PART II

Experimentation FACILITIES Best Practices and Flagship Projects

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Fed4FIRE – The Largest Federation of Testbeds in Europe

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3.1 Introduction

The Fed4FIRE[1] project has established a European Federation of experimentation facilities and testbeds and developed necessary technical and operational federation framework enabling the federation operation. With its 23 tesbeds, the Fed4FIRE represents the largest federation of testbeds in Europe which allows remote testing in different areas of interests; wireless, wireline, open flow, cloud, etc. Various user friendly tools established by the Fed4FIRE project enable remotely usage of the federated testbeds by experimenters who can combine different federation resources, independently on their location, and configure it as it is needed to perform the experiment.

The main idea behind the Fed4FIRE Federation of testbeds is to enable easy and efficient usage of already available experimental resources by the entire research and innovation community in broad area of Future Internet and Communications Technologies (ICT) as well as various vertical application sectors applying the ICT, such as Energy, Health, Automotive, Transport, Media, etc. To ensure it, the Fed4FIRE project worked on establishing the federation of testbed for benefit of both testbed providers and experimenters by taking into consideration their particular requirements and interests.

Until now, more than 50 experiments have been using the Fed4FIRE experimental facilities and tools. Part of them took opportunity of seven Open

[1]Fed4FIRE is an Integrating Project under the European Union's Seventh Framework Programme (FP7) addressing the work programme topic Future Internet Research and Experimentation. It started in October 2012 and has been running for 51 months, until the end of 2016 – http://www.fed4fire.eu/

Calls for Experiments organized by Fed4FIRE project in last three years. Other experimenters used the Fed4FIRE Open Access mechanism which allows free of charge access to the experimental facilities and support for setting up the experiments from Fed4FIRE team.

The Fed4FIRE experimenters had opportunity to experience all advantages of the Fed4FIRE tools, to configure and successfully execute planned experiments. The feedback received from the experimenters on usability of Fed4FIRE facilities and tools was very positive. Moreover, the most of the performed experiments would be even not possible without provision of the Fed4FIRE federation and its experimental facilities. Thus, the Fed4FIRE facilities helped the experimenters to further explore their research and business development based on results gathered from the experiments.

This chapter is organized as follows; In Section 3.2, overall needs for the federated experimentation facilities and scope of a federation of testbeds as well as Fed4FIRE approach to establish a testbed federation, including currently involved testbeds, have been elaborated. Common framework for establishing large-scale federation of testbeds, including its architecture, federation tools, and specific requirements for the involved testbeds are presented in Section 3.3, followed by discussion on experiments performed in Fed4FIRE and related added value for both experimenters and the federation, including support provided to various types of experiments performed by different type of organizations, in Section 3.4. The federation operation models and possible structures are presented in Section 3.5, where related sustainability issues are considered as well. The chapter is concluded with a brief summary of main Fed4FIRE achievements (Section 3.6).

3.2 Federated Experimentation Facilities

3.2.1 Requirements from Industry and Research

The Future Internet experimentation require a broad availability of facilities offering testing resources which apply the latest developed networking solutions and computing technologies, including testbeds established by the most relevant actual and recent research activities across Europe and worldwide. The researchers and developers from both industry and academic environments need to be able to perform experimental research by using the up-to-date testbeds as efficient as possible, to cope with nowadays' trends of a very fast development and implementation of innovative services and applications. Moreover, for the efficient experimental research and development of complex Future Internet solutions and systems, possibility to use combinations of different testing resources simultaneously is also extremely important. As the different testing resources are geographically distributed, a significant requirement on the Future Internet experimentation facilities is to be accessible and configurable from remote locations.

In order to meet the mentioned requirements, the future experimental facilities have to ensure the following:

- Simple, efficient, and cost effective experimental processes considering requirements and constraints of both experimenters and facility owners.
- Common frameworks that will be widely adopted by different experimentation facilities and used by different experimenter communities, and
- Increased trustworthiness and efficiency of the experimental facilities, including a sustainable environment for the needed testbeds continuously ensuring their updates in accordance with actual experimenters needs.

A specific requirement of the academic communities, such as universities and research centers is support for long-term research and the related scientific activities. On the other hand, the industry stakeholders, in particular SMEs, are interested to test systems and solutions under investigation for specific operational scenarios, directly aiming at exploitation of innovative products and services and establishing short-term close-to-market solutions. Of course, in lots of cases, interests of both industry and academia are overlapping, in particular in medium-term and applied research. Furthermore, there are joint undertakings by industry and academia in the research and innovation activities, including knowledge transfer, where interests of both communities are merging into common requirements towards the future experimental facilities.

However, contrary to the all research and industry requirements discussed above, the existing testbeds in Europe, which also apply for rest of the world, have been created to support experimentation in specific domain, targeting a narrow set of technology, and are usually a limited number of potential users and experimenters. The testbeds are implemented by various initiatives; e.g. EU or national research project, individually established partnerships among academia and industry, private investments in industry environments, publicly funded universities and research institutions, etc. Accordingly, all the individual testbeds are using different frameworks and tools to set-up and execute experiments creating of course a big disadvantage for experimenters, who need to get familiar with the different experimentation tools every time they use different testbeds. Furthermore, only a limited number of testbeds can be combined with other testing facilities placed in different locations and do not foresee remote configuration of the experiments and their execution.

Further important aspects of having appropriate experimental facilities is their maintenance to ensure that the testbeds are always ready to be used and are updated in accordance with the newest technological developments and trends. To ensure it, it is necessary to establish a common testbed framework supporting the testbed owners and operators to cope with this requirement within a kind of sustainable environment by involving both the experimenters and the testbed providers.

3.2.2 Establishing Fed4FIRE Federation of Testbesd

Fed4FIRE project defined its objectives along the broad requirements of the industry and research community on the Future Internet experimental research. Accordingly, establishment of a sustainable large-scale federation of testbeds has been identified as the main Fed4fFIRE project goal.

