



5G ZORRO

Grant Agreement 871533

H2020 Call identifier: H2020-ICT-2019-2

Topic: ICT-20-2019-2020 - 5G Long Term Evolution

D5.2: Intermediate Validation Results

Dissemination Level		
<input checked="" type="checkbox"/>	PU	Public
<input type="checkbox"/>	PP	Restricted to other programme participants (including the Commission Services)
<input type="checkbox"/>	RE	Restricted to a group specified by the consortium (including the Commission Services)
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Grant Agreement no: 871533	Project Acronym: 5GZORRO	Project title: Zero-touch security and trust for ubiquitous computing and connectivity in 5G networks.
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Lead Beneficiary: ICOM	Document version: v1.0
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Work package: WP5 – Validation through Use Cases
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Deliverable title: D5.2: Intermediate Validation Results
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Start date of the project: 01/11/2019 (duration 36 months)	Contractual delivery date: 31.01.2022	Actual delivery date: 02.02.2022
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Change History

Version	Date	Partners	Description/Comments
0.0	29/10/2021	ICOM	Table of Contents and editing assignments
0.1	3/11/2021	ICOM, I2CAT	Initial contributions by ICOM and I2CAT
0.2	15/11/2021	UMU, MCA, ICOM	New Table of Contents, comments and suggestions for previous inputs by UMU and MCA, new inputs (UC3 tests analysis) by ICOM
0.3	3/12/2021	UMU, ICOM	New contributions by UMU and updates by ICOM
0.4	20/12/2021	NXW	Updates on use case 3 tests
0.5	10/1/2022	ATOS, I2CAT	Contributions on infrastructure setup and use case tests by ATOS and I2CAT
0.6	17/1/2022	I2CAT, UC3M, ICOM	Updates on previous inputs

0.8	31/1	NXW, ICOM, I2CAT	Internal reviews, updates and test results
1.0	02/2	I2CAT, UW, ALB, UC3M, ICOM, NXW	Final document

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5GZORRO has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 871533. The content of this deliverable does not reflect the official opinion of the European Union. Responsibility for the information and views expressed in the deliverable lies entirely with the author(s).

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Executive Summary

This document presents the intermediate validation results for the use cases of the H2020 5GZORRO project. In addition, it describes the available infrastructure and the initial setup on the 5GZORRO testbeds (i.e., 5GBarcelona and 5TONIC).

The goal of the project is to design, develop and validate a 5G architecture capable of exploiting zero-touch automation solutions for orchestrating services and resources, coupled with a 5G multi-stakeholder market. 5GZORRO platform supports this goal by utilizing Artificial Intelligence (AI) over Data Lake technologies in order to provide service management automation. The platform also leverages the use of distributed ledger technologies to implement a reliable and scalable marketplace for tracking resource offers as well as related trust levels and actions.

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

1. Use Case 1 (UC1): Smart Contracts for Ubiquitous Computing/Connectivity, testing the DLT-based Smart Contracts and Oracles application in order to support a trusted Marketplace catalogue of 5G resource offers from many providers and stakeholders.
2. Use Case 2 (UC2): Dynamic spectrum allocation, which utilizes the Marketplace platform to trade licensed spectrum resources, configure the RAN elements of the relevant network slices accordingly, and monitor associated SLAs for breach verification.
3. Use Case 3 (UC3): Pervasive virtual Content Distribution Network (vCDN) Services, which covers the smart selection of resource offers from the Marketplace and the subsequent orchestrated provisioning and management of virtual CDN services, based on the developments of the first two use cases. Specifically, the goal is to evaluate the overall scalability of the vCDN service, in cases of different resource requirements, in order to maintain the required SLAs.

The document describes the details of the 5GBarcelona and 5TONIC testbeds that were used to validate the presented use case scenarios. These details refer to the actual components that are in use in the testbeds for 5GZORRO's purposes as well as the setup and configurations made in order to support the ongoing tests. Moreover, this deliverable contains results of the first tests executed for the three use cases with the intermediate release of the 5GZORRO platform components.

More specifically, the test cases of UC1 focus on providing the necessary mechanisms for trusted frictionless leasing of 5G resources and services within the 5GZORRO marketplace. The first set of tests, UC1.1 through UC1.3, measured KPIs associated with the onboarding of multiple stakeholders into the Marketplace including an Admin, Resource and Service Providers, and a Resource Consumer. Unique Decentralized Identifiers and permissions of the associated roles have been verified through the Portal and reported in the respective test tables in Section 3. In summary, the total time of processing the enrolment request measured 10s, and approval processing time 2s. The second set of UC1 tests presented in this deliverable, UC1.4, UC1.5, and UC1.13, look at resource/service offer creation and query in various scenarios including single and multiple offers, as well as offers composed of resources from multiple resource providers. KPIs related to offer creation and publishing times are presented and analysed in Section 3.2.1.4. The additional UC1 tests not reported in this deliverable incorporate 5GZORRO Platform components and features that are under development and will be performed and reported in deliverable D5.3.

For what concerns UC2, the intermediate results are oriented towards demonstrating the different capabilities of the necessary stakeholders for spectrum sharing and trading, naming spectrum resource provider, radio resource provider, resource consumer, and regulator. On a first set of tests (UC2.1 to UC2.4), the four different roles were on-boarded in the 5GZORRO platform, with similar outcomes and KPIs to those reported in UC1.1 to UC1.3 tests. Special attention was given to spectrum resource creation tests, since the spectrum is the only resource in the 5GZORRO platform that requires separate credentials (spectrum

certificate) and the explicit approval of these credentials by the Regulator. Test UC2.5a demonstrated the process by which the spectrum resource provider could send requests to the 5GZORRO platform to create a spectrum certificate. Processing a spectrum certificate request measured 10s average, and approval processing time 2s. In a further step, it was demonstrated via the Portal that the resource providers could register spectrum and radio resources (Test UC2.5b and Test UC2.7a) and create product offers out of them (Test UC2.5c and Test UC2.7b) or combine both types of resources in a slice service product (Test UC2.7c). Spectrum and radio resource offer creation and query provided similar results to the those reported in UC1.4, UC1.5, and UC1.13 for other kind of resources. The additional UC2 tests not reported in this deliverable incorporate 5GZORRO Platform components and features that are currently under development and will be performed and reported in deliverable D5.3. That being said, UC2 showed that the 5GZORRO platform is 5G-ready by deploying an operational 5G slice and automatically configure the radio infrastructure. For a 5G SA cell with 50MHz of bandwidth and numerology one, a User Equipment (UE) measured a maximum downlink throughput of 370Mbps on the radio segment, and a minimum latency of 9ms.

In UC3, the tests are focused on a single but complex scenario, which elaborates on the majority of 5GZORRO's services. The main idea is to monitor a CDN slice provided by a Communication Service Provider (CSP) (Test UC3.1a) and, based on the monitoring data and the anticipated future performance (Test UC3.1b), to decide on the slice expansion into a 3rd parties compute resource. This resource is selected from a number of offers available in a common marketplace (Test UC3.1c). In the end, the original slice is extended into the 3rd party infrastructure provider, where a new CDN server is instantiated (Test UC3.1d and Test UC3.1e). Each step of the scenario entails different platform components and, therefore, it is designed as an individual test evaluating the performance of the involved components. The tests verified that all the steps of the scenario can be performed. In respect to the slice creation and extension, the time of the application components deployment and the latency between Central CDN Server and Edge Servers were calculated and found to be within the boundaries set by the KPIs targets. Another key aspect evaluated in the tests was the prediction of a performance degradation, which eventually leads to the search of new resources. For this, a Machine Learning (ML) model with an accuracy of 97% was used. Additional tests were performed in order to verify the e-licensing validation and verification when instantiating a vCDN edge cache (Section 5.2.3). In this case, it was possible to verify that the slice orchestrator component requests the licensing validation before completing the instantiation of the vCDN edge cache. A positive test, i.e., with license confirmation and a negative test, i.e., with license that should not be confirmed, were deployed successfully. Additional tests are also planned to be executed and reported in D5.3 (Section 5.2.2), for what concerns a scenario where acquired 3rd party resources are both compute and RAN resources.

In summary, as main outcome of this deliverable, the test results cover all the three 5GZORRO use cases and allow to produce a preliminary analysis of the 5GZORRO benefits. The following table provides a highlight of the main relevant KPIs achieved (with reference to those identified and listed in D5.1) as part of the validation activities reported in this document. For each KPI, the measurements that were noticed are reported. Non-measurable KPIs, as well as those for which it was not possible to extract exact measurements, are marked as *PASSED*, indicating that the KPIs were satisfied. Moreover, few KPIs are marked with *PARTIALLY PASSED*, when only part of the related tests was executed so far and reported in this document. Indeed, the activities will be continued, aiming at testing the future and final releases of the 5GZORRO platform. The complete report on the validation of the whole set 5GZORRO KPIs will be reported in deliverable D5.3.

Table 1-1: Summary of KPIs achieved in D5.2

Specific KPI	Use case in scope	Result
[KPI1.1.1] New Resource Providers, Resource Consumers, Service Providers are enrolled into the platform.	UC1 UC2	PASSED [1 to 4 stakeholders enrolled]

Specific KPI	Use case in scope	Result
[KPI1.1.2] Each stakeholder participating in the 5GZORRO Marketplace is approved	UC1 UC2	PASSED
[KPI1.1.3] Acceptance/rejection (consensus) when joining of a new node to the DLT network should be completed in less than 15 minutes.	UC1 UC2	PASSED [The processing of the request has been measured as 10 - 11s, and approval has been measured as 2s.]
[KPI1.1.4] All actors have a unique identity that derives from their organisation's identity. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services.	UC1 UC2	PASSED
[KPI1.1.5] The process of bootstrapping a DLT node and provisioning 5GZORRO services should take no longer than 1 hour. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services.	UC1 UC2	PASSED
[KPI3.1.1] Smart Contract for 3 or more 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.	UC1 UC3	PARTIALLY PASSED [Part of the related tests are planned for D5.3]
[KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger).	UC1 UC3	PARTIALLY PASSED [Part of the related tests are planned for D5.3]
[KPI4.2.9] [KPI-UC3.1] Deployment time for application components (VNFs, CNFs) < 5 mins	UC3	PASSED [75 s]
[KPI4.2.10] [KPI-UC3.2] Deployment time for the complete graph of CDN application < 90 mins	UC3	PASSED
[KPI4.2.11] [KPI-UC3.3] Network Slice creation time < 3mins	UC3	PASSED
[KPI4.2.14] [KPI-UC3.6] Latency between Central CDN Server & Edge Server < 20ms	UC3	PASSED [0.3 – 1.1 ms]
[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	PASSED [5 spectrum certificate requests/minute and 30 spectrum certificate request decisions / minute]

Specific KPI	Use case in scope	Result
[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.	UC2	PASSED [Determined during on-boarding process]
[KPI7.1] Lab validation	UC1, UC2, UC3	PASSED
[KPI7.1] Demonstration of the three use cases in relevant testbed at 5GBarcelona and 5TONIC	UC1, UC2, UC3	PARTIALLY PASSED [Validated in 5GBarcelona only so far]

1. Introduction

The 5GZORRO project aims at implementing a 5G platform that can allow different stakeholders, in different geographical areas, to trade heterogeneous resources, such as spectrum, computing, network, Virtual Network Functions (VNFs) etc, and to use them to create 5G services on top. Three use cases have been defined and are being implemented in the project in order to validate the 5GZORRO platform. Namely, these use cases are:

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

The scenarios and requirements arising from each of the use cases are analysed in deliverables D2.1 [1], D2.3 [2], while D5.1 [3] provides detailed validation plans for the three use cases, including test scenarios, test plans and KPI measurement methodology. In particular, D5.1 represents the main baseline for the work reported in this document, as D5.1 introduces all the test cases that were initially scheduled. In the present document, the same tests are updated and presented in more depth. However, not all of them have been completed so far and, thus, the results presented in this this deliverable refer to a subset of the overall tests.

More analytically, this document includes an updated description of the infrastructure provided by the two target testbeds, i.e., 5GBarcelona Labs and 5TONIC. The deployment of the 5GZORRO platform components into the testbeds for the purposes of the use cases validation is already described in D5.1 [3], and it is still applicable. The current document focuses on the actual implementation of the use cases validation scenarios, reporting on the execution of tests and KPI measurements campaigns as identified in D5.1 [3]. For this, it contains refined descriptions of the D5.1 test cases, as well as first intermediate results for a subset of them. In general, for each use case and for each scenario of the use case (as described in previous deliverables), a number of tests are defined. These tests represent either individual steps of the overall scenario or simpler scenarios derived from the initial ones.

More specifically, UC1 trials focus on providing the mechanisms needed for reliable leasing of 5G resources and services within the 5GZORRO market. Additionally, some of the test cases examine the generation of a resource or a service offer as well as the process of querying offers.

Regarding UC2, it focuses on demonstrating the different capabilities of the spectrum sharing and marketing as well as the stakeholders involved. Different roles are integrated into the 5GZORRO platform. A special type of resource studied in this UC is spectrum. What makes spectrum special is the fact that it is the only resource that requires separate credentials and explicit approval of these credentials by a Regulatory Authority.

Finally, the main idea of UC3 refers to the extension of a CDN network slice based on monitoring data and expected future performance. This extension takes place to resources provided by a 3rd party infrastructure provider. The resources are selected from a number of available resource offers in the marketplace. Machine Learning algorithms are used in generating predictions for the future CDN performance as well as in selecting a resource offer.

All use case tests reported incorporate the available components and features of the 5GZORRO platform. For each use case, a common table template is used to report on the test execution. In particular, this table template provides the following test case information:

- Short description of the test
- Testbed(s) where the test has been executed
- Use case functionalities under test
- Key related use case requirements and KPIs

- 5GZORRO platform components involved
- Test procedure to follow for the test execution, including pre-conditions and step-wise description of the actions to be implemented
- KPI measurements, including the methodology followed and the calculation process
- Execution results

Moreover, as anticipated, this deliverable reports on the intermediate use case validation results, and therefore a subset of the KPIs identified and listed have been measured and assessed so far. The 5GZORRO use case validation work will continue as part of WP5 activities and final results will be reported in deliverable D5.3.

1.1. Document outline

The document's structure is the following:

- **Section 2** provides details on the 5GBarcelona and 5TONIC testbeds as well as on the infrastructure setup used in the tests.
- **Sections 3, 4 and 5** elaborate on the description of Use Cases 1, 2 and 3, respectively. They also analyse the validation scenarios and the initial tests planned and executed for each use case. Moreover, for use cases 1 and 3, the security and trust establishment are explained.
- **Section 6** concludes the document, summarizing the results from the initial tests.

2. 5GZORRO Testbeds

The 5GZORRO project makes use of two different testbed which are physically located in Spain and located in two different cities: 5GBarcelona in Barcelona, and 5TONIC in Madrid. There are few differences between both testbeds, due to the fact that radio infrastructure in Madrid is shared, and requires to be booked in advance. For this reason, the 5GZORRO radio-related resources and validation activities are mainly hosted and carried out in 5GBarcelona. Other than that, the two testbeds implements a similar logical infrastructure, implemented over two different hardware configurations (representing real life scenarios in which operators build their infrastructures following their needs). It is worth to mention that the 5GZORRO testbeds have been interconnected, offering the possibility of testing more elaborated scenarios and configurations.

The following subsections describe these two testbeds and their infrastructures, focusing on the main updates with respect to the descriptions provided in D5.1 [1].

2.1. 5GBarcelona Infrastructure for 5GZORRO

2.1.1. Infrastructure used for the tests

5G Barcelona testbed remains almost unaffected with respects to what it was described in D5.1 [1]. However, the following updates have been implemented:

- The addition of a new server that will be taking the role of a VIM (Virtual Infrastructure Manager). Operator services will be deployed in the VIM.
- 5G Barcelona and 5TONIC testbeds have been interconnected. The established link allows for a secure connection for both the data plane and the control plane communications. It enables richer use cases, with multiple operator domains distributed across the two testbed sites, allowing cross-testbed interactions. Moreover, 5GZORRO services deployed and running across testbeds can exchange data to fulfil the use case requirements and scenarios. For that connection to be secure, a dedicated VPN has been setup.

Figure 2-1 provides a diagram of the 5GBarcelona testbed in i2CAT premises, with updated information on the use of the VIM (deployed in the Omega building) and illustrating the connectivity with 5TONIC testbed in Madrid.

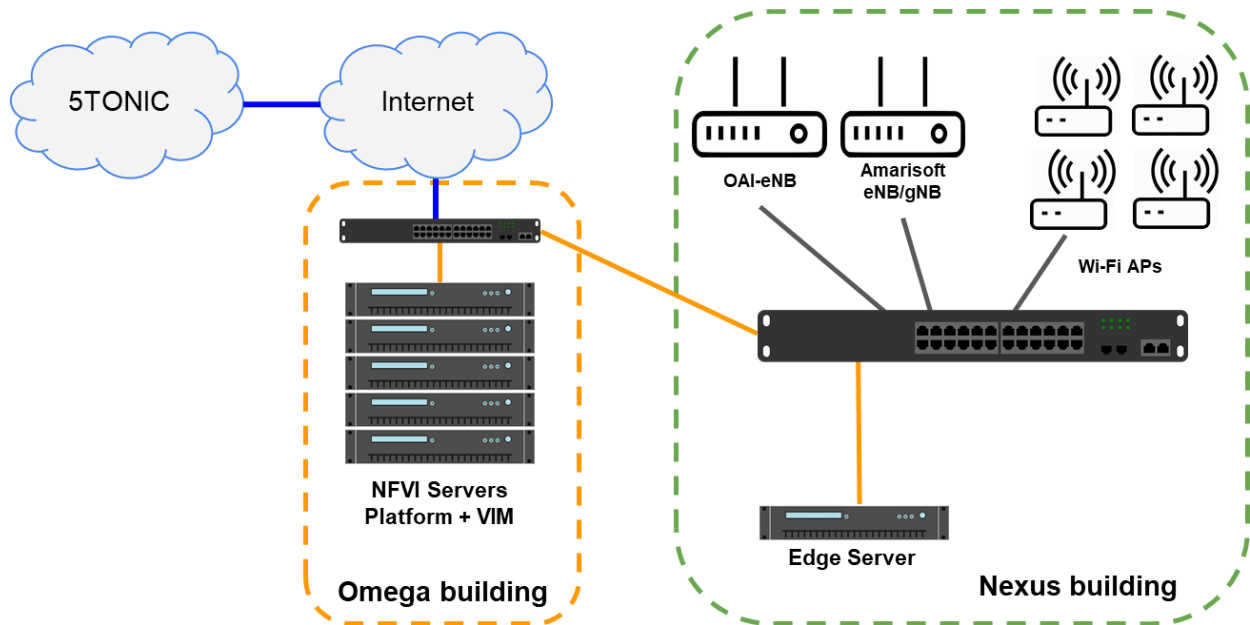


Figure 2-1: Updated 5G Barcelona testbed diagram (in i2CAT premises), and interconnectivity with 5TONIC testbed

2.1.2. 5GZORRO platform setup

The 5GZORRO platform setup in 5GBarcelona remains almost the same as compared with what was described in D5.1. There have been some updates in some of the components, but mainly in the deployment mechanism, from being deployed into a Virtual Machine (VM) in Openstack [6], to be now part of some of the available Kubernetes [5] clusters in the platform. In particular, catalogue and slice manager engine are now deployed as containers inside the platform components Kubernetes cluster.

Also, the ETSI OSM [4] used in 5GBarcelona has been upgraded to release 10 (from release 8) to make use of the new features added, as for example the use of ETSI NFV SOL006 standard formats for the NFV Network Service and VNF descriptors.

In terms of users, the platform now hosts up to 3 different operators and a spectrum regulator, to play the different roles specified in the various use cases. At the time of writing of this deliverable, the platform hosts 3 operators and 1 regulator. One of the operators acts both as an Admin and trader, while the other two act as traders only. These different operators are isolated using Kubernetes namespaces, which allows to share the same infrastructure but ensuring isolation in terms of resources and 5GZORRO platform components deployed among the different operators. Figure 2-2 shows the platform's logical view, and depicts the different Kubernetes clusters as well those services and components running as VMs on Openstack. The VIM server, in which services are deployed, can also be seen on the right-hand side of the picture. Lastly, 5GZORRO has successfully managed to deploy an open source 5G Core, free5GC [7], which can also be seen in the bottom right part of the diagram.

5GBarcelona Testbed

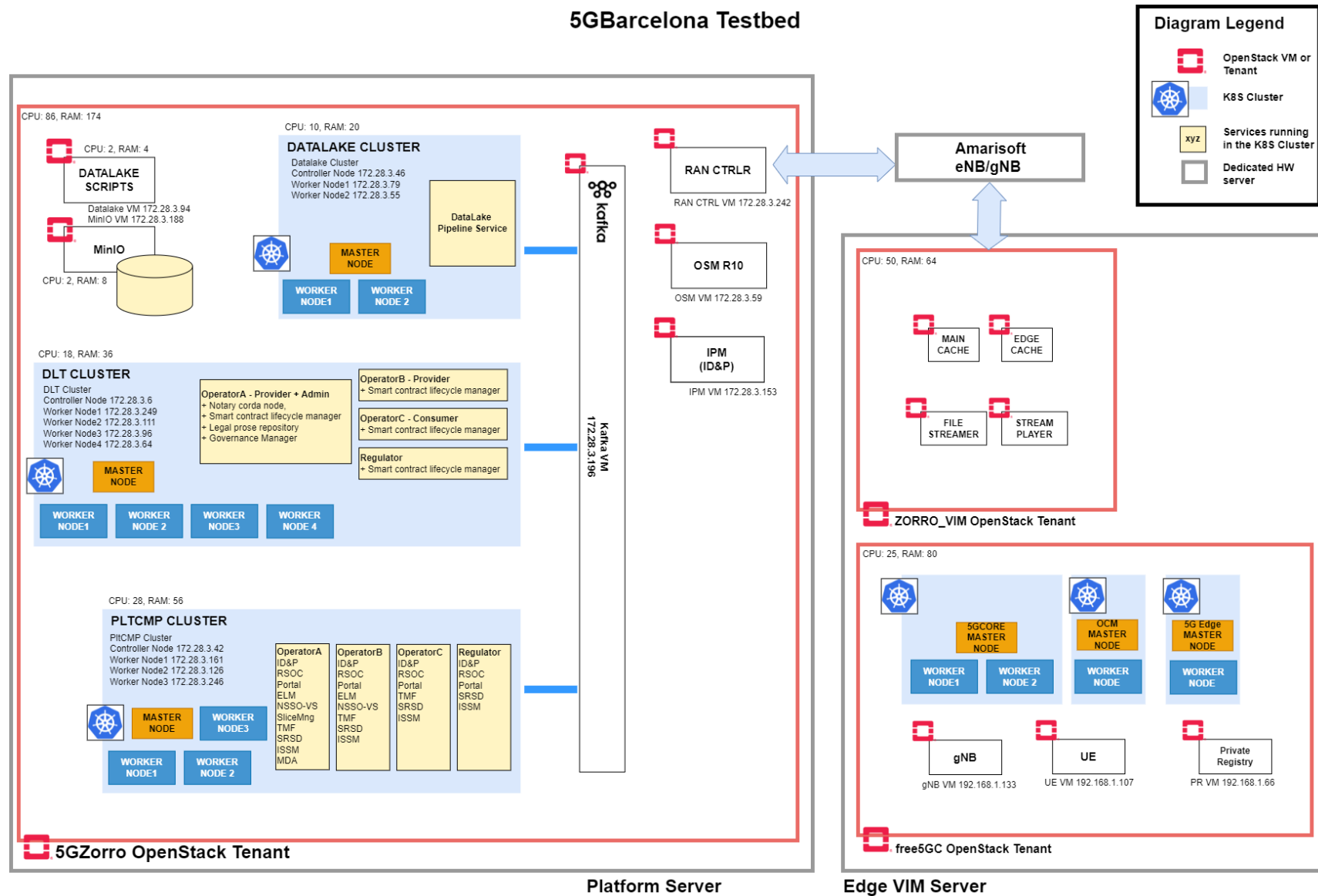


Figure 2-2: 5GBarcelona Testbed

The following table shows the sizing and dimensioning for the different Kubernetes clusters deployed in the platform server in the testbed.

Table 2-1: Dimensions of the Kubernetes clusters in the platform server

Cluster name	Node	vCPU	RAM(GB)	Disk(GB)
Datalake Cluster				
	Master	2	4	30
	Worker1	4	8	30
	Worker2	4	8	30
DLT Cluster				
	Master	2	4	40
	Worker1	4	8	60
	Worker2	4	8	60
	Worker3	4	8	60
	Worker4	4	8	60
PlatCmp Cluster				
	Master	4	8	20
	Worker1	8	16	40
	Worker2	8	16	40
	Worker3	8	16	40

2.2. 5TONIC Infrastructure for 5GZORRO

2.2.1. Infrastructure used for the tests

As already outlined in D5.1 [1], the use of the available resources on the 5TONIC testbed requires to prepare an experiment description (including required resources and time frame) to be approved by the 5TONIC Board so that it can be included into the testbed schedule. In this context, and after analysing and describing the potential experimentation requirements involved in the development and validation of the use cases defined in the following chapters, Figure 2-3 illustrates the identified and selected computing resources of the 5TONIC testbed.

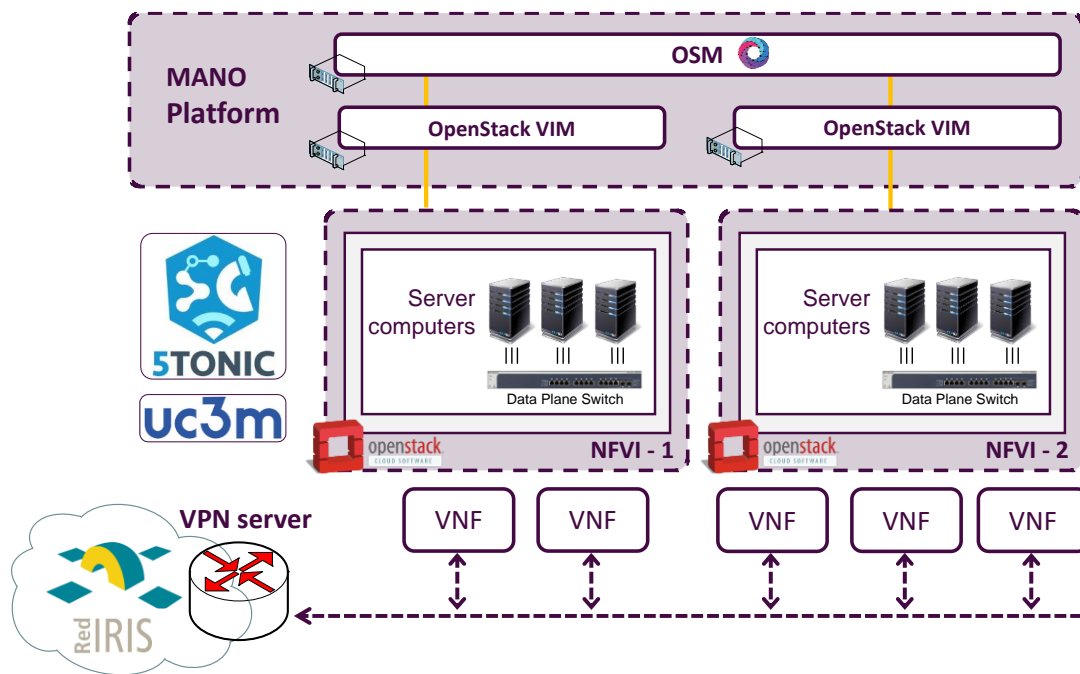


Figure 2-3: Approved computing resources of 5TONIC testbed for 5GZORRO

These resources include an NFV Management and Orchestration (MANO) platform that was deployed through a set of Virtual Machines (VMs) based on Open-Source MANO [4] and OpenStack [6]. Thus, this setup allows to have two independent NFV infrastructures (NFVIs), which are based on server computers with different computing capabilities with the aim of supporting different types of multi-site experiments. In addition, the virtualization of the components comprising the MANO platform allows to easily evolve and/or extend it (e.g., by incorporating additional entities to perform experimentation activities with different NFV domains).

The available computing capabilities of these individual infrastructures at 5TONIC for 5GZORRO are detailed in next table:

NFVI-1	NFVI-2
1x Physical Node (Executing OpenStack Wallaby Controller as a VM): <ul style="list-style-type: none"> - Dell server model PowerEdge R630. - 2x Intel Xeon CPU E5-2620 v4 @ 2.1GHz, 8 cores/16 threads. - 4x 32GB RDIMM RAM (2400MT/s). - 2x 1TB NLSAS and 2x 2TB. - 1x Intel i350 4xGbE with DPDK support. - 2x 10GbE optical transceivers SFP+ with SR-IOV capabilities. 	1x Physical Node (Executing OpenStack Wallaby Controller as a VM): <ul style="list-style-type: none"> - Dell server model PowerEdge R430. - 1x Intel Xeon CPU E5-2609 v4 @ 1.7 GHz, 8 cores/8 threads. - 2x 32GB RDIMM RAM (2400MT/s). - 2x 1TB NLSAS. - 1x Intel i350 4xGbE with DPDK support.
2x Physical NFVI Nodes (OpenStack Wallaby compute-node): <ul style="list-style-type: none"> - Dell server model PowerEdge R440. 	3x Physical NFVI Nodes (OpenStack Wallaby compute-node): <ul style="list-style-type: none"> - Dell server model PowerEdge R430.

<ul style="list-style-type: none">- 2x Intel Xeon Silver 4114 CPU @ 2.20GHz, 10 cores/20 threads.- 2x 32 GB RDIMM RAM (2666 MT/s).- 4x 4TB NLSAS.- 1x Intel i350 4xGbE ports with DPDK support.- 2x 10GbE optical transceivers SFP+ with SR-IOV capabilities. 1x Broadcom 5720 2xGbE ports.	<ul style="list-style-type: none">- 1x Intel Xeon CPU E5-2609 v4 @ 1.7 GHz, 8 cores/8 threads.- 2x 32GB RDIMM RAM (2400MT/s).- 2x 1TB NLSAS.- 1x Intel i350 4xGbE with DPDK support.
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Table 2-2: Detailed computing resources available at 5TONIC

Complementary to the above-mentioned computing resources, and following the methodology defined in [8], 5TONIC has enabled a secure link to support communications between the two testbeds involved in the project (*i.e.*, 5G Barcelona and 5TONIC testbeds) through its VPN service. This link is not only intended to communicate those virtualised functions that are deployed to provide the specific services defined under the umbrella of the different use cases from a data plane perspective, but also to enable the communications that may occur in the control plane. This latter would allow to implement the modules composing the 5GZORRO platform in a distributed manner between both testbeds, and to support their interoperations with the aim of providing the overall platform functionality. Moreover, this VPN service allows the 5GZORRO Platform developers to access to the allocated resources at 5TONIC to carry out the installation, configuration and development of the particularities of each module of the platform.

2.2.2. 5GZORRO platform setup

The distribution of the previously described computing resources available at 5TONIC (see Table 2-2) for 5GZORRO throughout two independent NFVIs allows to allocate a portion of those resources to realize the installation and configuration of the different modules encompassed by the 5GZORRO Platform. Thus, the components comprising the 5GZORRO Platform can be easily evolved and/or extended through this virtualization approach. For this purpose, a tenant has been created in the NFVIs implemented with OpenStack in order to assign the requested number of resources for the deployment of the platform's components and isolate them from the rest of the virtualised functions hosted by these multi-tenancy infrastructures (*e.g.*, from the virtual network functions or service applications deployed for the realization of the experimentation activities of the use cases).



