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Training, Consulting, Testing and Validation V2

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V09	Tiago Teixeira	UNPARALLEL	2018/06/21	Merge contributions
V10	Tiago Teixeira	UNPARALLEL	2018/06/22	Ready for submission

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TERMS AND ACRONYMS

API	Application Programming Interface
COAP	Constrained Application Protocol
CDMI	Cloud Data Management Interface
HTTP	Hypertext Transfer Protocol
IoT	Internet of Things
MQTT	Message Queuing Telemetry Transport
NGSI	Network Gateway Services Initiative
OC	Open-Call
REST	Representational State Transfer
RDF	Resource Description Framework
SOAP	Simple Object Access Protocol
TPI	Testbed Provider Interface
TPS	Testbed Provider Services
URI	Uniform Resource Identifiers
URL	Uniform Resource Locator
WP	Work Package
XMPP	Extensible Messaging and Presence Protocol

EXECUTIVE SUMMARY

This deliverable describes "Training, Consulting, Testing and Validation V2", being the 2nd version of the report on the work done in WP6. This document covers the topics: FIESTA-IoT Training Platform, FIESTA-IoT Training Workshops, the Follow-up Questionnaires to Experimenters and Extensions, the Final Report's Feedback and the IoT market Interoperability, Testing and Validation.

Chapter 1 covers in detail the FIESTA-IoT Training Platform which provides all the required information in order to use the FIESTA-IoT platform correctly. This training platform offers several and specific courses, that includes all the information of the "Handbook for Experts and Extensions" in a more dynamic and user-friendly approach.

During the last 39 months of the FIESTA-IoT project were organized specific Training Workshops in order to support the Experimenters and Extensions of the FIESTA-IoT Open-Calls and to present the FIESTA-IoT platform to third parties. The chapter 2 provides more information and all the material used on each of workshops.

Since this is the second release of this deliverable both the chapters (chapter 1 and 2) are respectively updated with new content. The courses previously presented are updated and the new courses are also presented. Also, all the information and content related to the Training Workshops of the latest FIESTA-IoT Open-Calls are provided.

Chapter 3 presents relevant information about the follow-up questionnaires made to the Experimenters and Extensions of each FIESTA-IoT Open-Call. These questionnaires had the objective of monitor the activities in the middle of the 6 months of the design and implementation phase of each Experimenter/Extension and evaluated if all the resources and material provided helped in their integration into FIESTA-IoT Platform.

Presented, in chapter 4, the results of the documentation extracted from the questionnaire that experimenters filled in their final reports. The results show the level of satisfaction of the experimenters in each of the Open-Call and how it evolved regarding the actions taken by the FIESTA-IoT consortium to improve the documentation.

Chapter 5 provides the FIESTA-IoT IoT Market Interoperability testing and validation analysis where is approached the IoT Interoperability Problem and the Certification of the FIESTA-IoT Specification Compliance.

1 TRAINING PLATFORM

The FIESTA-IoT Training platform is implemented through the Moodle learning platform[1], providing some helpful courses that offer information about the FIESTA-IoT platform, and describe how to use it correctly. Some courses were already available in the previous version of this deliverable. The new courses available are also presented in this deliverable.

Figure 1 - FIESTA-IoT Training Platform.

[1] https://moodle.org

The FIESTA-IoT Training Platform[2] provides resources and many types of material related to organisation and support of each FIESTA-IoT Open-Calls. These resources are categorised in the following courses:

- FIESTA-IoT: What is it?[3]: Is proposed to be used as a "Getting Started" guide, offering an overall description of the FIESTA-IoT project. It intends to provide a contextualization to FIESTA-IoT newcomers;
- Guide for 3rd Parties[4]: Intends to offer support to the FIESTA-IoT for 3rd parties, giving an overview of the FIESTA-IoT platform, detailed information on the FIESTA-IoT Security framework and extensive guides for 3rd parties Experimenters and for Testbed providers;
- FIESTA-IoT Open-Calls[5]: This course offers several support resources to the participants of the FIESTA-IoT Open-Calls;
- FIESTA-IoT Open-Call 1 – Extensions[6]: This is a private course, only accessible for the winners of the 1st Open-Call in the Extensions category;
- FIESTA-IoT Open-Call 1 – Experiments[7]: This is a private course, only accessible for the winners of the 1st Open-Call in the Experiments category;
- FIESTA-IoT Open-Call 2 – Extensions[8]: This is a private course, only accessible for the winners of the 2nd Open-Call in the Extensions category;
- FIESTA-IoT Open-Call 3 – Experiments[9]: This is a private course, only accessible for the winners of the 3rd Open-Call in the Experiments category;
- FIESTA-IoT Open-Call 4 – Experiments[10]: This is a private course, only accessible for the winners of the 4th Open-Call in the Experiments category;
- EVENT: FIESTA-IoT Hackathon - Experimentation-As-A-Service for Big IoT Testbed Data[11]: This is a private course, only accessible for the participants of the FIESTA-IoT Hackathon event "Experimentation-As-A-Service for Big IoT Testbed Data".
- EVENT: Semantic Interoperability of your Data[12]: This is a private course, only accessible for the participants of the FIESTA-IoT event "Semantic Interoperability of your Data".

[2] http://moodle.fiesta-iot.eu/

[3] http://moodle.fiesta-iot.eu/course/view.php?id=3

[4] http://moodle.fiesta-iot.eu/course/view.php?id=4

[5] http://moodle.fiesta-iot.eu/course/view.php?id=2

[6] http://moodle.fiesta-iot.eu/course/view.php?id=5

[7] http://moodle.fiesta-iot.eu/course/view.php?id=6

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[10] http://moodle.fiesta-iot.eu/course/view.php?id=9

[11] http://moodle.fiesta-iot.eu/course/view.php?id=11

[12] http://moodle.fiesta-iot.eu/course/view.php?id=10

1.1 FIESTA-IoT: What is it?

This "FIESTA-IoT: What is it?" course[13], shown in Figure 2, provides through the subsections all the fundamental documentation regarding FIESTA-IoT. In the "What is FIESTA-IoT" subsection it is described in detail the FIESTA-IoT main architecture, the access through a common Experiment-as-a-Service approach and the Interoperability Challenge of the FIESTA-IoT.

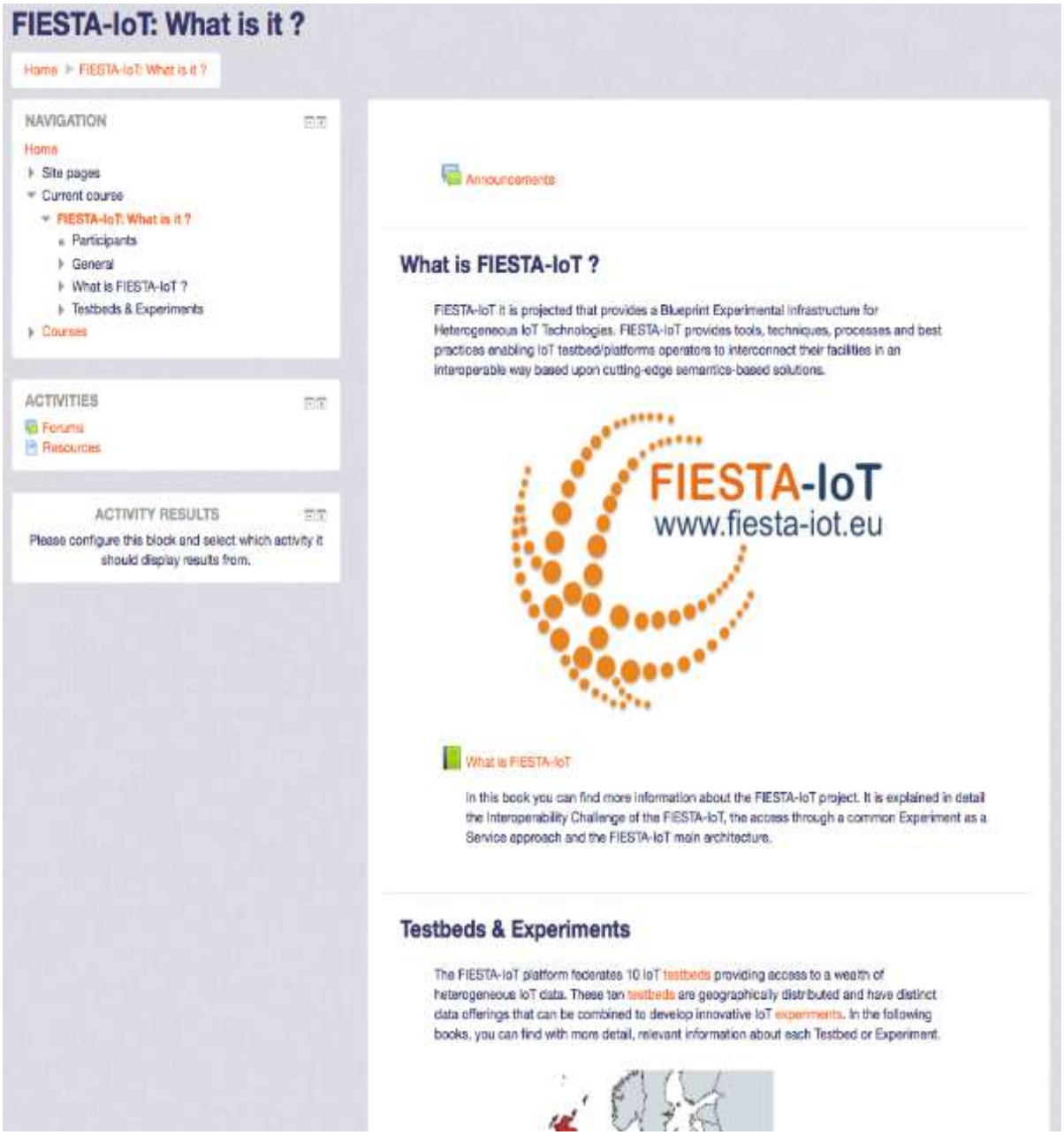


Figure 2 - Overview of the "What is FIESTA-IoT?" course

The FIESTA-IoT project has four in-house Testbeds and three in-house Experimenters and with the 4 Open-Calls made during the project, the number of testbeds increases to a total of 10 (4 in-house, 3 from OC1 and 3 from OC2).

[13] http://moodle.fiesta-iot.eu/course/view.php?id=3

In terms of Experimenters, the number increases to 27 (3 in-house, 6 from OC1, 13 from OC3 and 5 from OC4). This course provides a description of each Testbed and Experimenters within FIESTA-IoT Federation.

1.2 Guide for 3rd Parties

This course[14] is open to everyone and consequently no account or specific access permissions are required to access the training resources. It is composed by a range of section/subsections that covered essential information such as the FIESTA-IoT Overview, FIESTA-IoT Security Framework, Guide for Experimenters, Guide for Extensions, the FIESTA-IoT Workshops and the FIESTA-IoT Handbook.

The resources present on this course was regularly updated based on the "Handbook for Experimenters and Extensions", written by FIESTA-IoT consortium to provide guidelines to 3rd parties FIESTA-IoT platform users on how this platform works and on to use it.

Useful links

Provides an initial section, shown in Figure 3, with some helpful links to contact the FIESTA-IoT Open-Call Support team, the FIESTA-IoT GitHub page that can be used by the users to understand several characteristics of the FIESTA-IoT Platform, the link with relevant information about the FIESTA-IoT Help-Desk Support and the link to the FIESTA-IoT Platform.

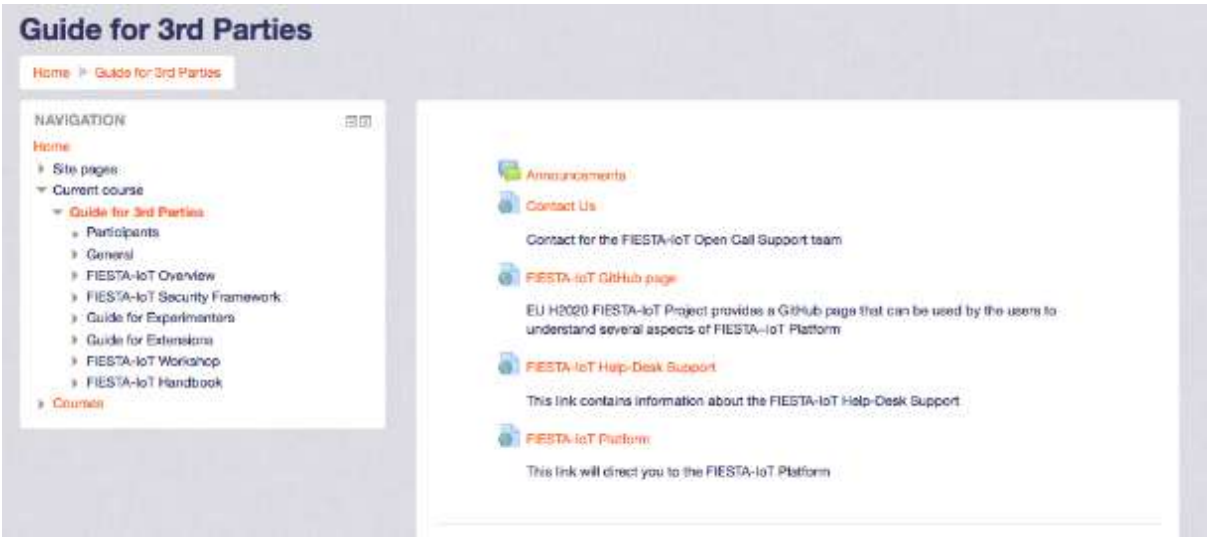


Figure 3 - Section with useful FIESTA-IoT links

FIESTA-IoT Overview

In the "FIESTA-IoT Overview" subsection[15], shown in Figure 4, a short introduction of the FIESTA-IoT platform is provided, highlighting the main external references that shall be taken into account (as support reading) such as API documentation, the

[14] http://moodle.fiesta-iot.eu/course/view.php?id=4

[15] http://moodle.fiesta-iot.eu/mod/book/view.php?id=110

FIESTA-IoT Web Portal and also external references that are recommended to be read before starting to play around with the platform.

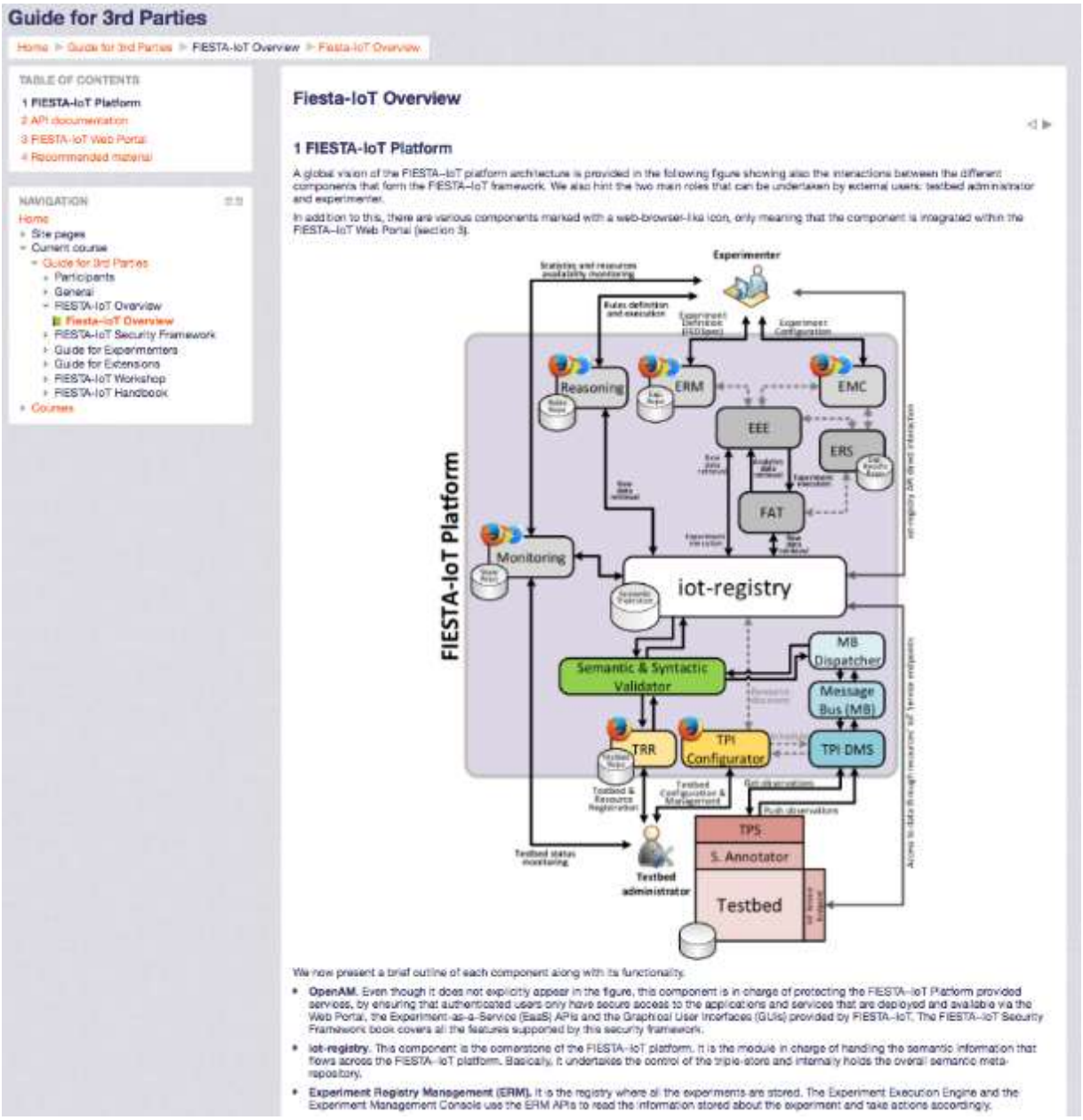


Figure 4 - FIESTA-IoT Overview subsection

FIESTA-IoT Security Framework

This "FIESTA-IoT Security Framework"[16] subsection, shown in Figure 5, presents the security processes of the FIESTA-IoT Framework that are common to administrators of Testbeds and Experimenters. The purpose of the information provided here is to guide on how to deal with all the process of the FIESTA-IoT authentication and authorization standpoint, covering the registration process, role definition, and subsequent use of user credentials to gain access to the FIESTA-IoT framework.

