Dynamic service management in heterogeneous environments using MPEG-21 DIA for multimedia content adaptation

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Abstract - **This paper presents the approach used in the ENTHRONE IST project to provide context and QoS-aware multimedia services. Through its Integrated Management Supervisor (IMS) system, ENTHRONE enables the distribution of multimedia content with dynamic end-to-end QoS guarantees over heterogeneous networks to different client devices. At its core is the adoption of open standards such as MPEG-21 and Web Services. The former, in particular MPEG-21 DIA, is instrumental to adapt multimedia content to the end-user terminals capabilities and to network conditions in order to achieve the best possible quality. The latter is instrumental to facilitate service provision to a wide range of devices. The integration of both technologies is facilitated by the fact that both are based in XML**

Key-Words – **multimedia adaptation, MPEG-21, context, heterogeneous, QoS**

1 Introduction

The perception that technology is evolving in such a way as to enable the consumption of virtually any kind of A/V content in an ever increasing type and number of terminals, is more and more a reality. Researchers worldwide have been working in collaboration towards the development of open specifications and tools that are able to fulfil this promise. Such is the case of the MPEG-21 tools specified in part 7 of the standard, the "Digital Item Adaptation" framework [1].

In fact, while technologies advances are pushing the creation of new and appealing content and services, in practice the diversity of terminals and the limited network support for QoS-enabled connections greatly constraints the universal access to this content. As such, the use of content adaptation tools is seen as a vehicle to allow content and service providers to further enlarge their market opportunities and provide a richer experience to the user, fulfilling the promise of ubiquitous access to any kind of multimedia content.

In this context, the ENTHRONE project [2], having as goal the support of multimedia services with end-to-end QoS in heterogeneous networked environments, has investigated the use of MPEG-21 DIA tools. ENTHRONE, IST-507637, is and Integrated project approved during the 1st call of IST-FP6 in June 2003. ENTHRONE stands for *End-to-End QoS through Integrated Management of Content, Networks and Terminals*. To attain the goal of enabling any user to consume any content, it is necessary to develop mechanisms to seamlessly adapt the content to specific usage conditions. Those mechanisms need to have the ability to understand and use information about the context of usage comprising network characteristics and conditions, terminal capabilities, user preferences and possibly environmental conditions. Furthermore, architectural support is needed to allow the networked access from a variety of client devices to distributed multimedia content repositories independently of the data models and technology in use.

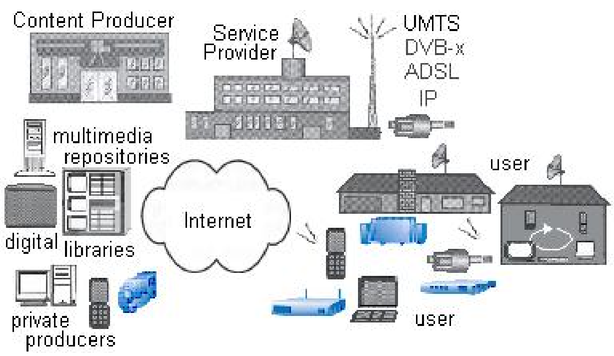

Figure 1 – The heterogeneity scenario

In this paper we present the ENTHRONE *Integrated Management Supervisor* (IMS) [4], [5], [6], to fulfil this goal, focussing on its service monitoring functionality which is supported by a quality-based content adaptation decision capability. The system is based on a standardised framework and it follows a Services Oriented Architecture (SOA) approach. The chosen standardised framework is the MPEG-21 specification [3]. It provides a unified method for the generation, exchange and manipulation of content and context metadata as well as of the multimedia resources themselves. The SOA approach is implemented through the use of Web Services technologies, facilitating service provisioning to a wide range of devices. Building on top of the MPEG-21 tools, the ENTHRONE IMS is able to provide context-aware A/V services to heterogeneous end-users in heterogeneous networked environments. It mediates the access of users to content and supervises the delivery of the content to ensure the level of QoS. This paper is organised as follows: section 2 provides a succinct description of the adaptation tools and metadata used in ENTHRONE. Section 3 provides a description of the IMS architecture focussing on its service level management and monitoring functionality. Section 4 describes in more detail the quality-based adaptation mechanism of ENTHRONE. Finally section 5 draws the final conclusions and points future directions of work.

