Outsourcing Electric Vehicle Smart Charging on the Web of Data

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Abstract—**This paper describes the results of a joint work between partners in ITEA2 12004 Smart Energy Aware Systems (SEAS) project, which aims at developing a SEAS ecosystem of distributed services that all target energy efficiency. This work focuses on the Compagnie Nationale du Rhône (CNR) Electric Vehicle Smart Charging Use Case, which tackles the emerging need for electric mobility. A new player named Smart Charging Provider (SCP) exposes a Charge plan optimization algorithm on the Web, that can be used by any Charging Station Operator (CSO) in the world. This service optimizes a charge plan with respect to economical or environmental criteria, while ensuring the satisfaction of constraints expressed by the Electric Vehicle driver and the CSO. Apart from describing the actual implementation and deployment of this service as a RESTful Web service, this paper also overviews three of the main contributions of the SEAS project that were used together to achieve this goal: (1) the SEAS Reference Architecture Model, designed to enable real-time interconnection of any energy actors; (2) the Multidimensional Quantities ontology, used throughout the SEAS ecosystem to quantify systems and their interconnections; (3) the SPARQL-Generate language and protocol, designed to ensure semantic and syntactic interoperability at low cost in the SEAS ecosystem.**

I. Introduction

Lately, the number of Electric Vehicle (EV) has been constantly increasing and it is expected to grow even more in the coming years. However, [1] estimated that EV charging may have a significant impact on electricity peak demand, at the level of giga watts, and at specific time and location. Indeed, EVs are charged at a constant amount of power as soon as they are plugged in. Hence according to [1], 90% of the charging is going to take place in the late mornings when drivers arrive at their office, or in the evenings when drivers come back home. These constant charging will therefore occur during already existing electricity demand peaks, leading to important fluctuations in energy consumption. Such situation will cause tremendous undesired effects for the distribution grid – power peaks, voltage drops, expensive generation and grid reinforcements, finally ending up with increased electricity costs.

However, in most cases, these EVs stay parked for several hours. Therefore, it would be possible to coordinate the charging during such period, this is known as the concept of smart charging. [2] defines smart charging as follows:

> Smart charging of an EV is when the charging cycle can be altered by external events, allowing for adaptive charging habits, providing the EV with the ability to integrate into the whole power system in a grid and user-friendly way.

Smart charging targets the following benefits for:

- Customers: it might reduce their Electricity costs;
- DSO[1]: it could assist grid management with control signals;
- The society: it could avoid grid and generation investments;
- The environment: it may facilitate integration of renewable energies (e.g. self-consumption of electricity with solar power and electric vehicles);
- Service providers and retailers: it would give them opportunity to provide customers with innovative products and services.

In a broaden perspective, these benefits are also targeted by ITEA2 SEAS project, which aims at designing a global ecosystem to help manage and optimize energy consumption, production and storage. This will be made possible by providing innovative services designed for various energy stakeholders and energy-aware systems. Apart from smart charging services, SEAS ecosystem includes a large spectrum of services, as depicted by Figure 1, which all contribute to better manage energy availability and needs.

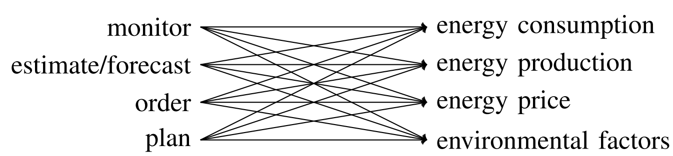

Figure 1. General services envisioned in SEAS ecosystem

The rest of this paper is structured as follows. Section II describes a Compagnie National du Rhône (CNR) Use Case (UC) that involves the concept of smart charging. Then, the paper focuses in Section III on CNR algorithm used to provide a smart charging Service. Then follows overviews of three of the main contributions of the SEAS project: the SEAS ecosystem architecture (§IV); the Multidimensional Quantities ontology (§V); and the SPARQL-Generate protocol that drastically lowers the costs for SEAS partners to become semantically interoperable (§VI). These three contributions were then used together to design an implementation of the smart charging service within SEAS ecosystem, whose deployment is described in Section VII. Finally, Section VIII concludes and shows how this work is generalized in the SEAS project.

