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Experiments Design and Specification

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TERMS AND ACRONYMS

Acronym	Definition
3G	3rd Generation of mobile telecommunication technology
3GPP	3rd Generation Partnership Project
5G	5th Generation of mobile telecommunication technology
API	Application Program Interface
ARM	Architecture Reference Model
dB	Decibel
DoW	Description of Work
DSL	Domain Specific Language
EaaS	Experiment as a Service
EV	Electric Vehicles
FC	Functional Component
FEMO	FIESTA-IoT Experiment Model Object
FG	Functional Group
FIRE	Future Internet Research and Experimentation
FISMO	FIESTA-IoT Service Model Object
GPS	Global Positioning System
IoT	Internet of Things
IoT-A	Internet of Things Architecture
IT	Information Technology
KPI	Key Performance Indicator
M2M	Machine to Machine
QoS	Quality of Service
SIM	Subscriber Identity Module
SPARQL	SPARQL Protocol and RDF Query Language
VE	Virtual Entity
VM	Virtual Machine
WP	Work Package

1 POSITIONING

1.1 FIESTA-IoT Scope

Recent advances in the Internet of Things (IoT) area have progressively moved in different directions (i.e. designing technology, deploying the systems into the cloud, increasing the number of inter-connected entities, improving the collection of information in real-time, and no less important—the security aspects in IoT). IoT advances have drawn a common grand challenge that focuses on the integration of the heterogeneous IoT generated data. This key challenge is to provide a common sharing model or a set of models organizing the information coming from the connected IoT services, IoT technology and systems, and more important to be able to offer them as experimental services in order to optimise the design of new IoT systems and facilitate the generation of solutions more rapidly.

In FIESTA-IoT we focus on the problem of formulating and managing IoT data from heterogeneous systems and environments and their entity resources (such as smart devices, sensors, actuators, etc.), this vision of integrating IoT platforms, testbeds and their associated silo applications within cloud infrastructures is related to several scientific challenges, such as the need to aggregate and ensure the interoperability of data streams stemming from different IoT platforms or testbeds, as well as the need to provide tools and techniques for building applications that horizontally integrate diverse IoT Solutions. The convergence of IoT with cloud computing is a key enabler for this integration and interoperability, since it allows the aggregation of multiple IoT data streams towards the development and deployment of scalable, elastic and reliable applications that are delivered on-demand according to a pay-as-you-go model.

The activity in FIESTA-IoT is distributed in 7 Work Packages (WPs). WP1 is dedicated to the project activities coordination, considering consortium administration, financial management, activity co-ordination, reporting and quality control. In FIESTA-IoT one of the main objectives is to include experimenters and new testbeds to test and provide feedback about the platform and tools, thus open calls for those tenders will be issued (these are also part of the WP1 activity and is called selection of third-parties).

WP2 focuses on stakeholder’s requirements and the analysis of IoT platforms and testbeds in order to define strategies for the definition and inclusion of experiments, tools and Key Performance Indicators (KPIs). The activities in WP2 are focused on studying the IoT platforms and testbeds and the specification of the experiments, the detail of the needed tools for experimentation, and the KPIs for validating the proposed solutions. This WP will conduct the design and development of the Meta-Cloud Architecture (including the relevant directory of IoT resources) and will define the technical specification of the project. WP2 also focuses on analysing the Global Market Confidence programme and establishes the Certification Programme Specifications that will drive the global market confidence and certification actions around the IoT experimentation model.

WP3 focuses on providing technologies, interfaces, methods and solutions to represent the device and network nodes of the testbeds as virtualized resources. The virtualized resources will be represented as services and will be accessible via common service interfaces and Application Program Interfaces - APIs (i.e. the FIESTA-IoT Testbed interfaces/APIs). The virtualized resources and their capabilities and interfaces will be also described using semantic metadata to enable (semi-) automated discovery, selection and access to the testbed devices and resources.

WP4 will implement an infrastructure for accessing data and services from multiple distributed diverse testbeds in a secure and testbed agnostic way. To this end, it will rely on the semantic interoperability of the various testbeds (realized in WP3) and implement a single entry point for accessing the FIESTA-IoT data and resources in a seamless way and according to an on-demand Experimentation-as-a-Service (EaaS) model. The infrastructure to be implemented will be deployed in a cloud environment and will be accessible through a unified portal infrastructure.

WP5 focuses on designing, deploying and delivering a set of experiments, so as to assess the feasibility and applicability of the integration and federation techniques, procedures and functions developed during the project lifetime. It will define a complete set of experiments to test the developments coming from other WPs (mainly WP3 and 4), covering all of the specifications and requirements of WP2. Developments will be tested over available IoT environments and/or smart cities platforms. WP5 will also provide evaluation of the KPIs defined for every experiment/pilot. The final deployed experiments will include a subset of those coming from WP2, 3 and 4, as well as those provided by FIESTA-IoT Open Calls.

WP6 focuses on the establishment and validation of the project's global market confidence on IoT interoperability, which will provide a vehicle for the sustainability and wider use of the project's results. The main activity in this WP focuses on specifying and designing an IoT interoperability programme, including a set of well-defined processes that will facilitate the participation of researchers and enterprises. WP6 works on providing a range of certification and compliance tools, aimed at auditing and ensuring the openness and interoperability of IoT platforms and technologies. WP6 also focuses on interoperability testing and validation and to provide training, consulting and support services to the FIESTA-IoT participants in order to facilitate platforms and tool usability, but also to maximize the value offered to them by using FIESTA-IoT suite and tools.

WP7 focuses on ensuring that the FIESTA-IoT suite, models and tools engage well with the community outside of the project; from promotion and engagement of new customers, to the front line support of current users, and the long-term exploitation of results and sustainability of the facility itself. This will be carried out in a coordinated manner such that a consistent message and professional service is maintained. Dissemination activities and the KPI to measure the impacts will be studied and used in this WP. An ecosystem plan including the specification of processes, responsibilities and targets will be generated and the evaluation and effectiveness of the operating model will be evaluated within this WP. In this WP the successes of stakeholder engagement and reports on their satisfaction with the services offered in FIESTA-IoT will be put in place at the end of the project.

1.2 WP5 Overview

The main objectives of this Work Package are the design, implementation and subsequent validation of three, so called, “in-house experiments” (referring to the fact that partners within the consortium are taking the experimenters role). Those experiments have already been sketched in WP2, and are aiming at covering a large subset of the requirements and KPIs that were originally proposed to evaluate the success of the FIESTA-IoT platform. These experiments are also thought to assess the enablers implemented and integrated in other WPs (mainly WP3 and WP4) producing from an early stage valuable feedback that can be used for enriching and enhancing the functionalities provided by these tools. Moreover, as WP5 focus is on experimentation, this WP will be the natural entry point for third-parties selected during the Open Calls. In this sense, the activities will be focused on facilitating, to the external experimenters, the lessons learnt about the experimentation lifecycle at the FIESTA-IoT platform from the “in-house experiments”. In addition, best practices from these third-parties will also be brought in so that it is possible to compile the most complete possible summary of recommendations to design, deploy and evaluate interoperable IoT experiments and/or services over different IoT platforms.

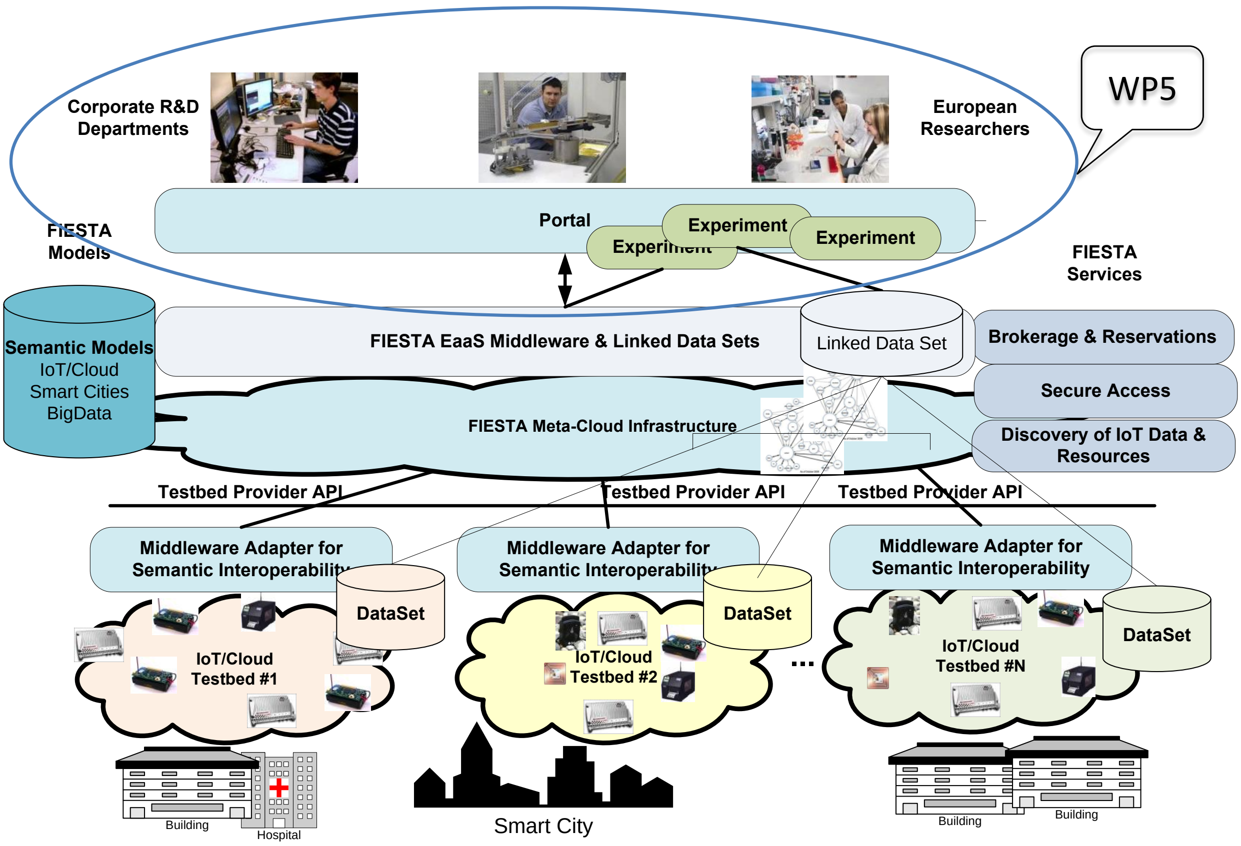

Figure 1. WP5 Overview

This WP mainly focuses on the experimentation layer and its interplay with the FIESTA-IoT infrastructure, as shown in Figure 1. Regarding its structure, it is split into five different (but tightly correlated) tasks, which are briefly depicted below:

Task 5.1. Design of Portable & Interoperable Experiments over Multiple Platforms and Testbeds: Having in mind the main aspects addressed in the FIESTA-IoT initiative (i.e. interoperability, portability and testbed/platform federation), this task addresses the design and implementation of the three "in-house experiments" (whose initial specification has been produced in WP2). One of the main challenges of these pilots is that they must provide the scenarios and use cases to validate the tools and innovation stemmed from WPs 3 & 4, together with the set of KPIs proposed to evaluate the success of this first bunch of experiments.

Task 5.2. Experiments Implementation and Integration (Portability, Testbed Agnostic Access to Mobile Data Sets). From the specification and design of the three in-house experiments undertaken in Task 5.1, this task focuses on the analysis of their actual behaviour once they are integrated within a fully-fledged version of the FIESTA-IoT platform, pursuing to demonstrate the objectives and innovation proposed in the scope of the project.

Task 5.3. Integration of Experiments from Third-Parties. One of the most challenging parts of this project is to foster experiments coming from external end-users (i.e. FIESTA-IoT Open Calls). In order to successfully achieve this, the FIESTA-IoT platform should support the integration from third-parties' experiments and their adequate execution within the framework. In addition, since the Open Calls process also contemplates the integration of external platforms and testbeds, they will be also handled in this task.

Task 5.4. Validation and Evaluation of Experiments. From the metrics and KPIs defined in the previous tasks, this one will be the responsible of the validation of all the experiments run over the FIESTA-IoT framework, either coming from inside the consortium (Task 5.1 and Task 5.2) or from those third-parties which have been selected during the Open Calls process (Task 5.3).

Task 5.5. Best Practices for Experiments Design and Conduction. From the feedback achieved throughout this WP, this task will yield the best practices guidelines of how to design, implement, deploy and evaluate different interoperable experiments and/or services over heterogeneous IoT platforms.

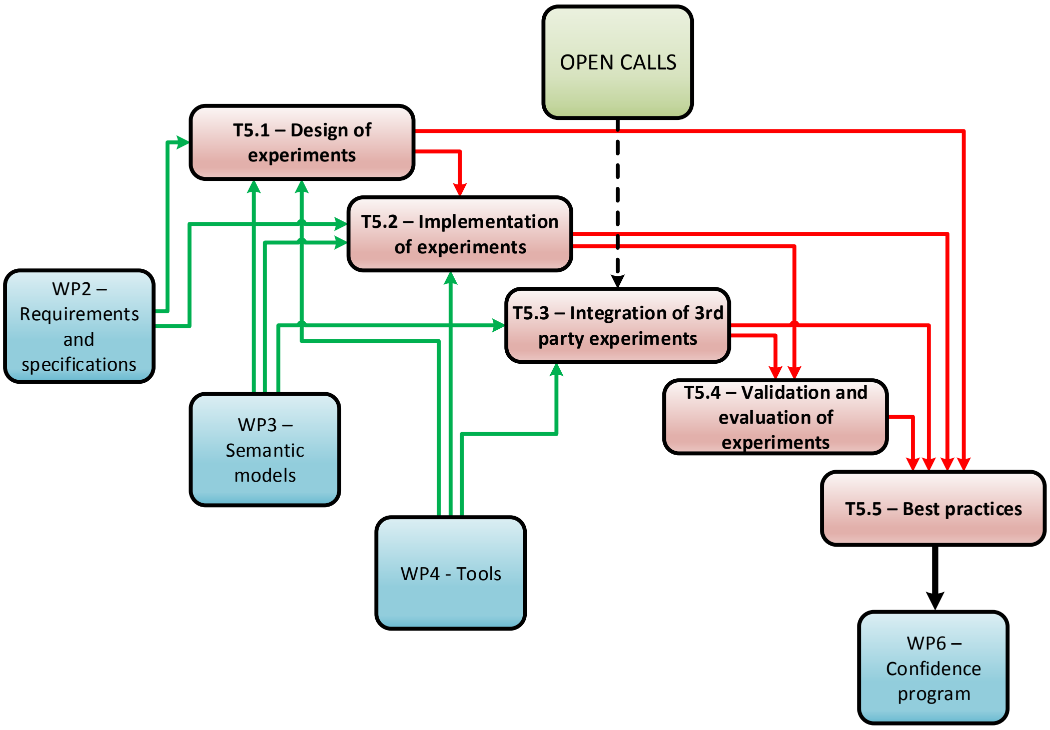

Figure 2. Relationship between WP5's tasks with other WPs

As can be inferred from the description of WP5's tasks, there is a strong dependency between them. Additionally, the integration of the WP within the overall project structure is also tight as it will also: i) rely on the developments and tools implemented in other WPs (i.e. WPs 4 & 5); ii) integrate third-party experiments and testbeds coming from the Open Calls processes; and iii) derive best practices and KPIs from the deployment and execution of interoperable experiments and services that will be one of the basis for the global market confidence program for IoT defined in WP6. The relations between these tasks and WPs are gathered in Figure 2.

Concerning to the FIESTA-IoT's general objectives, WP5 deals with a subset of them, listed below:

1) Specification and design of a set of (in-house) experiments that comply with the initial set of requirements and plans proposed in WP2. Namely, three experiments will be carried out under the direct responsibility of the FIESTA-IoT consortium members. It is deemed necessary that these experiments leverage the main elements that are being developed in WPs 3 & 4.
2) Implementation and execution of these three experiments over the real IoT platforms that will compose the final FIESTA-IoT Interoperable federation.
3) Integration of experiments and testbeds coming from third parties, whose participation will be decided during the Open Calls processes specified in the Description of Work (DoW).
4) Validation of all the experiments and testbed integration that have been carried out in the scope of this WP.
5) Elaboration of a best practices documentation guide that will be used by forthcoming end-users to design, implement deploy and evaluate their own interoperable experiments over IoT platforms.

