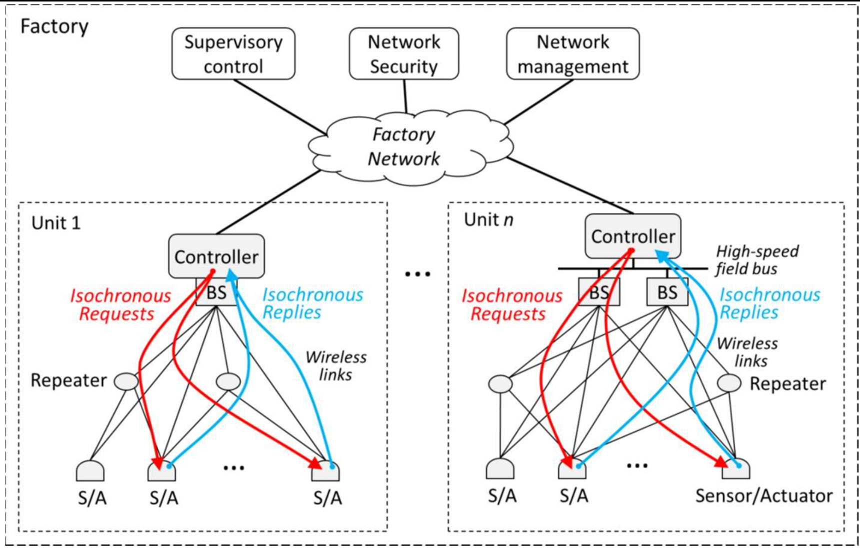

Figure 5 (taken from [22.261]): Communication path for isochronous control cycles within factory units. Step 1 (red): controller requests sensor data (or an actuator to conduct actuation) from the sensor/actuator (S/A). Step 2 (blue): sensor sends measurement information (or acknowledges actuation) to controller

2. **Factory automation**

Factory automation, also referred to as discrete automation/discrete manufacturing, pertains to production of discrete units, e.g., cars, TV sets, mobile phones, etc. Communications are required for supervisory, monitoring and open-loop control applications, and the uplink/downlink data flows are in principle asynchronous.

Figure 6 depicts an example of communication networking in discrete automation [22.261].

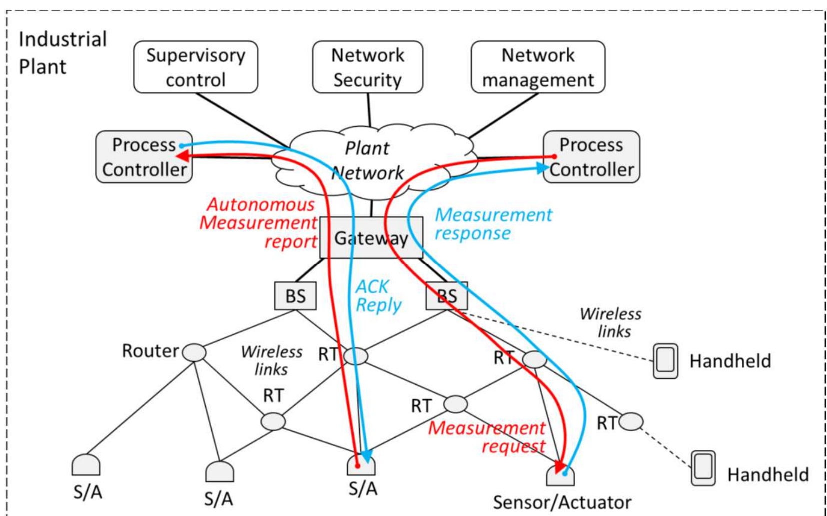

Figure 6 (taken from [22.261]): Communication path for service flows between process controllers and sensor/actuator devices. Left-hand side: Step 1 (red) – the sensor/actuator (S/A) sends measurement report autonomously, Step 2 (blue) controller acknowledges. Right-hand side: Step 1 (red) - controller requests sensor data (or an actuator to conduct actuation), Step 2 (blue): S/A sends measurement information (or acknowledges actuation) to controller

3. **Process automation**

Process automation, also referred to as process manufacturing, pertains to production of goods on bulk quantities, like chemicals, liquids, reactive gasses etc. In contrast to the previous two services, in process automation, motion control does not play a significant role.

4. **Automated guided vehicles**

This service pertains to control of mobile robots or drones used in industrial applications to move materials around a manufacturing facility or warehouse. The vehicles typically follow markers for orientation; e.g., markers could be wires, or of visual/magnetic kind.

5. **Automated management in smart airports/transportation hubs**

This service comprises resource management (efficient lighting, heating, power) based on passenger traffic as well as health monitoring of installed assets. This scenario bears a lot of similarities with process automation.

4.2.3 Relevant KPIs

4.2.3.1 Network and UE deployment KPIs

Network and UE deployment and KPIs	**Values or assumptions** **Scenario:** Indoor factory use/industrial plant areas/smart transportation hub	**Comments**
Layout and layers	Single-layer Indoor floor: (3,6,12) BSs per 120 m x 50 m	[38.802] Section A.2.4 / Indoor hotspot
ISD (m)	20 m (Equivalent to 12TRPs per 120m x 50m) 20 m – 1000 m	[38.802] Section A.2.4 / Indoor hotspot (taken from [38.913]) Smart transport hub – ranges for predictive traffic monitoring
Carrier frequency	4 GHz 4/30/70 GHz	[38.802] Section A.2.4 / Indoor hotspot Smart transport hub
Aggregated system bandwidth	Up to 200 MHz (DL+UL)	[38.802] Section A.2.4 / Indoor hotspot
BS / UE transmit power (dBm)	24 dBm per 20 MHz /23 dBm	[38.802] Section A.2.4 / Indoor hotspot
# BS antennas	Around 4GHz: Up to 256 Tx and Rx antenna elements	[38.802] Table A.2.4.-1. (same as in [38.913])
# UE antennas	Up to 8 Tx /Rx antenna elements	[38.802] Table A.2.4.-1. (same as in [38.913])
Traffic model	Unidirectional and bidirectional (DL or UL). URLLC: Both FTP Model 3 (with Poisson arrival) and periodic packet arrivals with packet size 32, 50, 200 bytes. eMBB: Option 1: Full buffer, Option 2: FTP model 3 with packet size, 0.1Mbytes and 0.5Mbytes	[38.802] Section A.2.4 / Indoor hotspot

Maximum # UEs[2]	Factory automation: 1 connection per 10 m^2 Process automation: - Motion control: 10 UEs per production cell (10 m x 10 m x 3 m) URLLC: 10 UE/floor/TRP eMBB: 0/10 UE/floor/TRP 10^5 Max 10^5/km2	[22.261] [22.261] [38.802] Section A.2.4 / Indoor hotspot [SIEMENS] Smart transport hub
UE distribution and speed	Follow Indoor Hotspot user distribution (TR 38.913) for both URLLC and eMBB UEs: 100% Indoor, 3 km/h Ranges between communication neighbours: 0.1 – 100 m, Speed: 50 km/h Cluster	[38.802] Section A.2.4 / Indoor hotspot [SIEMENS] Smart transport hub
Services mixture	At least combinations of the representative services of this use case should be supported.	
Network KPIs	**KPIs' Targets**	**Comments**
Network energy efficiency	Not defined yet.	
Area traffic capacity	4 GHz UL: 3 Mbps/m2, 4 GHz DL= 6 Mbps/m2 1Tbps/ km2	[38.913] Smart transport hub: [22.261] V15.1.0 Table 7.2.2-1
UE KPIs	**KPIs' Targets**	**Comments**
Reliability	URLLC: 99.999% for one transmission of a packet of length 32 bytes with a user plane latency of 1ms	[38.913] The foreseen reliability is inadequate for most of the representative services of this use case.
U-Plane average latency (ms)	URLLC: 0.5 ms	[38.913]
Experienced data rates (Mbps)	100 Mbps	Smart transport hub: [22.261]

[2] Note that (i) this use case consists of several services with varying KPIs and (ii) the values of KPIs within a service have different specifications in the available literature; this is reflected by having several entries for certain KPIs in the table.

		V15.1.0 Table 7.1.1
E2E latency	1 ms	Smart transport hub

4.2.3.2 Service KPIs

1. Service 1: Factory automation		
Service KPIs	**KPIs' Targets**	**Comments**
Cycle time	10 ms	[5GPPP], [22.261]
U-plane E2E latency	10 ms Siemens demand: 1 ms (local), 5 ms (long distance)	[22.261] [SIEMENS]
U-Plane maximum E2E jitter (ms)	100 µs Siemens demand: 1 µs (local)	[22.261] [SIEMENS]
U-plane reliability	99.99 % 99.9999999 % 100 %	[22.261] [EBR15] [SIEMENS]
User experienced data rates	10 Mbps 100 kbps (automation stream) up to 100 Mbps (remote access, video supervision)	[22.261] [SIEMENS]
Payload size	Small to big (small ≤ 256 bytes)	[22.261]
Traffic density	1 Tbps/km^2	[22.261]
Connection density	100 000 km^-2	[22.261]
Service area dimension	1000 m x 1000 m x 30 m	[22.261]
2. Service 2: Process automation[3]		
Service KPIs	**KPIs' Targets**	**Comments**
Cycle time	100 ms	[5GPPP]
U-plane E2E latency	50 ms Siemens demand: 1 ms (local), 5 ms (long distance)	[22.261] [SIEMENS]
U-Plane maximum E2E jitter (ms)	20 ms Siemens demand: 1 µs (local)	[22.261] [SIEMENS]
U-plane reliability	99.9999 % 99.9999999 % 100 %	[22.261] [EBR15] [SIEMENS]
User experienced data rate	1 Mbps up to 100 Mbps 100 kbit/s (automation stream) up to 100 Mbps (remote access, video supervision)	[22.261] [SIEMENS]
Payload size	Small to big (small ≤ 256 bytes)	[22.261]
Traffic density	100 Gbps/km^2	[22.261]
Connection density	1000 km^-2	[22.261]

[3] Note that Service 5: "Automated management in smart airports/transportation hubs" bears a lot of similarities with this service and is thus omitted in this table.

Service area dimension	300 m x 300 m x 50 m	[22.261]
3. Service 3: Motion control		
Service KPIs	**KPIs' Targets**	**Comments**
Cycle time	1 ms 2 ms	[5GPPP] [22.261]
U-plane E2E latency	1 ms	[22.261]
U-Plane maximum E2E jitter (ms)	1 µs	[5GPPP], [22.261]
U-plane reliability	99.9999 %	[22.261]
User experienced data rate	1 Mbps up to 10 Mbps	[22.261]
Payload size	Small (≤ 256 bytes, typically ≤ 56 bytes)	[22.261]
Traffic density	1 Tbps/km^2	[22.261]
Connection density	100 000 km^-2	[22.261]
Service area dimension	100 m x 100 m x 30 m	[22.261]
4. Service 4: Automated guided vehicles		
Service KPIs	**KPIs' Targets**	**Comments**
U-plane E2E latency	10ms	[EBR15]
U-plane reliability	99.99999 %	[EBR15]

4.3 Non time-critical processes and logistics (factories and smart cities)

4.3.1 Description

The focus on this use case is on use of mMTC in factories-of-the-future and smart cities.

Non time-critical processes and logistics (factories and smart cities) is defined to provide the required connectivity level to sensors, actuator and various connected things that will, during the 5G era, help to improve IoT device management in different contexts, from the factory localized in Underserved Areas with the management of assets and goods in on-site production and logistic processes, non-time critical quality control, or data capturing for later usage, to the management and infrastructures monitoring of large urban areas.

55% of the world's population is now living in urban areas and by 2050, 70 percent of the world's population will live in cities. The explosive growth in the number of city dwellers is posing a huge challenge for urban infrastructures, which are reaching their limits in many places. For example, today more than 50 percent of the world's population has settled on less than two percent of the earth's surface area. As a result, urban centers with their traffic, industry, and energy needs already account for up to 70 percent of global greenhouse gas emissions. Developing smart city applications and connecting entire cities will enable the dynamic and smart management and monitoring of entire city infrastructures and environments.

Figure 7 Illustration of the smart city

It will be possible to monitor waste tanks and waste collection. The air will also be monitored (temperature, pressure, humidity, CO_2). All the infrastructures will be equipped of sensors, from the parking to detect occupancy and inform citizens of parking-slots availability, to the traffic lightning.

Different applications are made possible thanks to IoT sensors:

Traffic management:

It consists in monitoring vehicle and pedestrians, traffic lightning to optimize driving and walking roads. Connected sensors for traffic management can be localized in a wide variety of locations to collect a wide variety of data. In-vehicle sensors can monitor their speed and location. Sensors can also be placed on the street or into the road surface, counting the number and type of vehicles.

Waste collection and management:

Sensors allow monitoring waste tanks, locating / tracking them to ensure no waste overflow. it allows also optimizing the waste collection plan and the recycling.

Parking detection and information:

Parking sensors allow detecting on street parking occupancy as well as informing citizens of parking-slots availability. Analytics can be provided to the city, reducing time to search a place as well as pollution. Collected data facilitate the day-to-day monitoring and payment supervision and feed the city parking planning and strategy.

Air monitoring:

Monitoring air (temperature, pressure, humidity, CO_2) helps to improve heating, air-conditioning, ventilation. It produces centralized analytics, optimizing the comfort in buildings and allowing energy savings and cost improvement.

Figure 8 Different possible services of the smart city

The same principle of monitored infrastructures applies to factories that could benefit from 5G in Underserved Areas scenario if not relying on any existing communications infrastructure to operate.

Smart factories or Industry 4.0, designates the current trend of automation and data exchange in manufacturing technologies. Its main components are cyber-physical systems, the Internet of things (IoT) and cloud computing. In a smart factory, all tools and workstation integrated into production and supply lines are interconnected continuously and almost instantaneously, so that remote control, self-configuration, self-diagnosis and self-optimisation are made possible. Once made digital, the smart factory and its reconfigurable tools enable product customization, as well as production line reconfiguration between different products. Such flexibility enables production to become at the same time massive and customisable.

Non-time critical factory processes and logistics include:

Access control and monitoring:

In this use case, doors, windows, and globally access usages are monitored. Alerts can be triggered in case of misuse, improving security and comfort and optimizing the usage of buildings and rooms.

Remote maintenance:

This application includes the control of machine commands, incident detection, radio command for hoisting equipment, industrial weighing as well as improved maintenance through remote operation indicators collect and control command.

Logistics-asset tracking:

The objective is to follow and locate valuable equipments, moving from one place to the next, providing an asset referential up to date, following up deliveries and improving scheduling.

Energy management:

Management of energy is performed through the gathering of all relevant production, consumption and energy data.

Figure 9 Illustration of the smart factory

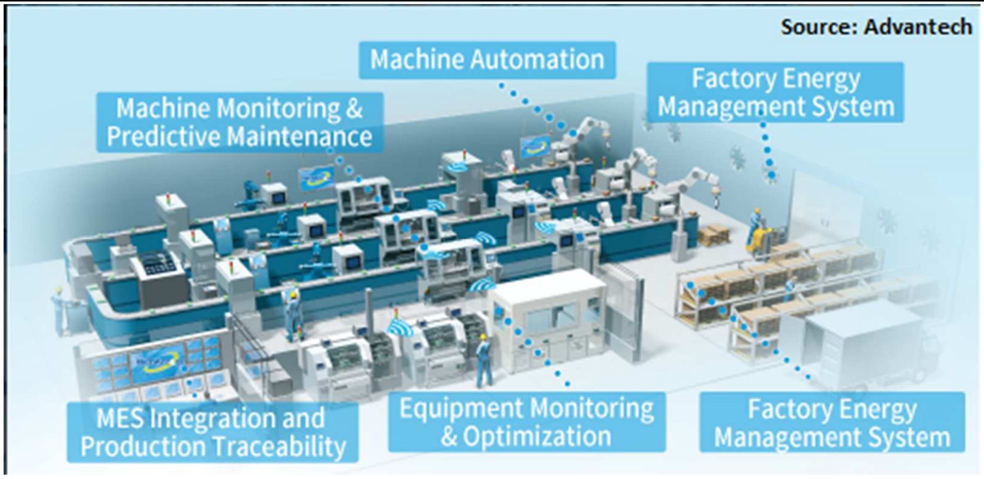

Figure 10 Different possible services of the smart factory

Tracking applications, which consists in following and locating valuable equipment, moving from one place to the next, will also benefit from 5G, whether for the Industry 4.0 when tracking assets and goods in on-site production or the Smart city when tracking personal goods or sending personalized mobile advertisements.

4.3.2 Services

1. **IoT communication**

This service encompasses the majority of applications described in the previous section: traffic management, waste collection and management, parking detection, air monitoring for smart cities, and access control and monitoring, remote maintenance as well as energy management for smart factories.

The key characteristic of this service will stay in the quite large density of connected devices.

- A large part of them will have to cope with stringent energy constraint as they operate on a non-rechargeable battery,
- A part of them might also face unfavorable location (basement, deep indoor, underground).
- Usually, due to the need to save energy, those devices have a low activity factor.
- However, in specific situations (reaction to a large scale event) a peak activity of a large part of the UE in the same area can occur.
- Per UE traffic volume is mostly limited compared to regular eMBB UE

2. **IoT Device positioning**

This service encompasses tracking applications, whether logistics-asset tracking for smart factories or personal goods tracking for smart cities.

General sources: [QUALC17], [SMART], [161321], [167790].

4.3.3 Relevant KPIs

In this context of quite large density of connected devices, a large part of them will have to cope with stringent energy constraint as they operate on a non-rechargeable battery. A part of them might also face unfavourable location (basement, deep indoor, underground). The main KPIs to consider will be the coverage in terms of Maximum Coupling Loss (MCL), the energy efficiency and the connection density.

Among the most relevant KPIs, the following ones can be highlighted.

1. Network and UE deployment KPIs			
Attribute	**Values or assumptions**		**Comments**
	Scenario#1 Megacities (dense urban and suburban areas management)	**Scenario#2 Underserved areas** (Sensing and factory logistics)	
Layout and layers	Macro only	Single-layer Indoor floor: (3,6,12) BSs per 120 m x 50 m (similar with "Time-critical reliable process optimization" (Vertical "Factories-of-the-future")	D2D can be an option in some cases for scenario#1 [38.802] Section A.2.4 / Indoor hotspot for scenario#2
ISD (m)	1732m, 500m	20 m (Equivalent to 12TRPs per 120m x 50m)	[38.802] Section A.2.4 / Indoor hotspot for scenario#2
Carrier frequency/ BW	700 / 800 MHz (10 MHz BW) (Optionally 2100 MHz)	4 GHz/ Up to 200 MHz (DL+UL)	In some very dense area, coverage on higher band could be possible for scenario#1
BS/UE transmit power (dBm)	UE:23 dBm	24 dBm per 20 MHz /UE: 23 dBm	14 dBm could also be relevant for small form factor devices
# BS/UE antennas	1	Around 4GHz: Up to 256 Tx and Rx antenna elements/ UE: Up to 8 Tx /Rx antenna elements	
Maximum # UEs	1 million per km²	10 000/km2	
Maximum / Average # Active UEs	max 30% / average 1%	N/A	When peak traffic occur, some level of overload control is acceptable.
UE distribution	Uniform Distribution 60% indoor / 40 outdoor	Follow Indoor Hotspot user distribution (TR 38.913) for both URLLC and eMBB UEs: 100% Indoor, 3 km/h	
UE speed	60% are indoor (less than 3 km/h) 20% are outdoor less than 120 km/h 20% are outdoor static	Mainly indoor	Marginal proportion of mobile UE can reach 200 km/h for scenario#2
Network KPIs	**KPIs' Targets**		**Comments**
Network energy efficiency	On going work - to be completed		
Area traffic capacity	10 Gbps/km2 for scenario#2		[22.261] (Table 7.2.2-1 Process automation-monitoring)
Connection density	1 Million per km² for scenario#1 10 000/km2 for scenario#2		[22.261] (Table 7.2.2-1 Process automation-monitoring)

# RRC Connections/Cell	N/A	
UE KPIs	**KPIs' Targets**	**Comments**
UE Battery consumption	up to 15 years	at least as defined in [38.913] section 7.11. Network Initiated Traffic as defined in [45.820] should be considered too. In addition, quantifying the impact of larger payload size (2kBytes / 200 Bytes) is desirable.
Reliability	95%	
U-Plane maximum latency (ms)	less than 0,5 second at maximum coupling loss	
Experienced data rates (Mbps)	1 Mbps for scenario#2	[22.261] (Table 7.2.2-1 Process automation-monitoring)

4.4 Long range connectivity in remote areas with smart farming application

4.4.1 Description

This use case applies specifically to Underserved Areas scenario e.g. regions that are currently not sufficiently covered by traditional networks. Two kinds of environments are considered:

- rural areas with large area coverage and low density of population,
- far remote areas with extreme coverage requirements and very low densities of population.