[1]DSO - Distribution System Operator

II. CNR SMART CHARGING SCENARIO

This section describes the innovative use case proposed by CNR in SEAS project. It then overviews the architectural, representational and interoperability needs arising from this UC, which are then answered in the next sections of this paper.

A. Roles Description

A charging station is an equipment comprised of one or several *Electric Vehicle Service Equipment* (EVSE). Each EVSE has a meter (m) to monitor any charging process and is connected to an electric junction via a metering place. This CNR UC targets private Charging Stations, which may own and used by : 1) households, to charge ones vehicle at home; 2) companies, to charge cars from corporate fleet at a workplace. Figure 2 illustrates this CNR Smart Charging UC.

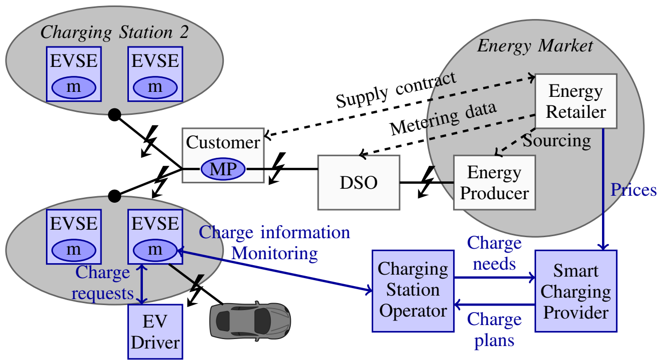

Figure 2. Illustration of CNR Smart Charging Use Case

Let us overview the main players of this scenario. The charging station is owned by a *Customer*, which pays electricity supply for the area to its *Energy Retailer* based on a Metering Point (MP) usually operated by a *DSO*. The charging station is used by *EV Drivers* – either a resident of an household or an employee of a given company – who plug their vehicles to an available EVSE. A charging station is controlled by a *Charging Station Operator* (CSO), who is responsible for monitoring and applying charge plans (which include switching on and off EVSE, but also charging with a limited power). The *Charging Station Operator* entrusts a new actor, the *Smart Charging Provider* (SCP), with the establishment of an optimal charge plan for each EV based on information provided. The SCP may request additional information – e.g. Electricity Tariff – from other actors – e.g. an *Energy Retailer* – in order to define such charge plans.

B. Interactions of the smart charging process

In Figure 2, power distribution is represented by a black line with a lightning bolt. Communications specific to this UC are represented with blue arrows, whereas other communications are represented with dashed arrows.

An EV Driver is authorized to use a charging station connected to the grid, and managed by a given CSO. When this EV Driver plugs its EV to an available EVSE, it first has to communicate with the CSO. The communication is made available either directly – via its smartphone or a web application – or through the charging station, in order for the EV Driver to specify the charging requirements : energy needs (related to battery situation) and preferences (in a given maximum charging time). This can boil down to the estimated departure time, but it may also include other information such as the price he is willing to pay, or whether he wants to consume only a local green energy production.

The CSO takes these information into account along with several other parameters such as power constraints (limitation of maximum instantaneous power at the delivery point, energy requested by other EV drivers connected to the same area) and ask SCP for an optimized charge plan.

SCP combines the received information with other data such as prices information (e.g. dynamic hourly price of energy) and control signals (e.g. maximum power demand). It then runs optimization algorithms to settle the EV charge plan, which is a series of consecutive blocks of maximal power value (Pmax) for defined time periods.

The CSO, receiving the resulting charge plan from SCP, applies this plan and monitors the charging station in accordance. The EV controls the actual power delivered by the charging station to the battery, which should be lower than the Pmax defined by the charge plan – according to the mode 3 charging process (international standard IEC 61851 and IEC 62196).

