D5.1 Initial validation KPIs and metrics

Dissemination level:	Public (PU)
Work package:	WP5
Task:	T5.1 Validation methodology and plan
Deliverable lead:	FSCOM
Version:	V1.0
Submission date:	19/10/2022
Due date:	30/09/2022
Partners:	

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101016427

www.5g-iana.eu

Authors

Authors in alphabetical order		
Name	**Organisation**	**Email**
Alexis Aivaliotis	O7	aaivaliotis@oseven.io
Claudio Russo	BYL	claudio.russo@bylogix.it
David Alemany Ibor	5CMM	david.alemany@fivecomm.eu
Dimitrios Klonidis	UBITECH	dklonidis@ubitech.eu
Fotis Foukalas	COGN	fotis@cogninn.com
Francesca Moscatelli	NXW	f.moscatelli@nextworks.it
Francois Fischer	FSCOM	Francois.fischer@fscom.fr
Jörg Schäpperle	NOKIA	joerg.schaepperle@nokia-bell-labs.com
Konstantinos Katsaros	ICCS	k.katsaros@iccs.gr
Manuel Fuentes	5CMM	manuel.fuentes@fivecomm.eu
Marios Zinonos	HIT	m.zinonos@hit-innovations.com
Markus Wimmer	NOKIA	markus.wimmer@nokia.com
Matteo Andolfi	NXW	m.andolfi@nextworks.it
Miriam Ortiz Monet	5CMM	miriam.ortiz@fivecomm.eu
Nehal Baganal-Krishna	UULM	Nehal.Baganal-Krishna@wiwinf.uni-due.de
Pasquale Marasco	BYL	pasquale.marasco@bylogix.it
Peter Schmitting	FSCOM	Peter.schmitting@fscom.fr
Rudolf Sušnik	ININ	rudolf.susnik@iinstitute.eu
Thanos Xirofotos	UBI	txirofotos@ubitech.eu
Yann Garcia	FSCOM	Yann.garcia@fscom.fr

Control sheet

Version history			
Version	**Date**	**Modified by**	**Summary of changes**
v0.1	21/06/2022	Peter Schmitting (FSCOM)	ToC
v0.2	28/06/2022	Matteo Andolfi (NXW)	Clause 3.3 content
v0.3	29/06/2021	Peter Schmitting (FSCOM)	KPI table(s) for UC requirements
v0.4	06-13/07/2022	Peter Schmitting (FSCOM), Nehal Baganal-Krishna (UULM), Rudolf Sušnik (ININ)	Inputs for UC6 and UC7 KPIs
V0.5	18/07/2022	Peter Schmitting (FSCOM), Fotis Foukalas (COGN), Alexis Aivaliotis (O7)	Inputs for UC4 and UC5 KPIs, Aggregation of all UC KPIs in one document
V0.6	25/07/2022	Peter Schmitting (FSCOM), Fotis Foukalas (COGN), Rudolf Susnik (ININ), Marios Zinonos (HIT)	"NOKIA-comments" addressed in UC3, UC4 and UC7 KPIs
V0.7	05/08/2022	Peter Schmitting (FSCOM), David Alemany (5COMM), Baganal-Krishna (UULM), Rudolf Susnik (ININ)	Inputs for UC1, additions to UC3, UC6 and UC7 KPIs

V0.8	14/09/2022	Peter Schmitting (FSCOM), all UC leaders	Merge of all inputs, clauses 2.5 & 2.6 review
V0.9	19/09/2022	Peter Schmitting (FSCOM), all UC leaders	Final UC KPI inputs, KPI introduction added
V0.10	20/09/2022	Peter Schmitting (FSCOM), Markus Wimmer (NOKIA), Marios Zinonos (HIT)	Executive summary and initial KPI clustering added; NOKIA comments resolved
V0.11	21/09/2022	Peter Schmitting (FSCOM), Amr Rizk (UULM)	First round peer review UULM, results from WP5 call #16
V0.12	22/09/2022	Peter Schmitting (FSCOM), Marios Zinonos (HIT)	Final KPI clustering added, order of clauses changed (AOEP before UC KPIs)
V0.13	22/09/2022	Matteo Andolfi (NXW)	UCs Service Chain Design
V0.14	26/09/2022	Peter Schmitting (FSCOM), Marios Zinonos (HIT), Alexis Aivaliotis (O7), Manuel Fuentes (5CMM), Nehal Baganal (UULM), Peter Zidar (TS)	UC1 and UC5 KPIs improved/completed, clustering modified accordingly, Service chain design inputs from UC1, UC3, UC6 integrated, TS peer-review comments resolved
V0.15	28/09/2022	Peter Schmitting (FSCOM), Matteo Andolfi (NXW), Marios Zinonos (HIT), Pasquale Marasco (BYL), Alexis Aivaliotis (O7), Fotis Foukalas (COGN)	Second round peer review UULM resolved, Service chain design inputs from UC2, UC4, UC5 integrated
V0.16	30/09/2022	Peter Schmitting (FSCOM), Matteo Andolfi (NXW), Fotis Foukalas (COGN), Nehal Baganal (UULM), Miriam Ortiz Monet (5CMM)	Service chain design inputs completed, Modifications in UC1, UC4 and UC6 KPIs
V0.17	07/10/2022	Dimitrios Klonidis, Thanos Xirofotos (UBI), Matteo Andolfi (NXW)	Clause 4 editing - Workplan
V0.18	16/10/2022	Peter Schmitting, Francois Fischer (FSCOM), Matteo Andolfi, Francesca Moscatelli (NXW), Dimitrios Klonidis, Marios Zinonos (HIT)	Final modifications in 2.6.3, 2.7.4, 3.4, 3.7, 4.4; deliverable clean-up
V1.0	16/10/2022	Eirini Liotou	Final version

Peer review		
	Reviewer name	**Date**
Reviewer 1	Peter Zidar (TS)	23/09/2022
Reviewer 2	Amr Rizk (UULM)	26/09/2022
Reviewer 3	Eirini Liotou (ICCS)	12/10/2022

Legal disclaimer

The information and views set out in this deliverable are those of the author(s) and do not necessarily reflect the official opinion of the European Union. The information in this document is provided "as is", and no guarantee or warranty is given that the information is fit for any specific purpose. Neither the European Union

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ABBREVIATIONS

Abbreviation	Definition
5G-IANA	5G Intelligent Automotive Network Applications
5G-PPP	5G Public Private Partnership
AI	Artificial Intelligence
AF	Application Function
AGV	Automated Guided Vehicle
AOEP	Automotive Open Experimental Platform
API	Application Programming Interface
AR	Augmented Reality
CE	(Gitlab) Community Edition
CI	Continuous Integration
CPU	Central Processing Unit
DL	downlink
DML	Decentralized Machine Learning
DoA	Description of Action
E2E	end-to-end
EC	European Commission
FOV	Field-of-View
GPS	Global Positioning System
HMD	Head Mounted Display
IPC	Inter-Process Communication
KPI	Key Performance Indicator
MANO	Management and Orchestration
MEC	Multi-access Edge Computing
ML	Machine Learning

MOS	Mean Opinion Score
NF	Network Function
NW	Network
OS	Operating System
PU	public
OBU	On-Board Unit
QoE	Quality of Experience
QoS	Quality of Service
RAN	Radio Access Network
RTT	Round-Trip-Time
SME	Small and Medium Sized Enterprise(s)
UC	Use Case
UDP	User Datagram Protocol
UE	User Equipment
UL	Uplink
VAO	Vertical Application Orchestrator)
VBT	Virtual Bus Tour
VNF	Virtual Network Function
WP	Work Package

Executive Summary

The present document is deliverable D5.1 ‘Initial validation KPIs and metrics’ of the 5G-IANA project. The main objective of the deliverable is to provide an initial set of Key Performance Indicators (KPIs) and metrics for evaluation and analysis of the 5G-IANA Use Cases (UC) with the vision of making the so defined KPIs available to third-party developers and experimenters wishing to use the 5G-IANA Automotive Open Experimental Platform (AOEP) for the development and evaluation of their own services and NetApps.

A top-down approach was chosen i.e., defining first the UC related KPIs including initial information on where and how to observe/measure/monitor them (see tables in clause 2.7). To ensure a relevant, useful, and re-useable set of KPIs, this approach has been preferred to a bottom-up approach of collecting generic KPIs from literature/past work. Three categories of KPIs have been defined:

- Network Level (NL) KPIs
  providing information on the baseline performance requirements from the 5G network.
- Service level (SL) KPIs
  providing information on the baseline performance expectations over the whole service chain.
- Business Level KPIs
  providing information used to quantify the business-related opportunities and value propositions.

Following this UC-based “exercise”, a KPI clustering has been made to derive a generic KPI pool that can be advertised to third parties as an incentive to test their applications in the 5G-IANA platform (see clause 0).

Furthermore, initial considerations in view of AOEP related KPIs have been summarized (see clause 2.6). The present deliverable provides the initial input overview of the validation KPIs which will be reiterated and finalized as per the working plan in the final report D5.2 ‘Validation methodology’ in M22 of the project.

Further clauses of D5.1 describe the service chain design (see 3) associated to each UC providing high level descriptions identifying the virtual functions (application or network oriented) that compose the end-to-end service.

The agreed integration workplan for the development and integration activities of 5G-IANA has been defined in detail and includes the planned interactions among a) the platform development activities, b) the NetApp UC and functions’ developments, c) the integration process, and d) the testbed infrastructure deployments. The workplan follows the two 12-month development cycles and proceeds respectively to testing and validation activities which are also mapped to the overall workplan. Beyond the overall project workplan, detailed plans have been extracted also for the NetApp Toolkit and AOEP developments, and the NetApp, application and network functions' developments for each UC. Moreover, the overall workplan has been mapped to the third-party promotion, selection and validation activities which also follow the two development cycles of the project.

Note that the final two clauses go beyond the original scope of the present deliverable and have been inserted to address comments stemming from the interim 5G-IANA project review.

1. Introduction

1.1. 5G-IANA concept and approach

5G-IANA aims at providing an open 5G experimentation platform, on top of which third party experimenters (i.e., SMEs) in the Automotive-related 5G-PPP vertical will have the opportunity to develop, deploy and test their services. An Automotive Open Experimental Platform (AOEP) will be specified, as the whole set of hardware and software resources that provides the computing and communication/transport infrastructure as well as the management and orchestration components, coupled with an enhanced NetApp Toolkit tailored to the Automotive sector. 5G-IANA will expose to experimenters secured and standardized APIs for facilitating all the different steps towards the production stage of a new service. 5G-IANA will target different virtualization technologies integrating different Management and Orchestration (MANO) frameworks for enabling the deployment of the end-to-end network services across different domains (vehicles, road infrastructure, MEC nodes and cloud resources). 5G-IANA NetApp toolkit will be linked with a new Automotive VNFs Repository including an extended list of ready to use open accessible Automotive-related VNFs and NetApp templates, which will form a repository for SMEs to use and develop new applications. Finally, 5G-IANA will develop a distributed AI/ML (DML) framework, which will provide functionalities for simplified management and orchestration of collections of AI/ML service components and will allow ML-based applications of OEMs and third parties to penetrate the Automotive world, due to its inherent privacy preserving nature. 5G-IANA will be demonstrated through seven Automotive-related use cases in two 5G SA testbeds. Moving beyond technological challenges, and exploiting input from the demonstration activities, 5G-IANA will perform a multi-stakeholder cost-benefit analysis that will identify and validate market conditions for innovative, yet sustainable business models supporting a long-term roadmap towards the pan-European deployment of 5G as key advanced Automotive services enabler.

1.2. Purpose of the deliverable

The purpose of this deliverable is to provide the initial KPIs and relevant metrics together with their evaluation methods to be used for the technical validation of the Intelligent NetApps. Furthermore, the present document provides a classification of the metrics according to a taxonomy of technical, service and business level KPIs that may be used by third party experimenters wanting to use the 5G-IANA platform for experimentation purposes.

The complete validation methodology to be used for measuring the efficiency of the 5G-IANA architecture and the corresponding system performance will be delivered in D5.2 'Validation methodology' in M22 of the project.

1.2.1. Intended audience

The dissemination level of this deliverable is "public" (PU). It is primarily aimed to be the reference document to be used by the 5G-IANA Consortium Members during the validation phases of the 5G-IANA project. Furthermore, this deliverable is addressed to any interested reader (i.e., public dissemination level) who wants to be informed about 5G-IANA validation methodology and especially third-party experimenters intending to use the open 5G-IANA experimentation platform.

1.2.2. Interface with other deliverables

The considerations of the present deliverable are based on and apply to the 5G-IANA architecture as described in D2.1 'Specifications of the 5G-IANA architecture' [1].

Furthermore, the present initial KPI considerations act as input to and will be further developed within WP5, namely in D5.2 'Validation methodology' due in M22.

2. KPI and Metrics Framework

2.1. Introduction

The present clause lists and describes the derived KPIs. The KPIs have been chosen considering that they should not be of use solely within the project's UC deployment evaluations but also for the use of third-party experimenters that want to use the 5G-IANA platform for the implementation and deployment of their services.

5G-IANA studied existing work on KPIs, namely the 5G-PPP whitepaper 'Service performance measurement methods over 5G experimental networks' [3] and for the project related application of KPIs 5G-PPP whitepaper 'Beyond 5G/6G KPIs and Target Values' [4]. Additionally, work from the 5GAA ([5] and [6]) and from 3GPP [7] was considered. Furthermore, 5G-MOBIX deliverable D.2.5 'Initial evaluation KPIs and metrics' [2] served as example for the KPI tables used in the present document.

The different subclauses contain:

- Definition of generic 5G KPIs on the network (NL), service (SL) and business (BL) level;
- Introduction to common template for the KPIs;
- An initial list of AOEP (platform) KPIs;
- UC specific KPI tables including metrics and planned evaluation method (how and where);
- Clustering of the UC KPIs to the generic KPIs which can then be advertised to third parties as an incentive to test their applications in the 5G-IANA platform;

2.2. 5G Network level KPIs

Network level KPIs provide information on the baseline performance requirements from the 5G network and the 5G-IANA platform, in order for the UC applications to operate optimally. Core KPIs should be generic and always applicable. It should be noted that some of the generic KPI definitions can be used as a basis for both the definition of 5G network KPIs and service level KPIs where both KPI definitions need to specify between which reference points they are measured.

The present clause first introduces a set of common definitions for 5G Network level KPIs followed by a number of relevant generic Network level KPIs actually measurable by the 5G-IANA platform and in the UC.

- **Performance KPIs** are defined as a quantity used for measuring performance (e.g., latency, data rate, packet loss rate, etc.).
- **Performance requirements** define a range or a target value for a KPI which is required for a service to work properly (e.g., latency < 20 ms). KPIs' measurement can be based on threshold values defined for each KPI; minimal, maximal and nominal value where an acceptable KPI value should be close to its nominal value and should not be less than its minimal threshold value or exceeding its maximal threshold value.

Reference points define a network interface or a node or a protocol layer used as a measurement point. Both 5G network KPIs and 5G-IANA KPIs definitions need to specify at which reference points they are measured. It should be noted that 5G network and service level performance KPIs will differ in the reference points. Within the present deliverable which defines initial KPIs the following network level KPIs have been considered.

- **5G Latency** is the time duration between the transmission of a message from a point A in a transmitter and the successful reception of the message at a point B in a receiver.
- **Round-trip time (RTT)** is defined as the time duration between the transmission of a message from a network node and the successful reception of the response message by the same point i.e., the time duration between the transmission of a message from a point A in a first network node and the successful reception of the message at a point B in a second network node plus the server response time at point B plus the time duration between the transmission of a response message from the point B in the second network node and the successful reception of the message at the point A in the first network node.
- **UL (DL) user data rate** is defined as the amount of user data transmitted by the UE (edge server) and received from the IP layer in the edge server (UE) divided by the total time between reception of the first packet and the reception of the last packet.
- **Max. user data rate** is defined as the user data rate with only one user active in the system, full transmit buffer and favourable radio channel conditions.
- **UL (DL) packet loss rate** is defined as the one minus the number of packets received from the IP layer in the edge server (UE) divided by the number of packets passed for transmission to the edge server (UE) to the IP layer in the UE (edge server).
- **Reliability** is defined as the one minus packets loss rate.

2.3. Service level KPIs

Service Level KPIs provide information on the baseline performance expectations of the service demonstrated in each UC. These KPIs target specific Vertical Services from a business perspective i.e., each set concerns a service focused on a specific industry or group of customers with specialized needs (e.g., automotive, entertainment etc).
Within the present deliverable the following (most commonly in UCs applied) service level KPIs have been considered:

- **E2E Latency** is the maximum accepted latency across the entire service chain (of a UC).
- **E2E Reliability** is defined as the percentage of correctly received packets over the total packets transmitted in the complete service chain.
- **Service Availability** is the percentage of time that an application is accessible and usable within a predefined QoS level e.g., the fraction of time a software component is functional (up) or the fraction of requests that are serviced correctly.
- **Application Jitter** is the statistical variation of the end-to-end latency for the communications across the entire service chain of the vertical service.
- **Quality of Experience (QoE)** is defined as the overall acceptability of an application or service, as perceived subjectively by the end-user.
- **Prediction Accuracy** in classification tasks is a measure of how well an algorithm correctly identifies or excludes a condition i.e., the proportion of correct predictions among the total number of cases examined.

2.4. Business level KPIs

Business level KPIs provide information used to quantify the business-related opportunities and value propositions for vertical industries and third-party users occurring by each UC related NetApp/Service. Same as SL KPIs, each KPI concerns a service focused on a specific industry or group of customers with specialized needs.
At the time of writing the present deliverable several UC leaders have already provided business level KPIs. Different UCs have different focus and those with clear business level KPIs can be studied in the subclauses for UC3 (2.7.4), UC4 (2.7.5) and UC7(2.7.8).

2.5. KPI table template

The following KPI table template is used in the present deliverable. This format is based on the template developed in the 5G-MOBIX project, see [2].

Table 1, KPI table template

KPI title	**Unique identifier for each KPI** **Example** **KPI_xx_yyy_##** **xx = NL, SL, BL** **yyy = UCx, AOEP** **## = 01 -99**
Description	High-level description of KPI
Context/Use Case	Associate the KPI with a particular use case/platform/NetApp.
Where to observe/measure/monitor	Point(s) of observation (e.g., reference points) to obtain a KPI "value".
How to observe/measure/monitor	A high-level description of the measurement methodology, including (where applicable): • Detailed definition of KPI e.g., what timestamps to use for latency, which packets to consider for throughput, etc. • Key (functional) requirements for the measurements e.g., endpoint synchronization, background, traffic generation (if any), etc.
How to evaluate	Definition of comparison approach i.e., what values the measured KPI data points are compared against. This can include Target Values or results retrieved by identified alternative setups/experiments.
Comments	If any

2.6. Automotive Open Experimental Platform (AOEP) KPIs

2.6.1. Introduction

AOEP KPIs provide a measurable value that demonstrates performances of the 5G-IANA platform. The present clause collects and presents initial considerations for such KPIs. The more generic types of KPIs (see 2.6.2) and the defined sets of AOEP service level

KPIs (see 2.6.3) may evolve and change during the lifetime of 5G-IANA. This can include the removal of certain KPIs or KPI categories in the future as discussions are ongoing within the 5G-IANA consortium on the exact technical scope of the 5G-IANA evaluation. Moreover, any feedback from third party experimenters following the first 5G-IANA open call could be found useful for such KPI revision. The evolution of the KPIs will be further reported in D5.2 based on the experiences made in the UC deployments.
Currently the following categories of AOEP KPIs are considered:

- Reliability and Availability KPIs
- Service deployment and Provisioning time

2.6.2. Reliability and Availability KPIs

The 5G-IANA platform is a complex software architecture. The reliability and availability of a such architecture can be evaluated by measuring the related KPIs of each component.

- The reliability is measured using cycles of uninterrupted working intervals (uptime), followed by a repair period after a failure has occurred (downtime).
- The availability (uptime) defines the time a component is running under nominal conditions. It considers the repair time and the restart time for the component. It is expressed in percentage e.g., downtime per month or per week.

The following factors have to be considered

- Mean Time Between Failures (MTBF)
  The MTBF is described as the time interval between the two successive failures i.e., Uptime. It is expressed in time units. The time units are entirely dependent on the system and can be expressed in days or months.
    - The formula to calculate the MTBF is:
      MTBF = Total operational time/Number of failures
- Mean Time To Repair (MTTR)
  Once failure occurs, MTTR measures the average time it takes to track the errors causing the failure and to fix them i.e., Downtime.
    - The formula to calculate the MTTR is:
      MTTR = Total repair time/Number of repairs

By using MTBF and MTTR and the formula below the availability of a 5G-IANA platform component can be determined as:

Availability = MTBF / (MTBF + MTTR) = Uptime / (Uptime + Downtime)

The availability considers and is influenced by both MTBF and MTTR, whereas the reliability can be measured by only using the MTBF. The reliability is a function of the availability: a component can be available but not reliable. This means that a component reaches only a high quality if it has both a good availability and a good reliability.

