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Experiments and evaluation

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Abstract: this document reports the Domain Specific Enablers that have been selected by the different scenario work packages after the feasibility study done in work package 8 of the project and the needed preparations and plans for their experimentation. The purpose is to have a clear idea of the scenarios and test used to perform the laboratory experiments of the domain specific enablers.

Keyword list: FI-PPP, FINSENY, Experimentation Lab, Common Framework, Evaluation Methodology, Feasibility, Relevance, Practicability, Domain Specific Enablers, Experimentation

Disclaimer:

N/A

Executive Summary

FINSENY emphasizes the necessity of a first level of experimentation of the domain specific enablers defined in the different scenario work packages before starting early trials in phase II. This early experimentation would impact in a more successful trial in phase II.

This first stage of the experimentation is defined and developed in work package 8 of the project, starting by the definition and selection of the main Domain Specific Enablers (DSEs) in the different areas where FINSENY is focused.
These DSEs have been selected by task T8.2 according the feasibility study done in the task. Finally one DSE per scenario work package has been selected for this early experimentation based on criteria of feasibility by answering 12 basic questions and a TELOS evaluation as explained in chapter 4. The list of selected DSEs is:

- Gateway for Secondary Substations using S3C General Enabler (GE): for WP2 – Distribution Network. The gateway consists of existing standard solutions (TCP/UDP/IP stack), GEs (S3C), and DSE's (IEC 60870-104). The experimentation (Aachen RTWH) consists of simulated devices and emulated connections (e.g. parameters according to an LTE network).
- IEC 61850 protocol adapter: for WP3 - Regional / Microgrid
- Supervisory Controller as Service: for WP4 – Smart Buildings
- Electric Vehicle Supply Equipment: for WP5 – Electric Mobility
- Demand side management: for WP6 – Electric marketplace for Energy

Through the experimentation in phase I not only the practicability of the existing requirements for the DSEs will be verified but also:

- The scope and content of the existing requirements could be improved.
- Additional requirements could be arise, that could not be obtained by the theoretical approach only.
- Further, the knowledge about the experimentation infrastructure in phase I, would deliver valuable sources for the next phases.

For each of the DSE selected, one or two already existing laboratories have been identified for performing the experimentation, each of one with specific characteristics:

- WP2: Gateway for Secondary Substations using S3C General Enabler. This DSE will be tested and evaluated in the laboratory facilities at RWTH Aachen University: the Automation of Complex Power System (ACS) lab supporting real-time simulation of the power system by using tools like the real-time simulator (RTDS®). ACS will provide a rough impact analysis of communication disturbances in the control loop for energy management. The experiments in the ACS lab will be complemented with the experiments carried out in the Grenoble INP Experiment Laboratory called PREDIS.
- WP3: IEC 61850 protocol adapter DSE will be experimented combined with the WP2 one as the WP2 experimentation is also relevant for the Microgrid scenario. Both WP2 and WP3 DSEs are related to the communications and connectivity and have overlapped requirements. This way a better use of the experimentation resources will be done.
- WP4: Supervisory Controller as Service. This DSE is going to be analysed using two different approaches: one with a simulation framework, MileSENS environment by Orange, and another one using real experimentation data from privates homes involved in the Energy@home project by Telecom Italia.

- WP5: Electric Vehicle Supply Equipment DSE will be experimented in the RWTH Aachen University (ACS lab) as the one for WP2. These simulation capabilities will be used to study and experiment the influence on the power grid of a huge amount of EVs to be charged.
- WP6: Demand side management DSE. The goal of this DSE is to manage the DSM signals from the operator side to the home area network in order to influence the flattening of the demand curve of the energy consumed in some areas. It will be experimented using two facilities: BeyWatch [12] and Energy@home[13]: while Energy@home is mainly focusing on the development of a communication infrastructure that enables provision of Value Added Energy Services in the Home Area Network (HAN), BeyWatch extends the scope from single homes to full neighbourhoods.

For each of these laboratories this document reports the needed preparations, plans, which parts have been simulated or tested in real scenarios, expected results and other useful information for the evaluation of the selected DSE.

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Table of Contents

List of Figures

Index of Tables

1. Glossary and List of Abbreviations

This document uses the list of abbreviations and terms defined in the general FINSENY Glossary and Terms [1]. The terms, which are not included in that glossary, are defined below.

Term	Definition
Enabler	According to [2], an enabler is a functional building block. Any implementation of an enabler is made up of a set of components which together supports a concrete set of functions and provides a concrete set of APIs and interoperable interfaces.
Capability	Capabilities in this deliverable are software artifacts and/or hardware components that provide particular services, capabilities and test facilities. For FINSENY, those capabilities heavily rely on experiences and results obtained in various other national and international research projects such as BeAware, BeyWatch, Energy@home, ESB trials, Smart Wheels, E-Energy. Furthermore smart grid specialised test equipment like the ACS Laboratory Infrastructure are relevant capabilities.
Experimentation Lab	It provides a common framework (in terms of methodology and capabilities) for the evaluation, validation and testing of enablers, which will ensure that enablers emerging from various scenarios can be evaluated through a feasibility analysis (based on common criteria) and also partially tested with respect to their practicability. The Experimentation Lab is composed by the above defined capabilities, which can be properly configured in order to satisfy the specific needs of the various scenarios.

2. Introduction

2.1 FINSENY WP8 Overview

The objective of FINSENY Work package 8 is the investigation of domain specific enablers by experimenting, prototyping, reviewing and the demonstration of their feasibility towards large scale trial as planned in phase II.

The relationship between different tasks in WP8 is shown in the following figure:

- **Task T8.1**: provides the list of experimental labs and intended experiments that will be executed.
- **Task T8.2**: provides the list of DSEs that will be experimented together with the list of ICT specific requirements covered by these DSEs.
- **Task T8.3**: specifies the details on how the selected DSEs are going to be experimented in each of the identified capabilities, defining an experimentation plan.
- **Task T8.4**: will execute the experimentation and will outcome its results.

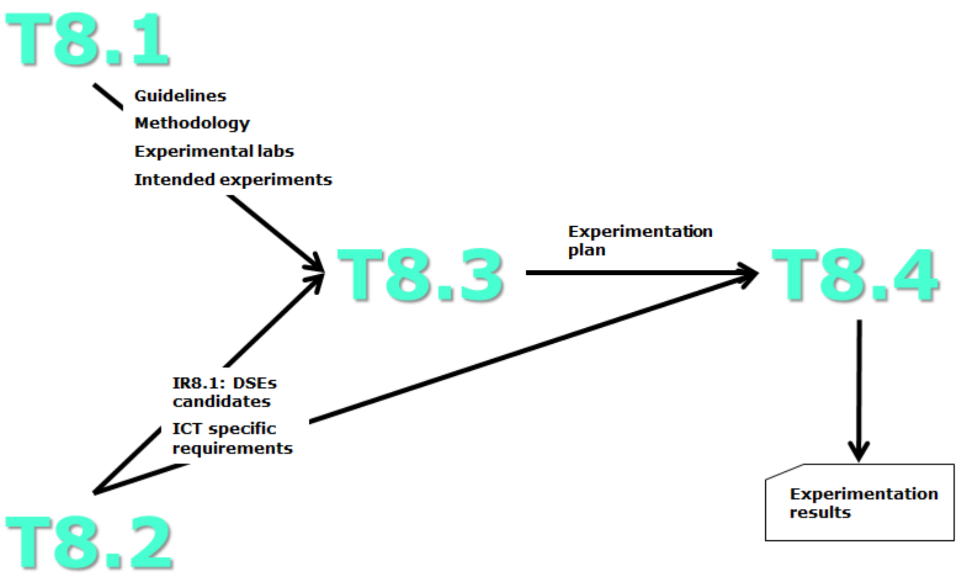

Figure 1: WP8 overview

2.2 Experimentation rationale

Why experimentation in phase I is considered is explained in the following paragraphs.
Looking at the features of all products we facing in our daily live (e.g. cars, ships, computers, smart meters, etc.) the portion of the preproduction requirements make up approximately 10 to 20 percent of the features, the major rest are resulted from experimentation, prototyping and deployment of the products. This awareness emphasizes the necessity of experimentation in phase I.
Starting in phase II with the large trials of the DSEs without having the feasibility analysis and experimentation in FINSENY phase I will impact the success of the phase II project negatively. Thus relaying on the requirements obtained only by the theoretical approach in FINSENY phase I though analysis of smart energy scenarios is not sufficient and experimentation is seen as necessary part of the FINSENY phase I.
Through the experimentation in phase I not only the practicability of the existing requirements for the DSEs will be verified but also:

- The scope and content of the existing requirements could be improved.

- Additional requirements could be arise, that could not be obtained by the theoretical approach only.
- Further, the knowledge about the experimentation infrastructure in phase I, would deliver valuable sources for the next phases.

2.3 Deliverable Scope

The initial purpose of this deliverable was to report the experimentation results of the domain specific enablers' candidates in each of the scenario Work Packages (WP2 to WP6) and outcome new or reviewed requirements that could come up. These evaluation processes have to outcome guidelines that could help scenario work packages refine and consolidate building blocks and guarantee the proper level of quality of phase II trials.
This initial plan changed in a more logical way in order to use the remaining months of the project for experimentations, and the experimentation results will be then shifted to the end of the project.

D8.1 selected some capabilities for performing this evaluation. Each of them provides practical information useful for the evaluation process, complementary to the information reported in D8.1.

This document reports the needed preparations and plans for the evaluation of the test of the selected DSEs of the different scenario work packages. The purpose is to have clear idea of the scenarios used to perform the laboratory experimentation.
In the following table is an overview of the relation between the DSEs and the laboratories where they will be tested.

WP	DSE	Experimentation Labs
WP2	Gateway for Secondary Substations using S3C GE	ACS laboratory and Grenoble INP Lab
WP3	IEC 61850 protocol adapter	ACS laboratory and Grenoble INP Lab
WP4	Supervisory Controller as Service	MileSENS and Energy@home
WP5	Electric Vehicle Supply Equipment	ACS laboratory
WP6	Demand side management	Energy@home and BeyWatch

Table 1: Overview of the Experimentation laboratories for DSE

2.4 Structure of the deliverable

The document is structured in the following chapters:

- Chapter 1: containing the glossary and the list of abbreviations.
- Chapter 2: with the introduction to the deliverable.
- Chapter 3: contains a short description about the practicability study that will be done over the defined DSEs in the different scenario WPs.
- Chapter 4: details the list of DSEs, one per scenario WP, that are going to be experimented.
- Chapter 5: reports the experimentation plans of the selected DSEs in each of the experimentation lab.
- Chapter 6: contains a final conclusion.
- Chapter 7: contains the list of the references used across the deliverable.

3. Practicability study rationale

The evaluation of the practicability of the different DSEs will be done by means of Simulation and Experimentation with real capabilities, which are usual approaches for evaluating behavior and performance of algorithms and modeled systems. The choice between simulation or real capabilities depends on the availability of the existing capabilities to implement the expected functions that support the specific requirements of the scenario. Moreover, each experimentation lab could tests some functions by simulations and others by using real capabilities as reported in the specific sections for each of the experimentation plan in chapter 5.

3.1 Real capabilities experimentation

Real capabilities experimentation has to consider some aspects that are not directly related with the functionality that is going to be tested as:

- Sometimes real systems are deployed in remote or hostile environments; it is often challenging to debug software in the field.
- Peculiarities and problems as latencies caused by page-faults, file handling locks, shared memory issues etc.
- Failures in the ICT systems involved in the experimentation can cause problems or results not directly related with the experimentation itself.

Consequently, the real capabilities that will experiment FINSENY DSEs will take into account the interaction needed with a changing physical environment, time constraints, safety requirements, etc. This way, new requirements, not initially identified, could arise for a better definition of functional blocks and definition of the FINSENY use cases.

3.2 Simulation experimentation

Due to the specific problem of the electrical networks, is not possible to perform experimentations over real infrastructures. So, several facilities provide simulation environments that will be used as the power grid for WP2, WP3 or WP5, building infrastructure for WP4 or home energy systems in WP6.

The common framework for the experimentation based on the simulation of real systems has been already described in detail in deliverable D8.1 [7]. Here, the paragraphs explaining why to use simulation is extracted from it in order to provide a view about what simulation is being considered in this deliverable.

Because the simulator functions in real time, the power system algorithms are calculated quickly enough to continuously produce output conditions that realistically represent conditions in a real network. Real-time simulation has many significant advantages:

- Allows fast, reliable, accurate and cost effective analysis, test and validation of power grid and its components.
- System-failure scenarios and/or physical damage event can be analyzed and detected without affecting the operation and security of the real power grid environment.
- Allows interconnection with real equipment e.g. for control and communication.

Further experimentation could then be planned in real environments, as trials in phase II, but considering the outcomes and new requirements identified during this simulation experimentation.

4. Description of the selected Domain Specific Enablers

This chapter provides details on the selected DSEs. These DSEs have been selected by the task T8.2 for the experimentations in the existing facilities for phase I as reported in D8.1 [7]. This selection is the result of the feasibility study performed by task T8.2 in two steps.
The targets in the first step of the feasibility study were:

- Is the functional specification of the DSE sufficient in this step to propose this DSE for the experimentation in phase I and the implementation in the next phases of FI-PPP projects? Due to the complexity of the scenarios this specification is not considered as the final one. Further steps of experimentations and implementations in the next phases of the FI-PPP projects are seen as necessary evolution path to achieve the final specification.
- Does the DSE cover the most relevant Domain Specific Requirement (DSR) obtained as the result of the investigation in different FINSENY scenario work packages? This is seen as one of the important criteria for the selection of the DSE.

In order to perform the first step of the feasibility a questionnaire, containing the following questions, were prepared and applied by T8.2 on DSEs.

Questions	Explanation
[Q01]	Is the DSE's functionality clearly detailed to ensure its understanding?
[Q02]	Is the DSE located in SGAM space (domain, zone and layer)?
[Q03]	Is the DSE mission critical for the domain (UC WP)?
[Q04]	The DSE has specific services to be provided.
[Q05]	Services are enough detailed by the DSE and/or FI-WARE GE´s to be interfaced and/or Specific services that could be interfaces to other DSE´s
[Q06]	The DSE has detailed data input description available
[Q07]	The DSE has detailed data output description available
[Q08]	The DSE has Standards (security, interoperability, etc.) related to it.
[Q09]	The DSE has the components required for addressing it.
[Q10]	The DSE has data requirements in information layer
[Q11]	The DSE has protocols requirements in communication layer
[Q12]	The DSE has other relevant information available

Table 2: Feasibility study questions

The result of the feasibility study, summarized in the following table (Table 3), provides important criteria why the 5 DSEs are selected for further evaluation and experimentations.

DSE Name	Questionnaire (Y/N)												
	Q01	Q02	Q03	Q04	Q05	Q06	Q07	Q08	Q09	Q10	Q11	Q12	SUM
GATEWAY for Secondary Substations using S3C GE (WP2)	Y	Y	Y	Y	N	Y	Y	Y	Y	N	Y	Y	10
IEC 61850 protocol adapter (WP3)	Y	Y	Y	Y	N	Y	Y	Y	N	Y	Y	Y	10

Supervisory Controller (WP4)	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	Y	Y	11
Electric Vehicle Supply Equipment (EVSE) (WP5)	Y	Y	Y	Y	N	Y	Y	Y	Y	Y	Y	Y	11
Demand Side Manager (DSMgr) (WP6)	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	Y	N	11

Table 3: Results of questionnaire evaluation

Once the questionnaire was finished, T8.2 performed the TELOS methodology on the DSEs as the second step of the feasibility study. The TELOS methodology is usually applied to a project prior to the start of the project. In this methodology the Technical, Economical, Legal, Operational and Scheduling preconditions of a project are evaluated to judge the feasibility of a project. To apply the TELOS methodology on DSEs, T8.2 assumed the selected capabilities in deliverable D8.1 [7] as the implementation platforms for the DSEs. Based on this assumption, the following implementation aspects were estimated for each DSE:

- Which additional hardware extension in the existing capability is required for the implementation of the DSE using this capability still in phase I for the experimentation? The extension is given in percentage of the existing hardware used for the experimentation in phase I.
- Which additional software extension in the existing capability is required for the implementation of the DSE using the existing software still in phase I for the experimentation? The extension is given in units of 1000 coded statements?
- Which man power is required for the hardware and software extension needed for this DSE? This is given in units of person/month.
- Which man power is required for the integration and test for this DSE? This is given in units of person/month.
- Which number of text lines are required for the documentation? This is given in units of 100 lines of text.
- Which man power is required for the documentation of the DSE? This is given in units of person/month.
- What time is needed (scheduling) to get the DSE on the existing capability available (lead-time)? This is given in units of month.
- Is there any legal regulation that would impact the realisation of the DSE?

Based on the results of this estimation, TELOS methodology was applied to each of the DSEs. The results of this methodology for the selected DSEs are detailed below:

DSE Name	WP	Technical	Economic	Legal	Operational	Schedule	Expected Issues
GATEWAY for Secondary Substations using S3C GE	2	Y	Y	Y	Y	Y	
IEC 61850 protocol adapter	3	Y	Y	Y	Y	Y	

Supervisory Controller	4	Y	Y	Y	Y	Y	Potential conflicts with manual control and dedicated control systems
Electric Vehicle Supply Equipment (EVSE)	5	Y	Y	Y	Y	Y	Different metering processes, regulations in different locations
Demand Side Manager (DSMgr)	6	Y	Y	Y	Y	N	

Table 4: Results of TELOS evaluation

The five DSE selected for the experimentations and further evaluation represent all scenario WPs in FINSENY and meet the relevant conditions considered by the feasibility study summarized above.

All DSEs selected by scenario WPs and T8.2 for the experimentations in phase I are seen as feasible for development, larger experimentation and deployment in the next phases of the FI-PPP. Only two of them have some issues related and in both cases the matters identified are related have legal and/or standardization backgrounds.

The selected DSEs are then reported in the following sections. First, a summary of each DSE (DSE template) is reported followed by a more complete description of each of them. The template contains several fields in order to address the challenge of enabling build a common enabler model that delivers semantic consistency of information shared between experimentation across laboratories.

