D3.1 Initial S4G Components, Interfaces and Architecture Specification

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Lead Editor	**UPB**
Main Contributors	Jinyong Fu, Riccardo Tomasi **(ISMB),** Vasco Delgado-Gomes **(UNINOVA),** Gitte Wad Thybo **(ENIIG),** Gustavo Aragon **(FRAUNHOFER),** Giovanni Paolucci **(EDYNA),** Rasmus Mosbaek **(LIBAL),** Mihai Sanduleac, Mihaela Albu, Marta Sturzeanu **(UPB)**

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Document History

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0.1	2017-06-12	UPB	First TOC proposed
0.2	2017-06-20	ISMB	Document restructured following ISO/IEC/IEEE 42010:2011
0.3	2017-06-30	ISMB,UPB	Added component views;
0.4	2017-07-06	LIBAL	Added component, and comments
0.5	2017-08-09	ISMB	New version incorporating results from the Bonn Plenary meeting
0.6	2017-08-14	LIBAL	LIBAL inputs
0.7	2017-08-23	UNINOVA	UNINOVA inputs
0.9	2016-08-15	UPB	Version Ready for internal review
1.0	2016-09-15	UPB	Final version, ready for submission to the EC

Internal Review History

Review Date	Reviewer	Summary of Comments
2016-09-05 (v1.04)	Vasco Delgado-Gomes (UNINOVA)	Approved: • Comments on section 6 needs to be address. • Not all the figures appear in the list of figures • Some acronyms are missing in the table • Missing the Conclusions section • General minor corrections for better readability
2016-08-15 (v0.9)	Giovanni Paolucci (EDYNA)	• General minor corrections for better readability

Table of Contents

Executive Summary

D3.1 describes the "Initial S4G Components, Interfaces and Architecture Specification" serving the objectives of the Storage4Grid project. This document is meant to provide the initial view of the system architecture developed in S4G, consolidating the work and developments as analysed and specified until M9 of the project.

Its main goal it to define a common architectural and technical framework that facilitates the work during all the subsequent development, integration, operation and exploitation phases in the project, and communication among S4G stakeholders both within and outside the project. Component views serve the purpose of identifying the main functional (software or hardware) components providing the S4G features. Functional views are recalled as associated with the three high level use cases and their foreseen deployment in the three demonstration locations (Bolzano, Fur, and Bucharest). Information view includes a description of main functional interfaces among high-level components within the Storage4Grid system. Finally, the communication layer identifies the optimal channels and protocols and is presented making use of deployment diagrams.

Specifications described in this document have been collaboratively derived by the Storage4Grid consortium, drawing inputs and requirements from the high-level scenarios, use cases documented in [S4G-D2.1] and requirements documented in [S4G-D2.5] as well as from the Description of Action (DoA) i.e. the contractual agreement signed by the consortium with the EC.

Diagrams included in this document use standard formatting including Unified Modelling Language (UML)-compliant[i] formats (Class, Component, Deployment or Sequence diagram).

Standards are described and adopted across all the different views, according to their relevant domain. Nevertheless, since the adoption, analysis and pre-design of standard protocols and data models is a key objective of S4G, a dedicated "cross-cutting" section (Section 8) has been defined to provide an overview of standards adopted and analysed across all the different S4G layers.

1 Introduction

This deliverable document the design and architectural specifications for all the tangible outcomes of the Storage4Grid project, ensuring proper mapping towards EU and International Smart Grid standards.
Its main goal it **to define a common architectural and technical framework** that facilitates communication during all the subsequent development, integration, operation and exploitation phases in the project.
Specifications described in this document have been built in collaborative fashion by the Storage4Grid consortium, drawing inputs and requirements from the high-level scenarios, use cases documented in [S4G-D2.1] and requirements documented in [S4G-D2.5] as well as from the DoA i.e. the contractual agreement signed by the consortium with the EC.

1.1 Formalisms and formats adopted in this document

This document follows the general definitions and guidelines specified in the ISO/IEC/IEEE 42010:2011(E) standard[ii], and it is therefore organized in multiple *architecture views*, each associated to a dedicated section of this document.
The sets of architecture views represented in this document has been chosen to match the Reference Architecture Elements defined by the Smart Grid Reference Architecture (SGAM) Framework[iii], namely the Functional, Information, Communication and Component Architecture. In general, all SGAM definitions for Interoperability Layers, Domains and Zones are used whereas applicable. The Business Architecture of the system has not been described in this document, as it is delegated to other documents issued by Storage4Grid, particularly D2.3 “Initial Business Models” and D2.4 “Final Business Models”.
Diagrams included in this document are use standard formats including: Unified Modelling Language (UML)-compliant[iv] formats (Class, Component, and Deployment or Sequence diagram).
According to the normal SGAM-oriented organization, standards are described and adopted across all the different views, according to their relevant domain. Nevertheless, since the adoption, analysis and pre-design of standard protocols and data models is a key objective of S4G, a dedicated “cross-cutting” section (Section 8) has been defined to provide an overview of standards adopted and analysed across all the different S4G layers.

1.2 Reading Guide

Architectural documentation structured in multiple views can be rather complex. In order to help readers in quickly finding their architectural concerns of interest in this document, Table 1 providers on overview of the key topics addressed by this and associated documents.

Table 1 - S4G Architecture Reading Guide

Topic	Doc.	Relevant Section
Generic functionalities provided to users (or to other components) by S4G components both individually or as part of integrated configurations	D3.1	Section 2 – “Functional View”
Main software or hardware platforms providing the S4G functionalities and the bonds between each other	D3.1	Section 3 – “Component Views”
Main data models and classes shared by multiple S4G components	D3.1	Section 4 – “Information View”
Main communication protocols used between multiple S4G components	D3.1	Section 5 – “Communication View”
How S4G components should be in general deployed on the field in concrete installations[1]	D3.1	Section 6 – “

[1] *This corresponds to the description of the deployment hypothetically targeted for achievement in the last phase of the project, under the assumption that all the developments targeted by S4G are verified to be feasible and deployable.*

		Deployment View"
What are the security counter-measures adopted in the system	D3.1	Section 7 – " Information Security View"
References to standards adopted or analysed by S4G; identified gaps.	D3.1	Section 8 – "Standards Overview"
Business Models and the possible Business Architecture for S4G outcomes	D2.3	N/A
Which tests and test configurations are planned by S4G in the first phase of the project	D6.1	N/A
Which deployments are planned by S4G in the first phase of the project	D6.1	N/A
Which installation steps have been performed to set-up components during the first phase of the project	D6.4	N/A

1.3 Deliverable Scope

This deliverable documents the results generated by Work Package 3 "S4G Architecture", and more specifically by tasks T3.1 "Analysis of architectures, systems and standards", task T3.2 "Energy Storage System (ESS) Control Specification" and task T3.3 "Decision Support Framework (DSF) Specification".
This document describes the specifications of Storage4Grid systems as analysed and specified until M9 of the project (September 2017). Two further issues are expected to update the information documented in this deliverable, namely D3.2 "Updated S4G Components, Interfaces and Architecture Specification" (due at M21, August 2018) and D3.3 "Final S4G Components, Interfaces and Architecture Specification" (due at M33, August 2019).

1.4 Related documents

ID	Title	Reference	Version	Date
D6.1	Phase 1 Test Site Plans	[S4G-D6.1]	V1.0	2017-07-16
D2.1	Initial Storage Scenarios and Use Cases	[S4G-D2.1]	V1.1	2017-06-08
D2.5	Initial Lessons Learned and Requirements Report	[S4G-D2.5]	V1.0	2017-05-30

2 Functional View

The M/490 framework[2] defines, the Smart Grid Reference Architecture, which includes two main elements: (i) the Smart Grid conceptual model; and (ii) the Smart Grids Architecture Model (SGAM) Framework. The conceptual model provides a high-level framework for the smart grid that defines seven high-level domains, and shows all the communication and electricity flows connecting each domain. It is inspired by the National Institute of Standards and Technology (NIST) conceptual model[3] and completes it by adding two new domains:

a) the Distributed Energy Resource (DER) domain and
b) the Flexibility concept, which groups consumption, production and storage together in a flexibility entity

Both new domains are important in S4G project. Figure 1 summarizes the Smart Grid European conceptual model.

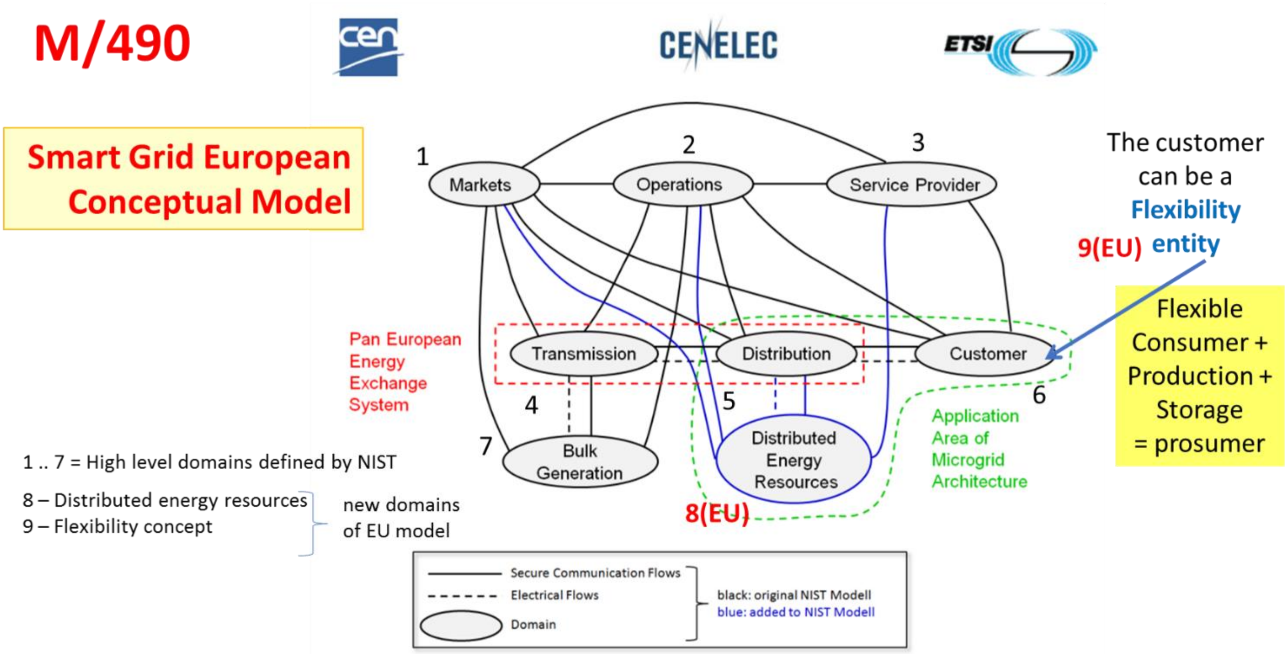

Figure 1 – Smart Grid European Conceptual Model[4]

Figure 1 shows that the domains “Distribution”, “DER” and “Customer” are becoming application areas of new electricity distribution and use architectures, thus being subject of new synergies and services. Initially, prosumers have been defined as dual entities (energy end-user and electricity generation unit) able to provide simultaneously generation and energy use, based on contractual/technical availability of these 2 function. In S4G we extend the concept by including storage as a separate entity to be operated on the same premises/contractual basis of the energy customer; theoretically, a storage unit is a prosumer which is using the same installation (storage and static converter) for providing the prosumer functionalities, however always asynchronously.

The SGAM is an important element of the Smart Grid Reference Architecture, and has been developed to provide a framework for the smart grid architectures. It is an architectural approach, allowing for a representation of interoperability viewpoints in a technology neutral manner, both for the current implementation of the electrical grid and vision of future smart grids. SGAM uses a layered structure, supporting the requirement of interoperability, combining organizational, informational and technical aspects of the smart grid. Figure 2 presents the basic template of SGAM.

[2] http://gridscientific.com/images/Smart_Grid_Reference_Artichtecture.pdf (page 14)
[3] https://www.nist.gov/sites/default/files/documents/smartgrid/NIST-SP-1108r3.pdf (page 135)
[4] http://gridscientific.com/images/Smart_Grid_Reference_Artichtecture.pdf (page 21)

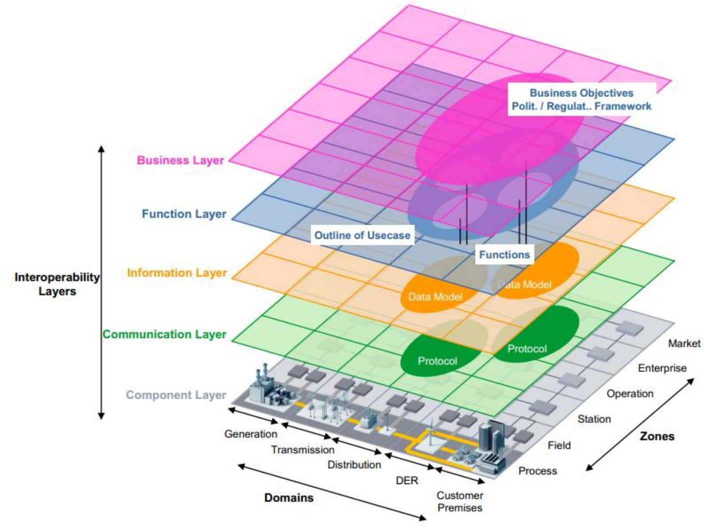

Figure 2 – SGAM template[5]

Although a complete analysis of SGAM mapping is not in the scope of this project, in the following are presented preliminary versions of two of the five layers: the component layer and the function layer, the last one being very relevant to the S4G use-cases.

Figure 3 gives a view of the component layer. All S4G components have been introduced on this layer, as a structured set of possible components which are needed in different high-level use-cases.

