D3.2 Updated S4G Components, Interfaces and Architecture Specification

Deliverable ID	**D3.2**
Deliverable Title	**Updated S4G Components, Interfaces and Architecture Specification**
Work Package	**WP3**
Dissemination Level	**PUBLIC**
Version	**1.0**
Date	**2018-08-31**
Status	**final**
Lead Editor	**ISMB**
Main Contributors	Orlando Tovar **(ISMB)**, Vasco Delgado Gomes **(UNINOVA)**, Gustavo Aragon **(FRAUNHOFER)**, Yini Xu **(LIBAL)**, Marta Sturzeanu **(UPB)**

Published by the Storage4Grid Consortium

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 731155.

Document History

Version	Date	Author(s)	Description
0.1	2018-07-27	ISMB	Documented restructured with respect to D3.1
0.2	2018-08-01	ISMB	Added Functional architecture view and updated previous architectural views
0.3	2018-08-07	UNINOVA	UNINOVA inputs
0.4	2018-08-07	Fraunhofer	Fraunhofer inputs
0.5	2018-08-08	LIBAL	LIBAL inputs
0.6	2018-08-18	ISMB	ISMB inputs
0.7	2018-08-26	ISMB	Updated Communication view and Standards overview
0.8	2018-08-26	ISMB	Document revision before internal review
0.9	2018-08-27	ISMB, UPB	Version Ready for internal review and UPB inputs
1.0	2018-08-31	ISMB	Final Version, ready for submission to the EC

Internal Review History

Review Date	Reviewer	Summary of Comments
2018-08-28	Yini Xu (LIBAL)	Approved. • Minor comments and changes on Section 3 and 5.
2018-08-30	Marta Sturzeanu (UPB)	Approved. • General minor corrections.

Table of Contents

Executive Summary

The deliverable D3.1 describes the *Initial S4G Components, Interfaces and Architecture Specification* serving the objectives of the Storage4Grid (S4G) project. This document is meant to provide an updated view of the system architecture developed in S4G, consolidating the work and developments as analysed and specified until M21. Refer to the previous document version D3.1 *Initial S4G Components, Interfaces and Architecture Specification* (M9) to keep track of the S4G architecture system evolution.

The main goal of this document is to update the common architectural and technical framework defined in D3.1, in order to facilitate 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.

This document presents multiple architectural views to assist the understanding of the S4G system and key properties about its behaviour, composition and evolution. Functional view shows the generic functionalities provided by S4G components both individually or as part of integrated configurations. Information view includes a description of main functional interfaces among high-level components within the S4G system. Communication view identifies the optimal channels and protocols and is presented making use of deployment diagrams. Deployment view presents a general deployment of the Storage4Grid system on the pilots (Bucharest, Fur/Skive, Bolzano). Finally, Information Security view shows what are the cyber security counter-measures adopted in the system.

Specifications described in this document have been collaboratively derived by the S4G consortium, drawing inputs and requirements from latest high-level scenarios, use cases documented in D2.2 and requirements documented in D2.6 as well as from the Description of Action (DoA) i.e. the contractual agreement signed by the consortium with the European Commission (EC).

Diagrams included in this document use standard formatting including Unified Modelling Language (UML)-compliant formats [9] (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 7) 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 (S4G) project, ensuring proper mapping towards European Union (EU) and International Smart Grid standards.

Its main goal is 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] [S4G-D2.2] and requirements documented in [S4G-D2.5] [S4G-D2.6] as well as from the description of project.

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 [1], and it is therefore organized in multiple *architectural views*, each one associated to a dedicated section of this document.

The set of architectural views represented in this document has been chosen to match the Reference Architecture Elements defined by the Smart Grid Reference Architecture (SGAM) Framework [2], 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 use standard formats including: Unified Modelling Language (UML) - compliant [3] 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 7) 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 provides an overview of the key topics addressed by this and associated documents.

Table 1 – S4G Architecture Reading Guide

Topic	Relevant Section
Generic functionalities provided by S4G components both individually or as part of integrated configurations	Section 2 –Functional View
Interfaces between components and the information shared among them	Section 3 –Information Views
Main communication protocols used between multiple S4G components	Section 4 – Communication View
General deployed of the Storage4Grid system on pilots	Section 5 – Deployment Views
What are the security counter-measures adopted in the system	Section 6 – Information Security View
References to standards adopted or analysed by S4G	Section 7 – Standards Overview

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 updates from D3.1 the specifications of Storage4Grid systems as analysed and specified until the M21 (August 2018). It is expected a final update of this deliverable, namely D3.3 *Final S4G Components, Interfaces and Architecture Specification* (due at M33, August 2019).

1.4 Related documents

Table 2 – List of deliverable referenced in this document

ID	Title	Reference	Version	Date
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
D6.1	Phase 1 Test Site Plans	[S4G-D6.1]	V1.0	2017-07-16
D2.2	Final Storage Scenarios and Use Cases	[S4G-D2.2]	V1.0	2018-07-31
D2.6	Updated Lessons Learned and Requirements Report	[S4G-D2.6]	V1.0	2018-05-18
D4.4	Initial Grid-side ESS control system	[S4G-D4.4]	V1.0	2018-07-18
D4.9	Updated USM Extensions for Storage System	[S4G-D4.9]	V1.0	2018-08-31
D5.2	Final DSF Hybrid Simulation Engine	[S4G-D5.2]	V1.0	2019-02-28
D5.4	Update DSF Connectors for external systems and services	[S4G-D5.4]	V1.0	2018-08-31
D6.2	Phase 2 Test Site Plans	[S4G-D6.2]	V1.0	2018-07-31
D6.8	Updated Interfaces for Professional and Residential Users	[S4G-D6.8]	V1.0	2018-08-31

2 Functional View

This section presents the S4G high-level functional architecture to give an overview of its main components, including their main functionalities. It has been defined after collecting and categorizing the technologies and software components that the S4G project partners brought in with them. Moreover, its view has been refined considering S4G UCs and related stake-holders requirements.
Section 2.1 shows how the S4G concept matches into the SGAM Framework, and recalls the three high level use cases and their foreseen deployment in the demonstration locations (Bolzano, Fur/Skive, and Bucharest). Section 2.2 presents the S4G functional view following guidelines by previous section.

2.1 Storage4Grid concept on SGAM Framework

The M/490 framework[1] 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[2] and completes it by adding two new domains:

a) the Distributed Energy Resource (DER) domain;
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.

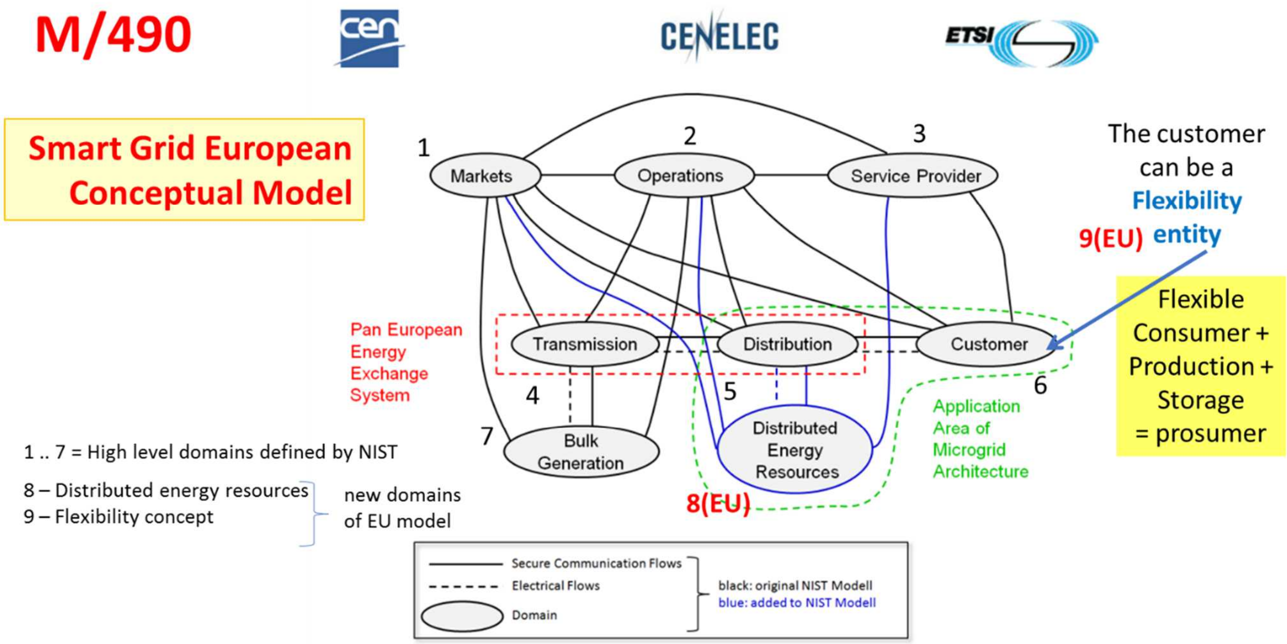

Figure 1 – Smart Grid European Conceptual Model[3]

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 two functions.

---

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

S4G extends 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.

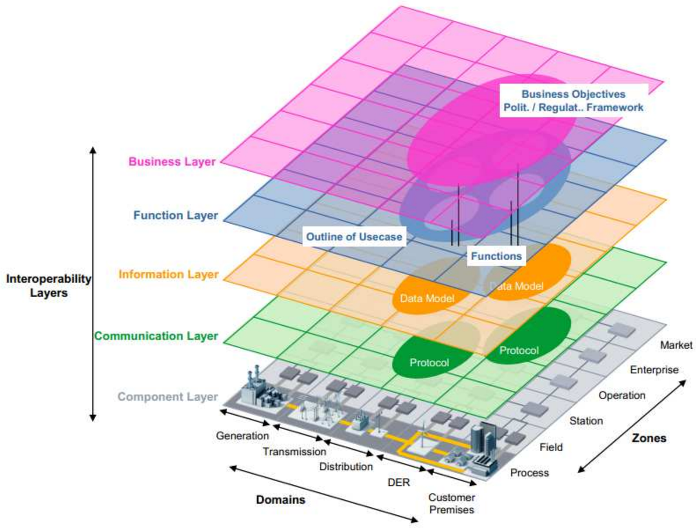

Figure 2 – SGAM template[4]

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.

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

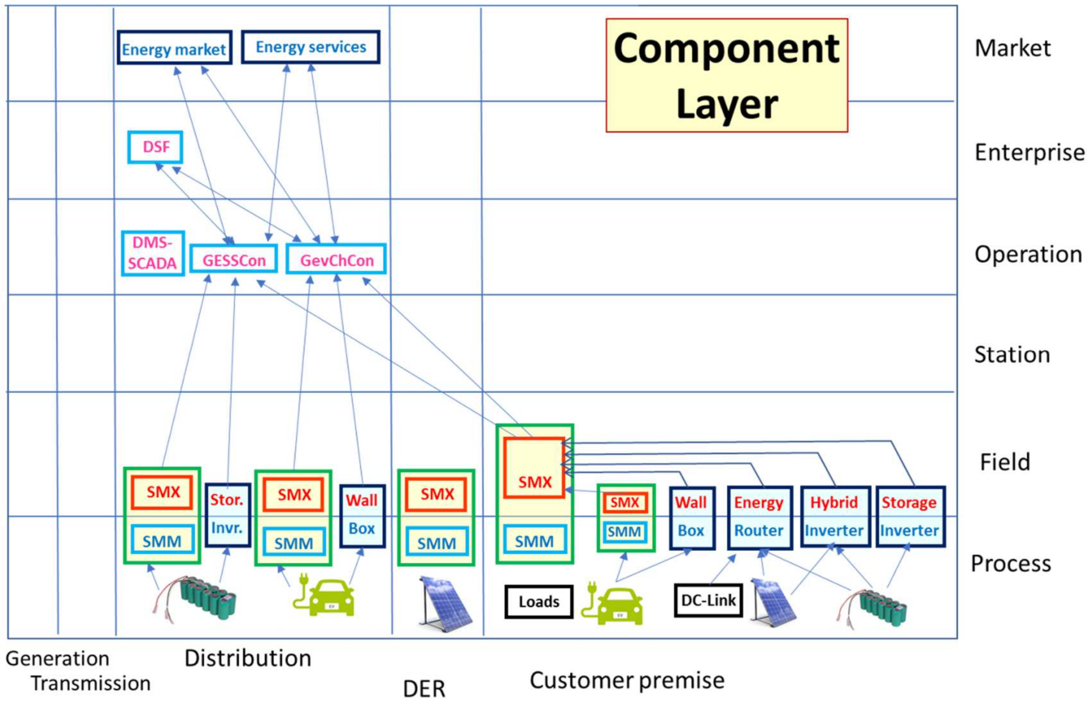

Figure 3 – S4G SGAM Component layer

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 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, 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)[5]. 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.

