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***Abstract*—Multimedia contents are accessible on a wide variety of devices, such as laptops, tablets and smartphones. The heterogeneity of such devices requires adaptation of these contents. Since the last decade, a fair amount of research has been conducted in order to develop adaptation frameworks. Most of them are exploiting profiles in order to guide adaptation processes. In some previous publications, we have proposed a model for specifying rich profiles containing complex constraints expressions. However, profiling information is currently mainly based on quantitative values. For example, if my battery level is less than 15%, do not play videos. In this paper, we improve our previous proposal by adding qualitative information to such profiles. For that purpose, we have defined a multi-level approach for specifying qualitative aspects and associating them to quantitative values. These terms will be used in our profiles for specifying rich semantic constraints, such as if my battery level is "low", do not play "high-quality" videos. We have proposed a meta-model that allows specifying these kind of constraints and have used Semantic Web technologies in order to serialize and query our profiles.**

I. Introduction

Multimedia contents are now present in our everyday life. Nowadays, users are able to capture, create, exchange and consume a wide variety of documents at anytime and anywhere with multiple devices (laptops, tablets and smartphones) [1]. The heterogeneity of such devices including networks capabilities and/or users' contextual preferences requires adaptation of these contents. Since the last decade, a fair amount of research has been conducted in order to develop adaptation frameworks, e.g., [2], [3], [4], [5], [6]. Most of them are exploiting profiles in order to guide adaptation, i.e., determine a set of transformations that must be applied onto a document in order to be correctly executed on dedicated target devices.

In some previous publications, we have proposed a model, named Semantic Generic Profile (SGP), for specifying rich profiles containing complex constraints expressions [7], [8]. Our SGP model is generic (it is not exclusively user and/or device specific), portable (profiles may migrate on several platforms without modifying multiple values) and expressive (it contains rich constraint expressions). However, profiling information is currently mainly based on quantitative values. For example, if my battery level is less than 15%, do not play videos. We have noticed that this is also the case for many other profiles, such as [9], [10], [11].

In this paper, we improve our previous proposal by adding qualitative information to such profiles. For that purpose, we have defined a multi-level approach for specifying qualitative aspects and associating them to quantitative values. These terms will be used in our profiles for specifying rich semantic constraints, such as if my battery level is "low", do not play "high-quality" videos. We have proposed a meta-model that allows specifying semantic constraints and have used Semantic Web technologies in order to serialize and query our profiles.

The remainder of the paper is structured as follows. In Section II, we give an overview of several profile modeling approaches, some of them are widely used on handheld devices, while others are able to express semantic information. Then, in Section III, we present our Semantic Generic Profile through an example and we emphasize the advantages and the weaknesses of such a model. In order to bridge the gap between quantitative and qualitative values, we propose in Section IV a multi-level approach for specifying qualitative aspects and associating them to quantitative values. In Section V, we detail the meta-model corresponding to our approach and illustrate it with a use-case example. A preliminary experimentation is presented in Section VI. Finally, we conclude and present some future work in Section VII.

II. Related work

Since the last decade, a fair amount of research has been proposed in order to model devices characteristics and users contexts that are further exploited by multimedia document adaptation processes [12], [13]. We have noticed that some of these approaches provide exclusively a descriptive view of context information (e.g., CC/PP, UAProf), while others propose enhancements with some constraints expressions (e.g., CSCP, Context-ADDICT). In this section, we present an overview of these approaches.

A. CC/PP

CC/PP (Composite Capability / Preference Profiles) [9] is a W3C recommendation for specifying device capabilities and user preferences. This profile language is based on RDF and was maintained by the W3C Ubiquitous Web Applications Working Group[1] (UWAWG). The profile structure is very

[1] http://www.w3.org/2007/uwa/UbiWebApps.html

descriptive since it lists sets of values which correspond to the screen size, the browser version, the memory capacity, etc.

However, the CC/PP structure lacks functionality, for instance it limits complex structure description by forcing a strict hierarchy with two levels. Furthermore, it does not consider the description of relationships and constraints between some context information. Finally, it is necessary to extend the vocabulary used in CC/PP in order to include new elements corresponding, for instance, to hardware profile [14] or in order to detail the location, the network characteristics and application dependencies [15].

B. UAProf

UAProf (User Agent Profile) [10] is based on RDF and is a specialization of CC/PP for mobile phones. More precisely, its vocabulary elements use the same basic format as the one used in CC/PP for describing capabilities and preferences for wireless devices. Thus, it describes specific items, such as the screen size, the supported media formats, the input and output capabilities, etc. UAProf is a standard adopted by a wide variety of mobile phones and it provides detailed lists of information about the terminal characteristics. However, this standard is limited to the description of wireless telephony equipments. Hence, it does not allow a user to express his/her requirements, such as avoiding playing videos while the mobile phone battery level is lower than 15%.

