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Deliverable D2.2

Targeted use cases and NetApp related requirements

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Glossary of terms and abbreviations used

Abbreviation / Term	Description
AGV	Automated Guided Vehicle
AI	Artificial Intelligence
AR	Augmented Reality
CPU	Central Processing Unit
CS	Cloud Service
CVM	Common Validation Metric
DN	Data Network
DRAM	Dynamic Random Access Memory
E2E	End-to-End
ExFa	Experimentation Facility
GPU	Graphics Processing Unit
HTTPS	Hypertext Transfer Protocol Secure
JSON	JavaScript Object Notation
KPI	Key Performance Indicator
MEC	Multi-Access Edge Computing
ML	Machine Learning
NAO	Network Application Orchestrator
NAT	Network Address Translation
NetApp	Network Application
NIC	Network Interface Controller
OSS	Operation Support System
PLC	Programmable Logic Controller
PNF	Physical Network Function
QoE	Quality of Experience
QoS	Quality of Service
RAM	Random Access Memory
RAN	Radio Access Network
RSSI	Received Signal Strength Indicator
SLA	Service Level Agreement
SLAM	Simultaneous Localization and Mapping
STUN	Session Traversal Utilities for NAT
TCP	Transmission (Transport) Control Protocol
TURN	Traversal Using Relays around NAT
UAV	Unmanned Aerial Vehicle

Abbreviation / Term	Description
UDP	User Datagram Protocol
UE	User End
VNF	Virtual Network Function
VR	Virtual Reality
WSS	Web Socket Server

Executive Summary

This deliverable provides the initial outcomes from the design phase of the 5G-INDUCE project, related to the definition of the targeted use cases, their requirements and the identification of the development and validation plan that will be followed during the course of the project.

All use cases are translated into specific NetApps which are defined as a set of lined Virtual Network Functions (VNFs), together with the required resources (compute, storage, network, etc.), being deployable over 5G and beyond networks, and distributed across the various end-to-end network infrastructures, including User Equipment (UE), Edge, Transport network, Core network and other Data Networks (DNs). The use case applications are logically split into independent functions (NetApp components) which are linked together according to the targeted service and its features. Moreover, use case applications are logically split over the infrastructure domain from the end-user device to the edge and the cloud or even across different domains. Their implementation follows the dockerised micro-services development approach and can be customised with the goal to meet the end-user requirements, or be generic and deployed in existing NetApps, extending this way their functionality, and providing additional features. This modular approach is favourable to NetApp developers, since it allows NetApps to be reusable artifacts that are adapted to the customer's needs. The NetApp Orchestrator (NAO) part of the 5G-INDUCE platform provides the means for the registration, deployment, reconfiguration and monitoring of the NetApps. The NAO provides the required policy mechanism for matching the NetApp deployment options to the end-user and service needs. The above features determine a set of key generic requirements that govern the development of 5G-INDUCE compatible NetApps able to fully utilise the offered capabilities.

For the evaluation of the developed platform and the showcasing of the 5G NetApp management solution in the Industry 4.0 vertical sector, 5G-INDUCE relies on 8 industry driven use cases that cover the fields of a) indoor Autonomous Guided Vehicle (AGV) fleet management, b) smart AGV operation through human gesture recognition, c) AGV control through VR immersion, d) Machine-Learning (ML) supported edge analytics for predictive maintenance, e) Drone-based services (inspection and surveillance) for critical infrastructures, f) Remote service platform for Inspection, Maintenance and Repair, g) Indoor logistics and safety of moving vehicles, and h) Drone assisted network performance and coverage monitoring. All use cases are designed as a set of linked NetApp components with specific properties and requirements. The requirements define key development characteristics that include (among others): the required interconnection parameters (latency, bandwidth), the computational needs for their deployment and the key policy criteria that should be met. An additional set of requirements originate from the end-customer (industry) point of view and relate to features such as coverage, availability, security, and more. The requirements are mapped to the generic use case requirements defined under category F of the Generic Platform Requirements (GPR.F) in D2.1 and specified according to the use case needs.

5G-INDUCE has defined a common validation plan for the use cases, that follows the design and development phases of the project. According to this plan, after the use case targeted functionalities and NetApp components are defined, two main parallel and linked activities are introduced. One focuses on the development of the main NetApp components. In parallel, a second activity evaluates the deployment requirements and needs for the integration, over the related experimentation facility (ExFa). The NetApp design and ExFa capabilities define the actual validation framework and testing procedures that will be followed during the integration and the final testing and demonstration. The validation will consider a set of common evaluation metrics and procedures defined by 3GPP and a recently presented work by the 5G PPP technical board members. Such metrics include: the validation of latency and latency jitter, the slice creation and NetApp deployment times (including also the related reconfiguration times, as this is supported by

5G-INDUCE), the measurement of achieved data rate and capacity, the evaluation of density and coverage, and the estimation of availability and reliability within the related testing scenarios under specific use cases. In addition to these metrics, use case application-specific metrics are also defined and relate to the edge-core processing allocation, the evaluation of the offered reconfigurability, the effectiveness of the resiliency, the added benefit of security mechanisms as function of the performance, the evaluation of mobility and high-resolution video quality, and the handling of multi-service interoperability by the 5G-INDUCE platform.

1 Introduction

This section introduces the studies presented in this deliverable and their main goal with respect to the overall project. The main objectives of the related work are explained first, and the adopted approach follows and is split in steps. Finally, the deliverable structure is presented.

1.1 Deliverable Purpose

This deliverable provides the initial outcomes from the design phase of the 5G-INDUCE project, related to the definition of the targeted use cases, their requirements and the identification of the development and validation plan that will be followed during the course of the project. The main objectives are:

- To introduce the generic system requirements that guide the NetApp design and onboarding according to the 5G-INDUCE platform capabilities
- To introduce the targeted use cases, by providing the functional descriptions of the use case actions within the industrial environments
- To present the list of the detailed use case requirements, being further split into functional application development, deployment and also industrial requirements
- To identify the NetApp components as functions and provide key design remarks related to their deployment
- To describe the overall NetApp design and validation process with respect to the project workplan
- To extract the initial targeted metrics for the validation, including both the common (system and network related) metrics for all use cases and some key use case application-specific metrics.

1.2 Approach

A detailed description of the overall approach during the design phase of the project (M01-M12) is presented in D2.1, sub-section 1.3 and figure 1. According to this, the actions related to the use cases and the extraction of their requirements are actions 3 and 6. Within these actions, the following steps have been followed, determining the generic approach:

- Step A (within action 3): The use cases are presented by the main use case developers. This step followed the very initial platform and system level definitions and is performed with the purpose to create a common understanding among multi-disciplinary research groups.
- Step B (within action 3): The platform requirements are communicated to the use case developers with the goal to identify the key functions that need to be used, extended or developed.
- Step C (within action 3): The application requirements that dictate a set of deployment needs and interdependences from edge to core cloud are in turn communicated both to the ExFa owners and the platform developers.
- Step D (linked to action 3 but logically under WP5): The consortium starts considering the potential DevOps testbed and ExFas capabilities, performing an initial integration planning to identify any related implementation issues that may arise, well ahead of the planned activities in WP5.
- Step E (within action 6): The main work focuses on the use case development activities, while maintaining links with the industry sector (ExFas infrastructure owners) for technical details.
- Step F (within action 6): The use case requirements are extracted and presented under MS1.

- Step G (within action 6): The NetApp development work initiates under WP4 while the key requirements are revised and reported in the current deliverable.

For the presentation of the generic and individual use case requirements, the same syntax as D2.1 is adopted. According to this:

- All sentences are clearly split into subject, action and object.
- Requirements therefore characterise very specific subjects.
- A condition may follow a subject in order to specify when the requirement applies.
- Objects are not combined together in order to be clear.
- Each object may be followed by specific constraints or values.
- The commitment level is characterised either by SHALL (mandatory requirement) or SHOULD (optional requirement that 5G-INDUCE will attempt to meet).

1.3 Structure of Deliverable

The structure of the deliverable is as follows:

Section 2 provides first a reference to the defined NetApps concept, which is followed by the NAO interface capabilities and offered options. Afterwards, they are used in order to extract the generic use case design and onboarding requirements, as common requirements, for any use case solution over the 5G-INDUCE platform.

Section 3 presents in detail the initial design and the extracted requirements for the eight targeted use cases in 5G-INDUCE. For each use case a description of the main functionalities is provided and translated into the linked NetApp components' design, required to support the application. The key requirements are then presented and split into the developer and end-user requirements. Lastly, a list of the NetApp components is given - including key design remarks.

Section 4 provides a clear reference roadmap for the use cases within the course of the project and sets the initial (core) metrics for the final validation that determines in turn the use case deployment and overall integration planning.

Finally, section 5 concludes on the main findings of the specific work presented in D2.2.

2 Generic use case requirements

This section presents the generic use case requirements considering the deployment needs over the 5G-INDUCE platform. The purpose of the work in this section is to provide the generic logic framework for the definition, structuring and implementation of the use cases. For this reason, the current section provides a link between the use cases and the defined NetApps concept (from D2.1), which is followed by the NAO interface capabilities and offered options. Based on these, the generic use case design and onboarding requirements are extracted as common requirements for any use case solution over the 5G-INDUCE platform.

2.1 Use cases and NetApps

Before moving to the essential generic use case requirements, it is important to define the relationship between the targeted use cases and the NetApps creation and onboarding concept adopted in 5G-INDUCE.

The definition of the NetApp and its key characteristics are provided in sub-section 2.1 of deliverable D2.1. According to this, a NetApp comprises a set of linked Virtual Network Functions (VNFs), together with the required resources (compute, storage, network, etc.), being deployable over 5G and beyond networks, and distributed across the various end-to-end network infrastructures, including User Equipment (UE), Edge, Transport network, Core network and other Data Networks (DNs). It is further specified that a NetApp employs customer-facing service VNFs (i.e., functions originating from the application domain of the targeted use cases), and may additionally utilise value-added VNFs (i.e., common non-3GPP network functions related to functional networking services). The network and resource-facing VNFs (typically defined by the 3GPP standards) are developed and deployed by network service providers and operators and therefore are excluded from a NetApp definition which has a customer-oriented origin.

The use cases (as defined in 5G-INDUCE) refer to complete sets of customer-oriented applications, as opposed to network functionality services, and are linked to application layer solutions requiring though intense connectivity, resource management and networking requirements. In this context, the use cases translate to specific NetApps composed by a set of application functions that must be properly linked together under strict policy and location criteria, in order to support the use case functional requirements (e.g., latency, connectivity, bandwidth, etc.). Such NetApps are reusable artefacts for related use cases under different infrastructures and deployment environment, maintaining flexible by design (upgradable and extendable) features that allow certain functions to be updated, removed and modified, while new functions can be easily added.

From the use case design and development perspective, and by adopting the NetApp concept, one can conclude that the key outcomes, which affect the way that use cases are handled within 5G-INDUCE, are the following:

a. Use case applications are logically split into independent functions (defined as NetApp components) which are linked together according to the targeted service and its features (e.g., mobility, security, reliability, connection to cloud server, end-user visualisation options, and more).

b. Use case applications are logically split over the infrastructure domain, from end user device to edge and to cloud, or even across different domains (e.g., interconnected edge domains with collaborative requirements).

c. NetApp components are implemented and deployed as dockerised application micro-services, providing a modular design approach for the use cases.

d. Specific NetApp components can be customised to meet the end user requirements while NetApp components of general purpose can be deployed in existing NetApps extending their functionality and providing additional features (e.g., enhanced security features).

e. NetApps components are designed as reusable artifacts, thus supporting the aforementioned modularity and expandability.

According to the above, use cases are designed in a modular fashion by decomposing all the key elements into functions. Thus, NetApps are defined and developed within the 5G-INDUCE framework with a view to be easily extendable and repeatable to other use cases. In this context, policy criteria play an important role and are utilised in order to adjust NetApp components to the use case requirements according to the infrastructure capabilities, or further to the adopted business models (private, operator driven, operator supported, multi-domain). Such policy criteria are defined per use case and are imported by the end-user through the NAO user interface, alongside with the selected NetApp components, as well as their interconnection. This enables the provision of customised solutions to the end-users, while certain NetApp components are reused (or modified and specialised per use case), offering, in turn, expandability towards advanced infrastructure features, such as the creation of secure and trusted environments, performance monitoring, and on-demand adaptation to capacity changes, failures and identified threat issues.

2.2 Interfacing with the NAO: Capabilities and options

The Network Application Orchestrator (NAO) of the 5G-INDUCE platform architecture allows software developers and service providers to quickly onboard any application over the cloud-native 5G infrastructure, while hiding tedious low-level details related to the underlying cloud and network infrastructure. It also allows the end users of the industrial manufacturing sector (or service and system integrators providing application integration services to industrial end users) to structure and combine NetApp components under specific policy criteria and create custom made applications with added dashboard visualization capabilities during runtime.

NAO functional purpose

To provide a competitive cloud-native ecosystem, the NAO leverages state-of-the-art cloud controllers, supporting both containerized workloads, via Kubernetes, and fully blown Infrastructure-as-a-Service deployments via OpenStack. Although these cloud platforms provide great APIs to manage cloud resources, these APIs are far too complicated to satisfy the high-level requirements of the 5G-INDUCE stakeholders' use cases. The NAO bridges this gap effectively, through a user-friendly dashboard which brings application deployment, policy, and runtime management much closer to the end-users. Further details about how the NAO goes beyond existing cloud platform controllers are provided initially in the context of the D2.1 architecture, while the adopted solutions and planned extensions are presented in D3.4. Some high-level details are provided immediately afterwards.