At any time, an EV Driver can change its charging needs. For instance, he might request an immediate battery charging, if he believes he will need its battery fully charged in a short amount of time. Therefore, the charge plan may be re-optimized by the SCP on CSO requests and at any time during the charging process – especially if new EV charging events occurs (plug/unplug), or if an EV Driver modify its requirements but also and above all, if a modification of available power is notified.

Concretely, some incentives can be used to make EV Driver accept the smart charging service: it can be economical (the charging will be cheaper), or environmental (the charging will save CO_2 emissions).

C. Decoupling Roles in the Use Case

Actually, CNR *virtually* already implements this UC for its Charging Stations. We use the term *virtually*, because CNR currently plays all the roles within this UC. Indeed, CNR is:

- The customer: CNR owns several charging stations located at its head office in Lyon (France) and different energy production sites along the Rhône river. These charging stations are used by employees to charge CNR's EV fleet.
- The energy supplier: charging stations consume electricity supplied by CNR. Even if the electricity is delivered by the grid, CNR is the electricity supplier for each metering point, and has to balance supply with its renewable production.
- The CSO: charging stations are controlled remotely from the CNR's head office.
- The SCP: CNR uses its own Energy Management System that embeds optimisation algorithms in order to provide optimised charge plans.

In order for any customers to use this smart charging service, it has been necessary to decouple each role and make the service available to others. It has therefore been a complex task and the methodology used was to progressively externalize roles from the original simplistic UC:

- How would it work if the EV Owner was not an employee of the CNR ?
- How would it work if the charging station was located in Turkey ?
- ...

As a consequence, any actor should be able to play any of the aforementioned roles. Yet, this modularity is not direct. Nevertheless, all of the information needed to run CNR's charge plan optimization algorithm is produced, modeled, exchanged, and processed internally in CNR Information System. Hence any change in the actor that plays a given role in the UC would require important integration efforts, which means important conception and development costs.

Sections IV to VI hence overview work that target seamless interoperability between actors, at the lowest possible cost. First, let us describe the Charge plan optimization algorithm

III. The Charge Plan Optimization Algorithm

It is incontestable that smartgrid and energy management would benefit from smart charging. [1] conducted a survey on the effects of e-mobility in autumn 2014, which also lists all its potential and benefits. In addition, the literature includes many studies related to the problem of coordinated EV charging and discharging in a smart grid, to cite but a few, [3], [4], [5], [6], [7], [8]. The various optimization approaches presented in these papers are based on either single or multi-objective optimization, according to solely current information, or including forecast-based solutions.

CNR is an hydroelectricity producer which has developed an electricity mixed production (wind power, solar power, small hydro-power). CNR has therefore become an expert in managing an intermittent energy, by forecasting, optimizing, marketing and supervising production. CNR uses its own algorithm in order to optimize EV consumption according to several strategies. The smart charging strategy tested in CNR UC is based on forecast and day-ahead electricity prices, the available power at the metering point, the real-time connection of the vehicles at the charging station and the EV driver requirements.

The goal of this optimization approach is to minimize the charging cost without negotiating the charging needs, as the customer satisfaction and the reliability of the charging service have higher priority than the system operating cost. It then integrates static and dynamic information related to:

- EV Drivers: their charging needs (maximum delay for charging completion);
- Electric vehicle: minimal and maximal charging power, and battery State of Charge (SoC);
- Charging station: minimal and maximal charging power;
- Consumption place: network access tariff and load curve;
- Electricity contract with the Energy Retailer based on time-varying prices (e.g. spot prices);
- Forecast and day-ahead electricity prices

Note that the aim in this paper is not to review the existing optimization algorithms, neither is to compare the CNR algorithm to the existing algorithms. Instead, we are interested in describing a methodology to make such an algorithm available, a) in a real deployment, b) at low cost, and c) to any actual CSO (via the Web). The result is the deployment of a SCP that runs an charge plan optimization algorithm. Any node on the Internet can contact this CNR SCP to obtain charge plans for all types of EVs and EVSEs.

