Context for Multimedia Services Adaptation

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ABSTRACT

Due to the heterogeneity and complexity of user environments, multimedia services and multimedia content in the communication domain, adaptation is of a paramount importance to interoperability. Adaptation decisions at the different stages of multimedia services delivery to the end user depends on contextual information, i.e. metadata that characterises the situation of entities involved in the interaction between the user and multimedia services. This paper presents how the Adaptation Manager processes and models contextual information, and how it complements the decision taking framework defined by MPEG-21 DIA. The use of important standards and technologies such as MPEG-21 DIA, XML, Description Logics and OWL is explained.

Categories and Subject Descriptors

H.3.5 [**Information Storage and Retrieval**]: Online Information Services – *Web-based services, Commercial services*.

General Terms

Design, Languages.

Keywords

Adaptation, context, interoperability, MPEG-21-DIA, metadata, multimedia services, multimedia content, semantic web.

1. INTRODUCTION

Users are connected to various types of networks virtually anywhere and anytime via a diverse range of mobile terminals. Multimedia Services are becoming a major source of revenue in today's and rather in tomorrow's communication business model. This is reflected by an increase in multimedia service providers and the diversity of available multimedia content. In the context of this paper, a multimedia service delivers multimedia content to end users in a specified manner and may provide functionality. Users can already access different types of multimedia services from their mobile devices such as video streaming, shopping, travel planning and news.

The success of service providers depends on their ability to provide personalised and adapted services to users' needs, preferences and delivery environments. Ideally, the complexity of delivery environments should be transparent to service providers and users should be able to access services using their devices regardless of their capabilities. For this purpose, a context-aware Adaptation Manager (AM) [2], a central entity in the content and service Adaptation Management Framework (AMF) [7], has been introduced by the author as part of the Mobile VCE Core 4 Removing the Barriers to Ubiquitous Services Project. The AM aims to provide context-aware service adaptation and personalisation according to the delivery context, including device characteristics, available user peripherals, network properties / state, user situation, user preferences, natural environment characteristics and service and content descriptions. The AM controls the adaptation process and calculates adaptation decisions to manipulate the content and alter the service delivery with the aim to render them to the applicable delivery context and tailor them to the user preferences [2].

Service and content adaptation systems need to be aware of delivery environments' capabilities, user preferences, content characteristics etc. This information forms the adaptation request context. This paper presents how the AM employs standards such as the MPEG-21 Digital Item Adaptation (DIA) and Semantic Web technologies such as Description Logics (DL) and OWL to model and process adaptation context for the purpose of multimedia services adaptation. The paper illustrates how the employed technologies and standards are used at different stages of the adaptation process. The AM design complements the decision taking framework defined by MPEG-21 DIA.

Section 2 presents a background to service adaptation, the importance of context and the main technologies for multimedia adaptation context. Section 3 introduces the architecture of the AM entity and the complexity of the adaptation management problem. Section 4 explains the technologies employed by the AM at the different stages of adaptation, and section 5 concludes the paper and outlines future work.

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2. BACKGROUND

To endure the competition, service providers need to be able to reach a wide range of users by adapting their services to a wide range of delivery context. Ideally, a multimedia service is dynamically and uniquely customised and personalised to each user. Figure 1 depicts the main stages in the life cycle of such a service. Adaptation decisions are taken at three main stages: content and functionality selection, content and functionality adaptation, and finally presentation and structure definition. Upon receiving requests from (or pushing a service to) users, certain content and functionality are selected. Content selection is performed according to users' preferences, browsing history and their current situation. Content selection is particularly important to push services, for example registering for specific alerts such as sport news. Once content and functionality are selected, the necessary adaptations that need to be performed on them are decided. These adaptations are necessary to fit services to delivery environments capabilities and personalise them to users' preferences. Adaptation decision taking involves input and output modalities (audio, video, images and text), coding formats (MPEG-4, JPEG, MP3…etc) and parameters (size, resolution, bit rate, code size…etc). This process also needs to be aware of available adaptation operations. In accordance with this process, the presentation and the structure of the service is defined to maximise users' experience based on their browsing preferences.

