



## **5G ExPerimentation Infrastructure hosting Cloud-native Netapps for public proTection and disaster RELief**

Innovation Action – ICT-41-2020 - 5G PPP – 5G  
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### **D3.3: 5G EPICENTRE User Interface**

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[www.5gepicentre.eu](https://www.5gepicentre.eu)

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Document Lead	Stavroula Ntoa (FORTH) Konstantinos C. Apostolakis (FORTH)
Contributors	Eirini Sykianaki (FORTH) George Margetis (FORTH) Ioannis Chatzakis (FORTH) Stefania Stamou (FORTH) Dimitrios Arampatzis (FORTH)
Internal Review	Yerasimos Yerasimou (EBOS) Daniel del Teso (NEM)

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## Project Partners

Logo	Partner	Country	Short name
	AIRBUS DS SLC	France	<b>ADS</b>
	NOVA TELECOMMUNICATIONS SINGLE MEMBER S.A.*	Greece	<b>NOVA</b>
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	ORamaVR SA	Switzerland	<b>ORAMA</b>

\* Please note that ELLINIKI ETAIRIA TILEPIKOINONION KAI TILEMATIKON EFARMOGON AE (FNET) has changed its legal name to NOVA TELECOMMUNICATIONS SINGLE MEMBER S.A. (NOVA)

## List of abbreviations

Abbreviation	Definition
<b>API</b>	Application Programming Interface
<b>AuthM</b>	User Authentication and Management
<b>CI/CD</b>	Continuous Integration / Continuous Delivery
<b>CNF</b>	Containerised Network Function
<b>eMBB</b>	Enhanced Mobile Broadband
<b>EPI</b>	Experiment Planning Interface
<b>ExCom</b>	Experiment Composer
<b>ExSch</b>	Experiment Scheduler
<b>GA</b>	Grant Agreement
<b>GUI</b>	Graphical User Interface
<b>HSPF</b>	Holistic Security and Privacy Framework
<b>HTTP</b>	Hypertext Transfer Protocol
<b>ICT</b>	Information and Communications Technology
<b>ITool</b>	Insights Tool
<b>ITU</b>	International Telecommunication Union
<b>JWT</b>	JSON Web Token
<b>KPI</b>	Key Performance Indicator
<b>MANO</b>	Management and Orchestration
<b>mMTC</b>	Massive Machine Type Communications
<b>nappD</b>	NetApps Creation and Management Dashboard
<b>NetApp</b>	Network Application

<b>NF</b>	Network Function
<b>No</b>	Experiment Order Number
<b>NS</b>	Network Service
<b>NSBR</b>	Network Service Browser
<b>NFV</b>	Network Functions Virtualisation
<b>NSRepo</b>	NS Repository
<b>PNF</b>	Physical Network Function
<b>PPDR</b>	Public Protection and Disaster Relief
<b>RBAC</b>	Role-Based Access Control
<b>SBD</b>	Security-by-Design
<b>SSO</b>	Single Sign-On
<b>UE</b>	User Equipment
<b>UI</b>	User Interface
<b>URI</b>	Uniform Resource Identifier
<b>URL</b>	Unique Resource Locator
<b>URLLC</b>	Ultra Reliable Low Latency Communications
<b>VNF</b>	Virtual Network Function

## Executive summary

This deliverable constitutes a report on the 5G-EPICENTRE Portal, a web-based user interface provided for the booking and reservation of testbed facilities' resources for experimentation. In addition, it delivers on workflows designed for network function developers to remotely provide their executable code to the 5G-EPICENTRE federated testbed sites, thus making them available for further experimentation and rapid prototyping. In this deliverable we provide a high-level overview of the different workflows and processes involved in experimentation for PPDR developers, and identify the key actors that will interact with the 5G-EPICENTRE platform. We present a robust and flexible solution for experiment preparation and network functions onboarding, informed by the end-users' requirements and corresponding to the functional blocks and specifications listed in the 5G-EPICENTRE architecture (D1.3). Also, this deliverable describes an intuitive graphical user interface that has been designed for the simplification of the complex process of service function chaining toward rapidly establishing network services for connecting to network applications. We present implemented workflows with comprehensive narratives for each of the functionalities provisioned by the currently implemented version of the solution. The 5G-EPICENTRE Portal will hence be made available for accommodating the preliminary version of the 5G-EPICENTRE experimentation facility (MS4 – M18), and will be further enriched and updated with additional functionality (including the outcomes of Task 3.2 "Novelty experiment insights visualization tools") until the end of the project implementation period (M30), through a continuous integration/continuous delivery approach.

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# 1 Introduction

5G-EPICENTRE aims to provide companies that offer PPDR Information and Communication Technology (ICT) solutions with a fully-fledged 5G experimentation environment where they will have the opportunity to test and evaluate the performance of their services. In this environment they can verify whether their services comply with 5G network key performance indicators (KPIs). In addition, experimenters will have the ability to simulate different network conditions (*e.g.*, network latency, jitter, various bandwidths) to test the performance of their services (via the 5G Traffic simulator). By conducting such experiments, ICT developers will identify any issues that need to be fixed in time and therefore can guarantee their customers (*i.e.*, PPDR end-users) seamless performance of their services. At the same time, this will advertise the need for end-users to advocate for a shift towards adopting 5G technology (a key objective for the 5G-EPICENTRE project).

Through 5G-EPICENTRE, companies that provide PPDR ICT solutions can deploy, configure, execute and evaluate their services on the unified 5G infrastructure available through the 5G testbed facilities located in the following cities: i) Malaga; ii) Aveiro; iii) Barcelona; and iv) Berlin. The overarching goal of the infrastructure will be to combine the resources of the aforementioned facilities in federation, in an attempt to make them more easily available and the experiment execution more streamlined (*e.g.*, quicker scheduling, better availability). The first step towards this direction is the provisioning of a single access point to the federated infrastructure by means of a web portal. In this deliverable we describe the preliminary version of such a portal, and elaborate on the currently implemented and future functionalities envisioned. This report aims at providing an overview of experimentation and workflows that correspond to functions that the Portal will serve within the integrated experimentation infrastructure.

The remainder of this deliverable is organised as follows:

- **Section 2** describes the processes involved in experimentation, and therefore contributes context to the eventual description of the developed solution.
- **Section 3** elaborates on the mappings drawn between the developed functionalities of the Portal and the project elicited requirements and technical component specifications.
- **Section 4** presents an overview of the functions available with this version of the 5G-EPICENTRE Portal, and how those relate to foreseen experimentation workflows using the integrated final infrastructure.
- **Section 5** summarises the presented content and indicates directions for future work.

## 1.1 Mapping of project's outputs

The purpose of this section is to map 5G-EPICENTRE Grant Agreement (GA) commitments, both within the formal Deliverable and Task description, against the project's respective outputs and work performed.

Table 1: Adherence to 5G-EPICENTRE's GA Deliverable & Tasks Descriptions

5G-EPICENTRE Task	Respective Document Chapters	Justification
T3.3: Experiment planning dashboard  <i>"This Task will deliver a web-based, information-rich graphical user interface (GUI)-driven portal"</i>	2 - Experimentation in 5G-EPICENTRE	Section 2 presents a general overview of experimentation in the context of 5G-EPICENTRE, defining the main actors and procedures involved in the delivered web Portal processes.

<p>for uploading VNFs and PPDR experiments to the 5G-EPICENTRE infrastructure”.</p>	3 - Adherence to project specifications	Section 3 lists the means through which the Portal fulfils elicited user and platform requirements, and maps the provisioned functionalities to the specified architectural components.
	4 - The 5G-EPICENTRE Portal overview	Section 4 presents an overview of the processes enabled by the current implementation of the Portal. This Section is supplemented with Annexes I-IV, which depict the rich GUI implementation in each case.
<p>T3.3: Experiment planning dashboard</p> <p><i>“Through this interface, high-level administrator access will be provided for both first party, as well as third-party experimenters, who will be able to define and set-up an experiment”.</i></p>	3.3.2.1 - User authentication and management	This Section describes the means through which user authentication and role-based access control are implemented.
	3.4 - Security-by-design considerations	This Section elaborates on the Security-by-Design approach employed to enforce Role-Based Access Control for the activities undertaken in the Portal, following the guidelines established in D1.5.
<p>T3.3: Experiment planning dashboard</p> <p><i>“In addition, the user interface will allow experimenters to browse the existing VNF/NetApp catalogues (T4.2) so as to select desired functionality, or chain together available VNFs (including third-party ones) toward specifying new NetApps to be hosted on the platform”.</i></p>	3.3.1.3 - NetApps creation and management dashboard	This Section describes the component that enables visual chaining of network resources (functions and service chains).
	4.1.4 - Visual NetApp composition	This Section elaborates on the specific journey users will undertake to create NetApps via chaining together network function components. Annex IV supplements this description with a visual walkthrough of implemented procedures.
<p>T3.3: Experiment planning dashboard</p> <p><i>“Apart from creating and managing VNF chains, the dashboard will further provide KPI and insights visualization leveraging on the plugins developed in the context of T3.2”.</i></p>	3.2 - Relation to the 5G-EPICENTRE architecture	This Section establishes the Insights Tools subsystem as a future complement to the 5G-EPICENTRE Portal, as specified in the 5G-EPICENTRE architecture.
	4.2 - Functionalities to be supported in the final version	This Section describes foreseen functionality of the Insights Tool subsystem for KPI visualisation, to

		be delivered as part of D3.2 “In-sights Tool”.
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## 2 Experimentation in 5G-EPICENTRE

In the context of this deliverable, we provide the notion of an **experiment** as the process in which the facility (either individually, or as part of a federation of resources) can provision a dynamic virtual environment, which accurately reproduces the operational conditions (*i.e.*, network characteristics and traffic) specified so as to carry out a variety of drafted test cases. For the experiment environment to function, the facility should contain adequate resources to reproduce the desired conditions, which is achieved through software packages developed to execute **network functions (NFs)**, either on dedicated hardware (Physical Network Functions - PNF) or by means of virtualisation (Virtual/Containerised Network Functions - V/CNFs). An experiment is characterised by an environment requiring network traffic to flow through one or more NFs “chained” together via service function chaining to form a more complex end-to-end **Network Service (NS)**. **Network Applications (NetApps)**, are defined as a “chain” of interconnected V/CNFs and NSs, configured to provide a vertical application over the network [1]<sup>1</sup>. NetApps may hence be comprised of one or more chains of NSs, V/CNFs, or combinations of the two, and will require some form of application to run on user equipment (UE) to perform a dedicated task for a specific end-user. 5G-EPICENTRE dedicates its facilities for the execution of experiments involving NetApps for Public Protection and Disaster Relief (PPDR)-specific end-users. Figure 1 provides an illustrative example of the three software classes described in the context of experimentation in the project.

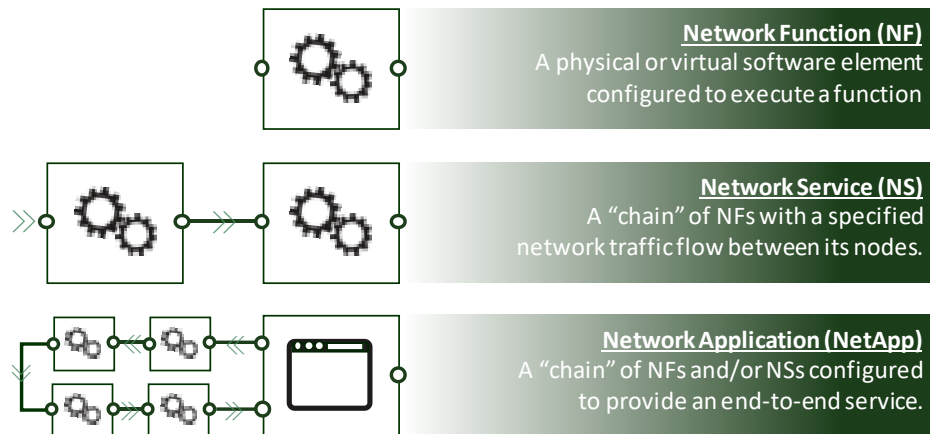


Figure 1: 5G-EPICENTRE key software components involved in experimentation

Having defined these concepts, the 5G-EPICENTRE Portal, as described in D1.3 “Experimentation requirements and architecture preliminary version”, provisions an interactive visual environment that allows interested stakeholders (*e.g.*, solution providers and software developers with a particular focus on PPDR applications) to define, execute and collect results regarding the performance of their NetApps, in the form of experiments. In the following section, we describe the Portal and the main actors that will interact with it.

### 2.1 The 5G-EPICENTRE Portal and main actors

Companies that wish to test their services will use the **5G-EPICENTRE Portal**, which acts as a point of access to the tools and services that the testbed facilities provide. Through this portal, individuals will be able to carry out a series of actions, *i.e.*, defining and requesting execution of experiments, launching and configuring experiments

<sup>1</sup> The definition originated in the European Commission’s Horizon 2020 Information and Communication Technologies (H2020-ICT-2018-20) Call Topic ID: ICT-41-2020 - 5G PPP – 5G innovations for verticals with third party services: “VNF’s may be chained across several domains to create Network Applications (NetApps) tailored to the requirements of specific tenants, as demonstrated under previous 5G PPP phases”. <https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/opportunities/topic-details/ict-41-2020>

and monitoring the evaluation results and KPIs. Related work in other ongoing 5G-PPP activities that have provided a blueprint for the definition of the 5G-EPICENTRE Portal services are the 5GENESIS project (Malaga testbed) [2] and 5G EVE [3].

Individuals in software solution companies usually have limited knowledge in telecommunications networking and they do not probably possess advanced technical skills, which highlights the importance of the Portal providing a seamless mechanism for experiment definition (*e.g.*, via provision of templates or visual means of service definition). On the other hand, an Actor with such experience should be in a position to “program” the Back-end Layer (Experiment composer[ExCom]) through the Portal. The process shall rely on provisioning a high-level description of the experiment in the form of an *experiment descriptor* file, and enable infrastructure managers to configure the actual experiment settings in the respective 5G-EPICENTRE infrastructure.

The Portal features shall include the following functions:

- i) Drafting of an experiment to be deployed and ran (*i.e.*, onboarded) on top of the experimentation infrastructure, by defining the NetApp(s) involved in its execution;
- ii) Forwarding an experiment scheduling request;
- iii) Secure provisioning of VNFs for their installation on the specified 5G-EPICENTRE infrastructure;
- iv) Capacity to schedule the automatic execution of an experiment once the environment is prepared.
- v) Capacity to supervise (*e.g.*, manually initiate and monitor) an experiment at the scheduled timeslot;
- vi) Capacity to deliver experiment monitoring results in real-time, and produce evaluation reports;
- vii) Providing a means for experimenters to connect with the testbed owners.

Put simply, the Portal acts as a storefront for PPDR software experiments comprised of one or more NetApps. As such, it should be noted that the Portal does not, and is not planned to, allow users to configure or install components on the infrastructure, nor does it provide any means for modifying the network/infrastructure during experimentation (*e.g.*, in case something fails to execute).

The foreseen actors of the Portal have been identified based on the combined information of D1.1 “5G-EPICENTRE experimentation scenarios preliminary version” and the requirements listed in Section 2 of D1.3. Each of the actors has specific access rights to the Portal. The foreseen actors are shown in Table 2.

Table 2: 5G-EPICENTRE Portal actors

Actor	Description	Actions taken in the Portal
<b>Generic User</b>	Someone who is not authenticated to the Portal	<ul style="list-style-type: none"> <li>May register to the Portal (create account)</li> <li>May log in (after log-in, will assume any of the other roles)</li> <li>No other Action is allowed to this role</li> </ul>
<b>Function developer</b>	Someone who develops and provides VNFs for (PPDR) network applications	<ul style="list-style-type: none"> <li>Upload VNF software packages</li> <li>Request the VNF packages uploaded be onboarded to a specific, or multiple testbed sites</li> </ul>
<b>Experimenter</b>	Someone who develops end-to-end solutions in the form of NetApps and who can request execution of an experiment involving those NetApps	<ul style="list-style-type: none"> <li>Define an experiment using a pre-specified template for PPDR applications using a graphical user interface (GUI)</li> <li>Request the scheduling of the defined experiment in one or more of the 5G-EPICENTRE testbeds</li> <li>Monitor the experiment’s execution</li> <li>Visualise measurements, KPIs and results</li> </ul>



<b>Testbed owner</b>	Someone who manages and operates the infrastructure in a particular 5G-EPICENTRE site	<ul style="list-style-type: none"> <li>• Receive VNF packages and inform on their validity and onboarding</li> <li>• Receive experiment execution request and inform on the preparedness of the site to deploy experiment</li> <li>• Validate preparedness of the environment and “programming” the execution of the experiment using the automated experiment scheduling and execution components in the Back-End Layer (Experiment Coordinator and Player).</li> </ul>
<b>Systems admin</b>	Someone who has access to all the functionalities provided by the Portal	All of the above

## 2.2 Software onboarding through the Portal

In general, an experiment should define one or more NetApps that need to execute on top of the network infrastructure to provide a particular service to the intended end-users (*e.g.*, PPDR practitioners, such as law enforcement units, firefighters and paramedics). Examples of NetApps that will be experimented on top of the envisioned federated experimentation platform have been specified in D1.1.

In order for the experiments (*e.g.*, the NetApps constituting the applications to be concurrently tested) to be executed, the test environment should provide the necessary services on the designated facility/ies. **Onboarding** refers to the process of ensuring that a particular software (NF, NS and/or NetApp) will execute on a specific virtualised or physical hardware system without issues. The onboarding process should be facilitated through the Portal, allowing remote experimenters to provision their software to the testbed owners for preparing the execution environment when the time to conduct the experiment arrives. Therefore, the Portal should provide a user-friendly means for developers of NFs to securely upload their executable software package (*i.e.*, one or more container images) to the specified sites, making it available for service function chaining purposes. Based on current practices, each NF should be accompanied by a **descriptor**, *i.e.*, a file that outlines parameters necessary for the instantiation and operation of the software, along with KPIs and requirements for its installation. In the current version of the Portal, these descriptors are provided by the function developer as part of the NF package upload, meaning, that the developer should accommodate the descriptor standard supported by the designated platform (*e.g.*, ETSI GS NFV-IFA 011 [4] for Malaga, Aveiro, Barcelona; TOSCA [5] for Berlin).

