International Arab Conference on Information Technology (ACIT'2016)

A comparison study of context-management approaches for the Internet of Things (ID 64)

Farida Retima [1], Saber Benharzallah [2], Laid Kahloul [3], Okba Kazar [4]

[1,2,3,4]Smart Computer Sciences Laboratory, Biskra University 07000, Algeria

Abstract: *Currently, the context management solutions for the Internet of Things are the subject of numerous studies which are achieved through the expansion of the context manager for ambient environments. In literature, there are different approaches enabling the context management for internet of things (IoT). This paper studies these approaches, which are well known according to our defined criteria such as heterogeneity, mobility, the influence of the physical world, scalability, security, privacy, quality of context, autonomous deployment of entities, characterization multi scales, and interoperability.*

Keywords: *Context management, Internet of things, Context-awareness, Context manager, middleware.*

1. Introduction

The increasing number of mobile objects used in our daily life has given birth for a number of new paradigms such as the Internet of Things (IoT), which relies on a wide range of hardware, network infrastructure, communication protocols and applications. This concept IoT aims to allow products or daily objects to interoperate with a large number of systems using Internet. The services offered by this paradigm must be smart and adapted or sensitive to context changes. The context management aims to link applications which have heterogeneous needs with heterogeneous capabilities of sensors, thus it must ensure compatibility between the different actors. This concept is a generally treated through ambient environments. In the Internet of things, context management becomes more complex. This is due to the heterogeneity of the data, the authorization of the mobility of architectural elements, and the provision of information on the context of the user, who exposes the privacy of individuals near to the objects connected to the Internet [1].Therefore, a context management approach to the Internet of Things should be developed, where it must take into account the requirements of such an environment. The rest of this paper is organized as follows: In Section 2, we introduce a software entity responsible for the management and presentation of context information to applications; this software entity is called a context manager. In section 3, we describe some technical and non-technical issues which need to be studied to enable the Internet of things to reach its full potential. In Section 4, we will do a comparison of these approaches

according to our defined criteria with their sub criteria well illustrated in Table 1. Finally, section 6 concludes this paper.

2. Context manager in ambient environment

A context manager is a software entity capable of calculating high-level information from various sources of context data. Its features include the acquisition of raw data, the processing of such data (fusion, aggregation, interpretation, inference) and then the presentation of the highest level of information to context-aware applications. These applications are typically viewed as end consumers of context information, as entities that provide the raw data are considered as original producers. The component which, in a context manager, is responsible for the context data processing is a context processor that is both a consumer and a producer, intermediate level, of context data [2]. The context information management infrastructure aims—to link applications that have heterogeneous needs with sensors that have heterogeneous capabilities; it must ensure compatibility between these different actors [3].

3. The difficulties emerged with the internet of things

When talking about the Internet of Things we distinguish numerous challenges currently posed in the literature that must be studied, among these issues we are interested to the following ones: heterogeneity, mobility, and influence of the physical world, scalability, security, privacy, quality of context, autonomous deployment of entities, characterization multi scales, and interoperability.

3.1 Heterogeneity of the Internet of Things

The Internet of Things is composed of heterogeneous objects that are composed of several levels: hardware, software and communication protocols. The equipment used is very varied, functioning with various operating systems, adopting different wireless technologies. Within the same network, the workstations with high computing capabilities and large storage can coexist with other devices with limited resources [4]. Heterogeneity criterion can be divided into two sub criteria:

- Semantic heterogeneity of objects and devices of an ambient system.
- Technological heterogeneity [5].

3.2 Influence of the physical world on the internet of things

Objects connected to the Internet are much more than simple connectivity or a message transported. The Internet of things is open, means that anyone can add and removed objects [6]. The detection capability of smartphones and user mobility [7]. influence on the physical world on the Internet of things that require for developers to take into account a mechanism for data representation and processing. We can divide this criterion into three sub criteria:

- Specific techniques of detection, correction or error attenuation: for flow data (flow measurements or events) produced by sensors.
- The capacity of mobile objects to adapt to changes
- The capacity of mobile objects to handle their energy limits [8].

3.3 Security

The IoT is extremely vulnerable to attacks for several reasons. First, its components often spend most of the time without supervision; and consequently, it is easy to attack them physically, second, most of the communication is wireless, which makes listening extremely simple. Finally, most of the IoT components are characterized by low capacity in terms of energy and computing resources (which is especially the case for passive components) and so, they cannot implement complex Systems for security support. Specifically, the main security problems are authentication and data integrity [9]. We can divide this criterion into two sub criteria:

- Secure communication for peers
- Secure topology: that handles authentication of the new peer, the access authorizations to the network, and protection of routing information exchanged in the network [9].