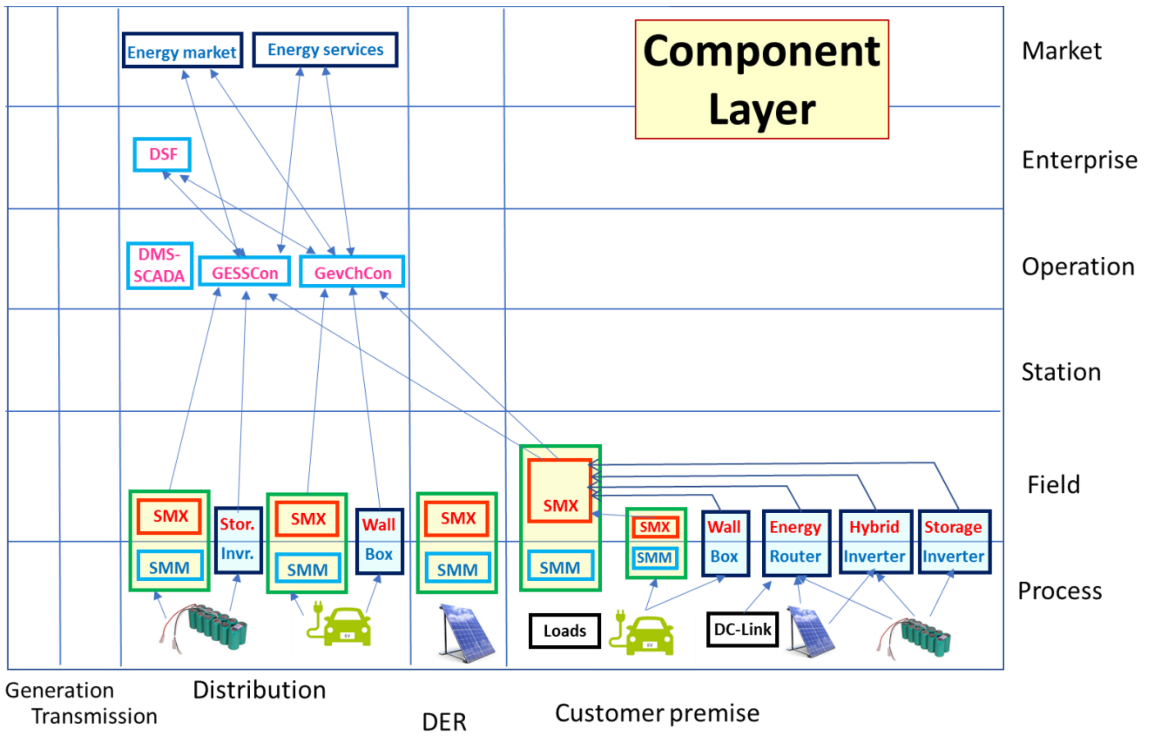

Figure 3 – S4G SGAM Component layer

It can be observed that only three [SGAM] domains are addressed, namely the distribution, DER and Customer premise. All zones except Substation have been also addressed, with most of the components lying

[5] http://gridscientific.com/images/Smart_Grid_Reference_Artichtecture.pdf (page 30)

on Process-field and operation zones (the grid-side storage has been considered as active in the process zone, however it may be a case that it is placed on Substation as well). Moreover, many of the components have two segments, one in the process zone and one in the field zone. Usually in the field zone is the controlling part of the equipment, e.g. the SMX of the USM, the microcontroller part of the hybrid inverter or the energy router. For this reason, some components are placed on both zones.

The S4G technology is also addressing the flexibility, cornerstone of Universal Smart Energy Framework (USEF)[6]. In USEF, the definition of demand response is extended and includes control of local generation units, these two groups of application being coined as Active Demand and Supply (ADS).
It is to be underlined that USEF is based on the assumption that "the new energy system must guarantee that flexibility will be sufficiently available and that peak loads can always be reduced whenever required to maintain network stability. This guarantee should be provided on both the long term and the short term. In current energy market processes to schedule the upcoming period, operators are inclined to ensure the distribution capacity required to support the market as far as possible in advance. This may conflict with the needs of energy suppliers, who prefer to keep flexibility available up to the last moment so they can adapt demand to unpredicted changes in energy production and consumption", which is fully in line with the work and use cases selected for demonstration in S4G

2.1 Overview of Functional aspects

The functional aspects are introduced in this deliverable through the function layer of SGAM, where a general function is associated to each high-level use-case. Detailed functional aspects will be developed in next phases of this deliverable (D3.2, D.3.3).
The SGAM Function layer represents the system design in terms of functionalities and services. The textual descriptions of the use cases that are defined in S4G Deliverable D2.1 are mapped to the SGAM by considering the logical actors that are involved in the high-level use cases. The high-level use case is placed on the smart grid plane in the appropriate parts of the domain and zone area. As next step, the use case can be transformed into an activity graph, which includes the information that is exchanged between actors. At this stage, it is considered a simplified view of the function layer by considering as logical actors the different components running their intelligence (software), thus making them operational for performing as use-case actors. Such logical actors can be considered the USM (with its components SMM and SMX), GESSCon, GevChCon and DSF. The next sub-chapters show for each high-level use case the simplified activity graph with generic interactions between the involved logical actors. Chapter 4 will develop in more details the information exchanged between different components.

2.2 Use case Bolzano – Implementing the function of optimizing and maximizing the EV charging

The high-level use case Bolzano is targeting the maximization the EV charging in an existing grid through the optimisation and the use of storage resources on residential and commercial areas, as pictured in Figure 4.

[6] https://www.usef.energy/app/uploads/ 2016/12/USEF_TheFrameworkExplained-18nov15.pdf#popup__overlay1

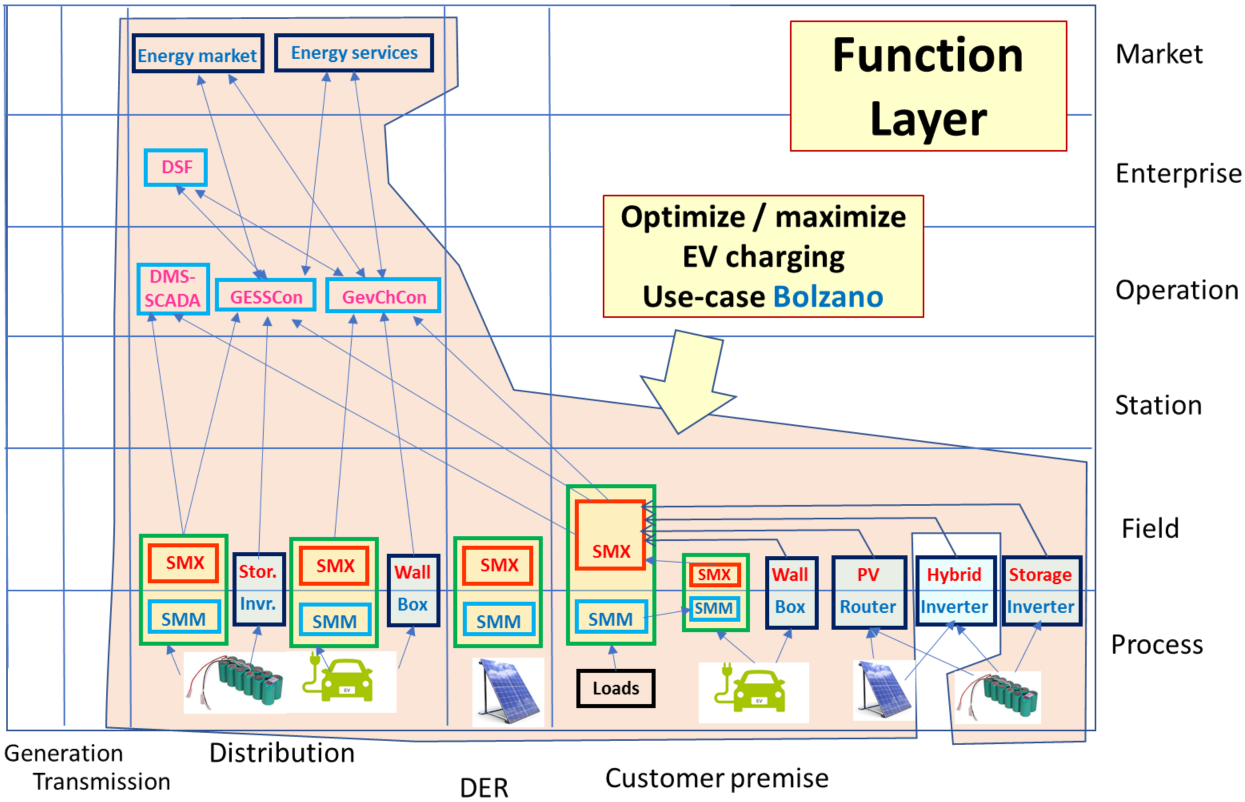

Figure 4 – S4G: SGAM Function layer for the high-level use-case Bolzano

The use-case is the most complex one in S4G and is using practically all components of the project (except Hybrid inverter in the practical implementation, but this logical actor can be also part of the general use-case) located in three of the five domains: *distribution* – for commercial EV charging assisted by distribution-based storage (ESS), *DER* – by considering the EV resource in the commercial area and *customer premises*, by considering a prosumer with charging points, PV production and distinct storage resource. A connection to the market logical actors is also generically considered, as functionality of GESSCon and GevChCon may be influenced by the market conditions. The information exchanged between actors is also only generically represented by arrows, mode detailed description between components being presented in Chapter 4.

2.3 Use case FUR – Implementing the function of optimizing and maximizing the EV chargings

The high-level use case FUR is targeting the maximization the PV integration in an existing or slightly enforced grid, through the optimisation of energy transfer and through the use of storage resources on residential and grid-side.

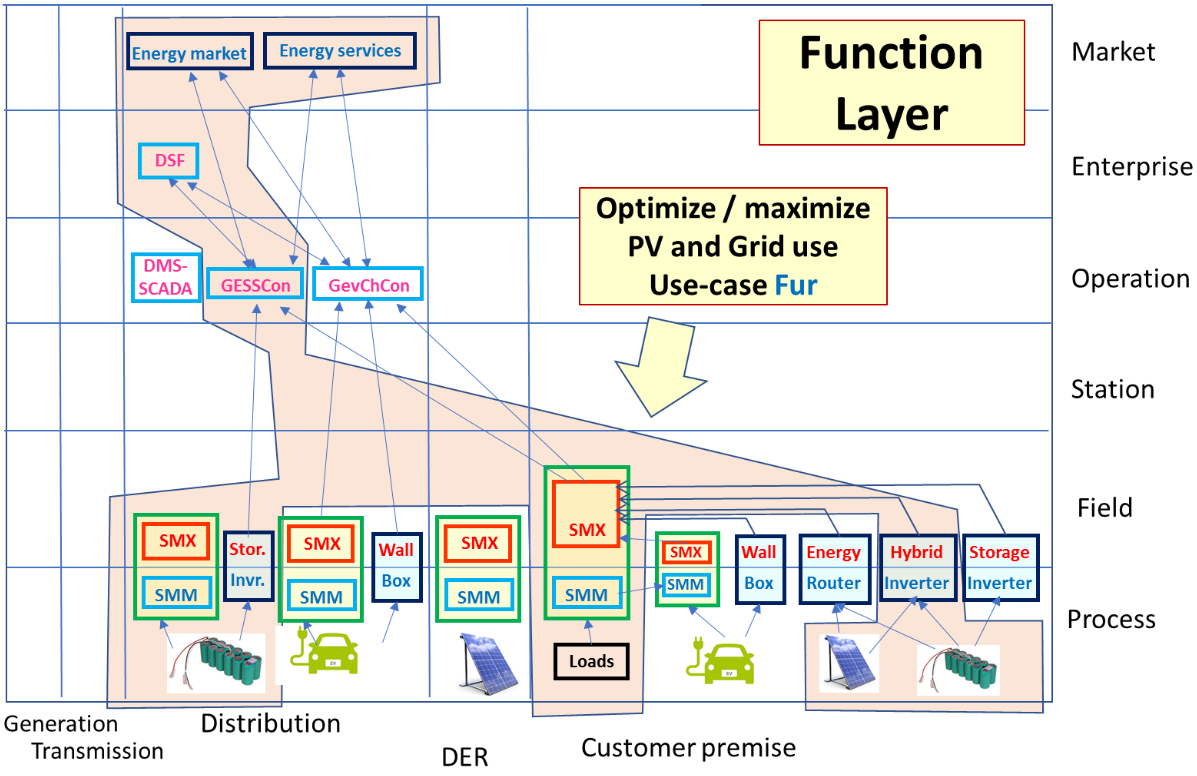

Figure 5 – S4G: SGAM Function layer for the high-level use-case FUR

It can be observed in Figure 5 that the high-level use case is targeting PV and storage at prosumer premises combined with grid-level storage, used for optimizing the grid operation. EV charging and bulk PV at the grid level are not involved.

The use-case is complex; it includes most of the project components (except storage inverter), located in two of the five domains: distribution and customer premises. A connection to the market logical actors is also generically considered, while the GESSCon behaviour can be influenced by the market conditions. The information exchange between actors is generically represented by arrows in Figure 5;, more detailed description of components is presented in Chapter 4.

2.4 Use case Bucharest – Advanced resilient prosumer

The high-level use case Bucharest is targeting an increased resilience of the prosumer using a new energy transfer architecture based on the energy router, a DC bus on the prosumer premises and DC energy exchange with neighbourhoods. The new microgrid functionality intelligently exploits the operation of storage connected to the DC bus of the prosumer. The use case also addresses grid services specific to the prosumer operation such as avoiding curtailment due to high PV production, avoiding congestion in peak hours and black start functionality.

Figure 6 presents the logical actors and their functionality. The information exchange is generically presented, with details given in Chapter 4.

