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Executive Summary

This document presents the validation plan for use cases of the H2020 5GZORRO project, together with the description of the available infrastructure and resources on the 5GZORRO testbeds and the initial setup on the testbeds.

The project goal is to design, develop and validate a 5G architecture capable to incorporate zero-touch automation solutions for the orchestration of services and resources, tightly coupled with a multi-stakeholder market of 5G resources. This objective is supported by the 5GZORRO platform, which leverages Artificial Intelligence (AI) on top of Data Lake technologies to provide service management automation, easing the overall service management through the identification of usage patterns. The platform also leverages the use of distributed ledger technologies to implement a trust enabled and scalable marketplace for the tracking the resource offers and the associated trust levels and actions.

The 5GZORRO platform will be validated in terms of overall functionality and in terms of KPIs using the three reference use cases:

1. *Smart Contracts for Ubiquitous Computing/Connectivity*, which tests the implementation of DLT-based Smart Contracts and Oracles in support of a trusted Marketplace catalogue of 5G resource offers from multiple providers and stakeholders.
2. *Dynamic spectrum allocation*, which leverages the Marketplace platform to specifically trade licensed spectrum resources, to configure accordingly the RAN elements of the related network slices and to monitor the associated SLAs for breach verification.
3. *Pervasive virtual Content Distribution Network (vCDN) Services*, which covers the intelligent selection of resource offers from Marketplace and the subsequent orchestrated provisioning and management of virtual CDN services, relying on the developments of the first two use cases. In particular, the goal is to assess the overall vCDN service scalability in cases of different resource demands to preserve the required SLAs.

This deliverable contains the validation plan for the three aforementioned use cases and describes the initial testbed infrastructure details for 5GBarcelona and 5TONIC which will be used to validate the use case scenarios.

The deliverable also describes initial deployment setups which illustrate how the different components will be integrated in the 5GZORRO testbeds to implement the test scenarios of the three reference use cases.

1 Introduction

The ultimate goal of the 5GZORRO project is to realize a 5G platform which can enable different stakeholders, across different geographical areas, to trade heterogeneous resources, i.e.: spectrum, computing, network, storage, virtual network functions (VNFs), and – depending on the business role – use them to establish 5G services on top.

In order to realize this, the 5GZORRO Consortium has defined and is developing an architecture comprising multiple sub-systems (5G Marketplace, intelligent orchestration, security and trust, etc) which can make possible to negotiate contracts, reserve/lease resources of the various kinds and manage the lifecycle of the diverse resources and services deployed in the virtualization infrastructures for 5G. The 5GZORRO platform is the key enabler for the trading, chaining and orchestration of provisioning actions on resources used to implement 5G service across multiple administrative and technological domains [1] [2].

Demonstrations and overall validation of the 5GZORRO architecture are planned to be performed by means of three use cases:

- Use Case 1 (UC1) – Smart Contracts for Ubiquitous Computing/Connectivity
- Use Case 2 (UC2) – Dynamic spectrum allocation
- Use Case 3 (UC3) – Pervasive vCDN Services.

Details on the scenarios and requirements originated by each of these use cases are described in deliverable D2.1 [3] and lately refined in deliverable D2.3 [2]

This document contains the description of the initial validation plan for the three 5GZORRO use cases. It also details the infrastructure available at the two target testbeds, i.e., 5GBarcelona Labs and 5TONIC, which will be used during the project to demonstrate use cases scenarios in more realistic environments. Finally, the document includes initial testbed setup information in order to define the infrastructure baseline reference for the tests and the deployment of the 5GZORRO platform components developed as per deliverables D3.1 [4] and D4.1 [5].

1.1 Document outline

This document is structured as follows:

- Section 2 extracts the key performance indicators (KPIs) which were identified in the project for the use case validation.
- Section 3 elaborates the description of the use cases of the project, establishing the validation scenarios and the initial validation test plan for the use cases.
- Section 4 provides details on the 5GBarcelona and 5TONIC testbed infrastructures available for the project tests.
- Section 5 aims to establish an initial use case in testbed deployment plan.
- Section 6 concludes the document summarizing the validation plan strategy.

2 5GZORRO use cases and related KPIs

The implementation of the use cases scenarios defined in D2.1 [3] and D2.3 [2] allows to verify functionalities of the designed 5GZORRO platform. For each of the 5GZORRO platform functionalities, specific KPIs have been identified in 5GZORRO Description of the Action (in relation to project objectives), as also reported in the conclusions of deliverable D2.2[1].

The majority of 5GZORRO KPIs refer to architecture and prototype performance indicators, thus having a direct relation with the technologies and implementation decisions of the various software components (e.g., Marketplace, DLTs, Data Lake, Orchestration, etc.) rather than a dependency on the test scenario.

However, some of the 5GZORRO project objectives and KPIs have impact on the way use case tests can be defined and testbed equipped in order to match the metric set.

Table 2-1 provides a selection of the 5GZORRO KPIs which are considered in direct relation with the validation plan of the three use cases.

Each KPI has been formatted as **[KPI<project objective>.<sequential number>]** in order to univocally identify the 5GZORRO objective for which it has been declared and the sequential number of the metric within the set defined for the specific objective.

KPIs formatted as per above, are used in the rest of the document to reference the specific metrics in scope of validation within the three use cases. The KPI numbering defined in this document will be also re-used in following test reports issued by the project to directly reference the target metrics and KPI definitions.

Table 2-1: 5GZORRO project KPIs to be directly validated through use cases

5GZORRO Technical Objective	Applicable Technical / Business KPI	KPI Target	Use case in scope
OBJ-1. Define a system level architecture combining zero-touch automation solutions and distributed ledger technologies to enable a secure, flexible and multi-stakeholder combination and composition of resources and services in 5G networks.	[KPI1.1] Support actual distributed multi-party service and business configurations.	More than 3 providers /operators of virtualized resources or services for spectrum, radio/edge/core compute & network.	UC1
	[KPI1.2] Support a real-time market for dynamic spectrum allocation allowing business agents to trade on spectrum allocations in space and time.	Time from transaction to spectrum availability in less than 10 minutes; support of 5G NR, LTE and WiFi technologies.	UC2
OBJ-3. Define a Smart Contract ecosystem anchored on a native distributed ledger to allow commercial and technical data provided by 3rd-party users to be standardised and mapped into Smart Contracts, which can be initiated "at will" between multiple untrusted parties.	[KPI3.1] Ability for untrusted parties to negotiate, set-up and operate a new technical/commercial relationship via a Smart Contract for 3rd-party resource leasing/allocation with associated SLA	Smart Contract for 3 or more untrusted parties	UC1 UC2 UC3
	[KPI3.2] Availability of an Oracle data layer to enable external data sources, processing and results to be	Oracle data layer accessed by 3 or more parties	UC1 UC2 UC3

5GZORRO Technical Objective	Applicable Technical / Business KPI	KPI Target	Use case in scope
	requested by SLA smart contracts		
OBI-4. Define solutions for secure, automated and intelligent resource discovery, brokerage and selection, operation with SLA to facilitate workload offloading to 3rd-party resources supporting pervasive computing across multiple 5G domains.	[KPI4.1] Automatically discover and “inventorize” various types of resources (i.e., compute, storage, network at core, edge, far-edge), spectrum and services capabilities from different domains and service providers	Distribution of resource updates and discovery in less than 10 mins	UC1 UC2 UC3
	[KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties	SLA measurements and validation from at least 3 operators involved in a multi-party service chain	UC1 UC3
OBI-5. Define and prototype a secure shared spectrum market to enable real-time trading of spectrum allocations between parties that do not have a pre-established trust relationship.	[KPI5.1] Time to process and enforce new spectrum transactions (i.e., from the moment the transaction is settled until the spectrum becomes available).	Complete new spectrum transactions in less than 10 minutes.	UC2 UC3
	[KPI5.2] Number of transactions per second handled by the market, which will determine the volume of spectrum transactions processed by the market.	20 transactions/second	UC1 UC2 UC3
	[KPI5.3] The authenticity of the market agents, preventing double spending that would allow an agent to trade spectrum rights that it does not own.	Verification of the built-in property of Blockchains.	UC1
	[KPI5.4] Linkability between market agents and their associated radio access points, which will allow providing the appropriate spectrum rights to each access point.	<10M cell towers should be linkable by the system, which is a reasonable EU nation-wide deployment.	UC2 UC3
	[KPI5.5] Ability to enforce the settled spectrum rights and obligations, which will build on lightweight Trusted Execution Environments (TEE) embedded in the radio access points to ensure that the reported spectrum measurements are faithful, and the spectrum allocations settled in the market are enforced.	Be able to detect spoofing attacks where a base station uses an allocation not authorized by the market.	UC2

5GZORRO Technical Objective	Applicable Technical / Business KPI	KPI Target	Use case in scope
	[KPI5.6] Agnostic support of various radio technologies, to ensure that the market will work regardless of the considered radio technology.	5G NR, LTE and WiFi will be supported.	UC2 UC3
OBJ-7. Validate the 5GZORRO zero-touch automation, security and trust in relevant use cases for the implementation of Smart Contracts for Ubiquitous Computing/Connectivity, Dynamic Spectrum Allocation, and Pervasive virtual CDN services over 3rd-party edge resources.	[KPI7.1] Lab validation environments for the three use cases.	3 lab testing environments for UC1, UC2, UC3 - suitable for TRL4 goals.	UC1 UC2 UC3
	[KPI7.2] Demonstration of the three use cases in relevant testbed at 5GBarcelona and 5TONIC	At least 1 demonstration for each of the use cases - suitable for TRL5/6 goals.	UC1, UC2, UC3 to be deployed in 5GBarcelona. Replication of some tests in 5TONIC depending on 5TONIC availability calendar
	[KPI7.3] Business models, techno-economic and legal analysis of selected scenarios.	Business model descriptions for the 3 use cases; techno-economic and legal analysis for at least Spectrum Market case.	UC1 UC2 UC3

3 Use case validation plan

This section details the initial use case validation plan.

The procedure followed to define a validation plan of the three use cases consisted of the following steps:

- Group the use case high-level objectives, stakeholders involved and workflows based on the description and requirements established in Deliverables D2.1 [3], D2.2 [1] and D2.3 [2].
- Define a set of use case-oriented tests, based on groupings of the 5GZORRO platform functionalities. The aim of these tests is to establish the dependencies of the use case in terms of 5GZORRO platform functionalities (and modules). The results obtained during these tests will also be used as input to platform validation.
- Identify the use case target KPIs, their mapping to project's KPIs and the testbed infrastructure required to execute the tests.
- Describe specific scenarios in which the use case can be validated, targeting to showcase the 5GZORRO platform in scenarios as much realistic as possible.

The following sections detail the result of applying the process above to each use case of the project.

3.1 Smart Contracts for Ubiquitous Computing/Connectivity

Use Case 1 is primarily focused on providing the necessary mechanisms for trusted frictionless leasing of 5G resources and services within the 5GZORRO marketplace. Distributed ledgers and smart contracts underpin this use case and as such, tests focus on demonstrating their role in realising a decentralised product catalogue, establishment and enforcement of agreement/SLA contract terms and 5G slice establishment.

A potentially interesting business scenario for the Use Case may mimic an automotive manufacturer who has an ad-hoc requirement for a private 5G network at a geographical location where they have no infrastructure. With the investment to provide the necessary infrastructure at one or more temporary locations being substantial and likely commercially unattractive, the manufacturer can reach out to a Communication Service Provider (CSP) for them to facilitate this network through the 5GZORRO marketplace. Further details on the scenario are discussed in more detail in deliverable D2.1 [3].

The scenarios identified in this test plan are designed to both address the KPIs identified in Section 2 and to simulate the various permutations around the CSP being able to meet the needs of their customer; namely, utilisation of the 5GZORRO marketplace to procure resources and services that itself does not have before being able to offer a complete service to their customer.

Stakeholders and platforms deployed by each scenario are described in the rest of the sections. A set of scenarios is outlined which demonstrates the trust and autonomy that underpin the 5GZORRO marketplace, achieved through the utilisation of smart contracts and distributed ledger. The key focus of this use case is to demonstrate the leasing of resources between potentially distrusting/competing stakeholders, the associated commercial agreements that arise from this and how their lifecycles are governed in a decentralised manner.

3.1.1 Involved Stakeholder & Required Platform Components

The decentralised marketplace has a number of stakeholders that may deploy varying 'flavours' of the platform depending on their desired role and associated required functionality; the description of the anticipated stakeholder roles can be found in D2.1 [3]. Table 3-1 describes the minimum set of stakeholders required to facilitate the test scenarios that are subsequently outlined. Each stakeholder is attributed a notional stakeholder name for identification purposes, the role(s) they will play and the platform components that will be deployed for each.

Table 3-1: UC1 stakeholders and resources overview

Stakeholder	Stakeholder Description	Roles	Platform components
Operator 1	Stakeholder with platform components deployed to support governance and trading functions	Resource Provider Governance Admin	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Governance Platform Core
Operator 2	Stakeholder with platform components deployed to support trading functions	Resource Provider	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Core
Operator 3	Stakeholder with platform components deployed to support trading functions	Resource Consumer Service Provider	<ul style="list-style-type: none"> Marketplace
Spectrum Regulator	Stakeholder with platform components deployed to support licensing functions	Regulator	<ul style="list-style-type: none"> Marketplace Governance Platform
Vertical	Consumer of the service	Service Consumer	N/A

3.1.2 Test scenarios

In each of the scenarios outlined below it is assumed that each of the three operators and the regulator have deployed the platforms named in the table above and have been onboarded onto the platform and therefore have the rights and permissions required to fulfil the use case scenario. Governance over this onboarding is realised through Regulator & Operator 1 deployed governance platform.

3.1.2.1 Scenario 1: Slice composition from a single provider

In this scenario, a Service Provider (Operator 3) leases a set of resources & services from a single Resource Provider (Operator 2). This represents the base scenario for the use case, as it demonstrates marketplace utilisation to support multi-resource slice establishment backed by a smart contract bi-lateral agreement and associated SLAs.

Table 3-2 outlines the resources & services being traded. In this instance, all product offers are leased from a single operator of the 5GZORRO platform; Operator 2.

Table 3-2: UC1 - Scenario 1 resources and providers

Resource / Service	Provider	Specification	Business terms associated with the offer
Edge	Operator 2	Compute Storage Networking	<p>A standard SLA definition will be derived that encompasses both the legal prose and the technical specification relating to an SLO for uptime. The technical specification will encapsulate the following</p> <ul style="list-style-type: none"> Uptime $\geq 99.5\%$ Compensation of 5% of billed amount \$XXX in event of breach
VNF	Operator 2	VNF Resource offer	License Terms will encapsulate the below pricing model (along with associated legal prose) and be associated with this offer in order for demonstrable billing-centric licensing to be demonstrated

			The cost of the first 2 users is 50 € per user and for each subsequent user charged at 40 € per user
RAN	Operator 2	RAN resource specification	Access terms to RAN resources (e.g., small cells, radio types, etc.)
Spectrum	Operator 2	Spectrum resource	A Spectrum License Agreement will be defined that reflecting standard spectrum license fair use terms as well as the, frequency and location of the spectrum licensed to the Spectrum Resource Provider etc.