C. CSCP

CSCP (Comprehensive Structured Context Profiles) [11] uses RDF and is also based on CC/PP. In contrast to CC/PP, CSCP has a multi-level structure and models alternative values according to predefined situations. Even if CSCP provides a description of the context, which is not limited to two hierarchical levels, this proposal does not allow the specification of complex user constraints (e.g., avoiding playing videos while the mobile phone battery level is lower than 15%) [15]. Moreover, [16] stated that this proposal was developed as a proprietary model for specific domains.

D. Context-ADDICT

Context-aware Data Integration Customization and Tailoring proposes the Context Dimension Tree [17]. In other words, the context can be represented with a hierarchical structure composed of a root and some level nodes. The authors propose constraints and relationships among values. In Context-ADDICT, the data sources are generally dynamic, transient and heterogeneous in both their data models (e.g., relational, XML, RDF) and schemas. The Context-ADDICT approach lacks some relevant features for the data-tailoring problem, such as context history, context quality monitoring, context reasoning, and ambiguity and incompleteness management. Moreover, this model strongly depends on the application used and does not permit portability between platforms.

III. Semantic Generic Profile

In [7], we have proposed a Semantic Generic Profile (SGP) which organizes profile information into facets. In order to demonstrate our proposal, we have currently considered three kind of facets which are related to (1) the device characteristics, (2) the user context information and (3) the document composition. Moreover, we have proposed to link profile information with the specification of high-level explicit constraints. These constraints enable to model different types of actions under rich conditions. For instance, Figure 1 illustrates an example of a SGP profile. It graphically explains that if the user is in a car and if his battery level is greater than 50% then the sound level of audio contents must be set to 70%.

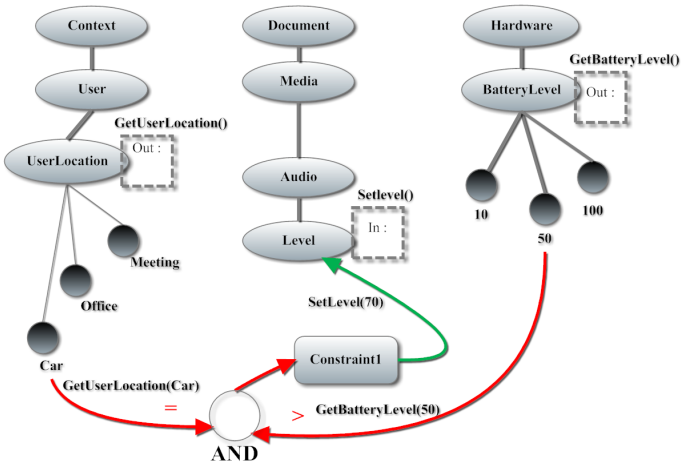

Fig. 1. An example of a SGP profile.

The advantages of specifying such kind of profiles are twofold. First, complex explicit constraints can be specified, thus guiding the adaptation process in order to provide an adapted document that complies with rich user constraints. Second, information about the device and the user are provided by services (e.g., *GetUserLocation*, *GetBatteryLevel*). Hence, profiles may migrate from different platforms without modifying several values.

However, as you may notice in Figure 1 constraints expressed in SGP profiles are currently referring to pure quantitative values, such as 50% and 70%. This is also the case for several standard profiles, such as CC/PP and UAProf. In fact, one may want to specify inside a profile that if the battery level is “low” and if the user location is “close” to his home then do not play “high-quality" videos.

In order to overcome this limitation, we have defined in the next section a framework that bridges the gap between quantitative and qualitative information specified in profiles.

IV. Bridging the Gap between Qualitative and Quantitative Information

Adding qualitative terms inside profiles is not straightforward. Indeed, a qualitative term, like “Low", may be applied on several profile aspects, such as the device battery level,

