A Ubiquitous Web Services Framework for Interoperability in Pervasive Environments

Hyung-Jun Yim and Kyu-Chul Lee*

Dept. of Computer Engineering, Chungnam National University
220 Gung-Dong, Yuseong-Gu, Daejeon, Korea
{hyungjun25, kclee}@cnu.ac.kr

Abstract

Advances in the areas of pervasive environments, computing, and networking are leading to an infrastructure composed of a large number of heterogeneous services/devices. Although some network protocols accommodate heterogeneity of services and/or devices, existing protocols have various design goals and solutions. This paper outlines a Ubiquitous Web Services Framework which aims to hide the heterogeneity of hardware, software, data formats and communication protocols that is present in today's pervasive environments. The proposed our framework enables user applications to interact with data from a wide range of networked services/devices using a high-level, abstract interface that features Web Services standards. The work presented here proposes the extended framework in an earlier work for an effective integration of heterogeneous services/devices in pervasive environments. The prototype of our framework have been implemented and evaluated. This paper also concludes with general remarks and a discussion of future works.

Keywords: *Ubiquitous Web Services, Framework, WSUN, u-ServiceBus, Interoperability*

1. Introduction

In pervasive computing, heterogeneity occurs in many aspects: hardware, software platforms, network protocols, and service providers. Future devices and services will increase this diversity. It is expected that this trend will continue, while in parallel the number of connected services/devices will explode. Although service discovery protocols accommodate heterogeneity, existing protocols have various design goals and solutions. Each has advantages and disadvantages in different situations, and so it seems unlikely that a single protocol could dominate in pervasive computing environments. With current protocols, this means clients and services cannot discover each other if they do not use a common protocol. As these devices need to interoperate, the service-oriented approach seems to be a promising solution. We should therefore establish a common platform to enable interoperability among service discovery protocols.

To address these problems, we proposed a Ubiquitous Web Services [1] framework based on Service-Oriented Architecture (SOA), originally described by the authors [2]. We refer to our framework as *Web Services on Universal Networks (WSUN)*. The present paper is a continuation and extension of earlier work. In [2], we presented a novel approach to design based on an architecture for interoperability among service discovery protocols. WSUN consists of a software layer that enables service discovery protocols of heterogeneous devices and services to interoperate in a user-friendly way across multiple networks and domains. It is a set of principles and methodologies for designing and developing software in the form of

* Corresponding Author

interoperable services.

The contribution of this paper is three-fold. First, we describe how to extend the work in an earlier paper to seamlessly integrate service discovery protocols in a pervasive computing environment. Second, our interoperability framework enables the service requester and provider to access and deliver information and services from anywhere, on any device, in a completely hassle-free, ad hoc manner. Lastly, we can provide cloud based services. Mobile users need to perform tasks anytime, anywhere, using functionalities of the pervasive computing environment. That is, applications on the current version of android devices to use to any cloud-connected services such as Google Cloud Print [3].

2. Related Works

There are several approaches to ensure interoperability among different service discovery protocols, and they can be grouped as one-to-one and one-to-any protocol conversion approaches. The typical solution of one-to-one protocol conversion is [4]. They provide interoperability described by between service discovery protocols, respectively. However, they are not sufficient to develop a single bridge that connects two specific service discovery protocols on a one to one basis, when new service discovery protocols are developed one after another. Therefore, while this approach offers interoperability that is adequate for both types of service discovery protocols, the conversion complexity of this approach is too high, (n*(n-1)) / 2, where n is the total number of service discovery protocols.

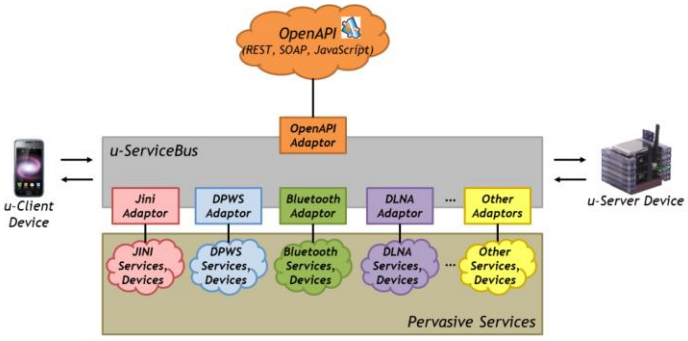

Figure 1. WSUN Framework Environments

In order to overcome the limitations of the one-to-one protocol conversion approach, the solutions developed in [5, 6, 7, 8] provide a framework that supports one-to-any protocol conversion for providing seamless interoperability of appliances and services, as depicted in Figure 1. These frameworks enable any appliances under any service discovery protocols to communicate with any other appliances and to deploy services without knowledge of the differences between service discovery protocols.

These frameworks are used to connect, integrate, and manage services provided by devices that are integrated in home appliances. None of them considers seamless interconnection and integration with external Internet services.

