A unified data model and system support for the context-aware access to multimedia content

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Abstract: Context-aware consumption of content implies that platforms mediating the access to content must be able to do that independently of the user location, type of terminal, network conditions and content formats. In addition, user preferences, environmental conditions and content owners and usage rights should be respected. The fulfillment of this concept requires the availability of a comprehensive set of metadata related with both the content and the usage environment. But how can systems coherently and easily exchange, inter-relate and use the different types of required meta–information? This paper presents the solution developed within the ENTHRONE project with this aim, describing the mechanisms designed for publishing multimedia content and all relevant metadata associated with the consumption of that content, in an open and unified form, for accessing that content upon request of end-users and decide if and what kind of adaptation operations are needed to provide a context-aware service to the end user. The solution is based on the MPEG-21 standard and on the adoption of a modular and distributed architecture to implement the required functionality.

Keywords: MPEG-21, context-awareness, flexibility, universal access, data model, DRM

1 Introduction

As technology continues to evolve at an accelerating rate, different multimedia-enabled devices aiming at the same field of application, but presenting diverse capabilities are continuously being introduced in the market. To this reality adds the large volumes of multimedia content available on-line, presenting a multiplicity of formats and the ever growing acceptance of the network-centric paradigm from the general public. Increasingly more consumers, equipped with different devices and having diverse interests and preferences, "navigate" in the Internet or get connected to some network looking for different types of multimedia information. An access to content that meets user expectations and demands must take into account all the different aspects of this heterogeneous scenario. A thorough characterization of both the content as well as of the context of usage is therefore needed to enable the selection and delivery of the content in the most adequate conditions given the current context of usage. This includes content format diversity, terminal capabilities, network characteristics, user preferences and user surrounding environment. The characterization of all these factors requires the use of metadata. Currently, there is no universally accepted solution, which results in the existence of multiple formats (standard and proprietary) that are (partially) overlapping or that aim to cover distinct aspects. To achieve interoperability and transparent access to media content it is necessary to find a solution where multiple formats and models may coexist and where the information can be consistently used throughout the delivery chain, thus contributing to the enhancement of the user's experience. This paper describes the developments made within the ENTHRONE* project towards meeting these goals. It focuses, in particular, on the development of a unified data model that supports the publishing and management of multimedia content together with the different sets of metadata related to the consumption of that content. It also addresses the aspects related with the protection and governed consumption of that content in heterogeneous terminals.

ENTHRONE aims at providing end-users with the capability of consuming multimedia content in a transparent way, with the best possible (or chosen) quality given the constraints or limitations of the context of usage. To that aim, the project has defined and developed an integrated management solution covering the entire audio-visual service distribution chain, from the generation and protection of content, through its distribution across various networks, to the reception and consumption at the user terminal.

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* ENTHRONE IST-507637, "*End-to-End QoS through Integrated Management of Content, Networks and Terminals"*. The project is now entering a second 2-year period.

This integrated solution provided by ENTHRONE is capable of harmonising the functionality and operation of each entity along the chain, rather than imposing a strategy on each one of them. Overall it provides a comprehensive infrastructure for the creation, archival and distribution of a variety of audio-visual content objects, which are delivered and consumed in various user terminals. This is accomplished essentially due to the horizontal use of metadata describing all the above mentioned aspects of the usage environment. This architecture relies on the use of open formats and specifications, notably the MPEG-21 standard [Bur06] and Web Services technologies. MPEG-21 is the emergent standard being developed in ISO/IEC with the scope of providing the tools and technologies to augment the use of multimedia content in heterogeneous environments. The use of Web Services provides the means to effectively enable the access of heterogeneous systems and applications to networked services.

By using these technologies, ENTHRONE has developed tools that enable:

- Content Providers to author, publish and protect their content in a unified way enabling its transparent access;
- Service Providers to build multimedia services and offer them adapted to the user context characteristics;
- Service Providers to maintain a quality-based monitoring of the service being paid to end-users;
- Network Providers to collaborate among them and with Service Providers to offer a quality-based network access to their costumers;
- End-users to search for and browse rich multimedia content that can then be transparently consumed.

The remainder of this paper is structured as follows. Section 2 provides a brief description of the core technologies used in ENTHRONE enabling the fulfilment of its goals. Section 3 introduces the ENTHRONE general architecture, listing its main functionality and services offered. Section 4 describes the ENTHRONE data model. Section 5 illustrates the publishing and archival processes of ENTHRONE. Section 6 addresses the aspects related to the access and consumption of content. Finally section 7 draws the conclusions and provides indication of future work.

