A Platform of Service Registry to Discover Service Resources in Ubiquitous Network

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Abstract

In a ubiquitous network, a variety of things such as environmental sensor, home appliance and mobile phone are connected to an information network, which can be regarded as a service resource. Combined via network, these service resources can provide value-added ubiquitous services anywhere at anytime. In a future ubiquitous network, it is expected to achieve an adaptive service platform, which can dynamically integrate various service resources to provide adaptive and context-aware services.

This paper presents a new service registry platform named UBI-REGI, which is used to support efficient and dynamic discovery of service resources in a ubiquitous network. To define the scope of operation within the real world and IT world, UBI-REGI divides every service operation into three categories: source service, transformation service and sink service. Furthermore, UBI-REGI specifies meta-data like physical location or device owner to manage physical devices, in addition to the conventional meta-data like service name, purpose and description.

In order to enable UBI-REGI to be easily used by external program, this paper designs and implements UBI-REGI API by using Web service technologies. With this API, external applications can find service resources by queries of service category, location, purpose keywords, and so on. As a case study, this paper demonstrates an environment continue service in a home network system to prove the feasibility of this proposal.

Keywords: service resources, service discovery, data model, home network system, UDDI, Web services, home network system

1. Introduction

A ubiquitous network, connecting a variety of things such as environmental sensor, home appliance and mobile phone to an information network, aims to provide various network services anywhere at anytime [1]. The study of such ubiquitous network is becoming more and more notable in recent years.

In a ubiquitous network, each feature of these devices can be regarded as a service resource. Such network achieves value-added ubiquitous services by combining these service resources via network.

For the conventional services, service resources are statically coupled within only one service (for example, a motion sensor embedded in a motion-sensing smart light cannot be accessed by other external services). But in the future ubiquitous network, it is expected to achieve an adaptive service platform, which can dynamically integrate
various service resources to provide adaptive and context-aware services depending on the surrounding environment and private requirements.

A challenging issue to realize such platform is how to find appropriate service resources from huge number of services in a ubiquitous network. For example, suppose a user wants a service to broadcast a weather forecast when he goes out. The service resources [SR1: a sensor detecting a user going out], [SR2: a service obtaining the weather forecast], [SR3: a service synthesizing voice from the forecast], and [SR4: a speaker playing back the voice] are required. However, since there’s large amount of devices in a ubiquitous network, it’s difficult for a user to find, use and manage these service resources.

To solve this problem, this paper presents a new service registry named UBI-REGI to support efficient and dynamic discovery of service resources in a ubiquitous network. UBI-REGI divides every service operation into three categories: source service, transformation service and sink service, so as to define the scope of the operation within the real world and IT world. In addition to the conventional meta-data like service name, purpose and description, UBI-REGI also specifies meta-data like physical location or device owner to manage physical devices.

In order to enable UBI-REGI to be easily used by external program, this paper designs and implements UBI-REGI API by using web service technologies in the research. With API, external applications can find service resources by queries of service category, location, purpose keywords, and so on. As a case study, this paper demonstrates an environment migration service in a home network system to prove the feasibility of this proposal.

2. Preliminaries

2.1 Ubiquitous Service, Service Resource and Service Operation

A ubiquitous service in this paper is defined as a value-added service by using various devices connected with a network. The appliance integrated service of Home Network System (HNS) is a typical ubiquitous service [6]. HNS is a system consisting of multiple network household appliances and sensors. Each appliance or sensor can be controlled and managed via the home network. It is one of the most promising applications about the emerging ubiquitous technologies. The biggest advantage of HNS is that it provides value-added and more powerful HNS services by integrating multiple appliances and various sensors [11]. For example, integrating a TV, a DVD player, lights, sound system and curtains implements a DVD theater service, which allows a user to watch movies in a theater-like atmosphere at home. Also we can create a “coming home service” by integrating room lights and door sensor, which can turn on a room light automatically when a door sensor detects user coming home.

Ubiquitous services are realized by using or integrating certain service resources. Service resources include not only the above physical devices but also information systems, such as translation system, e-mail application etc. For HNS, service resources include all home appliances and sensors such as TV, DVD, curtain and sensor.