For the execution of the test, each stakeholder is on-boarded onto the platform

- The regulator and Operator 1(acting as Resource Provider and Governance Admin Operator) provide the overarching platform governance both in terms of ensuring permissible spectrum trading and enforcing the marketplace governance mode; i.e., Regulator and Operator 1 decide who can onboard the platform;
- Operator 2 (acting as Resource Provider) publishes their resources (as per the above table) to the catalogue;
- Verification of spectrum offer publishing ensures that Operator 2 has the necessary spectrum rights to publish such an offer;
- Resources required to meet the needs of the vertical are queried & procured through Operator 3's 5GZORRO platform;
- An order to lease the resources is made through Operator 3's platform, entering into a bi-lateral agreement with Operator 2;
- The Vertical is a related party registered in a smart contract agreement & SLAs as applicable
- During the lifetime of the contract, the resources are monitored, and three sub-scenarios are simulated:
 - No SLAs are breached
 - An SLA breach is detected. Consequently, a violation is recorded on the DLT and on reaching the end of the contract period, the appropriate compensation as outlined in the SLA is owed to Operator 3
 - An SLA breach is predicted. A breach is predicted relating to the leased resource and reported to Operator 3. This gives Operator 3 the opportunity to react as they see fit to the predicted breach
- Contract termination and tear-down at the end of the lease period, releasing resources back to the catalogue making it available for leasing again

Figure 3-1: illustrates Operator 2 publishing its offers in the 5GZORRO marketplace, which are subsequently discovered and traded. The resulting bi-lateral contract agreement is established between Operator 3 and Operator 2, noting the vertical as a Related Party on the contract/SLAs. Operator 1 and the regulator are depicted here given their involvement in enforcing the governance model and regulatory aspects of the platform.

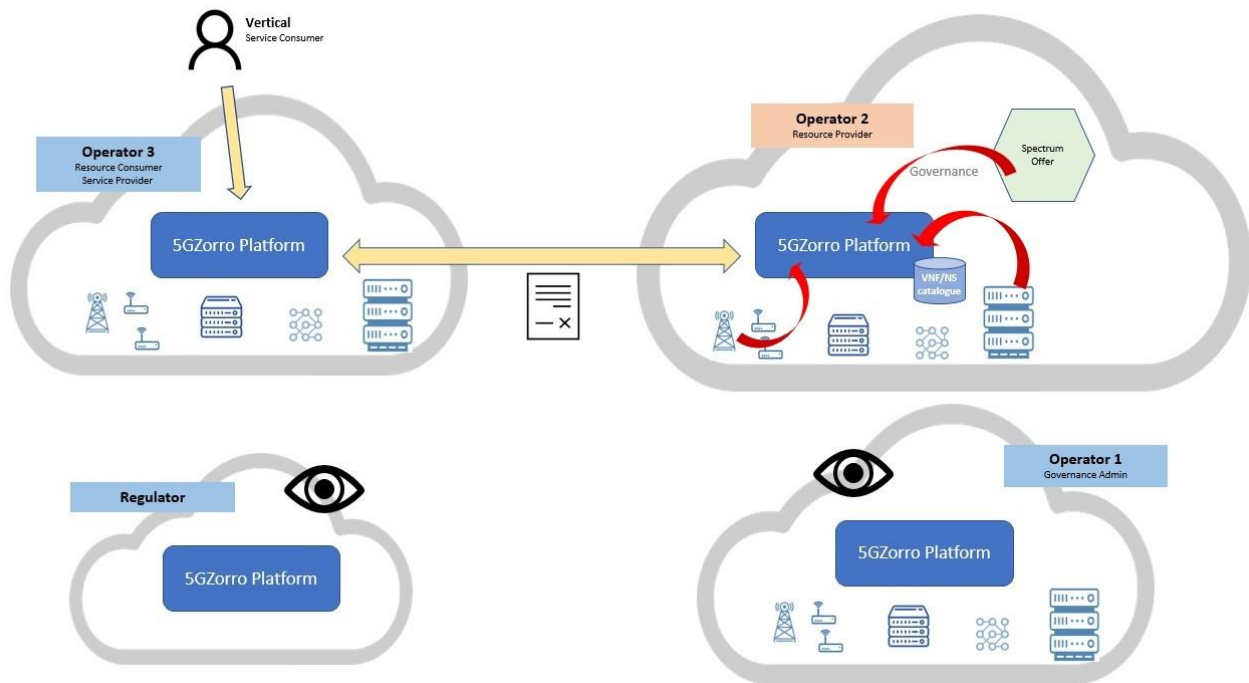


Figure 3-1: Scenario 1: Slice composition from two providers

3.1.2.2 Scenario 2: Slice composition from multiple providers

In this scenario, a Service Provider (Operator 3) leases a set of resources & services from multiple Resource Providers (Operators 1 & 2) in order to compose the required service to meet the needs of the vertical customer. This represents an extension of the previous scenario whereby multi-party multi-resource slice establishment supported by smart contracts and associated SLAs is demonstrated.

Table 3-3 outlines the resources & services involved and the providers offering them; specifications and terms remain as outlined in Scenario 1.

Table 3-3: UC1 - Scenario 2 resources and providers

Resource/Service	Provider
Edge	Operator 1
VNF	Operator 1
RAN	Operator 2
Spectrum	Operator 2

Figure 3-2 illustrates Operators 1 & 2 publishing their offers in the 5GZORRO marketplace, which are subsequently discovered and traded with Operator 3. The resulting bi-lateral contract agreements are established between Operator 3 & 1, and between Operator 3 & 2, noting the vertical as a Related Party on the contract/SLAs. Operator 1 and the regulator are depicted here given their involvement in enforcing the governance model and regulatory aspects of the platform.

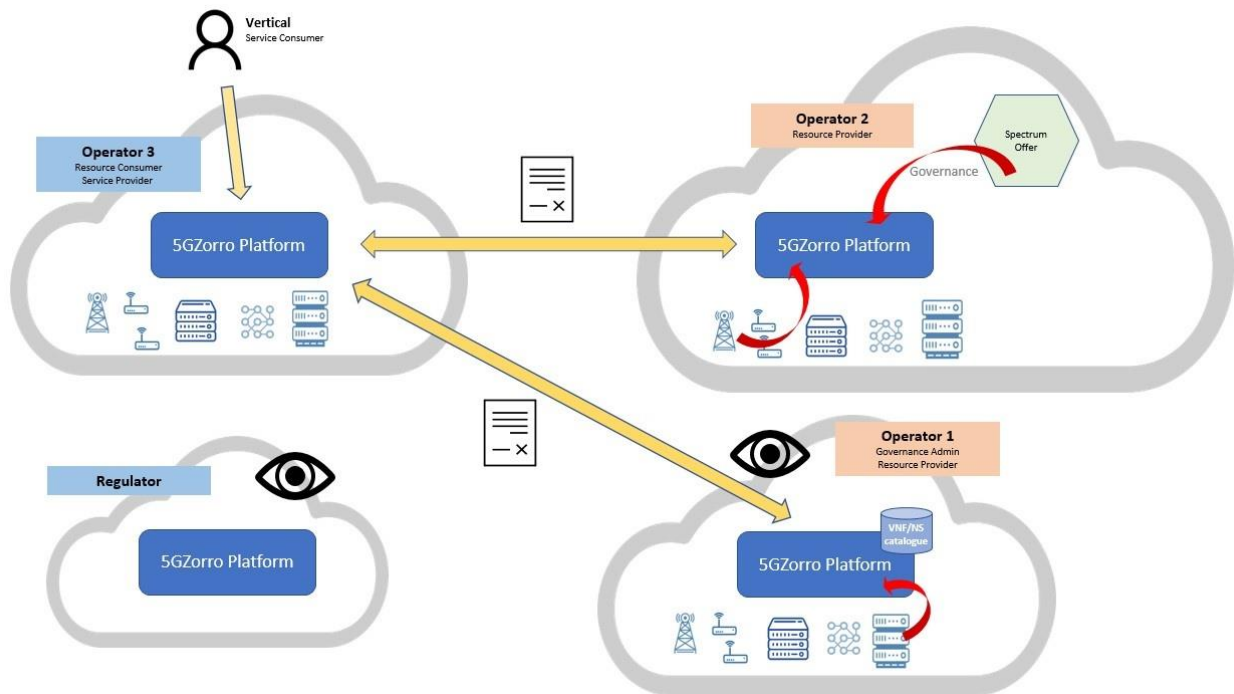


Figure 3-2: UC1 - Scenario 2 Slice composition from multiple providers

In this scenario the following capabilities are demonstrated in addition to Scenario 1:

1. Multi-Provider resource/service catalogue
2. Operator 3 discovers resources from multiple operators to meet the needs of their customer
3. Operator 3 makes an order to lease resources from multiple operators, entering into a bi-lateral agreement with both Operator 1 and Operator 2

3.1.2.3 Scenario 3: Slice extension to meet increased capacity requirement

In this scenario, a Service Provider (Operator 3) leases a VNF and attempts at scaling up their leased infrastructure to meet capacity requirements. This operation is governed by license terms encapsulated in smart contracts and as such will be recorded on the DLT for the purposes of providing automated billing once the contract term ends or billing period is reached.

Table 3-4 outlines the resources & services involved and the providers offering them:

Table 3-4: UC1 - Scenario 3 resources and providers

Resource/Service	Provider
Edge	Operator 1
VNF	Operator 1
RAN	Operator 2
Spectrum	Operator 2

3.1.3 Test plan

Table 3-5 describes the tests initially established for the validation of this use case. It is worth to highlight that the “5GZORRO Platform components” identify the main platform components which will be used during the specific test, in order to illustrate which components will be validated through the test. Finally, the “Related KPIs” column of the table maps the technical KPIs of the project that will be validated in the test, sometimes referring to specific metrics in the format [KPIx.y], sometimes referring to all KPIs in scope of the use case.

Table 3-5: Use Case 1 Test Plan

Test	Description	5GZORRO Platform components	Related KPIs
UC1.1.	Resource Provider is onboarded to the marketplace	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal 	[KPI1.1] [KPI1.2]
UC1.2.	Resource Consumer is onboarded to the marketplace	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal 	[KPI1.1] [KPI1.2]
UC1.3.	Governance admin is onboarded to the marketplace and added to the governance board	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal 	[KPI1.1] [KPI1.2]
UC1.4.	Resource/Service Provider creates Resource & Service Offers to be offered as a Product Offer in the Catalogue: <ul style="list-style-type: none"> Edge Resource Offer (storage-compute-networking) VNF Resource Offer RAN Service Offer 	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Virtual/Radio Resource Managers Catalogue 	All for UC1
UC1.5.	Extending UC1.4 Provider A creates the Edge and VNF resource offers and Provider B creates RAN service offer. Test will verify the purchase/ lease of product offers from multiple providers	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Virtual/Radio Resource Managers Catalogue 	All for UC1
UC1.6.	Resource Provider proposes a commercial Agreement Legal Prose Template. Governance Admins approve	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal 	[KPI1.2]
UC1.7.	Resource Provider proposes an uptime SLA Legal Prose Template and Governance Admins approve	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal 	[KPI1.2]
UC1.8.	Resource provider proposes a licensing agreement template for a VNF, and Governance Admins approve	<ul style="list-style-type: none"> Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal 	[KPI1.2]

Test	Description	5GZORRO Platform components	Related KPIs
UC1.9.	Resource provider creates an Agreement based on a Legal Prose Template, which can later be associated with a Product Offer	<ul style="list-style-type: none"> Marketplace Portal Catalogue Smart Contract Lifecycle Manager Legal Prose Repository Identity & Permissions Manager 	[KPI1.2]
UC1.10.	Resource Provider creates an Uptime SLA for edge resource based on a Legal Prose Template, which can later be associated with a Product Offer's Resource Offer	<ul style="list-style-type: none"> Marketplace Portal Catalogue Smart Contract Lifecycle Manager Legal Prose Repository Identity & Permissions Manager 	[KPI1.2]
UC1.11.	Resource Provider composes a Product Offer consisting of: <ul style="list-style-type: none"> Agreement (UC1.6) Edge Resource Offer with uptime SLA (UC1.4 & UC1.7) VNF with licensing terms for 1 instance (UC1.4 & UC1.8) RAN Service (UC1.4) 	<ul style="list-style-type: none"> Marketplace Portal Identity & Permissions Manager Catalogue Smart Contract Lifecycle Manager 	All for UC1
UC1.12.	Extending UC1.11 and aligning with the resources published in UC1.5 by 2 providers, Provider A and B publish offers to the marketplace.	<ul style="list-style-type: none"> Marketplace Portal Identity & Permissions Manager Catalogue Smart Contract Lifecycle Manager 	All for UC1
UC1.13.	Resource Consumer performs a simple query on the Catalogue to discover a set of resources matching their requirements criteria – Components specified Edge in location X with uptime greater than X, VNF and RAN	<ul style="list-style-type: none"> Marketplace Portal Catalogue 	All for UC1
UC1.14.	Resource Consumer performs an intelligent resource discovery query based on metrics received from breach prediction and virtual/radio resource management	<ul style="list-style-type: none"> Virtual/Radio Resource Managers Intelligent Network Slice & Service Optimization Intelligent SLA monitoring & breach prediction Catalogue Smart Resource & Service Discovery 	All for UC1
UC1.15.	Resource Consumer purchases a Product Offer and provider confirms they have capacity and accepts the agreement. Product Offer as per the one created in UC1.11 and discovered in UC1.13	<ul style="list-style-type: none"> Marketplace Portal Catalogue Smart Contract Lifecycle Manager Intelligent Network Slice & Service Optimization Virtual/Radio Resource Managers Service & Resource Monitoring Monitoring Data Aggregator Legal Prose Repository Intelligent SLA monitoring & breach prediction 	[KPI1.2] [KPI5.1] [KPI5.2]
UC1.16.	Resource Consumer purchases multiple Product Offers from multiple providers. Each provider confirms they have capacity and accepts the agreement. Product Offers as per	<ul style="list-style-type: none"> Marketplace Portal Catalogue Smart Contract Lifecycle Manager 	[KPI1.2] [KPI5.1] [KPI5.2]

Test	Description	5GZORRO Platform components	Related KPIs
	the one created in UC1.12 and discovered in UC1.13, Resulting agreements between 1 consumer and 2 providers.	<ul style="list-style-type: none"> Intelligent Network Slice & Service Optimization Virtual/Radio Resource Managers Service & Resource Monitoring Monitoring Data Aggregator Legal Prose Repository Intelligent SLA monitoring & breach prediction 	
UC1.17.	SLA Breach is detected by Service & Resource Monitoring and recorded on the DLT	<ul style="list-style-type: none"> Virtual/Radio Resource Managers Service & Resource Monitoring Monitoring Data Aggregator Smart Contract Lifecycle Manager TEE 	All for UC1
UC1.18.	Scaling action is attempted and blocked on account of the DLT successfully rejecting this due to the number of instances defined in the license agreement in the smart contract	<ul style="list-style-type: none"> Smart Contract Lifecycle Manager Intelligent Network Slice & Service Optimization Virtual/Radio Resource Managers eLicensing 	All for UC1
UC1.19.	Resource Consumer terminates an agreement	<ul style="list-style-type: none"> Marketplace Portal Smart Contract Lifecycle Manager Catalogue Virtual/Radio Resource Managers Service & Resource Monitoring Monitoring Data Aggregator 	All for UC1
UC1.20.	Intelligent SLA monitoring & breach prediction module predicts an SLA violation and issues notification to trigger resource discovery; see also UC1.7 & UC1.14	<ul style="list-style-type: none"> Intelligent SLA monitoring & breach prediction Intelligent and Automated Slice and Service Manager 	All for UC1

In terms of required infrastructure / resources from the testbeds, the execution of the tests will adapt to exemplary network services which will be composed across edge and core sections emulated in the testbeds, in order to populate the 5GZORRO platform with data from test application workflows in the data plane.

