IJCI V11-1(2024) 87-97
International Journal of Computers and Information (IJCI)
Available online at *https://ijci.journals.ekb.eg/*

A Review for Context-Aware Semantic Service Provisioning

Wael Haider[a,b], Hatem Abdelkader[b], Amira Abdelwahab[b,c]

[a]*Dept. of Management Information Systems, Higher Institute of Qualitative Studies, Heliopolis, Cairo 11757, Egypt*
[b]*Dept. of Information Systems, College of Computers and Information - Menoufia University, Shibin Al Kawm, Menoufia 32511, Egypt*
[c]*Dept. of Information Systems, College of Computer Sciences and Information Technology, King Faisal University, Al-Ahsa 31982, Saudi Arabia*

Abstract

In the Internet of Things (IoT) era, there is a need to develop applications in a standard way. Every smart object has its own embedded protocol and data format. The Interoperability of Smart objects is still a big challenge. Separation of context data from application data and standardizing the method to access Smart Objects are musts to facilitate IoT application development. IoT application developments have caught the attention of researchers and industries. Context-aware is the property of a system that uses context to provide related information or services to a user based on the user's task. Therefore, Context-Aware service discovery can be defined as discovering the most suitable services for the user based on context information. Combining context-aware concepts with the IoT facilitates the development of IoT systems dependent on complex environments with numerous sensors and actuators, the user, and their surroundings. This paper introduces an overview of context-aware and non-context-based service provisioning Frameworks and solutions. This paper presented the advantages, disadvantages, and comparison of the discussed Frameworks.

Keywords: Internet of Things (IoT); Context Awareness; Service Provisioning; OWL

1. Introduction

Integrating Internet connectivity into various objects within our surroundings, such as electricity meters, chairs, office equipment, curtains, and home appliances can enhance multiple application domains.

The Internet of Things (IoT) has evolved as a significant and influential phenomenon in recent years, facilitating the interconnection of billions of devices throughout the globe and resulting in the generation of vast quantities of data. The potential uses of these interconnected devices span across various domains, including Smart Cities, Industrial Automation, and Health Care. However, the considerable quantity and variety of IoT data can pose difficulties in extracting significant insights and improving user experiences.

A smart object can be described as a entity that comes equipped with essential components such as a sensor, a communication module, microprocessor, a power source, and memory. The Lowpower Wireless Personal Area Network (LoWPAN) holds a crucial role within the IoT due to its advantageous features, which include energy efficiency, wide accessibility, and the ability to effortlessly integrate smart devices with the Internet [1].

One potential approach to address this difficulty involves the integration of context aware within IoT technologies. Context aware concept refers to the capacity of a system to understand and respond to its surroundings by taking into account diverse contextual elements, including temporal aspects, spatial coordinates, and user preferences. Through the integration of context aware, IoT devices have the capability to adjust and conform to their surrounding environment, hence offering customized experiences to users.

This paper is organized as follows: an introduction is presented in section 1. Section 2 illustrates the background of the related works. Section 3 presents the literature review and shows a comparison of all presented frameworks. Section 4 presents the conclusion and future works.

2. Background

This section presents the concept used in this research. Four important concepts for building the research structure are discussed. The first part covers a general introduction to Context Aware. The second part presents an introduction to the IoT. The Third part highlights an introduction to Interoperability. The last part presents an introduction to the Web of Objects.

2.1. Context-Aware

Context, in the context-aware computing field, is described as data that helps depict the circumstances in which an entity exists. An entity here refers to a person, place, or object associated with the interaction between a user and an application, encompassing both the user and the application itself [2], [3].

Context-aware is characterized as a system's ability to utilize context to deliver pertinent services or information to the user, with the relevance determined by the user's specific task. As a result, context-aware service discovery can be described as the utilization of contextual data to identify the services that are most appropriate for the user [2]. Figure 1 show the context life cycle general architecture.

Adopting a service-oriented architecture (SOA) aims to simplify the intricacies associated with interacting with intelligent devices. This approach would allow for these devices to be conceptualized as services, thereby transforming them into entities that can be leveraged. Consequently, the development team responsible for creating intelligent systems can dedicate their efforts exclusively to meeting functional necessities, eliminating the need to delve into the specific technical intricacies of individual devices. From the standpoint of web services, context data can be categorized as the following:

- From the point of view of service requesters, the term context refers to the surrounding environment that influences the discovery and accessibility of web services for these requesters.
- From a services perspective, context refers to the surrounding environment that influences the delivery and execution of Web services.

