Grant Agreement No.: 732638
Call: H2020-ICT-2016-2017
Topic: ICT-13-2016
Type of action: RIA

D4.01: TaaS Gap Analysis Report

Work package	WP 4
Task	Task 4.1
Due date	30/06/2017
Submission date	26/09/2017
Deliverable lead	UPMC
Version	1.0
Authors	Radomir Klacza (UPMC), Frederic Vaissade (UPMC), Alexander Willner (Fraunhofer FOKUS), Zahoor Ahmed (TUB), Jonas Rook (TUB)
Reviewers	Serge Fdida (UPMC) / Jonas Rook (TUB)

Abstract	This deliverable defines and describes the dissemination and communication strategy and set of activities that will be pursued by the Fed4FIRE+ partners to guarantee broad and effective visibility, promotion and up-take of the project's work and outcomes.
Keywords	Dissemination, communication, events, impact creation.

Document Revision History

Version	Date	Description of change	List of contributor(s)
V0.1	01/06/2017	TOC	Radomir Klacza (UPMC), Alexander Willner (FOKUS)
V0.2	08/06/2017	Drafting Content	Alexander Willner (FOKUS), Zahoor Ahmed (TUB)
V0.3	28/06/2017	Overall Review	All
V0.4	18/07/2017	Finalized input, added MySlice input, added Odoo input	Alexander Willner (FOKUS), Radomir Klacza (UPMC), Federico Facca (Martel)
V0.5	11/09/2017	Internal Review	Jonas Rook (TUB)
V0.6	15/09/2017	Internal Review	Serge Fdida (UPMC)
V1.0	26/09/2017	Final document submitted	Alexander Willner (FOKUS)

DISCLAIMER

COPYRIGHT NOTICE

ACKNOWLEDGMENT

Co-funded by the European Union

Co-funded by the Swiss Confederation

This deliverable has been written in the context of a Horizon 2020 European research project, which is co-funded by the European Commission and the Swiss State Secretariat for Education, Research and Innovation. The opinions expressed and arguments employed do not engage the supporting parties.

Project co-funded by the European Commission in the H2020 Programme		
Nature of the deliverable:		**R**
Dissemination Level		
PU	Public, fully open, e.g. web	✓
CL	Classified, information as referred to in Commission Decision 2001/844/EC	
CO	Confidential to FED4FIRE+ project and Commission Services	

** R: Document, report (excluding the periodic and final reports)*

DEM: Demonstrator, pilot, prototype, plan designs

DEC: Websites, patents filing, press & media actions, videos, etc.

OTHER: Software, technical diagram, etc.

Co-funded by the Horizon 2020
Framework Programme of the European Union

EXECUTIVE SUMMARY

The global trend of Future Internet related experimentally driven research has caused the foundation of a large number of testing facilities worldwide. A particular issue in this context is their sustainable operation and the best use of developed infrastructures are highly critical. While many facilities have reached a level of maturity that allows them to be opened up to a wider use, mainly the academic sectors have been targeted. Within Work Package 4 the exploration of best practices, the execution of a gap analysis and the investigation in an applicable concept for the operation of a partly self-sustainable semi-commercial federation are targeted. Within this deliverable, lessons learned from other projects are described, a gap analysis is provided based on a standard framework that defines the required processes and applications for the carrier grade operation of telecommunication infrastructures and provisioning of services. As a result, an initial integration plan is outlined, particularly for realizing an intelligent Testbed as a Service (TaaS) matchmaker service.

Co-funded by the Horizon 2020
Framework Programme of the European Union

TABLE OF CONTENTS

Co-funded by the Horizon 2020
Framework Programme of the European Union

LIST OF FIGURES

Co-funded by the Horizon 2020 Framework Programme of the European Union

Co-funded by the Horizon 2020
Framework Programme of the European Union

LIST OF TABLES

Co-funded by the Horizon 2020
Framework Programme of the European Union

ABBREVIATIONS

API	Application Programmers Interface
BSS	Business Support System
CRM	Customer Relationship Management
eTOM	Enhanced Telecom Operations Map
FanTaastic	Fanning out Testbeds-as-a-Service for the EIT ICT Labs
FedSM	Federated IT Service Management
FIRE	Future Internet Research and Experimentation
KPI	Key Performance Indicator
OSS	Operations Support System
QoS	Quality of Service
SLA	Service Level Agreements
TaaS	Testbed as a Service

Co-funded by the Horizon 2020
Framework Programme of the European Union

1 INTRODUCTION

During the last couple of years, FIRE testbeds have matured by putting strong emphasis on the actual provisioning of experimentation services to experimenters. A multitude of experiments (small scale, large scale experiments) have already been conducted on FIRE testbeds, supporting not only researchers, but also helping FIRE facilities to mature, as for each experiment, the entire experiment lifecycle was iterated. Testbeds have always played a critical role for educational purposes, for research and experimentation purposes as well as for product testing and product hardening purposes. With the global trend of future internet related research initiatives and their numerous projects building technology-specific testing and experimentation facilities gained strong momentum. Numerous FIRE testbeds for the research and experimentation in various Future Internet related fields, such as the Internet of Things (IoT), the Network of the Future (NoF) and the Internet of Services (IoS) emerged in Europe.

Whereas initially, predominantly the instrument of open calls was applied for attracting experimenters and testers from academic, research and industry sectors, nowadays more and more experimenters are given free/open access to FIRE research infrastructures. To provide the reader some context for the subsequent discussion, a typical testing and/or experimentation lifecycle, from the perspective of an experimenter/tester, is depicted in cf. Figure 1:

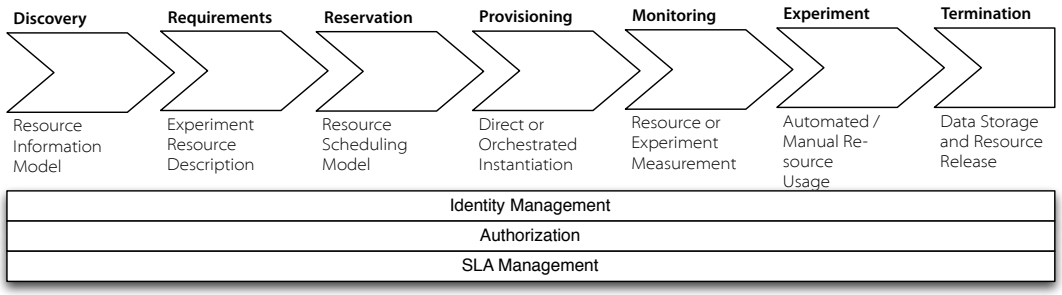


Figure 1 Testing Lifecycle (based on (Vandenberghe, et al., 2013))

- **Resource Discovery**: Users need to be able to discover available resources and services and verify their status.
- **Resource Requirements**: Based on the available information users specify their requirements. This specification needs to be provided in sufficient detail for the facility to identify the appropriate resources and tools for carrying out the test and experimentation. This might include compute, network, storage and software libraries. Additionally, any sort of supporting resources such as consultant services might be part of this set of requirements.
- **Resource Reservation**: Each testbed might provide its own functionalities for reserving resources through a common customer interface / portal. Options might include: (1) no hard reservation or best- effort (use of a calendar that is loosely linked to the facility), (2) hard reservation (once reserved, users have guaranteed resource availability). Other options: (1) users should reserve sufficient time in advance or (2) instant reservation capabilities are provided.

Co-funded by the Horizon 2020 Framework Programme of the European Union

- **Resource and Service Provisioning**: Once users have reserved the needed resources they should be able to access these resources provided by the corresponding testbed. The testbed needs to provide a common API and methods for accessing those resources. The Instantiation of specific resources are either directly possible through the facility API (responsibility of the experimenter to select individual resources) or via orchestration using a functional component, which is dispatching requests in order to decide which resources fit best with the experimenter's requirements.

- **Test and Experiment Monitoring and Data Aggregation:** Experiment monitoring mechanisms need to provide measurement points inside new or pre-existing applications. Experimenters running the applications can then direct the measurement streams from these measurement points to remote collection points, for storage in measurement databases.

- **Test and Experiment Control**: Experiment control needs to be realized by a common protocol and API. Users need to be able to execute their experiment across multiple testbeds and resources. Examples are: start-up or shutdown of compute nodes, change in wireless transmission frequency, and instantiation of software components during the experiment and breaking a link at a certain time in the experiment. Real-time interactions that depend on unpredictable events during the execution of the experiment are also considered.

- **Test and Experiment Termination**: Upon termination of an experiment and test, testbed resource need to be released, but measured results need to be maintained and stored for later retrieval.

So far, mainly the academic / research sectors have been targeted to support their requirements to execute this fairly complex workflow. In parallel to, a number of operational challenges have to be considered as well. This include federation-wide authentication mechanisms, distributed authorization decisions based on federation-wide roles, or the assurance of specific SLAs for the duration of the experiment.

The latter already implies the deployment of first level support services such as testbed, **r**esource and experiment specific monitoring and trouble ticketing. For a full commercial exploitation of ICT research testbeds, i.e. providing Testbeds as a Service (TaaS) to paying customers, however, a number of open issue arise. From an operational perspective, many testbeds offer their services/resource on a best effort basis, with limited means for automated fault management, Quality of Service (QoS) / Service-Level Agreement (SLA) assurance and validation; and with a focus on providing technical resources for experimentation purposes.

Elevating the level of expected service by providing commercial offerings might further introduce the requirement to stablish a professional customer relationship management (CRM) including phone-based hotline support and live chats, as well as accounting, charging, billing and auditing capabilities. Given the distributed nature of testing facilities, these services would need to be offered on both the federation and provider level.

Clearly, this venture entails a number of consequences and challenges that have to be taken into account when implementing a semi-commercial TaaS offering. This document in particular builds upon existing lessons learned from a similar attempt and derives suitable action items for Fed4FIRE+ Work Package 4.

Co-funded by the Horizon 2020
Framework Programme of the European Union

2 LESSONS LEARNED

2.1 RELATED WORK

Sustainability within the afore-mentioned context, beyond the duration of a particular funded project in many cases was difficult to achieve. Apart from non-commercial approaches such as PlanetLab in the US or in Europe, which provide access to a large-scale network of (mostly academic) computing resources through in-kind contributions models, numerous other facilities disappeared after the end of funded projects. However, as indicated in the introduction, providing a semi-commercial TaaS offering that support experiment life cycle within Fed4FIRE+ could implicate a number of technical, financial and legal challenges. Already a number of approaches and initiatives aimed at resolving aforementioned sustainability problems. Among others: EU FP6 SSA and EU FP7 IP project Panlab Office, the Betaplattform, the FIRE Portal and FIRE Office.

The approach of Panlab (which started in 2006 and in 2008 continued as an FP7 IP) was clearly focusing on rolling out the testbed service business on a commercial basis (Gavras, Bruggemann, Witaszek, Sunell, & Jimenez, 2006). Besides technological foundations (Campowsky, Magedanz, & Wahle, 2010) (Wahle, Harjoc, Campowsky, & Magedanz, 2010), it produced several relevant deliverables, amongst others the D2.1 Legal Framework (Gavras, et al., 2008), a vision for a Pan-European Laboratory as well as a business plan for the so called “Panlab Office”. However, the “Panlab Office” never saw the light of day, for several reasons, of which technical ones only partially account for.

Soon after the German government’s first IT summit, the German Beta-Plattform (Bub & Woesner, 2009) was set up and put into operation. Whereas in the long run also commercial usage was targeted the Beta-Plattform initially served as a sustainability plan for German nationally funded ICT project results. ICT research results / infrastructures cross-testbed federation of research infrastructures’ components and applications (e.g. in MAMSplus (Staiger, 2008), interconnecting distributed IMS/NGN platforms across research German projects partners via the Beta-Plattform’s VPN aggregator, sustaining / “keeping alive/in operation” project results / research infrastructure and services for ensuring continuity and re-use of results/infrastructures).

Another interesting project that stands out is the European Federated IT Service Management (FedSM) project. Techniques and approaches from commercial IT Service Management (ITSM) processes were analyzed and adopted in order to define and implement a lightweight framework for federated e-infrastructures. This includes in particular the identification of the business models Advisor, Matchmaker, One-Stop-Shop, and Integrator (Appleton, 2012).

In the context of FIRE (Tselentis, 2009), the basic federation idea was fully kept alive, technology-wise as well as from an operational viewpoint (Crowcroft & Demeester, 2009). After the FIRE-wide umbrella coordination action FIREWORK, FIRESTATION deliberately aimed for unification and harmonization of FIRE testbeds setting up a FIRE Portal for testbed information sharing, participation, collaboration. This initial service provided by the FIRE Portal/FIRE Office very well matches with the service provided by the Federation “Advisor” in FedSM and as such represents an intrinsic service building block of any Testbed as a Service Broker, Federator and Facilitator. In FIREWORK’s terms this initial service of the FIRE OFFICE was “for serving the FIRE Community members in administrative issues, such as maintaining information on testbeds, enabling exchange of information within the

Co-funded by the Horizon 2020 Framework Programme of the European Union

Community, organizing events, promoting testbeds and their development and raising awareness on FIRE".

One core activity within the Fed4FIRE+ project will be to kick-off a Federator entity within WP2, which will operate and manage the federation, provide policies through the Federation Board and deals with maintenance, requirements, improvements and sustainability. In Figure 2 a very preliminary overview of potential Key Performance Indicators (KPIs) are given. Independent of the final KPIs that will be defined, an important metric will be the utilisation of the testbeds resources in terms of experiments or by other means. WP4 will contribute to this aspect by identifying other opportunities how testbeds can be used.

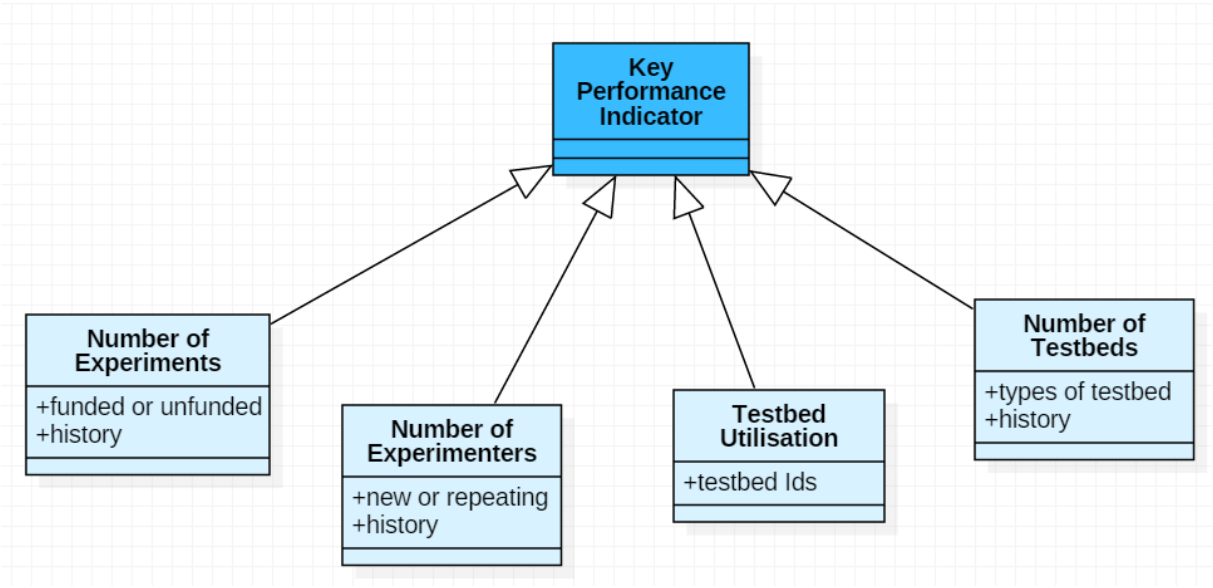


Figure 2: Preliminary Fed4FIRE+ Federation KPIs

2.2 FANTAASTIC

A notable project, that explored best practices, performed a gap analysis, investigated applicable business models and worked out an operational concept for the implementation of such a FIRE-related TaaS offering, was the "Fanning out Testbeds as a Service for the EIT ICT Labs" (FanTaaStic) project. Together with the FIRE initiative EIT ICT Labs promoted the concept of experimentally driven research to create a large-scale European experimental facility. The overarching goal was to provide a framework in which European research on Future Internet can flourish and Europe can be established as a key player in defining Future Internet concepts globally. For defining the operational concept/model, an analysis of available tools & frameworks from past and current FIRE / federation projects was carried out. With the goal of realizing sustainable EIT ICT testbed operations, standard frameworks defining the required processes and applications for the carrier grade operation of telecommunication infrastructures and provisioning of services were being used. The proposed operational model is specified based on the requirements analysis previously conducted and based on the enhanced TMForum's Telecom Operations Map (eTOM) framework (eTOM, 2007).

Co-funded by the Horizon 2020 Framework Programme of the European Union

As a result, generally speaking and as shown in Figure 3, a brokering facility offers different kinds of users (academic, research and SMEs) access to different kinds of testbeds comprised of different testbed resources, offered by different testbed providers:

- **Customers (SMEs, Researchers, Students):** utilizing testbeds, testbed resources and facilitating services.
- **Testbed providers:** a heterogeneous group of organizations or bodies that come together to form a federation, whether a loose or tightly bound one.
- **Brokering Facility:** In FedSM terminology, the "Federator", providing value-added services from advising customers, support in finding the appropriate testbeds and testbed resources, centralized contractual management and billing as well as cross-testbed access control and experimentation.

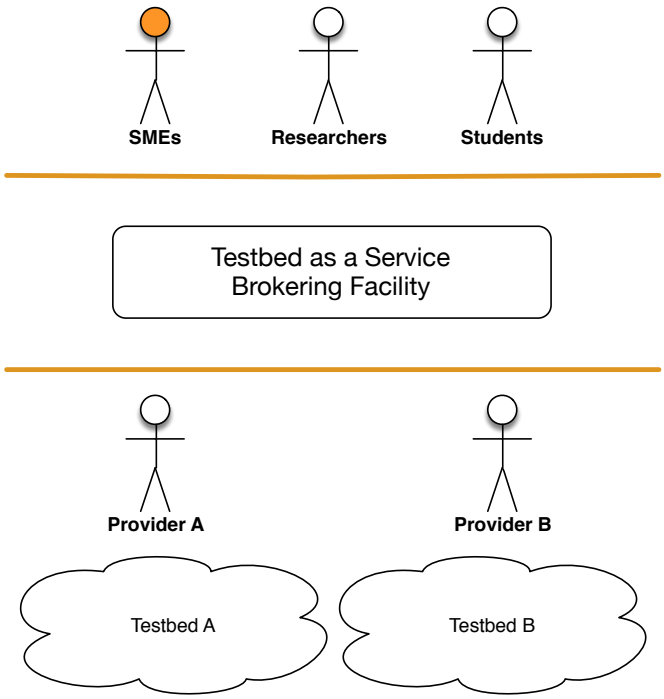


Figure 3: Basic TaaS Entities

The challenge faced when moving from best-effort, research infrastructures (currently predominantly provided by Future Internet testbeds/facilities such as FIRE facilities) to commercial and reliable provisioning of testing/testbed services for paying customers mainly relates to the following gaps / issues.

