Web Services Discovery Based on the Trade-off between Quality and Cost of Service: A Token-based Approach

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A Web service is an autonomous unit of application logic that provides either some business functionality or information to other applications through an Internet connection. Web services discovery is the process of finding most appropriate Web services providers needed by a Web services requestor. One of the important issues in the discovery process is for Web services providers and Web services requestors to negotiate and find an integrative solution that is optimal to both sides. Web services providers use resources to provide services to requestors in return for benefits. On the other hand, Web services requestors pay for services from providers in return for benefits as well. In this scenario, both parties should have their own cost-benefit models for making such a business decision. In convention, fixed pricing strategies are used for Internet-related business models such as online bookstores. However, these may not be suitable in some business models. For example, data mining services are always one-of-a-kind services, expensive and non-repetitive that usually require a more sophisticated business model. Therefore, sophisticated Web services providers should provide a list of trade-off alternatives between the Quality of Service (QoS) they offer and the Cost of Service (CoS) they use to requestors. In this model, the QoS relates to performance-oriented capabilities and the CoS relates to services' resource requirements. To achieve an integrative solution, both parties have to evaluate the list of QoS and CoS alternatives for obtaining an appropriate combination. One of the negotiation strategies for achieving integrative solutions is called logrolling. Traditionally logrolling in two-issue (i.e., the QoS and CoS) and two-party (i.e., the Web services provider and requestor) negotiation is defined as the exchange of loss in one issue for gain in other issues that result in an increase of the overall values for both parties. It means that each party can increase the overall value by trading the less preferred issue for the more preferred, provided that a trade-off ratio is satisfactory. This paper presents a token-based approach to quantify the QoS and CoS for achieving integrative solutions.

Categories and Subject Descriptors: J.4 [**Social and Behavioral Sciences**]: economics; H4.2 [**Types of Systems**]: Decision support;

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1. INTRODUCTION

In the past few years, many companies have been forced to reorganize their businesses by using the best technologies from different vendors in order to remain competitive in a business world. Current trends in Information and Communication Technology (ICT) may accelerate the widespread use of Web services in business [1]. Web services have become more and more popular in the research community as well as industry. Some studies [11] even show that the Web services market is expected to grow to USD$28 billion in sales in the coming three years.

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In this paper, a Web service is an autonomous unit of application logic that provides either some business functionality or information to other applications through an Internet connection. It is well known that Web services are based on a set of XML standards such as Simple Object Access Protocol (SOAP), Web Services Description Language (WSDL), and Universal Description, Discovery and Integration (UDDI). Web services have cost, but they also produce benefit. Like in any profit-making organizations, Web services providers use resources to provide services to requestors in return for benefits. On the other side, Web services requestors pay for services from providers in return for benefits as well. In such an environment, it is believed that some requestors may tend to find the geographically closest Web services, the cheapest, or any other combination of the above. Thus, both parties should have their own cost-benefit models for making such a business decision.

One can imagine that Web services providers should register their Web services descriptions at a business directory for public to access. In such an environment, there may have a mediator (i.e., a service locator) that finds appropriate Web services for requestors. This process is called matchmaking [34]. In convention, fixed pricing strategies are used for Internet-related business models such as online bookstores. However, these may not be suitable in some business models. For example, data mining services are always one-of-a-kind services, expensive and non-repetitive that usually require a more sophisticated business model. Therefore, sophisticated Web services providers should provide a list of trade-off alternatives between the Quality of Service (QoS) they offer and the Cost of Service (CoS) they use to requestors. Further, Web services providers can provide differentiated servicing by using the capacity model to determine the capacity needed for different Web services requestors and by ensuring appropriate QoS levels for different applications [39]. In this model, the QoS relates to performance-oriented capabilities (e.g., distance and time) and the CoS relates to services' resource requirements (e.g., funds, human resources and time). To achieve an integrative solution, both parties have to evaluate the list of QoS and CoS alternatives for obtaining an appropriate combination. In the literature, this commercial negotiation is generally concerned with buying and selling of goods or services and also with the associated topics of quality, specification, delivery, and service [7].