For the IoT solutions to be effective, it's essential to combine an IoT system with a context aware system.

Context-aware solutions face several obstacles. Firstly, they must grapple with the complex task of handling the diverse and immense volume of data produced by IoT devices. Secondly, they need to efficiently manage the storage and processing of events and deduce more advanced activities from a set of basic events. Lastly, they must execute applications across various domains using a versatile development framework [4]. Figure 1 preset reference architecture guide for developing more advanced context-aware frameworks.

The increasing number of IoT-enabled devices, technologies, and platforms has fragmented the landscape, resulting in interoperability problems for system deployments [5].

One of the major hurdles to the adoption of IoT and the encouragement of innovation is the issue of interoperability.

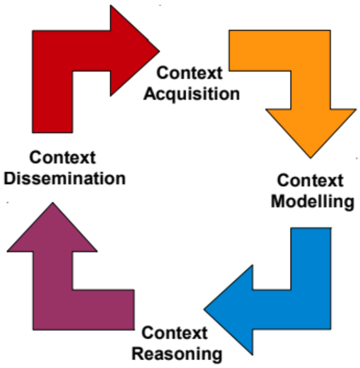

Fig. (1) Context Life Cycle [30]

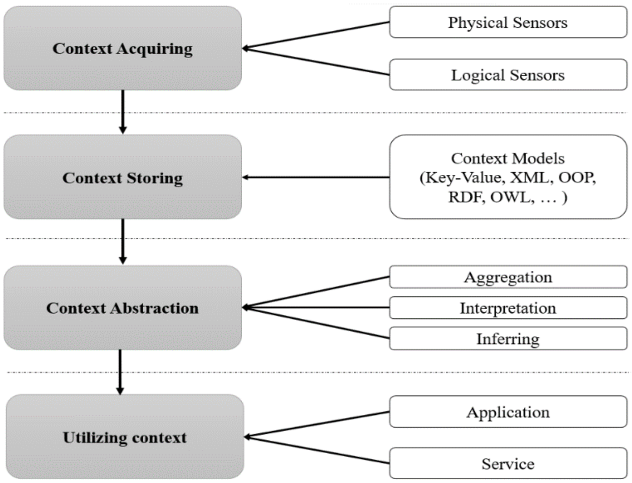

Fig. (2) General Reference Architecture for Context Aware System

2.2. *Internet of Things*

Kevin et al. introduced the concept of the IoT in 1999 during his tenure at MIT's Auto-ID Center, where the research primarily revolved around networked radio frequency identification (RFID) and sensor technologies [6], Where individuals and objects could share information about their present condition and environment in a significantly more effective way [7].

The IoT consists of wireless systems that which its size is small and connected to one another. These systems have the ability to send the data through the network automatically without the need for human intervention since they are computationally capable. These distinguishable smart items are programmed and can be accessible remotely over the Internet and locally through Bluetooth. They are intended to keep an eye on or manage smart areas [8]. IoT is essential in different domains, such as smart home [8], elderly healthcare [9], home safety [10], energy management and conservation [11], [12].

The concept of the IoT emerged from contemporary research centered on Connecting every physical object and information ecosystem to the internet, enabling users to access and manage devices remotely from any location and at any time. IoT enables smaller, simpler devices to carry out intricate tasks through improved intelligence and connectivity.

The IoT is turning smart environments from a concept into actuality. IoT lacks application-level standardization. IoT devices have limited processing capability and memory [13].

In recent years, the number of internet-connected devices has significantly increased. Digitizing specific parameters of interest to perceive the world can generate a vast amount of data. This data is subsequently transmitted across the network to other devices, applications, and infrastructure. The IoT concept is built upon this constantly evolving and dynamic environment. Many applications based on IoT have been developed for smart cities, intelligent transportation, and advanced industries [12].

IoT systems encounter various obstacles that hinder them from realizing the inherent potential of IoT devices, with one significant challenge being the diversity of devices and protocols, leading to constraints on interoperability.

Internet connectivity enables the IoT concept to blur the distinction between physical objects and computational devices. This connectivity contains the potential to provide user-centric services that take the user's context and profile information into account [13].