IV. Architecture

One important task for SEAS project was to define an architecture to enable real-time interconnection of any energy actors. Therefore, this architecture should meet some general requirements such as: a) being scalable, adaptable and dynamic; b) offering plug-and-play solutions (having as less manual configuration as possible); and c) providing secure communications and privacy of information.

SEAS project first defined different UCs that could suit these objectives on different domains (Electric Vehicle, House, Building, Microgrid, etc.). All these UCs have then been used to define functions and communication requirements that such an architecture should address. Several architectures exist such as [] but none of them address all SEAS project requirements. That is the reason why SEAS partners define their own architecture, named *SEAS-Reference Architecture Model (S-RAM)*.

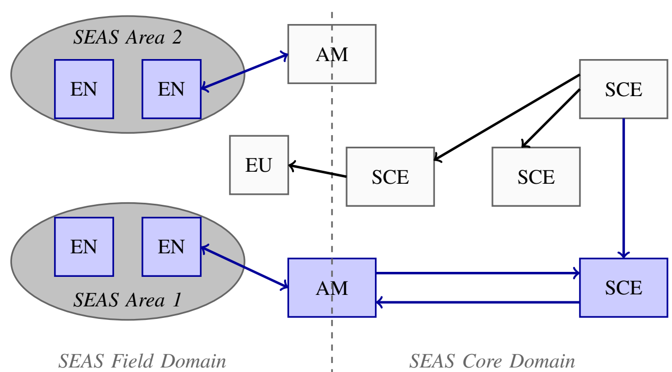

Figure 3. Illustration of SEAS Reference Architecture Model

As illustrated in Figure 3, S-RAM is divided in two domains, Field Domain (SFD) and Core Domain (SCD). Entities within SFD monitor and/or help control local consumption and production. SFD is divided in SEAS Areas (SAs), each one of them being managed/operated by an Area Manager (AM). This manager is aggregating data coming from all entities of its area, willing to participate in energy management. AMs might analyze data collected on the field in order to take decision to better manage energy of their SAs. AMs being at the edge between SCD and SFD, their decisions can also be taken considering information (informative or control) coming from outside the area. Indeed, entities within SCD might both send energy demands to SAs and/or provide information or services to help SAs in their energy management. With this architecture, any SA, via its AM, can participate in a Demand-Response (DR) system and so, help have better global energy consumption plan.

As any communication architecture, S-RAM requires to be secured so that information are not shared with untrustworthy entities. S-RAM relies on its security service that helps authenticate all entities participating in this architecture. Moreover, Internet Protocol (IP) is widely present in current objects deployed for energy related topics. And as it is assumed that it will be even more present in the future, SCD relies on IP and secured web protocols such as HTTPS. S-RAM Core Domain can therefore be seen as an overlay of IP/HTTPS.

SEAS project being an European project, it has several partners and is not dedicated to only one domain of energy management. Instead, it focuses on any energy management domain. Data representation is therefore crucial. In fact, it is important that all these potential actors can understand each other and use common services without having to configure each possible case manually. Furthermore, structure of energy networks are changing, and the current structure may not be the reference in coming years. This has to be taken into consideration in smart grid development, and as mentioned previously SEAS project want its architecture to be dynamic and adaptable, and so, auto-configurable. Therefore, S-RAM requires to rely on data standard providing a) links and relationships; b) abstraction in demands; and c) a common language. That is the reason why the Resource Description Framework [9] formalism have been chosen as an abstract data model in S-RAM.

Within S-RAM, a charging station from CNR UC belongs to a SEAS Area. This SA is operated by a Charging Station Operator (CSO), which is an Area Manager as defined in S-RAM. CNR smart charging service relies upon an algorithm that define charge plan based on different inputs such as EV driver departure, prices information and controls signals. These parameters are provided by different actors outside from the charging station such as actors from the Energy Market, which are SCE as defined by S-RAM. Finally, CNR Smart Charging Provider can also be seen as an SCE that provides a smart charging service to other entities of the architecture such as any house or company equipped with EVSE.

