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SARGON – Smart energy domain ontology

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Abstract: The internet of things (IoT) is a paradigm where the fragmentation of standards, platforms, services, and technologies, often scattered among different vertical domains. Consequently, the smart energy system is one of the vertical domains in which IoT technology is investigated. At the early stages of studying the IoT domains that deal with big data and interoperability, a semantic layer can be served to approach the difficulty of heterogeneity in information and data representation from IoT devices. In 2015, smart appliance reference ontology (SAREF) was introduced to interconnect data of smart devices and facilitate the communication between IoT devices that use different protocols and standards. The modular design of SAREF concedes the definition of any new vertical domain describing functions that the devices perform. In this study, SARGON – SmArt eneRGy dOmain oNtology is offered which extends SAREF to cross-cut domain-specific information representing the smart energy domain and includes building and electrical grid automation together. SARGON ontology is powered by smart energy standards and IoT initiatives, as well as real use cases. It involves classes, properties, and instances explicitly created to cover the building and electrical grid automation domain. This study exhibits the development of SARGON and demonstrates it through a web application.

1 Introduction

The evolution in the smart energy system brings several challenges such as changes in energy demand, grid infrastructure, penetration of renewables, electric vehicles, and energy storage. To discuss these challenges a power-less, low-cost, and on-demand infrastructure that promotes the scalability, consistency, and efficiency of the system is expected. Cloud computing is a possible solution to accommodate resource on-demand and control computing functions, storage, and network centrally [1]. Nevertheless, centralised cloud architecture provokes many difficulties such as network latency for real-time service requests and responses. To give a distributed resources on-demand and consider a less network latency, Edge computing and internet of things (IoT) technology [2, 3] paradigm have emerged into the cloud computing concept.

Concerning the presented concepts, thanks to the internet, many devices that are used in our daily life, can be controlled and monitored remotely and get more intelligent via IoT technology. Therefore, IoT technology becomes one of the wider research paradigms in the last few years. IoT provides an internet-connected world, where every object can capture the data from the environment and adapt it according to the usage.

Smart energy is one of the domains in which IoT technology is viewed as an efficient and cost-effective solution [4]. Accordingly, there are several examples where IoT technology performs a meaningful role in smart energy infrastructure and automation. Also, there exist many kinds of research in the smart energy domain that presents the advantage of using IoT technology. For instance, Taştan [5] studies IoT technology for smart-home energy management, Tiwary *et al*. [6] presented IoT technology in smart energy metering.

On the other hand, the integration of IoT to the daily operation of many industry sectors grows rapidly which encouraged the usage of IoT technique into smart energy domain scenarios. For example, emerging of IoT into the concept of the smart city which affects the quality of life of inhabitants like smart lighting, smart mobility, smart waste management, and so on.

In the future, IoT devices are required to be more intelligent and networked, features that may pose the challenges in the integration of products from different vendors and vertical sectors [7]. Hence, the demand for all these connected IoT devices needs to be addressed that can communicate among themselves and with the services of platforms. A strong connected IoT ecosystem requires open interfaces concerning the existing standardised solutions as a key role to grant interoperability [8].

To ensure such systems are technically and commercially successful and widely adopted, it must be possible to combine IoT devices from different vendors and industrial companies [9]. Additionally, these systems need to communicate with platforms from different energy service providers to manage and control energy usage [10]. According to the result of studies done in this field, the heterogeneity in communication, standardisation, devices etc. can be addressed by presenting comprehensive information of the domain [11].

Traditionally, information systems in an information communication technology (ICT) infrastructure used a common data representation and vocabulary which cause some new interoperability challenges in the smart grid scenarios. Accordingly, the integration of information from different domains becomes necessary to tackle functional silos which are defined as ‘compartmentalized operating units isolated from their environment’ [12] and rely more on heterogeneous technologies that are combining data residing in different sources and providing users with a unified view of them.

To tackle the introduced challenges, the semantic web is recommended on many descriptions of research in the IoT domain [13–15] such as the smart energy system. In particular, semantic web technologies have been employed to cross-cut domain-specific information and achieve a common understanding of information for humans besides providing machine-readable information. In this interest, ontology [16] as a semantic web language is intended to serve rich and complex knowledge about things, groups of things, and relations between things.

By considering the aforementioned concept, this study has built up upon the success achieved in the past years with smart appliance

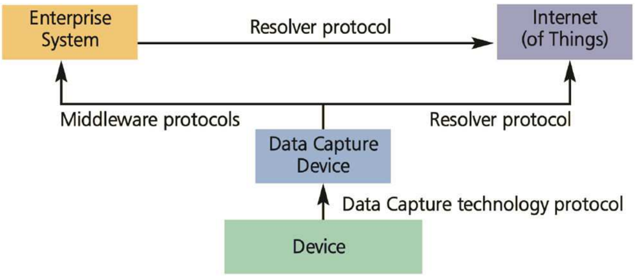


Fig. 1 *Overview of edge data capturing*

reference ontology (SAREF) ontology [17], which is a standard reference ontology for IoT.