The long-range connectivity in remote areas with smart farming application is defined to allow the provision of minimal services over long distances in the two kinds of environments listed above.

The key characteristics of this use case are macro cells with very large coverage up to 100km in far remote rural areas supporting basic data, voice and smart farming services with low to moderate user throughput, low user density, lower availability and potential restricted periods of service.

At peak hours, when large number of users attempt to connect to the network but serving all users simultaneously is not economically viable, connectivity can be shared in time between the users. This leads to periods of service unavailability from the user perspective but allows a reasonably costly network dimensioning.

Consistency of user experience across a wide territory is not mandatory. Only minimum services may be available everywhere, with higher bandwidth available only in some areas (e.g., where population is present).

Backhauling is also a challenge in those types of environments where distances to nearest Point of Presence (PoP) could be large without fiber connection available. Terrestrial wireless backhaul over long distance or satellite backhaul solutions shall be considered.

Automated smart farming and livestock tracking is an important application for smart agriculture vertical and is combined with the long range connectivity in remote areas. Smart farming is needed for monitoring irrigation of crops, water consumption, environment and weather parameters according to various sensors/actuators which are deployed in the field. Also remote monitoring of livestock is needed for tracking purposes as well as potential threats, feeding etc.

4.4.2 Services

1. **Provision of minimal voice and data services over long distances in low density areas.** Minimal services include Voice service over long distance plus best effort data services for smartphones, tablets, etc. The priority of this service is to provide a maximum coverage without strict requirements on throughput.

2. **Provision of Smart farming and tracking over long distances in low density areas**. Sensors / actuators are targeted for these services. Coverage extension is also one of the main objectives.

4.4.3 Relevant KPIs

Among the most relevant KPIs, the following ones can be highlighted. Other elements can be found in Annex B: full details of selected use cases.

4.4.3.1 Network and UE deployment KPIs

Network and UE deployment KPIs		
Attribute	**Values or assumptions** **Scenario**	**Comments**
Traffic Model	For far remote areas: ⇨ Approx. 11000 users/cell ⇨ **1.7 users/km²** For rural areas: ⇨ **Approx. 33 users/km²** Crops sensors and livestock tracking sensors are spread around each village area: ⇨ **Approx. thousands of sensors/km2 per village area**.	For far remote: from internal studies For rural: [NGMN liaison to 3GPP RAN72]
Network KPIs	**KPIs' Targets**	**Comments**
Minimum expected coverage	100km cell range for far remote areas 50km cell range for rural	100 km in far remote [38.913] 50km for rural as an enhancement of current technologies (#30km cell range)
Connection density	Traffic Model (details in annex) applied to an isolated cell of 100km range (6495km²) for far remote and 50km for rural: For far remote: ⇨ Approx. 11000 users/cell + thousands sensors/cell ⇨ **1.7 users/km² + thousands sensors/ km²** For rural:	Data from internal study on far remote areas, from [NGMN liaison to 3GPP RAN72] for rural.

	⇨ Approx. 53000 users/cell + thousands sensors/cell ⇨ **33 users/km² + thousands sensors/ km²**	
Cell throughput	For far remote: Average traffic at busy hour per active user * Activity Factor * number of users = 30 kbps * 10% * 11000 users/cell ⇨ **33 Mbps / cell** ⇨ **area traffic capacity: 0,051 Mbps/km²** For rural: ⇨ **area traffic capacity: 0,33 Gbps/km²** Cell throughput may be scaled down if minimum bit rates requirements are reduced.	[38.913] and internal study on far remote areas, [NGMN liaison to 3GPP RAN72] for rural.
Minimum number of devices	For far remote, approx. 11000/cell with 10% activity factor + thousands of sensors/cells. For rural, approx. 53000 users/cell with 20% activity factor + thousands sensors/cell	Internal studies for far remote areas, [NGMN liaison to 3GPP RAN72] for rural.

4.4.3.2 Service KPIs

1. Services		
1.1. Service 1: Provision of minimal voice and data services over long distances in low density areas		
Service attributes	**Values / assumptions**	**Comments**
UL/DL ratio	25% / 75%	
Service KPIs	**KPIs' Targets**	**Comments**
User Experienced data rates	For far remote: User experienced data rates target: - Up to 2 Mbps DL / 250 kbps UL while stationary - Up to 384 kbps DL / 64 kbps UL while moving For rural: - 50 Mbps DL / 25 Mbps UL **Minimum user experienced data rate may be further reduced to satisfy service coverage requirements.** **The idea would be to stretch the user coverage to its maximum extension capabilities, e.g. allow bit rates as low as Edge / GPRS.**	[38.913] for remote areas, [NGMN liaison to 3GPP RAN72] for rural.
E2E Latency	No specific E2E latency requirement for long range data services. Max [400] ms for Voice service.	To cope with that several solutions could be considered: Keep the service requirements for Voice QoS (i.e. 400 ms

	The system shall support a maximum of [400] ms E2E latency for voice services at the edge of voice coverage. This objective is the most challenging of all. Although 400 ms is an ideally reasonable target to match an acceptable user experience (beyond 400 ms, the delay may be audible for the user), achieving such E2E latency for voice will probably be incompatible with extremely long coverage due to the large numbers of retransmissions required.	E2E delay) but reduce the coverage requirement on voice compared to data services, with a revised requirement to be studied. This would lead to a lower voice coverage than data service coverage. Keep the coverage requirement for voice to remain similar to data but accept a substantial degradation of QoS service, leading to “push-to-talk” type of experience. However this may not be acceptable. Propose a mix of the 2 solutions, with both a reduced coverage and degraded QoS requirements, with target values to be studied further.
1.2. Service 2: Provision of Smart farming and tracking over long distances in low density areas		
Service attributes	**Values / assumptions**	**Comments**
UL/DL ratio	Mainly uplink traffic	
Maximum data rates	Up to some kbps	Low data rates [38.913]
Mean experienced data rates	Up to some kbps	[38.913]

4.5 Outdoor hotspots and smart offices with AR/VR and media applications

4.5.1 Description

This use case focuses on high user density and traffic loads under the service category of eMBB on both outdoor and indoor hotspots. It is mainly characterized by a high throughput demand and the use of services like augmented reality (AR), virtual reality (VR), high-quality video streaming or file transmission among others. This use case is related to the Megacity scenario.

Following with the description, the next paragraphs presents a user story highlighting the main features of the current use case.

Paul works as a project manager in a large architectural studio. Every morning, he checks his emails, last calls and daily agenda and reviews the status of the projects which he leads on. For that, he uses his assistant tablet and his augmented reality (AR) / virtual reality (VR) glasses, automatically connected to the cloud server. This equipment helps Paul, in rainy days, to visit and study the plots where the next projects will be built with no need to go outside or to check the status of the current constructions without any physical risk.

Crossing the office, on his way to the meeting rooms, his glasses show him an AR visual indication notifying which colleagues around have pending requests to ask for. Already at the meeting, he and his team connect with the client to show the first approach of the new city auditorium project via virtual reality conference. This way, using a virtual reality simulation, they can show a realistic look of the building with no need to make a scale model. In the current meeting room, as well as in the others in the building, there is a picocell providing the necessary high throughput for video recording of the activities and meeting exchange.

After a long day at the office, Paul finally gets to take the metro in a hurry. The basketball team he supports plays that night. On his cell phone, he receives all the information about the opposing team: statistics from previous matches, videos of their highlights… Since the game has already started, he decides to have a look at what is happening live at the stadium. For that, he opens a high-resolution video stream on his phone. He is late, but he will not miss any three-point shot. Without even noticing, his terminal changes from one serving base station to another, providing seamless eMBB coverage.

By the end of the first period, he arrives to the stadium. The place is crowded, thousands of people have come to the match. During the game, many spectators record the experience in high definition with their glasses or smartphones and upload it to the social networks. Online video is also streamed by TV reporters and drones flying around. Spectators can also get real time valuation of the different players. Although the data traffic demand is at its peak, network resources have been provided to the surrounding cellular bases station without any issue.

4.5.2 Services

1. **Augmented reality (AR), Virtual reality (VR)**. These services refer to the technology that add additional elements to a real environment and the technology that create a fully virtual environment respectively.
2. **High definition video**. This service encompasses services such as conversational streaming, collaborative gaming, etc., that require high fidelity media capabilities.

The next services are the classical office services that have to be reviewed in the 5G context.

3. **File transmission**. This service will be likely supported by the FTP protocol, providing a mean for the transmission of large files.
4. **Web.** This is the traditional web service, via HTTP protocol, characterized by greater DL traffic than UL traffic.
5. **Email.** This is the traditional email service.
6. **VoIP.** This service refers to the set of rules, devices and protocols that allow voice transmission through IP protocol. The main metrics that characterize the service are packet loss, packet jitter and packet latency.

All these previous services have to be served by the **security** features, such as subscriber AAA or subscriber privacy, specified in [NGMN15], [5GPPP17] or [5GENSURE17].

4.5.3 Relevant KPIs

4.5.3.1 Network and UE deployment KPIs

Among the most relevant KPIs, the following ones can be highlighted.

Network and UE deployment KPIs	**Scenario #1: Outdoor hotspot**	**Scenario #2: Indoor hotspot**	**Comments**
Layout and layers	Two layers: Macro + micro	Single layer: - Indoor floor (Open office) (12BSs per 120m x 50m) Candidate TRP numbers: 3, 6, 12	[38.913], Table 6.1.1-1: Attributes for indoor hotspot [38.802], Table A.2.1-1
ISD (m)	Macro: 200m Micro: 3 micro TRP per macro TRP	20m (Equivalent to 12TRPs per 120m x 50m)	[38.913], Table 6.1.1-1: Attributes for indoor hotspot Indoor scenarios assume a small ISD.
Carrier frequency/ BW	Around 4 GHz: Up to 200MHz (DL+UL) Around 30 GHz: Up to 1GHz (DL+UL) Around 70 GHz: Up to 1GHz (DL+UL) (Only indoor)		[38.913], Table 6.1.1-1: Attributes for indoor hotspot
BS / UE transmit power (dBm)	Macro: 40 dBm Micro: 33dBm UE: 23 dBm	DL: < 6 GHz → 24dBm; >6 GHz → 23 dBm UL: < 6 GHz → 23 dBm; 30 GHz → 23 dBm; 70 GHz → 21 dBm	Outdoor: [38.913] Indoor hotspot: To be defined in the new RAT study item. [RANGAN14] [38.802], Table A.2.1-1: System level evaluation assumptions.
# BS/UE antennas	**BS** Up to 256 Tx and Rx elements		[38.913]
	UE Around 4GHz: Up to 8 Tx and Rx antenna elements Above 4 GHz: Up to 32 Tx and Rx antenna elements		
Maximum # UEs	Uniform/macro TRP + clustered/micro TRP, 10 users per TRP	10 users per TRP; 100 % Indoor.	[38.913]
Maximum / Average # Active UEs	See "UE distribution and speed"		[38.913]
UE distribution	Uniform with temporal high concentration spots.		[38.803], Table 5.2.1.3-1: Single operator layout for indoor.
UE speed	Up to 30 km/h	3km/h	[38.913], Tables 6.1.1-1 and 6.1.1-2: Attributes respectively for indoor and outdoor hotspots.
Area traffic capacity	Peak value (w 3 Micro TRPs) - 4GHz DL → 0.347 Mbps/m2	30/70 GHz UL→15 Mbps/m^2 30/70 GHz DL→30 Mbps/m^2	[38.913], 7.14 Area traffic capacity.

	Peak value (w 3 Micro TRPs) - 4GHz UL → 0.173 Mbps/m2	4 GHz UL →3 Mbps/m^2 4 GHz DL → 6 Mbps/m^2	
Connection Density	200 – 2500/Km2	75/1000 m2	[NGMN15]
Traffic density	DL: 300 Mbps (750 Gbps/km^2) UL: 50 Mbps (125 Gbps/Km^2)	DL:15 Gbps / 1000 m^2 UL: 2 Gbps / 1000 m^2	Outdoor hotspot: [22.261] (Table 7-1-1) Indoor hotspot: [NGMN15]
Mobility interruption time	0ms	0 ms	[38.913], 7.7 Mobility interruption time It means the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions.
Experienced data rates (Mbps)	User Experienced Data Rate: DL: 300 Mbps, UL: 50 Mbps	User Experienced Data Rate: DL: 1 Gbps, UL: 500 Mbps	[NGMN15]
		• 10 to 50 Mbps: current-gen 360°video (4K) • 50 to 200 Mbps: next-gen 360°video (8K, 90+ FPS, HDR, stereoscopic) • 200 to 5000 Mbps: 6 DoF video or free-viewpoint.	[QUALC17]

4.5.3.2 Service KPIs

Service KPIs	**Service 1**	**Service 2**	**Service 3**	**Service 4**	**Service 5**	**Service 6**	**Comments**
U-plane maximum UL/DL radio latency (ms)	< 1 ms	< 200ms (streaming) < 30ms(conversational) < 1ms (Gaming)	10 ms	10 ms	10 ms	------	[QUALC17] [22.891]
C-plane maximum UL/DL radio latency (ms)	10 ms	------	------	------	------	------	[38.913]

U-plane maximum E2E latency (ms)	20 – 10 ms	< 1s (streaming) < 150ms (conversational) < 10ms (Gaming)	------	------	------	< 150 ms	[QUALC17] [22.891] ITU G.114, [CISCO14]
U-Plane reliability	99%	------	99.9 %	99.9 %	99.9 %	------	[METISD1.1]
U-Plane packet/frame loss (%)	< 1%	------	< 0.1 %	< 0.1 %	< 0.1 %	< 1 %	[METISD1.1] [CISCO14]
Average End User Throughput (Mbps)	------	100 Mbps (streaming) > 10 Mbps (conversational) > 50 Mbps (Gaming)	------	------	------	------	[22.891]
Video rebuffering time/ratio	------	< 5 s (streaming)	------	------	------	------	
Video startup time	------	< 1 s (streaming)	------	------	------	------	
Jitter	------	------		------	------	< 30 ms	[CISCO14]

4.6 Live Event Experience

4.6.1 Description

Within the eMBB service category and vertical domain as well as eMBMS, this use case addresses a large-scale event of sport or entertainment where customers are provided with great content experience at the event sites (e.g. stadiums, parks, hall parks, concert halls, cinemas). It is characterized by *large user density* (thousands simultaneous viewers or uploaders) and *high data rate requirement* and *large data consumption* (of live videos) [5GPPP 16].

An event can include:

- *Live content broadcast:* live streaming of parallel sessions of the event at UHD TV screens or on portable devices on the site from professional content providers.
- *On-demand (personalized) content:* providing replays, choosing a specific camera, language, including augmented reality to bring additional information, etc. on portable devices (smartphones, tablets, VR devices).
- P*ersonal content*: a massive number of users may share high-resolution videos and wide-view pictures of the event via social media. Those may be played live at large UHD TV screens on the site (i.e. crowdsourced live event coverage).

The use case is applicable both to Megacity and Underserved areas, where events may be held in indoor and/or outdoor hotspots within dense urban, urban macro and rural area.

4.6.2 Services

The key services and applications composing this use case are briefly listed below, and further description is provided in the table in the later subsection:

1. **Downlink video streaming 4k** (i.e. streaming to on-site viewers), and
2. **Uplink file transfer** (i.e. upload of high fidelity/definition video clips of the event), and
3. **Augmented/virtual reality** (optional, to be considered in a later phase if deemed necessary).

4.6.3 Relevant KPIs

Network and UE deployment and KPIs			
Attribute	**Values or assumptions**		**Comments**
	Scenario 1: Concert Hall	**Scenario 2: Stadium**	
Layout and layers	Macro + small cells	Macro + small cells	Only indicative.
ISD (m)	<200m	<200m	Only indicative.
Carrier frequency/ BW	n/a	n/a	
BS / UE transmit power (dBm)	Macro: 46 dBm Small cell: 33 dBm UE: 23 dBm	Macro: 46 dBm Small cell: 33 dBm UE: 23 dBm	Only indicative. [38.913]
# BS/UE antennas	>=2	>=2	Only indicative.
Maximum # UEs	30K	100K	Large arenas and stadium capacity
Connection density (i.e. average # active UEs assuming 30% activity factor)	10K	30K	Broadband access in a crowd [NGMN15]
UE distribution	Uniform (indoor)	Uniform at seating sections (outdoor / open-air)	
UE speed	Pedestrian	Pedestrian	[NGMN15]
Services mixture	n/a	n/a	
Network KPIs	**KPIs' Targets**		**Comments**
Traffic density	DL: 0.25 Tbps UL: 0.50 Tbps	DL: 0.75 Tbps UL: 1.5 Tbps	Connection density x User data rate [NGMN15]
Satisfied UEs [%]	95%	95%	See service-specific satisfaction criteria
UE KPIs	**KPIs' Targets**		**Comments**
N/a	N/a		None seen relevant
Service 1: Downlink Video Streaming 4k (i.e. streaming to on-site viewers)			
Service attributes	**Values / assumptions**		**Comments**
Protocol type	HTTP over TCP/IP RTP/UDP		Based on widely adopted protocols
Codec rate	Adaptive bitrate between minimum bitrate: 5 Mbps maximum bitrate: 25 Mbps		E.g. HTTP-based adaptive bitrate. Max bitrate=Traffic density/Connection density
Average video session duration	n/a		

UL/DL ratio	n/a	
Security	Data integrity and access control required	
Satisfaction criteria	Phase I: UEs exceeding 5-ile bitrate requirement Phase II: video rebuffering ratio below requirement	Additional metrics could be envisioned in later phases
Service KPIs	**KPIs' Targets**	**Comments**
Mean/5-ile video bitrate (Mbps)	**25** / 5 Mbps	Based on broadband access in a crowd [NGMN15]
Video rebuffering time/ratio	<5s / <2%	Based on [DIALLO14]
Video startup time	< 1s	Based on [DIALLO14]
U-Plane avg/max DL radio and E2E latency (ms)	Radio: 5 / 10 ms E2E: **10** / 20 ms	Based on [NGMN15]
U-Plane avg/max DL radio and E2E jitter (ms)	Radio: few ms E2E: few ms	Reference n/a
U-Plane DL packet/frame loss (%)	< 1.0 %	Reference n/a
U-Plane DL Reliability	99.0 % @ 10 ms latency	Reference n/a
Service 2: Uplink file transfer (i.e. upload of high fidelity/definition video clips in real-time)		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	FTP over TCP/IP	Based on TR 38.913
File size	100 MB (other values not precluded)	Corresponds to ~1 min of HD video. Reference n/a
Security	Data integrity and privacy required	
Satisfaction criteria	Phase I: UEs exceeding 5-ile bitrate requirement	
Service KPIs	**KPIs' Targets**	**Comments**
Mean/5-ile file transfer throughput (Mbps)	50 / 10 Mbps	Based on broadband access in a crowd [NGMN15]
Mean/5-ile file transfer latency s)	16 / 80 s	File size/Throughput
U-Plane UL packet/frame loss (%)	< 0.1 %	Reference n/a
U-Plane UL Reliability	99.9 % @ 10 ms latency	Reference n/a

4.7 Health/wellness monitoring

4.7.1 Description

Within the vertical area "eHealth and wellness" we have selected two different use cases:

- Continuous status monitoring of health data
- Event driven alarm

For the former case one or multiple device(s) (sensors) being either continuously carried/worn, regularly attached to the human body (e.g. blood pressure measurement device) or even being implanted into the human body, regularly measures a given human health state (e.g. blood sugar level, heart rate/pressure). Those measurements may be either stored within the device to be transmitted at a later point in time in an aggregated manner or instantly transmitted either via a direct 5G NR connection or via a relay/aggregator (e.g. smartphone). Targeted are either elderly people or persons having a chronic condition.