2.1.1 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 are presented in Section 2.2.

The SGAM Function layer represents the system design in terms of functionalities and services. The descriptions of the use cases that are defined in [S4G-D2.2] 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

[5] https://www.usef.energy/app/uploads/ 2016/12/USEF_TheFrameworkExplained-18nov15.pdf#popup_overlay1

appropriate parts of the domain and zone area. The next sub-chapters show for each high-level use case the simplified activity graph with generic interactions between the involved logical actors. Section 3 will develop in more details the information exchanged between different components.

2.1.1.1 Use case Bolzano – Cooperative EV charging

The high-level use case Bolzano is targeting the maximization the Electric Vehicle (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.

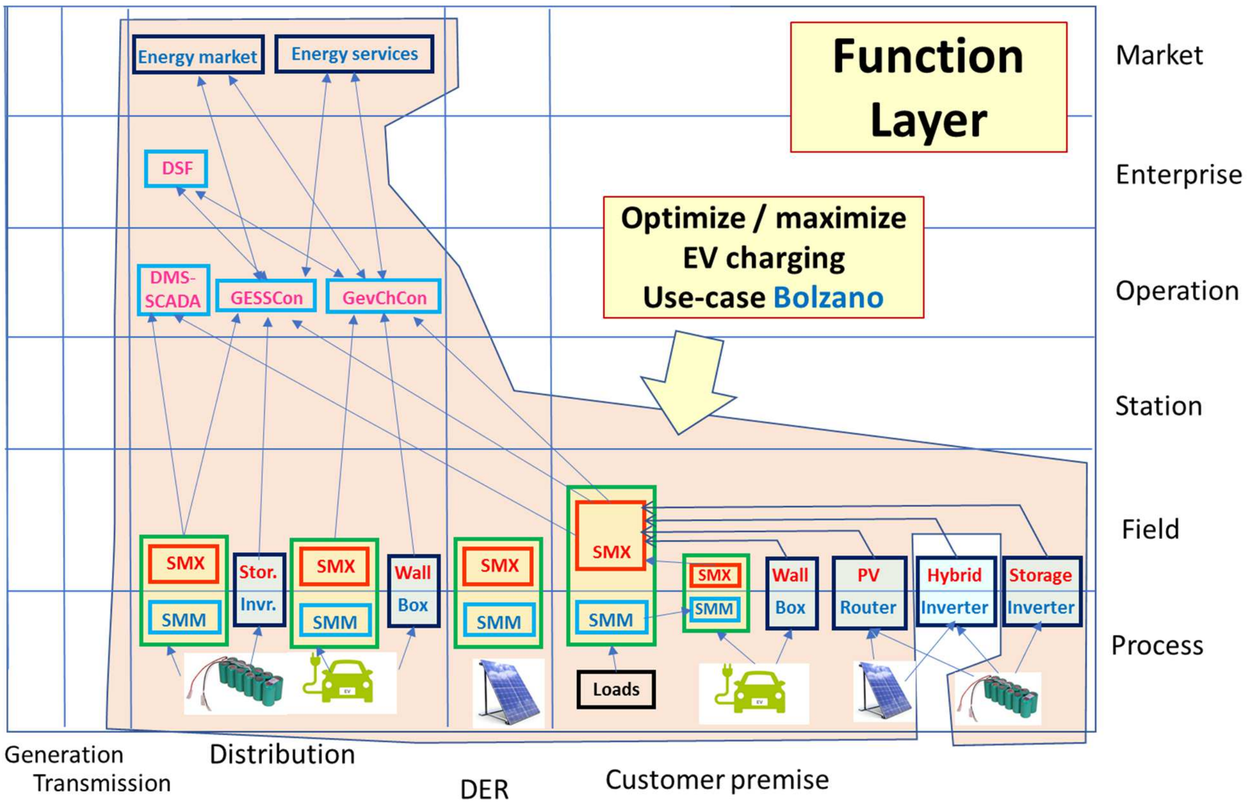

Figure 4 – S4G: SGAM Function layer for the high-level use-case Bolzano

This use-case is 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, Photovoltaic (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.

2.1.1.2 Use case FUR/Skive – Storage Coordination

The high-level use case FUR/Skive 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.

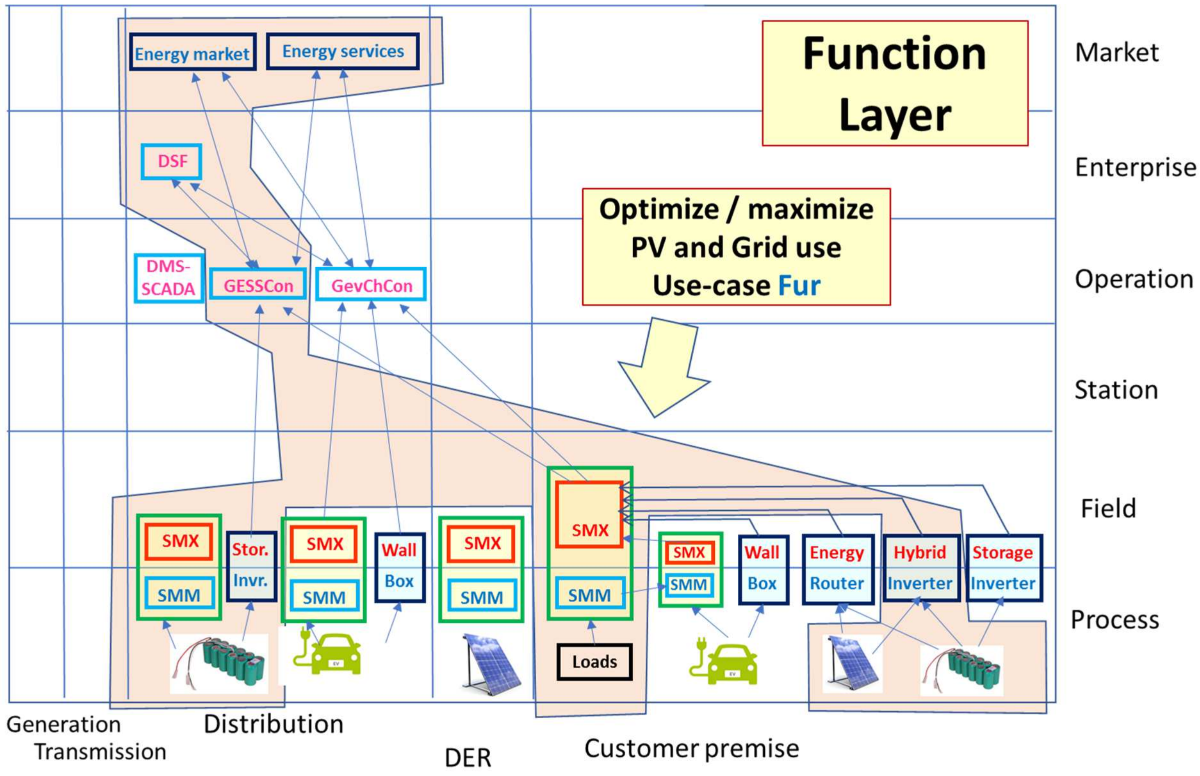

Figure 5 – S4G: SGAM Function layer for the high-level use-case FUR/Skive

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.

This use-case is 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.

2.1.1.3 Use case Bucharest – Resilient and efficient local ecosystem

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.

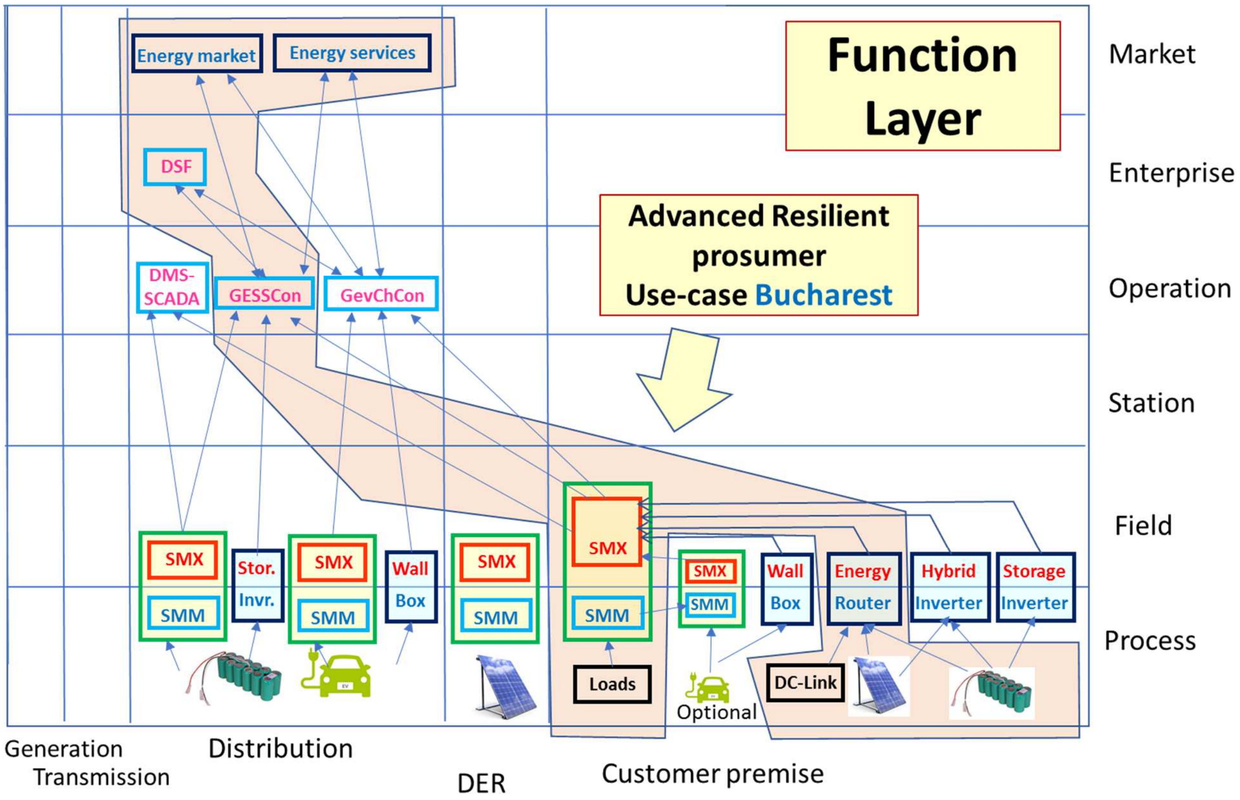

Figure 6 – S4G: SGAM Function layer for the high-level use-case Bucharest

Figure 6 presents the logical actors and their functionality. It can be observed that the logical actor "energy router" is in this case replacing the hybrid inverter used in previous high level use-cases, this solution allows the implementation of the DC bus and the DC link to neighbourhoods.

2.2 Storage4Grid Functional View

The S4G functional view (Figure 7) is inspired on the SGAM view of Component and Functional layers presented in Section 2.1. The S4G functional view has been proposed in order to provide more detail and to consider Information and Communication Technologies (ICT) aspects, not included in SGAM views, which are important for the S4G project, for instance middleware level. Five layers has been identified inspired from the zones presented in the SGAM template.

- The ***Physical Layer*** includes all components present in the Process zone which are involved in electrical processes.
- The ***Device Layer*** allows the effective communication and direct control of devices in the *Physical Layer* and communicates with the *Edge Layer*, presented hereafter, to receive specific control instructions or to send data of interest from/to the upper layers. This layer can be mapped into the Field zone.
- The ***Edge Layer*** allows in-site data collection from various sources in the *Device Layer* as well as to propagate remote messages from upper layers to specific S4G components in the *Device* and *Physical Layer*.
- The ***Communication Layer*** enables communication and management data among distributed S4G applications. It is a vertical layer and enables communication within *Service Layer*, *Edge Layer* and *Device Layer*. Besides, it enables communication with a Common Information Model (CIM) facilitating interaction or integration with new services.
- The ***Service Layer*** where the intelligence of the platform is implemented and specific processing modules are integrated to provide technical solutions compliant with the application requirements. This layer can be mapped in Operation and Enterprise zones. The services modules are combined

together with knowledge base components and decision support tools, whose aim is to assist human operators with storage analysis and planning, as well as to provide control actions to distributed ESS systems and EV charging stations at user premises and at substation level.

