WoT based Context-Aware Middleware Design for Integrating Real-World Object to SNS

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***Abstract*—In order to build a more user-friendly, intelligent IoT where interactions between Human-to-Human, Object-to-Object, and Human-to-Object coexists, real-world objects are assigned a social network identity on current SNS. Under this scenario, the contexts of the real-world objects become more complicated since it contains both social attributes and physical attributes. This paper proposed a context-aware middleware for infers the contexts of real-world objects in SNS. The deduced context of the object is generated from the physical contexts, which retrieved from WoT infrastructure and social network context from SNS, which results in the quality of the context more dependent to the real state of the object. Then, services or behavior will be triggered by the middleware after the reasoning process. Implementation on the MagicHome project will illustrate the feasibility and reasonability of middleware in a smart home scenario.**

Keywords-Web of Things; social network; context aware; context reasoning;

I. INTRODUCTION

Nowadays, it is necessary for people spending their free time on social network. It is a relationship constructed by blogs, comments and forwarding messages on their SNS web-sites. However, relationship in our daily life is much more complex. The success of Facebook and Twitter, which builds a virtual network of Human relationship over the digital world, challenges us to expanding the community to Object-to-Object, or especially Human-to-Object. In this paper, we try to assign SNS account for the objects in our daily life, it is an innovations for the current architecture.

The first problem needed to solve is how to involve objects in the real-world to the social web service. The recent advances in IoT industry is evolving into the Web of Things (WoT) environment where everyday objects are identifiable, readable, recognizable, addressable, and even controllable via the Internet [1], that eases the problem. The concepts of WoT try to abstract real-world entities, for example sensors and actuators, as web resources so that the topology of the device network and dynamism can be ignored by the developers and applications. Therefore, WoT is an open environment driven by RESTful API and web technologies, such as web protocol and XML formatted description. Based on that WoT is capable to accelerate the integration of social services and real-world entities.

Involving with social services, SWoT in [2] improves WoT platform with social attributes. The key function is the translation between raw data of structure and natural language. To be noticed it depends on context of the entities so that entities can talk in natural language in SNS. Context-aware technologies are applicable for ubiquitous services. [3] is an application using on the automatic control on the light with illuminate sensor and light switch, which is lack of scalability of sensors and devices. SWRL approach [4] is implemented on the camera motoring scenario with context-aware technologies. In this paper, a context-aware middleware is proposed which decouples the social module from the WoT platform. WoT is chosen as the underneath infrastructure to involve scalable real-world entities. Since the user is not only a real-world object in WoT but also a member in SNS, it requires the middleware having the functionality of inferring contexts of the real-world objects whose context containing both social attributes and physical attributes. The deduced context will be more related to the real context of entities.

The rest of this paper is organized as follows. The discussion of use cases and functionalities for the middleware starts at Section II. In section III, it describes the design of the architecture and relevant key technologies which analyze the middleware. The context modeling and reasoning technologies are detailed in section IV, while section V concludes the implementation on MagicHome project.

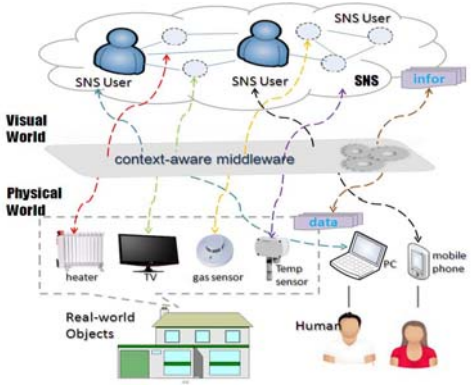

Figure 1. The idea applying in the smart home scenario, where appliance and sensors have their accounts on the SNS , creating social relationship to the host. The users can communicate, interact with other users.

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II. CASE OF USE

The use case of the middleware is applied to the home monitoring shown in Fig.1. When the host asks the state of the house, the temperature sensor in the living room will reply to the host with instant degree on the social network. Or when the illuminate sensor broadcasts the illumination, the relevant light will adjust its brightness.

