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Abstract

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Keywords

Dynamic, selection, service, peers, multiple, property, specifications

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Dynamic Selection of Service Peers with Multiple Property Specifications

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Abstract. Semantic Web services, one of the most significant areas in the emerging business process management systems, have attracted a great deal of effort from both academic and industry community. Traditional methodologies are still very inadequate to effectively and autonomously conduct service discovery and composition in a dynamic environment, as they seldom focus on dealing with real complex situations, such as simultaneously considering peers' multiple specifications which reflect different properties of e-services. Different ontology based e-service profiles have been proposed to enhance service oriented framework for the total or partial automation of service invocation, discovery, selection and composition, which are involved in either centralised or decentralised deployment of services. In this paper, we propose a modelling based approach to design and develop a peer-to-peer based service coordination system and their components. The peer profiles are described with the WSMO (Web Service Modelling Ontology) standard, mainly for quality of service and geographic features of the e-services, which would be invoked by various peers. To fully explore the usability of service categorisation and mining, we implemented an ontology driven unified algorithm to select the most appropriate peers. The UOW-SWS prototype also shows that the enhanced peer coordination is more adaptive and effective in dynamic business processes.

Keywords: semantic Web services, quality of service, geographic properties, WSMO, peer-to-peer

1. Introduction

Many researchers are interested in developing effective e-service or e-business applications based on various existing components for agents-based systems [8], due to increasing popularity and growth of Web services. As non-functional features of Web services play a very important role in performance management of a composite Web service, one of the biggest concerns in modelling intelligent selection framework is

how to properly describe quality of service (QoS) and spatial, especially for P2P-based or agents-based information systems.

In decentralised environments, QoS has been considered as a significant solution when running business processes. It is clear that the distributiveness, dynamics and heterogeneity of services become extremely important to both service requestors and service providers. Most research works presented so far are still mainly syntactic and have not effectively incorporated ontology approach for service description and composition within real applications. The discovery and integration of a new service in an existing infrastructure are not automatic and requires a lot of human effort. As a result, it's problematic that traditional methodologies can not autonomously conduct service discovery and composition in a complex dynamic environment. Even though quite a few groups have proposed numerous QoS specifications, most of them find it extremely difficult to clarify the correlation between one another consistently, especially when they try to unify different sets of metrics succinctly.

However, Web Service Modelling Ontology (WSMO) [11] considers many non-functional properties which can be used as a discriminator factor to facilitate P2P-based services selection in business workflows. In this paper, we present an autonomous and scalable ontology-based methodology to describe QoS and geographic features of the Web services and the peers who truly invoke them in a P2P-based environment. Moreover, semantic Web services selection is a process to automatically find appropriate Web services that effectively fulfil the requestor's requirements. Compared with existing work, two contributions are presented in this paper: we designed a service discovery model and propose a QoS-aware service mining method for processing various e-service profile specifications in dynamic decentralised network; another is UOW-SWS (Short for University of Wollongong-Semantic Web Services) prototype: we implemented the proposed unified selection algorithm with a new framework to testify the applicability of autonomous task allocation at different dynamic situations.

The paper is structured as follows. Section 2 will explain basic knowledge of WSMO and a typical use case. Section 3 will introduce the incorporation of WSMO features, with a focus on modelling support for non-functional properties. Beyond this, our algorithm for the peer selection process, which is based on unified correlation of different quality metrics, is introduced. Section 4 presents implementation details of a peers' quality ranking method in the UOW-SWS prototype under different dynamic situations. After comparing the related work in Section 5, conclusions are presented in Section 6.

2. Background

2.1 Web Service Modelling Ontology

In general, WSMO aims to create an ontology which can semantically describe a variety of perspectives of Web services, so as to solve the integration problem. As compared to OWL-S, WSMO introduces a set of core non-functional properties that are defined globally and that can be used by all the modelling elements of WSMO. OWL-S

does not define this kind of globally accessible and pre-defined non-functional properties, but it defines an expandable list of non-functional properties in addition to some non-functional properties such as service name and contact, in the profile, but they are not used for other modelling elements. Essentially, WSMO defines four high-level notions [15] which relate to semantic Web services, namely Ontologies, Goals, Mediators and Web services. Web services are descriptions of services that are requested by service requestors, provided by service providers, and agreed between service providers and requesters. Non-functional properties are usually utilised to describe non-functional aspects such as the creator and the creation date, and to provide natural-language descriptions, etc. All of the four WSMO elements have their own non-functional properties. In this paper, however, our QoS extension is of the same nature as the notion of non-functional properties in “Web services”. In other words, we mainly introduce the QoS, such as performance, availability, spatial features of distributed services, etc. The incorporated QoS properties could also be used in parallel with existing non-functional attributes proposed by other WSMO elements. Thus, it is consistent to consider QoS parameters as more general non-functional properties.

