http://www.5g-ppp.eu/

Living document on

5G PPP use cases and performance evaluation models

Version: 1.0

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Revision	Date	Description
1.0	2016-04-25	First revision

List of abbreviations and acronyms

3GPP	Third Generation Partnership Project
4G	4th generation
5G	5th generation
5G-PPP	5G Public-Private Partnership
AIV	Air interface variant
BS	Base station
CP	Control plane
D2D	Device-to-device
DL	Downlink
E2E	End –to-end
ECC	Electronic Communication Committee
FTP	File transfer protocol
HARQ	Hybrid automatic repeat request
HetNet	Heterogeneous network
HO	Handover
HW	Hardware
IEEE	Institute of Electrical and Electronics Engineers
IMT-A	International Mobile Telecommunication-Advanced
InH	Indoor hotspot
ISD	Inter-site distance
ITS	Intelligent Transport System
ITU	International Telecommunication Union
IoT	Internet of things
KPI	Key performance indicator
LoS	Line-of-sight
LTE	Long Term Evolution
LTE-A	LTE-Advanced
MBB	Mobile broadband
MIMO	Multiple input multiple output

mMTC	Massive MTC
mmW	Millimetre wave
MTC	Machine-type communication
MU-MIMO	Multi user-MIMO
NLoS	Non line-of-sight
PER	Packet error rate
QoE	Quality of experience
QoS	Quality of service
RACH	Random access channel
RAN	Radio access network
RAT	Radio access technology
RMa	Rural macro
RRM	Radio resource management
RTT	Round trip time
RX	Receiver
SINR	Signal to interference and noise ratio
SOTA	State-of-the-art
TTI	Transmission time interval
TX	Transmitter
UC	Use case
UDN	Ultra-dense network
UE	User equipment
UL	Uplink
UMa	Urban macro
UMi	Urban micro
uMTC	Ultra-reliable MTC
UP	User plane
V2X	Vehicle-to-anything
VoIP	Voice over Internet Protocol
WP5D	Working Party 5D
xMBB	Extreme MBB

Executive summary

This document provides an overview of the use cases and models that were developed for an early evaluation of different 5G radio access network concepts originating from various 5th generation (5G) Public-Private Partnership (5G-PPP) phase 1 projects. It covers 5G scenarios defined from the service perspective, requirements, definitions of key performance indicators (KPIs) and models (e.g., of channel, traffic or user's mobility). Developed use case families are mapped to a corresponding business cases identified in vertical industries. Additionally, performance evaluation approaches are compared with the latest version of performance evaluation framework proposed in Third Generation Partnership Project (3GPP).

Since the document contains a comprehensive assessment of the 5G use cases and models originating from 5G-PPP, it can be used to harmonize viewpoints of different projects, while in the same time ensuring that 5G-PPP covers entire 5G research space identified as relevant from the European point of view. As the document is expected to be revised throughout the duration of 5G-PPP phase 1, in the later stage it could be used to provide a coordinated early assessment of 5G performance.

1. Introduction

Structure of the document

The rest of this section contains basic time line information on the upcoming events and milestones, relevant from the perspective of 5G use cases and their performance assessment. Section 2 provides an overview on the 5G use cases developed by 5G-PPP projects involved in creation of this document. It also maps proposed use cases to corresponding business cases identified in various vertical industries. Section 3 focus on definitions of KPIs relevant for 5G, while Section 4 outlines models of e.g., traffic, mobility or wireless channel behaviour that should be uses for assessment of a 5G performance in a given use cases. Such performance assessment results are expected to populate Section 5 in the future. Finally, Section 6 provides an outline for the next revision of this document.

Time frame

Similarly as in the International Mobile Telecommunication-Advanced (IMT-A)/4th generation (4G), IMT-2020/5G will be subject to an evaluation process issued by the Radiocommunication Sector of International Telecommunication Union (ITU-R). Following meeting dates of Working Party 5D (WP5D) responsible in ITU-R for the overall radio aspects of IMT systems, are proposed and can be considered as potential opportunities for the dissemination of material captured in this document:

- WP5D meeting #24 (mid-June 2016, potential date 14 June – 22 June): approval of the IMT-2020 process. Agree on key parameter names and definitions
- WP5D meeting #25 (October 2016, potential date 4 October – 12 October): discussion on technical requirements values
- WP5D meeting #26 (mid-February 2017, potential date 14 February – 22 February) the performance requirements are approved. Report ITU-R M.[IMT-2020. TECH PERF REQ] finalized in this meeting. Finalize requirements
- WP5D meeting #32 (June 2019): initial technology submission (high-level description)
- …
- WP5D meeting #36 (October 2020): detailed specification submission (stage-3 specifications)

Taking into account European orientation of 5G-PPP, also meetings of Project Team 1 (PT1) of Electronic Communication Committee (ECC)/European Conference of Postal and Telecommunications Administrations (CEPT) should be taken into considerations:

- ECC PT1 #52, 19-21 April, Bucharest, Romania
- ECC PT1 #53, 12-16 September, Budapest, Hungary

In the context of direct contributions to the standard bodies, 3rd Generation Partnership Project (3GPP) is a clear candidate. Detailed time plan for introduction of 5G to the 3GPP standard is still under discussion and created 'on the go', however the first activities toward standardization of 5G has already started. For obtaining detailed meeting plan of 3GPP following link can be used http://www.3gpp.org/3gpp-calendar. Additionally, to monitor high-level planning of 3GPP outcomes of plenary meetings should be tracked:

- #71 7-10 March 2016
- #72 13-16 June 2016
- #73 19-22 September 2016
- #74 5-8 December 2016
- #75 6-9 March 2017

3GPP should submit the final specs at the 5D meeting in Feb 2020, based on functionally frozen specs by Dec 2019 [3GPPSP-150149].

2. 5G use cases and vertical industries

Even if different 5G-PPP projects have defined their own use cases, an in-depth analysis of these latter reveals similarities between them. This is because all 5G-PPP projects agree on the three 5G services (xMBB, uMTC and mMTC) and start in their use case definition from the results of METIS project, NGMN, ITU and other fora.

Use cases of 5G-PPP projects can thus be classified into 6 families, as detailed in the table below. The following ranges have been considered for the KPIs used for clustering the use cases:

- Device Density:
  - High : ⩾ 10000 devices per km^2
  - Medium : 1000 – 10000 devices per km^2
  - Low : < 1000 devices per km^2
- Mobility:
  - No: Static users
  - Low: Pedestrians (0-3 km/h)
  - Medium: Slow moving vehicles (3 – 50 km/h)
  - High: Fast moving vehicles, e.g. cars and trains (> 50 km/h)
- Infrastructure
  - Limited: No infrastructure available or only macro cell coverage
  - Medium density: Small amount of small cells
  - Highly available infrastructure: Big number of small cells available
- Traffic Type
  - Continuous
  - Bursty
  - Event driven
  - Periodic
  - All types

- User Data Rate
    - Very high data rate : $\geqslant$ 1 Gbps
    - High : 100 Mbps – 1 Gbps
    - Medium : 50 – 100 Mbps
    - Low : < 50 Mbps
- Latency
    - High: > 50 ms
    - Medium: 10 – 50 ms
    - Low: 1 – 10 ms
- Reliability
    - Low: < 95%
    - Medium: 95 – 99%
    - High: > 99%
- Availability (related to coverage)
    - Low: < 95%
    - Medium: 95 – 99%
    - High: > 99%
- 5G Service Type, comprising:
    - xMBB, where extreme Mobile Broadband is the key service requirement.
    - uMTC, where the reliability is the key service requirement of the UC.
    - mMTC, where the massive connectivity is the key service requirement of the UC.

In addition to these KPIs, localization and security requirements are important KPIs for vertical industries.

Table 1. 5G-PPP use case families.

Group	Comments	METIS-II	FANTASTIC-5G	mmMAGIC	SPEED-5G	5G-NORMA	Flex5GWare	VirtuWind
Dense urban	Both indoor and outdoor in dense urban environment	Dense urban information society	Dense urban information society below 6 GHz	Dense urban society with distributed crowds Cloud services Immersive 5G early	Dense urban information society; Future home environme	V2X + massive MTC communications in urban environments	Crowded venues Dynamic hotspots	Smart Meters and secondary substations in dense urban

				experience	nt			areas
Broadband (50+Mbps) everywhere	Focus on suburban, rural and high speed trains	Broad-band access every-where	50 Mbps everywhe-re High speed train	50+ Mbps everywhere Media on demand	Realistic extended suburban HetNet		50+ Mbps everywhere	Grid backhaul
Connected vehicles	uMTC and/or xMBB on cars. V2V and/or V2X	Connected cars	Automatic traffic control/ driving High speed train	Moving hot spots;		Traffic jam; Vehicular commu-nication	Mobile broadband in vehicles V2X communica-tions for enhanced driving	
Future smart offices	Very high data rates indoors and low latency	Virtual reality office		Smart offices	Future connected office			
Low bandwidth IoT	A very large number of connected objects	Massive deployment of sensors and actuators	Sensors networks				Smart cities	Smart metering in grid access
Tactile internet / automation	Ultra-reliable communi-cation with xMBB flavour		Tactile internet	Tactile internet/ video augmen-ted robotic control and remote-robot manipula-tion surgery				Grid backhaul and grid backbone have reliable, ultra-low latency require-ments

This classification into use case families allows having a general idea on the individual use cases and their requirements, e.g. a use case belonging to the family "Future smart offices" is necessarily characterized by an indoor environment and very high user rates. However, this general classification does not reveal the detailed requirements of the use case, which may differ depending on the targeted application and the underlying technical solution. Some use case families may feature enhanced diversity in terms of the mixed requirements as well as the application environments, e.g. "Dense urban" use case family, where early 5G users could experience services demanding extreme data rate, such as virtual reality and ultra-high definition video in both indoor and outdoor environments. In this regard, a more in-depth analysis of the use cases belonging to the different families is needed to achieve a quick understanding of the differences between them that may translate in different design solutions and different performance results. Even if a spider diagram where the different 5G KPIs are represented allows a complete representation, the large number of use cases per family will make the reading of such a spider diagram difficult. We choose to illustrate some of the families of use cases on two axes, representing the two most relevant KPIs, leading to a partial but clearer illustration. For instance, Figure 1 represents the requirements of use cases of the "Dense urban" family with respect to the user throughput and the device density requirements. It is worth noting that there are other secondary KPIs that differentiate these use cases, like for example mobility. We then introduce the mobility requirement within the figure for each use case.