2 Adaptation metadata

One of the challenges of the ENTHRONE project is to take the “perceived” quality of service into account. To that aim, ENTHRONE incorporates in its IMS, adaptation decision capability using a quality-based strategy. A quality-based adaptation requires the availability of engines capable of taking decisions about the need to perform adaptation, which in turn require the availability of meaningful descriptions about the content and the context of usage, providing a measure of the service quality. Content-related metadata should include not only description about the content itself, but also regarding the type of operations that can be performed upon it and the result that is obtained. Context-related metadata should provide a characterisation of the environment where the content is to be delivered and consumed. Examples are the capabilities of the terminal or the characteristics and conditions of networks.

MPEG-21 DIA [1], [7], [8], [9], specifies a set of tools to assist the adaptation of multimedia content in the form of Digital Items (DIs). MPEG-21 DIA tools provide the means to characterise the context of usage and to relate required resources, such ad bandwidth or network losses, with encoding parameters of available encoders and adaptation engines, to the perceptual quality of A/V signals. To be able to obtain these relations, ENTHRONE incorporates tools to constantly measure the quality of the delivered signal as perceived by the end users [10].

2.1 MPEG-21DIA

The MPEG-21 DIA framework can be seen as an enabler of ubiquitous access to multimedia content. It provides a set of tools to allow the description of characteristics and capabilities of networks and terminals and of user preferences. The set of tools also provides the definition of the operations that can be performed upon the content and the result that can be expected. Specific adaptation tools provide a definition of a set of descriptors and methodologies to describe the context of usage, the operations that can be performed upon the content and the result that can be expected. And even how to manipulate the content at the bit stream syntax level. Such is the case of the tools *Usage Environment Descripto*r (UED), *Adaptation Quality of Service* (AQoS) and *Universal Constraints Descriptor* (UCD). These tools can be used to analyse the status of the consumption environment, to decide upon the need to perform adaptation and, finally, to notify adaptation engines to adapt the stream to particular usage constraints. Adaptation engines may include encoders or servers, receivers or intermediate adaptation engines. Particular usage environment constraints may consist on available network bandwidth or terminal display capabilities and/or user preferences. A possible form of adaptation towards meeting user preferences may consist on the removal of undesired objects from an MPEG-4 stream or retrieval in the server of only some of the media components of a stored DI. Systems adopting this approach are able to, upon the same query, produce different results according to the diverse usage environment constraints and/or user preferences/profiles. Figure 2 illustrates the MPEG-21 concept of content adaptation

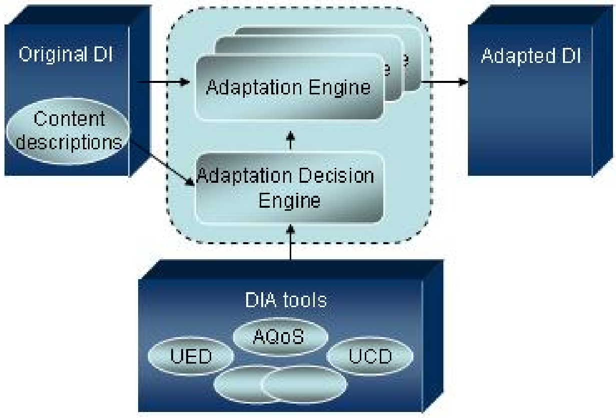

Figure 2 –MPEG-21 adaptation process

From the available MPEG-21 DIA tools, the UED, UCD and AQoS tools were selected for implementation in the testbed, to provide the platform with the required adaptation decision functionality. A concise description of these tools is provided bellow, whether for more details the reader is encouraged to refer to [1] and [9].

UED tools

Provide the mechanisms to describe the characteristics of the environment in which the content is to be consumed, notably the capabilities of the terminal, the characteristics of the network and information regarding the user and his/her surrounding natural environment.

Terminal capabilities

Refers to capabilities of the terminal where the content is to be consumed, in terms of the types of encoded formats that are supported - “codec capabilities” -, in terms of the display and audio output device characteristics and of several input devices – “input-output capabilities” – and finally physical characteristics of the terminal such as processing power, amount of available storage and memory, or data I/O capabilities – “device properties”.

