5G PPP phase II KPIs – Annex to Programme Management Report

1 Introduction

This document consolidates the available KPIs from different sources of the 5G PPP programme work group activities and projects. It tries to consolidate an agreed definition for each KPI and provide an agreed method of measurement. It restricts the analysis to the performance KPIs and does not consider business and societal KPIs of the 5G PPP programme.

1.1 Performance KPIs

The technical Annex to the 5G PPP contractual arrangement [1] defines the following KPIs:

- Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
- Saving up to 90% of energy per service provided.
- Reducing the average service creation time cycle from 90 hours to 90 minutes.
- Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.
- Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.

These KPIs have been refined in the course of the execution of the 5G PPP programme in various white papers, among others in "5G empowering vertical industries" [2]. A more detailed and partly formal definition of the KPIs that are relevant for the performance of the 5G system have been defined by standards bodies such as ITU-T and 3GPP.

Report ITU-R M.2410-0 (11/2017) defines KPIs specific to the radio interface. These include *Peak data rate*, *User experienced data rate*, *Mobility*, *Latency* – separately for user plane and control plane, *Connection density*, *Reliability*, *Area traffic capacity*, *Peak spectral efficiency*, *5th percentile user spectral efficiency*, *Average spectral efficiency*, *Energy efficiency*, *Mobility interruption time* and *Bandwidth*.

In TS 28.554 [3], 3GPP specifies end-to-end Key Performance Indicators (KPIs) for the 5G network and network slicing. 3GPP introduces KPI categories; *Accessibility*, *Integrity*, *Utilization*, *Retainability* and for future updates also *Availability* and *Mobility*. The categories are defined with reference to ITU-T Rec.E.800 [4].

Accessibility refers to Registered Subscribers of Network and Network Slice Instance through AMF and UDM, Registration success rate of one single network slice instance, as well as Data Radio Bearer (DRB) Accessibility for UE services. *Integrity* refers to End-to-end Latency of the 5G Network, Upstream/Downstream Throughput for network and network slice instance, Upstream/Downstream throughput at N3 Interface (between RAN and UPF) as well as throughput between RAN and UE. *Utilization* refers to the Mean number of PDU sessions of network and network Slice Instance and the Virtualised Resource Utilization of Network Slice Instance. Finally *Retainability* refers to QoS flow Retainability.

Furthermore NGMN published a Testing Framework for the NGMN 5G pre-commercial network trials. Among others this paper specifies general requirements for testing, deployment scenarios, trial setup requirements, trial test requirements and service or technology specific requirements for several identified KPIs, such as *Latency*, *User throughput*, *Cell Capacity*, *Spectral Efficiency*, *Coverage*, *Mobility*, *Reliability and Retainability*, *User Experience*, *Energy Efficiency*, *Inter-RAT procedures*, *RAN architecture split*, as well as *Location/Positioning service* and *Fixed Wireless Access*.

As can be derived from the main references above, there exists a large number of KPIs with partly diverging definitions, although these definitions are being consolidated by the standards bodies and the industry. The ad hoc work group of the 5G PPP has made an attempt to provide a consolidated view of the KPIs that are being addressed by the various projects of the 5G PPP programme.

1.2 Approach/options to measuring KPIs

In the context of KPI validation by the 5G PPP project an abstract 5G system partitioning has been used as illustrated in the figure below. The figure intentionally simplifies certain details of the architecture that pertain to the concept inside the presented segments, such as the functional split at the radio segment.

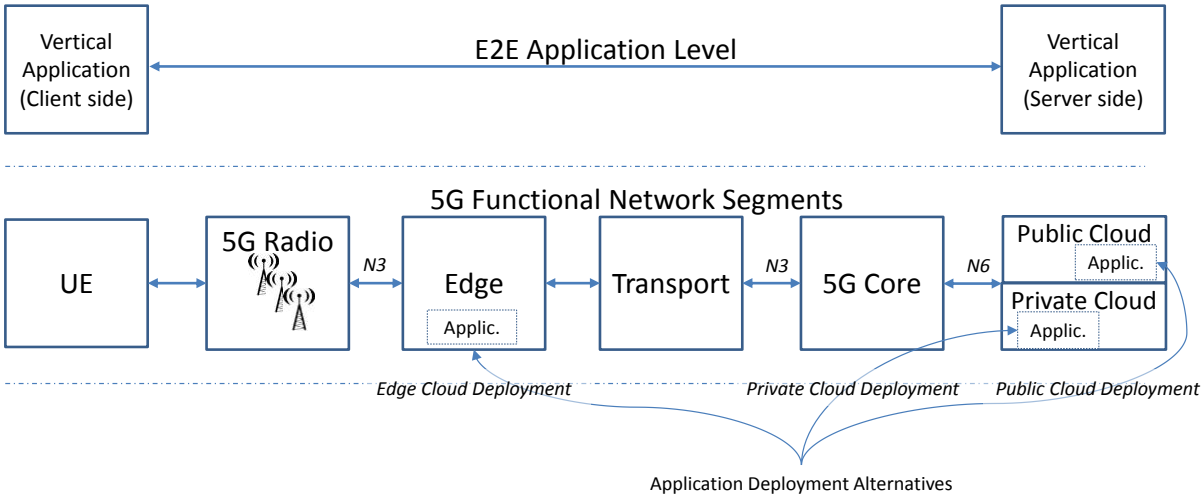

Figure 1 Functional Network Segments of a 5G System

1.3 Template for collecting Project KPIs and mapping to contractual KPIs

This section briefly outlines the methodology of mapping the 5G PPP phase II project KPIs to the 5G PPP programme contractual KPIs.

	Performance KPIs
P1	Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.
P2	Saving up to 90% of energy per service provided.
P3	Reducing the average service creation time cycle from 90 hours to 90 minutes.
P4	Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.
P5	Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.
P6	Enabling advanced user controlled privacy.

< project‘s> KPIs	5G PPP Performance KPIs					
	P1	P2	P3	P4	P5	P6
Name KPI 1						
Name KPI 2						
Name KPI 3						
Name KPI 4						
…						
…						
…						

1.3.1 Methodology – 7 Questions

1. Which KPIs can <project> address?

2. How do the KPIs been improved in <project>?
3. Where can the KPIs been measured?

   It needs to be done in a real testbed that exists in the project, so the answer is one of the PoCs in the project.

4. What are the use case/context of the KPIs?

   Describe the KPI under the context of our specific PoC. Which level/layer is the KPI important? Network? Application?

5. What are the definition of the KPIs in details with specific context?

   What the KPI means in the specific environment.

6. How can the KPIs been measured?

   How can we collect the numerical numbers in our PoC?

7. How can the KPIs been evaluated?

   How can we make comparison with others? This can be difficult as most of our KPIs are not in network level, so absolute numbers are not the way we evaluate it. Reference point/system is needed in most our cases to have relative measurements.

1.3.2 Name KPI X

Which KPI	Name KPI X
Definition of KPI	
Context/Use case	
Enhancement work	
Where to measure	
How to measure	
How to evaluate	

The following sections present the KPIs as defined by the phase II 5G PPP projects sorted by the high level performance KPIs.

In-depth attention was dedicated to consolidating the KPIs on *Latency* and *Service Creation Time*

2 Latency

2.1 Definition and measurement of latency

Based on the testbed and components of each use case proposed by the projects, a reference framework is proposed to facilitate the definition and measurement of latency when the different solutions are provided and compared. In this work the focus is on user plane latency.

2.1.1 Reference Framework for Latency in 5G

From the proposed testbed and components from each project we can see that the system architecture follows the key principles of the 3GPP TS 23.501, i.e. separating the User Plane functions from the Control Plane functions, allowing independent scalability, evolution and flexible deployments e.g. centralized location or distributed (remote) location. The components including the VNFs used to build the 5G system are illustrated as a service-based architecture in Figure 2. The VNFs involved in the user plane are UE, RAN, User Plane Function (UPF) and Data Networks (DN).

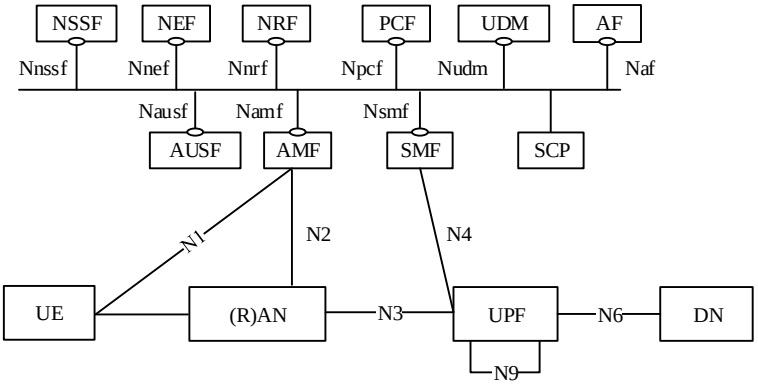

Figure 2 Service-based Architecture with separation of Control Plane and User Plane

Based on the analysis of the components and the contribution of latency in the user plane, a reference framework from user-plane latency aspect is proposed as the Fig. 10, where the latency is considered to be composed of three types of delay: network transmission time (depicted as *T*), network function processing time (depicted as *P*) and application response time (depicted as *R*). For example, P_{UE} denotes the processing time of a packet since it is sent from the UE's application layer until it is transmitted by the UE's physical layer, while T_{radio} denotes the network transmission time from the egress of UE to the ingress of RAN.

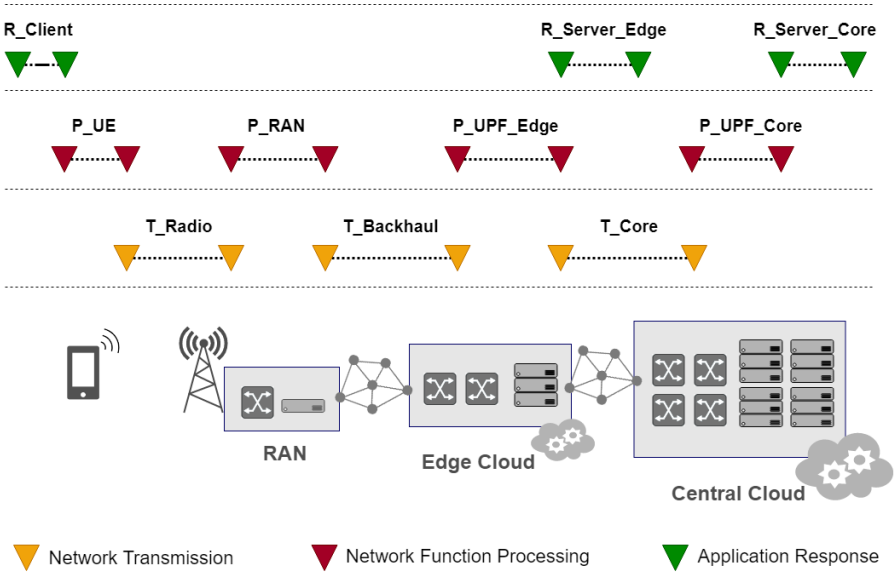

Figure 3 Reference framework of delay contributions of an end-to-end latency

2.2 Detailed definition of latency related KPIs by project

Project	blueSPACE
Project KPI name	Low latency fronthaul
Definition of KPI	Reduced physical layer E2E latency.
Context/Use case	UC4 (Industry 4.0), All (user application dependent)
Enhancement work/Innovation/Enablers	ARoF fronthaul avoids CPRI/eCPRI processing and framing overhead and minimizes jitter.
Where to measure (reference to the project testbed)	TU/e testbed, E2E link, blueSPACE BBU and emulated user terminal
How to measure	Measure E2E latency from ingress PHY layer BBU to egress PHY layer at user terminal. Measure fronthaul latency in loop configuration at RU.
How to evaluate (relative/absolute)	Benchmark measured latencies against latency and jitter for DRoF (CPRI/eCPRI) deployment over same fiber infrastructure.
Scope of Measured Latency	Partial latency. (Fronthaul latency). From ingress PHY layer BBU to egress PHY layer at user terminal

Project	5G-PHOS
Project KPI name	<4ms user plane latency for dense, ultra dense and hotspot areas.
Definition of KPI	This KPI refers to the time it takes to transfer a small data packet from user terminal to the Layer 2 / Layer 3 interface of the 5G system destination node, plus the equivalent time needed to carry the response back.
Context/Use case	This KPI will test the analog Fronthaul capability of the 5G-PHOS solution to support eMBB and if possible URLLC communications.
Enhancement work/Innovation/Enablers	5G-PHOS employs analog RoF technology which produces latency gains due to lack of intermediate digitization processes. If <4ms latency targets are not achieved 5G-PHOS will try to employ faster DSP and Medium-Transparent MAC (MT-MAC) procedures (in the Hotspot use case) to reduce the latency.
Where to measure (reference to the project testbed)	All 3 5G-PHOS demos will measure E2E latency.
How to measure	In Demo#1 an LTE transmission system will be deployed over the 5G-PHOS analog ROF solution and successful communication will prove the 5G-PHOS capacity to abide to fronthauling specifications. In Demo#2 we will employ netpipe-tcp or other similar software (such as MTP or Wireshark) to measure the produced latency. In Demo #3 we will measure the latency achieved at Layer 2 through our deployment of the MT-MAC on an FPGA module.
How to evaluate (relative/absolute)	Achieved results produced by the demonstrator platforms will be measured and evaluated against the ITU 5G eMBB and URLLC delay specification targets.
Scope of Measured Latency	E2E latency across multiple nodes.

Project	5G-XCast
Project KPI name	User plane E2E UL/DL latency (evaluated)
Definition of KPI	User plane latency (ms) is the contribution of the radio network to the time from when the source sends a packet to when the destination receives it [TR 37.910]. The process is formed by the packet transmission, followed by a HARQ petition and retransmission with probability p.
Context/Use case	M&E 3 (few milliseconds) Auto 1 (typical time for packet transit through the radio network below 5 milliseconds).

Enhancement work/Innovation/Enablers	The UP lantency has been evaluated for new innovative modes designed in the project for the use of multicast (Mixed Mode) and broadcast (Terrestrial Broadcast Mode) capabilities.The Mixed mode keeps latency values obtained with NR, with a minimum latency of 0.56 ms. The Terrestrial Broadcast mode introduces minimum latencies of 1.21 ms. These modes fulfill the requirement as defined for the use cases.
Where to measure (reference to the project testbed)	WP3 D3.2 (Air Interface), see section 5.2.2.
How to measure	By following an exhaustive analysis.The transmission and HARQ retransmission between UE and BS can be modelled as follows: t_UP=t_1+p(t_2+t_3) where t_1 represents the time needed to transmit from the source to the destination, t_2 is the time required for a HARQ request, t_3 is the time needed to retransmit the content.
How to evaluate (relative/absolute)	By comparing the obtained values with those defined for the specific use cases and designed modes.
Scope of Measured Latency	The analysis of our latency KPI is only User Plane and it depends on the Base station and the UE, as it is defined in the 3GPP.

Project	5G-MoNArch
Project KPI name	End-to-end Latency
Definition of KPI	The time that takes to transfer a given piece of information from a source to a destination, measured at the communication interface, from the moment it is transmitted by the source until a) the moment of successful delivery (one trip time) or b) acknowledgements are received from the receiving entity (round trip time)
Context/Use case	Smart port industrial use case & testbeds
Enhancement work/Innovation/Enablers	Resource orchestration, impact of VNF placement across network, Multi-connectivity, E2E slicing
Where to measure (reference to the project testbed)	Measurement in two testbeds (Sea port and venue of touristic interest) and 5GM PoC via analytical tool , WP5 and WP6 of 5GM
How to measure	One-trip and round-trip time. Latency is measured using ICMP over IP
How to evaluate (relative/absolute)	5 ms target, measure difference in E2E latency before and after applying 5GM enablers
Scope of Measured Latency	E2E latency across multiple nodes.