3.1.4 KPI Measurement Methodology

Table 3-6 outlines how each KPI identified as relating to this use case will be measured.

Table 3-6 UC1 KPI measurement methodology

KPI ID	Measurement methodology
[KPI1.1]	<p>To support actual distributed multi-party service and business configurations, the use case will count on different stakeholder roles.</p> <ul style="list-style-type: none"> one or more Resource Providers - in some scenarios a Resource Provider is permitted by the Regulator to issue spectokens in its area of application Regulator & Governance Admin – providing regulatory and governance oversight and enforcement Resource Consumer (Service Provider) - who discovers and leases these resources from one or more Resource Providers
[KPI1.2]	This KPI about supporting a real-time market for dynamic spectrum allocation allowing business agents to trade on spectrum allocations in space and time, is broken into [KPI5.1] and [KPI5.6].

	Consequently, [KPI1.2] will be measured as the aggregation of the measurements from [KPI5.1] and [KPI5.6]
[KPI5.1]	Measurement of the time spent from the moment a spectoken is purchased until the spectrum can be used in the radio access network.
[KPI5.2]	Measurement of the number of transactions per second handled by the market. The Resource & Service Offer Catalogue will be populated by a sufficiently large number of spectokens, ready to be sold. A number of stakeholders will place orders for spectokens. Spectokens might be selected randomly or recommended by the Smart Resource and Service discovery application.
[KPI5.3]	<p>The authenticity of the market agents will be evaluated through four stakeholder profiles:</p> <ol style="list-style-type: none"> 1. Regulator - who issues spectrum rights to Spectrum Resource Provider 2. Spectrum Provider – who offers Spectrum aligned with the certificate issued by the regulator 3. Resource Provider – with no spectrum rights 4. Spectrum Resource Consumer – who will lease the spectrum. <p>Prevention of double spends will in part be achieved through inherent DLT features, but also through smart contract business logic. Verification of permitted publication of a spectrum offer (i.e., whether the provider can prove through verifiable claims that they have the appropriate rights, will be enforced at the DLT level. The regulator will also be able to terminate a trade by reviewing through their marketplace portal and submitting a termination to the DLT. Each of these will be testable utilising the testbed setup and scenarios identified.</p>

3.2 Dynamic spectrum allocation

The second use case envisioned in 5GZORRO aims at efficient use of the licensed and unlicensed spectrum. Spectrum is a scarce resource and thus effective and efficient spectrum management is essential. In this context, achieving a high degree of efficiency implies maximising the usage of the spectrum over time and space, safeguarding against spectrum hoarding. Dynamic spectrum sharing aims at improving the spectrum efficiency by allowing unused licensed spectrum to be made available to other entities over a limited duration of time and for a specific geographic location.

The objective of the use case on dynamic spectrum allocation is to demonstrate the deployment of a network slice using some radio access network, which can operate in a licensed or an unlicensed band. In case of licensed spectrum, the use case shall cover the end-to-end lifecycle of a spectoken in the 5GZORRO platform, beginning from its generation and registration in the Resource & Service Offer Catalogue, the offer placement procedure by a 5GZORRO stakeholders with rights to acquire spectokens, the “activation” of the spectoken by configuring a cellular service in the bandwidth determined in the spectoken, and the monitoring of the correct use of the spectoken. In summary, the final target will comprise all the nine tests defined in the test plan in Section 3.2.2.

3.2.1 Involved Stakeholders & Required Platform Components

The 5GZORRO platform provides a spectrum market where spectrum providers, typically Mobile Network Operators (MNO), can trade idle chunks of their licensed spectrum. In particular, this use case deals with the trading of spectokens, which represent the right to use a certain radio bandwidth in a specific area for a limited amount of time. National Spectrum Regulators as the entity responsible of spectrum management, oversee the spectrum trade having also the possibility to annul trades. This is necessary to protect against market distortion, spectrum hoarding and ensure that license conditions are still respected.

A variety of 5G actors, stakeholders and verticals, may also benefit from the 5GZORRO spectrum market. This is the case of RAN infrastructure providers, who can lease part of their infrastructure to a spectrum resource consumer and deploy a radio service based on the spectoken details.

Table 3-7: UC2 stakeholders and resources overview

Stakeholder	Stakeholder Description	Roles	Platform components
Operator 1	Spectrum provider	Resource Provider	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Core
Operator 2	RAN infrastructure providers	Resource Provider	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Core
Operator 3	Spectrum resource consumer	Resource Consumer Service Provider	<ul style="list-style-type: none"> Marketplace
Spectrum Regulator	Stakeholder with platform components deployed to support spectrum management	Regulator	<ul style="list-style-type: none"> Marketplace Governance Platform

In the dynamic spectrum allocation use case, Regulators, spectrum providers, and radio infrastructure providers come together to allow stakeholders with no resources (radio and spectrum) to deploy a private network. To this aim, the resource consumer comes to the 5GZORRO platform and acquires the resources it needs from the Marketplace. The 5GZORRO platform guarantees that transactions occur securely and the resources are used as agreed on the defined business terms.

3.2.2 Test Scenarios

The validation workflow is summarised in Figure 3-3. In the first place, the generation of a spectrum certificate will be generated for a spectrum resource provider by the Regulator. This spectrum certificate acts as a verifiable claim inside the 5GZORRO platform of the spectoken generation capabilities of a given spectrum provider. Next, the spectrum provider will join the 5GZORRO platform and will show its interest in generating a spectoken and will provide the technical details, such as the frequency bands and area of application. If the spectoken creation request is accepted by the platform, the spectrum offer will be published in the Marketplace Catalogue. Then, a spectrum consumer stakeholder will join the platform and will purchase some of the spectokens available. If the transaction is completed, the spectoken will be activated and “deployed” in the RAN infrastructure, matching the spectoken requirements. Finally, after the spectoken activation, the RAN will generate telemetry on the spectrum use, which will be fed to the SLA monitoring component in the 5GZORRO platform.

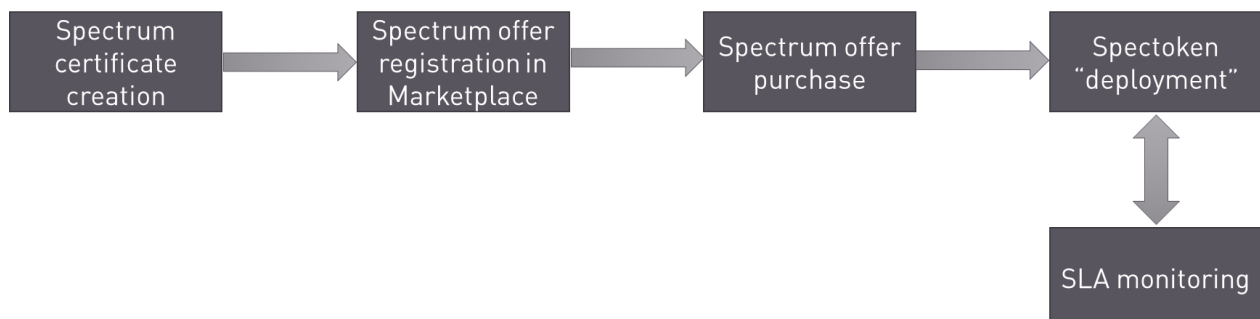


Figure 3-3: Use Case 2 workflow for dynamic spectrum allocation

The target test scenario is illustrated at high level in Figure 3-4. A 5G vertical, with no network infrastructure at all, wants to deploy a 5G private network in a specific area. For this reason, the vertical decides to join the 5GZORRO platform and get the necessary network resources from other participants in the platform, namely Spectrum Providers, Radio Infrastructure Providers under the oversight of the Spectrum Regulators, etc. This scenario assumes one stakeholder of each kind.

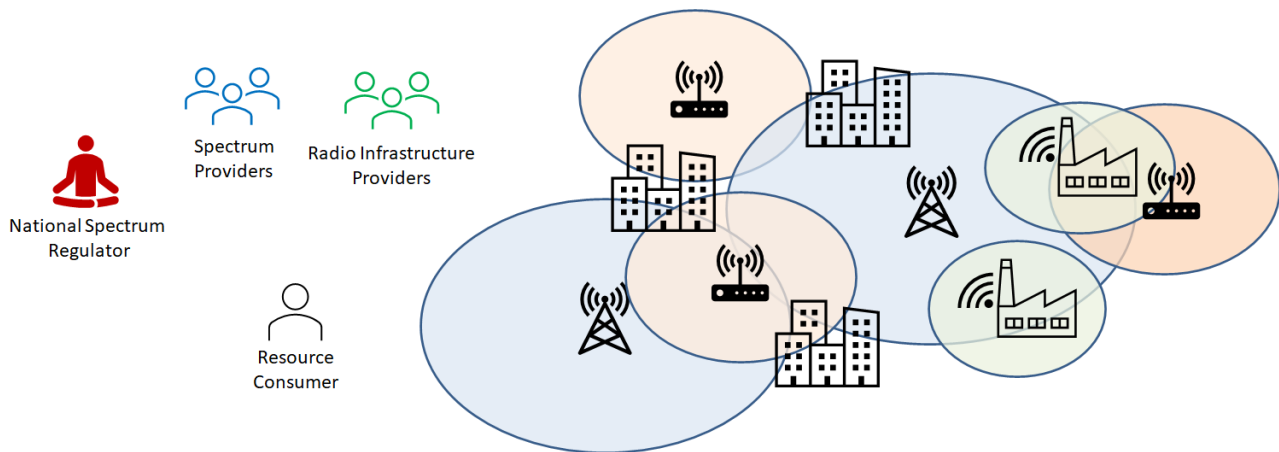


Figure 3-4: UC2 scenario and stakeholders involved in the spectrum use case

3.2.2.1 Resource offer publication

Prior to the vertical onboarding 5GZORRO platform, a number of resource providers are already onboarded and registered some resource offers. For the sake of the spectrum use case, the focus is on the spectrum resource provider and radio infrastructure provider onboarding. In the case of a spectrum resource provider, for instance, a Mobile Network Operator (MNO), which has been awarded rights to the use of specific licence lots nationally or over a specific geographical region, the National Spectrum Regulator generates a spectrum certificate allowing the spectrum resource providers to generate spectrum offers (spectokens) within the 5GZORRO platform to enable spectrum trading.

The spectrum resource provider decides to generate spectokens, and at least one of them issued for the geographical area the vertical is interested in for its private 5G network, as shown in Figure 3-5.

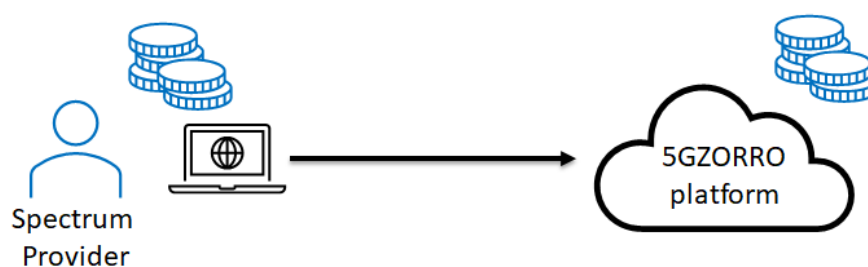


Figure 3-5: Spectrum resource provider publishes spectokens in 5GZORRO

Similarly, the radio infrastructure provider, as shown in Figure 3-6, also decides to register some radio resource offers in the 5GZORRO Marketplace, and at least one of them is for infrastructure in the geographical area the vertical is interested in. For simplification, it can be assumed that the spectokens are suitable for the operation band of the cellular infrastructure.

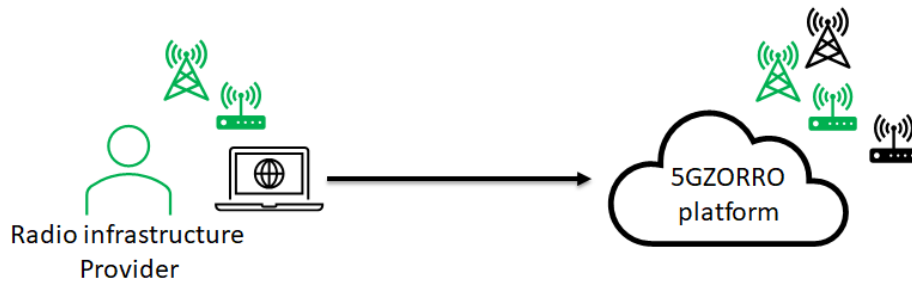


Figure 3-6: Radio resource provider publishes radio infrastructure offers in 5GZORRO

3.2.2.2 Resource selection by the vertical

The vertical is interested in deploying its 5G private network in the squared area in Figure 3-7. The vertical logs in the 5GZORRO Portal and browses the radio infrastructure offers available in the Marketplace Catalogue that are within the geographical area where the vertical wants to deploy its private network. Depending on the RAN technology availability, or the vertical preference, one of the following two scenarios may occur.

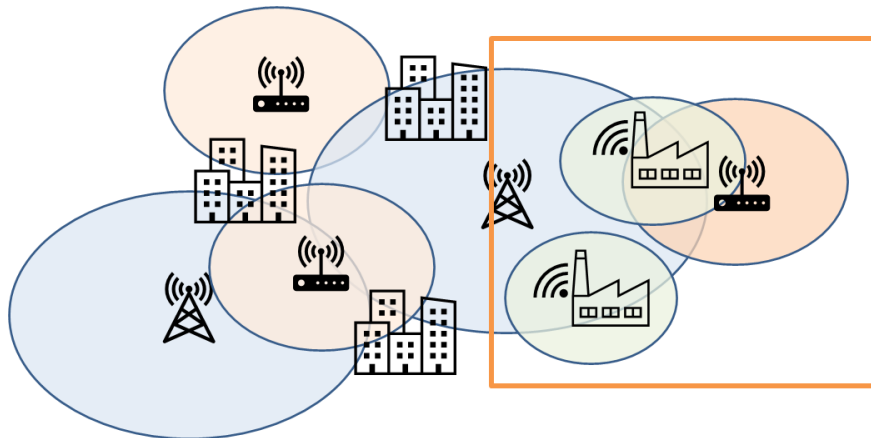


Figure 3-7: Coverage area where the vertical will deploy the private network

Cellular deployment on licensed spectrum

The vertical finds an interesting offer from a radio infrastructure provider leasing some cellular base stations, as illustrated in Figure 3-8, and decides to acquire it.

