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Usages of Semantic Web Services Technologies in IoT Ecosystems and its Impact in Services Delivery: A survey

Mutasim Elsadig Adam*

Sudan University of sciences and technology, Khartoum, Sudan
Email: mutasim.adam@sustech.edu , Abureham45@gmail.com

Abstract

Internet of things (IoT) has begun to emerge in our daily life through the huge number of smart services provided by the devices that deploy around us. Vague and uncertainty in attributes that using in describing services, different levels of quality of each service and the limitation in capabilities of IoT devices are affect and hinder the process of discovering or selecting services. The services in IoT need to be well described to enable users to receive their services that relevant to their query. This survey will investigate the most popular semantic services models and explore the use of these models in enhancing services discovery and services selection in IoT domain. Furthermore, the survey will investigate the evaluation metrics used by each study and compare the results that they obtained.

Keywords: Internet of Things; IoT; Semantic technology; service discovery; service selection; Web Service.

1. Introduction

The traditional network concept which based on communication between humans and computers has been evolved to a new paradigm called the Internet of Things (IoT). The increasing number of devices and sensors that deploy in a physical environment play a vital role in emerging of IoT. IoT as defined by International Telecommunication Union (ITU), is a universal infrastructure for the information society which provides sophisticated services by interconnecting (physical and virtual) things through utilizing the existing technologies of information and communication [1]. The communication between things or objects such as Radio-Frequency Identification (RFID) tags, sensors, actuators, mobile phones, etc, is done through the internet without intervention from a human. As on the internet every computer identified by IP address, in IoT thing or Object also uniquely addressed [2].

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* Corresponding author.

There is no consensus about the number of things that will connect to the internet. Must studies which were done by well-known corporations such as Gartner , HIS Markit and Ericson anticipated that the devices that will connect to the internet will reach almost 30 to 50 billion in 2020 (excluding smartphones, tablets, and computers) [3]. Furthermore, the recent study conducted by [4] showed that the number of connected devices will reach over 75 billion worldwide by 2025. These huge reported numbers of devices reflect the giant number of services that we will have and the anticipated dramatic increase that will happen in the number of services in the near future. Actually, there are no any statistics to show the number of services that will be generated by IoT devices, however, the investment and economic impact of these services will increase and expected to reach to 8.9 trillion in 2020 according to [5], and the value of IoT market projected to reach to almost 14 Trillion by 2025 [6]. This expected significant growth in IoT market which mentioned in the above reports refers mainly to the huge number of smart services that will be offered by IoT devices. thus, one of the most challenging questions that need to be answered is how to enable the end users to get the services that meet their specific quality and requirements among these huge number of services?, simply the answer to this question is by developing a well descriptive services model that enables to improve services discovery and selection. However, the IoT service environment surrounded by many constraints that hinder achieving the above mentioned goal. For example, IoT devices are low power and frequently change location [7], thus, affect the Quality of Services (QoS). Moreover, the uncertainty and vague attributes that describe the services are other issues need to be taken into account. Recently, many semantic services description models have been developed in order to provide a full description of the IoT services. Currently, there are some studies surveyed the use of semantic technologies in IoT. For example, [8] reviewed the studies that used ontologies in IoT domain. Another survey conducted by [9] investigated the usage of semantic technologies in IoT domain, the researchers explored the attitude of different participants about using semantic technologies in IoT by using the questionnaire method. As we have seen all the mentioned surveys talked about the use of semantic technologies in IoT domain in a generic way. However, this survey focuses on investigating the most popular *semantic service technologies* and usages of these technologies in enhancing services delivery to end users. The purpose of this paper is to survey the usages of semantic technologies in IoT domain, particularly the survey will focus on reviewing the most popular semantic services description models that used to describe IoT services and provide classification to these models. Then the paper reviews the usages of these models in improving some IoT services operations such as services discovery, services selection, and services composition. Furthermore, the survey will investigate the evaluation metrics used by each study and compare the results obtained. The rest of the paper will be categorized as follow: the second section will give background about the domain that will be reviewed, the third section will cover some related works, the fourth section will review the most popular models of semantic web that used to annotate IoT services and its usages in IoT domain, section six is a discussion and summary to some points, and conclusion is the last section.

2. Background

2.1 Semantic Web Technologies

Nowadays, the information on the Web not only for displaying and consuming by a human, but interoperability and integration between systems and applications is another vital purpose targeted by developers. One way to achieve the above mentioned purpose is by using a semantic web [10]. Semantic Web as defined by [11] "*is an* *extension of the current web in which information is given well-defined meaning, better enabling computers and people to work in cooperation.*"The architecture of the semantic web consist of several layers according to the fig (1), For the purpose of this study, we will explain briefly the only layers that associated with the semantic concept which are: RDF, RDfs, OWL.