In particular, this paper focuses on an integrative negotiation for both parties (i.e., the Web services provider and requestor) [28]. The term integrative negotiation refers to the processes by which both parties locate and adopt the option that provides greater joint utility to the parties taken collectively. The major reason to adopt integrative negotiation is that integrative negotiation always reduces the likelihood that negotiations will fail, by making it possible to locate options that satisfy parties' ultimate expectations [22]. One of the negotiation strategies for achieving integrative solutions is called logrolling [20, 26]. In logrolling, both parties can often discover integrative solutions. Traditionally logrolling in two-issue (i.e., the QoS and CoS) and two-party (i.e., the Web services provider and requestor) negotiation is defined as the exchange of loss in one issue for gain in other issues that result in an increase of the overall value for both parties [27, 35]. Each party can increase the overall value by trading the less preferred issue for the more preferred, provided that a trade-off ratio is satisfactory. Trade-offs can be arranged when two or more issues are considered simultaneously, in which logrolling potential may exist. In consequence, when both parties provide high benefit to one another their mutual attraction is likely to be enhanced [20]. Furthermore, attraction will probably produce trust, contributing to the capacity to find more integrative solutions in the future. This paper presents a token-based approach to quantify the QoS and CoS for achieving integrative solutions. The remainder of this paper is organized as follows: Section 2 discusses the background information and related work in the literature. Next, Section 3 discusses the trade-offs between QoS and CoS. Then, Section 4 proposes a multilateral matchmaking framework to support such a model. Lastly, Section 5 discusses the conclusions and future research.

2. BACKGROUND INFORMATION

Logrolling is not a new idea and it does exist for a long period of time in certain research areas. In political sciences, a logrolling situation exists in the trading of votes by legislators [31]. For example, a legislator offers to another to trade his vote on a certain bill in return for the other's votes on a second and a third bill. Further, there are two types of logrolling [29]. One is explicit logrolling that involves individuals who trade their votes on many individual issues to many others for votes on other issues. Another one is implicit logrolling that involves political parties or candidates who present platforms with different measures. Similarly, in public choice, a logrolling situation exists when two or more issues are defeated when an individual sincerely state his preferences of these issues and pass when some individuals trade votes [18].

Specifically Foroughi and Jelassi [6] point out that negotiators always have cognitive biases such as the consideration of issues one at a time, negative framing of the negotiation, the fixed-pie, win-lose mentality, premature closure, and preference for more available solutions. Therefore it is always hard to explore logrolling potential. In particular, Froman and Cohen [10] demonstrate the importance of logrolling. The results show that negotiators tend to consider issues one at one time for compromising, because it is cognitively difficult for negotiators to integrate multiple issues into a single package. By using such a strategy, it is hard to explore potential trade-offs between different issues. The results also point out that logrolling can always achieve a better solution. For illustration, here is an example of logrolling, *Party 1* (Web services requestor) and *Party 2* (Web services provider) are negotiating over two issues of a Web service: execution time and cost. The sets of alternatives in those two issues are represented in packages *A*, *B* or *C*. This is a typical situation where logrolling can be implemented between *Party 1* and *Party 2*. In convention, many parties place all issues on some common dimension such as a point scale [16]. Table 1 shows the points in the unit of dollars gained by each party on different alternatives. It is assumed that every rational party prefers a higher number of dollars than a lower number. If *Party 1* and *Party 2* bargain on the issue of time, *Party 1* will prefer *Alternative A* while *Party 2* will want *Alternative C*. In a result, the most likely outcome is a compromise at *Alternative B*. In a similar way, the negotiation process on cost will also be a compromise at *Alternative B*. In this situation, both parties will get a value of $8. However, if *Party 2* accepts *Alternative A* on the issue of time and *Party 1* accepts *Alternative A* on the issue of cost. Both parties will get a total value of $16, i.e., *Party 1* will get $18 (time) + $-2 (price) = $16 and *Party 2* will get $-2 (time) + $18 (price) = $16. This example illustrates the manner in which logrolling may be more efficient and effective than compromising. As a result, *Party 1* loses in the issue of cost and gains in the issue of time and *Party 2* loses in the issue of time and gains in the issue of cost.