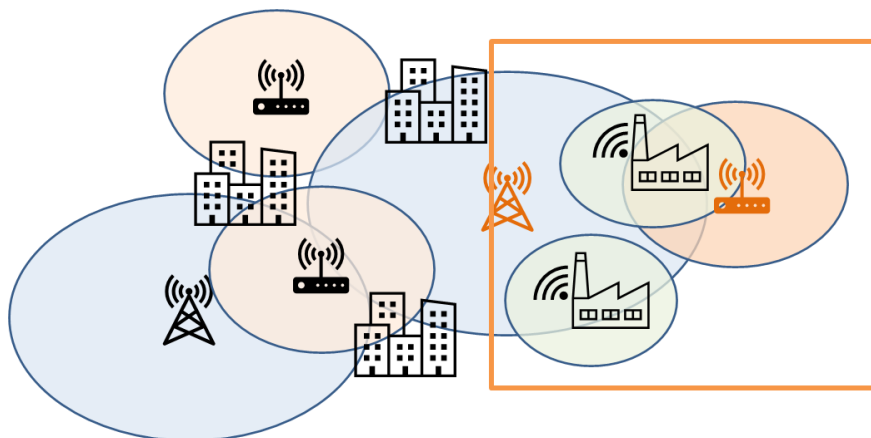


Figure 3-8: Selection of cellular infrastructure for the private 5G network

The vertical then browses the 5GZORRO Marketplace Catalogue, selects some spectokens as illustrated in Figure 3-9 (as many as necessary for the target bandwidth and operation bands, but at least one), and acquires them. At this point, the vertical can deploy its private 5G network over cellular technology.

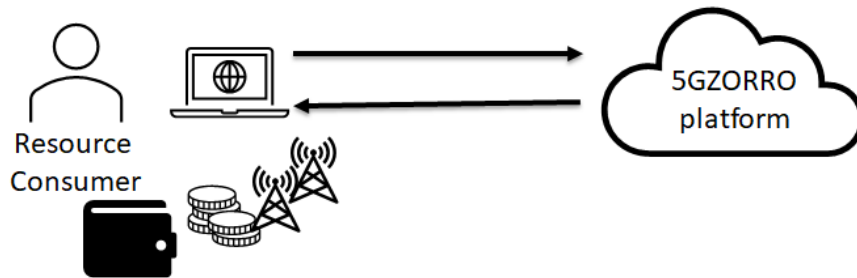


Figure 3-9: The vertical (resource consumer) acquires spectokens and cellular infrastructure

Wi-Fi deployment on unlicensed spectrum

The vertical finds an interesting offer from a radio infrastructure provider leasing some Wi-Fi access points, as illustrated in Figure 3-10.

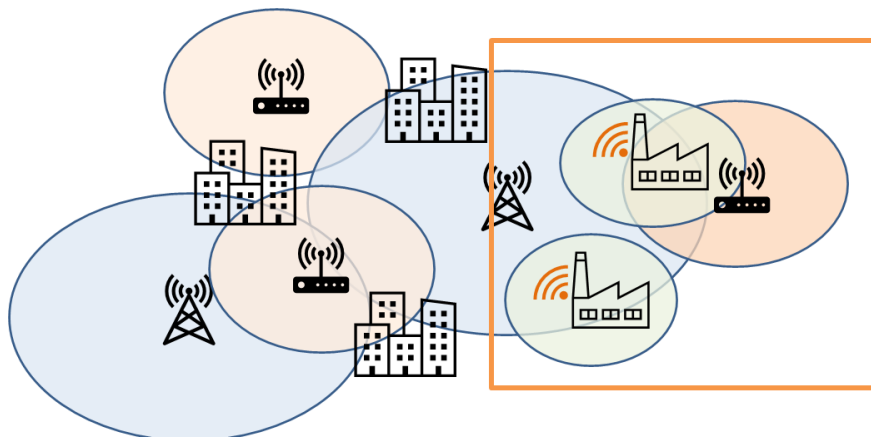


Figure 3-10: Selection of Wi-Fi infrastructure for the private 5G network

Once the vertical completes the purchase, as shown in Figure 3-11, it can deploy its private network over Wi-Fi.

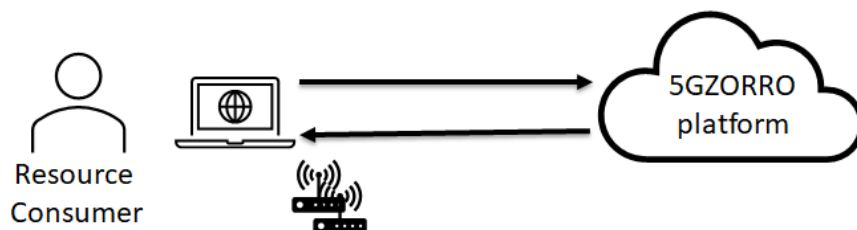


Figure 3-11: The vertical (resource consumer) acquires wireless infrastructure from the resource offers

3.2.2.3 SLA monitoring

Another purpose of this spectrum use case is that the spectrum is used effectively, from the business and also from the regulatory aspects of the use of the spectrum.

To this aim, the 5GZORRO platform can monitor metrics related to spectrum from the radio infrastructure, such as interference levels or the transmit power of the base stations.

This particular use case is interested in another regulatory aspect of the licensed spectrum, which is the time span between the spectrum is acquired and the spectrum is used (at least one base station is transmitting on the spectrum). In this case, the Regulator would determine which is this maximum deployment time. If the vertical does not deploy its network on the frequency band determined by the spectoken after this time, the Regulator has the right to remove the spectoken from the vertical, and the spectrum resource provider may put the spectoken again in the 5GZORRO Marketplace.

3.2.3 Test plan

The test plan of the use case consists of nine individual evaluation or tests of different functionalities needed for the dynamic spectrum allocation in 5GZORRO.

These minimum functionalities are based to the 5GZORRO use case requirements defined in 5GZORRO D2.1 for this specific use case. It is worth mentioning that the different tests cover all the use case requirements defined in D2.1. The table below lists the nine tests and maps each of the tests to their related KPIs from those available in Section 2.

Table 3-8: Use Case 2 Test Plan

Test	Description	5GZORRO Platform components	Related KPIs
UC2.1.	This test will focus on the onboarding of a National Regulator in the 5GZORRO platform and evaluate that the Regulator performs the actions a Regulator is expected to do in the 5GZORRO platform (for example: Issue spectrum certificates / Verifiable credentials, monitor on going trades)	<ul style="list-style-type: none"> Identity and Permissions Manager Governance Manager Governance Portal Governance DLT Marketplace Portal Marketplace DLT 	[KPI1.1], [KPI5.1], [KPI5.2], [KPI5.3], [KPI7.1]
UC2.2.	This test will focus on the onboarding of a spectrum resource provider in the 5GZORRO platform and evaluate that the spectrum resource provider performs the actions a spectrum resource provider is expected to do in the 5GZORRO platform	<ul style="list-style-type: none"> Identity and Permissions Manager Governance Manager Governance Portal Governance DLT Marketplace Portal Marketplace DLT Resource & Service Offer Catalogue Smart Contracts Lifecycle Manager 	[KPI1.1], [KPI5.1], [KPI5.2], [KPI5.3], [KPI5.5], [KPI7.1]
UC2.3.	This test will focus on the onboarding of a radio infrastructure provider in the 5GZORRO platform and evaluate that the radio infrastructure provider performs the actions a radio infrastructure provider is expected to do in the 5GZORRO platform	<ul style="list-style-type: none"> Identity and Permissions Manager Governance Manager Governance Portal Governance DLT Marketplace Portal Marketplace DLT Resource & Service Offer Catalogue Smart Contracts Lifecycle Manager 	[KPI1.1], [KPI5.3], [KPI7.1]

Test	Description	5GZORRO Platform components	Related KPIs
UC2.4.	This test will focus on the onboarding of a resource consumer in the 5GZORRO platform and evaluate that the resource consumer is able to access the 5GZORRO marketplace, browse resource offers and, eventually, select resources	<ul style="list-style-type: none"> • Identity and Permissions Manager • Governance Manager • Governance Portal • Governance DLT • Marketplace Portal • Marketplace DLT • Resource & Service Offer Catalogue • Smart Contracts Lifecycle Manager 	[KPI1.1], [KPI5.3], [KPI7.1]
UC2.5.	This test covers the generation of a spectoken and the process to put it in the 5GZORRO marketplace	<ul style="list-style-type: none"> • Identity and Permissions Manager • Governance Manager • Governance Portal • Governance DLT • Smart Contracts Lifecycle Manager • Marketplace DLT • Monitoring Data Aggregator • Resource & Service Offer Catalogue 	[KPI5.3], [KPI5.5], [KPI7.1]
UC2.6.	This test covers the selection of a spectoken	<ul style="list-style-type: none"> • Marketplace Portal • Resource & Service Offer Catalogue • Smart Contracts Lifecycle Manager • Marketplace DLT • Intelligent Slice and Service Manager • Network Slice and Service Orchestrator • Virtual (Radio) Resource Manager • SLA Manager 	[KPI1.2], [KPI5.1], [KPI5.2], [KPI5.3], [KPI5.4], [KPI5.5], [KPI5.6], [KPI7.1]
UC2.7.	This test covers the registration of a radio resource offer in the 5GZORRO marketplace	<ul style="list-style-type: none"> • Smart Contracts Lifecycle Manager • Marketplace DLT • Intelligent Slice and Service Manager • Network Slice and Service Orchestrator • Virtual (Radio) Resource Manager • SLA Manager 	[KPI1.2], [KPI5.1], [KPI5.2], [KPI5.3], [KPI5.4], [KPI5.5], [KPI5.6], [KPI7.1]
UC2.8.	This test covers the selection of a radio resource offer	<ul style="list-style-type: none"> • Smart Contracts Lifecycle Manager • Marketplace DLT • Intelligent Slice and Service Manager • Network Slice and Service Orchestrator • Virtual (Radio) Resource Manager • SLA Manager • Trusted Execution Environment (TEE) Security 	[KPI1.2], [KPI5.1], [KPI5.2], [KPI5.3], [KPI5.4], [KPI5.5], [KPI5.6], [KPI7.1]
UC2.9.	This test covers the creation of a slice with radio infrastructure. A spectoken may be used	<ul style="list-style-type: none"> • Smart Contracts Lifecycle Manager • Marketplace DLT 	[KPI5.4], [KPI5.5],

Test	Description	5GZORRO Platform components	Related KPIs
	based on the service requirements, radio technology, and availability	<ul style="list-style-type: none"> • Intelligent Slice and Service Manager • Network Slice and Service Orchestrator • Virtual (Radio) Resource Manager • Service and Resource Monitoring • Monitoring Data Aggregator • Data Lake • SLA Manager • Trusted Execution Environment (TEE) Security Management 	[KPI5.6], [KPI7.1]

In terms of required infrastructure / resources from the testbeds, the execution of the tests will require access to RAN controller and infrastructure, licensed spectrum authorised for use in the testbed area, compute resource to deploying a mobile core network.

3.2.4 KPI measurement methodology

The following table details how the different KPIs established for the test will be measured within this use case.

Table 3-9: UC2 KPI measurement methodology

KPI ID	Measurement methodology
[KPI1.1]	To support actual distributed multi-party service and business configurations, the use case will count on different stakeholder roles: Spectrum Resource Provider, which is allowed by the Regulator to issue spectokens in its area of application; Radio Resource Provider, which shares its RAN infrastructure; and a Resource Consumer, which acquires radio and spectrum resources.
[KPI1.2]	This KPI about supporting a real-time market for dynamic spectrum allocation allowing business agents to trade on spectrum allocations in space and time, is broken into [KPI5.1] and [KPI5.6]. Consequently, [KPI1.2] will be measured as the aggregation of the measurements from [KPI5.1] and [KPI5.6]
[KPI5.1]	It will measure the time spent from the moment a spectoken is purchased until the spectrum can be used in the radio access network.
[KPI5.2]	It will measure the number of transactions per second handled by the market. The Resource & Service Offer Catalogue will be populated by a sufficiently large number of spectokens, ready to be sold. A number of stakeholders will place orders for spectokens. Spectokens might be selected randomly or recommended by the Smart Resource and Service discovery application.
[KPI5.3]	The authenticity of the market agents will be evaluated by setting three stakeholder profiles: National Regulator, Spectrum Resource Provider or Trader, and Spectrum Resource Consumer. Each profile will attempt some actions in the 5GZORRO platform, and some of them might succeed, i.e., a Regulator can only perform actions of a Regulator, a Spectrum Provider can set prices for its spectokens, and the Spectrum Consumer can purchase spectokens.
[KPI5.4]	The association between market agents and their associated radio access points will be evaluated by querying the Virtual Resource Manager about the RAN infrastructure of the 5GZORRO stakeholder. The same RAN infrastructure elements will also be included in the Resource & Service Offer Catalogue.
[KPI5.5]	To measure the ability to enforce the settled spectrum rights and obligations, spectrum measurements will be fed into the RAN Controller in the Virtual Resource Manager and/or the shared datalake for SLA breach prediction, with the objective to ensure that a particular operation on a spectoken does not exceed the agreed terms.

[KPI5.6]	To measure the agnostic support of various radio technologies, different services with different service requirements will be instantiated. Based on these requirements, the 5GZORRO platform, via the joint operation of the Network Slice Service and Orchestration and the Virtual (Radio) Resource Manager, will provision the service in either a WiFi-only, cellular-only deployment.
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3.3 Pervasive vCDN Service

5GZORRO will build upon ICOM's commercial offering of a CDN solution, entitled fs|cdn™ Anywhere, and adapt it to fit the purposes of the project. The fs|cdn™ Anywhere is an end-to-end CDN solution that seamlessly integrates IPTV and value-added interactive services into the operator's back-office OSS / BSS and external Over-The-Top (OTT) content systems, through a rich set of available APIs. It includes components/features for the encryption, transcoding, distribution, caching & reception of content, with support for Smart Phone and Tablet devices.

For the purposes of 5GZORRO, the CDN edge network components will be virtualized to be offered as Virtual Network Functions (VNFs), hence leading to a virtual CDN (vCDN) solution. The functionality of the streaming servers and content caches are currently hosted in the CSP's infrastructure. The aim of this use case is to enable the scaling-out of video streamers and/or cache servers (offered as VNFs) using 3rd party resources. Moreover, there is a licensing scheme accompanying the deployment of fs|cdn™ Anywhere solution, which binds a particular CDN deployment to a maximum number of end-users that can be served by the CSP provider. This licensing covers the case of the instantiation of an arbitrary number of edge components, such as the ones that will be deployed on the CSP edge and the 3rd party, for scalability and performance optimizations, as long as the number of end-users remains bounded according to the licensing agreement.

3.3.1 Involved Stakeholder & Required Platform Components

In this Use Case, a CDN/OTT service provider will utilize vCDN technology to deliver high-definition video services to its subscribers. The CDN/OTT service provider leases a network slice instance from a CSP including performance guarantees related to throughput and low latency in certain areas of the network, based on a profiling of the service workload. During high workload situations (e.g., popular content, music/sports events), the CSP's edge infrastructure may not be able to satisfy the demand. In this case, the CSP's advanced auto-scaling policy results in the AI-based resource discovery process aimed to identify potential usable 3rd-party (spare) resources e.g., stadium compute infrastructure, nearby smart building or even smart city IT infrastructure, etc. The discovery process identifies the candidate 3rd party infrastructure. The matching is based on trusted information about current resource availability, as exposed and shared by infrastructure providers, as well as profile information related to latency guarantees. The reliability of this information derives from the trust models applied in the DLT infrastructure and 5GZORRO platform. The final selection of the 3rd party resources is based on an intelligent process taking into account resource availability, past and current KPI measurements, security/trust properties, pricing, etc, and results in a resource request for the establishment of a network slice extension reaching the third-party infrastructure. During the final stage, the network slice extension is realized. This includes the establishment of a secure connection between the CSP edge server and the new infrastructure site, the instantiation and/or potential migration of service components (application level) and the necessary load balancing adaptation (e.g., DNS server updates).

