WSMO-Lite Based Web Service Discovery Algorithm for Mobile Environment

Nor Azizah Saadon[1] and Radziah Mohamad[2]

Department of Software Engineering,
Faculty of Computing, Universiti Teknologi Malaysia,
81310 UTM Skudai, Johor, Malaysia.
e-mail: {[1] azizahsaadon, [2] radziahm}@utm.my

Abstract

The advancement of mobile and wireless technologies has led to widespread access of web services in a mobile environment, where mobile devices can host web service as a web service provider or service requester. Due to rapid proliferation of web services with similar functionalities, discovering appropriate mobile web services that match service requester is still a major obstruction to its advancement, especially with the stringent constraints currently relating to mobile devices. This paper proposes an enhancement of WSMO-Lite to describe Non-Functional Properties (NFPs) as a context and Quality of Web Service (QoWS) information for mobile computing environment targeted to support the discovery of web services in a mobile environment. Then, the similarity of the service requester with each of the offered services is measured using semantic matchmaking algorithm based on WSMO-Lite was proposed. As a lightweight semantic web service description language, WSMO-Lite improves flexibility of web service description and enhances the web service discovery mechanism. The applicability of the enhancement and algorithm is applied through a simple case study to demonstrate the effectiveness of the idea.

Keywords: *Mobile web service, mobile computing, web service discovery, WSMO-Lite.*

1   Introduction

Currently, mobile web services are growing dramatically with the convergence of web service technology and mobile computing. The area of mobile computing is becoming increasingly important with information being available anywhere and

anytime from a diversity of mobile devices, such as smart phones, tablets and handheld PC devices [1][2]. According to Gartner [3], in the third quarter of 2012, the worldwide sales for mobile phones generated nearly 428 million units, with smartphone sales increasing 46.9 percent compared to the third quarter of 2011. This report indicates that the advancement of wireless technologies and the important of new generations of smartphones with extra capabilities have led to a growing demand for accessing web services in a mobile computing environment.

Current research trends mostly focus on an entire web service life cycle and include: description, discovery, selection, composition and invocation [4]. Web service discovery in particular is the action of searching and matchmaking between available offered web services and service requester. Moreover, web service selection is the action of evaluating discovered web services in order to fulfill a set of NFP as requested by the user. Due to the increasing existing web services with similar functionalities and with mobile device constraints, the ability for the user to find the most relevant web services that meet their requests has become even more difficult and hence, challenging. Furthermore, the existing web services discovery techniques are designed for static environments and lack of a comprehensive mechanism for a mobile computing environment. There are three issues in web service discovery for mobile computing [5][6], namely: first, the diversity of mobile devices with different specifications, capabilities and constraints; second, the proliferation of web services with a variety of different specifications; and third, the lack of an enriched service description. Hence, there still remains an open research question as to how the variety of services can be fitted with a variety of mobile devices in order to meet user requirements. Thus, an efficient mechanism for web service discovery is needed to improve the ability to find the most relevant web services through mobile devices by comparing service requests with descriptions of the service offered.

Web Service Discovery (WSD) is the process of finding web services requests and their concrete web service offered for achieving the user's goal [7]. The process of discovery in mobile computing environment poses a new challenge due to the constraints of different capabilities in mobile devices. Semantic-based discovery seems to be the most promising approach nowadays which facilitates the matchmaking process.

Modeling of semantic web services such as Web Service Modeling Ontology (WSMO) [8] and Ontology Web Language for Service (OWL-S) [9] are the complete frameworks in top-down approach with recent improvement for web service technology. Nevertheless, this approach is hard to use with current industrial developments where most of the available web services use syntactic frameworks [10]. The effort in bottom-up approach starts with simple extension on semantic description defined by WSDL-S [11]. Then, the effort is grown by adding small enhancement on top of the WSDL, which provides the ground to service modeling as defined by the Semantic Annotation for WSDL (SAWSDL) [12]. The recent effort, known as the WSMO-Lite [10], is a lightweight

technology for annotating semantic web services. It uses SAWSDL annotation by introducing a service ontology with WSDL elements. The importance of adding semantics to web services is to improve automation of certain tasks and WSMO-Lite supports general task of discovery, negotiation, selection, composition and invocation of the services.

This paper proposes an enhancement of the WSMO-Lite to describe the NFPs as a context and the Quality of Web Service (QoWS) information for mobile computing environment targeted to support the discovery of web services in a mobile environment. Then, the similarity of the service requester with each of the offered services is measured using semantic matchmaking algorithm based on the proposed WSMO-Lite.