Inputs to NAO

The NAO supports both legacy (i.e., monolithic) application binaries and cloud-native microservices through a flexible onboarding mechanism, supported by a high-level user interface, which is the entry point for manufacturing 5G application stakeholders (and essentially to any vertical sector) to the 5G-INDUCE ecosystem. Application onboarding begins by providing a location for each application component, i.e., either a URL to an application binary for a monolithic application or an application artifact URL (e.g., a docker registry or maven artifact URL) for componentized applications. Apart from the application components themselves, the NAO also requires information on how these components are interconnected (in case of multi-component applications), essentially forming a direct acyclic graph of connected application components.

Once the NAO verifies the presence of all application components and forms the application graph (in case of multi-component applications), each vertex of the graph can be annotated with a set of policies. This allows application developers/providers to express both soft and hard resource requirements at the finest granularity of individual application components.

The NAO Policies

For the porting and deployment of 5G applications over the 5G-INDUCE platform, the NAO's policy engine supports the following policy types:

- detailed compute and storage requirements, such as number of CPU cores, amount of DRAM, and disk space per component, etc.;
- networking KPIs that need to be ensured in order to meet specific Service-Level Agreements (SLAs), such as maximum latency, minimum throughput, or minimum packet loss;
- transparent connectivity with an external network/system; for instance, a local 5G network deployment over a certain location/region in which users and IoT devices connect to heterogeneous RRUs. These RRUs, in turn, interface with the 5G core through the fronthaul adaptation layer, thus allowing access to the application;
- special processing requirements by an application component, such as the presence of specific hardware devices (e.g., GPUs or SmartNICs) or system library (e.g., CUDA);
- the ability to select a desired underlying cloud platform technology (e.g., Kubernetes); and
- elasticity requirements for application components, allowing independent orchestration and scaling procedures to be invoked when certain events are being triggered.

Some of the policies above cannot be realized by the NAO itself, as they fall within a different administrative domain. For example, the NAO should have no means to manage network-related resources, as such resources are managed by the underlying network orchestrator. In other words, the NAO is only responsible to grant policies strictly related to the application layer (e.g., about application scaling); the rest of these policies are relayed to lower-level components which expose services to realize them.

2.3 NetApp design and onboarding requirements

Based on the NetApp definition and the interfacing capabilities offered by the NAO module of the 5G-INDUCE platform, a set of generic requirements is extracted, that guides the overall design of the use cases and affects the development of the NetApp components, the structuring of the application graphs, and the selection of the policy criteria. These requirements, which are listed below, are common to any use case that interfaces with the 5G-INDUCE platform, and are the consolidated outcome collected from the use case providers in collaboration with the core 5G-platform module developers in 5G-INDUCE.

It is noted that related requirements (that focus on the supported functionalities of the NAO module) have been extracted for the definition of the platform design and the adopted technologies and are presented in D2.1, subsection 4.2.1, Table section D-User Interfacing requirements and information sharing.

Table 2-A: Common use case requirements related to the development of the NetApp components, the structuring of the application graphs, and the selection of the policy criteria

ID	Requirement		
	Subject + (Condition)	**Commitment**	**Action + Object + (constraint)**
Generic NAO implementation requirements			
UC-G.1	The design of a use case, (prior to its onboarding)	SHALL	follow a modular approach with a clear definition of independent use case application components
UC-G.2	The design of a use case, (prior to its onboarding)	SHALL	follow a clear knowledge of the interconnection options among the components (to be used for the construction of the application graph)
UC-G.3	The design of a use case, (prior to its onboarding)	SHALL	follow a clear knowledge on the potential location of the NetApp functions, according to the adopted business scenario by the end user
UC-G.4	The design of a use case, (prior to its onboarding)	SHALL	have knowledge of other available functions and their capabilities (e.g., in the form of a repository)
UC-G.5	The NetApp functions in support of the use case scenarios	SHALL	be provided in the form of stand-alone micro-services in a Docker Format
UC-G.6	The NetApp functions in support of the use case scenarios	SHALL	identify any interaction with potential end-user stakeholders and register the necessary interfaces
UC-G.7	The NetApp functions in support of the use case scenarios	SHALL	have a clear estimate of the required computational requirements (CPU, RAM, STORAGE) and claim the maximum values that satisfy their needs
UC-G.8	The NetApp functions in support of the use case scenarios	SHALL	be managed through the NAO during runtime and in terms of the required functional flexibility (including but not limited to mobility, resource expansion, scalability)
UC-G.9	The NetApp functions in support of the use case scenarios	SHOULD	allow policy updates and enforcement during runtime
UC-G.10	The NetApp functions in support of the use case scenarios	SHOULD	know the location of the edge servers that are deployed
UC-G.11	The registration of new use case functions	SHALL	be made after authentication of the attached end users/providers
UC-G.12	The registered use case functions	SHOULD	be followed by the required metadata that make them searchable
UC-G.13	The registered use case functions	SHOULD	include restrictions about ‘who’ (i.e., end user) or ‘which’ other applications can incorporate them in their application graph
UC-G.14	Application-level metrics that are collected during runtime	SHALL	be visible through a dashboard presentation framework and per component to registered end users

3 Use case design and requirements

This section presents in detail the initial design and the extracted requirements for the eight (8) targeted use cases in 5G-INDUCE. For each use case a description of the main functionalities is provided and translated into the linked NetApp components' design required to support the application. The key requirements are then presented and split into the developer and end user requirements. A list of the NetApp components is provided at the end, including key design remarks.

The NetApp related requirements affect the overall 5G-INDUCE platform specifications and therefore are directly linked to D2.1 activities. There, at the generic platform requirements sub-section, the category F – *Generic services' use case related requirements* is included providing the high-level requirements expected for the deployment and operation of use cases. These include the generic requirements related to: the data types supported and data traffic requirements (including voice and video requirements), the end user mobility support, the needed location information, the definition of latency by the end user, the operational requirements in terms of computational resources, the reliability and privacy addressing issues, and the coverage. In the following sub-sections, the use case requirements follow and further extend the initially set generic use case requirements providing also specific draft targeted numbers, as these are expected by the implemented use case NetApps.

REMARK: *The NetApp functional specifications are reported in deliverable D4.1 that follows. The report will include the Operational specifications per NetApp component, the network specifications per NetApp graph and the definition of policy related rules and values, for each use case individually.*

3.1 UC1: Autonomous indoor fleet management

3.1.1 Use case description

In this use case an automatic logistic process which involves indoor and outdoor AGVs will be enabled by the 5G communication. The fleet manager in charge of the orchestration of the AGVs will be defined by NetApps and run as a MEC application. Figure 3.1 shows the logistic process and the involved AGVs for the indoor and outdoor part of the industrial site.

In addition, the outdoor AGV will be equipped with a camera to complement the current navigation embedded in the AGV. The data provided by the camera will be processed in the MEC by vSLAM algorithms, which will also run as a NetApp.

The indoor AGV selected for this use case is an EBOT of ASTI Mobile Robotics. This AGV belongs to the platform line portfolio and provides excellent maneuverability. Thanks to its compact design and omnidirectional and turn on spot technology, this platform AGV can perform longitudinal and transversal movements, enabling greater agility and efficiency in intralogistics goods movements. On the other hand, the outdoor AGV is a robust tractor AGV of ASTI Mobile Robotics, and it is a strong, easy, safe, and flexible solution for logistics trains. This AGVs can transport several trolleys at the same time, leading to high productivity and lower operating costs in intralogistics operations.

ASTI and UBU must develop and deploy 4 software pieces in the edge as is shown in Figure 3.2.

Another key point in this use case is the way in which the trolley is designed to enable the interchange of loads between the indoor AGV and the outdoor AGV. The EBOT AGV must go under the trolley, pick up the load and then leave the trolley.

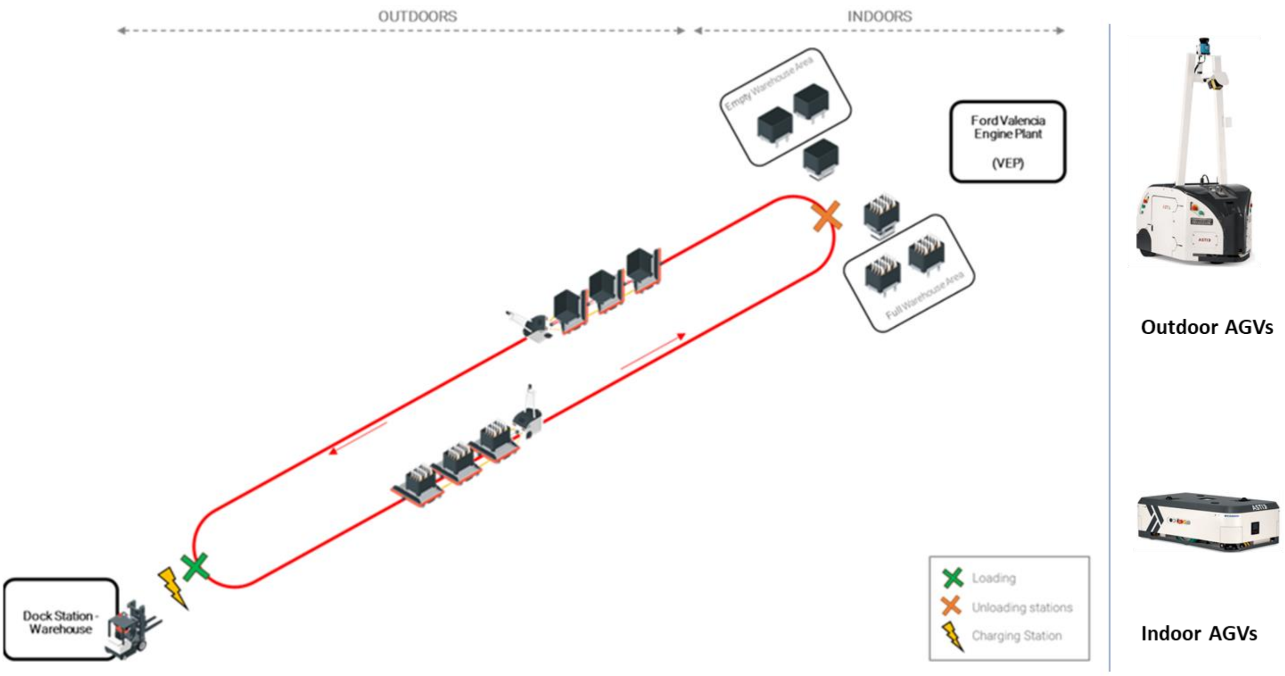

Figure 3.1: UC1 Automatic logistic process (Left) and involved AGVs (right)

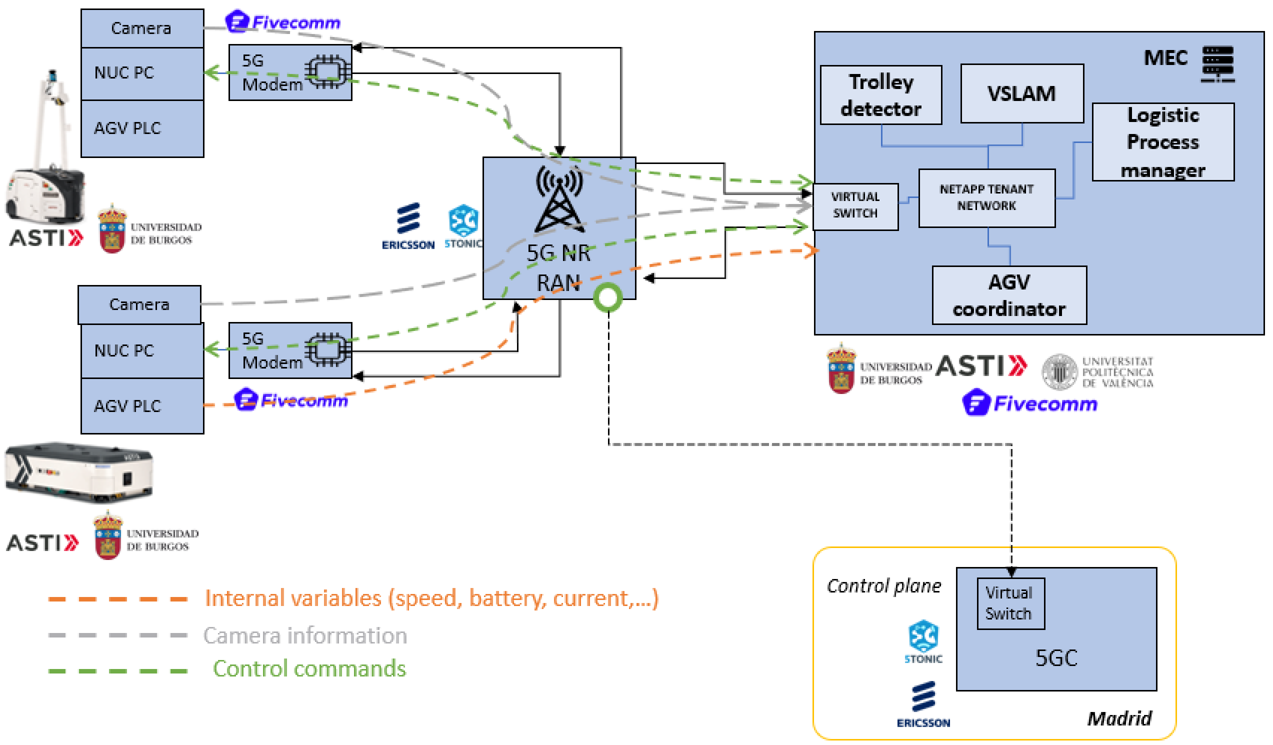

Figure 3.2: Use case 1 NetApp graph, components, and interconnections

Finally, it is important to highlight that in this pure industrial-driven use case an efficient data communication protocol is needed to manage the interoperability among a diverse set of processing units. For this reason, the CAN-bus (Controller Area Network) communication protocol is used, which is an industry protocol based on a bus topology for the transmission of messages in distributed environments. It is widely used in industrial environments and the automotive sector to manage networks of controllers, sensors, and actuators. With the integration of this protocol in the use case, a functional solution is offered for managing communication between multiple processing units. For instance, it is used inside cars to interconnect all the sensors, actuators, and controllers with the vehicle control unit. In the case of the AGVs used in UC1, it is the standard protocol to interconnect the sensors and the actuators with the PLC which governs the behaviour of the machine. Thanks to the low latency communication capabilities provided by 5G, we will extend the CANbus communication inside the AGV to wirelessly control external CANbus devices. This will enable the deployment of Industry 4.0 flexible industrial control scenarios without rigid wired bus networks. Its use will be extended also to UC2 and UC3.