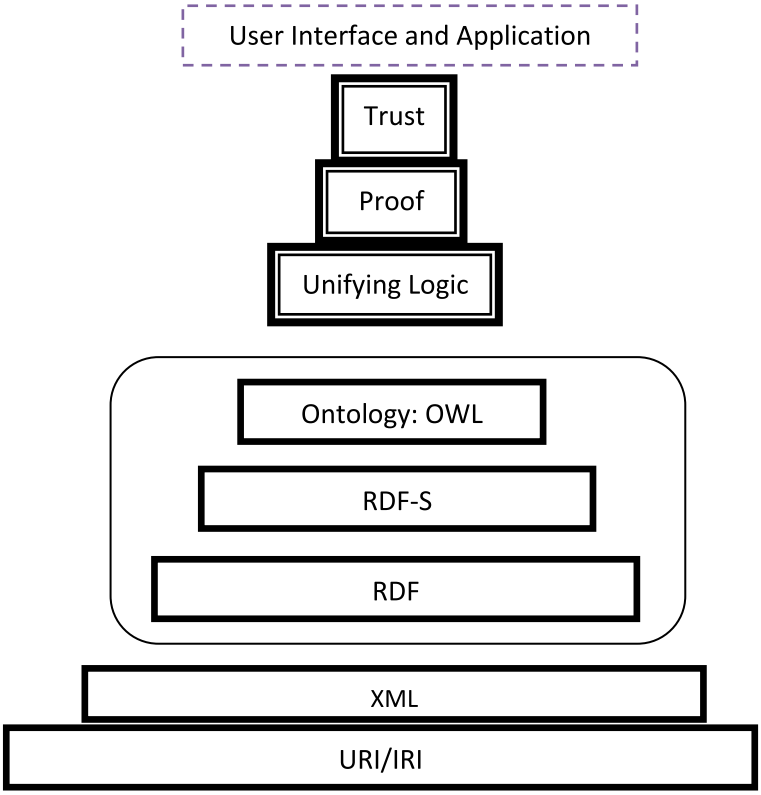

Figure 1: Semantic Web architecture

2.2 RDF (Resource Description Framework)

Its position at the top of XML and consider to be the first layer in giving a semantic description. RDF is mainly representing information of resource on the Web[12]. The resource represents in triple (subject, predicate, and object) and the representation format will be either in graphs or statements as showing below figure (2).

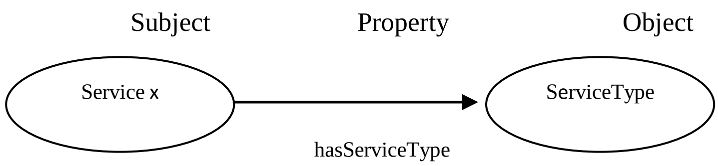

Figure 2: shows RDF graph

2.3 RDFs (RDF Schema)

One of the most prominent shortcomings of RDF that is unable to express knowledge about properties and classes, such as the relation between classes and the relationship between properties. Moreover, RDF unable to identify the particular type of subject or value of giving property. Therefore, W3C developed RDfs to overcome the shortcoming of RDF. According to [13] RDFS is a semantic extension and provides a data-modeling vocabulary for RDF data. It enriches RDF model by adding semantic to classes and subclasses, properties and sub-properties, type and properties.

2.4 Web Ontology Language (OWL)

OWL is a semantic markup language that provides explicit meaning to terms in vocabulary and represents the relation between terms which lead to a new concept called ontology [14]. OWL is developed in order to provide vocabulary extension to the RDF.

3. Semantic and Service

Recently semantic Web has played an essential role in many applications. Web service is one of the current applications that used semantic Web technologies for many purposes such as support automation of service discovery, service composition, service invocation, and data integration and interoperability. Many models have been developed to add semantic to web services such as OWL-s, WSMO, WSMO-Lite … etc. these models provide significant contributions to the Web content and enhance the automation of Web service processes. The great success achieved by the semantic Web in the Web services domain encourages many scholars in IoT domain to adopt semantic technologies as a means to enhance or improve interoperability, services discovery, services selection, service composition in IoT ecosystem. However, using semantic technologies in IoT domain face many challenges as the IoT environment differs from the web environment. IoT is consists of a huge number of heterogeneous devices and these devices characterized by small size, less computation power, little memory and limited battery and mobility [15]. These abovementioned limitations affect negatively and hinder the improvement in service discovery and services selection. Though the above mentioned challenges, many practitioners in IoT domain utilized the semantic technologies to handle many the different issues in IoT, either by extending the existing semantic models or improve new ones. One of the most important issues in IoT that attract the attention of many IoT scholars is how to develop efficient semantic models that improve and enhance services operation in IoT such as services discovery, services selection, service composition. The service in IoT has gained this attention because the service component plays a vital role in IoT ecosystem. The efficiency of each IoT system depends mainly on the services provided to the consumers. Providing services to the end users in IoT environment pass through many operations figure (3):

- **Services Discovery**: discover the services based on functional properties, in other words, find the services that have functional properties match with functional properties that specified in user request [16].
- **Services Selection**: select the most appropriate services from discovered services base on non-functional properties (quality of services that users requested) [17]
- **Services Composition** is the process of aggregating services by integrating some independent services

together in order to respond to the user request which cannot be achieved by a single service [18] .

- **Services Invoking**: invoking services refer to the processes of invoking a single WS or complex process, by providing it with all the necessary inputs for its execution [19].