5TONIC Testbed - 5GZORRO Platform

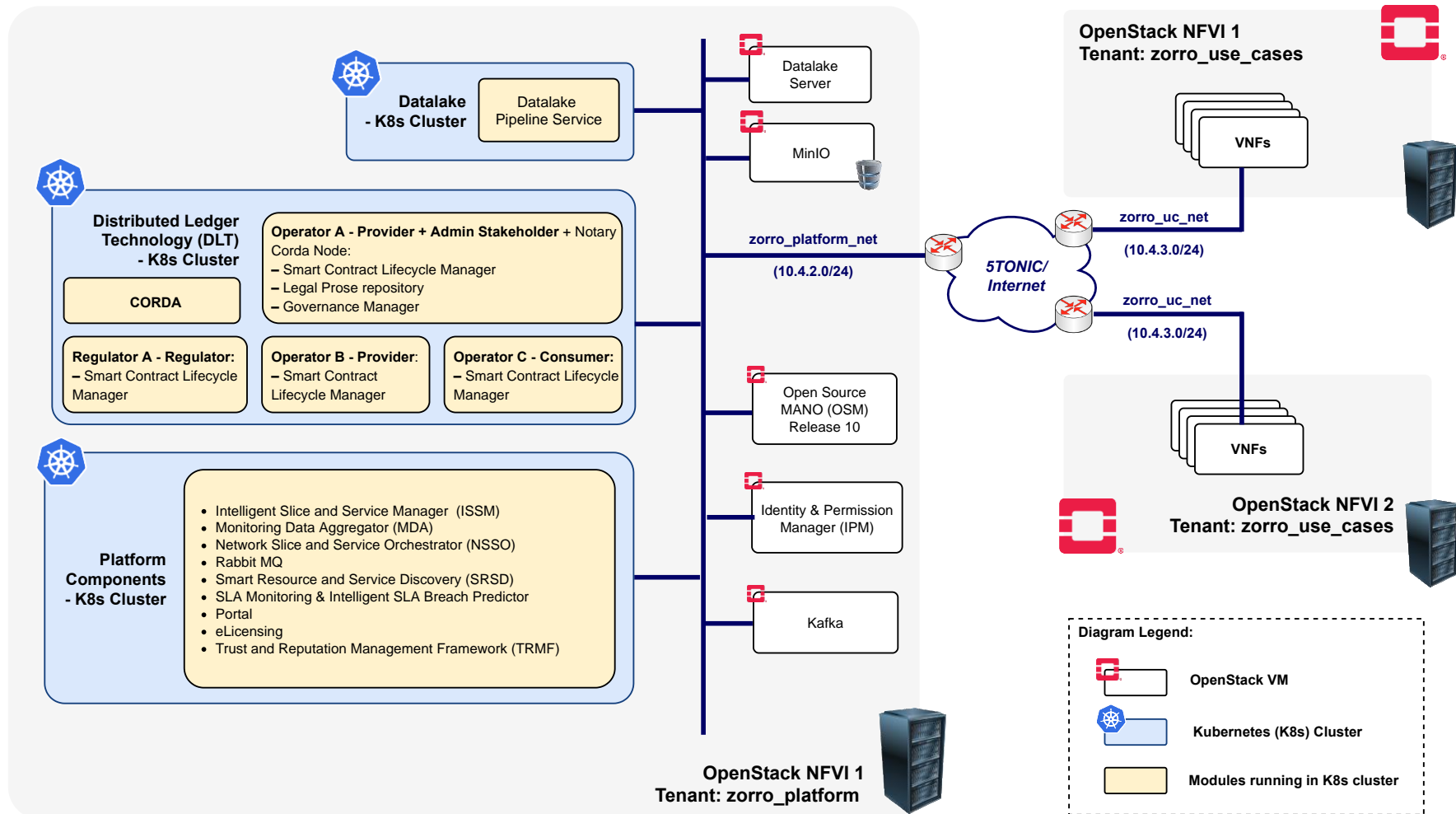


Figure 2-4: Overview of the 5GZORRO platform logical components at 5TONIC testbed

Figure 2-4 illustrates the portion of allocated resources (in terms of compute, storage and network) supporting the execution of different VMs that will host the source code for provisioning the functionality of the different modules. It is worth noting that several of these VMs have been used to support the creation of different clusters based on Kubernetes [5], which will be responsible for enabling the execution of the micro-services included within the platform of the project. In this regard, three standalone Kubernetes clusters have been created: one referred to as Platform Components Cluster, which will be responsible for hosting different modules of the platform whose development has been based on this containerization cloud technology; another cluster designated as DLT Cluster, which will be responsible for gathering the modules defined in the scope of the project to offer the functionality of a Distributed Ledger Technology (DLT) framework; and the Datalake cluster, hosting the functionalities defined within the so called module *Data-lake*. The Table 2-3 presents the technical specification in terms of computational resources utilized to build up the three mentioned clusters.

At the time of writing, the logical components of the 5GZORRO platform have been installed and configured within the 5TONIC testbed, replicating the design and implementation principles lined during their installation within the 5G Barcelona testbed. Thus, it would be possible to analyse not only the portability of the platform to be deployed in heterogeneous infrastructures with different resource capabilities, but also to explore the potential benefits of supporting the interoperation among different instances of the platform.

To allow developers to access their allocated resources corresponding to the individual modules, the systems administration team of 5TONIC provides the appropriate credentials of the VPN service. Once the developers execute the respective VPN credentials, they will have IP connectivity to access to the module through a secure channel (*e.g.*, accessing via SSH) to perform the installation and configuration activities according to the specific module requirements. In the case of the modules developed as components of any of the aforementioned clusters, 5TONIC also provides the appropriate configuration file (in this case, the file Kubernetes configuration file denoted as *kubeconfig*) that leverages the IP connectivity offered by the VPN service to enable the interaction of the developers with the corresponding cluster.

Cluster Name	Node	vCPUS	RAM (GB)	Disk (GB)
Platform Components	Controller	4	8	20
	Worker 1	8	16	30
	Worker 2	8	16	30
	Worker 3	8	16	30
DLT	Controller	2	4	40
	Worker 1	4	8	50
	Worker 1	4	8	50
	Worker 3	4	8	50
	Worker 4	4	8	50
Datalake	Controller	2	4	20
	Worker 1	4	8	30

	Worker 2	4	8	30
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Table 2-3: 5TONIC Testbed - Kubernetes clusters resource information

3. UC1: Smart Contracts for Ubiquitous Computing/Connectivity

3.1. Description

Use Case 1 (UC1) is focused on 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. The 5GZORRO 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 [1].

3.1.1. Specific security and trust validation aspects

UC1 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, the use case validation tests focus on demonstrating their role in realising a decentralised product catalogue, establishment and enforcement of agreement/SLA contract terms and 5G slice establishment.

3.2. Use Case 1 scenarios

The scenarios identified in D5.1 [3], and reported in the following sections, are designed 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. The goal of the scenarios is to demonstrate the trust and autonomy that underpin the 5GZORRO marketplace, achieved through the utilisation of smart contracts and distributed ledger. Table 3-1 lists the tests reported in this deliverable (according to the test plan reported in D5.1), along with tests that incorporate 5GZORRO Platform components and features that are under development and will be performed and reported in deliverable D5.3.

Table 3-1 List of UC1 tests with results in D5.2 and test postponed to D5.3

Tests in scope of D5.2	Tests planned for D5.3
Test UC1.1a Resource provider on-boarding	Test UC1.6a Approval of an Agreement Legal Prose Template
Test UC1.1b Additional resource provider on-boarding	Test UC1.6b Approval of an Agreement Legal Prose Template including multiple service providers
Test UC1.2 Resource consumer on-boarding	Test UC1.7a Approval of an SLA Legal Prose Template
Test UC1.3 Governance admin on-boarding	Test UC1.7b Approval of an SLA Legal Prose Template including multiple service providers
Test UC1.4a Resource offer creation	Test UC1.8a Approval of a licensing agreement template
Test UC1.4b Service offer creation	Test UC1.8b Approval of a licensing agreement template including multiple service providers
Test UC1.5 Multi provider resource offer creation	Test UC1.9a Agreement creation template including multiple service providers
Test UC1.13a Simple query request by Service Consumer	Test UC1.9b Agreement creation template including multiple service providers
Test UC1.13b Simple query request by Service Consumer including offers from multiple Providers	Test UC1.10a SLA creation
	Test UC1.10b SLA creation including multiple service providers

	Test UC1.11 Product offer creation
	Test UC1.12 Multi provider Product offer creation
	Test UC1.14a Intelligent resource discovery query by Resource Consumer
	Test UC1.14b Intelligent resource discovery query by Resource Consumer including offers from multiple Providers
	Test UC1.15 Resource Consumer purchases a Product Offer
	Test UC1.16 Resource Consumer purchases multiple Product Offers from multiple provider
	Test UC1.17 SLA Breach detected
	Test UC1.18 Scaling action is attempted and blocked
	Test UC1.19 Agreement termination
	Test UC1.20 SLA Breach prediction

3.2.1. Scenario 1.1: Slice composition from a single provider

In Scenario 1.1, a Resource Consumer/Service Provider leases a set of resources from a single Resource Provider to create multi-resource services in the Marketplace. This represents the base scenario for the use case, demonstrating marketplace utilisation to support multi-resource slice establishment backed by a smart contract bi-lateral agreement and associated SLAs. A full description of the test Scenario can be found in D5.1.

3.2.1.1. Test UC1.1a: Resource provider on-boarding

Table 3-2: Resource provider on-boarding

UC1.1a	Resource provider on-boarding	
Testbed	5G Barcelona	
Description	Resource Provider is onboarded to the marketplace	
Use-case functionalities	User and Organisation On-Boarding	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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.) <ul style="list-style-type: none"> • [KPI1.1.1] New Resource Providers, Resource Consumers, Service Providers are enrolled into the platform. • [KPI1.1.2] Each stakeholder participating in the 5GZORRO Marketplace is approved • [KPI1.1.3] Acceptance/rejection (consensus) when joining of a new node to the DLT network should be completed in less than 15 minutes. • [KPI1.1.4] All actors have a unique identity that derives from their organisation's identity. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. • [KPI1.1.5] The process of bootstrapping a DLT node and provisioning 5GZORRO services should take no longer than 1 hour. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. 	
Components	Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal	
Test Procedure	Pre-conditions	A Governance admin has been onboarded into the Portal

	Test Case steps	<ol style="list-style-type: none"> 1. Resource Provider accesses 5GZorro Portal and navigates to "Create New Account" page 2. Resource Provider selects the "Trader" role, the assets to provide and inputs his personal information (name, email and address) 3. Resource Provider sends a registering request by clicking on "Register" and receives his StakeholderDID 4. Resource Provider navigates to login page and tries to login 5. The Portal displays a message with the information that the account is not approved yet 6. Governance admin logs in the Portal 7. Governance admin navigates to his private interface showing all stakeholder certificates pending for approval 8. Governance admin approves the Resource Provider onboarding certificate 9. Resource Provider logs into 5GZORRO system with his StakeholderDID
Measurements	Methodology	Visually inspect that the Portal is active and the Trader interfaces are shown.
	Complementary measurements	UC1.3
	Calculation process	The available logs were used to measure the time it took to process the request, check on DB the time it took change to an approved state
Result	<ul style="list-style-type: none"> • [KPI1.1.1] <u>2 stakeholders are active in the Marketplace:</u> <ul style="list-style-type: none"> •Operator A acting as a Governance admin and as a Resource provider is enrolled •Operator B acting as a Resource provider is enrolled • [KPI1.1.2] Resource Provider is approved and joins the Marketplace • [KPI1.1.3] <u>The processing of the request has been measured as 10s, and approval has been measured as 2s.</u> • [KPI1.1.4] Onboarded actors are assigned a unique Decentralized Identifier. Permissions have been checked through the portal • [KPI1.1.5] Permissions have been checked through the portal 	

3.2.1.2. Test UC1.2: Resource consumer on-boarding

Table 3-3: Resource consumer on-boarding

UC1.2	Resource consumer on-boarding
Testbed	5G Barcelona
Description	Resource Consumer is onboarded to the marketplace
Use-case functionalities	User and Organisation On-Boarding
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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.) <ul style="list-style-type: none"> ○ [KPI1.1.1] New Resource Providers, Resource Consumers, Service Providers are enrolled into the platform. ○ [KPI1.1.2] Each stakeholder participating in the 5GZORRO Marketplace is approved ○ [KPI1.1.3] Acceptance/rejection (consensus) when adding a credential to the DLT network should be completed in less than 15 minutes.

	<ul style="list-style-type: none"> ○ [KPI1.1.4] All actors have a unique identity that derives from their organisation's identity. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. • [KPI1.1.5] The process of bootstrapping a DLT node and provisioning 5GZORRO services should take no longer than 1 hour. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. 	
Components	Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal	
Test Procedure	Pre-conditions	A Governance admin has been onboarded into the Portal
	Test Case steps	<ol style="list-style-type: none"> 1. Resource Consumer accesses 5GZorro Portal and navigates to "Create New Account" page 2. Resource Consumer selects the "Trader" role, the assets to consume and inputs his personal information (name, email and address) 3. Resource Consumer sends a registering request by clicking on "Register" and receives his StakeholderDID 4. Resource Consumer navigates to login page and tries to login 5. The Portal displays a message with the information that the account is not approved yet 6. Governance admin logs in the Portal 7. Governance admin navigates to his private interface showing all stakeholder certificates pending for approval 8. Governance admin approves the Resource Consumer onboarding certificate 9. Resource Consumer logs into 5GZORRO system with his StakeholderDID
Measurements	Methodology	Visually inspect that the Portal is active and the Trader interfaces are shown.
	Complementary measurements	UC1.1, UC1.3
	Calculation process	The available logs were used to measure the time it took to process the request, check on DB the time it took change to an approved state
Result	<ul style="list-style-type: none"> • [KPI1.1.1] <u>3 stakeholders are active in the Marketplace:</u> <ol style="list-style-type: none"> 1. Operator A acting as Governance admin and Resource Provider is enrolled 2. Operator B acting as a Resource Provider is enrolled 3. Operator C acting as Resource Consumer is enrolled • [KPI1.1.2] Resource Consumer is approved and joins the Marketplace • [KPI1.1.3] <u>The processing of the request has been measured as 10s, and approval has been measured as 2s.</u> • [KPI1.1.4] Onboarded actors are assigned a unique Decentralized Identifier. Permissions have been checked through the portal • [KPI1.1.5] Permissions have been checked through the portal 	

3.2.1.3. Test UC1.3: Governance admin on-boarding

Table 3-4 Governance admin on-boarding

UC1.3	Governance admin on-boarding
Testbed	5G Barcelona
Description	Governance admin is onboarded to the marketplace and added to the governance board
Use-case functionalities	User and Organisation On-Boarding

Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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.) <ul style="list-style-type: none"> ○ [KPI1.1.1] New Resource Providers, Resource Consumers, Service Providers are enrolled into the platform. ○ [KPI1.1.2] Each stakeholder participating in the 5GZORRO Marketplace is approved ○ [KPI1.1.3] Acceptance/rejection (consensus) when joining of a new node to the DLT network should be completed in less than 15 minutes. ○ [KPI1.1.4] All actors have a unique identity that derives from their organisation's identity. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. • [KPI1.1.5] The process of bootstrapping a DLT node and provisioning 5GZORRO services should take no longer than 1 hour. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. 	
Components	Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal	
Test Procedure	Test Case steps	The Governance Administrator joins the platform through bootstrap operations, which involve storing its own credential on the Blockchain Wallet
Measurements	Methodology	Visually inspect that the Portal is active and the Admin-exclusive interfaces are shown.
	Complementary measurements	None
	Calculation process	The available logs were used to measure the time it took to process the request, check on DB the time it took change to an approved state
Result	<ul style="list-style-type: none"> • [KPI1.1.1] 3 stakeholders are active in the Marketplace: 1.Operator A acting as Governance admin and Resource and Service Provider 2.Operator B acting as Resource and Service Provider 3.Operator C acting as Resource Consumer • [KPI1.1.2] Governance Admin is onboarded to manage new stakeholders who request to join the Marketplace • [KPI1.1.3] The processing of the bootstrap operation has been measured as <u>11 seconds</u> • [KPI1.1.4] Onboarded actors are assigned a unique Decentralized Identifier. Permissions have been checked through the portal • [KPI1.1.5] Permissions have been checked through the portal 	

3.2.1.4. Test UC1.4a: Resource/Service offer creation

In this test, the Resource Provider creates a Resource Offer describing a capability on the 5GZORRO marketplace via a smart contract, so that Resource Consumers can discover and consume those resources. Software Resource Offers may have licensing agreements associated.

Table 3-5: Resource offer creation

UC1.4a	Resource offer creation
Testbed	5G Barcelona
Description	Resource Provider creates Resource Offer to be offered in the Catalogue: <ul style="list-style-type: none"> • Edge Resource Offer (storage-compute-networking) • VNF Resource Offer

	<ul style="list-style-type: none"> • RAN Resource Offer 	
Use-case functionalities	Resource Provider creating a Resource Offer	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified. • [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) 	
Components and Configuration	Components	Identity & Permissions Manager Marketplace Portal Resource and Service Offer Catalogue Smart Contract Lifecycle Manager virtual Resource Managers
	Configuration	Descriptors for edge, RAN and VNF resources
Test Procedure	Pre-conditions	Resource Provider has been on-boarded onto the system
	Test Case steps	<ol style="list-style-type: none"> 1. Resource Provider Operator logs into 5GZORRO system. 2. Resource Provider Operator navigates to <i>Resource & Services</i> page that shows the list of available resources to include in the new offer. 3. Resource Provider Operator navigates to <i>Offer Creation</i> page. 4. Resource Provider Operator composes the offer by selecting Edge VNF RAN resource and defining its terms (e.g., location, category, validity period) and price. 5. Resource Provider Operator navigates to <i>My Offers</i> page and visualizes created offer.
Measurements	Methodology	KPI3.1.2 , offer creation time is defined as the time from submitting the request to the time the offer is published on the Marketplace DLT KPI4.1.2 , total time for offer publishing is defined as the time from when the offer is stored on the local Resource and Service Catalogue of the Resource/Service Provider creating the offer, to the time when the offer appears on all catalogues of registered Resource/Service Consumers KPI5.2 number of transactions handled by the Market is defined as the average times and standard deviations for the time from when the offer is stored on the local catalogue to the time the offer is published on the Marketplace DLT
	Complementary measurements	UC1.4b
	Calculation process	Tests performed using scripts to read timestamps
Result	See Table 3-7, Figure 3-1, Figure 3-2, and Figure 3-3	

Table 3-6: Service offer creation

UC1.4b	Service offer creation	
Testbed	5G Barcelona	
Description	Service Provider creates Service Offer to be offered in the Catalogue: <ul style="list-style-type: none"> • Network Slice Service • Network Service 	
Use-case functionalities	Service Provider creating a Service Offer	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified. • [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) 	
Components and Configuration	Components	Identity & Permissions Manager Marketplace Portal Resource and Service Offer Catalogue Smart Contract Lifecycle Manager virtual Resource Managers
	Configuration	Descriptors for Network Slice, and Network Service
Test Procedure	Pre-conditions	Service Provider has been on-boarded onto the system
	Test Case steps	<ol style="list-style-type: none"> 1. Service Provider Operator logs into 5GZORRO system. 2. Service Provider Operator navigates to <i>Resource & Services</i> page that shows the list of available resources to include in the new offer. 3. Service Provider Operator navigates to <i>Offer Creation</i> page. 4. Service Provider Operator composes the offer by selecting Network Service Slice service and defining its terms (e.g. location, category, validity period) and price. 5. Service Provider Operator navigates to <i>My Offers</i> page and visualizes created offer.
Measurements	Methodology	<p>KPI3.1.2, offer creation time is defined as the time from submitting the request to the time the offer is published on the Marketplace DLT</p> <p>KPI4.1.2, total time for offer publishing is defined as the time from when the offer is stored on the local Resource and Service Catalogue of the Resource/Service Provider creating the offer, to the time when the offer appears on all catalogues of registered Resource/Service Consumers</p> <p>KPI5.2 number of transactions handled by the Market is defined as the average times and standard deviations for the time from when the offer is stored on the local catalogue to the time the offer is published on the Marketplace DLT</p>
	Complementary measurements	UC1.4a

	Calculation process	Tests performed using scripts to read timestamps
Result	See Table 3-7, Figure 3-1, Figure 3-2, and Figure 3-3	

To address KPI3.1.2, the offer creation time is defined as the time from submitting the request to the time the offer is published on the Marketplace DLT. The total time for offer creation was measured for 3 different scenarios. The first involved 64 simultaneous requests for offer creations by a single resource/service provider, the second involved 128 simultaneous requests by a single resource/service provider, and the third involved 2 resource/service providers each making 64 requests simultaneously. The results are given in Table 3-7 under the 'Total time for offer creation' columns, and shown in Figure 3-1 .

The same 3 Operator scenarios were used to evaluate KPI4.1.1 and KPI5.2. For KPI4.1.1, the total time for offer publishing is defined as the time from when the offer is stored on the local Resource and Service Catalogue of the Resource/Service Provider creating the offer, to the time when the offer appears on all catalogues of registered Resource/Service Consumers. The results are given in Table 3-7 under the 'Total time for offer publishing' columns and shown in Figure 3-2. KPI5.2 measures the number of transactions handled by the Market, this was evaluated through the measurement of the average times and standard deviations for the time from when the offer is stored on the local catalogue to the time the offer is published on the Marketplace DLT. The results are given in Table 3-7 under the 'DLT publishing time' columns and shown in Figure 3-3.

From these measurements it has been found that the most significant contribution to resource/service offer creation comes from the Marketplace DLT publishing time. Further, as can be seen in Figure 3-1, Figure 3-2, and Figure 3-3, there is a linear increase in both offer creation and offer publication times when comparing 64 and 128 simultaneous requests.

Table 3-7: KPI measurements for UC1.4 and UC1.5

	Total time for offer creation		Local pre-storage time without DID		Local pre-storage time with DID		DLT publishing time		Total time for offer publishing	
	Average (sec)	STDEV (sec)	Average (sec)	STDEV (sec)	Average (sec)	STDEV (sec)	Average (sec)	STDEV (sec)	Average (sec)	STDEV (sec)
1 Operator 64 requests	20.91	8.19	1.90	1.28	2.35	1.15	16.66	8.01	30.13	12.12
1 Operator 128 requests	45.25	20.04	4.84	3.03	6.18	2.85	34.22	19.29	59.24	27.25
2 Operators 64 requests each	42.07	17.78	6.00	5.87	6.43	5.24	29.64	15.94	65.55	30.52

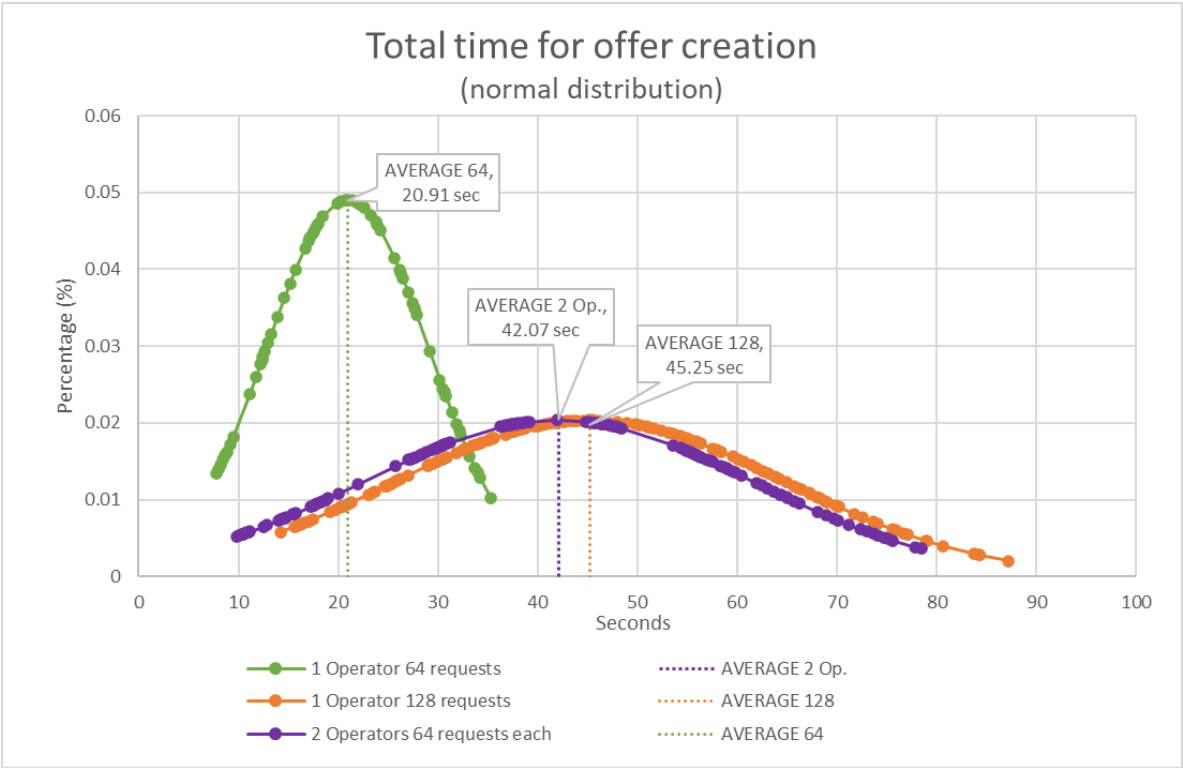


Figure 3-1: KPI3.1 Total time for offer creation

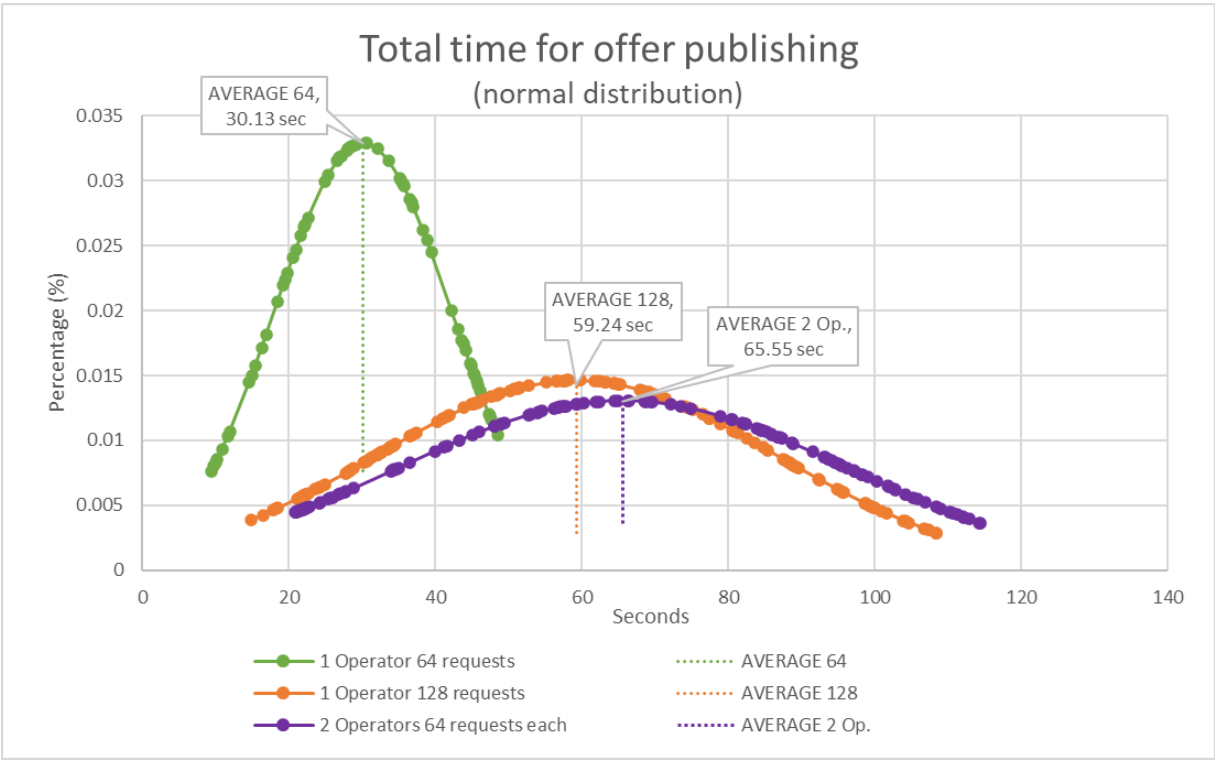


Figure 3-2: KPI4.1 Total time for offer publishing

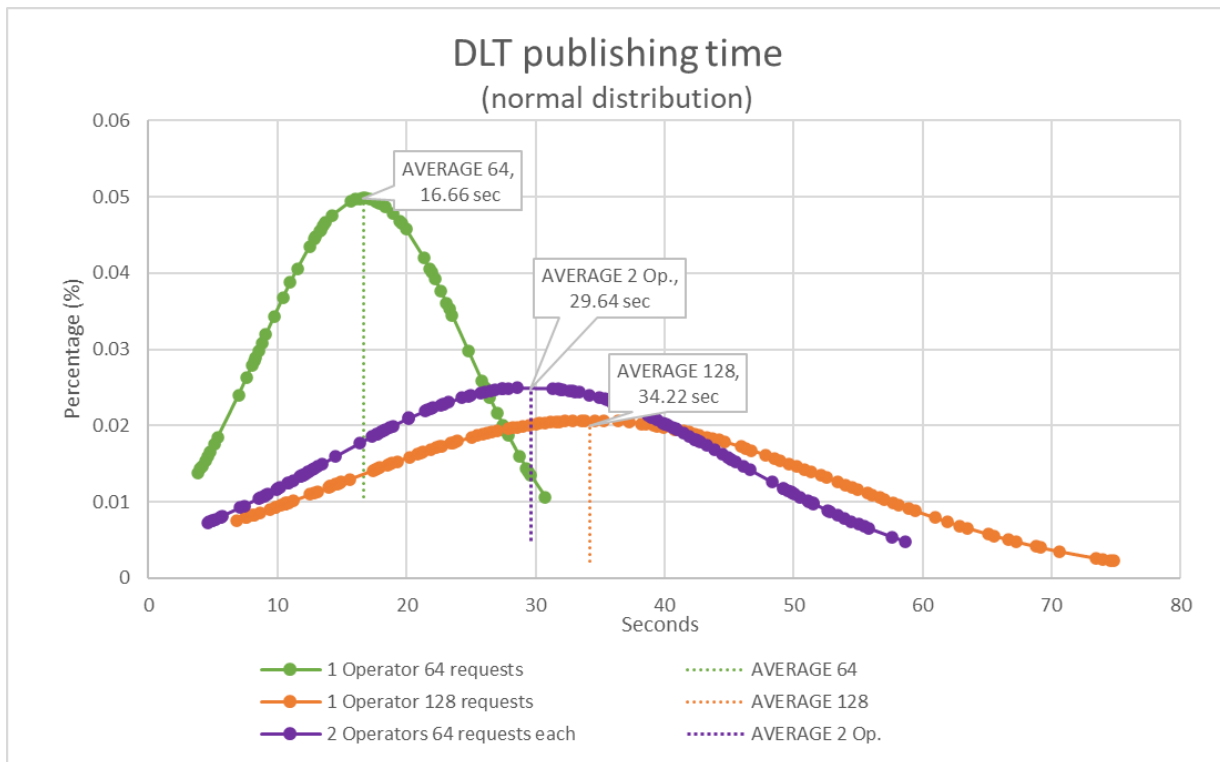


Figure 3-3: KPI5.2 Marketplace DLT publishing time

3.2.1.5. Test UC1.13a: Simple query request by Service Consumer

Table 3-8: Simple query request by Service Consumer

UC1.13a	Simple query request by Service Consumer
Testbed	5G Barcelona
Description	<p>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</p> <p>Service Consumer performs a simple query on the Catalogue to discover a set of services matching their requirements criteria – Components specified Edge in location X with uptime greater than X, VNF, RAN</p>
Use-case functionalities	<p>Resource Consumer Request</p> <p>Service Consumer Request</p>
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [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) <ul style="list-style-type: none"> [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes [KPI3.1.5] Service offer activation should be completed within 5 minutes [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) <ul style="list-style-type: none"> [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified.

