Orchestration in Distributed Web-of-Objects for Creation of User-centered IoT Service Capability

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***Abstract*— While advancing to a new concept of service it is essential to consider the integration of various objects which are already exists and services being provided with well-established technologies. In order to provide user based IoT service, this paper aims to suggest the construction of Web-of-Objects platform in the IoT service environment. Within the WoO platform, it provides user-centered IoT service with device profile objectification and semantic ontology based service orchestration between existing web service and device objectification. The use case elaborates the user-centered significant in Smart Home service and Smart Building service using WoO platform.**

***Keywords*— Device Objectification, User-Centeric, IoT service, Semantic Ontology, WoO platform, Orchestration.**

I. INTRODUCTION

The IoT environment talks about service that could provide connection and communication between IoT devices without any user recognition or interaction to the environment. The WoO (Web of Objects) [1], one of the studies ongoing in IoT is being processed by the EUREKA project [2] in Europe to enhance the technology of IoT. It is a research on making virtual things/devices by the use of objectification, and from combining these objectified things with various contexts information enables us to create and provide new services to the environment. Also, various standardized instruments are in process for the IoT standardization currently. This paper suggests based on WoO platform is to create orchestration from the various objects that could provide user-centered services in the IoT architecture platform. And it also suggests providing various user-centered IoT service using objectification method and semantic ontology based service orchestration mechanism in WoO platform.

The remainder of this paper is organized as follows: The second chapter is the related study that the paper referred. The third chapter explains WoO platform architecture for user-centered IoT service. The forth chapter describes objectification and semantic ontology based service orchestration mechanism in WoO platform. The fifth chapter presents the use case of user-centered IoT service using WoO platform. And lastly, the sixth chapter concludes the paper with a future research of the presented work.

II. RELATED WORKS

A. DiYSE

The DiYSE (Do-it-Yourself Smart Experiences) project [3] is part of ITEA2 that intends to enable the ordinary people to create easily, setup and control application in their own smart living environments as well as in the public Internet of Things domain. DiYSE project provides diverse business models and interconnecting the environments by the existence of intelligent devices it will empower the computing capabilities. The main objective is to interact and connect with non-technical people for them to participate in the IoT environment and capacitate to create and share their own smart events. Also, user can configure their own environment that could possibly pursue a customized environment and can be controlled depending to the user's interaction with the social activities. Additionally, DiYSE architecture shifted to user-centered paradigm to admit flexibility, interaction, adaptation and user-friendly by collaborating the variety of information.

B. SOCRADES

Reflecting the service environment of IoT and SOCRADES (Service-Oriented Cross-layer infRAstructure for Distributed smart Embedded devices) paradigm represents an important field of study for it could obtain and exploit benefits from the composition of devices connected with web server and to leads the automated system for next generation industry, and platform to enhance the execution and the management. SOCRADES will create new methodologies, technologies and tools for the modeling, design, implementation and operation of networked systems made up of smart embedded devices [4].

SIA (SOCRADES Integration Architecture) which is proposed from SOCRADES to provide a service that is integrated substantially using embedded devices, and the actions through hardware, software system modeling methods which are indicated [5]. SIA architecture provides a function for continuous monitoring and management of devices in automated industrial system [6]. The method of dynamic discovery is provided to transmit the device profiles and information which DPWS and REST that support IP devices and Non-IP devices [7]. The SIA architecture provides mash-up services and integrates various devices from Web 2.0, and it performs effective business process efficiently. The layers of the SIA can be distinguished in [5]. And significant functionalities are

provided to search for devices and integrate the ubiquitous computing environment by using three kinds of device discoveries which are the WS-Discovery, active and passive RESTful [7].

C. DPWS

The DPWS (Device Profile for Web Services) as a next generation version of UPnP (Universal Plug and Play) was developed to enable secure web service capabilities on resource constraint devices [8]. DPWS specification is a set of very general standards that provide interaction between embedded devices and services. Through the DPWS protocol, messaging, discovery, description, eventing and security provide integrating a variety of web services based on SOAP (Simple Object Access Protocol). Presently, SIRENA (Service Infrastructure for Real-time Embedded Networked Applications) project provides a variety of development tools for embedded devices, industrial automation, home automation, automotive and telecommunications [9]. And for the practical implementation and development of web services, the SIRENA project expands to the WS4D (Web Services for Devices), SODA (Service Oriented Device Architecture) and OSAMI (Open Source Ambient Intelligence) based on DPWS.