[16] http://moodle.fiesta-iot.eu/mod/book/view.php?id=106

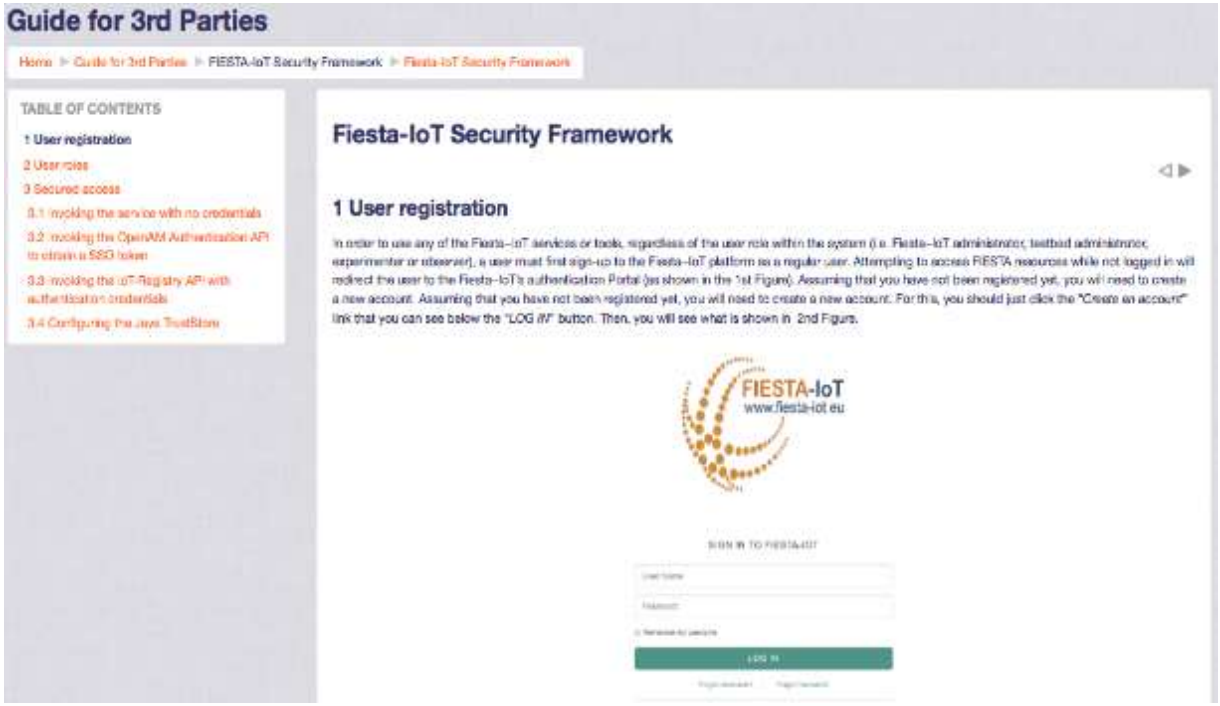


Figure 5 - FIESTA-IoT Security Framework subsection

Guide for Experimenters

This subsection[17] provides important information about the integration of Experimenters in the FIESTA-IoT Platform. A guide is provided to support in questions about the Experiment Management tools and IoT-Registry API for advanced experimenters.

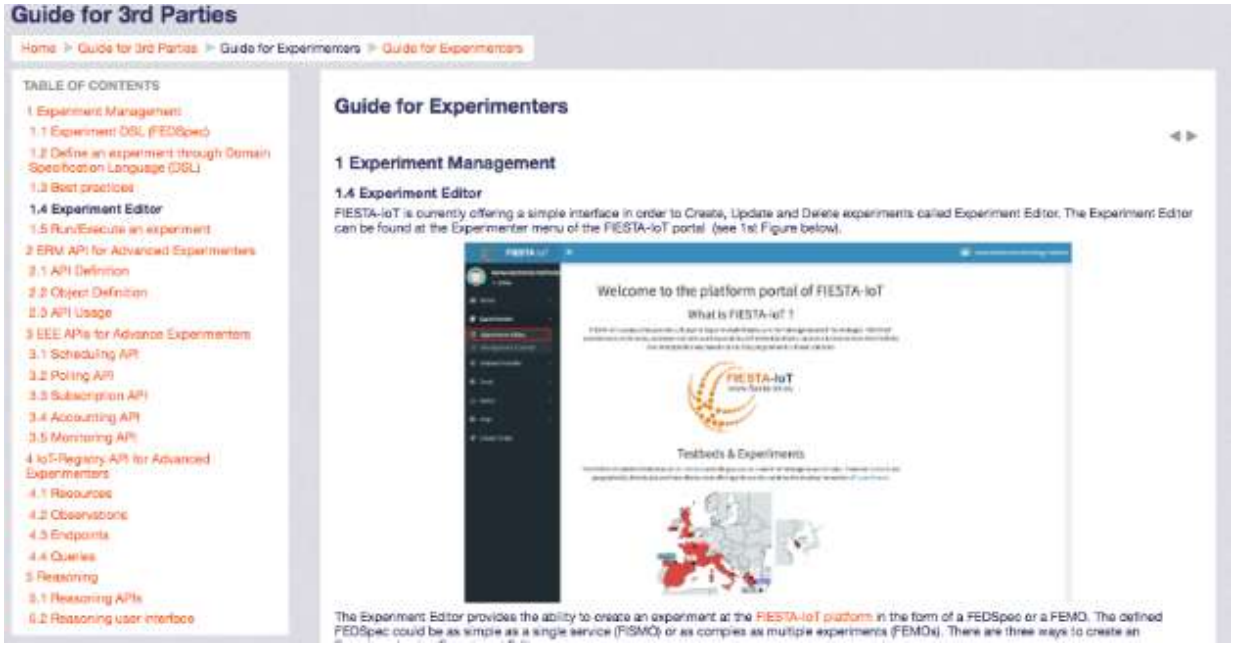


Figure 6 - Subsection with the Guide for Experimenters

[17] http://moodle.fiesta-iot.eu/mod/book/view.php?id=104

Guide for Extensions

The Guide for Extensions subsection[18], shown in Figure 7, addresses all the essential information about the integration of new testbeds with the FIESTA-IoT Platform. It addresses topics such as; how to semantically align with FIESTA-IoT's semantic data models, best practices for producing valid annotations, the certification suite, implementation of testbeds, testbed and resource registration and testbed configuration management.

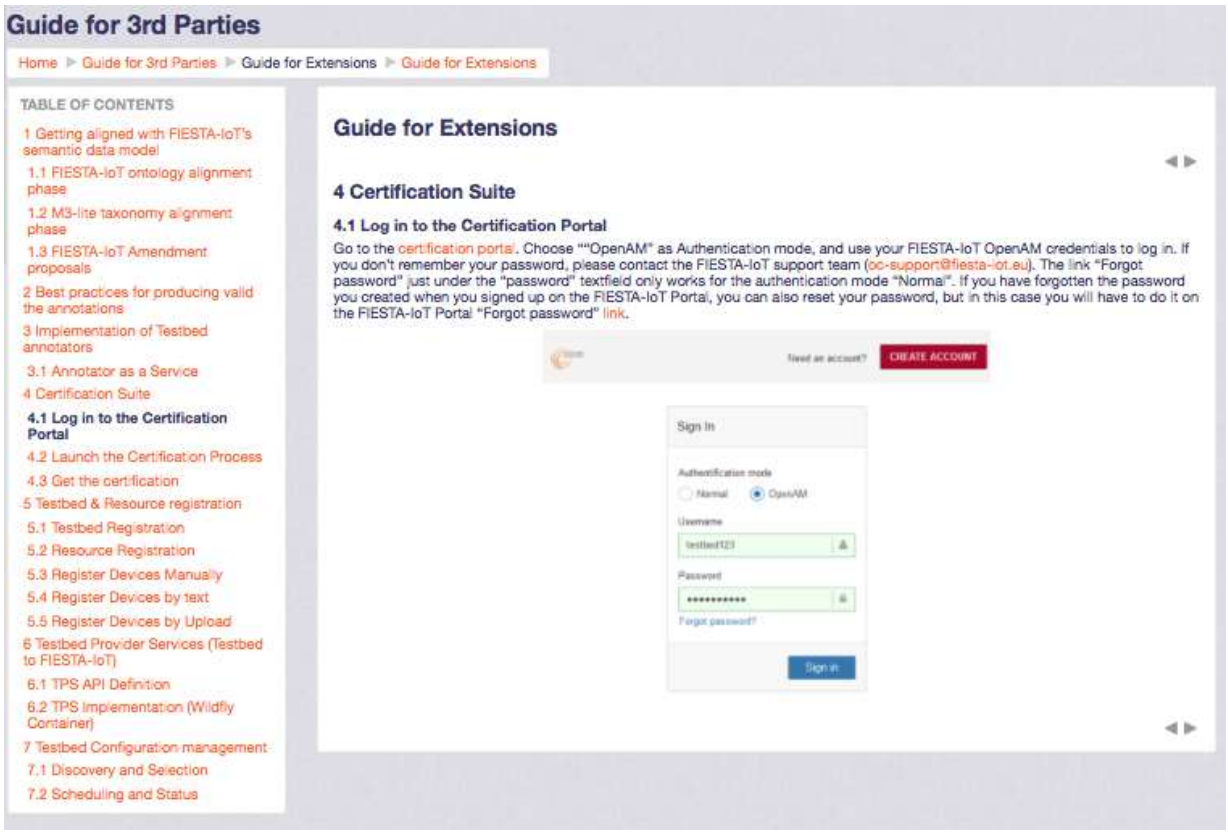


Figure 7 - Guide for Extensions subsection

FIESTA-IoT Workshop

The FIESTA-IoT Workshop is an added section that presents all the information regarding the physical FIESTA-IoT Workshops that occur and provide updated contents used/presented during each "Training Workshop" for Experimenters and for Extensions. More detailed information about each FIESTA-IoT Workshop will carried out in the following section (Section 2) of this deliverable.

FIESTA-IoT Handbook

This section[19], shown in Figure 8, provides the last and updated version of the "Handbook for Experimenters and Extensions" document, whose main objective is to provide a complete vision of all the features that FIESTA-IoT supports, to assist external users in using all the functionalities provided by FIESTA-IoT platform.

[18] http://moodle.fiesta-iot.eu/mod/book/view.php?id=96

[19] http://moodle.fiesta-iot.eu/pluginfile.php/711/mod_resource/content/6/FIESTA-IoT_Handbook4ThirdParties_v4.3.pdf

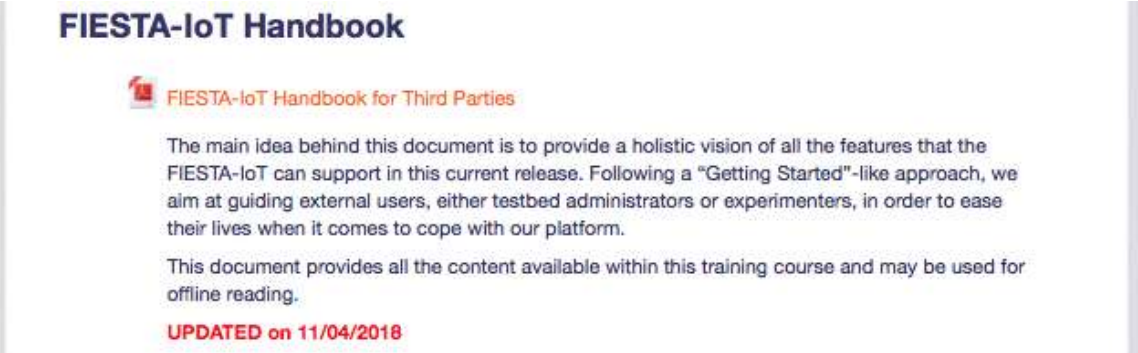


Figure 8 - FIESTA-IoT Handbook section

1.3 FIESTA-IoT Open-Calls

The FIESTA-IoT Open-Calls course[20], shown in Figure 9, offers a collection of indispensable support services to the participants of the FIESTA-IoT Open-Calls.

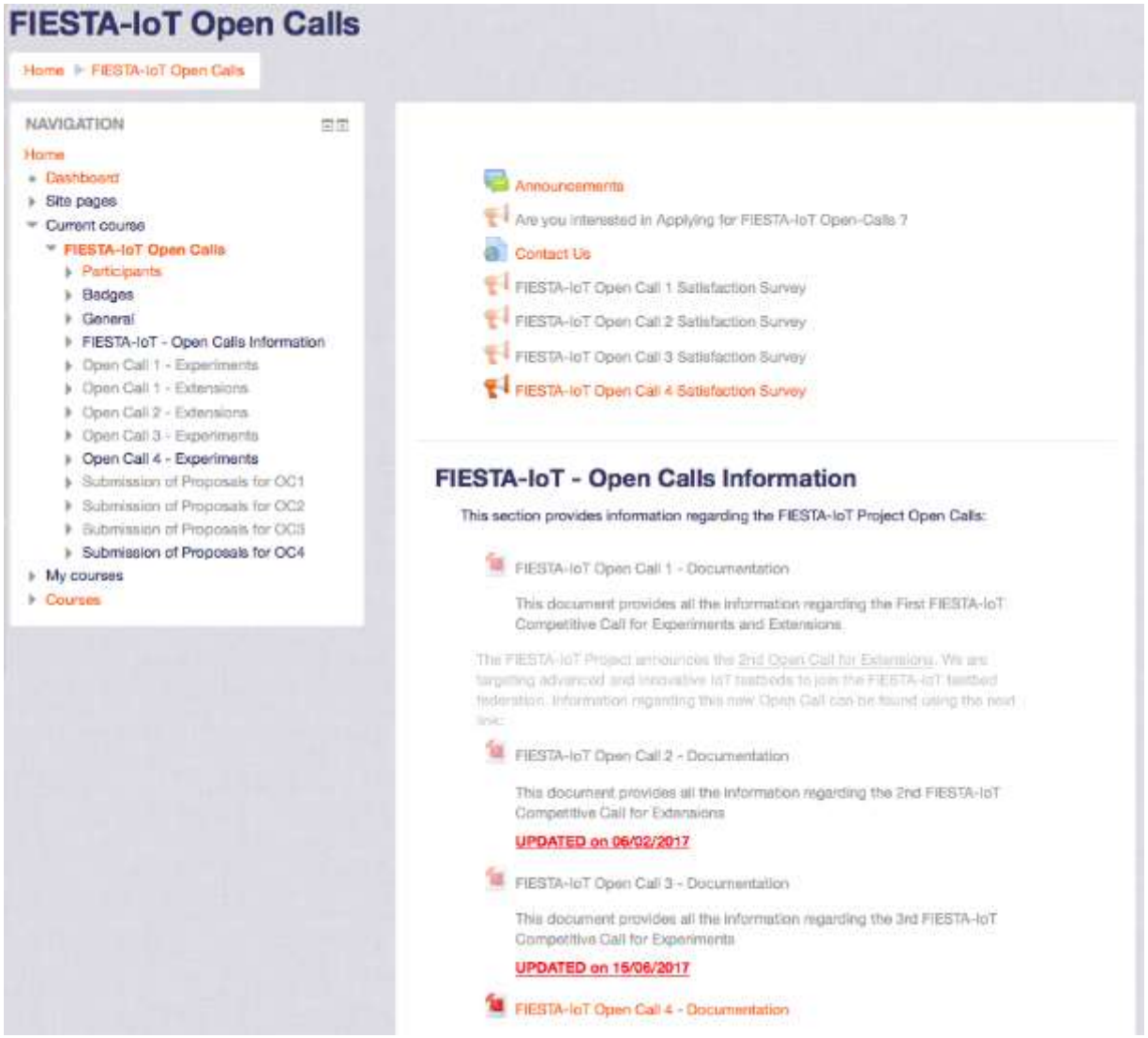


Figure 9 - FIESTA-IoT Open-Calls course.

[20] http://moodle.fiesta-iot.eu/course/view.php?id=2

This course has evolved during each Open-Call period, focusing on the details of the Open-Call that was in progress where the information was managed (when the Open-Call was closed the information was hidden). It includes documentation about the federated testbeds, guidelines on how prepare proposals for the upcoming FIESTA-IoT Open-Calls, and information about the submission mechanism for Open-Call proposals.

1.4 FIESTA-IoT Open-Call 1 – Extensions

The "FIESTA-IoT Open-Call 1 – Extensions", shown in Figure 10, is a private course[21] that is only available for the three testbeds that won the selection process in the 1st Open-Call for Extensions.

Figure 10 - FIESTA-IoT OC1 for Extensions course.

The winners (ADREAM, NITOS and EXTEND) were invited to create an account in the FIESTA-IoT Training platform and to join this course. This course provides a survey with 22 questions that had the objective of monitor the status and acquires feedback about the activities issues of the winners in the approximately half way of the 6 months of the design and implementation phase.

[21] http://moodle.fiesta-iot.eu/course/view.php?id=5

1.5 FIESTA-IoT Open-Call 1 – Experiments

This is a private course[22], shown in Figure 11, that is also only accessible for the winners of the 1st Open-Call for Experiments.

Figure 11 - FIESTA-IoT OC1 for Experiments course

The six Experimenters winners (DATAQUEST, DATE, CREDIT, Talk2Fiesta, SPIAM and SMT) were invited to create an account in the FIESTA-IoT Training platform and to join this course.

This course provides them a survey with 27 questions that also had the objective of monitoring the status and acquiring feedback about issues of their activities in the approximately half way of the 6 months of the design and implementation phase.

[22] http://moodle.fiesta-iot.eu/course/view.php?id=6

1.6 FIESTA-IoT Open-Call 2 – Extensions

The FIESTA-IoT Open-Call 2 – Extensions course[23], shown in Figure 12, is also private and was planned to only be accessible for the winners of the 2nd Open-Call for Extensions.

Figure 12 - FIESTA-IoT OC2 for Extensions course

The three testbeds that won this selection process (FINE, RealDC and Tera4Agri) were invited to register an account in the FIESTA-IoT Training platform and to join this course.

This course provides a survey that, such as the questionnaire for the 1st Open-Call for Extensions, had the objective of monitor the status and acquires feedback about the activities issues of the winners in the approximately half way of the 6 months of the design and implementation phase.

[23] http://moodle.fiesta-iot.eu/course/view.php?id=7

1.7 FIESTA-IoT Open-Call 3 – Experiments

It is a private course[24], shown in Figure 13, that is also only accessible for the thirteen Experiments that won the selection process in the 3rd Open-Call for Experiments. The winners (2CENTs, ENERGY-IoT, BeSmart, SURF, DC-IoT, KaaS_SCL, SmartComfort, RedEvents, SpyIoT, SmartPedestrian, FINETUNE, PARKNOW and FM2I) were also invited to register and create an account in the FIESTA-IoT Training platform and to join this course too.

Figure 13 - FIESTA-IoT OC3 for Experiments course

This course provides a questionnaire that, such as the survey for the previous Open-Call for Experiments, had the objective of monitor the status and acquires feedback about the activities issues of the winners in the approximately half way of the 6 months of the design and implementation phase.

[24] http://moodle.fiesta-iot.eu/course/view.php?id=8

1.8 FIESTA-IoT Open-Call 4 – Experiments

The "FIESTA-IoT Open-Call 4 – Experiments" course[25], shown in Figure 14, that is also only accessible for the five winners of the 4th Open-Call for Experiments (VIRTUS, StreamingQualityAnalyser, DDSP-GW, BMODEL and Agrolytics). They were invited to register and create an account in the FIESTA-IoT Training platform and to join this course.

Figure 14 - FIESTA-IoT OC4 for Experiments course

This course provides them a survey that, such as the questionnaire for the previous 1st and 3rd Open-Call for Experiments, had the objective of monitoring the status and collecting feedback about the activities and issues faced by the winners in the approximately half-way of the 6 months of the design and implementation phase.