Title	Name of the DSE
Lead partner	Responsible / Contact
Domain	Domains defined in the SGAM Model
Zone	Zone defined in the SGAM Model
Interoperability Layer	Layers defined in the SGAM Model
Entity (S/C) & References	Single o composed functional entity
Description	Short description of the DSE.
Detailed description	Detailed description of the DSE. Must include function and any other relevant information.
Expected inputs	Input data of the DSE
Expected outputs	Output data of the DSE
Interface to other functional entities or GEs	Needed interfaces to others entities or generic enablers of FI-WARE
Standards, encodings, data models & protocols	Used in the DSE
ICT Requirement name	List of generic and specific ICT requirements from deliverable D7.2 [6]

Table 5: DSE template

4.1 DSE WP2: Gateway for Secondary Substations using S3C GE

4.1.1 DSE template

Title	GATEWAY for Secondary Substations using S3C GE
Lead Partner	Timo Kyntäjä (WP2), Jukka Salo (WP8)
Domain	Distribution / DER
Zone	Station / Field
Interoperability Layer	Communication
Entity (S/C) & References	S (Single)
Description	Secondary substations can be identified as aggregation points for all sensors and actuators in the LV and MV network (sensor/actuator network based on PLC technology). XDSL or GPRS routers have been deployed in several secondary substations for communication with the central operation centre. This Domain Specific Enabler will develop a gateway fulfilling all xDSL/GPRS routers' current requirements, and adapting it for FTTH/LTE interfaces and for the use of S3C GE. The gateway consists of existing standard solutions (TCP/UDP/IP stack), GEs (S3C), and DSE's (IEC 60870-104)
Detailed Description	This gateway should use the S3C GE for an improved use of the public network. It may fulfil ICT requirements identified in WP2, and in concrete those for the MVDAC scenario. This equipment will be installed in all electrical locations, and special environmental conditions and dimensions shall be taken into account. In particular, it should be fed in VDC taking advantage of the already available batteries. The secondary substation is a kind of aggregator element of different services (Telecontrol, PLC Smart Metering aggregation, Safety, Other measures), so this router should manage different virtual networks. This router also will encrypt the communication using IPSEC or a similar method. This router should make it possible for the applications to use a static IP address even if the operator network would deliver only dynamic IP addresses. This kind of gateway could also be installed in a DER element, and the Distribution Company (SCADA) should access to this router through a specific virtual network even if the SIM card or the access has been contracted by a Third party.
Expected inputs	Data to be transferred between a grid control application and the RTUs, which interfaces with the actuators and sensors.
Expected outputs	Data transferred between a grid control application and the RTUs.
Interface to other functional entities or GEs	S3C
Standards, encodings, data model	LTE, FTTH, IEC 60870-104, DLSM COSEM, PLC
ICT Requirement name	Connectivity Infrastructure Interoperability on Communications Technology (CT) layer Connectivity Services Reliability and availability on Communications Technology (CT) layer Quality of Service for Connectivity Packet loss Connectivity Communication Services

	Dedicated or Shared Transport Infrastructure Latency Reliable data transport over heterogeneous networks

Table 6: WP2 DSE template

4.1.2 General Description

The energy supply system needs to evolve into a dynamic system to provide the smart energy infrastructure in the coming years and decades. At the heart of a smart grid is the Distribution System (DS), which is the final stage in the delivery of electricity to end users; A DS carries electricity from the high-voltage transmission system and delivers it to the consumers. It includes medium-voltage power lines, a control centre, substations, a protection scheme and its components, pole-mounted transformers, and a low-voltage grid, among others.

In order to tackle the future challenges of integration of the distributed and intermittent energy generation sources, the active flattening of the demand curve, an electrical vehicle charging infrastructure with its mobile loads, microgrids and customers taking an active role as prosumers, a smart grid DS has to support, among others, the functionalities such as:

- DS-wide monitoring of the grid status.
- Automation of grid operations.
- Automatic detection of fault conditions and restoration.
- Balancing of load / generation including reactive power.
- Efficient and reliable workforce management.
- Improved forecasting for the efficient alignment of the consumption to the generation.

This requires managing and controlling many devices in the smart grid DS, connected components and automation of processes. A variety of communication technologies will be applied in electricity networks, and in addition, participants and their devices need to be interconnected in a distributed way.
For defining the Future Internet ICT architecture for the smart grid Distribution Systems a number of five use cases were developed in the FINSENY WP2.
The selected use cases maximize coverage of critical functional requirements and they go beyond addressing traditional functionality by expanding the view to the field of Advanced Distribution Automation (ADA) and novel load and generation control (e.g. for DER). The selected use cases have been summarized in the following:

- **Medium Voltage Data Acquisition and Control (MVDAC)**: access to real and non-real time information of MV electrical network from the utility control center.
- **Smart Grid Energy Control of Power Inverter (SGEC):** interactions, mechanisms, and interfaces of power inverters.
- **Fault Location, Isolation and Restoration (FLIR)**: all procedures necessary to restore the services after a fault in the DS.
- **Dynamic Control of Active Components (DCAC):** automatic control of distributed active network components on substation level, ensuring stable and energy efficient network operation.

These use cases were the basis for deriving the ICT requirements for the smart grid DSs. The list of requirements was then the basis for identifying the generic and domain-specific enablers, which together build the functional DS ICT architecture.

4.1.2.1 MVDAC architecture and domain specific enablers

Based on the SGAM (Smart Grid Architecture Model) analysis of the use cases the quantitative requirements, critical in evaluating the FI-WARE´s generic enablers and their suitability for the

DS ICT architecture, were identified. They were examined for all interfaces from the following perspectives: # Devices, Payload, Latency, Time stamp resolution, Transmission internal, Redundancy and Response confidence.
In Figure 2, the MVDAC architecture model based on the SGAM domains and zones is presented. The MVDAC scenario covers data acquisition and control of different elements of the MV network (including DERs) from the utility Control Centre. Thus it covers the Distribution and the DER domains. In the Operation zone, a grid operator is in charge of network monitoring and control using a grid control application.
The SCADA front end is responsible for the collection of the time critical information from the Remote Terminal Units (RTUs), which are in charge of interfacing with sensors and actuators in remote locations.
In the Field zone, the complementary SCADA (Supervisory Control and Data Acquisition) protocol termination takes place in the RTUs. RTUs can be installed in secondary substations, reclosers or DERs.

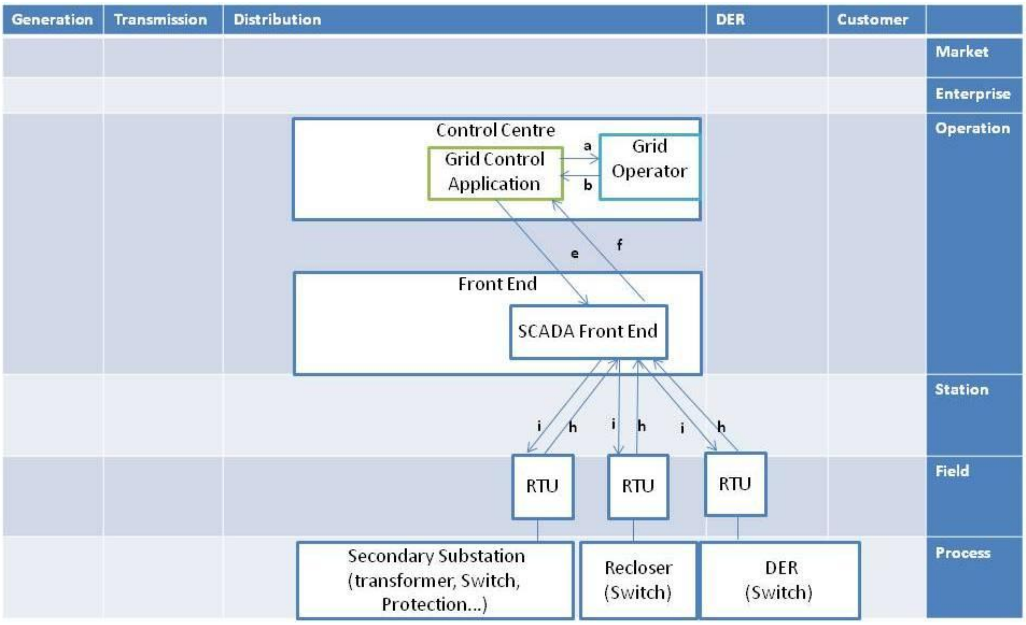

Figure 2: Example of MVDAC Architecture

Figure 3 shows a functional MVDAC architecture based on FI-WARE generic enablers and DS DSE. On the left, the grid control application which interfaces with the SCADA front-end is represented. On the right, the RTU which interfaces with the actuators and sensors is depicted. For communication the standard IEC 60870 [10] is used. IEC 60870 series defines point to point or point to multipoint communication for retrieving or updating electrical time critical information from the terminal locations. The substandard IEC 60870-5-104 defines the communication using TCP/IP.

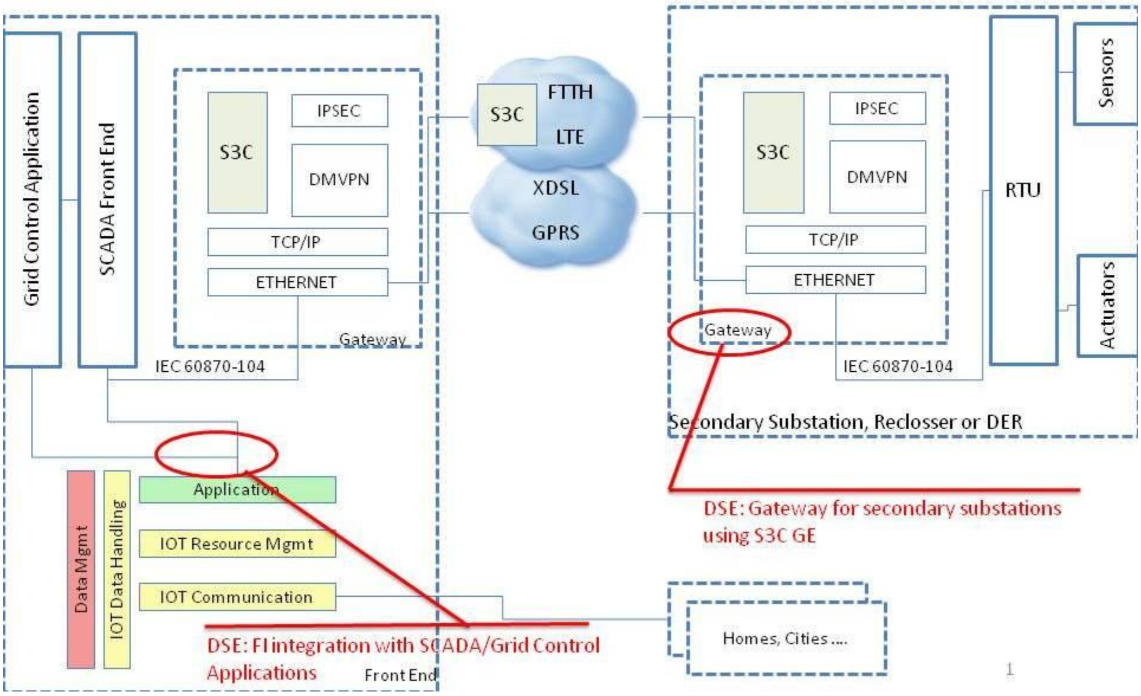

Figure 3: Example MVDAC Architecture with GEs and DSEs

At the RTU level, the generic enabler S3C was proposed to be used. It offers a fine-grained level of control by applications and services on fixed and mobile telecommunications operator networks through an interface to the control plane of the communication layer. One of the examples in which the generic enabler S3C can provide a clear advantage for MVDAC is the redundancy management of the connectivity of one or more operators or technologies. For this scenario a gateway which must meet the environmental requirements for the MVDAC scenario in a secondary substation, and allow S3C interfaces has to be developed as a domain specific enabler. For MVDAC, other generic enablers (IoT, Data management and Application and Services) have been identified to be useful at the Control Centre level.

4.1.3 Supported use cases

Use Case	Short description	Reference	How it is supported
MVDAC, MV Data Acquisition and Control from the utility control Centre	This Use Case covers data acquisition and control of MV network from the utility control centre. Three different categories of data are considered: Real-time information, Non-real-time information, Safety Alarms	D2.1 [3] Distribution Network Building Block, section 5.3	The Network Emulator of the experimentation system is able to emulate the different characteristics of the different communication systems

Table 7: Use cases supported by the DSE

4.2 DSE WP3: IEC 61850 protocol adapter

4.2.1 DSE template

Title	IEC 61850 protocol adapter
Lead partner	WP3
Domain	Distribution & DER & customer
Zone	Operation & Station & Field
Interoperability Layer	Communication/Information
Entity (S/C) & References	S(Single)
Description	IEC 61850 stack implementation (client and server). This stack will be used on Smart Energy Gateways for DERs, Secondary Substations or Home Energy Management Systems as well as in the communication front-end (CFE) of the Microgrid Control Center.
Detailed Description	To guarantee the efficient information exchange throughout a distributed control system common standards are a must. The complexity of the control task requires standardized information models, support for simple and complex data types, meta data and well-designed data repositories and processing units. For these conditions there are only a few standard solutions ready to be used in the near future, especially for devices of "classical" and renewable power generation in the electrical Smart Grid. One of the most prominent future-oriented solutions for electrical grids is the IEC 61850 protocol family. The main advantages of IEC 61850 are: • It uses the strengths of the OSI 7 layer communication model; • It standardizes data models for electrical applications; • It defines Data Types and Communication Services; • It models devices, functions, processes and architectures; • It describes the engineering and configuration Process; • It provides examples of typical applications in electrical substations; • The data is organized in devices in a standardized way; • The devices are "self-descriptive", either online (e.g. MMS protocol) or offline (SCL language); • IEDs not only provide the data itself but also the information about data types used, its structure and complete naming; • IEC 61850 supports application-oriented architectures by introducing meaningful semantics; • IEC 61850 defines application specific data like PTOC (Protection Time Overcurrent) logical node or XCBR (Circuit Breaker) logical node, etc.
Expected inputs	IEC61850 information to be translated into internal data format, internal data to be translated into IEC61850 information
Expected outputs	IEC61850 information translated into internal data format, internal data translated into IEC61850 information
Interface to other functional entities or GEs	IoT

Standards, encodings, data model	IEC 61850, TCP/IP
ICT Requirement name	Communication Services Creation of data set Request/Response for data set Publish/Subscribe for data set Set configuration Create control set Operate Select before operate

Table 8: WP3 DSE template

4.2.2 General Description

IEC 61850 protocol adapter DSE refers to an IEC 61850 stack implementation (client and server). This stack will be used on Smart Energy Gateways for DERs, Secondary Substations or Home Energy Management Systems as well as in the CFE (Communication Front End) of the Microgrid Control Centre.
In the current functional architecture of the Microgrid Control Center (MGCC) following communication components are distinguished (see deliverable D3.2 [3]):

Component	Description
Communication Front End for Network Devices	This component realizes the communication to the network smart devices, i.e. an intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches). In this component different communication protocol adapters might be supported to ensure flexibility and compatibility with respect to different standards (e.g. IEC 61850, IEC 60870-5-101/104).
Communication Front End for Prosumer Devices	This component realizes the communication to the devices owned and operated by a third party, e.g. a prosumer. These devices include DER and storage units as well as Home/Building Energy Management Systems (BEMS). Also in this component different communication protocol adapters are realized and supporting the same or similar standards as for network devices. Because these devices are not owned and operated by the Microgrid Operator communication is managed in a separate component.

Table 9: Communication components for WP3 DSE

These components will allow exposing interfaces towards external end-points defined as follows:

Interface	MGCC end-point	External end-point
IF2	Communication Front End for Network Devices	Network Smart Devices - An intelligent electrical device in the Microgrid that can be supervised and controlled (e.g. sensors, circuit-breakers or switches).
IF3	Communication Front End for Prosumer Devices	Devices operated and owned by third parties, e.g. the prosumer including DER and storage units and Home/Building Energy Management Units.

Table 10: Interfaces for WP3 DSE

The IEC 61850 standard describes complete communication architecture in Electrical Power Systems for the design of electrical substation automation. The International Electro-technical Commission's (IEC) Technical Committee 57 (TC57) is working on the definition of IEC 61850.

4.2.3 IEC 61850 Data Models

IEC 61850 uses a hierarchical model for modeling energy devices; primary process objects as well as protection and control functionality in the substation are modeled into different standard logical nodes which can be grouped under different logical devices.
The standard contains the following components:

- A Server, providing the communication access to an energy device. Certain communication parameters are assigned to an energy device, for instance an IP address and a port number.
- A server can comprise several Logical Devices offering a logical view on a device or device part. So you could define a Logical Device for a controllable load.
- A Logical Device consists of a number of Logical Nodes describing partial aspects of a device (e.g. motor, measurement device, control system of the device). Logical Nodes are defined in IEC 61850 by name and contents.
- A Logical Node is composed of a number of data values described by defined Data Classes providing certain values of the Logical Nodes. There are four types of data:
  - Status Information. These are data describing the state of a Logical Node, e.g. whether a device is switched on or off, or characteristic properties of a device like the maximal generated power of a generator. Status information is “read only”.
  - Settings. These are changeable configuration values, e.g. the target value of the power of a controllable load.
  - Measurement Values. These are values of actual measurements, for instance the immediate temperature of a transformer.
  - Controls. They offer activities on a device, e.g. to switch on or off a device.
- Data Classes are composed of other Data Classes or of Data Attributes belonging to a defined Data Attribute Type. For instance, a measurement value may consist of a Data Attribute for the value, for the unit and for the time stamp. The common data classes (CDCs) are described in IEC 61850-7-3; IEC 61850-7-2 defines more abstract data classes for the ACSI service (Abstract Communication Service Interface). Both parts of the standard comprise complex and metadata classes as well and will therefore support all kind of data classes required in FINSENY.
- A Data Attribute Type finally may be a “primitive” data type like an integer or a text string, or it may be composed of other Data Attribute Types, as for instance the Data Attribute Type for a unit may consist of a basis unit and a factor for the magnitude.

4.2.4 IEC 61850 Communication services

The abstract communication service interface (ACSI) of IEC 61850 can be mapped to a number of protocols. Current mappings in the standard are to MMS (Manufacturing Message Specification), GOOSE, SV, and alternatives like Web Services (like in IEC 61400-25-4 for wind turbines) are under discussion. The communication services are based on client-server communication architecture. They use the full services of the OSI model and provide reliable data transfer and information exchange like fault record, event record, measurement values, etc.

IEC 61850 consists of a lot of different parts. Its features include data modeling of primary process objects as well as protection and control functionality in the substation.

4.2.5 Supported use cases

Use Case	Short description	Reference	How it is supported
Balancing supply and demand on different time-scales	Reliable and efficient performance of a Microgrid is based on the central tasks of load balancing and power stabilization. Besides a permanent balance between power generation and consumption electrical stability is mainly handled through voltage and frequency control.	FINSENY/WP3 /CUC-1	It is necessary to receive real-time measurements of all energy generators, consumers and storage devices and perform control operations on energy devices.
Demand-side Management	Demand-side management includes the planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage.	FINSENY/WP3 /CUC-2	It is necessary to receive real-time measurements of all consumers and perform control operations: load shedding, load shifting.
Supply-side Management	Supply-side management includes the planning, implementation, and monitoring of utility activities designed to monitor and control Distributed Energy Resources (DERs).	FINSENY/WP3 /CUC-3	It is necessary to perform monitoring and control of decentralized supply in real-time.
Black Start in Islanding Mode	Black start in islanding mode describes the restoration procedure of the Microgrid after a general system black out.	FINSENY/WP3 /CUC-4	

Table 11: Use cases supported by the DSE

4.3 DSE WP4: Supervisory controller as service

4.3.1 DSE template

Title	Supervisory Controller
Lead partner	Orange
Domain	all
Zone	station & operation
Interoperability Layer	Information
Entity (S/C) & References	S
Description	Supervisory control refers to a lightweight joint control of several individual controlled entities. Its main role is to coordinate all the controlled entities in order to reach or avoid a prescribed joint state of the system comprising these entities. It is designed to be able to adapt itself to changing context and make decisions based on specific inputs and the current states of each controlled entity.