Selection, adaptation decision taking and presentation adaptation are all important stages in the lifecycle of a service that is uniquely personalised to users and that maximises their experiences. The three stages are subjects of continuing research. Adaptive content selection and presentation including navigation have been investigated by the adaptive hypermedia and web systems community [10]. Content adaptation decision taking has been the interest of the multimedia and communication communities [3]. The AM and the systems presented in [4, 5, 9, 15] deal with the two latter stages.

The system presented in [4] adapts HTML pages using a rule-based decision engine. A rule-based approach is adopted for its flexibility and extensibility to new adaptation scenarios. HTML forms such as buttons and labels are resized according to users' satisfaction which is modelled using fuzzy logic. The work in [5] presents a framework for multimedia web documents adaptation to mobile users. Multimedia web documents are decomposed and segmented according to adaptation rules to create a document structure suitable for mobile presentation, navigation and browsing. The framework defines modules to adapt multimedia content to match the user device capabilities. To ensure extensibility to new web page formats, the source and target web documents are XML based and hence HTML documents have to be first converted to XHTML. The adaptation system presented in [15] models users' preferences with regard to different content quality parameters in a score tree. Upon receiving an adaptation request, the system finds the best score node taking into account device capability, network condition and content metadata. More adaptation systems are presented in [2].

The surveyed work focuses on adaptation decision taking and content adaptation for constrained environments such as mobile environments. However, the processing and modelling of context was either not treated at all or treated superficially. Context is a core component in adaptation systems and is vital to the three main stages of adaptation defined in this section. The amount of information in context profiles defines the extent to which the multimedia service can be tailored to users. The efficiency of context processing and modelling greatly affects the quality of adaptation, the efficiency of the adaptation system and the extensibility of the adaptation logic to new adaptation scenarios.

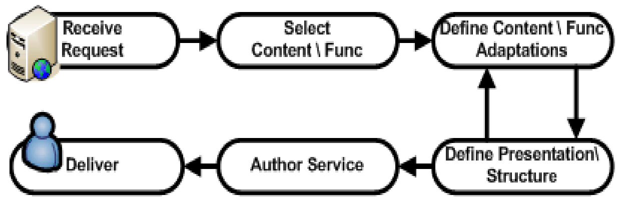

Figure 1. Service adaptation stages

This paper focuses on context, and how different standards and technologies can be employed for efficient modelling and processing of contextual information. In this paper, Context, descriptions and metadata are used interchangeably, and include any information that describes entities involved in the delivery of services to users including users and services. Thus, context encompasses the description of entities such as users, devices, access networks, usage environments, adaptation operations, content and services. Detailed information on context parameters for entities mentioned above are outlined in [1, 14]. However, this paper explains how the AM uses context standards and technologies to meet the following key requirements.

2.1 Multimedia services adaptation requirements

As context is a key enabler for adaptation, key multimedia service requirements are tied with context issues such as interoperability, comprehensiveness and extensibility. This section presents the main requirements and background on possible key solutions.

2.1.1 Interoperability

Entities in the multimedia service adaptation domain implement different context standards; this poses interoperability problems.

The main multimedia context standard is MPEG-7; it provides tools to annotate multimedia content at different stages including creation, storage and usage. The tools can describe low level features such as colour and sound features as well as temporal, spatial or tempo-spatial content structure. Other standards target multimedia annotations for a particular domain, such as SportML for sport news content and NewsML for news content. A survey of multimedia context standards is presented in [11]. MPEG-21 is the latest multimedia context standard. Among other tools, MPEG-21 provides tools to extend context profiles to descriptions of multimedia content usage and consumption environment including devices, networks, user preferences…etc. MPEG-21 aims to enable a transparent use of multimedia content by different communities via diverse consumption environments characterised by different devices and access technologies. The context standards just mentioned provide syntax interoperability because they are based on XML, which insures formal and platform independent syntax definition. However, XML is limited in specifying semantics. The importance of using semantic web

