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FESTIVAL: Heterogeneous Testbed Federation Across Europe and Japan

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Abstract

FESTIVAL is an H2020 EU-Japan collaborative project that aims to federate heterogeneous testbeds, making them interoperable and building an "Experimentation as a Service" (EaaS) model. Going beyond the traditional nature of experimental facilities, related to computational and networking large scale infrastructures, FESTIVAL testbeds have heterogeneous nature and in order to be federated they have been clustered in four categories: "Open Data" (i.e. open datasets), "IoT" (i.e. sensors and actuators), "IT" (i.e. computational resources) and "Living Labs" (i.e. people). Considering that every testbed category provides specific resources, the main challenge for FESTIVAL is to develop a platform that can allow experimenters to access very different assets in an homogeneous and transparent way, supporting them in the phases of the experiments. The FESTIVAL architecture, based on a multi-level federation approach, proposes a solution to this problem providing also a set of functionalities to manage and monitor the experiments. FESTIVAL tools, also,

include the possibility to access FIWARE Generic Enablers allowing to deploy predefined components to address specific needs in the experimentation (e.g. data analysis, big data management etc.). The FESTIVAL platform will be tested on three different smart city domains across Japan and Europe: smart energy, smart building and smart shopping.

28.1 Introduction

There have been long years of research work in Europe and Japan on federation of testbeds. More recently this research also involved Internet of Things (IoT) paradigm that is radically changing the way we interact with daily life objects at various environments such as home, work, transportation and city. FESTIVAL [1] is a H2020 European-Japanese collaborative project that aims to federate heterogeneous (IoT) testbeds, making them interoperable and building an "Experimentation as a Service" (EaaS) model. The objective of the project is also to facilitate the access to those testbeds to a large community of experimenters allowing them to perform their experiments taking benefit of various software and hardware enablers provided both in Europe and in Japan. FESTIVAL testbeds will connect cyber world to the physical world, from large scale deployments at a city scale, to small platforms in lab environments and dedicated physical spaces simulating real-life settings.

This chapter will describe the results achieved in the first 18 months of the FESTIVAL project in terms of platform design and development and use case and experiments definition. The first section of the chapter introduces the experimental testbed involved in the project that will be federated through the FESTIVAL platform: the testbeds have heterogeneous nature and, in order to be federated, they have been clustered in four categories: "Open Data" (i.e. open datasets), "IoT" (i.e. sensors and actuators), "IT" (i.e. computational resources) and "Living Labs" (i.e. people). The Section 28.2 presents the FESTIVAL EaaS approach, description of the main components of the architecture and the different federation layers: from the federation of the same resource types to the homogenous representation of all the heterogeneous resources in a common data model. The third section describes the technical details of the refe rence implementation of the architecture composed by both existing software components and new ones specifically developed for FESTIVAL. Section 28.4 presents the typical experiment workflow that can be performed by the experimenters using the FESTIVAL functionalities through a dedicated experimentation portal. The Section 28.5 describes the use case domains and some specific experiments that will be executed during the project. The last section

presents some conclusions related to the work performed, also indicating the next steps to be achieved in the following phases of the FESTIVAL project.

28.2 FESTIVAL Experimental Testbeds

FESTIVAL project aims to federate distributed and heterogeneous testbed among Europe and Japan. The different testbeds involved due to their heterogeneous nature have been classified in four different categories: Open Data, IoT, IT and Living Labs. In this document the specific testbeds included in these four clusters are presented.

28.2.1 Open Data Oriented Testbeds

Open Data oriented testbeds provide the experimenters with (Linked) Open Datasets. Open Data oriented testbeds consist in Open Data Management systems, specific web platforms, based on different technologies, designed to manage open datasets in various formats. In FESTIVAL there are four main platforms: Santander Datos Abiertos [2], Metropole of Lyon's Open Data [3], FIWARE Lab Data Portal [4] and FESTIVAL Japanese open data portal [5].

Santander Datos Abiertoss provided by Santander City Council, is a CKAN [6] based platform that includes Open Data about transport (e.g. buses, taxis, traffic information), urban planning and infrastructures (e.g. parks and gardens location, municipality buildings), shops, demography (current and historic census), society and well-being, culture and leisure (labour calendar and cultural programming). Metropole of Lyon's Open Data is related to the municipal territory of Lyon and provides wide-ranging access to public data such as the land register map for the conurbation, the surface area taken up by greenery, the availability of shared bikes or the locations of automatic car-sharing stations, real-time traffic data, highway events and traffic history. FIWARE Lab Data Portal is a CKAN based platform that provides a huge amount of data from different smart cities collected by FIWARE generic enablers instances [7]; FESTIVAL Japanese open data portal represents the CKAN node that will be used to collect the open data results of the use case experimentations and applications deployed in Japan.