This use case relates to the service category mMTC. The transmissions are either of periodic nature or triggered. If the measured data is directly transmitted to the medicinal database the packets to be transmitted are rather small. For more advanced devices having storing capabilities the transmissions are less frequent but the data to be transmitted is typically bigger in size. In general, those measuring devices need to have a high longevity (e.g. related to the battery live and robustness) and thus require to be of low complexity (both related to the transmission functionality of the device but as well related to its usage). The device density is strongly correlated with the demographic characteristics of the served area. The highest density occurs in areas including retirement centers and/or hospitals. For this kind of data privacy is of very high relevance (at least if it can be related to the respective human being) a highly secure connection is required (both related to authentication and authorization). Depending on the actual implementation of the actual measurement procedure (e.g. frequency) and the aspect being measured the reliability of the connection is presumably not required to be too high. Naturally, this only relates to cases where the measurement process is highly redundant (i.e. not a single measurement but only a sequence of measurements – e.g. the heart pressure is too high for a given time period including several measurements – potentially require special actions to happen e.g. being triggered by the medicinal personal remotely monitoring the health status). The other case with having a single measurement requiring instantaneous response is covered in the following. Regarding the required delay-time for the actual data transmission, this use case is highly relaxed. Typically, any those measurements are evaluated in a bulk (i.e. development of a given measure over a period of time) and not based upon a single entry.

The second use case mentioned above relates to a scenario where a device (sensor) is watch-dogging the person carrying this device by any of the following means (examples):

- The person leaves a predefined area (virtual fencing)
- The person has a condition potentially requiring instantaneous response
- The person is infirm and has the potential to fall

If a given event occurs (e.g. the sensor measuring the location of the person detects the person to have left the preset area), the device transmits a respective alert towards the monitoring server and the respective specialist (e.g. physician, care taker) is triggered.

This use case relates to the service category URLLC. The transmission is triggered and the data packet being transmitted is rather small. Those devices need to have a high longevity (e.g. related to the battery live and robustness) and thus require to be of low complexity (both related to the transmission functionality of the device but as well related to its usage). The device density is again strongly correlated with the demographic characteristics of the served area, but the overall number is typically much smaller than e.g. in the upper case. The highest density occurs in areas including retirement centers and/or hospitals. For this kind of data privacy is of very high relevance (at least if it can be related to the respective human being) and thus a highly secure connection is required (both related to authentication and authorization). On application level two potential failures may occur:

- Misdetection: The watch-dogged condition occurs, but the sensor either fails to detect it or the transmission is not successful.
- False alarm: The watch-dogged condition does not occur, but the sensor either falsely detects an event or the communication system wrongly detects such an event (e.g. due to transmission failures the received alarm is related to a wrong device).

The first failure would lead to the watch-dogged person to suffer. So, this case has to be avoided at any case. The second failure might lead to have the specialist move towards the assumed victim without the actual need. Naturally, the occurrence of this second failure should be minimized as well, however, if those two failures are to be traded of the minimization of the occurrence of the former is of higher importance. The avoidance of this kind of failures requires the transport of the actual messages via the communication system to be very reliable. Regarding the required tolerable delay for the alert, this use case is less critical. As in the end a human being has to react (e.g. move towards the patient, initiate others to collect the patient in case he has left the area), round-trip delays during the transmission do not significantly contribute to the overall delay as long as they are within reasonable amounts (few tens of ms).

Naturally, this kind of service includes ethical questions to be answered (e.g. related to the human right of privacy). However, this kind of questions is out of the scope of the project.

The related 3GPP use cases are [22.891]:

- 5.24: Bio-Connectivity
- 5.25: Wearable device communication
- 5.59: Massive internet of things and device identification
- 5.68: Telemedicine support

4.7.2 Services

Two kinds of services are part of this use case:

1. **Continuous status monitoring of health data**
2. **Event driven alarm**

The former is part of the service category mMTC and involves regular (and thus predictable) transmission of small messages (e.g. related to a chronic condition such as diabetes). The latter is part of the service category UR(LL)C (with less emphasis on the latency part) and involves the transmission of triggered alerts (e.g. if the person has fallen, a specific medical condition is met or the patient leaves a predefined area) and is thus not predictable.

At least in some areas the number of devices per area is expected to be rather high (e.g. in hospitals, retirement centers). The devices need to be rather cheap and be able to run on a single set of batteries for a long time.

Both the chance for false-alarm and the misdetection rates need to be minimized.

As this use case involves human health data the most important aspect is data privacy. While the actual measurements/alarms are less critical the actual link between the measurement/alarm and the measured person must be kept secure.

Those services are applicable to both Underserved Areas and Megacities.

4.7.3 Relevant KPIs

1. Network and UE deployment and KPIs **Those devices are carried by human beings. So, network deployment and UE distribution should be very similar to conventional eMBB services (smart phone users) with potentially a lower density (percentage of users requiring this kind of equipment vs. percentage of users having a smart phone, unless we include items alike pedometers and alike).** **Distribution: typically uniform with potentially some clusters (e.g. retirement centers, parks).** **Relevant use cases from [38.913]: 6.1.7 Urban coverage for massive connection (but with extension to rural and indoor support)**		
Attribute	**Values or assumptions**	**Comments**

	i) periodic meas.	ii) "watch-dogging"	
Layout and layers	Macro + small cells		Potentially with aggregator node between device and network (e.g. smartphone in case of pedometer, data collection unit in hospital …)
ISD (m)	Any option at macro and/or small cell layer. For coverage reasons smaller values preferable.		Applicable to dense urban as well as to rural and indoor.
Carrier frequency/ BW	700 / 800 MHz (10 MHz BW), optionally 2.1 GHz		For coverage reasons lower frequencies preferred
UE transmit power (dBm)	UE: 23 dBm		14 dBm could also be relevant for small form factor devices
#UE antennas	1		
Maximum # UEs	1.000.000 devices/km^2		Those numbers relate to other types of mMTC use cases. Here, the relevant number might be smaller (see below).
UE distribution	Uniform with potential for some clusters (e.g. retirement center, hospital, parks). Follows distribution of people.		For some of the cluster areas (retirement center and hospital) aggregators may be of use. "Keep data local". This helps security as well.
UE speed, "mobility level"	Dense urban: 80% indoor (3km/h), 20% outdoor (30km/h) Rural: 50% outdoor (120km/h) and 50% indoor (3km/h) Parts of this use case are rather stationary within a given area (e.g. hospitals, retirement centers) → the use of aggregator nodes efficient		From [38.913]. Though, potentially the dense urban characteristics may apply in general, i.e. more towards lower speeds. (pedometers are typically used on the walk, elderly people are less mobile …)
Network KPIs	**KPIs' Targets**		**Comments**
Min. Number of devices	(a) x% of smart phone users (adoption rate of this sort of devices), potentially x>1 per human being, but smart phone as aggregator very likely (b) x% of the number of human beings (x=20-30??), i.e. fraction of human beings having a condition to be monitored	x% of number of human beings (x=20-30??), i.e. fraction of human beings having a potential for emergency situation (elderly, people with chronic condition, children)	(a) Pedometers etc. (b) condition monitoring mMTC baseline from 38.913: 1.000.000 devices/km^2
Connection density (i.e. average # active UEs assuming x% activity factor)	(a) activity factor rather high (if device directly connected to the network) otherwise 0% (if connected to smart phone) (b) 100% activity rate (either towards the	Very low, as event driven.	(i) condition monitoring: Once a device is in use it transmits data (other than e.g. the usage of smart phones)

	network or towards an aggregation note).		
Area traffic capacity, cell throughput	<< smart phone traffic	<< smart phone traffic	Much smaller bandwidth per connection. Number of connections not necessarily higher than number of MBB connections (in contrast to other mMTC use cases).
UE KPIs	**KPIs' Targets**		**Comments**
Battery consumption	Up to 15 years	Up to 15 years	Especially use case i) is a good example for the use of RRC connected inactive, if the device is directly connected with the network.
Service attributes	**Values / assumptions**		**Comments**
UL/DL ratio	Mostly UL	Mostly UL	DL: potentially the option for remote configuration/trigger?
Security	Anonymity of the measurements has to be ensured. Correct source of the measurement has to be ensured (to avoid others to submit data on behalf of patient x).	Anonymity of the measurements has to be ensured. Correct source of the measurement has to be ensured (to avoid others to submit data on behalf of patient x).	Crucial: identity management, privacy protection. It needs to be confirmed, if id encryption is sufficient. Additionally, it needs to be checked, if known methods of encryption are feasible for usage within those low-end devices. While correct authentication is crucial it requires to be secured.
Traffic density and characteristics	Purely UL Periodic transmission of small message (x Bytes) << smart phone traffic	Purely UL Tiny message only very rarely, traffic density negligible. << smart phone traffic	i) SPS, grant-free UL, RRC connected inactive
Service KPIs	**KPIs' Targets**		**Comments**
C-plane latency	10 ms	10 ms	From 38.913. As human beings are involved in case the C-plane latency requirements become less stringent than e.g. in industrial applications.
U-plane latency	4ms Uncritical May potentially be relaxed.	4 ms While more critical, still not in the range of single digit ms as human beings are involved.	From 38.913 (MBB reference value)
U-plane E2E latency	100ms	100 ms	Latency aspect of this kind of use cases is less critical as human beings are in the loop (e.g. a human being needs to react to the

			alert/check the measurements)
U-plane reliability	90-99% Depends on the periodicity of the measurement and the relevant characteristics of the measured disease (i.e. how relevant is a single measured point in relation to the flow of measurements).	99.9999% or even higher false-alarm rate and misdetection need to be very low potentially at the cost of resource efficiency	

4.8 Smart grid, connected lighting and energy infrastructure

4.8.1 Description

According to 5G-PPP, data and communications which are used for the realization of smart grid are of paramount importance. In Europe, utilities have for many years developed robust and efficient infrastructure, especially at the transmission voltage level, to provide observability and control. Distribution Networks have lagged behind this due to the nature of the original design principles of building to meet the biggest peak demand expected.

Smart Grids are therefore focused between the transmission grid and beyond the meter to end consumers who are now becoming producers as well. Communication infrastructures will be needed to extend the observability and control to this level.

There is a complex web of interactions between the electricity smart grid and the communications networks, each one in need of the other. The smart grid becomes more flexible and efficient but critically depends on the availability of high-quality data collection, transmission and analysis for operations and marketing.

This use case is applicable mainly in Megacities scenario, providing remote observability and control in smart grid infrastructure, in order to enable monitoring and management for energy related services.

4.8.2 Services

1. **Provisioning of energy monitoring and management services.** This service takes into account the fact that smart metering and monitoring is essential for the realization of smart grids, connected lighting, energy supply infrastructure. The priority of this service is to provide a maximum coverage without strict requirements on throughput.

4.8.3 Relevant KPIs

4.8.3.1 Network and UE deployment KPIs

Network and UE deployment KPIs		
Attribute	**Values or assumptions** **Scenario**	**Comments**
Traffic Model	Monitoring/metering sensors are spread around each area:	NGMN liaison to 3GPP RAN72 and reference from use case on long-range connectivity

	• Approx. thousands of sensors/km2	
Network KPIs	**KPIs' Targets**	**Comments**
Minimum expected coverage	30-50km cell range for rural	Reference from use case on long-range connectivity
Connection density	• Approx. thousands sensors/km^2	NGMN liaison to 3GPP RAN72 and reference from use case on long-range connectivity
Minimum number of devices	• Approx. thousands sensors/km^2	NGMN liaison to 3GPP RAN72] for rural and reference from use case on long-range connectivity

4.8.3.2 Service KPIs

Service 1: Provisioning of energy monitoring and management services		
Service attributes	**Values / assumptions**	**Comments**
UL/DL ratio	Mainly uplink traffic	
Maximum data rates	Up to some kbps	Low data rates [38.913]
Mean experienced data rates	Up to some kbps	[38.913]

4.9 Ad-hoc airborne platforms for disasters and emergencies

4.9.1 Description

This use case aims to develop the solutions for rapidly deploying air-borne platforms like drones (0.5-1km) and/or high altitude (8-20 km) platforms, in disaster and emergency situations. The deployment can be only drones, in isolated emergencies like a building fire, or multiple drones complemented by a high altitude platform (HAP) in wide scale disaster situations like floods, hurricanes or earthquakes. The ability to rapidly deploy these platforms and connect them to the wider core networks and also to rescue/recovery command centres are the key attributes to this use case. The twin service types expected in this use case are elaborated as follows:

1. In a wide-scale disaster, deploy or utilize the HAPs to this wide area to provide life-line communications [NGMN15]. Based on UE messages received, the hotspots needing immediate attention can be mapped. The HAPs will be used to provide (in DL) low bit rate messages and also collect such messages from UEs in the DL. These are also delay tolerant, but should support a massive UE number. HAPs could also support some of the URLLC and eMBB (with multi-beam) communications, such as supporting rescue and recovery teams. The lower altitude drones can be also deployed to the specific locations (may be mapped by the HAPs), to support rescue missions.
2. In smaller scale emergencies, a drone can again be directly deployed above the scene to support emergency crews and robots, which are very useful in hazardous conditions. The services needed for the emergency crews will be like high resolution maps, AR/VR videos of the buildings (in the DL) and high resolution images and videos the crews will

upload (in UL). Also URLLC messaging (in UL and DL) is needed to pass on instructions and responses from/to the emergency crews including the control of robots.

The scenario for small scale/ isolated emergencies can be either in Megacities or rural/Underserved areas. The larger disaster support has also to be offered in either Megacities or in Underserved areas. The difference we see in large scale events is that the network infra-structure (if existed) will be damaged and destroyed – so HAPs are needed to quickly provide basic network coverage. The drones are deployed for much more targeted provision of services.

A schematic diagram for the drone based service provision is depicted below in Figure 11.

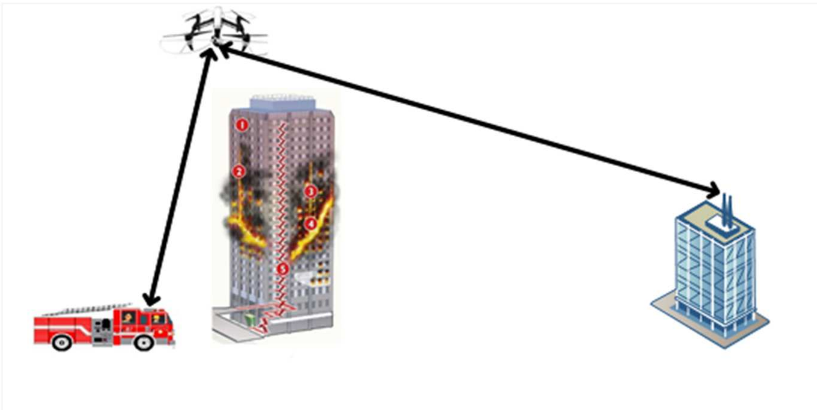

Figure 11: The deployment of drones to support emergency services

4.9.2 Services

The expected services from these air-borne platforms can be defined under the categories below:

1. **Lower data rate broadcast messaging** from HAPs (DL)
2. **Lower data rate response messaging, voice calls** from a very large number of UEs (UL)
3. Some basic **URLLC and eMBB direct support** from the HAPs.
4. **UHD/AR/VR maps, videos** from/to emergency service personnel in drone communications (UL/DL)
5. **URLLC commands/ responses** from/to emergency service personnel in drone communications.

4.9.3 Relevant KPIs

4.9.3.1 Network and UE deployment KPIs

Attribute	Values or assumptions		Comments
	Scenario#1: HAP coverage for wide scale disasters	**Scenario#2: Drone support for HAP guided and localized emergencies**	
Layout and layers	Large footprint HAP cell (>40km range)	Small footprint cells from drones (<200m range)	HAP values similar to Google Loon trials
ISD (m)	Likely to be>20km	Around 200m	
Carrier frequency/ BW	5.8GHz band /100MHz	5.8GHz band / 200MHz	5.8GHz unlicensed band used in Loon

			trial and also allows drone based FPV video transmissions.
BS / UE transmit power (dBm)	HAP=28dBm, UE=23dBm	Drone=28dBm, UE=23dBm	HAP values similar to Google Loon trials
# BS/UE antennas	HAP very large arrays UE – 4-8	Drone – large arrays UE 4-8	indicative
Maximum # UEs	100-500k	10-40	indicative
Maximum / Average # Active UEs	80% of UEs	100%	Indicative of the communication need
UE distribution	Uniform	clustered	
UE speed	pedestrian	pedestrian	
The gNB (or AP) speed	Upto 130kmph	Near stationary	HAP speeds from Google Loon and Facebook Aquila
Services mixture	mMTC type	UMB/URLLC type	
Network KPIs	**KPIs' Targets**		**Comments**
Traffic aggregation	6/6 Gbps (UL/ DL)	1.25/1.25 Gbps (UL/ DL)	median active UEs x median user data rate
Satisfied UEs [%]	95%	99.999%	
UE KPIs	**KPIs' Targets**		**Comments**
Battery life	Minimize battery drain for UE when communicating with HAPs. Aim to reduce the power budget to same levels of terrestrial links, at the expense of throughput, for mMTC type communications.		

4.9.3.2 Service KPIs

3. **Service 1: mMTC messaging from/to the HAPs**		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	TCP/IP	
Codec rate	n/a	
UL/DL ratio	50/50	
Security	medium	
Service KPIs	**KPIs' Targets**	**Comments**
User experienced data rate	0.1-1 Mbps (DL and UL)	[NGMN15]

5th percentile user data rates	0.1 Mbps	Indicative
U-plane maximum UL/DL latency	50 ms	(allowing for HARQ)
U plane maximum packet loss	1%	(after HARQ)
U-plane reliability	99%	Indicative
Service set-up time	Hours/ minutes	Indicative
Service interruption time	Seconds/ minutes	Allow for transition of HAP movements
4. **Service 2: eMBB video/content streaming from/to drones**		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	TCP/IP and UDP	
Codec rate	Adaptive rate 10-50Mbps	Assuming VP9 or H265 video codecs
UL/DL ratio	60/40	Assume higher UL content
Security	Very high	
Service KPIs	**KPIs' Targets**	**Comments**
User experienced data rate	Up to 100 Mbps (in UL and DL)	[NGMN15]
5th percentile user data rates	20 Mbps	
U-plane maximum UL/DL latency	5-10 ms	Very low to allow remote control of robots
U plane maximum packet loss	0.01%	An order lower than URLLC
U-plane reliability	99.999%	An order lower than URLLC
Service set-up time	minutes	
Service interruption time	Almost zero	
Service 3: URLLC commands/responses directed from/to drones		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	TCP/IP	
Codec rate	N/A	
UL/DL ratio	60/40	
Security	Very high	
Service KPIs	**KPIs' Targets**	**Comments**

User experienced data rate	From 50 kbps to 10 Mbps (in UL and DL)	[NGMN15]
5th percentile user data rates	50-100Kbps (in UL and DL)	
U-plane maximum UL/DL latency	5-10ms	
U plane maximum packet loss	0.001%	
U-plane reliability	99.99999%	For robotics
Service set-up time	seconds	
Service interruption time	Almost zero	

5 Baseline System Evaluation

5.1 Overview of One5G system level evaluation

As Figure 12 suggests for system level evaluation through simulations we need to take into account certain aspects related to configuration, environment, system and analytics.