This paper deals with the resulting ontology model so-called SARGON by extending the SAREF for the smart energy domain together with the methodology followed and modelling decisions appropriated during the development. SARGON embraces the monitoring and protection use cases (UCs) in the smart grid and building automation. Besides, it determines the ontology requirements by looking into the existing standards in the energy domain. With regard the research studies have been developed in this field, such an aggregate of new energy UCs and granting standardisation are innovative.

Furthermore, the result of implemented ontology has been demonstrated in the form of a web application to semantically provision and govern the IoT devices in the smart energy domain.

The paper is organised as follows: Section 2 covers the related research regarding standardisation and ontology in the energy domain. Section 3 outlines different methods in the ontology development process. Furthermore, it describes the chosen method to implement SARGON ontology. Section 4 illustrates the applied methodology on development of SARGON and Section 5 demonstrates the obtained results. Section 6 concludes this work and provides an outlook on the next steps to be taken.

2 Related work

Over the last few years, there have been several kinds of research and solutions to address heterogeneity challenges in the integration of IoT devices. In the following, the related works in standardisation and ontology research studies are presented.

2.1 Standardisation

There have been several efforts in terms of ICT standardisation in the smart home, energy and IoT. For instance, the European Committees for Standardisation (CEN and CENELEC), European Telecommunication Standards Institute (ETSI), International Electrotechnical Commission (IEC) etc. However, most of this standardisation effort focuses on a specific aspect of a smart system. For example, CENELEC performs standardisation work to enable domestic appliances and improve their functionality through the use of network communication in smart grids, smart homes, and smart networks. CEN defines a standard in the IoT environments that focuses on the interfaces between edge data capture technologies and the IoT [18].

In IoT infrastructure, collecting and storing data close to the source is needed to provide end-users value with real-time applications at the edge. The edge data store is a new storage technology that can be used to provide real-time data storage at the edge of networks. Besides, it provides the necessary infrastructure to deliver real-time edge applications to the cloud or IoT ecosystem.

Accordingly, Fig. 1 illustrates an example of edge data capturing, where particular encoding rules and a specified data capture technology protocol have to be used, which in turn restricts the choice of the data carrier.

To improve interoperability, the common information model (CIM) of the electrical power system [19] provides a unique model of the energy sector and the relation between them. This information model is also used to define messages for the wholesale energy market with the framework for energy market communications [19]. The high adaption of CIM among electrical companies and grid simulation environments encourage consideration of its information model for controlling, monitoring, and protecting of the smart energy domain [20]. On the other hand, IEC 61850 introduces its standard for digital substation and beyond [21]. The abstract information model of this standard can be mapped to the different communication protocols. Moreover, this standard is used in the defined UCs presented in Section 4.

2.2 Ontology in energy domain

A large volume of energy data needs to be collected in most cases in real-time to provide extensive knowledge for such a system. To improve efficiency, interoperability, and sustainability in the energy domain, recent research in the smart energy system has determined that the data representation and exchange technologies must change [22].

In the recent projects and research that proposed semantic ontologies to represent data in the smart energy system, the most common UCs applications are such as smart homes, demand response management, organisations, and micro-grids.

With respect to the existing studies, in this section, the most related ontologies in the smart energy domain are presented. For instance, ThinkHome ontology [14] which presents an ontology for home energy and weather condition without considering geographical data, the IEA-project [23] which improves energy management in compliance with the industrial recommendations, the SAREF for Smart Energy Domain (SAREF4ENER) ontology [15] which illustrates an extension on SAREF ontology for smart home appliance energy management and flexibility.

The BOnSAI [24] presents an ontology for building equipment that is used for energy management and monitoring. EnergyUse ontology [25] which is a type of collaborative web-based framework for users' climate awareness and the ProSGV3 [26] which introduces an ontology to predict smart energy consumption and used weather data, events, and information from consumers and producers of energy.

Between different existing ontology for the smart grid, MIRABEL [27] gives an ontology for the home end-user which has different energy actors for energy flexibility compared with the already mentioned ontologies. Last but not the least, the authors in [28] used an ontology to publish energy consumption data about cities' infrastructures. Table 1 classifies the ontologies in the smart grid domain reviewed in this paper, in the level of detail.