Table 1. WP5 Deliverables

No.	Deliverable	Related task	Responsible partner	Contributors
D5.1	Experiments design and specification	T5.1	UC	NEC, INRIA, Com4Innov, KETI
D5.2	Experiments Implementation, Integration and Evaluation	T5.2, T5.3, T5.4	NEC	UC, INRIA, Com4Innov, KETI
D5.3	Best Practices for Experiments Design and Conduction	T5.5	EGM	UC, NEC, NUIG-DERI

1.3 Audience

This deliverable is addressed to the following audiences:

- **Researchers and engineers within the FIESTA-IoT consortium**, who will take as input the specification of the experiments and description of its compounding use cases for the most technical WPs (i.e. 3 and 4) to have a detailed list of required tools to be provided.
- **Researcher on Future Internet Research and Experimentation (FIRE) focused on IoT and cloud computing systems experimenters at large,** who will find reference specification of potential interoperable IoT experiments as well as a guide for the definition of its own experiments. Additionally, detailed specification of experiments use cases will help in understanding FIESTA-IoT offered functionalities and realize viable added-value extensions to the IoT domain.
- **Members of other Internet of Things (IoT) communities and projects (such as projects of the IERC cluster),** who can take this document as an initial reference or inspiration to design and implement their own semantic interoperable experiments.
- **Entrepreneurs and application developers,** who can take this document as an initial reference or inspiration to design and implement added value services and applications leveraging semantic interoperable IoT platforms.

1.4 Terminology and definitions

This sub-section is intended to clarify the terminology used during this project. This initial step is intended to clarify all the important terms used, in order to minimise misunderstandings when referring to specific parts involved in the generation of data and the FIESTA-IoT concepts. The following definitions were set regarding the domain area of FIESTA-IoT, and so are aligned with terminologies used in FIRE community and in reference IoT-related projects (such as IoT-A).

Table 2. Terminology and Definitions table

Term	Definition
Device	Technical physical component (hardware) with communication capabilities to other Information Technology (IT) systems. A device can be attached to, or embedded inside a physical entity, or monitor a physical entity in its vicinity (IoT-A, 2013). The device could be: • **Sensor**: A sensor is a special device that perceives certain characteristics of the real world and transfers them into a digital representation (IoT-A, 2011). • **Actuator**: An actuator is a mechanical device for moving or controlling a mechanism or system. It takes energy, usually transported by air, electric current, or liquid, and converts that into some kind of motion (IoT-A, 2011).
Discovery	Discovery is a service to find unknown resources/entities/services based on a rough specification of the desired result. It may be utilized by a human or another service. Credentials for authorization are considered when executing the discovery (IoT-A, 2013).
Domain	Refers to an application area where the meaning of data corresponds to the same semantic context. For instance, pressure in Water Management Domain may refer to water pressure on pipes while in Air Quality Domain it refers to atmospheric pressure
Measurement	The important data for the experimenter. It represents the minimum piece of information sent by a specific resource, which the experimenter needs in order to fulfil the objective of the experiment
Metadata	The metadata is the additional information associated with the measurement, facilitating its understanding.

Physical Entity	Any physical object that is relevant from a user or application perspective. (IoT-A, 2011). Physical Entities are the objects from the real world that can be sensed and measured and they are virtualized in cyber-space using Virtual Entities.
Requirement	A quantitative statement of business-need that must be met by a particular architecture or work package (Haren, 2009).
Resource	Computational element that gives access to information about or actuation capabilities on a Physical Entity (IoT-A, 2011).
Testbed	A testbed is an environment that allows experimentation and testing for research and development products. A testbed provides a rigorous, transparent and replicable environment for experimentation and testing (Gavras, 2010)
Federated test-beds	A testbed federation or federated test-beds is the interconnection of two or more independent test-beds for the creation of a richer environment for experimentation and testing, and for the increased multilateral benefit of the users of the individual independent test-beds (Gavras, 2010)
Interoperability	The ability of two or more systems or components to exchange information and use the information that has been exchanged (IEEE, 1990)
Experiment	Experiment is a test under controlled conditions that is made to demonstrate a known truth, examine the validity of a hypothesis, or determine the efficacy of something previously untried (Soukhanov, Ellis, & Severynse, 1992)
Semantic Interoperability	Semantic interoperability is the ability of computer systems to exchange data with unambiguous, shared meaning. Semantic interoperability is a requirement to enable machine computable logic, inference, knowledge discovery, and data federation between information systems
Service	Services (Technology) are services designed to facilitate the use of technology by end users. This services provide specialized technology-oriented solutions by combining the processes/functions of software, hardware, networks, telecommunications and electronics
Virtual Entity	Computational or data element representing a Physical Entity. Virtual Entities can be either Active or Passive Digital Entities (IoT-A, 2013).

1.5 Executive Summary

This deliverable lays the foundations for the forthcoming implementation and validation of the initial set of three, so-called, “in-house experiments”. They have been proposed to be done by FIESTA-IoT first party members during the project’s lifetime. These (three) internal pilots will serve as a first approach for the operation and performance evaluation of the interoperability framework that is being built in the scope of the project.

Namely speaking, the document thoroughly addresses, from both logistic/operational and implementation-wise perspectives, the specification and planning strategies of the three experiments, whose initial steps were originally gathered in FIESTA-IoT Deliverable D2.3. Indeed, the authors encourage the reader to take a first overview of this D2.3 prior to face this one, since it covers some aspects (e.g. requirements, tools, etc.) that are only briefly outlined here.

Moreover, this deliverable aims at harvesting the advances and outcomes achieved in the previous WPs so far, in order to leverage and to integrate all the pieces defined there to shape, altogether, a holistic solution for supporting a federated and semantically interoperable framework for IoT. Namely, one of the main challenges undertaken by these experiments consists in the validation of the FIESTA IoT platform and, at the same time, the provision of feedback for the enhancement/optimization of the integrated tools. For this, the cornerstone of this deliverable focuses on the breakdown of these three experiments into individual use cases, aiming at highlighting all the Functional Components that will be “tweaked” during the execution of the experiments. The main goal behind the identification of these architecture-experiments bindings is twofold: 1- To showcase the experiments’ complementarity, since their joint operation spans all the functional components, groups and system use cases defined in the FIESTA-IoT functional and information views. 2- All these components will be assessed and tested before integrating new experiments coming from external users (i.e. through the different Open Calls processes).

Finally, this deliverable includes, as a complementary annex, a number of potential experiments that have been proposed (or have been already carried out) over some of the FIESTA-IoT’s consortium legacy testbeds (i.e. UNICAN, UniS, Com4Innov and KETI). External experimenters, such as entrepreneurs and application developers, might find them as an inspirational guideline prior to give rise to their own new experiments.

2 EXPERIMENTS OVERVIEW

This section offers a brief overview of the three, so called, in-house experiments that will be carried out in the scope of the FIESTA-IoT project, with particular emphasis on the different datasets and KPIs that are relevant to each experiment. Should the reader need a more concrete information on the experiments' requirements or tools, he/she might refer to FIESTA-IoT Deliverable D2.3.

2.1 Data Assembly and Services Portability

The main goal of this experiment is to verify the FIESTA-IoT Objectives present in the DoW, mainly Objective 2 ("Testbed Agnostic Access to IoT Datasets") and Objective 3 ("Tools and Techniques for IoT Testbeds Interoperability and Portability") with a FIESTA-IoT internal integrated experiment (Objective 5). Successful implementation of this experiment will also verify that the FIESTA-IoT EaaS infrastructure is a suitable infrastructure for large-scale IoT experiments (Objective 1). It will provide valuable insights and experimental facts as for the best practice (Objective 7) and support the Global Market Confidence Program (Objective 4).

This experiment has selected the topic of Smart City Performance Indicators (as for example highlighted by the World Bank study (Hoornweg & Blaha, 2006). The target is to compute relevant Smart City Performance Indicators from the available set of information. It can be easily seen that computing those indicators requires service portability across the different testbeds as the same indicators need to be computed for the different testbeds. It can also be seen that we need the discovery and semantic interoperability feature of FIESTA-IoT to ensure that we can have reliable indicators despite having to assembly data from very heterogeneous datasets available at the different testbeds.

The core function of the experiment is an IoT application that builds a Smart City Performance Indicator model based on sensor information. As a novel aspect, we wish to build not only a single indicator visualizing a general indicator like e.g. the "health" of a city. We wish to create a "zoomable" set of indicators where we can analyse the city performance along the following dimensions

- **Abstraction**: from general city indicators to specific indicators of a single aspect of city management, e.g. environmental monitoring.
- **Level of detail (space)**: from indicators considering the complete city to indicators on the level of places, streets, even houses or rooms.
- **Time**: zooming from the most current information to indicators capturing a longer time period.

These indicators can be used for visualization, trend analysis and triggering of notifications if a certain situation has occurred. The application will be designed in such a way that different types of sensor information relevant to different application areas can be used. Examples are the monitoring of environmental parameters like pollution, humidity, temperature, light and noise, but could also be: level of occupancy of parkings in a city/area, water/irrigation levels in a park or agricultural setting, or the activity level in a certain area.

The experiment serves the purpose of showing that semantic interoperability across different IoT infrastructures can be achieved, greatly simplifying the development of applications. Utilizing semantic interoperability for simplifying application development and increasing the portability across networks is highly relevant, thus looming a number of potential uses in different IoT domains, in particular smart cities.

2.1.1 Specification of Datasets

The computation of the Smart City indicators will be based on two different aspects.

1. **Observation-Oriented data:**
   - *Observation/Measurement*: this is the raw value (and associated metadata – see below) observed by the resource. The analytics we want to do is based on this information.
   - *Phenomenon*: every observation is tied to a physical phenomenon (indeed, it is measuring it); otherwise, the observation would be just a number.
   - *Unit*: together with the phenomenon, it completes the scope to give sense to the observation. This information is fundamental for avoiding misinterpretation of different observations, of the same phenomenon, in case of usage of multiples or submultiples of the same unit system or even usage of different unit systems.
   - *Timestamp*: since our experiments will be mainly analytics on time-series, this value is necessary for indicating the time at which the measurement has been observed and so enable the analytics.
   - *Location*: this value indicates the exact geographic position (i.e. latitude and longitude) where the measurement was recorded. If the resource producer is moving (like the buses in the Santander testbed) this information is of utmost importance since there are no other possibilities to infer such information.
   - *(If applicable) Description of Aggregation*: in case of aggregation of data (e.g. Average/Max/Min) or outcome of a script (or even another experiment), this information will help the experimenter to understand what kind of functions have been applied to which original data
   - *Resource producer*: this a unique resource ID, identifying the resource among the others (see Resource ID in the “Resource-Oriented experiments” paragraph of this section). Understanding the resource producer that has produced the observation will allow the detection of a malfunctioning resource and therefore the invalidation of the observations produced by such resource.
2. **Resource-Oriented data:**
   - *Resource ID*: this value will univocally indicate to which resource the other information refers. It is not important if such ID is generated by the FIESTA-IoT platform or directly by the testbed owner, what is important is that such ID is unique among the other resources (regardless the testbed) and that it is consistent during the time, i.e. it is not changing. The ID needs to be unique and consistent in order to make possible a creation of a time-series over a resource ID.
   - *Resource status*: this element reflects the current condition of a resource (e.g. online, offline, sleeping, under quarantine, etc.). Namely, it will provide

information regarding the availability status of the resource, feedback from users about malfunctioning (if available), etc.

- *Resource location*: This information will locate the resource in the space and therefore it will allow analytics for the scope of the Smart City Performance Model.
- *Timestamp*: this will identify the time at which the information regarding the resource has been recorded. For the Smart City Performance Model such information will allow analysis on varying of the status of the resource.
- *Testbed ownership*: this value is expected to be an ID and it will associate the resource to a specific testbed. Such information is necessary in order to make experiments focusing on the health of a testbed or the quality of its deployed resources.
- *Capability list*: the list of capabilities of a resource would give information of what phenomena (e.g. temperature, humidity, etc.) the resource is able to observe.

Other data analytics algorithm can be applied using a mixture of the previous two datasets or outcome from other data analytics process or even third party experiments output.

2.1.2 KPIs

The definition of this experiment has been thought to fulfil the following list of performance indicators, which have to be validated at the end of the experiment lifetime.

- 1 or more measurements are to be notified to the data analytics algorithm after a data subscription.
- Observations streams, due to a query or a subscription, from 2 or more testbeds.
- A data analytics algorithm receives 1 or more value(s) computed by another data analytics algorithm.
- 2 or more measurements, observed from the same device at different time, are returned in the historical query response.
- The data analytics algorithm is receiving 2 or more data messages after the authentication

2.2 Dynamic Discovery of IoT Resources for Testbed Agnostic Data Access

This experiment will exploit the FIESTA-IoT meta-cloud where resources (i.e. sources of data streams) will be registered in order to allow experimenters to dynamically discover and use data from one or more testbeds (in a seamless and testbed agnostic way). Hence, this meta-directory will be the core of the FIESTA-IoT EaaS infrastructure. It will also work with common templates (i.e. ontologies, datasets, etc.) to define, identify and classify resources from different environments or providers that can become similar sources of information or targets for actuation. This functional component and the way it provides access to registered resources and their

properties take an important step forward to a common semantic definition of testbed's resources.

The experiment will focus on the dynamic acquisition and processing of weather information (based on temperature, pressure, wind speed, UV and humidity level data streams), towards consolidating and visualizing data from multiple locations. The experimenter will be able to dynamically specify the locations/areas for which data will be collected, as well as e.g. the physical phenomena he/she wants to retrieve. The specification of these areas might lead to the simultaneous data acquisitions from one or multiple testbeds, which offer specified data streams e.g., based on the weather stations that these testbeds deploy. The added value of this experiment is that the experimenter will be able to dynamically select and process data streams needed for the forecasting process.

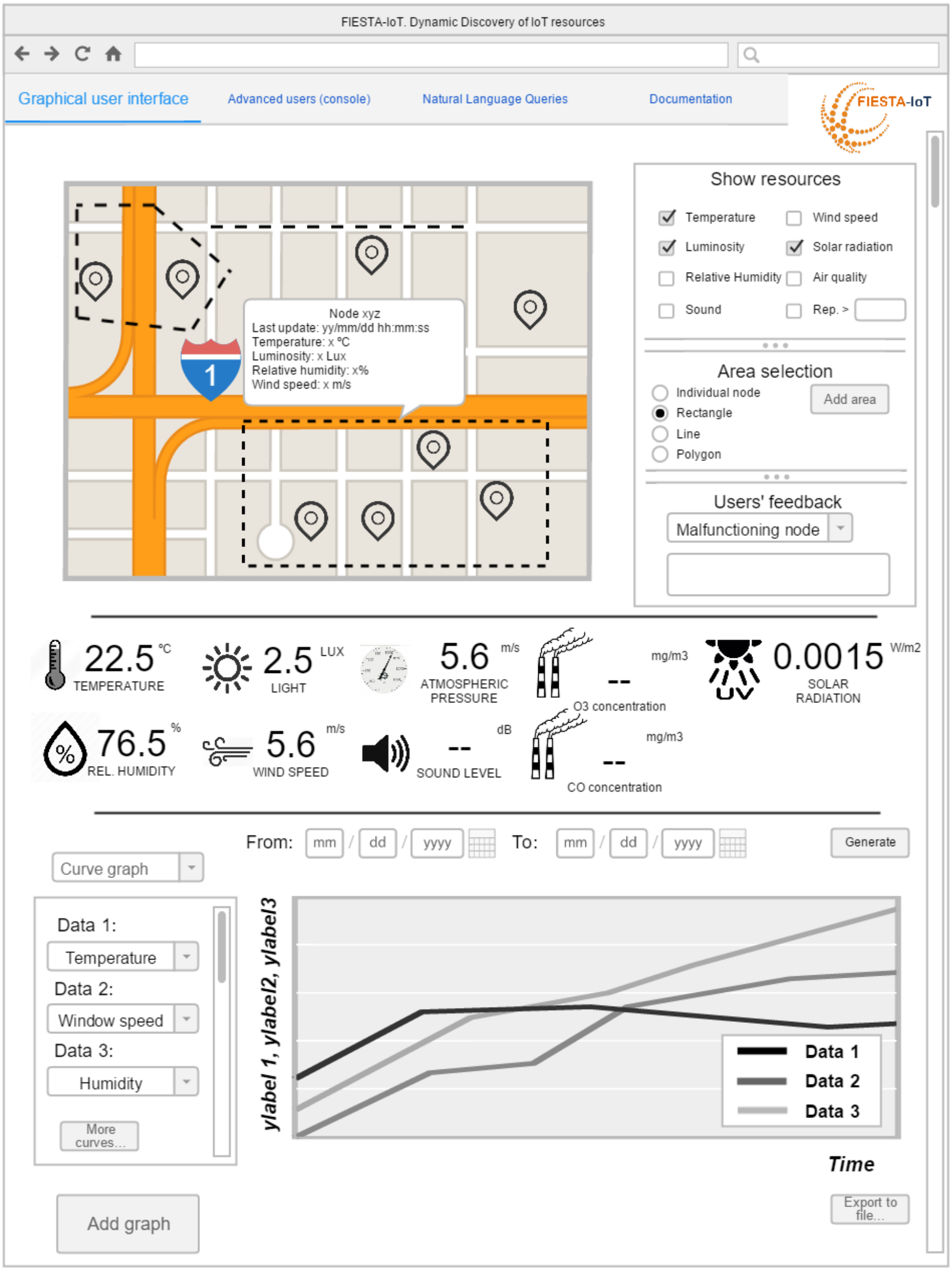

Figure 3. Initial mockup of the proposed experiment's web page

One of the main goals of this project is to provide a seamless access across different testbeds, disregarding their underlying architectures or communication models. For a very first practical experiment, we propose a simple approach, which will consist in the acquisition of a single data type, i.e. belonging to the weather domain. Yet simple, it demonstrates the potential of abstracting the legacy data sources so that an experimenter can get the information from any platform provider through a single interface.