[25] http://moodle.fiesta-iot.eu/course/view.php?id=9

1.9 FIESTA-IoT Hackathon: Experimentation-As-A-Service for Big IoT Testbed Data

It is a private course[26], shown in Figure 14, that is only accessible for the participants of the FIESTA-IoT Hackathon event "Experimentation-As-A-Service for Big IoT Testbed Data" that occurred on 19th and 20th March 2018 and was co-located in both Berlin, Germany and Sophia Antipolis, France.

The participants of this event were invited to register and create an account in the FIESTA-IoT Training platform and to join this course.

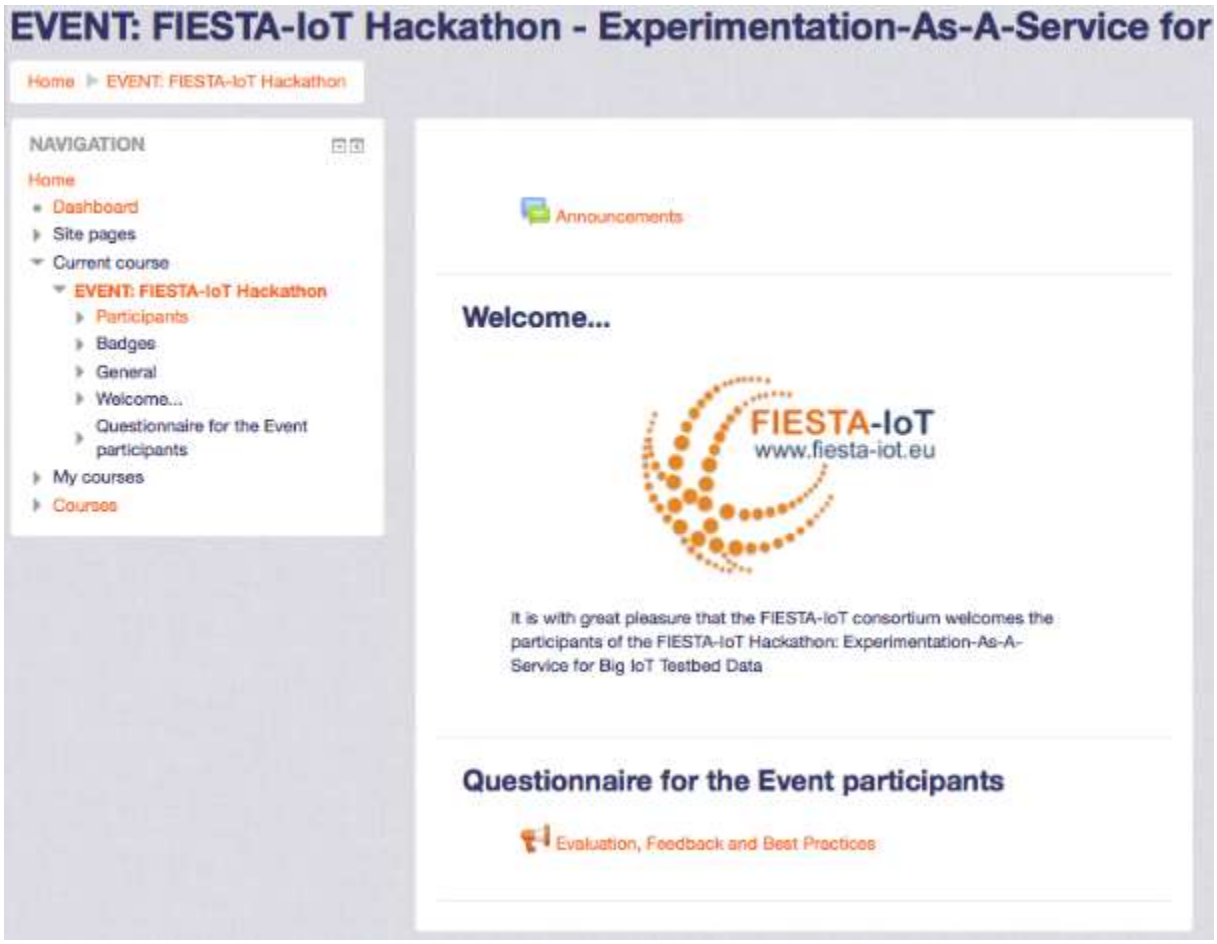


Figure 15 - FIESTA-IoT Hackathon Event course

This course provides to the participants of the event a survey with 14 questions that had the objective to obtain feedback about their activities in the hackathon. The survey intended to evaluate several subjects such as; whether the documentation for extensions provided in the training platform is relevant (to rate the documentation and if they believe that is missing some information), to evaluate the FIESTA-IoT Certification Portal, and to assess their experience on FIESTA-IoT platform.

[26] http://moodle.fiesta-iot.eu/course/view.php?id=11

1.10 FIESTA-IoT: Semantic Interoperability of your Data

This is also a private course[27], shown in Figure 16, that is only accessible for the participants of the FIESTA-IoT event "Semantic Interoperability of your Data". This event occurred in Sophia Antipolis, France, on 16th March 2018, was co-organized by Easy Global Market, SICTIAM, SCIC TETRIS and supported by European H2020 project FIESTA-IoT.

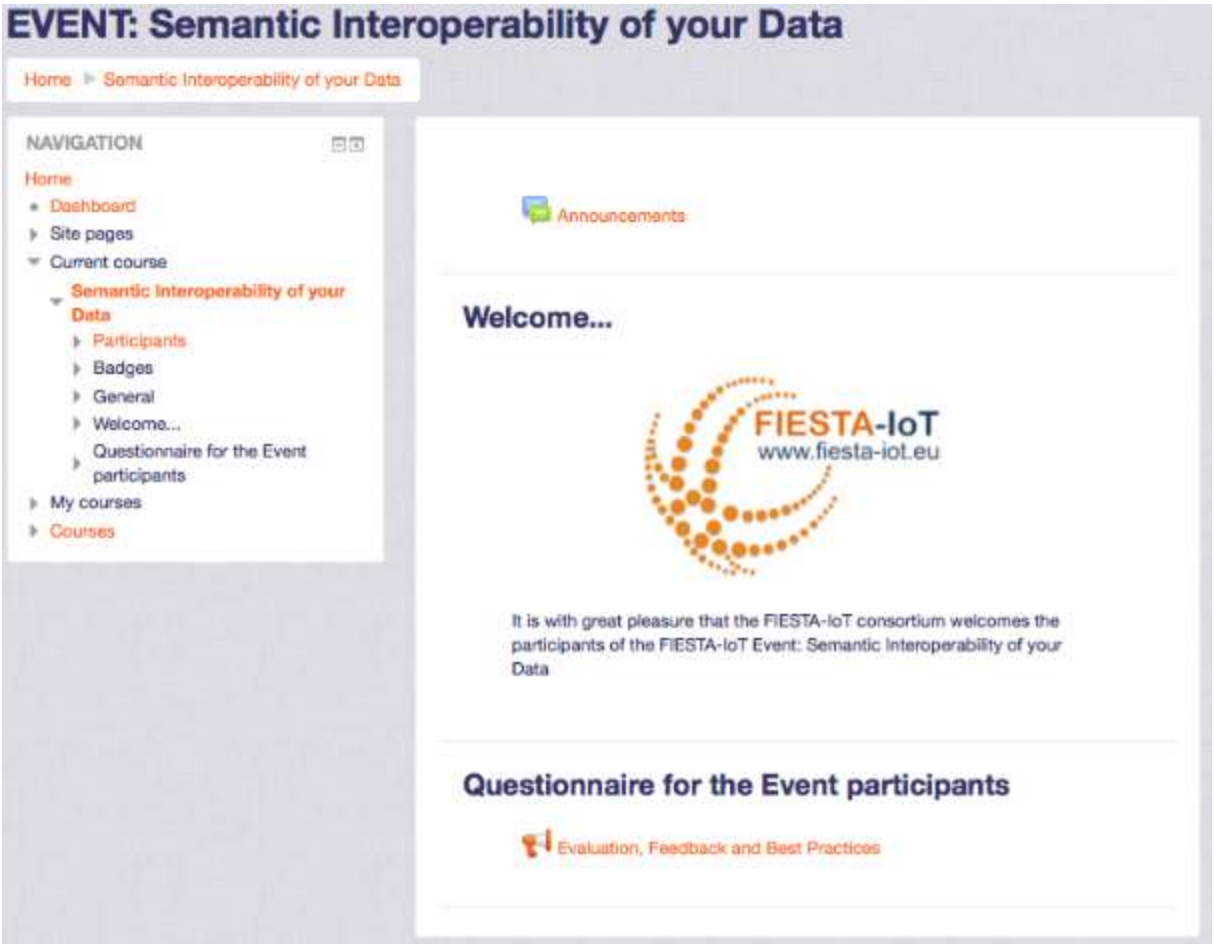


Figure 16 - FIESTA-IoT course for Semantic Interoperability of your Data event

The registered participants of this event were invited to create an account in the FIESTA-IoT Training platform and to join this course.

This course provides to them a survey that had the objective acquires their feedback about the activities of the event regarding subjects such as if the documentation for extensions provided in the training platform is relevant (to rate the documentation and if they believe that is missing some information), to evaluate the FIESTA-IoT Certification Portal and to qualify their experience on FIESTA-IoT platform.

[27] http://moodle.fiesta-iot.eu/course/view.php?id=10

2 TRAINING WORKSHOPS

In the scope of the FIESTA-IoT Open Calls, essential Training Workshops for Experimenters and for Extensions were organized, where the FIESTA-IoT Training Platform and its specific characteristics were presented to the 3rd parties.

2.1 Training Workshops for Experimenters

In the Training Workshops for Experimenters, important resources were presented to help Experimenters setup their experiments using the tools provided by the FIESTA-IoT Training Platform and the following subsections describes and provides all the information about each Workshop. All the Training Workshops for Experimenters occurred remotely through the GoToMeeting[28] web conferencing tool.

OC1 – 1st and 2nd Training Workshops for Experimenters

All the resources used/presented in the 1st workshop of the 1st Open-Call (OC1) can be accessed on a folder[29], shown in Figure 17, on the "Guide for 3rd Parties" module course. This folder was also available in the previous version of this deliverable and had all the resources regularly updated.

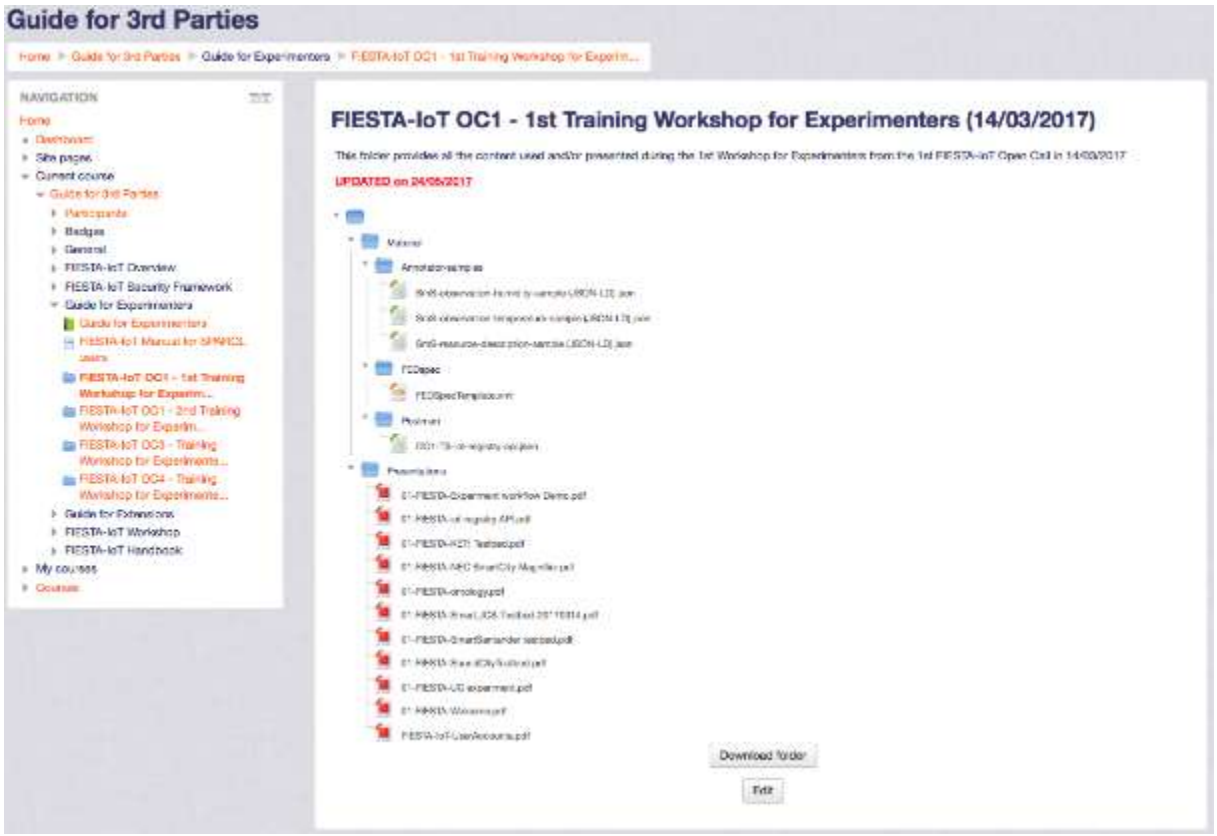


Figure 17 - Folder of OC1 1st Workshop for Experimenters

[28] https://www.gotomeeting.com/

[29] http://moodle.fiesta-iot.eu/mod/folder/view.php?id=108

This workshop was organized by the FIESTA-IoT consortium and occurred remotely through the GoToMeeting web conferencing tool on the 14th March 2017. The 3rd Parties were contacted and invited to participate in this workshop. These participants include the teams responsible for the Experiments accepted in the 1st Open-Call, which are:

- DATAQUEST (Data quality and easy services creation in FIESTA-IoT) from Technical University of Madrid;
- DATE (IoT data management at the network edge by decentralized community service) from UPC;
- CREDIT (CorRelations Between Data graphs and IoT topologies) from Institute of Communications and Computer Systems (ICCS);
- Talk2Fiesta (Conversational Information Services for FIESTA-IoT) from U-Hopper srl;
- SPIAM (Smart Polyhedron Indicator for Asset Management) from Heritas Soluciones Tecnológicas S.L.;
- SMT (Smart Monitoring) from SRC solution.

Some subjects about the training and support tool were presented and discussed, followed by a detailed description of:

- The four in-house Testbeds providers, the FIESTA-IoT Ontology,
- Methods for user authentication and authorization to access the FIESTA-IoT facility,
- the platform overview focused on northbound, the portal-based platform services
- A detailed description of the three in-house Experimenters. The complete agenda of this workshop can be found in *ANNEX A – Agenda: Open-call 1 - 1st training workshop for experimenters*.

The resources used and presented the in 2nd workshop of the 1st Open-Call (OC1) can be accessed on Moodle[30], as shown in Figure 18, under the “Guide for 3rd Parties” course module.

[30] http://moodle.fiesta-iot.eu/mod/folder/view.php?id=149

Figure 18 - Folder of OC1 2nd Workshop for Experimenters

The 2nd workshop for Experimenters was also organized by the FIESTA-IoT consortium, which took place remotely through the GoToMeeting web conferencing tool on the 20th July. The 3rd parties that were contacted and invited to participate were the same for the first workshop.

Some subjects were presented and discussed during this workshop. It was focused on:

- Understanding the Experimenters needs in order to match them with the FIESTA-IoT Platform,
- The platform-wide issues (regarding delays and timeouts performances, security policies and size of result-sets), a SPARQLs session and FEDSPecs section focused on the best practices on scheduling and FEDSpecs mgmt.

The complete agenda of this workshop can be found in *ANNEX B – Agenda: Open-call 1 - 2nd training workshop for experimenters*.

OC3 Training Workshop for Experimenters

The updated resources used and presented in the 3rd Open-Call (OC3) training workshop can be accessed on Moodle[31], as shown in Figure 19, on the "Guide for 3rd Parties" course module.

[31] http://moodle.fiesta-iot.eu/mod/folder/view.php?id=160

Figure 19 - Folder of OC3 Workshop for Experimenters

This workshop was carried out by the FIESTA-IoT consortium and occurred remotely through the GoToMeeting platform on the 13th September 2017. The 3rd parties that were previously contacted and invited to participate in this workshop include the teams responsible for the Experiments accepted in the 3rd Open-Call:

- DC-IoT (Monitoring Energy Efficiency for Data Centres by Correlating IoT Sensor Readings and Weather Conditions Data) from Cyta Hellas;
- KaaS_SCL (Knowledge as a Service for Assisted Living in Smart City) from WINGS ICT Solutions;
- SmartComfort (Internet of Things Application for a Better and Smart Comfort) from EUROB CREATIVE;RedEvents (KPI Model for social & business events) from ENEO Tecnología;
- SpyIoT (Security and Privacy for IoT infrastructures experiment) from Fincons Spa;
- SmartPedestrian (Smart Pedestrian Movement for Smart Cities) from Ingeniería Zero;
- FINETUNE (Fine grain Air Quality sensors calibration and cross-sensitivity tuning based on cross-validation with available Open Data) from HOP Ubiquitous S.L;
- PARKNOW (Car and pedestrian geolocation indoors and outdoors using the smartphone) from Situm;
- FM2I (Fault Management and Isolation for IoT field devices) from Sensinov;
- 2CENTs (SemantiC Coordination for intelligENT sensors) from University of Niš, Faculty of Electronic Engineering;
- ENERGY-IoT (Experimental validation of multivariate machine learning models for prediction of energy consumption in smart buildings) from Instituto Politécnico de Castelo Branco;

- BeSmart (Smart IoT Data Collection) from Athens University of Economics and Business - Research Center;
- SURF (Smart Urban Routing with FIESTA-IoT) from Politecnico di Milano;

The focus was to present:

- The FIESTA-IoT Training Platform
- The procedure to get support and to solve issues
- The available federated testbeds
- The general aspects of the FIESTA-IoT ontology with special emphasis to the M3-Lite taxonomy
- The methods for user authentication and authorization to access regarding the roles and access privileges

The platform overview focused on components that will be serving the experimenter and the success stories and best practices using the FIESTA-IoT Platform. The complete agenda of this workshop can be found in *ANNEX E – Agenda: Open-call 3 training workshop for experimenters.*

OC4 Training Workshop for Experimenters

All the resources used and presented in the 4th Open-Call (OC4) training workshop can be accessed on Moodle[32], as shown in Figure 20, under the Guide for 3rd Parties module course. This workshop was organized by the FIESTA-IoT consortium and occurred remotely through the GoToMeeting web conferencing tool on the 20th November 2017.