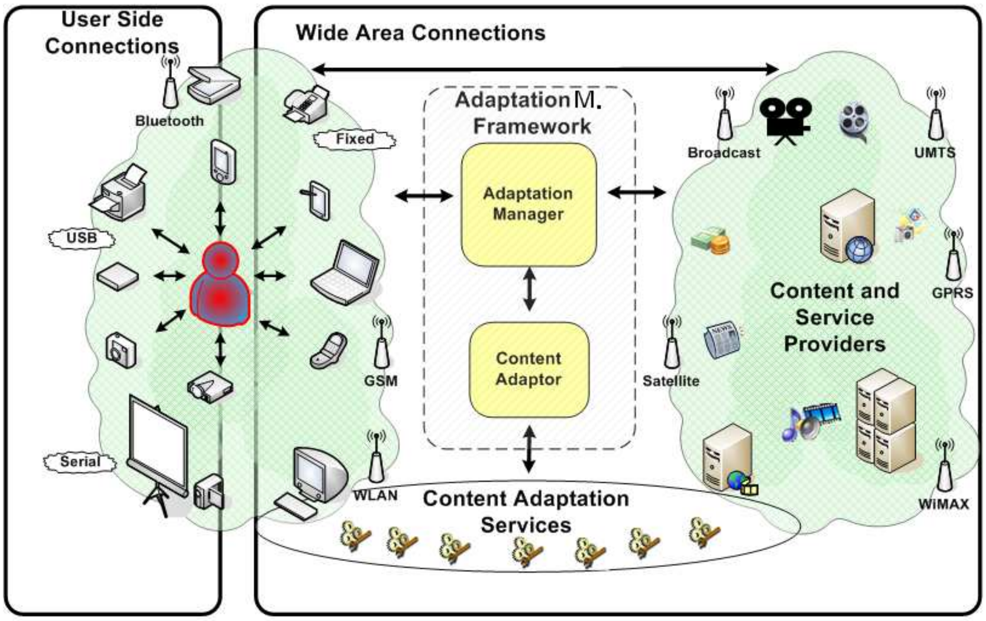

Figure 2. Adaptation Management Framework (AMF)

technologies such as Description Logics (DL) languages, to provide a formal definition of the underlying semantics and hence provide semantic interoperability (formal and shared understanding) is recognized by the multimedia community [12]. DL is a family of knowledge representation languages that provide a description of a domain in terms of concepts and roles between them, based on first order predicate logic. DL languages vary in expressiveness, complexity and decidability. Decidability and computational completeness are important features which ensure that the validity of a statement in the context can be computed and in a finite time. DL languages are powerful ontology formalisms. A number of XML syntax based DL languages have been developed, and Ontology Web Language (OWL) is the most widely used and has become a W3C recommendation. OWL-DL is one of three sublanguages of OWL that provides maximum expressiveness with ensuring decidability and computational completeness. Recently, OWL-1.1 has been proposed as an extension to OWL-DL to provide more expressiveness without loosing decidability and computational completeness. Section 4 presents how the AM employs these technologies

2.1.2 Comprehensiveness

For a worthwhile user experience, adaptation should be comprehensive and thus should take into account all available contextual information. Most adaptation systems focus only on communication environment context, i.e. device, network and content. Adaptation Context should cover information about usage environments and surrounding objects such as other available devices that could be involved in the service delivery, for example, a larger display. Content descriptions for different domains are also important. For comprehensiveness, different context standards describing different domains should be integrated. For example, NewsML and SportML can be used to complement MPEG-7 for multimedia content description.

2.1.3 Extensibility

The multimedia adaptation domain is a dynamic domain in which new technologies and user requirements emerge rapidly. This implies that adaptation context processing would need to be extended to accommodate for such changes. Such extensions should be possible and methodical. Semantic web technologies and XML provide the mechanisms to extend context processing both semantically and syntactically respectively.

3. ADAPTATION MANAGEMENT FRAMEWORK (AMF)

The content and service adaptation problem exhibits an inherent complexity (Figure 2). From the content and service providers' side, the complexity originates from the diversity in multimedia services and content. From the user environments' side, the complexity is the result of the availability of different end devices which may differ greatly in their software and hardware capabilities. Moreover, devices can be connected to different access technologies. The Adaptation Management Framework (AMF) [7](Figure 2) aims to bridge this gap by defining the necessary adaptations and performing them.