Project	5GCAR
Project KPI name	Latency
Definition of KPI	Latency is defined by ITU-R as the contribution by the radio network to the time from when the source sends a packet to when the destination receives it (typically expressed in ms). The intended layer in focus has to be indicated when the term latency is used. Unless specified otherwise, this would be the default value used. To be precise, the latency of layer-n is defined as the time from when the layer-(n+1) entity as the transmitter node requests transmission of a SDU until the SDU is delivered to the layer-(n+1) entity at the receiver node. In case an SDU is not delivered, due to transmission errors or other circumstances, the SDU is said to have infinite latency. For example, the time it takes to transmit a frame (i.e., a MAC layer SDU) from the ingress of the physical layer of node A to the egress of physical layer of node B should be specified as Physical Layer Latency of node A to node B. The Application Layer Latency, which is the time it takes to transmit an application message from the application layer of the source node to the application layer of the destination node, can also be referred to as “end-to-end

	delay" or "end-to-end latency".
Context/Use case	UC1 -Lane merge Provide trajectories for the vehicles that are on the main lane to merge smoothly into the main lane without collisions and with minimal impact on the traffic flow UC2 - See through To overcome the visibility limitation of a subject vehicle due to the occultation caused by the vehicle driving ahead by providing the driver of the subject vehicle with a direct overview of the scene in front of the vehicle driving ahead UC3 - Vulnerable Road use protection To detect the presence of vulnerable pedestrian users in proximity of a vehicle and deliver such information to the vehicle to avoid the potential collision with the help of accurate positioning technology
Enhancement work/Innovation/Enablers	Network Orchestration and Edge computing enhancements UC2 Meeting Low Latency in V2V Communication Scenarios
Where to measure (reference to the project testbed)	E2E on application layer, plus on nodes in the delivery path where the message is processed/inspected on application layer.
How to measure	By using the timestamps in the messages, and aggregating timestamped logs at a central measurement server, combined with tight clock synchronization. Complemented with dedicated measurements using artificial traffic.
How to evaluate (relative/absolute)	In a practical test in the field
Scope of Measured Latency	E2E latency across multiple nodes. From UE to application server.

Project	5G-PICTURE
Project KPI name	End-to-end data traffic time delay
Definition of KPI	Time delay for traffic originating from a data source (UE), until it reaches a data destination (Application Server at edge/core network node). We investigate the end-to-end data traffic delay achieved in a network deployment including a multi-domain, multi-technology transport network such as optical (optical ethernet flavors incl. G.metro, TSON (delivered with Flex-E, X-Etherent, Fusion products)), and wireless (mmWave, Sub-6 (delivered with IHP mmWave, Typhoon products, etc.)). We also investigate end-to-end data traffic delay achieved in special cases such as when special-purpose VNFs are introduced to support the service delivery in mobility environments (e.g. implemented via P4 OPP).
Context/Use case	Will test the 5G-PICTURE optical/wireless transport technologies to achieve e2e data plane delays of <10ms, under multiple Fronthaul/Backhaul functional splits. We will investigate performance in the following use cases namely UC1:Smart City UC2: Smart Stadium UC3: Fast train
Enhancement work/Innovation/Enablers	Key enhancements introduced in the project: 1. Time Sensitive Networking technologies (optical ethernet-based), 2. E2E slicing over optical and wireless transport domains, 3. Support of E2E slicing through a multi-domain hierahical orchestration framework/implementation4. Special purpose VNFs (exploiting P4 capabilities) to support service delivery in mobility scenarios.
Where to measure (reference to the project testbed)	With regard to Project structure: WP3 (platforms) and WP4 (network functions), WP5 (Control plane) integration activities. With regard to project demos, transport network segment and end-to-end latency will be measured: A. over the integrated multi-technology transport network in the following demo sites: Demo - UC1: Smart City pilot executed in Bristol. Demo - UC2: Smart Stadium pilot executed in Bristol

	B. over part of the multi-technology transport network, including the special purpose VNFs in: Demo - UC3: Fast train pilot executed in Barcelona.
How to measure	Round trip and single direction traffic. Exploit tools like iperf for traffic generation and ping for ICMP messaging and delay calculations. Generate multiple traffic classes of traffic from multiple source-destination pairs. At each UC addtional data traffic generation and data analysis tools will be used to measure delay if needed.
How to evaluate (relative/absolute)	Investigate traffic isolation and end-to-end latency guarantees under multitenancy on transport network segments as well as on end-to-end network deployment. Benchmark measured latencies: 1. in the fronthaul using eCPRI against plain Ethernet and single domain backhaul. 2. in the various backhaul functional splits against publiced results of other technologies. 3. in the application layer against the ITU 5G eMBB and URLLC delay specification targets.
Scope of Measured Latency	E2E latency across multiple nodes.

Project	SAT5G
Project KPI name	Latency
Definition of KPI	User to experience low latency in delivery of content that is not already in an edge cache / MEC platform.
Context/Use case	Note that there is no direct connection between the consumer UE and the satellite, the satellite link is in the backhaul. So the latency referred to here is overall delay in getting content including the delivery to the edge. Relevant use-cases are use-case (1), providing edge delivery of content and MEC software using broadcast / multicast to enhance the terrestrial links and use-case (4), moving platform backhaul.
Enhancement work/Innovation/Enablers	Integration of satellite links with CUPS to enable pre-fetching of data and broadcasting / multicasting to the network edge for storage / caching. Holding data at the base-station is the only viable way of reducing latency to the order of 1ms, because the delays in the scheduling, air interface and UE processing are already of this order. Sat5G use-cases 1 and 4 are relevant
Where to measure (reference to the project testbed)	Measure the delay between the user requesting content that is not already stored at the network edge, and the user receiving that content. The end to end path includes MEC / cache at network edge, plus a RAN of gNB and UE.
How to measure	QoE of video and data delivery, with and without satellite multicast provided.
How to evaluate (relative/absolute)	QoE and related business modelling.
Scope of Measured Latency	Latency for content delivery to user.

Project	ONE5G
Project KPI name	U-plane max E2E UL/DL latency
Definition of KPI	Two testbeds are concerned, and more specificlly for each testbed: In the AAU multi-node multi-link testbed, the performance of the studied techniques (e.g., multi-connectivity) is emulated based on live radio channel measurements using abstraction models. For example, the throughput is calculated based on estimated Signal-to-Interference plus Noise ratio (SINR) using the known Shannon formula. In that respect, also latency is not directly calculated. It can however be estimated

	based on the measured SINR. By defining a minimum SINR threshold for correct packet reception, we can indeed estimate whether an eventually transmitted packet would be correctly received or not. In case the packet is not correctly received, it will need to be retransmitted with a predefined temporization defined in the 5G NR standard. This will increase the latency. In other terms, the component involved in the potential definition of the latency is the estimated SINR at a receiving node, since this will determine whether retransmissions are needed, and such retransmissions lead to a latency increase. Concerning b<>com testbed, definition of latency is quite simple since it is time that takes to transfer a given piece of information from one 5G layer to another layer.
Context/Use case	UC1 – Assisted, cooperative and tele-operated driving / UC2 – Time-critical factory processes and logitics optimizaton (industry and smart airports)
Enhancement work/Innovation/Enablers	HW processing: Reduce the latency of the physical layer by use of hardware rather than software processing.- AAU testbed : enhanced HARQ retransmission techniques, usage of advanced receivers, and multi-connectivity techniques.- b-com testbed : per block optimization that permits overall latency reduction.- Bit level processing- Modulation and Demodulation- Mapping/Precoding- Channel Estimation & Equalization- FFT & IFFT- Resource mapping / de-mapping- Rx and Tx front ends
Where to measure (reference to the project testbed)	Wireless MES / PLC : ONE5G PoC#1: Aalborg University testbed HW processing: ONE5G PoC#2: BCOM testbed: At the physical layer level by analysing output logs produced during processing.
How to measure	Wireless MES / PLC: Transmission delay between control packets transmitted by Programmable Logic Controllers (PLCs) and workstations control modules to MES controller, or PLCs to actuatorsHW processing: Time passed in each processing steps/functions will be measured. We'll use a kind of '.VCD' log file containing timestamps and processing status.We have instead used a different testbed based on real LTE and WiFi commercial equipment. In particular, we have analyzed the performance of a joint multi-connectivity solutions which included both LTE and WiFi simultaneously. In this case, the latency is calculated on the transmitted packets, as the interval of time between their transmission and the reception at IP level.
How to evaluate (relative/absolute)	Wireless MES / PLC: Measured transmission delay over a wireless network to be compared with wired solutions, e.g. Gigabit Ethernet. HW processing: Output files will be compared to check that latency has been decreased when using hardware rather than software processing blocks.
Scope of Measured Latency	E2E latency

Project	NGPaaS
Project KPI name	Latency of decoding using FPGA framework
Definition of KPI	The latency addressed refers more particularly to the decoding time using FPGA framework in NGPaaS for the case study on a DVB-RCS2 decoder.
Context/Use case	A combined Telco-Broadcasting PaaS system on the cloud where a DVB-S2 player is able to bring its own components and integrate them with the connectivity services deployed on the PaaS by a Telco operator.
Enhancement work/Innovation/Enablers	FPGA acceleration of microservices as a telco grade enhancement.
Where to measure (reference to the project testbed)	5G PaaS pilot of NGPaaS, which consists of actual UE, RAN components and applications.

How to measure	The KPI will be measured by counting the decoding time of turbo decoder with different size of code block.
How to evaluate (relative/absolute)	The KPI evaluation will be done by comparing the latency of a software implementation of a decoder using SSE optimised CPU against the latency of a FPGA accelerated turbo decoder.
Scope of Measured Latency	Partial latency. (Decoding latency)

Project	NGPaaS
Project KPI name	Latency on RAN Service running on Kubernetes
Definition of KPI	The latency means the latency of packets sent from a client to a server based on the RAN Service running on top of Kubernetes with NUMA aware CPU pinning.
Context/Use case	5G PaaS connectivity service using Kubernetes, which is a prominent candidate for an efficient container-based VNF management and orchestration.
Enhancement work/Innovation/Enablers	NUMA aware CPU pinning of Kubernetes as a telco grade enhancement.
Where to measure (reference to the project testbed)	5G PaaS pilot of NGPaaS, which consists of actual UE, RAN components and applications.
How to measure	Network tools will be used to accurately measure the latency of a user flow. The CPU load of the server hosting the RAN components (RCC, RRU) will be progressively increased to measure its influence over quality of 5G PaaS connectivity service.
How to evaluate (relative/absolute)	The KPI evaluation will be done by comparing the latency using Kubernetes with NUMA aware CPU Pinning, CPU pinning and without any CPU Pinning.
Scope of Measured Latency	E2E latency. From UE to a server.

Project	5GCity
Project KPI name	Data Plane Delay
Definition of KPI	Time that takes to transfer a given piece of information in the data plane from a source to a destination, from the moment it is transmitted by the source to the moment it is successfully received at the destination. Multiple intermediate measurement points and delay measurements are identified: a) UE - Edge computing instance b) Edge - core data center network c) [end-to-end] UE - application server
Context/Use case	UC3 - Video Acquisition and Production (pilot facilities in Barcelona-ES & Bristol-UK) – for the synchronization of the production process based on acquired streamsUC4 - UHD Video Distribution & Immersive Services (pilot facilities in Lucca-IT & Bristol-UK) – for the immersive application componentsUC5 - Mobile Backpack Unit for Real-time Transmission (pilot facility in Barcelona-ES) – for the synchronization of the back-office production process based on transmitted streamsUC6 - Cooperative, Connected and Automated Mobility (pilot facility in Barcelona-ES) – all scenarios of CCAM being it an URLLC use case
Enhancement work/Innovation/Enablers	Resource orchestration and allocation to optimize network and application latency Functional split of the application core functions and distribution across the core and edge section of the 5GCity infrastructure See Deliverable D4.1 for details (https://zenodo.org/record/2558306#.XOFpN8gzaUk)
Where to measure (reference	Measurement in the three city pilots in Barcelona (ES), Bristol (UK), Lucca

to the project testbed)	(IT) (see D5.1, https://zenodo.org/record/2574001#.XOFo0MgzaUm)
How to measure	Repeated ICMP over IP between UE and the application server. At UE and at Application Server for e2e delay Intermediate RTD measures can be also retrieved for the intermediate network sections
How to evaluate (relative/absolute)	UC3 target e2e latency < 5s UC4 target e2e latency < 10ms UC5 target e2e latency < 1s UC6 target e2e latency < 1ms
Scope of Measured Latency	E2E latency across multiple nodes. From UE to application server.

Project	5GCity
Project KPI name	Control Plane Delay
Definition of KPI	Latency between components of the 5GCity platform Multiple intermediate measurement points and delay measurements are identified: a) 5GCity dashboard - Slice orchestrator (inlcudes MTO, multi-tier orchestrator, and RAN controller) b) MTO - Edge computing VIM instance c) MTO - Data center VIM instance d) RAN Controller - eNB/ Small Cell on lamppost e) RAN Controller - WiFi AP on lamppost
Context/Use case	UC2 - Neutral Host (pilot facilities in Barcelona-ES, Lucca-IT & Bristol-UK)UC4 - UHD Video Distribution & Immersive Services (pilot facilities in Lucca-IT & Bristol-UK) – for the immersive application componentsUC6 - Cooperative, Connected and Automated Mobility (pilot facility in Barcelona-ES) – all scenarios of CCAM being it an URLLC use case
Enhancement work/Innovation/Enablers	Resource orchestration and allocation to optimize network and application latency Functional split of the application core functions and distribution across the core and edge section of the 5GCity infrastructure See Deliverable D4.1 for details (https://zenodo.org/record/2558306#.XOFpN8gzaUk)
Where to measure (reference to the project testbed)	Measurement in the three city pilots in Barcelona (ES), Bristol (UK), Lucca (IT), specifically among the components of the 5GCity platform (see D4.1, https://zenodo.org/record/2558306#.XOFpN8gzaUk)
How to measure	ICMP over IP between admin requesting a control plane action and the 5GCity dashboard/orchestrator Parse timestamped logs of the 5GCity platform components software modules
How to evaluate (relative/absolute)	<20ms
Scope of Measured Latency	E2E latency across multiple nodes and software components

Project	MATILDA
Project KPI name	End to End latency
Definition of KPI	Packet round-trip time (RTT) between two endpoints. Measurement reference packet should be sent and its response must be received by the same UE device.
Context/Use case	Emergency communications and Media Demonstrators. Need to achieve specific QoS needs.
Enhancement work/Innovation/Enablers	Monitoring probes supported by the MATILDA Orchestrator. Implementation of QMON end to end QoS monitoring software as a VNF.
Where to measure (reference	Mainly in the testbeds in Cnit, Genoa and University of Bristol.

to the project testbed)	
How to measure	Usage of MATILDA monitoring mechanisms and QMON as a VNF.
How to evaluate (relative/absolute)	Based on extensive tests, measurements and evaluation
Scope of Measured Latency	E2E latency

Project	MATILDA
Project KPI name	Delay
Definition of KPI	One way delay among two endpoints
Context/Use case	Emergency communications and Media Demonstrators. Need to achieve specific QoS needs.
Enhancement work/Innovation/Enablers	Monitoring probes supported by the MATILDA Orchestrator. Implementation of QMON end to end QoS monitoring software as a VNF.
Where to measure (reference to the project testbed)	Mainly in the testbeds in Cnit, Genoa and University of Bristol.
How to measure	Usage of MATILDA monitoring mechanisms and QMON as a VNF.
How to evaluate (relative/absolute)	Based on extensive tests, measurements and evaluation
Scope of Measured Latency	Delay

Project	IoRL
Project KPI name	End to End latency
Definition of KPI	The latency means the latency of packets sent from a UE to another UE or terminal based on the RAN Service running on top of IoRL platform.
Context/Use case	IoRL connectivity service using container-based VNF management and orchestration.
Enhancement work/Innovation/Enablers	The using of optimized L1/L2/L3 server will reduce the air interface latency to less than 1ms
Where to measure (reference to the project testbed)	In UE of IoRL
How to measure	Network tools will be used to accurately measure the latency of a user flow. The CPU load of the server hosting the RAN components will be progressively increased to measure its influence over quality of IoRL connectivity service.
How to evaluate (relative/absolute)	The KPI evaluation will be done by comparing the latency using SDN and L2/L3 server CPU optimisation.
Scope of Measured Latency	E2E latency across multiple nodes.