2.6.3. AOEP Service Level KPIs

2.6.3.1. Service Creation Time

The Service Creation Time KPI indicates the time that is consumed by the end user of the AOEP to create the desired Vertical Service chain to be deployed. In particular, the evaluation of this KPI concerns the performances of the NetApp Toolkit component of the AOEP and how its exposed functionalities facilitate the process of creating a new Vertical Service chain.

Table 2, KPI_SL_AOEP_01 – Service Creation Time

Service Creation Time	KPI_SL_AOEP_01
Description	Time consumed by the end user of the platform to create a new Vertical Service chain through the functionalities provided by the NetApp Toolkit.
Context/Use Case	All UCs
Where to observe/measure/monitor	This KPI can be measured by processing relevant events reported by the NetApp Toolkit logging system.
How to observe/measure/monitor	This KPI is measured by automating the collection and processing of relevant events from the NetApp Toolkit log file. In particular the evaluation takes into consideration the time interval from the instant when the creation of a new Vertical Service chain is started from the user up to the instant when all the related packages and descriptors are fully available on the platform, and this is notified to the user.

	It should be noted that the time required by the user to interact with the platform has an impact on this KPI; for this reason, the KPI will be measured as an average of the time taken to execute the whole procedure involving users with different levels of expertise. These users will be classified in three categories (beginners, medium-expertise, experts) and the test will be repeated involving the same number of users from each category.
How to evaluate	The evaluation is performed taking into consideration the 5G-PPP KPIs evaluation reports. Currently the Service Creation & Activation Time as defined in [11] is expected to be no more than 90 minutes, including on-boarding of relevant templates and packages/descriptors, provisioning and configuration procedures. The Service Creation Time in 5G-IANA corresponds to the Service Creation & Activation Time Phase I (i.e., Onboarding), therefore, the targeted maximum value is set to 60 minutes.

2.6.3.2. Service Provisioning Time

The Service Provisioning Time KPI consists of: i) the time consumed by the AOEP to perform the selection and allocation of the needed compute resource quotas at the different segments (i.e., far-edge, edge, remote cloud) where the NetApps should be deployed and ii) the time consumed to orchestrate the NetApps in Vertical Service chain, including their deployment and configuration.

Table 3, KPI_SL_AOEP_02 – Service Provisioning Time

Service Provisioning Time	KPI_SL_AOEP_02

Description	Time consumed by the platform to provision a new Vertical Service chain through the functionalities provided by the Vertical Application Orchestrator (VAO), the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms.
Context/Use Case	All UCs
Where to observe/measure/monitor	This KPI can be measured by processing relevant events reported by the logging system of the VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms.
How to observe/measure/monitor	This KPI is measured by automating the collection and processing of relevant events from the log files produced by the VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms. In particular, the evaluation takes into consideration the time when the procedure for the provision of a new Vertical Service chain starts and when the same procedure is concluded by the platform. The overall provisioning time is decomposed in different time components: i) the time consumed by the VAO to process the provisioning request, ii) the time consumed by the Slice Manager / Resource Orchestrator to process the request coming from the VAO, to allocate the compute resource quota for the AFs/NFs, and iii) the time consumed by the VAO to orchestrate the Afs/NFs and iv) the time consumed at the different segment-specific orchestration platforms to deploy the NetApps in the Vertical Service chain.

	The decomposition of the overall Service Provisioning Time allows to understand which are the most demanding procedures among the ones performed to achieve the Vertical Service provisioning.
How to evaluate	The evaluation is performed in compliance with [11]. The Service Provisioning Time in 5G-IANA is defined as the time needed to provision a new Vertical Service across different infrastructure segments and corresponds to the Phase II (i.e., Instantiate, Configure & Activate) of the Service Creation & Activation Time. Therefore, including the activation and configuration of NetApps, the targeted maximum value is set to 5 minutes.

2.6.3.3. Service Modification Time

The Service Modification Time KPI consists in the time consumed by the AOEP to perform the scale-in/scale-out of NetApps in a given Vertical Service chain, including the re-configuration of the service.

Table 4, KPI_SL_AOEP_03 – Service Modification Time

Service Modification Time	**KPI_SL_AOEP_03**
Description	Time consumed by the platform to modify (scale-in/scale-out) a Vertical Service chain through the functionalities provided by the VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms.
Context/Use Case	All UCs
Where to observe/measure/monitor	This KPI can be measured by processing relevant events reported by the logging system of the VAO, the Slice Manager /

	Resource Orchestrator and segment-specific orchestration platforms.
How to observe/measure/monitor	This KPI is measured by automating the collection and processing of relevant events from the log files produced by the VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms. In particular the evaluation takes into consideration the time when the procedure for the modification of a Vertical Service chain starts and when the same procedure is concluded by the platform. The overall modification time is decomposed in different time components: i) the time consumed by the VAO to process the modification request, ii) the time consumed by the Slice Manager / Resource Orchestrator to process the request coming from the VAO, to modify the compute resource quota for the Afs/NFs and/or to scale-in/scale-out the NetApps, iii) the time consumed by the VAO to scale-in/scale-out Afs/NFs, and iv) the time consumed at the different segment-specific orchestration platforms to scale-in/scale-out the NetApps in the Vertical Service chain. The decomposition of the overall Service Modification Time allows to understand which are the most demanding procedures among the ones performed to achieve the Vertical Service modification.
How to evaluate	The evaluation is performed in compliancy with [11], however a specific target KPI value for the service modification phase is

	not explicitly defined. The Service Modification Time in 5G-IANA is defined as the time needed to modify a Vertical Service across different infrastructure segments and corresponds to the Phase III of the Service Creation & Activation Time (i.e., Modify). Since the target KPI value is not defined in the reference document, we assume the same boundary of the service provisioning time, with a targeted maximum value set to 5 minutes.

2.6.3.4. *Service Termination Time*

The Service Termination Time KPI consists in the time consumed by the AOEP to perform the termination of the NetApps and AFs in a given Vertical Service chain and de-allocate the provisioned resources across the different segments (i.e., far-edge, edge, remote cloud).

Table 5, KPI_SL_AOEP_04 – Service Termination Time

Service Termination Time	KPI_SL_AOEP_04
Description	Time consumed by the platform to terminate a Vertical Service chain through the functionalities provided by the VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms.
Context/Use Case	All UCs
Where to observe/measure/monitor	This KPI can be measured by processing relevant events reported by the logging system of the VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms.
How to observe/measure/monitor	This KPI is measured by automating the collection and processing of relevant events from the log files produced by the

	VAO, the Slice Manager / Resource Orchestrator and segment-specific orchestration platforms. In particular, the evaluation takes into consideration the time when the procedure for the termination of a Vertical Service chain starts and when the same procedure is concluded by the platform. The overall termination time is decomposed in different time components: i) the time consumed by the VAO to process the termination request and terminate the NetApps, ii) the time consumed by the Slice Manager / Resource Orchestrator to process the request coming from the VAO, to de-allocate the compute resource quota for the AFs, and iii) the time consumed at the different segment-specific orchestration platforms to terminate the AFs/NFs in the Vertical Service chain. The decomposition of the overall Service Termination Time allows to understand which are the most demanding procedures among the ones performed to achieve the Vertical Service termination.
How to evaluate	The evaluation is performed in compliancy with [11], however a specific target value is not defined for the termination phase. The Service Termination Time in 5G-IANA is defined as the time needed to terminate a Vertical Service across different infrastructure segments and corresponds to the Phase IV (i.e., Terminate) of the Service Creation & Activation Time. Since the target value is not defined in the

	reference document, in 5G-IANA we assume a maximum value set to 5 minutes on the basis of previous trials' experiences.

2.7. Use Case KPIs

2.7.1. Introduction

In the present clause, the KPIs that have been derived from the project-specific UCs (bottom-up approach) are described. However, particular attention has been given to propose "reusable" KPIs that will be of interest also to third party experimenters (subject to their applications). Moreover, at the end of the present clause (see 0), to further highlight the value of such KPIs beyond the project consortium UC scope, a clustering of the UC KPIs into broader categories is given as assistance for their application.

2.7.2. UC1 related KPIs

The main objective of UC1 is the integration, demonstration and validation of advanced remote driving functionalities in the open and enhanced experimentation platform developed in the 5G-IANA project. The aim is to use a vehicle connected through 5G, which is controlled remotely via a teleoperation platform. The vehicle is equipped with both a front and a rear camera to transmit the video to the edge of the 5G network. The vehicle to be used in this UC is an automated guided vehicle (AGV) with an "Ackerman" configuration, that is, the rear wheels provide traction force to the car, while the front wheels are adjustable and guide it. The 5G enabled vehicle will be equipped with an OBU and connected to the edge of the network, both sending information based on its on-board sensors and video (constant feed).

At the edge, an AI/ML algorithm will be processed and added on top of the video, providing information about the different elements located while driving on the road, such as pedestrians, cars, or traffic signals. An additional warning feature will be included by the use of sensors and lidars located in the vehicle, which permit to measure the distance to obstacles and to provide the driver additional information and/or stopping when a potential accident is about to happen.

Network Level (NL) KPIs are presented first in tables KPI_NL_UC1_01 and KPI_NL_UC1_02. In UC1, these KPIs are either measured on the Edge Server or the OBU.

Table 6, KPI_NL_UC1_01 - 5G RTT

5G RTT	KPI_NL_UC1_01
Description	5G Round Trip Time (RTT) between UE and Edge Server.
Context/Use Case	This KPI is required to guarantee a real-time experience when driving the vehicle, which is key to avoid delayed reactions and potential accidents.
Where to observe/measure/monitor	The RTT is determined between UE and Edge Server.
How to observe/measure/monitor	The RTT between UE and Edge Server is measured using PING. The measurement is started at the UE side.
How to evaluate	Average RTT <= 20ms
Comments	UC1 can be executed safely if the average RTT does not exceed 20ms.

Table 7, KPI_NL_UC1_02 -5G user data rate

User data rate	KPI_NL_UC1_02
Description	5G Uplink/Downlink Throughput rate between the UE and the Edge Server.
Context/Use Case	Minimum throughput, which is required to transmit: • Video and laser information from the AGV in UL direction • AGV control information in DL direction between the UE (vehicle) and the Edge Server.
Where to observe/measure/monitor	The 5G UL/DL throughput rate is determined between the UE (vehicle) and the Edge Server.

How to observe/measure/monitor	iperf is executed between the vehicle (UE) and Edge Server.
How to evaluate	Video from the AGV in UL direction: • When front camera is used: UL > 10 Mbps • When back camera is used: UL > 10 Mbps Laser information (UL only) rate > 4 Mbps AVG control data (DL only) rate > 50 kbps.
Comments	Front camera may use higher bit rate if available to provide higher video resolution.

Service Level (SL) KPIs are presented in tables KPI_SL_UC1_01 to KPI_SL_UC1_04. In UC1, these KPIs provide information on the baseline performance expectations of the demonstrated service at application level.

Table 8, KPI_SL_UC1_01 - E2E latency

E2E latency	KPI_SL_UC1_01
Description	The maximum accepted latency across the entire service chain, including the application.
Context/Use Case	UC1 requires low latency on the entire service chain to guarantee proper execution of the vehicle remote driving.
Where to observe/measure/monitor	Both at the vehicle and cockpit.
How to observe/measure/monitor	It will be measured by comparing two timestamps: the first input provided in the controller against the exact moment where the AGV is starting to move (by using a photodiode and laser system).
How to evaluate	• UL video < 150ms

	• UL laser information < 50 ms • AGV control orders < 50ms

Table 9, KPI_SL_UC1_02 – E2E reliability

E2E reliability	KPI_SL_UC1_02
Description	Percentage of correctly received packets over the total packets transmitted in the complete service chain.
Context/Use Case	To properly operate the remote driving and to safeguard the proper execution of it, avoiding potential accidents, a reliable connection is needed. The user is controlling the vehicle remotely, so it is key to keep the video and specially the control available.
Where to observe/measure/monitor	Both ends, the vehicle and the edge.
How to observe/measure/monitor	Execute ping for a consistent time with a packet size coherent with typical NetApp communication messages (as to stress network fragmentation) to measure the absolute packet loss.
How to evaluate	• UL video > 99.9% • UL laser information > 99.999% • AGV control orders > 99.999%

Table 10, KPI_SL_UC1_03 – AI object detection algorithm accuracy

AI Algorithm Accuracy	KPI_SL_UC1_03
Description	Accuracy of correctly detected elements located while driving on the road (pedestrians, cars, or traffic signals).
Context/Use Case	To inform the driver about obstacles/ signals on the road and/or stop the vehicle

	when a potential accident is about to happen, the reliability of the AI algorithm is provided
Where to observe/measure/monitor	Edge Server and User Interface.
How to observe/measure/monitor	The AI algorithm estimates the reliability of the detection which is stamped around the object on the current video frame.
How to evaluate	• Accuracy > 0,7 Requirements: • User speed < 50km/h • Objects detected < 20 objects/frame • Range < 10m
Comments	The accuracy of the algorithm must be greater than 0,7 under the requirements listed above (maximum speed, number of detected objects and distance). • In YOLO algorithm, 0,7 is considered a reliable margin (based on previous experience).

Table 11, KPI_SL_UC1_04 - Quality of Experience

Quality of Experience	KPI_SL_UC1_04
Description	General acceptability of the service, as subjectively perceived by the end user, covering the full effects of the end-to-end system (client, terminal, network, service infrastructure, etc.).
Context/Use Case	The NetApp will need to provide a high QoE to achieve high service reliability and a good user experience.

Where to observe/measure/monitor	The end-users will rate the service offered by the UC1 after its use.
How to observe/measure/monitor	The subjective measurement method MOS (Mean Opinion Score) will be used. Users rate the service quality by giving five different point scores, from 5 to 1, where 5 is the best quality and 1 is the worst quality. Quality can be classified as Bad [0 – 1], Poor [1 – 2], Fair [2 – 3], Good [3 – 4] and Excellent [4 – 5].
How to evaluate	MOS > 4.3

2.7.3. UC2 related KPIs

UC2 aims to showcase a real-to-life automotive-ready 5G-IANA NetApp using the 5G-IANA platform by developing a high-end connected and automated vehicles manoeuvre coordination service. With an eye on lowering the risk of collision in complex junction scenarios and the aim to enhance public safety by helping in heterogenous vehicles coexistence on the road, it implements a shared coordination system to direct connected and eventually automated vehicles through suitable paths and priorities. It ultimately provides a swift wireframe for developing new automotive Vertical Services relying on the 5G-IANA AOEP.

UC2 will showcase two real-to-life connected vehicles, an L3 AV and a car, driving through a road crossing with instructions coming from a centralized NetApp running at the Edge Server and transmitted to their respective OBUs via 5G connectivity. Different configurations can be executed adding Virtual Vehicles in a software simulator that interacts with the road crossing test thanks to 5G reliability and speed, fully exploiting the 5G-IANA AOEP system.

Network Level (NL) KPIs are presented first in tables KPI_NL_UC2_01 and KPI_NL_UC2_02. In UC2 these KPIs are either measured on the Edge Server or the OBU.

Table 12, KPI_NL_UC2_01 – 5G RTT

5G RTT	KPI_NL_UC2_01

Description	5G Round Trip Time (RTT) between UE and Edge Server.
Context/Use Case	Low latency on the access segment is required for UC2 to guarantee interaction of the real-to-life vehicles with the manoeuvre coordination service and with simulated vehicles.
Where to observe/measure/monitor	Both ends between the OBU and the Edge Server.
How to observe/measure/monitor	Execute ping for some time to measure the average round trip time.
How to evaluate	Average RTT <= 20ms

Table 13, KPI_NL_UC2_02 - E2E Reliability

E2E Reliability	KPI_NL_UC2_02
Description	E2E reliability, the minimum reliability to assure the proper service operation (e.g., safe driving).
Context/Use Case	To proper operate the manoeuvre coordination service and to safeguard the proper execution of manoeuvres on behalf of each involved vehicle, UC2 requires a very reliable connection.
Where to observe/measure/monitor	Both ends between the OBU and the Edge Server.
How to observe/measure/monitor	Execute ping for a consistent time with a packet size coherent with typical NetApp communication messages (as to stress network fragmentation) to measure the absolute packet loss.
How to evaluate	Packet loss rate < 10^-4

Service Level (SL) KPIs are following in tables KPI_SL_UC2_01 to KPI_SL_UC2_03. In UC2 these KPIs provide information on the baseline performance expectations of the demonstrated service.

Table 14, KPI_SL_UC2_01 - E2E Latency

E2E Latency	**KPI_SL_UC2_01**
Description	The maximum accepted latency across the entire service chain.
Context/Use Case	UC2 requires low latency on the entire service chain to guarantee proper execution of the vehicle coordination.
Where to observe/measure/monitor	On a gateway between the OBU and the Edge Server.
How to observe/measure/monitor	Wireshark observation of protocol packets timestamps.
How to evaluate	Average time for request/response transactions < 500ms.

Table 15, KPI_SL_UC2_02 - Service availability

Service availability	**KPI_SL_UC2_02**
Description	Service availability, the percentage of time the service is offered properly.
Context/Use Case	The NetApp must be considered always in the UC2 context as loss of service availability is very dangerous both for vehicles during manoeuvres and vehicles adding to the manoeuvres. Losing the ability to properly complete a manoeuvre or try to join the manoeuvre coordination without success exposes involved vehicles to high risk and produces traffic paralysis.
Where to observe/measure/monitor	At the AOEP and at the OBU through connections' logging and statistics.

How to observe/measure/monitor	Counting connection failures and timeouts over a proper considerable time.
How to evaluate	Service availability >= 99.999%

Table 16, KPI_SL_UC2_03 - Service deployment time

Service deployment time	KPI_SL_UC2_03
Description	Time for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.)
Context/Use Case	UC2 deeply relies on a prompt service access that resides in a fast setup of all the application's communications from the OBU to the entire AOEP. That is fundamental for reconnections as well as service scale out.
Where to observe/measure/monitor	At the AOEP and at the OBU.
How to observe/measure/monitor	Compute the duration of different service run levels from "service start" to "service ready" in server log entries.
How to evaluate	Service design <= 60 minutes Initial service deployment <= 3 min Service scale-out <= 1 min
Comments	This KPI relates to KPI_NL_UC2_01, KPI_NL_UC2_02, KPI_SL_UC2_01

2.7.4. UC3 related KPIs

UC3 (UC3-VBT) corresponds to a virtual tour, where virtual reality users will be joining a tour guide in a virtual environment of a double decker bus and will be represented in the VR space with their avatars. Users will be able to receive to their Head Mounted Display (HMD) the video of the tour surroundings streamed by a high resolution 360° camera mounted to a vehicle taking the real tour, along with GPS-driven landmark indicators providing information about the attractions. The users, via their avatars will be able to gesture, speak and listen to one another, from their dedicated virtual bus seats, which will be determined during their entry.

The first set of KPIs presented are Network Level KPIs in tables KPI_NL_UC3_01 to KPI_NL_UC3_04.

These KPIs are either measured on the Edge Server and/or the OBU. For the KPI NL_UC3_04 (Service deployment time), it is expected that the AOEP provides the measurements.

Table 17, KPI_NL_UC3_01 – 5G RTT

5G RTT	KPI_NL_UC3_01
Description	5G Round Trip Time (RTT) between Far Edge PC (UE) and Edge Server.
Context/Use Case	Low latency is required in the context of UC3 to achieve high fidelity in matching the avatars responses with the virtual tour 360° video stream.
Where to observe/measure/monitor	Far Edge PC used in UC3 to stream the 360° video & Edge.
How to observe/measure/monitor	Use ping from the Far Edge PC to the Edge Server.
How to evaluate	UC3 requires RTT <= 20ms

Table 18, KPI_NL_UC3_02 User Data Rate

User Data Rate	KPI_NL_UC3_02
Description	Bit rate used between Far Edge PC (UE) and Edge Server.
Context/Use Case	In UC3 the • uplink throughput rate should be enough to support a constant data flow for 4k video, otherwise

	chopping could be experienced in the receiver's end. • throughput rate should be enough to cover the exchange of high priority control data.
Where to observe/measure/monitor	This is measured between the Far Edge PC (UE) and the Edge Server.
How to observe/measure/monitor	The iPerf tool will used for measuring this KPI in UC3.
How to evaluate	UC3 requires for the video stream an • uplink throughput >= 8Mbps (minimum), 16 Mbps preferred UC3 requires for the control data an • uplink throughput >=100 kbps • downlink throughput >= 100kbps.

Table 19, KPI_NL_UC3_03 - Reliability

E2E reliability	KPI_NL_UC3_03
Description	The probability of successfully delivered packets from the Far Edge PC to the Edge Server within a target latency threshold i.e., the packets are not either erroneous, lost, or arrive too late.
Context/Use Case	UC3 requires near-real time response rates to match the avatars responses with the virtual tour 360° video stream, and to achieve an engaging and responsive experience: Packet error rate causes dropped packets which can result in lagging of the video stream.