III. FUNCTIONAL ARCHITECTURE OF WOO PLATFORM FOR USER-CENTERED IOT SERVICE

A. Approach of IoT Service on WoO Platform

The existing various projects that provides IoT service appeared to have limitation in provision to meet the user-centered IoT service. In the case of DIYSE, it is a project that builds user-centered service and providing environment that has limitation in connecting various objects and in creating new services, and providing a service by connecting objects according to each of the defined services as an initialized phase which the smart devices are also to be needed in IoT service. The SIA architecture of SOCRADES project can be used and utilized as management system like web service based automated industrial system. However, it is quite limited in consisting of several small units to provide IoT services and also appears limited over control scalability, local system actions over devices and external access. In order to solve the limits above, WoO platform requires interoperability, versatility, efficiency of communication, mobility, intelligence and active functionality to the user-centered IoT service. Also, in order to control and manage the fault operation within IoT service, service integration and service management, location management, context management, traffic management, security and privacy management is required.

The WoO platform proposed in this paper basically uses the structure of web based service platform. Web service platform contains versatility and scalability which multiple users or basic environment could easily apply. The WoO platform that this paper proposes, basically web based service platform structure is used. Web service platform is expandable and universal that it could adjust various users to the environment. And more over, from service orchestration the user-centered IoT service could be provided through Device Objectification, objectified device service with Ontology web service concept.

B. WoO Platform Architecture for Distributed Web-of-Objects

The WoO platform for providing user-centered IoT service, gathering information and data from the distributed objects and by using semantic ontology based service orchestration should be provided. In order to provide services through a distribute object, the WoO platform is consists of distributed structure and web service platform act as the core and responsible for the capability to provide services to the users [10].

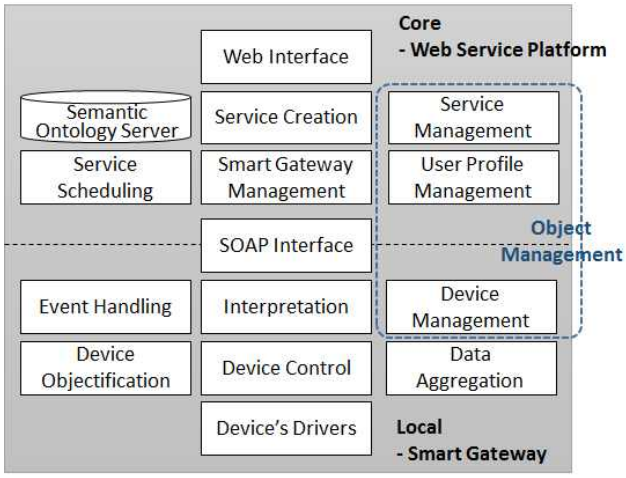

Figure 1. Functional architecture of WoO platform for user-centered IoT serivice

TABLE I. DESCRIPTION OF WEB OF OBJECTS PLATFORM FUNCTIONS

Web Interface	Web protocol interface for user service provision
Service Creation	User service generating function, object based service integration and creation
Semantic Ontology Server	Ontology server for providing IoT service scheduling using objects
Service Scheduling	Function provision to connect service objects when service integrates through service creation
S.G. Management	Information management of distributed structure of Smart Gateway
Service Management	Service management of currently registered users
User Profile Management	To manage user information, and related user context management
SOAP Interface	Web interface between web service platform and Smart Gateway
Interpretation	SOAP message analysis and transmission of each function received from web service platform
Event Handling	Device event handling of the service scheduling occurrence
Device Objectification	Running after device discovery and navigation from objectified web based IoT service provision of devices
Device Control	Function to control device actuators
Data Aggregation	Data collection from sensors
Device Mangement	Information and sensing data management of Device objectification
Device's Drivers	Driver to connect internal devices of the Smart Gateway domain

Smart Gateway is located in each of the decentralized structure of the local location and manages the located domain devices. Figure 1 shows the structure of the WoO platform

functions. In figure 1 depicts in the service management of web service platform, user profile management, and integrating the device management of Smart Gateway, connects with the cloud server and able to manage each of the resource information. Each of the functional explanation of WoO platform is listed in the table I.