3.1.2 Requirements

The specific functional requirements for UC1, from the NetApp developer and the Industry point of view are presented in the following table.

Table 3-A: UC1 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
Functional requirements (NetApp developer point of view)				
UC1-D-01	E2E Latency (Control Plane)	SHOULD	be 10 ms	GPR.F6
UC1-D-02	Video processing in Edge (Bitrate)	SHALL	be 5-10 Mbps per AGV	GPR.F3 GPR.F7
UC1-D-03	vSLAM algorithm runtime in Edge	SHALL	be 5 ms	GPR.F7
UC1-D-04	Internal variables (Bitrate)	SHALL	be 128000 bps	GPR.F1
UC1-D-05	Maximum % of packet loss Uplink (vSLAM)	SHALL	be 1%	GPR.F9
UC1-D-06	Maximum % of packet loss Downlink (Command)	SHALL	be 1%	GPR.F9
UC1-D-07	Data storage in MEC	SHOULD	be 7 GB	GPR.F8
UC1-D-08	Positioning accuracy	OPTIONAL	be 5 cm	GPR.F5
Functional requirements (Vertical end user point of view)				
UC1-V-01	Response time AGV (Command)	SHALL	be 20 ms	GPR.F6
UC1-V-02	vSLAM algorithm runtime in AGV	SHALL	be 15 ms (5ms_runtime in edge + 10 ms_5G Control Plane Latency)	GPR.F6
UC1-V-03	Uplink Communication Maintenance	SHALL	be 10 ms	GPR.F1 GPR.F9

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
UC1-V-04	Downlink Communication Maintenance	SHALL	be 10 ms	GPR.F1 GPR.F9
UC1-V-05	Velocity without loosing communication	SHALL	be 2 m/s	GPR.F4
UC1-V-06	Secure information transmission	SHALL	be assured	GPR.F11
UC1-V-07	Coverage area	SHALL	be 100%	GPR.F10

3.1.3 Design remarks and targeted NetApps

The NetApp under consideration is consisted of 4 main VNFs:

- ***Trolley detector***: This VNF processes information provided by sensors in the AGVs and indicates if the AGV is moving a trolley.
- ***VSLAM***: This VNF receives the video from a camera in the outdoor AGV and computes the localization based on SLAM algorithms
- ***AGV coordinator***: This VNF receives information from the AGVs and sends control commands to the AGV to enable the coordination.
- ***Logistic process manager***: This VNF is responsible for the supervision of the logistics process. It generates and supervises the transport orders.

3.2 UC2: Smart operation based on human gesture recognition

3.2.1 Use case description

Use case 2 is about controlling industrial operations of AGVs through human gestures without using any type of special equipment, i.e., haptic gloves or VR/AR glasses. In this use case, workers on the facility will have the ability to control an AGV without establishing direct contact with it. Operators will perform different hand gestures that will allow them to control the robot.

An overview of use case 2 is provided in Figure 3.3. AGVs, located in the Ford industrial park and shop floor, are able to receive RGB/depth information from any type of camera. Through a flexible 5G modem connected to the AGV, users can send the video/depth information to the 5G network. The NetApp, located at the edge, will get the video and gesture information, will process the order, and send it back to the AGV. Finally, the AGV will move, stop, or change its direction depending on the worker’s order.

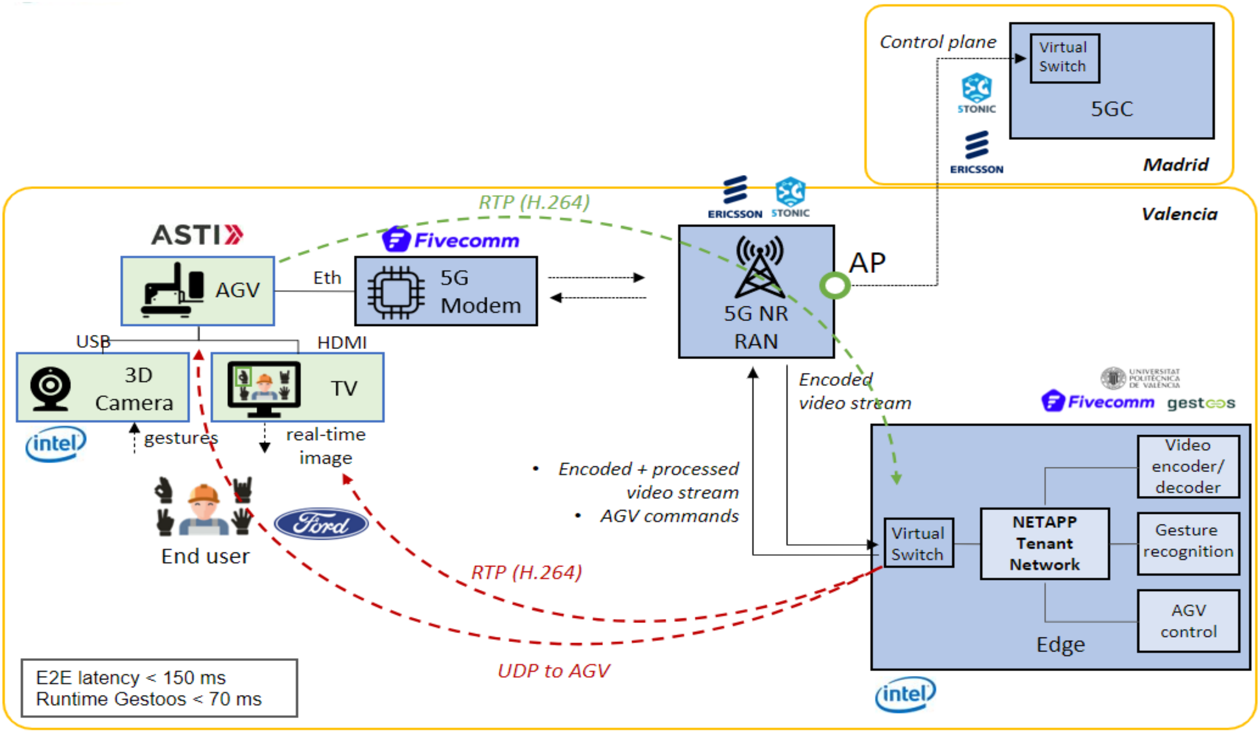

Figure 3.3: Use case 2 NetApp graph, components, and interconnections.

3.2.2 Requirements

The following requirements have been identified for the successful demonstration of use case 2. Such requirements have been classified into two fields, i.e., NetApp developer and end-user points of view.

Table 3-B: UC2 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
Functional requirements (NetApp developer point of view)				
UC2-D-01	The runtime cockpit (for AGV commands)	SHALL	be less than 10 ms (from when the gesture has been identified until the command is sent).	GPR.F6.
UC2-D-02	The runtime for gesture recognition	SHALL	be less than 70 ms (from when the video is received until the gesture is identified).	GPR.F6
UC2-D-03	The End-to-End latency	SHOULD	be less than 150 ms (including video + gesture recognition + 5G network).	GPR.F6.
UC2-D-04	The packet loss percentage for Uplink	SHALL	be less than 1% (for gesture recognition).	GPR.F9
UC2-D-05	The video bitrate from the camera (Uplink)	SHALL	be between 5 Mbps and 10 Mbps. 1080p video resolution.	GPR.F3
UC2-D-06	The bitrate from commands (Downlink)	SHOULD	be between 1Mbps and 5Mbps.	GPR.F1

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
UC2-D-07	The throughput	SHALL	be more than 10 Mbps (provided that the video bitrate is less than 10Mbps).	GPR.F3
UC2-D-08	The bandwidth	SHALL	be more than 10 Mb/s (RTP).	GPR.F3
UC2-D-09	The edge cloud processing (for gesture recognition)	SHOULD	be less than 100 ms. Edge computing.	GPR.F7
UC2-D-10	The OS version (for Gestoos software)	SHALL	be Windows® 8/10, Ubuntu 18.04 (64 bits) or NVIDIA Jetson operating on an Ubuntu 18.04 (arm64).	GPR.F7
UC2-D-11	The processor (for Gestoos software)	SHALL	be an Intel® i5 processor up to 2.70 GHz, or equivalent.	GPR.F7
UC2-D-12	The RAM memory	SHALL	be at least 8GB.	GPR.F7
Functional requirements (Vertical end-user point of view)				
UC1-V-01	The end user	SHALL	be able to control the AGV from at least 2 meters away.	n/a
UC1-V-02	The gesture detected	SHALL	be the same as the user is performing.	n/a
UC1-V-03	The application	SHALL	have almost immediate response time.	GPR.F6.
UC1-V-04	The AGV screen	SHALL	be able to show feedback about the gesture recognition.	n/a
UC1-V-05	The gesture recognition algorithm	SHALL	be able to adapt its operation for each user physical features.	n/a

3.2.3 Design remarks and targeted NetApps

The considered NetApp is formed by 3 main VNFs:

- ***Video encoding/decoding VNF***: That will allow to encode and decode the video to transmit it through the 5G network. In addition, it will be responsible for playing the received video processed by the Gestoos application, where the user will have feedback of the gesture that has been detected.
- ***Gesture recognition VNF***: This NF receives the video stream captured by the AGV camera, then the algorithm detects the gesture that is being made with the hand and selects the instruction to be sent to the AGV. In addition, the algorithm allows knowing the position of the operator's hand on the screen to drive the AGV remotely.
- ***AGV control VNF***: Is responsible for translating the selected command into a compatible AGV order, which is then sent using UDP frames with JSON format.

3.3 UC3: VR Immersion and AGV Control

3.3.1 Use case description

This use case introduces 360-video as a troubleshooting tool enabled by 5G infrastructure for industrial environments. Through this immersive experience, the industrial operator will get a quick high-quality interactive view of what is happening in each AGV. The overall use case concept is depicted in Figure 3.4.

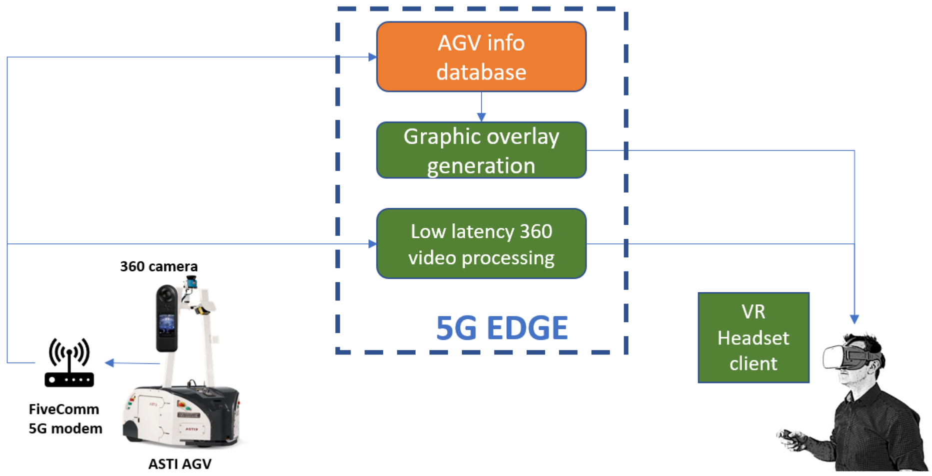

Figure 3.4: High level use case 3 NetApp structure

UC3 NetApp deals with the coordination of the ASTI-AGV and the FiveComm modem with the YBVR software modules. ASTI-AGV and FiveComm devices have to report status information to a status database hosted in the Edge. YBVR has to develop and deploy 3 software pieces, two of them in the edge and a third one in the operator's device, as shown in Figure 3.5.

The structure of the NetApp has been built over 3 main blocks:

- The ASTI's AGV premises, where the industrial vehicles have been equipped with a top-quality 360 camera connected to the 5G network using a FiveComm modem. Additionally, the AGVs and the modems are reporting tracking information to an edge-hosted status database periodically.
- The 5G network connects AGVs with the operators. In the 5G edge, YBVR software is processing the 360-video coming from the camera and relays the video processed to the operator's player device. In parallel, another YBVR software module is taking the updated tracking data from the status database and converting the data into graphic information.
- The YBVR software installed in the player device overlays the graphic information over the 360-video, giving a privileged point of view to the operator about what is happening into and around the AGV.