Network characteristics

Includes the description of the static attributes of networks such as maximum channel capacity – “network capabilities" - and the description of parameters of the network that may vary dynamically along time such as instantaneous available bandwidth, error rate or delay – "network conditions". The former tools are used upon set up of the connection assisting in the selection of the optimum operating point, whereas the later are used to monitor the state of the service and accordingly update the initial setup

User characteristics

There are 4 different subsets of descriptions that fall into this category. A first group of generic descriptions using MPEG-7 [15] description schemes ("User Agent" DS), provides information on the user himself as well as indications of general user preferences and usage history. A second group enables to express the preferences of the user regarding the way the audiovisual information is presented such as audio power and equalizer settings or video colour temperature, brightness and contrast. A third subset of descriptions provides indications regarding auditory and visual impairments of the user, such as hearing frequency thresholds or deficiencies on the perception of colours. Finally, a subset of descriptions related with the instantaneous mobility and destination of the user.

Natural environment characteristics

This kind of description tools provides information regarding the characteristics of the natural environment surrounding the user who wishes to consume the content. They comprehend information regarding the location and the time where the content is to be consumed using MPEG-7 description schemes, information describing audiovisual attributes of the usage environments such as noise levels experienced in the surrounding environment or the lightening conditions.

AQoS and UCD

When used together with UED, these tools: provide the mechanism to enable the implementation of a quality-based adaptation strategy. Using UCD to express as constraints the characteristics of the context and AQoS to express the relation between quality, operating points and required resources, it is possible to decide which (a-priori or reactive) measure to endorse when a quality degradation is detected. They enable the maximisation of user experience in terms of perceived quality, given the environment constraints. AQoS provides the indication of different sets of encoding parameters and the resulting quality of the encoded bit stream for each of those sets. UCD enables the transformation of the current conditions of the usage context conveyed as UED, into the form of restrictions that can be further used by adaptation decision engines.

2.2 Related work

In addition to the tools and descriptions being specified in MPEG-21, other standardisation bodies have also conducted work towards the support of context-aware applications and the assistance of adaptation operations. That is the case of the W3C or the IETF which have delivered related specifications in the last years.

Content adaptation at the network edges is already being performed by content distributed mediators in order to balance the network load or in the attempt to satisfy different user groups' profiles, redirecting requests based on geography or other profile characteristics. This is being achieved through the use of CDNs (Content Distribution Networks), P2P technologies and personalization techniques [11]. In the mobile world, content filtering services are being added to most caches. Wireless network proxies transform both protocol and Web content, converting HTML into WML for small-screen display and HTTP into WDP for wireless delivery. Adaptation of content, aiming increased penetration, is already happening, in particular in the mobile world. However it still offers somewhat limited functionality as it essentially accounts for bandwidth restrictions and devices' capabilities. The focus is still on the adaptation of the layout of the service rather than on the content itself. The same is happening in the TV broadcasting world, aiming the adaptation of interactive applications and Web-based content to multiple non-interoperable platforms.

IETF has produced the iCAP (Internet Content Adaptation Protocol) specification [14], which is it is basically a HTTP-based Remote Procedure Call protocol that allows clients to send HTTP messages to instruct iCAP servers or generic Web servers to perform some kind of operation over the content. iCAP servers are dedicated to perform specific tasks and are expected therefore to perform those tasks better or more efficiently than generic Web Servers. The targeted adaptation operations were defined from a business perspective and are seen as added-value services to the client. Examples of the envisaged adaptation operations are virus-scanning, ad-insertion and also some forms of content translation or content filtering.

The W3C has delivered the CC/PP (Composite Capability/Preferences Profiles) specification [12]. It provides the means to specify client capabilities (the "user agent" information) and user preferences using URIs and RDF (Resource Description Framework) text sent in HTTP requests [13]. The user agent specifies in the header of the client HTTP request, preferences of the user such as versions of content or languages and is empowered with negotiation capabilities. The W3C is quite active in the field of context-aware applications and as such is contributing to enabling the adaptation of content. Many of the current specifications and approaches being studied or developed towards the implementation of content adaptation operations rely in the use of W3C technologies.

3 The ENTHRONE IMS

The ENTHRONE project has developed a distributed context-aware content management system to enable the customised access to multimedia content from diverse client devices. The system, the ENTHRONE *Integrated Management Supervisor* (IMS) supports the transaction of multimedia content packaged as MPEG-21 Digital Items (DIs) and performs content adaptation operations according to the MPEG-21 standard when such is revealed necessary to meet specific usage scenarios characteristics and limitations. The adaptation decision adopts a quality-based strategy, trying to maximise the perceived quality given constraints imposed by terminal capabilities, network conditions and user preferences.

3.1 Overall IMS architecture

Figure 3 represents the high-level architecture of the IMS.