28.2.2 IoT Oriented Testbeds

IoT oriented testbeds are physical places in which sensors or other smart objects are deployed, these can be part of experiments in order to gather data or to perform actions. IoT oriented testbeds in FESTIVAL are: iHouse [8]

(Ishikawa, Japan) an experimental smart house facilities built by ISICO (Ishikawa Sunrise Industries Creation Organization); Connectivity Technologies Platform (PTL) [9] (Grenoble, France), a facility to test connectivity technologies in real environments, SmartSantander [10] (Santander, Spain), an experimental test facility for the research and experimentation of architectures, key enabling technologies, services and applications for the Internet of Things in the context of a city; ATR Data Center [11, 12], an experimental data center facility that aims to reduce total energy consumption using specific monitoring technologies and prediction algorithms; Maya & Kameoka Stations [13–15] two Japanese railways smart stations equipped with an environmental monitoring sensors network (pollen, PM2.5, vibration, acceleration, noise, temperature).

28.2.3 IT Oriented Testbed

IT oriented testbeds provide virtualised IT resources such as virtual machines or virtual networks that can be used by the experimenter to deploy and execute software components and applications for their experiments. In particular, in FESTIVAL the two main IT oriented testbeds are JOSE platform and the Engineering FIWARE-Lab.

JOSE (Japan) [16] provides a Japan-wide open testbed, which consists of a large number of wireless sensors, SDN capabilities and distributed "CLOUD" resources. The facilities of JOSE are connected via high-speed network with SDN features.

The FIWARE-Lab (Italy) [17] is an instance of FIWARE based on a cloud environment allowing users to deploy, configure and execute a set of Generic Enablers. The cloud infrastructure is based on OpenStack [18], an open source software for creating cloud platforms. This specific FIWARE-lab instance is will provide specific computational resources dedicated to the FESTIVAL project.

28.2.4 Living Lab Testbed

Living Lab testbeds are represented by the living labs participating in FESTIVAL project, that provide services, people and physical places to experimenters in order to perform different activities (e.g. service co-design with user involvement, event organisations, expert consultant etc.). Living labs and services they provide have an important role in experiments because they allow the active participation of people and experts with specific skills in the activities related to experiments. The two Living Labs involved in the

FESTIVAL project are The Lab [19] (Osaka, Japan) and TUBA [20] (Lyon, France). The Lab constitutes a space where general public (such as researchers, creators, artists, students, citizens) can experience the latest technologies and have interactions with exhibitors. Communicators are the specialised staff who bring visitors together to The Lab with other people, things, and information and play the role of gathering the comments and reactions of visiting members of the public, and feeding this information back to companies, researchers, and other event organizers.

TUBA, which stands for "Experimentation Urban Test Tube", is operated by Lyon Urban Data: an association based on a mixed consortium of public and private entities. TUBA is a 600 m^2 place dedicated to experimenting new services and helping developing new projects (from start-ups to SMEs and large companies) based on data.

28.3 EaaS Model and FESTIVAL Federation

The main concept behind the design of the FESTIVAL architecture is the definition of an Experimentation as a Service (EaaS) model and its realization through a multi-level federation approach.

The adoption of the EaaS model aims to implement a platform that allows experimenters to create replicable and scalable experiments and to access very different testbeds in a homogeneous and transparent way, supporting them in all the phases of the experiments.

Starting from a set of homogeneous access APIs, namely FESTIVAL EaaS APIs, the platform supports experimenters in performing and managing multi-domain experiments. It provides discovery functionalities to find resources matching requirements for their experiments and the ability to analyse results collected during the execution of experiments.

This objective is achieved by structuring the FESTIVAL architecture with two levels of federation: the first one federates the resources of the same categories ("resource-based" federation) and the second one provides unified access to them ("experiment-based" federation).

The Figure 28.1 depicts the high level overview of FESTIVAL architecture that presents the EaaS Model and the different federation levels.