On the first instance, the federation of testbeds has to be established for benefits of both experimenters and testbed providers (Figure 3.1) and to enable easy usage of experimental resources available in the federation for a broad range of experimenters as well as to allow testbeds to easily join the federation and offer their testing and experimental services.

To ensure it, Fed4FIRE has been working on definition nand implementation of a federation framework, which includes a set of federation tools ensuring the following:

- Easy discover of testing resources in the federation by the experimenters
- Easy set-up and configuration of the experiments, by combining various experimental resources available in the federation

Figure 3.1 Benefits for experiments to use and for testbeds to join the federation of testbeds – overview.

- Experiment execution, including experiment scheduling, monitoring, and gathering testing results

The Fed4FIRE project worked on establishment of the federation framework and tools in several development cycles. Between the cycles, Fed4FIRE offered its experimental facilities to a wide range of users to gather feedback on their usage, which was then taken into account while improving and upgrading the common framework and the experimentation tools. Furthermore, Fed4FIRE started with a number of testbeds involved and over the project life time further testbeds joined, so that the Fed4FIRE federation offer has been significantly enlarged and experience from joining process of the new testbeds has been gathered to improve the overall framework and the related tools.

3.2.3 Experimentation Facilities in Fed4FIRE

Fed4FIRE established a federation of 23 testbeds encompassing different technologies and stretching over Europe (Figure 3.2), also with connections outside Europe, and its represents the largest federation of testbeds in Europe

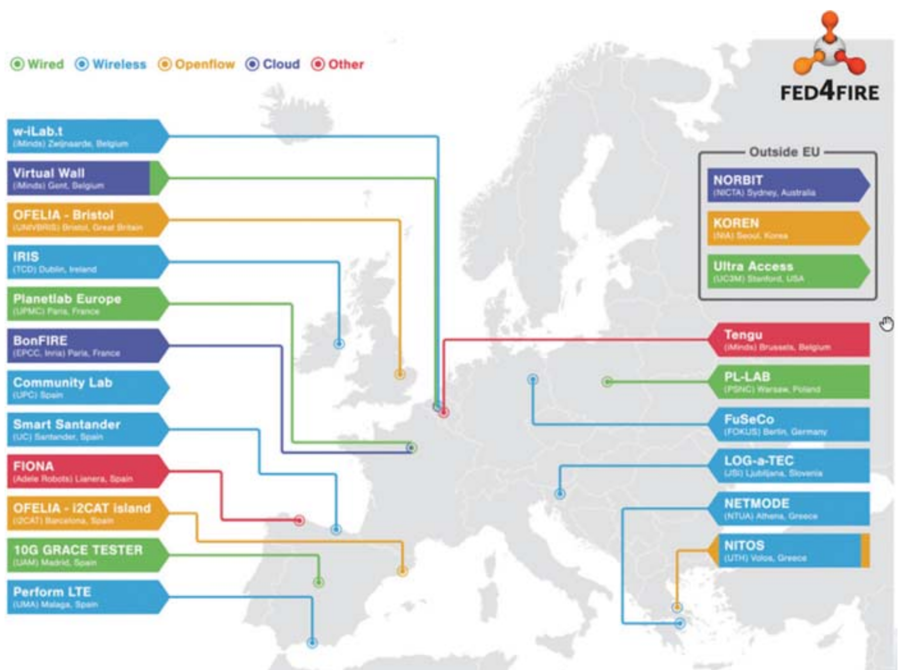

Figure 3.2 Testbeds involved in Fed4FIRE federation of testbeds.

and probably also world-wide. The federation involves testbeds focused on wired and wireless communications as well as open flow and cloud based technologies, including further specific testbeds (Table 3.1). The Fed4FIRE federation is open for new testbeds which are willing to join and is expected to grow further in the future.

Table 3.1 Brief description of Fed4FIRE facilities per testbed category

Wired Testbeds:	
Virtual Wall (iMinds)	Emulation environment with 100 nodes interconnected via a non-blocking 1.5 Tb/s Ethernet switch and a display wall for experiment visualization
PlanetLab Europe (UPMC)	European arm of the global PlanetLab system, providing access to Internet-connected Linux virtual machines world-wide
Ultra Access (UC3M, Stanford)	Next Generation of Optical Access research testbed
10G Trace Tester (UAM)	10 Gbps Trace Reproduction Testbed for Testing Software-Defined Networks
PL-LAB (PSNC)	Distributed laboratory in Poland focusing on Parallel Internet paradigms
Wireless Testbeds:	
Norbit (NICTA)	Indoor Wi-Fi testbed located in Sydney, Australia
w-iLab.t (iMinds)	For Wi-Fi and sensor networking experimentation
NITOS (UTH)	Outdoor testbed featuring Wi-Fi, WiMAX, and LTE
Netmode (NTUA)	Wi-Fi testbed with indoor facilities
SmartSantander (UC)	Large scale smart city deployment in the Spanish city of Santander
FuSeCo (FOKUS)	Future Seamless Communication Playground, integrating various state of the art wireless broadband networks
PerformLTE (UMA)	Realistic environment composed of radio access equipment, commercial user equipment, and core networks connected to Internet
C-Lab (UPC)	Community Network Lab involving people and technology to create digital social environments for experimentation
IRIS (TCD)	Implementing Radio In Software, a virtual computation platform for advanced wireless research
LOG-a-TEC (JSI)	Cognitive radio testbed for spectrum sensing in TV whitespaces and applications in sensor networks
Open Flow Testbeds:	
UBristol OFELIA island	Testbed for Future Internet technologies, specifically Software Defined Networking (SDN)/OpenFlow and virtualization

