Exploiting Aggregated Open Data from Smart Cities for the Future Internet Society

D2.2: Architecture and design of the SMART-FI platform

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Abstract	This document describes the architecture, which will integrate the requirements, functionalities and the developed services, and align a common platform for the integration of the FIWARE architecture.
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V1	27/04/17	Final version	Malena Donato(ATOS)

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Terms and abbreviations

WP	Work Package
MX	Month X
DX	Deliverable X
UC	Use Case
APP	Application
IoT	Internet of Things
IT	Information Technology
MiDAS	Micro Data Analytic Services
ESB	Enterprise Service Bus
EU	European Union
GE	Generic Enablers
QoS	Quality of Services
SLA	Service Level Agreement
URI	Uniform Resource Identifier
COSMOS	FIWARE Generic Enabler
IDM	FIWARE Generic Enabler

Executive Summary

In this document, we will provide the architecture, which will integrate the requirements, functionalities and the developed services, and align a common platform for the integration of the FIWARE architecture.

It contains the architecture and design for the SMART-FI platform, as outcome from Task 2.2, and connecting all the functionalities and tools developed in WP3, WP4 and WP5.

This architecture will provide a common framework that allows the integration of different services in a uniform manner.

The aim is to integrate different heterogeneous services into a unified and homogeneous platform, allowing for a sustainable and exploitable environment. Hence, it is the glue that integrates all the components with the FIWARE platform and provides useful solution to the case studies and the stakeholders (application developers, service providers, data system administrators, citizens and municipalities).

1 Introduction

This document presents the SMART-FI architecture, by describing the main components and functionalities of the platform. The architecture which will integrate the requirements, functionalities and developed services, and will combine with the FIWARE architecture.

1.1 Document structure

In Section 2, we describe the SMART-FI architecture, firstly the approach and facilities, and secondly the platform architecture itself. Section 3 presents the components and mechanisms in deep. In Section 4, it is introduced an initial mapping between the functionalities developed in SMART-FI and the ones used in the use cases. Finally, we conclude the document in Section 5.

2 SMART-FI Architecture

In this section, we describe the intermediate architecture and design of the SMART-FI platform, considering we will continue working of the technical aspects and possible modifications will be included in a final document to obtain the final architecture.

2.1 The SMART-FI Approach and Facilities

The SMART-FI approach is expected to help deploying and interconnecting services using real data from diverse sources, mainly from public administrations, but also from other third-party services or devices.

The aim is to provide services on top of FIWARE, a standard open IoT platform recognized at EU level, that facilitates the development of smart applications and with an environment where cities can publish their open data.

Therefore, SMART-FI main goal is to provide a novel Smart City platform and a set of facilities to deploy and interoperate services by exploiting aggregated open data from smart cities.

The project will provide methodologies to homogenize heterogeneous open data and data services, perform analysis and aggregation of data analytics services to predict patterns and make recommendations, as well as to facilitate services deployment.

In this sense, the three main components with the corresponding functionalities in the SMART-FI platform are the following (more details about the components and functionalities/facilities can be found in Deliverable D2.1 [1]):

1. **Data normalization in Smart Cities.**
   Functionality: Homogenization of heterogeneous open data and data services.
2. **Data analytics microservices for Smart Cities.**
   Functionality: Aggregation and development of data analytics services for predictions & recommendations.
3. **Services orchestration in Smart Cities.**
   Functionality: Development of methodologies to deploy and interoperate services.

2.2 Platform Architecture Overview

In this section, we present SMART-FI platform architecture overview.

The SMART-FI platform is the central facility of the SMART-FI ecosystem that serves as one of the main building blocks and a cornerstone for developing a sustainable SMART-FI ecosystem. It enables developing, managing and interoperating Smart City data analytics services, in order to facilitate exploiting Smart City open data and optimizing various city sectors, such as transportation, governance services and urban energy.

