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Resource virtualization and service selection in cloud logistics

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ABSTRACT

Cloud computing and Internet of Things have promoted a new logistics service mode, i.e., the cloud logistics mode. This work studies the resource virtualization and service encapsulation of a logistics center, and focuses on the technologies of resource expression and service encapsulation. After the resources of a logistics center are encapsulated in web services, how to find the "best" concrete web service among many is a critically important issue. This work considers service selection as an optimization problem and establishes a Particle Swarm Optimization (PSO)-based web service selection model with quality of service (QoS) constraints. It can be used to address the horizontal adaptation issues from the composite web services. The feasibility and effectiveness of the model are verified by several experiments.

1. Introduction

Human society, information space and physical world can be fully connected and integrated with the help of rapidly developing IT technologies such as cloud computing and Internet of Things (IoT). We are facing a trend where the service-based information systems blur the border between the physical and virtual worlds, providing a fertile ground for a new breed of real-world aware applications (Guinard et al., 2010). In logistics field, cloud computing allows scaling autonomous logistics applications flexibly based on the dynamically arising logistics demands (Schuldt et al., 2010). That has nurtured a new IT-based logistics service mode, namely cloud logistics.

Cloud logistics is a service mode for logistics service provisioning and management based on cloud computing. A cloud (Lombardi and Di Pietro 2011) here is a pool of virtualized resources across the internet that follows a pay-per-use model and can be dynamically reconfigured to satisfy user requests. It promises to enable both individual and complex logistics services (Holtkamp et al., 2010). Yet, some issues arise in theory and practice:

(1) Logistics resources have the characteristics of variability, geographical distribution, heterogeneity, morphological diversity and self-governing zone. These make resource sharing and management in a cloud logistics platform more complex than a cloud computing platform. The reason is that logistics resource virtualization is much more difficult than that of IT resources.
(2) Web services have the characteristics of distribution and heterogeneity in a cloud logistics platform. The number of concrete web services binding to each corresponding abstract service is too large in this platform. This causes the difficulty to find the "best" concrete web service. In addition, although there are a large number of web services online, some of them may be not available. Hence, many trust-based approaches could be used to deal with the possibility (Garruzzo and Rosaci, 2012; Sarvapali et al., 2004; Rosaci, 2012). For our work, we put emphasis on finding the "best" concrete web service on the premise that web services are available.

To well address the above issues, this paper presents a platform for the virtualization of resources and selection of composite services. The former includes resource expression and service encapsulation. A resource expression approach guarantees a universal description of logistics resources, while a service encapsulation approach guarantees that services could be found by encapsulating resources into services. The latter describes how to locate a web service from a number of web services with the same function and to match well web services with user needs.

The rest of this paper is organized as follows. First, we briefly overview the related work in Section 2. Section 3 presents the proposed resource virtualization and service encapsulation approaches. The service selection in a logistics center is described in detail in Section 4. Section 5 describes simulation results and analysis of resource virtualization and service selection solution. Finally, conclusions and future directions are discussed in Section 6.

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2. Related work

Cloud logistics focuses on the flexibility and scalability of cooperation among logistics resources. Logistics resource expression and encapsulation are two critical issues to be addressed for cloud logistics virtualization while service selection is important in ensuring the effective cooperation among logistics resources.

2.1. Resource virtualization

Virtualization is critical to resource sharing and dynamic allocation. In the early stages, virtualization meant the abstraction of computing resources. Its purpose is to improve resource utilization by providing a unified integrated operating platform for users and applications based on aggregation of heterogeneous and autonomous resources (Sahoo et al., 2010). More recently, with the development of cloud computing and IoT, virtualization also extends its application to other fields such as logistics and manufacturing. It becomes more and more important as a way to improve system security, reliability and availability, to reduce operational cost, and to provide greater flexibility.

In the logistics field, especially in a network environment, resource virtualization is able to provide flexibility in the use of resources, including logistics equipment and computing resources in the computer system of cloud logistics. Not only can it abstract physical resources to a unified logical resource view, but also can supply an advanced and more useful resource form by composing proper resources. A basic resource virtualization process is an application-oriented service (Wang et al., 2006). Like a manufacturing field, it mainly contains two tasks. One is to build a resource expression model by analyzing the features of resources (Vichare et al., 2009; Kim et al., 2011; Chen et al., 2011; Ren et al., 2011), while the other is to encapsulate resource information in services by building a service description method with web service technologies (Liu and Li, 2012; Shi et al., 2007).