Project	IoRL
Project KPI name	End to End latency
Definition of KPI	The latency means the latency of packets sent from a UE to another UE or terminal based on the RAN Service running on top of IoRL platform.
Context/Use case	IoRL connectivity service using container-based VNF management and orchestration.
Enhancement work/Innovation/Enablers	The using of optimized L1/L2/L3 server will reduce the air interface latency to less than 1ms
Where to measure (reference to the project testbed)	In UE of IoRL
How to measure	Network tools will be used to accurately measure the latency of a user flow. The CPU load of the server hosting the RAN components will be progressively increased to measure its influence over quality of IoRL

	connectivity service.
How to evaluate (relative/absolute)	The KPI evaluation will be done by comparing the latency using SDN and L2/L3 server CPU optimisation.
Scope of Measured Latency	E2E latency across multiple nodes.

Project	5GTANGO
Project KPI name	End-to-end latency
Definition of KPI	Maximum tolerable elapsed time from the instant a data packet is generated at the source application to the instant it is received by the destination application
Context/Use case	the Immersive Media pilot and the Communications pilot have end-to-end latency requirements that the overall solution has to support.
Enhancement work/Innovation/Enablers	The impact on the different assets 5GTANGO produces is on the support they give into a solution covering the services requirements: to achieve a latency lower than 100ms. Services that need such low latency express the need to be deployed at one of the PoPs that is close to the consumer of that data (the Edge).
Where to measure (reference to the project testbed)	Measurements must occur at the end-user side
How to measure	measure this KPI during the testing phase, by using the Validation and Verification (V&V) platform, and then extrapolate the obtained values into production-level hardware values.
How to evaluate (relative/absolute)	Deploy the NS, stimulate it with a data source of varying capabilities and collect results. The evaluation strongly depends on the particular service
Scope of Measured Latency	E2E latency across multiple nodes.

Project	NRG-5
Project KPI name	Communication Latency
Definition of KPI	The communication latency KPI refers either to the (round-trip) time for a data packet generated at the UE to reach its destination endpoint.
Context/Use case	UC2: Enabling aerial Predictive Maintenance for utility infrastructure- Drone remote controlUC3: Enabling resilience and high availability via Dispatchable Demand Response- Control of electricity rerouting at substation
Enhancement work/Innovation/Enablers	Orchestration and optimized placement of service specific VNF to the edge devices (MEC) close to the UE. Mobility tracking to anticipate logic handover.
Where to measure (reference to the project testbed)	Both at NRG-5 UEs and VNF
How to measure	By using synchronization techniques (e.g., GPS) at both the communication endpoints and computing the latency at L2/L3
How to evaluate (relative/absolute)	By comparing different VNF placement options (e.g., remote data centre, local MEC) under different network topologies
Scope of Measured Latency	E2E latency

Project	5G TRANSFORMER
Project KPI name	End to End Latency
Definition of KPI	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 another device. E2E latencies of 5G-Transformer vertical services are impacted by the

	latency at the air interface, latencies in the transport network as well as processing latencies themselves.
Context/Use case	Application/Automotive, Application/Entertainment, Application/eHealth, Application/eIndustry
Enhancement work/Innovation/Enablers	5G-TRANSFORMER platform has placement algorithms to deploy the resources at the edge of the network, ensuring the availability and reducing significantly the end to end latency of the network
Where to measure (reference to the project testbed)	Measurement will be done in 5Tonic Lab for Entertainment, eHealth and eIndustry UCs. For Automotive it will be done in 5Tonic, ARNO and CTTC testbeds.
How to measure	Passive probing: measuring the whole service workflow (e.g., for automotive the time elapsing between when a CAM message is sent and a DENM message is received is measured, eHealth); in Entertainment the application latency is measured (i.e., the time between the video chunk request and the reception of the video chunk). Active probing (e.g., ping e-Industry).
How to evaluate (relative/absolute)	Passive probing by exploiting application packet ID. Comparison with benchmark/former solutions. Definition harmonization. Identification of common reference points (e.g., application packet, TCP, UDP, IP, etc.)
Scope of Measured Latency	E2E latency across multiple nodes.

Project	5G-MEDIA
Project KPI name	End-to-end latency
Definition of KPI	Maximum tolerable elapsed time from the instant a data packet is generated at the source application to the instant it is received by the destination application. With focus on infrastructure, this includes the time needed for uplink, any necessary routing in the infrastructure, and downlink.
Context/Use case	Use Case 1: Immersive Media
Enhancement work/Innovation/Enablers	Cognitive network optimization, MAPE component that will optimize the transcoding in real-time to reduce latency
Where to measure (reference to the project testbed)	end-to-end propagation time between the media client and the source of the media stream
How to measure	using OTE's ixchariot measuring tools to retrieve accurate in-network measurements. (alternatively, we can develop new components to measure them by co-hosting a dummy consumer application with the producer)
How to evaluate (relative/absolute)	Absolute evaluation would entail comparison and benchmarking of the latency by comparing it against acceptable latencies for human reaction and communication (e.g. HCI and verbal communication).
Scope of Measured Latency	The scope will be so that we can get a relation of the round trip delay to the QoS and perceived QoE by the end user and spectator

Project	SLICENET
Project KPI name	Low latency communication
Definition of KPI	End-to-end between service execution point and source or sink of information at the physical end point
Context/Use case	Smart Grid UC: <= 10 ms (IEC 61850 GOOSE), <= 5 ms (SV) e-Health UC: 30-100 ms smart city UC: second to hours
Enhancement work/Innovation/Enablers	
Where to measure (reference to	Individually measured across each network segment and aggregation

the project testbed)	of measurements
How to measure	
How to evaluate (relative/absolute)	Through measurements
Scope of Measured Latency	E2E latency

3 Service creation time

In the period, most of 5G PPP phase 2 projects have worked towards the consolidation of a framework for definition of measurement approaches to Service Creation Time KPI.

With particular focus on the programmatic KPI related to Service Creation Time, a joint work has been started by a number of projects aimed at identifying commonalities of approaches and measurement scenarios, potential gaps to be filled and opportunities for convergence towards common definitions and alignment on measurement methodologies.

More specifically, the projects participating to this activity are: 5G ESSENCE, 5G TRANSFORMER, 5GCity, 5G-MEDIA, 5G-MoNArch, 5G-PICTURE, 5GTANGO, blueSPACE, MATILDA, SLICENET, IoRL, METRO-HAUL, 5GPaaS, SAT5G.

Each project has specified

- *Where to measure*, with reference to the project testbed and the specific elements of the platforms where time it tracked
- *How to measure*, i.e. the specific measurement intended to be implemented
- *How to evaluate*, i.e. the quantitative target of the measure, expressed as relative or absolute value to allow a more objective evaluation of the achieved improvement.

Based on the various definitions expressed by the each project participating to the study, it emerged a first need for a more complete definition of what "Creation & Activation Time KPI" should include, in order to cover with proper measurements various elements of the different orchestration workflows and deployment scenarios: for example, platform preparations in case of Platform as a Service (PaaS) scenarios, network slices, network services, VNFs, optical point to point connections, satellite backhaul services, etc.)

Each project has defined specific target metrics and related measurements, coherent with the research carried out in their workplan.

In the attempt to identify the various phases of service creation, the group has developed a reference timing flow into which each project has more specifically declared the intended contributions with innovation assets across the various phases of onboarding, activation, modification and termination for the different constructs (network slices, network services, virtual network functions, MEC applications, service chains, WAN, etc.).

The timing reference is provided in the table below.

Creation & Activation Time	
Phase 0. Platform Provision	
Time components	**Measurement Conditions**
Platform configuration	*Tstart = Start action of platform configuration* *Tend = Platform configuration completed*
Platform deployment	*Tstart = Request for platform deployment received in the system (e.g. request to deploy Cord in a Box via use of pre-packaged VM)* *Tend = Platform fully deployed available for operations*
Phase 1. Onboarding	
Time components	**Measurement Conditions**
Network Slice Template (NEST)	*Tstart = Request for onboard received in the system* *Tend = NEST fully onboarded in all the catalogues and available for LCM actions*
Network Service Descriptor	*Tstart = Request for onboard received in the system*

(NSD)	*Tend = NSD fully onboarded in all the catalogues and available for LCM actions*
VNF package (VNFD)	*Tstart = Request for onboard received in the system* *Tend = VND fully onboarded in all the catalogues and available for LCM actions*
MEC Application Descriptor (MEC AppD)	*Tstart = Request for onboard received in the system* *Tend = APpD fully onboarded in all the catalogues and available for LCM actions*
Other applications	*Tstart = Request for onboard received in the system* *Tend = Application fully onboarded in all the catalogues and available for LCM actions*
Phase 2. Instantiate, Configure & Activate	
Time components	**Measurement Conditions**
Instantiate Network Slice (NSI)	Tstart = Request for instantiate received in the system Tend = NSI fully instantiated, 'alive' and functional and available for monitoring actions
Instantiate & Activate Network Service (NS)	Tstart = Request for instantiate received in the system Tend = NS fully instantiated, 'alive' and functional and service performance (QoS) metrics meeting or exceeding the target performance (Ps) of the Network Service. Measure the service performance (QoS) metrics periodically (recommended once every 100 ms)
Instantiate & Configure VNFs in service chain (VNF)	Tstart = Request for instantiate logged in the system Tend = VNF fully instantiated, configuration complete, VNF 'alive' and functional
Instantiate & Configure MEC Application (MEC App)	Tstart = Request for instantiate logged in the system Tend = MEC App fully instantiated, configuration complete, 'alive' and functional
Instantiate & Configure other applications	Tstart = Request for instantiate logged in the system Tend = Other app fully instantiated, configuration complete, 'alive' and functional
Configure other NFVI elements	Tstart = Request for any other NFVI related configuration logged in the system (e.g. HW acceleration, fast-paths, private networks, gateways, etc.) Tend = NFVI configuration complete, 'alive' and functional
Configure SDN infrastructure	Tstart = Request for any SDN related configuration logged in the system Tend = SDN configuration complete, 'alive' and functional
Configure Optical WAN	Tstart = Request for Optical p2p circuit configuration logged in the system Tend = Optical p2p Circuit configuration complete, service 'alive' and functional
Configure satellite backhaul	Tstart = Request for Satellite link configuration logged in the system Tend = Satellite link configuration complete, service 'alive' and functional

Phase 3. Modify	
Time components	**Measurement Conditions**
Modify Network Slice configuration	Tstart = Request for modify received in the system Tend = NSI configuration modified and functional
Modify Network Service configuration	Tstart = Request for modify received in the system Tend = NS configuration modified and functional and service performance (QoS) metrics meeting or exceeding the target performance (Ps) of the Network Service. Measure the service performance (QoS) metrics periodically (recommended once every 100 ms)
Detect scale out/in decision	Tstart = Scale out/in condition generated in the system Tend = Scale out/int decision detected and trigger to scale (warning or autoscale action) issued
Implement manual scale out/in	Tstart = Request for manual scale out/in logged in the system Tend = Service scale out/in completed and service functional
Implement autoscale out/in	Tstart = Autoscale request logged in the system Tend = Service scale out/in completed and service functional
Modify VNF configuration in service chain	Tstart = Request for modify logged in the system Tend = VNF configuration modified and functional
Modify MEC App configuration	Tstart = Request for modify logged in the system Tend = MEC App configuration modified and functional
Modify configuration of other applications	Tstart = Request for modify logged in the system Tend = Other app configuration modified and functional
Modify configuration of other NFVI elements	Tstart = Request for modification of any other NFVI related configuration logged in the system (e.g. HW acceleration, fast-paths, private networks, gateways, etc.) Tend = NFVI re-configuration complete, 'alive' and functional
Modify configuration of SDN infrastructure	Tstart = Request for modification of any SDN related configuration logged in the system Tend = SDN re-configuration complete, 'alive' and functional
Modify Optical WAN circuit	Tstart = Request for modification of optical p2p circuit logged in the system Tend = Optical p2p Circuit re-configuration complete, service 'alive' and functional
Modify satellite backhaul configuration	Tstart = Request for modification of Satellite link logged in the system Tend = Satellite link re-configuration complete, service 'alive' and functional
Phase 4. Terminate	
Time components	**Measurement Conditions**
Terminate Network Slice (NSI)	Tstart = Request for termination received in the system Tend = NSI fully terminated

Terminate Network Service (NS)	Tstart = Request for termination received in the system Tend = NS fully terminated
Terminate VNFs in service chain (VNF)	Tstart = Request for termination received in the system Tend = VNFs fully terminated
Terminate MEC Application (MEC App)	Tstart = Request for termination received in the system Tend = MEC App fully terminated
Terminate other applications	Tstart = Request for termination received in the system Tend = Other app instances fully terminated
Remove configuration of other NFVI elements	Tstart = Request for removing any other NFVI related configuration logged in the system (e.g. HW acceleration, fast-paths, private networks, gateways, etc.) Tend = NFVI configuration complete
Remove configuration from SDN infrastructure	Tstart = Request for removing any SDN related configuration logged in the system Tend = SDN configuration complete
Terminate Optical WAN circuit	Tstart = Request for Optical p2p circuit termination logged in the system Tend = Optical p2p Circuit terminated
Terminate satellite backhaul circuit	Tstart = Request for Satellite link termination logged in the system Tend = Satellite link terminated

The group has set an ultimate goal of the activity the editing of a joint publication in which to give evidence of the progress done at group and program level. This publication is planned for the second semester of 2019.

The status of the work of the ad-hoc team on Service Creation Time is reported in the following tables. It shows that a significant number of projects identified areas of measurement of creation time and are expected to produce and share their results to assess the obtained benefits with respect to the programmatic target to shorten creation times from hours to minutes.