Last, but not least, in order to illustrate what we aim at doing with this experiment, we show in Figure 3 a first mockup representation of the web page that gathers all the functionalities we plan to showcase for this experiment. As can be extracted from the figure itself, it will be an interactive map, in which experimenters can both select those resources they want to interact with; in addition, they will (at the same time) visualize information received from the underlying testbeds. Besides, several ways to represent/process the information will be also available.

2.2.1 Specification of Datasets

During the execution of this experiment, different data types are to be gathered from the underlying federated testbeds. We list below the most important ones (to retrieve the whole list, the reader might refer to the Deliverable D2.3):

- *Phenomena & unit of measurement*. Without a shred of a doubt, these ones shape the cornerstone of the experiment. Focused on the weather and environmental domain, experimenters will retrieve, through a unique interface, the information gathered from the different sensors that are deployed throughout the various federated testbeds that will shape the FIESTA-IoT meta-cloud.
- *Location*. As can be easily inferred, every physical resource must have a physical location, either gathered from a built-in GPS device attached to each device or through a manual annotation. In most cases, a "latitude/longitude" pair will be generated (there are more advanced geo-spatial notations[1] though).
- *Timestamp*. Timing information will have an essential role for experimenters. Each time a resource catches/generates a measurement, it will go together (~atomic operation) with the time instant it was taken. Thus, historical data-based queries could be run and experimenters will be able to gather statistical information from the previously stored measurements.
- *(Optional) Local time zone*. Since different testbeds might be placed in different time zones, it might be necessary to explicitly transmit their local time zone so that experimenters can be able to distinguish between the various platforms. As an illustrative example, to compare the temperature measured at sunrise between Santander and Seoul.
- *(Optional) Resource description*. Apart from the raw data extracted from the physical devices/sensors, experimenters might need a minimum level of knowledge about some of their most noteworthy properties, such as its exposed services, sensors accuracy, sampling frequency, indoor/outdoor location, etc.

[1] http://geojson.org/

- (*Optional) Management info.* Additional metadata will be appended to share management-based information. Among its main fields, includes (new elements might be added in the future): hardware, firmware version, date of registration, last update, last measurement, etc.

2.2.2 KPIs

The development of this experiment fits some of the KPIs that were defined to elicit a scope of best practices. We list below the main ones that must be accomplished once its development has been concluded.

- Harvest data from at least four different testbeds, which have been previously registered as part of the FIESTA-IoT federation.
- Display information of a minimum of 5,000 IoT resources, coming from at least four different data sources (previous KPI).
- Encapsulate, in a single response, the resource descriptions (e.g. for resource look-ups) or data (i.e. measurements) from at least 4 different platforms.
- Support the following three IoT services: 1- last/current values, 2- historical data and 3- subscriptions.
- Have at least 50 different users running the experiment (does not mean simultaneously).
- Adapt the range of offered functionalities to at least three types of experimenters, e.g. basic, advanced, administrator, etc.
- (Added-value) Adequately process and generate both accurate and logical responses for at least 50 human-language queries.

2.3 Large Scale Crowdsensing

Modern smart cities are characterised in part by a prevalence of sensors, either fixed (e.g., municipally-managed environmental sensors) or mobile (e.g., those in mobile devices used by citizens). This opens up the opportunity of crowd sensing the urban environment, for better informing the individual citizens as well as the government, for the benefit of all.

As part of these experiments, experimenters will be able to specify a set of devices and data streams that could participate in a given crowdsourcing experiment (e.g., large scale environmental monitoring). The crowdsourcing experiments will be able to use data streams from participants interfacing to different IoT platforms/providers in order to provide/stream data acquired via their smart phones. FIESTA-IoT will provide an infrastructure where different data streams could be integrated regardless of the testbeds where their data are provided.

As part of the experiment, a living labs approach will be exploited in order to ensure the statistically appropriate representation of the various sensors/data streams in the experiment. The FIESTA-IoT EaaS infrastructure will incorporate novel crowd-sourcing/sensing algorithms into the mobile middleware of the testbeds in order to provide opportunity for dynamically selecting and using IoT resources (e.g., sensors,

devices) corresponding to the indicated statistical representation. This will be among the unique capabilities offered by FIESTA-IoT in the scope of the experiment.

A major goal of this experiment is to explore the ability of the FIESTA-IoT platform to manage and execute experiments on the data coming from mobile devices. Further, we would like to explore the ability to ultimately combine data from different co-located testbeds: one present as an app running on citizens' phones, and another present as a web-service that provides access to the data collected by the set of static sensors installed and managed by the city. As an example, as Figure 4, we provide the map of the city of Paris where noise data was collected from mobile devices. The map shows the noise heatmap in the city of Paris.

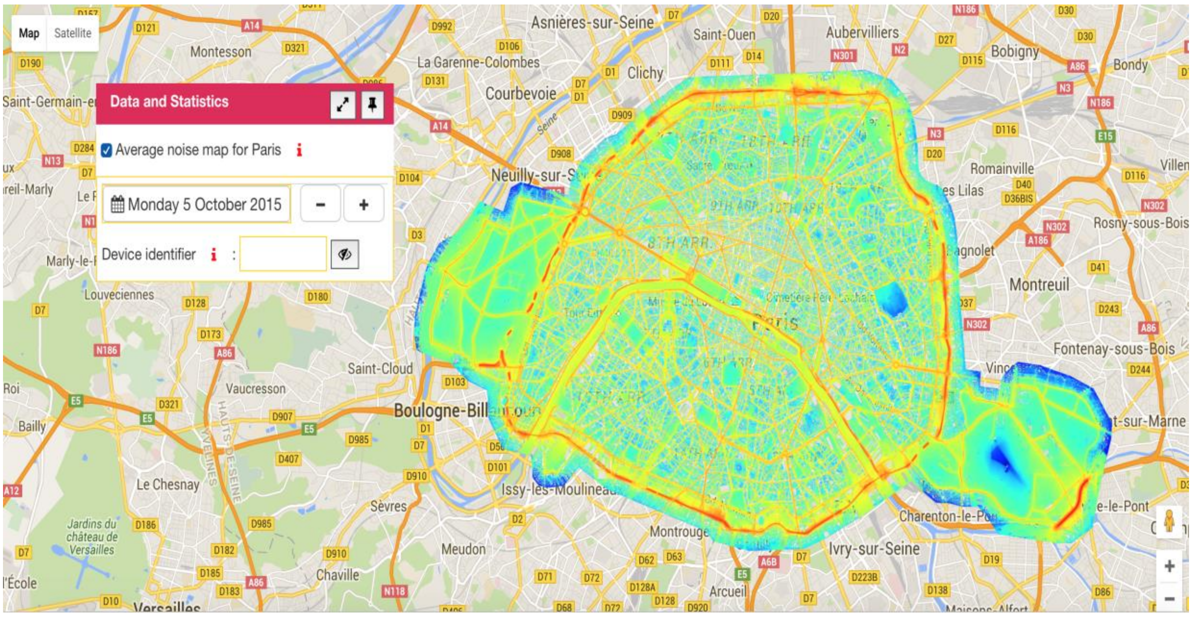

Figure 4. Initial mockup of the large crowdsensing experiment

2.3.1 Specification of Datasets

The experiment will use the data provided by each device, with the following attributes:

- *<u>Location</u>:* This would be expressed in *(Longitude, Latitude)*, and also accompanied by an *accuracy measure* and the *sensor type* (e.g. GPS, 3G, WiFi) used to determine this location
- *<u>(Anonymized) Device ID</u>:* This alphanumeric ID will be used to distinguish data coming from different devices, as well as to correlate data coming from the same mobile device over time. This is especially important since the sensors present on different devices will have different accuracies.
  - *Trade-off between duration of ID persistence and utility of data: We acknowledge that there is a trade-off between the anonymity provided to the users and the utility of the correlation between different data objects*. Further, persisting IDs will be the property that a testbed needs to decide. For Example: a testbed can randomly choose and give ID from a specific set of predefined IDs, while another testbed can randomize (may be) the last "n" digits. Nevertheless, a testbed can also

decide to not have any correlation in the IDs. In the above example note that a user specifically is not at all tracked, it is possible that 2 different users have same ID in the dataset for two different data samples. As an experimenter, this would still consider that the data sample was from the same user.

- *Sensed value of environmental data (noise):* This will indicate the noise level in the surroundings of the device.
- *Current Timestamp of the Sensed Value:* This will inform when the value was sensed by the device and will enable temporal aspects related to the value.
- *(Optional) Current state of phone's proximity sensor:* This will inform whether the phone was currently inside a purse/bag (which might affect the quality of sensed data), or uncovered (therefore in a better position to provide noise data)
- *(Optional) Current phone call state:* This will inform whether or not a call is currently active when the noise sample is taken.
- *(Optional) Current physical activity as reported by the phone:* This could be one of resting, walking, running, in vehicle, etc., to further provide context to the data being collected. This context relates to inference of mobility aspects attached to the device. This information is inferred thorough the use of Accelerometer and gyroscope sensor on the phone.
- (Optional) User-annotation about the source of noise*:* The user can optionally provide their input on what caused the noise at any given time.

We put "optional" to certain attributes because, if provided, they provide an added value to the experiment. Although some of the attributes are not available within current in-house testbeds, these properties might be made available in other testbed that would join FIESTA-IoT platform in the future; thereby opening an opportunity for the crowdsourcing experiments to evolve. This is also very much aligned with the use of the FIESTA-IoT infrastructure for setup and execution of range of crowd sensing experiments in conjunction with Inria@SiliconValley program and on the basis of the potential integration and use of testbeds from the USA.

2.3.2 KPIs

- (More than 1) Number of testbeds involved in the experiment. The experiment will request samples from different testbeds and generate an integrated view. Thereby focusing on *testbed-agnostic access* to data.
- (More than 100) Users that provide data to the experiment. Since ultimately we would like to involve users directly (instead of using historical data), it will also be good to know how many individuals and from which region one would need to recruit. Thus the experimenter will also be able to limit data to certain region.
- Number of data samples needed for high-quality results. For example, an experimenter that needs to build a heatmap that consumes 30 days of data from at least 1 sensor that produces high quality samples (location accuracy below 10m) every 5 mins, then the experimenter would require at least 30*12*24 high quality samples.

3 EXPERIMENTS SPECIFICATION

After having provided a short description of what the three "in-house" experiments are aimed at, we delve in this section into the details of each one of them. On the one hand, a high-level/strategic point of view attempts to define, from a management and work organization perspective, the definition of the experiments and their implementation phases, identifying at the same time the main outcomes that are expected to be demonstrated. Secondly, the experiments are split into a number of use cases that interact with different parts of the FIESTA-IoT architecture. Last, but not least, the objectives pursued by the experiments are summarized through a validation plan that enumerates the main goals to be accomplished by the end of the experiments' lifecycle.

3.1 Data Assembly and Services Portability

3.1.1 Experiment Plan and Outcomes

3.1.1.1 Motivation and expected outcomes

The mission we mean to be achieved within the FIESTA-IoT project as experimenters is the creation of a set of back-end services that can be useful to build a Smart City Performance Model up. The latter is meant to be the digital representation of a city with direct observed data and inferred data (by applying data analytics, sensor fusion, complex event discovery etc.). The overall idea is to offer the backend services for a city status platform where indicators (Hoornweg, 2006) about the "health" status of the city and its many subsystems are displayed. The experiments will have as outcome recognition of possible critical situations, trends that need monitoring, or even predictions of events (e.g. crowd forming).

It can be expected that large parts of the Smart City Performance Model might be empty as the needed information is not directly available through the reception of raw data coming from the invocation of simple IoT Services. In this case we can perform analytics for indirect indicators which compute the indicator from sensor information in related areas, e.g. the traffic situation of a street can be derived from the traffic information on its connected streets.

Figure 5 shows a mockup of the dashboard of our intended Smart City Performance Model. In the picture the *Environmental* group of indicators (also called *scope*) are shown, where for environmental are meant indicators about environment situations like traffic, pollution, crowds etc. Other groups of indicators can be selected by changing the tab on the top. For instance the *Safety* tab would have indicators such flood emergency, fire break emergency etc. Another example is the *Deployment* group of indicators where the indicators shown are, for instance, the status or the quality of the deployments.

The indicators refer to the area of the geographic region shown in the centre of the dashboard. The indicators itself are shown on its left part and summarized as a traffic light indicator: green means that such a situation is safe, yellow when the situation needs to be controlled and red when there is a problem to be taken care of. The same indicators are shown in graphs on the right side of the dashboard where the

real values of the indicators are plotted over the time. Each graph shows two lines: the full line is the actual value computed with the measured observations, the dashed line is the expected value done via analytics. The latter analytics is done in order to predict problems in advance and then change the traffic light from green to yellow, as it happened for the traffic indicators in the mockup figure, since although the actual value is under the defined threshold (the plotted red dashed line) the analytics has predicted that the traffic would increase till the threshold and beyond in the near future.

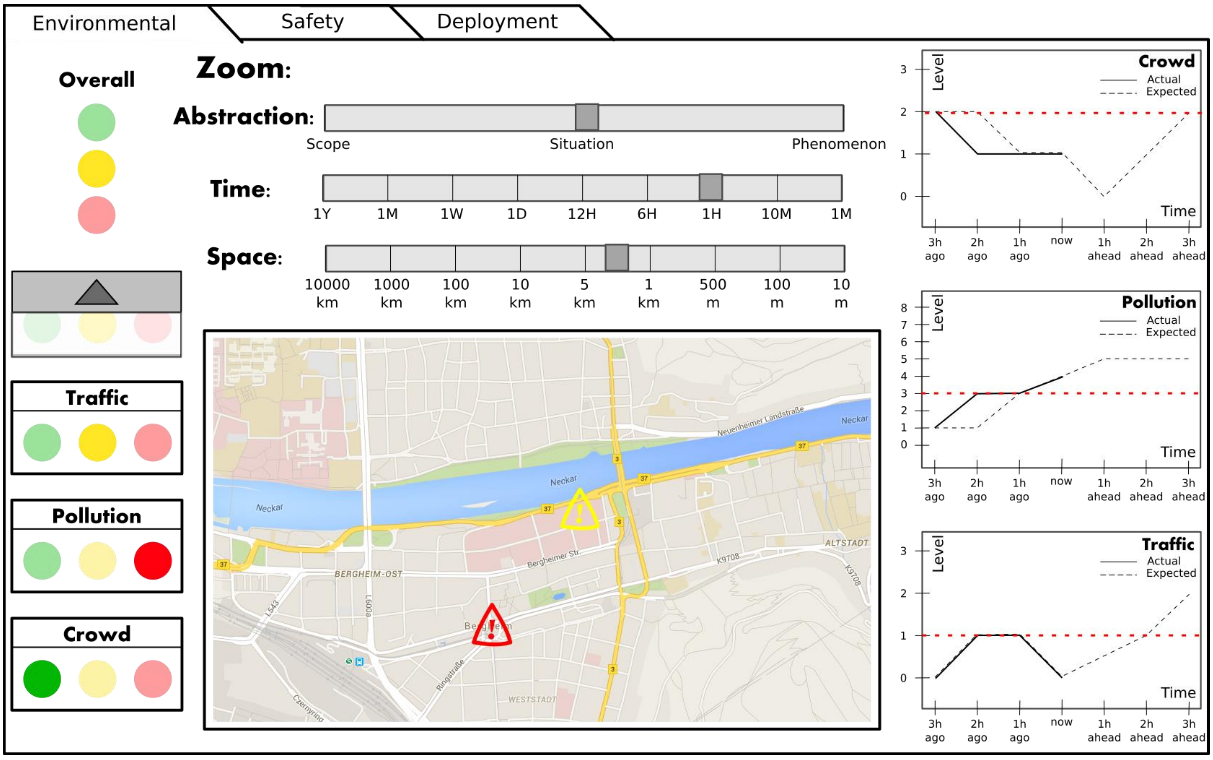

Figure 5. Mockup of the Smart City Performance Model dashboard

The overall situation (status) of the environment scope can be seen on the top left corner again with a traffic-light code ("yellow" state in the figure).