- **QoS assurance and Fault Management** mechanisms become highly critical when testbeds and testbed resources are offered on a commercial / pay-per-use basis. Required operational mechanisms (including operations at testbed level) need to be capable of

1) identifying QoS deteriorations,
2) locating faults / conducting root-cause-analysis and
3) implementing fault resolution mechanisms.

Co-funded by the Horizon 2020
Framework Programme of the European Union

Only by doing so the impact of faults can be minimized / time-to-resolution can be shortened, so that testing services can be provided on a commercial basis, where customer satisfaction can be assured.

- Cross-testbed / administrative domain **SLA management** mechanisms need to be in place for commercially offering TaaS services in federated environments. At each given point in time, the broker has to be aware of QoS deteriorations / SLA violations, their root cause (administrative domain) and not only trigger fault resolution mechanisms (as explained in the last section), but also trigger appropriate billing mechanisms so that users are not getting charged for services provided below negotiated service levels.

- **Accountability**, not only in the sense of logging resource access and usage (time, capacity), but also in the sense of being able to identify misuse of resources becomes critical for commercially offerings. Only if mechanisms are in place through which misuse of resources as well as the actual abuser can transparently be identified testbed providers are equipped with the appropriate means that assure non-liability in case of misuse.

- **Security** mechanisms when opening up testbeds for commercial (e.g. industrial) use become not only important for providing authorization and access control mechanism or intrusion prevention, but also for protecting the software and products of paying users (e.g. industry users) against theft, including also the protection of test results.

- As soon as pricing models different from flat rate pricing or membership fees are applied, namely when pay-per-use pricing models are applied **Charging and Billing** mechanisms have to support time-based as well as volume-/capacity-based charging models. This involves much more fine-grained resource reservation and charging mechanisms, which need to support also cross-testbed resource reservation and charging. Here, not only for reservation purposes of testbed's resources, but also for final compensation of testbed providers, enhanced charging and billing mechanisms already at the testbed level need to be in place.

- Last, but not least as the goal of any service oriented business should be to satisfy its customers, with a growing number of users / customers, the TaaS offering needs to put in place mechanisms capable of managing past and future customer relations. **Customer Relationship Management (CRM)** systems, not only need to maintain contact information, but also need to track past businesses with customers, as well as future opportunities, including those which involve additional support (consultation, test support) of testbed / technology experts.

In all of the above-mentioned areas, not only enhancements at the **federation level** need to be carried out, but also at the **testbed level**. It is foreseen that testbeds will only step-wise upgrade their capabilities for meeting these requirements. Nevertheless, the capabilities of each testbed to meet above mentioned challenges should be known upfront and clearly communicated to testbed users, even if some mechanisms are not supported. Only by doing so a trust-worthy market-place of testbeds / testbed resources can be established. Differentiators need to be put in place, specifying which levels/functionalities of/for QoS assurance, SLA management, Security, Accountability, Charging, Reservation, etc. are supported by a particular testbed.

Co-funded by the Horizon 2020
Framework Programme of the European Union

3 GAP ANALYSIS

3.1 BUSINESS ROLES

This document aims at exploiting the results of FanTaaStic, which itself used concepts developed within FedSM and eTOM, to identify gaps and to provide a first approach/plan for filling these gaps by using available technologies. Fed4FIRE+ is providing testbed federation, brokering and services that facilitate testing. This offering could roughly be mapped to the business models / roles from FedSM depicted in Figure 4. Each higher business model (highest here is Integrator) includes the services of all lower ones, i.e. Integrator > One Stop Shop > Matchmaker > Advisor:

- **Advisor Role**: providing advice on offerings, testing procedures.
- **Matchmaker Role**: supporting users finding the appropriate testbeds / tested resources for conducting their tests / experiments.
- **One Stop Shop Role**: providing federation overarching contractual support and unified billing and payment mechanisms.
- **Integrator Role**: Providing cross-testbed access control, testing and experiment control, results gathering and analysis mechanisms.

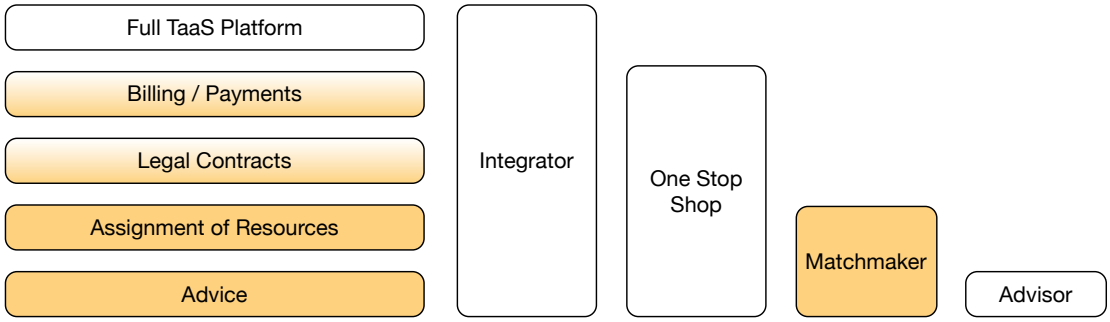


Figure 4 Potential Business Models and Services (based on FedSM (Appleton, 2012)

Given the complexity of executing scientific testing across federated infrastructures, the confidentiality and legal requirements of commercial resource usage and the potential offering of resources unrelated to experimentation (such as consulting services), we have identified the actual match making / brokering of testbed offerings to be the primary business case. Thereby the broker would initially cover the roles Advisor and Matchmaker. Depending on how non-technical issues related to the establishment of a legal entity proceeds within Fed4FIRE+ WP2, roles of the One Stop Shop business model might be applied as a gradually growing service offering, forming a Fed4FIRE+ roadmap.

3.2 SERVICES AND REQUIREMENTS

According to FedSM, in order to satisfied these defined roles / service models, several functionalities at different layers are required:

- **Service Management processes**
- **Consumer-facing services/components**
- **Federation-member facing services/components**

Co-funded by the Horizon 2020 Framework Programme of the European Union

- **Supporting service components**

The following Table 1 maps each required process to the eTOM Operations (Numbers in brackets).

Table 1 Processes Required by the Roles defined in the Business Plan mapped to eTOM Operations (based on FedSM (Appleton, 2012))

	Required Process / Service / Component Class Req. No. Process description (linked eTOM processes)	
Federator all Roles: **Matchmaker** **One-stop-Shop** **Advisor** **Integrator** **Invisible Coordinator** (Coordinated action)	***Service Management processes (for main federation service type)*** B-SM 1. Design & transition of new or changed services ( ) B-SM 2. Service Level management (SLAs, OLAs) (1.1.1.7) B-SM 3. Service reporting (1.1.2.4, 1.1.2.5) B-SM 4. Service continuity & availability management (1.1.2.1, 1.1.2.4) B-SM 5. Financial management (budgeting, accounting, charging) for services (1.1.4.5) B-SM 6. Capacity management (1.1.2.4) B-SM 7. Information security management ( ) B-SM 8. Incident & service request management (1.1.2.3) B-SM 9. Problem management (1.1.2.3) B-SM 10. Configuration management (1.1.2.2) B-SM 11. Change management (1.1.2.2, 1.1.3.2) B-SM 12. Release & deployment management (1.1.2.2, 1.1.3.2) B-SM 13. Continual service improvement (1.1.2.4)	Federation members (Uncoordinated action)
	Consumer-facing services/components B-CF 1. Provision of main technical service (1.1.1.5) B-CF 2. Advice (1.1.1.6) B-CF 3. Assignment of resources (1.1.1.5) B-CF 4. Legal contracts ( ) B-CF 5. Billing and payments (1.1.1.10 to 1.1.1.15) B-CF 6. Platform for using service (1.1.1.2)	
	Federation-member facing services/components B-FM 1. Collective bargaining ( ) B-FM 2. Internal mediation (1.1.2.5) B-FM 3. Promotion (1.1.1.3) B-FM 4. Validation (1.1.4.4) B-FM 5. Facilitate technical interoperation (1.1.4.2)	
	Supporting service components (technical) B-SC 1. Comparison platform ( )	

Fed4FIRE+ users, intending to utilize testbeds for carrying out experiments and tests, require several distinct capabilities from a TaaS facility. The main building blocks and TaaS service functions, required for executing the entire testing/experimentation lifecycle are summarized in.

Co-funded by the Horizon 2020 Framework Programme of the European Union

Table 2.

Table 2 TaaS Functions Required by TaaS Users (based on Fed4FIRE Deliverable 3.1 (Scognamiglio, et al., 2013) and 4.1 (Lobillo, et al., 2013))

Req. #	TaaS Service	Description
U1	Resource Discovery	Users need to be able to discover available resources, provided by testbeds that are federated by Fed4FIRE+
U2	Resource Provisioning	In order to set up a federated testbed, i.e. a testbed, which may be comprised of multiple resources that are residing in multiple testbed domains / locations, require mechanisms for provisioning resources not only for being able to access resource, but also for interconnecting resources
U3	Resource Requirements	TaaS users need to be able to understand which specific resources are able to satisfy their testing requirements
U4	Resource Reservation	TaaS users need to be able to reserve testbed resources in different modes, e.g. through on-demand reservation, scheduled reservation, advanced reservation
U5	Experiment Control	During the execution phase of an experiment / test, TaaS users need to control various parameters and elements, on a time- and/or event basis
U6	Authentication	TaaS users need to be able to authenticate themselves against the Fed4FIRE+ facility for subsequent usage of the facility and testbed resources
U7	Authorization	TaaS users need to gain authorization for the usage of testbed resources
U8	Monitoring and Results Gathering	TaaS users need to be able to initialize the monitoring of parameters of interest and need to subsequently be able to gather results of their experiments and tests
U9	Interconnectivity	Based on the required combination of testbed resources, specified by TaaS users, the latter have to be interconnected, within each testbed as well as across testbeds

TaaS providers, intending to provide their resources to the federation, require several distinct capabilities from a TaaS facility. The main, TaaS service functions, required by TaaS providers are summarized in Table 3.

Co-funded by the Horizon 2020 Framework Programme of the European Union

Table 3 TaaS Functions Required by TaaS Testbed Providers (based on Fed4FIRE Deliverable 3.1 (Scognamiglio, et al., 2013) and 4.1 (Lobillo, et al., 2013))

Req #	TaaS Service	Description
P1	Resource Description / Catalogue Provisioning	Testbed providers need to be able to describe their testbeds, testbed resources, and resource capabilities, for TaaS users to be able to discover and utilize their testbeds and resources
P2	Resource reservation	Testbed providers need to maintain updated information about the reservation of their resources
P3	Resource provisioning	Testbed providers need to operate provisioning systems and expose them through open interfaces for the federation to make use of them
P4	Experiment control	Testbeds need to interwork with experiment control tools
P5	Inter-connectivity	Testbeds need to provide systems through which connectivity and inter-connectivity can be realized

Co-funded by the Horizon 2020 Framework Programme of the European Union

Above mentioned services are the “basic ingredients” for realizing a full testing lifecycle. These mechanisms have been analyzed in depth throughout the last years (in the context of FIRE projects, as well as globally e.g. by GENI/US projects) and several solutions and standards are already available. Most of the above-mentioned services are made available to users either via Fed4FIRE+ Web- and Java-based tools (customer facing interface in eTOM) or through specific clients for testing and experimentation (e.g. special clients for cross-testbed experiment/test control). Nevertheless, the list of customer and provider facing services is yet incomplete, particularly those services that are required for commercial operation where particularly billing and payment related services and CRM systems need to be in place additionally.

3.3 ETOM

For identifying currently missing gaps / functions for rolling out a Fed4FIRE+ offering on a commercial basis we took TMForum’s enhanced Telecoms Operation Map (eTOM) (eTOM, 2007) as a blueprint of operational processes for a service-oriented service provider. eTOM, as shown in Figure 5, is comprised of three major process groupings, i.e.

1) the Strategy, Infrastructure and Product Processes,
2) the Operations processes and
3) the Enterprise Management Processes.

Thereby eTOM covers all different domains of a (telecommunication) service providing enterprise, including a discrete differentiation of stakeholders (customers, suppliers, enterprise workforce).

Co-funded by the Horizon 2020
Framework Programme of the European Union

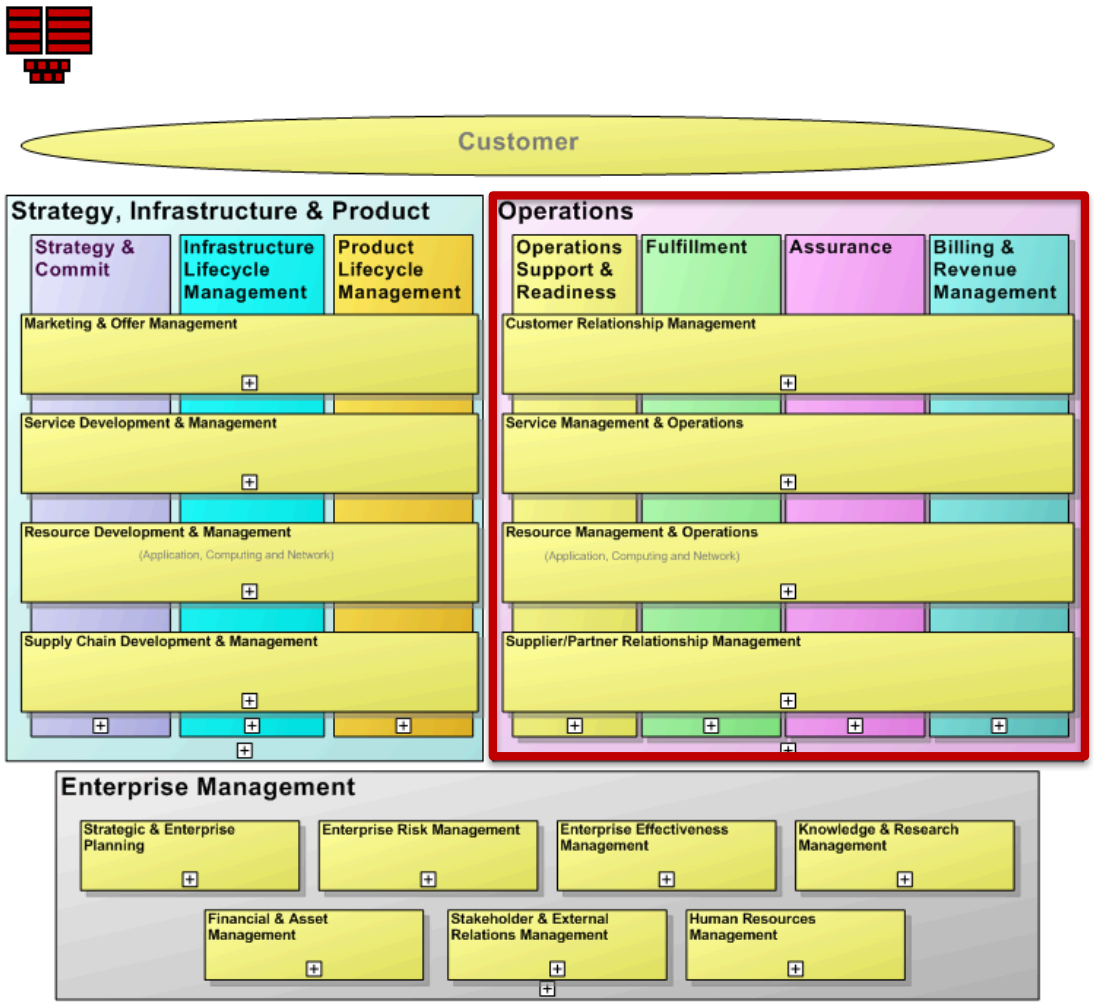


Figure 5 An eTOM Overview and Areas of Concern

For the scope of this document we **focus on the Operations process groupings**. The Strategy, Infrastructure and Product processes grouping as well as the Enterprise Management processes groupings might become more relevant after Fed4FIRE+ initial services are operational and offered on a commercial basis.

The rationale behind choosing the enhanced Telecom Operations Map (eTOM) as a blueprint is based on the following assumptions. eTOM provides the full scope of required **operational processes** for operating (telecommunication) services and providing the required **business processes** across an entire telecommunication enterprise, including Fed4FIRE+ suppliers/partners, i.e. testbed providers.

Co-funded by the Horizon 2020 Framework Programme of the European Union

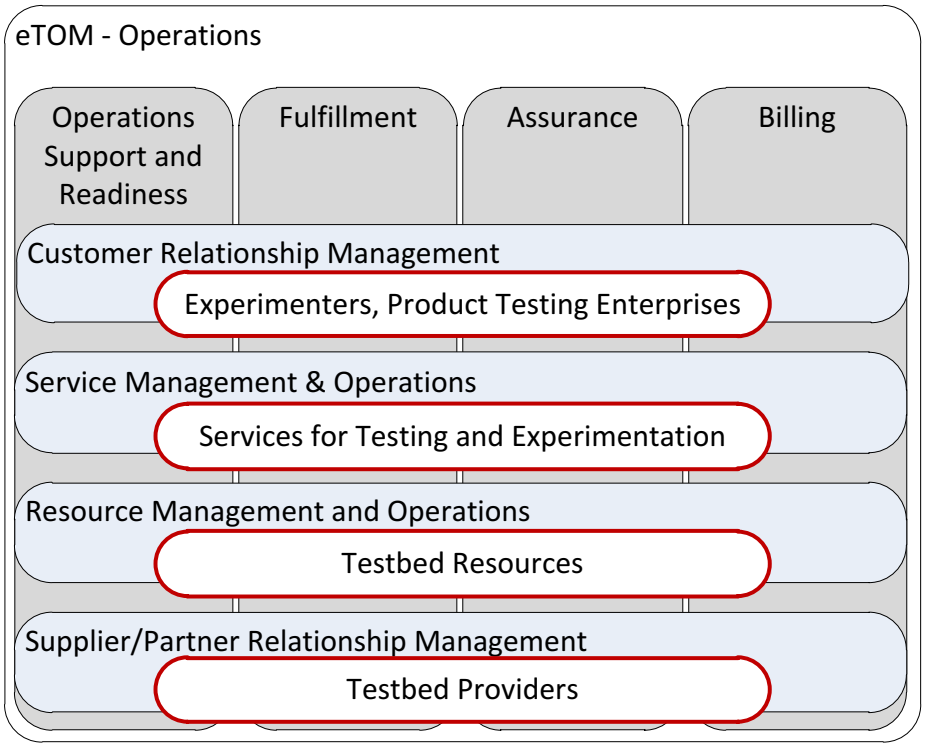


Figure 6 The eTOM Operations Process Groupings - Mapped to Fed4FIRE+

eTOM, as shown by the mapping provided in Figure 6, is conceived to provide a useful framework for understanding the required operational and business process for a TaaS, due to it's layered approach where

1. interfaces and process for the **management of customers** are being specified - in our case TaaS users, typically experimenters, product / software testing enterprises.
2. processes and operations for the **management of services** are specified - in our case services for testing and experimentation.
3. processes and operations for the **management of resources** are specified - in our case testbed resources.
4. interfaces and processes for the **management of suppliers/partners** are specified - in our case testbed providers.