Components	Marketplace Portal Catalogue	
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> Resource /Service Providers have been on-boarded onto the system Resource /Service Consumer have been on-boarded onto the system
	Test Case steps	<ol style="list-style-type: none"> Resource and Service offers are created by resource and service providers and stored in the Catalogue Resource /Service consumer logs into the portal Resource /Service consumer inputs criteria for service requirements Results visualized in the Portal
Measurements	Methodology	<p>[KPI3.1.2] time from offer being stored in the local catalogue to being registered in the DLT (taken from SCLCM)</p> <p>[KPI4.1.1] time to store offer from origin catalogue to destination catalogues (already has a DID)</p>
	Complementary measurements	none
	Calculation process	Tests performed using scripts to read timestamps
Result	See Table 3-7, Figure 3-2	

3.2.1.6. Upcoming tests

The following tests incorporate 5GZORRO Platform components and features that are under development and will be performed and reported in deliverable D5.3.

Table 3-9: Approval of an Agreement Legal Prose Template

UC1.6a	Approval of an Agreement Legal Prose Template
Testbed	5G Barcelona
Description	Service Provider proposes a commercial Agreement Legal Prose Template. Governance Admins approve
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [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) <ul style="list-style-type: none"> [KPI3.1.1] Smart Contract for 3 or more 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. [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). [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) <ul style="list-style-type: none"> [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified.
Components	Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal

Table 3-10: Approval of an SLA Legal Prose Template

UC1.7a	Approval of an SLA Legal Prose Template
Testbed	5G Barcelona
Description	Service Provider proposes an uptime SLA Legal Prose Template and Governance Admins approve
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified.
Components	Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal

Table 3-11: Approval of a licensing agreement template

UC1.8a	Approval of a licensing agreement template
Testbed	5G Barcelona
Description	Service provider proposes a licensing agreement template for a Service (e.g., 5G private network), and Governance Admins approve
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified.
Components	Identity & Permissions Manager Governance Manager

	Legal Prose Repository Marketplace Portal Governance Portal
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Table 3-12: Agreement creation

UC1.9b	Agreement creation
Testbed	5G Barcelona
Description	Resource provider creates an Agreement based on a Legal Prose Template, which can later be associated with a Product Offer Service provider creates an Agreement based on a Legal Prose Template, which can later be associated with a Product Offer
Use-case functionalities	Resource Consumer Request Service Consumer Request
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	Marketplace Portal Catalogue Smart Contract Lifecycle Manager Legal Prose Repository Identity & Permissions Manager

Table 3-13: SLA creation

UC1.10a	SLA creation
Testbed	5G Barcelona
Description	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 Service Provider creates an Uptime SLA for service based on a Legal Prose Template, which can later be associated with a Product Offer's Service Offer
Use-case functionalities	Resource Consumer Request Service Consumer Request
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	Marketplace Portal Catalogue Smart Contract Lifecycle Manager Legal Prose Repository

	Identity & Permissions Manager
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Table 3-14: Product offer creation

UC1.11	Product offer creation
Testbed	5G Barcelona
Description	<p>Resource Provider composes a Product Offer consisting of:</p> <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) <p>Service Provider composes a Product Offer consisting of:</p> <ul style="list-style-type: none"> • Agreement (UC1.6) • RAN Service (UC1.4) • Network Slice Service (UC1.4) • Network Service (UC1.4)
Use-case functionalities	<p>Resource Consumer Request</p> <p>Service Consumer Request</p>
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	<p>Marketplace Portal</p> <p>Identity & Permissions Manager</p> <p>Catalogue</p> <p>Smart Contract Lifecycle Manager</p>

Table 3-15: Intelligent resource discovery query by Resource Consumer

UC1.14a	Intelligent resource discovery query by Resource Consumer
Testbed	5G Barcelona
Description	Resource Consumer performs an intelligent resource discovery query based on metrics received from breach prediction and virtual/radio resource management
Use-case functionalities	Contract Lifecycle Management
Components	<p>Virtual/Radio Resource Managers</p> <p>Intelligent Network Slice & Service Optimization</p> <p>Intelligent SLA monitoring & breach prediction</p> <p>Catalogue</p> <p>Smart Resource & Service Discovery</p>

Table 3-16: Resource Consumer purchases a Product Offer

UC1.15	Resource Consumer purchases a Product Offer
Testbed	5G Barcelona
Description	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
Use-case functionalities	Contract Lifecycle Management
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	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

3.2.2. Scenario 1.2: Slice composition from multiple providers

As an extension of Scenario 1.1, in Scenario 1.2 a Resource Consumer/Service provider leases a set of resources & services from multiple Resource Providers in order to compose the required service to meet the needs of the vertical customer. This represents multi-party multi-resource slice establishment supported by smart contracts and associated SLAs. A full description of the test Scenario can be found in D5.1.

3.2.2.1. Test UC1.1b: Additional resource provider on-boarding

Table 3-17: Resource provider on-boarding

UC1.1b	Resource provider on-boarding
Testbed	5G Barcelona
Description	An additional Resource Provider is onboarded to the marketplace
Use-case functionalities	User and Organisation On-Boarding
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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.) <ul style="list-style-type: none"> • [KPI1.1.1] New Resource Providers, Resource Consumers, Service Providers are enrolled into the platform. • [KPI1.1.2] Each stakeholder participating in the 5GZORRO Marketplace is approved • [KPI1.1.3] Acceptance/rejection (consensus) when joining of a new node to the DLT network should be completed in less than 15 minutes.

	<ul style="list-style-type: none"> • [KPI1.1.4] All actors have a unique identity that derives from their organisation's identity. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. • [KPI1.1.5] The process of bootstrapping a DLT node and provisioning 5GZORRO services should take no longer than 1 hour. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services. 	
Components	Identity & Permissions Manager Governance Manager Marketplace Portal Governance Portal	
Test Procedure	Pre-conditions	A Governance admin has been onboarded into the Portal A Resource Provider have been onboarded into the Portal
	Test Case steps	Operator B is onboarded into the Marketplace using the registration process in the Portal
Measurements	Methodology	Visually inspect that the Portal is active and the Trader interfaces are shown.
	Complementary measurements	UC1.1, UC1.3
	Calculation process	Use the available logs to measure the time it took to process the request, check on DB the time it took change to an approved state
Result	<ul style="list-style-type: none"> • [KPI1.1.1] 3 stakeholders are active in the Marketplace: 1.Operator A acting as Governance admin and Resource and Service Provider 2.Operator B acting as Resource and Service Provider 3.Operator C acting as Resource Consumer • [KPI1.1.2] Governance Admin approved new stakeholders to join the Marketplace • [KPI1.1.3] <u>The processing of the request has been measured as 11 seconds, and approval has been measured as 2 seconds</u> • [KPI1.1.4] Onboarded actors are assigned a unique Decentralised Identifier. Permissions have been checked through the portal • [KPI1.1.5] Permissions have been checked through the portal 	

3.2.2.2. Test UC1.5: Multi provider resource offer creation

This test is an extension of UC1.4, where 2 resource providers create resource offers in the Marketplace.

Table 3-18: Multi provider resource offer creation

UC1.5	Multi provider resource offer creation
Testbed	5G Barcelona
Description	Provider A creates the Edge and RAN resource offers and Provider B creates Network Service offer.
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> • [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified. • [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) 	
Components and Configuration	Components	Identity & Permissions Manager Marketplace Portal Resource and Service Offer Catalogue Smart Contract Lifecycle Manager virtual Resource Managers
	Configuration	Descriptors for edge and RAN resources, and Network Service
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • Resource Provider has been on-boarded onto the system • Service Provider has been on-boarded onto the system
	Test Case steps	Same as UC1.4a for Resource Offer creation by Resource Provider Operator Same as UC1.4b for Service Offer creation by Service Provider Operator
Measurements	Methodology	KPI3.1.2 , offer creation time is defined as the time from submitting the request to the time the offer is published on the Marketplace DLT KPI4.1.2 , total time for offer publishing is defined as the time from when the offer is stored on the local Resource and Service Catalogue of the Resource/Service Provider creating the offer, to the time when the offer appears on all catalogues of registered Resource/Service Consumers KPI5.2 number of transactions handled by the Market is defined as the average times and standard deviations for the time from when the offer is stored on the local catalogue to the time the offer is published on the Marketplace DLT
	Complementary measurements	UC1.4a UC1.4b
	Calculation process	Tests performed using scripts to read timestamps
Result	See Table 3-7, Figure 3-1, Figure 3-2, and Figure 3-3	

3.2.2.3. Test UC1.13b: Simple query request by Service Consumer including offers from multiple Providers

Table 3-19: Simple query request by Service Consumer including offers from multiple Providers

UC1.13b	Simple query request by Service Consumer including offers from multiple Providers
Testbed	5G Barcelona
Description	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 Service Consumer performs a simple query on the Catalogue to discover a set of services matching their requirements criteria – Components specified Edge in location X with uptime greater than X, VNF, RAN
Use-case functionalities	Resource Consumer Request Service Consumer Request
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes.

	<ul style="list-style-type: none"> ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified. 	
Components	Marketplace Portal Catalogue	
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> ○ Resource /Service Providers have been on-boarded onto the system ○ Resource /Service Provider have been given resource publishing rights ○ Resource /Service Consumer have been on-boarded onto the system
	Test Case steps	<ol style="list-style-type: none"> 1. Resource and Service offers are created by resource and service providers and stored in the Catalogue 2. Resource /Service consumer logs into the portal 3. Resource /Service consumer inputs criteria for service requirements 4. Results visualized in the Portal
Measurements	Methodology	<p>[KPI3.1.2] time from offer being stored in the local catalog to being registered in the DLT (taken from SCLCM)</p> <p>[KPI4.1.1] time to store offer from origin catalog to destination catalogs (already has a DID)</p>
	Calculation process	tests performed using scripts to read timestamps
Result	See Table 3-7, Figure 3-2	

3.2.2.4. Upcoming tests

The following tests incorporate 5GZORRO Platform components and features that are under development and will be performed and reported in deliverable D5.3.

Table 3-20: Approval of an Agreement Legal Prose Template including multiple service providers

UC1.6b	Approval of an Agreement Legal Prose Template
Testbed	5G Barcelona
Description	Service Provider proposes a commercial Agreement Legal Prose Template. Governance Admins approve
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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)	
	<ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified. 	
Components and Configuration	Components	Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal

Table 3-21: Approval of an SLA Legal Prose Template including multiple service providers

UC1.7b	Approval of an SLA Legal Prose Template	
Testbed	5G Barcelona	
Description	Service Provider proposes an uptime SLA Legal Prose Template and Governance Admins approve	
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified. 	
Components	Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal	

Table 3-22: Approval of a licensing agreement template including multiple service providers

UC1.8b	Approval of a licensing agreement template	
Testbed	5G Barcelona	
Description	Service provider proposes a licensing agreement template for a Service (e.g., 5G private network), and Governance Admins approve	
Use-case functionalities	Resource Provider creating a Resource Offer Service Provider creating a Service Offer	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.1] Smart Contract for 3 or more 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. 	

	<ul style="list-style-type: none"> ○ [KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger). • [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) <ul style="list-style-type: none"> ○ [KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified.
Components	Identity & Permissions Manager Governance Manager Legal Prose Repository Marketplace Portal Governance Portal

Table 3-23: Agreement creation template including multiple service providers

UC1.9b	Agreement creation
Testbed	5G Barcelona
Description	Resource provider creates an Agreement based on a Legal Prose Template, which can later be associated with a Product Offer Service provider creates an Agreement based on a Legal Prose Template, which can later be associated with a Product Offer
Use-case functionalities	Resource Consumer Request Service Consumer Request
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	Marketplace Portal Catalogue Smart Contract Lifecycle Manager Legal Prose Repository Identity & Permissions Manager

Table 3-24: SLA creation including multiple service providers

UC1.10b	SLA creation
Testbed	5G Barcelona
Description	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 Service Provider creates an Uptime SLA for service based on a Legal Prose Template, which can later be associated with a Product Offer's Service Offer
Use-case functionalities	Resource Consumer Request Service Consumer Request

Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes • [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	Marketplace Portal Catalogue Smart Contract Lifecycle Manager Legal Prose Repository Identity & Permissions Manager

Table 3-25: Multi provider Product offer creation

UC1.12	Multi provider Product offer creation
Testbed	5G Barcelona
Description	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) Service Provider composes a Product Offer consisting of: <ul style="list-style-type: none"> • Agreement (UC1.6) • RAN Service (UC1.4) • Network Slice Service (UC1.4) • Network Service (UC1.4)
Use-case functionalities	Resource Consumer Request Service Consumer Request
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes

Table 3-26: Intelligent resource discovery query by Resource Consumer including offers from multiple Providers

UC1.14b	Intelligent resource discovery query by Resource Consumer
Testbed	5G Barcelona
Description	Resource Consumer performs an intelligent resource discovery query based on metrics received from breach prediction and virtual/radio resource management
Use-case functionalities	Contract Lifecycle Management
Components	Virtual/Radio Resource Managers Intelligent Network Slice & Service Optimization

	Intelligent SLA monitoring & breach prediction Catalogue Smart Resource & Service Discovery
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Table 3-27: Resource Consumer purchases multiple Product Offers from multiple provider

UC1.16	Resource Consumer purchases multiple Product Offers from multiple provider
Testbed	5G Barcelona
Description	Resource Consumer purchases multiple Product Offers from multiple providers. Each provider confirms they have capacity and accepts the agreement. Product Offers as per the one created in UC1.12 and discovered in UC1.13, Resulting agreements between 1 consumer and 2 providers.
Use-case functionalities	Contract Lifecycle Management
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	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

3.2.3. Scenario 1.3: Slice Lifecycle Management with analytics

In this final UC1 scenario, a Resource Consumer leases a VNF and attempts a scaling of 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. A full description of the test scenario can be found in D5.1.

For this specific scenario, no use case validation tests have been performed yet. The list of tests to be performed and reported in deliverable D5.3 is provided in the following sub-section.

3.2.3.1. Upcoming tests

The following tests incorporate 5GZORRO Platform components and features that are under development and will be performed and reported in deliverable D5.3.

Table 3-28: SLA Breach detected

UC1.17	SLA Breach detected
Testbed	5G Barcelona
Description	SLA Breach is detected by Service & Resource Monitoring and recorded on the DLT

Use-case functionalities	Contract Lifecycle Management
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. ○ [KPI4.2.2] SLA measurements and validation from at least 3 operators involved in a multi-party service chain ○ [KPI4.2.3] An SLA violation is recorded on the DLT for a given resource within 15 minutes of occurrence
Components	Virtual/Radio Resource Managers Service & Resource Monitoring Monitoring Data Aggregator Smart Contract Lifecycle Manager TEE

Table 3-29: Scaling action is attempted and blocked

UC1.18	Scaling action is attempted and blocked
Testbed	5G Barcelona
Description	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
Use-case functionalities	Contract Lifecycle Management
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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) <ul style="list-style-type: none"> ○ [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. ○ [KPI4.2.2] SLA measurements and validation from at least 3 operators involved in a multi-party service chain ○ [KPI4.2.3] An SLA violation is recorded on the DLT for a given resource within 15 minutes of occurrence
Components	Smart Contract Lifecycle Manager Intelligent Network Slice & Service Optimization Virtual/Radio Resource Managers eLicensing

Table 3-30: Agreement termination

UC1.19	Agreement termination
Testbed	5G Barcelona
Description	Resource Consumer terminates an agreement
Use-case functionalities	Contract Lifecycle Management
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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)

	<ul style="list-style-type: none"> ○ [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. ○ [KPI4.2.2] SLA measurements and validation from at least 3 operators involved in a multi-party service chain ○ [KPI4.2.3] An SLA violation is recorded on the DLT for a given resource within 15 minutes of occurrence • [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) <ul style="list-style-type: none"> ○ [KPI3.1.3] Establishment of smart contract (service agreement) should be completed within 5 minutes. ○ [KPI3.1.4] After the completion of Smart Contract negotiation, resource allocation should take < 5 minutes ○ [KPI3.1.5] Service offer activation should be completed within 5 minutes
Components	Marketplace Portal Smart Contract Lifecycle Manager Catalogue Virtual/Radio Resource Managers Service & Resource Monitoring Monitoring Data Aggregator

Table 3-31: SLA Breach prediction

UC1.20	SLA Breach prediction
Testbed	5G Barcelona
Description	Intelligent SLA monitoring & breach prediction module predicts an SLA violation and issues notification to trigger resource discovery; see also UC1.7 & UC1.14
Use-case functionalities	Contract Lifecycle Management
Components	Intelligent SLA monitoring & breach prediction Intelligent and Automated Slice and Service Manager

4. UC2: Dynamic Spectrum Allocation

4.1. Description

The objective of the use case on dynamic spectrum allocation is to demonstrate that the 5GZORRO platform can be used to:

- trade or lease¹ licensed spectrum and
- dynamically change the assignment of both licensed and unlicensed spectrum.

This will be demonstrated via the deployment of an end-to-end network slice including the selection and automatic configuration of radio nodes. The selected radio access network may operate in a licensed or an unlicensed band. Deploying a slice that uses license spectrum is more complex than using unlicensed spectrum. For example, the slice can be crafted from different resource types, including spectrum resources, all fit together to create the service. Another possibility explored in this use case is a complete slice offering that includes cellular base stations operating in licensed bands. In this latter situation, the spectrum is not traded, it remains under the control of the slice provider, and the spectrum is shared with other possible slices. Most of the UC2 tests are targeting the licensed spectrum since it is the most challenging spectrum trading case to handle with a zero-touch approach.

Another important consideration is the fact that the use of a licensed band with zero-touch configuration imposes intermediate validation steps from the moment that the spectrum resource is registered in the marketplace. In this moment, the 5GZORRO platform compares the technical information of the spectrum resource against stakeholder's valid spectrum certificates. At a later stage, when the spectrum resource is selected to be included in a spectrum resource offer or slice, the 5GZORRO platforms ensures that the spectrum is not utilized in other offers in the same area or time frame to prevent from double spending. Finally, by the time of spectrum offer ordering, the buyer must be recognised as valid by the Regulator, and the platform guarantees that the spectrum is going to be applied as mandated by the technical information contained in the spectrum resource.

The validation roadmap has already started and the initial use case tests have already been undertaken in the 5GBarcelona tested. For this use case, one spectrum regulator (Regulator A) and three resource traders (Operator A, Operator B and Operator C) are considered and, therefore, to be deployed during the tests. Each operator takes a different role, according to Table 4-1.

Table 4-1: UC2 stakeholders and regulator roles

Stakeholder name	Operator A	Operator B	Operator C	Regulator A
Acting as	Spectrum resource provider, radio resource provider	Radio Resource Provider	Resource consumer	Spectrum regulator

4.1.1. Specific security and trust validation aspects

5GZORRO includes assets and functionalities to provide a high degree of reliability in the transactions. It is also worth mentioning that National Regulatory Authorities responsible of spectrum management are

¹ Spectrum trade or lease involves the transfer of rights of use of licensed spectrum from one entity to another.

mandated with the task of ensuring that spectrum is used efficiently and assigned in a manner that promotes competition and safeguards the socio-economic interests that can be reaped from the use of spectrum. A Regulator is responsible of overseeing both the spectrum assignment of licensed spectrum and also any subsequent spectrum trading to avoid market distortion and to carry out the necessary due diligence. The 5GZorro platform facilitates this by allowing regulators to remove spectrum certificates; issue temporary bans on potential spectrum buyers and also annulling a product offer or product order. In the case that these corrective actions are needed, active certificates will be revoked and a new certificate will be issued, so the owner will not be allowed to access the spectrum market.

A spectrum certificate represents the digitalisation of a spectrum license. With a spectrum license, a National Regulator Authority recognises to its tenant, typically a Mobile Network Operator (MNO), the right to use a portion of the spectrum band in a region and for a number of years. In 5GZORRO, SRPs provide in their Portal the details of the spectrum license. With this action, the SRP demonstrates its intention to trade with spectrum resources of a specific spectrum license in the spectrum market. The 5GZORRO Governance layer, with the Regulator, inspects that the information provided by the SRP is correct and coincides with a spectrum license. Only in that case, the 5GZORRO platform emits a spectrum certificate (credential) for the SRP with the technical details of the spectrum license.

By owning a spectrum certificate, the 5GZORRO platform authorises an SRP to create spectrum resource offerings, which can be discovered by other stakeholders. But before the offering is registered in the 5GZORRO Marketplace, its technical spectrum information is validated. This is a necessary validation process in order to avoid 1) unlawful claims on spectrum resources; and 2) duplications of the same spectrum resource in overlapped areas or time frames. Therefore, validating a spectrum offer is, in essence, a comparison between the offering information, the spectrum certificate, and other existing spectrum resources.

In order to make use of a spectrum resource within the 5GZORRO platform, it is mandatory to associate it with a spectoken. The spectoken helps keeping track of 1) the historical of transactions of the spectrum resource; and 2) the use of the spectrum resource since the very first moment a radio resource made use of it.

As an additional characteristic, 5GZORRO introduces a smart mechanism to discover spectrum offers based on reputation scores. In particular, the 5G-enabled Trust and Reputation Management Framework (5G-TRMF) together with the Smart Resource and Service Discovery bring the functionality to rank a set of spectrum offerings based on the trust a consumer has in them. Especially, the consumer will employ an adapted PeerTrust model under the 5G-TRMF that allow predicting a trust score taking into account previous interactions and feedback. In order to determine the trustworthiness of a spectrum provider, the PeerTrust model considers the consumer's satisfaction, credibility, transaction context factor and community context factor (more information about PeerTrust model can be found in Deliverable 4.2). At the same time, the 5G-TRMF boosts the fulfilment of the zero-trust principle since it evades implicit trust in any spectrum provider in an intra- or inter-domain scenario. Therefore, the 5G-TRMF and trust not only introduce a novel mechanism to automatically filter a set of candidate spectrum providers but also help the consumers ameliorate their decision-making in the 5GZORRO ecosystem through knowledge-sharing and establish trustworthy end-to-end communications.

To keep track of the spectrum usage, the Radio Resource Manager component of the 5GZORRO platform configures the radio infrastructure associated to a spectoken to generate metrics and telemetry regarding the use of the spectrum. This information is pushed to the 5GZORRO datalake, so the platform can continuously evaluate if the use of the spectrum is correct and fulfils the active spectrum SLAs.

4.2. Modelling of Spectrum Certificate

This section introduces the data model used for the spectrum certificate in Table 4-2. This data model was conceived with the assistance of the Malta Communication Authority (MCA), who distilled the elementary information from a real spectrum license. This information model contains, in the Regulator's view, the minimum information that should be digitalised and utilised at the spectrum resource creation time.

Table 4-2: Spectrum certificate information model

Parameter	Type	Description
Licence Title	String	Title of the license
Licence Reference No	String	Reference number of the Reference
Governing Legislation:	String	Legislation description/title (a law) that governs the use of the spectrum
Term of Grant	String	Duration of the spectrum grant
Commencement Date	String	Starting date of the spectrum grant
Expiry Date	String	End date of the spectrum grant
Name of Licensee	String	Name of the spectrum grant receiver, typically a Mobile Network Operator (MNO)
Registered Address	String	Address of the spectrum grant receiver
Country	String	Country where the license applies
Company Registered Number:	String	Company Registered Number of the spectrum grant receiver
Spectrum Fee	String	Monetary conditions of the use of the spectrum resources that compose the spectrum license
Duplex Mode Of Operation	String	Operation mode allowed in the band: "TDD" or "FDD"
TDD Synchronisation - default frame structure	String	In case of TDD duplex mode, the TDD pattern to use
Radio Spectrum - Start UL Frequency	String	Start UL frequency
Radio Spectrum - End UL Frequency	String	End UL frequency
Radio Spectrum - Start DL Frequency	String	Start DL frequency
Radio Spectrum - End DL Frequency	String	End DL frequency

4.3. Use Case 2 scenarios

This Section contains all the use case 2 tests targeted for each of the three UC2 scenarios that were defined in 5GZORRO D5.1 [3].

It is worth highlighting that given the extensiveness of some of the UC2 tests defined in D5.1, they have been split in several smaller tests in D5.2. Table 4-3 aims at facilitating the mapping between the former nine UC2 tests in D5.1 to the list of tests in D5.2.

Table 4-3 Decomposition and mapping of UC2 tests from D5.1 to D5.2

Tests in scope of D5.2	Tests planned for D5.3
UC2.1	Test UC2.1: Regulator on-boarding
UC2.2	Test UC2.2: Spectrum resource provider on-boarding
UC2.3	Test UC2.3: Radio infrastructure provider on-boarding
UC2.4	Test UC2.4: Resource consumer on-boarding
UC2.5	Test UC2.5a: Spectrum certificate creation request
	Test UC2.5b: Spectrum resource registration
	Test UC2.5c: Registration of a spectrum resource offer
UC2.6	Test UC2.6a: Selection of a spectrum resource offer
	Test UC2.6b: Selection of a slice offer
UC2.7	Test UC2.7a: Registration of a radio resource
	Test UC2.7b: Registration of a radio resource offer
	Test UC2.7c: Registration of a slice offer
UC2.8	Test UC2.8: Selection of a radio resource offer
UC2.9	Test UC2.9a: Automatic selection of resources and slice composition
	Test UC2.9b: Deployment of a slice with configurable radio infrastructure
	Test UC2.9c: Deployment of a slice with non-configurable radio infrastructure
	Test UC2.9d: Spectrum telemetry collection
	Test UC2.9e: SLA breach detection on time to deploy spectrum
	Test UC2.9f: SLA breach detection on interference levels
	Test UC2.9g: SLA breach detection on geofencing spectrum
	Test UC2.9h: SLA breach correction on time to deploy spectrum
	Test UC2.9i: SLA breach correction on interference levels
	Test UC2.9j: SLA breach correction on geofencing spectrum

At the time of writing this new deliverable, some of the Use Case 2 tests have been completed and some results and KPIs have been provided in their corresponding descriptions. The tests that have been completed so far are all related to the on-boarding of the different business actors involved in Use Case 2 and the creation of spectrum and radio product offerings. The remaining tests are still to be carried out as the implementations of the different software components mature and results will be provided in the future deliverable D5.3. Table 4-4 summarises the Use Case 2 tests that have results in D5.2, and which other tests will present results in D5.3.

Table 4-4: List of UC2 tests with results in D5.2 and test with no results but will be provided in D5.3

Tests with results	Tests with no results
Test UC2.1: Regulator on-boarding	Test UC2.6a: Selection of a spectrum resource offer
Test UC2.2: Spectrum resource provider on-boarding	Test UC2.6b: Selection of a slice offer
Test UC2.3: Radio infrastructure provider on-boarding	Test UC2.8: Selection of a radio resource offer
Test UC2.4: Resource consumer on-boarding	Test UC2.9a: Automatic selection of resources and slice composition
Test UC2.5a: Spectrum certificate creation request	Test UC2.9b: Deployment of a slice with configurable radio infrastructure
Test UC2.5b: Spectrum resource registration	Test UC2.9c: Deployment of a slice with non-configurable radio infrastructure
Test UC2.5c: Registration of a spectrum resource offer	Test UC2.9d: Spectrum telemetry collection
Test UC2.7a: Registration of a radio resource	Test UC2.9e: SLA breach detection on time to deploy spectrum
Test UC2.7b: Registration of a radio resource offer	Test UC2.9f: SLA breach detection on interference levels

Test UC2.7c: Registration of a slice offer	Test UC2.9g: SLA breach detection on geofencing spectrum
	Test UC2.9h: SLA breach correction on time to deploy spectrum
	Test UC2.9i: SLA breach correction on interference levels
	Test UC2.9j: SLA breach correction on geofencing spectrum

4.3.1. Scenario 2.1: Resource offer publication

4.3.1.1. Test UC2.1: Regulator on-boarding

The Regulator (Regulator-A) on-boarding test is the continuation of UC1's Governance admin on-boarding test described in Section 3.2.1.3. The UC2 part of the test focuses on showing Regulator specific interfaces in the Portal.

Table 4-5 Regulator on-boarding

UC2.1	Regulator on-boarding	
Testbed	5GBarcelona	
Description	Onboarding of a National Spectrum Regulator in the 5GZORRO platform. The Regulator logs in the Portal and can perform the following actions: 1) make decisions on spectrum certificate requests (approve or reject); 2) list all the spectrum certificates that the Regulator has approved or rejected; and 3) get notifications of any spectrum transaction occurring in the platform	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: Distributed multi-party service and business configurations • [KPI5.3] The authenticity of the market agents will be evaluated by setting three stakeholder profiles • [KPI7.1] Lab validation 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Identity and Permissions Manager (Id&P) • Governance DLT
	Configuration	Id&P has an initial credential for the Regulator
Test Procedure	Pre-conditions	A Governance admin has been onboarded into the Portal. No spectrum certificates issued to any spectrum resource provider
	Test Case steps	<ol style="list-style-type: none"> 1. Regulator accesses 5GZorro Portal and navigates to "Create New Account" page 2. Regulator selects "Regulator" role and inputs his personal information (name, email and address) 3. Regulator sends a registering request by clicking on "Register" and receives his StakeholderDID 4. Regulator navigates to login page and tries to login 5. The Portal displays a message with the information that the account is not approved yet 6. Governance admin logs in the Portal 7. Governance admin navigates to his private interface showing all stakeholder certificates pending for approval 8. Governance admin approves the Regulator onboarding certificate 9. Regulator logs into 5GZORRO system with his StakeholderDID
Measurements	Methodology	Visually inspect that the Portal is active and a Regulator-exclusive interface is shown.

	Complementary measurements	Those defined in Section 3.2.1.3
	Calculation process	None
Result	<p>Measured Time: 12 seconds (10 seconds for request processing + 2 seconds for Administrator approval process)</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 1 (1 Regulator deployed in 5GZORRO) • [KPI5.3] Authenticity of the Regulator: yes, determined during the on-boarding process in Section 3.2.1.3 • [KPI7.1] Lab validation: yes, in 5Gbarcelona <p>Spectrum product ordering is not part of the set of UC2 test for this deliverable. For this reason, spectrum resource transaction notifications are not evaluated now.</p>	

The Regulator has the possibility to list in the Portal all the certificates that have been issued, approved, or rejected. The lists of certificates will be populated with spectrum certificates requested by spectrum resource providers.