According to the available studies in the smart energy domain, the UCs for monitoring and protection of the smart grid are not considered in the process of ontology development. Moreover, integration of the UCs from two domains in the smart energy system such as the smart grid and building automation are not taken into account.

An ontology may be developed by collecting raw common knowledge in a domain or by interconnecting the existing ontologies, which is known as an ontology network [29]. This networking of ontologies helps to reuse of existing ontologies to the different energy data and scenarios. The modularity of this approach would improve the reusability and extensibility of developed ontologies.

Concerning the studies that have been done in the IoT field, it is shown that to prevent fragmentation, domain-specific, and protocol-dependent, a semantic layer provides interoperability [30] at the information level.

The semantic model of information is not just the packaging of data, but the simultaneous transmission of the meaning with the data. This characteristic of the semantic data model is accomplished by adding data about the data named metadata, and linking each data element to a controlled, and shared vocabulary.

Accordingly, the SAREF ontology of ETSI [17] as demonstrated by the support of standardisation commission and industry [31] appears an interesting option. Diversity of covered standards, protocols, and platforms in the IoT landscape encourages the usage of SAREF among different vertical domains [32, 33] and makes it usable as a global standard ontology for IoT interoperability and cross-domain specific information. Moreover,

Table 1 Energy domains ontologies representation with the level of details in the specific consideration (H = High / M = Medium / L = Low)

	ThinkHome	SAREF4ENER	BOnSAI	ProSGV3
infrastructure technical data	H	L	M	M
energy consumption systems data	H	M	L	H
energy performance data	H	H	H	H
sensors/ actuators data	H	M	M	M
energy stakeholdersâ€™ data	M	—	L	L
weather/climate data	H	L	L	M
geographical data	—	—	—	L
environmental data	M	—	M	—
distributed energy sources data	M	L	L	M
energy demand-response operations	—	M	—	L

the modularity of the SAREF ontology helps for further investigation and extension according to any other standard in the specific domain.

The SAREF ontology was created with the intention to share a general model of IoT domains and facilitate the mapping of existing assets like standards, protocols, data models etc. in the defined smart appliances domain. The SAREF ontology provides building blocks that ease the integration and decoupling of the ontologies according to the specific needs.

The starting point of SAREF is the concept of device which is a physical object designed to accomplish one or more functions in households, common public buildings or offices. A list of basic functions of the device is defined in the SAREF ontology that can be integrated into other domains to build more complex functions. As it is impossible to anticipate all future devices, the implementation of a semantic model that fits all the needs of any domain is not feasible. However, the modular construction of SAREF supports the creation of additional elements and possible extensions in various domains. Concerning the common agreement between industry and research, there is a concrete possibility to extend the SAREF ontology by adopting the related standards and specifications for devices, appliances, and UCs. Hence, a certain number of UCs have been identified as possible domains for extending SAREF such as agriculture, transport, industry etc.

According to the modularity concept, there exists an extension of SAREF in the energy domain so-called SAREF for energy (SAREF4ENER) [34], which gets direct inputs from EEBus and Energy@home. It considers smart machines to machine developments where energy, environment, and building sectors are a part of normative work. SAREF4ENER is meant to enable the currently missing interoperability among various proprietary solutions developed by different consortia in the smart home domain.

By using SAREF4ENER, smart appliances from manufacturers that support the EEBus or E@H data models will easily communicate with one another. The UCs that have been considered in the development of SAREF4ENER are mainly about the demand response scenarios, in which the flexibility of the smart grid in the management of the smart home devices is focused on customer energy manager (CEM).

The CEM gives the list of logical functions that are used for the optimisation in the home gateway or in the cloud energy that can be consumed or produced. Moreover, the CEM can influence the number of patterns of use of the energy consumed by customers when energy-supply systems are constrained, e.g. during peak hours. The CEM involves the following UCs in the configuration of devices that want to connect in the home network:

- Smart energy management/(re-)scheduling appliances in certain modes and preferred times using power profiles to optimise energy efficiency and accommodate the customer's preferences.
- Monitoring, and controlling of the start and status of the appliances.
- Reaction to special requests from the smart grid.

These UCs are associated with the customer energy consumption which describe systems interface between the customer energy management system and the power management system.

In particular, this study emerges from the research project N5GEH [35] which identified UCs in the smart grid and building automation. SARGON covers controlling and monitoring of distribution electrical grids in medium voltage and integrates it with building energy automation. More details of the UC are presented in Section 4.

3 Method to implement ontology

Starting from the 1990s, several activities have been performed in defining methodologies for ontology development. All these approaches target transforming the art of ontology development into an engineering activity.

For instance, the well-known methodologies are METHONTOLOGY [36], On-To-Knowledge [37] and DILIGENT [38], as well as NeOn [29]. All of these methods propose a time and resource-consuming activities instead of considering a simple semi-automatic process in the ontology design pattern.

