A Comparative Analysis of Service Discovery Approaches for the Internet of Things

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***Abstract*—The Internet of Things (IOT) has gained a significant attention in the last years. It covers multiple domains and applications such as smart home, smart healthcare, IT transportation...etc. the highly dynamic nature of the IOT environment brings to the service discovery new challenges and requirements. As a result, discovering the desirable services has become very challenging. In this paper, we aim to address the IoT service discovery problem and investigate the existing solutions to tackle this problem in many aspects, therefore we present a full comparative analysis of the most representative (or outstanding) service discovery approaches in the literature over four perspectives: (1) the IoT service description model, (2) the mechanism of IoT service discovery, (3) the adopted architecture and (4) the context awareness.**

***Index Terms*: Internet of Things, Service Discovery, IoT services.**

I. INTRODUCTION

The IoT envisions a multitude of heterogeneous objects and interactions with the physical environment. The functionalities provided by these objects can be termed as real-world services as they provide a near real time state of the physical world [14]. In this environment, the task of discovering desirable services faces many new challenges and requirements.

The IoT services are operated in a highly dynamic environment with a large number of devices will be connected to the internet; Cisco forecasts 50 billion devices connected by 2020, as well as the wide distribution and heterogeneity of the available resources. Besides, the IoT services are deployed in resource-constrained devices that are characterized by the mobility nature and the limit capabilities in terms of limited battery, computing, communication and storage capabilities. In other side, traditional service discovery solutions are not suitable for the discovery of IOT services as affirmed by several works such [1], [5] and [23] because it demand heavy communication and use bulky formats, which are unsuitable for these resource-constrained devices incorporating sleep cycles to save energy [12]. The key challenge is the lack of IoT standardization in terms of architectures and new technologies adopted to meet the IoT needs. Therefore, an effective mechanism of discovery is needed to meet the requirements of both IoT environment and IoT services.

In this paper, we analyze different approaches for the service discovery in IoT aiming at providing an overview and comparison of different proposed solutions in the literature based on four perspectives: (1) the IoT service description model, (2) the mechanism of IoT service discovery, (3) the adopted architecture and (4) the context awareness.

In section II, we present the different service description models for the IoT services and we propose a set of requirements that need to be considered when defining an IoT service in the internet of things. The section III is dedicated for discussing the most current solutions to tackle the service discovery problem based on the mechanism of discovery. In the section IV we discuss the architecture adopted by approaches. Finally in section V, we discuss the role of context awareness and how the service discovery approaches apply the context. Comparing with other papers in this particular field, we perform a comparative analysis of multi-category and recent approaches for service discovery in the internet of things over many aspects, however the work [15] analyzes just five EPC (Electronic Product Code) based approaches.

II. IOT SERVICE DESCRIPTION MODEL

Describing the IOT services in a formal and unambiguous way is vital for facilitating the discovery of these services. We discuss in this section the prevailing trends to describe the IoT services.

The Ontology Web Language for Services (OWL-S) is a widely used language for semantic describing of services. Several works such [3] and [25] use the standard OWL-S in their experiments. Other work [10] proposes a model that extends the OWL-S with two more properties: has Service Area and has Service Schedule. However [5] proposes a detailed service description model for IOT services, the proposed model is a trade-off between OWL-S and hREST. The model defines some properties linking to concepts on platform, network and deployment which are important and specific for IOT services, and also the "hasTest" property to test the availability of services.

Several works adopts the rest (representational state transfer) style to describe IoT services. [9] Uses a Context-aware restful web services for things in order to implement smart web services efficiently and easily. [18] Uses RESTful web services to expose the functionalities of the discovery framework to the consumers. However [27] applies RAML (RESTful API Modeling Language) for making resource and service exposition more simple and practical. RESTful based model meets the need of a lightweight service description for IoT services, but it does not include a profile and grounding which are important for service discovery and access.

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DPWS (Devices Profile for Web Services) and COAP (Constrained Application Protocol)) are two promising technologies for implementing services on resource constrained devices. Several works apply these two technologies to meet the IoT service requirements in terms of resource constrained devices support. [7] Uses the WSDL (Web Services Description Language) containing DPWS metadata to allow a seamless integration of device-provided services. However [12] chooses to adopt COAP to define the IoT services as the same as [4].

