# Using MPEG-21 and Web Services to achieve end-to-end QoS management

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***Abstract*- With the advent of the World Wide Web (WWW), large volumes of multimedia content are now available on-line in multiple formats. Furthermore, with the proliferation in the mass market of a diversity of multimedia-enabled end-user devices, consumers increasingly expect to be able to access any kind of content anywhere and at any time, regardless of the capabilities of their terminals and the networks to which they are attached. Access to content that meets user expectations and demands, must take into account all the different aspects of this heterogeneous environment. This paper describes the approach adopted within the European project ENTHRONE-2 to address this challenge. ENTHRONE-2 has conceived, designed and implemented a distributed platform, based on open standards, notably MPEG-21 and Web Services technologies, that supports the kind of network multimedia content access users expect. In particular, it focus on the ENTHRONE Integrated Management Supervisor, the entity that coordinates all the actions required for the provision of quality and context-aware, multimedia services to end-users.**

## I. INTRODUCTION

Today, the audiovisual and multimedia services industry is facing new challenges driven by two simultaneous technology phenomena: heterogeneity and convergence. Every day, new and diversified multimedia-enabled devices appear. Likewise, advanced network protocols and compression schemes are introduced, enabling the delivery of various types of content through networks and media other than their traditional channels. Content and Service Providers are therefore facing new challenges, trying to maximize their reach through different channels and using varied content formats and protocols aiming at satisfying the demands of their heterogeneous audience.

Access to content that meets user expectations and demands, must take into account all the different aspects of the current heterogeneous scenario: on one end, the large amount of content and services available out there to be searched, accessed and consumed; on the other end, an heterogeneous population of potential consumers; in between, a number of different access network technologies. Figure 1 illustrates this scenario.

The main goal of the ENTHRONE project is to ensure end-to-end QoS in heterogeneous multimedia networked services. To achieve that goal, ENTHRONE proposes an integrated management solution covering the entire audio-visual service distribution chain. It aims at delivering an open and flexible end-to-end architecture, enabling business actors to enhance their services, better satisfying users' expectations.

The challenge addressed by ENTHRONE is a complex one, involving a number of different aspects, notably, among others:

- gathering, representing and processing useful contextual information;
- describing, indexing and managing multimedia content:
- coordinating meaningful context-driven content adaptation;
- ensuring interoperability across diversified content repositories, different network equipment and technologies and heterogeneous client devices;
- ensuring security and management of digital rights.

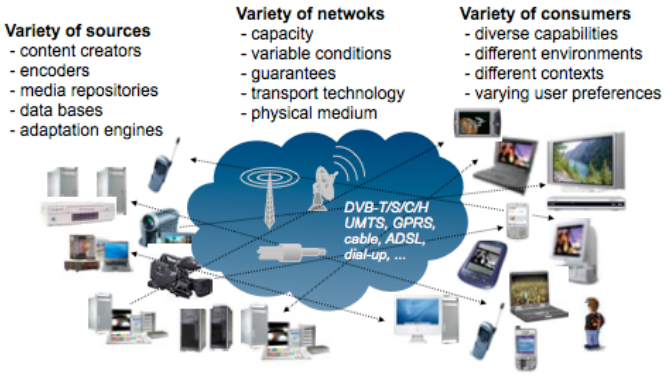


**Figure 1 - Heterogeneity in a converged scenario**

ENTHRONE has addressed this challenge by designing architectural support for the provision of context-aware multimedia services in an integrated manner, looking at implications and dependencies across the different aspects. It has adopted an approach relying on the use of distributed technologies to build a Service Oriented Architecture (SOA) based on open standards, notably MPEG-21 and Web Services. It elaborated a complete design process, from the identification of usage scenarios and elicitation of associated requirements, through the formal specification of the necessary functionality, mostly in the form of services, to the development of a prototype system.

In this paper, we describe the ENTHRONE Integrated Management Supervisor (EIMS), the entity in ENTHRONE that coordinates the actions required for the delivery of context-aware and quality-aware multimedia services to end-users.

This paper is organized as follows: Section 2 provides a general description of ENTHRONE's objectives and architecture. Section 3 introduces the EIMS from the application-level perspective. Section 4 describes the role of MPEG-21 within the EIMS, explaining how it contributes to the end-to-end context-aware service management and provisioning. Section 5 details the functional specification of the EIMS. Finally section 6 provides the concluding remarks.