2 The Core Technologies

2.1 MPEG-21

MPEG-21 aims at describing how the various elements of the multimedia content delivery chain fit together to create a truly interoperable multimedia framework where content is conveyed as Digital Items (DI) [IS102]. MPEG-21 presents itself as a solution for augmenting the consumption of multimedia content. The objective is to provide a platform that will enable users to access multimedia content in a transparent way. This standard is currently composed of 17 parts: 1 - Vision, Technologies and Strategy; 2 - Digital Item Declaration (DID); 3 - Digital Item Identification and Description (DII); 4 - Intellectual Property Management and Protection Components (IPMP Components); 5 - Rights Expression Language (REL); 6 - Rights Data Dictionary (RDD); 7 - Digital Item Adaptation (DIA); 8 - Reference Software; 9 - File Format (FF); 10 - Digital Item Processing (DIP); 11 - Evaluation Tools for Persistent Association; 12 - Test Bed for MPEG-21 Resource Delivery; 14 – Conformance; 15 - Event Reporting (ER); 16 - Binary format; 17 - Fragment Identification for MPEG Media Types; 18 – Digital Item Streaming.

For the rest of the document we will assume the reader is familiar with MPEG-21. If it is not the case, the reader is referred to [Bor03], [Bur06] and [IS102]. Being an essential aspect of MPEG-21 and due to its overall use in this paper, we provide a brief description of the concept of Digital Item and respective Digital Item Declaration.

MPEG-21 states:

> *"A Digital Item is a structured digital object with a standard representation, identification and meta-data within the MPEG-21 framework. This entity is also the fundamental unit of distribution and transaction within this framework" [IS102].*

A DI can be a complex object encompassing a great variety of media and metadata. Part 2 of the standard specifies the Digital Item Declaration Language (DIDL). This language is used to generate the Digital Item Declaration (DID), typically an XML document, which describes the structure of the DI. Inside the DID, standardized MPEG-21 mechanisms are used to either convey the resources embedded directly in the DID, or to provide information on the location of the resources that make up the DI [IS203]. As the DID may contain a great diversity of components, its declaration can be quite complex. However, a DI is more than a set of media resources to be presented to end users. It may include, as an example, descriptive information (about content and context) in multiple formats, rights expressions and configuration information that may require the intervention of the end user or of the terminal among others.

2.2 Web Services

Essential to any networked platform operating in heterogeneous environments, is the use of communication middleware. This layer enables the system components to be deployed, replicated or divided at different locations, ensuring the communication and signalling between them and enabling the provision of remote added-value services. The use of Web Services (WS) came as a natural choice to ENTHRONE to satisfy these needs. It enabled the development of a service oriented architecture for ENTHRONE, facilitating the inter operation between the different components of the system and the easy deployment in a wide range of scenarios. The exchange of information is accomplished using SOAP (Simple Object Access Protocol) [SOAP], which is a technology that pairs well with MPEG-21 as both are based on XML. WS technologies provide an open and universal mode for client devices and external applications to access and use the platform services. As it is widely used across the Internet and universally supported, it enables the establishment of a variety of business models [ve01, Vir, W3C].

3 ENTHRONE System

The ENTHRONE project has developed a distributed context-aware content management system to enable the publishing of multimedia content and the customised access to that content from diverse client devices The system, designated of ENTHRONE Integrated Management Supervisor (EIMS) is represented at the functional level, in Figure 1. It is a modular and distributed system, comprising different subsystems with well-defined goals. Although the present paper focus on the ENTRHONE data model, a succinct description of the EIMS will be here provided, to assist the reader in better understanding the overall operation of ENTHRONE towards the delivery of context-aware services. More detailed descriptions of the EIMS can be found in previously published work [AnM06].

The tasks implemented by each subsystem are normally under the responsibility of a different entity in the content value chain namely, Content Providers (CP), Service Providers (SP), Network Providers (NP), End-users. Communication is accomplished via Web Services. For convenience and clarity, the EIMS sub-systems will be here briefly described, as grouped according to this more usual distribution of responsibilities. Nonetheless, they could all be deployed and used at the same location, managed by the same entity or even grouped together in different ways. Given the scope of this paper we will focus on the main flows of metadata within the system, namely generation, publication and consumption.