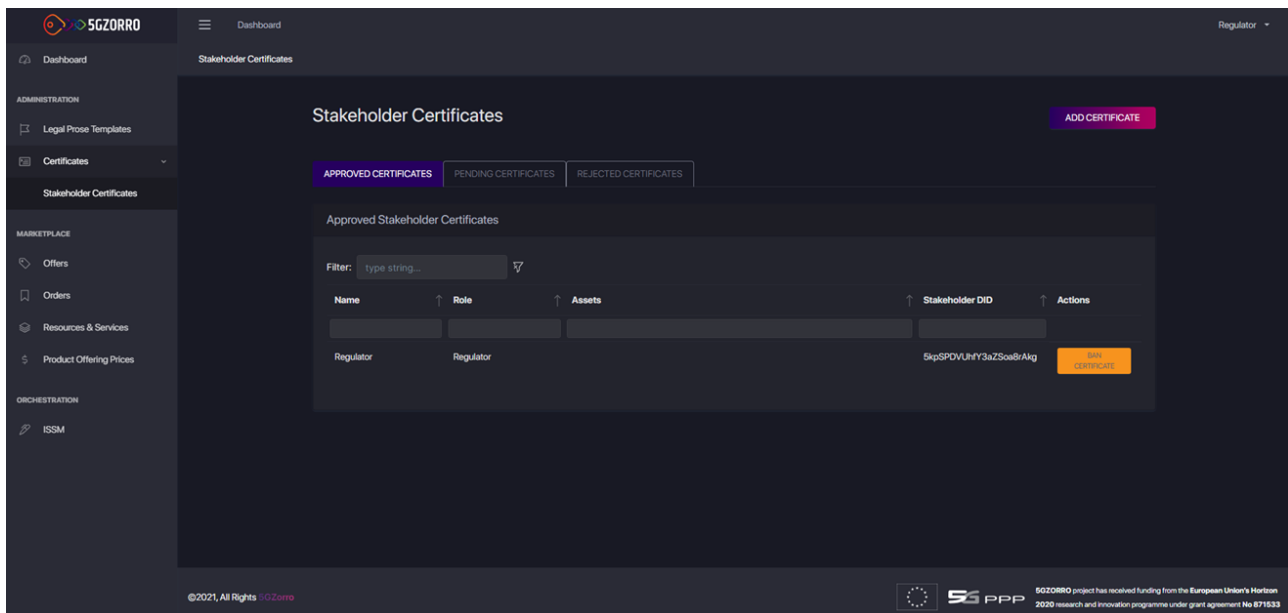


Figure 4-1: List of certificates submitted to the Regulator

4.3.1.2. Test UC2.2: Spectrum resource provider on-boarding

This test aims at on-boarding an Operator (Operator-A) in the 5GZORRO platform. This operator behaves as a Spectrum Resource Provider (SRP). This test is the continuation of the broader UC1's resource provider on-boarding test in Section 3.2.1.1, and focuses on the particularities of the SRP role. The most significant difference of the SRP and the other resource providers in 5GZORRO is the ability of creating spectrum offers in the 5GZORRO platform. This test will solely consist of showing the spectrum resource offers in the Catalogue. Note that the SRP could be able to register other kind of resources. For UC2's interests, the SRP may be able to register radio infrastructure resource offers into the Marketplace. This way, the SRP may be able to create slice service offers, which bundles compute and radio resources that utilizes part of the SPR spectrum with other possible slices.

Table 4-6: Spectrum resource provider on-boarding

UC2.2	Spectrum resource provider on-boarding	
Testbed	5GBarcelona	
Description	Onboarding of a Spectrum Resource Provider (SRP) in the 5GZORRO platform. The SRP logs in the Portal and can create spectrum product offers from spectrum resources. It can also create slice service offers, which combines compute and radio resources and a shared used of the SRP's spectrum	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.3] Authenticity of the market agents • [KPI7.1] Lab validation 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Identity and Permissions Manager (Id&P) • Governance DLT
	Configuration	Id&P has an initial credential for the SRP
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • Resource provider on-boarding in Section 3.2.1.1 • Marketplace contains spectrum, radio, and compute resources to create spectrum and slice offers
	Test Case steps	<ol style="list-style-type: none"> 1. The SRP logs in the Portal 2. The SRP visits the resource marketplace and filters active spectrum resource offers 3. The SRP can create spectrum offers in the resource offer creation page in the Portal
Measurements	Methodology	Visually inspect that the Portal is active and the SRP-exclusive interfaces and actions are shown.
	Complementary measurements	Those defined in Section 3.2.1.1
	Calculation process	Not applicable
Result	<p>The Portal shows some spectrum resources, as seen in Figure 4-2. The resource offer creation page will let the SRP create spectrum or slice offers, but no spectrum nor radio resource is shown to the SRP</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 1 (1 SRP deployed in 5GZORRO) • [KPI5.3] Authenticity of the SRP: yes, determined during the on-boarding process in Section 3.2.1.1 • [KPI7.1] Lab validation: yes, in 5GBarcelona 	

As it can be seen in Figure 4-2, the SRP (Operator-A) has spectrum and radio resources on the 5G band n78. Spectrum resources can be used to compose spectrum product offers, whereas the listed 5G cells can be used with compute resources to create slice service offers.

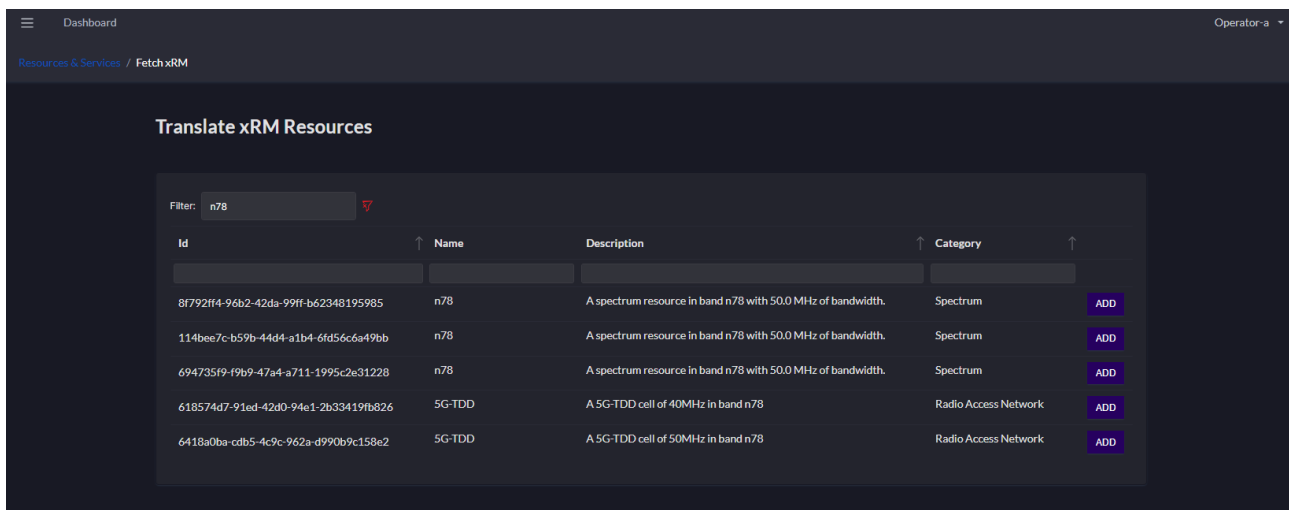


Figure 4-2: The Spectrum Resource Provider's Portal shows three spectrum resources that can be used in future spectrum product offers, or with slice product offers if combined with other resources like radio

4.3.1.3. Test UC2.3: Radio infrastructure provider on-boarding

This test aims at on-boarding an Operator (Operator-B) in the 5GZORRO platform. This operator behaves as a Radio Resource Provider (RRP). This test is the continuation of the broader UC1's resource provider on-boarding test in Section 3.2.1.1, and focuses on the particularities of the RRP role. In UC2, the RRP will be limited to trade radio resources in the 5GZORRO Marketplace. This means that the RRP is not allowed to create spectrum product offers. The objective of this test is to show that different stakeholders may have different roles in the platform and trade with different resources.

Table 4-7 Radio infrastructure provider on-boarding

UC2.3	Radio infrastructure provider on-boarding	
Testbed	5GBarcelona	
Description	Onboarding of a Radio Resource Provider (RRP) in the 5GZORRO platform. The RRP logs in the Portal and visits the list of resources available in the Marketplace.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations [KPI5.3] Authenticity of the market agents [KPI7.1] Lab validation 	
Components and Configuration	Components	<ul style="list-style-type: none"> Portal Identity and Permissions Manager (Id&P) Governance DLT
	Configuration	Id&P has an initial credential for the RRP
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> Resource provider on-boarding in Section 3.2.1.1 Marketplace contains one dummy spectrum resource offer Marketplace contains one dummy radio resource offer
	Test Case steps	<ol style="list-style-type: none"> The RRP logs in the Portal The RRP visits the resource marketplace and tries to filter active spectrum resource offers The RRP can create radio resource offers in the resource offer creation page in the Portal

Measurements	Methodology	Visually inspect that the Portal is active and the RRP-exclusive interfaces and actions are shown.
	Complementary measurements	Those performed in Section 3.2.1.1
	Calculation process	Not applicable
Result	<p>The Portal shows some radio product offers to include in offerings, as illustrated in Figure 4-4. The resource offer creation page will let the RRP create radio resource offers</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 1 (1 RRP deployed in 5GZORRO) • [KPI5.3] Authenticity of the RRP: yes, determined during the on-boarding process in Section 3.2.1.1 • [KPI7.1] Lab validation: yes, in 5GBarcelona 	

Figure 4-3: Operator B logs in and determines that it only trades with radio resources

Figure 4-4 shows the radio resources that the radio resource provider can include in the 5GZORRO Resource and Service Catalogue to be used in radio product offers.

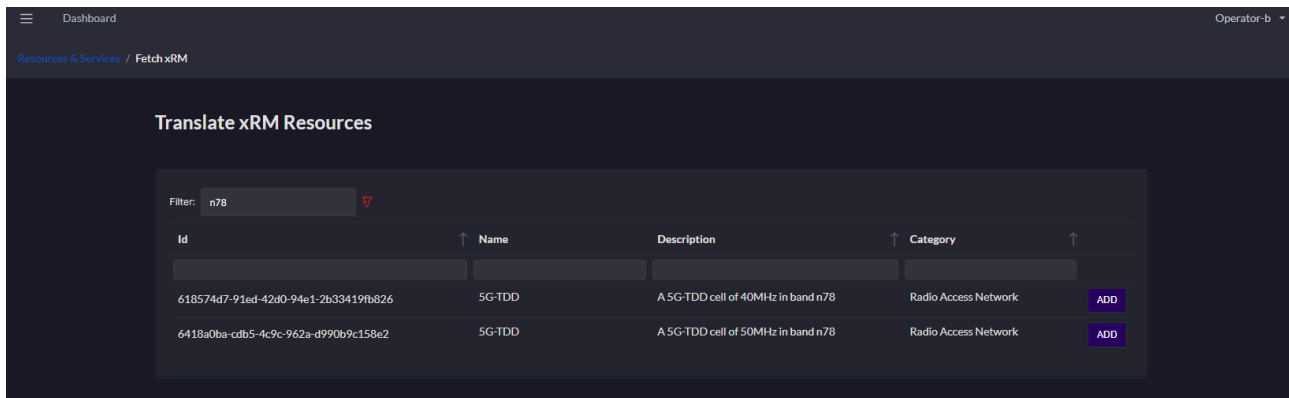


Figure 4-4: Operator B has some radio infrastructure (5G cells) to use in radio product offerings, but no spectrum resources

4.3.1.4. Test UC2.4: Resource consumer on-boarding

This test aims at on-boarding an Operator (Operator-C) in the 5GZORRO platform. This operator behaves as a resource consumer. Essentially, this test is the continuation of the broader UC1's resource consumer on-boarding in Section 3.2.1.2. The resource consumer will be allowed to list radio, slice and spectrum resource product offers available in the 5GZORRO Marketplace. The consumer has no spectrum license and, consequently, cannot be recognized as an SRP and it is not allowed to publish spectrum resource offers. The objective of this test is to show that an Operator can get all the resources it needs to deploy a 5G slice from the 5GZORRO Product and Service Catalogue.

Table 4-8: Resource consumer on-boarding

UC2.4	Resource consumer on-boarding	
Testbed	5GBarcelona	
Description	Onboarding of a resource consumer in the 5GZORRO platform. The resource consumer logs in the Portal and visits the list of resources available in the Marketplace.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations [KPI5.3] Authenticity of the market agents [KPI7.1] Lab validation 	
Components and Configuration	Components	<ul style="list-style-type: none"> Portal Identity and Permissions Manager (Id&P) 5GZORRO Resource and Service Catalogue Governance DLT
	Configuration	Id&P has an initial credential for the RRP
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> Resource consumer on-boarding in Section 3.2.1.2 Marketplace contains at least one spectrum resource offer Marketplace contains at least one radio resource offer Marketplace contains at least one slice offer
	Test steps	<ol style="list-style-type: none"> The resource consumer logs in the Portal The resource consumer visits the resource marketplace and filters active spectrum product offers The resource consumer visits the resource marketplace and filters active radio resource offers The resource consumer visits the resource marketplace and filters active slice service product offers

Measurements	Methodology	Visually inspect that the Portal is active and the resource offers are all listed
	Complementary measurements	Those defined in Section 3.2.1.2
	Calculation process	Not applicable
Result	The Portal shows the dummy spectrum, radio and slice offers, as shown in Figure 4-5: <ul style="list-style-type: none"> • [KPI11.1] Distributed multi-party service and business configurations: 1 (1 resource consumer deployed in 5GZORRO) • [KPI5.3] Authenticity of the resource consumer: yes, determined during the on-boarding process in Section 3.2.1.2 • [KPI7.1] Lab validation: yes, in 5GBarcelona 	

The resource consumer is able to discover offers from other Operators participating in the 5GZORRO platform, as it can be seen in Figure 4-5. Instead of showing dummy offers, it shows the offers that were created in tests UC2.5c, UC2.7b, and UC2.7c, to show that the newly created offers are also visible to the resource consumer.

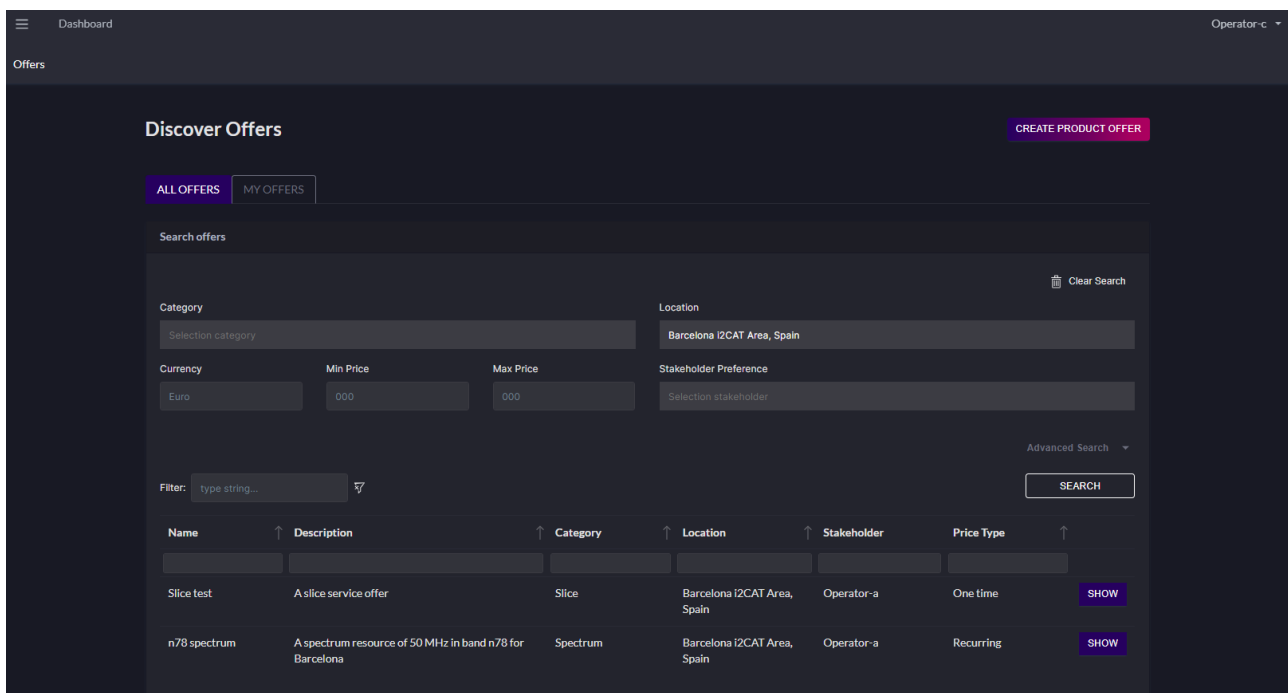


Figure 4-5: Operator C is capable of viewing the spectrum product offer registered by Operator A

4.3.1.5. Test UC2.5a: Spectrum certificate creation request

This test will evaluate the multi-certificate characteristic of the spectrum resource provider stakeholders in 5GZORRO platform. SRPs are the only stakeholders that can have more than one valid certificate in the platform at the same time. Each of these additional certificates represents the digitalization of a real spectrum license. An SRP, typically a Mobile Network Operator (MNO), shows interest in trading with some spectrum resources of a particular spectrum license by requesting the registration of a spectrum certificate to the 5GZORRO platform.

After the SRM requests a new spectrum certificate, the Regulator validates the information therein offline. The result of this validation determines if the request is accepted or rejected. This test will cover the two results of the request in Table 4-9 and Table 4-10. Table 4-11 contains the data models of the approved and rejected spectrum certificates.

Table 4-9: Spectrum certificate creation request acceptance

UC2.5a-1	Spectrum certificate creation request acceptance	
Testbed	5GBarcelona	
Description	The SRP requests the creation of a spectrum certificate in 5GZORRO Portal. The SRP attaches the original or a copy of the spectrum license in the form of a digital document with a hash. The Regulator gets a notification in the Portal and inspects the request alongside the spectrum license. The Regulator determines that the request is valid and the SRP is the legit owner of the spectrum and accepts the creation of the spectrum certificate.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled by the market • [KPI5.3] The authenticity of the market agents will be evaluated by setting three stakeholder profiles 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Identity and Permissions Manager (Id&P)
	Configuration	<ul style="list-style-type: none"> • Id&P has an initial credential for SRP • No spectrum license is registered yet
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • SRP and Regulator are both onboarded • SRP has at least one spectrum certificate to digitalise in the platform
	Test Case steps	<ol style="list-style-type: none"> 1. The SRP logs in the Portal 2. SRP goes to the interface in the Portal to send request to generate the spectrum license 3. SRP populates the information of the spectrum certificate creation page in the Portal and sends the request 4. The Regulator gets a notification in the Portal 5. The Regulator goes to the page where the spectrum certificate request still pending to be processed are listed and there is one from the SRP 6. The Regulator inspects the technical information in the request 7. The information is correct, and the Regulator clicks the "Approve" button 8. A valid spectrum certificate is created and register as accepted
Measurements	Methodology	Visually inspect that the spectrum certificate is created by polling the specific endpoint in the Id&P and the certificate is marked as valid.
	Complementary measurements	Measure time to process the spectrum certificate creation request and notify the Regulator.
	Calculation process	<p>For the number of operators, regulators, and business agents, simply check the operator and regulator domains that are involved in the test. For instance, the IP addresses of the SRP and Regulator Portal.</p> <p>For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation.</p>
Result	<p>The certificate is created and stored in the Id&P as marked as valid, as shown in Figure 4-8</p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 2 (1 SRP operator and 1 Regulator) • [KPI5.2] Number of spectrum certificate requests per minute: 5 (12 seconds per request) • [KPI5.2] Number of spectrum certificate request decisions processed per minute: 30 (2 seconds per request) 	

	<ul style="list-style-type: none"> • [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 and with the offline inspection of the spectrum license information submitted in the spectrum certificate request • [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 • [KPI7.1] Lab validation: yes, in 5GBarcelona
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Table 4-10: Spectrum certificate creation request rejection

UC2.5a-2	Spectrum certificate creation request rejection	
Testbed	5GBarcelona	
Description	The SRP requests the creation of a spectrum certificate in 5GZORRO Portal. The SRP attaches the original or a copy of the spectrum license in the form of a digital document with a hash. The Regulator gets a notification in the Portal and inspects the request alongside the spectrum license. The Regulator concludes that the request is not valid and rejects the creation of the spectrum certificate.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled by the market • [KPI5.3] The authenticity of the market agents will be evaluated by setting three stakeholder profiles 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Identity and Permissions Manager (Id&P)
	Configuration	Id&P has an initial credential for the SRP and no spectrum license is registered yet
Test Procedure	Pre-conditions	SRP and Regulator are both onboarded
	Test Case steps	<ol style="list-style-type: none"> 1. The SRP logs in the Portal 2. SRP goes to the interface in the Portal to send request to generate the spectrum license 3. SRP populates the information of the spectrum certificate creation page in the Portal and sends the request 4. The Regulator gets a notification in the Portal 5. The Regulator goes to the page where the spectrum certificate request still pending to be processed are listed and there is one from the SRP 6. The Regulator inspects the technical information in the request 7. The information is not correct, and the Regulator clicks the "Reject" button 8. No spectrum certificate is created and the requests is registered as rejected
Measurements	Methodology	Visually inspect that the spectrum certificate is created by polling the specific endpoint in the Id&P and the certificate is marked as valid
	Complementary measurements	Measure time to process the spectrum certificate creation request and notify the Regulator
	Calculation process	<p>For the number of operators, regulators, and business agents, simply check the operator and regulator domains that are involved in the test. For instance, the IP addresses of the SRP and Regulator Portal.</p> <p>For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation.</p>
Result	<p>The certificate is not created</p> <p>Measured KPIs:</p>	

	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 2 (1 SRP operator and 1 Regulator) • [KPI5.2] Number of spectrum certificate requests per minute: 5 (12 seconds per request) • [KPI5.2] Number of spectrum certificate request decisions proceed per minute: 30 (2 seconds per request) • [KPI5.3] Authenticity of the Regulator: yes, determined during the on-boarding process in Section 4.3.1.1 • [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 and with the offline inspection of the spectrum license information submitted in the spectrum certificate request • [KPI7.1] Lab validation: yes, in 5GBarcelona
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Table 4-11: Approved and rejected credentials in this test

Approved Cedentials	Rejected Credentials
{ "Licence Title": "Grant Of Rights Of Use Of Radio Spectrum For The Establishment And Operation Of A Terrestrial System Capable Of Providing Wireless Broadband Electronic Communication Services", "Licence Reference No": "MCA/L/21-4207", "Governing Legislation": "The Electronic Communications (Regulation) Act (Chapter 399, Laws of Malta)", "Term of Grant": "15 years", "Commencement Date": "17/05/2021", "Expiry Date": "16/05/2036", "Name of Licensee": "Melita Limited", "Registered Address": "Gasat Centre, Triq il-Mergat, Zone 1, Central Business District, B'Kara", "Country": "Malta", "Company Registered Number": "C 12715", "Spectrum Fee": "€ 9,000 per 5 MHz of unpaired spectrum", "Duplex Mode Of Operation": "TDD", "TDD Synchronisation - default frame structure": "Frame A of ECC/Rec(20)03", "Radio Spectrum - Start UL Frequency": "3600 MHz", "Radio Spectrum - End UL Frequency": "3700 MHz", "Radio Spectrum - Start DL Frequency": "3600 MHz", "Radio Spectrum - End DL Frequency": "3700 MHz", "Base station maximum transmit power": "[Power/dBm]" }	{ "Licence Title": "Grant Of Rights Of Use Of Radio Spectrum For The Establishment And Operation Of A Terrestrial System Capable Of Providing Wireless Broadband Electronic Communication Services", "Licence Reference No": "MCA/L/21-4207", "Governing Legislation": "The Electronic Communications (Regulation) Act (Chapter 399, Laws of Malta)", "Term of Grant": "15 years", "Commencement Date": "17/05/2021", "Expiry Date": "16/05/2036", "Name of Licensee": "Melita Limited", "Registered Address": "Gasat Centre, Triq il-Mergat, Zone 1, Central Business District, B'Kara", "Country": "Malta", "Company Registered Number": "C 12715", "Spectrum Fee": "€ 9,000 per 5 MHz of unpaired spectrum", "Duplex Mode Of Operation": "TDD", "TDD Synchronisation - default frame structure": "Frame A of ECC/Rec(20)03", "Radio Spectrum - Start UL Frequency": "3400 MHz", "Radio Spectrum - End UL Frequency": "3500 MHz", "Radio Spectrum - Start DL Frequency": "3400 MHz", "Radio Spectrum - End DL Frequency": "3500 MHz", "Base station maximum transmit power": "[Power/dBm]" }

The SRP provides the essential details of the spectrum license to be digitalized in the form of a spectrum certificate, that it can be used in the 5GZORRO for creating spectrum resources to trade with.

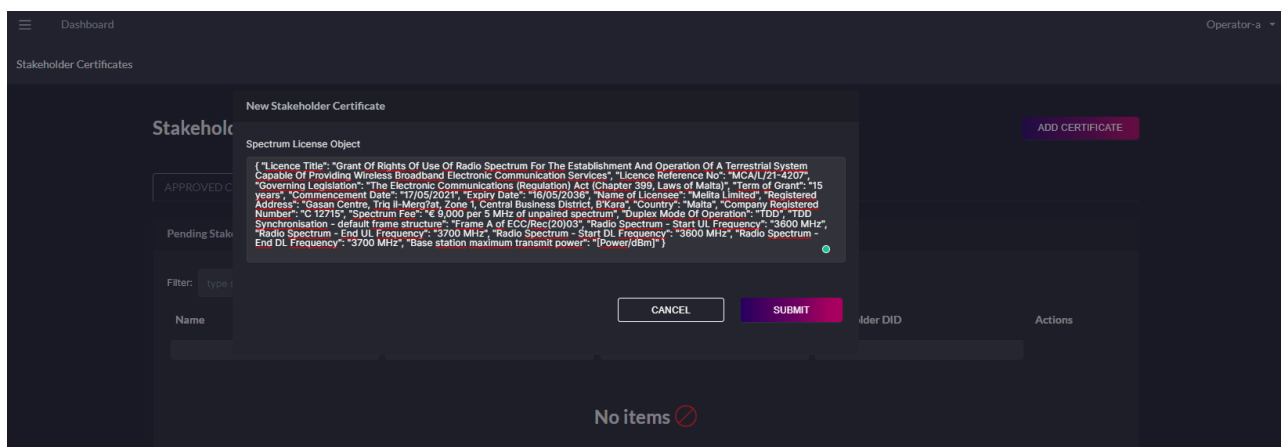


Figure 4-6: Operator A providing the details of one of its spectrum licenses for the spectrum certificate creation request

When the request is sent to the 5GZORRO platform, the Regulator decides in its Portal view in Figure 4-7 whether to accept or decline the request, based on the information that the SRP submitted.

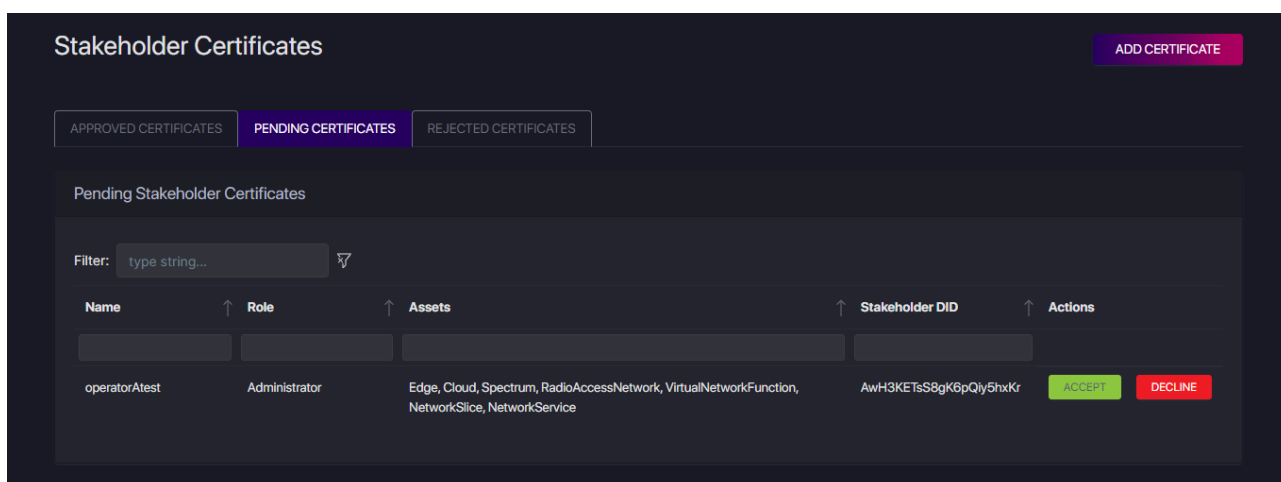


Figure 4-7 Regulator can decide whether to accept or reject the spectrum certificate request

Depending on the decision made by the Regulator, the spectrum certificate will be listed under the “Approved certificates” in Figure 4-8 or the “Rejected certificates” tab in Figure 4-9. In Figure 4-8, the list of certificates is filtered by the certificate’s DID reported in Figure 4-7.

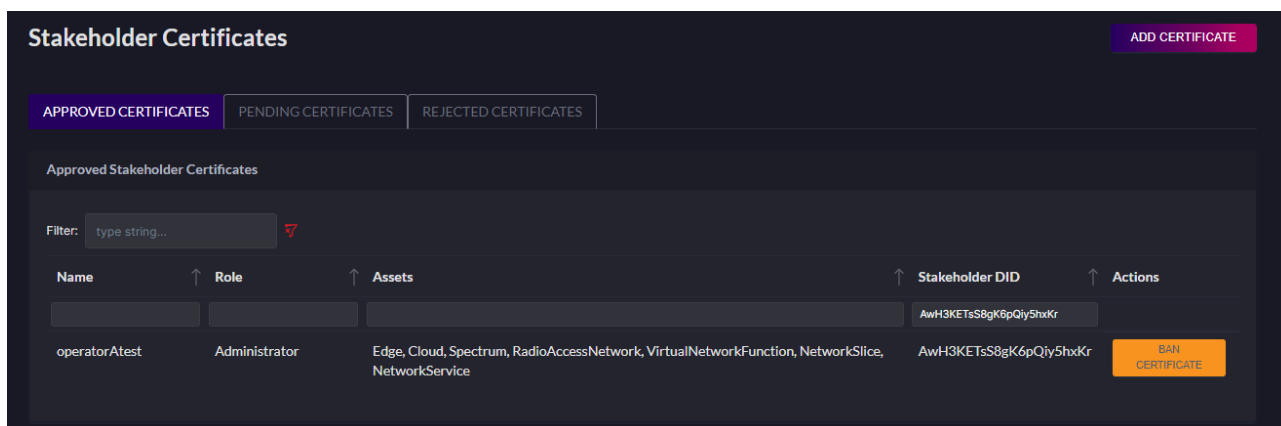


Figure 4-8: The spectrum certificate request was approved and appears as such

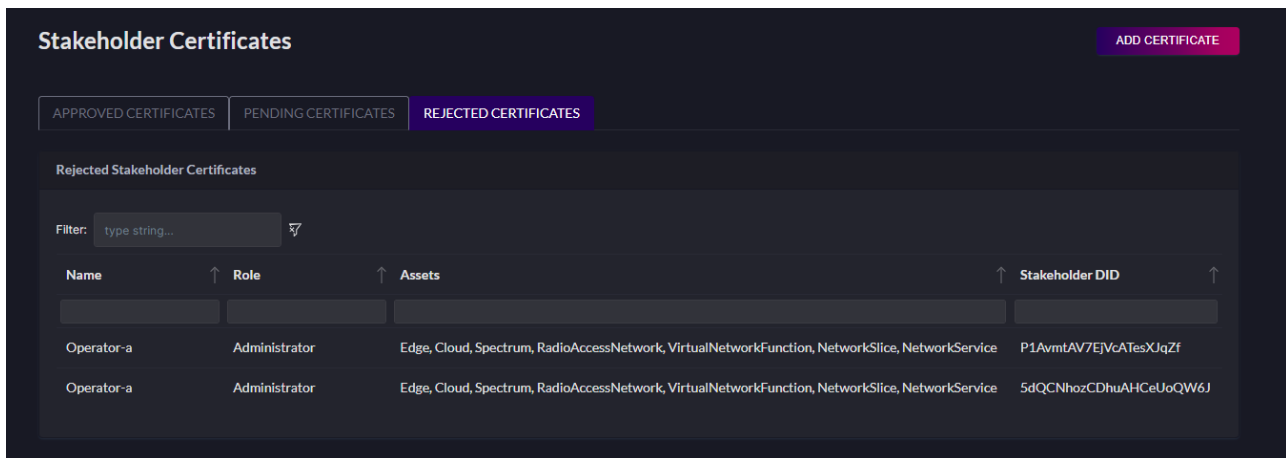


Figure 4-9: View of past spectrum certificate creation request that were rejected

4.3.1.6. Test UC2.5b: Spectrum resource registration

This test aims at demonstrating the registration of the spectrum resource in the stakeholder's domain. This is a necessary step before creating a spectrum resource offer in the Marketplace. Note that in the process of creating a spectrum resource offer, the SRP selects the spectrum resources that will be included in the offer.

