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## Disciplines

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# QoS-Aware Service Selection in P2P-Based Business Process Frameworks

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## Abstract

*With the advances and evolution of semantic Web services, service providers need to be more competitive, efficient, flexible, and integrated in the service network at different scenarios, including static and dynamic deployments and interactions. Recently, OWL-S and QoS-aware services have been distinguished due to their significance and their impact on decentralised network. JXTA and BPEL allow peers to cooperate and automate business processes and reengineer their structure, so as to rationally select and make use of all resource in decentralised environment; in addition, they increase efficiency and reduce costs. We incorporated several typical constraints to testify the possibility of the application of QoS-aware services in a P2P network, and enhanced the performance of the relevant prototype.*

## 1. Introduction

In a dynamic e-service environment, it is desirable for service consumers and providers to offer and obtain guarantees regarding their capabilities and requirements [13]. Thus, the innovation and development of semantic Web service will play a significant role in better exploiting service at the business and technical level [20]. While quality of service (QoS) has been a major concern in the area of networking, only a few research groups have concentrated their efforts on improving the composition of Web services to support management of complex services execution in dynamical environment for decentralised network, though, some e-business researchers are interested on developing QoS for Web services [22, 25]. Yet, the dynamic composition of distributed services [2] has triggered a few new challenges for grid computing, due to the high demand on Peer-to-Peer (P2P) network. For example, previously, there was little QoS and OWL-S [14] ontology consideration in our SwinDeW-B [19]. To enhance QoS specification with OWL-S ontology, herein we present a framework based on a P2P model for execution of Web service and a set of functions to fulfill the overall QoS with OWL-S ontology.

For service providers and service requestors, to characterize peer's performance, we proposed QoS-OWL, which means that the description and specifications of QoS are associated with OWL-S ontology, and it has the following four distinct advantages. First, it allows service providers to translate their service information into OWL-S description more efficiently, since the OWL-S ontology can enrich the QoS profile semantic description for service requestors. For e-commerce processes it is important to know what the QoS application will exhibit before making the service available to its requestors. Second, it allows for the allocation and execution of tasks performed by different peers, to better fulfill customer expectations. As P2P network carries out more complex and mission-critical applications, QoS architecture serves to ensure that each application peer meets the requirements for providing customers the better services. Thirdly, it makes the monitoring of peer's performing with QoS restrictions possible. The execution of peer must be rigorously and constantly monitored throughout their life cycles to assure its compliance with both initial QoS requirements and targeted objectives. QoS monitoring allows adaptation strategies to be triggered when undesired metrics are identified or when threshold values are reached. Last but not least, it allows for the evaluation of alternative strategies when adaptation becomes necessary. The unpredictable nature of the surrounding environment has an important impact on the strategies, methodologies, and structure of service processes. Thus, in order to suit for dynamical environment according to initial QoS requirements, it is necessary to adapt and reschedule a strategy in response to unexpected technical conditions.

This paper presents a typical application for the QoS specification of P2P as well as the methods to

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design and utilize QoS-OWL. We start by investigating the relevant QoS features that are necessary to correctly characterize Web services. We not only target the QoS profile for Web services, but also investigate the metrics required to develop a real and usable QoS model with OWL-S ontology. Once the QoS profile and associated metrics are selected, it is possible to develop algorithms or policies and to select methods to apply them in application model. In our SwinDeW-B, quality metrics are associated with the criteria in choosing peer and tasks' allocation. The evaluation of peer's QoS is done based on the requirements and metrics. We present a method and also show how SwinDeW-B can be coupled with a typical Web service in order to apply QoS and OWL-S ontology.

This paper is structured as follows. Section 2 describes the background and requirements analysis about the OWL-S and QoS for SwinDeW-B. Based on our scenario, OWL-S requirement is derived and the current limitations of QoS in P2P model are stated. In section 3, we introduce QoS-OWL's structural design and the implementation in SwinDeW-B, such as QoS profile with OWL-S ontology and the QoS Metrics. Then we demonstrate how QoS-OWL in our prototype is fulfilled in section 4. Section 5 compares related work on QoS and OWL for Web service. Finally, section 6 presents our conclusions and further research.