The AMF has two main components, the Adaptation Manager (AM) and the Content Adaptor (CA). The AM receives adaptation requests and calculates adaptation decisions in three main stages discussed in section 4. The CA executes adaptation decisions using adaptation tools and if necessary dynamically invokes adaptation services that may be offered by the service provider, the user environment or third parties. The AMF can be deployed in three different scenarios. Service providers could implement such a framework to adapt services they provide. User environments could have a simple version of such a framework in order to enable the user to access, store and use their content with their heterogeneous devices. Such a framework can also be

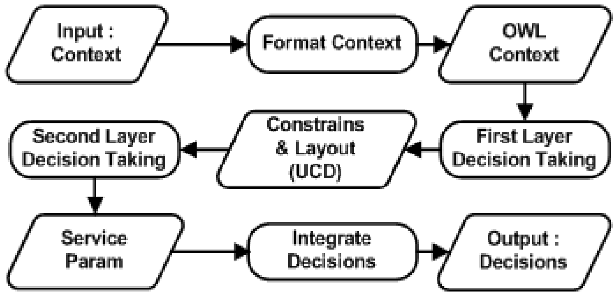

Figure 4. Context processing stages

provided by a third party as a proxy that provides adaptation to both user environments and content and service providers.

The AM has three main components (Figure 5). The context provider acquires and formats the context. The other two components, context reasoner and adaptation decision taking engine process context and calculate adaptation decisions. The context reasoner refines the context and calculates first layer adaptation decisions, and the adaptation decision taking engine calculates second layer decisions. The functionalities of the components and the two layers of decisions are further explained in section 4

4. ADAPTATION MANAGER CONTEXT PROCESSING

The AM uses tools from the MPEG-21 Digital Item Adaptation (DIA) standard [1]. A Digital Item (DI) is a fundamental unit of transaction in the MPEG-21 framework, and contains a presentation, identification and metadata. A decision framework is proposed by DIA which consists of the adaptation decision taking engine (ADTE). The DIA bit-stream adaptation engine (BAE) executes the decisions taken by the ADTE. The ADTE takes as input Usage Environment Descriptions (UED), Universal Constraints Descriptions (UCD) and Adaptation Quality of Service descriptions (AdaptationQoS). The output is the decisions which are the settings of the parameters such as bit-rate, resolution and frame rate. UED, UCD and AdaptationQoS are defined by DIA and supported by the AM. UED is used in the implementation of the AM KB as described in the next section. It provides description tools for multimedia usage environments including devices, networks and users. UCD provides description tools for restrictions, for example, an adaptation is needed to achieve a certain quality level, a resolution less than 50% of the device resolution, a certain maxim code size and match the device colour capabilities. UCD is output of the context reasoner and input to the adaptation decision taking engine (ADTE). AdaptationQoS is also input to the ADTE to assist the decision taking process by describing the relationships between adaptation operations, content parameters and the resulting quality metrics.

The AM extends the MPEG-21 DIA decision framework by providing a first layer of decision taking to handle services with multiple multimedia content items; the ADTE takes second layer decisions. The Content Adaptor may use adaptation tools or services that are based on the bit-stream adaptation engine (BAE). Key context processing stages defined by this paper are depicted by Figure 4. The AM architecture to realise the stages and how it relates to DIA is depicted by Figure 5. The first stage is context formatting and the final stage is integrating decisions. Next sections explain how the AM employs several technologies to efficiently realise the defined context stages.