The rest of this paper is organised as follow: Section 2 discusses the related work, Section 3 outlines the background of WSMO-Lite, Section 4 discusses the NFPs with respect to the context model and QoWS model in WSMO-Lite elements, Section 5 discusses the proposed matchmaking algorithm in mobile computing and Section 6 shows the applicability of the proposed algorithm with simple case study. Finally, a conclusion and future work are given in Section 7.

2   Related Work

Functional and non-functional properties (NFPs) are the important properties in the discovery and selection processes of web services. Most of the common approaches refer only to functional properties and too little attention is given to the NFPs. By enhancing the web service description language, it enriches the expressiveness of language and it can express the metadata of services using various matching algorithm.

Recently, a lot of matchmaking algorithms have been presented to improve the performance of semantic web service discovery process in mobile computing environment. By exploiting Composite Capabilities/Preference Profile (CC/PP) standard for device profile properties, the research works in [13] and [14] propose a device-aware web service discovery where the context information are extracted from the device profile. Nevertheless, these works cannot represent the user's real intention as their approach uses the keyword-based technique [15].

Peng, *et al*. [16] presented an OWL-S based approach in web service discovery for mobile users. They extended Service Profile ontology in OWL-S model with User Profile for mobile users. However, they do not consider the properties of QoWS in their approach. Another work [17] considers the properties within the QoWS and presented an OWL-S based discovery algorithm to their approach. However, there was no description in detail on the construction of the properties of QoWS to web service.

The study by Niazi and Mahmoud [5] proposes a profile-based service description and to attach it with Delivery Context Ontology for discovering mobile web service. They provide an enriched service profile and framework for mobile web service discovery, but they too did not consider the properties of QoWS.

Another work by Zhou and Li proposes the WSMO, which considers the Quality of Service (QoS), known as WSMO-QoS, for web service discovery. They propose three level of discovery process, which is presented in their matching algorithm approach. Even though they consider the properties of QoWS, they should consider context information as well as far as mobile computing environment is concerned.

In comparison to the work described above, our work proposes WSMO-Lite based as a lightweight web service description language which is suitable for mobile computing environment. This paper emphasizes the extension of NFPs which are context information and QoWS models for refining and improving the discovery of mobile web services based on mobile user request with multi-level aggregation algorithm.

3   Service Description with WSMO-Lite

WSMO-Lite is a lightweight technology that inherits the design principles from WSMO which is related to the semantic web services. WSMO-Lite is an emerging technology by improving SAWSDL annotation with concrete semantic web service description and introducing a service ontology. In WSMO-Lite model conceptual, SAWSDL is considered as a bridge between the non-semantic layer and semantic layer as a ground. There are three extension attributes where SAWSDL allows WSDL components to be annotated with semantic elements; modelReference, loweringSchemaMapping and liftingSchemaMapping.

At semantic level, WSMO-Lite distinguishes the following four types of web service semantics [10]:
  (i)   **Information Model** defines the semantic input, output and fault messages.
  (ii) **Functional semantics** define service functionality or capabilities, or in other words, what a service can offer to the requester when it is invoked.
  (iii) **Non-functional semantics** define any incident details specific using an ontology, semantically represent NFPs or policy.
  (iv) **Behavioral semantics** specify the operation or protocol that a requester needs to follow when the services are invoked.

WSMO-Lite seems to be the most competitive approach as the concept can be used via available web services by adding semantic annotations. The semantic approach enhances the automation of discovery and selection for web service or any general task. Besides, the framework is lightweight, which is suitable for mobile computing environment.

4   Non-Functional Properties in WSMO-Lite

In Service Oriented Computing (SOC) domain, the properties that specify web services can be classified as functional and non-functional properties. Functional properties in the web service represent the description of the service tasks in terms of operation signature or simply what the web service is able to do. Meanwhile, non-functional properties can be described as how the web service can do by representing the description of the service characteristics that are not directly related to the functional properties [7].

Such kinds of NFPs definition are neither expressive nor flexible enough for the context and QoWS attributes. WSMO-Lite does not provide NFPs model for web service. WSMO-Lite does not take into consideration NFPs for context information, especially for mobile computing. To overcome such limitations, two categories of NFPs are proposed, which are context and QoWS models. The essential part of matchmaking process based on NFP is referred to these elements. he combination of both properties (QoWS and context) will enhance the accuracy of web services discovered in the mobile computing environment. The major challenge in extending NFPs in WSMO is how to model the context and QoWS properties that are tailored to mobile computing environment. Moreover, the challenge is how to attach the context and QoWS properties to the web service and goal in service description.