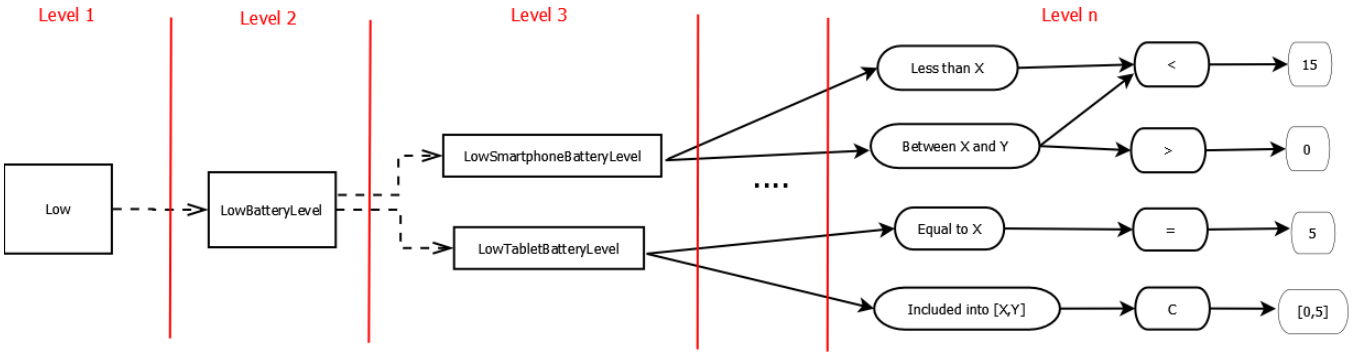

Fig. 2. The multi-level approach in order to bridge the gap between quantitative and qualitative information.

the sound output level, the bandwidth. Hence, the meaning of a term can be completely different depending on the used context. Moreover, even in a specific context, for several domains, a term may have different interpretations. For instance, the term "Low" in the context of the battery level corresponds to different quantitative values if we consider a smartphone or a laptop.

In order to bridge the gap between qualitative and quantitative information contained in profiles, we have defined a multi-level approach (Figure 2):

- **Level 1:** This is the higher semantic level and it refers to the qualitative term that one may want to use in a profile. In the figure, we want to define the qualitative term "Low".
- **Level 2:** This level corresponds to the contexts which are attached to the qualitative terms. In the figure, the term "Low" is attached to the battery level context (*LowBatteryLevel*). Of course, several contexts may be attached to a qualitative term.
- **Level 3:** For a particular qualitative term in a specific context, multiple application domains may be specified in this level. In the figure, a smartphone and a tablet may have different interpretations of a low battery level (*LowSmartphoneBatteryLevel* and *LowTabletBatteryLevel*).
- **Level i (i<n):** Subdomains may be defined in order to associate a qualitative term to more specific application domains. Moreover, depending on subdomains, the qualitative terms may refer to different quantitative values. For instance, one may define different low level batteries for particular device types or brands.
- **Level n:** This is the lower level and it refers to the corresponding quantitative values which are associated to the qualitative term for a specific context and a particular application domain. For instance, in Figure 2, we have defined that a low battery level on a smartphone corresponds to a value which is less than 15%. As you may see, several conditions can be specified in order to determine the quantitative values which correspond to the qualitative situation, e.g., a low battery level on smartphones is between 0% and 15%.

This multi-level approach for bridging the gap between qualitative and quantitative information described in profiles is generic. Actually, this proposal may be used for a wide variety of qualitative terms. For instance, one may define qualitative terms for spatial information, such as "close", "far", "intersect", etc. These qualitative terms may be attached to particular contexts, like location or surrounding devices. It may be associated to particular domains, e.g., GPS, street names, hotspot identifiers, etc. Furthermore, one may also define qualitative terms for temporal information, such as "before", "after", "during", etc.

In the next section, we have formalized our proposal and serialized examples using Semantic Web technologies.

V. The Meta-Model By-Example

We have proposed in Figure 3 a meta-model illustrated through a UML diagram, which corresponds to the multi-level approach presented in Section IV.

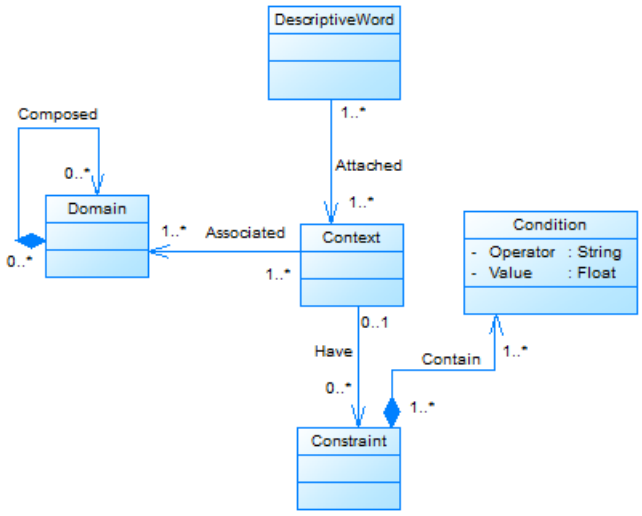

Fig. 3. A meta-model which corresponds to our multi-level approach.

A *DescriptiveWord* corresponds to a qualitative term (Level 1). Each qualitative term is attached to one or more *Context* (Level 2). Each context can be associated to one or more *Domain* or subdomains (Level 3 and i). Finally, a *Constraint* associates quantitative values to the qualitative term depending on the context used (Level n).