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## II. ENTHRONE

ENTHRONE (IST-038463) is an Integrated Project partially funded under the European Union Framework Programme 6. ENTHRONE proposes an integrated management solution that covers the entire audio-visual service distribution chain, including protected content handling, distribution across networks and reception at user terminals. ENTHRONE aims at delivering an open and flexible end-to-end architecture to enable equally open and flexible business models, assisting business actors to enhance their services and move towards new business models eventually satisfying users' expectations. For that purpose, the project extensively employs open standards, notably the MPEG-21 standard, for 1) content representation (Digital Item Declaration, DID and Digital Item Identification, DII); 2) context representation (Usage Environment Descriptions, UED); 3) content adaptation (Adaptation Quality of Service, AQoS and Universal Constraints Descriptions, UCD); and 4) content protection (Rights Expression Language, REL and Intellectual Property and Management Protection, IPMP).

At the heart of the ENTHRONE architecture lies the EIMS, the ENTHRONE Integrated Management Supervisor. The EIMS is a distributed platform that interacts with the different players in the provision of multimedia services to end-users. EIMS can be seen as the coordinating unit of ENTHRONE, receiving and processing user requests, contacting various sources of content to find useful results for the user queries, determining the restrictions imposed by the context of usage and accordingly select the best service parameters and subscribing required resources to support the selected service. Figure 2 provides a view of the high-level architecture of ENTHRONE.

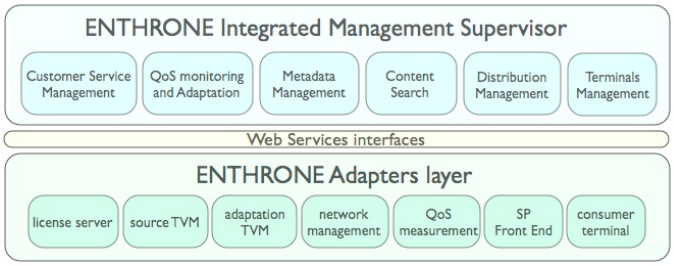


**Figure 2 - ENTHRONE high-level architecture**

In ENTHRONE we assume that the entity that makes the content available for the end-user to search, browse and play it, is always an SP. Content Providers (CP) are seen as the entities that only produce content. Some CPs may assume also the role of SP (in which case they are referred to as Service Providers), while others will always rely on agreements with third-party SPs to expose their assets to the public. A Service Provider (SP) may build a complete system on top of ENTHRONE, but ENTHRONE does not provide all the components needed by an SP. In particular, an SP has to add a Front-End through which a user will be able to access services. This is designated as Service Provider Front-End (SP-FE).

Accordingly, it is assumed that the most straightforward way of using the EIMS is to install its core functionality at a Service Provider, which will need to establish agreements with Content Providers to secure the desired content. Likewise, SPs also need to establish agreements with other entities involved in the content value chain, if they want to provide networked access to protected content to the end-user: Network Providers (NP), License Authorities (LA) and Consumer Electronics (CE) Manufacturers. The latter are not directly considered in ENTHRONE, as the interaction is made directly with the terminal equipment of the end-users. Nevertheless, a successful deployment of ENTHRONE may also involve off-line, a-priori agreements with CE manufacturers. This would allow having some EIMS modules natively incorporated into end-user devices.

## III. ARCHITECTURAL SUPPORT AT THE APPLICATION LEVEL

The EIMS, a software system comprising a number of cooperating sub-systems, provides the coordinating functionality to deliver context-aware multimedia services to the end-user. The EIMS can be seen as a context-aware content management and mediation platform based on MPEG-21 and distributed technologies. Its goal is to provide transparent access to multimedia content and services, offering a quality-controlled delivery.

To achieve this, it needs to be capable of interpreting content-related metadata in order to locate the content and to learn its characteristics and the operations possible to be performed upon it. Likewise it needs to gather, process and interpret context-related metadata in order to learn about the terminal and networks characteristics, as well as user preferences and possibly natural environment conditions. Only in possession of this information it is possible to adapt the content to meet the current context constraints. To operate in heterogeneous environments, it is desirable to have a single common framework to express and convey all this metadata. ENTHRONE uses the MPEG-21 standard as such a framework.