The three sliding bars on the top of the map are the three degrees of freedom initially described in Section 2.1.

- The first bar handles the *abstraction* level of the indicators: sliding to *Scope* the indicators would summarize in only one value and one traffic light indicator intended to show the state of the overall scope (in that case the environmental one); sliding to the *Situation* value the indicators are shown like in the picture, where the dashboard are showing an indicator for each situation; finally sliding to the *Sensors* level (and contextually selecting one situation indicator) the pure sensor values used for computing the selected indicator are shown in the graphs.
- Secondly by sliding the *Space* bar the map in the centre will zoom in and out and the indicators will compute their value using all the observed measurement within such area.
- The third sliding bar is in charge of the time window size. Sliding left to right the indicators are computed on values queried on a smaller and smaller time window and therefore the prediction becomes more and more accurate.

3.1.1.2 Experiment implementation plan

For reaching the goal of having the Smart City Performance Model we will perform 5 steps.

1. To identify which indicator and which Smart City scope (i.e. environmental, safety etc.) can be of interest for such platform. We can name this step as Smart City Performance Model study period and the goal is to have it done by the end of M18. The outcome of such period can be extended in the future with the integration of new testbeds consequently to the Open Calls or the extension of the actual ones. Even the integration of third party experiments could affect the outcome of this step.
2. To choose the indicators that will be actually designed and implemented. The choice is meant to be done also according to the available testbeds and the available resources. This step is supposed to be done by the end of M21. Also the outcome of this step can be affected by the integration of new testbeds (since the list of possible indicators changes).
3. To study the available datasets and design the data analytics algorithm(s). The outcome of this period will be the final definition of the datasets and the data analytics algorithm.
4. To implement and test the data analytics algorithms. Such a step is a continuous iteration along with the third step. The targeted ending of those two periods is M31.
5. To integrate the indicators into the Smart City Performance model. This final period is overlapping together with the implementation period and it should end at M33.

All the previous periods are not sharply defined and they can be affected by the integration of new testbeds, by the implementation of new experiments by third parts but also by the advancement of the state-of-the-art of IoT analytics.

3.1.2 Experiment Use Cases

The main idea is to show the status of a geographic region regarding different environmental aspects via predefined indicators. The computation of these indicators might need dynamic IoT analytic processes, thus discovering the available IoT resources and the using semantic interoperability for ensuring that all available data is taken into account, regardless the actual originator (i.e. testbed). By “environmental” we mean not only the natural environment (e.g. water quality, air pollution, temperature trend etc.) but also urban environment (e.g. crowd forming, traffic situation, structure conditions etc.).

We conceived four typologies of indicators based on four data analytics use cases. Such use cases leverage most of the functionalities of the FIESTA-IoT platform:

- **Resource Oriented analytics**. The input data in this context is the description of the resources and IoT services that expose them, semantically annotated according to the ontology defined in FIESTA-IoT Deliverable D3.1. The outcome of such analytics is the inferred information about the resources and the testbeds, hence inferred information of the IoT infrastructure.

- **Observation Oriented analytics.** The input data are mainly the observations/measurements produced by the resources deployed over the federated testbeds. In the same way as for resources, this raw data will arrive semantically annotated. The output of this kind of analytics is the inferred observation of a situation that happened in the real world.
- **Knowledge Produced analytics.** The input data are the outcomes of other analytics (of any typology data oriented and resource oriented) and experiments (even from third party). The output would be high level knowledge of a broader scope or more complex situation discovery.
- **Hybrid analytics.** This kind of analytics is a combination of the previous three analytic typologies.

Our experiment vision focuses on the backend of the mockup dashboard shown in Figure 5. The backend data analytics have as outcome the evaluation of indicators. Such indicators can refer to Resource Oriented analytics (see use case a), to Observation Oriented analytics (see use case b) or to Knowledge Producer analytics (use case c). The difference between use cases b) and c) is the level of their detail, which is defined by the “Abstraction” axis of the 3 dimensions of freedom of “zoomability” (see previous section).

The other two 2 dimensions of freedom (time and space) will have effect – respectively – on the historical query to the meta-cloud endpoint (see use case b and c) and to the bounding box of both discovery query to the IoT Service Registry and/or VE registry and of the Meta-Cloud Data endpoint (see use case b and c).

a) Resource-Oriented analytics

A resource oriented analytics is interested on getting data about the resources itself and to infer from such information added value information (such as the density of the deployment or the heterogeneity of it).

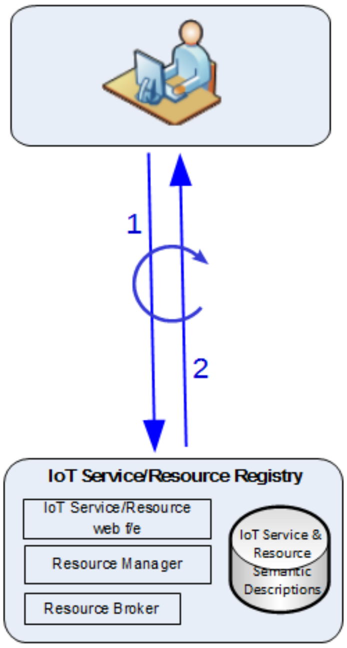

Figure 6. Resource-Oriented analytics use case

In such case, referring to Figure 6, the following steps will be performed:

1. The analytics algorithms perform a resources discovery contacting the IoT Service/Resource Registry specifying the geographic bounding box within the resource have to be allocated and the type of resource (which depends on the indicator).
2. The IoT Service/Resource Registry will generate a response containing a list of resources that have matched the query received from the previous step.

Since resource-oriented analytics are meant to be real-time, this operation will be re-iterated in polling in order to get always fresh data, meaning that the indicators about the deployment will be constantly updated.

An optimization of this use case would be to have a publish/subscribe system for the resources availability changes and to resources metadata updates of the resources already available.

b) Observation-Oriented analytics

An observation oriented analytics is interested on actual measurements made by resources combining historical data and new observations coming from the underlying testbeds.

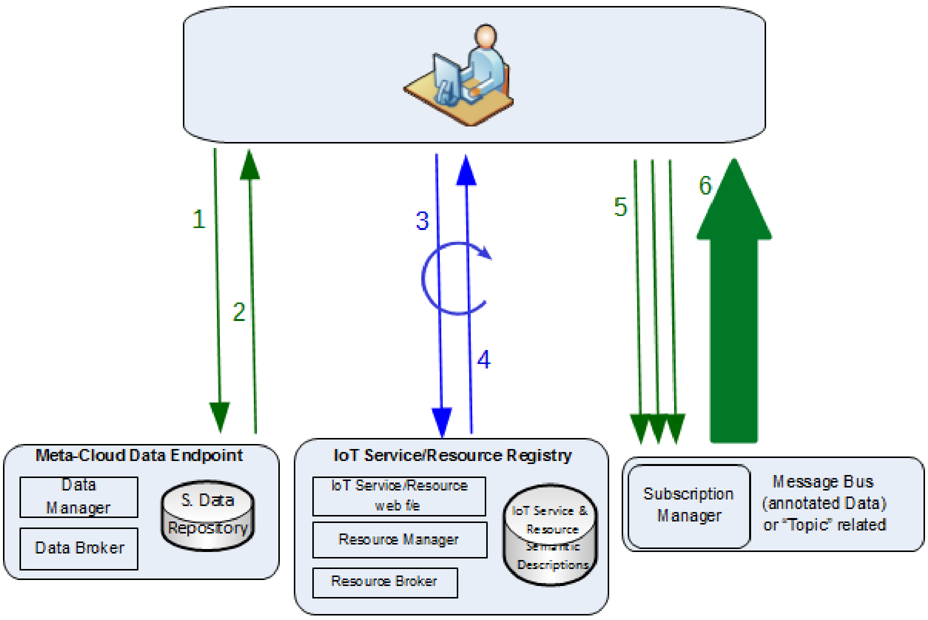

Figure 7. Observation-Oriented analytics use case

In this case, referring to Figure 7, the following steps will be performed:

1. The analytics algorithm first executes a query to the Meta-Cloud Data Endpoint in order to get all the historical data within a time, of certain type and within a defined geographic bounding box.
2. After step 2 has been concluded, the indicator evaluated needs to be kept up-to-date, for this reason the analytics algorithm will make a discovery of all the IoT services and resources available of a certain type and within the interested geographic bounding box by sending a request to the IoT Service/Resource Registry.

3. The IoT Service/Resource Registry will respond with a list of IoT Service endpoint and the corresponding "Topic".
4. The analytics algorithm then will send a subscription request to the Message Bus FC for each of the resulting topic in order to get the forthcoming available measurements.
5. The Message Bus FC will send a notification to the analytics algorithm whenever a new observation of the requested topics is available. The analytics algorithm will use such data for updating the indicator value.

The step 3 and 4 will be re-iterated in polling in order to discovery always new IoT services. Whenever a new IoT Service is available, the Message Bus will be requested with a new subscription.

In case the Message Bus is not implemented in the FIESTA-IoT platform the analytics algorithm can still run by polling the IoT Service/Resource registry for every IoT Services.

c) Knowledge-Produced analytics

A high level detail analytics is interested on added value data inferred from the actual measured data. In other words, the analytics is interested on the VE property generated by observation oriented analytics.

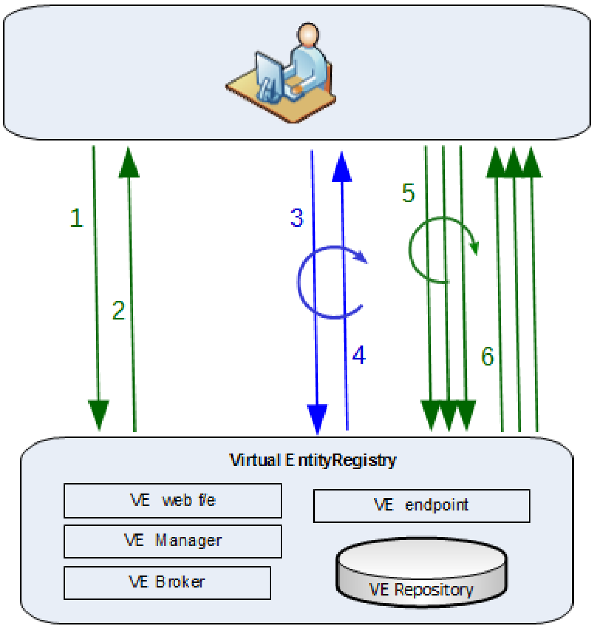

Figure 8. Knowledge-Produced analytics use case

This use case can be achieved by the following steps (depicted in Figure 8):

1. The analytics algorithm first executes a query to the VE Registry in order to get all the historical data within a time interval (depending on the Time granularity specified within the Smart City Performance Model), a number of Virtual Entities (depending on the indicators that are going to be evaluated) and within a defined geographic bounding box (in accordance to the parameters specified in the Smart City Performance Model, i.e. focus of the map and Space granularity).

2. The VE responds with a dataset that will be analysed in order to get the status of the indicator of the time chosen.
3. At this point the indicator evaluated needs to be kept up-to-date, thus the analytics algorithm performs a discovery of all the Virtual Entities available of a certain type (and/or with certain VE properties) and within the interested geographic bounding box by sending a request to the Virtual Entity Registry.
4. The Virtual Entity Registry responds with a list of Virtual Entity endpoints.
5. The analytics algorithm then sends a VE invocation to each VE endpoint resulting from step 4.
6. The analytics algorithm receives the responses from each VE.

Steps 3 and 4 are re-iterated in polling in order to continuously discover new Virtual Entities endpoint.

Steps 5 and 6 are also re-iterated periodically in order to have always the latest evaluation of VE properties (changing with the changes of the measured data by the underlying IoT data). Therefore the analytics algorithm can always evaluate in real-time the actual indicator.

An optimization of this use case would be to have a continuously evaluation of VE properties and have a publish/subscribe paradigm to each of them. This would avoid the redundant invocation of a VE endpoint if the associated VE property is not changed. Furthermore if more than one analytics algorithm is interested in a VE property, all of the former would be notified by only one execution of the latter.

d) Hybrid analytics

Some data analytics may need to handle data from different level of abstraction, i.e. directly measured by a resources or Virtual Entity properties. For such reason a data analytics algorithm might follow a combination of use cases b) and c).

Furthermore it would be possible that some indicators would be a mixture of Resource Oriented analytics and Observation Oriented analytics. In this case it would be possible to have a combination of all the use cases.

3.1.3 Experiment Validation Plan

With the execution and utilization of the Smart City Performance Model we will achieve the validating the FIESTA-IoT platform in the following points:

- *Experiment portability between testbeds.* The Smart City Performance Model will be able to change focus on a city by simply changing the focus of the map in the dashboard. The backend of the platform will perform the same use cases described in the previous section with the same steps but changing only the geographic bounding box. The FIESTA-IoT platform will be in charge of retrieving the data from the matching testbed(s), in a complete transparent manner to the Smart City Performance platform.
- *Using more than one testbed at the same time.* The indicators of the Smart City Performance platform are not limited to analysing data only from a certain city point of view, but if the focus is on an entire region (the space sliding-bar is set to hundreds or thousands kilometres, the indicators need to cope with data coming from different testbeds, spread among different cities. Retrieving

the data from different testbeds and homogenizing them is a task done transparently by the FIESTA-IoT platform.

- *Historical data storage and Asynchronous notification from the message bus.* The indicators of the Smart City Performance Model are based the time-series analysis. Thus, in order to have a meaningful outcome, the indicators need to start to evaluate the data from the historical data (historical data storage validator) and then keep the indicator waiting for new data (asynchronous notification from the message bus).
- *Scalability of the FIESTA-IoT platform.* Modifying the value of the Time and Space axes of the Smart City Performance platform implies a change of the data query, which will be addressed to the Meta-Cloud endpoint, the IoT Service/Resource registry, the VE registry or the Message Bus FC, since these changes might trigger modifications on the subscription plane.

3.2 Dynamic Discovery of IoT Resources for Testbed Agnostic Data Access

3.2.1 Experiment Plan and Outcomes

3.2.1.1 Motivation and expected outcomes

Regarding the main outcomes that we will extract from this experiment, we can emphasize the following two:

1. To provide a testbed agnostic access to the different datasets gathered from the various testbeds federated under the FIESTA-IoT meta-platform. Thanks to this, the experimenter will only have to deal with a unique interface, i.e. experimenter ↔ FIESTA-IoT, instead of accessing to each of the subjacent testbeds according to their (likely) proprietary format.
2. To demonstrate that the FIESTA-IoT platform can actually support a dynamic discovery of IoT services exposing IoT resources.

3.2.1.2 Experiment implementation plan

In order to follow a plan/strategy to deal with this experiment, we have split its development into various phases, providing as well an approximate deadline for each of them. It is worth noting here that they are not exact dates and might be subject to changes during the actual development of the experiment.