The real-world entities are independent in WoT, but they are related and connected in SNS. Additionally, social relationship is extended to the host and other human user. Therefore, the real-world objects in SNS has more complicated context. On one hand, they are living object so that they have the physical context, which depends on their sensing ability. On the other hand, the social attributes brings the relationship context and social activities of the objects. So we proposes a context-aware middleware with following functions :

- Inferring the complex context of the real-world objects in SNS using the context reasoning rules. Deduced context generated from both SNS and physical world.
- Context-aware responding to the deduced context
- Diversifying the responses to the real-world objects in SNS, including literal operations in the traditional SNS as well as the physical operation on the object.

III. STRUCTURE OF THE MIDDLEWARE

The motivation of the middleware is to analyse the contexts of the real-world entities from both SNS and WoT and responses to the messages from the applications based on the contexts. Fig. 2 shows the overview architecture with three functional modules in the context-aware middleware.

A. Overview of the System

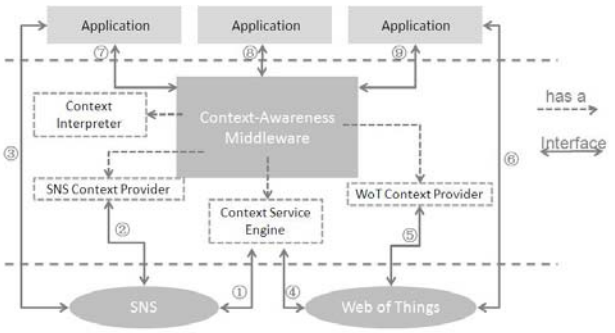

Figure 2. Overview of system architecture containing middleware, which having the key modules to achieve the functionalities required.

In the overall system, three kinds of the interface are applied, these are **S**NS **I**nter**F**ace **P**rotocol (**SIFP**), **W**oT **I**nterFace **P**rotocol-**a**pplication (**WIFP_a**) and Middleware **I**nterFace **P**rotocol(**MIFP**). Examples of partial important interfaces are shown on the TABLE I, and what API is applied to which interface is also listed.

SIFP indicates the set of RESTful APIs provided by the open SNS. Currently, SNS[6][7] is becoming an open platform providing access to the SNS user's status, comment, friendship, favorite or relevant information on the SNS. The read interfaces of SIFP are specially provided for interface ② so that SNS provider retrieved the context status on SNS of real-world objects.

WIFP indicates the set of APIs provided by WoT platform. The sectional APIs, named WIFP_a, is a special interface open to third application and developer to involve physical objects in the applications using web technologies. Similarly, the interface of WoT context provider is only applied to the read ones of WIFP_a in order to capture the physical context of the objects.

MIFP provides the application access to the usage of the context-aware middleware. The SWoT applications can interact with objects in the SNS and trigger its operations. It is a user information interface and message interface that will be discussed, which are relevant to the system.

User information interface provides the access of real-world object in SNS. The information provided not only the user information on SNS but also the physical status of the object. Physical status means the state of the real-world entities, for example the brightness of a light, the IP address of a TV, and the actual owner of a device.

Message interface used when the application sending messages to the middleware and triggers the object with its ID. Similar to the format in twitter, posted a message:

"@temp what's the degree?"

The middleware will reply to the user and twit with natural language. Such as:

"Sir, it's 10℃. keep warm and coats on."

The message said by the real-world objects in SNS will not be the words that only understood by machine or developer. It can be understood by human and displayed directly without translation.

TABLE I. EXAMPLE OF APIS USING IN THE SYSTEM

API Name	Description		Applied At
	Type	***Operation***	
SNS **I**nter**F**ace **P**rotocol **(SIFP)**	User profile	Read	①②③
		Write	①③
		Search	①②③
	Blogging	Read	①②③
		Write	①③
		Search	①②③
	Relationships	Read	①②③
		Write	①③
		Search	①②③
WoT **I**nter**F**ace **P**rotocol-**a**pplication **(WIFP_a)**	Data	Read	④⑤⑥
		Write	④⑥
	Control	Write	④⑥
Middleware **I**nter**F**ace **P**rotocol **(MIFP)**	User Infor	Read	⑦⑧⑨
	Message	Write	⑦⑧⑨