4.1   Context properties

There are three types of context properties identified in order to rank the list of appropriate Web services and they are:

(i) **User preferences**: The discovered services may satisfy service requesters via user preferences application. The consideration of mobile user preferences would help refine the discovery of retrieved web services which implies the requirement of **device capabilities** and **context properties**. A detailed user preferences model, which is developed by Garcia et al.[18], is capable to distinguish between mandatory requirements and preferred requirements.

(ii) **Device profile**: The main factor for the inclusion of the device profile information in matching the elements for the web service discovery process is

to ensure that the discovered web service is compatible with the mobile device constraints which comply with the requirement of **device capabilities**. Al-Masri et al. [14] have introduced the device-aware service discovery mechanism and exploits WSDL with the extension to mobile device profiles, namely, WSDL-M. The mechanism also supports caching of information regarding disconnected devices, where the network connectivity is either unstable or the devices leave the network. This complies with the requirement of **network connectivity**.

(iii) **Environment**: The environment context information may change frequently as mobile service providers or mobile service requesters are always on the move in wireless network environments. This complies with the requirement of **mobility**. Furthermore, the environment context information incorporated in a web service discovery process ensures that the current states of mobile users, such as location information, could help the mobile user to locate its current location and identify any service nearby. Besides, with the capability of dynamic context information, the adaptive behavior of web services to adapt to environment changes with an unstable data bandwidth of mobile users could be an advantage of this mechanism. This complies with the requirement of **network access,** which supports the multiple capacities service with current environment changes and would be able to respond promptly.

Figure 1 shows the Context-M model which consists of three types of context information described above, namely: (i) Environment; (ii) Device Profile and (iii) User Preferences. Each element class of the contexts has its own characteristics, for example, the context *Environment* has characteristics of *Bandwidth* and *Location*. Moreover, each characteristics has its own dimension, for example, the characteristic of Bandwidth has dimensions of *Data* where its context expression is defined by *SingleValueExpression*, *Data Type* and *Unit*. Furthermore, constraint operator for *SingleValueExpression* is defined by *BinaryOperator.*
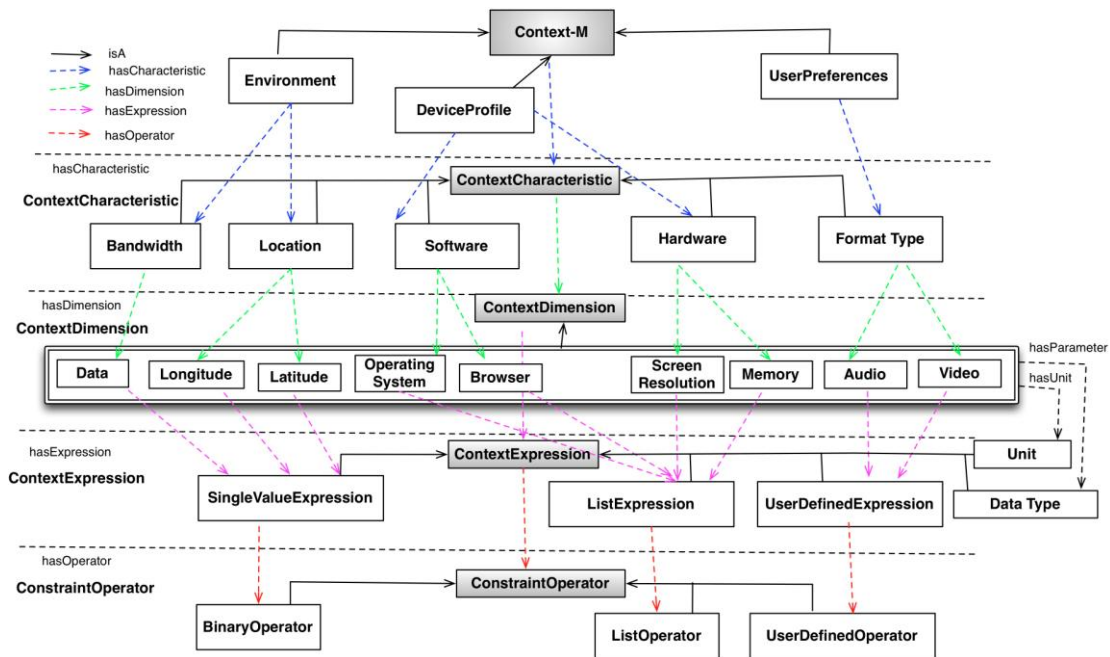
Fig.1: Context-M Model