## 2. Background and Requirements Analysis

### 2.1 SwinDeW-B: Extending SwinDeW with BPEL4WS

SwinDeW [24] is a JXTA-based [7, 21] decentralised workflow management system developed by our previous researchers to overcome the problems like poor performance, poor scalability, unsatisfactory system openness, and lack of support for incomplete process. SwinDeW-B is the extension of SwinDeW based on BPEL4WS [1, 6] technology.

The SwinDeW-B's architecture is composed of a P2P system built in the JXTA framework. BPEL is chosen as the language to orchestrate composite Web services. A composite Web service is described by a BPEL file and a set of WSDL files. By processing the files a Coordinator peer obtains the knowledge of which activities to be performed and the temporal order of performing them to complete a composite Web service. The Coordinator peer then converts the knowledge into the format that can be distributed into the P2P network without losing any information about the structure of the process. The member peers hosted elsewhere on P2P network are chosen to allocate parts of the process based on their capabilities. One capability is the ability whether a peer can invoke a Web service when its owner plugs a specific Web service invocation component in it, i.e. a relevant task in whole business process. The process is executed by executing its activities hosted by individual member peers. The output result of the execution on a peer is transferred to the other peers of the post activities through messaging mechanisms of the JXTA pipes [21]. Communications between the peers and their Web services are via the SOAP protocol.

Each peer that was appointed for a task by coordinator in a group can invoke the required Web service from service providers, and there is no difference between coordinator and peer after the coordinator assigning the tasks, so they actively cooperate in the P2P network to execute the invocation of Web services with same manner.

In SwinDeW-B, a BPEL4WS process can be converted into the CFG (Control Flow Graph) [17, 12] form so as to ensure the coordinator split the process without constraints. For the purpose of orchestrating and executing composite services, nodes in a CFG graph are basic activities. Each node knows a set of its predecessors and a set of successors as well as the conditions for it to be executed, if any. The decentralised run-time environment can be coordinated and self-managed effectively with services being located to wide area peer hosts, who communicate with each other according to the de facto standard business process or workflow definitions.

### 2.2 Requirements Analysis on OWL-S and QoS

OWL-S [14] is ontology to describe Web services with rich semantics. It allows software agents to discover, invoke, compose and monitor Web services with high degree of automation in dynamical situations. OWL-S ontology consists of three main components: the service profile, the process model and the grounding. The service profile is for advertising and discovering Web services. The process model is used to describe detailed operations of services and define composite Web services. And the grounding is used to map the abstract definition of services to concrete specifications of how to access the services.

In this paper, we just present an overview of the service profile component of the ontology. The service profile does not mandate any representation of services; rather, using the OWL subclass it is possible to create specialized representations of services that can be used as service profiles. OWL-S provides one possible representation through the class Profile. An OWL-S profile describes a service as a function of three basic types of information: what organization provides the

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service, what functions the service computes, and a host of features that specify characteristics of the service. For instance, the descriptions about Web services including the quality of service can be included in the service profile, so that we can enhance and improve the automation and reliability of Web services' composition in dynamical circumstance.

Quality of Service (QoS) is an important criterion for Web service selection in dynamic environment [9]. Generally speaking, QoS refers to the capability of a network to provide better service to selected network traffic over various technologies. The dynamic e-business vision calls for a seamless integration of business processes, applications, and Web services over the Internet. Delivering QoS in the P2P network is a critical and significant challenge because of its dynamic and unpredictable nature. Changes and delay in traffic patterns, denial-of-service attacks and the effects of infrastructure failures, low performance of Web protocols, and security issues over the Web are creating QoS complications for decentralised network. Often, unresolved QoS issues cause critical transactional applications to suffer from unacceptable performance degradation.

