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A semantic web vision for an intelligent community transport service brokering system

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Abstract

Advances in semantic web research in recent years offer an opportunity for heterogeneous objects to exchange data and information in an interoperable way to make data and services machine-accessible and machine-processable. This paper describes a semantic web vision for an intelligent community transport service brokering system. The use of ontological approach to develop a semantic web brokering system opens up the data set for agent-based planning in reservation and scheduling. As ontologies are the building blocks of the semantic web and small simple ontologies are often constructed individually by different users, ontology integration approach is proposed to achieve data interoperability in the proposed system. An application scenario is used to demonstrate how the semantic web based system will be used. Future research of this project is to construct the community transport service ontology to conduct proof of concept for the intelligent brokering system.

Keywords

service, brokering, community, system, semantic, intelligent, transport, vision, web

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***Abstract*—Advances in semantic web research in recent years offer an opportunity for heterogeneous objects to exchange data and information in an interoperable way to make data and services machine-accessible and machine-processable. This paper describes a semantic web vision for an intelligent community transport service brokering system. The use of ontological approach to develop a semantic web brokering system opens up the data set for agent-based planning in reservation and scheduling. As ontologies are the building blocks of the semantic web and small simple ontologies are often constructed individually by different users, ontology integration approach is proposed to achieve data interoperability in the proposed system. An application scenario is used to demonstrate how the semantic web based system will be used. Future research of this project is to construct the community transport service ontology to conduct proof of concept for the intelligent brokering system.**

Keywords-Semantic web, Ontology, Community transport service

I. INTRODUCTION

The World Bank defines an intelligent transport system as a system that has the capability to "gather, organize, analyze, use and share information about transportation systems" [1, p.3]. Technological prerequisites required to successfully introduce and deploy intelligent transport systems include: a common data model, communications standards for data exchange, communications infrastructure, and international standards to ensure data interoperability [1].

In Australia, community transport system is a service provided by not for profit organizations to cater for the needs of transport disadvantaged people (such as the frail elderly and people with disabilities) who often cannot make use of and/or do not have access to private or public transport systems. It is a demand-response point-to-point transport service operates on a local service provision model, generally within a local government area. They provide services that may include regular group trips such as shopping trips and social outings as well as individual transport trips for personal matters (for example to attend banking business) or health-related appointments. These service providers receive the bulk of funding from the Australian Commonwealth and State governments, but there are no common binding policies and guidelines for service delivery [2]. One of the problems faced by the community transport service providers is the under-utilized and idle vehicle resources that impede the service delivery. Attempts have been made to develop a brokering system to share and increase utilization of idle vehicles and to improve performance delivery [3].

This paper proposes a semantic web vision for an intelligent brokering system using ontology approach with the aim to enable data interoperability on vehicle sharing among different community transport service providers. The ontology model facilitates data sharing and data interoperability in the proposed system. This way representational vocabularies in terms of objects and their interrelated describable relationships and properties can be defined to ensure a common data model is used to facilitate data interoperability [4].

The rest of the paper is organized as follow. The concept of ontology is presented in Section 2 and ontology integration approach is discussed in Section 3. Section 4 presents an application scenario in the semantic web environment. Finally Section 5 concludes the paper.

II. ONTOLOGY

The use of common vocabularies in metadata and data format is a key component to achieve data interoperability to allow effective collaboration and exchange of data and information among different community transport service providers. The use of ontological approach to develop a semantic web brokering system opens up the data set for agent-based planning in reservation and scheduling.

In the context of knowledge representation, ontology is a specification of conceptualization which defines concepts and relationships [5, 6]. The role of ontology is to help data integration so that ambiguities on terms used in heterogeneous data sets can be avoided. This way a machine-readable and machine-processable system can be developed. The Web Ontology Language (OWL) is the ontology language designed for knowledge representation to facilitate greater machine interpretability along with formal semantics [7]. Simply, ontology formally defines relations among terms by having structures and semantics to make its use transparent. In this way it provides a basis for structured domain modelling. By expressing both knowledge and semantic mappings in formal ontology, a unified model can be created which jointly translate and integrate knowledge in the domain of interest.