Table 3-10 describes the minimum set of stakeholders required to facilitate the test scenarios that are subsequently outlined.

Table 3-10: UC3 stakeholders and resources overview

Stakeholder	Stakeholder Description	Roles	Platform components
CSP	An operator of the 5G network (and typically the owner of the 5G infrastructure) who also provides network slices to the verticals service providers (CDN service provider in this case)	Service Provider	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Core
3 rd party Infrastructure provider	Stakeholder with infrastructure components at edge to support extension of computing and/or radio coverage connectivity services	Resource Provider	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Core
Spectrum Regulator	Stakeholder with platform components deployed to support licensing functions	Regulator	<ul style="list-style-type: none"> Marketplace Governance Platform
CDN/OTT Service Provider	operator of the content delivery network	Service Provider	<ul style="list-style-type: none"> Marketplace Cross-domain Monitoring & Analytics Core
End users	CDN/OTT service consumers	CDN Service consumers	N/A

3.3.2 Test scenarios

The test scenarios for Use Case 3 aims to verify the smooth on-boarding and deployment of CDN components into the provided infrastructure. These are described in the following subsections.

For both, the total time of CDN components' on-boarding and deployment shall be less than 90 minutes. Moreover, when all the vCDN, as well as the 5GZORRO, components are up and running, it should be verified that the End-to-End (E2E) slice is successfully established, enabling in this way an E2E connectivity with no packet loss and with adequate connection capacity.

In regard with the evaluation of the SLA Monitoring and Breach Prediction functionality, there is the need to firstly define the conditions under which the compute resources at the MEC Host are getting saturated. In this way, it is possible to compare the overall performance with and without the breach prediction and slice extension functions. Additionally, it is possible to calculate the success rate of the SLA breach prediction module. Particularly, while generating the conditions that could potentially reach a resource saturation, it should be possible to verify that the SLA Breach Prediction module will generate a notification prior to reaching this saturation point, where the performance will start to get worse. The notification on approaching saturation points is expected early enough to implement the appropriate reactions and avoid the performance degradation.

With respect to the resource discovery test case, this procedure should be completed during the time defined in the KPIs, that is during 10 minutes. Also, it is needed to verify that this function performs as anticipated, which means that it finds the best suitable resources for a given request.

3.3.2.1 Slice extension to increase edge processing power

In the first scenario (Figure 3-12), the need for the slice extension derives from the upcoming overloading of the streaming server that is located at the CSP Edge Server of an instantiated slice.

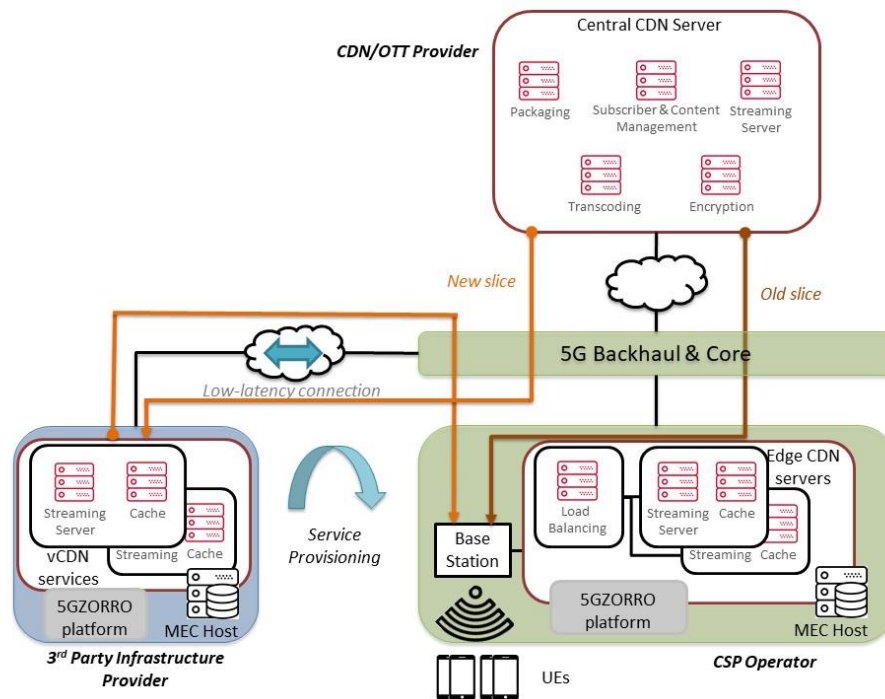


Figure 3-12: Use Case 3 Scenario 1 – Slice extension to increase edge processing power

3.3.2.2 Slice extension to increase vCDN wireless coverage

The second scenario (Figure 3-13) refers to a setup where the third-party resources are connected to the main (virtualized) infrastructure through a wireless connection, namely as ordinary terminal devices.

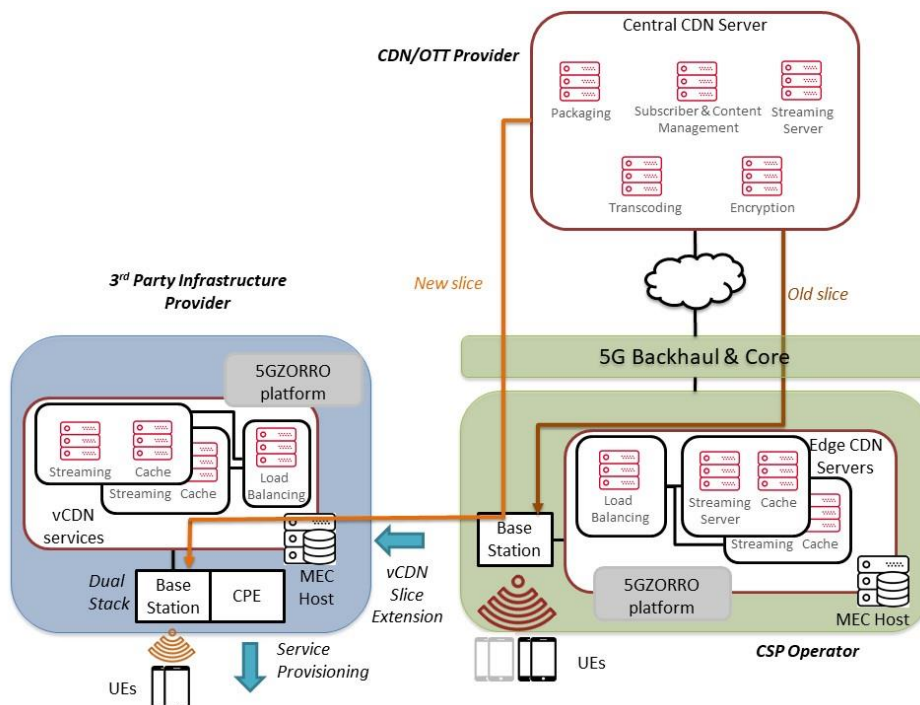


Figure 3-13: Use Case 3 Scenario 2 – Slice extension to increase wireless coverage

3.3.3 Test plan

Table 3-11 describes the tests established for this use case, as initial validation plan. The plan has been rolled-out targeting first the vCDN service provisioning using the 5GZORRO platform services, then SLA validation and breach features of the platform and finally the acquisition of resources and extension of the network slices in order to prevent or mitigate this SLA breaches. It is worth to highlight that, the “Related KPIs” column of the table maps the technical KPIs of the project that will be validated in the test as well as the vCDN service KPIs identified in D2.1. In this specific use case, additional KPIs are defined which relate to the orchestration actions and related deployment times, due to the specific nature of the use case application (vCDN) being tested. These UC3 specific KPIs are listed here below:

- **[KPI-UC3.1].** Deployment time for application components (VNFs, CNFs) < 5 mins
- **[KPI-UC3.2].** Deployment time for the complete graph of CDN application < 90 mins
- **[KPI-UC3.3].** Network Slice creation time < 3mins
- **[KPI-UC3.4].** Network Slice extension time < 2mins
- **[KPI-UC3.5].** Data rate between Central CDN Server & Edge Server > 200Mbps
- **[KPI-UC3.6].** Latency between Central CDN Server & Edge Server < 20ms
- **[KPI-UC3.7].** End-to-end Latency < 50ms
- **[KPI-UC3.8].** Prediction of SLA breach > 5 mins before the breach occurrence

Table 3-11: UC3 Initial validation plan

Test	Description	5GZORRO Platform components	Related KPIs
UC3.1a	CDN Application Deployment - The initial test case aims at validating and evaluating the deployment of CDN components (as VNFs) over the 5GBarcelona facility through its orchestration layer, setting up the slice and verifying initial connectivity between all components. Focus will be put on the evaluation of aspects related to easiness and speed of deployment, creation of interfaces, steps required for fine tuning of deployment, etc. Additionally, it aims at verifying and evaluating the end-to-end (E2E) connectivity across all CDN components, by examining, for example, the aspects related to data rate and latency achieved between the various CDN interfaces.	<ul style="list-style-type: none"> • Network Slice and Service Orchestrator 	[KPI1.2] [KPI-UC3.1] [KPI-UC3.2] [KPI-UC3.3] [KPI-UC3.5] [KPI-UC3.6] [KPI-UC3.7]
UC3.1b	SLA Breach Prediction Validation – The first step of this test case is to create so many requests to the CDN Streaming Server located at the MEC Host so that it will cause resource saturation and performance degradation. It is needed to find out which is the saturation point and how is the application performance affected by the number of users and/or requests without the enablement of SLA Breach Prediction process. Afterwards the SLA	<ul style="list-style-type: none"> • SLA Monitoring & Breach Prediction • Data Monitoring Aggregator 	[KPI4.1] [KPI4.2] [KPI5.2] [KPI-UC3.8]

Test	Description	5GZORRO Platform components	Related KPIs
	Breach Prediction functionality is added in order to see how well this module performs. It also requires the integration of Data Lake components and SLA management to trigger a Breach Prediction process from the SLA Breach Prediction module.		
UC3.1c	Discovery and Acquisition of Compute Resource - This test case focuses on finding available compute resources on the Marketplace and acquiring them for the CSP's purposes.	<ul style="list-style-type: none"> • DLT Agent / Resource Proxy for the CSP • Other DLT Nodes participating on the Marketplace • Intelligent SLA Monitoring & Breach Predictor • Smart Resource & Service Discovery application • Virtual Resource Manager • Identity & Permissions Manager • Resource & Service Offer Catalogue • Smart Contract Lifecycle Manager • Marketplace DLT • Intelligent Slice & Service Manager 	[KPI4.1] [KPI4.2] [KPI5.2] [KPI5.4]
UC3.1d	Slice extension to 3 rd party edge server - This test case focuses on the process of extending the slice to the acquired 3 rd party resources and the establishment and instantiation of CDN VNFs on these resources.	<ul style="list-style-type: none"> • Intelligent Slice & Service Manager 	[KPI5.6] [KPI-UC3.4] [KPI-UC3.5] [KPI-UC3.6] [KPI-UC3.7]
UC3.1e	Application based load balancing – The CDN application is aware of the new vCDN server, which is hosted on the the 3 rd party infrastructure. So, it will add the new server on its list and it will assign users to this server, based on internal load balancing rules. The goal of the current test case is to verify that users are successfully served by the new server and to study how system performance and users' QoS are improved with the presence of the new vCDN server.	<ul style="list-style-type: none"> • Intelligent Slice & Service Manager 	[KPI-UC3.1] [KPI-UC3.2] [KPI-UC3.5] [KPI-UC3.6] [KPI-UC3.7]
UC3.2a	Predict RAN resource saturation – This is similar to test case UC3.1b, with the difference that in this case to stretch the Base Station of the CSP. So, the first step is to connect and adequate number of users and create requests in order to cause resource saturation for the RAN resources. As in UC3.1b, it will be found the saturation point and how is the performance affected. Then, the SLA Breach Prediction functionality will be added.	<ul style="list-style-type: none"> • SLA Monitoring & Breach Prediction • Data Monitoring Aggregator 	[KPI4.1] [KPI4.2] [KPI5.2] [KPI-UC3.8]

Test	Description	5GZORRO Platform components	Related KPIs
UC3.2b	Discovery and Acquisition of RAN Resource - This test case is similar to UC3.1c, with the additional requirement of finding also available RAN resources, besides the compute ones.	<ul style="list-style-type: none"> • DLT Agent / Resource Proxy for the CSP • Other DLT Nodes participating on the Marketplace • Intelligent SLA Monitoring & Breach Predictor • Smart Resource & Service Discovery application • Virtual Resource Manager • Identity & Permissions Manager • Resource & Service Offer Catalogue • Smart Contract Lifecycle Manager • Marketplace DLT • Intelligent Slice & Service Manager 	[KPI4.1] [KPI4.2] [KPI5.2] [KPI5.4]
UC3.2c	Slice extension to 3 rd party Base Station and edge server – Similarly to UC3.1d, this test case focuses on the slice extension to the acquired 3 rd party RAN and compute resources.	<ul style="list-style-type: none"> • Intelligent Slice & Service Manager 	[KPI5.6] [KPI-UC3.4] [KPI-UC3.5] [KPI-UC3.6] [KPI-UC3.7]
UC3.2d	Apply load balancing at the RAN level – Initially, all new users will try to connect to the CSP's Base Station. However, some of them will be redirected to the 3 rd party's Base Station, based on load balancing rules. The goal of this test case is to verify that users are successfully connected and served by the 3 rd party resource provider. It is also needed a study on how the system's performance and the users' QoS are improved.	<ul style="list-style-type: none"> • Intelligent Slice & Service Manager 	[KPI-UC3.1] [KPI-UC3.2] [KPI-UC3.5] [KPI-UC3.6] [KPI-UC3.7]

In terms of required infrastructure / resources from the testbeds, this use case requires the following items:

- From Content or CDN/OTT provider
 - Transcoder & VoD/live test contents to be streamed
 - Central CDN Server / Content receiver
- From CSP
 - Edge server / MEC Host, where to host securely vCDN services like load balancing, edge streaming server, edge cache
 - 5G Base station & core network
 - 3rd party infrastructure (Base Stations and Edge/MEC servers)
- User's mobile devices

3.3.4 KPI Measurement Methodology

The following table illustrates how the different KPIs identified in the initial use case validation tests will be effectively measured.