3. Our Approach

As mentioned above, WSUN is based on SOA, which integrates pervasive systems through a set of services that can be reused and combined to address changing pervasive environment priorities. It is a natural way to create interoperable, loosely-coupled mobile applications. Services are software components with well-defined interfaces, and they are independent of

the programming language and the computing platforms on which they run. WSUN would be responsible for encapsulating devices as services, dealing with the device-specific connections and protocols as well as with network interfaces needed to publish the data over a defined SOA protocol. A standard specified device service can have a wide variety of underlying hardware, software, and networking implementations that do not affect the consumer of the service, As shown in Figure 2.

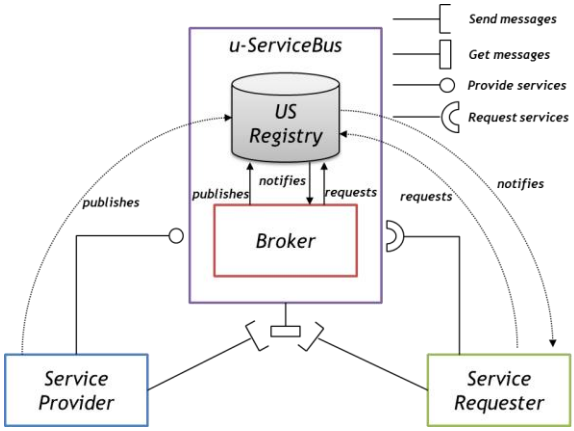

Figure 2. WSUN is based on SOA

As shown in Figure 3, since different service discovery protocol domains must be seen as virtually the same physical devices in the same service discovery protocol domain, each adaptor allows physical devices with its own service discovery protocol to virtually expose the abstracted devices that wrap the original appliances to the entire service discovery protocol's domain. In the case where the device is plugged in on a specific service discovery protocol, each adaptor overlaid on that service discovery protocol converts the physical device into the virtually abstracted service described by Web Services Description Language (WSDL).

We provide the ability of service discovery protocols to communicate and co-operate despite differences in the implementation language, the execution environment, and/or the model abstraction. As all adaptors convert their own service to Web Services for exposure to the outside world, we refer to this as Virtual Web Services (VWS). Each service discovery protocol's client simply recognizes their own services on the network. Thus, the client can use the service discovery method, binding protocol, and subscribing events without additional work. That is, the DPWS client can discover, bind, and communicate with Jini services based on Java RMI, Bluetooth services based on the SDP, and various Web Services without additional work such as DPWS-hosted services. This principle is similar to u-Client Device. Thus, the proposed method provides any client with adaptive interoperability.

4. Web Services on Universal Networks

In this section we describe WSUN, an interoperability framework that enables seamless device interaction over diverse service discovery protocols. Our goal for WSUN is to provide a universal, interoperable, and scalable framework that also enables platform-independent application development without requiring changes to existing devices. The WSUN framework would be responsible for encapsulating devices as services, and dealing with the device-specific connections and protocols as well as with network interfaces needed to

publish the data over a defined SOA protocol. It is a set of principles and methodologies for designing and developing software in the form of interoperable services. The WSUN framework consists of u-ServiceBus, u-Client Device, and u-Server Device.

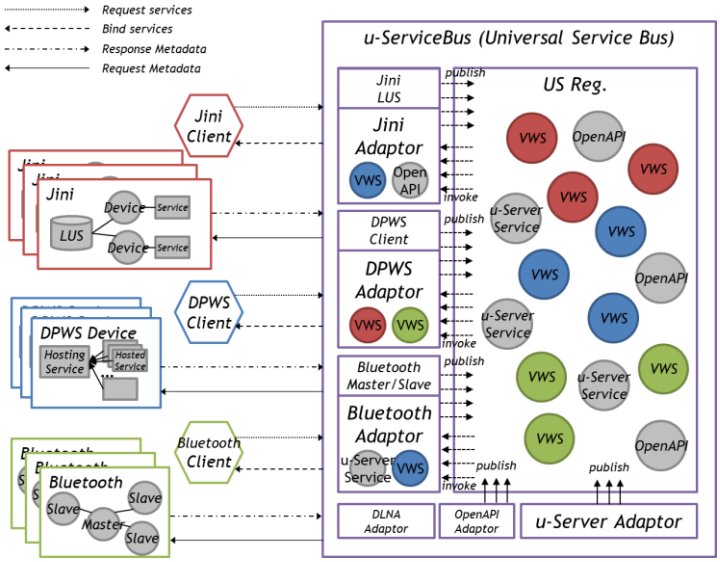

Figure 3. The Principle of Virtual Web Services

4.1. Universal Service Bus

To realize an effective integration of the capabilities offered by the pervasive environments, we have designed an architecture (depicted in Figure 4) that exposes real-world devices with embedded services to users by making them accessible in a service-oriented way. The specifications foster open and standardized communication via Web Services at all layers. u-ServiceBus has the following eight core components: Listener, US Registry, Publish Agent, Query Agent, Discovery Proxy, Routing Proxy, Event Manager and Adaptor Manager. We originally described these modules by the authors [2].