Where to observe/measure/monitor	This KPI will be observed in the communications between the Edge Server and the Far Edge PC.
How to observe/measure/monitor	The Wireshark software will be used.
How to evaluate	UC3 requires reliability >= 99.99% (packet error rate < 10^{-4}) within a latency threshold of 20 ms (per KPI_NL_UC3_01).

Table 20, KPI_NL_UC3_04 - Mobility interruption time

Mobility interruption time	KPI_NL_UC3_04
Description	The time duration during which a user terminal cannot exchange user plane packets with any base station. The mobility interruption time includes the time required to execute any radio access network procedure, radio resource control signalling protocol, or other message exchanges between the mobile station and the radio access network.
Context/Use Case	In UC3-VBT a buffering mechanism will be employed to maintain video fidelity to the end users, even in no network service availability scenarios. Network disconnection exceeding the duration of 6s when in mobile network coverage, will inhibit the real time aspects of the virtual tour.
Where to observe/measure/monitor	Vehicle/OBU.
How to observe/measure/monitor	This KPI will be measured utilizing the Active Network Monitoring Module AF developed for UC3. This module will provide a mechanism that will estimate

	the available network bandwidth utilizing active probing.
How to evaluate	Number of network disconnection occurrences between the OBU and the network that exceed 6s. The target is a Mobility interruption time < 0.01% during the execution of the entire UC3 scenario i.e., the completion of a Bus Tour in the city of Ulm.
Comments	Defined in [2]

The following tables (KPI_SL_UC3_01 to KPI_SL_UC3_07) Service Level (SL) KPIs provide information on the baseline performance expectations of the service demonstrated in UC3 and are relevant to infotainment or virtual reality related UCs.

Table 21, KPI_SL_UC3_01 - E2E Latency

E2E Latency	KPI_SL_UC3_01
Description	The duration required to send data between two points of the service chain.
Context/Use Case	In UC3 a maximum latency of 200ms is required to maintain the communication between the users, who via their avatars will be able to gesture, speak and listen to one another.
Where to observe/measure/monitor	This KPI will be calculated by performing measurements between the Far Edge PC and the VR application server, and between the VR user application and the VR server components of the UC.
How to observe/measure/monitor	By measuring duration from when data is offered from the camera and responsible AFs/NFs until it is processed, rendered

	and displayed to the VR headset of the user.
How to evaluate	UC3 requires UL video latency <= 200 ms.
Comments	This KPI relates to the following NL KPI: KPI_NL_UC3_01.

Table 22, KPI_SL_UC3_02 - Service Availability

Service Availability	KPI_SL_UC3_02
Description	The percentage of time the service is offered properly.
Context/Use Case	Application needs to be available and provide continuous sessions after the user is successfully connected.
Where to observe/measure/monitor	This KPI will be calculated by performing availability checks in the UC components located in the Edge PC, VR application server, VR user application components.
How to observe/measure/monitor	This KPI will based by monitoring the End-to-End availability between each interconnected component. When a component of the service will not be available, while a Virtual Tour is taking place, then it will be assumed that the service is not available.
How to evaluate	UC3 requires Service availability >= 99.999%.
Comments	This KPI relates to the following NL KPI: KPI_NL_UC3_01, KPI_NL_UC3_03, KPI_NL_UC3_05

Table 23, KPI_SL_UC3_03 - Quality of Experience

Quality of Experience	**KPI_SL_UC3_03**
Description	The overall acceptability of an application or service, as perceived subjectively by the end-user. The ability to measure QoE can provide a sense of the contribution of the network's performance to the overall customer satisfaction, in terms of reliability, availability, scalability, speed, accuracy and efficiency. The factors that affect the user perceived QoE are bandwidth, jitter, delay and packet loss rate. We will ask users to rate the entire VR service and the individual aspects of it (Video, Audio communication, Gesture Communication, Spatialized Audio).
Context/Use Case	The NetApp will need to provide a high QoE to be enjoyable by the end users.
Where to observe/measure/monitor	The end-users will fill questionnaires rating the NetApp presented in UC3 after using it.
How to observe/measure/monitor	The MOS will be used as a subjective measurement method. Refer to KPI_SL_UC1_04 for details on the calculation of the score. .
How to evaluate	User mean opinion score must be larger than 4.3.
Comments	This KPI relates to the following NL KPI: KPI_NL_UC3_01, KPI_NL_UC3_02, KPI_NL_UC3_03, KPI_NL_UC3_05. Defined in ITU-T Recommendation P.10/G.100 [9] and expanded in [4].

Table 24, KPI_SL_UC3_04 – Application Jitter

Jitter	KPI_SL_UC3_04
Description	Jitter is the variation of the end-to-end latency for the communications between specific components of the vertical service.
Context/Use Case	In UC3-VBT to ensure stability and reliability of the communication channel, low jitter values need to be maintained.
Where to observe/measure/monitor	E2E jitter for the VR Server Module of the NetApp and the VR application of the End Users.
How to observe/measure/monitor	The VR synchronization protocol will provide jitter measurements.
How to evaluate	UC3 requires mean Jitter < 30 ms per user for the duration of the demonstration.
Comments	This KPI relates to the following NL KPI: KPI_NL_UC3_01, KPI_NL_UC3_03. Defined in [3].

Table 25, KPI_SL_UC3_05 – Maximum number of simultaneous Users

Maximum number of simultaneous Users	KPI_SL_UC3_05
Description	The maximum number of users that can be accommodated by the service per area for predefined levels of service.
Context/Use Case	The UC NetApp will be stress-tested by using a differing number of artificial end users (bots) under different QoS levels.
Where to observe/measure/monitor	The robustness of the NetApp will be tested by artificially raising the number of users until the KPI requirements of KPI_NL_UC3_03, KPI_SL_UC3_01,

	KPI_SL_UC3_02, KPI_SL_UC3_04 are not met.
How to observe/measure/monitor	Dependent of the measurement of KPI_NL_UC3_03, KPI_SL_UC3_01, KPI_SL_UC3_02, KPI_SL_UC3_04. Please refer to the related tables.
How to evaluate	Artificial end users (bots) will be incrementally added to the app until the point where the requirements for NL and SL KPIs KPI_NL_UC3_03, KPI_SL_UC3_01, KPI_SL_UC3_02, KPI_SL_UC3_04 are not met. At least number of users > 10 is expected.
Comments	This KPI relates to the following NL and SL KPIs KPI_NL_UC3_03, KPI_SL_UC3_01, KPI_SL_UC3_02, KPI_SL_UC3_04.

Table 26, KPI_SL_UC3_06 - Service deployment time

Service deployment time	KPI_NL_UC3_06
Description	The duration required for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.).
Context/Use Case	In UC3 a per demand infotainment service is used. Being able to setup and deploy such a service in a quick manner can allow the vertical offering the service to only deploy it when needed, thus leading to less operational costs.
Where to observe/measure/monitor	On the AOEP platform and the corresponding network.

How to observe/measure/monitor	Start the task (service creation/ deployment/reconfiguration/scale-out) and measure time till full functionality is reached – use Prometheus/Orchestrator.
How to evaluate	Service design <= 60 minutes Initial service deployment <= 3 min Service scale-out <= 1 min

Table 27, KPI_SL_UC3_07 - FOV Prediction Accuracy

FOV Prediction Accuracy	KPI_SL_UC3_07
Description	Accuracy in classification tasks is a measure of how well an algorithm correctly identifies or excludes a condition i.e., the proportion of correct predictions among the total number of cases examined (expressed in a percentage).
Context/Use Case	In the NetApp developed in UC3 an AI mechanism is used to predict the Field-of-View (FoV) of the VR users. This KPI will be used to evaluate the effectiveness of the proposed mechanism to predict the future location of the end users' FoV in the 360º video of the tour.
Where to observe/measure/monitor	The AI module of the NetApp will log its prediction while the VR server of the NetApp will log the ground truth of the users' FoV i.e., it will record the actual users' FoV.
How to observe/measure/monitor	This will be validated comparing the predicted FoV against the actual FoV of the users. The FoV will be stored for each

	user via mechanisms provided by the NetApp.
How to evaluate	The proposed AI mechanism will predict the users' FoV with an accuracy between 85% and 90% based on the horizon used for of the prediction.

Table KPI_BL_UC3_01 provides information that can be used to quantify the business-related opportunities and value propositions for vertical industries occurring by the service demonstrated in UC3. It relevant and can be generalized to other on-demand infotainment or virtual reality related UCs.

Table 28, KPI_BL_UC3_01 - Willingness to Pay

Willingness to Pay	**KPI_BL_UC3_01**
Description	Willingness to pay is the maximum price a customer is willing to pay for a product or service. It can indicate if there is a commercial incentive for guided tours operators to invest in creating a virtual tour product.
Context/Use Case	This KPI will help quantify the business-related opportunities and value propositions occurring from the Virtual Bus Tour presented in UC3.
Where to observe/measure/monitor	The end-users will fill questionnaires rating their willingness to pay for the virtual bus tour presented in UC3 after using it.
How to observe/measure/monitor	The end users will be presented with a closed type question concerning the Willingness to pay. They will be able to choose between various monetary amounts.

How to evaluate	Willingness to pay at least €10. This value is based on the results of a survey presented in the 5G Monarch project [10].
Comments	This KPI relates to the following service level KPIs: KPI_SL_UC3_01, KPI_SL_UC3_02, KPI_SL_UC3_03, KPI_SL_UC3_04, KPI_SL_UC3_05.

2.7.5. UC4 related KPIs

UC4 is considered a NetApp that will use a combination of edge computing and AR technology to offload the computing power needed to display high-quality 3D objects, rendered by an AR engine, and stream them down to AR-enabled devices. The 3D-objects streaming will be provided to the 3D navigation environment of Live View by using ARCore Geospatial API and Edge Server. It is challenging for AR applications to support marker-based (and not marker-less) AR streaming content with the help of Edge elements to minimize the battery consumption of the mobile device. Marker-less AR is used to denote an AR application that does not need prior knowledge of a user's environment. Marker-based AR apps use markers (i.e., target images) to indicate things in a given space. Apart from that, where the battery issue is not considered anymore, the 3D objects streaming is useful in case of real-time collaborative experience with other users by using Cloud Anchor and through a unique 3D object descriptor including ID. Such AR streaming application will take into account different settings of the UE such as location, context, speed and throughput. A significant aspect of the Intelligent NetApp is that it will exploit the Edge Server existence and capabilities, bringing the services of the application closer to the user. This will satisfy the need for QoE, delivering a high-quality AR content including virtual 3D objects in low latency as well as maximizing the availability and reliability of the functions. The Intelligent NetApp will also take into consideration the coverage of the offered network in Ulm combined with the user's speed so it will adjust to the system requirements. It is obvious that such an AR content streaming NetApp requires a set of KPIs that is explained in detail below.

Below the Network Level KPIs in the tables KPI_NL_UC4_01 to KPI_NL_UC4_04 are presented. The NL KPIs are either measured on the Edge Server and the mobile device.

Table 29, KPI_NL_UC4_01 - 5G latency

5G latency	KPI_NL_UC4_01

Description	5G Round Trip Time (RTT) between mobile phone and Edge Server.
Context/Use Case	Low latency on the access segment is required in the context of UC4 to achieve high fidelity in the transferring of live data between drivers.
Where to observe/measure/monitor	Edge smartphone used in UC4 to receive data from Edge Server.
How to observe/measure/monitor	Using ping and other tracing techniques to the network.
How to evaluate	By measuring in ms the time it takes for AR content to be sent plus the amount of time it takes for acknowledgement of that signal to be received. UC4 requires RTT <= 20ms.

Table 30, KPI_NL_UC4_02 - E2E latency

E2E latency	KPI_NL_UC4_02
Description	E2E latency, the maximum accepted latency across the entire service chain.
Context/Use Case	UC4 requires an E2E latency <= 50 ms to transmit AR content efficiently.
Where to observe/measure/monitor	It will be observed at the mobile user device in collaboration with Edge Server while the monitoring will take place across both access and core network.
How to observe/measure/monitor	Using ping and other tracing techniques within the network.
How to evaluate	By measuring duration from when data is offered from the sensors and responsible AFs/NFs until it is processed, rendered, and displayed to the screen of the user.

Table 31, KPI_NL_UC4_03 - E2E reliability

E2E reliability	KPI_NL_UC4_03
Description	E2E reliability, the minimum reliability to assure the proper service operation (e.g., safe driving).
Context/Use Case	UC4 requires an E2E reliability >= 99.99% to transmit AR content efficiently (packet error rate < 10^{-4}).
Where to observe/measure/monitor	E2E Reliability between the mobile device and the Edge Server will be observed by using edge AI at the Edge Server.
How to observe/measure/monitor	To be determined with the developments of the specific monitoring framework.
How to evaluate	By measuring the percentage of lossless data that is reaching the UE, where it is in particular a packet error rate < 10^{-4}.

Table 32, KPI_NL_UC4_04 - E2E user data rate

E2E user data rate	KPI_NL_UC4_04
Description	E2E user data rate, the minimum bit rate to allow for media streaming of AR content across the network.
Context/Use Case	UC4 requires Uplink throughput >= 20Mb/s and Downlink throughput >= 50Mb/s to transmit AR content efficiently.
Where to observe/measure/monitor	The E2E user data rate is determined between the mobile device and Edge Server and measured at the mobile device.
How to observe/measure/monitor	To use measurement tracing mechanisms at the mobile device.

How to evaluate	By measuring the DL rate at the UE or at the application running on the mobile device.

The following tables KPI_SL_UC4_01 and KPI_SL_UC4_02 describe the Service Level (SL) KPIs, which provide information regarding the performance expectations of the AR streaming service that UC4 will provide.

Table 33, KPI_SL_UC4_01 - Service availability

Service availability	KPI_SL_UC4_01
Description	Service availability, the percentage of time the service is offered properly.
Context/Use Case	UC4 requires a Service availability >= 99.999% to provide AR streaming efficiently.
Where to observe/measure/monitor	It will be observed at the mobile user device through the Edge Server.
How to observe/measure/monitor	Using ping and other tracing mechanisms.
How to evaluate	By measuring the duration from when data is offered from the sensors and responsible VNFs until it is processed, rendered, and displayed to the screen of the user.

Table 34, KPI_SL_UC4_02 - Service deployment time

Service deployment time	KPI_SL_UC4_02
Description	Service deployment time, the duration required for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.).
Context/Use Case	UC4 requires Service design <= 60 minutes, Initial service deployment <= 3 min and Service scale-out <= 1 min.

Where to observe/measure/monitor	It will be observed at the mobile user device in collaboration with Edge Server.
How to observe/measure/monitor	Using different tracing mechanisms.
How to evaluate	By measuring the Duration required for setting up end-to-end logical network service.

Table KPI_BL_UC4_01 is the business level KPI of AR streaming application over wireless 5G networks.

Table 35, KPI_BL_UC4_01 – Sales Growth Rate

Sales Growth Rate	KPI_BL_UC4_01
Description	Sales growth is one of the most basic barometers of success for a business. By monitoring the growth of our sales over time, we will be able to identify which elements of our strategy are positively impacting sales and which are falling flat.
Context/Use Case	AR streaming applications that UC4 represents are going to be in high demand in the future networks.
How to evaluate	The formula to calculate sales growth rate is: Sales Growth Rate = (Current Net Sales – Previous Net Sales) / Previous Net Sales x 100
Comments	This KPI should always report a positive percentage as this signifies that the overall strategy is working.

2.7.6. UC5 related KPIs

UC5 will focus on the identification of hazardous events and risk assessment of road networks, combining ML algorithms to be trained on the edge based on aggregated data as well as real-time driving behaviour data. UC5 will develop an ML model that will be trained over a specific time period for the detection of hazardous driving events (harsh braking, harsh acceleration, speeding, mobile use, crashes) that will assign risk levels along road networks based on aggregated data. Then, we will employ 5G network capabilities to detect said events in real-time, providing users with alerts that will inform them on increased risk levels due to more frequent appearance of hazardous events. Latency here is of critical importance (decreasing the time needed for the driver to be notified, saving critical meters in their reaction time for the avoidance of a crash), utilizing O7's expertise as road safety and driving behaviour experts.
Table KPI_NL_UC5_01 presents the Network Level KPI.

Table 36, KPI_NL_UC5_01 – 5G latency

5G latency	**KPI_NL_UC5_01**
Description	5G Round Trip Time (RTT) between OBU and Edge Server.
Context/Use Case	Low latency on the access segment is required in the context of UC5 to achieve high fidelity in the transferring of live data between drivers.
Where to observe/measure/monitor	OBU used in UC5 to receive data from smartphones.
How to observe/measure/monitor	Using ping against the network.
How to evaluate	UC5 requires RTT <= 20ms.

The following tables KPI_SL_UC5_01 through to KPI_SL_UC5_05 describe the Service Level (SL) KPIs, which provide information regarding the performance expectations of the services that UC5 will provide.

Table 37, KPI_SL_UC5_01 – E2E latency

E2E Latency	**KPI_SL_UC5_01**
Description	The maximum accepted latency across the entire service chain.

Context/Use Case	In UC5 a maximum latency of 200ms is required to maintain the communication between the vehicles.
Where to observe/measure/monitor	This KPI will be calculated by performing measurements in the Far Edge i.e., in smartphones and OBUs.
How to observe/measure/monitor	By measuring duration from when data is offered from the smartphone/OBU and responsible VNFs until it is processed, rendered, and displayed to the driver's smartphone.
How to evaluate	UC5 requires latency <= 200 ms.

Table 38, KPI_SL_UC5_02 – E2E reliability

E2E reliability	**KPI_SL_UC5_02**
Description	E2E reliability, the reliability to assure the proper service operation (e.g., safe driving).
Context/Use Case	UC5 requires near real-time response rates to process harsh events and transmit the information to nearby vehicles, and to achieve a non-tedious experience.
Where to observe/measure/monitor	This KPI will be observed in the Edge Server.
How to observe/measure/monitor	Package loss between the OBU and the Edge server will be measured at an application level.
How to evaluate	UC5 requires E2E reliability >= 99.99% (packet error rate < 10^{-4}).

Table 39, KPI_SL_UC5_03 – Service availability

Service Availability	**KPI_SL_UC5_03**

Description	The percentage of time the service is offered properly.
Context/Use Case	Application needs to be available and provide continuous stream of information after the user is successfully connected.
Where to observe/measure/monitor	This KPI will be calculated by performing availability checks in the UC components located in the Edge smartphone/OBUs.
How to observe/measure/monitor	End-to-End availability between each interconnected component.
How to evaluate	UC5 requires Service availability >= 99.999%.

Table 40, KPI_SL_UC5_04 – Service deployment time

Service deployment time	KPI_SL_UC5_04
Description	The duration required for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.).
Context/Use Case	In UC5, a live data stream service. Being able to setup and deploy such a service in a quick manner can allow the vertical offering the service to only deploy it when needed, thus leading to less operational costs.
Where to observe/measure/monitor	On the AOEP platform and the corresponding network.
How to observe/measure/monitor	Start the task (service creation/ deployment/reconfiguration/scale-out) and measure time till full functionality is reached – use Prometheus/Orchestrator.

How to evaluate	Service design <= 60 minutes Initial service deployment <= 3 min Service scale-out <= 1 min.

Table 41, KPI_SL_UC5_05 – Quality of experience

Quality of Experience	KPI_SL_UC5_05
Description	The overall acceptability of an application or service, as perceived subjectively by the end-user. The ability to measure QoE can provide a sense of the contribution of the network's performance to the overall customer satisfaction, in terms of reliability, availability, scalability, speed, accuracy and efficiency. The factors that affect the user perceived QoE are bandwidth, jitter, delay and packet loss rate. We will ask users to rate the entire service and the individual aspects of it (app functionality, connectivity, exactness of information).
Context/Use Case	UC5 requires MOS value > 4.3.
Where to observe/measure/monitor	The end-users will fill questionnaires rating the NetApp presented in UC5 after using it.
How to observe/measure/monito	The MOS will be used as a subjective measurement method.
How to evaluate	User mean opinion score must be larger than 4.3.
Comments	Defined in ITU-T Recommendation P.10/G.100 [9] and expanded in [4].

2.7.7. UC6 related KPIs

UC6 provides an overview of the status of network components or virtual network functions and draws conclusions and predictions with respect to the performance of the monitored components. It utilizes V2X communications to deliver predictions of the network quality to a central computation entity at the Edge Server. The goal is to minimize the data collection overhead through utilizing a distributed Machine Learning approach, i.e., instead of collecting large amounts of network monitoring data to be centrally analysed, the ML analysis/prediction model is distributed on the AFs/NFs located at the Far Edge. The goal of the ML model is (1) to learn data traffic patterns for data traffic prediction, (2) to learn network condition models to provide QoS predictions, and (3) to learn to distinguish between normal and abnormal network behaviours to detect and predict faults.