Figure 20 - Folder of OC4 Workshop for Experimenters

[32] http://moodle.fiesta-iot.eu/mod/folder/view.php?id=166

The 3rd Parties were contacted and invited to participate in this workshop. The participants include the teams responsible for the Experiments accepted in the 4th Open-Call:

- VIRTUS (Virtual IoT Gateway for the provision of SDN/NFV-based multi-tenant Service Isolation and Interoperability over Heterogeneous IoT Domains) from INFOLYSiS;
- StreamingQualityAnalyser (Real-time data quality assessment in IoT environments) from Modio Computing PC;
- DDSP-GW (Distributed Data Stream Process Gateway Service Empowering FIESTA-IoT Applications) from FlairBit;
- BMODEL (Advanced predictive models for energy consumption in Buildings and Data Centers) from AllbeSmart Lda;
- Agrolytics (Experimentation for developing business services that use real-time data analytics for realizing proactive micro-environmental monitoring in agriculture) from Nissatech.

During this workshop the focus was to present and discuss:

- The training and support platform and the procedure to get support and to solve issues,
- The general aspects of the FIESTA-IoT ontology also with special emphasis on the M3-Lite taxonomy,
- The methods for user authentication and authorization for access (regarding the roles and access privileges),
- The platform services (focused on the monitoring, the FIESTA-IoT analytics tools, reasoning and the experiment editor),
- The success stories and best practices using the FIESTA-IoT Platform.

The complete agenda of this workshop can be found in *ANNEX F – Agenda: Open-call 4 training workshop for experimenters*.

The presentations of the Training Workshops for Experimenters are also available in video in the Guide for Experimenter section, as shown in Figure 21, of the “Guide for 3rd Parties” course[33] and is available publicly. The presentations of the 1st Open-Call Workshop was available in the previous version of this deliverable. The presentations for the 4th Open-Call were updated and a subsection[34] was added relating to the FIESTA-IoT Manual for SPARQL users.

[33] http://moodle.fiesta-iot.eu/course/view.php?id=4

[34] http://moodle.fiesta-iot.eu/mod/page/view.php?id=146

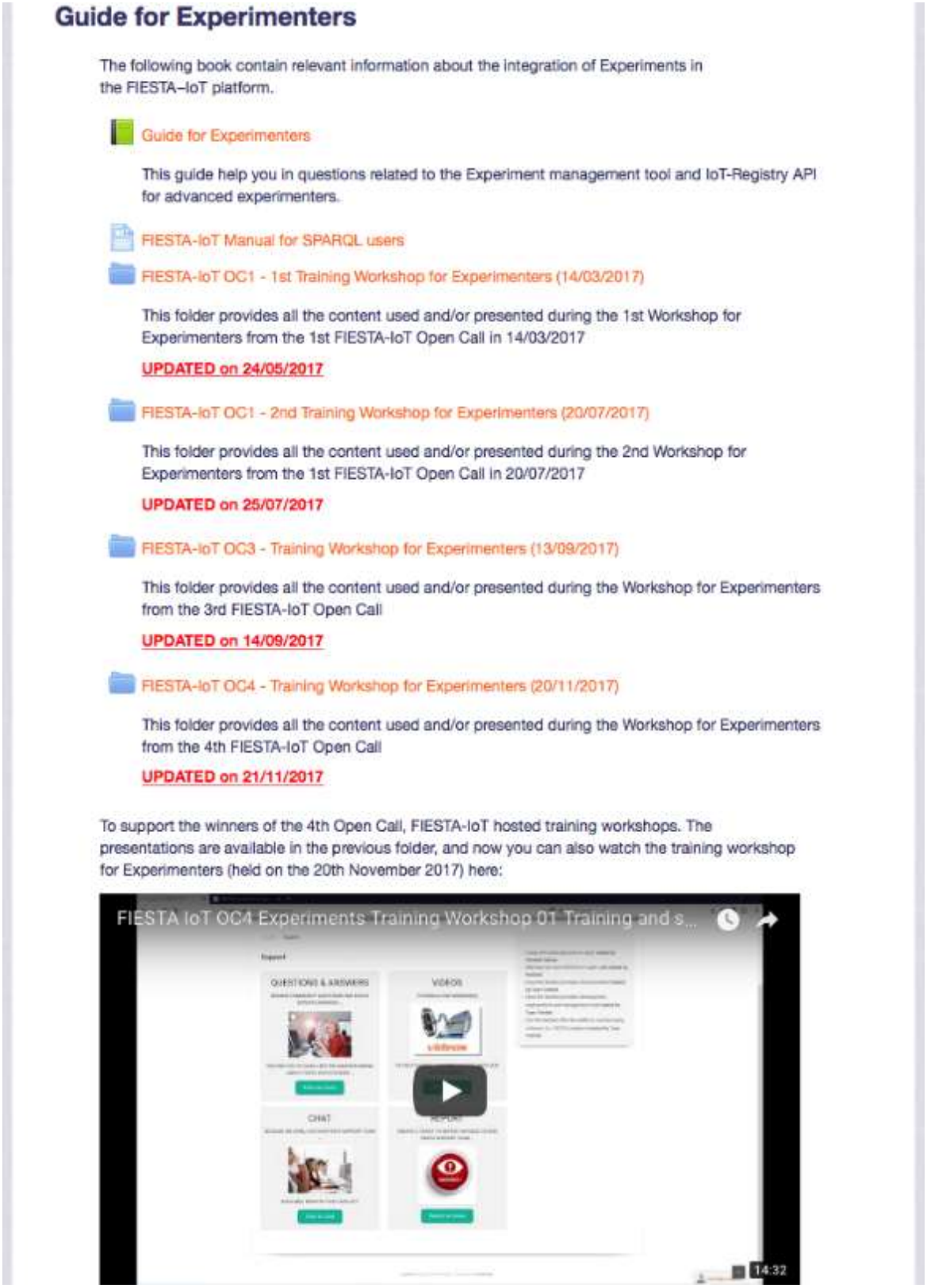


Figure 21 - Guide for Experimenter section on the Guide for 3rd Parties course

2.2 Training Workshops for Extensions

The Training Workshops for Extensions of the FIESTA-IoT Open-Calls follow the same objective that the workshops for Experimenters. They were organized by the FIESTA-IoT consortium and took place remotely through the GoToMeeting[35] web conferencing tool where important information was presented to help the integration of Extensions with the FIESTA-IoT platform.

Common topics in the training workshop for Experimenters were presented, such as the FIESTA-IoT Ontology, the FIESTA-IoT Training and Support tool and the methods for user authentication and authorization. The specific topics for Extensions were the Testbed Provider Services (TPS), Development and the Annotator as a Service, how to develop the required annotation and validation tools, the required components for the registration of a Testbed or a Resource, and the Testbed Provider Interface (TPI) Configurator usage.

All the resources used and presented in both 1st Open-Call (OC1) and 2nd Open-Call (OC2) workshops can be accessed on a folder[36], shown in Figure 22, on the Guide for 3rd Parties module course[37]. This folder was also available in the previous version of this deliverable and had all the resources regularly updated.

Figure 22 - Folder of OC1 & OC2 Workshops for Extensions

OC1 Training Workshop for Extensions

This workshop was organized by the FIESTA-IoT consortium and occurred remotely through the GoToMeeting platform on the 17th March 2017. The complete agenda of this workshop can be found in *ANNEX C – Agenda: Open-call 1 training workshop for extensions*. The 3rd Parties were contacted and invited to participate in this workshop.

[35] https://www.gotomeeting.com/

[36] http://moodle.fiesta-iot.eu/mod/folder/view.php?id=114

[37] http://moodle.fiesta-iot.eu/course/view.php?id=4

The participants include the teams responsible for the Extensions accepted in the 1st Open-Call:

- NITOS (Network Implementation Testbed using Open Source Platforms) from University of Thessaly (UTH);
- EXTEND (EXpand The ENvironmental Diversity of FIESTA-IoT testbeds) from GRIDNET S.A.;
- ADREAM FIESTA from LAAS-CNRS.

OC2 Training Workshop for Extensions

The 2nd workshop occurred in 29th May 2017 remotely through the GoToMeeting web conferencing tool, according to the agenda available in *ANNEX D – Agenda: Open-call 2 training workshop for extensions*. This workshop was organized by the FIESTA-IoT consortium and the 3rd Parties accepted via the 2nd Open-Call were previously contacted and invited to participate:

- Tera4Agri (Tera testbed in smart agriculture domain) from TERA Srl;
- REALDC (Operational Data Centre, Campus Energy and Weather Sensors) from WIT;
- FINE (A FIESTA-enabled IoT Architecture based on RERUM) from FORTH.

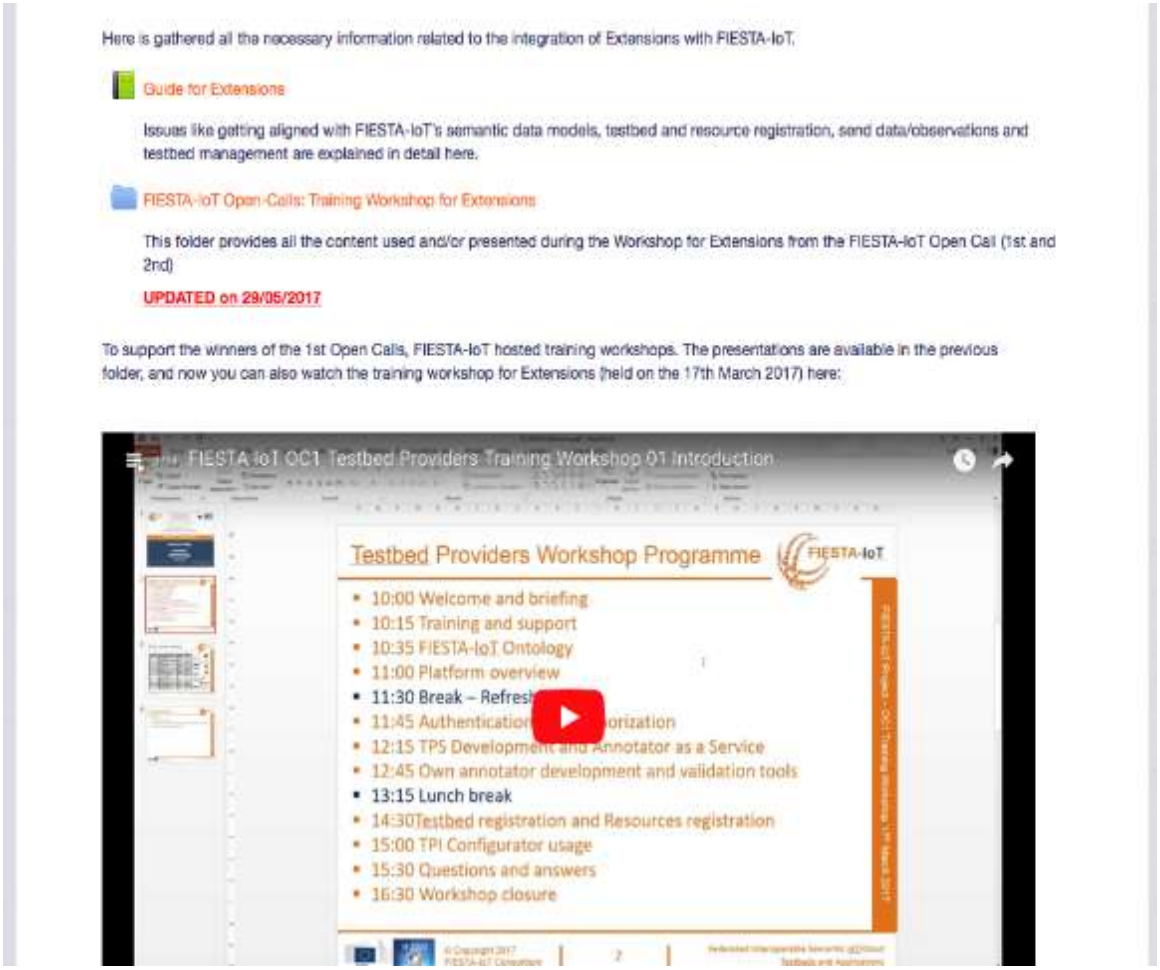


Figure 23 - Guide for Extensions section on the Guide for 3rd Parties course

The presentations of the Training Workshops for Extensions are also available in video in the Guide for Extensions section, as shown in Figure 23, of the Guide for 3rd Parties course[38]. The presentation of the 1st workshop was available in the previous version of this deliverable.

2.3 Training Workshop at IoT Week 2017

The FIESTA-IoT consortium organized a physical training workshop that occurred on 8th June 2017 at IoT Week 2017 in International Conference Centre of Geneva (CICG) according to the agenda available in *ANNEX G – Agenda: Training Workshop at IoT Week 2017*.

The "FIESTA-IoT - Experimentation as a Service over Interoperable IoT Testbeds" presented the latest results from the FIESTA-IoT project. All the updated resources used and presented in this training workshop can be accessed on Moodle[39], shown in Figure 24, on the Guide for 3rd Parties course.

Figure 24 - Folder of the Training Workshop at IoT Week 2017

The focus was on the description of the IoT experimentation that is enabled by the FIESTA-IoT Platform not only from a technical and practical perspective but also through the presentation of the 3rd FIESTA-IoT Open-Call for Experimentation that was open and hosted proposals till the 15th of June.

[38] http://moodle.fiesta-iot.eu/course/view.php?id=4

[39] http://moodle.fiesta-iot.eu/mod/folder/view.php?id=136

3 FOLLOW-UP QUESTIONNAIRE

The Experimenters and Extensions that won the selection process on each FIESTA-IoT Open-Call, as described in section 1, were invited to register and create an account in the FIESTA-IoT Training Platform and invited to join the private courses that are only accessible form them.

In the respective course of each Open-Call (OC) they were requested to answer a set of questions in the form of a questionnaire that had the objective to provide the appropriate steps that they need to take, monitoring their status and obtaining feedback regarding the issues of their activities in the middle of the 6 months of the design and implementation phase.

3.1 Questionnaire for Experimenters

The questionnaire for Experimenters was the same in each Open-Call for Experimenters and covered a set of 28 questions and are also available in *ANNEX H – QuestionNaire for Experimenters*. It was composed by 22 questions that had two options of response (yes or no), four questions that had three options of response (yes, no and not need), and two of them were open-answers.

In terms of answers to this questionnaire a total of 18 Experimenters responded. In the OC1 all the six Experimenters responded, in the OC3 only eight of the thirteen Experimenters responded and in the OC4 four of the five Experimenters responded. The number of Experimenters who answered to the questions with yes or no, respectively, is shown in the following Table 1.

Table 1 - Yes/No answers to the Experimenters questionnaire

Questions	OC1 Answers		OC3 Answers		OC4 Answers	
	Yes	No	Yes	No	Yes	No
Q1: Have you attended the training workshop?	**6**	0	**7**	1	2	2
Q2: Have you used the helpdesk email?	**4**	2	**6**	2	**3**	1
Q3: Have you used the ticketing system?	**4**	2	**8**	0	**4**	0
Q4: Have you used the live chat?	0	**6**	0	**8**	1	**3**
Q5: Have you gone through the training courses made available to you?	**5**	1	**7**	1	**4**	0
Q6: Have you consulted the on-line documentation?	**6**	0	**8**	0	**4**	0
Q7: Have you used the available sample material?	**6**	0	**8**	0	**4**	0

Q9: Have you found all the needed information about the APIs?	**4**	2	**6**	2	**3**	1
Q10: Have you found all the needed information about the ontology?	**4**	2	**6**	2	**4**	0
Q13: Have you conveyed the objective KPIs to the FIESTA-IoT Consortium?	3	3	2	**6**	2	2
Q14: Have you used the experiment related tools from the FIESTA-IoT platform portfolio?	**5**	1	**6**	2	2	2
Q16: Have you used the SPARQL endpoint from the FIESTA-IoT platform portfolio?	**6**	0	**7**	1	**3**	1
Q17: Have you used SPARQL query catalogue?	**4**	2	**5**	3	**3**	1
Q18: Have you used the Resource browser from the FIESTA-IoT platform portfolio?	**4**	2	**4**	4	2	2
Q19: Have you used the REST access to datasets from the FIESTA-IoT platform portfolio?	**4**	2	**7**	1	**4**	0
Q20: Were you able to receive data?	**6**	0	**6**	2	**3**	1
Q21: Have you proposed code/enhancements/modules/tools that could be beneficial for future experiments?	1	**5**	1	**7**	1	**3**
Q24: Does the experiment allow objective assessment of the FIESTA-IoT platform non-functional requirements?	**5**	1	**5**	3	2	2
Q25: Did you get adequate support from FIESTA-IoT members?	**5**	1	**8**	0	**4**	0
Q26: Is your experiment currently deployed?	**5**	1	**2**	6	2	2
Q27: Have you followed the suggested best-practices?	**6**	0	**7**	1	**4**	0
Q28: Do you expect to continue collecting data from the FIESTA-IoT platform once your experiment contract time ends?	(N/A)	(N/A)	**7**	1	**3**	1

Note that the question "**Q28: Do you expect to continue collecting data from the FIESTA-IoT platform once your experiment contract time ends?"** presented in the previous table was not made in the questionnaire for the Experimenters of the OC1 (the answers for this question are presented in the table as N/A).

The question "**Q21: Have you proposed code/enhancements/modules/tools that could be beneficial for future experiments?**" had two additional questions to the Experimenters who answered yes.

The first question "**Q22: If yes which one(s)?**" and the second question "**Q23: If yes, have you proposed additional functionalities that could be beneficial for future experiments?**". The obtained Experimenters answers in each OC to these questions are showed in the Table 2 below.

Table 2 - Experimenters answers to Q22 and Q23 questions

Open-Calls Experimenters Answers	Q22: If yes, which one(s)?	Q23: If yes, have you proposed additional functionalities that could be beneficial for future experiments?
OC1 Answers	• "Not yet, but we plan to do so towards the end of our experiments"	• "We plan to do so, towards the final stages of our experiments."
OC3 Answers	• "An interactive application for visualization of correlation between sensors' locations and availability of their readings"	• "Existing FIESTA-IoT ontologies are extended with ontologies to enable integration of semantic description of the correlation as well as wireless network status into the existing FIESTA-IoT framework"
OC4 Answers	• "A REST API service which will implement the following data quality assessment algorithms: GARCH with ARMA mean value estimator and GARCH with Kalman filters mean value estimators" • "A web application which will render the quality results"	• "Feedback on the performance of each monitoring algorithm (GARCH algorithms, as mentioned above)" • "Outlier detection"

The number of Experimenters who answered to the questions with three options of response (yes, no or not need) is shown in the following Table 3. Note that in the question **Q15: Have you conveyed your developed FEDSpec to the FIESTA-IoT Consortium?** the option "Not need" means that was not developed a FEDSpec for the Experiment.

Table 3 - Yes/No/Not need answers to the Experimenters questionnaire

Questions	OC1 Answers			OC3 Answers			OC4 Answers		
	Yes	No	Not need	Yes	No	Not need	Yes	No	Not need
Q8: Have you found all the needed information about FEDSpec?	2	**3**	1	2	1	**5**	1	1	**2**
Q11: Have you found all the needed information about the Experiment Data Receiver?	**4**	1	1	2	2	**4**	**3**	0	1

Q12: Have you found all the needed information about the Experiment execution process?	**5**	0	1	**4**	1	3	**2**	1	1
Q15: Have you conveyed your developed FEDSpec to the FIESTA-IoT Consortium?	2	2	2[40]	0	1	**7**[40]	0	0	**4**[40]

Analysing the tables of this questionnaire is observed a pattern in the obtained answers for each of the three Open-Calls for Experimenters where for the majority of the questions, the Experimenters respond the same answer.