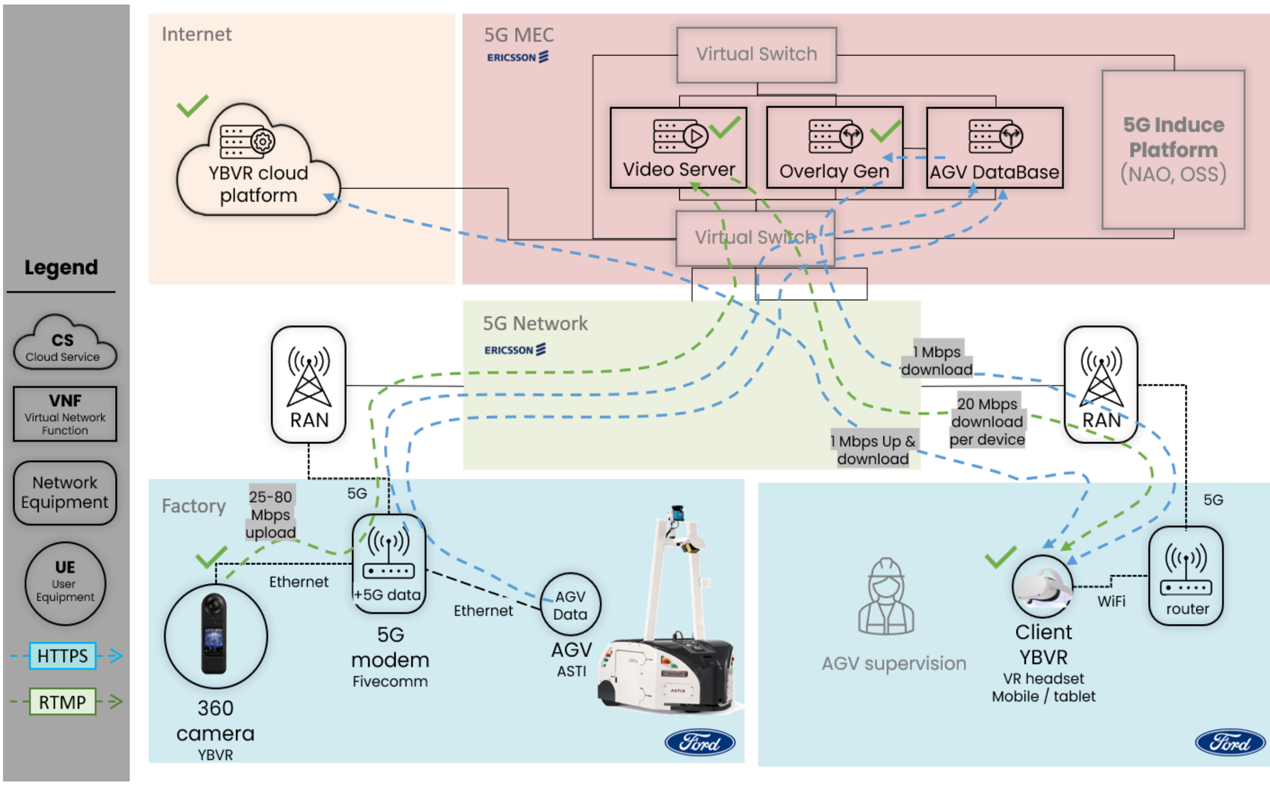

Figure 3.5: Use case 3 NetApp graph, components, and interconnections

3.3.2 Requirements

The following requirements have been identified for the successful demonstration of use case 3. Such requirements have been classified into two fields, i.e., the NetApp developer and the end-user points of view.

Table 3-C: UC3 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
Functional requirements (NetApp developer point of view)				
UC3-D-01	Runtime VNF video server	SHOULD	be < 500 ms (between input and output of the video server)	GPR.F7 GPR.F8
UC3-D-02	Runtime VNF overlay gen	SHOULD	be < 100 ms (from html capture to graphic file availability)	GPR.F7
UC3-D-03	Database answer time	SHOULD	be < 100 ms (from data request to answer reception)	GPR.F6
UC3-D-04	Downstream latency	SHOULD	be < 20 ms (from video server to client device)	GPR.F1 GPR.F3
UC3-D-05	Upstream latency	SHOULD	be < 20 ms (from camera to video server)	GPR.F1 GPR.F3 GPR.F4
UC3-D-06	Client software runtime	SHOULD	be < 100 ms (from reception to visualization)	n/a (Device)

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
UC3-D-07	Throughput	SHALL	upload min 20 Mbps, max 80 Mbps.	GPR.F3
UC3-D-08	Maximum % of packet loss	SHALL	be 0.30%	GPR.F9 GPR.F4
UC3-D-09	Jitter	SHALL	be between 10 and 30 ms.	GPR.F6
Functional requirements (Vertical end-user point of view)				
UC3-V-01	Glass to glass latency	SHOULD	be between 0.8 and 2 seconds, the lower the better	GPR.F6
UC3-V-02	Data latency	SHOULD	be < 500 ms (from data capture to visualization)	GPR.F6
UC3-V-03	Data refresh	SHOULD	be < 2 s	n/a (Device)

3.3.3 Design remarks and targeted NetApps

The considered NetApp is formed by 2 main VNFs:

- ***Overlay generator VNF***: This VNF gathers the last status of some variables from the status database and generates a graphical view with this information.
- ***Video Server VNF***: This VNF receives the video from the AGV's 360 camera, optimizes the video streaming and relays the stream to the player devices.
- ***AGV control VNF***: Is responsible for translating the selected command into a compatible AGV order, then forwards it using UDP frames with JSON format.

Also, an important software module is required in the user device. This software receives the processed 360-video and overlays the data graphic information, refreshing periodically.

3.4 UC4: ML-Supported Edge Analytics for Predictive Maintenance

3.4.1 Use case description

In this use case a robust and flexible modular analytics engine will be deployed in a factory setting, to deal with tasks relevant to predictive maintenance of different machinery. The use case will be based on a NetApp receiving input from different sensors placed in production lines/shop floor as well as from other data sources that can be internal or external to the manufacturing setting, providing, in this manner, a more holistic approach relevant to the maintenance schedule definition. A high-level view of the NetApp placement is depicted in Figure 3.6.

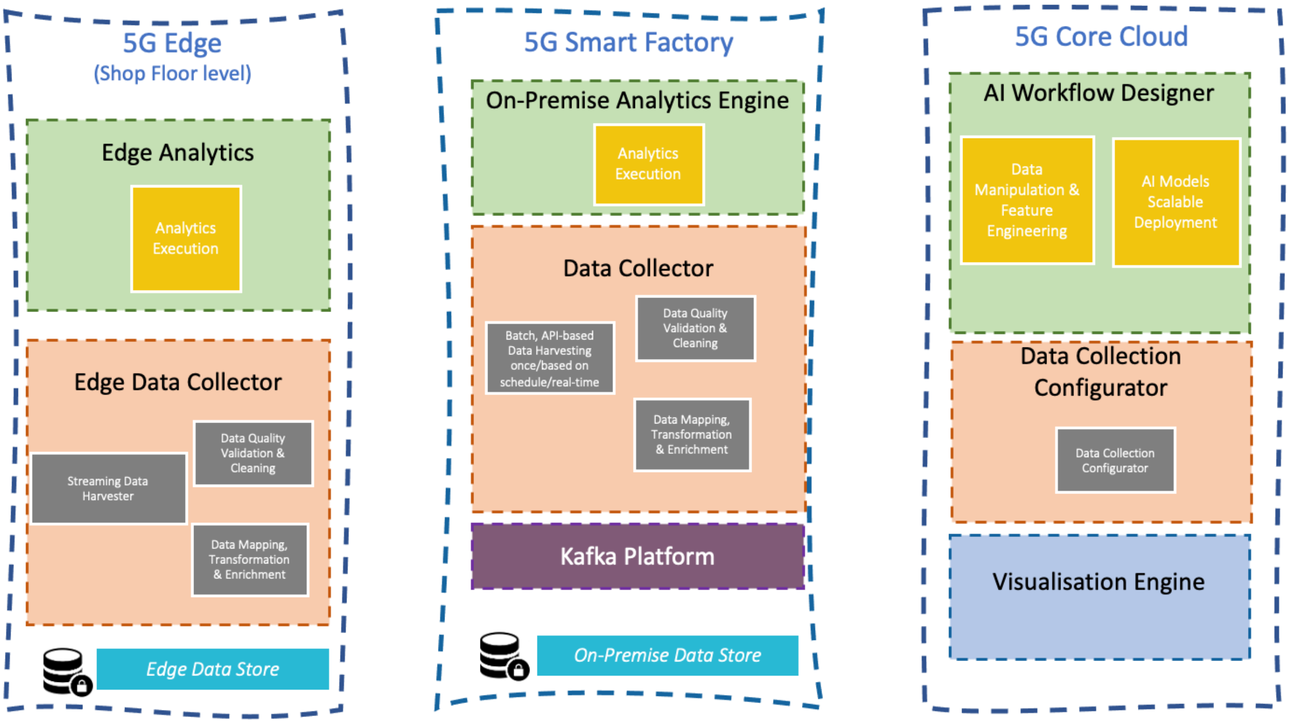

Figure 3.6: UC4 main concept and high-level View

Based on the analysis of the use case to be implemented in the factory settings of Whirlpool and PPC, at the shop floor, data will be collected from different sensors and sources, such as thermal cameras as well as PLCs, which are all connected to the MEC via a 5G link, which is conceptually demonstrated in Figure 3.7. As shown in Figure 3.7, the MEC will host an edge deployment of the specific NetApp components that are necessary for running analytics at the edge, and those are namely the Edge Data Collector, the Edge Analytics Engine and the Edge Data Store. Using a cloud-based configurator, the necessary settings for the operation of the Edge part will be defined, such as out of which sources data should be retrieved, which algorithms to execute, what results to provide, etc., leaving all the resources provisioning policies and schedules to be handled by the NAO.

All the data and the analytics to be executed at the edge will be forwarded to the "smart factory" level, where similar functions will be deployed, with the difference that at this level data from different sources shall be aggregated (e.g., different edge nodes, other cross-organization systems like MES, ERPS, as well as external data sources).

All the above components are bundled as separate VNFs, and during the implementation for the Use Case it might be that, for performance and flexibility purposes, those VNFs will be further fleshed out into smaller functions.

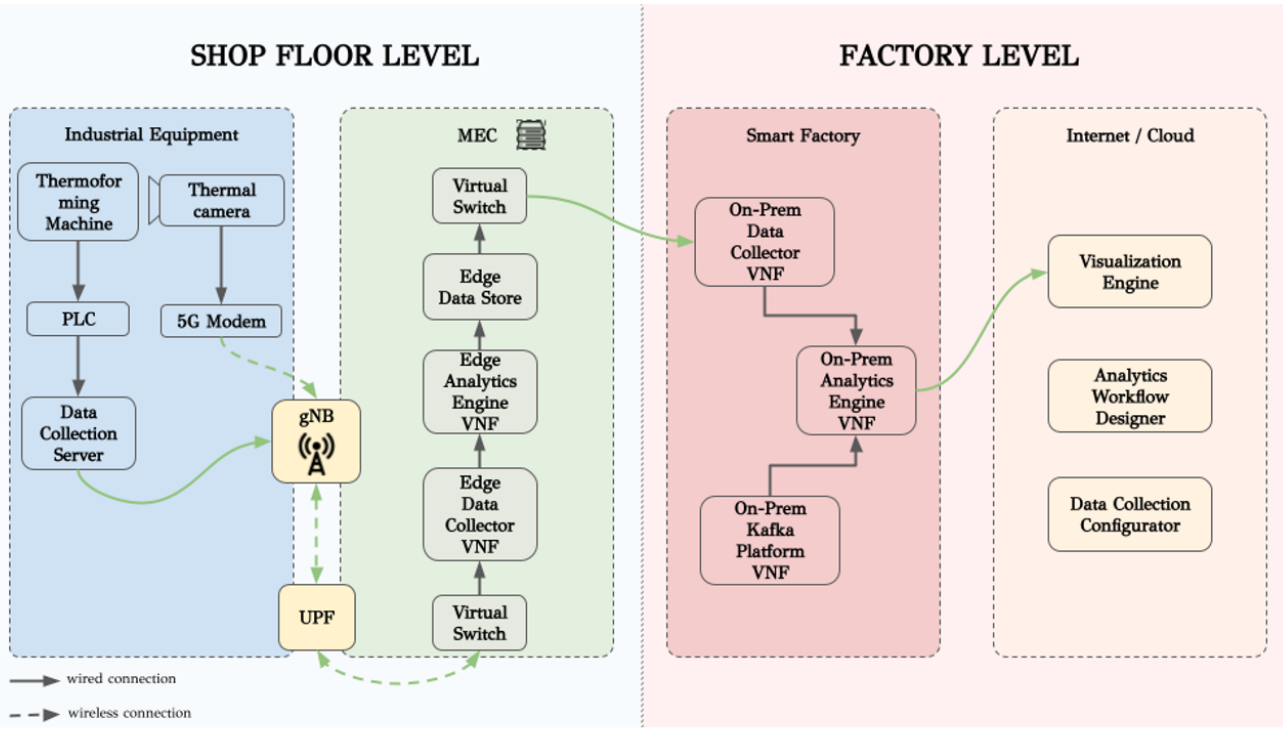

Figure 3.7: Use case 4 NetApp graph, components, and interconnections (WHR case example)

3.4.2 Requirements

The specific functional requirements for UC4, from the NetApp developer and the Industry point of view are presented in the following table.