The spectrum resource is defined at the Spectrum Resource Manager (sRM) within the SRP's domain. The technical information of the spectrum resource is validated against the spectrum certificates that the SRP has previously registered in the 5GZORRO platform. If no spectrum certificate matches the criteria specified in the spectrum resource, the spectrum resource will not be registered in the spectrum resource manager.

This test considers the two possible outcomes of the spectrum resource registration in the spectrum resource manager: accepted in Table 4-12, and rejected in Table 4-13

Table 4-12: Spectrum resource created

UC2.5b-1	Spectrum resource created	
Testbed	5GBarcelona	
Description	The SRP tries to register a spectrum resource in the sRM. The sRM retrieves all the spectrum certificates from the Id&P and then, checks if at least one certificate is compatible with the technical specifications of the spectrum resource. Optionally, the SRP can provide the spectrum certificate DID in order to retrieve that specific certificate instead of all of them. Only valid spectrum certificates will be considered.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Spectrum Resource Manager (sRM) • Identity and Permissions Manager (Id&P)
	Configuration	<ul style="list-style-type: none"> • SRP has some spectrum certificates in the Id&P • sRM has no registered spectrum resource
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • SRP and Regulator are both onboarded
	Test Case steps	1. The SRP accesses the sRM API

		<ol style="list-style-type: none"> The SRP goes to the create spectrum resource endpoint (POST) and provides the technical information of the spectrum resource sRM retrieves all the spectrum certificates, or just one if a DID was provided with the spectrum resource technical information sRM iterates along the spectrum certificates retrieves and check one by one if the spectrum resource technical information matches the certificate sRM found a compatible and valid certificate and stores the spectrum resource specification internally sRM returns a success code (201) and the id of the spectrum resource in the sRM
Measurements	Methodology	Check that the recently registered spectrum resource in the sRM can be retrieved by providing its id in the GET method in the sRM's API.
	Complementary measurements	Measure the time it takes the sRM to validate the spectrum resource and register it internally
	Calculation process	For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation. The process is launched multiple times and the reported value corresponds to the average.
Result	<p><u>The spectrum resource is registered in the sRM and it has an id</u>, as illustrated in Figure 4-10</p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations: 1 (1 SRP operator is needed) [KPI5.2] Number of spectrum resource requests processed per second: 13.614 (all requests had a spectrum certificate and could be approved) [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 [KPI7.1] Lab validation: yes, in 5GBarcelona 	

Table 4-13: Spectrum resource not created

UC2.5b-2	Spectrum resource not created	
Testbed	5GBarcelona	
Description	The SRP tries to register a spectrum resource in the sRM. The sRM retrieves all the spectrum certificates from the Id&P and then, checks if at least one certificate is compatible with the technical specifications of the spectrum resource. Optionally, the SRP can provide the spectrum certificate DID in order to retrieve that specific certificate instead of all of them. Only valid spectrum certificates will be considered.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations [KPI5.2] Number of transactions per second handled [KPI5.3] The authenticity of the market agents 	
Components and Configuration	Components	<ul style="list-style-type: none"> Spectrum Resource Manager (sRM) Identity and Permissions Manager (Id&P)
	Configuration	<ul style="list-style-type: none"> SRP has some spectrum certificates in the Id&P sRM has no registered spectrum resource
Test Procedure	Pre-conditions	SRP and Regulator are both onboarded. SRP has at least one valid spectrum certificate
	Test Case steps	<ol style="list-style-type: none"> The SRP accesses the sRM API The SRP goes to the create spectrum resource endpoint (POST) and provides the technical information of the spectrum resource

		<ol style="list-style-type: none"> sRM retrieves all the spectrum certificates, or just one if a DID was provided with the spectrum resource technical information sRM iterates along the spectrum certificates retrieves and check one by one if the spectrum resource technical information matches the certificate sRM could not find a compatible and valid certificate and does not store the spectrum resource specification internally sRM returns a not found error code (404)
Measurements	Methodology	Visually inspect that no additional spectrum resource is not registered in the sRM. The complete list of spectrum resources can be obtained from the corresponding endpoint.
	Complementary measurements	Not applicable.
	Calculation process	Not applicable.
Result	<p><u>The spectrum resource is not registered</u> in the sRM</p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations: 1 (1 SRP operator is needed) [KPI5.2] Number of spectrum resource requests processed per second: 21.277 (none of the requests had a valid spectrum certificate and could not be approved) [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 [KPI7.1] Lab validation: yes, in 5GBarcelona 	

Figure 4-10 illustrates a view on Operator-A's portal (SRP) of the list of spectrum certificates created after running this test. As it can be seen, all resources look similar, and the only difference is the resource id used by the sRM. The details of the spectrum resource in Figure 4-11 shows that it is in line with the spectrum certificate that was issued in test UC2.5a (accepted spectrum certificate request).

Id	Name	Description	Category
c5d45bd6-bc13-443f-9362-0481b5e95041	n78	A spectrum resource in band n78 with 50.0 MHz of bandwidth.	Spectrum
686d7cbb-37e5-4382-93e4-e758bc66c261	n78	A spectrum resource in band n78 with 50.0 MHz of bandwidth.	Spectrum
858c4cac-1f8d-45d2-86b5-b0099058cc77	n78	A spectrum resource in band n78 with 50.0 MHz of bandwidth.	Spectrum
9b01adff-fb1d-4b1b-9e10-52a41ce8590a	n78	A spectrum resource in band n78 with 50.0 MHz of bandwidth.	Spectrum
bb2b179b-f22d-48f0-a057-27e2b40b690a	n78	A spectrum resource in band n78 with 50.0 MHz of bandwidth.	Spectrum

Figure 4-10: Spectrum resources automatically registered in the sRM

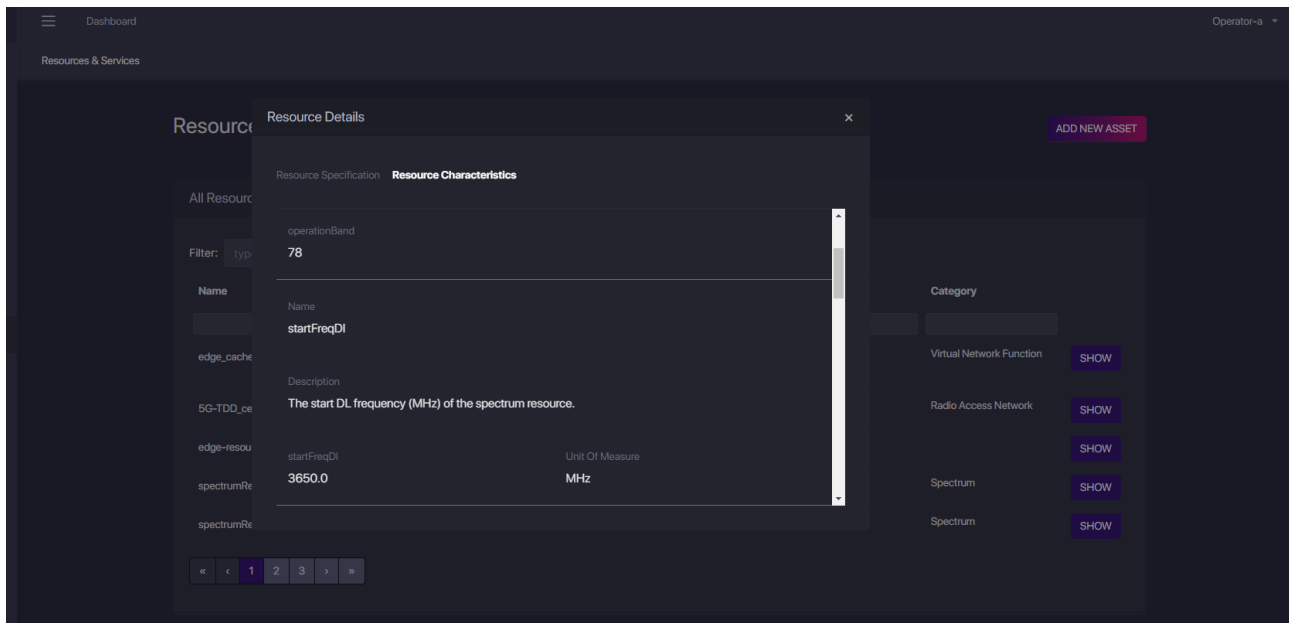


Figure 4-11: The spectrum resource details view shows that it is in line with the spectrum certificate

4.3.1.7. Test UC2.5c: Registration of a spectrum resource offer

This test will cover the particularities of registering a spectrum resource offer, extending the broad product offer creation detailed in UC1 test in Section 3.2.1.6. Note that in the process of creating a spectrum resource offer, the SRP selects the spectrum resources that will be included in the offer. Before admitting the creation of the spectrum resource offer, the Oracle in the 5GZORRO platform checks that the spectrum resources included in the new offer are not being used as a part of a prior offering. The Oracle will simply check that there are no valid spectokens matching the spectrum resources included in the new offering.

Table 4-14: Registration of a spectrum resource offer

UC2.5c	Registration of a spectrum resource offer	
Testbed	5GBarcelona	
Description	The SRP tries to register a spectrum resource offer into the 5GZORRO Marketplace. The SRP selects some spectrum resources to include in the offer.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations [KPI5.2] Number of transactions per second handled [KPI5.3] The authenticity of the market agents [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> Portal Spectrum Resource Manager (sRM) 5GZORRO Resource and Service Offer Catalogue Marketplace DLT
	Configuration	<ul style="list-style-type: none"> SRP has some spectrum certificates in the Id&P SRP has registered some spectrum resources matching the spectrum certificates
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> SRP is on-boarded A spectrum resource has been registered as in Section 4.3.1.6
	Test Case steps	1. The SRP logs in the Portal

		<ol style="list-style-type: none"> The SRP opens the page in the Portal to create a resource offer The Portal shows the list of resources to include in the new offer The SRP selects one spectrum resource The SRP provides the resource location information The SRP provides the resource offering pricing The SRP provides the rest of the offer information The SRP submits the spectrum offer and it is registered in the 5GZORRO Resource and Service Offer Catalogue
Measurements	Methodology	Check that the just registered spectrum resource offer is included in the Catalogue (matching description).
	Complementary measurements	Measure the time it takes the Marketplace to register the spectrum resource offer
	Calculation process	For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation. A testing script will help by automating the creation of spectrum resource offers by interacting with the appropriate endpoints in the 5GZORRO platform.
Result	<p><u>The spectrum resource offer is registered in the Catalogue</u></p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations: 1 (1 SRP operator is needed) [KPI5.2] Number of spectrum resource offers registered per second: the time for the Marketplace DLT to published a single offer was 0.95 seconds, the average time for 128 offers to be published simultaneously by the Marketplace DLT was 34 seconds with a standard deviation of 19 seconds. The average time for 128 offers to be published simultaneously published and appear in all catalogues was 60 seconds with a standard deviation of 27 seconds. [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 [KPI7.1] Lab validation: yes, in 5GBarcelona 	

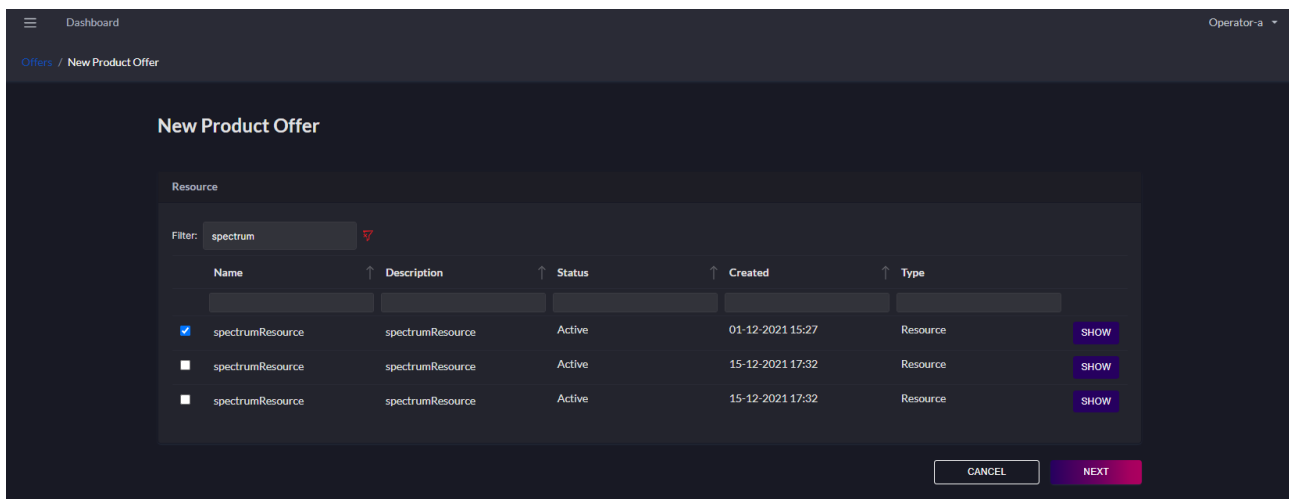


Figure 4-12: Selection of one of the spectrum resources for the spectrum product offer creation

Dashboard

Operator-a

Offers / New Product Offer / Detail Product Offer

New Product Offer

Product offer creation

Name

n78 spectrum

Location

Barcelona I2CAT Area, Spain

Description

A spectrum resource of 50 MHz in band n78 for Barcelona

Valid For

24/01/2022

→

31/01/2022

Category

Spectrum

Product Offering Price

Filter: type string...

Name	Description	Type	Unit	Value	
<input type="checkbox"/> pop-edge	pop-edge	One time	EUR	31	SHOW
<input checked="" type="checkbox"/> pop-ran	pop-ran	Recurring	EUR	165	SHOW
<input type="checkbox"/> pop-slice	pop-slice	One time	EUR	1663	SHOW

Figure 4-13: Providing details of the spectrum product offering

Dashboard

Operator-a

Product Offering Prices

Product C

Product Offer Price

ADD PRODUCT OFFERING PRICES

Filter: type i

Name

pop-edge

Description

pop-ran

Price

165

Price Type

Recurring

Recurring Charge Period Type

monthly

Recurring Charge Period Length

1

Valid for:

1

Is Bundle

False

Figure 4-14: Details of the product offer price (POP) associated to spectrum offers for Operator A

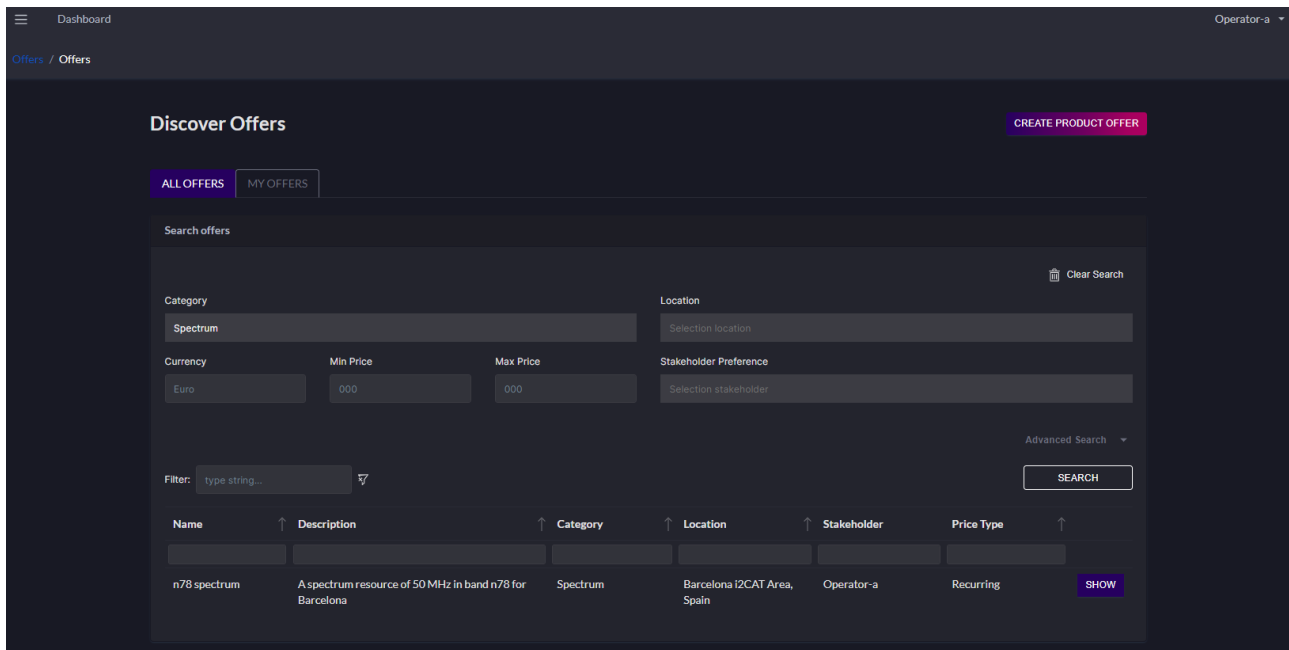


Figure 4-15: Spectrum product offer was registered and visible in Operator A's Portal

4.3.1.8. Test UC2.7a: Registration of a radio resource

This test aims at demonstrating the registration of the radio resource in the stakeholder's domain. This is a necessary step before creating a radio resource offer in the Marketplace. Note that in the process of creating a radio resource offer, the stakeholder selects the radio resources that will be included in the offer. This test assumes that an RRM is on-boarded as detailed in UC2 test in Section 4.3.1.3.

The radio resource is defined at the Radio Resource Manager (rRM) within the SRP's domain.

Table 4-15: Radio resource creation

UC2.7a	Radio resource creation	
Testbed	5GBarcelona	
Description	The RRP tries to register a spectrum resource in the rRM.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations [KPI5.2] Number of transactions per second handled [KPI5.3] The authenticity of the market agents 	
Components and Configuration	Components	<ul style="list-style-type: none"> Radio Resource Manager (rRM)
	Configuration	rRM has no registered radio resource
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> RRM has successfully on-boarded as in UC2.3 test described in Section 4.3.1.3
	Test Case steps	<ol style="list-style-type: none"> The RRP accesses the rRM API The RRP goes to the create radio resource endpoint (POST) and provides the technical information of the radio rRM returns a success code (201) and the id of the radio resource in the rRM
Measurements	Methodology	Check that the recently registered radio resource in the rRM can be retrieved by providing its id in the GET method in the rRM's API.

	Complementary measurements	Not applicable
	Calculation process	For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation.
Result	<p>The radio resource is registered in the rRM and it has an id</p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 1 (1 RRP operator is needed, but it could be replicated with an SRP since it is also considered as a radio resource provider as detailed in Section 4.3.1.2) • [KPI5.2] Number of radio resource requests processed per second: 16.614 • [KPI5.3] Authenticity of the radio resource provider: yes, determined during the on-boarding process in Section 4.3.1.3 • [KPI7.1] Lab validation: yes, in 5GBarcelona 	

4.3.1.9. Test UC2.7b: Registration of a radio resource offer

This test has no substantial difference with the broad UC1 “Product offer creation” test described in Section 3.2.1.6. This test is the generalisation of the test for the case of using a radio resource.

Table 4-16: Registration of a radio resource offer

UC2.7b	Registration of a radio resource offer	
Testbed	5GBarcelona	
Description	The RRP tries to register a radio in a radio resource offer into the 5GZORRO Marketplace.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Radio Resource Manager (rRM) • 5GZORRO Resource and Service Offer Catalogue • Marketplace DLT
	Configuration	<ul style="list-style-type: none"> • RRP has some spectrum certificates in the Id&P • RRP has registered some radio resources
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • RRP is on-boarded • A radio resource has been registered as in Test UC2.5c • Test UC2.7a
	Test steps	<ol style="list-style-type: none"> 1. The RRP logs in the Portal 2. The RRP opens the page in the Portal to create a resource offer 3. The Portal shows the list of resources to include in the new offer 4. The SRP selects one radio resource 5. The SRP provides the resource offering pricing 6. The SRP provides the SLA template 7. The SRP provides the rest of the offer information 8. The SRP confirms the offering 9. The radio resource offer is registered in the Catalogue
Measurements	Methodology	Check that the just registered spectrum resource offer is included in the Catalogue (matching offer id).

	Complementary measurements	Measure the time it takes the Marketplace to register the spectrum resource offer
	Calculation process	For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation. A testing script will help by automating the creation of radio resource offer by interacting with the appropriate endpoints in the 5GZORRO platform.
Result	<p>The radio resource offer is registered in the Catalogue</p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 1 (1 RRP operator is needed) • [KPI5.2] Number of radio resource offers registered per second: the time for the Marketplace DLT to published a single offer was 0.95 seconds, the average time for 128 offers to be published simultaneously by the Marketplace DLT was 34 seconds with a standard deviation of 19 seconds. The average time for 128 offers to be published simultaneously published and appear in all catalogues was 60 seconds with a standard deviation of 27 seconds. • [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 • [KPI7.1] Lab validation: yes, in 5GBarcelona 	

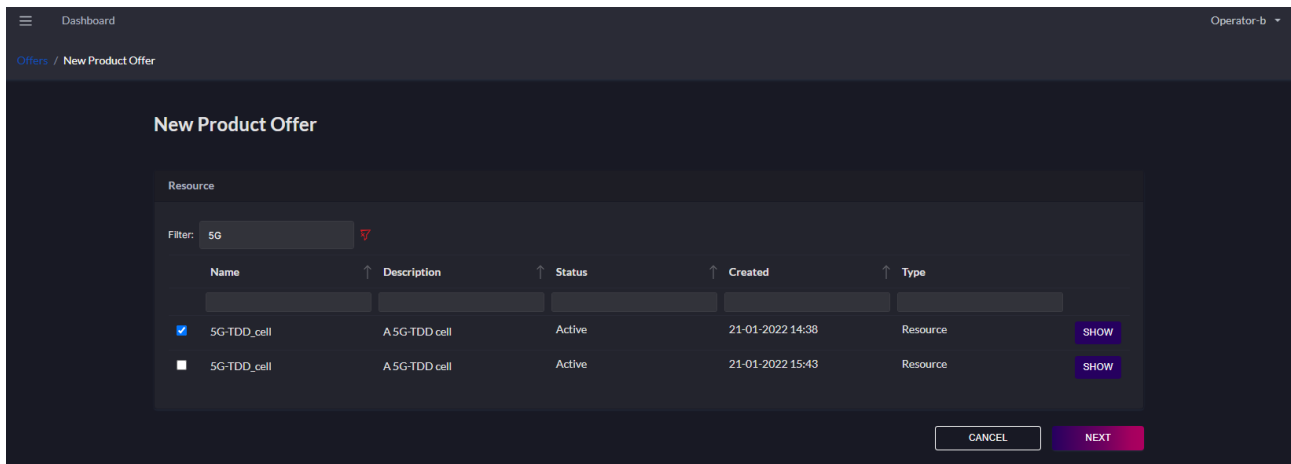


Figure 4-16: Selection of one of the radio resources (5G-TDD cell) for the radio product offer creation

Dashboard

Operator-b

Offers / New Product Offer / Detail Product Offer

New Product Offer

Product offer creation

Name

5G cell

Location

Barcelona Area

Description

5G cell in n78 with 50 MHz bandwidth

Valid For

24/01/2022 → 31/01/2022

Category

RAN x

Product Offering Price

Filter: type string...

Name	Description	Type	Unit	Value	
edge cache VNF POP	This pricing describes the recurring charge for edge cache network function	usage	EUR	15	SHOW
edge cache VNF POP	This pricing describes the recurring charge for edge cache network function	usage	EUR	15	SHOW
<input checked="" type="checkbox"/> ran-pop	ran-pop	recurring	1	100	SHOW

Figure 4-17: Providing details of the radio product offering

Dashboard

Operator-b

Offers / Offers

Discover Offers

CREATE PRODUCT OFFER

ALL OFFERS

MY OFFERS

Search offers

Category

RAN

Location

Selection location

Currency

Euro

Min Price

000

Max Price

000

Stakeholder Preference

Selection stakeholder

Filter: type string...

Advanced Search

SEARCH

Name	Description	Category	Location	Stakeholder	Price Type	
5G cell	5G cell in n78 with 50 MHz bandwidth	RAN	Barcelona Area	operator-b	recurring	SHOW

Figure 4-18: Radio product offer was registered and visible in Operator B’s Portal

4.3.1.10. Test UC2.7c: Registration of a slice offer

This test covers the case of registering a slice offer. The slice offer includes some radio infrastructure which is already configured to operate on a given portion of the spectrum. The radio parameters of the infrastructure are fixed, and the buyer cannot alter them.

This test focuses on the use of a licensed spectrum band. It is important to know that no spectrum rights are being transferred to the buyer of the slice offer. The rights remain on the SRP side, and the stakeholder acquiring the slice offer will have shared access to the spectrum.

Table 4-17: Registration of a slice offer

UC2.7c	Registration of a slice offer	
Testbed	5GBarcelona	
Description	The SRP tries to register a 5G spectrum resource and a 5G radio resource in a slice offer into the 5GZORRO Marketplace. Similar to UC2.5c, the 5GZORRO platform ensures that the spectrum resources are not used by any consumed (purchased by a stakeholder) spectrum resource offer. This validation is required to prevent from spectrum resource double-spending.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Spectrum Resource Manager (sRM) • 5GZORRO Resource and Service Catalogue • Marketplace DLT
	Configuration	<ul style="list-style-type: none"> • SRP has some spectrum certificates in the Id&P • SRP has registered some spectrum resources matching the spectrum certificates
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • SRP is on-boarded • A spectrum resource has been registered as in Section 4.3.1.6
	Test Case steps	<ol style="list-style-type: none"> 1. The SRP logs in the Portal 2. The SRP opens the page in the Portal to create a resource offer 3. The Portal shows the list of resources to include in the new offer 4. The SRP selects one spectrum resource 5. The SRP provides the resource offering pricing 6. The SRP completes the rest of the offer information 7. The SRP submits the offering 8. The spectrum resource offer is registered in the Catalogue.
Measurements	Methodology	Check that the just registered spectrum resource offer is included in the Catalogue (matching offer id).
	Complementary measurements	Measure the time it takes the Marketplace to register the spectrum resource offer
	Calculation process	For the estimation of the request processing time, it is measured by capturing the timestamps of each interaction/process initiation and finalisation. A testing script will help by automating the creation of slice offers by interacting with the appropriate endpoints in the 5GZORRO platform.
Result	<p>The slice offer is registered in the Catalogue</p> <p>Measured KPIs:</p> <ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations: 1 (1 SRP operator is needed) • [KPI5.2] Number of slice offers registered per second: the time for the Marketplace DLT to published a single offer was 0.95 seconds, the average time for 128 offers to be published simultaneously by the Marketplace DLT was 34 seconds with a standard deviation of 19 seconds. The average time for 128 offers to be published simultaneously published and appear in all catalogues was 60 seconds with a standard deviation of 27 seconds. • [KPI5.3] Authenticity of the spectrum resource provider: yes, determined during the on-boarding process in Section 4.3.1.2 	

	<ul style="list-style-type: none">• [KPI7.1] Lab validation: yes, in 5GBarcelona
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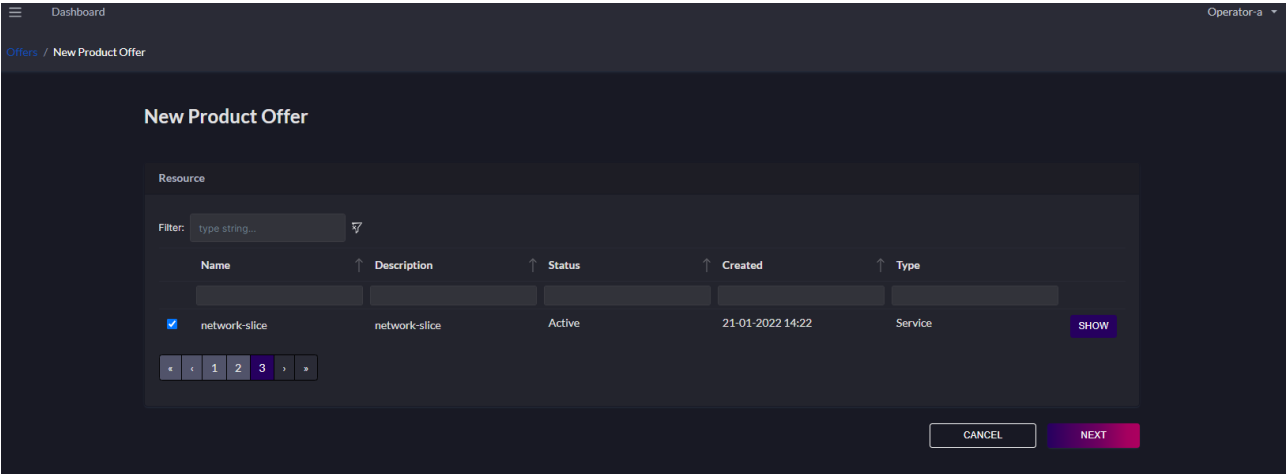


Figure 4-19: Operator A selection of a network slice service for a new product offer

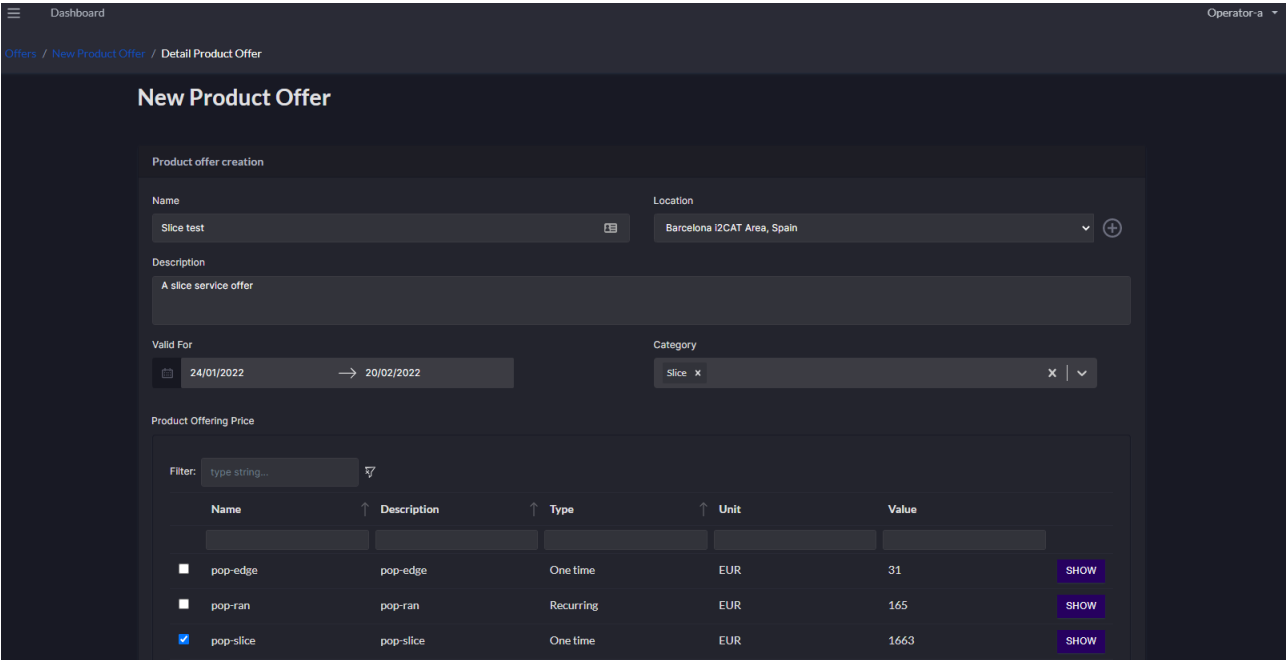


Figure 4-20: Operator A providing slice service offer details

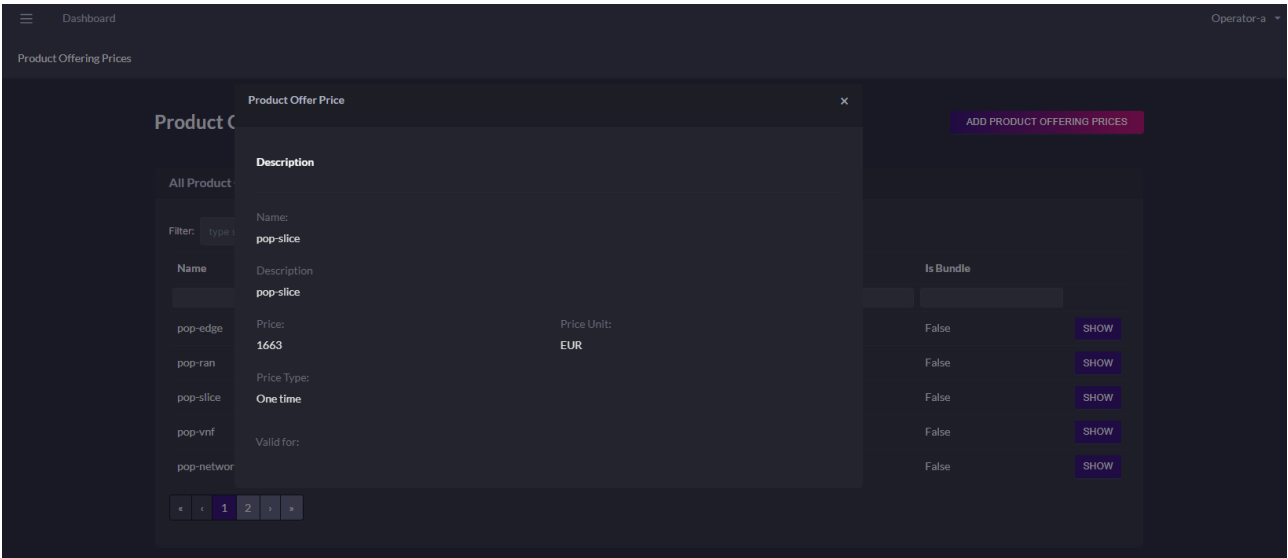


Figure 4-21: Details of the product offer price (POP) associated to slice offers for Operator A