Moreover, there are some agile methods for ontology development, but most of them are unsuitable when working with linked data. The eXtreme method [39] develops an ontology by assuming that the requirements are defined at the beginning and can not be changed which is not possible while working with linked data. Other approaches like XD methodology [40] design an ontology as a kind of resource to be reused during the development and do not consider ontological resources. RapidOWL [41] as an agile methodology considers ontological resources that must be reused instead of building an ontology according to the available terms in the linked data cloud.

Additionally, none of the aforementioned methods include ontology requirements specification and vocabularies that are used in a linked data environment.

A summary of described methods in ontology development is shown in Fig. 2. The figure categories the methods into two main groups of heavyweight and lightweight.

By considering the presented methods on ontology development, the linked open terms (LOTs) method [42] introduces a reusable and light-weight method for developing linked data ontologies and vocabularies. Furthermore, LOT is investigated in VICINITY project [43] which builds and demonstrates a platform for IoT infrastructures that offers interoperability as a service. This method also has been used on top of ontological engineering activities introduced in NeON [44].

With respect to the fact that LOT offers a design pattern that is applied in linked data ontology development. Also, ETSI as a standardisation organisation reports directly to the use of the LOT method in the development of the SAREF ontology. In this study, the LOT method is used as an ontology design pattern. Accordingly, a brief overview of the steps in the LOT method is illustrated in the following.

3.1 Linked open terms method

The LOT method is defined based on agile technologies which are a kind of iterative approach to developing the ontology. Following