Detailed Description	Supervisory controller is considered as belonging in the service layer because: 1) it is at a level of above entities because it monitors and controls a plurality of entities in the entity layer, 2) it may provide an intermediate layer and common functions to all applications in an upper layer. Just like other normal services, there can be several supervisory controllers for different purposes. The mapping between the supervisory controllers and the entities in the Building Abstraction Layer (BAL) is many to many, which means one entity can be associated with several supervisory controllers and one supervisory controller, will control several entities. Supervisory control in the service level will not replace the more comprehensive and complex dedicated application-specific control being affected by applications in the upper application layer. They are for different purposes and designed in different ways. Supervisory control service is designed in a bottom-up approach, which means it starts from the entity models in the lower level and ends in providing lightweight control functions based on exclusion or sequence criteria, such as general safety and energy-saving constraints., By contrast, application-layer control, adopts rather a top-down approach, which means it aims at some specific goal, such as energy optimization, and should achieves it by taking into account many different criteria between which it seeks to find an optimal tradeoff (such as e.g. carbon footprint, cost, demand-response constraints, etc.). Supervisory control service will provide a basic minimal system control to ensure safety and basic energy-saving that should not conflict with this comprehensive optimization.
Expected inputs	Observed states of controlled entities, e.g. a room being controlled is in an “unoccupied” state.
Expected outputs	Desired states of controlled entities, e.g. a target room should be unheated or unlit, a target appliance should be in standby mode. The corresponding entity proxy relays this state to the required actuators.
Interface to other functional entities or GEs	Receives model description from entity configuration GE
Standards, encodings, data model	IEC CIM (for models of electrical controlled entities)
ICT Requirement name	Supervisory Control (generic) Control Capability Monitoring and Control Services Control Apps Conditional Control

Table 12: WP4 DSE template

4.3.2 General Description

Supervisory control refers to a lightweight joint control of several individual controlled entities. Its main role is to coordinate entities in order to reach or avoid a prescribed joint state of the system comprising these entities. It is designed to be able to adapt itself to changing context and make decisions based on specific inputs, context events and the current states of each controlled entity.

4.3.2.1 Entity Abstraction Layer

In the building or even larger scales of the smart grid, all kinds of electrical equipment and energy-relevant physical entities can get integrated in a local energy management system. These entities may thus be considered to directly or indirectly connected to a perimeter of the grid and they are so numerous and heterogeneous that a complexity explosion would easily come up. We are in urgent need of a method which enables auto-integration of all kinds of entities into the local management system and their self-configuration after the integration.

- **Dynamical creation of proxy for non-ICT entities**: The approach is to dynamically create a proxy or representation ICT component for each individual target physical entity which connects to the physical subsystem through a dynamically configured set of potentially shared sensors and actuators, chosen among those available in the relevant environment. This ontology subsumes several relevant categorizations of the target entities and it is possible that an entity belongs to several of them. It can be useful for finding a model as specific as it can to a detected entity. The following example is about the identification of a washing machine. At the root is the main class Entity, as explained above, according to the data received from sensors and the determination criteria, we may find out that the target entity belongs to several categories and their intersection indicates that this is a washing machine as illustrated in the following figure.

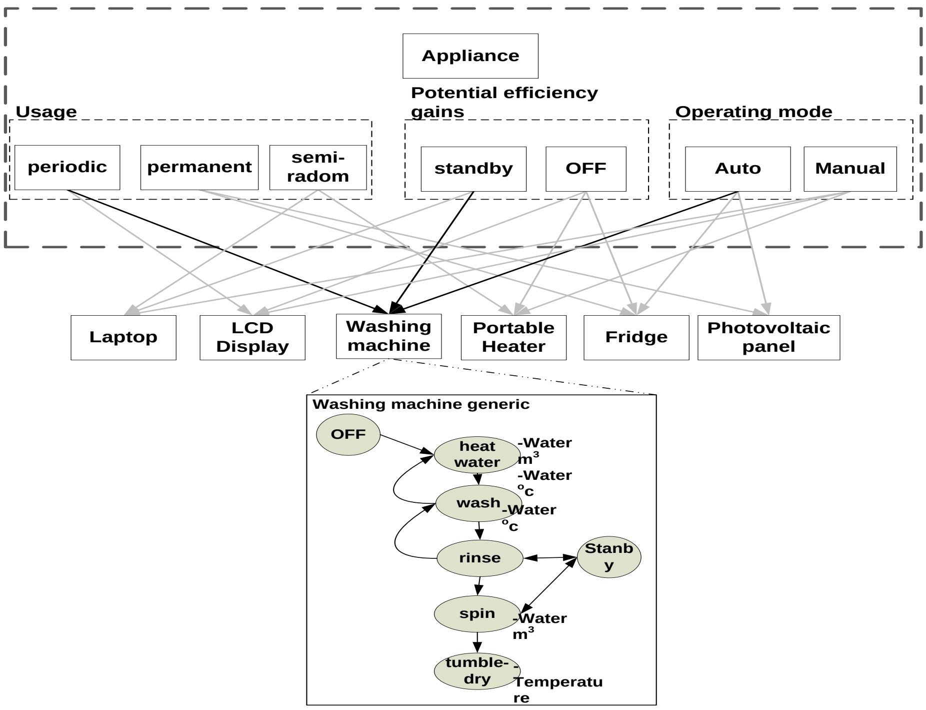

Figure 4: Home entity ontology and corresponding discrete state model example for home appliances

- **Automata models:** The automata to model target entities represent a tradeoff between expressivity and ease of identification. The full description of a physical system such as the target appliance would normally require a continuous-state and continuous-time model, but the automatic identification of the parameters of such models would be impossible.

4.3.3 Supervisory controller

Supervisory controllers are known under the name of SCADA, which has been existing for some decades and play a very important role in automatic and control system. They monitor on system's behaviour by data coming from sensors and control it by giving orders to actuators.
As the control interface is directly lying on the sensor and actuator device layer, it cannot benefit from the auto-integration and auto-configuration functionalities provided by the entity abstraction layer which lies on the sensor and actuator device layer as well.
WP4 proposes thus here a new supervisory controller considered as a component in the service layer just above the abstraction layer, where it controls only the abstract entities identified which shadow the sensor and actuator devices. Additionally, it will act as an intermediate between entities and applications by providing common functions to applications in the upper layer.
Just like other normal services, there can be several supervisory controllers for different purposes, e.g. building security, comfort, energy consumption optimization. Each of them can work independently or cooperate together. Therefore, a modular concept will be interesting in supervisory controller design in order to reduce the complexity and improve maintainability.

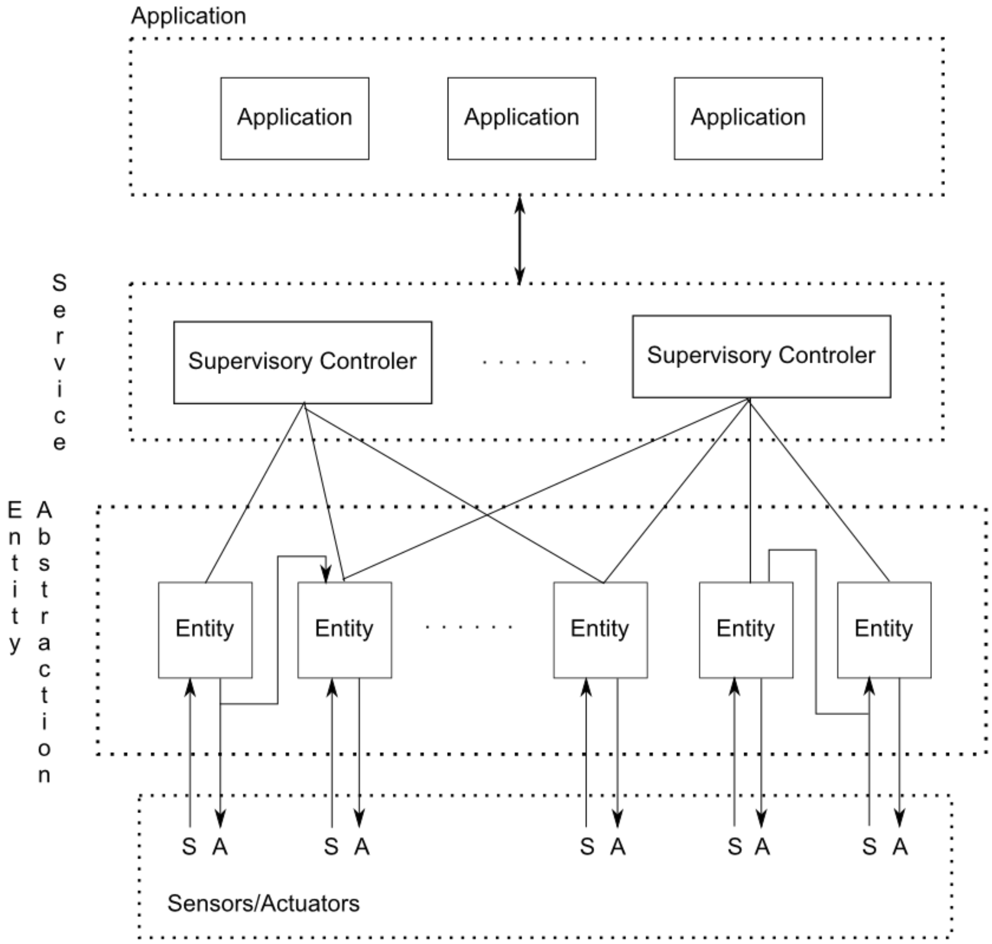

Figure 5: Supervisory control in service layer

Supervisory control in the service layer will not replace the more comprehensive and complex dedicated application-specific control being affected by applications in the upper application layer. They are for different purposes and designed by different approaches. Supervisory control is designed in bottom-up approach, which means it starts from the entity models in the lower level and ends in providing lightweight control functions based on exclusion or sequence criteria, such as general safety and energy-saving constraints.

4.3.4 Experimentation by simulation

Before deployment of new equipment and software systems in a real-world building environment, a simulation purely software is essential to validate the system to be implemented. Domain specific enablers among whom there is our proposed supervisory controller are supposed to use the simulator as a testing ground.

4.3.4.1 Multilevel architecture

To be consistent with the general multilevel architecture, the simulation environment contains layers corresponding to those in the general architecture. The validation of a DSE depends on its execution results based on an environment where all the lower layers compared to the one it stays in, simulated or not, are complete and ready to use.
The purpose of the simulation environment proposed here is to provide such an environment to validate DSEs in any layer. However, the priority will be given to those in the service layer, e.g. the supervisory controller of entities, because there are already other simulation environments for the layers below. The simulator adopts thus the following architecture where only Physical Model, Sensor and Actuator Device and Entity Abstraction layers are present.

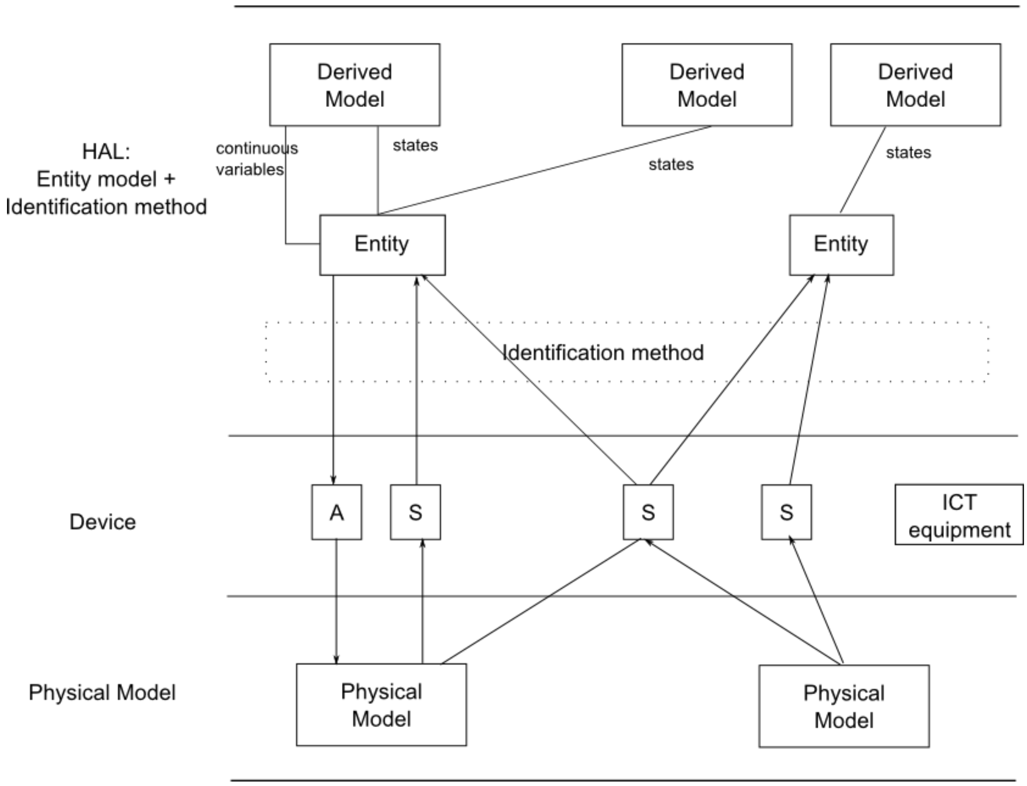

Figure 6: Simulator Architecture

4.3.5 Supported use cases

Use Case	Short description	Reference	How it is supported
Residential Building energy use control		RB1, RB6, RB14, RB15	With predefined energy control scenarios in the supervisory controllers
Office/Home safety		In every elementary use case concerning office and home environment	Ref. requirement 1

Office/Home energy use optimization		SH2, SH3, SH12, OB1, OB3	Same principle as in Residential Building use cases
Hotel energy control	Automatically turn off the light/heating/water when a room is checked out, etc.		Same principle as in Residential Building use cases
Data center energy control		DC1, DC2, DC3, DC5, DC6	Same principle as in Residential Building use cases

Table 13: Use cases supported by the DSE

4.4 DSE WP5: Electric Vehicle Supply Equipment

4.4.1 DSE template

Title	Electric Vehicle Supply Equipment (EVSE)
Lead Partner	Jesse Kielthy (WP5), Thomas Loewel (WP8)
Domain	Electric Mobility; Customer
Zone	Customer
Interoperability Layer	Communication
Entity (S/C) & References	S (Single)
Description	Metering and charging information is concerned with all metered information of charging processes. This includes the metered data at the EVSE, in particular in relation to the time. Significantly, a smart EVSE utilises intelligent technology to allow remote monitoring and control. In this instance, the smart EVSE will enable Grid Operators to stop, start or limit the charge to an EV as part of an overall demand side management solution. End-users will also be able to remotely communicate with the EVSE to schedule a charge or receive information updates. Overall the EVSE supports actively the load balancing process and thus the optimal use of renewable energy.
Detailed Description	Deployment requirements: • Charging Points • Mobility Data Management Functional Requirements: • Technological: All this information is of technical nature and is needed as an input for (planning) (dis)charging processes. However, this information is typically derived from the respective systems. • Economic: The domain is set to the customer as electric vehicles consume energy triggered by the consumers, and they can be used as a DER in the V2G scenario. Besides the information available in the EVSE and the supporting systems, also respective messages send to electric vehicles and their users (e.g., information regarding the current or scheduled (dis)charging processes, connection messages inside the electric vehicles) represent information on charging process and equipment. • Legal: As cars are used by humans, status information of cars might

	• be mapped to individuals. This requires the same privacy protection as with user information • Operational: Information on the EVSE can be of static nature (e.g., supported charging modes and payment methods) or dynamic nature (e.g., current and planned availability and reservation). • Schedule: In the SGAM framework, electric-vehicle information is located in the customer and DER domain and in the operation zone. • Cultural: Privacy protection for user information
Expected inputs	Communication-Interface (from EV and from Back-end) to exchange meter data with EV, to get price signals, to support the authorization, etc.
Expected outputs	PWM-Signal (to set the charging mode); Communication-Interface (to EV and to Back-end) to exchange meter data with the Back-end, to support the authorization, etc.
Interface to other functional entities or GEs	I2ND.CDI; I2ND.NetIC
Standards, encodings, data model	3GPP; Charging points and devices, information exchange, communications
ICT Requirements name	Monitoring of EVSE Aggregate EVs to virtual power plants Control of EV (charging signals)

Table 14: WP5 DSE template

4.4.2 General Description

One major stability criteria for the distribution grid is the compliance with the 50 Hz frequency. Only a small deviation is tolerable (±0.2 Hz). One reason for deviation is a strong and unpredictable load. Today’s distribution grids are optimized for current needs. But with the introduction of renewable energies and electric mobility the distribution grids reach their limits. Especially the charging stations or Electric Vehicle Supply Equipment (EVSE) are new unpredictable and strong loads. Furthermore the expected huge amount of EVSEs increases the load.
Intelligent EVSE are needed to avoid large unpredictable loads und thus the deviation from 50 Hz. Intelligent means, that the EVSE is able to reduce the charge current or to stop the charging process. Also the EVSE should be remote controllable/manageable and remote upgradeable. Additional the EVSE should support scheduled charging and adjustable charging. The following list summarizes a set of requirements of an intelligent EVSE:

- Remote manageable.
- Remote upgradable.
- Scheduled charging.
- Adjustable charging.
- Communication with the electric car.
- Communication with one or more energy management systems.
- Smart metering.

To support these requirements the EVSE should be equipment with a Meter, a Wi-Fi Module and a Mobile Network Module (2G/3G). The meter continuously meters the delivered charge to the Electric Vehicle (EV) and provides this information via the communication modules (Wi-Fi, 2G/3G). The following figure shows the main elements of the EVSE.