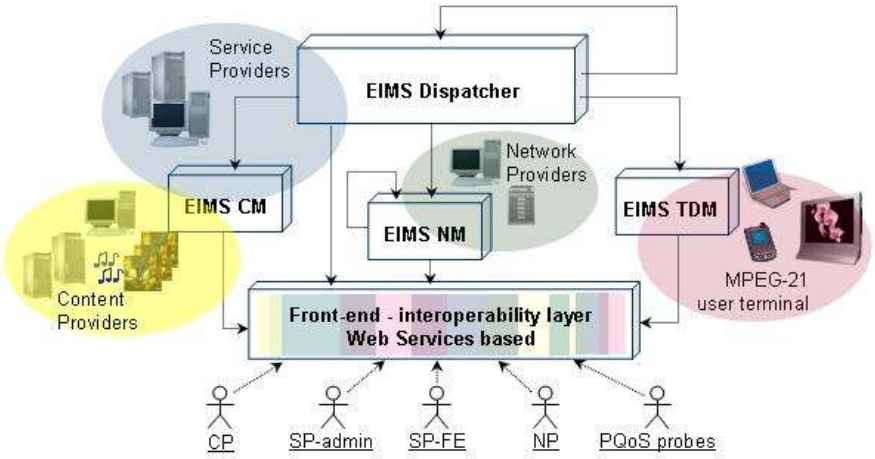

Figure 1 – The EIMS high-level architecture

1) The CP modules

a) EIMS Content Manager @ Content Provider (EIMS-CM) - The EIMS-CM is responsible for content and metadata management. It is typically a distributed system, deployed at two different sites, with two distinct sets of functionality. The EIMS-CM@CP is located at the CP premises. This module provides the functionalities that enable CP to aggregate or generate the several types of descriptive metadata associated to one or more pieces of content (content descriptive metadata, adaptation related metadata, scheduling information, Digital Rights Management (DRM) information, etc.) and wrap it in a package – the DI. It also allows for DIs to be uploaded to the ENTHRONE server making it available to end-users. The other module that makes up the EIMS CM (EIMS-CM @ Service Provider (EIMS-CM@SP)) is described in 2)b).

2) The SP modules

a) EIMS Dispatcher - The kernel of the EIMS is the EIMS-Dispatcher. It is responsible for the overall coordination of the EIMS, performing the management of user requests. It is able to monitor a multimedia content delivery service throughout its lifetime to control the delivered quality and initiating reactive measures when it detects quality degradation. This ensures that the content is adapted to the usage environment and to the selected service quality. To accomplish its tasks, it processes content and context metadata, which it collects from different points of the content value chain

b) EIMS Content Manager @ Service Provider (EIMS-CM@SP) - Although SPs may not be the creators of the content they offer, they usually aggregate in their own repositories content coming from diverse sources. To enable the management of and control the access to this aggregated content, the ENTHRONE platform supplies the EIMS-CM@SP. This module offers a service for the upload of metadata in the form of MPEG-21 DIDs and maintains a repository and data base of the received information. It supports distributed content searches based on semantically meaningful keywords (currently TVA Program Information metadata).

3) The NP modules

EIMS Network Manager - The Network Manager subsystem will be deployed at the Network Providers (NP). It is responsible for network resource negotiation and allocation, and for managing Quality of Service (QoS) adaptation in the network. This subsystem collaborates with the EIMS Dispatcher in finding an optimizing delivery path for DIs by supplying it with relevant MPEG-21 metadata describing available network conditions.

4) The terminal modules

EIMS Terminal Device Manager (EIMS-TDM) - The EIMS-TDM provides a platform-neutral interface to various kinds of terminals. Its main purpose is to report back to the Dispatcher the characteristics of the terminal and to perform local QoS management, license management and event scheduling. The characteristics of the Terminal are described using the *Terminal Capabilities* tool of the MPEG-21 Digital Item Adaptation.

4 ENTHRONE Data model

The Enthrone system deals with a large and varied amount of metadata. A significant part of this metadata consists of content and context description metadata. The system is required to store and manage information published as MPEG-21 DIs in a way that makes access to DIs easier and more flexible, optimizing metadata interpretability and coordinating overall metadata management.

The metadata within a DID can be logically categorized as either content or context descriptive. The former involves both a low level description of the media content's characteristics as well as a human understandable description of the media's semantic content. This type of characterization was accomplished through the use of MPEG-21, MPEG-7 [ISO07] and EPG (Electronic Programme Guide) based metadata.

The description of context includes, among others, the description of terminal and network characteristics, information about the chronological availability of content and modes of provision. For these descriptions, MPEG-21, MPEG-7 and TV-Anytime (TVA) were used. The choice of these standards was driven by the specific needs of the ENTHRONE system and also to be in a close agreement with the standards being used in the universe of commercial TV or video production, annotation and broadcasting, as identified by partners of ENTHRONE (RBB and France Telecom).

4.1 Overall structure of the ENTHRONE MPEG-21 DIDs

The MPEG-21 standard allows a myriad of possibilities for DI declaration. Given the needs and specificities of ENTHRONE, only a restricted subset of the standard was used. In particular, some restrictions were applied to the DID concerning the depth of the DID tree structure. Nevertheless, the used sub-portion is MPEG-21 compliant. The overall structure of the employed DID is presented in Figure 2.