As soon as NFs are available on the platform, experimenters and/or function developers can utilise them in rapid service prototyping activities supporting these actors in defining service function chains for NetApp execution. Such chains are usually defined by their own descriptor (a network service descriptor), which essentially documents the NFs interlinked within the chain, along with those links. To simplify the process for Portal actors (people who may not necessarily have the knowledge to properly draft such descriptor files), we employ a GUI environment for the generation of such descriptors, abstracting the creation process behind an intuitive GUI enabling actors to rapidly set up NSs and onboard their descriptors to the target platforms. In the current implementation, we support ETSI GS NFV-IFA 014 [6] for modelling NS descriptors automatically generated by the tool<sup>2</sup>. These

<sup>2</sup> It is important to note at this point that, as part of the proposed shift to a Kubernetes-based Network Functions Virtualisation (NFV) Management and Orchestration (MANO) environment, NFs onboarding using NF and NS descriptor packages is expected to be replaced by the drafting of Helm Charts (<https://helm.sh/>). Helm Charts will be utilised in the southbound exchange between the Network Services Repository and Cross-Testbed MANO orchestrator for setting up and instantiating Kubernetes clusters executing containerised NFs over the testbeds. The development will be followed up based on evolution

NetApp chains can then be deployed in accordance with the availability of their components (NFs) at the testbed sites to accommodate a particular end-to-end service that the application (*e.g.*, an augmented reality app running on a head-mounted display) shall request from the network (*e.g.*, caching, multicasting, traffic engineering).

## 2.3 General experimentation procedures supported

In the context of 5G-EPICENTRE, every experiment will consist of two main phases: i) experiment preparation; and ii) experiment execution. For the purposes of this deliverable, we accept that each experiment (including the ones specified in D1.1, as well as those that third parties external to the project will deploy on top of the 5G-EPICENTRE infrastructure) has been thoroughly defined (*e.g.*, identifying VNFs, defining components and KPIs, *etc.*) and is outside the scope of the Portal, and this deliverable.

The **experiment preparation** mainly involves the experimenters and the testbed owners. In this phase, it is verified that the resources required for the experiment execution are available. First, the experimenter defines the characteristics of the experiment by using the templates provided by the Portal. This leads to the creation of a ‘request’ experiment descriptor, which is onboarded to the Portal and constitutes the starting point of the *experiment order*. An experiment order, much like its counterpart in an online storefront, allows experimenters and testbed owners to track the progress of an experiment from its specification in the Portal, to its completion, and is always referenced using a unique Experiment Order Number (No).

The experiment order will always contain a proposed timeslot for experiment execution specified by the experimenter. The experiment will however be scheduled in a specific time period (either matching the one proposed, or after a negotiation period) by the testbed owner. The testbed owner is responsible for making sure that the infrastructure which the experimenter has requested and the resources needed for the execution of the experiment are available at that time. The actor can then supplement the system with the experiment ‘execution’ descriptor, thus “programming” experiment scheduler (ExSch) component in the Back-End Layer to anticipate, query and invoke the necessary resources when the time to execute arrives (more information on this will be provided in D2.5 “5G-EPICENTRE Experiment Coordinator”).

The **experiment execution** phase mainly involves the experimenters, and can be performed either automatically or manually (*i.e.*, supervised) through the Portal. The first step of this phase consists of the instantiation of the virtual environment where the experiment will run, and the arrangement of the elements that are required for the successful execution of the experiment. Based on the experiment execution descriptor, the instantiation may take place automatically at a pre-designated time and date specified by the experimenter, or manually, in which case the Portal shall grant the experimenter the functionality to execute an experiment by pressing a button on the Portal. After the virtual environment has been set up, it will carry out the execution of the experiment test plan, as specified in the experiment specification during the preparation phase. Metrics of interest to the experimenter will be harvested in real time as the experiment runs its lifecycle, and will be made available via the Portal using innovative information visualisation techniques (developed in Task T3.2 “Novelty experiment insights visualization tools”).

It should be noted that the present deliverable will deal with the activities supported in the current version of the Portal regarding the experiment preparation stage. Integration with the experiment execution routines (*i.e.*, metrics collection, aggregation, organisation and presentation) will be integrated as part of the Continuous Integration/Continuous Delivery (CI/CD) activity undertaken in Task T4.4 “End-to-end platform integration activities”. Hence, it is understood that D3.3 constitutes a first version of the Portal, with the final version of the Portal being completed by M30, with a Section report being added to D4.5 “5G-EPICENTRE experimentation facility

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of activities in Tasks 4.2 “Container Network Functions and NetApp repositories” and 4.3 “Cross-testbed federation & synchronization”.

final version”, and in time for the planned innovation hackathons (T5.2 “PPDR innovation hackathons”) in the third year of the project.

To summarise, the seven basic steps involved when conducting the experiment are described in Table 3.

Table 3: 5G-EPICENTRE Experiment Journey

Phase	Step	Description
Experiment preparation	Scheduling	The experimenter offers all information regarding the experiment to the testbed owner(s) in the form of a <b>request experiment descriptor</b> . An “order” is generated and sent out to the proper testbed owner(s).
	Approval	The testbed owner checks the request experiment descriptor and either approves or disapproves of the experiment. If approved, any potential configuration will take place outside the scope of the Portal. The Portal should inform the experimenter on the dates when the experiment will be available.
	Ready	The testbed owner onboards the final <b>execution experiment descriptor</b> , which includes all the necessary information for experiment coordination and lifecycle management (Task 2.5), and also updates the experiment order, informing the experimenter that the experiment is ready and can be ran on the selected infrastructure.
Experiment execution	Instantiation	The experimenter can start the execution of the experiment within the specific time window allotted to the experiment (the environment should/must have been configured by the testbed owner(s) to reach the “Ready” state before that time window).
	Execution	Experiment is running according to the test cases.
	Reporting	The experiment has terminated and produced the requested reports.
	Error	A problem occurred during experiment execution.

## 2.4 Experiment descriptors

One of the main outputs of the 5G-EPICENTRE Portal should be the appropriate documentation describing the experiment processes, requirements, test cases and network services involved in its execution. Based on practices followed in the individual testbeds partaking in the 5G-EPICENTRE federation, we employ the use of experiment descriptors, which are template files containing all necessary information in a comprehensive format so as to be readable and comprehensible by a human operator of the testbed facilities. In the context of the project, and to account for potential inexperience of experimenters with 5G experimentation procedures, we employ two different experiment descriptor types, one for *requesting* the experiment (request experiment descriptor), and the other for *programming* its execution (execution experiment descriptor). The goal of the former is to deliver information regarding the deployment and execution needs of an experiment to a testbed owner in a user-friendly manner. The goal of the latter is to supply the autonomous coordination and lifecycle management components with the necessary details for instantiating and managing the experiment.

Toward defining the request experiment descriptor template (which is automatically created during the experiment preparation stage by the Portal), we have accumulated information and best practices followed in projects where experiment descriptors have been used to order experiments in the individual testbed environments in our project, namely 5GENESIS (Malaga) [7] and 5GROWTH (Aveiro) [8]. The eventual request descriptor currently produced by the Portal can be seen in Table 4. Based on feedback from both the testbed owners and first-party experimenters in the project (gathered in the context of WP5 “Experimentation”, and specifically T5.3 “Feedback-driven evaluation”), we will update this template to best match the requirements expressed by both sides.

Table 4: 5G-EPICENTRE preliminary request experiment descriptor template

```
{
  # General information
  DescriptorType : String      # either 'request' or 'execution'.
  OrderNo       : Int         # unique experiment Order no.
  Name          : String      # Name of the experiment.
  Reservation    : String      # Proposed reservation date for the experiment.
  Supervised    : Bool        # indicates whether site will be attended or execution
                              # will be remote.

  # networking requirements information
  CrossTestbed : Bool         # indicates whether experiment spans multiple testbeds
  SliceType    : String       # 5G service type slice to provision

  # experiment info
  TestCases: List<String>      # describe the test cases to execute (step-by-step)
  UEs: List<String>            # define identifiers for user equipment involved
  NetAppEndPoints: List<Endpoint> # define NetApp Endpoints
  NSs: List<Tuple<String, String>> # pairs of (NSD Id, Site Location)

  # evaluation info
  KPIs: Map<str, str>          # determines how experiment KPIs are extracted from metrics
}
```

Toward the definition of the execution experiment descriptor, we envision the addition of a start and end time (for autonomous experiment execution) programmed by the testbed owner, as well as an elaboration of the evaluation information (*e.g.*, actual metrics to be returned by the platform with regard to the information provided).

### 3 Adherence to project specifications

In this Section, we explore how the current implementation of the 5G-EPICENTRE Portal supports project documentation with respect to requirements (Section 3.1) and architecture specifications (Section 3.2). We then opt to elaborate on the specific implementation details of the internal component architecture for the Portal (Section 3.3), before providing details on the alignment to the provisions of the project Security-by-Design (SBD) Framework (Section 3.4).

#### 3.1 5G-EPICENTRE requirements adherence

The 5G-EPICENTRE Portal design has been informed by the requirements specified in D1.3. We briefly discuss adherence to the project elicited requirements (including stakeholders' and platform requirements) in Table 5. It is noted that, while visualisation requirements are pertinent to the Portal, we do not include those in the following list, as they pertain to functionalities provisioned by the Insights tools subsystem (D3.2), with an expected delivery date in M30. In the Table below, requirements are identified using the codes QR, FR, NFR defined in D1.3. The definition of these codes is given below:

- QR: stakeholders' requirement
- FR: functional requirement
- NFR: non-functional requirement

Table 5: 5G-EPICENTRE Portal adherence to stakeholders' and platform requirements

Req.	Description	Adherence	Implemented
<b>Stakeholders' requirements</b>			
<b>QR3</b>	The platform should provide network resource repository and the ability to use.	Through the 5G-EPICENTRE Portal, experimenters can gain access to the resources available for each site by means of the Network service browser (NSBR) component. The user interface (UI) functionality is provided, yet full functionality is awaiting implementation of the Curated NetApp image repository component in T4.2, due in M28 (after the delivery of this report).	Partially implemented in this version
<b>QR4</b>	The platform should provide VNF/NetApps repository and the ability to use.	Through the 5G-EPICENTRE Portal, experimenters can gain access to the VNF/NetApps available for each site by means of the NSBR component. The UI-functionality is provided, yet full functionality is awaiting implementation of the Curated NetApp image repository component in T4.2, due in M28 (after the delivery of this report).	Partially implemented in this version
<b>QR5</b>	The platform should provide service on-boarding / parametrisation functionality.	Through the 5G-EPICENTRE Portal, function developers are provisioned the means to both onboard their NFs to any of the sites,	Fully implemented

		as well as introduce them into service function chains with parameterisation options exposed.	
<b>QR6</b>	Friendly user interface, guiding to perform testing.	The 5G-EPICENTRE Portal has been designed following fundamental principles of effective web design, informed by the user requirements.	Fully implemented
<b>QR11</b>	On-line tools for one-stop reservation of facilities.	The 5G-EPICENTRE Portal is offered as a single point of access to the federated facilities, having been designed to act as a digital storefront for 5G PPDR experiments and services onboarding.	Fully implemented
<b>QR12</b>	Avoid complexity and over-dimensioning.	Following fundamental principles of effective web design, the 5G-EPICENTRE Portal presents an intuitive user experience, abstracting much of the complexity involved in networking infrastructure configuration. It has been designed with the purpose of enabling users to order an experiment, without possessing knowledge on virtual or physical network infrastructure.	Fully implemented
<b>QR13</b>	Provide technical support for network configuration and service operation	The 5G-EPICENTRE Portal displays tooltip dialogue boxes, along with “Help” items to provide basic guidelines throughout the experiment journey.	Fully implemented
<b>QR14</b>	Different subscription schemes should be supported.	The 5G-EPICENTRE Portal will support a variety of remuneration options for the use of the provisioned services. The functionality must be informed by the Business Models (D6.6, “5G-EPICENTRE business model and exploitation plan”), M30, and will be incorporated in a future version of the Portal, as part of the CI/CD procedures followed.	Not implemented in this version
<b>QR16</b>	Remote monitor of testbed execution	The Portal shall provide means to monitor execution of an experiment in real time, in terms of collecting and provisioning data in rich visualisation structures. This functionality will be developed alongside the developments on experiment execution (D2.4) and visualisation (D3.2).	Not implemented in this version

<b>QR20</b>	Compliance to standards	The 5G-EPICENTRE Portal supports the following standards: i) RFC 7519 [9] for URL-safe user authentication; and ii) ETSI GS NFV-IFA 014 [6] for modelling Network Service descriptors.	Fully implemented
<b>Platform requirements</b>			
<b>FR1</b>	The system must allow a user to define experiments	The 5G-EPICENTRE Portal implements functionality for an experimenter to prepare an experiment, resulting in the generation of an experiment descriptor.	Fully implemented
<b>FR2</b>	The system must allow a user to define experiment-specific KPIs	The 5G-EPICENTRE Portal experiment descriptor supports definition of experiment KPIs, defined by means of the experiment preparation processes (see Table 3).	Fully implemented
<b>FR3</b>	The system must support onboarding of network functions (NFs).	The 5G-EPICENTRE Portal implements functionality for a function developer to provide and request onboarding of an NF on the specified infrastructure.	Fully implemented
<b>FR6</b>	The system must support service function chaining of NFs into end-to-end services (NetApps).	The 5G-EPICENTRE Portal implements functionality for both onboarding of NetApps (by means of a descriptor template and enabling a visual means for composing NetApps out of existing V/CNF components by means of the NetApps creation and management dashboard.	Fully implemented
<b>FR10</b>	The system should support remote access to the definition and monitoring of experiments	<b>[Direct relation to QR16]</b> The Portal shall provide means to monitor execution of an experiment in real time, in terms of collecting and provisioning data in rich visualisation structures. This functionality will be developed alongside the developments on experiment execution (D2.4) and visualisation (D3.2).	Not implemented in this version
<b>FR11</b>	The system should provide a proper abstraction of the underlying network technologies.	<b>[Direct relation to QR12]</b> Following fundamental principles of effective web design, the 5G-EPICENTRE Portal presents a clean and sleek UI experience, abstracting much of the complexity involved in networking infrastructure configuration. It has been designed with the purpose of enabling us-	Fully implemented



		ers to order an experiment, without possessing knowledge on virtual or physical network infrastructure.	
<b>FR12</b>	The system should expose easy-to-consume APIs toward the experimenter.	The Portal shall notify on the provision of simple application programming interface (API) endpoints to connect user equipment to custom NetApp chains drafted using the Portal. This functionality will be delivered in tandem to the Northbound interface developments taking place in T3.1 (D3.1 “5G EPICENTRE Northbound API”, due in M18).	Not implemented in this version
<b>FR16</b>	The system should expose a requirements catalogue for the underlying network resources.	<b>[Direct relation to QR3]</b> Through the 5G-EPICENTRE Portal, experimenters can gain access to the resources available for each site by means of the NSBR component. The UI functionality is provided, yet full functionality is awaiting implementation of the Curated NetApp image repository component in T4.2, due in M28 (after the delivery of this report).	Partially implemented in this version
<b>FR17</b>	The system should provide a user with appropriate network resource inventories and means to means to configure and (re)use them.	<b>[Direct relation to QR4]</b> Through the 5G-EPICENTRE Portal, experimenters can gain access to the VNF/NetApps available at each site by means of the NSBR component. The UI functionality is provided, yet full functionality is awaiting implementation of the Curated NetApp image repository component in T4.2, due in M28 (after the delivery of this report).	Partially implemented in this version
<b>FR18</b>	The system should allow experimenters to repeat and re-parameterise experiments.	The 5G-EPICENTRE Portal enables users to store experiments on their profile, which can be repeated, modified, deleted or used as templates for future experiments ( <i>e.g.</i> , when an application is updated).	Fully implemented
<b>FR19</b>	The system should provide means to customise network slices for NetApp requirements under eMBB, URLLC and mMTC service types.	The 5G-EPICENTRE Portal provides templates for experiment descriptors corresponding to the three supported service types (eMBB, mMTC, URLLC), as well as combinations of them. To avoid asking the experimenter directly, a short “wizard” is provided to detect intent and select the appropriate descriptor template.	Partially implemented in this version



<b>FR27</b>	The system should provide guidance to the user in order to train them on using it.	<b>[Direct relation to QR13]</b> The 5G-EPICENTRE Portal displays tooltip dialogue boxes, along with “Help” items to provide basic guidelines throughout the experiment journey.	Fully implemented
<b>FR30</b>	The system could enable the calibration of individual testbed components from a singular control point.	The Portal shall enable the actors to view specific details on NFs and NetApps stored on the platform’s Network Service Repository. The information will relate to isolated limitations, like the infrastructures to run over, the minimum required slice or the location of the service workspace, and will support a REST-ful interface to modify network services accordingly.	Partially implemented in this version
<b>FR31</b>	The system could support role-based access control (RBAC) policies.	The 5G-EPICENTRE Portal implements RBAC by means of the user authentication and management component.	Fully implemented
<b>NFR1</b>	The system must be secure.	<b>[Direct relation to FR31]</b> The 5G-EPICENTRE Portal implements RBAC by means of the user authentication and management component.	Fully implemented
<b>NFR3</b>	The system must be privacy-compliant.	The 5G-EPICENTRE Portal supports compliance with privacy regulations by means of its RBAC policy, and ensures that there is not “leak” of information related to an experiment or experimenter in a way that compromises personal data or intellectual property.	Fully implemented
<b>NFR4</b>	The system must be performant/responsive.	All actions that can be performed inside the 5G-EPICENTRE Portal have been designed to be responsive and clearly present outcomes of such actions in a manner expected by the end-user, to facilitate their experience.	Fully implemented
<b>NFR6</b>	The system should be user-friendly.	<b>[Direct relation to QR6]</b> The 5G-EPICENTRE Portal has been designed following fundamental principles of effective web design, informed by the user requirements.	Fully implemented
<b>NFR9</b>	The system could be documented.	The Portal will be accompanied by a thorough usage manual upon completion (M30). The present deliverable serves as a	Partially implemented in this version

first version of documentation for the Portal.

### 3.2 Relation to the 5G-EPICENTRE architecture

With respect to the 5G-EPICENTRE architecture (D1.3) the core Portal functional blocks are depicted in Figure 2. The Portal is seen as the overall solution to enable users to carry out the two experimentation procedures described in Section 2.2, *i.e.*, experiment preparation and experiment execution. As can be seen in Figure 2, two dedicated sub-systems are defined for each stage, namely the Experiment Planning Interface (EPI) and Insights tools (ITools) respectively. The contents of this deliverable will describe the components comprising the EPI, with the ITool components being considered under the scope of T3.2 and the contents of D3.2 “5G EPICENTRE Insights Tool”.



Figure 2: 5G-EPICENTRE Portal, with the contents covered in this deliverable highlighted in red (Image adapted from the 5G-EPICENTRE architecture functional view in D1.3).

In addition, this deliverable will elaborate more on the internal architecture of the 5G-EPICENTRE Portal, which has been structured based on the provisions of the functional architectural view of the 5G-EPICENTRE experimentation facility, defined in D1.3. This internal, high-level architecture diagram is provided in Figure 3.