Generally speaking, a single service resource has several functions, which are called service operations in this paper. For example, an air conditioner (service resource) has service operations like “heating”, “cooling”, “dehumidifying”, etc. Ubiquitous services can be realized with integrating these service operations provided by service resources.
2.2 Future Ubiquitous Service

Current ubiquitous services including service resources and service operations are statically predetermined by service provider. In the near future, more and more varied services will be included in a network. Future ubiquitous service will be able to integrate service with these service resources dynamically to satisfy users' request.

In the earlier study, service-oriented architecture (SOA) technology was selected to integrate service resources. Service operations of each service resource were designed as web services, and the developer can integrate service resources by accessing web service APIs. Depending on this design, an experimental HNS named CS27-HNS was developed. In this environment, a developer can operate each appliance and sensor by using standard HTTP protocols without relying on vendor-dependent control ways. The developer can also integrate other non-physical service resources such as weather forecast provided in the worldwide internet.

3. Research Goal and Approach

3.1 Research Goal

In the previous study of CS27-HNS, it was supposed that a developer knew the details of every ubiquitous service, so the endpoints of service operations were statically hard-coded in each program. Therefore, whenever new service resources are published, service developers need to fix and revise their programs. It is impossible to add service resources or to integrate service resources dynamically.

This paper focuses on how to implement a platform to search and manage numerous service resources efficiently and dynamically in a ubiquitous network. To achieve this purpose, a service registry named UBI-REGI was developed, which supports efficient and dynamic discovery of service resources in a ubiquitous network.

3.2 Key Idea

Considering the characteristic of ubiquitous service resources, a data modeling of UBI-REGI was conducted based on the following key ideas.

- **(K1) Categorize service operations:** Categorize all the service operations into three types: the source type, the transformation type and the sink type.
- **(K2) Associate physical location:** Associate the source and sink service with physical location.
- **(K3) Associate purpose keyword:** Associate every service operation with a set of keywords representing its purpose.

3.2.1 Categorize Service Operations: In a ubiquitous network, many service resources are involved in both real and IT worlds. The real world includes appliances, sensors, etc., and the IT word includes ubiquitous services, service operations, etc. The sensors of the real world provide the value to services of the IT world. The appliance of the real world is operated by the services of IT world depending on the value of sensors. Value-added service is provided to a user who is in the real world. Figure 1 depicts the information flow among ubiquitous resources. It can be seen that the source services including sensors and weather forecast are placed at the boundary from the real world to the IT world. Based on the observation, it is proposed to categorize every service operation into the following three types.

- **(C1) Source Service:** A service that obtains physical information of the real world, and imports it as digital data to the IT world. Typical source services
include sensor services measuring temperature and humidity as well as RSS feeds providing news as digital data.

- **(C2) Transformation Service:** A service that converts data into another data (usually with more value) and outputs it into the IT world again. Typical services include text-to-speech service converting text data to voice, or language translation service translating English text into Japanese.

- **(C3) Sink Service:** A service that causes a physical impact to the real world based on data in the IT worlds. Typical services include the air-conditioner service heating a room, the email service sending a message to a human user, or the speaker service playing the voice data in a room.

![Figure 1. Different Scope of Existing Services (UDDI) and Ubiquitous Services](image)

Transformation service is shown in the middle, which is within the IT world. Sink services including appliances and email are located in the exit from the IT world to the real world. The proposed three categories clarify the role of service operations. Generally, a ubiquitous service can be implemented in this order like the source, transformation, and sink services. A user can search appropriate service resources/operations by categories, and use them as components of the desired ubiquitous service. For example, if a user wants sensor services, he searches them from the source services. If he wants output devices, he searches them from the sink services.

**3.2.2 Associate Physical Location:** According to the definition above (in section 3.1.1), it’s known that source service and sink service are tightly linked to the physical environment (location information). Therefore, the location information is needed to show where the obtaining information is from and where the service affects. For example, there are several air-conditioner services in a building. If there is no information about where each air-conditioner is installed, a user can not identify the most suitable service from them. Thus it is proposed to associate every source service or sink service with physical location to show where the service resource is installed.