At the lowest layer, the figure shows all the testbeds involved in FES-TIVAL, and classified according to a specific typology: Open Data, IoT, IT and Living Lab. The first federation level, "resource-based federation", provides functionalities for the integration and harmonization of each types of resource, using ad-hoc components called *Aggregators*. Each Aggregator
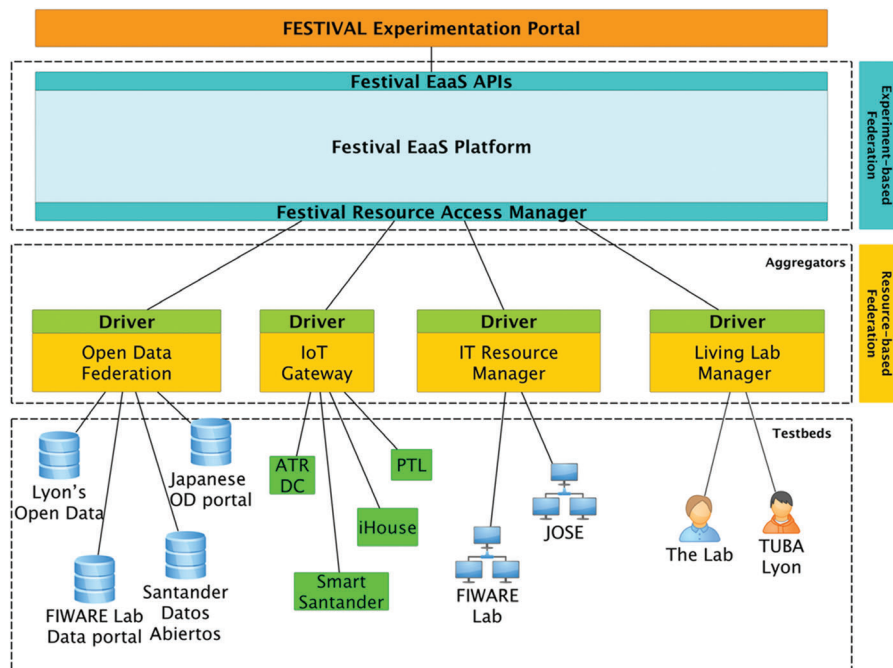
Figure 28.1   FESTIVAL architecture.

is independent from the FESTIVAL platform and federates resources of the same type, providing a common data model describing them in a uniform way.

FESTIVAL supports the following aggregators:

- **Open Data Federation**: it is the component in charge of federating different Open Data Management Systems (ODMS), providing functionalities to search generic open data and to perform queries on Linked Open Data (e.g. RDF).
- **IoT Gateway**: this component provides a uniform access to different IoT devices such as sensors or more generally smart objects, supporting different IoT protocols.
- **IT Resource Manager**: this component realizes the federation of computational resources, and in particular it is in charge of managing all the aspects related to the reservation and access of the virtual machines.
- **Living Lab Manager**: this component is able to federate living labs considering their services, methodologies used and expertise of its members as resources that can be involved in an experiment. The component allows to manage all of these living lab assets in a uniform way.

FESTIVAL platform is designed to be flexible and scalable: it is able to federate new types of resources, in addition to the already supported ones, adding new instances of aggregators of the same categories or completely new ones. (e.g. support more IoT devices adding more IoT gateway aggregators).

The aggregators are connected to the FESTIVAL platform through their specific "drivers" which are in charge of translating the heterogeneous resources in the "FESTIVAL resource data model" that will be used in the upper layer. FESTIVAL resource data model is designed to represent heterogeneous types of resources in the same way and at the same time to maintain their specific peculiarities.

Translation performed by drivers completes the federation process, allowing to the **FESTIVAL EaaS layer** to implement the "experiment-based federation", managing the resources without taking into account their different nature. The **FESTIVAL EaaS layer** contains the core components of the platform and manages the resources in all the phases of an experiment, executing the business logic to create and define the experiment, to access and reserve the resources and finally to execute and monitor the experiment. All the EaaS layer functionalities are accessible by external applications through a set of APIs (FESTIVAL EaaS API). FESTIVAL in particular provides the **Experimentation portal**, a web application designed to facilitate experimenters in the managing of their experiments and in the discovery of resources provided by the different federated testbeds.

28.4 FESTIVAL Reference Implementation

The following section presents some of the most relevant technologies and components used to implement the FESTIVAL architecture already presented in the previous sections:

28.4.1 Aggregators

The aggregators represent the components that federate the resources of a specific category of testbeds. The concrete components that implements the aggregators in the FESTIVAL reference implementation are the following:

Federated Open data platform: it is the component that implements the open data federation. It is an open source server-side JEE based components that is able to connect, to retrieve, search and visualize datasets of different types coming from open data repositories using specific connectors. It supports connectors for CKAN and SOCRATA [21] portals, but new open data nodes

based on different technologies can join the federation by implementing specific REST API (Federation API). The platform includes also the Federated Open Data Catalogue, a web interface allowing end users to access directly to the Open Data Federation functionalities.