Several works uses a simple records representation to describe the IoT services. In his DNS based discovery approach, [13] describes the services using four DNS records (service name, IP address, port and if it wants to be found in the network). However in [2], the context information has been included in the service metadata proposed to describe the service, the service metadata includes (service description, context description, Identification of the related objects, URI of the service). [26] Designs a service table that constitutes the status information of the resource capabilities required to instantiate a service. The records based service description model is not suitable to describe the IoT service; this is due to the dynamic features requiring for the IoT services. [20] Provides service model that describe the service by its functional properties (Input, Output, Action) and non-functional properties (QoS attributes, energy profile), the energy profile and the QoS profile are also modeled.

[11] Is the only approach proposing his own service description language. [11] Proposes an XML-based language, trying to make a template to describe any type of service. The proposed service model includes service information's (Service ID, Service Type, Keywords, Properties), function description (Function Name, Function Description, Input, Output, Pre-constraint, Post-constraint) and description of service quality (Service Quality Value, User Context, Service Context, Network Context).But this proposed model doesn't adapt perfectly to the features of IOT services.

A conceptual model is proposed in [21] to describe physical services in the IoT in terms of spatio-temporal features, the service is defined by properties of Input, Output, Effect, Service Name, Service Type and Identifier and the spatio-temporal features are represented by Available Time and Working Range properties. Note that there are many approaches such [1][6][8][19][24] that did not mentioned any service description in their works.

Discussion: The key challenge is how to perform a service description that can adapt to the dynamic features of IoT services. We propose the following requirements for describing services in the internet of things environment.

Well described: There is a strong need for describing the IoT services in an unambiguous way for facilitating the discovery of these services in the highly dynamic IoT environment;

Lightweight: A lightweight IoT service description is needed;

Adapt to the constrained devices: The IoT service description should be able to adapt the constraints of resource constrained environments, COAP and DPWS are two promising approaches for that. But they have not yet been standardized;

Availability: dealing with the dynamic changes of services availability, and performing strong test capabilities;

Context aware: The IoT services should be aware of the surrounding environment, therefore it is suitable to rich the IoT services description with the context information's;

Most of the service discovery approaches do not address the requirements of IoT services. There is a difference between the IoT services and the traditional web services; therefore applying traditional web services technologies is not straightforward. Using semantic Web technologies like OWL-S can provide rich descriptions about their functionalities and facilitate their discovery but they demand heavy communication and use bulky formats wish is not suitable for the constrained environments required by the IoT, even if these models are extended by new attributes like many approaches did, the problem of heavyweight service description is rising.

In Other hand, using the Rest style can provide a lightweight service description and a simple and fast mechanism of discovery but do not support many security requirements. The properties related to the spatio-temporal features are included by some works such as [21] but it is not sufficient to guarantee the service availability. Therefore a new IoT service description is needed respecting many requirements.

III. THE MECHANISM OF DISCOVERY

Such a service discovery mechanism is needed for locating services responding to the changes of the IoT environment and to the user's situation. Based on the mechanism of discovery, we can classify the IoT service discovery approaches into six main categories:

A. Semantic Based Approaches

Several IoT service discovery approaches adopt the semantic web technologies for semantically matching the required service using different techniques. The authors in [3] present an efficient mechanism for the service discovery by applying a Dynamic clustering of services and calculating the semantic similarity between services and requests based on quasi-metric. The implementation of these semantic mechanisms minimizes the discovery cost but the work does not perform any architecture. [5] Provides a hybrid semantic service matchmaking method for IOT services that combines probabilistic service matchmaking using latent semantic analysis, with a logical signature matchmaking method based

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on the concept of individual Links between a source parameter and a destination parameter.

The proposed method exhibits higher performance but a central registration of services has been made. Also [6] raises a service matching algorithm based on ontology to the service discovery in IOT combining semantic similarity and semantic relativity. The work does not perform any architecture. Finally, in [10] the authors propose a suite of ontologies that models entity, resources and IOT services. The proposed model is then used by the framework to publish instances of the IoT related resources and entities and to link them to existing resources on the Web. This work does not perform a mechanism to discover IoT services.

B. *Context Based Approaches*

Several works are focused on the context to provide services based on the right context. The approach [1] provides an efficient infrastructure to support user-centric and environment-aware service provision. The system has the ability to sense the dynamic changes of environment and provides the right services for user without service request. The system also provides a traditional context-aware web service discovery by returning the services matching user's request with considering user's context (e.g. location, preference.) The authors in [9] propose a novel smart Web service based on the context of things using REST techniques.