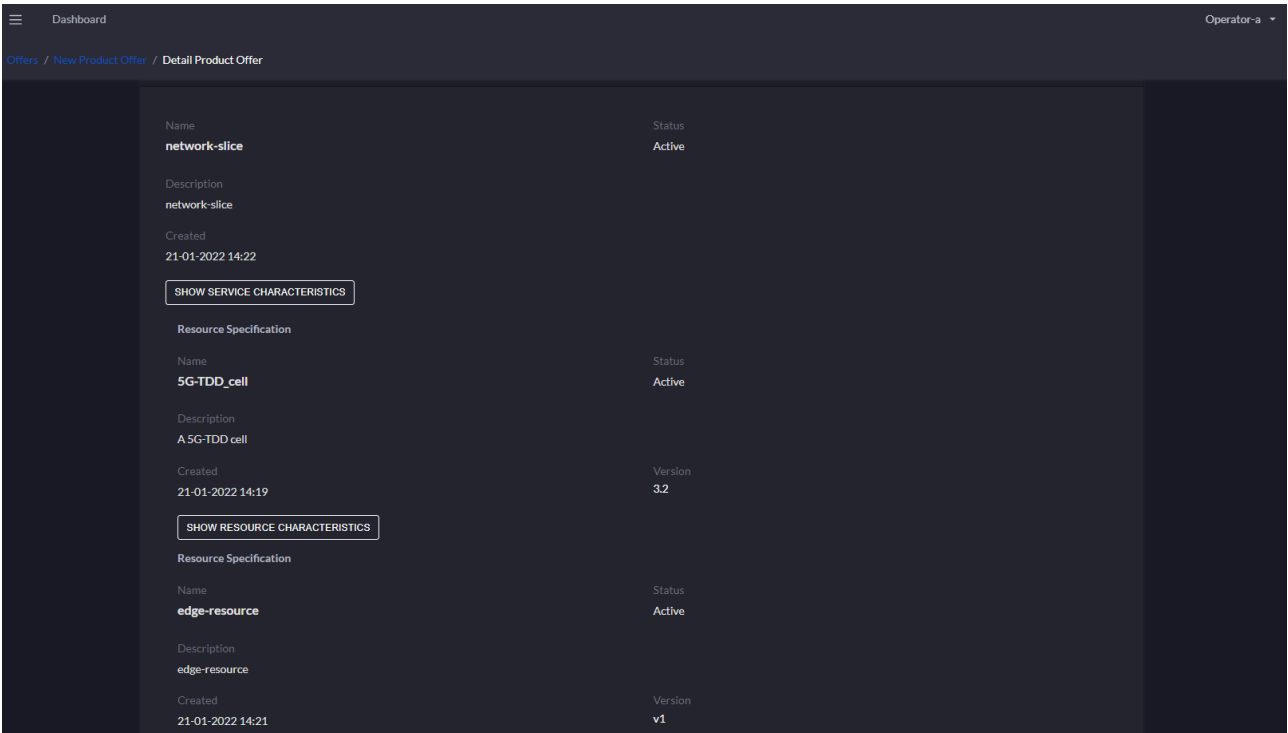


Figure 4-22: View on the details of the resource that composes the slice service

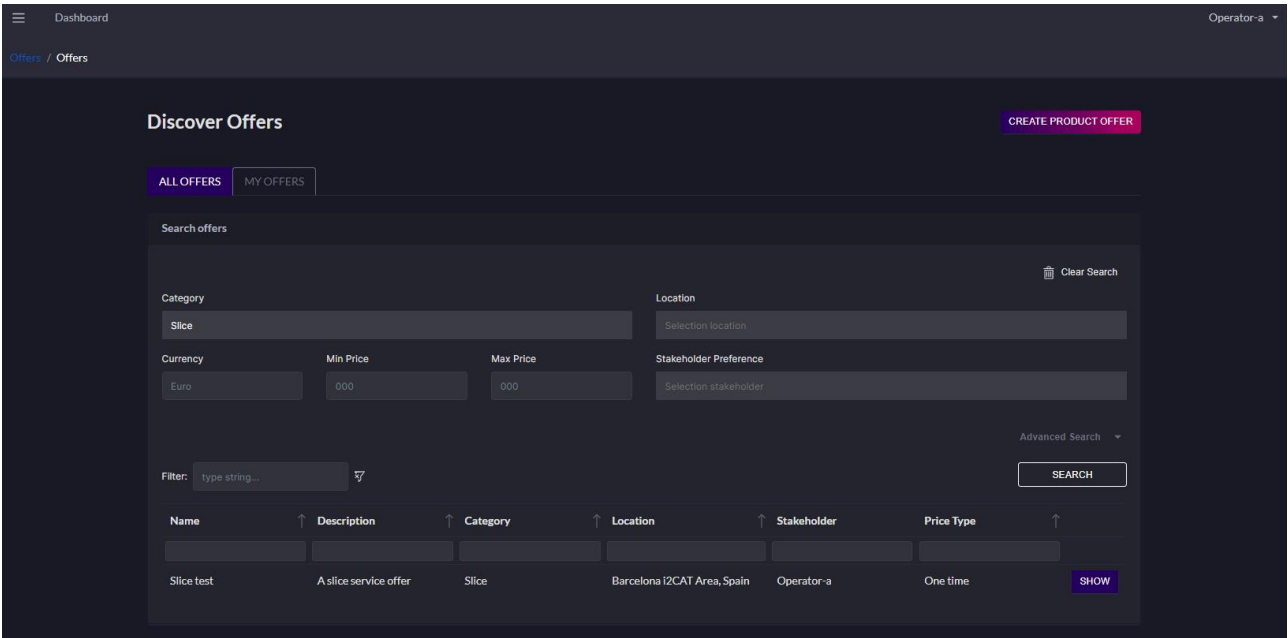


Figure 4-23: Operator A’s slice product offer is registered and visible in the Catalogue

4.3.2. Scenario 2.2: Resource selection by the resource consumer

This scenario aims at testing the consumption of all the different kinds of resource offers considered in 5GZORRO that are related to the use of the spectrum. The result of the consumption of the offer will always be a smart contract and, sometimes, a “derivative” spectoken.

4.3.2.1. Test UC2.6a: Selection of a spectrum resource offer

This test will cover the selection of a spectrum resource offer by a resource consumer. The resource consumer is allowed to participate in the spectrum market and all the spectrum resource offers are visible in the consumer’s Portal.

Note that the Catalogue may show active spectrum offers referred to a single spectrum resource. In such case, the consumption of one of these spectrum resource offers will remove it from the Catalogue and also all the offers that are not compatible with the recently consumed offer to prevent from spectrum double spending.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-18: Selection of a spectrum resource offer

UC2.6a	Selection of a spectrum resource offer	
Testbed	5GBarcelona	
Description	The resource consumer purchases a spectrum resource offer and consumes the offering. A smart contract with the SRP is registered in the governance DLT. A spectoken is also registered in the marketplace DLT and owned by the resource consumer.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none">[KPI1.1] Distributed multi-party service and business configurations[KPI5.2] Number of transactions per second handled[KPI5.3] The authenticity of the market agents[KPI7.1] Lab validation environment	
	Components	<ul style="list-style-type: none">Portal

Components and Configuration		<ul style="list-style-type: none"> • 5GZORRO Catalogue • Marketplace DLT • Smart Contract Life-Cycle Manager (SCLCM) • Governance DLT
	Configuration	The catalogue contains a spectrum resource

4.3.2.2. Test UC2.6b: Selection of a slice offer

This test will cover the selection of a slice offer by a resource consumer. The resource consumer is allowed to participate in the spectrum market and all the spectrum resource offers are visible in the consumer's Portal.

Note that the Catalogue may show active spectrum offers referred to the same spectrum resource used by the slice offer. In such case, the consumption of the slice offer will remove from the Catalogue all the spectrum resource offers that are not compatible with the slice. The spectrum used by the slice is now set to be used in a shared access scheme and, thus, the spectrum rights cannot be transmitted.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-19: Selection of a slice offer

UC2.6b	Selection of a slice offer	
Testbed	5GBarcelona	
Description	The resource consumer purchases a spectrum resource offer and consumes the offering. A smart contract with the SRP is registered in the governance DLT. The first time the spectrum resource within the slice is consumed, a "derivative" spectoken is registered in the marketplace DLT and owned by the SRP. Concurrent slice orderings using the same spectrum resource will also use the same "derivative" spectoken.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • 5GZORRO Catalogue • Marketplace DLT • Smart Contract Life-Cycle Manager (SCLCM) • Governance DLT
	Configuration	<ul style="list-style-type: none"> • The catalogue contains a spectrum resource

4.3.2.3. Test UC2.8: Selection of a radio resource offer

This test will cover the selection of a spectrum resource offer by a stakeholder. This test inherits all the steps shown in UC1 in Section 3.2.1.4 and does not include any additional step.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

4.3.2.4. Test UC2.9a: Automatic selection of resources and slice composition

This test will cover the automatic selection of the resources needed to deploy a slice (spectrum, radio, compute) without manual intervention of the resource consumer. Note that the resource consumer is allowed to participate in the spectrum market and all the spectrum, radio, and slice product offers are visible in the consumer's Portal. Right after the automatic selection of resources, the 5G slice is deployed.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-20: Automatic selection of resources

UC2.9a	Automatic selection of resources	
Testbed	5GBarcelona	
Description	The resource consumer wants to deploy a slice and provides the 5GZORRO platform some criteria or KPIs. The 5GZORRO automatically selects the best resources for this new slice. Smart contracts are set with the different resource providers.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • 5GZORRO Catalogue • Marketplace DLT • Smart Resource & Service Discovery (SRSD) • Smart Contract Life-Cycle Manager (SCLCM) • Governance DLT • Network Slice and Service Orchestrator (NSSO) • Radio Resource Controller (rRM)
	Configuration	The catalogue contains multiple spectrum and radio resource offers from different providers

4.3.3. Scenario 2.3: SLA monitoring

In this scenario, the slice deployment is the mean to start a service over the radio nodes and start collecting spectrum use telemetry data. For the point of view of the SLA breach monitoring and prediction services, the fundamental spectrum metrics are

- Transmission power
- Interference levels (and interferers)
- Location of the radio stations (Wi-Fi access points or cellular base stations)

4.3.3.1. Test UC2.9b: Deployment of a slice with configurable radio infrastructure

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Nevertheless, slice provisioning is operational in 5GZORRO. For this intermediate report, a 5G slice was deployed in the 5GBarcelona testbed. This 5G slice used an Amarisoft's stand-alone 5G cell with a single carrier in band n78 with 50MHz of bandwidth. This 5G cell was connected to a 5G core (Open5Gs) which was automatically deployed on 5GBarcelona's premises.

To evaluate the performance of the 5G radio access network, different tests were run for different TDD patterns. The TDD pattern determines the number of downlink and uplink consecutive transmission opportunities or slots. In 5G TDD, a slot can be fully downlink (D) or fully uplink (U), with a special (S) slot to let transceivers switch from downlink to uplink operation. In this test, four TDD patterns were considered: 7DS2U, 2DS7U, 2DS2U, and 3DSU. Each slot had a fixed duration of 0.5ms, which corresponds to a subcarrier spacing (SCS) of 30 kHz.

A Quectel RM500QL 5G modem was connected to the 5G cell and throughput and delay metrics were collected for downlink and uplink communications for each of the four TDD patterns. To this aim, TCP and UDP traffic user traffic was generated, with a constant data rate of 500 Mbps, which is slightly superior than the 5G cell capacity. As it can be seen in Figure 4-24 and Figure 4-25, different TDD patterns provide different maximum throughput values. It was observed some deviation from TCP to UDP traffic, especially in downlink,

due to the different protocol implementations. Figure 4-26 shows the average and minimum latencies measured for each of the TDD patterns. It can be seen that the patters that switch downlink and uplink transmissions more frequently (2DS2U and 3DSU) provides the lowest latencies.

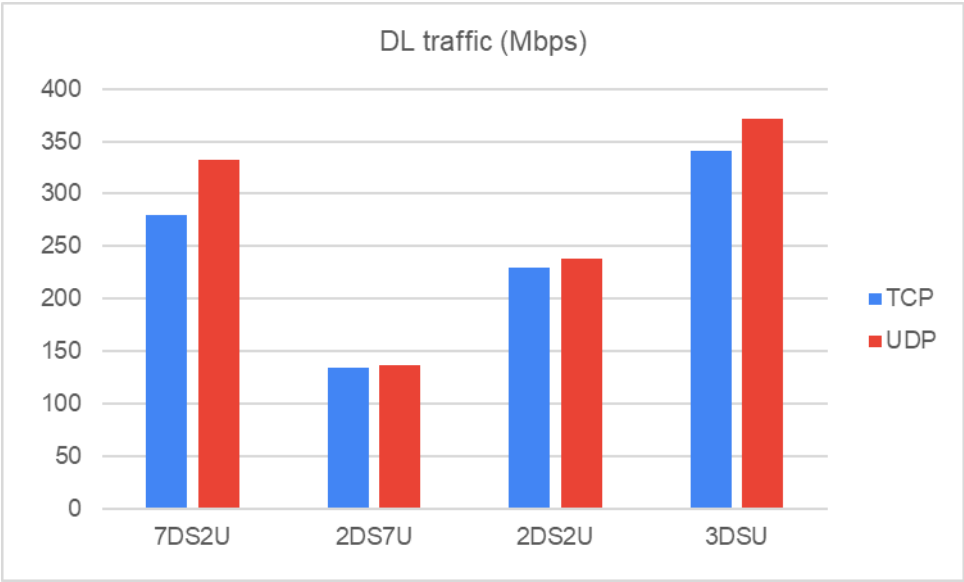


Figure 4-24: Radio segment maximum downlink data rate

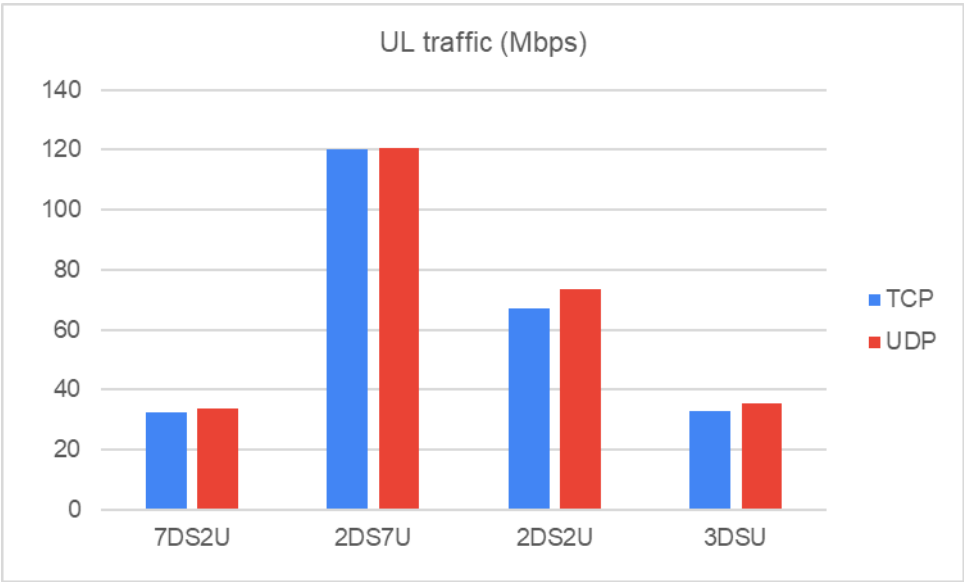


Figure 4-25: Radio segment maximum uplink data rate

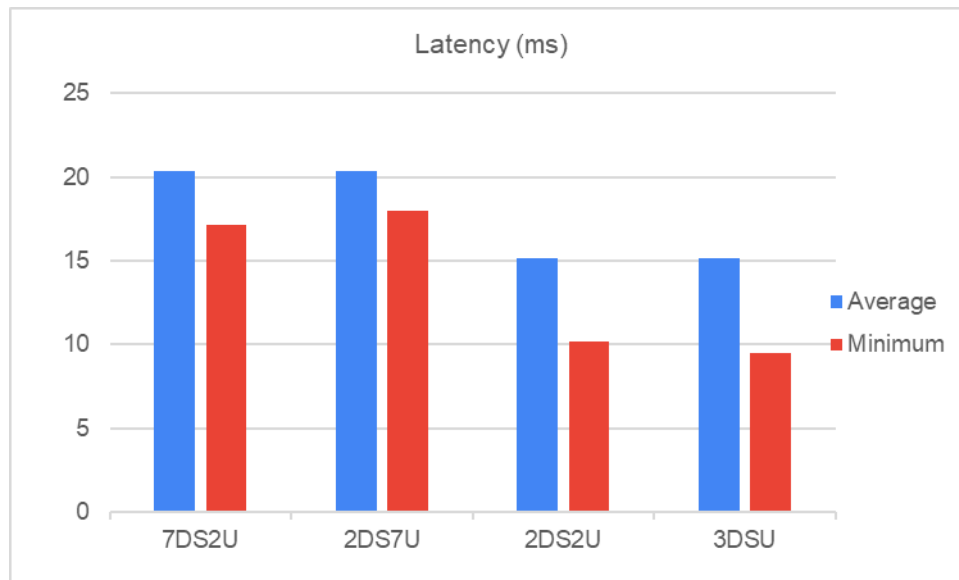


Figure 4-26: Average and minimum delay

Table 4-21: Deployment of a slice with configurable radio

UC2.9b	Deployment of a slice with configurable radio	
Testbed	5GBarcelona	
Description	The resource consumer deploys a slice over a given geographical area by selecting a set of the radio and spectrum resources that the resource consumer acquired beforehand from the 5GZORRO Marketplace.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Network Slice and Service Orchestrator (NSSO) • Smart Contract Life-Cycle Manager (SCLCM) • Radio Resource Controller (rRM)
	Configuration	The resource consumer obtained a spectrum resource and a compatible radio resource from different stakeholders. For example, the spectrum resource ranges from 3600 to 3640 MHz (5G band n78) and the radio resource is 5G-capable and can operate from 3600 to 3700 MHz

4.3.3.2. Test UC2.9c: Deployment of a slice with non-configurable radio infrastructure

This test will cover the deployment of a slice with some fixed radio nodes. This deployment can be possible after the ordering of a slice offer as detailed in Section 4.3.2.3.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-22: Deployment of a slice with non-configurable radio

UC2.9c	Deployment of a slice with non-configurable radio
Testbed	5GBarcelona

Description	The resource consumer deploys a slice acquired from the 5GZORRO Marketplace.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI5.3] The authenticity of the market agents • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Network Slice and Service Orchestrator (NSSO) • Smart Contract Life-Cycle Manager (SCLCM) • Radio Resource Controller (rRM)
	Configuration	The resource consumer obtained a slice offer from the SRP. The slice is set to operate in the 5G band n78, between 3600 and 3650 MHz

4.3.3.3. Test UC2.9d: Spectrum telemetry collection

This test will cover the collection of spectrum telemetry in the 5GZORRO datalake. The radio resource manager of the 5GZORRO platform instructs the radio infrastructure to collect spectrum use data. This data is pushed to the stakeholder's private datalake in the 5GZORRO platform for a posterior data processing by the SLA monitoring and breach detection service. The test aims at demonstrating that the spectrum use of the slice gets to the datalake.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-23: Spectrum telemetry collection

UC2.9d	Spectrum telemetry collection	
Testbed	5GBarcelona	
Description	A slice is deployed with some radio infrastructure. At the deployment time, the radio resource manager of the 5GZORRO platform instructs the radio infrastructure to collect spectrum use metrics.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.5] Spectrum telemetry • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Radio resource manager (rRM) • Monitoring data aggregator (MDA) • Network Slice and Service Orchestrator (NSSO) • Datalake
	Configuration	The slice is set to operate in the 5G band n78, between 3600 and 3650 MHz, over a given geographical area. At least one user equipment (UE) is connected to the slice

4.3.3.4. Test UC2.9e: SLA breach detection on time to deploy spectrum

This test will cover the detection of a spectoken not being used in any radio infrastructure/slice. Note that the SLA breach is related to the use of a spectoken and not to a spectrum resource because the spectoken implies that some sort of business with licensed spectrum has occurred within the 5GZORRO platform. For the sake of spectrum efficiency, the platform enforces the owners of the spectokens to rapidly use the spectrum resources they refer to. The breach detection can be as simple as not registering any spectrum use information related to a spectoken after some time threshold defined by the SRP.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-24: SLA breach detection on time to deploy spectrum

UC2.9e	SLA breach detection on time to deploy spectrum	
Testbed	5GBarcelona	
Description	The resource consumer ordered a spectrum resource offer from the 5GZORRO Marketplace. But this spectrum resource is never used effectively in any transmission and violates the SLA on the time to spend the spectrum resource.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.5] Spectrum telemetry • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Radio Resource Controller (rRM) • Monitoring data aggregator (MDA) • Datalake • SLA Breach detection service
	Configuration	The resource consumer obtained a spectrum resource, but it will not use it on any radio node

4.3.3.5. Test UC2.9f: SLA breach detection on interference levels

This test will cover the detection of an excessive interference level inside the area of application of a spectoken. The smart contract determines a maximum level of inter-network interferences. This test will emulate a scenario where this tolerance level of interferences is exceeded, and the parties involved in the spectrum transaction gets notified. The breach detection is based on the radio use telemetry data that the radio nodes push to the 5GZORRO datalake.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-25: SLA breach detection on interference levels

UC2.9f	SLA breach detection on interference levels	
Testbed	5GBarcelona	
Description	The resource consumer deploys a slice over a given geographical area by selecting a set of the radio and spectrum resources that the resource consumer acquired beforehand from the 5GZORRO Marketplace. A rogue gNB operating in the same frequency range appears and generates high interferences to the UE. The interference is superior to the acceptable level agreed in the SLA of the smart contract.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.5] Spectrum telemetry • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Portal • Network Slice and Service Orchestrator (NSSO) • Radio Resource Controller (rRM) • Monitoring data aggregator (MDA) • Datalake
	Configuration	

		<ul style="list-style-type: none"> SLA Breach detection service
	Configuration	The slice is set to operate in the 5G band n78, between 3600 and 3650 MHz, over a given geographical area. At least one user equipment (UE) is connected to the slice. A rogue base station operates on the same frequency range and causes a high level of interferences to the UE.

4.3.3.6. Test UC2.9g: SLA breach detection on geofencing spectrum

This test will cover the detection of an incorrect use of the spectrum as agreed on the smart contract. The violation of the contract will consist of a base station transmitting out-of-the bounds of the area of application of the spectoken. This test will emulate a base station that changes its location, which might be the case of a cell-on-wheels used to provide extra 5G coverage or capacity. The SLA breach will be force by changing the position of the base station in such a way that the base station falls outside the spectoken the radio is using. The breach detection is based on the radio use telemetry data that the radio nodes push to the 5GZORRO datalake, which includes the location of the base station. All commercial 4G and 5G base stations are equipped with GPS-like connectivity for the sake of synchronising the transmissions of the radio provider's infrastructure. So, it is fair to assume that base stations know their location and can report it.

Even though 4G and 5G user equipment (UE) also has GPS connectivity, the 3GPP standards do not contemplate the reporting of their location coordinates to the serving base stations. Even though the location of the UEs can be derived by performing some sort of triangulation of the signal strength received from at least 3 base stations, it will be assumed that the 5G network cannot geographically locate UEs. For this reason, geofencing spectrum is only applied to the base stations and not to UEs.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-26: SLA breach detection on geofencing spectrum

UC2.9g	SLA breach detection on geofencing spectrum	
Testbed	5GBarcelona	
Description	The resource consumer deploys a slice over a given geographical area by selecting a set of the radio and spectrum resources that the resource consumer acquired beforehand from the 5GZORRO Marketplace. The base station has mobility and goes beyond the limits of the spectoken.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI1.1] Distributed multi-party service and business configurations [KPI5.5] Spectrum telemetry [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> Portal Network Slice and Service Orchestrator (NSSO) Radio Resource Controller (rRM) Monitoring data aggregator (MDA) Datalake SLA Breach detection service
	Configuration	The slice is set to operate in the 5G band n78, between 3600 and 3650 MHz, over a given geographical area. At least one user equipment (UE) can be connected to the gNB. The gNB changes its location periodically following a trajectory and goes beyond the limits of the spectoken area of application.

4.3.3.7. Test UC2.9h: SLA breach correction on time to deploy spectrum

This test will cover the correction actions to perform after the time to deploy spectrum SLA breach detection described in Section 4.3.3.4. For the sake of spectrum efficiency, the platform enforces the owners of the spectokens to rapidly use the spectrum resource referred in the spectoken. If the spectrum is not used in a timely manner, the 5GZORRO platform will automatically apply a corrective action. The corrective action consists of transferring the spectoken from the resource consumer to the original SRP.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-27: SLA breach correction on time to deploy spectrum

UC2.9h	SLA breach correction on time to deploy spectrum	
Testbed	5GBarcelona	
Description	The resource consumer deploys a slice over a given geographical area by selecting a set of the radio and spectrum resources that the resource consumer acquired beforehand from the 5GZORRO Marketplace.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • SLA Monitoring & Breach Prediction • Marketplace DLT • Smart Contract Life-Cycle Manager (SCLCM) • Monitoring Data Aggregator (MDA) • Datalake • Trust Management Framework
	Configuration	The resource consumer obtained a spectrum resource, but it will not use it on any radio node

4.3.3.8. Test UC2.9i: SLA breach correction on interference levels

This test will cover the correction actions to perform after the detection of an SLA breach on high interference levels inside the area of application of a spectoken, which test was described in Section 4.3.3.5. A spectoken guarantees its owner the exclusive access to the spectrum resources inside the area of application of the spectoken. By transferring a spectoken (and the rights to use the spectrum resource) to the resource consumer, the SRP takes the necessary configurations in its radio access network to cease its operation inside the area of application of the spectoken and keep interferences from outside this area to a minimum. This tolerance level of interference was registered in the SLA terms and signed by the buyer and the seller in the smart contract reflecting the spectrum trading operation.

Different correction actions could be applied, depending on the level of intervention of the 5GZORRO platform on the configuration of the SRP's radio infrastructure (assuming that the SRP is responsible for generating high interferences). This test assumes that the rogue gNB causing interferences in Section 4.3.3.5. is managed by 5GZORRO's Radio Resource Manager in the SRP's domain. This enables the platform to re-configure the radio parameters of the rogue gNB.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-28: SLA breach correction on interference levels

UC2.9i	SLA breach correction on interference levels	
Testbed	5GBarcelona	
Description	The resource consumer deploys a slice over a given geographical area by selecting a set of the radio and spectrum resources that the resource consumer acquired beforehand from the 5GZORRO Marketplace. The SRP had a running slice near that area, close enough to generate interferences to resource consumer's UEs. A resource consumer UE reports high interferences during some time. An SLA breach is determined, and the mitigation action is to reduce the transmit power of the rogue gNB.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI7.1] Lab validation environment 	
Components and Configuration	Components	<ul style="list-style-type: none"> • SLA Monitoring & Breach Prediction • Monitoring Data Aggregator (MDA) • Radio Resource Manager (rRM) • Datalake • Trust Management Framework
	Configuration	The resource consumer obtained a slice offer from the SRP. The slice is set to operate in the 5G band n78, between 3600 and 3650 MHz

4.3.3.9. Test UC2.9j: SLA breach correction on geofencing spectrum

This test will cover the correction actions to perform after the geofencing spectrum SLA breach detection test described in Section 4.3.3.6. If the gNB falls outside the area of application of the spectoken, the slice will be deprovisioned, and the gNB transmissions will be turned off.

In this test, it is assumed that the resource consumer's nomadic gNB is originally located in region A. A slice is deployed using spectoken that applies for Region A. Sometime later, the nomadic gNB moves to Region B, where the spectoken does not apply. When the SLA breach is detected, the slice is deprovisioned. The slice will not be able to be re-deployed until the nomadic gNB goes within the borders of the spectoken (Region A). Another possibility not covered in this test would be to deploy the slice using spectoken with similar spectrum ranges that applies for Region B.

This test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 4-29: SLA breach correction on geofencing spectrum

UC2.9j	SLA breach correction on geofencing spectrum	
Testbed	5GBarcelona	
Description	The resource consumer deploys a slice over a given geographical area by selecting a set of the radio and spectrum resources that the resource consumer acquired beforehand from the 5GZORRO Marketplace. The base station has mobility and goes beyond the limits of the spectoken. The SLA breach is detected and maintained during a given time period. As a consequence, the 5GZORRO platform performs the correction action and temporary disables the radio transmissions	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI1.1] Distributed multi-party service and business configurations • [KPI5.2] Number of transactions per second handled • [KPI7.1] Lab validation environment 	
	Components	<ul style="list-style-type: none"> • SLA Monitoring & Breach Prediction

Components and Configuration		<ul style="list-style-type: none">• Network Slice and Service Orchestrator (NSSO)• Radio Resource Manager (rRM)• Monitoring Data Aggregator (MDA)• Datalake• Trust Management Framework
	Configuration	The resource consumer obtained two spectrum resource offers from the SRP and one nomadic gNB. The two spectrum resources are in the 5G band n78, between 3600 and 3650 MHz, but they apply to two contiguous regions, Region A and Region B. The nomadic gNB is originally located in Region A. A slice is deployed using spectoken for Region A. Nomadic gNB moves to Region B

5. UC3: Pervasive vCDN Services

5.1. Description

This Use Case is built on ICOM's commercial offering of a CDN solution, i.e. fs|cdn™ Anywhere, which is modified in order to suit the project requirements. The fs|cdn™ Anywhere is an end-to-end CDN solution that allows to seamlessly integrate 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. Moreover, it includes features for the encryption, transcoding, distribution, caching and reception of content, with support for Set-Top-Boxes (STBs) as well as Smart TV, Smart Phone and Tablet devices (iOS and Android). Especially for the case of mobile clients, fs|cdn™ Anywhere adopts the HTTP Live Streaming (HLS) and Dynamic Adaptive Streaming over HTTP (MPEG-DASH) protocols and creates a hierarchical (tree-like) topology of HTTP servers (video streamers and content caches) to emulate a multicast delivery tree. These video streamers and content caches are placed in key locations of the CSP's network and allow for reaching all the CSP's CDN subscribers.