The main objective of the SMART-FI platform is to allow horizontal integration of open city data and data analytics services by providing a set of generic component and mechanism that will enable development of higher-level, added-value Smart city applications and services.

SMART-FI is focused to provide functionality to different stakeholders, considering the following ones:

- Application developers
- Service providers
- Data system administrators
- Citizens
- Municipalities

The SMART-FI platform is based on the FIWARE infrastructure and it utilizes its several components. However, it goes one step beyond by developing generic components and mechanisms based on microservices technologies, in such a way that other Smart City platforms could seamlessly adapt and incorporate SMART-FI components to suit their needs. Also, the supported facilities could be extended in a future, in a simple way, for instance, in order to include a more complex service for data mining, or for service deployment using cloud providers.

Figure 1 shows the SMART-FI platform architecture overview. The SMART-FI platform follows a layered architecture with the main layers including: i) Data normalization, ii) Data analytics microservices, and iii) Services orchestration.

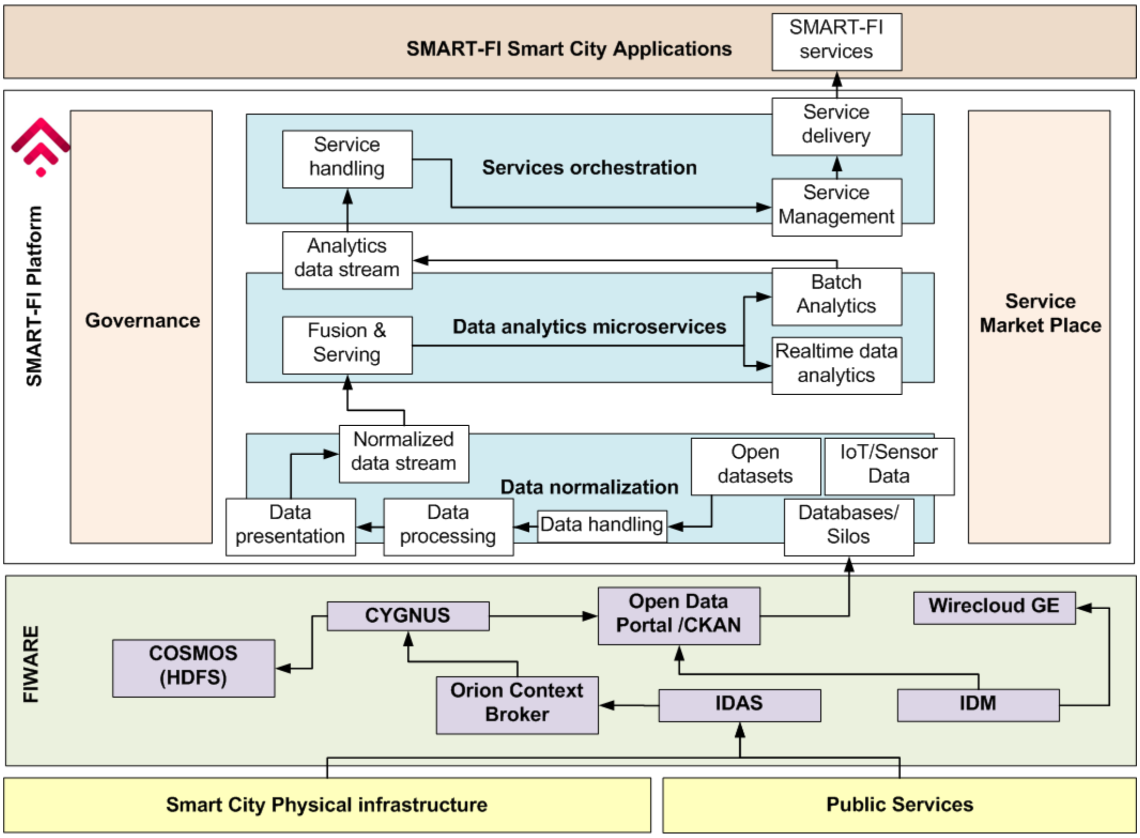

Figure 1. SMART-FI Platform Architecture.