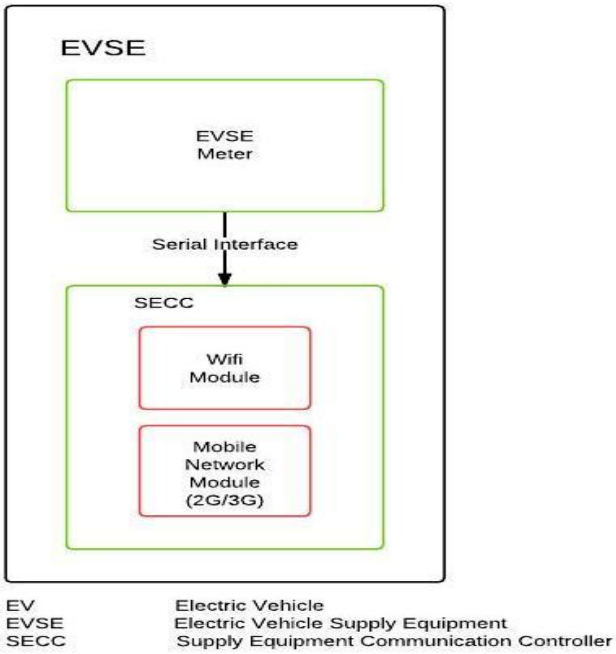

Figure 7: EVSE Block Diagram

Beside the EVSE the Home Energy Manager (HEM), the Grid Operator (DSO) and the EV are additional entities to complete the intelligent charging process. Figure 8 summarizes all involved entities and their interfaces:

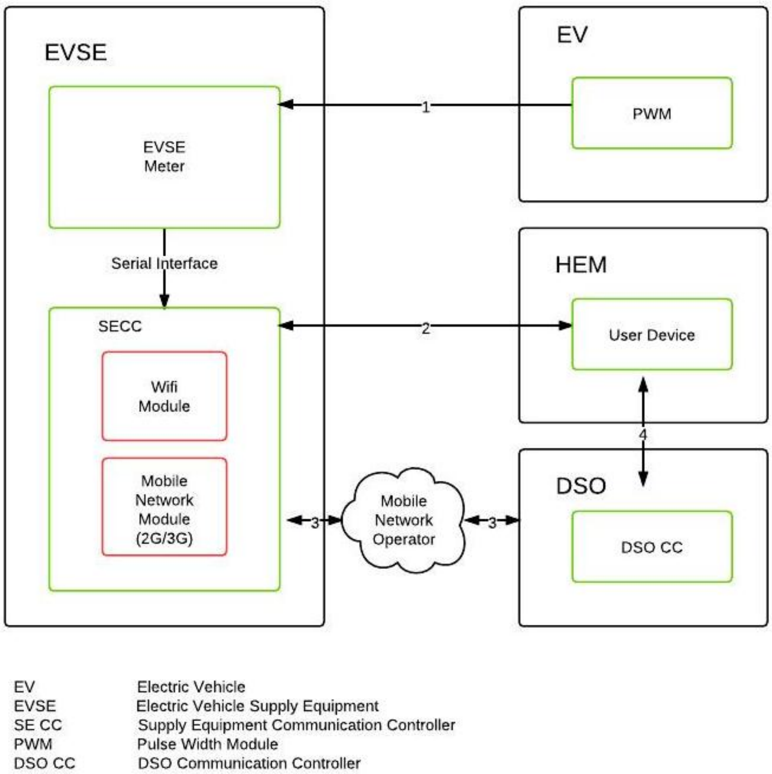

Figure 8: EVSE Communication Interfaces

The EV needs a communication link (1) with the EVSE to support the active charging process (charge on/off or limit the charge) and to control the charge current to the battery from the charger. This is done via the Pulse Width Modulation (PWM) functionality of the EVSE Meter.
The Home Energy Manager (HEM) is one of the management entities for the EVSE. The communication with the HEM (2) is done via the Wi-Fi Module or the Mobile Network Module. Additional the link with the HEM is necessary to set preferences or view the status of the EVSE via the HEM. By using the Wi-Fi interface the EVSE is a Wi-Fi endpoint within the Home Area Network (HAN). As a result, the EVSE can be remotely controlled and managed via the HEM (see requirements of the EVSE).
Furthermore a Mobile Network should exits as a backup solution in the case of the absence of a Wi-Fi connection. Possible mobile networks are 2G (GSM/EDGE) and 3G (UMTS/HSxPA). Both modules (Wi-Fi and Mobile Network) are integrated in the Supply Equipment Communication Controller (SECC). The SECC can communicate as already mentioned with the HEM (2) and with the Grid Operator (DSO) (3). The DSO instructs the EVSE to start/stop or to limit the charging process.
Both links (to the HEM (2) and to the DSO (3)) are bi-directional. In the uplink case (3), (4) the SECC or the HEM transmits usage data and other data e.g. information on EVSEs' location, status (occupied), features, etc. to the DSO Communication Controller (CC). In the downlink (3), (4) case the HEM or the SECC receives instructions to turn the EVSE on/off or to limit the charge to the EV.
The following figure summarizes the grid frequency reaction by using this intelligent EVSE.

50 to 49.8Hz	• No reaction
49.8 to 49.5Hz	• Reduce current 25% (5 min)
49.5 to 49.3Hz	• Reduce current 50% (5 min)
Below 49.3Hz	• Stop charging (10 min)
Post-Stability	• Ramp back for 15 minutes

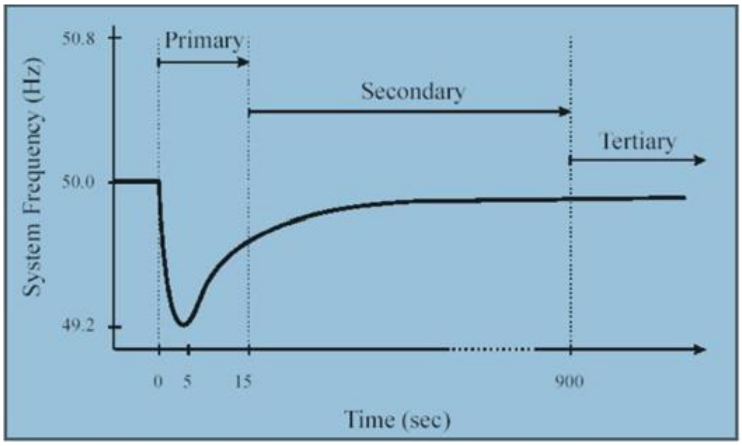

Figure 9: Grid Frequency Reaction

4.4.3 Experimentation of the DSE

The main reason for using the intelligent EVSE is the stabilization of the grid frequency (that means by comparing with traditional charging stations). The EVSE is in that case the domain specific enabler (DSE). By using this DSE fluctuation caused by normal charging stations can be avoided. To experiment with this DSE a grid simulator is necessary.

As new and additional element the EVSE must be introduced. The key functionality is the controllable charging of the EV. For the grid stability only the taken charge is important. That means, for the experimentation a controllable capacitor must be modeled and connected to the grid simulator. To get a realistic experiment, a huge amount of this element must be connected to grid simulator. Furthermore a small management unit is necessary, which measured the grid frequency (the simulated grid frequency with help of the ACS Laboratory) and derived from the result the action according the figure above for each controllable capacitor.

4.4.4 Grid status dependent charge control algorithm

The smart EVSE described in 4.4.2 can be either controlled by the connected HEM or by the connected DSO. Control commands are issued by the DSO control center that monitors the status of the distribution grid and gets information of EVSE connected EVs that can be utilized to shape the current grid load to certain extend technically depending on three main characteristics:

- EVSE charge power capabilities,
- EV charge interface capabilities and
- EVSE smartness i.e., support for dynamic charge rate adaptation like it is described in 4.4.2.

Other factors might play a role e.g., charging preferences like minimum SoC allowed at any time for a given EV. These factors are of individual nature and should also be considered for charging control.
The control algorithm could be implemented centrally or in a distributed way. In case of a central implementation the algorithm only has the requirement to output results within a defined period of time that is prerequisite to fulfil the overall control timing constraint.

Things get a bit more complicated if distributed entities e.g., each HEM implements its own local control based on a predefined parameter set e.g. voltage deviation, parameter set by the DSO. The quality of power supply must be measured locally in that case. In addition to the timing constraint that must be reached in the central algorithm case, the need for coordinated charge control remains since otherwise the positive effects could turn to the opposite. That is the case if all connected EVs gets a charge rate change command at the same time which would result in power spikes within the grid.

Several algorithms are known and already utilized in networking protocols that can be reused to avoid these spikes. Carrier Sense Multiple Access with Collision Avoidance (CSMA/CA), to name just one, uses a random back off time before resending frames if the channel has not been idle and therefore has not been ready for transmission. If we translate that into the charge control domain, the local control algorithm would simply calculate a random number of a defined range and wait for a specified time period associated with that random number before issuing the charge rate change command. The art with that approach lies in finding a good tradeoff between reaction time on grid events and smoothing out charge rate changes between affected EVSEs. Instead of a random number one can also use a predefined number for each individual EV such that the total number of EVs having the same number, and resulting in a total amount of power, is at maximum the power that can be sustained by the grid.

Suppose a maximum reaction time (duration from initiation to complete execution) on grid events dg is needed in which the requested power should be completely available. Then there is a maximum time duration dE left for the set of EVs E={e0, …, en} to finish the process of charge rate changing with n+1 being the number of EVs under control. Each EV ek has an associated wait interval wk from a set of wait intervals is W={w0, …, wn} such that dE=max(W). This is the first constraint the algorithm has to comply with.

The second one can be formulated as $\Delta PE / \Delta t \leq \Delta Pmax$ with ΔPE the power difference in time interval Δt of all EVs charging and $\Delta Pmax$ the maximum power change rate for all controlled EVs for any given point in time.

This DSE can also be hosted in an orchestrating element that is connected to several HEMs or EVSEs anyhow. Such an element is the Micro Grid Controller Center (MGCC) that already implements scheduling algorithms in order to increase energy efficiency within the covered region. In this covered region a coordinated control could be realized within the MGCC and therefore this entity could host this DSE.

4.4.5 Supported use cases

Use Case	Short description	Reference	How it is supported
ICT Enabled Demand Side Management	The control of system frequency is a vital aspect of secure and stable power system operation. A continuous balance between active power generated and active power consumed by the load and losses is required to maintain frequency constant at nominal system frequency (50Hz). Any imbalance in active power will result in a frequency deviation. While precise instantaneous balancing of active power is not viable, frequency control ensures that the system frequency remains within acceptable frequency limits. Frequency control can be called upon for a variety of conditions ranging from a gradual change in load levels over time to a sudden loss of generation or step increase in demand.	WP5_ICT_DSM	Controllable storages (e.g. batteries) are one potential way to support the stabilization of power grids. Such storages can be also realized with electrical vehicles and EVSEs. The planned experiment supports this use case with experiments about the influence of a huge amount of storages to the power grid.

Table 15: Use cases supported by the DSE

4.5 DSE WP6: Demand side manager

When energy retailers experience energy shortages during a day, they buy energy at intra-day exchanges. When renewable production is low, this can be very expensive and it might be a better option to ask their customers to consume less energy within a certain time frame. Similarly, grid operators monitor the electricity grid and may want to ask consumers to temporarily reduce their consumption in order to achieve grid stability. In a nutshell, such actions contribute to peak shaving in the benefit of grid performance and reduce the need of auxiliary non-environmental friendly peak production.

4.5.1 DSE template

Title	Demand Side Manager (DSMgr)
Lead partner	Engineering S.p.A.
Domain	Market and Enterprise
Zone	Distribution, DER, Customer
Interoperability Layer	Information, Communication
Entity (S/C) & References	S (Single)
Description	The Domain Specific Enabler "Demand Side Manager (DSMgr)" is a SW module included in an Energy Management System in charge of the management of DSM signals intended to flatten the electrical demand curve in a specific area. A B2C marketplace (eMarket4DSM) assumes the availability of an infrastructure (HW+SW on board / bundled) where consumers have installed an energy-efficiency control system (EECS) at home that monitors and controls the energy consumption of appliances, by changing their programming parameters. An EECS equipped with a Demand Side Manager (DSMgr) will be able to be activated by DSM signals from the demand-side operator (typically the DSO) based on the subscribed conditions and user preferences.
Detailed Description	The core idea of the domain specific enabler is to manage the DSM signals from the operator side to the home area network (via a device control system) in order to influence the flattening of the demand curve of the energy consumed in some areas. This is only possible with an entity (normally software) in each electrical installation (buildings, houses ...) that can ensure security and effective programming of the appliances to avoid any inconvenience. The approach is that the DSM operator can effect some “changes” in the default contract values / parameters of the various contract classes with the aim of incentivizing / dis-incentivizing consumers / residential agents to exhibit the expected or hoped for consumer behavior (with regard to electricity consumption during critical hours). For that intent, the DSM operator sends signals to the installations affected in the target area. These signals should be managed for a re-scheduling in the operation of the electric appliances (consumer appliance control actions) depending on some conditions as the incentives, contra-incentives, power cap, penalized power, sell/buy price (of electricity) and the preferences of the final user. Anyway, the final user has always the option to cancel the response of the DSM signals at any moment or any period of time no matter the DSM conditions subscribed in the contracts.
Expected inputs	DSM signals from the demand-side managers (from the smart grid); incentives / disincentives; user preferences (e.g. type of energy such as nuclear or solar) / priorities (time range in a day when automatic actions are allowed); price information; contract information (from the eMarket4DSM); rough power consumption data (coming from the energy monitoring systems provided by the EECS); (eventually) rejection of the forthcoming actions on the controlled appliances activated by the DSMgr
Expected outputs	Consumer's appliance control actions; Notification (to the consumer) of forthcoming actions on the controlled appliances activated by the

	DSMgr and the incentives/contra-incentives for attending DSM signals
Interface to other functional entities or GEs	IoT - Gateway Data Handling, IoT - Device Management, I2ND - Connected Devices Interfacing, SECURITY- Identity and Privacy Management, DATA - Publish/Subscribe Broker and APPS - MarketPlace
Standards, encodings, data model	Communication protocol among GEs and DSE: REST, HTTP(S)
ICT Requirement name	User Software Agent System Power limits information Contract information Tariffing signals and profile Energy source information hourly-daily

Table 16: WP6 DSE template

4.5.2 General Description

The DSE assumes an infrastructure where consumers have installed an energy-efficiency control system (EECS) at home that monitors and controls the energy consumption of appliances, by changing their programming parameters, and allowing receiving DSM signals from the demand-side manager based on the subscribed conditions and user preferences. This is only possible with an entity (normally software) that can ensure security and effective programming of the appliances to avoid any inconvenience.

The users have access to the B2C marketplace on the Internet where they can see different offerings for demand-side management programs from demand-side managers. These offerings could be based on real time tariff schemes only in the case that the energy retailer is also the demand manager; users can then choose to contract one of these services. Contracting one of these services aims at reducing the monthly bills. The offers might be coupled with energy contracts and vary in the incentives how much money is paid (or reduced from the bill) when a user actually reacts to load-shifting requests. By contracting such a service, the user allows the grid operator to send demand-response signals to her/his energy-efficiency control system. The signals are used to initiate actions in the appliances connected to the energy-efficiency control system, in order to schedule operations (e.g. electric-vehicle charging, starting a washing machine) or lower/increase the temperature of the customers building by some degrees (within a certain range). It must be noted that the contract need to reflect the possibility for the user to not accept DSM signals at any time in order to allow user's manual decisions on how and when to use the contracted energy.

When consumers have contracted with demand-side managers and an infrastructure is available that can execute demand-response measures, the B2B marketplace described in the following uses market mechanisms for trading flexible loads for demand-response purposes. Energy retailers considering a demand-response measure can send their request to the electronic B2B marketplace. The demand-side managers then send priority signals to energy-efficiency control systems of their contracted consumers (Step 1, Figure 10). These systems then take the best decision based on DSM signals, incentives, and user preferences to send the signal to intelligent devices in the consumer's premises as well as charging infrastructure of electric vehicles (Steps 2-4). Anyway, the user must be able at any moment to avoid DSM signals (Step 3a).

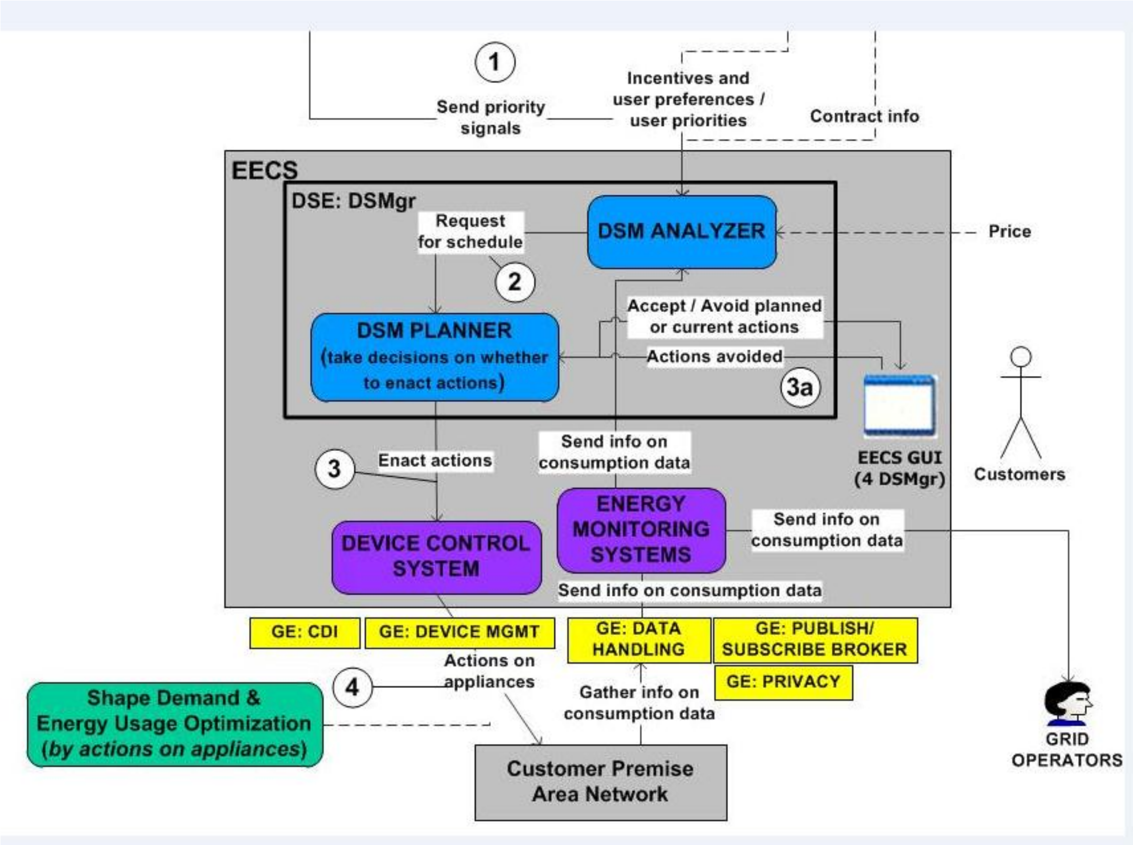

Figure 10: DSE steps and functionality

4.5.3 Supported use cases

Use Case	Short description	Reference	How it is supported
Flatten demand curve	The Scenario describes how an ICT application may contact the customers via a market and effectively manages DSM signals to reduce the power consumption in customer homes.	WP6_DSM_SC1	The B2C DSM Marketplace sends incentive / counter incentive signals for re-scheduling appliances operation and flatten the demand curve.
Detailed consumption information	Give the users the opportunity to get detailed information of the consumption related to the most consuming devices in their homes. At the same time, the user will be able to get information from the utilities on the tariffs and get energy consumption costs in a granular way.	WP6_IFUCEU_SC1	The users get the information from the B2C marketplace, with the DSM signals and the incentive and counter incentive signals, along with the re-scheduled plan. Then the user can accept it or reject it.