Altogether there are 31 distinctly different OSS and BSS detailed eTOM processes across all four layers (customer, service, resource, partner) and across all four functional areas (operations support and readiness, fulfillment, assurance and billing), as shown in Figure 7.

Co-funded by the Horizon 2020 Framework Programme of the European Union

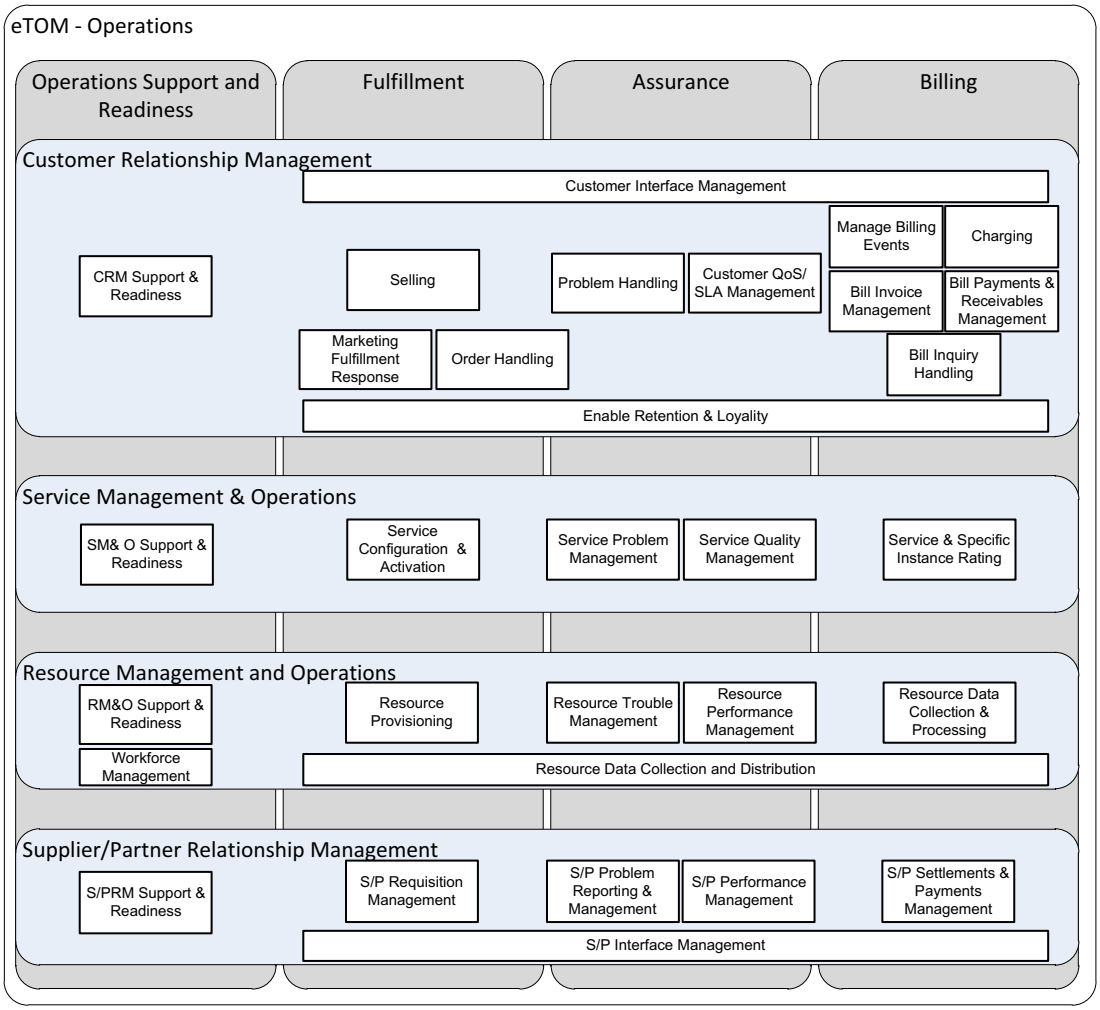


Figure 7 The eTOM Processes – Full Overview

Each of the 31 procedural domains have been analyzed in the following way:

1. its **relevance** for operating Fed4FIRE+ on a commercial basis by attributing the following relevance levels:
    1) highly relevant
    2) fairly relevant
    3) marginally relevant
    4) irrelevant

2. an **estimation of efforts for implementation / integration** of each specific functionality is provided according to the following categories:
    1) High Effort
    2) Moderate to High Effort
    3) Moderate Effort
    4) Low to Moderate Effort
    5) Low Effort
    6) Unknown Effort

Co-funded by the Horizon 2020 Framework Programme of the European Union

3.3.1 Customer Relationship Management

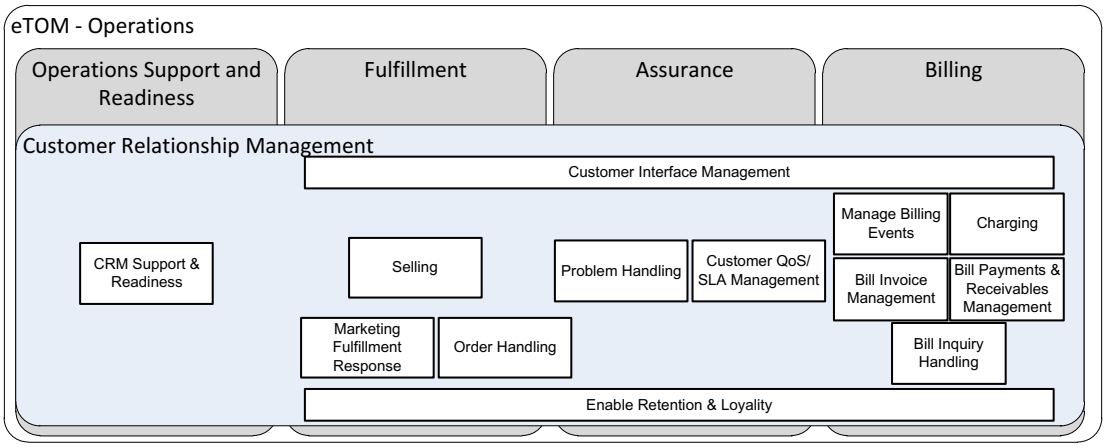


Figure 8 The eTOM - Customer Relationship Management Processes

eTOM Description: This functional process grouping considers the fundamental knowledge of customers' needs and includes all functionalities necessary for the acquisition, enhancement and retention of a relationship with a customer. It is about customer service and support, whether storefront, telephone, web or field service. It is also about retention management, cross-selling, up-selling and direct marketing for the purpose of selling to customers. CRM also includes the collection of customer information and its application to personalize, customize and integrate delivery of service to a customer, as well as to identify opportunities for increasing the value of the customer to the enterprise. CRM applies to both conventional retail customer interactions, as well as to wholesale interactions, such as when an enterprise is selling to another enterprise that is acting as the 'retailer'.

Fed4FIRE+ Scope: Customer Interface Management processes are responsible for managing all interfaces between the enterprise and potential and existing customers. They deal with contact management, understanding the reason for contact, directing customer contacts to the appropriate process, contact closure, exception management, contact results analysis and reporting. CRM contact may be related to one or several of Service Fulfillment, Service Assurance (service quality management and trouble or problem management) and Billing related customer enquiries or contacts.

3.3.2 Service Management & Operations

Co-funded by the Horizon 2020 Framework Programme of the European Union

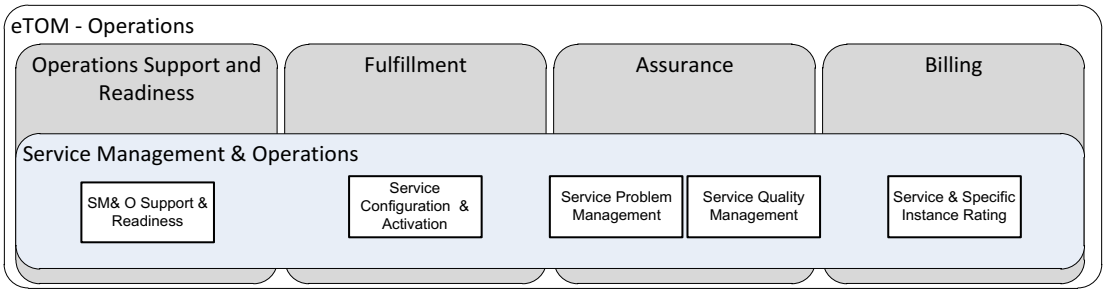


Figure 9 The eTOM - Service Management and Operations Processes

eTOM Description: This horizontal functional process grouping focuses on the knowledge of services (Access, Connectivity, Content, etc.) and includes all functionalities necessary for the management and operations of communications and information services required by or proposed to customers.

Fed4FIRE+ Scope: Services in Fed4FIRE+ allow the customer to access infrastructure and software resources of the testbeds. In a simple scenario example, a customer that needs to test his application using wireless nodes can use a "booking wireless service" that will allow him to reserve those resources. Subsequently when the same customer will need to deploy his application and run the experiment on the reserved nodes he will be able to do it by using a provided software service. Services for Testing and Experimentation, can be divided in two main categories:

- **Infrastructure services:** a service that provides access to a resource that can be hardware resources installed in a facility or virtualized hardware resources.
- **Software services:** a service providing high-level applications offering ready-to-use functionality.

3.3.3 Resource Management & Operations

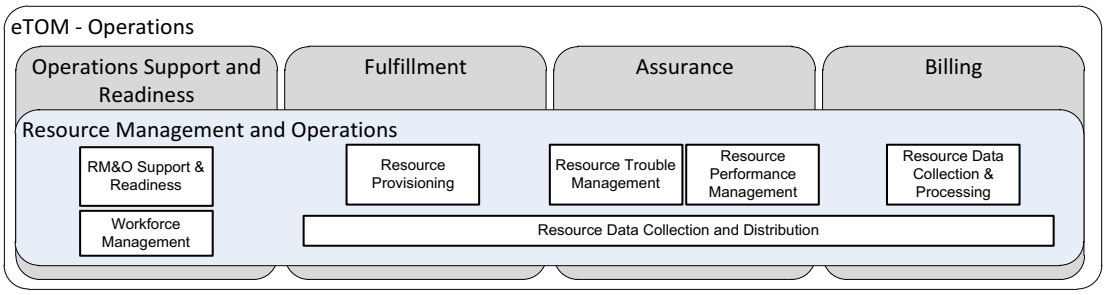


Figure 10 The eTOM - Resource Management and Operations Processes

eTOM Description: This process grouping maintains knowledge of resources (application, computing and network infrastructures) and is responsible for managing all these resources (e.g. networks, IT systems, servers, routers, etc.) utilized to deliver and support services required by or proposed to customers. It also includes all functionalities responsible for the direct management of all such resources (network elements, computers, servers, etc.) utilized within the enterprise. These processes are responsible for ensuring that the network and information technologies infrastructure supports the end-to-end delivery of the required services. The purpose of these processes is to ensure that infrastructure runs smoothly, is accessible to services and employees, is maintained and is responsive to the needs, whether directly or indirectly, of services, customers and employees. RM & O also has the basic

Co-funded by the Horizon 2020 Framework Programme of the European Union

function to assemble information about the resources (e.g. from network elements and/or element management systems), and then integrate, correlate, and in many cases, summarize that data to pass on the relevant information to Service Management systems, or to take action in the appropriate resource. In the original TOM Business Process Framework, the “Network and Systems Management” processes were included at the highest, most general level. This is no longer adequate in an e-business world. Application and computing management are as important as network management. Moreover, network, computing and applications resources must increasingly be managed in a joint and integrated fashion. To cope with these needs, eTOM has introduced the Resource Management & Operations process grouping (together with the corresponding Resource Development & Management grouping within SIP), to provide integrated management across these three sets of resources: applications, computing and network. These areas also combine the Network Element Management processes of the TOM, since these processes are actually critical components of any resource management process, as opposed to a separate process layer. The RM&O processes thus manage the complete service provider network and sub-network and information technology architectures. ETOM differentiates day-to-day operations and support from planning and development, and other strategy and lifecycle processes. In the TOM, these resource layer processes were not differentiated or were not addressed. The eTOM structure better depicts the structure of an enterprise, especially in an e-business era.

Fed4FIRE+ Scope: The eTOM Resource Management and Operations processes treat the core operational components of Fed4FIRE+ testbeds. In particular exiting work from other testbed federation contexts, such as FIRE, can be mapped into this section.

3.3.4 Supplier/Partner Relationship Management

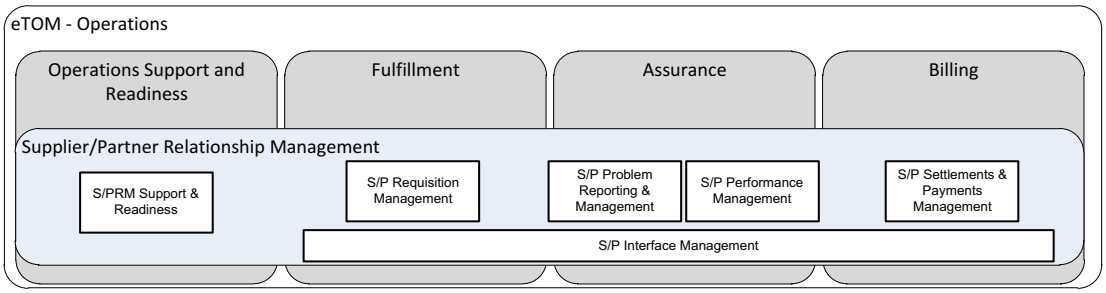


Figure 11 The eTOM - Supplier Partner Relationship Management Processes

eTOM Description: This process grouping supports the core operational processes, both the customer instance processes of Fulfillment, Assurance and Billing and the functional operations processes. Supplier/Partner Relationship Management (S/PRM) processes align closely with a supplier’s or partner’s Customer Relationship Management processes. The inclusion of Supplier/Partner Relationship Management processes in eTOM is one of the key ways that eTOM differentiates itself from the vertically integrated enterprise framework that was in the TOM. The existence of distinct S/PRM processes enables the direct interface with the appropriate lifecycle, end-to-end customer operations or functional processes with suppliers and/or partners. The processes include issuing RFPs as part of the buy process, issuing purchase orders and tracking them through to delivering, handling problems, validating billing and authorizing payment, as well as quality management of suppliers and partners. It is important to note that when the enterprise sells its products to a partner or supplier, this is done through the enterprise CRM processes, which act on behalf of the supplier or the enterprise in such cases. Supplier/Partner processes only cover the buying of services by the enterprise.

Co-funded by the Horizon 2020 Framework Programme of the European Union

Fed4FIRE+ Scope: The Fed4FIRE+ federation resources are not offered directly by a centralized entity, but instead by the testbeds themselves. However, services have been implemented for optional centralized management (such as first level support monitoring or testbed registration). Therefore, the interface to these services is a crucial component of the complete architecture.

3.4 RELEVANCE

The relevance of the afore mentioned eTOM procedural domains for a semi-commercial service offering within Fed4FIRE+ is depicted in Figure 12 and further detailed below.