Table 3-12: UC3 KPI measurement methodology

KPI ID	Measurement methodology
[KPI5.1]	It will measure the time spent from the moment the vCDN service or part of the vCDN is requested on a certain area, and the time where the part of the service is effectively allocated using the required resources.
[KPI5.2]	It will measure the number of transactions per second handled by the market given the computing power allocated to the marketplace related components of the platform, and extrapolating the obtained results towards more realistic scenarios. This will be used in particular, when addressing SLA breach test, in order to confirm the marketplace is able to process the number of transactions required to trace SLA violations.
[KPI5.4]	This KPI will be measured registering the capability of the 5GZORRO marketplace to respond to a certain query for resources, and evaluating the amount of candidate resource offers replied.
[KPI5.6]	During the execution of the tests different types of spectrum resources will be allocated, and therefore this KPI will be measured based on the capability of the 5GZORRO Platform to allocate or not these resources.
[KPI-UC3.1]	<i>Deployment time for application components (VNFs, CNFs).</i> This time is measured from the trigger raised by the Intelligent Slice & Service Manager to instantiate and the confirmation of application component up and running retrieved from the service monitoring platform.
[KPI-UC3.2]	<i>Deployment time for the complete graph of CDN.</i> This time is measured from the trigger raised by the Intelligent Slice & Service Manager to instantiate a CDN graph and the confirmation from the service monitoring platform of all the application of application components up and running
[KPI-UC3.3]	<i>Network Slice creation time.</i> time it takes the Intelligent Slice & Service Manager to return the results of a submitted slice creation request to an end user. This operation includes the sequential creation of all the elements belonging to the slice and the grouping of those resource chunks into the resulting slice.
[KPI-UC3.4]	<i>Network Slice extension time.</i> Time it takes the Intelligent Slice & Service Manager to return the results of a submitted slice extension request to an end user. This operation includes the sequential creation of all the elements belonging to the slice and the grouping of those resource chunks into the resulting slice.
[KPI-UC3.5]	<i>Data rate between Central CDN Server & Edge Server.</i> In 3GPP TS 22.261 [6], the user experienced data rate is defined as the minimum data rate required to achieve a sufficient quality experience in the user plane (without considering the scenario of broadcast services). This definition is adapted in the scope of 5GZORRO to extend the concept of user plane in 3GPP radio to the data plane in general where the traffic from devices to virtual application servers in edge/cloud are deployed.
[KPI-UC3.6]	<i>Latency between Central CDN Server & Edge Server.</i> In 3GPP TS 22.261 [6], the service latency is the time elapsed between the event that triggers the service execution and the availability of the service response at the system interface. In 5GZORRO, the latency is measured as average of 100 ICMP packets sent between a source and destination
[KPI-UC3.7]	<i>End-to-end Latency.</i> Measurement as per [KPIUC3.6]
[KPI-UC3.8]	<i>Prediction of SLA breach.</i> Time between the trigger of an SLA breach prediction and the occurrence of breach in case of no reaction applied

4 5GZORRO Testbeds

4.1 5GBarcelona Infrastructure for 5GZORRO

i2CAT brings to 5GZORRO a testbed that will be used for platform development, integration, and use case validation.

The infrastructure can host three different environments:

- A development environment for developers to produce and test their software modules.
- An integration environment, in which techniques of CI/CD will be used.
- And a production environment, used for Use Case validation

The 5GZORRO testbed is part of the 5GBarcelona Labs [7], which are spread over different locations in Barcelona.

The testbed infrastructure for 5GZORRO consists of two possible compute locations (or zones) to be able to validate different setups with services or resources located at the network edge or in the main Data Centre.

The main location for testbed equipment is in i2CAT's laboratory in the Nexus building which is connected to the adjacent Data Centre at the Omega building inside the UPC campus.

The testbed has connectivity to a street infrastructure in 22@ District where smart lampposts and edge resources are located.

A diagram summarizing the 5GBarcelona infrastructure is illustrated in Figure 4-1, and the locations of the testbed zones in Barcelona are shown in the map of Figure 4-2.

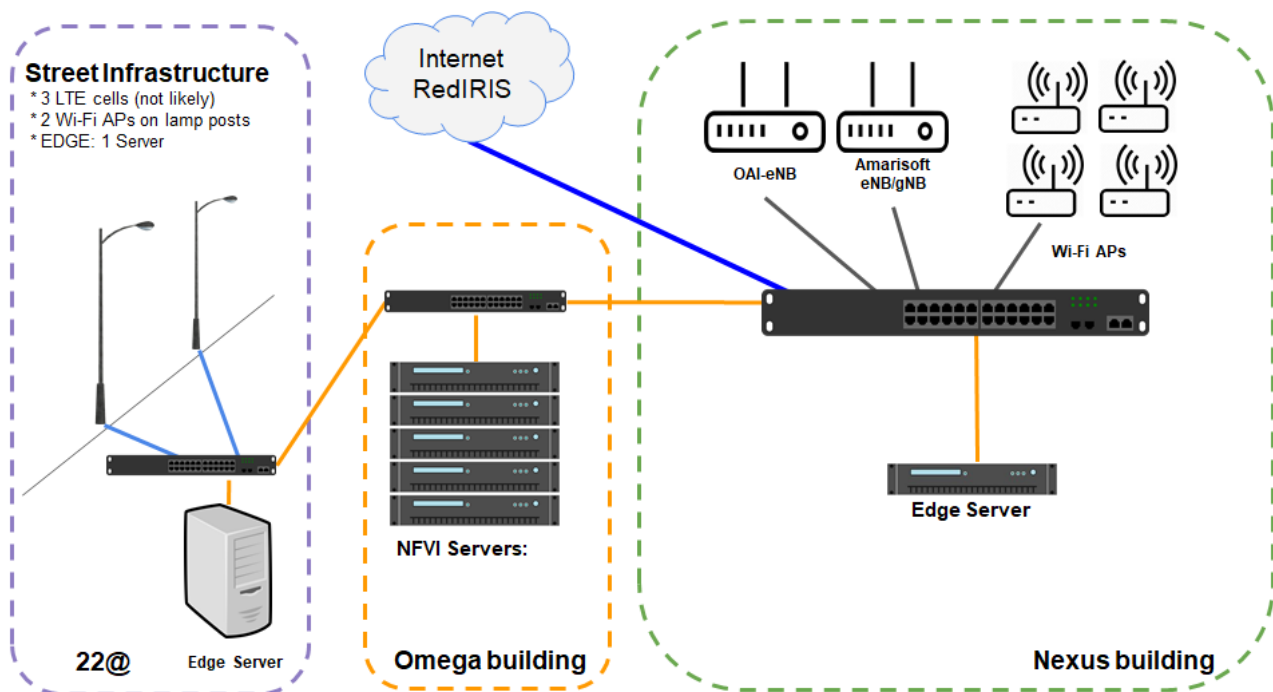


Figure 4-1: 5GBarcelona testbed

The infrastructure is shared with other research projects and initiatives of 5GBarcelona; therefore, its availability depends on a calendar of activities known to i2CAT.

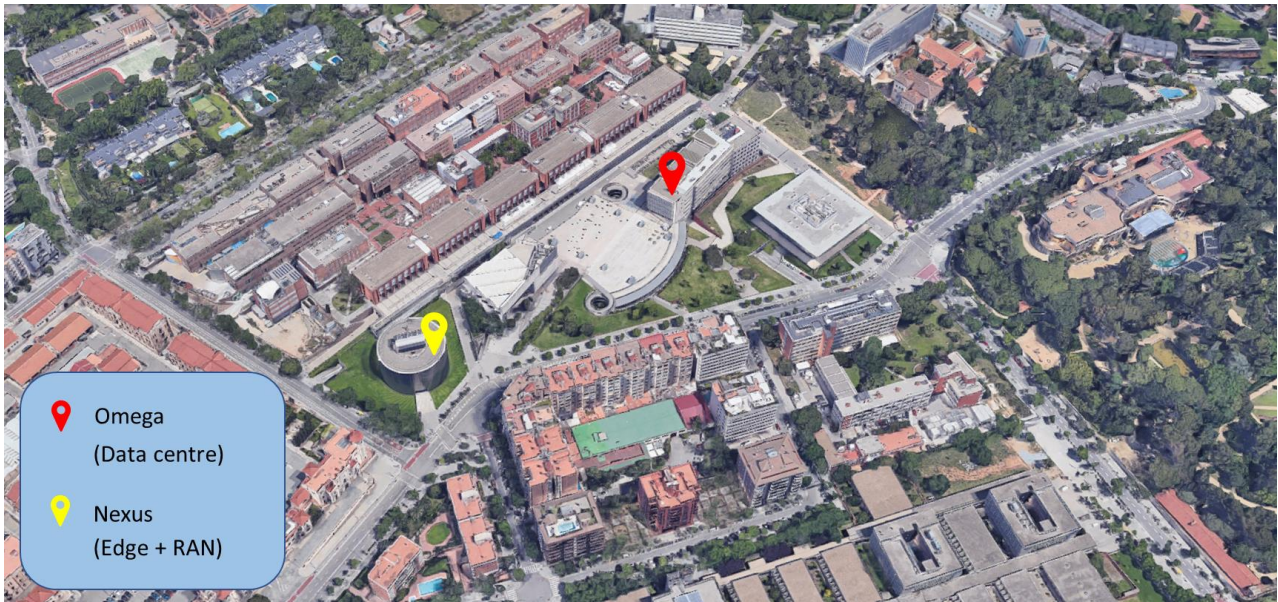


Figure 4-2: Aerial view of the locations of the 5GBarcelona testbed

Resources available for 5GZORRO in the 5GBarcelona testbed for 5GZORRO are detailed in the next subsections.

4.1.1 5G RAN and mobile core network elements

As for the radio resources, the following elements are included in the 5GZORRO testbed:

- **OAI-RAN** [8]: A couple of LTE base stations based on OpenAirInterface (OAI) eNB (OAI-eNB). Currently, the software partially supports gNB in operation mode 3 or ENDC (gNB attaches to an anchor/master eNB). Each OAI-RAN node is equipped with one USRP B210 from ETTUS, which supports central frequencies up to 6 GHz with a maximum bandwidth of 56 MHz.
- **4G Small Cells on street** [9]: 5GBarcelona offers 3 Accelleran On-Street Small Cells, LTE/4G Small Cells that could potentially be used for testing and validation purposes.
- **eNodeB/gNodeB in lab** [10]: Amarisoft CallBox Pro, a 3GPP compliant eNodeB (Release 14) / gNodeB (Release 15) from Amarisoft. Up to 6 cells, with a maximum bandwidth of 50 MHz each. Supports NSA and SA operation for 5G. FR1. MIMO support (up to 4x4).
- **Wi-Fi nodes**: 6 Nodes supporting Wi-Fi 5 (Wi-Fi 6 in near future). Street-level access points could potentially be used for testing and validation purposes.

In terms of mobile core network solutions, 5GBarcelona offers two alternatives:

- **OpenAirInterface LTE core network** [11] (EPC, 3GPP R14)
- **Open5GS** [12] to implement either EPC (3GPP R14) or 5G Core - 5GC (3GPP R16).

The cellular technology, present in the infrastructure, is moving towards the support of 5G NR, as NSA (Non-Stand-Alone) mode first, but evolving towards SA (stand-alone)

The current Wi-Fi 5 nodes will be upgraded to newer Wi-Fi 6 nodes.

4.1.2 Virtualization infrastructure and MANO

5GBarcelona offers a virtualized environment running on top of an **OpenStack Virtual Infrastructure Manager (VIM)**. The currently deployed OpenStack is based on **OpenStack Victoria** release [13], which has been configured in High Availability (HA) mode to be extremely available. This platform manages natively virtual machines, but with the addition of **Zun [14]**, one of the OpenStack main projects for container services., the same infrastructure is capable of managing containers too.

Within the OpenStack deployment, a Kubernetes cluster is deployed.

In the 5GZORRO testbed, **ETSI OSM** [16] will be deployed as MANO element.

The **OSM Release 8** of the orchestrator is deployed with plans to update version as they are matured from the ETSI OSM community.

4.1.3 Computer resources for NFVI

The main computing infrastructure cluster has been installed with a total of 5 servers, configured for high availability. On top of that, there is an edge server closer to the lab.

The hardware characteristics of the servers are provided in Table 4-1.

Table 4-1: Hardware characteristics of the servers for 5GZORRO testbed in 5GBarcelona

Host Name	Operating System	VIM SW	Location	vCPUs	Mem (GB)	Disk (GB)	Eth ifaces (1Gbps)	SFP+ LAN (10 Gbps)
4x NFVI Servers	Ubuntu Bionic (18.04.5 LTS)	OpenStack Victoria (controller)	Omega DC	76C/152T	608	19T	12	4
1x Edge	Ubuntu Bionic (18.04.5 LTS)	OpenStack Victoria (compute)	Nexus Building	12C/24T Intel (R) Xeon (R) CPU D-1557 (1.5 GHz)	128	2x894	2	2

4.2 5TONIC Infrastructure for 5GZORRO

The global 5G Telefonica Open Innovation Laboratory (5TONIC, [17]) has been established in Madrid (Spain) as a leading European hub for knowledge sharing and industry collaboration in the area of 5G technologies. It provides an open research and innovation ecosystem for industry and academia that promotes joint project development, joint entrepreneurial ventures, discussion fora, and a site for events and conferences, all in an international environment of the highest impact. The laboratory also serves to evaluate and demonstrate the capabilities and interoperation of pre-commercial 5G equipment, services, and applications. Currently, the 5TONIC laboratory has ten members: Telefonica, IMDEA Networks Institute, Ericsson, Intel, CommScope, Universidad Carlos III de Madrid, Cohere Technologies, InterDigital and Altran.

5TONIC is currently structured in two main areas:

1. The *5G Virtual Software Network Area* allows the development and advanced experimentation on Network Function Virtualization (NFV), Software Defined Networking (SDN), security services, network control and management planes, cloud services, signalling and related areas.
2. The *5G Wireless Systems Area* focuses on the air interface, radio aspects, duplexing, multiplexing, media access control, spectrum, interference, mobility tracking, all based on a Multi-Radio Access Technology (multi-RAT) approach.

The diagram in Figure 4-3 illustrates the infrastructure that is currently available for experimentation in the 5TONIC laboratory.

5TONIC is a shared environment structured around experiments. The use of the testbed requires to prepare an experiment description (including required resources and time frame) and submit it to the testbed Board for approval to be included in the testbed schedule. In the project case, these experiments would correspond to the availability for deployment and integration, and the execution of use case demonstrators.

Table 4-2: 5TONIC Transport Technologies/Infrastructure

Transport Technologies/ Infrastructure	Description
Internet	The 5TONIC site is connected through a high-speed network access to the Internet via RediMadrid, RedIRIS and GEANT
TEF	Telefonica's own optical transport network is used to interconnect the site to Telefónica premises (labs inn Almagro and Distrito Telefonica)
Internal	All devices are interconnected by 24-port 10Gbps Ethernet switches

5TONIC supports VPN access to experimenters, as well as for data and control planes by means of IPsec VPNs, according to well-defined procedures and specific routing arrangements. A detailed description of the procedures for connecting any remote infrastructure to the 5TONIC testbed is available at <https://www.jove.com/t/61946/integration-5g-experimentation-infrastructures-into-multi-site-nfv>.