We develop the non-functional properties in WSMO in order to support adaptive P2P-based service composition. More importantly, we also apply geographic features in these non-functional properties, as location information of peers is always needed as extremely useful and essential aspects to enhance P2P-based computing. QoS deployment and strategic spatial consideration for a Web service are not only desired to provide more satisfactory service and better information systems, but also able to bring considerable competitive advantages to service providers.

2.2 UOW-SWS: A Business Process Application Prototype

UOW-SWS is a JXTA-based [2] peer-to-peer workflow information system upgraded from SwinDeW-B [14], which was designed and developed to overcome the problems like poor performance, poor scalability, unsatisfactory system openness, and lack of support for incomplete process. UOW-SWS have been functionally extended to incorporate WSMO features so as to facilitate Web services selection via QoS and spatial information.

There is a typical case [17] used by many e-commerce application prototypes, so we’d like to utilise it in UOW-SWS to explain and demonstrate our selection method in an empirical way. That case introduces a loan application process deployed in our prototype. At the beginning, Customer sends a loan request to financial organisation, and then a Coordinator peer, who has the knowledge of whole BPEL [13] process, will seek appropriate peers/agents to fulfil the whole task by sending Pipe messages and evaluating peers/agents’ performance.

In Figure 1, it consists of two predefined atomic services (i.e., task or activity): “riskAssessment” and “loanApproval”. “riskAssessment” is to provide the service (Assessor) about evaluating customer’s reputation and loan amount, so that it will generate the risk assessment of loan. Only when the risk assessment meets the requirement (e.g. higher reputation with more permitted loan amount) of “loanApproval” (Approver), can the loan application be approved; otherwise, the loan request will be turned down. In this paper, we will design a more effective and

qualitative way in P2P information systems to distinguish which peer (or agent) is the most appropriate for a requested service.

Fig. 1. Flow Chart of Service Process in UOW-SWS

3. Modelling Peers and Extending Non-functional Properties

3.1 A generic method for selection of multiple property specifications

In order to evaluate different non-functional properties of e-service peers, there are three important concepts in our design: PreferredValueType, Weight, and Unified Value. PreferredValueType has two kinds of values: “low” and “high”. We utilise them to quantitatively identify two different types of properties among numerous non-functional properties in real use cases. For example, “ResponseTime” usually is expected as short as possible when choosing an appropriate peer, so the PreferredValueType of “ResponseTime” is “low”. Likewise, “Distance” also usually relates to “low”, as no one would choose a service with a long distance. However, “Reputation” and “AvailableDuration” often fit into “high”, since their values are often expected as high as possible. Accordingly, all peers’ various properties are viable to be categorised into the two types. With regard to “Weight”, it indicates the importance and

priority of certain properties during the service composition, so weight value varies from service to service, and from property to property. Lastly, “Unified Value” indicates the each peer’s overall quality with numerically indicating results. With a set of equations as defined below, we can calculate a “Unified Value” so as to evaluate and rank each peer’s overall capability to meet requirements against a requested service.

If “PreferredValueType” = “high”, then the property ratio (PR) of a peer’s service should be calculated by:

$$PR(i, j) = \frac{nf(i, j) - nf(min)}{nf(max) - nf(min)} \quad (1)$$

“PR(i,j)” presents the ratio value of non-functional Property(j) of Peer(i), and “nf” stands for non-functional. nf(min) and nf(max) refer to the minimum and maximum values of the Property(j) among all relevant peers. On the contrary, if “PreferredValueType” = “low”, then the ratio should be determined based on:

$$PR(i, j) = \frac{nf(max) - nf(i, j)}{nf(max) - nf(min)} \quad (2)$$

Our main aim is to scale the value ranges with the maximum and minimum values by this means. Hence, any value with different “PreferredValueType” can be converted into the standardised value between 0 and 1. Through this approach, every property of each peer can be compared and evaluated fairly and also quickly.