Table 3.1 Continued

i2CAT OFELIA island	Testbed for Future Internet technologies, specifically Software Defined Networking (SDN)/OpenFlow and virtualization
Koren (NIA)	High-speed research network in Korea interconnecting six nodes with OpenFlow and DCN switchess
NITOS (UTH)	Outdoor testbed featuring Wi-Fi, WiMAX, and LTE
Cloud Computing Testbeds:	
BonFIRE (EPCC, Inria)	Multi-cloud testbed for services experimentation
Virtual Wall (iMinds)	Emulation environment with 100 nodes interconnected via a non-blocking 1.5 Tb/s Ethernet switch and a display wall for experiment visualization
Other Technologies:	
FIONA (Adele Robots)	Cloud platform for creating, improving and using virtual robots
Tengu (iMinds)	Big data analysis (iMinds)

3.3 Framework for Large-scale Federation of Testbeds

3.3.1 Framework Architecture and Tools

3.3.1.1 Experiment lifecycle

The Fed4FIRE architecture has been built taking requirements from various stakeholders into account, including testbed and service providers and experimenters, with sustainability in mind and aiming to support as many actions from the experiment lifecycle as possible. The experiment lifecycle covers a number of functionalities summarized in Table 3.2.

Table 3.2 Functionalities of Fed4FIRE lifecycle

Function		Description
Resource discovery		Finding available resources across all testbeds, and acquiring the necessary information to match required specifications.
Resource specification		Specification of the resources required during the experiment, including compute, network, storage and software libraries.
Resource reservation		Allocation of a time slot in which exclusive access and control of particular resources is granted.
Resource provisioning	Direct (API)	Instantiation of specific resources directly through the testbed API, responsibility of the experimenter to select individual resources.

(*Continued*)

Table 3.2 Continued

Function		Description
	Orchestrated	Instantiation of resources through a functional component, which automatically chooses resources that best fit the experimenter's requirements.
Experiment control		Control of the testbed resources and experimenter scripts during experiment execution through predefined or real-time interactions and commands.
Monitoring	Facility monitoring	Instrumentation of resources to supervise the behavior and performance of testbeds, allowing system administrators or first level support operators to verify that testbeds performance.
	Infrastructure monitoring	Instrumentation by the testbed itself of resources to collect data on the behavior and performance of services, technologies, and protocols.
Measuring	Experiment measuring	Collection of experimental data generated by frameworks or services that the experimenter can deploy on its own.
Permanent storage		Storage of experiment related information beyond the experiment lifetime, such as experiment description, disk images and measurements.
Resource release		Release of experiment resources after deletion or expiration the experiment.

3.3.1.2 Resource discovery, specification, reservation and provisioning

3.3.1.2.1 *Architectural components*

Figure 3.3 details the part of the architecture responsible for resource discovery, specification, reservation and provisioning, from the viewpoints of the federator, the testbed provider, the experimenter and actors outside of the federation.

At the federator side, the following components are located: the portal (central starting place for new experimenters), the member and slice authority (registration), the aggregate manager (AM) directory (overview of the contact information of the AMs of all available testbeds available in the federation), the documentation center (http://doc.fed4fire.eu), the authority directory (authentication/authorization between experimenters and testbeds, supported through specific experimenter properties included in the experimenter's certificate, signed by an authority), the service directory (federation and application services), the reservation broker (for both instant and future reservations).

At the testbed side, the resources (virtual or physical nodes) are located, as well as the testbed management component (AM, responsible for discovery, reservation and provisioning of local resources through any desired software

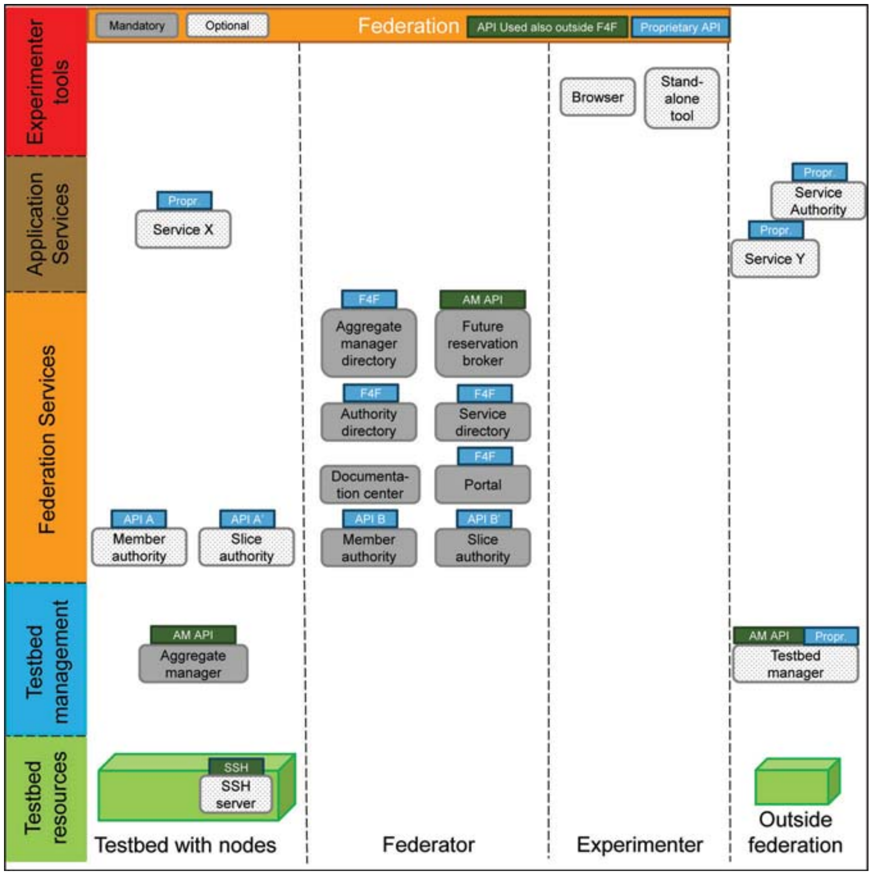

Figure 3.3 Fed4FIRE architecture components.

framework), an optional authority (member and slice) and optional application services (abstracting the underlying technical details of the provided services, relying on X.509 certificates for authentication and authorization).