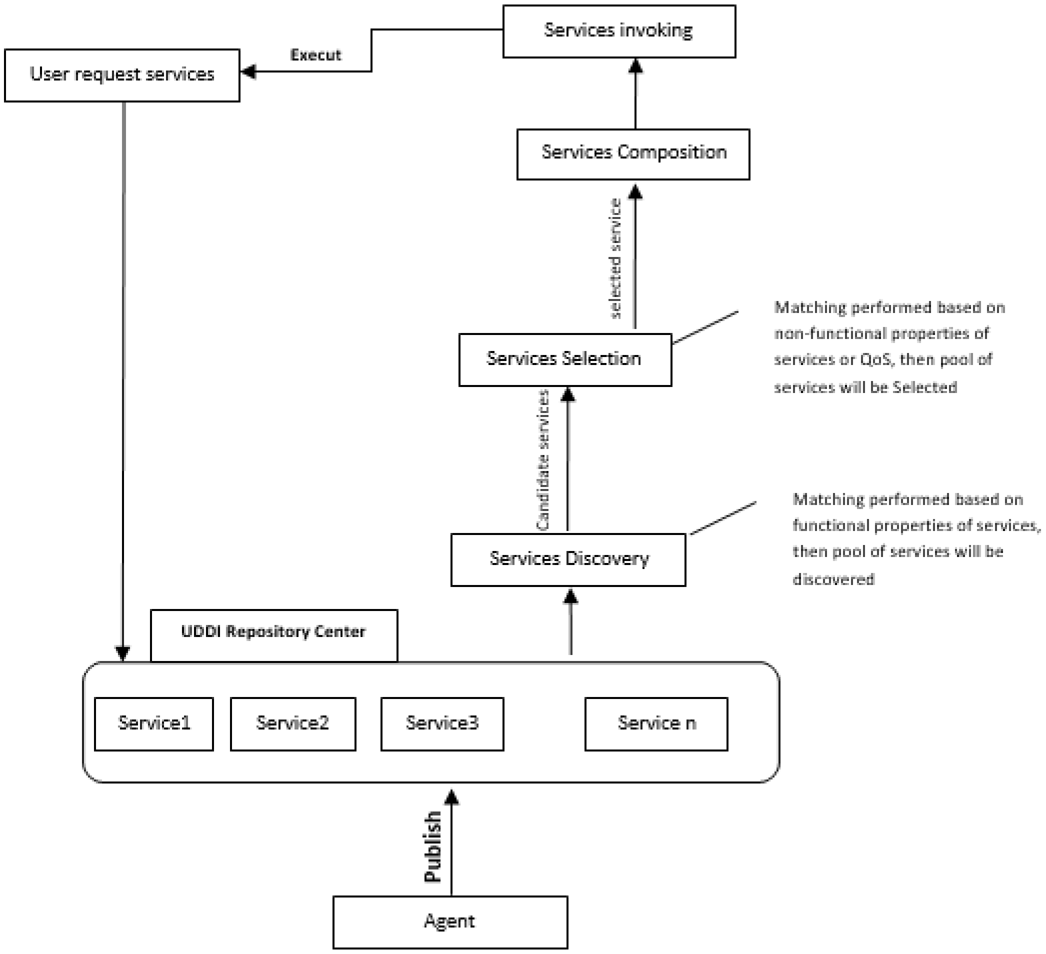

Figure 3: shows the life cycle of IoT Service

However, the above mentioned operations cannot be achieved accurately unless the services in IoT system are well defined and described. Thus, many practitioners resort to semantic web service technologies in order to describe and annotate services. the main goal of using semantic web service technologies is to increase the automation of service discovery, service selection, service composition and service invoking [20].

4. Overall Structure of Service

Understanding the structure of service is the first step in building a semantic service model. From a semantic perspective, the service consists of four main models as shown in tables (3)

Table 1: semantic description of service (definition & usage)

Semantic Description Model	Definition	Usage
Information Semantic	Defines domain knowledge that uses by service in its input or output messages	Perform data mediation through ontology merging or mapping/aligning.
Functional Semantic	What service offer to a client	Service discovery
Non-functional Semantic	Reflects the user requirements	Service selection
Behavioral Semantic	Describe public and private behavior of service : **Choreography**: what protocol that must be followed by each client when he wants to use specific service **Orchestrating**: info of WS to access other WSs	Service invocation, Service discovery, Service composition

5. Related Work

Many surveys have been made that discussed the usages of semantic technologies in handling different issues in IoT layers. [8] investigated the sensor ontologies used in IoT domain based on different applications. Their survey is classified into three categories which are: generic ontologies, domain specific ontologies and, location based Ontologies. Moreover, they surveyed the evaluation techniques used to check the performance of ontologies. A questionnaire to investigated the adoption of semantic technologies in IoT domain conducted by [9], the researchers targeted different persons form industry and academic fields. The goal of the survey is to explore the attitude of participants in this survey towards applying semantic in IoT.