Research on ontology for transportation systems has been reported in [8-15]. This paper adopts the abstract scheduling model proposed by Smith and Becker [13] (see Figure 1). Table 1 shows the definitions of concepts used in this model. According to Smith and Becker [13], scheduling is a process of coordinating the allocation and use of resources by activities to satisfy the demands. In the case of community transport system, an *activity* is a transport service to carry the customer from the pickup location to the destination and back to the point of origin at a specified start and end times with *resources* that satisfy customer's *constraints* such as a specific time for health appointment, a vehicle that meets customer's needs such as a wheelchair accessible vehicle and a driver available to drive the vehicle. In this case the *demand* is an input request for a service requested by the customer and the *product* is a transport schedule that satisfies the demand of the customer subject to the imposed constraints.

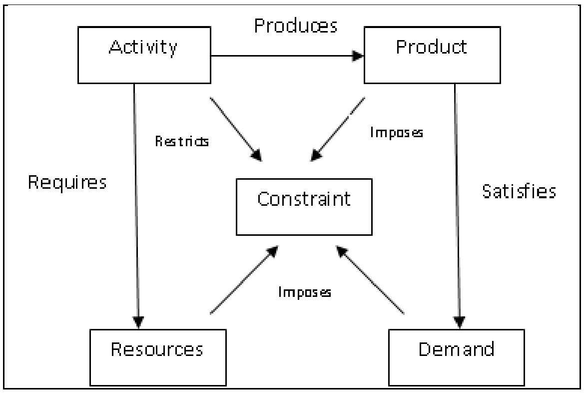

Figure 1. The abstract scheduling model of Smith and Becker [13, p.122]

Table 1. Definitions of concepts in scheduling model by Smith and Becker [13]

Concept	Definition
Activity	An activity is a process that requires resources to be executed over a certain time period.
Constraint	A constraint restricts the start and end times of an activity and allocation of resources.
Demand	A demand is a request for products and services. Demands specify the input goals subject to satisfying any constraints imposed.
Product	A product is a good or service. A product is realized through execution of some set of activities.
Resource	A resource is an entity that enables the execution of activities.

III. ONTOLOGY INTEGRATION

It is impractical for all users and organizations to agree on one common ontological model as the model will not reflect the actual business requirements of individual users and organizations [4, 16]. In general small simple ontologies are constructed individually by different users and these decentralized small-sized ontologies are linked with other ontologies to share the repositories [17]. This observation is supported by recent survey conducted by Cardoso [18] which showed the large majority of ontologies developed are rather small. In the case of ontologies related to transportation domain, various transportation-related ontologies such as spatial geographical data, transport network, road infrastructure and traffic management have been developed and reported in the literature [8-12, 14, 15].

However the adoption of multiple ontologies can cause ontology mismatch. In this case, heterogeneity caused by multiple ontologies can become an obstacle for systems interoperability as the defined vocabularies and relationships can be inconsistent resulting in difficulty for data exchange and data interoperability. This paper proposes to adopt the collaborative inter-organizational knowledge management network methodology developed by Leung et al. [4] to allow different users and organizations to share the ontological models.

In the proposed method, different organizations will use concepts and relations developed in the individual organizations to represent individual ontology model. Then an ontology mediation approach is used to allow participating organizations to share data in the inter-organisational model within the community of network. Mutual agreement will be established to permit individual organizations to retrieve agreed data for the purpose of sharing data.