At the physical level, we consider the data sets are coming from different sources, such as public services, devices, and the possible smart physical infrastructure installed in specific cities. FIWARE would be our intermediate piece in order to acquire the data and services. The main FIWARE Generic Enablers (GE) and components are depicted in Figure 1 (they are described in more details in Section 2.3).

At the SMART-FI platform facilities level, three layers represent the main components, as well as a Governance and Service Market Place. Each facility is capable to perform a set of processes to get its main goal. Here we describe briefly the main flow that will be detailed for each component in Section 3.

Heterogeneous data sets will be managed in the Data normalization component. It generates data sets with access rules and a normalized schema, based on urban ontologies, which are stored in semantic data store. Next, these normalized data streams are used by the Data analytics microservices and Service orchestration components. The data analytics services enable the development and management of data analytic services in Smart Cities, providing elastic data analytic services to analyse the aggregated data for predictions and recommendations, as well as developing and managing the called Micro Data Analytic Services (MiDAS). With the Service orchestration facility, mechanisms for deploying and integrating existing or new services and applications will be provided, obtaining more advanced and complex applications (mashups of services) and creating a marketplace that considers the FIWARE Lab and third-party applications.

At the application level, our platform will create SMART-FI services to be used for Smart City Applications.

2.3 FIWARE Platform and SMART-FI Ecosystem

As previously mentioned, SMART-FI will produce a set of facilities aligned to FIWARE platform. As an open source platform, supported by companies, universities and research institutions, the FIWARE platform will play a key role in the cities of the future [2]. Its massive adoption may help to speed up the replication of key components for setting up and consolidating the smart city ecosystem.

The FIWARE cloud and software platform is a good catalyst for an open ecosystem of entrepreneurs aiming at developing state-of-the-art data-driven applications. This ecosystem is formed by application developers, technology and infrastructure providers and entities who aim to leverage the impact of developing new applications based on the data they produce and publish.

In this context cities will play a unique role, especially those implementing Smart City strategy, which open up their data to facilitate the creation of applications built by developers that form part of this ecosystem. FIWARE enables quick and easy application development because they make use of prefabricated components known as generic enablers in its cloud, sharing their own data as well as accessing open data from cities.

In SMART-FI platform will uses several FIWARE generic enablers [3], such as CKAN, COSMOS, IDM, Cygnus and Orion Context Broker. For example, CKAN is intended for data publishers, e.g., national and regional governments, companies and organizations that want to make their data open and available. IDM covers a number of aspects involving users' access to networks, services and applications, including secure and private authentication from users to devices, networks and services, authorization and trust management, user profile management, privacy-preserving disposition of personal data, Single Sign-On (SSO) to service domains and Identity Federation towards applications. IDAS enable connecting IoT devices/gateways to FIWARE-based solutions, by translating IoT-specific protocols into a standardized NGSI context information protocol. Finally, Wirecloud GE builds on cutting-edge end-user development, RIA and semantic technologies in order to offer a next-generation end-user centred web application mashup platform aimed at leveraging the long tail of the Internet of Services.

3 Core platform components and mechanisms

In this section, we describe the main components of the SMART-FI platform, as well as the description of the processes and mechanisms to be developed in each component and their relationships.

3.1 Data normalization in Smart Cities

In order to efficiently create new public services, the vast city data sets should be homogenized and normalized to create urban ontologies where data services will be based on. For this purpose, SMART-FI platform uses Linked Data technologies and the Linked USDL language, in order to give structure and semantics to urban environment and smart city related heterogeneous open data sets and data-as-a-services, generating SPARQL Endpoints. This will enable the development of third-party applications taking advantage of data increasing their exploitation and advanced use by citizens.