Environment and configuration: Environment concerns aspects related to traffic (e.g. proper modeling of eMBB, mMTC etc., anticipated load, mobility and radio conditions (e.g. propagation models). This is triggered by the fact that project use cases deal with Megacities and Underserved Areas and as a result, different traffic characteristics apply depending on the use case. Such aspects will be properly documented for the considered use cases in order to consider them in the simulations later on.

System: System aspects include considerations relevant to network deployment (e.g. small cells and macro cells for use cases in Underserved Areas and Megacities). Also, spectrum aspects are considered for utilization of bands below 6GHz (to be expanded in mm-wave as well). Abstraction of PHY/MAC is taken into account e.g. for spectral efficiency (b/s/Hz vs. SINR, mainly from using input from 5G-PPP Phase 1 projects such as FANTASTIC-5G etc.). RRM algorithms are also considered.

Analytics: The simulation results will be evaluated against the KPI targets (e.g. in terms of throughput, latency). The results are analyzed and visualized. KPIs are carefully elaborated in WP2 as well as related standards. Key Quality Indicators are also studied in the context of WP2 and WP3 in order to offer a framework to reflect objectively the service performance and quality, inherently from an E2E perspective.

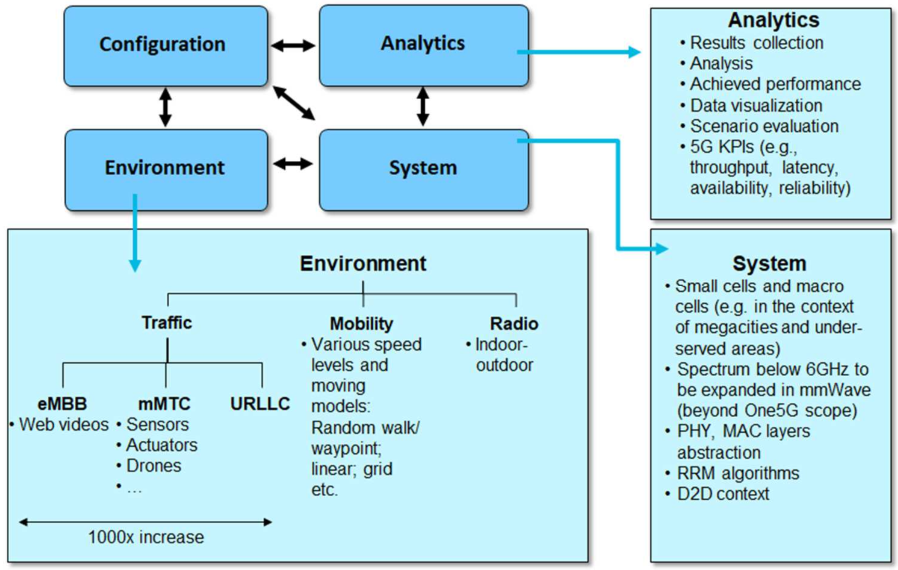

Figure 12: Overall features of system level evaluation

5.2 Baseline for the project

5.2.1 3GPP related baseline for the project (release 15)

The status of 3GPP (release 15) with respect to the technical definition and specification of New Radio (NR) is covered by the document series 38.xyz. Their current versions are the basis for the project to be in-line with 3GPP. This document series includes more than 50 documents, though not all are relevant for the project. The ones being of major relevance are:

- TS 38.2yz: Actual specifics related to the physical layer (e.g. channel design, modulation, coding)
- TS 38.3yz: Protocol architecture (e.g. MAC, RLC and PDCP specifications)
- TR 38.801-38.804: Documents collecting the outcomes of the study item “Study on New Radio Access Technology” [RP161596] related to the areas the project is working on.

The documents related to the first two items of the list above are too detailed to be explicitly covered, here. They carry the current status of the actual specification of NR. Instead, the project partners are expected to directly access the ones being relevant for their technical work.

For the documents carrying the outcomes of the study item (38.801-38.804), we have extracted the relevant information (see Annex A: Relevant 3GPP status). The following ones have been covered:

- TR 38.801: Radio access architecture and interfaces
- TR 38.802: Physical layer aspects
- TR 38.803: Radio Frequency (RF) and co-existence aspects
- TR 38.804: Radio interface protocol aspects

These documents are particularly important, as they set the main technical orientations decided in 3GPP, and build the foundations for the technical investigations in the project. Target has not been to replicate the specifications as given by 3GPP, but instead, it is intended to act as a summary collecting the relevant statements and to host a set of pointers to the relevant sections (relevant for the functionalities ONE5G is dealing with) within those documents. Too specific and lengthy details (e.g. the actual design of the LDPC codes) are omitted here (in that case we simply provide the info on “xxx is presented” or “yyy is given” with xxx and yyy being specific functionalities). So, in in some parts the following tables gather actual decisions being taken by

3GPP (if available) while others indicate the current status and assumptions for future studies. Furthermore, insights on where NR offers which degrees of freedom are given. So, the intention is to provide the set of key characteristics the project can built upon and to help the consortium of the project by providing support (e.g. by providing the respective reference) for digging deeper into the details within the respective 3GPP document.

In general, it becomes obvious that 5G – at least for the time being – intends to keep most of the design considerations to be as flexible as possible by only providing the range/set of options and to allow many aspects to be configured. While 4G had made a number of hard selections (e.g. related to synchronization signals), 5G targets to allow for a much higher degree of configurability – especially at the physical layer. This opens up a wide range of opportunities for designing the related techniques (e.g. related to multi-antenna implementations within WP4) and for system optimization (e.g. within WP3).

5.2.2 H2020 phase 1 related baseline for the project

5.2.2.1 FANTASTIC-5G

FANTASTIC-5G – one of the feeding projects of ONE5G – has dealt with various technical enablers on PHY, MAC and RRM. It has mainly focussed on the effects originating at and targets being provided for the air interface without taking an E2E perspective. The specific techniques FANTASTIC-5G has worked on and being relevant for ONE5G are:

- Waveform design and techniques for PAPR reduction
- Channel coding
- Enhanced modulation
- Link-level advancements for MIMO
- Multiple access techniques and multi-user detection
- Preamble design for random access
- Techniques for multicast/broadcast
- Channel and frame design
- Control channel design
- Radio resource control, radio resource management
- Multi-node connectivity
- Mobility enhancements
- Dynamic resource allocation
- DL non-orthogonal multiple access
- Enablers for D2D
- Efficient massive access protocols
- Inter-cell interference coordination
- System level integration of advanced MIMO with and without cooperation
- HARQ
- Random access procedure

Naturally, this list of items is to be filtered having the current status of 3GPP in mind. We will focus on items being of relevance in the light of the current status and of developments in the near future in 3GPP. While FANTASTIC-5G has focused on the toolbox (of relevant techniques), ONE5G goes one step ahead to design the network edge of NR for optimally making use of the tools in this toolbox for serving the E2E needs of the targeted services and under the light of specific scenarios. Additionally, while some areas are already rather far advanced in 3GPP others are yet to be studied (e.g. related to the application of mMIMO and enablers for high reliability in the framework of URLLC). So, ONE5G will take this up and develop the respective technologies for being fed towards the next evolutions of NR in 3GPP.

5.2.2.2 METIS-II

METIS-II (July 2015-June 2017) aimed at developing the overall 5G RAN design, focusing particularly on designing the technology for an efficient integration of legacy and novel radio access network concepts into one holistic 5G system. METIS-II considered the following aspects:

- Enablers and scenarios for future spectrum usage
- Harmonization of the user planes of the different air interface candidates (e.g. different waveforms), both below 6 GHz and for mm-waves.
- Common user plane design for the 5G RAN that provides flexible support for a multitude of frequency bands, services, nodes, layers and use cases
- Enablers for tight integration of LTE-A and NR
- Agile Resource Management Framework that integrates interference management, flexible short term spectrum usage and dynamic traffic steering
- 5G RAN configuration modes for RAN slicing
- SON architecture for efficient resource management on a high level
- State handling for UE battery consumption gains and lower C-plane latency
- Initial access techniques for reducing the collisions rates for mMTC and prioritizing URLLC services
- inter-RAT mobility and multi-connectivity

METIS-II also performed extensive system level simulations for assessing the performance of the technical components and the RAN design. A techno-economic assessment of the RAN deployment in dense urban areas was also performed.

ONE5G will build on some of the concepts developed in METIS-II, and will take the holistic RAN design framework of METIS-II a step further into a practical RAN design for a selected set of technical components, such as multi-connectivity, optimized access techniques for mMTC and URLLC, or agile resource management.

5.2.2.3 mmMAGIC

The mmMAGIC project (July 2015 – June 2017) focussed on investigating the technical components needed to develop an mm-wave (6-100 GHz) RAN for mobile communications. The eMBB type services were extensively investigated, categorized into 8 use cases. The following technical contributions from mmMAGIC are relevant to the ONE5G project, when investigating the mm-wave (3GPP NR type) systems.

- The mmMAGIC project developed a quasi-deterministic channel model (Quadriga), which is available as open source. This is broadly in-line with the 3GPP channel model, but offers additional features like the ground reflection and Outdoor to Indoor (O2I) penetration modules.
- On analysis for hardware impairments, mmMAGIC project developed a comprehensive phase noise model, which is available as open source. A lot of work in antenna parameterisation and modelling was conducted. The gains and losses for specific mm-wave antenna array configurations and their radiation patterns are also openly available.
- On higher layer aspects, the mmMAGIC project investigated multi-connectivity, cell clustering and network slicing. The RRC-inactive state was studied, which has since been investigated in 3GPP. Multi-RAT, multi-layer interoperation, including tight interworking with LTE was also considered in the project.
- On the air interface, the studies have revealed the suitability of OFDM based waveforms for eMBB applications. Modifications have been proposed to enhance the robustness against mm-wave hardware and channel impairments. Under channel coding, LDPC and Polar codes have been evaluated. Scalable and mixed numerology schemes have been proposed, which can facilitate novel schemes like IAB (Integrated Access and Backhaul).
- On multi-antenna and multi-node aspects, the hybrid beamforming (HBF) has been extensively studied. It is proposed as the recommended BF architecture for mm-wave access, due to its flexibility and robustness against hardware and channel impairments.

The multi-node connectivity is shown to be an essential feature for mm-wave systems, to improve the coverage reliability. Several multi-node schemes, including the provision of additional high rise nodes and the use of hybrid mm-wave and FSO (Free Space Optical) links are introduced.

5.3 Methodology for system-level evaluation

Our ultimate target is to create and use a table as the one visualized below with suggested parameters for the use cases (e.g. traffic, mobility, propagation, load), network layout (e.g. macro/ small cells, devices) and analytics (e.g. throughput, latency etc.) for specific use cases as defined in the project. Figure 13 illustrates the overall goal of methodology for system-level evaluation by filling-up a similar table for the considered use cases based on input from WP2 (e.g. D2.1) and standards wherever available.

Use case	Environment				Network layout	Analytics
	Traffic model	Mobility	Propagation	Load	Macro/ small cells, devices	Throughput, latency etc.
1	...	...	...	...	...	...
2	...	...	...	...	...	...

Figure 13: Main target of methodology for system-level evaluation

Figure 14 illustrates also the main points of the methodology which consists of three phases, namely Phase 1: Modelling/ Input, Phase 2: Implementation/ Integration, Phase 3: Evaluation results.

Phase 1- Modelling/ Input: This phase consists of the collection of environment-related parameters (traffic model, mobility, propagation, load), network layout (macro/small cells, devices) and relevant analytics. The aforementioned information will mainly come by WP2 and standards (especially by partners who follow standardization bodies such as 3GPP etc.). Also, in this phase it is anticipated to have certain, indicative functional components from WP3 and WP4, suitable for use cases (and also based on availability of components and resources). Phase 1 is expected to run until around M7 of the project.

Phase 2- Implementation/ Integration: The modelling and input from Phase 1 will be used for implementation and integration into the system level simulator. Specifically, implementation of environment and network parameters will take place during this phase in order to support the defined use cases of the project. Moreover, it is expected that certain, indicative functional components from WP3 and WP4, suitable for use cases will be also integrated and evaluated. A first version of the implementation will be done by M12 (which is the deadline of IR2.1) and first version of evaluation results to be available by M15 (for D2.2).

Phase 3: Evaluation results: The integrated technical components will be evaluated through a set of meaningful simulation test cases. Also, certain functional components will be evaluated not as standalone but in combination, in order to assess their combined performance in a realistic environment. In this direction, the simulation scenarios will be designed and configured based on the project use cases as defined in WP2, while the simulation results will be evaluated against the KPI and KQI targets defined in WP2 as well.

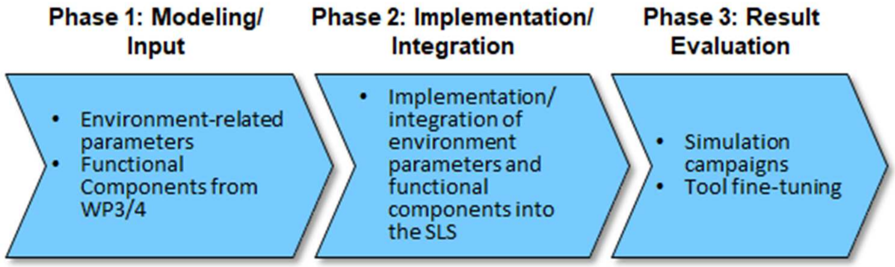

Figure 14: Methodology overview

6 Conclusions

This deliverable contains full details of the use cases identified by the consortium as the most promising candidates for application of 5G technologies beyond 3GPP Release 15. Among the selected use cases and services, six are considered core use cases (for which full technical analysis will be conducted, including PoCs) and three additional associated use cases (still to be technically analyzed, but with no PoCs involved). In contrast with past cellular generations, the use cases presented here comprise a wide range of industries and vertical businesses, thus reflecting the holistic nature that 5G technologies intend to have, especially when targeting 3GPP Release 16 and beyond.

Detailed KPIs are provided as per the most updated information available in the technical literature. In some cases discussions are still ongoing in the different fora, hence some variations are expected for some of the described parameters. In other cases, further feedback from the associated industries will be beneficial and will serve to refine the contents. Many of such industries do not have yet a complete and clear set of KPIs for their businesses, and a significant amount of the work towards 5G Release 16 will be to clarify what actual requirements will have to be included for the envisioned services.

3GPP is referenced as technical source in most of the current use cases, but in others the progress has been too low to actually provide consistent values. Industries in some cases may require more stringent values than those considered so far in 3GPP, particularly regarding latency and reliability requirements, and full alignment of all parties is still an ongoing work to be conducted in standards as well as in other industry fora.

The section on Baseline System Evaluation contains the current status of 5G standardization and general progress in both 3GPP and H2020 projects. Such status will serve as a baseline for system level simulations in the project. Finally, a summary of the methodology that will be used by the consortium for such system-level evaluations is provided.

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Annex A: Relevant 3GPP status

This section contains further details of the 3GPP status at the time of creation of this document, related to the topics handled by the project. The numbers used in the tables and subsequent sections are related to the numbering in the covered document from 3GPP.

Table 4: TR 38.801 V14.00 (2017-03) - Architecture and Interface:

Category and chapter	**Topic and sections**	**Decisions, relevant statements**
5. Deployment scenarios	5.2-5.5 Deployment variants	Both non-centralised and centralised. Co-sited with E-UTRA and shared RAN deployments (supporting multiple hosted Core Operators) are supported.
6. Overall RAN functions	6.1 RAN-CN functional split	See TR 23.799
	6.2 RAN functions	Extensive list to be found in 38.802. Basic functions: high similarity with E-UTRAN New functionalities: Network slicing, Interworking with E-UTRA, etc.
7. RAN architecture and interfaces	7.1 New RAN architecture	gNBs providing U- and C-plane terminations for NR eLTE eNBs providing U- and C-plane terminations for E-UTRA Interface between nodes: Xn Interface between nodes and NGC (next generation core) supports many-to-many relations.
	7.2 5G architecture options	A high number of options available (e.g. ranging from standalone to non-standalone and the relation of and between eLTE eNBs and NR gNBs). Still under discussion.
	7.3 RAN-CN interface	The general principles are set (e.g. it requires to support control plane and user plane separation, it shall separate the radio network layer and the transport network layer, etc.), the functions the interface shall support and the respective procedures are given. The basic protocol stacks are defined.
	7.4 RAN internal interface (Xn interface)	The general principles are set (e.g. to support control plane and user plane separation) and the required interface functionalities (e.g. handover preparation) and procedures (e.g. related to dual connectivity) have been set. The protocol stacks (both for control and user plane) have been defined.

8 Realization of network slicing	8.1 key principles	The RAN is aware of the implemented slices and is to support a differentiated handling of the respective traffic. A single RAN node should be able to support multiple slices and requires to keep the respective service level agreements and has to support QoS differentiation within a slice while being allowed to freely apply the optimal RRM strategy. Those strategies need to support resource isolation to avoid that shortage of shared resources in one slice breaks SLAs in another slice. Full dedication of RAN resources to a certain slices needs to be enabled. Different slices may be served via shared resources. Some slices may only be locally present. Awareness on this in a given gNB related to its neighbour gNBs may be beneficial (e.g. via Xn). Shared or dedicated radio resources (between slices) may be assigned.
10 Radio access network procedures	10.1 Dual Connectivity between NR and LTE	A high number of variants for implementing this feature (both related to the interfaces and to architectural and procedural aspects) are given in 10.1.x
	10.2 New RAN operation	Details related to Intra-system (gNB to gNB) and inter-system (NR with E-UTRA) mobility are given. The very high layer aspects of initial access are provided.
11 RAN logical architecture for NR	11.1 split options between central and distributed unit	8 split options are provided (ranging from above PDCP to after PHY). Those candidates are described and pros/cons are listed. The respective requirements to the transport network are exemplified. For the time being it is decided to focus on a higher layer split (between PDCP and RLC). The potential specification of a lower layer split is postponed and open for further study.
	11.2 U-plane-C-plane separation	It should be possible to serve U-plane and C-plane via separate nodes. Advantages of this feature and a description of U-plane and C-plane functions including groupings are given.

	11.3 Realization of RAN Network Functions	NFV (Network Function Virtualization) shall be supported.
12 SON	12.1 Scope of SON for NR	SON – as introduced in LTE, e.g. related to mobility robustness optimization, load balancing, etc. – is to be supported in NR as well. New SON functionalities, e.g. related to NR features, new use cases, etc., may be considered.
	12.2 Self configuration procedures	Procedures for coordinating between adjacent nodes are to be foreseen via Xn (e.g. for CoMP, load balancing, etc.).
13 Wireless relay	13.1 Scenarios	Various scenarios are foreseen for the application of wireless relays (single-hop stationary, multi-hop, multiple donor relay, mobile relay).
14 Migration towards RAN for NR	14.1 potential migration paths	5 different potential migration paths and their implication on RAN3 are given.