4.2   QoWS properties

Liu et al. [4], Wang et al. [19] and Al-Masri et al. [20] highlight the predominant parameters that define the Quality of Web Service. Although a great deal of quality criteria has been proposed, the quality dimension common to the majority of the related work is presented here. The final list of NFPs for Quality of Web Service, particularly in mobile devices, is composed of the six properties shown below:

(i) **Price**: The fee that the service requestor is expected to pay invokes a service operation. A service provider can offer the same services but with different pricing models. This is an important criterion as the service requestor needs to operate the service by referring to their financial plan.

(ii) **Reputation**: The trustworthiness of service operation measurement is based on user feedback. Users can provide feedback of the service and rate the service operation based on their experience after using the service. This is an important criterion as it reflects the users' satisfaction. The measurement can be expressed as the average ranking of user feedback for the service invoked.

(iii)**Throughput**: This refers to the total number of invocations for a given period of time. This is an important criterion, as time is the common measurement for

performance quality. The measurement can be expressed as invocations per second.

(iv) **Response Time**: This refers to the duration of the service to execute or, simply speaking, is time taken to send a request and receive the response. When the response time is more than the acceptable value, the service is considered not available. This is an important criterion, as time is the common measurement for performance quality, whereas the shorter service execution time is an excellent indication of the service. The measurement can be expressed in time units, for example, milliseconds per unit.

(v) **Availability**: Simply speaking, readiness of service refers to the probability that a service is accessible at a given time. This is an important criterion as most of the related works establish the availability quality criterion. The measurement can be expressed in percentage, where the total number denotes successful invocations per total invocations.

(vi) **Reliability**: This refers to the probability that a service operates correctly after being invoked. This is an important criterion as the reputation of the service provider is bound closely with the reliability of the services. The measurement can be expressed as a ratio of the number of error messages to the total messages in percentage units.

Figure 2 shows the QoWS-M model, which consists of two types of QoWS information, namely: (i) Business and (ii) Runtime. Each element class of QoWS has their own dimension; for example *Business* has a dimension of *Price* and *Reputation*. There are six dimensions in QoWS which are, namely: (i) *Price*, (ii) *Reputation*, (iii) *Throughput*, (iv) *Response Time*, (v) *Availability* and (vi) *Reliability*. Its QoWS expression is defined by a *SingleValueExpression*, *Data Type* and *Unit*. Furthermore, constraint operator for *SingleValueExpression* is defined by *BinaryOperator*.
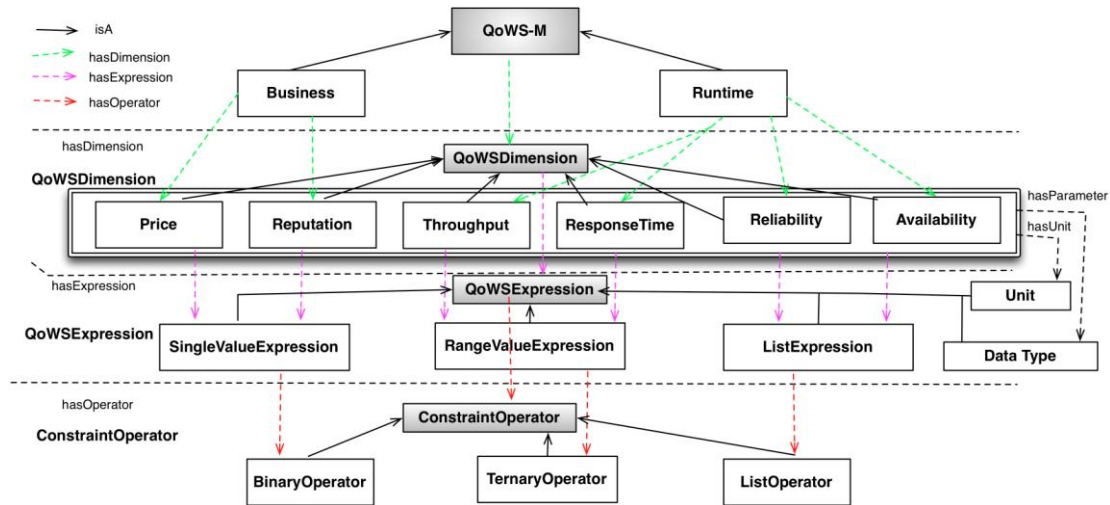
Fig.2: QoWS-M Model