Three Thing-REST-based mashup structures have been developed to loosely couple ontology Web services, domain-knowledge Web services, and event-report web services for implementing a smart web service. However [12] provides a service selection technique to offer the appropriate service to the user application depending on the available context information of user and services. The work applies grouping and adaptive timer mechanisms in order to reduce the communication overhead and to decrease the service invocation delay. Also the authors in [24] exploit the social properties of SIoT and cognitive context-aware computing to make the adaptive and personalized smart services manageable. The service discovery task is implemented by listing services which match the set of rules based on a goal involved in the detected event.

C. *QoS Based Approaches*

With the increasing emergence of massive services with various Quality f services (QoS) in the pervasive environment of IoT, several works aim to address the issue of selecting the required service based on QoS parameters. [20] proposes an energy-centered and QoS-Aware Services Selection for IoT environments, the proposed selection approach consists of two phases: preselecting the services offering the QoS level required for user's satisfaction using a lexicographic optimization strategy and QoS constraints relaxation technique. The candidate services obtained from the preselection phase are compared using the concept of relative dominance of services, where the relative dominance of a candidate service depends on its energy profile and QoS attributes, and user's preferences.

A similar approach [21] proposes a Physical Service Model (PSM) to describe heterogeneous IoT physical service in terms of spatiotemporal features and identifies three types of Quality of Service (QoS) including spatio-temporal, positive, and negative attributes. A Physical Service Selection (PSS) method is also proposed for aggregating and evaluating the QoS values of Candidate Physical Services (CPSs) based on a user preference.

D. *Bio inspired based approaches*

Considerable research has been devoted to the adoption of bio inspired computing paradigms, using this paradigm is very suitable for pervasive environments such IoT, taking advantages of their inherent capability such as effective management of resources, self organization, self adaptively.

The approach [19] proposes a decentralized service discovery and selection model inspired from Response Threshold Model taking advantage of the inherent capability of social insect colonies to operate without any central control. In this work the service provision nodes (SPNs) are modeled as agents which act locally based on the bio-inspired response threshold model, and the satisfaction of a user request emerges as the result of individual agent actions. Other approach [11] Provides a selection algorithm to find the best service based on ANN (Artificial Neural Network), the approach performs a detailed architecture for the service selection, and uses three kind of context (User context, Service context, Network context) for the selection of the most appropriate service for user.

E. *Federated Search Based Approaches*

The federated search consists of organizing service information in a set of information repositories and managing them to perform the service discovery tasks. There are many IOT discovery approaches applying federated search mechanisms wish are usually involve structured P2P networks for implementing scalable and robust distributed service discovery system for IOT. The work [2] Proposes a service discovery mechanism that can effectively locate services based on the context requirements and supporting content and path locality using SkipNet overlay nodes and SkipNet routing algorithms.

However [4] Proposes a scalable and self-configuring architecture for service and resource discovery in large scale IOT networks using IOT Gateway, The approach support both local scale discovery by using zero-configuration mechanisms and large scale discovery by using P2P overlays, IOT Gateway and CoAP. And [8] proposes a DHT distributed Discovery Service for IoT scenarios supporting multi-attribute and range queries. The approach provides a layered functional architecture over DHTs based on a peer-to-peer overlay network. He uses different mechanisms such as SFC linearization technique, Prefix Hash Tree (PHT) distributed data structure and Kademlia routing Algorithm.

Other solutions adopt other structures except P2P networks such the work of [26] who proposes a fast and flexible approach for discovering IoT-based services by applying

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Bloom filters to the configuration and management of distributed service registries. The approach supports two search methods: bottom-up and top-down discovery of service instances that are needed to perform a user task. Required resource capabilities of a service are presented in a service table. After comparing service tables with identified resource capability points, available services can be identified.

A similar effort has been proposed by [25] comprising a collection of autonomous repositories cooperating with each other to perform data and service discovery tasks. This work adopts RDO (repository domain ontology) documents composing the information model of ForwarDS-IoT. These documents are mapped and managed with the federation of registries. The Client Interface complies with the REST architectural style, relying on the HTTP protocol to perform operations like Synchronous/Asynchronous search, Repository insertion, Record update, RDO update.

F. Other Based Approaches

There are some approaches use different mechanisms for the service discovery in IoT.