The first set of KPIs presented are Network Level KPIs (tables KPI_NL_UC6_01 and KPI_NL_UC6_02). In UC6, these KPIs are either measured on the Edge or the OBUs.

Table 42, KPI_NL_UC6_01 – 5G RTT

5G RTT	KPI_NL_UC6_01
Description	Round-Trip Latency in the 5G network.
Context/Use Case	For each particular VNF component a certain E2E RTT is required in order to meet service requirements.
Where to observe	OBU
How to observe	Performance KPI: The measurement follows an active approach wherein the sender Far Edge transmits RTT measurement packets (e.g., ping or application layer-based ping). The Latency is the time elapsed from the transmission of packets until the sender (Far Edge/EDGE) receives an ACK from the 5G network.
How to evaluate	UC6 targets that the average RTT does not exceed 20ms.

Table 43, KPI_NL_UC6_02 - E2E Reliability

E2E Reliability	KPI_NL_UC6_02
Description	The probability of failure of packets that are not successfully delivered to the receiver within a target latency bound, as they are either erroneous, lost, or arrive too late.
Context/Use Case	A reliable connection is needed between Edge and OBUs in order to communicate models and other training parameters in between them.
Where to observe	EDGE and Far Edge.
How to measure	Out of 10^5 sent packets from Far Edge to EDGE, the quantile of packets received by the EDGE is measured.
How to evaluate	UC6 targets that this quantile is higher than 99.99%.

The following tables (tables KPI_SL_UC6_01 to KPI_SL_UC6_11) on Service Level KPIs provide information on the baseline performance expectations of the service demonstrated in UC6.

Table 44, KPI_SL_UC6_01 – Global model download time

Global model download time	KPI_SL_UC6_01
Description	The average time required by the worker nodes on the Far Edge to download the global model from the Edge during an iteration.
Context/Use Case	In the DML functionality, working nodes get the aggregated model for training from Edge and a smaller model download time is necessary. Third parties can take this into account for the configuration of DML training algorithms.
Where to observe	OBU

How to measure	The average time elapsed since Far Edge requests the Global model from the Edge until it receives the global model (per client / Far Edge).
How to evaluate	UC6 targets that this is less than 2 sec.

Table 45, KPI_SL_UC6_02 – Model upload time

Model upload time	KPI_SL_UC6_02
Description	The time required by the worker nodes to upload the locally trained model to the Edge after each iteration of local training.
Context/Use Case	UC6 requires the model upload time to be small which reduces the waiting time of Edge to start the aggregation process. Third parties can take this into account for the configuration of DML training algorithms.
Where to observe	Far Edge
How to measure	It is the average time elapsed since Far Edge finishes the training until the Far Edge completes upload of locally trained model to the Edge (per client).
How to evaluate	UC6 targets that this is less than 2 sec.

Table 46, KPI_SL_UC6_03 – Aggregation time

Aggregation time	KPI_SL_UC6_03
Description	The time required by the Aggregation VNF to aggregate all the locally trained models sent by working nodes.
Context/Use Case	Aiming at a smaller aggregation time reduces the idle time of the working nodes where they are waiting for aggregated global model. Third parties can take this

	into account for the configuration of DML training algorithms.
Where to observe	Edge.
How to measure	It is the average time elapsed since the reception of all the locally trained model at the aggregation node till it generates a global model (per ML training iteration).
How to evaluate	UC6 targets that this is less than 5 sec.

Table 47, KPI_SL_UC6_04 – Data per-processing time

Data per-processing time	KPI_SL_UC6_04
Description	The time required by the working node to pre-process all the collected data by network monitoring VNF.
Context/Use Case	As the network monitoring function collects huge amounts of data, the data pre-processing function needs a lot of time before it can provide some data to training nodes. Aiming at a smaller pre-processing time means that most recent data collected by the network monitoring function is available for training. Third parties can take this into account for the configuration of DML training algorithms.
Where to observe	Far Edge.
How to measure	The average time elapsed since the collection of data by the network monitoring VNF until the data is prepared for training.
How to evaluate	UC6 targets that this is less than 1 min.
Comments	Once the network monitoring VNF collects a certain volume of data, it has to be pre-processed, i.e., the data should be

	cleaned, arranged and clustered in batches.

Table 48, KPI_SL_UC6_05 – Model training time

Model training time	KPI_SL_UC6_05
Description	The time required by the working node to complete the training process over a set of training data.
Context/Use Case	Model training time impacts the total time required by the model to train (over multiple cycles) such that the aggregated global model is accurate in predicting QoS. Third parties can take this into account for the configuration of DML training algorithms.
Where to observe	Far Edge.
How to measure	It is the average time taken by the working node to train the received global model over local data.
How to evaluate	UC6 targets that this is less than 4 min.

Table 49, KPI_SL_UC6_06 – Inference time

Inference time	KPI_SL_UC6_06
Description	The time required by the Predictive QoS VNF to provide a response to an inference request.
Context/Use Case	In the automated vehicular scenario, inference time impacts the decision making of the vehicle. Increase in inference time delays the decision to be taken by the Vehicle. Third parties can take this into account for the configuration of DML training algorithms.

Where to observe	Far Edge.
How to measure	From the time the predictive QoS module is called with the latest latency value observed, until the predictive QoS module returns the prediction on the predicted latency.
How to evaluate	UC6 targets that this is less than 200msec.

Table 50, KPI_SL_UC6_07- Latency Prediction Error

Latency Prediction Error	**KPI_SL_UC6_07**
Description	The error in the predictive QoS / Latency predictions. A prediction error occurs when the measured latency violates the predicted quantile.
Context/Use Case	Achieving higher prediction accuracy helps in creating very accurate spatio-temporal latency maps. Third parties can take this into account for their applications using the DML framework.
Where to observe	Far Edge.
How to measure	Performance KPI: Based on the round-trip latency measurement a comparison between the predicted delay quantile (from the model) and the measured delay value is undertaken. In a window of 10^4 prediction and measurement values we calculate the ratio of the measured values that violate the prediction. This is denoted the latency prediction error.
How to evaluate	Prediction error is targeted below 10%.

Table 51, KPI_SL_UC6_08 – Network traffic overhead (UL)

Network traffic overhead (UL)	KPI_SL_UC6_08
Description	Volume of data transmitted from working node towards the aggregation server.
Context/Use Case	One of the features of DML is to reduce the data traffic between Edge and OBUs. Achieving less data overhead allows other necessary applications to use the available bandwidth. Third parties can take this into account for the configuration of DML training algorithms and inference.
Where to observe	Far Edge.
How to measure	It is the average volume of data transmitted over from Far Edge to Edge summed over all the Far Edge per iteration.
How to evaluate	UC6 targets that this is less than 10 MB.

Table 52, KPI_SL_UC6_09 – Network traffic overhead (DL)

Network traffic overhead (DL)	KPI_SL_UC6_09
Description	Volume of data transmitted from the aggregation server towards the working node.
Context/Use Case	One of the features of DML is to reduce the data traffic between Edge and OBUs. Achieving less data overhead allows other necessary applications to use the available bandwidth. Third parties can take this into account for the configuration of DML training algorithms and inference.
Where to observe	Far Edge.
How to measure	It is the average volume of data transmitted over from the Edge to the Far

	Edge summed over all the Far Edges per iteration.
How to evaluate	UC6 targets that this is less than 10 MB.

Table 53, KPI_SL_UC6_10 – Local training success rate

Local training success rate	KPI_SL_UC6_10
Description	Percentage of successfully uploaded locally trained models.
Context/Use Case	This information can be used in client selection for next training cycle. Third parties can take this into account for the configuration of DML training algorithms and the number of Edge devices required.
Where to observe	Far Edge.
How to measure	It is the average number of successfully uploaded locally trained models over the total number of successful global model downloads.
How to evaluate	UC6 targets that this is greater than 90%.

Table 54, KPI_SL_UC6_11 – Global training success rate

Global training success rate	KPI_SL_UC6_11
Description	Percentage of successfully uploaded locally trained models per iteration.
Context/Use Case	This metric gives an estimate on the number of working nodes which function properly. This information can be used in client selection for next training cycle. Third parties can take this into account for the configuration of DML training algorithms and the number of Edge devices required.

Where to observe	Far Edge.
How to measure	It is the average of number of successfully uploaded locally trained models over the total number of DML clients (Far Edge).
How to evaluate	UC6 targets that this is greater than 90%.

2.7.8. UC7 related KPIs

UC7 will develop and integrate necessary the components (e.g., VNFs, RSU, OBUs, sensors and cameras) to provide situational awareness for first responders operating in a road tunnel. In case of an accident in a (cross-border) road tunnel, situational awareness systems enable first responders to perceive environmental elements and events based on data collected by video camera and several sensors. One of the most important benefits expected to be achieved by using a 5G network and the 5G-IANA platform is cross-border collaboration of first responders without a need to use UEs dedicated to each single administrative domain as is usual practice today (e.g., each of the two bordering countries having its own communication system). All components forming the solution will be generic and therefore applicable to any 5G network providing required conditions (e.g., eMBB network slice, latency requirements, etc.).

To observe, measure and/or monitor certain KPI parameters, the existing performance monitoring and testing tool qMON (a product developed by ININ) will be used within UC7. qMON primarily serves as a solution for quality assurance in any kind of IP network, although specialized for mobile networks. The solution introduces the concept of qMON Agents and qMON Reference Servers, both serving as measurement endpoints providing measurements and tests that can be applied between any two of them. qMON Agents are intended to be installed at UEs, while qMON Reference Servers are usually installed on servers. The solution enables various active and passive measurement/testing procedures to be implemented, some of them will be used for evaluating UC7 KPIs as explained in the following tables.

The first set of KPIs presented are Network Level KPIs (tables KPI_NL_UC7_01 to KPI_NL_UC7_05). In UC7, these KPIs are mostly measured between the UE and the Edge Server. In KPI_NL_UC7_05 measurement is done between different Edge Servers.

Table 55, KPI_NL_UC7_01 - 5G RTT

5G RTT	KPI_NL_UC7_01

Description	5G Round Trip Time (RTT) between UE and local Edge Server.
Context/Use Case	Suitable RTT provides conditions that will allow for smooth video streaming from the (fixed) video camera located in the field to the end user (i.e., video stream consumer who may be receiving multiple video streams simultaneously) which may be mobile (e.g., in the context of the UC7 - a first responder driving to the incident location).
Where to observe/measure/monitor	Between the UE and Edge Server. The measuring/ monitoring method requires L3 connectivity between the end points.
How to observe/measure/monitor	qMON system – qMON Agent installed at UE, qMON Reference Server installed at the Edge Server (L3 connectivity).
How to evaluate	RTT <= 20ms

Table 56, KPI_NL_UC7_02 - Reliability

Reliability	**KPI_NL_UC7_02**
Description	Reliability required to assure the proper service operation (e.g., video streaming).
Context/Use Case	Suitable network reliability allows for proper (real-time) operation of the business application related to the UC7, i.e., minimizing potential interruptions that may affect the customer's experience due to the excessive packet loss.
Where to observe/measure/monitor	Between the UE and the Edge Server.
How to observe/measure/monitor	qMON system – qMON Agents installed at UEs and qMON Reference Server installed at the Edge Server.

How to evaluate	Reliability >= 99.99% (i.e., Packet Loss Rate< 10^{-4})

Table 57, KPI_NL_UC7_03 – UL (DL) user data rate

UL (DL) user data rate	KPI_ NL_UC7_03
Description	Required user data bit rate to allow for video streaming, as the most demanding service in terms of bandwidth consumption.
Context/Use Case	DL throughput should be greater than UL throughput due to the possibility of receiving multiple video-streams simultaneously to a single UE used by a customer ("Situational Awareness" business logic assumes the situational awareness for the user may be enhanced by providing multiple video-streams to the user from multiple locations).
Where to observe/measure/monitor	Between the UE and Edge Server.
How to observe/measure/monitor	qMON system – speed-test between the UE (qMON Agent) and Edge Server (qMON Reference Server) in both UL and DL directions (regularly measure/monitor bit rate available).
How to evaluate	UL user data rate >= 20Mb/s and DL user data rate >= 50Mb/s.
Comments	Downlink threshold is set higher than uplink due to the possibility of streaming from several sources/cameras to one user device.

Table 58, KPI_NL_UC7_04 - Jitter

Jitter	KPI_ NL_UC7_04

Description	Jitter, the maximum accepted average jitter between the UE and Edge Server.
Context/Use Case	Acceptable jitter allows conditions for smooth video streaming (as the most demanding service in terms of bandwidth consumption) from the (fixed) video camera located in the field to the end user.
Where to observe/measure/monitor	Between the UE and Edge Server. The measuring/monitoring method requires L3 connectivity between the end points.
How to observe/measure/monitor	qMON system – qMON Agent installed at UE, qMON Reference Server installed at the Edge Server (L3 connectivity required).
How to evaluate	UC7 requires average jitter of 2 ms.

Table 59, KPI_NL_UC7_05 – Cross-border connectivity between Nokia and TS testbeds

Cross-border connectivity between Nokia and TS testbeds	KPI_ NL_UC7_05
Description	RTT, packet loss rate, and minimum UL/DL user data rate between the two testbeds.
Context/Use Case	In order to provide cross-border operations, connectivity between the two (cross-border) networks should meet some minimum performances such as RTT, packet loss rate and user data rate.
Where to observe/measure/monitor	Between the TS Edge Server and Nokia Edge Server. The measuring/monitoring method requires L3 connectivity between the end points.
How to observe/measure/monitor	qMON system – qMON Agent and qMON Reference Server installed at both testbed Edge Servers.

How to evaluate	UC7 requires certain connectivity conditions in order to ensure proper service functioning, i.e.: - RTT <= 20 ms - Packet loss rate < 10^{-4} User data rate: > 20 Mbit/s (UL), > 50 Mbit/s (DL).

The following tables (tables KPI_SL_UC7_01 to KPI_SL_UC7_03) on Service Level KPIs provide information on the baseline performance expectations of the service demonstrated in UC7.

Table 60, KPI_SL_UC7_01 – Service deployment and scale-out time

Service deployment and scale-out time	KPI_SL_UC7_01
Description	Service deployment time, the duration needed for setting up E2E logical services characterized by respective network level guarantees (such as bandwidth, end-to-end latency, reliability, etc.).
Context/Use Case	The service deployment and scale-out time are important factors from the perspective of the customer support and service maintenance, e.g., related to SLA.
Where to observe/measure/monitor	On the AOEP platform and the corresponding network.
How to observe/measure/monitor	Start the task (service creation/ deployment/reconfiguration/scale-out) and measure time till full functionality is reached – use Prometheus/Orchestrator.
How to evaluate	UC7 requires: Service design <= 60 minutes Initial service deployment <= 3 min Service scale-out <= 1 min.

Comments	The KPI values mostly depend on AOEP platform performance.

Table 61, KPI_SL_UC7_02 – E2E RTT

E2E RTT	KPI_SL_UC7_02
Description	The maximum accepted RTT between the UE and VNF components (Monitoring, Analytics and Streaming) deployed at the Edge Server.
Context/Use Case	For each particular VNF component (Monitoring VNF, Analytics VNF, Streaming VNF), a certain E2E RTT is required in order to meet service requirements.
Where to observe/measure/monitor	Between the UE and certain VNF component (Monitoring, Analytics and Streaming) deployed at the Edge Server.
How to observe/measure/monitor	qMON system – qMON Agent installed at UE.
How to evaluate	E2E RTT < RTT* + 15% (20ms + 15%) (*) see also KPI_NL_UC7_01 – Round Trip Time (RTT).

Table 62, KPI_SL_UC7_03 – E2E Reliability

E2E Reliability	KPI_SL_UC7_03
Description	The minimum reliability required to assure the proper service operation of each particular VNF component deployed at the Edge Server (Monitoring, Analytics, Streaming).
Context/Use Case	Sufficient reliability is necessary to minimize interruptions of the service and thus allow for proper service operation.

Where to observe/measure/monitor	Between the UE and certain VNF component (Monitoring, Analytics and Streaming) deployed at the Edge Server.
How to observe/measure/monitor	qMON system - qMON Agent installed at UEs and qMON Reference Server installed at the Edge Server.
How to evaluate	UC7 requires E2E Reliability >= 99.99% (i.e., Packet Loss Rate< 10^{-4}) for each single VNF component.

Table KPI_BL_UC7_01 provides a business level KPI information that relates to the deployable infrastructure for the service demonstrated in UC7.

Table 63, KPI_BL_UC7_01 – NetApp is Vendor Agnostic

NetApp is Vendor Agnostic	KPI_BL_UC7_01
Description	NetApp SW components are vendor agnostic, i.e., they should function properly no matter the vendor of the infrastructure.
Context/Use Case	UC7 requires NetApp SW components are working properly without any dependency on a specific infrastructure vendor.
Where to observe/measure/monitor	In both testbeds, i.e., Ljubljana/TS and Ulm/Nokia.
How to observe/measure/monitor	Deploy NetApp SW components in both testbeds and check/compare whether functionalities work as expected (i.e., pass/fail).
How to evaluate	Compare NetApp functionalities observed in both testbeds.

2.7.9. Service Level KPI clustering and mapping to Network & Platform KPIs

Service level KPIs target service performance i.e., the evaluation of the overall behaviour of a high layer service. This evaluation will be based on the performance requirements of the relevant KPIs that will be measured during the UC demonstrations, taking into account network performance results as well.

In order to investigate the interrelationship between Service and Network Level KPIs, a methodology [4] is proposed by the 5GPP "Test, Measurement and KPI validation" working group. This methodology urges for the mapping of the proposed KPI as an analysis tool to investigate possible aggregation/correlation between different KPI levels. In the remaining clauses an expanded version of this methodology is proposed, to adapt it to the large number of Service Level KPIs proposed due to the diverse needs of the UCs of the project: Before mapping the service KPIs to the Network/Platform Level KPIs, they are clustered to ten categories based on a methodology [3] proposed by the same 5GPP WG. Then each cluster is mapped to the Network/Platform Level KPIs.

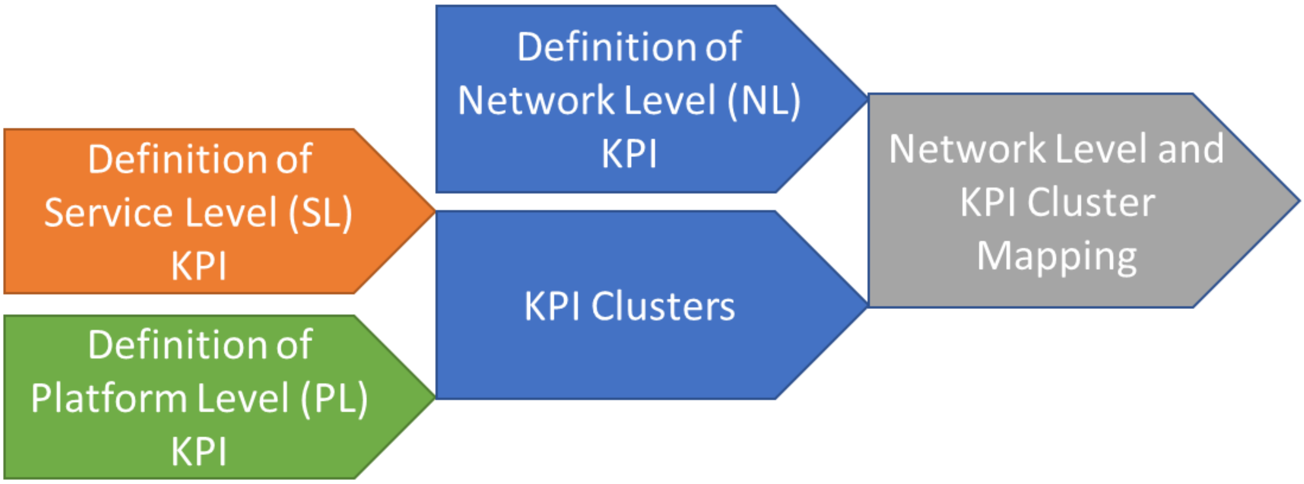

Figure 1, Procedure of mapping Service and Platform Level KPI to Network Level KPI

The aim of the methodology proposed is two-fold:

- Assist the UCs on the task of the validation of the components/mechanisms developed, in terms of investigating the factors that will affect the performance requirements set for the KPIs chosen for validation.
- Provide a starting point for third party experimenters, by preparing a pool of KPIs that they can consider for the validation of their NetApps. Once the KPIs of interest

are identified by the external experimenter, then they can look up the relevant entries in clauses 2.7.2 through to 2.7.8 and discover details on the pertinent interfaces, the rationale between the KPI requirements set by each UC, etc.