Subsequently, all candidate peers’ non-functional properties would be put in a matrix, which looks like (for n properties in m peers):

$$Mnf = \begin{bmatrix} PR(1,1) & PR(1,2) & PR(1,3) & \dots & PR(1,n) \\ PR(2,1) & PR(2,2) & PR(2,3) & \dots & PR(2,n) \\ PR(3,1) & PR(3,2) & PR(3,3) & \dots & PR(3,n) \\ \dots & \dots & \dots & \dots & \dots \\ PR(m,1) & PR(m,2) & PR(m,3) & \dots & PR(m,n) \end{bmatrix}$$

“Mnf” refers to matrix of non-functional properties. For uniformity, matrix Mnf has to be normalised to map all real values to a relatively small range through equations (1) (2), i.e., all elements of the final matrix are real numbers in the closed interval [0, 1].

Having Weight (W) values assigned to each property, we apply the following equation to generate the “Unified Values (UV)” for each peer:

$$UV = Mnf \times W, i.e., UV(i) = \sum_{j=1}^n (PR(i, j) \times w(j)), i = 1..m \quad (3)$$

w(j) stands for a weight value of different property (jth) for service composition. As a result, it is reasonable to indicate which peer (ith) would be able to conduct a specific task more effectively, by means of achieving the highest value UV(i), i ranges from 1 to m. In section 4, we will give an example for this principal ranking.

3.2 QoS Aspects in WSMO

Based on [16], we define an extensible class QoSProperty which aims to extend nonFunctionalProperties class in WSMO for P2P-based service selection.

```
Class nonFunctionalProperties
    ...other existing properties...
    hasQoSProperty type QoSProperty

Class QoSProperty sub-Class nonFunctionalProperties
    hasPropertyName type string
    hasPropertyValue type {int, float, long, others}
    hasPreferredValueType type {low, high}
    hasWeight type float
```

Each QoS Property is generally described by PropertyName and PropertyValue. For the purpose of QoS-based selection, there are two additional attributes defined, namely: “hasPreferredValueType” and “hasWeight”. The “hasPreferredValueType” is an object property representing the expected tendency of the value for the ideal attribute. The “hasWeight” is a value denoting the weight of the property, especially when synthetically measuring several different property metrics. In this context we define the weight value within range [0, 1], while different end users may have different weight values for their service requirements.

3.3 Spatial properties of Web services in WSMO

In a decentralised network, geographical location is also an important factor in both service selection and composition. Quite usually, there is no guarantee that a service can be selected or composed meanwhile it would exactly satisfy the requested location requirements. In practical applications, business process managers must deal with alternatives that deviate from the requested service locations. We are interested in identifying those alternatives where the deviation is minimal, such as the nearest available service. In a P2P-based business process, a peer’s geographic information is usually related to services’ accessibility, particularly for pervasive location based service, which integrates a mobile device’s location with other information in order to provide added value to a context-aware user [3]. In order to effectively enhance services’ quality regarding accessibility in P2P network, we herein consider basic geographic information about a would-be task-allocated peer and incorporate it into the QoS profile as an extension of previous QoS specification.

```
Class GeoProperty sub-Class QoSProperty
    hasGeoName type string
    hasGeoValue type {int, float, long, others}
    hasPreferredValueType type {low, high}
    hasWeight type float
    isEssential type boolean
```


The above is a definition of class “GeoProperty” which is the subclass of QoSProperty. In order to effectively enhance service quality for accessibility in a P2P network, we herein consider the geographic property about the peer and incorporate it into the QoSProperty Class as an extension of QoS specification.

Fig. 2. Extensible High-Level Relationships between Properties

Figure 2 denotes the relationships between the QoS property and Geo property in WSMO, and the logic of using extensible geographic features for distributed services. In a real environment, it is not unusual that different applications often have different requirements, that is to say, some geographic properties (e.g. angle and region) do not need to be considered or evaluated for some applications (e.g. loan application case or simpler local services). Therefore, in order to be more flexible and practical, we define an attribute named “Essential” in GeoProperty, which means if “isEssential”=1, this kind of attribute is regarded as necessary and cannot be neglected.