The participating organisations need to make four important decisions regarding ontology mediation, whether: (a) top-level ontology or one-to-one mapping approach should be adopted; (b) merging, mapping and/or integration should be selected as the mediation method; (c) mediation to be performed automatically or semiautomatically; (d) single or multiple matching techniques should be used for the selected mediation method [4]. Then the ontology integration process is achieved using merging tools to combine common views of inter-organizational ontology in the community of network to create a shared ontology. If an organization does not have an ontology model, integration method will be used to allow the organization to reuse the inter-organizational ontology to build the individual organization ontology [4, 16, 19]. The benefit of using the proposed ontology integration approach is individual organization can reuse the inter-organizational model instead of creating its own model from scratch.

IV. AN APPLICATION SCENARIO IN A SEMANTIC WEB ENVIRONMENT

A. Semantic Web

In semantic web data and information have well-defined meaning to allow computers and people to work together [20]. The semantic web presents an environment where software agents can roam in the World Wide Web to carry out tasks for the users autonomously. The structure of semantic web can be represented as a strata of layer cake consisting of hierarchies that include knowledge terms, ontology vocabulary, logic, proofs, rules and trust (see Figure 2) [17, 21].

In order for the semantic web vision to be realized, data and information must be in a machine readable form. To achieve this, ontology is used to allow data and information to be given well-defined meanings in the lower layers of the semantic web layer cake using XML, RDF, RDFS and OWL. By expressing both knowledge and semantic mappings, concepts and relationships can be used to describe an area of domain so that vocabularies are used to classify terms, properties and relationships. Sets of inference rules are used in the semantic web to enable automated reasoning using rules. In addition, proof layer explains how an answer is derived and to justify reasoning, and the trust layer establishes trust relationships to ensure data sharing is conducted in a secure manner. [17, 20].

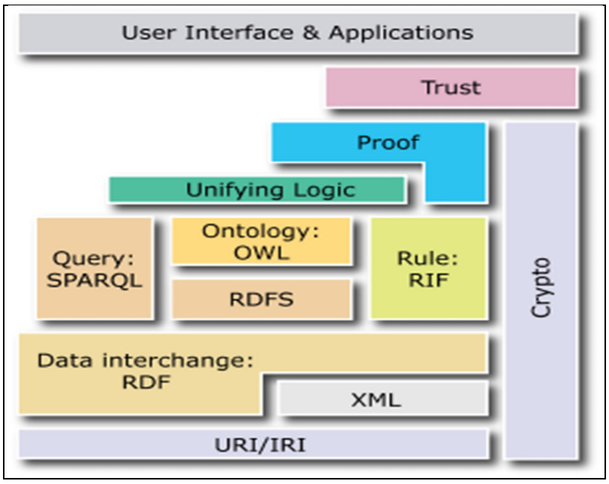

Figure 2. The semantic web layer cake (Source: [21])

B. Application scenario

Consider a hypothetical scenario of an elderly man Peter wishes to attend a doctor appointment scheduled for Monday next week. In the semantic web environment, a software agent coordinates the transport scheduling activity for Peter. Using the scheduling model depicted in Figure 1, Peter's agent requests a *demand* for a transport service via the online reservation webpage of his local community transport service provider. The demand stipulates that Peter wants to arrive at the doctor's office ten minutes before the scheduled appointment time of 10.00am on Monday. When the request is submitted online, the agent for the local community transport service provider will execute the *activity* with the aim to deliver the *product* (in this case a schedule of transport service) to meet Peter's demand by satisfying the imposed *constraints* and the availability of the *resources*.

The agent will retrieve Peter's records from the customer database to determine his eligibility for the service, his address and his condition such as identifying Peter is wheelchair bound. The scheduling ontology will mediate with the customer ontology to define meanings of the terms used in this activity and to map Peter's details to the scheduling ontology. For example the health condition recorded in Peter's customer profile will be mapped with the constraints of the scheduling ontology to be included as one of the constraints imposed which results in an inference that a wheelchair accessible vehicle is required. The address will be mapped with geographical ontology to identify geo-location of Peter's residence to calculate distance travel and thus the schedule for a pickup time that meets Peter's demand. For instance, the agent makes an inference that the driver must leave the depot at 9.00am as it takes 20 minutes to drive to Peter's residence from the depot and it takes 30 minutes to travel from Peter's residence to the doctor's office.