For 5GZORRO purposes, CDN edge network components are virtualized and offered as Virtual Network Functions (VNFs), thus leading to a virtual CDN (vCDN) solution. Streaming servers and content caches are hosted on a CSP infrastructure. The purpose of this use case is to allow video streamers and / or cache servers to be scaled using 3rd party resources. In addition, there is a licensing system that accompanies the CDN solution, which binds a specific CDN deployment to a maximum number of end-users.

In our scenarios, a CDN / OTT service provider hires a network slice instance from a CSP that includes performance guarantees in some areas of the network, based on a service workload profile. In high workload situations, there is a chance that the CSP's edge infrastructure cannot meet the demand. As a result, an advanced auto-scaling policy triggers the resource discovery process aimed at identifying potential usable 3rd party edge resources. The discovery process identifies the candidate product offers and rates them based on how much they satisfy the offer request as well as on profile information related to the resource (e.g., trust properties, pricing, etc.). Upon selecting the offer with the highest score, the CSP orders it from the Marketplace. In the final stage, the network section is expanded to the 3rd party infrastructure. This includes establishing a secure connection between the CSP edge server and the new infrastructure site and instantiating the service components on the new resources.

This Use Case comprises of three general scenarios which will be analysed in section 5.2.

5.1.1. Specific security and trust validation aspects

The use of 5GZORRO platform allows the seamless and secure integration of 3rd party resources to existing 5G resources. Also, all of the connections between services and software components should be secured.

Regarding the exchange of resources and services, the platform leverages the security aspects related to DLT, such as data encryption, access control, tamper-resistant data, identity management and fault tolerance. DLT is perceived as a trusted and transparent shared resource that contributes to the automation and decentralization of processes, minimizing the trust necessary in a manual or centralized solution. In this way, DLT provides a tool of trust that minimizes (or eliminates) the need of an auditing intermediary as it enables real-time auditing. Therefore, it is especially beneficial for this use case, where untrusted stakeholders seek to build a trusted infrastructure for sharing data in a secure and accountable manner.

Additionally, on the business layer, the required trust among the various, involved parties (i.e., CDN provider, CSP and 3rd party infrastructure provider) is further established through the Smart Contracts Management and Secure SLA Monitoring services which are appropriately configured for any newly established SLA.

Another paramount aspect linked to trust is the reputation, in particular, the CSP's reputation based on previous interactions in the 5GZORRO ecosystem. Owing to the fact that this use case is inspired by the selection of 3rd party infrastructure providers, it is required to analyse the trustworthiness of each one before establishing a relationship.

For this purpose, the Smart Resource and Service Discovery (SRSD) module uses the 5G-enabled Trust and Reputation Management Framework (5G-TRMF) in order to rank the available offers. Hence, the SRSD will forward an initial list of product offers to be analysed by the 5G-TRMF as feasible 3rd party infrastructure providers. In order to determine the trust scores, an adapted PeerTrust model is leveraged, contemplating feedback from recommenders and provider's satisfaction, among other features (more information about PeerTrust model can be found in Deliverable 4.2). In addition, the 5G-TRMF will ensure the zero-trust principle as it avoids implicit trust regardless of whether a trust relationship is located in an intra- or inter-domain scenario.

All in all, in the following tests, the security level of the communications among the different components is evaluated. Moreover, the ability of the 5G-enabled Trust and Reputation Management Framework in calculating trust scores for resource offers as well as the successful inclusion of these scores into SRSD's processes is validated.

5.2. UC3 Scenarios

The UC3 scenarios and test cases have been already presented in deliverable D5.1 [3]. One of the major updates on UC3 tests is that UC3.2d, i.e., "Apply load balancing at the RAN level", which was mentioned in D5.1, has been removed. The reason for this is that 5GZORRO does not plan to address RAN's load balancing mechanisms. On the other hand, it is required that both RANs (CSP's and 3rd party's) serve the CDN users, which it will be included in other tests, particularly in UC3.2c. Similarly, UC3.1e is now renamed into "Traffic distribution to all CDN edge servers", as the goal is not to manually apply a load balancing rule, but to verify that the new edge cache is included in the CDN policies for dividing the requests into available servers. Moreover, in the current document, two more tests have been added, namely UC3.3a and UC3.3b. These tests refer to the 3rd scenario which was firstly presented in deliverable D2.1 [1].

In the next subsections we describe all the scenarios and tests that are planned for UC3. However, not all of them have been completed by the time of this deliverable's submission. Therefore, we are presenting only the results for the implemented tests. In the following table we indicate for which test cases the results are presented in the current deliverable and for which they will be presented in D5.3. These tests refer to 5G Barcelona testbed.

Table 5-1: Plan for UC3 tests in 5G Barcelona testbed

Tests in scope of D5.2	Tests planned for D5.3
Test UC3.1a: CDN application deployment	Test UC3.2a: Predict RAN resource saturation
Test UC3.1b: SLA breach prediction validation	Test UC3.2b: Discovery and acquisition of RAN resource
Test UC3.1c: Discovery and acquisition of compute resources	Test UC3.2c: Slice extension to 3rd party Base Station and edge server
Test UC3.1d: Slice extension to 3rd party edge server	Test UC3.3b: Licensing validation with multiple monitoring metrics
Test UC3.1e: Traffic distribution to all CDN edge servers	
Test UC3.3a: Licensing validation with a single monitoring metric	

The tests presented in Table 5-1 will be also repeated at 5Tonic testbed, where ETSI OSM is used for managing the edge resources. The results of the 5Tonic testbed trials will be presented in D5.3. Therefore, in the present document the analysis of the tests is focused in 5G Barcelona's trials.

5.2.1. Scenario 3.1: Slice extension to increase edge processing power

In the first scenario (Figure 5-1), the need for slice expansion stems from the impending overload of the CDN edge server located on the CSP Edge server. In this case we look for compute resources at the Edge. We assume that the 3rd party maintains network connectivity to the 5G Core. For the users served by the edge servers located at the 3rd party, the subsequent CDN downlink data path passes from Central CDN to the CDN edge servers at the 3rd party and from there, through 5G Core, to the CSP's gNB. In this scenario, the End Users continue to connect to the original CSP Base Station, as there is no wireless access bottleneck.

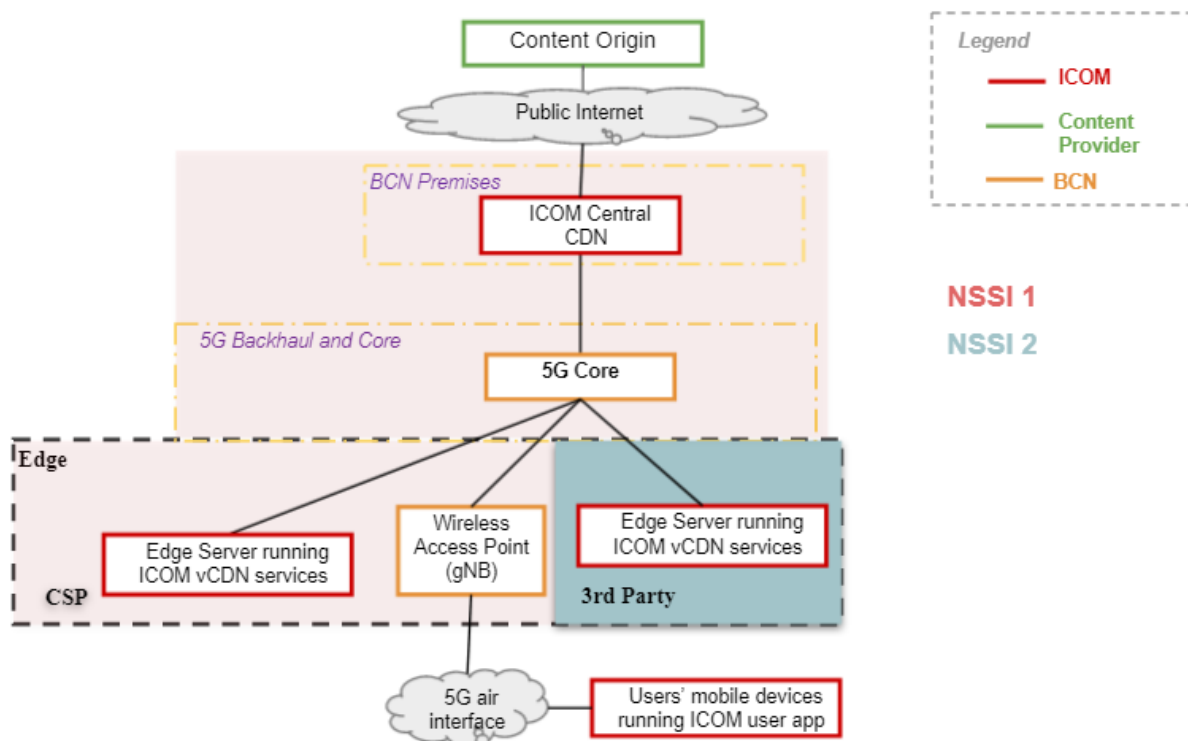


Figure 5-1: Deployment architecture for the 1st scenario of UC3 (leasing compute resources)

5.2.1.1. Test UC3.1a: CDN application deployment

This Test Case refers to the initial deployment of the CDN slice for the CSP, as described in Table 5-2.

Table 5-2: Test UC3.1a - CDN application deployment

UC3.1a	CDN application deployment
Testbed	5G Barcelona
Description	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 E2E connectivity across all CDN components, by examining, for example, the aspects related to data rate and latency achieved between the various CDN interfaces.

Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [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-UC3.5]. 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 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Network Slice and Service Orchestrator (NSSO)
	Configuration	<ul style="list-style-type: none"> • The Central CDN server includes the following software modules (deployed as VNFs): Packaging, Subscriber & Content Management, Streaming Server, Transcoding, Encryption, Main Cache. • One of ICOM's CDN software modules named Edge Cache is deployed on the Edge server as VNF. • Ping between CDN components is enabled.
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> • Connectivity shall be available across all infrastructure components.
	Test Case steps	<ol style="list-style-type: none"> 1. The software components of the ICOM CDN application get on-boarded. 2. The users are connected to the CDN application. Simple end-to-end connectivity at Application Layer is verified.
Measurements	Methodology	The measurements are extracted from CDN application's metrics, like latency, bandwidth, number of requests etc.
	Complementary measurements	Monitoring metrics: <ul style="list-style-type: none"> • Deployment metrics (from Openstack) • Application metrics (using Juju charms)
	Calculation process	<ul style="list-style-type: none"> • The VNFs deployment time is computed by NSSO. To measure this, 10 instantiations were performed and the average value is reported. • The latency reported is the average value of the latency that was monitored during the execution. Also, the maximum value is noted
Results	<p>The CDN descriptors were successfully uploaded on 5G Barcelona testbed and instantiated from NSSO.</p> <ul style="list-style-type: none"> • [KPI-UC3.1]. Deployment time for application components (VNFs, CNFs): <u>75 s</u> • [KPI-UC3.6]. Latency between Central CDN Server & Edge Server: <ul style="list-style-type: none"> ○ Average value: <u>0.42 ms</u> ○ Maximum value: <u>0.61 ms</u> <p>The progress of other CDN metrics over time is shown in Figures Figure 5-2 and Figure 5-3. All the measurements were extracted from the Edge Cache running at the CSP.</p>	

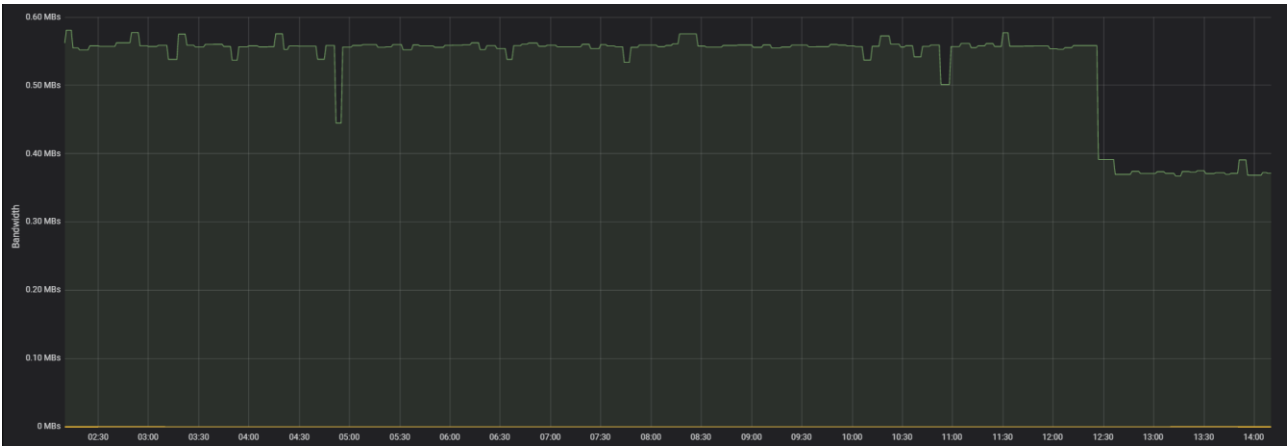


Figure 5-2: Bandwidth consumed by CDN Edge Cache hosted at CSP’s infrastructure

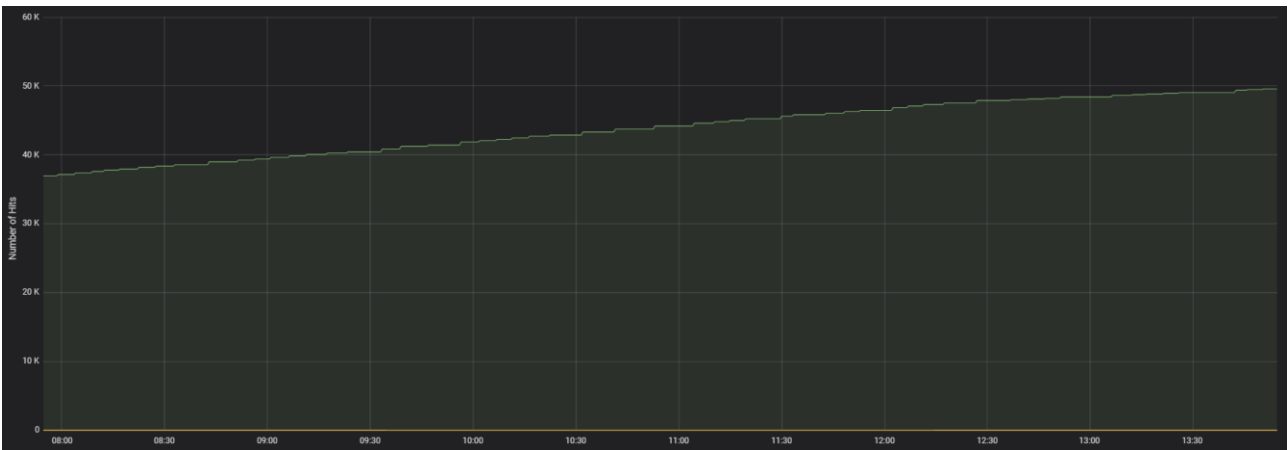


Figure 5-3: Number of hits at the CDN Edge Cache hosted at CSP’s infrastructure

5.2.1.2. Test UC3.1b: SLA breach prediction validation

Once the CDN application is deployed on the network slice, a data pipeline is triggered that continuously extracts application and/or infrastructure metrics and feeds them to the appropriate 5GZORRO platform components for storage and analysis. Responsible for the latter is the Intelligent SLA Breach Predictor (ISBP) component. ISBP acts as the client side of a publish/subscribe mechanism, consuming the metrics and correlating them to the corresponding SLA. ISBP then employs a variety of Machine Learning models to produce a forecast of the next value of a sequence of 3 values given as input. This value is compared against a threshold value retrieved by the correlation mentioned previously. If the forecasted value exceeds the threshold, a notification is dispatched to the appropriate component for corrective measures on the network slice. Intuitively, the next value that arrives after the forecast is the one we tried to predict, so it is used to assess the model’s performance over a number of consecutive predictions. If that performance is deemed insufficient, ISBP will order a re-training of the model with new data. The evaluation procedure of ISBP is shown in Table 5-3.

Table 5-3: Test UC3.1b – SLA Breach Prediction Validation

UC3.1b	SLA breach prediction validation
Testbed	5G Barcelona
Description	The first step of this test case is to create a large number of requests to the CDN Streaming Server located at the edge, so that it will cause resource saturation and performance degradation. This step is required in order to find out which the saturation point is and how the application performance is affected by the number of users and/or requests. Afterwards, the SLA

	Breach Prediction functionality is added in order to see how well this module performs. It requires the integration of Data Lake components and SLA management to trigger a Breach Prediction process from the SLA Breach Prediction module.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties <ul style="list-style-type: none"> [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. [KPI-UC3.8]. Prediction of SLA breach > 5 mins before the breach occurrence 	
Components and Configuration	Components	<ul style="list-style-type: none"> Smart Contract Lifecycle Manager (SCLCM) Catalogue Intelligent Slice and Service Manager (ISSM) Intelligent SLA Breach Predictor (ISBP) Monitoring Data Aggregator (MDA) NSSO Data lake
	Configuration	<p>The setup configuration is similar to the one described in Table 5-2, with the integration of the additional 5GZORRO components, which are required for SLA monitoring and breach prediction.</p> <p>The data used for the test is the number of requests every 5 minutes. This is generated and passed to MDA. In particular, MDA receives, for the edge server, the total number of requests from the beginning of the execution until the time that the call was made and generates the number of requests for the last 5 minutes. This is the metric needed for the ISBP.</p>
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> CDN software components are up and running Relevant 5GZORRO components are up and running User connectivity is verified The prediction model is already trained with an existing dataset
	Test Case steps	<ol style="list-style-type: none"> The users open the CDN web application and select the content to watch. When making the test, only one CDN channel was available. The Edge server starts streaming the content The SLA Breach Predictor receives application monitoring data, particularly the number of requests, make the predictions and, in case of a possible SLA violation, it notifies the ISSM.
Measurements	Methodology	<ul style="list-style-type: none"> Keep track of notification events coming from the ISBP
	Complementary measurements	Total number of requests
Result	<p>When executing the test, it was not possible to include a big number of users and actually stress the edge server. Thus, for the sake of testing, the threshold of the SLO (i.e. number of metrics) was set to lower levels. Figure 5-4 shows the total number requests in a given time period. It should be noted that each value represents the number of requests from the time when the Edge Cache start running until the time the measurement was taken. This is why the value is progressively increasing.</p> <ul style="list-style-type: none"> [KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties: yes, 1 SLA agreement between CDN and CSP [KPI-UC3.8] Prediction of SLA breach > 5 mins before the breach occurrence: yes, when the breach is successfully predicted. Given that the measurements are taken every 5 minutes and the prediction refers to the value that the metric will have in the next 5 minutes, the breach is predicted at least five minutes before it happens. Of course, this depends on the accuracy of the model, which is high. <p>The accuracy of the prediction model used was calculated to 97%.</p>	

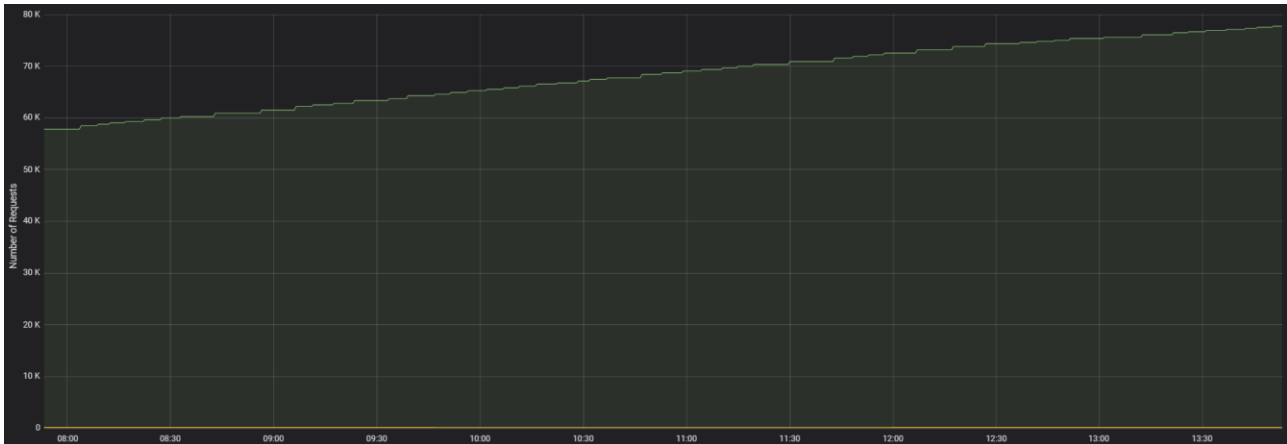


Figure 5-4: Number of requests at the CDN Edge Cache hosted at CSP's infrastructure

5.2.1.3. Test UC3.1c: Discovery and acquisition of compute resources

This Test Case refers to the evaluation of the resource discovery process, with a focus on compute edge resources, as described in Table 5-4.

Table 5-4: Test UC3.1c - Discovery and acquisition of compute resources

UC3.1c	Discovery and acquisition of compute resources	
Testbed	5G Barcelona	
Description	This test focuses on finding and acquiring available compute resources from the Marketplace. Particularly, the Smart Resource and Service Discovery (SRSD) module negotiates and selects resources for vCDN services.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [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. [KPI5.2] Number of transactions per second handled by the market. [KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties <ul style="list-style-type: none"> [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. 	
Components and Configuration	Components	<ul style="list-style-type: none"> Virtual Resource Manager (xRM) Resource & Service Offer Catalogue Smart Resource & Service Discovery (SRSD) Smart Contract Lifecycle Manager (SCLCM) Marketplace Intelligent Slice & Service Manager (ISSM) 5G-enabled Trust and Reputation Management Framework (5G-TRMF)
	Configuration	Communication between 5GZORRO components is established
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> Smart Contract SLA between CDN and CSP DLT network is configured There are resource and product offers in the catalogue 5GZORRO modules in all of the participating stakeholders are up and running
	Test Case steps	<ol style="list-style-type: none"> Resource Providers register their Resource Offers to the marketplace. Repeat the steps in Table 5-3.

		<ol style="list-style-type: none"> 3. The SLA Breach Prediction notifies the ISSM about the upcoming resource saturation. 4. ISSM triggers the SRSD, which searches for resources in the Marketplace. 5. SRSD selects an offer, after consulting 5G-TRMF. 6. The resource consumer (CSP) places an order for the selected resource offer. 7. The resource provider (3rd party) accepts the order and sends the SLA (specifically a link to the agreement) to CSP to be accepted. 8. The CSP accepts the agreement. 9. Both parties sign the contract. 10. The contract is created and saved in the DLT.
Measurements	Methodology	<ul style="list-style-type: none"> • Verify that the selected offer was the best one • Keep track of notification events coming from the involved 5GZORRO Software Modules
Result	<p>During the test, there were three offers in the catalogue, belonging to the same provider, but located in different locations. So, the selection at the SRSD side was done based on location.</p> <ul style="list-style-type: none"> • [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: yes, done for compute resources • [KPI5.2] Number of transactions per second handled by the market: Not calculated. In this test, there was only one transaction • [KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties: yes, SLA between CSP and selected 3rd party. 	

5.2.1.4. Test UC3.1d: Slice extension to 3rd party edge server

This Test Case refers to the process of the CDN slice extension to the obtained compute edge resources, where a new CDN VNF will be instantiated. The full test procedure is shown in Table 5-5.

Table 5-5: Test UC3.1d - Slice extension to 3rd party edge server

UC3.1d	Slice extension to 3rd part edge server	
Testbed	5G Barcelona	
Description	This test focuses on the process of extending the initial CDN slice provided by the CSP to the acquired 3 rd party resources and the establishment and instantiation of CDN VNFs on these resources. ISSM and NSSO components will be needed in order to manage the Network Slice extension to a 3 rd party edge server.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI-UC3.4]. Network Slice extension time < 2mins • [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-UC3.5]. 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 	
Components and Configuration	Components	<ul style="list-style-type: none"> • Intelligent Slice & Service Manager (ISSM) • Network Slice and Service Orchestrator (NSSO)
	Configuration	The ISSM and NSSO 5GZORRO components should be configured accordingly in order to create the Network Slice Sub-Instance in 3 rd party resources and connect it with the initial CSP slice.
Test Procedure	Pre-conditions	UC3.1c has been completed and the ISSM (at the CSP side) knows how to access the 3 rd party resources.

		For the sake of the test, the 3rd party is considered to be a tenant different from CSP. This means that it shares the same infrastructure with the CSP and they are at the same network, but they are isolated and don't communicate with each other before the slice extension.
	Test Case steps	<ul style="list-style-type: none"> The ISSM invokes to NSSO in charge of orchestrating the service on the 3rd party resource and: <ul style="list-style-type: none"> Creates a Vertical Service Descriptor (VSD) that incorporates the vCDN cache descriptor Requests the instantiation of the above VSD The NSSO fulfils the request by executing the following steps: <ul style="list-style-type: none"> VNF license check against the eLicensing Manager Instantiation of the service through the NVFO (OSM) Configuration of the MDA for collecting service metrics
Measurements	Methodology	CDN related measurements are extracted from application's metrics, like latency, bandwidth, number of requests etc.
	Complementary measurements	Monitoring metrics: <ul style="list-style-type: none"> Deployment metrics (from Openstack) Application metrics (using Juju charms)
	Calculation process	<ul style="list-style-type: none"> The VNFs deployment time is computed by NSSO
Result	The slice extension and the inclusion of the new Edge Cache into the CDN network is done successfully. <ul style="list-style-type: none"> [KPI-UC3.1]. Deployment time for application components (VNFs, CNFs): 75 s. This is similar to UC3.1a (Table 5-2), because in both cases, the only VNF instantiated is the edge cache and because the time measurement is done at the NSSO level. [KPI-UC3.6]. Latency between Central CDN Server & Edge Server: The average latency value is 0.42 ms for the 1st Edge Server (hosted at CSP) and 0.47ms for the 2nd Edge Cache (hosted at 3rd party). The values in this experiment are pretty close, as both providers are located in the same infrastructure. 	

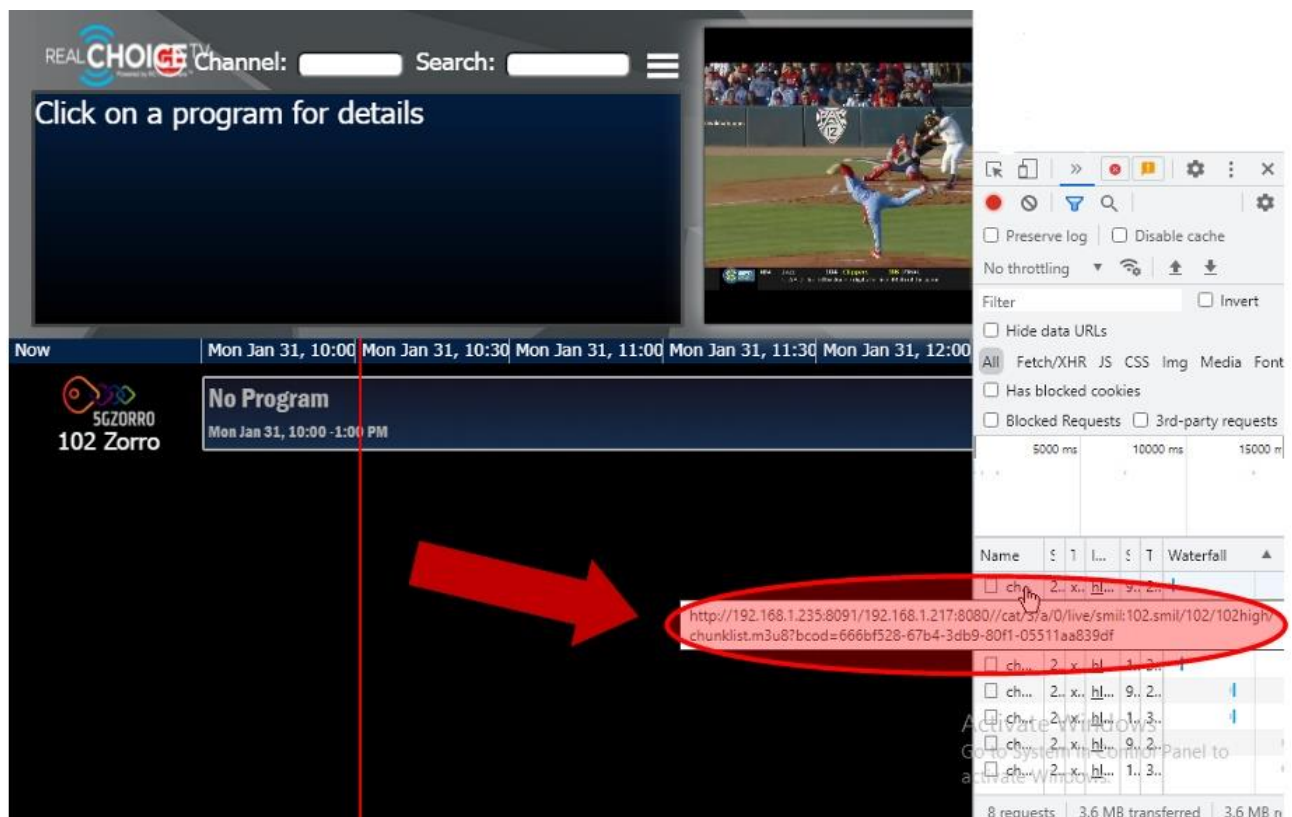
5.2.1.5. Test UC3.1e: Traffic distribution to all CDN edge servers

This Test Case focuses on verifying that the new vCDN edge server located at the 3rd party infrastructure successfully communicates with the rest CDN components and serves some user. In other words, we need to make sure that users are served by both servers (at the CSP and at the 3rd party side). The test is analysed in Table 5-6.