1. To implement the Graphical User Interface (frontend) from the initial draft we have presented in the wireframe version shown in Figure 3. Nonetheless, the final version does not have to be a 1:1 port of this mockup, and might include modifications in its final aspect, tailoring different features that were not envisaged during the initial specification of the experiment carried out in FIESTA-IoT Deliverable D2.3. (M16)
2. First approach to the actual FIESTA-IoT architecture, whose main components shall be already available to use. At least, it should provide a limited set of functionalities, including the ones that both IoT service and Resource Registry

and the Meta-Cloud Data Repository should support, thus providing two out of the three IoT services that we are willing to use in the experiment, i.e. access to 1- last/current value and 2- historical data. In order to receive future measurement once the experiment is running, we will stick to periodic polls instead of having a fully-fledged asynchronous subscription-like system, which will be deployed in a later stage. (M20)

3. First iteration of FIESTA-IoT Deliverable D5.2, documenting the results achieved so far. By this date, we expect to cover a minimum set of functionalities, including the ones described above, together with e.g. the integration of the authentication and authorization mechanisms, coming from the Security Functional Group (FG) that is currently being studied in T4.2. (M24)
4. Add different functionalities to the context of the experiment, such as the asynchronous service (i.e. pub/sub), the availability of Composed IoT services (e.g. wind chill, weather forecast, etc.), the feedback from experimenters, the console for advanced users and the documentation. (M31)
5. Integration of the natural query-based interpreter to solve and answer human language questions. It is worth recalling that this feature is an added value that we want to include in the final version of the experiment, demonstrating the potential that semantic interoperability might bring about over IoT frameworks. (M34)
6. Evaluation of the whole experiment, with all its components ready and functional. Besides, we include in this phase the interpretation of results and writing of the final report, FIESTA-IoT Deliverable D5.2. (M35)

3.2.2 Experiment use cases

In order to describe, piece-by-piece, the main functionalities that this experiment will cope with, we have decomposed its Graphical User Interface (GUI) into up to eight main different use cases, as shown in Figure 9. This wireframe will serve us to illustrate the features that we plan to support in the final version of the experiment. Each of them will have a different operation and will interact with different Functional Component (FC) of the FIESTA-IoT framework, as will be reflected below. For the sake of a better understanding, readers might refer to FIESTA-IoT Deliverable D2.4 so as to have a deeper explanation of the components and system use cases addressed henceforth. Throughout this section we will describe all of them, focusing on their relationship with the FIESTA-IoT architecture.

Before delving into the description of the use cases *per se*, it is worth highlighting that the experiment implementation or, said in other words, what is behind this graphical interface, is out of the scope of this deliverable (many of the parts are currently being designed in WPs 3 & 4), and will be addressed in the subsequent FIESTA-IoT deliverable D5.2. Then, once we have defined all the components and tools, we will be able to specify the concrete technical aspects we have addressed in order to implement the experiment.

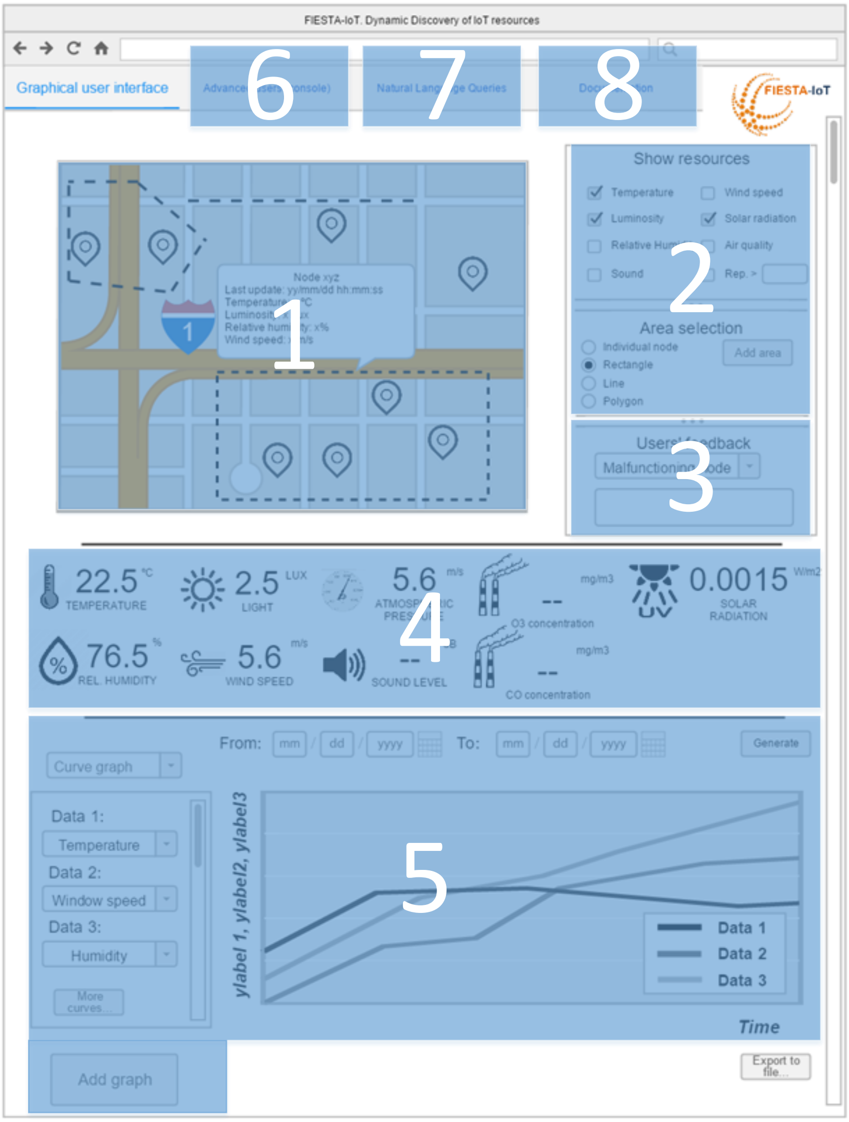

Figure 9. Breakdown of the experiment into independent use cases

Having commented the scope of this document, we will start outlining the use cases that compose the experiment, which are spread into four main categories:

The first one, which spans use cases a) to e), corresponds with the default visualization tool, addressed to newbies or non-technical end-users who only want to have a shallow interplay with the experiment. In this case, all the functionalities are implemented and are ready to be tampered. Technically speaking, experimenters do not need to generate any piece of code, since the experiment itself is ready to be executed, providing a predefined set of features.

After this initial contact, there might be the case in which more skilled or advanced users need another set of functionalities that the legacy version of the experiment just lacks. For that purpose, use case f) will support a high degree of flexibility, allowing those users to create enhanced versions of the experiment, directly addressing the API that connects the experimentation layer to the FIESTA-IoT platform (e.g. new layout, integration of different services fostered or reused from other experiments, etc.).

The third category (use case g) is more an added-value that we want to give to the experiment rather than an actual goal imposed by the project's requirements. Through a natural language interpreter, we will support a basic human-language-based processing engine that constructs the responses upon this type of queries.

Last, but not least, a good documentation (use case h) is essential in order to ease the adaptation phase of external (and even internal) experimenters. Following one of the overall project's objective, we plan to include here an interactive tutorial to help users play around with the experiment in their first steps and, after this initial stage, to enhance their experience when playing around with the experiment.

After this classification, we analyse below the eight use cases individually.

a) IoT Resources output + Area query input

The first and most noteworthy element to be highlighted is a map interface on which we will support a bidirectional interplay between end-users and the FIESTA-IoT platform. Figure 10 shows an arbitrary representation of the map and the elements that will be displayed on it. As hinted before with the word "bidirectional", we split into two different types of interaction, depending on the directionality between the source and its actual destination:

Figure 10. Interactive heat map

a1. *Experimenter → FIESTA-IoT*. As a very first step of the experiment execution, the interface shows all the resources/IoT services that are online and available within the region shown in the map. Behind this, a dynamic discovery of resources is carried out. Technically speaking, the experimenter sends an IoT service/Resource Discovery query (system use case 5.1.2.4 in FIESTA-IoT Deliverable D2.4) to the FIESTA-IoT IoT Service/Resource Registry FC, aiming at retrieving a list/array with all the online resources located within that area, bounded by e.g. the north-west and south-east corners of the map. As can be appreciated in the figure, additional areas might be selected in order to retrieve a subset of all the resources deployed over the displayed scenario, yielding the possibility of generating location-based queries (this part will be completed in the next use case).

a2. *FIESTA-IoT → Experimenter.* As a response to the above queries, the FIESTA-IoT IoT Service/Resource Registry will send back a response with an array containing all the semantic resource descriptions (and the IoT services that expose those resources) that have matched the criteria imposed by those requests. As mentioned before, this message returns, by default the subset of resources/IoT services that are deployed in the area delimited by the user. The experiment will catch some of the parts of these descriptions, i.e. resource ID, physical phenomenon measured by the resources, location and IoT service endpoint. Whereas the three first ones will be primarily used for displaying issues, the last one will be the link through which the corresponding IoT Service will be invoked, gathering the last values measured by the concrete resource that is manually clicked in the map (corresponding to the system use case 5.1.2.5 in FIESTA-IoT Deliverable D2.4).

b) Phenomena-based queries

Experimenters might not be interested in retrieving all the information coming from the underlying testbeds, but only a subset of the available resources. As an illustrative example, users that are willing to implement a weather forecast should not pay attention on the traffic information or the noise level in a concrete part of the city. Therefore, through a number of toggles (see Figure 11), experimenters can select those ones that they are interested the most.

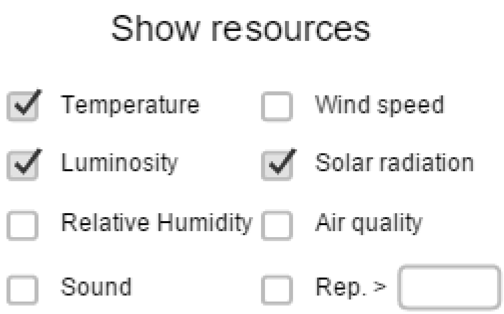

Figure 11. Phenomena-based filters to discover resources

These queries (IoT Service/Resource Discovery or Data Retrieval) can be addressed either to the Meta-Cloud Data Repository or the IoT Service/Resource Endpoint, depending on the type of service the experimenter is invoking. By default, the execution of this query will lead to a map update, showing the resources that match with the filter established in this part of the interface.

c) Users feedback

Although it cannot be considered as one of the most important requirements of the project, the FIESTA-IoT platform envisages (as depicted in two different requirements in FIESTA-IoT Deliverable D2.1) the possibility of allowing experimenters to provide feedback concerning different types of issues that may arise during the execution of the experiment. Hence, we have defined a basic yet complete tool to assess the operation of this requirement in this experiment.

As illustrated in Figure 12, users can provide their feedback on individual resources' issues (which will be selected by clicking them in the map), notifying the FIESTA-IoT administration staff the reasons behind those reports. Choosing among a number of

issues, e.g. malfunctioning node, offline resource, non-logical measurement, etc., together with an optional text, experimenters can help the consortium detect potential problems arisen at testbed level.

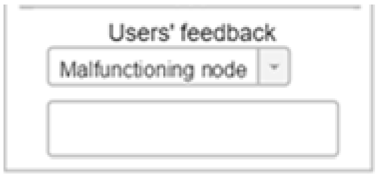

Figure 12. Feedback from users input tool (Combobox + prompt)

Then, the platform will put in contact with the affected testbed provider in order to fix the concrete problem(s). Regarding the part of the architecture that is involved in this use case, the Management FG is the one that will have to face these problems (probably with the manual intervention of an administrator/system maintainer).

d) Basic output: average values

Taking into account that this experiment only focuses on the weather/environmental domain, a straightforward widget is the one shown in Figure 13, showing the average values of all the resources that are shown in the map.

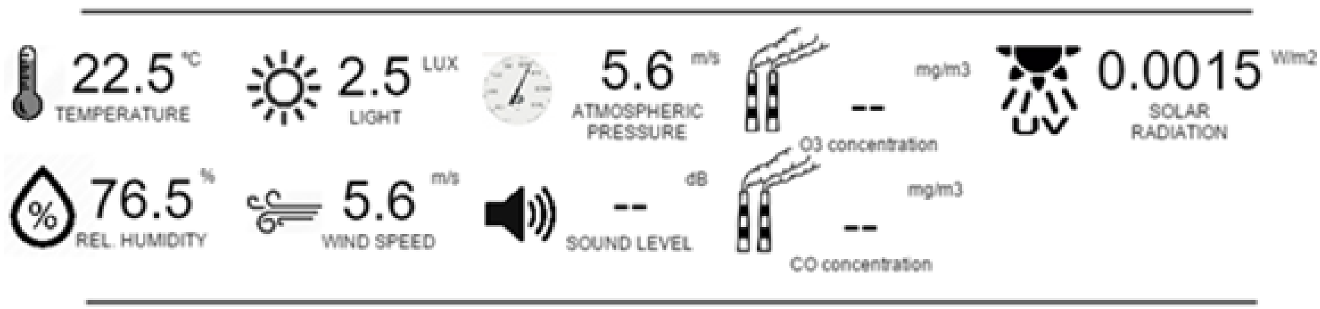

Figure 13. Weather station output

It is easily inferred that, for this use case, we cannot stick to the raw information, but we need to process this raw data in order to generate a composed IoT service, interacting with the IoT Composed Service Execution Engine located at the Service Organization FG in the FIESTA-IoT framework.

Moreover, it is worth highlighting the types of "simple" IoT services invoked in this concrete use case. As of the experiment gets started, this tool will display the average values (if there is any resource capable of measuring these phenomena in the area). In a first step, the last/current value service is invoked (the same way as we have seen in use cases a and b). After this single value has been retrieved, the experiment will carry out a subscription so as to gather the future measurements of all those resources. To do so, it will have to interact with the Message Bus FC, which will be the responsible of managing this asynchronous service, delivering the data to subscribers upon the reception of new observation events.

Then, this weather station will also cover some new system use cases (extracted from FIESTA-IoT Deliverable D2.4) that have not been named till now: 5.1.2.2 – Experiment makes reservation of resource(s) and request asynchronous publishing of data, 5.1.2.3 – Experiment subscribes to asynchronously pushed data streams.

e) Advanced output: data/IoT service composition

Aside from the averaging service described in the previous case, this experiment will provide a visualization tool for generating a number of different plots, chosen among the Composed Service Repository located at the Service Organization FG. The idea here is that all the composed IoT services registered previously in the FIESTA-IoT platform will be available for any experimenter that might need these functions in the future. However, it is worth noting that this only takes already-implemented services and not allow the creation of new ones (this is out of the scope of the experiment).

As can be appreciated in Figure 14, experimenters can select among a number a functions/composed services (top left corner), choosing as well the variables (i.e. phenomena that will compose the x-axis) that will shape the input of that function, as shown in the left frame of the figure.

Besides, we can also observe at the top of the figure a region in which we can select the time interval within which we want to represent the values. This time selection or time-based query will be addressed towards the Meta-Cloud Data repository, corresponding to one of the following system use cases in FIESTA-IoT Deliverable D2.4: 5.1.3.2 and 5.1.3.3, depending on the classification of the underlying testbeds.