6. Proposed Classifications

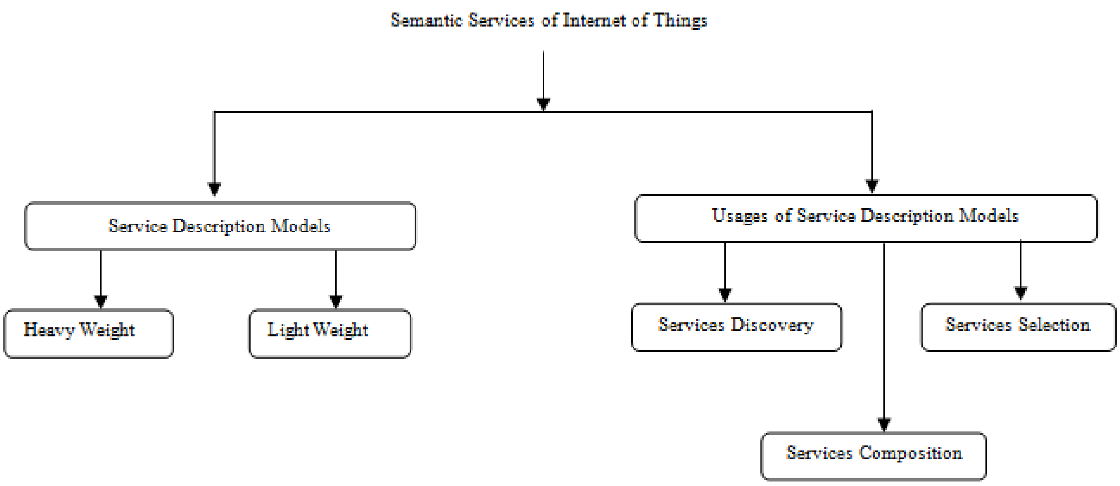

Figure 4

The survey in this paper will be classified into two mains parts figure (4). The first part focuses on reviewing the semantic models using in services description. The second part focuses on the usages of semantic services models in different services operations and metrics evaluation that used to assess the performance of semantic services models.

6.1 Semantic Service Description Models

This section will give a general overview of the most popular semantic services models recommended by the World Wide Web Consortium (W3C) as a standard ontology language for services description. These models will be classified into two categories which are Heavyweight models and lightweight models. Moreover, the services components in each model and its associated parameters will be defined as shown in table (2)

6.2 Heavyweight Models

6.3 OWL-S formally (DAML-S) (DARPA Agent Markup Language project (DAML-S)

DAML-s is a time based model. DAML-s, as defined by [8] describes a service in terms of profile, process and time. These three items are known as the temporal concept that required when we need to define a service. This model has two features that distinguish it from other models. The first one, the model describes the services in the application layer and describes what is being sent across the wires, and the second one that, the model describes not only how the service performs a task but also describes what a service can do [21]. To go further, [22] provide more details about the service components in DAML-s model, they stated that, the service profile consists of three main parts which are:

A. **Service Profile**: mainly used for service discovery and gives a description of what service does. The purpose of this part is to support service discovery by semantically describe functionality and non-functionality of web service. The parameters used to define the functional of web service are: hasInput, hasOutput, precondition, and effect (IOPEs).
B. **Service Grounding:** it provides details about message format and transfer protocol that needed in service invoking. For service grounding OWL-s uses WSDL which responsible for carrying OWL-s message on standard network protocols as OWL-s cannot deal with the standard transfer protocol [23]
C. **Service Model**: this provides a description to one or more services that composite for specific service.

6.4 Semantic-Based IoT Service Description Language OWLS

$OWLS_{IoT}$ is evolved from OWLs by [24] to add semantic to the services in the registry to support integration and interaction in the services layer in IoT environment. The model focuses only on service profile and added some ontologies such as context ontology and QoE ontology to enrich the service profile.

6.5 Web Service Modelling Ontology (WSMO)

This model has been used widely by many scholars. The model is recommended by W3C and it provides a conceptual model for description of Web services [25]. The part of service in WSMO model consists of three parts which are: capability, interface, and non-functional information part. Moreover, the request part is gained more attention in this model and represented by a goal component in order to provide a description to the consumer requirement, table (2).

6.6 Context Service Description Language (CSDL)

CSDL is the most recent semantic model developed by [26]. It is similar to OWL-S in terms of its structure, but it can be distinguished from other models by its capability to describe service not only in terms of semantic signature but also in terms of contextual behavioral specifications.

6.7 The First-order Logic Ontology for Web Services (FLOWS)

Known as the Semantic Web Services Ontology (SWSO). The goal of developing this model is to support the description of the process model of Web service which responsible for describing the program that implements Web services [27]. FLOWS focuses on representing service behavior rather than representing the complete service.

Table 2: The building block of Service from semantic models perspective: (heavyweight)

Semantic Model	Services Components	Sub-components	Parameters
OWL-s (formally) DAML-S Ref.[8,21,22]	Service profile	Service description part	Name, contact info, text desc. … etc
		Functionality description part	I**OPR**: Input, Output, Precondition, Result
	Service model	The process The process control	
	Service grounding		Communication protocol Port No Data exchange format
OWLs$_{IoT}$ Ref.[24]	Service profile	Service description part	Name, contact info, text desc. … etc
		Functionality description part	I**OPR**: Input, Output, Precondition, Effect
WSMO Ref. [25]	Web service part	Service capability	**NFP** = QoS attributes **PAPE** : Precondition, Assumption, Postcondition, Effect
		Service interface	**Choreography**: info of accessing WS **Orchestrating**: info of WS to access other WSs
	Goal part (request part	Service capability Service interface	PE: Precondition, Effect

7. lightweight Models

7.1 WSMO-Lit

As IoT environment characterized by resource constraints such as limitation of power and memory, thus, many researchers believe that the heavyweight models are not a convenient option in such an environment. Therefore, the trend is to develop lightweight models to cope with constrained IoT resources.