Table 3-D: UC4 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
Functional requirements (NetApp developer point of view)				
UC4-D-01	The VNF deployment	SHALL	be supported in 5G Core and Edge network segment	n/a
UC4-D-02	Data Collector VNF	SHALL	allow deployment at the core factory level	GPR.F1
UC4-D-03	On-Prem Analytics Engine VNF	SHALL	allow deployment at the core factory level	
UC4-D-04	Edge Data Collector VNF	SHALL	allow deployment at the edge level	GPR.F1
UC4-D-05	Edge Analytics VNF	SHALL	allow deployment at the edge level	GPR.F7
UC4-D-06	The edge storage infrastructure	SHOULD	be 16 GB of capacity	GPR.F8

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
UC4-D-07	The smart Factory level storage infrastructure	SHALL	be 200 GB of capacity	n/a
UC4-D-08	GPU	SHOULD	be available at the edge	GPR.F7
UC4-D-09	Factory Equipment	SHALL	connect to the 5G Edge placed Engines via 5G	n/a
UC4-D-10	ER, MRP, etc., data coming from factory level APIs	SHALL	be made available to the 5G Smart Factory Analytics Engine	GPR.F1
UC4-D-11	Third Party data coming from external APIs	SHALL	be supported	GPR.F1
UC4-D-12	Capturing Real-time /streaming incoming data via Kafka	SHALL	be supported	GPR.F1 FPR.F3
UC4-D-13	Uploading of batch data as files	SHALL	be supported	GPR.F1
UC4-D-14	Periodic pulling of batch data	SHALL	be supported	GPR.F1
UC4-D-15	Data coming from within the factory	SHOULD	not leave the factory premises	GPR.F11
UC4-D-16	Factory Equipment	SHALL	connect to the 5G Edge and 5G Smart Factory via 5G	n/a
UC4-D-17	Data to be ingested	SHALL	be structured and based on defined schemas	GPR.F1 GPR.F12
UC4-D-18	The Edge Analytics Engine	SHALL	have 2 vCPUs	GPR.F7
UC4-D-19	The Edge Data Collector	SHALL	have 2 vCPUs	GPR.F1
UC4-D-20	The Edge Analytics Engine	SHALL	have 16 GB RAM	GPR.F7
UC4-D-21	The Edge Data Collector	SHALL	have 8 GB RAM	GPR.F1
UC4-D-22	The On-Prem Analytics Engine	SHALL	have 8 vCPUs	n/a
UC4-D-23	The On-Prem Data Collector	SHALL	have 4 vCPUs	GPR.F1
UC4-D-24	The On-Prem Kafka Platform	SHALL	have 2 vCPUs	GPR.F1
UC4-D-25	The On-Prem Analytics Engine	SHALL	have 64 GB RAM	n/a
UC4-D-26	The On-Prem Data Collector	SHALL	have 16GB RAM	GPR.F1
UC4-D-27	The On-Prem Kafka Platform	SHALL	have 4 GB RAM	GPR.F1
UC4-D-28	The Edge Analytics Engine	SHOULD	have an nVidia GPU available	GPR.F7
UC4-D-29	Tensorflow framework for analytics	SHALL	be supported	n/a
UC4-D-30	Data to be processed	SHALL	be transformed based on a specific predictive maintenance data model	GPR.F1

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
Functional requirements (Vertical end-user point of view)				
UC4-V-01	The NetApp availability	SHOULD	be 99.9%.	GPR.F9
UC4-V-02	The Analytics Engine of the NetApp	SHALL	support analytics for different shop floors/machineries	GPR.F7
UC4-V-03	The NetApp	SHALL	provide alerts to users when a prediction is made	n/a
UC4-V-04	The Analytics Engine of the NetApp	SHOULD	allow the design of different data analytics pipelines	n/a
UC4-V-05	The Analytics Engine of the NetApp	SHALL	provide analysis output APIs files to be visualised by other components	n/a
UC4-V-06	The Data Collector part of the NetApp	SHALL	be able to ingest data coming from PLCs	GPR.F1
UC4-V-07	The Data Collector part of the NetApp	SHOULD	be able to ingest image data	GPR.F1 GPR.F3
UC4-V-07	The NetApp	SHOULD	support Historical data visualization	n/a

3.4.3 Design remarks and targeted NetApps

The considered NetApp currently consists of 5 main VNFs:

- ***Edge Data Collector.*** This VNF is the one that will be used to collect data at the shop floor level.
- ***Edge Analytics Engine.*** This VNF is a lightweight (in terms of available analytic libraries) analytics engine able to run at the edge, processing the shopfloor collected data.
- ***On-Prem Kafka Platform.*** This VNF is used to collect streaming data made available through Kafka streams at the factory level.
- ***On-Prem Data Collector.*** This VNF is the one that will be used to collect data at the factory floor level.
- ***On-Prem Analytics Engine.*** This VNF will host the factory level analytics engine that will provide complex analytics and ML algorithms over the collected data.

3.5 UC5: Inspection and surveillance services for critical infrastructures

3.5.1 Use case description

The aim of use case 5 is to have automatic UAV-based tank and pipeline inspection to assist reduce corrosion maintenance cost by at least 10%, and area surveillance monitoring to detect intruders in real-time with very short E2E latency, based on advance AI-based models running on the edge with end-user monitoring devices located both locally (at infrastructure premises) and remotely. Figure 3.8 depicts the overview of UC5 NetApp structure. The received video from the UAV at the pilot's end device is forwarded to the NetApp for processing the information of the corroded areas and intruders. Both the video and the extracted information are also shared with the Commander.

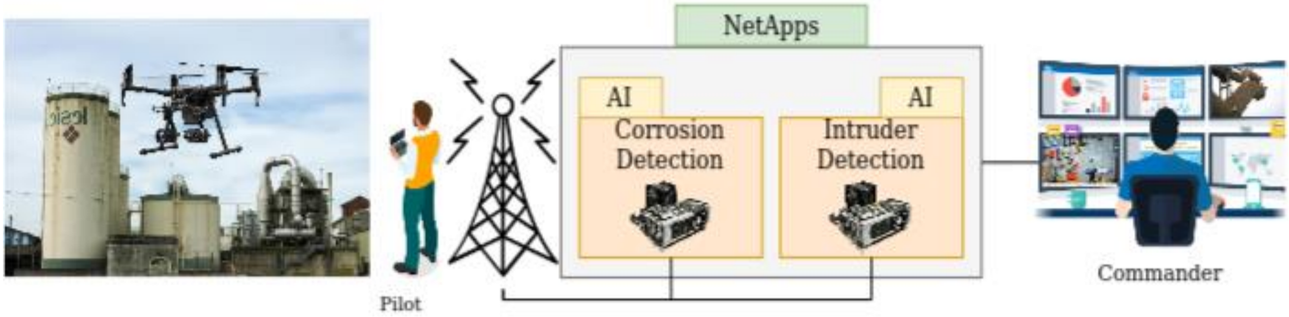

Figure 3.8: High-level use case 5 NetApp structure

3.5.2 Requirements

The specific functional requirements for UC5, from the NetApp developer and the Industry point of view are presented in the following table.

Table 3-E: UC5 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
Functional requirements (NetApp developer point of view)				
UC5-D-01	End-to-end latency (considering UE-edge-core-edge-UE)	SHOULD	be less than 10 ms (if processing at core is achieved within 5ms)	GPR.F6
UC5-D-02	The Video proxy VNF	SHOULD	deliver multiple video streams in less than 400 ms	GPR.F6
UC5-D-03	The AI-based (intrusion/corrosion) VNFs	SHOULD	achieve the detection accuracy of at least 70%	GPR.F7
UC5-D-04	The algorithm processing latency	SHOULD	be less than 200 ms	GPR.F6
UC5-D-05	The message-bus	SHOULD	allow communications of multiple VNF instances and in less than 100 ms	GPR.F6
UC5-D-06	The bandwidth	SHOULD	be 40 Mb/s for Proxy VNF (RTMP) and 1Mb/s for message bus VNF (AMPQ)	GPR.F1 GPR.F3
UC5-D-07	The one-way communication latency between the control application and the drone	SHALL	be up to 3 ms	GPR.F6
UC5-D-08	The commander VNF	SHOULD	allow video rendering in less than 400ms	GPR.F6
UC5-D-09	Uplink Ultra-Reliable Low Latency Communication	SHOULD	be 40 Mb/s	GPR.F6

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
UC5-D-10	The video proxy, Corrosion and intruder VNFs	SHOULD	support mobility	GPR.F4
UC5-D-11	GPU computing	SHOULD	be provided for corrosion and intruder VNFs at the edge	GPR.F7
UC5-D-12	All the VNFs (video proxy, corrosion, and message bus VNFs)	SHOULD	be located at the edge	GPR.F7
UC5-D-13	Corrosion and Intrusion VNFs	SHALL	have 8 GB RAM each	GPR.F7
UC5-D-14	Video proxy and Message bus VNFs	SHALL	have 2 GB RAM each	GPR.F7
UC5-D-15	The storage infrastructure of the VNFs (video proxy, corrosion, intrusion, and message bus)	SHALL	be 80 GB of capacity (20 GB each)	GPR.F8
Functional requirements (Vertical end-user point of view)				
UC1-V-01	The corrosion detection application	SHOULD	have a detection accuracy above 70%, for achieving the targeted cost reduction	GPR.F7
UC1-V-02	Reduced Corrosion Maintenance Costs	SHOULD	be over 30%, depending on the corrosion detection accuracy	GPR.F7
UC1-V-03	The intrusion detection application	SHOULD	have a false positive accuracy of 99% in order to avoid unwanted system downturn	GPR.F7
UC1-V-04	The application cover area	SHOULD	be at least 500 m in diameter and extendable to 1 km	
UC1-V-05	The data transferred from deployed sensors	SHALL	Utilize encrypted communication channels to transmit collected data	GPR.F11

3.5.3 Design remarks and targeted NetApps

Use Case 5 consists of 5 VNFs:

- **Video Proxy VNF**: This VNF is responsible for streaming the video to other three distinct VNFs: “Corrosion Detection”, “Intruder Detection”, and “Commander Observation Tool” VNFs.
- **Corrosion Detection VNF**: The “Corrosion Detection” VNF is responsible for receiving the video from the “Video Proxy” VNF and detecting the corroded areas on tanks and pipes using a machine learning-based corrosion detection algorithm.
- **Intruder Detection VNF:** The aim of the “Intruder Detection” VNF is to detect the humans that may trespass non-authorised areas in this critical infrastructure using machine learning-based intrusion detection algorithms to locate the unauthorised trespassers.

- **Message Bus VNF:** The aim of the "Message Bus" VNF is to receive the detection results obtained from the "Corrosion Detection" and "Intruder Detection" VNFs and to send them to the "Commander Observation Tool" VNF and the "Android UAV Control Application" controlled by the pilot.
- **Commander Observation Tool VNF:** The aim of the "Commander Observation Tool" VNF is to receive the video stream from the "Video Proxy" VNF and overlay the results of the detections processed by the "Message Bus" VNF. These results are provided by the "Corrosion Detection" and the "Intruder Detection" VNFs.

3.6 UC6: Remote Service Platform for Inspection, Maintenance and Repair

3.6.1 Use case description

For this use case, Remote Service Platform for Inspection, Maintenance and Repair, the ***Remote Support*** module of Oculavis SHARE will be used. It enables a broad and high-quality remote support call, through the combination of high-quality video and audio streams, collaborative working tools such as diverse AR annotation and documentation tools and linking of respective data. The application enables the execution of maintenance, inspection and repair tasks remotely, so that travel time and costs of service technicians can be reduced, and the machine availability increased. Figure 3.9 visualizes the high-level NetApp structure which will be realized within the project, such as use case related photos which help understand the situation.

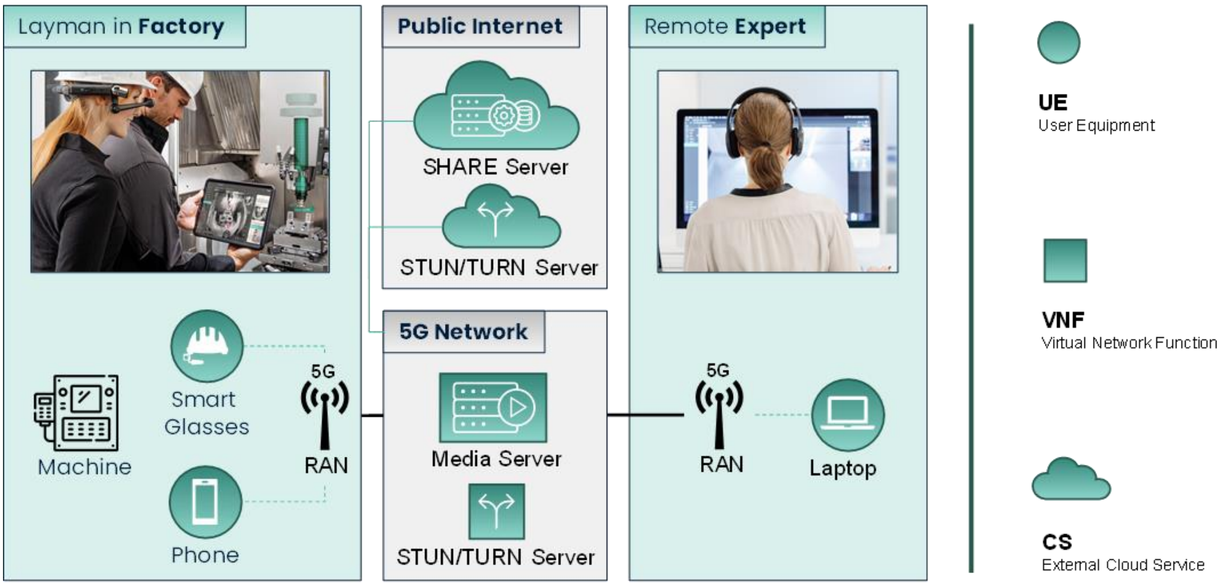

Figure 3.9: High level view UC6 NetApp structure and use case

Within the 5G-Induce project the newly developed star topology architecture is used and further developed to modularly deploy and configure the media server as a dockerised VNF in a 5G network. With this hybrid on-premises deployment setup the benefits of the 5G network, such as higher bandwidth and lower latency for videos, audio and annotation communication, will be evaluated in comparison to the standard non-5G cloud setup of Oculavis SHARE. Therefore, an overlay of network statistics per client (e.g., used bitrate for video and audio tracks, sent and received resolution and framerates of video tracks, codec, etc.) will be developed.