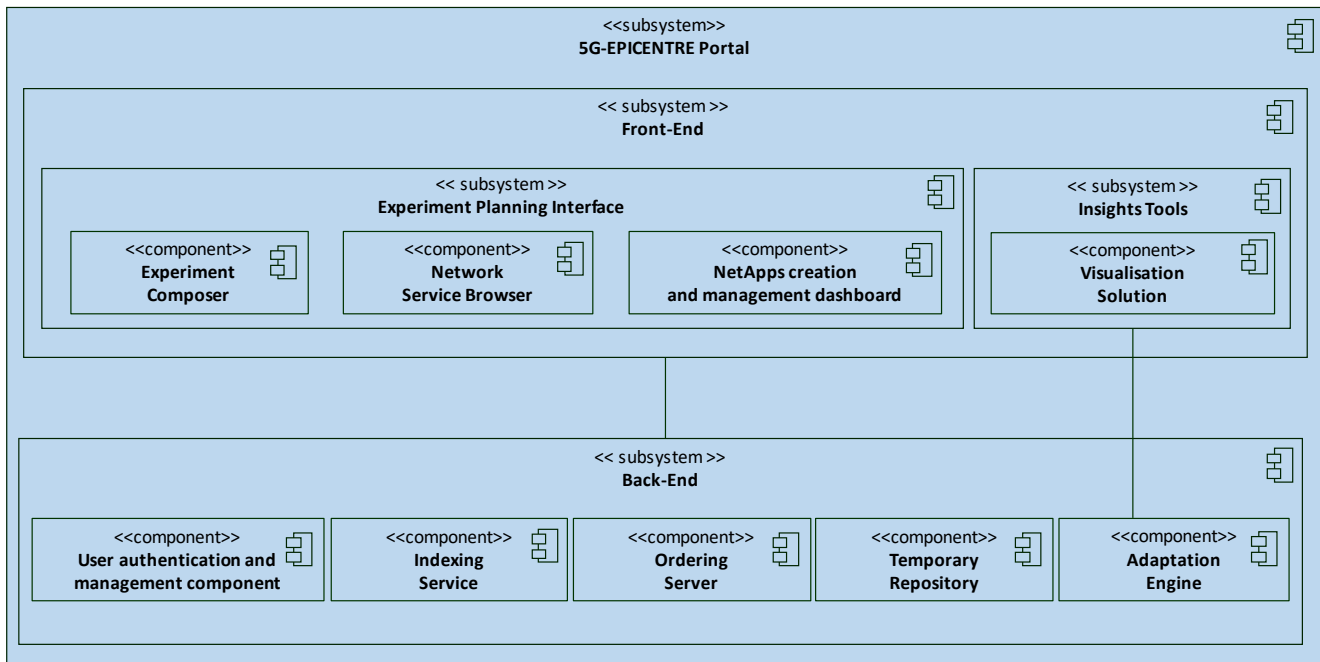


Figure 3: 5G-EPICENTRE Portal internal component architecture (as of M14)

### 3.3 Implementation

The following Sub-sections will provide more details on the individual components depicted in the Figure 3 diagram. Specifically, this Section will focus on the components within the EPI functional block, also mentioned in the previous Section.

#### 3.3.1 Front-End

The EPI Front-end comprises a collection of tools provided to Portal actors, organised in a single, coherent web-based UI. The primary aim is to provision a solution for the booking and reservation of the infrastructure facilities for the purposes of experimentation. Essentially, it fulfils the Portal's design as a web-based marketplace application aiming at delivering a rich UI experience for experimenters to request execution of their experiments, and function developers to browse through the various available NFs and NetApp chains available for experimentation. It also features an administrative UI space for testbed owners to manage and program experiment scheduling, and receive NF onboarding requests.

The Front-End UI is developed using Angular 11<sup>3</sup>, a typescript-based open-source web framework developed by Google. Angular is based on a component-driven, hierarchical architecture, where pages are treated as components comprised of smaller sub-components. Components are structure predisposed with the presentation of information, and can be reused across the entire project, rendering each component agnostic and autonomous. Management of data (e.g., fetching or provisioning of data to and from components) is handled by Angular services, with Pipes being used whenever data needs to be filtered or sorted. Routing of the web space is handled by Angular Router, which utilises Guards as a means to impose restrictions on the access to specific data or information to only permitted users. This is particularly important in relation to user authentication and security, enabling only authorised users to access a specific functionality provided by the Portal. This functionality is offered through communication with the Portal Back-End, which further caters to the provisioning of the different services needed to satisfy user requests. Below, we elaborate on the main components comprising the EPI front-end.

##### 3.3.1.1 Experiment composer

The ExCom enables experimenters to easily define and customise an experiment. It allows experimenters to store a particular request experiment descriptor as a “template”, enabling its modification and reuse (private/public), and browse a list of experiments and experiment templates (own or created by others). Through this module, experimenters can also open an experiment order and view experiment details, and can modify experiment details for experiments that are pending. In the future version of the Portal, through this component, the testbed owner will also be able to essentially onboard the execution experiment descriptor toward programming the coordination and lifecycle management components to automatically execute the specified experiment.

##### 3.3.1.2 Network service browser

The NSBR represents a visual catalogue of all NFs and NetApps that are currently available on the testbeds and to which the actor has the proper access rights. This space is intended for local storage and visualisation of the descriptors for the software artefacts in a comprehensive format (for instance, visualising the graph of NF chain nodes comprising a NetApp traffic chain). In this respect it supports queries for NFs and NetApps, thus providing search functionality by means of various filters and indexing keywords. To fetch this information, the NSBR facilitates communication with the 5G-EPICENTRE Back-End Layer, and more specifically the Network Service Repository component, by consuming the latter's northbound interface methods (as specified in D4.1).

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<sup>3</sup> <https://angular.io/>

### 3.3.1.3 NetApps creation and management dashboard

The NetApps creation and management dashboard (nappD) is an intuitive GUI for the rapid prototyping of NetApp service chains using components that are available on the 5G-EPICENTRE testbed catalogues. Its goal is to abstract the process of painstakingly drafting NS descriptors, thus streamlining the process of service function chaining, especially with novice users in mind (to reduce entry barrier to the 5G PPDR market). The component allows users to pull NetApps' NS descriptors and graphically depict them as a chain with interactive elements. The concept borrows heavily from related scientific literature (and motivation) presented in works such as *Containernet 2.0* [10] and *Switchboard* [11].

Within the 5G-EPICENTRE Portal, chains can be rapidly generated by selecting from the available components (by connecting to the NSBR) and therefore graphs can be effortlessly edited, parameterised and stored for generating new NS descriptors (and at a later stage, Kubernetes Helm Charts) on-the-fly.

### 3.3.2 Back-End

The Portal Back-End is responsible for incorporating functionality related to storing and managing experiment and onboarding request orders, by provisioning and executing functionality based on user input. It also hosts a temporary repository space for users to upload NF packages for distribution to the testbed owners. The different microservices comprising the 5G-EPICENTRE Portal Back-End at the time of writing are described below.

#### 3.3.2.1 User authentication and management

In compliance with requirements regarding the efficient and secure provisioning of the 5G-EPICENTRE Portal service, this component implements a solid authentication mechanism based on a single-sign-on (SSO) process that enables users access to the various functions supported by the Portal using a single set of login credentials. The component deals with security considerations at the front-end layer, implementing **Northbound Security** layer features of the Holistic Security and Privacy Framework (HSPF) pertaining to access control, single sign-on, and credential authentication, as specified in D2.1 "Cloud-native security specification". These security features have been implemented by following the provisions of D1.5 "Security-by-design toolkit". More details on the security considerations in the Portal's design are provided in Section 3.4.

The User authentication and management (AuthM) component implements SSO by means of the JSON Web Token (JWT) open standard (RFC 7519) [9], which defines secure information transmission between remote parties using JSON data objects. JWT is self-contained, consisting of three parts separated by periods ("."). The three components of JWT are the following: i) *header*; ii) *payload*; and iii) *signature*. Using this scheme, whenever users (Generic User actors, as specified in Section 2.1) supply their credentials to the system, a JWT is generated by the AuthM containing basic information about users, the token expiration date, and the name of the encryption algorithm. In this way, all subsequent requests sent from users will include the JWT as a Hypertext Transfer Protocol (HTTP) header, granting access to routes, services and resources permitted with that token.

As can be seen, the AuthM supports RBAC in the form of restricting access on the grounds of permissions granted to specific user roles. Hence, each user is identified by the Portal under a specific role, which grants the user specific access rights to resources and services. By imposing RBAC, specific functionalities and API endpoints within the 5G-EPICENTRE Portal (*e.g.*, access to a specific Uniform Resource Identifier [URI] endpoint containing an uploaded VNF package) are accessible only to users who possess the proper access clearance (in our example, the designated testbed owner).

#### 3.3.2.2 Indexing service

Every NF uploaded to the 5G-EPICENTRE Portal will be indexed by means of both front-end and back-end keywords (*i.e.*, keywords visible to the function developer, and keywords used only within the Portal Back-End). This module will be responsible for associating these keywords to the NF unique identification number, optimising search engine functionality and results to NSBR queries.

### 3.3.2.3 Ordering Engine

The Ordering Engine implements the experiment and onboarding ordering logic. It will be responsible for creating an order (for either an experiment or a NF onboarding request) and forwarding it to the appropriate testbed owner account, with support for administrative functions (e.g., accept, decline, modify) and notifications triggering. The service will support multiple order processes simultaneously, and will eventually integrate remuneration mechanisms in a future version of the Portal.

## 3.4 Security-by-design considerations

In accordance to the guidelines set forth in D1.5, in this sub-Section we elaborate on the adherence to the SBD Framework and the security considerations integrated in the design of the Portal.

UMLSec has been used to model security implications for the Portal. UMLSec provides the necessary stereotypes for RBAC, complete with tags and constraints [12], which we apply to the various activity diagrams describing the processes that the Portal should support. An indicative activity diagram for experiment preparation through the Portal, shown carrying the <<rbac>> UMLSec stereotype is shown in Figure 4. Similar diagrams have been prepared for all activities that are supported in the current version by the Portal, and more will be prepared as functionality is added via CI/CD to accommodate the SBD framework within the DevOps systems development lifecycle (as specified in D1.5). In the interest of space, we will elaborate on how security policies are taken into consideration in the Portal's design using this diagram as a guide, opting not to disclose the full range of security designs in this present report.

In the Figure 4 diagram, the <<rbac>> stereotype enforces security policies being applied to the actions themselves, meaning that both the Experimenter's and Testbed Owner's actions on the Portal will lead to secure actions executed by the system. These system actions correspond to the insertion of experiment data, inspection of experiment data, updating of experiment data, scheduling of an experiment, inspection of the proposed experiment date and time, and rescheduling of the experiment.

Insertion of experiment data by an Experimenter (e.g., "John Doe") will only be executed if an associated tag is defined where the following information has been specified:

AT#1:

```
{ protected = Insert experiment data }
{ role = (John Doe, Experimenter) }
{ right = (Experimenter, Insert experiment data) }
```

The above tag translates as follows: *Insert experiment data* is defined as a protected action, that can only be executed if there exists a user with the *Experimenter* role assigned to her profile (e.g., *John Doe*), and the *Experimenter* is the actor enforcing the *Insert experiment data* action.

Similar tags are defined for all other protected actions displayed in the Figure 4 diagram. Some actions enable multiple roles to enforce them, therefore warranting definition of multiple tags (e.g., *View experiment data* being enforced by both *Experimenter* and *Testbed Owner* roles).

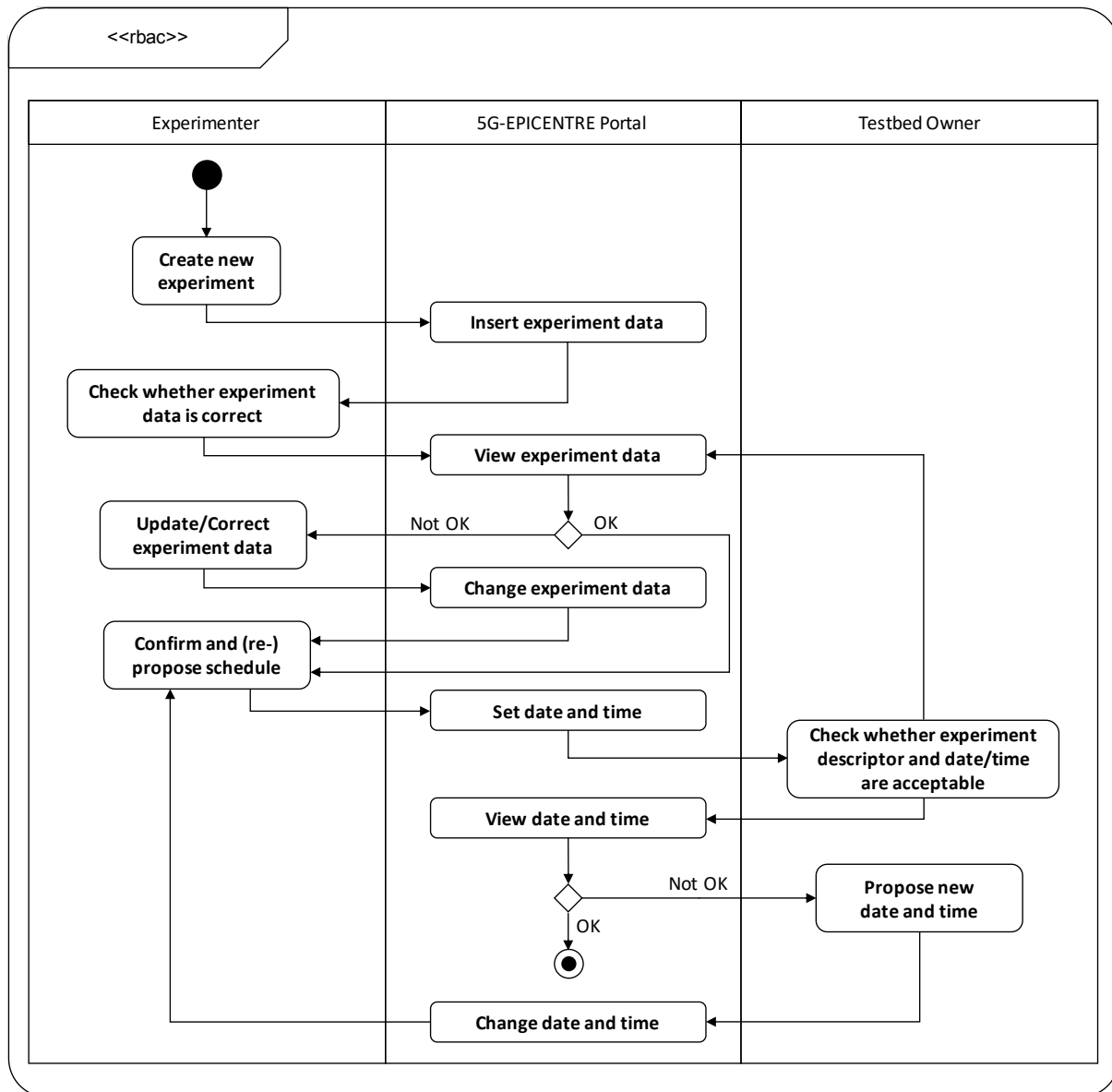


Figure 4: UMLSec activity diagram for experiment preparation via the 5G-EPICENTRE Portal.

## 4 The 5G-EPICENTRE Portal overview

This Section will highlight the functionality provisioned by the current version of the 5G-EPICENTRE Portal at M14.

### 4.1 Functionalities supported in this version

The following Sub-sections describe examples of the 5G-EPICENTRE Portal usage involving the various actors listed in Section 2. Through these examples, we aim at illustrating the various means through which the Portal supports the elicited stakeholders' and platform requirements, indicating whenever necessary which component in the 5G-EPICENTRE architecture is triggered to support the described functionality.

It is important to note that these processes, while considered final (in terms of supporting an elicited requirement, or set of requirements in a 100% capacity), may be prone to changes introduced in the evaluation stages of the project (WP5), along with the foreseen updates to deliverables D1.1 and D1.3 at the end of the second year of the project (*i.e.*, D1.2 and D1.4 respectively). Therefore, a final version of these processes will be added in the report regarding the final integrated 5G-EPICENTRE experimentation facility (D4.5: "5G-EPICENTRE experimentation facility final version", due in M30), which will be the result of a CI/CD methodology, where new features and updates shall be introduced to developed components in the context of the integration Task activities (T4.4).

#### 4.1.1 User authentication

This particular function involves the processes of authenticating and authorising a Generic User to specific access rights and privileges within the 5G-EPICENTRE Platform. The process is supported by means of the AuthM, and is considered a prerequisite for every other process described in the remaining Sub-sections. Prior to this point, it is implied that the user has created an account by registering with a pair of unique credentials on the Portal web space. The steps followed to authenticate a Portal user are described below, and are depicted in the sequence diagram shown in Figure 5:

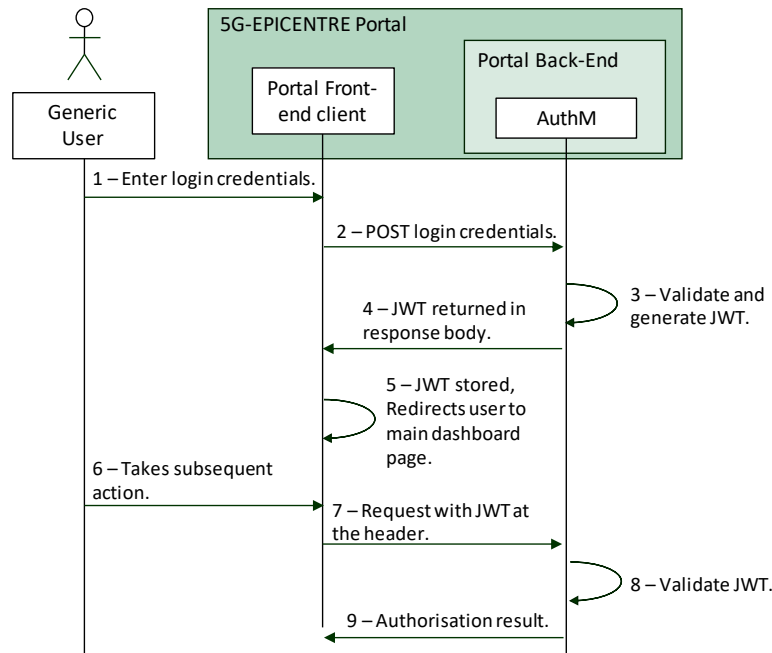


Figure 5: Sequence diagram depicting user authentication in the 5G-EPICENTRE Portal



- **Step 1:** Considered by the system as a Generic User in the beginning, the user visits the 5G-EPICENTRE Portal web space and logs in using his/her issued credentials.
- **Step 2:** Credentials are processed by the AuthM component, which either validates the provisioned username and password combination or returns in an error state (*e.g.*, 400 Bad Request, 401 Unauthorized, etc.).
- **Step 3:** In case of a successful authorisation request (200 OK), the AuthM constructs the JWT and returns it to the Portal Front-End client in the response message body.
- **Step 4:** The JWT is stored by the Portal client, and included in the authorisation header for every subsequent request made by the (now authorised) user, for as long as the JWT is within its expiration date.