3.4 Protection of privacy

The growing number of interactions between entities becoming closer to the user pushes to reconsider personal data security. Indeed, users transmit authentication data to many systems, often through unsecured communication channels. And because applications or services are personalized for users, the transmitted data is more sensitive than ever, in the sense that they can lead to a disclosure of their privacy [10], so to promote the acceptability by users of new applications, it is essential to provide a mechanisms to ensure respect for the privacy of users and the protection of the data handled [11]. We can divide this criterion into two sub criteria:

- The hardware layer: should ensure confidentiality during temporary collection and storage in the device.
- The protocol layer: ensure that communication is well protected.
- The application layer: monitoring and control who can see or use the context [12].

3.5 Mobility

A coherent and stable vision of the network topology is an important factor for the management of IoT applications. However, mobility related to everything makes this coherency difficult and inefficient [13]. because the smart objects in IoT are not static and change their physical location this leads to rapid changes in network topology which in its turn affects the routing efficiency because there are many paths that become unavailable. Update routing information after the mobility of objects can cause major general costs especially when there are many nodes that have changed their physical locations simultaneously [14].

3.6 Quality of context

The QoC enables to qualify the context information using criteria such as accuracy, completeness, freshness, allows a context aware application to adapt its reactions according to QoC delivered by the Manager [15].We can divide this criterion into three sub criteria:

- QoC of the context information acquisition phase.
- QoC of the context information of the processing phase.
- QoC of the delivery phase of contextual information to context-aware applications [16].

3.7 Scalability

IoT is composed of a growing number of smart objects these objects communicate together. The proposed middleware should maintain its stability and should have the ability to effectively manage the increasing number of objects and perform their functions with the required efficiency, although the number of connected devices is increasing and varies from place to other [14]. The scalability criterion facing in various sub criteria, including:

- Naming and addressing: because of the large scale and rapid growth of IoT devices.
- Data communication and networks: due to the high level of interconnection between many entities.
- The management of information and knowledge.
- Service management: because of the massive number of services that might be available and the need to manage heterogeneous resources [17].

3.8 Multiscale characterisation

A characterization of scenarios multi-scale aims to target specifically the design requirements of context manager, including the requirements for multi-scale. The multi-scale feature of a system can be considered according to several views as equipment, network, data ... etc. For each view, we select one or more dimensions, and for each dimension we propose a set of scales relevant to the multi-scale characterization of the studied system and therefore each system can lead to special multi-scale characterization [18].

3.9 Standalone deployment of entities

The software deployment is a complex process which aims the provision and the operational maintenance of the software. The deployment involves two categories of sites: a producer site that hosts software components and installation procedures, and a consumer site that is the target of the deployment, on which a software element is to be executed. The deployment of a system can be performed on several consumer sites. All of these sites are deployment domains requiring to write the distribution of components, which is called a deployment plan [19].

3.10 Interoperability

It is the ability of two or more systems or components to exchange information and to use the information that has been exchanged. Two possible types of interoperability can be achieved. On the one hand, inner components can interact with each other and share information. On the other hand, different context aware middleware can communicate with each other and make use of exchanged information [20].

3.11 Context life cycle

- Context Acquisition: the aim of context acquisition is to obtain a maximum amount of data, such that the possibilities for applications to be intelligent could be maximized due to richer context information [20]. We discuss three factors: Acquisition technique, data source support (any sensors, physical sensors, virtual sensors, or logic sensors), context discovery (There are many types of context that can be used to enrich sensor data)[12]

- Context modeling: referred to as context representation. There are several popular context modeling techniques used in context-aware computing. We discuss in this phase the factor modeling techniques [12].

- Context reasoning: a process of giving high-level context deductions from a set of contexts. We discuss two factors: reasoning techniques, quality of context [12].

- Context Distribution**:** Context distribution is responsible for disseminating useful context information to corresponding applications. We discuss in this phase the factor distribution techniques [20].

4. The comparison of the different approaches proposed for context management in IoT

In the literature, different approaches exist to allow the context management in the Internet of Things. The study of different approaches and their characteristics according to different issues is presented in this section. The considered criteria include: Heterogeneity, influence of the physical world, the security, protection of privacy, mobility, scalability, Multi-scale characterisation, Standalone deployment of entities, Interoperability, Quality of context.