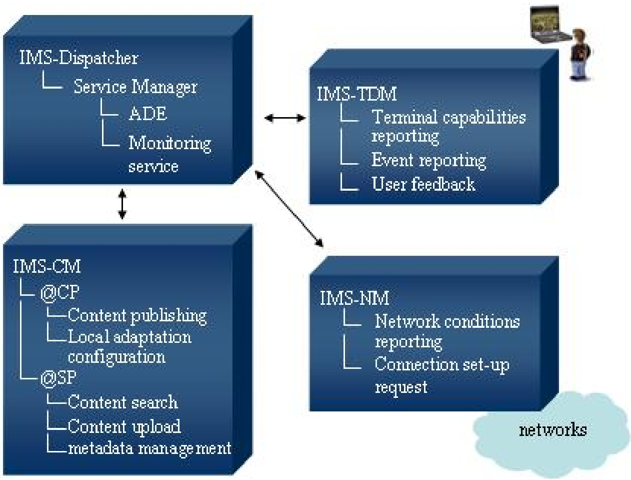

Figure 3 – The IMS functional architecture

It is a modular and distributed system, comprising different subsystems with well-defined goals. The kernel of the IMS is the *IMS-Dispatcher*. This is the subsystem responsible for the overall coordination of the IMS, management user requests and monitoring the agreed services. Using the value delivered by the other sub-systems, it processes user requests to search and consume multimedia content with a given quality and adapted to the user environment and monitors the service throughout its lifetime. The *IMS-Dispatcher* thus performs service-level management functions. When attending user requests, it processes content and context metadata related with the request and accordingly initiates a set of operations.

In a simplistic way, all the IMS subsystems can be seen as providing services to feed the *IMS-Dispatcher*, or better its ADE subsystem, with the metadata it requires to take its adaptation decisions, and to convey these decisions to lower level systems as for example transcoders.

The *IMS-Network Manager* (IMS-NM) is the subsystem responsible for the aspects related to the management of the network service. It provides a bridge between the content/user-oriented environment at the Service Provider side and the transmission-oriented world at the Network Provider side, each one using different terminology. Whilst the SP and its *IMS-Dispatcher* operate in the MPEG-21 world, the IMS-NM operates at the level of network parameters. The translation is achieved at the Network Management level of the IMS, by converting the MPEG-21 UEDs and AQoS into Service Level Agreements (SLAs) and subsequently into Service Level Specifications (SLSs). The process is illustrated in Figure 4. During service negotiation, the IMS-NM receives inquiries regarding the network conditions and accordingly supplies the requested information to the *IMS-Dispatcher*. Once the service has been agreed with the customer, it receives requests to set up the QoS-enabled connection.

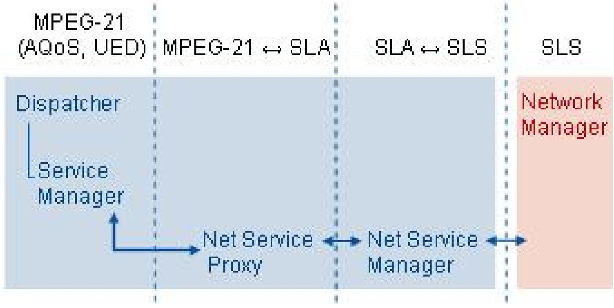

Figure 4 –Service-level to network-level conversion

The *IMS-Terminal Device Manager* (IMS-TDM) provides a platform-independent interface to various types of terminals, enabling their seamless interaction with the IMS-Dispatcher. Among other tasks, it collects and passes onto the *IMS-Dispatcher*, information concerning the terminal, the user and the surrounding environment and notifies the occurrence of events. The *IMS Content Manager* (IMS-CM) is the subsystem responsible for the storage, access to and handling of multimedia metadata and resources. It has specific modules installed and running at the Content Provider side (IMS-CM@CP) together with the sources of content, codecs and adaptation engines, enabling their local configuration. The IMS-CM@CP is responsible for the publishing of content in the form of MPEG-21 Digital Items (DIs), containing all the content-related metadata as required by the *IMS-Dispatcher* to perform its service-level management functionality (referred in the previous section). The *IMS-Content Manager* also has other modules installed at the Service Provider side (IMS-CM@SP), managing the access to metadata and resources using a data base and repository thus providing the support for content search. DIDs are generated at the Content Provider side, and published via a SOAP interface into the CM@SP. Metadata consisting in high-level semantic annotations (TV-Anytime or MPEG-7) and MPEG-21 identifiers are indexed in a relational data base and used for content searching. The CM@SP also maintains a file repository of the received DIDs and of each single item contained in the DIDs. When the *IMS-Dispatcher* issues a search request, the CM@SP builds a “volatile” DID composed of all the items in the repository that match the search. Search results are thus provided to the user as a new DID through which the user can navigate to eventually select the actual content he/she wants to consume.