Phase 0. Platform Provision											
Time components	**5G TRANSFORMER**	**5G-MEDIA**	**5G-MoNArch**	**blueSPACE**	**SLICENET**	**5G ESSENCE**	**5GCity**	**5G-PICTURE**	**5GTANGO**	**MATILDA**	**NGPaaS**
Platform configuration										Y	
Platform deployment		Y								Y	Y

Phase 1. Onboarding											
Time components	**5G TRANSFORMER**	**5G-MEDIA**	**5G-MoNArch**	**blueSPACE**	**SLICENET**	**5G ESSENCE**	**5GCity**	**5G-PICTURE**	**5GTANGO**	**MATILDA**	**NGPaaS**
Network Slice Template (NEST)			Y						Y	Y	
Network Service Descriptor (NSD)	Y	Y	Y	Y		Y	Y		Y	Y	
VNF package (VNFD)	Y	Y	Y	Y		Y	Y		Y	Y	Y
MEC Application Descriptor (MEC AppD)	Y			Y			Y			Y	
Other applications			Y	Y					Y	Y	

Phase 2. Instantiate, Configure & Activate											
Time components	**5G TRANSFORMER**	**5G-MEDIA**	**5G-MoNArch**	**blueSPACE**	**SLICENET**	**5G ESSENCE**	**5GCity**	**5G-PICTURE**	**5GTANGO**	**MATILDA**	**NGPaaS**
Instantiate Network Slice (NSI)	Y		Y	Y	Y		Y	Y	Y	Y	Y
Instantiate & Activate Network Service (NS)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	
Instantiate & Configure VNFs in service chain (VNF)	Y	Y	Y	Y	Y	Y	Y		Y	Y	
Instantiate & Configure MEC Application (MEC App)	Y			Y	Y		Y			Y	
Instantiate & Configure other applications			Y	Y	Y				Y	Y	
Configure other NFVI elements	Y	Y	Y	Y	Y	Y	Y		Y	Y	
Configure SDN infrastructure	Y		Y	Y	Y	Y	Y	Y	Y	Y	Y
Configure Optical WAN	Y			Y	Y			Y	Y		

Phase 3. Modify											
Time components	**5G TRANSFORMER**	**5G-MEDIA**	**5G-MoNArch**	**blueSPACE**	**SLICENET**	**5G ESSENCE**	**5GCity**	**5G-PICTURE**	**5GTANGO**	**MATILDA**	**NGPaaS**
Modify Network Slice configuration			Y						Y	Y	
Modify Network Service configuration		Y	Y			Y		Y	Y	Y	
Detect scale out/in decision	Y	Y	Y	Y					Y	Y	
Implement manual scale out/in	Y	Y	Y	Y				Y	Y	Y	
Implement autoscale out/in	Y	Y	Y	Y					Y	Y	
Modify VNF configuration in service chain		Y	Y	Y		Y			Y	Y	
Modify MEC App configuration				Y						Y	
Modify configuration of other applications			Y	Y					Y	Y	
Modify configuration of other NFVI elements			Y	Y		Y					
Modify configuration	Y					Y		Y	Y	Y	

of SDN infrastructure											
Modify Optical WAN circuit	Y							Y	Y		

Phase 4. Terminate											
Time components	5G TRANSFORMER	5G-MEDIA	5G-MoNArch	blueSPACE	SLICENET	5G ESSENCE	5GCity	5G-PICTURE	5GTANGO	MATILDA	NGPaaS
Terminate Network Slice (NSI)	Y			Y			Y	Y	Y	Y	
Terminate Network Service (NS)	Y	Y		Y		Y	Y	Y	Y	Y	
Terminate VNFs in service chain (VNF)	Y	Y		Y		Y	Y		Y	Y	Y
Terminate MEC Application (MEC App)	Y			Y			Y			Y	
Terminate other applications				Y					Y	Y	
Remove configuration of other NFVI elements				Y		Y					
Remove configuration from SDN infrastructure	Y			Y		Y	Y	Y	Y	Y	

Terminate WAN circuit	**Optical**	**Y**		**Y**			**Y**	**Y**		

4 Programme related project KPI definitions

4.1 P1 – Providing 1000 times higher wireless area capacity and more varied service capabilities compared to 2010.

4.1.1 Data rate

Project	5GCAR
Which KPI	Data rate
Definition of KPI	Data rate is the number of bits sent per unit of time, typically measured in bit/s. For the transmission of a single SDU, this is given as (Service data unit size)/(Latency requirement). For a stream of SDUs that arrive with a rate R SDUs/s, then the average data rate is $R \times$(Service data unit size).
Context/Use case	Data rate KPI of any of the 3 use cases that will be demonstrated
Enhancement work	Adaptive and Robust Beam Management in mmWave Spectrum Bands
Where to measure	In the radio level by measuring how many MB/s can be supported
How to measure	With a network system simulation
How to evaluate	Changing the number of UEs and / or changing the traffic density

4.1.2 User Experienced Data Rate

Project	5GCity
Which KPI	User Experienced Data Rate
Definition of KPI	Minimum data rate required to achieve a sufficient quality experience. No broadcast scenarios are considered, just unicast Ref. 3GPP TS 22.261 V16.5.0
Context/Use case	UC1 - Unauthorized Waste Dumping Prevention (pilot facility in Lucca-IT) UC3 - Video Acquisition and Production (pilot facilities in Barcelona-ES & Bristol-UK) UC4 - UHD Video Distribution & Immersive Services (pilot facilities in Lucca-IT & Bristol-UK) UC5 - Mobile Backpack Unit for Real-time Transmission (pilot facility in Barcelona-ES) UC6 - Cooperative, Connected and Automated Mobility (pilot facility in Barcelona-ES)
Enhancement work	Guarantee bandwidth in the network slice across various fixed/wireless technologies Guarantee traffic isolation among different network slices
Where to measure	Measure throughput at application server, monitor bandwidth at intermediate routing interfaces
How to measure	Monitor uplink bandwidth when a single UE generates traffic towards the application server
How to evaluate	UC1 target User Experienced Data Rate: 4-10 Mbps per camera UC3 target User Experienced Data Rate: 2-8 Mbps per mobile device UC4 target User Experienced Data Rate: 4-10 Mbps per HD, UHD 4K and Video 360 UC5 target User Experienced Data Rate > 8Mbps per camera for a HD transmission UC6 target User Experienced Data Rate: up to 1Gbps per lamp-post

4.1.3 User experienced Data Rate

Project	5G-MonArch
Which KPI	User experienced Data Rate
Definition of KPI	The achievable data rate that is available ubiquitously across the coverage area to a mobile user/device (in bps). Related to the minimum data rate required to achieve a sufficient quality experience (dependent on the selected service type)
Context/Use case	Reliability of QoS for different services, in an industrial setting (smart sea port) and temporary very high demand hotspots use cases
Enhancement work	Resource orchestration, Inter-slice control and resource elasticity enablers, slice

	isolation
Where to measure	5GM PoC via MxArt network level simulator in WP6 of 5GM
How to measure	Impact of MCS selection in VNF elasticity approach
How to evaluate	Measure difference in UE Data Rate before and after applying 5GM enablers, compare measured values against the service requirements showing an improvement in meeting those service requirements more reliably.

4.1.4 User experienced Data Rate

Project	5G-XCast
Which KPI	User experienced data rate (future work)
Definition of KPI	User experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time.
Context/Use case	M&E1 #23 – eMBB: 50Mb/s
Enhancement work	Main enhancements compared to LTE to improve user data rate are the use of MIMO for PTM, improved layer 1 and possibly layer 2 FEC schemes and advanced receivers and increased bandwidth.
Where to measure	WP3 D3.4 (RAN protocols)
How to measure	System level simulation
How to evaluate	Following system level simulation methodology of ITU-R M.2412-0 in indoor, urban and rural scenarios. For a single frequency band it can be analytically computed as a product of the 5th percentile user spectral efficiency and the channel bandwidth.

4.1.5 User experienced data rate on RAN service running on Kubernetes

Project	NGPaaS
Which KPI	User experienced data rate on RAN service running on Kubernetes
Definition of KPI	The user experience data rate means the throughput between a client and a server based on the RAN Service running on top of Kubernetes with NUMA aware CPU pinning.
Context/Use case	5G PaaS connectivity service using Kubernetes, which is a prominent candidate for an efficient container-based VNF management and orchestration.
Enhancement work	NUMA aware CPU pinning of Kubernetes as a telco grade enhancement.
Where to measure	5G PaaS PoC in WP5 of NGPaaS
How to measure	Network tools will be used to accurately measure the throughput of a user flow. The CPU load of the server hosting the RAN components (RCC, RRU) will be progressively increased to measure its influence over quality of 5G PaaS connectivity service.
How to evaluate	The KPI evaluation will be done by comparing the throughput using Kubernetes with NUMA aware CPU Pinning, CPU pinning and without any CPU Pinning.

4.1.6 User Data Rate

Project	5G TRANSFORMER
Which KPI	User Data Rate
Definition of KPI	Application bit rate
Context/Use case	Application level/Entertainment
Enhancement work	As for E2E latency
Where to measure	Entertainment
How to measure	Measure application data rate: The data rate of the video chunks as received a the video player in the user equipment.
How to evaluate	Comparison with benchmark/former solutions. Identification of common reference

	points (e.g., application packet, TCP, UDP, IP, etc.)

4.1.7 User data rate

Project	IoRL
Which KPI	User data rate
Definition of KPI	The user data rate means the throughput between a client and a server based on the RAN Service running on top of SDN platform with CPU optimisation.
Context/Use case	IoRL connectivity service using efficient VNF management and orchestration
Enhancement work	The using mmWave is to provide large user data rate
Where to measure	In SDN
How to measure	Network tools will be used to accurately measure the volume of a user flow. The CPU load of the server hosting the RAN components will be progressively increased to measure its influence over quality of IoRL connectivity service.
How to evaluate	The KPI evaluation will be done by comparing the data volume using SDN and L2/L3 server CPU optimisation.

4.1.8 User Data Rate

Project	MATILDA
Which KPI	User Data Rate
Definition of KPI	Minimum provided user data rate: ~10 Mbps/user
Context/Use case	Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE)
Enhancement work	Provide high-valued video services during
Where to measure	Bristol testbed
How to measure	Quality of Service/Experience Tests
How to evaluate	Expected level of Quality of Experience of the provided video applications

4.1.9 UE experienced Data rate

Project	ONE5G
Which KPI	UE experienced data rate
Definition of KPI	User experienced data rate is the 5% point of the cumulative distribution function (CDF) of the user throughput. User throughput (during active time) is defined as the number of correctly received bits, i.e. the number of bits contained in the service data units (SDUs) delivered to Layer 3, over a certain period of time. (ITU-R M.2410-0 (11/2017)) Additionally to Layer 3, the throughput and the QoE associated to it is considered at application layer and for different services (e.g. FTP, web browsing).
Context/Use case	UC5 – Outdoor hotspots and smart offices with AR/VR and media applications
Enhancement work	Massive MIMO: Possibility to serve more users with low bit error rate; better spectrum efficiency QoE-aware optimization : Developed QoE- aware optimization mechanisms improve the UE service-performance by balancing the traffic demand between different cells of the network. This is achieved by monitoring the service experienced by the UEs and modifying handover and transmission power parameters in the cells.
Where to measure	Massive MIMO in ONE5G PoC#3: Physical layer transmission with HHI hardware in the loop testbed. QoE-aware optimization in ONE5G PoC#2: University of Malaga full indoor LTE network testbed
How to measure	Massive MIMO:Each user transmits simultaneously a mixed OFDM and root-raised-cosine filtered BPSK signal. After receive filtering, the erroneous bits are determined by a comparison with the transmitted signal. QoE-aware optimization: Drive test terminals are used to measured the L3 throughput. By specific software tools different services are executed and the KPI can be also measured at application-layer.
How to evaluate	Massive MIMO : Error rate with different number of single-antenna UEs and receive

	antennas at the BS. QoE-aware optimization: The KPI will be evaluated in different situations (UE locations, movements and services) and in comparison to the case without optimization and/or with previous baseline algorithms.

4.1.10 Guaranteed user data rate

Project	5G-MEDIA
Which KPI	Guaranteed user data rate
Definition of KPI	Guaranteed bit rate for the application to function correctly. It corresponds to the user experienced data rate as defined by ITU.
Context/Use case	Use Case 1: Immersive Media Use Case 2: Mobile Contribution, Remote and Smart Production in Broadcasting Use Case 3: Ultra-high Definition (UHD) over Content Distribution Networks
Enhancement work	• UC1: DL >= 25 Mbit/s, UL >= 25 Mbit/s • UC2: DL >= 200 Mbit/s, UL >= 50 Mbit/s • UC3: DL >= 200 Mbit/s (at least 10-15 flows in parallel at 15 Mbit/s), UL >= 50 Mbit/s
Where to measure	
How to measure	
How to evaluate	As measured by each receiving client (downlink). In addition, the production data rate (uplink) will also be measured, as well as the transcoding data rates.

4.1.11 Guaranteed user data rate

Project	5G-PICTURE
Which KPI	Guaranteed user data rate
Definition of KPI	The end-to-end throughput that can be guaranteed for specific traffic classes.
Context/Use case	In the LTE network an EPS bearer, having a GBR resource type means the bandwidth of the bearer is guaranteed. For the mobile network part (Dissagregated-RAN and Core) we respect the GBR approach and we investigate novel ways to provide throughput guarantees over an integrated transport network. Use cases addressed by the project: Use Case #1 - Smart City Use Case #2 - Stadium Use Case #3 – Railway
Enhancement work	In packet level networking traditional ways to provide data rate guarantees rely on WFQ with token buckets. The project advances state of the art research by investigated the following key technologies that can be used to provide service guarantees by means of throughput Flex-E, X-Ethernet, OPP, Fusion, TSON.
Where to measure	Use Case Demonstrator #1 - Smart City: at a smart city environment available in the 5GUK testbed in Bristol, UK, using a VR application requiring high guaranteed user data rate. Use Case Demonstrator #2: at a City Stadium facility in Bristol, UK.
How to measure	Traditional Network monitoring tools will be used to measure the guaranteed user data rates.
How to evaluate	Achieved data rates will be compared with the relevant values requested depending on the use case.

4.1.12 Guaranteed user data rate

Project	5GTANGO
Which KPI	Guaranteed user data rate
Definition of KPI	Minimum bit rate as experienced by the user for the application to function correctly in varying circumstances
Context/Use case	Two of the 5GTANGO pilots, the Immersive Media pilot and the Communications pilot have throughput data rates that the overall solution has to support (throughput of at

	least 10Mbps, usually between 50 and 100Mbps).
Enhancement work	the impact on the different assets to be produced by the project is mainly to give them the necessary capabilities to allow the usage of an infrastructure that supports the achievement of such a value for this KPI. More specifically, services that have special needs in terms of throughput state those requirements in the NS descriptors and the placement mechanisms find Points-of-Presence (PoPs) with adequate support (e.g., SR-IOV) for such demands.
Where to measure	Measurements must occur at the end-user side
How to measure	We plan to measure these KPIs during the Validation and Verification (V&V) of several services, by using our V&V platform, and then extrapolate the obtained values into production-level hardware values.
How to evaluate	Deploy the NS, stimulate it with a data source of varying capabilities and collect results. The evaluation strongly depends on the particular service

4.1.13 Peak user data rate

Project	5G-MEDIA
Which KPI	Peak user data rate
Definition of KPI	Peak bit rate for the application to function correctly. It corresponds to the user experienced data rate as defined by ITU.
Context/Use case	
Enhancement work	The 5G-MEDIA virtualisation infrastructure supports line rates up to 1 Gbit/s
Where to measure	
How to measure	
How to evaluate	

4.1.14 Peak user data rate

Project	5G-PICTURE
Which KPI	Peak user data rate
Definition of KPI	The per user achieved peak data rate, in downstream/upstream direction, for unicast/broadcast services/links.
Context/Use case	Use Case #1 - Smart City Use Case #2 - Stadium Use Case #3 – Railway
Enhancement work	The project advances state of the art research by investigating the following key technologies Flex-E, X-Ethernet, OPP, Fusion, TSON to provide higher access, aggregation and backbone transport datarates, while it also advances state of the art research at wireless access level with regard to mmWave and Sub-6 technologies along with massive MIMO schemes in order to achieve higher wireless (access and transport) network capacity.
Where to measure	Use Case Demonstrator #1 - Smart City: at a smart city environment available in the 5GUK testbed in Bristol, UK, using a VR application to provide a VR Dance service. Use Case Demonstrator #2: at a City Stadium facility in Bristol, UK, using UHQ (ultra-high quality) video as well as crowd-sourced video services, which by default require high peak user data rates (video streaming in downstream and crowd-sourced video in upstream and downstream) and other services. Use Case Demonstrator #3: at a demo railway environment operated by FGC in Barcelona, Spain, using common internet traffic, as well as CCTV systems and other services.
How to measure	Traditional Network monitoring tools will be used to measure the achieved user data rates.
How to evaluate	Achieved data rates will be compared with specific values per use case (to be defined in due course).

4.1.15 Peak Data Rate

Project	5G-XCast
Which KPI	Peak data rate (evaluated)
Definition of KPI	Maximum number of received data bits per second (bps) assuming error-free conditions assignable to a single mobile station, when all assignable radio resources for the corresponding link direction are utilized (i.e. excluding radio resources that are used for physical layer synchronization, reference signals or pilots, control region, guard bands and guard times).
Context/Use case	Media & Entertainment.
Enhancement work	5G-Xcast Mixed Mode and Terrestrial Broadcast provides a clear PTM data rate gain compared to PTP services thanks to the use of a fixed CORESET, especially for high numbers of users. The gain can reach values up to 9.15 Gbps.
Where to measure	WP3 Deliverable 3.2 - Section 5.1.2.
How to measure	Analysis.
How to evaluate	Same PTP peak data rate expression is used.

4.1.15.1 Peak Data rate values

PTM:

- With 16 CC and 135 users, Mixed Mode provides a fixed data rate of 38.62 Gbps regardless of the number of users.
- Compared to PTP, MM is able to provide data rate gains up to 9.15 Gbps.