Table 5: TR 38.802 V14.10 (2017-06) - Physical layer:

Category and chapter	**Topic and sections**	**Decisions, relevant statements**
5 General description of layer 1	5.1 Duplexing	FDD on paired spectrum, TDD on unpaired spectrum with fixed transmission directions and with dynamically changing transmission directions (dynamic TDD).
	5.2 Forward compatibility	Reserved resources: Explicit signalling to NR UEs possible, some are indicated by using at least RRC signaling.
	5.3 Numerologies and frame structure	Numerology = sub-carrier spacing + CP overhead. Scaling law: 15kHz*2^n (n being an integer) Maximum channel bandwidth in release 15: 400 MHz. At least up to 100 MHz will be defined in Release 15. Max number of subcarriers: 3300 or 6600. Subframe duration: 1 ms; Frame length: 10 ms Symbol boundaries are aligned every 1 ms (for >15 kHz). As with 4G: the first symbol within 0.5 ms is longer by 16 T_s (= sampling duration). Added to CP. Resource Element (RE) = 1 subcarrier in 1 symbol Extended CP supported.

		PRB (physical resource block) = 12 subcarrier. 1 slot = 7 or 14 OFDM symbols (for up to 60 kHz) and 14 OFDM symbols above 60 kHz with normal CP. Slot may carry DL or UL or both. Slot aggregation supported. Mini-slots = 1 symbol supported (at least > 6 GHz). In general: length between 2 and slot length – 1. Mini-slot can start at any OFDM symbol (at least >6 GHz). Further design considerations for mini-slots are given in [38.802].
	5.4 LTE-NR co-existence	NR requires to support various LTE features (e.g. MBSFN configuration, TDD UL subframe, etc.). Further required features: Bandwidth adaptation for NR carrier (s) at least as fast as LTE carrier aggregation schemes. Symbols carrying LTE SRS need to be blanked (by NR). Support of flexible starting point and duration of scheduled resources in NR is key element (e.g. to avoid control regions of MBSFN). NR DL is supported in LTE MBSFN subframes. NR UE is not expected to understand LTE signals/channels in shared bands. NR UL: (a) shared frequency with LTE UL subframes, (b) separate frequencies (paired spectrum) – both NR standalone and dual connectivity possible.
	5.5 Carrier aggregation / dual connectivity	Within NR carriers over e.g. around 1 GHz contiguous and non-contiguous spectrum is supported. Different carriers may have the same and different numerologies. Max number of carriers: 16 (may be increased in later phases). DL and UL to be configured separately. Cross-carrier scheduling supported, joint UCI feedback allowed. Per-carrier TB mapping allowed.
6 DL concepts	6.1 Basic transmission scheme	Separately listed after the table (control and data channel design, waveform, multiple access scheme, channel coding, multi-antenna scheme including reference symbol designs).

	6.2 Physical layer procedure	Separately listed after the table (scheduling, HARQ, initial access and mobility, paging).
8 UL concepts	8.1 Basic transmission scheme	Separately listed after the table (control and data channel design, waveform, multiple access scheme, channel coding, multi-antenna scheme including reference symbol designs).
	8.2 Physical layer procedure	Separately listed after the table (random access, scheduling, Power control, HARQ).
10 Duplexing flexibility and cross-link interference mitigation (IM)	A very high number of IM technique candidates are provided (performance evaluation ongoing). Target is to have a common framework for both paired and unpaired spectra.	

As outlined in the table some sub-topics are too wide and comprehensive to be fit into the table. Therefore, they are covered in the following:

6.1 Basic transmission scheme

QPSK, 16QAM, 64QAM and 256QAM, constellation mapping is reused from LTE.

A single PRB (physical resource block) consists of 12 subcarriers (for all numerologies).

Different numerologies within the same NR carrier bandwidth us supported (from the view-point of the network) in TDM and/or FDM manner both for UL and DL. For the UE: TDM and/or FDM within or across subframe duration(s). Placement of variable subcarrier spacings (and respective PRBs) need to be done in a nested manner in frequency domain.
eMBB and URLLC may be multiplexed in DL both by using the same numerology und with different subcarrier spacings. URLLC may be scheduled in resources already being assigned to eMBB transmissions (pre-emption). gNB may inform the eMBB UE about the impacted eMBB resources.

6.1.2.3 Control channel (NR-PDCCH)

NR-PDCCH may at least use QPSK. NR-CCEs (control channel elements) consisting of a fixed number of REGs (resource element groups) are the building blocks for the NR-PDCCH. A REG is one PRB (12 subcarrier) within a single OFDM symbol w/ or w/o DM-RS. At least for eMBB, multiple NR-CCEs must not use the same REG (exception: different UEs, i.e. MU-MIMO). NR-PDCCH can be contiguous and non-contiguous in frequency (REG-level, i.e. the REGs being combined in a CCE may be spread in frequency). Initial search space is derived during initial access (MIB/system information/implicit). Additional search spaces may be RRC signalled.

Group common PDCCH: Carries at least slot format related info (e.g. which symbols in a slot are UL or DL or other). Not necessarily common per cell but to a group of UEs.

NR-PDCCH may use precoding and transmit diversity. UE may assume same precoding for NR-PDCCH and the respective DM-RS. RS (in at least one search space) do not depend on RNTI or UE-identity. May be configured in further search spaces.

6.1.3 Waveform

CP-OFDM based (at least up to 40 GHz). Spectral utilization may be greater than for LTE (LTE: 90%). Spectral confinement techniques are supported (filtering, windowing) but need to be transparent for the receiver.

6.1.4 Multiple Access Scheme

Synchronous and scheduling based at least for DL eMBB

6.1.5 Channel coding

eMBB data: flexible LDPC (supporting both incremental redundancy and chase combining)

DCIs (downlink control information element) for eMBB: polar coding. Very small block lengths: repetition/block coding.

6.1.6 Multi-antenna scheme

A wide range of details (still to some extent with several options and too many to explicitly cover them here) are given. In the following we focus on key items. For details the interested reader is referred to 38.802.

6.1.6.1 Beam Management

Beam determination, beam measurement, beam reporting and beam sweeping are to be treated. Too many details are covered in 38.802 to be covered, here. The reader is thus referred to 38.802. The same or different beams may be used for control channel and the corresponding data channel transmissions.

6.1.6.2 MIMO schemes

For 1- to 4-layers 1 codeword, for 5- to 8-layers 2 codewords are to be applied (per PDSCH assignment per UE).

DL DMRS based spatial multiplexing: SU-MIMO with 8 orthogonal DL DMRS ports, MU-MIMO with up to 12 orthogonal DL DMRS ports.

Both closed-loop transmissions (with data and DMRS using the same precoding) and open/semi-open loop transmissions (DMRS may or may not use the same precoding) are supported. In the latter case knowledge of the relation between DMRS ports and data layers may be required.

DL diversity schemes at least for some control information is supported.

6.1.6.3 CSI measurement and reporting

Both CSI-RS and SRS are supported for CSI acquisition. CSI reporting may be aperiodic, semi-persistent (can be activated and de-activated) and periodic (configured by higher layer: periodicity and timing offset).

Feedback types:

- Type I: Codebook based PMI feedback (codebook has at least two stages W_1 and W_2, W_1 codebook comprises beam groups/vectors).
    - Parameters being reported: Resource selection indicator, rank indicator, PMI, channel quality
- Type II: explicit feedback and/or codebook based with higher spatial resolution
    - Various categories are defined, but still open for discussion (for details: see 38.802)

CSI Feedback per subband, partial band and/or wideband is supported.

Interference measurement is supported (based upon ZP CSI-RS, NZP CSI-RS, and DMRS).

6.1.6.4 Reference signals

CSI-RS: for CSI acquisition and beam management. May be periodic, aperiodic and semi-persistent. May be configured for wideband and for partial-band. 'Number of antenna ports' needs to be configured (up to at least 32 ports for a given UE). Many aspects such as mapping, density, etc. are configurable.

DMRS: data and control demodulation. Patterns may be variable/configurable. At least a variant with front-loaded DMRS is foreseen. SU-MIMO: up to 8 orthogonal DL DMRS ports, MU-MIMO: up to 12 orthogonal DL DMRS ports. Options for port multiplexing: FDM (including comb), CDM (including OCC – orthogonal cover code - and cyclic shift) and TDM. PN sequence is supported (for CP-OFDM).

PTRS: This is a new reference signal for NR, to track the CPE (Common Phase Error). PTRS density can be configured, depending on the MCS and BW allocated per UE, by RRC. The default PTRS density is every symbol and every 2nd RB. For multi-layer (MIMO), the PTRS port is mapped to the lowest DMRS port. PTRS offsets (at RB level and RE level) are supported to randomize interference. PTRS power boosting is supported for SU-MIMO, using the vacant RE power where orthogonal PTRS/Data multiplexing is used. For UL DFT-s-OFDM, chunk based pre DFT PTRS is inserted, where the chunk size k={2,4}.

TRS: TRS is introduced in NR to do fine frequency/time tracking. TRS can be supported for both below and above 6 GHz and configured as one-port CSI-RS resource(s). For below 6GHz, TRS periodicity 10ms, 20ms, 40ms and 80ms are supported. UE can be configured multiple TRS if the UE supports multi-TRP/multi-panel deployment. TRS sequence is based on PN generator.

6.1.6.6 Network coordination and advanced receiver

Co-located and non-co-located TRPs considered. Semi-static and dynamic schemes supported. Different coordination levels should be considered (e.g. centralized/distributed scheduling, etc.). Both the same data streams (data duplication) and different data streams (data split) may be transmitted by different TRPs.

6.2 Physical layer procedure

6.2.1 Scheduling

Timing between resource assignment and actual resource is configurable. Resource allocation for Data (with CP-OFDM) may be both contiguous and non-contiguous. The pre-emption of eMBB data (due to URLLC data) may be communicated to the victim device.

6.2.2 HARQ

Feedback with one bit per TB is supported. Both support of more than one HARQ process for a given UE and one process for another given UE is supported. HARQ processing time becomes relevant for the overall procedure and may be different for different UEs (UE needs to indicate its capabilities).

Asynchronous and adaptive DL HARQ is supported. ACK/NACK feedbacks for several DL transmissions from a single UE may be bundled into one UL transmission. The relation between ACK/NACK and the respective DL transmission is signalled.

Code Block Group (CBG)-based transmission (per transport block) with single/multi-bit HARQ feedback is supported.

6.2.3 Initial access and mobility

6.2.3.1 Synchronization signal and DL broadcast signal/channel structure

NR-PSS (CP-OFDM), NR-SSS (CP-OFDM) and NR-PBCH are the means for initial access.
NR-PSS: initial symbol boundary synch,
NR-SSS: cell ID (at least parts of). Target for # of cell-ids ~1000. NR-SSS placement has fixed time/frequency relationship to NR-PSS.

For carriers supporting initial access minimum bandwidth is either 5 MHz or 10 MHz (<6 GHz) and either 40 or 80 MHz (for between 6 GHz and 52.6 GHz).

NR-PBCH has fixed relationship with NR-PSS and/or NR-SSS resource position. NR-PBCH is non-scheduled, carries at least a part of system information and has a fixed payload size. Periodicity is predefined in the specification and depends on the carrier frequency range.

NR-PSS, NR-SSS and NR-PBCH are organized in terms of SS blocks (= N OFDM symbols). A single SS burst contains one or multiple SS block(s). A single SS burst set contains one or multiple SS burst(s). Across different SS burst blocks within a SS burst set the number of physical beams and the selection of physical beams may vary across different SS-blocks.

SS burst set periodicity and information to derive measurement timing/duration is indicated by the network. If no indication is provided by the network the assumption is 5 ms to be the SS burst set periodicity.

NR-PSS: Zadoff-Chu is assumed as baseline sequence (for study). NR-PSS employs 1 antenna port.

NR-PBCH: a single fixed number of antenna port(s) is supported. PBCH numerology is the same as NR-SS. PBCH contains at least parts of the system information. Remaining information is transmitted via NR-PDSCH.

6.2.3.2 Mobility

For RRM measurement both single-beam and multi-beam operation supported. Cell-level mobility based on DL cell-level measurements (e.g. RSRP for each cell) are supported. UEs in IDLE mode make (at least) use of NR-SSS for RRM measurement for L3 mobility, UEs in CONNECTED mode may use CSI-RS in addition. Neighbor cell detection is based on NR-SS.

6.2.3.3 Paging

Multi-beam operation and beam sweeping is supported. Paging message is scheduled by DCI (carried by NR-PDCCH) and is transmitted in the respective NR-PDSCH resource (at least for RRC idle mode).

8 UL concepts

QPSK, 16QAM, 64QAM and 256QAM are support. Constellation mapping is reused from LTE. 0.5 pi-BPSK is supported for DFT-s-OFDM

8.1.2 Physical layer channel

8.1.2.1 Data channel

UL transmissions are based on scheduling.

For URLLC a UL transmission scheme without grant is supported. Resources are (re-)configured semi-statically. RS are multiplexed with the data. K repetitions including initial transmission for the same transport block are supported.

8.1.2.2 Control channel

Short NR-PUCCH: located around the last transmitted UL symbol(s) of a slot. Control channel is TDM and/or FDM with UL data channel within a slot. Short UL control channel may span a single symbol (further details in 38.802).

Long NR-PUCCH: Spanning multiple OFDM symbols for coverage reasons. FDM with UL data within a slot. Intra-TTI slot frequency-hopping, DFT-s-OFDM and transmit antenna diversity are supported (further details in 38.802).

Long NR-PUCCH and short NR-PUCCH may use TDM and FDM at least for different UEs in one slot. A PRB is the minimum resource unit size (in frequency direction).

For URLLC, time between scheduling request and the resources being configured may be smaller than a slot.

8.1.3 Waveform

CP-OFDM based (at least up to 40 GHz). Spectral utilization may be greater than for LTE (LTE: 90%). Spectral confinement techniques are supported (filtering, windowing) but need to be transparent for the receiver.

DFT-S-OFDM is supported, e.g. for link budget limited cases (at least for eMBB up to 40 GHz), but only for single stream transmission.

Both options are mandatory for UEs.

8.1.4 Multiple access scheme

Synchronous (i.e. within the C-plane) and scheduling based. Target is to support non-orthogonal multiple access (at least for mMTC)

8.1.5 Channel coding

eMBB: flexible LDPC UL control for eMBB: polar coding. Very small block lengths: repetition/block coding

8.1.6 Multi-antenna scheme

8.1.6.1 Beam management and CSI acquisition

Multiple SRS resources may be configured (for CSI acquisition). Max number of supported spatial is to be reported by the UE. Aspects related to the design of the codebook(s) are still rather open and open for discussion.

8.1.6.2 MIMO schemes

For 1 to 4-layer transmission 1 codeword is applied.
Supported MIMO schemes: Codebook based, non-codedbook based, diversity based. Precoding may be frequency selective. Rank is determined by the gNB. PRB bundling is supported (keeping precoder fixed). UL DMRS based spatial multiplexing (both SU and MU) is supported. SU: max 3 layers.
UL SRS based precoded/non-precoded link adaptation is supported (various options are given including a very high degree of configurability).

8.1.6.3 Reference signals

SRS for CSI acquisition and beam management. DM-RS for data and control demodulation. RT-RS for phase tracking.

SRS may be precoded (either transparent to gNB or indicated by gNB). High degree of configurability: Number of SRS ports (1,2 and 4 at least), comb levels (2 and 4), frequency hopping, SRS bandwidth (partial band and full band). SRS transmission may be aperiodic, periodic and semi-persistent. NR supports gNB to configure SRS resource in time domain only by UE-specific parameters and NR should also support UE specific configured bandwidth. SRS resource can span 1, 2, or 4 adjacent OFDM symbols within the same slot. At least 2, 5, 10, 20, 40, 80, 160, 320 slots periodicity are supported for 15KHz SCS. SRS sequence for NR is supported by using LTE SRS sequences generation equation.

8.2 Physical layer procedure

8.2.1.1 Preamble (random access)

Based on random access preamble formats (including one or multiple random access preambles, a random access preamble consists a preamble sequence and a CP, a preamble sequence may include one or multiple RACH OFDM symbols). Many different preamble formats supported (preamble length, with repeated preambles, numerology depending on the frequency range). Numerology may be different or the same than/as for data/control.

PRACH region is aligned with UL symbol/slot/subframe. Length of CP/GT (guard time) and number of repeated RACH preambles and RACH symbols is flexible.

8.2.1.2 Procedure (random access)

4-steps (preamble transmission (message 1), random access response (message 2), message 3 (not specified in 38.802), message 4 (not specified in 38.802)). Use of one or multiple/repeated (e.g. for Rx beam sweeping) preambles may be configured.

Preamble indices may be grouped and associated to specific means. Power ramping is supported (for a given beam). Initial power may be derived based on path loss estimates.

8.2.2 Scheduling

The same-slot and cross-slot scheduling is allowed. The timing between assignment and actual UL resource is indicated in DCI (from a set of options, which are configured by higher layer). Both contiguous and non-contiguous allocation possible.

Grant-free access for URLLC supported (and is targeted to be supported for mMTC). Resource configuration includes: time/frequency resource, modulation and coding scheme, redundancy version, reference signal parameters. Transmission may be repeated until UL grant is received, the max number of repetitions is reached.

8.2.3 Power control (PC)

Both open-loop (path-loss estimate base on DL RS beam measurement) and closed-loop (based on network signalling) PC supported for NR-PUSCH at least for eMBB. Fractional PC supported. Beam specific PC as baseline.

8.2.4 HARQ

UE may have one or more than one HARQ processes. At least for eMBB: asynchronous and adaptive UL HARQ.

Table 6: TR 38.803 V14.2.0 (2017-09) - Radio-Frequency (RF) and co-existence aspects:

Category and chapter	Topic and sections	Decisions, relevant statements
5. Co-existence study	5.1-5.2 Co-existence scenario, assumption	Network layout models for urban macro, dense urban and indoor environments, propagation models, antenna and beam-forming modelling, transmission power control model, received power model, ACLR and ACS modeling (BS ACLR modeled as flat in space
	5.3 Co-existence simulation methodology and results	simulation results for average throughput loss and 5%-tile throughput loss in different scenarios are provided. 13 simulation scenarios are provided, involving different parameters: - frequencies (30 GHz, 45 GHz, and 70 GHz) - DL/UL - indoor / urban macro / dense urban
6. RF feasibility	6.1 Common issues for UE and BS	Feasible subcarrier spacings are identified for bands below 6 GHz, and candidate values are identified for bands above 6 GHz. Maximum channel bandwidth is identified from RF feasibility perspective. Further studies on possibility to support these BW are needed. Common issues for mm-Waves frequency bands are raised: - power amplifier efficiency in relation to unwanted power emissions - Noise figure, dynamic range and bandwidth dependencies: simplified receiver model is

		derived, formulas are provided for the noise factor and noise floor. Impact the loss and non-linearities are stressed at higher frequencies. - Filtering aspect for mm-Wave technologies different compromises between implementation constraints, cost, power consumption and filtering efficiency are given - impact of increasing the carrier frequency on circuit design is stressed - Different strategies on the implementation of local oscillator (LO) signal generation and distribution are described
	6.2 UE requirements	Recommendations are provided on UE implementation of multiple antennas in mm-waves frequency bands, as well as to consider in RAN4 two candidate RF architectures for mmWaves NR UE. An analysis of the main RF impairments and key requirements to achieve high performance are provided. Methodologies are developed for UE Transmitter and Receiver characteristic, identifying the metric, the type of tests to be performed, the need for further studies or discussions and the expected outputs from RAN4
	6.3 BS Requirements	The definitions of NR BS classes are agreed. Output power limit will be based on TRP [R4-1610923]. The testing methodology, metrics and requirements, type of tests to be performed, are developed.
7. Relation with the existing specifications		The relations between the MSR (Multi-Standard Radio) BS, AAS BS and UE specifications, as well as EMC requirements to the existing TS documents are provided. Similarly, EMC requirements and UE specifications are related to existing specifications. The different requirements to be captured in NR, for both NSA and SA, are also summarized.