For example, conventional temperature control in a meeting room typically involves turning on the air conditioner to the desired temperature and relying on the built-in thermostat for regulation. In contrast, a sophisticated IoT system can optimize meeting room temperature by incorporating context aware, ontology, and IoT technology. For instance, it can analyze data from internal thermometers, the current time, online weather services, and the number of people present to determine whether simply opening a window would be more energy-efficient than activating the air conditioner. Additionally, the system can dynamically adjust the temperature based on the occupancy level, automatically turning off the air conditioner when the room is unoccupied. This highlights the importance of effectively managing data and events collected from sensors and devices. Basic events like door openings and activities such as employees leaving the meeting room can be translated into contextual information. This information can be accessed by a monitoring service responsible for the meeting room, which can, for example, send notifications when a meeting concludes to the person overseeing the room.

With the advancement of sensor networks, radio-frequency identification technology, and web services, the Web is evolving into the Web of Things and services[14]. A new generation of context-aware web services is emerging as a crucial technology for developing innovative applications.

The Web of Objects (WoOs) concept involves representing and virtualizing real - world objects in the physical world. This allows for the integration of intelligent functionalities and the provision of real-time data. These objects are represented as Web resources, which can be accessed through lightweight REST-based APIs instead of the more complex SOAP-based architecture. An object possessing a sensor or actuator, central processing unit (CPU), memory, communication capabilities, and a power supply is classified as a smart object. The utilization of the Internet as a global platform for IoT applications is advantageous due to its adherence to open standards and compatibility with various devices. Within the realm of web-based systems, sensors, and actuators possess the ability to provide their functionalities through a Representational State Transfer (REST) application programming interface (API). This API, exemplified by Uniform Resource Identifiers (URIs) such as URI/lightON and URI/lightOFF, facilitates dynamic interactions between objects. Service provisioning refers to the systematic method of delivering smart object services to the World Wide Web, which is akin to the conventional web services that are accessible on the Internet. An IoT application on the Web is defined as a web-based application that utilizes communication networks and adheres to Web standards to establish communication with smart objects [15].

A smart environment consists of sensors, actuators, interfaces, and devices designed to provide both local and remote control of the environment. Temperature, humidity, light, and motion are environmental monitoring and sensing elements. The actuator with dedicated hardware interfaces and computing capabilities controls the environment, including heaters and fans ON/OFF operation. Bluetooth provides localized control, whereas WiFi provides remote access. The RESTful architecture enables Interoperability in the Web of Objects Architecture for Smart Space.

Semantic ontology assists ubiquitous environments in tackling important challenges like Interoperability, knowledge modelling, and dynamic discovery of the service. It also serves as a robust foundation for creating interactive applications that are highly adaptive and context-aware.

The ability of information systems to interact with smart objects has been hindered by the following factors:

- A lot of devices depend on exclusive protocols to execute their tasks.
- A lot of devices contain embedded software that remains unchanged throughout their lifetimes.
- Annotation of physical objects and services with semantic data.
- Discovering services and subscribing to them.
- Concurrent requests.

2.3. *Interoperability*

Currently, the ecosystem of the IoT is experiencing a deficiency in terms of Interoperability among the diverse competing platforms that are currently available. [16].

The utilization of Semantic Web (SW) technologies, containing a comprehensive set of standards for establishing connections between data and their formal meaning, has been proven to be an effective approach for achieving data interoperability inside IoT systems. The utilization of SW technologies is motivated by their ability to infer data that has been semantically annotated [17].

The objective of the Semantic Web vision is to establish connections between data on the internet. Similarly, scholarly work on the application of Semantic Web technologies to the IoT emphasizes the significance of incorporating semantic annotations into the data produced by intelligent things. The predominant approach to describing semantics is through the utilization of the Resource Description Framework (RDF). RDF organizes knowledge in the form of triples, consisting of a subject, predicate, and object. For instance, examples of RDF triples include [TemperatureSensor208, Value, 27] and [TemperatureSensor208, Location, Room3]. The aforementioned triples generate a graph that encompasses subjects, objects, and predicates. RDF and graph-based data structures include the inherent capability to derive novel knowledge through the process of inference, utilizing the information contained inside an established graph. Through the utilization of domain expertise, a system has the capability to infer, for example, that the temperature within Room3 measures 27 degrees Fahrenheit, thereby exemplifying the application of the transitive property. The OWL is a widely used language, alongside RDF schema, for the purpose of constructing ontologies on the internet. It is commonly utilized to express domain knowledge and aid in the process of intelligent data annotation [18], [19]. Recent research has focused on how SW technologies, specifically OWL ontologies, can be used to enhance the IoT industry's poor interoperability [8].