- The **Cyber *Security and Privacy Framework*** enables trust-based communication, policy management and technical support across all levels of the platform. More specifically, this framework ensures secure data flows and storage, protected information exchange and trusted federation mechanism to facilitate private information sharing.
- The ***External Application Services and Platforms*** are data sources, suitable to support analysis, planning, forecast and optimization of storage systems behaviour.

Further details about the behaviour of each system's component and related subcomponents, including architectural elements that deliver the system's functionality are presented in Section 2.3.

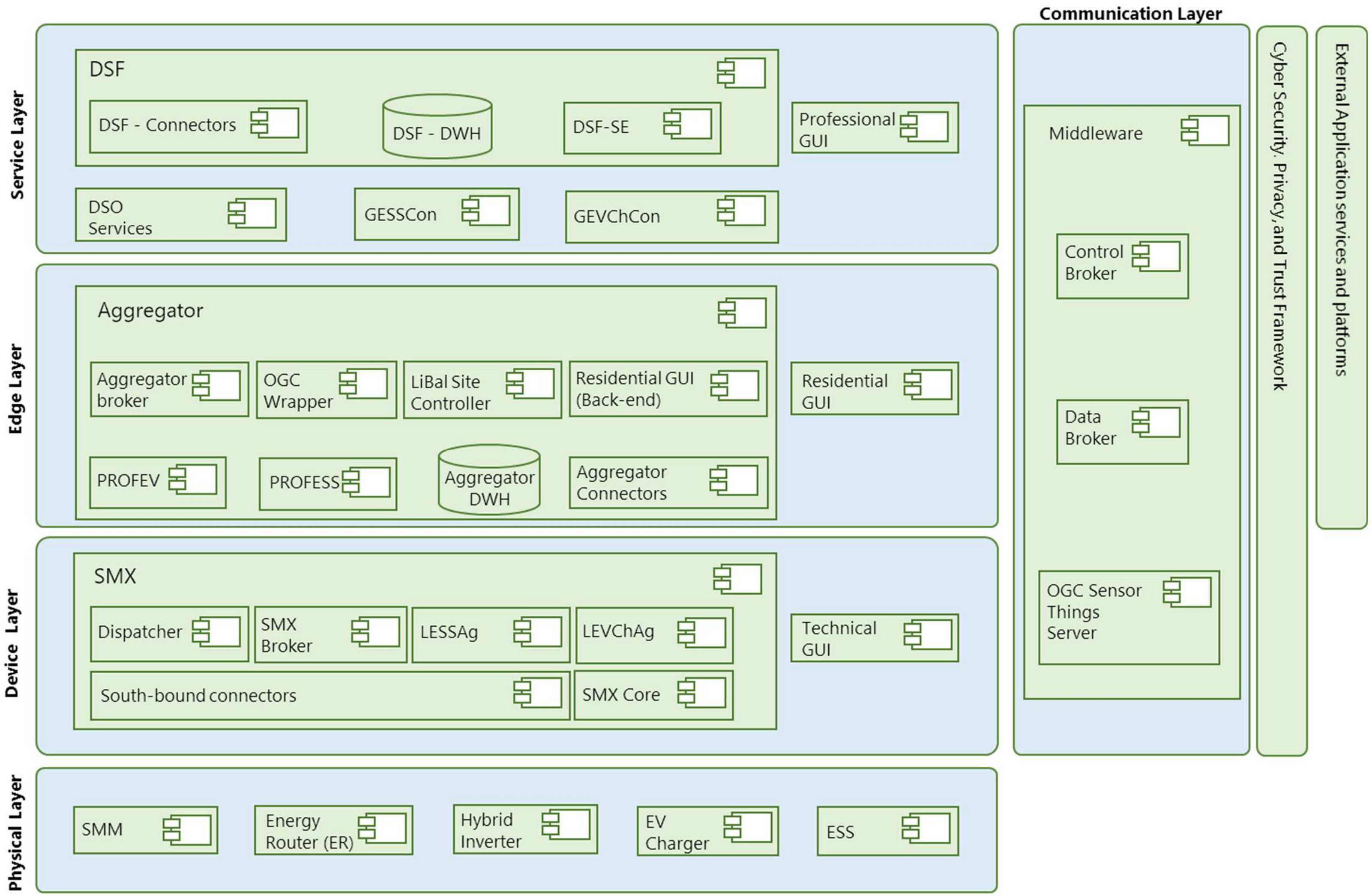

Figure 7 – S4G Functional architecture

2.3 Components Functionalities

This section provides a functional description of S4G components by architecture layers.

2.3.1 Physical Layer

- **Smart Metrology Meter (SMM):** A certified Smart Meters suitable to be inter-connected to external systems and to measure energy consumption in a trusted/certified way.
- **Energy router (ER):** The ER is a power electronics device that manages the energy transfer from/to different sources (distribution grid, RES-based distributed generators DGs), loads and ESS.
- **Hybrid inverter (HI):** This inverter combines a battery charging system, battery inverter, hybrid inverter, controller and system monitoring solution in one device. The inverter is able to supply household consumers with energy and to temporarily store surplus energy from a photovoltaic system in an ESS.
- **Electric Vehicle (EV) Charger:** 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.
- **Energy Storage System (ESS):** An energy storage system includes lithium battery racks, battery management system (BMS) and inverter. Battery management system is able to protect and monitor lithium battery. Inverter connects battery and local grid which enables energy exchange.

2.3.2 Device Layer

- **Technical GUI:** It is able to show in real time on an associated web link data recorded by SMX at a certain measurement point by subscription to different MQTT topics. More information can be found in S4G-D4.9. Final details about this component will be written in D4.10 "*Final USM Extensions for Storage Systems*" on M33.
- **Smart Meter eXtention (SMX):** The SMX is a modular software component, running on a dedicated computer (namely the SMX hardware), which can host plug-in components providing added-value services (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.).
  The SMX is often related to the SMM and they are put together because of their key role in handling all S4G features which take place on the field. Such combination is called Unbundled Smart Meter (USM), and it is 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.
  Physically, USM is composed by a SMM and an SMX hardware, hosting the SMX Core and one or more SMX components. The USM concept will be used in this deliverable specially to represent the deployment views. Further details about USM functionalities are presented in D4.9 [S4G-D4.9].
  The SMX components are described below:
  - **South-bound connectors:** These are a group of SMX connectors components providing bi-directional interoperability towards/from local devices on the field (e.g. local ESS systems, hybrid inverters, etc.). Further details about these connectors are described in D4.9 [S4G-D4.9].
  - **Dispatcher:** It subscribes to the SMX Broker to receive data coming from the Physical Layer and to forward them to the upper layers such as Edge Layer. Further details about this component are presented in D5.4 [S4G-D5.4].
  - **SMX Broker:** It is an MQTT broker enabling communicating between the SMX components.
  - **SMX Core:** It implements a real-time database, preserving the communication with SMM and with all extensions running around SMX Core. It uses Role Base Access Control (RBAC) system to preserve security and privacy for the used data.
  - **LESSAg:** It is a software component used in "Advanced Cooperative Storage Systems" scenario and developed by UPB partner. The tool is in charge of running site-wise ESS control algorithms enabling functionalities for advanced prosumers. It receives in quasi-real-time all

available information from local devices (ESS systems, PV energy meters, load-side energy meters, EV chargers, etc.) DC link via the Energy Router to which those devices are electrically connected. Also, it needs to subscribes to load predictions from the PROFESS which publish this information as a MQTT topic in the *SMX Broker*. The PV generation profile, the DC loads profile, the storage bidirectional power and the information on State of Charge (SoC) will come from ER. The most important aspect of this software is to match the information received from ER with conditions of the PCC in a certain period of time.
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 an open source tool, complying with GPL rules.

  - **LEVChAg:** A software component acting as a slave of the LESSAg - is a field control and monitor agent that controls the EV charger according to the instruction received from GEVChCon (or LESSAg in stand-alone operation) and sends the EV charging monitored data towards the LESSAg. Thus LEVChAg lacks the decision intelligence such as LESSAg.

2.3.3 Edge Layer

- **Residential GUI:** It is a user-friendly web-based application for residential sites to provide interaction with smart energy emerging systems. It allows to check, in a secure way, the health level of renewable resources as well as data gathered from local Renewable Energy Resources (RES) systems. In particular, it shows status of electric vehicles (EV) (i.e. plugged/unplugged, charging status, remaining charging time) and energy storage systems (i.e., remaining charging time), real-time household production and consumption and data analysis over various time frames. Further details about these components are in D6.8 [S4G-D6.8].
- **Aggregator:** It is a set of components involved in data collection and control processes providing specific services with respect to the S4G requirements. It communicates directly with the SMXs belonging to the same physical area and with the services in *Service Layer* trough the *Communication Layer*. Further details about the Aggregator functionalities, associated to each sub-component, are described below.
  - **PROFEV:** It is a framework that combines information from various energy sources and offers a flexible optimization setting environment for controlling EVs and ESS together. The architecture includes modules for management and signal processing of sensor data (SMM), linking of predictive algorithms to deliver inputs to the optimization model, optimization modelling, linking of a solver, an optimization controller and a post-processer module for formatting the results or creating events. The framework offers an API that describes the insertion of new optimization models, allows the registration of data input and output and presents a set of commands to control the start of the framework. PROFEV will be used in S4G for the optimal control of EVs. Therefore, PROFEV is able of running stochastic dynamic programming**.**
  - **PROFESS:** It is a framework that combines data from various sources and offers a flexible optimization setting environment for controlling ESS. The architecture includes modules for management and signal processing of sensor data (SMM), linking of predictive algorithms to deliver inputs to the optimization model, optimization modelling, linking of a solver, an optimization controller and a post-processer module for formatting the results or creating events. The framework offers an API that describes the insertion of new optimization models, allows the registration of data input and output and presents a set of commands to control the start of the framework. PROFESS will be used in S4G for the optimal control of ESS.
  - **Aggregator DWH:** It is a time-series data base containing data from the SMXs which are associated to the Aggregator. It is used by Residential GUI to show data in specific time slots as well as by services such as PROFESS and PROFEV to produce the related optimization settings. The Aggregator Data Warehouse (DWH) is based on the same software of DSF-DWH

but contains only local data. Further details about Aggregator DWH are referred to DSF-DWH (Section 2.3.5).

  - **Aggregator Connectors:** A software component providing interoperability between specific third-party services and other S4G components through the DSF-connectors (Section 2.3.5).
  - **Aggregator broker:** It is an MQTT broker enabling communicating between the Aggregator components as well as with the associated SMXs components.
  - **OGC Wrapper:** It is a software based on MQTT. It propagates SMXs data to the *Service Layer*, from *Service Layer* to the Aggregator services, and from the Aggregator to a specific SMX. It is compliant with OGC Sensors Things standard and allows to keep a CIM among S4G components. Moreover, it describes components in *Device* and *Edge Layers* and generates a virtual association between specific SMXs and the Aggregator hosting it (i.e. the Aggregator is considered as a single resource hosting N SMXs with specific functionalities). Finally, It supports interoperability among S4G components exploiting the registration of its "resources" to the OGC Sensor Things Server. Further details about this component are described in D5.4 [S4G-D5.4].
  - **Residential GUI back-end:** It is the server controlling main functionalities of the Residential GUI. It takes care of security related aspects, provides user authentication services, access to data bases and allows the interaction with other S4G components. Further details are referred in D6.8 [S4G-D6.8].
  - **LiBal Site Controller:** LiBal Site Controller is a Linux device which connects to ESS through CAN bus and Modbus RTU. In HLUC-3-PUC-3 which described in D2.2 [S4G-D2.2], LiBal Site Controller will deliver voltage control according to local DSO's voltage set-point at the transformer secondary side.

2.3.4 Communication Layer

- **Middleware:** It is one of the key elements of the S4G Platform as it integrates heterogeneous resources and systems. In this integration context, it provides modelling abstractions of services and resources enabling the search and discovery of them.
  - **Control Broker:** A scalable software component, based on MQTT, handling dispatch of asynchronous data from S4G services components, in charge in control functionalities (e.g. GESSCon), in an event-oriented fashion (publish/subscribe communication pattern). It is deployed and maintained as a private cloud service or on the premises of the entity operating S4G-based services. Its access is restricted to only control components.
  - **Data Broker:** A scalable software component, based on MQTT, handling dispatch of asynchronous raw data from S4G field components to the grid-side components, in an event-oriented fashion (publish/subscribe communication pattern). It is deployed and maintained as a private cloud service or on the premises of the entity operating S4G-based services.
  - **OGC Sensor Things (ST) Server:** It is based on GOST[6] (Go-SensorThings). It implements the Sensing profile (part 1) of the OGC SensorThings API[7]. The OGC ST server provides an open standard-based and geospatial-enabled framework to interconnect the devices, data, and applications over the Web with the registration of resources and services. This component has been introduced in order to achieve the technical objective **TO1** described in Description of Action (DoA), thus it guarantees that the S4G components joint a CIM suitable for monitoring and control of heterogeneous storage systems.