At the experimenter side, we find the toolset to facilitate experimentation, such as a browser to access the hosted tools (portal, future reservation broker, documentation center, application services, etc.) and stand-alone tools to handle testbed resources (Omni, SFI, NEPI, jFed, etc.).

Outside of the federation, relevant components include the resources of testbeds that are not part of the federation, the testbed manager to handle these resources, any application services on top of resources in- or outside of the federation, and services authorities.

Several aspects of this architecture originate from the Slice-based Federation Architecture (SFA)[2]: the Aggregate Manager API, the member authorities and the slice authorities. A slice bundles resources belonging together in an experiment or a series of similar experiments, over multiple testbeds. A sliver is the part of that slice which contains resources of a single testbed. One uses an RSpec (Resource Specification) on a single testbed to define the sliver on the testbed. The RSpec and thus the sliver can contain multiple resources. The GENI AM API details can be found at the documentation website[3].

3.3.1.3 Other functionality

Similar architecture diagrams are available for monitoring and measurement, experiment control, SLA management and reputation services.

For monitoring, the following components can be distinguished at the testbed side: (1) facility monitoring (to see if the testbed is up and running) that exports an Open Measurement Library (OML) stream to the federator's central OML server, (2) infrastructure monitoring (to collect data on behavior and performance of local services, technologies, and protocols, as well as on resources from a specific experiment), (3) the OML measurement library (for measuring specific experiment metrics), an optional OML server (the endpoint of a monitoring or measurement OML stream that stores that in a database) and (4) an optional measurement service with proprietary interface. The federator then offers the FLS dashboard to give a real-time view on the facilities' health status, the central OML server for FLS data, nightly login testing and the (optional) data broker for experiment data from OML streams.

For experiment control, the testbed provides (1) an SSH server on each resource, (2) a resource controller that invokes actions through the Federated Resource Control Protocol (FRCP), (3) an Advanced Message Queuing Protocol (AMQP) server to communicate the FRCP messages, (4) the Policy Decision Point (PDP) that enables authorization and (5) the experiment control server to execute the experiment's control scenario.

Related to SLAs, the SLA management module at each testbed is responsible for supervising the agreement metrics and processes all relevant measurements from the monitoring system. The SLA collector acts as a broker between these modules and the client tools, such as the SLA front-end tool provided in the Portal, and gathers warnings and experimenter-specific evaluations. The SLA dashboard allows testbed providers to view the status of active SLAs on their facilities.

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[2]http://groups.geni.net/geni/attachment/wiki/SliceFedArch/SFA2.0.pdf
[3]https://fed4fire-testbeds.ilabt.iminds.be/asciidoc/federation-am-api.html

The architecture further supports layer two connectivity between testbeds, service composition (through YourEPM), speaks-for credentials for trust chain relationships, ontology-based resource selection and first level support (FLS) monitoring.

3.3.2 Federating Experimentation Facilities

In order to support the federation of experimentation facilities, we define different classes of testbeds and different types of federation.

3.3.2.1 Classes of testbeds

A testbed is a combination of hardware and testbed management software. We make a difference between two classes of testbeds which could join the federation or be compatible with Fed4FIRE: (1) type A, which includes testbeds with resources that can be controlled through SSH, FRCP or Openflow, and (2) type B, which are accessible through service APIs only. Type A testbeds have the ability to share resources between different users, shared over time or in parallel (through multiplexing or slicing) and support the concept of credentials and dedicated access (e.g. through SSH). Type B testbeds offer a particular service with a (proprietary or standard) API and support the concept of credentials.

As an example, the Virtual Wall which provides physical or virtual machines with SSH access is type A, while SmartSantander, providing a proprietary REST API to fetch the measurement results, is a type B testbed.

3.3.2.2 Types of federation

Three types of federation are defined: (1) association, (2) light federation and (3) advanced federation. Associated testbeds are not technically federated, but are mentioned on the Fed4FIRE website with a link to the testbed specific documentation. These testbeds have to organize their own support.

Light federation is the same for type A and type B testbeds. The testbeds need to provide support for Fed4FIRE credentials in a client based SSL API, maintain specific documentation for experimenters (on a webpage maintained by the testbed), adhere to the policy that everyone with a valid Fed4FIRE certificate can execute the basic experiment that is document without extra approval, provide facility monitoring and ensure a public IPv4 address for connectivity to the API server. The Fed4FIRE federation in turn offers test credentials for testing the federation, information on enabling PKCS12 authentication, a central monitor dashboard, at least one client tool exporting PKCS12 credentials from the X.509 certificate, at least one authority to provide credentials, a central documentation website linking to all testbeds and central support (google group and NOC) for first help and single point of contact. This light federation makes it possible to have an easy way to federate with Fed4FIRE and as such testbeds can easily join a very ad-hoc and dynamic way for a short period of time.

For advanced federation, type A and type B testbeds are treated differently. Type A testbeds need to provide support for GENI AMv2 or AMv3 (or later versions), maintain specific documentation (on a webpage maintained by the testbed), adhere to the policy that everyone with a valid Fed4FIRE certificate can execute the basic experiment that is document without extra approval, provide facility monitoring through the GENI AM API and ensure a public IPv4 address for the AM and a public IPv4 or IPv6 address for SSH login to the testbeds resources, and offer basic support on the testbed functionalities towards experimenters. In turn, the Fed4FIRE federation offers testing tools for the AM API, nightly testing of the federation functionality, a central monitor dashboard, at least one client tool having support for all federated infrastructure testbeds, at least one authority to provide credentials, an SSH gateway (to bridge e.g. to IPv6, VPNs, etc.), a central documentation linking to all testbeds and central support (google group and NOC) for first help and single point of contact.