B. *The Structure of Middleware*

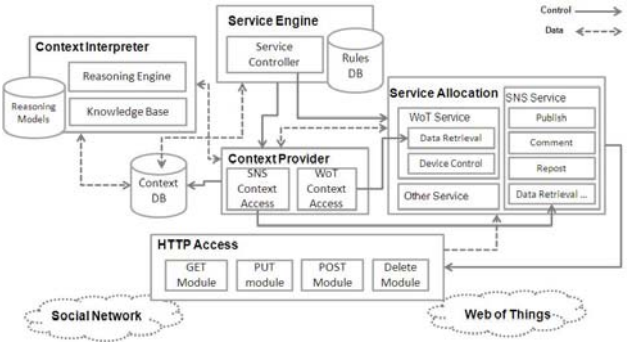

Figure 3. Overview of middleware structure

Context Service Engine is the controller for the whole middleware. It controls context providers which retrieves the low-level context from the real-world and the social network, to offer the context information to the Context Interpreter which deduced the high-level context. The deduced or high-level context is referred to trigger the registry service on the middleware.

1) Context Provider

It is context abstraction module to separate the low-level context sensed from the high-level context manipulation. SNS context providers obtain contexts from sources of social network, e.g. latest tweet from the relevant lights to a host. WoT context provider acquires contexts directly from ubiquitous sensors which register to WoT platform. For example, a camera used for environment monitoring with wireless assessment or smart switch using inferred.

2) Context Interpreter

It is a logic module for context processing. The tasks for context processing may include deriving high-level contexts from low-level contexts which is captured by context provider, querying reasoning module and knowledge bases. It acts as a context provider as it can provide deduced contexts and from that the middleware finally triggers services required in the system.

It consists of a reasoning engine and a Knowledge Base (KB). The function of the reasoning engine is providing deduced contexts based on low-level contexts derived from the context provider.

3) Context Database

It can be categorized into cashed context database and permanent context database. Cashed context database is used to save the raw context information, which will probably be upgraded or removed. Permanent context database manage the current context of the WoT objects. It is upgraded when the context of objects are changed. The deduced contexts saved in the permanent one and are retrieved by the service engine for locating the services.

4) Context Service Engine

It is a manager level module for middleware. It is responsible of controlling the context services with the rules, especially triggers the reaction of the real-world entities attached to WoT. The services register to the middleware are also managed in this module, but only WoT services and fundamental social network service are provided in this proposal.

a) HTTP Access Module: RESTful API is a popular architectural-style for web services, such as [6] which is the SINA platform owns open APIs. However, in WoT infrastructure, devices are identified by URI as web resource. HTTP is the application protocol and HTTP method (GET, PUT, POST, and DELETE) towards resources. So the Http access acts like an unified access point for the context retrieval. Additionally, it is used to trigger the web services.

b) Service Allocation Module: It acts as the service pool in the middleware. The services provided in the middleware are WoT services and SNS services. The WoT services are related to the response of the objects in real-world. With the deduced context, the middleware can obtain the current temperature using the identifier assigned by the WoT platform, when the social change. Moreover, the light related to the illuminate sensor can adjust its brightness when the sensor reports that the house is dark. The SNS services object can response by SNS and broadcast the information to the follower immediately in natural language with the language DB.

IV. CONTEXT MODELING AND REASONING

The context models and reasoning tools are concluded in [5]. Ontology-based Context Model and Forward Chain Rules are selected to analysis the concepts in context-aware. Both of them are applied in the implementation cases.

A. *An Ontology-based Context Model*

The contexts of the object in the system are generated from both social network and the physical world. What should be noticed is that the context model used for this context-aware service can be categorized into physical context and social network context. The instance of Context Entity presents a set of descendant classes, like CompEntity, Location, Environment, User, Activity shown in Fig. 5. The context for the real-world objects in SNS is similar to the sensing object in [8]. However, the objects applied in the system having the identity in social network, the User class highlights the social contexts of the object, like friendship. When a friend posts a new message, the context of the user changes since its social contexts changed.

```
<Data xmlns:xsi="http://www.w3.org/2001/XMLSchema-instance"
xmlns:xsd="http://www.w3.org/2001/XMLSchema"
svc_ID="55b21276-7b5f-4d3c-b2a4-571fce0d222c">
<Datapoints>
<value datatype="illuminance" Unit="lux" Time="2012-07-16T13:32:17">141</value>
</Datapoints>
```