4.1.16 Peak Data Rate

Project	blueSPACE
Which KPI	Peak Data Rate
Definition of KPI	Peak rate assignable to a single mobile station, assuming full utilization of all radio resources (excl. OH) and error free conditions (ref: ITU-R M.2410-0).
Context/Use case	UC1 (Fixed wireless), UC3 (Indoor high-speed broadband), (UC2)
Enhancement work	High-BW fronthaul (ARoF and DRoF) and mm-wave signal. Beamforming for increased SNR. Extended 5G NR spec (M4E, ≥800MHz, 240kHz, 4096 SC, 256QAM).
Where to measure	TU/e testbed, E2E link, blueSPACE BBU and emulated user terminal
How to measure	Direct PHY throughput measurement for single user under controlled conditions.
How to evaluate	Raw PHY throughput, less OH for FEC/coding and signaling.

4.1.17 [Aggregate] Peak Data Rate

Project	5GCity
Which KPI	[Aggregate] Peak Data Rate
Definition of KPI	Data rate for the uplink between UE and AP, aggregate of AP and edge computing, etc.
Context/Use case	UC1 - Unauthorized Waste Dumping Prevention (pilot facility in Lucca-IT) UC3 - Video Acquisition and Production (pilot facilities in Barcelona-ES & Bristol-UK) UC4 - UHD Video Distribution & Immersive Services (pilot facilities in Lucca-IT & Bristol-UK) UC5 - Mobile Backpack Unit for Real-time Transmission (pilot facility in Barcelona-ES) UC6 - Cooperative, Connected and Automated Mobility (pilot facility in Barcelona-ES)
Enhancement work	Guarantee bandwidth in the network slice across various fixed/wireless technologies Guarantee traffic isolation among different network slices Wireless virtualization for 802.11 radios with throughput > 1 Gb/s
Where to measure	Measure bandwidth at intermediate routing interfaces as flow aggregates
How to measure	Monitor link bandwidth when multiple UEs generate traffic towards the application

	server
How to evaluate	UC1 target Aggregate Peak Data Rate > 200Mbps UC3 target Aggregate Peak Data Rate > 200Mbps UC4 target Aggregate Peak Data Rate: 20 Gbps DL/ 10 Gbps UL on access point UC5 target Aggregate Peak Data Rate > 100Mbps uplink to Internet UC6 target Aggregate Peak Data Rate: min 5Gbps at backhaul link

4.1.18 Mobile data volume per geographical area

Project	5G-PICTURE
Which KPI	Mobile data volume per geographical area
Definition of KPI	The total quantity of information transferred (uplink & downlink) per time interval by the access network per geographic area, measured in bit/s/km2. ACC TO ESSENCE: Quantity of information transferred (uplink) per time interval over a dedicated area (e.g. 5G Infrastructure PPP targets a maximum of 10 Tb/s/km2)
Context/Use case	Use Case #2 - Stadium
Enhancement work	The project advances state of the art research by investigating the following key technologies Flex-E, X-Ethernet, OPP, Fusion, TSON to provide higher access, aggregation and backbone transport datarates, while it also advances state of the art research at wireless access level with regard to mmWave and Sub-6 technologies along with massive MIMO schemes in order to achieve higher wireless (access and transport) network capacity.
Where to measure	The mobile data volume per geographical area will be measured in: Use Case Demonstrator #1: Smart City (Bristol, UK) Use Case Demonstrator #2: Smart Stadium (Bristol, UK)
How to measure	Theoretical evaluation taking into account the access network coverage area and the network capacity provided over this area.
How to evaluate	Achieved results produced by the demonstrator platforms will be measured and evaluated against the ITU 5G specification targets.

4.1.19 Mobile data volume per geographical area

Project	5G ESSENCE
Which KPI	Mobile data volume per geographical area
Definition of KPI	Quantity of information transferred (uplink) per time interval over a dedicated area (e.g. 5G Infrastructure PPP targets a maximum of 10 Tb/s/km2)
Context/Use case	Video streaming in crowded areas, the project is anticipated to validate the KPI in (i) Airplane Entrainment, and (ii) Stadium
Enhancement work	Dense deployment using Small Cells with MEC infrastructure (e.g. efficient Network Management and edge caching to handle large data volume, optimising the backhaul)
Where to measure	Measurement of Dataplane volume at the level of S1-U either at the GW serving the Small Cell infrastructure or per Small Cell. In addition data overhead for S1 (signaling) should be taken into consideration.
How to measure	Total Data Volume = SUM (data_eNB(i)) / km^2
How to evaluate	Probes will be deployed in the Dataplane between EPC and eNB / Small Cells. In addition network element monitoring information will be collected in order to calculate data volumes across the infrastructure during the execution of the Use Case under real conditions and in-vitro. 5G-ESSENCE has a monitoring framework (i.e. Prometheus) that facilitates the measurement process

4.1.20 Area Traffic Capacity

Project	5G-MonArch
Which KPI	Area Traffic Capacity
Definition of KPI	The total traffic throughput served per geographic area (in bps/m^2).
Context/Use case	Ability to meet the relative busy hours demand for different services, in smart port industrial and very high temporary demand hotspots use cases

Enhancement work	Inter-slice control and resource elasticity related enablers
Where to measure	5GM PoC via CAPisce network took in WP6 of 5GM
How to measure	Density of traffic carried by the network
How to evaluate	Show that the network can carry traffic of certain density in busy hour. Improvement by factor of ~10 compared to network without enablers

4.1.21 Coverage Area Probability

Project	5G-MonArch
Which KPI	Coverage Area Probability
Definition of KPI	The coverage area probability is defined as the percentage of the area under consideration, in which a service is provided by the mobile radio network to the end user in a quality (i.e., data rate, latency, packet loss rate) that is sufficient for the intended application (QoS/QoE level)
Context/Use case	Reliability for different services, in an industrial setting (smart sea port) and temporary very high demand hotspots use cases
Enhancement work	Based data duplication techniques via multi-connectivity , reduce number of Radio Link Failures (RLF)
Where to measure	5GM PoC via Mx-Art network level simulator in WP6 of 5GM
How to measure	Number of RLF calculated via SINR values
How to evaluate	Measure RLF before and after applying 5GM enablers

4.1.22 Traffic Type

Project	5G TRANSFORMER
Which KPI	Traffic Type
Definition of KPI	Amount of data moving across a network at a given point of time. For example: Continuous, Bursty, Event driven, Periodic
Context/Use case	Application/Automotive
Enhancement work	
Where to measure	Automotive
How to measure	Measuring the amount of data at the service level.
How to evaluate	In testbed, measuring the application level traffic through wireshark. Simulation.

4.1.23 Peak Spectral Efficiency

Project	5G-XCast
Which KPI	Peak spectral efficiency (evaluated)
Definition of KPI	Maximum data rate under ideal conditions normalised by the channel bandwidth. Expressed in bit/s/Hz.
Context/Use case	Media & Entertainment.
Enhancement work	There is a direct relationship between spectral efficiency and data rate and therefore PTM gains up to 23.51%.
Where to measure	WP3 Deliverable 3.2 - Section 5.1.3.
How to measure	Analysis.
How to evaluate	Same PTP peak spectral efficiency expression is used.

4.1.24 5th Percentile Spectral Efficiency

Project	5G-XCast
Which KPI	5th percentile user spectral efficiency (future work)
Definition of KPI	The 5th percentile user spectral efficiency is the 5% point of the CDF of the normalized user throughput in PTM mode. The normalized user throughput is defined as the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time, divided by the channel bandwidth and is measured in bit/s/Hz.
Context/Use case	---
Enhancement	Main enhancements compared to LTE to improve spectral efficiency are the use of MIMO

work	for PTM, improved layer 1 and possibly layer 2 FEC schemes and advanced receivers.
Where to measure	WP3 D3.4 (RAN protocols)
How to measure	System level simulation
How to evaluate	Following system level simulation methodology of ITU-R M.2412-0 in indoor, urban and rural scenarios.

4.1.25 Average Spectral Efficiency

Project	5G-XCast
Which KPI	Average spectral efficiency (future work)
Definition of KPI	Average spectral efficiency is the aggregate throughput of all users (the number of correctly received bits, i.e. the number of bits contained in the SDUs delivered to Layer 3, over a certain period of time) divided by the channel bandwidth of a specific band divided by the number of TRxPs and is measured in bit/s/Hz/TRxP.
Context/Use case	---
Enhancement work	Main enhancements compared to LTE to improve spectral efficiency are the use of MIMO for PTM, improved layer 1 and possibly layer 2 FEC schemes and advanced receivers.
Where to measure	WP3 D3.4 (RAN protocols)
How to measure	System level simulation
How to evaluate	Following system level simulation methodology of ITU-R M.2412-0 in indoor, urban and rural scenarios. As transmission errors cannot be corrected under all circumstances, packet loss rates are evaluated, as well.

4.1.26 Spatial Efficiency of Spectrum Usage

Project	blueSPACE
Which KPI	Spatial Efficiency of Spectrum Usage
Definition of KPI	Density of spectrum re-use and spatial multiplexing. Minimization of unwanted emissions and interference.
Context/Use case	UC1 (Fixed wireless), All
Enhancement work	High-BW fronthaul with optical beamforming and multi-beam transmission.
Where to measure	TU/e testbed with optical beamformer, blueSPACE BBU and multi-beam transmission.
How to measure	Measurement of beam spatial dimensions in target direction and level of unwanted emissions in other directions. Evaluation of the number of available beams for RU and resulting maximum spatial efficiency of spectrum reuse.
How to evaluate	Calculation of maximum frequency re-use without beam overlap and while maintaining unwanted emissions and interference below regulation levels. Calculation of overall spatial multiplicity in given network and deployment scenario and with available number of beams per RU.

4.1.27 Bandwidth

Project	5G-XCast
Which KPI	Bandwidth (evaluated)
Definition of KPI	Maximum aggregated system bandwidth including frequency guard bands. The maximum supported bandwidth may be composed of either a single or multiple radio frequency (RF) carriers. It is measured in Hz.
Context/Use case	Media & Entertainment, Public Warning, Automotive, Internet of Things.
Enhancement work	5G-Xcast Mixed Mode and Terrestrial Broadcast define a scalable bandwidth solution where 50 MHz is defined as the maximum value for all narrower subcarrier spacings defined in new PTM numerologies.
Where to measure	WP3 Deliverable 3.2 - Section 5.1.1.
How to measure	Inspection
How to evaluate	PTM bandwidth configuration is inherited from numerology $\mu = 0$ in 5G NR Rel'15. For further references look at the same field within the PTP bandwidth KPI.

4.1.28 Device Bandwidth Capacity (radio part)

Project	MATILDA
Which KPI	Device Bandwidth Capacity (radio part)
Definition of KPI	Evaluates the transfer capacity volume of information collected from sensors to IoT platform
Context/Use case	Smart City Intelligent Lighting System
Enhancement work	What is bandwidth capacity allocated for each device in radio access
Where to measure	ORO testbed
How to measure	FlexMon tool
How to evaluate	~ 0.1 Mbps

4.1.29 Total Slice Bandwidth

Project	MATILDA
Which KPI	Total Slice Bandwidth
Definition of KPI	Evaluates the transfer capacity volume of aggregated information from sensors to IoT platform. Calculated as (device number) x (bandwidth/device) (helpful for VNFs system parametrization)
Context/Use case	Smart City Intelligent Lighting System
Enhancement work	Ensuring bandwidth usage for application over testbed network
Where to measure	ORO testbed
How to measure	Monitoring application (part of application graph)
How to evaluate	~ 100 Mbps

4.1.30 Flexible Bandwidth Allocation

Project	MATILDA
Which KPI	Flexible Bandwidth Allocation
Definition of KPI	Flexible bandwidth allocation is needed between geographically distributed systems / sub-systems under test to ensure the integrity and required performance of distributed functional and integration testingL2/L3: server running consumption
Context/Use case	Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive.
Enhancement work	Ensuring flexible bandwidth usage over the MATILDA network to increase the efficiency of the entire consumer network demand.
Where to measure	Testbed Bristol
How to measure	Tracking of network statistic (input vs. Output)
How to evaluate	Flexible network that supports data rates of up to: 10 Mbit/s (Mbps) per Node (FastWAN Unit)

4.1.31 Device Status

Project	MATILDA
Which KPI	Device Status
Definition of KPI	Evaluates the number of smart light sensors deployed on testbed platform
Context/Use case	Smart City Intelligent Lighting System
Enhancement work	How many devices are handled by testbed
Where to measure	ORO testbed
How to measure	Monitoring application (part of application graph)
How to evaluate	100 Smart Light sensors

4.1.32 Edge Computing

Project	MATILDA
Which KPI	Edge Computing
Definition of KPI	Availability of Edge Computing capabilities
Context/Use case	Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE)

Enhancement work	Exploit IT and networking resources in proximity of end users
Where to measure	Bristol testbed
How to measure	Deployment of Edge Computing-based Apps
How to evaluate	Must be available

4.1.33 Capacity of Metro-Haul Controller

Project	METRO-HAUL
Which KPI	Capacity of Metro-Haul Controller
Definition of KPI	Number of supported devices: the maximum number of Netconf devices that a single SDN optical controller can support
Context/Use case	
Enhancement work	
Where to measure	To be defined
How to measure	To be defined
How to evaluate	To be defined

4.1.34 Capacity of Metro-Haul infrastructure

Project	METRO-HAUL
Which KPI	Capacity of Metro-Haul infrastructure
Definition of KPI	Measured in number of service instances that can be supported. This capacity combines the optical connections, and AMEN capacities (throughput, storage, and computing). The specific services that are used to assess the capacity and the specific services configuration is to be defined. The measure also needs to be normalised, which needs to be defined.
Context/Use case	
Enhancement work	
Where to measure	To be defined
How to measure	To be defined
How to evaluate	Target: 100x more 5G capacity supported over the same optical fibre infrastructure

4.1.35 1000x Capacity

Project	SAT5G
Which KPI	1000x Capacity
Definition of KPI	1000x higher mobile data volume per geographical area
Context/Use case	Delivery of content and MEC software to the network edge using broadcast / multicast to add capacity to the backhaul network in both fixed and mobile services. Providing additional or only capacity to cells in difficult to reach areas or on moving platforms. Sat5G use-cases 1 and 4 are relevant.
Enhancement work	Multicast / broadcast of content and software to platforms at network edge. Pre-fetching of data.
Where to measure	At the network edge.
How to measure	Test multicast VNF against list of MANO steps, and test UE access to streamed and stored data without special user action.
How to evaluate	Using test MANO procedures and traffic profiles on our test-beds. Evaluation also through business modelling activity.

4.1.36 Better / increased / ubiquitous coverage including in low density areas

Project	SAT5G
Which KPI	Better / increased / ubiquitous coverage including in low density areas
Definition of KPI	Self-explanatory
Context/Use case	A strong point for satellite because of its high vantage point.
Enhancement work	Integration of satellite (NTN) UEs in relay and transport modes to allow eNBs to connect to 5G core networks over satellite links. All four Sat-5G use-cases are relevant.
Where to measure	At network edge

How to measure	QoE and bit-rate
How to evaluate	QoE and bit-rate, and related business modelling.