Existing solutions facilitate Interoperability between various IoT platforms and application domains. The W3C consortium presented the Web of Things (WoT) architecture as one such solution [20].

The WoT builds upon the IoT concept and offers standardized methods for communicating with various devices across different automated systems. This communication is facilitated through a descriptive JSON file known as a Thing Description [21].

Rule-based programming methods are well-suited for IoT automation systems because they are straightforward and user-friendly. While IFTTT stands out as a leading tool for creating IoT scenarios using trigger-action rules, it does have several drawbacks, including limited abstraction and a lack of generality [8], [22]

This paper is structured as follows: Section 1 contains an introduction. Section 2 present background about the concepts used to build the research structure. Section 3 provides an overview of related literature and studies. Section 4 presents conclusions.

3. Literature Review

Several studies have investigated the application of Web paradigms and protocols to service provisioning, including SOA (REST, SOAP), Semantic based, and the WoT.

Traditional context-aware frameworks have several limitations when it comes to developing context-aware services, including those listed below.

• If the context is constantly changing (such as location), a context-aware service must be invoked with the updated context data. Consequently, the service must be invoked multiple times, which increases network traffic and the cost of using the service.

• Large messages: sending a large message to the context manager.

In this section we will show a set of frameworks for service provision we will group them by the use of context-aware-based frameworks and non-context-aware-based frameworks.

3.1. Context-Aware Based Frameworks

Kim et al., introduce a middleware architecture specifically designed for the implementation of context-aware systems in the setting of a smart home environment. In order to derive high-level contexts from low-level contexts, the suggested architecture incorporates an advanced rule-based reasoning algorithm that is augmented with profiles. Contexts are typically represented using the OWL ontology. The experimental findings provide evidence that the utilization of this middleware yields reasoning conclusions that are both more accurate and faster in comparison to traditional rule-based approaches. Furthermore, the process of selecting context-aware services is achieved using a rule-based algorithm, which facilitates the seamless augmentation of services by including new rules into the pre-existing rule base [23].

In this study, Gochhayat et al. present the Lightweight Context-Aware IoT Service Architecture (LISA), a framework that has been developed with the objective of effectively delivering and managing push-based services inside IoT settings. The main goal is to reduce the amount of communication and processing required by utilizing contextual information, such as the capabilities of devices, user preferences, and ambient circumstances. The objective of this strategy is to provide IoT services that are tailored to individual needs and are highly effective in their implementation. The LISA system utilizes contextual comprehension in order to choose to convey the most pertinent and significant services to users. In order to analyze the scalability of LISA, the study employs simulations to evaluate its capacity to accommodate a substantial quantity of IoT services and devices. The findings suggest that the LISA system demonstrates efficient scalability in managing a large number of devices and services, while also maintaining adequate levels of performance. Nevertheless, the study also notes specific constraints associated with LISA, such as its restricted capacity to handle intricate services and its limited scalability when implemented in a centralized fashion [13].

Krati et al. explore the difficulties linked to maintaining an ideal indoor air quality. The research introduces an IoT system that is context-aware, gathering data, making predictions about ventilation conditions, and delivering alerts and recommendations to users. A smartphone application serves as a tool for keeping users informed about the indoor environment and ventilation status. Moreover, the system is capable of offering guidance on how to enhance ventilation and reduce indoor pollutants, which may involve actions like opening windows, using air purifiers, or adjusting HVAC systems. The system calculates ventilation rates by examining indoor CO2 levels and utilizes a multilevel logistic regression approach to define different ventilation states. To predict ambient ventilation, the K-Nearest Neighbors (K-NN) classification algorithm is employed [24].

Reda et al. present a knowledge-based methodology for home automation systems implementation that utilizes IoT devices. The primary objective of the suggested strategy is to enhance expressivity and increase the level of abstraction required for the development of systems that possess knowledge-based capabilities and reasoning abilities. This will enable the comprehensive utilization of the potential provided by IoT devices. This study showcases the viability and effectiveness of the suggested methodology within a simulated residential setting. It makes a valuable contribution to the advancement of home automation systems by introducing a novel methodology that leverages web technology standards and publicly available ontologies to facilitate structured inferring. This eliminates the requirement for improvised control programs or ontologies. Additionally, the research proposes a number of potential future endeavors. These include examining the scalability of the proposed methodology, assessing its performance in a practical context, contrasting it with alternative existing methodologies, expanding its functionality to encompass more sophisticated inferring capabilities, and creating a user-friendly design for setting up and overseeing the proposed methodology [8].