The reason behind this choice is twofold: 1) the need to implement an interoperability layer to bridge across different content formats, repositories and databases; 2) the desire of handling in an integrated and consistent manner all types of information in play: content, content-related metadata and contextual information. MPEG-21 provides a mean to accomplish these aims. Each unit of content made available to the end-user may consist of a number of resources of different media types. In order to be efficiently searched, it needs to be indexed and stored together with (or linked to) its descriptions. A mechanism is needed to enable the declaration of the parts that make up each content unit, and a publishing model must be set in place to allow handling the variety of items that may be published to it. Among the available emerging standards for content representation and description, MPEG-21 can be considered as one of the most advanced, complete and flexible, and therefore of great interest towards the objective of efficient use of multimedia repositories and universal multimedia access.

Furthermore, the EIMS needs to interact with a number of different entities, namely content providers, network operators, service providers and end-users, who are involved in the delivery of a multimedia service across networks. For this reason the EIMS is composed of different sub-systems, with well-defined functionality, each one interacting with one of those entities. Figure 3 shows how the EIMS could be used and deployed among the different participating entities, for the provision of context-aware multimedia services, enabling the transaction of protected content.

Functionality that is meant to be externally accessible is offered as services, either to other EIMS sub-systems, to other ENTHRONE systems or to external applications. The EIMS thus presents a services-oriented architecture (SOA), which facilitates its usage in different environments and contexts, and effectively enables the access of multiple, heterogeneous client devices to multiple heterogeneous sources of content. The SOAP protocol is used for the exchange of messages between sub-systems or external applications. Web Services Description Language (WSDL) is used for the specification of service interfaces. EIMS functionalities can be directly accessed and combined to support the requirements of different applications (such as unicast VoD, multicast NVoD, file downloading, real-time streaming, news-on-demand, broadcast iTV, etc).

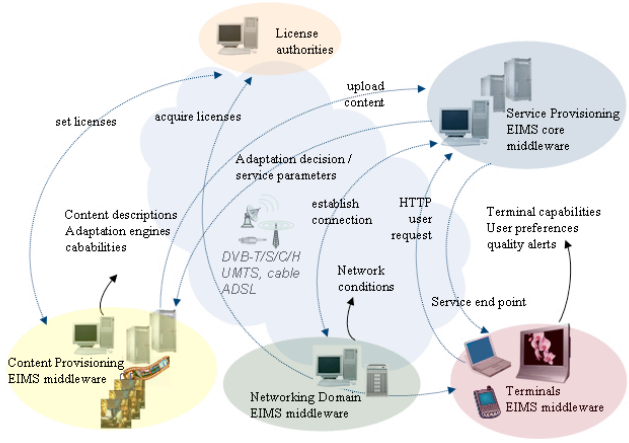


**Figure 3 - Conceptual deployment of the EIMS**

The EIMS orchestrates the end-to-end QoS management process delegating the actual tasks to ENTHRONE adapters, such as end-user terminals, routers or TVM (Television and Multimedia) processors. The diagram of Figure 3 shows five actors that have been identified at a high abstraction level, as the people or things that interact with EIMS and therefore to whom or to what EIMS delivers value. The EIMS presents a modular and layered architecture, composed of several software sub-systems with well defined roles. The functional architecture of the EIMS and the role of each sub-system will be described in Section 5.

The main idea behind this high-level architecture is the one of obtaining a distributed system that can interact with the key players in the multimedia content value chain, being deployed in varied forms according to the services to be offered and the business models to be adopted. Moreover, it allows to offer additional functionality on top of existing equipment, enabling the delivery of added-value services to the end-user. In particular the following additional functionality was identified:

• publishing multimedia content according to a common and open format (MPEG-21) in externally accessible repositories;

• seamless access to the offered services from any kind of networked multimedia-enabled device, thus enabling any user to search, browse and consume the published content;

• possibility of implementing multimedia services sensitive to the context of usage, therefore being able to collect and process contextual metadata coming from users (e.g., user preferences in terms of quality versus price), terminals (in terms of capabilities such as supported codecs or screen size) and networks (capacity and conditions);

• possibility to maintain a negotiation procedure between the user and the provider of the desired service;

• ability to monitor the offered service throughout its lifetime, assessing the level of the agreed QoS and the conditions of the context of usage and accordingly react to changes;

• allow different entities to share these tasks, maintaining an on-line cooperation through the exchange of information (mostly contextual descriptions) using open protocols and common data formats;

• flexible forms of business model configurations, thereby allowing either one single entity to assemble all the business roles within the content value chain (content creation and publishing, service offering, network provisioning, license issuing and management, content adaptation) or having different physical entities for each of those roles;

• support the use of efficient network distribution approaches, notably Content Distribution Networks (CDNs) and multicast.