WSMO-lit is a prominent lightweight model. In this model, we can distinguish four semantics which are: functional, non-functional, behavioral and information model semantics. The main purpose of creating WSMO-lit is to meet the need for a lightweight service ontology that directly builds on the newest W3C standards. Furthermore, the model is developed to provide bottom-up modeling of services [28].

7.2 IoT-Lit

IoT-Lit is an ontology proposed by [29] and the goal of this ontology is to develop a semantic model that capable to work in a large scale IoT application without increasing the memory and computational cost of query processing which most developers concern about. The design of ontology response to the above concerns by defined only the most used terms and ease the access to these concepts without the need for complex queries.

Table 3: The building block of IoT service from semantic models perspective (Lightweight)

Semantic Model	Services Components	Sub-components	Parameters
WSMO-lite Ref. [28]	Information model		Input, Output, fault messages
	Functional semantic	Service capability	CE : Condition, Effect
	Non-functional semantic	Non-functional property	NFP = QoS attributes
	Behavioral semantic	Service external behavior	**Choreography**: specifies the protocol that a client needs to follow when consuming a service's functionality
		Service internal behavior	**Orchestrating:** describes a workflow, i.e., how the functionality of the service is aggregated out of services.
IoT-Lite Ref. [29]	Service		Area , endpoint , resource , schedule , entity Input, output, effect, condition

To sum up, as we have seen there are many semantic models some of them are heavyweight models and others are lightweight models. According to the table (2), the block of services is different from model to model. In addition to that, we notice that all the heavyweight models follow the top-down approach whereas the lightweight models follow the bottom-up approach. Moreover, in the heavyweight model such OWL-s and WSMO they used grounding techniques to connect between semantic and technical description because both models are conceptually separate underlying technical description (e.g. WSDL) from the semantic description of service [30].

8. Usages of Semantic Service Models In IoT

Semantic technologies have been used widely to tackle some challenging issues of IoT environment. As mentioned before, the service that provided by IoT device is a vital component in IoT ecosystem and the success of IoT systems rely on how the end users can find his specific services that he requested. Therefore, improving operations like service discovery and service selection have gained considerable attention among the recent studies of practitioners. Many approaches have been adopted by researchers with a goal to enhance service delivery. Semantic service models are among the most promising solution that exploited by many studies in order to tackle some challenges that hinder the improvement of service discovery and service selection in IoT environment. In this section, we are going to review the previous studies that used semantic service models as a means to annotate IoT service and we will discuss the metrics that used to evaluate the performance of developed models.

The survey will focus on the following points: the model used to describe the IoT services, the parameters that used and evaluation methods of the proposed model.

8.1 Service Discovery

Service discovery is the most important operation in the lifecycle of IoT service. It is a leading operation and the success of other operations depends on it. Therefore, many researchers resorted to semantic technologies and developed different various models shared one goal that is to improve service discovery [31]. Developed a multi-stage semantic service matching algorithm. The researchers aimed to solve the problem of time consuming when matching all parameters together. In this study, OWL-s is used to describe IoT services and requests as well. The discovery model consists of four layers which are: interactive interface layer, parsing annotation layer, service matching layer and data semantic layer. To examine the efficiency of the model "owls-tc3 OWL-S 1.1" which contains more than 1000 semantic web service description files and provides service requests in OWL-S format. The service file and service requests are extended by semantic information for the purpose of the experiment. The result of experiments showed an improvement in recall and precision when matching the services using the multi-stage semantic service matching algorithm. The recall and precision reach almost to 82% and 88% respectively. In IoT environment the devices are not fixed in one place, thus the services are added and removed frequently. This problem hinders the improvement of service discovery. To tackle this problem [32], adopted a semantic gateway approach in order to enhance IoT services discovery in a dynamic environment. The model based on OWL-S, it provides a semantic description to the services that help in services discovery by matching the semantic input/output signature of a service to a request and returns the desired services. However, with the huge number of services, the discovery becomes more costly [33]. Therefore, in the semantic gateway approach, all similar services are clustered and, in each gateway, there is a mechanism to adapt change in services that happen due to the mobility of devices. *ForwarDS-IoT,* is a model developed by [34] in order to discover the resources of IoT systems. As service is a vital resource in IoT system, hence it is important to be described. OWL-S is used to provide a semantic description of the service in proposed systems. Reference [35] resorted to OWL-S to describe service and two attributes were added which *are hasServiceArea hasServiceSchedule* for service location and service availability respectively. Reference