Advanced federation for type B testbeds can be supported through service orchestration on the 'YourEPM' (Your Experiment Process Model) tool which is designed to provide high level service orchestration for experimenters, based on open standards such as BPMN (Business Process Model and Notation) and BPEL (Business Process Execution Language). YourEPM presents a web GUI that automatically obtains information on available services from the service directory that collects service descriptions from the specific URL provided by each testbed. The communication with the services from YourEPM is ensured using general wrappers to specific technologies (i.e. REST, SFA). This tool can also be integrated with the jFed tool to extend the orchestration to include testbed resources. In order for YourEPM to use application services available in the federation, type B testbeds which want to have an advanced federation with Fed4FIRE have to provide a description of the service API in RAML, so that the tool can invoke it automatically.

3.3.2.3 Workflow for federation

Figure 3.4 highlights the typical workflow for a new testbed to be federated, starting with the existing documentation on how experimenters can use already federated testbeds.

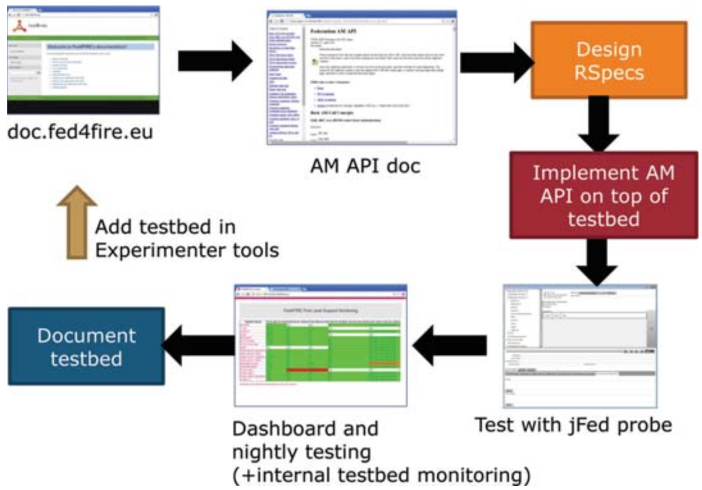

Figure 3.4 Workflow for testbeds joining the federation.

3.3.3 Federation Tools

3.3.3.1 Portal

The Fed4FIRE portal[4] is the central starting place for new experimenters and provides the testbed and tools directory, links to the project website and to the First Level Support service, support for the registration of new users. Furthermore, it acts as an experimentation tool for discovery, reservation and provisioning of resources and as a bridge to experiment control tools. It is powered by MySlice software[5].

3.3.3.2 jFed

jFed[6] is a java-based framework to support experimenters to provision and manage experiments, to assist testbed developers in testing their API implementations and to perform extensive full-automated tests of the testbed APIs and testbeds, in which the complete workflow of an experiment is followed.

3.3.3.3 NEPI

NEPI[7], the Network Experimentation Programming Interface, is a life-cycle management tool for network experiments, that helps to design, deploy and

[4]https://portal.fed4fire.eu
[5]http://myslice.info
[6]http://jfed.iminds.be
[7]http://nepi.inria.fr

control network experiments, and gather the experiment results. It supports design and control through the federated resource control protocol FRCP.

3.3.3.4 YourEPM

YourEPM is an Experiment Process Manager that allows high level application service orchestration in the federation. It connects experiment owners, testbed facilities and federator central coordination with both automated and manual processes for experiment planning, execution and analysis.

3.4 Federated Testing in Fed4FIRE

3.4.1 Overview of Experiments on Fed4FIRE

Fed4FIRE offers its testbeds for use and experimentation to a wide community and to all interested parties. This is offered through a system of either Open Calls by which selected proposals received financial support to carry out the experiments or through a system of Open Access by which any interested party can set up and run an experiment on the facility. Since its initial set up as a federation, Fed4FIRE has supported over 50 experiments through its Open Calls, out of over 150 submitted proposals, which were oriented towards SMEs, industry, academic or research parties (Figure 3.5).

Utilization of the federation testbeds used by different experiments accepted in the Open Calls is presented in Figure 3.6 (colors indicate type of the testbeds used according to testbed overview from Figure 3.2).

3.4.2 Complexity of the Fed4FIRE Experiments

One measure which can be used to indicate the complexity of the experiment which is run on the Fed4FIRE facilities is the number of testbeds in use.

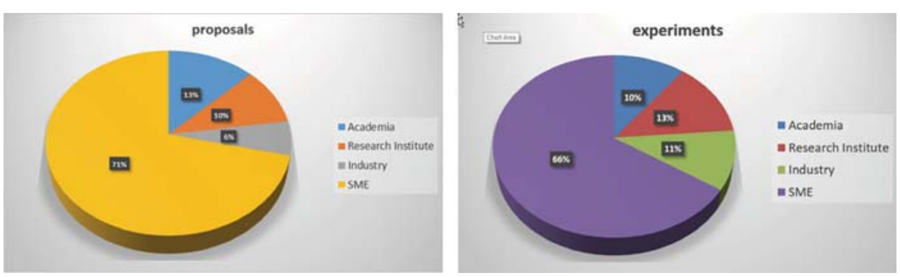

Figure 3.5 Overview of the proposals and accepted experiments through the open call mechanism.