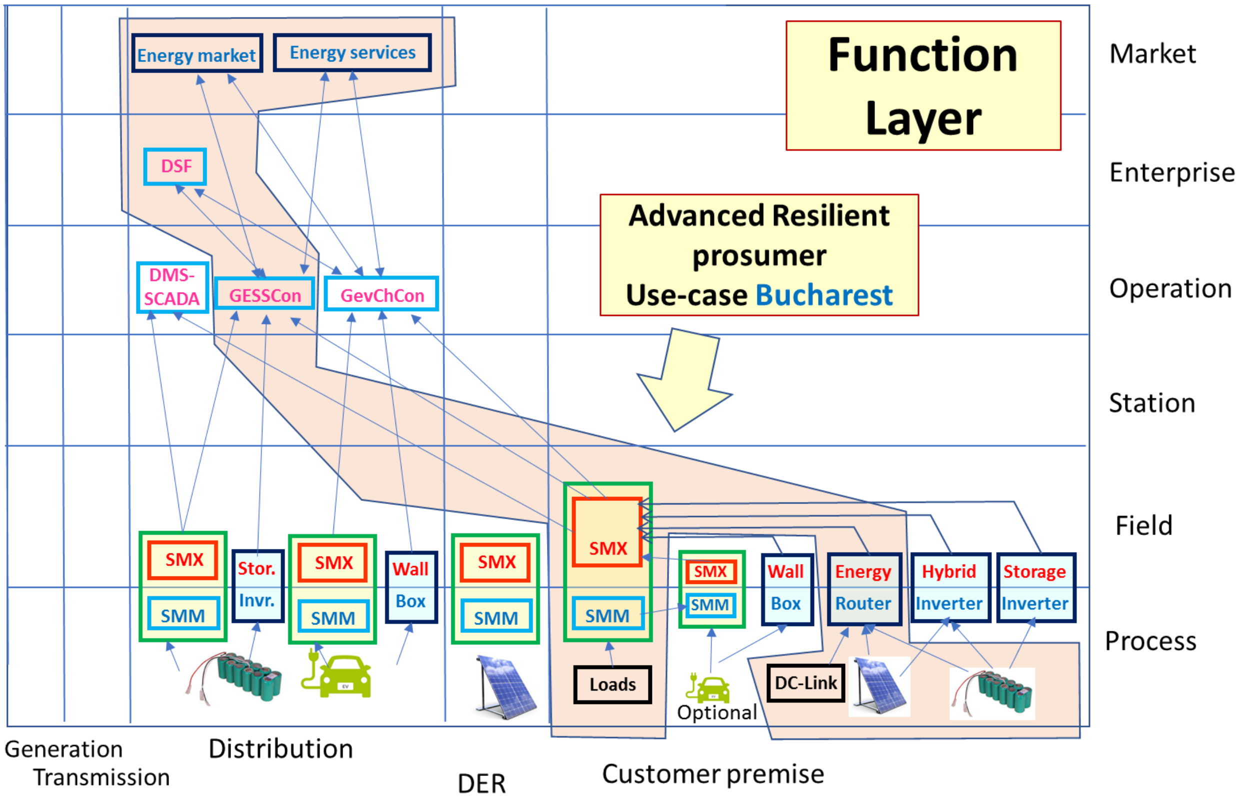

Figure 6 – S4G: SGAM Function layer for the high-level use-case Bucharest

It can be observed that the logical actor "energy router" is in this case replacing the hybrid inverterused in previous high level use-cases, this solution allowing the implementation of the DC bus and the DC link to neighbourhoods.

3 Component Views

Component views serve the purpose of identifying the main functional (software or hardware) components providing all S4G features and explain how they interact with each other from the functional point of view to realize the features described in Section 2 - "Functional View".

This type of view does not aim at reflecting the exact deployment architecture, but rather to outline the functional connections. For example, two components could be represented close to each other and connected by a single interface, even though from the network point of view their communication is mediated by a number of proxies and router components.
In order to make subsequent description easier to understand, a full list of components is summarized in Table 2.

Table 2 - S4G Components List

Full Component name	Short name	Description
Charging Point, Charging Point Wall Box	CP, CPWB	An embedded device controlling a single point of energy delivery used for charging Electrical Vehicles. They can be connected to both public and private (residential) charging points.
Decision Support Framework	DSF	A loosely-coupled collection of interoperable software components which can be combined in different configurations to perform simulation-based analysis, optimization and planning tasks.
DSF Adapter	-	A software component providing interoperability between specific third-party services and other S4G components. It is typically deployed and maintained on the premises of the entity operating S4G-based services (e.g. Distribution System Operators (DSO) or Aggregator).
DSF Data Warehouse	DSF-DWH	A central database used to store all raw data from the S4G deployments. It is installed and maintained either as a private cloud service or in the premises of the entity operating S4G-based services (e.g. DSO or Aggregator).
DSF Simulation Engine	DSF-SE	A software component which is able to execute smart (distribution) grid simulations featuring heterogeneous ESS, loads (including Electrical Vehicles (EVs)) and renewables-based electricity generation.
Event Broker	EB	A scalable software component handling dispatch of raw data from S4G field components to the grid-side components, in an event-oriented fashion. It is deployed and maintained as a private cloud service or on the premises of the entity operating S4G-based services (e.g. DSO or Aggregator).
Local ESS Control Agent	LESSAg	A software component in charge of running site-wise ESS control algorithms. It receives in quasi-real-time all available information from local devices (ESS systems, PV energy meters, load-side energy meters, EV chargers, etc.). In some applications (e.g. related to distributed energy management) it can be configured to act as the main Local Energy Management System (LEMS). It is implemented in form of a Smart Meter eXtensions (SMX), running as part of an Unbundled Smart Meter (USM)

Grid-side ESS Controller	GESSCon	A centralized component able to remotely control populations of LESSAg e.g. by remotely changing set-points.
Grid-side EV Charging Controller	GEVChCon	A centralized component able to remotely control populations of LEVChAg e.g. by remotely changing their main set-points.
Professional GUI	-	A dedicated S4G GUI used by professional (DSO or Aggregator) users
Residential GUI	-	A dedicated S4G Graphical User Interface (GUI) used by residential users who are hosting a residential ESS and/or a controllable EV charging system.
Smart Meter eXtension	SMX	Plug-in framework for the USM suitable to offer added-value functionalities (e.g. control, data storage, etc.) or interoperability with specific local systems (e.g. controllable loads, storage systems, sub-meters, etc.) or remote devices (e.g. aggregator services, price signal services, etc.). A usual SMX installation includes the SMX core functionalities plus one or more SMX extensions.
Smart Metrology Meter	SMM	A certified Smart Meters suitable to be inter-connected to external systems.
SMX Hardware	-	A small-size, reliable embedded PC suitable to run the SMX software components. It is typically deployed in field installations and often physically connected to an SMM by means of a wired connection (e.g. RS-232 or RS-485)
Unbundled Smart Meter	USM	A next-generation Smart Meter suitable to offer unbundling services while keeping the level of trust and security required to support energy billing and certified measurements. It is composed by a SMM and an SMX Box, hosting the SMX Core and one or more SMX extensions.

3.1 Component View: Data Collection

Figure 7 depicts the relationship among S4G components involved in generic data collection functionalities i.e. functionalities resulting in unidirectional collection, preserving and organizing data from the field.
Each physical site where S4G-related components are deployed must have a main *Local ESS control agent (LESSAg)*. The LESSAg runs on-board the main USM of the site (named USM 0) and receives data from all the ESS-related devices by means of various, heterogeneous wired or wireless local interfaces. While this is a component designed mainly for local control purposes, its main purpose from the data-collection viewpoint is to feed such data to higher-level components, through a dedicated, event-oriented interface, namely the *EB#LESSAg* interface.
When EV-related devices, such as a Charging Points (CP), are also deployed in the specific local site, a *Local EV Charging Control Agent (LEVChAg*) shall be instantiated. The LEVChAg locally feeds data towards the LESSAg through the *LEVChAg#LESSAg* Interface, which in turn forwards it to higher-level components through the same *LESSAg#EB* interface.
Data can also be collected (using both push or pull approaches) from third-party cloud-services e.g. providing weather or price forecast. This is done by means of dedicated *DSF Adapter* components, each providing full interoperability with a specific service of interest and feeding data towards the EB through the DSF-Adapter#EB Interface.

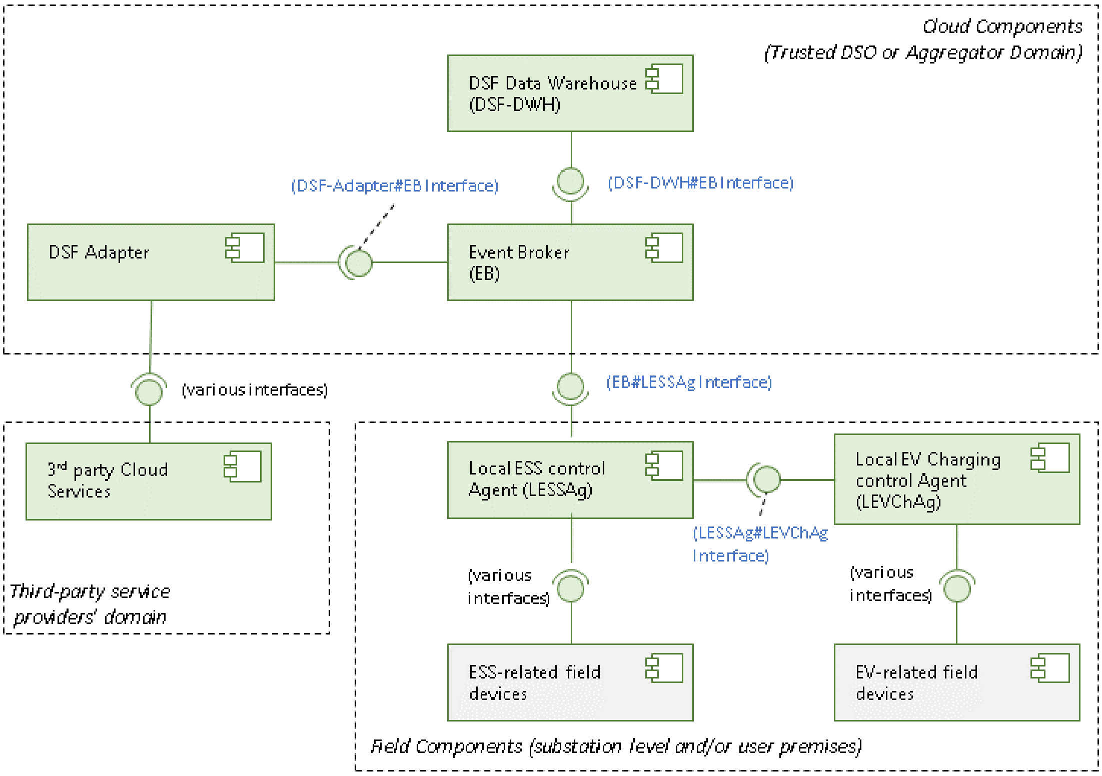

Figure 7 - Component View - Data Collection

All data from field or third-party components is fed to a single *Event Broker (EB)* component, typically deployed at the premises of the entity operating S4G-based services (e.g. DSO or Aggregator). The main purpose of the EB is to make data available to all S4G-related application and services, in secure and scalable fashion.

All data is fed to the *DSF Data Warehouse (DSF-DWH)*, a database component optimized for time-series data, which is able to receive data through the EB#DSF-DWH interface. The DSF-DWH is in charge of receiving and storing all raw data from field installations.

Field and service components (LESSAg, LEVChAg and DSF Adapters) are designed to support a variable number of different south-bound interfaces, and provide interoperability to different devices and services, typically compliant with open standards. More details about specific hardware devices supported in each test site are available in Sections 0 and 6.

The interfaces for connection with the cloud components of LESSAg, LEVChAg and DSF Adapters must be compliant with the S4G Common Information Model and Communication protocol, which is aligned with the data model implemented within the DSF-DWH as described in Sections 4.1 and 5.1. In other words, the *LESSAg#EB*, *LEVChAg#LESSAg*, DSF-Adapter#EV and the EB#DSF-DWH interfaces must be semantically mapped to the same reference data/event model.

3.2 Component View: Control

Figure 8 depicts the relationship among S4G components from the point of view of distributed monitoring and control functionalities.

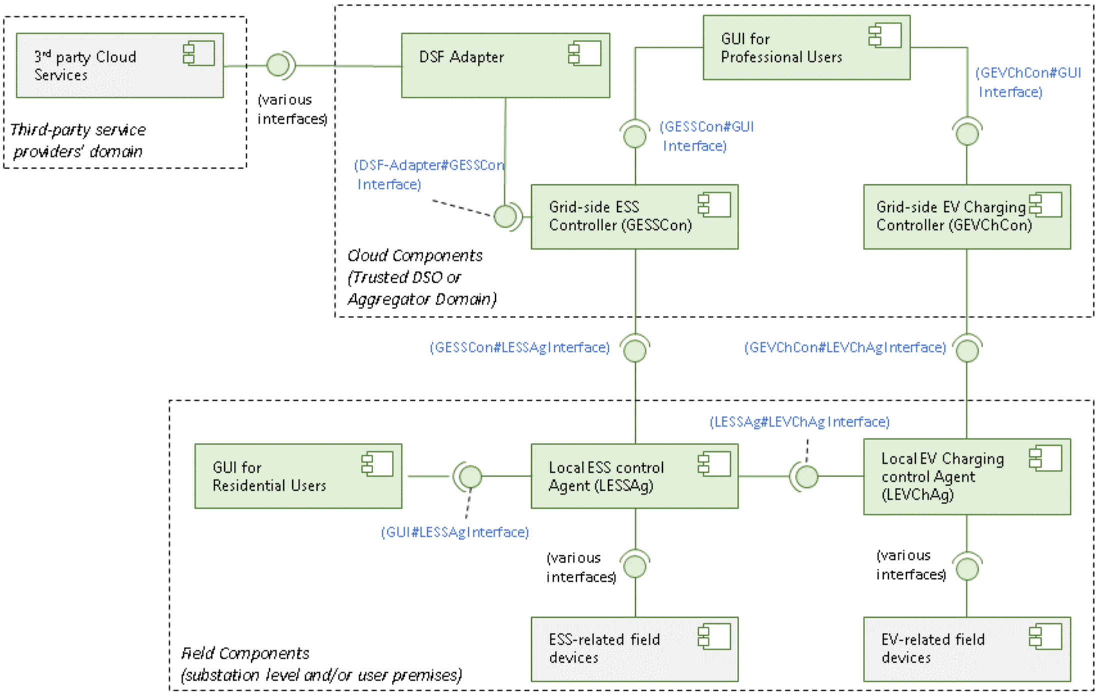

Figure 8 - Component View - Control

From the point of view of monitoring and control, the bottom part of the architecture relies on the same infrastructure used for data collection, leveraging the LESSAg as main field component collecting data from ESS devices and the presence of the LEVChAg when EV charging devices are available on the site.

From the control point of view, the main reference control master for the whole test site is the LESSAg of the USM 0, which is able to host and execute ESS control algorithm to optimize the behaviour of the ESS, based on signals from DSO/Aggregator and the status of local devices.

The LESSAg is the most "knowledgeable" local component. The LEVChAg always acts as a slave of the LESSAg.

Two dedicated components, namely the *Grid-side ESS Controller* (*GESSCon*) and the *Grid-side EV Charging Controller* (*GEVChCon*) are in charge of remotely controlling respectively the LESSAg and LEVChAg components i.e. by remotely changing their main set-points. GESSCon and GEVChCon are hosted in remote, cloud-premises (e.g. in facilities operated by the DSO or Aggregator) and associated with many local sites (i.e. to many LESSAg components).