Information about energy generation sources: being green	Getting to the customer information about the energy that is being generated a given time in relation to their own consumption so they can get statistically if the energy they consumed comes from a “green” (renewables) energy source.	WP6_IFUCEU_SC5	User is informed on the incentives / counter incentives signals for re-scheduling appliances operation. Based on that the user can choose between using the new schedule or not depending on the green sources offered.
Colored ethical bid	The Energy Information Provider (EIP) provides information to the final user about the mix of the available energy sources: each kind of energy is represented with a different colour	WP6_IFUCEU_SC3	User is informed on the incentives / counter incentives signals for re-scheduling appliances operation. Based on that the user can choose between using the new schedule or not depending on the green sources offered.
Transparency in the green market	Customers would like to measure, in real time, energy costs and monitor the consumption to be able to personalize his contract depending on the costs and program accordingly his BMS to comply to the latter	WP6_IFUCEU_SC2	User is informed on the incentives / counter incentives signals for re-scheduling appliances operation by the B2C marketplace. Based on that data, the user can personalize his contract depending on what is offered.
Energy Contract Brokering	Providing mechanism in place for adapting electricity generation to demand and vice versa	WP6_IFUCEU_SC4	The B2C DSM Marketplace sends incentive / counter incentive signals for re-scheduling appliances operation.

Table 17: Use cases supported by the DSE

5. Experimentation plan

This chapter reports the plan for the experimentation of the selected DSEs in the different experimentation labs.

5.1 DSE WP2: Gateway for Secondary Substations using S3C GE and DSE WP3: IEC 61850 protocol adapter

The experimentation of the WP2 DSE ‘Gateway for Secondary Substations using S3C GE’ will be carried out by using the laboratory facilities at the RWTH Aachen University That laboratory is called Automation of Complex Power Systems (ACS) lab and supports real-time simulation of the power system by using tools like the real-time digital simulator (RTDS®). ACS will provide a rough impact analysis of communication disturbances in the control loop for energy management.

The experiments in the ACS lab will be complemented with the experiments carried out in the Grenoble INP Experiment Laboratory in the context of the EU fp6 funded project called INTEGRAL [14]. That laboratory is called PREDIS.

The experimentation of the WP3 DSE: ‘IEC 61850 protocol adapter’ is very limited within available Experimentation Lab capabilities. Since WP2 experimentation is also relevant for the Microgrid scenario and for the better use of resources the two experiments were agreed to be combined. Both WP2 and WP3 DSEs are related to the communications and connectivity and have the overlapping requirements as Microgrid comprises local low-voltage (LV) and even medium-voltage (MV) distribution systems. Tested functionalities of distribution systems are required in distribution grid and in Microgrid as well.

5.1.1 The experiments in the ACS laboratory

5.1.1.1 Set-up of the ACS laboratory lab for testing the DSE

The set-up of the ACS laboratory for testing the DSE has been described in section 5.3 DSE WP5: Electric Vehicle Supply Equipment and in more detail in deliverable D8.1 [7].

5.1.1.2 Description of the scenario

The following figure illustrates the main elements of the scenario to be experimented.

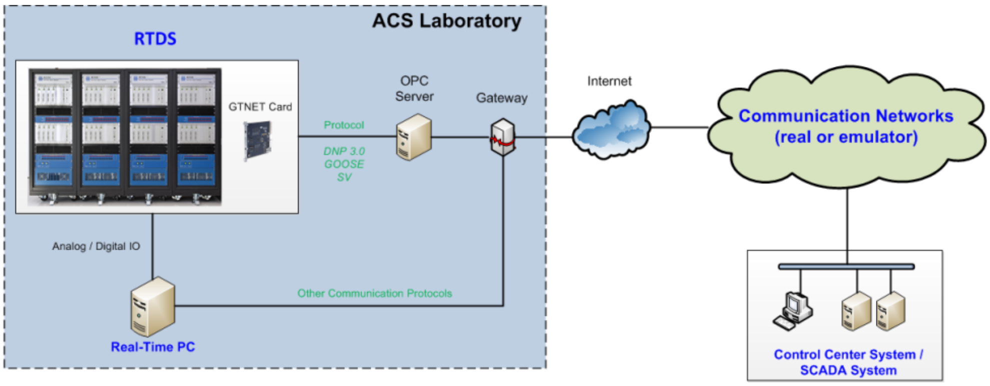

Figure 11: Basic elements of the experimentation system

The test scenarios include the transfer of data across different emulated communication links, including the fixed line link, GPRS link and LTE link. The parameters of the emulator will be

changed in order to show the impact of the different communication characteristics on the Distribution System behavior and control loop. Different types of data related to the Distribution System behavior will be collected from the RTDS simulator and analyzed. Final conclusions will be made about the suitability of the different types of communication links for the MVDAC communication in the Distribution System.
The steps for conducting the experiment in the ACS laboratory are the following:

1. Establish a virtual power grid (DS) at the ACS simulator.
2. Set the to-be-emulated communication link parameters at the Communication Networks emulator: Time Delay, Packet loss, Packet corruption, Disconnections, Packet re-ordering, Jitter, etc.
3. Exchange data between the Control Center System /SCADA system and the simulated electrical network devices.
4. Observe the power grid behavior.
5. Change the communication link parameters at the communication Networks emulator and observe the impact on the power grid behavior.

5.1.1.3 Experiments

A Smart Grid DS has to support several functionalities in order to tackle the future challenges of integration of the different energy generation sources, the active flattening of the demand curve, an electrical vehicle charging infrastructure, microgrids and customers with an active role as prosumers. Such functionalities have been listed in the following:

- DS-wide monitoring of the grid status.
- Automation of grid operations.
- Automatic detection of fault conditions and restoration.
- Balancing of load / generation including reactive power.
- Efficient and reliable workforce management.
- Improved forecasting for the efficient alignment of the consumption to the generation.

This requires managing and controlling many connected devices in the smart grid DS, and automation of processes. A variety of communication technologies will be applied in electricity networks, and in addition, participants and their devices need to be interconnected in a distributed way.

Due to the availability of only a limited amount of resources for the experiments, the DSE 'Gateway for Secondary Substations using S3C GE' will be tested only with a limited scope. The experimentation (Aachen RTWH) consists of simulated devices and emulated connections (e.g. parameters according to an LTE network). The work, which will be carried out to test the WP5 DSE, will be exploited to the maximum extent when experimenting in the WP2 DSE.

5.1.1.4 Simulation

The power grid will be simulated for this experiment. The Communication Network will be emulated.

5.1.1.5 Real structure

The basic structure of the experimentation lab is described in section 5.3.5.

5.1.1.6 Requirements for a real test

The real communication links (fixed, GPRS, LTE) are necessary when investigating the impact of the communication link capacity and characteristics on the simulated Distribution System. It may not be realistic to expect that a Distribution System Operator (DSO) would allow testing in the real Distribution System environment.

5.1.1.7 Type of services that can be used

This DSE supports all kinds of data transfer over a public communication network between the Control Center and Remote Terminal Unit (RTU) of the Distribution System.

5.1.1.8 Schedule

This experimentation will be run in parallel to the WP5 DSE experimentation, see section 5.3.8.

5.1.1.9 Expected Results

Different communication technologies come along with a different set of communication characteristics, which may influence the control of power grid functions and as such the power grid behaviour. It is assumed that in the normal operating situations both the 3G and LTE networks fulfil the requirements on the electrical grid communication links. The **objective** of this experiment is to better understand how the changes in the communication links may impact on controlling the grid and on the load management.
The impacts of the different communication technologies and communication disturbances will be investigated with regards to the control loop and resulting grid behavior. The findings will be based on an example electricity grid and, as such, may not be directly considered as generic findings.

5.1.1.10 Competition

Not applicable.

5.1.1.11 Part of the business that is going to be examined

Not applicable.

5.1.1.12 Expected problems

Not known.

5.1.1.13 Comments

No.

5.1.2 The Experiments in the Grenoble INP Lab

The Grenoble INP Experimentation Lab is located at Grenoble INP premises and is called PREDIS as described in deliverable D8.1 “FINSENY Experimentation Lab Set-up” [7].
The experiments in the PREDIS laboratory are being run in the context of the EU fp6 funded project called INTEGRAL [14], and the aim of their experiments is to provide solutions to reduce outage time and operation costs due to the fault occurrence within the grid.

The impacts of the communication network performances (latency, error and bandwidth) on detecting, localizing and isolating the fault within in the grid will be analyzed in the FINSENY project.

5.1.2.1 Description of the scenario

One of the emerging ideas to protect the electric power system against catastrophic failure is the use of self-healing approaches (SHA). The objective of these advanced approaches consists consecutively in detecting, localizing and isolating the fault before re-supplying the maximum of consumers, who were affected by the disturbance. Once it is determined that a wide area of the system has been perturbed, SHA breaks up the system into small parts to reduce the effects of the fault occurrence by limiting them to the smallest part. The sane parts of the network can be re-supplied. The communication network performance plays a key role in detecting, localizing and isolating the faults.

5.1.2.2 Experiments

The tested scenarios in the INTEGRAL project [14] are modifications on:

- Fault location (seven lines can handle overloads in the distribution network).
- Grounding of the substation (both resistive and impedance grounding are available).
- Type of the fault (single phase, two phase, two phase to ground and three phase faults).
- Communication network performances (latency, error rate and bandwidth).
- Power flow inside the network (loads and sources),
- Topology of the network before the fault (normally open point location in loopable structures).

5.1.2.3 Simulation

It consists to represent the behavior of a real network during a fault (overload done with a fault resistance) by a simulation of the reduced scale emulated distribution network.

5.1.2.4 Real structure

To be able to evaluate the ICT performances requested by the self-healing agent, different layers of communication (RTU to SCADA/intra substation/PAC to SCADA/RTU to agent to SCADA) and associated monitoring have been developed. Figure 12 presents the ICT structure of the experiment test bench. The communications needed for the self-healing process are completely controlled by an emulated ICT system based on TCP/IP. This network (Level 1 in Figure 12) is able to control bandwidth, latency and error rates but also analyzing, in off-line mode, all the protocols used between RTUs, agent and SCADA during a fault. The level 2 presents the different RTUs (real communicating fault passage indicator, fault recorders) a distributed database, the agent and the SCADA server. The level 3 is presents the PACs (Programmable Automation Controllers) and other controllers of the test bench.

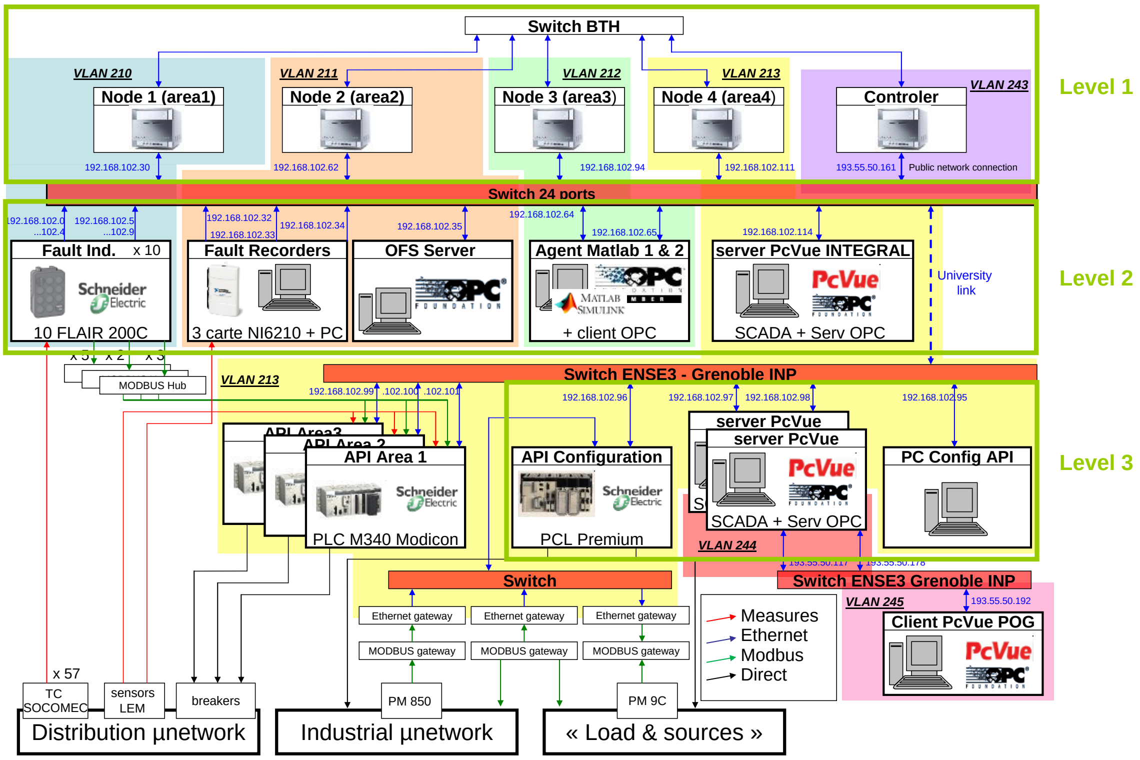

Figure 12: Developed ICT infrastructure to modulate the communication performances and to record protocols between ICT actors

5.1.2.5 Requirements for a real test

Not applicable.

5.1.2.6 Type of services that can be used

Not applicable.

5.1.2.7 Schedule

The INTEGRAL project results will be analyzed for the FINSENY use in January 2013.

5.1.2.8 Expected Results

The results are expected to show the impact of the disturbances in the communication network on detecting, localizing and isolating the fault in the grid.

5.1.2.9 Competition

Not applicable.

5.1.2.10 Part of the business that is going to be examined

Not applicable.

5.1.2.11 Expected problems

No specific problems are expected.

5.1.2.12 Comments

No.

5.2 DSE WP4: Supervisory controller as service

In this chapter the "Supervisory Controller" DSE is analyzed with the two following approaches:

1) At first this DSE is parsed in a sophisticated simulation framework, using an environment to validate it in any layer.
2) The second approach consists in experimenting this DSE through the Energy@home, a physical infrastructure for conduct experimentations within private homes with the goal to monitor, control and optimize the electrical power consumption.

These two approaches are here described in separate paragraph in order to avoid confusion between real and simulated parameters.

Anyway their contributions are very synergistic to cover the complete testing of this DSE: while Energy@home is mainly focusing on the development of a communication infrastructure that enables provision of Value Added Energy Services in the Home Area Network (HAN), the simulation framework extends the scope from single homes to full neighborhoods.

5.2.1 Environmental simulation for the DSE

A DSE is supposed to be situated in either the entity, service or application layers in the system's architecture presented above. The validation of a DSE depends on its execution results based on an environment where all the lower layers compared to the one it stays in, simulated or not, are complete and ready to use.

5.2.1.1 Description of the Experimentation Lab

The purpose of the simulator proposed here is to provide such an environment to validate DSEs in any layer. However, the priority will be given to those in the service layer, e.g. the supervisory controller of entities, because there are already other simulation environments for the layers below.

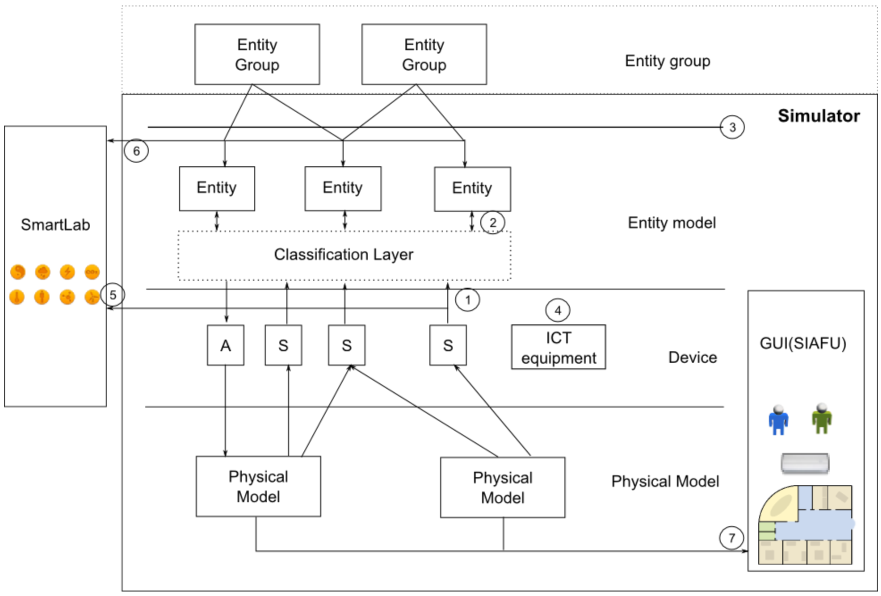

Figure 13: Simulator Architecture

Though a complete simulation starts from the bottom layer (Physical Model) to the one on the top (Entity Model), the simulation doesn't need to include all of the layers. With the interfaces provided between every two layers, every simulation layer is independent from each other and can work alone. For example, it can simulate only the Entity Model level by directly taking entity information from the external BAL (Building Abstraction Layer) service and generating and pushing actuator data as output value.

Layers & Components:

- Physical Model is the software representation of physical entities in the real world. They are continuous-time and continuous-space models, using e.g. differential equations. The simulator will provide a library of ready-to-use physical models if needed and relevant.
- Device Layer is where networked entities exist, including sensors, actuators. Sensors and actuators are intermediate between the legacy or non-networked entities and their abstract model which can be integrated into the system. Simulated sensors and actuators are independent instances of functions representing the behavior of the real sensors and actuators. Some of them act only as interface between physical models and while some of them have their own behavior functions which generate contextual data alone. Results of this layer are shared by all the entities in the upper layer.
- Entity Model Layer contains two essential components:
    - Entity Model (Entity in the schema) is the basic simple model of building identified physical entity. It is modeled as automaton which only contains the intrinsic states of the entity. It can contain continuous variables of the entity as well. The simulator will provide a library of basic entity models with specified input/output value type, continuous variable type, states and transition events.
    - Classification Layer is the part of the functionality of the service (Ref the next section) which takes in charge of identification of entities and their current states. According to available data from sensors, it identifies events in the context and makes necessary state changes on target entities. BAL is an independent service which runs on OSGi platform and provides interfaces of different types: socket, REST, etc.

Interfaces and communication protocols:

- Device/Classification Layer (1). This is the output of sensors and input of actuators. As the entry interface of BAL service is already defined (data in XML format, refer to BAL specifications), the output of simulated sensors should respect this format. Data structure of exchanged actuator information will be discussed in the near future. At present, as a RESTful service, it accepts an HTTP PUT request to receive sensor data. It can also go to read periodically an XML file in a specific containing output data of sensors.
- Classification Layer/Entity Model (2). The output of the Classification Layer contains information about the identified entity such as: type of the entity, its current state, value of its attributes, in an XML format exposed as a REST interface.
- Entity Model/Service (3). This is the top interface of the simulator which will be used directly by the services to be validated. Both basic entity model and derived entity model are available here as well as some environment variables to be provided to services. Services will need to know the automata in details such as their input/output variable's type, states and transitions, and they should be able to give input to entity models and trigger transition events.
- Communication protocols appropriate for RESTful Web Service. We choose the REST style for our web service because it is based on the universally understood protocol HTTP and impose few constrains for design and development. By using the basic HTTP

verbs, there is no need for developing other special interfaces which saves a lot of work and makes it easy to access. Other components of the simulator can query it to get or put data. A Publish-Subscribe style may be appropriate for the system/environment to simulate which is usually event-driven.