The agent at the community transport service provider will check the constraints imposed by this demand (i.e. the availability of a wheelchair accessible vehicle and a driver) before the demand is fulfilled. If these constraints are satisfied, the agent will execute a scheduling activity to produce a schedule that satisfies Peter's demand. Then Peter's agent will be informed to confirm a transport service request has been made for Peter at 9.20am on Monday. Peter's calendar on his smart phone will be updated by the agent and a reminder message has been set up by the agent to remind Peter of the scheduled pickup time on Monday.

In this simple scenario, Peter's demand is executed by two agents who have an established well-defined common structure to share data. We will now consider the next scenario in which no established common structure is available. Assume that a wheelchair accessible vehicle is not available to satisfy Peter's demand. In this case the agent from the community transport service provider will submit Peter's demand to the online reservation website of a service provider from the neighbouring area.

As the community transport service provider operates in a local service provision model, the neighbouring community transport service provider would not have Peter's details as Peter is not classified as a client for this provider. However mutual agreement has been established between the two service providers to allow resource sharing. Thus the trust layer in the semantic web will establish the authenticity of Peter's eligibility in receiving the community transport service by accessing Peter's record from Peter's community transport service provider. An authorization will be established between the two service providers to share Peter's data through the trust layer in the semantic web.

Let us assume that the ontological model of the neighbouring service provider is different from Peter's community service provider in such a way that all vehicles in the neighbouring community service provider are wheelchair accessible. Thus it is not required to include the constraint to determine if the vehicle is wheelchair accessible. In this case the ontology mediation mechanism is evoked to coordinate the mapping of vehicle concept to remove the wheelchair accessible constraint from the demand. When the demand is fulfilled, Peter's agent will be informed of the schedule and Peter's calendar will be updated and a reminder message is set up.

In this hypothetical scenario, multiple ontology models are used to coordinate a scheduling *activity* to meet the *demand* based on the imposed *constraint*s to enable a *product* (in this case a schedule for the transport service) to be delivered. The agents exchange and share data through an ontology integration mechanism which provides the capability of data interoperability without having a common ontology model.

C. *Future research*

Future research of this project is to construct the community transport service ontology to conduct proof of concept for the intelligent brokering system. Protégé [22] will be used to develop a prototype of the intelligent brokering system based on the abstract scheduling model of Smith and Becker [13]. Protégé is an open-source platform that can be used to construct domain models and applications with ontologies. In addition the plug-in architecture of Protégé enables rule-based systems to be easily integrated to develop the intelligent brokering system [22]. Rule-based system is proposed as it is necessary to prioritize the demand for service subject to the constraints imposed. A priority concept can be introduced to enable allocation of resources that meet the demand requested by the customer.

V. CONCLUSION

This paper describes a semantic web vision for an intelligent community transport service brokering system using the ontology approach. The heterogeneity of multiple ontologies in the brokering system can be resolved using ontology integration method to allow ontology mediation to occur using ontology mapping. A hypothetical application scenario has been described to illustrate the semantic web-based brokering system for the community transport service providers and their customers. The semantic web vision proposed in this paper contributes to understanding of a future semantic web application of intelligent brokering system for the community transport service sector.

The future trend in Internet of Things requires deployment of new services capable of supporting interoperable and multi-domain applications [23, 24]. In the Internet of Things environment, data and information are to be shared and communicated over the Internet networks so that objects in the environments can act autonomously. To achieve this, heterogeneous objects need to exchange data and information in an interoperable way to make data and services machine-accessible and machine-processable. Glance [25] foresees the elderly will benefit from this future trend as it provides an opportunity to help the elderly to live independently. In the application scenario described in this paper, the agent will coordinate the transport service for the elderly man Peter when the doctor's appointment is updated in the calendar of his smart phone. Then the agents will act autonomously to arrange for the transport service with the community transport service provider as described in the application scenario.

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