The EIMS is independent of network technology and capable to harmonize inter-domain operation while not intervening in each domain resource management. This is achieved through the adoption of the pSLS/cSLS concept and a service planning approach, for the allocation of resources in the network. Service Level Specifications (SLS) are XML documents that describe the technical aspects of contracts established between an entity, notably a Service Provider, and a Network Operator, for the provision of QoS-enabled network channels. To serve a community of users within the same region (i.e., served by the same access network), an SP may negotiate with a NO a large capacity channel for a long-term period (e.g., several weeks, or months), thus establishing with the NO a pSLS (provider SLS). By performing an adequate planning, the SP may establish several pSLS with NOs, in such a way as to contract sufficient network capacity to potentially serve all of its customers. Then, whenever the SP receives requests from end-users, it uses a previously contracted pSLS to deliver the requested service. The network resources needed to deliver that service are allocated from the pSLS, by subscribing a customer SLS (cSLS) and deducting the used resources in the pSLS. Thus pSLSs provide the EIMS with an abstraction of the network that is used during service negotiation with end-users. Typically, several user requests corresponding to different streams assigned to different cSLSs, are multiplexed simultaneously over one single pSLS.

## IV. MPEG-21 IN END-TO-END MANAGEMENT

The diversity of end-user terminals and of transport networks implies a need for flexible content formats with high-level description, including digital rights. Formats specifically tailored for one type of terminal or for one network technology are no longer suitable. It is necessary to have flexibility to handle different usage scenarios with an optimal QoS.

In addition to the advantage of having flexible content encoding formats such as Scalable Video Coding (SVC) for better network resources utilization and for supporting different terminal capabilities, it is of utmost importance to have powerful description tools. These can provide the required assistance for deciding useful content adaptation operations, thus enabling the use of any kind of encoding format. The MPEG-21 stan-

dard defines tools to handle, identify, protect and adapt multimedia content. MPEG-21 Digital Item Adaptation (DIA) allows the description of the usage environment or context (user preferences and terminal, network and natural environment characteristics and conditions) and defines tools that use this metadata to build systems for content adaptation. The content and context metadata are used to assist adaptation operations. Concerning intellectual property rights protection, MPEG-21 defines a language to allow content owners to express usage rights (the Rights Expression Language, REL). A license appended to the content specifies how it can be consumed, by whom and under which conditions. The use of MPEG-21 to implement systems able to operate across the IP and the Broadcasting worlds is therefore very attractive. Content and all required metadata, including content adaptation descriptions, context descriptions and REL, are generated at creation time and included or referenced in MPEG-21 DIDs.

MPEG-21 is the ISO/IEC standard currently under its final phase of development within MPEG. It focuses on the development of an extensive set of specifications, descriptions and tools to facilitate the transactions of multimedia content in heterogeneous network environments. An MPEG-21 Digital Item (DI) is the smallest unit of content for transaction and consumption and, at the conceptual level, it can be seen as a package of multimedia resources related to a certain subject or theme. Part 2 of the standard (Digital Item Declaration Language, DIDL) specifies a standard method based on XML Schema for declaring the structure of the DI. Inside this XML document, the DID, standard MPEG-21 mechanisms are used to either convey resources and descriptions embedded directly in the DID or to provide information on the location of the resources to be fetched. The DID provides a description of the composition of the DI in terms of media resources and metadata, as well as of its structure in terms of the relationships among its several constituents. A DI is thus used to create the concept of a package or single unit, around a variety of multimedia information bounded by some common attribute, usually the topic they refer to.

Part 7 of the standard (Digital Item Adaptation, DIA) provides a set of tools, such as Usage Environment Descriptor (UED), Adaptation Quality of Service (AQoS) and Universal Constraints Descriptor (UCD), allowing to describe the characteristics and capabilities of networks, terminals and environments,as well as the preferences of users. In addition, 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. Figure 4 provides an illustration of the available tools of MPEG-21 DIA and its use for adaptation purposes.