[6] https://www.gostserver.xyz/

[7] http://docs.opengeospatial.org/is/15-078r6/15-078r6.html

2.3.5 Service Layer

- **Professional GUI:** A dedicated S4G GUI used by professional (DSO or Aggregator) users to simulate the impact of storage systems in a selected grid radial over a certain time frame. The professional GUI originates from the use case HLUC-3-PUC-1 described in D2.2 [M20] and is further described in D6.8 [M21]. It enables professional end-users to interact with the functionalities of the DSF-SE.
- **DSO Services:** It makes reference to the available DSO tools and SCADA infrastructures with relevant data to S4G purposes. Relevant information includes: grid topology information from GIS systems, normative and contractual constraints in ERPs and historic and real-time information from deployed systems (meters, sub-stations, EV charging stations, etc.) via the DSO SCADA.
- **GESSCon:** It is an important cloud component, which receives inputs from DSF such as 24 hours foresight on user's load profile, PV production, electricity price, etc. The output data from GESSCon is a 24 hours scheduling of charge/discharge of the ESS systems. The output will be published to the MQTT Control Broker. PROFESS will subscribe to the respective topic, so it can execute the ESS control schedule with its own intelligence.
- **GEVChCon:** It is a cloud component able to remotely control local EV charger (charging station) through its main set-points. This component is a slave of GESSCon.
- **Decision Support Framework (DSF):** It is a loosely-coupled collection of interoperable software components, integrated with the DSO SCADA and other relevant 3rd party data sources, they can be combined in different configurations to perform analysis, planning, forecast and optimization tasks of distributed storage systems. Analysis, planning and optimization tasks are supported by a set of simulation tools as well as by static, historic and real-time information from the DSO SCADA infrastructure. In particular, the simulation tools support analysis of feasibility and potential impacts of different scales of Electrical Storage Systems (from substation-level to user-level systems) and Electric Vehicles (from private to commercial fleets) on hypothetical grid scenarios. Besides, DSF allows performance evaluation of innovative cooperative strategies and predictive control algorithms.

  In addition, the DSF provides users means to evaluate the impact of controllable storage systems in terms of economic sustainability, expected effect on RES exploitation, control policies impact and lifetime estimation. The economic sustainability can be evaluated by choosing which BESS size maximizes the profits or even if a certain scenario is reasonable; the DSF provides this by estimating earning or saving patterns and also useful life of batteries. The expected effect on RES exploitation is evaluated by looking at which sizing and sitting model maximizes RES exploitation the most, the DSF allows to assess RES curtailment reduction after inserting new BESS(s) under an operation zone. The control policies impact estimation is handled by interpreting users problems into objective functions and by trying them as control policies, eventually they can communicate their interests by monetary terms to end-users or the other way around set the tariffs and incentives based on the existing (expecting) situation. The lifetime estimation is handle by the DSF thanks to the implementation of algorithms with the aim to address this issue.

  The main components DSF are described below:
    - **DSF-Connectors:** A set of software components providing interoperability between specific third-party services and other S4G components. The DSF connectors can be accessible with a common server. It is typically deployed and maintained on the premises of the entity operating S4G-based services. The DSF connectors are described in D5.4 [S4G-D5.4].
    - **DSF Data Warehouse (DSF-DWH):** It is an open source distributed platform providing ad-hoc services for Smart Grid applications to support monitoring and control systems, as well as to support analysis, planning, forecast and optimization of storage systems behaviour. In particular, it is a central database used to store all raw data from the S4G deployments. Moreover, it provides core services to accumulate, analyse, and act on time series data with strictly data access control policies to preserve privacy. It is installed and maintained either as a private cloud service or in the premises of the entity operating S4G-based services. Further details are provided in D5.4 [S4G-D5.4].

- **DSF Simulation Engine (DSF-SE):** A software component acting as a service, which is able to execute power flow simulations of a grid featuring heterogeneous ESS, loads (including Electrical Vehicles (EVs)) and renewables-based electricity generation. The DSF-SE presents an Application Programming Interface (API) for its interaction. In S4G the DSF-SE works together with the professional GUI for demonstrating HLUC3-UC-1.

3 Information View

This section provides a focused view on data handled by the S4G system presenting their respective interfaces and the corresponding data models. In order to reduce the complexity, the S4G information views are presented from three perspective *data collection* (Section 3.1), *control* (Section 3.2) and *simulation* (Section 3.3). Section 3.4 presents a table summarizing the different information and communication models used within S4G.

3.1 Information Data Collection View

Figure 8 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. The identified interfaces are listed in Table 3.

Each physical site where S4G-related components are deployed must have at least an *Aggregator*. The *Aggregator* receives *Physical Layer* devices data from SMX devices by means of various, heterogeneous wired or wireless local interfaces (*ER#SMX interface*, *ESS#SMX interface*, *EV Charger#SMX interface*, *PV#SMX interface*, *SMM#SMX interface*, *SMX#Aggregator interface*). Then, the *Aggregator* feed the data to higher-level components, through a dedicated, event-oriented interface, namely the *Aggregator#Data Broker interface*. Finally, *Physical Layer* devices data is feed directly to the *DSF-DWH* thanks to the *Data Broker#DSF interface*.

All data from field is fed to the *Data Broker* component, typically deployed at the premises of the entity operating S4G-based services, making them available to every S4G component, in secure and scalable fashion. The interfaces for connection with the *Service Layer* components must be compliant with the S4G CIM and communication protocol.

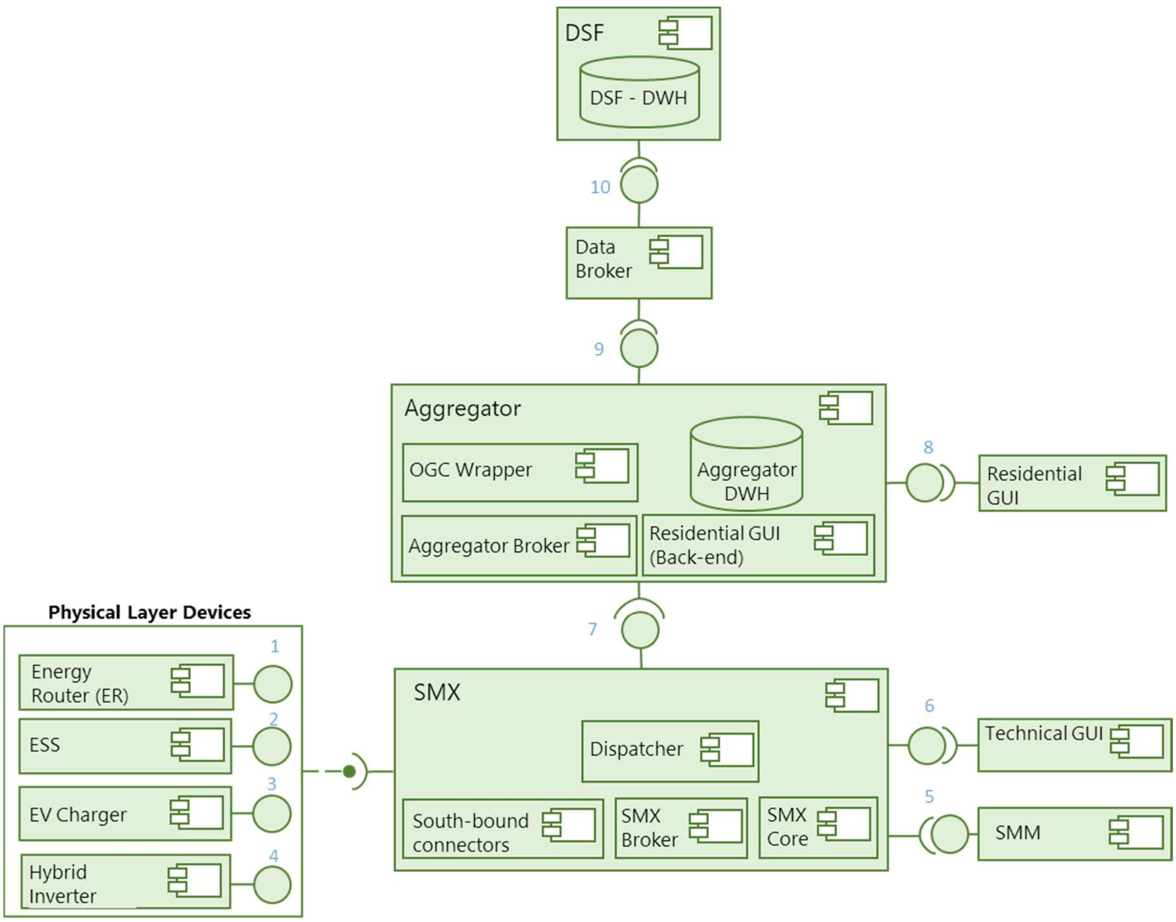

Figure 8 – Information Data Collection View

Table 3 – List of S4G interfaces involved in data collection

Interface	Name
1	ER#SMX interface
2	ESS#SMX interface
3	EV Charger#SMX interface
4	PV#SMX interface
5	SMM#SMX interface
6	SMX#Technical GUI interface
7	SMX#Aggregator interface
8	Aggregator#Residential GUI interface
9	Aggregator#Data Broker interface
10	Data Broker#DSF interface

The interfaces listed in Table 3 are described below.

- **ER#SMX interface:** This interface uses the *IEC 61850-90-7* standard to measure data from the ER. The Abstract Communication Service Interface (ACSI) GetDataValues service is used, to retrieve data from the ER according to Functional Constrained Data Attribute (FCDA) parameter. The complete list of possible ER measurements is available in D4.9 [S4G-D4.9].
- **ESS#SMX interface:** This interface uses CAN bus ICAN to obtain ESS status from BMS (Battery Management System). Table 4 provides more details about the messages

Table 4 – ESS#SMX interface messages

Message ID	Description	Variables (with units)	Periodicity
Status Event	ESS System data	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 (%)	
		ESS System status and errors	
Measurement/ monitoring Event	Measurement data send from ESS system	Device identification number	Every minute
		Timestamp for measurement (s)	
		Timestamp for set point (s)	
		Timestamp for last GESSCon request (s)	
		DC power measured (kW)	
		DC power set point (kW)	
		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)	

- **EV Charger#SMX interface:** This interface uses OCPP to obtain information related to the electric vehicle charging point. A charging point may sample the energy meter or other sensor/transducer hardware to provide extra information about its meter values. It is up to the charging point to decide when it will send meter values. More related messages are described in Table 5 below.

Table 5 – EV Charger#SMX interface messages

Message ID	Description	Variables (with units)	Periodicity
Status event	Return the status of the charging points	Electric vehicle charging point status	Varies
		Charging point time (s)	
Measurement event	Return the values of the measured parameters from the charging point	Power (kW)	Every 1 – 10 seconds
		Voltage (V)	
		State of charge (SoC) (%)	
		Enable/Disable	

- **Hybrid Inverter#SMX interface:** The interface uses Modbus TCP/IP to measure data from the HI. Single or multiple registers can be read in order to measure data from the HI. A more detailed description of this interface is available in D4.9 [S4G-D4.9].
- **SMM#SMX interface:** The interface uses DMLS/COSEM transforming electrical parameters data from load, RES sources, point common coupling, etc. into bytes. A more detailed description of this interface is available in D4.9 [S4G-D4.9].
- **SMX#Technical GUI interface:** This interface is able to show in real time an associated web link data recorded by SMX at a certain measurement point by subscribing to specific MQTT topics.
- **SMX#Aggregator interface:** This interfaces uses MQTT to forward messages from field devices to the *Aggregator*. The messages are the same as the ones published to the *SMX Broker*. Details about messages inside the SMX are available in D4.9 [S4G-D4.9].
- **Aggregator#Residential GUI interface:** This interface uses MQTT to send real-time data from *SMX Broker* to the *Residential GUI*; it also uses REST providing historical data from *Aggregator DWH*. The *Residential GUI (Back-end)* is the component interfacing with the *Residential GUI*. A more detail description of this interface is available in D6.8 [S4G-D6.8].
- **Aggregator#Data Broker, Data Broker#DSF interface:** These interfaces use MQTT to forward *Physical layer* devices data adopting OGC specifications. The format of data is compliant with the *DSF-DWH* component. A more detail description of this interface is available in D5.4 [S4G-D5.4].