Besides the ***Remote Support*** module, the application enables the creation of bidirectional step-by-step instructions (***Workflows*** module), linking to assets hierarchies (***Asset Relation*** module) and delivery to specific individuals. The three modules of the software are also shown in Figure 3.10.

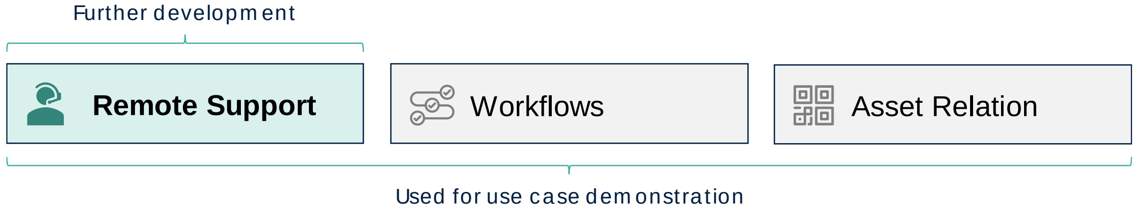

Figure 3.10: Module overview Oculavis SHARE

Furthermore, 3D models can be shown and overlayed as AR models over real assets. These models might be included to showcase the use case but are not planned to be part of further development within the 5G Induce project.

3.6.2 Requirements

The specific functional requirements for UC6, from the NetApp developer and the industry point of view are presented in the following table.

Table 3-F: UC6 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
Functional requirements (NetApp developer point of view)				
UC6-D-01	The media server	SHALL	have 8 vCPUs as available CPU resources.	GPR.F7 GPR.F9
UC6-D-02	The media server VNF	SHOULD	have 16 vCPUs as available CPU resources.	GPR.F7 GPR.F9
UC6-D-03	The media server VNF	SHALL	have 16 GB as available RAM resources.	n/a
UC6-D-04	The media server VNF	SHALL	have 30 GB (SSD) + 30 GB (HDD) available disk space.	GPR.F11 GPR.F9
UC6-D-05	The STUN/TURN server VNF	SHALL	have 8 vCPUs as available CPU resources.	GPR.F7 GPR.F9
UC6-D-06	The STUN/TURN server VNF	SHALL	have 16 GB as available RAM resources.	n/a
UC6-D-07	The STUN/TURN server VNF	SHALL	have 20 GB (SSD) available disk space.	GPR.F8
UC6-D-08	The CPU resources for the media server VNF	SHOULD	be configurable so that they can be adapted (e.g., to the number of parallel users in video calls or general number of platform users.)	n/a

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
UC6-D-09	The CPU resources for the STUN/TURN server VNF	SHOULD	be configurable so that they can be adapted (e.g., to the number of parallel users in video calls or general number of platform users.)	n/a
UC6-D-11	The media server VNF	SHALL	be reachable via the TCP from the Internet so that the SHARE platform, which will be hosted on an external cloud service provider, can communicate with the media server VNF.	GPR.F12
UC6-D-12	The incoming connections to the media server via a specific TCP port	SHALL	be only possible by the SHARE platform server in a secure way (e.g., VPN tunnel and IP whitelist, restricted by a firewall)	GPR.F12
UC6-D-13	The client applications (user equipment) operating in the 5G network	SHALL	be allowed to communicate via Internet with the SHARE platform server (which will be hosted on an external cloud provider) using WSS and HTTPS.	GPR.F4 GPR.F12
UC6-D-14	The client applications (user equipment) operating in the 5G network	SHALL	be able to receive and send data using WebRTC to the media server and (potentially) TURN server.	GPR.F4 GPR.F12
UC6-D-15	The client applications (user equipment) operating in the 5G network	SHALL	be able to receive and send data using HTTPS and WSS protocols to the SHARE platform server which will be hosted on an external cloud provider.	GPR.F4 GPR.F12
UC6-D-16	The available bandwidth for a single user point	SHALL	be 10 Mbit/s upload and 10 Mbit/s download.	GPR.F1 GPR.F4
UC6-D-17	The NetApp	SHOULD	be able to monitor and visualize relevant network statistics (e.g., used bitrate for video and audio tracks, sent and received resolution and framerates of video tracks, codec, etc.) per client application (user equipment).	n/a
Functional requirements (Vertical end-user point of view)				
UC6-V-01	The NetApp availability	SHOULD	be 99.9%.	GPR.F9
UC6-V-02	The NetApp	SHALL	be able to support video calls between two or more client applications (user equipment) in the local 5G network.	GPR.F1 GPR.F3

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
UC6-V-03	The NetApp	SHOULD	be able to support video calls with client applications (user equipment) which are connected via public internet.	GPR.F1 GPR.F3
UC6-V-04	The NetApp	SHALL	support the use of smart glasses (Realwear HMT-1) and smart phones to access the remote support video call.	GPR.F3 GPR.F4
UC6-V-05	The video and audio latency of the NetApps Remote Support module	SHOULD	be less than 200 milliseconds.	GPR.F6
UC6-V-06	The NetApp	SHOULD	support remote collaboration tools such as zoom, drawing annotations, triggering screenshot or having a pointer on the screen while all actions should be shared between collaborators.	n/a
UC6-V-07	The NetApp	SHOULD	be able to visualize 3D models on smart phones as an overlay over the camera stream (not in remote support call).	GPR.F1
UC6-V-08	The NetApp	SHOULD	support 2D Annotation visualization as an overlay on smart glasses for the maintenance operator.	n/a
UC6-V-09	The NetApp	SHALL	ensure an application response time of < 200 ms comparable with current worker assistance interfaces.	n/a
UC6-V-10	The remote support video call module	SHOULD	support video streams up to full high definition (FHD 1920 x 1080 pixels) with a framerate of up to 30 frames per second (30 FPS) depending on the network conditions.	GPR.F3

3.6.3 Design remarks and targeted NetApps

The planned and aimed NetApp structure is based on two main Virtual Network Functions (VNFs) which will be deployed within the 5G infrastructure.

- **Media Server VNF**: The media server VNF is a Selective Forwarding Unit (SFU) and acts as a media plane for the Remote Support module of the Remote Service Application Oculavis SHARE. More specifically, it is responsible for receiving and relaying videos, audio and data tracks of all connected end-client applications (user devices). Through the media server VNF the media traffic can be transmitted in a WebRTC star topology which further enables the scalability of the whole system.

Furthermore, the media server VNF needs to communicate with the SHARE platform server which will be hosted on an external cloud service provider, so that it can be reachable via the Internet.

- **STUN/TURN Server VNF**: This VNF is needed whenever a direct communication between the end-client application (user equipment) and the media server VNF is not possible. A STUN server is therefore used when the client and the media server are in different LANs which are separated through a NAT-router. With the help of the STUN server, the client can determine their public IP address and port so that a direct connection can be established. In case a symmetric NAT is used the media traffic needs to be relayed via a TURN server. The public IP address and ports of the TURN server are made known to the client and the media server so that the connection can be established.

Also, up to 20 end-client applications (user equipment) are part of the NetApp structure. Additional components such as the SHARE platform server, which is hosted on external cloud service providers, will be included in the NetApp scenario but not deployed in the 5G network and therefore be excluded from the orchestration via the NAO.

3.7 UC7: Crossroad control for safety

3.7.1 Use case description

Use case7 provides a means of alerting when collision probability is increasing as forklifts move inside factories, due to limited visibility. Forklift drivers as well as workers moving around the plant (using the corridors of the factory) will be notified promptly about any potential danger, in order to take all necessary actions. The main aim of this NetApp is to reduce the number of accidents that take place inside factories due to forklifts' routes.

In Figure 3.11, an overview of the UC7 is shown. More specifically, BLE beacons are installed throughout the warehouses' corridors and transmit signals that are then received by the Android devices on the forklifts. The received RSSI is converted into the location of the forklift inside the warehouse using a positioning algorithm. Through a 5G antenna, the data is sent and processed by the server. At this point, a sophisticated optimization and prediction algorithm estimates the probability of an accident at specific cross-corridors and, if necessary, initiates the alarm process to notify the potentially involved parties in the accident. In case of a possible collision, a visual and auricular alerting system is enabled in the mobile devices located on the forklifts.

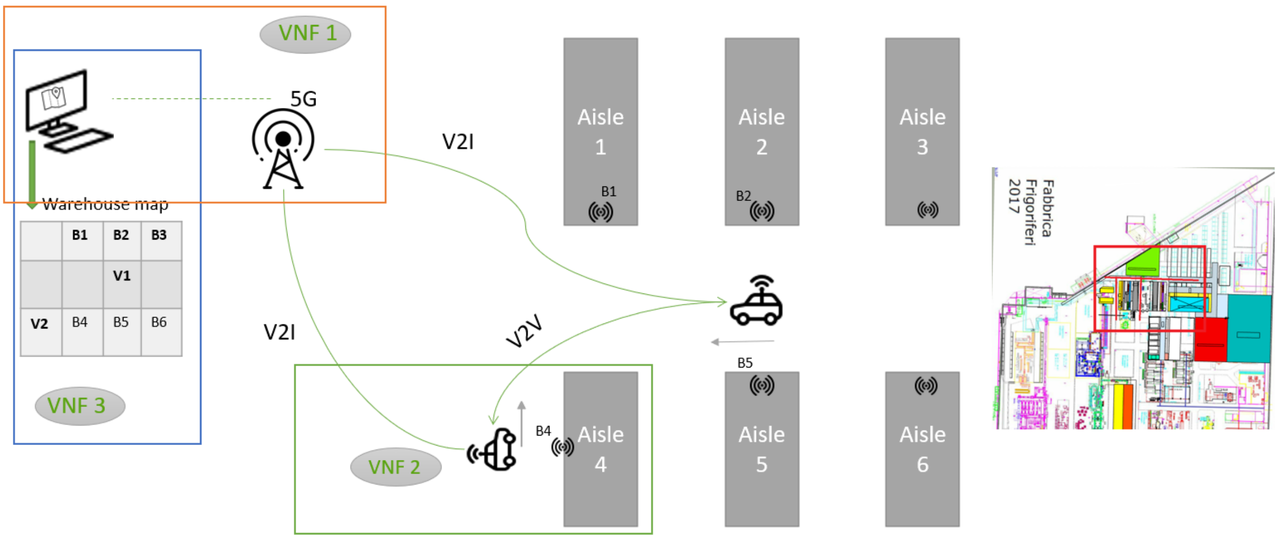

Figure 3.11: Use case 7 NetApp graph, components, and interconnections

3.7.2 Requirements

The specific functional requirements for UC7, from the NetApp developer and the Industry point of view are presented in the following table.

Table 3-G: UC7 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
Functional requirements (NetApp developer point of view)				
UC1-D-01	Signal strength	SHOULD	be > -76dBm on covered area	GPR.F1
UC1-D-02	Bandwidth Availability	SHALL	be > 99%	GPR.F1
UC1-D-03	Communication latency	SHALL	be < 150ms	GPR.F6
UC1-D-04	Processing Latency (including transport)	SHALL	be < 150 ms for alerting purposes < 250ms for monitoring purposes	GPR.F6
UC1-D-05	Data uploading	SHOULD	be 10 Mb/s for single user point	GPR.F4
UC1-D-06	Bluetooth	SHALL	be 5.0 or latest – to provide accurate proximity	GPR.F5
UC1-D-07	RAM memory	SHALL	be at least 28 GB (total memory)	GPR.F7
UC1-D-08	CPU cores	SHALL	have at least 14 cores (total cores)	GPR.F7
UC1-D-09	SSD storage	SHALL	be at least 650 GB (total storage)	GPR.F8
UC1-D-10	Location information	SHALL	be able to locate moving entities +/-2m accuracy	GPR.F5
Functional requirements (Vertical end-user point of view)				
UC1-V-01	The portion of plant warehouse area (max 1000 m^2)	SHOULD	have indoor/outdoor 5G coverage (industrial environment)	GPR.F10
UC1-V-02	Signal stability within covered area	SHALL	have +/-5% divergence	GPR.F9
UC1-V-03	The application	SHALL	provide: - forklifts versus human identification - proximity to the crossroad detection - movements' direction prediction - alerting system	GPR.F5
UC1-V-04	The application	SHOULD	support historical data visualization	GPR.F8
UC1-V-05	The application	SHALL	support Android v10 or later	GPR.F4

3.7.3 Design remarks and targeted NetApps

The specific NetApp structure is based on the following network application functions:

- **VNF1:** Vehicle to Infrastructure (V2I) service that uses beacons for location detection and is responsible for vehicle mapping in application server.
- **VNF2**: Vehicle to Vehicle (V2V) service that uses the mobile phone to intercommunicate vehicles through 5G antenna.
- **VNF3:** Collision detection software service that sends alert mechanism, in case of detected possible collision, from the server to the vehicles.

3.8 UC8: Drone assisted network performance and coverage monitoring for industrial infrastructures

3.8.1 Use case description

Use case 8 utilizes continuous and on-demand monitoring of various 5G network performance parameters and network radio coverage parameters (utilizing both fixed and drone-mounted agent probes), coupled with comprehensive data analytics and reporting tools to enable real-time insight into the conditions/QoS available to UEs connected to the network and verifying SLA KPIs. As an add-on, monitoring equipment mounted on a drone provides vertical dimension of monitored parameters and enables video stream of monitored facility area to be used for additional post-analytics for the network optimization and for the root-cause analysis (e.g., identifying potential sources of interferences, metal obstacles causing signal scattering, etc.). Besides, the collected results might potentially serve as feedback to the network OSS for automated network tuning.