A generic layered model to achieve the development of context-aware systems must contain minimally the following:

- **The physical entities layer** contains a collection of sensors for capturing the environment context. Then, this information is classified to enable services to request context information.
- **The context management layer** stores classified context information in a database.
- **Service provisioning layer** responsible for discovery, composition, and execution of the service.
- **Application Layer:** This facilitates the development of context-aware services by consumers.

Hassan et al. introduce a novel architecture for Smart Home Systems (SHSs) designed to enable remote automation and control of household appliances. This architecture leverages emerging technologies like IoT, Context-aware, and Cloud Computing, aiming to simplify the development of Smart Home systems and enhance their management capabilities. The fundamental building blocks of this proposed architecture encompass Classic Smart Homes, IoT, Context-aware, Cloud Computing, and Rule-based Event Processing Systems (RbEPS). Additionally, the paper offers a new schematic guide to facilitate the creation of comprehensive Smart Home Systems and optimize data processing. To validate and evaluate the proposed architecture, the authors implemented a smart home system using ultrasonic sensors. This system serves as a house navigator, capable of monitoring and regulating room temperatures, detecting fires, water leaks, smoke, and motion within the home. However, the paper does not furnish specific outcomes or results related to the proposed architecture or the functioning smart home system [25].

Ortiz et al. propose a new architecture for the IoT that is designed to be more scalable, efficient, and secure than traditional IoT architectures. The architecture, called Atmosphere, is a three-tier architecture that consists of edge nodes, fog nodes, and cloud nodes. Edge nodes are located close to the IoT devices and are responsible for collecting data from the devices and performing basic processing tasks. Fog nodes are located between the edge nodes and the cloud and are responsible for performing more complex processing tasks and managing the edge node resources. Cloud nodes are located in the cloud and are responsible for storing and analyzing large amounts of data. Atmosphere uses a context-aware and situational-aware approach to processing IoT data. This means that the architecture takes into account the context of the data, such as the location of the data, the time of day, and the current situation when making decisions about how to process the data. This approach allows Atmosphere to make more efficient use of resources and to provide more accurate and timely results. Atmosphere also uses a collaborative approach to processing IoT data. This means that the edge, fog, and cloud nodes work together to process the data. This approach allows Atmosphere to scale to large numbers of IoT devices and to provide more reliable results. The authors of the article evaluated Atmosphere through a case study of respiratory disease surveillance in hospitals. The evaluation results showed that Atmosphere could provide more efficient, secure, and scalable IoT solutions than traditional IoT architectures [26].

Haider et al. suggest an overarching framework for delivering smart objects as a service by incorporating context-aware principles while accounting for limitations in bandwidth, scalability, and performance. This framework comprises key components like data acquisition and management services, data aggregation, and rule-based reasoning. To validate and assess the effectiveness of this proposed framework, the authors conducted simulations within an IoT network. They compared the outcomes of accessing the service using the traditional approach with those achieved through the application of the proposed framework. The paper highlights the importance of context-aware in IoT systems and the use of semantic web technologies for achieving data interoperability [27].

3.2. *Non-Context-Aware Based Frameworks*

Iqbal et al. present a proposed IoT platform that aims to facilitate interoperability and is well-suited for seamless integration within a smart home setting. This platform integrates the utilization of WoO with cloud architecture. The assessed platform showcases its capacity to attain interoperability among a wide range of household products, multiple communication methods, and protocols. The main objective of this technology is to facilitate the remote control of domestic appliances, while also allowing for the storage of home-related data in a cloud-based system. The aforementioned data can thereafter be retrieved by diverse service provider applications for the aim of analysis. The study moreover proposes many prospective avenues for future investigation, encompassing the incorporation of machine learning algorithms, the creation of a mobile application, and the installation of a security framework for the smart home system. The architectural design being discussed exhibits a notable level of adaptability, rendering it well-suited for diverse applications within the domain of intelligent building systems [15].

Sciullo et al. propose the introduction of a WoT Store, a centralized repository designed to enhance resource and application management within the WoT. Although this particular strategy presents a number of possible advantages, it is crucial to acknowledge and evaluate its limitations and disadvantages. The potential reliance of the WoT Store system on a centralized infrastructure raises questions regarding scalability, dependability, and security. Furthermore, it is conceivable that the system could impose the use of specific communication protocols and application programming interfaces (APIs), hence possibly constraining the flexibility and interoperability of IoT devices and applications. However, this study proposes a prototype for the WoT Store system and assesses its performance in terms of the time taken for resource identification and application deployment. This evaluation showcases the efficacy of the proposed prototype in effectively overseeing IoT resources and applications within the WoT [5].