3.2 Information Control View

Figure 9 depicts the relationship among S4G components from the point of view of distributed monitoringand control functionalities. The identified interfaces are listed in

Table 6.

Monitoring and control rely on *LESSAg* as main field component to run site-wise ESS control algorithms while *LEVChAg* to run site-wise EV control algorithms as a slave of *LESSAg*. Besides, both *PROFESS* and *PROFEV* are in charge of providing optimal set points for ESS and EV respectively based on signals from DSO and the status of local devices. Moreover, *GESSCon* and *GEVChCon* are in charge of remotely controlling respectively LESSAg and LEVChAg components by remotely changing their main set-points. Also, such main set-points are used by *PROFESS* and *PROFEV* to provide optimal local set-points together with data from third-party cloud-services e.g. providing weather or price forecast from DSF (*DSF#Aggregator* interface). *GESSCon* and *GEVChCon* are hosted in remote, cloud-premises (e.g. in facilities operated by the DSO) 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 *GESSCOn#Control Broker*, *Control Broker#Aggregator*. These interfaces provide messages from *GESSCon* and *GEVChCon*, with *GESSCon* as master, to the related *PROFESS* and *PROFEV* in charge of local optimization. Consecutively, the *Aggregator* forwards *GESSCON* and *GEVChCon* messages to the specific *SMX* (*Aggegator#SMX* interface) attached the ESS/EV to be controlled by *LESSAg/LEVChAg*.
The *GESSCon* collects data from *PROFESS/PROFEV* (Agregator#Control Broker, Control Broker#GESSCon interfaces) as well as from third-party systems (e.g. price/weather forecast) (*DSF#GESSC*on interface) to perform high level control. 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.
Finally, other strategies for monitoring and control are done by means of the *Residential GUI* (through the *Residential GUI#Aggregator* interface) enabling residential users with both monitoring and dedicated control/configuration features. Moreover, the hybrid simulation enabling hardware-in-loop simulation to evaluate new field components uses the *DSF#Control Broker, Control Broker#Aggregator* interfaces to contact specific field components.

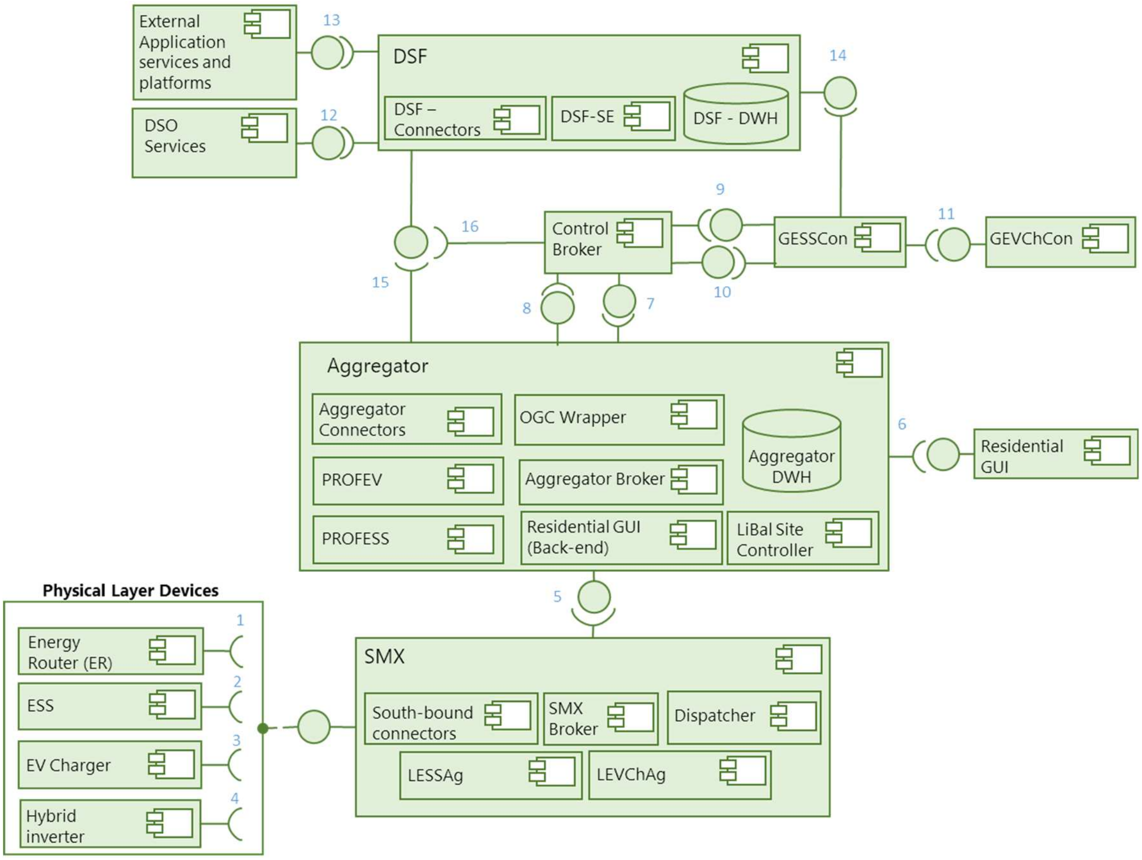

Figure 9 – Information Control View

Table 6 - List of S4G interfaces involved in control processes

Interface	Name
1	SMX#ER interface
2	SMX#ESS interface
3	SMX#EV Charger interface
4	SMX#PV interface
5	Aggregator#SMX interface
6	Residential GUI#Aggregator interface
7	Control Broker#Aggregator interface
8	Aggregator#Control Broker interface
9	GESSCOn#Control Broker interface
10	Control Broker#GESSCOn interface
11	GEVCHCon#GESSCon interface
12	DSO Services#DSF interface
13	External Application services and platforms#DSF interface
14	DSF#GESSCOn interface

15	DSF#Aggregator interface
16	DSF#Control Broker interface

- **SMX#ER interface:** This interface uses the IEC 61850-90-7 standard to send control commands to the ER. The ACSI SetDataValues service is used, to send control commands to the ER according to FCDA parameter. The complete list of possible ER control commands is available in D4.9 [S4G-D4.9].
- **SMX#ESS interface:** This interface requires both CAN bus and Modbus RTU. ESS mode switch request such as charge/load mode is through CAN bus to BMS, where inverter set-point is through Modbus RTU. Details about this interface will be provided in the next version of this document.
- **SMX#EV Charger interface:** This interface uses OCPP to send optimal set points to the electric vehicle charging points.

Table 7 – SMX#EV Charger interface messages

Message ID	Description	Variables (with units)	Periodicity
Command event	Command needed to change the load at the EV side	Load reduction(Array of a load profile (kW))	Varies
		Enable/Disable	

- **SMX#Hybrid Inverter interface:** The interface uses Modbus TCP/IP to send control commands to the HI. Single or multiple registers can be written in order to control the HI. A more detailed description of this interface is available in D4.9 [S4G-D4.9].
- **Aggregator#SMX interface:** This interface uses MQTT SMX – Broker for publishing the control set-points calculated by PROFESS or PROFEV defining the power of the different components (ESS, EV, etc). The set-points will be set to the respective components by the south-bound connectors. Details about messages will be provided in the next version of this document.
- **Residential GUI#Aggregator interface:** As mentioned above, this interface enables users to enable local control/configuration features from the *Residential GUI*. This messages (MQTT-based) will be forwarded by the *Residential GUI (back-end)* to the *Aggregator Broker*, the interested components will react accordingly. Details about messages will be provided in the next version of this document.
- **GESSCon#Control Broker, Control Broker#Aggregator interface:** *GESSCon* will send an optimized 24 hours charge schedule to *Control Broker* in OGC format, and this charge schedule will further be subscribed by *PROFESS* at *Control Broker#Aggregator interface*. *PROFESS* will operate the ESS according to the charge schedule and its own intelligence. Table 8 provides details about the messages.

Table 8 – GESSCon#Control Broker, Control Broker#Aggregator interface messages

Message ID	Description	Variables (with units)	Periodicity
Command Event	Battery power exchange setpoint	Timestamp for set point (s)	With hourly resolution in a data package sent every 24 hours
		DC power (W)	

- **Aggregator#Control Broker, Control Broker#GESSCon interface:** The real-time set-points for ESS calculated by PROFESS or PROFEV will be also published into the Aggregator broker. Through the OGC wrapper, the messages will be sent to the Control broker. The objective is that these set-points can be submitted by the GESSCon for further analysis. Details about messages will be provided in the next version of this document.
- **GEVCHCon#GESSCon interface:** *GEVChCon* generates the forecasted electric vehicle load profile of a region and sends it to the *GESSCon*. Further details about this interfaces will be provided in the next version of this document.

- **DSO Services#DSF interface:** This interface is based on REST. This interface allows DSO users to update their local data (i.e. prices, grid models) into the DSF, at the same time the DSF makes available these data to the S4G components. A more detailed description of this interface is available in D5.4 [S4G-D5.4]. Moreover, the DSF reads measurements from Fronius ESS systems deployed in the field from the Fronius SCADA system. The Fronius measurements are sent directly to the *DSF-DWH*. Table 9 provides details about Fronius system messages.

Table 9 – DSO Services#DSF interface messages

Message ID	Description	Variables (with units)	Periodicity
Measurement event	Return the values of the parameters measured by the ESS system	Generation power (kW)	Every 1 – 10 seconds
		State of charge (%)	
		ESS power (kW) and energy (kWh)	

- **External Application services and platforms#DSF interface:** This interfaces relies on REST services to obtain data from 3rd party services such as weather forecast. This is managed by the *DSF-Connectors* while they also provide these information to the S4G components. A more detailed description of this interface is available in D4.4 [S4G-D4.4] and D5.4 [S4G-D5.4].
- **DSF#GESSCOn interface:** This interface is to enable the *DSF-Connectors* to provide data from 3rd party services to GESSCon. It is based on REST, the *DSF-Connectors* acts as a REST server. A more detailed description of this interface is available in D5.4 [S4G-D5.4].
- **DSF#Aggregator interface:** This interface is to enable the *DSF-Connectors* to provide data from 3rd party services to *Aggregator Connectors*. The *Aggregator Connectors* are contacted by other *Aggregator* components during optimization processes. This interfaces is the same as *DSF#GESSCOn* interface, already explained above.
- **DSF#Control Broker, Control Broker#Aggregator interface:** As explained above, these interfaces enable the real-time hybrid simulation. In this process the DSF-SE performs simulations of specific grid models considering real measurements. The hybrid simulation provides outputs that are send in real-time to the field components. Further details about this interfaces will be provided in the next version of this document.

3.3 Information Simulation View

Figure 10 depicts the relationship among S4G components from the point of view of simulation functionalities, namely for analysis, optimization and planning tasks. The identified interfaces are listed in Table 10.
As previously mentioned, the DSF enables the analysis and planning of electrical grids composed of ESS and EV. The core of this asset is the DSF-SE acting as a cloud service and allowing power-flow simulation of the grid, taking into consideration optimal control of ESS and EVs. Its main goal is to provide a tool able to analyse different scenarios featuring combinations of loads, ESS, renewables and EVs of a given grid. The DSF-SE uses available information from 3rd party services and *DSO services* (*DSO Services#DSF interface*, *External Application services and platforms#DSF interface*), field data from *DSF-DWH* and inputs from the *Professional GUI* to perform the simulation analysis. Details about DSF-SE regarding analysis and planning of electrical grids with ESS and EV are described in D5.1 [S4G-D5.1] and the final implementation will be documented in D5.2 [S4G-D5.2].