Flow Based Approach: This work [27] proposes architecture that aim to facilitate discovery, accessing, and programming of functionalities and services offered in IoT environments. Where the IoT services are exposing as APIs and are composing via creating API flows to achieve more complex functionalities. The user requests have been matched to different flow templates (Flow Design, Flow Composition, Flow Execution Engine, and Flow Template Management).

Security Based Approach: The approach of [18] proposes a framework for thing and service discovery for IoT solutions deployed in the smart home domain. This work focuses on security mechanisms related to thing authentication and access control for the thing discovery in IoT based smart home systems.

DNS Based Approach: [13] Implements a service discovery for contiki wish is an operating system for embedded devices; it is based on multicast DNS and DNS-service discovery and it is adopted for resource constrained devices.

DPWS Based Approach: The work [7] uses DPWS discovery mechanisms to dynamically find devices as they connect to the network, and dynamically retrieve metadata about the device and the services it hosts.

Discussion

The key challenge is *how to find the required service in IoT* respecting the vast amount, mobility, heterogeneity, and wide distribution of services deployed in constrained devices and in the same time been desirable for users. Most of the IoT service discovery solutions do not meet the IoT requirements effectively. Actually, the IoT faces many challenges in terms of availability, reliability, dynamicity, performance, scalability, interoperability, security, management, and trust [22]. These requirements should be considered when implementing an efficient IoT service discovery mechanism.

Some of the requirements have attracted a lot of attention by the service discovery approaches like large scale and scalability, the federated search based approaches [2][4][8][25][26] meet these two requirements by implementing scalable and robust distributed service discovery system for IOT. The semantic based solutions specially the work [3] aim at achieving the interoperability requirement by managing the heterogeneity of services and providing machine-readable and machine-interpretable descriptions of services. The context based approaches try to meet the dynamicity requirement relying on the role of context for providing desirable services to the users based on their surrounding environment, besides the context can help IoT services to adapt with the dynamic environment changes and making the right decision. The QoS based approaches deal with the requirement of reliability by consider it within the QoS attributes, taking the example of the work [21] who defines it to guarantee if the service will correctly respond to a request within the expected time. The bio inspired approaches aim at providing effective management of resources, self organization and self adaptively.

However other IoT requirements like availability, security, real-time management still require more attention by the service discovery approaches. The security requirement is carried out only by the approach of [18] who meets the security requirement by focusing on the security mechanisms like things authentication and access control. The availability is an important requirement to be considered when enabling an efficient mechanism of discovery, the IoT services are not available all the time, they degrade, vanish, and possibly re-appear due to the intermittent connectivity, most of the approaches don't meet this requirement except the work [20] who maximize energy conservation to ensure a high services availability. The continuous updates in real-time of both service descriptions and discovery has not been applied by the existing service discovery solutions.

IV. THE ADOPTED ARCHITECTURE

A. *Level of Decentralization:* Some approaches such [1][5][7] are implemented using a centralized architecture wish means a central registration of resource descriptions. This solution reveals well-known drawbacks related to scalability, fault-tolerance, and security threats as said in [25]. The centralized architecture is unsuitable for the IoT features in terms of the wide distribution of resources, the increasing number of connected devices and the dynamic changes of the environment therefore distributed service discovery architecture is required. While other approaches are implemented using distributed registries to overshoot the aforementioned drawbacks such [8][2][24][25][26].

B. *Architecture Model:* The layered functional model is widely used by the approaches such [10][11][18][24-27] to implement their architectures. Peer to peer overlays are

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also applied in some approaches such [2][4][8]. The authors in [12][19] choose to implement their architecture using agents. However some approaches do not perform any architecture such [3] [13][20][21].

V. THE CONTEXT AWARENESS

The context plays a significant role to enable provision of adequate services to the users based on their surrounding environments. Besides, the context awareness should be considered in the IoT service discovery solutions for many reasons: (1) Bu using context, services can become smarter, besides a smart and provision of services can be achieved as affirmed by [1] and [9]. (2) Ensure the dynamicity of IoT services. (3) Allow achieving the minimal human interventions requirement for IoT. (4) Generally most of the context aware approaches enabling user centric.

We can identify if the approach is context aware or not depending on this useful definition: "A system is context-aware if it uses context to provide relevant information and/or services to the user, where relevancy depends on the user's task." [16] The context awareness can be applied using three main phases [17]:

- *Context acquisition*: defines the process of acquiring context information's from various sources (physical/virtual/logical sensors).
- *Context modeling*: defines the process of representing collected data in meaningful manner. The most popular context modeling techniques are: key-value, markup schemes, graphical, object based, logic based, and ontology based modeling.
- *Context reasoning*: defines the process of inferring new knowledge based on the available context. Six context reasoning techniques are identified by [17] as follows: supervised learning, unsupervised learning, rules, fuzzy logic, ontological reasoning and probabilistic reasoning.