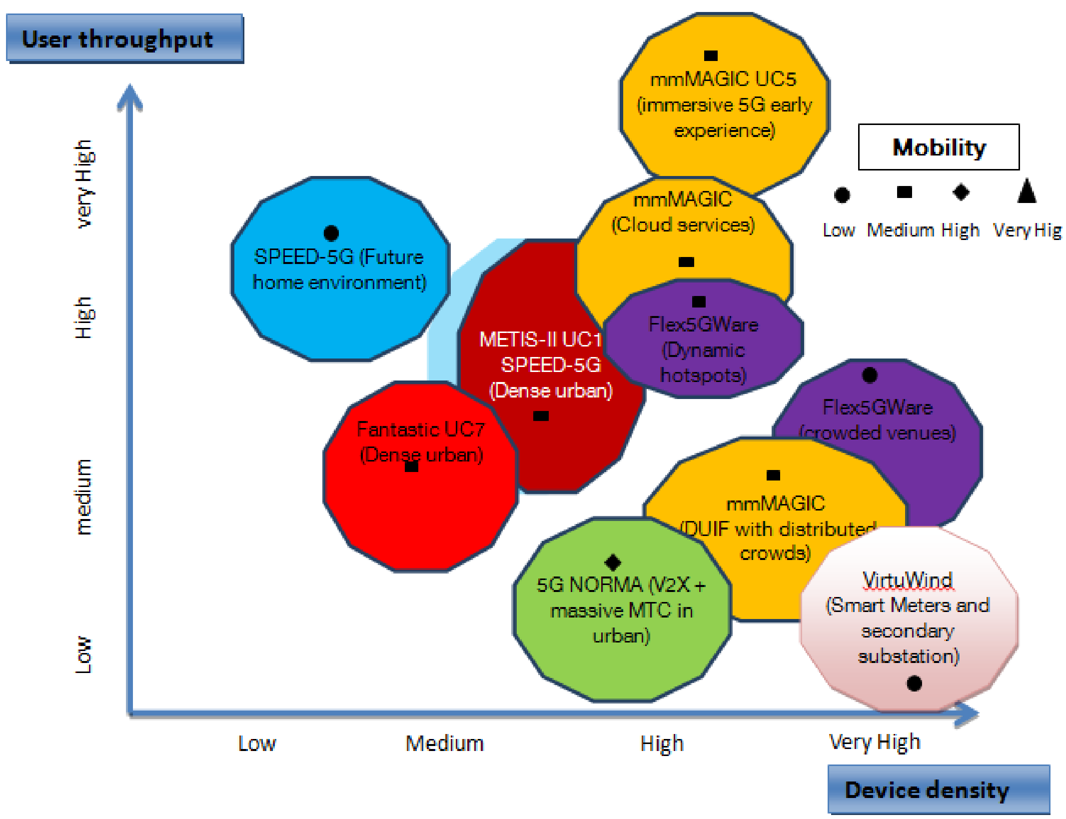

Figure 1. Illustration of use cases for the “Dense urban” group

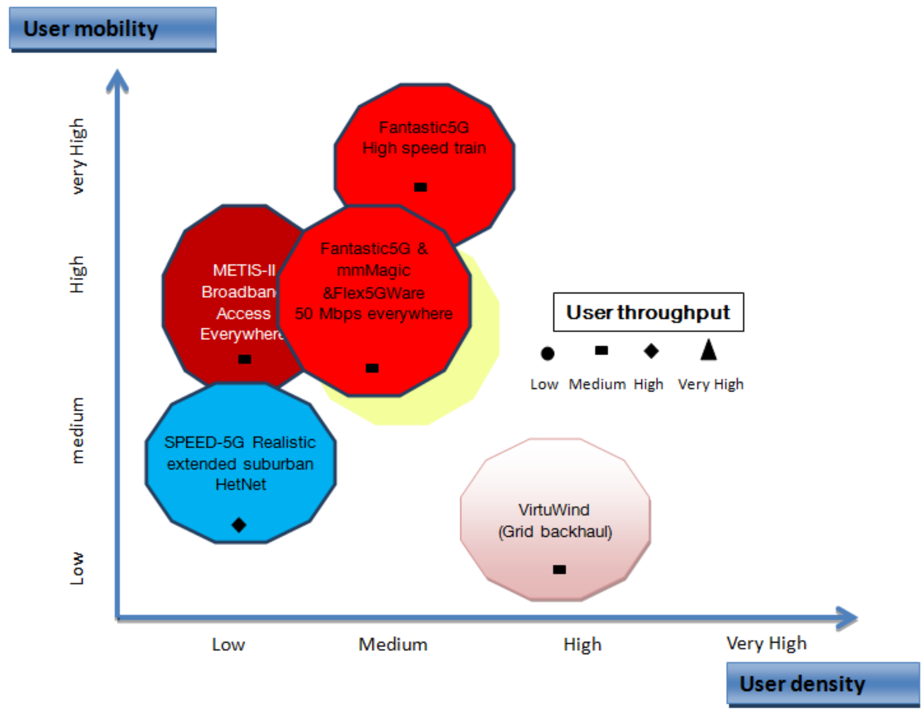

Figure 2. Illustration of use cases for the “Broadband (50+ Mbps) everywhere” group