Monitoring and control is performed top-down by means of open interfaces, namely the *GESSCon#LESSAg* and the *GEVChCon#LEVChAg* interfaces further detailed in Sections 4.1 and 5.1.

The high-level control performed by GESSCon and GEVChCon is typically a "slower" type of control (control loops cycling with intervals in the order of minutes) – therefore strong reliability and real-time constraints on the communication link hosting such interfaces are not critical..

GESSCon and GEVChCon are stand-alone systems which can be monitored and configured by Professional users through their dedicated GUI for Professional users, enabled by the *GESSCon#GUI* and *GEVChCon#GUI* open interfaces.

The GESSCon supports automatic collection of data from third-party systems (e.g. price/weather forecast).

Similarly, a local GUI for residential users, enabled by the LESSAg#GUI open interfaces can be offered to residential users enabling both monitoring and dedicated control/configuration features.

3.3 Component View: Simulation

Figure 9 depicts the relationship among S4G components from the point of view of simulation functionalities, namely for analysis, optimization and planning tasks.

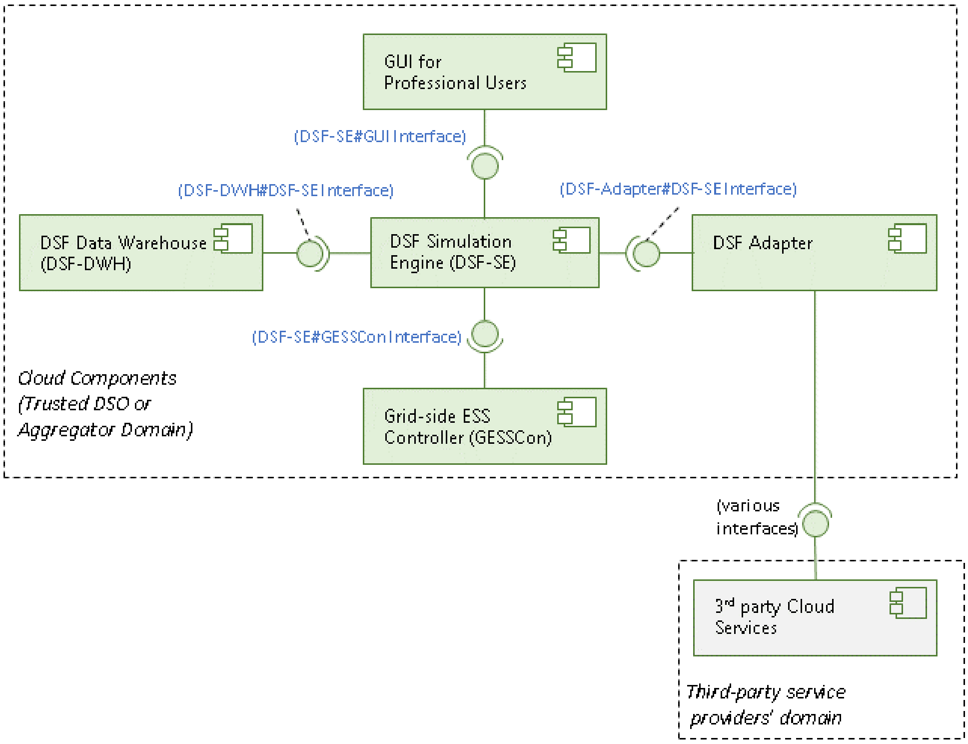

Figure 9 - Component View - Simulation

The core of simulation-related features in S4G is the *DSF Simulation Engine (DSF-SE)* component, namely a software component which is able to execute numerical simulations of the energy transfer in smart (distribution) grids, featuring heterogeneous ESS, loads (including EVs) and renewables-based electricity generators. This is done by integrating pre-existing open smart grid simulation tools and open simulation models and by reflecting in the simulation environment the control features enabled by S4G in the real test sites.

The DSF-SE is designed to be used in two very different configurations i.e. for user-assisted and for automatic, scenario-based numerical simulations.

In user-assisted mode, the DSF-SE is used through a GUI for the so-called *professional user*, which must be consistent (if not even matching) with the GUI for professional users deployed for control and described in section 0.

An open *DSF-SE#GUI* interface is defined to standardize interactions required in order to carry on modelling and simulation tasks.

In automatic mode, the DSF-SE is directly connected to a specific GESSCon entity by means of a pre-defined *DSF-SE#GESSCon* interface. In such mode, the DSF-SE loads a pre-configured model of the grid where the GESSCon is operating and allows the GESSCon to calculate optimized parameters (e.g. set-points) running hypothetical simulation scenarios.

In order to serve both operating modes, the DSF-SE is integrated with the DSF-DWH (*DSF-SE#DSF-DWH* interface) and one or more DSF Adapters (*DSF-SE#DSF*-Adapter interface).

This is needed on the one hand, to load historical grid data (useful e.g. to simulate performance of various control strategies with real data, or to train and verify predictive control models) and, on the other hand, to access third-party services (e.g. weather or price forecasts) directly from simulations.

3.4 Component View: Inter-connection of devices and services to the USM

The Unbundled Smart Meter (USM) is a central component in the S4G project, connecting and playing a key role in handling all S4G features which take place on the field.

Due to its highly-modular architecture, it is impossible to represent the USM and its sub-components in a unique fashion across all its possible configurations. For this reason, it has been decided to provide an overview of the generic architecture and some of its possible deployment configurations, so that in subsequent pictures (e.g. in section 6), the USM and its sub-components can be represented in simplified fashion.

The generalized architecture of the USM as adopted in S4G is summarized in Figure 10.

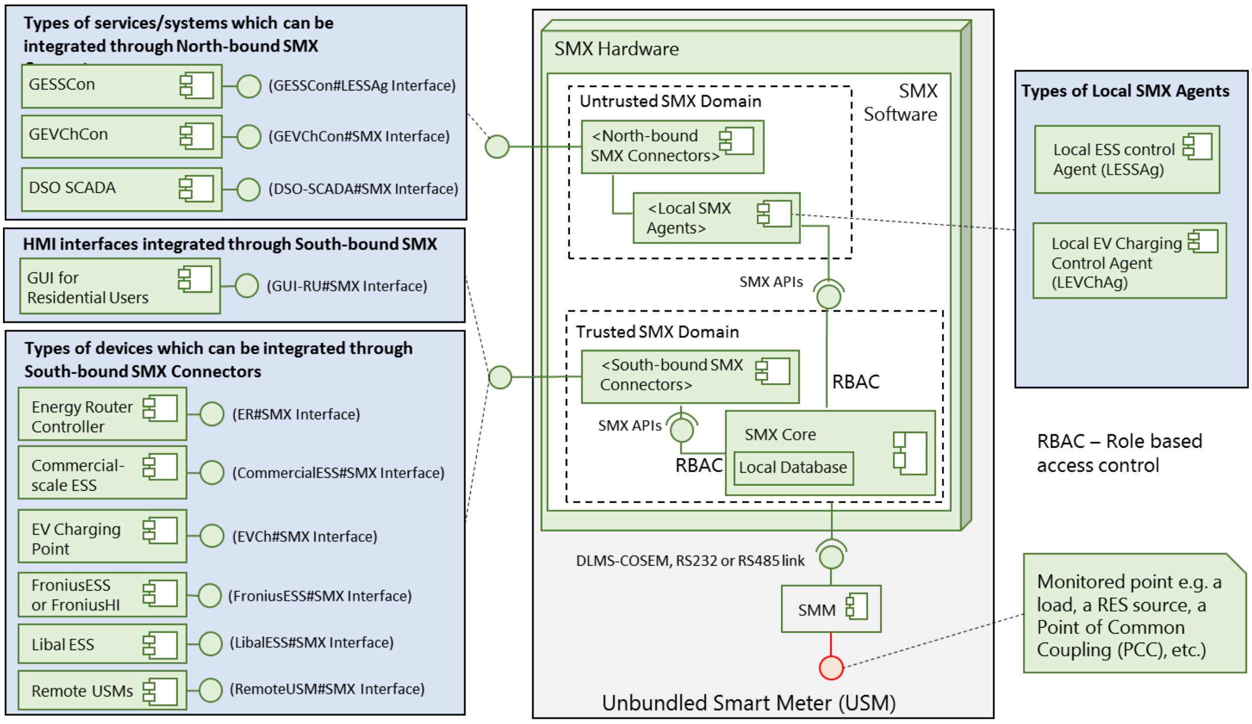

Figure 10 - USM High-level Architecture

The USM is composed by (i) a Smart Metrology Meter (SMM) i.e. a certified smart meter suitable to measure energy consumption in a trusted/certified way, and (ii) the Smart Meter eXtention (SMX) system i.e. a modular software, running on a dedicated computer (namely the SMX hardware), which can host plug-in components providing added-value services.

In S4G we define three different types of SMX plug-ins:

- *South-bound SMX connectors plug-ins:* SMX connectors components providing bi-directional interoperability towards/from local devices on the field (e.g. local ESS systems, hybrid inverters, etc.)
- *North-bound SMX connectors plug-ins:* SMX connectors components providing connectivity towards remote cloud components (e.g. DSO SCADA systems, GESSCon etc.)
- *Local SMX plug-ins*: locally-running SMX plugins implementing local logics based on the data received or transmitted by connectors (e.g. the LESSAg, Local databases etc.)

In general, with the only limitation of the number of hardware ports and CPU resources on-board the specific model chosen as SMX hardware, each SMX instance can have a variable number of plug-ins, defined at commissioning time.

Figure 11 depicts two possible examples of USM configurations.

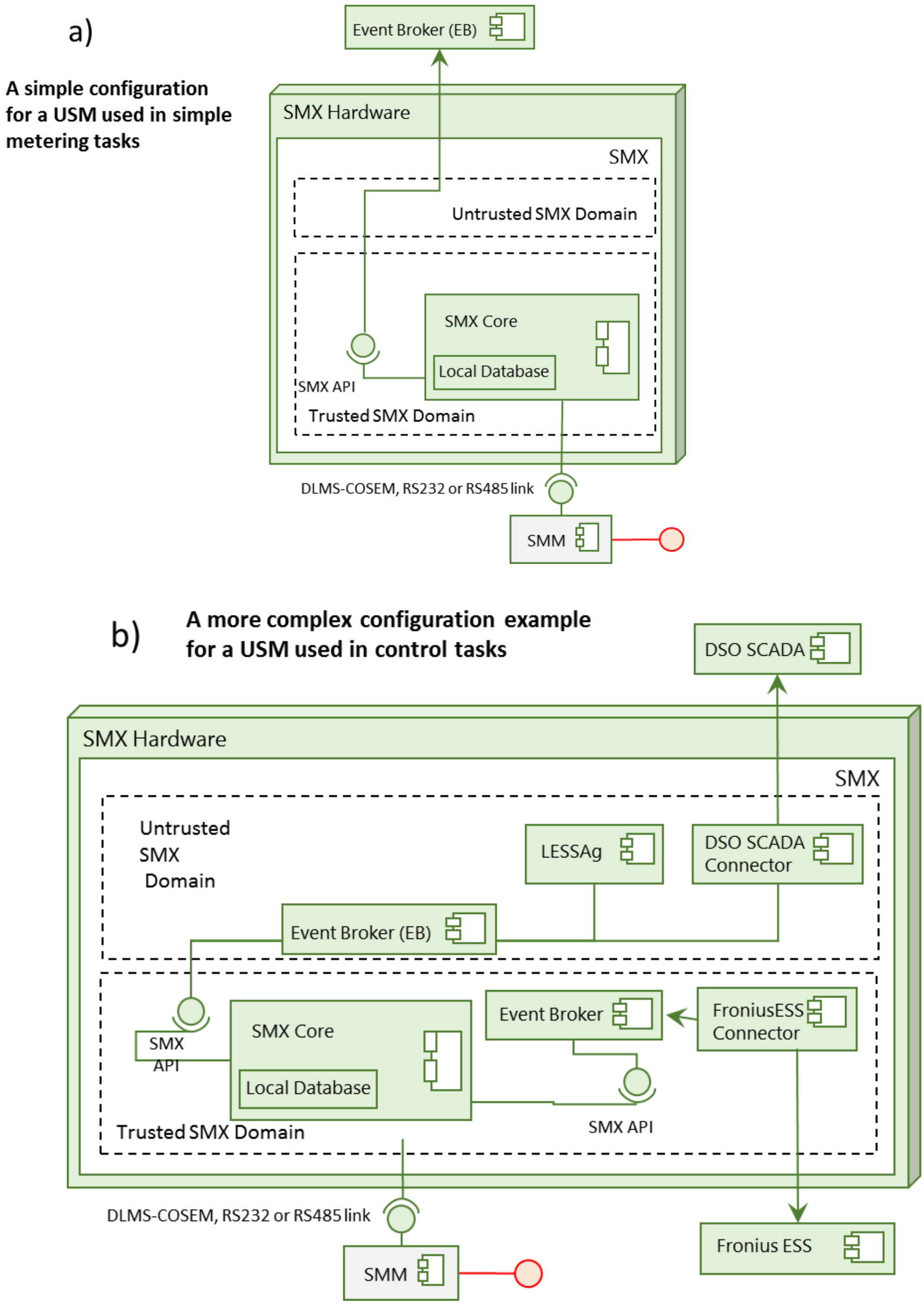

Figure 11 - Two possible USM configurations: a) - A simple configuration for a USM used in simple energy metering tasks and b) - A more complex configuration example for a USM used in control tasks

The simple configuration (a) shows a basic USM with no SMX plug-ins. This configuration is used e.g. when only monitoring capabilities are needed: e.g. to monitor the energy generated by a PV installation, or to monitor the overall consumption measured at the Point of Common Coupling (PCC).

In Figure 11 (b), a more complex configuration is depicted, showing a south-bound connector (i.e. the FroniusESS connector), a north-bound connector (i.e. the DSO SCADA Connector) and a local connector (i.e. the LESSAg). This type of configuration is normally used when control capabilities or interaction across multiple USMs is needed.

4 Information View

This section provides a focused view on data handled by the S4G system, with particular attention given to data and information models that will be used in the interfaces of S4G system, in order to effectively handle the generated data streams. Firstly, an overview of the adopted interfaces and the corresponding data model is presented. Secondly, the different standard information models necessary in the S4G system are listed and explained. This is the initial information model. Additional variables might be added (if needed) through the development process of the different systems in the S4G project.