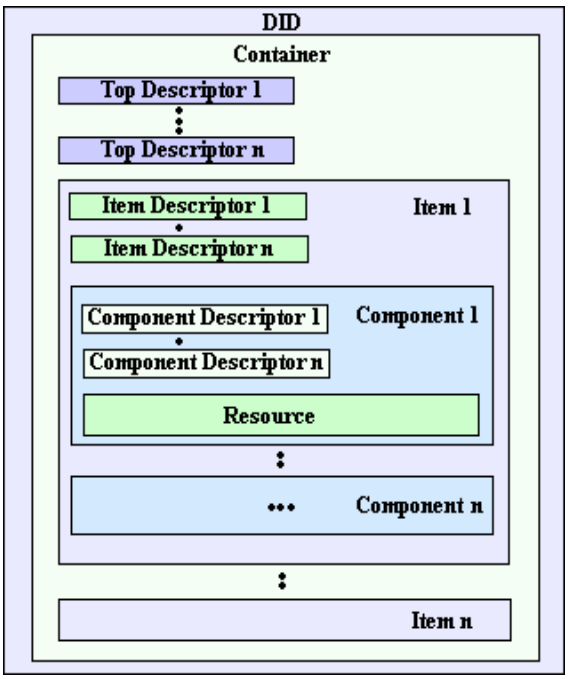

Figure 2 - Enthrone DID Structure

The employed DID format consists of an outer container, inside of witch are stored individual Item declarations. Each of these declarations is encapsulated by an Item element. DIs may be composed of one or more independent media resources. This translates into the employed format through the introduction of a Component, child of an Item, for the representation of every individual resource comprised by the DI. The overall container as well as every Item and Component carries descriptive metadata contained in the respective Descriptor elements.

The Descriptors characterize the instance represented or encapsulated by its parent node. The possible types for the Descriptors and the information they carry is listed next:

- DI identifier - univocally identifies a DI within the system's DI database, using MPEG21 DII. The information within this Descriptor allows the system to differentiate between DIs.
- DI content semantic - identifies the type of content (semantically speaking), that its parent Item represents. This data is to be used for the matching of DIs with user searches for desired content. TVA and Enthrone specific metadata were employed. An example is presented bellow;

```
<Descriptor ims:metadataType="ims:ProgramInformation">
   ……..
   <Statement mimeType="text/xml">
      <ims:ProgramInformation programId="crid://www.optibase.com/TVM/8660">
         <BasicDescription xmlns="urn:tva:metadata:2004">
            <Title>Funny Clip</Title>
            <Synopsis>A funny news clip</Synopsis>
            <Language>de</Language>
         </BasicDescription>
      </ims:ProgramInformation>
   </Statement>
</Descriptor>
```

- DI adaptation possibilities - specifies the "adaptation space", i.e., it specifies all the combinations of possible adaptation operations, for a DI's multimedia content, and the respective quality results. MPEG21 DIA AQoS metadata was used.
- DI content available encoding formats describer – if for a particular DI, its "adaptation possibilities space" is for any reason, further restricted, this Descriptor is used to specify the "operation points" of that space that are acceptable. MPEG21 DIA and MPEG7 metadata was used.
- DI content temporal/web-location availability - specifies the time interval when and the web-location where, the content will be available. TVA metadata wrapped inside Enthrone specific metadata was employed. An example is presented bellow:

```
<Descriptor ims:metadataType="ims:Schedule">
   …….
   <Statement mimeType="text/xml">
      <ims:Schedule serviceIDRef="MGW-EPG">
         <tva:ScheduleEvent>
            <Program xmlns="urn:tva:metadata:2004" crid="crid://www.optibase.com/" />
            <ProgramURL
xmlns="urn:tva:metadata:2004">http://www.test2006.org/videos/funnyclip/funnyclip_0.sdp@2006-05-
01T00:00:00.0Z
            </ProgramURL>
            <PublishedStartTime xmlns="urn:tva:metadata:2004">2006-05-01T00:00:00.0Z
            </PublishedStartTime>
            <PublishedEndTime xmlns="urn:tva:metadata:2004">2006-06-30T00:00:00:0Z
            </PublishedEndTime>
            <PublishedDuration xmlns="urn:tva:metadata:2004">P56D</PublishedDuration>
         </tva:ScheduleEvent>
      </ims:Schedule>
   </Statement>
</Descriptor>
```

- DI delivery method and delivery service describer - specifies the type of service (Unicast vs. Broadcast) under which the content is distributed, and identifies the specific service through which the content is made available. Enthrone specific metadata was employed. An example is presented bellow.

```
<Descriptor ims:metadataType="TVMConfig">
   ........
   <Statement mimeType="text/xml">
      <ims:TVMConfiguration>
         <tvm:TVMCfg_Service_Type>UNICAST</tvm:TVMCfg_Service_Type>
         <tvm:TVMCfg_ServiceID>200.100.100.100_5</tvm:TVMCfg_ServiceID>
      </ims:TVMConfiguration>
   </Statement>
</Descriptor>
```

- DI content source identifier - identifies the entity which is responsible for the service through which the content is supplied.

4.2 Database Model

The main principles of the Enthrone Database Model (EDM) will be presented in the sequel as well as their instantiations in the model. The current work is based on previous work related to the organization of multimedia repositories [RDC04], [CRD05].