Figure 2 shows the general component architecture for the Data Characterization and Normalization process in SMART-FI. Data Characterization provides a concise and succinct summarization of the given collection of data. Generally SMART-FI considers cities data streams including Open Data Portals, Open Data Sets and Services, Internet of Things (IoT) and Sensor data sets and silos of legacy databases as data input streams. The main components of the Data Normalization layer include: i) Data Handling, ii) Data Processing and iii) Data Presentation components.

Next, we discuss the first two components in more details.

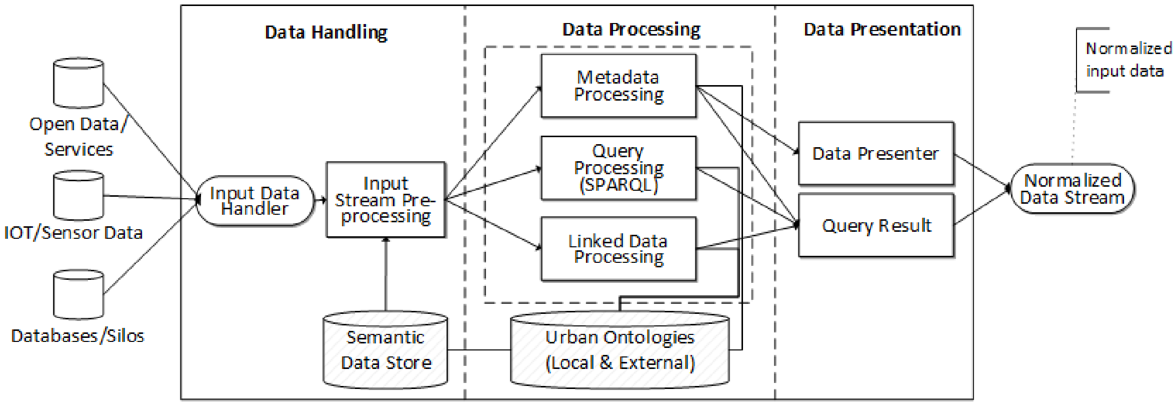

Figure 2. Data Normalization Process.

Data Handling layer will receive heterogeneous data sets via the Input Handler and apply pre-processing to produce a list of data sets with access rules and a schema. The data will reside in semantic data stores. During the data processing period, Metadata processing, SPARQL based Query processing and Linked Open and Linked Sensor Data processing techniques will be applied using several different Urban Ontologies to create Urban Environment Ontology and the Data Presentation layer will provide Data Services to both Analytics components and Service Orchestration components.

Data processing layer will homogenize the data using urban ontology definitions and will provide a uniform data format. SMART-FI Data Normalization components will ease the discovery, the standards based normalized data sharing and reduce redundancy by also adding value to build ecosystems around cities data and contents. This component also includes Linked Data processing capabilities which is one of the best means for publishing and interlinking structured data for access by both humans and machines via the use of the RDF (Resource Description Framework) family of standards for data interchange and SPARQL for query. Here SPARQL-based solutions will be used to facilitate the discovery compared to conventional search mechanisms.

3.2 Data analytics microservices for Smart Cities

Whereas the data normalization resembles the bloodstream of the SMART-FI platform, the data analytics represents its vital organs. Generally, the main purpose of Smart City data analytics services is enabling transforming the city data into disruptive innovation building blocks for the Smart Cities of the future, based on microservices technologies. To this end, this part of the platform provides models and components that allow for developing and managing value-added data analytic services in Smart Cities. Its purpose is twofold: First, it provides advanced models for programming generic, elastic data analytic services, in order to facilitate analyzing the aggregated data for predictions and recommendations. Second, it implements tooling support for developing and managing such Micro Data Analytic Services (MiDAS).