For Web service, due to the dynamic and unpredictable nature of the Web, providing the acceptable QoS is really a significant concern. In addition to this, the different applications that are collaborating for Web services interaction with different requirements will compete for network resources. The above factors will force service providers to understand and achieve Web services QoS. Also, a better QoS specification for a Web service will bring competitive advantage over others by being a unique selling point for service provider. The Web services QoS requirement mainly refers to the quality, both functional and non-functional, aspects of a Web service. This includes performance, reliability, integrity, accessibility, availability, interoperability, and security [10]. The properties become even more complex when adding the need for transactional features to Web services. Therefore, quality of services is an important requirement of cooperation in P2P network and thus a necessary element in Web services.

## 3. Design and Implementation

We are focusing on automatic services composition in decentralised environment, and found the quality of service is a big issue in dynamic composition and the P2P network's performance is being enhanced. As the OWL-S ontology developing quickly, the semantic requirement for service's description is becoming necessary for more complicated and unpredictable nature of services process. QoS and OWL-S can be used to relief this pressing situation for distributed Web services application in real business case. For this purpose, we designed a set of strategies to meet the dynamical demands in decentralised network.

### 3.1 Typical Application Case

The administrator of a SwinDeW-B peer can register Web services with the peer. When a Web service is registered with the peer, the peer can be discovered by a SwinDeW-B Coordinator peer to perform the <invoke> activity which needs the Web service. The register information includes the description of the Web service and the full name of a Java class and method which is plugged into the peer so that the peer is able to call the Web service.

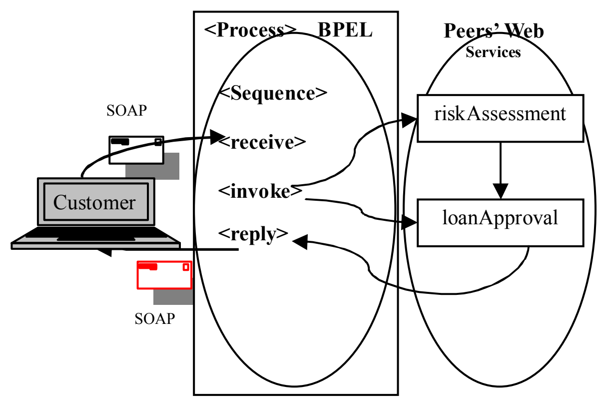


**Figure 1: Application for Loan Case**

Figure 1 shows a typical loan application process deployed in SwinDeW-B. At the beginning, Customer sent a loan request to financial organization, and then a Coordinator peer, who has the knowledge of whole BPEL process, will seek the right peers to fulfill the whole task by sending Pipe messages and selecting the most appropriate one. For the whole task, it consists of two small single services: 'riskAssessment' and 'loanApproval'. 'riskAssessment' is to provide the service 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 loan amount) of 'loanApproval', can the loan application be approved, otherwise, the loan request will be rejected.

### 3.2 QoS-OWL Approach

Simply speaking, service providers can proactively provide high QoS to the service requestors, by using

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the two approaches: generating QoS information according to different services and pre-loading the QoS-OWL by Peer. In the JXTA network, the two approaches can be done at both Coordinator level and at Peer service level. Pre-loading the QoS-OWL is to prioritize various types of QoS parameters such as ResponseTime and the services' availability in order to ensure that each request is treated appropriately to the performance value as it represents. A Web service provider can advertise its capacity through the broadcast function in JXTA and pass its QoS information to the Coordinator so that the Coordinator would be able to choose the appropriate peers to perform the service task. A service provider can also categorize the QoS for Web service by different standards for different tasks, like the risk assessment and loan approval. The Coordinator can provide differentiated servicing by identifying the capacities of Peers to determine the capacity needed for different tasks and service types and by ensuring appropriate QoS levels for different applications by Peers.