Referenced the spatial modeling method [3], the physical location is defined by a tree model of location entities. The tree model is described by spatial inclusion relations such
as buildings, rooms and devices. For example, Figure 2 shows a tree model of physical location of a house. There is a living room, a kitchen and a bedroom in the house. Also, there is the location of a TV in the living room.

![Figure 2. Tree Model of Physical Location](image)

By associating every service resource with a location entity, it is possible to search service resources by physical location. In the example of air conditioner services, a user can identify the suitable air-conditioner by a location where the user is currently staying. This tree model also enables the search queries with the inclusion relations. For example, in Figure 2, all air conditioners installed in the house can be searched by traversing the tree from the root to the leaves. Even if a motion sensor is not directly associated with the living room, we can use the sensor in front of the TV as a substitute.

3.2.3 Associate Purpose Keywords: As seen in Web search, when a user searches a service operation whose name is unknown to him, it would be convenient for him to search it by keywords closely related to the purpose and feature of the service operation. Therefore, purpose keywords are defined to represent the purpose of service operations. In this proposal, input/output attribute name and function name are used as purpose keywords. For the source or sink services, keywords are defined by the names of environment properties affected by the service operation. For example, `air-conditioner.heating()` is associated with keywords like temperature, air-flow, humidity. A user can identify `air-conditioner.heating()` by specifying “temperature” as the purpose, and “sink” as the category. He does not need to specify the concrete device name.

3.3 Data Model of the UBI-REGI

Based on the above key idea, a data modeling of UBI-REGI that consists of three portions are conducted. Figure 3 shows the ER diagram. A box represents an entity (i.e., table) consisting of an entity name, a primary key and attributes. Instances below each entity are enumerated. A line represents a relationship between entities, where △ denotes a parent-children relationship, and ▲ denotes a reference relationship.

3.3.1 Definition of Physical Location: The physical location is managed by a LOCATION table which has three columns: a location ID as the primary key, a reference to parent location, and a set of location descriptions.

3.3.2 Definition of Purpose Keyword: The purpose keywords are managed by a KEYWORD table which has two columns: a keyword ID as the primary key and a set of keywords. An instance K002 in Figure 3 represents a set of keywords describing the temperature. By registering synonyms in the same set, it is possible to search service operations by various words like “air temperature, room air temperature and ambient temperature”.

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3.3.3 Definition of Service Resources: The service resources are managed by three tables: the SERVICE RESOURCE table, the SERVICE OPERATION table and the PARAMETER table.

The SERVICE RESOURCE table has five columns: a resource ID, a device class, an endpoint, a physical location and a description. The device class represents an appliance or an abstract type of the software. Note that a unique resource ID is given to every instance of resource. If there are two TVs in a house, they must be distinguished as “tv01” in the living room, and “tv02” in the bed room.

The device classes are determined by standardized data model for home network system proposed in [4]. The instance tv01 in Figure 3 represents a TV in a living room, whose physical location is L002 and the endpoint of the Web service is http://cs27-hns/tv.wsdl.

The service operations provided by each service resources are managed by SERVICE OPERATION table. A resource ID and an operation name form a composite primary key. There is a service category (source, transformation or sink), a type of return value, an operation description and the purpose keyword. One service operation is associated with a set of keywords. An instance “tv01.on” in Figure 3 represents that the operation provides a sink service, and that the type of return value is void and associated with keywords like “movie” and “video”.

On the other hand, “tempSensor01.getValue” is a source service, which acquires data from the real worlds. The type of return value is temperature. The associated keywords are temperature, air temperature, room air temperature and ambient temperature.

The parameters are managed by PARAMETER table with 5 columns. A primary key is composed of a resource ID, an operation name and a parameter name. As for the attributes, there is a parameter type, a parameter domain and a parameter description. An instance “tv01.setChannel.channel” in Figure 3 represents that the parameter is typed by Channel and takes a value from 100 to 200.

![Figure 3. Data Model of the UBI-REGI](image-url)
3.4 UBI-REGI API

In order to enable UBI-REGI to be easily used by external program, UBI-REGI API “getService()” is defined by using Web service technologies. Figure 4 shows the details about the API getService().