A visual walkthrough of the described processes, as implemented in the current version of the 5G-EPICENTRE Portal, is provided in Annex I.

#### 4.1.2 Network function onboarding

This particular function primarily involves the Function Developer and Testbed Owner actors (see Section 2.1), and describes the processes that take place when the former wishes to make use of the 5G-EPICENTRE Portal for the onboarding of an NF on one or more of the 5G-EPICENTRE federated testbeds. Prior to this point, it is implied that each actor in this scenario has been authenticated as either a Function Developer or Testbed Owner via the processes described in Section 4.1.1. The steps below describe the detailed NF onboarding journey, from beginning to end, complemented by the sequence diagram depicted in Figure 6:

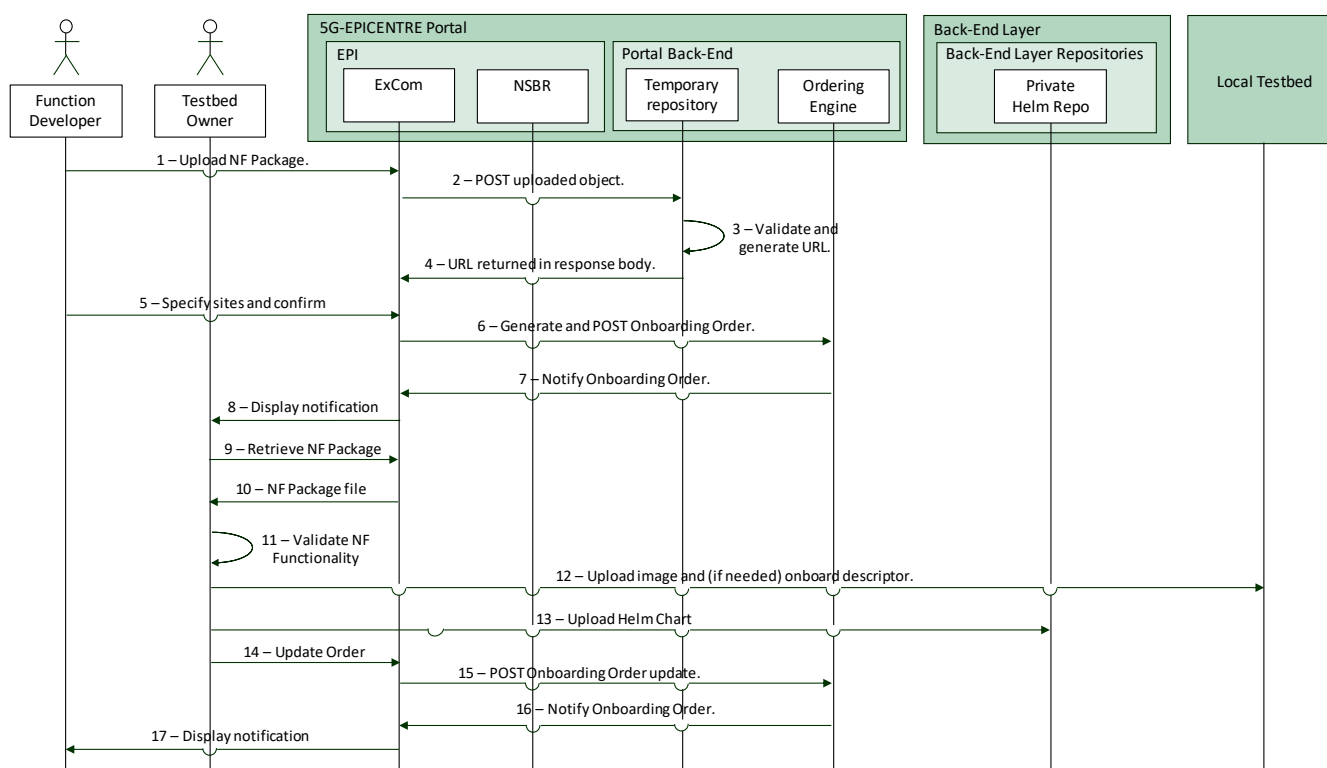


Figure 6: Sequence diagram depicting NF onboarding processes using the 5G-EPICENTRE Portal components

- **Step 1:** Through the main dashboard provided by the Portal, the Function Developer enters the EPI.
- **Step 2:** The Function Developer enters the nappD space.
- **Step 3:** The FD selects the “Upload New” option.



- **Step 4:** Using a file upload interface, the Function Developer uploads an NF Package to the 5G-EPICENTRE Portal. The package should include the image of the developed software, along with any other material needed for the application to execute (including a descriptor/Helm chart file). A Unique Resource Locator (URL) is generated pointing to the location of the uploaded file on a temporary repository.
- **Step 5:** The Function Developer specifies the testbed sites where s/he wishes to onboard her/his NF Package out of a list of available options. More than one site may be selected (including an “All” option).
- **Step 6:** The Portal presents the Function Developer with a final confirmation page, where the Function Developer can review her/his order and proceed with its confirmation, cancellation, or store it as a draft for future completion.
- **Step 7:** The Function Developer confirms the onboarding request. A new Onboarding Order request is constructed, including the URL and other onboarding-related information in the message body.
- **Step 8:** A confirmation message is displayed when the request is successfully relayed, and the Order is listed on the Function Developer’s “Pending” items list, where the Function Developer can review progress of the request based on the subsequent actions undertaken by the Testbed Owner(s).
- **Step 9:** The Testbed Owner is notified on the reception of a new Onboarding Order through the main dashboard. The Order is listed on the Testbed Owner’s “Pending” items list, where the Testbed Owner can modify the status of the Order to inform the Function Developer of the progress made.
- **Step 10:** Upon entering the Order, the Testbed Owner gains access to the NF Package and downloads the file locally.
- **Step 11 (Outside the Portal):** The Testbed Owner validates integrity and functionality of the received files. Upon successful execution at her/his site, the Testbed Owner can onboard it, following the site’s supported onboarding procedures (including uploading the appropriate Helm chart onto the centralised Helm chart repository).
- **Step 12:** The Testbed Owner updates the status on the Onboarding Order.
- **Step 13:** The Function Developer is notified on the updated status of her/his Onboarding Order through the main dashboard.

A visual walkthrough of the described processes, as implemented in the current version of the 5G-EPICENTRE Portal, is provided in Annex II.

#### 4.1.3 Experiment preparation

This particular function primarily involves the Experimenter and Testbed Owner actors (see Section 2.1), and describes the processes that take place when the former wishes to make use of the 5G-EPICENTRE Portal for requesting onboarding of an experiment on one or more of the 5G-EPICENTRE federated testbeds. Prior to this point, it is implied that each actor in this scenario has been authenticated as either an Experimenter or Testbed Owner via the processes described in Section 4.1.1. The steps below describe the detailed experiment onboarding journey, from beginning to end, complemented by the sequence diagram depicted in Figure 7:

- **Step 1:** Through the main dashboard provided by the Portal Client, the Experimenter elects to enter the EPI space.
- **Step 2:** The Experimenter elects to enter the ExCom space. The Experimenter can see a list of past experiments (if any), each with the option to repeat, modify, turn into a template, or delete.
- **Step 3:** The Experimenter can opt to “Create New”, in which case s/he is transferred to the descriptor creator page. The Experimenter can opt to leave at any time, in which case the process is stored in the “Pending” items list for the Experimenter to either delete, modify or continue working on.
- **Step 4:** The Experimenter fills in the different fields in the experiment descriptor form, and requests the scheduling of the experiment at a specific timeslot, along with the testbed site(s) on top of which the experiment shall be executed.

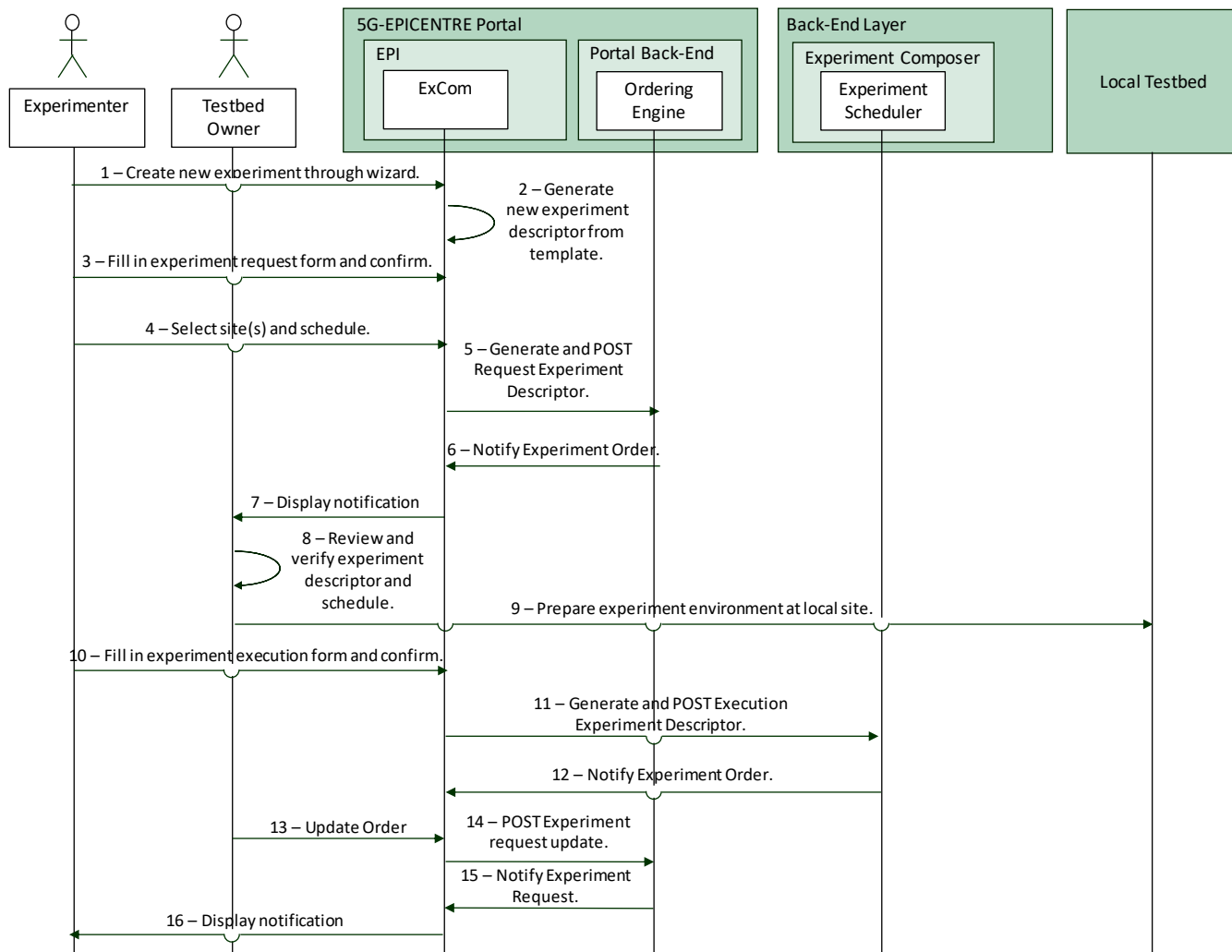


Figure 7: Sequence diagram depicting experiment onboarding processes using the 5G-EPICENTRE Portal components

- **Step 5:** The Experimenter opts to generate an Experiment Order request, in which case the ExCom checks validity of the descriptor (e.g., all mandatory fields have been filled in by the Experimenter). It halts progress, and notifies the Experimenter if something is wrong with the currently constructed request.
- **Step 6:** The ExCom generates a request experiment descriptor file “attached” to the Experiment Order. A review page is displayed to the Experimenter prompting her/him for final confirmation.
- **Step 7:** The Experimenter confirms the Experiment Order request clicking on the corresponding button. The ExCom constructs the proper request body to be sent to the Portal Back-End components, pending confirmation by the Testbed Owner(s). A confirmation message is displayed when the request is successfully relayed, and the Order is listed on the Experimenter’s “Pending” items list, where the s/he can review progress of the request based on the subsequent actions undertaken by the Testbed Owner(s).
- **Step 8:** The Testbed Owner is notified on the reception of a new Experiment request Order through the main dashboard. The Order is listed on the Testbed Owner’s “Pending” items list, where the Testbed Owner can modify the status of the Order to inform the Experimenter of the progress made.
- **Step 9:** The Testbed Owner can review the Order, and gain access to the request experiment descriptor and proposed schedule. Based on a variety of factors (e.g., availability due to maintenance, conflicts or difficulty of setting up the environment), the Testbed Owner may elect to return the Order with a different date (see **Step 7**).

- **Step 10 (Outside the Portal):** The Testbed Owner starts preparing the environment on their local testbed for the experiment.
- **Step 11:** When complete, the Testbed Owner uses the Portal to fill in the execution experiment descriptor, essentially programming the Experiment Scheduler to automatically prepare the experiment environment upon reaching the descriptor designated date and time.
- **Step 12:** The Testbed Owner updates the status on the Experiment Order, or (as in **Step 9**) may propose a re-scheduling. As soon as the Testbed Owner designates an Experiment Order as “Ready”, it will “unlock” the option for the Experimenter to instantiate, in case of manual execution (no other action takes place otherwise, as the experiment is automatically deployed and instantiated in the unsupervised experimentation case).
- **Step 13:** The Experimenter is notified on the updated status of her Experiment Order through the main dashboard.

A visual walkthrough of the described processes, as implemented in the current version of the 5G-EPICENTRE Portal, is provided in Annex III.

#### 4.1.4 Visual NetApp composition

This particular function involves either a Function Developer or Experimenter and the Testbed Owner actors (see Section 2.1), and describes the processes that take place when any of the former two wishes to make use of the 5G-EPICENTRE Portal to design a new NetApp using available components onboarded to the 5G-EPICENTRE federated testbed infrastructure. Prior to this point, it is implied that each actor in this scenario has been authenticated as either a Function Developer / Experimenter or Testbed Owner via the processes described in Section 4.1.1. The steps below describe the detailed NetApp design and onboarding journey, from beginning to end (as undertaken by an Experimenter), complemented by the sequence diagram depicted in Figure 8:

- **Step 1:** Through the main dashboard provided by the Portal Client, the Experimenter elects to enter the EPI space.
- **Step 2:** The Experimenter elects to enter the nappD.
- **Step 3:** The Experimenter elects to create a new NetApp chain, selecting the option from a list of available options on the dashboard page.
- **Step 4:** The Experimenter opts to add NFs through a visual, “browser” interface, displaying information on each item (such as available sites, keywords describing functionality, *etc.*).
- **Step 5:** After selecting her/his NFs, the Experimenter may confirm the selection. The Experimenter is returned to the main nappD page, where a Canvas-like visual sandbox is shown containing all NFs as draggable visual elements.
- **Step 6:** Using the drag-and-drop functionality, the Experimenter may chain NF visual elements together and specify traffic flow from one NF element to another.
- **Step 7:** When the chain is finished, the Experimenter can opt to generate the NetApp, in which case an NS descriptor is generated by the nappD, enabling the instantiation of the NFs and defining their links. Hence, a new NetApp Order request is constructed, including the NS descriptor in the message body.
- **Step 8:** The nappD forwards the descriptor via the NSBR to the NS Repository (NSRepo), from where it can be onboarded to the Kubernetes-powered cross-testbed MANO in the form of Helm charts that are mapped via an NSRepo - private Helm chart repository automated connection (essentially, creating a new chart for the custom NetApp).

A visual walkthrough of the described processes, as implemented in the current version of the 5G-EPICENTRE Portal, is provided in Annex IV.

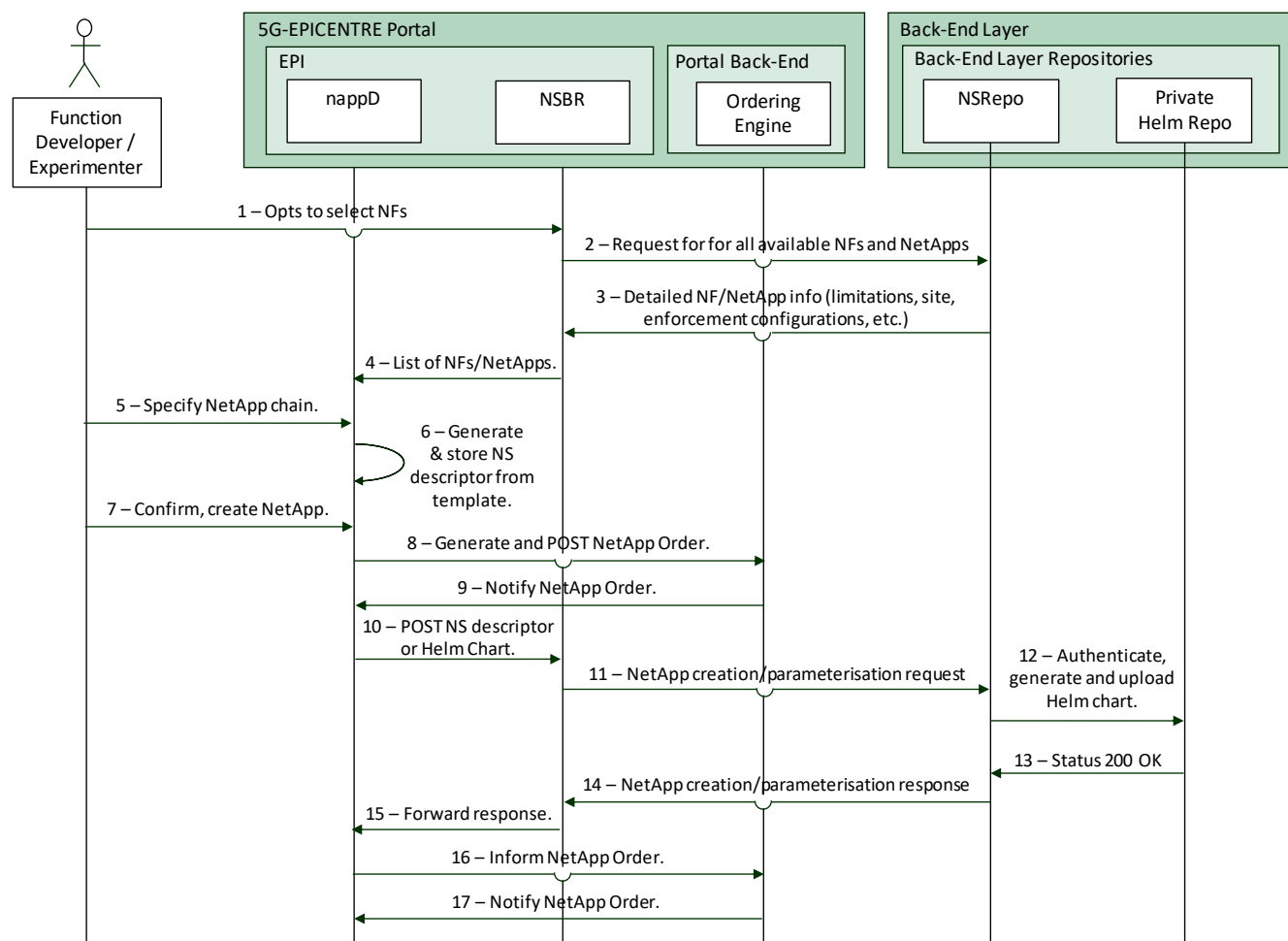


Figure 8: Sequence diagram depicting NetApp visual design processes using the 5G-EPICENTRE Portal components

## 4.2 Functionalities to be supported in the final version (M30)

The workflows described in the above Sections correspond to functionality that has been prepared for the release of this deliverable (M14), and constitutes the first version of the 5G-EPICENTRE Portal. In line with project expectations, along with final versions of key architectural components corresponding to future deliverables, additional functionality will be implemented and integrated into the Portal following a CI/CD mindset. The Portal developers will be responsible to incrementally improve and add features to the Portal prototype, by adding functionality introduced in the most recent updated versions of the individual components in frequent integration and delivery steps, as shown in Figure 9. The final version of the 5G-EPICENTRE Portal will be ready in M30, and will be elaborated in detail as part of the report and software delivery of the 5G-EPICENTRE experimentation facility final version (D4.5).