The figure 2 shows the relationship between QoS and OWL-S in SwinDeW-B model. OWL-S is used to describe the QoS information for service provider with its semantic features. QoS Metrics are pre-loaded by Coordinator to identify which peer can satisfy the QoS requirements, where there are a few specifications, such as Response Time, Start Time, End Time, etc. The QoS information of individual peer is filled according to the QoS profile, based on its QoS performance, i.e. a different peer usually has different QoS values. Through this way, we can ensure that Coordinator always chooses the most appropriate peer to fulfill tasks despite there are too much complicated dynamical changes.

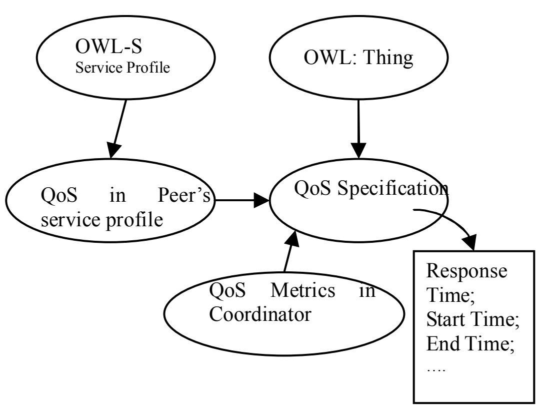


**Figure 2: Associated QoS with OWL-S**

### 3.3 Implementation in SwinDeW-B

We designed the QoS-OWL ontology together with its QoS-aware services discovery framework in P2P environment. This is an ontology designed for the QoS-Aware service discovery and measurement for SwinDeW-B model. This new ontology is designed as a complementary OWL-S ontology to provide the semantic description about QoS-Aware service discovery and measurement service. For our SwinDeW-B model, the Coordinator can extract the Peers' QoS information in OWL file and then choose the right peer according to the QoS requirement of service requestor. The matchmaking method for QoS property constraints with multiple matching requirements has been implemented. Well-defined metrics can be further utilized by Coordinator to check whether the service provider conforms to the agreement. For different usage phases of the QoS-OWL, we designed the QoS description framework and the matchmaking framework for SwinDeW-B. Furthermore, based on the ontology level, semantics in the specification helps to achieve better interoperability, automation and extensibility. To prove the applicability of the system in real e-business world, we tested the prototype framework and found its potential usage in real Web service environment.

The following are samples of profiles we had developed.

**Profile definitions used in DefineQoS.owl:**

```
<owl:DatatypeProperty
   rdf:about="http://localhost:8080/DefineQoS.owl#res
   ponseTime">
      <rdfs:domain>
         <owl:Class
rdf:about="http://localhost:8080/DefineQoS.owl#QoS
Profile"/>
      </rdfs:domain>
          <rdfs:range
             rdf:resource="http://www.w3.org/2001/X
             MLSchema#dateTime"/>
</owl:DatatypeProperty>
```

The 'responseTime' is used for measuring the service performance of peer. This parameter is loaded by peers who can provide the requested services. The values of 'responseTime' are sent to Coordinator peer, then the Coordinator peer would select the most appropriate one to fulfill the requested service.

```
<owl:DatatypeProperty
    rdf:about="http://localhost:8080/DefineQoS.owl#st
    artTime">
     <rdfs:domain>
         <owl:Class
```

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```
rdf:about="http://localhost:8080/DefineQoS.owl#QoS
Profile"/>
        </rdfs:domain>
            <rdfs:range
                rdf:resource="http://www.w3.org/2001
                /XMLSchema#dateTime"/>
</owl:DatatypeProperty>
<owl:DatatypeProperty
rdf:about="http://localhost:8080/DefineQoS.owl#endT
ime">
    <rdfs:domain>
        <owl:Class
rdf:about="http://localhost:8080/DefineQoS.owl#QoS
Profile"/>
      </rdfs:domain>
        <rdfs:range
rdf:resource="http://www.w3.org/2001/XMLSchema#
dateTime"/>
</owl:DatatypeProperty>
```

The ‘startTime’ and ‘endTime’ provide the restriction to choose the available peers to fulfill the service task, avoiding allocating the task to an inappropriate and unavailable peer. The date format is ‘XMLSchema#dateTime’ that is a standard format of date. Based on the properties in QoS profile, we’ve built a series of mechanism to value peers’ performance of service in dynamic situations, especially for the beginning task of choosing the right peer at present.

The following is a sample of QoS metric for Coordinator to select peers.

**Metric definition about ‘currentTime’ and ‘responseTime’:**