4.2 P2 – Saving up to 90% of energy per service provided.

4.2.1 Energy consumption

Project	5G-MEDIA
Which KPI	Energy consumption
Definition of KPI	Relative enhancement of energy consumption of 5G devices
Context/Use case	
Enhancement work	5G-MEDIA will achieve better energy footprint as indirect impact of use of virtualisation technologies
Where to measure	
How to measure	
How to evaluate	

4.2.2 Energy consumption

Project	5G-PICTURE
Which KPI	Energy consumption
Definition of KPI	Energy consumption is the amount of energy or power used of the integrated transport system together with the cloud Computing infrastructure that supports Disaggregated-RAN deployments.
Context/Use case	Highly variable bandwidth requirements of future RANs, while also the suitable functional split is selected based on factors such as the transport network and service characteristics for resource and energy efficiency.
Enhancement work	Integrated fixed network transport networks with mmWave technologies, Sub-6 technologies and massive MIMO techniques using much greater numbers of antennas at the base stations (BSs) to improve data rates, reliability as well as energy efficiency. To maximise the converged 5G infrastructure energy efficiency, a two-stage optimisation for the wireless/optical and the intra-DC network domains is proposed. In the first stage, the optical transport network provisioning problem is formulated so as to identify the necessary optical network resources for the interconnection of the RUs with the DCs. Then, a second sub-problem linked to the allocation of the FH functions to the disaggregated pool of compute/storage resources is provided.
Where to measure	Theoretical investigation considering a converged transport underlay network.
How to measure	Simulations and also investigation in the context of the Smart City Use Case.
How to evaluate	Evaluation results for 10x10 km^2 area with 50 uniformly distributed BSs and using real data traces. The power consumption per RU will be compared with ranges between 600 and 1200 Watts under idle and full load conditions, respectively for the Traditional-RAN deployments.

4.2.3 Energy Consumption

Project	METRO-HAUL
Which KPI	Energy Consumption
Definition of KPI	Consumption reduction related to new node technology (e.g. PIC, filter-less technology), dynamic service infrastructure (set-up/tear-down services) with respect Baseline Metro Network
Context/Use case	
Enhancement work	
Where to measure	
How to measure	Modelling
How to evaluate	To be defined

4.2.4 Energy Reduction

Project	5G TRANSFORMER
Which KPI	Energy Reduction
Definition of KPI	Reduction of the energy consumption of the overall system. The most common metric that is used to characterize this KPI is the reduction in the consumed Joules per delivered bit.
Context/Use case	Service-Resource/MNO/M(v)NO
Enhancement work	Devising algorithms for NFV placement to reduce energy consumption
Where to measure	5G-MTP, 5G-SO
How to measure	Computing the CAPEX and OPEX reduction.
How to evaluate	Based on simulation comparing the effectiveness of the algorithm.

4.2.5 Energy Efficiency

Project	5G-PHOS
Which KPI	55 nJ/bit in dense areas 12 nJ/bit in ultra dense areas
Definition of KPI	The energy consumed per useful bit transferred from the MNO's Central Office to the user area using the 5G-PHOS analog Radio-over-Fiber solution.
Context/Use case	Providing ultra-high bandwidth mm-wave eMBB fronthaul for dense and ultra-dense areas over a converged FiWi network.
Enhancement work	Currently 5G-PHOS employs only 2GHz out of 7GHz of the available mm-wave 60GHz bandwidth, but the same hardware is capable of transmitting 8 parallel data streams. The production of additional antenna panels tuned to different part of the 60GHz spectrum would increase power consumption only by a small factor (added RF equipment) but would multiply the data transmission, therefore increasing the energy efficiency metric.
Where to measure	Demo #1 and Demo #2 will be jointly employed in order to measure the energy consumption of the 5G-PHOS solution in the Dense and Ultra-dense area scenarios.
How to measure	Power meters will be deployed in every active element of the network, starting from the centralized unit that contains the transceivers, FPGA and network processor, down to the lamppost antennas that contain the transceivers, RF equipment and FPGA module. The derived results will be combined with the results obtained by the "Capacity Density" KPI in order to derive the energy consumption per bit.
How to evaluate	Achieved results produced by the demonstrator platforms will be measured and evaluated if they abide by NGMN's energy efficiency success criteria for the 5G pre-commercial field trials.

4.2.6 Energy Efficient ARoF Fronthaul

Project	blueSPACE
Which KPI	Energy Efficient ARoF Fronthaul
Definition of KPI	a) Energy consumption at RU. b) Remote energy efficiency optimization at RU and resulting overall energy savings.
Context/Use case	All
Enhancement work	a) Reduced power consumption due to ARoF fronthaul (no need for DAC/ADC at RU). b) Improved switch-off/deep sleep state and usage efficiency due to availability of remote-fed energy via power-over-fiber.
Where to measure	a) Measurement of on-chip/subsystem power demands of developed HW components at HW developing partners and in TU/e testbed. b) PoF testbed with critical RU components and PoF pooling simulations framework.
How to measure	a) On-chip/subsystem power directly measured, extrapolated to overall power requirement estimation with typical conversion efficiencies of commercial devices. b) Sleep mode operation power requirements measured, PoF transmission efficiency measured, relative saving from enhanced sleep state estimated vs non-sleeping operation and operation with binary on/off states only.
How to evaluate	a) Benchmark measured/calculated requirements for ARoF RU against DRoF RU power

	requirements for a RU with equivalent capabilities/performance. b) Benchmark calculated consumption of sleep-enhanced ARoF RU against non-enhanced RU in different network, traffic and load scenarios.

4.2.7 Network Management OPEX – Energy Savings (for MNO)

Project	IoRL
Which KPI	Network Management OPEX Energy Savings (for MNO)
Definition of KPI	The power consumption for the whole RAN: L1: power consumption of 8 RRLH controllers and 8*6 RRLH, excluded illumination consumption. L2/L3: server running consumption
Context/Use case	The use cases will cover training, museum, home and media
Enhancement work	The using of VLC will reduce the network operation power
Where to measure	In SDN
How to measure	The power consumption for the whole RAN with different system load
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.3 P3 – Reducing the average service creation time cycle from 90 hours to 90 minutes.

See section 3

4.4 P4 – Creating a secure, reliable and dependable Internet with a "zero perceived" downtime for services provision.

4.4.1 Availability

Project	5GCAR
Which KPI	Availability
Definition of KPI	Availability is the probability that the requested service is declared as available. If the communication system declares that the service is unavailable, then the application needs to initiate a fallback procedure to e.g. limit the risk of an accident. One often has a tradeoff between Availability and Reliability, in the sense that one can make a system more available by reducing the Reliability, and vice versa. A further discussion of the interrelation between Availability and Reliability is given below in the main text.
Context/Use case	See Through
Enhancement work	Meeting Low Latency and High Reliability Requirements in V2X Communication Scenarios
Where to measure	In both UEs (the cars involved in the demo)
How to measure	Signal quality
How to evaluate	In a practical test in the field

4.4.2 Availability

Project	5GCity
Which KPI	Availability
Definition of KPI	Percentage value of the amount of time the end-to-end communication service is delivered according to an agreed QoS, divided by the amount of time the system is expected to deliver the end-to-end service according to the specification in a specific area Ref. 3GPP TS 22.261 V16.5.0
Context/Use case	UC3 - Video Acquisition and Production (pilot facilities in Barcelona-ES & Bristol-UK) UC4 - UHD Video Distribution & Immersive Services (pilot facilities in Lucca-IT & Bristol-UK)
Enhancement work	Guarantee bandwidth in the network slice across various fixed/wireless technologies Guarantee traffic isolation among different network slices

	Wireless virtualization for 802.11 radios with throughput > 1 Gb/s
Where to measure	Measure availability of the various infrastructure components (compute node of the NFVI)
How to measure	As per definition, via correlation of system logs in the monitoring system
How to evaluate	UC3 target availability > 99.5% (fail for max 1.83 days/year) UC4 target availability > 99,999% (fail for max 5.26 minutes/year)

4.4.3 Availability (related to coverage)

Project	5G TRANSFORMER
Which KPI	Availability (related to coverage)
Definition of KPI	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.
Context/Use case	Application/eHealth
Enhancement work	As for E2E latency
Where to measure	eHealth
How to measure	Measuring the percentage of users from which we receive regular/periodic monitoring data in a certain area.
How to evaluate	Comparison with benchmark/former solutions. Identification of common reference points (e.g., application packet, TCP, UDP, IP, etc.)

4.4.4 Service Availability

Project	NGPaaS
Which KPI	Service Availability
Definition of KPI	The amount of time/requests that the service remains available /is able to serve during the experiment (set up -> normal operation -> fault -> recovery -> normal operation).
Context/Use case	Service availability as a value added service for the VNFs and the 5G components.
Enhancement work	Combination of Anomaly detection and failure prediction customised on the monitoring goals chosen.
Where to measure	Individual testbed firstly, Telco PaaS and 5G PaaS later on.
How to measure	Compare the total number of requests sent with the number of requests served within the experiment.
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.4.5 Service availability / reliability

Project	SLICENET
Which KPI	Service availability / reliability
Definition of KPI	As defined in standards
Context/Use case	All UCs: 99.999%
Enhancement work	
Where to measure	TBD
How to measure	TBD
How to evaluate	TBD

4.4.6 High Availability

Project	MATILDA
Which KPI	High Availability
Definition of KPI	• The test systems interconnection infrastructure/services shall be always available. • Calculated as network down time/total time, reflects in percentage the availability/stability performance of Smart City demo platform • Network availability as percentage of time being available

Context/Use case	• Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive. • Smart City Intelligent Lighting System • Critical communications
Enhancement work	• The test systems interconnection shall provide extremely high QoS with respect to availability • High level of availability of services offered by testbed • Provide real-time QoS monitoring application
Where to measure	• Testbed Bristol • ORO test bed (demonstrator in Polytechnics University) • CNIT Test bed, Genoa
How to measure	• Long duration test • QoS monitoring application (part of application graph, e.g. qMON Agent or smart phone application for RAN)
How to evaluate	99.99% of operational time available

4.4.7 Connectivity availability

Project	NRG-5
Which KPI	Connectivity availability
Definition of KPI	Percentage of successfully received and processed packets at the destination endpoint
Context/Use case	UC1: Realizing decentralized, trusted lock-in free "Plug & Play vision" - Smart meters connectivity UC2: Enabling aerial Predictive Maintenance for utility infrastructure - Drones piloting
Enhancement work	Implementing SatCom integration in 5G. Investigate multi-RAT strategies to be included in the same NRG-5 slice
Where to measure	At the UE
How to measure	Employ networking measurement to test connectivity towards the service endpoint
How to evaluate	Identify areas where one RAT technology does not guarantee availability, test by employing multi-RAT. It is possible to compute analytically the aggregate connectivity availability given the single technology availability and assuming that connectivity unavailability is mutually independent among technologies.

4.4.8 Reliability

Project	5GCAR
Which KPI	Reliability
Definition of KPI	Reliability is the probability that the actual layer-n latency is less or equal to the latency requirement, subject to the other relevant requirements and conditions, e.g., SDU size and Communication range, transmit power, propagation conditions, and mobility.
Context/Use case	See through, Lane merge
Enhancement work	Meeting Low Latency and High Reliability Requirements in V2X Communication Scenarios Network procedures
Where to measure	In the UE verifying that different traffics in the network does not affect the UE
How to measure	To overload the traffic in a network
How to evaluate	Compare with a non overloaded situation

4.4.9 Reliability

Project	5G TRANSFORMER
Which KPI	Reliability

Definition of KPI	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).
Context/Use case	Application/Automotive, Application/eHealth, Application/eIndustry
Enhancement work	As for E2E latency
Where to measure	Automotive, eHealth, eIndustry
How to measure	Measuring how many messages have been sent and received correctly (Automotive: passive probing. Measuring the number of sent and received CAM and DENM). Measuring the availability of the service (%) for duration of a period of time (e.g., day, week, month, etc) (eHealth, eIndustry).
How to evaluate	Comparison with benchmark/former solutions. Identification of common reference points (e.g., application packet, TCP, UDP, IP, etc.)

4.4.10 Reliability

Project	NRG-5
Which KPI	Reliability
Definition of KPI	Percentage of successfully received and processed packets at the destination (service) endpoint
Context/Use case	UC1: Realizing decentralized, trusted lock-in free “Plug & Play vision” - AAA and MME functionalities for smart meters UC3: Enabling resilience and high availability via Dispatchable Demand Response - Control of electricity rerouting at substation
Enhancement work	Define a SLA including the notion of criticality for a service, work on orchestrator to assure reliable functioning of deployed VNFs, monitoring and telemetry to assess the status of VNFs
Where to measure	Both at NRG-5 UEs and VNF.
How to measure	By performing stress test on the running VNF, simulating failures in hardware and software to test the response of the orchestrator
How to evaluate	By compare the NRG-5 solution with respect to other available solutions

4.4.11 Service reliability

Project	5G ESSENCE
Which KPI	Service reliability
Definition of KPI	Maximum tolerable packet loss rate at the application layer within the maximum tolerable end-to-end latency for that application
Context/Use case	5G-ESSENCE defines a First Responder Use Case, that requires that the service is deployed reliably
Enhancement work	The CESC-M framework, supports reliability functions that are able to re-direct and re-allocate in alternative (stand-by) MEC or Small Cell infrastructure able to serve the deployment of the Use Case VNFs in case of failures
Where to measure	At the management framework (i.e CESC-M), where the health of deployed components and infrastructure elements is monitored and decisions on actions for preserving operation are executed
How to measure	Percentage of Service Status over time = Operational (uptime)
How to evaluate	Failure actions that will be realised during the test event will activate the remedial actions to be taken in order to continue the smooth operation of the service. Up-time will be logged in the monitoring system and evaluated from the logs

4.4.12 Service reliability

Project	5G-MEDIA
Which KPI	Service reliability
Definition of KPI	Maximum tolerable packet loss rate at the application layer within the maximum tolerable end-to-end latency for that application. The most demanding vertical use cases are related to eHealth with values up to 99.99999%

Context/Use case	Use Case 2: Mobile Contribution, Remote and Smart Production in Broadcasting Use Case 3: Ultra-high Definition (UHD) over Content Distribution Networks
Enhancement work	5G-MEDIA Network Service blueprints include media service resiliency which can contribute to achieve service unavailability of <= 80 ms/hour.
Where to measure	
How to measure	
How to evaluate	

4.4.13 Service reliability

Project	5G-PICTURE
Which KPI	Service reliability
Definition of KPI	Investigation of reliability by means of availability meaning amount of time that the service should be available over the reporting period.
Context/Use case	The services we are targeting are mobile network services in the RU, DU, CU and CN while also transport network services that support connectivity between the relevant elements.
Enhancement work	In the case of failure or errors advanced orchestration procedures and notification mechanisms will trigger the creation of the necessary functions and connectivity services that will bring the integrated system again fully functional.
Where to measure	Use Case Demonstrator #1: Smart City use case (Bistol, UK) Use Case Demonstrator #2: Stadium use case (Bistol, UK) Use Case Demonstrator #3: Railway use case (FGC, Spain)
How to measure	Accurate timestamping in an end-to-end synchronized transport network, will be used to measure the time of operation while also downtimes.
How to evaluate	First step is the definition of availability targets and evaluation based on the agreed amount of time that the service should be available (X) over the reporting period and the measured downtime during that period (Y). Availability is the percentage (X-Y)/X.

4.4.14 Service reliability

Project	5GTANGO
Which KPI	Service reliability
Definition of KPI	(not maximum tolerable packet loss rate) The service is considered reliable if it is available 99.9% of the time
Context/Use case	All three 5GTANGO pilots require an availability from the whole end-to-end solution of at least 99.9% (one work shift downtime per year).
Enhancement work	In 5GTANGO, all layers involved affects this value, but it is limited by the least reliable one. It is the 5GTANGO Service Platform (SP) that needs to provide this reliability, besides the infrastructure the NSs use, since it doesn't just deploy the service: it keeps a connection to it, collecting monitoring data and possibly taking actions related to that data, such as using the Policy Manager to scale the deployed service out or in, registering any Service Level Agreement (SLA) violation, etc. We can envisage scenarios in which the SP is cut out from connecting to the service instances, therefore not being able to act upon that instance or to collect monitoring data, but this strongly depends on the specifics of each service, the capacity each one has for temporarily storing monitoring data, etc.
Where to measure	Measurements must occur at the end-user side
How to measure	Measure this KPI from a set of specific experiments on a number of services, since directly testing service reliability is not obvious. We also plan to indirectly test service reliability, by, e.g., testing service fail-over: a service that successfully implements fail-over will for sure achieve a higher reliability than one that does not. This measurement will take advantage of the Service/Function Specific Managers (S/FSMs), so that these values can be measured more accurately for different kinds of services and functions
How to evaluate	We will setup concrete scenarios in which these measurements can be collected, shown and evaluated. The extrapolation into the real world will not always be possible.