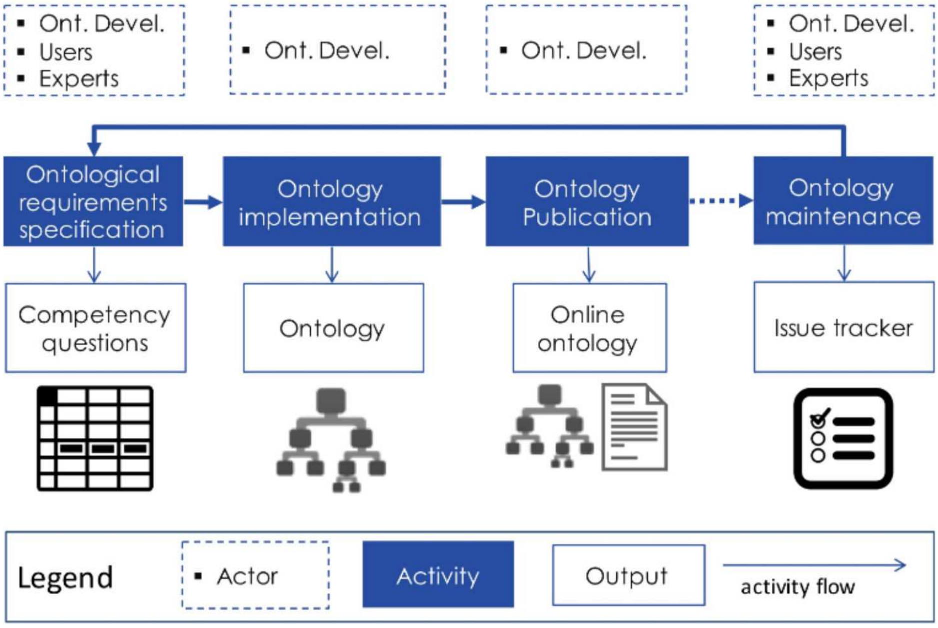


Fig. 2 *Overview of the ontology development methods*

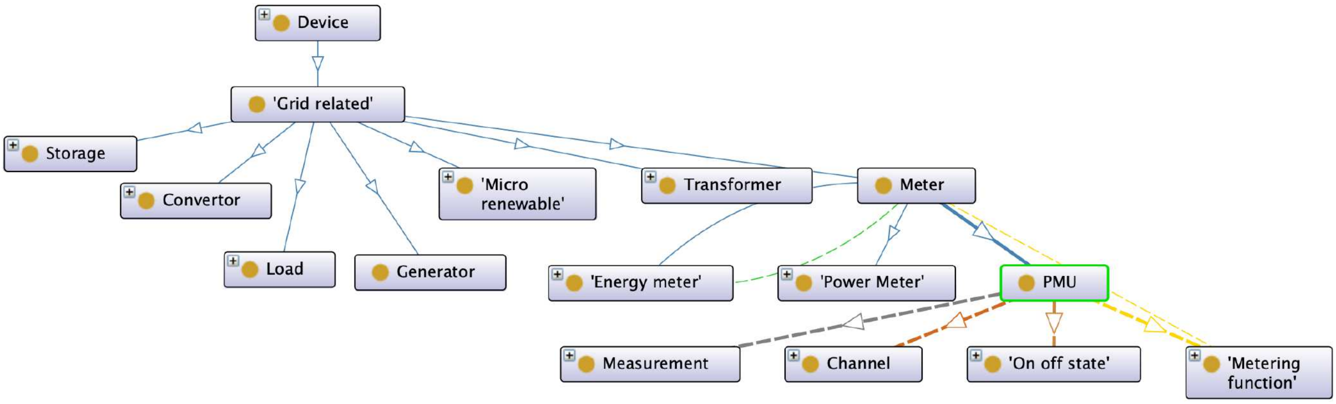


Fig. 3 *LOT methodology workflow to state inputs, outputs and actors [45]*

the available online document related to LOT methodology result in Fig. 3.

The figure shows multiple steps that are required in the process of developing an ontology according to the LOT method: requirements specification, ontology implementation, ontology publication, and ontology maintenance.

3.1.1 Step 1: ontology requirements specification: The first step consists of the formulation of the ontology requirements and specifications, which are also used for the validation and implementation of the ontology. This step answers to the sort of questions such as what is the reason for building ontology, who will use it, and for what purpose is it designed. In general, the list of requirements is categorised into two groups of functional and non-functional.

According to the presented definition in [29], functional requirements mean the groups of competency questions. Functional requirements are the content-specific requirements that the ontology should fulfil in the form of groups of competency questions and their answers, including optional priorities for each group and each competency question. Non-functional requirements are the characteristics, qualities, or general aspects without considering the ontology.

In the following, the LOT method exchanges the gathered requirement specifications defined in different aspects such as application programming interface (API), data-sets, manuals, standards or format used between domain experts, ontology users, and ontology development team. The outcome of these exchanges of information defines a list of functional and non-functional requirement specifications.

The result of this step is given as a document that is used for the development of an ontology and answers to the competency questions [46].

3.1.2 Step 2: ontology implementation: To start implementing an ontology, the input obtained during the information acquisition process must be modelled at the conceptual level and it must be according to the ontology specification document defined in [44].

A conceptual model is a representation of a system, made of the composition of concepts that are used to help people know, understand, or simulate a subject the model represents. Therefore, in this step, the provided input from Step 1 is used to form a conceptual model of domain information. The given conceptual model helps humans to understand the system but it needs to be converted into a machine-readable model in the ontology development processes.

In the following, the conceptual model of information conducted from the first step is encoded into a machine-readable model. A machine-readable model is defined according to the syntax of formal ontology representation languages such as OWL [44] and RDF.

To develop a machine-readable model, tools such as Protégé [47] or TopBraid [48] can be taken. Protégé and TopBraid automatically generate formal ontology languages from the conceptual model.

Additionally, in the process of ontology implementation, it is necessary to check the technical quality of the implemented

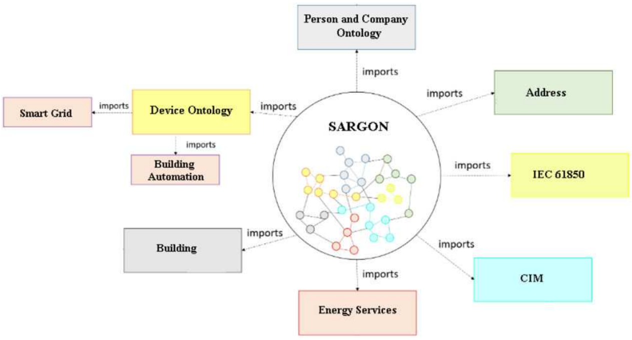


Fig. 4 *Conceptual overview of classes for PMU created in Protégé*

ontology against a frame of reference presented in Neon [44]. This reference presents criteria like logical consistency or completeness. There exist some tools that can be used to automatically check the quality of implemented ontology based on Neon reference criteria. For example, OntOlogy Pitfall Scanner (OOPS!) [49] to detect the presence of errors which are occurred in design time, Themis [50] to check the validation of requirements, Hermit or Pellet to check the consistency.

3.1.3 Step 3: ontology publication: The goal of Step 3 is to make the ontology online and publicly available. The published ontology presents human-readable and machine-readable documentation. In the ontology implementation process based on LOT, the formal standard ontology languages such as OWL and RDF are used to develop a machine-readable format of information.

Furthermore, the human-readable document can be formulated with hypertext modelling language (HTML) pages or any other descriptive format of documents. Besides the human-readable document, the provided conceptual model from Step 2 adds more inputs for a better understanding of the information.