3.2 Service Management and monitoring

The *IMS-Dispatcher* through its *Service Manager* module, implements all the functionality required at the application layer to support end-to-end QoS. The high-level architecture of the *Service Manager* sub-system is illustrated in Figure 5.

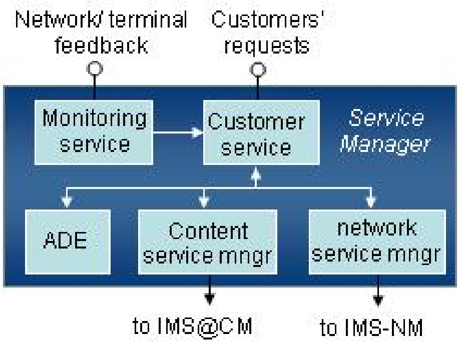

Figure 5 – The IMS-Dispatcher Service Manager

This sub-system encompasses functionality to process user requests and perform service-level negotiation. It establishes the interface with network-level mechanisms in order to request and invoke QoS-enabled paths. It includes monitoring services to interact with external components that supply feedback information concerning the service conditions. It takes decisions regarding the need and type of adaptation required in order to satisfy the user request with the best possible quality.

The *Customer Service* module is composed of different software components to directly attend user requests and to coordinate the operations required for the adaptation decision taking In order to deliver a context- and quality-aware service to end-users, the *Service Manager* relies on the *Adaptation Decision Engine* (ADE). This is the component of the *IMS-Dispatcher* that actually performs the quality-based adaptation decision. To perform its role, it needs to be fed with useful descriptions to allow to establishing a relation between the quality of the A/V stream, the network conditions, the terminal capabilities and the possible adaptation operations. It can be invoked both before and during content streaming. The latter can be triggered by the reception of an event at the monitoring service of the *IMS-Dispatcher*, indicating that the service conditions have been degraded (for example, a notification that the perceived QoS has fallen below an agreed value or that network losses have increased). In both cases it determines the set of service parameters that provide the best quality, given the current conditions. The module *Content Service Manager* is responsible to establishing communication with external adaptation engines, passing them the new encoding parameter values. The module *Service Monitoring* provides an interface towards external quality measurements devices. It is an essential element of the service monitoring functionality provided by the *Service Manager*. Mechanisms measuring the perceived quality of the service can be installed along the delivery path. In ENTHRONE, Perceive QoS (PQoS) probes have been developed and installed at the user terminal [10]. These probes are initialised with the agreed quality value at negotiation phase via the IMS-TDM. Whenever a loss of quality is detected, an alert is generated and sent back to the *IMS-Dispatcher*. This alert is further processed by the *Monitoring Service* and may initiate a new content adaptation decision process. Finally the *Network Service Manager* performs the interface with the IMS-NM as explained above, thus providing to the *Service Manager* the information concerning network conditions, essential for the adaptation decision taking process. Figure 6 illustrates the interoperation between these software modules and the type of information received and returned by each of them. All information exchanged between modules and with the external systems is encapsulated in MPEG-21 DIDL (Digital Item Declaration Language [3]), except when this reveals to be inefficient (very short messages or commands)

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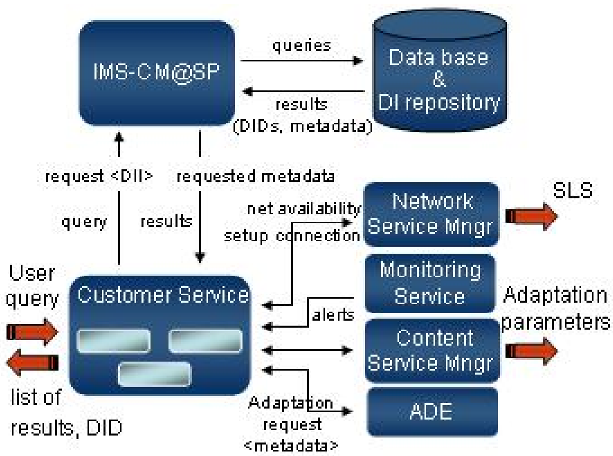