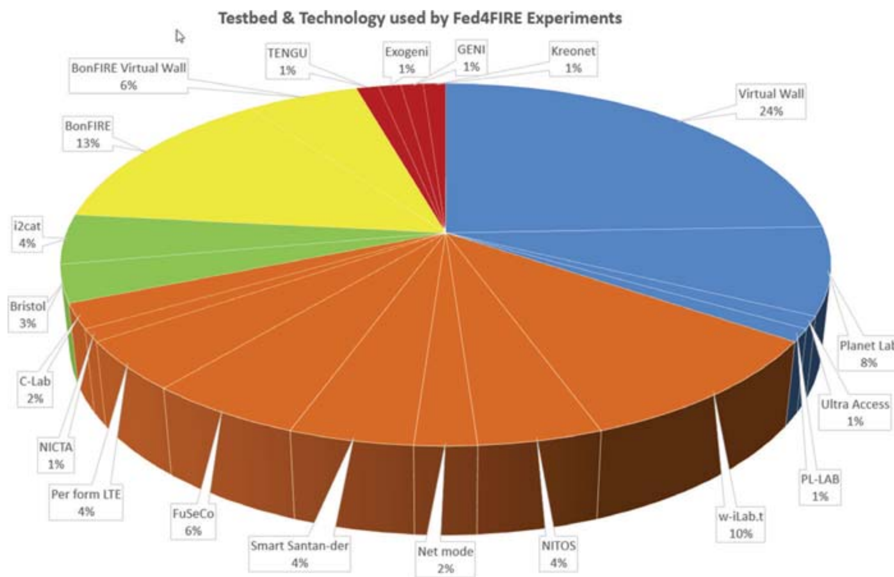

Figure 3.6 Utilization of Fd4FIRE testbeds by experiments.

Figure 3.7 already illustrates the need for a federated facility as more than 70% of the experiments make use of more than 1 testbed. What is even more clearly demonstrating the value of Fed4FIRE is the fact that if one uses the categories of technologies as defined above (wired/wireless/cloud/open flow/other), more than half of the experiments use testbeds which are positioned

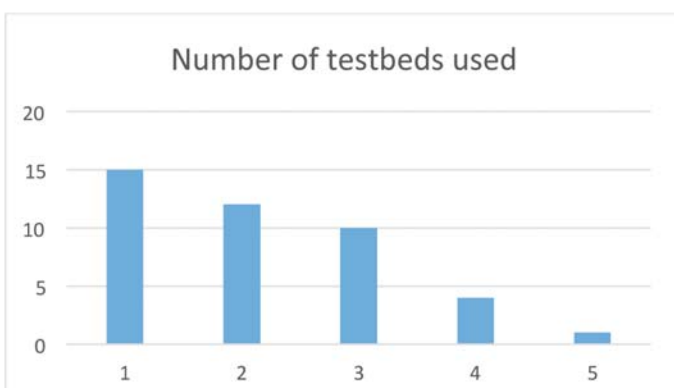

Figure 3.7 Number of simultaneously used testbeds in experiments.

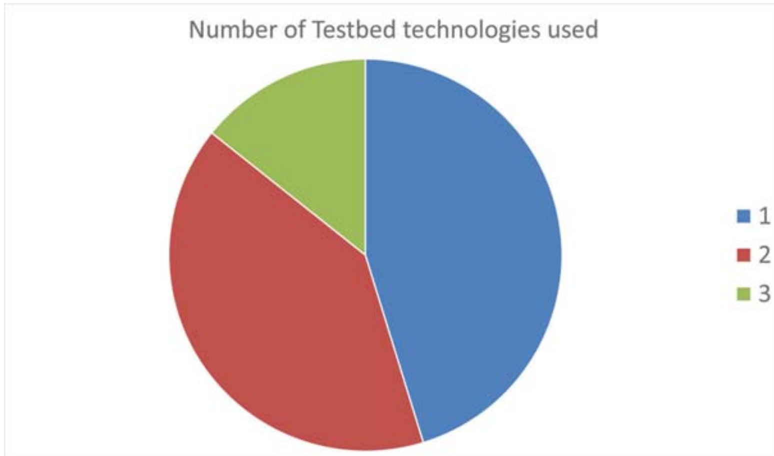

Figure 3.8 Number of simultaneously used test bed technologies in experiments.

in different technology areas (Figure 3.8). This clearly demonstrates the added value of a federated facility like Fed4FIRE covering different technologies.

3.4.3 Value to the Experimenter

Nearly all of the experimenters have chosen to submit an experiment to Fed4FIRE:

- To test and evaluate their products in a real environment which is by some companies used as sales argument and proof of the performance or reliability of their product to potential customers **"To test in a real testbed scenario some of the algorithms devised on paper"**
- To prepare their products for the market. "Fed4FIRE learned us that we are market-ready for large business"
- To test and evaluate scalability of their products or to carry out stress-tests on their products. Fed4FIRE clearly has the size to carry out these tests **"To identify problems with scalability"**
- Because of the uniqueness of the Fed4FIRE testbeds offering technologies which are not available in commercial testbeds: **"To access infrastructures that otherwise would not be reachable"**
- Because of the financial support received, an argument which is repeated by nearly all SMEs which ran an experiment on Fed4FIRE **"We would have spent thousands of euros to create an infrastructure for testing"**

From this feedback, which is collected from all experiments, it is clear that all experimenters indicate a significant to extreme impact on their business from the experiment. This impact slightly differs over the calls, but it is clear that the impact for SME's is more significant than for the standard Open Call experiments in which larger research groups or industrial partners participate.

3.4.4 Support Provided by the Federation to SMEs

Through its Open Calls for SMEs, Fed4FIRE has the objective to make the federated infrastructure easier and more directly available for execution of innovative experiments by experimenters at SMEs. The experiments envisaged were of a short duration (maximum 4 months) and examples included but were not limited to testing of new protocols or algorithms, performance measurements, service experiments.