The getService() has argument that includes service category, resource class, physical location and purpose keyword. The API returns a list of service operations objects. The fields of the return object include method, endPoint, locationIDPath, locationNamePath, classID, returnType, description and parameterObject. The fields of parameterObject include type, name, domain and descriptions.

<table>
<thead>
<tr>
<th>Fields</th>
<th>Detail</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>method</td>
<td>The name of method</td>
<td>setChannel</td>
</tr>
<tr>
<td>endPoint</td>
<td>End point</td>
<td><a href="http://cs27-hns/tv.wsdl">http://cs27-hns/tv.wsdl</a></td>
</tr>
<tr>
<td>locationIDPath</td>
<td>The path from location ID</td>
<td>L001/L002</td>
</tr>
<tr>
<td>locationNamePath</td>
<td>The path from location name</td>
<td>Home/Living room</td>
</tr>
<tr>
<td>class</td>
<td>The name of resource class</td>
<td>Tv</td>
</tr>
<tr>
<td>returnType</td>
<td>The type of return value</td>
<td>Void</td>
</tr>
<tr>
<td>description</td>
<td>The details about service</td>
<td>Setting TV channel</td>
</tr>
<tr>
<td>parameterObject[]</td>
<td>The details about parameter</td>
<td>-</td>
</tr>
</tbody>
</table>

Table 2. The Details of ParameterObject

<table>
<thead>
<tr>
<th>Fields</th>
<th>Detail</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>type</td>
<td>The type of parameter</td>
<td>int</td>
</tr>
<tr>
<td>name</td>
<td>The name of parameter</td>
<td>Channel</td>
</tr>
<tr>
<td>domain</td>
<td>The value of the parameter</td>
<td>[100 .. 200]</td>
</tr>
<tr>
<td>description</td>
<td>The description about parameter</td>
<td>The channel of TV</td>
</tr>
</tbody>
</table>
4. Case Study

4.1 Implementation of UBI-REGI

Depending on the above discussion, UBI-REGI was implemented in our testing environment CS27-HNS. The developing environment and the technique we used are as follows:

- Development Tools: Eclipse3.4.0
- API Development Language: Java
- Database: MySQL 5.1
- Web Server & Engine: Apache Tomcat 5.5 & Apache Axis 2.1.3

4.2 Case Study

In this section, a case study is used to prove the effectiveness of this proposal. The case study selected [environment continue service] of CS27-HNS as an implementing object. This service means if the user moves from living room to bedroom, the [environment continue service] will translate the same environment of the living room in the bedroom, such as temperature, brightness, etc. The scenario of service is as follows:

1. When the service detected the user leaving the living room, it will acquire the temperature and the brightness of the living room.
2. After (1), when the service detected the user entering the bedroom, the service will operate the equipments of the bedroom to reproduce the same environment in the living room.

Depending on the key idea (K1) in section 3.2, the [environment continue service] should be achieved by three kinds of services: the source service, the transformation service and the sink service. In this case study, the source service is to obtain the temperature and the brightness of living room, to detect the user is leaving the living room or not, and to detect the user is entering the bedroom or not. After obtaining these data, the source service will import them to the IT world (transformation service). The sink service is to set the same environment in the bedroom based on the data and logic which are imported and implemented in the transformation service (IT world).

Based on the analysis of the environment continue service’s scenario above, it’s known that six source services and two sink services are needed to achieve the service (Table 3).

Table 3. The Details of Source Service and Sink Service

<table>
<thead>
<tr>
<th>source services</th>
<th>environment continue service</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SO1]</td>
<td>The service to acquire the temperature of the living room.</td>
</tr>
<tr>
<td>[SO2]</td>
<td>The service to acquire the brightness of the living room.</td>
</tr>
<tr>
<td>[SO3]</td>
<td>The service to acquire the temperature of the bedroom.</td>
</tr>
<tr>
<td>[SO4]</td>
<td>The service to acquire the brightness of the bedroom.</td>
</tr>
<tr>
<td>[SO5]</td>
<td>The service to detect people entering or leaving the living room.</td>
</tr>
<tr>
<td>[SO6]</td>
<td>The service to detect people entering or leaving the bedroom.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>sink services</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>[SI1]</td>
<td>The service to change the temperature of the bedroom.</td>
</tr>
<tr>
<td>[SI2]</td>
<td>The service to change the illumination of the bedroom.</td>
</tr>
</tbody>
</table>
Now the biggest issue is how to search and select suitable resource service and sink service to achieve the [environment continue service]. In this case study, we use UBI-REGI platform to search the suitable resource service with the following queries (Figure 5).