The Platform and Service level KPIs of the 5G IANA UCs belong to the following five clusters defined in [3]:

- **Latency Related (KPI_CL_01):** "Latency" is usually defined as the contribution of a network unit to the time from when the source sends a packet to when the destination receives it. A network unit can be a network segment or processing node. On the basis of this definition, the "Latency KPIs" category includes all KPIs that refer to latency or to latency components (contribution) of various segments/ functions/ components, at various planes.
- **Packet Loss Related (KPI_CL_02):** The "Packet Loss" KPIs category refers to KPIs used to evaluate the packet transmission success rate of a system to transmit a defined amount of traffic within a predetermined time.
- **Service Availability and Reliability Related (KPI_CL_03):** This KPI family cover KPIs related to service availability and reliability. Service is intentionally not defined in a specific manner, so it can cover different entities that relate to different domains.
- **Capacity Related (KPI_CL_04):** The "Capacity" KPIs category refers to metrics that are used to evaluate the amount of network resources provided to end-users. This category includes KPIs evaluating the bandwidth resources provided per user (i.e., user data rate), the bandwidth resources provided per area surface or node (i.e., node capacity, area traffic density, etc.), and the number of connections/devices that can be served per area; as being multiple metrics of the network resources capability.
- **Compute Related (KPI_CL_05):** This KPI cluster involves all KPIs that measurements of computing resources or computational tasks or service level KPIs that evaluate the efficiency of algorithms. This category reflects the importance of computing elements, and the fact that the use of computing resources is determinant in 5G and beyond 5G implementation, usage and performance.

Table 64 presents the assignment of the Service and Platform Level KPIs to each cluster, while in Table 65 each cluster is mapped to the Network KPI levels. It should be noted that a KPI e.g., maximum number of Simultaneous users (KPI_SL_UC3_05) might belong to more than one cluster.

Table 64, Service and Platform Level KPI clustering results

Cluster Name	Cluster KPIs
KPI_CL_01 - Latency Related	E2E Latency (KPI_SL_UC1_01, KPI_SL_UC2_01, KPI_SL_UC3_01, KPI_SL_UC5_01, KPI_SL_UC7_02), Application Jitter (KPI_SL_UC3_04)
KPI_CL_02 – Packet Loss Related	E2E Reliability (KPI_SL_UC1_02, KPI_SL_UC5_02, KPI_SL_UC7_03)
KPI_CL_03 – Service Availability & Reliability Related	Service Availability (KPI_SL_UC2_02, KPI_SL_UC3_02, KPI_SL_UC4_01, KPI_SL_UC5_03), Service Deployment Time (KPI_SL_UC2_03, KPI_SL_UC3_06, KPI_SL_UC4_02, KPI_SL_UC5_04, KPI_SL_UC7_01), Maximum number of simultaneous Users (KPI_SL_UC3_05), Quality of Experience (KPI_SL_UC1_04, KPI_SL_UC3_03, KPI_SL_UC5_05), Platform Availability, Platform Reliability
KPI_CL_04 Capacity Related	Network traffic overhead (UL) (KPI_SL_UC6_08), Network traffic overhead (DL) (KPI_SL_UC6_09), Maximum number of simultaneous Users (KPI_SL_UC3_05)
KPI_CL_05 Compute Related	Local training success rate (KPI_SL_UC6_10), Global training success rate (KPI_SL_UC6_11), FOV Prediction Accuracy (KPI_SL_UC3_07), Model training time (KPI_SL_UC6_05), Inference Time (KPI_SL_UC6_06), Latency Prediction Error (KPI_SL_UC6_07), Global model download time (KPI_SL_UC6_01), Model upload time (KPI_SL_UC6_02), Aggregation time (KPI_SL_UC6_03), Data pre-processing time (KPI_SL_UC6_04), AI object detection algorithm accuracy (KPI_SL_UC1_03), Platform Performance KPIs

Table 65, KPI clusters to Network Level KPI Mapping

Network Level KPI/ Cluster Name	Latency	User Data Rate	Reliability	Jitter	Cross-border connectivity between Nokia & TS edge servers	Mobility interruption time
KPI_CL_01 - Latency Related	X			X		
KPI_CL_02 – Packet Loss Related			X		X	
KPI_CL_03 – Service Availability & Reliability Related	X		X		X	X
KPI_CL_04 Capacity Related		X	X			
KPI_CL_05 Compute Related	X	X	X	X		X

3. USE CASE SERVICE CHAIN DESIGN

3.1. Introduction

The present clause describes the service chain design for each UC described in the previous clause.

The service chains implementing the 5G IANA UCs are composed of several application and network functions, potentially provided by multiple partners, which can be organized in one or more NetApps. The following sub clauses provide high level descriptions of the service chain associated to each UC, identifying the virtual functions (application or network oriented) that compose the end-to-end service, their interactions, their placement in the 5G infrastructure (i.e., at cloud or edge nodes, in OBU or RSU, etc.), and their communication with the physical devices deployed for each UC. For each application, a brief description is provided, and the partner responsible for its implementation is named.

3.2. UC1 – Remote driving

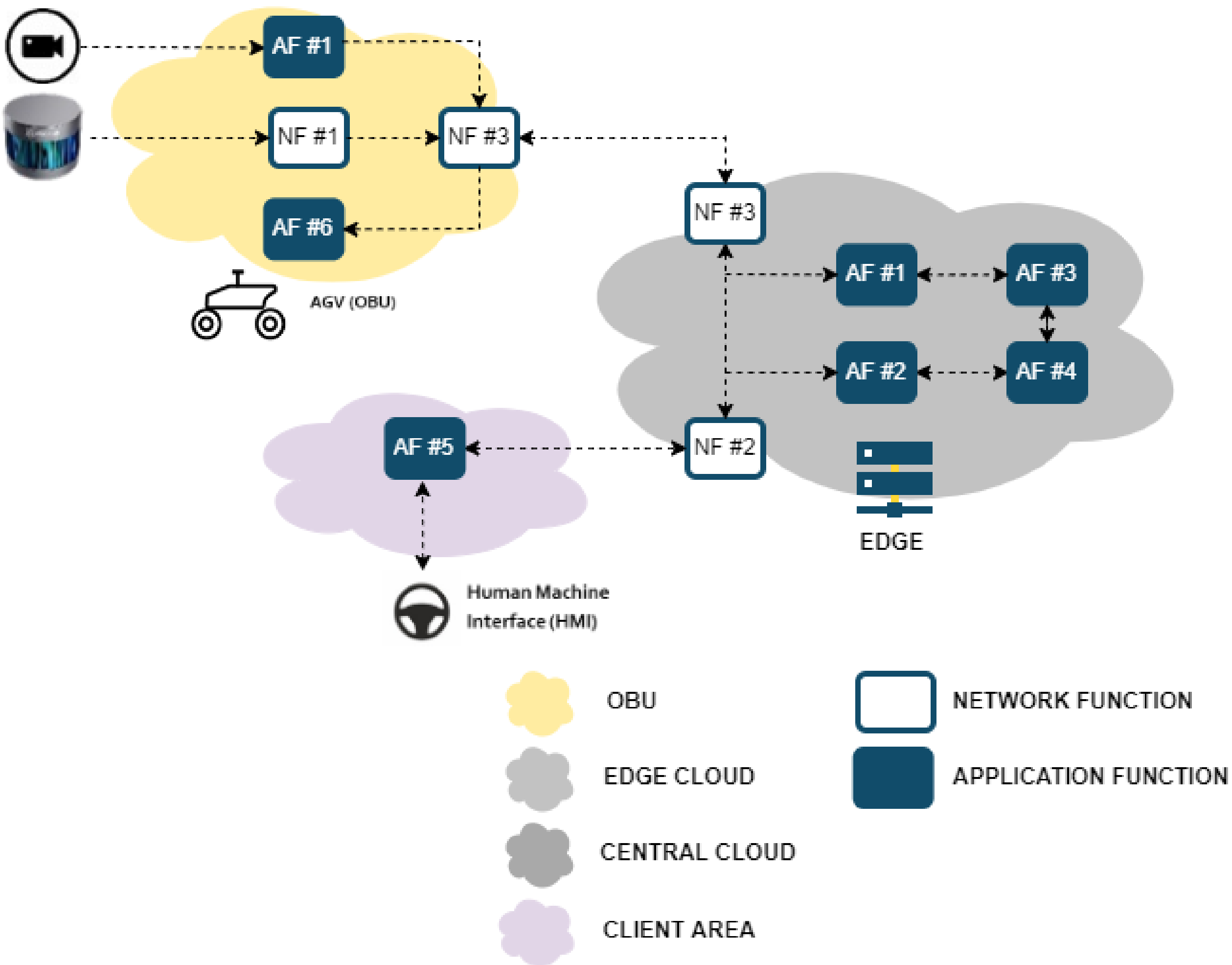

Figure 2, UC1 - Service chain design

Table 66, UC1 – AF/NF list

#	Name	Description	Provider
AF #1	Video encoding/decoding	This AF encodes the video to be transmitted through the 5G network. Also responsible for decoding and playing the received video on a web application.	5COMM

AF #2	Sensors' data analysis	Collects from sensors data related to distance and angle to near obstacles.	5COMM
AF #3	Object detection with deep learning	The video captured is processed on the edge to detect pedestrians, cars, and/or road elements such as traffic signals.	VIC/5COMM
AF #4	Vehicle condition warning service	Representation of warning signals and alerts in the user interface.	VIC/5COMM
AF #5	Remote driving central control	This AF is the responsible of collecting the information from the driver. Uses a steering wheel and sends it to the server to be processed by the actuator.	5COMM
AF #6	Remote driving module	This AF receives the orders from the actuator and moves the vehicle accordingly.	5COMM
NF #1	Sensors' data capturing	Processes the information from the vehicle sensors and takes decisions regarding movement.	5COMM
NF #2	Actuator interface	Receives the commands from the user and generates the control	5COMM

		order in a language understood by the vehicle.	
NF #3	Long-distance data communication	This VNF is in charge to transmit and to receive data for other VNFs for long-distance 5G communication channel to specific edge/cloud services.	5COMM

3.3. UC2 – Manoeuvres coordination for autonomous driving

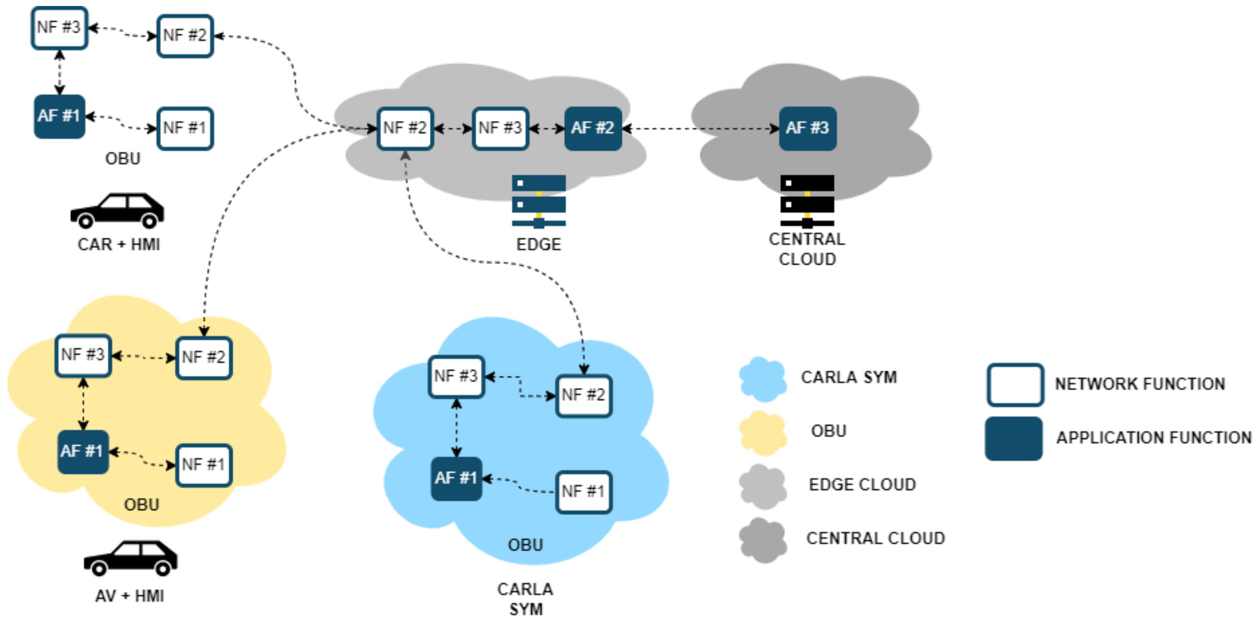

Figure 3, UC 2 - Service chain design

Table 67, UC2 – AF/NF list

#	Name	Description	Provider
AF #1	Vehicle interface	Receives commands from the Manoeuvre Planning user and	LINKS

		semantically adapts it for the vehicle.	
AF #2	Manoeuvre planning	This AF receives information from subscription service for enrolling and from OBUs to compute the available manoeuvres for the vehicle to act.	BYL
AF #3	Subscription service	The service enables the enrolling of vehicles to the MCAD Net App to let them participate to the manoeuvre coordination.	BYL/NOKIA
NF #1	Vehicle abstraction service	This NF guarantees protocol compatibility between vehicle and the Vehicle Interface.	BYL
NF #2	C-ITS messages long-distance communication	This NF is in charge to transmit and to receive data for other VNFs for long-distance 5G communication channel to specific edge/cloud services.	LINKS
NF #3	ETSI manoeuvre coordination service	This NF implements the functionalities of the ETSI Manoeuvre Coordination Service.	LINKS

3.4. UC3 – Virtual bus tour

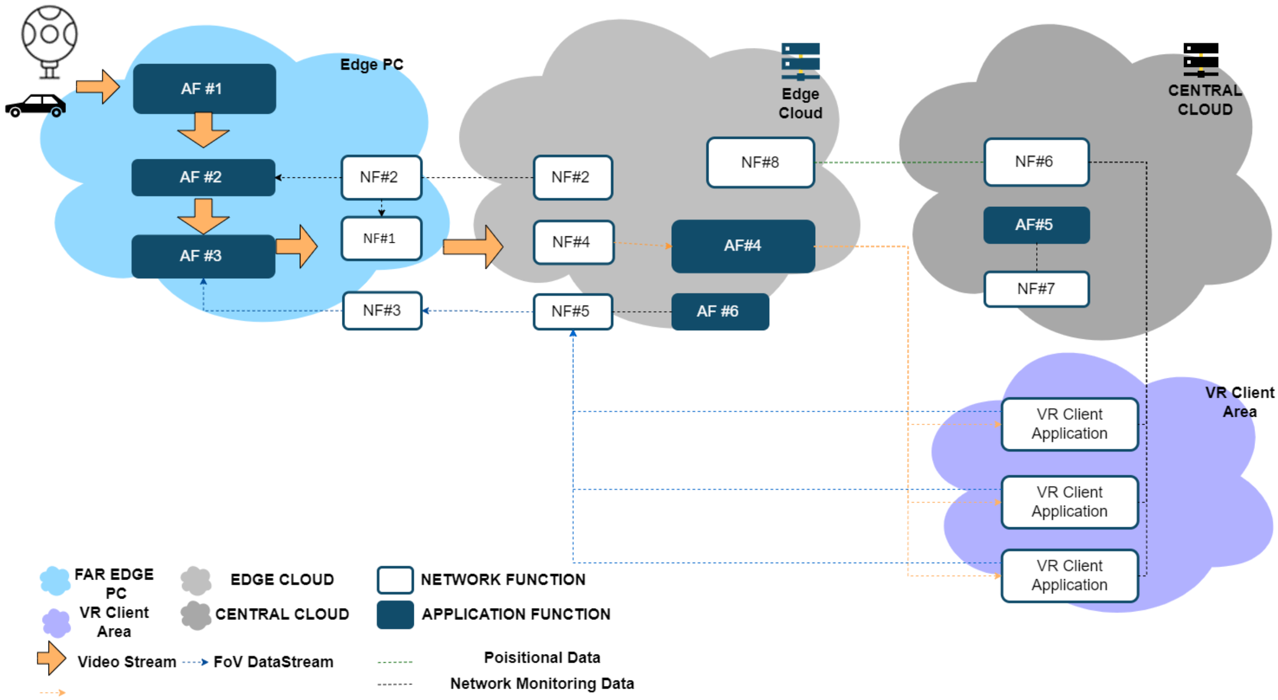

Figure 4, UC3 - Service chain design

Table 68, UC3 – AF/NF list

#	Name	Description	Provider
AF #1	Privacy masking module	This AF applies privacy masking to the 360° video stream used in UC3, meaning that footage of pedestrians passing by, car plates, etc. is blurred for anonymization.	HIT
AF #2	Live stream encoder	This AF handles the video encoding i.e., compressions and re-encoding tasks.	HIT
AF #3	360° video slicer	This AF masks the 360° video so that the parts where the users focus have high resolution, while	HIT

		the remaining parts have low resolution.	
AF #4	Load balancer	The Load Balancer is based on the open-source HAPROXY software. It provides load balancing functionalities for applications based on HTTP/TCP, basically performing HTTP redirects towards application servers.	NXW
AF #5	UC-specific log reporting service	A Database that is utilized to save logs related to the UC.	HIT
AF #6	Field of view predictor	This AF utilizes Deep Learning AI techniques to predict the future Points-of-View for the VR users.	HIT
NF #1	360° video stream endpoint	This NF facilitates sending the 360° Video Stream from the Far Edge to Edge Cloud.	HIT
NF #2	Active network monitoring module	This NF provides a mechanism that will estimate the available network bandwidth utilizing active probing.	HIT
NF #2*	Network status monitoring mechanism	Apart for NF #2, a mechanism developed in UC6, that performs the same task by using AI methods will be also tested. The use of this mechanism will be complimentary, but the synergy adds value to the UC.	UULM
NF #3	Foveated rendering sink	This VNF receives foveatic data (i.e., “fixation points”) from the Field of View Predictor AF and provides it to the Video Slicer AF.	HIT

NF #4	360° Video stream cache	This NF handles the 360° Video Stream and acts as a buffering mechanism that will be employed to maintain video fidelity to the end users, even in no network service availability scenarios.	HIT
NF #5	Foveated rendering data broker	This NF is a data broker that receives foveatic data (i.e., point of view) from the VR users and acts as broker for related modules located in the Far Edge.	HIT
NF #6	VR server module	This NF is an authoritative Unity server. It is the backbone of the VR application facilitating the Virtual Bus Tour presented in UC3.	HIT
NF #7	Log reporting service data broker	A network function that exposes UC related data e.g., location-based data stored in the UC-Specific Log Reporting Service AF.	HIT
NF #8	OBU localization service	The OBU localization service will provide the coordinates of the OBU to the VR Server Module so it can provide location specific information.	LINKS

3.5. UC4 – AR content delivery for vehicular networks

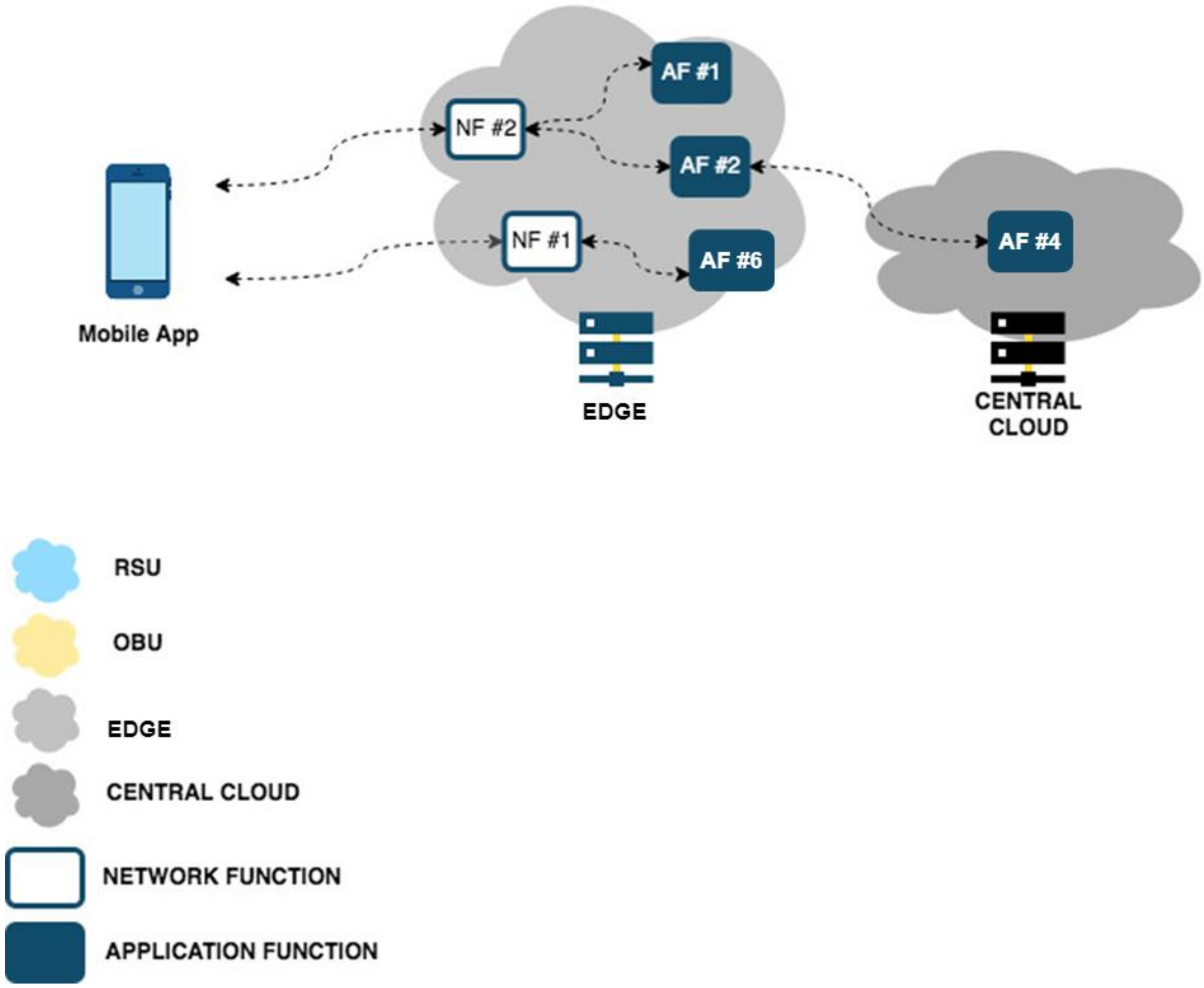

Figure 5, UC4 - Service Chain design

Table 69, UC4 - AF/NF list

#	Name	Description	Provider
AF #1	Virtualized cache – vCache	This AF is the cache on the Edge Server.	NXW
AF #2	AR content repository	Storage for AR content such as 3D objects.	O7
AF #4	Load balancer	Load balancing between cloud and edge.	NXW