IV. Semantic Ontology Based Service Orchestration Mechanism using Objectification in WoO Platform

A. *Objectification Method of WoO Platform for IoT Service Capability*

The Device Objectification is to make objects which are capable of interlocking services using device profile, device information in able to configure and provide web service from IoT environment of various objects and devices. Through the objectification of devices IoT service, it can be provided from a user-centric service connection of the device with existing web service. In this paper, a device object scheme is to provide Device Objectification after profiling devices based on the DP WS by the functionality of Device Objectification in Smart Gateway.

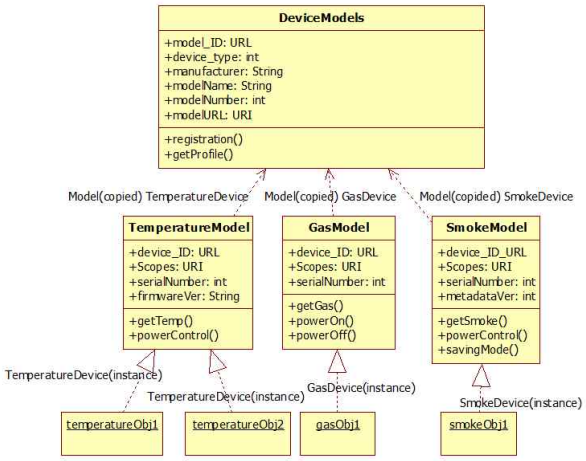

Figure 2. Device class structure using device profile for Device Objectification

Figure 2 shows the structural example for the Device Objectification. In figure 2, the device models have the basic method of request and each profile parameters and profile registers. And each device also includes a method for their unique features and profiles which are inherited from device models. The objectified device information is sent to the Web Service Platform by the Smart Gateway using SOAP based WSDL (Web Services Description Language). Figure 3 shows the example of WSDL document of devices.

B. *Semantic Ontology based Service Orchestration Mechanism of WoO Platform for Service Creation*

Service orchestration provides new service from diversity of service cooperation and combination. However, a ways to provide unified existing web service with services that use various devices are needed in IoT environment. In this paper, service orchestration mechanism is proposed using semantic ontology based objectification in WoO platform service scheduling. The Semantic Ontology based service orchestration provides unified service of extracted objects, and by using IoT service through ontology among diverse IoT service objects and extracts the objects that are related to the user. Therefore, the user may easily create, configure and control IoT service.

```
<?xml version="1.0" encoding="UTF-8"?>

<definitions>
  <types>
        ……
  </types>
  <message>
        ……
  </message>
  <portType name="model_ID">
    <operation name="registration" parameterOrder="… …">
      <input message="tns:deviceID_registration"/>
      <output message="tns:deviceID_registrationResponse"/>
    </operation>
    <operation name="getProfile" parameterOrder="… …">
      <input message="tns:deviceID_getProfile"/>
      <output message="tns:deviceID_getProfileResponse"/>
    </operation>
    <operation name="getSensingData" parameterOrder="… …">
      <input message="tns:deviceID_getSensingData"/>
      <output message="tns:deviceID_getSensingDataResponse"/>
    </operation>
    <operation name="deviceControl" parameterOrder="… …">
      <input message="tns:deviceID_deviceControl"/>
      <output message="tns:deviceID_deviceControlResponse"/>
    </operation>
  </portType>
  <binding>
        ……
  </binding>
  <service>
    <port>
        ……
    </port>
  </service>
</definitions>
```

Figure 3. A sample of device's WSDL document

In order to provide user-centric service using different IoT objects of distributed structure, the service orchestration based on semantic ontology is necessary. Among the different web based objects and various device objects that provide IoT service, this paper suggest the approach that service scheduling may apply using semantic ontology. With this approach, extracting the objects that the user needs and uses from those large amounts of object are made to construct a service which is needed by the user. Therefore, during the scheduling the service that the user demands and those objects which are ready to use are to be used by going through the ontology server.

Through the Smart Gateway's Device Objectification Function the generated information of devices' objects will be passed to Web Service Platform as WSDL file. The Web Service Platform creates a form of object structure that provides IoT service in the use of semantic ontology server's device ontology map (RDF) for object information. Using the semantic ontology server, not only creating an object but it also provides formalized form of object creation using device profiles. And also, in case of using semantic ontology server it is easily to create variety of object, and through object ID the object search and service provision are capable.