Continuous and on-demand monitoring of 5G network in industrial environments assures high availability of critical communications, needed for the main process to run (e.g., automated fork-lift operations), and, at the same time, assures high availability of services needed for the main process to run (e.g., video-based remote-control operation). It supports automatic optimization of 5G network quality of service (QoS) utilizing collected monitoring data, while it supports optimization of 5G network radio coverage as well, supported by identifying obstacles and/or interference sources through video stream provided by drone-mounted agent probes.

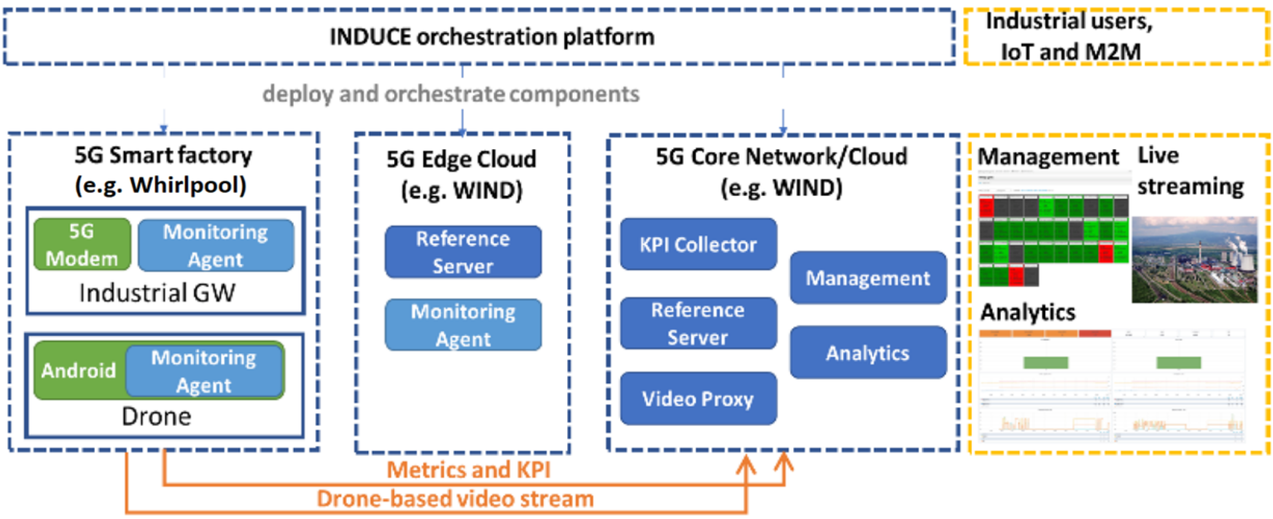

Figure 3.12: Use case 8 NetApp graph, components, and interconnections

3.8.2 Requirements

The specific functional requirements for UC8, from the NetApp developer and the Industry point of view are presented in the following table.

Table 3-H: UC8 functional requirements

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	Commitment	Action + Subject + (constraint)	
Functional requirements (NetApp developer point of view)				
UC8-D-01	NetApp availability	SHOULD	be at least 99.99%	GPR.F9
UC8-D-02	Drone assistance	SHALL	prepare drone and mount required equipment to it	GPR.F4 GPR.F5 GPR.F10 GPR.F12
UC8-D-03	Component #1: qMON KPI collector	SHALL	collect KPIs from qMON Agent probes	GPR.F7 GPR.F8
UC8-D-04	Component #2: qMON reference server	SHALL	reference measurement endpoint for qMON Agent probes	GPR.F7 GPR.F8 GPR.F12
UC8-D-05	Component #3: qMON management server	SHALL	Perform centralized management of qMON Agent probes	GPR.F7 GPR.F8 GPR.F12
UC8-D-06	Component #4: qMON insight server	SHALL	display analytics and dashboards for KPIs gathered by qMON Agent probes	GPR.F7 GPR.F8 GPR.F12
UC8-D-07	Component #5: qMON video proxy	SHALL	proxy video streams from camera devices	GPR.F3 GPR.F12
UC8-D-08	Enable required qMON datasets	SHALL	collect application-level KPIs, network-level KPIs, radio KPIs	n/a
UC8-D-09	Prepare helm charts	SHALL	prepare charts for qMON KPI collector, qMON reference server, qMON management server, qMON insight server, qMON video proxy	n/a
Functional requirements (Vertical end-user point of view)				
UC8-U-01	Area of the operation	SHALL	operate in Cassinetta site area indoor/outdoor (industrial environment)	GPR.F10
UC8-U-02	Continuous network performance monitoring schedule	SHALL	perform 24/7 operations	GPR.F9
UC8-U-03	Spatial radio KPIs awareness	SHALL	represent radio KPIs	GPR.F4 GPR.F5 GPR.F10

ID	Requirement			Targeted D2.1 GPR.Fx requirement
	Object+ (condition)	**Commitment**	**Action + Subject + (constraint)**	
UC8-U-04	User friendly visualization of results/data and KPIs	SHALL	use suitable visualization tools	n/a
UC8-U-05	Alarm management for performance KPIs drop	SHOULD	provide thresholds to be adjustable	GPR.F9
UC8-U-06	Capture/record video and images	SHALL	also provide anonymization for sensitive data protection (GDPR compliance)	GPR.F3 GPR.F11
UC8-U-07	Health and safety compliance	SHALL	comply with DPCM 8.7.2003 (GU 199 29.08.2003)	n/a

3.8.3 Design remarks and targeted NetApps

The following NetApp components are identified for the use case design:

- **Network Monitoring** (qMON KPI Collector component): collecting KPIs/parameters data from Agent probes, forwarding data to Analytics and Presentation component.
- **Measurement References** (qMON Reference Server component): receives test traffic from Agent Probes (e.g., upload bandwidth test) and forwards data to Agent Probes (e.g., download bandwidth test).
- **Agent Probes Management** (qMON Management Server component): centralised management of Agent Probes, e.g., provisioning, configuring, upgrading, etc.
- **Analytics and Presentation** (qMON Insight Server component): receives data from Network monitoring component, analyses and presents it to the customer via dashboards.
- **Video Monitoring** (qMON Video Proxy component): receiving video streams from Agent Probes.

4 Validation plan and key metrics

The purpose of this section is to provide a clear reference roadmap for the use cases within the course of the project and set the initial (core) metrics for the final validation that determine in turn the use case deployment and overall integration planning. This section begins with a detailed description of the validation process adopted within 5G-INDUCE, which is linked to the NetApp use case design, deployment, and integration phases over the DevOps testbed and later the experimental facilities (ExFas). The common performance metrics are then defined, according to the established procedures followed within other 5G PPP projects. A set of use case specific metrics is also defined as initial validation targets of the project.

4.1 Process: from design to validation

Within 5G-INDUCE, all use cases follow a certain process from the initial design to the final validation. This process includes the following steps:

STEP 1: Detailed definition of use case targeted functionalities and demonstration targets.
STEP 2: Definition of the main use case NetApp as linked functions deployable over the 5G-INDUCE platform.
STEP 3: Development of the main NetApp components (in three release phases).
STEP 4: Evaluation of deployment requirements and needs for integration over ExFas.
STEP 5: Definition of the validation framework and testing procedures (according to infrastructure capabilities).
STEP 6: Integration of the NetApp (initially over the DevOps testbed (releases 1 and 2) and then over the targeted ExFa (releases 2 and 3)).
STEP 7: Validation (testing and performance evaluation).

These steps represent a logical procedure and do not constitute discrete implementation steps. In particular, steps 3 and 6 include parallel processes, since the development, deployment and integration are performed in multiple releases. Moreover, the final validation follows the release cycles and includes several preliminary tests (from proof of concept to functional test for identifying fixes and required modifications) before the final use case validation and later demonstration of the use case occurs.

Figure 4.1 shows the positioning of the use case procedural steps within the overall workplan of the 5G-INDUCE project. Steps 1 and 2 relate to the initial design phase of the project, and their outcomes are presented in detail in the previous section of the current deliverable. Steps 3 to 6 are core processes in the development phase and relate to the releases of the NetApps, their integration over the testbeds and the specific validations to be performed. Step 7 belongs to the final evaluation and showcasing phase.

4.2 Implementation of the validation process within 5G-INDUCE

The overall process from the design to the final validation of the use cases, within the 5G-INDUCE project timeframe (M01-M36), is performed primarily within the 3 following tasks:

T4.2 on NetApp development (M04-M30): Here the NetApps for each use case are developed. The effort includes 3 release cycles. The first one is an early release that follows the defined NetApp structure, broken down into linked components with specific properties that serve the overall use case requirements. This follows the specifications defined in Section 3 of this deliverable. The goal of the initial release is to provide a structured use case solution that can be evaluated as proof of concept in the DevOps testbed. The following two releases provide updates and additions on the NetApp functionalities, as well as adaptations to the experimentation facility requirements. The final release cycle also includes possible additions and extensions (e.g., for enhanced security, alternative functionalities with improved KPIs, functions offering additional analytics and performance metrics, etc.). A back-up period is optionally inserted after the final release in order to allow potential fixes and adaptations to ExFas after feedback is received during the evaluation phase.

T5.1 on Experimentation and integration work plan (M10-M24): The goal here is to evaluate the deployment capabilities of the ExFas together with the NetApp use case implementation processes and conclude to a realistic workplan that will coordinate the integration activities among the 5G-INDUCE Platform, the use case NetApps, and the ExFas. This task defines the validation procedures and the KPIs to be evaluated according to the testbed capabilities. The outcomes of this task define what will be validated and showcased during the final evaluation phase of the project. The task concludes with the integration of the use cases over the ExFas according to the defined procedures and in view of the validation scenarios to be deployed.

T6.2 on the actual Verification-Validation and performance estimation (M18-M36): The Validation and Verification process is carried out first in the DevOps testbed (T6.1) and then transferred to the designated ExFas as described by the related use case scenarios. The overall process targets the evaluation of the targeted KPIs for each use case, under different implementation and deployment scenarios, in an effort to identify key operational parameters, including (and not limited to): the achieved latency as function of the reliability and location of the NetApp and VNF processing components in the network, the service time creation as slice creation and NetApp deployment time, the service modification time due to policy and connectivity requirements changes and the optimised use of computational resources at different network levels (on premise nodes, telco edge nodes, core).

The lower part of Figure 4.1 depicts the above-mentioned task processes within the work plan time frame of the project.

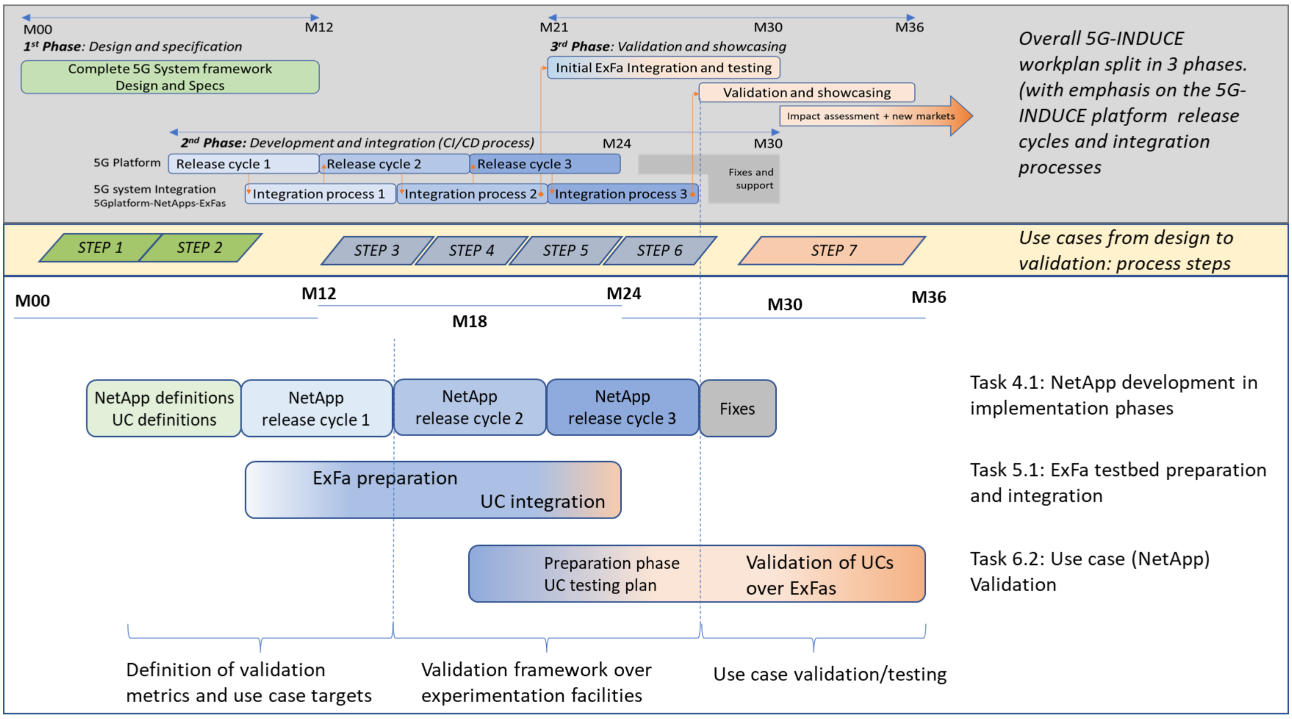

Figure 4.1: Overall 5G-INDUCE implementation workplan split in 3 phases (upper grey highlighted part), followed by a representation of the use case implementation steps (yellow highlighted part). Detailed representation of the use case related implementation processes (lower part)

According to the above, the overall use case design-development-validation process allows:

a) the initial definition of validation metrics and use case targets, as outcome of the current definition deliverable and the actual work from the first NetApp release, expected by M15 of the project,

b) the structuring of the detailed validation framework over the ExFas, in parallel to the main NetApp development efforts and the deployment of the ExFa sites, alongside with the definition of the exact use case validation scenarios,

c) the final NetApp validation and verification following the defined use case scenarios and the targeted validation metrics; the process may include multiple scenarios for the same use case according to different deployments, such as edge or core processing, and including potential extensions and improvements.