Co-funded by the Horizon 2020
Framework Programme of the European Union

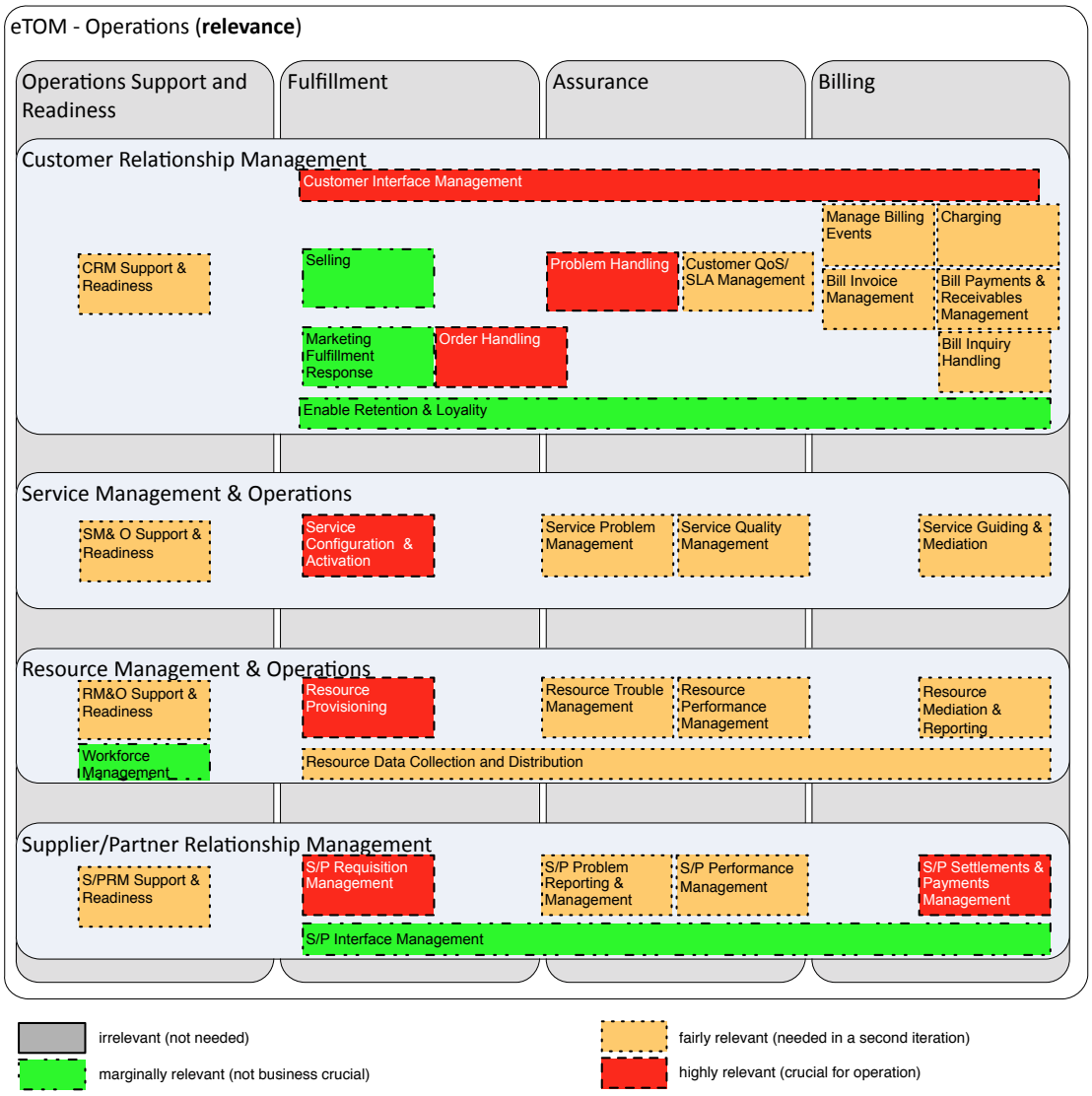


Figure 12 The relevant eTOM procedural domains

3.4.1 Highly Relevant

Most critical for the immediate, commercial use of available approaches are proper mechanisms for:

- Customer Interface Management
- Order Handling
- Problem Handling
- Service Configuration & Activation
- Resource Provisioning
- S/P Requisition Management
- S/P Settlements & Payments Management

3.4.2 Fairly Relevant

Although important for the Fed4FIRE+ context and needed to implement the described business model(s), these processes should be handled as minor importance:

Co-funded by the Horizon 2020 Framework Programme of the European Union

- Operations Support & Readiness
- Customer QoS/SLA Management
- Bill Invoice Management
- Bill Payments & Receivables Management
- Bill Inquiry Handling
- Charging
- Manage Billing Events
- Manage Balances
- SM&O Support & Readiness
- Service Problem Management
- Service Quality Management
- Service Guiding & Mediation
- RM&O Support & Readiness
- Resource Trouble Management
- Resource Performance Management
- Resource Data Collection & Distribution
- Resource Mediation & Reporting
- S/PRM Support & Readiness
- S/P Problem Reporting & Management
- S/P Performance Management

3.4.3 Marginally Relevant

The following eTOM processes are considered as negligible for the first iteration of the implementation:

- Marketing Fulfillment Response
- Selling
- Retention & Loyalty
- Workforce Management
- S/P Interface Management

3.5 EFFORTS

The estimated efforts to implement the relevant eTOM procedural domains within the Fed4FIRE+ federation is depicted in Figure 13. The estimation might be updated in the development phase to reflect a more realistic rating based on experiences gained in later stages of the project.

Co-funded by the Horizon 2020 Framework Programme of the European Union

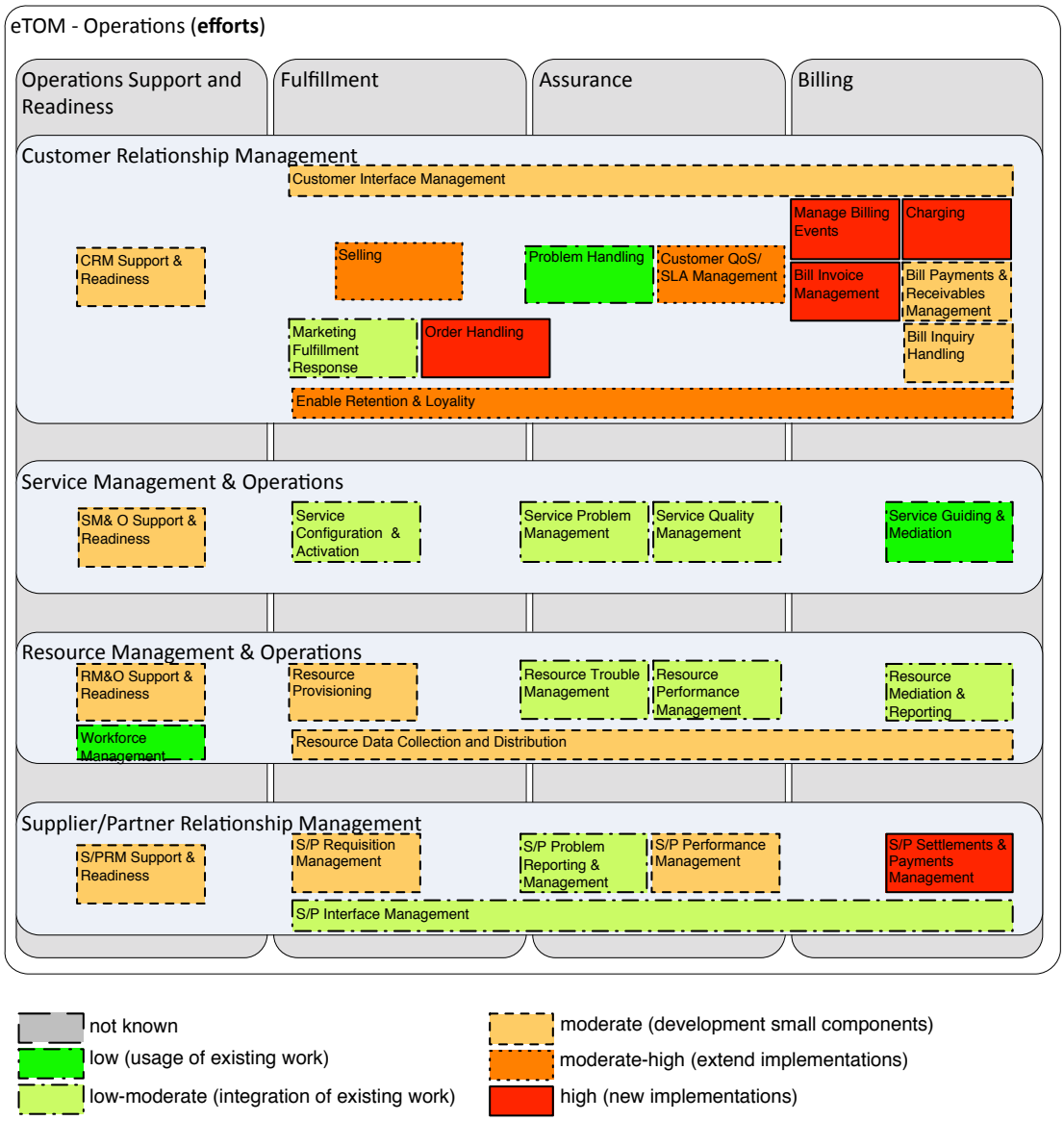


Figure 13 The eTOM based FanTaaStic Gap Analysis (efforts)

3.5.1 High Effort

Because of the lack of available implementations and experiences within the FIRE context, it is estimated that the implementation of the following eTOM processes will require a significant amount of work:

- Order Handling
- Bill Invoice Management
- Charging
- Manage Billing Events
- S/P Settlements & Payments Management

Co-funded by the Horizon 2020 Framework Programme of the European Union

3.5.2 Moderate-High Effort

Components to fulfil these processes have to be implemented / integrated without preceding work in the FIRE context, but the estimated efforts are slightly lower:

- Selling
- Customer QoS/SLA Management
- Retention & Loyalty

3.5.3 Moderate Effort

It is foreseeable that new developments are needed to fulfil the following processes, based on existing developments within FIRE and similar contexts:

- Operations Support & Readiness
- Customer Interface Management
- Bill Payments & Receivables Management
- Bill Inquiry Handling
- Manage Balances
- SM&O Support & Readiness
- RM&O Support & Readiness
- Resource Provisioning
- Resource Data Collection & Distribution
- S/PRM Support & Readiness
- S/P Requisition Management
- S/P Performance Management

3.5.4 Low-Moderate Effort

Since existing work can be reused and slightly modified the required working time to implement these processes are reasonable:

- Marketing Fulfilment Response
- Service Configuration & Activation
- Service Problem Management
- Service Quality Management
- Resource Trouble Management
- Resource Performance Management
- Resource Mediation & Reporting
- S/P Problem Reporting & Management
- S/P Interface Management

3.5.5 Low Effort

Existing work can be reused with only minor modifications to implement these eTOM processes:

- Problem Handling
- Service Guiding & Mediation
- Workforce Management

Co-funded by the Horizon 2020 Framework Programme of the European Union

4 INTEGRATION PLAN

4.1 OVERVIEW

Based on the analysis in Section 3, the existing work developed within Fed4FIRE and given the time and resource boundary condition within Fed4FIRE+, a focus within WP4 will initially be set on aspects related to the eTOM Customer Relationship Management processes and the FedSM Matchmaking business model. Basically, as shown in Figure 10, development will interface three main stakeholders: the customers (potentially paying users), the broker (WP2 facility) and the testbed providers (existing within Fed4FIRE+).

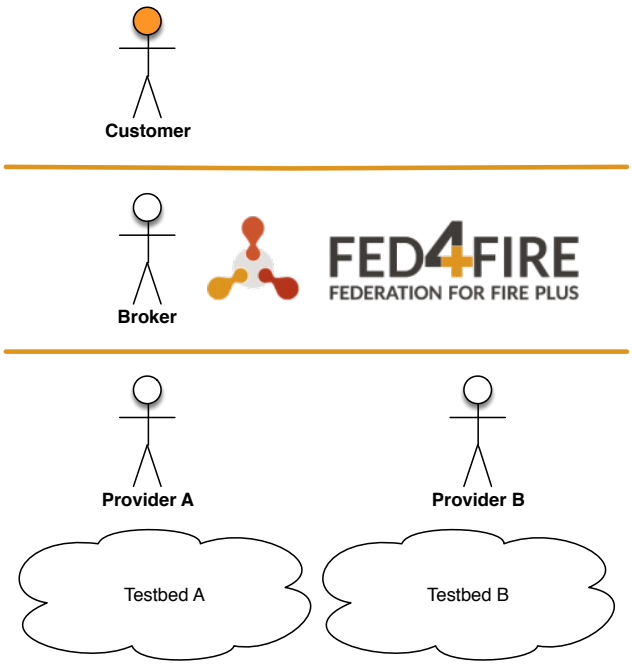


Figure 14: Basic stakeholders

More specifically the basic interaction between the stakeholders are depicted in Figure 15. The customer has means (e.g., based on a web based GUI) to discover and request technical and non-technical commercial service offerings that are available within the federation (e.g., published automatically by each testbed). The broker acts as an intermediate layer between the customer and the testbed providers (e.g., supported by a CRM system). The implementation will be focused on the integration of existing work with the required services, such as ticketing, monitoring and charging systems.

Co-funded by the Horizon 2020
Framework Programme of the European Union

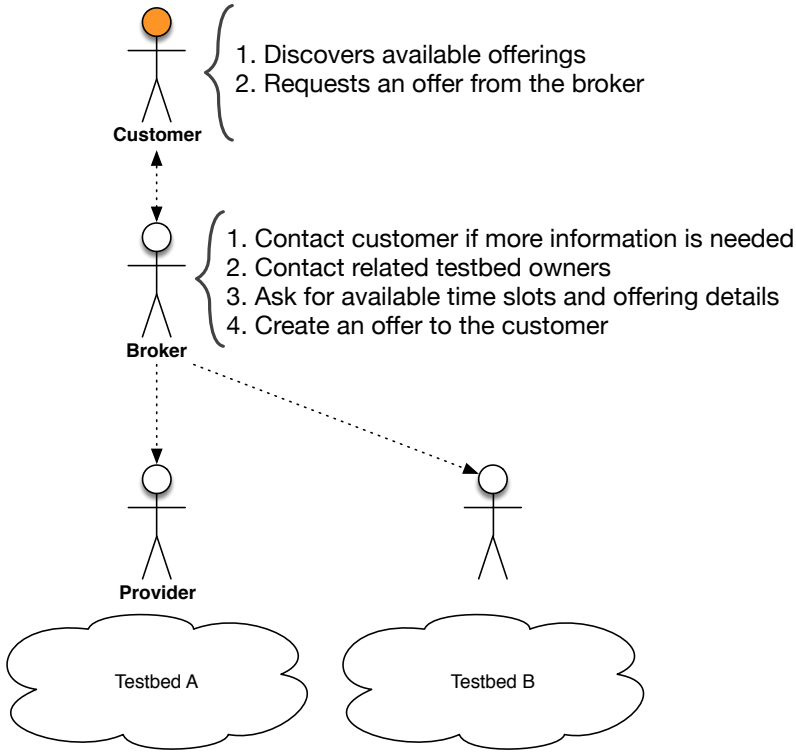


Figure 15: Basic stakeholder interaction

After the initial contact has been established, the further execution/implementation of the service will be negotiated directly between the involved parties, as indicated in Figure 16.

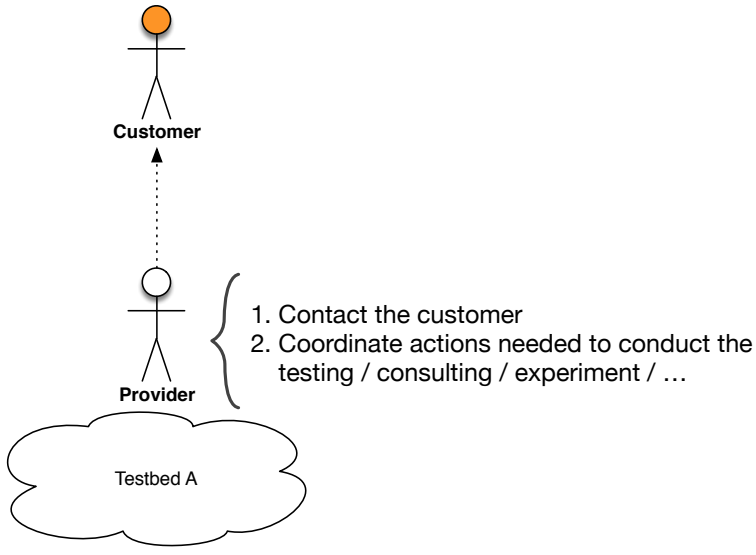
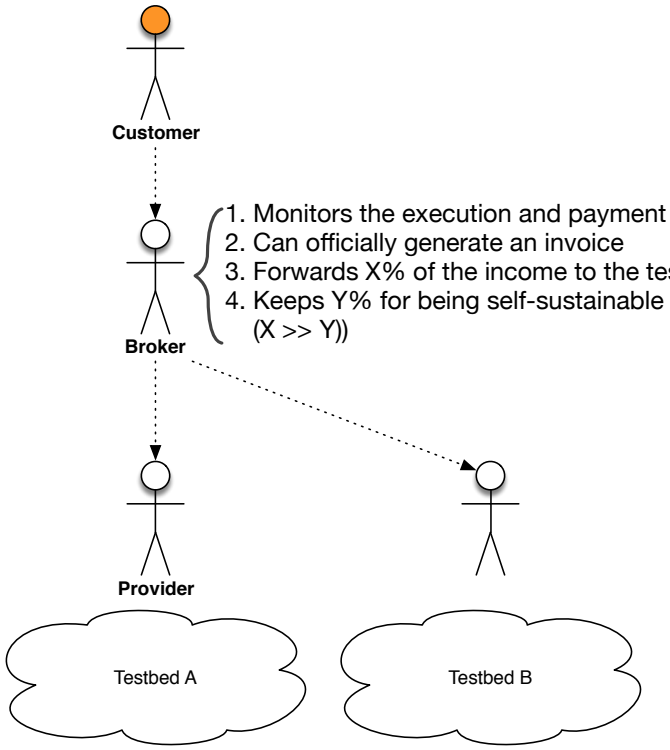


Figure 16: Initiation of the service consumption

Co-funded by the Horizon 2020 Framework Programme of the European Union



Finally, as shown in Figure 17, the overall process will be monitored by the broker (e.g., by help of a CRM) to assure that after the initial contact the service consumption took place. Depending on the result of the collaboration between the customer and the provider, an invoice can be generated for the service and the turnover will be divided between the broker and service providers.

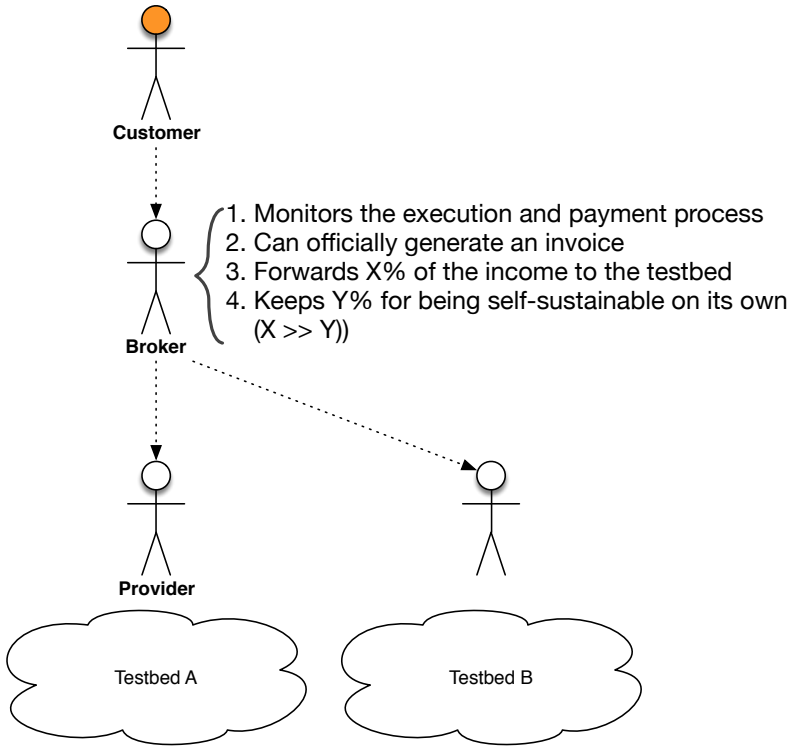


Figure 17: Completion of the service consumption

Co-funded by the Horizon 2020 Framework Programme of the European Union

4.2 TECHNICAL IMPLEMENTATION

The afore mentioned workflow can be implemented using a number of different technologies. The goal is to reuse as much work from the Fed4FIRE project as possible, adding missing functionality by integrating existing tools, and to initially focus on the intelligent Matchmaking business model. As depicted in Figure 18 basically three major components will influence the work within WP4:

1. **A web-based GUI (e.g. MySlice):** the initial contact point for customers to discover available offerings without any requirements for user authentication.
2. **A web-based CRM (e.g. odoo):** a central management system to track customer requests, service consumptions, and that has the ability to create invoices and potentially handle payment processes.
3. **A service catalogue (e.g. Fed4FIRE+ directories):** an aggregation of existing information about testbed offerings and required extensions to complement service offerings for non-technical resources.