Table 1. Example of Logrolling and Compromise

	Time		
Party	**A**	**B**	**C**
1	**$18**	**$8**	**$-3**
2	**$-2**	**$0**	**$2**

	Cost		
Party	**A**	**B**	**C**
1	**$-2**	**$0**	**$2**
2	**$18**	**$8**	**$-3**

The example demonstrates that each party can increase the overall value by trading the less preferred issue for the more preferred, especially when an acceptable trade-off ratio (exchange rate) is provided. In addition, the relationship between the trade-off ratio and other negotiation entities [36] in logrolling is depicted in Figure 1. Referring to Figure 1, negotiation involves a set of issues and every issue contains a set of alternatives. Further, the set of issues may also be constrained by a set of criteria. In order to reach a settlement, all parties must take complementary actions on each issue. Each party has a set of preferences with respect to what alternatives are taken on each issue and how important these matters are. In general, the trade-off ratios are referred to the preferences on the selected issues with related alternatives and also constrained by the criteria (if any).

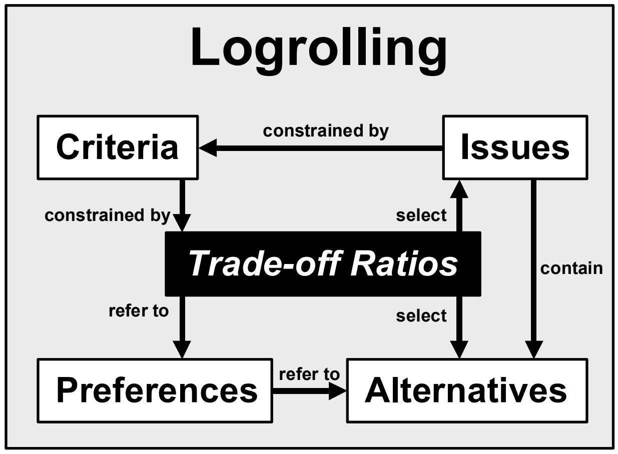

Figure 1. Trade-off Ratios in Logrolling

3. TRADE-OFFS BETWEEN QUALITY OF SERVICE AND COST OF SERVICE

One of the major processes in a loosely coupled Web services execution environment is matchmaking, that is, an appropriate Web service is assigned to satisfy a requestor's requirements with or without the assistance of a service locator [37]. Alternatively, matchmaking can also provide a ranked list of the *n* best candidates with respect to the requestor's requirements [30]. Usually, more than one Web services claim that they have the same or very similar capabilities to accomplish a requestor's requirements. In many cases, the QoS may vary from Web service to Web service. In many cases, the majority of Web services providers are not concerned about the level of QoS provided to their requestors [32]. However, there exist an increasing number of concerns to maintain their popularity and reputation about the QoS [15]. It is obvious that the QoS perceived by the requestors is thus becoming a dominant factor for the success of a Web service in the future. In general, the principal QoS attributes of a Web service include a diverse set of service requirements such as the service availability, accessibility, performance, time, efficiency, reliability, scalability, dependability, regulatory, integrity and security [2, 5, 39]. CoS is measured by the resources required to procure the QoS such as capital, hardware, software or network bandwidth. Thus, matchmaking can be based on binding support, historical performance, QoS and CoS classifications [12]. As Web services become more popular and complex, the need for locating Web services with specific capabilities at the service locator become more and more important.

When several issues are related, they are often packed together as an issue group [21]. This paper considers the QoS and CoS as two issue groups. All the sub-issues included in QoS [39] and CoS [14] are out of scope of this paper. This paper presents a token-based approach [33] to quantify these two issue groups. Figure 2 shows a conceptual model of QoS and CoS that involves two parties (i.e., Web services providers and requestors) and two issue groups (i.e., QoS and CoS). A Web services provider uses certain resources (R) to provide services in return for dollars (D) from Web services requestors. Dollars can be added, subtracted, multiplied, divided, integrated and differentiated, making it possible to evaluate trade-offs explicitly [9]. From another point of view, R is the costs and D is the benefits to the Web services provider. Benefits are the consequence of an action that protects, aids, improves, or promotes the well being of the party. Benefits take the form of cost savings, cost avoidance, and improved operational performance. On the other hand, a Web services requestor pays D to get R from Web services providers. Similarly, D is the costs and R is the benefits to the Web services requestor. Usually the Web services requestor expects a basic QoS from the Web services provider and also the Web services provider promises to provide the QoS based on a basic CoS from the Web services requestor. In such a relation, both parties should have their own cost-benefit analyses to estimate and compare the costs and benefits of an undertaking situation [14]. To maximize the possible benefits for both sides, both parties may have to share knowledge about the range of QoS and CoS alternatives for both provider and requestor in order to evaluate the best alternative.