[36] developed a new semantic model for smart objects description and user request resolution. The purpose of this study is to establish a comprehensive IoT semantic model in order to support interoperability among devices by utilizing the combination of ontological techniques and description logics. The model consists of two main parts which are the device part and the services description part. The service description part is represented by the main concept called Ambient Service (AS). The functionality of AS is represented mainly by output parameters, observed parameters, and effects. Output parameters are defined as a concept, sup concept or individual and given names that correspond to a common vocabulary in a well known ontology called references ontology. Output parameters provided only on demand, on the other hand, observed parameters continuously provided. The effect is represented by RDF statements. In each RDF triple, subject and object represented by OWL classes, on the other hand, predicate expressed by OWL properties. Similar to output parameters, subject of effect must be concept, sub-concept or individual from reference ontology to exhibit the relation between AS and associated entities [37] developed a lightweight IoT service model based on OWLs model which consists of two models: 1) Service profile that described non-functional attributes of IoT service, 2) grounding model which provided information about accessing of IoT services. The model excluded the process model. The model also linked each service with its associated resource and its domain knowledge as well. The model used Input and Output parameters to represent the functionality of services. The model is examined by applied the hyper matchmaker technique to the dataset consists of 1007 services and 29 queries from OWLS-TC. The evaluation is done based on precision @n and Normalised Discounted Cumulative Gain: NDCGn. The result showed that the model showed a high precision compared to the other matchmaker models. A semi-automated approach for discovering and invoking IoT services is developed by [38] with the purpose of enhancing services composition. A services model is core model in this study that provides a semantic description of the services. The functional properties (IOPE) are modeled as a subclass and the property (hasParameterType) is used for annotation. To improve the efficiency of the model, researchers utilized SYNAISTHISI platform which developed by [39]. This platform is semantically enriched using ontologies. For instance, in order to describe physical quantities (e.g. temperature) and their associated measuring, the existing ontologies such as QU and QUDT are imported and used for this purpose. To enable intelligent services discovery and reduce energy consumption in IoT environment, Reference [40] proposed a semantic aware Framework for Service Definition and Discovery. The concept Things Description Document (TDD) which developed by [41] is used to save the information of resources properties and services offered by each entity. A linked data sterilization format (JSON-LD) is used in order to represent services. In addition to that, ontologies which defined for API definition languages such as Swagger and RAML are utilized in order to support semantic annotation of services. For searching and matching services, C-SPARQL is used instead of SPARQL. Efficiency and interaction are an essential demand in huge amounts, however, the dynamic and heterogeneous nature of IoT services framework are influence the processes of services discovery and services selection. Thus, Reference [24] proposed a cross-layer services platform that used semantics techniques to extend the services in the UDDI repository. The platform consists of mainly four parts which are: service management, demand computing, service discovery, and service selection. To semantically describe the service, semantic-based IoT service description language OWL-Siot is developed based on OWLs model, and context ontology and QoE ontology are added to form IoT service profile. In this model, the required services will be selected form the services obtained by the services discovery algorithm (a centralized service discovery algorithm). The main goal of this study is to tackle the problem of the delay that

happens when the client requests a service. To handle this issue, the researchers proposed a new concept called the formation of service clusters. The node which represents a service can join any cluster head after receiving messages from different clusters. The role of the clusters head is to interact with the client's service request and with each other as well. Moreover, the cluster heads used the sleep scheduling model which based on the "game of life". This model mange the communication between cluster nodes and cluster heads and put the cluster node in awake or sleep (working and dormant) status by utilizing the game of life" and sleep scheduling rules. The purpose of this model is to reduce the delay during service discovery, hence save energy. The evaluation of the model showed that the delay is decreased when there are many client requests, however, the delay increased slightly because many nodes put in dormant. After all, the clients need to wait until requested nodes transfer from dormant status to working status.