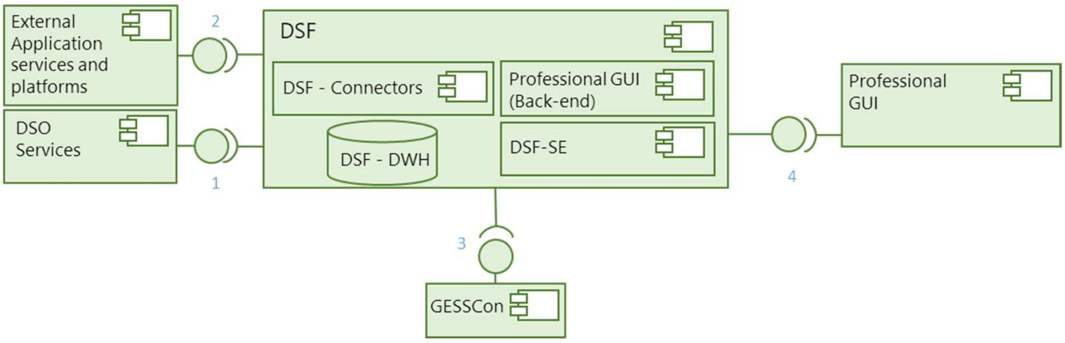

Figure 10 – Information Simulation View

Table 10 - List of S4G interfaces involved in simulation

Interface	Name
1	DSO Services#DSF interface
2	External Application services and platforms#DSF interface
3	GESSCon#DSF interface
4	DSF#Professional GUI interface

- **DSO Services#DSF interface:** This interface allows to read data from *DSO Services* provided by the *DSF Connectors* to the *DSF-SE*. This interface has been already explained in sections above.
- **External Application services and platforms#DSF interface:** This interface allows to read data from 3rd party services provided by the *DSF Connectors* to the *DSF-SE*. This interfaces has been already explained in sections above.
- **DSF#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. Further details about this interfaces will be provided in the next version of this document.
- **DSF-SE#Professional GUI interface:** DSF-SE works as a service and presents an API for interacting with the other applications. Professional GUI uses this API to insert grid models into the DSF-SE and for running power flow simulations of these models.

3.4 Information Models and Protocols

Table 11 shows the different Information Models and Protocols that are used in S4G.

Table 11 – Information Models and Protocol

Model	Use in S4G
MQTT[8]	- Communication between components in *Edge Layer*, *Communication Layer* and *Services Layer;* - Communication between components inside the *Aggregator;* - Communication between components inside the *SMX;* - Communication between *SMX* and *Aggregator*.
SenML[9]	- Communication between the local ESS control agent (PROFESS) and the Grid-side ESS controller (GESSCon);

[8] http://mqtt.org/
[9] https://www.iab.org/wp-content/IAB-uploads/2016/03/IAB_IOTSI_Keranen_Jennings_SenML.pdf

	- Communication between the EV charging controller (GEVChCon) and the Global ESS controller (GESSCon).
OCPP[10]	- Communication between the SMX and the wall box of a charging point.
IEC 61850-90-7[11]	- Communication between the energy router and the SMX.
Fronius Solar API[12]	- JavaScript Object Notation (JSON) based proprietary API for the communication between the SMX and ESS.
SunSpec Alliance Interoperability Specifications SunSpec Energy Storage Models[13]	- Data models and MODBUS register mapping for the communication between the SMX and the ESS of the storage through MODBUS.
DMLS/COSEM[14]	- Communication between SMX and SMM.
HTTP[15]	- Communication with Web services.

4 Communication View

The *Communication view* identifies the optimal channels and protocols to connect the implicated components in LAN and Wi-Fi networks considering cyber-security aspects. Figure 11 depicts the high-level communication view for a deployment involving S4G components. Since security and privacy protections are considered key requirements in S4G, a more detailed view is provided in Section 6.

In the *field domain*, an IP-based LAN, shall be available. This is not necessarily a homogeneous network, and can be optionally extended. The LAN is interconnected to the public Internet by means of a router which provides bi-directional internet connectivity from and towards every local component.

At least a *SMX Hardware* is available in the field domain, although it has to be observed that more than one *SMX* can be deployed in a single site, associated to the same or different routers.

Beyond to sharing internet connectivity, the local LAN has two key purposes:

1) allow IP-enabled Local Systems to connect to the local SMXs;
2) allow OpenVPN clients running on-board SMXs 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), which is used in the project for all secure communications between field and cloud components.

[10] https://www.openchargealliance.org/
[11] https://webstore.iec.ch/preview/info_iec61850-90-7%7Bed1.0%7Den.pdf
[12] http://www.fronius.com/en/photovoltaics/products/home/system-monitoring/open-interfaces/fronius-solar-api-json-
[13] http://sunspec.org/wp-content/uploads/2015/06/SunSpec-Techonology-Overview-12040.pdf
[14] http://dlms.com/documents/archive/Excerpt_GB6.pdf
[15] https://www.w3.org/Protocols/HTTP/1.1/rfc2616bis/draft-lafon-rfc2616bis-03.html

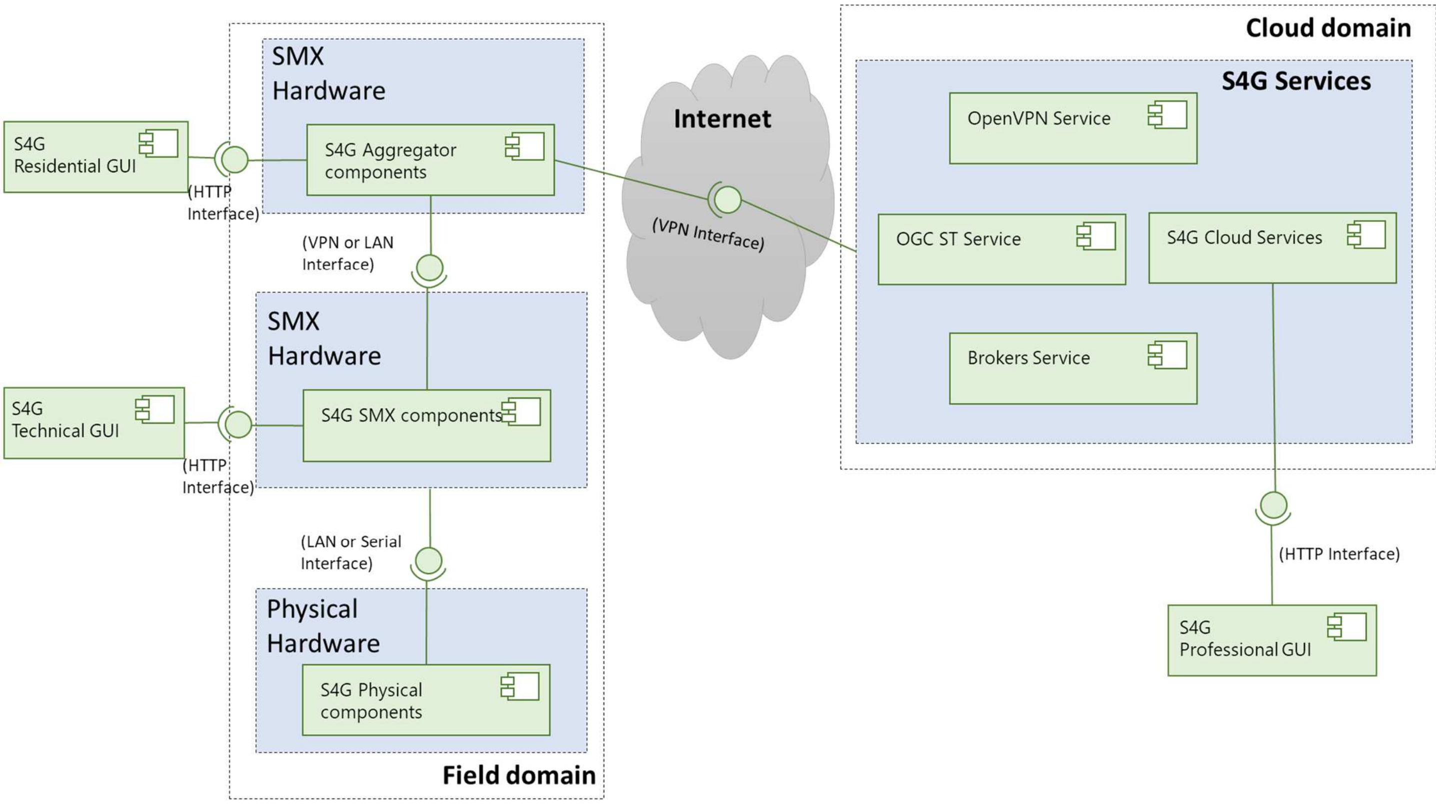

Figure 11 - General Communication View (Deployment Diagram)

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 12 – Communication protocols summary below summarises the used communication protocols and provides more details about other security mechanism considered within S4G for each communication protocol and location (details about deployment are provided in Section 5).

Table 12 – Communication protocols summary

Protocol	Segment	Use in S4G	Security mechanism employed
IP over wired or wireless LAN Protocols e.g. Wi-Fi [4], Ethernet [5], etc.	LAN Interfaces	Local Area Network in field locations at user premises	Basic security features in place in Wired/Wireless LANs including WPA2 [6]
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	State-of-the-art transport security layers including e.g. TLS [7], DTLS [8], typically

		running within the SMX) and Cloud components, as well as among cloud components	used in conjunction with security features of upper-layer application protocols (e.g. MQTT) when available

5 Deployment Views

In this view, it is generally described the hardware deployed on the field. Details about the specific test sites plans and planned deployments are described in D6.2 [S4G-D6.2].

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.

5.1 Resilient and efficient local ecosystem - BUCHAREST

Figure 12 indicates a deployment of a Storage4Grid system related to a resilient and efficient local ecosystem.

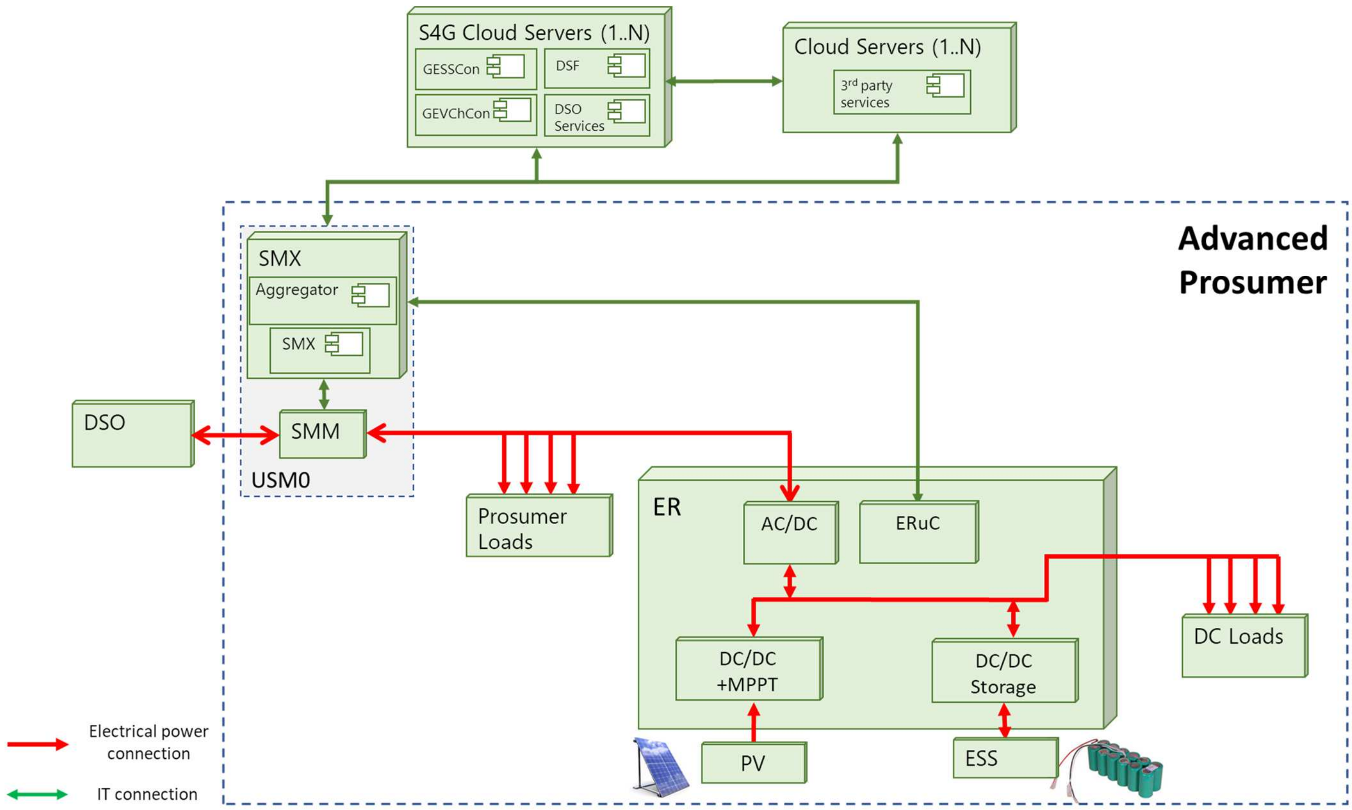

Figure 12 – Typical deployment for Bucharest pilot (Deployment diagram)

AC loads are deployed in the lab-scale test-site, monitored by a dedicated USM (*SMM* + *SMX Hardware*) – USM0, featuring a *LESSAg* component. The Energy Router will be also available and physically interconnected to a dedicated *SMX Hardware* through its main controller, Energy Router micro controller (ERuC). Besides, the *DSF* is available providing support and used to simulate scenarios of interest. Monitored data is fed in the *DSF-DWH*.