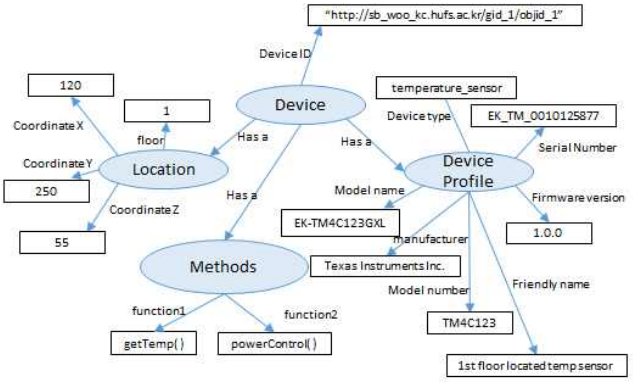

Figure 4. A Sample of Semantic Ontolgoy Map for Device Object

Figure 4 shows the structure of device object through device ontology map. Device ID, device metadata (device profile), device logical location information and methods that can be used for devices are defined. Since Web service platform by using the device object ID it can provide controlling of device based on device method information used to define WSDL or in acquisition of device profile information.

```
<device>
   <deviceID>"http://sb_woo_kc.hufs.ac.kr/gid_1/objid_1"</deviceID>

   <device_profile>
      <deviceType>temperature_sensor</deviceType>
      <modelName>EK-TM4C123GXL</modelName>
      <manufacturer>Texas Instruments Inc.</manufacturer>
      <modelNumber>TM4C123</modelNumber>
      <serialNumber>EK_TM_0010125877</serialNumber>
      <friendlyName>1st floor located temp sensor</friendlyName>
   </device_profile>

   <location>
      <floor>1</floor>
      <coordinate_X>120</coordinate_X>
      <coordinate_Y>250</coordinate_Y>
      <coordinate_Z>55</coordinate_Z>
   </location>

   <Methods>
      <function1>getTemp( )</function1>
      <function2>powerControl( )</function2>
   </Methods>
</device>
```

Figure 5. A Sample of XML Structure for Device Ontology Map

Device Ontology map as it is defined in figure 4, Web service platform can be applied easily to the object as variety of device object that newly connects through Smart Gateway. In the Figure 5, it shows the created XML data structure or the RDF format by using the device ontology map of figure 4. When using RDF format which is defined by device ontology map, it may extracts information from a variety of devices or uses as a services.

The Ontology server configures through user objects using user's profile and related service objects through ontology map, and when configuring service schedules the extracted list of user objects related it can provide orchestration service of related objects. Provided through each objects includes trigger, condition needed for next service activation and time needed for next service execution of the service. Figure 6 shows the connected structure of scheduled objects list that service scheduling provides.

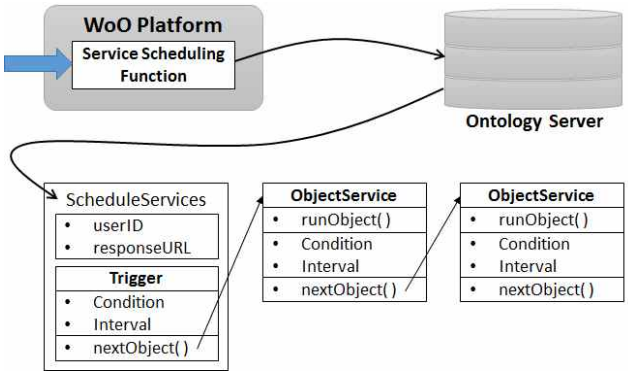

Figure 6. Structure of scheduling objects in service scheduling function

The service scheduling functionality should be configured as a linked list of scheduling objects. The trigger is the methods calling for conditions, interval and next objects. And it also considers the method of calling each of the condition, interval and next object. The explanation of operation and each variable used in scheduling objects are listed in the following table II:

TABLE II. DESCRIPTION OF VARIABLE AND OPERATION IN SCHEDULING OBJECTS STRUCTURE

	Explanation	Default Value
userID	User ID [int] that uses device web service	0
responseURL	Destination URL [URL] of return message after service scheduling execution	NULL
Condition	Conditional [Boolean] for device web service execution	FALSE
Interval	Device execution for timer [unsigned int]	0
nextObject()	Object class call operation	NULL
runObject()	Object RMI call operation	NULL

V. USE CASE OF USER-CENTERED IOT SERVICE USING WOO PLATFORM

A. *Pet Care Service using WoO Platform in Smart Home*

Through WoO platform, sensor devices like temperature sensor, hygrometer, motion sensor, IP camera, various sensors and actuator which are door sensor, venting fan, boiler, air-conditioner which are internally deployed in Smart Home are objectified and profile information are provided. Each of the data collected from the sensor devices and object classified as sub-objects elements are combined with existing web services, combination of IoT services to meet the user's requirements can be generated, and depending on the type of service that is generated to the reflected requirements of the user objects and data elements can be used suiting their ambition for a various purposes.