Thanks to the meta-model presented in Figure 3, we have encoded the example illustrated in Figure 2 using RDF/XML [18]. A part of the RDF description is presented in Figure 4.

```
<t2i:DescriptiveWord rdf:about="t2i#Low">
<t2i:attached>
 <t2i:Context rdf:about="t2i#LowBatteryLevel">
 <t2i:associated>
  <t2i:Domain rdf:about="t2i#LowSmartphoneBattery">
  <t2i:have>
   <rdf:Description rdf:about="t2i#Constraint1">
   <t2i:contain>
    <rdf:Description rdf:about="t2i#Condition1">
    <t2i:operator>&lt;</t2i:operator>
    <t2i:value>15</t2i:value>
    </rdf:Description>
   </t2i:contain>
   </rdf:Description>
  </t2i:have>
  </t2i:Domain>
 </t2i:associated>
 </t2i:Context>
</t2i:attached>
</t2i:DescriptiveWord>
```

Fig. 4. A RDF/XML example of a term declared using our meta-model which corresponds to our multi-level approach.

Consequently, it is now possible to exploit qualitative terms inside profiles, e.g., in order to express that a battery has a "Low" level. Furthermore, it is also possible to use these qualitative terms in order to express rich semantic constraints inside profiles, such as if my battery level is "Low" do not play videos.

Our proposal can be used for two kind of applications. The first one is to control inside profiles that qualitative terms are used in correct contexts and related domains. The second one is to retrieve the quantitative values associated to the qualitative term in order to test profile constraints (e.g., Is it true that my smartphone battery level is low?). Concretely, SPARQL queries [19] can be executed on our RDF descriptions, like the one presented in Figure 4, in order to retrieve the quantitative values that corresponds to the qualitative term used.

In the next section, we show how we can manage such rich profile constraints in an adaptation infrastructure.

VI. Preliminary Experimentation

In order to manage our profiling qualitative terms in an adaptation infrastructure, we have proposed a workflow illustrated in Figure 5. From several devices used by an end-user, a profile is maintained, e.g., a SGP profile. This one may contain multiple constraints: some of them may describe constraints with exclusively quantitative values, while others may handle qualitative terms (Step 1). Each constraint that handles qualitative terms is further analyzed by a semantic analyzer in order to provide the corresponding quantitative values (Steps 2 and 3). Of course, the semantic analyzer may control the validity and the consistency of a profile. For instance, a descriptive word may appear in a profile but it is not well-defined in the meta-model (i.e., the qualitative term is not defined in Level 1 or it is not associated to a valid context). Thereafter, when a multimedia document has to be played on a device, from the profile we determine the potential adaptation actions in order to comply with the profile, such as transcoding, transmoding or transforming a particular media (Step 4). Finally, thanks to adaptation services, we provide an adapted multimedia document (Step 5).

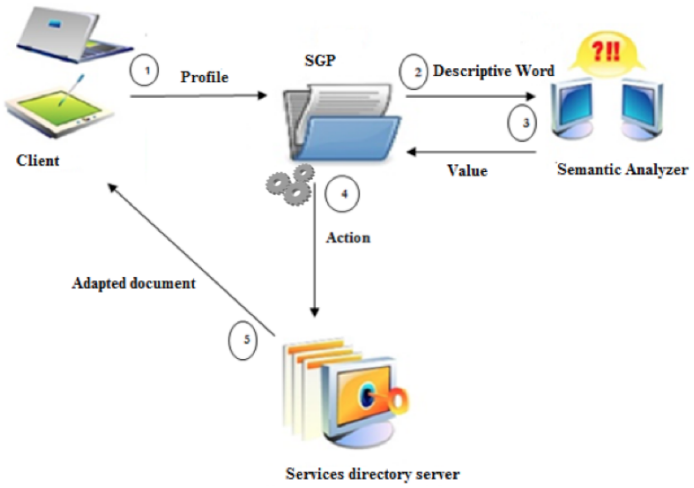

Fig. 5. A workflow for managing rich profile constraints.

We have partially implemented the workflow proposed in Figure 5 (from Step 1 to 4) on Androïd platforms using the AndroJENA framework[2]. This framework allows to maintain RDF profile descriptions on tablets and smartphones, and to query them with the support of SPARQL queries.

VII. Conclusion

Most of research works on profiles are based on quantitative criteria. The multi-level approach that we described in this paper aims at providing qualitative approaches for specifying qualitative aspects and associating them to quantitative values. Such proposition can help designers to express rich semantic constraints. We proposed a meta-model in order to specify quality oriented constraints and have used Semantic Web oriented technologies. We are currently implementing and integrating the proposition using SGP profiles in order to include such qualitative aspects into a global adaptation framework. Of course, we will evaluate the benefits of our proposal during the adaptation of multimedia documents and we will compare it to current approaches that use standard profiles. Perspectives are important and particularly in the domain of Linked Open Data [20].

[2]http://code.google.com/p/androjena/

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