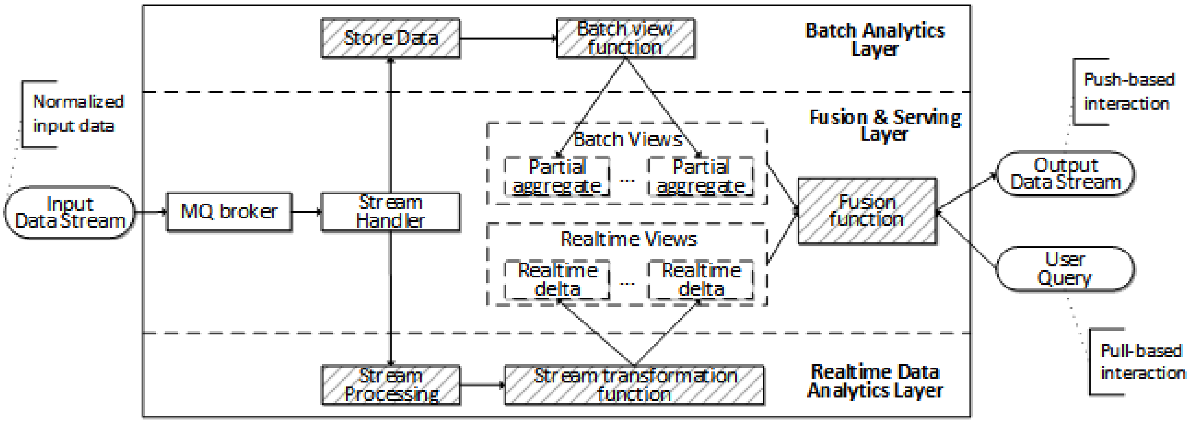

Figure 3. Data Analytics Microservices.

Figure 3, shows the architecture overview of the micro data analytics services that are capable to support both online and offline Smart City data analytics in a uniform way. The overall data analytics architecture of SMART-FI platform is based on the Lambda architecture [4].

It comprises three main layers: Realtime Data Analytic Layer, Batch Analytics Layer and Fusion and Serving Layer. The most important components of the data analytics are the micro data analytics services (depicted as shaded boxes in Figure 3) include:

- Batch view function, used to precompute static (slow-changing) partial aggregate views.
- Stream transformation function, used to compute realtime window deltas (realtime delta views).
- Fusion function, used to combine partial aggregate with realtime delta views and serve the results proactively or on-demand, enabling push or pull based interaction.

Subsequently, we describe these components in more details, mainly focusing on the Realtime Data Analytic Layer. The components depicted as shaded boxes in Figure 3 represent the computed data views. They are not directly exposed to users and serve as inputs to the Fusion functions.

In our platform, we provide a novel model for realtime data analytics, which treats the data streams as first class citizens. In general, there is one-to-one mapping between MiDAS and data streams. A MiDAS is a logical entity identified by an ID (e.g., URI) and its model is characterized by the following main three elements:

- Stream data: the sequence of events that constitutes the stream. Every new event.
- Stream Processing component that triggers the update of the downstream MiDAS, i.e., the streams in a dependent relationship with the current one. The events in a stream can be volatile or temporary stored.
- Stream Transformation function: this is a stateless function defined by the user, which transforms the incoming events in new events, according to the contract definition. The transformation function is automatically managed by the execution environment to support elastic scaling, runtime governance and QoS.
- MiDAS contract: Generally, the contract defines the type of the stream and encapsulates its most important properties, such as operational mode (i.e., window-based, partition-based mode), side effects and SLAs. Therefore, MiDAS contract can be seen as complex data type in a type system, which is related to the data transformation function.

3.3 Service orchestration in Smart Cities

Since it is not possible to predict all the services and application that will emerge in the Smart Cities of the future, cities need an environment that enables innovation and layering of multiple services (data services, analytics services, etc.) on a common infrastructure. This should also allow the introduction of new elements and re-use of existing resources. To ensure the right service is delivered with the right quality and performance to the right users, mechanisms enabling careful planning, orchestration and assurance is required. By facilitating orchestration and integration of different public services, several business and Smart City functionalities, coming from different services, are exposed to the end users as a single service endpoint or as a comprehensive Smart City application.