5   Matchmaking Algorithm

The purpose of web service discovery is to locate the most relevant web services according to user functional and non-functional properties which may consider the device capabilities of the users' mobile phones. The matchmaking algorithm in this work is constructed by multilevel matching which means the matchmaking process is performed at many levels. The matchmaking algorithm in this work involves five steps. Firstly, the matching involves functional properties that include input and output properties. Secondly, the matching involves NFPs of context properties. Thirdly, the matching involves NFPs of QoWS properties. Next, the Degree of Match (DoM) calculation is presented for all properties. Finally, the web services with high value results are listed based on mobile users' requirements. Such approach exploits as much information as possible with the available functional and non-functional web service information.

Mobile web service (MWS) is defined as two-tuple that consists of functional and non-functional properties, where `MWS = {F, NF}`. Functional properties are the input and output properties of MWS. NFP web service is defined as two-tuple where `NFP = {C, Q}`, whereby C represents context properties and Q represents QoWS properties. Figure 3 shows the matchmaking algorithm deployed in our work with aggregation of four DoM. The first line of algorithm in figure 3 is input, which is the service offer of WSMO-Lite web service description, marked as S_O, and the user goal description marked as U_G. The second line of algorithm is output as the list of services matched. The function DegreeofMatch (DoM) implements the rules of semantic matching. At last, the algorithm returns an ordered list of matching services which are restored in the set MatchedPairList.

```
1. Input: The set of WSMO-Lite Service Offer (S_O),
          A User Goal (U_G);
2. Output: List of services (S[n])
3. MatchedPairList: ∅;
4. S[n]=[∅];
5. U_G → Temp_G ;
6. for all M_i ∈ S_O do
7.     M_i → Temp_M;
8.        for i ←1,n do
9.              DoMI = allMatched(S_O.I, U_G.I);
10.             DoMO = allMatched((S_O.O, U_G.O);
11.             DoMCon= Context match (S_O.Con, U_G.Con);
12.             DomQWS=QWS match (S_O.QWS, U_G..QWS);
13. Return (DoM = aggregate (DoMI, DoMO,
              DoMCon, DoMQWS));
14.        endfor
15. MatchedPairList = < M_i , DoM>;
16. Return S;
```

Fig. 3: Matchmaking Algoritm

The basic semantic matching relationship that are considered in this discovery approach are:

(i) **Exact-match** : The goal description is equivalent to the web service description, $S_O = U_G$.

(ii) **Plugin-match** : The goal description is a subset of the web service description $U_G \subset S_O$

(iii) **Subsume-match**: The web service description is a subset of the goal description, $U_G \supset S_O$

(iv) **Intersection-match**: Common elements between the goal and web service description, $U_G \cap S_O = \varnothing$

(v) **Fail**: None of the elements, neither goal nor web service is similar, $U_G \neq S_O$

5.1 Matching elements

The considered matching elements of NFP are context and QoWS properties for discovering the most appropriate web services based on user's goal. In order to determine which web service is appropriate for each mobile device, it is necessary to extract context profile features and QoWS properties from the web service description. Table 1 shows some of the common context profile and QOWS profile with ID number for each feature to be represented in matrix form.

Table 1: Context Profile

ID	Context feature	ID	QoWS feature
1	Operating system	1	Price
2	Browser	2	Reputation
3	Screen resolution	3	Throughput
4	Memory	4	Response Time
5	Audio	5	Reliability
6	Video	6	Availability
7	Longitude		
8	Latitude		
9	Bandwidth data		

QoWS attributes could be either positive or negative, thus some QoWS values need to be maximized, (i.e., the higher the value, the higher the quality) for example availability and reliability, whereas other values have to be minimized, (i.e., the higher the value, the lower the quality). This includes criteria such as response time and price. To cope with this issue, the scaling phase normalizes every QoWS attribute value according to the following formula, whereas the values of negative attributes are normalized by expression (1) and the values of positive attributes are normalized by (2). The scaling phase normalizes the value Q_{ij} of each MWS and produces a new value Q'_{ij} that lies in the [0, 1] interval.