The main functionalities to be integrated into the Portal are listed in Table 6.

Table 6: Future 5G-EPICENTRE Portal functionalities to be integrated

Functionality	Description	Related deliverables	Project Month
<b>Supervised experiment execution</b>	The Portal will incorporate functionality to enable an Experimenter to enter a dedicated web space where the	D2.4	M30

	management of an ongoing experiment will be possible from a remote location. The option to execute/instantiate an experiment will be incorporated, and functionality shall be implemented enabling the Portal to trigger functionality within the Experiment Player to execute an experiment from start to finish. The functionality will be properly defined depending on the internal workings of the “5G-EPI-CENTRE Experiment Player” (D2.4).		
<b>Insights Tools</b>	The Portal will integrate an additional subsystem to work in parallel with the EPI, and which will be responsible for the collection, representation and compilation of experiment measurements and KPIs into comprehensive visual data stories. Toward this end, creative information visualisations will be developed to represent key insights for the different data gathered by the Analytics Engine. As such, this functionality will be integrated gradually, taking inputs from D3.2 (development of the visualisation tools), D2.6 (“5G-EPICENTRE Analytics Engine”), and essentially D2.4.	D2.4 D2.6 D3.2	M30

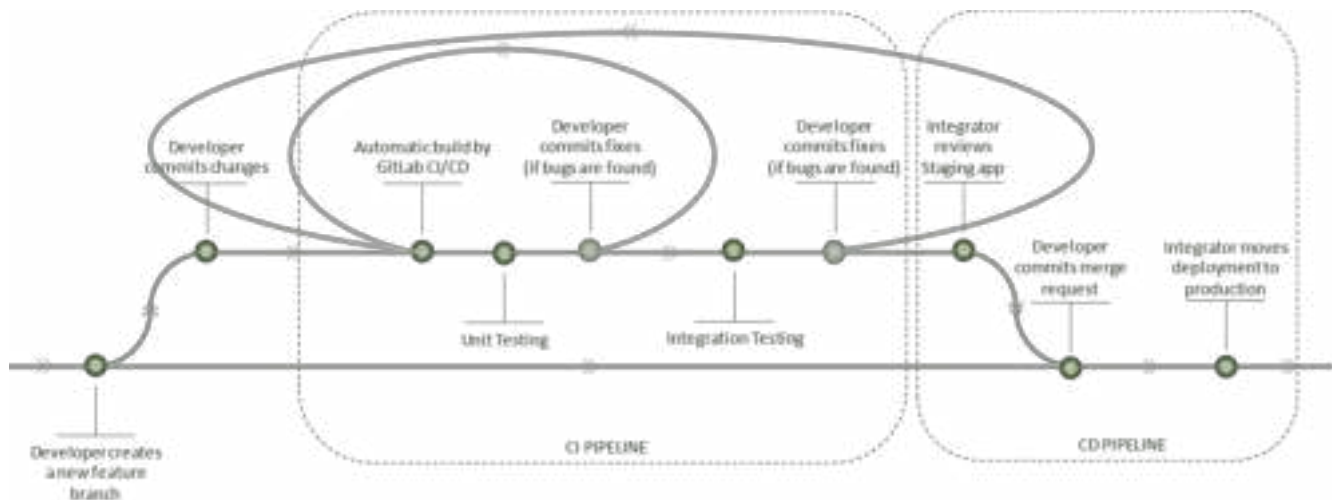


Figure 9: The CI/CD process underpinning development of the 5G-EPICENTRE Portal

## 5 Conclusions

In the current document, we presented the key concepts describing 5G-EPICENTRE experiments, and how processes relate to the planning and execution stages of experiments on top of the infrastructure by means of the 5G-EPICENTRE Portal as the access point. We elaborated on the different actors that will interact with the Portal functions, describing their roles and access rights. Furthermore, we mapped the provisioned functionalities onto the project requirements (both those elicited by the PPDR solution providers as key stakeholders informing the platform design and the analysed and documented platform functional and non-functional requirements), and elaborated on the Portal internal architectural structure using the 5G experimentation framework architecture as the reference frame. We then proceeded to describe how basic functions, such as requesting an experiment, uploading a network function, or designing a novel NetApp chain, are accommodated by the Portal and the currently implemented functionality. The Portal has been designed following fundamental web design practices to facilitate usability and user experience and the eventual design aesthetics reflect a sleek and clean design reminiscent of online storefronts, which implements an order-based PPDR experiments transactions system between end-users and testbed owners.

This deliverable constitutes the first version of the 5G-EPICENTRE user interface, establishing the visual design language of the project throughout its lifetime and until completion. Functionality will be added, informed by individual components' integration milestones (*e.g.*, MS4 "Platform tools and content ready for full-stack validation", and particularly MS7 "Platform tools and content ready for third-party user evaluation"), to ensure that the final system complies fully with requirements and expectations of the intended end-users, and delivers on the functionalities specified in the GA. These updates will be incorporated into this design framework and prototype following established DevOps practices of CI/CD.

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## Annex I: Visual walkthrough of the user authentication functionality

This Annex illustrates the steps followed to authenticate a Generic User, by displaying screenshots of the developed Portal spaces and thus providing a step-by-step usage manual. The contents in this Annex may be prone to change as functionality is added and/or updated throughout the project implementation lifetime.

**Step 1:** Users visit the Portal space and are redirected to the **Login Screen**, where they use the brackets (in light orange colour) to type in their email used for signing up, and password associated with their account and clicking on the bright orange “Sign in” button. The screen offers users an option to retrieve a lost or forgotten password (“Forgot password?” button), command the browser to store a cookie for automatic sign-in (“Remember me” option), as well as allowing users to redirect to the new user registration page, where an account can be requested. The Login Screen can be seen in Figure 10.

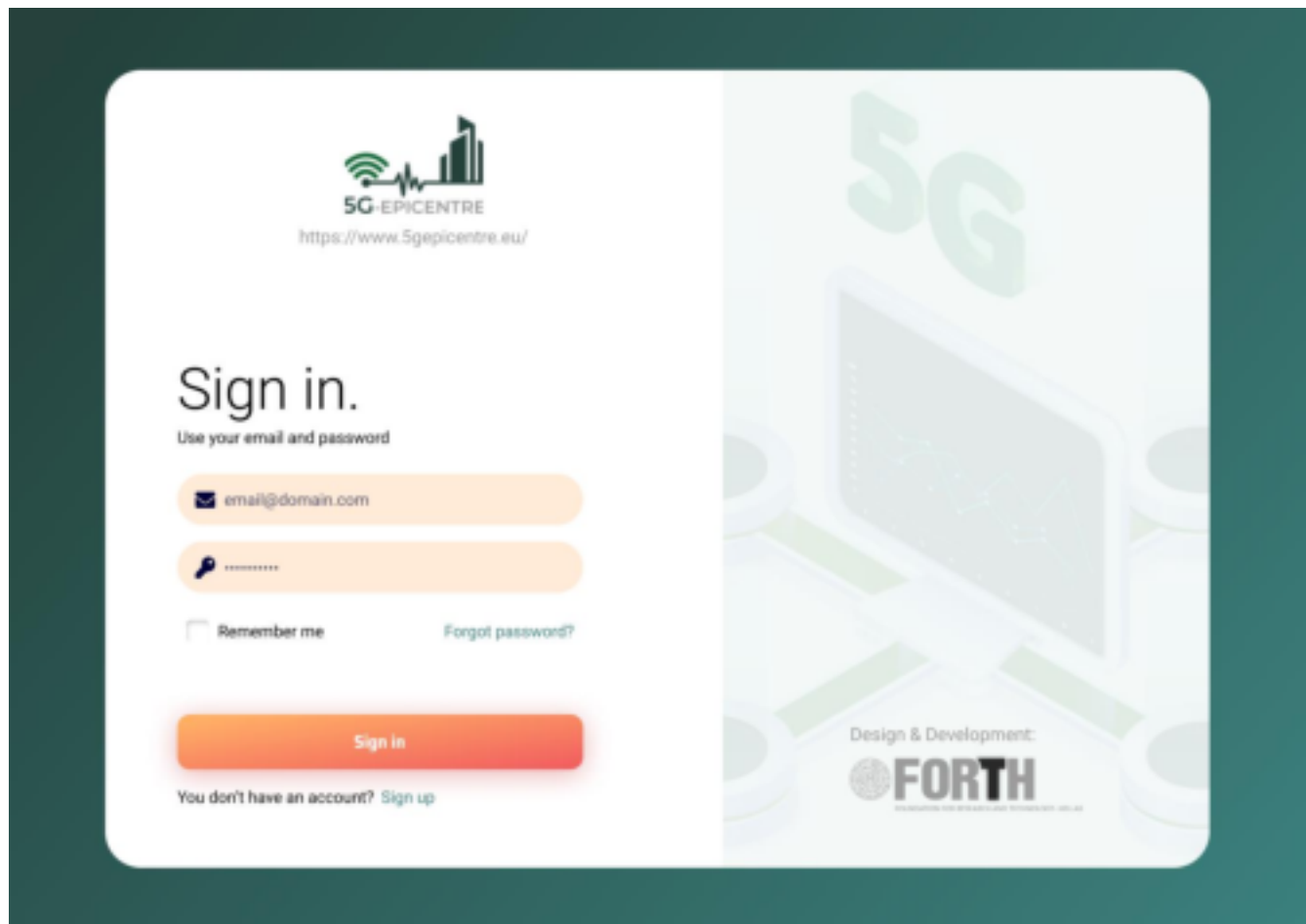


Figure 10: 5G-EPICENTRE Portal Login Screen

**Step 2:** Upon a successful login attempt, the Portal redirects the user to the main **Dashboard** page. The Dashboard page is different for the different user roles accommodated by the Portal. Its main purpose is to summarize information in a meaningful and succinct manner, allowing users to have an overview of their content. For instance, an experiment should have a preview of the currently active experiments, an overview of KPIs achieved in their experiments, as well as quick access buttons for their most common actions (*e.g.*, create a new experiment) and links to items of current interest (*e.g.*, currently running or forthcoming experiments).

In addition, after logging in, users gain access to several persistent UI elements, such as the following: i) the navigation pane shown on the left side of the browser window, which enables users to access the different services available to their Actor’s role; ii) a Search function to rapidly find content without navigating to it; iii) a



notifications icon for reviewing new items added to the user's notifications list (e.g., a new experiment request); and iv) the Account details, where users can manage their account (e.g., switch password, etc.). The Dashboard page, along with the described elements, can be seen in Figure 11.

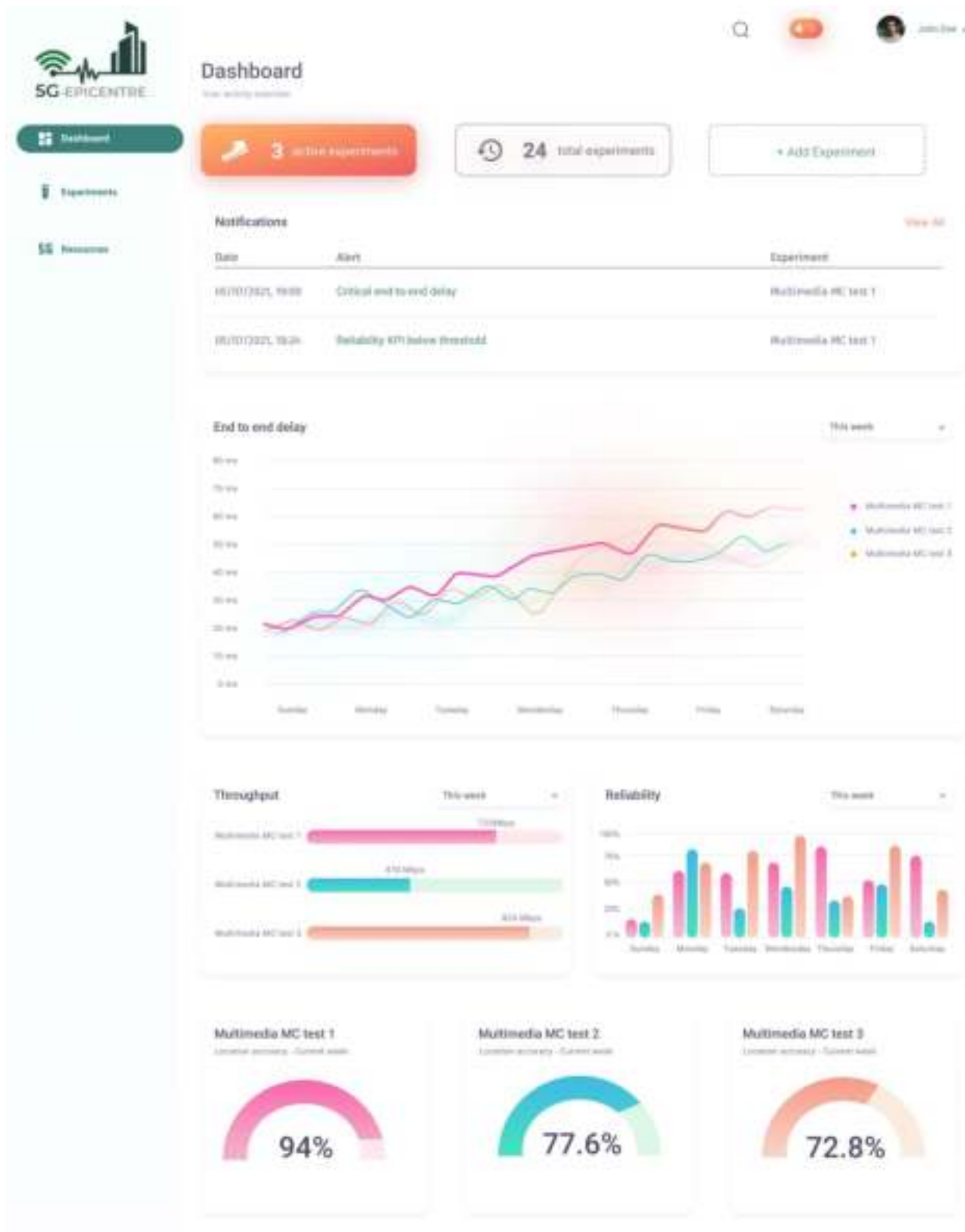


Figure 11: 5G-EPICENTRE Main Dashboard page (for an Experimenter).

## Annex II: Visual walkthrough of the NF onboarding functionality

This Annex illustrates the steps followed by a Function Developer to request onboarding of an NF. In the following step-by-step walkthrough, we display screenshots of the developed Portal spaces, which we present in the form of a hands-on manual. The contents in this Annex may be prone to change as functionality is added and/or updated throughout the project implementation lifetime.

**Step 1:** As a Function Developer, the user is granted access to the **Resources** page, where the various requests for the onboarding of NetApp resources (*i.e.*, VNFs and NetApp chains) created by this user are displayed. A “Search” bar is provided to locate a request item more efficiently, while options to view all items in each list are available (“View All” buttons – example for VNFs shown in Figure 13). Items shown on this page will correspond to the most relevant three items (per list) based on the sorting method that the user has specified (by means of the top right drop-down menu). Items on each list show the following: i) the item’s creation date and time; ii) their titles; iii) a list of front-end keywords that the user has associated to that item in order to characterize the target category; and iv) its current status as notified by the Testbed Owner. Small notification icons are displayed for summarising why an item was declined, or returned to the user, while the option to edit or delete a request is provided on the right-hand side of each item on the list. Clicking on an item will reveal more details on it (Figure 16, Figure 18, Figure 21, Figure 22). The Resources page for Function Developers can be seen in Figure 12.