8. Regulatory aspects	8.1-8.3 Overview of international and regional regulation, Boundary between spurious and OOB domain	For bands above 6 GHz, some regulatory aspects be taken into account are stressed. Some guidelines from ITU-R Recommendation SM.1539.1 for the boundary of the spurious domain are provided.
9. Radio Resource Management	9.1 Mobility aspects	The mobility procedures are provided for the UE states: RRC_IDLE and RRC_CONNECTED. The mobility procedure for the new state RRC_INACTIVE may be different. Intra-RAT and inter-RAT mobility between at least standalone NR and LTE will have to be supported. The RRM requirements to be defined by RAN4 to support this mobility are described.
	9.2 Beam management	The RRM procedures related to beam management (beam determination, measurement, reporting and sweeping), to be defined in RAN4, are given.
	9.4 Power consumption related aspects	Power consumption models are provided for both the UE and gNB. A list of possible techniques for power saving for NR RRM is given, with power saving opportunities for transmission of reference signals, and for receiving and measuring signals.
	9.5 Measurements and measurement related requirements	The requirements for measurements performed by NR UE for the purpose of mobility and beam management are provided
10. Testability	10.1 RRM requirements testability	Below 6 GHz, NR RRM testing can generally be performed using the antenna connectors and following the procedure as for E-UTRA UE or eNB. Above 6 GHz, OTA testing is the baseline approach.
	10.2 UE RF requirements testability	The baseline measurement setup of UE RF characteristics above 6 GHz is provided. Equivalence criteria are defined, with 11 points to be satisfied for an OTA test methodology.
	10.3 BS RF requirements testability	NR BS testing will consist of both conducted testing at transceiver level and OTA testing at BS level. The current specifications, to be used as baseline for below 6 GHz bands are provided, and the test setup for the key parameters (EIRP, EIS, TRP) are given.

As outlined in the table some sub-topics are too wide and comprehensive to be fit into the table. Therefore, they are covered in the following:

5 – Co-existence study

Co-existence simulation scenario (5.1) and assumptions (5.2) are defined: Network layout models for urban macro, dense urban and indoor environments, propagation models (including path loss, LoSprobability and O2I penetration loss), antenna and beam-forming modelling, transmission power control model, received power model, ACLR and ACS modeling, noise figure. The co-existence simulation methodology (5.3) is defined, and co-existence simulation results are provided (5.4: simulation results for average throughput loss and 5%-tile throughput loss in different scenarios:

- 30 GHz DL Indoor scenario
- 30 GHz DL urban macro (ISD = 200m and 300m)
- 30 GHz DL dense urban scenario
- 30 GHz UL indoor scenario
- 30 GHz UL urban macro (ISD = 200m and 300m)
- 30 GHz UL dense urban scenario
- 70 GHz DL Indoor scenario
- 70 GHz DL urban macro
- 70 GHz UL indoor scenario
- 45 GHz DL indoor
- 45 GHz DL urban macro
- 45 GHz DL urban macro
- 45 GHz UL urban macro

Co-existence studies are aimed here at providing insights on the expected behavior foreseen for NR based on the available information and knowledge. For the UL, minimum values to be satisfied for BS ACS and UE ACLR are determined based on the interpolated ACIR values to meet the 5% throughput loss criteria. For the DL, UE ACS and BS ACLR are determined based on the interpolated ACIR values to meet the 5% throughput loss criteria.

6 – RF feasibility

6.1 – Common issues for UE and BS

Feasible subcarrier spacing values are identified for bands below 6 GHz, and candidate values are identified for bands above 6 GHz. Maximum channel bandwidth is identified from RF feasibility perspective. Further studies are needed on the possibility to support these BW.

NR in-band requirements (6.1.8): methodology and assumptions for developing DL and UL in-band emission and requirements (EVM, selectivity) are set, with pre-defined interactions with RAN4.

Common issue for mmWaves (6.1.9): this section highlights some issues

- Power amplifier efficiency in relation to unwanted power emissions: the complex interrelation between linearity, saturated power added efficiency and output power need to be taken into account, considering the heat dissipation aspects and significantly reduced area/volume for mm-waves products.
- Noise figure, dynamic range and bandwidth dependencies: a simplified receiver model is derived, formulas are provided for the noise factor and noise floor. The impact of the loss and non-linearity are stressed at higher frequencies.
- Filtering aspect for mm-Waves technologies: filtering can be challenging at mm-waves frequencies considering the limited area/volume and level of integration needed. Three places where it makes senses to insert filter (behind or inside the antenna element pattern, behind the first amplifiers and on high frequency side of the mixers), and the deeper in

the RF chain, the better protected the circuits. There are two types of implementation: low-cost monolithic integration with one or a few multi-chain CMOS/BiCMOS core-chips (limited possibilities for high-performance filters along the RF chains) and high performance heterogeneous integration with several CMOS/BiCMOS core-chips, combined with external amplifiers and mixers (allow for external filters along the RF chain but with the drawbacks of complexity, size and power consumption). For the monolithic integration, it will be difficult to put filter at deeper positions in the RF chain.

- Carrier frequency: different impacts of increasing the carrier frequency on the circuit design (internal voltages) are given: increased power due to higher bandwidth, low-voltage technology needed for speed, power dissipation, dynamic range
- Phase noise limitation provided, to be taken into account for the selection of achievable values for mm-waves frequency ranges
- Different strategies on the implementation of local oscillator (LO) signal generation and distribution are described, with pros and cons: centralized LO generation (single PLL but high performance requirement on the PLL, and distribution of LO signals over antenna array will be power consuming, and potential impact on spurious emissions), distributed LO generation (beneficial from EVM perspective but increased circuit complexity), semi-distributed LO generation.

6.2 – UE requirements

UE antenna arrangement and feasibility of UE beamforming (6.2.1): recommendations are provided on UE implementation of multiple antennas in mm-waves frequency bands (realistic number of antenna elements, possible antenna arrangements, description of 5G NR stand-alone UE RF architecture). Recommendation is provided to RAN4 to consider two candidate RF architectures for mmWaves NR UE.

Simulation results illustrating the estimated UE beamforming performance with 4 or 8 antennas arranged in an array are provided, at 15 GHz. the results show important gains with UL beamforming for the serving BS and reduced interference at other BS compared to isotropic antenna, for both reciprocity and feedback-based precoding. Similar performance gains should be seen at lower frequencies, below 6 GHz if physical dimensions are scaled with the wavelength.

An analysis of the main RF impairments and key requirements to achieve high performance are provided:

- transceiver architectures: impact of conversion from digital to analogue, either direct conversion (Homodyne) or IF (Heterodyne)
- UE reference architecture: identification of the key components in the FR front end, to be further studied in NR, with descriptions of main design constraints for each block and their impacts on the Tx/Rx performance
    - Tx: power amplifier, phase shifter
    - Rx: Low Noise Amplifier, Phase shifter, Filter
- Beamforming approaches (digital, analog) are presented, with their pros and cons

UE transmitter characteristic (6.2.2): the different requirements are provided for two ranges: Range 1 corresponds to frequency bands below 6 GHz, with conducted tests (OTA test not precluded) and Range 2 corresponds to frequency bands above 6 GHz, with only OTA test. Methodologies are developed for each characteristic, identifying the metric, the type of tests to be performed, the need for further studies or discussions and the expected outputs from RAN4. Table 6.2.1-1 provides a summary of the outcome in the Study item and the topics to be addressed in the Work Item.

UE Receiver characteristics (6.2.3): Similarly to the transmitter characteristic, the testing methodology, metrics identified, type of tests to be performed, are identified. Table 6.2.1-1 provides a summary of the outcome in the Study item and the topics to be addressed in the Work Item.

6.3 – BS requirements

Similarly to the UE requirements, the agreements in the Study item and issues to be addressed in the WI, considering two frequency ranges (Range 1 = below 6 GHz, with both conducted and TA requirements, Range 2 = at least above 24 GHz, only OTA requirements).

General requirements: the definitions of NR BS classes were agreed

- NR BS classes for BS without antenna connectors (Wide Area / Medium Range / Local Area BS, characterized in terms of requirements derived from scenarios and BS to UE minimum distance from the ground)
- NR BS classes for BS with antenna connectors (Wide Area / Medium Range / Local Area BS, characterized in terms of requirements derived from scenarios and BS to UE minimum coupling loss)

Output power limit will be based on TRP [R4-1610923]

BS Transmitter characteristic (6.3.2) and BS Receiver characteristics (6.3.3): the different characteristics are provided for the two ranges. The testing methodology, metrics and requirements, type of tests to be performed, are identified. Table 6.3.1-1 provides a summary of the outcome in the Study item and the topics to be addressed in the Work Item. Several topics are for further studies.

7 – Relation with the existing specifications

This section relates the MSR (Multi-Standard Radio) BS and AAS BS specifications to the existing TS documents. Similarly, EMC requirements and UE specifications are related to existing specifications.

This section also outlines requirements which will be needed and integrated into NR, for NSA and SA NR, for both Range 1 and Range 2.

8 – Regulatory aspects

8.1 – Overview of international and regional regulation

The main regulation bodies are presented:

- ITU-R: ITU-R recommendations on generic limits, terminology and definitions, guidance to specify unwanted emissions and recommended values are provided
- European regulation: European recommendations on unwanted emissions from CEPT/ECC are provided. The roles of the different bodies (CEPT, ECC, ...) are explained
- US regulation (FCC): the recent rues published by the FCC on spectrum bands above 24 GHz are explained

8.2 – Boundary between spurious and OOB domain

This section explains how the boundary between these two categories of unwanted emissions had been settled for UMTS and LTE below 6 GHz, and how it was adapted for wideband, multi-carrier and multi-RAT transmissions with LTE (when MSR standard was developed and intra-band Carrier Aggregation was defined). For bands above 6 GHz, some regulatory aspects to be taken into account are stressed, showing that the way of specifying unwanted emissions must evolve. Some guidelines from ITU-R Recommendation SM.1539.1 for the boundary of the spurious domain are provided.

8.3 – Suitability of technical conditions of ECC DEC(11)06 for 5G

The requirements and technical conditions specified in ECC DEC (11)06 are evaluated in 3GPP. This decision specifies emission requirements for BS in frequency bands 3400-3600 MHz and 3600-3800 MHz.

9 – Radio Resource Management

9.1 – Mobility aspects

The mobility procedures are provided for the UE states: RRC_IDLE and RRC_CONNECTED. The mobility procedure for the new state RRC_INACTIVE may be different. Intra-RAT and inter-RAT mobility between at least standalone NR and LTE will have to be supported. The RRM requirements to be defined by RAN4 to support this mobility are described.

9.2 – Beam management

The RRM procedures related to beam management (beam determination, measurement, reporting and sweeping), to be defined in RAN4, are given.

9.3 – Timing aspects: to be investigated in NR WI

9.4 – Power consumption related aspects

Power consumption models are provided for both the UE and gNB. A list of possible techniques for power saving for NR RRM is given, with power saving opportunities for transmission of reference signals, and for receiving and measuring signals.

9.5 – Measurements and measurement related requirements

The requirements for measurements performed by NR UE for the purpose of mobility and beam management are provided, and the related topics to be investigated by RAN4 are defined.

10 – Testability

10.1 – RRM requirements testability

Below 6 GHz, NR RRM testing can generally be performed using the antenna connectors and following the procedure as for E-UTRA UE or eNB below 6 GHz. Above 6 GHz, OTA testing is considered as the baseline approach for NR RRM testability.

10.2 – UE RF requirements testability

The baseline measurement setup of UE RF characteristics above 6 GHz is provided. Equivalence criteria are defined, with 11 points to be satisfied for an OTA test methodology. The Far Field Criteria for the baseline measurement setup are also provided, as well as the TRP measurements in the radiative near field

10.3 – BS RF requirements testability

NR BS testing will consist of both conducted testing at transceiver level and OTA testing at BS level. The current specifications which can be used as baseline for below 6 GHz bands are provided, and the test setup for the key parameters (EIRP, EIS, TRP) are given.

11 – WP 5D for WRC-19 agenda item 1.13

The request from WP5D on system characteristics in the frequency range (24.25 – 86 GHz) is explained, and response from 3GPP is provided, with the proposed specification of system characteristics.

Table 7: TR 38.804 V14.0.0 (2017-03) - Radio Interface Protocol Aspects:

Category and chapter	**Topic and sections**	**Decisions, relevant statements**
4. Deployment scenarios and guidelines	4.1 Deployment scenarios	Both homogeneous (i.e. macro only or small cell only) and heterogeneous are supported. LTE and NR may be co-located or not co-located.

		LTE and NR may provide similar or different coverage. NR may serve small cells, while LTE serves macro sell or the opposite around.
		NR gNB may be master node LTE eNB may be master node eNB connected to NextGen Core may be master node Inter-RAT mobility supported: LTE eNB connected to EPC and NR gNB connected to NextGen Core eNB and NR gNB connected to NextGen Core.
		WLAN integration options: Interworking with NR via NextGen Core (C-plane via NR, U-plane via WLAN) Aggregation with NR via NextGen Core (U-plane and C-plane via NR gNB, U-plane between NR gNB and WT)
	4.2 Guidelines	As much commonality should be targeted for between the two cases (tight interworking with LTE and standalone operation). Most essential functions such as initial access: need to be future proof and common to different use cases and service. LTE layer 2 and RRC is baseline for NR. Intra-NR mobility: - Network controlled (measurements and the related messaging should be minimized) - UE based (UE context transfer should be minimized) Interruption time should be close to zero (with single link connection) and exactly 0 ms (with the UE supporting dual-connectivity to both source and target cell). For URLLC: - Focus on coverage, mobility, radio link features (e.g. low latency and/or high reliability) - QoS requirements are aimed to be met after C-plane signalling for session setup is completed - RLC reTx (ARQ) is not used to meet the strict U-plane latency requirements - It will be distinguished between use cases w/ and w/o cell changes o For the latter (w/o): latency and requirement targets are to be met

		o For the former (w/): targets are to be met "as best as possible" For system information delivery: - e.g. should be highly configurable Related to UE design: - e.g. potential for hardware sharing with other radio techs to be maximized
5. Overall System architecture		NG-RAN elements: - gNB: user plane and control plane termination towards the UE - gNBs interconnected via the Xn interface - gNBs connected to the NGC (NextGen Core) via N2 interface (Access and Mobility Management, AMF) and N3 interface (user plane, UPF)
	5.1 Functional split	Functions being covered by gNB, AMF, UPF and SMF (session management function) are given
	5.2 Radio interface protocol architecture	Both lower layer aggregation (like carrier aggregation) and upper layer aggregation (like dual-connectivity) targeted. User plane and control plane stacks for NR are given. Relevant aspects related to dual-connectivity with LTE are handled.
	5.3 Physical Layer	Most aspects are already covered in 38.802 (see above) and only summarized in 38.804. The list of physical channels of NR and their mapping to transport channels are given.
	5.4 Layer 2	Layer 2 structure of NR is given (functionalities related to MAC, RLC, PDCP and the new AS – access stratum - sublayer and their separation between gNB and UE). Layer 2 data flow is presented. A TTI is a number of consecutive symbols in time domain in one transmission direction. RRC signalling is used to configure/reconfigure the mapping of a logical channel of a radio bearer to the numerologies and/or TTI durations. This mapping is not visible to RLC. A single MAC entity supports one or multiple numerologies and/or TTI durations.
	5.5 RRC	Services and functions related to the RRC sublayer are given. NR supports 3 UE states (RRC_IDLE, RRC_INACTIVE, RRC_CONNECTED) and the respective state transitions. In particular, for RRC_INACTIVE: - Cell re-selection mobility - Connection between CN and NR RAN has been established

		- UE AS context is stored in at least on gNB and the UE - Paging is initiated by NR RAN - RAN-based notification area is managed by NR RAN - NR RAN is aware of the RAN-based notification area the UE belongs to. A notification area can cover one or several cells and may be smaller than a CN area. While being within the notification area, the UE does not send location updates. Once leaving this area the UE sends a location update. Different options for the configuration of this area are given. The process to handle the System Information (SI) is given. The minimum SI, comprising basic information for initial access to a cell and information to acquire any other SI, is periodically broadcasted. Other SI may be broadcasted or provisioned in a dedicated manner. For cell-level mobility driven by RRC, the baseline for RRM measurements for DL is similar to LTE. In multi-cell operation, the gNB should have the mechanisms to consider the measurements results of multiple DL beams for handling handovers. UE should be able to differentiate beams from its serving cell and from neighbour cells. To control access, the different mechanisms defined in LTE should be replaced by a unified access barring mechanism. The UE capability retrieval framework is provided, with UE reporting capabilities at least upon request from the network.
6. ARQ and HARQ		Secondary ARQ in RLC layer on top of HARQ. Asynchronous HARQ in UL and DL should only be supported.
7. Scheduling		The description of scheduler operation is given. The scheduler accounts for the UE buffer status and QoS requirement of each UE and associated radio bearer, to assign resource blocks in unit of TTI. The scheduler relies on measurements, including transport volume and measurements of UEs radio environment. UE is notified by reception of a scheduling channel, assigning resources.
8 QoS control	8.1 QoS architecture in NR and NextGen Core	The QoS architecture in NR and NextGen Core is described. Quality of Service is ensured through the appropriate mapping of packets to QoS flows and Data Radio Bearers (DRBs).

		In the UL, this mapping may be processed either by reflective mapping (similar QoS flows IDs than in the DL) or explicit configuration (UL mapping configured by RRC).
9 Initial Access	9.1 Cell selection	The two procedures are described: initial cell selection (without prior knowledge of RF channels corresponding to NR carriers, implying to scan all RF channels in NR bands to find the strongest cell) and cell selection by leveraging stored information (measurements, …) Three level of services are defined while a UE is in RRC_IDLE: limited service, normal service and operator service.
	9.2 Random access procedure	The procedure, supporting both contention-based and contention-free random access, as in LTE.
10 Mobility	10.1 Intra NR	UE based mobility: several cell reselection methods are described, providing rules and priorities guiding the selection of the cell: intra-frequency reselection based on ranking of cells, inter-frequency (and potentially inter-RAT) reselection based on absolute priorities, frequency specific cell reselection parameters common to all neighbouring cells on a frequency, service specific prioritisation, RAN and CN-initiated paging are used to reach UE in RRC_IDLE and RRC_INACTIVE when using Discontinuous Reception DRX. A set of rules defining the paging mechanism (paging occasion per DRX cycle, cycle length…). Network controlled mobility: for UEs in RRC_CONNECTED, mobility is either driven by RRC or without RRC. In the former case, cell level mobility is handled through handover procedures as defined for LTE Rel. 13. In the latter case, mobility (e.g. intra-cell) is handled with PHY and MAC on the beam or TRPs.
	10.2 inter-RAT	The procedures enabling the mobility support between NR and LTE connected to NG Core and EPC are provided. The UE state machine, state transition and mobility procedure between NR and E-UTRA connected to NextGen Core are to be discussed in the normative phase.
	10.3 Dual connectivity between LTE and NR	The baseline procedure for Dual Connectivity between LTE and NR, such as nodes responsible for triggering the addition or release of a secondary node
11 Security		Security key refresh is not performed at every mobility procedure.

12 UE power saving		DRX will be further improved during normative phase to support multiple services, but will not be optimized for URLLC.
13 RAN support of Network Slicing		Implementation of Network slicing at RAN level is handled through different PDU sessions, by scheduling and providing different L1/L2 configurations.
14 E-UTRA with NextGen Core		E-UTRA may connect to the NextGen Core via the NG interfaces. U-plane will be the LTE U-plane, with some enhancements to support NextGen Core.