Vichare et al. (2009) propose a Unified Manufacturing Resource Model termed UMRM to represent manufacturing equipment and use it to produce product information relating to a product's design, geometry and required processes. UMRM not only has the novel capability to provide the information to define the various elements of a machining system, but also has the capability to provide support for automation of process planning and decision making. Ren et al. (2011) propose a layered framework for resource virtualization in Cloud Manufacturing to realize overall resource sharing. Liu and Li (2012) build a manufacturing resource virtual description model, which includes both non-functional and functional features of manufacturing resources. The model provides a comprehensive manufacturing resource view and information for various manufacturing applications. Shi et al. (2007) propose a manufacturing resource hierarchy model in which manufacturing resource information is encapsulated in an XML schema. However, their research pays attention to the basic level resource management only, and makes simple abstraction in syntax and semantics layers. System-level application-oriented models are lacking.

2.2. Service selection

Service selection is to find an appropriate web service that meets certain functional and non-functional criteria. Its process is important as it allows a service requester and provider to agree on the functional and non-functional attributes that will govern the interaction (Majithia et al., 2008). Several solutions to the service selection problem have been reported. In the first category, service selection mainly including some Quality of Service (QoS) attributes in the search process is usually considered as an optimization problem, which is resolved by the approaches such as mixed integer programming (Zeng et al., 2004; Kritikos and Plexousakis, 2009), description logic (DL)-based reasoning (Peng et al., 2008) and constraint programming (Ma et al., 2008), and multi-criteria decision making (Herssens et al., 2008; Tran et al., 2009; Wang, 2009). Regarding mixed integer programming solutions, Zeng et al. (2004) assume the linearity of the constraints and objective function. Towards DL-based reasoning and constraint programming method, Peng et al. (2008) present a Dynamic Description Logic (DDL)-based approach to the description and matching of semantic web services. They adopt DDL actions to describe the goal service of a service consumer and the atomic services from service providers. After using DL reasoning to guarantee the semantic compatibility, Ma et al. (2008) translate QoS conditions into constraints and use constraint programming to select services by optimizing the global utility function. Wang (2009) propose a fuzzy decision model under vague information and extend the Max–Min–Max composition of intuitionistic fuzzy sets to select web services.

The second category of selection methods is based on intelligent optimization techniques. Swarm intelligence algorithms are adopted to solve a service selection problem by translating it into the optimization problem (Canfora et al., 2005; Wang et al., 2011). Canfora et al. (2005) propose genetic algorithm (GA)-based approach to QoS-aware service selection and composition. Wang et al. (2011) propose a web service dynamic selection approach based on the decomposition of global QoS constraints. It uses an adaptive adjustment method based on fuzzy logic and adaptive particle swarm optimization algorithm.

Service selection or composition modeling is another method such as agent-based modeling (D'Mello and Ananthanarayana, 2010; Garruzzo and Rosaci, 2010; Na et al., 2008; Caceres et al., 2006) and Petri Nets modeling (Xiong et al., 2008, 2009; Tan et al., 2010). D'Mello and Ananthanarayana (2010) present the modeling and selection mechanism for the requester's alternative constraints defined in terms of QoS, and implemented a QoS broker agent-based system to prove the correctness of the proposed web service selection mechanism. Na et al. (2008) propose a reputation-based service discovery in a multi-agent system, to take the reputation information that is locally generated as a result of an interaction between agents, and spread it throughout the network to produce a global reputation value based on agents' semantic similarity. Xiong et al. (2008) build a web service configuration net model based on Petri nets in order to exhibit web service configurations in a formal way and present an optimal algorithm to help choose the best configuration with the highest quality of service to meet users' non-functional requirements.

These methods could solve service selection or discovery. We consider a service selection problem as a multi-objective optimization problem and propose a solution by building a composed service selection model with Quality of Service (QoS) constraints.

3. Resource virtualization of a logistics center

3.1. Resource expression and service encapsulation

The characteristics of resources in a logistics center such as heterogeneity, diversity, dynamic and complexity cause a great difficulty to unify their expression. The existing standards (XML/SOAP/WSDL/OWL) related to web services cannot be applied to encapsulate logistics resource information directly, because the meaning and usage of logistics services are different from those of traditional web services. Therefore, resource expression and service encapsulation in a logistics center mainly focus on how to