Based on these context phases we aim to discuss how the IoT service discovery approaches apply the context.

Most of the analyzed approaches don't take into account the context; some of them take just the geographic location. On the other hand several works are focused on the context, for example the authors in [1] adopt the three phases of context by supporting the context acquisition from different sources (user profile, sensed data, information of RFID-tagged things, descriptions of devices.) and provide an ontological based model for the context modeling with the ability to handle uncertainty and temporal aspects of context. Also Dynamic Bayesian networks (DBN) is adopted for the context reasoning phase.

Other approaches are focused much more on the context modeling. The work of [11] provides a Markup Scheme Model for context wish is be included in the xml based service description. Three types of context are applied -User context, Service context, and Network context. However the work of [12] chooses to model the context using an Attribute-value pair format to represent two kinds of context (user context and network context). The two phases of modeling and reasoning are adopted by the work of [2]. An ontological context model is provided in wish the context information are not limited to a fixed set of attributes, instead providing freedom of meaning choices to users in different applications. However the context reasoning is adopted using Logic-based context reasoning.

In other side, the works of [7] and [9] are focusing on the context acquisition and modeling without reasoning. In [7] the context acquisition is extracted on the developer side, the work does not model the context in a formal way (Digital environment and physical environment context properties.) However in [9] the context acquisition is adopted using Semantic context (user's description) and sensing context (sensor reports). An ontological context model is performed including user's web-access devices, user's preferences, user's physical situations, and user's things. In [24] the context acquisition is extracted from the application layer protocols. The work adopts a logical context reasoning mechanism based on user's situations, current interests, relationships and whom they trust, without performing a context model.

VI. CONCLUSION

In this paper, we have analyzed the different solutions proposed in the literature for the service discovery in the IoT domain. Enabling the efficient discovery of the required services in IoT is facing challenging issues in many aspects. Traditional web service discovery approaches and their used technologies are unsuitable for the discovery of IOT services. This is due to the difference between IOT services and traditional web services. The services in the IoT are linked directly to the physical world because they are provided by objects in the real world, they are deployed in resource constrained devices with limit capabilities also they are operated in highly dynamic environment.

All these features make the task of locating the desirable services difficult to be accomplished. The existing service discovery approaches do not effectively adapt to the features of IOT services, especially that there is no new standard language for describing the IOT services in a formal way, and concerning the solution of extending the traditional web services technologies like OWL-S with new attributes or WSDL with DPWS or COAP services has to take in consideration the balance between to be lightweight to support the limit capabilities of devices and to adapt to the IOT services features. The IoT requirements such availability, scalability, dynamicity, security should also be considered when implementing IoT service discovery solution. And the context is vital in the IoT domain therefore it require more attention by the approaches.

REFERENCES

[1] Q.Wei, Z.Jin. "Service discovery for Internet of Things: A context awareness perspective." Proceedings of the Fourth Asia-Pacific Symposium on Internet ware. ACM.2012. pp. 25.

[2] J.Li, N.Zaman, H.Li."A Decentralized Locality-preserving Context-aware Service Discovery Framework for the