```
<owl:DatatypeProperty
    rdf:about="http://localhost:8080/QoSMetrics.owl#c
    urrentTime">
      <rdfs:domain>
        <owl:Class
rdf:about="http://localhost:8080/DefineQoS.owl#QoS
Profile"/>
      </rdfs:domain>
          <rdfs:range
              rdf:resource="http://www.w3.org/2001/X
              MLSchema#dateTime"/>
</owl:DatatypeProperty>
<owl:Restriction>
   <owl:onProperty
      rdf:resource="http://localhost:8080/QoSMetrics.o
      wl#responseTimeMS"/>
        <owl:maxCardinality
          rdf:datatype="http://www.w3.org/2001/XML
          Schema#nonNegativeInteger">5000</owl:m
          axCardinality>
</owl:Restriction>
```

Coordinator can use the current time to compare with peers’ service start time and end time, the peers would be considered to perform a task as long as its service’s start time is after the current time, and the service end time is earlier than the current time. Another metric is for a Coordinator to identify peers’ ‘responseTime’ of processing a service. This parameter in an OWL file can be read initially by Coordinator as a criterion of choosing appropriate peer. For example, in some scenario, only the ‘responseTime’ of a peer is less than 5000ms, will the peer be chosen to perform the task.

## 4. Prototype

We designed these QoS specifications and integrated them successfully onto SwinDeW-B, so that it enhanced the performance of decentralised service providers. Metrics such as responseTime, startTime and endTime are the example and representative requirements for the QoS for Web services. The following is a peer’s QoS profile for the Web service.