AF #6	Network monitoring	Network monitoring for KPIs.	NXW
NF #1	Long-distance data communication	This VNF is in charge to transmit and to receive data for other VNFs for long-distance 5G communication channel to specific edge/cloud services.	5COMM
NF #2	AR media access function	This AF provides the access to the AR content.	COG

3.6. UC5 – Real-time road network risk assessment

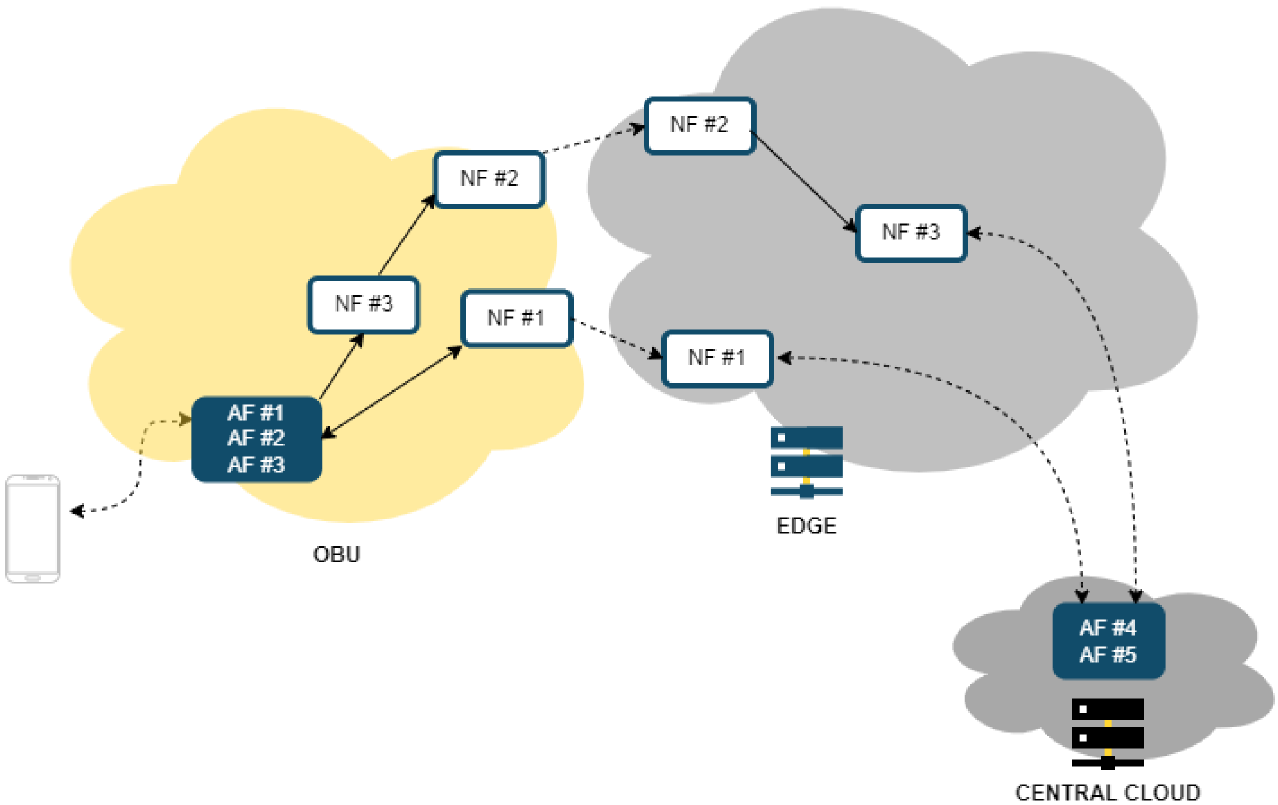

Figure 6, UC5 - Service Chain design

Table 70, UC5 - AF/NF list

#	Name	Description	Provider
AF #1	Position and time service	Implements the position and time service in order to provide accurate information about the vehicle's position and time to other VNFs. The localisation service is based on Real Time Kinematik (RTK).	LINKS
AF #2	Hazardous event receiver and display	Receives and displays a warning notification on hazardous events on the road.	O7
AF #3	Hazardous driving behaviour detection	Detects hazardous events during driving: harsh braking, harsh acceleration, speeding, and mobile use.	O7
AF #4	Elastic search service	Implements the Elasticsearch stack (Logstash, Elasticsearch and kibana) for monitored data management, analysis and storage and for processing applications' data and logs' events.	NXW
AF #5	Log reporting service	Retrieves the information to insert in the log and it sends the log to the proper cloud logging service through the Long-distance data communication VNF. The log details are defined by the NetApp implementing the log service on the vehicle, which is also in charge to trigger the sending of the log.	HIT
NF #1	Long distance data communication	Transmits and receives data for other VNFs for long-distance	LINKS

		communication channel to specific edge/cloud services.	
NF #2	C-ITS messages long-distance communication	Transmits and receive C-ITS messages for long-distance communication channel interacting with a Message Broker located on Edge Server.	LINKS
NF #3	ETSI decentralized environmental notification service	Generates Decentralized Notification Messaged that are sent to NF #1 and NF #2 for the transmission of alerts.	LINKS

3.7. UC6 – Network status monitoring

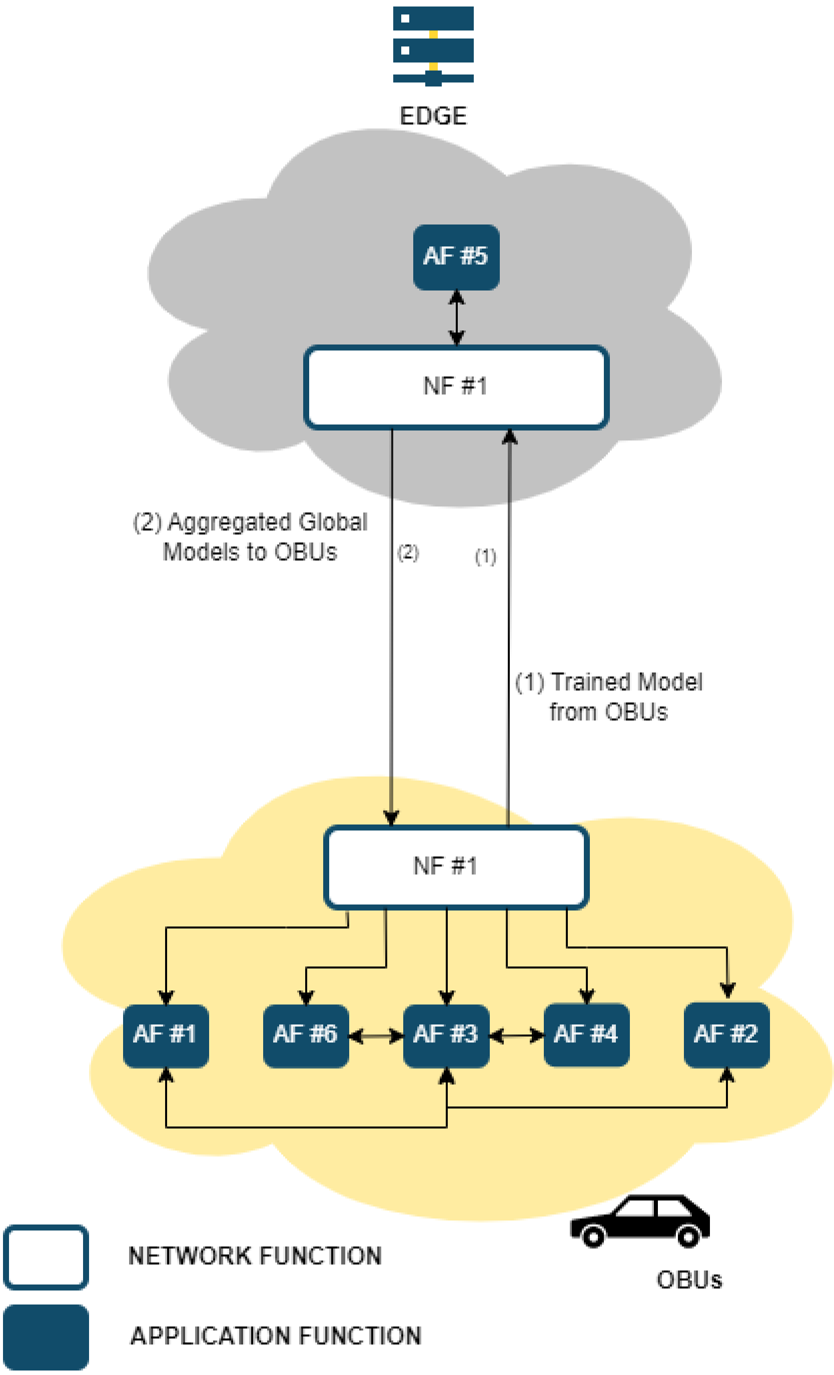

Figure 7, UC6 - Service chain design

Table 71, UC6 – AF/NF list

#	Name	Description	Provider

AF #1	Position and time service	The VNF collects the information about the current location of the worker nodes (far-edge devices) to facilitate the generation of spatio-temporal latency maps.	LINKS
AF #2	QoS prediction	An LSTM prediction model is trained (locally) on each worker node, then all local models are aggregated to a global model at the edge server (DML Aggregation Node) and the updated global model is sent back to the worker nodes for further training. After several repetitions (training rounds), when the global model has converged, it is sent to the worker nodes for inference i.e., for QoS prediction.	ICCS-UULM
AF #3	ML pre-processing	The VNF gets the collected data from Network Monitoring function and prepares the data to be fed into ML training node.	ICCS-UULM
AF #4	ML node-training agent	The VNF trains the model using a locally collected data set. This model is sent to the aggregation VNF. After the aggregation, the VNF receives a new globally trained model for further training.	ICCS-UULM

AF #5	DML aggregation node	The VNF receives the locally trained ML models from all the worker nodes (from the far-edge devices) and aggregates them.	ICCS-UULM
AF #6	Network monitoring	The VNF monitors the network behaviour passively and actively at the far-edge device. It sniffs the application packets received by the edge/cloud services and calculates network-based metrics (such as data rate and latency)	NXW
NF #1	Long distance data communication	This VNF is in charge to transmit and to receive data for other VNFs for long-distance 5G communication channel to specific edge/cloud services	LINKS

3.8. UC7 – Situational awareness in cross-border tunnel accidents

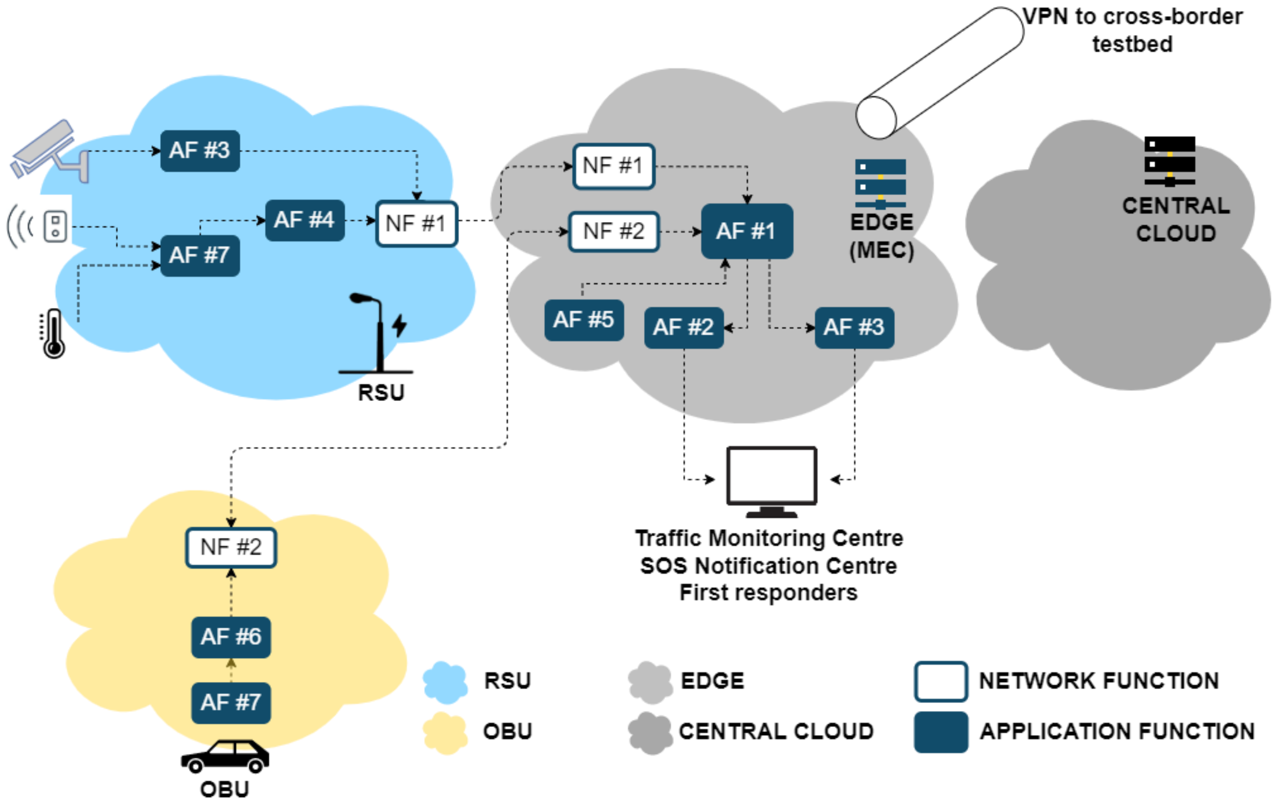

Figure 8, UC7 – Service chain design

Table 72, UC7 – AF/NF list

#	Name	Description	Provider
AF #1	Monitoring	Collecting data from the field (sensors, cameras, cooperative awareness service, etc.) and storing them. Also distributing data (including video streams) to third parties, e.g., other VNFs.	ININ
AF #2	Analytics	Analytics VNF serves for data visualization and reports creation. Data visualization and report structure is based on customer requirements.	ININ

AF #3	Streaming	Streaming VNF is a video proxy component receiving video stream from cameras and forwarding it to the end users.	ININ
AF #4	Sensors' data interface (sensor awareness service)	This VNF is in charge to received data from available connected sensors and to provide the retrieved information to other VNFs.	LINKS
AF #5	Simulator of ETSI cooperative awareness service	This VNF simulates the same functionalities of the "ETSI Cooperative Awareness Basic Service" (AF #6).	LINKS
AF #6	ETSI cooperative awareness service	This VNF implements the functionalities of the ETSI Cooperative Awareness Basic Service in compliance to standard ETSI EN 302 637-2 V1.4.1 [12].	LINKS
AF #7	Enhanced local dynamic map service	This VNF implements a Local Dynamic Map (LDM) Service that provides information to applications about local events, real time dynamic object information and other nearby connected vehicles.	LINKS
NF #1	Long-distance data communication	This VNF is in charge to transmit and to receive non-C-ITS based data (to/from VNFs not processing C-ITS data) for long-distance communication channel to specific edge/cloud services.	LINKS
NF #2	C-ITS message long-distance communication	This VNF is in charge to transmit and to receive C-ITS messages for long-distance communication	LINKS

		channel interacting with a Message Broker located on Edge Server or in the Cloud.	

4. WORK PLAN

4.1. Introduction

The present clause provides the agreed integration workplan for the development and integration activities of the 5G-IANA project. Initially, the overall workplan is presented which includes the planned interactions among a) the platform development activities, b) the NetApp UC and functions' developments, c) the integration process, and d) the testbed infrastructure deployments. The workplan follows the two development cycles and proceeds respectively to testing and validation activities which are also mapped to the overall workplan. Next, the detailed workplan for the AOEP and NetApp toolkit development efforts is presented and broken down to the developments of the individual platform modules and their interfaces. The interfaces also define the integration among the platform modules. Finally, the overall workplan is mapped to the third-party promotion, selection and validation activities which also follow the two development cycles of the project.

It is noted that the detailed experimentation and performance validation plan is not included in the present deliverable as it will be extracted after the completion of the testbed design process and the initiation of the cycle A integration action. It will be therefore presented by M22 in deliverable D5.2.

4.2. Overall development and integration workplan

The overall development and integration workplan is presented in Figure 9 and updates the generic workplan provided in Annex B of the GA. The workplan refers to the development and validation phases of the project and therefore extends from M13 to M42, excluding the initial design phase (M01-M12). The development and integration activities follow two cycles of 12M (Cycle A – M13 to M24, Cycle B – M25 to M36), while the remaining 6 months (M37-M42) are devoted to the completion of the final demonstration activities and the reporting work on the collected outcomes, also including a backup period for potential fixes or repetitions of validation actions. The related workflow among the workplan components is presented in Figure 10.

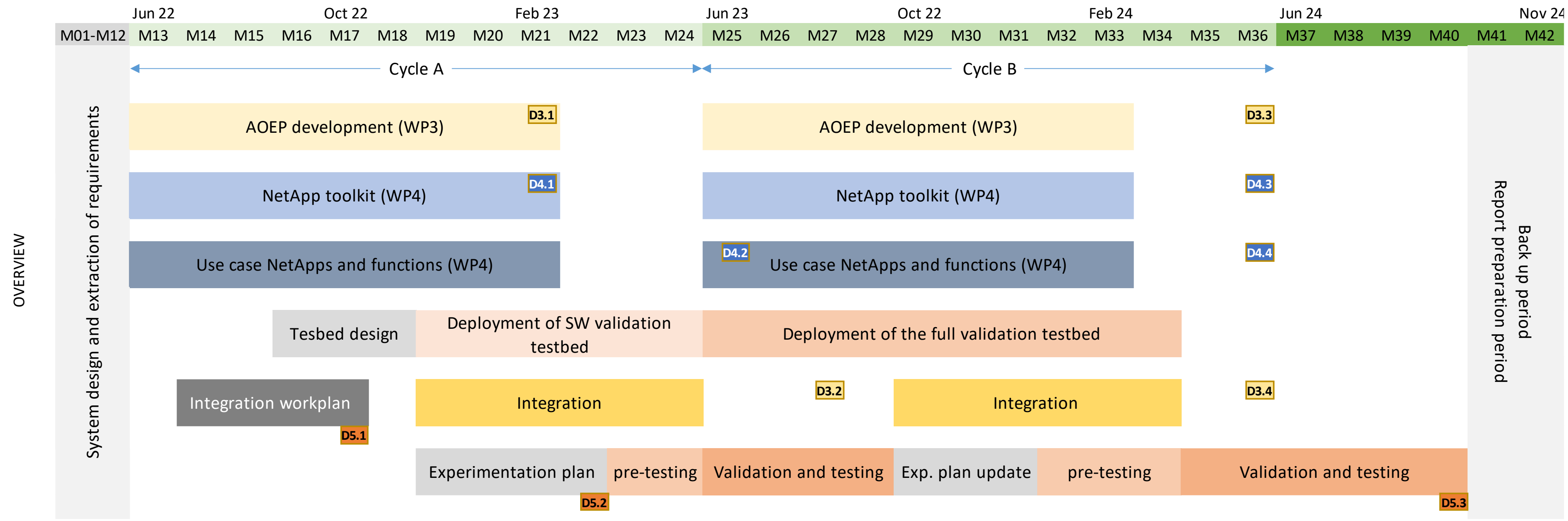

Figure 9, Workplan overview

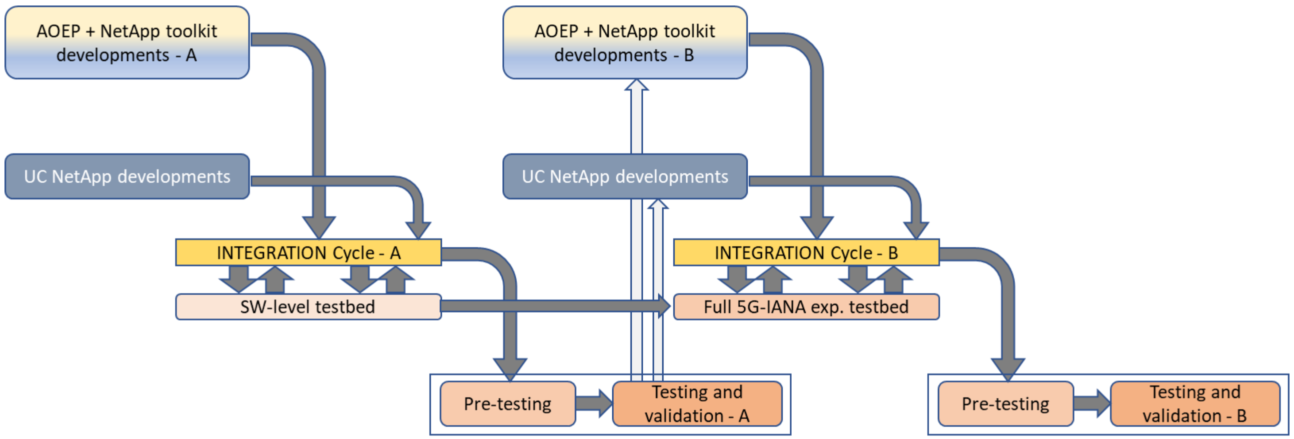

Figure 10, Workflow and dependencies

The next paragraphs describe in more detail the development, integration, and validation workplan per implementation cycle as well as the flow of information and dependencies among the different activities.