- GUI: MileSENS based on an open source context simulator SIAFU will mainly provide animation of physical entities such as people, room space. Knowing the position of a moving person on the graphical background, it can generate as output data to simulated sensors the presence of a person in a given space, etc. It provides also the functionality of planning a person's itinerary during the simulation by interaction with user, e.g. mouse click on the room's layout. Physical models are presented on the MileSENS via the interface (4).

5.2.1.2 Description of the scenario

As we expect the DSE can be applied in different scale of environment, we propose 2 simulation scenarios to demonstrate 2 scales of environment.

Home environment:

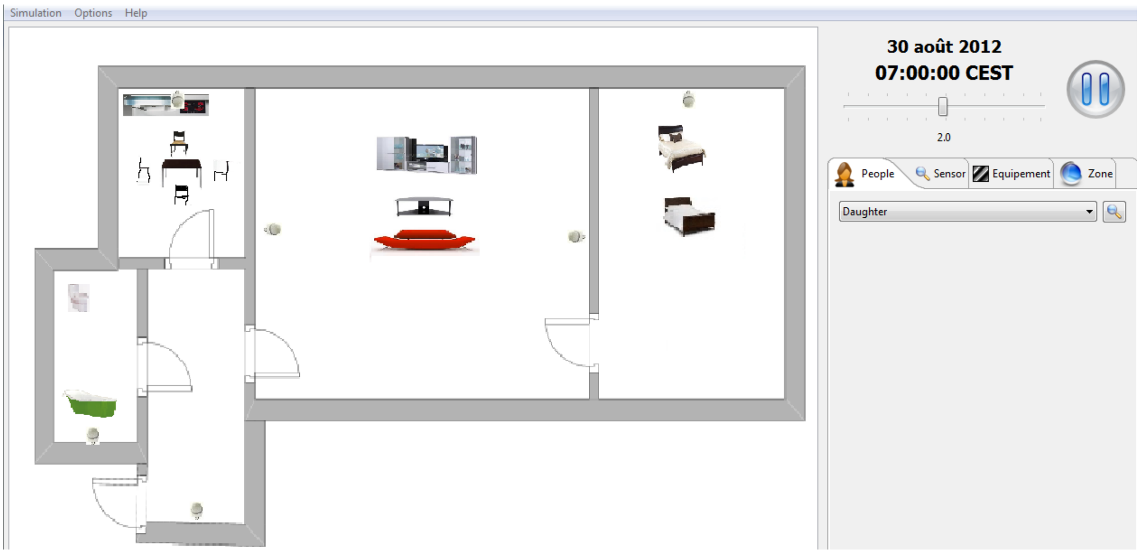

Figure 14: The home environment interface

The layout is an apartment with 4 rooms: bedroom, living room, kitchen and bathroom with 2 people in the home

- 1st scenario: during the night:
  - One person leaves the bedroom for the bathroom. He passes through the living room where there is no light → the lamp is turned on by the system once the presence is detected→the person moves more quickly in light.
  - He goes into the bathroom→ the door of the bathroom is closed and other person should wait outside if he wants to use the bathroom → as there is no presence of anyone in the living room, the lamp is turned off.
  - The person comes out of the bathroom and goes back to the bedroom → the lamp in the living room is turned on when the person enters the living room and turned off when he enters the bedroom.
- 2nd scenario: during the day:
  - People leave for work →apartment is considered empty→turn off all electrical appliance, heating and close windows.

  - Around noon, the sun is too strong that heats the room enormously → the shields are put down by the system.
  - When people return, the system turn on the heating.
  - During cooking time, if oven is on, the heating will be lowered.
  - One person open the window, the heating is turned lower.

Office environment:

The layout is an office environment with 2 individual office rooms, a corridor, 2 bathrooms (male/female) and a meeting room with 6 office workers in the scene. The proposed scenario is intended to show other control capabilities other than the ones already showed in the home environment scenarios:

- The heating begins half an hour before the opening of the site.
- People come to work. One person opens the window of his office, the heating of this room decreases its power until the window is closed.
- The light in the corridor is brighter when there is somebody, darker when there is no body and turned off when there is no body for some time.
- The shield is put down during the daytime if the sun is too strong and pulled up when the sun is right for working.
- Based on the indoor luminosity, the artificial light in the office room will be adjusted (the light is not on when the shield is put down).
- Bathroom is locked when somebody is inside.
- The shield of the meeting room is put down during the meeting and open the window for a while after a meeting.
- The heating ends when everyone is left so as the light.

5.2.1.3 Experiments

Run the scenarios on the simulator.

5.2.1.4 Simulation

This is a software experimentation, which means all the scenarios are implemented and tested by simulation.

5.2.1.5 Real structure

Ref. the simulation structure.

5.2.1.6 Requirements for a real test

Not applicable.

5.2.1.7 Type of services that can be used

Not applicable.

5.2.1.8 Schedule

A first demonstration of home environment in the simulator is planned for the end of November. For the scenarios of office environment, the results should be ready by the end of January 2013.

5.2.1.9 Expected Results

- The scenarios demonstrate all the essential control capabilities of the DSE, such as state exclusivity of some equipment in the environment.
- The simulated environment is reactive enough that itself can evolve according to internal events.

5.2.1.10 Competition

Not applicable.

5.2.1.11 Part of the business that is going to be examined

Not applicable.

5.2.1.12 Expected problems

Not applicable.

5.2.1.13 Comments

No.

5.2.2 Real experimentation for the DSE

The “Supervisory control” DSE refers to a lightweight joint control of several individual controlled entities. Its main role is to coordinate all the controlled entities in order to reach or avoid a prescribed joint state of the system comprising these entities. It is designed to be able to adapt itself to changing context and make decisions based on specific inputs and the current states of each controlled entity. In this context Energy@home, described below, is able to satisfy these supervisory actions because it is able to adapt itself to make decisions based on specific inputs and on current states of each controlled entity.

5.2.2.1 Description of the Experimentation Lab

This experimentation lab is a test infrastructure that enables provision of Value Added Services based upon information exchange related to energy usage, energy consumption and energy tariffs in the Smart Buildings. This test infrastructure envisions a protocol that shall be used to build an integrated platform to allow cooperation between the main devices involved in residential energy management.
From the final customer side, these devices are:

- The Electronic Meter, responsible for providing certified metering data. The meter shall be interfaced via a new-generation device called Smart Info to enable communication with the telecommunication infrastructure and the household appliances.
- The Smart Appliances, able to cooperate in order to adjust power consumption by modifying their behaviour, while preserving the quality of service and user experience.
- The Smart Plugs, able to collect metering data and to implement a simple on/off control on the plugged energy loads other than Smart Appliances.
- The Energy Box which is also the HAN controller. It is an Alice home gateway (a device of Telecom Italia) with OSGi (Open Service Gateway initiative) framework and HAN wireless communication capability.
- The Customer Interfaces, i.e. all the devices used by the customer to monitor and configure his/her energy behaviour.

From the demand side manager (see section 5.4.2) side, there is:

- A remote Service Platform that manages, together with any the Home Gateway, the HAN devices and provides service oriented interfaces for the development of third-party applications. It monitors and controls a plurality of individual entities and it includes de-facto the “Supervisory control” DSE. This Platform is unique for the entire experimentation involved house and it includes the DSE FINSENY "Supervisory Control". In fact, the “Supervisory control” DSE refers to a lightweight joint control of several individual controlled entities. In other words, this DSE acts not only for a smart-home but also for one or more Smart Buildings. This remote Service Platform actually runs on servers in Innovation Lab and it is planned to be moved on Telecom Italia Cloud Computing Services.

These actors identify the main categories of devices in the Smart Building Domain, without any limitation to the possibility for a device to implement functionalities from more than a category. As an example, an advanced Smart Appliance, provided with a rich user interface, could also implement functionalities typical of a Customer Interface. In the same way, a personal computer might be considered a Smart Appliance from the protocol point of view if it was able to behave like a white good within the HAN.
From a functional point of view, Energy@home envisions a system that can provide users with information on their household consumption directly on the display of the appliance itself, on the smart phone or on their computer. It is expected that, through easy access to information on consumption and through the possibility of downloading custom applications, consumers will be able to use their appliances in a “smart” way by enhancing the energy efficiency of the entire house system. For instance, Smart Appliances can start functioning at non-peak (and therefore less expensive) times of day as well as they can cooperate to avoid overloads by automatically balancing consumption without jeopardising the proper execution of cycles.

5.2.2.2 Description of the scenario

At the time of writing, Energy@home test infrastructure is installed:

- In a Living Lab, the “Innovation Lab” of Telecom Italia in Torino.
- In 30 private houses. By the first quarterly 2013 it is planned to extend this to 100 houses.

The experimentation is in progress in both the installations.
The Innovation Lab is a show room of Telecom Italia located in Torino and dedicated to allow visitors to experiment all the novel services and most relevant prototypes and demonstrators produced by the labs of the company. It is composed of two main areas:

- The “Network” area shows scenarios related to Next Generation Access Network, GPON, switching plants, public streets, and building sites.
- The “Home/Office” area shows instead scenarios and applications related to home, business and small office including demonstrators strongly related to FINSENY (cloud computing, home automation and electricity smart metering, etc.) based on a plethora of communication technologies (Wi-Fi, Radio over Fiber, POF, Bluetooth, ZigBee, femto-cells, LTE, …).

Figure 15: Experimentation scenario in Innovation lab

As shown in Figure 15, in the Innovation Lab, the Energy@home system includes a large number of devices, all connected to the Internet via the home broadband gateway: smart meters for electricity, two smart appliances (a washing machine with ZigBee radio and an oven with ZigBee radio), two traditional appliances (a fridge and a dishwasher) connected via smart plugs, a connected TV and an old CRT TV, some connected PCs, tablets and smart phones, plus a number of small devices like a stove, a fan, etc. A maximum electrical load of 3 kW of power is permitted and an overload control system switches off lower priority loads in case such a threshold is reached.

With the obvious exception of the remote Service Platform, which is centralized and unique for all the houses (*it is a demand side manager, see 5.4 section*) this Innovation Lab scenario has been reproduced also in each private house hosting the "Energy@home KIT" trial that is equipped as follows:

- Smart meter.
- SmartInfo device of Enel that bridges the Smart Meter communication with the Home Area Network.
- Energy Box which is also the HAN controller. It is an Alice gateway (a device of Telecom Italia) with OSGi (Open Service Gateway initiative) framework and HAN wireless communication capability.
- 5 smart plugs with a local meter, a switch, and radio communication.
- 1 smart appliance with embedded radio communication.

Energy@home is open and fully controlled by FINSENY partners. It can be easily extended to include communication with other devices, to implement new functionalities and to interact with other FINSENY experimentation domains.
Another "Energy@home characteristic, is the ability of the Home Gateway (HG) to communicate with the smart meter in order to obtain the POD (Point Of Delivery), an alphanumeric code displayed on the Italian smart meter that uniquely identifies the point of collection (or delivery) of electricity. So, in a completely automatic way, it is possible to know the retailer of the final user and to compute a set of economic aspects through the association with the user consumption profile (e.g.: current utility bill, estimates of future energy bills, best retailer in function of user profile, etc.).

5.2.2.3 Experiments

The experiments listed below relate tests in progress on a physical trial and on the real data analysis coming from it. More in detail, the experiments make use of real data coming from private houses where it has been installed the "Energy@home KIT" above described.
The three experiments are:

1) Verify the capability to collected metering data and implement on/off control on simple plugged energy loads. In this context it will also be respected the autonomy of Smart Appliances in order to assure the correct execution of its working procedure, its results and performance.
2) Verify the capability to interface, in wireless mode, with Smart Appliances and with other user's devices and then to provide a broadband connection to internet for supervision and remote control.
3) Verify the capability to exchange information between utilities and appliances in the houses to enable each customer to "self-manage" his/her energy behaviour depending on both power supply availability and price.

5.2.2.4 Simulation

All the experiments described above make use of real data coming from private houses. So, the only used SW does not perform simulation but it aggregates the real data in order to interpret them and represent them graphically.

5.2.2.5 Real structure

The real structure shown in Figure 16 is intended to identify the main categories of devices in the Home Domain, without any limitation to the possibility for a device to implement functionalities from more than a category. As an example, an advanced Smart Appliance, provided with a rich user interface, could also implement functionalities typical of a Customer Interface. In the same way, while typical smart appliances are smart white goods, also a personal computer, able to perform such operations, should be considered an appliance from this perspective.
It is essential to clarify that the structure shown in Figure 16 is reproduced for a single house, while the Service Platform is unique for the entire experimentation involved house and it coincides with the DSE FINSENY "Supervisory Control". In fact, the "Supervisory control" DSE refers to a lightweight joint control of several individual controlled entities. In other words, this DSE acts not only for a smart-home but also for one or more Smart Buildings. Anyway the customers are always able to impose own choices by making use of their customer interface.

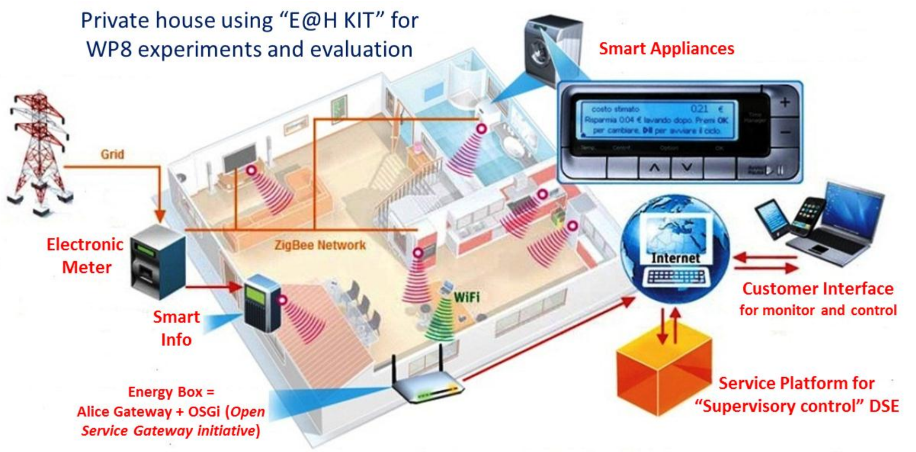

Figure 16: real structure for the experimentation plan

With reference to the Figure 16, here following is described the functional flow:

- Information from the ENEL electronic meter is distributed to the smart appliances that will adjust their cycles according to the available power and the energy tariff in order to optimize the consumption and to reduce the energy bill to the customer.
- The smart info gathers the data sent via powerline from the electronic meter and distribute them wirelessly inside the house.
- The smart appliance receive the data from the smart info and manage their processes according the power availability and in agreement with the user preferences.
- The Energy Box, which is also the HAN controller, is a Alice gateway (a device of Telecom Italia) with OSGi (Open Service Gateway initiative) framework and HAN wireless communication capability. It collects all the data sent from the domestic wireless network and forwards them outside thanks a broadband always-on connection giving the possibility to display the info about energy on the WEB portal or a smart-phone.
- The remote Service Platform manages, together with any the Home Gateway, the HAN devices and provides service oriented interfaces for the development of third-party applications. It monitors and controls a plurality of individual entities and it represent de-facto the “Supervisory control” DSE.

The experimentation plan to check the DSE functionality and get its results is articulated in the following domains and sub-domains:

(1) <u>Smart metering and control test</u>:

(1a): Check that, involving smart plugs and Smart meters, will be collected metering data and implement on/off control on simple plugged energy loads.

(1b): Check that, for the Smart Appliances, the remote load control will be subject to its control in order to assure the correct execution of its working procedure, its results and performance. For example, a smart washing machine, when requested to modify its consumption behaviour, shall assure the result of the washing cycle.

(2) <u>Communication and Data Protocol test</u>:

(2a): Check that, the communication and data Protocol interface Smart Appliances and other user’s devices and provide a broadband connection to internet.

(2b): Check that, the communication and data Protocol collects energy data from the Smart Info and additional information from Smart Appliances, publish them in the HAN (Home Area Network) and use all collected data to control Smart Appliances and optimize their behaviour.

(2c): Check that, the communication and data Protocol offers a web user interface and provides an execution environment (e.g. Java OSGi framework) to host third-party application (e.g. a SW component implementing the algorithm to calculate the energy price at a given time, provided by the energy retailer).

(3) Detailed Consumption Information:

(<u>3a</u>): Check that it is possible to display information on energy usage like instant power, historical data, contractual information and similar, from the whole house (coming from the Smart Info) and from every single smart appliance. The level of details and graphical layout of their user interface is freely defined by every device.

(<u>3b</u>): Check that it is possible to transmit control message to Smart Appliances to request a modification of their behaviour.

(3c): Check that it is possible to configure Smart Appliances to modify their power consumption profile (e.g. a personal computer used to configure a thermostat to activate the controlled load only in certain time slots).

(3d): Check that the software application, which implements the user interface, could be local in the device or remotely hosted in another device (e.g. the Home Gateway) and accessed through web-services.

5.2.2.6 Requirements for a real test

For the real test of the "Supervisory control" DSE is needed:

- In each private house hosting the "Energy@home KIT" that is equipped as follows:
  - 1 Smart meter.
  - 1 Smart Info.
  - 1 Energy Box.
  - 5 smart plugs with a local meter, a switch, and radio communication.
  - 1 smart appliance with embedded radio communication.
- A SW service platform (Supervisory Control DSE) actually running on servers in Innovation Lab (Telecom Italia Lab in Turin) and it is planned to be moved on Telecom Italia Cloud Computing Services).

5.2.2.7 Type of services that can be used

"Supervisory controller" DSE is considered as belonging in the service layer because it monitors and controls a plurality of objects in the entity layers. This DSE allows the following type of services:

- Automatic control of electrical loads: in this service, the single electrical load regulates its behavior upon home power availability. The aim is to foster the use the loads when there is enough power in order to avoid overloading. The "Supervisory controller" DSE will execute the coordination logic. This automatic and remote control, may however be resumed under the control of the end customer at any time through its customer interface.
- Remote access for monitoring and control: it is a service for the final user that through its customer interface (e.g. smart-phone, tablet etc.) can monitor and control the electrical load also from a remote location.
- Alarm (overload): the customer is promptly informed when the overall power drawn exceeds the maximum available power, hence causing a Home Domain Overload. The notification shall be notified local alarms (e.g. acoustic) or sent in the remote (smart-phone) through Internet from the remote service platform. The customer can also access to an historical view of any alarm.

Energy@home test infrastructure also allows additional services related to the DSE "Demand side manager", as explained in section 5.4.2.

5.2.2.8 Schedule

The described DSE experimentation has begun on December 2011 and it will be analyzed a period of one year, that means to get the coming real data coming from 30 private houses till November 30th, 2012.
The final set-up for the information extraction from the big data set and their transformation into an understandable structure for further use (*data mining*) should be done by mid of December 2012.
The complete results coming from the data mining should be ready by end of January 2013.