4.4.15 U-plane reliability

Project	ONE5G
Which KPI	U-plane reliability
Definition of KPI	Reliability relates to the capability of transmitting a given amount of traffic within a predetermined time duration with high success probability. Reliability is the success probability of transmitting a layer 2/3 packet within a required maximum time, which is the time it takes to deliver a small data packet from the radio protocol layer 2/3 SDU ingress point to the radio protocol layer 2/3 SDU egress point of the radio interface at a certain channel quality. (ITU-R M.2410-0 (11/2017)).
Context/Use case	UC1 – Assisted, cooperative and tele-operated driving / UC2 – Time-critical factory processes and logitics optimizaton (industry and smar airports)
Enhancement work	Design of multi-connectivity techniques for improving reliability of the communication link
Where to measure	ONE5G PoC#1: Aalborg University multi-link multi-node testbed
How to measure	Measure the instantaneous Signal-to-Interference plus Noise ratio (SINR) of the user demanding high reliable service, and calculate the occurrence rate of failure events, i.e. such SINR dropping below the minimum threshold which guarantees communication service.
How to evaluate	The rate of failure of multi-connectivity techniques is compared to the rate of failure of single connectivity in different deployments and interference scenarios.

4.4.16 End-to-end Reliability

Project	5G-MonArch
Which KPI	End-to-end Reliability
Definition of KPI	The probability that all network components, including the virtualised and non-virtualised part of the network, are capable to support a required function (taken from the set of computation; networking; storage) for a given time interval
Context/Use case	Smart port industrial use case
Enhancement work	a) Network coding based on compute-and-forward method for uplink / network coding based on broadcasting with feedback for downlink b) Contribution towards higher RAN reliability, by duplicating packets across multiple links c) Anomaly detection in network operation along with the root cause and recovery/healing. Work enhancing SotA and adaptation to a network with slicing
Where to measure	5GM PoC via Mx Art and analytical tool in WP6 of 5GM
How to measure	Packet loss and CDF of successfully transmitted packets over latency
How to evaluate	Comparison of results before and after applying 5GM enablers

4.4.17 Reliability of the telco cloud

Project	5G-MonArch
Which KPI	Reliability of the telco cloud
Definition of KPI	Probability that a telco cloud component can perform a required function (taken from the set of computation; networking; storage) under stated conditions for a given time interval.
Context/Use case	Smart port industrial use case
Enhancement work	Detect the anomaly in network operation along with the root cause and perform recovery/healing. Work enhancing SotA and adaptation to a network with slicing.
Where to measure	5GM PoC via Mx-Art network level simulator in WP6 of 5GM
How to measure	Failure of a chain of VNFs providing a service modelled in MxArt with different strategies i.e. having hot servers available to migrate NFs to.
How to evaluate	Comparison of results before and after applying 5GM enablers

4.4.18 Reliability (packet loss)

Project	5GCity
Which KPI	Reliability (packet loss)

Definition of KPI	Percentage value of the amount of sent network layer packets successfully delivered to a given system entity within the time constraint required by the targeted service, divided by the total number of sent network layer packets Ref. 3GPP TS 22.261 V16.5.0
Context/Use case	UC6 - Cooperative, Connected and Automated Mobility (pilot facility in Barcelona-ES)
Enhancement work	Resource orchestration and allocation to minimize packet loss Functional split of the application core functions and distribution across the core and edge section of the 5GCity infrastructure
Where to measure	At UE and at Application Server Intermediate packet loss measures can be also retrieved
How to measure	Count packet loss from UE and systems
How to evaluate	Avg packet loss/Reliability for UC6: Radio link > 99% Midhaul/backhaul > 95%

4.4.19 Packet Loss

Project	MATILDA
Which KPI	Packet Loss
Definition of KPI	• Shows the percentage of packets lost during transfer between sensors and IoT platform. The Smart Lighting service is not critical, therefore retransmission is being allowed, without affecting end-to-end application functionality. • Reliability and high availability of the services in extreme conditions is essential for emergency systems. Therefore packet loss should be made as little as possible.
Context/Use case	• Smart City Intelligent Lighting System • Critical communications
Enhancement work	To ensure QoS with respect to application needs
Where to measure	• ORO testbed • CNIT Test bed, Genoa
How to measure	• Monitoring application (part of application graph) • QoS monitoring application (part of application graph, e.g. qMON Agent or smart phone application for RAN)
How to evaluate	< 0.1% < 0.01%

4.4.20 Network management OPEX

Project	5G-MEDIA
Which KPI	Network management OPEX
Definition of KPI	Sum of all the Operating Expenditure for the 5G Network Management including cost for running the 5G network, form its configuration, maintenance, etc.
Context/Use case	Use Case 1: Immersive Media Use Case 3: Ultra-high Definition (UHD) over Content Distribution Networks
Enhancement work	5G-MEDIA will use virtualisation platforms and MANO platforms to automate service lifecycle management
Where to measure	
How to measure	
How to evaluate	Sum of all the Operating Expenditure for the 5G Network Management including cost for running the 5G network, form its configuration, maintenance, etc.

4.4.21 Service elasticity

Project	5G-MEDIA
Which KPI	Service elasticity
Definition of KPI	Ability to increase or decrease the system capacity (e.g. CPU, storage, RAM, network capacity, service coverage, etc.) on demand and/or in an automated way

Context/Use case	Use Case 1: Immersive Media
Enhancement work	• SDK will support microservice-based application development for both hypervisor-based and containerised approaches, specifically supporting at least Docker, unikernel, and LXC. • Path prolongation between automatic VNFFG and optimal forwarding path will not exceed 15%. • The platform will take into consideration at least 5 supported networking parameters and performance metrics for VNFFG selection.
Where to measure	
How to measure	
How to evaluate	Through the integration of a serverless VIM, we gain the elasticity offered by the OpenWhisk platform. Detailed measurements will be offered by the FaaS platform.

4.4.22 Service and SLA monitoring

Project	5G-MEDIA
Which KPI	Service and SLA monitoring
Definition of KPI	Ability to define service and network metrics to monitor performances
Context/Use case	Use Case 1: Immersive Media Use Case 2: Mobile Contribution, Remote and Smart Production in Broadcasting
Enhancement work	• Full traceability of the microservice components throughout their lifecycle even when placed/migrated to nodes administered by different actors. • Automatic negotiation and monitoring of specific SLA between different actors.
Where to measure	
How to measure	
How to evaluate	Through the integration of a serverless VIM, we gain the monitoring offered by the OpenWhisk platform. Detailed measurements will be offered by the FaaS platform.

4.4.23 Virtualisation infrastructure scalability

Project	5G-MEDIA
Which KPI	Virtualisation infrastructure scalability
Definition of KPI	Ability to support, seamlessly instantiate and migrate media-related virtualised services over different NFVIs, with various Virtualised Functions
Context/Use case	Use Case 2: Mobile Contribution, Remote and Smart Production in Broadcasting Use Case 3: Ultra-high Definition (UHD) over Content Distribution Networks
Enhancement work	• Re-use and/or extend at least 4 major components or platforms from at least 3 5G-PPP Phase 1 projects (e.g. SDK toolbox, Repository, MANO framework, monitoring system, etc.). • Reuse and/or extend at least 3 virtual network functions already available as open source. • Develop at least 5 open source VNF implementations. • Develop or extend at least 6 media components related to 5G-MEDIA use case requirements.
Where to measure	
How to measure	
How to evaluate	

4.4.24 Network resources provisioning and reconfiguration delay

Project	5G-PHOS
Which KPI	Network resources provisioning and reconfiguration delay
Definition of KPI	Time needed for the network to perform actions ranging from the onetime configuration of devices to the runtime reconfiguration of algorithms, adapting the operation of previously configured devices with respect to resource allocation management e.g. activation/ deactivation of network elements, traffic routing and

	rate limiting based on QoS requirements.
Context/Use case	Ultra Dense area served by optical and wireless access, where traffic monitoring & analytics for enabling provisioning will be available through the NPO. Functionalities will involve: ability to monitor network KPIs & analytics, activation/ deactivation of network elements and/or traffic shaping and rate limiting based on QoS profile (i.e. based on traffic characteristics, e.g. per service type or source/destination IP).
Enhancement work	5G-PHOS aspires to contribute in SDN for FiWi networks through the development of a joint optical and wireless Network Planning and Operation tool (NPO), implemented through an SDN platform. The Flexbox will interface the SDN commands, enforced by the 5G-PHOS SDN control framework, and coordinate and orchestrate the FiWi C-RAN resources using advanced analytics to ensure resource provisioning. NPO will be able to set-up, manage and optimize various aspects of the converged FiWi network infrastructure and analytics is a critical part, providing intelligence on which services/traffic models are being used, when, on which devices and by whom. FiWi network resources can then be allocated to improve network management and deployment of vertical services, maximizing the user's quality of experience.
Where to measure	Demo #2: Ultra Dense Area Use Case
How to measure	For service provisioning per QoS profile: Measuring latency to validate that originally set QoS requirements were adhered, using the iPerf software.
How to evaluate	Achieved results produced by the demonstrator platform will be measured and evaluated against the ITU 5G specification targets for the specific service type.

4.4.25 Interoperability with Various Access Networks (WLAN, LTE, Ethernet)

Project	MATILDA
Which KPI	Interoperability with Various Access Networks (WLAN, LTE, Ethernet)
Definition of KPI	The infrastructure/services for deploying FastWAN Test Systems shall be supported seamlessly over various Access Networks.
Context/Use case	• Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive. • Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE)
Enhancement work	To ensure the seamless integration of various physical communication protocols.
Where to measure	Testbed Bristol
How to measure	Functional test of different hardware interfaces
How to evaluate	Available - WLAN - LTE - Ethernet

4.4.26 Component scalability

Project	MATILDA
Which KPI	Component scalability
Definition of KPI	• Dynamically scaling is needed to fulfil actual user communication requests • Web components (instances providing services to end users) of the iMON dashboard must support horizontal scaling
Context/Use case	• Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive. • Critical communications
Enhancement work	• To ensure scalability of signal interfaces to end customers. • Provide stateless web component that allows horizontal scaling
Where to measure	• Testbed Bristol • CNIT Test bed, Genoa
How to measure	• Based on service usage, components will be launched or stopped • QoS monitoring application (part of application graph, e.g. qMON Agent or smart phone application for RAN) to trigger many user requests, the

	component should be scaled according to preconfigured threshold
How to evaluate	Must be available

4.4.27 Jitter

Project	MATILDA
Which KPI	Jitter
Definition of KPI	• Evaluates packet delay variation in latency between IoT platform and device sensor. • Time-critical communications should be stable and reliable, timing variation must be minimal. It is measured as packet delay variation between endpoints.
Context/Use case	• Smart City Intelligent Lighting System • Critical communications
Enhancement work	To ensure QoS with respect to application needs
Where to measure	• ORO testbed • CNIT Test bed, Genoa
How to measure	• Monitoring application (part of application graph) • QoS monitoring application (part of application graph, e.g. qMON Agent or smart phone application for RAN)
How to evaluate	< 100ms < 1ms

4.4.28 HW video acceleration management

Project	MATILDA
Which KPI	HW video acceleration management
Definition of KPI	Availability of HW video acceleration capabilities
Context/Use case	Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE)
Enhancement work	Enable the use of HW acceleration in video applications, in view of one order of magnitude energy saving
Where to measure	Bristol testbed
How to measure	Deployment of App which make use of HW acceleration
How to evaluate	Must be available. Power consumption measurements and comparison with non-accelerated Apps.

4.4.29 Fault/degradation detection time

Project	METRO-HAUL
Which KPI	Fault/degradation detection time
Definition of KPI	To be defined
Context/Use case	
Enhancement work	
Where to measure	To be defined
How to measure	To be defined
How to evaluate	To be defined

4.4.30 Problem Detection Latency and Problem Recovery Latency

Project	NGPaaS
Which KPI	Problem Detection Latency and Problem Recovery Latency
Definition of KPI	Problem Detection Latency: The time between the instant in which the problem appears and the instant in which it is detected by the Monitoring Framework. Problem Recovery Latency: The time between the instant in which the problem appears and the instant in which it is resolved by the healing component of the Monitoring Framework.
Context/Use case	Service availability as a value added service for the VNFs and the 5G components.

Enhancement work	Combination of Anomaly detection and failure prediction customised on the monitoring goals chosen.
Where to measure	Individual testbed firstly, Telco PaaS and 5G PaaS later on.
How to measure	Problem Detection Latency: measure time from the fault injection to the first fault related data in the ELK stack. Problem Recovery Latency: measure time from the fault injection to the moment in which the healed service is back online.
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.4.31 Relay of Out of Coverage Nodes

Project	NRG-5
Which KPI	Relay of Out of Coverage Nodes
Definition of KPI	Number of UE nodes without 5G coverage succeeding in authentication and data exchange via network relaying – affect also the computation of network availability
Context/Use case	UC1: Realizing decentralized, trusted lock-in free “Plug & Play vision” - Relay of smart meters in basements
Enhancement work	Developing a relay functionality and a device discovery and registration for out of coverage nodes (named vTSD)
Where to measure	At the AAA or MME functionality deployed in the core.
How to measure	Deploy UEs in a topology with devices out of the macro coverage. Analyse the log both at the MME and vTSD to confirm their registration
How to evaluate	Evaluate up to which conditions, the registration for out of coverage UEs goes well. Modify the topology of nodes, and evaluate the maximum load of the vTSD and relaying functionality

4.4.32 Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision

Project	SAT5G
Which KPI	Creating a secure, reliable and dependable Internet with a “zero perceived” downtime for services provision.
Definition of KPI	Self-explanatory
Context/Use case	Satellite links can deliver improved resilience because they have fewer interconnected nodes over long distances and are less susceptible to events on the ground. Sat5G use-case 3 is relevant.
Enhancement work	Integration of satellite (NTN) UEs in relay and transport modes to allow eNBs to connect to 5G core networks over satellite links, including in parallel with terrestrial connections, for fixed and mobile services, using for example MPQUIC.
Where to measure	At network edge
How to measure	Effectiveness of resilience through mechanisms like MPQUIC over satellite.
How to evaluate	QoE sustainability in defined conditions

4.4.33 Quality of Experience

Project	SLICENET
Which KPI	Quality of Experience
Definition of KPI	The degree of delight or annoyance of the user of an application or service It results from the fulfilment of his or her expectations with respect to the utility and / or enjoyment of the application or service in the light of the user’s personality and current state. Defined in ITU-T P.10/G100 (11/17) and https://hal.archives-ouvertes.fr/hal-00977812
Context/Use case	
Enhancement work	Development of QoE sensors that aggregate monitoring data and according to UC specific algorithms calculate QoE values
Where to measure	At QoE sensors
How to measure	The process of measuring or estimating the QoE for a set of users of an application or a service with a dedicated procedure, and considering the influencing factors (possibly

	controlled, measured, or simply collected and reported). The output of the process may be a scalar value, multi-dimensional representation of the results, and/or verbal descriptors. All assessments of QoE should be accompanied by the description of the influencing factors that are included. The assessment of QoE can be described as comprehensive when it includes many of the specific factors, for example a majority of the known factors. Therefore, a limited QoE assessment would include only one or a small number of factors.
How to evaluate	QoE includes the type and characteristics of the application or service, context of use, the user's expectations with respect to the application or service and their fulfilment, the user's cultural background, socio-economic issues, psychological profiles, emotional state of the user, and other factors whose number will likely expand with further research. Evaluation against defined metrics specified in SliceNet deliverable D5.2

4.5 P5 – Facilitating very dense deployments of wireless communication links to connect over 7 trillion wireless devices serving over 7 billion people.