9. Service Selection

Service selection also one of the important operations in IoT service life cycle. While the services discovery performed based on functional properties of services, services selection performed based on Quality of Services (QoS) [42]. Thus, the main goal of service selection is to respond to the request of users and deliver them the required service based on quality and specific properties such as price, reliability, the security of services response time, availability, privacy, and reputation. These properties are known as quality of services (QoS) and represent the non-functional properties of services. Enhance or improve service selection is one of the challenges that need to be solved. Recently, there have been great efforts done in order to improve the services selection in IoT domain. In Ambient Intelligence (AmI) and IoT environment where a large number of heterogeneous devices are dedicated to serving different users by inelegancy discover and select the most relevant services that meet user's requirements, some challenges hinder the supply of the services. For example, the frequent changes that happen in the services due to many factors such as the heterogeneous network that distributes the services, the services provided by small and low power devices. All the above mentioned issues affect in quality of services since the services can leave or join without any prior notification. These challenges have been handled by [42] who developed a framework called a *Framework for Ambient Services and Events Monitoring (FASEM).* The framework aims to improve the service discovery and selection by controlling the event that triggering the services in AmI and IoT environment. The model consists of three Event-aware services, Context-aware services, and Devices control services and RDF has been used to represent the elements of three components of FASEM. To improve service selection, Reference [43] developed a descriptive semantic model built in a hierarchical form and consists of two layers semantic QoS ontology. The purpose of this model is two provides a description to the QoS in detail and declaration as well. The researchers used five essential parameters with their sub-attributes to represent QoS which are: *Performance (latency, throughput), Availability (MTTR, UpTime, MoadBalancing), Security (Encryption, Authentication, Audibility), Economic (Cost, Energy), Reliability (MTBF, Fault Tolerance, Consistency, Recoverable).* OWLs is extended to form the proposed model (QoS ontology) to provide a full description to the QoS. The model is evaluated by comparing it against other approaches such as OWL-Q, non-semantic service ranking approach (WSQoS-Onto) and SSCO. Tow metrics are used to measure the performance which are precision and recall. The result of the evaluation showed that the accuracy of services selection is higher in QoS ontology and OWL-Q compared to the other two models, however, QoS ontology has higher accuracy than OWL-Q. Reference [36] resort to ambient service concept in their comprehensive semantic model which aimed to improve service requests. The model enables to annotate some non- functional attributes such as time, price and availability. The model not only allows the users to request the service based on a specific quality of service but they can identify the level of QoS that they want. The model successfully provides the user with the required services based on his specifications, however, there are some limitations that may hinder the efficiency of this model if applied to a large IoT environment. For instance, Users need to have specific information about the entities of IoT environment. Moreover, the model applied in a limited environment which contains few IoT devices. In addition to that, the performance evaluation of the model has not been stated. The problem of the resource constraint is a challenging issue in IoT domain and influences negatively in the deployment of IoT systems. To handle this problem [44] used WSMO-Lite as means of the semantic model to annotate IoT services. The semantic lighter of WSMO can be seen in using minimum items in WSMO-lite. To illustrate, WSMO-lite adopts only web services and ontologies and ignores the other components of WSMO (goals, mediators). In terms of Service's capability, WSMO-lite uses only preconditions and effects to represent the capabilities of IoT services and neglect the other components of WSMO preconditions, assumptions. As WSMO-lite doesn't deal well with some problems such as location and environment of devices change, hence, two solutions have been adopted: Firstly, the feature of context is captured by the supplied environmental entity model. Secondly, to handle the problem of service availability, more properties added to the service model such as location, available time, resource and mobility, besides using probabilistic automation to represent the dynamic behavior of services. The researchers proposed this semantic model to overcome the problem of resource constraints of IoT environment, however, the performance of the model has not been evaluated or compared with other models.

10. Service Composition

In some cases, a single discovered service is not fulfill the need of users who request a specific service. Therefore, there is a need some times to composite some discovered services to deliver a new service [45]. For example [38], developed a semi-automatic approach to allow developers to discover services and composite them to form new complex services. The model is consists of two main parts which are the recourse model and services model. The service itself is defined by three types which are: 1) S-type services, 2) P-type services and 3) A-type services. Each service is semantically described by many functional properties and non-functional properties. **In a nutshell**, resorting to semantic technologies in order to improve the services delivery in IoT ecosystems has gained more attention from a wide range of scholars as we have seen in the existing studies. Many semantic models have been used for this purpose, however, this survey showed that OWLs is more preferable compared to the WSMO-lit model. This point raises a question. What is the recommended model for IoT environment?

Referring to the features of OWLs and WSMO-lit we found out that there some features that make OWLs is more convenient in IoT environment compared to WSMO-lit. In the following points, we will explain our argument. In IoT architecture, it is known that the sensors are the main source of services. Unlike the source of web services, Sensors in IoT can be fixed in one place or it can be attached to moveable objects such as human, animal, car … etc. Therefore, it is important to identify these sensors in any developed model. Comparing OWLs and WSMO-lit based on this point, Reference [46] stated OWLs in its upper ontology defines the source that provides services, whereas WSMO-lit does not. In addition to that WSMO-lit focuses on a specific application domain whereas OWLs does not focus on the certain application domain.

11. Discussion

This section highlights some points and gives a summary and analysis of the whole survey. Moreover, the discussion will give an overview of some problems that need to be considered in future researches.

1- According to the summarization made in the table (4), the OWL-s model is the most popular semantic model adopted by developers to describe services compared to the few attempts made by few researchers that used lightweight models such as OWL-s lit and WSMO-Lit.

2- From table (4) we notice most of the studies that reviewed did not use clear evolution methods to assess the efficiency of the developed models. There are only two studies that used recall and precision metrics to measure the efficiency of proposed models, and surprisingly the result of recall that obtained by the study that adopted heavyweight model (OWL-s) is better than the result of recall that obtained by the study that adopted lightweight model (OWL-s lit). This indicates that the recall and precision are not influenced by the type of model (heavyweight or lightweight).