A first principle is that the objects are organized as part-of hierarchies. A second principle which is frequently used in the area of digital libraries is that of uniform description i.e., the same descriptors are used both for an individual item and for the collection including it. By combining hierarchical organization and uniform description, the EDM can accommodate flexible hierarchical structures with variable depths, having attributes inherited from the collection level to sub-collection, down to an individual Item. For example, we can treat a collection of MPEG-21 DIs as a higher-level DI; if the entire DIs collection shares the same digital rights, those can be specified at collection level only. A third principle of the EDM is to allow specific fragments (segments) of DIs to have specialized descriptors. For example, the video track of a specific DI may require motion activity and color descriptors, while audio track of the same DI may require a melody contour descriptor.

Figure 3 depicts the UML (Unified Modelling Language) diagram of the main concepts of the EDM. The Description Unit (DU) class captures the notion of an object or collection of objects that can be given a specific context. The structure of DUs follows the principles of hierarchical organization and uniform description. At the level of DUs we store contextual information such as authors, dates, technical details.

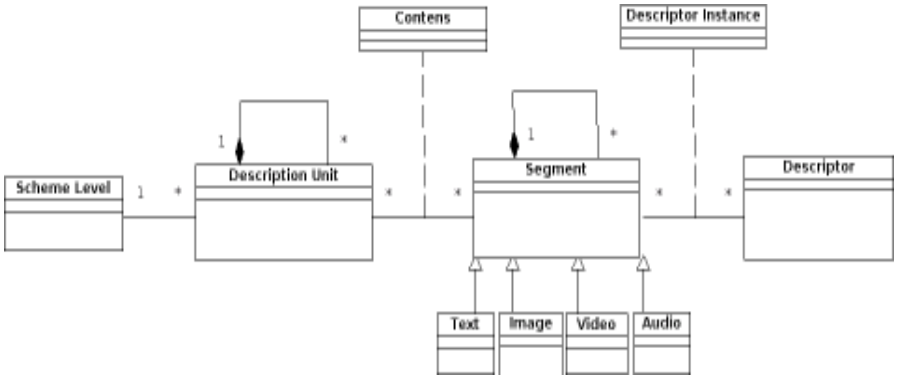

Figure 3 - The ENTHRONE Database Model

The Segment class models the notion of a part of a DI that can be independently analyzed and consumed in terms of content. A Segment has no context of its own, getting it from its associated Description Unit or from the object that includes it (an upper level Description Unit). The Segments are also organized as part-of hierarchies.

At the segment level we must deal with a large variety of descriptors. We can have descriptors from TV-Anytime, such as Program Information or Schedule, from MPEG-21 such as DII, DIA, REL and from MPEG-7 as well. As the set of descriptors is not fixed, the EDM is as open-ended as possible with respect to the specialized descriptors that can be

attached to Segments. The Descriptors and Descriptor Instances classes capture the relation between segments and specialized descriptors in the following way: the descriptor is first added to the set of existing descriptors (i.e. the Descriptors table) and then its identifier is associated to a specific segment in the Segments table.

In Enthrone, we require that the hierarchies introduced by the structure of the Digital Items to comply with a certain semantic structure. The mechanism that controls the structure of the hierarchy is modelled with the Scheme Level class. The flexibility is maintained, as there are no restrictions on the nature of the schemes that can be defined. An example of how a Digital Item is effectively being stored in our database is illustrated in Figure. 4.

The MMDB for the first phase of ENTHRONE combines a relational storage model and an XML repository. The relational model is mostly used for capturing the structure of the DIs, storing the information that is needed in the search process, whereas the repository is mostly used at retrieval time. The most relevant concepts in the model are: Description Units, Scheme/Scheme Level, Segment and Descriptor and Descriptor Instance. Their use is based on analysis of various standards (ISAD(G) [ISAD], ISAAR [ISAA], Dublin Core [DCR], MPEG-7, MPEG-21 and TV-Anytime) .

When uploading a DI to be stored in the database, the input is an XML string containing a MPEG-21 DID, which in few words is a hierarchy of *Container*, *Item*, *Component* elements, each one with its own *Descriptors*. The DID being uploaded it must be parsed and afterwards its structure will be mapped in hierarchiesm of *Description Units* **(**DUs**)**. Each DU corresponds to a record in the Description Units table (see Figure. 4). It can have one or more *Segments*, with corresponding *Descriptor* types **(**TVA**,** *ProgramInformation***,** DIA**,** DII**,** REL, etc**)**.

At this point it is important to underline that the *Descriptor* concept in our model is mapped to an MPEG-21 *Descriptor* element. The *Descriptor Instance* class captures instances of *Descriptors*. MPEG-21 *Descriptors* are parsed at the upload time, and useful attributes are stored in fields of their corresponding Description Units.