4.1 Context formatting

This stage corresponds to the “Format Context” stage defined in Figure 4. Context input may be in the form of several context standards, such as MPEG-7/21, CC\PP, NewsML and SportML. Because the standards are based on XML, AM uses XSLT to convert context profiles into the required format. The context formatter, part of the context provider, manages several XSLT transformation tools to format different context standards to the required format, which is the AM KB, as explained in this section. The XSLT tools contains statements that map constructs from input context profiles to corresponding concepts in the AM KB. For instance, Figure 6 depicts a fragment of an XSLT transformation tool implemented by the AM that deals with the Colour Temperature Preference defined in MPEG-21 DIA UED (Figure 3) [1]. Concepts involved in the definition of the Colour Temperature Preference concept are Display Presentation Preferences Type, Users Type and Usage Environment Type (Figure 3). The depicted fragment in Figure 6 maps Colour Temperature Preference to the OWL object property has_ColourTemperaturePreference which links a certain user to that preference. The preference is modelled as an instance of the OWL class ColorTemperaturePreference. To enforce unique names as required by OWL, the name of the instance is an id generated by XSLT (ID = {generate-id()}). Similarly, the concepts BinNumber, which describes the quantization level that PreferredValue and ReferenceValue take [1], is defined. PreferredValue and ReferenceValue are mapped to the corresponding AM KB OWL concepts.

If the description of the content or service is not provided, the context extractor (Figure 5) uses available extraction tools to extract descriptions from the content or services.

In such a heterogeneous environment, system interoperability is of paramount importance. XML ensures syntax interoperability by enforcing formal syntax. Semantic interoperability is to have a common and formal understanding of context concepts such as

```
<DIA>
 <Description xsi:type="UsageEnvironmentType">
  <UsageEnvironmentProperty xsi:type="UsersType">
   <User>
    <UserCharacteristic
     xsi:type="DisplayPresentationPreferencesType">
      <ColorTemperaturePreference>
          <BinNumber>255</BinNumber>
          <Value>
             <PreferredValue>110</PreferredValue>
             <ReferenceValue>127</ReferenceValue>
          </Value>
          <Value>
             <PreferredValue>156</PreferredValue>
             <ReferenceValue>151</ReferenceValue>
          </Value>
       </ColorTemperaturePreference>
```

Figure 3. MPEG-21 DIA UED color temperature preference

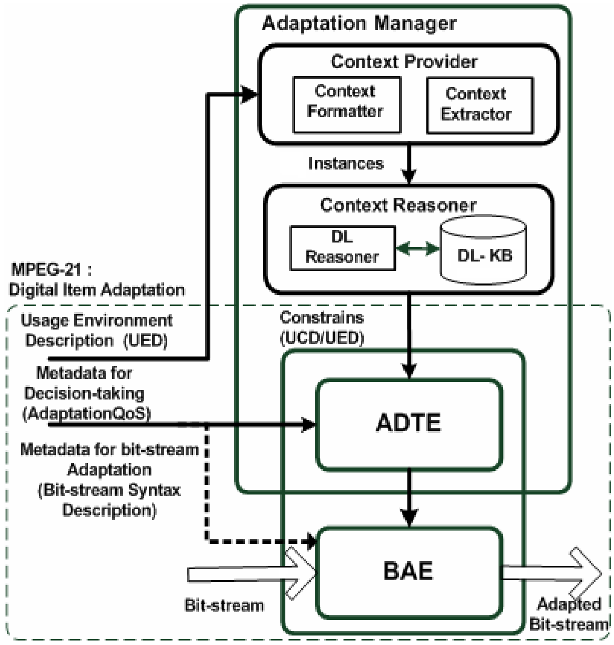

Figure 5. Adaptation manager and MPEG-21 DIA

Display, User Characteristic and Presentation Preference. DL is suited for such a purpose, i.e. describing the domain concepts and formally defining the relationships between them. To ensure both syntax interoperability and semantic interoperability, a combination of XML and DL is needed. Ontology Web Language (OWL) is the most widely used and deployed solution. The difference between DL and ontology is that ontology is a concept and DL provides a powerful formalism to implementing it.

The AM Knowledge Base (AM KB) is an OWL ontology that models the adaptation domain context. The AM KB , presented in [6], is the format to which all input context is converted. The base terminology and concepts underlying the AM KB are defined in MPEG-21 DIA Universal Environment Description (UED) and MPEG-7 Multimedia Description Schemes (MDS). The AM KB is constructed by manual conversion of the MPEG-21 DIA UED and MPEG-7 MDS from their XML format to the AM KB OWL based format, because OWL is based on XML and DL and hence provides the advantages of both. MPEG-21 DIA UED and MPEG-7 MDS were chosen because they are the most comprehensive standards that define general concepts in the adaptation domain such as device, device display, network, user preference, device capability etc. The AM KB can be extended to domain specific concepts defined by domain specific standards such as NewsML and SportML. As semantic web technologies such as OWL can define context elements formally and unambiguously; extensions to such elements can be incorporated without causing redundancies or inconsistencies. Syntax wise, XML is designed to allow extensibility. As a consequence, the AM KB extension is possible and methodical.