SensiNact Platform [22] is the gateway responsible for the aggregation of the IoT resources. SensiNact supports different protocols and API layers such as MQTT, REST API, JSON-RPC and Bluetooth 4.0, among others. In order to aggregate the IoT FESTIVAL testbeds, new bridges have been developed, which communicate with the testbeds resources: KNX Bridge connects SensiNact to PTL testbeds, using the KNX Worldwide Standard for Home and Building Control [23]; Orion Bridge connects SensiNact to SmartSantander testbeds, using the Orion Context Broker [24], a Generic Enabler provided by FIWARE; EchoNet Bridge: this bridge connects SensiNact to EchoNet Lite devices. EchoNet Lite [25] is a communication protocol developed in Japan focused in devices for SmartHome; OpenHab Bridge/Discovery: this bridge connects SensiNact to OpenHab [26] (a platform to control Smart Objects) running instances in the local network and provides access and discovery capabilities to items configured in OpenHab as devices into SensiNact.

SFA aggregator: it aims at federating IT virtual resources, that in the projects are provided by JOSE and FIWARE-Lab testbeds. In the perspective of reusing solutions already implemented in other FIRE initiatives, the approach followed is the implementation of a SFA [27] (Slice-based Federation Architecture) component for OpenStack, a solution implemented in other international research projects and more recently in the Fed4Fire European project [28]. Different implementation of this framework are available and among them, SFAWrap [29] was chosen as basis for FESTIVAL IT Aggregator. SFAWrap uses a specific driver to communicate with OpenStack services via Python API.

Living Lab Manager is the component in charge of managing the living labs federated in FESTIVAL. It has been implemented as a Java EE application that provides a set of APIs to add, update and delete living labs data in the federation.

The Living Lab Manager manages living labs and their resources according to a specific data model designed in the FESTIVAL project; this data model defines resources of living labs in terms of their main assets. The resources identified are:

- Services: identifies which activities can be performed in the Living Lab.
- Methodologies: each service can be composed by one or more tasks that can be executed by using specific methodologies.
- Expertise: special skills and knowledge of the members of the Living Lab (e.g.: legal expertise, social science, user-centred design, etc...).
- LL communities/stakeholder groups: from the experiment point of view it is important to define some features that the people involved in the LLs task should have, by identifying specific stakeholder groups.

The interactions between the experimenter and the Living Labs have to be managed differently than other aggregators because a Living Lab involves human resources, so the process cannot be completely automated. Living Lab manager provides functionalities to manage requests coming from experimenters in order to define and confirm participation in the experiment, through an asynchronous communication process.

FESTIVAL platform provides a set of specifications, Driver APIs, to federate Aggregators. Each aggregator has to implement this set of APIs, using their specific technologies exposing them as REST services. This mechanism allows to federate any kind of aggregator with minimal effort, because only the implementation of the corresponding driver is required.

28.4.2 FESTIVAL Resource Model

In order to integrate and harmonize the different types of resources that will be available and accessed through FESTIVAL platform, a common representation of them was investigated and a specific model was defined: FESTIVAL Resource Model.

The FESTIVAL Resource Model is composed of two sections: a general section containing a list of attributes to provide generic information in order to allow the identification of the resources in the system. In particular, a combination of three IDs (IDs of the resource, the testbed and the aggregator as assigned by the driver) identifies univocally each resource available in FESTIVAL platform. The second one is a custom section containing a list of attributes allowing experimenters to know the right way to manage the resource in the experiment: the actions that an experimenter can perform on the resource, additional information useful to manage the resource and a state variable that informs the experimenter about the possibility or not to lock the resource for a period of time for an exclusive access.

28.4.3 FESTIVAL EaaS Platform

The FESTIVAL Platform provides to the experimenters the core functionalities to create, manage and monitor experiments using the resources of the federated testbeds: the main EaaS platform modules are:

Platform Administration: it is in charge of providing the specific functionalities to manage the platform, such as assignment of given roles to the platform experimenters and performing actions on existent experiments such as extending the duration or deleting an experiment.