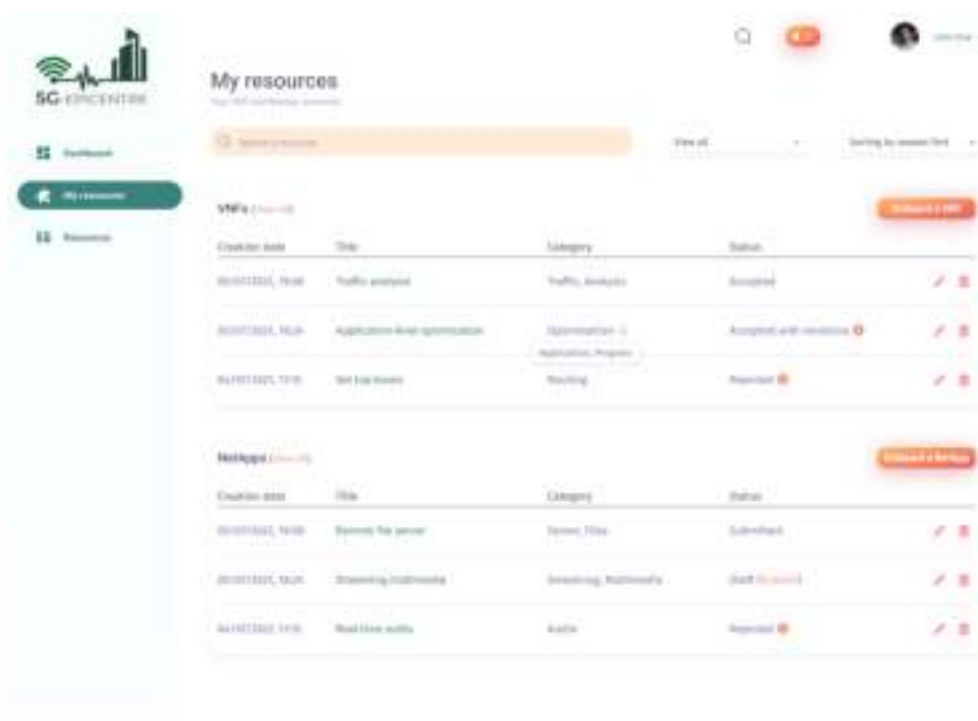
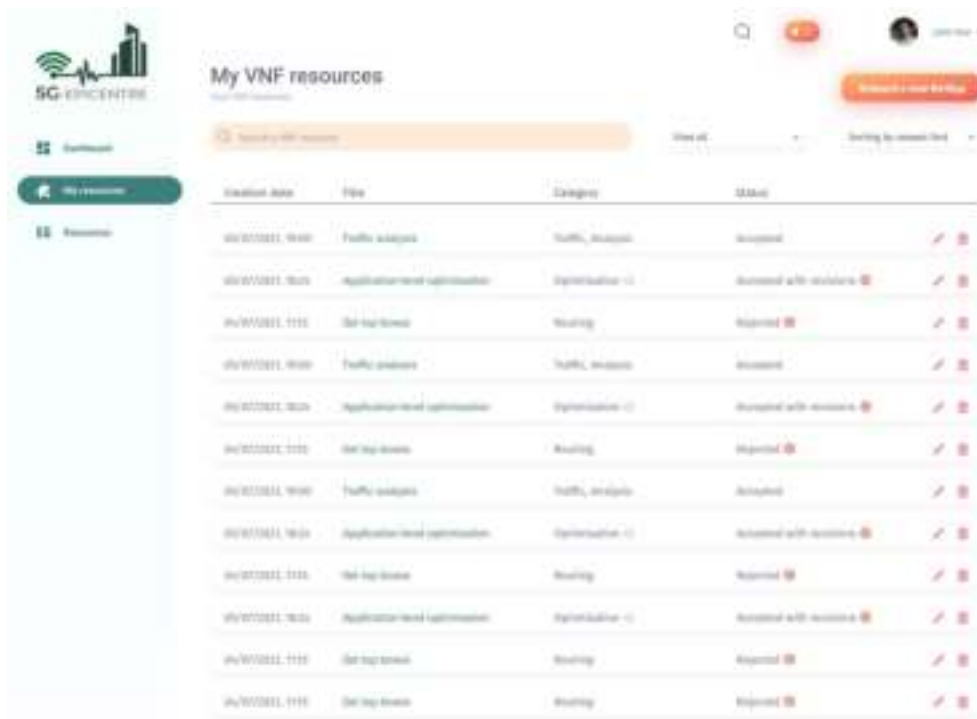


Figure 12: 5G-EPICENTRE Function Developer Resources page (showing tooltip for front-end keywords).

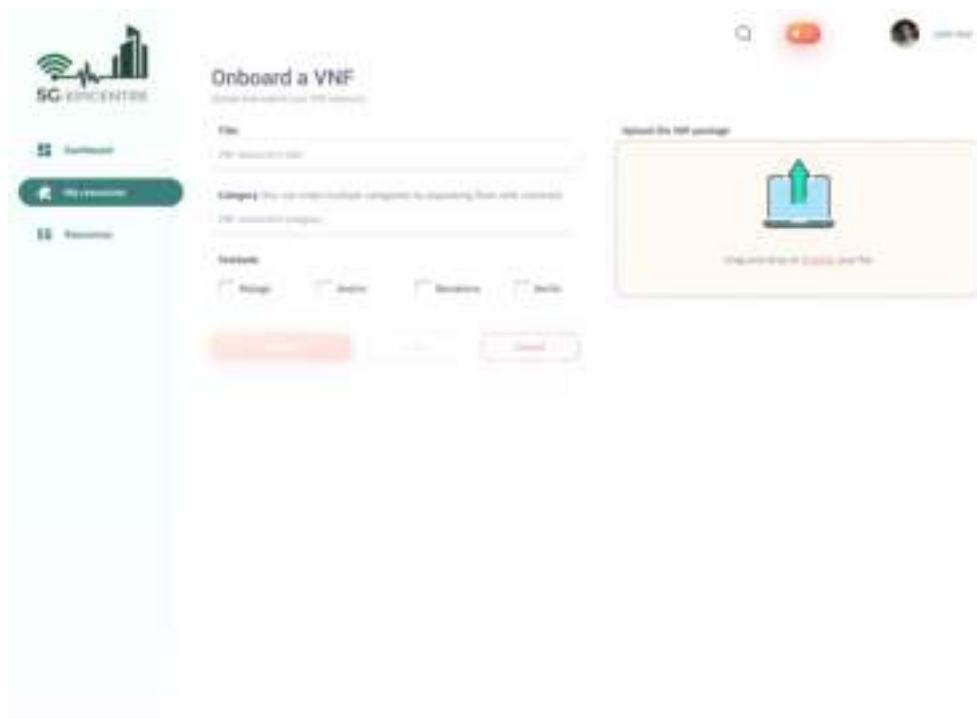
**Step 2:** Users may opt to click on the bright orange “Onboard a VNF” button displayed next to the VNFs list header space. Clicking on this button will redirect users to the **VNF Onboarding** page (Figure 14).

**Step 3:** Users can type in a name for their VNF using the empty bracket under “Title”, and provide several front-end keywords for making the VNF more easily discoverable during search operations. The page further allows the Function Developer to specify one or more testbeds onto which the VNF should be onboarded (Figure 15). The large rectangular area on the right side is used for uploading the VNF package file to the Portal’s temporary repository.



Created Date	File	Category	Status
02/07/2021 16:00	Traffic analyzer	Traffic analyzer	Accepted
02/07/2021 16:00	Application-level optimization	Optimization ->	Accepted with warnings
02/07/2021 11:10	5G-App-Insights	Monitoring	Rejected
02/07/2021 16:00	Traffic analyzer	Traffic analyzer	Accepted
02/07/2021 16:00	Application-level optimization	Optimization ->	Accepted with warnings
02/07/2021 11:10	5G-App-Insights	Monitoring	Rejected
02/07/2021 16:00	Traffic analyzer	Traffic analyzer	Accepted
02/07/2021 16:00	Application-level optimization	Optimization ->	Accepted with warnings
02/07/2021 11:10	5G-App-Insights	Monitoring	Rejected
02/07/2021 16:00	Application-level optimization	Optimization ->	Accepted with warnings
02/07/2021 11:10	5G-App-Insights	Monitoring	Rejected
02/07/2021 11:10	5G-App-Insights	Monitoring	Rejected

Figure 13: 5G-EPICENTRE Function Developer Resources page – expanding VNF items list through the “View All” option



**Onboard a VNF**

File:

Category:

Features:

☐ Storage ☐ Security ☐ Monitoring ☐ Billing

Figure 14: 5G-EPICENTRE VNF Onboarding page – landing on a blank onboarding order

At any point, users may opt to “Cancel” their request (in which case all unsaved work shall be lost, while a new request will not be listed on the Resources page), or “Save” it as a draft for a future date (in which case a new onboarding request will be generated, or updated). In the latter case, the new request item will be placed among the latest VNFs associated to users’ profile, whenever users browse the Resources page (Figure 12). The item

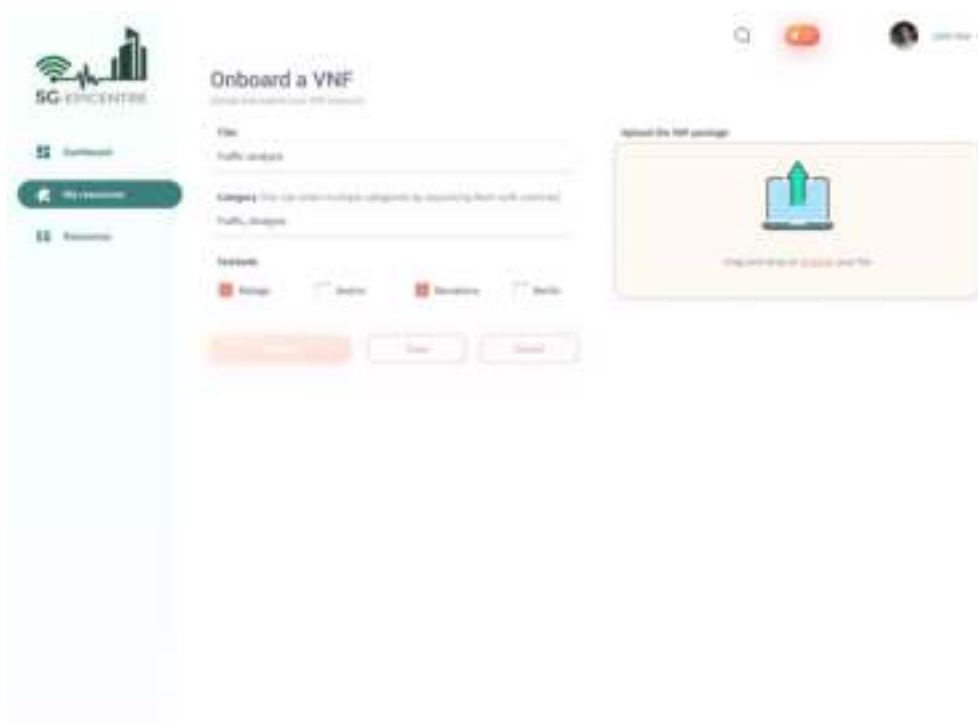


Figure 15: 5G-EPICENTRE VNF Onboarding page – specifying VNF details and sites to onboard to



Figure 16: 5G-EPICENTRE VNF Inspector page – reviewing an onboarding order draft

shall be marked as “Draft” in the “Status” field, and clicking on it shall redirect users to a new area (Figure 16) where the request can either be edited, submitted or deleted.

**Step 4:** When all information on the VNF Onboarding page has been provided, and a VNF Package has been successfully uploaded, the option to “Submit” the request will be made available (Figure 17). Upon clicking on the bright orange button, the request will be forwarded to the designated Testbed Owner(s) for each site that

was specified in the onboarding form. After the submission process, users will be redirected to the Resources page (Figure 12), where they will be able to see the new request item among the latest VNFs associated to their profile. Clicking on this item will reveal a similar Inspection page as shown in Figure 16, albeit without the option to “Submit” (Figure 18).

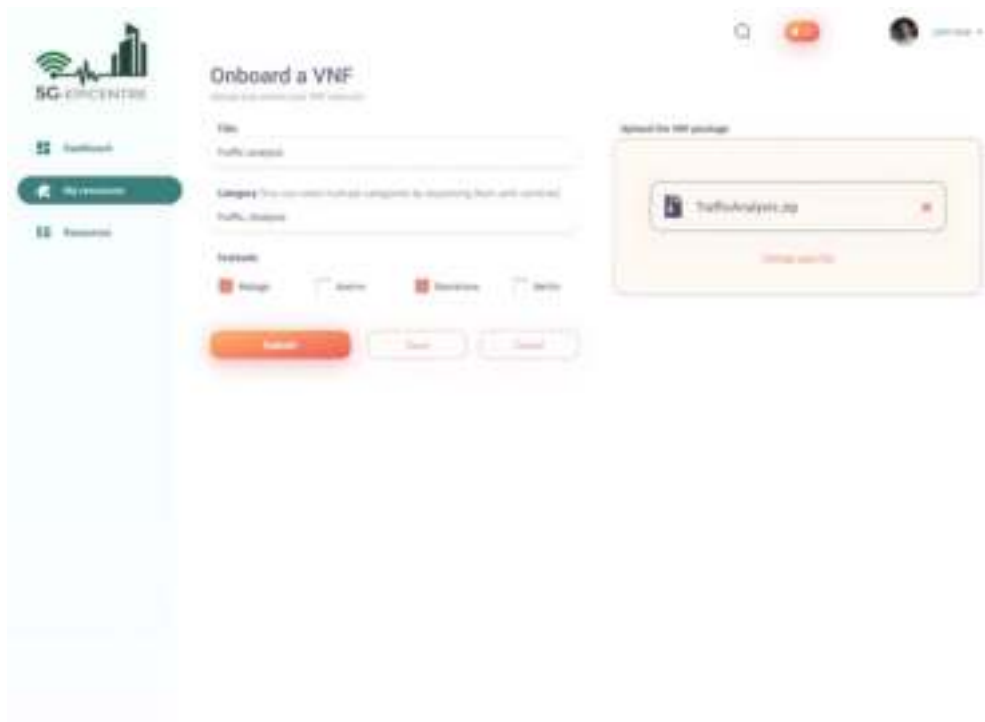


Figure 17: 5G-EPICENTRE VNF Onboarding page – uploaded package and ‘Submit’ button highlight

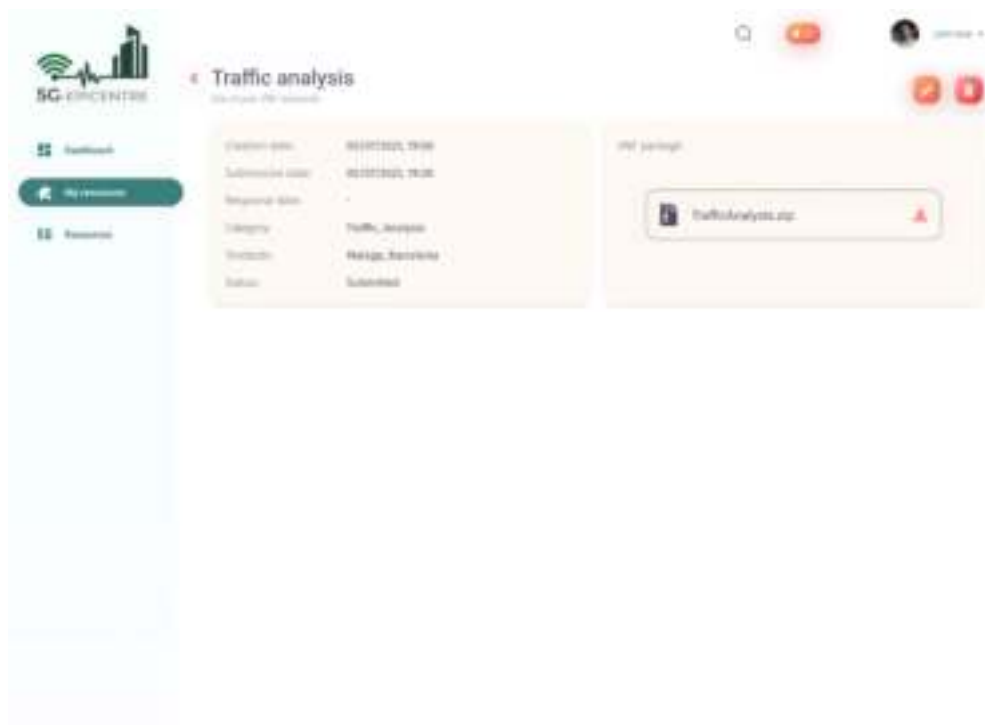
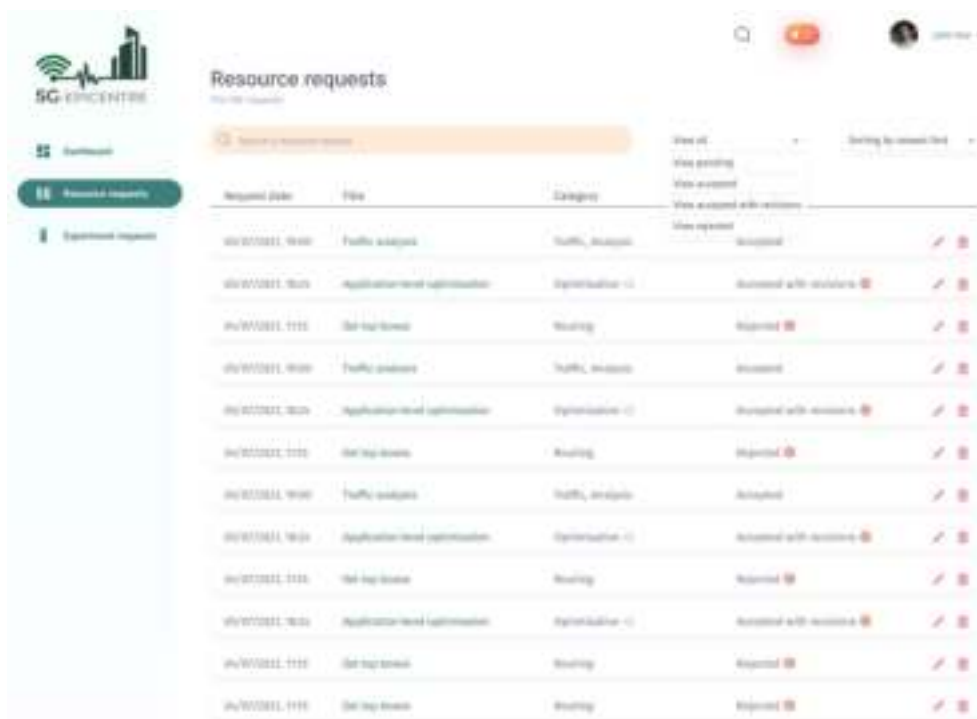


Figure 18: 5G-EPICENTRE VNF Inspector page – reviewing a submitted onboarding order

**Step 5:** The request should arrive at the Testbed Owner’s account, who shall be able to review all requests (both past and present) through Resource Requests page (Figure 19). Clicking on an item in this list shall redirect the Testbed Owner to an Inspection page for the selected item (e.g., Figure 18), where they can download the VNF package for validating its integrity and functionality. Clicking on the “Edit” button will invoke a new window for the Testbed Owner to notify on the decision of the onboarding request (Figure 20), and “Submit”.



