An Ontology-enabled Service Oriented Architecture for Pervasive Computing

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Abstract

In this paper, we propose a new Ontology-enabled Service Oriented Architecture (OSOA) for Pervasive Computing that is built on Web Services architecture, and incorporates Universal Plug and Play (UPnP). OSOA aims to combine context awareness and human-centric requirements related to ubiquitous computing with a new ontology-based approach to ad-hoc and goal-driven service composition.

Keywords: Ontology, pervasive computing, policy, service composition, web services

1. Introduction

Many projects for Pervasive Computing are based on distributed object technologies such as Java RMI, CORBA or DCOM. One.world [1] is dependent on Java so does not interoperate with other technologies and lacks flexibility. GAIA[2] is CORBA based, but does not support interaction between multiple independent GAIA systems so is unsuitable for ad hoc networks. Aura[3] has similar limitations[4]. CORBA is not usually supported on portable devices such as PDAs and even the JAVA implementations are often limited. Task Computing[5] does support ontology-based service composition and uses UpnP but is limited to only single input and output parameters and so does not cater for control of the devices used in service composition etc.

2. Scenario

We describe a simple scenario of Lifang's activities in a guest room in a hotel to elaborate our ideas. After Lifang opens her room door, lights are turned on to 500 lux, a heater turns on to 20˚C, and a HDTV turns on to BBC 4. 500 lux, 20˚C, Channel 4 are obtained by related devices from her profile. When the doorbell rings, Lifang's PDA automatically determines that is can display the video image from a security video camera above the door, as well as control the zoom, tilt and panning angle of the camera. After Lifang lists her goal of touring Tianjian for two days, her Personal Intelligent Assistant (PIA) running on her PDA automatically generates several feasible itineraries through querying well known services and checking her personal habits.

The above scenario, though simple, show several important issues in Pervasive Computing: i) context awareness. ii) interoperability and ad hoc service composition. iii) goal-driven service composition, which are our focus.

3. Our Approach

We present our own approach for Pervasive Computing as an Ontology-enabled, Service-Oriented Architecture (OSOA), shown in Figure 1 which applies Web Services Architecture as the main framework and supports UPnP devices. Ontology will be used to solve problems which Web Services cannot deal with well, such as syntax diversity, service composition etc. We assume all of devices can be classified into two categories: embedded devices such as heater and interaction devices such as PDA which can provide many different kinds of services as well as controlling the embedded devices.

A device could be a UPnP 1.0 device, a Web Services enabled device, and a Semantic Web Service enabled devices, see Table 1 for possible specification.

Table 1 Specifications for devices

	UPNP DEVICE	WS DEVICE	SWS DEVICE
Description	UPnP template language	WSDL, WSDP	WSDL, WSDP, OWL-S
Discovery	SSDP	WS-Discovery	WS-Discovery
Messaging	SOAP	SOAP	SOAP
Eventing	GENA	WS-Eventing	WS-Eventing

WSDL is Web Service Description Language; WSDP is Device Profile for Web Services; OWL-S is Semantic Markup for Web Services; WS-Discovery is Web Services Dynamic Discovery; WS-Eventing is Web Services Eventing; SOAP is Simple Object Access Protocol.

OSOA uses standard Web service based protocols, simplifies adding new functionality – e.g. a security camera needs the ability to transfer media data through a messaging layer, such as MTOM (SOAP Message Transmission Optimization Mechanism) and we can use Web Services Security: SOAP Message Security if required (see Figure 2).

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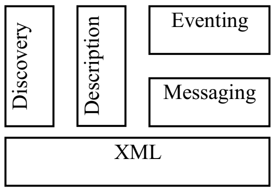

Figure 1 simplest OSOA

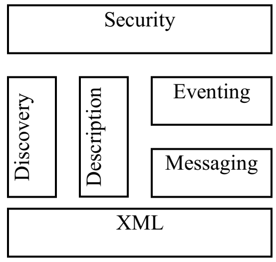

Figure 2 OSOA

OSOA for interaction devices, such as PDA, has no major differences from OSOA for embedded devices. A new metadata layer, Policy, which helps realize context awareness is added. In order to embody human-centric adaptation, a Person ontology layer which describes information about the user, including his interests and privacy and environmental preference etc., is also be required.

4. Context Awareness

Events, Policy(event-condition-action rules), and Person ontology help to realize context awareness. The syntax diversity of context and personal profile descriptions may be solved by ontology techniques. We are investigating the use of SWRL (A Semantic Web Rule Language Combining OWL and RuleML) to describe policies.

5. Service Composition

We support *ad-hoc service composition* for ubiquitous devices which performs serendipitous compositions of any available services to find those which may be of use to non-expert users who will not know in advance how to achieve their goals or even what those goals are. The techniques used in ad-hoc service composition are: i) distinguishing the functional services provided by a device from control services; ii) determine all exact and generic semantic matches between the inputs and outputs of functional services; iii) make control services of embedded devices available directly to an interaction device. E.g., after composing a capturing service (a functional service from the security camera) and a media play service (a functional local service from a PDA), the control panel in the PDA will ask a user for input tilting angle, panning angle, and zoom number for the camera.

Goal-driven service composition applies a different approach that could compose both services from devices and well known services from the Internet. A goal ontology consists of its category, template, inputs, outputs, constraints and composer profile. The template defines profiles of concrete services which realize the goal. Complex templates may include a data flow. Constraints include conditions and rules which help find and choose the most suitable services. The composer profile is used to find the best composition of services to implement the goal.

In our scenario, the PIA is given a goal of "touring" and obtains the goal specification from its own dictionary or by querying a well known ontology server. The Touring Template could specify: Touring is an abstract service (not invokable directly) but the PIA determines 4 sub-services which can be invoked directly: i) visiting historical places; ii) eating in gourmet restaurants; iii) buying architectural artifacts; iv) attending local theatre. Each of these services may have many providers which need conditions and rules specified by user and service provider for PIA to choose the best one.

6. Conclusion

Although OSOA is ongoing work, we believe it is a promising solution for pervasive computing. Web Services ensure that we need not carry out repetitive research like discovery and focus on other interesting and challenging issues, such as service composition. Ontologies allow a better solution for service composition and human centered computing.

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