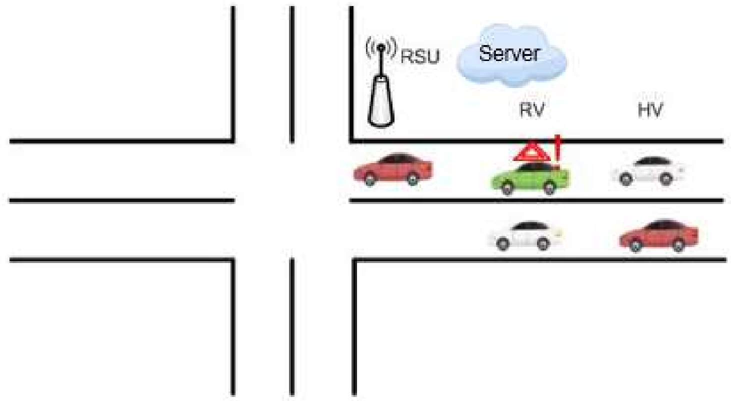
Annex B: full details of selected use cases

Use case 1: Assisted, cooperative and tele-operated driving

In the following we describe the full details of this use case, in table format, for an easier navigation through its characteristics.

1. General description	
Use case name	Assisted, cooperative and tele-operated driving (Vertical 1: Automotive Industry)
Description	A vehicle is driving in a road in presence of other vehicles. Assisted/cooperative driving use case enables vehicles to interact with each other, as well as with the network infrastructure and any available roadside unit (RSU), in order to avoid potential collisions and improve driving safety. Tele-operated driving involves a human driver physically located outside of the vehicle. When routes are predictable, such as in public transportation, driving based on cloud computing can be considered. Access to cloud-based back-end service platform can also be considered. High reliability and short latencies are the main requirements [22.886] 3GPP SA1 defines RSU as a logical entity that combines V2X application logic with the functionality of an eNB (referred to as eNB-type RSU) or UE (referred to as UE-type RSU). Therefore a RSU can communicate with vehicles via D2D link or cellular DL/UL [38.913]. Roadside units may comprise any roadside element with connection capabilities towards other vehicles and/or the cellular network.
Scenario	Megacities (Urban grid for connected car), and Underserved areas (Highway Scenario), with or without presence of roadside units.
Services category	eMBB / URLLC / mMTC
Services	#1: Assisted driving aided by roadside infrastructure. This service assumes the presence of RSUs as an enabler for improved coverage and very low-latencies. The network infrastructure is generally present, but car-to-car communication should be possible even in the absence of

network coverage. An example (taken from 5G Automotive Association, 5GAA) is provided below:



#2: Cooperative driving between nearby vehicles. In this service, RSUs are not present and communication is purely car-to-car based, with the aid of the network infrastructure (wherever available). Car-to-car communication should be possible even in the absence of network coverage.

#3: Tele-operated driving. This service requires the cellular communication providing URLLC for the control data transmission in the downlink as well as reliable and low-latency video (plus other sensor data) transmission in the uplink.

2. Network and UE deployment and KPIs

Attribute	**Values or assumptions**		**Comments**
	Scenario#1 Megacities (urban grid for connected car and highways)	**Scenario#2** Underserved areas (Highway Scenario)	
Layout and layers	Macro grid, with presence of RSU in Service #1 and optionally in Service #3	Macro grid, with presence of RSU in Service #1 and optionally in Service #3	RSUs may be deployed in an opportunistic way, i.e. any location can be valid for testing this use case. [38.913] defines some possible layouts.
ISD (m)	500 m in urban, 1732 m in highways. Eventual presence of RSUs in e.g. street intersections or semaphores in Service #1. Inter-RSU distance = 50/100 m for highways.	1732 m (optionally 500 m), with presence of RSUs at convenient locations in Service #1 and optionally in Service #3. Inter-RSU distance = 50/100 m.	As per [38.913].
Carrier frequency	Below 6 GHz (e.g. ETSI ITS band) for vehicle to vehicle/RSU. Any	Below 6 GHz (e.g. ETSI ITS band) for vehicle to vehicle/RSU. Any	[38.913] ETSI ITS band includes 30 MHz in 5.875 – 5.925 GHz.

	licensed band <6 GHz for connection to base station.	licensed band <6 GHz for connection to base station.	Other options might appear in the future.
Aggregated system bandwidth	Up to 200 MHz (DL+UL) for connection to base station. Up to 100 MHz (SL) for connection to vehicle to vehicle/RSUs.	Up to 200 MHz (DL+UL) for connection to base station. Up to 100 MHz (SL) for connection to vehicle to vehicle/RSUs.	The aggregated system bandwidth is the total bandwidth typically assumed to derive the values for some KPIs such as area traffic capacity and user experienced data rate [38.913].(1)
BS / UE transmit power (dBm)	BS: +46 dBm UE: +23 dBm RSU: +23 dBm	BS: +49 dBm UE: +23 dBm RSU: +23 dBm	Actual values may change according to the partners' assumptions. Transmit power is assumed larger for Underserved areas, but Transmit power + antenna gain should not exceed the max. EIRP.
# BS antennas	Up to 256 TX/RX	Up to 256 TX/RX	[38.913]
# UE antennas	Up to 8 TX/RX	Up to 8 TX/RX	[38.913] UEs can be RSU, vehicles, pedestrians and/or bicycles
Traffic model	50 messages per 1 second with 60 km/h, 10 messages per 1 second with 15 km/h	50 messages per 1 second with absolute average speed of either: • 100–250 km/h (relative speed: 200–500 km/h), or • 30 km/h	Tentative in 3GPP and could be modified after SA1 input [38.913].
Maximum # UEs	1000 vehicles	1000 vehicles	Number of UEs attached to base station (see #RRC connections per cell)
Maximum / Average # Active UEs	Max: 200 active UEs. Avg: 50 active UEs	Max: 200 active UEs. Avg: 50 active UEs	An RSU shall be able to communicate with up to 200 UEs supporting a V2X application [22.886]. A lower value is taken for the average #connections.
UE distribution	Urban grid model (car lanes and	100% in vehicles.	Tentative in 3GPP and could be

	pedestrian/bicycle sidewalks are placed around a road block. 2 lanes in each direction, 4 lanes in total, 1 sidewalk, one block size: 433m x 250m). Average inter-vehicle distance (between two vehicles' center) in the same lane is 1sec * average vehicle speed (average speed 15 – 120 km/h) Pedestrian/bicycle dropping: average distance between UEs is 20m.	Average inter-vehicle distance (between two vehicles' center) in the same lane is 0.5sec or 1sec * average vehicle speed (average speed: 100-300km/h).	modified after SA1 input [38.913].
UE speed	Up to 250 km/h	Up to 250 km/h	As per [22.886].
Services mixture	50% / 50% split	10% / 90%	Split between services #1 and #2. Underserved areas may assume little presence of RSUs.
Network KPIs	**KPIs' Targets**		**Comments**
Area traffic capacity	Megacities: 1500 Mbps / km^2 (DL), 30 Gbps / km^2 (UL) Underserved areas: 64 Mbps / km^2 (DL), 1280 Mbps / km^2 (UL)		Total traffic throughput served per geographical area (in Mbit/s/m2), obtained from [22.886] and assumed connection density (see below). [22.886] assumes 1 Mbps DL/20 Mbps UL.
Connection density	1000 veh. / km^2 (Megacities), 85 veh. / km^2 (Underserved areas)		Obtained with ISD = 500/1732 m and 200 active UEs, assuming omni-directional coverage.
# RRC Connections/Cell	1000 veh. / cell		No. UEs camping in the cell
UE KPIs	**KPIs' Targets**		**Comments**
-			
3. Service #1: Assisted driving aided by roadside infrastructure.			
Service attributes	**Values / assumptions**		**Comments**
Protocol type	Road Safety Application protocol [102.638] over Basic Transport Protocol (BTP)/IP [102.636-5-		As defined in e.g. ETSI ITS specs.

	1]. Safety-related messages are sent, like Co-operative Awareness Messages (CAMs), Basic Safety Messages (BSMs), or Decentralized Environmental Notification Messages (DENMs).	Other protocol types are also possible as per the partners' preferences.
Codec rate	Ongoing work.	To be clarified by ETSI ITS specs.
UL/DL ratio	Ongoing work.	To be clarified by ETSI ITS specs.
Security level	Data integrity, mutual authentication and confidentiality should be observed.	To be clarified by ETSI ITS specs.
Service KPIs	**KPIs' Targets**	**Comments**
U-plane maximum UL/DL radio latency (ms)	0.5 ms	The radio protocol layer in which it is measured (e.g. MAC, PDCP, RRC) should be specified. Taken as 1/10th of E2E U-plane latency
C-plane maximum UL/DL radio latency (ms)	10 ms	Max. time for C-plane state transition to "connected state". Taken from [38.913].
U-plane maximum E2E latency (ms)	5 ms	Taken from [22.886].
U-Plane maximum DL/UL radio packet loss (%)	0.001%	Tentatively taken as (100 - reliability)%
U-plane reliability	99.999%	Probability that IP packets are correctly received within the latency time. Taken from [22.886].
4. Service #2: Cooperative driving between nearby vehicles.		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	Road Safety Application protocol [102.638] over Basic Transport Protocol (BTP)/IP [102.636-5-1]. Safety-related messages are to be sent, like Co-operative Awareness Messages (CAMs), Basic Safety Messages (BSMs), or Decentralized Environmental Notification Messages (DENMs).	As defined in e.g. ETSI ITS specs. Other protocol types are also possible as per the partners' preferences.
Codec rate	Ongoing work.	To be clarified by ETSI ITS specs.

UL/DL ratio	Ongoing work.	To be clarified by ETSI ITS specs.
Security level	Data integrity, mutual authentication and confidentiality should be observed.	To be clarified by ETSI ITS specs.
Service KPIs	**KPIs' Targets**	**Comments**
U-plane maximum UL/DL radio latency (ms)	0.1 ms	The radio protocol layer in which it is measured (e.g. MAC, PDCP, RRC) should be specified. More stringent than service #1 as per the direct car-to-car communication.
C-plane maximum UL/DL radio latency (ms)	2 ms	Max. time for C-plane state transition to "connected state". More stringent than service #1 as per the direct car-to-car communication.
U-plane maximum E2E latency (ms)	1 ms	More stringent than service #1 as per the direct car-to-car communication.
U-Plane maximum DL/UL radio packet loss (%)	0.001%	Tentatively taken as (100 - reliability)%
U-plane reliability	99.999%	Probability that IP packets are correctly received within the latency time. Taken from [22.886].
5. Service #3: Tele-operated driving.		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	Application-specific car-to-cloud protocols are envisioned which could be specified within the ETSI ITS framework or other standardization bodies.	Teleoperated driving is at an early stage or research and the scope of standardization, particularly in the protocols is unclear.
Codec rate	Ongoing work.	To be clarified by ETSI ITS specs. Scenario-specific

		compression schemes may be applied at the vehicle side to reduce data rate on the uplink.
UL/DL ratio	Higher proportion of UL is expected.	UL carries the higher throughput video and other sensor streams; DL carries the low throughput driving control commands,
Security level	Generally, any data related to driving control that is exchanged over the telecommunications network can be assumed to be encrypted.	To be clarified by ETSI ITS specs.
Service KPIs	**KPIs' Targets**	**Comments**
U-Plane maximum latency	End-to-end latency 20 ms between V2X application server and UE supporting safety-related V2X application for an absolute speed of up to 250 km/h.	As per [22.886].
U-plane reliability	Ultra-high UL and DL reliability (99.999 % or higher) for UE supporting safety-related V2X application for an absolute speed of up to 250 km/h.	As per [22.886]. The 3GPP system shall be capable of supporting high reliability without requiring application-layer message retransmissions.
Experienced data rates	Up to 1 Mbps at DL and 25 Mbps at UL for UE supporting V2X application between V2X application server and UE for an absolute speed of up to 250 km/h.	As per [22.886].

1. It is allowed to simulate a smaller bandwidth than the aggregated system bandwidth and transform the results to a larger bandwidth. The transformation method should then be described, including the modelling of power limitations.

Use case 2: Time-critical factory processes and logistics optimization (industry and smart airports)

In the following we provide the full details of this use case in table format.

1. General description	
Use case name	Time-critical factory processes and logistics optimization (industry and smart airports)
Description	Highly-reliable (low-latency) wireless communication to integrate mobile robots, automated guided vehicles, etc. into the control and monitoring processes [5GPPP]: - Real-time closed loop communication between machines to increase efficiency and flexibility. - Real time open-loop supervision and control. - 3D augmented reality applications for training and maintenance. - 3D video-driven interaction between collaborative robots and humans. - automated management in smart airport/transportation hubs.
Scenario	Megacities (indoor)

Services category	URLLC / eMBB
Services	Representative services: • Factory automation/discrete manufacturing/discrete automation [5GPPP], [EBR15], [SIEMENS], [22.261]: Production of distinct items - automobiles, furniture, industrial machinery, consumer electronics, etc. • Process automation/process manufacturing [5GPPP], [EBR15], [SIEMENS], [22.261]: Production of goods that are typically produced in bulk quantities – chemicals, food and beverage, gasoline, powerplants, etc. • Motion control [5GPPP], [22.261]: Communications for closed-loop control of robots, machine tools, printing machines, textiles, paper mills, etc. • Automatic guided vehicles [EBR15]: Control of mobile robots or drones used in industrial applications to move materials around a manufacturing facility or warehouse. • Resource management (efficient lighting, heating, power) based on passenger traffic. Health monitoring of installed assets. Note: Table 7.2.2-1 and Annex D in [22.261] provide a lot of relevant information for most of the services in this use case.

2. Network and UE deployment and KPIs

Attribute	Values or assumptions **Scenario:** Indoor factory use/ industrial plant areas	Comments
Layout and layers	Single-layer Indoor floor: (3,6,12) BSs per 120 m x 50 m	[38.802] Section A.2.4 / Indoor hotspot
ISD (m)	20 m (Equivalent to 12TRPs per 120m x 50m) 20 m – 1000 m	[38.802] Section A.2.4 / Indoor hotspot (taken from [38.913]) Smart transport hub – ranges for predictive traffic monitoring
Carrier frequency	4 GHz 4/30/70 GHz	[38.802] Section A.2.4 / Indoor hotspot Smart transport hub
Aggregated system bandwidth	Up to 200 MHz (DL+UL)	[38.802] Section A.2.4 / Indoor hotspot
BS / UE transmit power (dBm)	24 dBm per 20 MHz / 23 dBm	[38.802] Section A.2.4 / Indoor hotspot
# BS antennas	Around 4GHz: Up to 256 Tx and Rx antenna elements	[38.802] Table A.2.4.-1. (same as in [38.913])
# UE antennas	Up to 8 Tx /Rx antenna elements	[38.802] Table A.2.4.-1. (same as in [38.913])

Traffic model	Unidirectional and bidirectional (DL or UL). URLLC: Both FTP Model 3 (with Poisson arrival) and periodic packet arrivals with packet size 32, 50, 200 bytes. eMBB: Option 1: Full buffer, Option 2: FTP model 3 with packet size, 0.1Mbytes and 0.5Mbytes	[38.802] Section A.2.4 / Indoor hotspot
Maximum # UEs	Factory automation: 1 connection per 10 m^2 Process automation: - Motion control: 10 UEs per production cell (10 m x 10 m x 3 m) URLLC: 10 UE/floor/TRP eMBB: 0/10 UE/floor/TRP 10^5 Max 10^5/km2	[22.261] [22.261] [38.802] Section A.2.4 / Indoor hotspot [SIEMENS] Smart transport hub
Maximum / Average # Active UEs	On going work – to be completed.	
UE distribution and speed	Follow Indoor Hotspot user distribution (TR 38.913) for both URLLC and eMBB UEs: 100% Indoor, 3 km/h Ranges between communication neighbours: 0.1 – 100 m Speed: 50 km/h Cluster	[38.802] Section A.2.4 / Indoor hotspot [SIEMENS] Smart transport hub
Services mixture	At least combinations of the representative services of this use case should be supported.	
Network KPIs	**KPIs' Targets**	**Comments**
Network energy efficiency	On going work – to be completed	
Area traffic capacity	4 GHz UL: ((12/ (120 x 50)) x (100x106) x (15)) = 3 Mbps/m2 4 GHz DL: ((12/ (120 x 50)) x(100x106) x (30)) = 6 Mbps/m2	[38.913], 7.14 Area traffic capacity. Total traffic throughput served per geographical area (in Mbit/s/m2) area capacity (bps/m2) = site density (site/m2) × bandwidth (Hz) × spectrum efficiency (bps/Hz/site)

	1Tbps/ km2	Peak area traffic capacity since: - 38.913, 7.2 Peak Spectral efficiency - Maximum BW Smart transport hub: [22.261] V15.1.0 Table 7.2.2-1
UE KPIs	**KPIs' Targets**	**Comments**
Reliability	URLLC: 99.999% for one transmission of a packet of length 32 bytes with a user plane latency of 1ms	[38.913] The foreseen reliability is inadequate for most of the representative services of this use case.
U-Plane average latency (ms)	URLLC: 0.5 ms	[38.913]
Experienced data rates (Mbps)	100 Mbps	Smart transport hub: [22.261] V15.1.0 Table 7.1.1
E2E latency	1 ms	Smart transport hub
3. Service 1: Factory automation		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	IEC 61558 & IEC 61784 (Fieldbus)	[5GPPP]
Codec rate		
UL/DL ratio		
Security	Zone concept: restricted physical and logical access and unencrypted communication inside them. Private 5G. Note: Security framework for factories has been described in IEC 62443.	[5GPPP], [22.261] [SIEMENS]
Service KPIs	**KPIs' Targets**	**Comments**
Cycle time	10 ms	[5GPPP], [22.261]
U-plane E2E latency	10 ms Siemens demand: 1 ms (local) 5 ms (long distance)	[22.261] [SIEMENS]
U-Plane maximum E2E jitter (ms)	100 µs Siemens demand: 1 µs (local)	[22.261] [SIEMENS]
U-plane reliability	99.99 % 99.9999999 %	[22.261] [EBR15]

	100 %	[SIEMENS]
User experienced data rates	10 Mbps 100 kbps (automation stream) up to 100 Mbps (remote access, video supervision)	[22.261] [SIEMENS]
Survival time	0	[22.261]
Communication service availability	99.99 %	[22.261]
Service setup time	hours	[SIEMENS]
Service interruption time	0	[SIEMENS]
Payload size	Small to big (small ≤ 256 bytes)	[22.261]
Traffic density	1 Tbps/km^2	[22.261]
Connection density	100 000 km^-2	[22.261]
Service area dimension	1000 m x 1000 m x 30 m	[22.261]
4. Service 2: Process automation		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	IEC 61558 & IEC 61784 (Fieldbus)	[5GPPP]
Codec rate		
UL/DL ratio		
Security	Zone concept: restricted physical and logical access and unencrypted communication inside them. Private 5G. Note: Security framework for factories has been described in IEC 62443.	[5GPPP] [SIEMENS]
Service KPIs	**KPIs' Targets**	**Comments**
Cycle time	100 ms	[5GPPP]
U-plane E2E latency	50 ms 20ms (local) 1s (long distance) Siemens demand: 1 ms (local) 5 ms (long distance)	[22.261] [SIEMENS]
U-Plane maximum E2E jitter (ms)	20 ms Simens demand: 1 µs (local)	[22.261] [SIEMENS]
U-plane reliability	99.9999 % 99.9999999 % 100 %	[22.261] [EBR15] [SIEMENS]

User experienced data rate	1 Mbps up to 100 Mbps 100 kbit/s (automation stream) up to 100 Mbps (remote access, video supervision)	[22.261] [SIEMENS]
Survival time	100 ms	[22.261]
Communication service availability	99.9999 %	[22.261]
Service setup time	hours	[SIEMENS]
Service interruption time	100 ms	[SIEMENS]
Payload size	Small to big (small ≤ 256 bytes)	[22.261]
Traffic density	100 Gbps/km^2	[22.261]
Connection density	1000 km^-2	[22.261]
Service area dimension	300 m x 300 m x 50 m	[22.261]
5. Service 3: Motion control		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	IEC 61558 & IEC 61784 (Fieldbus) SERCOS (belongs to Fieldbus)	[5GPPP]
Codec rate		
UL/DL ratio		
Security	Zone concept: restricted physical and logical access and unencrypted communication inside them. Note: Security framework for factories has been described in IEC 62443.	[5GPPP]
Service KPIs	**KPIs' Targets**	**Comments**
Cycle time	1 ms 2 ms	[5GPPP] [22.261]
U-plane E2E latency	1 ms	[22.261]
U-Plane maximum E2E jitter (ms)	1 µs	[5GPPP], [22.261]
U-plane reliability	99.9999 %	[22.261]
User experienced data rate	1 Mbps up to 10 Mbps	[22.261]
Survival time	0	[22.261]
Communication service availability	99.9999 %	[22.261]
Payload size	Small (≤ 256 bytes, typically ≤ 56 bytes)	[22.261]
Traffic density	1 Tbps/km^2	[22.261]
Connection density	100 000 km^-2	[22.261]
Service area dimension	100 m x 100 m x 30 m	[22.261]
6. Service 4: Automated guided vehicles		
Service attributes	**Values / assumptions**	**Comments**
Protocol type		

Codec rate		
UL/DL ratio		
Security	Zone concept: restricted physical and logical access and unencrypted communication inside them.	[5GPPP]
Service KPIs	**KPIs' Targets**	**Comments**
U-plane E2E latency	10ms	[EBR15]
U-plane reliability	99.99999 %	[EBR15]

Use case 3: Non time-critical processes and logistics (factories and smart cities)

Additional description of the use case can be found below.