An example of how a Digital Item is effectively being stored in our database is illustrated in Figure. 4. The table names closely follow the class names in the model. The MPEG-21 DI in the left part of the figure is structured as a three level-hierarchy: Container, Item and Component. Each level is captured as a separate entry in the Description Units table and is identified by *code*, *parent_code* and *scheme_level* attributes. Information such as title, synopsis, genre, and other descriptive details in the DID are also uniformly present in each record of the Description Units table (in each DU**)**. Such information is taken mostly from the TV-Anytime *ProgramInformation* descriptor and represents the searchable set of attributes. The association between Segments and their corresponding Description Units is realized through the Contents table, while the Descriptor and Descriptor Instance tables

capture the specialized descriptors of each Segment. The records of the Contents table illustrate that only a sub-set of the segments -0, 1, 2, 3 and 9- are directly associated with DUs. The others -4, 5, 6, 7, 8- take their contexts from the DUs of their parent segments.

The Descriptor Instances table shows how segments can have specialized descriptors. For example the segment with code 2 (the video component of the Digital Item) is described by an instance of the descriptor with code 2 (MotionActivity).

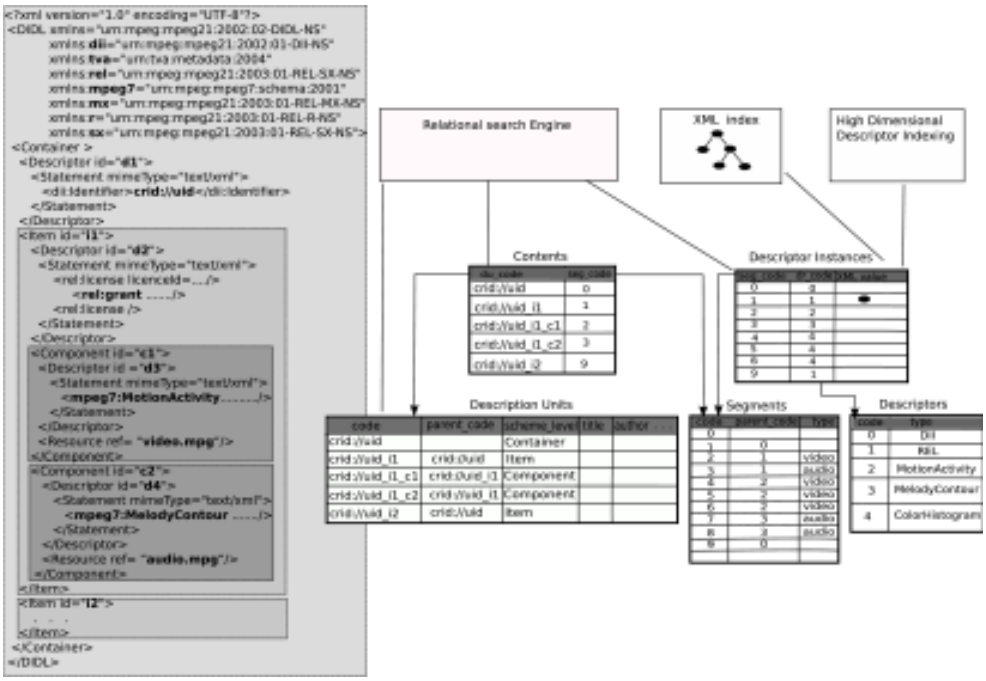

Figure. 4 - Mapping a DI to the ENTHRONE Data Model

The search mechanism is designed to support indexing structures adapted to the various datatypes: text/XML, numeric and high-dimensional descriptors. Depending on the query type, the retrievable units can be either a single Digital Item or a collection thereof. The query is sent as an XML file containing the list of the search parameters. The list of the available parameters together with the XML is presented below:

```
<searchDI_Request>
<Query>
        <parameter name="Title" value="Landesschau am Samstag"/>
        <parameter name="ShortTitle" value=""/>
        <parameter name="Synopsis" value=""/>
        <parameter name="Genre" value=""/>
        <parameter name="Language" value=""/>
        <parameter name="Release Date" value=""/>
        <parameter name="Keyword" value=""/>
</Query>
</searchDI_Request>
```

Search on the database is based on string matching. It consists of an SQL query executed on the Description Units table. The wildcard character, '%', matches any string and can be combined with other strings to narrow the search. E.g., "%Samstag%" will match any string that includes the string "Samstag". The result of a query consists of a list of references to temporary DIs. A temporary DI is composed of a copy of an Item containing one or more matchings. The list of results is itself wrapped as a DI where each entry on the list corresponds to an individual Item that references the corresponding temporary DI.. An example is provide below:

```
<?xml version="1.0" encoding="UTF-8"?>
<DIDL xmlns="urn:mpeg:mpeg21:2002:02-DIDL-NS">
   <Container id="result_id">
       <Descriptor>
                   <Statement mimeType="text/plain">List of resources found for search parameters
[title="%Tagesschau%",language="de",keyword="%ess%"]
</Statement>
       </Descriptor>
       <Item id="dii_item_67"
        .....
       </Item>
       .....
       <Item id="uri:enthrone:rbb:1_item_17"
        .....
       </Item>
   </Container>
</DIDL>
```