$$Q'_{ij} = \begin{cases} \dfrac{Q_j^{max} - Q_{ij}}{Q_j^{max} - Q_j^{min}}, & \text{if} \sim Q_j^{max} - Q_j^{min} \neq 0 \\ 1, & Q_j^{max} - Q_j^{min} = 0 \end{cases} \qquad \text{... (1)}$$

$$Q'_{ij} = \begin{cases} \dfrac{Q_{ij} - Q_j^{min}}{Q_j^{max} - Q_j^{min}}, & \text{if} \sim Q_j^{max} - Q_j^{min} \neq 0 \\ 1, & Q_j^{max} - Q_j^{min} = 0 \end{cases} \qquad \text{… (2)}$$

Assuming that there is a set of mobile web services (MWS) with similar functional properties but varying in the values of QoWS features, where `MWS` `[MWS = (mws₁,mws₂,mws₃,…,mwsᵢ)]` and QoWS , `Q` `[Q = (Q₁,Q₂,Q₃,…,Qⱼ)]`, a NFP-based matchmaking algorithm determines which

$\mathtt{mws_i}$ is relevant based on QoWS and context features information. With QoWS features information, (same as ID from Table 1) the following QoWS matrix (equation 3) where each row represents a mobile web service ($\mathtt{mws_i}$) while each column represents each QoWS features, are presented. The context matrix is constructed similarly to the QoWS matrix.

$$Q_i = \begin{bmatrix} mws_{1,1} & mws_{1,2} & mws_{1,3} & mws_{1,j} \\ mws_{2,1} & . & . & . \\ mws_{3,1} & . & . & . \\ mws_{4,1} & . & . & mws_{i,j} \end{bmatrix} \quad \ldots(3)$$

5.2   Degree of Match (DoM)

The next process of discovery is to calculate the similarity of user request and service offered based on the Degree of Match (DoM). Equation 4 shows the example of DoM for QoWS. This paper shows the applicability of the idea to discover the suitable web service based on NFPs in mobile computing environment.

$$DoMQWS(U_G, S_O) = \sum_{i=1} w_i * Q_{ij} \quad \ldots(4)$$

where,
Q_i = the score of properties in U_G and S_O
w_i = weight for each properties in S_O and S_O

6   Prototype Implementation

In order to illustrate the importance of NFP in web service discovery, an example of use case scenario was presented. The context and QoWS model that were proposed were taken into consideration in this scenario to show the applicability. For example: John was involved in a Malaysia Software Engineering Conference (MySEC) event in Malaysia. John wanted to take the bus to reach the event location. John used the bus service website to identify which bus that he needed to take. Based on his current location, the bus information was retrieved and it was indicated there would be a delay on the bus arrival, which meant that John would miss part of the keynote speech of his research area of interest.

At the location of the event, some participants (mobile providers) offered coverage of the event with different smart phone capabilities. They offered video and audio streamings and real-time photo updates of the event. With this simple scenario, we will show how John can use this approach to be connected to the event, even though he has not arrived. We assume that John has 3G connectivity with his smart phone. John uses the web service query to construct a request of web service discovery.

The web service query content is "Malaysia Software Engineering Conference (MySEC) coverage with video streaming in format mp4 and priced less than RM2", as the user preferences. The information required for matching process is based on context and QoWS information. The local context information, such as current environment condition, device profile and user preferences, are retrieved accordingly. At the same time, QoWS information such as price, reputation, throughput, response time, availability and reliability are retrieved in order to rank the most relevant web services for John as a requester. When the 3G signal is sufficiently strong, the adaptive behavior mechanism would detect the changes in John's current location and adapt to the mobile provider, which provides real-time video streaming in mp4 format.

However, when John's current location has only a weak 3G signal, the changes of environment would adapt the audio streaming accordingly. This is the most frequently distinguished characteristic of mobile web services, whereby the mobile user is always on the move, which leads to dynamic context changes as well.

From the discussion above, the importance of NFPs, especially in mobile computing with limitation of device capabilities, is highlighted. The degree of matching with ranking results of web services gives an accuracy to the mobile users in order to select the most appropriate web service based on users' requirements and device capabilities.