The importance of semantic descriptions and semantic interoperability is recognised by the multimedia community. In [13], an ontology based on MPEG-21/7 has been constructed, and was used in the DS-MIRF framework to facilitate the development of knowledge-based multimedia applications such as multimedia information retrieval, filtering, browsing, interaction, extraction, segmentation, and content description. As opposed to the AM KB, The ontology in [13] was constructed using automatic conversion rules. Automatic conversion converts XML elements into owl constructs using fixed rules, for example converting every XML complex type to an OWL class. However, manual conversion examines and models each XML element according to its semantics. The difference between automatic and manual conversion is outlined in [6]. The main advantage of manual conversion is that it defines the semantics accurately. Rather than merely writing an XML document tree in an OWL format, as performed by automatic conversion, manual conversion could remove XML elements or add OWL concepts depending on the semantics of the XML element being converted form XML to OWL. This is because some XML elements in XML documents do not have semantic significance and are created, for example, to make the syntax easily readable.

Manual conversion is necessary only once when constructing the AM KB. Input context represents instance ontologies, which consist of instances such as Nokia 95, Tom and contentX, and can be converted automatically using XSLT by the context formatter. The definition of the concepts: device, user and content are pre-defined in the manually constructed KB.

4.2 First layer decision taking

This stage is represented by the “First Layer Decision Taking” stage in Figure 4. It is performed by the context reasoner to analyse context and derive two types of decisions: service layout/structure and constraints. Constraints define the resources such as battery life, processing power and memory allocated to content items delivered by the service, based on the limitations of the delivery environment and the user preferences. Constraints are specified in the form of MPEG-21 Universal Constraints Description (UCD).The AM employs DL (OWL 1.1) reasoning using OWL API, Pellet and FACT++. Pellet and Fact ++ are both DL reasoners that implement the full functionalities of OWL 1.1. As opposed to other reasoners such as Racer, which uses the DL Implementation Group (DIG) HTTP based interface, Pellet and Fact++ provide a java interface; this saves the communication overhead introduced by the DIG interface. The feasibility of using rule based reasoning built on OWL such as the Semantic Web Rule Language (SWRL) was studied. The current architecture does not use SWRL because on one hand the new features introduced in OWL 1.1 satisfies the need for SWRL and on the other hand the SWRL APIs and ontology introduce considerable overhead.

This stage calculates the types of instances in the context, for example, the types of a device might be: battery-limited, memory-limited, mp3-limited…etc, and uses them to define the layout and constraints (UCD). For example, the context reasoner deduces that there is a memory limitation if the multimedia service required memory is more than the user’s device available memory. This simple limitation is modelled in OWL 1.1 and in DL notation as follows:

$$\text{device\_memory\_limited} \equiv \exists\, \text{availableMemory} < x$$

This statement means that the device_memory_limitation concept is equivalent to instances where there exists an availableMemory datatype property relation such that the value of that property is

```
<xsl:for-each select="schema/DIA">
    <xsl:for-each select="Description[@type= 'UsageEnvironmentType']">
        <xsl:for-each select="UsageEnvironment[@type='UserCharacteristicsType']">
     <xsl:for-each select="UserCharacteristics[@type='PresentationPreferencesType']">
        <xsl:for-each select="Display">
            <xsl:for-each select="ColorTemperaturePreference">
                <DIA: has_ColorTemperaturePreference>
                  <DIA:ColorTemperaturePreference rdf:ID="{generate-id()}">
                    <DIA:binNumber rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                      <xsl:value-of select="BinNumber"/>
                       </DIA:binNumber>
                        <xsl:for-each select="Value">
                           <DIA:has_value>
                              <DIA:value rdf:ID="{generate-id()}">
                           <DIA:preferredValue rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                               <xsl:value-of select="PreferredValue"/>
                           </DIA:preferredValue>
                            <DIA:referenceValue rdf:datatype="http://www.w3.org/2001/XMLSchema#int">
                               <xsl:value-of select="ReferenceValue"/>
                           </DIA:referenceValue>
                              </DIA:value>
                           </DIA:has_value>
                        </xsl:for-each>
                     </DIA:ColorTemperaturePreference>
                  </DIA: has_ColorTemperaturePreference>
                </xsl:for-each>
```