Ibaseta et al. propose an approach that employs WoT technology to effectively monitor and manage energy use in construction projects. The proposed solution aims to integrate various building systems and devices, such as lighting, occupancy sensors, and smart plugs, using a cloud-based platform that utilizes web protocols and standards. This paper introduces a novel methodology through the analysis of a case study carried out on a refit project executed within the premises of an office building. The results indicate that the proposed methodology exhibits cost-effectiveness and energy efficiency, as well as interoperability and scalability. Furthermore, the findings of the research suggest that this particular methodology possesses the capacity to be implemented in real-world scenarios [28].

In summary, we've gained insights into various frameworks after reviewing different studies. In Table 1, we'll compare these frameworks to understand their relevance to our specific study.

Table (1). Frameworks Comparison

Refs.	Year	Domain	Proposed Solution	Web Technology	Context Aware	Context Reasoning	Strength	Weakness
[23]	2016	Smart home	• Middleware Architecture	• OWL	✔	✔	• Context inferring • Sensor abstraction • Rule based context aware service selection	• Scalability • Generalization • Comprehensive evaluation of the proposed architecture
[15]	2018	Smart home	• Platform • (Architecture, Prototype)	• WoO • Cloud	✕	✕	• Interoperable • Standard technologies	• Lack of empirical evaluation • Limited scope • Scalability
[13]	2019	General	• Architecture	• SOA	✔	✕	• Minimizes overhead of communication and processing	• Scalability • Context Inference
[5]	2020	General	• WoT Store Platform	• W3C WoT • Micro-services oriented	✕	✕	• Resources dynamic discovery • Simplified management	• Scalability • limited Interoperability
[28]	2021	Building	• Architecture • Real-world application	• W3C WoT • Cloud	✕	✕	• Interoperable • Scalable • Energy consumption • Real-world Application	• Generalization • Limited Interoperability
[24]	2021	Building	• System	• AWS • MangoDB	✔	✔	• Machine Learning	• Generalization • No separation between layers in application development and context aware.
[8]	2022	Smart home	• Knowledge-based home automation	• OWL • SWRL • SAREF [29]	✔	✔	• Interoperable • Inference	• Scalability • Generalizability • Limited Interoperability • Hard to use
[25]	2022	Smart home	• Architecture	• Cloud Computing	✔	✕	• Cloud based. • Real-world implementation	• Limited Interoperability • Evaluation details not available
[26]	2022	Hospitals	• Architecture	• Event Driven SOA • Cloud, Fog, and edge.	✔	✕	• Integrates edge, fog, and cloud computing. • Situational-aware • Event-Driven SOA (ED-SOA)	• Comprehensive evaluation and comparison • Addressing potential challenges in implementing the proposed architecture in real-world scenarios
[27]	2023	General	• Framework	• OWL • SWRL • SOA	✔	✔	• Minimizes the overhead of communication and processing. • Standard technologies	• Testing using real world environment. • Limited Interoperability

4. Conclusions

In the era of IoT, developing applications to support smart spaces faces many challenges, and one of the biggest challenges is interoperability. Also, transferring IoT applications from the network to the web is an important step to running and accessing the physical world in a standard environment. Merging the concepts of IoT and context awareness is important, where context has the concept of how to model sensor data with situation awareness data.

Context awareness services provisioning (CaSSP) is a novel approach that leverages the rich and dynamic contexts of smart objects and users to provide relevant and personalized services over the IoT. CaSSP aims to address the challenges of service discovery and allocation in IoT systems, especially in complex and heterogeneous environments. In this paper, we have introduced an overview of the context-based and non-context-based IoT solutions, the context based IoT solutions advantages and disadvantages, and the comparison of the most important solutions.

In conclusion, the burgeoning field of context-aware IoT semantic service provisioning presents a revolutionary paradigm shift in how we leverage the vast potential of the IoT. This paper has comprehensively reviewed the state-of-the-art in this domain, delving into the key concepts, enabling technologies, and existing approaches. We have highlighted the critical role of context awareness in tailoring service provision to the dynamic needs of users and devices within the IoT ecosystem. Semantic technologies, particularly ontologies and reasoning techniques, have emerged as crucial enablers for effectively capturing and utilizing contextual information, thereby facilitating the discovery, composition, and adaptation of relevant services.