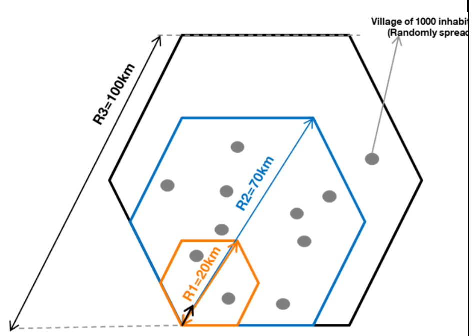
1. Service 1: IoT Communication			
Service attributes	**Values / assumptions**		**Comments**
	Scenario#1	**Scenario#2**	
Protocol type	IP and NIDD	IEC 61558 & IEC 61784 (similar with "Time-critical reliable process optimization" (Vertical "Factories-of-the-future"))	
Codec rate	N/A		
UL/DL ratio	70 / 30	N/A	
Security	data integrity, mutual authentication, user privacy		
Service KPIs	**KPIs' Targets**		**Comments**
Service setup time	Ongoing work - to be completed		The goal here is to allow a fast service set-up when UE is leaving deep-sleep mode
U-plane maximum UL/DL radio latency	less than 0,5 second at maximum coupling loss Ongoing work - to be completed in regular coverage		It is accepted that coverage extension will impact latency
5th percentile DL/UL experienced data rates (Mbps)	not less than 1 kbit/s at the applicative layer for a UE situated at maximal coupling loss for scenario#1		To evaluate performance delivered to UE at cell edges / coverage extension
U-plane reliability	95%		
Maximum Coupling Loss	**-164 dB**		[45.820] and [38.913]
Control Plane KPIs	Control traffic need to be small versus user plane traffic.		user data on control plane are

		considered as user plane traffic
2. Service 2: IoT Devices Positioning		
Service attributes	**Values / assumptions**	**Comments**
Service setup time	Ongoing work - to be completed	the goals here is to allow a fast service set-up when UE is leaving deep-sleep mode, [167790]
Positioning accuracy	Less than 50m in 90% of the case in outdoor At the building level while indoor	
Positioning latency	less than 2 second at maximum coupling loss Ongoing work - to be completed in regular coverage	it is accepted that positioning while in coverage extension will impact latency
Positioning reliability	Less than 100m error in 95% of the case	To evaluate performance delivered to UE at cell edges / coverage extension
U-plane reliability	95%	

Use case 4: Long range connectivity in remote areas with smart farming application

Below are the additional elements describing the long range connectivity in remote areas with smart farming application.

Network and UE deployment and KPIs		
Attribute	**Values or assumptions** **Scenario**	**Comments**
Layout and layers	Single layer – isolated macro cells	[38.913]
ISD (m)	- 150 km for far remote - 75km for rural	150 km in far remote if cell range of 100km targeted [38.913] 75km for rural as an enhancement of current technologies (#30km cell range)
Carrier frequency/ BW	Frequency below 3 GHz with a priority on bands below 1 GHz Bandwidth of 40 MHz (DL + UL)	[38.913]
Traffic Model	Population distribution for far remote as follow:	For far remote: from internal studies

	- Approx. 20% of the population lives in 5% of the area. - Approx. 70% of the population lives in 45% of the area. - Approx. 10% of the population lives in 50% of the area. Applied to an isolated cell of 100km range (6495km²), with population spread in villages of 1000 users. each: - 2 villages in 20kms range from BS - 8 villages in 20 to 70kms from BS - 1 village in 70 to 100kms from BS  Villages are randomly spread in their relevant areas.	For rural: [NGMN liaison to 3GPP RAN72]
BS / UE transmit power (dBm)	External CPE might be considered. • higher cell range expected • deployed in isolated villages • CPE could act as a wireless relay to end users High Power UE might be considered as well.	
# BS/UE antennas	1 antenna for sensor Up to 2 Rx antennas for smartphones	
Network KPIs	**KPIs' Targets**	**Comments**
Network energy efficiency	At least, no more energy consumption than current LTE but if considering no broadband traffic at night (e.g., between 2 and 6 am) where the minimum services can be offered by mMTC connectivity, we expect extra energy saving. Quantitative evaluation approach is preferred (see. [38.913]).	5G overall objective is to stay on same energy consumption levels than LTE but offering improved capacity. In the context of long range, we require more saving (especially at night), that could be provided by deep sleep mode 3 (10ms) or even

		better mode 4 (1000ms) [VTC15]
Area traffic capacity	Isolated cell layout, so Area Traffic Capacity is equivalent to Cell Throughput.	
UE KPIs	**KPIs' Targets**	**Comments**
UE battery consumption	Battery consumption is critical in remote areas	Battery life (15 years) in [38.913]
UE energy efficiency	Very critical KPI for remote areas where energy is not available hugely	Qualitative KPI [38.913]
UE mobility KPI	- Pedestrian speed sufficient in many cases in far remote areas - Speed up to 120km/h in rural areas (50% outdoor vehicles and 50% indoor)	Speed up to 160km/h in [38.913] but not relevant in far remote areas
2. Services		
2.1. Service 1: Provision of minimal voice and data services over long distances in low density areas		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	Nothing specific	
Codec rate	Low data rate codecs able to support low latency to cope with links having high values for latency, jitter and error rate.	Ex.: Opus, iLBC for VoIP. See below comments on E2E latency.
Security	Nothing specific	
Service KPIs	**KPIs' Targets**	**Comments**
Maximum data rates	Nothing specific	
Reliability	Nothing specific	Should not be relaxed
2.2. Service 2: Provision of Smart farming and tracking over long distances in low density areas		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	IP	
Codec rate		Ex.: Opus, iLBC for VoIP
Security	Authentication, data accuracy	
Service KPIs	**KPIs' Targets**	**Comments**
Reliability	Nothing specific	Should not be relaxed

Use case 5: Outdoor hotspots and smart offices with AR/VR and media applications

1. General description

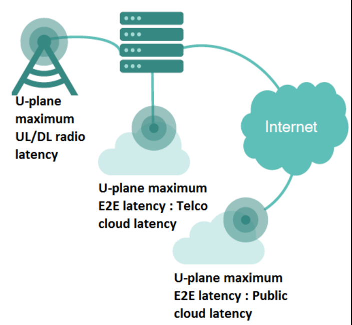
Use case name	Outdoor hotspots and smart offices with AR/VR and media applications
Description	This use case focuses on high user density and traffic loads under the service category of eMBB on both outdoor and indoor hotspots. It is mainly characterized by a high throughput demand and the use of services like augmented reality (AR), virtual reality (VR), high-quality video streaming or file transmission among others.
Scenario	Megacity. Dense indoor and outdoor hotspot
Services category	eMBB
Services	• AR/VR • High definition video • File transmission • Web • Email • VoIP • Security

2. Network and UE deployment and KPIs

Attribute	Values or assumptions		Comments
	Scenario #1: Outdoor hotspot	**Scenario #2: Indoor hotspot**	
Layout and layers	Two layers: Macro + micro	Single layer: - Indoor floor (Open office) (12BSs per 120m x 50m) Candidate TRP numbers: 3, 6, 12	[38.913], Table 6.1.1-1: Attributes for indoor hotspot [38.802], Table A.2.1-1
ISD (m)	Macro: 200m Micro: 3 micro TRP per macro TRP	20m (Equivalent to 12 TRPs per 120m x 50m)	[38.913], Table 6.1.1-1: Attributes for indoor hotspot Indoor scenarios assume a small ISD.
Carrier frequency/ BW	Around 4 GHz: Up to 200MHz (DL+UL) Around 30 GHz: Up to 1GHz (DL+UL) Around 70 GHz: Up to 1GHz (DL+UL) (**Only indoor**)		[38.913], Table 6.1.1-1: Attributes for indoor hotspot
BS / UE transmit power (dBm)	Macro: 40 dBm Micro: 33dBm UE: 23 dBm	DL: < 6 GHz → 24dBm; >6 GHz → 23 dBm	Outdoor: [38.913] Indoor hotspot: To be defined in the new RAT study item. [RANGAN14] [38.802], Table A.2.1-1: System level evaluation assumptions.

		UL: < 6 GHz → 23 dBm; 30 GHz → 23 dBm; 70 GHz → 21 dBm	
# BS/UE antennas	**BS** Up to 256 Tx and Rx elements		[38.913]
	UE Around 4GHz: Up to 8 Tx and Rx antenna elements Above 4 GHz: Up to 32 Tx and Rx antenna elements		
Maximum # UEs	Uniform/macro TRP + clustered/micro TRP, 10 users per TRP	10 users per TRP; 100 % Indoor.	[38.913]
Maximum / Average # Active UEs	See "UE distribution and speed"		[38.913]
UE distribution	Uniform with temporal high concentration spots.		[38.803], Table 5.2.1.3-1: Single operator layout for indoor.
UE speed	Up to 30 km/h	3km/h	[38.913], Tables 6.1.1-1 and 6.1.1-2: Attributes respectively for indoor and outdoor hotspots.
Network KPIs	**KPIs' Targets**		**Comments**
Area traffic capacity	1 Macro layer (+Micro), Hex Grid (ISD = 200m) : 1 macro TRP (+3 Micro TRPs) per 34600 m2 **Peak value** (w 3 Micro TRPs) - 4GHz DL → 4x(1/34600)x(100 x10^6)x(30)= 0.347 Mbps/m2 **Peak value** (w 3 Micro TRPs) - 4GHz UL → ,x(1/34600)x(100	**30/70 GHz UL**→ ((12/ (120 x 50)) x ($500x10^6$) x (15)) = 15 $Mbps/m^2$ **30/70 GHz DL**→ ((12/(120 x 50)) x ($500x10^6$) x (30)) = 30 $Mbps/m^2$ **4 GHz UL** → ((12/ (120 x 50)) x ($100x10^6$) x (15)) = 3 $Mbps/m^2$	[38.913], 7.14 Area traffic capacity. Total traffic throughput served per geographical area (in $Mbit/s/m^2$) **area capacity** (bps/m^2) = site density ($site/m^2$) × bandwidth (Hz) × spectrum efficiency (bps/Hz/site) Peak area traffic capacity since: • 38.913, 7.2 **Peak** Spectral efficiency • Maximum BW

	x10^6)x(15)= 0.173 Mbps/m2	**4 GHz DL →** ((12/ (120 x 50)) x(100x10^6) x (30)) = 6 Mbps/m^2	
Connection Density	200 – 2500/Km2	75/1000 m2	[NGMN15]
Traffic density	DL: 300 Mbps (750 Gbps/km^2) UL: 50 Mbps (125 Gbps/Km^2)	DL:15 Gbps / 1000 m^2 UL: 2 Gbps / 1000 m^2	Outdoor hotspot: [22.261] (Table 7-1-1) Indoor hotspot: [NGMN15]
UE KPIs	**KPIs' Targets**		**Comments**
Mobility interruption time	0ms	0 ms	[38.913], 7.7 Mobility interruption time It means the shortest time duration supported by the system during which a user terminal cannot exchange user plane packets with any base station during transitions.
Experienced data rates (Mbps)	User Experienced Data Rate: DL: 300 Mbps, UL: 50 Mbps	User Experienced Data Rate: DL: 1 Gbps, UL: 500 Mbps	[NGMN15]
		• 10 to 50 Mbps: current-gen 360°video (4K) • 50 to 200 Mbps: next-gen 360°video (8K, 90+ FPS, HDR, stereoscopic) • 200 to 5000 Mbps: 6 DoF video or free-viewpoint.	**[**QUALC17]
3. Service 1: AR/VR			
Service attributes	**Values / assumptions**		**Comments**
Protocol type	DASH DASH over MBMS		[26.918], 4.2.5.8 Delivery, 4.4.2 Streaming architecture

Codec rate	**Audio formats:** • ITU-R BS.2076-0 – Audio Definition Model (ADM) • ETSI TS 103 223 – Multi-Dimensional Audio (MDA) • AmbiX • ETSI TS 103 190 (AC-4) • ISO/IEC 23008-3 MPEG-H 3D Audio	[26.918], 4.3.4.2 Survey of existing spatial audio formats
	Video formats: • H.265 or MPEG-H II or HEVC	[QUALC16] and [26.918], 7.2.1.4 Content preparation
UL/DL ratio	1:1	
Service KPIs	**KPIs' Targets**	**Comments**
U-plane **maximum** UL/DL radio latency (ms)	down to ~1 ms	**[**QUALC17] The radio protocol layer in which it is measured (e.g. MAC, PDCP, RRC) should be specified.
C-plane **maximum** UL/DL radio latency (ms)	10 ms	[38.913], 7.4 Control plane latency Max. time for C-plane state transition to "connected state"
U-plane **maximum** E2E latency (ms)	• Telco cloud latency (~20 - 50 ms) • Public cloud latency (~50 -100 ms)	[QUALC17] 
Audio/Video synchronization	15 ms (audio delayed) and 5 ms (audio advanced)	[26.918], 8.2 Audio/Video synchronization Due to the relatively slower speed of sound compared to light it is natural that users are more accustomed to, and therefore tolerant of, sound being relatively delayed with respect to the video component than sound being relatively in advance of the video component.
U-Plane reliability	99% working hours	[METISD1.1]

U-Plane packet/frame loss (%)	< 1%	Based on [METISD1.1]
4. Service 2: High definition video		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	HTTP over TCP/IP RTP/UDP, or H.265 or MPEG	
Codec rate	Adaptive bitrate between 5 Mbps and 25 Mbps	
Average video session duration	n/a	
UL/DL ratio	Conversational: 1/1 Streaming n/a Gaming: 1/1	
Security	Data integrity and access control required	
Service KPIs	**KPIs' Targets**	**Comments**
Average End User Throughput (Mbps)	100 Mbps (streaming) > 10 Mbps (conversational) > 50 Mbps (Gaming)	[22.891]
Video rebuffering time/ratio	< 5 s (streaming)	
Video startup time	< 1 s (streaming)	
E2E latency (ms)	< 1 s (streaming) < 150ms (conversational) < 10ms (Gaming)	[22.891]
Latency (over the air)	< 200ms (streaming) < 30ms (conversational) < 1ms (Gaming)	[22.891]
5. Service 3: File transmission		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	FTP/FTPS	FTPS: Extension to FTP that adds support for the Transport Layer Security (TLS) and the Secure Sockets Layer (SSL) cryptographic protocols.
Codec rate (mean/max)	DL: 100 Mbps/1 Gbps, UL: 50 Mbps/500 Mbps	Based on [NGMN15].
UL/DL Ratio	2:1	
File size	100 MB	For calculation purposes
Security	Authentication, confidentiality, and message integrity.	[RFC4217]

Service KPIs	**KPIs' Targets**	**Comments**
File transfer latency (mean and 5th percentile)	Down to 0.8 / 0.1 s (given maximum throughput)	
U-Plane reliability	99.9 % @ 10 ms latency	
U-Plane packet/frame loss (%)	< 0.1 %	
6. Service 4: Web		
Protocol type	HTTPS	[RFC2818]
Security	Authentication of the website based on certificates and encrypted bidirectional connection by TLS.	[RFC2818]
Service KPIs	**KPIs' Targets**	**Comments**
File transfer latency	10 ms	[NGMN15] *E2E Latency: Measures the duration between the transmission of a small data packet from the application layer at the source node and the successful reception at the application layer at the destination node plus the equivalent time needed to carry the response back.*
U-Plane reliability	99.9 % @ 10 ms latency	
U-Plane packet/frame loss (%)	< 0.1 %	
7. Service 5: Email		
Protocol type	SMTPS, IMAPS, POPS	[RFC7817]
Security	Client authentication, data encryption and data integrity checks	
Service KPIs	**KPIs' Targets**	**Comments**
U-Plane reliability	99.9 % @ 10 ms latency	
U-Plane packet/frame loss (%)	< 0.1 %	
8. Service 6: VoIP		
Service attributes	**Values / assumptions**	**Comments**
Protocol type	H.323 protocols suite SIP (call management) RTP and RTCP	Based on widely adopted protocols.
Codec rate	2 / 64 kbps	Speech codec / G.711
UL/DL Ratio	1:1	
Security	Authentication and confidentiality	[MARJALAAKSO]

Service KPIs	KPIs' Targets	Comments
One-way end-to-end Delay	< 150 ms	ITU G.114 and [CISCO14]
U-Plane packet/frame loss (%)	< 1 %	[CISCO14]
Average one-way jitter	< 30 ms	[CISCO14]
9. Service 7: Security		
Service attributes	**Values / assumptions**	**Comments**
Subscriber Authentication, Authorization and Accounting (AAA)	- Lightweight authentication and key agreement protocol for massive IoT communications [SPEED-5G] - Family of group-based AKA protocol [5G-ENSURE]	[NGMN15] → 4.4.3 Security (Attribute), [5GPPP17] → 4. Access Control to 5G (Value) EPS-AKA used in 4G requires signaling between each device that requires network access, the local serving network and the device's remote home network. Regarding anticipated 5G use cases, analysts forecast more than 25 billion of devices to be interconnected in 2020. Providing connectivity to such a large amount of devices, which may require simultaneous network access, may lead to a potential signaling overload, so it is why of these new lines of investigation.
Subscriber privacy	**Privacy enhanced identity protection enabler:** Encryption, authentication and anonymization mechanisms to protect the privacy of the subscriber's identity (i.e., IMSI, but also temporal identities) in all the situations where it is currently sent in clear text over the access network	[NGMN15] → 4.4.3 Security, [5GPPP17] → 5. Privacy, [5GENSURE17] → 3. Privacy enablers open specification
	End-to-end encryption: 5G end-to-end encryption service able to guarantee the privacy of all users' communications from their source to their destination 5G devices.	
	Device identifier privacy: anonymization mechanisms for protecting the privacy of device	

	identifiers for both UICC (Universal Integrated Circuit Card) and UICC-less devices attaching to 5G networks via various network technologies	
	Privacy policy analysis: offers 5G users the ability to be in control of their own privacy, which is configurable and controlled at the application level.	
	Device based anonymization: provide anonymization techniques on the user's device, offering protection against disclosure of sensitive information stored mainly on the SIM.	
Service providers privacy	Homomorphic encryption (HE) + VNF class specific encryption	[NGMN15] → 4.4.3 Security, [5GPPP17] → 5. Privacy