Figure 7 shows the use case diagram of Pet Care service using Smart Home in WoO platform. The data transaction is made through devices consisting of wireless sensor network in

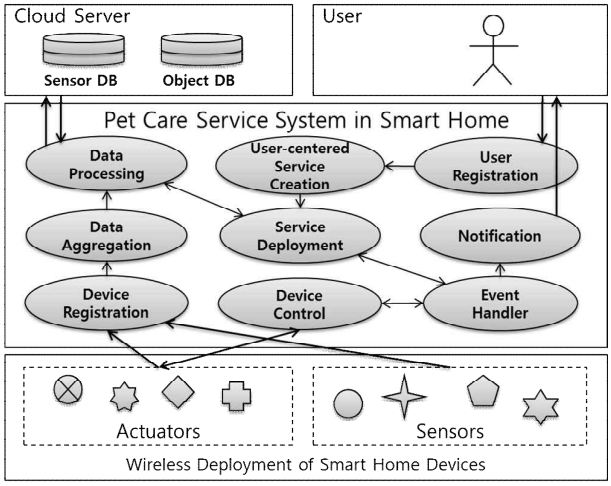

Figure 7. Use case Diagram of Pet Care service in Smart Home using WoO Platform

Smart Home and device registration and device profiling is formed through WoO platform. The location information of the devices and collected sensing data are saved and stored through the cloud server. And also user registration and requirements according to the users are configured by appropriate to devices, and this service are generated and registered incapable for deployment. In the WoO platform, when each of the data object components detects the condition which meets the threshold condition from the Pet Care service, the notification and remotely control command are operated and basic service provision like home monitoring, temperature, humidity and other environmental control of IoT service is provided. The following figure 8 indicates the Pet Care service procedure using Smart Home WoO platform.

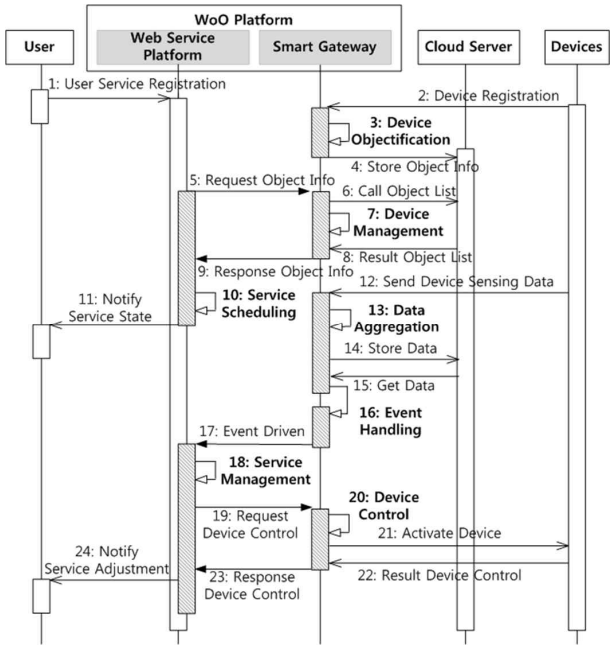

Figure 8. Procedure of Pet Care service using WoO platform

The procedure of Pet Care service using WoO platform provides user-centered service through device controlling and device management, and also device objectification goes through user registration service and web service platform with Smart Gateway functionalities.

B. Emergency Service using WoO Platform in Smart Building

In the Smart Building Emergency Service in order to prevent disaster like fire, explosion, gas and other risks are monitored by WoO platform capability, and can reduce the amount of damage through accurate processing and quick follow-up action of proactive detection that when and wherever that may occur. Each Smart Gateway that are distributed in the environment will objectify the sensor devices deployed in specific area, IP camera need for monitoring and actuators that are need for fire occurrence action, and it will also detects the situation when collected data exceeds the threshold condition. WoO platform in Smart Building manages the distributed Smart Gateways and extract essential elements that are needed for provision of emergency service. And it creates services that reflect the user's requirements, and can be controlled.