For example, the metric of “Distance” can be viewed as a basic criterion when choosing appropriate peer to invoke requested services, so as to improve the service accessibility. It is feasible to not only establish a better link between a potential service (or partially composed service) and an expected or requested set of location requirements, and also use this approach to rule out less viable compositions earlier in the whole process.

3.4 Unified peer selection algorithm

For a peer selection process, we designed an algorithm for UOW-SWS model. The following is the pseudo code:

```

Begin Function Mining Peers ( $P_1, P_2, \dots P_m$ )
    for i=1 to m do
        getQoSProperties( $P_i$ );
        normalise input ( $P_i$ ) using equation (1)/(2) in section 3.1;
        then store the normalised value into array ( $Mnf$ );
    end
    getWeight() for the different properties;
    calculate the unified values by using equation (3) in section 3.1;
    choose  $P_i$  with maximum unified value;
    return ( $P_i$ );
end function

```

This algorithm aims to address the selection method with multiple peer profile specifications, and facilitate the above modelling approach. The algorithm can also be used for service/peer matchmaking, since we may set a goal for each QoSProperty if necessary. With regard to the loan use case, it is usually required that a selected peer should have better quality than others, thus a coordinator can apply this algorithm to efficiently allocate tasks to the most appropriate peers.

4. Experimental prototypes

As we mentioned in section 3, QoS and spatial perspectives would involve many non-functional properties of e-services, such as: service availability, service accessibility, service performance, service geographic features, etc. In dynamic circumstances, the service selection with combined QoS and geographic specifications is often a quite complex process, due to the diversity of various metrics with different value types, value range, and measurements. Taking account of correlations between those different specifications, we simplify and unify those combined various specifications so as to make the selection process less complicated and more effective.

In our experiment, firstly, we assign a set of random data and demonstrate the evaluation of four peers who are available in our loan case in UOW-SWS prototype, i.e., pre-deployed in the JXTA network.

Table 1. Peers' Non-functional Property Values

	ResponseTime	AvailableDuration	Reputation	Distance
Peer 1	500	80	0.8	100
Peer 2	1000	60	1	300
Peer 3	600	200	0.7	50
Peer 4	300	140	0.5	180

As we see from Table 1, each peer's properties use different metric units with correspondingly varying values. If peer's properties are numerous, it would be extremely hard to distinguish and make an optimal decision on which peer is the most appropriate for service composition.

According to equations (1) (2) in section 3.1, the property ratios of the four peers are calculated, and filled in Matrix Mnf .

$$Mnf = \begin{bmatrix} 0.7143 & 0.1429 & 0.6 & 0.8 \\ 0 & 0 & 1 & 0 \\ 0.5714 & 1 & 0.4 & 1 \\ 1 & 0.5714 & 0 & 0.48 \end{bmatrix}$$

As for Weight values, they often vary from different requirements and situations in real environment. Based on the importance of properties, the weight value for the four properties can be $W = (0.8, 0.5, 0.85, 0.6)^T$ in the loan case, distinguishing ResponseTime, AvailableDuration, Reputation and Distance respectively. Thus, by

applying equation (3), the peers' unified quality values will be $UV = (1.6329, 0.85, 1.8971, 1.3737)^T$.

Table2 . Peers' Non-functional Property Values (At different stage)

	ResponseTime	AvailableDuration	Reputation	Distance
Peer 1	600	60	0.9	220
Peer 2	700	40	1	80
Peer 3	1000	180	0.8	160
Peer 4	200	120	0.3	100

However, in real dynamic environment, a peer's quality and properties can vary from time to time, particularly at the different stages of a business process. Thus, it would not be reasonable for coordinator to statically select and therefore trust the first chosen peer as the best one over all the time. For example, as Table 2 shows, the four peers' situations have been dramatically changed after the task 'Invoke Assessor', and their property values are dramatically different from the earlier scenario (Table 1).