5 Data Publication

5.1 Information Gathering and encapsulation

One of the main goals of the ENTHRONE System is to provide the users with a variety of content available from different sources (broadcasted or on-demand). This is achieved through unified gathering and distribution of context and content information about the available media. The information about the various contents that are made available by ENTHRONE is generated either from existing EPG metadata found in today's digital broadcasting distribution channels, such as DVB-T (Digital Video Broadcasting - Terrestrial), or directly from the content provider.

When the content is available over DVB channels, some metadata is typically already injected by the broadcaster in the DVB stream using PSI/SI tables. These tables contain various content descriptive information such as: title, language, start time, duration, genre, synopsis of each programme. In the ENTHRONE System this metadata is received by an MPEG-2 TS (Transport Stream) decoder and then transformed into a standard TV-Anytime description [ER3] before further processing. A complete TVA description is generated for each audiovisual channel. In a second step these TVA documents are given to an authoring tool, called the Mtool, which allows the manual edition of the descriptions (e.g, for addition of further information), and the encapsulation into an MPEG-21 DID. In the case when the content is available on demand (e.g. through the Internet), the Mtool is called with empty MPEG-21 DID templates (containing empty TV-Anytime content descriptions). These templates are used to easily edit complete content descriptions (such as genre, cast, duration, etc.) in the right format. Once the DIDs embedding TVA content descriptions are created (either automatically or manually), they are completed with context-related MPEG-21 descriptions that will be used by the other ENTHRONE components along the delivery chain to select/adapt the content according to the QoS levels required by the user/terminal. These consist of UED (Usage Environment Description) DIA descriptions associated to the content, and the location information of the different versions available for a given content.

The encapsulation of TV-Anytime content descriptive and context-related information in the ENTHRONE DID is achieved through successive XSLT transformations, potentially assisted by the content provider (using the Mtool to manually edit/complete some descriptions). The resulting DID is then ready for publication.

5.2 Publication Process

The publishing of information in the form of MPEG-21 DIs in the ENTHRONE system (more specifically, into the EIMS), is achieved through the EIMS Content Manager (EIMS-CM) sub-system. The EIMS-CM is responsible for the storage and pre-processing of content and context metadata contained in DIs. As stated is section 3, the EIMS-CM is composed of two parts. One is located at the Service Provider (EIMS-CM@SP) and the other at the Content Provider (EIMS-CM@CP). The EIMS-CM@CP is responsible for the generation of valid DIDs describing actual content (DIs), and for there upload and updating. On its end, the EIMS-CM@SP offers an upload Web Service (UploadDID) to allow the insertion, of MPEG-21 DIDs into IMS-CM's database. The publishing process consists of the uploading of the DIDs, carrying human and machine readable data about available consumable content, into the EIMS system via the EIMS-CM on the respective storage at the system database.

5.3 Upload Service

As stated above, the web service supplies the facilities for the remote upload of DIDs into IMS-CP@SP. Client server communication is handled through the exchange of SOAP messages over the HTTP protocol. The uploading process is composed of the following steps:

- Encoding of the DID;
- Adding the encoded DID to a proper SOAP message, as a binary attachment002E;
- Transmission of the SOAP message;
- Extraction and decoding of the attached DID (at the CM@SP side);
- DID processing and insertion in the EIMS;

The encoding process consists of the compression of XML data and its encoding in a binary form. This is performed according to the MPEG BiM [IS231] open standard for binary encoding of XML documents, which is the preferred method for the encoding of MPEG-21 descriptions [IS16]. Encoding of the DID before upload to the EIMS database achieves significant gains of bandwidth because XML is highly verbose and ENTHRONE DIDs may hold the description of the programmed content for a channel for several days. Additionally, this allows the automatic checking of XML format and validity. This is performed through the use of the BinXML tool.

The EIMS-CM@SP sub-system is responsible for the retrieval of the received DIDs, from the SOAP messages, their processing and storage. Upon reception of such a DID, the EIMS-CM@SP subsystem pre-processes it, storing it to disk, along with an automatically generated file for each individual Item within the DID. These generated files will each store the content of one Item, as an xml fragment. DI related data is also stored in the EIMS database whose model supports the DID format as described in section 4.2. Not all information contained in the DIDs is stored in the database, but only the information that is necessary to distinguish between DIs and that specifies semantic characteristics about the actual media content. This information, within each Item, is respectively contained in the DI identifier and the DI content semantic descriptions, referred in section 4.1, and will be the target of the search process as described in section 4.2. This dual approach to data storage was chosen to allow speed and efficiency in dealing with user demands for DI searching and browsing (which will interact mostly with the database), and to make the retrieval, reconstruction and processing of DIs by the EIMS, easier, upon user requests for content consumption.