Table1.Summary table of evaluation criteria

		Context management approaches for IoT				
The comparison criteria	**Sub criteria**	**INCOME Approach**	**SITAC Approach**	**FIWARE Approach**	**CA4IOT Approach**	**SAMURAI Approach**
Quality of context	QoC of acquisition phase	✓	-	-	-	✓
	QoC of transformation Phase	✓	-	-	-	✓
	QoC of de delivery phase	✓	-	-	-	✓
Influence of the physical world	detection, correction, error attenuation techniques	✓	-	-	-	-
	objects mobiles adaptation	✓	✓	✓	✓	-
	energy limitation treatment	-	✓	-	-	-
Heterogeneity of objects	semantic heterogeneity	✓	✓	✓	✓	✓
	technological heterogeneity	✓	✓	✓	✓	✓
Security	Peers communication	✓	✓	✓	-	✓
	Topology management	✓	✓	✓	-	✓
Privacy Protection	Hardware level	✓	??	✓	-	-
	Protocol level	✓	??	✓	-	-
	Application level	✓	??	✓	-	-

Standalone deployment of entities		✓	-	-	-	✓
information processing style		QoC at every step of the information life cycle	Semantic interoperability	Performs operations (update, query, notify, registration)	Query-response	Performs request: Create (POST), Read (GET), Update (PUT) Delete (DELETE) events.
Scalability	Scale of IoT	✓	✓	✓	✓	✓
	data and network communication	✓	✓	✓	✓	✓
	Management information	✓	✓	✓	✓	✓
	Service management	✓	✓	✓	✓	✓
Multiscale characterization		✓	-	-	-	-
Architectural style		Distributed	Distributed	Distributed	Distributed & layered	distributed
Context acquisition	Data source support	Any sensors	Any sensors	Any sensors	Any sensors	Any sensors
	Acquisition technique	Context collector (pull& push)	??	Context provider	Acquire through a middleware(SDAL)	RESTful APIs
	Context discovery	✓	✓	✓	✓	✓
Context modeling	Modelling Techniques	Ontology based(context information) QoCIM(QoC)	??	Ontology	Ontology	MLContext model
Context reasoning	Reasoning Techniques	Ontology based	??	ontology	Ontology and statistical	??
	Quality of context	Conflict resolution & Validation	??	-	-	??
Context Distribution	Distribution Techniques	Publish and Subscribe	??	Publish and Subscribe	Query	Publish and Subscribe
Interoperability	Internal	✓	✓	✓	✓	✓
	External	✓	✓	✓	✓	✓
mobility of objects		✓	✓	✓	✓	✓

✓ Problem solved

\- Unsolved problem

?? Not cited in detail on the project

5. Discussion

This paper has presented a review on the latest prominent solutions for context management of IoT which are based on decoupling between the participants of the IoT, namely the context information owners and consumers of such context information.

Currently, in most proposed solutions, the functionalities of middleware are achieved by distributing the tasks in a layered/distributed architecture among these solutions are INCOME approach, SITAC approach, FIWARE approach, CAIoT approach, SAMURAI approach. Only two middleware architectures take security and privacy into account by applying different strategies e.g. INCOME and FIWARE projects. The criterion of scalability is focused on the stability of functioning with the large number of entities, in this light; cloud-oriented techniques are an excellent solution [20] to solve the scalability problem from different aspects all the approaches that we studied are achieved this issue. It becomes possible to guarantee good applications functioning taking account management of the QoC and so more trust between participants of IoT as the case of INCOME and SAMURAI projects which achieved this issue by proposing software architecture to enforce QoC contracts between producers and consumers in the IoT. Each middleware solution focuses on different aspects in IoT such as interoperability, Multiscale characterization, Standalone deployment of entities and many more. In conclusion, the major goal is to design a solution to help users to automating the task of selecting the sensors according to the tasks at hand, such as CAIoT approach which is security, privacy and QoC are missing in this middleware. Several technical challenges have been detected in the development of future middleware architectures and more efforts should be taken into account to drive the current middleware proposals towards better ones with high level of context awareness by combining the architecture, models, and techniques into existing IoT middleware solutions, which intend to fulfill the demands in IoT paradigm. A generic domain-focused middleware solution should take into account the protecting privacy of information, ensuring the information security during processing or probably creating private clouds dedicated to public sectors, QoC resolution and realization a middleware that could adequately understand any change of current environment based on all available context information.

6. Conclusion

In this paper, we have demonstrated that the new challenges emerged with IoT in terms of large-scale, heterogeneous objects, the scalability, interoperability, security, and privacy and other problems already mentioned previously require to design a software solution for multi-scale context management, from production context information until used by an application. This paper has given an overview of some approaches that exist in the literature such as the INCOME, SITAC, FIWARE, CA4IoT, SAMURAI projects and make study in different well-focused criteria.