Cycle A – Development and Integration: The core of the development activities is defined in three development areas. The first deals with the required modules to build the AOEP system architecture and provide the main functionalities of the Application Orchestrator, Slice Manager and Multi-domain Orchestrator. The second includes the development of the NetApp toolkit functional blocks and is performed in close alignment with the AOEP activities under a common development and interfacing workplan. The third activity runs in parallel to the previous two and deals with the identified functions in support of the UC NetApps and in the form of linked container images (application and network functions). The target is to provide by M21 all the core building blocks that enable the main functionality of the AOEP, as well as functional NetApp versions. After M19 the AOEP modules will start being combined towards an integrated platform version, while in parallel the software level validation testbed framework is deployed to accommodate the first version of the integrated platform. The integration process relies on the development of the interfaces among the various modules and individual pre-testing activities to guarantee proper communication. The whole process is expected to be concluded by M24. Prior to this the detailed testbed design effort is introduced to define the exact infrastructure and workspace for hosting the integrated AOEP as well as to define the extension to accommodate the UC NetApps and the links to the final experimentation testbed at the NOKIA premises.

Validation and testing following Cycle A: The validation and testing of the Cycle A development activities extends beyond the cycle duration until M28. It will initiate in M23 with important pre-testing activities that evaluate the proper communication and integration among AOEP modules as well as the independent evaluation of the NetApp functions' developments. In M25, the available NetApp solutions (i.e., UC NetApps) will be onboarded to the Cycle A AOEP version and the testing and validation activities initiate. The exact experimentation workplan and validation process will be defined from M18 to M22 and reported in detail in D5.2. It will include the validation of both the basic AOEP functionalities, and the UC KPIs as defined in clause 2 of the present deliverable. The testing in this phase will be mostly restricted to the software module validation in the form of a DevOps testbed and evaluated in terms of readiness for integration to the final experimentation testbed. This will include specific functionalities and features related to the service deployment time, usage of operational resources, reconfiguration times as well as some quality measures related to the usage of the platform and the onboarding process.

Cycle B – Development and integration: The second development and integration cycle will run from M25 to M36 and accommodates all the advanced AOEP features that target to improve the platform performance and functionalities. Such features include the development and integration of the monitoring mechanism, the usage of the distributed machine learning orchestration features, and the interfacing with the OBU/RSU domains. In addition, important fixes and updates are expected with respect to the cycle A integrated modules following the testing and validation activities and in view of achieving the targeted KPIs.

The integration effort is linked to the deployment of the final validation testbed at the Nokia premises and incorporates the already integrated software platform with the required deployments at the infrastructure level including the interfaces for collecting the monitored data and interconnecting with the end users. The latter is deployed first in order to enable the full experimentation testbed. The platform integration is transferred from the initial cycle A testbed to the final one.

It is noted that since the process of development and integration is already established from the first cycle and follows the CI/CD process, the final integration process does not require to be extended beyond M34, thus providing enough time for the final validation activities as well as a reasonable back up time for potential correction and reporting. This also allows the integration actions to be performed almost in parallel to the final development activities which are transferred directly to the deployed platform.

Validation and testing following Cycle B: The final validation and testing activities will start in M32 and conclude by M40. Pre-testing type of activities are planned for the first three months (M32-M34) to accompany the final stage of the cycle B integration and more specifically to examine the proper functionality of the infrastructure elements with the updated version of the AOEP (e.g., OBUs/RSU, end user devices, monitoring modules) and to prepare the final testbed for the inclusion of the NetApp UCs. The validation and demonstration actions will run from M35 to M40 and represent the main technical activity of the project, requiring also most of the effort. The final two months of the project are considered as critical back up time in order to accommodate any delays in the validation of the UCs or additional preparations for demonstration purposes.

It is important also to highlight that a potential update to the experimentation plan is expected between the two testing cycles to optimize the final testing procedures and possibly also alter certain methodologies in order to provide more results or results with higher accuracy.

4.3. AOEP and NetApp toolkit development workplan

In view of the cycle A development and integration activities, a detailed listing and analysis of the AOEP and NetApp toolkit modules has been performed in WP3 and WP4. The goal of this analysis was to create a clear understanding of the modules that will be created or extended, their interfacing requirements and the exact functionalities that must be supported. This enhances and details the development and integration workplan over the two cycles and provides a solid development environment with specific targets and API structures and in turn enables modules to be developed in parallel with minimum dependencies across individual partner developments.

The following Table 73 lists all the development activities per module. The modules are grouped according to the functional platform subsystem where they belong, and the expected release cycles of the supported functionalities. Modules with functionalities that are implemented in both cycles are split into two versions. The overall split is also aligned to the architecture defined in D2.1. For each module, the supporting functionalities are defined. This is important in order to prioritise the specific developments within the modules. Moreover, for each module their interfaces are defined and linked to other components. The interfaces provide the required connectivity among the various modules and in turn define the integration process. Next for each module, the expected delivery date is provided. Finally, the key implementation dependencies per module functionality are defined. The dependencies may point to other modules and module functionalities or to specific underlay platforms that are required.

Table 73, Module-based breakdown of AOEP and NetApp Toolkit development and integration

Components	Supported functionalities	Attached Interfaces	Delivery	Dependencies
A. NetApp Toolkit				
A1. (v1) NetApp Catalogue	A1.1. NetApp Package Management operations (On-boarding, Query, Update, Delete) without images uploading implementation	IF-[A1-NetApp developers and NetApp providers] - NetApp Toolkit NBI Connection to NetApp developers and the NetApp providers	Cycle A M21	
A1. (v2) NetApp Catalogue v2	A1.2. Dynamic uploading of images in the centralized registry	IF-[A1-A2] – NetApp Toolkit SBI to centralized registry NBI	Cycle B M31	For A1.2 Existence of centralized registry (A2.)
A2. Centralized Registry	A2.1 Centralized Registry of NetApps, NF/AFs	IF-[A2-A1] Centralized Registry NBI to NetApp Toolkit SBI IF-[A2-A3] – Vertical Composition & Customization module to centralized registry	Cycle A M21	
A3. (v1) Vertical Composition & Customization module	A3.1 Vertical Service Composition (Create, Update, Remove) A3.2 Vertical Service QoS Parameters Editing A3.3 Application Function Management (Create/Onboard, Update, Remove)	IF-[A3-B1] - NetApp Toolkit to AO interface regarding NetApp graphs, IF-[A3-Service creators and service providers] – NetApp Toolkit NBI to service creators and service providers IF-[A3-A2] – Vertical Composition & Customization module to centralized registry	Cycle A A3.1 M16 A3.2 M17 A3.3 M19	
A3. (v2) Vertical Composition & Customization module V2	A3.4 Policy definition (Create, Update, Remove) A3.5 Exposure of the available NetApp Templates to the service creators and service providers during the composition of the NetApp. A3.6 Exposure of the Available registered Edges/OBU to the service creators and service providers for selection A3.7 Exposure of specific information per selected Edge/OBU to the service	IF-[A3-B5] - NetApp Toolkit to AO interface regarding policies, IF-[A3-Service creators and service providers] - NetApp Toolkit to service creators and service providers IF-[A3-C3] NetApp Toolkit to Resource inventory	Cycle B M31	For A3.4 Policy Manager (AO) - B5 For A3.6 and A3.7 Resource inventory - C3

	creators and service providers			
B. Application Orchestrator				
B1. Deployment Manager	B1.1 Deployment Management of Application Functions	IF-[B1-A1] - NetApp toolkit to AO interface IF-[B1-D1] - Interface for Service Orchestration on OBU/RSU	Cycle A M19	
B2. Lifecycle Manager	B2.1 Lifecycle Management of the Application Functions	IF-[B2-B1] - Connection with Deployment Manager (AO)	Cycle A M19	For B2.1 **Requires** Deployment Manager B1
B3. Slice Handler	B3.1 Resource Allocation request B3.2 Slice Intent Formulation	IF-[B3-C1] - AO-SM interface for providing slice intend	Cycle A M19	
B4. Monitoring Engine	B4.1 Application Monitoring	IF-[B4-B1] - Connection with Deployment manager IF-[B4-B5] - Connection with Policies IF-[B4-B6] - Connection with analytics and profile engine IF-[B4-E4] - Connection with DMLO	Cycle A M21	
B5. Policy Manager	B5.1 Policy Execution	IF-[B5-A2] - Selecting CEP actions over the deployed NetApps -- Connection with NetApp toolkit for retrieving the instantiating NetApp Graphs IF-[B5-B2] - Internal Interface for triggering actions IF-[B5-B4] - Connection with Monitoring	Cycle B M28	For B5.1 **Requires** Monitoring Engine B4
B6. Analytics and Profiling Engine	B6.1 Application Profiling	IF-[B6-B4] Interface with Monitoring Engine	Cycle B M29	For B6.1 **Requires** Monitoring Engine B4
C. Slice management & resource orchestration				
C1. Slice Manager	C1.1 Network slice instances management C1.2 Network slice verification and selection C1.3 Quota provisioning coordination	IF-[C1-B3] – Slice Manager NBI to AO SBI IF-[C1-C2] – Slice Manager to Quota Manager (internal) IF-[C1-E4]- Interface with DMLO	Cycle A M21	C1.3 requires C2
C2. Quota Manager	C2.1 Processing of computational requirements C2.2 Namespaces management on far-edge/edge/remote cloud hosts	IF-[C2-C3] – Quota Manager to Resource Inventory (internal) IF-[C2-C1] – Quota Manager to Slice Manager (internal) IF-[C2-K8s] – Quota Manager to Kubernetes Controller	Cycle A M21	C2.2 requires C3
C2. Quota Manager v2	C2.3 Hosts/resource availability check C2.4 Processing of location constraints for OBU/RSU	IF-[C2-K8s] – Quota Manager to Kubernetes Controller	Cycle B M31	C2.3 requires K8s and C3

	selection			
C3. Resource inventory	C3.1 Edge/Cloud Resource Inventory implementation C3.2 Far Edge Resource Inventory implementation	IF-[C3-C2] – Resource Inventory to Quota Manager (internal) IF-[C3-E4] - Interface with DMLO IF-[D3-D1] – OBU/RSU information & Localization service registration	Cycle A M21	
C3. Resource inventory v2	C3.3 Far Edge Resource inventory extensions to model additional OBU/RSU information		Cycle B M31	
D. OBU/RSU management and orchestration				
D1. OBU/RSU services 1 OBU/RSU services 2	D1.1. Local Service Orchestration D1.2. Local Resource Orchestration D1.3. Local Resource Registry D1.4. Local Infrastructure Virtualization and Management D1.5. Package/Descriptor Management D1.6. Information & Localization Service D1.7. Resource Monitoring Agent	IF-[D1-C3] – OBU/RSU information & Localization service to Resource inventory IF-[D1-C2] - OBU/RSU Interface for Quota Allocation IF-[D1-B1] - Service Orchestration on OBU/RSU	Cycle A E1.1-E1.5 M18 E1.6-E1.7 M21	For all D1.2/7 Connection with K8s required
E. Distributed ML				
E1. Client for training (AggNode)	E1.1. AggNode VNF: Backend functionality i.e., Flower server implementation	IF-[E1-E2]- AggNode VNF: Interface with TrainingNode	Cycle A M18	Requires FLOWER, PyTorch
E2. Server for aggregating (TrainNode)	E2.1. TrainNode VNF: Backend functionality i.e., Flower client implementation	IF-[E2-E1]- AggNode VNF: Interface with TrainingNode IF-[E2-E3]- TrainNode VNF: Interface with PreprocessingNode	Cycle A M18	Requires FLOWER, PyTorch
E3. Pre-processing Node	E3.1 .PreprocessingNode VNF: Backend functionality i.e., pre-processing, data cleaning, pQoS ML-specific data manipulation	IF-[E3-E2]- Interface with Trainingnode	Cycle A M21	
E4. DMLO	E4.1. Backend Orchestration functionality	IF-[E4-E1]- Interface with AggNode (Internal) IF-[E4-B4]- Interface with App monitor for Vertical Application Data collection IF-[E4-C1]- Interface with SliceManager (SM) IF-[E4-C3] - Interface with Resource Inventory	Cycle B M31	AO -SM-MSO

The workplan for the development of the Platform and NetApp Toolkit modules is depicted in Figure 12. The targeted developments are split per module as these are defined in Table 73 and spread accordingly over the two implementation cycles.

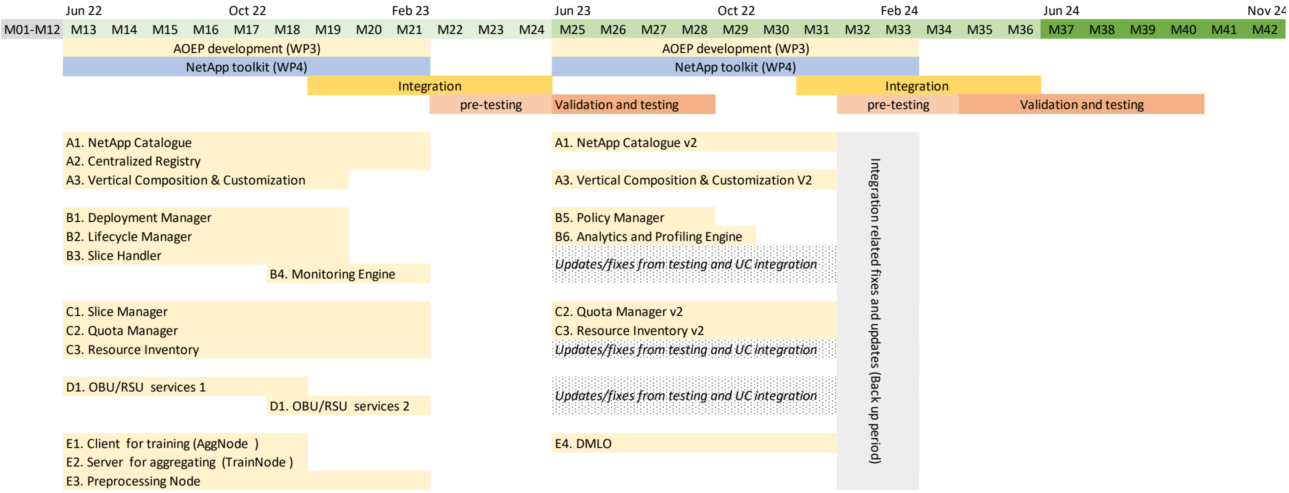

Figure 11, AOEP and NetApp toolkit modules' development workplan

It is important to highlight some key remarks with respect to the planned development effort and the follow up integration actions:

- All the core modules of the AOEP platform are expected to be potentially updated and/or corrected during Cycle B and according to the input that is received from the initial testing and verification cycle as well as the UC deployment scenarios and infrastructure capabilities. This effort is highlighted with the dotted areas in the workplan figure.
- A two-month back-up period is planned at the end of Cycle B. This period is intended to accommodate any final updates and fixes as the project proceeds to the full integration phase and the completion of the experimentation testbed. It also coincides with the pre-testing activities to receive the required feedback for potential corrections to the platform modules.
- The integration effort overlaps with the final months of the development period in Cycle A. This is due to the need to proceed first with individual integrations among modules (e.g., the interfacing between the vertical composer (A3) and the deployment manager in AO (B1) or the deployment and slice manager API (B1-C1)) before implementing the complete platform integration.

4.4. Use Case Application and Network Functions development workplan

4.4.1. Overview

The workplans for the UCs are specified in the following tables. As stated in clause 3, each UC is composed by a combination of several application and network function to achieve the desired goal. Each provider has aligned the development and the integration of each function to the overall development, integration and verification workplan.

The following tables are composed by the following columns:

- Functions to be implemented
  - The application and network functions to be implemented in the UC and the provider of it.
- Existing
  - If the function to be implemented has already been developed in another project or activity (yes)
  - If the function to be implemented has been partially developed in another project or it needs to be tailored to the desired goal (partially)
  - If the function to be implemented is brand new (no)
- Where it comes from
  - If the function has already been developed and from which project/activity it originates
- Functionalities
  - A short description of the function
- Interfaces
  - Which other functions are communicating with the function to be implemented
- Maturity level
  - Indicates the effort to provide the function to be implemented, if there is a completely new development, or could be reused with small modifications from another project.
- Targeted cycle
  - The implementation cycle in which the functionalities will be provided (A or B).