The coherence in the answers to this questionnaire permit to understand that all the resources used were appropriate to support and engage the Experimenters of each Open-Call with the FIESTA-IoT Platform.

3.2 Questionnaire for Extensions

This questionnaire, like the questionnaire for Experimenters, was the same in both the two Open-Calls for Extensions and covered the 22 questions that are also available in *ANNEX I – QuestionNaire for Extensions*. It was composed by 14 questions that had yes or no options for response, and 8 questions had three types of response (yes, no and not applicable).

Regarding the answers to the questionnaire, a total of 6 Experimenters responded. In the OC1 all the three Extensions responded and in the OC2 also all the three Extensions responded too. Table 4 presents the number of Extensions who answered respectively to the questions with the yes or no options of response.

Table 4 - Yes/No answers to the Extensions questionnaire

Questions	**OC1 Answers**		**OC2 Answers**	
	Yes	**No**	**Yes**	**No**
Q1: Have you analysed the FIESTA-IoT Ontology to check the compatibility with your existing datasets to find out necessary classes and relationships for the annotation?	**3**	0	**3**	0
Q2: Have you requested for Taxonomy/ontology modifications to span your testbed requirements (e.g. new concepts to be added to the taxonomy)?	**2**	1	1	**2**
Q3: Have you checked that all your propositions have been successfully carried out and have been mapped onto the FIESTA-IoT ontology?	**3**	0	**2**	1
Q9: Have you accomplished the validation of your resource description(s) using the FIESTA-IoT Certification Suite?	0	**3**	**3**	0

[40] Not need / not developed a FEDSpec for the Experiment

Q10: Have you accomplished the validation of your observation(s) using the FIESTA-IoT Certification suite?	0	**3**	**3**	0
Q11: Have you been promoted to "testbedAdmin" in order to have the permissions to proceed to the next steps of pushing your annotations?	**2**	1	1	**2**
Q12: Have you registered your testbed into the FIESTA-IoT Federation through the portal?	0	**3**	**3**	0
Q13: Have you successfully registered (at least one) resource(s) through the portal?	0	**3**	**2**	1
Q14: Have you defined the operation mode (reactive - e.g. GetObservations or proactive – e.g. PushObservations) of your testbed	1	**2**	**3**	0
Q15: Have you implemented your TPS, including the corresponding endpoints (Reactive) and run internal tests?	0	**3**	**3**	0
Q16: Have you implemented your TPS, including the corresponding endpoints (Proactive) and successfully run internal tests?	0	**3**	1	**2**
Q20: Have you used the TPI Configurator in order to select the devices that will become active for FIESTA-IoT, thus sending information to the platform?	0	**3**	**2**	1
Q21: Have you make sure that your system is running, thereby sending information automatically to FIESTA-IoT and not producing Bad Requests?	1	**2**	**2**	1
Q22: Have you followed the set of Best Practices recommended by the FIESTA-IoT consortium?	**2**	1	**3**	0

From the analysis of the previous table, it is noted that the majority of the answers given by the Extensions to the questions in the OC1 were the option "No", and in the OC2 the majority of the answers given by the Extensions to the same questions were the option "Yes". The number of Extensions who answered to the questions with three options of response (yes, no or not applicable) is shown in Table 5 below.

Table 5 - Yes/No/Not Applicable answers to the Extensions questionnaire

Questions	**OC1 Answers**			**OC2 Answers**		
	Yes	**No**	**N/A**	**Yes**	**No**	**N/A**
Q4: Have you managed to get your own FIESTA-IoT annotations for resource description(s) through your own tailored annotator?	1	1	1	0	0	**3**

Q5: Have you managed to get your own FIESTA-IoT annotations for observation(s) through your own tailored annotator?	1	1	1	0	0	**3**
Q6: Have you managed to get your own FIESTA-IoT annotations for resource description(s) through FIESTA-IoT AaaS API (in case N/A in question Q5)?	1	1	1	**3**	0	0
Q7: Have you managed to get your own FIESTA-IoT annotations for observation(s) through FIESTA-IoT AaaS API (in case N/A in question Q6)?	1	1	1	**3**	0	0
Q8: Have you included an IoT Service Endpoint as part of the resource description?	0	**3**	0	**2**	0	1
Q17: If authenticated access to testbed is enabled, you provide an API key?	0	1	**2**	0	1	**2**
Q18: If using HTTPS for communicating with the testbed, you provide the certificate chain?	0	1	**2**	0	1	**2**
Q19: For the proactive mode, have you implemented the methods that trigger or stop the data flow (Start/Stop PushObservations)?	0	1	**2**	1	0	**2**

From Table 5 can be noted that most of the answers given by the Extensions in the OC1 were the option “No” or “Not Applicable” and in OC2 the majority of the answers to the same questions were the option “Yes” or “Not Applicable”.

It can be understood from analysing the answers to the questions of the Extensions questionnaire that significant progress occurred from the OC1 to the OC2 in terms of the resources used to support the Extensions with the FIESTA-IoT Platform.

In overall, based on the acquired feedback and through the answers obtained from the both questionnaires made to the Experimenters and Extensions, it can be observed that during the last year of the FIESTA-IoT project, all the resources and material used or presented in each of the specifics Training Workshops and available in the several courses of the FIESTA-IoT Training Platform had a significant role, providing a smooth path and helped the integration of each Experimenter and Extension with the FIESTA-IoT Platform.

4 FINAL REPORT'S FEEDBACK

In the final report of the selected Extensions and Experimenters, the OC participants need to give the FIESTA-IoT consortium some feedback of using the platform by answering a questionnaire. 5 questions among the 20 (for Extensions) or 22 (for Experimenters) questions in total address the quality of the documentation, which is part of the evaluation of the FIESTA-IoT Training Platform. The questions are provided in *ANNEX J – Questions for documentation evaluation*.

In terms of answers to this questionnaire all the 6 Extensions and 24 Experimenters have responded. The following tables show the statistics of the answers.

Table 6 - Result from the Experimenters questionnaire about documentation

Questions	Options	OC1 Answers	OC3 Answers	OC4 Answers
Q1: Did you use the documentation for experimenters provided on the Moodle?	Yes, we consulted almost all the documents	5	11	2
	Yes, but only some documents	1	1	3
	No, I didn't	0	1	0
Q2: Were you able to find the needed information?	Always	1	4	2
	Most of the time	5	6	3
	Sometimes	0	3	0
	Never	0	0	0
Q3: Do you believe that some documentation is missing?	Yes	4 sparql examples	6 sparql examples	1 Query example
	No	2	7	4
Q4: How would you rate the quality of the documentation provided to discover the platform?	Documentation about FEDSPEC	**Good**	**Very good**	**Very good**
	Documentation about APIs	**Good**	**Very good**	**Very good**
	Documentation about Ontology	**Good**	**Very good**	**Excellent**
	Documentation about SPARQL queries	**Good**	**Very good**	**Very good**
	Documentation about installing Experiment Data Receiver	**Excellent**	**Good**	**Very good**
	Experiment Execution process and guidelines	**Very good**	**Good**	**Very good**
	Overall documentation in the Project Handbook	**Good**	**Very good**	**Very good**
Q5: How would you rate the relevance	Documentation about FEDSPEC	**Very good**	**Good**	**Very good**

of the documentation provided to discover the platform?	Documentation about APIs	**Very good**	**Very good**	**Excellent**
	Documentation about Ontology	**Very good**	**Good**	**Excellent**
	Documentation about SPARQL queries	**Very good**	**Very good**	**Excellent**
	Documentation about installing Experiment Data Receiver	**Very good**	**Good**	**NA**
	Experiment Execution process and guidelines	**Very good**	**Good**	**Excellent**
	Overall documentation in the Project Handbook	**Very good**	**Very good**	**Excellent**

We can clearly see that in general, OC Experimenters are satisfied with the documentation provided by the FIESTA-IoT Training Platform. The quality and the relevance of documents are noted as more than good. When experimenters are asked about if there are missing documents, among the "Yes" answers, most of them reported to prefer to have more examples of SPARQL query, which gives the FIESTA-IoT consortium more insight about the difficulties on using semantic technologies from developers' perspectives.

The percentage of reporting "missing document" drops from 66.6% in OC1 to 20% in OC4, which indicates that more documents have been created during the Open-Call period to respond to experimenters' demand.

Table 7 - Result from the testbed provider questionnaire about documentation

Questions	Options	OC1 Answers	OC2 Answers
Q1: Did you use the documentation for experimenters provided on the Moodle?	Yes, we consulted almost all the documents	3	3
	Yes, but only some documents	0	0
	No, I didn't	0	0
Q2: Were you able to find the needed information?	Always	0	0
	Most of the time	3	3
	Sometimes	0	0
	Never	0	0
Q3: Do you believe that some documentation is missing?	Yes	1	3
	No	2	0
Q4: How would you rate the quality of the documentation	Documentation about APIs	**Good**	**Very good**

provided to discover the platform?	Documentation about Ontology	**Excellent**	**Excellent**
	Documentation about Annotator	**Very good**	**Very good**
	Documentation about Annotator as a Service	**Very good**	**Very good**
	Documentation about Testbed Provider Services	**Good**	**Excellent**
	Testbed integration process and guidelines	**Very good**	**Very good**
	Overall documentation in the Project Handbook	**Very good**	**Very good**
Q5: How would you rate the relevance of the documentation provided to discover the platform?	Documentation about APIs	**Very good**	**Very good**
	Documentation about Ontology	**Excellent**	**Excellent**
	Documentation about Annotator	**Very good**	**Excellent**
	Documentation about Annotator as a Service	**Very good**	**Very good**
	Documentation about Testbed Provider Services	**Excellent**	**Excellent**
	Testbed integration process and guidelines	**Excellent**	**Excellent**
	Overall documentation in the Project Handbook	**Excellent**	**Very good**

From the result of testbed provider questionnaire, it is clear that they are satisfied with the documentation provided through the FIESTA-IoT Training Platform and the documentation is of good quality.

Though the testbed providers claim some missing document through the questionnaire, they declare that the necessary assistance was available from the FIESTA-IoT consortium via other channels such as the supporting system or the email contact.

5 IOT MARKET INTEROPERABILITY TESTING AND VALIDATION

5.1 Introduction

In Deliverable D6.3[41] and the previous version of this deliverable D6.4[42] we described the development of the interoperability testing tool, both in its desktop form (model-interop[43]) and the certification portal version[44]. These descriptions concentrated on the domain of FIESTA-IoT technologies i.e. testing that FIESTA-IoT testbeds interoperated with the FIESTA-IoT Platform, and the certification that they were technologically aligned before final integration.

In this version of the deliverable, we look beyond FIESTA-IoT technologies and consider how the same tools and techniques that have been created to perform interoperability testing and certification can be applied to a broader range of IoT technologies that currently exist in the marketplace. We first examine the current state-of-play in IoT standards and specifications and identify those where FIESTA-IoT interoperability testing tools can provide support. Secondly, we then discuss how the interoperability testing tools can be used to perform market standards compliance and certification. In turn, we then look at five market standards where FIESTA-IoT testing tools have been applied; and then finally we compare the FIESTA-IoT solutions against competing testing tools and research projects.

5.2 The IoT Interoperability Problem

5.2.1 Isn't Interoperability a Solved Problem?

The IoT Interoperability problem is well known; the heterogeneity in terms of technology, communication protocols, and data formats makes it a hard challenge to make two or more systems understand and interact with one another[45]. This is further evidenced by the developers of IoT systems, who identified interoperability as the second most important development challenge to overcome[46]. In some respects, interoperability is a solved problem—a standard defines the technologies for interoperability (e.g. communication protocol, data interface, etc.) and all parties implement their technologies in compliance with this standard. Hence, if the IoT community were to agree on such global standards, then the interoperability problem would be solved, as has been the case with Internet routing, transport, and application protocols. However, there are three fundamental reasons why universal interoperability standards will never be fully realised in the IoT domain:

[41] FIESTA-IoT Consortium, "Certification Suite V2", December 2017

[42] FIESTA-IoT Consortium, "Training, Consulting, Testing and Validation", June 2017

[43] https://github.com/fiesta-iot/model-interop

[44] http://certificate.fiesta-iot.eu/

[45] Paul Grace, Justan Barbosa, Brian Pickering, and Mike Surridge. 2014. Taming the interoperability challenges of complex IoT systems. In Proceedings of the 1st ACM Workshop on Middleware for Context-Aware Applications in the IoT (M4IOT '14). ACM, New York, NY, USA, 1-6.

[46] [15] IEEE. IoT Developer Survey 2016. http://iot.ieee.org/images/files/pdf/iot-developer-survey-2016-report-final.pdf

- A one-size-fits-all standard isn't suited to the heterogeneity of IoT systems: from small-scale sensor applications, to mobile and embedded devices, to large-scale Internet applications[47]. Such a standard would be overly complex, difficult to implement and difficult to comply with. Not to mention, it would require significant resources to both define and maintain. Further, IoT considers a broad range of vertical applications domains (smart cities, smart manufacturing, farming of the future, eHealth, and many more)—each with its own set of domain specific technologies and requirements.
- New IoT technologies and applications emerge fast, whereas standards development is a slow, incremental process. Hence, new competing IoT technologies will likely appear to make any pre-existing interoperability standard obsolete.
- Current thinking considers alternative approaches to standardization. These typically embrace *simplicity*, as exemplified by the REST philosophy—where a common architecture and single standard allow rapid publication of easy to use interfaces that are essentially de-facto standards for developers to work with. Consider, the Amazon Web Services APIs, Facebook APIs, as examples of these technologies that IoT systems can be composed with.

Hence, we cannot expect that a manageable set of IoT standards will eventually be agreed upon and hence the interoperability problem must be reduced in other ways. Methods such as Smart Gateways[48] have emerged which are similar to the Enterprise Service Bus patterns adopted previously to address enterprise interoperability problems. But protocol translators and bridges cannot solve all of the interoperability problems, i.e. it is challenging to map between different protocol behaviours and data content[49]. More blue-sky approaches have looked at automatically calculating mappings between systems, such emergent Middleware solutions[50] rely on machine-readable software artefacts, e.g., interface descriptions and ontologies, being available for run-time analysis. Yet, the reality is that systems do not typically publish such information and hence these solutions can only be applied to a handful of situations.

All these elements identify that IoT interoperability remains largely in the hands of the developers of IoT systems. Therefore, we must look at developer-centred solutions to better address the interoperability problem:

- Ease developers understanding of how systems interoperate, and if they fail to interoperate be able to use tools to pinpoint the problem to be fixed.
- The ability to quickly test if one or systems interoperate with one another. Essentially promoting test-driven interoperability.

[47] G. Blair and P. Grace, "Emergent Middleware: Tackling the Interoperability Problem," in IEEE Internet Computing, vol. 16, no. 1, pp. 78-82, Jan.-Feb. 2012.

[48] https://www.devicegateway.com/

[49] Blair G.S., Paolucci M., Grace P., Georgantas N. (2011) Interoperability in Complex Distributed Systems. In: Bernardo M., Issarny V. (eds) Formal Methods for Eternal Networked Software Systems. SFM 2011. Lecture Notes in Computer Science, vol 6659. Springer, Berlin, Heidelberg

[50] Gordon S. Blair, Amel Bennaceur, Nikolaos Georgantas, Paul Grace, Val´erie Issarny, Vatsala Nundloll, and Massimo Paolucci. The role of ontologies in emergent middleware: Supporting interoperability in complex distributed systems. In Middleware 2011, pages 410–430.

In the next subsection we look at the current state of the IoT standards in the marketplace and identifying where the FIESTA-IoT interoperability testing tools can have value in the marketplace.

5.2.2 IoT Standards Compliance

Much has already been written about the plethora of IoT standards. An ETSI review of the IoT landscape[51] identifies (as of October 2016) that there are 329 IoT standards; of these 150 can be seen as common standards (horizontal standards) and 179 are vertical standards in application domains such as smart living and smart manufacturing.

Simply looking at the protocol space, the following categories of protocols have been employed[52]:

- *Infrastructure* protocols for routing and radio communication such as IPv6, 6LOWPAN, Bluetooth, ZigBee (IEEE 802.15.4), NFC and many others.
- *Discovery protocols* to discover devices and services such as UPnP, Apple's Bonjour, HyperCat, and many others.
- *Data Protocols* to exchange data between communicating parties e.g. MQTT, HTTP, COAP, XMPP, SOAP and many others.

On top of this there are then cross-layer frameworks for describing, deploying, discovering and interacting with IoT systems, e.g. OneM2M[53], AllJoyn[54], IoTivity[55], OMA LightweightM2M v1.0 and others. Some of these are backed by standards, whereas others are frameworks for development that are essentially de-facto standards backed by reference implementations.

While interoperability testing of radio and infrastructure protocols is an important issue to address—it can follow existing standards-driven solutions because there is known required behaviour (radio communication of network packets) and a small group of chip/device manufacturers who need to perform this testing. Instead we consider that the FIESTA-IoT testing tools are **better suited to testing the interoperability of data, discovery and IoT frameworks** (particularly when used in combination), which may be carried out by any developer creating an IoT system or looking to develop software to integrate with existing IoT solutions.

There are three ways in which the interoperability testing can provide value to the user in terms of market standards:

- *Implementation Conformance*. A developer implements a service/technology that delivers a solution according to a market standard. The developer wishes to test that their implementation conforms to the standard (in order that clients will automatically interoperate with them). For example, see the HyperCat, NGSI-9 and OneM2M conformance tests later. The developer may also seek to

[51] ETSI, "SmartM2M; IoT Standards landscape and future evolutions", ETSI TR 103 375, October 2016.

[52] https://www.postscapes.com/internet-of-things-protocols/

[53] http://www.onem2m.org/

[54] https://openconnectivity.org/

[55] https://www.iotivity.org/

receive a certificate that will advertise their successful implementation of the standard.

- *Client Conformance*. A developer creates a client (mobile app, new sensor, etc.) that will need to integrate with market standards. The developer wishes to test that their technology will successfully interoperate with services that have implemented this standard.
- *Interoperability testing*. A developer of a technology wishes to test that one or more instances interoperate correctly with one another. For example, they want to test that N sensors interoperate according to one or more standards.

5.3 Certification of FIESTA-IoT Specification Compliance

5.3.1 Introduction

In this section we define the compliance tests for five different IoT standards; these consider both standards from recognised standards bodies, and de-facto standards that emerge in the market place:

- **OneM2M**[56]. The model-interop tool defines the 67 tests as defined in the OneM2M interoperability testing specifications[57] that contain tests to certify if a service implements the OneM2M specification, or individual OneM2M elements interoperate with one another.
- **NGSI-9/10**[58]. The Network Gateway Services Initiative is a standard defining the exchange of context events between devices, systems and context brokers; a common pattern employed to integrate IoT elements.
- **HyperCat**[59]. A catalogue protocol for advertising the available IoT resources along with the interaction mechanism (URL). As previously described, discovery standards offer an important element of IoT systems that query resources to find relevant data.
- **CitySDK**[60]. A RESTful interface specification that forms a de-facto standard for smart city services.
- **CDMI**[61]. The Cloud Data Management Interface (CDMI) is a SNIA standard that specifies a protocol for self-provisioning, administering and accessing cloud storage. IoT applications will typically be integrated with a cloud storage.