4.1 S4G Common Information Model for ESS Monitoring and Control

Below are presented all main functional interfaces among high-level components within the Storage4Grid system.

Table 3 - Summary of all the key interfaces of the S4G system

Interface ID	Interface ID	Interface ID
1. DSF-Adapter#DSF-SE	7. DSF-SE#GESSCon	12. GESSCon#GUI
2. DSF-Adapter#EB	8. DSO-SCADA#LESSAg	13. GEVChCon#GUI
3. DSF-Adapter#GESSCon	9. EB#LESSAg	14. GEVChCon#LEVChAg
4. DSF-DWH#EB	10. EVChCon#EV-SCADA	15. GUI#LESSAg
5. DSF-DWH#DSF-SE	11. GESSCon#LESSAg	16. LESSAg#LEVChAg
6. DSF-SE#GUI		

In the following subsections, the data model adopted within the different interfaces of the S4G system will be shortly presented in a tabular format. The table includes the messages ID, a description of them, the components that interact during this communication, the variables or parameters to be communicated and the frequency in which every parameter is communicated through the interface.

4.1.1 DSF-Adapter#DSF-SE Interface, DSF-Adapter#EB Interface, DSF-Adapter#GESSCon Interface

The *DSF-Adapter#(*)* classes of interfaces are used to retrieve and abstract Information from third party cloud services within S4G components, namely the DSF-Simulation Engine, the Event Broker or the Grid-side ESS Controller. DSF Adapters do not feature a specific data model on their own: their data model simply maps the specific data types provided by the third-party cloud service of interest to the internal common data models used by S4G components.
Examples of third-party information sources currently identified as potentially relevant for Storage4Grid include:

- Weather Forecast Services
- Price Forecast Services
- Existing cloud-based ESS management platform of specific vendors (e.g. Fronius)

It has to be observed that the advantage of developing a re-usable DSF-Adapter versus an ad-hoc interface integrating a specific service with a single S4G component depends on how many S4G components need to inter-operate with the specific service, within or beyond the specific needs of the Storage4Grid project.

Therefore, depending on implementation aspects, it is possible that the features of some DSF-Adapter are instead embedded directly in a specific component (e.g. the GESSCon).

4.1.2 DSF-DWH#EB Interface

Table 4 - DSF-DWH#EB Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Monitoring event	Measured values read from different interfaces of the S4G	EB→DSF-DWH	Generated power (kW)	1-10 seconds
			ESS power (kW)	
			Grid power (kW)	
			Loads power (kW)	
			Back generation power (kW)	
			State of charge (%)	
			Household busbar Voltage (V)	
			Grid Voltage (V)	
			Timestamp (s)	
Status event	Metadata and status information from different devices in the system	EB→DSF-DWH	Device ID	Variable
			Device Status	
			Radial ID	
			Position	
			Manufacturer Information	

4.1.3 DSF-DWH#DSF-SE Interface

This interface provides the historical data (e.g. Load profile, generation profile, storage profile, etc) that the DSF-SE needs to run its simulations. The results from the simulations are also saved into the DSF-DWH through this interface. The data model will be defined in the next deliverables.

4.1.4 DSF-SE#GUI Interface

This interface provides the data needed for transferring the configurations and input of the professional user to the DSF-SE component, in order to start optimization and simulation activities. The results of the optimization and/or simulation will be displayed in the GUI using this interface. The data model will be defined in the next deliverables.

4.1.5 DSF-SE#GESSCon Interface

This interface provides the data for transferring the configurations and inputs of the DSF to the GESSCon, in order to grid input from grid simulation activities. This interface will be the same as the aggregator interface described in the following subsections. The data model will be defined in the next deliverables.

4.1.6 Aggregator#GESSCon Interface

Table 5 - Aggregator#GESSCon Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Command Event	Commands to GESSCon	Aggregator → GESSCON	Timestamp for set point (s) Command start time (s) Command stop time (s) Radial identification number Radial solution code fx: initiate peak shaving or prevent flicker	Event triggered
Status Event	Status from GESSCon to Aggregator	GESSCON → Aggregator	Timestamp for set point (s) Command accepted (Boolean) Command error Overview of all ESS System Status Overview of all ESS Systems are within normal operating bounds	Event triggered

The Aggregator is not specifically addressed, as it is considered that this actor exists and it has already the necessary interaction with GESSCon, so further descriptions will refer only at GESSCon and its interaction with the project logical actors.

4.1.7 DSO-SCADA#LESSAg Interface

The *DSO-SCADA#LESSAg* interface is used to upload ESS-related data directly into DSO SCADA system already in use in the DSO infrastructure. This interface and its associated data model are compliant with specific SCADA such as standard IEC 60870-5-104.

4.1.8 EB#LESSAg Interface

Table 6 - EB#LESSAg Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Measurement/monitoring event	Measured values read from the different interfaces of S4G devices	LESSAg → EB	Generated power (kW) ESS power (kW) Grid power (kW) Loads power (kW) Back generation power (kW) State of charge (%) Household busbar Voltage (V)	1-10 seconds

			Grid Voltage (V)	
			Timestamp (s)	
Status event	Metadata and status information of the different devices in the system	LESSAg → EB	Device ID	Varies
			Device Status	
			Radial ID	
			Position	
			Manufacturer Information	

4.1.9 EVChCon#EV-SCADA Interface

The *EVChCon#EV-SCADA* interface is used to exchange data between the EV Charing Controller and the dedicated DSO SCADA system already in use in the DSO infrastructure for the specific purpose of managing EV charging points. This interface and its associated data model is compliant with the OCPP standard[7].

4.1.10 GESSCon#LESSAg Interface

Table 7 - GESSCon#LESSAg Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Command Event	Battery power exchange setpoint	GESSCON → LESSAg	Timestamp for set point (s)	Every minute in a data package sent every 24 hours
			DC power (W)	
			DC Power Setpoint Priority	
Status Event	ESS System data	LESSAg → GESSCON	Device identification number	Every time there is made changes to the variables
			Radial identification number	
			GPS coordinates (Decimal Degrees)	
			ESS System Manufacturer	
			ESS Product Name	
			Maximum capacity (Wh)	
			Maximum Power (W)	
			Minimum State of Charge (%)	
			Maximum State of Charge (%)	
Measurement/ monitoring Event	Measurement data send from ESS system	LESSAg → GESSCON	Device identification number	Every minute
			Timestamp for measurement (s)	
			Timestamp for set point (s)	
			Timestamp for last GESSCon request (s)	
			DC power measured (kW)	

[7] http://www.openchargealliance.org/protocols/ocpp/ocpp-16/

			DC power set point (kW)	
			DC Power Setpoint Priority	
			DC Power Setpoint accepted (Boolean)	
			State of Charge (%)	
			Active power import/export (W)	
			Reactive power import/export (var)	
			Grid voltage of each individual phases (V)	
			PV power production (W)	
			Local (household) Power consumption (W)	
			ESS System status and errors	

4.1.11 GESSCon#GUI Interface

Table 8 - GESSCon#GUI Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Status Event	Status to be displayed in the GUI provided by the GESSCon	GESSCON → GUI	Simple overview of radials	Event triggered
			Radial solution code fx: initiate peak shaving or prevent grid flicker	
			Simple overview of all ESS System Status	
			Simple overview of all ESS Systems are within normal operating bounds	

4.1.12 GEVChCon#GUI Interface

Table 9 - GEVChCon#GUI Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Status event	Messages with the status of the command event	GEVChCon → GUI	Return value (error, acept)	Varies
			Error codes	

Command event	Commands to avoid overload and provide voltage control in a radial	GUI → GEVChCon	Avoid_overload (radial_id, timespan)	Varies
			Voltage_control (radial_id, timespan)	

4.1.13 GEVChCon#LEVChAg Interface

Table 10 - GEVChCon#LEVChAg Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Status event	Messages with the status parameters of the different LEVChAg	LEVChAg → GEVChCon	Device ID	Once per day
			Device Status	
			Radial ID	
			Position	
			Manufacturer Information	
Measurement event	Measurements obtained from every charging point	LEVChAg → GEVChCon	Power (kW)	Every 1 – 10 seconds
			Voltage (V)	
			SoC (%)	
Command event	Commands to set the forecasted EV load profile into each LEVChAg of the system	GEVChCon → LEVChAg	Array of power values for the forecasted EV charging load profiles (kW)	Once per day or event oriented

4.1.14 GUI#LESSAg Interface

This interface is intended to allow the interaction of local user with the local ESS agent.
The interface details are presented in D6.7, Initial interfaces for professional and residential users.
The types of exchanged messages are presented in Table 11.

Table 11 - GUI#LESSAg Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Request of LESSAg variables	Message that contains request of variables used by LESSAg	GUI → LESSAg → GUI	State of charge [%]; Power of the ESS in the current time interval and in next periods, up to 24 hours [kW]; priority of orders	Varies, usually at least once per minute
Change setpoints on LESSAg	Message that contains request of changing setpoints in LESSAg	GUI → LESSAg	Setpoint for the power of ESS [kW]	On request
Request of	Message that	GUI	Active power and voltage on	At least once per

meter variables at the PCC	contains request of meter variables used by LESSAg	→ LESSAg → GUI	the DSO meter	minute

PCC: Point of common coupling between DSO and the prosumer / ESS resource

4.1.15 LESSAg#LEVChAg Interface

Table 12 - LESSAg#LEVChAg Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Status Event	Message that contains forecasted EV charging load profiles	LEVChAg → LESSAg	Array of power values for the forecasted EV charging load profiles (kW)	Once per day
Command event	Command needed to change the load at the EV side	LESSAg → LEVChAg	Load reduction(Power load profile for EV, priority)	Varies

Table 13 - List of interfaces on the SMX

Interface ID	Interface ID
17. CommercialESS#SMX	23. GESSCon#SMX
18. DSO-SCADA#SMX	24. GEVChCon#SMX
19. EB#SMX	25. GUI-RU#SMX
20. ER#SMX	26. LibalESS#SMX
21. EVCh#SMX	27. RemoteUSM#SMX
22. FroniusESS#SMX	

4.1.16 CommercialESS#SMX Interface

Table 14 - CommercialESS#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Measurement event	Measured values of the ESS in the commercial place of Bolzano and handled by the SMX	CommercialESS → SMX	Voltage (V)	1-10 seconds
			Power supplied to the ESS (kW)	
			Power released from the ESS (kW)	
			State of charge (%)	
			Timestamp (s)	
Command event	Commands needed to control	SMX → CommercialESS	Power (kW) exchanged with the ESS. The sign of the	Every 15 minutes

	the ESS system		power indicates a charge or discharge of the battery	

4.1.17 EB#SMX Interface

EB is implemented in SMX as client connector using Message Queuing Telemetry Transport (MQTT) messaging. All the messages which exist in the SMXCore real-time database can be accessed through this MQTT client interface.
A role based access control (RBAC) policy is implemented for each different client, allowing that any information requested by the different interfaces listed in this document can be exchanged only if they are allowed by RBAC system.

4.1.18 ER#SMX Interface

This interface currently uses the IEC61850 protocol. It is expected to use the IEC61850-90-7 since is more suitable for the communication with power converters and RES.

Table 15 - ER#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Set-points event	Send the set points to the ER	SMX → ER	Grid Power (min, max) (kW). Keeps the power injected in the grid between the minimal and maximal value. Grid Reactive Power (min, max) (kvar). Keeps the reactive power injected in the grid between the minimal and maximal value.	Every 15 minutes (or when changes are needed)
Operation event	An operation mode is sent to the ER, prioritising the ESS, the grid, or the PV production.	SMX → ER	Operation mode 1) Provide reference value if possible, otherwise charge the battery and disconnect (surplus to battery) 2) If only reactive is available, do not inject active. If battery is available, charge the battery. 3) Inject all to grid from PV and battery (if available) 4) Inject all to the grid from the PV 5) Disconnect from the grid (charge the battery and disconnect)	Every 15 minutes (or when changes are needed)

4.1.19 **EVCh#SMX Interface**

Table 16 - EVCh#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Status event	Return the status of the charging points	EVCh → SMX	CP Status	Varies
			CP Time (s)	
Measurement event	Return the values of the measured parameters from the CP	EVCh → SMX	Power (kW)	Every 1 – 10 seconds
			Voltage (V)	
			SoC (%)	
Command event	Command needed to change the load at the EV side	SMX → EVCh	Load reduction(Array of a load profile (kW))	Varies
			Enable/Disable	

4.1.20 **FroniusESS#SMX Interface**

Table 17 - FroniusESS#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Measurement event	Return the values of the parameters measured by the ESS system	FroniusESS → SMX	Generation power (kW)	Every 1 – 10 seconds
			State of charge (%)	
			ESS power (kW) and energy (kWh)	
Command event	Commands needed to control the ESS system	SMX → FroniusESS	Power (kW) exchanged with the ESS. The sign of the power indicates a charge or discharge of the battery	Every 15 minutes

4.1.21 **GESSCon#SMX Interface**

Table 18 - GESSCon#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Measurement Event	Measurement data send from Smart Meter	SMX → GESSCON	Device identification number	Every minute
			Timestamp for measurement (s)	
			Active power import/export (W)	
			Reactive power import/export (var)	
			Grid voltage (rms) on each individual phase (V)	

4.1.22 GUI-RU#SMX Interface

This interface is intended to allow the interaction of local user with the SMX and ER. The ER information is acquired by SMX and is provided to the GUI through SMX.
The types of exchanged messages are presented in Table 19.

Table 19 - GUI-RU#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Request of ER variables	Message that contains request of variables used by ER	GUI → SMX → GUI	State of charge [%]; Power to AC grid [kW]; power of PV [kW]; power of storage device [kW]; power of local consumption (calculated) [kW]	Varies, usually at least once per minute
Change setpoints on ER	Message that contains request of changing setpoints in ER	GUI → SMX → ER	Setpoint for the power of ER on AC side [kW], power on storage [kW], voltage of ER on AC side [V],	On request
Request of meter variables at the PCC	Message that contains request of meter variables used by SMX	GUI → SMX → GUI	Active power [kW]; and voltage [V] on the sub-meter, on each phase Index of active energy A+, A- [kWh]	At least once per minute

PCC: Point of common coupling between DSO and the prosumer / ESS resource

4.1.23 RemoteUSM#SMX Interface

Message ID	Description	Directions	Variables (with units)	Periodicity
Request of sub-meter variables	Message that contains request of sub meter variables used by SMX	RemoteUSM → SMX	Active power [kW], and voltage [V] on the sub-meter, on each phase Index of active energy A+, A- [kWh]	At least once per minute, advisable every 1 to 5 seconds

4.2 Information Models

Table 20 shows the different Information Models and Protocols that are used in S4G and concatenate them to the specific S4G-interface that implements them. Each Information Model will be described in the following subsections.