4.4.2. UC1 – Remote driving workplan

Table 74, UC1 – Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level	Targeted cycle
AF#1: video encoding / decoding **(5COMM)**	Yes	Open source	This AF encodes the video to be transmitted through the 5G network. Also responsible for decoding and playing the received video on a web application.	NF#3, AF#3: RTSP/H.264	Available	A
AF#2: sensors' data analysis **(5COMM)**	Partially	Previous activities	Collects from sensors data related to distance and angle to near obstacles.	NF#3, AF#4: WebSocket NF#1: ROS	Small modifications	A
AF#3: object detection with Deep Learning **(5COMM + VICOM)**	Yes	SoA (open source) code	The video captured is processed on the edge to detect pedestrians, cars, and/or road elements such as traffic signals.	AF#1: RTSP/H.264 AF#4: RTSP/H.264	Large modifications	A - Release of a stable version B – Extensions with a set of new features to enhance the UC
AF#4: vehicle condition warning service **(5COMM + VICOM)**	No	-	Representation of warning signals and alerts in the user interface.	AF#2: WebSocket AF#3: RTSP/H.264	Large modifications	A - Release of a stable version B – Extensions with a set of new features to enhance the UC
AF#5: remote driving central control **(5COMM)**	Yes	Previous activities	This AF is the responsible of collecting the information from the driver. Uses a steering wheel and sends it to the server to be processed by the actuator.	NF#2: WebSocket	Small modifications	A - Release of a stable version B – Minor modifications to better fit the UC
AF#6: remote driving module **(5COMM)**	Yes	Previous activities	This AF receives the orders from the actuator and moves the vehicle accordingly.	NF#3, NF#2: ROS	Small modifications	A - Release of a stable version B – Minor modifications to better fit the UC

NF#1: sensors' data capturing **(5COMM)**	Partially	Previous activities	Processes the information from the vehicle sensors and takes decisions regarding movement.	NF#3, NF#2, AF#2: ROS	Available	A
NF#2: actuator interface **(5COMM)**	Yes	Previous activities	Receives the commands from the user and generates the control order in a language understood by the vehicle.	AF#5: websocket AF#6: ROS	Small modifications	A
NF#3: long-distance data communication **(5COMM)**	Yes	Several IP based TX/RX standards	This VNF is in charge to transmit and to receive data for other VNFs for long-distance 5G communication channel to specific edge/cloud service.	AF#1: RTSP/H.264 AF#2, websocket AF#6, NF#1: ROS	Available	A

4.4.3. UC2 – Manoeuvres coordination for autonomous driving

Table 75, UC2 - Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level	Targeted cycle
AF#1 Vehicle interface **(LINKS)**	No	-	Receives commands from the Manoeuvre Planning user and semantically adapts it for the vehicle.	NF#1, NF#3	New development EDT: 8 weeks	A
AF#2 Manoeuvres planning **(BYLO)**	No	-	This AF receive information from subscription service for enrolling and from OBUs to compute the available manoeuvres for the vehicles to act.	NF#3	New development EDT: 16 weeks	A - Release of a stable version B – Minor modifications to better fit the UC
AF#3 Subscription service **(BYLO + NOKIA)**	No	-	The services enable the enrolling of vehicles to the MCAD Net App to let them participate to the manoeuvre coordination.	AF#2	New development EDT: 4 weeks	B
NF#1 Vehicle abstraction service **(BYLO)**	No	-	This NF guarantees protocol compatibility between vehicle and the Vehicle Interface.	AF#1	New development EDT: 8 weeks	A
NF#2 C-ITS messages long-distance communication **(LINKS)**	Yes	Past European projects	Transmits and receive C-ITS messages for long-distance communication channel interacting with a Message Broker located on Edge server.	NF#3	Small modifications EDT: 4 weeks	A
NF#3 ETSI maneuver coordination service **(LINKS)**	No	-	This VNF implements the functionalities of the ETSI Manoeuvre Coordination Service.	AF#1, AF#2, NF#2	New development EDT: 6 weeks	B

4.4.4. UC3 – Virtual bus tour

Table 76, UC3 – Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level	Targeted cycle
AF#1: Privacy Masking Module **(HIT)**	Partially	Uses an open-source algorithm from Python OpenCV (not written by HIT). Needs to be tested and adapted to a 360o video stream and then packaged and integrated	This AF applies privacy masking to the 360o video stream used in UC3, meaning that footage of pedestrians passing by, car plates etc. is blurred for anonymization.	#AF2: RTMP	Modifications	A
AF#2: Live stream Encoder **(HIT)**	No		This AF handles the video encoding i.e., compressions and re-encoding tasks. It receives information from the Active Network Monitoring Module to decide if compression is needed.	#AF3: RTMP #NF7: HTTP	Completely new development, started during the project.	A
AF#3: 360 Video Slicer **(HIT)**	No		This AF masks the 360o video so that the parts where the users focus have high resolution while the remaining parts have low resolution.	#NF1: HTTP	Completely new development, started during the project.	B
AF#4: Load Balancer **(NXW)**	Yes	5G-MEDIA	The Load Balancer is based on HAProxy and BIND9. It is currently available as a VM and it's needed to containerize it.	#NF4: HTTP	Small modifications EDT: TBA	A
AF#5: UC-Specific Log Reporting Service **(HIT)**	Partially	Will use an open-source database to consume and save the data from the Log reporting Service Data broker. It will use mysql and relevant data structures need to be setup, however it will not	A Database that is utilized to save logs related to the UC.	#NF5: MQTT Protocol #AF5: MySQL	EDT: 1-2 weeks	A

		require much effort to be ready. Needs to be tested then packaged and integrated.				
AF#6: Field of View Predictor **(HIT)**	No	-	This AF utilizes Deep Learning AI techniques to predict the future Points-of-View for the VR users.	#NF5: MQTT Protocol #NF7: HTTP	New development EDT: 8-10 weeks	B
NF#1: 360o video stream Endpoint **(HIT)**	No	-	This NF facilitates sending the 360° Video Stream from the Far Edge to Edge Cloud.	#NF4: MPEG-	New development EDT: TBA	B
NF#2: Active Network Monitoring Module **(HIT)**	No	-	This NF provides a mechanism that will estimate the available network bandwidth utilizing active probing. This estimation will be used as input to the Video Encoder AF.	#NF2: TCP #AF2: HTTP	Completely new development, started during the project.	A
NF#3: Foveated Rendering Sink **(HIT)**	No	-	This VNF receives foveatic data (i.e., “fixation points”) from the Field of View Predictor AF and provides it to the Video Slicer AF.	#AF3: MQTT	Small modifications EDT: 1-2 weeks	B
NF#4: 360° Video Stream Cache **(HIT)**	No	-	This NF handles the 360° Video Stream and acts as a buffering mechanism that will be employed to maintain video fidelity to the end users, even in no network service availability scenarios.	#AF9: RTMP	New development EDT: TBA	B
NF#5: Foveated Rendering Data Broker **(HIT)**	Partially	Will use an open source MQTT broker (mosquitto or rabbitmq). Relevant mqtt topics need to be set up, however it will not require much effort to be ready. Needs to be tested then packaged and integrated.	This VNF is a data broker that receives foveatic data (i.e., point of view) from the VR users and acts as a broker for related modules located in the Far Edge.	NF3: MQTT Protocol AF4: MQTT Protocol	Small modifications EDT: 1-2 weeks	B

NF#6: VR Server Module **(HIT)**	No	-	An authoritative Unity server that is the backbone the VR application facilitating the Virtual Bus Tour presented in UC3	#NF7: MQTT Protocol	New development EDT: TBA	B
NF#7: Log Reporting Service Data Broker **(HIT)**	Partially	Will use an open source MQTT broker (mosquitto or rabbitmq). Relevant MQTT topics need to be set up, however it will not require much effort to be ready. Needs to be tested then packaged and integrated.	A network function that exposes UC related data e.g., location-based data stored in the UC-Specific Log Reporting Service AF. This data is used either for UC specific functionalities and for debugging/monitoring purposes.	#AF5: MQTT Protocol	Small modification EDT: 1-2 weeks	A- Setup the Broker and some initial topics B- Expand topics
NF#8: OBU localization service **(LINKS)**	No	-	This NF provides at the edge server the position of OBUs that are in the geographical area of the edge server.	#NF6: HTTP	New development EDT: TBA	A

4.4.5. UC4 – AR content delivery for vehicular network

Table 77, UC4 - Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level	Targeted cycle
AF#1: Virtualized Cache – vCache **(NXW)**	Yes	5G-MEDIA	This AF is the cache on the Edge Server.	NF#2 Media access function	Available, Small modifications	B
AF#2: AR content repository **(COG)**	No	-	The storage with the AR objects.	NF#2 Media access function	New development	B
AF#4: Load Balancer **(NXW)**	Yes	5G-MEDIA	Load balancing between cloud and edge.	AF#1: Virtualized Cache – vCache	Available, Small modifications	
AF#6: Network Monitoring **(UULM)**	Partially	Built on top of open-source software tool: ntopng, influxdb	Network monitoring for KPIs.	NF#2 Media access function	Large modifications	B
NF#1: Long-distance data communication **(LINKS)**	Yes	Several IP based TX/RX standards	This VNF is in charge to transmit and to receive data for other VNFs for long-distance 5G communication channel to specific edge/cloud services.	NF#2 Media access function	Available, small modifications	A
NF #2:AR Media Access Function **(COG)**	No	-	This AF provides the access to the AR content.	AF#1: Virtualized Cache – vCache	New Development	B

4.4.6. UC5 – Real-time Road network risk assessment

Table 78, UC5 - Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level	Targeted cycle
AF#1 Position and time service **(LINKS)**	Yes	Past European projects	Implements the position and time service in order to provide accurate information about the vehicle's position and time to other VNFs. The localisation service is based on Real Time Kinematik (RTK).	AF #2, AF #3, mobile phone	Small modifications EDT: 1-2 weeks	A
AF#2 Hazardous event receiver and display **(O7)**	No	-	Receives and displays a warning notification on hazardous events on the road.	AF #1, AF #3, mobile phone	New development	A
AF#3 Hazardous driving behaviour detection **(O7)**	No	-	Detects hazardous events during driving: harsh braking, harsh acceleration, speeding, and mobile use.	AF #1, AF #2, mobile phone	New development	A
AF#4 Elastic Search Service **(NXW)**	Yes	Open-source project – community version	Implements the Elasticsearch stack (Logstash, Elasticsearch and kibana) for monitored data management, analysis and storage and for processing applications' data and logs' events.	AF #5	Available, small modifications	A
AF#5 Log Reporting Service **(HIT)**	Partially	Will use an open-source database to consume and save the data from the Log reporting Service Data broker. It will use mysql and relevant data structures need to be setup, however it will not require much effort to be ready. Needs to be tested then packaged and integrated.	Retrieves the information to insert in the log and it sends the log to the proper cloud logging service through the Long-distance data communication VNF. The log details are defined by the NetApp implementing the log service on the vehicle, which is also in charge to trigger the sending of the log.	AF #4	Available, small modifications	A

NF#1 Long distance data communication **(LINKS)**	No	-	Transmits and receives data for other VNFs for long-distance communication channel to specific edge/cloud services.	AF #1, AF #2, AF #3	New Development EDT: 2-3 weeks	A
NF#2 C-ITS messages long-distance communication **(LINKS)**	Yes	Past European projects	Transmits and receive C-ITS messages for long-distance communication channel interacting with a Message Broker located on Edge server.	NF #3	Small modifications EDT: 1-2 weeks	A
NF#3 ETSI Decentralized Environmental Notification Service **(LINKS)**	yes	Past European projects	Generates Decentralized Notification Messaged that are sent to NF #1 and NF #2 for the transmission of alerts.	NF #2, AF #1, AF #2, AF #3, AF #4, AF #5	Small modifications EDT: 1-2 weeks	A

4.4.7. UC6 – Network status monitoring

Table 79, UC6 - Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level	Targeted cycle
AF#1 Position and time service **(LINKS)**	Yes	Past European project	Implements the position and time service in order to provide accurate information about the vehicle's position and time to other VNFs. The localisation service is based on Real Time Kinematik (RTK).		Small modifications EDT: 1-2 weeks	A
AF#2: QoS Prediction **(UULM/ICCS)**	No	-	This VNF is based on the trained Distributed ML model present at the Edge node. An LSTM prediction model is trained on each edge node and aggregated at the DML server. This aggregated global model is then transmitted to all the Edge nodes for training and inference.	AF#2: sockets		A
AF #3: ML pre-processing **(UULM/ICCS)**			The VNF gets the collected data from Network Monitoring function and prepares the data to be fed into ML training node.			
AF#4: ML node-Training Agent **(UULM/ICCS)**	No	-	The VNF trains the model using a locally collected data set. This model is sent to the aggregation VNF. After the aggregation, the VNF receives a new globally trained model for further training.	AF#2: sockets		A
AF#5: DML Aggregation Node **(UULM/ICCS)**	No	-	The VNF receives the locally trained DML models from all the worker nodes(edges) and aggregates them.	AF#3: sockets		A
AF#6: Network Monitoring **(NXW)**	Partially	Built on top of open-source software tool: ntopng, influxdb	The VNF monitors the network behaviour passively and actively from the edge. It sniffs the application packets received by the edge and calculates network-based metrics (such as data rate and latency)	AF#3: sockets	Large modifications	A
NF#1 Long distance data communication **(LINKS)**	No		Transmits and receives data for other VNFs for long-distance communication channel to specific edge/cloud services.		New Development EDT: 2-3 weeks	A

4.4.8. UC7 – Situational awareness in cross-border tunnel accidents

Table 80, UC7 - Functions workplan

Functions to be implemented	Existing	Where it comes from?	Functionalities	Interfaces	Maturity level.	Targeted cycle
AF#1 Monitoring **(ININ)**	Yes	5G-INDUCE	Basic module exists already, no specific/customized functionalities available. Full functionality to be developed within cycle A (improvements only planned in Cycle B).	AF#2: https, mysql AF#3: https, rtsp AF#4, AF #6: https	Large modification	A
AF#2 Analytics **(ININ)**	Yes	5G-INDUCE	Basic module exists already, no specific/customized functionalities available. Full functionality to be developed within cycle A (improvements only planned in Cycle B).	AF#1: https, mysql UE: https	Large modification	A
AF#3 Streaming **(ININ)**	Yes	5G-INDUCE	Basic module exists already, no specific/customized functionalities available. Full functionality to be developed within cycle A (improvements only planned in Cycle B).	AF#1: https, rtsp UE: https, rtsp	Small Modification	A
AF#4 Sensor Awareness Service **(LINKS)**	No	-	full functionality developed (improvements only planned in Cycle B).	AF #1: https AF #7: postgresql	New development	A
AF#5 Simulator of ETSI Cooperative Awareness Service **(LINKS)**	Yes	Past commercial activity	Basic module, to be updated to better suit context of 5G-IANA. Full functionality developed (improvements only planned in Cycle B).	AF #1: https AF #6: socket	Small modifications EDT: 1-2 weeks	A
AF#6 ETSI Cooperative Awareness Service **(LINKS)**	Yes	Past European projects	Basic module, to be packaged, to revise some interface. Full functionality developed (improvements only planned in Cycle B).	AF #5: socket AF #7: postgresql	Small modifications EDT: 1-2 weeks	A
AF#7 Enhanced Local Dynamic Map Service **(LINKS)**	Yes	Past European projects	Basic module, no specific/customized functionalities available, interfaces to be added. Basic functionality needed for the UC, extended functionality in Cycle B.	AF #6: postgresql AF #4: postgresql	Small modifications EDT: 1-2 weeks	A
NF#1 Long-distance data communication **(LINKS)**	No	-	Full functionality developed (improvements only planned in Cycle B).		New Development EDT: 2-3 weeks	A
NF#3 C-ITS long-distance communication **(LINKS)**	Yes	Past European projects	Basic module, to be packaged and interfaces to be revised. Full functionality developed (improvements only planned in Cycle B).		Small modifications EDT: 1-2 weeks	A

4.5. Integration of third-party activities to the overall workplan

The workplan for the third-party activities has been extracted and aligned to the overall development, integration, and verification workplan (see clause 4.2). The key requirement is that any third-party related integration, testing and validation work should follow the core integration and testing activities in order to enable proper and on time execution of the targeted functionalities.

The workplan for the complete third-party involvement process is shown in the lower part of Figure 12 and is mapped to the overall project workplan. According to this the process is split into two overlapping cycles that match the development and integration cycles of the project. Both cycles have a 12-month duration and include the actions of: a) 5G-IANA concept and activities promotion, b) Open call proposal collection and selection, c) Pre-testing and integration, d) Validation and reporting of final outcomes. An initial preparatory phase is also considered outside of the defined cycles to assemble the required material and targeted areas.

The third-party involvement workplan structure, across the two cycles, is presented below:

Research and preparation (M16-M19) **and updated** (M28-M29) **phases** – The key topics for third party involvement are analysed in the initial research and preparation phase. The analysis considers the expected UC developments and the platform capabilities. The initial focus is on the potential cycle A outcomes. The promotion actions as well as the specific open call procedures are defined in this period. During the updated phase, the ongoing cycle B development activities as well as the initially selected open call initiatives are taken into consideration with the goal to enhance the descriptions for the expected 2nd open call contributions.

Promotion | Cycle A (M19-M21), Cycle B (M29-M31) – The identified topics are disseminated with the goal to attract the attention of potential end users and developers. Specific activities such as preparation of presentation material and webinars are also executed. In principle this process is continuous throughout the project and linked to the overall dissemination action. The indicated period reflects a number of intense efforts linked to the promotion of the open call.

Open Call | Cycle A (M21-M24) Cycle A (M31-M34) – Two open calls are released after the finalisation of the integration processes in the two development cycles. Each open call is followed by specific instructions on the format of proposal for the deployment over the 5G-IANA platform or for the integration of planned extensions to existing UC NetApps. The last month in each of the open call period is devoted to the selection process and the administrative/legal issues and arrangements for the distribution of funding to the third parties and the procedures that will follow.

Third party Pre-testing period | Cycle A (M25-M26) Cycle B (M35-M36) – The selected third-party contributions are adapted to the platform requirements and integrated. A series of functional tests are performed in order to identify the proper connectivity with the platform and the onboarding of the application and/or network functions. If applicable, the linking with the existing NetApps is performed and verified. "Education" of the third parties is therefore also included in the beginning of this phase.

Third party Validation and reporting period | Cycle A (M27-M30) Cycle B (M37-M40) – The onboarded third party NetApps and/or functions are validated following the same experimentation plan as defined for the project UCs. The measured metrics depend on the type of the contributed solution and the offered functionalities. The selected contributions from the 1st open call are validated over the software platform testbed only and therefore the validation is restricted to specific metrics related mainly to service deployment times, reconfiguration, scalability and function reusability. It is noted that the software platform testbed, once fully deployed and finalised by M24, will remain available and fully functional for the testing of new or updated NetApps and functions, including the third-party contributions.
The selected contributions from the 2nd open call are validated initially over the software platform testbed and then integrated over the full validation testbed. It is noted that selected third party contributions from the 1st call that can provide new NetApp solutions and advanced functionalities will be invited to participate in the extended validation and demonstration actions over the final full test bed. The outcomes from all testing activities will be collected (including measurements and configuration datasets) and reported at the end of each period.

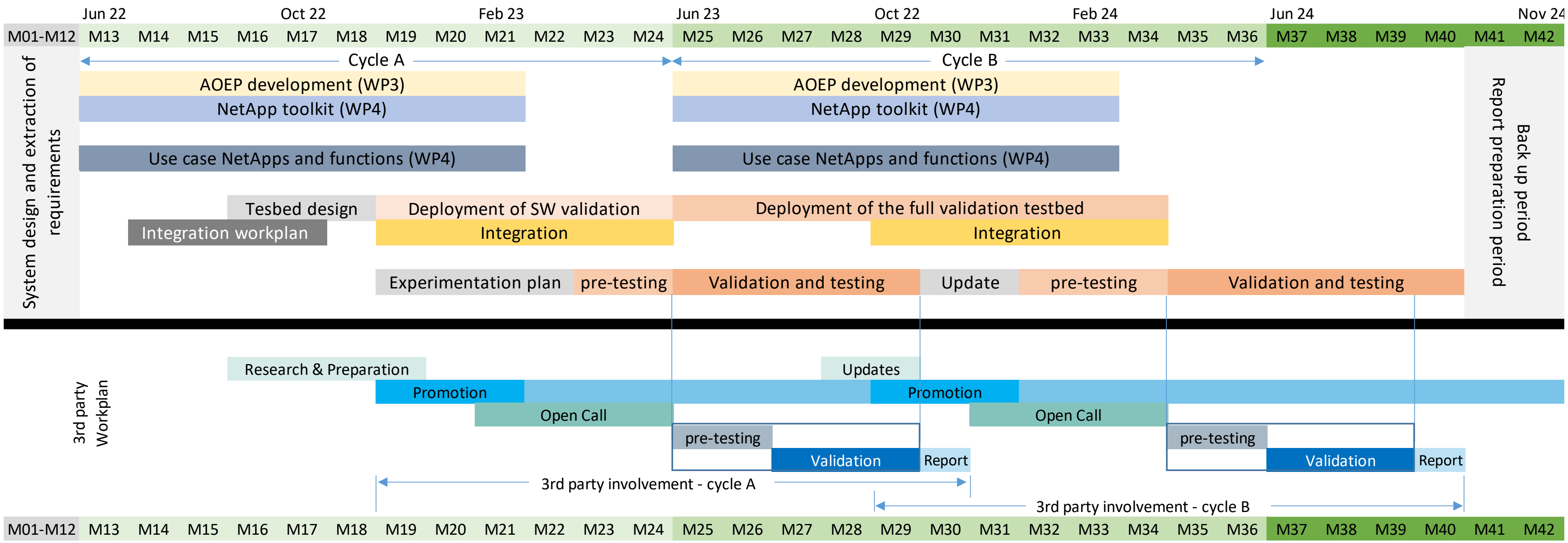

Figure 12, Workplan for the attraction, selection, testing and validation of third-party contributions to the 5G-IANA, mapped to the overall workplan.

REFERENCES

[1] “D2.1: Specifications of the 5G-IANA architecture“, 5G-IANA, 2022.

[2] “D2.5: Initial evaluation KPIs and metrics”, 5G-MOBIX, 2019.

[3] “Service performance measurement methods over 5G experimental networks; White paper – ICT-19 performance KPIs”, 5G-PPP, 2021.

[4] “Whitepaper: Beyond 5G/6G KPIs and Target Values”, 5G-PPP Test, Measurement and KPIs Validation Working Group, 2022.

[5] “C-V2X Use Cases and Service Level Requirements Volume I”, 5GAA, 2020.

[6] “C-V2X Use Cases Volume II: Examples and Service Level Requirements”, 5GAA, 2020.

[7] “3GPP TS 22.186 v17.0.0; 5G; Service requirements for enhanced V2X scenarios”, 3GPP, 2022.

[8] “View on 5G Architecture”, 5G-PPP Architecture Working Group, 2022.

[9] “ITU-T Recommendation P.10/G.100; Vocabulary for performance, quality of service and quality of experience“, ITU-T, 2017.

[10] “D6.3: Final report on architectural verification and validation “, 5G-MONARCH, 2019.

[11] “5G PPP phase II KPIs – Annex to Programme Management Report”, 5G-PPP, 2020.

[12] “ETSI EN 302 637-2 V1.4.1: Intelligent Transport Systems (ITS); Vehicular Communications; Basic Set of Applications; Part 2: Specification of Cooperative Awareness Basic Service”, ETSI, 2019