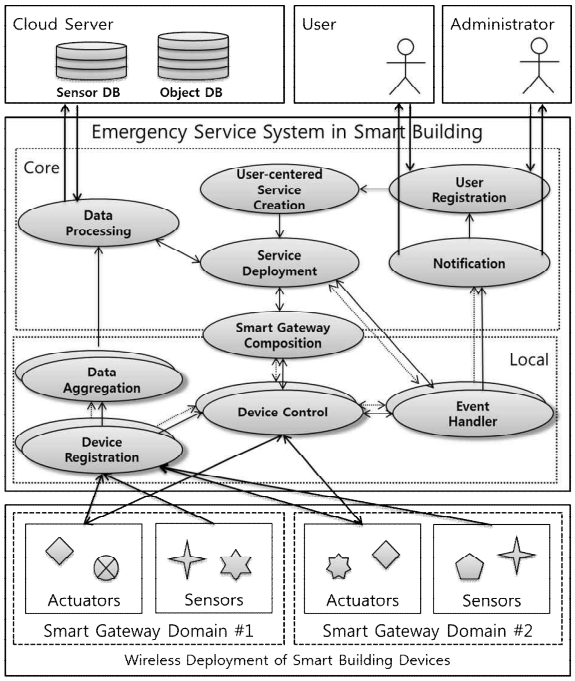

Figure 9. Use case Diagram of Emergency service in Smart Building using WoO Platform

Use case diagram of emergency service in Smart Building using WoO platform is showed in figure 9. The massive numbers of object located at Smart Building in the diverged environment, provides expansion by storing, managing and connecting the sensing information and device objects of each Smart Gateway domain each WoO platform. Likewise, extracts device objects information, user context information and web service information through semantic ontology based. And by integration it is able to mutually connect additional external information and connects the meaning of the information.

In figure 10, as a procedure of emergency service of WoO platform shows the configuration of distributed Smart Gateway of registered user, administrator and devices. And through service scheduling the specific user-centric Smart Building emergency situation may be provided by semantic ontology based service orchestration which users are extracted differrently based on object.

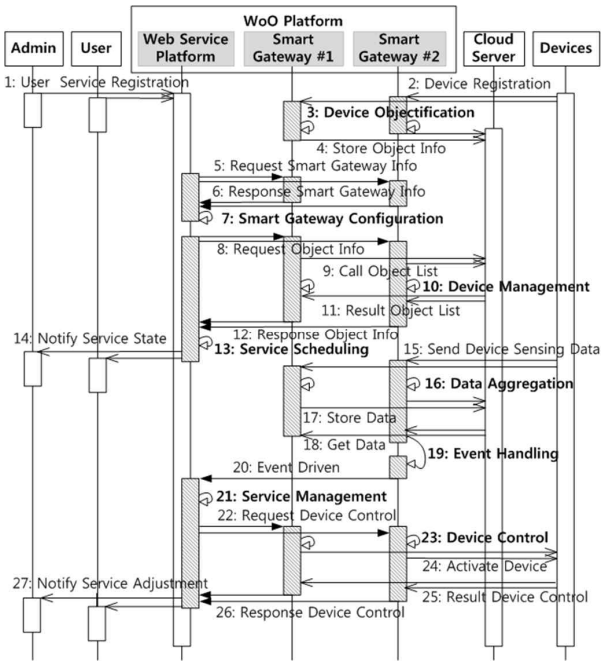

Figure 10. Procedure of Emergency Service using WoO Platform

VI. CONCLUSION

IoT services can be a solution which reflects various requirements for the users when the IoT services are provided through the Device Objectification and orchestration. In this paper, the architecture of WoO platform was designed for the creation of the user-centered IoT service capable and proposing Device Objectification and sematic ontology based service orchestration mechanism of the IoT services. In addition, the service interface is provided through web based Device Objectification, and new services can be created through the combination of various objects from the existing web services. And IoT service examples are showed through the use case.

However, the analysis of QoS/QoE is needed in order to provide service stability to the users and providing the service integration of the distributed objects with expandability, intelligence and activeness.

ACKNOWLEDGMENT

This research is result of the project “A Research on Interface Model of WoT service Platform” supported and supervised by ETRI for 2013, and its mother project “Development of Meta-Bus based WoT Cooperative Service Technology” is funded by the Ministry of Science, ICT & Future Planning,

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