Accordingly, there are some reliable tools that can auto-generate HTML document from ontology such as Widoco [51], LODE [52], OnToology [53].

3.1.4 Step 4: ontology maintenance: The last step of the LOT method is about the activities related to maintenance of the ontology. The maintenance of developed ontology is achieved by adopting the changes according to the new information that can occur after passing all previous steps. The new version of the ontology needs to be developed if users or experts report an issue. In this case, all steps in the LOT method must be iterated.

4 SARGON ontology

According to the presented information in Section 3, the LOT method is used in the process of developing the SARGON ontology. The development of SARGON begins with defining the requirements specification with respect to the analysis of standards in the power grid network and building automation.

Additionally, in the smart energy domain, the role of CIM and IEC standards are undeniable. Therefore, the requirements specification of SARGON is carried out according to the CIM and IEC standard. These two standards are taken as a pattern to identify terms, relations, and to extract the domain model. In particular, CIM and IEC 61850 data model have been considered to describe the basic components and data model, terms, and relations used to transmit electricity and manage the building energy domain besides monitoring and protection of smart grids.

By considering the aforementioned input, a set of UCs and existing data models are identified and initiated that are summarised as follows:

(1) *Automation of medium voltage distribution grids*: It is considered in the proposed activity, in particular considering the inclusion of direct current (DC) technology for which the grid is operated as a hybrid AC–DC electrical network. For this use case, the intelligent electrical device (IED) is used to monitor the grid. Currently, the standard IEC-61850 constitutes a well-received reference for the automation of distribution grids. The proposed extension consists of reformulating the data structure used in IEC-61850 according to an ontology description, as well as introducing devices specifically related to hybrid AC/DC grids such as power converters or DC switches. With respect to the requirements of this use case, a list of converters that are already defined in the IEC standard is considered such as AC–DC, CT–VT, HV–DC, DC–DC.

(2) *PMU interaction and data visualisation*: Phasor measurement units (PMUs) find more and more applications in the monitoring and control of the electrical grid, not only in the transmission networks but also in the distribution ones. The PMUs interaction with the connected devices, as well as the data-driven applications that exploit the obtained measurements, constitute a worthwhile field for the SAREF expansion. Therefore, PMU as a type of metering device is included in the SARGON ontology.

(3) *Building automation and monitoring*: The control of energy demand in buildings such as gas, electricity, hot water etc. and its optimisation. It involves the deployment of building energy management (BEM) systems, which rely on the interaction with smart meters and actuator devices for the effective operation of each functionality. Moreover, the user involvement in the overall process is an undeniable constituent, which has to be included in the ontology representation of the building automation domain.

(4) *Energy management with residential/non-residential involvement*: In order to optimise the overall energy management with residential/non-residential involvement, the utilities have to expand the energy control. Therefore, SARGON ontology must include the entire city district, as building agglomeration. Control algorithms are implemented on local hardware Programmable Logic Controller (PLC) and the connection between the PLC, sensors, and actuators is frequently realised by either wired analogue signals (0–10 V) or by wired bus systems. SARGON has been considered for the modern building energy systems, especially in residential/non-residential buildings, which includes plenty of sensors and actuators in order to achieve a proper operation besides the building operation task.

(5) *Energy management in building/districts level*: It targets the interaction between the energy management of building/districts and their electrical automation. Hence, it considers the control functionalities and the data/measurements that involve the combination of both these aspects. For instance, SARGON includes use cases to control the installed electrical devices in the building. For this reason, it has building information domain connected to the list of devices defined for building automation and electrical system monitoring.

According to Section 3.1.2 of LOT method, the ontology requirement specification activity was carried out with respect to the listed use cases (automation of medium voltage distribution grids, building automation and monitoring, PMUs interaction and data visualisation, energy management of building/districts, energy management with residential/non-residential involvement). Taking input from this activity, a conceptual model of the domain was proposed. It results in the addition of 42 classes and 95 object properties into the existing SAREF ontology. This conceptual model represents the composition of concepts that help people understand the model of the smart energy domain which is the network of use cases for controlling, monitoring, management, measuring etc.

According to the variety of instances that are described in SARGON, Fig. 4 shows an overview of a conceptual model given for PMU which is described in use case 2 in Section 4. Where arrows with white triangles on top represent the *rdf:subClassOf* relation with two classes. The origin of the arrow is the class to be declared as a parent of the subclass which is at the destination of the arrow. Additionally, properties that are characteristics of classes are represented by directed arrows.

Once the SARGON conceptualisation model is designed, Protégé is used as an open-source tool to encode the model into a machine-readable format.