References

[1] Sam R., Sébastien L., Claire L., Chantal T., "Vers une définition d'un système réparti multi-échelle", *8émes journées francophones Mobilité et Ubiquité*, France, pp.178-183, 2012.

[2] Jean-Paul A., Sophie C., Denis C.," Gestion de contexte multi échelle pour l'Internet des objets", *Journées francophones Mobilité et Ubiquité*, France, 2014.

[3] Jérôme P., "Une infrastructure de gestion de l'information de contexte pour l'intelligence ambiante", Thèse doctoral à l'Université Joseph Fourier - Grenoble 1, 2009

[4] Gaëtan R.,"Modélisation du contexte et Adaptation" ,2010

[5] Peter W, *Learning IoTs*, website PACKT, Mumbai, 2015.

[6] Song G., Xiaofei L., Fangming L., Yanmin Z.," CollaborativeComputing:Networking, Applications,and Worksharing", *11th International Conference, CollaborateCom 2015*, Wuhan, China, 2015.

[7] Benjamin B., "Systeme de gestion de flux pour l'Internet des objets intelligents", Thèse doctoral, Université de Versailles-Saint Quentin, France, 2015.

[8] Luigi A.,Antonio I., Giacomo M.,"The IoTs:A survey", *Computer Networks*,Vol.54,No.15, pp.2787-2805, 2010.

[9] Soma B.,"Role of middleware for IoTs: a study", *International Journal of Computer Science & Engineering Survey (IJCSES)*, Vol.2, No.3, 2011.

[10] Ahmed Malek N., "L'intelligence ambiante et les systèmes de transport intelligents", Mémoire du diplôme magister en informatique; Université Badji Mokhtar Annaba, 2014.

[11] Zied A.,"Gestion de la qualite de contexte pour l'intelligence ambient", Thèse doctoral de

Télécom, Université d'Evry-Val -D'Essonne Sud Paris, 2012.
[12] Charith P., ArkadyZ., Peter C., Dimitrios G.,"Context Aware Computing for The IoTs:A Survey",*IEEE Communications Surveys & Tutorials Journal*, Vol.16, No.1, pp. 414 – 454, 2014.
[13] Jun young K., "Secure and Efficient Management Architecture for the IoTs", *proceedings of the 13th ACM Conference on Embedded Networked Sensor Systems*, School of Computer Science and Engineering, UNSW Australia, 499-500;2015.
[14] Fersi G., "Middleware for IoTs: a study"; *International Conference Distributed Computing in Sensor Systems (DCOSS),* Tunisia , 2015.
[15] Jean-Paul A, "Projet INCOME : INfrastructure de gestion de COntexte Multi-Echelle pour l'Internet des Objets", *In Conférence Francophone sur les Architectures Logicielles (CAL*), Université de Toulouse, pp. 1–2 , 2014.
[16] Jean-Paul A.," Gestion de bout en bout de la Qualité de Contexte pour l'Internet des Objets: le cadriciel QoCIM", thése doctoral; l'Université Toulouse, 2015.
[17] Daniele M.,Sabrina S.,fransisco P.,"IoTs: Vision, applications and research challenges", *in Ad Hoc Networks journal*, Vol.10, No.7, pp.1497-1516, 2010.
[18] Sam R.," Modèles, méthodes et outils pour les systèmes répartis multiéchelle", Thèse doctorat, Télécom SudParis école doctorale S&I avec l'Université d'Évry-Val-d'Essonne, 2015.
[19] Raja B.," Déploiement de systémes répartis multi-échelles processus, langage et outils intergiciels", Thèse Doctoral de l'université de Toulouse, 2015.
[20] Xin L.,Martina E.,José M.," Context Aware Middleware Architectures: Survey and Challenges", *in Sensors journal*, Vol.15, No.8, pp. 20570-20607, 2015.

Retima Farida is a phd student in intelligent Computer Science Laboratory University Mohamed Khider Biskra, Algeria. Her interests include context management, Quality of context, and Internet of things.

Dr. Saber Benharzallah is an associate professor and researcher in the computer science department of Biskra University (Algeria). Dr Benharzallah is currently the team leader of semantic interoperability and their applications in information systems and web services, in LINFI laboratory (Biskra University). His current research interests include internet of things, semantic interoperability, and context management

Dr. Laid Kahloul is currently an associate professor with the Computer Science Department, Biskra University. His current research interests include Petri nets, High Level Petri Nets, and Software Engineering.

Pr. Okba Kazar, professor in the Computer Science Department of Biskra. He is a member of international conference program committees and the "editorial board" for various magazines. His research interests are artificial intelligence, multi-agent systems, web applications and information systems.