4.5.1 Device Density

Project	5G TRANSFORMER
Which KPI	Device Density
Definition of KPI	Maximum number of devices per unit area under which the specified reliability should be achieved.
Context/Use case	Application/Automotive, Application/eHealth
Enhancement work	As for E2E latency
Where to measure	Automotive, eHealth
How to measure	Measuring the maximum number of vehicles in considered area, where reliability is >99% (automotive), Measuring the maximum number of users that are connected to the service in a certain area (eHealth)
How to evaluate	Initial evaluation through simulation.

4.5.2 Device Density

Project	MATILDA
Which KPI	Device Density
Definition of KPI	Number of connected device per Small Cell/ WIFI Hot Spot
Context/Use case	Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE)
Enhancement work	Provide high-valued services during Crowded Events
Where to measure	Bristol testbed
How to measure	Number of 5GPACE users per Small Cell (~32/64)/Hot spot (~50)
How to evaluate	The expected number of users must concurrently access the 5GPACE service

4.5.3 Capacity Density

Project	5G-PHOS
Which KPI	1.7 Tbit/s/km2 in dense areas 28 Tbit/s/km2 in ultra dense areas >1.5 Tbit/s/km2/wavelength in hotspot areas
Definition of KPI	The total traffic throughput that can be served by the network per geographic area, measured in bit/s/km2.
Context/Use case	Providing ultra-high bandwidth mm-wave eMBB fronthaul for dense, ultra-dense and hostspot areas over a converged FiWi network.
Enhancement work	5G-PHOS currently produces HW capable of exploiting 2GHz only out of the 7GHz available mm-wave 60GHz ISM band. Production of more HW that spans across the entire 7GHz band can triple the KPI capacity figures. Also, current FPGA HW enables

	only the use of modulation schemes up to QAM16. Dedicated modulation production HW would enable higher modulation formats.
Where to measure	Demo #2 will measure capacity density in both dense and ultra dense areas. Demo #3 will measure capacity density for the Hotspot Area.
How to measure	Maximum achieved capacity will be measured through the use of iPerf software connection established between a server located in the BBU side and a client PC located in the user area. Also in order to have a practical display of the 5G-PHOS capacity density, very high definition video with high frame rate (such as 4K at 60 FPS) will be streamed. Given the achievable transmission range of the 5G-PHOS mm-wave antenna, the results will be translated to area capacity density.
How to evaluate	Achieved results produced by the demonstrator platforms will be measured and evaluated against the ITU 5G specification targets.

4.5.4 Traffic volume density

Project	SLICENET
Which KPI	Traffic volume density
Definition of KPI	As defined by 5G PPP contractual agreement
Context/Use case	Smart City UC: 700 Gbps/km^2
Enhancement work	
Where to measure	TBD
How to measure	Traffic monitoring points
How to evaluate	Through trials and estimation through modelling and extrapolation

4.5.5 Connection density

Project	SLICENET
Which KPI	Connection density
Definition of KPI	Maximum number of devices per unit area that are 5G capable
Context/Use case	Smart Grid UC: <0.5 device / km^2 Smart City UC: 200000 users/km^2
Enhancement work	
Where to measure	During trial and evaluation of UCs
How to measure	Use case trial and evaluation for Smart Grid Use case trial and modelling
How to evaluate	Use case trial and evaluation for Smart Grid Use case trial and modelling

4.5.6 Connection density (indoor)

Project	IoRL
Which KPI	Connection density (indoor)
Definition of KPI	Connection Density is the number of simultaneously connected devices per square metre.
Context/Use case	IoRL connection density as service using efficient VNF management and orchestration
Enhancement work	The indoor connection density will increased by combining the VLC and mmWave
Where to measure	In SDN
How to measure	Low: 1 UEs/square metre Medium: 3 UEs/square metre High: 5 UEs/square metre With different system load
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.5.7 Minimum Expected Coverage

Project	5G-XCast
Which KPI	Minimum Expected Coverage [M&E1_R14] (evaluated)
Definition of KPI	99% Population with 95% Location Availability and 99% Time Availability
Context/Use case	M&E 1 – Hybrid broadcast service

Enhancement work	A set of extended CPs is proposed beyond those considered in LTE FeMBMS targeting, among others, better SFN coverage for HPHT networks (with e.g. 400 μs - 120 km ISD). The solution to enhance the coverage capability is to use numerologies with negative μ factors (in general) and extended CP with extended OFDM symbol for static reception.
Where to measure	WP3, D3.2 Section 5
How to measure	Analytical and simulations
How to evaluate	Analytical and simulations for different inter-site distances (echo delays) and CP/OFDM parameters SFN coverage is expressed as the variation of the available SINR in the network depending on the relative echo delay and CP/OFDM parameters.

4.5.8 Coverage (Indoor)

Project	IoRL
Which KPI	Coverage (Indoor)
Definition of KPI	mmWave: maximum transmission distance with a typical Rx power -15dBm and dynamic range UL: [-30, 0]dBm DL: [-60, 0]dBm VLC:maximum transmission distance with a typical Rx power -15dBm and dynamic range UL: [-30, 0]dBm DL: [-60, 0]dBm
Context/Use case	IoRL coverage service using efficient VNF management and orchestration
Enhancement work	The indoor coverage will increased by combining the VLC and mmWave
Where to measure	In RRLH L1
How to measure	The QoS table for individual UE at individual location.
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.5.9 Multi-site management

Project	MATILDA
Which KPI	Multi-site management
Definition of KPI	Functionality at its core is implemented as a distributed application
Context/Use case	• Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive. • Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE)
Enhancement work	• Providing users with location independent management functionality • Enable the deployment of Apps with distributed architecture
Where to measure	Testbed Bristol
How to measure	Testing the application management from multiple locations
How to evaluate	Must be available

4.5.10 CapEx Reduction

Project	METRO-HAUL
Which KPI	CapEx Reduction
Definition of KPI	Relative cost reduction with respect to baseline network cost to support a predefined set of vertical services (to be defined).
Context/Use case	
Enhancement work	
Where to measure	AMEN/MCEN relevant components and optical layer components to support the vertical services.
How to measure	Techno-economic modelling comparing resulting Metro-Haul with Baseline architecture
How to evaluate	To be defined

4.6 P6 – Enabling advanced user controlled privacy.

Although several projects such as 5GCAR, 5G-MonArch, 5G-PHOS, IoRL, MATILDA, SAT5G and SLICENET reported wok on *P6 – Enabling advanced user controlled privacy*, no refined definition of related KPIs was developed and therefore is not included.

4.7 Other KPIs

The reported KPIs in this sub-section are not easily included in the 5G PPP programme level KPIs and are mostly related to providing service at speed for moving objects and localisation accuracy. Such KPIs – although not originally included in the 5G PPP contractual arrangement are included in the related standards documents (see section 1.1).

4.7.1 Localisation

Project	5GCAR
Which KPI	Localization
Definition of KPI	The localization is the needed geographical position accuracy.
Context/Use case	Vulnerable Road User protection
Enhancement work	Accurate and Ubiquitous Real-time Positioning
Where to measure	In the location server.
How to measure	Compare the estimated position with the position from GNSS
How to evaluate	In a practical test in the field

4.7.2 Locality Awareness

Project	MATILDA
Which KPI	Locality Awareness
Definition of KPI	Locality awareness needed for optimized scalability and communication
Context/Use case	Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive.
Enhancement work	To ensure fastest route to obtain data via a defined communication path.
Where to measure	Testbed Bristol
How to measure	Server route analysis
How to evaluate	Must be available

4.7.3 Positioning Accuracy

Project	5G TRANSFORMER
Which KPI	Positioning Accuracy
Definition of KPI	Positioning error
Context/Use case	Application/eHealth
Enhancement work	As for E2E latency
Where to measure	eHealth
How to measure	Measuring the reported position from the user's device and the actual position of the user that the ambulance detects once it arrives to the emergency site (only in emergency scenario).
How to evaluate	Maximum positioning error tolerated by the application, where a high positioning accuracy means a little error.

4.7.4 Position accuracy (indoor)

Project	IoRL
Which KPI	Position accuracy (indoor)
Definition of KPI	Position Accuracy is the maximum positioning error in 3D coordinate system for mmWave and VLC. Due to the IoRL systems inside buidings, the expected precision of about 10cm.
Context/Use case	IoRL positioning service using efficient VNF management and orchestration
Enhancement work	The indoor positioning accuracy will increased by combining the VLC and mmWave

Where to measure	In SDN positioning VNF
How to measure	The UE position service will be deployed in VNF an Positioning Error = ||Actual Position – Measured Position||
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.7.5 Communication range

Project	5GCAR
Which KPI	Communication range
Definition of KPI	Communication range is the maximum distance between a transmitter and its intended receiver allowing communication with a targeted Service Data Unit (SDU) size, Latency, and Reliability, and for a given effective transmit power and receiver sensitivity. This definition applies to both the communication between vehicles and between vehicles and infrastructure.
Context/Use case	See Through
Enhancement work	Meeting Low Latency and High Reliability Requirements in V2X Communication Scenarios
Where to measure	Between the cars involved in the demo
How to measure	From the host car to the remote car
How to evaluate	With a demo

4.7.6 Mobility support at speed

Project	5G-MEDIA
Which KPI	Mobility support at speed
Definition of KPI	Maximum relative speed under which the specified reliability should be achieved.
Context/Use case	Use Case 3: Ultra-high Definition (UHD) over Content Distribution Networks
Enhancement work	In UC3, media caching logic is designed to work also with fast moving vehicles (from pedestrians, 0-3 km/h to slow moving vehicles 3 – 50 km/h)
Where to measure	
How to measure	
How to evaluate	

4.7.7 High Mobility

Project	5G-PICTURE
Which KPI	High Mobility
Definition of KPI	High throughput, uninterrupted traffic in the case of high mobility in railway applications.
Context/Use case	Novel 5G enabled platforms are expected to offer services ranging from delay sensitive video to infotainment services, and from best effort applications to ultra-reliable ones such as M2M (Machine-to-Machine) communications in very high mobility of train transportation systems beyond 2020 that in many cases may exceed 500 km/h.
Enhancement work	To support the transport network requirements associated with C-RAN in railway environment, we propose the adoption of an optical transport solution offering high capacity and advanced features including dynamic bandwidth allocation both in the time and frequency domain. The combination of mmWave radio links (as a channel for high quality mobile broadband) and passive WDM (which provides point-to-point logical connections through a physical point-to-multipoint network topology) results in the most appropriate technology for building a new communications infrastructure for railway infrastructures.
Where to measure	Use Case Demonstrator : Railway use case (FGC, Spain). Each train unit consists of two components: Antenna Module fixed to the train roof and Host Processor Module fixed inside the train. A separate Host Processor Module is required for each Antenna Module. Typhoon devices are used to support the necessary functionalities.
How to measure	Traditional Network monitoring tools and traffic generators, while also spectrum analysers and Radio measurement tools to evaluate mmWave and beamforming

	operations. Redundancy considerations will also be investigated.
How to evaluate	Benchmark against static solutions where for example at a given moment, a mmWave AP provides up to a 4 Gb/s TDD clear channel connection with the mmWave unit on top of the train.

4.7.8 Mobility (walking speed indoor)

Project	IoRL
Which KPI	Mobility (walking speed indoor)
Definition of KPI	Spatially Restricted Mobility: cross back and forth in two cells with a fixed walking speed(around 1.4m/s) Fully Mobility: Move freely between two cells with random speeds.
Context/Use case	The use cases will cover training, museum, home and media
Enhancement work	The indoor mobility will increased by combining the VLC and mmWave
Where to measure	In UE and RRLH
How to measure	One UE move between two RRLH to measure the Ping-pong Handover Ratio, Handover Failure Rate, Radio Link Failure Ratio with different system load
How to evaluate	We can compare our combined-solution with respect to other available solutions.

4.7.9 Mobility

Project	5G TRANSFORMER
Which KPI	Mobility
Definition of KPI	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)
Context/Use case	Application/Automotive
Enhancement work	As for E2E latency
Where to measure	Automotive
How to measure	Measuring the availability of the service, considering different car speeds (automotive)
How to evaluate	Definition of different mobility speeds: 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). Initial evaluation performed through simulation.

4.7.10 UE User Speed / Mobility

Project	5G-XCast
Which KPI	UE user speed, mobility (evaluated)
Definition of KPI	Maximum mobile station speed at which a defined QoS can be achieved (in km/h) [TR 37.910].
Context/Use case	M&E 1 – Hybrid broadcast service (> 250 km/h specifically mentioned for PTM)
Enhancement work	Mixed Mode designed to reach speeds higher than 500 km/h at 700 MHz if the MCS selected is robust enough. Speeds up to 250 km/h for 4 GHz. Terrestrial Broadcast, although focused on large SFN coverage, supports maximum speed values up to 400 km/h @ 700 MHz band.
Where to measure	WP3 D3.2, see section 5.2.1.
How to measure	Analytical + Link-level simulations with mobile reception conditions
How to evaluate	Theoretical Doppler shift and user speed associated to target frequency bands. In order to evaluate the mobility performance of NR in the IMT-2020 evaluation context, a Typical Urban (TU-6) channel model with variable speed has been selected.

4.7.11 Minimum Data Rate from Moving Objects

Project	NRG-5
Which KPI	Minimum Data Rate from Moving Objects
Definition of KPI	Minimum guaranteed throughput achievable by a UE moving in a tri-dimensional space with linear trajectory and fixed speed

Context/Use case	UC2: Enabling aerial Predictive Maintenance for utility infrastructure - Drone camera streaming
Enhancement work	Orchestration and optimized placement of service specific VNF to the edge devices (MEC) as close as possible to the UE in order to avoid loss due to transport protocols. Mobility tracking to anticipate logic handover. Using data-plane acceleration techniques to limit the virtualisation overhead.
Where to measure	Either at the UE or at the network service endpoint
How to measure	Using specific networking tools (e.g., iperf)
How to evaluate	Quantify losses in data rates due to the non optimal VNF placement, lack of mobility tracking, and lack of data plane acceleration techniques

4.7.12 New business models for 5G empowered media industry

Project	5G-MEDIA
Which KPI	New business models for 5G empowered media industry
Definition of KPI	Sustainable business models for network operators as well as for applications, device and service providers to ensure improved network and end-to-end service quality and to enhance customer experience.
Context/Use case	
Enhancement work	New business models are defined in 5G-MEDIA, based on Streaming as a Service innovative concept in the edge-to-cloud fabric
Where to measure	
How to measure	
How to evaluate	

4.7.13 Widespread adoption, impact creation & standardisation

Project	5G-MEDIA
Which KPI	Widespread adoption, impact creation & standardisation
Definition of KPI	Actions to implement project impact and engage with scientific and industrial communities
Context/Use case	
Enhancement work	• The 5G-MEDIA platform will be demonstrated to at least 3 large events such as international workshops, conferences and industry fairs. • At least 3 open source communities, 3 Celtic-Plus Eureka projects to participate on the 5G-MEDIA platform validation. • Evaluation of 5G-MEDIA platform offerings by at least 30 developers participating in the hackathons organised by 5G-MEDIA. • Promote 5G-MEDIA offerings to at least 50 B2B customers of the consortium partners.
Where to measure	
How to measure	
How to evaluate	

4.7.14 Resource Usage Monitoring

Project	MATILDA
Which KPI	Resource Usage Monitoring
Definition of KPI	• To allow preparation of dynamical scaling, the monitoring of the current resource usage is needed. • Acquisition of compute/storage/networking resource usage data for a specific App
Context/Use case	• Distributed signal/data acquisition, management & processing for testing of complex mobile systems e.g. automotive. • Multimedia sharing and Retail Recommendation use case: 5G Personal Assistance in Crowded Events (5GPACE) • Critical communications

Enhancement work	• To ensure comprehensive monitoring (including statistics etc.) of the network. • Optimization of 5G App lifecycle management • Provide various service and network KPIs
Where to measure	• Testbed Bristol • CNIT Test bed, Genoa
How to measure	• MATILDA infrastructure will provide this information. • QoS monitoring application (part of application graph, e.g. qMON Agent or smart phone application for RAN), Prometheus monitoring for cloud-based compute resources
How to evaluate	Must be available

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