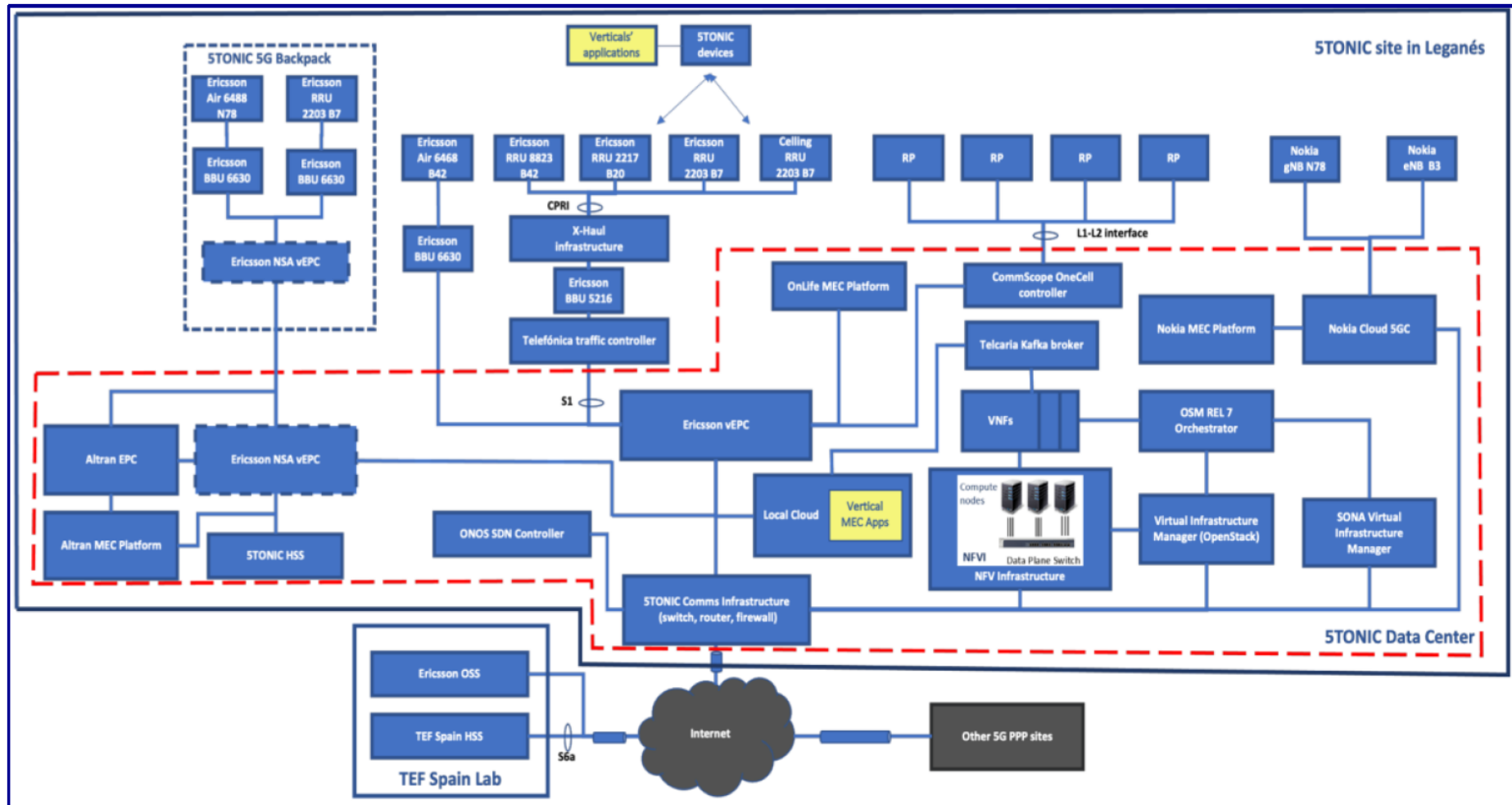


Figure 4-3: 5TONIC testbed infrastructure

Resources available for 5GZORRO in the 5TONIC testbed for 5GZORRO are detailed in the next subsections.

4.2.1 5G RAN and mobile core network elements

The 5G RAN and mobile core options available in 5TONIC are briefly summarised in the following tables.

All devices are interconnected by 24-port 10Gbps Ethernet switches

Table 4-3 : 5TONIC RAN Technologies/Infrastructure

RAN Technologies/ Infrastructure	Description
OAI [8]	OpenSource OpenAirInterface NR. The initial deployment of the radio was a srsLTE solution that is currently migrating to an OAI LTE/5G ecosystem with 5G NR support. The radio hardware is based on USRP B200 mini.
Ericsson [18]	Ericsson NR. The radio access network comprises the Baseband 6630, and new radio unit AIR 6468 B42. The hardware is 5G NR ready, fully compliant to 3GPP R15 and later. 5G Plug-in Massive MIMO over LTE TDD is also available. The support of an SA 5G deployment is currently ongoing.

Table 4-4: 5TONIC Core technologies/Infrastructure

Core Technologies/ Infrastructure	Description
OAI [11]	OpenSource OpenAirInterface NGC
Ericsson [18]	Ericsson NGC. The core network equipment is a vEPC-in-a-box that fulfills the vEPG, vSGSN-MME, and vPCRF. New HT with more VNFs flexibility is also available. Both types of core hardware have support for 5G NR NSA and the second one could support SA with software upgrade. The support of an SA 5G deployment is currently ongoing, with the upgrade of the EPC to NGC.

Moreover, 5TONIC supports VPN access to experimenters, as well as for data and control planes by means of IPsec VPNs, according to well-defined procedures and specific routing arrangements. A detailed description of the procedures for connecting any remote infrastructure to the 5TONIC testbed is available at <https://www.jove.com/t/61946/integration-5g-experimentation-infrastructures-into-multi-site-nfv>.

4.2.2 Virtualization infrastructure and MANO

The orchestration stack at 5TONIC composed of:

- At the VIM level, **OpenStack Stein** as cloud orchestrator, **KVM [19]** as VM manager, and a **Kubernetes** cluster. **Open vSwitch [20]** and whitebox switches are used to provide SDN-enabled infrastructural networking in case of need.
- NFVO and VNFM functionalities are provided by **ETSI OSM Release SEVEN**
- Monitoring of hardware and RAN/core elements is based on **Nagios [21]**
- Service orchestration is based on **OpenSlice [22]**, supporting a Network Slice as a Service (NSaaS) model
- An **OpenNESS** instance [23], the Intel's MEC solution following ETSI GR MEC 017, is also available. The OpenNESS controller is part of the NFs orchestrated by the MANO solution (OSM SEVEN) and the OpenNESS compute node is a dedicated physical server within the NFVI. Edge apps running as VMs or OS containers are both supported

4.2.3 Computer resources for NFVI

The following compute resources are available for VNFs and control plane:

- 1 NFVI Physical Node
 - Intel® Xeon® Silver 4114 (2.20GHz, 40 cores)
 - 2x 16GB DDR4 (2666MHz)
 - 4x 3TB HDD SAS (7200rpm)
 - 1x Broadcom 5720 (1Gbps, 2 ports)
 - 1x Intel Eth.i350 (1Gb, 4 ports)
 - 1x Integrated LOM (1Gb, 2 ports)
- 1 NFVI Physical Node
 - Intel® Xeon® Gold 6152 (2.10GHz, 88 cores) 2x 16GB DDR4 (2666MHz)
 - 2x 32GB DDR4 (2666MHz)
 - 4x 2TB HDD SAS (7200rpm)
 - 1x Broadcom 5720 (1Gbps, 2 ports)
 - 1x Intel Eth.i350 (1Gb, 4 ports)
 - 1x Integrated LOM (1Gb, 2 ports)

5 Plans for deployments in testbeds

This section aims to illustrate at high level how the different use cases are currently being rolled-out in the 5GZORRO testbeds, including setup of the 5GZORRO Platform. This setup will be evolved in future deliverables in order to fulfil the technical [KPI7.2] of the project described in Section 2.

5.1 Smart Contracts for Ubiquitous Computing/Connectivity

The Smart Contracts for Ubiquitous Computing/Connectivity use case covers the potentially highly dynamic scenarios that different stakeholders will come across in a 5G-enabled ecosystem, where they will have to establish smart contracts between many different providers.

In the scenario 1 “slice composition from a single provider” (see Figure 5-1), the relevant 5GZORRO components are deployed to allow a slice composition from a single provider. As described in the picture, the initial setup for UC1 currently contains three operators (each performing a different role) and one regulator. Each of these stakeholders, has its own and customized deployment of the 5GZORRO Platform components relying on a shared Cloud Native Data Lake infrastructure. It is important to highlight that in this scenario only “Operator 3” provides resources.

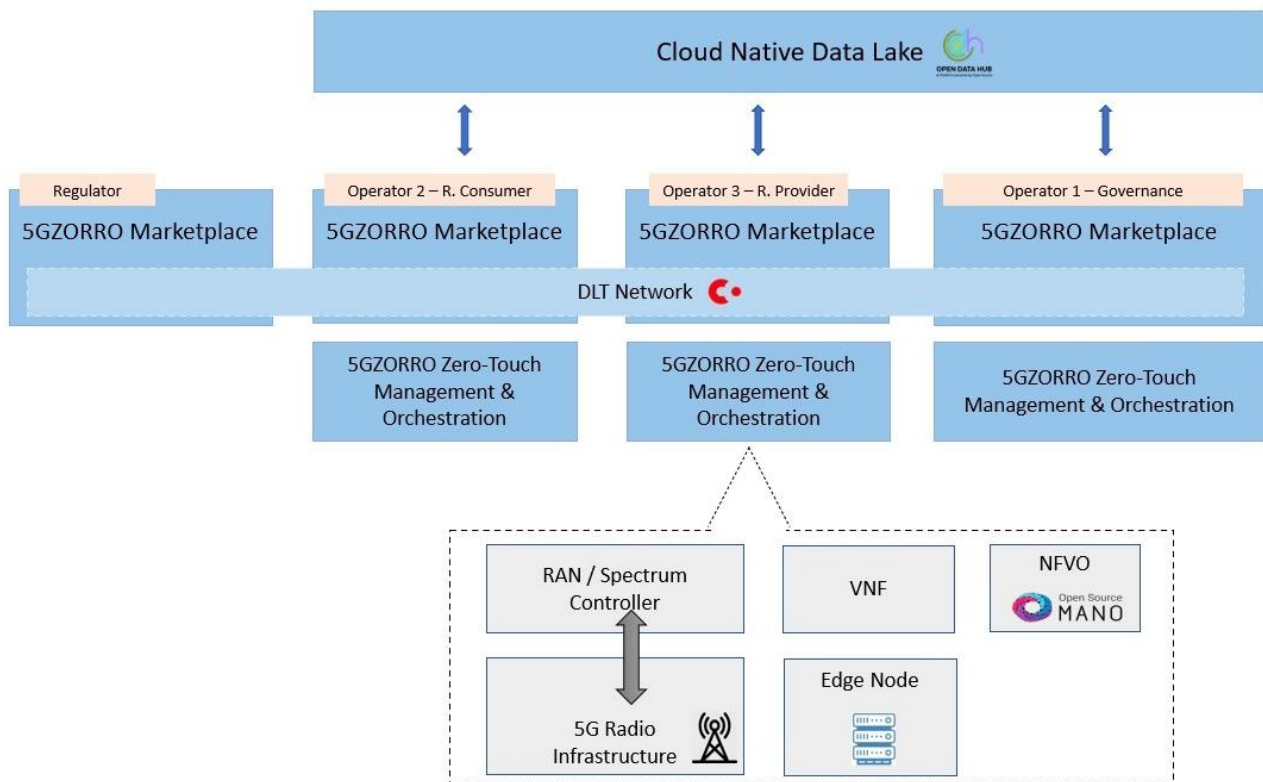


Figure 5-1: Deployment for slice composition from a single provider (UC1 – scenario 1).

In the second setup for scenario 2 “slice composition from multiple providers”, presented in Figure 5-2, the previously described configuration is extended with a second resource provider. In this case “Operator 2”, acts as the entry point exposing all the resources available from the different 5GZORRO resource providers, while the different parts of the infrastructure to be used to deploy the network slices of the service belong to “Operator 1” and “Operator 3”.

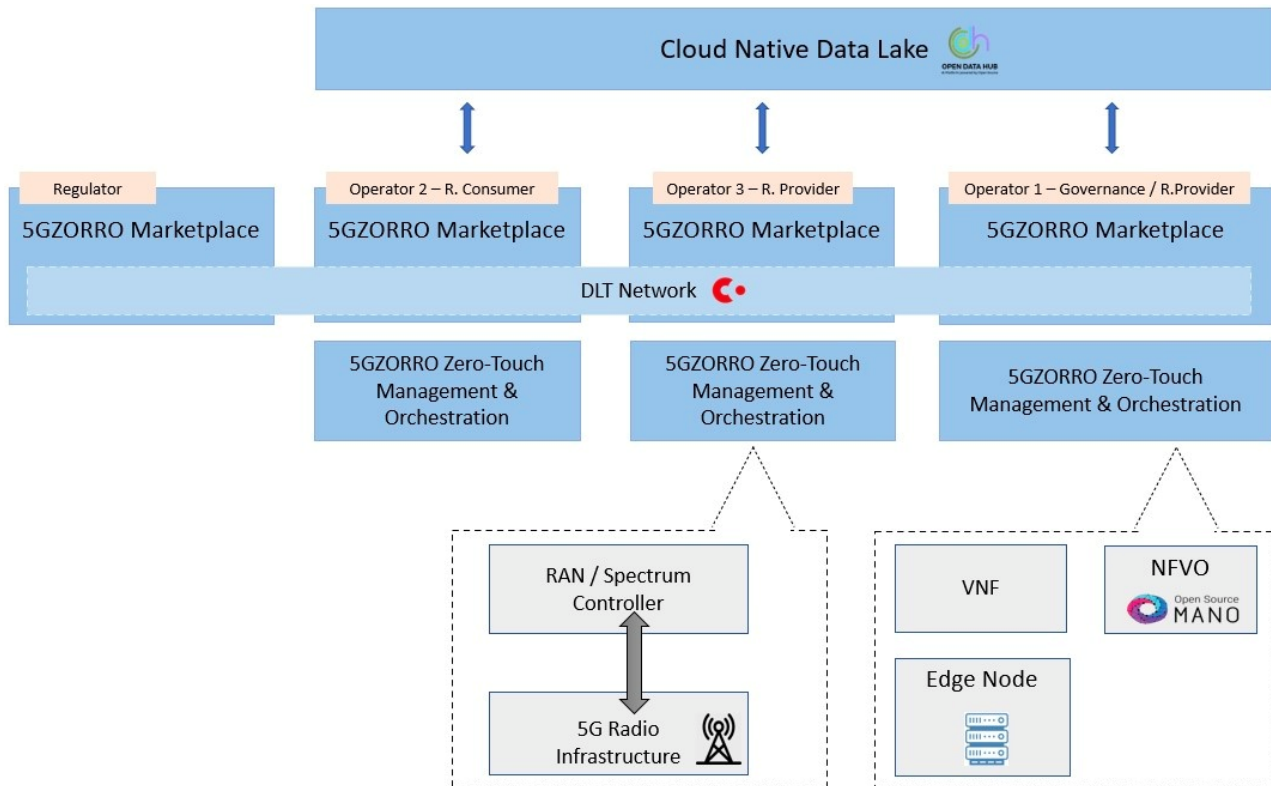


Figure 5-2 : Deployment for slice composition from multiple providers (UC1 – scenario 2)

The deployment of scenario 3 “Slice extension to meet increased capacity requirements” follows the same principles depicted in Figure 5-2 where additional resources are contracted from another operator domain to cope with the increased capacity demand.

5.2 Dynamic spectrum allocation

The elements of the 5GZORRO platform required to demonstrate this use case in the 5GBarcelona testbed are shown in Figure 5-3.