Table 20 - Information Models and Protocols

Model	Interface ID	Use in S4G
SenML + OGC SensorThings Data Model	GESSCon#LESSAg	Communication between the local ESS control agent (LESSAg) and the Grid-side ESS controller (GESSCon)
	GEVChCon#LEVChAg	Communication between the local EV

		charging control agent (LEVChAg) and the EV charging controller (GEVChCon)
	LESSAg#LEVChAg	Communication between the local EV charging control agent (LEVChAg) and the local ESS control agent (LESSAg)
	DSF-DWH#EB	Communication via Event Broker with the Data warehouse
	EB#LESSAg	Communication via Event Broker with the local ESS control agent (LESSAg)
OCPP	EVCh#SMX	Communication between the SMX and the wall box of a charging point
IEC 61850-90-7	ER#SMX	Communication between the energy router and the SMX
Fronius Solar API	FroniusESS#SMX	JavaScript Object Notation (JSON) based proprietary API for the communication between the SMX and the Fronius management system of the storage
SunSpec Alliance Interoperability Specifications SunSpec Energy Storage Models	FroniusESS#SMX	Data models and MODBUS register mapping for the communication between the SMX and the Fronius management system of the storage through MODBUS

4.2.1 OGC SensorThings Data Model

The OGC SensorThings Data Model [v] [vi] will be used for data representation in the communication between LESSag and the GridESSCon within S4G platform architecture. This data model has been designed for sensors in the IoT application domain and can be easily adopted for the S4G architecture, enabling the standardization of data required in the S4G system.

The UML diagram of the SensorThings API data model can be found in [vii]. The OGC SensorThings API data model consists of the Sensing and Tasking profiles.

The Sensing profile allows IoT devices and applications to CREATE, READ, UPDATE, and DELETE (i.e., HTTP POST, GET, PATCH, and DELETE) IoT data and metadata in a Thing service. Managing and retrieving observations and metadata from IoT sensor systems is one of the most common use cases. As a result, the Sensing profile is designed based on the ISO/OGC Observation and Measurement (O&M) model (OGC and ISO 19156:2011).

The key the modelling of an Observation as an act that produces a result whose value is an estimation of a property of the observation target or FeatureOfInterest. An Observation instance is classified by its event time (e.g., resultTime and phenomenonTime), FeatureOfInterest, ObservedProperty, and the procedure used (often corresponding to a Sensor). Things are also modelled in the SensorThings API, together with the historical set of their geographical positions.

More specifically, in the Sensing profile, a Thing has Locations and HistoricalLocations. It can also have multiple Datastreams associated. A Datastream is a collection of Observations grouped by the same ObservedProperty and Sensor. An Observation is an event performed by a Sensor that produces a result whose value is an estimate of an ObservedProperty of the FeatureOfInterest.

4.2.2 **SenML**

SenML [viii] [ix] is an information model used in IoT applications for sensor measurements and device parameters. The information model is composed of a unique device name, an application specific name, information of the value presented in the value field ("unit"), and an optional timestamp. SenML defines a data model for JSON, XML, Concise Binary Object Representation (CBOR), and Efficient XML Interchange (EXI). The SenML in the JSON description form can be used together with the OGC SensorThings Data Model in the Observation field. This application will be tested in the S4G project.

4.2.3 **OCPP**

The purpose of this protocol is to provide a standard communication between a charging station and a central system[x]. The standard uses REST over HTTP for data exchange, in a Simple Object Access Protocol (SOAP) or JSON implementation. In this context, S4G is trying to use the OCPP protocol to interface the different charging points in the Bolzano use cases. However, its implementation depends on the availability of information provided by the charging stations through this interface that fulfil the requirements found in the S4G system (D2.5).

4.2.4 **IEC 61850-90-7**

The International Electrotechnical Commission (IEC) [xi] is a worldwide organization for standardization composed of national electro-technical committees (IEC National Committees). This entity promotes international co-operation in standardization themes relating to electrical and electronic fields. In this context, the international standard IEC 61850-90-7 [xii] has been prepared by IEC technical committee 57: Power systems management and associated information exchange. The namespace "IEC 61850-90-7" is considered as transitional and will be included in the IEC 61850-7-420[xiii].
The IEC 61850-90-7 describes the functions for power converter-based distributed energy resources (DER) including photovoltaic systems (PV), battery storage systems, electric vehicle (EV) charging systems, and any other DER systems with a controllable power converter. Because of the increasing share of distributed energy resources (DER), the IEC 61850-7-420 standard presents a data model for communication and control of all DER devices. In this data model the communication of DER devices is not only meant between them and their control systems, but also with operators or aggregators managing the system. The standard associated with some guidelines and procedures simplifies the implementation, reduce installation costs, maintenance costs and improve reliability of power systems.
The IEC 61850 standard separates the communication between DERs in four parts:

1. Information modelling
2. Services modelling
3. Communication protocols
4. Telecommunication media

In this context, different documents of the IEC 61850 standard address the four parts above. The IEC 61850-7-420 addresses the information modelling for DER, the IEC 61850-7-2 addresses the services modelling and the IEC 61850-8-x the mapping to communication protocols.
Moreover, IEC TC 57 has developed a common information model (CIM) that relates power system elements to other information elements, allowing the communication of this relationship between systems.

4.2.5 **Fronius Solar API**

The Fronius Solar API [xiv] is a proprietary API meant for third parties to get data from various Fronius devices. The devices include inverters, Sensor-Cards and StringControls. The Fronius Solar API is an Ethernet-based open JSON interface, which can be found working in Fronius Datalogger Web or Fronius Solar.web.

The interaction with the API works with HTTP requests to specific CGIs. The URLs for the particular requests and the devices that support them are listed at the beginning of the request descriptions in the Fronius Solar API description.

4.2.6 SunSpec Alliance Interoperability Specifications

SunSpec Alliance Interoperability Specifications[xv] describe information models, data exchange formats and communication protocols used in DER systems[xvi]. To define the information in SunSpec, a set of Information Models is needed. Therefore, the device definition concatenates a collection of SunSpec Information Models, which contain: common model, standard model(s), vendor model(s) and end model. Even though, SunSpec Information Models are communication protocol agnostic, the communication between gateways and devices uses typically the Modbus protocol. This is the communication protocol that Fronius offers as an interface and that S4G will also use for the communication between the LESSAg and the Fronius device.

5 Communication View

Communication view identifies the optimal channels and protocols to connect the implicated components. In this section, the key words are: cyber-security aspects, LAN, routers, Wi-Fi, Internet and secure communication.

5.1 S4G Common Communication Protocol for ESS Monitoring and Control

Figure 12 depicts the high-level communication view for a deployment involving S4G components.
Since security and privacy protections are considered key requirements in S4G, this section outlines also communication cyber-security aspects. More details about cyber-security aspects are provided in Section 7.

In the field domain, an IP-based Local Area Network (LAN), identified as segment A in Figure 1212, shall be available. This is not necessarily a homogeneous network, and can be optionally extended by additional routers or Wi-Fi Extenders. The local LAN, is interconnected to the public Internet by means of a Local Internet Router, which provide bi-directional internet connectivity (B) from and towards all local components.

At least a SMX Box is available in the field domain, although it has to be observed that more than one SMX Box can be deployed in a single site, associated to the same or different Local Internet Routers.
Beyond sharing internet connectivity, the local LAN serves two key purposes: (i) allow IP-enabled Local Systems to connect to the local SMX Box(es); (ii) to allow OpenVPN clients running on-board SMX Boxes to reach the public OpenVPN server available in the cloud domain. These two key purposes enable the established of a secure, IP-based Virtual Private Network (VPN) as marked with segment B in 12, which is used in the project for all secure communications between field and cloud components.
Communication protocols used by S4G components and applications (marked with E in Figure 12) are tunnelled through the secure VPN.

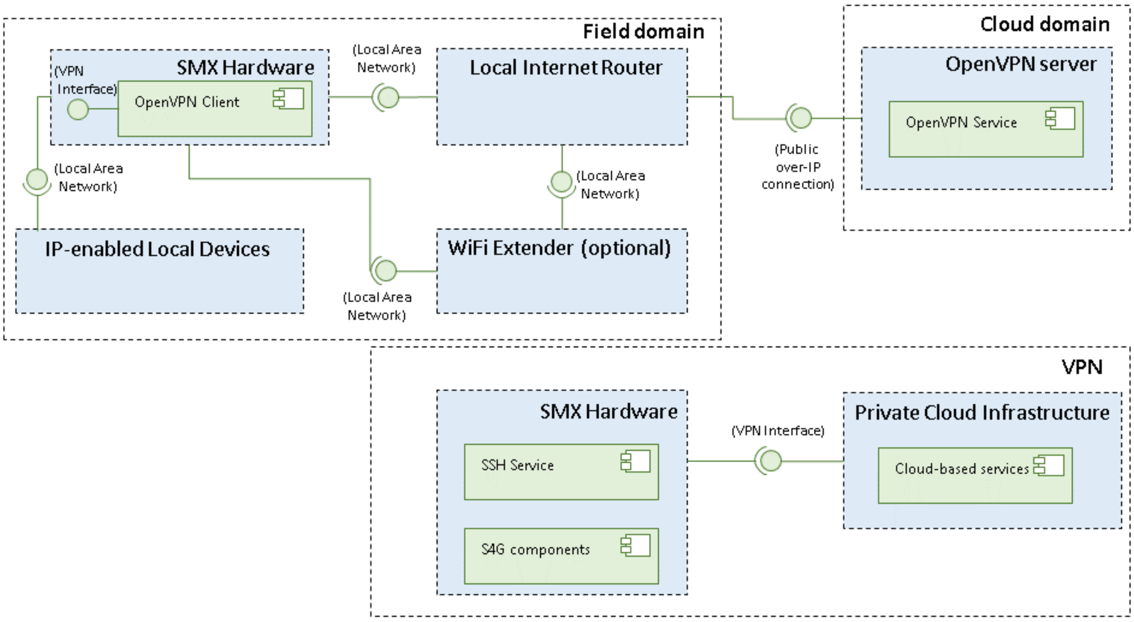

Figure 12 - General Communication View (Deployment Diagram)

It must be additionally observed that the described VPN is used for additional security, but it is not considered the main instrument used to provide secure, tamper-proof communication. Table 21, summarizes the main protocols used for secure communications, each associated with a reference to the State-of-the-art security mechanism in place to ensure secure operations.

Table 21 - Communication Protocols Summary

Protocol	Segment	Use in S4G	Security mechanism employed
IP over wired or wireless LAN Protocols e.g. Wi-Fi[xvii], Ethernet[xviii], etc.	LAN Interfaces	Local Area Network in field locations at user premises	Basic security features in place in Wired/Wireless LANs including WPA2[xix]
IP over wired LAN Protocols e.g. Ethernet	LAN Interfaces	Local Area Network in field locations at user premises at substation level	Closed, wired networks; L2 security mechanisms (e.g. MAC filtering); Intrusion Detection Systems (IDS)
IP	Public Internet	Bridging Field Locations with Cloud Locations	Provider/Transport dependant
VPN Protocols	LAN, Public Internet	Additional layer of security to ensure that only authorized device can access the system	State-of-the-art OpenVPN security mechanisms
Transport protocols (any)	Open-VPN	Direct connection between field components (the majority running within the SMX Box) and Cloud components, as well as among cloud components	State-of-the-art transport security layers including e.g. TLS[xx], DTLS[xxi], typically used in conjunction with security features of upper-layer application protocols (e.g. MQTT) when available

6 Deployment Views

In this view, it is described the hardware deployed on the field in general. The specific deployment that is targeted for Y1 deployment, should be described (using the same formalism) in deliverable D6.4. In general, the description in D6.4 will be a subset of what we describe in this section.
The deployment viewpoint focuses on the physical environment in which the S4G project components will be deployed and running. It covers the hardware environment, technical environment requirements for each node of the S4G system and the mapping of all software components to the runtime environment that will execute them.

6.1 Advanced Cooperative Storage Systems Deployment View

Figure 13 presents a possible deployment of a Storage4Grid system related to the advanced cooperative storage systems.

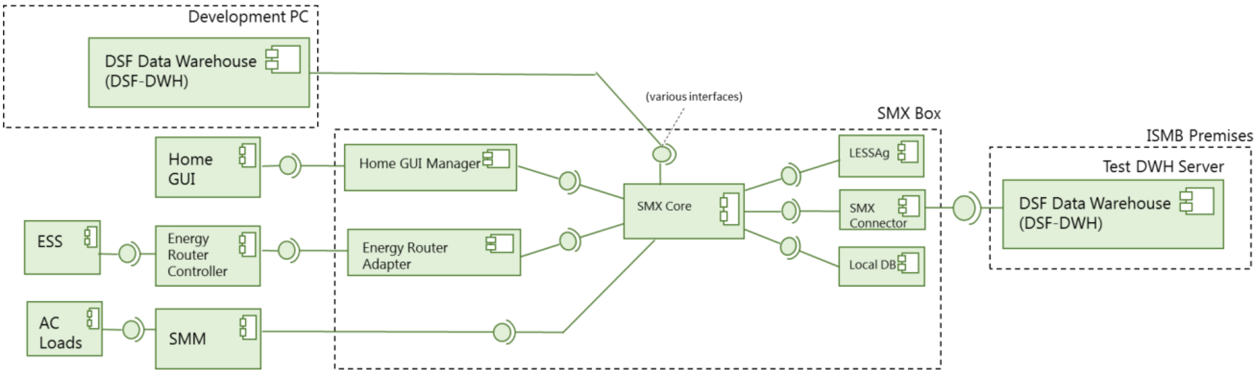

Figure 13 - Typical Deployment for Advanced Cooperative Storage System (Deployment Diagram)

AC loads are deployed in the lab-scale test-site, monitored by a dedicated USM (SMM + SMX Box). The Energy Router is also available and physically interconnected to a dedicated SMX Box through its main controller. An instance of the DSF Data warehouse is deployed in a dedicated Development PC, and used to simulate scenarios of interest. All monitored data is fed in a dedicated instance of the DSF-DWH.