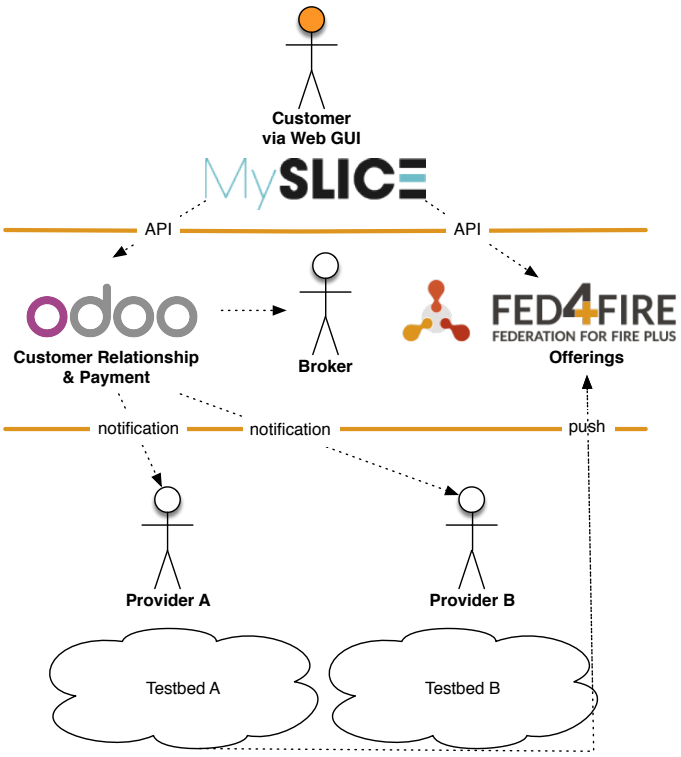


Figure 18: Technological Candidates and Messages

4.2.1 GUI

The goal of the GUI component is to provide a simple to use, low barrier entry point to allow customers to discover available offerings (technical and non-technical). While the initial discovery phase should not require any prerequisite from the user (e.g., only a modern web browser or client for RESTful services), a handover to an authenticated service request is envisioned.

Co-funded by the Horizon 2020
Framework Programme of the European Union

One existing tool that can be reused and extended is MySlice, which has already been developed and used within a number of FIRE projects. It is envisioned to extend it towards the specific requirements for WP4. Its architecture is depicted in Figure 19 and services are responsible for gathering data from the distributed sources of the architecture. The Web frontend interacts with a document database (RethinkDB), which is used as a caching system. It is also used to store data specific to the frontend. This real-time database offers the possibility to the services of the MySlice API to subscribe to events. As soon as the web frontend updates a record, the services are notified and can trigger events. This architecture allows decoupling the frontend from the complexity of processing results from distributed data sources (AMs, Registry)

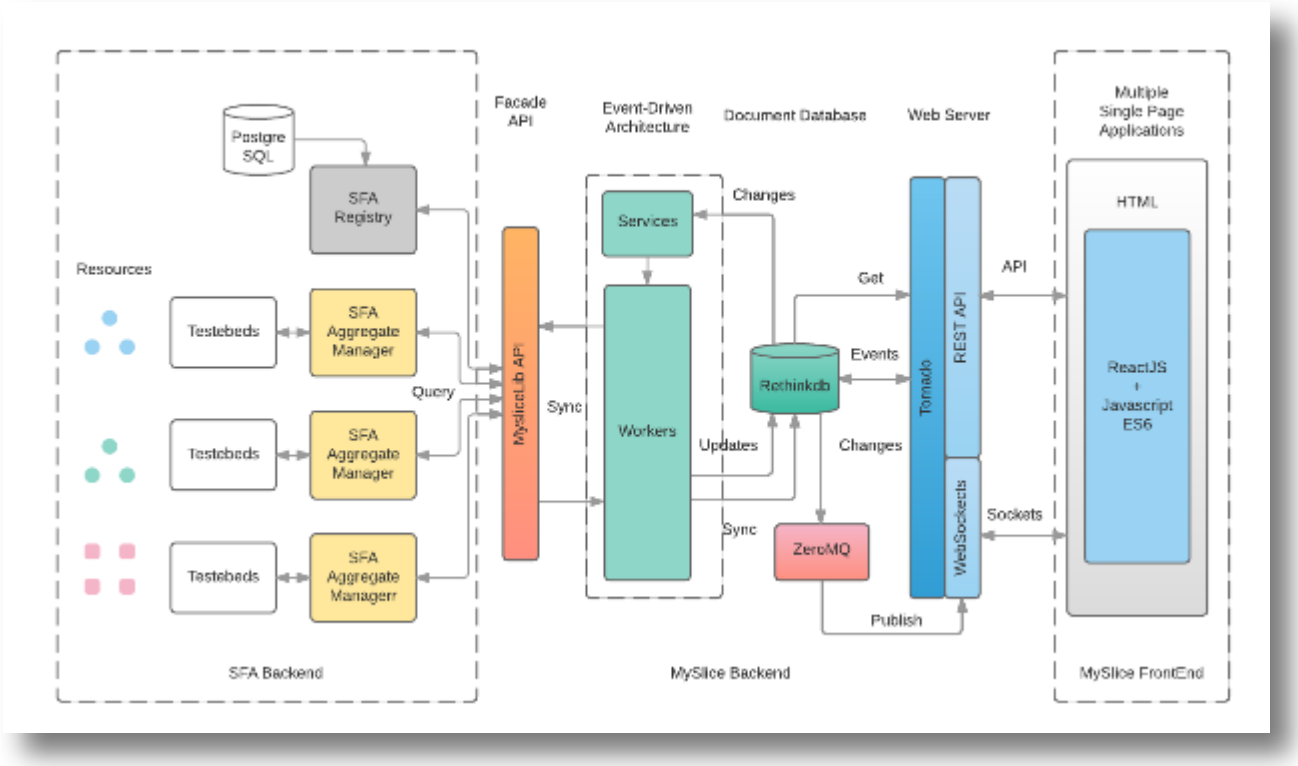


Figure 19: MySlice Architecture

The web frontend (see Figure 20) is composed of different plugins developed by different contributors. Therefore, this modular architecture allows to be extended on both sides either to support new services or to enhance the web frontend. In the Fed4FIRE+ context it will be extended with matchmaking functionality and allow users to reserve not only Fed4FIRE+ specific physical/virtual resources but also to match specific user requests related to non-technical resources.

MySlice also provides the functionality to register and manage users. The communication with the testbeds is ensured using the SFA AM API. The communication with the Registry relies on the SFA Registry API. This will be extended to support Odoo auth module.

Co-funded by the Horizon 2020 Framework Programme of the European Union

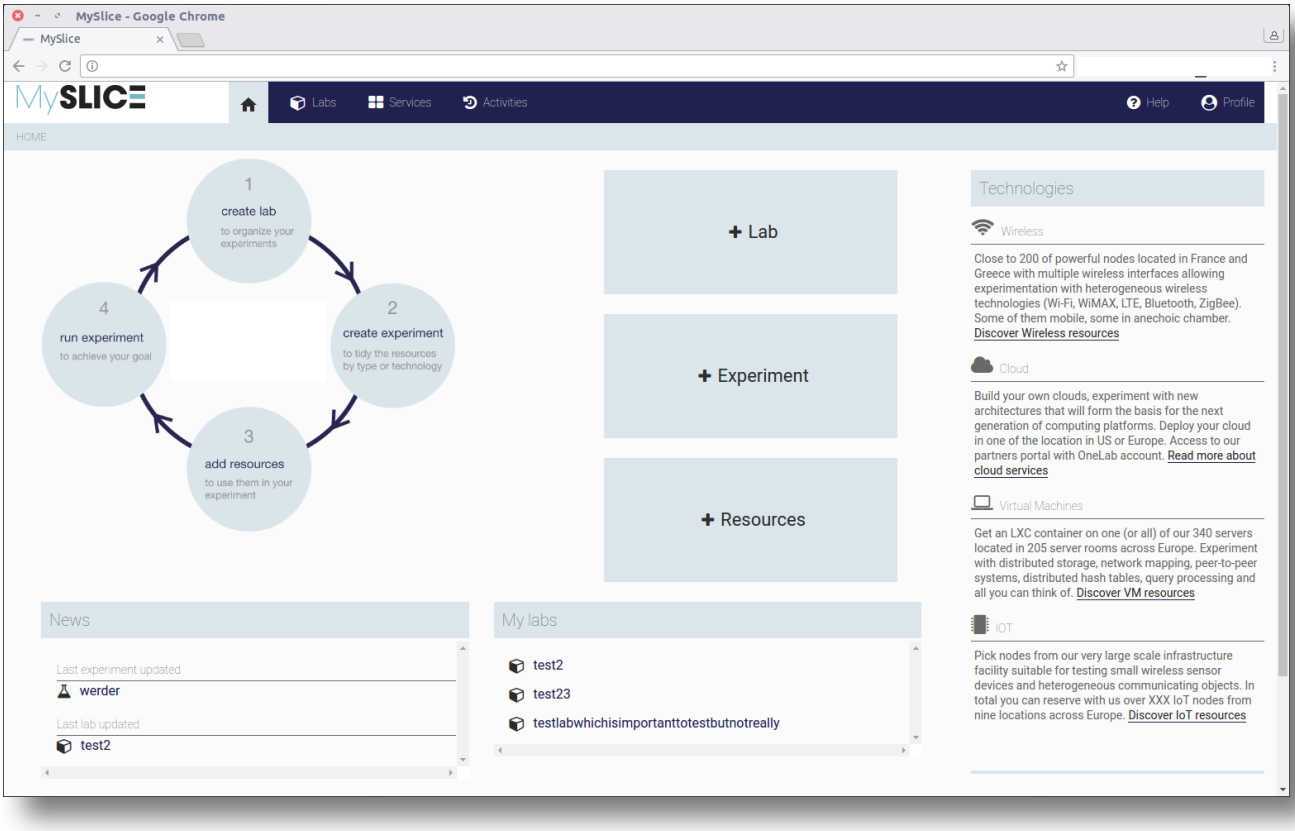


Figure 20: MySlice Dashboard

4.2.2 CRM

To cover the functionalities related to customer support and billing, the obvious solution is the integration of a Customer Relationship Management (CRM) solution. Several Open Source CRM are currently available on the market, such as vTiger (https://www.vtiger.com), SugarCRM (https://www.sugarcrm.com) and Odoo (https://www.odoo.com). Such CRM should be analysed according to the key requirements for the federation management. A number of key requirements include:

- **Customer Helpdesk Management:** i.e. the ability to track all the customer requests in relation to its infrastructure order.
- **Customer Quotation Management:** i.e. the ability to provide customers with quotation for a specific infrastructure configuration fulfilling their requirements.
- **Customer Billing Management:** i.e. the ability to create an invoice to a customer based on its usage of the infrastructure.

Among the above Open Source solutions, at the time being the most promising solutions for Fed4FIRE federation services seems to be Odoo. Odoo offers the following interesting features:

- APIs for Customer Billing Management and Customer Helpdesk Management; this would simplify the integration with Fed4FIRE APIs, allowing for example to create quotation

Co-funded by the Horizon 2020 Framework Programme of the European Union

requests from the Fed4FIRE catalogue and insert them in Odoo where they will be managed. Customers will be able then to get notification related to the quotation and any other issue related to their account directly from Odoo.

- Support for multi-vendor companies in a single set-up; this will allow to support scenarios in which the Billing rather than being processed by the Federation, will be done directly by the single Infrastructure provider.
- Integration with online payment solutions such as PayPal; this will allow to charge online the customers based on the services they acquired.

Odoo supports the creation of projects attached to customers, where it is possible to define tasks associated with customer's project (e.g. provide vm) and issues (e.g. a given help desk request). Further, it supports to track issues, create invoices and can help in the billing process. A number of these functionalities is shown in the screenshots below.