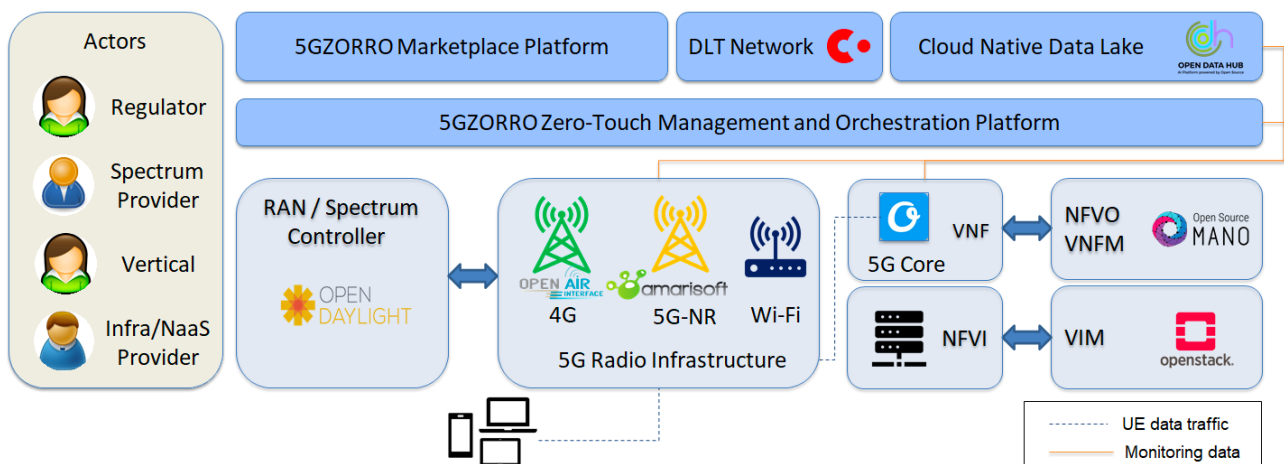


Figure 5-3: Testing scenario for use case 2 in the 5GZORRO testbed.

The radio service can be instantiated over a selection or combination of Wi-Fi Access Points (APs) and cellular base stations (cells).

The testbed considers two cellular technologies: OpenAirInterface, which supports 4G and 5G NSA; and Amarisoft software, which supports 4G, 5G NSA, and 5G SA. In case of deploying a service over any of the cellular technologies, the testbed also provides the core network functionality of the Evolved Packet Core (4G) and 5GCore (5GC) with Open5GS.

The radio infrastructure is managed by 5GZORRO's RAN Controller, which enables the discovery of the RAN elements in the testbed and their configuration by the 5GZORRO Zero-Touch Management and Orchestration Platform. In addition, the RAN Controller instructs the RAN infrastructure to push monitoring data of the RAN and spectrum resources utilisation to the 5GZORRO platform.

The Spectrum Controller is responsible for the generation of the licensed spectrum offers (spectokens) and storage of the licensed spectrum resources acquired in the 5GZORRO Marketplace.

5GZORRO Zero-Touch Management and Orchestration Platform uses the spectrum information when setting the RAN slice with cellular technologies. In the scope of this use case, the 5GZORRO Zero-Touch Management and Orchestration Platform interacts with other 5GZORRO platform components, naming Intelligent SLA Monitoring & Breach Predictor, Monitor Data Aggregator, and Service and Resource Offer Catalogue.

5.3 Pervasive vCDN Service

For the Pervasive vCDN Service three different options are defined for deploying this use case, as described in the following, which differentiate on where to deploy the centralized CDN servers.

5.3.1 Option 1: Physical server built outside and deployed connected to the testbed

This option includes building a server and deploying it in the 5GBarcelona testbed, in the same network as VNF (see Figure 5-4).

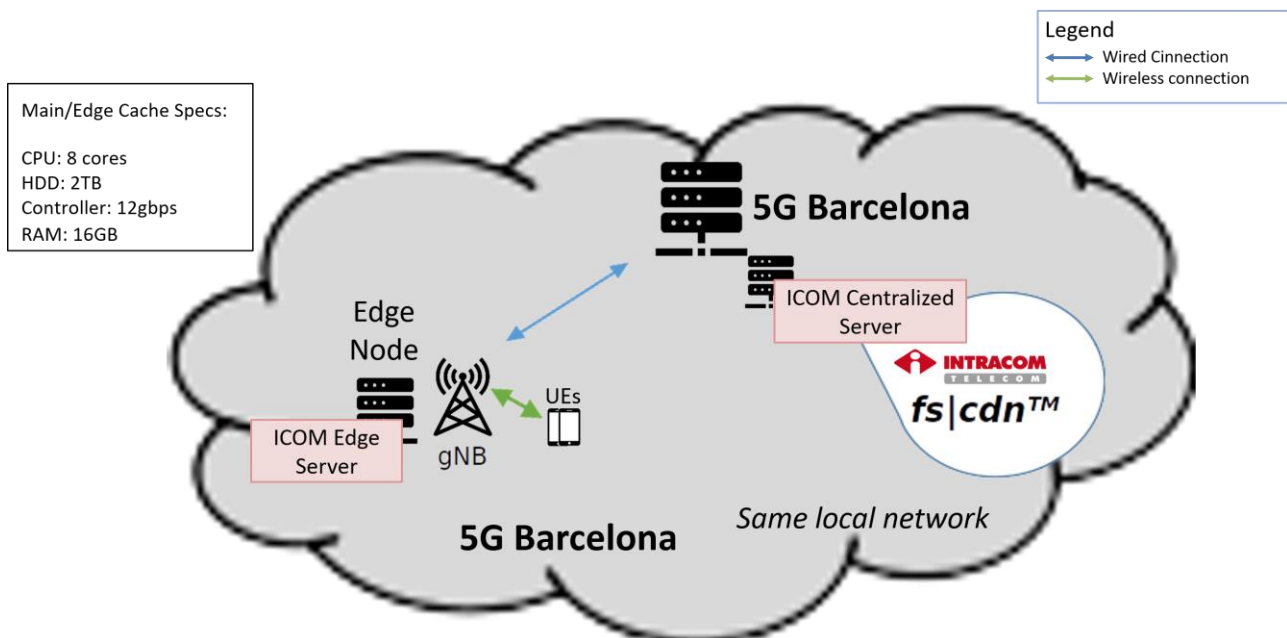


Figure 5-4: Use Case 3 deployment option 1

In this setup both the central and the edge CDN servers are hosted at the 5GBarcelona infrastructure. The components at the top right of the figure represent the centralized servers of the testbed (big server) and a server where the CDN core is executed (small server). In this option, the second server is a physical computer

(PC/laptop) that belongs to ICOM. In other words, ICOM sets up the CDN core components to be executed and carries the server to the testbed infrastructure. In this way, the core CDN components will be close to the edge ones and all are placed in the same local network.

At the left side of Figure 5-4, the edge components that are required for the tests are shown. These are the following:

- Edge Node: It's basically an edge server where the CDN VNFs, which are designed to implement a CDN edge server, are deployed and executed.
- gNB (or any other wireless access point): This is the wireless access point where the users will be connected.
- UEs: These are the User Equipment's (5G devices) that will run the CDN client application

5.3.2 Option 2: Host the centralized VNF services in VMs provided by 5GBarcelona testbed

This option includes deploying all needed VMs in the 5GBarcelona testbed (see Figure 5-5).

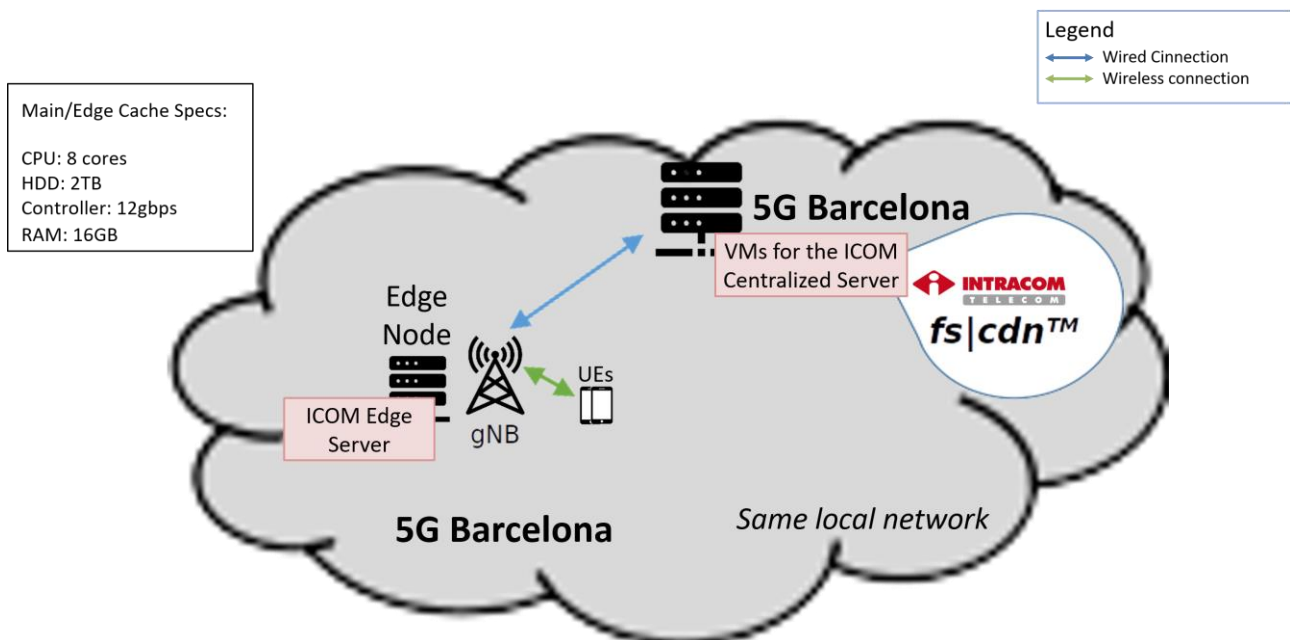


Figure 5-5: Use Case 3 deployment option 2.

This option is similar to Option 1, with the exception that instead of having a physical device for running the CDN core, VM images for the central CDN servers are created and instantiated at the central servers provided by the testbed.

5.3.3 Option 3: Central CDN server is not deployed in 5GBarcelona testbed

This option includes deploying only the VMs needed for the edge part in the 5GBarcelona Testbed (see Figure 5-6). The centralized CDN servers are hosted either on the Cloud or on ICOM premises.

As shown in Figure 5-6, in this option, the ICOM Centralized Server is hosted in a cloud component that will be connected to the testbed infrastructure where the edge component will be hosted. This cloud infrastructure can be provided either by ICOM, meaning that the central CDN server will be located at ICOM's premises in Athens, or it can be provided by another cloud provider, such as AWS.

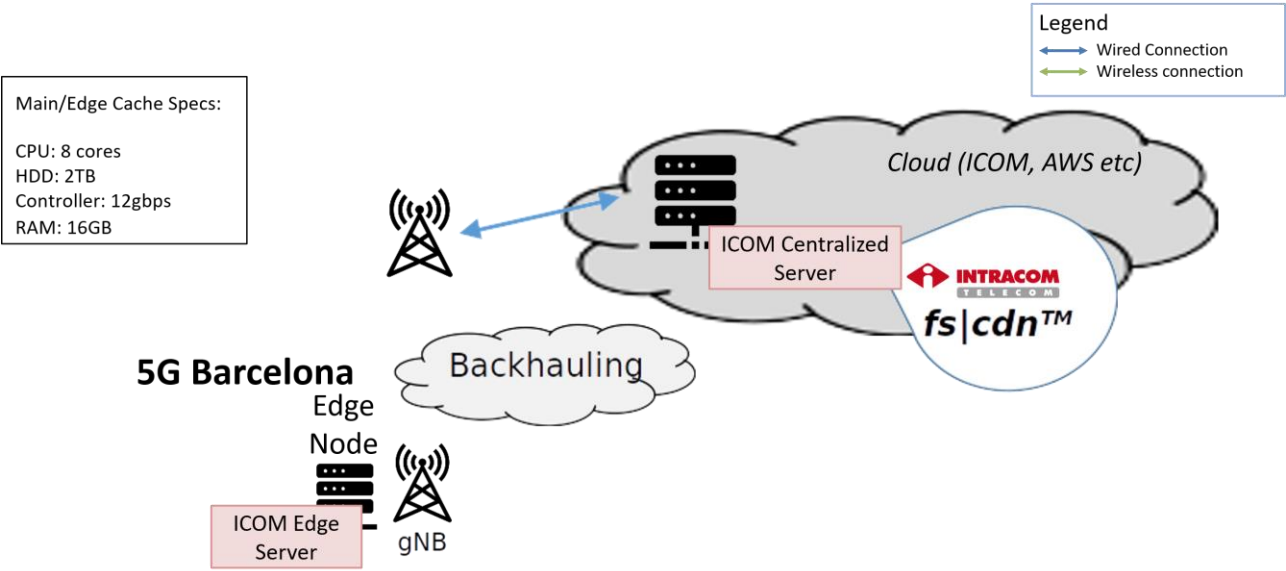


Figure 5-6: Use Case 3 deployment option 3

6 Conclusions

This deliverable fulfils the objective of defining an initial validation plan for the 5GZORRO use cases.

For each use case, the document describes:

- the target functionalities and validation scenarios,
- a test plan for the validation of the various features and use case requirements,
- the involved 5GZORRO platform modules,
- the reference KPI metrics to test and validate together with related measurement methodologies.

The use case validation plans have been provided in relation to the resources and components for testbeds made available in 5GBarcelona and 5TONIC. High level schematics of use case deployments setups have also been provided.

The contribution of this deliverable to the objectives and KPIs of the 5GZORRO Description of the Action has also been highlighted in Table 2-1 and it is not repeated here for sake of compactness.

This deliverable D5.1 serves as first reference for the testbed integration and low-level configuration activities executed within workpackage WP5. Configuration details of public relevance will be provided together with test result in documents D5.2 and D5.3 planned for the next period.

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8 Abbreviations and Definitions

8.1 Definitions

No definition introduced in this deliverable.

8.2 Abbreviations

5G IA	5G Infrastructure Association
5G PPP	5G Public Private Partnership
AIOps	Artificial Intelligence for IT operations
CNF	Cloud Native Function
DoA	Description of Action
DID	Distributed Identifier
DLT	Distributed Ledger Technology
EC	European Commission
ENI	Experiential Networked Intelligence
IPR	Intellectual Property Rights
LCM	LifeCycle Management
MANO	Management and Orchestration
NFV	Networks Function Virtualization
NFVI	Networks Function Virtualization Infrastructure
NFVO	Networks Function Virtualization Orchestrator
NSD	Network Service Descriptor
NSM	Network Service Mesh
OSM	OpenSourceMANO
PDL	Permissioned Distributed Ledgers
PoC	Proof of Concept
PPP	Public Private partnership
SBA	Service Based Architecture
SBI	Service Based Interface
SC	Smart Contract
SDO	Standard Developing Organization
SM	Service Mesh
VIM	Virtual Infrastructure Manager
VNF	Virtual Network Function
VNFM	Virtual Network Function Manager
WG	Working Group
WP	Work Package
ZSM	Zero touch network & Service Management

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