To this end, SMART-FI platform provides methods and tools for deploying and integrating existing or new services and applications, for producing more advanced applications with the composition and orchestration of simpler ones (mashups of services). In order to provide assurance, SMART-FI also aims to create a marketplace that will be generated or enriched considering the Store in FIWARE and third-party applications giving value to the public data.

For this purpose, SMART-FI platform provides model-based techniques to facilitate the interoperability among applications and methodologies for orchestration and adaptation to create an integrated service development, implementation, deployment and management framework to ensure the governance on the creation and operation of services and their testing procedures.

SMART-FI will also support: i) discovery of added-value combinations of service components and automatically composing and refining these to the needs of the user, ii) delivery of these composed services at the right time and right place across different platforms and devices in a qualitative and dependable way, and iii) use of rigorous and lightweight model-based techniques to facilitate interoperability among applications running in an isolated based on orchestration and adaptation methodologies.

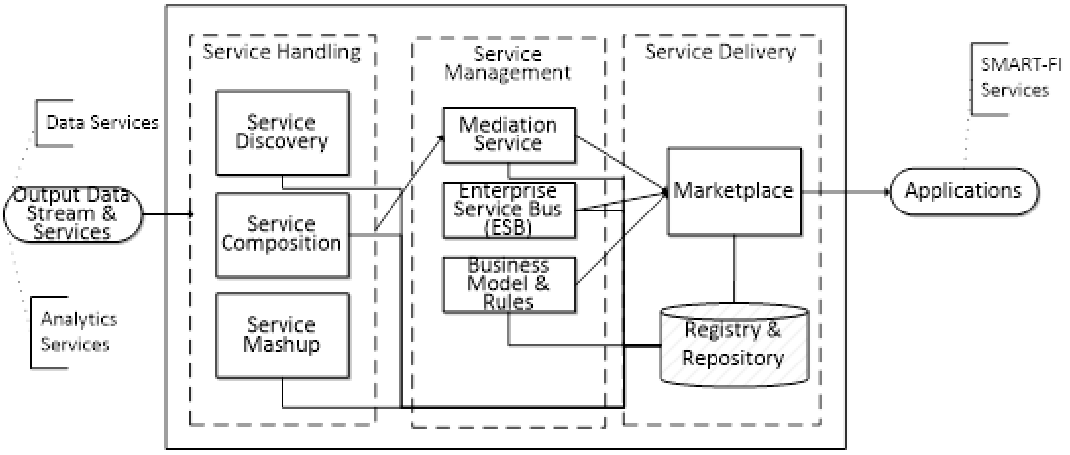

Figure 4. Service Orchestration.

Figure 4 shows the basic architecture of service orchestration in SMART-FI platform. It has three different layers when enabling different set of data and analytics services to be provided for the use of smart city based applications. Service Handling is responsible for handling output data stream and services that may come from normalized data services or data analytic services. It comprises different characteristics of Service Discovery, Service Composition and Service Mashup delivery. Service Management is responsible for the mediation of services, business rules and Enterprise Service Bus (ESB) management. The Mediation Service here is a middleware component responsible for providing interoperability among different communication protocols and among different data models. For the effective Service Delivery all services are combined in the Registry and Repository. Composed and integrated services are delivered to the application layer through the Marketplace component.

SMART-FI platform offers generative techniques based on integration services to make them pervasive and transparent to the user. Based on intuitive natural-language queries and user profile, mechanisms will infer the requirements and preferences and discover services to provide the desired functionality. Services will be automatically

orchestrated on-demand to fulfil functional and QoS requirements. Mashups will be performed by users of the platform using the provided service orchestration and mediation capabilities.
Service orchestration and exposure process is going to be achieved with the usage of Enterprise Service Bus (ESB) services. ESB service designers will be used to ease the life of smart city professionals to manage two service endpoints and transform the result into a new data or service. Mediator and sequence based components will used for message mediation and flow construction and holding and transferring the series of mediators respectively.