4.2. Universal Client Device

As seen in Figure 4, u-Client Device is a GUI-based application for searching and using all services of WSUN without the knowledge of differences between service discovery protocols.

4.3. Universal Server Device

As shown in Figure 4, the u-Server Device supports automatic configuration PnP functionality and follows the US-Discovery. Accordingly, u-Server Device is immediately interconnected with any other appliances. Although the u-Server Device target to the printer prototype currently, any service can be applied to the u-Server Device through changing Service Provider module.

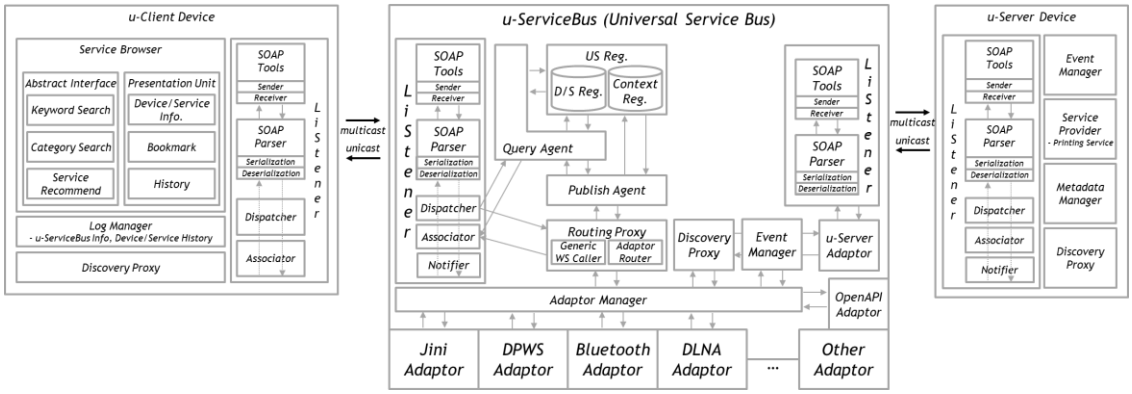

Figure 4. u-ServiceBus, u-Client Device and u-Server Device Architecture

5. Implementation

To demonstrate that the aforementioned ideas can be realized, we have used state of the art technologies to implement prototypes. And we introduce our development environments and verify through codes that several prototypes have been implemented as proof of concept. Table 1 summarizes specifications of the environment.

u-Client Device uses attributes form the entry to build the request message using ksoap2-android. All of the communication is done via Web Services technologies and the realization of this specific scenario became possible by having a interoperability of the available functionality that all devices and services expose as a Web Services. An android app. of the u-Client Device is available at https://play.google.com/store/apps/details?id=cnu.dblab.uclient.

6. Qualitative Evaluation

We evaluate the WSUN framework from qualitative perspectives to clarify the similarities and differences between the proposed framework and related works according to particular criteria for providing seamless interoperability under heterogeneity. Our qualitative evaluation compares features of a one-to-any protocol conversion approach supporting interoperability among service discovery protocols(Figure 5 and Figure 6). Table 2 shows the results of our qualitative evaluation. We just discuss the typical research of related works [5, 6, 7].

WSUN and all related works provide the interoperability among service discovery protocols via a one-to-any protocol conversion. Therefore the cost of implementation is n-1, 1. All approaches enable interoperability without any modification of appliances under heterogeneous service discovery protocols, and globally managing the entire service discovery protocols. Related works are implemented based on hybrid discovery system, they can provide flexible query. Since [7] is implemented based on DPWS technology, they only search portType and Scope of WS-Discovery.

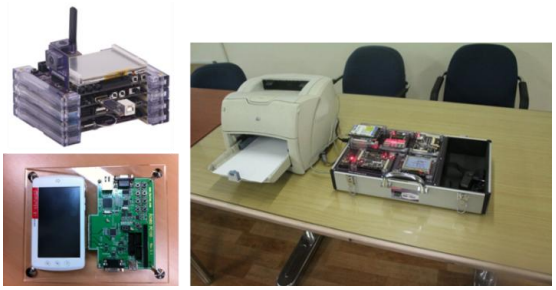

Figure 5. u-ServiceBus and u-Server Prototypes **Figure 6. Android App. and u-Client**