Specific benefits for SMEs were identified as:

- Possibility to perform experiments that break the boundaries of different FIRE testbeds or domains (wireless, wired, OpenFlow, cloud computing, smart cities, services, etc.)
- Easily access all the required resources with a single account.
- Focus on your core task of experimentation, instead of on practical aspects such as learning to work with different tools for each testbed, requesting accounts on each testbed separately, etc.
- A simplified application process with a dedicated review process by external judges

An extra benefit which is offered towards SMEs is the dedicated support from specific Fed4FIRE members. Each SME, preparing a proposal was appointed a supporting Fed4FIRE consortium partner (the "Patron") which was in charge of dedicated (advanced) support of the experiment. This Patron received additional funding to provide this support in setting up, running and analysing the results of the experiment.

This support was provided in 2 layers:

A. Basic support

- Guaranteeing that the facility is up and running (e.g. answering/solving "could it be that server X is down?")
- Providing pointers to documentation on how the facility can be used (e.g. "how to use the virtual wall testbed" => answer: check out our tutorial online at page x")

- Providing pointers to technical questions as far as relevant (e.g. answering "do you know how I could change the WiFi channel" => answer: yes, it is described on following page: y"; irrelevant questions are for example "how to copy a directory under Linux")

B. Dedicated (advanced) support includes all of the following supporting activities by the patron:

- Deeper study of the problem of the SME: invest effort to fully understand what their goals are, suggest (alternative) ways to reach their goals. To put it more concretely (again using the example of the Virtual Wall testbed), these SMEs do not need to know the details on the Virtual Wall or how it should be used, they will be told what is relevant to them and can focus on their problem, not on how to solve it.
- Help with setting up the experiments (e.g. "how to use the virtual wall" => answer: the tutorial is there, but let me show you how what is relevant for you, let me sit together with you while going through this example and let us then also make (together) an experiment description that matches what you are trying to do.
- (Joint) solving of practical technical problems (e.g. "do you know how I could change the WiFi channel" => yes, it is described on page y, in your case you could implement this as following: . . ., perhaps we should quickly make a script that helps you to do it more easily, . . .).
- Custom modifications if needed: e.g. adding third-party hardware and preparing an API for this.
- Technical consultancy during/after the experiments (e.g. "I do get result x but would have expected y, what could be the problem?").

All of the SMEs, submitting a proposal to run an experiment sought this support already while preparing their proposal.

3.4.5 Added Value of the Federation

The following quotes are taken form some of the reports of the experiments that ran on Fed4FIRE. They clearly illustrate why experimenters come to Fed4FIRE

- We wouldn't be in this position now if we hadn't had access to Fed4FIRE facilities
- There is no alternative to Fed4FIRE as a platform hosting different technologies

- Fed4FIRE is independent of any other infrastructure, ... for companies is very important to avoid vendor lock-in, ...
- Running the experiment at a commercially available testbed infrastructure would have been unlikely mainly because of the novelty of some implemented solutions.
- The federation's main contribution is making individual facilities visible and usable through a homogenous set of standards and tools.
- Diversity and quantity of the nodes ... different technologies, types -outdoor/indoor-, different locations, possibility to combine infrastructures and resources.
- To develop projects that can provide services at European level, with millions of potential users at the same time, it is necessary to have a test infrastructure with sufficient technical resources.
- An experiment in Fed4FIRE is so close to reality that any development carried out in the environment can be migrated to a commercial platform.
- Thanks to the Fed4FIRE federation we had the chance to test our platform in a production – like environment. If there were no federation, our tests would have been less effective for our business objectives.

3.5 Operating the Federation

3.5.1 Federation Model, Structure and Roles

The operational model follows a service oriented approach that crucially provides services to both experimenters and testbeds, as both experimenters and testbeds are needed in adequate quantities and varieties for a successful federation.

Towards experimenters, the Federator offers identity management through single sign-on, a portal with basic information about the federation, at least one stand-alone tool for resource management, comprehensive documentation, First Level Support, advice and brokering, and reporting on KPIs (testbed availability, usage, performance of federation services, etc). Towards testbed providers, the Federator facilitates technical interoperation, provides compliant tools and portal, promotes the federation, and acts as a broker between experimenters and testbeds and reports on KPIs. The Federator also promotes the usage of tools that are developed externally to the federation and can provide added value. Towards the European Commission, the Federator reports on KPIs about the federation's operation.

Through these tools and the "one-stop shop" approach (Figure 3.9), Fed4FIRE natively supports the "Experimentation as a Service" concept, where the resources needed for an experiment can be acquired and accessed as one package by the experimenter. Fed4FIRE follows the FitSM management approach for its federation services. FitSM[8] is a free and lightweight standards family aimed at facilitating service management in IT service provision, including federated scenarios.

3.5.2 Financial Approach of the Federation

In the financial model, funding and revenues are coming from national, regional and local sources, the European Commission and private/industry sources (note that the latter will typically be limited). The costs are made by the federator, the facility providers and the experimenters (Figure 3.10).

The federation will organize Open Calls for experimentation, with a budget per experiment ranging from 5K to 100K euro, including financial support for testbed providers to provide technical support and consultancy services where required.