5.2.2.9 Expected Results

From the above described in the experimentation plan, five results are expected:

1) To keep under control and manage (at home and outside), the household electrical devices avoiding power-off for excess of load.
2) To help the end user to choose the best dynamic rate when the retailers offer him/her multiple time-slot rate.
3) To offer at the end user the ability to sign a contract to more low power thanks to the possibility to keep under control the peak load, saving so money every month.
4) To have a consistent data-history, collected at a set time, in order to obtain important information about the contractual choice of energy retailers and to optimize the use of energy available.
5) To check the functionality of the management of priorities among all the smart appliances and the traditional ones.

5.2.2.10 Competition

The “Supervisory control” is a strategic DSE on which numerous HW/SW infrastructures are approaching for the control of several individual controlled entities in the smart buildings. In FINSENY project, the IR 4.4-“Trial Candidate” it has been identifies the Energy@home and BeyWatch trial as the solutions that support this DSE and the most relevant UCs identified in WP4. They are not competing, rather they are complementary as can be seen from their functional descriptions in this document.

At worldwide level, the “smart building” energy management/control ecosystem is rife with competition across the entire value chain, creating a range of viable solutions for consumers.
Several organizations (*e.g. ZigBee and Sigma Designs*) have developed standards that enable stand-alone devices to become intelligent networked nodes that can be controlled and monitored wirelessly. This enables interoperability between home entertainment, security systems, lighting, HVAC systems and appliances.

Other companies (*e.g. Savant*, *Tendril and ThinkEco*) have developed platforms that give users control over their building/home energy use. Typically they offer a whole-building platform that features intelligent controls that interacts with the smart-phone, tablet, etc. of the final customers. The company's approach illustrates how the ubiquity of smartphones and tablets, regardless of brand, is opening up the market to increasing numbers of consumers.

5.2.2.11 Part of the business that is going to be examined

The experimentation of the “Supervisory control” DSE is related with one of the most important parts of the for smart power management business. The “smart buildings” energy management market continues to struggle for more traction.

By now, with major deployments of smart grid infrastructure in place, the expectation had been that a smarter grid would be enabling the wider use of new tools and incentives for consumers to use energy more efficiently.

People would save money, and utilities would benefit from lower overall consumption and not having to spend capital so quickly on new power generating plants.

The “smart buildings” energy management market exceeds a turnover of $40 million worldwide by 2020 (*Pike Research report*). The change in the market, until recently characterized by a small volume of sales and consumers who are not dropped in the field, revealing a trend now increasingly interested in energy saving systems whether devices for household and corporate.

5.2.2.12 Expected problems

As previously described, this DSE experimentation is running from about a year and this has allowed to detect the most critical points, which are currently being remedied through guidelines directed to the end user or to the installer. The problems so identified were:

- Problem of radio coverage of the HAN nodes due to thick walls but also due to the different OEM quality of radio node. Moreover, even if the adopted radio protocols were detected robust to interference with other radio technologies present (e.g. ZigBee, Wi-Fi, Bluetooth etc.), there are special cases to be avoided, such as put a radio node in the proximity of a microwave oven.
- It is required an incoming data filtering, because on the power line may appear random spikes that alter the reality of captured data.
- It is necessary to instruct the final customer or the “Energy@home KIT” installer on the behavior to keep in respect of the KIT devices: for example remember to keep always on the ADSL gateway and do not remove without notice any smart plug, creating so "holes" in the frame of the data that are sent.

5.2.2.13 Comments

A not-for-profit association of companies is going to be established in order to promote the standard technologies used in the Energy@home system and extend its aims to a pan European domain.
Formal liaisons have been already established between Energy@home and international industrial associations with the purpose of defining common technical specifications. Other interactions with German EEBus association are also in progress.

5.3 DSE WP5: Electric Vehicle Supply Equipment

5.3.1 Set-up of the Experimentation Lab for testing the DSE

The experimentation lab was described in deliverable D8.1 “FINSENY Experimentation Lab Set-up” [7]. The laboratory is located at the RWTH Aachen University, called Automation of Complex Power Systems (ACS) lab and supports real-time simulation of power system by using tools like the real-time digital simulator (RTDS®). These simulation capabilities can be used to study and experiment the influence on the power grid of a huge amount of EVs to be charged.

5.3.2 Description of the scenario

The experimentation will be done in the ACS lab. The following figure shows the main elements of the scenario to be experiment.

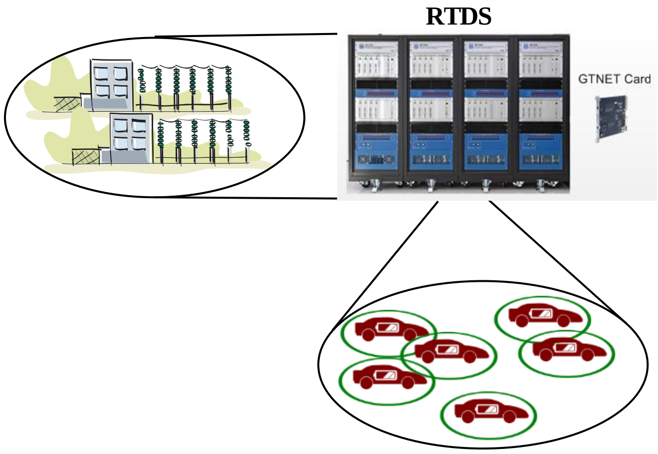

Figure 17: Basic scenario elements

The way of conducting the simulation experiment in the ACS is following:

1) Establish a virtual power grid at the ACS simulator.
2) Provide aggregated models of EVs that mean especially battery models.
3) Start the simulation and analyze the impact on grid frequency.
4) Connect a lot of EVs or batteries (the models) to the simulation that means a lot of EVs start simultaneously the charging process.
5) Observe the power grid frequency.
6) Increase step by step the amount of EVs or batteries connected to the power grid and continuously analyze the impact on grid frequency.
7) Upon changes to the grid frequency, control the charging rates to support frequency recovery.

5.3.3 Experiments

The experiments should investigate the effect (especially the grid frequency) of the charging behavior of mass charging of storage entities connected to the distribution grid.

Another experiment in this environment is the demonstration of the adaption of charging rates of the electric vehicles for supporting frequency recovery. In order to experiment this, a basic control algorithm communicating with the simulated electrical grid is needed. An additional experimentation step (related to WP2) will include control and communication simulation. This task will be conducted in parallel to the above task and requires further development and implementation effort.

5.3.4 Simulation

The power grid will be simulated for this experiment. The EVs will be represented as pure batteries. Models for those batteries will be included in the simulation.

5.3.5 Real structure

The power system used for this experiment is derived from an industrial practice of energy storage modeling [8] as shown in Figure 18. It consists of an aggregated generator model representing the generation units and an aggregated load model representing the traditional load without battery energy storage system connected to the distribution bus. In order to study the impact of connected electrical vehicles in this model, a battery energy storage system to represent the aggregation of EVs additionally connected to the bus will be considered.

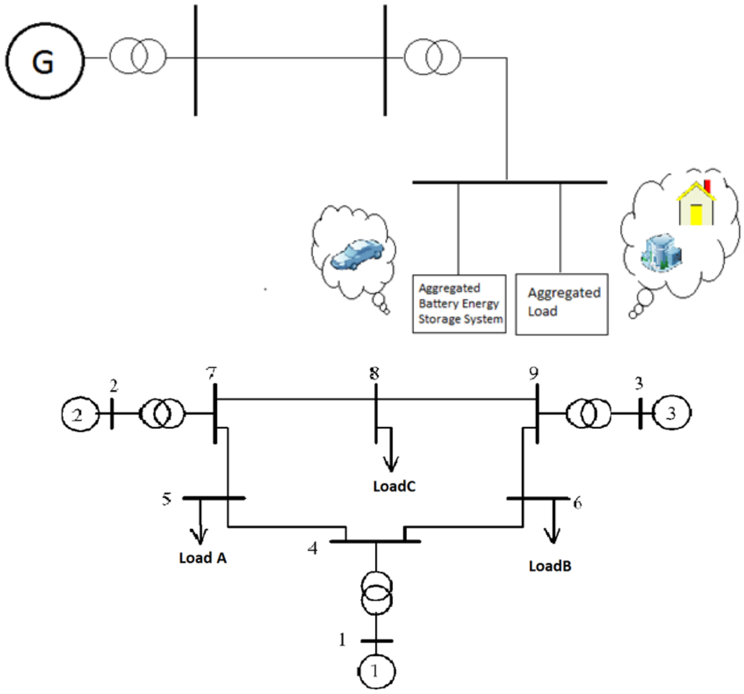

Figure 18: Single line diagram of power system with energy storage test case

The power system model is implemented in the RTDS® (Real-Time Digital Simulator), which is a fully digital electromagnetic transient power system simulator. The simulator works in continuous, sustained real time. That is, it can solve the power system equations fast enough to continuously produce output conditions that realistically represent conditions in the real network. This is a significant advantage over traditional simulation platforms such as MATLAB (Matrix laboratory) and PSPICE (Power Simulation Program with Integrated Circuit Emphasis) and PSASP (Power System Analysis Software Package), in which the simulation is done in a time rate depending on the computational capabilities of the machine. Using RTDS for real-time simulation provides the basis for a further step which includes real communication interfaces. In addition, the RTDS-racks-based models represent the system performance over a large frequency range (DC to approximately 3 kHz). With this frequency range, the RTDS Simulator is an ideal tool for thoroughly analyzing power systems phenomena [9].

In order to adapt the charging rates of the electric vehicles for supporting frequency recovery, the vehicles or charging stations have to receive control signals from an external control unit, i.e. a control center. The planned first step of the control loop consists of generating and sending of the control signals. An external control platform computes the required signals based on information received from the transmission system. As a first implementation aiming at proving the concept, the information from the transmission system can be assumed to be non-real-time or available directly to the control unit. In a later step the control platform can receive this information directly via real-time measurements for closing the control loop.

For this additional experimentation step that is related to the work package distribution network, the following is planned: Via the GTNET (Giga-Transceiver Network Communication Card) interface of RTDS, communication can be set up towards external devices. The control strategies as described above will be implemented on an external PC. The derived control signals shall be sent to the simulated and aggregated models of electric vehicles through the RTDS communication interface GTNET. This interface provides a real time communication link to and from the simulator via Ethernet [10]. GTNET can support several communication standards such as IEC 61850 GSE binary messaging and IEC 61850-9-2 sampled values or DNP. It is envisaged to set up the communication for this use case experimentation via DNP3.0.

An OPC server can be used on the interface between RTDS and the external PC. OPC (Object Linking and Embedding for Process Control) is a software interface standard that allows Windows programs to communicate with industrial hardware devices [11].

5.3.6 Requirements for a real test

A lot of EVs (connected to the power grid) are necessary to study the impact of a huge amount of charging EVs to the grid stability. EVSEs are necessary to demonstrate the adaption of charging rates and a management system is needed to control this intelligence charging process.

5.3.7 Type of services that can be used

One kind of service is the controlled turn on/off of the EVSE in the event of a significant fluctuation in grid frequency. Another user service is the price related charging process of the EV. By using this DSE at home the battery of the EV can be also used as home energy storage device.

5.3.8 Schedule

The modeling and rating of electrical power system including power storages, i.e. EVs or batteries, in RTDS should be done by end of November 2012.
The final set-up of experimentation should be also done end of November 2012.
The definition of the evaluation scenarios for the integration of power storages should be done mid of December 2012. A number of different scenarios will be considered and run to evaluate the potential contributions of the aggregated EV / battery model to improve power system frequency stability. The simulation should be finalized during December 2012.
The simulation results should be ready end of January 2013.

5.3.9 Expected Results

The charging of a huge amount of EVs or batteries could / should influence the power grid stability, including the grid frequency. This behavior can be monitored. Furthermore the relationship between the amount of connected batteries (connected capacity to the power grid) and the power grid stability can be established.

5.3.10 Competition

The EVSE and the batteries are the basic elements of the E-Mobility and cannot be replaced by another infrastructure or DSE.

5.3.11 Part of the business that is going to be examined

New businesses like vehicle to grid or energy storage are imaginable by introducing the EV batteries as storages for the grid support (via the EVSE).

5.3.12 Expected problems

Problems can occur if the development of the battery models takes more time than expected or the integration of the batteries in the virtual power grid at the ACS simulator together with the control algorithm that has to be developed is critical in the limited time.

5.3.13 Comments

The experimentation examines the influence of batteries to the stability of the power grid. This is a necessary prerequisite for the introduction of the respective DSE (the EVSE).

5.4 DSE WP6: Demand side manager

The goal of the "Demand Side Manager (DSMgr)" DSE is to manage the DSM signals from the operator side to the home area network (via a device control system) in order to influence the flattening of the demand curve of the energy consumed in some areas. This is only possible with an entity (normally software agent) in each electrical installation (buildings, houses ...) that can ensure security and effective programming of the appliances to avoid any inconvenience.

To test thoroughly this DSE is thus needful to perform experiments ranging from physical collection of power consumption data to their use to flatten the electrical demand curve in a specific area and/or emulate the consequent eMarket4E trading and forecasts.

The purpose of the two experimentations here following proposed (BeyWatch [12] and Energy@home [13]) is to verify demand-response using market mechanisms, which helps to prevent problems with the electricity grid with ICT in both markets B2C (influencing the contract schemes established between the customers and the Grid Users) and B2B (managing business relationship between grid users, electricity providers and demand-side managers).

The BeyWatch emulation environment and the Energy@home physical infrastructure are here described in separate paragraph in order to avoid confusion between real and emulated parameters.

Anyway their contributions are very synergistic to cover the complete testing of this DSE: while Energy@home is mainly focusing on the development of a communication infrastructure that enables provision of Value Added Energy Services in the Home Area Network (HAN), BeyWatch extends the scope from single homes to full neighborhoods.

5.4.1 BeyWatch

5.4.1.1 Set-up of the Experimentation Lab for testing the DSE

For FINSENY, the BeyWatch (http://www.beywatch.eu) experimentation lab results will be used in order to derive the conclusions and results for the defined DSEs for the demand side manager. During the BeyWatch experimentation phase a lot of information was generated, but its analysis was done for fulfilling the project requirements.
Now, the huge amount of data generated during this experimentation can be analysed from FINSENY demand side manager DSE point of view. So, no new experimentation is going to be done, but the analysis of the existing data.

Several tests were done in order to tests how demand side signals were attended by the hole BeyWatch system, but there were not analyzed from the point of view of providing a DSE for the management of these kind of signals. This analysis is going to be done during the FINSENY experimentation phase I.

5.4.1.2 Description of the scenario

The experimentation to be done by BeyWatch is going to be an emulation using real measurements from the BeyWatch trial in Paris.

The French pilot trial took place on the EDF R&D “Les Renardières” premises that integrate a test facility named the “multi-energy house” that can be used to test energy systems for homes in real-life conditions (real weather, real systems, real occupants, etc.).

Figure 19: EDF R&D Les Renardières Multi-energy House Test Facility

This multi-energy house is already equipped with solar and PV panels; it has a kitchen that can be equipped with a BeyWatch energy aware dishwasher and fridge. In the garage, there is enough room for an energy aware washing machine and a solar hot water tank.

Figure 20: The EDF R&D Multi-energy House

5.4.1.3 Experiments

In the next table there are enumerated the experiments to be done by this laboratory.

Intended experiments	Type of experiments	Way of conducting the experiments
User is informed on the DSM signals, incentives/counter incentives and re-scheduling. The user can then reject or accept them.	Emulation using real measurements from the BeyWatch EDF trial in Paris	The DSE receives a DSM signal, the incentive/counter incentive signals, the new scheduling and are shown to the user GUI according to the contract. By default the signals are accepted by users have the option to reject them. 1. The user doesn't do anything, the new schedule is applied. 2. The user accesses the GUI and rejects the re-scheduling.
Flatten demand curve	Emulation using real measurements from the BeyWatch EDF trial in Paris	1. One DSM signal is sent to several households in a defined area. 2. By default, these signals are accepted by the user

Table 18: List of experiments to be elaborated by BeyWatch

In the next figure there is a schema of the experimentation. There are two experiments to be done, both of them like an emulation using real measurements from BeyWatch EDF:

- User is informed on the DSM signals, incentives/counter incentives and re-scheduling. The DSE receives the DSM signal and show them to the user GUI according to the contract. The user can then reject or accept them. By default the signals will be accepted, to reject them the user must access the GUI. The expected output is to see whether the new schedule is activated or not depending on the user decision.
- Flatten demand curve. One DSM signal is sent to several households in a defined area, and by default it is accepted. As a result the overall demand curve is changed.

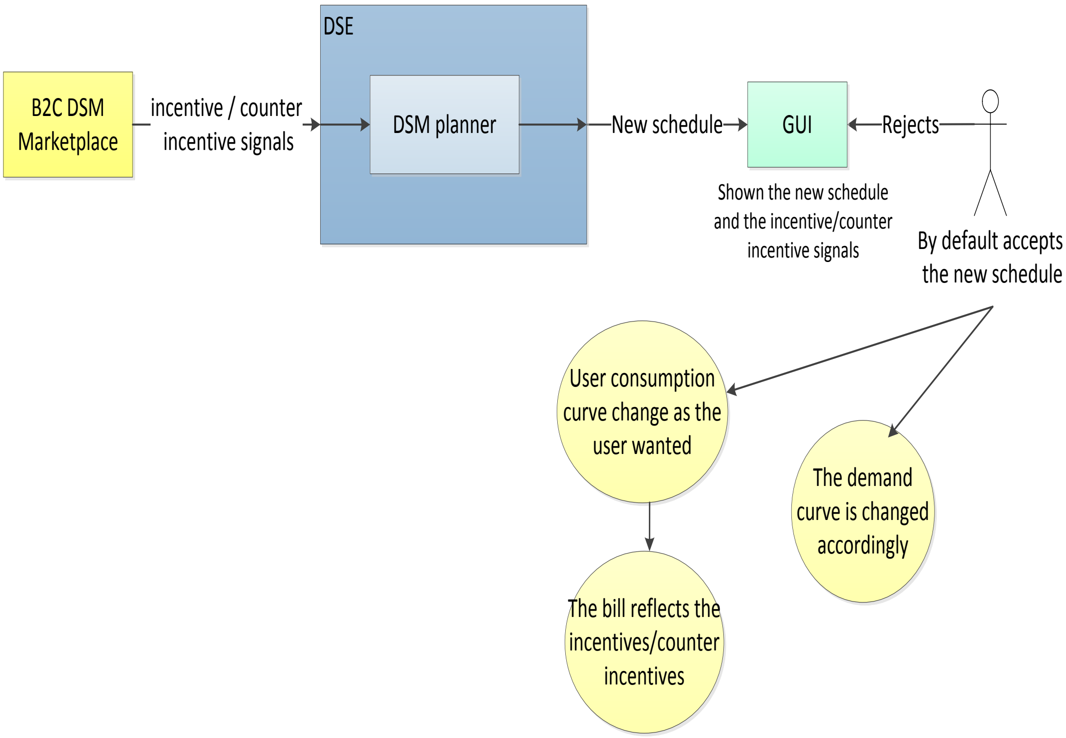

Figure 21: Experimentation schema

5.4.1.4 Simulation

In this case, as it is going to be emulation, all the experimentation is simulated.