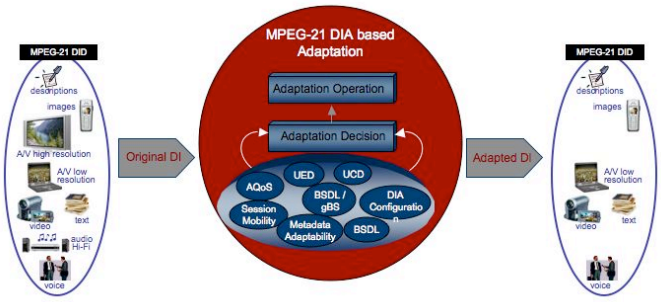


**Figure 4 - Adaptation using MPEG-21 DIA**

Accordingly, these tools can be used to implement context-aware content adaptation systems. They can be used to describe the current consumption environment and to assist the decision upon the type of adaptation to perform, if any. The outcome of this process can be used to configure encoders or servers, receivers or intermediate adaptation engines, to adapt the stream to particular usage constraints or/and user preferences. The former can include, for example, the available network bandwidth or terminal display capabilities. The latter can, for example, indicate the removal of undesired objects from an MPEG-4 video scene or filtering out some of the media components of a DI. In addition, MPEG-21 DIA provides the means, in the form of declarative restrictions and conversion descriptions, to enable finer-grained control over the operations that can be performed when interacting with the content (playing, modifying, or adapting digital items).

The EIMS allows the seamless consumption of the same content under distinct context conditions by implementing a quality-controlled, metadata-based content adaptation through the use of the MPEG-21 specifications, notably part 7 of the standard. It communicates with network-level management in order to obtain network availability and request the set-up of QoS-enabled paths. The EIMS can decide how to adapt the content to meet the current context constraints, based on the capabilities of the terminals, characteristics and conditions of the transport networks and the preferences expressed by the user. MPEG-21 part 7 is essential for the EIMS to accomplish its objectives. The standard provides the means to describe the context and offers guidance on the adaptation decision process. It defines the means to relate the constraints with possible adaptation operations and with the resulting quality. If the metrics used to express this quality provide a subjective measure that matches the human perception of quality then, using these tools our system is capable to deliver a user-centered quality-controlled service across distinct domains.

QoS is a concept that involves many different factors and the interaction amongst a number of diverse entities along the transmission chain and across different levels. At the user level, QoS can be expressed in terms of the subjective quality as experienced by the user when consuming an A/V service, i.e. Perceived QoS(PQoS), at his/her terminal. The user should not need to be aware of the technical parameters that affect the quality of encoded A/V scenes. At application level and service set-up time, the user selection is translated transparently into encoding parameters (AppQoS), which are then mapped onto network-level parameters (NetQoS), using top-down cross-layer approach. Figure 5 illustrates the process by which QoS is mapped between the levels.

The translation process is implemented through the use of the MPEG-21 AQoS specification, which provides the means to express the relationships between PQoS, AppQoS and NetQoS. The AppQoS determines the appropriate service/encoding parameters for achieving the desired PQoS given the context constraints (obtained via MPEG-21 UED). The corresponding NetQoS parameters determine the networking requirements, guiding the SP/NP for assigning the proper resources. Different techniques can be used to derive values of PQoS parameters from network-level QoS parameters measured across network boundaries or end-to-end. The result of

this mapping can be used as feedback to SP's decision-making process to compute new application parameters, when adaptation is necessary.

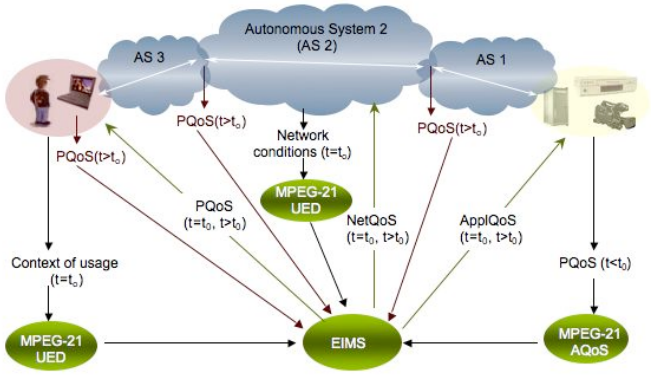


**Figure 5- QoS mapping process**

V. DESIGN

This section presents the EIMS high-level design in terms of functional blocks, their interfaces and associated value delivered. This design aims at supporting a set of use cases required for the deployment of ENTHRONE audiovisual services. Figure 6 shows the EIMS sub-systems using UML notation. Below, it is given a short description of the value delivered by each subsystem.