Table 4: gives a summary to the usages of semantic service models with their metrics evaluation:

Reference	Usage In Service:	Semantic Service Models	Metrics Evaluation used			Results%		
			Recall	Precision	Other	Recall	Precision	Other
Ref. [31]	Discovery	OWL-s	√	√		82	88	
Ref. [32]	Discovery	OWL	NA	NA	NA	NA	NA	NA
Ref. [34]	Discovery	OWL	NA	NA	NA	NA	NA	NA
Ref. [35]	Discovery	OWL	NA	NA	NA	NA	NA	NA
Ref. [36]	Discovery + Selection	RDF + OWL	NA	NA	NA	NA	NA	NA
Ref. [37]	Selection	OWL-s lit		√	NDCG	70		87
Ref. [38]	Discovery + Composition	OWL-s	NA	NA	NA	NA	NA	NA
Ref. [40]	Discovery	RDF	NA	NA	NA	NA	NA	NA
Ref. [42]	Discovery+ Selection	RDF						80
Ref. [43]	Selection	OWL-s	√	√				
Ref. [44]	Selection	WSMO-Lit	NA	NA	NA	NA	NA	NA

3- Parameters used to annotate service also play a vital role in the success of any new semantic model. From the previous studies and according to the classification that we made in this survey in the table (5), (6), (7), we notice that IOPE parameters are essential parameters in each model because they play important role in services discovery.

Table 5: shows the parameters used to describe IoT services in the developed models based on OWLs

Reference	Service Profile												Service Model	Service Grounding		
	Service description			Functional description				Non-Functional description								
	Service Name	Text Description	Contact Information	Input	Output	Precondition	Effect	Performance	Availability	Reliability	Security	Economic		Protocol	Port No	Data exchange format
Ref. [31]				√	√	√	√									
Ref. [32]				√	√											
Ref . [34]				√	√									√		
Ref. [35]				√	√	√	√									
Ref. [36]				√	√											
Ref. [37]		√		√	√	√	√									√
Ref. [38]				√	√	√	√									
Ref. [43]								√	√	√	√	√				

Table 6: shows the parameters used to describe IoT services in the developed models based on WSMO-Lite

References	Information Model		Functional Descriptions		None- Functional Descriptions					Behavioral Descriptions	Technical Descriptions
	Input	Output	Condition	Effect	Price	Availability	Reliability	Security	Reputation		
Ref. [44]			√	√		√	√				

Table 7: shows the parameters used to describe IoT services in the developed models that based on other models

Reference	Service Profile												Service Model	Service Grounding		
	Service description			Functional description				Non-Functional description								
	Service Name	Text Description	Contact Information	Input	Output	Precondition	Effect	Energy	Reliability	Response	Security	Economic		Protocol	Port No	Data exchange format
Ref.[36]					√		√	√	√	√						

4- Most of the existing studies revealed that the new semantic models are focused on describing the service profile which combines the functional and non-functional properties of service. The reason behind this, that most of matchmaker techniques that use in searching for service are designed based on functional properties or non-functional properties of service. Moreover, most of the quires of users are focused on what service does (function properties) or what quality of service (non-function properties). On the other hand, the other components of service such as service model and service grounding are gained less attention compared to the service profile. The justification of this, these models are represented the technical side of service ((port number, protocol, data exchange ....etc table (2), (3)), which are not concern of naive users who just need a service that meet his specific quality and perform their task with their specific quality regardless of the port number or protocol that are used. Furthermore, the service discovery performed based on functional properties and service selection performed based on non-functional properties

5- finally, this survey showed that the existing studies have provided some promising solutions to some problems that hinder the processes of service delivery such as mobility, time consuming and energy consumption of IoT devices. However, there is still some issue need to be regarded in future researches as it has a negative impact on service delivery. Even though the developed models discussed in this research provide a full description to the IoT services in order to enhance service discovery and selection and provide users with services that meet their requirements, however, still there are some issues that need to be taken into account in future researches. For instance, some developed models provide description to the non-functional properties of service such as time, availability, reliability and cost in numerical form, but most of these existing model do not support uncertainty thinking of human who uses uncertain term such as old/young, big/small, and cheap/expensive in his daily life when requesting information or services on IoT environment. Hence, affect negatively in the efficiency of matchmaking services.

12. Conclusion

As we have seen Semantic Web technologies have been adopted widely in previous studies to tackle some challenging issues in IoT ecosystems. Semantic services description models that based on OWL-s, WSMO-lit have been utilized by many researchers to develop semantic models for IoT services with the purpose of enhancing services discovery service selection, hence provides users with appropriate services that meet their requirements. However, the evaluation of the developed models reviewed in this survey showed that the accuracy of delivering services still not at a sufficient level. There are many challenging issues that affect negatively in the processes of service discovery and selection as a result, we gain a low accuracy rate of service delivery. These challenging issues represented in: firstly, the resource constraints of IoT environment, secondly, the uncertainty in attributes that use to describe the services, thirdly, the heterogeneous IoT environment. These above mentioned challenged can be handled by developing a sophisticated IoT service model based on semantic technologies. However, according to this survey the research in this area subject to some limitations. Like the majority of previous studies, the evaluation of the new model cannot be achieved due to the lack of the dataset of IoT services. Therefore, we found out that most of the researchers evaluated their new IoT service models by using the dataset of Web services. Moreover, there is no standard that identify the values of non-functional properties (accuracy, reliability, security, availability) of the IoT services. The future research will focus on the following issue: identifying the standard of the values of non-functional properties of IoT services, problem of uncertainty and the vague of information in IoT. Mobility of IoT devices which leads to frequent change in the parameters of IoT service.

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