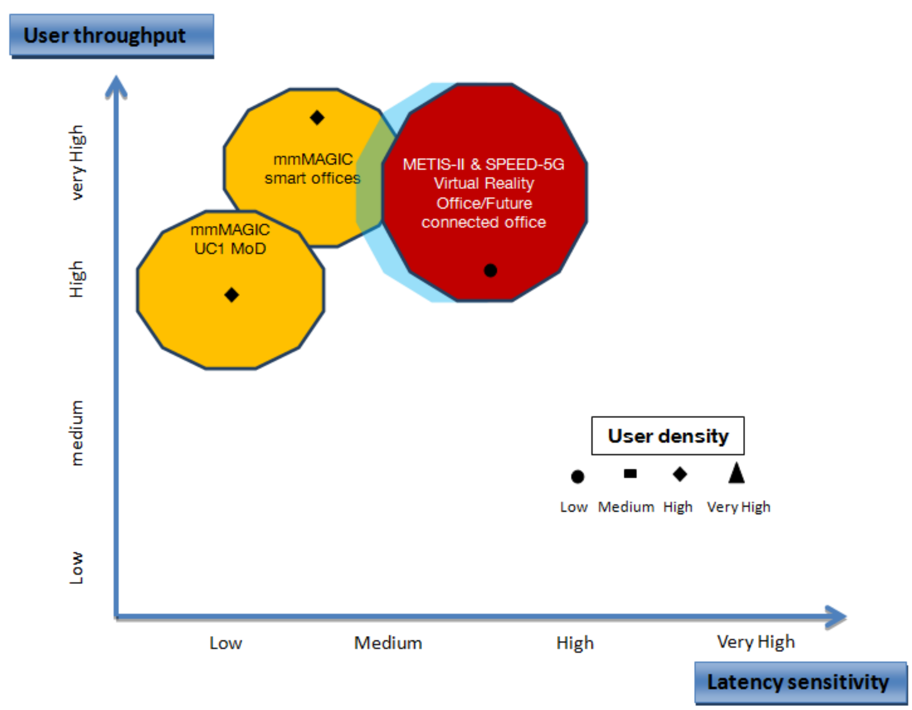

Figure 3. Illustration of use cases for the "Future smart offices" group

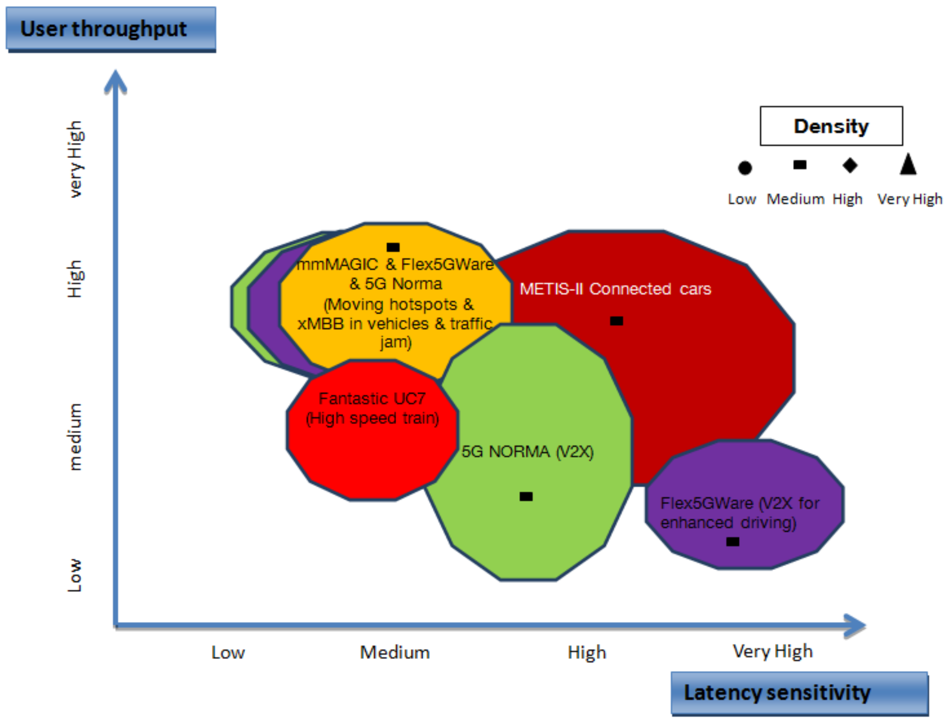

Figure 4. Illustration of use cases for the "Connected vehicles" group

Mapping of the 5G-PPP use case families to the vertical use cases

While the 5G-PPP projects have been intentionally mixing services with different requirements for the purpose of challenging the 5G RAN design, 5G-PPP adopted a vertical industry driven approach in its business cases definition, where each business case describes a specific vertical need and its requirements, as described in the 5G-PPP white papers on verticals requirements. Table 2 illustrates the ambition of 5G-PPP for a 5G network federating the needs of vertical industries.

Table 2. Vertical industries business cases.

Vertical Industry	Associated business cases
Automotive	A1-Automated driving A2-Road safety and traffic efficiency services A3-Digitalization of transport and logistics A4-Intelligent navigation A5-Information society on the road A6-Nomadic nodes

eHealth	H1-Assets and interventions management in hospitals H2-Robotics (remote surgery, cloud service robotics for assisted living) H3-Remote monitoring of health or wellness data H4-Smarter medication
Energy	E1-Grid access E2-Grid backhaul E3-Grid backbone
Media & Entertainment	ME1-Ultra high fidelity media ME2-On-site live event experience ME3-User generated content & machine generated content ME4-Immersive and integrated media ME5-Cooperative media production ME6-Collaborative gaming
Factories of the future	F1-Time-critical process optimization inside factory to support zero-defect manufacturing F2-Non time-critical optimizations inside factory to realize increased flexibility and ecosustainability, and to increase operational efficiency F3-Remote maintenance and control optimizing the cost of operation while increasing uptime F4-Seamless intra-/inter-enterprise communication, allowing the monitoring of assets distributed in larger areas, the efficient coordination of cross value chain activities and the optimization of logistic flows F5-Connected goods, to facilitate the creation of new value added services

Having a closer look of the business cases of Table 2, we can see that 5G-PPP use case families cover the requirements of most of them as follows:

- The “Dense urban” UC family covers requirements of business cases H3, H4, E1, ME2, ME6, F2, F3, F4, F5.
- The “Future smart offices” UC family focusing on xMBB service for indoor environments and static users, covers requirements of ME5.

- The “Broadband (50+ Mbps) everywhere” UC family focusing on high availability for xMBB service in areas with limited infrastructure covers requirements of H3, H4, F2, F4, E3, ME1, ME3, ME4.
- The “IoT” UC family focusing on massive connectivity of objects, covers requirements of F5, E1, H3.
- The “Connected vehicles” UC family focusing on very highly reliable communications in vehicles, combined with xMBB aspects for on-board entertainment, covers the requirements of the automotive business cases, A1 to A5.
- The “Tactile Internet/automation” UC family focusing on very highly reliable communications with xMBB flavor covers the requirements of F1, F3, H2, H3, E2, E3.

3. 5G key performance indicators

In order to quantify how certain technical solutions would affect a quality of experience (QoE) of end users or what would be the 5G system performance in a desired used case, specific evaluation metrics are needed. This section gives definitions of 5G main characteristics and KPIs, similar to the ones defined in [ITUR15-M2083], and provides basic info on how to evaluate them through inspection, analysis or simulation:

- In case of evaluation through inspection the evaluation is based on statements
- In case of analytical procedure, the evaluation is to be based on calculations using the technical information provided by the technology component owner (methodology, algorithm, module or protocol that enables features of the 5G system is a technology component or enabler)
- Evaluations through simulations contain both system level simulations and link level simulations although it is expected that majority of solutions will be assessed using system level evaluation.

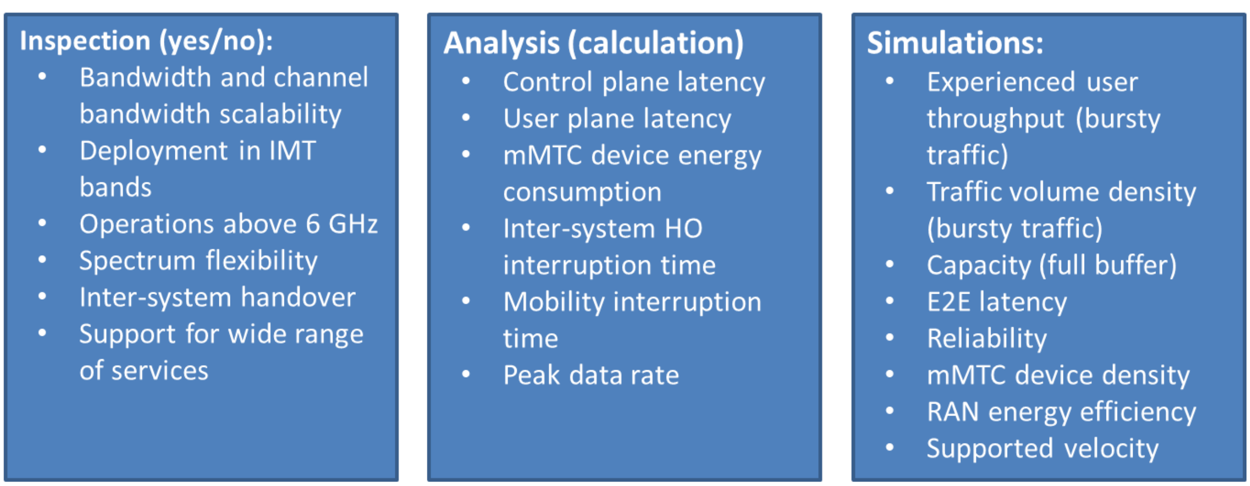

Figure 5. 5G KPIs and their assessment method

Inspection methods

Inspection methods are applied to 5G KPIs that are design-dependent and can be assessed by looking into general system design information. Despite the fact that these KPIs require only simple yes/no answer for assessment, it should be highlighted that all KPIs that are listed in this section will play a fundamental role in 5G and are basis for high performing wireless system.

Bandwidth and channel bandwidth scalability

Scalable bandwidth is the ability of the 5G system to operate with different bandwidth allocations. This bandwidth may be supported by single or multiple radio frequency carriers.

The 5G system shall support a scalable bandwidth of at least 1 GHz. Proponents of proposed 5G system solution are encouraged to consider extensions to support operation in wider bandwidths (e.g. up to 2 GHz).

Deployment in IMT bands

Deployment of the 5G system must be possible in at least one of the identified IMT bands. Proponents are encouraged to clarify the preferred bands for the proposed candidate(s).

Operation above 6 GHz

The candidate air interface shall be able to operate in centimetre wave and/or mmW bands with one or several air interference variants (AIVs) especially suited to these bands.

Spectrum flexibility

The ability of the access technology to be adapted to suit different DL/UL traffic patterns and capacity needs for both paired and unpaired frequency bands [3GPP15-152129].

Inter-system handover

Inter-system handovers between the 5G system and at least one legacy radio access technology (2G/3G/4G) shall be supported.

Support for wide range of services

The ability of the access technology to meet the connectivity requirements of a range of existing and future (as yet unknown) services to be operable on a single continuous block of spectrum in an efficient manner [3GPP15-152129].

Note that hybrid services including xMBB, mMTC and uMTC may be supported in the same band.

Analysis method

Analysis methods are applied for 5G KPIs that can be assessed using elementary calculations. Although some input parameters for such KPIs depend on e.g., network load, and can be specified using simple simulations, in general their value is repetitive or static during regular network operations.

Control plane latency

The following steps should be detailed, included their need and, if appropriate, the time required for each one of the steps. Total latency must be provided together with the latencies of all intermediate steps, if any. Note that the full set of steps represents the idle to active state transition. However, the proponent must clarify intermediate states that could be included in the AIV, like a connected-inactive state, and the latencies associated with each intermediate state.