Once again, according to equations (1) (2) in section 3.1, the property ratios of the four peers are calculated, and filled in Matrix Mnf.

$$Mnf = \begin{bmatrix} 0.5 & 0.1429 & 0.8571 & 0 \\ 0.375 & 0 & 1 & 1 \\ 0 & 1 & 0.7143 & 0.4286 \\ 1 & 0.5714 & 0 & 0.8571 \end{bmatrix}$$

Within a whole service process, the set of weight values are not changed constantly. That is, $W = (0.8, 0.5, 0.85, 0.6)^T$ in the loan case is remains as is. Thus, by applying equation (3), the peers' unified quality values will be $UV = (1.2, 1.75, 1.3644, 1.6)^T$.

We implemented the proposed algorithm from section 3.4 in our prototype. In the screenshot of UOW-SWS (Figure 3), we can see the Coordinator peer precisely selected Peer 3 as the most appropriate one (for invoking the assessor) after a round of communications among peers.

Fig. 3. Selection Process for Peers (Invoke Assessor)

Fig. 4. Selection Process for Peers (Invoke Approver)

From Figure 4 we can observe that Peer 2 is the best choice under present circumstance instead of Peer 3. Likewise, with regard to the coordinator's choice, Figure 4 shows Peer 2 has been selected as the current best one as the service conductor for invoking the approver. This selection method for peers' combined specifications is reasonably suitable and effective to be fully adapted in the real dynamic environment, especially in the sense of an autonomous way to select a best peer to perform any specific task at different stages.

5. Related Work

In our previous work [17] we presented a first sketch of the approach, however with special attention to the extraction of the ontological description of services and design of the selection process with OWL-S. With regard to the selection process, the previous prototype has the limitation in terms of deal with multi-specifications, and it only considers "ResponseTime" as the selection criteria, by which the selection is not quite realistic for effective services composition. Instead, this paper extends the description of non-functional properties via modelling-driven WSMO specification, and also presents an algorithm for coordinator to automatically identify the best peers through unifying qualities and properties. Moreover, we demonstrate our implementation at different service stages, and prove that our method can reasonably improve the efficiency and adaption of autonomous P2P-based business process. In the rest of this section, we would summarise and compare other approaches in this area. They aimed at providing the same goal to ease semantic Web services development for business process management systems.

Most related works focus on the development of QoS ontology languages and vocabularies, as well as the identification of various QoS metrics and their measurements with respect to semantic e-services. In [18], authors have provided QoS ontology as a complement for DAML-S [1] ontology to provide a better QoS metrics model. Articles [10] and [4] emphasized a definition of QoS aspects and metrics, but have not noticed the extensible aspects in QoS, like incorporating Geo features. In [10],

all of the possible quality requirements were introduced and divided into several categories, such as runtime-related, transaction support related, configuration management and cost related, and security-related QoS. Both of them present their definitions and possible determinants. Unfortunately, so all are too abstract to suit the implementation requirement. So, they did not tend to present a practical methodology for real services selection. In [9] and [16], authors focused on the creation of QoS ontology models, which proposed QoS ontology frameworks aiming to formally describe arbitrary QoS parameters. Additionally, [5] and [7] attempted to conduct a proper evaluation framework and proposed QoS-based service selection, despite the authors failing to present a fair and effective evaluation algorithm.

On the other hand, existing work targeting on P2P-based Web service discovery includes several major relevant proposals. METEOR-S [6] and HyperCup [12] base the distribution of semantic Web service descriptions on a classification system expressed in service or registry ontologies. In our opinion, these solutions are good in terms of organizing registries to benefit service management rather than for the service discovery or selection itself. Though it is relatively effective to publish and update service description information based on their categories, it would be difficult for service requestors to select certain services without understanding details of their principles. In contrast, our new UOW-SWS is built by taking considerations of new intuitive correlations between various service quality measurements and also testified upon a well-founded peer-to-peer e-service workflow system, which the authors have developed in the past [14].

6. Conclusion

In dynamic and decentralised environments, how to utilise WSMO to extend QoS and spatial-featured mechanism into e-services' composition is a significant issue, and it brings a new set of critical challenges and requirements yet to be explored and answered. In this paper, we present an autonomous and scalable ontology-based methodology to describe QoS and geographic features of the Web services and the peers who truly invoke them in a P2P-based environment. Moreover, semantic Web services selection is a process to automatically find appropriate Web services that effectively fulfil the requestor's requirements. We augmented WSMO description by involving real QoS perspectives and geographic profiles, and also designed and implemented a generic and effective algorithm to facilitate the peer selection.

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