Experiment Control: this module is responsible for taking care of all activities linked to the experiment execution: execution control, resource allocation and failure control.

Resource Access Manager: it manages the access to the resources. The module provides the business logic to perform the corresponding requests to the different drivers.

Experiment Monitoring: this module will provide experimenter with the possibility to monitor the experiments in the platform. To manage collecting of measures, FESTIVAL platform provides an OML server [30].

Storage Service: the role of this module is to normalize the data access and manage the connection to the databases. Every EaaS module usee the storage service to store and retrieve platform data.

Analysis and Software Tools Repository: it provides a repository of several software and analysis tools to support experiments; in addition to this, the module manages some predefined VM templates that include specific libraries or services useful for the experimenter (e.g. instances of FIWARE GE).

EaaS KPI Monitoring: this module interacts with other EaaS modules to centralize the KPI measurement features. The general approach for KPI measurement collection is to implement a "probe" to related EaaS module that raises the necessary data using EaaS API or other technologies (e.g. sniffer). This data is then sent to the EaaS KPI Monitoring module to be analysed.

Security: it is the module in charge of providing the Authentication, Authorization and Accounting for the FESTIVAL platform. The implementation follows an approach based on PeP Proxy [31] using Keyrock [32] as authentication system.
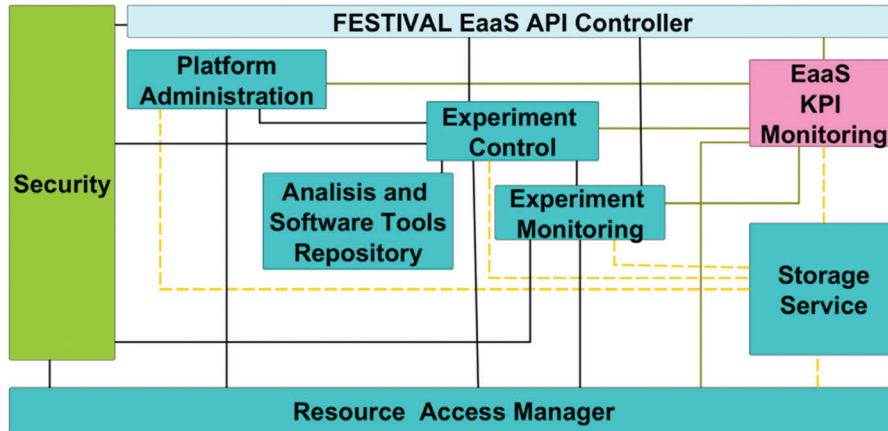
Figure 28.2 FESTIVAL EaaS platform modules.

FESTIVAL platform provides a REST interface represented by EaaS APIs to enable experimenters and in general any client application to access and to interact with FESTIVAL platform and to manage experiments and resources involved in their execution. The EaaS Controller manages the request to the API performing security access and redirecting it to the underlying EaaS modules.

28.5 FESTIVAL Portal and Experiment Workflow

The FESTIVAL experimenter portal is the main access point to the platform for new experimenters. Its main purpose is to provide a graphical user interface to the experimenter in order to use the EaaS platform functionalities. In particular, the user will be able to perform generic experiments that are based on a typical workflow composed by four different phases, as explained below:

Account creation and documentation: firstly, the experimenter will access to the experimentation portal to learn about the resources offered in the platform, as well as the testbeds that have been federated. Afterwards, if he/she wants to continue with the experiment in FESTIVAL, he/she will be requested to create an account to obtain the credentials to access the experimenter API. Finally, the experimenter will have access to the documentation of the EaaS API and to access the resources.

Experiment definition: during this phase, the experimenter will have the opportunity to create a new experiment, define its characteristics, (e.g. title and description) select the resources that will be used to perform the experiment and include the other experimenters that will be part of it. The experimenter will be able to search through the federated resources and lock them, whenever the resources are available, in the chosen time period and the experimenter has the required rights.

Execution of the experiment: at the beginning of this third phase, the experimenter will trigger the final reservation of the resources, including the instantiation of the VMs and the subscription to different information elements (sensors). This is the longest phase and it will last until the experiment time period is over. In the meanwhile, the experimenter will be able to add resources or remove those previously reserved. Furthermore, it will be also possible to communicate with the living labs managers to request the involvement, in the experiment, of real end-users if needed. During this phase the monitoring of the experiments is also performed in terms of resource availability and collection of results.