Figure 4. Resource description on WoT

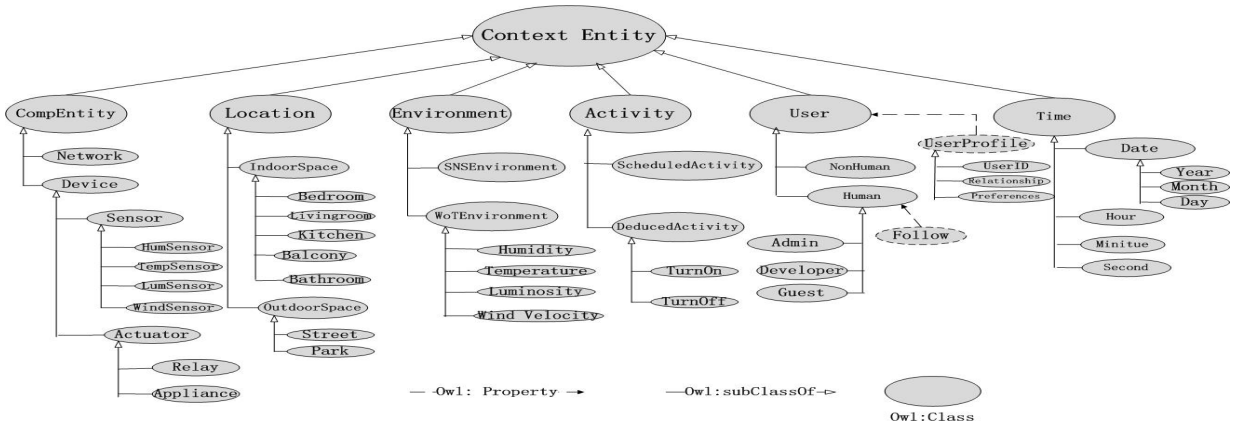

Figure 5. Ontology-based Context Model for objects applied to the middleware

Advance to WoT platform, the physical context of an object can be resolute from its description. Devices, or precisely called recourses in WOT, are described with markup, such as WADL(Fig.4). Implicit meaning within description document can be inferred by abstract the markups according to the context model. While physical context can be perceived directly from social network, context information finds a new source to obtain relationship among the identities and interaction between members in a community, such as commended, blogging in SNS network. In this way, context information of object in real-world will be perceived more related to the actual state of the object.

B. Contextual inference rules

Context inference itself has been addressed using different techniques such as Kohonen Self-Organizing Maps (KSOMs), k-Nearest Neighbor, Neural Networks, and Hidden Markov Models (HMMs). Concepts in forward chain rules is applied in the MagicHome project. For example: •A Illumination Sensor A of living room posted a message:

"@A: The house is lightless currently."

The smart curtain B received the message from the SNS and decided to open itself. Also, the smart Light E, which is in the living room, obtains the information from its SNS, so it adjusts the lightness itself. But the smart Light F in the bathroom has no reaction to the same information.

For A and B:

SENSOR_ILL (?A, "lightless") ∧ FRIENDSHIP(A,B) ∧ CURTAIN(?B)→CURTAIN_OFF(B)

For A and E:

SENSOR_ILL (?A, "lightless") ∧ FRIENDSHIP(A,E) ∧ Light (?E)→Light_ON (E)

For A and F, as there is none defined relationship on SNS, the context of F won't change and the services won't trigger.

V. IMPLEMENTATION

The usage of the system can be more general and applicable to different industry. For example, the broadcasting from the perceiving objects is also applicable to traffic-jam observation or emergency alarming. The messages can be sent out directly from sophisticated equipment and received by the followers. And the passengers can interact with the traffic lights when catching jam.

The MagicHome project tries to construct a WoT service environment to solve the living problems, with sensors which are applied to perceive environment parameters, and actuators as well as inferred controller which are used to control the devices and smart nodes. Applying the context-aware middleware, MagicHome produces a series story of the daily appliance, from sensing devices by catching the conversation between them can create an life of fairy-tale for the house.