Table 2 Results of the SARGON ontology evaluation performed in OOPS! (I = Important / M = Minor)

Description	Cases	Importance
missing annotations	102	M
missing domain or range	88	I
equivalent properties not declared	1	I
inverse relationships not declared	55	M
different naming conversations in the ontology	0	M
using recursive definitions	4	I
equivalent classes not explicitly declared	1	I

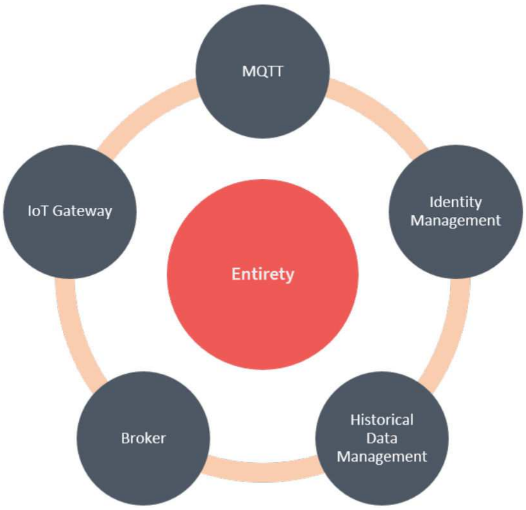
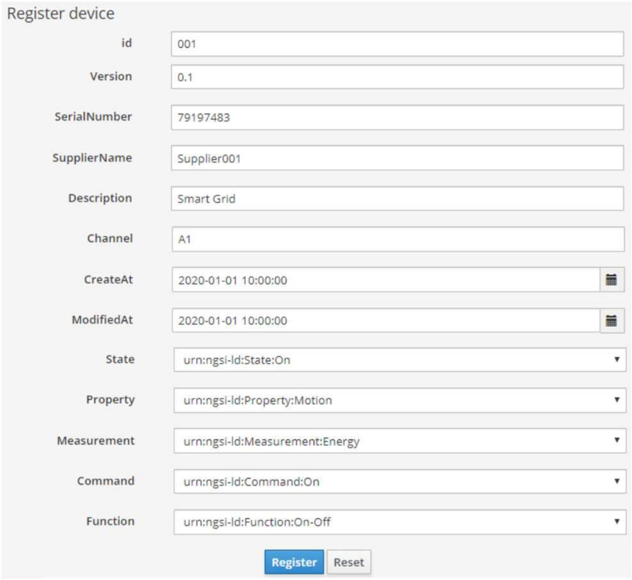


Fig. 5 *SARGON ontology network structure*


Register device

id	001
Version	0.1
SerialNumber	79197483
SupplierName	Supplier001
Description	Smart Grid
Channel	A1
CreateAt	2020-01-01 10:00:00
ModifiedAt	2020-01-01 10:00:00
State	urn:ngsi-ld:State:On
Property	urn:ngsi-ld:Property:Motion
Measurement	urn:ngsi-ld:Measurement:Energy
Command	urn:ngsi-ld:Command:On
Function	urn:ngsi-ld:Function:On-Off

Fig. 6 *Set of services in N5GEH cloud-based platform*

Finally, the ontology validation, debugging, and verification during the development process are done with OOPS! as a tool to ease these steps. The outcome of this step is shown in Table 2.

The table presents a list of important and minor pitfalls that have been detected. However, these given pitfalls do not affect the consistency, reasoning or applicability of the SARGON ontology. For instance, some of the pitfalls refer to 'missing domain or range', but it was a modelling decision to not add domain or range to certain properties in order not to be restrictive with them. Hence, this list of pitfalls is not considered as a mistake in the ontology implementation. The minor pitfalls mostly refer to the missing annotations. Semantic annotation or tagging is the process of attaching additional information to various concepts in a given text or any other content [54]. The missing annotations can be fixed in the final version. The pitfalls detected by OOPS! have been corrected for SARGON ontology.

According to the LOT method, the encoded and evaluated ontology has to be published and be available online. This task is done with OnToology which is a web-based tool. OnToology supports auto-generate activities such as documentation, evaluation, and publication of the ontology. It is built on top of the Git-based environment and can automatically adapt to the changes from Git. Additionally, it integrates a set of other existing tools to support all activities which need for publishing an ontology. Accordingly, the result of published SARGON ontology can be seen in OnToology page [55]. This Git repository includes all auto-generated documentation, diagrams, and evaluation that are generated for SARGON. Afterwards, Pellet [56] reasoner has been used to check the consistency of SARGON ontology by computing the classification hierarchy and querying the information.