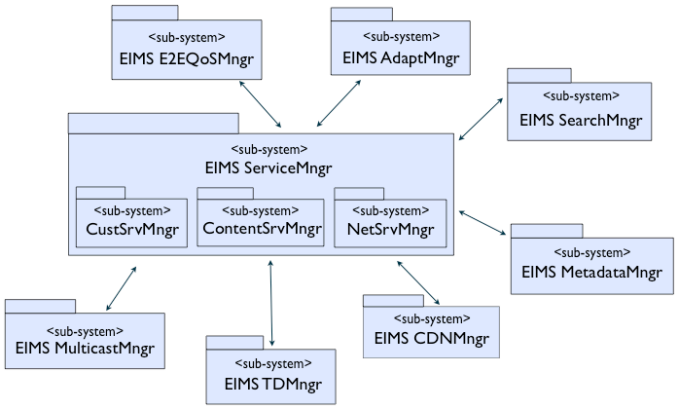


**Figure 6 – EIMS high-level architecture**

*A. Customer Service Manager*

This subsystem is responsible for service level management of the service provided to a consumer. Its functionality includes handling of the service negotiation and invocation as well as service monitoring. In this context it supports rich semantics for cSLS negotiation and invocation, interaction with active elements of the monitoring system, distributed adaptation and varied forms of efficient content delivery such as multicast and Content Distribution Networks (CDNs).

For efficiency reasons and considering scalability aspects, the Customer Service Manager is partitioned into two distinct sub-systems: CustSrvMngr@SP and CustSrvMngr@TVM. The former handles service negotiation and delegates handling of service invocation to the latter. For the full support of distributed adaptation (i.e. adaptation at multiple points along the distribution chain), the CustSrvMngr@SP, which is normally deployed at the Service Provider site, closely interoperates with multiple CusSrvMngrs@TVM, deployed close to the sources of content or adaptation engines (designated as source/adaptation TV and Multimedia processor, s/aTVM). In these scenarios, the CustSrvMngr@TVM in each of those s/aTVMs also cooperate among themselves, in order to ensure that content is properly streamed down the chain.

The monitoring of the quality of the service provided to the consumer is accomplished through direct interaction with the active elements of the ENTHRONE monitoring system, the Perceived and Network QoS probes (PQoS and NQoS). During the whole service lifetime, these probes report, either periodically or on an event-driven basis, quality measurements. In the case of event-driven reporting, whenever the QoS measured values are below a given threshold, the probes send alerts to the EIMS Service Manager. PQoS measured by PQoS probes installed at the terminal are pushed to the CustSrvMngr associated to the TVM closest to the terminal. PQoS values derived from NQoS measurements in the network are pushed to the CustSrvMngr associated with the TVM at the entry end of the cSLS where PQoS fluctuations were detected. This allows for responsive corrective measures at the upstream TVM closest to where service level is experiencing problems.

*B Content Service Manager*

This subsystem comprises the functionality for content-sourcing service level management. Essentially it is used to hide from the CustSrvMngr the details of negotiation and of invocation of the service provided by the Content Provider.

*C. End-to-end QoS Manager*

The E2EQoSMngr is responsible for selecting the initial content variation and selecting one or more Adaptation Managers, each associated to one s/aTVM. It selects the most appropriate variation of the requested content based on the usage environment and the content characteristics. It also selects one of more pairs AdaptationMngr-s/aTVM based on the capabilities of the TVMs, which need to be able to process the chosen content. A feedback loop is needed between these two tasks to optimize the complete selection process.

*D. Adaptation Manager*

The EIMS AdaptMngr is responsible for steering exactly one TVM, by configuring its service parameters based on adaptation decisions. These are obtained taking into account the usage environment constraints, the characteristics of the content, and the available TVM processors including their capabilities. The AdaptMngr is invoked by the CustSrvMngr, which passes it all required metadata previously gathered.