Table 3. Steps for the control plane (CP) latency analysis. Not all steps are required.

Step	Description	5G aspects for considerations
0	UE wakeup time	Wakeup time may significantly depend on the implementation (e.g., different for mMTC water meter sensor and for automotive uMTC device). Additionally, 5G may introduce intermediate states in addition to 4G LTE idle and connected, for the purpose of CP latency reduction and device energy consumption savings. The new introduced intermediate state might provide a widely configurable discontinuous reception (DRX) and thus contribute to different CP latency for different traffic patterns and battery requirement. Since UE can be configured by the network with different DRX in different situations, this delay component might be better reflected with simulation approach.
1	DL scanning and synchronization + broadcast channel acquisition	This step includes also beam finding / sweeping procedures in the terminal side, if needed. On the other hand, 5G may introduce different forms of multi-connectivity which may allow skipping this step e.g., broadcast information for the idle AIV could be delivered over other AIV where UE is able to receive it. With different configuration of multi-connectivity, broadcast information for the idle AIV might be delivered in different ways. In case of CP/user plane (UP) decoupling between two or more cells, detection of UP cells discovery signals needs to be taken into account. Detection of UP cell should not be longer than duration of steps 2-7. Note also that in novel AIVs the periodicity of certain common signals/channels for access may vary. These details shall be included in the description of this step duration calculation.
2	Random access procedure	In case random access channel (RACH) preamble is used for the transmission of small payloads, it shall be specified these characteristics. In case where collision of random access occurs, most likely for mMTC type traffic, evaluation of this delay component can be more precisely conducted with simulation approach.
3	UL synchronization	Current research points towards the fact that some waveforms may reduce the requirements for UL synchronization. This should be clearly stated in terms of duration. In case of totally

		asynchronous proposals, this duration shall be equal to zero.
4	Capability negotiation + hybrid automatic repeat request (HARQ) retransmission probability	Capability information may be already available in some of new states potentially introduced by 5G. In case of CP/UP decoupling between two or more cells, capabilities of UP and CP cell needs to be acquired
5	Authorization and authentication/ key exchange +HARQ retransmission probability	Security information may be already available in some of new states potentially introduced by 5G. It shall be specified if the security context is not discarded in the transition between the states.
6	Registration with the BS + HARQ retransmission probability	In case of UP/CP split, UE may register to the cell that is handling CP. In case when UP and CP are located in different RAN domains, UE may also register to both cells. In case of CP multi-connectivity, UE may register in multiple cells which are involved for CP functionalities. If the air interface does not require registration, this step can be omitted, e.g. due to reservation of context from a previous encounter.
7	Radio resource control (RRC) connection establishment/ resume + HARQ retransmission probability	In case of potential new 5G multi-connectivity configurations (e.g. RRC/CP diversity), this step is considered as done when RRC connection allowing for exchange of data information over a desired AIV is established In case if aggregation is located in the CN, RRC connection should be set up over multiple AIVs.

User plane latency

UP latency is defined as the one way transmission time of a packet between the transmitter and the availability of this packet in the receiver. The measurement reference is the MAC layer in both transmitter and receiver side. Analysis must distinguish between UP latency in an infrastructure-based communications and in a direct device-to-device (D2D) communication.

Table 4. Steps for the user plane latency analysis. Not all steps are required.

Step	Description	5G aspects for considerations
0	Transmitter processing delay	
1	Frame alignment	
2	Synchronization	In D2D communications, the user terminal may need some time for synchronization

3	Number of TTIs used for data packet transmission (includes UE scheduling request and access grant reception)	Assumption of unloaded condition is probably not valid any more, packets with fixed size might be used for specific traffic patterns, i.e. uMTC and mMTC services. Thus, number of TTIs used for each packet transmission depends on channel quality, allocated spectrum resource and exploitation of multi-connectivity. Introduced delay could be better reflected with simulations. However, analysis option is the preferred one. In case of UP multi-connectivity, this delay component should be derived w.r.t. different multi-connectivity configuration, i.e. whether different data streams are transmitted over different links or multiple links are simply used for data redundancy transmission. In 5G, both transmitter and receiver can be user devices considering D2D communication
4	HARQ retransmission	Instead of exploiting error probability of each transmission or retransmission for calculation of this delay component, the characteristics can be more precisely captured if the designed 5G protocol can be properly reflected in simulation. However, analysis option is the preferred option. Both CP and UP multi-connectivity impose impact on this delay component.
5	Receiver processing delay	

mMTC device energy consumption improvement

mMTC device energy consumption improvement is defined as the relative enhancement of energy consumption of 5G devices over LTE-A ones, under the assumption that device is stationary and uploads a 125 byte message every second. If not mentioned explicitly, energy consumption in RRC idle state is assumed the same for LTE-A and 5G devices.

Table 5. Steps included in the mMTC device consumption analysis.

Step	Description	5G aspects for considerations
0	Synchronization	5G devices can synchronize faster, depending on the allocation of synchronization signals
1	Transmit scheduling request	5G is expected to have shorter frame lengths enabling faster transmission of scheduling requests
2	Receive grant	5G is expected to introduce shorter frame lengths enabling faster reception of transmission grants
3	Transmit data	5G is expected to introduce shorter frame lengths enabling faster

		transmission of small payloads
4	HARQ retransmission	5G may enable faster reception of acknowledge/not-acknowledge info comparing to LTE-A solutions

Inter-system handover interruption time

The time duration during which a UE cannot exchange UP packets with any BS during transitions between 5G new AIVs and another legacy technology, like LTE-A which is of mandatory study. Additional other AIVs, including non-3GPP ones, are for future studies (FFS) [3GPP15-152129].

Mobility interruption time

Mobility interruption time is defined as the time span during which a UE cannot exchange UP packets with any BS during transitions [3GPP15-152129]. It can be regarded as intra-system handover interruption time.

Note that in 5G system, handover between adjacent BS may no longer exist due to solutions based on multi-connectivity and CP / UP decoupling.

Peak data rate

The peak data rate is the highest theoretical single user data rate, i.e., assuming error-free transmission conditions, when all available radio resources for the corresponding link direction are utilized (i.e., excluding radio resources that are used for physical layer synchronization, reference signals or pilots, guard bands and guard times). Peak data rate calculation shall include the details on the assumed MIMO configuration and bandwidth.

Simulation method

Simulation methods are applied for 5G KPIs that are heavily dependent on the instantaneous network conditions, such as available infrastructure and related radio resources, number of users, radio conditions, etc. Precise assessment of these KPIs is impossible without system level simulations.

Experienced user throughput

Experienced user throughput refers to an instantaneous data rate between Layer 2 and Layer 3. It is evaluated through system level simulations in respective deployment scenarios proposed in Section 4, according to simulation assumptions from Section 4 and using bursty traffic models. Note that experienced user throughput depends on the system bandwidth, and therefore this parameter shall be clearly identified in the simulation analysis. Experienced user throughput is calculated as:

$$U_{Tput} = \frac{S}{T},$$

where S is the transmitted packet size and T is the packet transmission duration calculated as the difference between the time when the entire packet is correctly received at the destination and the time when packet is available for transmission. Experienced user throughput is calculated separately for DL (transmission from source radio points to UE), UL (transmission from UE to destination radio points) and (potentially) for D2D (transmission directly between involved UEs).

Experienced user throughput is linked with availability and retainability.

Traffic volume density

Traffic volume density is defined as the aggregated number of correctly transferred bits received by all destination UEs from source radio points (DL traffic) or sent from all source UEs to destination radio points (UL traffic), over the active time of the network to the area size covered by the radio points belonging to the RAN(s) where UEs can be deployed. Thus, traffic volume density can have the following units: [Gbps/m2] or [Gbps/km2].

Here active time of the network is the duration in which at least one session in any radio point of RAN is activated.

Traffic volume density evaluated through system level simulations, in respective deployment scenarios and assumptions proposed in Section 4.

Note that D2D traffic should be evaluated independently from the cellular one. Besides, the link between source and destination may cover multiple hops especially when non-ideal backhaul is taken into consideration.

Again, system bandwidth assumption must be clearly identified.

E2E latency

Different types of latency are relevant for different applications. E2E latency, or one trip time (OTT) latency, refers to the time it takes from when a data packet is sent from the transmitting end to when it is received at the receiving entity, e.g., internet server or other device. Another latency measure is the round trip time (RTT) latency which refers to the time from when a data packet is sent from the transmitting end until acknowledgements are received from the receiving entity. The measurement reference in both cases is the interface between Layer 2 and 3.

Reliability

Refers to the continuity in the time domain of correct service and is associate with a maximum latency requirement. More specifically, reliability accounts for the percentage of packets properly received within the given maximum E2E latency (OTT or RTT depending on the service). For its evaluation dynamic simulations are needed, and realistic traffic models are encouraged.

More specifically, reliability for uMTC is evaluated through the packet reception ratio (PRR), following the 3GPP definition [3GPP15-36885]. PRR is calculated for each transmitted packet as X/Y, where Y is the number of UEs/vehicles located in the range of up to 150 m from the transmitter, and X is the number of UEs/vehicles with successful reception among Y. Distance intervals of 20 m from the transmitter are assumed.