Table 13 outlines the number and models of different physical components foreseen in this scenario.

Table 13 - Number and models of different physical components foreseen - Bucharest

Component	Brand/Model	# of components deployed
SMX	Raspberry PI model 3	1
SMM	DLMS-COSEM-based meter (ZMG310CT)	2
Development PC	Existing	1
Energy Router	S4G Prototype	1

5.2 Cooperative EV Charging - BOLZANO

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.

5.2.1 Commercial test site

The EV Charging Deployment in the commercial test-site is depicted in Figure 13.

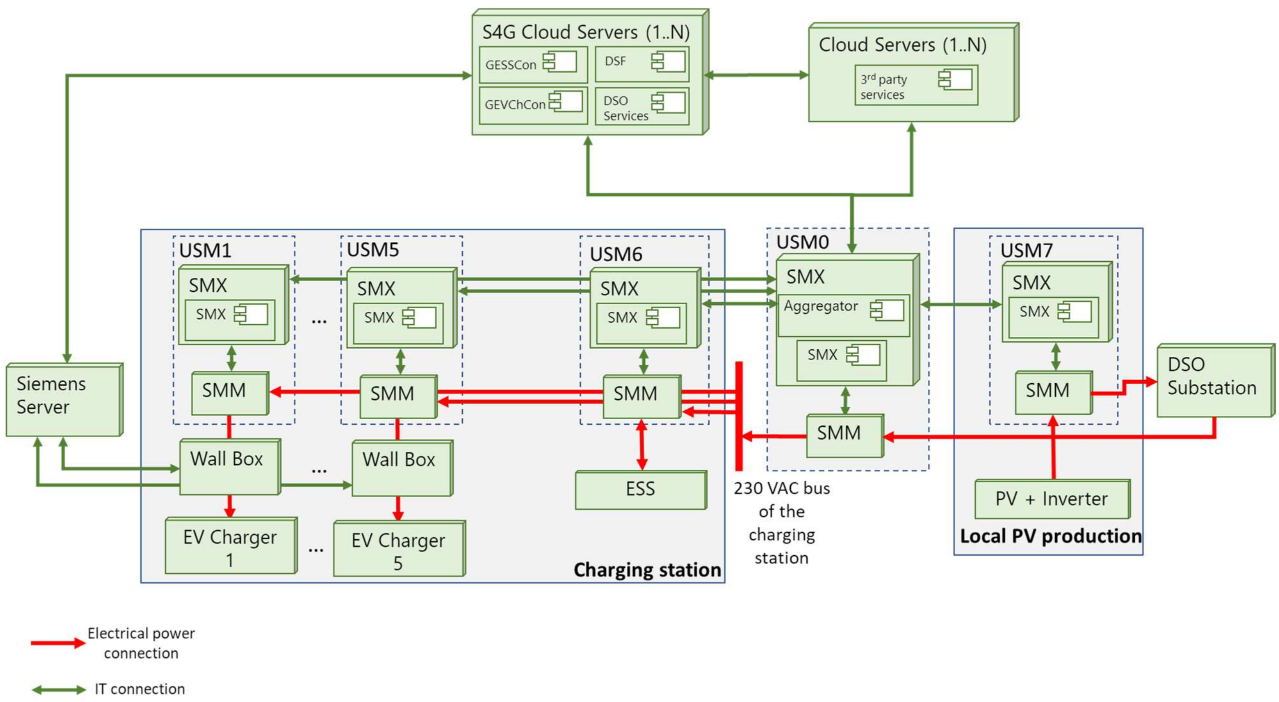

Figure 13 – Typical Deployment for Cooperative EV Charging, commercial site case (Deployment Diagram)

In the commercial test site a number of EV Charging Points (1 … *M*) is deployed. Each of them is associated to a specific USM (1 … *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 (*SMX#EV Charger* and *EV Charger#SMX* interfaces). 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 (USM6) is available to monitor and provide interoperability towards the local commercial ESS available on site. The local medium-scale PV installation available on-side is monitored by its dedicated USM (USM 7).

A main USM (USM0) is deployed to host the local LESSAg and LEVChAg through the SMX, as well as to act as main data collector for the test site by means of the *Aggregator* component. The SMM of USM0 is also active to monitor the exchange of energy at the Point of Common Coupling (PCC) with the grid.

USM0 also serves the *Service Layer* components, most notably GEVChCon, 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. It has to be observed that the GEVChCon is also provided with an additional connector, which allows interoperability with the legacy EV SCADA.

Table 14 outlines the number and models of different physical components foreseen in this scenario during the first phase.

Table 14 – Number and models of different physical components foreseen – Bolzano (commercial site)

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

5.2.2 Residential test site

The EV Charging Deployment in the residential test-site is depicted in Figure 14. Three dedicated meters are deployed to monitor respectively home Loads, PV Production and Grid Exchange, all interconnected to dedicated USMs, feeding data to the *SMX* component in the USM0. The local USM0 also acts as main end-point for the *Residential GUI* which is managed by the *Aggregator* component, featuring the *PROFESS* component.

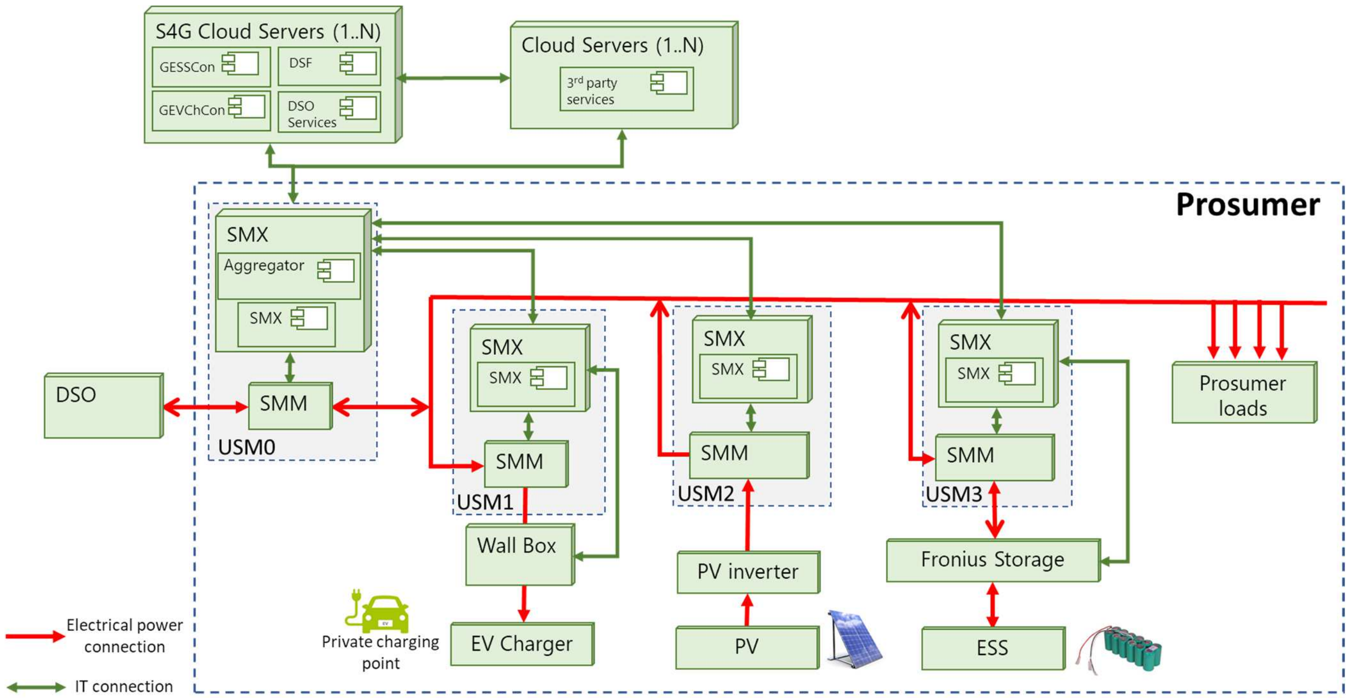

Figure 14 – Typical Deployment for Cooperative EV Charging, residential site case (Deployment diagram)

Table 15 outlines the number and models of different physical components foreseen in this scenario.

Table 15 – Number and models of different physical components foreseen – Bolzano (residential site)

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

5.3 Storage Coordination – Fur/Skive

Figure 15 and Figure 16, represents the high-level deployment of a Storage4Grid system related to the storage coordination scenario at commercial (Skive), grid case scenario, and residential (Fur) levels respectively.
In Figure 15 a large-scale ESS is deployed, locally controlled by a dedicated site control system (LIBAL system/site controller) able to communicate with cloud servers. At high level, the scenario is controlled by a dedicated GESSCon, which coordinates the different battery management systems also using forecast and signals from DSO and third-party services.

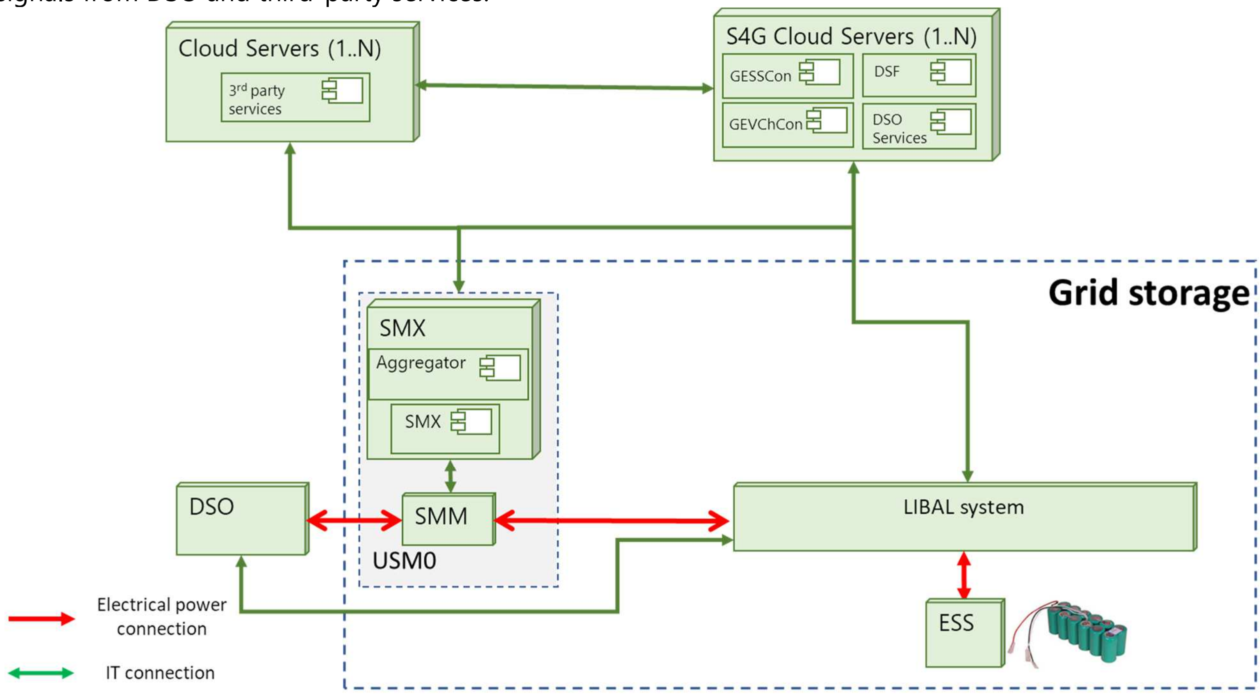

Figure 15 - Typical Deployment for the Storage Coordination – Commercial site (Deployment diagram)

In Figure 16, the test site features in each residential site a hybrid inverter associated with a Lithium-based Fronius ESS. The inverter/ESS is integrated to the *USM0* by means of a dedicated connector implementing one of the interfaces offered by the Fronius system. The residential site will also feature the three-phase Energy Router connected similarly like the Fronius system but using its IEC61850-90-7 connector in the *USM0*. Additionally, the *SMX Hardware* is interconnected with a *SMM* monitoring the grid exchange for the house and features the *PROFESS* component running in the *SMX* component. All data is conveyed to the *GESSCon* installed at *DSO* premises.