Here we do not present the complete interoperability specification tests; instead we highlight two/three examples from each standard; these shows how the standard was mapped onto an interoperability test model, and then how these tests are executed by the model-interop tool to generate a certificate of compliance. Subsequently, we

[56] http://www.onem2m.org

[57] http://www.onem2m.org/images/files/deliverables/TS-0013-Interoperability_Testing-V1_0_0.pdf

[58] http://www.openmobilealliance.org/release/NGSI/V1_0-20120529-A/OMA-TS-NGSI_Context_Management-V1_0-20120529-A.pdf

[59] British Standards Institute. “Automatic resource discovery for the Internet of Things. Specification”, PAS 212:2016, November 2016

[60] https://www.citysdk.eu

[61] https://www.snia.org/sites/default/files/CDMI_Spec_v1.1.1.pdf

provide a link to the complete test specification that can be executed in order to obtain a certificate for the market standard compliance.

5.3.2 OneM2M Compliance

The following two tests are taken directly from the Interoperability test specifications for OneM2M, which defines tests on the OneM2M standard.

[OneM2M-1: AE-Registrar CSE Interop test]

Objective: AE retrieves the CSEBase resource

Configuration:

References: TS-0001, clause 10.2.3.2 TS-0004 [2], clause 7.3.2

Steps for HTTP:

1. AE is requested to send a retrieve Request to CSE with name {CSEBaseName}
2. AE send GET request with the following rules

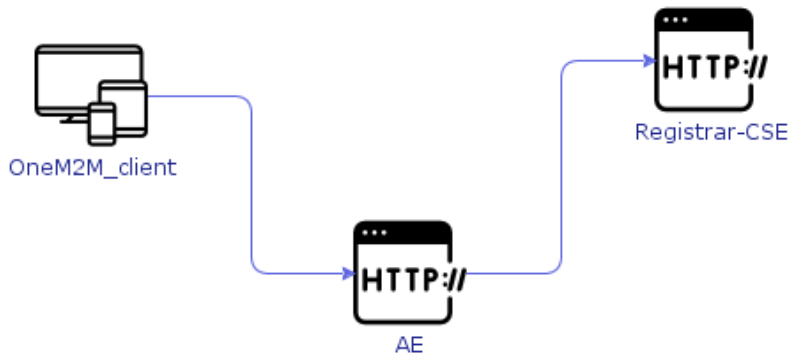
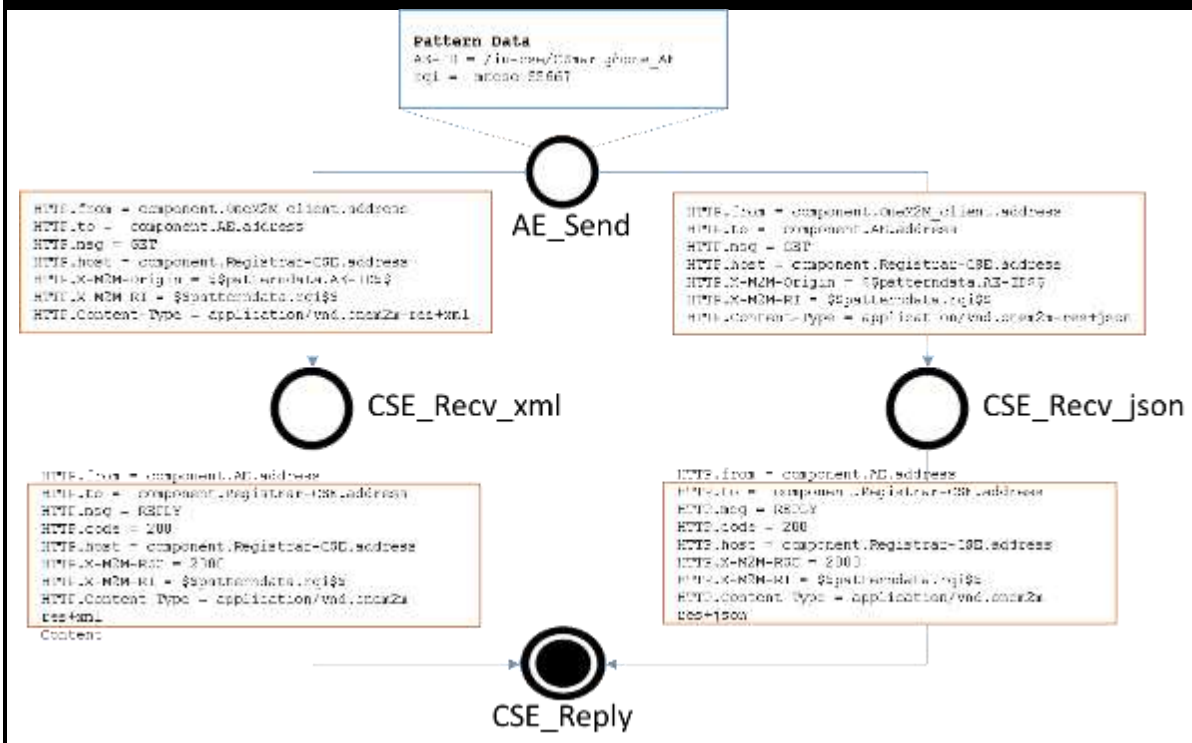
```
Request method = GET
Request-Target:{CSEBaseName}
Host: Host Address of registrar CSE
Header - X-M2M-RI: value of rqi primitive parameter
Header - X-M2M-Origin: AE-ID
Payload: empty
```

3. Registrar CSE sends response containing:

```
HTTP Status Code = 200
X-M2M-RSC: 2000
X-M2M-RI: value of rqi primitive parameter
Content-Type;          application/vnd.onem2m-res+xml          or
application/vnd.onem2m-res+json
Content-Length = size of payload in the message body in bytes
Payload: Serialized Representation of <CSEBase> resource
```

4. AE indicates successful operation

[OneM2M-1: FIESTA-IoT Interoperability Test Specification]

Deployment Model

A OneM2M_client node is created that produces the stimulant to enact step 1. The AE node and Registrar-CSE node then model the HTTP nodes between which the interoperability is tested.
Behaviour Model

The AE_Send state awaits the event and depending on the content-type moves to the state where the message has been sent (provided all interoperability rules are passed). The response is then check to move to state CSE_Reply (and the test has been fully passed).

[OneM2M-2: Registree-CSE to CSE Interop test]

Objective: Registree-CSE registers to Registrar CSE

Configuration:

References: TS-0001 [1], clause 10.2.2.1 TS-0004 [2], clause 7.3.3.2.1

Steps for HTTP:

1. Registree CSE is requested to send a RemoteCSE Create request to Registrar-CSE.
2. CSE send POST request with the following rules:

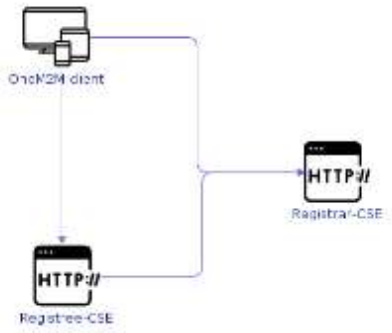
```
Request method = POST
Request-Target:{CSEBaseName}
Host: IP address or the FQDN of Registrar CSE
X-M2M-RI: (token-string)
X-M2M-Origin: Registree CSE-ID
Content-Type: application/vnd.onem2m-res+xml; ty=16 or application/vnd.onem2mres+json; ty=16
Message-body: Serialized representation of resource
```

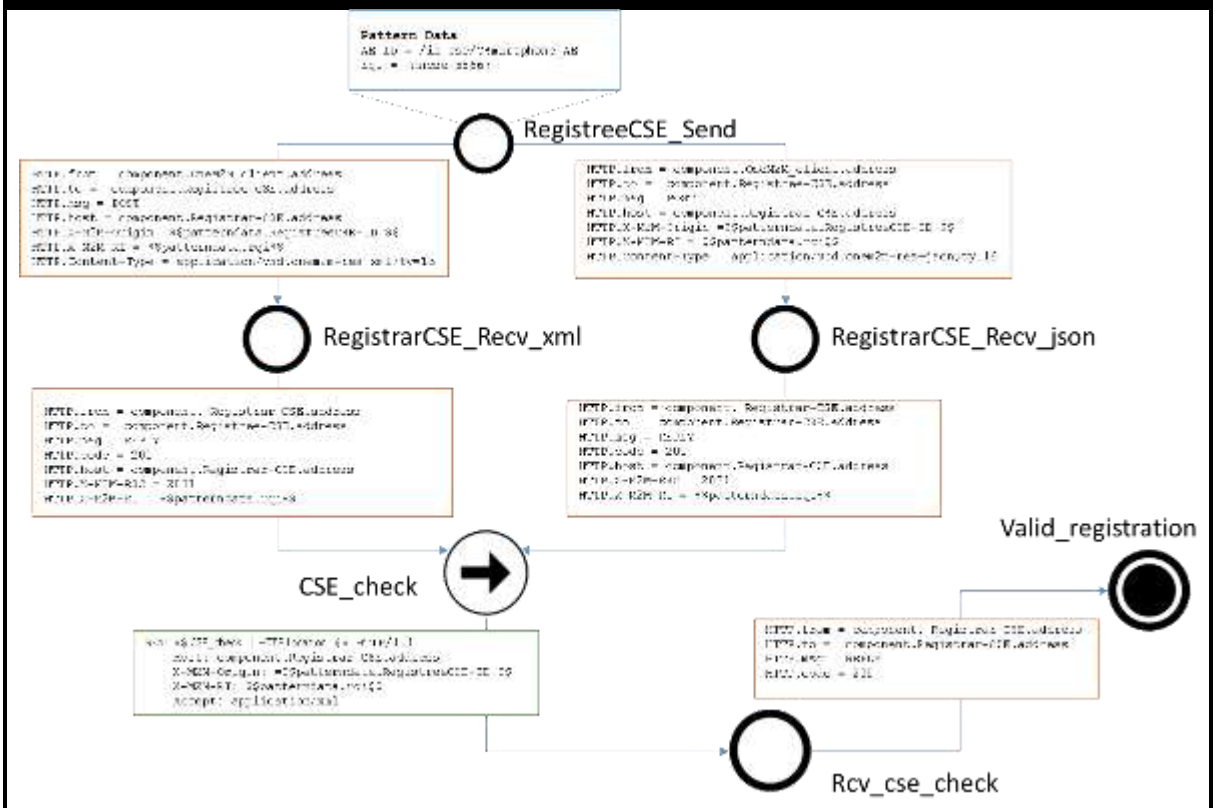
3. Registrar CSE sends response containing:

```
HTTP Status Code = 201 (Created)
X-M2M-RSC: 2001
X-M2M-RI: (token-string) same as received in request message
Content-Location: URI of the created RemoteCSE resource.
```

4. Check resource has been created in registrar CSE
5. Registree CSE indicates successful operation.

[OneM2M-2: FIESTA-IoT Interoperability Test Specification]

Deployment Model

A OneM2M_client node is created that produces the stimulant to enact step 1. The Registree-CS node and Registrar-CSE node then model the HTTP nodes between which the interoperability is tested. The OneM2MClient then tests step 4 and 5 to evaluate if the resource has been correctly created.

Behaviour Model

The AE_Send state awaits the event, and depending on the content-type moves to the state where the message has been sent (provided all interoperability rules are passed). The response is then check to move to state CSE_Reply (and the test has been fully passed).

[OneM2M Market Test Summary]

Number of interoperability tests	**65**
Number of Protocols	**3 (HTTP, COAP, and MQTT)**
Number of Model-Interop Specs	**195**
Technologies validated as Proof-of-correctness	**2** • **Ocean - Mobius platform http://www.iotocean.org/main/** • **Eclipse OneM2M - http://www.eclipse.org/om2m/**

Note: The breakdown of tests to 65 means that individual tests are understandable with no test containing more than 10 states. The ability to run “collections” of tests means that only a subset of the 195 tests is needed in particular cases.

5.3.3 NGSI-9/10 Tests

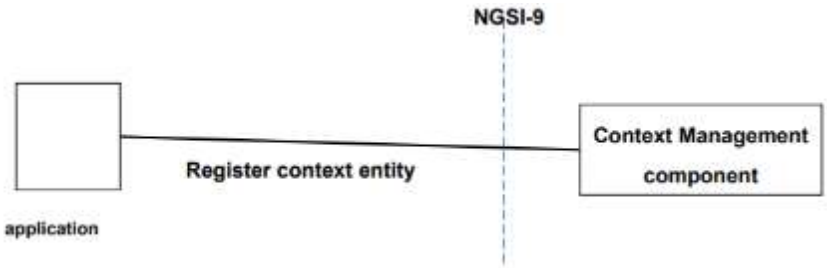
The following two tests have been developed as part of FIESTA-IoT based upon the information from Open Mobile Alliance Network Services Gateway Interface Standard which defines operations to register, query and subscribe to context events; a pattern well suited to the exchange of information in IoT systems. These two tests consider the same functionality but test for two specific purposes:

- **NGSI-1-interop: RegisterContext Interop test** tests that an application interoperates correctly with a service (context broker) that implements the NGSI-9 API specification (in terms of the register context functionality).
- **NGSI-1-comply: RegisterContext Compliance test** tests that a service correctly implements the NGSI-9 API specification for registering context functionality.

[NGSI-1-interop: RegisterContext Interop test]

Objective: Application registers a new context entity (e.g. sensor) to the Context Broker via the NGSI-9 API. This interface is bound to HTTP.

Configuration:



References: Open Mobile Alliance, OMA-TS-NGSI_Context_Management-V1_0-20120529-A, Section 5.1.2.1

Steps for HTTP:

1. External event stimulates the application to register new context
2. Application sends a HTTP request to register the new context entity

```
Request method = POST
Request-Target:{Service}
Host: Host Address of Service
Content-Type: application/json or application/xml
Payload: contextRegistrations data structure with ID set
```

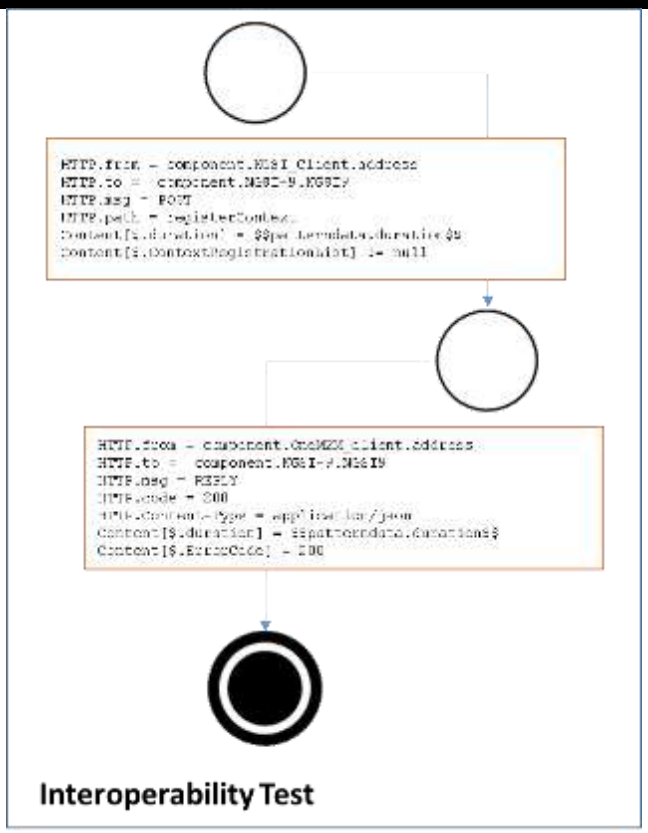
3. Context Broker responds with entity created operation:

```
HTTP Status Code = 200
Content-Type;          application/vnd.onem2m-res+xml          or
application/vnd.onem2m-res+json
Payload: Content with a registration id
```

4. Application indicates successful operation

[NGSI-1-interop: FIESTA-IoT Interoperability Test Specification]

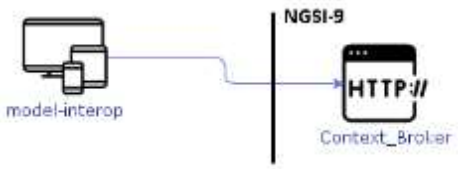
Deployment Model

The interoperability test evaluates the exchange of the register context message between the NGSI client application and the context broker implementing the NGSI-9 interface.
Behaviour Model

The above shows the interoperability test where the client sends a registration message to the ngsi-9 api.

[NGSI-1- comply: RegisterContext Compliance test]

Objective: Context Broker implements the register context functionality to comply with the NGSI-9 API. This interface is bound to HTTP.

Configuration:



References: Open Mobile Alliance, OMA-TS-NGSI_Context_Management-V1_0-20120529-A, Section 5.1.2.1

Steps for HTTP:

1. Model-interop tool sends a HTTP request to register the new context entity

```
Request method = POST
Request-Target:{Service}
Host: Host Address of Service
Content-Type: application/json or application/xml
Payload: contextRegistrations data structure with ID set
```

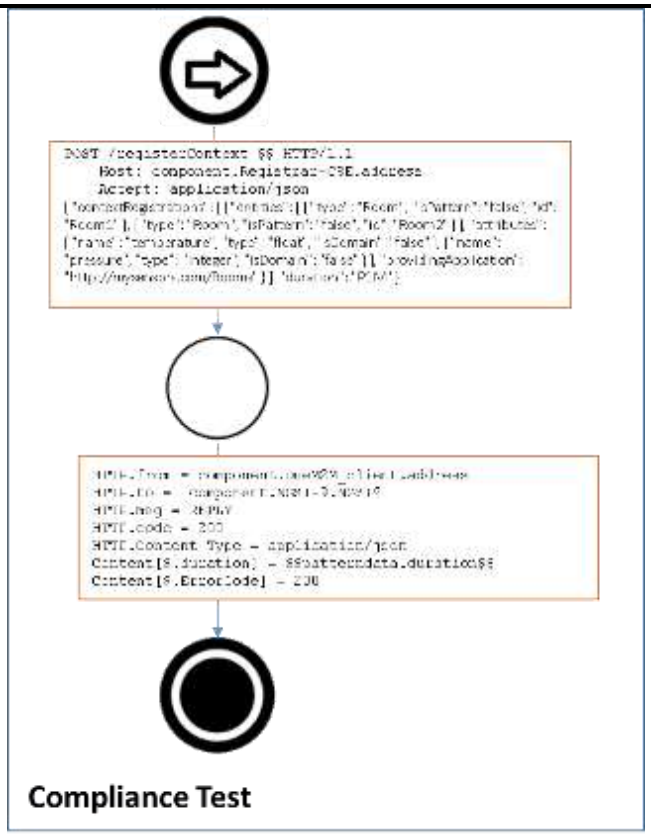
2. Context Broker responds with entity created operation:

```
HTTP Status Code = 200
Content-Type;          application/vnd.onem2m-res+xml          or
application/vnd.onem2m-res+json
Payload: Content with a registration
```

[NGSI-1-comply: FIESTA-IoT Interoperability Test Specification]

Deployment Model

As a compliance test, only the services under test are deployed for the model-interop tool to interact with
Behaviour Model



The model-interop sends the test compliance message for register a new context to the service under a test and the response is validated.