Reliability of uMTC at specific level is achieved when a given PRR (equal to the reliability) can be guaranteed at a specific distance, for the messages successfully received within a specific time interval.

In general reliability is linked with availability and retainability.

Availability

The availability in percentage is defined as the number of places (related to a predefined area unit or pixel size) where the QoE level requested by the end-user is achieved divided by the total coverage area of a single radio cell or multi-cell area (equal to the total number of pixels) times 100.

(*note*: FANTASTIC-5G defines availability as equal to (1 – service blocking probability), where service blocking probability is due to lack of enough resources to access, grant and provide the service, even in case of adequate coverage).

Retainability

Retainability is defined as the percentage of time where transmissions meet the target experienced user throughput or reliability.

mMTC device density

Given mMTC device density is achieved when radio network infrastructure specified in Section 4 can correctly receive a specific percentage of messages (equal to availability) transmitted by mMTC devices deployed according to models given in Section 4.

RAN energy efficiency

Energy efficient network operation is one of the key design objectives for 5G. It is defined as the overall energy consumption of 5G infrastructure in the RAN comparing to a performance of legacy infrastructure. In order to prove expected energy savings both spatial (entire network) and temporal (24 hours) variations need to be taken into account, therefore direct evaluation in proposed UCs is inaccurate.

Supported velocity

Following steps should be taken to evaluate the high velocity support:

1. Run system level simulations with parameters as defined RMa deployment scenario from Table 9 with setting the speed to a given value and using full buffer traffic model to collect the overall statistics for downlink cumulative distribution function (CDF) of pilot signal power.
2. Use the CDF of this received power to collect the given CDF percentile value required by desired availability (e.g., for availability of 95% a 5th percentile value should be chosen).
3. Run the downlink link-level simulations for RMa settings defined in Table 9 and given velocity for both LoS and NLoS conditions to obtain link data rate and bit error rate as a function of the pilot signal power.
4. Proposal support desired velocity requirement if obtained link data rate is equal or greater than required value and required bit error rate. It is sufficient if one of the spectral efficiency values of either LoS or NLoS channel conditions fulfils the threshold.

Complexity

Even if many attempts have been made, complexity is, in general, difficult to measure. Under the complexity KPI a wide variety of technical aspects can be considered. For example, in the analogue hardware domain, complexity is often characterized by the integration level (size, footprint) of the device/component, whereas in the digital baseband and software domains, complexity is often described in terms of algorithmic complexity. Thus, it seems clear that different parts of the mobile communication networks will use different KPIs to measure this complexity. Consequently, they cannot be compared directly. In these cases, the most meaningful metric for complexity comparison is based on cost. The cost KPI is defined as the expenditure of resources, such as time, materials or labour, for the attainment of a certain objective (be it the execution of a function or the production of a HW component).

Nonetheless, whenever the complexity of a technical component needs to be assessed compared to a given reference of its same kind, it is always preferable to use a magnitude for complexity that is natural given the specific nature of the components to be compared. For example, as stated previously:

- Analogue HW device/component: use the KPI related to the HW footprint like size/volume.
- Digital baseband and software domain: use the computational complexity KPI expressed as the scaling order of the number of operations required to execute a given function in terms of certain input parameters (like number of antennas, samples, subcarriers, etc.)

Exemplary evaluation of different waveforms implementation complexity can be found in [BBB+16].

4. Performance evaluation models for 5G

This section covers performance evaluation models proposed for 5G KPIs evaluated by simulation means. It should be noted, that although this document captures most up-to-date status in contributing 5G-PPP projects, values proposed in this section shouldn't be considered as the final ones, and may be updated in the later stage of individual project duration. More information on the models and use cases captured below can be found in [FAN15-IR21] (FANTASTIC-5G), [MET16-D11] (METIS-II), [MMM16-D11] (mmMAGIC), [SPE16-D32] (SPEED-5G) and [3GPP16-38913] (3GPP),

BS configuration in synthetic deployment scenarios

Table 6. BS configuration for indoor hotspot.

Project deployment scenario	METIS-II/ Indoor hotspot	mmMAGIC/ Indoor hotspot	SPEED5G/ Indoor hotspot	3GPP/ Indoor hotspot
BS layout	Dual stripe office (12 BS in two lines)		Dual stripe office (one line of BSs) in and 1 BS in Future home	Open office (12 TRPs per 120x50 m)
BS antenna height	3 m, mounted on ceiling	3-5 m, mounted on wall or ceiling	3-6 m, mounted on wall or ceiling	
Number of BS antennas	Up to 256/256 >6 GHz	Up to 256	Up to 16/16 <6 GHz	Up to 256/256

elements (TX/RX)	Up to 16/16 <6 GHz			
Number of BS antenna ports	Up to 8	Up to 8	Up to 8	
BS antenna gain	5 dBi (per element)	5 dBi (per element)	0 dBi (per element)	
Maximum BS transmit power	40 dBm EIRP for >6 GHz (in 1 GHz), 21 dBm for <6 GHz (in 20 MHz)	Around 15 dBm	24 dBm for Future office and 20 dBm for Future home	
Carrier centre frequency for evaluation (per BS)	3.5 GHz and 70 GHz	>6 GHz	0.8 – 6 GHz	4 GHz or 30 GHz or 70 GHz
Carrier bandwidth for evaluation (per BS) *	100 MHz at 3.5 GHz and 1 GHz at 70 GHz	1 GHz/270 MHz (DL/UL in mmMAGIC Smart office), 0.5 GHz/10 MHz (DL/UL in Media on demand)	Up to 80 MHz	200 MHz at 4 GHz and 1 GHz at >6 GHz
Inter-site distance	20 m	20-30 m	10 m	20 m

Table 7. BS configuration for urban macro.

Project deployment scenario	FANTASTIC-5G/ Urban macro	METIS-II/ Urban macro	mmMAGIC/ Urban macro	SPEED5G/ Urban macro	3GPP/ Urban macro
BS layout	Hexagonal grid	Hexagonal grid	Hexagonal/Manhattan grid	Hexagonal grid	Hexagonal grid
BS antenna height	25 m, above rooftop	25 m, above rooftop	25 m, above rooftop	25 m, above rooftop	
Number of BS antennas elements (TX/RX)		Up to 32/32	Up to 256		Up to 256/256 (or up to 32/32 for Connected cars urban)
Number of BS antenna ports		Up to 16	Up to 8		
BS antenna gain	15 dBi	17 dBi	~30 dBi	17 dBi	
Maximum	46 dBm	49 dBm per	30-40 dBm	49 dBm	

BS transmit power		band (in 20 MHz			
Carrier centre frequency for evaluation (per BS)	< 6 GHz	2 GHz for Massive distribution and Connected cars, 3.5 GHz for Dense urban	> 6 GHz	< 6 GHz	2 GHz or 4 GHz or 30 GHz (joint options possible) (or around 6 GHz in connected cars urban)
Carrier bandwidth for evaluation (per BS) *		Up to 10 Hz at 2 GHz for Massive distribution and Connected cars Up to 100 MHz at 3.5 GHz for Dense urban	Up to 1 GHz (?)	Different combinations of channelization BWs, but using 10 MHz and 20 MHz at 2 GHz and 20 MHz or 40 MHz at 3.5 GHz and 5 GHz	(1 GHz at 30 GHz and 200 MHz at 4 GHz in dense urban)
Inter-site distance	500 m (250 m)	200 m for Dense urban, and 500 m for Massive distribution and Connected cars	Up to 250 m	500 m	500 m (or 200 m for dense urban)

Table 8. BS configuration for outdoor small cells.

Project deployment scenario	FANTASTIC-5G/outdoor small cells	METIS-II/ outdoor small cells	mmMAGIC/ outdoor small cells	SPEED5G/ outdoor small cells	3GPP/ Dense urban outdoor micro
BS layout	Clustered (random for Sensors network)	Random (8 per macro cell)	Clustered small cells (as in a hotspot), Support from 4G macro cells (HetNet) foreseen for 5G immersive experience UC	Clustered (4 per macro cell)	Random (3 per macro TRP) or along the road for RSU
BS antenna height	10 m on the lamppost /	10 m on the lamppost /	6-10 m	10 m on the lamppost /	

	below the rooftop (15 m above rooftop for Sensors networks	below the rooftop		below the rooftop	
Number of BS antennas elements (TX/RX)		Up to 256/256 >6 GHz Up to 16/16 <6 GHz	Up to 256/16 (DL) depending on the carrier frequency		Up to 256/256 or up to 32/32 for RSU
Number of BS antenna ports		Up to 8 < 6 GHz	Up to 8		
BS antenna gain		5 dBi (per element)	5 dBi (per element). Up to 30 dBi for 5G immersive experience UC		
Maximum BS transmit power	30 dBm	40 dBm EIRP for >6 GHz (in 1 GHz), 30 dBm <6 GHz (in 20 MHz)	30 dBm. Up to 23 dBm for 5G immersive experience UC	30 dBm	
Carrier centre frequency for evaluation (per BS)	< 6 GHz	25 GHz in Dense urban, 5.9 GHz for RSU in Connected cars	> 6GHz	0.9 – 6 GHz	4 GHz and 30 GHz (or 6 GHz for RSU)
Carrier bandwidth for evaluation (per BS) *		1 GHz at 25 GHz in Dense urban 10 MHz at 5.9 GHz for RSU in Connected cars	1175 MHz / 2250 MHz DL/UL in Distributed crowds, 300/50 in Cloud services, 1640/820 MHz in early experience	80 MHz	1 GHz at 30 GHz and 200 MHz at 4 GHz
Inter-site distance	50 m	>= 20 m	< 50-100 m	20 m	At each intersection/ 100 m when configured as RSU in urban/highway or 25 m for high speed

Table 9. BS configuration for rural macro and long distance.