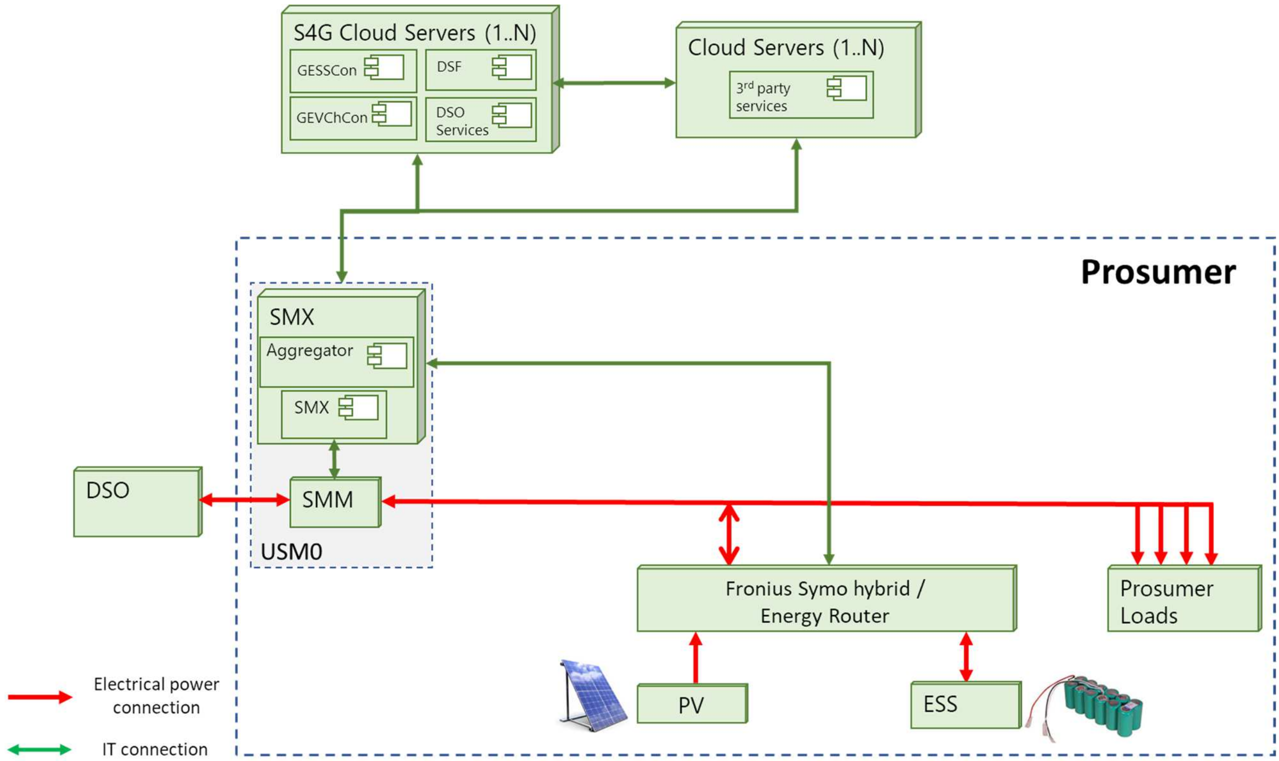

Figure 16 - Typical Deployment for the Storage Coordination – Residential site (Deployment diagram)

Table 16 outlines the number and models of different physical components foreseen in this scenario during the first phase.

Table 16 – Number and models of different physical components foreseen – FUR/Skive (commercial and residential sites)

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/1 per commercial site
SMM	Landis+Gyr/An optimal model	1 per house/1 per commercial site
LIBAL System	S4G Prototype	1 per commercial site
Energy Router	S4G Prototype	1 per residential site

6 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.

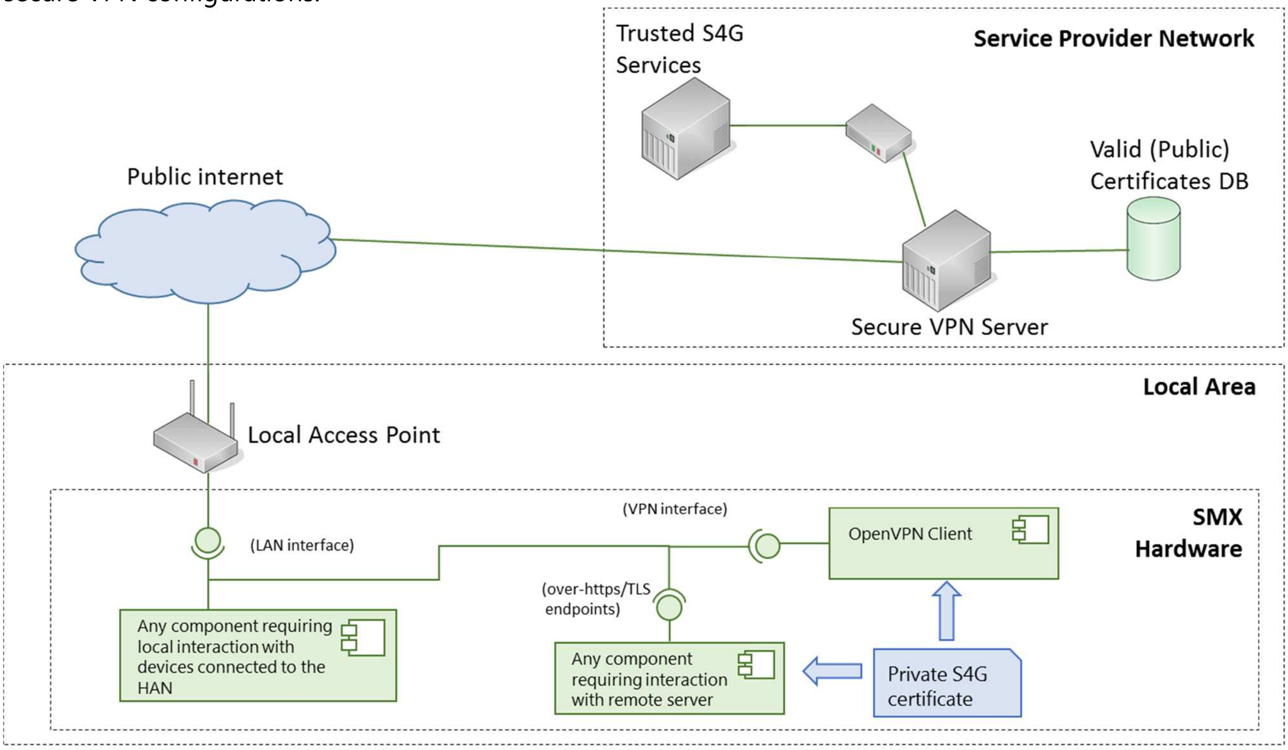

Figure 17 - Network Security View (Network Diagram)

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.

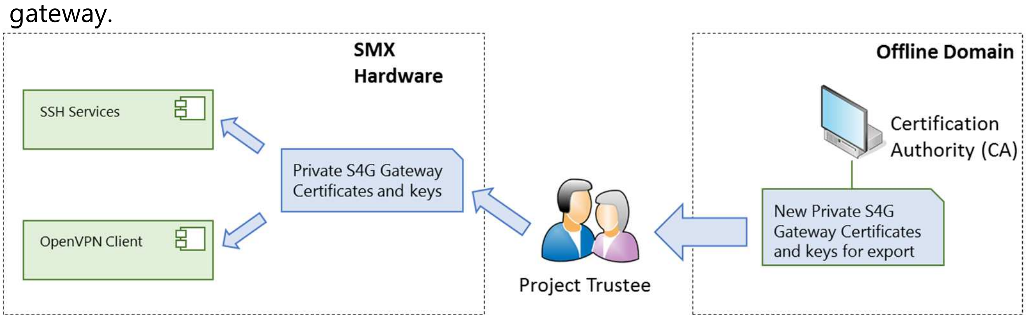

Figure 18 - Certification Authority (CA) work-flow

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.

7 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.[16]

S4G uses the following standards in the system implementation:

- *IEC62056* for communication with *SMM* meters;
- *IEC61850* for communication between *ER* and *SMX* and from *SMX* to *DSO SCADA;*
- *ISO/IEC PRF* 20922 for publish/subscribe messaging (MQTT-based) enabling communication between different software modules.
- *REST* enabling communication with web services.
- OGC SensorThings[17] providing an open and unified framework to interconnect devices, data and applications over the WEB. It is used during communication among components at *Edge*, *Communication* and *Service* layers.

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.

The set of used standards is basically covering the S4G needs and no gaps which may need additional work on standardization is needed. However, based on the project activity, the following proposals could be considered, to be more refined during the project activities:

- The project addresses low voltage DC network; by analysing the existing standardization, we realized that there is no power quality standard adapted for DC networks and such standard need to be elaborated.
- The Bucharest 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.

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

[17] http://www.opengeospatial.org/standards/sensorthings

8 Conclusions

This deliverable presented an updated specification of the S4G components, interfaces and architectural views to facilitate the integration between components over the third period of the project. The update of the S4G architecture has been done with respect to the initial architecture specification provided in deliverable D3.1 "*Initial S4G Components, Interfaces and Architecture Specification*" at M9.

The document presented different architectural views following to the standard ISO/IEC/IEEE 42010:2011(E). The architectural views have been divided in: functional, information, communication, deployment, and information security. The functional view has been extended, with respect to the previous version, by following the SGAM view. The S4G functional view provides a more detail functional view including important ICT aspects, such as a middleware level, not included in the SGAM views. Besides, the integration with middleware allowed to introduce the OGC SensorThings server providing means to reach a S4G Common Information Model. The information, communication, deployment and information security views have been updated according to the new components included in this document version and inputs from other deliverables such as D2.2 "*Final Storage Scenarios and Use Cases*", D2.6 "*Updated Lessons Learned and Requirement Report*" and D6.2 "*Phase 2 Test Site Plans*".

Standard protocols and data models are key objectives of S4G. Therefore, this deliverable included a dedicated section describing the used information models and the integration of vendor specific protocols needed and deployed on specific interfaces.

Acronyms

Acronym	Explanation
AC	Alternative Current
ACSI	Abstract Communication Service Interface
ADS	Active Demand and Supply
API	Application Programming Interface
BMS	Battery Management System
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
DWH	Data Warehouse
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
FCDA	Functional Constrained Data Attribute
GESSCon	Grid Side ESS Controller

GEVChCon	Grid EV Charging Controller
GPS	Global Positioning System
GUI	Graphical User Interface
HI	Hybrid Inverter
HTTP	Hypertext Transfer Protocol
ICT	Information and Communication Technologies
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
LEVChAg	Local EV charging 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
PV	Photovoltaic
RBAC	Role Based Access Control
RES	Renewable Energy Sources
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
SoC	State of Charge
SUC	Secondary Use Case
S4G	Storage4Grid
ST	Sensor Things
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

List of figures

List of Tables

APPENDIX A – Adopted Standards and Protocols

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.[18]	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.[19]	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 of Things (IoT).	ICT	Communication between various internal modules and logical actors

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

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
OGC SensorThings	It has been designed for sensors in the IoT application domain. It is an open standard addressing the syntactic interoperability and semantic interoperability of IoT.	ICT	It has been adopted for the S4G architecture, enabling the standardization of data required in the S4G system. It allows to stablish a CIM for S4G.

References

[1] *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/]*

[2] *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]*

[3] *Object Management Group (OMG), "OMG Unified Modeling Language (OMG UML)", Version 2.5, March 2015 [https://www.omg.org/spec/UML/About-UML/]*

[4] *IEEE 802.11 – Wireless Lans [http://standards.ieee.org/about/get/802/802.11.html]*

[5] *IEEE 802.3 – Ethernet [http://standards.ieee.org/about/get/802/802.3.html]*

[6] *IEEE 802.11i-2004, known as Wi-Fi Protected Access II (WPA2) [http://standards.ieee.org/findstds/interps/802.11i-2004.html]*

[7] *RFC 5246 - The Transport Layer Security (TLS) Protocol [https://tools.ietf.org/html/rfc5246]*

[8] *RFC 6347 - Datagram Transport Layer Security Version 1.2 [https://tools.ietf.org/html/rfc6347]*

[9] *Object Management Group (OMG), "OMG Unified Modeling Language (OMG UML)", Version 2.5, March 2015 [https://www.omg.org/spec/UML/About-UML/]*