6.1.1 Physical components

The following table outlines the number and models of different physical components foreseen in this scenario.

Table 22 - Number and models of different physical components foreseen - Bucharest

Component	Brand/Model	# of components deployed
SMX	Raspberry PI model 3	1
SMM	DLMS-COSEM compatible meter, e.g. ZMG310CT	2
Development PC	Existing	1
Energy Router Controller	S4G Prototype	1

6.2 Cooperative EV Charging Deployment View

This section describes deployment views for the Cooperative EV Charging Scenarios. This scenario is divided in two separated sub-scenarios (commercial and residential), both sharing the majority of data collection and control components.

6.2.1 Commercial test site

The EV Charging Deployment in the commercial test-site is depicted in Figure 14.

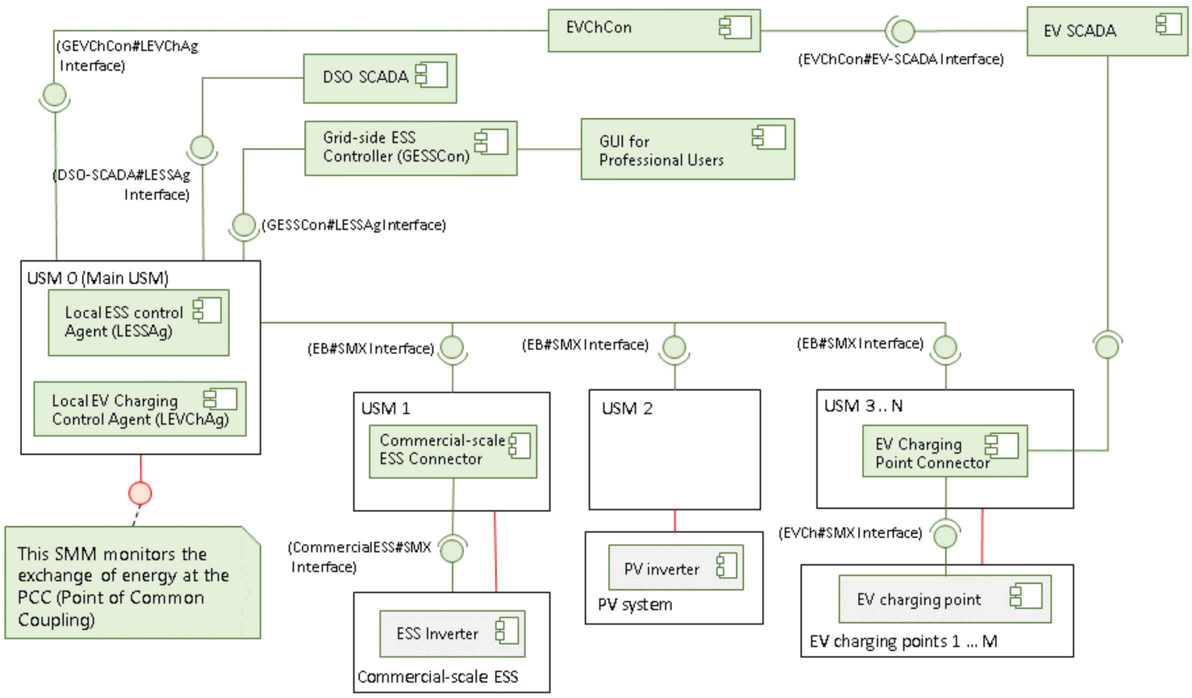

Figure 14 - Typical Deployment for Cooperative EV Charging, Commercial test cases (Deployment Diagram)

In the commercial test site a number of EV Charging Points (1..M) is deployed. Each of them is associated to a specific USM (3..N) which is in charge of monitoring the load of each charging point (via the SMM), as well as hosting the EV Charging Point connector enabling interoperability towards the local OCPP end-point available on the charging point (EVCh#SMX Interface). This component also acts as "Proxy" to allow the legacy EV SCADA system in place to keep functioning in transparent fashion, while still allowing the charging point to be controlled locally.

A dedicated USM (USM1) is available to monitor and provide interoperability towards the local Commercial-scale ESS available on site, planned for installation during the second phase of the S4G project. The local medium-scale PV installation available on-side is monitored by its dedicated USM (USM 2).

A main USM (USM 0) is deployed to host the local LESSAg and LEVChAg, as well as to act as main data collector for the test site. The SMM of USM 0 is also active to monitor the exchange of energy at the Point of Common Coupling (PCC) with the grid.

USM0 also hosts a number of north-bound connectors to serve the different higher-order components, most notably the EVChCon, the GESSCon and the DSO SCADA. For the specific integration of the DSO SCADA, a specific SMX connector compatible with the IEC60870-5-104 standard is targeted for development (LESSAg#DSO-SCADA interface).

It has to be observed that the EVChCon is also provided with an additional connector, which allows interoperability with the legacy EV SCADA (EVChCon#EVScada Interface).

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6.2.1.1 Physical components

The following table outlines the number and models of different physical components foreseen in this scenario during the first phase.

Table 23 - Number and models of different physical components foreseen - Bolzano

Component	Brand/Model	# of components deployed
DSO SCADA	SELTA Scada eXPert	1
EV Management System	Siemens Ecar operation center	1
SMX Box	Raspberry PI model 3	According to SMM brand/model
SMM	Iskra MT831/ Landis+Gyr/An optimal model	According to SMM brand/model
Smart Wall Box	Circontrol Wall Box smart	5

6.2.2 Residential test site

The EV Charging Deployment in the residential test-site is depicted in Figure 15. Three dedicated meters are deployed to monitor respectively Home Loads, PV Production and Grid Exchange, all interconnected to dedicated USMs, feeding data to the local LESSAg and LEVChAg deployed in the main USM 0.

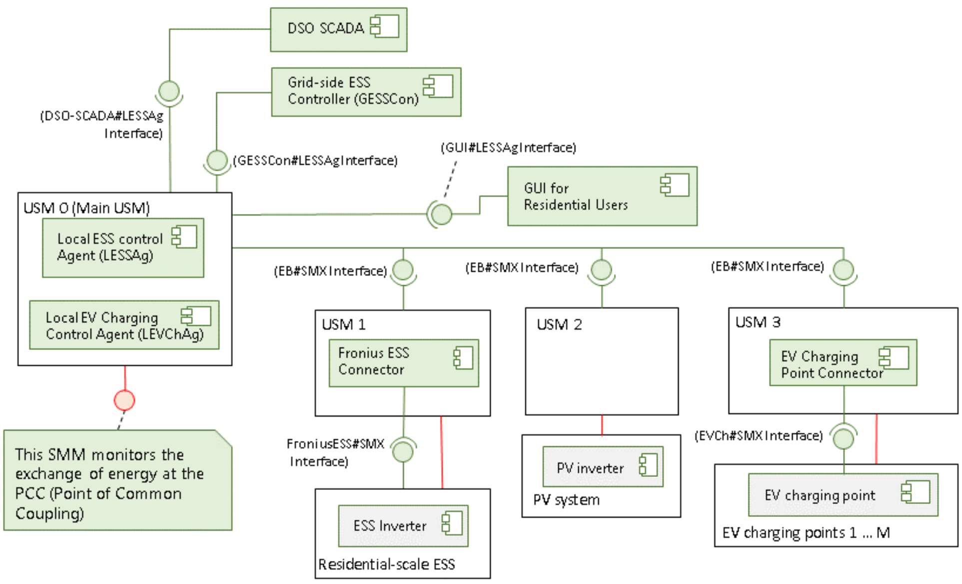

Figure 15 - Typical Deployment for Cooperative EV Charging, Residential test cases (Deployment Diagram)

The local USM0 also acts as main end-point for the Residential GUI.

6.2.2.1 Physical components

The following table outlines the number and models of different physical components foreseen in this scenario during the first phase.

Table 24 - Number and models of different physical components foreseen - Bolzano

Component	Brand/Model	# of components deployed
Fronius ESS with Hybrid Inverter	Fronius Solar Battery 12.0 Fronius Symo Hybrid 5.0-3-S	1
SMX Box	Raspberry PI model 3	According to SMM brand/model

SMM	Iskra MT831/ Landis+Gyr/An optimal model	According to SMM brand/model
Smart Wall Box	Circontrol Wall Box smart	1

6.3 Storage Coordination Deployment View

Figure 16 represents the high-level deployment of a Storage4Grid system related to Storage Coordination Scenario, both at substation level and user premises.
The test site features in each house a hybrid inverter associated with a Lithium-based Fronius ESS. The inverter/ESS is integrated to the USM1 by means of a dedicated connector implementing one of the interfaces offered by the Fronius system. Additionally, the SMX Box is interconnected with a SMM monitoring the grid exchange for the house and features a LESSAg component. All data is conveyed to the GESSCon installed at DSO or Aggregation premises.

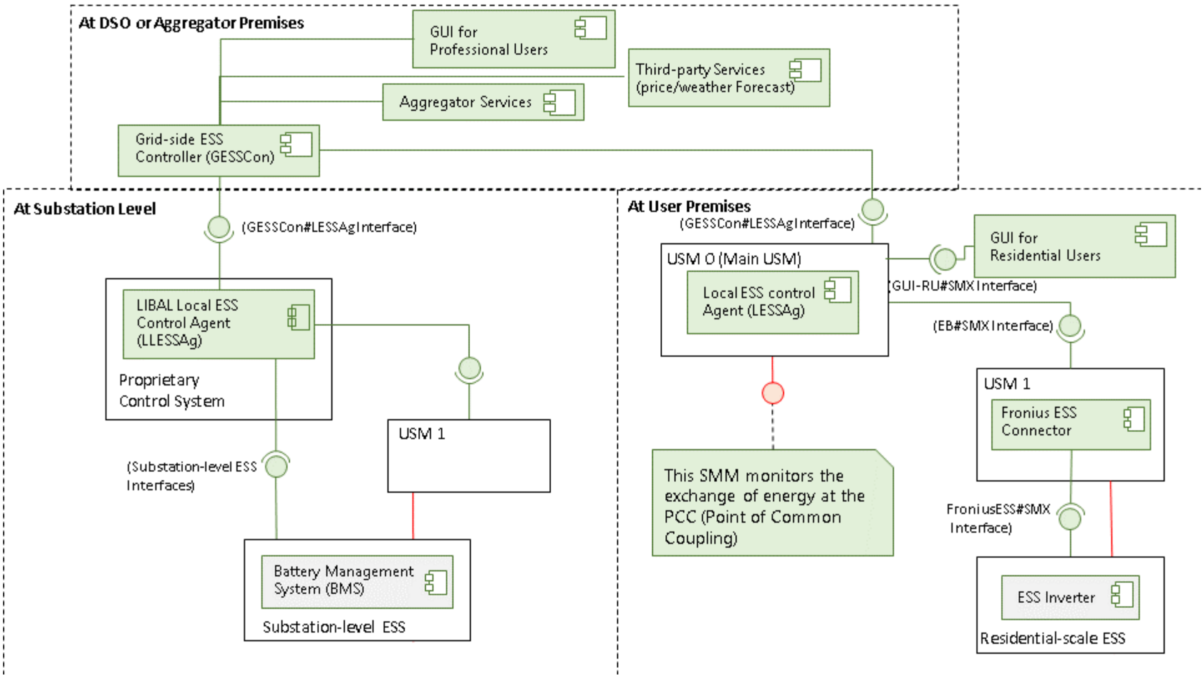

Figure 16 - Typical Deployment for the Storage Coordination test cases (Deployment Diagram)

On the side of the substation-level (grid-side) storage, a larger-scale ESS is deployed, locally controlled by a dedicated Battery Management System, in turn controlled by a special version of the LESSAg developed by LIBAL (LLESSAg). This component implements on the north-bound the same interface by all the other LESSAg components.
At higher level, the scenario is controlled by a dedicated GESSCon, which coordinate the different LESSAgs (one at substation level and one in each of the residential/user premises) also using forecast and signals from third-party services.

6.3.1 Physical components

The following table outlines the number and models of different physical components foreseen in this scenario during the first phase.

Table 25 - Number and models of different physical components foreseen - Fur

Component	Brand/Model	# of components deployed
Fronius ESS with Hybrid Inverter	Fronius Symo Hybrid	1 per house

SMX Box	Raspberry PI model 3	1 per house
SMM	Landis+Gyr/An optimal model	1 per house

7 Information Security View

S4G adopts secure-by-design communication protocols. The choice of secure communication protocols, guarantees levels of security compliant with the requirements of the proposed infrastructure, in conjunction with two system security best practices adopted by the S4G design, namely: (i) the use of secure services and systems built adopting open-source components; (ii) the unique use of certificate-based authentication against less secure password-oriented security approaches for all remote systems. Figure 17 highlights the network/communication view how secure domains are handled within S4G. As depicted in Figure 17, in Local Area network security is delegated to security features specific of each site, trusted S4G services are only conveyed over secure transports (i.e. TLS) and over dedicated VPN interfaces. In other words, trusted S4G services running in the cloud, are logically insulated from the public networks using secure VPN configurations.