Table 1. Specification of Prototypes

	u-ServiceBus	u-Server Device	u-Client Device
Kit	HBE-SM II-P320	HBE-EMPOS II-P320	Android Kit
CPU	806 MHz Marvell PXA 320		ARM Cortex-A8 833MHz
Memory	Samsung 128M*8bit NAND Flash memory 12Mbytes Mobile-DDR RAM		DDR2 512MB
OS	Embedded Linux Kernel 2.6.25		Android 2.1 Éclair
Java VM	Embedded Java runtime (EJRE 1.6)		-
DBMS	JavaDB 10.5.1.1		-
LAN	IEEE 802.11b/g wireless LAN		

Table 2. Evaluation of Qualitative Perspectives

Features	Our	[5]	[6]	[7]
Interoperability	O	O	O	O
Cost for Interoperability	n-1, 1	n-1, 1	n-1, 1	n-1, 1
Resource Management	Global	Global	Global	Global
Resource Discovery	Dynamic	Hybrid	Hybrid	Hybrid
Appliance Abstraction	O	O	O	O
Binding	Dynamic	Dynamic	Dynamic	Dynamic
Query Level	Flexible	Flexible	Flexible	simple
Mapping Mechanism	Automatic	Automatic	Automatic	Automatic
Standard based Mechanism	O	X	X	O
Event Management	O	X	O	X
Metadata Management	O	X	O	X
Include Service State	O	X	O	X
Design Constraints	O	X	X	X

On the other hand, WSUN support keyword (device name and/or service name) based search, category based search, and system recommendation (the count of using service). We can also provide available services at query time. All related works abstract the functionality of appliances with well-defined script based on XML. However, [5], and [6] have their description language. A state of devices and/or services is an important element for the interoperation of appliances. When the status is changed after the execution of a service of a particular device, WSUN and [6] act as an event to trigger. These approaches also have registry or cache for metadata management. WSUN and [6] provide available services at query time because they control the service status. The key to the design constrains, WSUN, is that devices, services, and networks "teach" each other how to seamlessly interoperate, thereby eliminating the need for users to worry about compatibility issues, and allowing easy configuration.

7. Final Remarks

Interoperability is an important issue with a growing interest. This paper introduced a Ubiquitous Web Services framework that is termed the WSUN. It is an infrastructure of adaptive interoperability for multiple heterogeneous services that utilizes SOA technology. In the future, the authors intend to continue to work on connectors to incorporate Internet of Things protocols including RFID, Zigbee and even more service discovery protocols to WSUN. Internet of Things still remains some grey zones in the definition of which technology are included and which have to be taken out from the framework in order not to pose a too strict limit to the system. In addition the WSUN components will be evaluated in terms of their ability to ensure high scalability and reliability.

Acknowledgements

This research was supported by Basic Science Research Program through the National Research Foundation of Korea(NRF) funded by the Ministry of Education, Science and Technology(2012R1A1A4A01015696).

References

[1] M. Attard, "Ubiquitous Web Services", In Proceedings of the 2007 Computer Science Annual Workshop (CSAW'03), (2003) July 10-17.

[2] Y.-Y. Hwang and K.-C. Lee, "Web Services on Universal Networks", International Journal of Web Services Research, **(2011)** December, pp.108-126.

[3] Google, Google Cloud Print, http://www.google.com/cloudprint/learn/index.html.

[4] J. Allard, V. Chinta, S. Gundala and G. G. Richard III, "Jini Meets UPnP: An Architecture for Jini/UPnP Interoperability", In Proceedings of the 2003 Symposium on Applications and the Internet, **(2003)**.

[5] V. Miori, L. Tarrini, M. Manca and G. Tolomei, "An Open Standard Solution for Domotic Interoperability". In Proceedings of the 2006 Consumer Electronics, IEEE Transactions on, **(2006)** February, pp. 97-103.

[6] H. J. Lee and S. J. Kim, "A Standard Method-Based User-Oriented Integrated Architecture for Supporting Interoperability among Heterogeneous Home Network Middlewares", International Journal of Smart Home, vol. 1, no. 1, **(2007)** January.

[7] G. M. Araújo and F. Siqueira, "The Device Service Bus: A Solution for Embedded Device Integration through Web Services", In Proceedings of the 2009 ACM symposium on Applied Computing, **(2009)** March, pp. 185-189.

[8] J. Bresser, "A Service-Oriented middleware for device interoperation in the smart home", **(2010)** August.

Authors

Hyung-Jun Yim

Hyung-Jun Yim is a Ph.D Candidate in Chungnam National University, Daejeon, Korea. His current research interests are in the areas of Internet of Things, Data Distribution Service and Ubiquitous Web Services.

Kyu-Chul Lee

Kyu-Chul Lee is a professor in the Dept. of Computer Engineering in Chungnam National University, Daejeon, Korea. He received his Ph.D from Seoul National University in 1989. His current research interests are in the areas of XML, Web Services, Cloud Computing and Internet of Things. He has been responsible for several industrial projects and published numerous papers.