V. Ontologies

This section overviews one of the ontologies that has been developed in the SEAS project, namely the Multidimensional Quantities (MDQ) ontology. This ontology is used throughout the SEAS ecosystem to ensure inter-operability. Let us first recall some basics about Knowledge Representation and the Semantic Web.

A. *Overview of the Semantic Web Stack*

In the domain of Smart Grids, a huge amount of knowledge is available and produced in heterogeneous and distributed manner. Knowledge Engineering and the Semantic Web actually aim at answering generic needs that arise from the production of knowledge. One wants to represent, manipulate, exchange, query, reason with, update, validate the knowledge.

The Wold Wide Web consortium standardized a full stack of standards for the Semantic Web, on top of the Unicode and URI standards. The first step towards inter-operationalization of data is to unambiguously name things with a URI. Second, the Resource Description Format (RDF) [9] enables to describe anything in terms of a set of triples (*subject*, *predicate*, *object*). RDF is hence an abstract data model (a directed acyclic graph), and has multiple concrete syntaxes RDF/XML, Turtle[2], JSON-LD. For instance, the following Turtle snippet serializes a RDF Graph with exactly five triples, which describes the geolocation of a charging station.

```
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix geo: <http://www.w3.org/2003/01/geo/wgs84_pos#> .
@prefix seas: <http://purl.org/NET/seas#> .
@base <http://data.mycsocompany.org/rest/> .

<cs/10001> a seas:ChargingStation ;
 rdfs:comment "CSO Charging Station with id 10001."@en ;
 geo:location [ geo:lat 45.763084 ; geo:long 5.692196 ] ;
```

`geo:location` is a prefixed URI, its expanded form is `http://www.w3.org/2003/01/geo/wgs84_pos#location`. Then, `<cs/10001>` is a relative URI, that needs to be resolved against some base URI, which in this case is `http://data.mycsocompany.org/rest/`. These URIs are not chosen randomly. There are multiple RDF *vocabularies* on the Web that can be used, each defining its own set of URIs. For instance, URIs `geo:location`, `geo:lat`, `geo:long` are defined by the W3C Basic Geo (WGS84 lat/long) Vocabulary. The Linked Data principle defines four simple principles to publish RDF knowledge on the web [10]: (1) Use URIs as names for things (2) Use HTTP URIs so that people can look up those names. (3) When someone looks up a URI, provide useful information, using the standards (RDF*, SPARQL) (4) Include links to other URIs. so that they can discover more things. One may check that looking up any of the mentioned URIs in this paper actually leads to some document (except for the dummy CSO company website, and the SAREF ontology).

For reasoning with RDF, one must choose some formal semantics, and build inference engines (or reasoners) to understand such axioms and infer new knowledge (or reason) with RDF graphs. Among other, [11] define semantics for RDF and RDFS. [12] grounds the Web Ontology Language constructors (e.g., **allValuesFrom**) and axioms (e.g., **subClassOf**) on the First Order Logics. Hence, RDF enables to represent knowledge about things that are identified by URIs, and ontologies enable to capture the semantics of this knowledge, and to reason. For example, using OWL 2 direct semantics, the RDF Graph and the logical formula below are equivalent.

```
saref:Currency owl:oneOf ( om:euro om:United_States_dollar
     om:pound_sterling );
```

$$(\forall x)[\text{Currency}(x) \Rightarrow (x = \text{EUR}) \vee (x = \text{USD}) \vee (x = \text{GBP})]$$

This example illustrates a clear design flaw in the current SAREF ontology http://ontology.tno.nl/saref. It also illustrates that one must take extra care when reusing existing ontologies.

B. *The Multidimensional Quantity Ontology*

An important task in the SEAS project was hence to design ontologies to represent and reason with knowledge about the energy domain. We followed a three-step knowledge engineering methodology [13]: (1) agree on a conceptualization of the domain; (2) develop the ontology for the domain, formally grounded on an appropriate knowledge representation formalism; (3) operationalize it for the domain.