[NGSI-9/10 Market Test Summary]

Number of interoperability tests	**7**
Number of compliance tests	**7**
Number of Model-Interop Specs	**14**
Technologies validated as Proof-of-correctness	**1 FIWARE Orion Context Broker https://fiware-orion.readthedocs.io**

5.3.4 HyperCat Tests

Generally known as HyperCat, "PAS-212:2016-Automatic resource discovery for the Internet of Things – Specification" is an IoT standard defined by the British Standards Institute. *"PAS 212 specifies a common catalogue format that clients can use to discover data in servers that they can use. It describes an open, lightweight JSON-based hypermedia catalogue format for exposing collections of uniform resource identifiers (URIs). Each catalogue may expose any number of URIs, each with any number of resource description framework (RDF)-like triple statements about it. This allows developers to publish linked-data descriptions of resources"*[62].

[62] BSI, "PAS-212:2016-Automatic resource discovery for the Internet of Things", May 2016

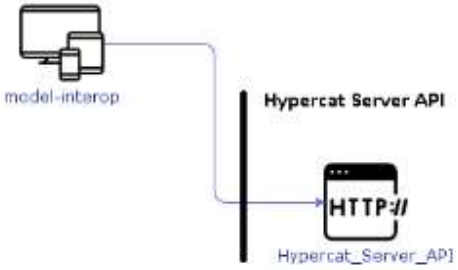
The following test have been developed as part of FIESTA-IoT based upon the information from the BSI standard documentation (this serves as an illustration of the full set of tests not repeated here):

- **HyperCat-1-comply: GetCatalogue test** tests that the catalogue service has been correctly implemented against the standard specification.

[HyperCat-1-comply: GetCatalogue Compliance test]

Objective: A HyperCat endpoint correctly implements the catalogue functionality to comply correctly with the standard

Configuration:

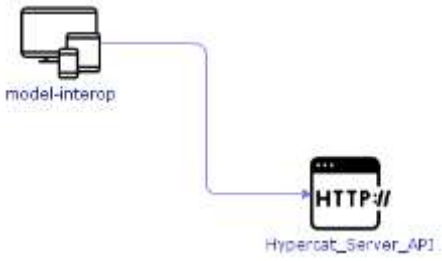


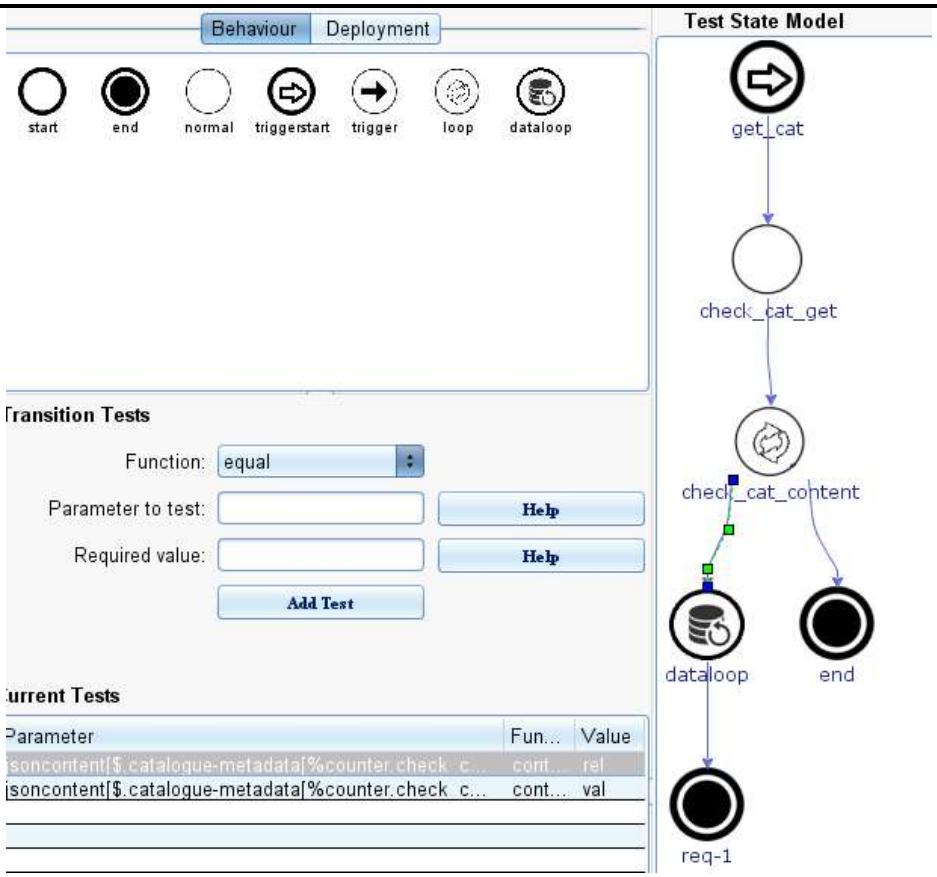
References: BSI, "PAS-212:2016-Automatic resource discovery for the Internet of Things – Specification", May 2016

Test requirements from the standard:

1. Section 5 Server API
    a. General. Where an HTTP(S) application programming interface (API) is provided to allow clients to interact with catalogues, the server shall conform to the requirements set out in 5.2 to 5.3.
2. **Req-5.2** Every server shall provide a publicly readable /cat endpoint serving a catalogue.
3. **Req-5.3** Read catalogue
    a. **Req-5.3.1** Where a client wishes to read an entire catalogue, the client shall GET the catalogue URL.
    b. **Req-5.3.2** Where a server successfully serves an entire catalogue, the server shall respond with: an HTTP 200 status code; and the catalogue.

[HyperCat-1-comply: FIESTA-IoT Compliance Test Specification]

Deployment Model

As a compliance test, only the services under test are deployed for the model-interop tool to interact with – in this case the HyperCat server API
Behaviour Model



The test sends a request to get the catalogue and then loops through the data (contains lists of resources) to check that each statement in the data complies with the standard specification. Note, we present a screenshot of the tool with the behaviour model with the loop transitions showing the checks on the catalogue meta-data.

[HyperCat Market Test Summary]

Number of interoperability tests	**9**
Number of compliance tests	**9**
Number of Model-Interop Specs	**18**
Technologies validated as Proof-of-correctness	**1** • **BT CityVerve HyperCat API https://portal.bt-hypercat.com/**

5.3.5 CitySDK Tests

CitySDK[63] is a de-facto standard providing a harmonized API instead of a city-specific interface to provide access to a range of common services found in smart cities. It has

[63] https://www.citysdk.eu

been deployed and tested across 8 cities (as more cities employ the greater the impact of the specification).

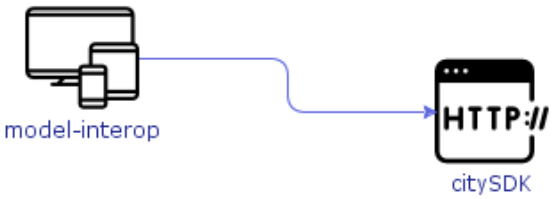
The following test has been developed as part of FIESTA-IoT based upon the information from the CitySDK standard documentation – it illustrates part of the set of tests for the specification:

- **CitySDK -1-comply: find-poi test** tests that the tourism api service has been correctly implemented against the standard specification.

[CitySDK-1- comply: find-poi test]

Objective: A CitySDK endpoint correctly implements the point-of-interest functionality to comply correctly with the standard

Configuration:



References: http://tourism.citysdk.eu

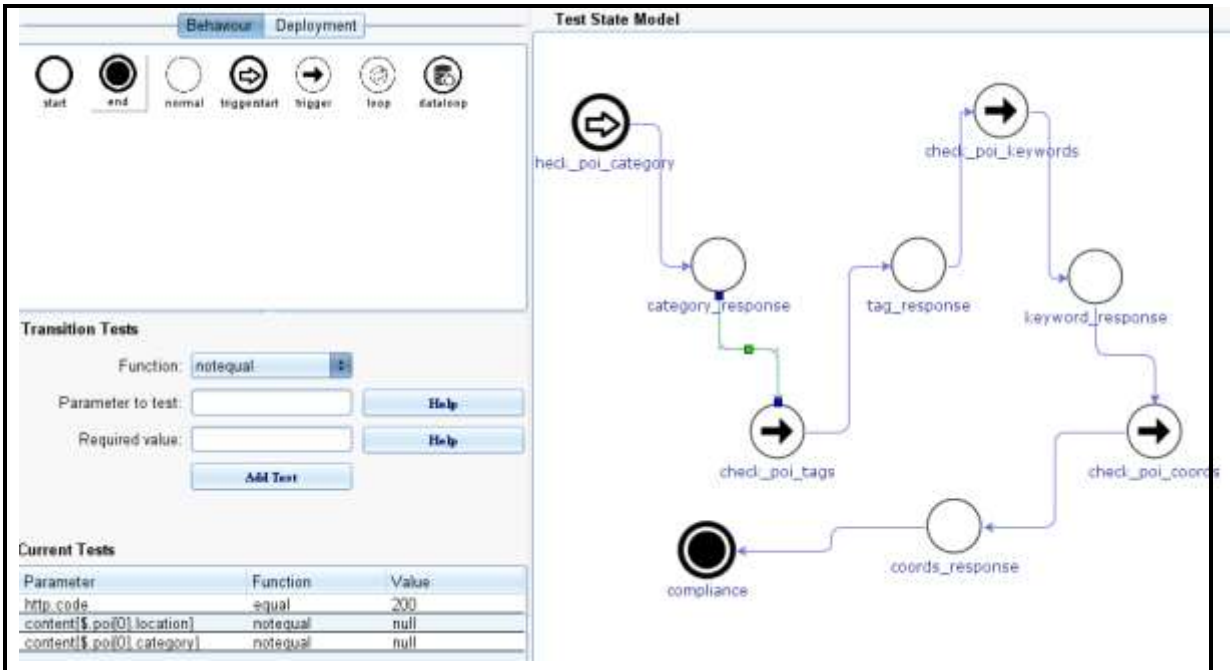
Test requirements from the specification:

Parameters:

1. **Search using category** – search using a category API HTTP parameter;
2. **Receive a valid** list of Points of Interest corresponding to the category;
3. **Search using tag -** search using a tag API HTTP parameter;
4. **Receive a valid** list of Points of Interest corresponding to the tag;
5. **Search using keyword -** search using a minimal keyword API HTTP parameter;
6. **Receive a valid** list of Points of Interest corresponding to the keyword;
7. **Search using co-ordinates -** location search using a set of co-ordinates as path parameters;
8. **Receive a valid** list of Points of Interest corresponding to the location;

Deployment Model

The HTTP server API endpoint under test for compliance to CitySDK.
Behaviour Model



The test carries out the series of individual requests with changing parameters according to the above specification. For the POI api all parameters types must be implemented to achieve compliance. The example highlighted shows that the request for category search checks the validity of the JSON POI data.

[CitySDK Market Test Summary]

Number of interoperability tests	**8**
Number of compliance tests	**8**
Number of Model-Interop Specs	**16**
Technologies validated as Proof-of-correctness	**2** • **Lisbon City Tourist API http://tourism.citysdk.cm-lisboa.pt** • **Helsinki City Tourist API http://citysdk.dmci.hva.nl:80**

5.3.6 CDMI

Cloud Data Management Interface (CDMI™) Version 1.1.1 is an International Standard is intended for application developers who are implementing or using cloud storage. It documents how to access cloud storage and to manage the data stored there. This is an important example for IoT services where data is collected, analysed and stored in the cloud.

The following test have been developed as part of FIESTA-IoT based upon the information from the CDMI standard documentation (this illustrates a subset of the

available interoperability and compliance tests for this standard. There are 8 tests, one for create, read, update and delete on both data objects and containers):

- **CDMI-1-comply: Read Data Object Compliance test** tests that a service correctly implements the read data object value from a cloud storage service.

[CDMI-1-comply: Read Data Object Test]

Objective: Read a data object value that is stored in the cloud storage via the

Configuration:

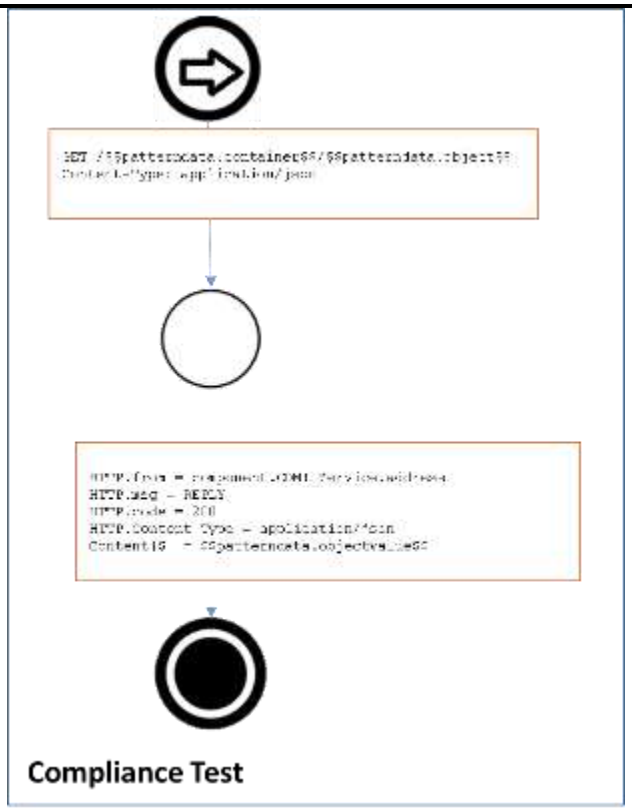
References: https://www.snia.org/sites/default/files/CDMI_Spec_v1.1.1.pdf

Test requirements from the specification:

The following HTTP GET reads from an existing data object at the specified URI: GET <root URI>/<ContainerName>/<DataObjectName> Where: • <root URI> is the path to the CDMI cloud. • <ContainerName> is zero or more intermediate containers. • <DataObjectName> is the name of the data object to be read from.

Deployment Model

The Cloud storage service with a CDMI API under test to check it complies with the standard.
Behaviour Model



Assuming we have created a data object (json) with a given value, we check that the data read matches this to pass the compliance test.

[CitySDK Market Test Summary]

Number of interoperability tests	**8**
Number of compliance tests	**8**
Number of Model-Interop Specs	**16**
Technologies validated as Proof-of-correctness	**1** • **SNIA reference implementation: https://github.com/SNIA/CDMI**

5.4 Evaluation

5.4.1 Summary of Model-Interop Usage

Table 8 shows an overview of the usage of the model-interop tools as both part of the Global Market Confidence Programme to certify FIESTA-IoT technologies; and also as used to define and execute IoT interoperability tests on IoT market standards. The tool forms part of the approach to validate testbeds joining the FIESTA-IoT platform (as described in earlier WP6 deliverables). As part of this process, 10 testbeds used the interoperability testing tools; 4 the original FIESTA-IoT testbeds, and 6 the testbeds that joined as part of the Open Call. These results show that all testbeds internal and external used the tools to validate their technologies and allow them to join the platofm.

The table also shows that the methods and technologies employed are suited to a range of market standards.

Table 8 - Summary of model-interop application

Number of Internal FIESTA-IoT testbeds certified using model-interop certification test	**4**
Number of External FIESTA-IoT testbeds certified using model-interop certification test	**6**
Number of Model-Interop Specification Tests	**249**
Market Technologies validated as Proof-of-correctness	**6**

5.4.2 General Interoperability Testing Approaches

With a lack of specific tools to test protocol interoperability or conformance, general purpose tools such as WireShark[64] or network analysers are still commonly used to manually examine packets on the wire. However, such testing methods are error-prone and can realize the misunderstanding of standards. TTCN (The Tree and Tabular Combined Notation) is a well-established notation for the specification of test cases for OSI protocol conformance testing which has now been extended for more general purpose distributed system testing (TTCN-3). TTCN essentially provides an abstract programming language to specify tests such that they can then be shared between developers and a common understanding is maintained. TTCN tools (the majority are commercial tools, notably TITAN[65] is available open source) then provide concrete implementations that map and bind the language to protocols (e.g. HTTP, SIP, etc.) and data formats (e.g ASN1.0, XSD, etc.). TTCN is well suited to conformance testing but given the generic programming constructs it is equally possible to define interoperability tests between remote systems. While TTCN raises the level of abstraction, it has a significant learning curve, and test specifications can be difficult to understand and/or develop by non-experts. Therefore, it is ideally suited to niche communities, e.g. the testing of communication protocols. This has led to the emergence of MBT (model-based testing) tools that automate the generation of TTCN tests from models of system behaviour: Conformiq Creator[66] enables the creation of requirement based graphical models. Users create flow and structure diagrams of the system using BPMN, WSDL and XSD artifacts to model the behaviour of the system TTCN tests are generated from this model and automatically executed against the distributed system implementation. Pragmadev Tester[67] generates and automatically executes TTCN tests from UML like sequence and state diagrams. However, such models are better suited to functional testing (i.e. a distributed system fulfils its

[64] https://www.wireshark.org/

[65] https://projects.eclipse.org/projects/tools.titan

[66] http://www.conformiq.com/

[67] http://www.pragmadev.com/

requirements); and these models require everything to be specified (and are hence very complex) not just aspects related to interoperability testing.

Further, the complexity of engineering models means they are no longer widely-used throughout the development lifecycle; in the domain of Internet Services, RESTful APIs (e.g. Twitter, Facebook, and others) provide documentation and SDKs to help developers interoperate without having to create and implement complex specifications. Then, API testing tools such as SOAP UI[68] and RestAssured[69] are used to functionally test that a service correctly implements an API specification.

Hence, this demonstrates the need for simplicity in modelling and testing that are close in nature to the development tools. Model-interop provides both the simplicity of modelling of different types of data and protocol in such a manner that strong coverage of interoperability testing requirements are realised.

5.4.3 F-Interop

F-Interop[70] is a H2020 European research project specifically examining the integration and testing of IoT infrastructures and technologies. In particular it concentrates on online interoperability and conformance testing. The testing architecture is shown in Figure 25. In comparison with model-interop and the FIESTA-IoT approach to interoperability testing:

- F-Interop provides a set of heterogeneous testing tools (per protocol, standard) build on top of the common testing architecture. Model-Interop and FIESTA-IoT presents a common testing tool (and portal) to perform multiple tests.
- F-Interop concentrates on low level network protocols (COAP, 6Tisch, etc.), whereas Model-Interop concentrates on application protocols, data and Quality of Service at the application level. The number of testers for network protocols is small (there are a small number of developers creating products to meet low level network standards); whereas there are significantly greater numbers of application clients (apps) and IoT service developers to increase the potential impact of the model-interop tool.
- F-Interop uses agents to observe network messages in-situ; and then sends these to F-Interop servers (as seen in Figure 25). This type of online testing is only suited to cases where no personal data is transported in the packets, or where the developer is unconcerned about information about their testing (going out of house). Model-Interop provides a full testing and certification solution that keeps all data within a tester's premise (only the results of the tests are validated remotely by FIESTA-IoT).