The information in the EIMS database and the associated data on disk, accessed through the CM@SP's functionalities, allows the search and browsing of contents, and provides support for the dynamical adaptation of media assets offered by the Enthrone system.

6 Access to Information

A DI can be very complex and consequently its processing and final presentation may not be straightforward. The ENTHRONE system provides functionalities that allow Content Providers to publish their contents and enables Content Consumers to search through published contents and consume its selections while transparently dealing with the metadata processing, QoS negotiation and license management.

In order to provide a friendly presentation of the metadata contained in a DID to the end user, the front-end of the ENTHRONE Terminal is implemented as a DID Browser.

In this view over DI presentation, the process of DI access and consumption usually does not imply a single step to get the whole information associated with a DI (except in the case of very basic DIDs). Access to metadata associated to DIs is progressive and interactive, the user's experience is a sort of exploration that relies and makes use of the standardized functionalities of the DID. The navigation between Items follows an approach similar to the navigation between web [Car04].

Figure 5 depicts the general layout of the DID Browser GUI. In order to try to make use, as much as possible, of the functionalities provided by the DID, the DID Browser can present several types of descriptive metadata. Currently only simple text, TV Anytime and media resources (e.g., thumbnail) are supported. One of the reasons for this first filtering is to hide to the user low level metadata (e.g., DIA metadata about terminal capabilities). In the case of structured descriptive metadata as is the case of TV Anytime, a previous formatting is performed.

Figure 5 - DID Browser GUI

Together with the presentation of content, the DID Browser, in its role of front-end of the terminal, also provides the functionalities for searching for content. When performing a search, a form is presented to the user assisting him with the definition of the parameters to be used. The entered parameters are sent to the EIMS, which in turn queries its database. The response to the query is conveyed as a MPEG-21 DI as described in section x. This enables the transparent transmission of information since only DIs are transacted, and these are content-unaware, and the presentation of the search results as any other piece of content.

7 Conclusions and future work

This paper has described the developments made within the ENTHRONE project with the aim of enabling the transparent access to diversified multimedia content and its consumption in heterogeneous devices. The accomplishment of this objective required the horizontal support and use of different types of metadata formats. It has in particular addressed the aspects related with the publishing and archival of multimedia content and associated metadata using a unified and open format and the presentation and controlled consumption of that content.

It has been shown that the ENTHRONE platform through the use of MPEG-21 tools and specifications and WS technologies was able to effectively offer the support for Content Providers to make their content available to diversified audiences, meeting different usage environment constraints. Many research groups are currently addressing the topics of context-aware services and Universal Multimedia Access [Car04, Vet04, Ke04]. Nevertheless a complete system that actually offers a universal mode of interconnecting different end-user devices, systems and applications using open standards and formats has not still be presented. ENTHRONE offers the means for Content Providers to publish their content as MPEG-21 Digital Items, creating Digital Items repositories which can be universally accessed. It offers the tools for allowing end-users through diverse terminal devices to browse these repositories and consume content in a format adapted to their requirements and preferences The following major strengths of the ENTHRONE system can be highlighted:

- MPEG-21 DID based media inventory. The usage of the DIDL supports the creation of very rich and flexible media inventory. All media related aspects, like media description, media identification and rights management can be handled with a interoperable standardised metadata format;
- MPEG-21 DIs presentation and consumption at various user terminals. The integration of the DID Browser in the ENTHRONE Terminal enabled the transparent presentation of MPEG-21 DIs, i.e., of the information and meta-information contained in the DI. Also, the flexibility of this application enables its use in different scenarios with different requirements. It was possible to test the DID Browser accessible through a PC and a PDA. Nevertheless, additional work is still necessary to: support other parts of MPEG-21, especially DIP; better adapt the application and content presented to different usage scenarios, particularly to different terminal device capabilities. The DID Browser implements a user-friendly philosophy for DI consumption based on the well established Web navigation principles, while hiding the actual structure of DI and other information that is not intended for end-users.

Although a full working prototype has been implemented, there is still room for further developments and enhancements. It is in particular envisaged to extend the support of the platform for context description, notably concerning user preferences and natural environment characteristics. Also to look at aspects related with the verification of the digital rights associated to the content before actually deciding upon adaptation operations when delivering a context-aware service to the end-user. Another important area is the semantic-based content search and to study and implement forms of bridging the well-known problem of the "semantic gap". Major research efforts are on-going to solve this problem. Strategies include the extended use of semantic concepts, the definition of semantic dictionaries and the use of relevance feedback. Work will be conducted in this area, notably towards the definition of efficient search engines that combine the use of low level and high-level descriptions and the use of relevance feedback.

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