Figure 6 - Servide level functionality

3.3 Generation of UEDs and AQoS

In order to implement a quality-based adaptation strategy the IMS needs to generate the required metadata. As seen previously, this metadata needs to provide information concerning the content, content-related metadata, and concerning the characteristics and conditions of the context of usage, context-related metadata. The context-related metadata can be seen as indicating the constraints imposed by the environment in terms of available resources, such as bandwidth or packet losses in respect to the network, or display resolution and processing power regarding the terminal capabilities. The content-related metadata must include the relation between resources and perceived quality. In ENTHRONE it was decided to use the MPEG-21 DIA tools UED, UCD and AQoS to represent this metadata. The ADE component of the IMS uses these tools to decide upon the need to adapt the content. The processing required to perform adaptation operations involve basically three major steps:

1) To collect content-related metadata and its context of usage characteristics (terminal capabilities, network characteristics and user preferences), then

2) to decide if, and what kind of adaptation must be applied, determining the correct adaptation parameters, and finally

3) to invoke relevant adaptation engines passing them the obtained adaptation parameters.

These three steps are performed by the IMS through the ADE and using other components to collect the required metadata to feed the ADE and likewise to pass the ADE response onto relevant adaptation engines (described in the previous sub-section). The adaptation of the resources themselves is accomplished by other ENTHRONE components when invoked by the ADE. Adaptation Decision engines manipulate and interpret this metadata, take decisions about the need to adapt the content and instruct adaptation engines (such as transcoders or filters) to transform the content.

In ENTHRONE, the required adaptation metadata is instantiated from information retrieved from the IMS data base, previously gathered by the IMS, or from information dynamically generated and/or requested by the *IMS-Dispatcher* to external components. The later is the case of network conditions and PQoS alerts. Using this metadata, the *IMS-Dispatcher*, via its ADE, decides if and what kind of adaptation is required to fulfil the customer's request with the best possible quality.

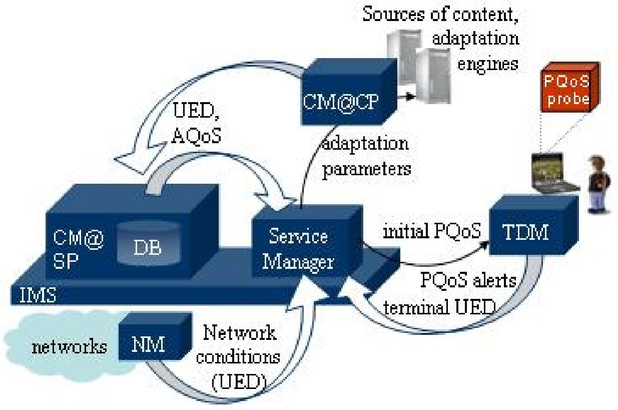

Figure 7 - Sources of adaptation metadata

Terminal UEDs are generated by the IMS-TDM and passed onto the I*MS-Dispatcher* as a parameter of a user request. This information is associated to a given service identifier and kept on a local repository maintained by the IMS-CM@SP. It is fetched by the *Service Manager* of the *IMS-Dispatcher* whenever it decides to invoke the ADE. In addition, whenever alerts are generated due to quality degradation, a new UED is generated, reflecting the new environment conditions. Network UEDs need to be generated at the precise instant when the ADE is invoked as they should reflect the current conditions on the network. They are generated by the *Network Service Manager* upon request of the *Service Manager*. As explained in sub-section 3.1, UEDs are built using the information passed by the IMS-NM in the form of SLSs.

The AQoS metadata is essential for the ADE to perform its role. In ENTHRONE it is obtained through the use of a stand-alone application, the *AQoSDescriptionGenerator* This component generates AQoS metadata relating different codec operation points, environment constraints and resources' values to achieve a given perceived quality. As such it provides useful metadata for a quality-based adaptation decision, where the possible adaptation operations are related to the encoding/transcoding process. The AQoS descriptions, being a type of content-related metadata, can be generated off-line, included in the DIDs that are uploaded to IMS database and thus be available a-priori. The *AQoSDescriptionGenerator* module is described in more detail in section 4. Figure 7 shows the instantiation of the different types of adaptation metadata used in ENTHRONE.