Project deployment scenario	FANTAS5G/ Rural-macro	METIS-II/ Rural-macro	3GPP/ Rural-macro, long range/distance
BS layout	Hexagonal Grid	Hexagonal Grid	Hexagonal Grid (isolated cells)
BS antenna height	30 m	35 m, above rooftop	
Number of BS antennas elements (TX/RX)		Up to 32/32	Up to 256/256 at 4 GHz and up to 64/64 at 700 MHz
Number of BS antenna ports		Up to 8	
BS antenna gain		17 dBi	
Maximum BS transmit power	46 dBm	49 dBm per band (in 30 MHz)	
Carrier centre frequency for evaluation (per BS)	< 6 GHz	800 MHz	700 MHz (and 2 MHz for ISD = 5000 m) or 4 GHz
Carrier bandwidth for evaluation (per BS) *		30 MHz at 800 MHz, assuming carrier aggregation	Up to 20 MHz (40 MHz for long distance/range) at 700 MHz and up to 200 MHz at 4 GHz
Inter-site distance	1 732 or 4330	1 732 m	1 732 m or 5000 m (100-400 km for long range/distance)

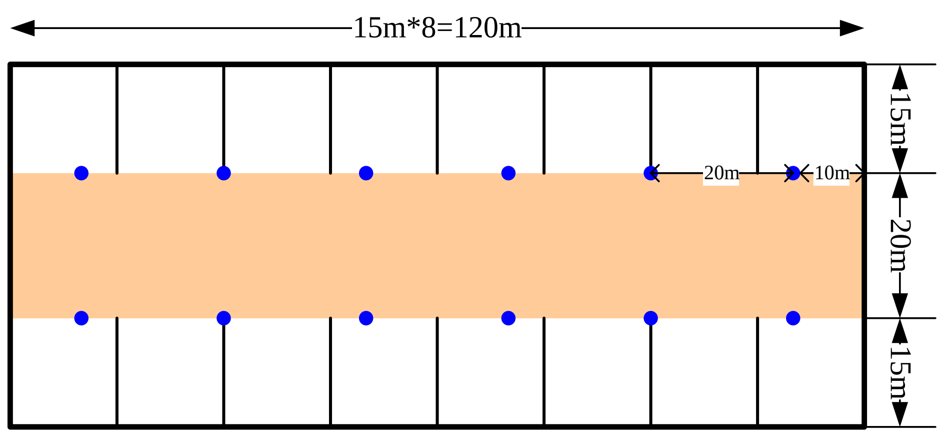

Figure 6. Indoor hotspot dual BS line configuration

Realistic deployment scenarios

Indoor office (METIS-II)

A realistic office environmental model is attained by explicitly considering walls, screens, desks, chairs and people [MET13-D61]. The environmental model geometry is given by the dimensions of the rooms, cubicle offices and tables. The width and depth of these objects are illustrated in the Figure 7.

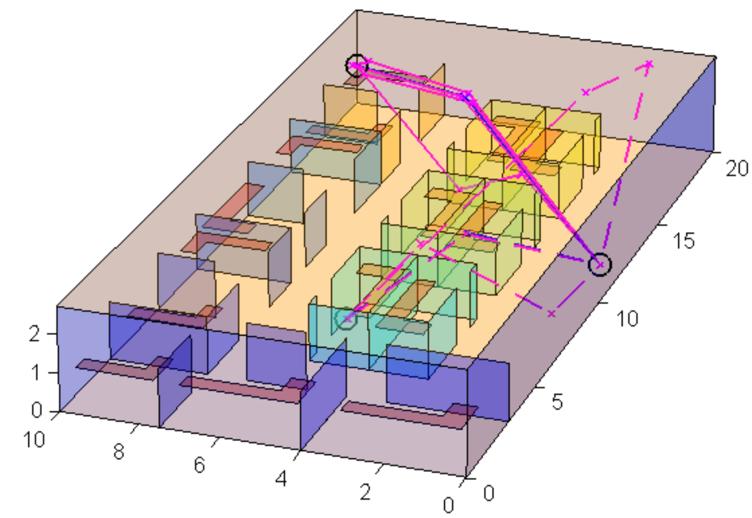

Figure 7. 3D sketch of the realistic indoor office.

Madrid Grid (METIS-II)

Madrid Grid is a realistic extension of a popular Manhattan Grid model [ETSI-125951]. Its basic elements are regular, multi-storied blocks of different sizes and heights, park area, roads and pavements. This environment was developed in METIS project [MET13-D61] for the purpose of capturing dynamic traffic variations (in both space and time) in a typical European dense urban environment.

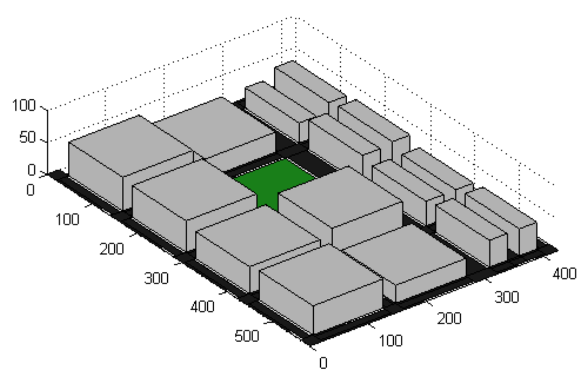

Figure 8. 3D visualization of the Madrid grid.

Future Home Environment (SPEED-5G)

This scenario aims at representing the typical environment of a future house. Typical figures and devices that are present in such an environment are, for instance: 5 to 10 UEs (including smartphones and wireless laptops) and 10 to 30 IoT devices (including home appliances such as dish washer, washing machines, light switches, gates and doors, fire alarms, security devices, proximity sensors, etc.).

This scenario is an ideal environment for the deployment of a small cell, that must be capable of operating in both licensed band (for voice traffic, emergency calls and mission-critical sensors) as well as in unlicensed band (shown to be fundamental for the provision of broadband coverage for band consuming applications such as online video streaming and file sharing).

In the Figure 9 a distinctive home environment is represented, showing a two-floor house with a garden in the backyard, using an external macro cell for providing the control plane signalling.

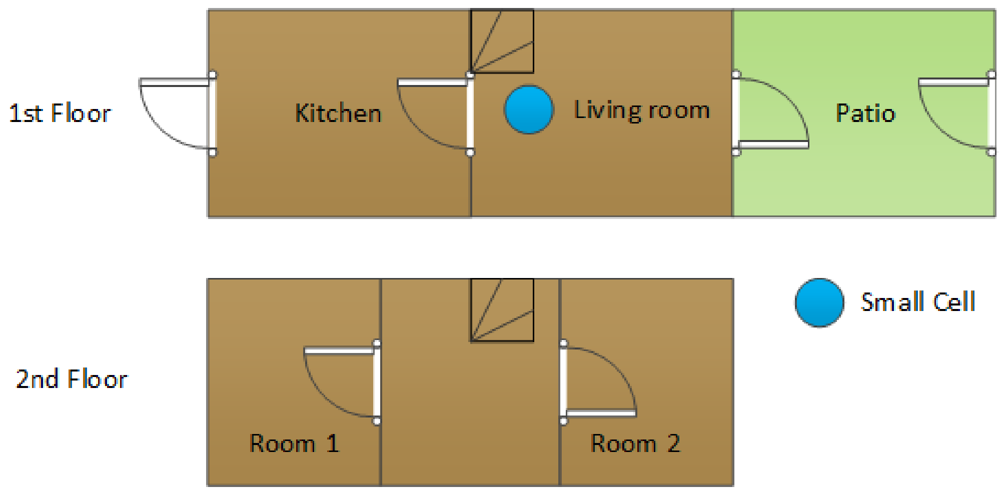

Figure 9. 2D floor map of the Future Home Environment.

Extended Suburban HetNet (SPEED-5G)

Extended Suburban HetNet scenario has been defined in SPEED-5G [SPE16-D32] for the purpose of analysing a highly important space where people live, very meaningful for knowing the 5G HetNet performance in both space and time in a typical European Suburban area, which is also common in the US and in some areas in Asia. The scenario is quite flexible, and does not require simulating the whole floorplan if it is not needed, as it contains several areas of interest, so different studies can be performed using this scenario.

Table 10. Evaluation parameters for Extended Suburban HetNet.