4.1 SARGON ontology network

With respect to the aforementioned information, the SARGON ontology network is made of several interconnected domain ontologies related to the smart grid and building automation. Each ontology represents one or more interconnected ontologies that are connected to the core ontology. For instance, information on device ontology is divided into two sub-domain ontologies named smart grid and building automation. Fig. 5 shows a top-level structure of the SARGON ontology. According to the figure:

- *Person, Company, Building, and Address:* Ontologies contain data for describing the nature of a person, company, building, and address, besides spaces and geometrical data such as area, place, floors etc.
- *Device:* Inherits all classes of SAREF ontology and extends it according to energy equipment's which include industrial equipment, energy generators and system resources such as PMU, PID controller, converters etc.
- *Services:* Provides ontologies for services in the smart grid and building automation like controlling, monitoring and protection.
- *CIM and IEC 61850:* Present terms and relations in the electrical networks. It identifies the list of classes and variant instances that can be used for monitoring and controlling of smart grids according to the standards.

Such fragmented domain information is gathered in SARGON ontology which deals with cross-cut domain-specific information. Additionally, the modular development of SARGON supports any further development of information. Properties and relationships can again be further described with another level of properties and relationships.

5 SARGON demonstration

SARGON ontology was developed according to the requirements specification of N5GEH, a German funding research project which looked into the usage of fifth generation (5G) mobile standard for applications in smart energy technology, with special reference to building energy technology. The N5GEH cloud-based platform [35] is developed according to service oriented architecture (SOA) pattern which enables application software development through discrete units of functionality, which are self-contained interoperable and technology-neutral. In SOA, the application components provide services to other components via a communication protocol and web standards such as simple object access protocol (SOAP) and relational state transfer (RESTful) [57, 58]. Accordingly, the goal is achieved by a combination of multiple services which are presented in Fig. 6.

The main services designed to fulfil the requirements of the use cases are a broker to manage context information, IoT gateway to translate device communication protocols, Historical data management to store and retrieve historical data from the database, Message Queuing Telemetry Transport (MQTT) protocol to communicate with the IoT gateway, identity management to manage user and device authorisation, and entirety to automate and facilitate the process of device provisioning and governing through the cloud-based platform and the aforementioned list of services.

One possible approach in IoT technology for device provisioning is the usage of semantic web and ontology for device information representation. However, the direct use of semantic data is not supported by devices, it can be achieved by adding a mediator that can understand the ontology. To automate the process of semantic device provisioning and governing, entirety works such as a semantic mediator which gets SARGON ontology as a data representation of devices and from the other side maps the ontology to the API of the services. Additionally, entirety provides a graphical user interface (GUI) and a dashboard that eases the user access, monitoring and also simplified usage of SARGON for a manual device registry.

From a technical point of view, the same as all web applications, entirety has a backend and frontend part which are powered by Flask and PatternFly. One of the biggest issues with ontology is that it is hard to integrate an ontology file with other systems and services, especially with a database. Entirety uses a template-based approach for mediating data models and platform services. The template-based approach uses an ontology file as a template and populates the data from the web forms into the template. In this regard, Jinja as a templating language for Python developers is well known. Jinja template engine is taken to develop a template for data model which supports full Unicode, an optional integrated sandboxed execution environment. This template engine provides the possibilities of auto-generating an interactive web application forms for the provisioning of IoT devices based on the data model. Additionally, it gives several patterns for data representation such as the priority of information presentation, optional or required data, and many others. For instance, id property for PMU device is defined as *PMU: {{id_0_Id_string_req}}* where the first part is static information, and the second part *{{id_0_Id_string_req}}* is the dynamic part of the template which shows a property of PMU, where *id* – name of property according to the data model, *0* – order in the form, *Id* – label in the form, *string* – type of property and *req* – being required or optional property. Eternity processes templates and generate a web form for auto-provisioning and governing of IoT devices.

6 Conclusion and outlook

In this work, the process to develop SARGON, an ontology for the controlling and monitoring of distribution electrical grids and building energy automation domains, has been described. furthermore, an agile methodology for the development of SARGON ontology is used and presented in detail.

Concerning the concept of a German-funded project named N5GEH, requirements specification of the SARGON have been shaped which aims to cross-cut domain-specific information under the umbrella of 5G mobile network and semantic web technologies. We focused on the future of IoT devices which enables technologies like 5G network and semantic web to process and retrieve massive data and address heterogeneity challenges.

SARGON ontology has been developed as a network ontology by interconnecting standards, published and presented together with an example of how the ontology can be instantiated for automatic provisioning and governing of IoT devices.

This study is a step forward to the research area, industry, and standardisation, as it describes LOT method to develop the ontology, industrial productions besides already approved standards in the electrical network.

Beyond what is presented and evaluated, the actual impact of SARGON ontology should be driven by real, strong demand that is willing to adopt it in specific applications, instead of as an abstract promise for interoperability.

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