An Ontological Framework for Semantic Description of Devices

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1. Introduction & Motivation

Services are generally viewed as functional components offered via the web, by software Agents or as Grid Services. Such services may be introduced within an open service community, and consequently located, possibly added to a workflow model, and subsequently invoked. However, whilst this type of functionality is typically implemented as software components, some services specifically support, or are offered by *Devices* (i.e. hardware components), whereby the characteristics/ capabilities of the device may play an integral role in the description and behaviour of the services it offers. Whilst several service discovery protocols currently exist for discovering devices in open, dynamic environments (e.g. UPnP, Bluetooth etc), characterization of these services is limited to static data structures, and agreed, implicitly defined key-word based categorisations. In the current protocols matching of service requests and advertisements is done at a syntactic level by using key word searches and string comparisons. These limitations are also shared by more traditional software-based services, and although open discovery mechanisms have been improved (such as UDDI), these still lack extensibility, and any form of declarative semantics.

Several emerging frameworks (e.g. OWL-S, WSMO and IRS-II) provide an ontological framework whereby service descriptions can be defined in terms of concepts or instances with formally defined semantics. The advantage of such frameworks include the ability to extend and adapt the vocabulary used to describe services, to utilise existing concepts defined in alternate ontologies, and to harness the inferential benefits of logical reasoning over such descriptions. Such benefits are necessary within dynamic, evolving environments (particularly with respect to mobile computing), where no assumptions can be made about the availability of any given service, nor can such services be expected to adhere to any given standard.

Describing services using an ontology is superior to using other forms of data structures such as service templates etc. used in the current standards, because the former method provides a structure that makes it possible to reason about and derive knowledge from the given descriptions. By using an ontology, the relationships between entities can be more clearly expressed and it allows for better reasoning.

Although there is some related work which concerns the description of devices, so far there has been no collective effort to come out with a formal framework to describe devices which aims to facilitate semantic service discovery. Hence an OWL-based ontology has been proposed in this work, with the aim of providing a formal framework to describe devices and their services to support effective service discovery.

2. The need for a Device Ontology

When a service involves a hardware device (for example printing service, scanning service) some level of detail about the device in which it is hosted will be required for service selection purposes. For example in the case of a printer service, the location of the printer might be useful when determining the appropriateness of the available printer services. Such information relating to the device could be included along with the service description itself (in the service ontology), but having separate ontologies to describe devices and services promotes ease of use, readability and reusability and is therefore a better design.

In certain cases of service composition where hardware devices are involved, it will be necessary to reason about the capabilities of available devices in order to determine a broker platform, where the execution and coordination of the services takes place. The broker platform may need to be selected based on factors such as resource capability, proximity of the device to individual services etc. In such cases the device ontology will become useful in describing the capabilities of the devices available on the network.

3. Proposed Device Ontology

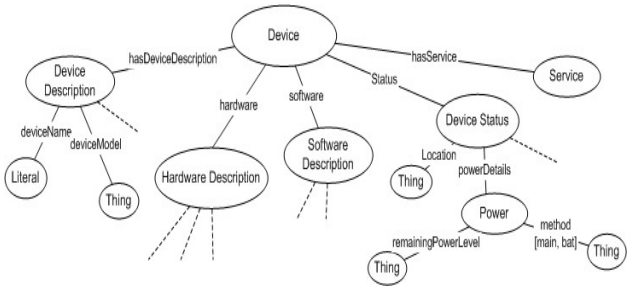

Figure 1: Proposed Device Ontology

Figure 1 illustrates a section of the proposed device ontology. (The ellipses represent classes and the edges represent properties.) The information related to a device is logically divided into five classes depending on the type of information they provide: namely Device Description, Hardware Description, Software Description, Device Status and Service.

Device Description contains basic information related to a device such as the device name, vendor details etc. Hardware Description and Software Description are used to describe hardware and software resources of the device. The Device Status contains volatile information pertaining to the device such as the details of its location, CPU

usage, remaining power level, method of power supply etc. The details of power supply and power level becomes important when it is necessary to determine the resource capability of a device. Location details will be required when service selection needs to consider the location of the device in choosing the right service.

The Service class provides the information about the service(s) hosted on the device concerned. OWL-S could be potentially used to describe these individual services. There is a 1:n relationship between the Device class and the Service class. For example if a particular device has a printer service, scanner service and a photocopy service, there will be three Service classes in the device ontology for this particular device.

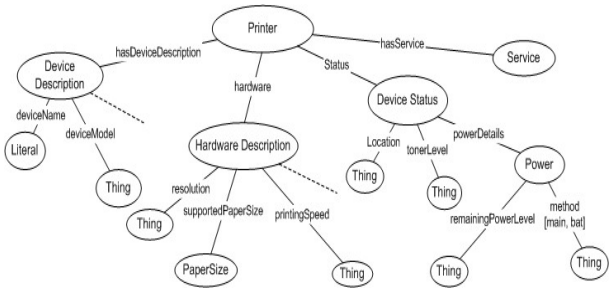

Figure 2: Printer Class Example

The Device Ontology is intended to provide a general framework to describe any type of device. But to describe specific types of devices more precisely, the concept of class hierarchies can be used. A hierarchy of sub-classes can be constructed, that inherits from the Device class to provide an effective device categorization. For example there can be a Printer sub-class that inherits from the device class and builds on additional properties as necessary to effectively describe printers. Figure 2 illustrates such an example where a Printer class is created as a subclass of the Device class and builds on additional properties of Resolution, Paper Size, Printing Speed and Toner Level. In the case where a device does not fall into any of the available categories, or when it is not clear to which category a device belongs to, it could be specified as an instance of the Device class itself and thereby avoiding the use of the hierarchical classification.

4. Comparison with Existing Work

As with OWL-S which is a collective effort to come up with an agreed ontology to describe web services, there has been no such effort to come up with a framework to semantically describe devices in order to make semantic discovery possible and effective. Instead individual researches have produced their own ontologies to facilitate their research work on semantic discovery. Also there is some related work done in FIPA device ontology [FIPA, 2002] and CC/PP [W3C, 2004] but with different objectives.

In Dreggie [Chakraborty et al., 2001] a DAML-based ontology has been developed to semantically describe services. But in this work, device details and service details are described in the same ontology; having separate ontologies to describe devices and services is a better design as pointed out in Section 2. In [Avancha et al., 2001] an RDF-based ontology has been used to describe services. Although RDF is good at representing semantic information it is not as powerful as OWL; OWL facilitates greater machine interpretability of semantic content than that supported by RDF. As with the DReggie work, the ontology used here describes device information along with the service information.

FIPA Device Ontology [FIPA, 2002] specifies a frame-based structure to describe devices, and is intended to facilitate agent communication for purposes such as content adaptation. Though terminal devices like PC's, PDA's and the like could be described using this ontology, it does not facilitate an effective description of devices like printers, scanners etc. But the device ontology introduced in this paper is intended to provide a general framework to describe any type of device from PC's, Notebooks to printers, scanners and headsets. In CC/PP framework [W3C, 2004] an RDF-based framework for describing software and hardware profiles of devices is defined. CC/PP is developed specifically to facilitate the decision making process of a server, on how to customize and transfer web content to a client device in a suitable format. The goal of the device ontology described in this paper has a wider objective of describing devices and services to facilitate service discovery.

5. Conclusions & Future Work

The Device Ontology proposed in this paper provides a framework to describe devices and their services in a rich and expressive way thus enabling effective semantic discovery of services. But the usability and appropriateness of this ontology should be further investigated and refined accordingly.

Acknowledgments

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