	Indoor scenario (baseline)	**Outdoor scenario (baseline)**
Channel model	ITU InH [ITUR08-M2135]	ITU UMa [ITUR08-M2135]
Distance-dependent path loss	3D distance between BS and UE	

Walls penetration path loss and shadowing	[ITUR15-P1238] residential building	[ITUR15-P1411] with the LoS to NLoS threshold of 200 m
Mobility model	Stationary	Stationary Optional: indoor fixed (80%), walking people (4%) 3km/h, people standing at bus stop or traffic lights: (1%), people in a vehicle: (15%) 30km/h
Total BS transmit power	21 dBm for 20 MHz	46 dBm for 20 MHz
UE power class	21 dBm	
Bandwidth	20 + 20 MHz (FDD)	
Antenna pattern	2D omni-directional is baseline; directional antenna is not precluded, as the macro cell coverage is mainly used for signalling purposes	
Antenna height:	3.5 m	35 m
UE antenna Height	1.5 m	
BS noise figure	5 dB	
UE noise figure	7 dB	
Antenna gain of BS + connector loss	0 dBi	17 dBi
Antenna gain of UE	0 dBi	
Indoor/outdoor UE ratio	80/20	
Number of UEs	5 UEs & 5 IoT devices per small cell	
UE dropping for each network	Random	
Minimum ISD (2D)	18 m	1000 m
Traffic model	Full buffer, bursty traffic (application driven traffic)	
Number of antennas	Up to 8/8 for <6 GHz	
UE receiver	MMSE	
Frequency	2.6 GHz + 5 GHz (optional)	800 MHz
Scheduler	Round robin / proportional fair both in frequency and time domains	
SINR Estimation	Ideal	
Closed subscriber group	Open	
Cell selection	Based on received power	
Control overhead	1 OFDM symbol	

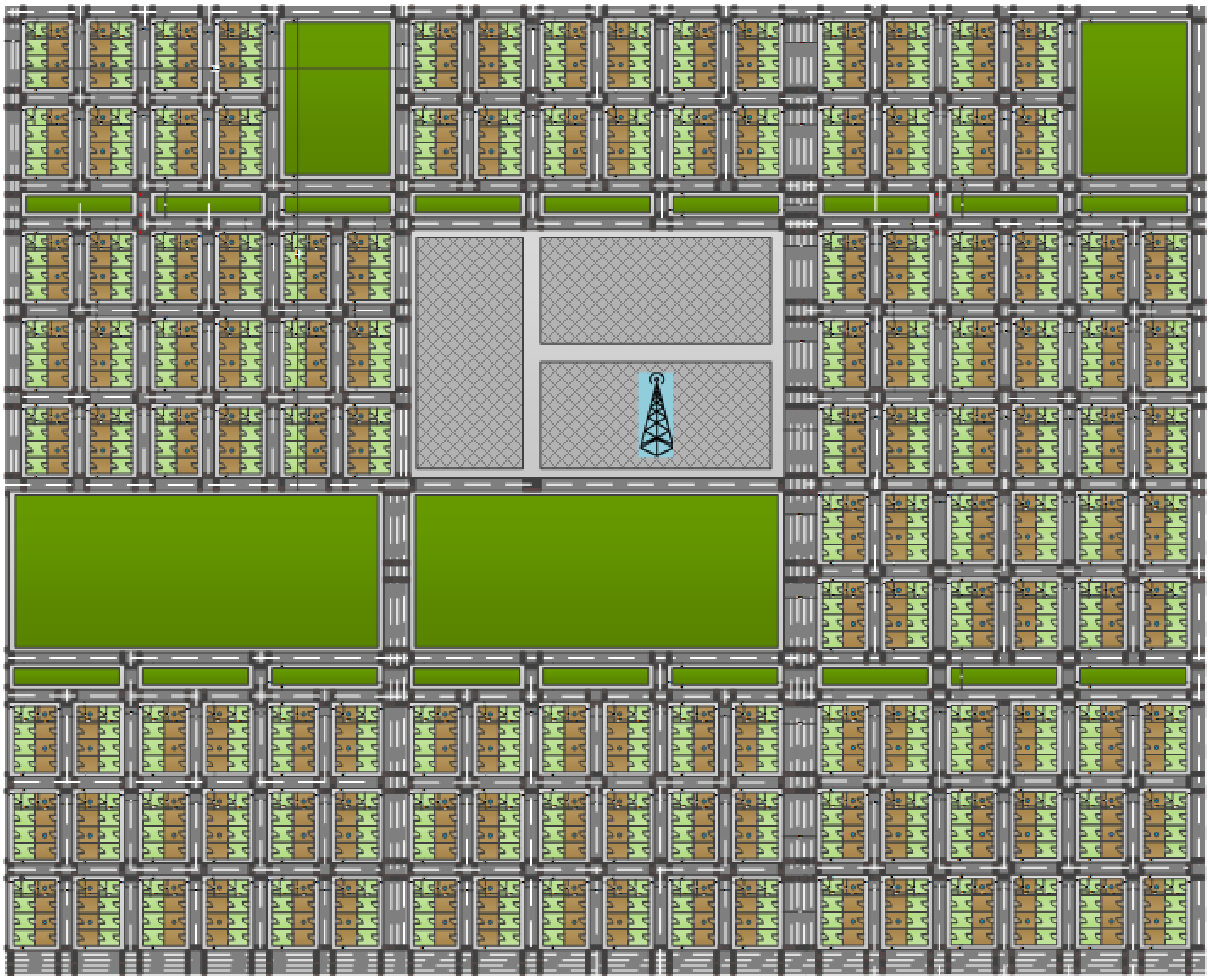

Figure 10. 2D floor map of the Extended Suburban Hetnet

Mapping of deployment scenarios to specific use cases

Table 11. Mapping of deployment scenarios to specific use cases.

Project /use case	Synthetic deployment scenario	Realistic deployment scenario	Comment
FANTASTIC-5G/ Dense urban information society	UMa + outdoor small cells		
FANTASTIC-5G/ 50 Mbps everywhere	UMa		

FANTASTIC-5G/ High speed train	RMa		
FANTASTIC-5G/ Sensors network	UMa + outdoor small cells		
FANTASTIC-5G/ Tactile internet	UMa + outdoor small cells		
FANTASTIC-5G/ Automated traffic	RMa + outdoor small cells		RMa used as a coverage layer
FANTASTIC-5G/ Broadcast like service	UMa/RMa?		
METIS-II/ Dense urban information society	UMa + outdoor small cells	Madrid grid	UMa ISD = 200 m
METIS-II/ Virtual reality office	InH	Virtual reality office	
METIS-II/ Broadband access everywhere	RMa	n.a.	
METIS-II/ Massive deployment of sensors and actuators	UMa	Madrid grid	UMa ISD = 500 m
METIS-II/ Connected cars	UMa, RMa	Madrid grid	UMa (ISD = 500 m) for urban case (60 km/h speed), RMa for highway scenario (140 km/h). Madrid grid applicable to urban case
mmMAGIC/Media on demand	UMa		UMa (ISD = 200 m). Propagation outdoor to indoor
mmMAGIC/Smart offices	InH		Ultra-dense deployment of small cells
mmMAGIC/Cloud services	UMa + small cells /UMa		ISD between 50 and 200 m
mmMAGIC/Dense urban with distributed crowds	UMa + small cells + InH		ISD between 50 and 100 m
mmMAGIC/50+ Mbps everywhere	UMa/RMa		ISD between 50 and 250 m
mmMAGIC/Early 5G in hot spots	UMa + small cells		Coverage layer is a legacy 4G?
mmMAGIC/Moving hot spots	UMa + small cells		Both cases: small cells mounted in/on a car and vehicles without antenna
SPEED-5G/Future connected office	InH	Virtual Reality Office	
SPEED-5G/Future home environment	UMa + InH	Future Home Environment	One indoor small cells, outdoor UMa for signalling
SPEED-5G/Future dense urban	UMa + small cells	Madrid Grid	Small cells both indoor and outdoor
SPEED-5G/Realistic extended suburban HetNet	SuMa + small cells	Realistic Extended Suburban HetNet	Outdoor macro cell and indoor small cells. HeNBs inter-site distance is 9 or 18 m depending on the scenario cell density configuration.

User, traffic, channel and mobility models for specific use cases

Table 12. Models for indoor environment use cases.