```
<?xml version="1.0" encoding="ISO-8859-1" ?>
<rdf:RDF
    xmlns:rdf=http://www.w3.org/1999/02/22-rdf-synt
    ax-ns#
xmlns:rdfs=http://www.w3.org/2000/01/rdf-schema#
xmlns:owl=http://www.w3.org/2002/07/owl#
xmlns:xsd="http://www.w3.org/2001/XMLSchema#"
xmlns:serviceqos="http://localhost:8080/DefineQoS.o
wl#"
xmlns:PeerProfile="http://localhost:8080/PeerProfile.o
wl#">
……
<serviceqos:startTime
    rdf:datatype="http://www.w3.org/2001/XMLSche
    ma#dateTime">2006-09-24T09:00:00</serviceqos
    :startTime>
<serviceqos:endTime
  rdf:datatype="http://www.w3.org/2001/XMLSchem
  a#dateTime">2008-09-24T09:00:00</serviceqos:en
  dTime>
<serviceqos:responseTime
  rdf:datatype="http://www.w3.org/2001/XMLSchem
  a#string">200</serviceqos:responseTime>
…</rdf:RDF>
```

This quality of service model is developed to allow for the specification of P2P workflow QoS metrics.

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This model allows service suppliers to specify the duration, quality, response time, etc., of the services. Specifications can be set at design-time, when designers build workflow applications, or can be adjusted on-the-fly at run-time. Algorithms and methods are developed to estimate the quality of service of a peer both before instances are started (e.g. responseTtime) and during instance execution (e.g. busyRate). The estimation of QoS before instantiation allows service suppliers to ensure that the processes to be executed will indeed exhibit the quality of service requested by customers. The monitoring of Peer QoS during instance execution allows Coordinator to constantly check and adjust the peer's performance according to the QoS metrics.

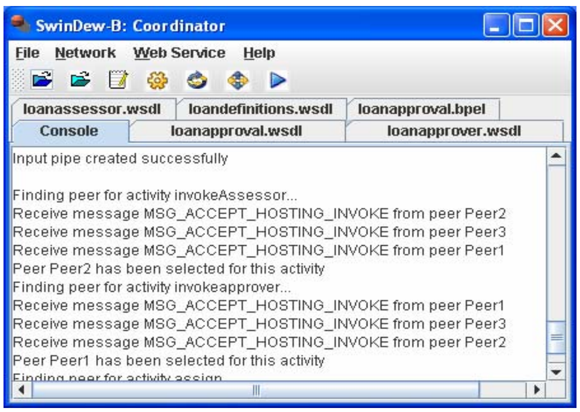


**Figure 3: The process of Previous SwinDeW-B Model**

In figure 3, Coordinator tried to find a peer who can perform the 'invokeAssessor' activity, and received three messages from peer1, peer2 and peer3 respectively. Because there is no any QoS premise for selection, the three peers are regarded as same, and peer2 is chosen randomly to fulfill the task. Nevertheless, for the real dynamic circumstance, it is not reasonable for Coordinator to allocate tasks without any consideration on different peers' performance in decentralised network.

From figure 4, we can see that the Coordinator also received the messages from three peers. Peer1's response time is 200ms, and Peer2's is 500ms, and Peer3's is 8000ms, but the QoS requirement on Response Time is 5000ms, so obviously the Peer3 cannot meet the requirement of Coordinator, and Peer1 is the most appropriate one to fulfill the task. Then the Peer1 can be assigned to perform that activity. Furthermore, Coordinator is monitoring the peers' situation, and using the busy rate to identify the burden and performance of current peer, for example, if Peer1 has been assigned a task, then the Peer1's busy rate would be set to 1 (0 is the default value), likewise, once Peer1 got another task assigned, its busy rate will be increased by 1. And each time when Coordinator is going to choose a peer to fulfill an activity, the peer who with the lowest busy rate will be assigned the task. Thus, the resources of Peer can be utilized completely and rationally.

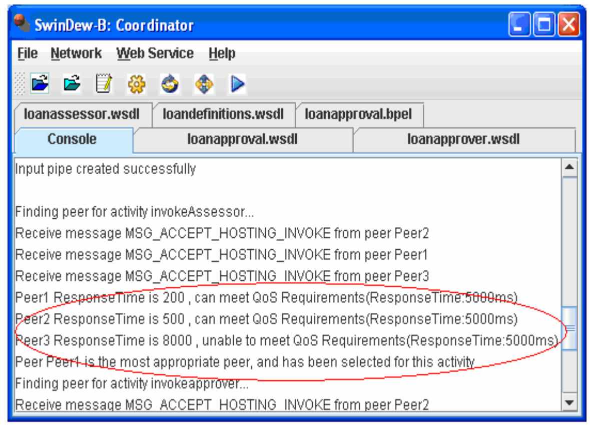


**Figure 4: Enhanced SwinDeW-B Model with QoS-OWL**

## 5. Related Work

Functionality and non-functional properties are two essential aspects for semantic Web service. Functionality is used to measure whether this Web service meets all the functional requirements of an anticipated Web service, i.e. Web services matchmaking; while non-functional properties are qualified to evaluate the performance of the Web service. This has been viewed as a sufficient means to distinguish functionally similar Web services. Recently, QoS-Aware service selection and composition have gotten considerable attention. In [26], authors provide QoS ontology as a complement for DAML-S [3] ontology to provide a better QoS metrics model, which is very significant for enhancing non-functional properties. Furthermore, the authors of [27] briefly propose the QoS matchmaking algorithm with multiple matching degrees. On other hand, authors of [13] developed so-called WS-Agreement and agreement matching, so that service providers and consumers may automatically make the most accurate and effective partnerships which are tailored to user preferences. In practice, the METEOR-S project [11] proposes a framework for the annotation of Web services and analyses the dimensions of cost, time and reliability. The use of semantics in describing the functional and non-functional capabilities of Web services is the approach in [23] for process configuration.

Many research works have been done to take QoS