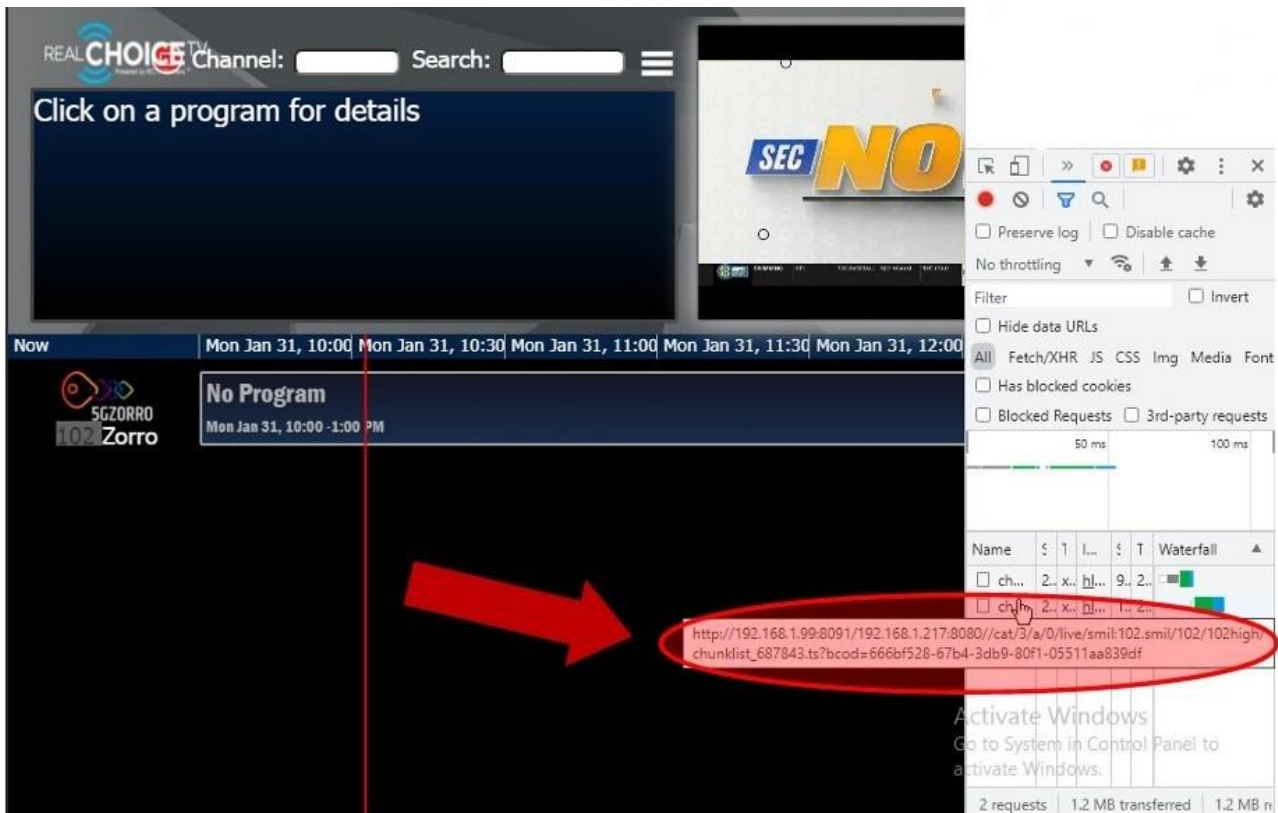
Table 5-6: Test UC3.1e - Traffic distribution to all CDN edge servers

UC3.1e	Traffic distribution to all CDN edge servers	
Testbed	5G Barcelona	
Description	The CDN application will add the new server on its list and it will redirect user traffic to this server. The goal 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.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [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 	
Configuration	The Central CDN services should include the new CDN edge server on its tables, so that part of the user requests will be handled by that server.	
Test Procedure	Pre-conditions	<ul style="list-style-type: none"> UC3.1d has been completed and the slice is updated and active.

		<ul style="list-style-type: none"> Connectivity shall be ensured between the servers that will host the Central CDN and the edge servers (including the one at the 3rd party).
	Test Case steps	The users are connected the CDN web application. Simple end-to-end connectivity at Application Layer is verified.
Measurements	Complementary measurements	Application metrics (per Edge Cache): bandwidth, number of requests, number of hits, number of users
	Calculation process	Supplementary application layer metrics are monitored
Result	<p>Same as in Table 5-5.</p> <p>It was verified that the requests are sent to both servers, according to the Round Robin algorithm applied for sharing the traffic between available Edge Caches. This is expressed in Figure 5-5, which shows the screen of a single user. The user gets content from both edge servers alternatively.</p>	



(a)



(b)

Figure 5-5: View from a laptop user. The user receives, alternatively, content from (a) the 1st Edge Cache located at the CSP and (b) the 2nd Edge Cache located at the 3rd party

5.2.2. Scenario 3.2: Slice extension to increase vCDN wireless coverage

The second scenario (Figure 5-6) refers to the case where the CSP asks for both compute and RAN resources. Unlike the first scenario, in this case there is an overload of the CSP Base Station and, therefore, this is the main saturation point. Thus, CSP requests an infrastructure provider that has a network interface and maintains a connection to 5G Core. The subsequent downstream data path, for the CDN flows directed to the 3rd party's servers, travels through 5G Core to 3rd party edge infrastructure. Then, the 3rd party's gNB transmits the content to the connected users.

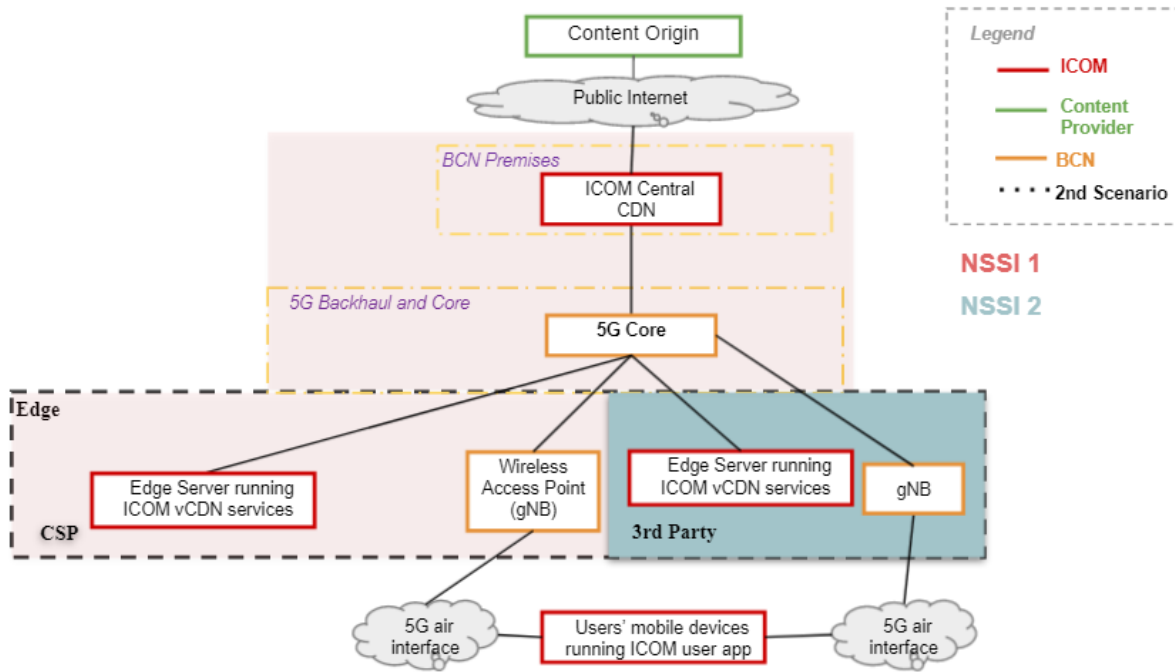


Figure 5-6: Deployment architecture for the 2nd scenario of UC3 (leasing compute & network resources)

5.2.2.1. Test UC3.2a: Predict RAN resource saturation

This Test Case refers to the prediction of the upcoming saturation at the RAN part, as described in Table 5-7. The test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 5-7: Test UC3.2a - Predict RAN resource saturation

UC3.2a	Predict RAN resource saturation	
Description	This is similar to test UC3.1b, with the difference that in this case the CSP's RAN resources should be stretched. So, the first step is to connect an adequate number of users and create requests in order to cause resource saturation for the RAN resources. As in UC3.1b, the saturation point and how the performance is affected will be found.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties <ul style="list-style-type: none"> [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. [KPI-UC3.8]. Prediction of SLA breach > 5 mins before the breach occurrence 	
Components and Configuration	Components	<ul style="list-style-type: none"> Intelligent_SLA Breach Prediction (ISBP) Monitoring Data Aggregator NSSO Data Lake
	Configuration	The setup configuration in similar to test UC3.1b (Table 5-3).

5.2.2.2. Test UC3.2b: Discovery and acquisition of RAN resource

This Test Case refers to the evaluation of the resource discovery process in finding both RAN and compute edge resources, as described in Table 5-8. The test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 5-8: Test UC3.b - Discovery and acquisition of RAN resource

UC3.2b	Discovery and acquisition of RAN resource	
Description	This test is similar to UC3.1c, with the additional requirement of finding also available RAN resources, besides the compute ones.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [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. [KPI5.2] Number of transactions per second handled by the market. [KPI4.2] Implement/correlate technical service configurations and SLA monitoring interactions between multiple parties. <ul style="list-style-type: none"> [KPI4.2.1] Services can be composed of one or more resources and from one or more providers. [KPI5.4] Linkability between market agents and their associated radio access points, which will allow providing the appropriate spectrum rights to each access point 	
Components and Configuration	Components	<ul style="list-style-type: none"> xRM Id&P Catalogue SRSD SC-LCM Marketplace ISSM 5G-TRMF
	Configuration	Communication between 5GZORRO components is established

5.2.2.3. Test UC3.2c: Slice extension to 3rd party Base Station and edge server

This Test Case refers to the process of the CDN slice extension to the 3rd party infrastructure, as described in Table 5-9. The test is yet to be performed. The results will be reported in the following deliverable D5.3.

Table 5-9: Test UC3.2c - Slice extension to 3rd party Base Station and edge server

UC3.2c	Slice extension to 3 rd party Base Station and edge server	
Description	Similar to UC3.1d, this test case focuses on the slice extension to the acquired 3 rd party RAN and compute resources	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI5.6] Agnostic support of various radio technologies, to ensure that the market will work regardless of the considered radio technology [KPI-UC3.4]. Network Slice extension time < 2mins [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-UC3.5]. 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 	
Components and Configuration	Components	<ul style="list-style-type: none"> NSSO ISSM
	Configuration	The ISSM and NSSO 5GZORRO components should be configured accordingly in order to create the Network Slice Sub-Instance in 3 rd party resources and connect it with the initial CSP slice.

5.2.3. Scenario 3.3: Licensing validation

Finally, in the third scenario (Figure 5-7), we also include some licensing validation features. The rationale in this is that when automated Network Slice adaptation and service instantiation are applied, there are licensing costs (e.g. activation of a VNF, scalability decision, etc) that need to be considered in the decision algorithm and enforced by NFV MANO. 5GZORRO offers a platform that allows the trade of hardware and software resources from different entities, and also the software resource composition by a Service Provider. Therefore, mechanisms to provide the trace of the software resources (e.g VNFs) usage for its subsequent processing for the billing are required. Vendor independent license templates are created and attached to the contract agreed for the use of this software resource. This is achieved through the eLicensing module, which provides the ability of keeping the trace of the resource usage in all the entities that are proposed in the previous scenarios.

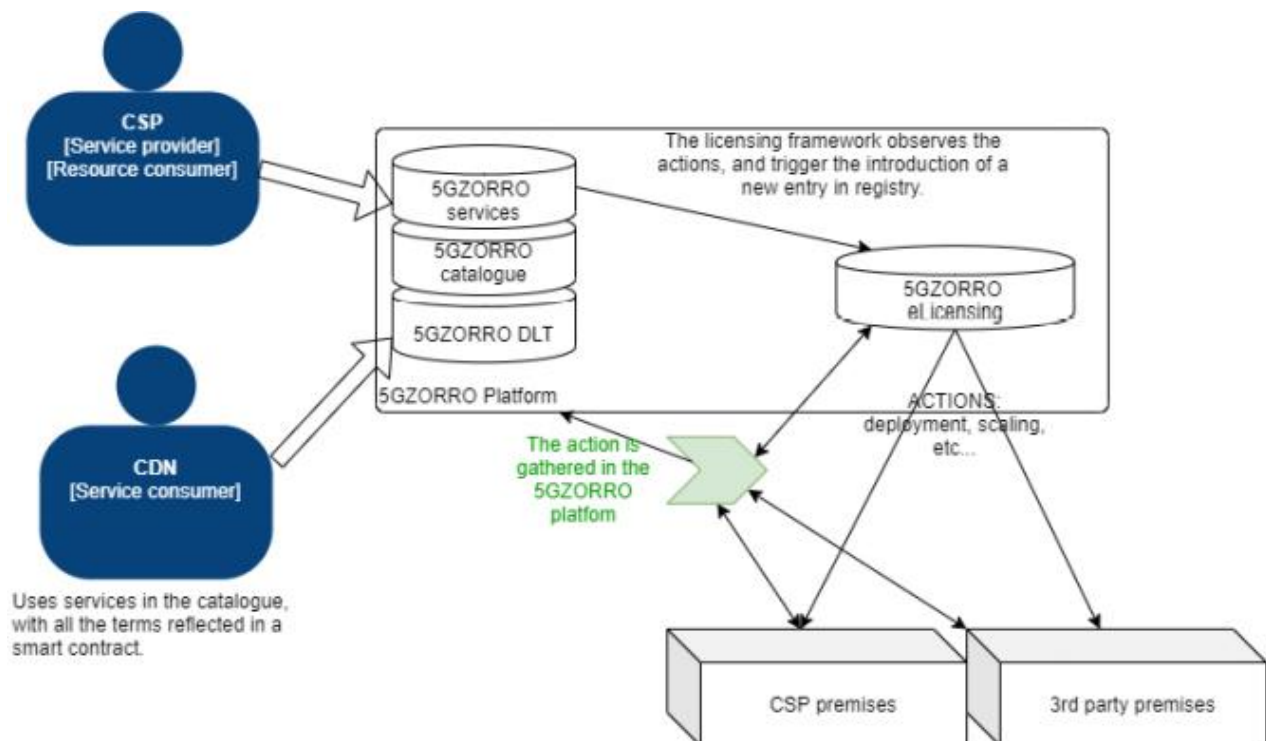


Figure 5-7: Functional architecture for the 3rd scenario (eLicensing validation) of UC3

5.2.3.1. Test UC3.3a: Licensing validation with a single monitoring metric

This Test Case refers to the validation of the eLicensing scenario when having only one monitoring metric, which is the time of usage. The test is further analysed in Table 5-10.

Table 5-10: Test UC3.3a: Licensing validation with a single monitoring metric

UC3.3a	Licensing validation with a single monitoring metric
Testbed	5G Barcelona
Description	The goal is to test the e-licensing validation at instantiation of vCDN edge cache from emulated VNF provider as well as the e-licensing verification by VNF provider after instantiation and configuration of vCDN edge cache. Here we consider only one monitoring metric, which is the time of usage.

Key Use-case requirements and KPIs	<ul style="list-style-type: none"> • [KPI-UC3.4]. Network Slice extension time < 2mins • [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 	
Components and Configuration	Components	eLicensing Manager NSSO Catalogue Marketplace xRM
	Configuration	All the involved components should be configured to execute the process. The purchased offer must be present in the marketplace with an agreement of type time of use according to this test.
Test Procedure	Pre-conditions	<p>It is required to perform positive and negative tests. Positive tests are successful deployment test, in the sense that the VNF is purchased in the marketplace, so the ELM will allow the deployment. In the case of negative test, the VNF is not purchased, so the ELM will not allow the deployment.</p> <p>The common pre-condition is:</p> <ul style="list-style-type: none"> • vCDN VNF needs to be onboarded in the 5GZORRO catalogue with licensing agreements associated. <p>For the positive test:</p> <ul style="list-style-type: none"> • The purchase of the VNF must happen before the deployment of the VNF. • A related smart contract is deployed in the SCLCM. <p>For the negative test:</p> <ul style="list-style-type: none"> • The purchase of the VNF must not happen before the deployment of the VNF. • The ELM should not find any POP in the marketplace
	Test Case steps	<p>For the positive test:</p> <ul style="list-style-type: none"> • NSSO onboard the descriptors for the service that aims to deploy and notifies the ELM. • ELM checks in the marketplace that the service has been purchased in the marketplace • ELM receives from the marketplace the related licensing agreements. • ELM notifies the NSSO that the service can be deployed. • NSSO deploys the service. <p>For the negative test:</p> <ul style="list-style-type: none"> • NSSO onboard the descriptors for the service that aims to deploy and notifies the ELM. • ELM checks in the marketplace that the service has been purchased in the marketplace • ELM cannot find purchase of the requested service. • ELM notifies the NSSO that it is forbidden to deploy the service. • NSSO does not deploy the service.
Measurements	Methodology	In case of the positive test, the ELM observes the execution of the VNFs and keeps the track of the time that are running. If the execution of the VNF ends for any reason, the ELM will be aware of this and send to the SCLCM the time of usage that this deployment had.
	Complementary measurements	Total duration of licensing validation.
	Calculation process	The ELM requests the time metric to OSM via the xRM component every certain time determined by the ELM and the licensing terms.
Result	Using a correct agreement, it was possible to verify that the NSSO requests the licensing validation before completing the instantiation of the Edge Cache which was confirmed by the	

	eLicensing module and resulted in a successful deployment of the service. The non-conformance to deploy the licensed VNFs was also confirmed in a negative test by providing an erroneous reference to the marketplace resources (resembling that it had not been purchased correctly) thus blocking the instantiation sequence orchestrated by the NSSO.
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5.2.3.2. Test UC3.3b: Licensing validation with multiple monitoring metrics

This Test Case refers to the validation of the eLicensing scenario when having more than one monitoring metrics, as described in Table 5-11.

This Test Case builds on top of the previous scenario to prove that it is possible to combine generic metrics such as time of use with application-specific metrics when configuring the licensing terms of a NS. Number of active users was selected as the application metric that the Edge Cache should expose for the eLicensing system to monitor its usage.

Table 5-11: Test UC3.3b - Licensing validation with multiple monitoring metrics

UC3.3b	Licensing validation with multiple monitoring metrics	
Testbed	5B Barcelona, 5Tonic	
Description	This is similar to test UC3.3a, extended to multiple monitoring metrics. These are the time of usage and the number of users.	
Key Use-case requirements and KPIs	<ul style="list-style-type: none"> [KPI-UC3.4]. Network Slice extension time < 2mins [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 	
Components and Configuration	Components	eLicensing Manager Catalogue Marketplace NSSO xRM Data Lake
	Configuration	All the involved components should be configured to execute the process. The purchased offer must be present in the marketplace with an agreement of type time of use according to this test.
Test Procedure	Pre-conditions	<p>It is required to perform positive and negative tests. Positive tests are successful deployment test, in the sense that the VNF is purchased in the marketplace, so the ELM will allow the deployment. In the case of negative test, the VNF is not purchased, so the ELM will not allow the deployment.</p> <p>The common pre-condition is:</p> <ul style="list-style-type: none"> vCDN VNF needs to be onboarded in the 5GZORRO catalogue with licensing agreements (POPs) associated of the type, time of use and number of users. <p>For the positive test:</p> <ul style="list-style-type: none"> The purchase of the VNF must happen before the deployment of the VNF. A related smart contract is deployed in the SCLCM. <p>For the negative test:</p> <ul style="list-style-type: none"> The purchase of the VNF must not happen before the deployment of the VNF. The ELM should not find any POP in the marketplace.
	Test Case steps	<p>For the positive test:</p> <ul style="list-style-type: none"> NSSO onboard the descriptors for the service that aims to deploy and notifies the ELM.

		<ul style="list-style-type: none"> • ELM checks in the marketplace that the service has been purchased in the marketplace • ELM receives from the marketplace the related licensing agreements. • ELM notifies the NSSO that the service can be deployed. • NSSO deploys the service. <p>For the negative test:</p> <ul style="list-style-type: none"> • NSSO onboard the descriptors for the service that aims to deploy and notifies the ELM. • ELM checks in the marketplace that the service has been purchased in the marketplace • ELM cannot find prove of purchase of the requested service. • ELM notifies the NSSO that it is forbidden to deploy the service. • NSSO does not deploy the service.
Measurements	Methodology	In case of the positive test, the ELM observes the execution of the VNFs and keeps the track of the time that are running and also the concrete metric related. If the execution of the VNF ends for any reason, the ELM will be aware of this and send to the SCLCM the time of usage and the concrete metrics that this deployment had.
	Complementary measurements	Total duration of licensing validation
	Calculation process	The ELM requests the time metric to OSM via the xRM every certain time determined by the ELM and the licensing term. The metric for number of users has been configured to be pushed to the data lake and thus the ELM is also able to fetch it from the data lake catalogue API.
Result		<ul style="list-style-type: none"> • The metrics that report the usage of the licensed VNFs in the infrastructure in case of positive test. • The negative to deploy the licensed VNFs if they have not been purchased in the marketplace.

6. Conclusions

This deliverable provides refined descriptions for the available testbeds, the implementation setups and the scenarios and tests for the three 5GZORRO use cases. Moreover, it presents the results from the initial tests, where the current 5GZORRO version (5gzorro-core-1.0RC) was used.

For each use case, the document describes:

- the overall use case concept and goal,
- the security and trust validation, if applicable,
- the validation scenarios and test cases for each scenario.

Each test case is represented by a table, which includes the testbed (either 5G Barcelona or 5Tonic) where the test has or will be executed, a general description of the test and reference KPIs related to the test. These KPIs are analytically described in D5.1 [3]. Moreover, each table presents the testbed components and 5GZORRO platform units involved in the test, an analysis of the test procedure and the methodology for obtaining the measurements and the final results.

All the test cases that are planned for the three use cases are analysed in the present deliverable. However, not all of them were executed during this implementation cycle. For each case, it is explicitly mentioned which are the tests that have been completed by the time of the deliverable editing. The results for the rest ones will be included in a future document, namely in D5.3.

6.1. Findings

All the tests for which the results are shown in this document were demonstrated at 5GBarcelona testbed. The reason for this was, on the one hand, the maturity level of all 5GZORRO software components which was higher in 5G Barcelona and, on the other hand, the ability to make tests with a real RAN infrastructure.

The tests that were performed and reported in this deliverable confirmed the ability of various stakeholders, such as regulators and resource providers and consumers, to register in the 5GZORRO Portal and be authenticated by the platform (UC1, UC2). Moreover, the creation of certificates was tested and it was found that it takes about 12 seconds to request for a spectrum certificate. In addition to stakeholder registrations, the registration of resources into the respective Resource Managers as well as the registration of the respective resource offers into the Catalogue were also verified. The types of offers tested are mostly services, including various kinds of resources, such as spectrum, radio and compute resources. Along with the publication of resources, the process of discovering and selecting an offer, either manually or automatically, was also tested. In addition, the implementation of technical service configurations and SLA monitoring interactions between multiple parties was also verified (UC1, UC2). During the test cases, the deployment of slices with compute, radio and spectrum resources was achieved. The slices can entail resources either from a single provider or from multiple ones.

6.2. Summary of results, contribution to KPIs and project objectives

Table 6-1 reports the KPIs that are measured and verified in the present document. The table includes the KPIs analysed in D5.1 and achieved in the tests presented in the current deliverable. Each KPI achieved is marked as *PASSED* and, if it is measurable, the actual experimental measurement is reported. For non-measurable KPIs, the respective field is marked as not applicable (*N/A*). Additionally, there are some KPIs for which it was not possible to extract exact measurements, but they were anyway fulfilled (e.g., the target is

in the range of minutes while the achieved value was clearly in the range of a few seconds). These are also marked as *PASSED* in the *Achievement* field and *N/A* in *Measurement* field. In addition, those KPIs where the achievement is reported as *PARTIALLY PASSED* refer to use case validations with only part of the related tests executed, and thus are planned to be fully achieved as part of the upcoming validation activities that will be reported in D5.3.

Table 6-1: Summary of results and KPIs achievement

Applicable Technical / Business KPI (general target)	KPI Target	Specific KPI	UC	Achievement (PASSED)	Measurement	Testcase reference
[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.	[KPI1.1.1] New Resource Providers, Resource Consumers, Service Providers are enrolled into the platform.	UC1 UC2	PASSED	1 – 4 stakeholders	UC1.1, UC1.2, UC1.3, UC2.1, UC2.2, UC2.3, UC2.4
		[KPI1.1.2] Each stakeholder participating in the 5GZORRO Marketplace is approved	UC1 UC2	PASSED	N/A	UC1.1, UC1.2, UC1.3, UC2.1, UC2.2, UC2.3, UC2.4
		[KPI1.1.3] Acceptance/rejection (consensus) when joining of a new node to the DLT network should be completed in less than 15 minutes.	UC1 UC2	PASSED	Processing of a request: 10 - 11s Approval: 2s	UC1.1, UC1.2, UC1.3, UC2.1, UC2.2, UC2.3, UC2.4
		[KPI1.1.4] All actors have a unique identity that derives from their organisation's identity. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services.	UC1 UC2	PASSED	N/A	UC1.1, UC1.2, UC1.3, UC2.1, UC2.2, UC2.3, UC2.4

Applicable Technical / Business KPI (general target)	KPI Target	Specific KPI	UC	Achievement (PASSED)	Measurement	Testcase reference
		[KPI1.1.5] The process of bootstrapping a DLT node and provisioning 5GZORRO services should take no longer than 1 hour. Permissions are assigned to a new Resource Provider / Service Provider to allow them to offer resources/services.	UC1 UC2	PASSED	N/A It was not possible to measure the actual time in current tests, but it was no more than a few minutes	UC1.1, UC1.2, UC1.3, UC2.1, UC2.2, UC2.3, UC2.4
[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	[KPI3.1.1] Smart Contract for 3 or more 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.	UC1 UC3	PARTIALLY PASSED (Part of the related tests are planned for D5.3)	N/A	UC1.4, UC1.5, UC1.6, UC1.6, UC1.8, UC1.13
		[KPI3.1.2] The addition of a new resource offer to the catalogue should complete in less than 1 minute (from transaction request to being committed to the ledger).	UC1 UC3	PARTIALLY PASSED (Part of the related tests are planned for D5.3)	N/A It was not possible to measure the actual time in current tests, but it was in the range of a few minutes	UC1.4, UC1.5, UC1.6, UC1.6, UC1.8, UC1.13

Applicable Technical / Business KPI (general target)	KPI Target	Specific KPI	UC	Achievement (PASSED)	Measurement	Testcase reference
[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	[KPI4.1.1] Resources are discoverable in the catalogue by all registered consumers within 5 minutes of being registered and verified.	UC1 UC2 UC3	PASSED	30 – 66 s	UC1.4, UC1.5, UC1.6, UC1.7, UC1.8, UC1.13, UC2.5c, UC2.6a, UC2.6b, UC2.7b, UC2.7c, UC2.8, UC2.9a UC3.1c, UC3.2b
[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	[KPI4.2.9] [KPI-UC3.1] Deployment time for application components (VNFs, CNFs) < 5 mins	UC3	PASSED	75 s	UC3.1a, UC3.1d, UC3.2c, UC3.3a, UC3.3b
		[KPI4.2.10] [KPI-UC3.2] Deployment time for the complete graph of CDN application < 90 mins	UC3	PASSED	N/A: It was not calculated during the current tests, but the overall CDN slice establishment and Day 0, Day 1 and Day 2 configurations lasted for a few minutes	UC3.1a, UC3.1d, UC3.2c, UC3.3a, UC3.3b
		[KPI4.2.11] [KPI-UC3.3] Network Slice creation time < 3mins	UC3	PASSED	In the range of a few seconds	UC3.1a
		[KPI4.2.14] [KPI-UC3.6] Latency between Central CDN Server & Edge Server < 20ms	UC3	PASSED	0.3 – 1.1 ms	UC3.1a, UC3.1d, UC3.1e, UC3.2c

Applicable Technical / Business KPI (general target)	KPI Target	Specific KPI	UC	Achievement (PASSED)	Measurement	Testcase reference
		[KPI4.2.16] [KPI-UC3.8] Prediction of SLA breach > 5 mins before the breach occurrence	UC3	PASSED	On true positive, the prediction is done at least 5 minutes before the actual occurrence	UC3.1b, UC3.2a
[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	PASSED	5 spectrum certificate requests/minute and 30 spectrum certificate request decisions / minute	UC1.4, UC1.5, UC2.5c, UC2.6a, UC2.6b, UC2.7b, UC2.7c, UC2.8, UC2.9a, UC3.1c, UC3.2b
[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	PASSED	3 UCs tested on 5GBarcelona testbed	By inspection
[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.	UCs to be deployed in 5GBarcelona and 5Tonic. Replication of some tests in 5TONIC depending on 5TONIC availability calendar	UC1 UC2 UC3	PARTIALLY PASSED (Only 5GBarcelona so far)	Demonstration on 5GBarcelona testbed	By inspection

The Table 6-2 below summarizes the D5.2 contributions to the 5GZORRO objectives.

Table 6-2: Summary of contributions to 5GZORRO objectives

5GZORRO Technical Objective	Use case in scope	Achievement
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.	UC1 UC2	PARTIALLY PASSED (KPI1.1 achieved, other KPIs for D5.3)

5GZORRO Technical Objective	Use case in scope	Achievement
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.	UC1 UC2 UC3	PASSED
OBJ-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.	UC1 UC2 UC3	PARTIALLY PASSED (KPI4.1.1, KPI4.2.9, KPI4.2.10, KPI4.2.11, KPI4.2.14, KPI4.2.16 achieved, other KPIs for D5.3)
OBJ-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.	UC2 UC3	PATIALY PASSED (KPI5.2 achieved, other KPIs for D5.3)
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.	UC1 UC2 UC3	PATIALY PASSED (KPI7.1 and KPI7.2 achieved, KPI7.3 for D5.3)

6.3. 5GZORRO Benefits

The 5GZORRO platform supports distributed multi-part services and business configurations, which is required in the use case scenarios. The different stakeholder roles appearing in this document are:

- Regulator & Governance Manager, who provides regulatory oversight and enforcement
- Resource Providers, who are allowed to publish resource offers in the Marketplace. A special category of this stakeholder type is the Spectrum Resource Providers, who is allowed by the Regulator to issue spectokens in his area of application.
- Resource Consumers, who discover and lease resources from one or more resource providers

The 5GZORRO platform provides a marketplace where various kinds of resources are offered for trading. A special type of resource is spectrum which is exchanged among different spectrum providers, typically Mobile Network Operators (MNOs). The spectrum trading was tested in UC2, which deals with the marketing of certain radio bandwidth in specific areas for a limited period of time. Market distortion, spectrum accumulation and violations of license terms are monitored and prevented by National Spectrum Regulators. On the other hand, in UC3, the type of resource that was traded was the compute resources, which were used to extend the capacity of a vertical application. In general, a variety of 5G players, stakeholders and vertical operators can also benefit from purchasing from the 5GZORRO market, as they can lease only the number of resources they need and for the period of time required, reducing CAPEX and OPEX costs.

In addition, 5GZORRO mechanisms allow for the rapid development and integration of new VNFs into a slice as well as the appropriate Day-0/1/2 configurations. In order to integrate external resources into a new slice, a secure communication between the involved parties is established.

References

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7. Abbreviations and Definitions

7.1. Definitions

No definitions introduced in this deliverable.

7.2. Abbreviations

5G IA	5G Infrastructure Association
5G-TRMF	5G-enabled Trust and Reputation Management Framework
AI	Artificial Intelligence
CSP	Communication Service Provider
DID	Distributed IDentifier
DLT	Distributed Ledger Technology
DoA	Description of Action
EC	European Commission
ELM	E-Licensing manager
HLS	HTTP Live Streaming
Id&P	Identity and Permissions Manager
IPR	Intellectual Property Rights
ISBP	Intelligent SLA Breach Predictor
ISSM	Intelligent Slice & Service Manager
MANO	Management and Orchestration
MDA	Monitoring data aggregator
MNO	Mobile Network Operator
MPEG-DASH	MPEG Dynamic Adaptive Streaming over HTTP
NFV	Networks Function Virtualization
NFVI	Networks Function Virtualization Infrastructure
NFVO	NFV Orchestrator
NS	Network Services
NSSO	Network Slice and Service Orchestrator
OTT	Over-The-Top
POP	Product Offer Price
PPP	Public Private partnership
rRM	Radio Resource Manager
RRP	Radio Resource Provider
SCLCM	Smart Contract Lifecycle Manager
SDO	Standard Developing Organization
STB	Set-Top-Box
SLA	Service Level Agreement
SLO	Service Level Objective
sRM	Spectrum Resource Manager
SRP	Spectrum Resource Provider
SRSD	Smart Resource and Service Discovery
UC	Use Case
UE	User Equipment
vCDN	virtual Content Distribution Network
VIM	Virtual Infrastructure Manager

VM	Virtual Machine
VNF	Virtual Network Function
VSD	Vertical Service Descriptor
WG	Working group
WP	Work Package
xRM	virtual/network/compute/radio/spectrum Resource Manager

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