With the data obtained in the experimentation in EDF in Paris there are going to be predicted the results to the listed experiments.

As the energy cost is the main function that is optimized by the BeyWatch agent and also the value type that been found to assess the flexibility in energy use that is brought by BeyWatch, it is important to use a price schedule that can reveal it and that looks realistic in short / middle term.

For the evaluation a dynamic tariff following the spot tariff that has been be registered in France at the time of the tests, assuming that the tariff to the customer is following roughly the same price curve (but with higher level of prices).
The BeyWatch system had been installed and remained under almost continuous operation and monitoring for a period of approximately 7 months up to August 2011. In this period, a significant amount of data (more than 50GBytes) was collected from various probes. A particularly interesting kind of trace is the set of "exercise" files which were created by the BeyWatch Agent over the course of its operation for a number of appliances. In short, these

exercise files (and their accompanying solution files) represent scheduling tasks which were given to the BeyWatch Agent together with the solution the Agent arrived at.

The interesting thing about these files is that the exercise file also captures the state of the system at the time when the optimization problem was solved (they are, in a sense, a "core dump" of the system's state). This enables testers and developers to take any such single pair of files (the "exercise" file and the "solution" file that accompanies it), examine it without access to the "real" system and still draw pertinent conclusions as to whether the optimization scheduled was effective or not. In fact a visualization application was developed just to aid this procedure. The exercise files logged in the system's auditing hard drive numbered several tens of thousands at the end of the trial period.

Among the experiments done, the relevant to this DSE are the results to the tests of:

- the impact on the application on the dynamic tariff
- the impact of a power cap of a dynamic tariff

And the cases:

- Cost savings for washing machine and dishwasher
- Cost-determined scheduling for a number of appliances

5.4.1.5 Real structure

As it is going to be based on emulation, there is no real structure. The real structure used to the previous experimentation is already shown in section 5.4.1.2.

5.4.1.6 Requirements for a real test

For a real test there would be needed the real structures explained in previous sections. A neighbourhood with the technology needed, and all the houses conditioned with the user GUI to be able to control the consumption, agents to control the signals and a supervisor.

5.4.1.7 Type of services that can be used

The services applied at this “Demand Side Manager” DSE experimentation in BeyWatch are:

- <u>Acceptance by the user of the DSM signals</u>: The DSE receives a DSM signal, then, the incentive/counter incentive applicable for the final user and the new scheduling of the electrical appliances are shown to the user GUI according to the contract. If no answer from the user is received, the system accepts DSM signal by default, but the user has the option to reject them and DSM signal to be ignored.
- <u>Flatten the electrical demand curve</u>: DSM signals are sent to several households in a defined area where the demand curve is willing to be flattened. It is supposed that most of the household will accept them as it would have several incentives for the user. At the end the demand curve is flattened during peak hours.

5.4.1.8 Schedule

The described experimentation in BeyWatch remained under almost continuous operation and monitoring for a period of approximately 7 months up to August 2011. In this period, a significant amount of data (more than 50GBytes) was collected from various probes.

The final set-up for the information extraction from the big data set and their transformation into an understandable structure for further use (*data mining*) should be done by mid of December 2012.

The complete results coming from the data mining should be ready by end of January 2013.

5.4.1.9 Expected Results

From the above described experiments, the expected results are:

- The information about the DSM signals, incentives/counter incentives and re-scheduling available in the user GUI is compliant with the output of the DSE and provides a clear overview of what a customer is able to obtain from a B2C Marketplace as defined in the DSE.
- As a result of the data mining of the information extracted from the existing results and the extrapolation of them, we can outcome a pattern about how this DSE is affecting to the flatten of the energy demand curve.

5.4.1.10 Competition

As the demand side management is an increasing business in diverse sectors of smart grids, growing competition of solutions performing similar functionality is shown. Moreover, a lot of investment is being done in this sense and expectation is to continue in this sector.

5.4.1.11 Part of the business that is going to be examined

New business actors and relationship between stakeholders affected by the demand side management are involved with this DSE.
In the scope of WP1 exploitation work the business models resulting from the demand side management will be investigated.

5.4.1.12 Expected problems

There are not expected problems for this experimentation as the data that is going to be analyzed is already available from the already done experimentation in the BeyWatch project.

5.4.1.13 Comments

The results and outcomes from the experimentation could be extrapolated in order to consider a large amount of households needed, in real cases, for the flattening of the electricity demand curve.

5.4.2 Energy@home

NOTE: In the following sub-paragraphs, many of the requested information have already been given in section 5.2.2**.** To avoid making this document verbose and repeated, from time to time it will be redirected to that chapter.

5.4.2.1 Description of the Experimentation Lab

A detailed description has already been provided in section 5.2.2.1. With references to Figure 22, the only differences for the "*Demand Side Manager*" DSE are:

- From the final customer side, the Energy box is simply replaced by the Home Residential Gateway that allows data exchange, through Internet, between the devices operating in the Home Area Network and the Remote Service Platform.
- From the demand side manager side, the Remote Service Platform hosts powerful software requested by the DSMgr services. In other words, unlike the scenario shown in section 5.2.2.1, here great part of the "*intelligence*" to manage this DSE has moved from the Energy Box (*Home Gateway+OSGi*) to the Remote Service Platform.

5.4.2.2 Description of the scenario

A detailed description has been provided in section 5.2.2.2**.**

5.4.2.3 Experiments

This DSE takes into account possible requirements to be provided by different ongoing projects aimed to define the future interactions between clients and electricity market. In the scope of those projects, the clients shall be presented with daily (or even hourly) offers coming from other actors and aimed to modify clients' behavior. Offers shall be probably issued by a new player in the energy market called the Aggregator, which has the mission to aggregate many small clients and to operate into the energy market presenting them as a whole. The Aggregator shall reply to market needs offering services such as:

- Power limitation within a given geographical region and temporal slot.
- Peak clipping.
- Peak shifting.

To assure clients' participation to the services, the Aggregator shall provide them with offers, for example providing them with a remuneration for power reduction within the required temporal slots. To achieve this goal there should be a mechanism to provide the clients with the offer details (temporal slot, needed reduction, remuneration mechanism, etc.), which are generally indicated as price/volume signals. For example the Aggregator could require its clients to limit the power below 2 kWh between 14.00 to 16.00, granting a remuneration for those who accept the offer. It is also possible that the same energy retailer could play the aggregation, hence offering discounts on energy price.

In addition to the list of the experiments described in section 5.2.2.3 the Energy@home trial provides, for this DSE, through the remote service platform, the following experiments:

1) <u>Demand response management</u>

In this experiment the Aggregator, in order to perform power limitation within a given geographical region and temporal slot, (*through peak clipping or peak shifting*), send to the devices within the HAN info about price/volume. The Home Gateway hosts the application that allows the aggregator to provide price/volume signals to the devices within the HAN.

2) <u>Multi-tariff energy use remote optimization in case of smart and non-smart appliances</u>

This experiment provides a remote optimization of appliances usage in order to optimize energy cost according to the variable energy tariffs. This experimentation is meaningful for all those appliances which are activated by the customer and perform a specific operating cycle, such as a washing machine, oven and dishwasher. The most important exception is the fridge, which operates continuously. This automatic and remote control, may however be resumed under the control of the end customer at any time through its customer interface. In fact, the Home Gateway provides a WEB customer interface for these functionalities in case that the customer moves from outdoor remote operations to the indoor ones.

3) <u>Historical data management</u>: the Remote Service Platform stores all the electrical loads energy consumption. A software is used to filter and aggregate the received data in order to interpret and represent graphically them. The Home Gateway can access at those data and present them to the user through a browser for the remote consultations. Historical data management is very important to raise awareness of the final customer on the optimization of consumption and, at the same time, it serves to update the "*intelligence*" of the DSM DSE to learn better the habits and the future customer needs.

5.4.2.4 Simulation

All the experiments described above make use of real data coming from private houses. The received data are then applied to the following two software components:

- The first software is used to filter and aggregate the received data in order to interpret and represent graphically them.
- A second software, starting from the real coming data, simulates the energy costs for the final customer as function of the daily period of use in the multi-tariff environment

5.4.2.5 Real structure

NOTE: the difference between the architecture shown in chapter 5.2.2.5 and the one shown in Figure 22 is due to the fact that here the "*intelligence*" to manage the "demand side manager" DSE has moved from the Energy Box (*Home Gateway+OSGi*) to the Remote Service Platform.

The reason of this is simple: in certain SW applications, the Demand Side Manager DSE requires more power computation than was available in the Home Gateway.

The Remote Service Platform actually running on servers in Innovation Lab (*Telecom Italia Lab in Turin*) and it is planned to be moved on Telecom Italia Cloud Computing Services).

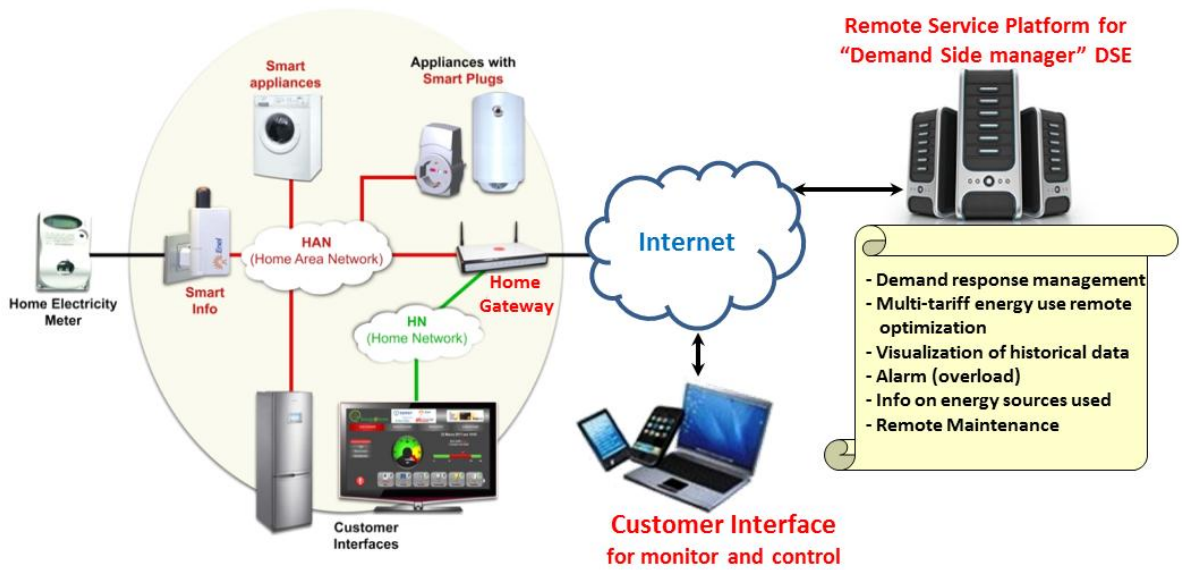

Figure 22: Real structure for the experimentation plan

For the rest of the real structure parts the description is the same of the one in section 5.2.2.5.

5.4.2.6 Requirements for a real test

For the real test of the "Demand Side Manager" DSE is needed:

- A HW remote service platform to support the software needed to run the test of the "Demand Side Manager" DSE.
- A SW running on the remote service platform to provide services such as: demand response management, multi-tariff energy use remote optimization, visualization of historical data, alarm (overload), info on energy sources used and remote maintenance.
- In each private house hosting the "Energy@home KIT" that is equipped as follows:
    - 1 Smart meter.

- 1 Smart Info.
- 1 Energy Box.
- 5 smart plugs with a local meter, a switch, and radio communication.
- 1 smart appliance with embedded radio communication.

5.4.2.7 Type of services that can be used

The services applied at this “Demand Side Manager” DSE experimentation are:

- Demand response management: it acts a mechanism to manage customer consumption of electricity in response to supply conditions, for example, having electricity customers reduce their consumption at critical times or in response to market prices.
- Multi-tariff energy use remote optimization: it provides an optimization of appliances usage in order to optimize energy cost according to the variable energy tariffs. This is meaningful for all those appliances which are activated by the customer and perform a specific operating cycle, such as a washing machine, oven and dishwasher. The most important exception is the fridge, which operates continuously.
- Visualization of historical data: this service provides customers historical and statistical information on their energy consumption, disaggregating the global energy time variations with the one coming from the single Smart Appliances. The Remote Service Platform allows the storage of the total and single appliance’s energy consumption. The Home Gateway can access and aggregate those data to present them to the user through a Browser. The Home Gateway allows external applications in the HN to retrieve the stored data.
- Info on energy sources used: through this service, the energy retailer could deploy an application able to provide clients with the energy sources mix used to supply his/her appliance, specifying the percentage of renewable sources, the CO2 footprint and similar information. This allows to increase the final customer ethical awareness.
- Remote Maintenance: thanks to this remote service, if the customer experienced some problems with the home energy management, a Web application on the Home Gateway could present the status of the HAN including the devices list, the devices status (i.e. joined to the HAN but not responding), etc. Also warning and alarm could be activated in case of communication problems.

5.4.2.8 Schedule

The whole Energy@home experimentations in progress, that includes the “Supervisory control” and “Demand Side Manager” DSE has begun on December 2011 and it will be analyzed a period of un year, that means to get the coming real data coming from 30 private houses till November 30th, 2012.

The final set-up for the information extraction from the big data set and their transformation into an understandable structure for further use (*data mining*) should be done by mid of December 2012. The complete results and interpretations coming from the data mining should be ready by end of January 2013.

5.4.2.9 Expected Results

From the above described in the experimentation plan, three results are expected:

- To receive on the customer interface a signal about price/volume of energy coming from the Aggregator coming from remote location.
- To obtain a remote optimization of appliances usage in order to optimize energy cost according to the variable energy tariffs and to resume the remote control through the customer interface.

- To use the historical data stored on Remote Service Platform to raise awareness of the final customer on the optimization of consumption and, at the same time, to update the "intelligence" of the DSM DSE to learn better the habits and the future customer needs.

5.4.2.10 Competition

From day to day growing competition between producers of platforms HW/SW that perform functions similar to those described here for the "Demand Side Manager" DSE. A list of these competitors is too long to report here and, anyway, it can easily found with an Internet search.

In confirmation of this, in diverse sectors of smart grids, more and more investment and market focus is shifting toward customer engagement and developing business models that can take advantage of the enhanced demand side management capabilities smart grid platforms provide, particularly when it comes to enhanced energy conservation, improving energy efficiency and reducing carbon dioxide and greenhouse gas emissions. Expect this trend to continue as the industry looks ahead to greater deregulation.

5.4.2.11 Part of the business that is going to be examined

This "Demand Side Manager" DSE embraces a huge number of business aspects related to the future energy market. For this reason the HW/SW platform based on the "Demand Side Manager" DSE will always be more requested and today we are seeing a growing number of OEMs interested in the production and sale of platforms for the DSM. The reason is simple: the DSM is convenient for everybody from the producer, retailers and final customers. In fact it contributes at the power system security and at the electricity market efficiency as follows:

- Time of Use Pricing: this approach shifts power consumption from peak periods where the probability of high market prices and transmission congestion are high.
- Real Time Pricing: this demand-side control strategy allows the load to reallocate energy utilization to lower market price hours and when power transmission usage is lower.
- Demand-side Bidding: this category assists the system operator in maintaining generation-load balance and in managing of zonal congestion; tends to lower the operating cost of the consumer and demand-side assists in alleviating generation resource shortage.
- Direct Load Control: this strategy employs the usage of automated controls to reduce or curtail demand consumption during the occurrence of price spikes.
- Interruptible Load Program: demand is reduced or cut-off from the grid to maintain secured system operation during emergencies where system continuous service can be put at risk. System operators can utilize interruptible load for economic benefit and eliminating system operating constraints.

5.4.2.12 Expected problems

The performance of this DSE experimentation depends from the computing power of the Remote Service Platform. This computing power demand increases with the increase of the number of end-users who use this platform. In particular, when multiple users require services that involve the use of heavy algorithms it was observed a drop in performance of response times. This means that in future, the switch from the testing phase to the one on large scale service will be necessary to use structures of cloud computing. Precisely for this reason short will move the Remote Service Platform from the servers in Innovation Lab (*Telecom Italia Lab in Turin*) to the Telecom Italia Cloud Computing Services.
Last but not least, also for this DSE remain the problems described in section 5.2.2.12.

5.4.2.13 Comments

The testing of this “Demand Side Manager” DSE will subsequently receive more validations thanks to the Energy@home Association that has been founded and registered as legal non-profit association. The goal of the association is to promote technologies and services for the home energy efficiency and for the proactive participation of the end users. The association will leverage technical specifications and test results of the running project but it will also extend past activities to cover new use cases and new technologies. The Association is open to any company and anyone who is wishing to contribute to its purposes.

6. Conclusion

The five domain specific enablers (DSE) selected are a representation of the scenario work packages in FINSENY that have been selected from an initial list of identified DSEs by using a feasibility study performed in WP8 as described in chapter 3.

These DSEs have then been analysed to find how they could be experimented in one or several of the already existing laboratory facilities in FINSENY consortium, considering both real test and simulated one, in order to have a first test of the practicability of the DSEs for the phase II of the FI-PPP program focused in early trials.

Based on this analysis, this deliverable reports the experimentation plan for the DSEs in the different laboratories that will be performed during the last months of the FINSENY project. This plan contains practical information that will be the base to start the experimentation, setup of the laboratories, requirements needed to cope with the identified experiments, expected results, etc. as detailed in chapter 5.

This deliverable will be the input for the next task in work package 8 (task 8.4) that will perform the identified experiments and will outcome the experiment results that will be a useful input for the realization of the trials in phase II.

7. References

[1] General FINSENY Glossary of Terms v2.4
[2] Summary of Key Concepts in FI-WARE Vision - available at: https://forge.fi-ware.eu/plugins/mediawiki/wiki/fiware/index.php/FI-WARE_Product_Vision
[3] FINSENY deliverable D2.1: Distribution Network Scenario use cases
[4] FINSENY deliverable D3.2: Interim results: Data models, interfaces and key building blocks
[5] FINSENY deliverable D5.1: Electric Mobility Scenario building blocks
[6] FINSENY deliverable D7.2: ICT Requirements specifications
[7] FINSENY deliverable D8.1: Set-up of FINSENY Experimentation Lab.
[8] http://www.forosing.cl/neo_2011/pdf/2010/6oct2010/MODULO4/5.pdf
[9] http://www.rtds.com/applications/high-speed-power-system-studies/high-speed-power-system-studies.html
[10] http://www.rtds.com/hardware/gtnet/gtnet.html
[11] http://www.opcdatahub.com/WhatIsOPC.html
[12] BeyWatch project: http://www.beywatch.eu
[13] Energy@home project: http://www.energy-home.it
[14] INTEGRAL fp6 project: http://www.integral-eu.com/