[68] https://www.soapui.org/

[69] http://rest-assured.io/

[70] http://www.f-interop.eu

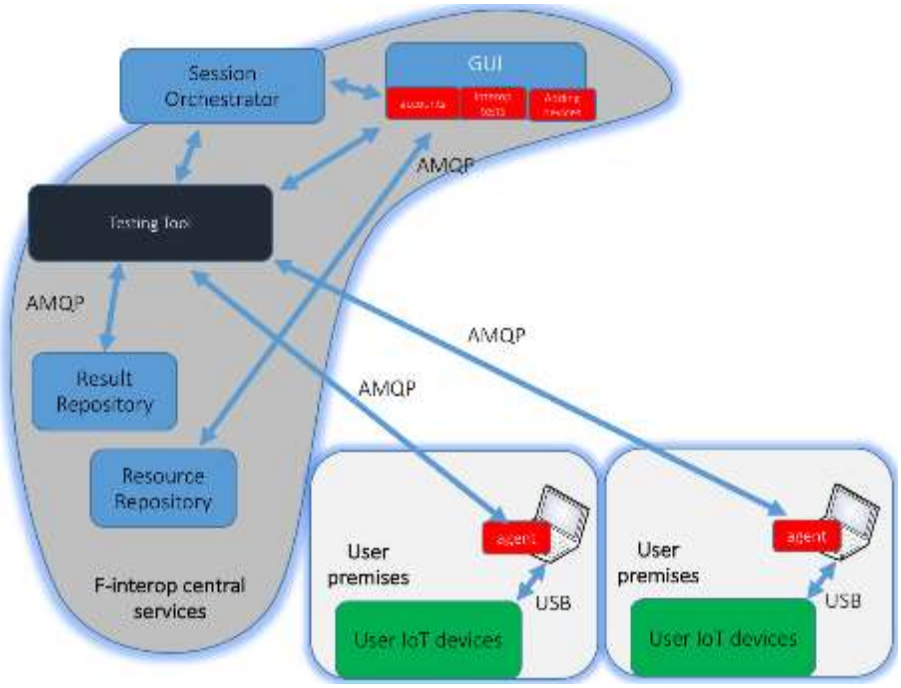


Figure 25 - The F-Interop Online Testing Architecture

5.5 Summary

We have presented the model-interop tool and certification portal and described how they have been employed originally to successfully test the certification of testbeds with FIESTA-IoT, and then subsequently to a range of market standards. This has shown the following key values of the approach:

- Testing and certification tools provide a simple to understand method for developers to execute interoperability and compliance tests in order to certify with given standards.
- New interoperability and compliance tests can be quickly created with the tools to react to the changing marketplace (new IoT standards, new de-facto standards, or changing standards).
- Certification can be carried out in a secure and private fashion without risking breaches on personal data, or disclosure of IPR.

6 CONCLUSION

This document is the 2nd version of the report that gave continuity to the work carried out during the last 39 months of the FIESTA-IoT Work Package 6 focusing on the "Training, Consulting and Validation" where regard in-depth the FIESTA-IoT Training Platform and its functionalities.

Through the performance of the FIESTA-IoT Training Platform and the feedback acquired was analysed that each section of the Training Platform offers all the necessary material to support users in the appropriate use of the FIESTA-IoT Platform and that each the FIESTA-IoT Training Workshops, that were organized during the project in order to support the Experimenters and Extensions of the FIESTA-IoT Open-Calls and to present the FIESTA-IoT Platform to the third parties, also provides all the resources related to the training workshops of the latest FIESTA-IoT Open-Calls.

This feedback also outcomes from the information extracted in all the follow-up questionnaires made to the FIESTA-IoT Open-Call Experimenters and Extensions, whose objective was to monitor their activities in the middle of the 6 months of the design and implementation phase, and also allow to analyse the level of satisfaction of the researchers in each FIESTA-IoT Open-Call and how it evolved in relation to the actions of the FIESTA-IoT consortium to improve the documentation of the FIESTA-IoT Training Platform.

This report addressed the FIESTA-IoT Market Interoperability testing and validation analysis where has analysed that the provided tools for testing and certification enable to perform interoperability testing easily, the implementation of new interoperability tests with the tools to react to the market and that the certification process can be performed safely and privately.

7 BIBLIOGRAPHY

[1] IEEE, IEEE Standard Computer Dictionary: A Compilation of IEEE Standard Computer Glossaries., New York, 1990.

[2] FIESTA-IoT, Specification and implementation of common Testbed interfaces V2, 2017.

[3] FIESTA-IoT, Semantic models for testbeds, interoperability and mobility support and best practices V2, 2016.

ANNEX A – AGENDA: OPEN-CALL 1 - 1ST TRAINING WORKSHOP FOR EXPERIMENTERS

Date: **14TH March 2017**

10:00 – Welcome and briefing

10:15 – Training and support

Present training platform and the procedure to get support and to solve issues.

10:35 – FIESTA-IoT available testbeds descriptions – Focus on datasets available

SmartSantander (Smart City)

SmartICS (Smart Building)

KETI (Smart Building)

Inria (Crowdsourcing noise information)

11:00 – FIESTA-IoT Ontology

General aspects of the ontology. Special emphasis to M3-Lite taxonomy

11:25 – Break and refresh

11:40 – Authentication and Authorization – SSO Token

Get and use the token. Roles and access privileges (how to be upgraded)

12:10 – Platform overview

Focus on components that will be actually serving the experimenter. Experimenter Workflow

12:40 – Portal-based platform services

13:15 – Lunch break

14:30 – Meta-Directory REST-based services

SPARQL endpoint, Queries storage; SPARQL Templates

15:00 – Already existing experiments description

Success stories and best practices using the FIESTA-IoT Platform

15:15 – Questions and answers

Time to briefly (5 minutes per experiment) present the experiments

16:30 – Workshop closure

ANNEX B – AGENDA: OPEN-CALL 1 - 2ND TRAINING WORKSHOP FOR EXPERIMENTERS

Date: **25TH July 2017**

10:00 – Welcome and briefing

10:05 – Experiments actual needs

Understanding what you need and matching it to what the FIESTA-IoT Platform can provide

11:20 – Platform-wide issues

Performance (delays, timeouts), Security policies and Size of result-sets

11:30 – SPARQLs session

Best practices review over the provided queries and Hands-on execution of queries and discussion

12:15 – FEDSpecs session

Best practices on scheduling and Best practices on FEDSpec mgmt.

12:45 – Workshop closure

ANNEX C – AGENDA: OPEN-CALL 1 TRAINING WORKSHOP FOR EXTENSIONS

Date: **17TH March 2017**

10:00 – Welcome and briefing

10:15 – Training and support

Present training platform and the procedure to get support and to solve issues.

10:35 – FIESTA-IoT Ontology

General aspects of the ontology. Special emphasis to M3-Lite taxonomy. Template for gathering requirements

11:00 – Platform overview

Focus on Testbed Provider Interface (TPI). Testbed Provider Workflow

11:30 – Break and refresh

11:45 – Authentication and Authorization – SSO Token

Get and use the token. Roles and access privileges (how to be upgraded)

12:15 – TPS Development and Annotator as a Service

Testbed Provider Services (TPS) API description

12:45 – Own annotator development and validation tools

Annotator development best practices and Minimum valid document. Validator and Certification Portal

13:15 – Lunch break

14:30 – Testbed registration and Resources registration process

15:00 – TPI Configurator usage

15:30 – Questions and answers

Time to briefly (5 minutes per testbed) present the testbeds

16:30 – Workshop closure

ANNEX D – AGENDA: OPEN-CALL 2 TRAINING WORKSHOP FOR EXTENSIONS

Date: **29TH May 2017**

10:00 – Welcome and briefing

10:15 – Training and support

Present training platform and the procedure to get support and to solve issues.

10:35 – FIESTA-IoT Ontology

General aspects of the ontology. Special emphasis to M3-Lite taxonomy. Template for gathering requirements

11:00 – Platform overview

Focus on Testbed Provider Interface (TPI). Testbed Provider Workflow

11:30 – Break and refresh

11:45 – Authentication and Authorization – SSO Token

Get and use the token. Roles and access privileges (how to be upgraded)

12:15 – TPS Development and Annotator as a Service

Testbed Provider Services (TPS) API description

12:45 – Own annotator development and validation tools

Annotator development best practices and Minimum valid document. Validator and Certification Portal

13:15 – Lunch break

14:30 – Testbed registration and Resources registration process

15:00 – TPI Configurator usage

15:30 – Questions and answers

Time to briefly (5 minutes per testbed) present the testbeds

16:30 – Workshop closure

ANNEX E – AGENDA: OPEN-CALL 3 TRAINING WORKSHOP FOR EXPERIMENTERS

Date: **13TH Semptember 2017**

10:00 – Welcome and briefing

10:15 – Training and support

Present training platform and the procedure to get support and to solve issues. 10:35 – FIESTA-IoT available testbeds descriptions – Focus on datasets available

SmartSantander (Smart City)	NITOS (Smart Environment – Indoor/Outdoor)
SmartICS (Smart Building)	EXTEND (Smart Environment – Water)
KETI (Smart Building)	FINE (Smart Environment – Outdoor)
Inria (Crowdsourcing noise information)	REALDC (Smart Grid – DataCentre)
ADREAM (Smart Building)	Tera4Agri (Smart Agriculture)

11:00 – FIESTA-IoT Ontology

General aspects of the ontology. Special emphasis to M3-Lite taxonomy

11:25 – Break and refresh

11:40 – Authentication and Authorization – SSO Token

Get and use the token. Roles and access privileges (how to be upgraded)

12:10 – Platform overview

Focus on components that will be actually serving the experimenter. Experimenter Workflow

12:40 – Portal-based platform services

13:15 – Lunch break

14:30 – Meta-Directory REST-based services

SPARQL endpoint, Queries storage; SPARQL Templates

15:00 – Already existing experiments description

Success stories and best practices using the FIESTA-IoT Platform

15:15 – Questions and answers

Time to briefly (3 minutes per experiment) present the experiments

16:30 – Workshop closure

ANNEX F – AGENDA: OPEN-CALL 4 TRAINING WORKSHOP FOR EXPERIMENTERS

Date: **20TH November 2017**

10:00 – Welcome and briefing

10:15 – Training and support

Present training platform and the procedure to get support and to solve issues.

10:30 – FIESTA-IoT Ontology

General aspects of the ontology. Special emphasis to M3-Lite taxonomy

10:45 – Authentication and Authorization – SSO Token

Get and use the token. Roles and access privileges (how to be upgraded)

11:00 – Break and refresh

11:10 – Platform overview

Focus on components that will be actually serving the experimenter. Experimenter Workflow

11:40 – Portal-based platform services

- Portal introduction (5 min)
- Monitoring (5 min)
- FIESTA-IoT Analytics Tools (15 min) • Reasoning (10 min)
- Experiment Editor (10 min)

12:25 – Meta-Directory REST-based services

SPARQL endpoint, Queries storage; SPARQL Templates

12:55 – Already existing experiments description

Success stories and best practices using the FIESTA-IoT Platform

13:10 – Questions and answers

Time to briefly (5 minutes per experiment) present the experiments

13:35 – Workshop closure

ANNEX G – AGENDA: TRAINING WORKSHOP AT IOT WEEK 2017

Date: **8TH June 2017**

16:15 – Welcome and presentation of the session

10:20 – Overview of the EaaS tools for experimentation on top of the FIESTA-IoT platform

16:50 – FIESTA-IoT Training and Support for 3rd Parties

17:10 – FIESTA-IoT NEC SmartCity Magnifier demonstrator

17:30 – FIESTA-IoT 3rd and 4th Open-Calls and conclusions

ANNEX H – QUESTIONNAIRE FOR EXPERIMENTERS

Q1: Have you attended the training workshop? (Yes / No)

Q2: Have you used the helpdesk email? (Yes / No)

Q3: Have you used the ticketing system? (Yes / No)

Q4: Have you used the live chat? (Yes / No)

Q5: Have you gone through the training courses made available to you? (Yes / No)

Q6: Have you consulted the on-line documentation? (Yes / No)

Q7: Have you used the available sample material? (Yes / No)

Q8: Have you found all the needed information about FEDSpec? (Yes / No / Not Need)

Q9: Have you found all the needed information about the APIs? (Yes / No)

Q10: Have you found all the needed information about the ontology? (Yes / No)

Q11: Have you found all the needed information about the Experiment Data Receiver?

(Yes / No / Not Need)

Q12: Have you found all the needed information about the Experiment execution process?

(Yes / No / Not Need)

Q13: Have you conveyed the objective KPIs to the FIESTA-IoT Consortium? (Yes / No)

Q14: Have you used the experiment related tools from the FIESTA-IoT platform portfolio?

(Yes / No)

Q15: Have you conveyed your developed FEDSpec to the FIESTA-IoT Consortium?

(Yes / No / Not Need)

Q16: Have you used the SPARQL endpoint from the FIESTA-IoT platform portfolio? (Yes / No)

Q17: Have you used SPARQL query catalogue? (Yes / No)

Q18: Have you used the Resource browser from the FIESTA-IoT platform portfolio? (Yes / No)

Q19: Have you used the REST access to datasets from the FIESTA-IoT platform portfolio?

(Yes / No)

Q20: Were you able to receive data? (Yes / No)

Q21: Have you proposed code/enhancements/modules/tools that could be beneficial for future experiments? (Yes / No)

Q22: If yes, which one(s)?

Q23: If yes, have you proposed additional functionalities that could be beneficial for future experiments?

Q24: Does the experiment allow objective assessment of the FIESTA-IoT platform non-functional requirements? (Yes / No)

Q25: Did you get adequate support from FIESTA-IoT members? (Yes / No)

Q26: Is your experiment currently deployed? (Yes / No)

Q27: Have you followed the suggested best-practices? (Yes / No)

Q28: Do you expect to continue collecting data from the FIESTA-IoT platform once your experiment contract time ends? (Yes / No)

ANNEX I – QUESTIONNAIRE FOR EXTENSIONS

Q1: Have you analysed the FIESTA-IoT Ontology to check the compatibility with your existing datasets to find out necessary classes and relationships for the annotation? (Yes / No)

Q2: Have you requested for Taxonomy/ontology modifications to span your testbed requirements (e.g. new concepts to be added to the taxonomy)? (Yes / No)

Q3: Have you checked that all your propositions have been successfully carried out and have been mapped onto the FIESTA-IoT ontology? (Yes / No)

Q4: Have you managed to get your own FIESTA-IoT annotations for resource description(s) through your own tailored annotator? (Yes / No / Not Applicable)

Q5: Have you managed to get your own FIESTA-IoT annotations for observation(s) through your own tailored annotator? (Yes / No / Not Applicable)

Q6: Have you managed to get your own FIESTA-IoT annotations for resource description(s) through FIESTA-IoT AaaS API (in case N/A in question Q5)? (Yes / No / Not Applicable)

Q7: Have you managed to get your own FIESTA-IoT annotations for observation(s) through FIESTA-IoT AaaS API (in case N/A in question Q6)? (Yes / No / Not Applicable)

Q8: Have you included an IoT Service Endpoint as part of the resource description?

(Yes / No / Not Applicable)

Q9: Have you accomplished the validation of your resource description(s) using the FIESTA-IoT Certification Suite? (Yes / No)

Q10: Have you accomplished the validation of your observation(s) using the FIESTA-IoT Certification suite? (Yes / No)

Q11: Have you been promoted to "testbedAdmin" in order to have the permissions to proceed to the next steps of pushing your annotations? (Yes / No)

Q12: Have you registered your testbed into the FIESTA-IoT Federation through the portal?

(Yes / No)

Q13: Have you successfully registered (at least one) resource(s) through the portal? (Yes / No)

Q14: Have you defined the operation mode (reactive - e.g. GetObservations or proactive – e.g. PushObservations) of your testbed? (NOTE: Recall that you only have to implement one of them (having the two is welcome, though) (Yes / No)

Q15: Have you implemented your TPS, including the corresponding endpoints (Reactive) and run internal tests? (Yes / No)

Q16: Have you implemented your TPS, including the corresponding endpoints (Proactive) and successfully run internal tests? (Yes / No)

Q17: If authenticated access to testbed is enabled, you provide an API key?

(Yes / No / Not Applicable)

Q18: If using HTTPS for communicating with the testbed, you provide the certificate chain?

(Yes / No / Not Applicable)

Q19: For the proactive mode, have you implemented the methods that trigger or stop the data flow (Start/Stop PushObservations)? (Yes / No / Not Applicable)

Q20: Have you used the TPI Configurator in order to select the devices that will become active for FIESTA-IoT, thus sending information to the platform? (NOTE: Only registered resources will be visible at this point) (Yes / No)

Q21: Have you make sure that your system is running, thereby sending information automatically to FIESTA-IoT and not producing Bad Requests? (Yes / No)

Q22: Have you followed the set of Best Practices recommended by the FIESTA-IoT consortium? (Yes / No)

ANNEX J – QUESTIONS FOR DOCUMENTATION EVALUATION

Q1. Did you use the documentation for experimenters provided on the Moodle?

- Yes, we consulted almost all the documents
- Yes, but only some documents
- No, I didn't

Q2. Were you able to find the needed information?

- Always
- Most of the time
- Sometimes
- Never

Q3. Do you believe that some documentation is missing?

- Yes
  - List the missing document(s)
- No

Q4. How would you rate the <u>quality</u> of the documentation provided to discover the platform?

	Excellent	Very good	Good	Fair	Poor	N/A
➢ Documentation about FEDSPEC	☐	☐	☐	☐	☐	☐
➢ Documentation about APIs	☐	☐	☐	☐	☐	☐
➢ Documentation about Ontology	☐	☐	☐	☐	☐	☐
➢ Documentation about SPARQL queries	☐	☐	☐	☐	☐	☐
➢ Documentation about installing Experiment Data Receiver	☐	☐	☐	☐	☐	☐
➢ Experiment Execution process and guidelines	☐	☐	☐	☐	☐	☐
➢ Overall documentation in the Project Handbook	☐	☐	☐	☐	☐	☐

Q5. How would you rate the <u>relevance</u> of the documentation to support you to set up your experimentation?

	Excellent	Very good	Good	Fair	Poor	N/A
➢ Documentation about FEDSPEC	☐	☐	☐	☐	☐	☐
➢ Documentation about APIs	☐	☐	☐	☐	☐	☐
➢ Documentation about Ontology	☐	☐	☐	☐	☐	☐
➢ Documentation about SPARQL queries	☐	☐	☐	☐	☐	☐
➢ Documentation about installing Experiment Data Receiver	☐	☐	☐	☐	☐	☐
➢ Experiment Execution process and guidelines	☐	☐	☐	☐	☐	☐
➢ Overall documentation in the Project Handbook	☐	☐	☐	☐	☐	☐