4 ENTHRONE’s quality based adaptation mechanisms

4.1 Adaptation Decision Engine (ADE)

The ADE is the module of the *IMS-Dispatche*r that takes DI adaptation decisions to provide the best quality given usage environment constraints (on the terminal, networks and encoders) and user preferences. It can be invoked both before and during content streaming. The latter can happen in case the measured perceived QoS falls below a pre-configured value. In both cases it determines the set of service parameters that provide the best quality, given the above mentioned constraints. Figure 8 shows the structure of the ENTRHONE ADE.

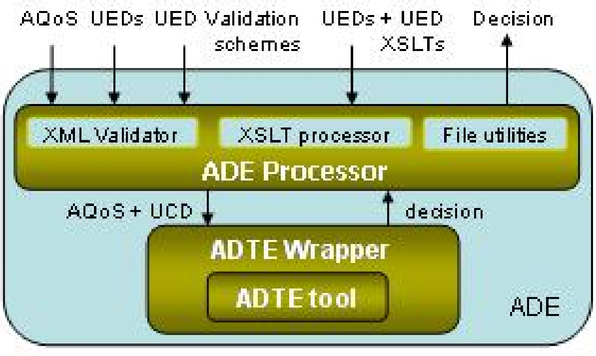

Figure 8 – Architecture of the ENTHRONE ADE

The ADE takes as inputs DIA descriptions (UEDs and AQoS). In a first stage, the ADE processor module validates the received descriptions and then transforms UEDs into UCDs. This way, the capabilities of terminals and the user preferences, the characteristics of available adaptation engines and the capacity of the network are transformed into constraints, which are fed along with AQoS metadata into the Adaptation Decision Taking Engine (ADTE). Figure 9 shows a excerpt of an UED with terminal characteristics and the corresponding excerpt of the UCD produced by the ADE processor

The ADTE is the module of the ADE that performs the actual decision taking and is based on open software submitted to the official MPEG software repository [16]. The AQoS descriptions can be expressed in three different modes: *UtilityFunction*, *StackFunction* and *LookupTable*. These three modes essentially provide different ways of establishing the relationship between the operating point and the result in terms of resources (e.g. bit rate or spatial resolution) and in terms of quality. The ADTE can use any of these modes to implement a quality optimization algorithm. The ADE output is a set of "name-value" pairs selected among the AQoS descriptors originally provided. This output is used to configure different resources, including the encoding parameters of the streamer. In the current implementation, this configuration is done using different Web Services and associated SOAP messages.

The use of XSLT endows the ADE of great flexibility, decoupling the ADE from other components. For example, it is possible to seamlessly replace the ADTE and/or accept different UEDs or use different transformations of UEDs into UCDs.

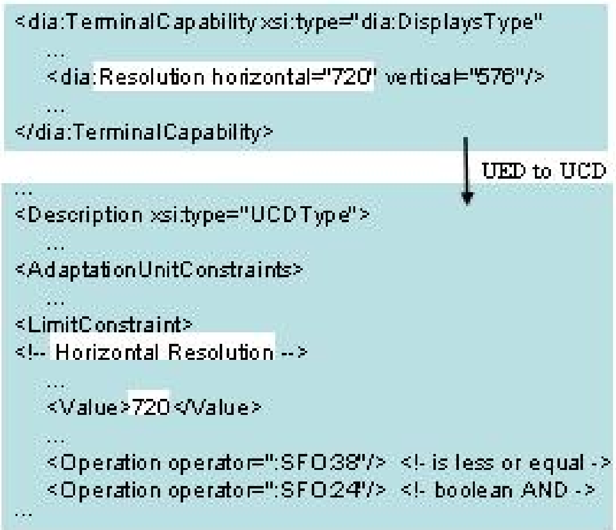

Figure 9 – Example of a conversion between UED and UCD

4.2 *AQoSDescriptionGenerator*

This component generates metadata useful for quality-based adaptation decision operations in the form of DIA AQoS descriptions. It is used off-line as a Web Service, delivering its output upon request through SOAP messages. The AQoS descriptions arrive to the IMS inside the DIDs, being subsequently extracted and separately stored in the IMS data base. Upon solicited, the ADE receives and uses this information to take an adaptation decision that will result in the best estimated quality given a set of usage constraints. As referred above, AQoS provides a means to relate different codec operation points, constraints and operators' values to achieve a given perceived quality.