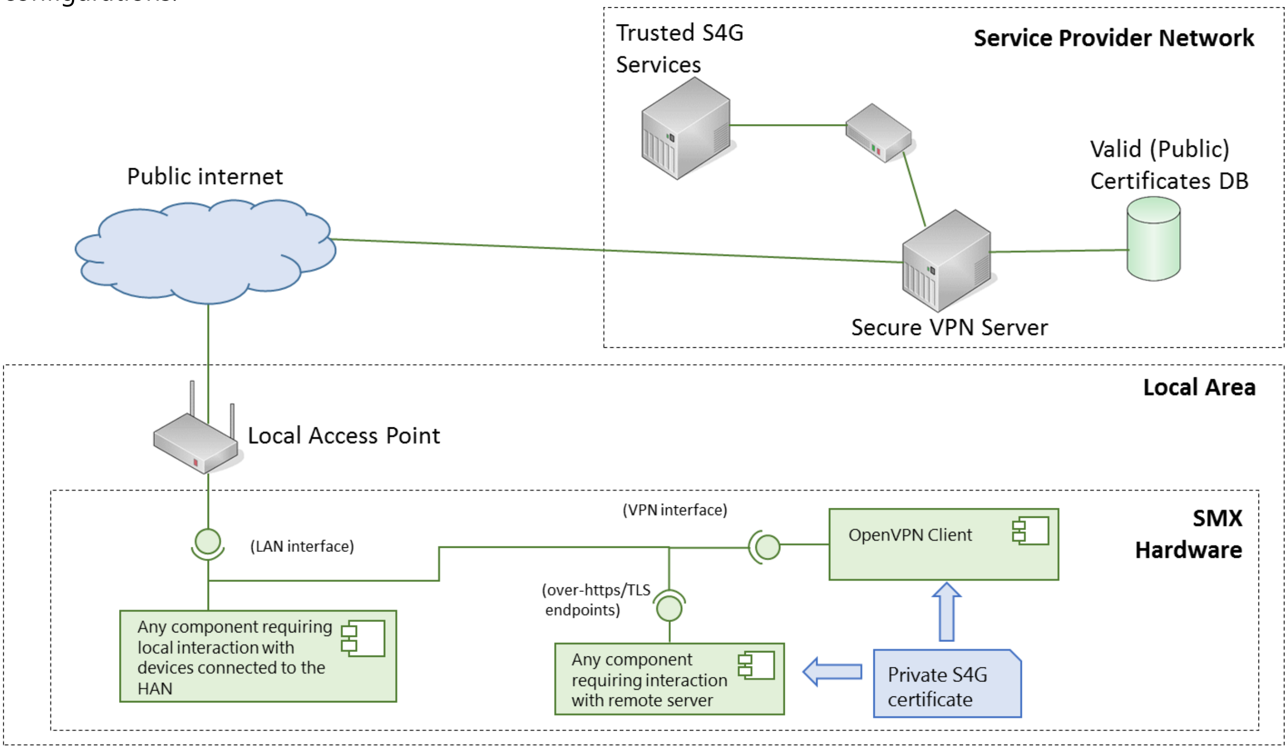

Figure 17 - Network Security View (Network Diagram)

Access to VPN is controlled by means of certificates maintained by a dedicated Certification Authority (CA), maintained by the project in an off-line domain, as depicted in Figure 18, and deployed manually in each authorized gateway.

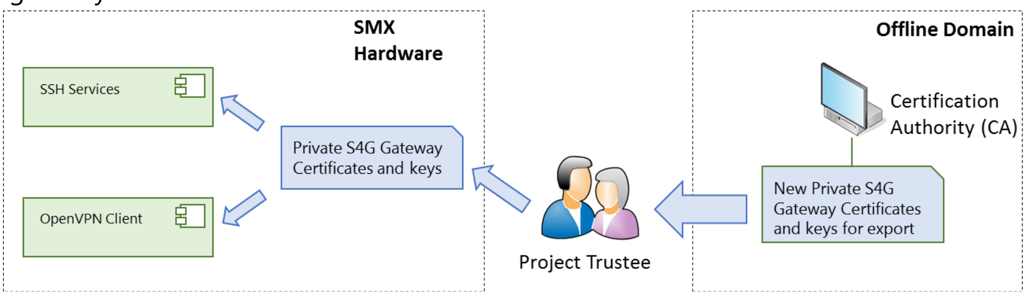

Figure 18 - Certification Authority (CA) work-flow

As foreseen in state-of-the-art VPN solutions, the project maintains a Certificate Revocation List (CRL) to enable the possibility of de-authorizing specific (e.g. compromised) gateways or systems.

8 Standards Overview

In order to facilitate adoption and reuse of generated outcomes, whereas feasible, S4G aims for adoption of existing standards. An overview of the full set of Smart Grid standards is reported in “Final report of the CEN/CENELEC/ETSI Joint Working Group on Standards for Smart Grids”, CEN/CENELEC/ETSI, 2011.[8]
S4G uses the following standards in the system implementation:

- DLMS/COSEM for communication with meters
- IEC61850 for communication between ER and SMX and from SMX to DSO SCADA
- MQTT pub-sub messaging for the basic communication between different software modules inside USM and from USM to high level applications.
- OCCP for the communication between a charging station and SMX. The standard uses REST over HTTP for data exchange, in a SOAP or JSON implementation

As having to integrate market existing equipment, vendor specific communication standards will be also used, based on vendor interfacing capabilities:

- Fronius Solar API
- SunSpec Alliance Interoperability Specifications (standard supported by an alliance, however not in the CEN/CENELE/ETSI list)
- Libal specific communication standard for its ESS market product
- Other communication standards may be used as well, based on the needs during implementation.

Standards for DC: IEC 60038 Ed.7: IEC standard voltages

The set of used standards is basically covering the S4G needs and no gaps which may need additional work on standardisation is needed.

However, based on the project activity, the following proposals can be considered, to be more refined during the next project activity:

- The project addresses low voltage DC network in the UPB demonstrator; by analyzing the existing standardization, we realized that there is no power quality standard adapted for DC networks and such standard need to be elaborated.
- The UPB demonstrator is using different low voltage loads, including white appliances and computers, some of them being already tested in lab that they work in both 230 VAC and 220 VDC. However, there is no obligation at the time for the low voltage equipment manufacturers to declare not only 230 VAC functionality, but also if the equipment can handle DC power supply and in which range. We are considering to be proposed during the project activity that the manufacturers should specify which the DC power supply characteristics are, if it is possible. By asking the manufacturers to declare the DC supply capability, the loads can be safely connected also to DC grids, which are an emerging technology in hybrid networks). The declarations should be based on specific tests made by the manufacturers in-house, thus bringing commercial guarantee that the equipment can be also used safely in DC networks.

[8] ftp://ftp.cen.eu/CEN/Sectors/List/Energy/SmartGrids/SmartGridFinalReport.pdf

9 Conclusions

This deliverable presents a description of initial interfaces designed to mediate the information transfer between the components used in the S4G project corresponding to an initial architecture specification further used to demonstrate the project high level use cases. The descriptions are based on different views: functional, components, information, communication and deployment. The functional view is presented in a simplified manner inside a SGAM plane, to be correlated with the S4G components of the corresponding SGAM layer. Three SGAM domains are targeted in the project: distribution, DER and customer premise. The other views are more IT-oriented and bring details on the interfacing between different components, building an architectural specification as guide for the project developments and for system integration. Standard protocols and data models are key objectives of S4G; therefore in this deliverable is included a chapter dedicated to the information model describing the set of standard protocols to be used in the project possible and the integration of vendor specific protocols needed and deployed on specific interfaces. The architecture is compatible with the first version of the test site plans developed in D6.1. Business architecture is not part of this document and will be developed in D2.3.

Acronyms

Acronym	Explanation
AC	Alternative Current
ADS	Active Demand and Supply
API	Application Programming Interface
CA	Certification Authority
CBOR	Concise Binary Object Representation
CIM	Common Information Model
CP	Charging Point
CPWB	Charging Point Wall Box
CRL	Certificate Revocation List
DC	Direct Current
DER	Distributed Energy Resources
DoA	Description of Action
DSF	Decision Support Framework
DSF - DWH	Decision Support Framework - Data Warehouse
DSF - SE	Decision Support Framework – Simulation Engine
DSO	Distribution System Operators

DTLS	Datagram Transport Layer Security
EB	Event Broker
EC	European Commission
ER	Energy Router
ESS	Energy Storage System
EU	European Union
EV	Electrical Vehicle
EVCh	Electrical Vehicle Charger
EXI	Efficient XML Interchange
GESSCon	Grid Side ESS Controller
GEVChCon	Grid EV Charging Controller
GPS	Global Positioning System
GUI	Graphical User Interface
HTTP	Hypertext Transfer Protocol
ID	Identification
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
IoT	Internet of Things
ISO	International Organization for Standardization
JSON	JavaScript Object Notation
LAN	Local Area Network
LESSAg	Local ESS control Agent
LEMS	Local Energy Management System
MQTT	Message Queuing Telemetry Transport
NIST	National Institute of Standards and Technology
OGC	Open Geospatial Consortium
OCPP	Open Charge Point Protocol
PC	Personal Computer
PCC	Point of Common Coupling
PUC	Primary Use Case
RBAC	Role Based Access Control
S4G	Storage 4 Grid

SCADA	Supervisory Control And Data Acquisition
SenML	Sensor Markup Language
SGAM	Smart Grid Architecture Model
SMM	Smart Metrology Meter
SMX	Smart Meter eXtensions
SOAP	Simple Object Access Protocol
SUC	Secondary Use Case
S4G	Storage4Grid
TLS	Transport Layer Security
TOC	Table of Contents
UML	Unified Modelling Language
USM	Unbundled Smart Meter
USEF	Universal Smart Energy Framework
URL	Universal Resource Locator
VPN	Virtual Private Network
XML	eXtensible Markup Language

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APPENDIX A – Adopted Standards

Standard ID and title	Short Description	Domain(s)	Where and how it is used in Storage4Grid
DLMS/COSEM	- An object model, to view the functionality of the meter, as it is seen at its interface(s). - An identification system for all metering data. - A messaging method to communicate with the model and to turn the data to a series of bytes. - A transporting method to carry the information between the metering equipment and the data collection system.[9]	Smart Metering / Smart Grids	Readout of SMM in USM
IEC61850-90-7	Describes the functions for power converter-based distributed energy resources (DER) systems, focused on DC-to-AC and AC-to-AC conversions and including photovoltaic systems (PV), battery storage systems, electric vehicle (EV) charging systems, and any other DER systems with a controllable power converter.[10]	Smart Grids	Communication with ER, communication with DMS-SCADA
MQTT	Is a lightweight messaging protocol that provides resource-constrained network clients with a simple way to distribute telemetry information. The protocol, which uses a publish/subscribe communication pattern, is used for machine-to-machine (M2M) communication and plays an important role in the Internet	ICT standard	Communication between various internal modules and logical actors

[9] http://dlms.com/information/whatisdlmscosem/index.html
[10] https://webstore.iec.ch/publication/6027

	of Things (IoT).		
OCCP	Is an application protocol for communication between EV charging stations and a central management system, also known as a charging station network, similar to cell phones and cell phone networks.	EV charging standard	Communication between a charging station and SMX. The standard uses REST over HTTP for data exchange, in a SOAP or JSON implementation
Fronius Solar API	The Fronius Solar API is an Ethernet-based, open JSON interface integrated in Fronius Galvo and Fronius Symo inverters as standard. It is available on other Fronius inverters in combination with the Fronius Datamanager 1.0 / 2.0 or Fronius Datalogger Web. This interface allows the current values for the inverter to be read easily.	Inverters	Proprietary standard for Fronius inverters
IEC 60038	Specifies standard voltage values which are intended to serve as preferential values for the nominal voltage of electrical supply systems, and as reference values for equipment and system design.	Voltage level	Standard for voltage levels on AC and DC, used for the ER design

APPENDIX B – Relevant Standards

The work of CEN/CENELEC/ETSI on Smart Grids has selected different standards for specific high-level use cases. A reference document to be considered during S4G development is "Final report of the CEN/CENELEC/ETSI Joint Working Group on Standards for Smart Grids", CEN/CENELEC/ETSI .[11]

APPENDIX C – Relevant on-going standardization efforts

Effort ID and title (e.g. WG, organization, etc.)	Short Description	Domain(s)	Why it is relevant for Storage4Grid
prEN 50549-1:2017 CLC/TC 8X "System aspects of electrical energy supply"	Specifies the technical requirements for the protection functions and the operational capabilities for generating plants, intended to operate in parallel with LV distribution networks.	Grid connection, Smart Grids	This European Standard specifies the technical requirements for the protection functions and the operational capabilities for generating plants, intended to operate in parallel with LV distribution networks.

References

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[ii] ISO/IEC/IEEE Systems and software engineering -- Architecture description," in ISO/IEC/IEEE 42010:2011(E) (Revision of ISO/IEC 42010:2007 and IEEE Std 1471-2000) , vol., no., pp.1-46, Dec. 1 2011 doi: 10.1109/IEEESTD.2011.6129467 [http://ieeexplore.ieee.org/document/6129467/]

[iii] CEN-CENELEC-ETSI Smart Grid Coordination Group, "Smart Grid Reference Architecture", version v3.0, November 2012 (Final TR for adoption by M/490) [https://ec.europa.eu/energy/sites/ener/files/documents/xpert_group1_reference_architecture.pdf]

[iv] Object Management Group (OMG), "OMG Unified Modeling Language (OMG UML)", Version 2.5, March 2015 [web link]

[v] http://ogc-iot.github.io/ogc-iot-api/datamodel.html

[vi] http://www.opengeospatial.org/

[vii] http://ogc-iot.github.io/ogc-iot-api/datamodel.html

[viii] "Media Types for Sensor Markup Language (SenML)". C. Jennings, Z. Shelby, J. Arkko, A. Keranen. January 13, 2016. Work in progress.

[ix] https://tools.ietf.org/id/draft-jennings-core- senml- 04

[11] ftp://ftp.cen.eu/CEN/Sectors/List/Energy/SmartGrids/SmartGridFinalReport.pdf

[x] *Open Charge Point Protocol 1.6, http://www.openchargealliance.org/downloads/*
[xi] *http://www.iec.ch/*
[xii] *https://webstore.iec.ch/preview/info_iec61850-90-7%7Bed1.0%7Den.pdf*
[xiii] *IEC 61850-7-420, Communication networks and systems for power utility automation – Part 7-420: Basic communication structure – Distributed energy resources logical nodes, https://webstore.iec.ch/preview/info_iec61850-7-420%7Bed1.0%7Den.pdf*
[xiv] *Fronius Solar API V1, Fronius*
[xv] *http://sunspec.org/about-sunspec-specifications/*
[xvi] *SunSpec Technology Overview, SunSpec Alliance, http://sunspec.org/wp-content/uploads/2015/06/SunSpec-Techonology-Overview-12040.pdf*
[xvii] *IEEE 802.11 – Wireless Lans [*http://standards.ieee.org/about/get/802/802.11.html*]*
[xviii] *IEEE 802.3 – Ethernet [*http://standards.ieee.org/about/get/802/802.3.html*]*
[xix] *IEEE 802.11i-2004, known as Wi-Fi Protected Access II (WPA2) [*http://standards.ieee.org/findstds/interps/802.11i-2004.html*]*
[xx] *RFC 5246 - The Transport Layer Security (TLS) Protocol [*https://tools.ietf.org/html/rfc5246*]*
[xxi] *RFC 6347 - Datagram Transport Layer Security Version 1.2 [*https://tools.ietf.org/html/rfc6347*]*