**For the six resource services:**

- **qo1** = \{category\=> "Source", class\=> "ANY", location\=> "living room", keyword\=> "temperature"\}
- **qo2** = \{category\=> "Source", class\=> "ANY", location\=> "living room", keyword\=> "Light"\}
- **qo3** = \{category\=> "Source", class\=> "ANY", location\=> "bed room", keyword\=> "temperature"\}
- **qo4** = \{category\=> "Source", class\=> "ANY", location\=> "bed room", keyword\=> "Light"\}
- **qo5** = \{category\=> "Source", class\=> "ANY", location\=> "living room", keyword\=> "leaving"\}
- **qo6** = \{category\=> "Source", class\=> "ANY", location\=> "bed room", keyword\=> "entering"\}

**For the two sink services:**

- **si1** = \{category\=> "sink", class\=> "ANY", location\=> "bed room", keyword\=> "temperature"\}
- **si2** = \{category\=> "sink", class\=> "ANY", location\=> "bed room", keyword\=> "Light"\}

**Figure 5. The Details of the Queries**

In figure 5, the queries qo1 to qo4 is to obtain the temperature and the brightness of the leaving room (or the bedroom); qo5 to qo6 is to detect a person is leaving (or entering) the living room (or the bedroom); the si1 to si2 is to change the temperature and brightness of the bedroom.

<table>
<thead>
<tr>
<th>source services</th>
<th>Service Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SO1]</td>
<td>tempSensor01.getValue()</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>sink services</th>
<th>Service Resource</th>
</tr>
</thead>
<tbody>
<tr>
<td>[SI1]</td>
<td>airCon.on()</td>
</tr>
</tbody>
</table>

**Table 4. The Searching Result**

Table 4 shows the searching result based on the data molding in section 3.3. After this, the developer only needs to implement service logic such as “if the [brightness of the living room > brightness of the bedroom], call the ceilLight.on()”. The [environment continue service] can be realized by using these resource service operations. Just like this, a developer can dynamically search and select the suitable service resources in a
ubiquitous network by appointing key words like service category, physical location and the purpose key word.

5. Discussion

5.1. Summary of Contribution

In this paper, a new service registry platform called UBI-REGI is presented to support the efficient and dynamic discovery of service resources in a ubiquitous network. In this proposal, UBI-REGI categorizes service operation into source service, transformation service and sink service, which can define the scope of the operation within the real and the IT worlds.

The Source Service is to obtain physical information of the real world, and import it as digital data to the IT world. The Transformation Service is to convert data into another data (usually with more value) and output it into the IT world again. The sink service is to cause the physical impact to the real world based on data in the IT worlds.

Furthermore, in order to support a developer to search and select suitable service resources in a ubiquitous network, meta-data are specified like physical location, device owner, service name, purpose and description in the data modeling of UBI-REGI. An UBI-REGI API is also designed and implemented to enable UBI-REGI to be used easily by external program. With the API, the external applications can dynamically find service and select suitable service resources with the queries of service category, location, purpose keywords, and so on.

At last, as a case study, an environment migration service is demonstrated in a home network system to prove the feasibility of this proposal.

5.2. Related Work

In the area of SOA, UDDI (universal description, discovery and integration) has been a standard of service registries, with which clients can find and manage the service resources [2]. However, in a ubiquitous network, every service resources are heavily associated with the physical worlds. For example, if a user wants to use a speaker in a living room, the user must find an appropriate one from a lot of speaker services in the network. The conventional UDDI does not cover the physical system, so it cannot be directly used.

5.3. Future Work

As for the future work, the definition of resource class will be elaborated to improve the quality of resource search. The effectiveness of UBI-REGI will also be evaluated through other applications, including a ubiquitous cloud. Finally, it is interesting to introduce the ontology in the purpose keywords, which enables semantic-based service discovery.

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