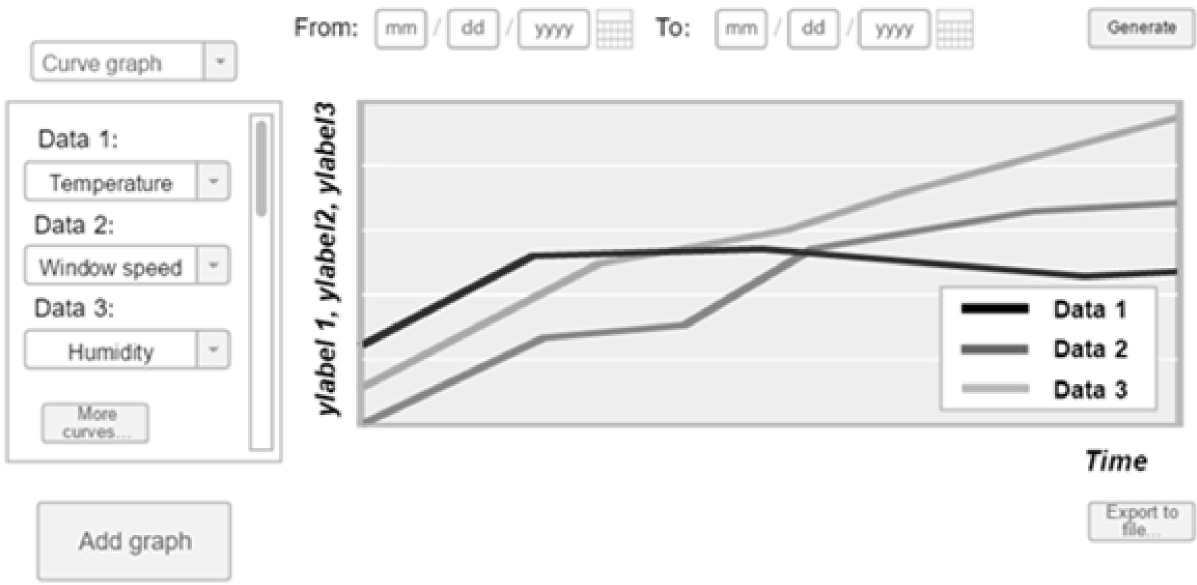

Figure 14. Arbitrary preview of an advanced output

Last, but not least, this tool presents the possibility of dynamically adding as many graphs as an experimenter might needs, allowing as well the possibility of exporting all the data (raw or processed) into various output formats (e.g. csv, xlsx, etc.) in case users want to handle this information either online or through another tool.

f) Prompt-based console for advanced users

Although the tools provided in these first five use cases offer a complete vision of what we have envisaged for this experiment, accomplishing all the “hard”

requirements and KPIs proposed to validate it, it is also true that some users might not find everything they need. In order to allow them to “manually” fix these potential gaps, we will include a separate tool through which they can freely tamper the experiment implementation. The way to do this is limited by the methods and mechanisms provided by the API that connect the experimentation layer with the FIESTA-IoT platform. Technically speaking, they will be able to: 1- Directly see and modify the source code that defines the experiment, 2- Instead of accessing to the raw code, they might prefer to tweak the user-friendly tools that are currently being under study in WP4 so as to help experimenters build their own experiments, 3- A combination of the former options, where users only “code” those parts that require a deeper modification (or that does not exist in the scope of the experiment).

Due to the flexibility that surrounds this tool, we cannot limit the number of system use cases bound to this one, since experimenters will have the potential freedom to tweak all the elements of the architecture, as long as the API allows these interactions.

g) Natural language queries

An interesting challenge that we have included as part of this experiment consists in the utilization of questions expressed in human language so that the FIESTA-IoT platform can parse and transform them to computer-friendly queries. By means of an external tool (the implementation of this engine is clearly out of the scope of the project), gathered from one of the off-the-shelf open source libraries that suits our experiment’s specification, we will generate accurate responses to this queries. Putting an example on the table, we will provide an answer to questions like: “What was the hottest day at Santander in 2016?”, “Which city is windier, Santander or Seoul?”

However, the format of these responses are not still defined. Depending on the depth we can get during the implementation time and the flexibility supported by the tools we choose as interpreter(s), we might go from simple text-based messages that answer simple and straightforward questions to stylish graphical outputs that matches complex queries.

Regarding the parts of the architecture and system use cases that will be involved here, we would include this reasoning engine within the Service Organization FG, group responsible of the orchestration of services and the integration of aggregators or reasoners. Then, when the interpreter is running, from the queries received from the experimenter, it will address individual queries to various FCs, like the VE registry, the Meta-Cloud Data Endpoint, the IoT Service/Resource Registry or even the Message Bus, if the query has to deal with subscriptions.

h) Documentation

Although at a first glance this use might seem uncorrelated from the others presented above, there are off-the-shelf frameworks that allow the description, production and visualization of RESTful-based APIs, such as Swagger[2] or RAML[3]. These specification tools have been designed to ease the management of the whole API lifecycle, from its initial design stages to the very final sharing ones, like the

[2] http://swagger.io/

[3] http://raml.org/

documentation phase that this concrete scenario is dealing with. In other words, they are thought not only for designing or building the interfaces, but also to test and document them in a sort of interactive way. Therefore, all the system use cases and parts of the FIESTA-IoT framework that we have presented in this section are prone to be used here.

3.2.3 Experiment Validation Plan

In order to consider this experiment as successful, there are a number of points that must be validated, as the ones shown below.

- Present and display IoT resources from, at least, four different testbeds.
- Dynamically discover potential resource outages in any of the underlying testbeds, as well as alike new resources that are registered during the execution of the experiment.
- Showcase that the FIESTA-IoT platform is able to provide at least three different IoT services: 1- delivery of the last value measured at the nodes, 2- select a time frame within which the Meta-Cloud Data Repository has stored the corresponding historical data and 3- Permit the subscription to future (and asynchronous) events, triggered by the legacy testbeds' resources when they generate a new observation/measurement.
- Receive a minimum of 50 issues from the experimenters' feedback function. Although there exists the possibility of having a perfect performance without any incidence to raise, testbeds usually have behaviour anomalies, so we expect that users can produce this number of feedback messages.
- Bear a minimum of 500 simultaneous subscriptions during the experiment lifetime. It is worth taking into account here that multiple users might run this pilot at the same time (together with a number of different experiments), thus the FIESTA-IoT platform should be prepared to handle thousands of simultaneous requests and
- Generate a minimum of 50 different VEs, built upon the IoT services/resources.
- Compose a minimum of 10 different IoT composed services and store them into the FIESTA-IoT Service Organization FG.

3.3 Large Scale Crowdsensing

3.3.1 Experiment Plan and Outcomes

3.3.1.1 Motivation and expected outcomes

The summary of benefits of the experiment use cases described in section 3.3.2 is provided below. More explanation is provided in the KPIs section 2.3.2.

- Testbed agnostic access: The experiment use cases are not testbed dependent. Changes in the number of registered testbeds will definitely impact the size of the result obtained but will be a transparent process for experimenters, who will

seamlessly interact with the different testbeds' resources through a single and unique interface.

- Large scale data access: Due to spatio-temporal nature of the experiment use cases, the requested set of results will span over a large area where samples are gathered from large number of devices in the region of interest.

3.3.1.2 Experiment implementation plan

As discussed in Section 2.3, the major goal of this experiment is to explore the ability of the FIESTA-IoT platform to manage and execute experiments over the data coming from mobile devices and to explore the ability to ultimately combine data from different co-located testbeds: one materialised as an app running on citizens' smartphones, and another present as a web-service that provides access to the data collected by the set of static sensors installed and managed by the city. The experiment focuses on providing better understanding to the experimenter about the variations in the sensed value of environmental data - in our case noise-levels - and help experimenters create policies as a part of living labs approach.

The experiment is divided into following phases:

1. Learning Phase: This phase will enable us to understand clearly about FIESTA-IoT tools and Functional Components (FC) that are necessary for the experiment, especially: inputs and output of each functional component, etc. This will be the learning phase for an experimenter like us. Once subsequent learning has been achieved "Development" phase will eventually start. The initial learning phase will be the longest phase. This phase will use the "User Management FC" where experimenter will create their user accounts and will register themselves as experimenters. This phase is already ongoing and the first initial learning phase is expected to finish by M16 when all the interfaces and tools are expected to be available. Further this phase will be longest and is expected to end by M31.

2. Development Phase: This phase will enable experimenters to create the FIESTA-IoT Experiment Model Object (FEMO) using the available DSL for the experiments. This phase will rely on the "Security FG", "Web Browsing and Configuration FC" and the "FIESTA-IoT Experiment modelling" component. After the development of the experiment next phase ("Execution") will start. This phase will also provide implementation of the GUI for the experiment as shown in Figure 4.This is an iterative phase and will be expected to end by M32.

3. Execution Phase: This phase will be associated to the submission and execution of the experiment. The duration of the phase will depend on the temporal aspects specified in the FIESTA-IoT Service Model Object (FISMO) of the FEMO per use case. With regard to the former use case, for instance, it does not have temporal aspects associated to it. Thus, the execution of the experiment as per use case 1 will not last long. However, as other use cases depend on temporal aspects, the execution of the experiment will last until the specified time in the FISMO. This phase will use the "Experiment Execution Engine" component that will in turn query the "Meta-Cloud Data Endpoint". This phase depends on the temporal

aspects specified in the use case thus specifying a specific expected end period is unrealistic. However, for use case 1, the phase is expected to last some seconds after the experiment use case is developed and submitted to the "Experiment Execution Engine".

4. Interpretation of the results obtained: Once the experiment has been executed, FIESTA-IoT platform will provide the results based on the FEMO specified in the "Development" phase. The results obtained will then be interpreted and understood. Any anomaly present in the results will be identified. The anomalies will lead to modifications in the experiment FEMO and the re-execution of the experiment. This will lead to the "management" phase of the experiment. Again as this depends on the phase 3 where temporal aspects can be specified in the use case, a specific expected end period is unrealistic. However, again for use case 1, the phase is expected to last some days after the experiment use case results are obtained and provided to the experimenter. This phase is experimenter dependent.

5. Management Phase: The management phase of the experiment will ensure that the experiment is updated and complies with the policies and technicalities of the FIESTA-IoT platform. As said before, this phase will require updates based on a) the anomalies found in the set of results and b) changes in the FIESTA-IoT APIs and ontologies, etc. and will loop back to "Learning" phase. This phase will also help experimenters to report and provide feedback back to FIESTA-IoT platform. As this is also an iterative phase and will be expected to end by M30.

3.3.2 Experiment use cases

In this section we provide the use cases that can be achieved using the large-scale crowdsensing experiment. The use cases are built using the requested attributes as specified in the section 2.3.1 ("Specification of dataset"). The experiment use cases use data made available via the FIESTA-IoT platform. The experimenters, using the DSL, describe their experiment use case that uses subset of the attributes mentioned in section 2.3.1. The results-set obtained from the FIESTA-IoT platform's Meta-Cloud Data endpoint is then displayed via a user interface. A mockup of the user interface is provided as in Figure 4. In the use cases below, we refer to the "environmental data" as "noise". The use cases are realized using the required tools mentioned in the section 3.3.5 ("Required Tools") of the Task 2.3 deliverable "Specification of Experiments, Tools and KPIs". The use cases below do not depend on the class (Class I, II or III) of the testbed. Please refer to the Deliverable 2.4 "FIESTA-IoT Meta-Cloud Architecture" for more information on the testbed classes.

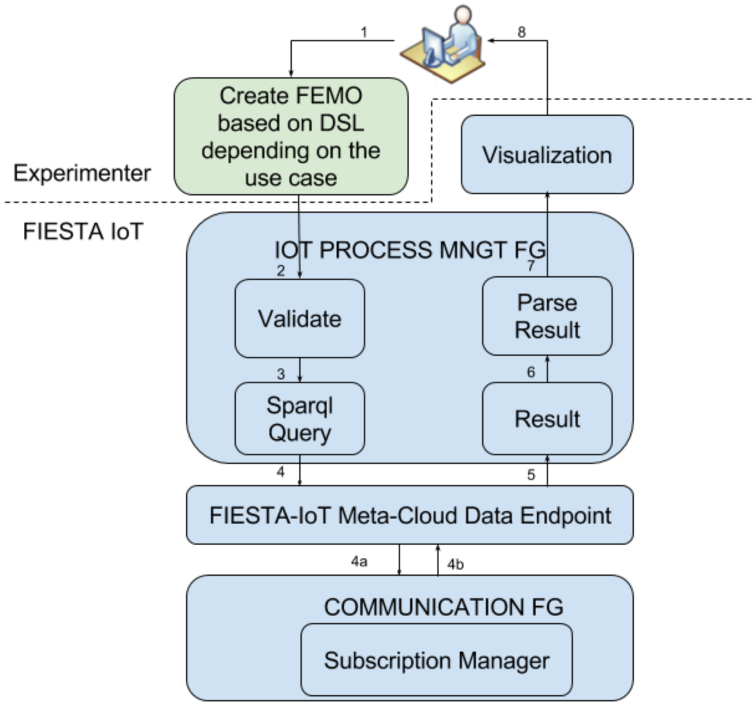

Figure 15. Use case diagram (large crowdsensing experiment)

All the use cases can be presented as in Figure 15, where:

1. Experimenter provides the FEMO depending on the use case.
2. The FEMO is validated. If FEMO is valid then the flow goes to step 3, otherwise, a message is returned to the experimenter.
3. The FEMO is converted to a SPARQL query.
4. The SPARQL query is executed via FIESTA IoT Meta-Cloud Data Endpoint
   a. If the subscription is made for the future values then Subscription manager (which is part of the Message Bus FC) is notified.
   b. Whenever the new values are available the Subscription Manager notifies the FIESTA IoT Meta-Cloud Data Endpoint.
5. The result is obtained.
6. The result is parsed either is the human readable format or presented to the visualizer.
7. The Visualizer creates visualization and
8. Provides the visualization to the experimenter

The use cases are the following ones:

a) **Based on spatial information and the sensed environmental data**: The experimenter wants to understand the sensed environmental data over a certain area and would like to view the heat-map of the sensed environmental data over that area. To do so, the experimenter specifies in the FEMO the bounding box of the region (in terms of latitude and longitude) and requests for the samples of the sensed environmental data. The FEMO is processed and all the samples related to sensed environmental data that has location within the bounding box is provided irrespective of the testbed that provides data relating to sensed environmental data. The returned data is then processed and is provided to the experimenter in the form of heat map as shown in the Figure 4. As the data is also time stamped, depending on the policy implemented by the FIESTA-IoT Meta-Cloud Data endpoint either:

- An average of sensed values over entire time period for each location within the bounding box is provided (Figure 4 shows average of sensed value over entire time period), or
- The latest sensed value is provided for each location within the bounding box.
- The above use case requires *Location* and *Sensed value of environmental data (noise) attributes* to be realized.

b) **Based on temporal information and the sensed environmental data over a location identified by latitude and longitude**: The experimenter wants to understand the sensed environmental data at a certain location that is identified by latitude and longitude and would like to view the variations in the sensed environmental data over time. To do so, the experimenter specifies in the FEMO, the bounds for the time in terms of start and end time, the latitude and longitude of the location, and requests for the samples of sensed environmental data. Note that the start and end time pair can have values where a) both start and end time are historic times, b) both start and end time are future times, and c) start time is historic and end time is in future. The FEMO is processed and all the samples related to the sensed environmental data that are present in the FIESTA-IoT platform that has time property where the time is within the time bound and has the specified location is provided. The returned data is then processed and is provided to the experimenter as the time series map. As, in this use case, the end time can be in future, the FIESTA-IoT platform should schedule the experiment such that whenever the data is made available within FIESTA-IoT platform the map is updated with the new data. Also note that this is also true when start time is in future. The provision of new data available depends on the policy implemented by FIESTA-IoT Meta-Cloud Data endpoint and the Message Bus FC, i.e., provide the data instantaneously as it is made available or provide the data in chunks.

- The above use case requires *Sensed value of environmental data (noise)* and *Current Timestamp of the Sensed Value* attributes to be realized.
- Note that in the use cases c), d) and e) similarly to this scenario the start and end time in the time period can have values where 1- both start and end time are historic times, 2- both start and end time are future times, and 3- start time is historic and end time is in future.

c) **Based on spatio-temporal information and the sensed environment data**: The experimenter wants to understand the dynamics of the sensed environment data. By “dynamics”, we mean the behaviour of the sensed environment data. This behaviour can relate to, for example, how the sensed environment data vary over time and location. To do so, the experimenter specifies in the FEMO, the bounding box of the region (in terms of latitude and longitude) and requests for the sensed environmental data over a period of time. The FEMO is then processed and all the samples related to the sensed environmental data that are made available via FIESTA-IoT platform that have location property where the location is within the bounding box and where the time is within the period specified is provided. The returned data is then processed and is provided to the experimenter as the dynamic heat-map.

   - The above use case requires *Location, Sensed value of environmental data (noise),* and *Current Timestamp of the Sensed Value* attributes to be realized.

d) **Based on spatio-temporal information where the sensed environmental data is more than a certain value**: The experimenter wants to understand the dynamics of loudness (noise being sensed environmental data). To do so, the experimenter specifies in the FEMO, the bounding box of the region (in terms of latitude and longitude) and requests samples for the sensed environmental data where the sensed value is more than “x” (x dBA in our case) over a period of time. The FEMO is processed and all the samples related to sensed environmental data that have value more than “x”, are made available via FIESTA-IoT platform, have location property where the location is within the bounding box and time is within the period specified is provided. The returned data is then processed and is provided to the experimenter as the dynamic heat-map.