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Internet of Things." IEEE International Conference on Services Computing. IEEE.2015.pp.317-323.
[3] S.Fredj, M.Boussard et al."Efficient semantic-based IoT service discovery mechanism for dynamic environments," 25th International Symposium on Personal, Indoor and Mobile Radio Communications,.IEEE .2014.pp. 2088-2092.
[4] S.Cirani, L.Davoli et al."A Scalable and Self-Configuring Architecture for Service Discovery in the Internet of Things." internet of things journal, VOL. 1, NO. 5. IEEE. 2014.pp. 508-524.
[5] G. Cassar, P. Barnaghi et al."A Hybrid Semantic Matchmaker for IoT Services." in Internet of Things (iThings), IEEE International Conference. IEEE.2012.pp. 210-216.
[6] M.Zhou, Y.Ma, "A web service discovery computational method for IOT system."In Cloud Computing and Intelligent Systems (CCIS), 2nd International Conference v03.IEEE. 2012. pp. 1009-1012.
[7] D. Guinard, V. Trifa, et al. "Interacting with the SOA-Based Internet of Things: Discovery, Query, Selection, and On-Demand Provisioning of Web Services." Transactionson Services Computing.IEEE.2010.pp.223-235.
[8] F. Paganelli, D. Parlanti."A DHT-based discovery service for the Internet of Things." Journal of Computer Networks and Communications. 2012.
[9] J.He, Y.Zhang, et al. "A Smart Web Service Based on the Context of Things."ACM Transactions on Internet Technology.ACM. 2012.pp.13.
[10] S. De, T. Elsaleh et al. "An Internet of Things Platform for Real-World and Digital Objects." Journal of Scalable Computing: Practice and Experience. 2012.pp.45-58.
[11] J.Bao, Y.Ding et al."A New Service Selection Algorithm in USPIOT." Computer Science and Automation Engineering (CSAE). IEEE, 2012.pp.22-26.
[12] T. Butt, I. Phillips et al. "Adaptive and Context-Aware Service Discovery for the Internet of Things." In the Internet of Things, Smart Spaces, and Next Generation Networking. Springer.2013.pp. 36–47.
[13] R. Klauck , M. Kirsche. "Bonjour Contiki: A Case Study of a DNS-Based Discovery Service for the Internet of Things." In Ad-hoc, Mobile, and Wireless Networks. Springer. 2012.pp.316–329.
[14] S. De, P. Barnagh et al. "Service modelling for the internet of things." in Computer Science and Information Systems (FedCSIS), Federated Conference. 2011. pp. 949 –955.
[15] S. Evdokimov, B.Fabian et al."Comparison of discovery service architectures for the internet of things." Proceedings of IEEE Conf. Sensor Networks, Ubiquitous, and Trustworthy Computing (SUTC'10), Newport Beach, CA, 2010, pp. 237–244.
[16] G.D. Abowd, A.K. Dey et al. "Towards a better understanding of context and context-awareness." In Proceedings of the 1st international symposium on Handheld and Ubiquitous Computing.Springer-Verlag.1999,pp. 304–307.
[17] C.Perera, A.Zaslavsky et al. "Context aware computing for the internet of things: A survey." In IEEE Communications Surveys \& Tutorials.IEEE.2014.pp 414-454.
[18] Soumya.K.Datta. "Towards Securing Discovery Services in Internet of Things."In International Conference on Consumer Electronics (ICCE).IEEE.2016.
[19] E.Rapti, C.Houstis et al. "A Bio-inspired Service Discovery and Selection Approach for IoT Applications." In IEEE International Conference on Services Computing. IEEE.2016.pp 868-871.
[20] M.Khanouche, Y.Amirat et al. "Energy-Centered and QoS-Aware Services Selection for Internet of Things."In IEEE Transactions On Automation Science And Engineering.IEEE.2016.pp 1545-5955
[21] X.Jin, S.Chun et al. "A fast and scalable approach for IoT service selection based on a physical service model."In Information Systems Frontiers.Springer.2016.pp 1-16.
[22] A. Al-Fuqaha, M.Guizani et al. "Internet of things: A survey on enabling technologies, protocols, and applications." Communications Surveys& Tutorials. IEEE. 2015. pp2347-2376.
[23] W.Wang, S.De et al."Knowledge Representation in the Internet of Things: Semantic Modelling and its Applications." In Automatika–Journal for Control, Measurement, Electronics, Computing and Communications, 2013.
[24] D. Hussein, S. Park, and N. Crespi. "A Cognitive Context-aware Approach for Adaptive Services Provisioning in Social Internet of Things." In IEEE ICCE Conference Proceeding. 2015.
[25] P.Gomes, E.Cavalcante et al. "A Federated Discovery Service for the Internet of Things." Proceedings of the 2nd Workshop on Middleware for Context-Aware Applications in the IoT. ACM. 2015. pp. 25-30.
[26] H. Jo, J. Kwon and I. Ko. "Distributed Service Discovery in Mobile IoT Environments Using Hierarchical Bloom Filters." In Engineering the Web in the Big Data Era.Springer.2015.pp.498-514.
[27] F. Khodadadi, A.V. Dastjerdi, R. Buyya. "Simurgh: a framework for effective discovery, programming, and integration of services exposed in IoT." In International Conference on Recent Advances in Internet of Things (RioT).IEEE.2015.pp.1-6.

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