Based on our review, future work in this area must focus on the following points: Firstly, the development of a framework for context-aware semantic service discovery and recommendation based on ontologies, rules, and machine learning techniques. Secondly, we will explore the use of blockchain technology for secure and transparent context-aware semantic service provisioning. Thirdly, develop context-aware service provisioning solutions tailored to specific domains like smart cities, personalized healthcare, and industrial automation, leveraging domain-specific ontologies and knowledge graphs for enhanced service discovery and adaptation. Finally, develop scalable service matchmaking algorithms and distributed architectures that can efficiently manage the vast and dynamic service landscape in large-scale IoT deployments.

References

[1] S. N. Han and N. Crespi, "Semantic service provisioning for smart objects: Integrating IoT applications into the web," *Future Generation Computer Systems*, vol. 76, pp. 180–197, 2017, doi: 10.1016/J.FUTURE.2016.12.037.

[2] V. Ponce and B. Abdulrazak, "Context-Aware End-User Development Review," *Applied Sciences 2022, Vol. 12, Page 479*, vol. 12, no. 1, p. 479, 2022, doi: 10.3390/APP12010479.

[3] G. D. Abowd, A. K. Dey, P. J. Brown, N. Davies, M. Smith, and P. Steggles, "Towards a better understanding of context and context-awareness," *Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)*, vol. 1707, pp. 304–307, 1999, doi: 10.1007/3-540-48157-5_29/COVER.

[4] M. Elkady, A. Elkorany, and A. Allam, "ACAIOT: A framework for adaptable context-aware IoT applications," *International Journal of Intelligent Engineering and Systems*, vol. 13, no. 4, pp. 271–282, 2020, doi: 10.22266/IJIES2020.0831.24.

[5] L. Sciullo, L. Gigli, A. Trotta, and M. Di Felice, "WoT Store: Managing resources and applications on the web of things," *Internet of Things*, vol. 9, p. 100164, 2020, doi: 10.1016/J.IOT.2020.100164.

[6] K. Avila, P. Sanmartin, D. Jabba, and M. Jimeno, "Applications Based on Service-Oriented Architecture (SOA) in the Field of Home Healthcare," *Sensors (Basel)*, vol. 17, no. 8, 2017, doi: 10.3390/S17081703.

[7] Kevin Ashton, "That 'internet of things' thing," *RFID journal*, vol. 22, no. 7, 2009.

[8] R. Reda *et al.*, "Supporting Smart Home Scenarios Using OWL and SWRL Rules," *Sensors (Basel)*, vol. 22, no. 11, 2022, doi: 10.3390/S22114131.

[9] S. Y. Y. Tun, S. Madanian, and F. Mirza, “Internet of things (IoT) applications for elderly care: a reflective review,” *Aging Clin Exp Res*, vol. 33, no. 4, pp. 855–867, 2021, doi: 10.1007/S40520-020-01545-9/TABLES/4.

[10] Taryudi, D. B. Adriano, and W. A. Ciptoning Budi, “Iot-based Integrated Home Security and Monitoring System,” *J Phys Conf Ser*, vol. 1140, no. 1, p. 012006, 2018, doi: 10.1088/1742-6596/1140/1/012006.

[11] V. Marinakis and H. Doukas, “An Advanced IoT-based System for Intelligent Energy Management in Buildings,” *Sensors (Basel)*, vol. 18, no. 2, 2018, doi: 10.3390/S18020610.

[12] M. Lombardi, F. Pascale, and D. Santaniello, “Internet of Things: A General Overview between Architectures, Protocols and Applications,” *Information 2021, Vol. 12, Page 87*, vol. 12, no. 2, p. 87, 2021, doi: 10.3390/INFO12020087.

[13] S. P. Gochhayat *et al.*, “LISA: Lightweight context-aware IoT service architecture,” *J Clean Prod*, vol. 212, pp. 1345–1356, 2019, doi: 10.1016/J.JCLEPRO.2018.12.096.

[14] Q. Z. Sheng, J. Yu, A. Segev, and K. Liao, “Techniques on developing context-aware Web services,” *Article in International Journal of Web Information Systems*, 2010, doi: 10.1108/17440081011070141.

[15] A. Iqbal *et al.*, “Interoperable Internet-of-Things platform for smart home system using Web-of-Objects and cloud,” *Sustain Cities Soc*, vol. 38, pp. 636–646, 2018, doi: 10.1016/J.SCS.2018.01.044.