*E. Network Service Manager*

The Network Service Manager is the subsystem of the EIMS EIMS Service Manager that manages the network connectivity service to transport the content with QoS guarantees from its source to its consumer. This subsystem encompasses the functionality for provisioning, offering and fulfillment of the connectivity service, in a multi-domain context. It mediates the interaction established between the content service functionality and the network to obtain reservation of resources. Those interactions are related to SLS management, i.e. subscription and invocation of SLSs. The Network Service Manager deals with two types of SLSs: 1) end-to-end provider SLSs (pSLSs), and 2) consumer SLSs (cSLSs). The former consists of large capacity channels with agreed QoS, contracted by a Service

Provider for a relatively long-term time span, between the source of content and potential populations of customers (between the Access Network where the source of content is and Access Networks serving geographically co-located customers). The latter represent logical individual channels, subscribed and invoked upon the request of a singe user and using part of the resources allocated to previously established pSLSs. Multiple cSLSs are typically multiplexed on a single pSLS. The commitment of network resources to support a pSLS is called *pSLS invocation* and may occur at a time instant different from its subscription time. Both pSLS subscription and invocation are important tasks of the Network Service Manager: in ENTHRONE, a SP can provide QoS-enabled content delivery only if it has previously negotiated, subscribed and invoked a pSLS.

### *F. Multicast Manager*

The EIMS Multicast Manager is the EIMS subsystem that is responsible for all the tasks related to the management of multicast communication services in ENTHRONE. It comprises two components: the Multicast Service Manager and the Multicast Network Manager. The former binds multicast streaming services to multicast cSLSs. The latter configures and manages the multicast overlay network, including the E-cast trees, and possibly manages the cross-layer multicast agent to take advantage of IP multicast in the last core domain..

### *G. Caching and CDN Manager*

The Caching and CDN Manager (CCDNMngr) is the EIMS subsystem that is responsible for all the tasks related to supporting caching and CDNs in ENTHRONE. From a logical point of view, it can be seen as belonging to the EIMS Service Manager. It interacts with the ContSrvMngr during service provisioning and with the CustSrvMngr during service delivery.

### *H. Metadata Manager*

The EIMS Metadata Manager is devised as the metadata backplane of the EIMS. It is responsible for all tasks related with the handling of metadata notably, management, collection, conversion, and reconstruction. In particular it offers suitable interfaces to Content Service Providers to build DIDs, thus enabling them to publish their contents according to the MPEG-21 standard. The EIMS Metadata Manager is a complex system composed of three different components: 1) Context Collection Manager, to collect metadata concerning the context of usage; 2) Metadata Aggregation Manager, to aggregate and reconstruct metadata from different sources; and 3) Metadata Conversion Manager, converting metadata between different formats.

### *I. Search Manager*

The Search Manager comprises an MPEG-21 DID repository and a relational database to support search and retrieval of DIs/DIDs upon user requests. It offers its functionality in the form of a set of remotely accessible operations, via a Web Services interface. It maintains a database synchronized with that of the Metadata Manager but it stores only metadata relevant for search purposes (i.e., content-related metadata, both high-level semantic descriptions, as well as low-level content features). Search can be done in a local cache or in remote DID data bases of Content Providers or even of other Service Providers, which the initial Service Provider has contracts with.

### *J. Terminal Device Manager*

The Terminal Device Manager (TDM) is the EIMS subsystem responsible for the interaction with the ENTHRONE Terminal. The TDM Architecture is partitioned in a server part and a client part, in order to support thin clients. The TDM conveys all the requests of the user to the EIMS Service Manager as well as required contextual information concerning capabilities of the terminal. In addition it is responsible for configuring PQoS probes installed at the terminal and issuing PQoS alarms when triggered by the PQoS probe The server part of TDM is in charge of communicating with the rest of EIMS.

## VI. CONCLUSIONS

The EIMS architecture described in this paper empowers ENTHRONE to provide context-aware multimedia services while performing and end-to-end management of all resources used. It makes extensive use of both metadata and open standards. More precisely, the MPEG-21 framework and Web Services technologies.

The MPEG-21 framework serves two main purposes:

- to provide a common unified format for content description. The use of Digital Items allows two content resources created under different, possibly incompatible formats, to be equally searched using the same search engines, their existence equally communicated to interested users, and then be eventually consumed under their original format or after operating some kind of transformation upon the content.
- to provide a suite of standards-based tools to describe context of usage and assist in a consistent way, adaptation operations.

## ACKNOWLEDGMENT

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