[2]Turtle - Terse RDF Triple Language - http://w3.org/TR/turtle/

Step 1 has been through with interviews between knowledge engineering researchers and energy domain experts, especially during a workshop we organized[3]. During this step, it appeared that representing knowledge such as time series, aggregated values, and quantity integration and derivations is crucial for the domain. Yet, there exists no ontology on the Web to represent these knowledge. Furthermore, the first order logics formalism, on which the Web Ontology Language (OWL) is based, is not appropriate to reason with time series and sums.

The result of step 2 is the Multidimensional-Quantity ontology (MDQ)[4], and its specialization for the energy domain. Figure 4 illustrates the core of this ontology which consists of concepts *systems*, *connections* between these systems, and *connection points* of a system where connections may occur.

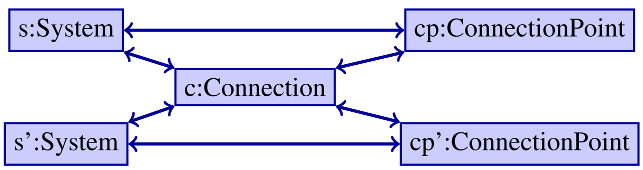

Figure 4. The core of the Multidimensional Quantity Ontology

Then, each of these three ground concepts are specialized for the energy domain, and described in terms of physical quantities. More precisely, they form shapes in a multidimensional space. For instance, figure 5 lists a few dimensions defined for *energy system*, *energy connections*, and *energy connection points*.

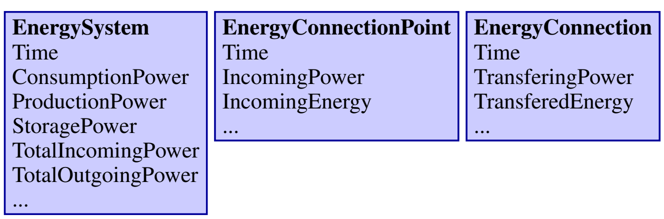

Figure 5. Extract of dimensions defined for Energy systems, connections, and connection points

The energy part of the MDQ ontology is automatically generated from a JSON configuration file in the GitHub repository of the MDQ website[5], and every expert in the SEAS project can contribute to this file. Hence, the MDQ ontology can be reused for any other domain (e.g., water or waste management), provided that a new JSON configuration file is written for that domain. The MDQ ontology enables to describe time series, aggregations of quantities, derivations and integration of quantities. The formal semantics of the MDQ ontology is grounded on algebraic axioms.

Hence, this ontology is used to model the input and output of the CNR Smart Charging Provider algorithm: the EV and the EVSE are connected energy systems, and the need and the plans are different *evaluations* of the energy connection between these system. Particularly describing the interrelations between the Time and the TransferingPower dimension of that multidimensional space.

[3]SEAS Knowledge Engineering workshop - http://data.the-smart-energy.com/workshop/2015/12/

[4]MDQ Ontology - http://w3id.org/multidimensional-quantity/

[5]MDQ on GitHub - https://github.com/thesmartenergy/mdq-ontology-site

VI. Semantic and Syntactic Interoperability

As previously mentioned, RDF is an abstract data model. Much like in communication models, the emissor node must encode the RDF graph in a serialized form that is sent to the receiver node, which must then decode the message. The everlasting issue is hence to ensure that the receiver "understands" the message exactly as the emissor expected. This is almost impossible with human communication, but we want machines to do so.

With RDF, one trivial solution to this issue is to choose one of the concrete RDF syntaxes, and to impose every node to be able to encode and decode messages with this syntax. Yet, this method is not practical for two reasons. First, SEAS partners want to keep on using their legacy system, they are used to exchange messages in CSV, XML or JSON with their legacy partners, so it would be too expansive for them to completely switch to RDF. Second, for simple messages sent by resource constrained SEAS nodes (e.g., simple time series of consumption values for instance) it would be absurd to switch to existing RDF syntaxes because messages would be way too verbose.

Hence, one crucial piece of work in SEAS was to drastically lower the cost for adapting existing systems to the new RDF-based solution. The result of this work is SPARQL-Generate, which is both a language and a protocol.