[16] J. Lanza, L. Sánchez, D. Gómez, J. R. Santana, and P. Sotres, “A Semantic-Enabled Platform for Realizing an Interoperable Web of Things,” *Sensors (Basel)*, vol. 19, no. 4, 2019, doi: 10.3390/S19040869.

[17] D. Andročec, M. Novak, and D. Oreški, “Using Semantic Web for Internet of Things Interoperability,” *Int J Semant Web Inf Syst*, vol. 14, no. 4, pp. 147–171, 2018, doi: 10.4018/IJSWIS.2018100108.

[18] F. Z. Amara, M. Hemam, M. Djezzar, and M. Maimour, “Semantic Web Technologies for Internet of Things Semantic Interoperability,” *Lecture Notes in Networks and Systems*, vol. 357 LNNS, pp. 133–143, 2022, doi: 10.1007/978-3-030-91738-8_13/COVER.

[19] B. Elsharkawy, H. Ahmed, and R. Salem, “Semantic-based Approach for Solving the Heterogeneity of Clinical Data,” *IJCI. International Journal of Computers and Information*, vol. 5, no. 1, pp. 35–45, 2016, doi: 10.21608/IJCI.2016.33955.

[20] “Solution for IoT Interoperability - W3C Web of Things (WoT).” Accessed: Apr. 01, 2023. [Online]. Available: https://www.w3.org/2020/04/pressrelease-wot-rec.html.en

[21] S. Murawat *et al.*, “WoT Communication Protocol Security and Privacy Issues,” *International Journal of Advanced Computer Science and Applications*, vol. 11, no. 3, pp. 155–161, 2020, doi: 10.14569/IJACSA.2020.0110319.

[22] “IFTTT - Connect Your Apps.” Accessed: Dec. 18, 2022. [Online]. Available: https://ifttt.com/

[23] H. W. Kim, M. R. Hoque, H. Seo, and S. H. Yang, “Development of middleware architecture to realize context-aware service in smart home environment,” *Computer Science and Information Systems*, vol. 13, no. 2, pp. 427–452, 2016, doi: 10.2298/CSIS150701010H.

[24] K. Rastogi, D. Lohani, and D. Acharya, “Context-Aware Monitoring and Control of Ventilation Rate in Indoor Environments Using Internet of Things,” *IEEE Internet Things J*, vol. 8, no. 11, pp. 9257–9267, 2021, doi: 10.1109/JIOT.2021.3057919.

[25] S. A. Z. Hassan and A. M. Eassa, “A Proposed Architecture for Smart Home Systems Based on IoT, Context-awareness and Cloud Computing,” *International Journal of Advanced Computer Science and Applications*, vol. 13, no. 6, pp. 89–96, 2022, doi: 10.14569/IJACSA.2022.0130612.

[26] G. Ortiz, M. Zouai, O. Kazar, A. Garcia-de-Prado, and J. Boubeta-Puig, “Atmosphere: Context and situational-aware collaborative IoT architecture for edge-fog-cloud computing,” *Comput Stand Interfaces*, vol. 79, p. 103550, 2022, doi: 10.1016/J.CSI.2021.103550.

[27] W. Haider, H. Abdelkader, and A. Abdelwahab, “A Proposed Framework for Context-Aware Semantic Service Provisioning,” *International Journal of Advanced Computer Science and Applications*, vol. 14, no. 8, p. 2023, 2023, doi: 10.14569/IJACSA.2023.0140860.

[28] D. Ibaseta *et al.*, “Monitoring and control of energy consumption in buildings using WoT: A novel approach for smart retrofit,” *Sustain Cities Soc*, vol. 65, p. 102637, 2021, doi: 10.1016/J.SCS.2020.102637.
[29] L. Daniele, F. den Hartog, and J. Roes, “Created in Close Interaction with the Industry: The Smart Appliances REFerence (SAREF) Ontology,” *Lecture Notes in Business Information Processing*, vol. 225, pp. 100–112, 2015, doi: 10.1007/978-3-319-21545-7_9/FIGURES/3.
[30] C. Perera, A. Zaslavsky, P. Christen, and D. Georgakopoulos, “Context aware computing for the internet of things: A survey,” *IEEE Communications Surveys and Tutorials*, vol. 16, no. 1, pp. 414–454, 2014, doi: 10.1109/SURV.2013.042313.00197.