4.3 Performance metrics and definitions

In 5G-INDUCE the performance metrics are related to the performance of the use case applications, since the innovation is on the deployment and management of the NetApps rather than the network performance. The performance of deployed applications refers to the performance of the higher layer and the interfacing to the end user. The network performance is a part of this, and significantly determines the outcome; however, higher layer processes should also be taken into consideration. These, in principle, relate to the processes within the NAO part of the 5G-INDUCE platform. It is also important to note that the existence of the NAO permits the actual measurements of such application related metrics, (in contrast to many other 5G PPP projects on vertical deployments that only provided an estimation of the related services).

The mapping between the application performance metrics and the typical 5G network performance metrics concludes in a set of common metrics. Here the term "common" characterises the performance metrics that can be used by any vertical use case, in order to highlight the 5G related networking benefits on the application behaviour. In addition to common metrics, use case specific metrics are also defined to be purely related to the application-level deployment and the supported functionalities. These two metric types are defined in the following subsections.

4.3.1 Common metrics

This section includes the metrics that are common to all use cases and in principle to all 5G vertical sectors. These metrics are affected by the 5G network performance; however, they extend to the application layer. They are primarily driven by the 3GPP definitions provided in [[1]] and [[2]] and adapted to the specific needs of the project with respect to the targeted application use cases.

<u>Latency/Delay</u>: The end-to-end latency at the application level is defined as the total time required for the end-user to receive an application response message after a request message is sent by the end-user. It can be further split into specific processes executed within the network and through the 5G-INDUCE platform. This is required for the contributions of each process to the overall end-to-end delay to be analysed.

The 5G-INDUCE platform provides the means to measure both the overall end-to-end latency, as well as the latency of specific processes, by monitoring the response time of the nodes and the applications.

In all cases, if the latency does not refer to the end-to-end latency defined above, it must be defined specifically when measured, in order to avoid any misconceptions. In addition, the end-to-end latency should

[1] 3GPP TS 22.261 v.18.5.0 Release 18, "Technical Specification Group Services and System Aspects; Service requirements for the 5G system; Stage 1", Dec. 2021.
[2] 3GPP TS 28.554 v.17.5.0 Release 17, "5G Management and orchestration; 5G end to end Key Performance Indicators", Dec. 2021.

make reference to specific use case processes at the end user level. It is noted that the specific metric assumes that the NetApp is properly onboarded and deployed, and it is fully functional.

Delay Jitter: Following the definition of the application-level latency, the jitter metric is defined as the variation of the end-to-end application latency for the communication between specific components of the use case measured at the end-user.

Slice creation and adaptation time: This metric is defined as the total time elapsed from the triggering of the creation (or reconfiguration) of a slice through the NAO slice intent module to the OSS, until the slice is fully established and operational, notified by the slice response module to the NAO.

NetApp deployment and adaptation time: This metric is defined as the total time elapsed from the triggering of the NetApp deployment (or reconfiguration) by the end user through the NAO user interface, until the end user is notified that the NetApp is fully deployed and functional.

This metric includes the slice creation/adaptation time, but it can also support alternative approaches according to which already established slices are reused or reconfigured.

Data rate: This refers to the effective application-level data rate and is defined as the number of application bits per second transferred over a specific use case interface.

This specific metric ignores any service layer bits, used for the management of the applications, and is obtained during runtime operation. It is a parameter that is monitored by the NAO on the NetApp component level.

Data capacity/volume: This metric follows the data rate and is also defined at the application level. It measures the total quantity of use case information bits transferred over a given application interface during specific use case operations, measured in bits.

End user scalability (density): This metric characterises the number of end-users/devices that can be connected simultaneously to the access network infrastructure for a given application use case, without degrading the overall performance (i.e., the targeted performance metrics for the application) below the defined numbers and for all users/devices in the coverage area.

Availability: For NetApp services, this metric is defined as the percentage value of the amount of time the end-to-end application is properly delivered according to the specified performance metrics, divided by the amount of time the system is expected to deliver the end-to-end NetApp service.

Reliability: This metric is strictly connected to the “availability” metric and is defined with respect to the network layer packet transmissions that are successfully delivered for a given end-to-end application, within the time constraint required by the targeted application, and as a percentage out of all the packets transmitted.

As such, this metric is inversely proportional to the packet loss rate, which is typically defined at the end-to-end transport level. Reliability is defined here at the application layer, meaning that a resiliency mechanism may allow correct packet delivery although an individual connection loss rate is high.

Coverage: This is the radio access coverage area over the actual experimentation facility. (It is noted that use case 8 provides this measurement alongside the achieved signal quality and is in principle use case dependent; as, for example, a low data rate communication to an end user device for a certain application may allow a longer coverage compared to a stricter signal quality in another application use case).

Received signal quality: The metric refers to the quality of the received signal, as a ratio with respect to the best possible connection quality referring to the highest modulation format (i.e., peak data rate) at adequate power level and minimum SNR. This is an abstract value compounding multiple low-level signal properties and remains to be further defined closer to the final release of UC8 NetApp. The metric is linked to the data rate and data capacity metrics and affects the coverage estimation for a specific use case.

The following table summarizes the defined metrics and provides a short description.

Table 4-A: List of defined common validation metrics for 5G-INDUCE use cases

Code	Metric Name	Description	Unit
CVM-01	Latency/Delay	Total time required for the end user to receive an application response message after a request message is sent by the end-user, or a triggered action.	[s]
CVM-02	Delay Jitter	The variation of the end-to-end application latency for the communications between specific components of the use case measured at the end user.	[s]
CVM-03	Slice creation and adaptation time	Total time elapsed from the triggering of the creation (or reconfiguration) of a slice through the NAO slice intent module to the OSS, until the slice is fully established and operational, notified by the slice response module to the NAO.	[s]
CVM-04	NetApp deployment and adaptation time	Total time elapsed from the triggering of the NetApp deployment (or reconfiguration) by the end user through the NAO user interface, until the end user is notified that the NetApp is fully deployed and functional.	[s]
CVM-05	Data rate	Number of application bits per second transferred over a specific use case interface	[bits/s]
CVM-06	Data capacity/volume	Total quantity of use case information bits transferred over a given application interface during specific use case operations, measured in bits.	[bits]
CVM-07	End user scalability (density)	Number of end users/devices that can be connected simultaneously to the access network infrastructure for a given application use case, without degrading the overall performance.	[per m^2]
CVM-08	Availability	The amount of time the end-to-end application is properly delivered according to the specified performance metrics, over the amount of time the that is expected to deliver the end-to-end NetApp service.	%
CVM-09	Reliability	The network layer packet transmissions that are successfully delivered for a given end-to-end application, within the time constraint required by the targeted application, and as a percentage out of all the packets transmitted.	%
CVM-10	Coverage	The radio access coverage area that provides the targeted application performance	[m^2]
CVM-11	Received signal quality	Quality of the received signal, as a ratio with respect to the best possible connection quality (abstract value – remains to be defined in detail).	%

4.3.2 Use case application-specific metrics

The scenario-specific metrics depend on the use cases and their deployment over the ExFas. According to the overall validation plan, the integration workplan of the specific use case scenarios is conducted within the Task 5.1 activities. The first plan is issued in M18 (marked by MS07) and concluded by M24 (reported in Deliverable 5.1). The plan includes a detailed description of the use case application-specific metrics that will be evaluated according to the use case needs and the ExFas capabilities.

Some initial application metrics are identified below as generic cases, applicable to various project use cases, and required to highlight the benefits and offered capabilities of the 5G-INDUCE platform.

Edge vs. Core processing: Certain NetApp components are required to run at close proximity to the end users or devices in order to minimise the overall latency. In various cases, the actual benefit by allocating a component at the edge is required to be defined. This is when latency values can be tolerated against other business-related parameters, as for example the selection of public (e.g., operator driven) infrastructures for cost effective application deployments in comparison to privately owned edge processing infrastructures. The goal here is to allow different NetApp deployments and evaluate their performance metrics and the related system conditions.

Reconfigurability: A key advantage of the 5G-INDUCE platform is its ability to reconfigure automatically or on-demand the utilised NetApp resources as the conditions are changing (e.g., when traffic load or processing demands increase). This is further extended to the ability to reconfigure slices when requests appear for additional processes in the NetApp (e.g., on demand security enhancements). The goal in this case is to validate the response to the requested modifications both in comparison to the overall NetApp deployment time, as well as with respect to the changes in the performance of the existing application.

Resiliency: This is linked to the “reconfigurability” metric, with the key difference that typically the resiliency outcome is pre-calculated and included in the original deployment. Therefore, a much faster reconfiguration is possible immediately when a triggering event appears (e.g., failure of a node). This reconfiguration can be triggered directly by the network orchestrator or as a response to a monitored parameter at the application life-time management level. The goal is to evaluate the restoration time and then validate the performance of the restored service in comparison to the initial state.

Enhanced security vs performance: Certain NetApps will be extended to include enhanced security features, as for example deep packet inspection and analysis mechanisms, advanced firewalling and potentially end-user attestation engines. The goal in this case is to evaluate the level that the added enhanced security components affect the performance of the initial NetApp services.

Mobility: Specific use cases (UC1, UC3, UC7, UC8) require that end devices are moving within the designated industrial area. The metric evaluates the capability of the overall platform to properly allocate the application components as end user devices are moved between at least two cells, allowing uninterrupted NetApp performance, while maintaining performance within the targeted limits.

High-resolution Real-time Video Quality: This is applicable to specific use cases (UC3, UC5, UC6) requiring real-time video streaming of high-quality resolution, as critical means, for the proper operation of the targeted vertical application. The goal here is to evaluate the Quality of Experience (QoE) at the end-user level, or as a feed for the correct extraction of the targeted outcomes (e.g., the performance of the video processing algorithms).

Optimum multi-service interoperability: This metric evaluates the interoperability of multiple types of applications that are integrated over a common NetApp in a specific ExFas area, while having different performance requirements. The goal here is to make sure that the co-existence of such applications does not degrade the overall performance and properly meets the applications' requirements.

Dynamic and geo-spatial deployment: The goal is to showcase support of NetApps being deployed at different locations providing the same type of service. This applies to UC6 targeting first the geo-spatial deployment of VNFs (supporting multiple media servers connected to one SHARE server platform) and second the dynamic allocation of computational resources. The possibility to adapt these deployment setups is needed to always address the industry needs (i.e., number of employees which are related to the number of active users, industry locations, etc.). While a pilot of using the NetApp might be conducted by one department of an industry company at one location, a bigger roll-out of multiple departments in multiple locations changes the above-described deployment setup.

It is noted that the use case application-specific metrics will be mapped to the common validation metrics following the methodology defined in the recent 5G PPP white paper on KPIs definition and measurement for various vertical sectors [3].

[3] 5GPPP white paper, "Service performance measurement methods over 5G experimental networks", DOI: 10.5281/zenodo.4748385, May 2021. https://5g-ppp.eu/wp-content/uploads/2021/06/Service-performance-measurement-methods-over-5G-experimental-networks_08052021-Final.pdf

5 Conclusion

This deliverable presented the outcomes of the use case definition work and the identification of the requirements related to the implementation of the use cases.

The use cases are translated into specific NetApps and composed by a set of networked Functions that are potentially provided by NetApp developers, either in the form of customer-driven applications or customer-oriented network services. This excludes in principle the network services' related VNFs that are provided by the infrastructure owner (i.e., operator).

Based on the NetApp definition, all use case owners have extracted the set of linked application components that constitute the targeted NetApp and also specified the functional requirements for them. This work has combined the outcomes from the application component developers with respect to the service-related functions and the needs of the targeted vertical end users. These outcomes form the basis for the development of the use case NetApp in the following releases according to 5G-INDUCE WP4 activities. They are also used in the planning of the verification activities and the initial set-up of the experimentation facilities that will host the testing. In addition, the generic NAO requirements are extracted that provide feedback to the functionalities of the NAO end-user interface, the repositories, the management of the end-users and lifecycle management of the NetApps.

The last part of this deliverable focuses on the definition of a common validation plan for the use cases, which follows the design and development phases of the project. According to this plan, one major activity provides the development of the main NetApp components, while a parallel activity evaluates the deployment requirements and needs for the integration, over the targeted ExFa. The NetApp design and ExFa capabilities define the actual validation framework and testing procedures that will be followed during the integration and the final testing and demonstration. A set of common evaluation metrics and procedures are defined according to related standardisation activities and include: the validation of latency and latency jitter, the slice creation and NetApp deployment times (including also the related reconfiguration times, as this is supported by 5G-INDUCE), the measurement of achieved data rate and capacity, the evaluation of density and coverage, and the estimation of availability and reliability within the related testing scenarios under specific use cases. In addition to these metrics, use case application-specific metrics are also defined and relate to the edge-core processing allocation, the evaluation of the offered reconfigurability, the effectiveness of the resiliency, the added benefit of security mechanisms as function of the performance, the evaluation of mobility and high-resolution video quality, and the handling of multi-service interoperability by the 5G-INDUCE platform.