Figure 6. Formatting MPEG-21 DIA color temperature preference to the AM KB

less than a certain value x. In this case, x represents the required memory resource by the multimedia service. Similarly, other limitations are defined. Complex limitations can be defined using simple limitations and logical constructs such as intersection and union. For example:

$$\text{video\_limited\_delivery} \equiv \text{video\_unable} \cup$$

$$(\text{video\_able} \cap \text{video\_resolution\_limited}) \cup$$

$$(\text{video\_able} \cap \text{video\_format\_limited})$$

After deducing the limitations, the context reasoner calculates the constraints that will be represented as UCD and passed as input to the next stage of decision taking. For example, knowing that the device has the limitations video_resolution_limited and battery_limited, the context reasoner calculates the maximum resolution that all service video files shall not exceed. The value should be less than the maximum resolution supported by the device display and should consume battery resources according to the deduced battery limitation.

There are several advantages of using DL and OWL. The definition of the reasoning logic in terms of concepts (types) and relationships reduces the complexity of construction and maintenance. Because of the clear structure, modifying a complex reasoning logic is easier as opposed to a rule based approach for instance. The availability of well studied and researched DL reasoners makes it possible to check the consistency of the KB to ensure that extensions or modifications does not cause inconsistencies or incorrect results of reasoning. The same advantages apply With regard to the OWL based AM KB. In the ideal situation where an ontology for multimedia context is standardised, the formatting overhead is saved. Furthermore, the AM KB can be extended to such standard ontology because it is based on recognised standard such as MPEG-21 and OWL

4.3 Second layer decision taking

The next stage of decision taking is second layer decision taking; it is represented by the “Second Layer Decision Taking” stage in Figure 4. The ADTE defines the service parameters based on metrics represented in restrictions (UCD), environment characteristics (formatted UED) and AdaptationQoS. The output is the service parameters such as the exact resolution and bit-rate. An example of an ADTE implementation based on MPEG-21-DIA is presented in [8]. This research does not focus on this stage at the moment. The focus is on the other context processing stages , which are defined in previous sections, and how they complement the second layer decision taking stage, which is based on MPEG-21-DIA ADTE and implemented in [8].

5. CONCLUSION

Adaptation is essential to multimedia services personalisation and interoperability with user environments. Context is a core component to adaptation. The AM adaptation decision process is divided into distinct and well defined stages, and employs well recognised standards and technologies. In such a dynamic domain, employment of established metadata standards, such as MPEG-7/21, and system extensibility to new ones must be inherent features of the design as they are fundamental to interoperability with entities in the adaptation environment. Description logics, OWL and XML provide powerful mechanisms to allow extensibility to new context standards because they provide an extensible, formal and semantic context modelling and knowledge representation. The AM adaptation decision framework is based on MPEG-21 DIA and provides a higher level of decision taking to handle services with multiple multimedia content items. Thus the AM can interoperate with external DIA based ADTEs in the case where some adaptation decision logic is not supported by the AM.

Future plans include working on service structure and layout adaptation using service context described in OWL. Several research projects are working on automatic extraction of service context. Service context would describe relationships between multimedia content delivered by the service. These relationships are used in two main aspects. The first aspect is to identify content elements that together constitute a coherent unit. The second aspect is to identify the interrelationships between content elements such as: is content A essential or optional for content B, i.e. would content B make sense if content A is removed and vice versa. After all context processing stages are implemented, the AM needs to be evaluated in terms of performance, accuracy of adaptation and usability.

6. ACKNOWLEDGMENTS

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