Project/Use Case	METIS-II Virtual reality office	mmMAGIC Smart offices	SPEED-5G Virtual reality office	SPEED-5G Future home environment	3GPP xMBB InH
UE deployment	10 or 50 UEs per cell	7500/km2		5-10 UEs per cell	10 UEs per TRP
UE height	1.5 m				
Number of UE antenna elements (TX/RX)	16/16				32/32 >6 GHz and 8/8 <6GHz
Number of UE RF chains (TX/RX)	8/8 for <6 GHz, 4/4 for >6 GHz				
UE antenna gain	0 dBi				
UE max TX power	24 dBm				
Min 2D UE-BS distance	10 m				
Indoor / outdoor ratio	100/0	80/20			100/0
Channel model	<6 GHz 2D InH [3GPP10-36814], >6 GHz 3D InH [5GCM15]				
Traffic model	Full buffer, bursty traffic FTP model 3 (file size = 3.5 MB, varying IAT)		Full Buffer / 20 Mb packet generated according to a Poisson process with mean IAT = 20ms, UL/DL/D2D/no transmission probability = (50/50/0/0) or (40/40/10/10)		

Mobility model	User position fixed, for fast fading 3 km/h and 30 km/h are assumed for small cells and macro	Limited mobility	User position is fixed, for fast fading 3 km/h and 30 km/h are assumed for small cells and		3 km/h

Table 13. Models for dense urban uses cases

Project/ Use case	FANTASTIC -5G Dense urban < 6GHz	METIS-II Dense urban	mmMAGIC Cloud services	mmMAGIC Dense urban with distributed crowds	mmMAGIC Media on demand	SPEED-5G Dense urban	3GPP xMBB dense urban
UE deploym ent	• 200-2500 users/km2 • 2/3 of users randomly and uniformly dropped within the clusters, 1/3 of users randomly and uniformly dropped in macro area	10 UEs per macro cell, 5 UEs per small cell, random uniform	2500/km2	150k/km2	4000/km2		10 UEs per TRP
UE height		3D distribu-tion (3GPP model ([MET16-D21] Section 4.1.2)	1.5 m	1.5 m			
Number of UE antenna elements (TX/RX)		16/16					32/32 for >6 GHz, 8/8 for <6GHz

Number of UE RF chains (TX/RX)		8/8 for <6 GHz, 4/4 for >6 GHz					
UE antenna gain		0 dBi					
UE max TX power		24 dBm					
Min 2D UE-BS distance		10 m for small cells, 35 m for UMa					
Indoor / outdoor ratio	80/20	80/20		80/20	100/0		80/20
Channel model	3D models as in [3GPP15-36873]	< 6 GHz 3D UMa [3GPP15-36873], > 6 GHz 3D UMa [5GCM15]				[ITUR08-M2135]	
Traffic model		Full buffer, bursty traffic FTP model 3 (file size of 3.5 MB, varying IAT)	Full buffer and finite buffer traffic model	Full buffer traffic model	FTP		
Mobility model		User position is fixed, for fast fading 3 km/h is assumed	50 km/h (functional support up to 100 km/h)	3km/h or no mobility considered	Low or no mobility	3 km/h for small cell, 30 km/h for macro (users don't change their position during simula-tion)	3/30 km/h for indoor/ outdoor UEs

Table 14. Models for broadband access everywhere use cases

Project/Use Case	FANTASTIC-5G/ 50 Mbps everywhere	METIS-II/ Broadband access everywhere	mmMAGIC/ 50+ Mbps everywhere	SPEED-5G/ Realistic extended suburban HetNet	3GPP/ xMBB rural macro
UE deployment	Random uniform, 400/100 users/km2 for suburban and rural (respectively	10 UEs per cell	400-2500 users/km2		10 UEs per TRP
UE height		1.5 m	1.5 m		
Number of UE antenna elements (TX/RX)		8/8			
Number of UE RF chains (TX/RX)		4/4			
UE antenna gain		0 dBi			
UE max TX power		24 dBm			
Min 2D UE-BS distance		35 m			
Indoor / outdoor ratio	80/20	0/100	50/50		50/50
Channel model	As in [3GPP15-36873]	2D RMa [3GPP10-36814]	Full buffer and finite buffer traffic model	As in [ITUR08-M2135]	

Traffic model	Mix of BUD, VT, BAD and RTAD traffic [MET13-D61] • Bursty user-driven (BUD) traffic: 3GPP FTP model 2 (exponential reading time) [3GPP10-36814][MET13-D61] • Non real-time video traffic (VT): 3GPP FTP model 2 (exponential reading time) [3GPP10-36814][MET13-D61] • Bursty application-driven (BAD) traffic: 3GPP FTP Model 2 (exponential Reading Time) [3GPP10-36814][MET13- D61] Real-time video application driven (RTAD) traffic: Constant interarrival time (36ms) [MET13- D61] annex 8.2.2.	Full buffer, bursty traffic FTP model 3 (file size = 3.5 MB, varying IAT)			
Mobility model	0-50 and 0-120 km/h for suburban and rural (respectively)	User position is fixed, for fast fading 120 km/h is assumed		3 km/h for small cell, 30 km/h for macro	

Table 15. Models for high speed use cases

Project/Use Case	FANTASTIC-5G/ High speed train	3GPP/ High speed
UE deployment	2000 users/km2 (each 500 users in the train in a straight line), 4 trains containing 500 users	1000 users per high speed train, at least 10% activity ratio (100 UEs per macro cell)
UE height		
Number of UE antenna elements (TX/RX)		256/256
Number of UE RF chains (TX/RX)		
UE antenna gain		
UE max TX power	23 dBm	
Min 2D UE-BS distance		
Indoor / outdoor ratio	80/20	All users in the train

Channel model	As in [3GPP16-36942] (see section 4.5.3)	
Traffic model	Mix of V2I (UL), I2V (DL), and V2V traffic. • V2I traffic is mapped with Bursty User-Driven (BUD) traffic. See UC1 and [MET13-D61] • V2V traffic: Messages of 1.6 kbytes [MET13-D61] I2V: mix of BUD, VT, BAD and RTAD traffic as defined for "50Mbps everywhere"	
Mobility model	0-500 km/h	500 km/h

Table 16. Models for mMTC use cases

Project/Use Case	FANTASTIC-5G/ Sensors networks	METIS-II/ Massive distribution of sensors and actuators	3GPP / Massive Connection
UE deployment	up to 600 k devices/km2, • households/km2 [MET13-36888] (uniform) • 13 devices/ household (uniform) • 500 cars/km2 (uniform) • 6 devices/car	24 000 UEs per cell	
UE height		3D distribution (3GPP model ([MET16-D21], Section 4.1.2)	
Number of UE antenna elements (TX/RX)		2/2	1/1
Number of UE RF chains (TX/RX)		1/1	
UE antenna gain		0 dBi	
UE max TX power		21 dBm	
Min 2D UE-BS distance		35 m	
Indoor / outdoor ratio		80/20	80/20
Channel model	UMa as in [3GPP16-36942], UMi as in [3GPP16-36931]	3D UMa [3GPP15-36873]	
Traffic model	Constant packet generation intervals (uplink) [3GPP13-36888]	Bursty traffic FTP model 3, file size = 125 B, IAT down to 1 s	Non-full buffer with small packets

Mobility model	Random walk, linear movement, Manhattan mobility for car mounted sensors	User position is fixed, for fast fading 3 km/h is assumed	3/100 km/h for indoor/outdoor UEs

Table 17. Models for vehicular safety use cases.

Project/Use Case	FANTASTIC-5G/ Automated traffic	METIS-II/ Connected Cars	3GPP/Highway Scenario	3GPP/Urban Grid
UE deployment	Up to 20000 users/km2, Urban: 3000 devices/km² Suburban: 2000 dev/km² Rural: 1000 devices/km²	According to [3GPP15-36885]	According to [3GPP15-36885]	According to [3GPP15-36885]
UE height		1.5 m		
Number of UE antenna elements (TX/RX)		2/4	8/8	8/8
Number of UE RF chains (TX/RX)		1/2		
UE antenna gain		3 dBi		
UE max TX power		23 dBm		
Min 2D UE-BS distance		10 m for small cells, 35 m for macro		
Indoor / outdoor ratio		0/100	0/100	0/100
Channel model		See Section 4.5.5 in [MET16-D21]		
Traffic model		Bursty traffic [3GPP15-36885]	50 messages per second	[tbd]/50/15 messages per second at the speed of 120/60/10 km/h

Mobility model	-Highway: 250 (abs.) 500 (rel.) km/h -Rural: 120 (abs.) 240 (rel.) km/h -Urban: 60 (abs.) 120 (rel.) km/h VRUs: 3 30 km/h	60/140 km/h (urban/highway), explicitly modelled as in [3GPP15-36885]	100-250 km/h	15-120 km/h

Table 18. Models for broadcast and moving hot spot use case

Project/Use Case	FANTASTIC-5G/ Broadcast-like services	mmMAGIC/ Moving hot spots	3GPP/ Long distances	3GPP/ Long range
UE deployment	Relevant for multicast service (in order to select the connection density to be used as a threshold above which to establish an MBMS session and under which to establish p2p connections), Suburban: 400 users/Km2 (uniform) Rural:100 users/ km2 (uniform)			
UE height				
Number of UE antenna elements (TX/RX)				
Number of UE RF chains (TX/RX)				
UE antenna gain				
UE max TX power				
Min 2D UE-BS distance				
Indoor / outdoor ratio				
Channel model	Hata model, based on equation in section 4.5.3 of [3GPP16-36942]	UMa as in [3GPP16-36942], outdoor small cells as in [3GPP16-36931]		

Traffic model	Mix of V2I and V2V traffic. • V2I traffic is mapped with Bursty User-Driven (BUD) traffic. [MET13-D61] • V2V traffic: Messages of 1.6 kbytes payload (MAC) [MET13-D11, MET13-D61]	Constant packet generation intervals (uplink) [3GPP13-36888]		
Mobility model	65% of devices are stationary, 30% of devices: 0-120km/h, 5% of devices: 0-500 km/h, random walk	30-500 km/h	Up to 160 km/h	Up to 160 km/h

5. Performance evaluation results of specific use cases

[*Placeholder for future performance evaluation of 5G solutions in 5G-PPP]*

6. Outlook

This document has captured the most up-to-date views and considerations of 5G-PPP projects related to activities in wireless strand on 5G use cases and performance evaluation models. Proposed assumptions will be used to provide assessment of individual technical solutions, as well as overall 5G RAN design and its performance. The next update of this document will be provided in the time frame of 4Q 2016.

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