4.2.2.1 Track Tasks and Issues

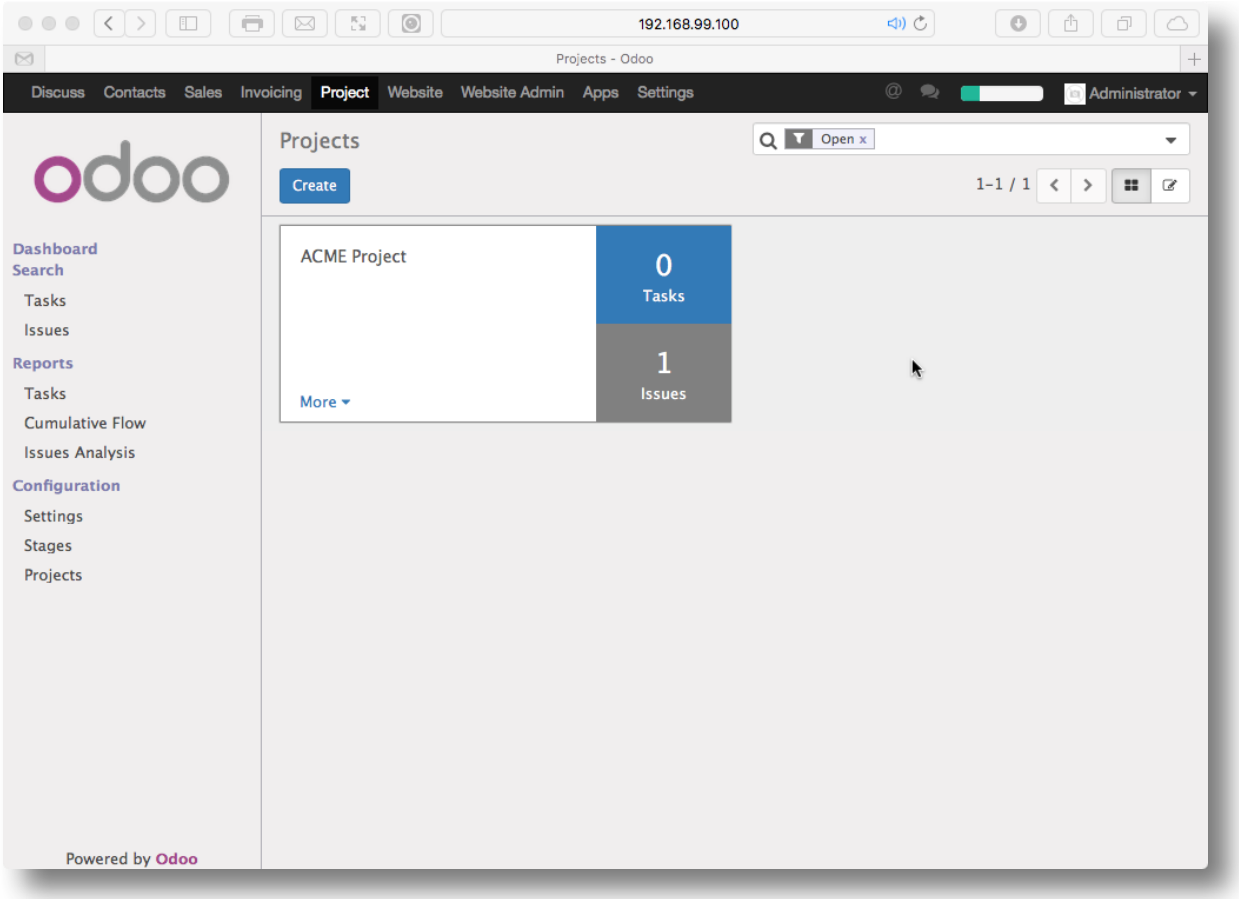


Figure 21: Odoo Project Management

Co-funded by the Horizon 2020 Framework Programme of the European Union

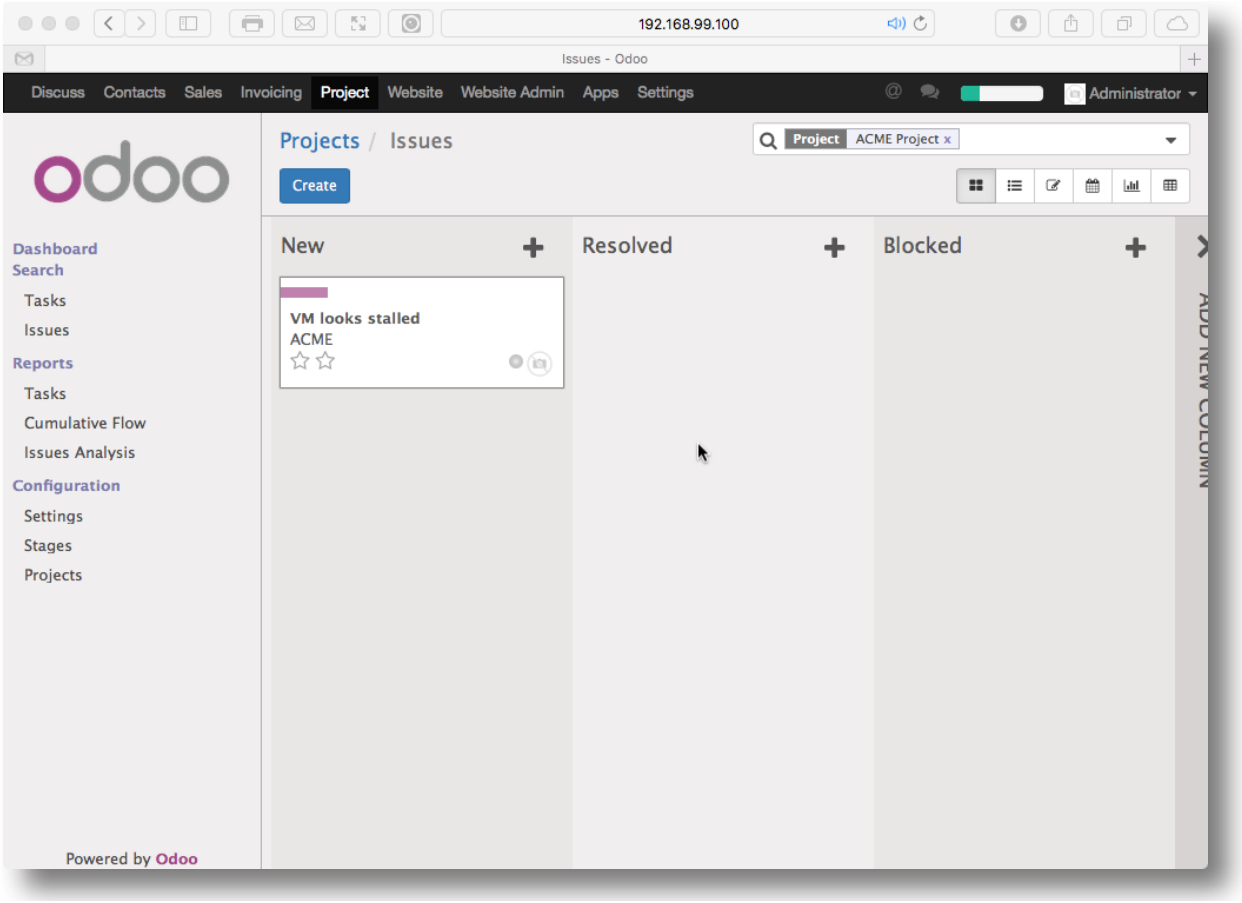


Figure 22: Odoo Issue Management

4.2.2.2 Products and Quotations

Co-funded by the Horizon 2020 Framework Programme of the European Union

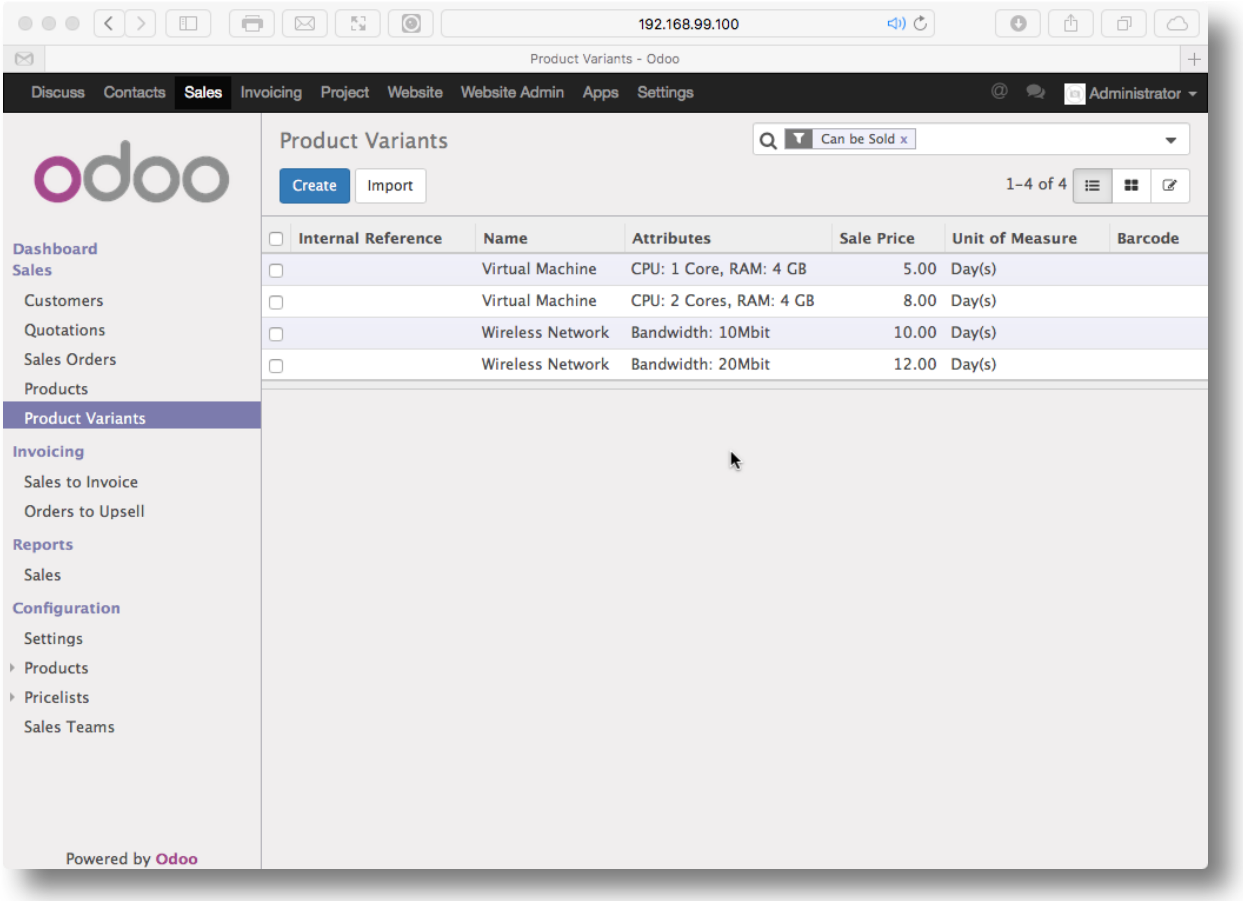


Figure 23: Odoo Product (i.e. Service) Management

Co-funded by the Horizon 2020
Framework Programme of the European Union

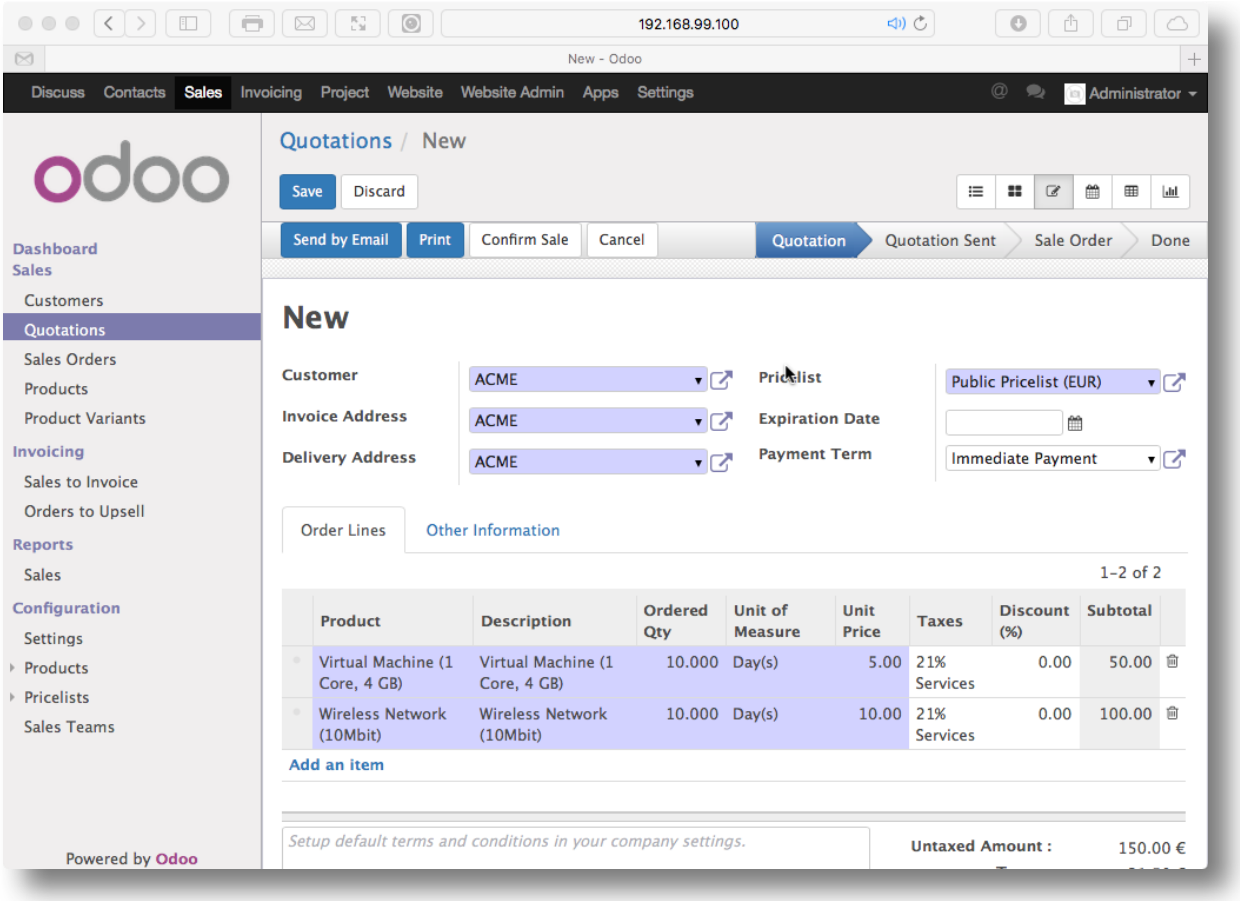


Figure 24: Odoo Quotations

Co-funded by the Horizon 2020 Framework Programme of the European Union

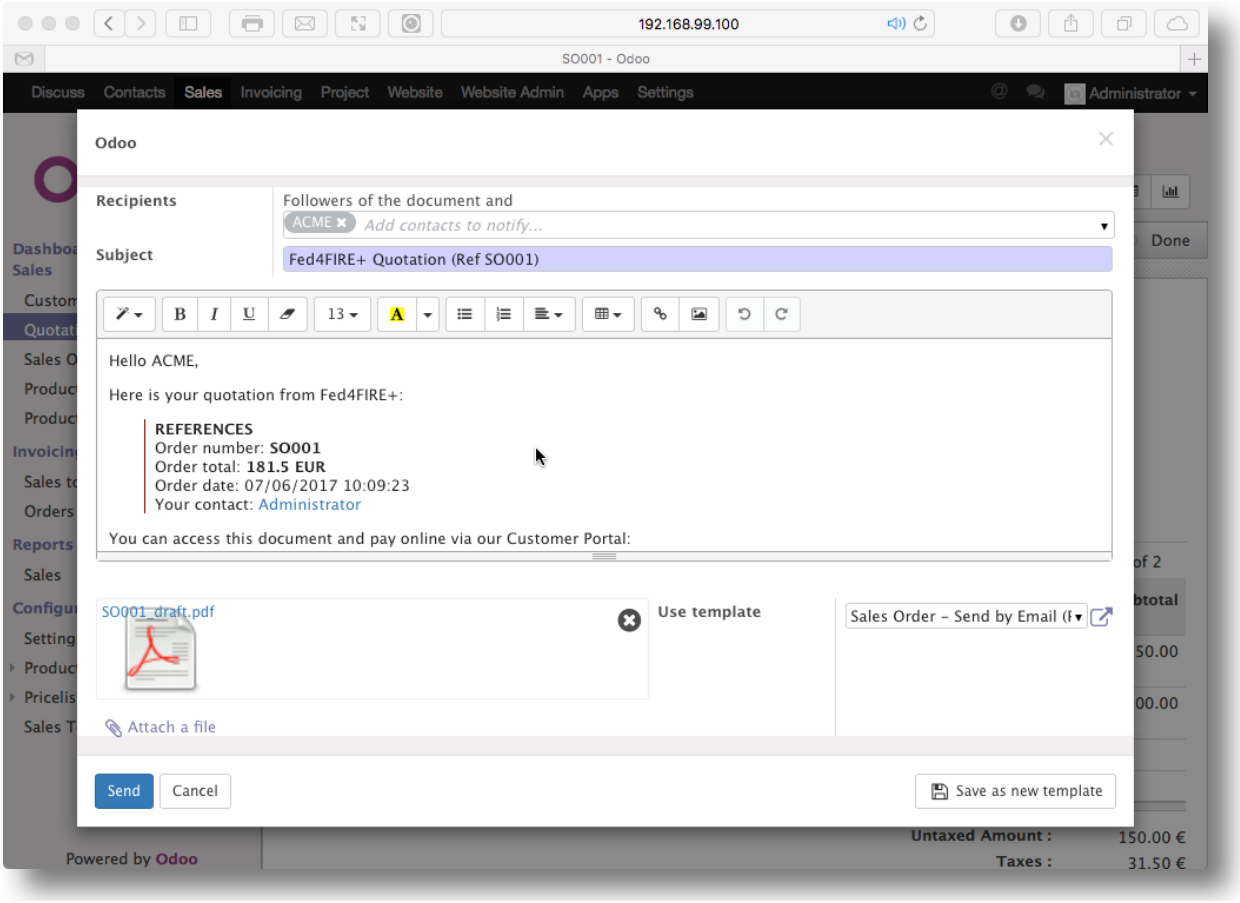


Figure 25: Odoo Mail Support

Co-funded by the Horizon 2020 Framework Programme of the European Union

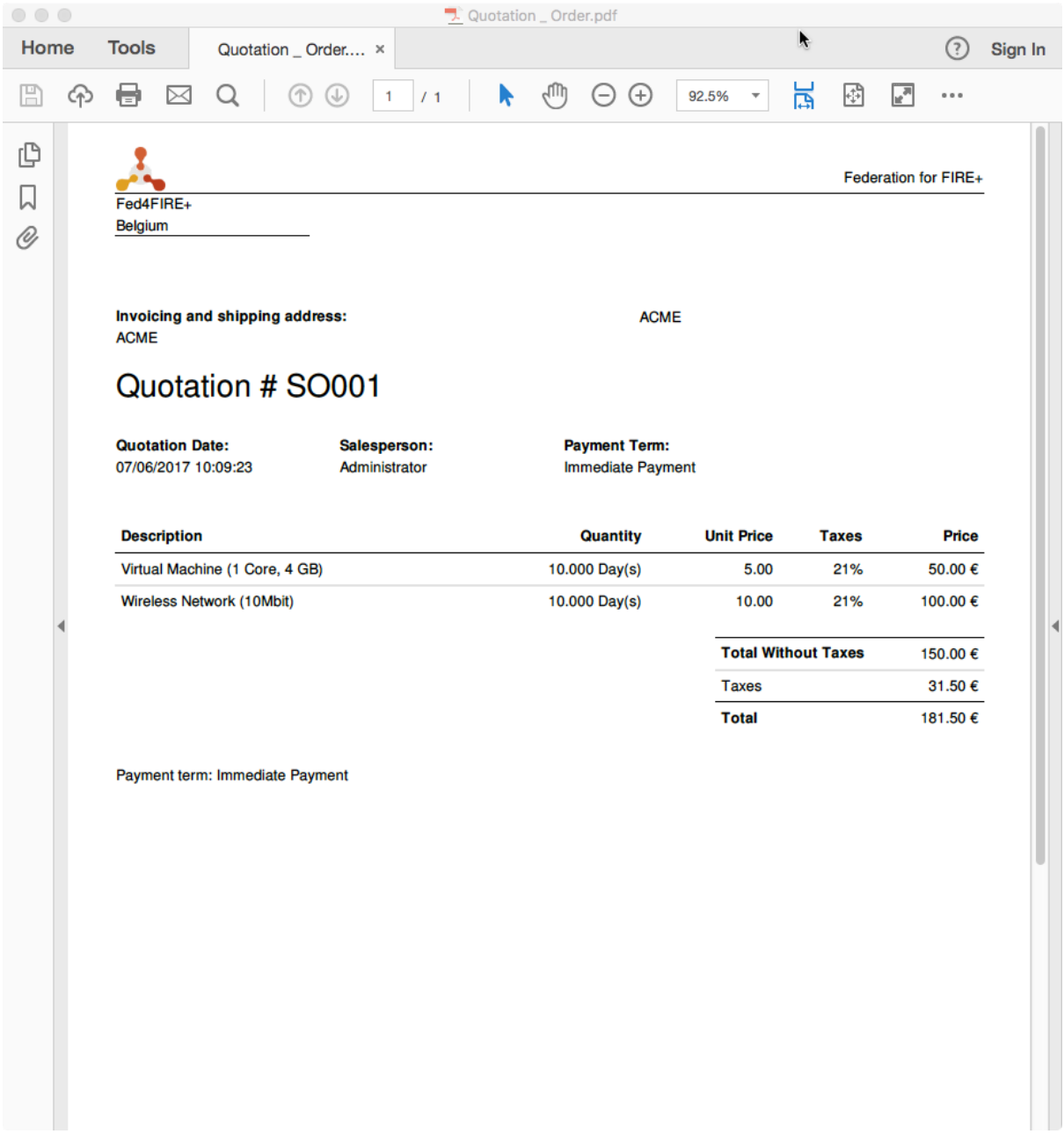


Figure 26: Odoo Example Quotation

4.2.2.3 Customer Login and Payment

Co-funded by the Horizon 2020 Framework Programme of the European Union

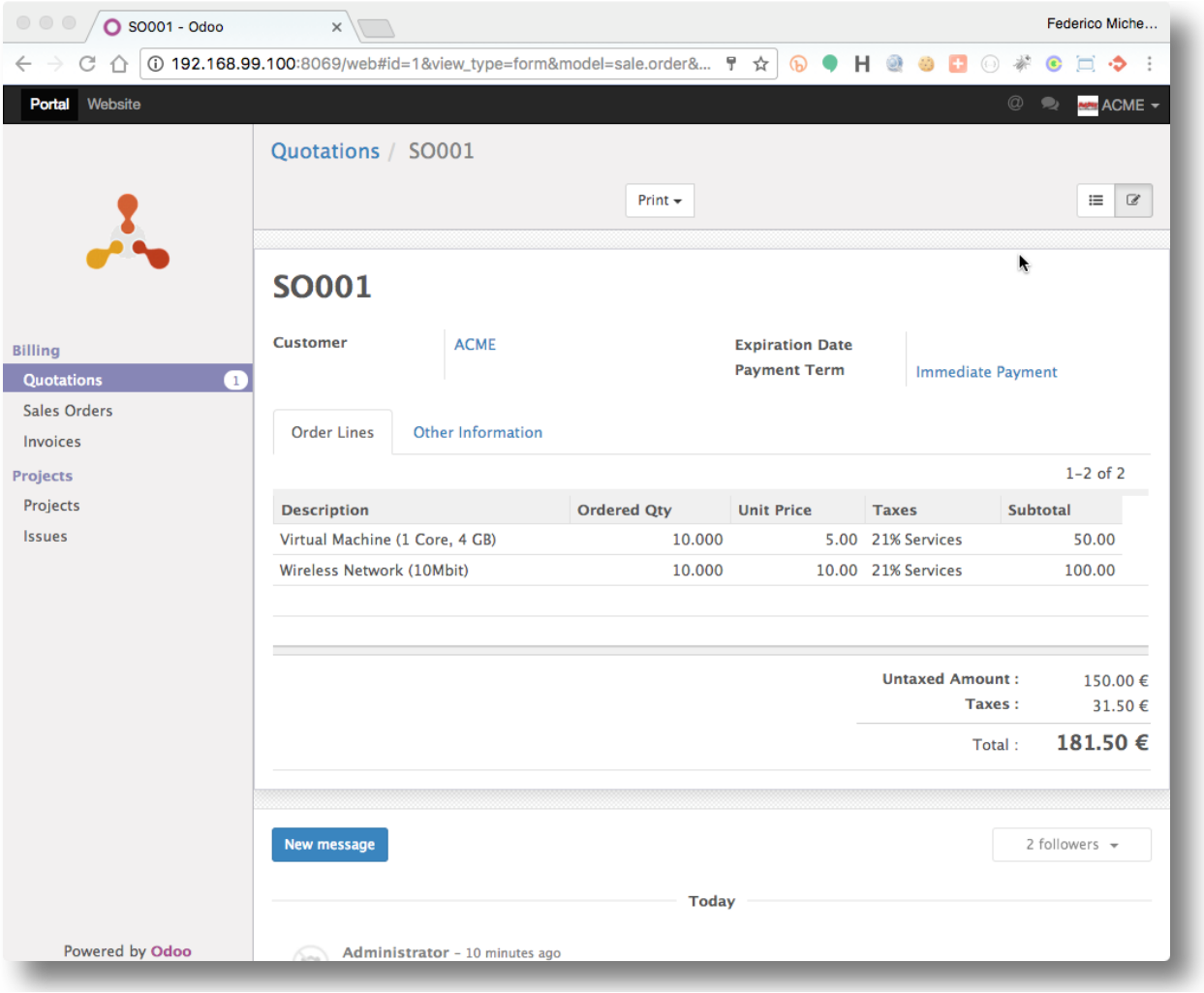


Figure 27: Odoo User Login

4.2.2.4 Invoicing

Once quotation are converted into sales, invoices can be created and sent to customers, including online payment details.