4 Mapping with Use Cases

SMART-FI provides a platform to manage the varying density of data in devices and services using them and solving their interoperability, with the three facilities detailed in previous sections (listed in

Table 1. SMART-FI facilities matching with the Use Cases.

).

The next table summarizes the contribution we expect from the SMART-FI tools to the development of the different use cases to validate the proposal, with the explanation connected with deliverable D6.2 Pilot implementation plan [4]. The functionalities offered by the Use Cases are characterized by grades in a 1 to 5 scale (1 = less important to 5 = very important) concerning the level of the importance of the development of the functionalities.

SMART-FI basic Facilities / Functionalities	**Malaga Use Case Transport**	**Malatya Use Case Governance**	**Karlshamn Use Case 1 Transport**	**Karlshamn Use Case 2 Energy**
Data normalization: Homogenization of heterogeneous open data and data services.	**[Grade=4]** - Bus locations from Malaga Municipality as open data - Parking area information from Malaga Municipality as open data - Bicycle stations data from Malaga Municipality as open data	**[Grade=4]** - Search for POI - Search for governance services	**[Grade=4]** - Bus locations from Blekingetrafiken as open data - Static data from Blekingetrafiken as open data - Publish bus data from Blekingetrafken - Publish static data from	**[Grade=3]** - Energy consumption as open data via Raybased - Static data as open data via Raybased - Publish real time building data from Raybased - Publish static

	- Browse transportation options (real time and static) for Malaga city		Blekingetrafiken - Classify data from Blekingetrafiken - Bus locations on a map, web - Bus locations on a map, mobile app	building data from Raybased - Classify data from Raybased
Data analytics: Aggregation and development of data analytics services for predictions & recommendations.	**[Grade=4]** - Check weather forecast - Provide recommendations to the citizens - Provide stats graphs in web dashboard	**[Grade=3]** - Evaluate feedbacks	**[Grade=4]** - Bus flow assistance - Bus arrival prediction - Bus departure assistance	**[Grade=2]** - Energy consumption as open data via Raybased? - Building control as open interface via Raybased? - Visualization of energy consumtion, web - Workplace Assistant - Building alarms
Services orchestration: Development of methodologies to deploy and interoperate services.	**[Grade=3]** - Browse transportation options (real time and static) for Malaga city - Provide cultural events information	**[Grade=3]** - Feedback - Integration	**[Grade=3]** - Mashup for Blekingetrafiken - Bus departure assistance	**[Grade=3]** - Publish building control interface to Raybased installation - Visualization of energy consumtion, web - Workplace Assistant - Visualization of energy consumption,

				mobile app

Table 1. SMART-FI facilities matching with the Use Cases.

5 Conclusions

This document describes the intermediate architecture and design of the SMART-FI platform. Thus, the platform provides the architecture, which will integrate the requirements, functionalities and the developed services, and align a common platform for the integration of the FIWARE architecture.

We have described along this deliverable, the platform, the components, functionalities, and the FIWARE components used in SMART-FI.

6 References

- [1] SMART-FI Consortium. Deliverable 2.1: Requirements for the SMART-FI platform v1.
- [2] FIWARE Smart Cities. https://www.fiware.org/tag/smart-cities/
- [3] FIWARE Genering Enablers. https://catalogue.fiware.org/enablers
- [4] SMART-FI Consortium. Deliverable 6.2: Pilot implementation plan.
- FIWARE Consortium. Lambda Architecture
- http://lambda-architecture.net/}} https://catalogue.fiware.org/enablers

Annex I: Glossary Terms used in SMART-FI

https://docs.google.com/document/d/1nTYBqkbW5BYtpGw8C-KVKZ6YH3WZVxhL6R9Rl05kwPE/edit