Request date	Title	Category	Status	Actions
02/07/2021, 16:00	Traffic analysis	Traffic, analysis	Accepted	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]
02/07/2021, 16:00	Traffic analysis	Traffic, analysis	Accepted	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]
02/07/2021, 16:00	Traffic analysis	Traffic, analysis	Accepted	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]
02/07/2021, 16:00	Traffic analysis	Traffic, analysis	Accepted	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]
02/07/2021, 16:00	Traffic analysis	Traffic, analysis	Accepted	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]
02/07/2021, 16:00	Traffic analysis	Traffic, analysis	Accepted	[Edit] [Delete]
02/07/2021, 16:00	Application-level optimization	Optimization - L	Rejected with reasons	[Edit] [Delete]
02/07/2021, 17:15	Get top flows	Routing	Rejected	[Edit] [Delete]

Figure 19: 5G-EPICENTRE Testbed Owner Resource Requests page

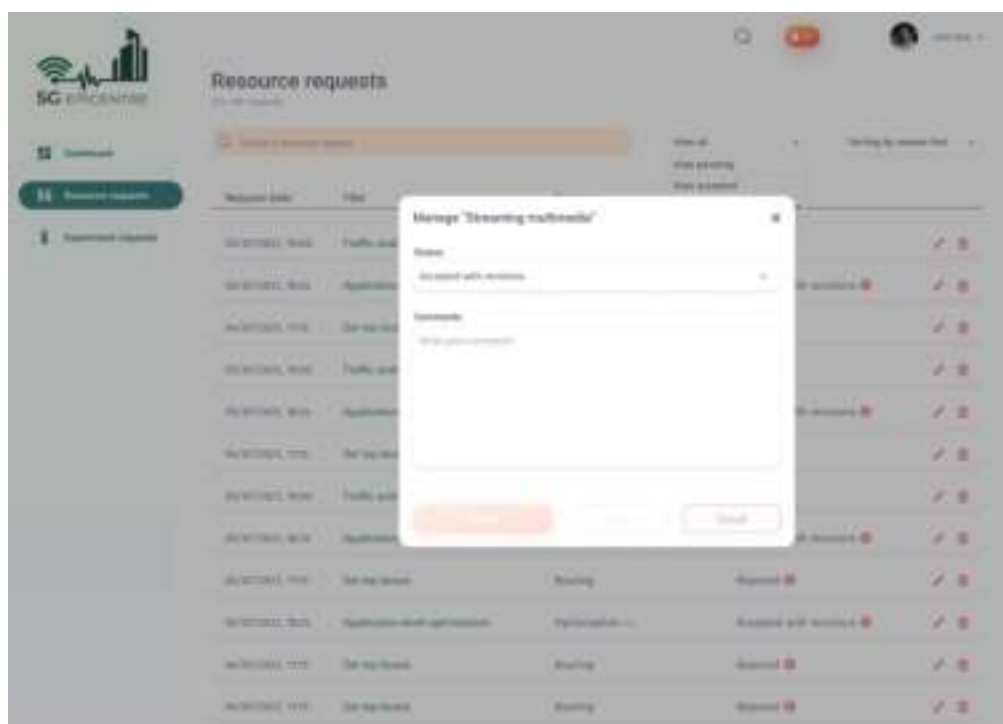


Figure 20: 5G-EPICENTRE Testbed Owner Resource Requests page – Notifying the onboarding outcome

**Step 6:** A notification will be generated at the Function Developer’s dashboard, notifying on the outcome of the onboarding request. The Inspector page is once again invoked to deliver the onboarding decision result (Figure 21). The Function Developer is able to re-enter the VNF Onboarding page (Figure 17) to re-upload a new package and re-trigger the procedure (Steps 4-6). The process is repeated until the VNF onboarding request is eventually “Accepted” (Figure 22), or “Rejected” (e.g., malicious software is located in the Package).



Figure 21: 5G-EPICENTRE VNF Inspector page - reviewing an informed onboarding order

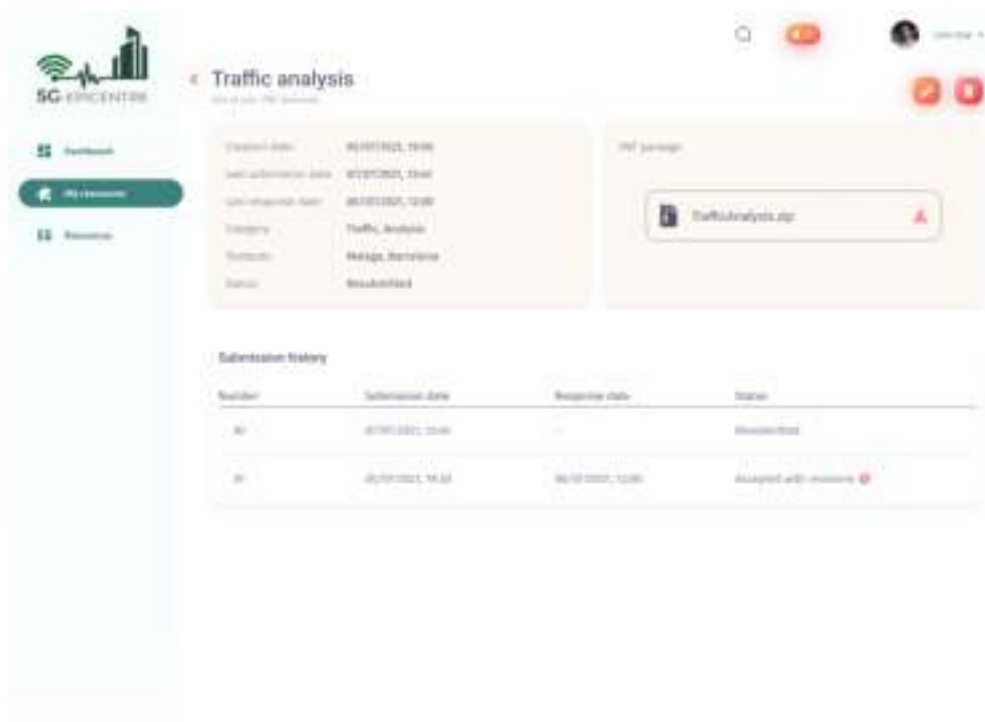


Figure 22: 5G-EPICENTRE VNF Inspector page - reviewing an “Accepted” onboarding order

## Annex III: Visual walkthrough of the experiment preparation functionality

This Annex illustrates the steps followed by an Experimenter to request the scheduling of an experiment. In the following step-by-step walkthrough, we display screenshots of the developed Portal spaces, which we present in the form of a hands-on manual. The contents in this Annex may be prone to change as functionality is added and/or updated throughout the project implementation lifetime.

**Step 1:** As Experimenters, users are granted access to the **Experiments** page, where the various applications for experiments created by these users are displayed. Experiments may appear in either “Scheduled”, “Completed” or “Requested” sub-pages (Figure 23). From whichever area, users may opt to “Create a new experiment” by clicking on the bright orange button at the top right corner of the screen.

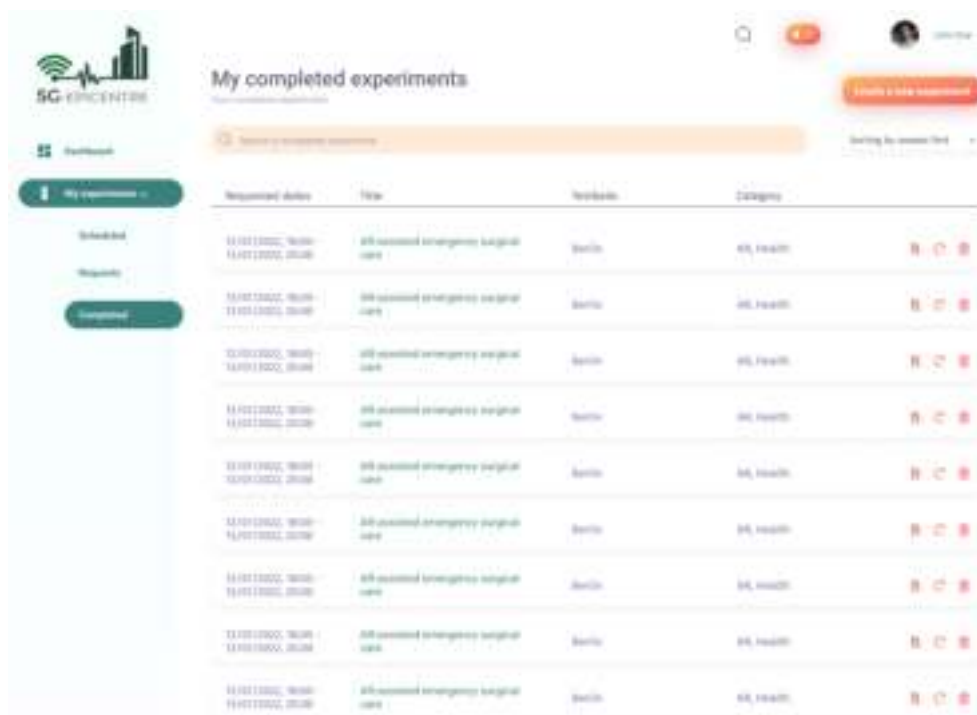
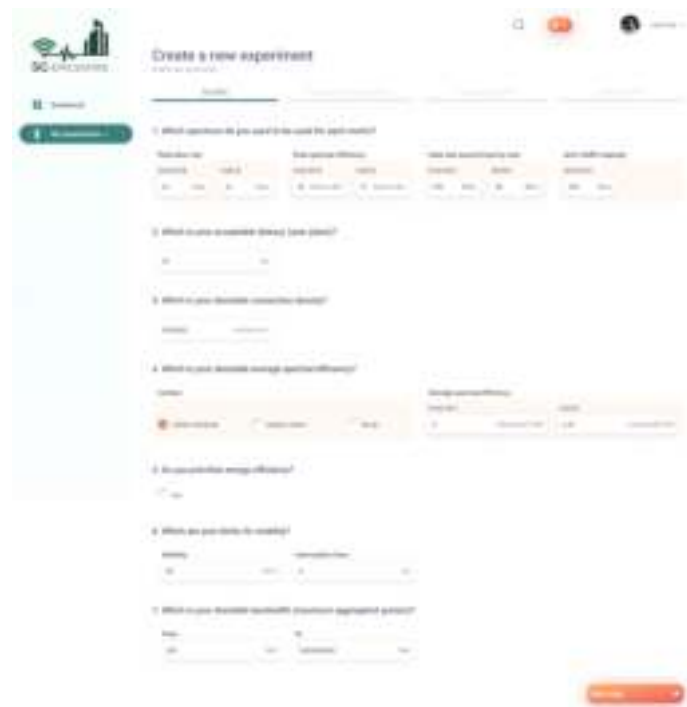


Figure 23: 5G-EPICENTRE Experiments page – viewing users’ “Completed” experiments

**Step 2:** To accommodate experimenters’ potential inexperience with 5G terminology, the inner workings of network slices and the need to have a solid understanding of network slice configuration, a “Wizard” is executed at the start of the Experiment Composer journey to allow the experimenter to specify slice requirements in the form of simple KPI-related questions (Figure 24). Questions correspond to basic 5G KPIs related to the three service types defined by International Telecommunication Union (ITU), e.g., enhanced Mobile Broadband (eMBB), massive Machine Type Communications (mMTC), and Ultra Reliable Low Latency Communications (URLLC).

**Step 3:** Once the experiment slice type has been identified, the Experiment Composer presents the various fields required for the definition of the request experiment descriptor in an online form document, through the ‘Experiment Information’ page. Experimenters can specify a title, desirable start and end date for an experiment, whether the experiment will be attended or remotely supervised, and whether multiple testbed cross-orchestration of resources should be taken into consideration in the scheduling. In addition, text fields are provided to describe the test cases, and specify identifiers for user equipment. Finally, the user may specify NetApps involved in the experiment execution. The landing page for the ‘Experiment Information’ form can be seen in Figure 25.





**Create a new experiment**

Step 1: Select experiment to be used in the experiment

Experiment:  Experiment duration:  Experiment location:  Experiment resources:

Step 2: Select experiment to be used in the experiment

Experiment:  Experiment duration:  Experiment location:  Experiment resources:

Step 3: Select experiment to be used in the experiment

Experiment:  Experiment duration:  Experiment location:  Experiment resources:

Step 4: Select experiment to be used in the experiment

Experiment:  Experiment duration:  Experiment location:  Experiment resources:

Step 5: Select experiment to be used in the experiment

Experiment:  Experiment duration:  Experiment location:  Experiment resources:

Step 6: Select experiment to be used in the experiment

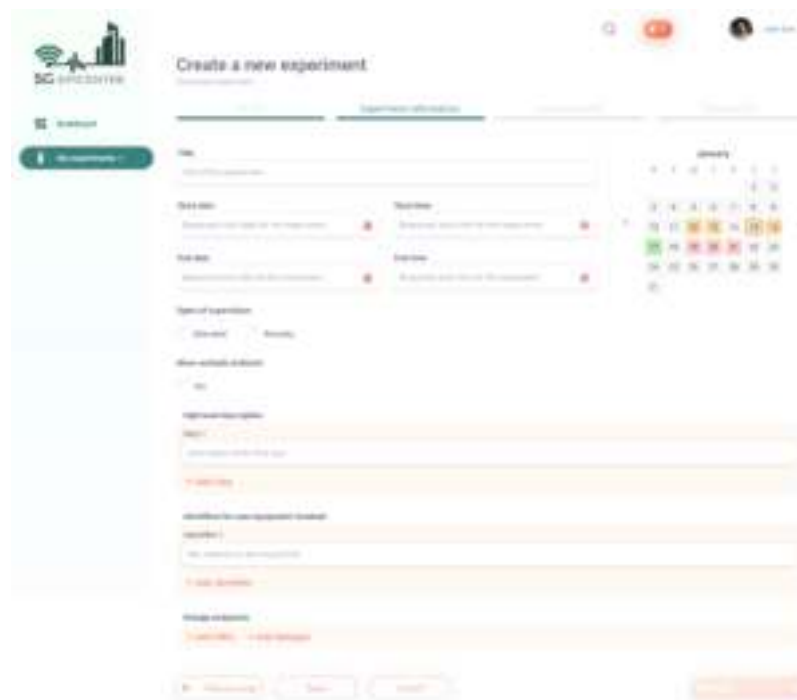
Experiment:  Experiment duration:  Experiment location:  Experiment resources:

Step 7: Select experiment to be used in the experiment

Experiment:  Experiment duration:  Experiment location:  Experiment resources:

**Create experiment**

Figure 24: 5G-EPICENTRE Experiment Composer – network slice wizard.



**Create a new experiment**

Step 2: Experiment information

Name:

Start date:  End date:

Start time:  End time:

Experiment location:  Experiment resources:

Experiment duration:

**Create experiment**

Figure 25: 5G-EPICENTRE Experiment Composer – Experiment Information landing page

**Step 4:** The user specifies start and end dates for an experiment, along with proposed start and end times to be negotiated with the testbed owner(s). The process, as depicted in Figure 26, is assisted by calendar shown on the right side of the screen, indicating the availability of the selected testbed(s).

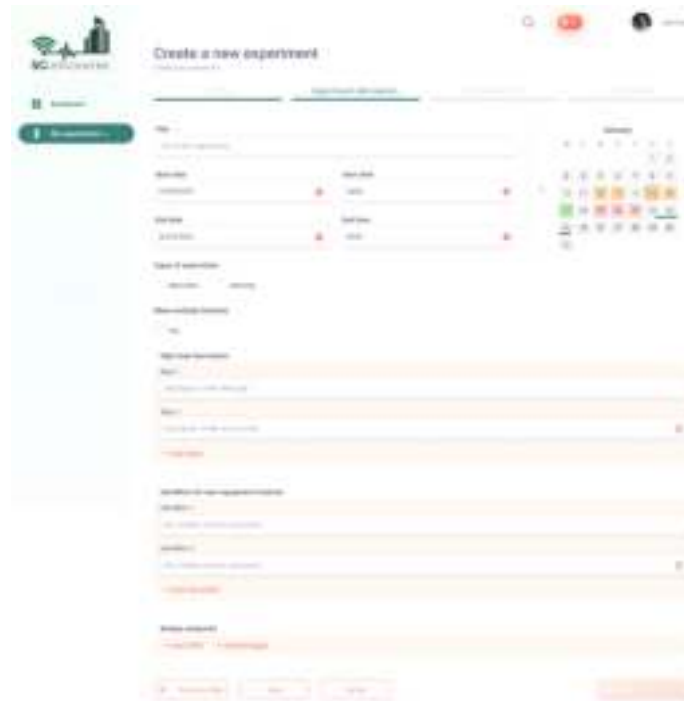


Figure 26: 5G-EPICENTRE Experiment Composer – elaborating on the experiment schedule

**Step 5:** The user may specify VNFs (Figure 27) and/or NetApps (Figure 28) to be included in the experiment through a simple selection wizard. For NetApps in particular, the NetApp chain may be visualized by opting to expand on the listed item through the orange icon shown in the right.