Co-funded by the Horizon 2020 Framework Programme of the European Union

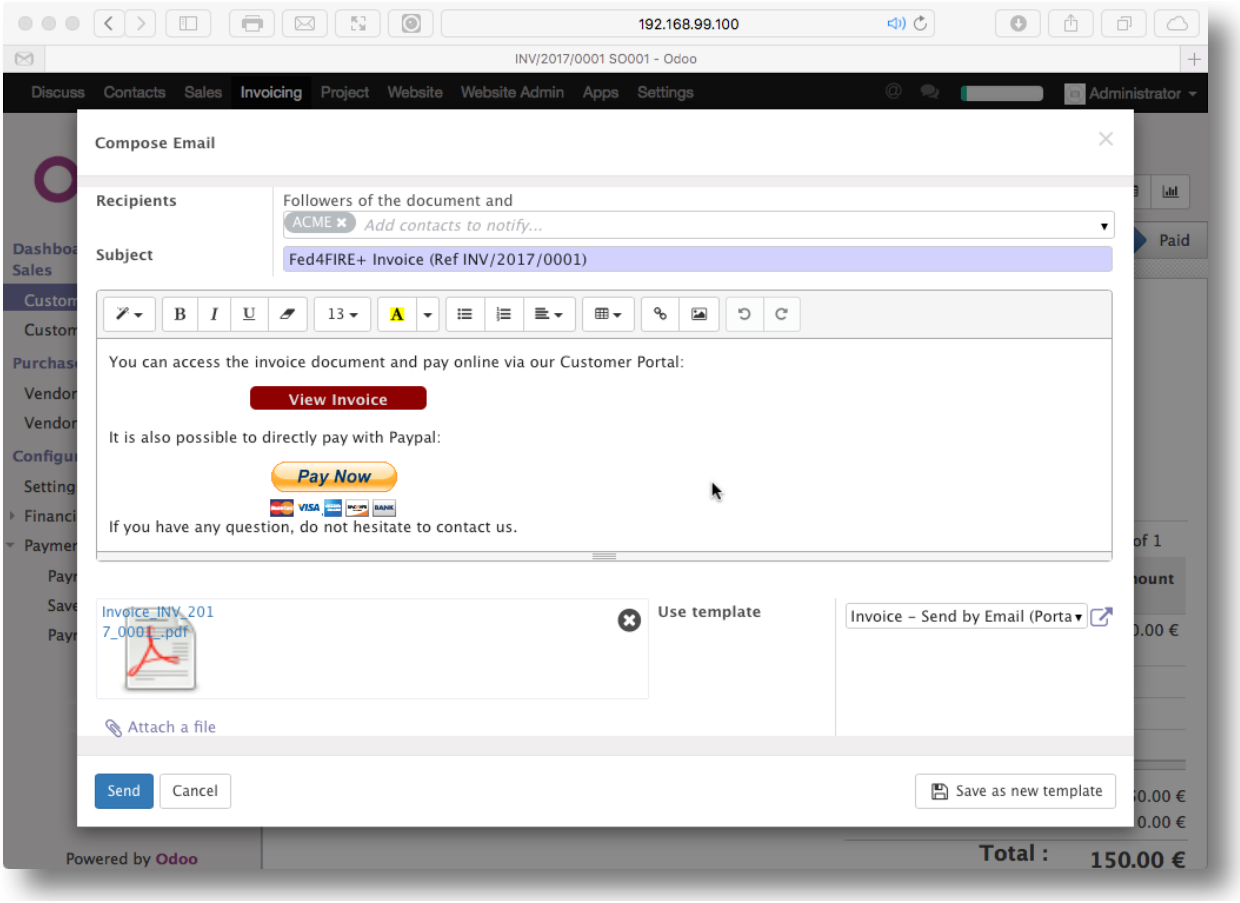


Figure 28: Odoo Invoice

4.2.3 Service Catalogue

Services (i.e. technical and non-technical offerings) that are available within the federation are offered by the involved testbeds. Within Fed4FIRE an according architecture has been designed and implemented (Figure 29). Within the Federation layer the service discovery, future reservation broker, authority directory, testbed directory, member authority and tool directory are existing components that can act as valuable input for the WP4 service catalogue.

Co-funded by the Horizon 2020
Framework Programme of the European Union

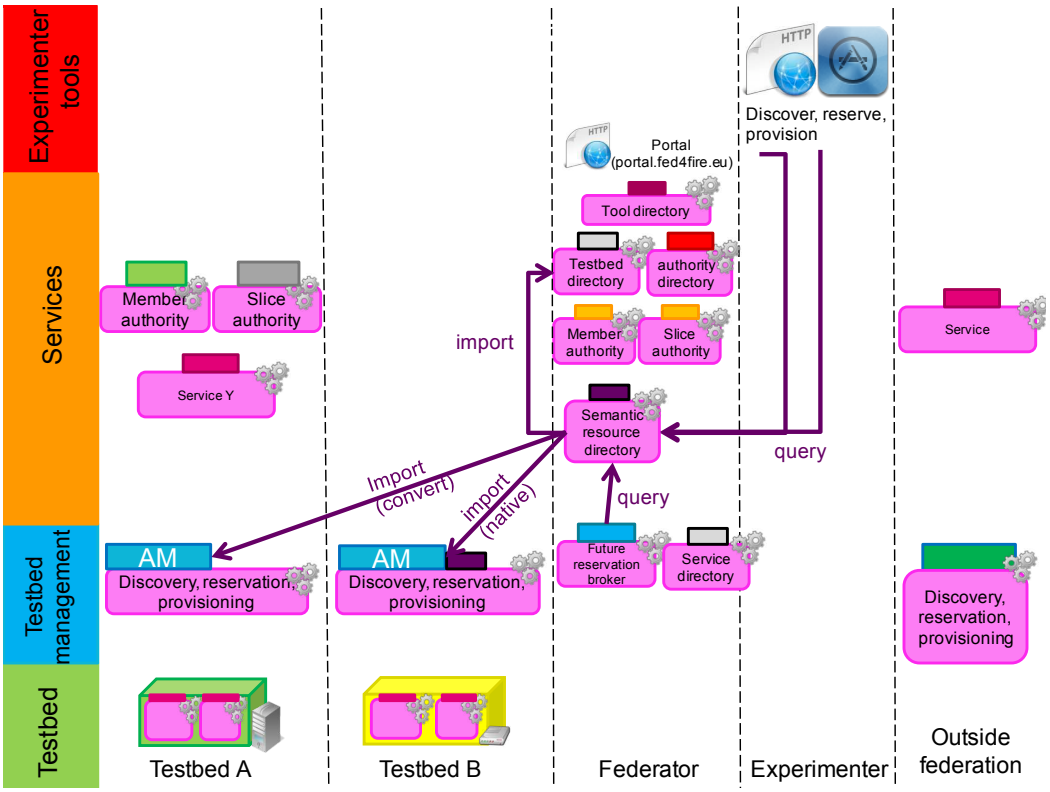


Figure 29 Fed4FIRE Architecture (Lobillo, et al., 2013)

In terms of implementation details, it is expected to work closely with Fed4FIRE Task 3.5 in order to harmonize and link information from these available sources, to aggregate the data in a semantic resource directory and allow intelligent queries / matchmaking processes. Additionally, each testbed should be provided by means to automatically publish further services and related details that have not been in the focus of Fed4FIRE and earlies FIRE projects. As testbed providers are potentially a great source of scientific knowledge and often conduct vendor-independent research themselves, they can offer consulting, development and testing services to customers. While the description and publication of these services might not depend on the extension of the already existing Aggregate Managers (AMs), the description should be provided in a machine-readable format and support/tools shall be provided by WP4.

A starting point for this work has been developed within Fed4FIRE and can directly integrated with MySlice. In its core information about the federation is encoded in a semantic

Co-funded by the Horizon 2020 Framework Programme of the European Union

database that can be queried (see Figure 30) of visualized as HTML (see Figure 31) or Graph (see Figure 32).

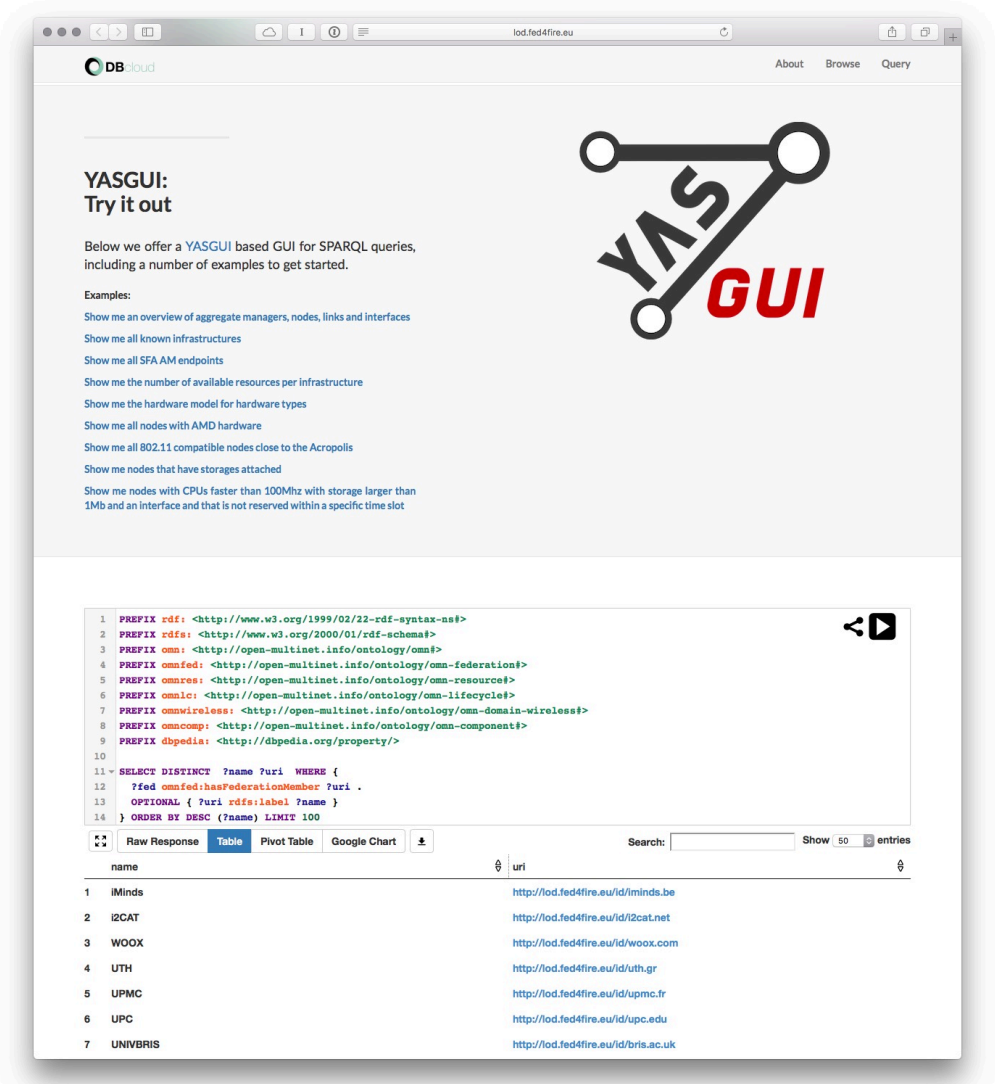


Figure 30: Catalogue Query

Co-funded by the Horizon 2020 Framework Programme of the European Union

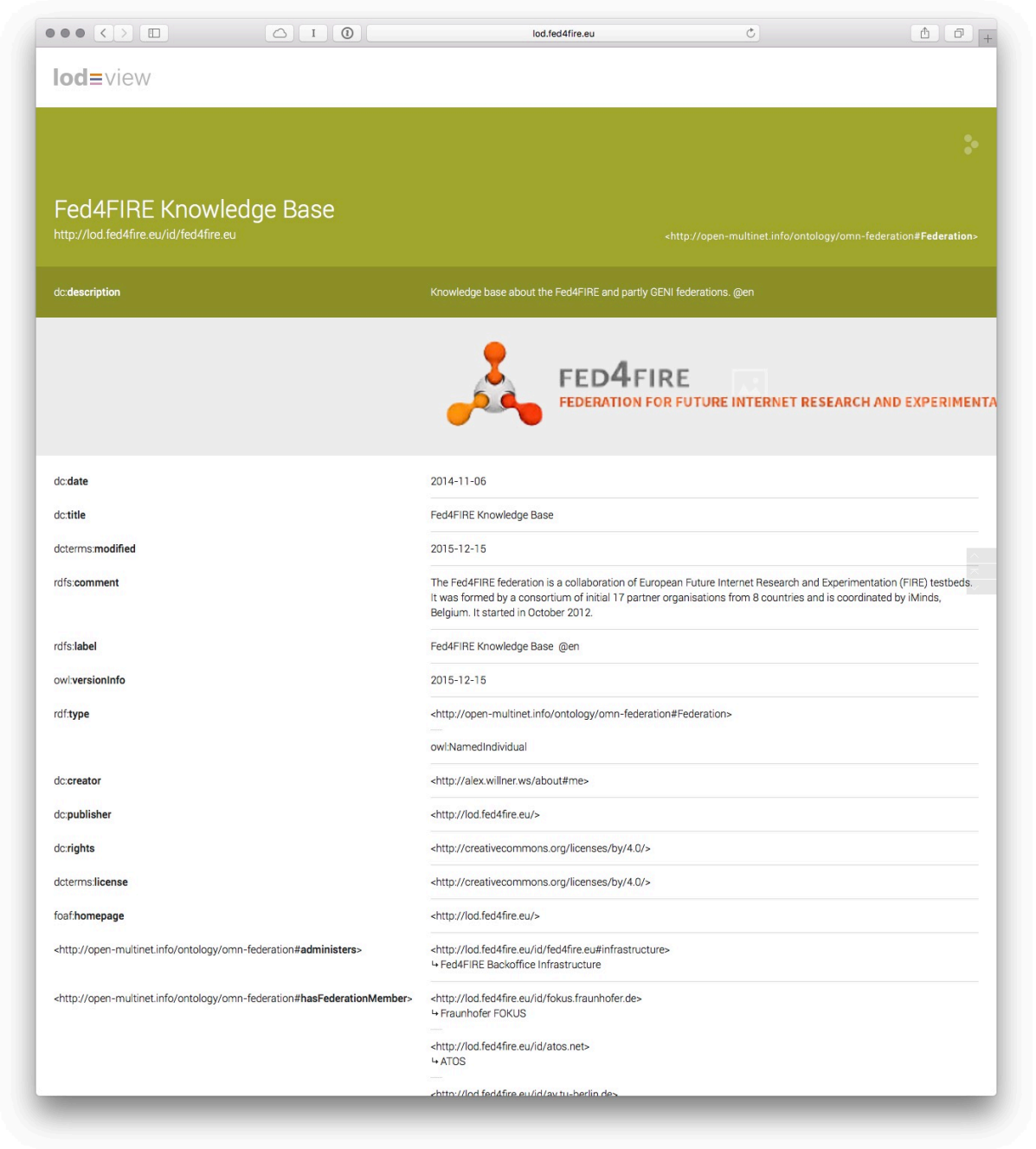


Figure 31: Catalogue HTML Visualization

Co-funded by the Horizon 2020
Framework Programme of the European Union

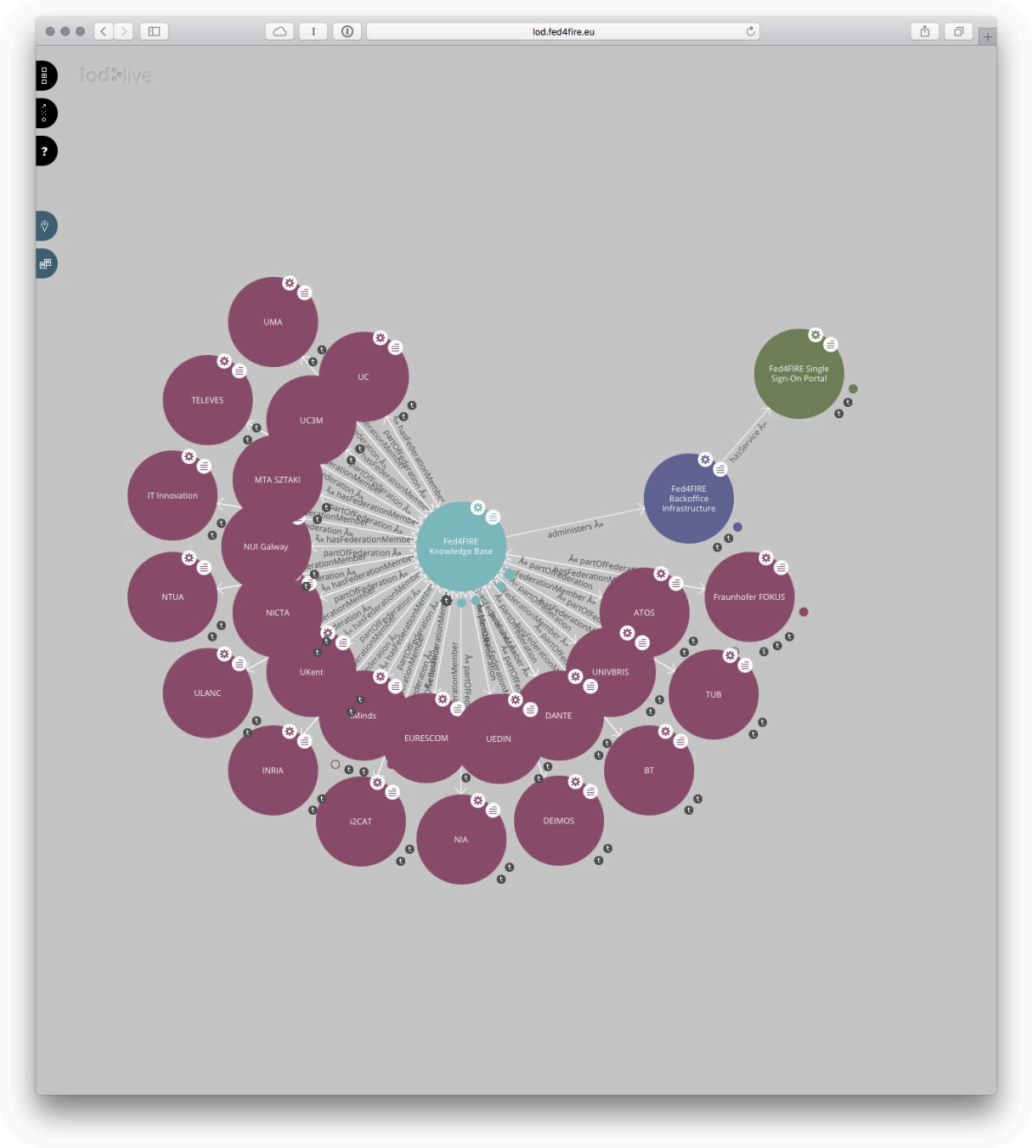


Figure 32: Catalogue Graph Visualization

Co-funded by the Horizon 2020 Framework Programme of the European Union

5 CONCLUSIONS

The goal of this deliverable was to describe the lessons learned from other projects, to provide a gap analysis and to outline an initial integration plan. As a result and after a short overview of the related work, the results of the FanTaaStic and FedSM projects have been described and adopted to discuss a concept for the operation of a partly self-sustainable semi-commercial federation.