The language part of SPARQL-Generate is an extension of SPARQL 1.1 [14], which enables to declaratively describe how messages (in XML, CSV, JSON, or whatever) may be interpreted in RDF. This language is more expressive than SPARQL 1.1 itself, and is already implemented on top of Apache Jena[6].

The protocol part of SPARQL-Generate enables the following scenarios:

- a HTTP client sends its request in a legacy format to a server *along with a SPARQL-Generate query*, thus the server may interpret the message properly in RDF using SPARQL-Generate.
- a HTTP server answers in a legacy format to its client *along with a SPARQL-Generate query*, thus the client may interpret the message properly in RDF using SPARQL-Generate.

The CNR Smart Charging Provider implementation makes use of the SPARQL-Generate protocol: it sends information in the CNR legacy XML format, but sends a SPARQL-Generate query along the HTTP response that allow any client to properly interpret the response in RDF using SPARQL-Generate.

VII. Implementation of CNR Smart Charging Provider Entity within SEAS Project

The Smart Charging Provider service is implemented as a RESTful Web Service, which defines two interactions with SEAS Client Nodes:

[6]SPARQL-Generate over Apache Jena - http://thesmartenergy.github.io/sparql-generate-jena/

1) The Charging Station Operator requests for the SCP algorithm execution. It sends a XML document with static information about the charging station and the EVSEs, and charging needs as formulated by the EV Drivers. The Smart Charging Provider sends back an acknowledgment, that mainly consists of the location where the response will be retrievable.
2) The Charging Station Operator requests the SCP algorithm execution result at the previously given location. If available, the Smart Charging Provider sends back a XML document containing the optimized charge plan, along with a link to a SPARQL-Generate query that can be used to interpret the XML document as RDF, according to the SEAS ontologies.

This web service is available for testing, and documented on the web: http://cnr-seas.cloudapp.net/scp/. Moreover, the code is openly available on GitHub and other partners in the SEAS project started using it to implement their own service[7].

VIII. Conclusions and Perspectives

This paper reported on a joint work between partners in ITEA2 12004 Smart Energy Aware Systems (SEAS) project, which aims at developing a SEAS ecosystem of distributed services that all target energy efficiency. This work focuses on the design,implementation, and deployment of the Compagnie Nationale du Rhône (CNR) Electric Vehicle Smart Charging Use Case, which tackles the emerging need for electric mobility.

A new player named Smart Charging Provider (SCP) exposes a Charge plan optimization algorithm on the Web, that can be used by any Charging Station Operator (CSO) in the world. This service optimizes a charge plan with respect to economical or environmental criteria, while ensuring the satisfaction of constraints expressed by the Electric Vehicle driver and the CSO. Originally, the CNR plays all of the roles in this Use Case. So We described the methodology we followed to decouple roles, and identify the role of the SCP and the interactions it would have with other players.

This paper also overviews three of the main contributions of the SEAS project that were used together to achieve this goal: (1) the SEAS Reference Architecture Model, designed to enable real-time interconnection of any energy actors; (2) the Multidimensional Quantities ontology, used throughout the SEAS ecosystem to quantify systems and their interconnections; (3) the SPARQL-Generate language and protocol, designed to ensure semantic and syntactic interoperability at low cost in the SEAS ecosystem.

Finally, we described the actual implementation and deployment of the CNR Smart Charging Provider as a RESTful Web service. Its code is openly available on the GitHub of the SEAS project. Hence, this UC can now be instantiated anywhere, and any CSO can entrust the CNR with the role of the Smart Charging Provider.

Further work include the interconnection of this service with other energy optimization services, or data generation services. Also for the CNR SCP service, and as any other RESTful HTTP Web service, it can be made secured using HTTPS, or it can be made monetized.