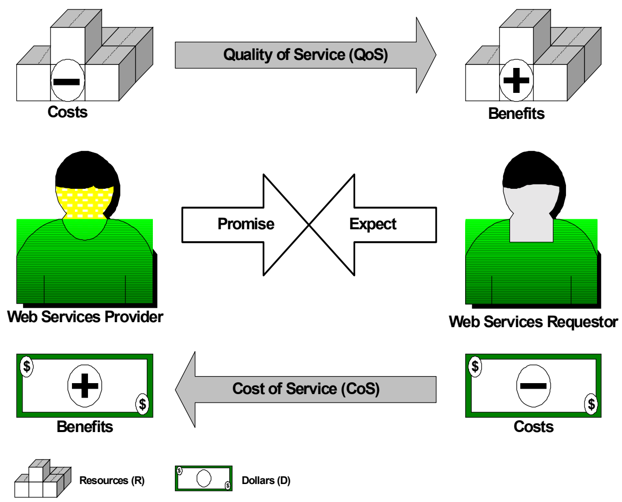

Figure 2. A Conceptual Model of QoS and CoS

A Web service should not only quote the best QoS it can offer, but also list a range of alternatives and their associated costs as other options instead. The Web services providers should make their different modes of services explicit by stating the different possible qualities and their associated costs. Further, both parties may have to set best- and worst-case boundaries on the value of the intangible benefits because this would provide a reliable range of predicted benefits to consider. Though this best- and worst-case topic is out of the scope of this paper, there are generally three general criteria to compare alternatives when performing cost-benefit analyses [14]:

- Maximize benefits for given costs and minimize costs of a given level of benefits;
- Maximize the ratio of benefits over costs;
- Maximize the internal rate of return on the investment.

Then trade-offs among the intangible benefits can be calculated based on the alternatives that involve similar tangible benefits. When both sources of information are available from both parties, an optimization can be carried out to select an appropriate combination of QoS and CoS for a particular situation [3].

R and *D* are measured by tokens as shown in Figure 3. *R* is measured in the unit of QoS-token and *D* is measured in the unit of CoS-token. Note that the quantities of tokens may have a linear relation or even an exponential relation with the semantic meaning of the related issue group. For example, the higher the quantities of QoS-tokens are, the higher the level of QoS is. Once the QoS and CoS are measured in tokens, actual token trading between two parties is possible once an equilibrium set of exchange rates has been established. As a result, QoS-tokens and CoS-tokens exchange can lead to an efficient allocation of resources [26]. To understand this token-based approach, this paper develops an abstract model in the context of one single Web service, one single Web service provider and one single Web service requestor as follows. The Web services provider (WSP) has its reservation price (RP_{WSP}) for the Web service, where the RP_{WSP} is the minimum acceptable price for providing the service with basic quality of service (QoS_{basic}). In addition, the maximum QoS (i.e., QoS_{max}) that can be provided by the WSP is also quantified by QoS-tokens, where $|QoS_{max}| \geq |QoS_{basic}|$. Note that the QoS_{basic} and QoS_{max} are the sets of QoS-tokens. On the other hand, Web services requestor (WSR) also has its reservation price (RP_{WSR}) for the Web service, where the RP_{WSR} is the maximum acceptable price for paying the service in the assumption of QoS_{basic} is provided. If the $RP_{WSR} \geq RP_{WSP}$, then there exists a potential business deal with the basic cost of service (CoS_{basic}), where CoS_{basic} = Convert-to-CoS-tokens(RP_{WSP}). Otherwise there is no potential business deal if $RP_{WSP} > RP_{WSR}$. In addition, the WSR may be willing to pay a maximum cost as CoS_{max}, for a better level of QoS, to the WSP if and only if $RP_{WSR} > RP_{WSP}$, where (CoS_{max} = Convert-to-CoS-tokens(RP_{WSR})) and ($|QoS_{max}| > |QoS_{basic}|$). The CoS_{basic} and CoS_{max} are the sets of CoS-tokens. Specifically there exists a negotiation zone for determining trade-off ratio (T) between QoS-tokens and CoS-tokens if and only if ($|QoS_{max}| > |QoS_{basic}|$) and ($|CoS_{max}| > |CoS_{basic}|$). Otherwise, there is no negotiation zone for determining T if ($|QoS_{max}| = |QoS_{basic}|$) or ($|CoS_{max}| = |CoS_{basic}|$). Here are four important sets that are used as state variables in this abstract model:

- QoS_{WSP}, QoS_{WSR} = the set of QoS-tokens holding at WSP and WSR respectively, where $|QoS_{WSP}| + |QoS_{WSR}| = |QoS_{max}|$ and $|QoS_{WSR}| \geq |QoS_{basic}|$.
- CoS_{WSP}, CoS_{WSR} = the set of CoS-tokens holding at WSP and WSR respectively, where $|CoS_{WSP}| + |CoS_{WSR}| = |CoS_{max}|$ and $|CoS_{WSP}| \geq |CoS_{basic}|$.

Next both WSP and WSR have to specify their preferences on those sets of QoS-tokens and CoS-tokens constrained by weight(QoS_{WSP}) + weight(CoS_{WSP}) = 1 and weight(QoS_{WSR}) + weight(CoS_{WSR}) = 1. For example, the WSP may specify weight(QoS_{WSP}) = 0.3 and weight(CoS_{WSP}) = 0.7 that means the WSP prefers to hold more CoS-tokens than QoS-tokens. It may also mean that the WSP prefers to use more resources to improve the level of QoS in return for higher $|CoS_{WSP}|$ value. On the other hand, the WSR may also specify weight(QoS_{WSR}) = 0.8 and weight(CoS_{WSR}) = 0.2 that means the WSR prefers to hold more QoS-tokens than CoS-tokens. It may also mean that the WSR prefers to pay more dollars to increase the level of CoS in return for higher $|QoS_{WSR}|$ value. In an extreme case, the WSR may be well satisfied with the current $|QoS_{WSR}|$ value provided by the WSP and the WSR does not want to have any further improvement if and only if weight(QoS_{WSR}) = 1 and weight(CoS_{WSR}) = 0 are specified. Similarly, the WSP may prefer to save the resources for other purposes (e.g., allocating resources for other works) and the WSP does not want to provide higher QoS to the WSR if and only if the WSP assigns weight(QoS_{WSP}) = 1 and weight(CoS_{WSP}) = 0.

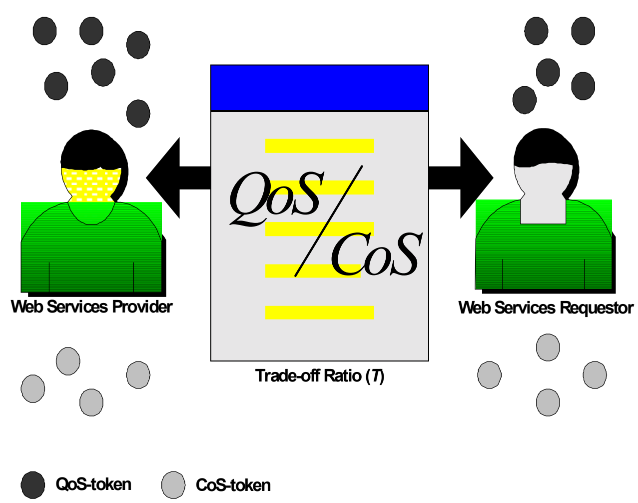

Figure 3. Token-based Approach for Generating Trade-off Ratio

In a general situation, the Web service providers want to sell a service with a price as high as possible and the Web services requestors want to buy a service with a price as low as possible [4]. Logrolling can lead to a Pareto-optimal allocation of resources when side payments are allowed [26], and it can also increase aggregate utility for both parties. Utility [19] is a numerical representation of preference among different alternatives that is not tied into a single measure of value. Utility serves many useful purposes because it can also be added, subtracted, multiplied, divided, integrated and differentiated. If a party chooses alternative *A* in preference to alternative *B*, *A* is said to have a greater utility for this party than *B*. If a party's preferences among certain items have a certain pattern such as a linear curve, then his preferences can be represented by a utility function such as $U(x_1, \ldots, x_n)$ where $x_1, \ldots, x_n$ is the set of *n* attributes. Referring to the QoS and CoS, each party should have a multi-attribute utility function such as $U_P(|QoS_P|, |CoS_P|)$ where P = WSP or WSP. Joint utility is defined as the sum of the utilities incurred by each party as an individual [23]. Expected utility in each party is maximized when costs of improving the level of QoS equal benefits from obtaining another level of QoS for both parties [25]. In this paper, the utility function for two attributes (i.e., QoS and CoS) would have the multiplicative-additive form [8] as follows:

$$\mathbf{U_P(|QoS_P|, |CoS_P|) = k_1 U_{P\text{-}QoS}(|QoS_P|) + k_2 U_{P\text{-}CoS}(|CoS_P|) + k_3 U_{P\text{-}QoS}(|QoS_P|) U_{P\text{-}CoS}(|CoS_P|)}$$

where $U_{P\text{-}QoS}(|QoS_P|)$ is a utility function assessed on QoS_P and $U_{P\text{-}CoS}(|CoS_P|)$ is a utility function assessed on CoS_P, and k_1, k_2 and k_3 are weights (i.e., constants). The weights are constrained by $k_1 + k_2 + k_3 = 1$, where $0 \le k_1, k_2, k_3 \le 1$. The value of $U_P(|QoS_P|, |CoS_P|)$ is from 0 to 1.

4. MATCHMAKING FRAMEWORK

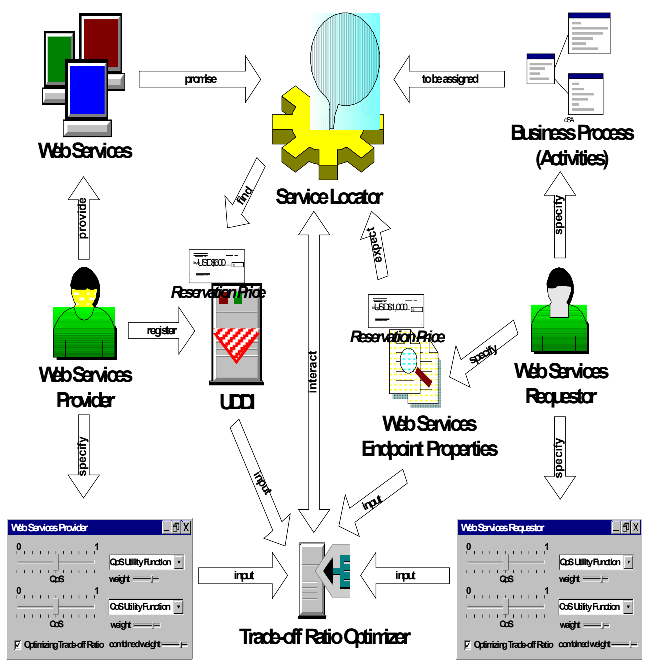

Figure 4. Service Locator and Trade-off Ratio Optimizer

The principle of equality states that both parties should receive rewards of equal value [4]. Based on the principle of equality, both parties have to examine the appropriate trade-offs and to decide whether one alternative combination of QoS and CoS is superior to another. To reveal the existence of an option that offers equal profit to both parties, both parties have to exchange information. Information exchange is a process of joint problem solving in which the negotiators view their separate interests as a common problem [22]. In this model, the form of information exchange is direct and explicit. Without knowing something about the other's needs and priorities, it will be hard to locate an integrative solution. All the information involved in the abstract model discussed above must be known before hand. In this work, we do not attempt to address the issue of semantic mismatch between negotiation parties. Due to the security concerns, an appropriate approach to handle this scenario is to introduce a service locator for collecting the information from both parties and avoiding both parties to know each other's information. Figure 4 shows a multilateral matchmaking framework [24] process that involves multi-participants in the matchmaking process such as a Web services provider, a Web services requestor, a service locator, UDDI and a trade-off ratio optimizer. Specifically service locator (i.e., matchmaker) architectures are good for finding optimal matches since the matchmaker is in a position to compare all available possibilities. In particular, experiments [13] have shown matchmaking process to be most useful in two different ways: locating information sources or services that appear dynamically, and notification of information changes. The Web service provider registers their Web services at the UDDI, and the service locator finds an appropriate Web service from the UDDI for each activity in a business process [17]. In addition, the service locator has to match the expectations of the Web service requestor described in the Web services endpoint properties and the promises from the Web services provider. The Web service provider specifies its reservation price for each service at the UDDI. This paper proposes to specify the reservation price as part of the service description (i.e., Green Page) in the UDDI. In addition, a new system called UX (UDDI extension) [38] has recently been developed to facilitate Web services requestors to discover Web services with the QoS requirements. The requirement of a more sophisticated patterns of negotiation such as tradeoffs between QoS and CoS is also raised in [38]. Thus, the UDDI in the proposed framework is enhanced with the UX server. On the other hand, the Web services requestor specifies its reservation price as one of the assertions in Web services endpoint properties. For illustration, this paper proposes and demonstrates this new assertion in the context of Web Services Endpoint Language (WSEL) proposed by Leymann [17]. Referring to Figure 5, there are four endpoint properties as extensibility elements in WSEL [17]:

- *Execution Limits*: It specifies a duration controlling the maximum time of execution by the <duration> element, and it also sets the maximum number of attempts by the <retry> element.
- *Escalation*: It specifies a contact person to be notified once the thresholds set in <duration> and <retry> are violated.
- *Observation*: It specifies a person who has the right to track the execution of an activity by the <observed> element.
- *Contacts*: It specifies a contact person to be notified once there is any violation in the endpoint properties by the <staff> element.
- Here this paper introduces the new assertion in WSEL as follows:

- *Price*: It specifies the requestor's reservation price in a specific currency by the <price> element.

```
<activity name="processPO">
  <wsel:duration limit="30" metric="minutes"/>

  <wsel:retry maxNumber="10"/>

  <wsel:escalate>
    <wsel:staff
        who="select PID from Person where skill > 15"
        Invoke="c:\programs\org_query.exe"/>
  </wsel:escalate>

  <wsel:observed>
    <wsel:staff
```

```
        who="select BID
          from Flows
          where FlowName= "TotalSupplyFlow" "
        Invoke="c:\programs\org_query.exe"/>
  </wsel:observed>

  <wsel:price currency=="USD" value="1000"/>

</activity>
```

Figure 5. Encoding in WSEL (Based on the example on pages 83-84 in [17])

5. CONCLUSIONS AND FUTURE WORK

In the future, one may expect that Web services providers should provide a list of trade-off alternatives between the QoS and the CoS to Web services providers, especially in those one-of-a-kind services. Thus, Web services requestors can evaluate every trade-off alternative for their own benefits. One of the negotiation strategies for achieving integrative solutions for both parties is called logrolling. In our view, logrolling is an important step in web service discovery process in which both web services providers and web services requestors can find appropriate partners. Traditionally, the concept of logrolling is being applied in the trading of votes by legislators. For example, a legislator offers to another to trade his vote on a certain bill in return for the other’s votes on other bills. Beside the area of political sciences, not much research work in logrolling has been applied in other research areas such as in ICT. In this paper, logrolling in two-issue (i.e., QoS and CoS) and two-party (i.e., Web services provider and requestor) negotiation is defined as the exchange of loss in one issue for gain in other issues that result in an increase of the overall value for both parties. This paper presents a token-based approach to quantify the QoS and CoS for achieving integrative solutions. To our best knowledge, this paper is the first work of applying all these negotiation concepts into the context of Web services QoS and CoS.

The major purpose of this work is to bring some insights for future work. There are several directions that can be explored to expand this work. The first direction is to develop a logical model for specifying and managing the issues involved in QoS and CoS in a loosely coupled Web services execution environment. Based on the logical model, this research can investigate an approach for handling multi-issue multi-party logrolling instead of only two issue groups. Second, this research can apply other optimization models such as linear programming, integer programming and mixed integer programming for optimizing trade-off ratios. Lastly, the prototype system of the proposed framework is currently being developed and both the service locator and the trade-off ratio optimizer are also built on the Web services architecture. There exists some limitations of this work, the proposed approach assumes that both parties must state the true value of their costs and benefits as well as their own utility function. Although the assumption is true in most business cases, a few negotiators always want to “outsmart” the negotiation partners by cheating on their preferences. In conclusion, this paper brings up an important topic for developing an adaptive and sophisticated Web services-business in the future. As there are increasing demands for negotiation technologies in the context of Web services [38, 39], we are now preparing and trying to raise a new XML specification called ***WS-Negotiation*** by a new working group in the World Wide Web (W3C) Consortium.

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