   - The above use case requires *Location, Sensed value of environmental data (noise),* and *Current Timestamp of the Sensed Value* attributes to be realized.

e) **Based on spatio-temporal information where the sensed environmental data is less than a certain value**: The experimenter wants to understand the dynamics of quite-ness (noise being sensed environmental data). To do so, the experimenter specifies in the FEMO, the bounding box of the region (in terms of latitude and longitude) and requests samples for the sensed environmental data where the sensed value is less than “x” (x dBA in our case) over a period of time. The FEMO is processed and all the samples related to sensed environmental data that have value less than “x”, are made available via FIESTA-IoT platform, have location property where the location is within the bounding box and time is within the period specified is provided. The returned data is then processed and is provided to the experimenter as the dynamic heat-map.

   - The above use case requires *Location, Sensed value of environmental data (noise),* and *Current Timestamp of the Sensed Value* attributes to be realized.

f) **Other use case scenarios**. It refers to the optional data requested as in section 2.3.1 and made available via FIESTA-IoT platform. One out of the many use cases that an experimenter might be interested in that uses the optional attributes is: the experimenter wants to understand the relation between the *physical activity as reported by the phone* and the sensed environment data. To do so, the experimenter specifies in the FEMO, the requirements for the data. The FEMO is processed and result-set is returned to the experimenter.

3.3.3 Experiment Validation Plan

Below we list objectives of FIESTA-IoT that will be validated by the Experiment use cases:

- Number of testbeds involved in the experiment: The experiment use cases request samples from FIESTA-IoT platform and are not testbed specific. In a federated scenario, if a testbed provides the requested environmental data, the samples are provided to the experimenters. If the testbed does not support the requested environmental data, then the data from the particular testbed is not provided to the experimenter. Thus, the samples that come from different testbed are first integrated and then provided to the experimenter. Thereby focusing on "testbed-agnostic access" to data.

- The experimenter needs to submit the FEMO in order to request the data, a successful submission and execution of the FEMO would validate the "implement a portal infrastructure enabling the submission of experiments over semantically interoperable testbeds" objective of FIESTA-IoT.

- Number of data samples needed for high-quality results: As the experiment use cases focus on large scale crowdsensing, an experiment that needs to build a heatmap that consumes 30 days of data from at least 1 sensor that produces high quality samples (location accuracy below 10m) every 5 minutes, would require at least 30*12*24 high quality samples. This would validate the high quality "volume of data that is consumed" by an experiment objective of FIESTA-IoT. Further, as some of the use cases within the experiment are based on temporal information and execution, FIESTA-IoT's objective of "the timing of the execution of the various experiments" will also be validated.

- Users/sensors data was used in the experiment: as the experiment is over large scale, it involves more than one users/sensors data for experimenter to understand what they want (as described in the use cases in section 3.3.2). This would also validate the "volume of data that is consumed" objective.

4 POTENTIAL RISKS AND CONTINGENCY PLAN

Beside the "envisaged" operation that shapes the construction and execution of our experiments, we must take into account a number of potential risks that might arise during different phases of the whole experiment lifecycle. Below we enumerate some of the most critical ones, in order to identify them in advance and to have an alternative solution in case they come on the scenes.

- FIESTA-IoT platform not ready by the dates we have foreseen. In case the legacy components were not ready by the date we have planned to interact with it, our first option would be to implement a basic set of services or "lite" versions of the pieces required in that moment in time.
- DSL not ready by the dates we have foreseen in the previous schedule. The contingency plan would be to use well-known tools to define and implement the experiment, accessing through the Experimenters ↔ FIESTA-IoT API, which should be available and operative.
- From the previous point, we might find the case in which the API is not complete. This case would correspond to a critical situation, since this interface will define the unique entry point for experimenters.
- Experimentation of technical issues coming from the Security FG. For instance, this functional group might be not operative at some moment in time, so every sign in request would be immediately refused (neither authentication nor authorization stages could be carried out). In order to bypass this potential failure, we can build a backdoor through which we can get access in these emergency situations. Of course, this kind of technique would lead to new security threats.
- Testbed outage, meaning that the experiment cannot retrieve data from one (or more) of the underlying platforms during a not-so-negligible time gap. During this period, the platform would be only able to cater data stored at its meta-cloud, but not from the lower levels (i.e. testbeds).
- There might be the case in which the number of requests generated by the experiments cannot be handled by the FIESTA-IoT platform within a reasonable time. In order to avoid endless waiting periods, we will set a timeout value that prevents the experiment from long waiting times that will harass the users' experience.
- Due to the nature of the experiment (Spatio-Temporal), there is a possibility that the result obtained is very limited (can be an empty observation). This void data will lead to no inferences and thus, the experiment will be worthless. These empty data streams can be obtained due to various reasons such as: a) no testbed has resources in the required spatial region, b) the device's sampling frequency is high while the requested time period is extremely low, c) the time period of the requested data is of future thus the data not available in FIESTA-IoT platform, and d) invalid FEMO, etc. The invalid FEMO will lead to modification in the FEMO and subsequently will loop back to "Development" phase.
- Re-execution might lead to performing inferences again on the new results-set and might include further delays. Thus to mitigate this challenge, it would be

beneficial that the experimenter has a complete and thorough knowledge of the FCs needed for the experiment.

- Modification in the FIESTA-IoT platform architecture and the ontologies will produce results that are undesirable and would need modifications in the experiment FEMO.

5 INTERACTION BETWEEN THE EXPERIMENTS AND THE FIESTA-IOT PLATFORM

Having described all the experiments and individual use cases that they deal with, Figure 16 shows the FIESTA-IoT system architecture defined in FIESTA-IoT Deliverable D2.4, shading those FCs which the experiments interact with (either through a direct or indirect interplay), according to their current version. As can be seen in the figure, we identify which of the experiments tweak each component in the architecture, showcasing the complementary followed during the experiments specification, since they cover, altogether, all the elements that shape the system architecture.

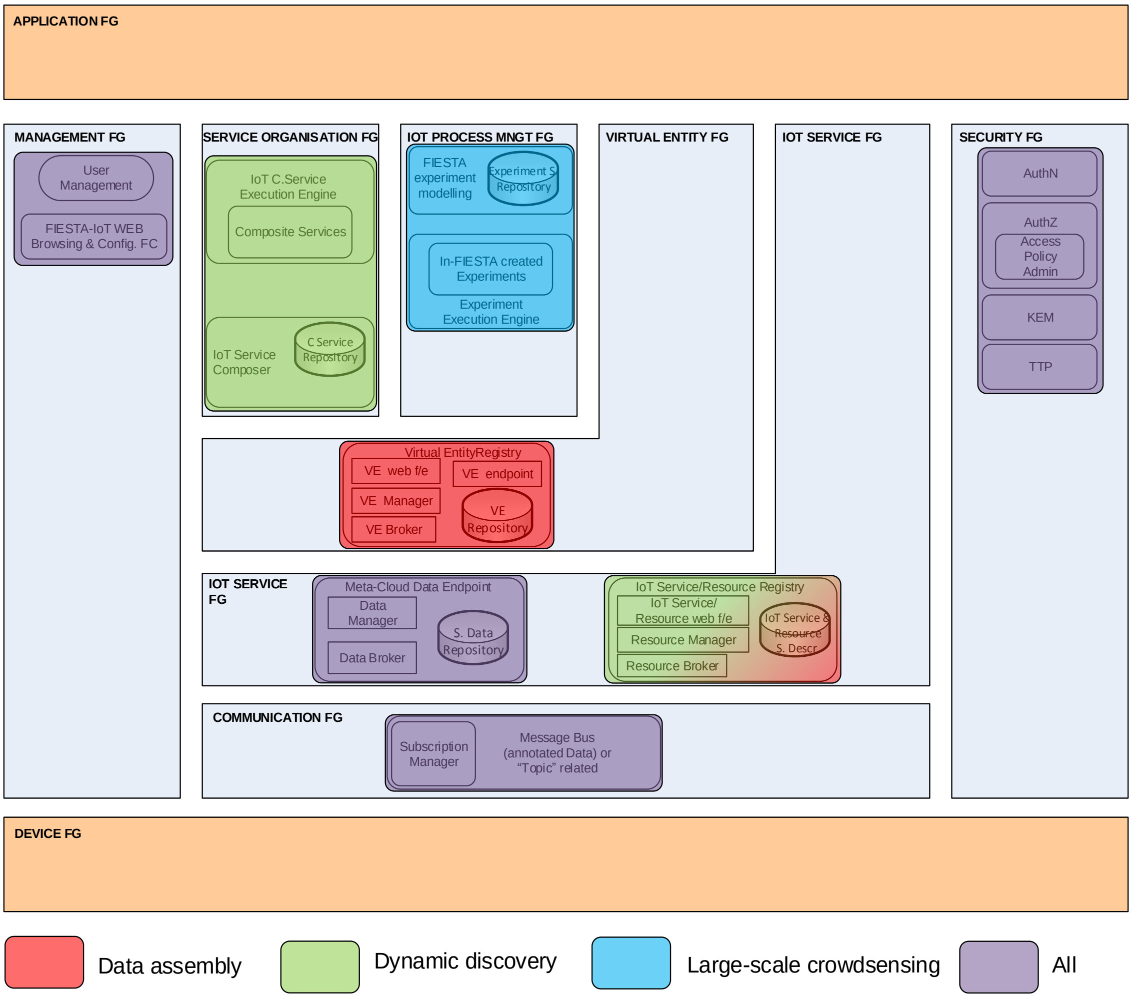

Figure 16. Interaction between the experiments and the FIESTA-IoT system architecture

Below we go through each of the FCs, justifying their role within the experiments lifecycle.

- Security FG. This group will play an essential role on the authentication and authorization of external experimenters. Besides, it will provide them with adequate levels of security and privacy. For further details about its implementation, the reader might refer to the forthcoming FIESTA-IoT Deliverable D4.2.
- Management FG. Working together with the Security FG, this group deals with, as its name hints, the management plane. In the particular case of these experiments, its main function will be the registration of new users (through the User Management FC). Besides, its FIESTA-IoT Web Browsing & Configuration FC might be used for browsing and displaying the resources registered at the FIESTA-IoT IoT Service/Resource Registry FC.
- Service Organization FG. In order to put a place to store the composed IoT services created by the experiments, the FIESTA IoT framework goes a step beyond the production of raw data and allow the generation of higher order knowledge. Through this group, users take e.g. off-the-shelf analytics algorithm and receive the processed data instead of having to do by themselves at the experimentation layer.
- IoT Process Management FG. With a similar functionality than the Service Organization FG, this group aims to help users create their own experiments by means of graphical tools and even execute them. In the case of the crowdsensing experiment, we will rely on the DSLs studied at FIESTA-IoT Deliverable D4.1 in order to define the pilot.
- Virtual Entity FG. One of the key features that loomed from the IoT-A specification (IoT-A, 2013) is the introduction of VEs as a core part of future IoT platforms. Designed to be an object level abstraction layer, this group takes the responsibility of binding the VE properties to a variable number of IoT Services that expose their underlying resources. Besides, it provides the tools to discover, browse and visualize the available VEs (and, of course, to store them).
- IoT Service FG – IoT Service/Resource Registry FC. This first half of the IoT Service FG will handle every resource-oriented use cases. Its main task will be clearly tied to the discovery of resources phase, receiving queries from the upper part of the framework (e.g. Experiment Execution Engine FC, FIESTA-IoT Web Browsing & Configuration FC, experimenters accessing directly through the API, etc.) and generating responses with the semantically annotated resource descriptions (and the IoT services that expose them) that match those queries.
- IoT Service FG – Meta-Cloud Data Endpoint FC. If in the above point we spoke about resource-oriented use cases, this component does an analogous approach, this time focusing on data-oriented ones. Experimenters might want to generate a data-based query (e.g. “Give me the temperature in this area from January 1st to February 24th), thus retrieving a list/array of all the observations/measurements that suit the request.

- Communication FG – Message Bus. Whenever a experimenter wants to be aware to future events (those ones that come after the experiment is executed), they have two options: whereas the simplest one should be based on sending periodic polls, which would lead to the direct interaction either the Virtual Entity or the IoT Service FGs, the wisest way to act would be to go through a publish/subscribe mechanism so that this experimenter could just listen to the Message Bus FC and grasp the new measurements as soon as they are generated. This way the way is twofold: 1- the experiment reduces the overload bound to the transmission of periodic queries/IoT service invocations; 2- the experimenter receives the information with a much lower latency.

6 CONCLUSIONS

This deliverable has described the different scenarios and use cases that define an initial set of experiments that will serve as the basis for analysing and evaluating the operation and performance of the implemented innovations developed towards the FIESTA-IoT interoperability framework.

In this sense, for each of the three, so called, “in-house experiments” a brief overview of the different datasets and KPIs that are relevant to each experiment have been made. Should the reader need a more concrete information on the experiments’ requirements or tools, he/she might refer to FIESTA-IoT Deliverable D2.3. For the description of these datasets, a close collaboration has been established with the testbeds that are being initially federated through the FIESTA-IoT platform in order to guarantee the availability of the information that is required by the experiments and in some cases to tune demand and offer for them to fit. This has created as a side product interesting best practices on how available information sets and streams should be announced and described for potential experimenters to be attracted towards carrying IoT experimentation on top of the FIESTA-IoT Meta-Cloud.

Moreover, implementation plans for each of the experiments have been created in order to define the steps which will be taken for the realization of the experimentation and plan ahead potential risks and contingency countermeasures to be adopted so that experiment success is not jeopardised.

Additionally, the main motivation and outcomes resulting from each experiments have been briefly described. In this sense, it is important to highlight that besides specific objectives and results from the experiments, their common aim is the validation of the FIESTA-IoT platform and the provision of feedback for the optimization of the integrated tools.

The detailed specification of the use cases composing each of the experiments serves as input for the activities within the project in charge of the implementation and integration of the tools and enablers that will altogether form the FIESTA-IoT platform.

Finally, the complementarity of the experiments has been highlighted by summarizing the functional components from the FIESTA-IoT architecture that are required for the execution of the experiments. As expected, the core of the architecture, namely the components at the IoT Service FG and Communication FG, is extensively employed

by the experiments while the rest of functionalities provided (and implicitly the tools and enablers in charge of them) by the FIESTA-IoT platform will be respectively used by one or another of the three experiments. Fulfilling this complementarity and completeness is of utmost importance in order to be able to totally assess and validate the FIESTA-IoT platform.

REFERENCES

FIESTA-IoT D2.1. (2015). *Project Deliverable D2.1 - Stakeholders requirements.*

FIESTA-IoT D2.3. (2015). *Project Deliverable - FIESTA Specification of Experiments, Tools and KPIs.*

FIESTA-IoT D2.4. (2015). *Project Deliverable D2.4 - FIESTA Meta-Cloud Architecture and Technical Specifications.*

FIESTA-IoT D3.1. (2016). *Project Deliverable D3.1 - Semantic models for testbeds, interoperability and mobility support and best practices.*

FIESTA-IoT D4.1. (2016). *Project Deliverable - FIESTA Meta-Cloud and EaaS Model Implementation.*

FIESTA-IoT D4.2. (2016). *Project Deliverable - Techniques for Secure Access and Reservation of Resources.*

FIESTA-IoT D5.2. (2016). *Project Deliverable - Experiments Implementation, Integration and Evaluation.*

Gavras, A. (2010). *Experimentally driven research white paper .* ICT-FIREWORKS .

Haren, V. (2009). *TOGAF Verson 9.0.*

Hoornweg, D., & Blaha, D. (2006). *The Current Status of City Indicators.* The World Bank.

IEEE. (1990). *IEEE standard glossary of software engineering terminology.* IEEE.

IEEE. (2007). *Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems.* IEEE.

IoT-A. (2011). Project Deliverable D1.2 – Initial Architectural Reference Model for IoT: http://www.iot-a.eu/public/public-documents/d1.2/view

IoT-A. (2013).Project Deliverable D1.5 – Final architectural reference model for the IoT v3.0: http://www.iot-a.eu/public/public-documents/d1.5/view

MyFIRE. (2011). Project Deliverable D1.2 Taxonomy on common interpretation of testing, testing approaches and test beds models

Project Management Institute. (2013). *A Guide to the Project Management Body of Knowledge* (5th Edition ed.). USA.

Shvachko, K. a. (2010). The Hadoop Distributed File System. *Proceedings of the 2010 IEEE 26th Symposium on Mass Storage Systems and Technologies (MSST)* (págs. 1-10). IEEE Computer Society.

Soukhanov, A. H., Ellis, K., & Severynse, M. (1992). *The american heritage dictionary of the english language.* Boston, MA: Houghton Mifflin.