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requirements into evaluation as well as selection and composition of Web service. Some significant QoS attributes for Web service are discussed in [16], and those attributes can be adopted to evaluate and monitor the performance of service execution, but our main purpose in this paper is to testify the possibility of QoS-aware service in P2P network by a set of typical and simple specifications. In [15], the author proposed a QoS model which offers a QoS certified to verify QoS specification from the Web service providers. This approach lacks the ability to satisfy the dynamic situations where the performances of service providers are constantly changed, especially in decentralised network [18]. In [25], authors proposed a global planning approach to optimally select component services during the execution of a composite service. This proposed approach is quality-driven and using Multiple Attribute Decision Making (MADM) [8] approach to select optimal execution plan. Currently, this approach is not efficient and appropriate for P2P network composite distributed services, despite that it can process much more complicated services selection and composition in dynamic environment. The main problem is that it requires generating all possible execution plans, and the computation cost is higher for P2P network. On the contrary, the QoS-Aware Web service profiles in our SwinDeW-B, are based on inherent decentralised Web services composition, so we can improve the composition efficiency and performance of Web service in decentralised network.

There are many work have been done to develop languages for specifying the QoS description for Web services. OWL-S ontology [14] is the most popular QoS Web service approach that supports the description of nonfunctional requirements parameters. In [5], an ontology QoSOnt was proposed as an extension to OWL-S and works in symbiosis with OWL-S. It is designed to provide a common QoS conceptualisation for services provider, services requesters or a third party inter-mediator. In addition, [4] is to produce a unified QoS ontology, and the authors evaluated existing QoS ontologies by explaining deficiencies and possible improvements, so their research results would be helpful for development of QoS-Aware service.

## 6. Conclusion and Future Work

In dynamic decentralised environment, how to incorporate QoS and OWL-S semantic features into Web services' composition is a significant issue, and it brings a new set of challenges and requirements that need to be explored and answered. Many e-commerce applications are composed of Web services in workflow form with BPEL, which in turns represents an abstraction of cross-organizational business processes. The use of JXTA to conduct and coordinate peer's services in a heterogeneous and distributed environment has an immediate operational requirement: the management of distributed services provided by peers. The composition of Web services, and therefore non-functional semantics of Web services, cannot be undertaken while ignoring the importance of QoS consideration. Service agreements between suppliers and requestors include the specification of QoS items such as services' available time, expiration, response time, and busy rate. The correct design of such QoS specification directly impacts the success of service organizations participating in e-commerce P2P network and also directly impacts the success and evolution of e-commerce itself.

In this paper, we showed the importance of semantic QoS developing for Web services' composition. We presented a comprehensive background about QoS and OWL-S. Those allow for the semantic description of Web services from a QoS perspective. The specification of QoS increases the added value of performance to P2P service network, since non-functional aspects of service providers can be described. For the QoS of service requirements (tasks or Web services), the QoS parameters and values can be automatically loaded before services' selection. This feature is important, especially for large and complex processes that in some cases may contain hundreds of tasks. We present a basic model that describes the essential QoS metrics for a banking loan case. Based on these aspects, we have developed QoS-OWL specifications to automatically choose the right peer to fulfill the allocated task by Coordinator. We also describe how SwinDeW-B can be enhanced with QoS features to carry out efficient service request.

In the near future, the QoS-OWL will be designed to incorporate much more comprehensive service profile and metrics, and also P2P based SwinDeW-B will be able to be applied to develop those strategies and policies under the dynamic circumstance more effectively. Thus, we will be developing more complicated and useful specifications as well as protocols to enhance the accessibility, reliability and availability of Web services in P2P network.

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