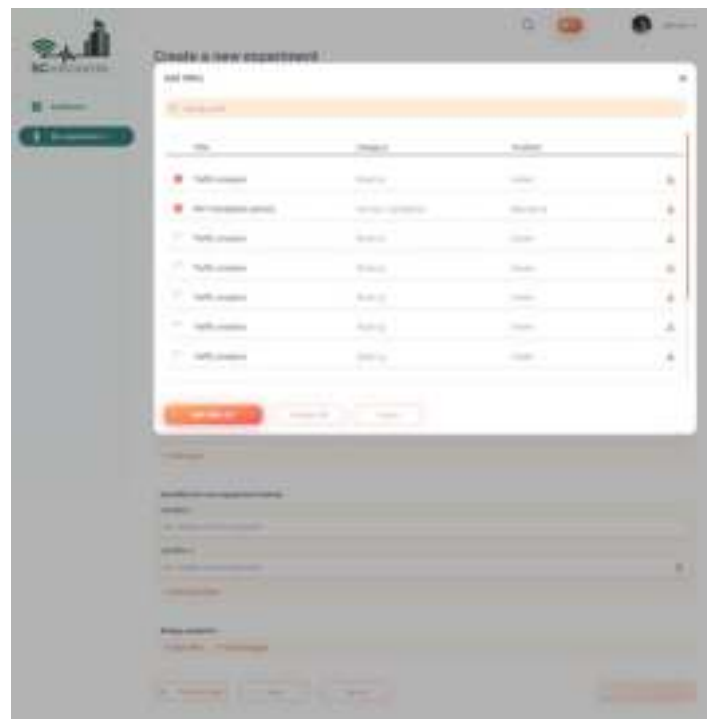


Figure 27: 5G-EPICENTRE Experiment Composer – adding VNFs to the experiment descriptor

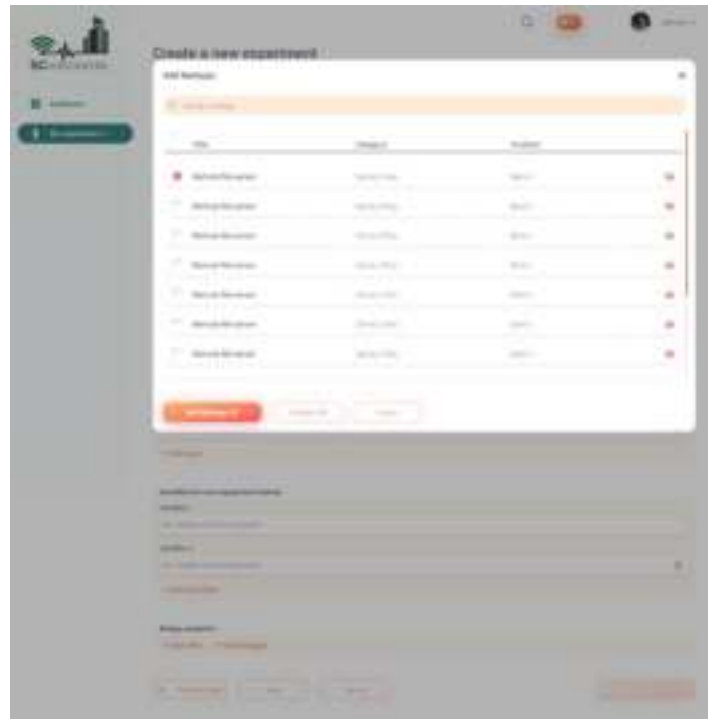


Figure 28: 5G-EPICENTRE Experiment Composer – adding NetApps to the experiment descriptor

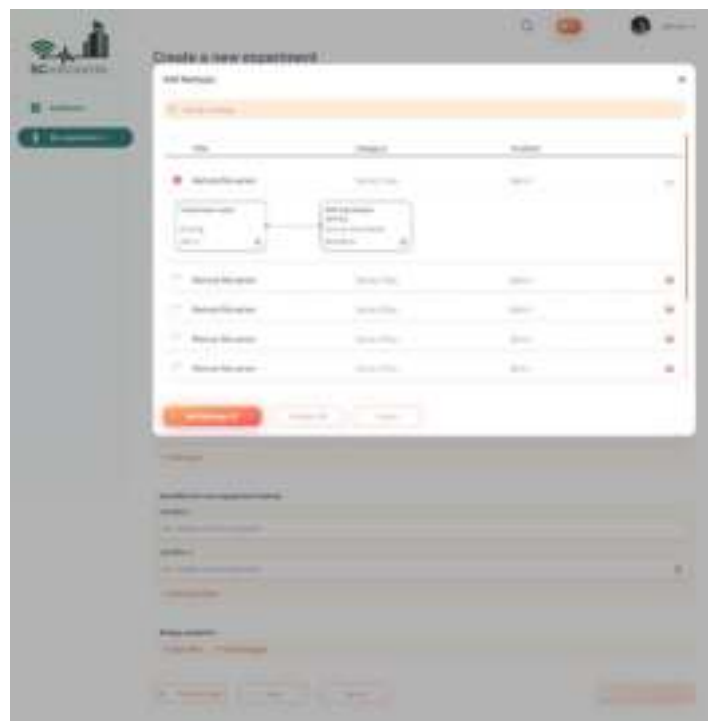
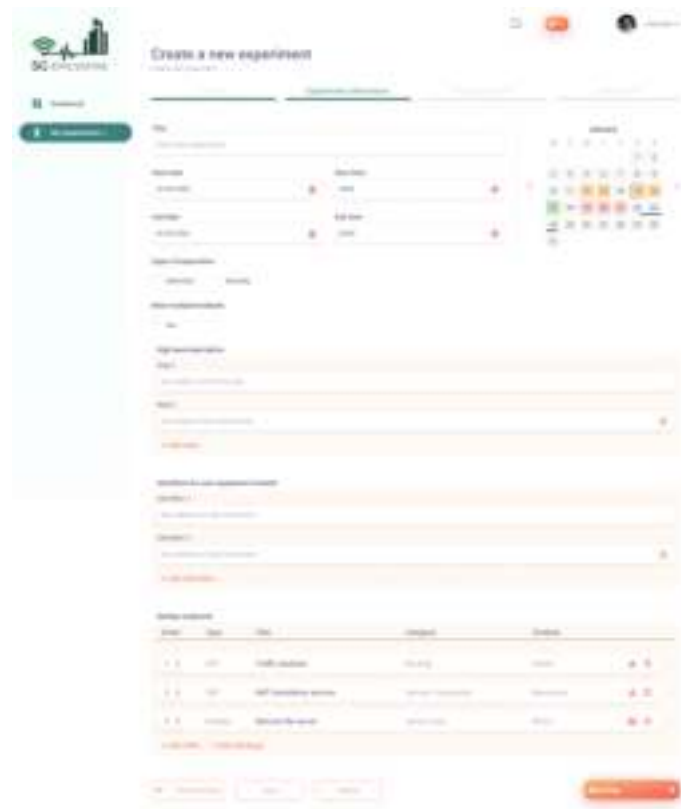


Figure 29: 5G-EPICENTRE Experiment Composer – adding NetApps to the experiment descriptor (detailed view)

**Step 6:** As soon as every aspect of the experiment has been specified to the experimenter's preferences, the user may opt to forward to the 'Next Step' by clicking on the bright orange button highlighted at the bottom of the screen (Figure 30).



**Create a new experiment**

**Experiment information**

Name:

Description:

Start Date:  End Date:

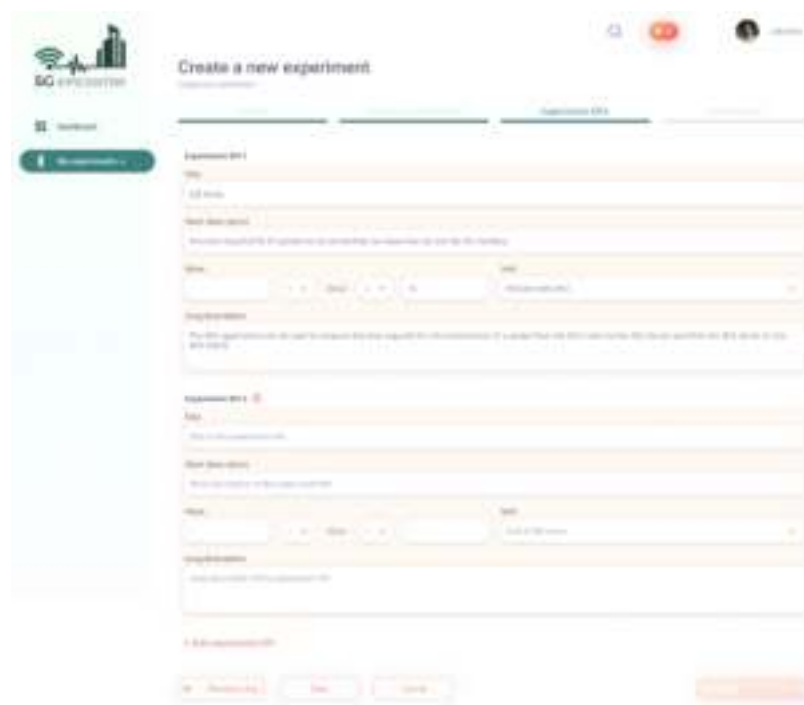
Experiment components:

Order	Type	Name	Category	Status
1	5G	5G Network	Network	Active
2	5G	5G Network	Network	Active
3	5G	5G Network	Network	Active

[Add new component](#)

Figure 30: 5G-EPICENTRE Experiment Composer – advancing to the experiment KPIs page.

**Step 7:** The next step requires the user to specify quantitative KPIs for the experiment. A visual interface is provided to enable users to elaborate on those KPIs, while text fields are present to allow experimenters to elaborate on the means by which the KPI should be calculated in the context of their applications (Figure 31).



**Create a new experiment**

**Experiment KPIs**

KPI Name:

Description:

Experiment components:

Order	Type	Name	Category	Status
1	5G	5G Network	Network	Active
2	5G	5G Network	Network	Active
3	5G	5G Network	Network	Active

[Add new component](#)

Figure 31: 5G-EPICENTRE Experiment Composer – Experiment KPIs page.



## Annex IV: Visual walkthrough of visual NetApp composition functionality

This Annex illustrates the steps followed by a Function Developer to request onboarding of an NS descriptor through the NetApps creation and management dashboard. In the following step-by-step walkthrough, we display screenshots of the developed Portal spaces, which we present in the form of a hands-on manual. The contents in this Annex may be prone to change as functionality is added and/or updated throughout the project implementation lifetime.

**Step 1:** Corresponds to Step 1 as specified in Annex II.

**Step 2:** Users may opt to click on the bright orange “Onboard a NetApp” button displayed next to the NetApps list header space. Clicking on this button will redirect users to the **NetApps creation and management dashboard** page (Figure 33).

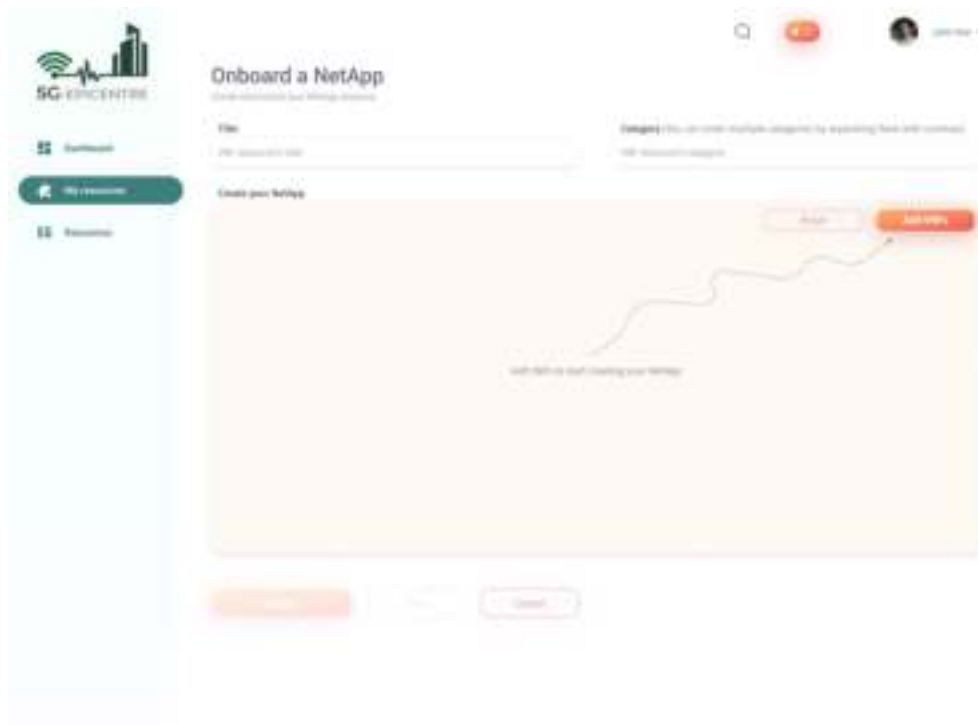


Figure 33: 5G-EPICENTRE NetApps creation and management dashboard – landing page

**Step 3:** Users can type in a name for their NetApp using the empty bracket under “Title”, and provide several front-end keywords for making the NetApp more easily discoverable during search operations. Under the “Create your NetApp” Canvas space, the user may opt to “Add VNFs” onto the Canvas to start creating their chain.

**Step 4:** After clicking on the bright orange button, a new window is opened where users may select one or more NFs (represented as rectangular boxes) to add to the Canvas (Figure 34). Once the selection has been made, users may either “Deselect All” to reset the view, “Cancel” the operation (returning to the main screen depicted in Figure 33), or click on the “Add VNFs” button to deploy their selection onto the Canvas interface (Figure 35).

**Step 5:** Each NF is represented in the Canvas space as a rectangular box with four circular connector interfaces at the centre of each edge. Each box can be dragged on the Canvas to place it at the most convenient location for users to visualise their NetApp chain. Using a similar drag-and-drop input method, users may click on any of the connectors and “drag” a connection line between the current component (ingress) and any of the connectors of another component (egress). This functionality is depicted in Figure 36.

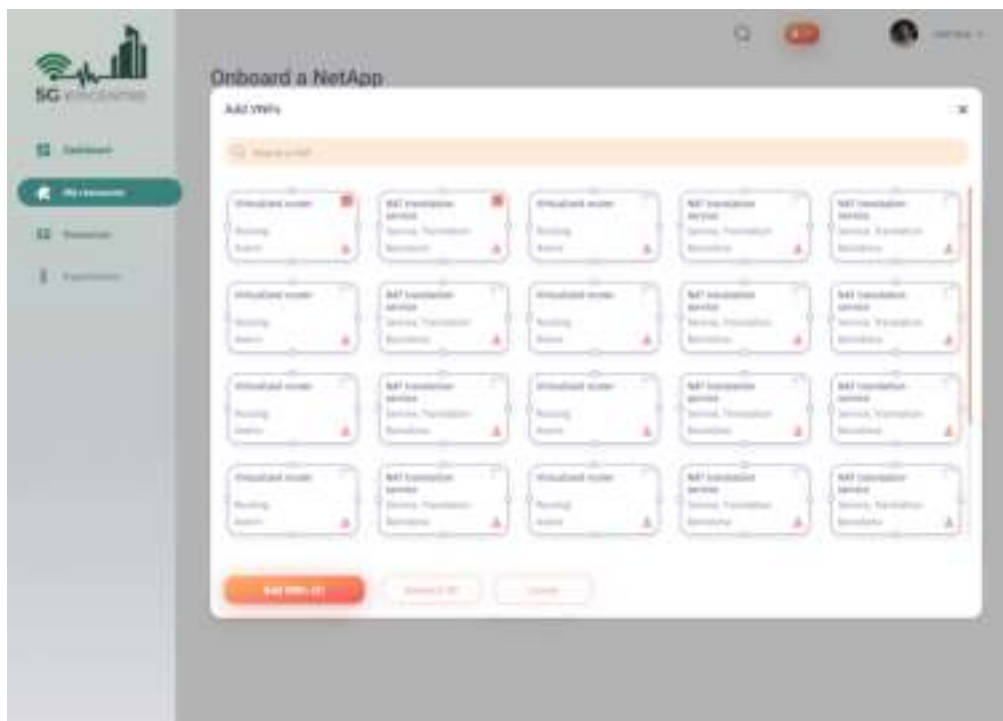


Figure 34: 5G-EPICENTRE NetApps creation and management dashboard – selecting NFs to add to the Canvas

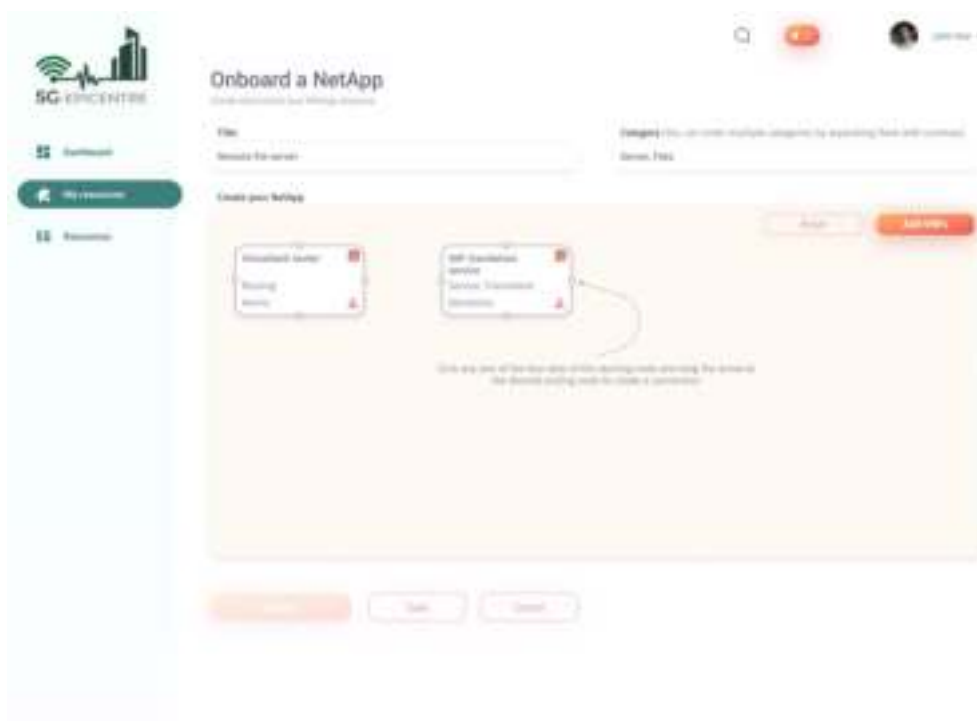


Figure 35: 5G-EPICENTRE NetApps creation and management dashboard – selected NFs on Canvas

**Step 6:** After establishing all connections, users may opt to either “Save” the current schematic as a draft (invoking a similar behaviour as described in Step 3 in Annex II), or “Submit” in order to automatically generate the ETSI-compliant NS descriptor file for the containerised functions to be integrated into the NetApp chain. The resulting NetApp chain will then become available in the Resources page (Figure 12) for further inspection and use in experimentation.

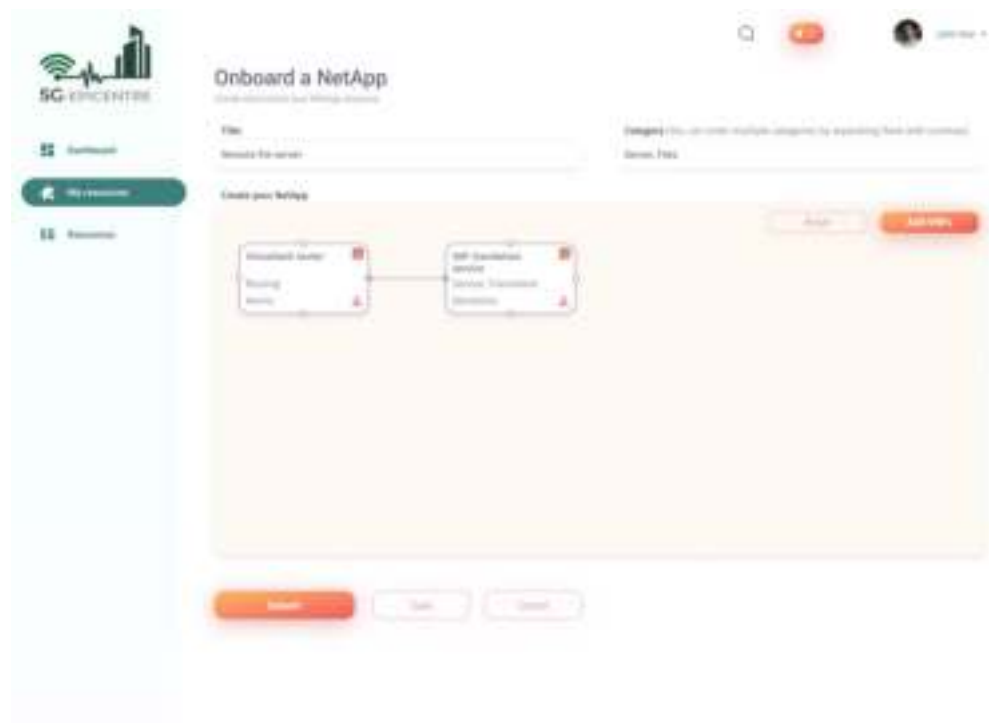


Figure 36: 5G-EPICENTRE NetApps creation and management dashboard – NF chaining process