Figure 4 shows the example of matching results obtained from the user case scenario. The example only refers to one possible dimension class for each characteristic, which are namely: *Bandwidth*, *Software*, *Format Type*, *Price* and *Response Time*. The right column is the description for a mobile provider while the left column is the service requester, in this example, John.
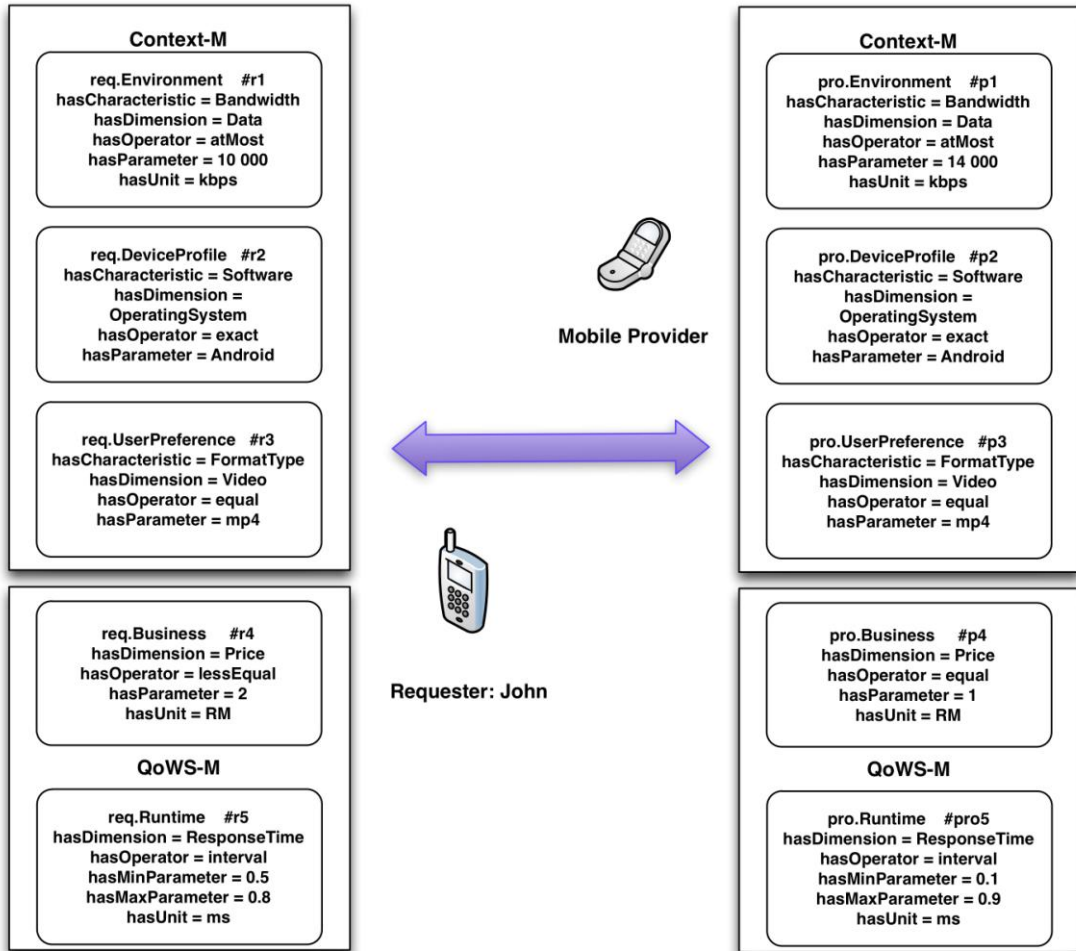
Fig. 4: A case scenario based on NFP

7   Conclusion

The analysis of web services discovery based on NFPs in mobile computing environment is presented in this paper. The aim is to enhance the accuracy and performance of relevant web service discovered by improving the expressiveness of the web service description. Device capability and user preferences are the important parts for discovery of mobile web services based on the requester. The enhancement of mobile web services description based on NFPs in WSMO-Lite model is proposed in this paper. The NFPs consist of two properties, which are, QoWS and context model, that follow the WSMO-Lite conceptual model. Elements to describe the context and QoWS model as NFPs in mobile web services are proposed. With these properties, the semantic algorithm and Degree of Match (DoM) calculation are presented in order to rank the web services results based on the users' requirements and services offered. The applicability of the

enhancement was demonstrated through a simple case study. Therefore, the importance of NFPs with a high degree of matching results is highlighted. In future studies, we will enhance the algorithm for selection process to automate the process during web service discovery in mobile computing environment before invoking the service.

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