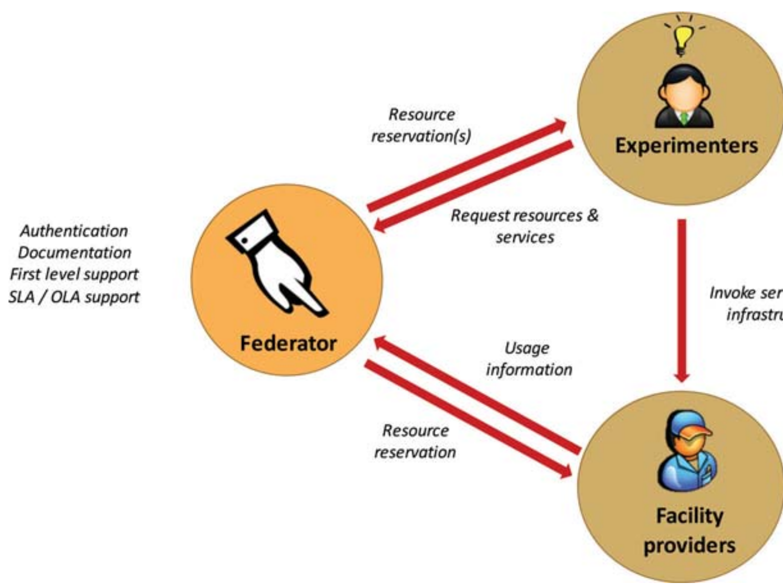

Figure 3.9 One-stop shop approach in Fed4FIRE federation.

[8]http://www.fitsm.temo.org

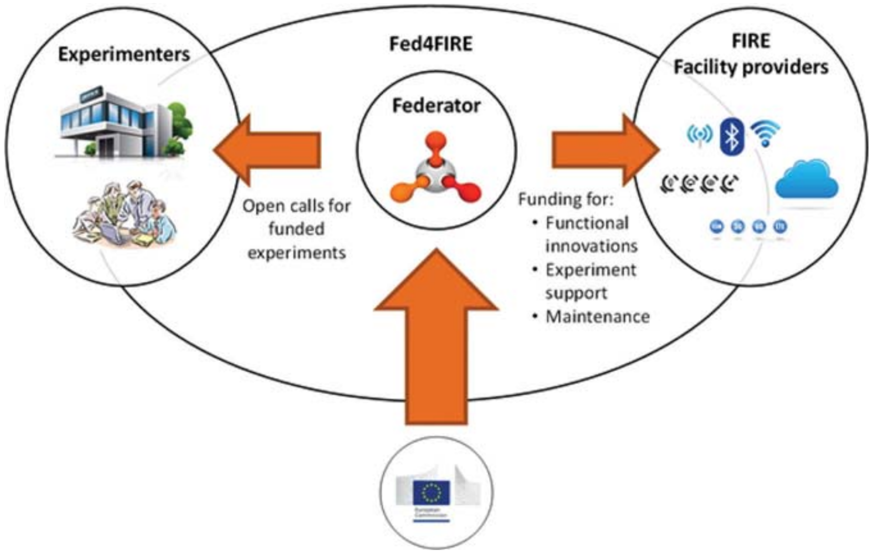

Figure 3.10 Financial flow within federation of testbeds.

3.5.3 Organization of the Federation

The primary stakeholders in the federation, the experimenters and the testbed providers, delegate the management of the federation to the Federator and the control of the federation to the Federation Board, the policy-making body.

The federation's governance model is based on three layers, related to governance (how the Federator and Federation Board are managed), operational issues (how the Federator operates) and financial aspects (costs and revenue/funding). The federation deals with policies in the following areas:

- Testbed and Experimenter Commitments and Eligibility Requirements: the key policy is to be as open and accommodating as possible, because a major success factor is to expand the federation membership.
- Resource Management: although the federator will allow the reservation of the resources on the testbeds, it is the final responsibility of the testbeds to manage the usage of their resources, as long as they fulfil the agreed Service Level Agreements (e.g. provide a minimum amount of resources, guaranty a certain up-time).
- Stakeholder Engagement (Communications and Marketing): the key objectives of these policies are to recruit experimenters and testbeds to expand the federation.

- Future Direction for the Federation: this is determined through the use of four key metrics: Fairness, Cost efficiency, Robustness and Versatility.
- Contractual Relationships and Terms and Conditions: the terms and conditions (T+C) for the federation cover a set of T+C for experimenters and another compatible set of T+C for testbed facilities.

Furthermore, the federator is responsible for the operation of and support for the federation services, for community building through Summer Schools (for experimenters) and Engineering Conferences (to drive technical developments) and for international collaboration with US, Brazil, China, South-Korea, Japan and others.

3.6 Summary

The Future Internet experimentation require a broad availability of facilities offering testing resources which apply the latest developed networking solutions and computing technologies, including testbeds established by the most relevant actual and recent research activities across Europe and world-wide. The Fed4FIRE project has established a European Federation of Testbeds and developed necessary technical and operational federation framework enabling the federation operation. With its 23 tesbeds, the Fed4FIRE represents the largest federation of testbeds in Europe which allows remote testing in different areas of interests; wireless, wireline, open flow, cloud, etc.

The Fed4FIRE architecture has been built by taking requirements from various stakeholders into account, including testbed providers and experimenters, with sustainability in mind and aiming to support as many actions from the experiment lifecycle as possible. Various user friendly tools established by the Fed4FIRE project enable remotely usage of the federated testbeds by experimenters who can combine different federation resources, independently on their location, and configure it as it is needed to perform the experiment.

The Fed4FIRE Federation offers its testbeds for use and experimentation to a wide community and to all interested parties, which can use the federation facilities through the mechanism of Open Calls for Experiments, partially funded by EC, or by using Open Access to the federation facilities. Since start of Fed4FIRE operation, more than 50 experiments have been completed and more than 150 experimentation proposals have been received from SMEs, other industry stakeholders, as well as academic and research institutions.

In respect to the federation operation, by using its powerful federation tools Fede4FIRE is applying so-called "one-stop shop" approach, natively supporting the “Experimentation as a Service” concept, where the resources needed for an experiment can be acquired and accessed by the experimenter through one single contact point of the federation – its Federator. Finally, Fed4FIRE elaborated a number of possible organization and funding models for the federation, which are planned to be exploited in the near future, aiming at establishment of a sustainable European Federation of Testbeds.