End of the experiment: the last phase of an experiment over the EaaS FESTIVAL platform is the conclusion of the experiment and obtaining results. The experiment can terminate when: 1) the experimenter considers that the experiment being performed is finished even if the time planned is not over; 2) the defined time period for the experimenter is finished and it is automatically stopped. Once an experiment is considered as finished, the platform will release the involved resources, which entails closing all the remaining subscriptions, deleting the VMs that were instantiated, and stopping the FESTIVAL functionalities used by the experimenter.

28.6 FESTIVAL Use Case Experiments

As one of the main pillars of the FESTIVAL initiative, the project envisions the development and research of several experiments in three domains, which are described below.

- **Smart Energy**: this domain includes the experiments that deal with energy management, and energy savings related to the modification of different actuators. The experiments consider the automation of energy distribution and consumption based on the measurements provided by IoT devices.

- **Smart Building**: this domain includes all the related applications in building automation in different building facilities, such as houses or big buildings. Automation processes are performed by interpreting values returned for IoT devices using different techniques, such as machine learning.
- **Smart Shopping**: this last domain refers to all applications relating to shopping areas. The applications found in this domain envision to improve the relationship of the customers and the shopping area, by taking different measurements such as customer position or environmental parameters. In addition, it aims at improving direct communication of customers and shop owners through new channels, such as smartphones.

Within the framework of the different domains, the experiments serve also as an example of what can be done using the EaaS FESTIVAL platform. Among others, the description of some of the experiments being carried out in FESTIVAL can be found below.

In the Smart Energy domain, the "xEMS" project aims at reducing the power consumption of data centres. This is carried out implementing machine learning techniques to modify the local energy management system depending on the conditions of the data centre, which are provided by the deployed sensors. The "SNS-like EMS", or social networking system for energy management, is also another example of the use of different sensors that are deployed in several locations within the same building to reduce power consumption. In this case, data is gathered not only from the sensors but also from the users that shares their perception through chat-based messages. Both experiments take advantage of the existing facilities in FESTIVAL, such as the Knowledge capital living lab or the ATR data centre. Furthermore, the platform also provides the infrastructure to deploy the applications to process the algorithms.

Regarding the Smart Building domain, there are several experiments being carried out in the facilities of FESTIVAL. The "Smart Camera" experiments take advantage of the PTL facility for the tests, where modified cameras gather specific image features, avoiding privacy issues, to perform statistical analysis, such as counting people or providing signals to actuators. Other experiment related to the Smart Building domain is the "Smart Station". This experiment consists in the deployment of sensors in some railways stations in Japan, in order to retrieve environmental parameters and other data, such as occupancy or traffic information for multimodal transportation.

Finally, there are several projects under the Smart Shopping paradigm. One of them, the "Connected Shop" experiment intends to analyse the Probe Request packets sent by the IEEE 802.11 interfaces, found in all the smartphones nowadays, to locate customers and predict their behaviour. Other parameters, such as humidity and temperature are also considered in this experiment, which take advantage of the EaaS FESTIVAL platform to access to the sensor data and make use of the storage capabilities. In this sense, also using the processing capabilities from the IT testbed federated in FESTIVAL to perform highly demanding processing capabilities, the "Smart Shopping System and Recommendation Analysis" applies big data techniques to Smart Shopping applications. The goal of this experiment is to obtain the customers' preferences and the best configurations for the exhibitors to increase the customer attention and hence the the sales.

28.7 Conclusions

This chapter has shown the progresses of the FESTIVAL project, in particular in terms of design and implementation of the testbed federation platform. As shown, the project tried to propose a solution in the field of testbed federation with a specific focus on IoT: the novelty of the solution proposed by FESTIVAL is specifically related to the problem of the heterogeneity of the testbeds involved, going beyond the traditional federation of estbed that provides virtual computational resources. FESTIVAL defines an architecture that harmonises very different resources that include open data, IoT devices, cloud IT resources and human resources.

The FESTIVAL reference implementation, developed using new technical solutions and existing relevant Japanese and European assets, will provide to the experimenters with the possibility to access to heterogeneous large scale testbeds to perform experiments in different domains (e.g. Smart Energy, Smart Building, Smart shopping). The platform will be released for project members by October 2016 and will be freely accessible for external experimenters by January 2017: in this second part of the project all the technical achievements described in this chapter will be validated by concrete use cases. This will demonstrate the impact of the FESTIVAL EaaS approach, on the number and quality of the experimentations that are run on the testbeds, thus presenting both small and large scale trials over various application domains.

Acknowledgments

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