In particular the relevant business roles, services and requirements have been identified and, following the eTOM business framework, the relevance and implementation efforts of 31 distinct processes have roughly been estimated. The identification of currently missing functionalities for rolling out and operating European ICT research testbeds on a commercial basis was an important first step. By utilizing TMForum's eTOM model, we identified currently missing functionalities and we took into account a broad spectrum of operational processes usually required for running a service-oriented, (telecommunication) service providing enterprise (mainly related to QoS assurance, SLA management, billing and charging, customer relationship management, selling, order handling, marketing and testbed provider compensation).

Whereas we achieved to identify currently missing gaps at a level of granularity, useful for determining the immediate next steps, full specification of a Fed4FIRE+ wide operational and business workflows, will require evaluation of possible solutions, selection of appropriate candidates and detailed planning of their integration into already available systems. However, based on these insights, an initial integration plan has been presented that includes three major components: an initial user-friendly entry point for customers, a customer relationship management system to handle incoming requests and a catalogue of federation wide services for intelligent matchmaking processes.

Future steps foresee significant enhancement of the commercial parts of Fed4FIRE+, which are (but not limited to):

- Improvements of the customer facing Interface for enhanced Billing, Payment and Charging.
- Improvements of the SLA management, i.e., mechanisms for customer retention and loyalty, that are assuring that customers will not get charged (rather compensated) for service level violations
- Enhanced federation-wide Fault Management mechanisms.
- Improvement of a portal/marketplace (enhanced resource descriptions, matchmaking, testbed & resource registration, means for Testbed & Resource instance rating & recommendation), including mechanisms and a forum for customers, testing community self-help and self-management.

Co-funded by the Horizon 2020 Framework Programme of the European Union

6 WORKS CITED

Appleton, O. (2012). *D3.1: Business models for Federated e-Infrastructures.* FedSM.

Bub, U., & Woesner, H. (2009). The National Beta Platform, Repository and Infrastructure for Sustainable Research Environments. Kassel,: Gesellschaft für Informatik (GI).

Campowsky, K., Magedanz, T., & Wahle, S. (2010). Resource management in large scale experimental facilities. (pp. 930-933). IEEE.

Coplien, J. O., & rnvig, G. B. (2010). *Lean Architecture: for Agile Software Development.* Wiley.

Crowcroft, J., & Demeester, P. (2009). Towards a collaboration and high-level federation structure for the FIRE Facility.

eTOM, E. T. (2007). eTOM Solution Suite (GB921) Release 7.0. *TeleManagement Forum,[TMForum].*

Freeman, S., & Pryce, N. (2009). *Growing Object-Oriented Software, Guided by Tests.* Addison-Wesley Professional.

Gavras, A., Bruggemann, H., Witaszek, D., Sunell, K., & Jimenez, J. (2006). Pan European Laboratory for Next Generation Networks and Services. (pp. 436-441). IEEE.

Gavras, A., Magedanz, T., Wahle, S., Hrasnica, H., Avéssta, S., & Imbeaux, J.-C. (2008). *Deliverable D2.1: Legal Framework.* Panlab.

Imbeaux, J.-C., Gavras, A., Hrasnica, H., Wahle, S., Martinot, O., & Avéssta, S. (2007). *Deliverable D2.1: Vision for a Pan-European Laboratory (Version 2).* Panlab.

Jacobson, I., Christerson, M., & Jonsson, P. (1992). *Object-oriented software engineering - a use case driven approach* (4. A. ed.). Reno,: ACM Press.

Lobillo, F., Sawyer, M., Taylor, S., Kavoussanakis, K., Lanza, J., Muñoz, L., . . . Margery, D. (2013). *Deliverable D4.1: First input from community to architecture.* Fed4FIRE.

Martin, R. C. (1996). The dependency inversion principle. *8*(6), 61-66.

Martin, R. C. (2003). *Agile Software Development: Principles, Patterns, and Practices.* Upper Saddle River, NJ, USA: Prentice Hall PTR.

Palermo, J. (2008). The Onion Architecture. *The Onion Architecture*.

Scognamiglio, C., Sioutis, M., Vandenberghe, W., Bouckaert, S., Ntofon, O.-D., Androulidakis, G., . . . Niavis, H. (2013). *Deliverable D3.1: Infrastructures Community Federation Requirements, Version 1.* Fed4FIRE.

Staiger, U. (2008). MAMSplus-Individuelle Dienste für jedermann. VDE VERLAG GmbH.

Tselentis, G. (2009). *Towards the Future Internet: A European Research Perspective.* IOS Press.

Co-funded by the Horizon 2020 Framework Programme of the European Union

Vandenberghe, W., Vermeulen, B., Demeester, P., Willner, A., Papavassiliou, S., Gavras, A., . . . Androulidakis, G. (2013). Architecture for the Heterogeneous Federation of Future Internet Experimentation Facilities.

Wahle, S., Harjoc, B., Campowsky, K., & Magedanz, T. (2010). Pan-European testbed and experimental facility federation–architecture refinement and implementation. *5*(1), 67

Co-funded by the Horizon 2020
Framework Programme of the European Union

7 APPENDIX

7.1 MYSLICE FUNCTIONAL COMPONENTS

7.1.1 SFA Registry

This module provides a registry service as specified by the SFA. It can be queried by the MySlice core as well as by remote registries and provides information about the SFA objects which this domain is responsible for.

7.1.2 MySliceLib

This module supports the interaction of MySlice with multiple Aggregate Managers that are part of a federation of testbeds.

7.1.3 MySlice Backend

This module support all the advanced functionality provided by MySlice, such as, the distributed management of queries, asynchronous handling of the queries, caching of the results.

7.1.4 MySlice Frontend

This module realize the front-end that exposes the underlying MySlice functionality to various

users/experimenters.

7.2 MYSLICE GUI SCREENSHOTS

MySlice is composed of a modern web fronted (please see screen shots below).

Co-funded by the Horizon 2020
Framework Programme of the European Union

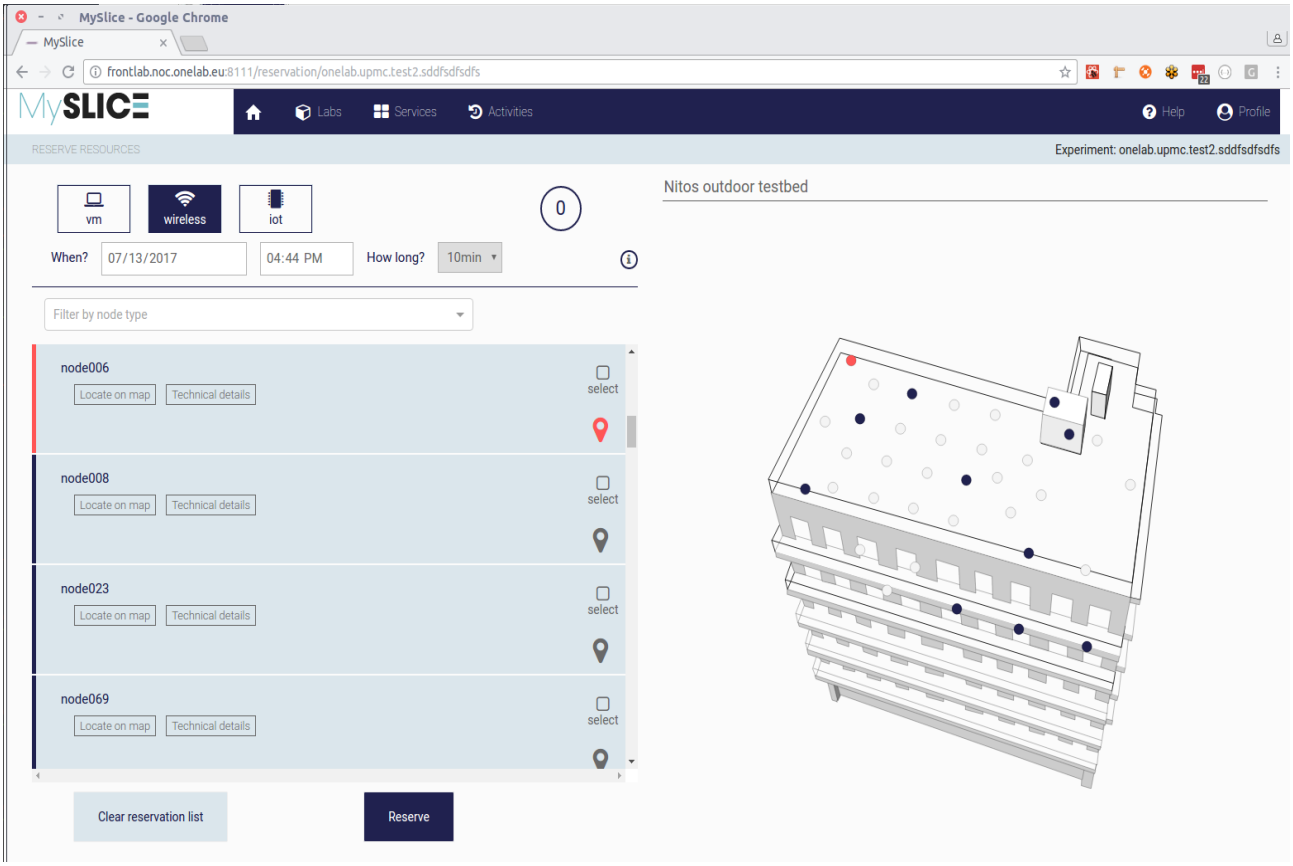


Figure 22: MySlice reservation WIFI resource

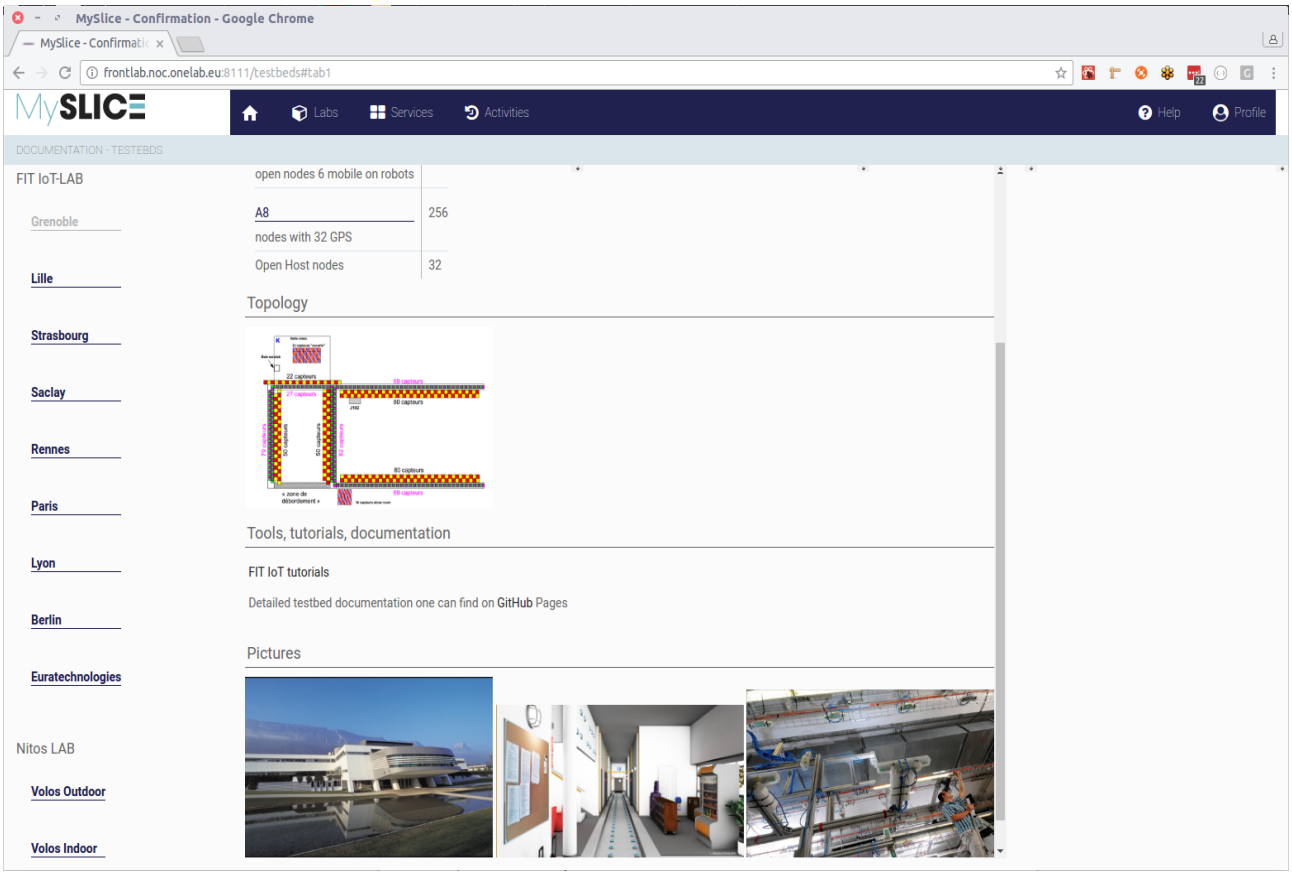


Figure 24: MySlice testbed description

Co-funded by the Horizon 2020 Framework Programme of the European Union

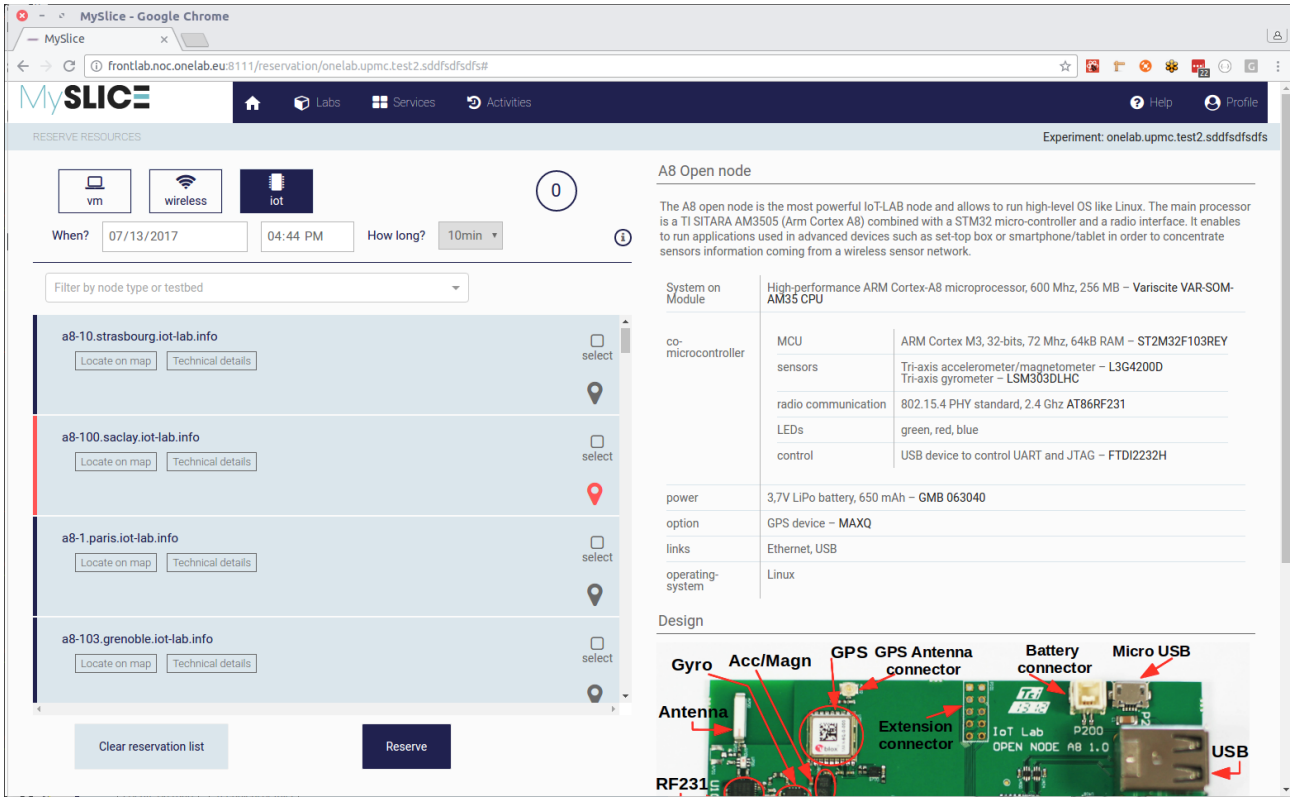


Figure 33: MySlice IoT Reservation IoT Resource

Co-funded by the Horizon 2020 Framework Programme of the European Union