Figure 6. MagicHome Project: creating an life fairy-tale for the house

VI. CONCLUSION

In this paper, we propose a context-aware middleware enabling the real-world object integration to SNS where context becomes more complex. The upgraded context model used by the middleware contains social and physical attributes aiming to improve the context reasoning quality. The architecture of overall system involves SNS and WoT platform, which is one of scalable IoT infrastructures. So the middleware can deduced the high-level context and operates on the real-world object according to the result. The concept of this middleware has been proved to be useful in the MagicHome project. In the future, the reasoning process will be improved for the problems like reasoning conflict, etc.

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REFERENCES

[1] Mathew, S.S.; Atif, Y.; Sheng, Q.Z.; Maamar, Z.; , "Web of Things: Description, Discovery and Integration," Internet of Things (iThings/CPSCom), 2011 International Conference on and 4th International Conference on Cyber, Physical and Social Computing , vol., no., pp.9-15, 19-22 Oct. 2011

[2] "Architecture Design for Social Web of Things",unpublished

[3] Chao Li, Lijun Suna, Xiangpei Hua, "A context-aware lighting control system for smart meeting rooms", Systems Engineering Procedia, Volume 4, 2012, Pages 314-323, ISSN 2211-3819

[4] Ricquebourg, V.; Durand, D.; Menga, D.; Marine, B.; Delahoche, L.; Loge, C.; Jolly-Desodt, A.-M.; , "Context Inferring in the Smart Home: An SWRL Approach", Advanced Information Networking and Applications Workshops, 2007, AINAW '07. 21st International Conference on , vol.2, no., pp.290-295, 21-23 May 2007

[5] Claudio Bettini, Oliver Brdiczka, Karen Henricksen, Jadwiga Indulska, Daniela Nicklas, Anand Ranganathan, Daniele Riboni, "A survey of context modelling and reasoning techniques, Pervasive and Mobile Computing", Volume 6, Issue 2, April 2010, Pages 161-180, ISSN 1574-1192,

[6] http://open.weibo.com

[7] http://dev.t.qq.com/

[8] Tao Gu, Hung Keng Pung, Da Qing Zhang, "A service‐oriented middleware for building context‐aware services", Journal of Network and Computer Applications, Volume 28, Issue 1, January 2005, Pages 1-18, ISSN 1084-8045

[9] Guinard, D.; Trifa, V.; Wilde, E.; , "A resource oriented architecture for the Web of Things," Internet of Things (IOT), 2010 , vol., no., pp.1-8, Nov. 29 2010-Dec. 1 2010

[10] Zhenyu Wu; Chunhong Zhang; Yang Ji; Yunjie Liu; , "Web of X Service Environment for Ubiquitous Network and Computing," Internet of Things (iThings/CPSCom), 2011 International Conference on and 4th International Conference on Cyber, Physical and Social Computing , vol., no., pp.592-597, 19-22 Oct. 2011

[11] Guinard, D.; , "Towards opportunistic applications in a Web of Things," Pervasive Computing and Communications Workshops (PERCOM Workshops), 2010 8th IEEE International Conference on , vol., no., pp.863-864, March 29 2010-April 2 2010

[12] D. Guinard, V. Trifa, F. Mattern, and E. Wilde, From the Internet of Things to the Web of Things: Resource Oriented Architecture and Best Practices. Springer, Dec. 2010, ch. 5.

[13] Zhenyu Wu, Timo Itälä, "A Web-based Two-layered Integration Framework for Smart Devices", EURASIP Journal on Wireless Communications and Networking, 2012

[14] Dongwon Jeong , Hyejin Jeong , Soo-Hyun Park , Young-Sik Jeong , Sangkyung Kim , Changhwa Kim, A Security Model Based on Relational Model for Semantic Sensor Networks, Wireless Personal Communications: An International Journal, v.56 n.1, p.131-146, January 2011

[15] Joachim Schwieren , Gottfried Vossen, ID-Services: an RFID middleware architecture for mobile applications, Information Systems Frontiers, v.12 n.5, p.529-539, November 2010