The biggest challenge when generating AQoS descriptions is to obtain an accurate match between perceived quality and the adaptation operations that can be performed upon the content to yield such quality. The Enthrone *AQoSDescriptionGenerator* is designed around a database that holds the perceived quality of a variety of codecs, obtained off-line using different subjective and instrumental measurement tools. Having measurement results stemming from different sources increases the reliability of the final estimate used in the AQoS description. Examples of two such subjective tools are the ones developed or improved within ENTHRONE and described in [10]. Accurate quality estimates require that the perceptual quality of A/V signals is assessed for each set of encoding parameters. This would however lead to a huge effort. In ENTHRONE we have adopted an approach where AQoS metadata is generated per classes of DIs. Classes are distinguished through the use of an *MPEG-7 codec classifier*, the *bit rate* and the *genre*. Classification schemes for codec type, genre and AQoS are used to provide a system wide common definition of identifiers. Table 1 summarizes some of the most relevant input parameters, which are based on the MPEG-7 MediaFormatType [15].

Name	**Example**	**Description**
CodecClassifier	urn:mpeg:mpeg7:cs:VisualCodingFormatCS:2001:3.1.2	Unique classifier for the specific codec type MPEG-4 Visual Simple Profile @ Level 1
GenreClassifier	urn:enthrone:cs:2005:GenreQuality:1.	E.g. Speech, Music, Football, Al
qualityMeasure	urn:mpeg:mpeg21:2003:01-DIA-AdaptationQoSCS-NS:1.2.1	A measure of the perceptual quality of a video signal using PSNR
Bitrate	64	Net bitrate of the streams in kbit/s
BitrateRange	32-1500	Net bitrate of the streams in kbit/s
imageSize	320x240	Picture size in pixels

Table 1 Some of the most relevant input parameters to the AQoSDescriptionGenerator

Different classes of content, differing for example in the genre, will most probably present different AQoS descriptions. However, to be able to present meaningful results regarding this aspect, the authors still need to conduct further tests using more comprehensive sets of content.

The example in Figure 10 illustrates a possible AQoS description. The utility for describing the perceived quality is the DVQ measure developed in Enthrone [10].

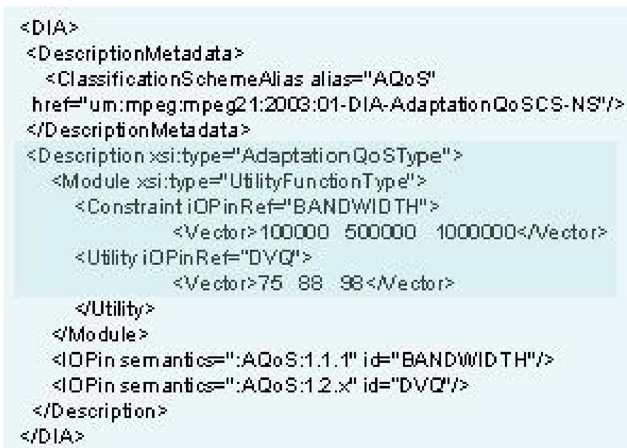

Figure 10 - Possible AQoS description

5 Conclusions

This paper provides an overview of the concepts and architecture of the IMS system developed in the ENTHRONE project. It describes in more detail its functionality to provide support for multimedia content adaptation. Major strengths of the described system rely on its extended coverage and use of MPEG-21 tools and its ability to support QoS- and context-aware universal access to multimedia content. Nonetheless, full use of the MPEG-21 potential hasn't yet been achieved. Support for more elaborated forms of content adaptation is envisaged. It is, in particular, possible to develop adaptation mechanisms based on scalable encoders and on the use of binary descriptions of the bit-stream. The later can be used to perform less demanding adaptation operations, which can be done by general-purpose engines in a distributed fashion, without the need to know the intricacies of the encoding algorithm. Further work concerning the particular type of adaptation decision engine here described, include in a short-term, the provision of an XSLT file as input to ADE for specifying the format of the returned decision response. In this way it will be possible to customize the response to requirements of specific adaptation engines and thus enlarge the scope of applicability of the ADE. In a longer-term, it is envisaged to:

- extend the support for context description, in particular concerning user preferences and natural environment characteristics;
- further study the use of feedback from PQoS probes to enhance dynamic operation;
- include the verification of the digital rights associated to the content before actually deciding upon adaptation operations;
- further explore the use of a distributed architecture for the ADE, where decisions and adaptation or only the decisions might be made at the client, with the client sending back to the server instructions for the adaptation.

Finally, another aspect that can be explored to augment the adaptation decision performance of the IMS is the use of high-level semantic information concerning the perceived quality of experience of the user.

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