APPENDIX I – EXTERNAL EXPERIMENTS

In this appendix we include a number of experiments that have been proposed to be carried out over the consortium legacy testbeds. Throughout this section, we go through some of the most relevant examples that might provide inspiration to users who want to develop their own experiments in the scope of the FIESTA project.

I.1. Urban shopping

This experiment will consist in the aggregation of IoT information to an off-the-shelf smart shopping implementation. The original solution was conceived as a module for e-commerce platforms that permits geo-localized offers for smartphone users, i.e. processing their position and historical data, like movement patterns or frequent visits to a concrete shop, for instance. Upon this legacy implementation, the use of IoT-based sensor data information is foreseen to play an essential role in this environment, thus giving rise to a number of new possibilities.

The experiment will include field trials in order to be validated the system performance under real conditions. In terms of feedback, the experiment plans to deliver (at least) information related to the integration between sites (easiness, speed, additional aspects), stability of the architecture, possibility to be integrated with third party developments, as well as its impact and benefits for the experiment results.

I.2. Smart battery management system for electric vehicles

The main goal of this experiment is the implementation and subsequent validation of a smart system for the management and optimization of a fully-fledged Electric Vehicles' (EVs) ecosystem. To deal with this objective function, this proposal aims at enabling an efficient and scalable deployment of an electric charging infrastructure over a real facility (i.e. the city of Santander), while promoting low operational and maintenance costs. The platform is based on the service management of the battery recharge of these EVs with the objectives of enhancing 1- users experience in their daily activities (e.g. optimizing the recharge time) and 2- electricity grid performance (e.g. minimizing peaks demands). This framework is built upon an interconnected mesh of residential/commercial charging docks (or charging stations). The SMS-EV features an intelligent service layer capable of providing customized information and services to drivers based on specific policies. In fact, the system is capable of taking optimal decisions about addressing the requesting EV to the most suitable (e.g. closer) power station based on the users' preferences, the available power stations and the current traffic status.

Once the experiment is running, a set of routing strategies are to be considered in order to evaluate the performance of users satisfaction, in terms of e.g. average waiting time, overall energy supplied, etc. This will allow, on the one hand, the validation of the sustainability of an EV charging infrastructure; besides, we will explore and assess the design of policies for an efficient usage of the infrastructure. All in all, this approach will require a sophisticated information system, providing remote access to real-time availability data of the sensors deployed over the SmartSantander facility.

I.3. Predictive Traffic Condition Analytics

The following experiment aims to check whether a traffic monitoring prediction system can be scalable enough through the utilization of commercially off-the-shelf tools. Its main goal is to have a Hadoop Distributed File System (HDFS)-based setup (Shvachko, 2010), which gathers real-time traffic sensor data. Whilst the data is being harvested, a set of machine-learning tasks are executed, detecting potential incremental changes (e.g. through Weka[4] or PredictionIO[5], well-known data mining and machine learning frameworks). Based on these deltas, a set of machine-learning algorithms will predict the near-term future, e.g. future traffic congestions, emergency routes, etc. A separate process will periodically examine the entire dataset to devise future traffic patterns (e.g. through R[6]). Finally, the near-term future will be saved in an ephemeral manner, whereby it can be disseminated to emergency response staffs and subscribers for immediate actions. Moreover, the long-term data will be disseminated to planning authorities.

Then, the overall objective of the experiment is therefore to discover if it is possible to have a functional framework, built upon commercially off-the-shelf tools that can perform predictive analysis in near real-time on a large dataset, populated via sensors in an "Internet of Things" scenario, like the city of Santander.

I.4. Environmental Noise Monitoring using Acoustic Data

Europe is considered to have one of the most restrictive and extensive environmental laws in the world. The environmental policies in Europe seek to be as much environmental-friendly as possible, increasing their citizens' quality of life as much as possible while leading the fight against the upcoming environmental challenges.

The Eurozone has addressed some of these issues, such as the acid rain, ozone layer and waste and water pollution among others. One of the main issues addressed is the noise pollution, especially in cities, with proper regulation. This emphasis become true through the European directive regarding assessment and management of environmental noise was released on June 2002 so as to achieve a high level of health and environmental protection, focusing on noise contamination. In addition to city noise maps, all the major airports, roads and railways were also required to be analysed.

This experiment, which runs over the SmartSantander facility, aims to create a real-time noise monitoring map using acoustic data which can even substitute expensive off-the-shelf offline noise map techniques. The acoustic data as it is, is not sufficient to give a precise noise map, because there is coarse spatial sampling of the urban environment by acoustic/noise sensors, which prevents their combination and visualization in a suitable form. It requires post-processing of the sensor data to improve and get appropriate data. However, the measurements are highly dependent on several factors:

[4] Weka - Waikato environment for knowledge analysis. Website: http://www.cs.waikato.ac.nz/ml/weka/

[5] https://prediction.io

[6] R: Revolution Analytics' R Tool for Big Data analysis. Website: http://www.revolutionanalytics.com/

- Location and proximity to noise sources.
- Malfunctioning sensors.
- Sensor calibration to a common reference.
- Sensor dynamic range (which is slightly variable among them while gathering data but all of them are able to measure between 50 and 100 dBA).

Using data gathered form acoustic sensors that fulfil the aforementioned factors, a regression analysis can be performed, thus calculate the second order polynomial function to all the data measurements. The representation of the noise map in real time can be done using a straightforward web interface.

I.5. Register and analyse noise samples from smartphones

This experiment relies on the usage of a smartphone application which, by activating the microphone of the smartphone, is able to record sound/noise sample during few seconds in a loop (whose periodicity is configurable). The smartphone will be attached to the Com4Innov core network through a link which will be used to track the activity monitored by the microphone. This experiment is in the domain of the crowdsourcing applications/experiments. The objective of this experiment would be to get a large dataset of samples through crowdsourcing as well as to perform modelling of signatures of «noise ambiance».

Regarding the current status of this potential experiment, INRIA has started an experiment with volunteers, who use the application in their smartphones (SoundCity app) and provide noise data.

Com4Innov is proposing to include the service on the Operator grade network and to retrieve data from the Subscriber Identity Module (SIM) card of the subscriber on Com4Innov network. An advantage of this experiment is that there is no need of using supplementary sensors or devices, as this role is already taken by Com4Innov subscribers' smartphones.

I.6. Exploit the sensing capabilities of smart vehicles

At the time a car has sensing capabilities, we can leverage the information gathered from its sensors for e.g. assisting drivers or providing a better experience. Focusing on the research realm, this could be exploited for experimental issues; for this particular trial, two aspects stand out above the rest:

- GPS will become mandatory by safety regulation
- The 4G/5G network will support the 112 Emergency calls as a standalone service.

The objective of this experiment is to gather values of external temperature, speed, wipers activity, airbags trigger and localization from vehicles equipped with such sensors. With all this data, the experiment aims at providing a precise map from the embedded resources present in the cars (e.g. frost, rain, traffic jam, accidents, etc.). Regarding the current status of this potential experiment the cities, the municipalities and the motorway companies can implement a service to alert citizens upon severe meteorological conditions without installing a new infrastructure from sensors. The ambulance or assistance can be alerted on real time.

I.7. Provide real time traffic situation and traffic jam alert

The main goal of this experiment is to collect speed indication from a car correlated with GPS tracking. The objective is to propose a Waze-like[7] application automatically updated; i.e. without a direct contribution from the driver, the application is smart enough to draw conclusions and to have results, by only taking into account the measurements (e.g. velocity and GPS location). The experiment will use that application which will be able to get speed and localization from vehicle equipped with such sensors and then it can make a correlation of them and finally come up with some results. It is a citizen-friendly application. The goal of the experiment will be to implement a service to guide drivers through the mode fluid traffic or to provide time slot when the probability of coming across a traffic jam is lower.

I.8. Energy savings by adaptive operation of 4G/5G Network

The context of this potential experiment is that the present networks' antennas are always "ON", waiting for a subscriber's call and, thanks to the interconnection of Com4Innov's core network, a new and smarter system, carried out by means of the installation of smalls cells, will bring the possibility of switching on and off these antennae on demand. In that context we could track subscribers so as to estimate their movements (e.g. logging their handover between different cells/antennas) or get the number of subscribers attached to each antenna (statistical purposes). Also, in order to improve the performance of the network, there is the possibility to check the QoS (Quality of Service) on neighbors' antennas. Regarding the status of this experiment the necessary 4G features that are needed in order to accomplish this experiment are still on development. The standardization body (i.e. 3rd Generation Partnership Project - 3GPP) is taking into account this service and the requirements for this effort will be probably released before end of 2016. Hopefully, test and evaluation will be available during 2017, through a preliminary 5G release.

I.9. SIMless subscriber identification

Historically speaking, a subscriber in a telecommunications network is authenticated by a SIM card. Nowadays, these people are searching a solution that allows them to share a common service in multiple devices with a single card. To tackle this issue, Com4Innov proposes an experiment in which, by using a (Bluetooth/NFC) wristlet containing personal authentication to transport the contents from one device (with SIM card) to any other device (without SIM card).

This "multi-device" technology will rely on an Over The Air (OTA) architecture in order to validate the connectivity of each device. Regarding the status of this experiment, current 4G technologies limit the number of attempts that is already implemented, but with the deployment of the 5G networks there will be a simplification.

[7] https://www.waze.com/

I.10. Integrity of Data with security mechanisms (Transport layer)

The remote data collection is now entering into a mass market. IoT protocols normally use simplified security mechanisms which are neither powerful nor reliable enough to encrypt the data in 100% secure way. Hackers have already launched attacks to corrupt these kinds of data. In this direction people would accept to pay per use if the value of the measurements can be guaranteed over an end-to-end transmission. The objective of this potential experiment running in the Com4Innov IoT platform is to insert "marking technics" inside the binary code of the data in order to protect the integrity of the data. This is possible when using the Transport layer of the telecom network. The status for this experiment is that Com4Innov participates into Work Group "IoT Security" with Pole SCS in PACA (Provence-Alpes-Cote d'Azur) region in order to provide secured data transmission through network (from sensors up to APIs).

I.11. Bidirectional remote control of Things

The overall context of this potential experiment that could run in the Com4Innov IoT platform is that there could be a possibility of controlling remotely operations such as the acquisition of data and actuation over devices in real time. The goal is to control systems like autonomous cars, machinery like robots etc. The 4G has already relevant characteristics to demonstrate the feasibility but also limitations refraining to deploy thousands of Things. The objective of this experiment is to use the 5G improvement such as latency, guarantee of service and narrow band management in order to expand the usage.

As far as the status of this experiment is concerned, the NB-IOT will be specified in the release 13 of the 3GPP, which is expected by the end of 2016 and the pre-commercial experimentation possible during the year 2017. Also, Com4Innov is participating to the 5G-PPP TA called MTC.

I.12. Data selection from users' preferences in a Smartcity

This experiment is addressed to the smart city domain and aims at evaluating the data discovery and retrieval processes, which can be tailored according to experimenters' preferences. This data is provided from a smart street lighting system, which consists in a set of physical streetlamps, vibration sensors, and noise measuring sensors.

Upon the reception of a query, the core framework parses the content of the request, i.e. abstracting the data type, user preferences (i.e. discovery conditions) if any, and then execute the experiment processing functions. Finally, FIESTA-IoT platform returns the response back to the experimenters. The data domain and experimenters' preferences are the key points that need to be checked in the experiment processing result. If the result contains traffic data attached with as same timestamp also the location information as experimenters requested, then this experiment is validated, otherwise the execution of the current experiment is seen as a failure.

I.13. Secure parking manager with access control policies

The experiment is designed to evaluate that the authenticated access to the data located at registered testbeds has to be guaranteed from FIESTA-IoT platform and from testbed providers themselves.

The data is generated from the smart parking system, where a number of car detection sensors are deployed inside the Parking lot to detect the in and out of cars passing the cars.

Authenticated experimenters can receive data from testbed providers through FIESTA-IoT platform even though experimenters do not need to have knowledge upon the testbeds. Otherwise, the data sent back to the experimenters is not complete i.e. FIESTA-IoT platform might fail to retrieve some data from specific testbeds, which are supposed to provide data to the experimenter, resulted from unauthenticated user status.

The experimenters send request to FIESTA-IoT platform for specific data, but the FIESTA-IoT platform finally sends an error message indicating the current experimenters' access control policies have expired. In this case, a help message including the method to extend the access control policies should be send back to the experiment together with the error message.

Experimenters send messages to FIESTA-IoT platform for requesting data of their interest, and the FIESTA-IoT platform will process their request and returns the result to the experimenter after collecting all the required data from registered testbeds. FIESTA-IoT platform provides authentication mechanism to ensure each testbed only can be accessed by authenticated experimenters. Even though the experimenters do not have to communicate directly with registered testbeds, the experimenters somehow have to gain the credentials and the credentials are supposed to allow the experimenters to access all the data that are published and exposed to experimenters by all registered testbeds.

When experimenters have no credentials to access some registered testbeds, the FIESTA-IoT platform cannot provide the data originated from these testbeds to the experimenters. Suppose there are experimenters who are never get credentials from KETI testbed. Having these experimenters sent message to request KETI testbed data, if error messages like "NO PERMISSION" are alerted, the objective of "access control policies are utilized to guarantee only can authenticated users access to testbed including the resources" will be validated.

For those who gained credentials ever but the credentials are expired, in addition to the error messages indicating "NO PERMISSION", the credential extension interface might be activated if experimenters agree to extend their credentials for KETI testbed access. The objective of "KETI testbed should be able to manage the access control policies for experimenters" will be validated

I.14. Data consistency evaluator for a smart pilot system

The experiment is designed to evaluate data consistency between testbed and FIESTA-IoT meta-cloud. When the testbed providers add new devices into their testbeds, or the semantic resources are updated, the relevant data related to the added devices or semantic resources should be simultaneously added or updated in the FIESTA-IoT meta-repository in order to keep the data in the meta-repository consistent with that of testbeds.

The experiment allows to access to data generated from the Smart Pilot system. The Smart Pilot system aims to monitor the seashore for security and send the recorded video to the multimedia server for storage and analysis. If emergency accidents are monitored, the drone can send alerts calls to marine police office so that the marine police forces nearby can join for the rescue.

In the current smart pilot system, a few number of drones have been already deployed in the KETI testbed and we assume the metadata about these drones have stored in FIESTA-IoT meta-repository. In case that there are several new drones need to be deployed in the KETI testbed. These new drone devices have to firstly registered with KETI testbed and then add all information about the new drones including semantic descriptions into FIESTA meta-repository through an interface provided by FIESTA-IoT platform. The experimenters could discovery the new added drones and request data generated from these new added drones.

The FIESTA-IoT platform should allow the testbed providers to manage the data associated with physical devices (i.e. create, retrieve, update, and delete) and reflect the changes to the data in the FIESTA-IoT meta-repository. If this is the case, the testbed providers may update the semantic descriptions of drones, e.g. update the ontology references. From experimenters' perspective, these changes should be as visible as possible once these submitted changes are verified by FIESTA-IoT administrator somehow.

When testbed providers successfully add new devices to their testbed and add the metadata related to the new added devices in the meta-repository, experimenters can send a request to discovery the latest added devices and the data generated from these new added devices. If the information of these new added devices is correctly returned, the objective of "new added devices should be able to easily integrated into fiesta meta-cloud" will be evaluated.

I.15. Semantic reasoning over a smart energy saver framework

This experiment is designed to evaluate the device actuation based on semantic reasoning. It will run on the smart mart management system, which consists of multiple sensors e.g. temperature, electricity, cam sensors, and gateway.

The smart mart management system is suitable for large-scale supermarkets, especially with many chain stores. In this case, all the chain stores are monitored and managed in real-time manner together and the collected data is analysed.

The experimental data including CO_2, humidity, temperature of inside supermarket is collected and analysed as a basis input to smart energy saver system. In the cases

that the experimental data exceeds the pre-specified threshold value, the smart energy saver system is actuated to motivate corresponding devices to reduce the energy consumption.

When the experiment is executed in FIESTA-IoT platform, the experimental data is inputted to FIESTA meta-cloud for processing, if there are parameters with abnormal values, the FIESTA meta-cloud would trigger the devices registered in the KETI testbeds. All the experimental data and trigger actions are conducted automatically and intelligently by devices.

In case of new devices are deployed into KETI testbed, the semantic information about the new added devices will be updated simultaneously in the meta-repository of FIESTA-IoT platform so that the new added devices and the resources associated with them can be discovered and retrieved. These new devices will be automatically integrated into smart actuation system.

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