[7]Code of the SCP service - https://github.com/thesmartenergy/CNR-SmartChargingProvider

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References

[1] "Smart Charging: steering the charge, driving the change," Eurelectric, Eurelectric paper D/2015/12.105/7, March 2015. [Online]. Available: http://www.eurelectric.org/media/169888/20032015_paper_on_smart_charging_of_electric_vehicles_finalpsf-2015-2301-0001-01-e.pdf

[2] E-Mobility Coordination Group (M/468) and CEN-CENELEC-ETSI Smart Grid Coordination Group (M/490), "Smart Charging of Electric Vehicles in relation to smart grid," CEN-CENELEC, WG Smart Charging Report, May 2015. [Online]. Available: ftp://ftp.cen.eu/EN/EuropeanStandardization/HotTopics/ElectricVehicles/SmartChargingReport.pdf

[3] S. Deilami, A. S. Masoum, P. S. Moses, and M. A. Masoum, "Real-time coordination of plug-in electric vehicle charging in smart grids to minimize power losses and improve voltage profile," Smart Grid, IEEE Transactions on, vol. 2, no. 3, 2011, pp. 456–467.

[4] O. Sundström and C. Binding, "Flexible charging optimization for electric vehicles considering distribution grid constraints," Smart Grid, IEEE Transactions on, vol. 3, no. 1, 2012, pp. 26–37.

[5] Y. Cao, S. Tang, C. Li, P. Zhang, Y. Tan, Z. Zhang, and J. Li, "An optimized ev charging model considering tou price and soc curve," Smart Grid, IEEE Transactions on, vol. 3, no. 1, 2012, pp. 388–393.

[6] M. A. Ortega-Vazquez, F. Bouffard, and V. Silva, "Electric vehicle aggregator/system operator coordination for charging scheduling and services procurement," Power Systems, IEEE Transactions on, vol. 28, no. 2, 2013, pp. 1806–1815.

[7] E. L. Karfopoulos and N. D. Hatziargyriou, "A multi-agent system for controlled charging of a large population of electric vehicles," Power Systems, IEEE Transactions on, vol. 28, no. 2, 2013, pp. 1196–1204.

[8] A. Zakariazadeh, S. Jadid, and P. Siano, "Multi-objective scheduling of electric vehicles in smart distribution system," Energy Conversion and Management, vol. 79, 2014, pp. 43–53.

[9] R. Cyganiak, D. Wood, and M. Lanthaler, "RDF 1.1 Concepts and Abstract Syntax, W3C Recommendation 25 February 2014," W3C, W3C Recommendation, Feb. 25 2014. [Online]. Available: http://www.w3.org/TR/2014/REC-rdf11-concepts-20140225/

[10] T. Berners-Lee, "Linked Data - Design Issues," 2006. [Online]. Available: http://www.w3.org/DesignIssues/LinkedData.html

[11] P. Hayes and P. F. Patel-Schneider, "RDF 1.1 Semantics, W3C Recommendation 25 February 2014," W3C, W3C Recommendation, Feb. 25 2014. [Online]. Available: http://www.w3.org/TR/2014/REC-rdf11-mt-20140225/

[12] B. Motik, P. F. Patel-Schneider, and B. Cuenca-Grau, "OWL 2 Web Ontology Language Direct Semantics W3C Recommendation 27 October 2009," W3C, W3C Recommendation, Oct. 27 2009. [Online]. Available: http://www.w3.org/TR/2009/WD-owl2-semantics-20091027/

[13] B. Bachimont, "Engagement sémantique et engagement ontologique: conception et réalisation d'ontologies en ingénierie des connaissances," in Ingénierie des connaissances, évolutions récentes et nouveaux défis, J. Charlet, M. Zacklad, G. Kassel, and D. Bourigault, Eds. Eyrolles, 2000, ch. 19. [Online]. Available: http://www.cndwebzine.hcp.ma/img/pdf/engagement_semantique_et_engagement_ontologique_conception_et_realisation_d_ontologies_en_ingenierie_des_connaissances.pdf

[14] S. Harris and A. Seaborne, "SPARQL 1.1 Query Language - W3C Recommendation 21 March 2013," W3C, W3C Recommendation, Mar. 21 2013. [Online]. Available: https://www.w3.org/TR/sparql11-query/